

# *Impact of particle physics on Education*

*Pasquale Di Nezza*  
(Laboratori Nazionali di Frascati)



INFN starts thinking systematically at divulgation and dissemination, formation, and public engagement about 20 years ago

It is not by chance that this starts at the Frascati National Laboratories (LNF), an accelerator science center, and “the” particle physics laboratory of INFN

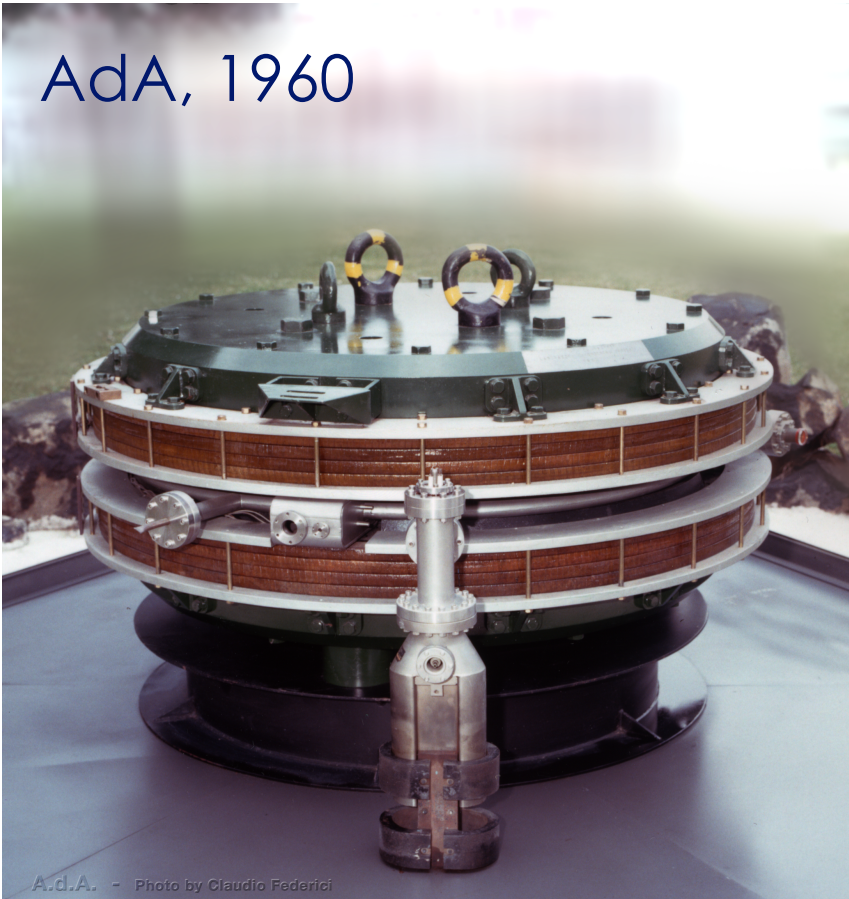


# The context

The Laboratori Nazionali di Frascati (EPS historical site) are the place where the colliders were born



AdA, 1960

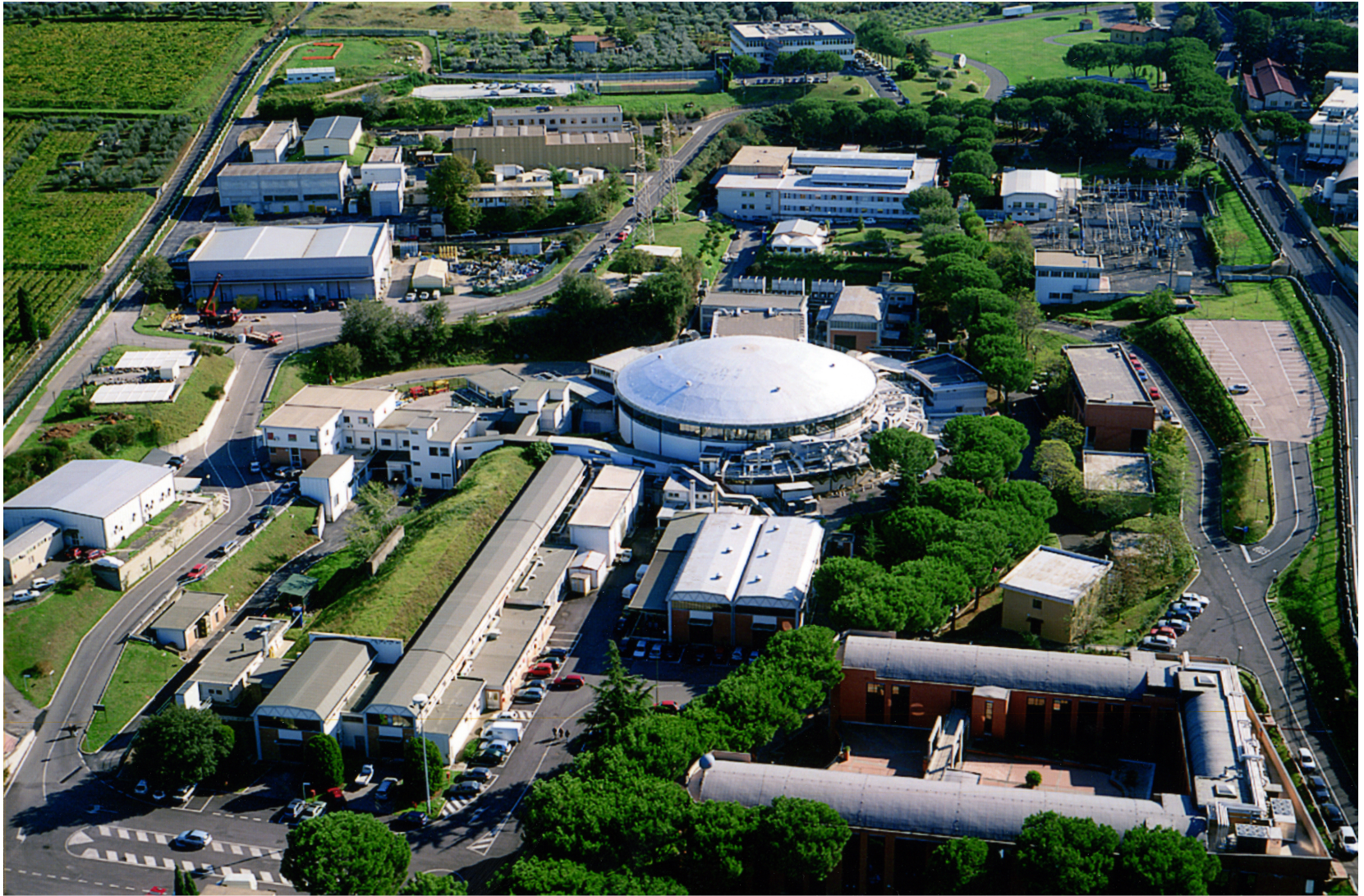


A.d.A. - Photo by Claudio Federici

B. Touschek



60 years later



The Laboratories have a clear and compelling strategic educational activity directly linked to their mission and vision

# The vision

Particle Physics educational programs are used to:

- enrich scholarship
- create knowledge
- create a scientific consciousness
- prepare educated, engaged, students (citizens)
- develop coordination and capacity building



# Methods

## ... scaffolding

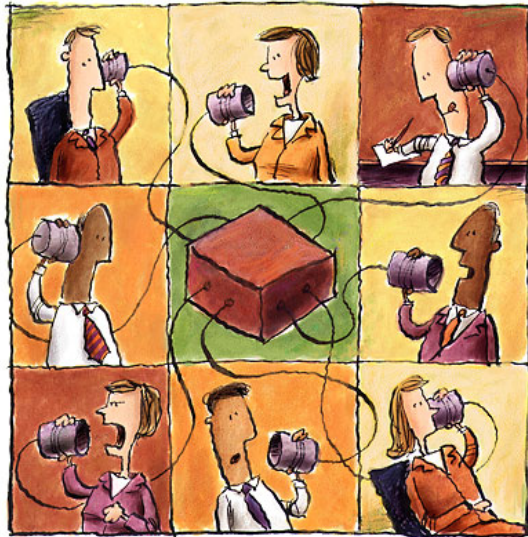


Communicate shifting the learning responsibility to the audience

- Cooperative learning
- Peer education

# Methods

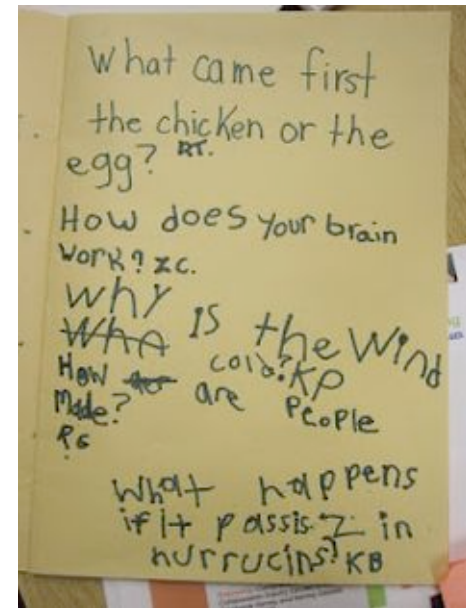
## ... scaffolding



Communicate shifting the learning responsibility to the audience

- Cooperative learning
- Peer education

- Team working (+experts)
- Compare and discuss results
- Respect rules and safety rules
- Compare different education systems around the world



