Research based proposals to build modern physics way of thinking in secondary students.

Marisa Michelini,

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Abstract

Conceptual knots in classical physics are often quoted to argue the exclusion of modern physics in secondary school, but the physics of the last century is now part of the secondary school curricula in many EU countries and in the last 10 years appear in secondary textbooks, even if in not organic way and with a prevalent narrative approach. Therefore, a wide discussion on goals, rationale, contents, instruments and methods for its introduction in secondary school curriculum is now increasing. Modern physics in secondary school is a challenge which involves the possibility to transfer to the future generations a culture in which physics is an integrated part, not a marginal one, involving curricula innovation, teacher education and physics education research in a way that allows the students to manage them in moments of organized analysis, in everyday life, in social decisions. In the theoretical framework of the Model of Educational Reconstruction, we developed a research based educational proposal organized in five perspective directions: 1) the analysis of some fundamental concepts in different theories, i.e. state, measure, cross section; 2) problem solving by means of a semi-classical interpretation of some physics research experimental analysis techniques; 3) the study of phenomena bridging different theories in physics interpretation, i.e. diffraction; 4) phenomenological exploration of new phenomena, i.e. superconductivity, 5) approaching the basic concepts in quantum mechanics to develop formal thinking starting from phenomena exploration of simple experiments of light polarization. Research is focus on contributing to practice developing vertical coherent content related learning proposals by means of Design Based Research to produce learning progression and finding ways to offer opportunities for understanding and experience what physics is, what it deals with and how it works in operative way. Empirical data analysis of student reasoning in intervention modules support proposed strategies. The talk will present the research outcomes in terms of the approaches and the paths proposed for the last three perspectives: diffraction proposal, superconductivity phenomena exploration and quantum mechanics proposal.

thanks

- Thank you so much for this kind invitation
- I am honored to be here, because
  - I remember how much I learned by George Marx and his group
  - the Hungarian contribute to GIREP is up to now those of higherst level and original
- I hope you will partecipate to the 50° birday of GIREP Seminar in Krakow next year (August 2016)

Research based proposals to build modern physics way of thinking in secondary students

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Udine Physics Education Research Unit

- Marisa Michelini – Full professor in Physics Education
- Lorenzo Santi – Associate professor in general physics
- Alberto Stefanel – Researcher in physics education
- Luca Benciolini – Researcher in geological education
- Diego Cauz – 50% Researcher in physics education
- Boscolo Ilario retired full professor, still working
- **1 PhD Students**: Giacomo Zuccarini
- **11 post doc**: Sri Prasad Challapalli, Giuseppe Fera, Mario Colombo, Mario Gervasio, Alessandra Mossenta, Emanuele Pugliese, Maria Luisa Scillia, Giovanni Tarantino, Stefano Vercellati, Rossana Viola, Emanuela Vidic
- **15 Teachers Researchers …**G Burba, A Borgnolo, L Decio, F Leto, L Marcolini, S Martini, R Maurizio, GP Meneghin, D Novel, L Sabaz, I. Sciarratta, D Strani, G Vidus, …more
- **40 teachers cooperating**

Modern Physics in secondary school

- **Is now included in all EU curricula**
- **In the last 10 years appear in all secondary textbooks,** even if not in organic way

Altought there are

- Very different position as concern its introduction: conceptual knots in classical physics are quoted to argue the exclusion of MP in secondary school
- There is a wide discussion ON:
  - Goals, contents, instruments and methods, target students

Aspects discussed

- Goals/rationale
  - Culture of citicens
  - Guidance
  - Popularization
  - Education
- Contents: what is usefull to treat?
  - Fundamenta
  - Technologies
  - Applications

How?

- Story telling of the main results ...
- Argumentation of crucial problems
- Integrated in CP..
- At the end of curriculum as an additional / Complementary part

To whom?

All citicien?

Talent students?

Liceum students?

MODERN PHYSICS IN SECONDARY SCHOOL

is a challenge

which involves

the possibility to transfer to the future generations

a culture

in which physics is an integrated part, not a marginal one

it **imply**

- **curriculum innovation**
- **teacher education**
- **Physics education research**

in a way

that allows the students to manage them

-> in moments of organized analysis

-> in everyday life

-> in social decisions

Our perspective for modern physics

- Research based proposals
  - In cultural perspective focused on foundation of basic concepts as well as methods and applications in physics research
  - Integrated in physics curriculum and not as a final appendix
  - Offering experience of what modern physics is in active research.
- Vertical paths are identified,
  - as learning corridor (diSessa 2004, Michelini 2010, Psillos 2010) for individual learning trajectories and
  - steps by steps concept appropriation modalities (Fedele 2005, Bradamante 2006, Vercellati 2012).

ATTENTION IS PAID TO

- Identify **strategic angles** and **critical details** used by common knowledge to interpret phenomenology (Viennot, 1994)
- Study spontaneous dynamical path of reasonings (Michelini 2010).
- Find new approaches to physics knowledge (Viennot, 1994; 2003; McDermott, 1993-2006; Michelini 2010).

- Avoiding the reductionism to offer opportunities of:
  - Learning and not only understanding of information, build interpretative solutions and results (to become able to manage fundamental concepts)
  - Gain competences of instruments and methods

Theoretical framework of our Research approaches: MER (Duit 2008)

- **The first step in research task is**
  - **to rethink scientific content as a problematic issue,**
  - **to rebuild this with an educative perspective.**
- **This task is often integrated with**
  - **empirical research on student reasoning and learning progress**
  - **DBR: Design based research** in planning intervention modules
  - **action –research in a collaborative dialectic between school and university**
- to
  - contribute to classroom practice
  - develop vertical T/L path proposals experimented by means of different interventions in schools.
- **The approaches in our work are therefore not purely based upon disciplinary content** (Fischer 2005) **in order to identify strategies for conceptual change** (Vosniadou, 2008).

the research approach on learning processes

- **Rather than**
  - **general results or**
  - **catalogues of difficulties,**

  we are interested in the obstacles that must be overcome to reach a scientific level of understanding and the construction of formal thinking.
- **We are interested in**
  - **the internal logic of reasoning,**
  - **Spontaneous *Mental Models***
  - **their dynamic evolution following problematic stimula (inquiry learning) in proposed paths.**
  - **The ways for building of formal thinking**

Empirical data analysis

is carried out on 4 main research problems:

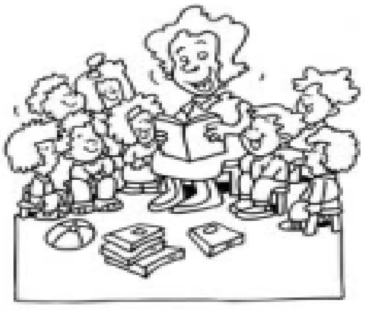
1. individual common sense perspective with which different phenomena are viewed and idea organization, in order to activate modeling perspective in phenomena interpretation,
2. the exploration of spontaneous reasoning and its evolution in relationship with series of **problematic stimuli** in specific situations, in order to formulate activity proposals, and
3. finding the modalities for overcoming conceptual knots in the learning environment.
4. **Learning progression** from defined low anchor to specific learning outcomes by means of detailed paths

MONITORING LEARNING PROGRESS

Data collection is carried out by means of

- Test in-out in intervention modules
- IBL Tutorials monitoring learning process
- Interviews
  - Semi structured
  - Rogersian

- Video-recording of
  - Small group discussions
  - large group interactions



The different proposals for Modern Physics mutually inclusive

1. **Phenomena bridging theories (Diffraction) (*)**
2. **The physics in modern research analysis technics: RBS, TRR, R&H (*)**
3. **Explorative approach to superconductivity (a coherent path) (**)**
4. Discussion of some crucial / transversal concepts both in CP and MP : **state, measure, cross section**
5. **Foundation of theoretical thinking: QM (*)**

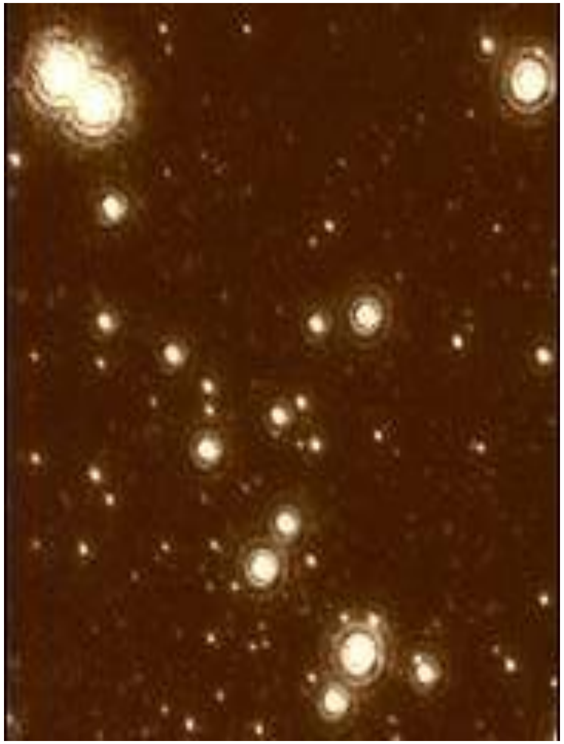
(*) Only an overview to have an idea
(**) description following the reasoning for an explanation in CP

1. Phenomena bridging theories: Diffraction

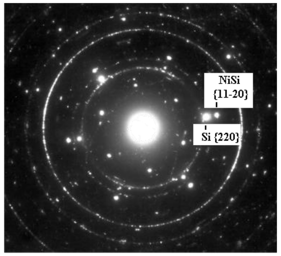
- Is a common phenomenon aroud us
- Have a large employ in research analysis

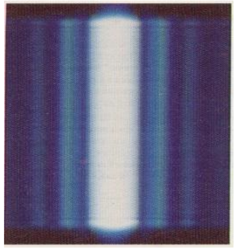
Its interpretation bridge:

- Geometric and physics optics
- Classical Phys and QM



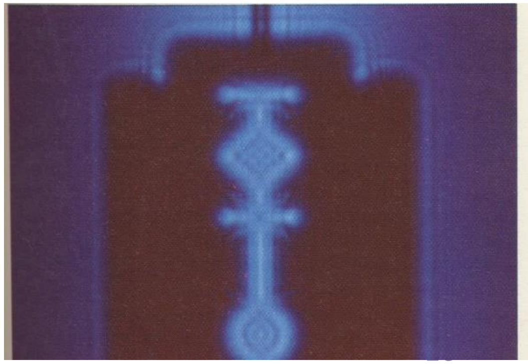
Resolution limit in stars' identification

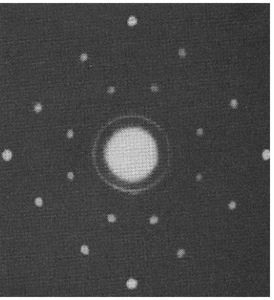




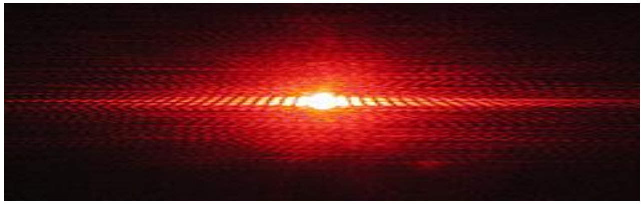
Electron diffraction on NiSi

Van Gog and puntinists



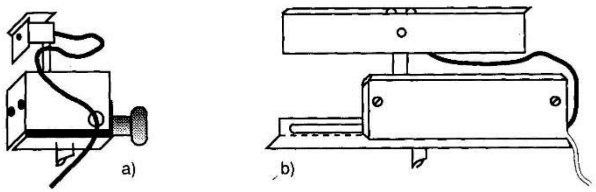


Neutron diffraction on NiSi



Light Diffraction

Light intensity data vs position

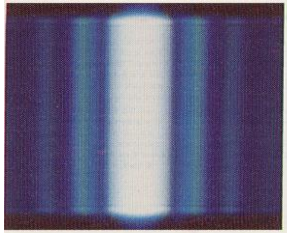


A path with qualitative and quantitative analysis of the diffraction pattern to individuate the relationships amoung quantities

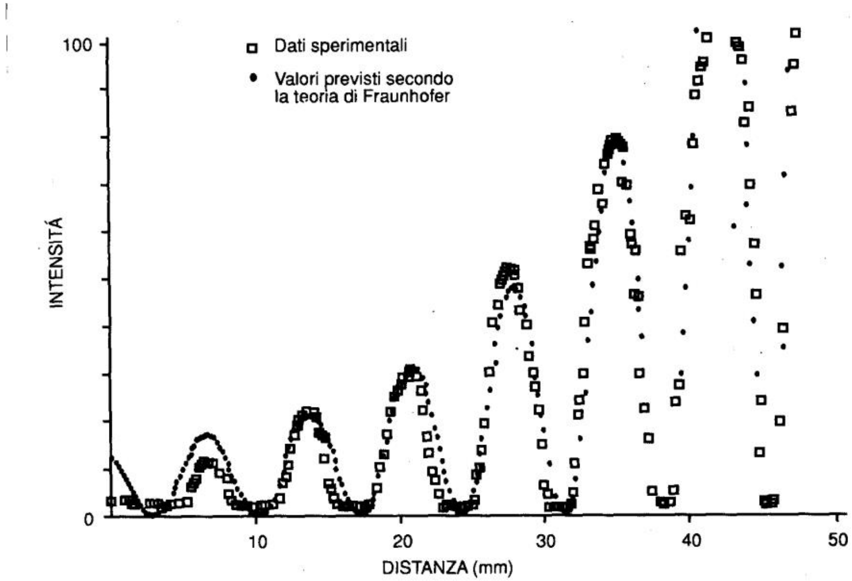
We developed

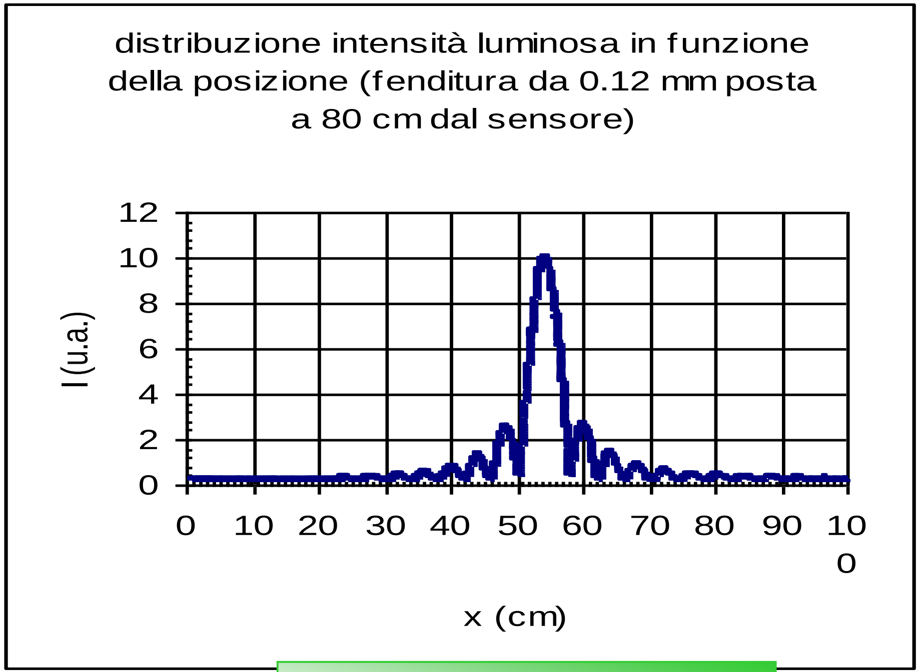
LUCEGRAFO hw-sw system for light intensity measurements

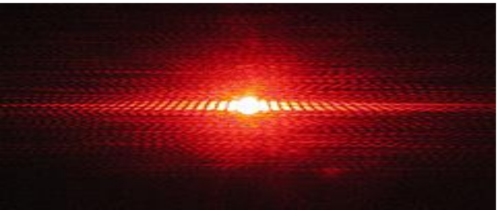
$$\frac{\Delta x_m}{D} = \cos t$$



Fitting data by means of the theoretical expression





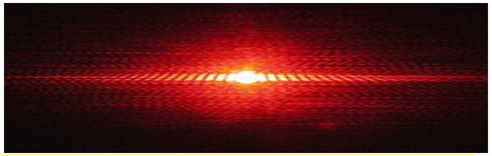


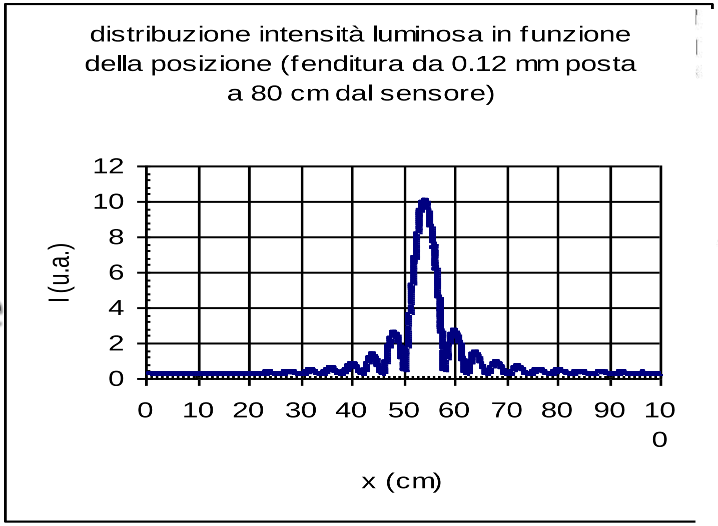
$$\frac{I_M}{I_0} = \left(\frac{D\lambda}{\pi a}\right)^2 \frac{1}{(x_M - x_0)^2}$$

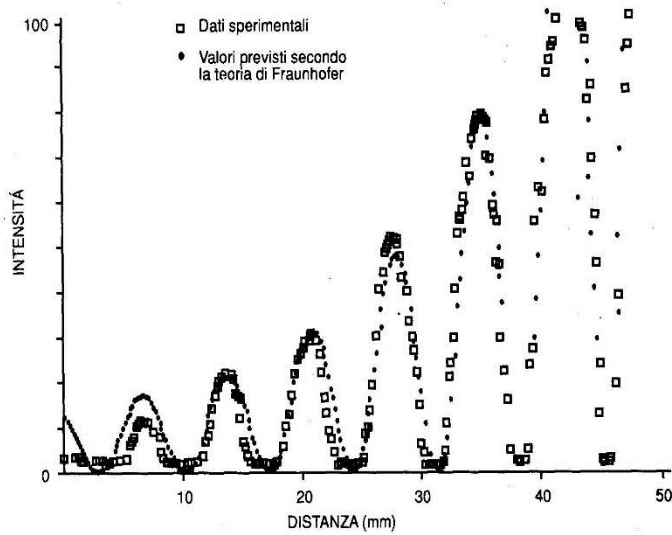
$$\frac{x_m - x_0}{D} = (2m+1)\frac{\lambda}{2a}$$

The rationale of diffraction path ranges from data analysis to fitting … to the data comparison with the theoretical model

1. Phenomena bridging theories

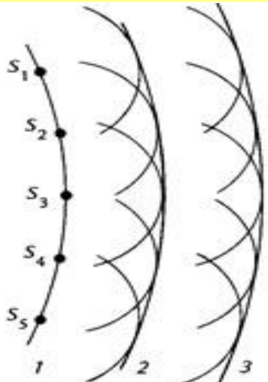


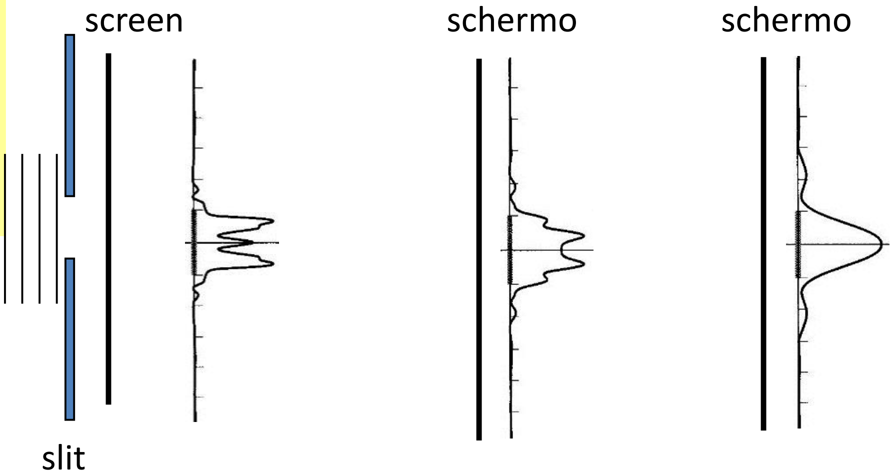


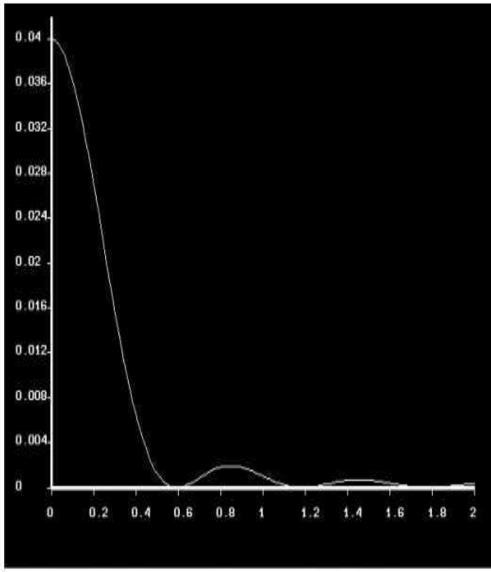


Gaining interpretation in CP&MQ

…To modelling by means of Huygens priciple, analysing the conseguences of the interference of point sources on wave front







N = 50 Distribuzione di intensita' luminosa sullo schermo

Comparing theoretical prevision with data collected

2. The physics in modern research analysis technics

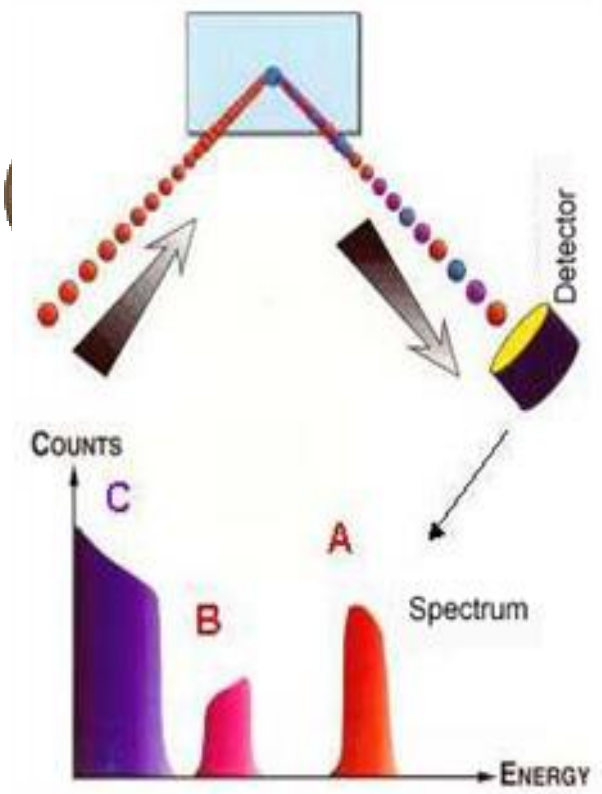
RBS

Rutherford Backscatterig Spectroscopy

The measurement consists in collecting the energy spectra of ions (He++ of 2 MeV) backscattered along a certain direction, after a collision with the atoms of a target, in a linear accelerator.

RBS provides information about the depth distribution of the constituent elements of the first 500 nm of the surface of a sample.

Semi-classical treatment of data.



2. The physics in modern research analysis technics

RBS

The Priciples of measure and semi-classical data treatment are discussed with students and Spectra

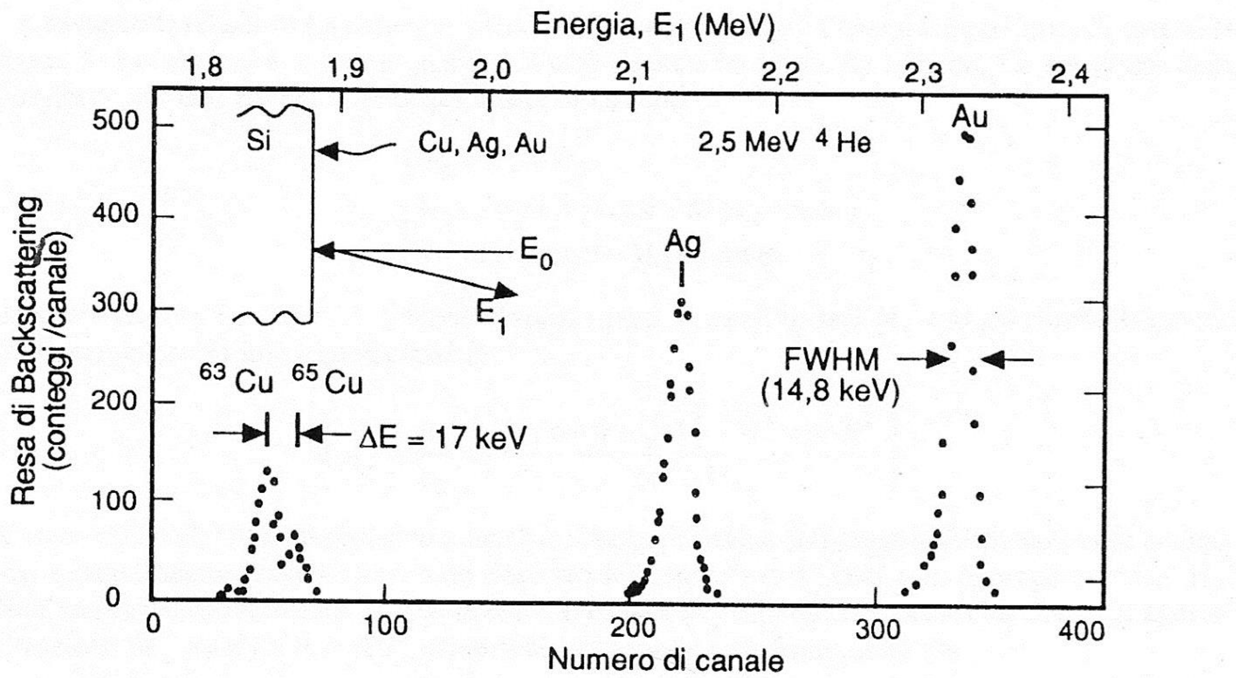
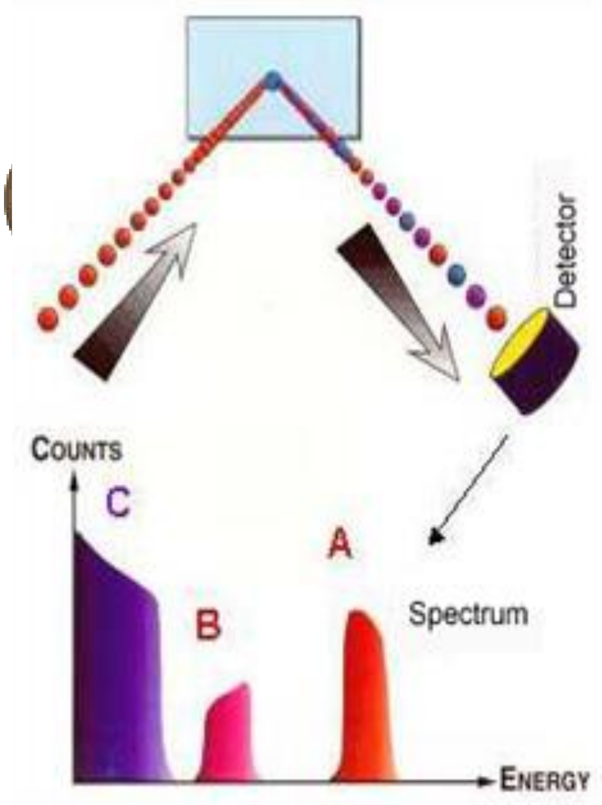


Figura 3. Spettro RBS di uno strato monoatomico di rame, argento e oro in ugual concentrazione depositato su silicio (segnale non visibile). Gli ioni del fascio sono He^+ a 2,5 MeV e l'angolo di scattering è $\theta = 170°$. Figura riportata dal riferimento bibliografico [1].



- Interpret spectra as problem solving activity

2. The physics in modern research analysis technics – R&H

Resistivity & Hall coefficient

Electrical transport properties of metals, semiconductors and superconductors

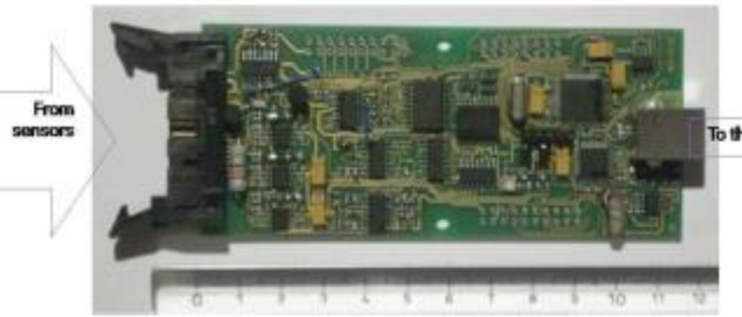
R&H – An RTL system provide measurements for:

- resistivity vs T for metals, semiconductors and superconductors
- Hall coefficient at room temperature for metal and semiconductors

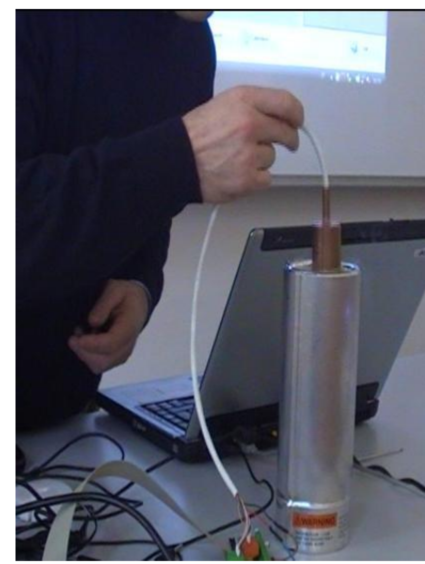
Kind and mobility of carriers can be obtained

