SPES @ LNL

(… and Laser @ SPES)

Aggiornamento per docenti di scuola secondaria di II grado
LNL-INFN

Daniele Scarpa

- Tortona (AL) 1979
- I.T.I.S. G. Marconi => Perito Elettronica e Telecomunicazioni
- Università degli studi di Pavia => Ing. Elettronica (2004)

  Dott. Elettronica (2007)

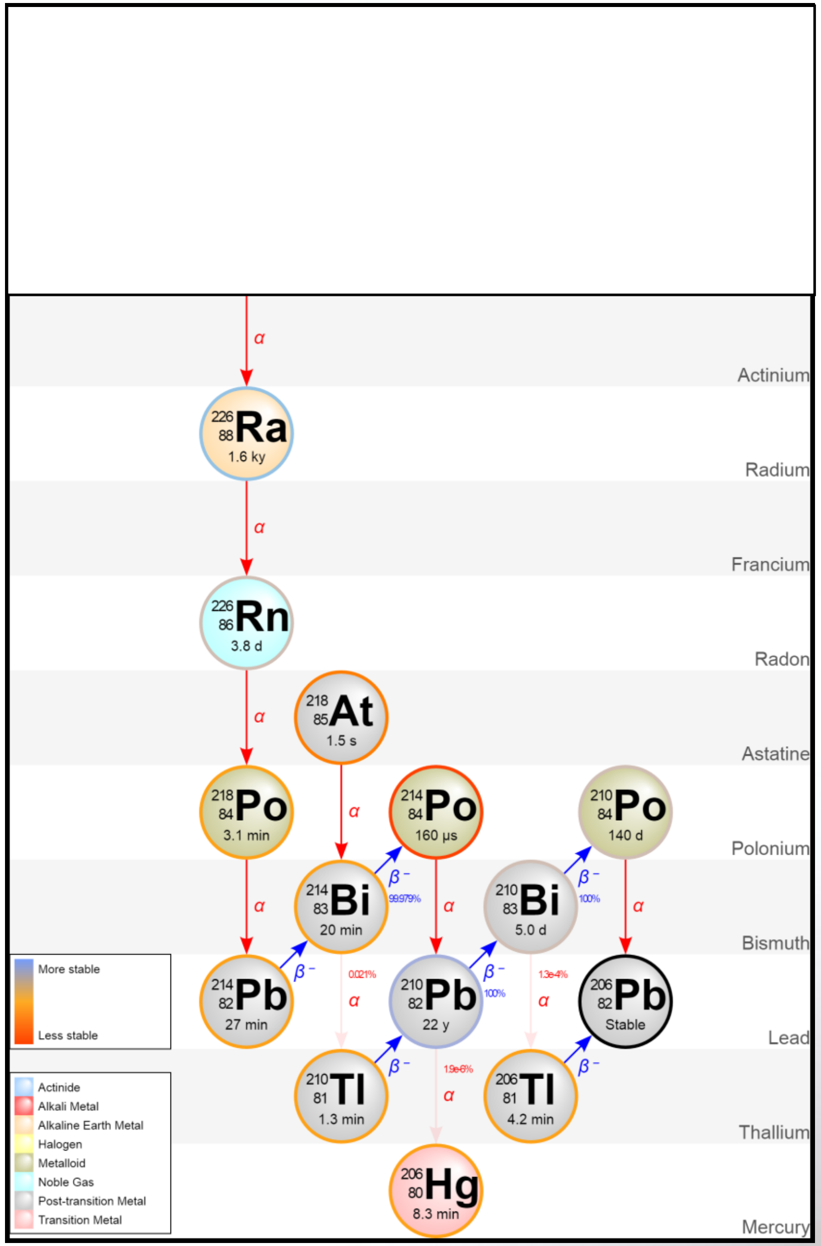
  Assegno di Ric. (2008)
- INFN => Pavia (2009) AdR

  LNL (2013)

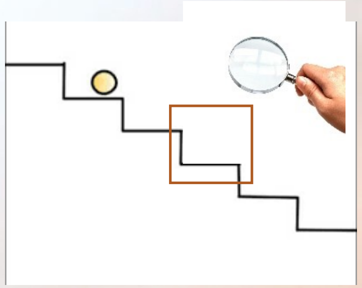
Topics

- SPES Project
- Exotic species and radioactivity
- SPES α,β,γ,δ
- SPES and Lasers
- Laser labs @ LNL

The SPES project (Selective Production of Exotic Species)

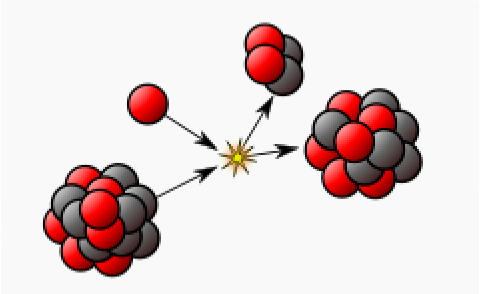


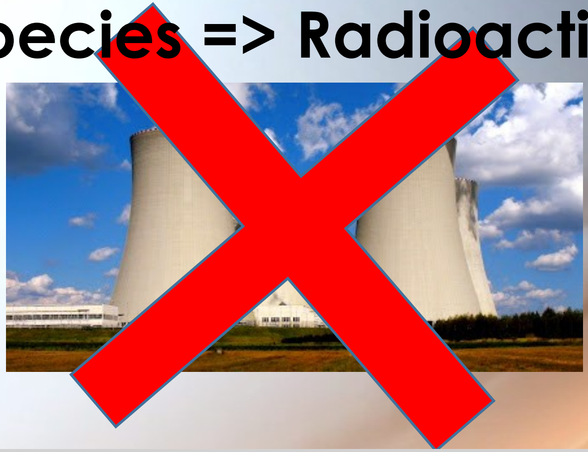
What? Exotic Species => Radioactive Atoms

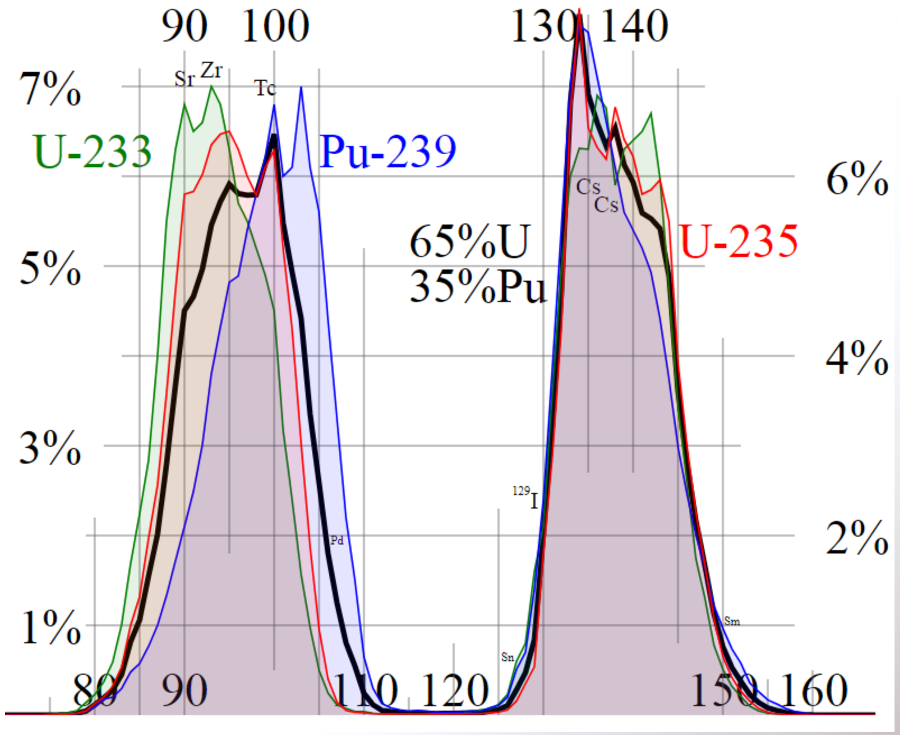


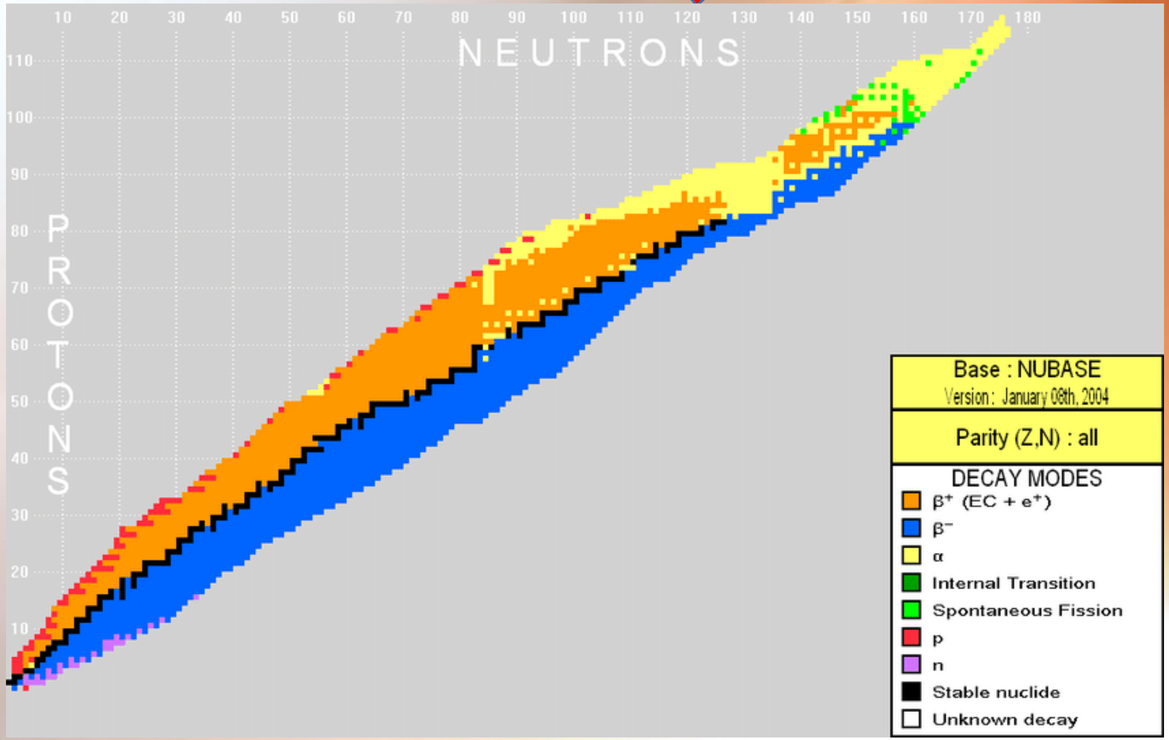
The SPES project (Selective Production of Exotic Species)

What? **Exotic Species => Radioactive Atoms**









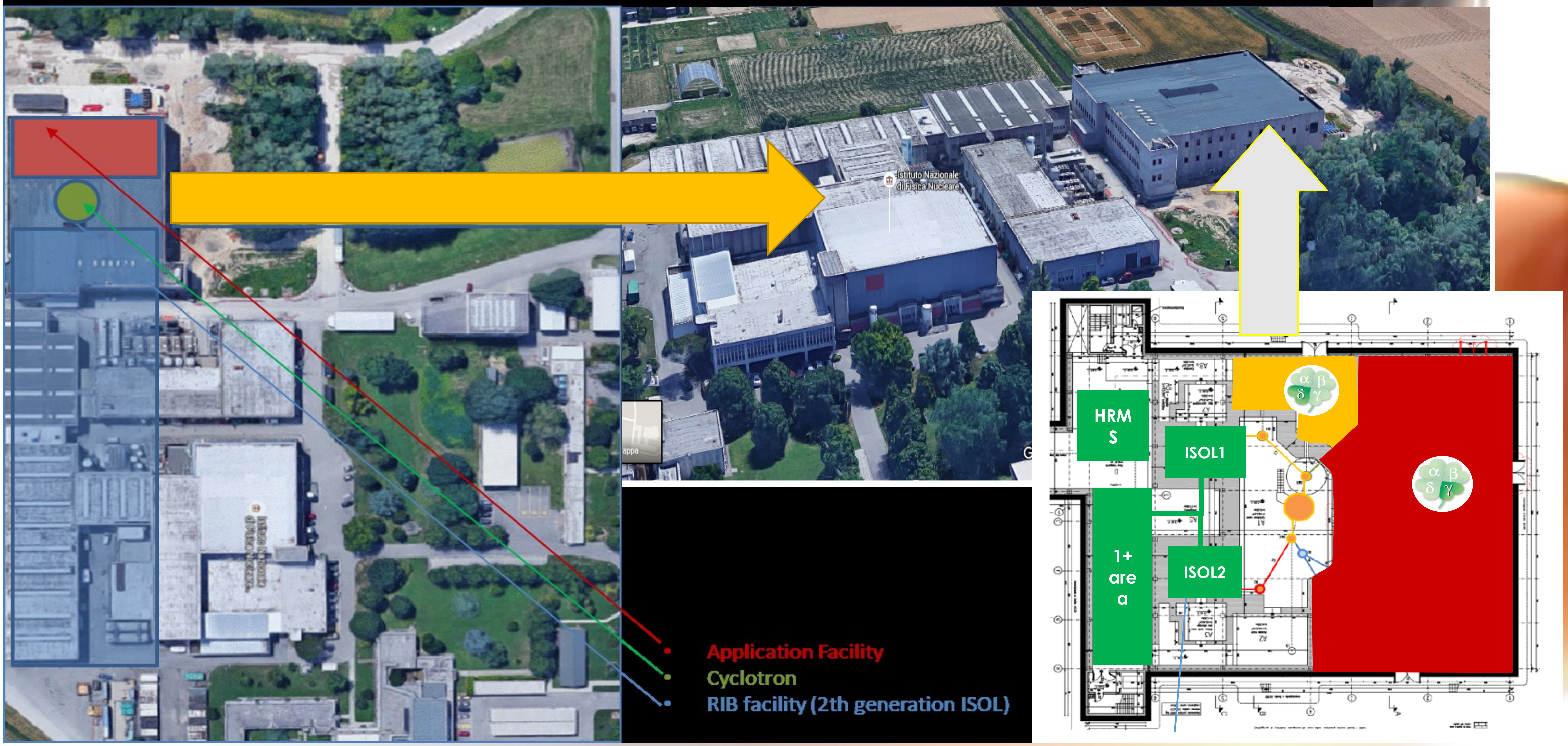
The SPES project (Selective Production of Exotic Species)

Where? Nature and its laws

How take a picture of a world record?

Easy Way?

SPES @ Laboratori Nazionali di Legnaro



The SPES project (Selective Production of Exotic Species)

Why? **Demand & Supply**

Easy Way?

