Symposium Italy- Japan 2012 on Nuclear Physics
Milano 20-23 November 2012

Overview of the activity at the INFN Laboratori Nazionali del Sud (LNS)

Stefano Romano
University of Catania & INFN-LNS
(on behalf of Giacomo Cuttone – LNS Director)

INFN - Laboratori Nazionali del Sud are located in the Catania University campus area

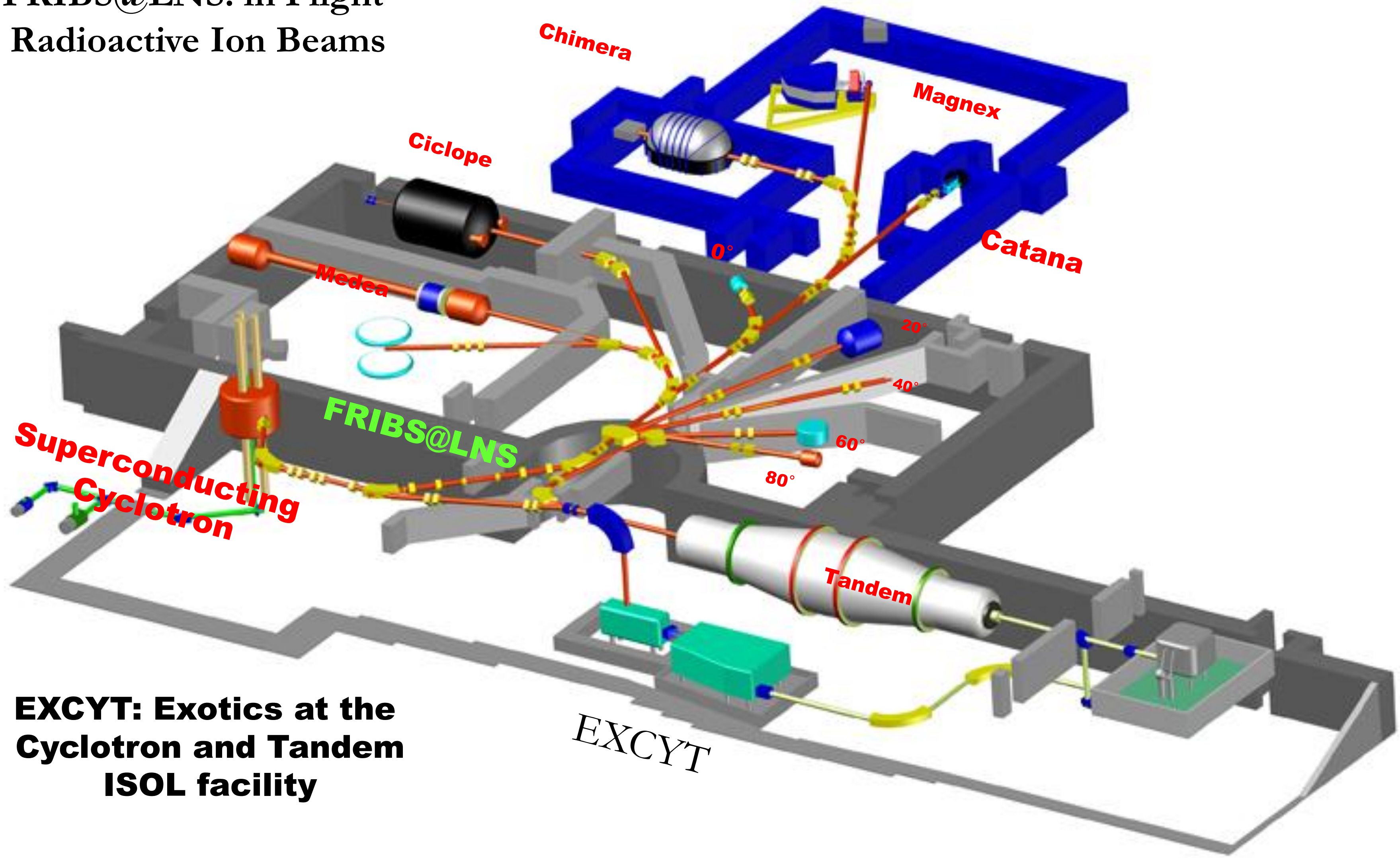
LNS in numbers

- ***Total area: 35000 m^2***
- ***Total volume: 97000 m^3***

- Staff members: 120 (35 phys. + eng.)
- Associated researchers: 39
- Users (in the last 3 years): 545
- Foreign users: 180
- Annual scientific production: about 150 (papers and proceedings)
- Budget: ~ 11 M€/year (excl. Salaries)

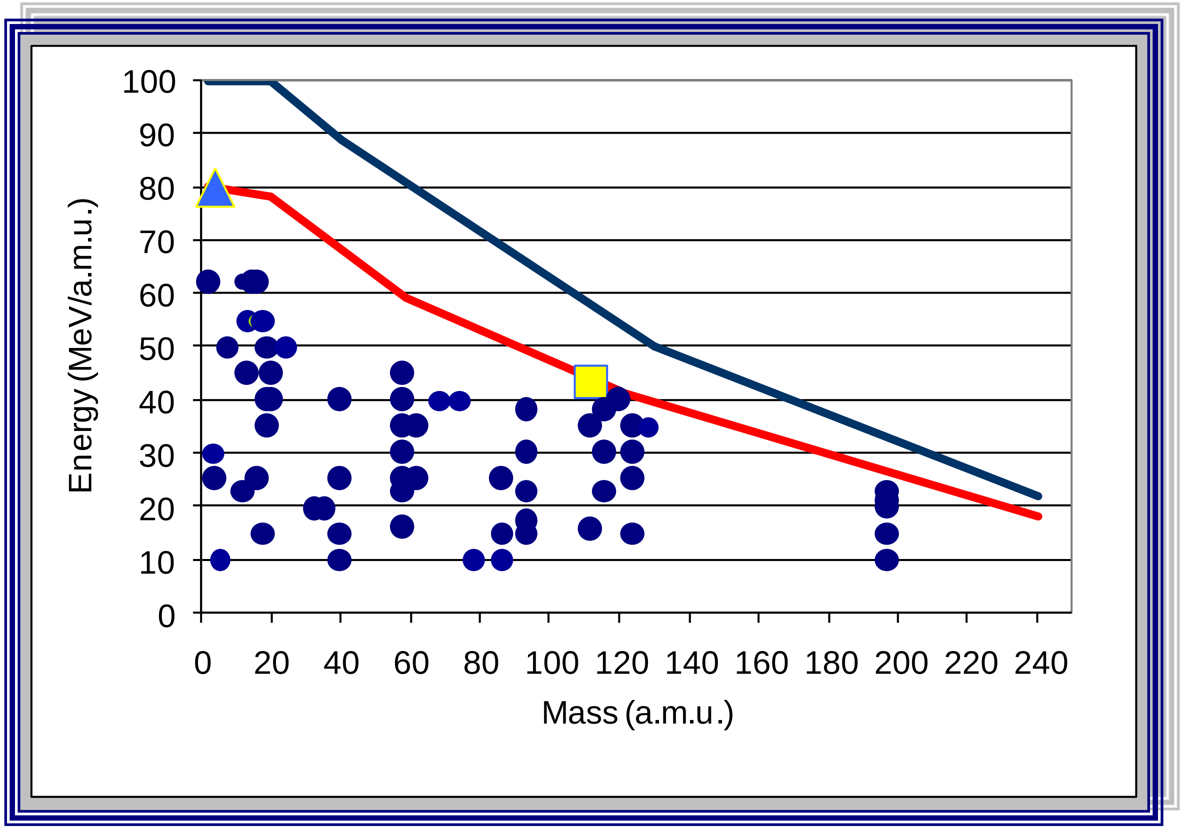
LNS lay-out: accelerators and experimental halls

FRIBS@LNS: in Flight Radioactive Ion Beams



EXCYT: Exotics at the Cyclotron and Tandem ISOL facility

Superconducting Cyclotron status: beams developed

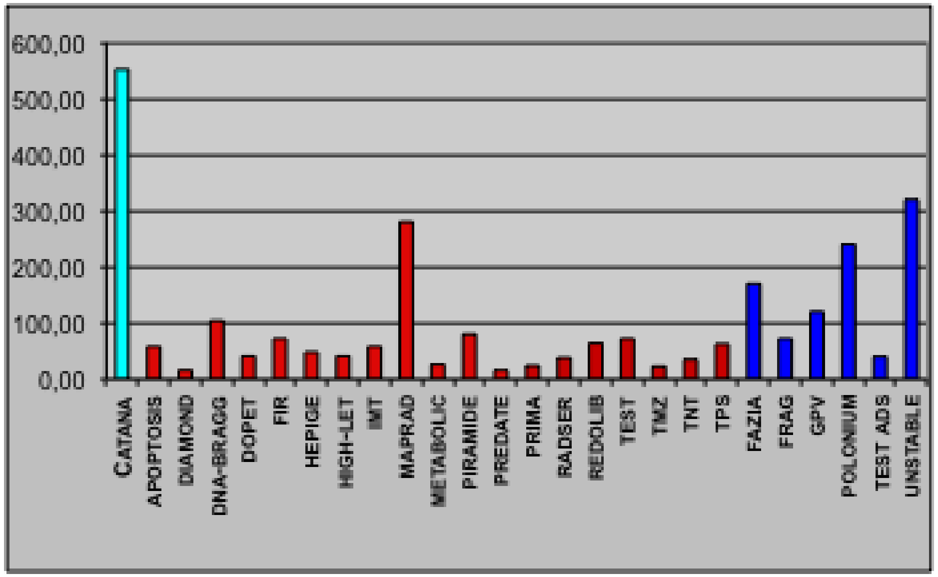


^{4}He 80 MeV/a.m.u.