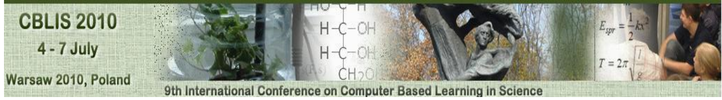
R&H

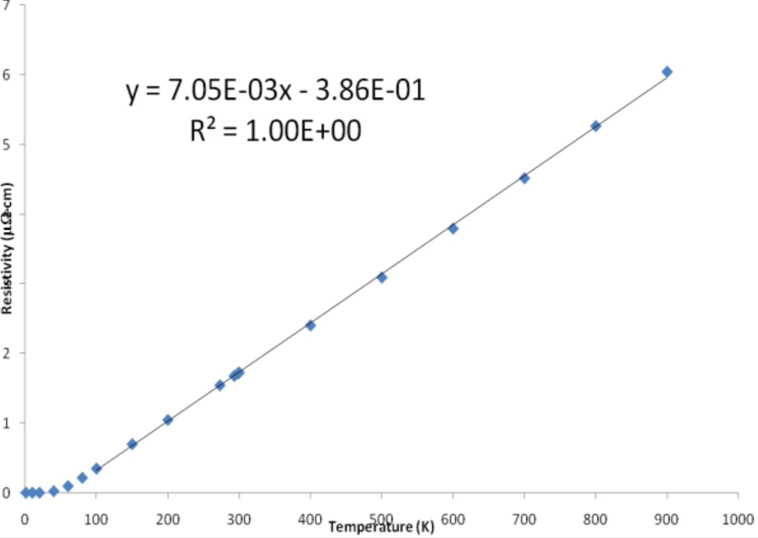
The system



- the interface card for the USB connection to the computer

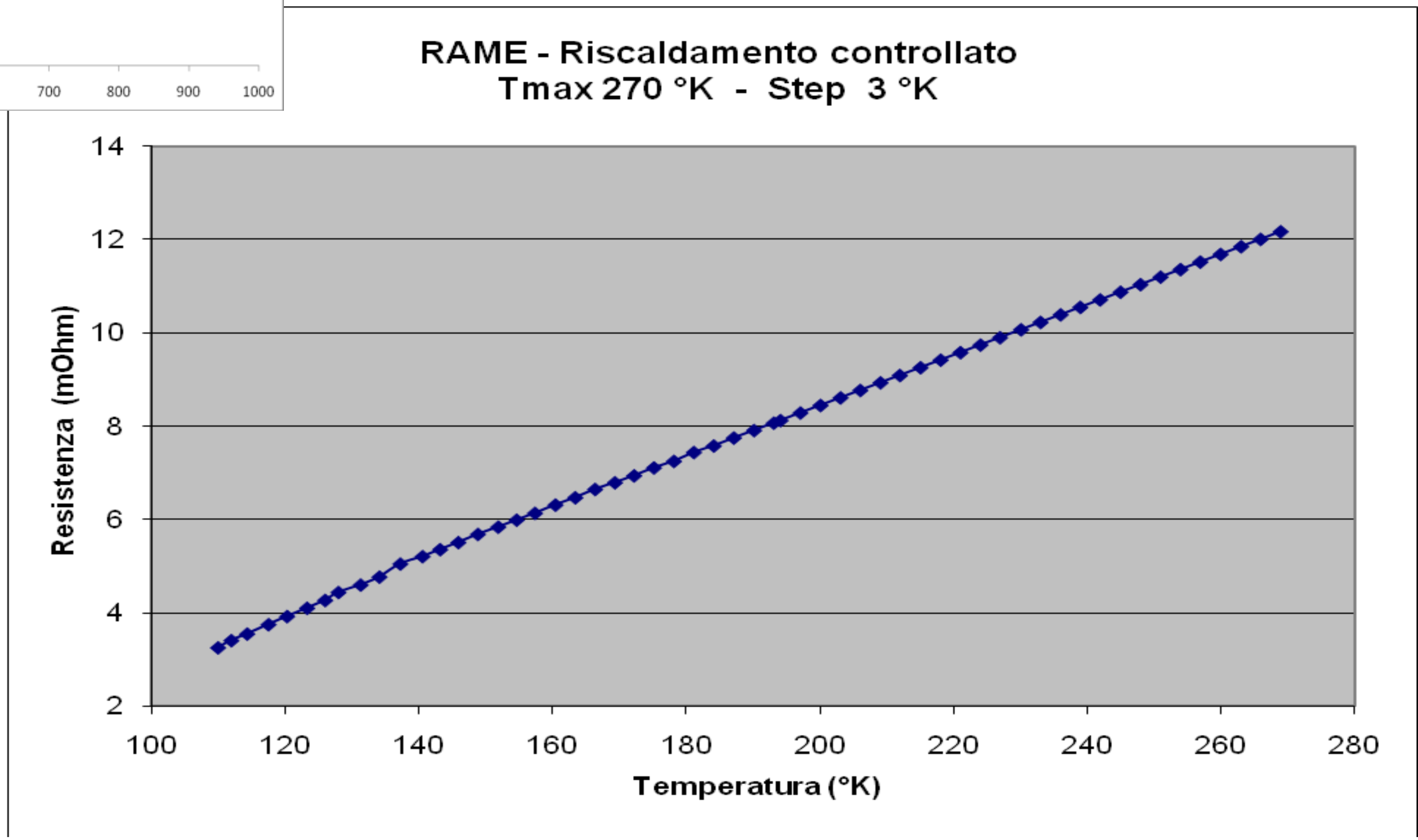




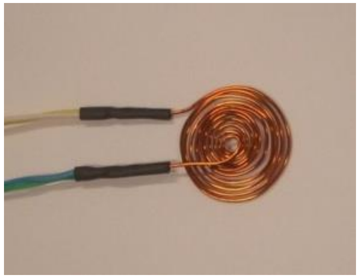


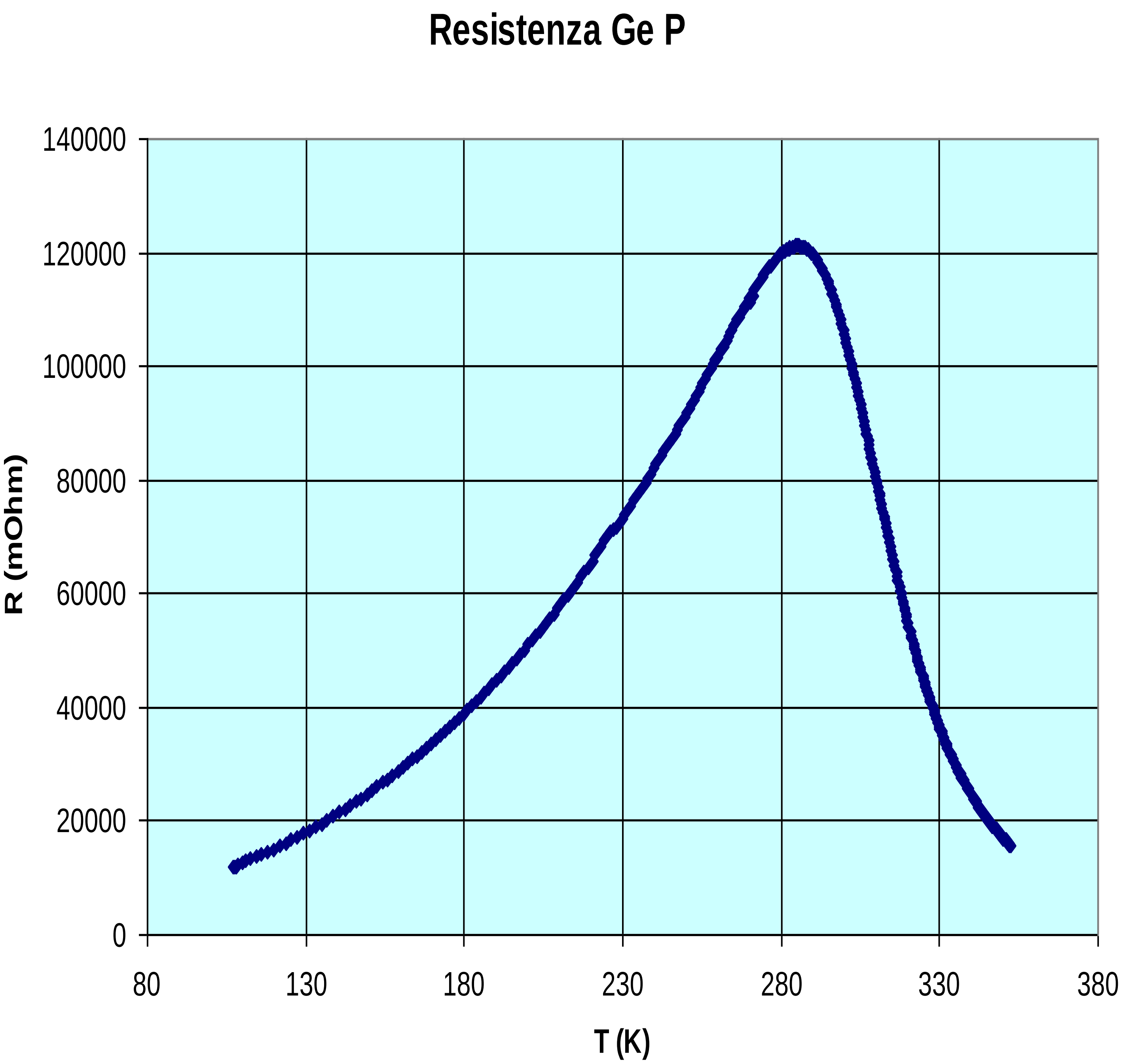
Resistivity in temperature for metals

copper

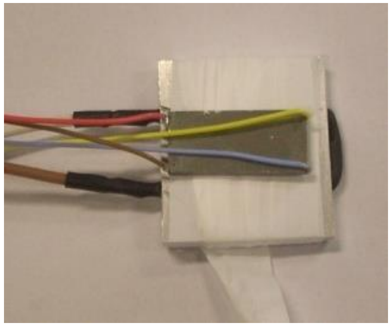


RESISTIVITA' vs T

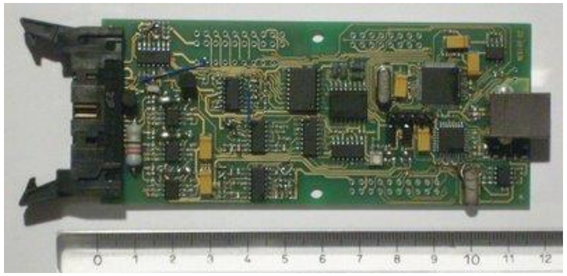


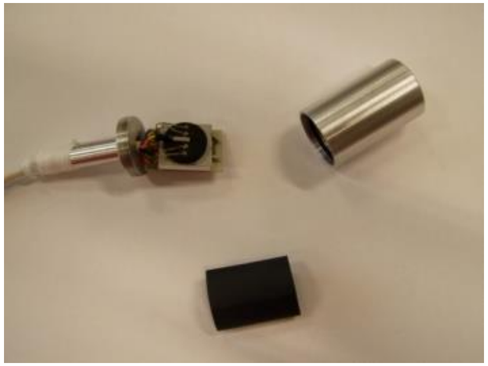


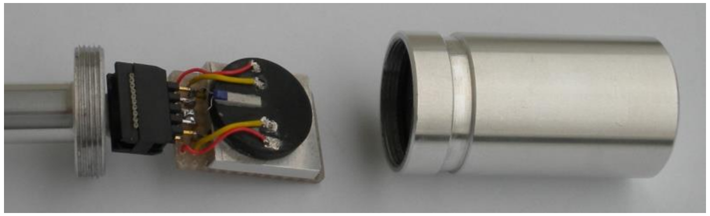
semiconductor

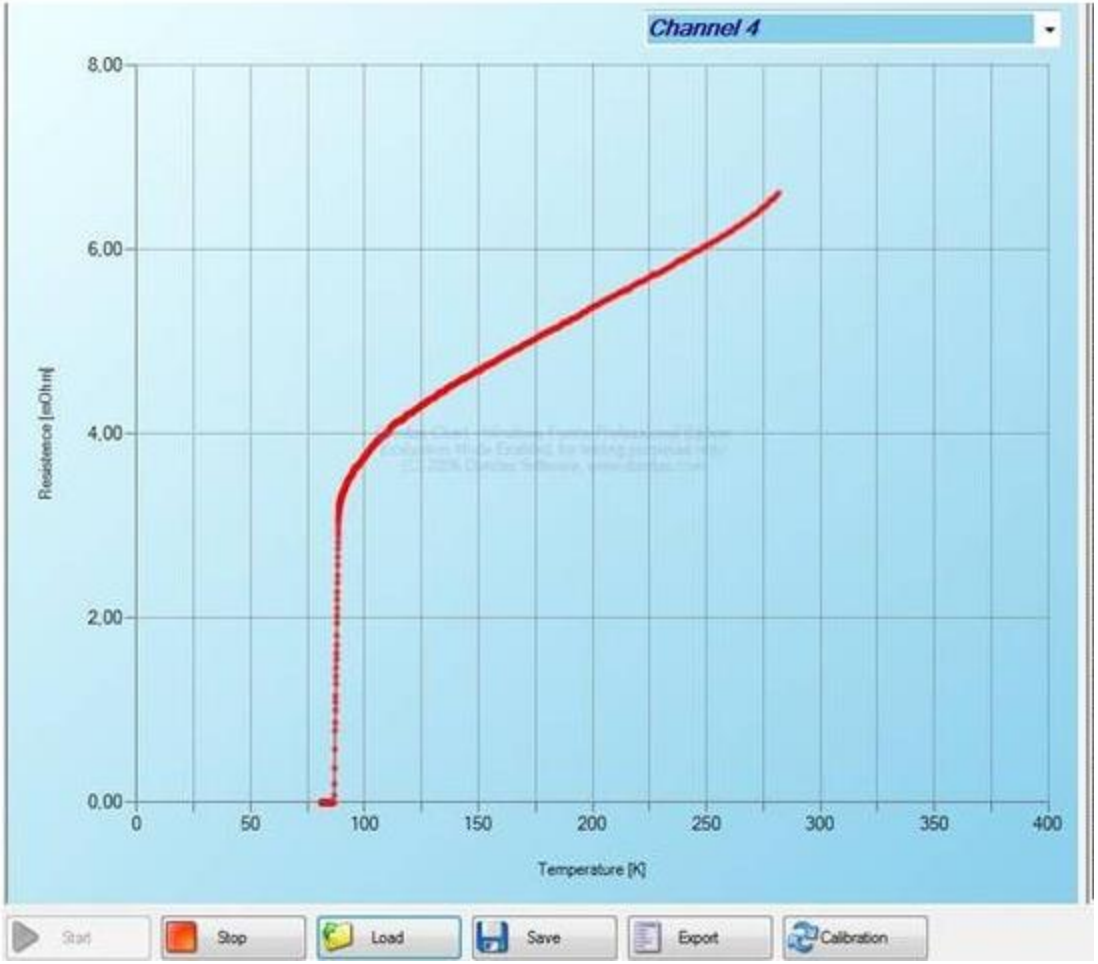


A patent for the R&H system
Hall coefficient and resistivity in temperature (70-500K) measurement via USB in real time

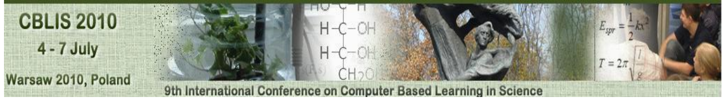








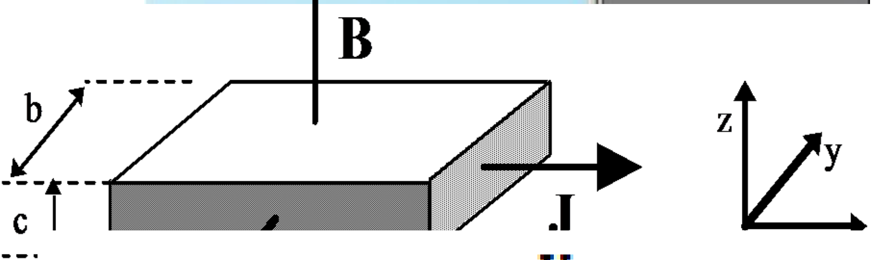
3. R_{HALL} MEASUREMENT



Hall Effect.

Current		Tension		Gain
Counts	Current	Counts	Tension	171,5
116	10,3294	683	-3,98251	
162	14,1566	975	-5,68513	
213	18,3998	1293	-7,53936	
270	23,1422	1651	-9,62682	
322	27,4686	1980	-11,5452	
382	32,4606	2346	-13,6793	
443	37,5358	2730	-15,9184	
530	44,7742	3267	-19,0496	
582	49,1006	3591	-20,9388	
616	51,9294	3796	-22,1341	

Hall effect



Misuring V_H ,*B, I we obtain*

$R_H = 1/(qn)$

$$R_H = V_H * \frac{s}{(I * B)} = \left(\frac{V_H}{I}\right) * \frac{s}{B} = -0{,}4363 * \frac{1{,}7 * 10^{-3}}{0{,}21} = -3{,}53 * 10^{-3}\ m^3/C$$

Hall coefficient

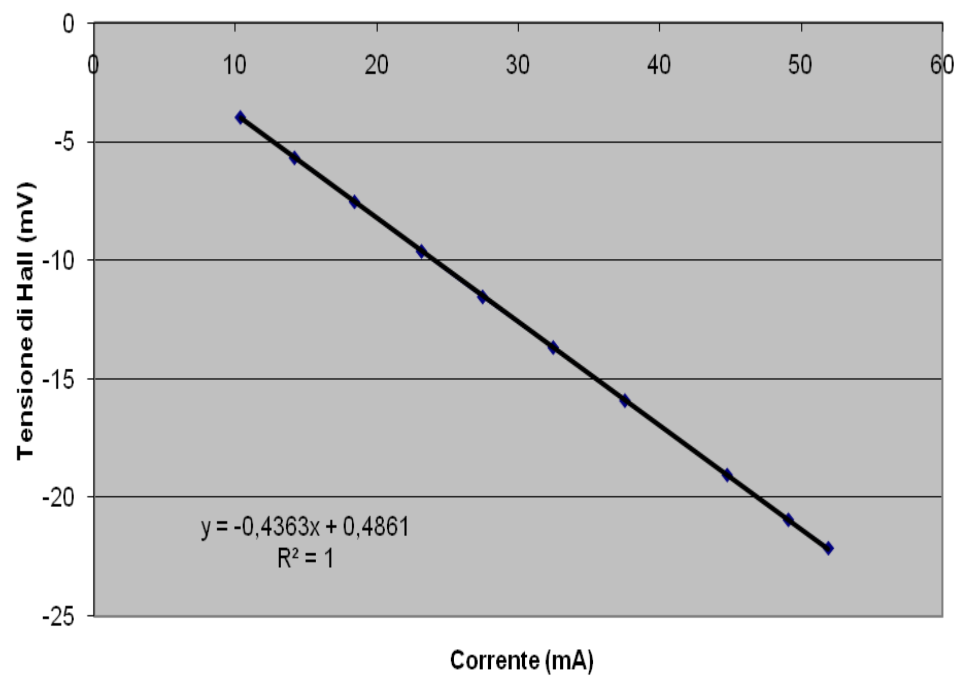
$R_H = E_H / (J_x B)$

$J_x = I_x /(b\ c) = q\ n\ v_d$

Misuring resistivity ρ

Mobility of carriers can be determined

$\mu = R_H / \rho$



The different proposals for Modern Physics mutually inclusive

1. **Phenomena bridging theories (Diffraction)**
2. **The physics in modern research analysis technics: R&H, RBS, TRR**
3. **Explorative approach to superconductivity (a coherent path)**
4. Discussion of some crucial / transversal concepts both in CP and MP : **state, measure, cross section**
5. **Foundation of theoretical thinking: QM**

3. The explorative approach to superconductivity

is integrated in a vertical path on electromagnetism. Secondary school students explore and explain Superconductivity in CP than look at QM interpretation

the research based path includes:

- IBL (hands/minds-on) e-m approach to SC;
- ICT learning based, integrating
  - measurements carried out by sensors,
  - modeling,
  - simulations,

… focusing on reasoning for phenomena interpretation

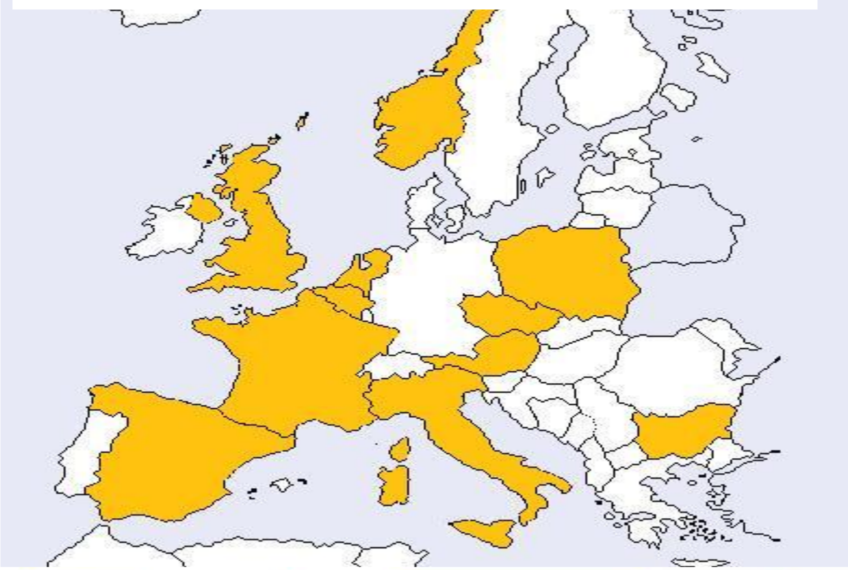
European Projects MOSEM e MOSEM^2

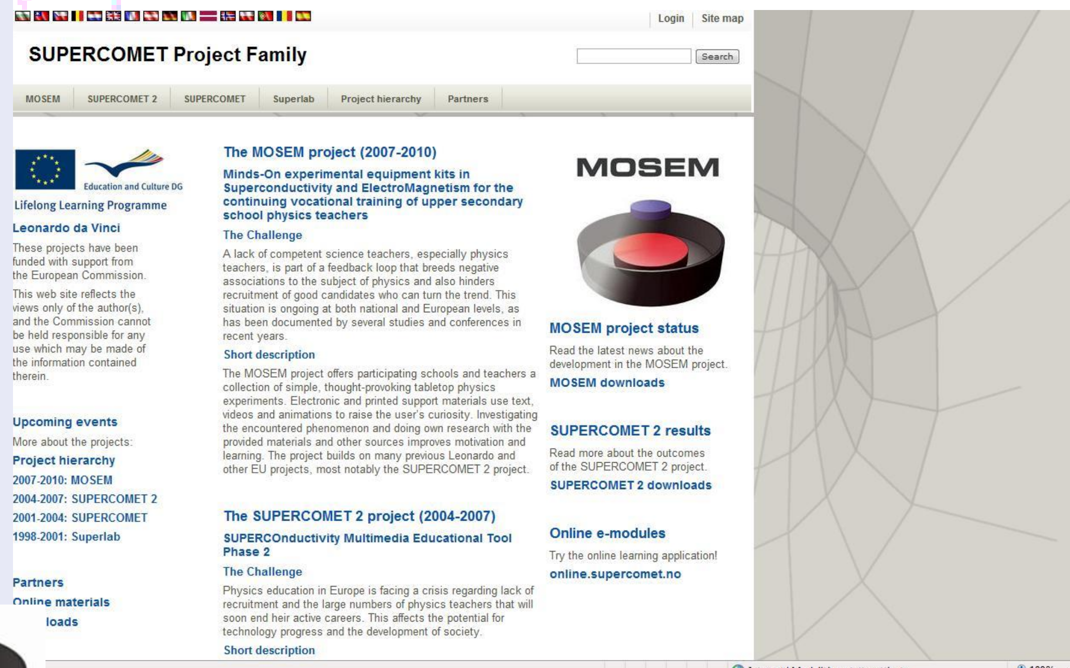
Minds-**O**n experimental equipment kits in **S**uperconductivity and **E**lectro**M**agnetism for the continuing vocational training of upper secondary school physics teachers

MOdelling and data acquisition for the continuing vocational training of upper secondary school physics teachers in pupil-active learning of **S**uperconductivity and **E**lectro**M**agnetism based on **M**inds-**O**n **S**imple **E**xperi**M**ents

LIFELONG LEARNING PROGRAMME Leonardo da Vinci

Partners from 11 European countries





Education and Culture DG

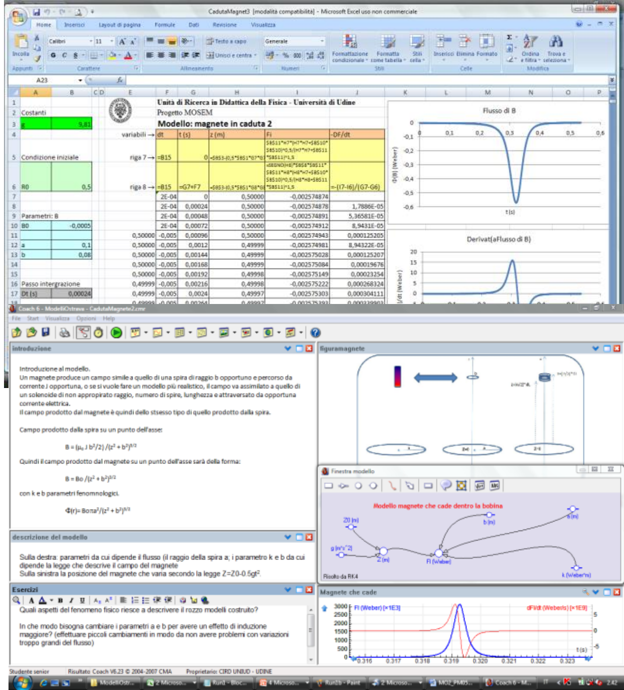
Lifelong Learning Programme

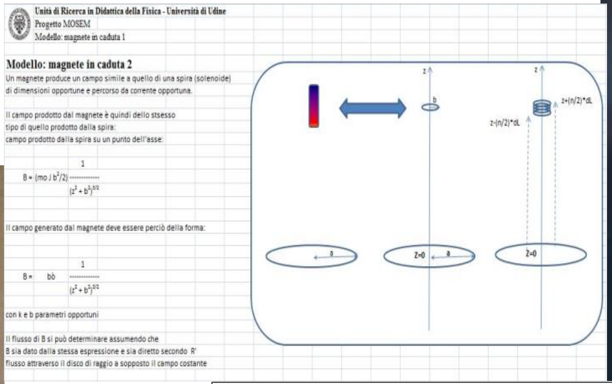
MOSEM²
Leonardo da Vinci project
NO/08/LLP-LdV/TOI/131013
www.mosem.eu

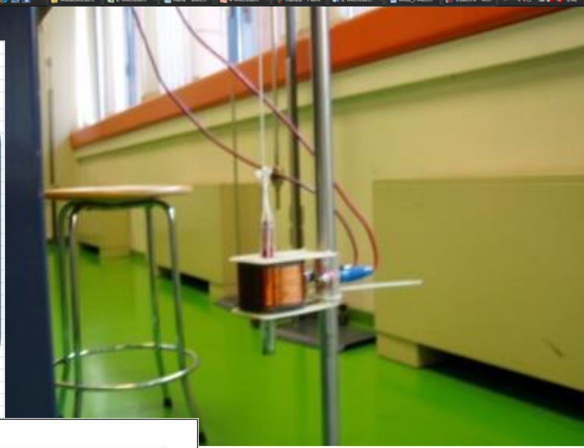
http://supercomet.no/

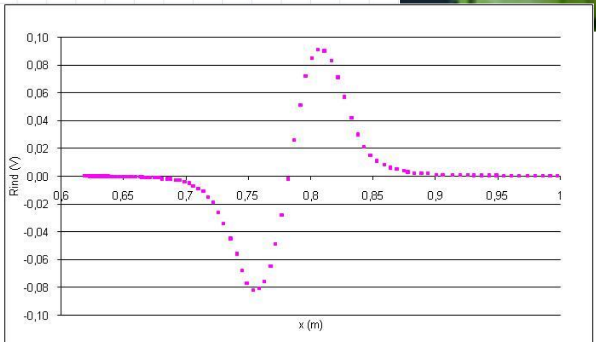
The educational path of Mosem^2 includes:

- more than 100 simple low tech experimental explorative activities
- 8 high tech experiments on electromagnetism and SC
- Computer modeling proposals
- 20 simulatons



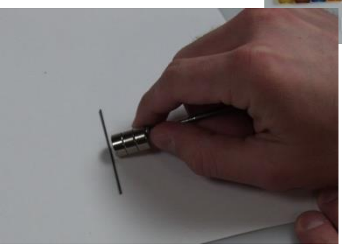


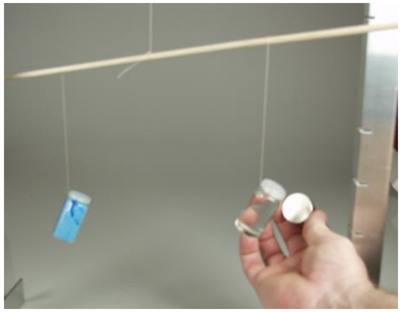


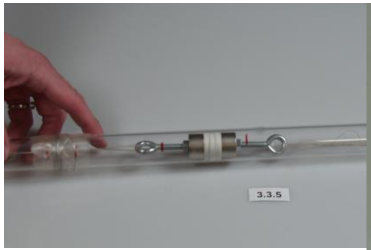


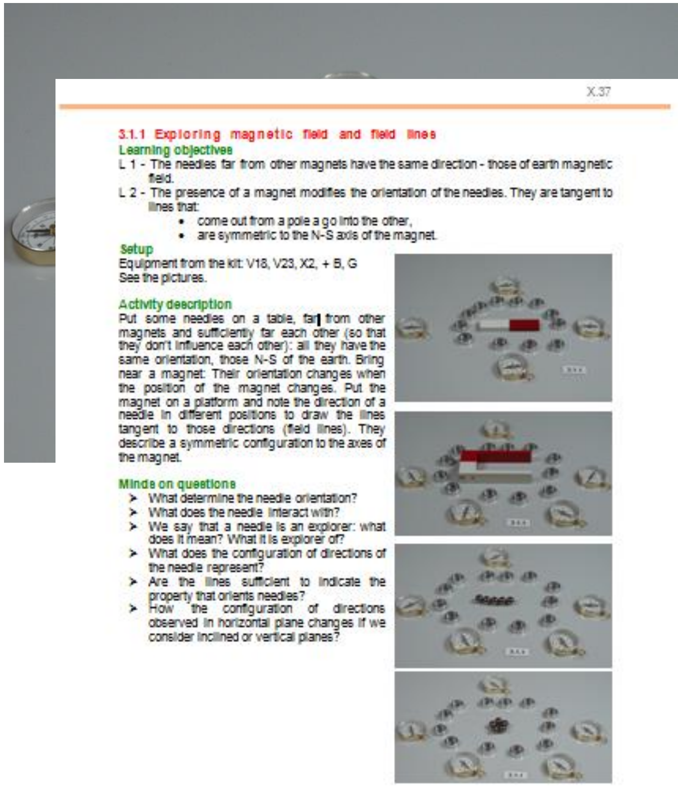
The educational tools - bag

Magnetic interactions,
E.M. induction, Eddy currents









X.37

3.1.1 Exploring magnetic field and field lines

Learning objectives

L 1 - The needles far from other magnets have the same direction - those of earth magnetic field.

L 2 - The presence of a magnet modifies the orientation of the needles. They are tangent to lines that:

- come out from a pole a go into the other,
- are symmetric to the N-S axis of the magnet.

Setup

Equipment from the kit: V18, V23, X2, + B, G
See the pictures.

Activity description

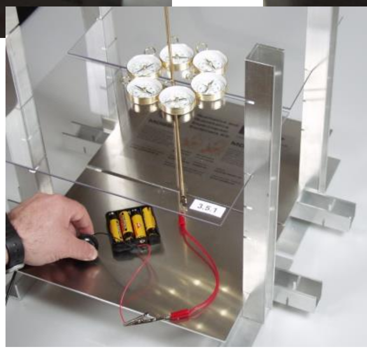
Put some needles on a table, far from other magnets and sufficiently far each other (so that they don't influence each other): all they have the same orientation, those N-S of the earth. Bring near a magnet: Their orientation changes when the position of the magnet changes. Put the magnet on a platform and note the direction of a needle in different positions to draw the lines tangent to those directions (field lines). They describe a symmetric configuration to the axes of the magnet.

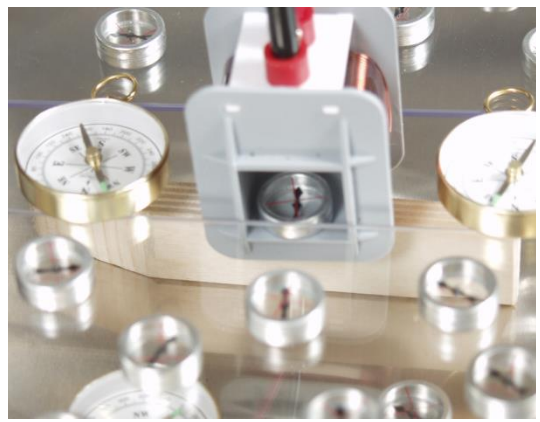
Minds on questions

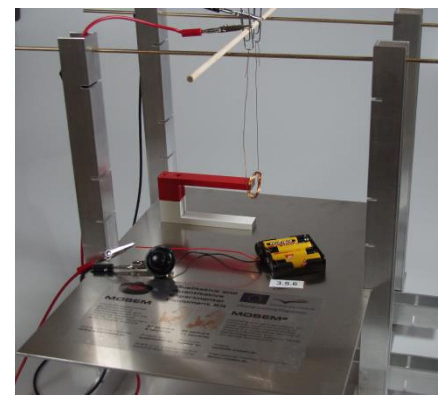
- What determine the needle orientation?
- What does the needle interact with?
- We say that a needle is an explorer: what does it mean? What it is explorer of?
- What does the configuration of directions of the needle represent?
- Are the lines sufficient to indicate the property that orients needles?
- How the configuration of directions observed in horizontal plane changes if we consider inclined or vertical planes?