...inquiry-base  
...hands-on

# The educational programs



• Winter stage in Italian (9 x 4h)	110 participants
• Winter stage in English (1 week)	50
• Masterclasses (1 week)	60
• Summer stage (2 or 3 weeks)	120
• Incontri di Fisica - Meetings for Physics (3 days)	300
• Matinee + experiment (7 x 1 morning)	120
• Divulgation Seminars (10 /yr)	300
• Physics Lessons (10 x1 afternoon)	200
• <i>School-Work Alternation</i> (80 h per student)	
• <i>e-learning portal (LifeLongLearning)</i>	



# The educational programs



- Winter stage in Italian (9 x 4h) 110 participants
- Winter stage in English (1 week) 50
- Masterclasses (1 week) 60
- Summer stage (2 or 3 weeks) 120
- Incontri di Fisica - Meetings for Physics (3 days) 300
- Matinee + experiment (7 x 1 morning) 120
- Divulcation Seminars (10 /yr) 300
- Physics Lessons (10 x1 afternoon) 200
- *School-Work Alternation* (80 h per student)
- *e-learning portal (LifeLongLearning)*
  
- Formation paths in high schools of the territory
- Guided tours including a seminar ~3000
- Open day (once a year) ~2500 (+110 students)
- European Research Night ~500
- Career day

Many of these initiatives are on streaming and on the LNF  
YouTube channel

# Stage for students

	2000	2001	2002	2003	2004	2005	2006	2007	...	2016
N. Students IV e V year of high school	12 F=1 M=11	14 F=3 M=11	57 F=15 M=42	56 F=11 M=45	114 F=34 M=80	154 F=42 M=112	161 F=48 M=113	163 F=45 M=118	...	411 F=157 M=254
N. School Institutes	1	1	8	14	21	29	46	51	...	131
INFN Tutors	7	14	50	22	25	56	58	55	...	85

# Stage for students

	2000	2001	2002	2003	2004	2005	2006	2007	...	2016
N. Students IV e V year of high school	12 F=1 M=11	14 F=3 M=11	57 F=15 M=42	56 F=11 M=45	114 F=34 M=80	154 F=42 M=112	161 F=48 M=113	163 F=45 M=118	...	411 F=157 M=254
N. School Institutes	1	1	8	14	21	29	46	51	...	131
INFN Tutors	7	14	50	22	25	56	58	55	...	85

## The selection method

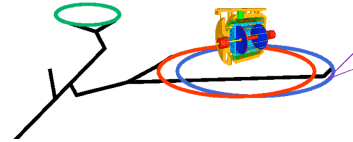
It is quite simple:

- a call is sent around and published on web
- schools send maximum 2-3 candidates per institute supporting them with reference letters
- we stop when the available positions are saturated

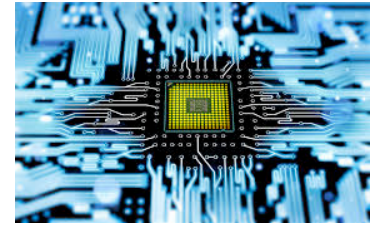
# A representative list of the HEP activities

- Beam Tests at the Facility
- Measurements at Synchrotron Light source
- Slow Control by Arduino
- Electronic circuits for HEP: Planck constant
- SiPM and scintillator materials
- Cloud chamber construction
- Cosmic Ray detection and  $\mu$  speed calculation
- $D^0$  life time measurement through LHCb data
- Theory: Modern Physics

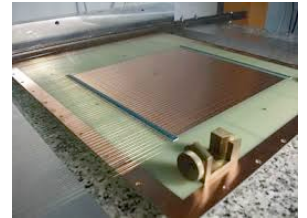
accelerators



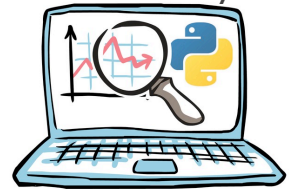
electronics



detectors



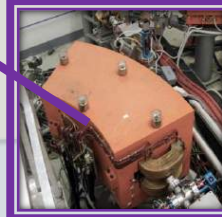
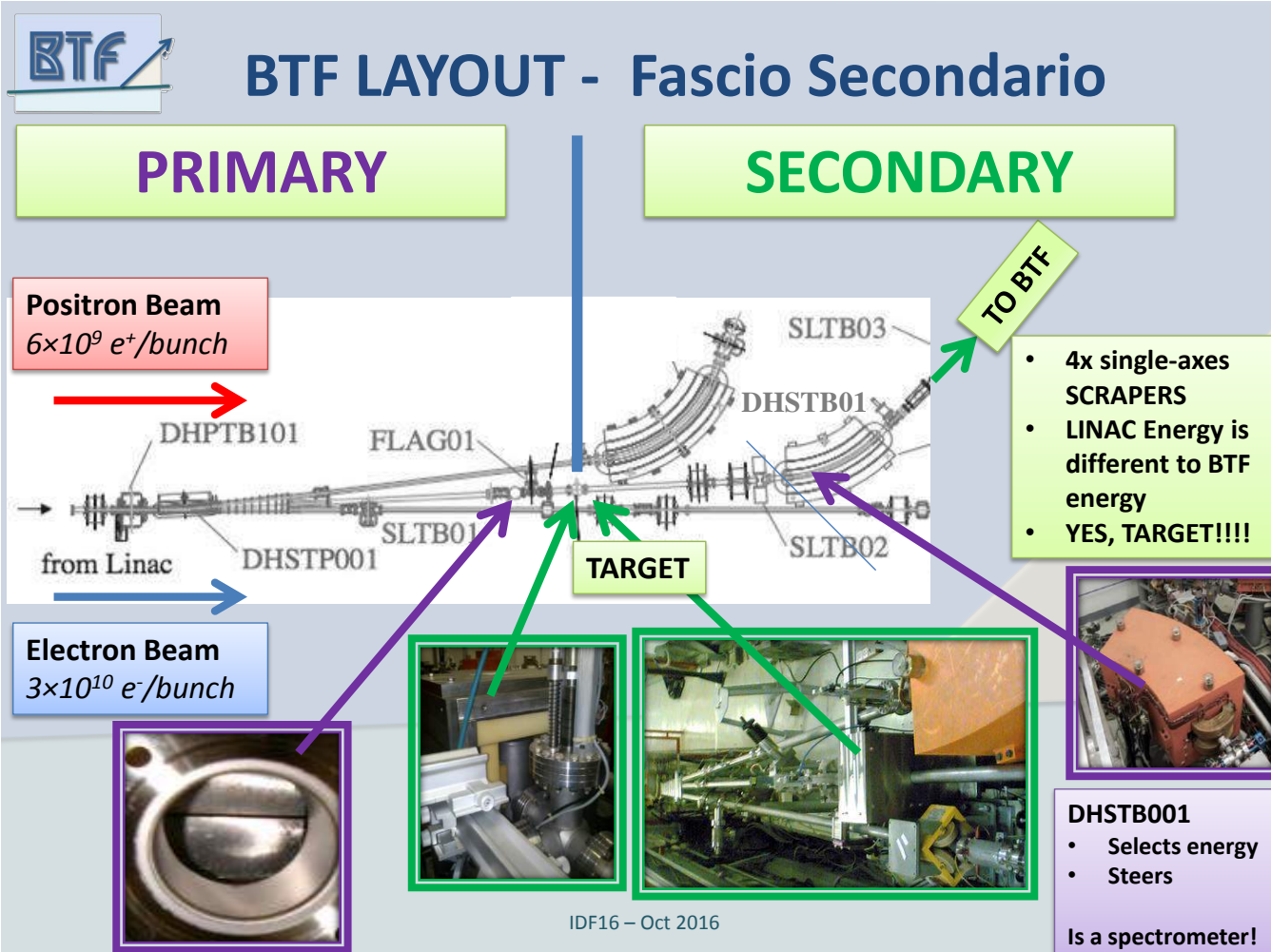
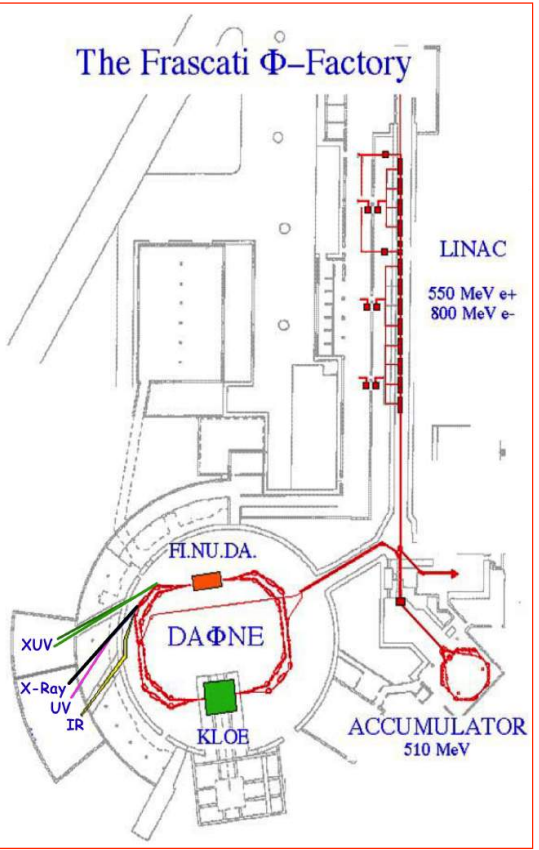
data analysis



$$n = \frac{1}{4\pi} \int \mathbf{M} \cdot \left( \frac{\partial \mathbf{M}}{\partial x} \times \frac{\partial \mathbf{M}}{\partial x} \right) d\text{vol}$$
$$H|\Psi\rangle = E|\Psi\rangle$$
$$\frac{\partial \mathbf{M}}{\partial x} = -\mathbf{M} \times \mathbf{B} + \frac{1}{M} \mathbf{M} \times (\mathbf{M} \times \mathbf{B})$$
$$H = -\frac{\hbar^2}{2m} \nabla^2 + V(\mathbf{r})$$