Get fruit salad
& separate each fruit

Topics

- SPES Project
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- SPES α,β,γ,δ
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- Laser labs @ LNL

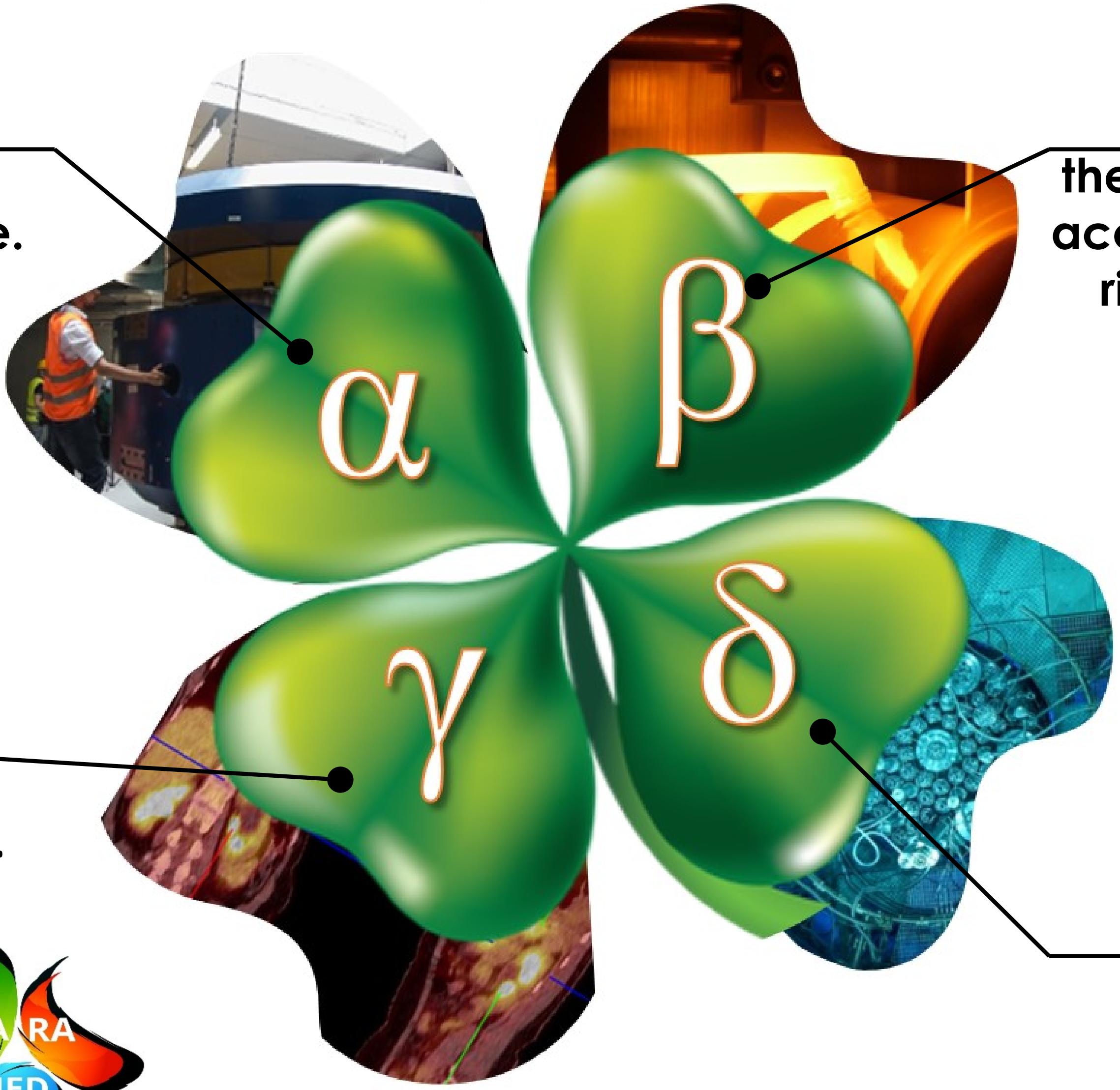
The SPES project (Selective Production of Exotic Species)

SPES-α

The cyclotron and related infrastructure.

SPES-β

the ISOL facility and the acceleration of neutron-rich unstable nuclei.



SPES-γ

The production of radionuclides for applications.

SPES-δ

The multidisciplinary neutron sources.

ISOLPHARM
SPES exotic beams for medicine

&

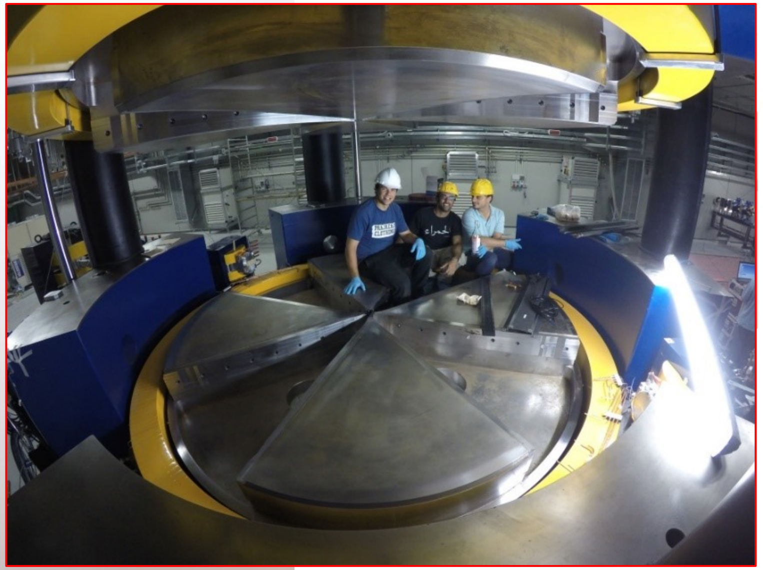
LARAMED

SPES-α: The cyclotron and related infrastructure.

High Power Cyclotron:

Several application at LNL

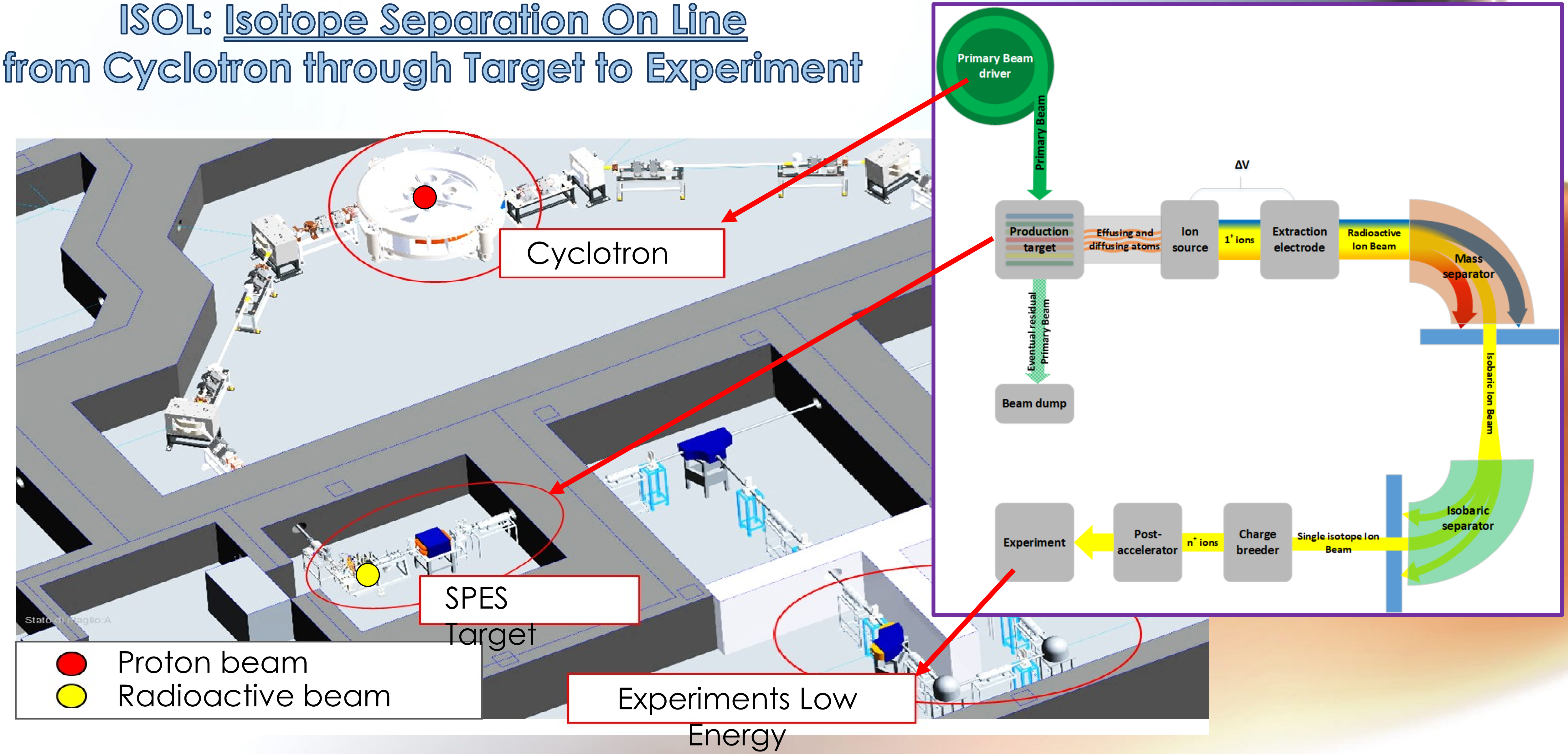
- ✓ Fundamental Research:
  - SPES and its phases
  - …
- ✓ Applied Research
  - Medical application
  - …



Main Parameters	
Accelerator type	Cyclotron AVF with 4 sectors, Resistive Magnet
Particle	Protons (H^- accelerated)
Energy range	35-70 MeV
Max Current Intensity	700 μA (variable within the range 1μA-700μA)
Extraction	Dual stripping extraction
Max Magnetic Field	1.6 T (Bo = 1 T)
RF System	nr. 2 delta cavities; harmonic mode=4; f_{RF} =56 MHz; 70 kV peak voltage; 50 kW RF power (2 RF amplifiers)
Ion Source	Multi-cusp volume H^- source; I_{ext} =8mA; V_{ext}=40 kV; axial injection
Dimensions	Φ=4.5 m, h=2 m, W=190 tons

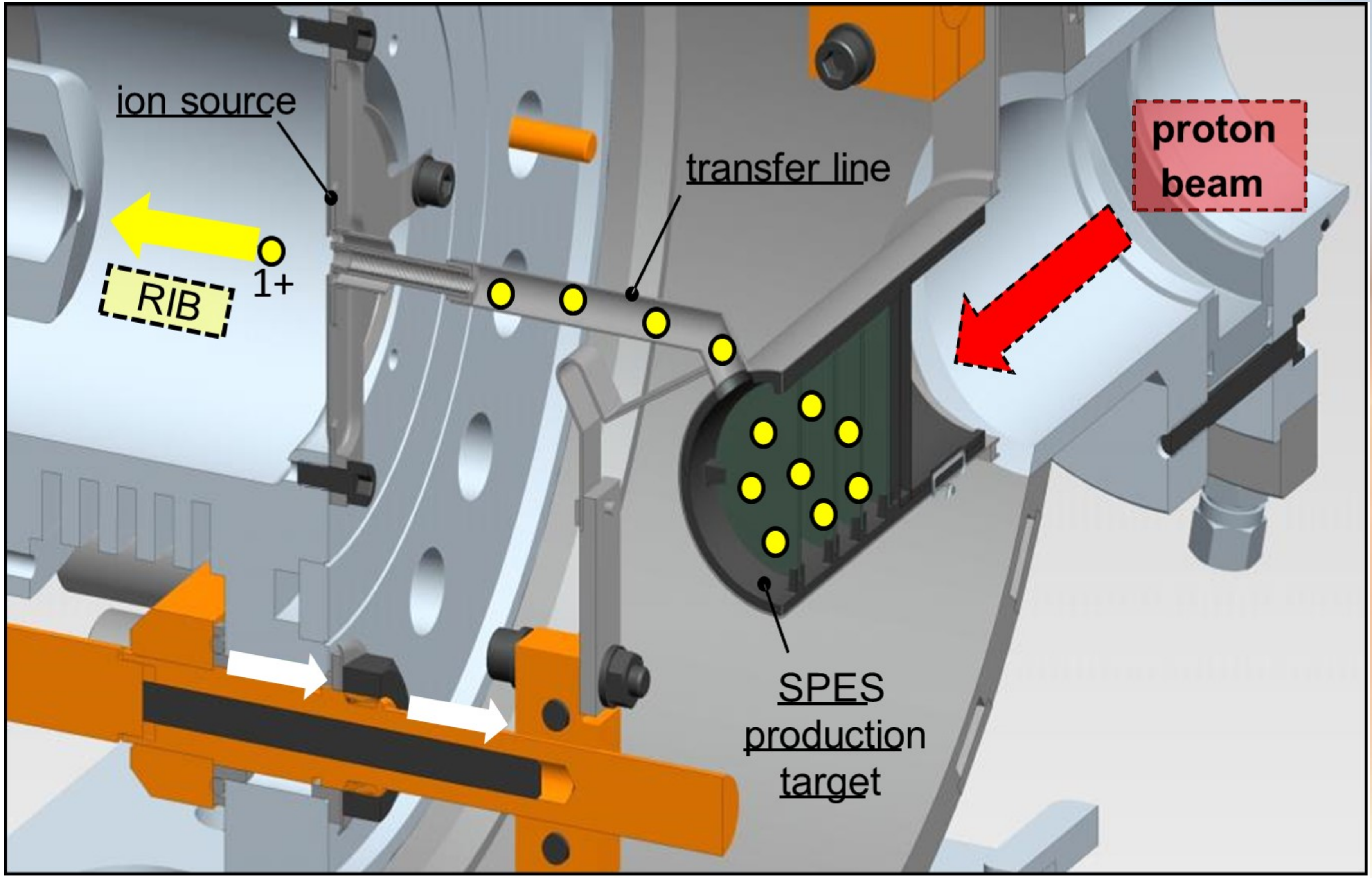
SPES-β: The ISOL facility and the acceleration of neutron-rich unstable nuclei.

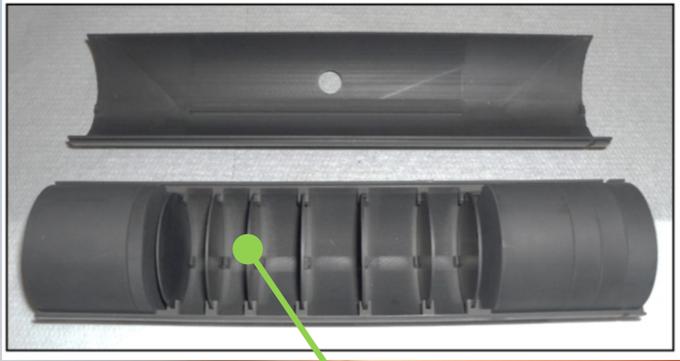
ISOL: Isotope Separation On Line
from Cyclotron through Target to Experiment

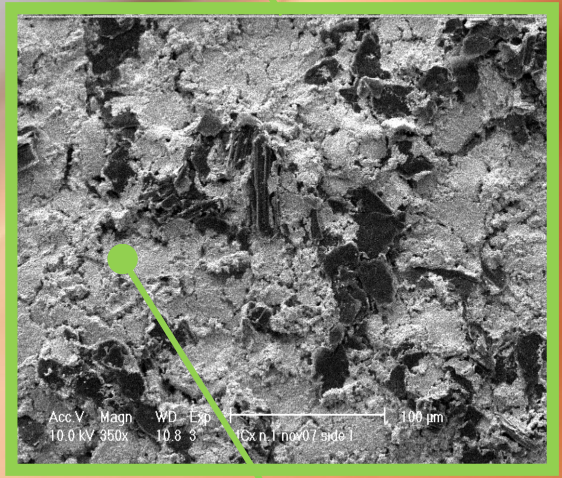


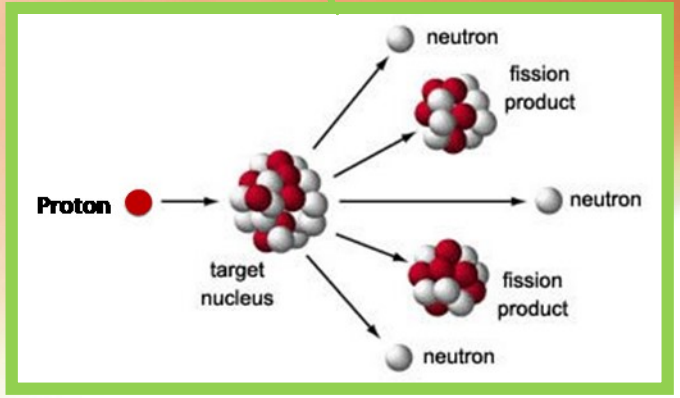
SPES-β: The ISOL facility and the acceleration of neutron-rich unstable nuclei.