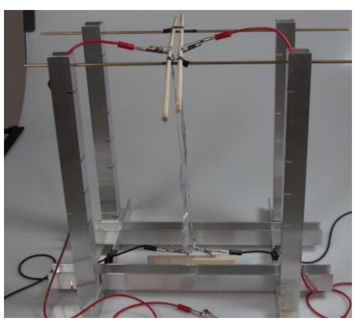
The educational materials

LOW TECH KIT



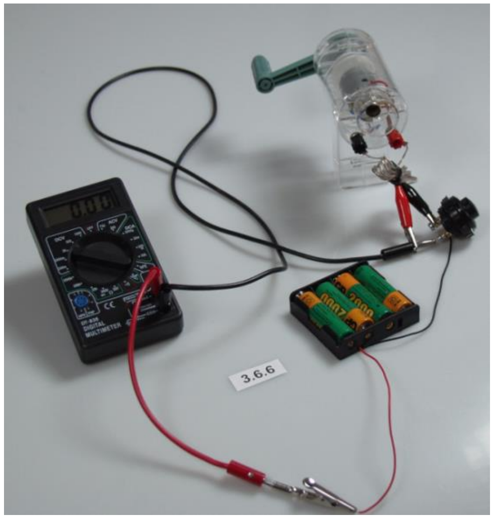


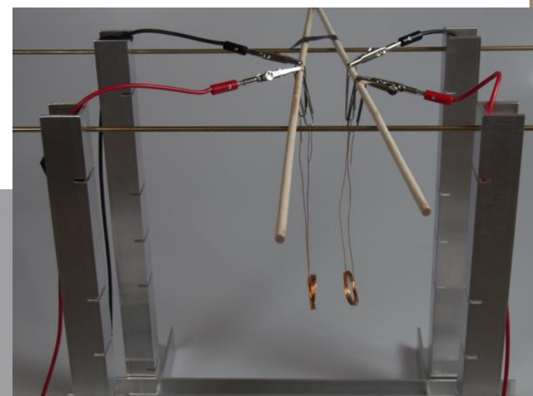




The educational tools

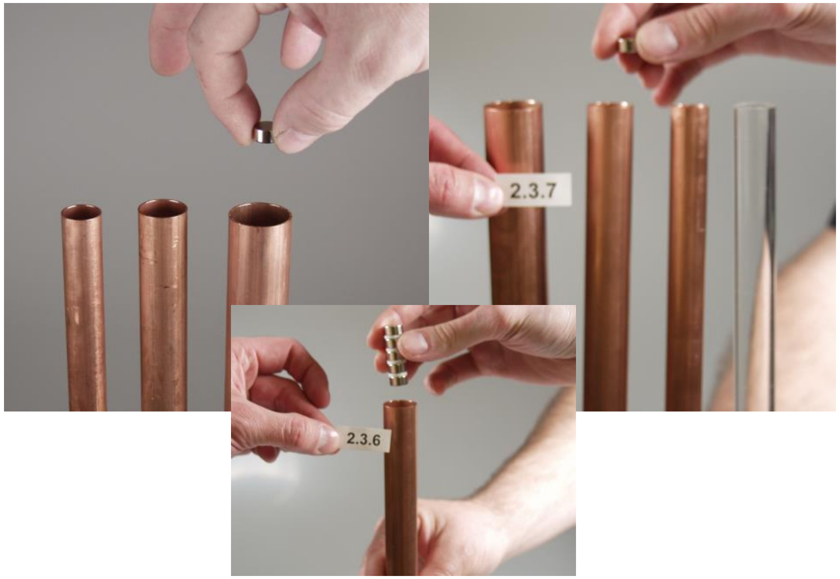
LOW TECH KIT

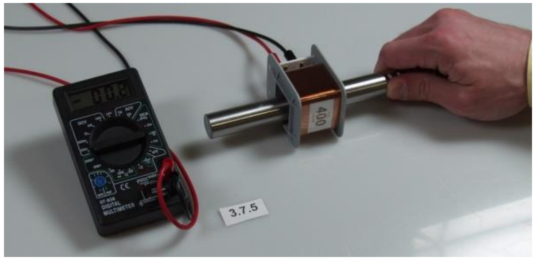


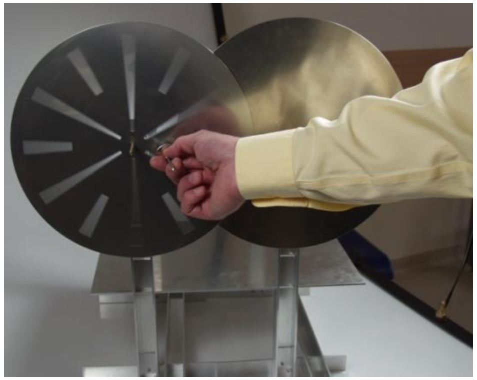


The educational tools

LOW TECH KIT







The educational tools

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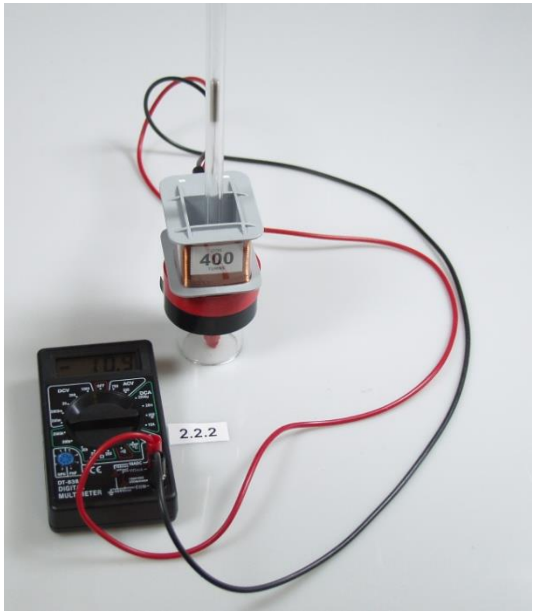
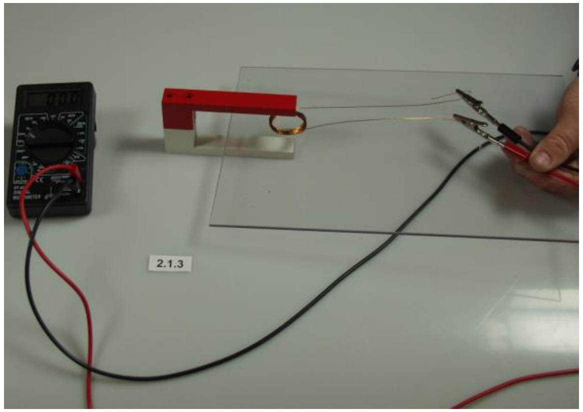
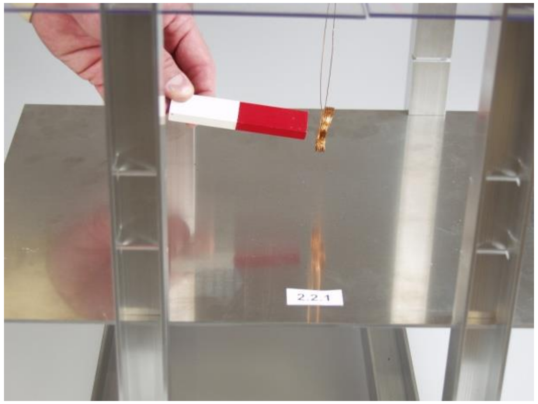
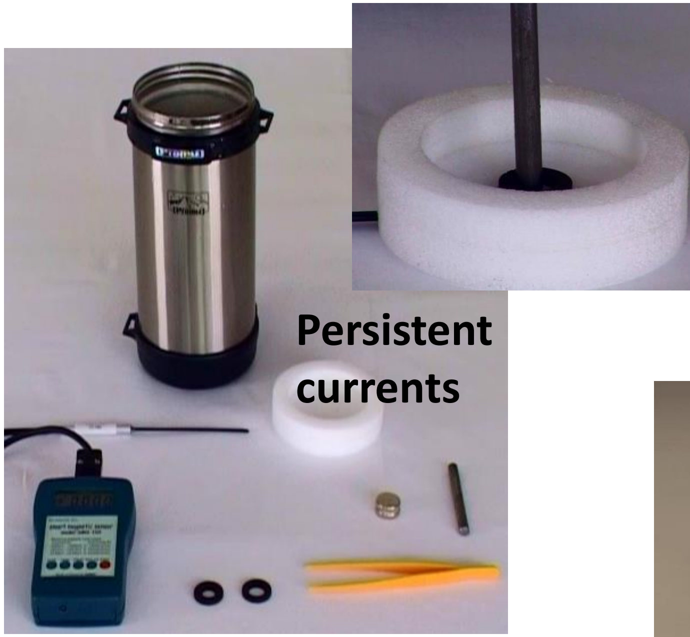




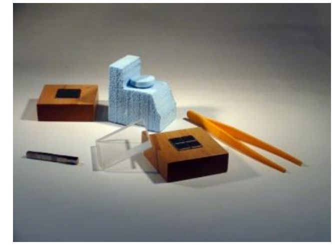


HIGH TECH KIT for 8 experiments

The educational tools



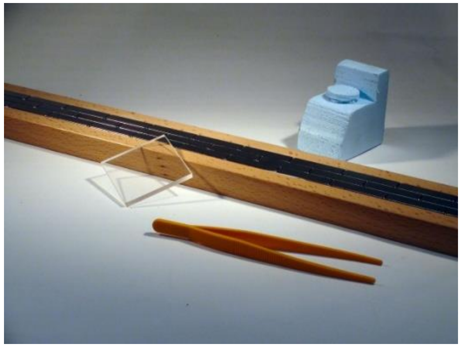
Persistent currents



Levitation

pinning

Para-Ferromagnetic transistion (gandolynium)



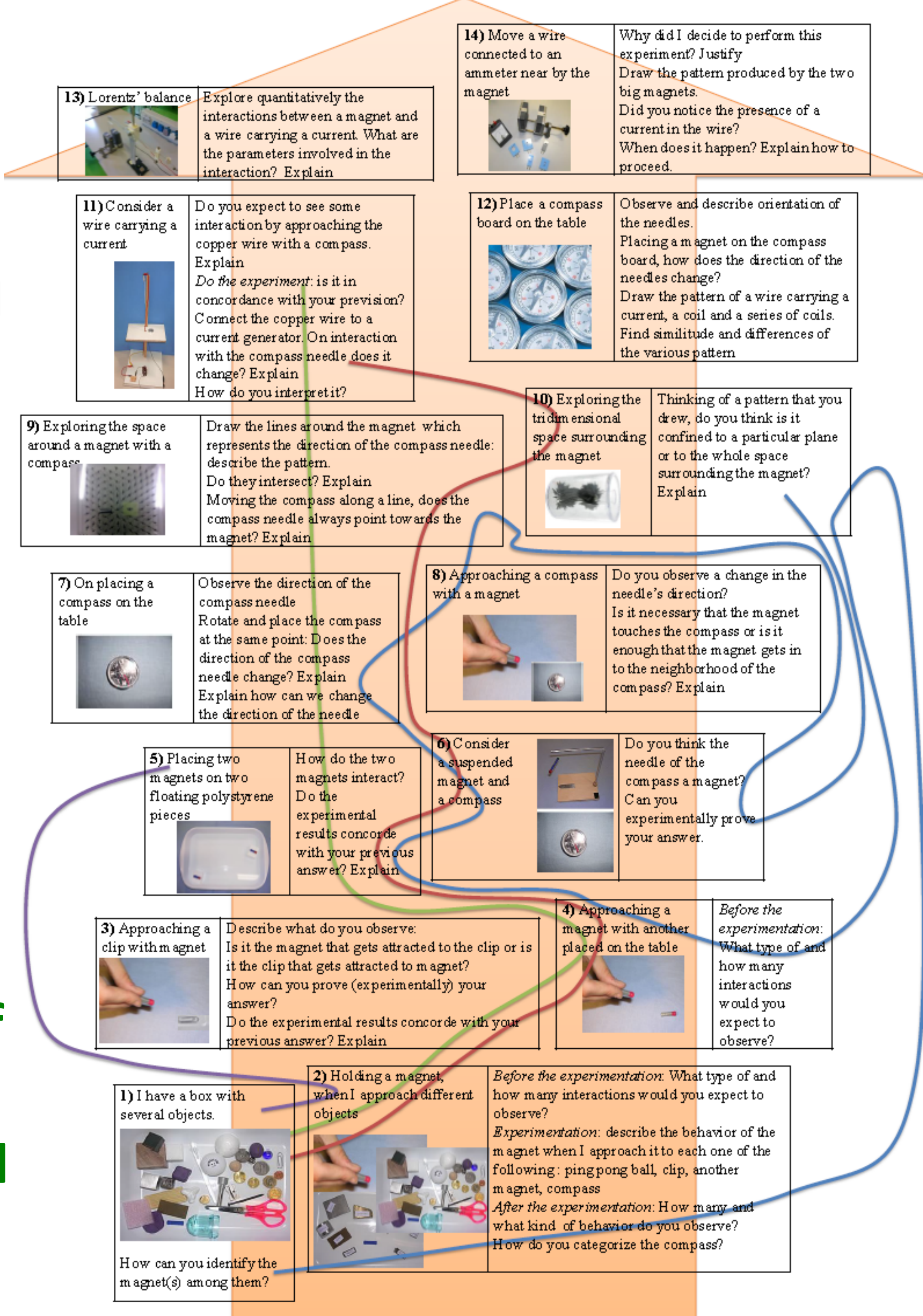
The MAGLEV train

Developing vertical paths on electromagnetism and superconductivity from primary to upper secondary school

Our research involved

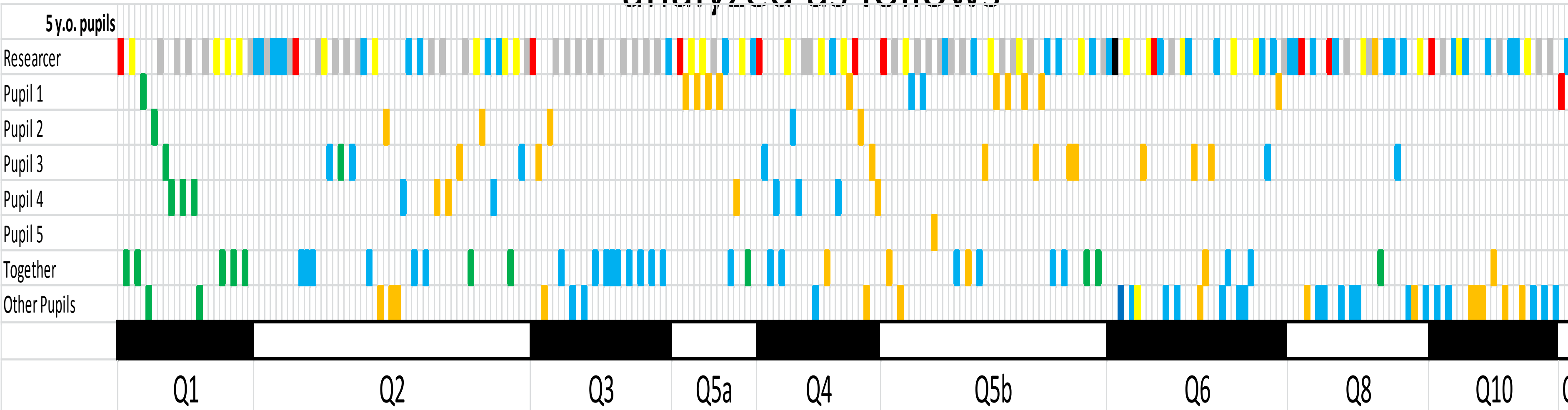
- T/L proposals development by means of DBR
- Learning processes analysis by means of Empirical Research – conceptual change
- R&D of new ICT system
- Teachers' professional development

Micro-steps of Conceptual Lab of Operative Exploration (CLOE) are carried out in building the formal quantities characterizing B



CLOE ACTIVITY

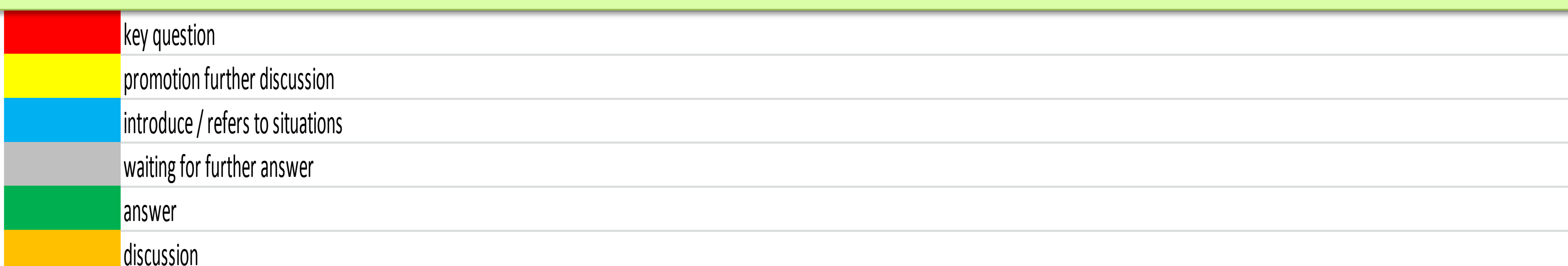
Audio-Video recording of discussions were analyzed as follows



Looking at the color of the intervention of students is evident how:

- simple answers almost disappear (color green)
- leaving space to the quotation of experimental situation (blue) and
- discussion/argumentation (orange).

The time spent on the different situations and the number of interventions depends by the situation, as well as the spectra of interpretations.

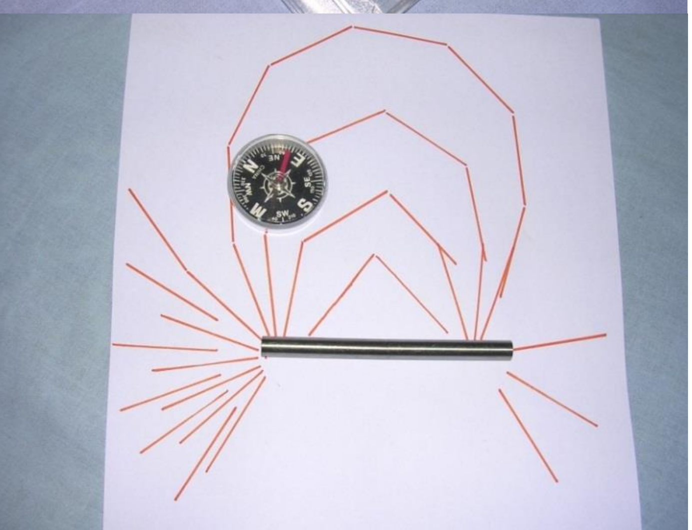


experimenting the same explorative path in secondary school

Magnetic field lines assume the roles of

a model – a conceptual tool

sample: 8 schools - 160 students – 17yo

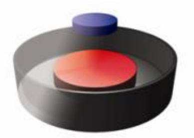


- To interpret magnetic interactions (65%)
- To distinguish magnetic (55%):
  - Field: direction of orientation
  - Force: direction of starting motion
- to produce reasoning in terms of flux,
  - individuating that it is a constant quantity in field line system (80%)
  - with relate consequences
    - magnetic field lines closed (68%),
    - not separability of poles (50%) or **div**=0
  - interpreting e-m induction (76%)
  - identifying the related applications (56%)

The SC path is structured in 2 parts

1) Magnetic properties of superconductor

- Meissner effect
- E.M. induction and eddy currents for interpretative analogy
- The pinning effect



2) Resistivity vs temperature

Different perspective:

- Hystorical
- Phenomena exploration
- Applications

Let us follow the path reasonings proposed

Starting from Meissner effect

Focused on understanding correctly the effect in the framework of the magnetic interactions

- How students face the main interpretative knots?

Exploring Meissner effect

Preliminar exploration with compasses or magnets

→The YBCO, at room temperature, does not interact with any magnet

At LN temperature:

When the YBCO is at thermal equilibrium … in a bath of LN(77K)

-> it interacts with the magnet → Levitation occur

- the magnet is repulse by the cooled YBCO

- It oscillate around the equilibrium position

Discussing Meissner effect

What is changed in cooling the system?

• the properties of the magnet?

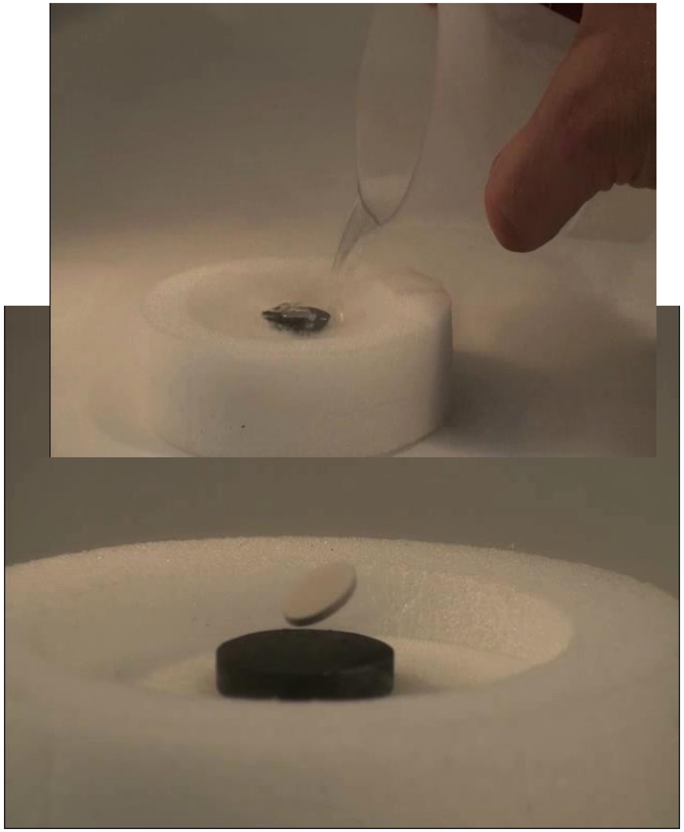
NO: testing by means of a B probe

•the properties of the YBCO disk? YES

How?

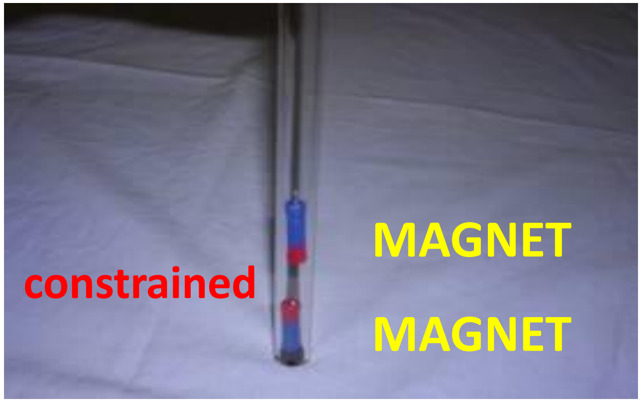
•How can we interpret the changes?

- Is YBCO becoming a magnet and it interacts with another magnet as they are facing with the same polarity?

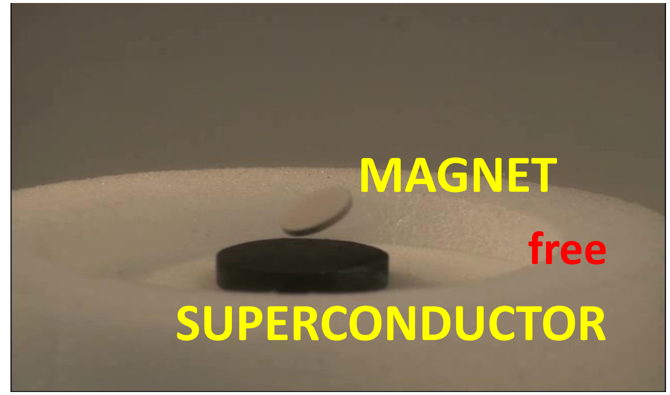


- Is the levitation a case of suspended magnets?

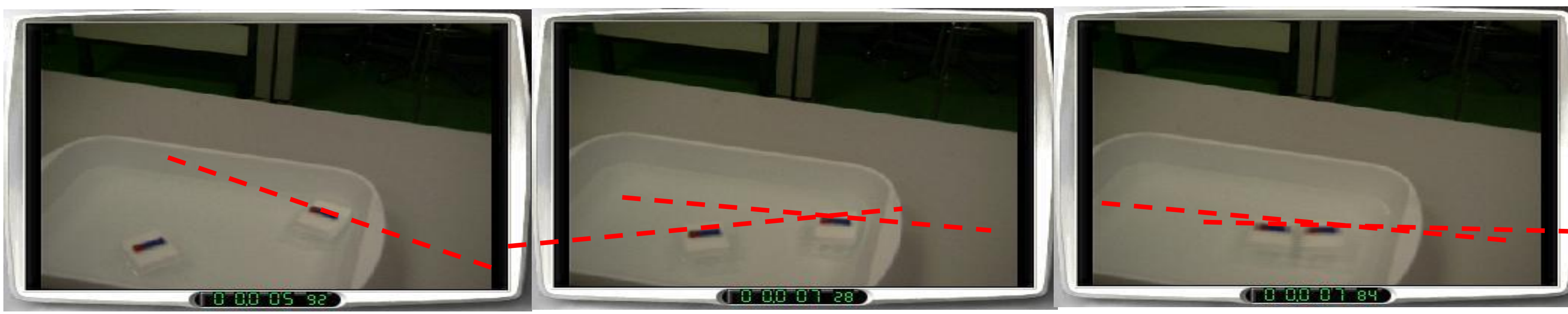
Suspended Magnets



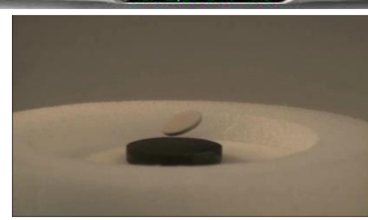
Magnetic levitation of a magnet on a SC



! Two magnets repeal each other only when they are constrained to face with the same polarity



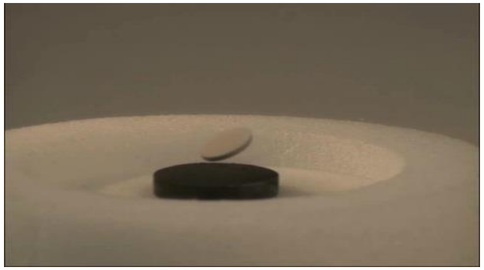
In levitation the magnet and YBCO are free



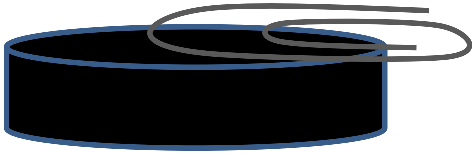
and repulsion occur

No: the YBCO disk does not become a magnet

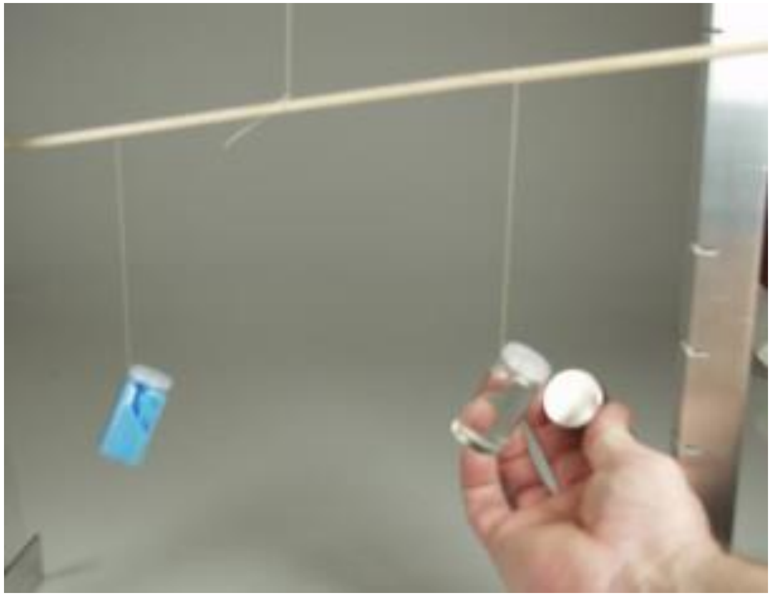
- Is the YBCO disk at $T = T_{NL}$ "acting" magnetically without the magnet close to it?



NO: no interaction between an iron clip and the YBCO disc → The YBCO disk at low temperature becomes diamagnetic



Which kind of magnetic property are we analyzing?



Exploring the interaction of a magnet with different kinds of materials (aluminum, copper, water, wood, graphite)

by means of a simple torsion balance, by hanging these and see if they are attracted, repulsed or not affected by the magnet,

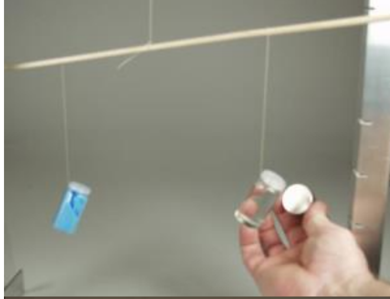
We see that Diamagnetic materials:
they show "magnetic properties" (repulsive)
only in presence of a magnet

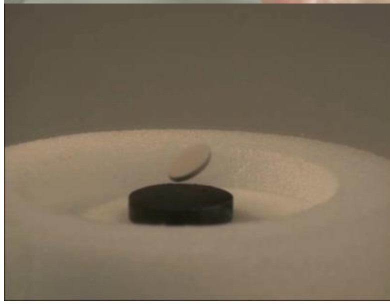
The diamagnetic phenomena are usually weak!!!

In the case of the SC the diamagnetic effects are very intense.

To understand, we have to "see" what happens inside the YBCO.

-Does the external field of the magnet penetrate the YBCO?





We can test it making a **sandwich: magnet – YBCO – iron slab**

At T_{NL} this effect usually disappears and you can't lift YBCO and iron (Note: this is not completly true if there is some pinning effect).

→ The B field of the magnet can't "arrive" on the iron and we can conclude that it is really small or negligibile through the YBCO

→ **The magnetic field inside a YBCO at T_{NL} is negligibile.**

→ **The magnetic behavior of YBCO appear to be induced**

→ **Let us try an analogy to explain the phenomenon**

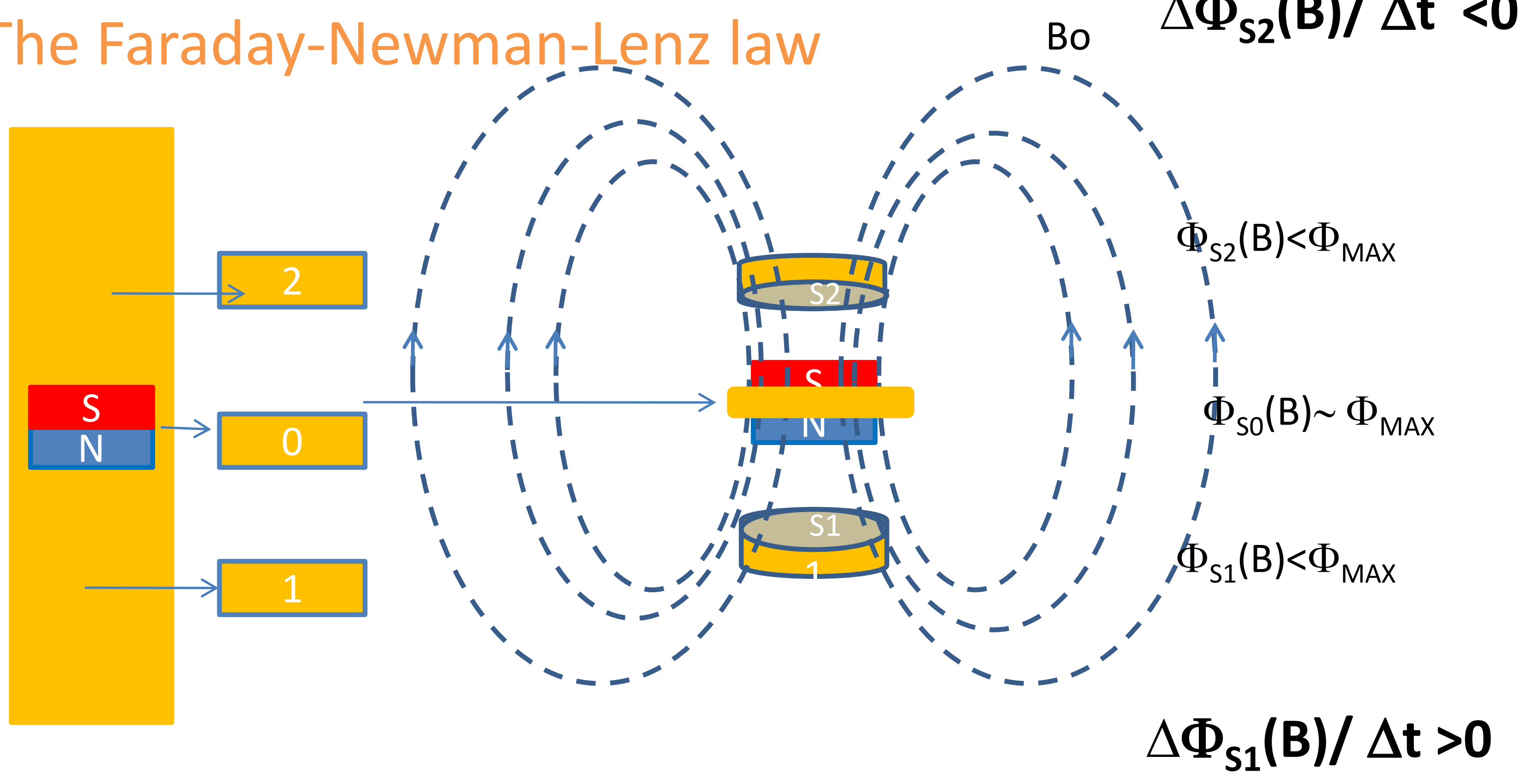
E.M. Induction and eddy currents

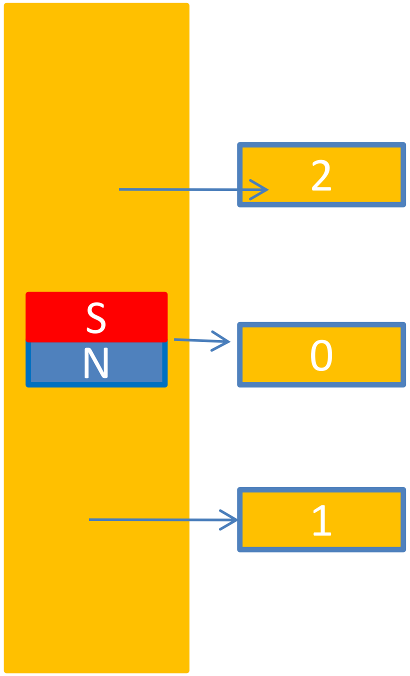
A falling magnet on a copper bar decrease its velocity gradually and than fall at constant velocity. The falling velocity is lower for lower resistivity of the metal tube

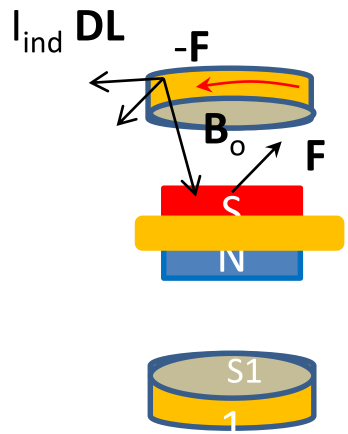
Interpreting falling magnet in copper tube

Conceptual tools:

- Field lines (operative definition)
- The flux of B ($\Phi(B)$)
- The Faraday-Newman-Lenz law







Induced current interact with the **B** of the magnet producing a force

$$-F = I_{ind}\ (\Delta L \wedge B)$$

Causing the
lifting (braking) effect

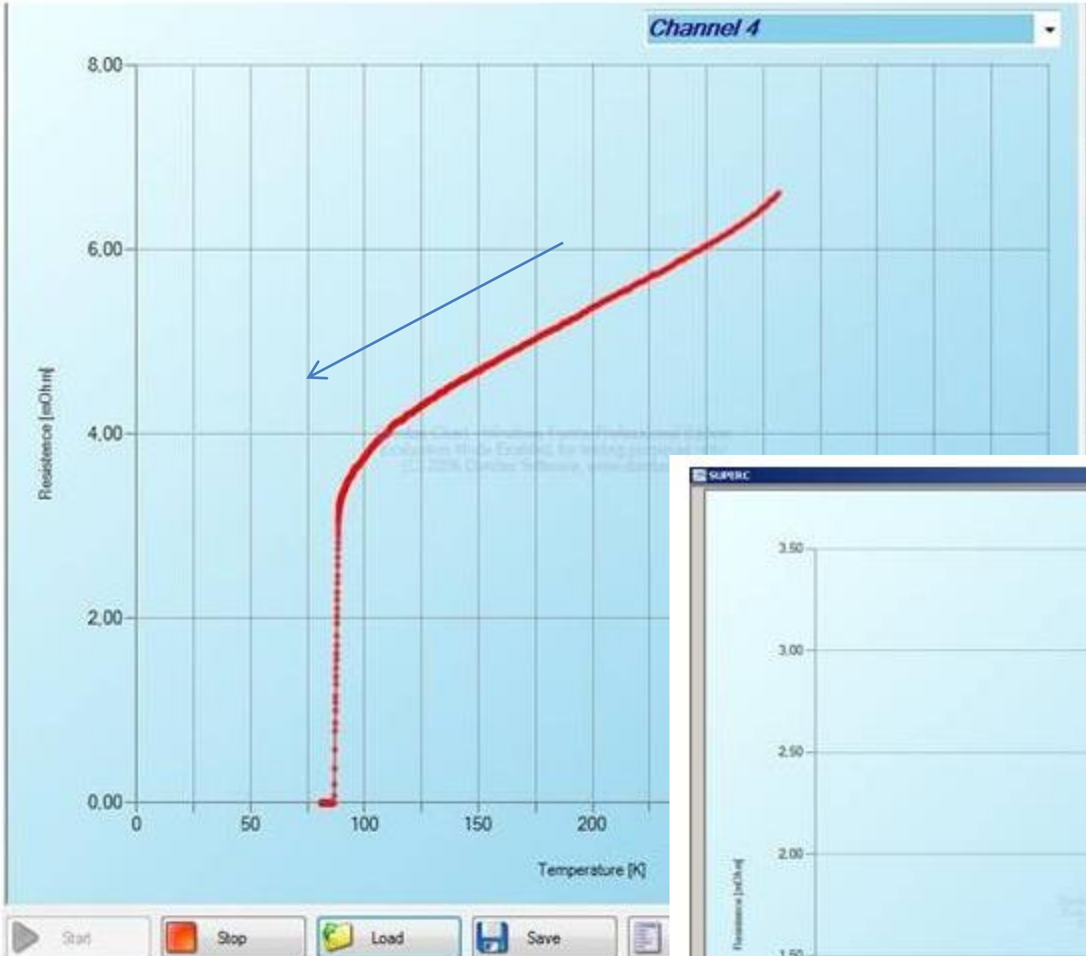
The analogy between

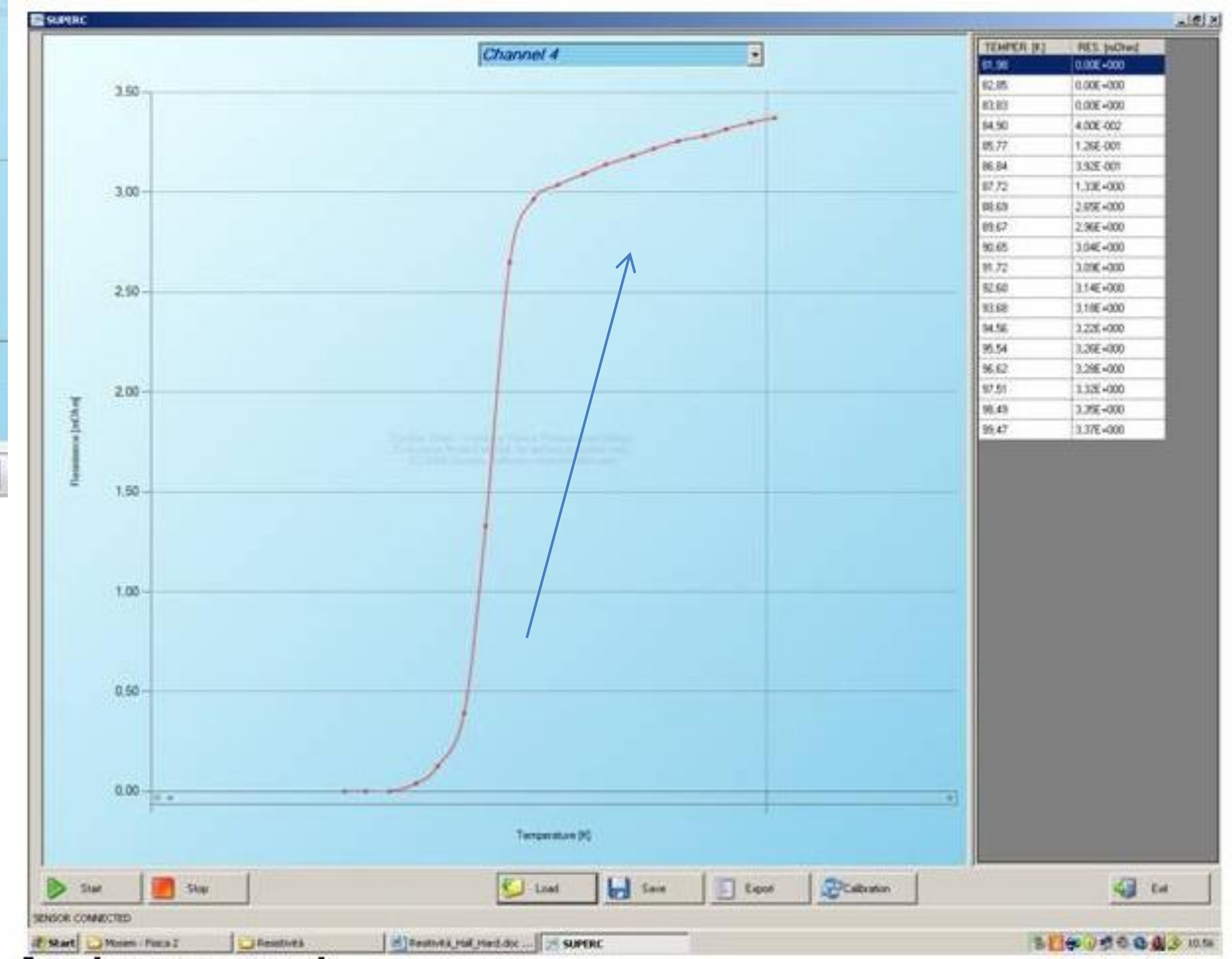
the "braking" of the magnet in presence of a conductor and

the levitation, **appear to work**

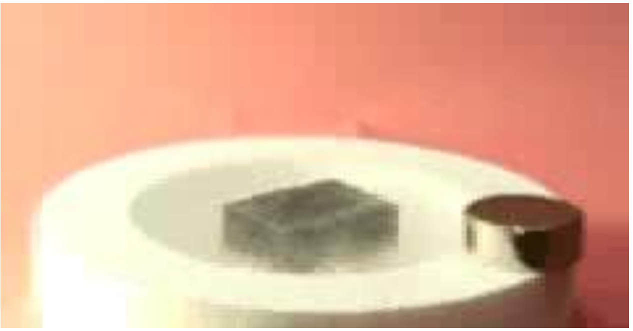
So a current have to be present into the SC and
if the conductor is "perfect" (R=0)
the currents initially induced by the magnet never stop.
→ Superconductor : a system with B=0 and R=0!