^{112}Sn 43.5 MeV/a.m.u.

^{A}X	E (MeV/a.m.u.)
H_2^+	62,80
H_3^+	30,35,45
$^{2}D^{+}$	35,62,80
^{4}He	25,80
He-H	10, 21
^{9}Be	45
^{11}B	50
^{12}C	23,62,80
^{13}C	45,55
^{14}N	62,80
^{16}O	21,25,55,62,80
^{18}O	15,55
^{19}F	35,40,50
^{20}Ne	20,40,45,62
^{24}Mg	50
^{36}Ar	16,38
^{40}Ar	15,20,40
^{40}Ca	10,25,40,45
^{48}Ca	10,45
^{58}Ni	16,23,25,30,35,40,45
^{64}Ni	25,35
^{68,70}Zn	40
^{74}Ge	40
^{78}Kr	10
^{84}Kr	10,15,20,25
^{93}Nb	15,17,23,30,38
^{112}Sn	15.5,35,43.5
^{116}Sn	23,30,38
^{124}Sn	15,25,30,35
^{129}Xe	20,21,23,35
^{197}Au	10,15,20,21,23
^{208}Pb	10

Use of the Superconducting Cyclotron and Tandem beams in 2011

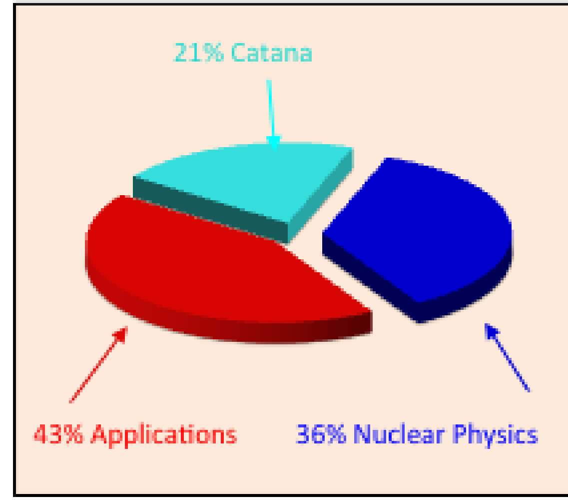


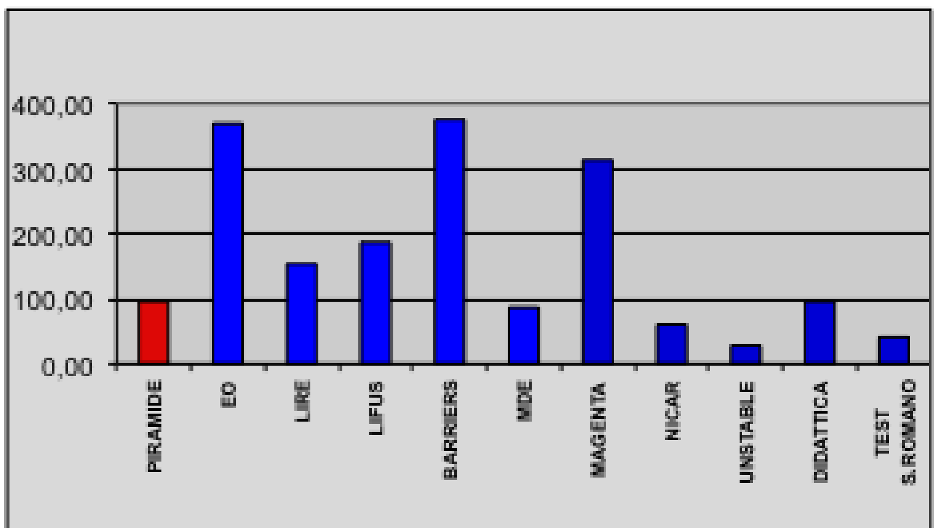
Cyclotron
2672 hours

36% Nuclear Physics

21% Catana

43% Applications

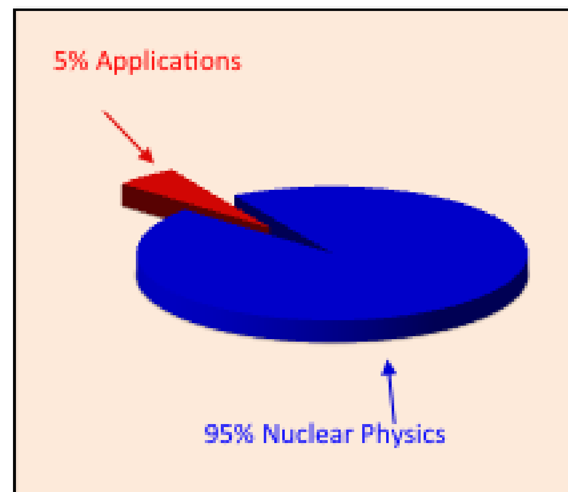




Tandem
1810 hours

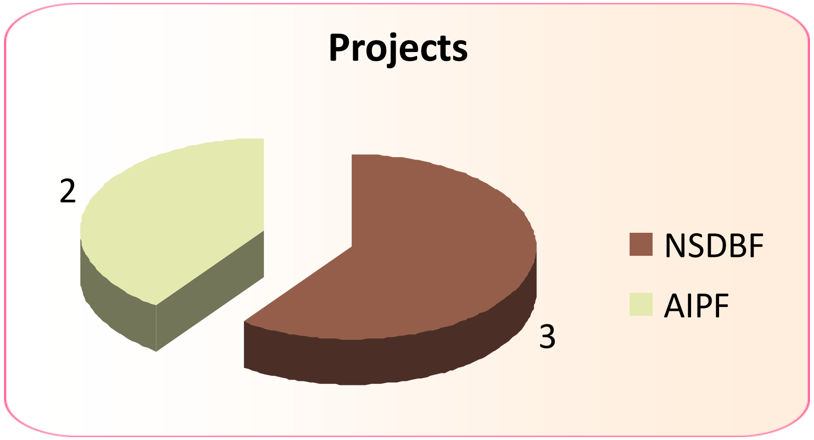
95% Nuclear Physics

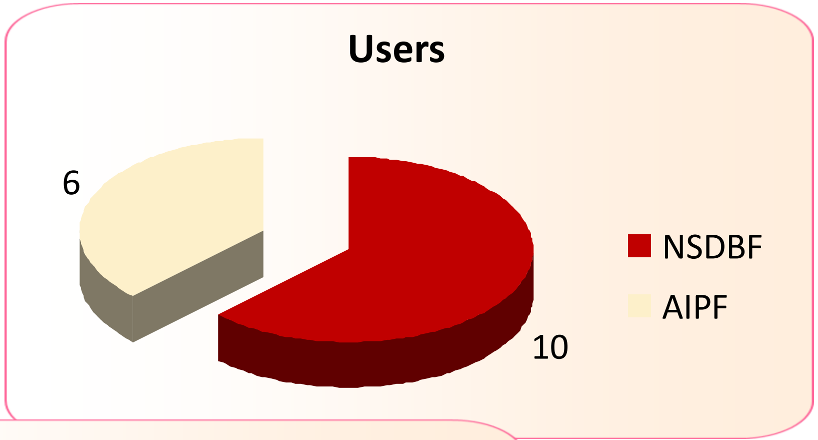
5% Applications

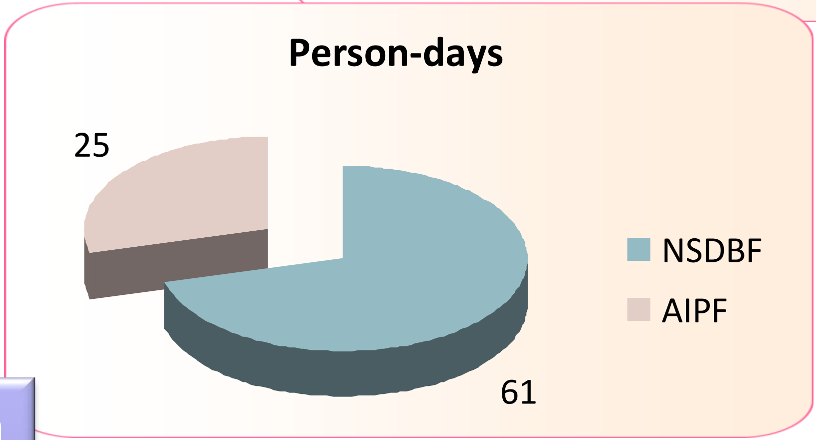


2011: ENSAR Transnational access

TNA03 – Activity at LNS up to July 2012 (1 year)