SPES Zoom IN: Inside SPES Target (>10 Years of R&D)



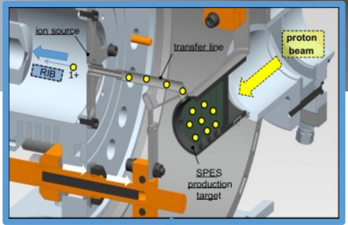


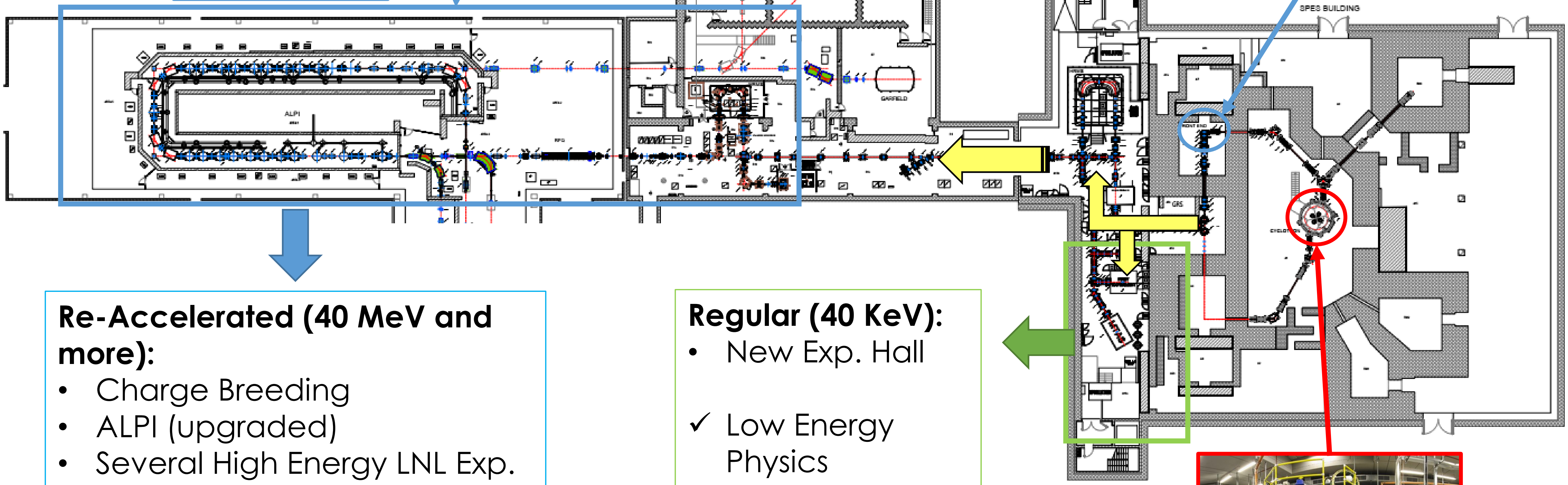




SPES-β: The ISOL facility and the acceleration of neutron-rich unstable nuclei.

SPES Zoom OUT: the whole LNL acceleration complex





Re-Accelerated (40 MeV and more):
- Charge Breeding
- ALPI (upgraded)
- Several High Energy LNL Exp. Hall

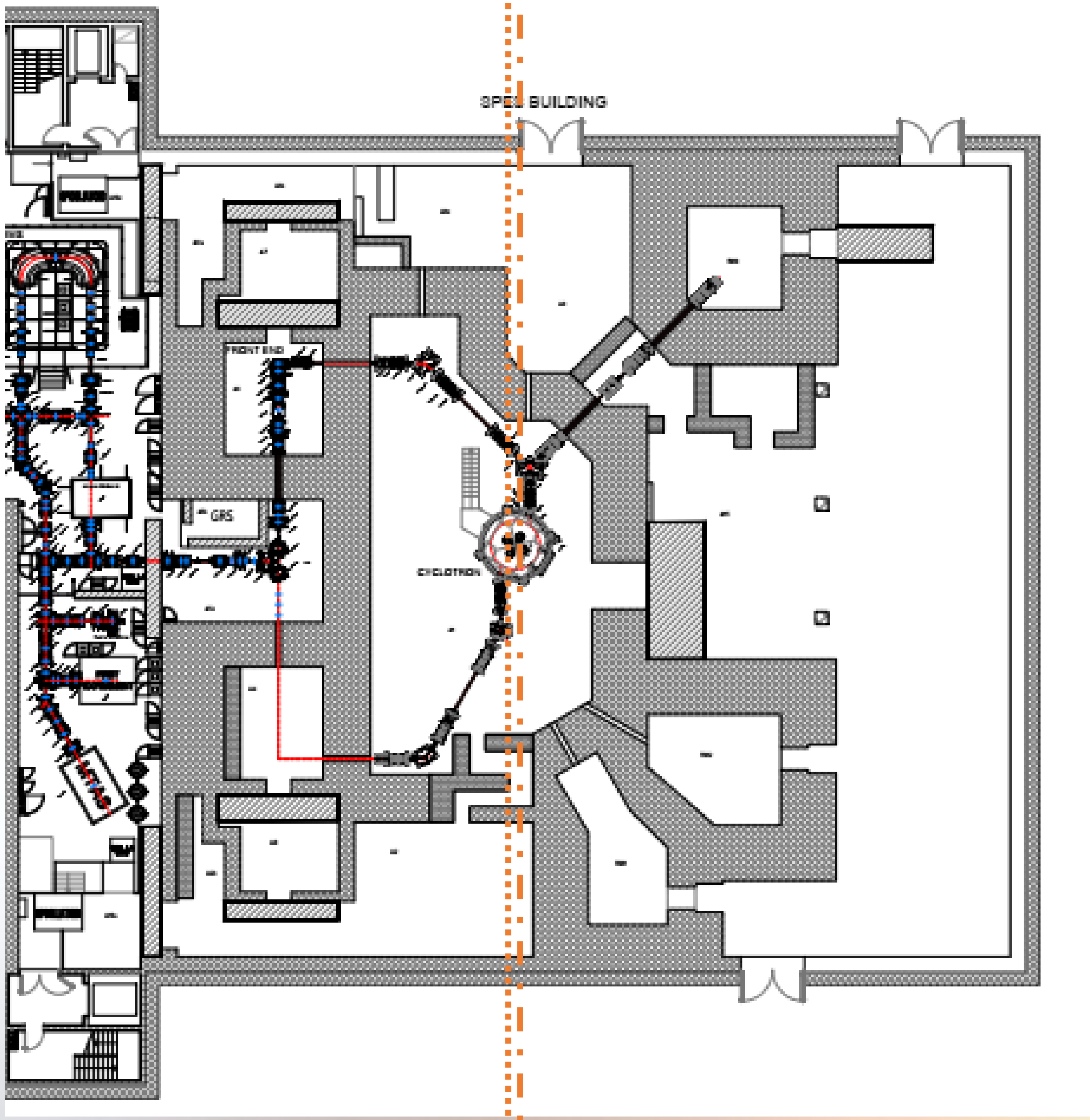
✓ High Energy Physics Experiments

Regular (40 KeV):
- New Exp. Hall

✓ Low Energy Physics Experiments

SPES-γ: The production of radionuclides for applications.

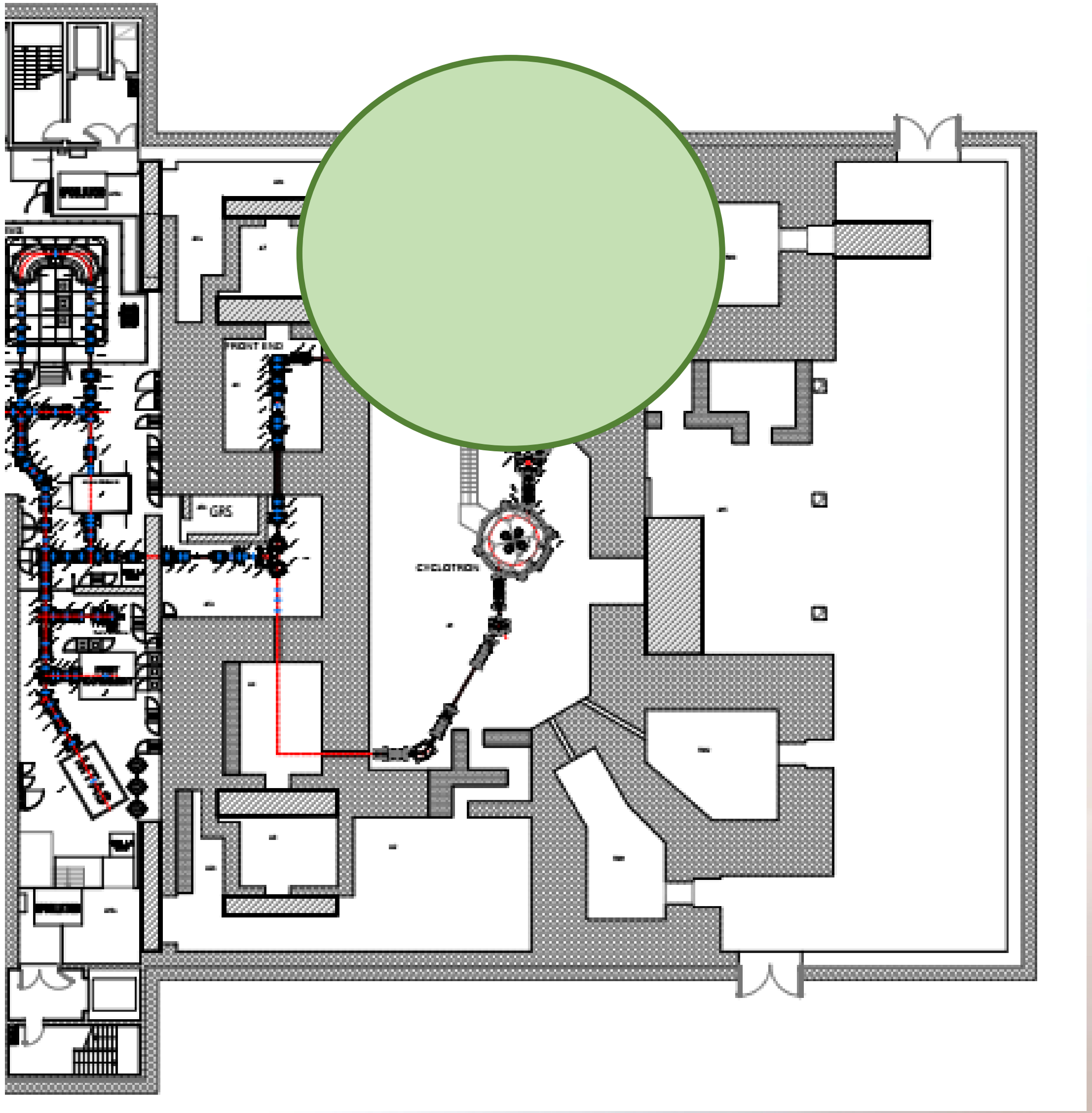
Direct production of Medical-Radio-Isotope using the ISOL technique



Direct production of Medical-Radio-Isotope using the Cyclotron

SPES-δ: The multidisciplinary neutron sources.

Neutrons: Several ideas in the future



- NEPIR: (NEutron and Proton IRradiation facility) project
- QMN: Quasi Mono-energetic Neutron source with a controllable energy peak in the 20-70Mev energy range
- ANEM: Atmospheric Neutron Emulator to get a fast neutrons (E>1 MeV) with a continuous energy distribution similar to that of neutrons found at flight-altitudes and sea-level for SEE testing
- SLOWNE: a high intensity slow neutron (E < MeV) flux for applications

Topics

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- SPES α,β,γ,δ
- SPES and Lasers
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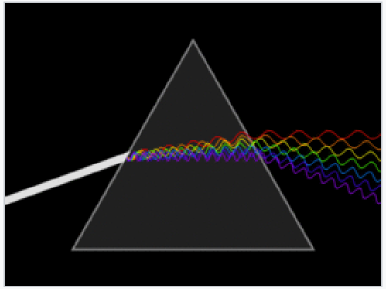
Light

From Wikipedia, the free encyclopedia

"Visible light" redirects here. For light that cannot be seen with human eye, see Electromagnetic radiation. For other uses, see Light (disambiguation) and Visible light (disambiguation).

"Lightsource" redirects here. For the solar energy developer named Lightsource, see Lightsource Renewable Energy.

Light is electromagnetic radiation within a certain portion of the electromagnetic spectrum. The word usually refers to **visible light**, which is the visible spectrum that is visible to the human eye and is responsible for the sense of sight.[1] Visible light is usually defined as having wavelengths in the range of 400–700 nanometres (nm), or 4.00×10^{-7} to 7.00×10^{-7} m, between the infrared (with longer wavelengths) and the ultraviolet (with shorter wavelengths).[2][3] This wavelength means a frequency range of roughly 430–750 terahertz (THz).



A triangular prism dispersing a beam of white light. The longer wavelengths (red) and the shorter wavelengths (blue) are separated.

The main source of light on Earth is the Sun. Sunlight provides the energy that green plants use to create sugars mostly in the form of starches, which release energy into the living things that digest them. This process of photosynthesis provides virtually all the energy used by living things. Historically, another important source of light for humans has been fire, from ancient campfires to modern kerosene lamps. With the development of electric lights and power systems, electric lighting has effectively replaced firelight. Some species of animals generate their own light, a process called bioluminescence. For example, fireflies use light to locate mates, and vampire squids use it to hide themselves from prey.

The primary properties of visible light are intensity, propagation direction, frequency or wavelength spectrum, and polarization, while its speed in a vacuum, 299,792,458 metres per second, is one of the fundamental constants of nature. Visible light, as with all types of electromagnetic radiation (EMR), is experimentally found to always move at this speed in a vacuum.[4]

In physics, the term *light* sometimes refers to electromagnetic radiation of any wavelength, whether visible or not.[5][6] In this sense, gamma rays, X-rays, microwaves and radio waves are also light. Like all types of EM radiation, visible light propagates as waves. However, the energy imparted by the waves is absorbed at single locations the way particles are absorbed. The absorbed energy of the EM waves is called a photon, and represents the quanta of light. When a wave of light is transformed and absorbed as a photon, the energy of the wave instantly collapses to a single location, and this location is where the photon "arrives." This is what is called the wave function collapse. This dual wave-like and particle-like nature of light is known as the wave–particle duality. The study of light, known as optics, is an important research area in modern physics.

Modern physics

$$\hat{H}|\psi_n(t)\rangle = i\hbar\frac{\partial}{\partial t}|\psi_n(t)\rangle$$

$$\frac{1}{c^2}\frac{\partial^2\phi_n}{\partial t^2} - \nabla^2\phi_n + \left(\frac{mc}{\hbar}\right)^2\phi_n = 0$$

Manifold dynamics: Schrödinger and Klein–Gordon equations

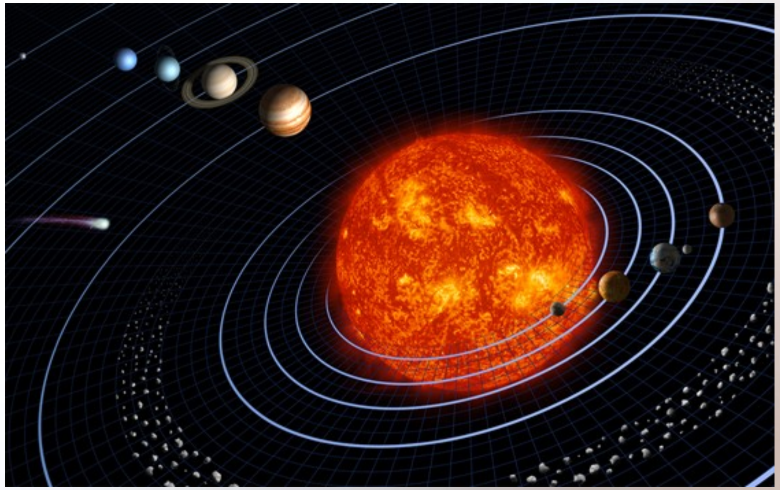
Contents [hide]

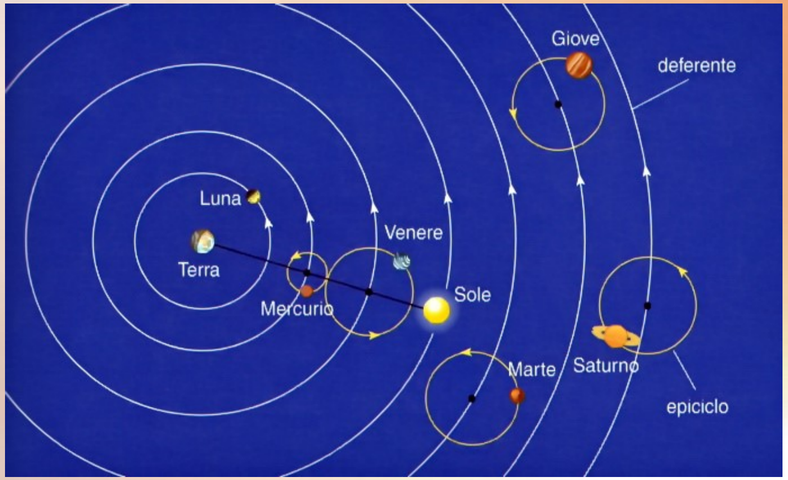
Light (Laser)

- Energy
- Wavelength
- Propagation
- Wave…. Particle….