Free cooling in LN

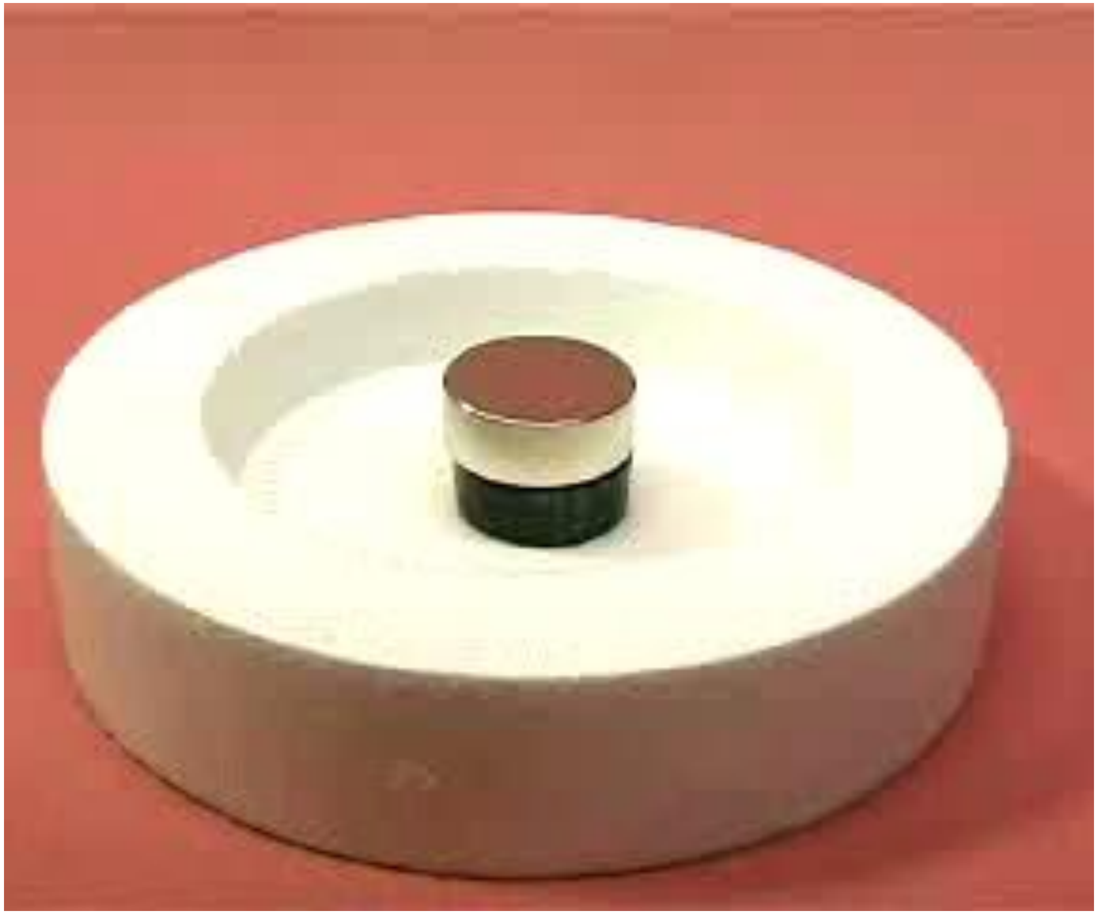




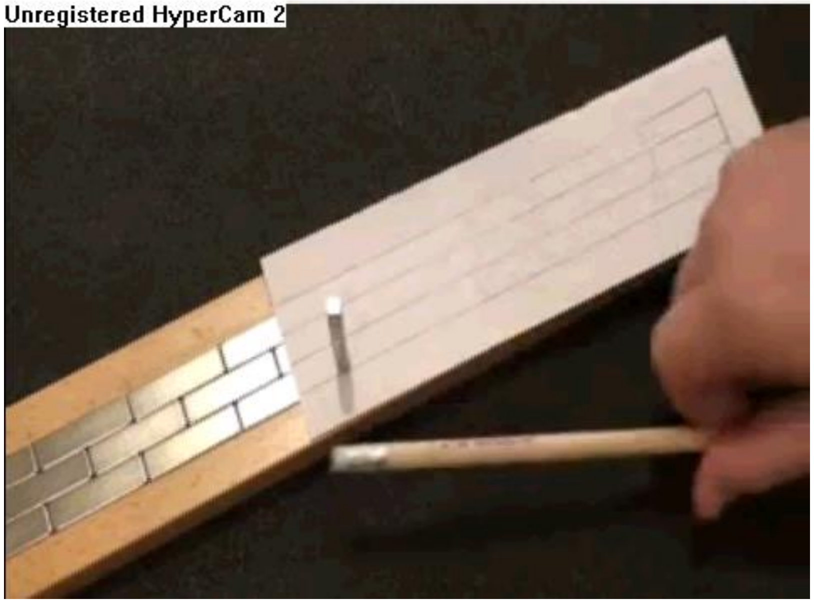
Heating step by step



Meissner and pinning

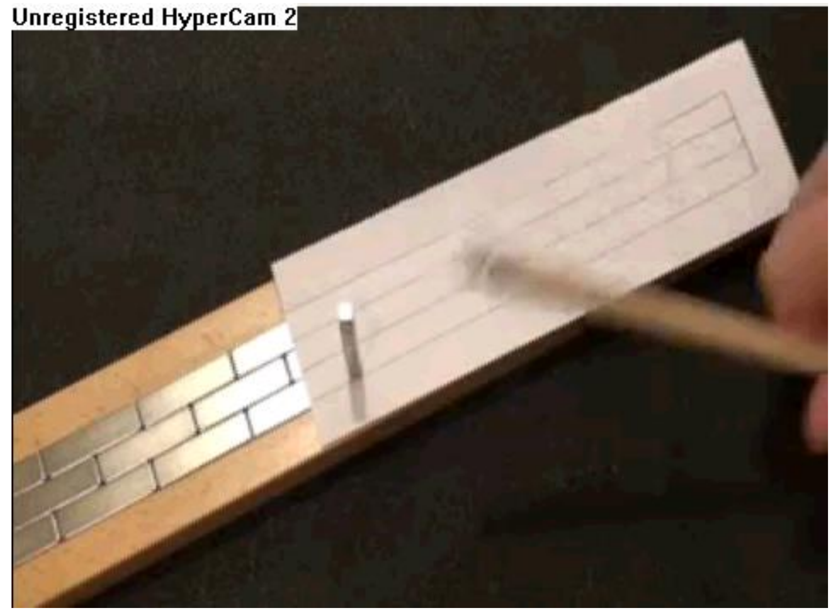


Meissner effect vs pinning



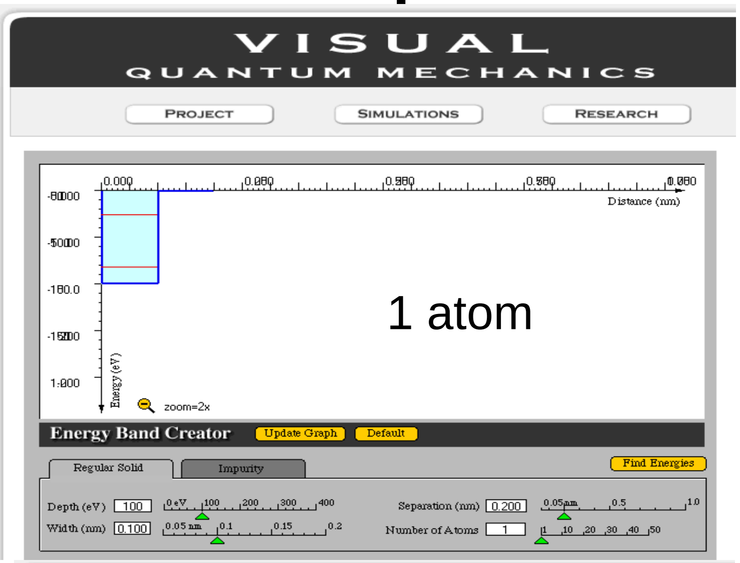
Train a la Meissner

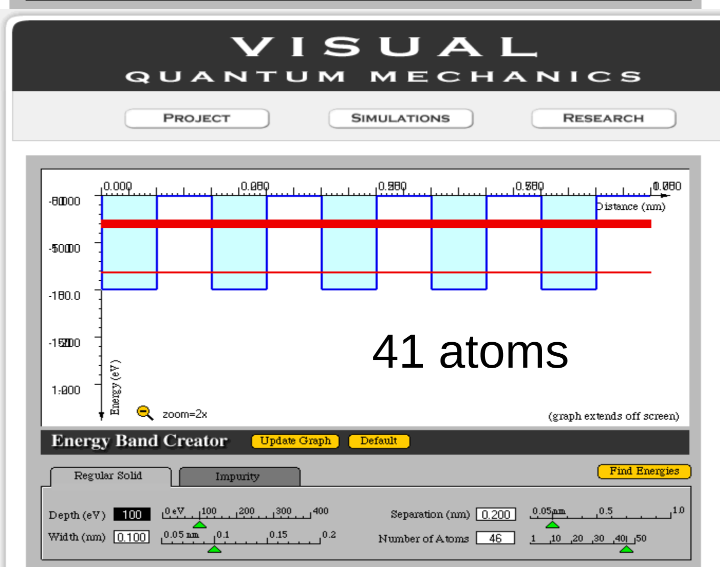
2003 Il primo treno Maglev in commercio: Shanghai Transrapid
http://en.wikipedia.org/wiki/Image:Shanghai_Transrapid_002.jpg



Train "pinned"
the train was not derailed
and remains on track

Interpretation by means of Energy levels





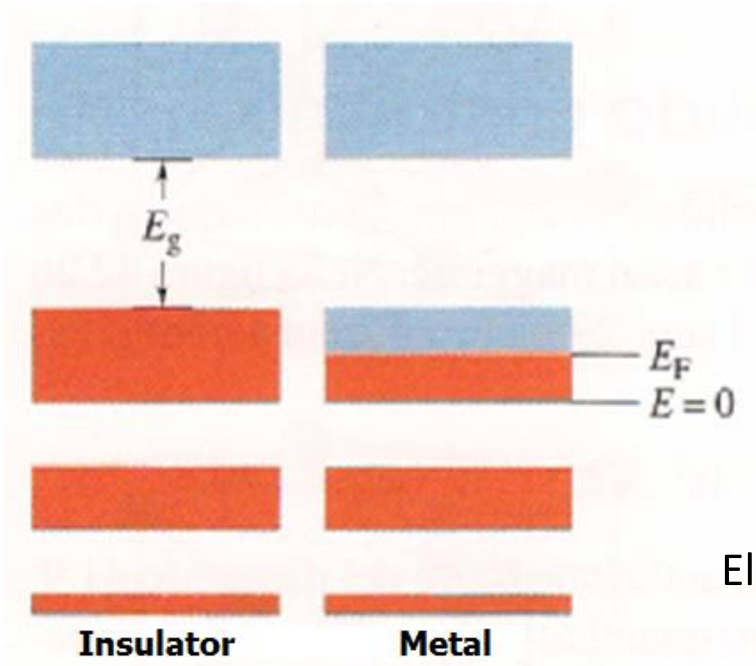
When isolated atoms are combined to build a crystal, the energy levels of electrons change dramatically

From the energy levels of a chair to the energy levels of electrons in a crystal

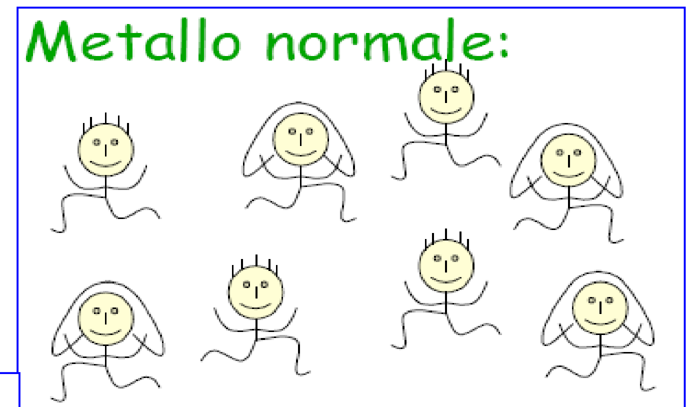
http://phys.educ.ksu.edu/vqm/html/eband.html

(Zollman's simulation)

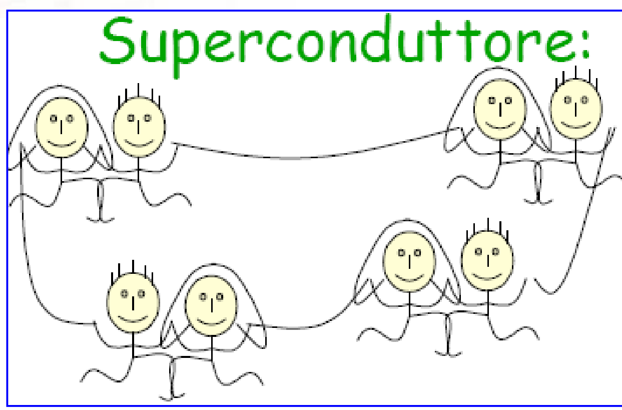
Electrical transport properties

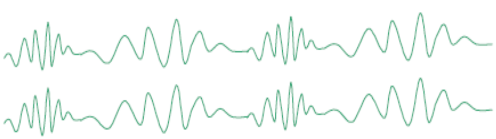


of a solid it depend from band structure and from electron states



Electron pairs





Teoria di Bardeen, Cooper e Schrieffer (BCS, 1957)

The different proposals for Modern Physics mutually inclusive

1. **Phenomena bridging theories (Diffraction)**
2. **The physics in modern research analysis technics: R&H, RBS, TRR**
3. **Explorative approach to superconductivity (a coherent path)**
4. Discussion of some crucial / transversal concepts both in CP and MP : **state, measure, cross section**.
5. **Foundation of theoretical thinking: QM – A path inspired to the Dirac approach to QM**

A little clarification

…physics of quanta /

…quantum physics /

…quantum mechanics

Are very different things

The descriptive dimension

if acceptable on popularization plan

- **it appears NOT to be satisfactory on a educational plan**

Often in the school **the birth of the theory of quanta** is priviledge and the narrative treatment of the discussions on the interpretative hypothesis
(proposed by teacher and not inside to students' reasoning)
prevail over aspects relating to the subject itself

There is the need

- **To produce the awareness of the reference assumptions of the new mechanics**
- **To offer some indications on the formalism that is adopted,**

=> The formalism, in fact, assumes in QM a conceptual role.

Our proposal
Two plans

Esperiments
That classical physics cannot interpret to focus on the problems

Approaching theory of MQ

➔ **strategy: approaching to the new ideas of theory by discussing simple experiments in a context**

Fotoelectric effect
Compton effect
Frank & Hertz experiment
Millikan
Zeeman effect (normal and anomalous)
Emission and adsorbtion spectra
Diffraction of light and particles
Ramsauer effect

The core proposal is for
Quantum mechanics
(not quantum physics or physics of quanta)
in secondary school

We have chosen to

Approach the theory of quantum mechanics

The first step toward a coherent interpretation with a supporting formalism

An introduction to the ideas of the theory

through the treatment

-crucial aspects
-cardinal concepts
-elements peculiar to QM

Our core proposal for MQ may be divided into two levels.

• On the **disciplinary level** we have chosen to begin with and focus on **the principle of superposition and its implications**

• On the **educational level** we have chosen **in-depth discussion of specific situations** in a context that allows for the

polarization as a quantum property of light

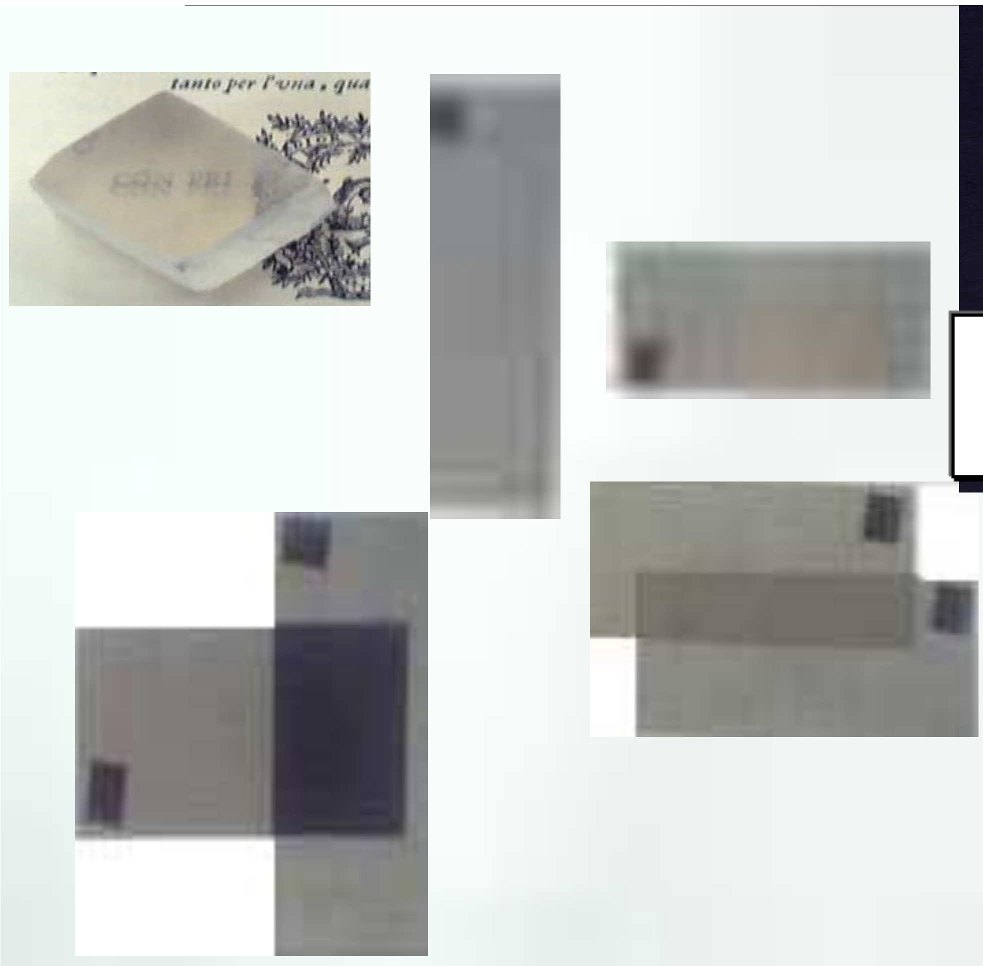
The basic elements

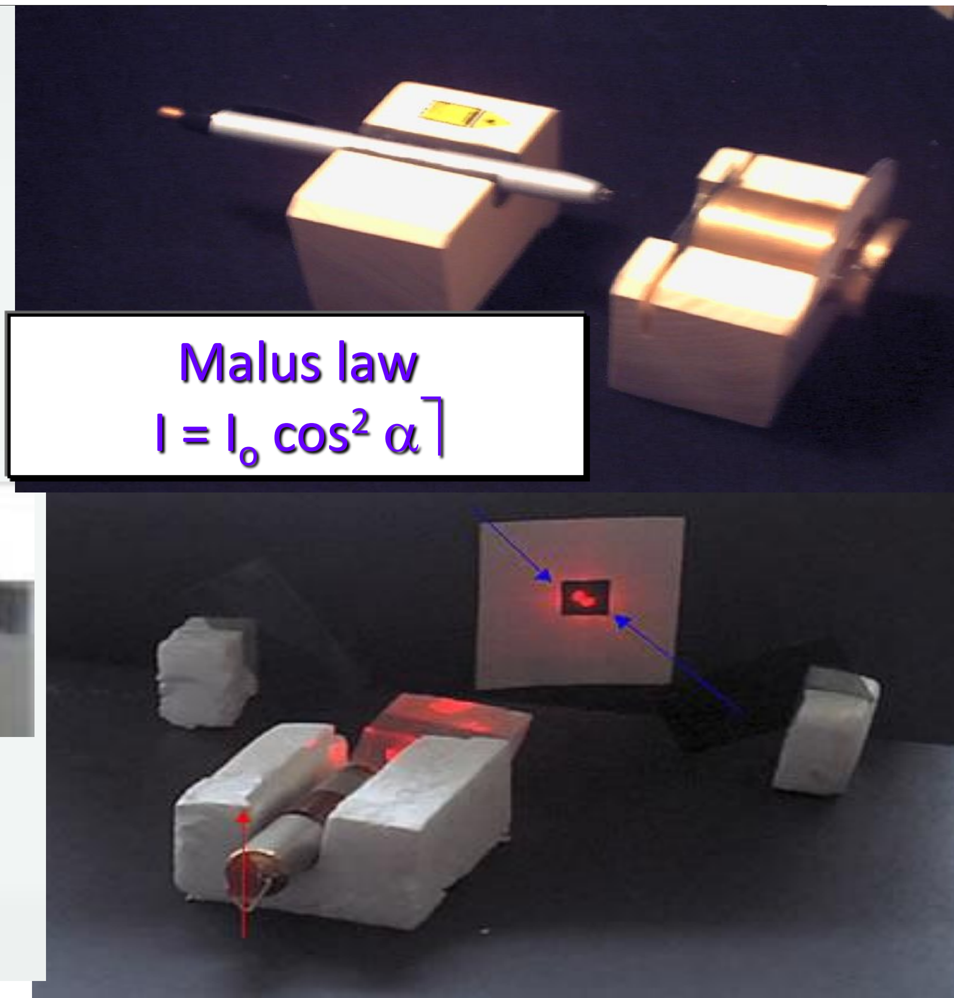
- to explore light polarization on experimental, conceptual and formal levels
- to discuss ideal simple experiments involving interactions of single photons with polaroids and birefringent materials (calcite crystals).
- to describe in quantum terms by two-dimensional vector spaces the states of polarization of light (as it is possible for spin).

I st Part

The superposition principle

Discussion of a series of experiments with polaroids and calcite crystals





Malus law

$I = I_o \cos^2 \alpha$

Ist **Part**

The superposition principle

Discussion of a series of experiments with polaroids and calcite crystals

The consequences

- **The uncertainty principle**
- **The undeterminism**
- **The description of macro-ojects and the problem of the measure**
- **The non locality**

The renouce to the clasical way of thinking

A discussion from two different perspectives

QM rationale

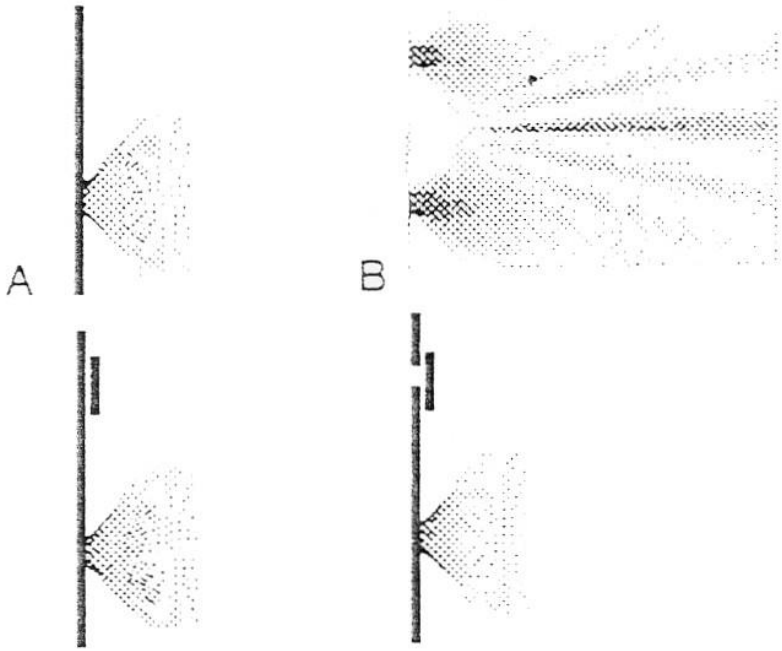
- Malus law is valid reducing light intensity -> polarization: property of single photon
- Exploring interaction of polarized photons (pp) with polaroid, identification of:
  - Mutually excusive properties
  - Incompatible properties and uncertainty principle
- The **state** of pp identify by a **vector** and introduction of the superposition principle **w=u+v**
- *Distinction between state (vector) and polarization property, identifyed by icons living in different spaces*
- QM **measurement** as a transition of the pp in a new state: the precipitation of the system in those measured and its genuine stocastic nature
- Interaction of pp with birifrangent crystals to understand
  - Entangled state
  - No trajectory
  - No locality

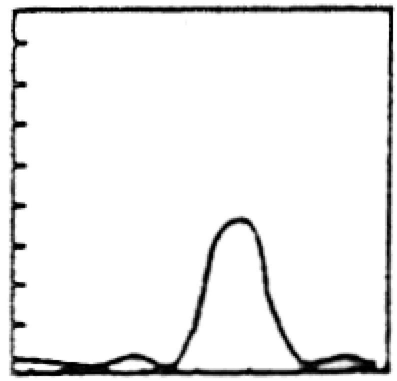
$$Pt = Nt/N = \cos^2\theta = (\mathbf{u} \cdot \mathbf{w})^2$$

- FORMALISM -Transition probability from state **u** to state **w** as projector

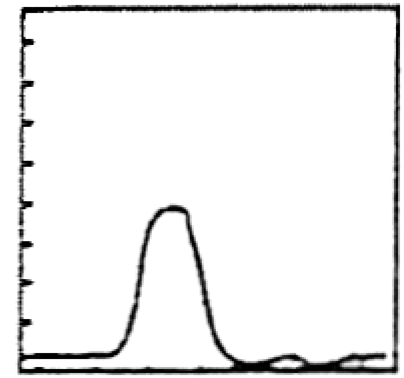
Figura 11

Two slit diffraction



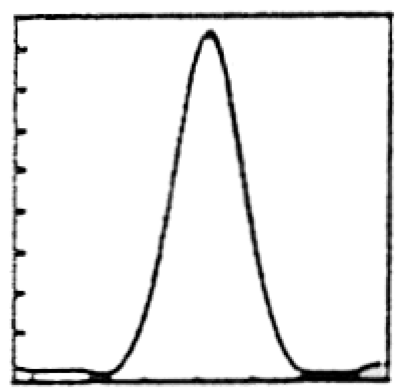


$[\psi_a]^2$

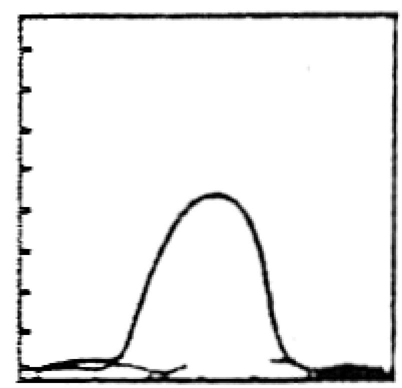


$[\psi_b]^2$

The comparison



$[\psi_a + \psi_b]^2$



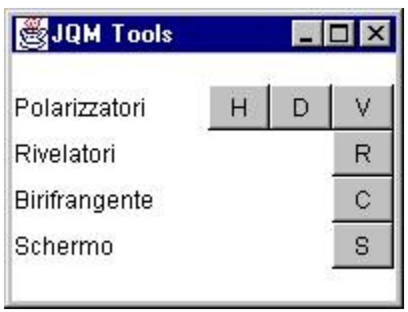
$[\psi_a]^2 + [\psi_b]^2$

CONCLUSION
we cannot say that photons
(material particles) pass one of the
two slits

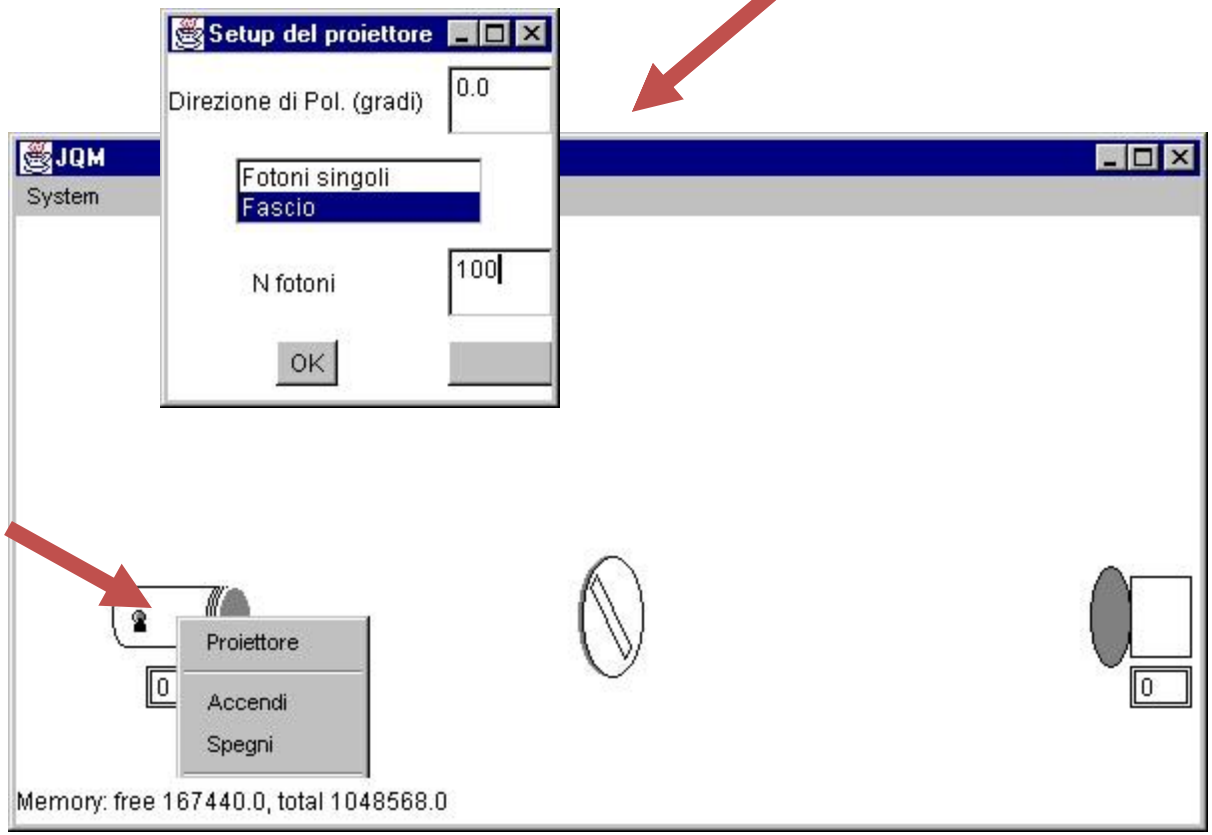
the applet

JQM

Differents objects are availabe



The acces to the properties of an instrument is by a menu (rigth click)



Università degli Studi di Udine

UNITÀ DI RICERCA IN DIDATTICA DELLA FISICA

SeCiF

In this context the Udine Research Unit has produced three web environments

SeCiF
Spiegare e Capire in Fisica

Università degli Studi di Udine

UNITÀ DI RICERCA IN DIDATTICA DELLA FISICA

[www.uniud.it/Cird/secif/]

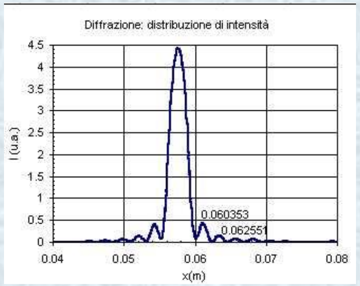
Primi passi nei fenomeni termici

Il cuscino di ottica

Elementi di crisi della fisica classica
Discussione e esperimenti

one on quantum mechanics for the secondary school

Avvicinarsi alla teoria della fisica quantistica



IDIFO Project (2006-2015)
PER contribution for
Innovation in Physics Education and Guidance

Piano Lauree Scientifiche

20 universities cooperating in

- Master for teacher formation on modern physics (QM + Rel + Stat + Solid state phys)
- Summer school for talent students
- Educational Labs, co-planned with teachers, to experiment innovation in the school

MASTER IDIFO4

162 cts articulated in clusters of 3cts courses on the following area for (60cts)

FM - Modern Physics

FCCS – Physics in contexts (in art, sport...)