# Beam Test Facility

Extracted beam from the Dafne linac (up to 510 MeV)



# Beam Test Facility

8 students

- Theory introduction to accelerators and to this specific linac
- Detectors used in the experimental hall or previously tested
- Beam online diagnostic

Calorimeter test at BTF:

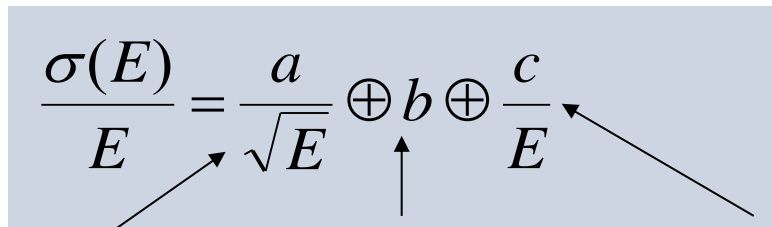
build the power line (Scint + Calo)

build the whole acquisition chain

start runs and diagnostic

calibration

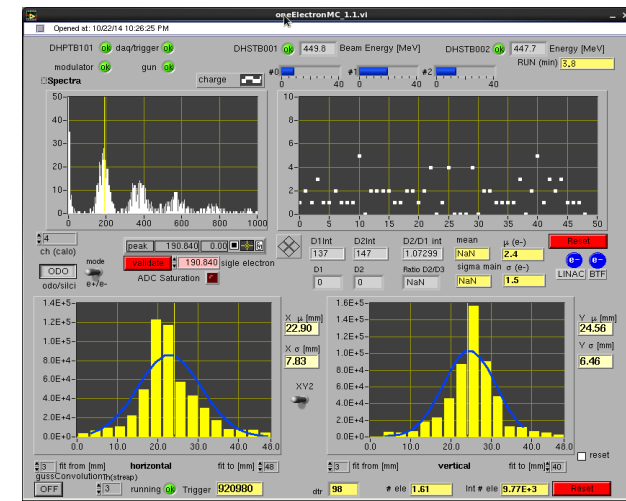
determine the calorimeter performances

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \oplus b \oplus \frac{c}{E}$$


Stochastic  
term

Constant  
term

Noise



LabVIEW Tools ... MaskMaker

@TFy5527\_2\_0\_lv12b64.vi

oneElectronMC\_13\_slow.vi

DHPTB101 daq/trigger DHSTB001 450 Beam Energy [T  
modulator gun e+/e- charge #0 #1

Spectra

4 peak 20.3199 0 D1Int 2284 D2Int 115196  
ch (calo) CaloVolt CaloVolt\_req validate 20.320 single electron D1 D2  
900.75 900.5 req\_submit Autotracking 0 0

Silicon/fiber FITPDK Peakfinder Press to OFF

threshold	Locations	Amplitudes	error
0.00	18.1383	369.043	0
width	39.0485	377.89	Peakfound
	60.5357	295.061	262
pede end	83.1126	159.605	
	103.848	76.1027	
	127.274	47.0386	

Tab Control running Trigger 404224 dtr 40 # ele 36.67 Int # ele 3.51E+10 Reset

fitpix\_simplepoll\_mc.vi

File Edit View Project Operate Tools Window Help

Graphs Graphs adv data

Intensity Graph

Intensity cumulus

stop STOP waiting

running ave

resetcount count 9760 count\_ms 1.278E+9  
PX over TH 37.05  
PX SUM 37.05  
CALO Mult 36.67  
Fpix-CALO 0.37  
Fipix/CALO 1.01

resetcursor

Acquire? ON

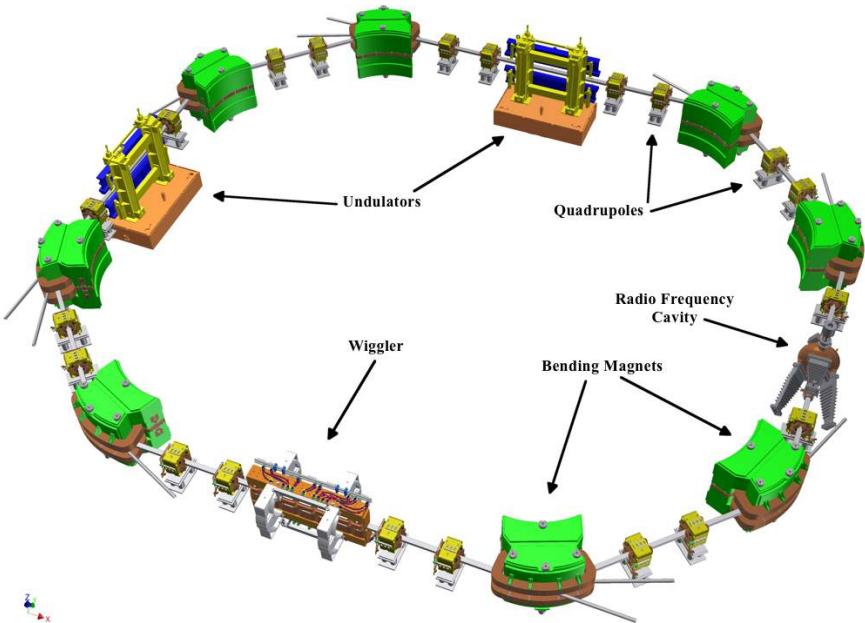
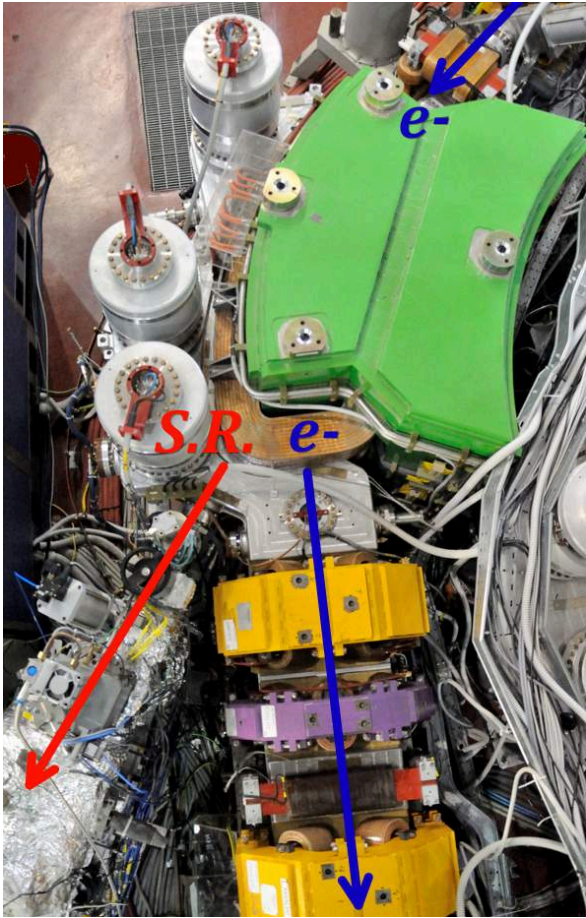
initialize OFF (Histogram)

Histogram

Max	8E+6
11810.5	7E+6
Min	6E+6
-0.5	5E+6
Bins	4E+6
11811	3E+6
mean hit	3E+6
37.05	2E+6
mean sum	1E+6
37.05	0
mean length	0
40	0

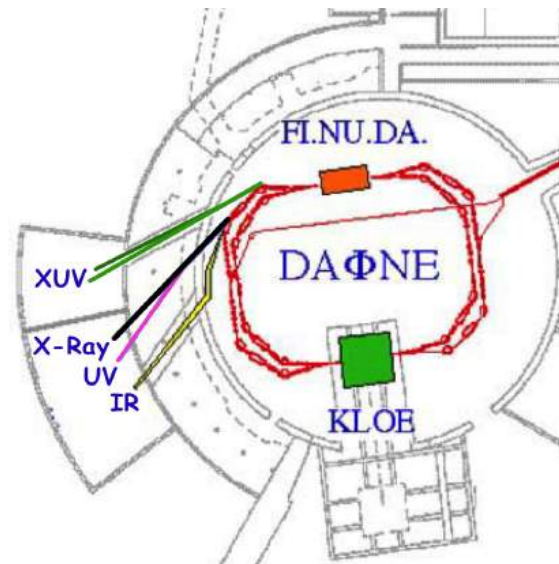
hit pixel pixel sum last f/C ratio mean F/C saveloop SAVEpict path to JPEG file  
50 50 1.01022 0.99 2583279 %C:\Users\btfstaff\Desktop\user\workers\photontag\150MeV\_photon.jpg

