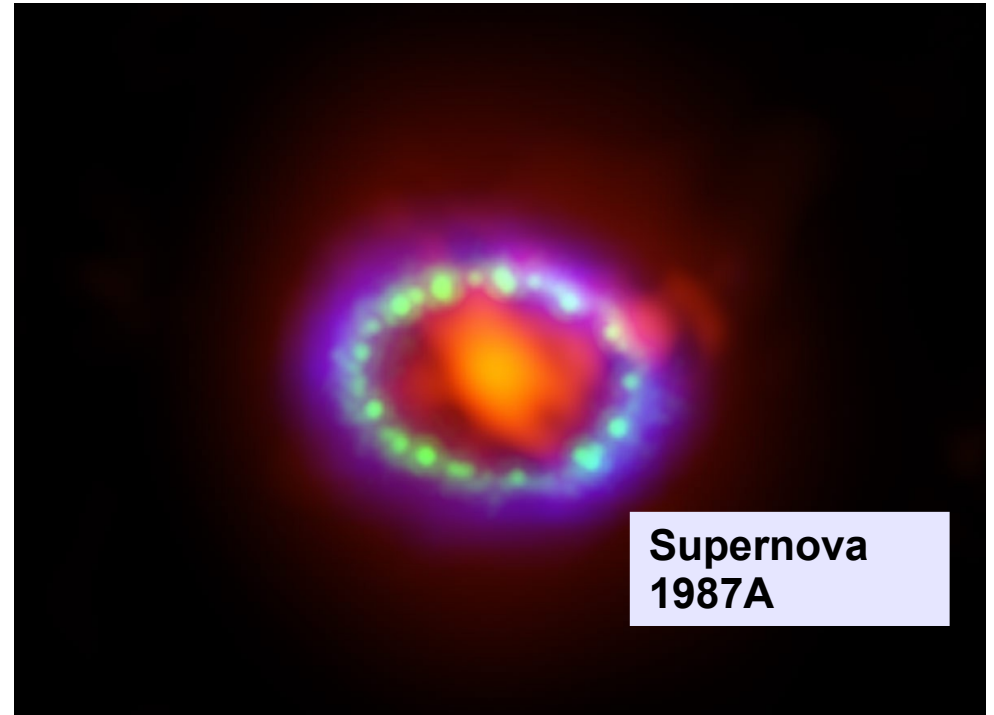
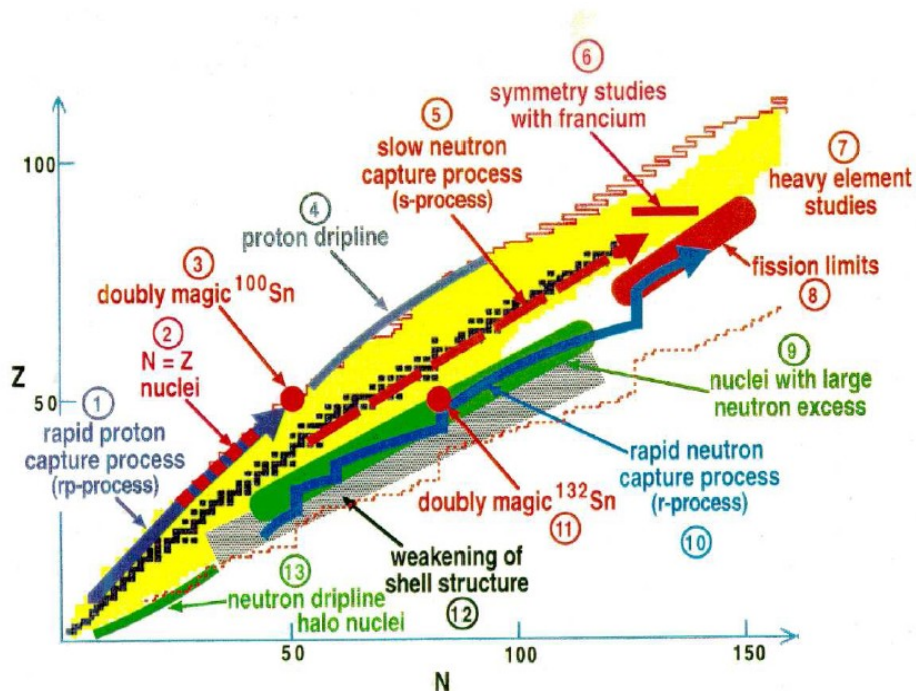


# From valleys to stars

italian experimental opportunities to explore the challenging world of (exotic) nuclei