RTL&M – Real time Labs and modeling

OR- Formative guidance

SPER – School experimentation

Offerta formativa istituzionale IDIFO4

Master Corso di Perfezionamento Singolo Corso

in

INNOVAZIONE DIDATTICA IN FISICA E ORIENTAMENTO

Piano Lauree Scientifiche

Corsi istituzionali in attuazione a quanto previsto nelle linee guida del PLS e nel Documento del Gruppo di lavoro per la Cultura Scientifica e Tecnologica "Proposte per un programma di sviluppo professionale in servizio dei docenti di discipline scientifiche", riportato all'indirizzo: http://www.pubblica.istruzione.it/argomenti/gst/allegati/sviluppo_discipline_scientifiche.pdf

OFFERTA FORMATIVA

MASTER M-IDIFO4 (60 cfu)
Un percorso biennale di 8 moduli caratterizzanti (24 cfu) pari a circa 200 ore, di 36 ore di sperimentazione (18 cfu) e 18 cfu per la Tesi finale

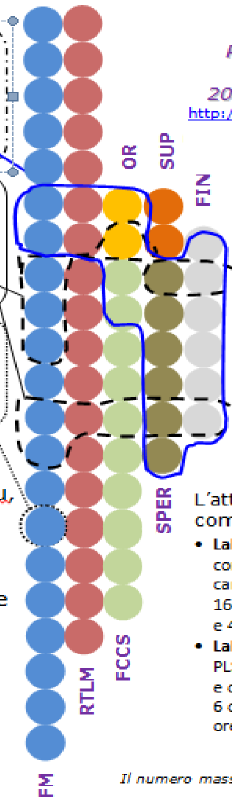
CORSO DI PERFEZIONAMENTO CP-IDIFO4 (18 cfu)
Un percorso annuale di 4 moduli (12 cfu~100 ore), 16 ore di sperimentazione e 3 cfu per prova finale (Project Work)

SINGOLO CORSO (3 cfu)
Può essere certificata la frequenza di un singolo corso del piano formativo effettuando l'iscrizione come uditore

Ciascuno può scegliere il percorso formativo in base alle proprie esigenze nell'ambito di 65 moduli, ciascuno di 3 cfu, organizzati nelle seguenti macroaree:

- **FM** - Fisica Moderna ed in particolare fisica quantistica e relativistica
- **RTLM** – Laboratori con sensori on-line e modellizzazione
- **FCCS** - Fisica in Contesti e Comunicazione della Scienza
- **OR**- Orientamento Formativo
- **SUPP** – Supporto alle attività
- **SPER** – Sperimentazione didattica a scuola
- **FIN** – Preparazione della prova finale

I moduli RTLM e parte di FCCS sono erogati in presenza, tutti gli altri in e-learning.



Il Progetto IDIFO4 è proposto nell'ambito del Piano Lauree Scientifiche (PLS) come iniziativa congiunta di 20 sedi universitarie e 3 sedi INFN
http://www.fisica.uniud.it/URDF/laurea/index.htm

L'attività didattica dei moduli formativi comprende:

- **Laboratori PLS** – Didattica Laboratoriale - comprensivi di 6-10 ore di formazione generale e caratterizzante, 4-6 ore di progettazione didattica, 16-8 ore di sperimentazione in classe con studenti e 4-6 ore di analisi dati e rielaborazione;
- **LabIDIFO4** – Laboratori di formazione insegnanti PLS - comprensivi di 14 ore di formazione generale e caratterizzante, 5 ore di progettazione didattica, 6 ore di sperimentazione in classe con studenti e 5 ore di analisi dati e rielaborazione.

Il numero massimo di iscritti al Master è di 30
Il numero massimo di iscritti al Corso di Perfezionamento è di 30

Informazioni e materiali del Master e del Corso di Perfezionamento sono reperibili agli indirizzi
http://www.fisica.uniud.it/URDF/laurea/index.htm

ISCRIZIONE E AMMISSIONE

Per l'iscrizione al M-IDIFO4 e al CP-IDIFO4 è richiesto un titolo di laurea magistrale o vecchio ordinamento. È prevista una riserva di posti distribuita sulle sedi universitarie proponenti.

BORSE DI STUDIO

Sono previste 15 borse da 1000,00 Euro cadauna a copertura dei costi di iscrizione al Master M-IDIFO4 e 15 borse da 500,00 Euro cadauna a copertura dei costi di iscrizione al CP-IDIFO4.

PER MAGGIORI INFORMAZIONI

Segreteria del Master e del Corso di Perfezionamento IDIFO4

CIRD - tel. 0432 558211
cird@uniud.it

DCFA – tel. 0432 558800

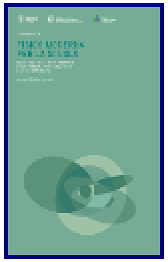
Master universitario di II livello in Innovazione didattica in Fisica e Orientamento - IDIFO

Università degli Studi di Udine

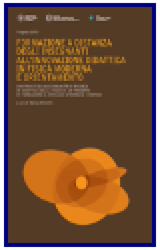
I materiali in rete telematica di IDIFO

I libri

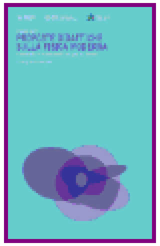
Fisica moderna per la scuola



Formazione a distanza



Proposte didattiche sulla fisica moderna



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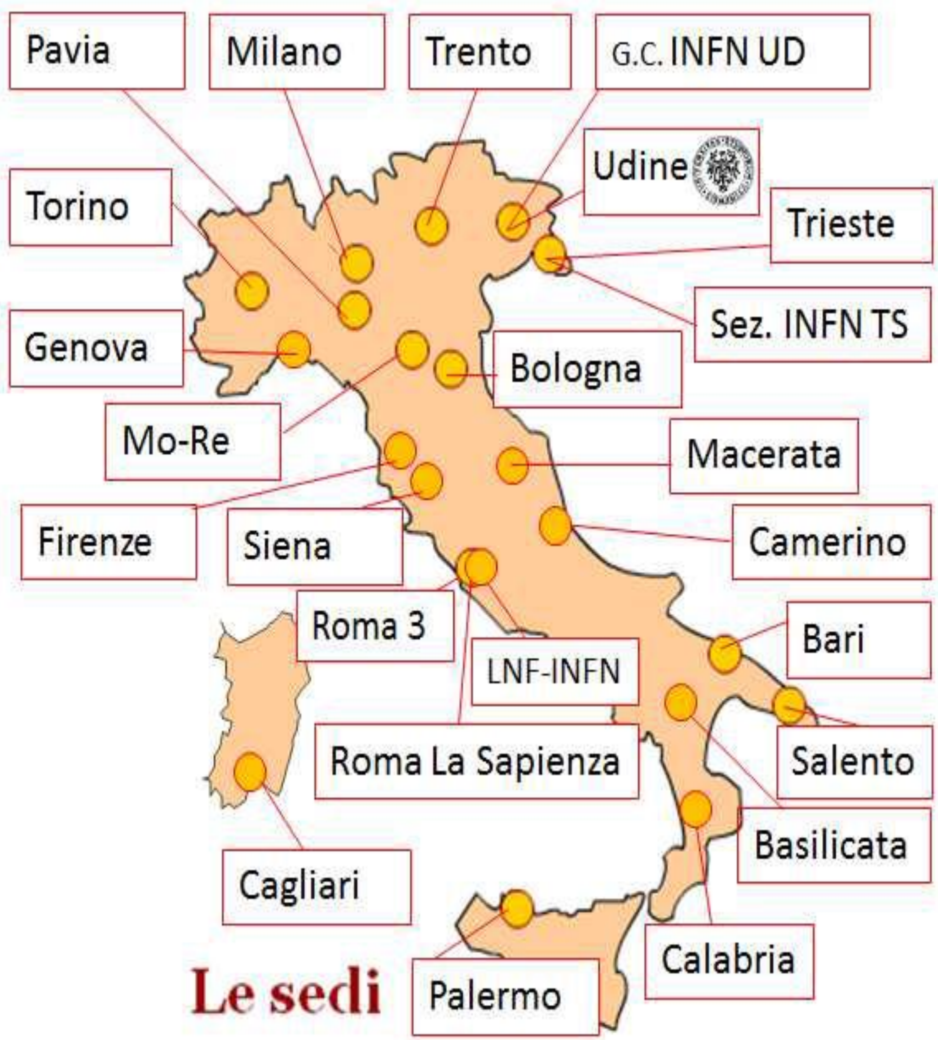


Research Experimentations on teaching/learning QM

Performed by teachers

	School	*Site*	*Class*	*Years of phys*	*H per week*	*age*	*N Student*	*s.y.*	*h*	*Driver*
1	Sci. Lic.	Pordenone	5-PNI	5	3	18	24	2001/2002	10	PT
2	Sci. Lic.	Pordenone	5-Brocca	3	2/3	18	11	2002/2003	10	PT
3	Sci. Lic.	Udine	5-PNI	5	3	18	28	2004/2005	8	PT
4	Sci. Lic.	Udine	5-Ord	3	2/3	18	29	2002/2003	10	PT
5	Sci. Lic.	Gemona	5-Ord	3	2/3	18	20	2002/2003	10	PT
6	Sci. Lic.	Pordenone	5-PNI	5	3	18	18	2002/2003	10	PT
7	Different	All Italy	4-5	3/5	3	17/18	25	2007	10	ST
8	Different	All Italy	4-5	3/5	3	17/18	25	2007	10	ST

Type of school	School of the students
City	Palce where the school is
Class	4 and 5 are the two last classes of the high school
Phys Y	Physics courses number of years
hours per week	Number of hour per weeek in the courses

Age	Student age
Students	Numbers of students involved in the experimentation
S.Y.	Schoolastic year when the experimentation was carried out
h	Number of hours of the experimentation
Driver	Who conducted the activity: Researcher (R) ; Prospective Teacher (PT); In Service Teacher (ST)

Research Experimentations on teaching/learning QM

	School	Site	Class	Years of phys	H per week	age	N Student	s.y.	h	Driver
1	Sci Lyc.	Udine	5 -PNI	5	3	18	21	1998/1999	10	R/T
2	Sci Lyc.	Udine	5/5PNI	3/5	2/3	18	17	2003/2004	12	R
3	Sci Lyc.	**Udine**	**5-Ord**	**3**	**2/3**	**18**	**22**	**2004/2005**	**11**	**R**
4	Sci Lyc.	**Udine**	**5-PNI**	**5**	**3**	**18**	**18**	**2005/2006**	**12**	**R**
5	Different	UD-PN-TV	4-5	3/5	3	17/18	40	2008	6	R
6	Different	All Italy	4-5	3/5	3	17/18	42	2009	8	R
7	Different	All Italy	4-5	3/5	3	17/18	41	2011	6	R
8	Sci Lyc.	Crotone	5	3/5	3	17/18	22	2012	8	R
9	Sci Lyc.	Crotone	5	3/5	3	17/18	30	2013	8	R
10	Tec Schoo	Tolmezzo	4	2	2	17	16	2013	10	R/T
11	Different	All Italy	4-5	3/5	3	17/18	36	2013	6	R
12	Different	All Italy	4	3/5	3	17/18	30	2014	6	R
13	Sci Lyc.	Crema	5	5	3	18	25	2014	8	R
14	Sci Lyc.	Ancona	5	5	3	18	27	2014	8	R

Type of school	School of the students
City	Palce where the school is
Class	4 and 5 are the two last classes of the high school
Phys Y	Physics courses number of years
hours per week	Number of hour per weeek in the courses

Age	Student age
Students	Numbers of students involved in the experimentation
S.Y.	Schoolastic year when the experimentation was carried out
h	Number of hours of the experimentation
Driver	Who conducted the activity: Researcher (R) ; Prospective Teacher (PT); In Service Teacher (ST)

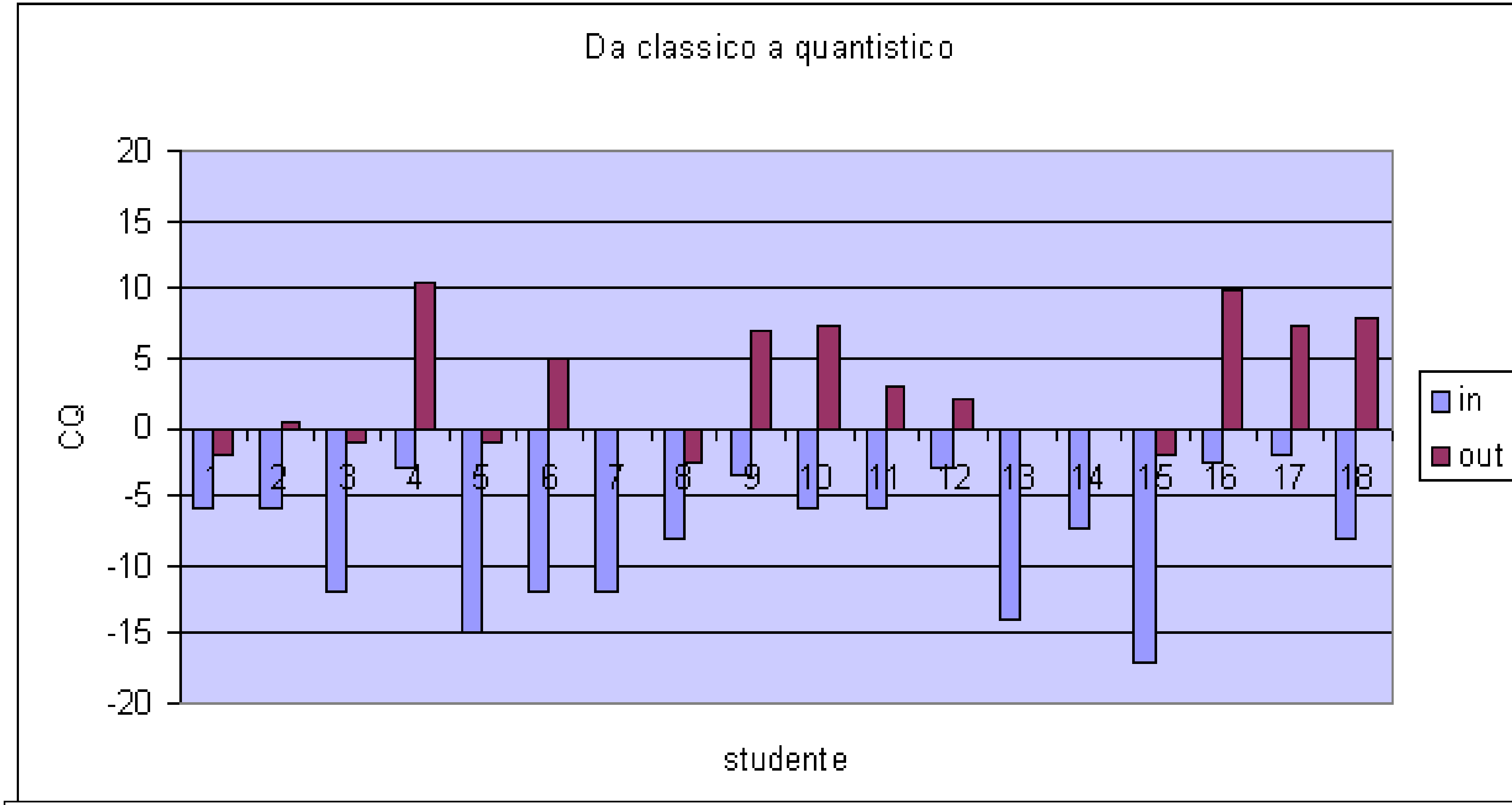
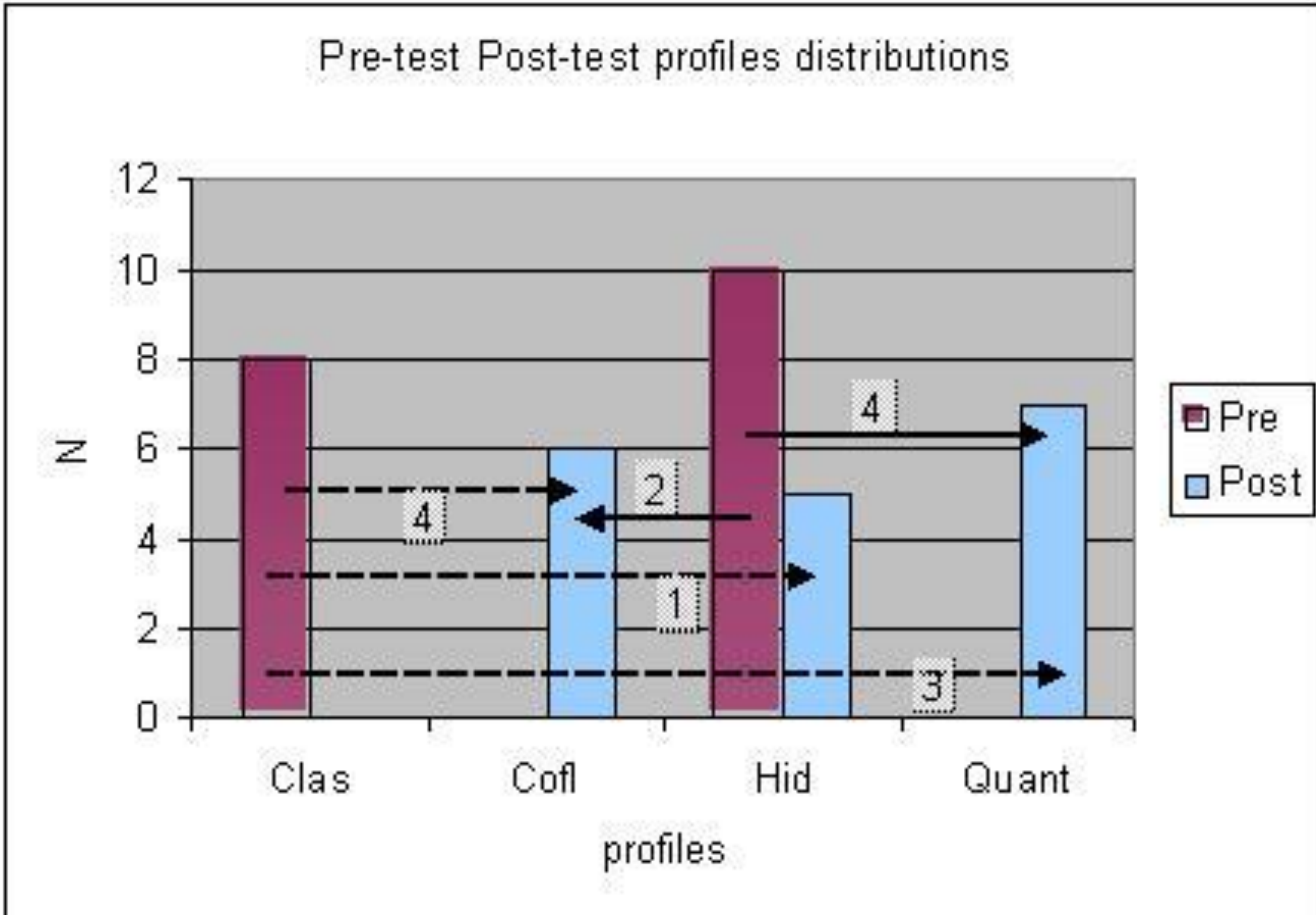


Fig.1

QC index (calcolated according with Müller, Wiesner 2002) for pre-test (IN) and post-test (OUT) (QC>0 quantum mechanics ideas; QC<0 classical ideas)



Pre-test Post-test profiles distributions
N
12
10
8
6
4
2
0
Clas
Cofl
Hid
Quant
profiles
Pre
Post
4
2
4
1
3

Research results

- Student **profit of the iconographic proposal** and **discuss in a proper way** on
  - **mutual exclusive properties** (80%) and
  - **incompatible properties** (55%)
- **The employ of**
  - **the iconographic representation and**
  - formalism facilitate reasoning in the framework of QM
- The **rigorous reasoning** proposed promote
  - its spontaneous used in new contexts (50%)
  - the construction of a coherent framework (80%)

Learning outcomes from experimentations of our 5 MP proposals suggest to:

- focus on the coherence of reasoning to create reference frameworks for explanations
- integrate
  - hand-on / mind-on phenomena exploration
  - Macro-micro interpretation of results,
  - real and ideal EXPERIMENTS and modelling
- use iconographic representation as conceptual tool
- introduce formalism and use it to reinterpret explored situations
- analyze students ideas in the framework of different interpretative schema (CP-MP)
- Integrate MP research technique in CP
- developing coherent paths of conceptual understanding

Concluding remarks

- **from our research in physics education we developed 5** different perspective of proposals mutually inclusive for the Modern Physics
  to build in young people:
  - physics identity
  - physics as a cultural issue
  - the idea of phys epistemic nature
- Avoiding the reductionism to offer opportunities of:
  - Experience quantitative exploration of crucial phenomena (diffraction) individuating laws, fitting data and testing basic priciple ideas and results with experimental data
  - Understand the crucial role of CP in modern research techniques (RBS, R&H) manipulating data and interpretation like in a research lab
  - Focusing on reasoning to conduct a phenomena exploration (superconductivity) understanding the role of analogies for finding explanations
  - Reflect on physics meaning of basic concepts in different theories (state, measure, cross section) revising meanings in CP and understanding the different perspectives of new theories
  - Approaching to the new ideas of QM theory: **the first step toward a coherent interpretation with a supporting formalism experiencing aspects, cardinal concepts, elements peculiar to QM**

Thank you!

marisa.michelini@uniud.it

Physics Education Research Unit

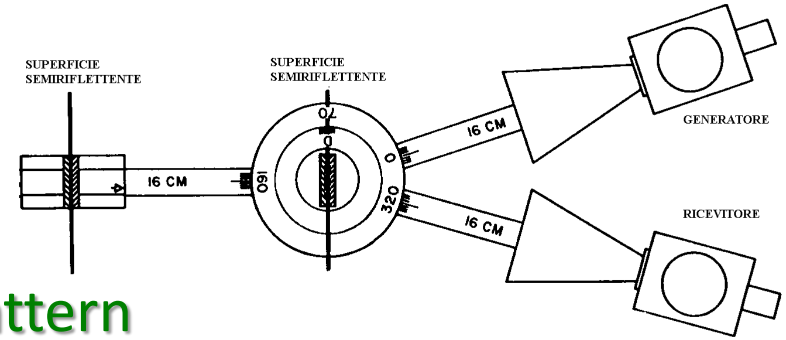
University of Udine

Italy

LUCIDI DI RISERVA

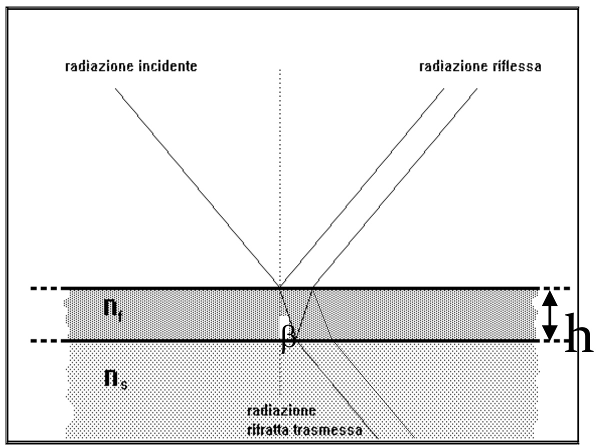
2. The physics in modern research analysis technics - TRR

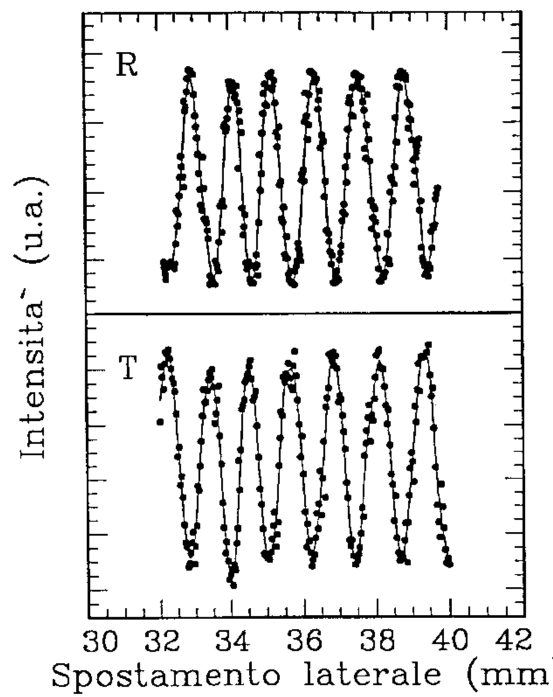
TRR – Time Resolved Reflectivity



Intensità riflessa e trasmessa (aria, $\lambda = 632.8\ nm$)

Interference pattern changes of the two laser beams reflected by two interfaces, when one of them is changing is used to study the epitassial grown of a sample





Students carried out measurements with microwaves and laser light, measuring thikness of various thin films of materials

$$\ldots \pm 0.1)\ mm \Rightarrow \alpha = \frac{H}{H'} = \frac{\lambda}{2H'} = (2.6 \pm 0.2) \times 10^{-4}\ ra\ldots$$

MQ PATH

Proposals on QP in secondary school

There are almost more than for classical physics
(Cataloglu, Robinett 2002).

- **No consensus as concern**
  - **the aspects to be treated and**
  - **approach to be adopted (Am. J. P. 2002; Phys. Educ. 2000)**
- **The different possible formulations and interpretation of QM has been used as starting point for different educational proposals:**
  1. **Historical development of interpretative problems**
  2. **A rational reconstruction of the historical developments: crucial experiments and the birth of the theory of quanta.**
  3. **Wave formulation**
  4. **Vector formulation, proposed by Dirac .**

  Than different strategies for learning path are adopted

Comments on the proposals to quantum physics

A rational reconstruction of the historical developments:

- **crucial experiments**
- **the birth of the theory of quanta.**

- **Advantages**
  - **general vision**
  - **interdisciplinary bridges**

- **Disadvantages:**
  - a serious drawback, especially in elementary treatments:
    - the discussions about experiments
    - the narrative treatment of the discussions on the subject

    prevail over aspects relating to the subject itself

Comments on the proposals to quantum physics

Wave formulation proposal

* **rigorous**

* **demanding strong competencies**
    * **in physics and**
    * **in mathematics,**

  that they can be only partially decreased by using computer simulation to 'visualize' quantum situations.

Historical development of interpretative problems

There are two main proposals

1. **Story telling on qualitative level** (many secondary school books)
2. **Very long and diffucult semiclassical treatment** (Born).

A little clarification

…physics of quanta /

…quantum physics /

…quantum mechanics

The descriptive dimension

Are very different things

if acceptable on popularization plan

it appears NOT to be satisfactory on a educational plan

There is the need

- **To produce the awareness of the reference assumptions of the new mechanics**
- **To offer some indications on the formalism that is adopted,**

=> The formalism, in fact, assumes in QM a conceptual role.

Our proposal

Two plans

Esperiments

That classical physics cannot interpret to focus on the problems

Approaching theory of MQ

→ strategy: approaching to the new ideas of theory by discussing simple experiments in a context

Fotoelectric effect
Compton effect
Frank & Hertz experiment
Millikan
Zeeman effect (normal and anomalous)
Emission and adsorbtion spectra
Diffraction of light and particles
Ramsauer effect

The core proposal is for
Quantum mechanics
(not quantum physics or physics of quanta)
in secondary school

We have chosen to

Approach the theory of quantum mechanics

The first step toward a coherent interpretation with a supporting formalism

An introduction to the ideas of the theory

through the treatment

- -crucial aspects
- -cardinal concepts
- -elements peculiar to QM

Our core proposal for MQ may be divided into two levels.

- On the **disciplinary level** we have chosen to begin with and focus on **the principle of superposition and its implications**

- On the **educational level** we have chosen **in-depth discussion of specific situations** in a context that allows for the

polarization as a quantum property of light

The basic elements

- to explore light polarization on experimental, conceptual and formal levels
- to discuss ideal simple experiments involving interactions of single photons with polaroids and birefringent materials (calcite crystals).
- to describe in quantum terms by two-dimensional vector spaces the states of polarization of light (as it is possible for spin).

I st Part

The superposition principle

Discussion of a series of experiments with polaroids and calcite crystals

The consequences

- **The uncertainty principle**
- **The undeterminism**
- **The description of macro-ojects and the problem of the measure**
- **The non locality**

The renouce to the clasical way of thinking

A discussion from two different perspectives

To introduce the phenomenology of light polarization

we use **polaroids** as explorers on an overhead projector

When light pass 2 polaroid with permitted direction at 90°, the light intensity is reduced quasi zero

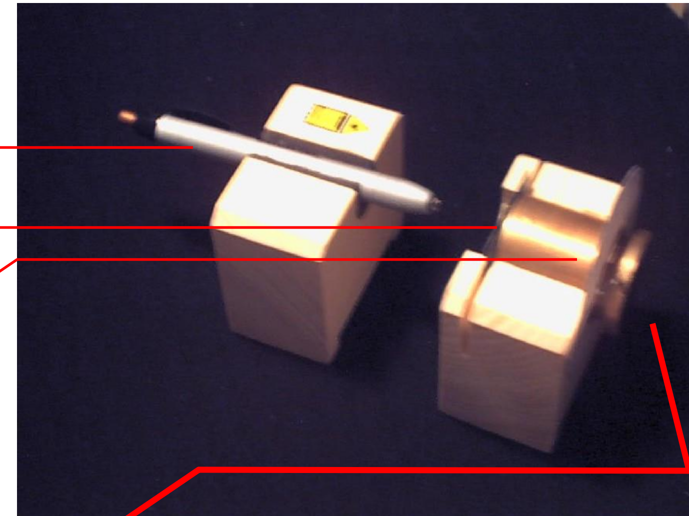
There is another property of light that I can produce with a polaroid and detect with another polaroid: POLARIZATION

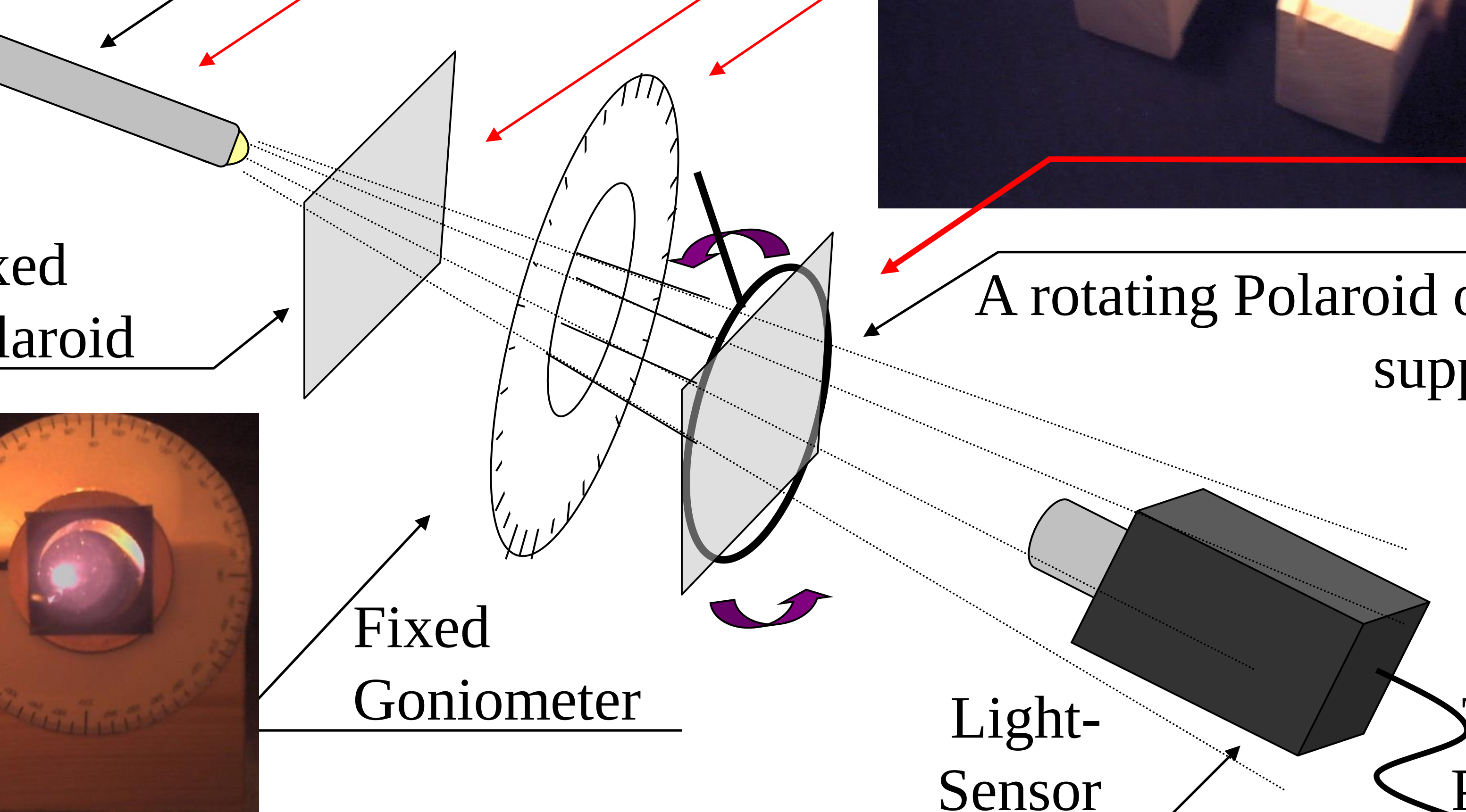
The measure

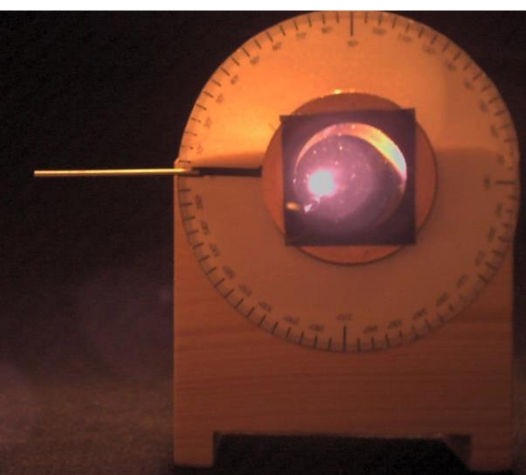
Malus law

$I = I_o \cos^2 \alpha$

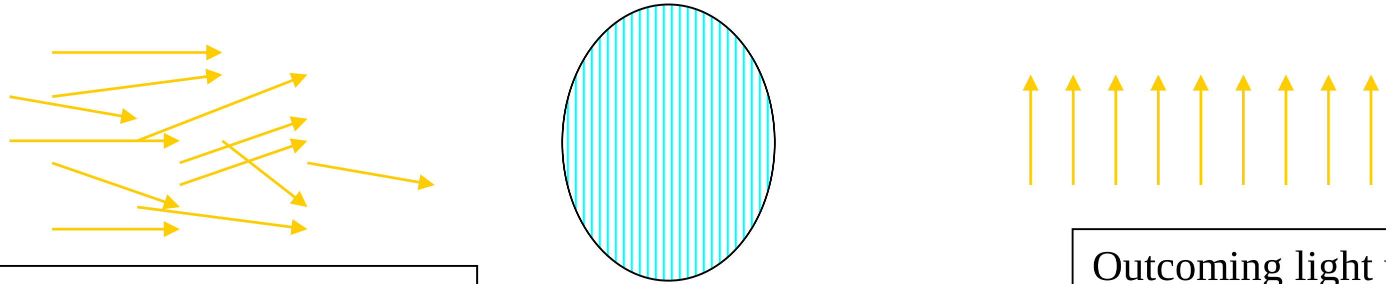
The measure can be carried out with a very simple set up







Ist Part: phenomenology of linear polarized photons



Incident light not polarized

Polaroid with vertical permitted direction

Outcoming light with vertical polarization

Not polarized light is incident to the polaroid with vertical permitted direction:

The emerging light from the polaroid is always polarized along the permitted direction of the polaroid

This is the way for the preparation of linear polarized light in a chosen direction

Reducing the light intensity → same behaviour.