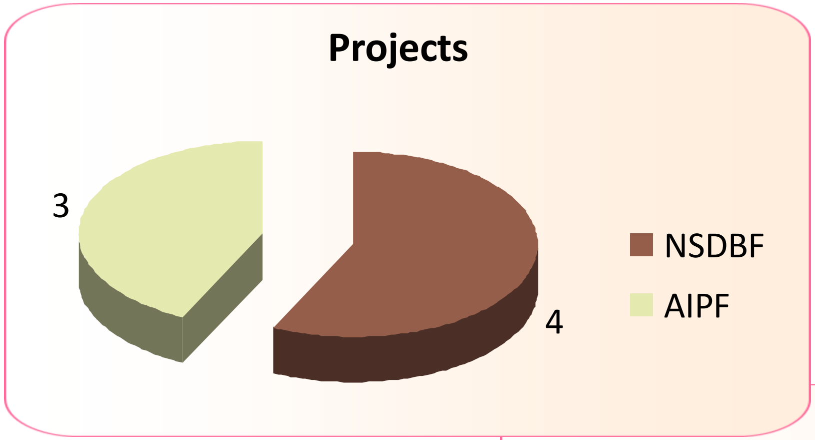


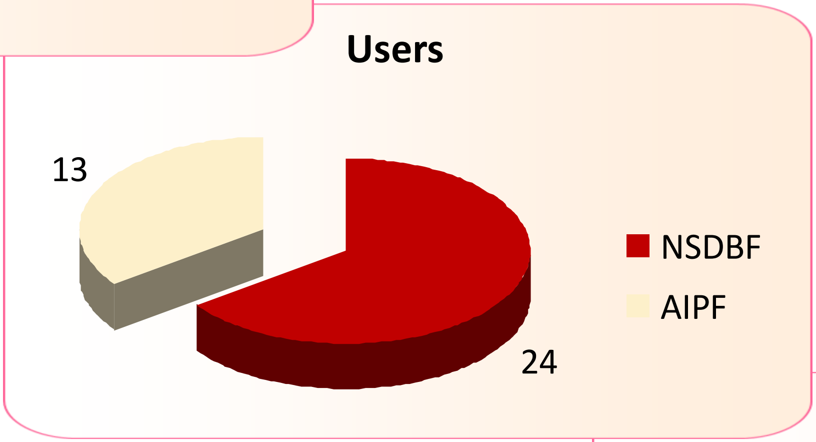
6 new users
5 @ NSDBF , 1 @AIPF

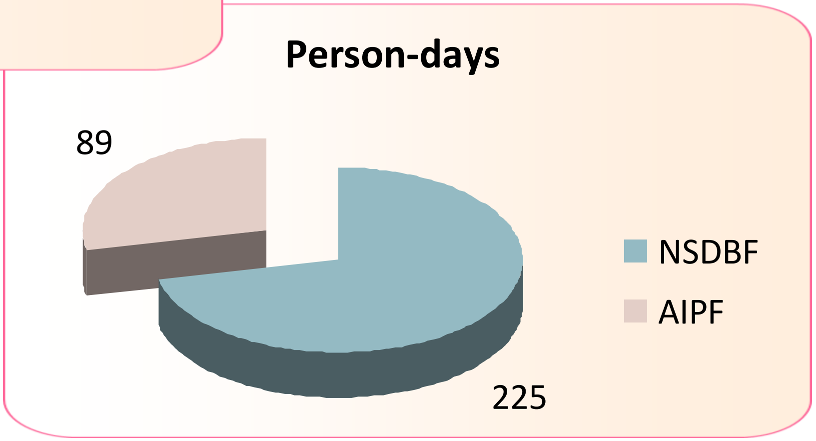
Deliverables/y (mean values)
6 projects
20 users
178 Person-days

→ Differences, mainly due to a serious TANDEM failure, are expected to be compensated in 2013

TNA03 – To be performed at LNS - July 2013 (only CS)







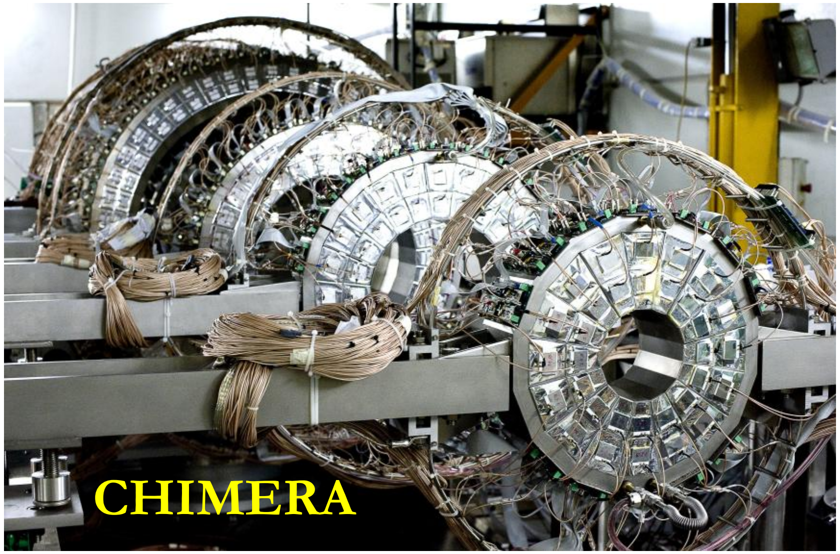
13 new users
10 @ NSDBF , 3 @AIPF

NSDBF → Nuclear Structure and Dynamics Based Facilities
AIPF → Applied and Interdisciplinary Physics Facilities

Main LNS experimental apparata for Nuclear Physics

MAGNEX*EDEN

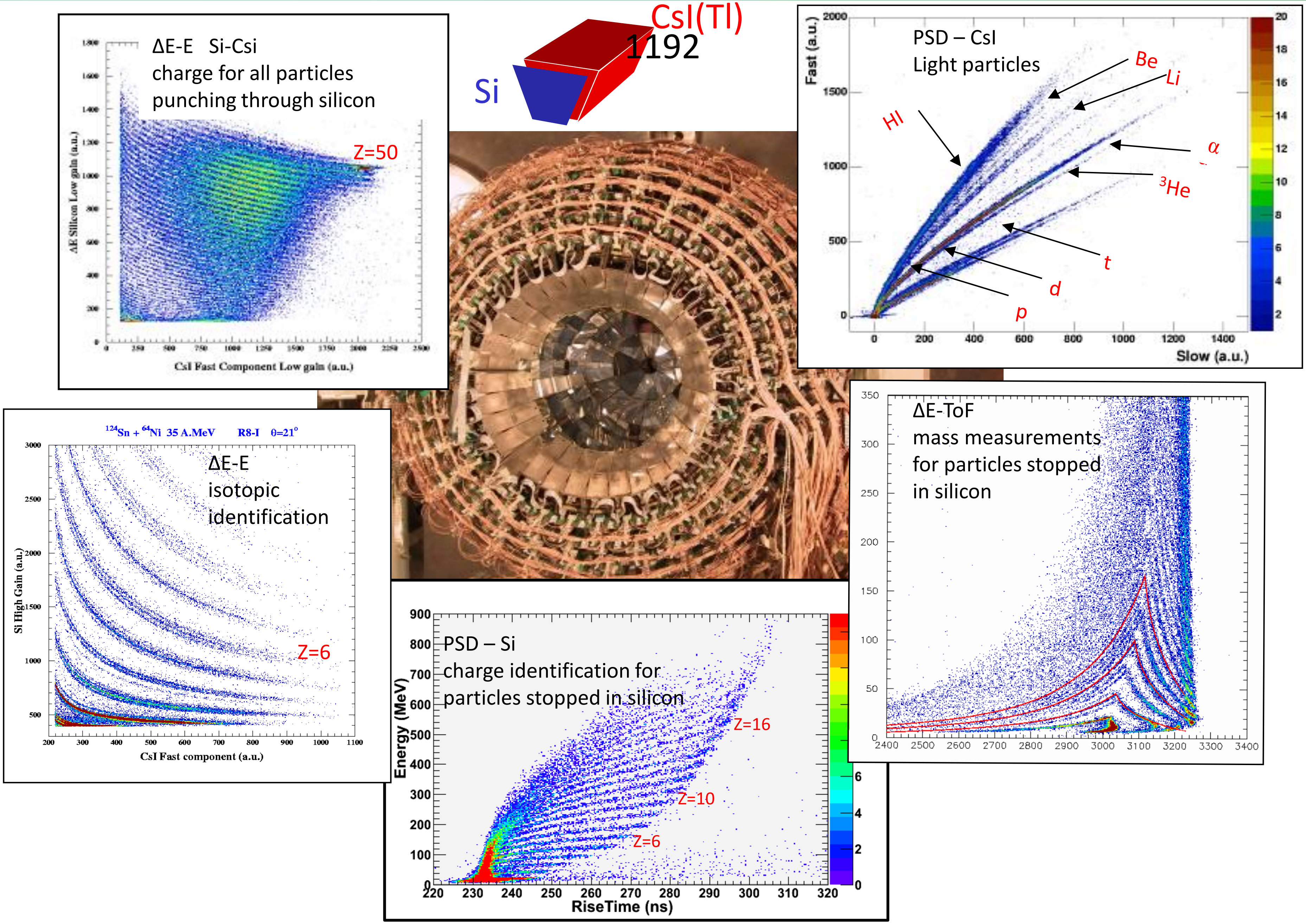
- **Light nuclei structure**
- **Nuclear astrophysics**
- **Spectroscopy**
- **Structure effects on reaction mechanism**