Giovanni Casini, INFN Florence

PISA2015 Student week, July 20-24

# Which approach for you ?



Instrumentation side

Experiment side

Geographical side

Physics subject side

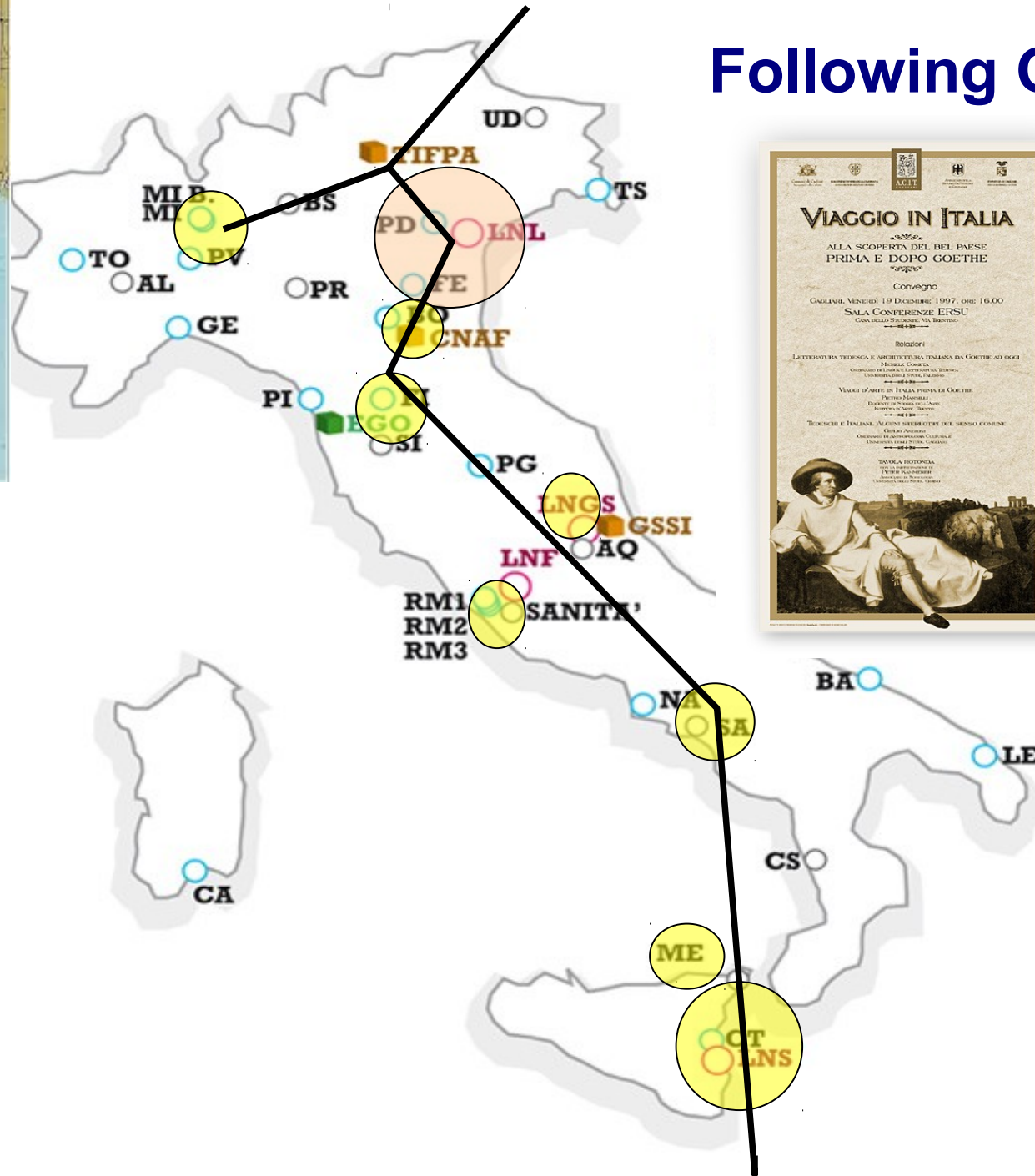
Collaboration side

**AIM?**

**NOT** to explain well everything (me) or to understand well everything (you)

**YES** to rise up your curiosity and to give you guidelines for future contacts

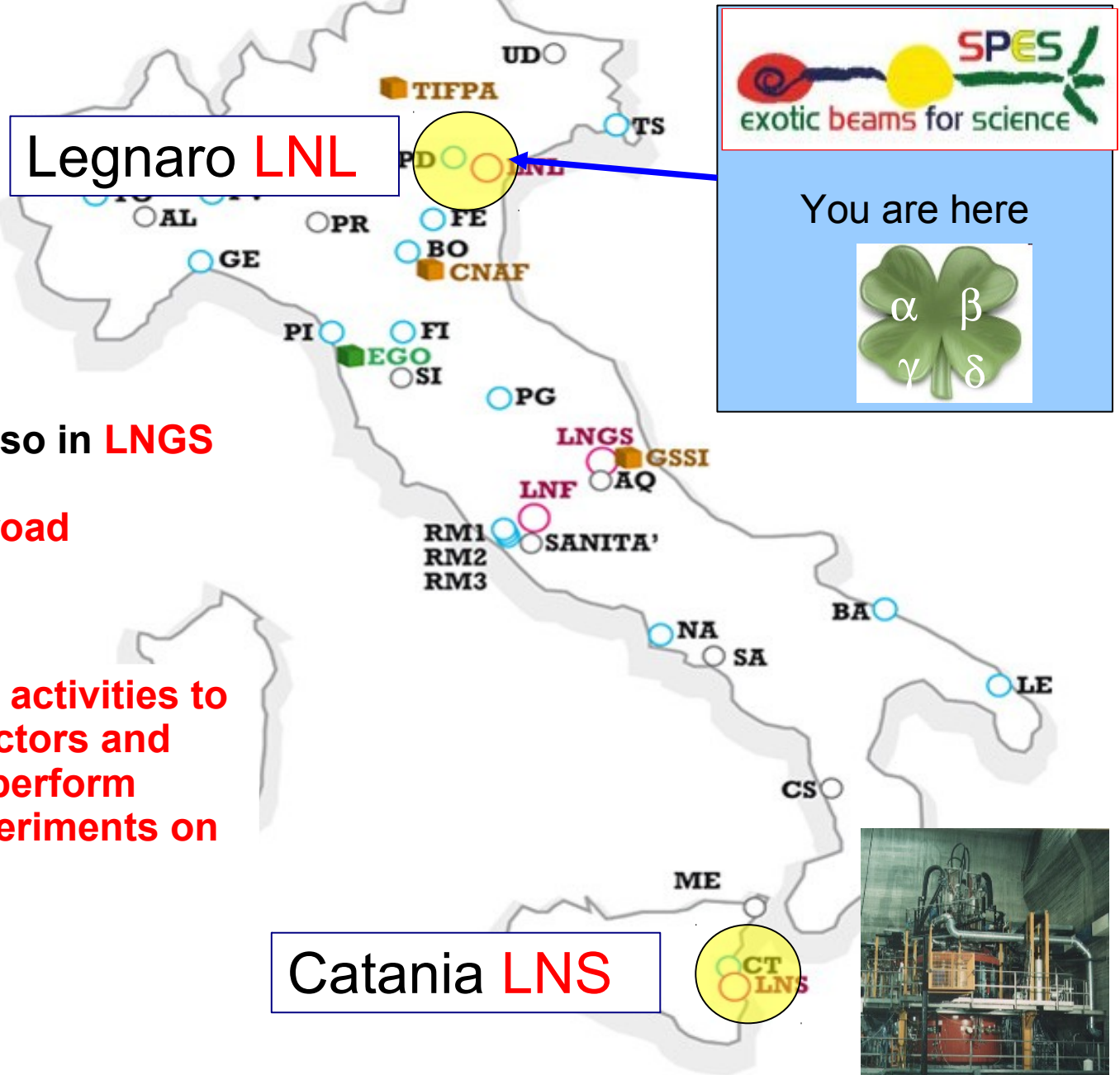
# Following Goethe...



- Padova
- Legnaro LNL
- Milano
- Firenze
- Roma
- Napoli
- Catania-LNS
- Messina

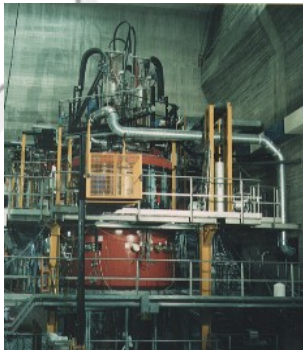
PISA2015 Student week, July 20-24

# ITALY: main nuclear laboratories



Some activity also in **LNGS**  
Also, links with  
**laboratories abroad**

**Experimental activities to  
develop detectors and  
tools and to perform  
'training' experiments on  
RIB**



# A summary on experimental activities with theses at various levels

- **Beam production, handling, selection**
- **Nuclear structure (single particle states) via advanced gamma detectors towards n-rich and n-deficient nuclei**
- **Nuclear structure (single particle states) via coulomb excitation**
- **Nuclear structure (single particle states) via gamma array coupled to (mainly charged) particle detectors**
- **Collective excitations in nuclei via gamma detectors, possibly coupled with other arrays**
- **Reaction mechanisms induced by (exotic) light nuclei, n-poor or n-deficient**
- **Reaction mechanisms with spectrometers and recoil separators**
- **Reaction mechanisms and nuclear EOS via large acceptance fragment detectors.**
- **Nuclear astrophysics**
- **Neutron skin experiments**

# The activity in LNL +

**EXPERIMENT NAME: SPES**

**CONTACTS:**

**A.Andrighetto INFN LNL**

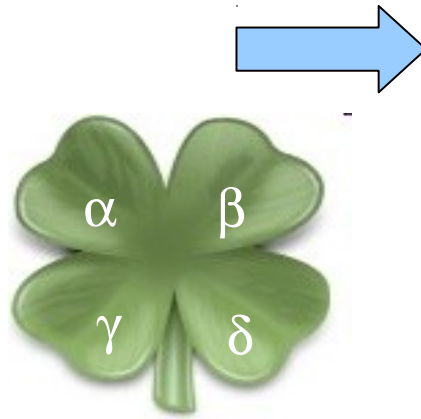
**G.Prete INFN LNL**

**F. Gramegna INFN LNL**

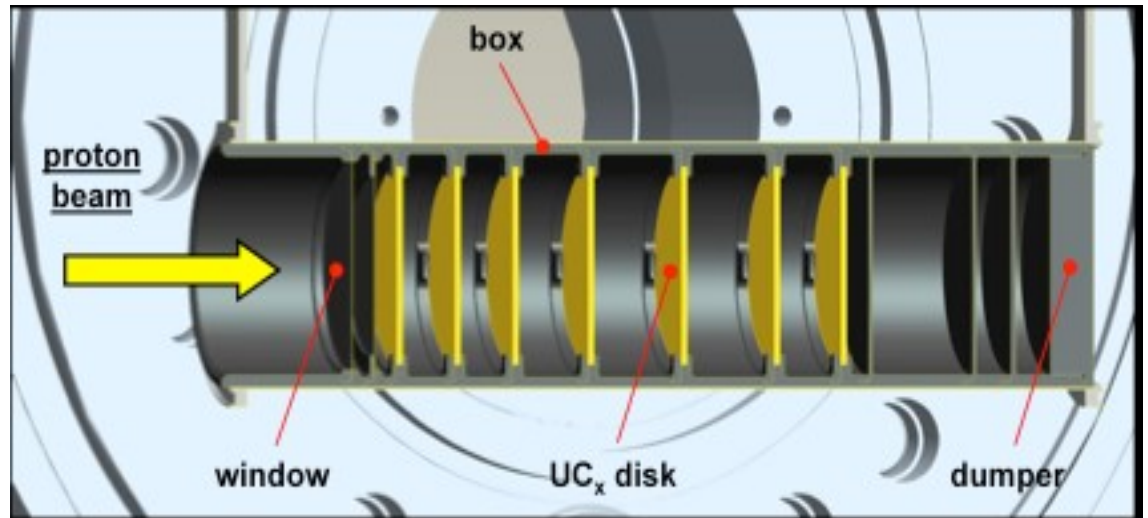
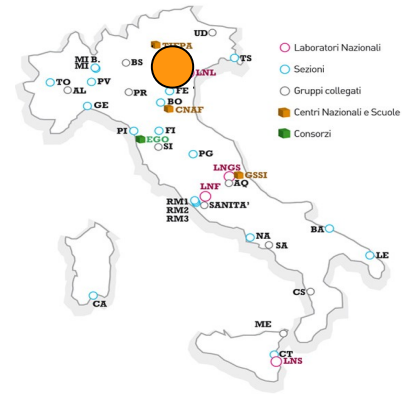
**SHORTLY:**