The results of the Malus law does NOT depend on collective phenomena relative to the interaction between photons

Validity of Malus law for a single photon

The polarisation property is a property of the single photon → due to its state

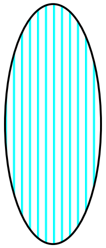
Photons with VERTICAL polarization

Property Δ

State v

Incoming photons with **vertical** polarization

ΔΔ



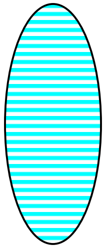
ΔΔ

All pass

Polaroid with **Vertical** permitted direction

Incoming photons with **vertical** polarization

ΔΔ

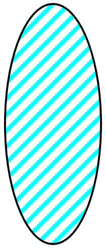


No one pass

Polaroid with **Horizontal** permitted direction

Incoming photons with **vertical** polarization

ΔΔ



The 50% pass

◊

acquiring a new polarization property

Polaroid with **45°** permitted direction

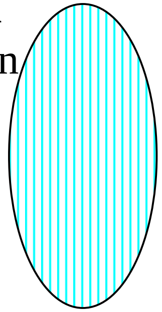
Photons with HORIZONTAL polarization

Property *

State u

Incoming photons with **horizontal** polarization

**

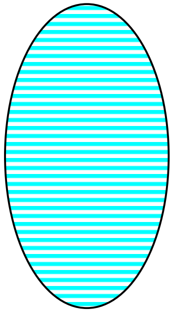


No one pass

Polaroid with **Vertical** permitted direction

Incoming photons with **horizontal** polarization

**



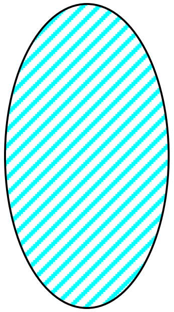
**

All pass

Polaroid with **Horizontal** permitted direction

Incoming photons with **horizontal** polarization

**



◊

The 50% pass

acquiring a new polarization property

Polaroid with **45°** permitted direction

Mutually exclusive properties

Certainty in an interaction with a system
- Pass and mantain the same polarization
- Adsorbion

The photons

- in the **v** state and property Δ :
  - **pass with certainty the polaroid wih vertical permitted direction (all of them always)**
  - **are all absorbed by the polaroid with horizontal permitted direction**

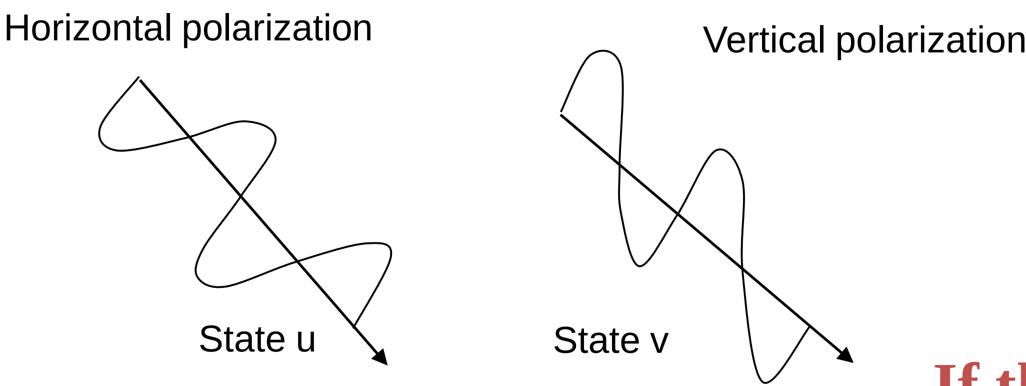
-In the **u** state and property * :

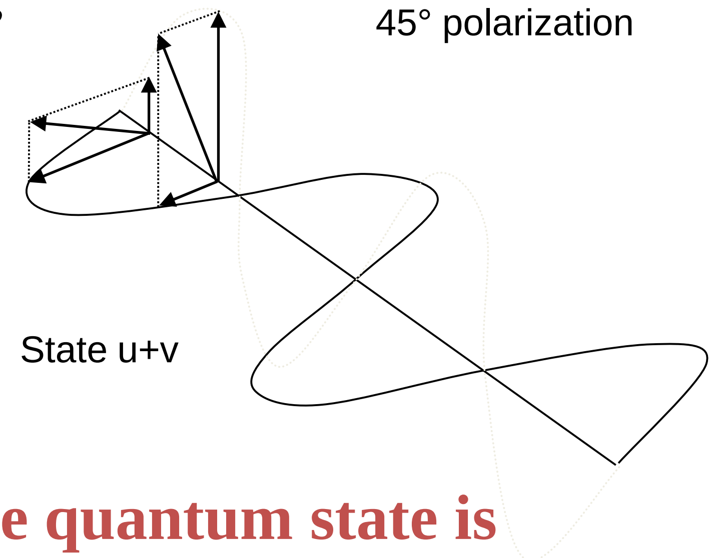
  - **pass with certainty the polaroid wih horizontal permitted direction (all of them always)**
  - **are all absorbed by the polaroid with vertical permitted direction**

Spin up and spin down in the interaction of atoms in a Stern and Gerlach apparatus along a chosen direction

The properties Δ and * are *mutually exclusive*

Linear POLARIZATION - *Classical case*

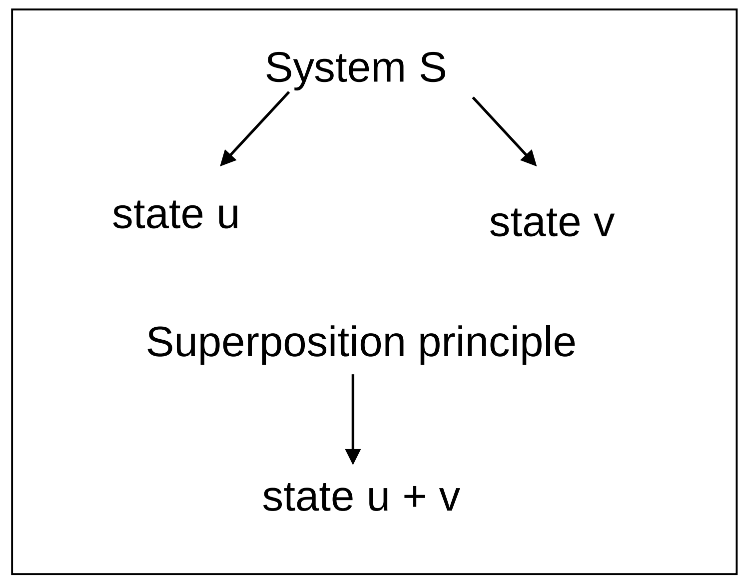




If the quantum state is a vector

Superposition principle

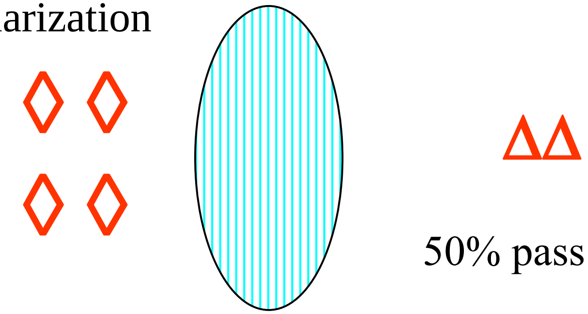
If **u** and **v** are two vectors corresponding to two possible states of the system S, then even **w=u+v**
Is a possible state of the system S



NOTE: The meaning of quantum state requires a gradual in depht discussion on the space in which the state is living, associated to the new meaning of the mesure

Incompatible properties and the superposition state u+v

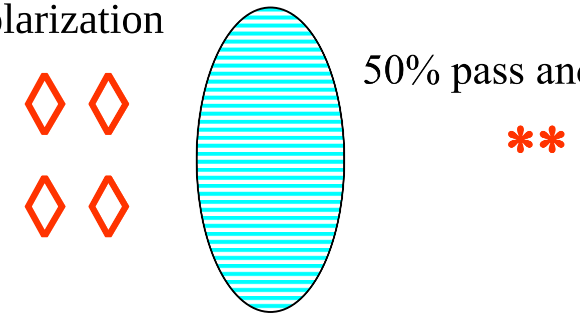
Incoming photons with **45°** polarization



50% pass and are…

Polaroid with **Vertical** permitted direction

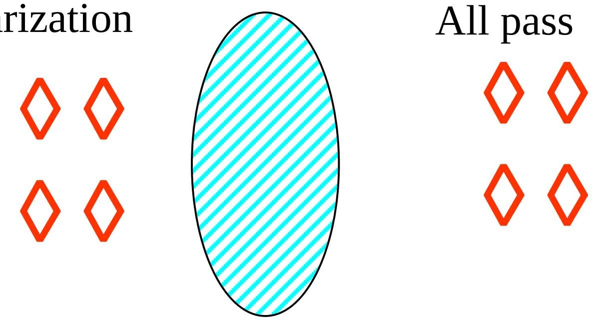
Incoming photons with **45°** polarization



50% pass and are…

Polaroid with **Horizontal** permitted direction

Incoming photons with **45°** polarization



All pass

Polaroid with **45°** permitted direction

Photons with 45° polarization

Which property?
Which state?

incompatibility

- New and relevant concept
- Different perspectives in the analysis of the meaning
  - Nature of the property
  - Corresponding state
  - Evolution in an interaction with a system
  - Measurement results prevision

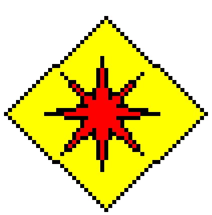
Some interpretative hypotesis!

The ensemble of **45° polarized photons** which are in the state **(u+v)** with associated property (romboid) ◊

- **HP1**: It could be thought as an ensamble of photons constituted by a **statistical mixture** of photons with properties * and **Δ.**

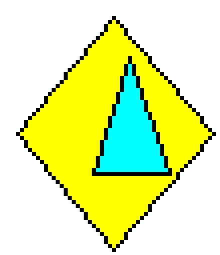
- **HP2**: It could be thought as an ensamble of photons which have **simultaneouly two properties, with the same weight**:

le proprietà ◊ e *



oppure

le proprietà ◊ e Δ

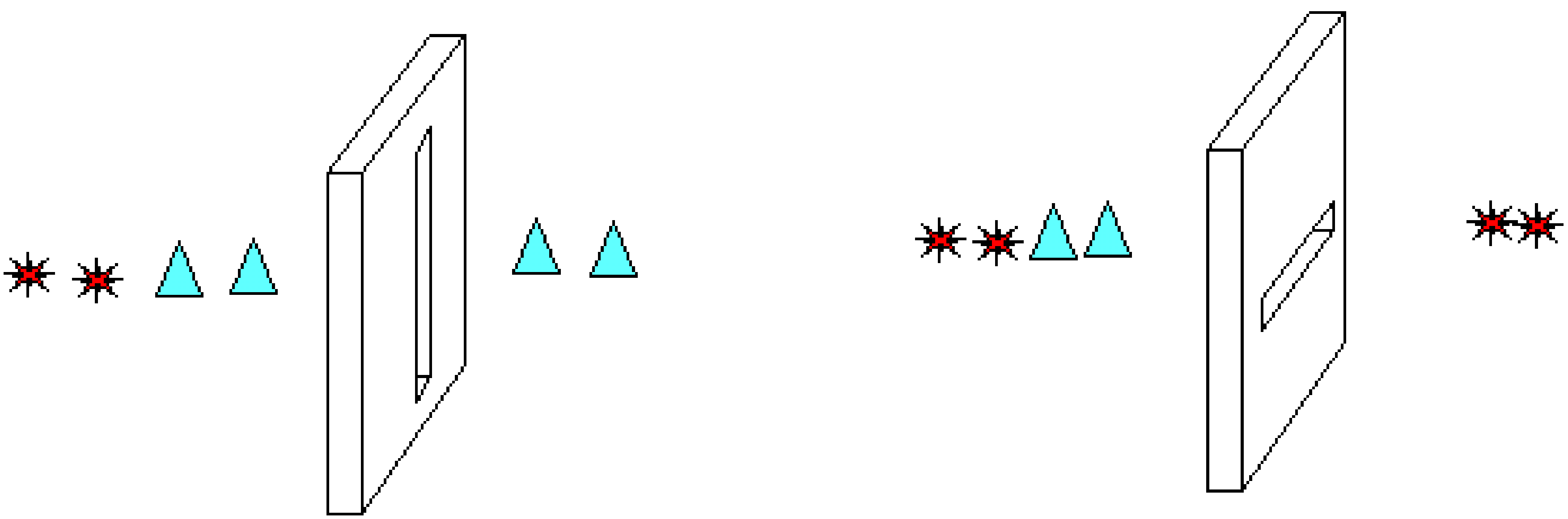


By means of ideal experiments in a simulation environment

In the case of statistical mixture

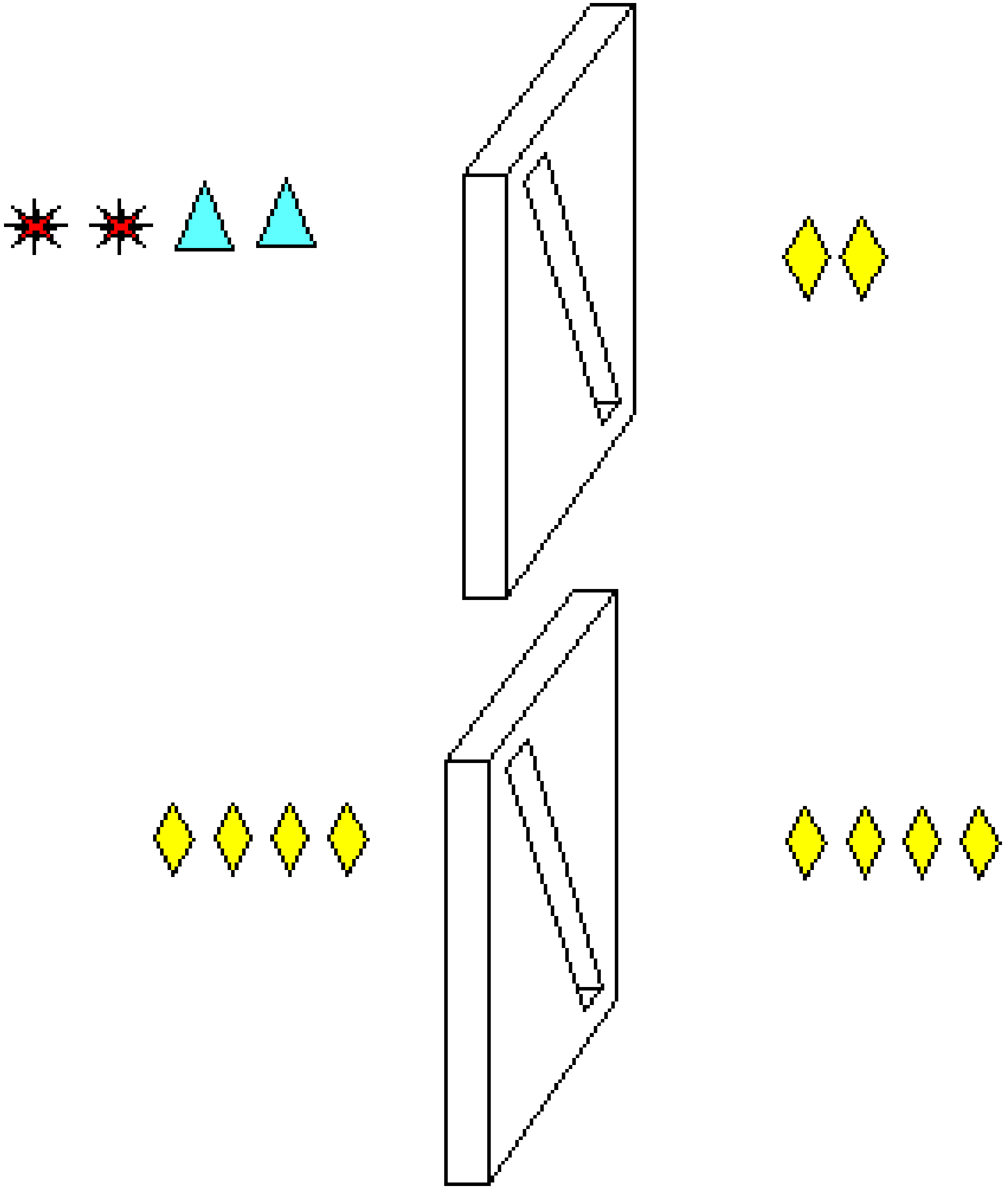
It is as if one could think that the polaroids:

Selecting the photons which have the property corresponding to their permitted direction



If there were a statistical mixture of the photons with property * **and** Δ then a different result is obtained in comparison with the case of all the photons with the same property ◊.

=> In conclusion: there is not a statistical mixture of properties and not a Union of photons in the state of **u** and **v**.

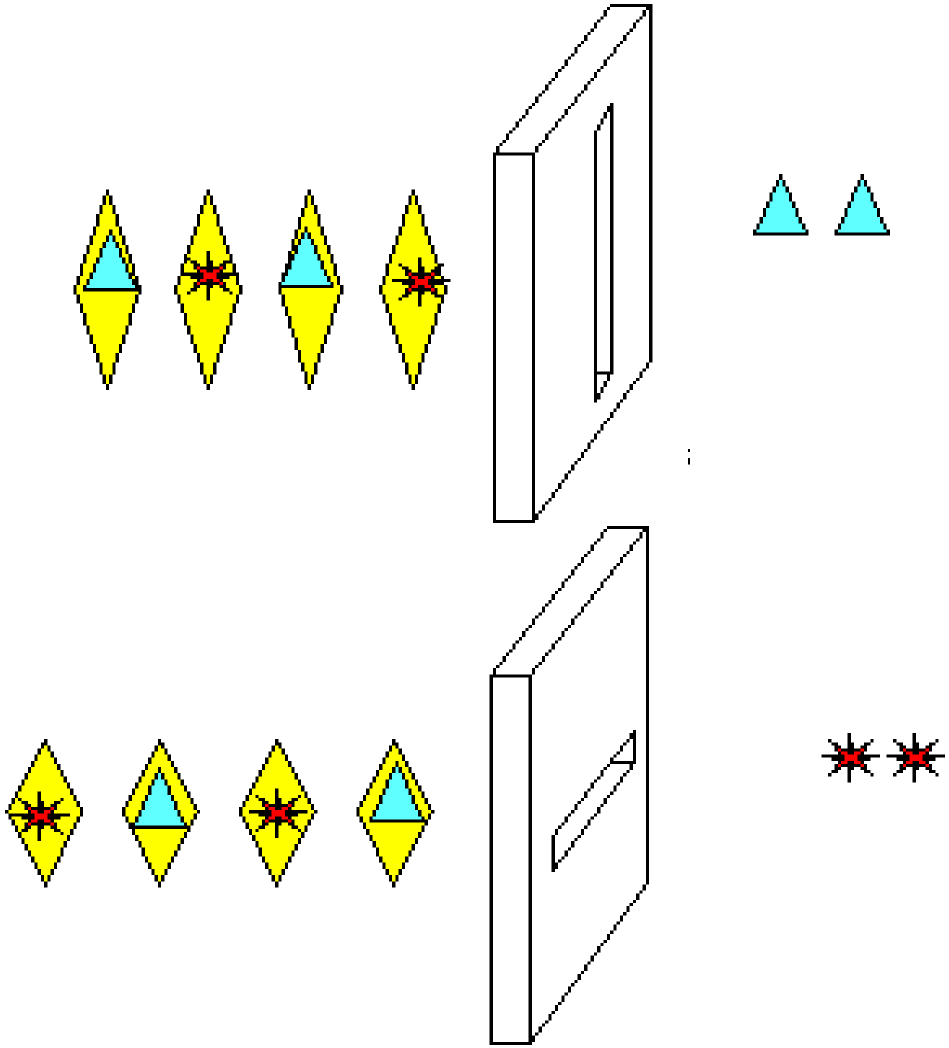


◊ ◊ ◊ ◊		* * * *
◊ ◊ ◊ ◊	=	* * * *
◊ ◊ ◊ ◊	?	Δ Δ Δ Δ
◊ ◊ ◊ ◊	≠	Δ Δ Δ Δ
u+v		**u∪v**

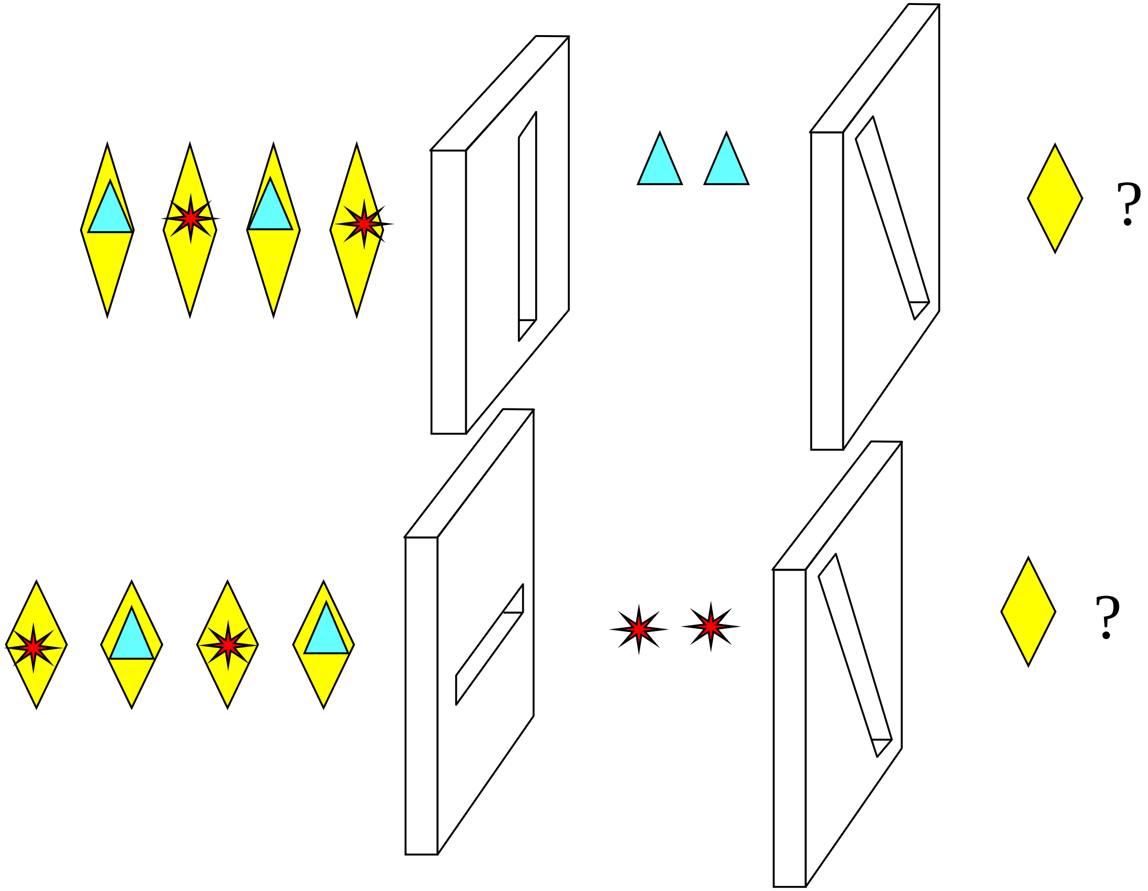
Is not the same as

In the case of simultaneous properties

It is as if one could think that the polaroids take off



the property of the photons not corresponding to the permitted direction of the polaroid



If the photons could have two properties at the same time and the polaroid has the role of selecting the known properties correspomding to its permitted direction.

Not one selected photon will overcome the second polaroid with 45° permitted direction:

This is in contradiction with the fact that half of the incoming photons pass the second polaroid and have 45° polarization.

Incompatible properties

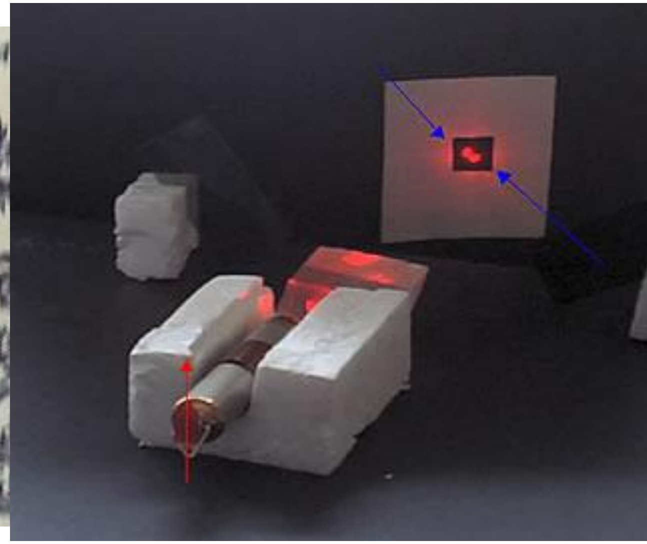
A photon with property ◊
Cannot even have the property * or Δ.

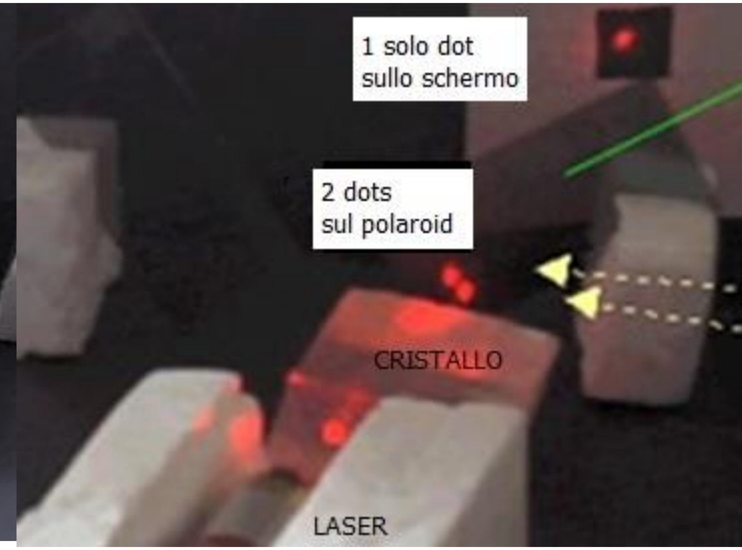
For that reason the property
◊ e *
or
◊ e Δ
Are called ***incompatibles***.

This can be seen as a democracy of QM with respect to the photons: which wants to consider them all equals.

This illustrate the UNCERTAINTY PRINCIPLE
which is an expression of the impossibility to observe two incompatible properties.

Conseguences of the linear superposition principle





- Calcite crystals is a birefringent crystal which may be cut and placed according to the optic axis such that incident light is deflected and emerge:
- vertically polarized light in the direction of the ordinary ray, while
- horizontally polarized light in the direction of the extraordinary ray.

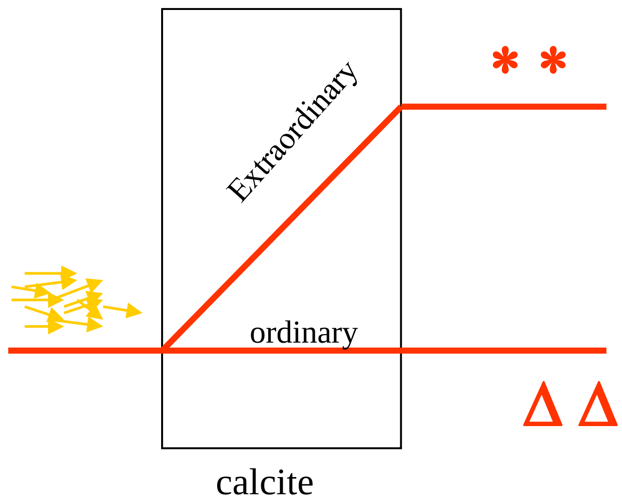
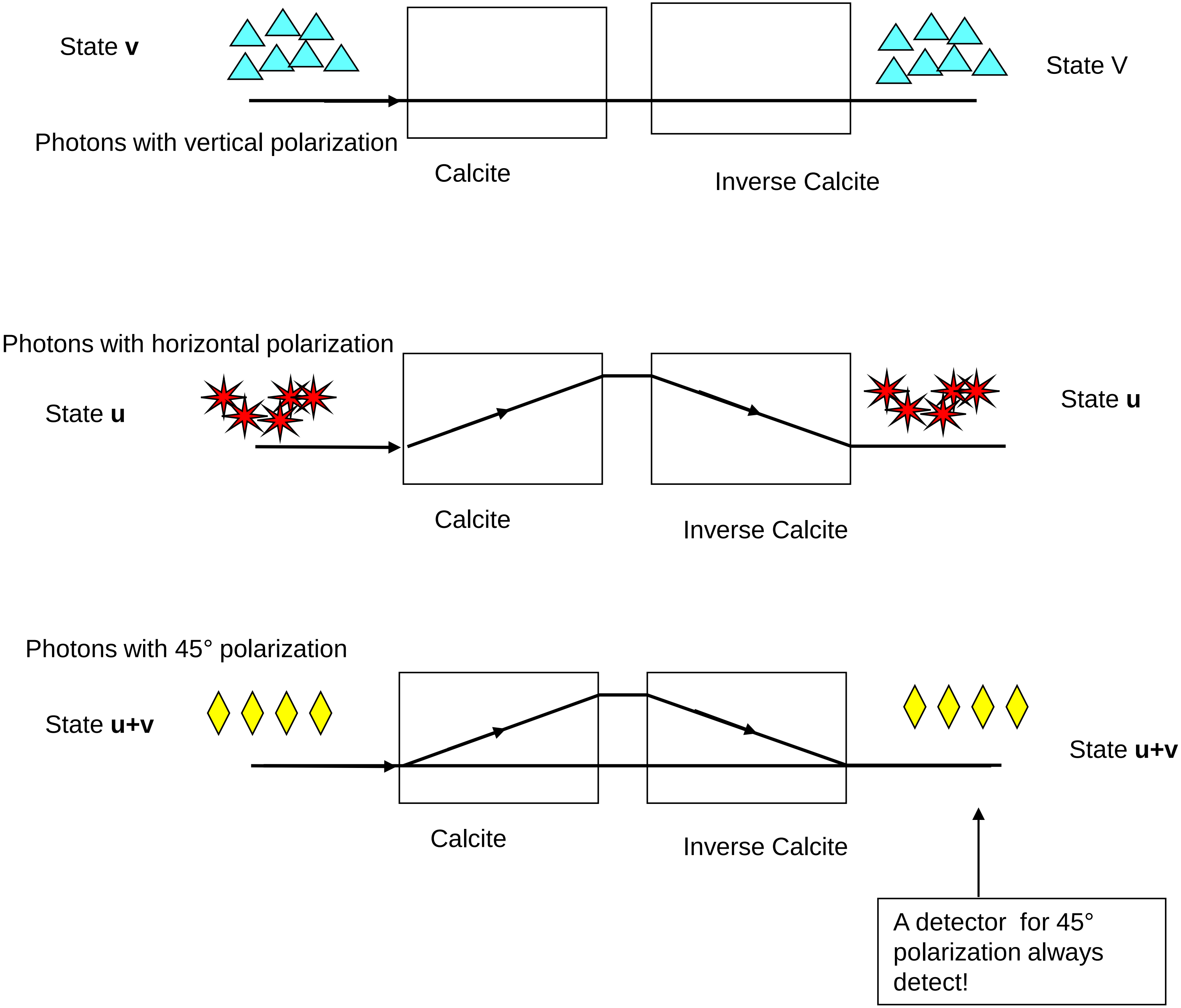
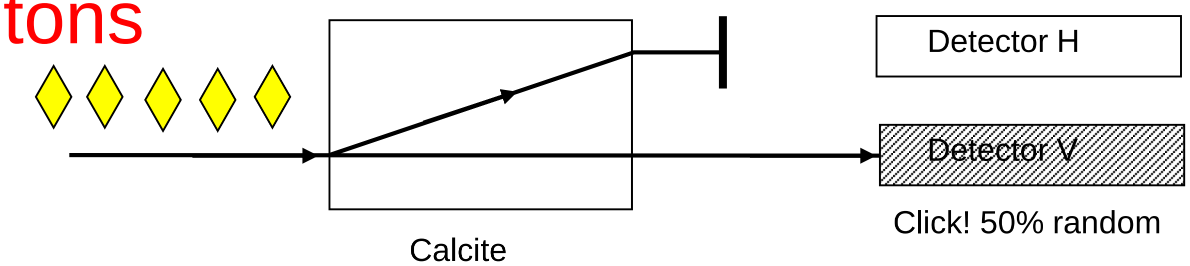


Figura 6


State **v**
Photons with vertical polarization
Calcite
Inverse Calcite
State V
Photons with horizontal polarization
State **u**
Calcite
Inverse Calcite
State **u**
Photons with 45° polarization
State **u+v**
Calcite
Inverse Calcite
State **u+v**
A detector for 45° polarization always detect!