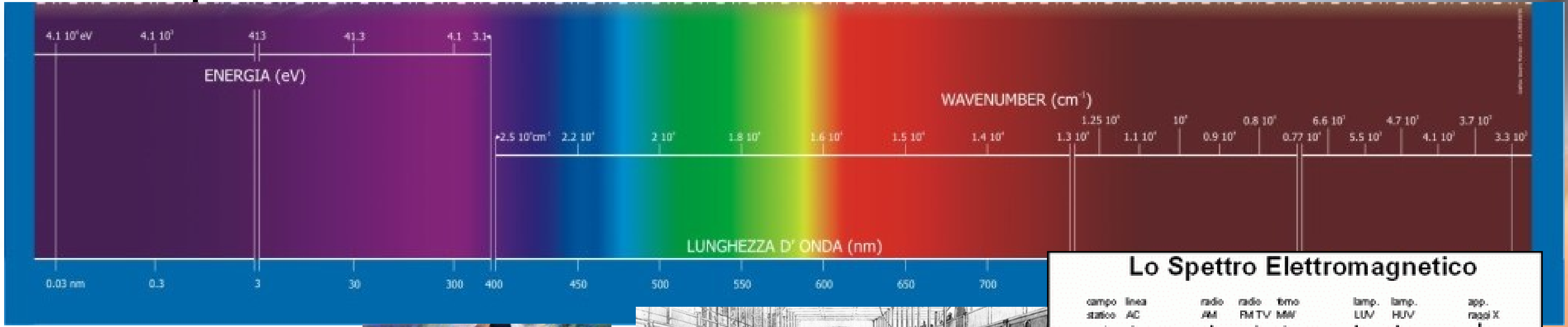
$$E = \hbar\omega = h\nu = \frac{hc}{\lambda}$$

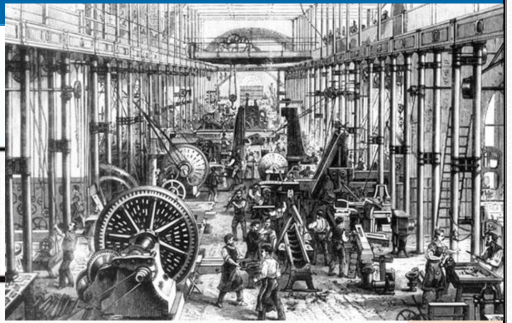
$$\boldsymbol{p} = \hbar\boldsymbol{k},$$

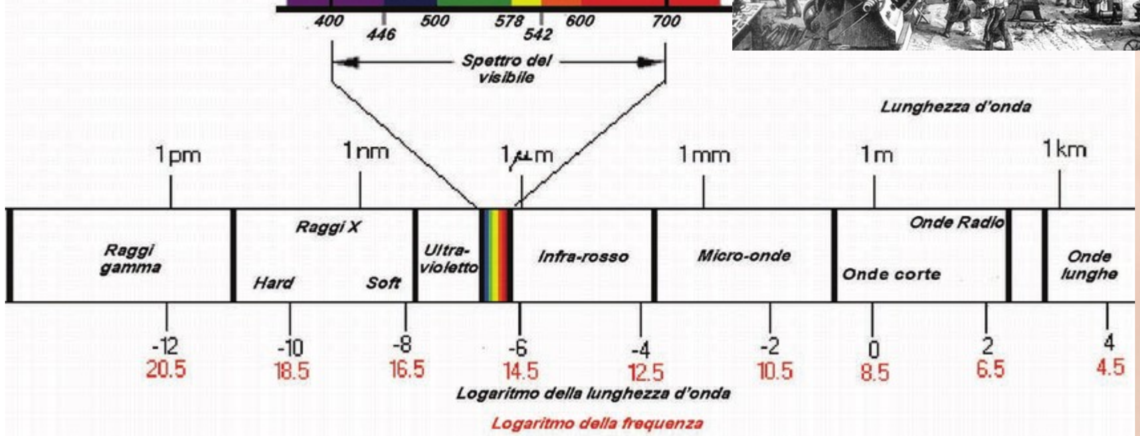


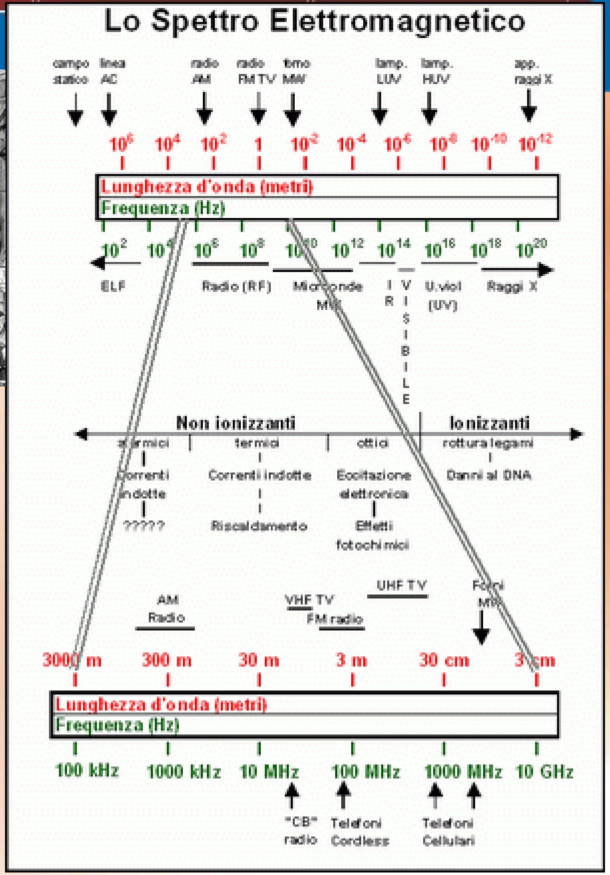


Light Properties: Color







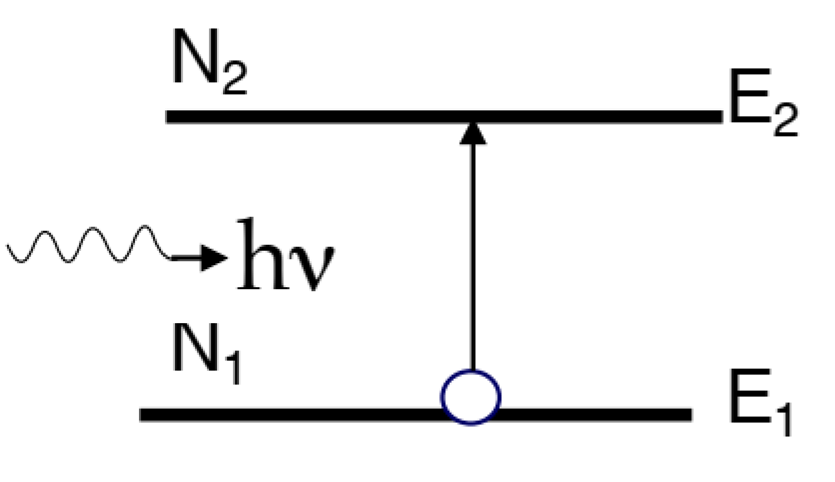


Light emission….. Absorption firts

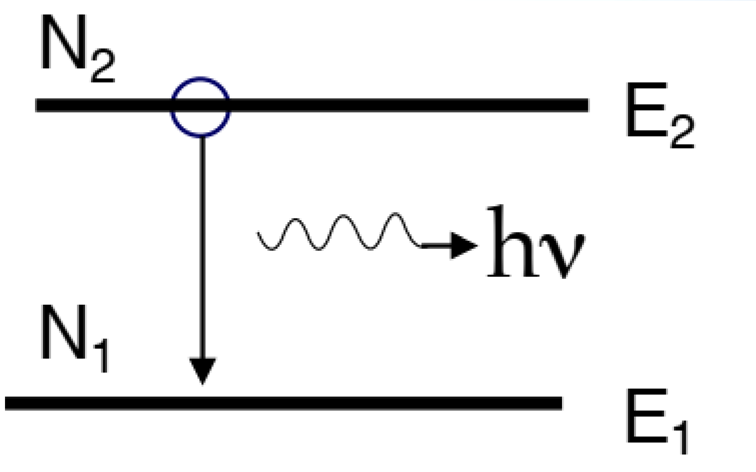
- Light absorption

$$E = \hbar\omega = h\nu = \frac{hc}{\lambda}$$

$$\boldsymbol{p} = \hbar\boldsymbol{k},$$

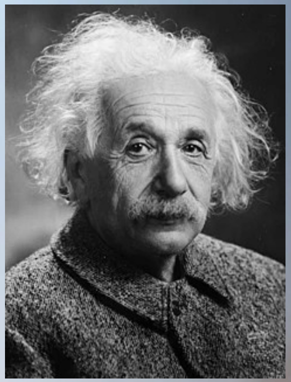


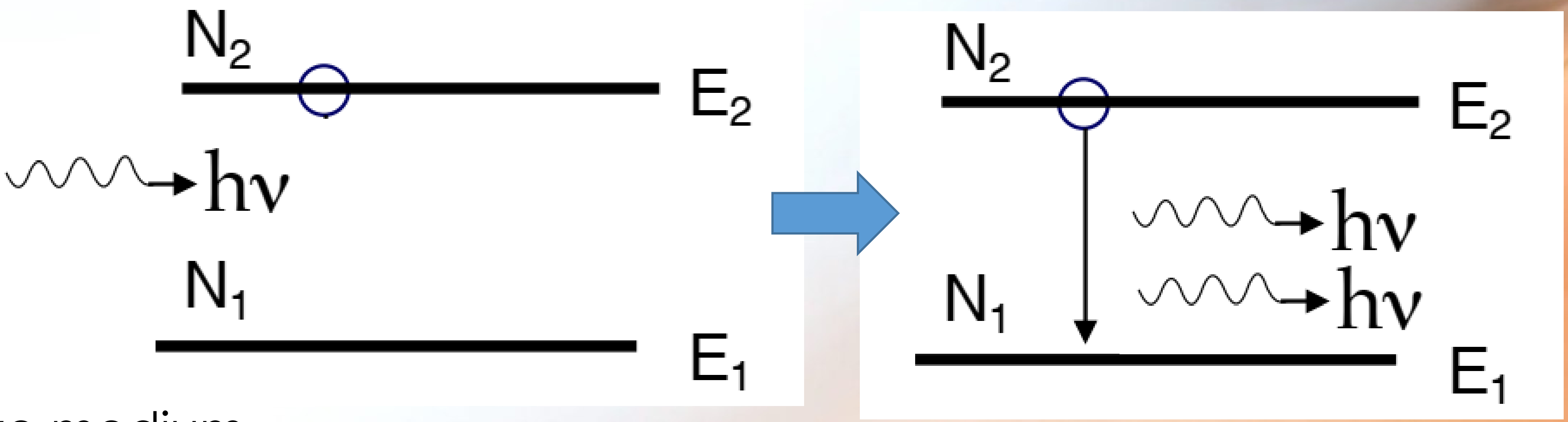
Emission….. Spontaneous



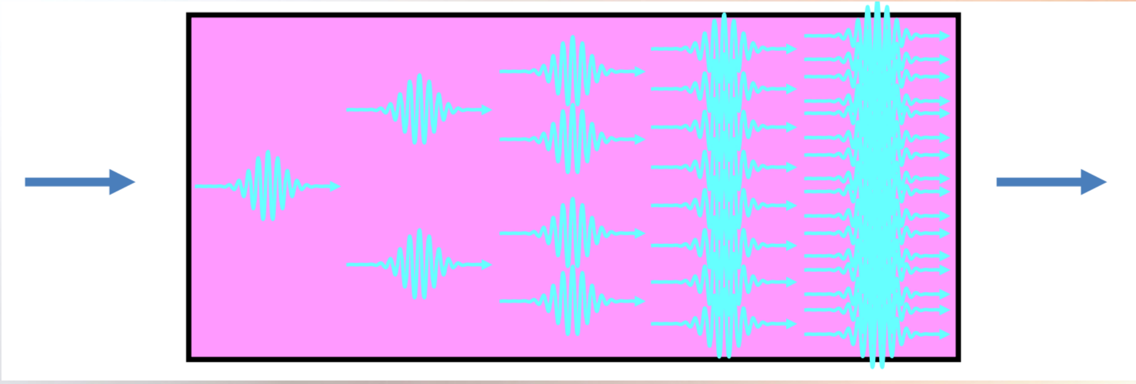
- LED => Electrical power
- Fluorescence => Light!!! => absorption

Emission….. Stimulated(1905)