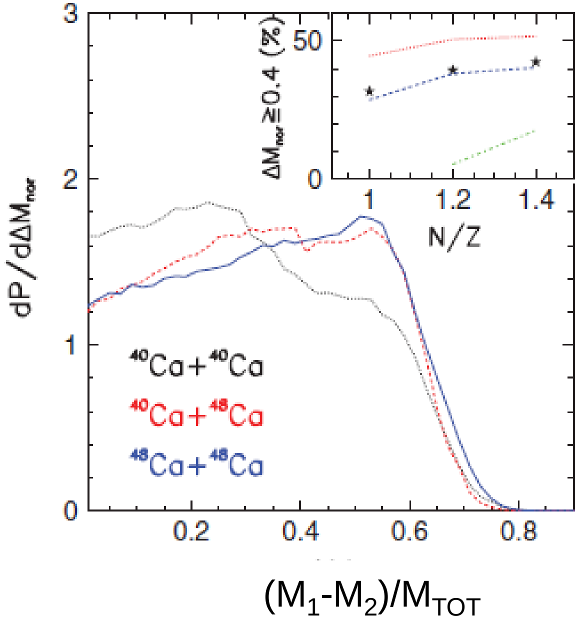
CHIMERA

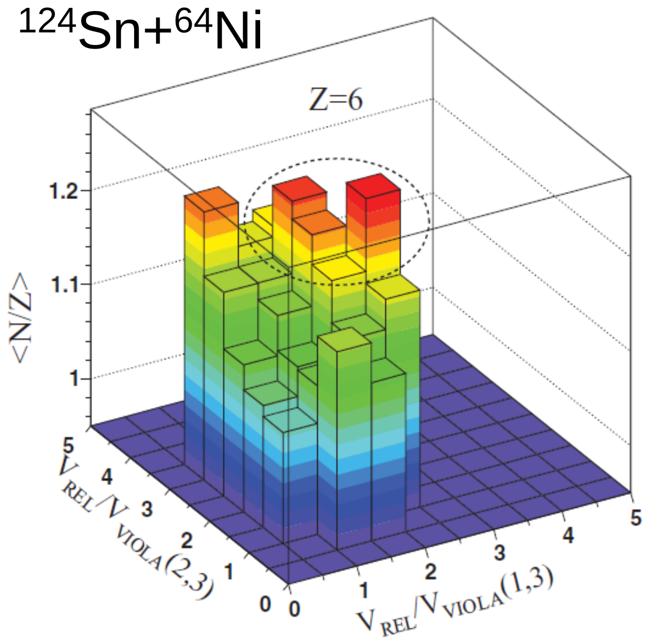
- **GDR**
- **Caloric curve & phase transition**
- **Multifragmentation**
- **Isospin dependence of EoS**
- **Di-proton decay**

CHIMERA Detector: Identification methods



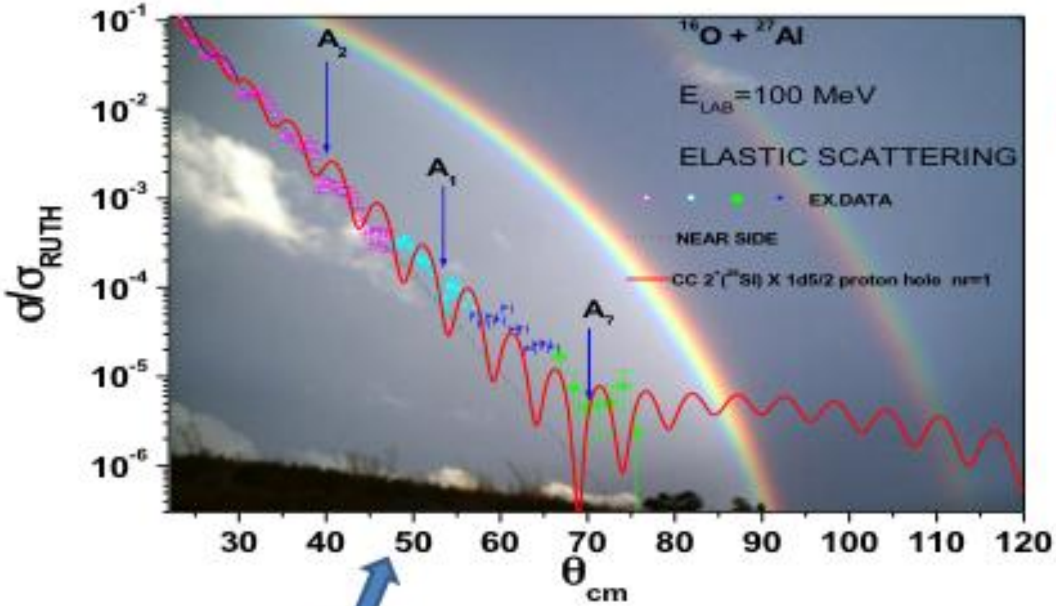
Very recent results





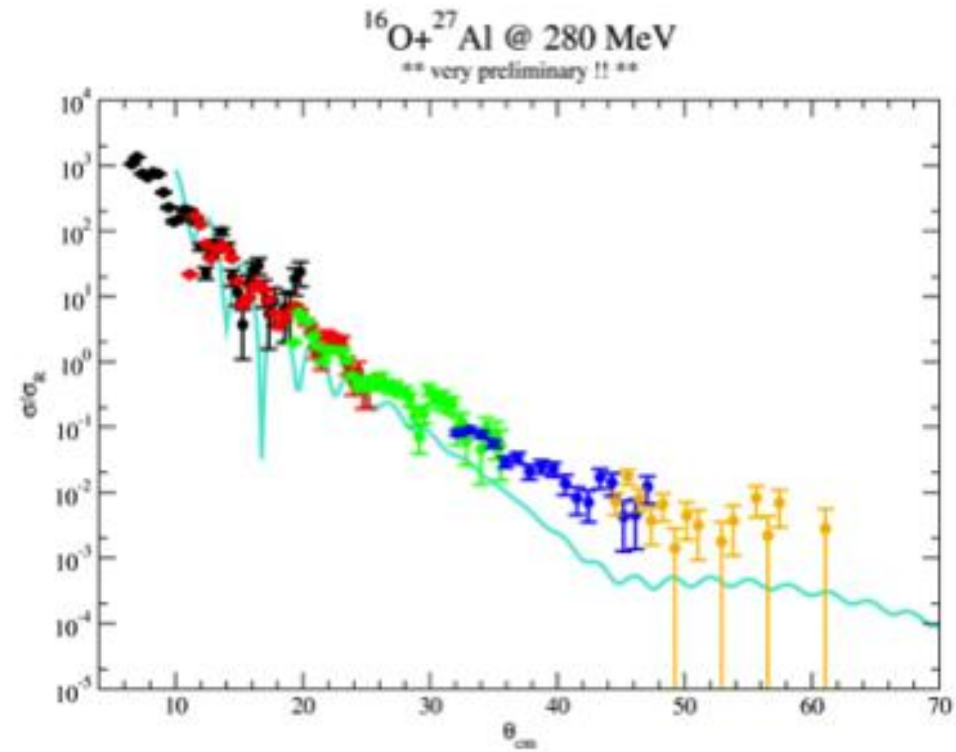
CHIMERA-EXOCHIM collaboration: *on the left, for the reactions ^{48}Ca+^{48}Ca (neutron rich), ^{40}Ca+^{40}Ca (neutron poor) and ^{40}Ca+^{48}Ca is shown the difference in mass (M_1-M_2) of the two biggest fragments emitted in the reaction normalized to the total mass. Surprisingly the neutron richness of the entrance channel (blue line) greatly favors the formation of big fusion residues having more than 60% of the mass of the system (see Phys. Rev. Lett. 102, 112701, 2009 and Phys. Rev. C85, 04609, 2012). On the right, for the reaction ^{124}Sn+^{64}Ni the isotopic composition of Carbon isotopes (<N/Z>) is studied as a function of fragments velocity correlations that gives information on fragments emission mechanism and time scales. A strong neutron enrichment is found for fragments emitted in the early stages of the reaction (see: Phys. Rev. C86, 014610, 2012).* ***These observables have both been used to constraint the elusive symmetry term of nuclear equation of state that is a key ingredient for astrophysics and nuclear dynamics studies.***