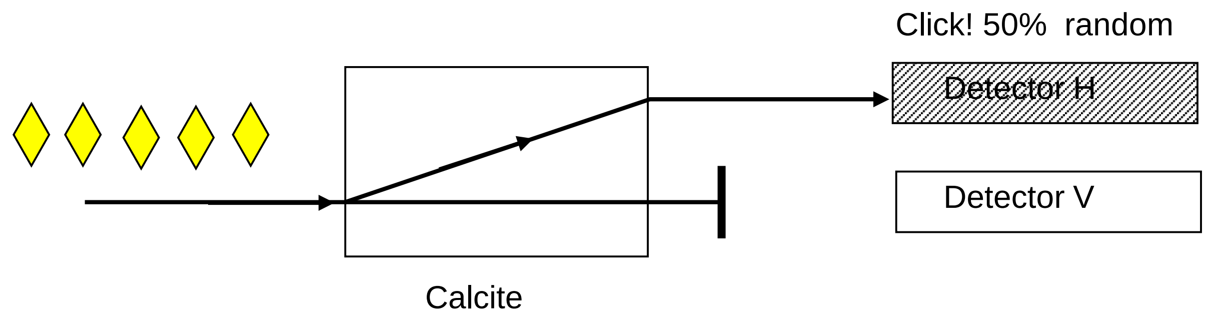
Trajectory of photons

45° polarized photons



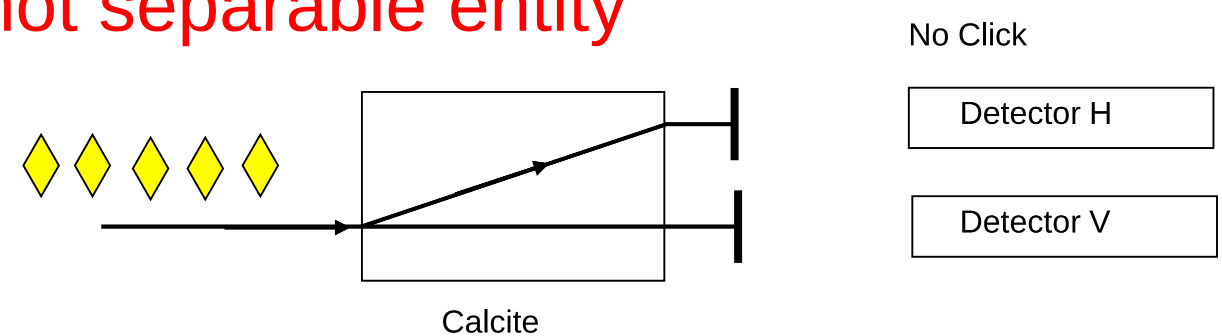
We have genuine statistical results

45° polarized photons



The photon is not separable entity

45° polarized photons

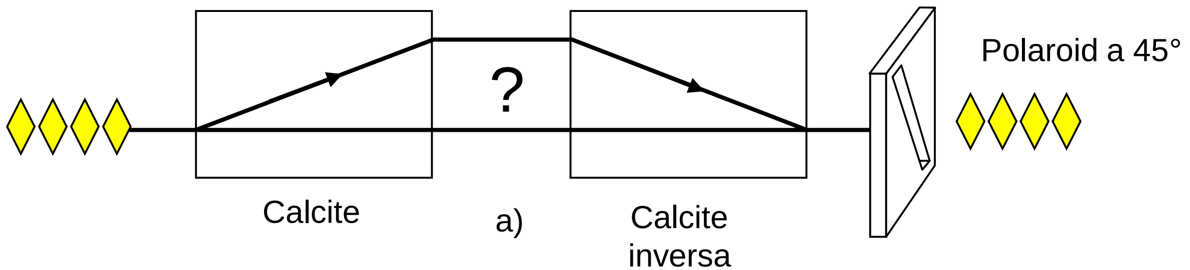


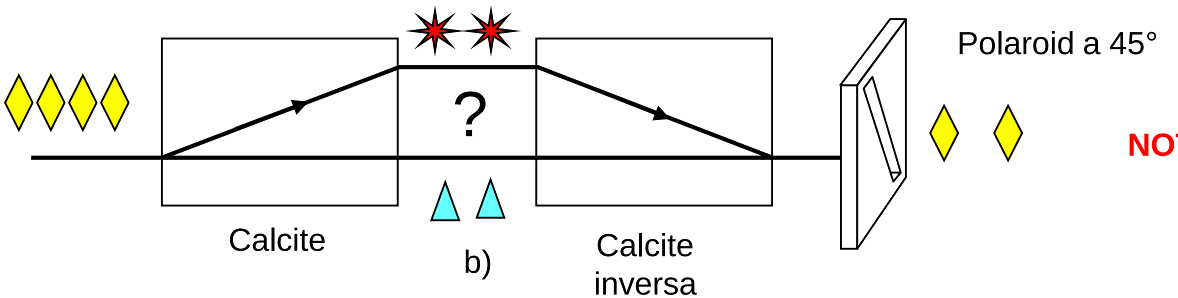
Outcomes: The photons can follow only the two considered path and they do not follow other paths!

Can we affirm that a single photon follows one of the two paths?

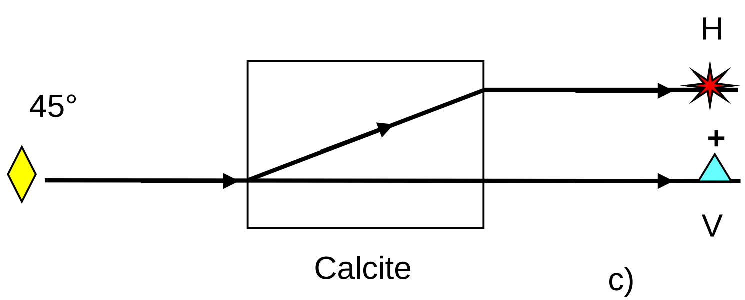
Figura 7

I can consider the ensamble of 45° polarized photons as a Union of 2 subensamble (with the same weight) of photons with vertical (Δ) and horizontal ( ) polarization.





NOT EXPERIMENTAL RESULT!



IN THE STATE OF SUPERPOSITION u+v

The single photon
DOES NOT FOLOW THE ORDINARY PATH
DOES NOT FOLLOW THE EXTRAORDINARY PATH
DOES NOT FOLLOWS BOTH PATHS
DOES NOT FOLLOW A DIFFERENT PATH

NO TRAJECTORY

NO LOCALITY

PROPERTY IN THE SUPERPOSITION STATE CAN BE KNOWN ONLY WHEN WE MEASURE IT

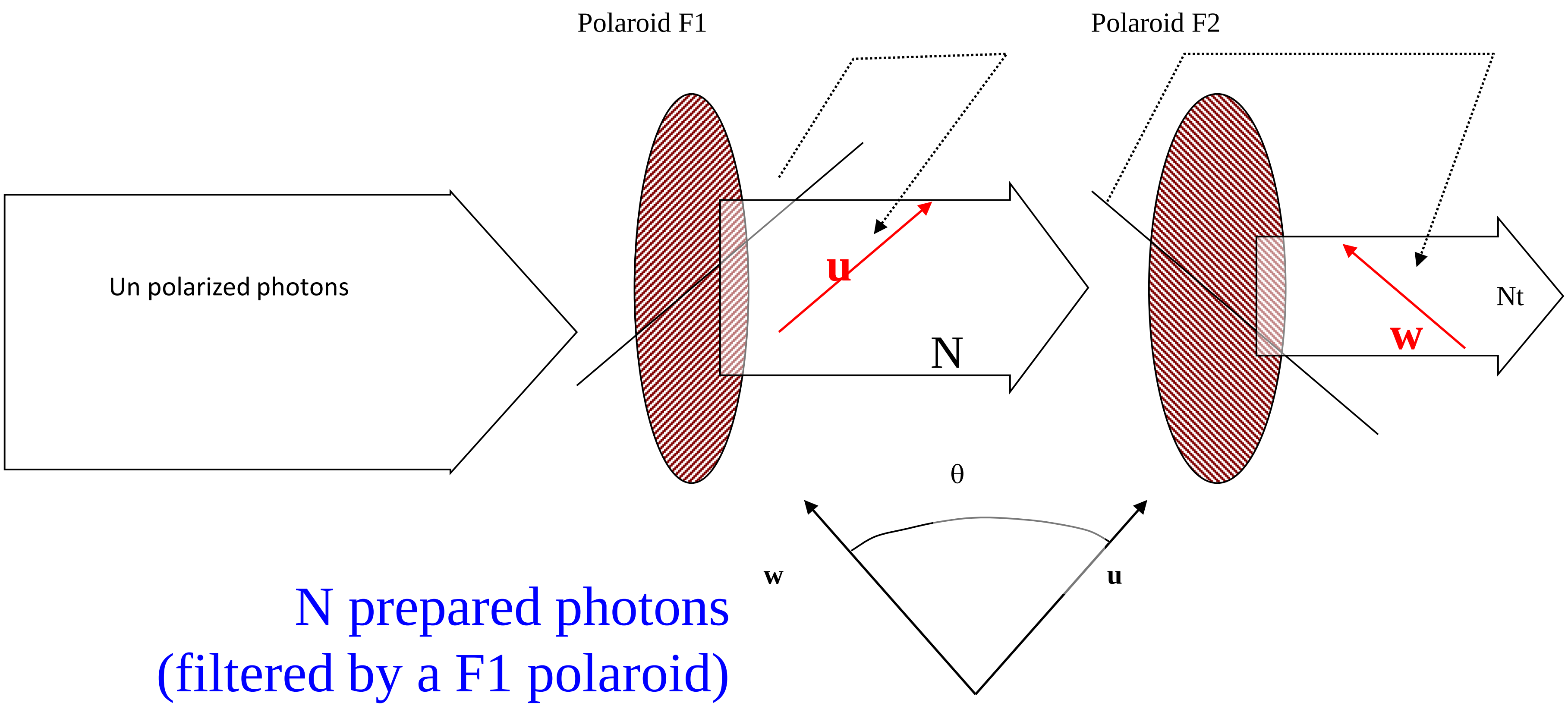
The quantum way of thinking

- A photon with ◊ property
  - cannot even have a property * **or** Δ

    The properties * and Δ are mutually exclusive.

- ***Uncertainty principle :*** **The property * or Δ (each one) is incompatible with the property ◊,** because corresponding to incompatible observables

- the interaction with a polaroid **produce the transition of a photon in a new state**
- **no trajectory can be attributed**
- no locality
- **the measure** of the corresponding property with **the polaroid** means to produce **a precipitation** of the system in those measured



N prepared photons
(filtered by a F1 polaroid)

Transition probability Pt:

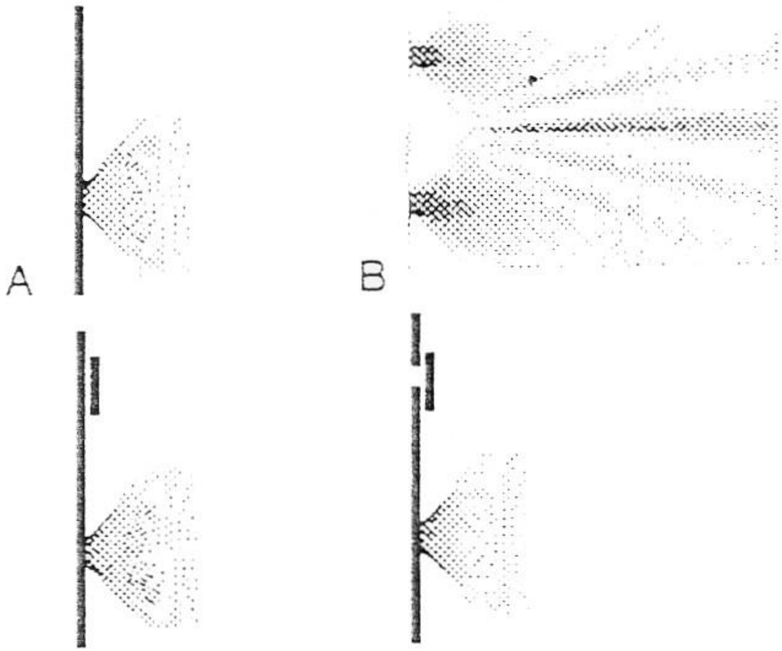
$$Pt = Nt/N = \cos^2\theta,$$

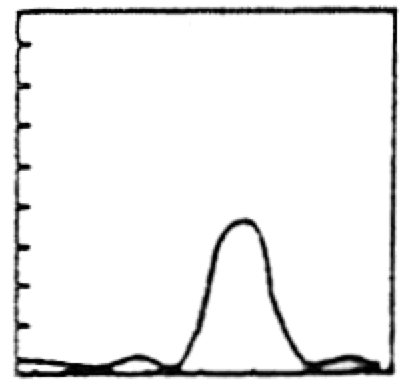
$$Pt = \cos^2\theta = (\mathbf{u} \cdot \mathbf{w})^2 \longrightarrow$$

Transition probability from state u to state w.

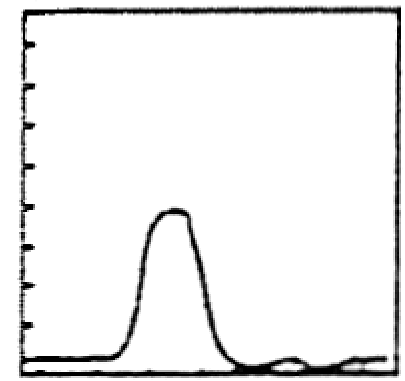
Figura 11

Two slit diffraction



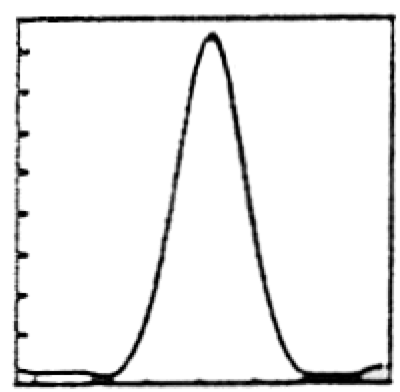


$[\psi_a]^2$

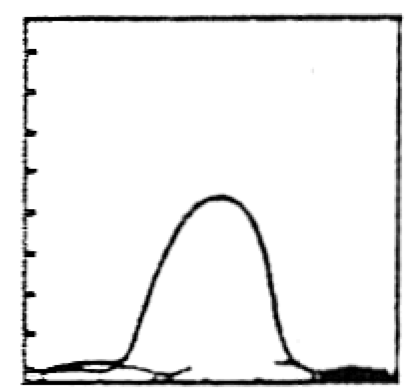


$[\psi_b]^2$

The comparison



$[\psi_a + \psi_b]^2$



$[\psi_a]^2 + [\psi_b]^2$

CONCLUSION
we cannot say that photons (material particles) pass one of the two slits

Uncertainty principle and indeterminism

photons polarized at 45°, i.e. in the state **u+v**,
they have neither the property of **u** state nor the property of **v**

Indeterminism

Results obtained from a measure of polarization along the directions H and V on photons polarized at 45° *are genuinely stochastic and not determined by pre-existing properties of the photon.*

Non locality

Two distant systems that have interacted in the past are generally found to be linked

Entagled state

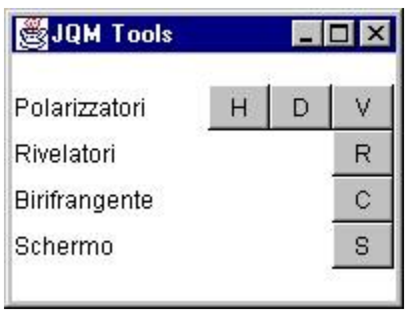
Description of macroscopic systems and the problem of measure

- If **u** and **v** correspond to macroscopically different states of a system, the states **u+v** does not correspond to the macroscopic properties defined by the system.
- **See: *Schrödínger's cat***
- **Quantum mechanics does not become classical at a macroscopic level.**

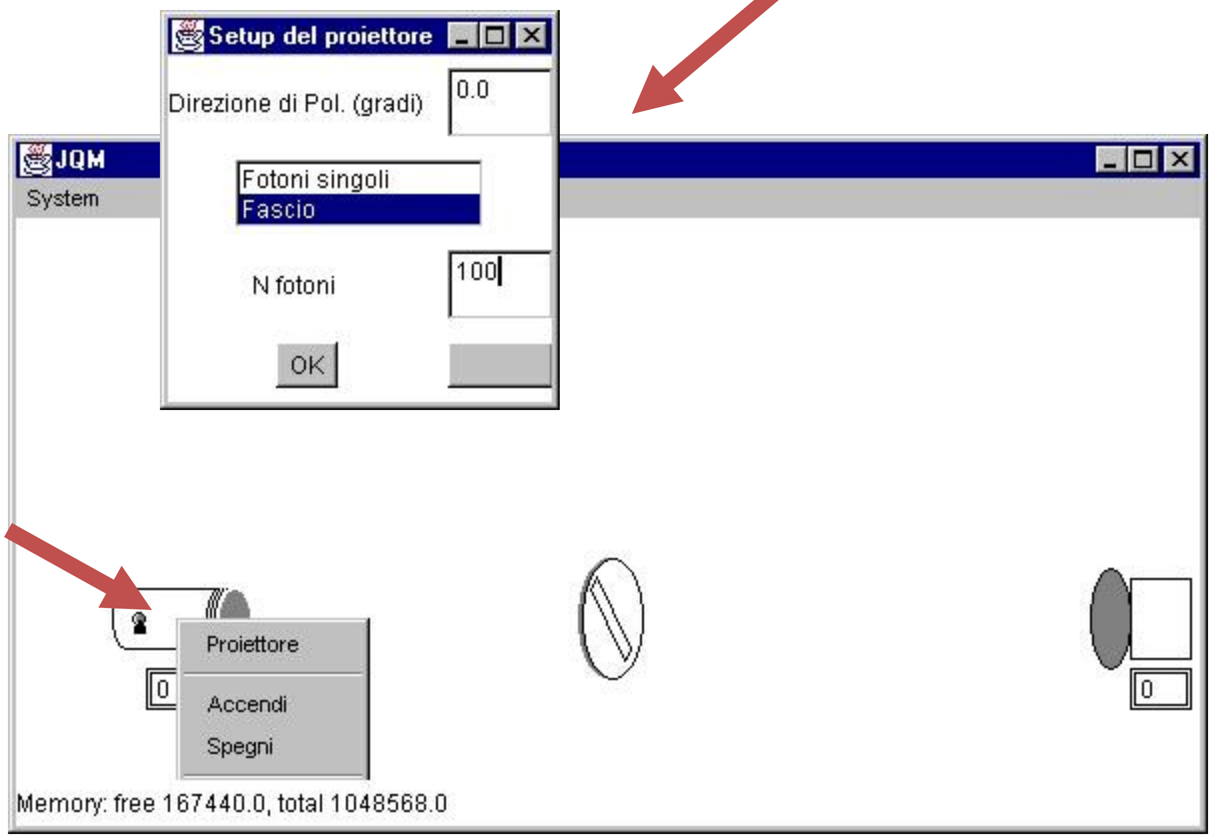
the applet

JQM

Differents objects are availabe



The acces to the properties of an instrument is by a menu (rigth click)



Università degli Studi di Udine

UNITÀ DI RICERCA IN DIDATTICA DELLA FISICA

SeCiF

In this context the Udine Research Unit has produced three web environments

SeCiF

Spiegare e Capire in Fisica

Università degli Studi di Udine

UNITÀ DI RICERCA IN DIDATTICA DELLA FISICA

[www.uniud.it/Cird/secif/]

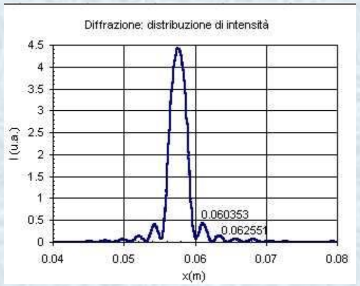
Primi passi nei fenomeni termici

Il cuscino di ottica

one on quantum mechanics for the secondary school

Elementi di crisi della fisica classica
Discussione e esperimenti

Awicinarsi alla teoria
della fisica quantistica



IDIFO Project (2006-2015)
PER contribution for
Innovation in Physics Education and Guidance

Piano Lauree Scientifiche

20 universities cooperating in

- Master for teacher formation on modern physics (QM + Rel + Stat + Solid state phys)
- Summer school for talent students
- Educational Labs, co-planned with teachers, to experiment innovation in the school

MASTER IDIFO4
162 cts articulated in clusters of 3cts courses on the following area for (60cts)

FM - Modern Physics

FCCS – Physics in contexts (in art, sport...)

RTL&M – Real time Labs and modeling

OR- Formative guidance

SPER – School experimentation

Offerta formativa istituzionale IDIFO4

Master Corso di Perfezionamento Singolo Corso

in

INNOVAZIONE DIDATTICA IN FISICA E ORIENTAMENTO

Piano Lauree Scientifiche

Corsi istituzionali in attuazione a quanto previsto nelle linee guida del PLS e nel Documento del Gruppo di lavoro per la Cultura Scientifica e Tecnologica "Proposte per un programma di sviluppo professionale in servizio dei docenti di discipline scientifiche", riportato all'indirizzo: http://www.pubblica.istruzione.it/argomenti/gst/allegati/sviluppo_discipline_scientifiche.pdf

OFFERTA FORMATIVA

MASTER M-IDIFO4 (60 cfu)
Un percorso biennale di 8 moduli caratterizzanti (24 cfu) pari a circa 200 ore, di 36 ore di sperimentazione (18 cfu) e 18 cfu per la Tesi finale

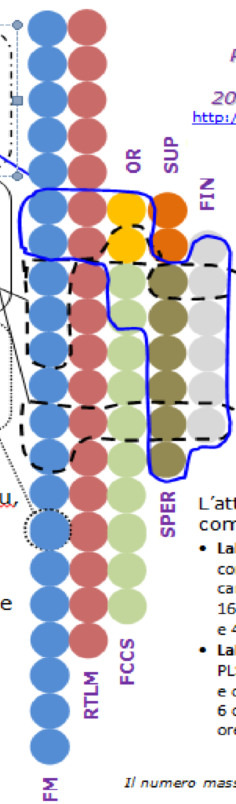
CORSO DI PERFEZIONAMENTO CP-IDIFO4 (18 cfu)
Un percorso annuale di 4 moduli (12 cfu~100 ore), 16 ore di sperimentazione e 3 cfu per prova finale (Project Work)

SINGOLO CORSO (3 cfu)
Può essere certificata la frequenza di un singolo corso del piano formativo effettuando l'iscrizione come uditore

Ciascuno può scegliere il percorso formativo in base alle proprie esigenze nell'ambito di 65 moduli, ciascuno di 3 cfu, organizzati nelle seguenti macroaree:

- **FM** - Fisica Moderna ed in particolare fisica quantistica e relativistica
- **RTLM** – Laboratori con sensori on-line e modellizzazione
- **FCCS** - Fisica in Contesti e Comunicazione della Scienza
- **OR**- Orientamento Formativo
- **SUPP** – Supporto alle attività
- **SPER** – Sperimentazione didattica a scuola
- **FIN** – Preparazione della prova finale

I moduli RTLM e parte di FCCS sono erogati in presenza, tutti gli altri in e-learning.



Il Progetto IDIFO4 è proposto nell'ambito del Piano Lauree Scientifiche (PLS) come iniziativa congiunta di 20 sedi universitarie e 3 sedi INFN
http://www.fisica.uniud.it/URDF/laurea/index.htm

Le sedi

L'attività didattica dei moduli formativi comprende:

- **Laboratori PLS** – Didattica Laboratoriale - comprensivi di 6-10 ore di formazione generale e caratterizzante, 4-6 ore di progettazione didattica, 16-8 ore di sperimentazione in classe con studenti e 4-6 ore di analisi dati e rielaborazione;
- **LabIDIFO4** – Laboratori di formazione insegnanti PLS - comprensivi di 14 ore di formazione generale e caratterizzante, 5 ore di progettazione didattica, 6 ore di sperimentazione in classe con studenti e 5 ore di analisi dati e rielaborazione.

Il numero massimo di iscritti al Master è di 30
Il numero massimo di iscritti al Corso di Perfezionamento è di 30

Informazioni e materiali del Master e del Corso di Perfezionamento sono reperibili agli indirizzi
http://www.fisica.uniud.it/URDF/laurea/index.htm

ISCRIZIONE E AMMISSIONE

Per l'iscrizione al M-IDIFO4 e al CP-IDIFO4 è richiesto un titolo di laurea magistrale o vecchio ordinamento. È prevista una riserva di posti distribuita sulle sedi universitarie proponenti.

BORSE DI STUDIO

Sono previste 15 borse da 1000,00 Euro cadauna a copertura dei costi di iscrizione al Master M-IDIFO4 e 15 borse da 500,00 Euro cadauna a copertura dei costi di iscrizione al CP-IDIFO4.

PER MAGGIORI INFORMAZIONI

Segreteria del Master e del Corso di Perfezionamento IDIFO4
CIRD - tel. 0432 558211
cird@uniud.it
DCFA – tel. 0432 558800

Materiali prodotti - Windows Internet Explorer

http://www.fisica.uniud.it/URDF/laurea/materiali/index.htm

Materiali prodotti

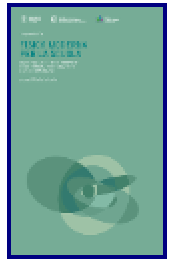
Master universitario di II livello in Innovazione didattica in Fisica e Orientamento - IDIFO

Università degli Studi di Udine

I materiali in rete telematica di IDIFO

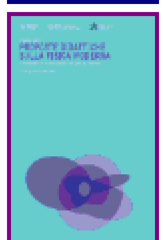
I libri

Fisica moderna per la scuola

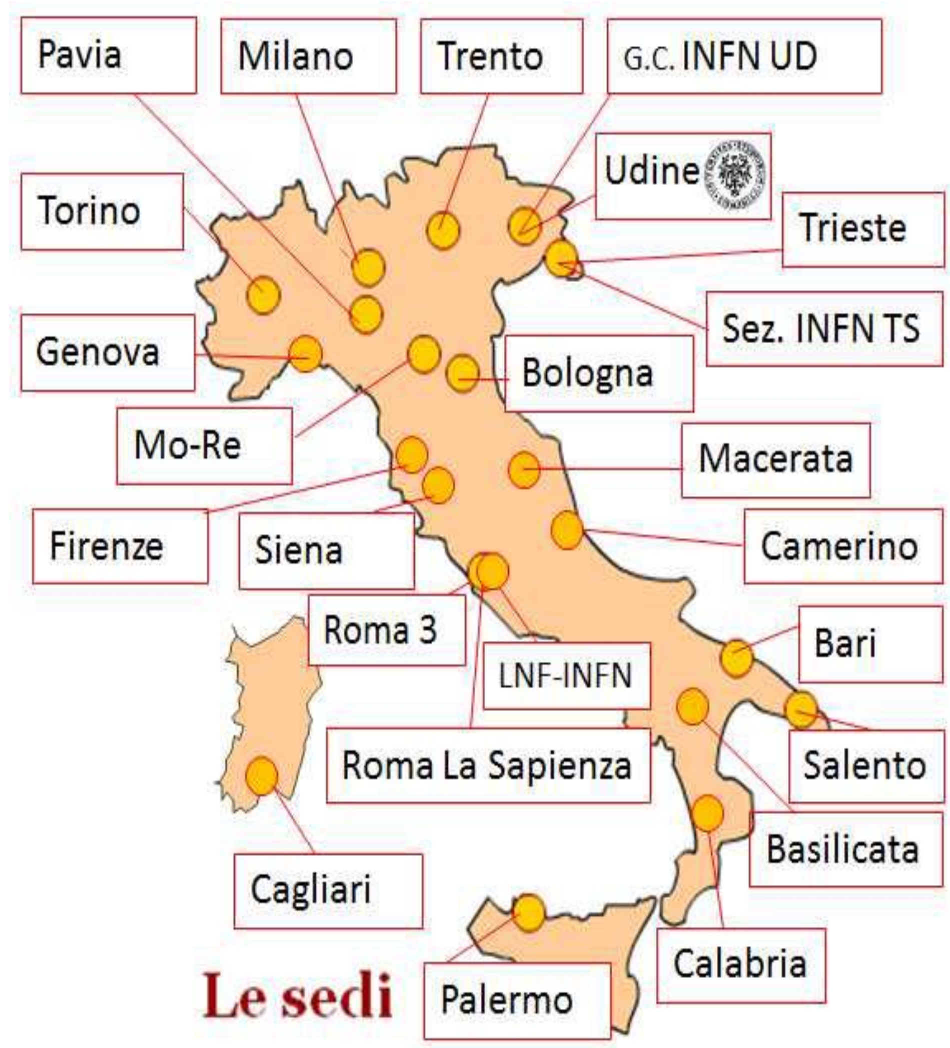


Formazione a distanza

Proposte didattiche sulla fisica moderna



[Home]



Research Experimentations on teaching/learning QM

Performed by teachers

	School	Site	Class	Years of phys	H per week	age	N Student	s.y.	h	Driver
1	Sci. Lic.	Pordenone	5-PNI	5	3	18	24	2001/2002	10	PT
2	Sci. Lic.	Pordenone	5-Brocca	3	2/3	18	11	2002/2003	10	PT
3	Sci. Lic.	Udine	5-PNI	5	3	18	28	2004/2005	8	PT
4	Sci. Lic.	Udine	5-Ord	3	2/3	18	29	2002/2003	10	PT
5	Sci. Lic.	Gemona	5-Ord	3	2/3	18	20	2002/2003	10	PT
6	Sci. Lic.	Pordenone	5-PNI	5	3	18	18	2002/2003	10	PT
7	Different	All Italy	4-5	3/5	3	17/18	25	2007	10	ST
8	Different	All Italy	4-5	3/5	3	17/18	25	2007	10	ST

Type of school	School of the students
City	Palce where the school is
Class	4 and 5 are the two last classes of the high school
Phys Y	Physics courses number of years
hours per week	Number of hour per weeek in the courses

Age	Student age
Students	Numbers of students involved in the experimentation
S.Y.	Schoolastic year when the experimentation was carried out
h	Number of hours of the experimentation
Driver	Who conducted the activity: Researcher (R) ; Prospective Teacher (PT); In Service Teacher (ST)

Research Experimentations on teaching/learning QM

	School	Site	Class	Years of phys	H per week	age	N Student	s.y.	h	Driver
1	Sci Lyc.	Udine	5 -PNI	5	3	18	21	1998/1999	10	R/T
2	Sci Lyc.	Udine	5/5PNI	3/5	2/3	18	17	2003/2004	12	R
3	Sci Lyc.	**Udine**	**5-Ord**	**3**	**2/3**	**18**	**22**	**2004/2005**	**11**	**R**
4	Sci Lyc.	**Udine**	**5-PNI**	**5**	**3**	**18**	**18**	**2005/2006**	**12**	**R**
5	Different	UD-PN-TV	4-5	3/5	3	17/18	40	2008	6	R
6	Different	All Italy	4-5	3/5	3	17/18	42	2009	8	R
7	Different	All Italy	4-5	3/5	3	17/18	41	2011	6	R
8	Sci Lyc.	Crotone	5	3/5	3	17/18	22	2012	8	R
9	Sci Lyc.	Crotone	5	3/5	3	17/18	30	2013	8	R
10	Tec Schoo	Tolmezzo	4	2	2	17	16	2013	10	R/T
11	Different	All Italy	4-5	3/5	3	17/18	36	2013	6	R
12	Different	All Italy	4	3/5	3	17/18	30	2014	6	R
13	Sci Lyc.	Crema	5	5	3	18	25	2014	8	R
14	Sci Lyc.	Ancona	5	5	3	18	27	2014	8	R

Type of school	School of the students
City	Palce where the school is
Class	4 and 5 are the two last classes of the high school
Phys Y	Physics courses number of years
hours per week	Number of hour per weeek in the courses

Age	Student age
Students	Numbers of students involved in the experimentation
S.Y.	Schoolastic year when the experimentation was carried out
h	Number of hours of the experimentation
Driver	Who conducted the activity: Researcher (R) ; Prospective Teacher (PT); In Service Teacher (ST)

MQ - Some research results

DATA from (2000-2008): 15 schools – 18 years old stu. – 8-12 hours of experimentation with tutorial or worksheet and test in- out- / 250 students

- Students
  - appear to be **familiar** with
    - The **meaning of interaction of photons with polaroids** (80-90%) and less with calcite cristals (70%)
    - **quantum state** (70%) with respect to **classical state** (40%)
  - have **difficulties to abandon the classical idea of pre-existing properties to be able to do a prevision** (40%)
  - are **able to explicit consequences only when they have in the hands the formalism** (70%)

Research results

- Student **profit of the iconographic proposal** and **discuss in a proper way** on
  - **mutual exclusive properties** (80%) and
  - **incompatible properties** (55%)
- **the employ of**
  - **the iconographic representation and**
  - formalism facilitate reasoning in the framework of QM
- The **rigorous reasoning** proposed promote
  - the spontaneously used in new contexts (50%)
  - the construction of a coherent framework (80%), even if in other perspective