- Production of atoms from fission induced by protons on Uranium (Carbide)
- Selection of the various ions, possibly with very selective techniques
- Different kind of ion sources to optimize ionization according to atoms

## BEAM PRODUCTION



Strong overlap with many italian and foreing sites and laboratories

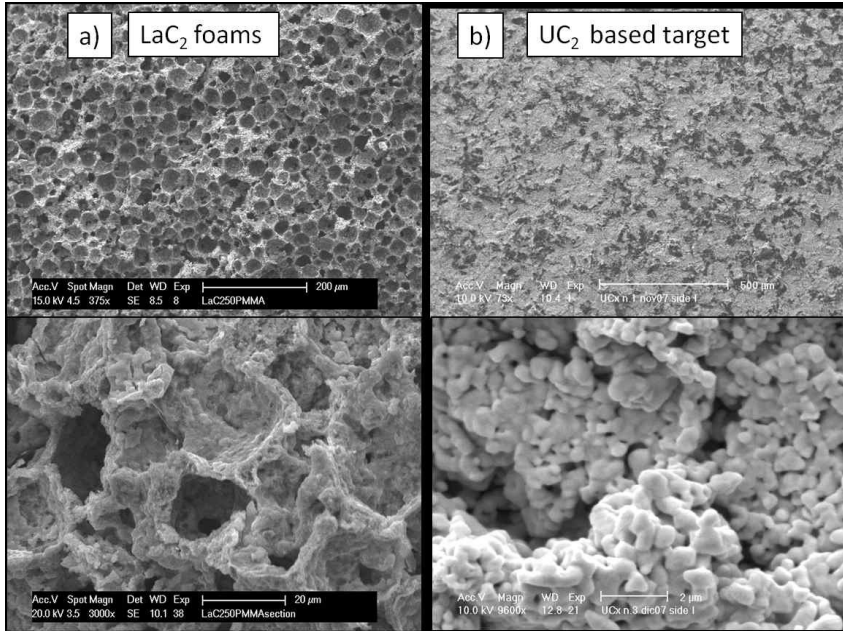
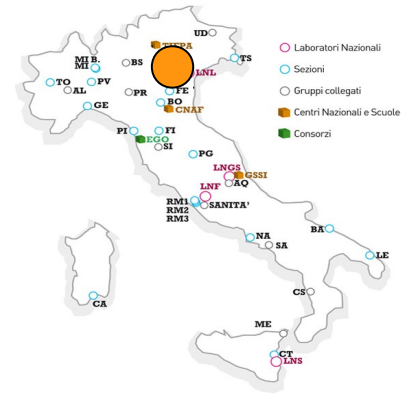


beams



# The activity in LNL +

# BEAM PRODUCTION



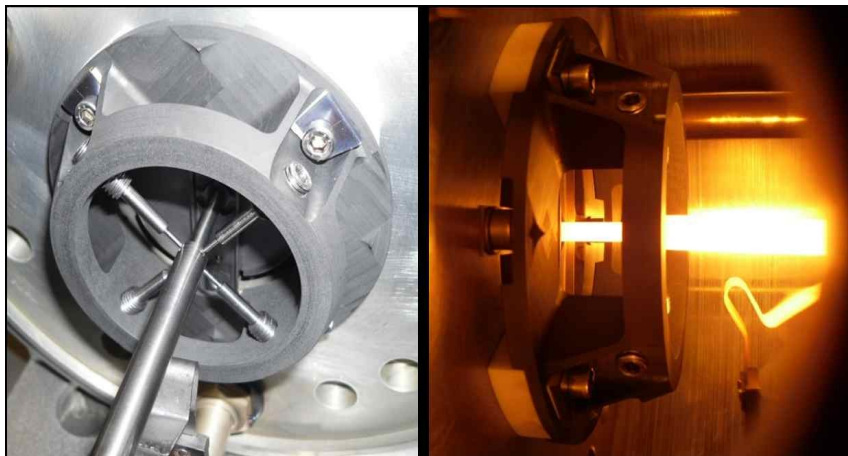
**SUBJECTS FOR STUDENTS:**  
Material and Transport Simulations  
Beam handling  
Ion beam transport  
Interface between nuclear and atomic phys

**Thesis available:**

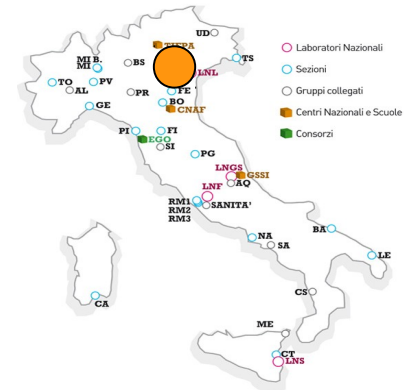
Study, characterization and optimization of the **Front End optics** of the SPES project

Study of the reaction induced **damage** on the devices of the SPES accelerator

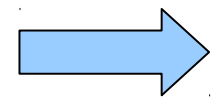
**Isotopic release** mechanisms in the SPES production target



# The activity in LNL-Padova



EXPERIMENT NAME: **GAMMA**



Strong overlap with Milan, Florence, Naples

CONTACTS:

**Jose' J. Valiente-Dobon, INFN LNL**

**Daniele Mengoni, Universita' di Padova**

SHORTLY:



- + Experiments mainly using **gamma rays**
- + **STABLE** and **UNSTABLE** beams in several labs (LNL, GANIL, GSI, RIKEN)
- + advanced detector **AGATA** based on segmented Germanium crystals and digital tracking
- + Construction of a modern national gamma array for SPES beams (**GALILEO**)
- + **Silicon strip detectors** for accurate reaction channel selection.

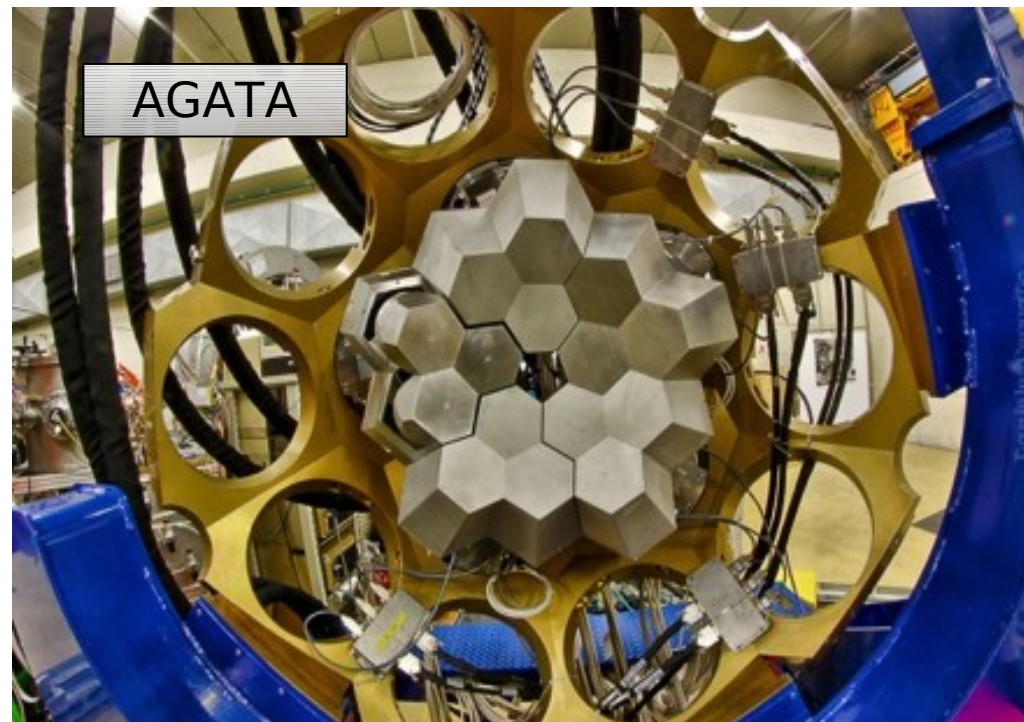
## Gamma and Nuclear structure



# The activity in LNL-Padova

EXPERIMENT NAME: **GAMMA**

Jose' J. Valiente-Dobon, INFN LNL  
Daniele Mengoni, Universita' di Padova



**Thesis available:**

the structure of exotic nuclei :