# Synchrotron light source at Dafne



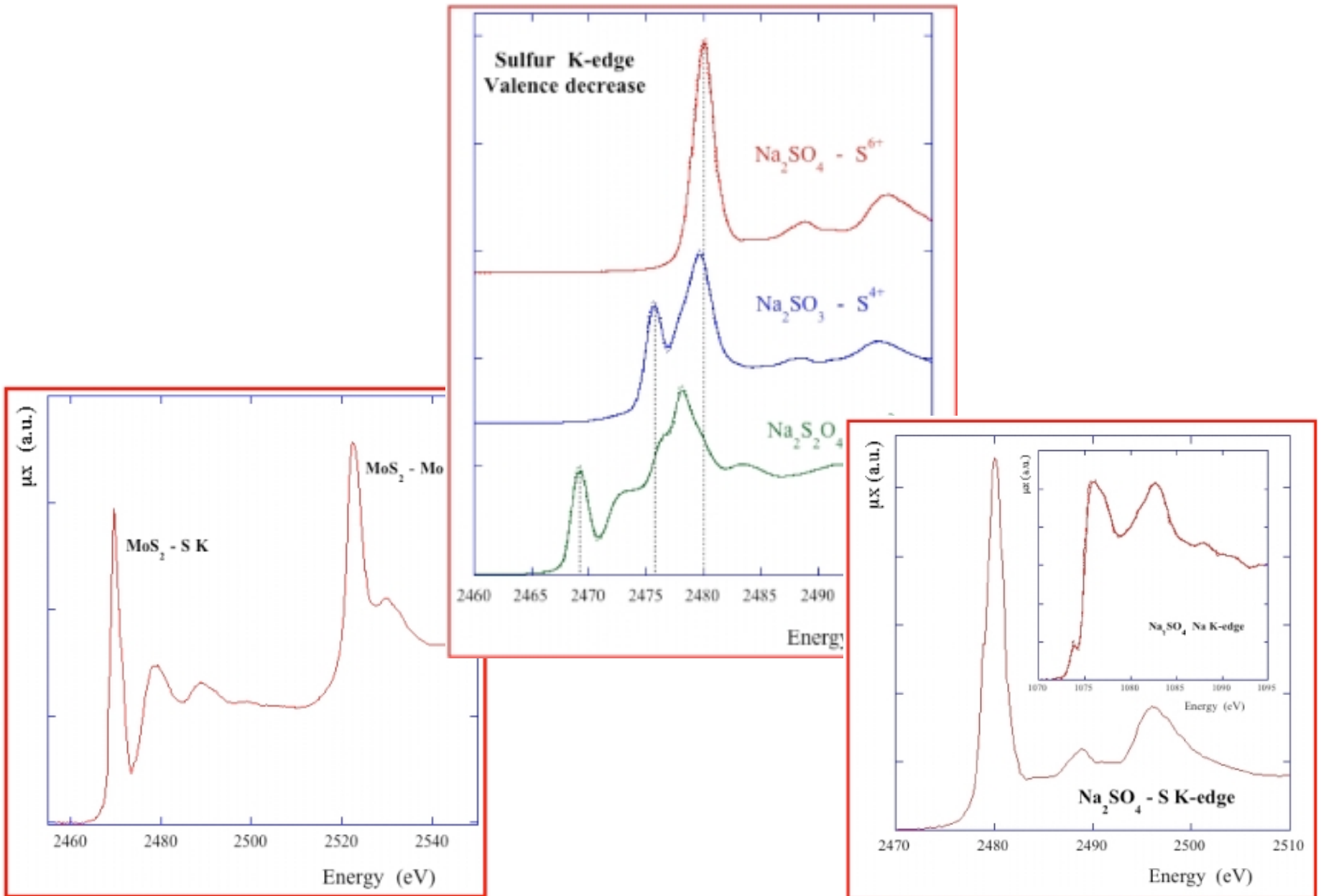


- Theory introduction to S.L. emission and interaction with matter (scattering, diffraction)
- The lines @LNF



- 
- 1) SINBAD - IR beamline (1.24 meV - 1.24 eV)
  - 2) DXR1- Soft x-ray beamline (900-3000 eV)
  - 3) DXR2 – UV-VIS beamline (2-10 eV)
- XUV beamlines
- 4) Low Energy Beamline (35-200 eV)  
pronta per il commissioning;
  - 5) High Energy Beamline (60-1000eV)

# Revealing the atomic structures of dust and films



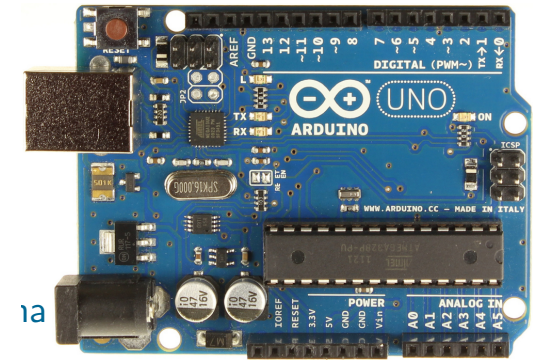
# Electronics with Plarduino

A didactic platform where to learn how to:

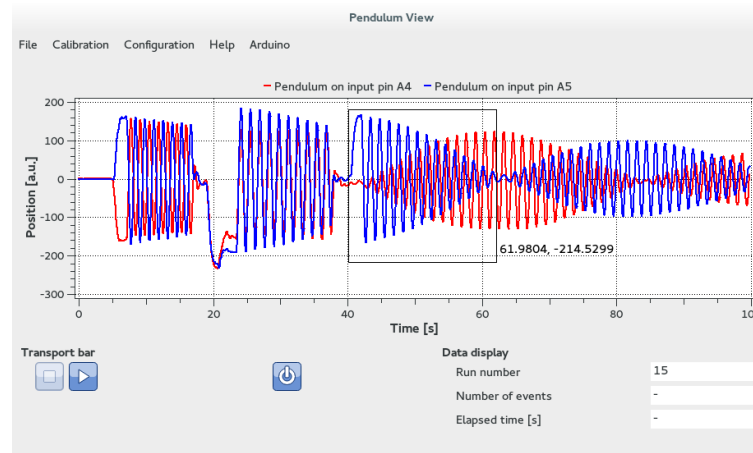
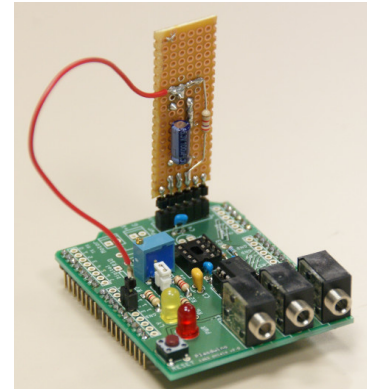
- program (python)
- build electronic circuits
- perform measurements of physics quantities

Experience 1)