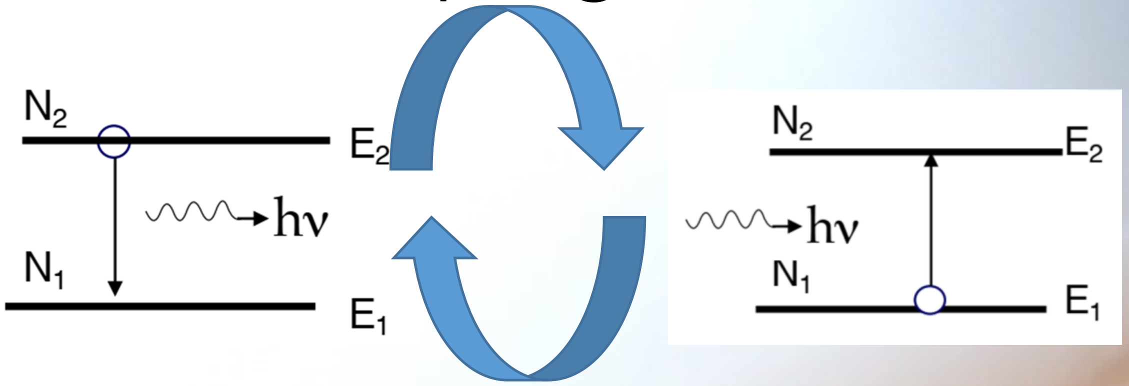




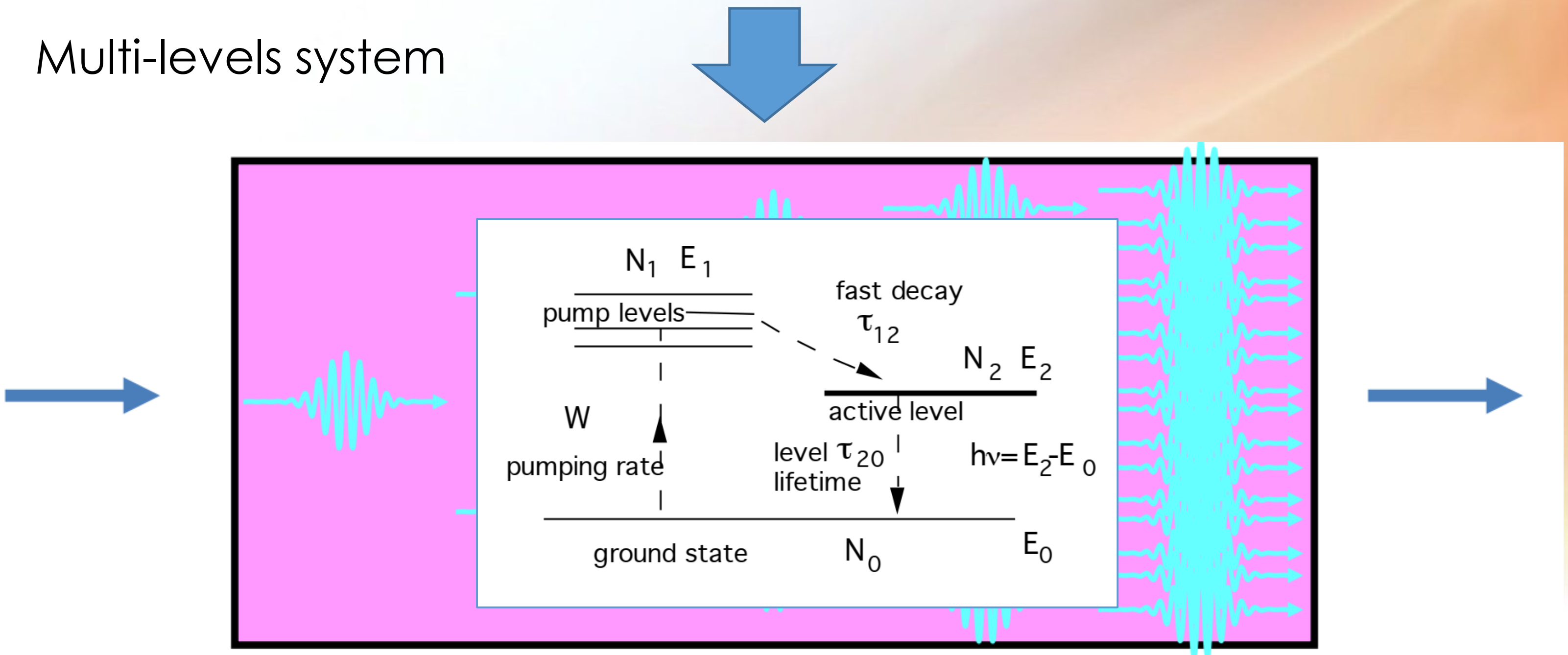
- Active medium



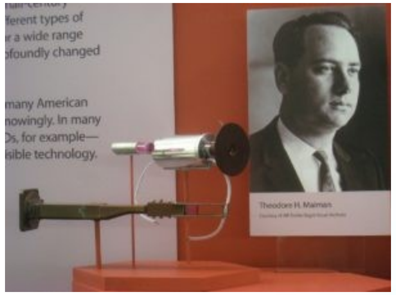
Active medium => Pumping



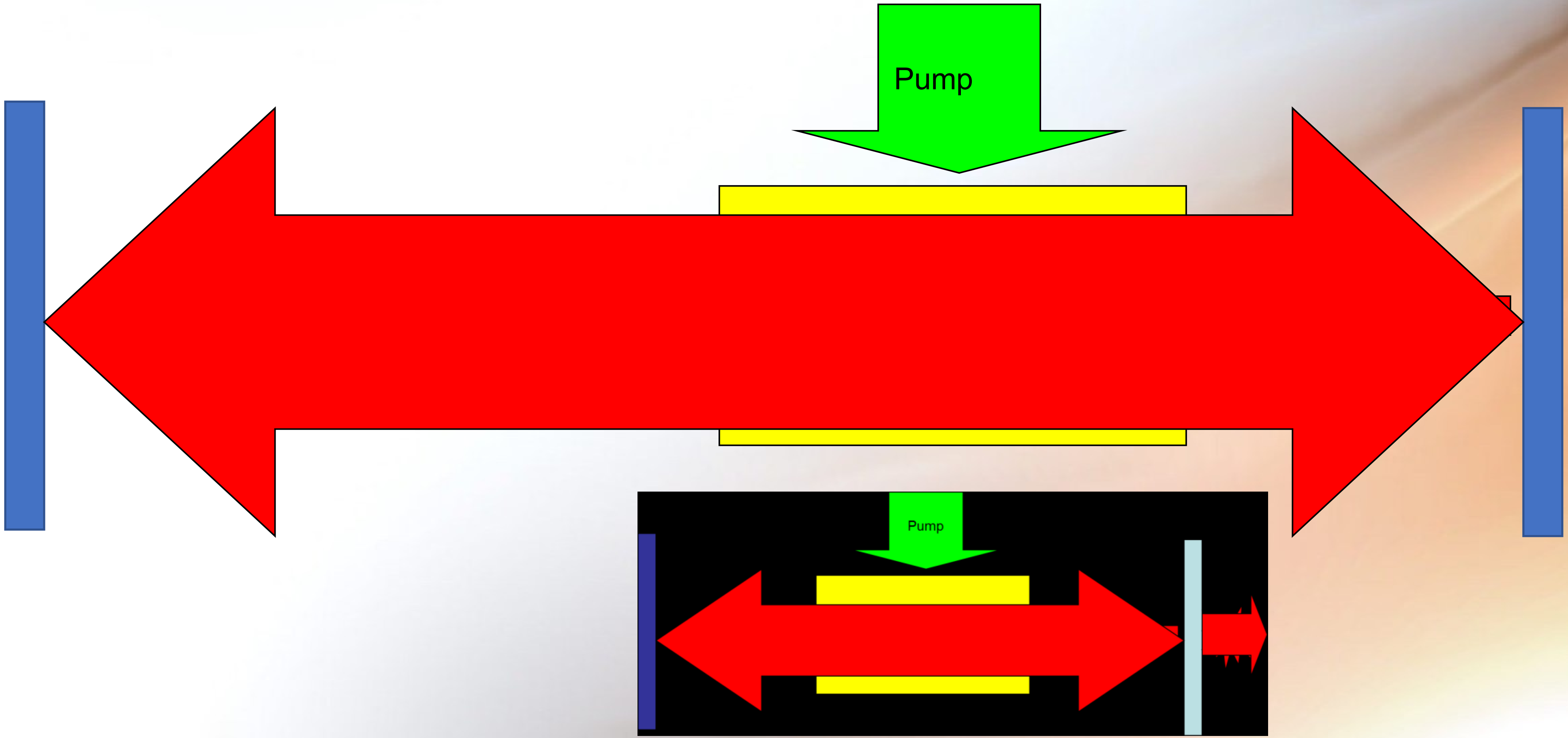
- Multi-levels system



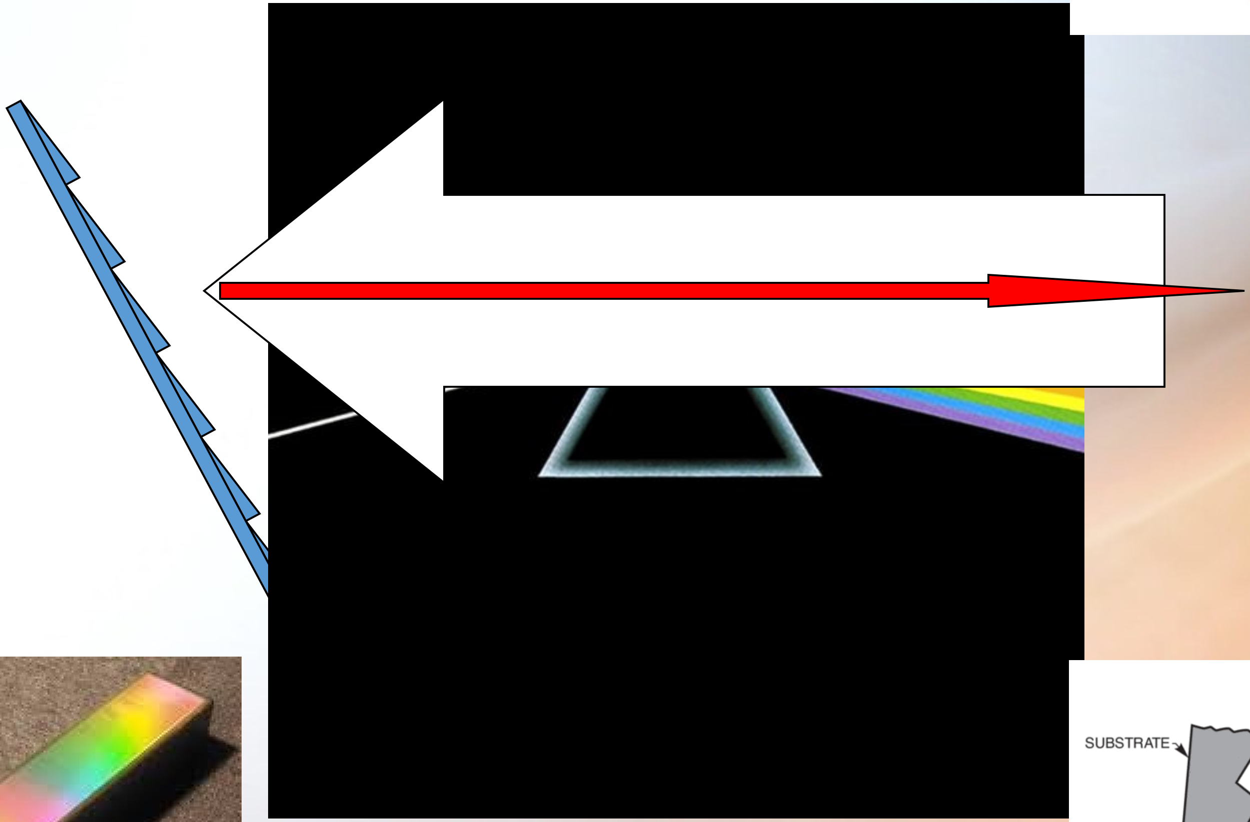
Laser (1960)

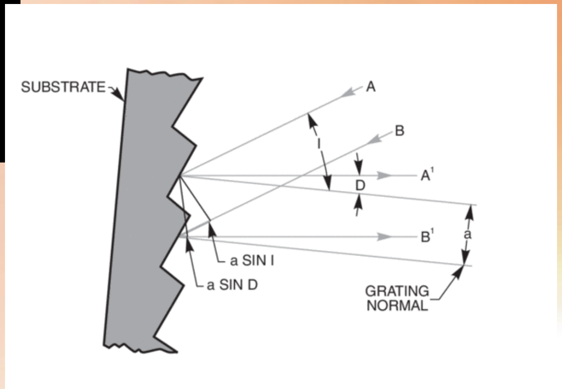


- **l**ight **a**mplification by **s**timulated **e**mission of **r**adiation



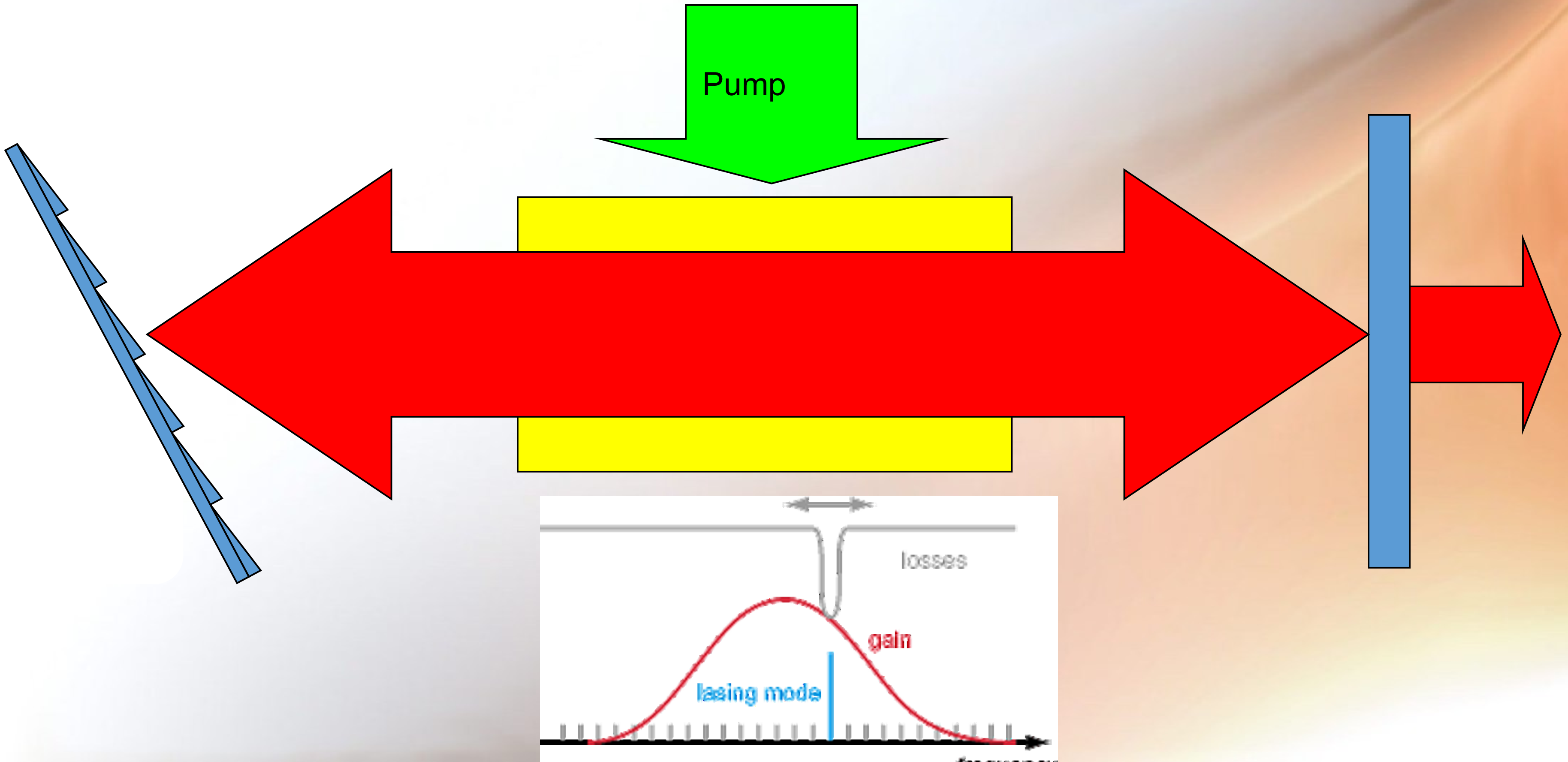
Selecting color...





Color?