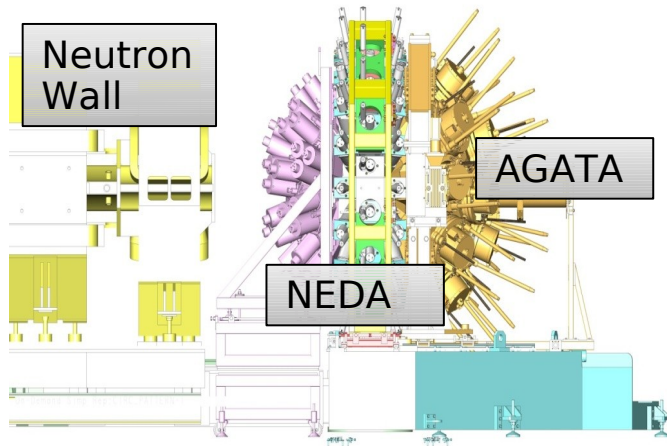
- **shape coexistence** in nuclei of Zn  $N = Z$
- **the double magic**  $100\text{Sn}$  - Transition probabilities
- **octupolar shapes** in the  $N = Z$  Ba isotopes - Symmetries CP

# The activity in LNL-Padova

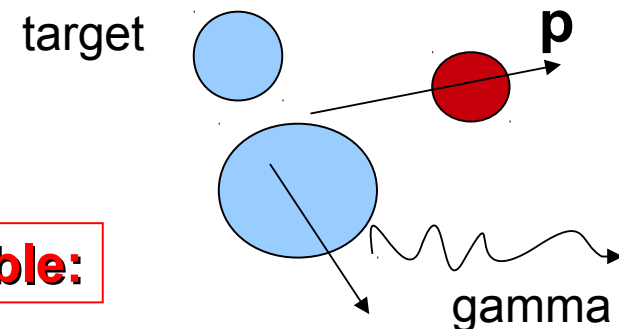
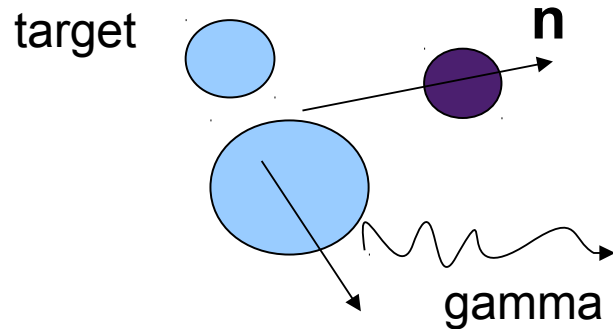
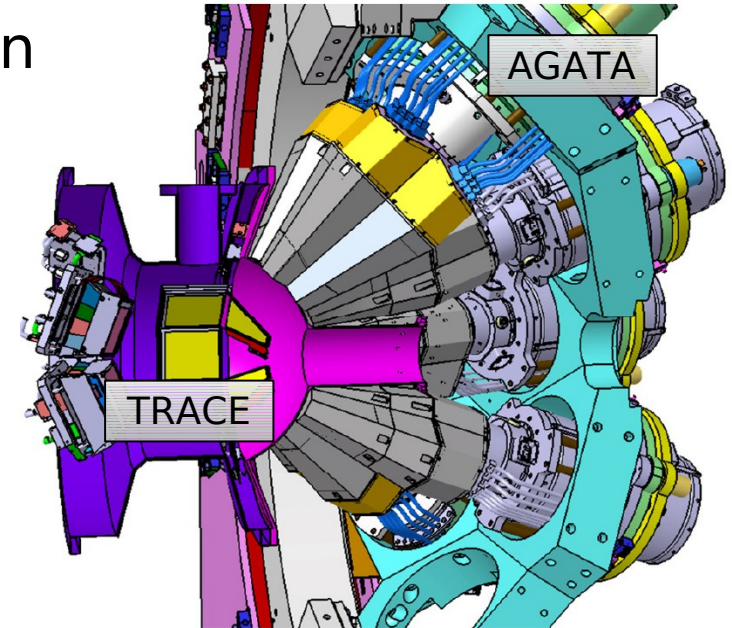
Jose' J. Valiente-Dobon, INFN LNL  
Daniele Mengoni, Universita' di Padova

EXPERIMENT NAME: **GAMMA**

Towards specific SPES instrumentation



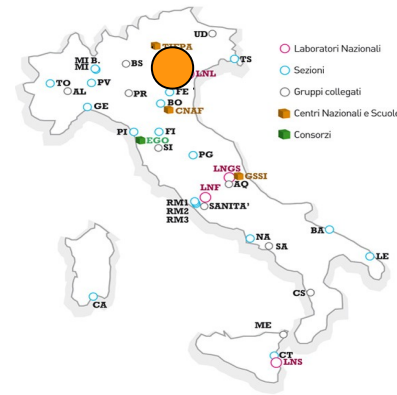
DIRECT REACTIONS



**Thesis available:**

- **shell structure in neutron-rich nuclei** - (**TRACE**)
- **fast neutrons** to study the spectroscopy of **neutron-deficient** nuclei - (**NEDA**)

# The activity in Padova-LNL



EXPERIMENT NAME: **GAMMA**

CONTACTS:

**S. M. Lenzi, Univerisita' di Padova**

**F. Recchia, Universita' di Padova**

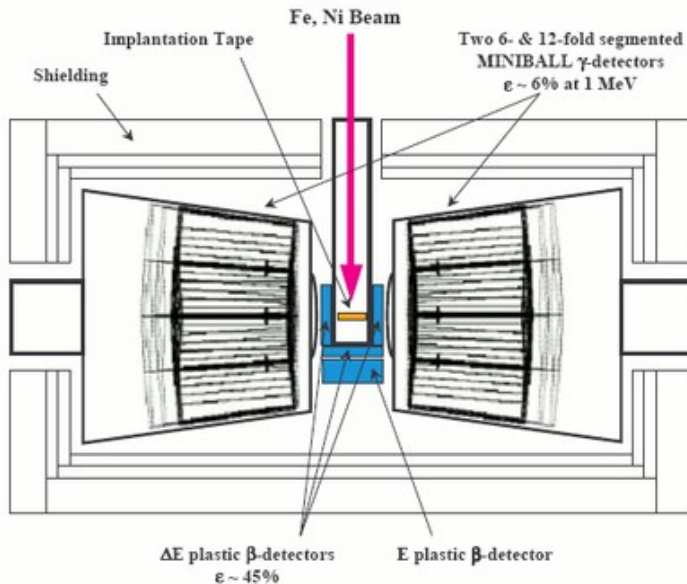
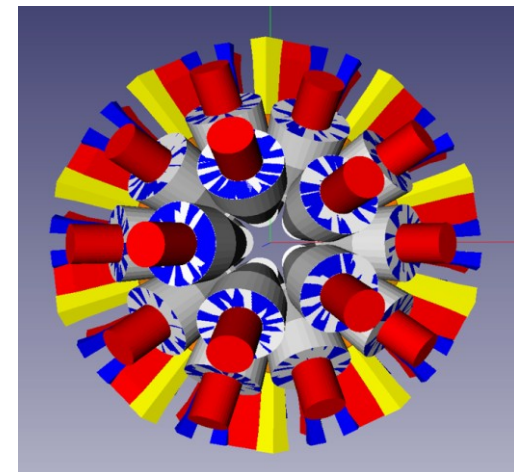