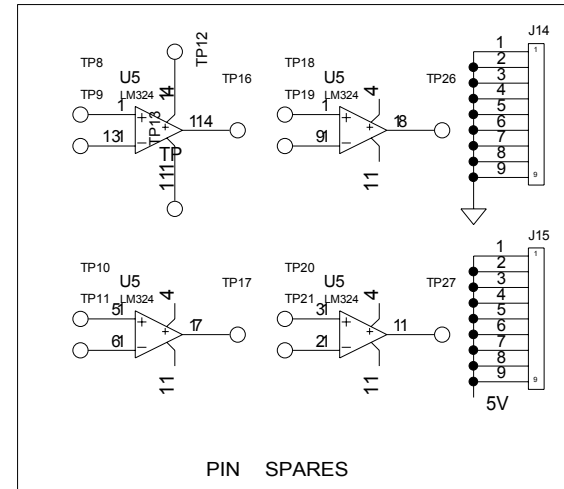
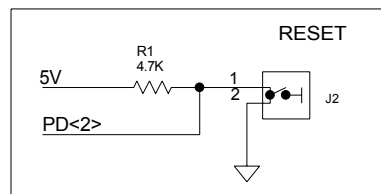
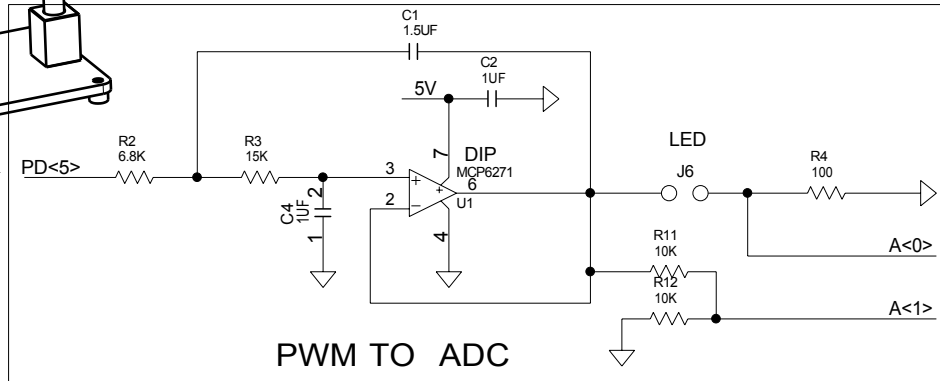
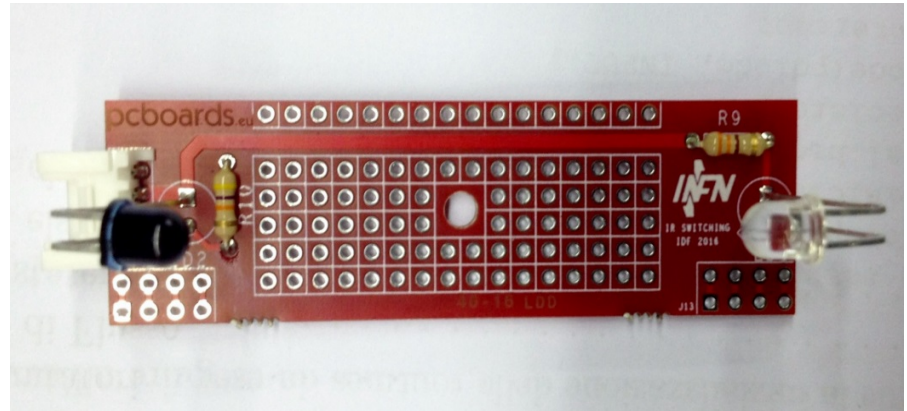
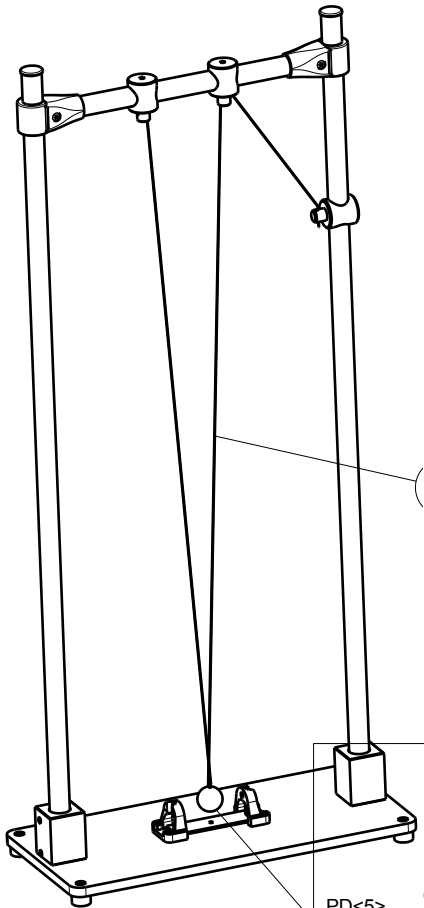
To build a slow control for an experimental apparatus: temperature, pressure, or tuning and monitoring of a condensator charge/discharge,



1a



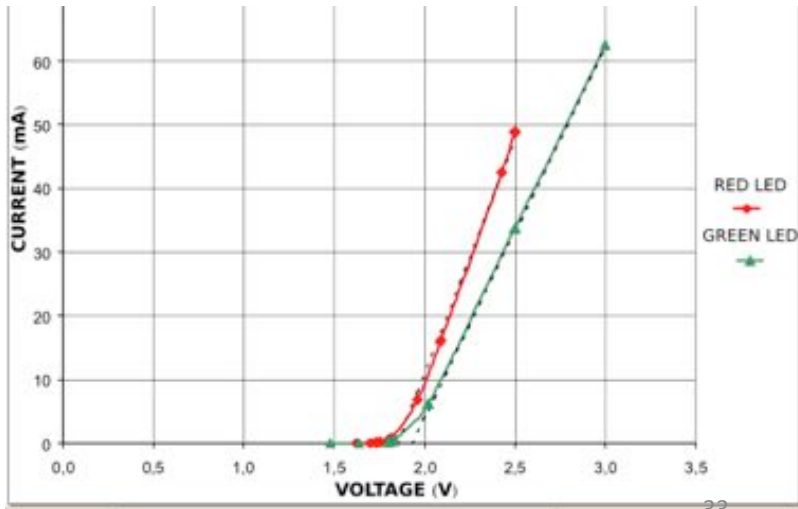
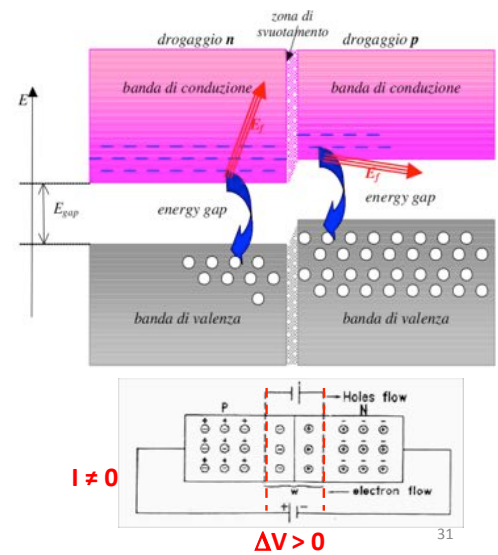
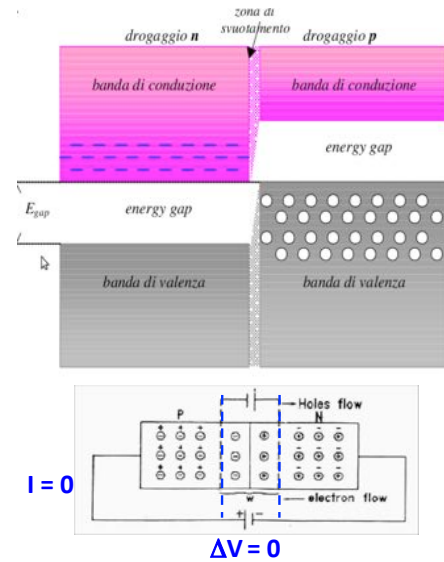
Experience 2)  
Study both of a  
pendulum and a  
coupled pendulum



TITLE:	ARDUINO SHIELD IDF2016	DATE:	OTT 2016
ENGINEER:	M.GATTA U.DENNI	PAGE:	2/3
	P.ALBICOCCO		

# Electronics for measuring the Planck constant

- Introduction to Quantum Mechanics
- Semiconductors and p-type n-type diodes
- Light Emitting Diodes



$$eV_{th} = hf$$

Extracted with an accuracy of ~10%



# Construction of a cosmic ray telescope

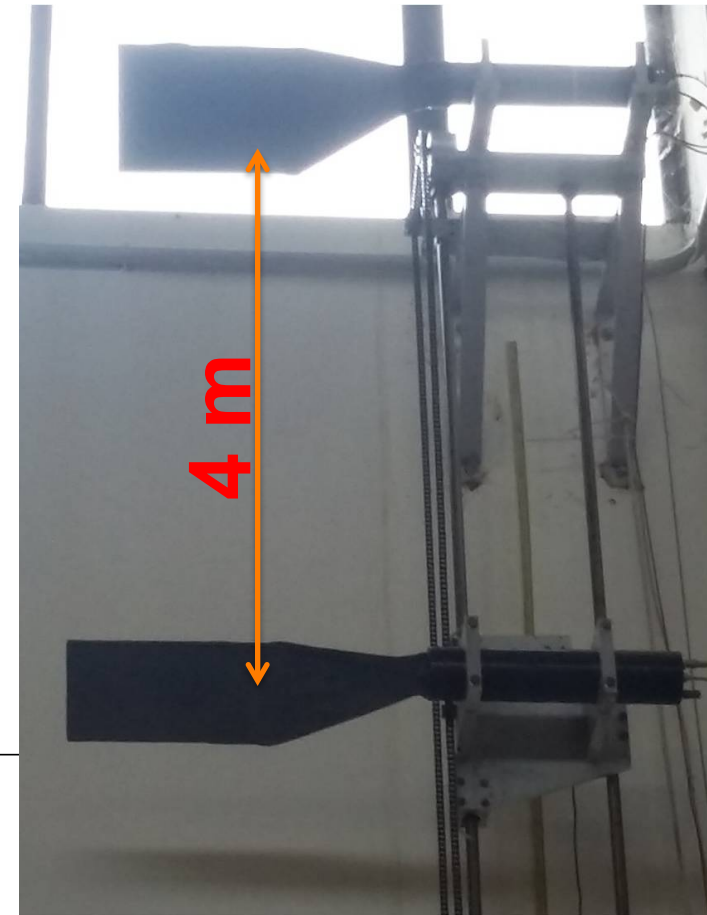
12 students

Introduction phase: how to build a data taking chain  
(scintillators, PMT, ADC, TDC, form a coincidence, ... )

- Detect muons from cosmic rays
- Measure properties of muons using the assembled chain
- Measure the muon velocity

Data analysis:

- Show how elementary statistics can be applied to particle physics measurements
- Compute average, rms, statistical and systematic error