- Who drive the laser color? => Active medium & Losses



Topics

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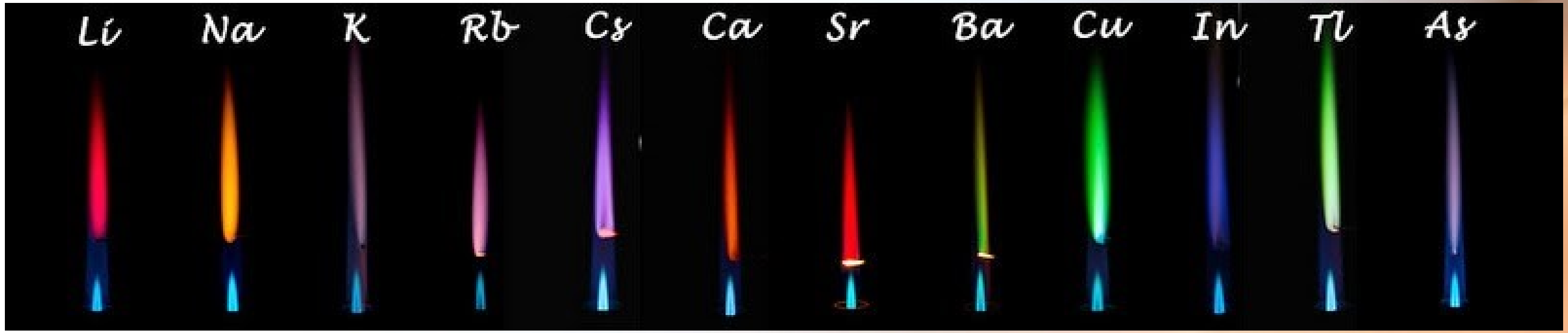
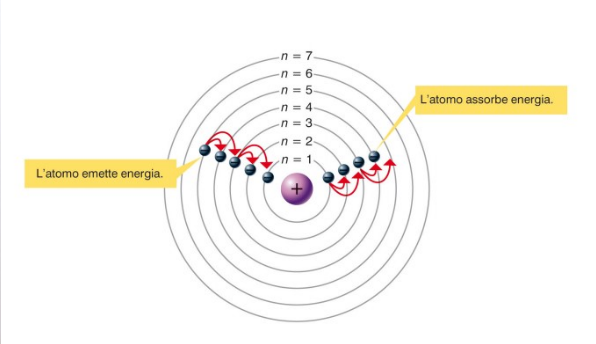
Flame test

- «Each element has its own favorite color»

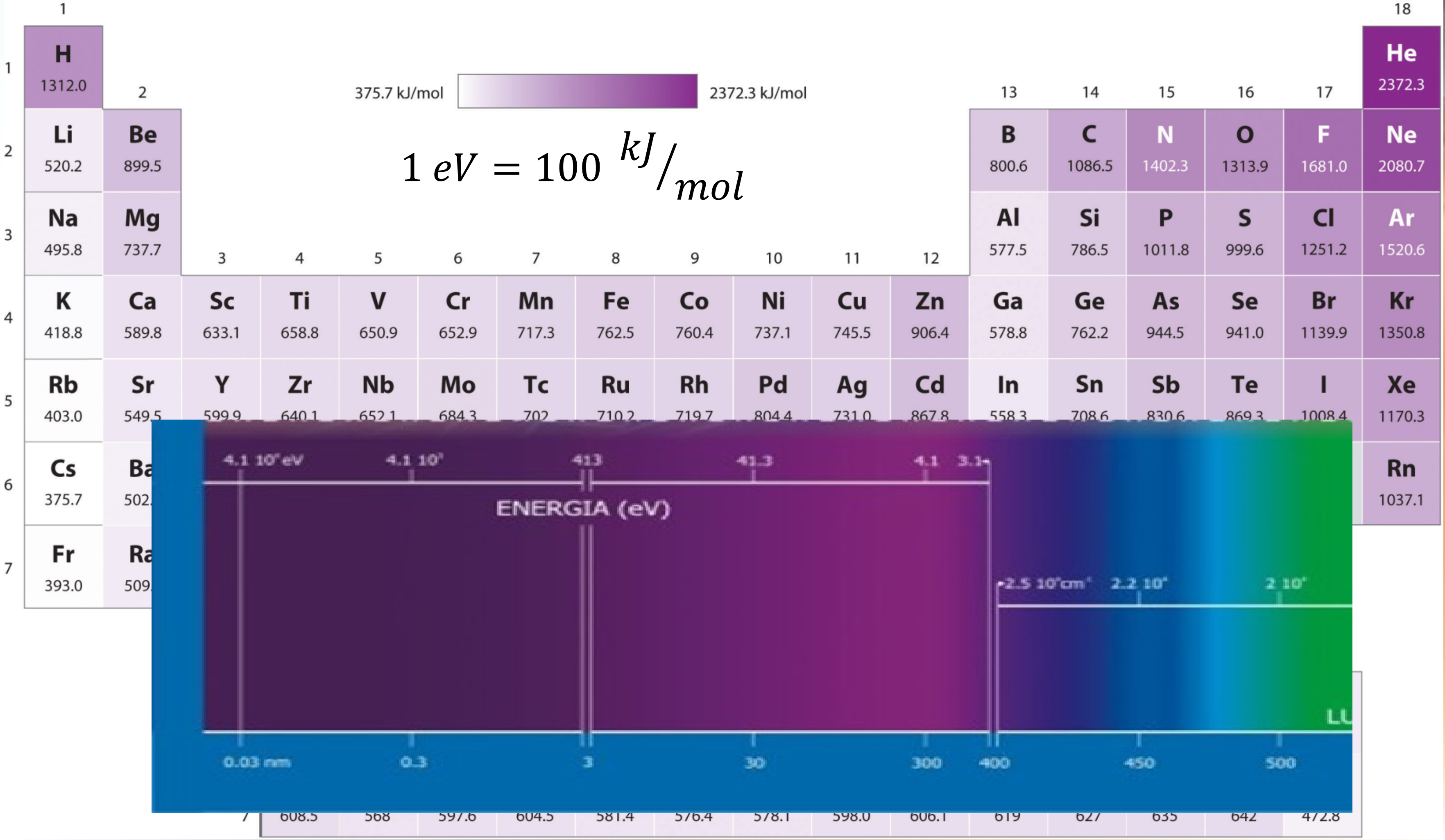


- Emission/Absorbtion

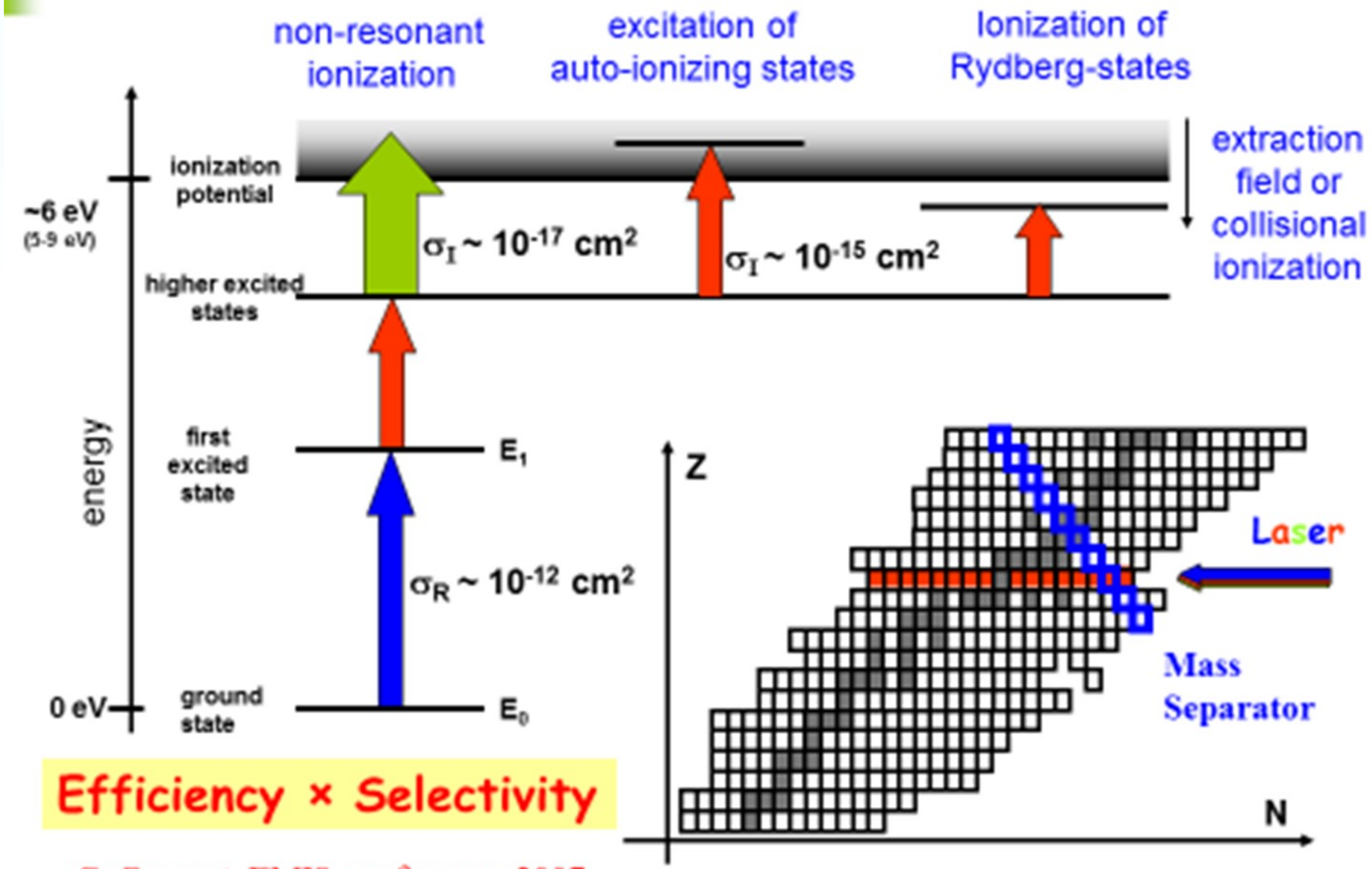


Ionization Potential

$$1\ eV = 100\ {}^{kJ}/_{mol}$$



Principles of resonant laser ionization

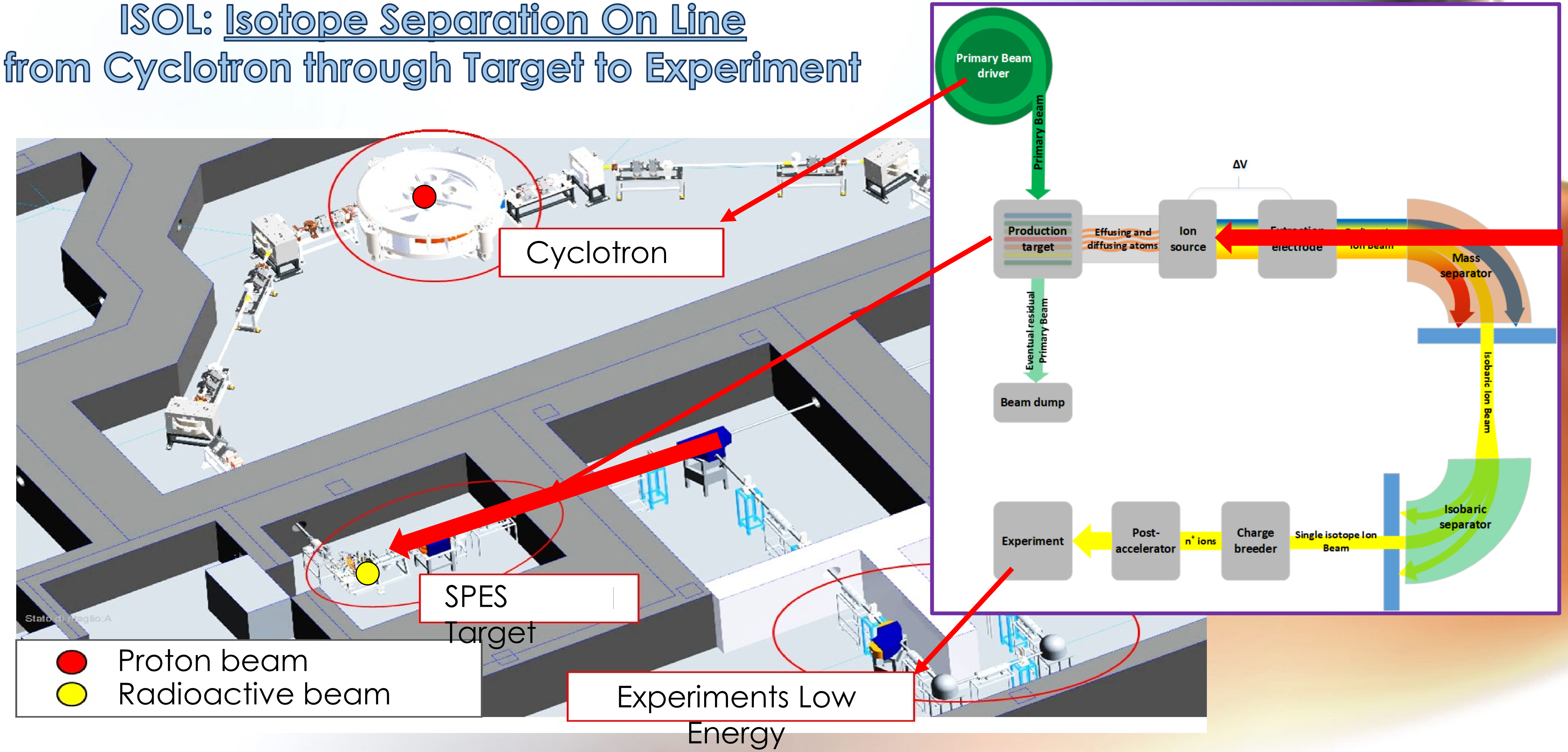


Efficiency × Selectivity

C. Geppert, EMIS conference, 2007.

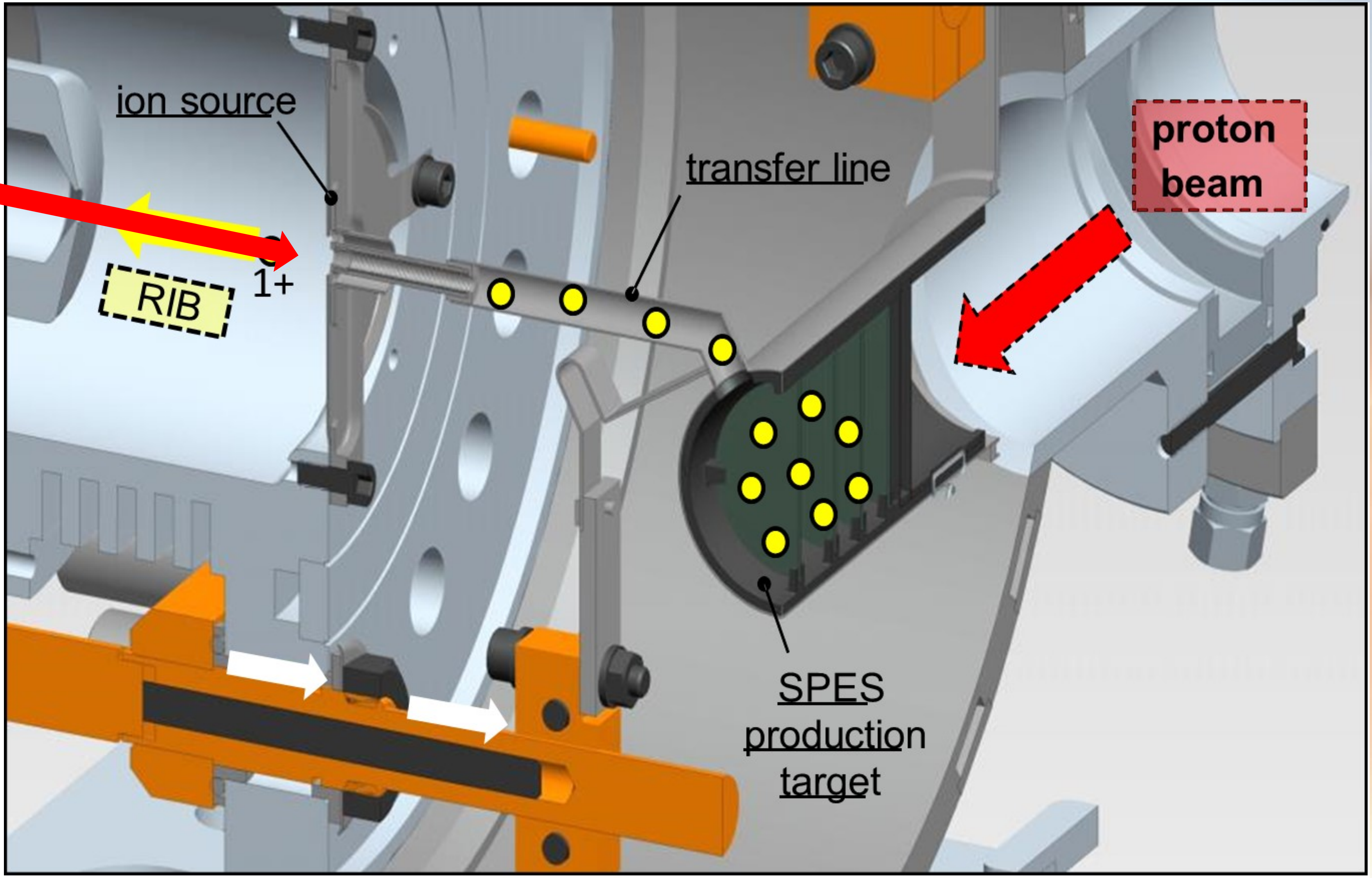
SPES-β: The ISOL facility and the acceleration of neutron-rich unstable nuclei.