Strong overlap with LNL, Milano, Florence

**Thesis available:**

## Galileo: array at LNL and the Neutron Wall

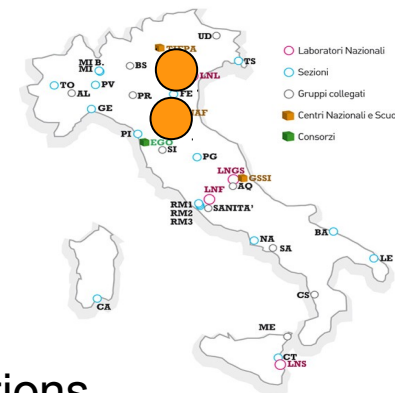
- Study of nuclei near the  $N=Z$  line to test isospin symmetry (stable and radioactive beams)



## Beta decay station

- shell evolution at the limit of nuclear binding with SPES facility
- Beta decay experiments
- Design of a new experimental setup

# The activity in LNL +



EXPERIMENT NAME: **NUCL-EX**



Strong overlap  
with Florence,  
Bologna, Naples

+ International collaborations

## CONTACTS:

**F. Gramegna INFN LNL**

**M. Cinausero INFN LNL**

**T. Marchi INFN LNL**

**L. Morelli INFN Bologna**

**SUBJECTS FOR STUDENTS:**  
**Detector construction**  
**Electronics development**  
**Data acquisition development**  
**Computing, simulations**  
**Data analysis**

## SHORTLY:

- Now experiments with LNL beams with the GARFIELD array
- **Cluster** effects in nuclei
- From evaporating to **multifragmenting** systems
- Fast sampling **electronics** and ion identification
- Advanced **detectors** for charge particles
- Toward an **active target** detector for SPES studies

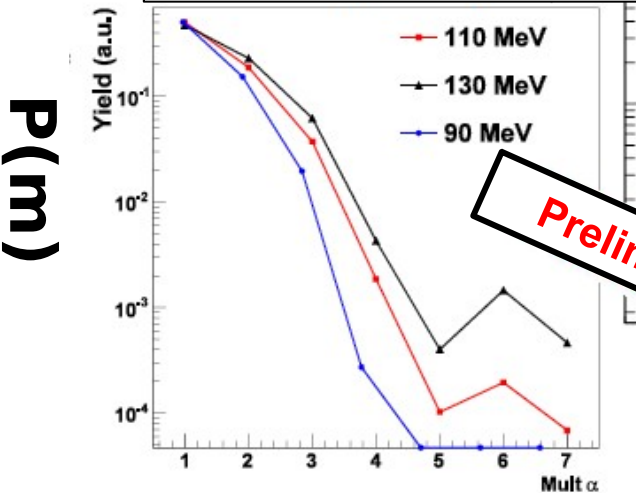
# Charged products and reactions

# The activity in LNL

**EXPERIMENT NAME: NUCLEX**

In how many alphas can we break a nucleus?

e.g:  $16\text{O} + 12\text{C} \rightarrow 28\text{Si}^*$  (N=Z nuclei)



**Preliminary**

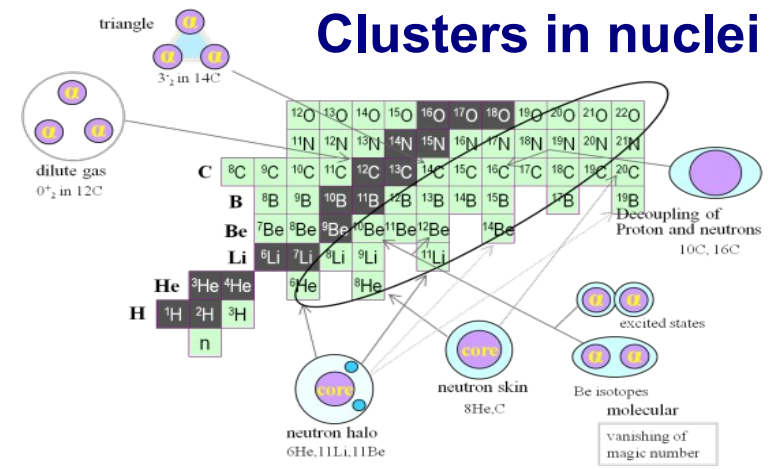
How alpha structure survive at high excitation?

**Thesis available:**

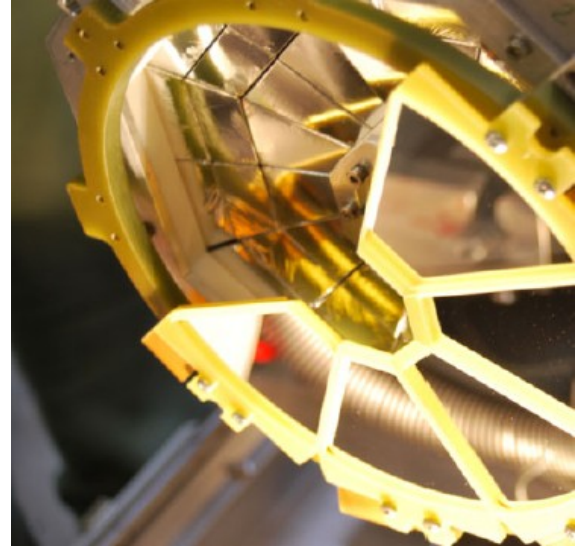
- alpha clustering in nuclei via pre-equilibrium emission of LCP
- Persistency of alpha structure well above the particle separation energy in nuclei
- Proposals for future exotic light SPES beams

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## Exotic structures in light nuclei

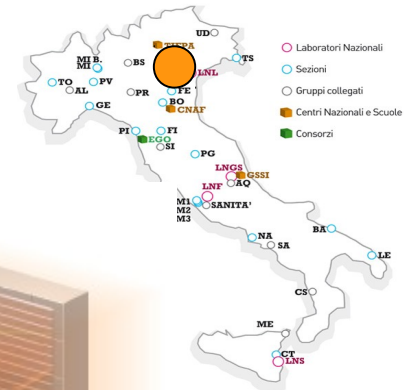


## Garfield-RCO at LNL



**T. Marchi INFN LNL**  
**L. Morelli INFN Bologna**

# The activity in LNL +

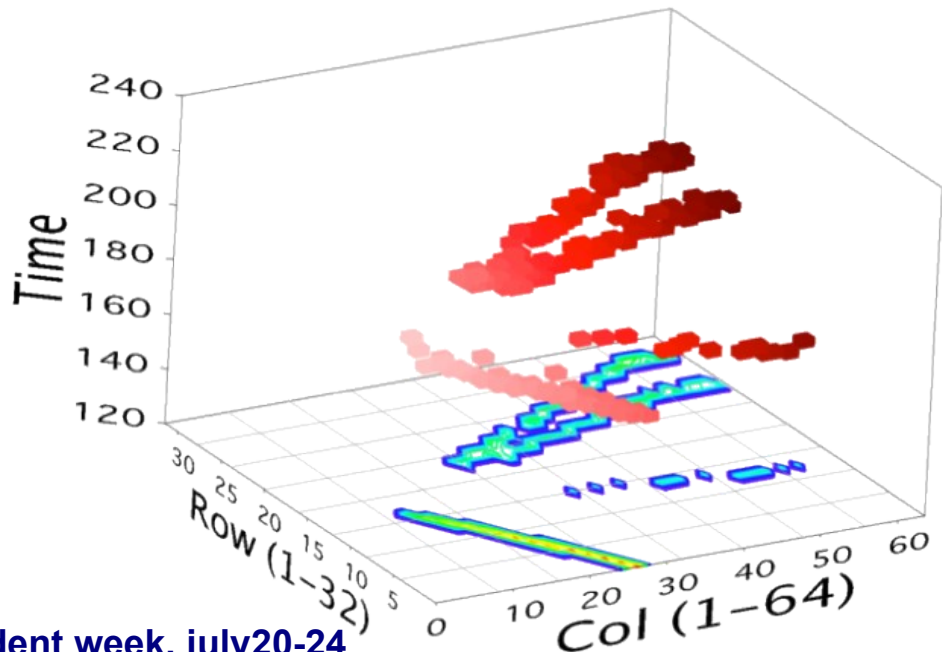
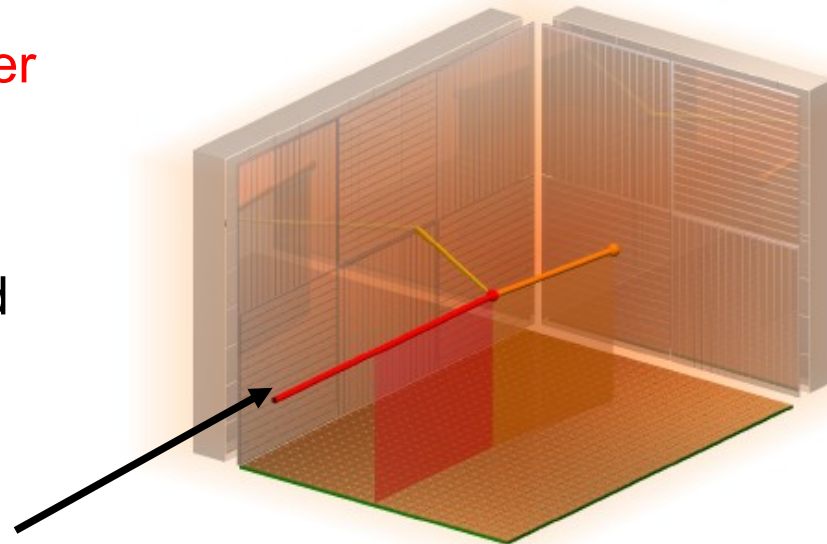