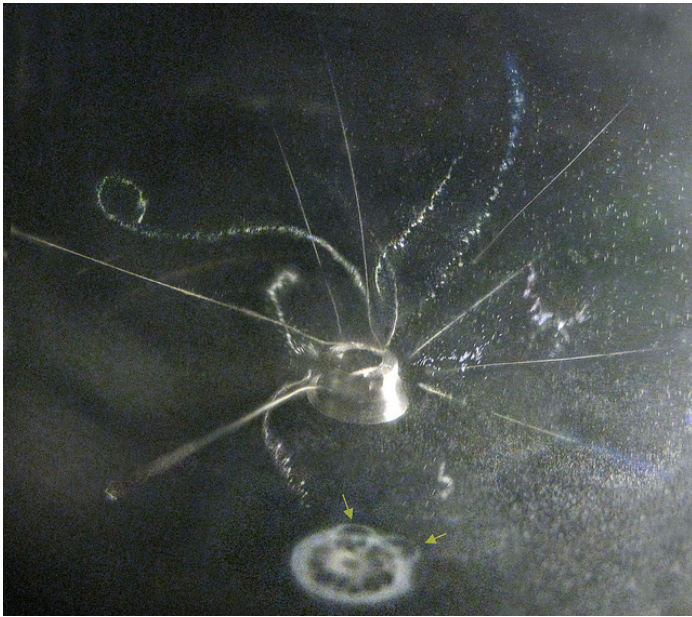




# Cloud chamber

15 students

- Interaction particles-matter: ionization
- Radioactive emission
- Construction of the chamber

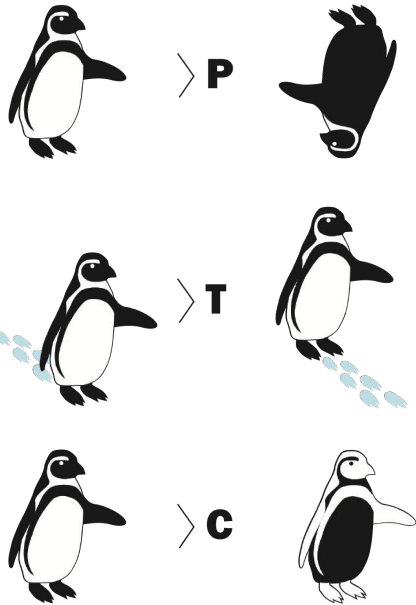




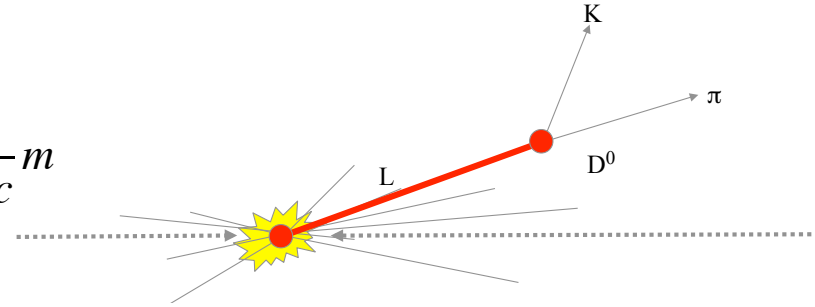
# D<sup>0</sup> life time through LHCb data

30 students

Credits: Asimmetrie

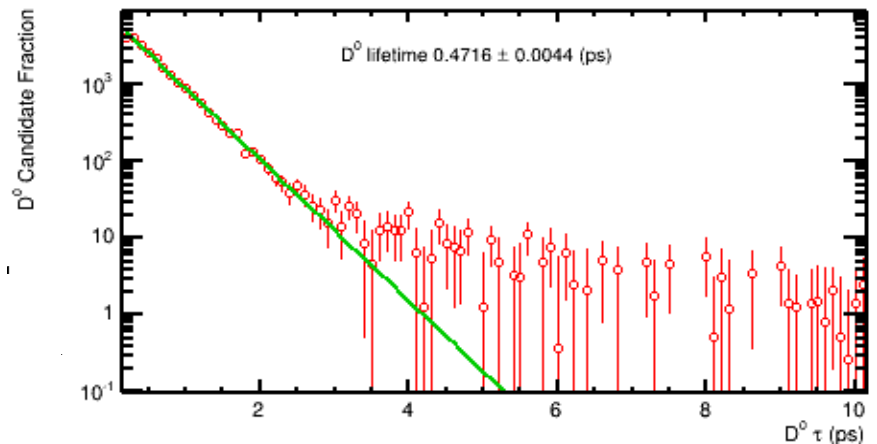
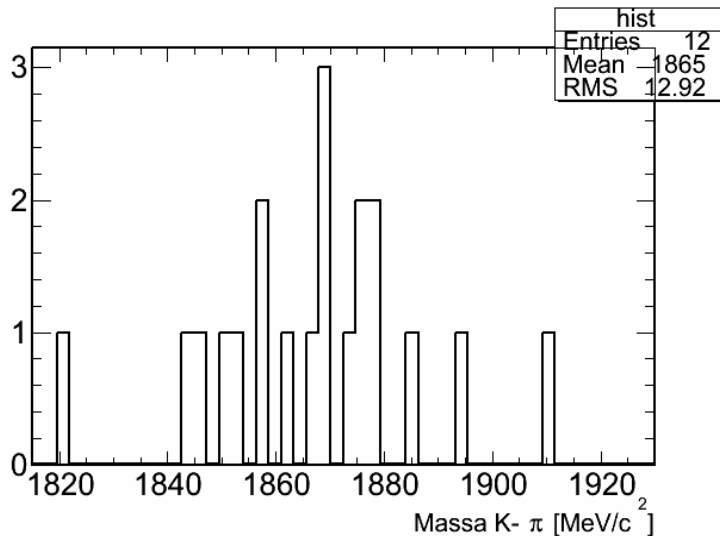


$$t = \frac{x}{\gamma\beta c} = \frac{x}{pc} m$$



By a graphic interface:

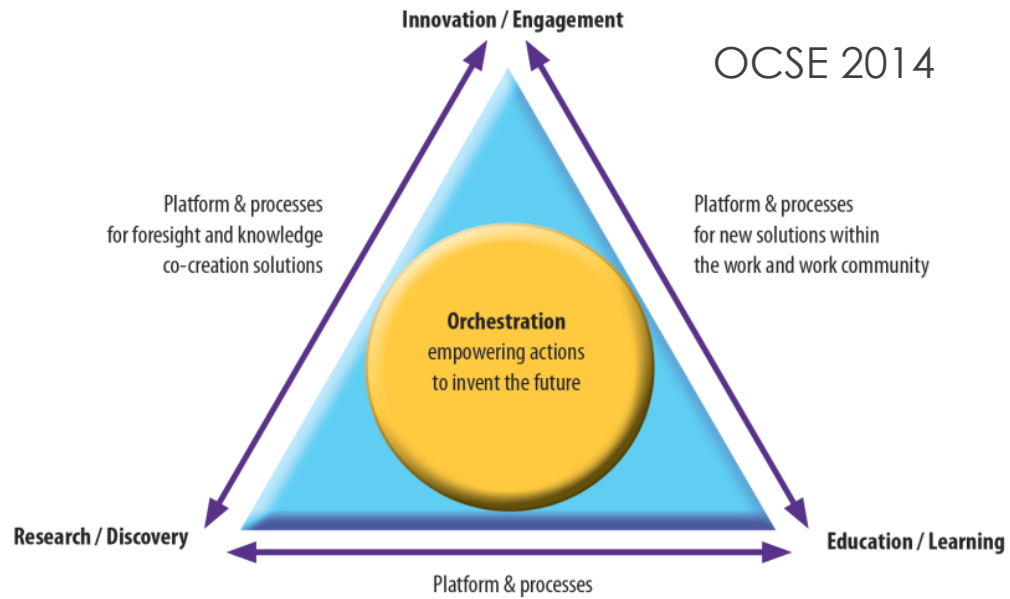
- Reconstruct and identify K + π
  - Reconstruct the Invariant Mass
- Then using a large number of events:
- Signal/Background
  - Identify the decay vertex
  - Extraction of the life time