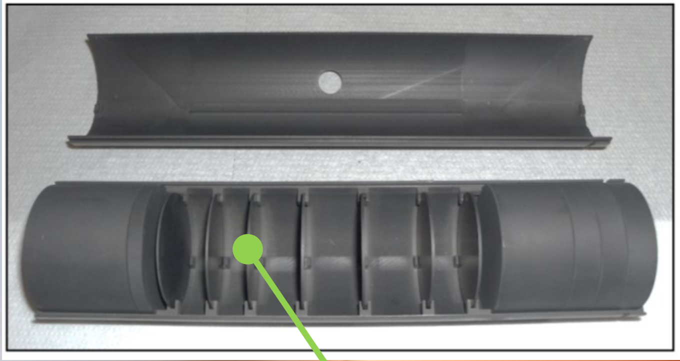
ISOL: Isotope Separation On Line
from Cyclotron through Target to Experiment

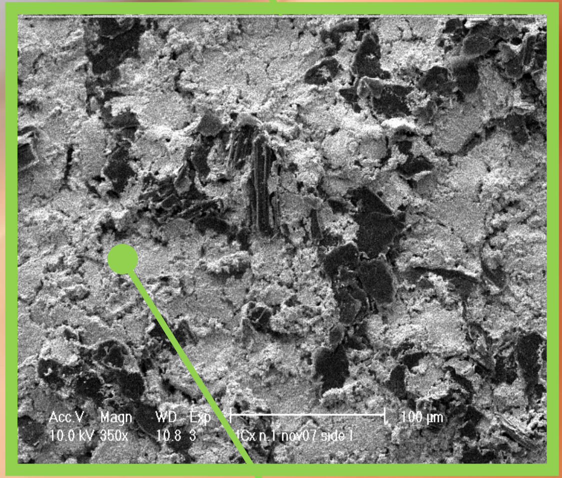


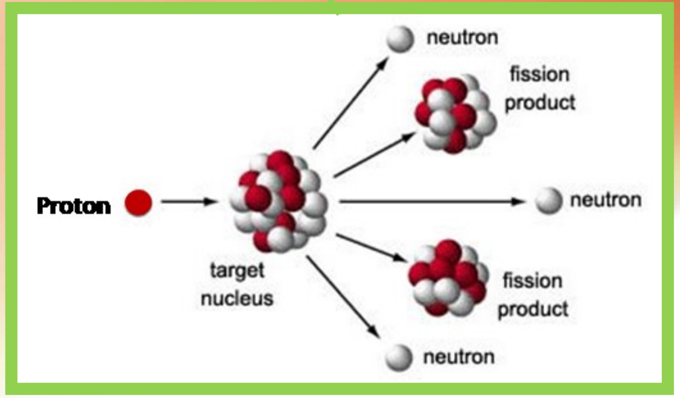
SPES-β: The ISOL facility and the acceleration of neutron-rich unstable nuclei.

SPES Zoom IN: Inside SPES Target (>10 Years of R&D)









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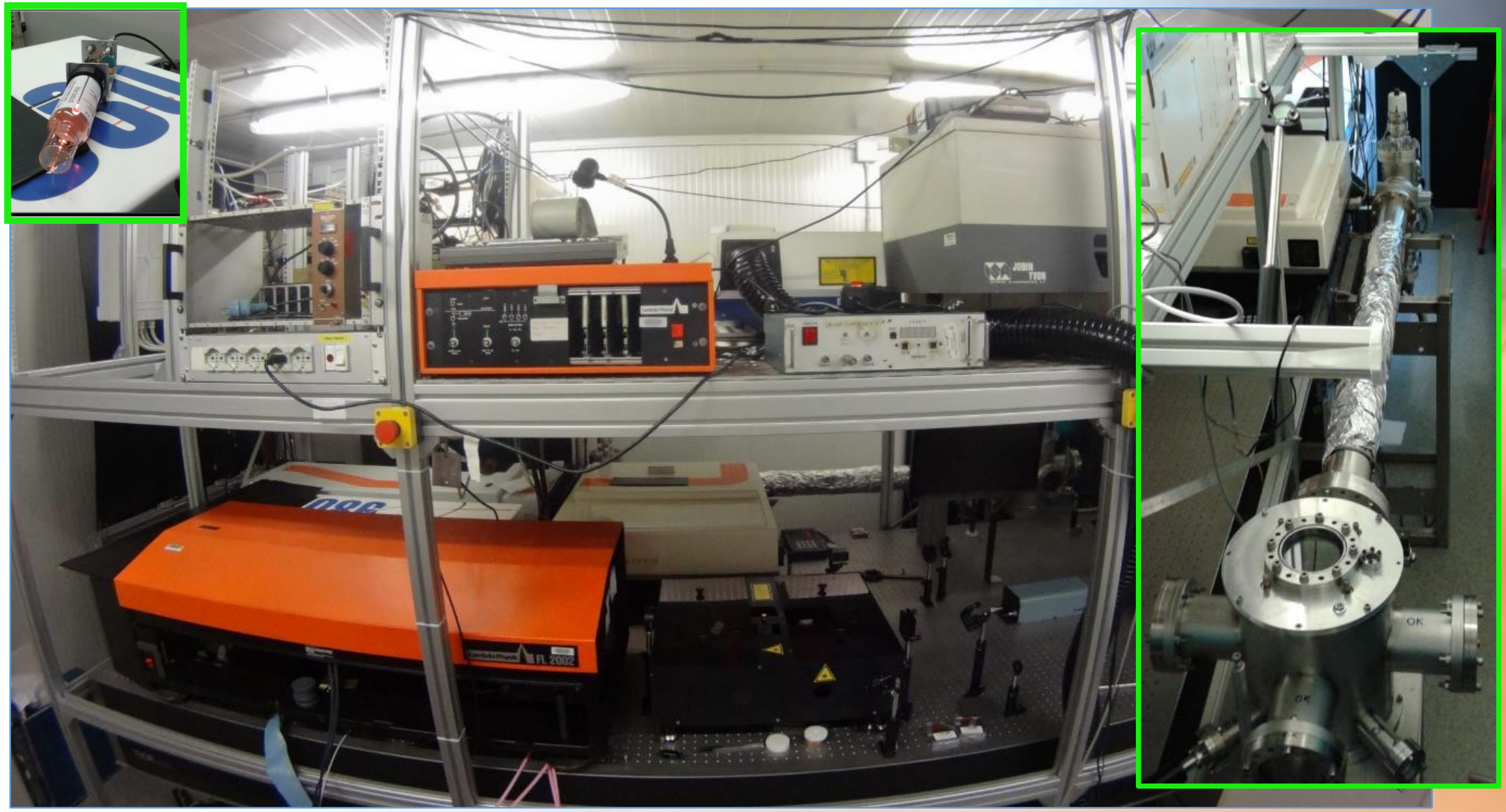
LNL-INFN SPES Offline Laser Laboratory



Lasers:
3 Dye lasers pumped by 2 Nd:YAG 10Hz rep rate lasers; Nd:YAG for ablation
Measurement systems:
Hollow Cathode Lamps and Time of Flight Mass Spectrometer

Hollow cathode lamps

Designed to provide spectral emission of different elements.

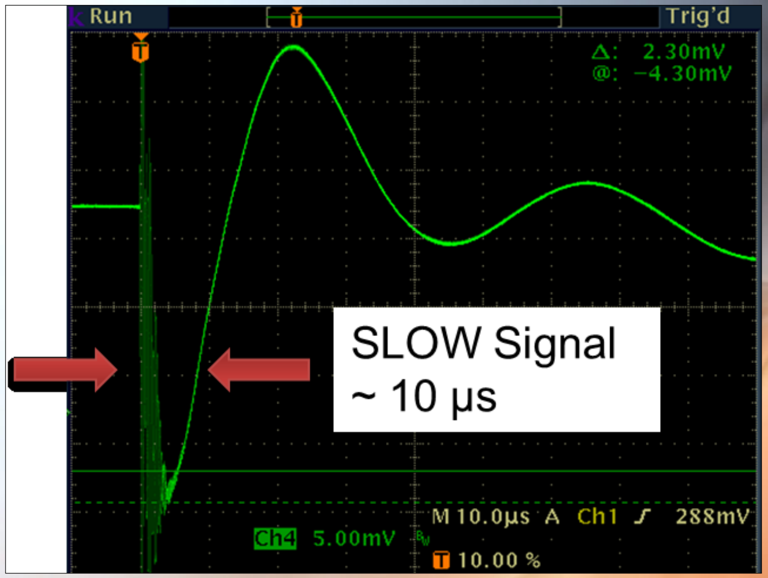
- Commercial for Opto Galvanic application
- Inexpensive
- Available for almost the whole periodic table
- Electrical noise is very small, comparable with the level of shot noise
- Easy setup

The OG effect arises from the interaction of resonant radiation with atoms present in a discharge.
Lawler, 1980, observed that the OG effect can be considered proportional to the number of photons absorbed [1]

[1]Beniamino Barbieri, Nicolò Beverini, Antonio Sasso: “Optogalvanic spectroscopy”, Reviews of Modern Physics, Vol. 62, No.3, July 1990

Optogalvanic Signals

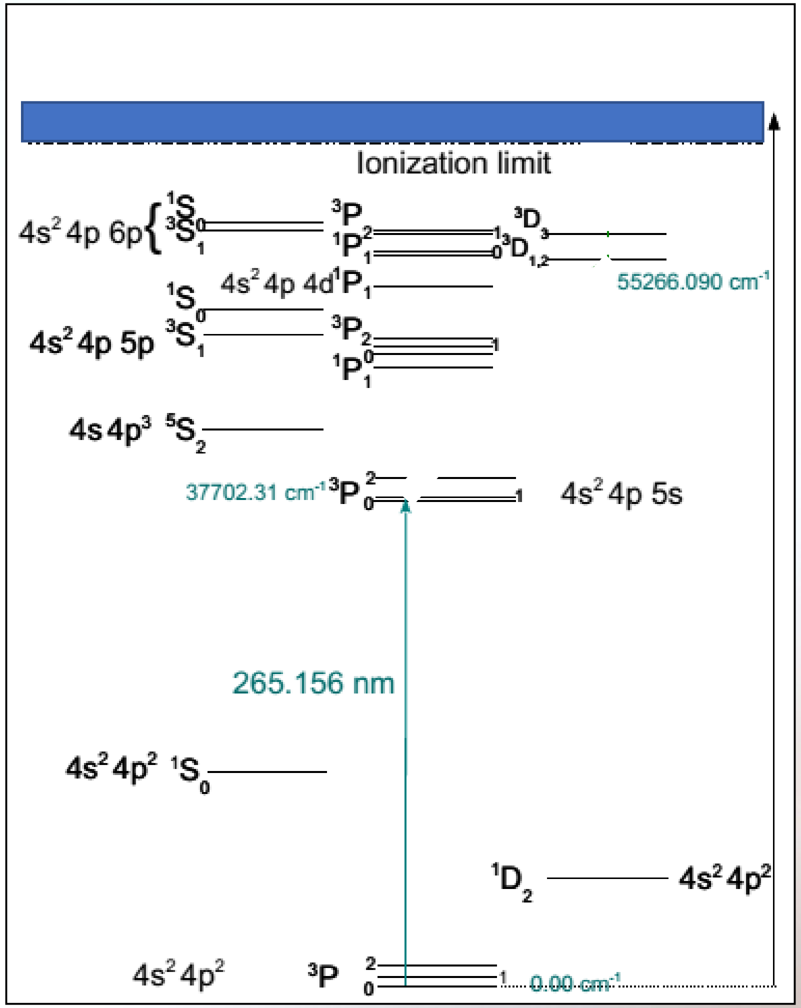
SLOW Opto-Galvanic Signal:
The absorption of laser radiation in the discharge results in a change in the steady-state population of bound atomic or molecular levels. Since different levels will have different ionization cross-sections, a perturbation to the steady-state situation results in a net change in the discharge current or equivalently a change in the discharge impedance. The electric signal detected is the slow signal, negative and lasting µs.

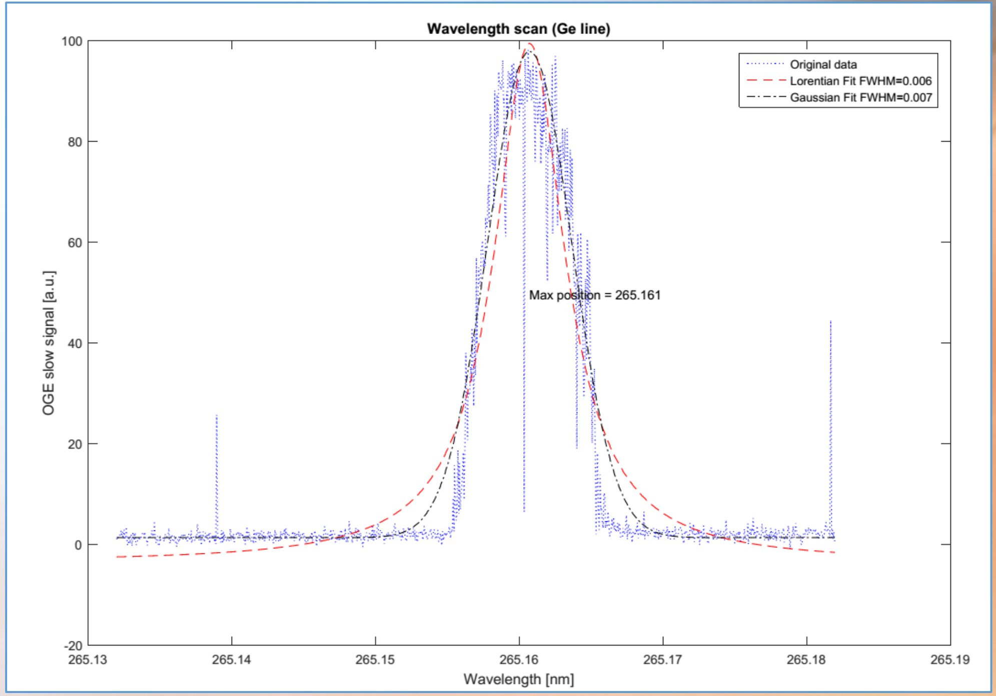


FAST Opto-Galvanic Signal:
It is a direct ionization process during laser pulse. The laser radiation brings the selectively excited atoms directly to ionization. Electrons are immediately available as carriers.
This effect produces a fast electric signal. It was found (Broglia et al 1983 [3]) that this fast signal follows the laser pulse temporal behavior (ns).