## EXPERIMENT NAME: NUCLEX

Charge and Time projection Chamber  
(also) for SPES studies

Innovative multipixel projection chamber where gas is the target and also the detector (**ACTAR**)

High efficiency  
Low-thresholds



### Contacts

T.Marchi INFN LNL  
F.Gramegna INFN LNL

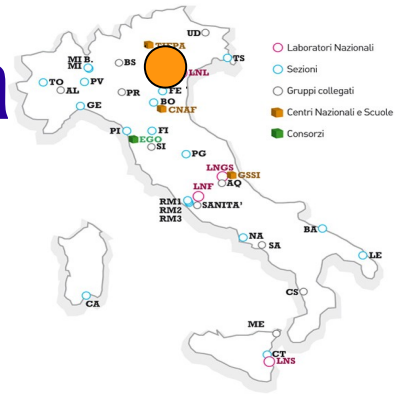
**Thesis available:**

Toward d,p reactions with SPES

◆ preliminary test:  
 **$^{120}\text{Sn}(d,p)^{121}\text{Sn}$  @ LNL**

◆  **$^{134}\text{Sn}(d,p)^{135}\text{Sn}$  @ SPES**

# The activity in LNL-Padova



EXPERIMENT NAME: **PRISMA-FIDES**

## CONTACTS:

**G.Montagnoli, Universita' Padova**

**L.Corradi, INFN LNL**

**E.Fioretto , INFN LNL**

**A.M.Stefanini, INFN LNL**

## SUBJECTS FOR STUDENTS:

**Fusion reactions at low E**

**Transfer reactions**

**Data analysis**

**Computing, simulations**

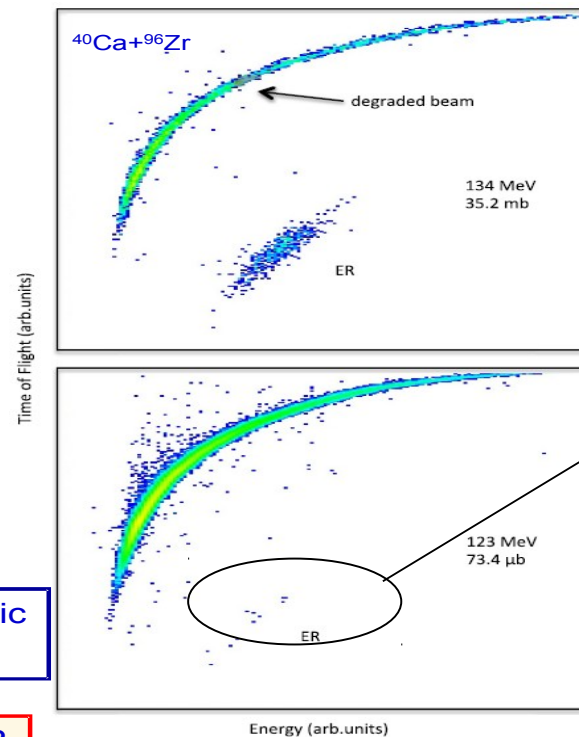
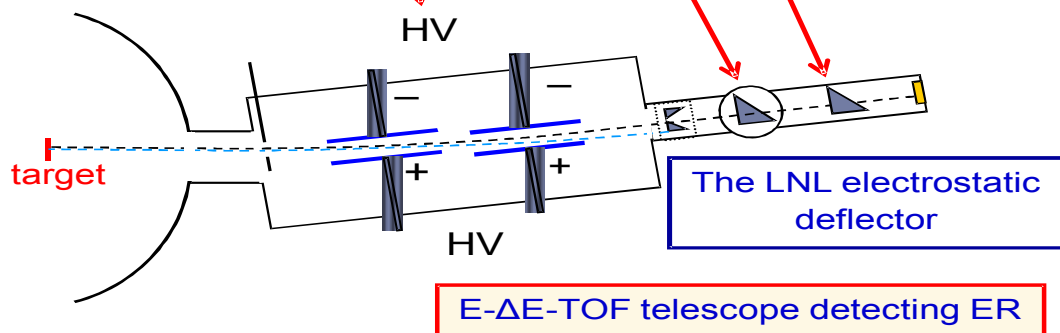
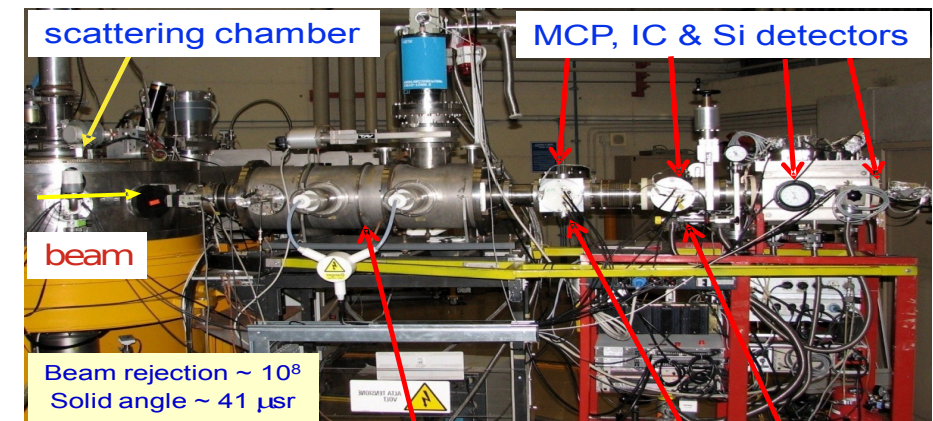
**Detectors calibration**

## SHORTLY:

- Experiments with big **spectrometers**
- **Subbarrier fusion** (at very low energy: quantum tunneling)
- **Transfer reactions** to study pairing and n-rich species
- Focal plane **detectors** (gas and silicon detectors)
- Use of a Tof arm to detect recoil fragment

# Charged products and reactions

# The activity in LNL-Padova



Very Low yields

Thesis available:

## Contacts

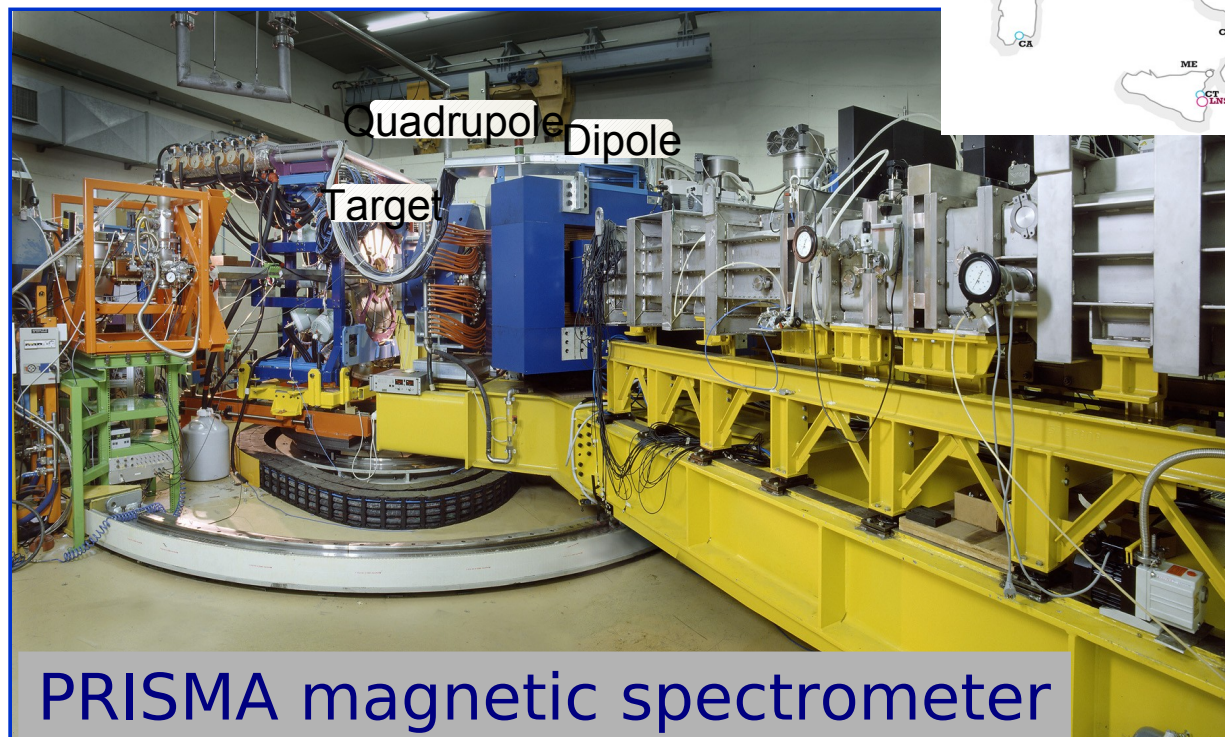
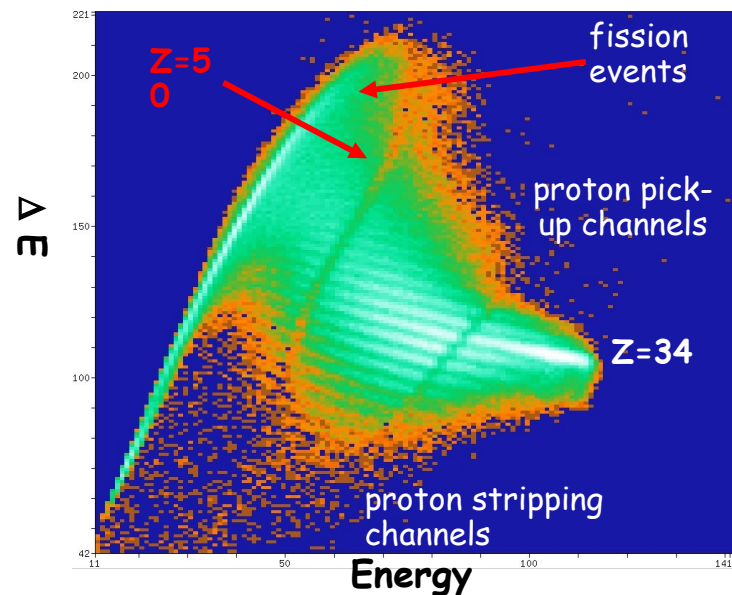
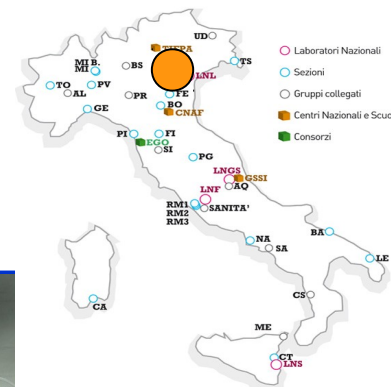
A.M. Stefanini, INFN LNL

G.Montagnoli, UNI Pd)

- Heavy-Ion fusion reactions below the Coulomb Barrier: influence of nuclear structure on quantum tunneling
- effects of cross section hindrance on astrophysical subjects



# The activity in LNL-Padova

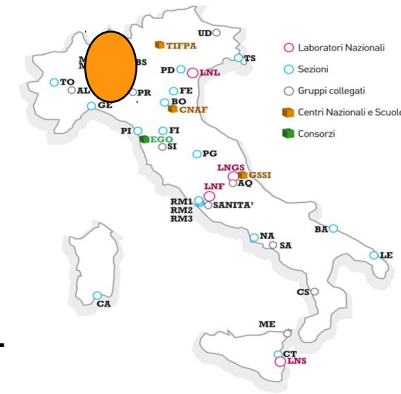


**Thesis available:**

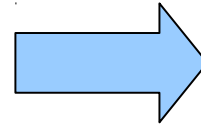
- **Heavy-Ion transfer reactions** around the Coulomb Barrier: pairing interaction at sub-barrier energies (L. Corradi)
- **heavy neutron-rich nuclei** populated in grazing collisions (E. Fioretto)

L. Corradi, INFN LNL  
E. Fioretto, INFN LNL

# The activity in Milano



EXPERIMENT NAME: **GAMMA**



Strong overlap  
with Padova, LNL  
Florence, Naples

CONTACTS:

**S.Leoni** Università' di Milano  
**A.Bracco** Università' di Milano  
**F.Camera** Università' di Milano  
**O.Wieland** INFN Milano  
**G.Benzoni** INFN Milano

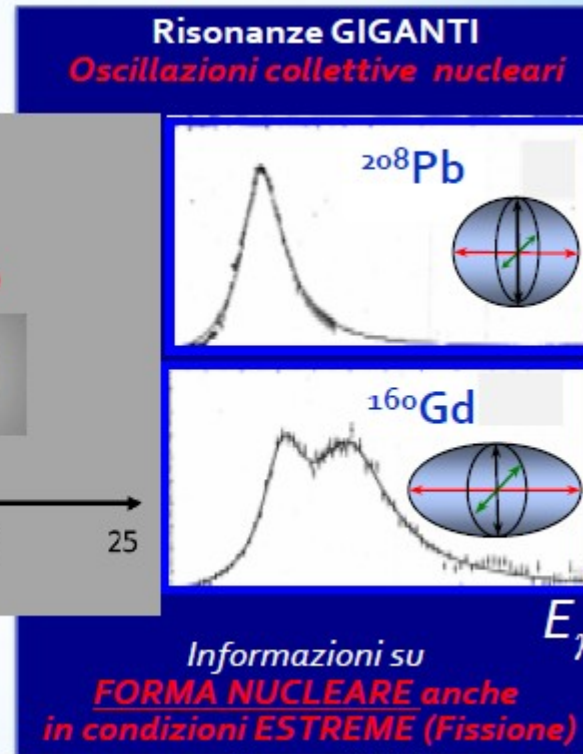
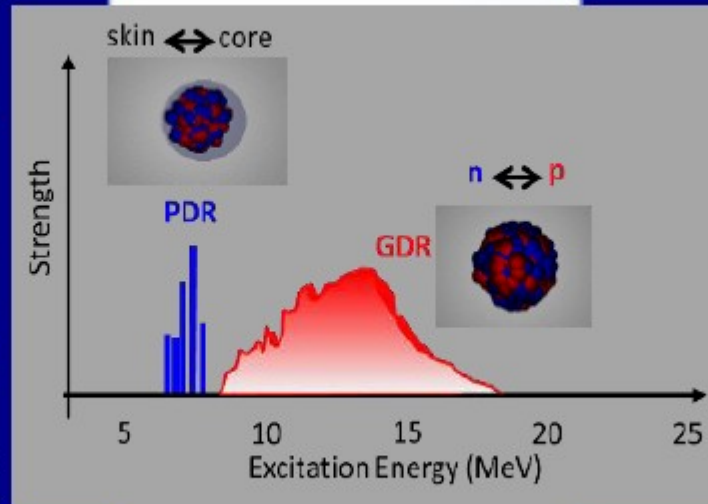
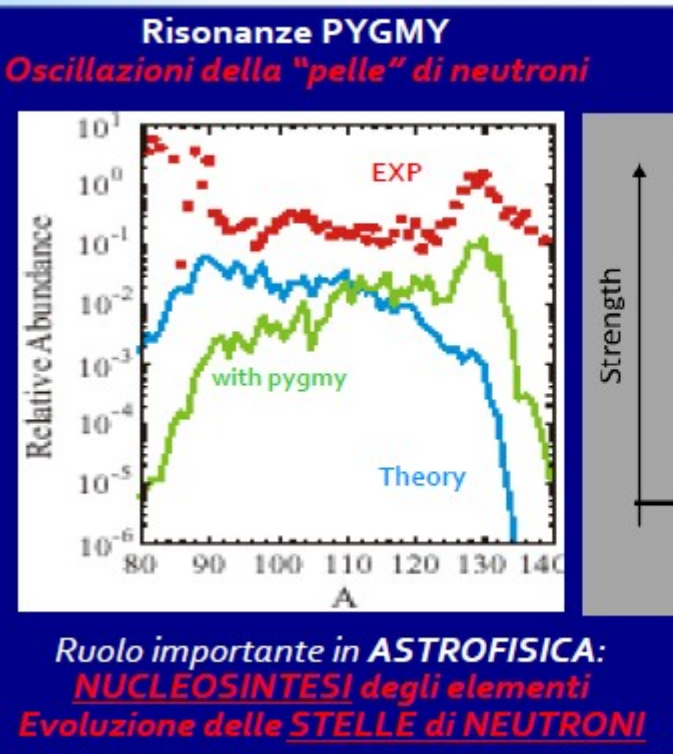
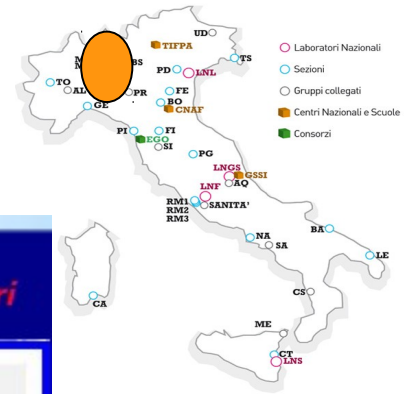
+ International collaborations