Nuclear Rainbow in $^{16}O + ^{27}Al$ elastic scattering



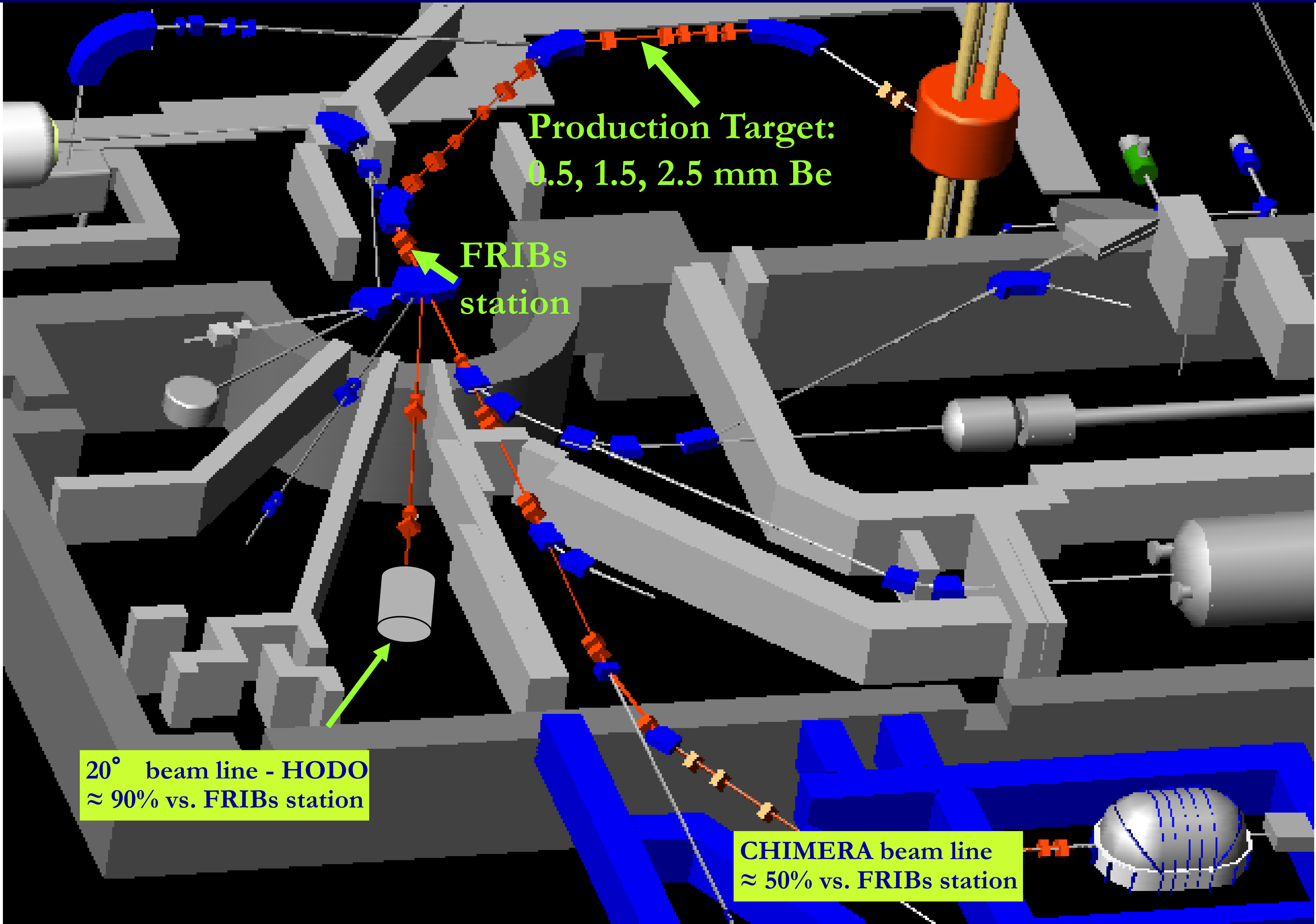
Tandem beam

Cyclotron beam



MAGNEX

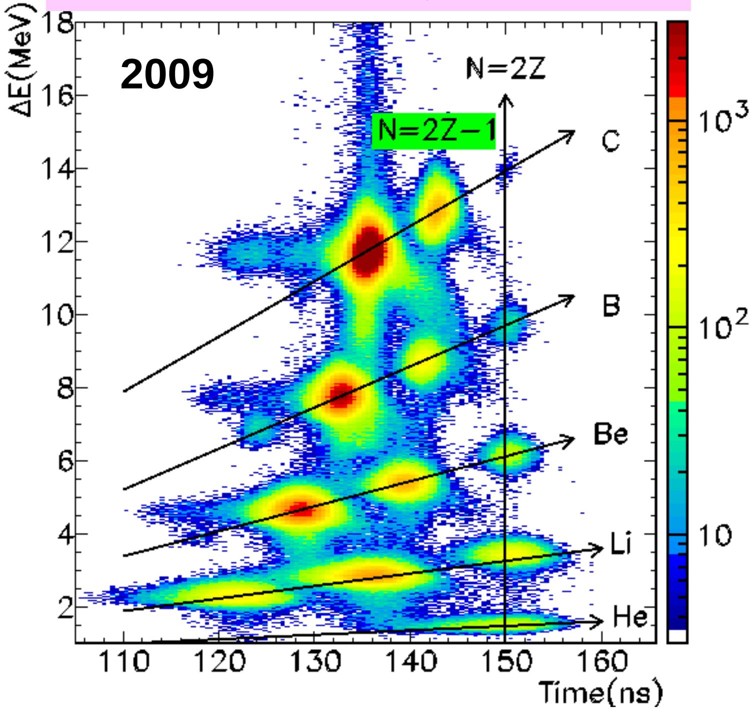
FRIBS@LNS: in Flight Radioactive Ion Beams



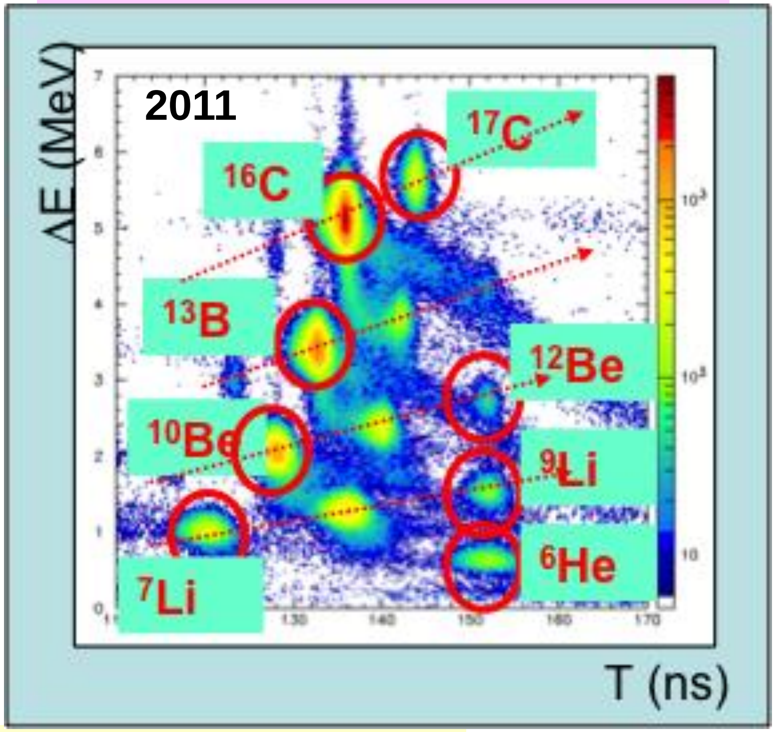
FRIBS@LNS

Using a primary $^{18}O^{7+}$ beam (used also as pilot beam to set the Bρ of the dipoles) We have repeated the transport of beams around ^{11}Be performed in December 2009 to test the increase of production after the upgrading of the fragmentation beam

16x16 DSSSD 140μm (5x5cm^2)



24x24 DSSSD 62μm (2.4x2.4cm^2)



Yields normalized to 100 W beam (6.3x10^{11} p/s)

beam	kHz	kHz
^{16}C	9	59
^{13}B	4.5	37

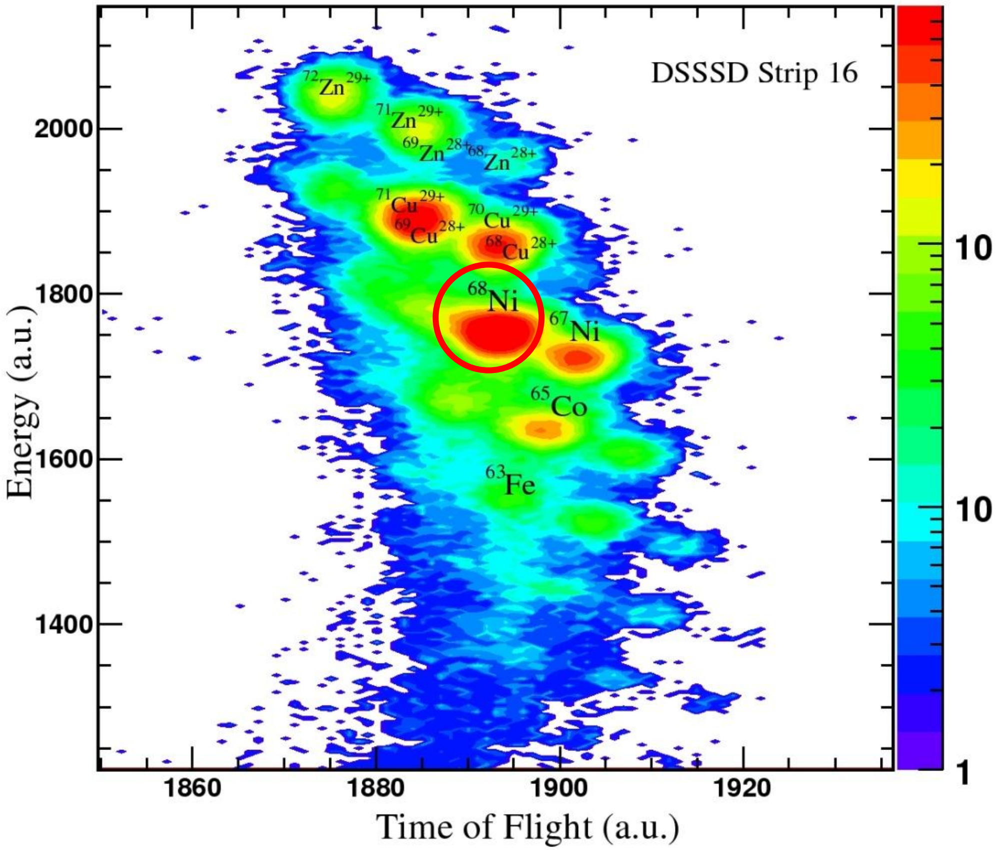
E~50 MeV/A ΔP/P <1%

Beams developed at FRIBS@LNS

primary beam	beam	intensity (kHz/100W)
18O 55MeV/A	16C	120
setting 11Be	17C	12
	13B	80
	11Be	20
	10Be	60
	8Li	20
18O 55MeV/A	14B	3
setting 12Be	12Be	5
	9Li	6
	6He	12
13C 55 MeV	11be	50
setting 11Be	12B	100
36Ar 42 MeV	37K	100
setting 34Ar	35Ar	70
	36Ar	100
	37Ar	25
	33Cl	10
	34Cl	50
	35Cl	50
20Ne 35 MeV	18Ne	50
setting ne18	17F	20
	21Na	100
70Zn 42MeV		
setting 68Ni	68Ni	20

A gain factor around 8 has been found out thanks to the 2010 upgrading

NEW – MARCH 2012 : ^{68}Ni production with ^{70}Zn primary beam



Production of a ≈30 A.MeV ^{68}Ni beam at LNS (TimeScaleZn test)

We used a $^{70}Zn^{19+}$ (40 A.MeV) primary beam impinging on a 250 µm ^{9}Be target. The maximum intensity obtained for the primary beam was ≈300 enA (0.03 kW)

Beams identification was obtained using the CHIMERA-IFEB tagging system constituted by a large surface MicroChannel plate followed by a Double Side 32x32 Silicon Strip Detector (DSSSD)

The production rate was 7 KHz / 30 Watt; reaching 100 Watt of primary beam current, we could obtain $2x10^4$ pps rate (Lise++ prediction is $5x10^4$ pps / 0.1 kW)

We verified that contamination due to not fully stripped ions can be neglected due to the low probability of charge state 27+ (<10%) and to the stripping effect of the MCP foil

Nuclear astrophysics: LNS excellence

A great interest in the scientific community moves to the study of nuclear reactions of astrophysical interest. The main goal of nuclear astrophysics is the measurement of cross sections for nuclear reactions that are crucial for the understanding the evolution of the Universe. These reactions are involved in different stellar scenarios, from the first few seconds of the Big Bang which created the seed material for our universe, through to the present energy generation in our Sun which keeps us alive.