[3] M.Broglia, F.Catoni, P.Zampetti: "Temporal behaviour of the optogalvanic signal in a hollow cathode lamp", Journal de Physique, Colloque C7, supplement au n° 11, Tome 44, novembre 1983

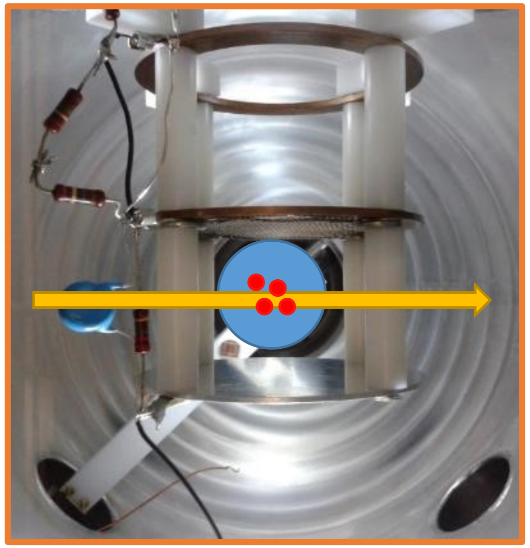
Laser resonant ionization

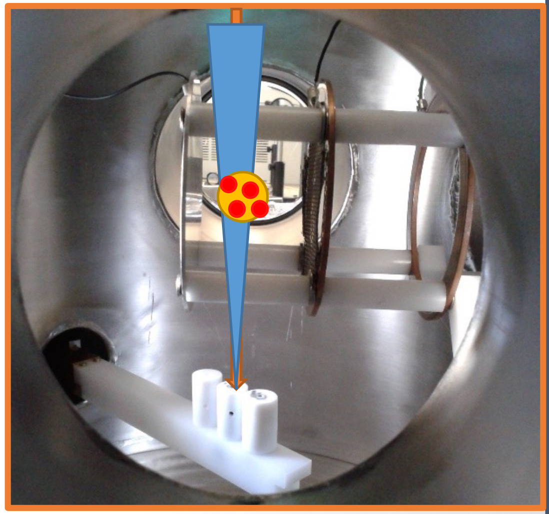


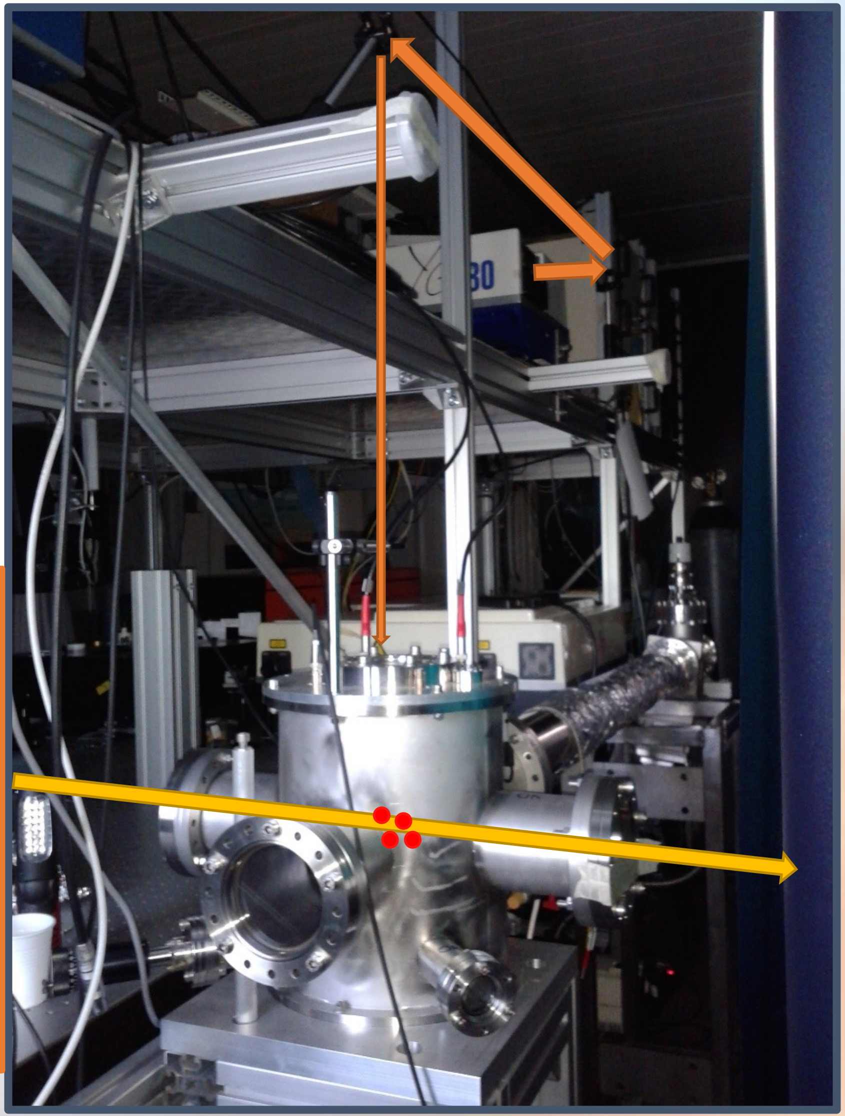


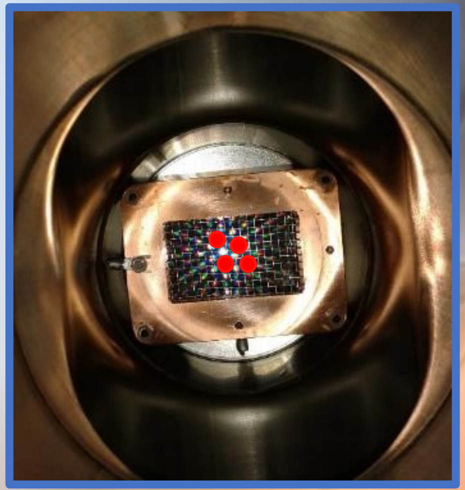
Time of flight mass spectrometer

Measure Sequence:





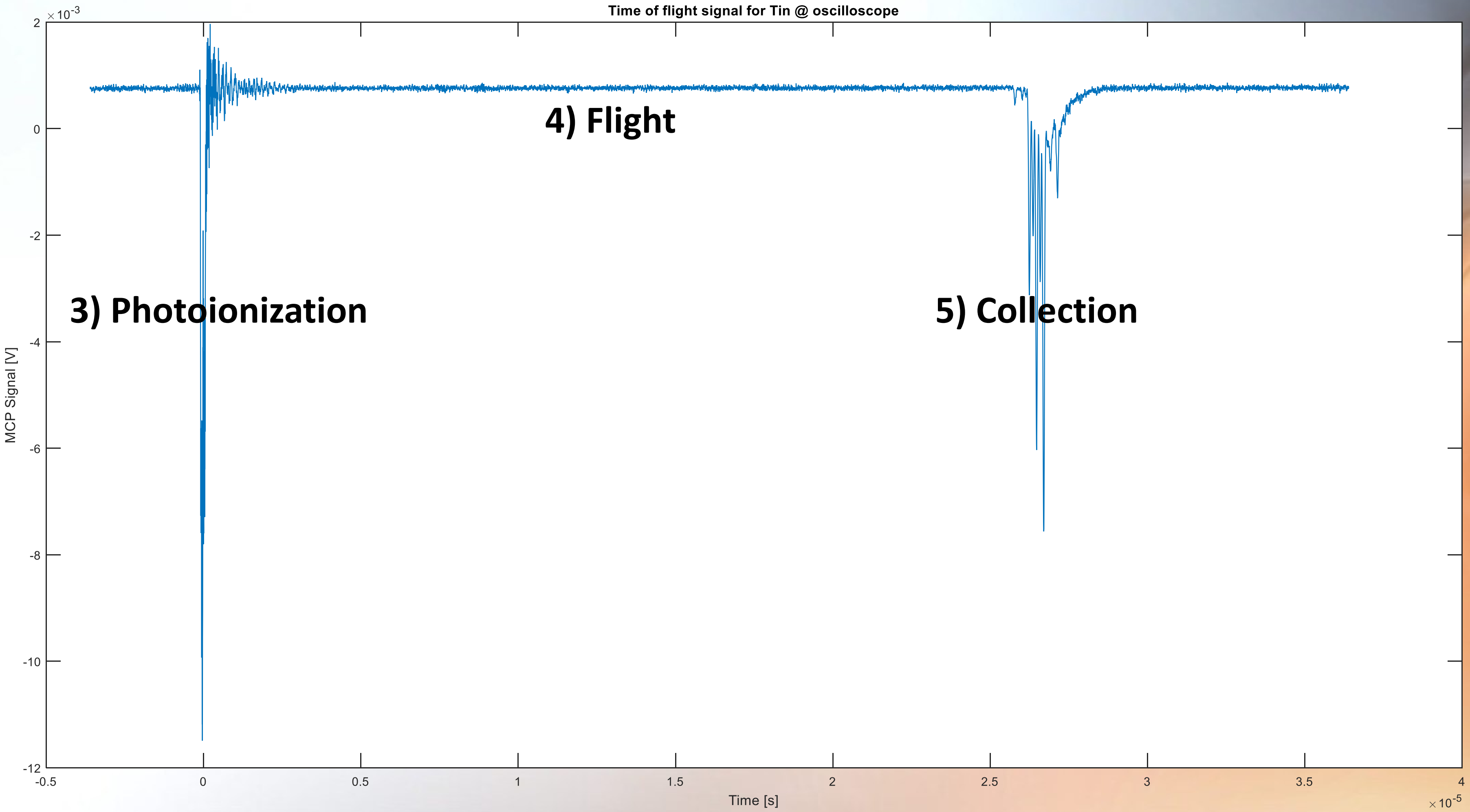




1) Ablation
2) Plume Expansion
3) Photoionization
4) Flight
5) Collection

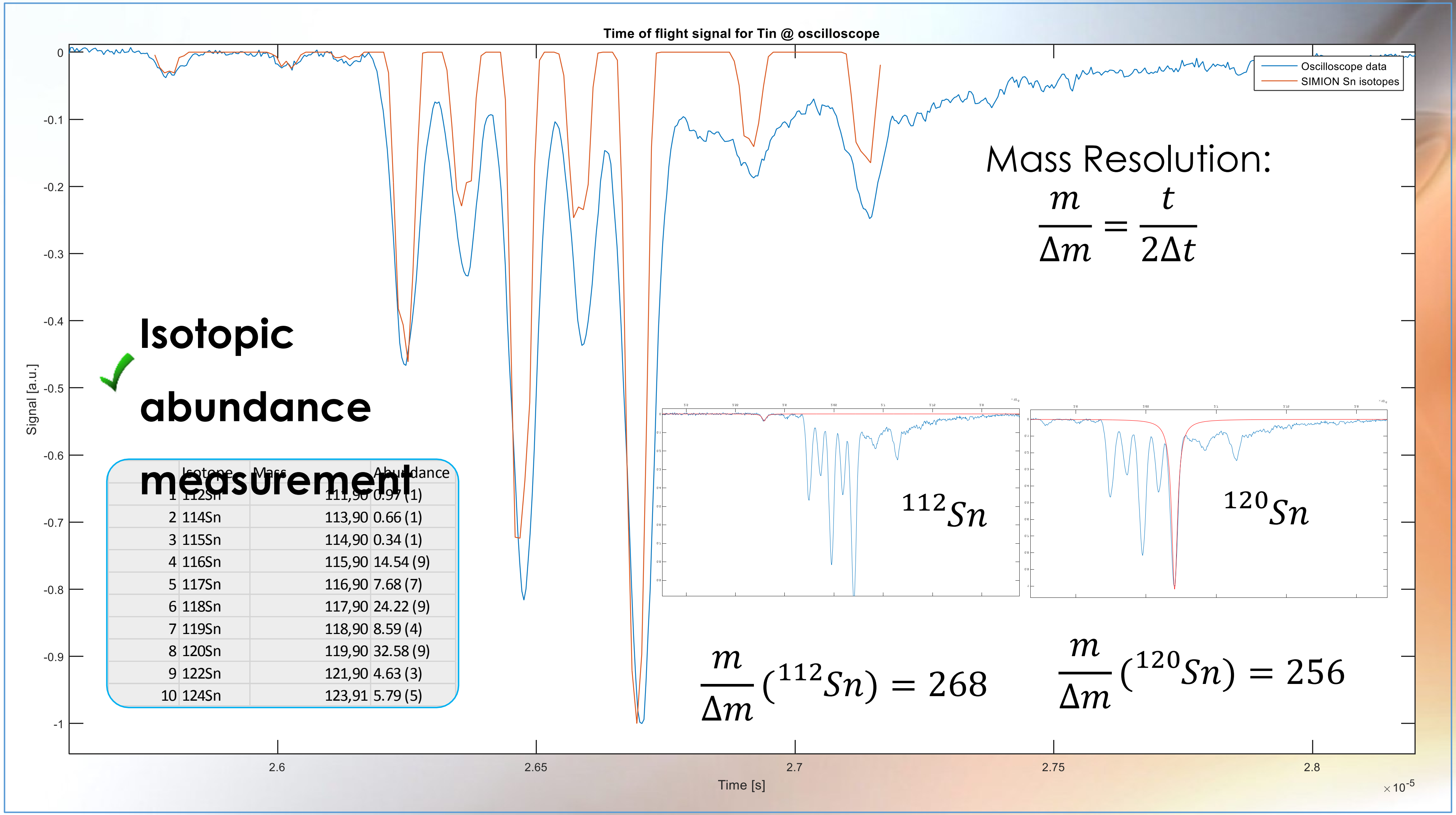
Time of flight mass spectrometer

Typical Signal:



Time of flight mass spectrometer

Simion® simulation VS ToF acquisition & ToF mass resolution



Isotopic abundance measurement

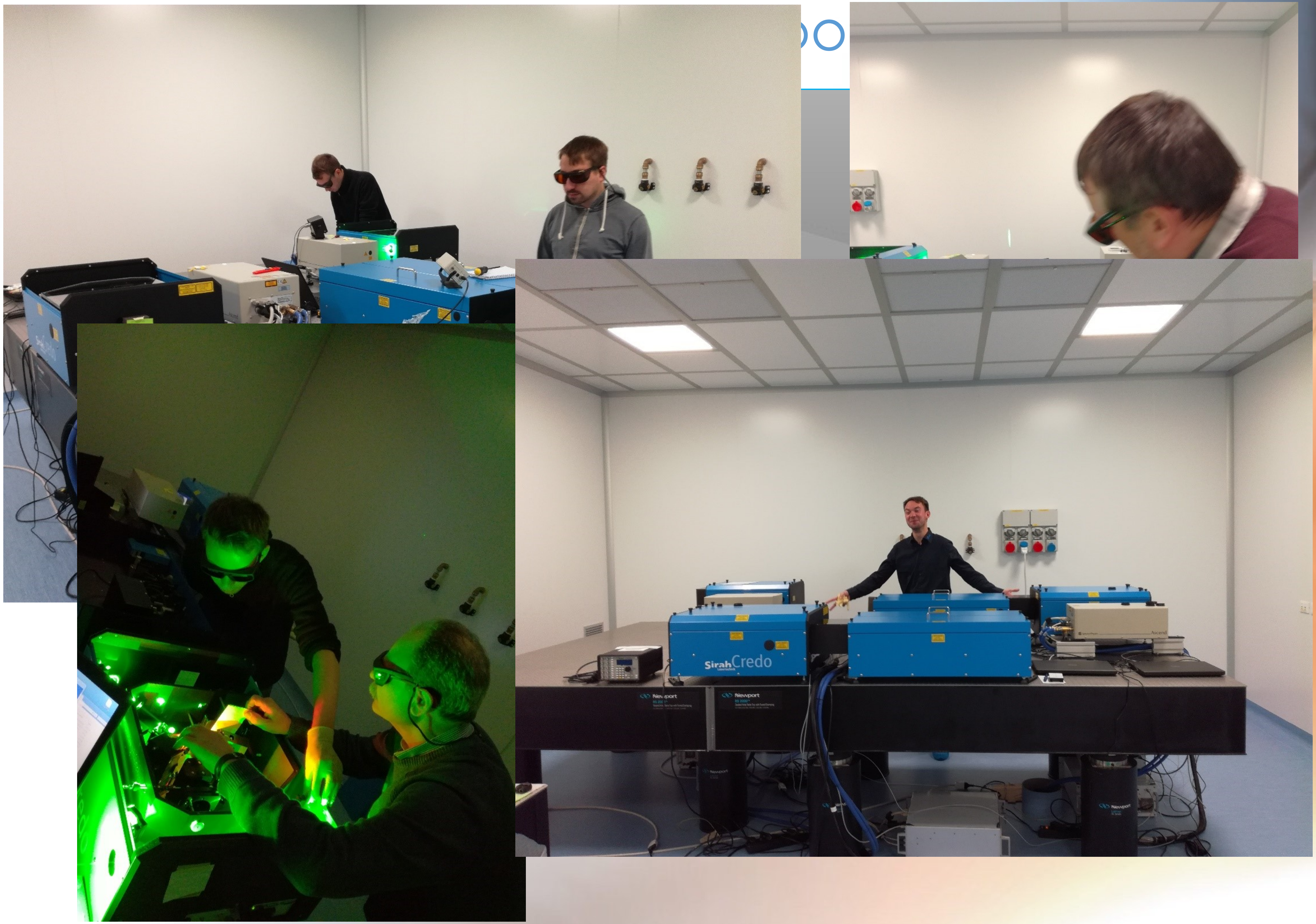
	Isotope	Mass	Abundance
1	112Sn	111,90	0.97 (1)
2	114Sn	113,90	0.66 (1)
3	115Sn	114,90	0.34 (1)
4	116Sn	115,90	14.54 (9)
5	117Sn	116,90	7.68 (7)
6	118Sn	117,90	24.22 (9)
7	119Sn	118,90	8.59 (4)
8	120Sn	119,90	32.58 (9)
9	122Sn	121,90	4.63 (3)
10	124Sn	123,91	5.79 (5)

Mass Resolution:

$$\frac{m}{\Delta m} = \frac{t}{2\Delta t}$$

$$\frac{m}{\Delta m}(^{112}Sn) = 268$$

$$\frac{m}{\Delta m}(^{120}Sn) = 256$$


Sirah Credo
Newport
Newport

Thank You

Aggiornamento per docenti di scuola secondaria di II grado
LNL-INFN