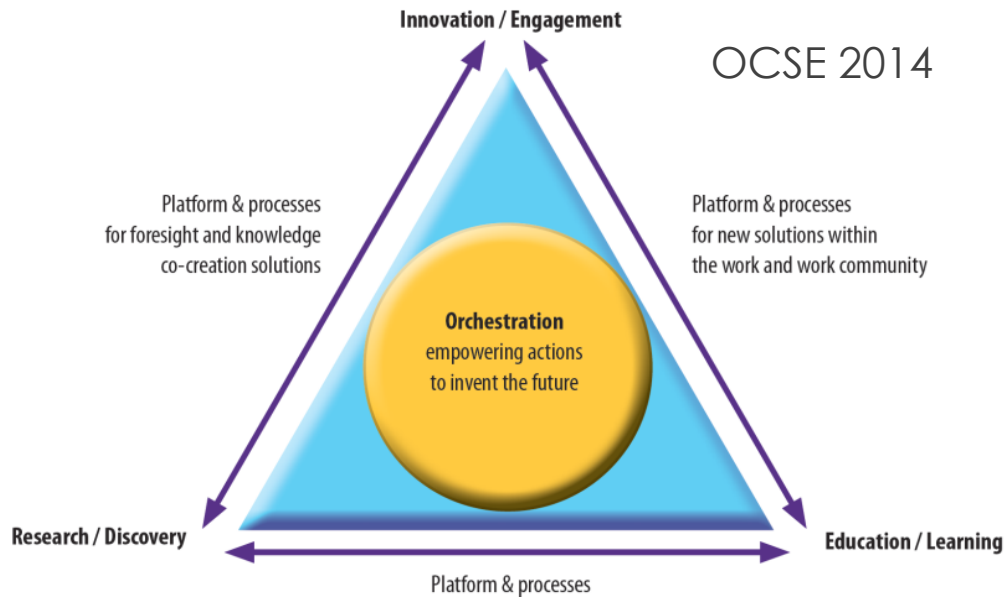
# What's the status

## The "Innovation Triangle" connects



# What's the status

The “Innovation Triangle” connects



However ... the feedback from researchers is distressing

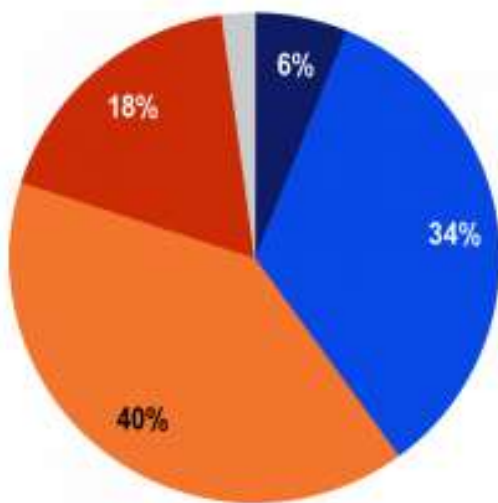
- 25% Leave me alone, I have to work
- 23% Oh, no: I have to communicate!
- 18% It's important to communicate
- 18% Let's talk ...
- 16% Let me explain it in my terms

*A cultural problem!*

# Fortunately the signals from the society are cheering

## How informed people are about science and technology

QD1. How informed do you feel about developments in science and technology?



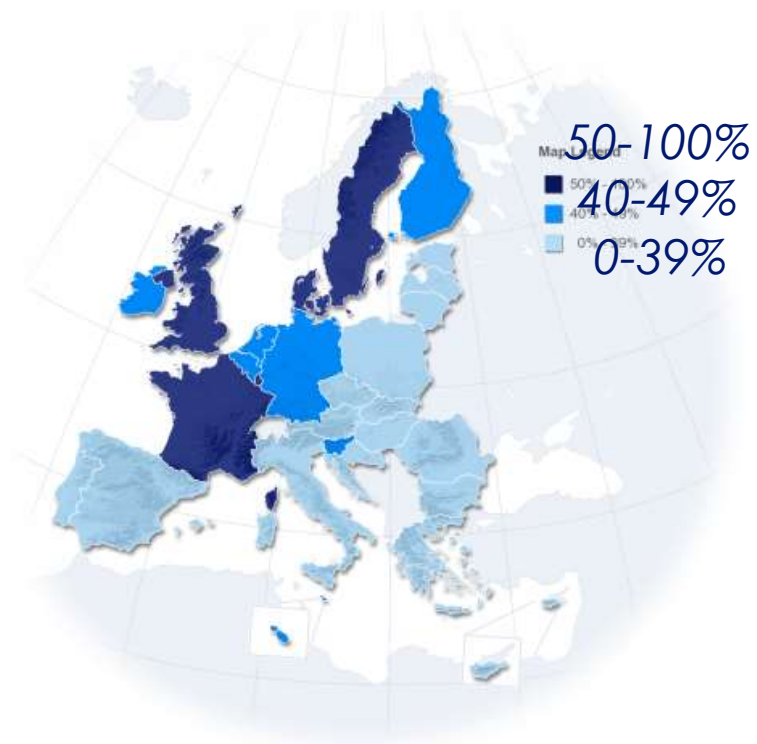
- Very well informed
- Fairly well informed
- Not very well informed
- Not at all informed
- Don't know



DK	65%
SE	61%
LU	58%
UK	56%
FR	51%
FI	48%
MT	48%
IE	47%
NL	47%
DE	43%
BE	41%
EU	40%
SI	40%
CY	37%
EE	37%
PL	37%
LV	34%
LT	33%
PT	32%
ES	32%
EL	32%
SK	31%
AT	30%
IT	29%
CZ	29%
RO	25%
BG	25%
HU	25%
HR	32%

Question: QD1. How informed do you feel about developments in science and technology?

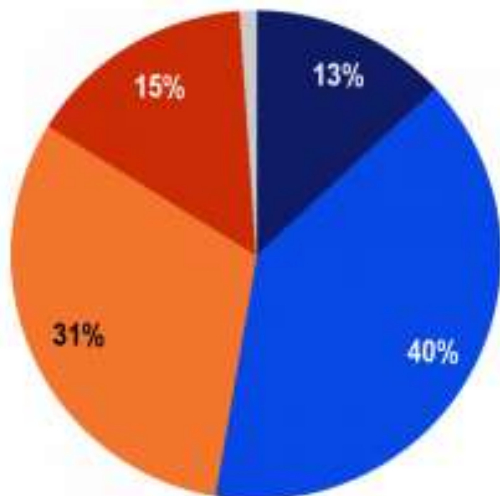
Answers: Total 'Informed'



Fortunately the signals from the society are *cheering*

## How interested people are in science and technology

QD2. How interested are you in developments in science and technology?

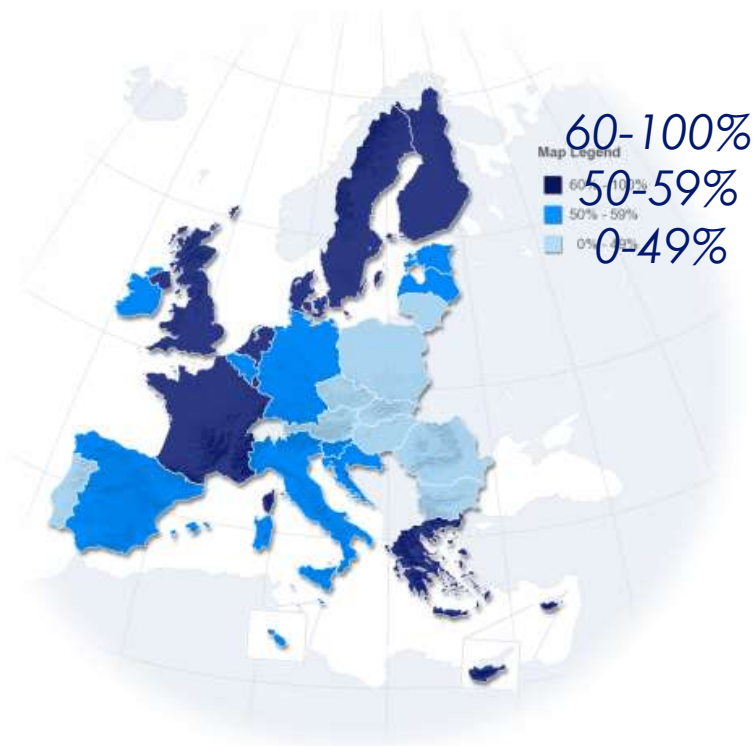


- Very interested
- Fairly interested
- Not very interested
- Not at all interested
- Don't know

EU27

SE	77%
LU	69%
NL	66%
DK	66%
UK	64%
CY	64%
FR	62%
FI	61%
EL	60%
BE	57%
EE	56%
IE	56%
DE	54%
EU	53%
SI	53%
MT	52%
LV	52%
ES	52%
IT	50%
LT	47%
PL	46%
AT	45%
PT	44%
SK	44%
HU	39%
RO	37%
BG	35%
CZ	34%
HR	30%

Question: QD2. How interested are you in developments in science and technology?  
Answers: Total 'Interested'



# Direct Feedback

Extremely positive both from students and teachers



## INFN-LNF STAGES ESTIVI RESIDENZIALI

### Analisi questionari studenti (104)

Studenti Liceo Classico/Scientifico, Scientifico Tecnologico e ITIS,  
classi quarte, provenienti da tutta Italia



### Informazioni sull'attività svolta

Domanda 1: La durata dello stage è stata sufficiente?

Domanda 2: Gli argomenti trattati sono coerenti con l'indirizzo degli studi?

Domanda 3: Le conoscenze scolastiche sono state sufficienti ad affrontare lo stage?

Domanda 4: Le attività pratiche sono state interessanti?