## Gamma spectrometry

SHORTLY:

- Study of gamma rays both from **discrete levels** and from **collective excitations**
- STABLE and UNSTABLE beams in several labs (LNL, GANIL, GSI, RIKEN)
- advanced detector **AGATA** based on segmented Germanium crystals
- R&D and use of many type of detectors also innovative.
- Expertise on scintillators for gammas and neutrons

# The activity in Milano



O.Wieland  
S.Leoni  
A.Bracco  
UNI MI e INFN

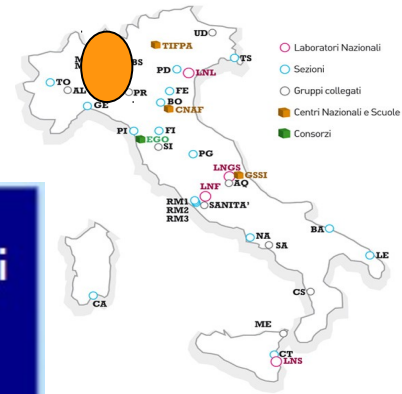
Nuclear Resonances

**Thesis available:**

**PIGMY OSCILLATION:** neutron 'skin' oscillates with respect to nuclear core  
**GIANT DIPOLAR OSCILLATION:** the neutron and proton centres of masses oscillate one vs each other

DETECTORS: hard gamma measured with scintillators or Ge (last generation modules)

# The activity in Milano



**Nuclei di O, C e Ne ricchi di neutroni**  
*Struttura Nucleare alla dripline*

**16C**

*Comprensione della natura della FORZA NUCLEARE*  
*Interazione a DUE o TRE corpi*

**Robustezza Chiusure di SHELL**  
**lontano dalla Stabilità, Nuovi Numeri Magici**

*Stati di particella singola e accoppiamenti alle vibrazioni*

**N=82 shell gap**

**shell gap Z=50**

**132Sn**

G.Benzoni  
S.Leoni  
A.Bracco  
UNI MI e INFN

Nuclear gamma decay to access:

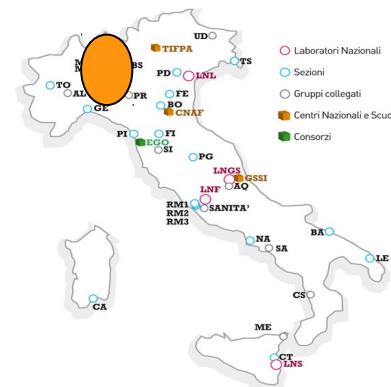
**Thesis available:**

**Strong force nature:** two, three particle correlations

**Shell Sctructure:** how magicity changes going out of beta-stability

DETECTORS: precise gamma spectroscopy (<8MeV) with the help of particles  
Using Gee, Si, and last generation array (AGATA, GALILEO)

# The activity in Milano

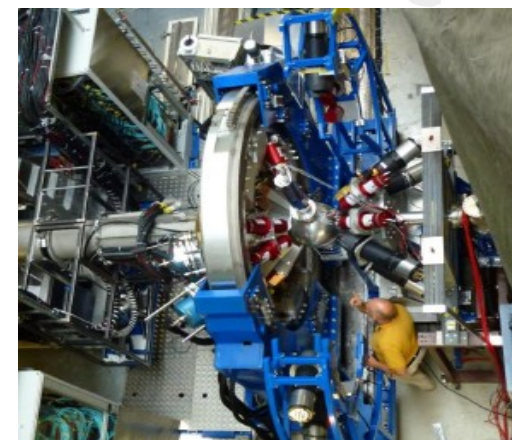
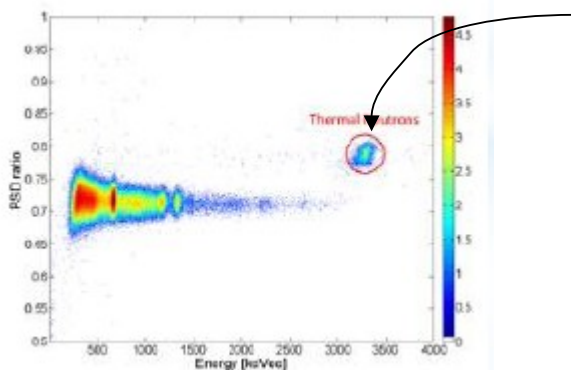


EXPERIMENT NAME: **GAMMA**

F.Camera Universita' di Milano

## Neutron spectrometry and detection

CLYC-6/7 doped with 6,7Li  
In alternative to the costly 3He  
CLYC-6 :thermal neutrons  
CLYC-7: fast neutrons



**Neutron detectors:** new 'cheaper' materials doped with Li  
**Gamma detectors :** the case of LaBr3

**Thesis available:**

- R&D on detectors and electronics:
- Neutron and gamma detectors
- Dedicated Electronics
- Test with sources and with beams

From KNOLL textbook

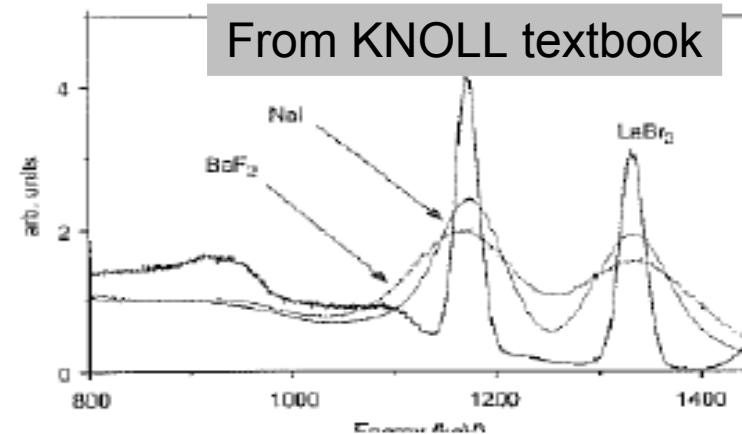


Figure 8.14 Comparison of the <sup>60</sup>Co pulse height spectrum measured with 1-inch x 1-inch LaBr<sub>3</sub>, NaI, and BaF<sub>2</sub> (From Nicolini et al.<sup>215</sup>).