The LNS experimental activity in nuclear astrophysics is mainly based on the **Trojan Horse Method (THM)**, which has been developed at LNS and successfully applied in several reactions. Today the THM is considered as the unique indirect technique which allows to overcome the coulomb field effects - coulomb barrier and electron screening - in the **measurements of nuclear reaction cross sections at the astrophysical energies (< 100 keV).**

The INFN ASFIN EXPERIMENT

- Asfin is the name of the research project that has been approved by the INFN scientific committee for nuclear physics 15 years ago. Over the past 10 years the Asfin group has reached a leading role in the international scientific community, thanks to the important results obtained through the THM application on several astrophysically relevant nuclear reactions.
- The group has established many international collaborations and has performed experiments in several laboratories in the world.
- The Asfin activity is also confirmed by hundreds of publications, hundreds of seminars and lessons, tens of invited talks.

ASFIN
2008-2012 publications

Experiments (26)

1) Rez ^{3}He + d $\rightarrow$ ^{3}He + n + p_s
2) Rez ^{3}He + d $\rightarrow$ ^{3}H + p
3) Rez 14N + d
4) ORSAY 24(Mg,3He,n)2
5) FSU 13C + a
6) Notre Dame 17O + d
7) Napoli p + d $\rightarrow$ p + p + n
8) **LNS** ^{9}Be + p $\rightarrow$ 6Li + a
9) RIKEN ^{18}F + p $\rightarrow$ 15O + a
10) **LNS** 9Be + p -> 8Be + d
11) **LNS** 19F + p $\rightarrow$ 16O + a
12) **LNS** 16O + 12C
13) Rez 3He + p $\rightarrow$ 3H + p
14) Rez 3He + 17O (ANC)
15) Rez 3He + 19F
16) College Station TECSA
17) Bucarest ^{16}O + ^{12}C $\rightarrow$ ^{20}Ne+a+a_s (ANC)
18) Debrecen ^{6}Li + ^{3}He $\rightarrow$ ^{7}Be+d
19) FSU ^{13}C + ^{6}Li $\rightarrow$ ^{16}O + n + d_s
20) Rez ^{17}O + ^{3}He (ANC)
21) College Station TECSA (II run)
22) CIAE – Pechino 9Be + d
23)College Station TECSA (III run)
24) Rez ^{18}O + ^{3}He (ANC)
24)25) Debrecen ^{6}Li + ^{3}He (II run)
26) LNL ^{19}F + p

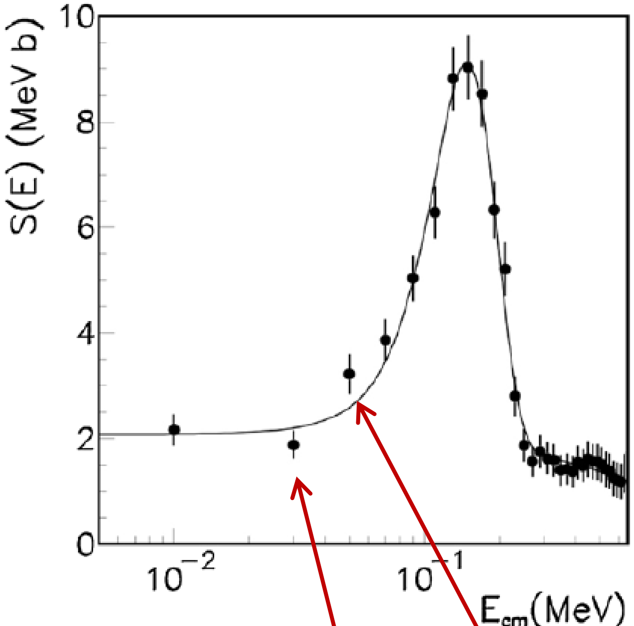
Publications (108), (58) journal, (50) other

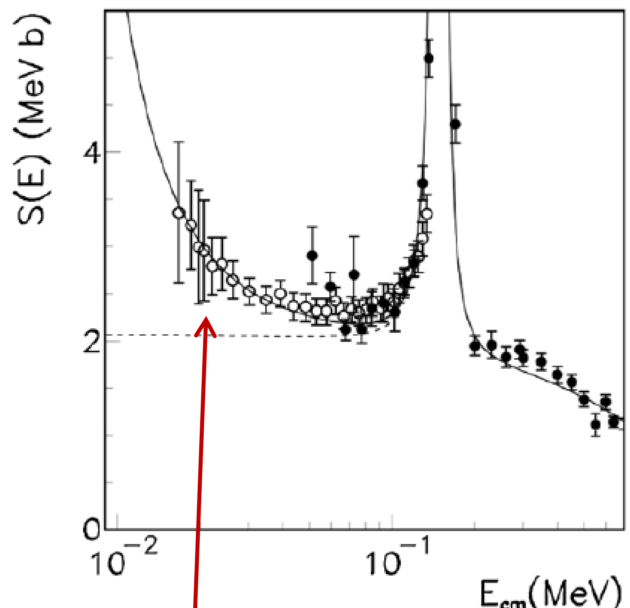
PLB 2
PRC 9
APJ 1
APJ lett. 2
NPA 1
NPAc 4
FB 5
AIP 6
PLB 2
NIM 1
POS 1
A&A 1

PRL 2
RMP 1
JPG 7
JPGc 5
PAN 1
MSAIT 4
PASA 1
NP NEW 1
NC 1
other 50

ASFIN

New measurement of the $^{11}B(p,\alpha_0)^8Be$ bare-nucleus S(E) factor via the Trojan horse method L. Lamia et al., JPG 39(2012)015106





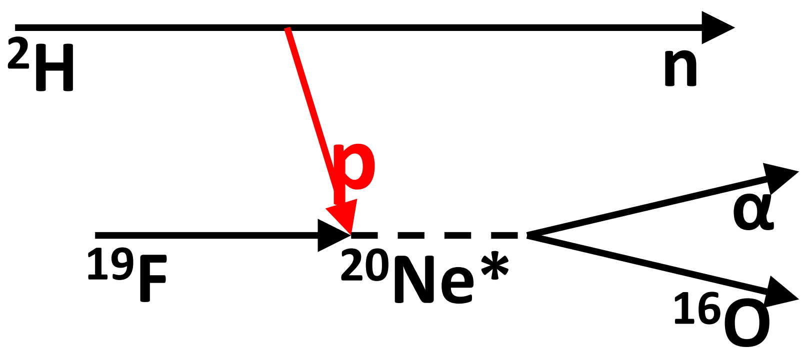
THM data + fit

From the comparison between direct data (affected by the electron screening) and the THM data (without screening effects) it is possible to extract the electron screening potential.

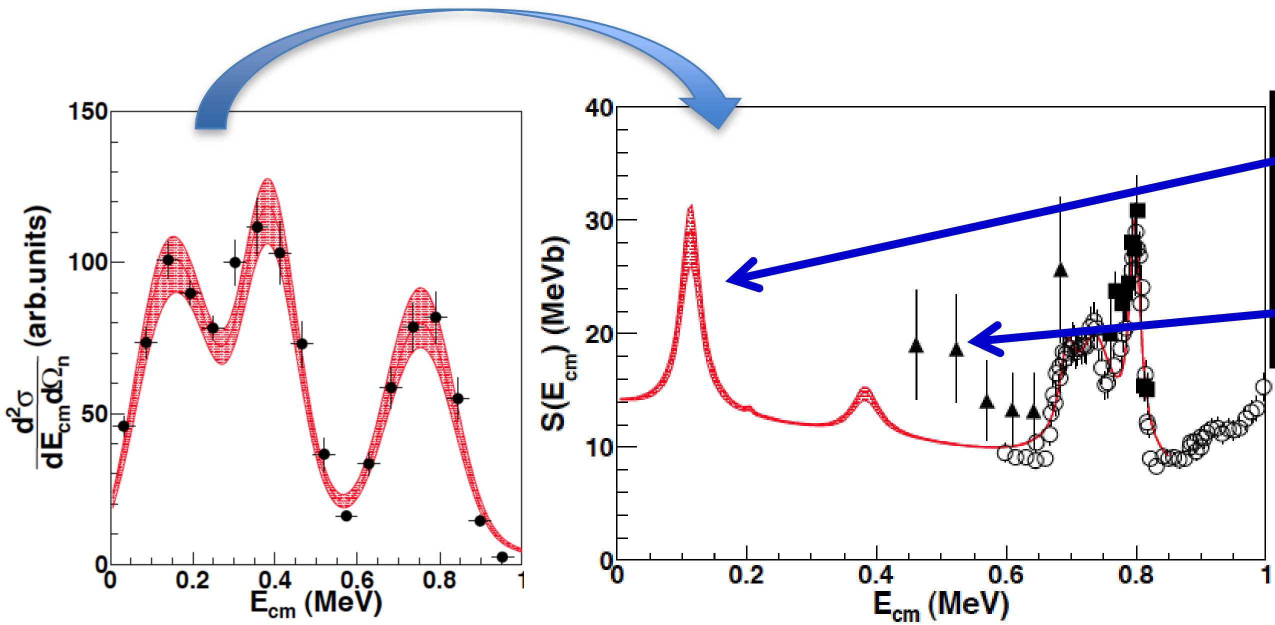
$$U_e^{\mathrm{THM}} = 472 \pm 160 \text{ eV}$$