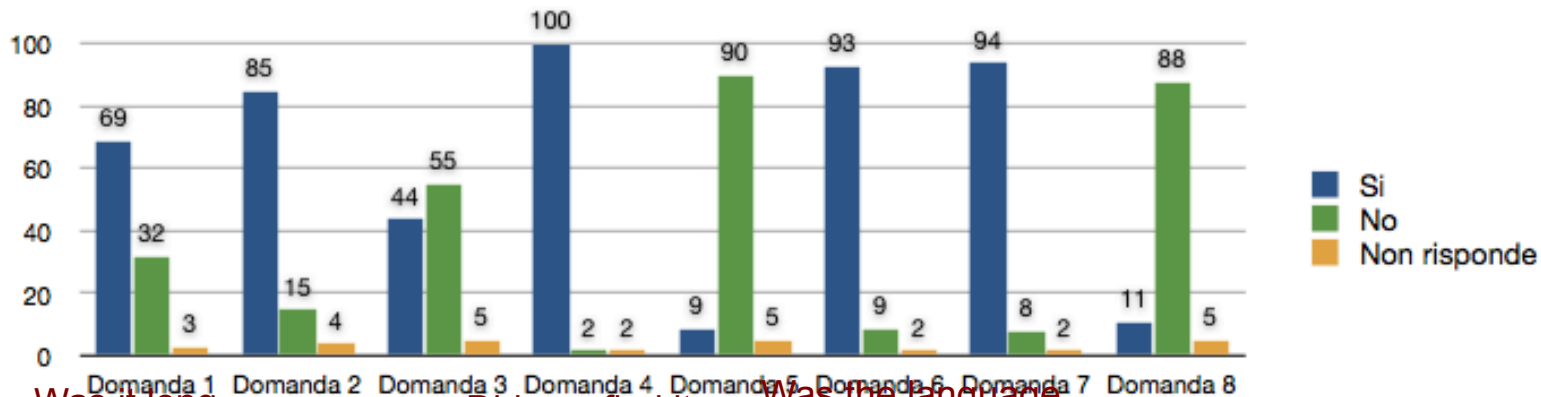
Domanda 5: Le conoscenze acquisite sono troppo teoriche?

Domanda 6: Il linguaggio usato dal tutore è stato facilmente comprensibile?

Domanda 7: Il lavoro svolto ti è sembrato sufficientemente approfondito?

Domanda 8: Le attività sono state ripetitive?

	Domanda 1	Domanda 2	Domanda 3	Domanda 4	Domanda 5	Domanda 6	Domanda 7	Domanda 8
Si	69	85	44	100	9	93	94	11
No	32	15	55	2	90	9	8	88
Non risponde	3	4	5	2	5	2	2	5



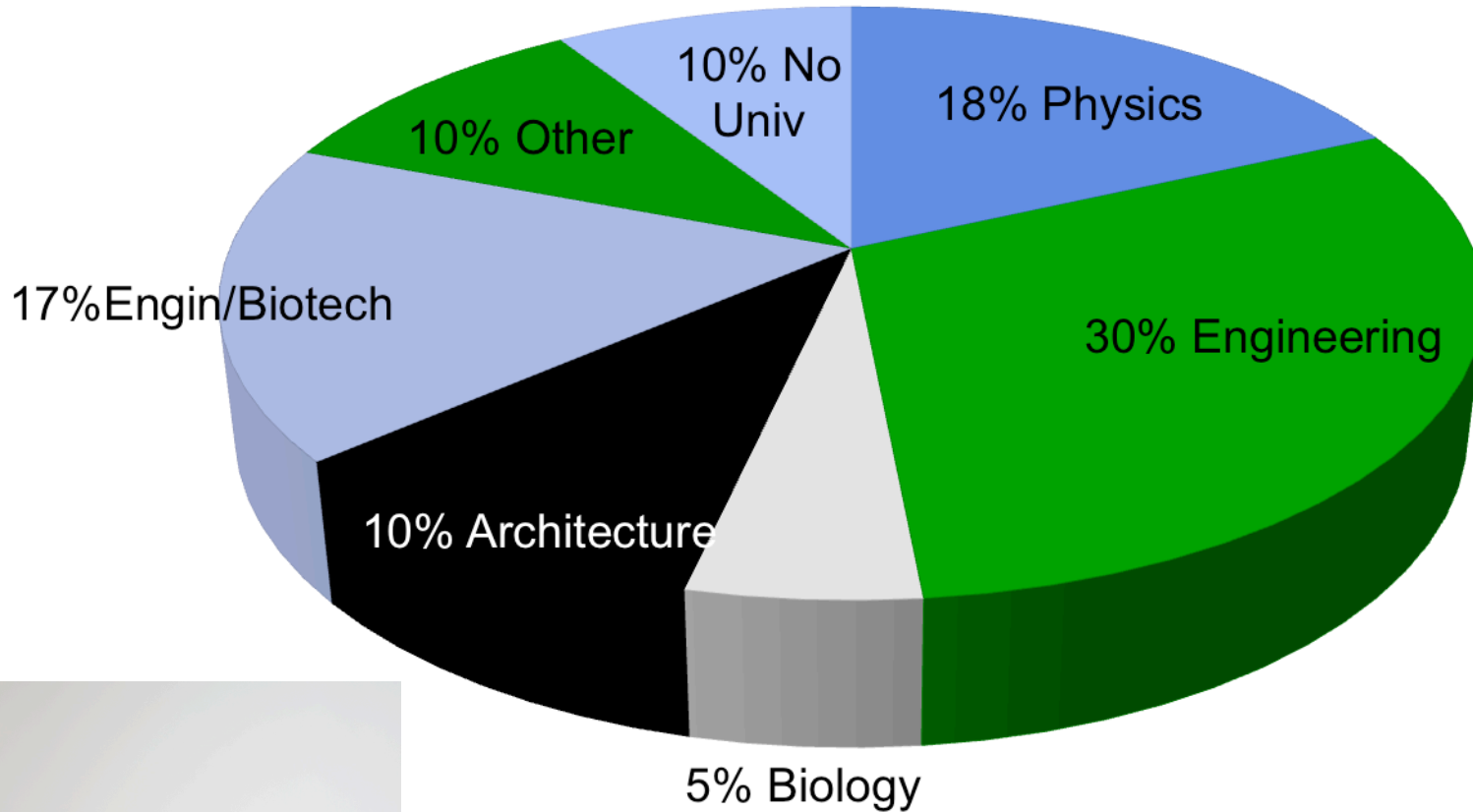
Was it long enough?

Did you find it interesting?

Was the language used comprehensible?

# The career

Where these students go after the high school (data from LNF)



... of course there is the bias due to the *a priori* selection

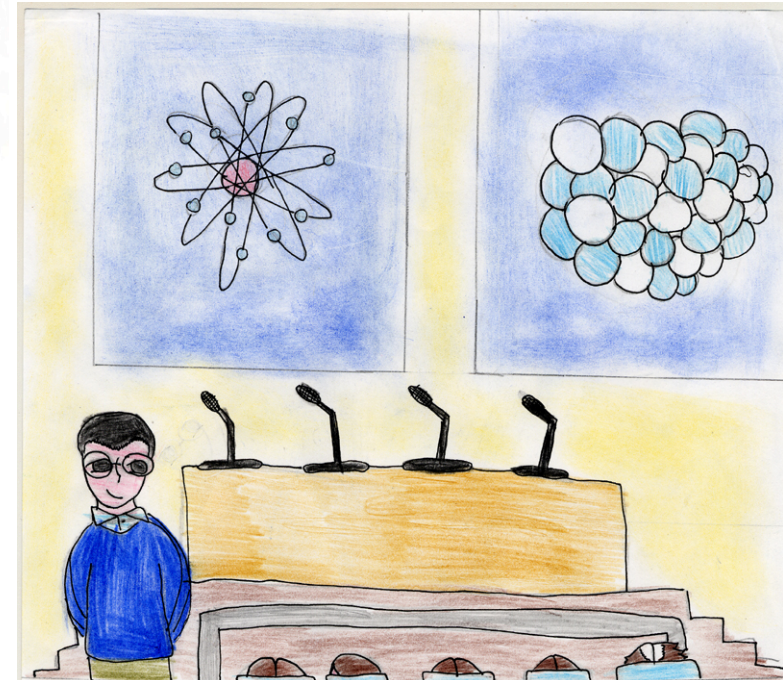
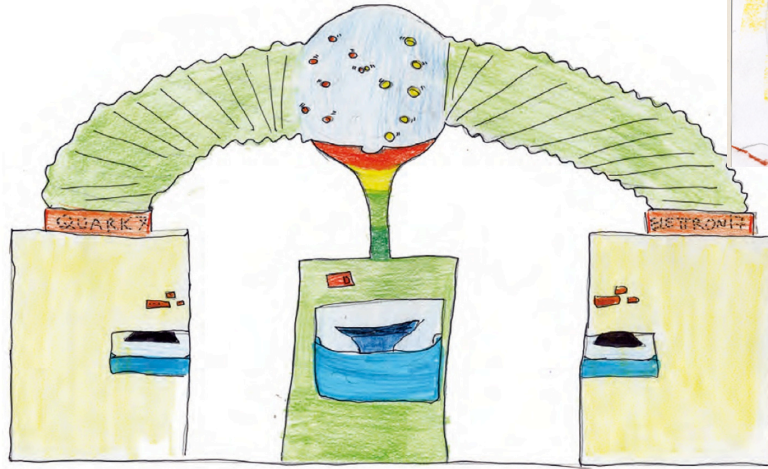


There are also many activities for kids:

... bricks of matter

... what's an atom

.. what's an accelerator





The scientist is the one who creates the scientific consciousness and teaches the scientific knowledge

Modern and advanced educational programs based on **HEP** are among the most efficient ways to reach students and ordinary people

***Better public understanding of science can be a major element in promoting national prosperity, in raising the quality of public and private decision-making and in enriching the life of the individual***

Public Understanding of Science  
Bodmer Report 1985