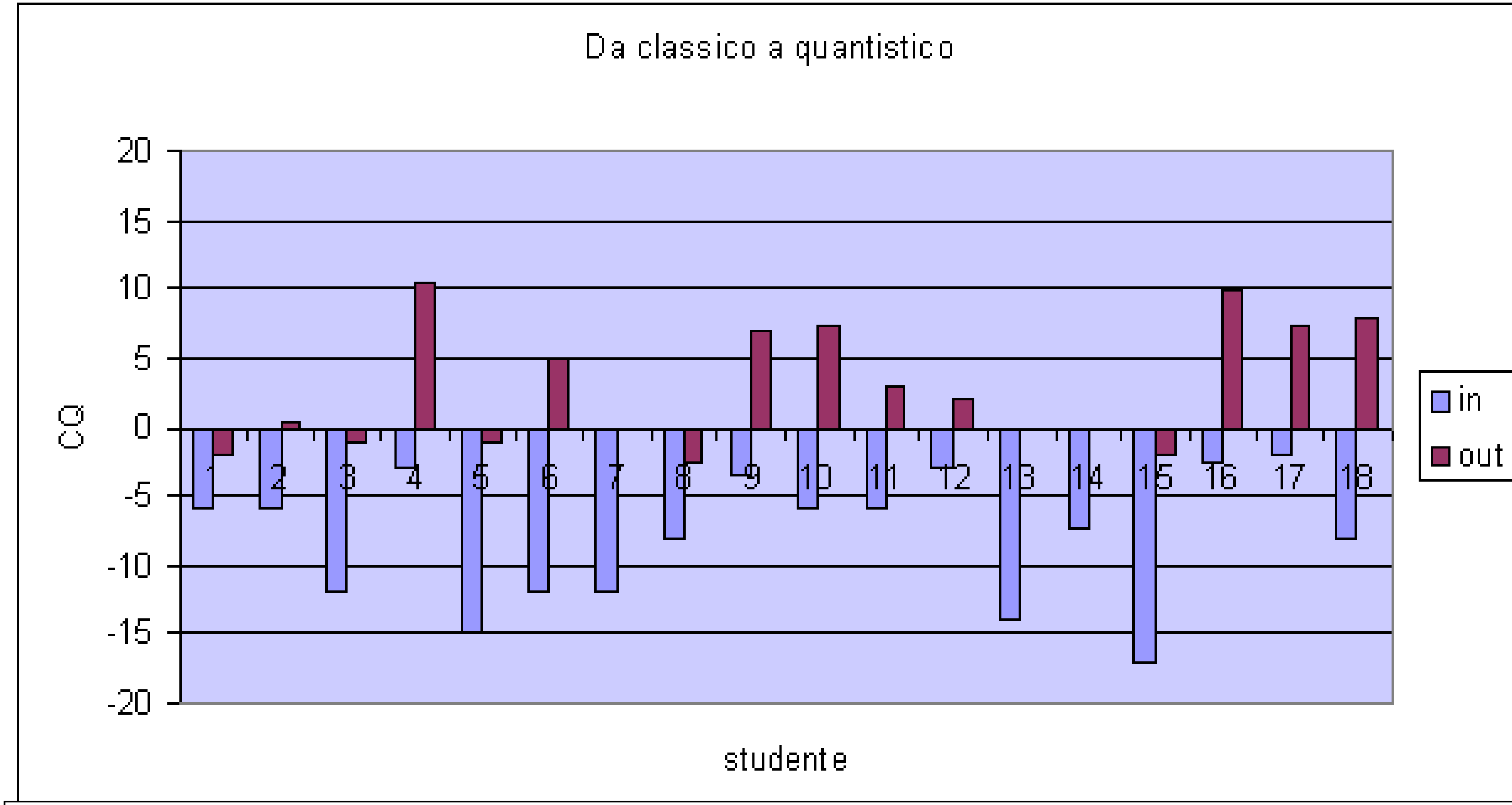
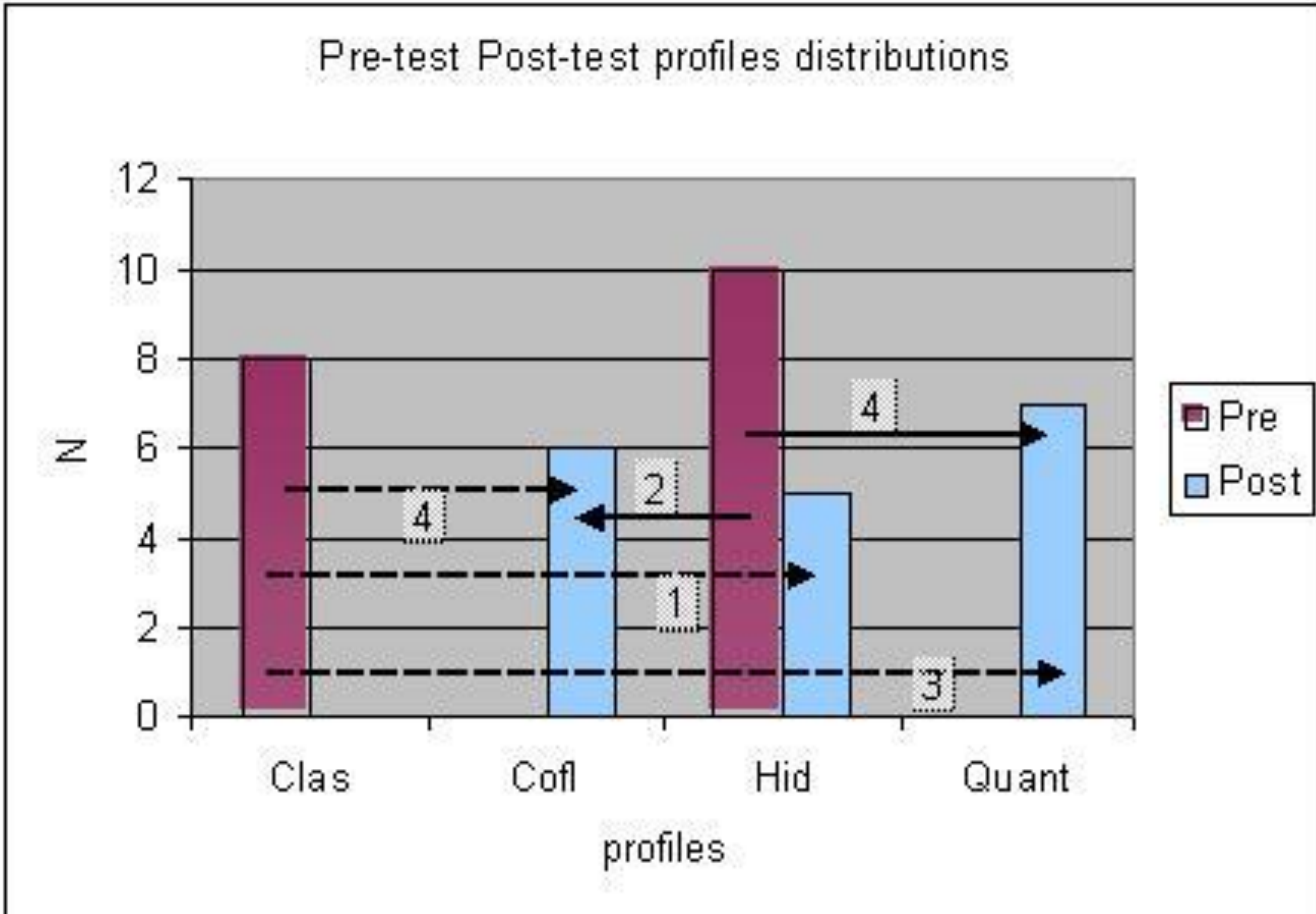


Fig.1

QC index (calcolated according with Müller, Wiesner 2002) for pre-test (IN) and post-test (OUT) (QC>0 quantum mechanics ideas; QC<0 classical ideas)



Pre-test Post-test profiles distributions
12
10
8
6
4
2
0
N
4
2
4
1
3
Clas
Cofl
Hid
Quant
profiles
Pre
Post

FINE MQ PATH

ATTENTION IS PAID TO

- Identify **strategic angles** and **critical details** used by common knowledge to interpret phenomenology (Viennot, 1994)
- Study spontaneous dynamical path of reasoning (Michelini 2010).
- Find new approaches to physics knowledge (Viennot, 1994; 2003; McDermott, 1993-2006; Michelini 2010).
- Avoiding the reductionism to offer opportunities of:
  - Learning and not only understanding of information, interpretative solutions and results (to become able to manage fundamental concepts)
  - competences of instruments and methods

CONCLUSION

Our research contribution is on content-based reseach and conceptual understanding in the perspective of learning progression with empirical research to study learning trajectories, appropriation and kind of reasoning

The building of formal thinking involve

- **CLOE labs**
    - **Methodological spects**
    - **New tools (objectual models)**
- **ICT**
- **MODERN PHYSICS**
    - **The building theoretical thinkingn**
    - **Foundation of theoretical thinking: MQ**

Crucial aspects considered are:

- Basic knowledge in physics for the foudation of the new interpretations
- Phenomenological analogies to evidence in interpretation
- Formalism to be adopted
- Avoiding to the reductionism to offer opportunities of:
  - Learning and not only understanding of information, interpretative solutions and results (to become able to manage fundamental concepts)
  - competences of instruments and methods

GOALS of our proposal

To build theoretical thinking according with Dirac formulation of QM

@ First steps towards:

- **a sintetic vision of QM**
- **the formalism on the backgroud.**

STRUCTURE: IN TWO PARTS

@ Introduction to the ideas of QM starting from the superposition principle on phenomenological base: the polarization of photons interacting with polaroids and birefrangent crystals

@ Gradual building of the formalism, discussing concepts on formal plane

The following interpretative hypotesis
for ◊ property and **(u+v) photon state**

- **HP1**: It could be thought as an ensamble of photons constituted by a **statistical mixture** (* and Δ).
- **HP2**: It could be thought as an ensamble of photons which have **simultaneouly two properties, with the same weight**

Are discussed considering
The interaction of **45° polarized photons with polaroids**
Having H and V permitted direction and than with one with 45° permitted direction
to put in evidence that

◊ ◊ ◊ ◊ **u+v**	≠	* * Δ Δ **u∪v**

and to introduce **Incompatible properties**

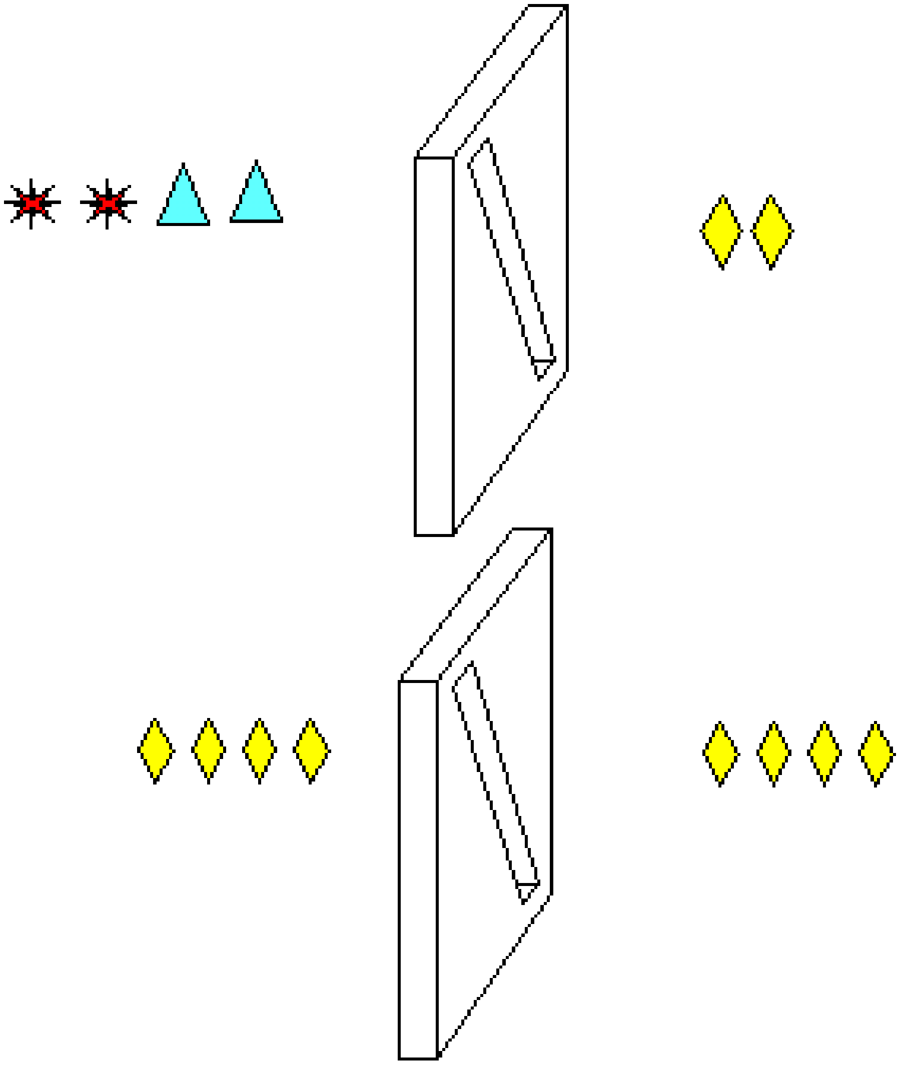
The following interpretative hypotesy for photons having ◊ property and **(u+v) state**

- **HP1**: It could be thought as an ensamble of photons constituted by a **statistical mixture** (***** and **Δ**)

This HP1 is discussed on experimental prevision plan

to evidence that

◊ ◊ ◊ ◊ **u+v**	≠	* * Δ Δ **u∪v**



The following interpretative hypotesis
for ◊ property and **relative photon state**

- **HP1**: It could be thought as an ensamble of photons constituted by a **statistical mixture** (***** and **Δ**).
- **HP2**: It could be thought as an ensamble of photons which have **simultaneouly two properties, with the same weight**

Are discussed considering
The interaction of **45° polarized photons with polaroids**
Having H and V permitted direction and than with one with 45° permitted direction
to put in evidence that

◊ ◊ ◊ ◊		* * Δ Δ
$\mathbf{u+v}$	$\neq$	$\mathbf{u \cup v}$

and to introduce **Incompatible properties**

The following interpretative hypotesis for photons having ◊ property and **(u+v) state**

HP2: It could be thought as an ensamble of photons which have **simultaneouly two properties, with the same weight**

This HP2 is discussed considering

The interaction of

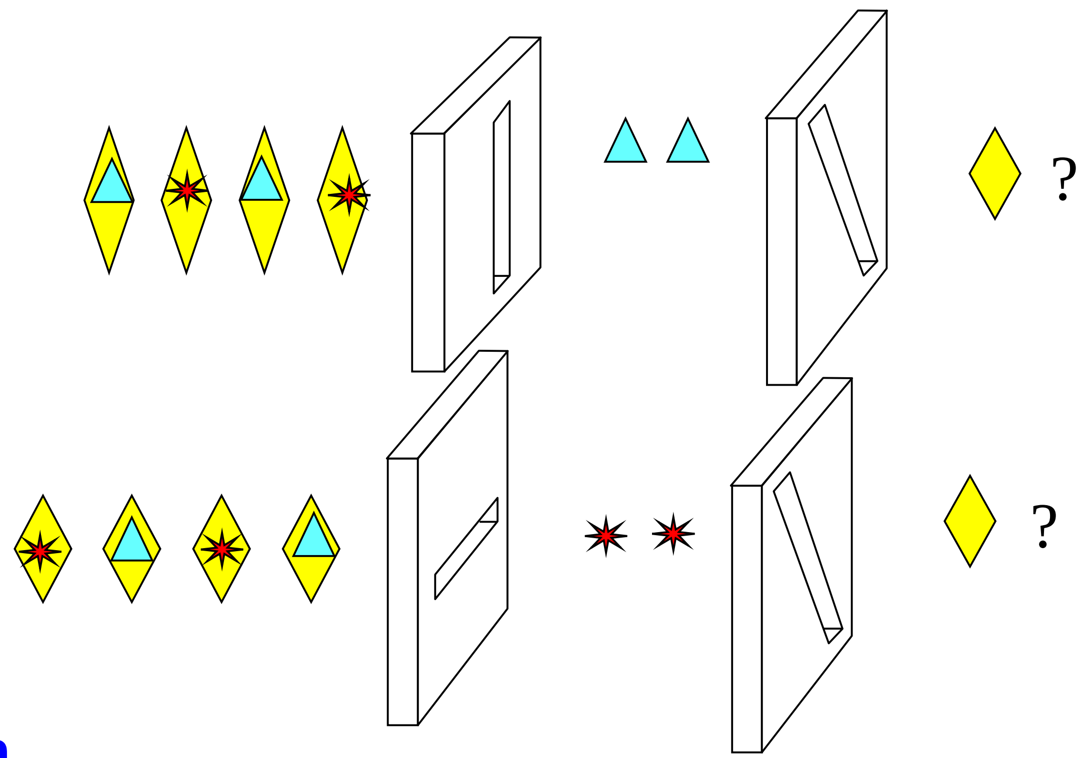
45° polarized photons

with polaroids

- **having H or V permitted direction**

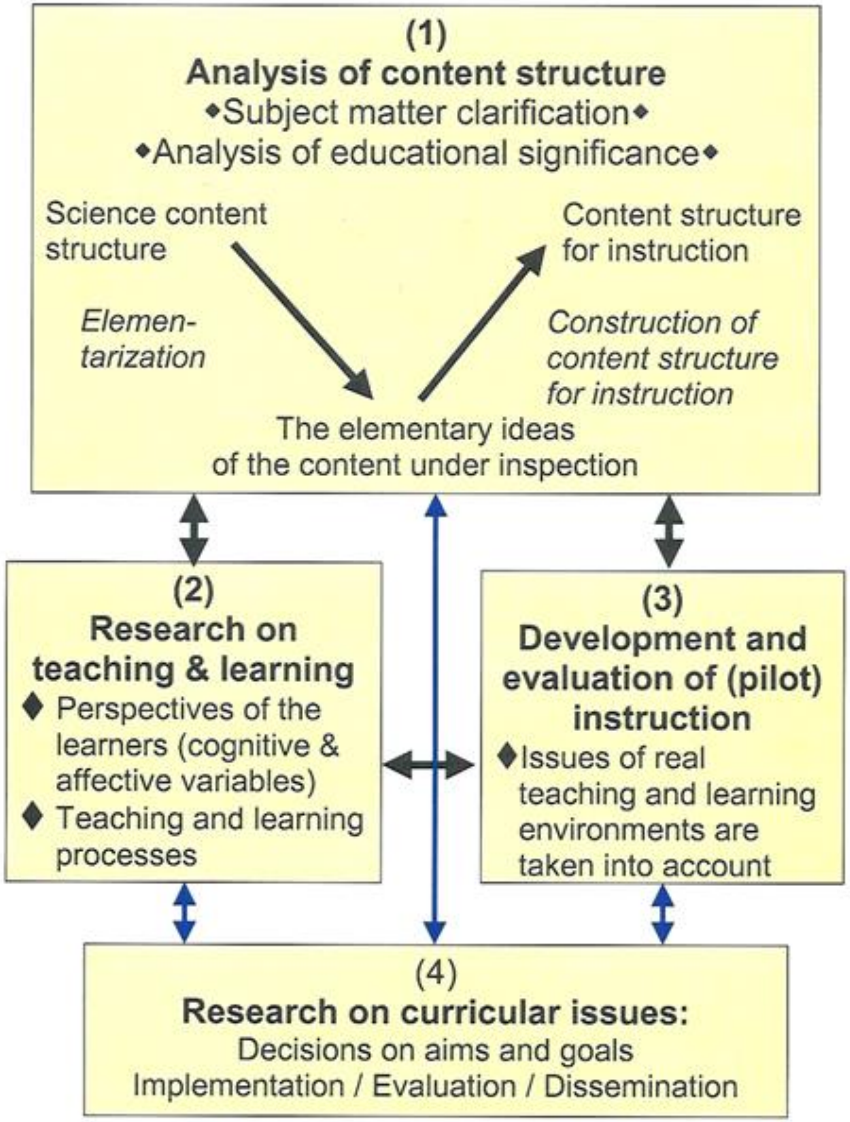
  and than with a polaroid having

- **45° permitted direction**



to exclude it and to introduce **Incompatible properties**

Domains of Science Education Research



(1) Analysis of content structure
Subject matter clarification
Analysis of educational significance

(2) Research on teaching and learning
Students‘ perspectives
Teachers‘ views
Teaching & learning processes

(3) Development and evaluation of instruction / Instructional design
Intimate link between R & D

(4) Research on curricular issues and science education policies

Duit R, Girep 2008

Theoretical framework

The Model of Educational Reconstruction

Reinders Duit 2006

MRE structure

A. Analysis of the structure of content

- **A1. Clarification of the subject:**
  - **A1.1 - text books and key publications**
  - **A1.2 - Historical development of ideas**
  - **A1.3 - Conceptions and Ideas of children**
- **A2. Analysis of educative significance**

B. Research on Teaching and Learning (T/L)

C. Development of

- **materials and related research activities**
- **T/L with new methods.**

Physics Education Research

in Udine University

The building of formal thinking in our researches

is in 3 directions

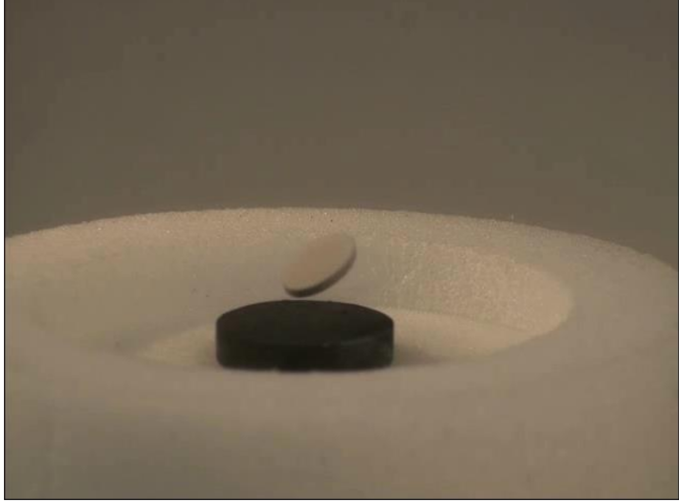
1. **Informal Learning, Learning processes and role of:**
    1. **Operativity: hands-on & minds-on to interpret phenomena**
    2. **Objectual models: tools to bridge common sense to physics ideas**
2. **ICT contribution: RTL & modeling**
3. **MODERN PHYSICS - Building theoretical way of thinking: a path inspired of Dirac approach to QM**

EXAMPLE - Exploring Meissner effect

When the YBCO is at LN(77K) -> it interacts with the magnet

→ Levitation occur

- the magnet is repulse by the cooled YBCO
- It oscillate around the equilibrium position



2 questions are posed:

- Describe/ explain the Meissner levitation
- Argue and interprets the phenomenology

[sample 2 classes 15+16 students – 18yo]

Describe/explain the Meissner levitation of a magnet over a YBCO disc at T=TNL

- 27/31 change in the magnetic properties of YBCO,
  - *YBCO become "magnetic" (4)*
  - *YBCO becomes diamagnetic*
  - *The levitation observed indicates that the properties of YBCO are are changed. (not those of the magnet who do not change behaviour changing temperature)*
  - *As the effect is repulsive it follows that it has become diamagnetic diamagnetic*
  - *There is a re-arrangment at micro level*

  -4/27 – added that *YBCO repels the magnet with a force that is equal to the weight force*
- 6/27 - change in the electric properties
- 4/31 remains at descriptive level (*YBCO repels the magnet*)

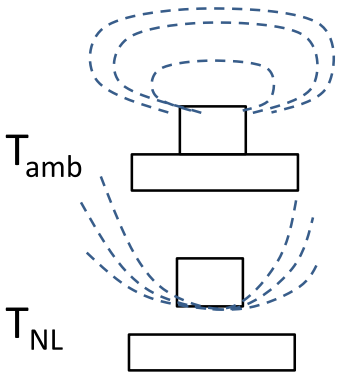
note

LOCAL INTERPRETATIONS LOOKING TO SINGLE ASPECTS

NO EXPLANATION CONNECTING ASPECTS

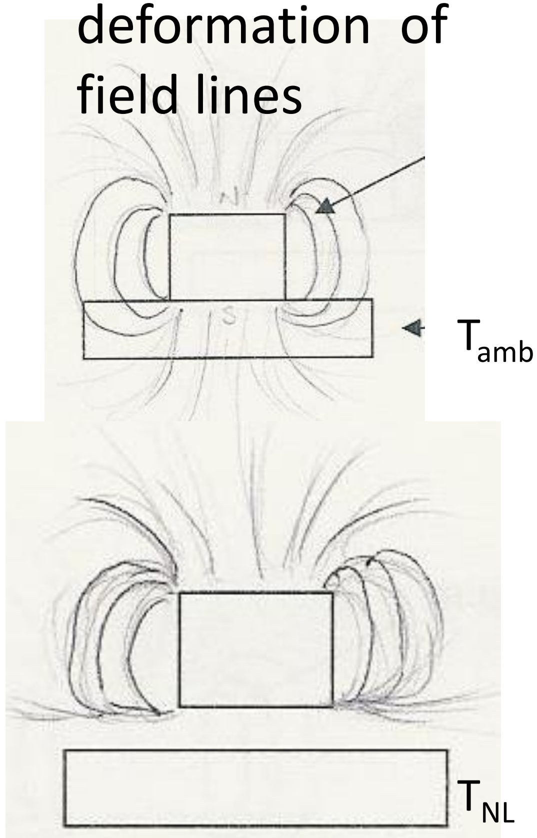
Argue and interprets the phenomenology

The new magnetic (diamagnetic) property of YBCO is associated to a representation by means of field lines

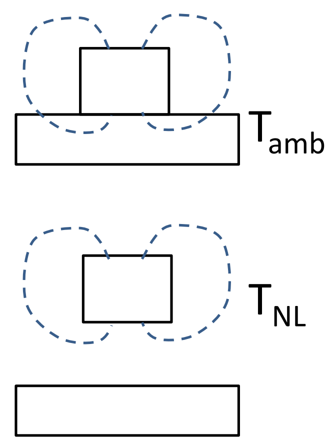


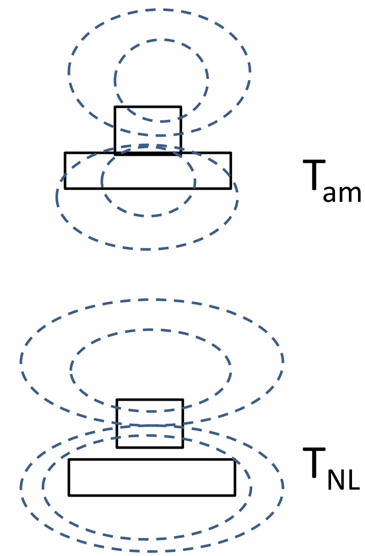
11% Repulsion of field lines

25% local deformation of field lines



13% no field deformation , but distancing the same pattern





11% field lines are no more penetrating in YBCO

Magnetic field representation as gobal result

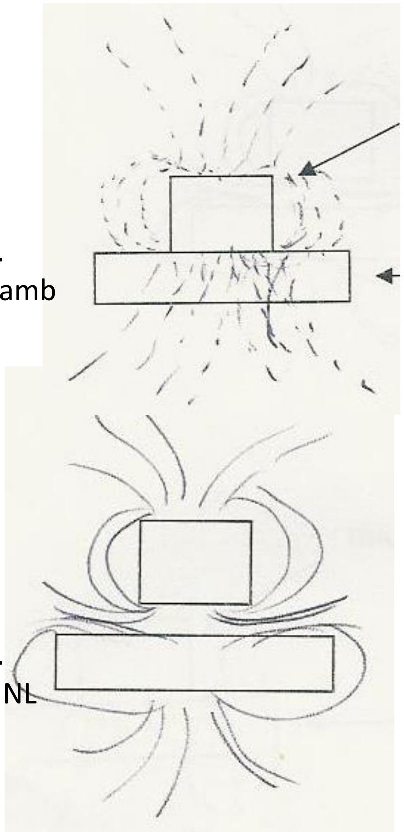
55% → the field lines do not penetrate the Ybco if T<TNL

Argue and interprets the phenomenology

The new magnetic (diamagnetic) property of YBCO is associated to a representation by means of field lines

T_{amb}

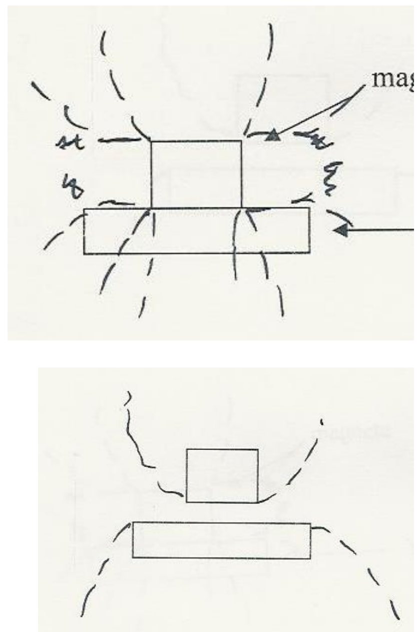
T_{NL}



7% SUSPENSION LIKE

T_{amb}

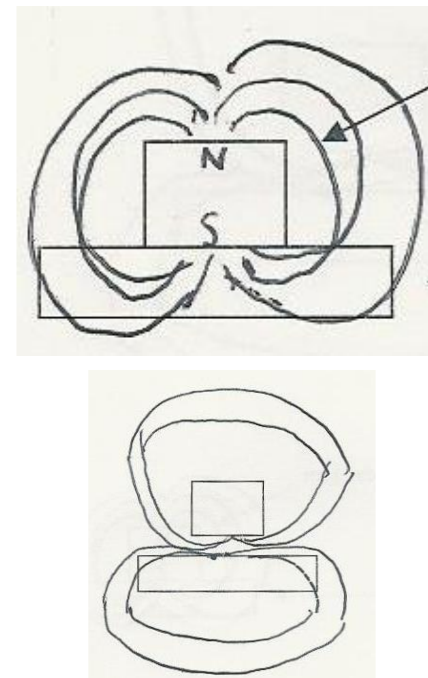
T_{NL}



13% SUSPENSION LIKE

T_{amb}

T_{NL}



20% ROTATION

40% ***the YBCO produces a field*** **(model magnet/magnet)**

Summary of the results

Field line representation offers

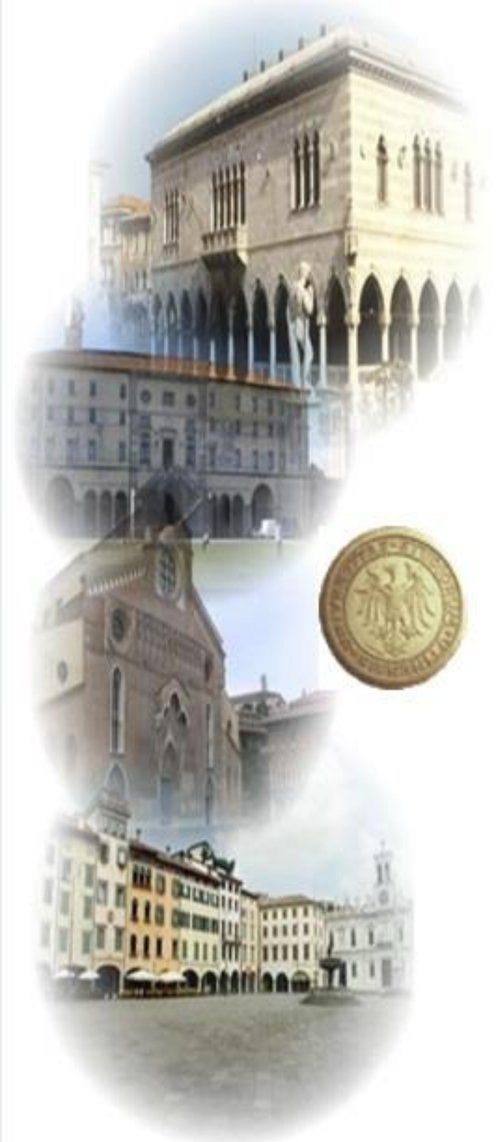
- the clarification on:
  - The Nature of magnetic field and peculiar properties
  - The Distinction between
    - **B** and **F**
    - magnetic and electric phenomena
- **the operative definition of the flux and its physics meaning**
- The field line representation is a conceptual referent used to:
  - esplain the levitation (93%, but 1/3 following the magnet magnet repulsion scheme) in Meissner effect
  - identify the peculiarity of YBCO (B=0) (63% in the rappresentation, 66% in the explanations) in Meissner effect
  - Individuate a transition in the magnetic properties of ybco: para->diamagnetic

conclusion

- Field line representation in e-m and SC phenomena is
  - the first level of the formal representation of quanties characterizing magnetic field
  - a conceptual tool for developing formal thinking
  - a mediator in mathematisation process, producing the link between math and physics meaning
- Developing formal thinking in e-m (as in mechanics and TD) is a gradual process which require **direct involvent of students in**
  - Local level simple phenomena explanation and
  - Finding interpretative bridges on key experimental situations
  - building global representation tools
  - Use of math relationships for the interpretation, strong linked with representation tools
- For a research oriented to practice **we need to put attention to students' way of thinking** in a research process, MER like, **integrating DBR** with **ER and including R&D**

Physics Education Research

Our main research fields



1. Innovation in physics Teaching and Learning (T/L)

2. Methodological aspects in learning physics

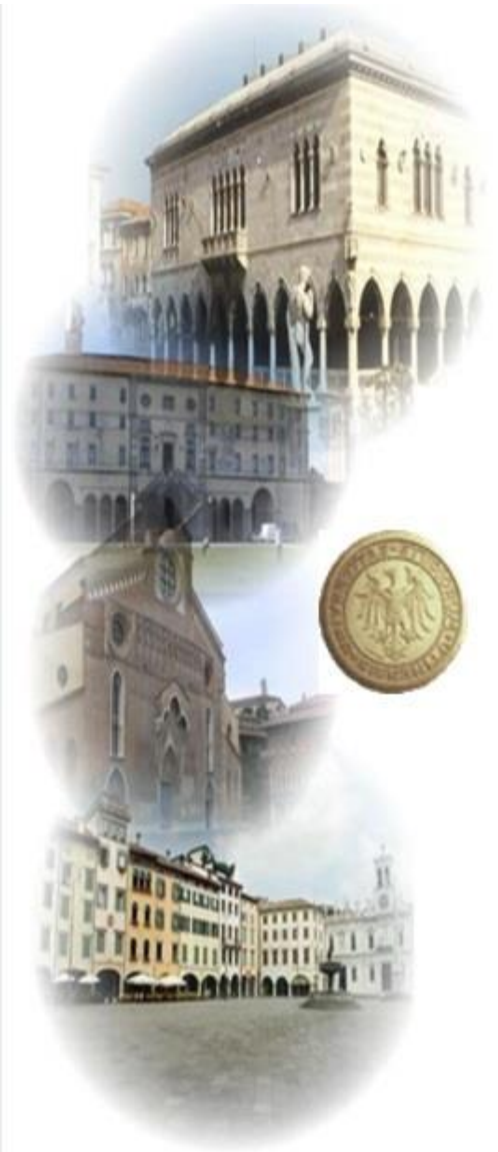
3. Informal learning

4. Teacher Education

Physics Education Research

Our main research fields

1. Innovation in physics Teaching and Learning (T/L) by means



- **R&D** research and development methods:
- **New topics**: Moessbauer Effect, QM, Superconductivity, Mass-Energy path, background physics in research methods (RBS, TRR, Electrical Transport Properties of materials…)
- **New hw&sw systems**: modelling environments, ideal experiments in QM, sensor on –line hw&sw systems via USB (4 point Temperature measurements, Light intensity-position measurements, R&H measurements)

- **Paths for learning progression** by means of **DBR** and research based ***intervention modules in vertical perspective*** on: motion-mechanics, fluids, thermal phenomena, energy, sound, electromagnetic phenomena, light

Physics Education Research

Our main research fields

2. Methodological aspects by means of empirical research and conceptual change approach, mainly on the role of:

- the ICTs in overcoming concept
- Representation in physic ation and in macro-mic
- Exploratio
- CLO E
- Ro
- **the g,**

3. Infor g

Spont ous models and reasoning

the role for learning of games, playing, planning

4. Teacher Education: pre-in service models (PPT)

Mutual fertilization of the different kind of researches produce research based proposals for teaching / learning physics and proposals for teacher education