Trojan Horse

The $^{19}F(p,\alpha)^{15}O$ reaction



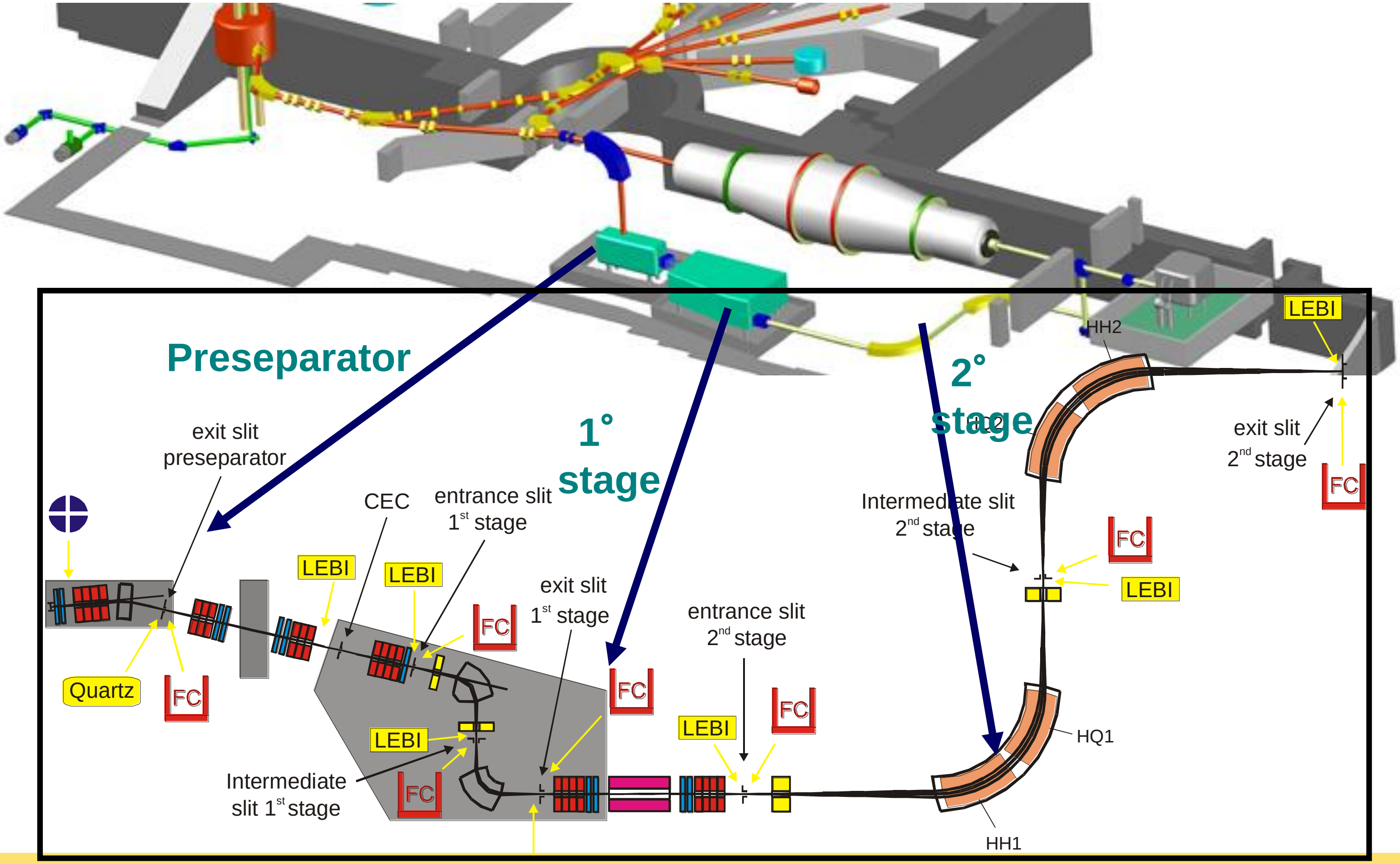
^{19}F abundance depends on the physical conditions in the AGB stars. The knowledge of the ^{19}F abundance is very important for the understanding the AGB evolution.



First experimental evidence of resonance in the very low energy region where the direct measurements are often forbidden.

M. La Cognata et al., The Astrophysical Journal Letters 739, 54 (2011)

EXCYT: the mass separator



The mass separator system consists of a pre-separator and 2 main stages, the pre-separator and the first stage being assembled on two 250 kV platforms

$(M/\Delta M)_{Pre}$ ≈ 180 (pre-separator : 18° magnet and a quadruplet of 4 electrostatic quadrupoles)

$(M/\Delta M)_{1st}$ ≈ 2000 (I stage: 2 magnets (77°, 90°) and 2 quadruplets of 4 electrostatic quadrupoles)

$(M/\Delta M)_{2nd}$ ≈ 20000 (II stage: 2 magnets (90°) and a quadruplet of 4 electrostatic quadrupoles)

First Results with EXCYT

The $^{8}Li(^{4}He,n)^{11}B$ reaction in astrophysics

1. Production of A>8 elements during the Big Bang

These elements are observed in the oldest stars. Can their existence be traced back to the Big Bang?

The candidate reaction chain is

$$^{1}H(n,\gamma)^{2}H(n,\gamma)^{3}H(^{2}H,n)^{4}He(^{3}H,\gamma)^{7}Li(n,\gamma)^{8}Li(^{4}He,n)^{11}B(n,\gamma)^{12}B(\beta)^{12}C$$

2. Heavy-element nucleosynthesis in Supernova explosion

r-process: rapid neutron capture on seed nuclei that are made through α-captures starting with the two reaction chains:

$$^{4}He(^{4}He\ n,\gamma)^{9}Be(^{4}He,n)\ ^{12}C$$

$$^{4}He(^{3}H,\gamma)^{7}Li(n,\gamma)^{8}Li(^{4}He,n)^{11}B$$

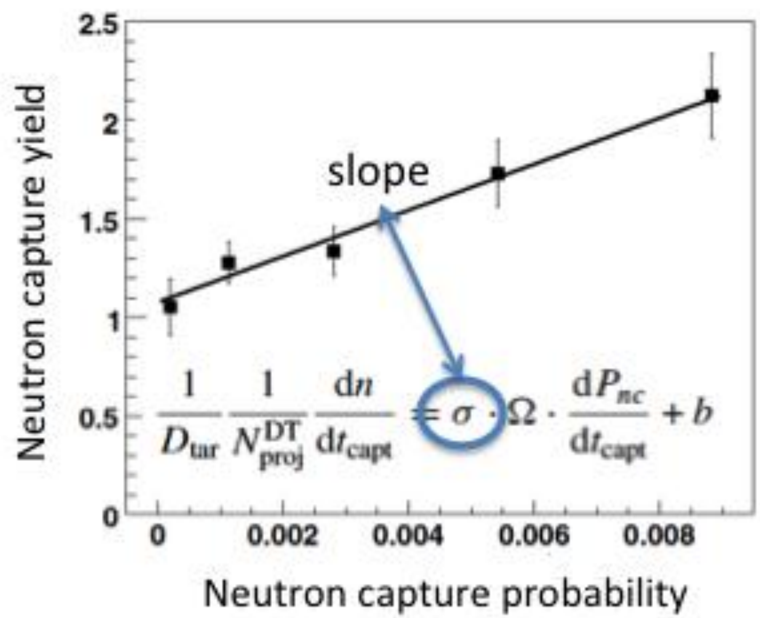
The latter significantly enhances the production of seed nuclei → constraints on models for the r-process

Threshold-less, 4π capture-time measurement of neutrons from the $^{8}Li(^{4}He,n)^{11}B$ reaction at EXCYT

- Start detector: microchannel plate (MCP)
- Stop detector: thermalization counter

First Results with EXCYT

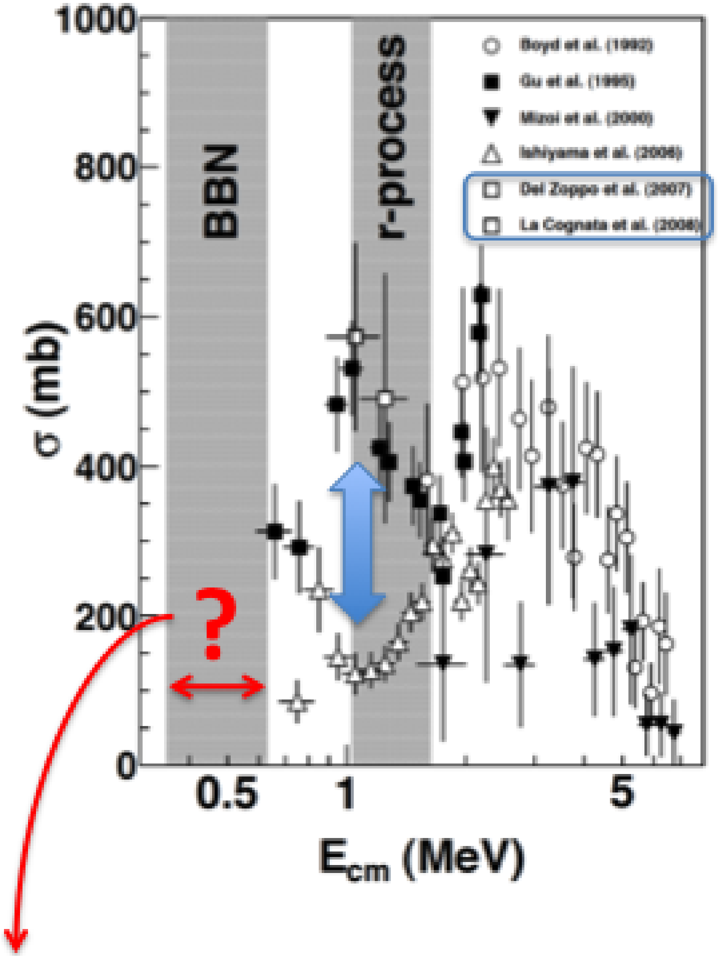
  - ❑ 12 ^{3}He tubes → neutrons are detected by means of the $^{3}He(n,p)^{3}H$ reaction
  - ❑ capture times (τ ~ 100 μs) compatible with low intensity beams (<10^3 pps)



σ → cross section
dn/dt_{capt} → neutron capture yield
dP_{nc}/dt_{capt} → neutron capture probability
D_{tar} → target thickness
N_{proj} → number of incident nuclei
Ω → average detection efficiency
b → background contribution

First Results with EXCYT

The $^{8}Li(^{4}He,n)^{11}B$ reaction cross section

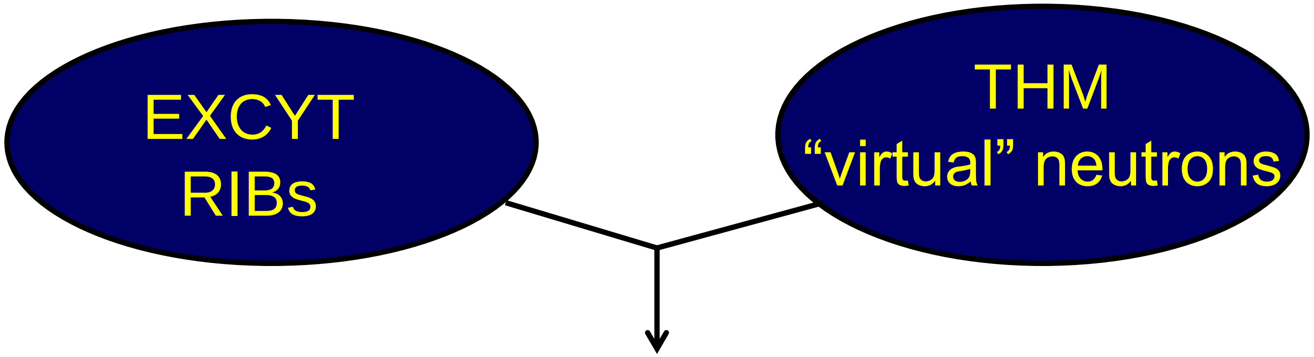


Factor of 5 discrepancy at r-process energies solved
La Cognata et al., The Astrophysical Journal Letters 706(2009)251

Recommended rate
La Cognata & Del Zoppo, The Astrophysical Journal 736(2011)148

LNS results have been selected by A. Coc et al. [The Astrophysical Journal 744(2012)158] to estimate the recommended rate in the frame of a new and extended nuclear network for Big Bang nucleosynthesis (BBN).

“LNS experimental upgrade for excellence researches in Nuclear Astrophysics, with stable and radioactive beams”



The LNS can become the first laboratory where it is possible to perform reactions between neutrons and instable nuclei, important for Nuclear Astrophysics, Nuclear structure and reaction mechanisms studies.

This will be possible thanks to the upgrade of the LNS experimental resources, supported essentially by “Premiali” funds, for excellence researches in Nuclear Astrophysics.

- **The aim of this project is to perform "bare" nucleus cross sections measurements of key astrophysics reactions in the astrophysics energy range and thermonuclear fusions reactions that concern the fusion energy production.**
- ***<u>For example, to know the $^{10}B(p,\alpha_0)^7Be$ cross section it is crucial to understand the natural B usability as clean fuel.</u>***
- **On the other hand, the same reaction $^{10}B(p,\alpha 0)^7Be$ has the peculiarity to present a resonance at E_R=10keV, that is the same energy of astrophysics interest. To assess the cross section at this energy is complex because of a "tail" of a resonance under threshold at the same energy. The ^{11}C spectroscopy studies became crucial to disentangle between the two different contributions to the resonance and to value correctly the reaction "rate".**
  - **This is an example that shows the strong correlations between Nuclear structure and Nuclear Astrophysics studies.**

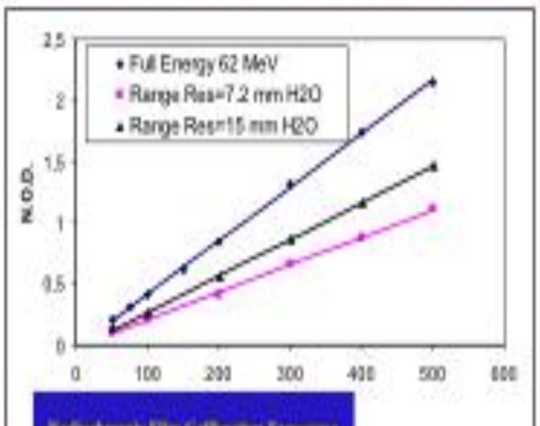
Such scientific activity will be possible thanks to the upgrading both of the TANDEM and of the SERSE source, to produce radioactive beams with the proper intensity necessary for the Nuclear Astrophysics measurementes proposed.

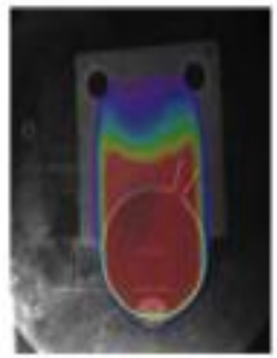
Moreover, these studies will make use also of the upgrade of the particles detector ASTRHO, already working at LNS, and the magnetic spectrometer MAGNEX, using also the neutron detector EDEN (MoU IN2P3 - INFN).

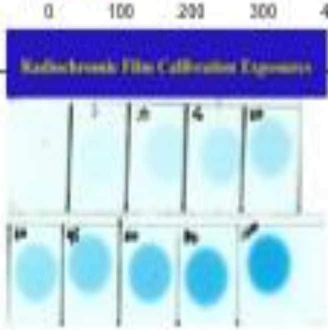
Such kind of upgrading activities, that exploit the tecnological knowledge in order to put in forefront the accelerators and detectors already existingis is in line with one of the NuPECC Long Range Plan 2010 recommendations: support and upgrade the existing facility in the European Laboratories that can produce beams with some specific features.

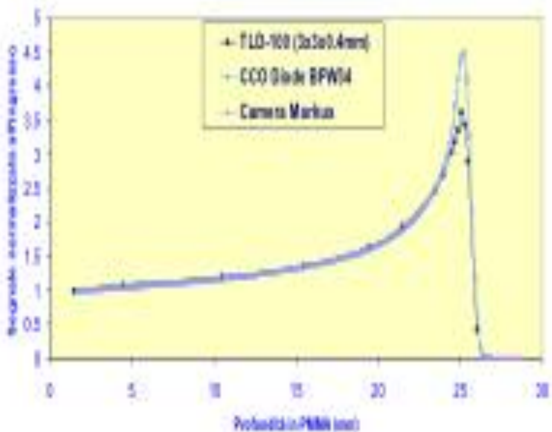
- CATANA: first Italian protontherapy facility
    - p @ 62 MeV by CS for treatment of ocular tumours[1]
    - More than 330 patients treated
    - Tumour local control of 95%[2]
- Expertise in the development and test of detector for relative and absolute dosimetry

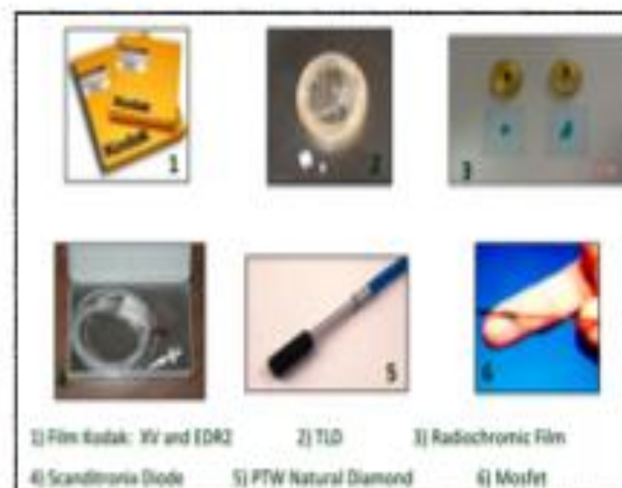
[1] G. A. P. Cirrone *et al.*, IEEE Transaction on Nuclear Science, Vol. 51, N. 3, (2004).
[2] G. Cuttone *et al.*, THE EUROPEAN PHYSICAL JOURNAL PLUS, vol. 126, 65 (2011)











PATIENTS FOLLOW-UP

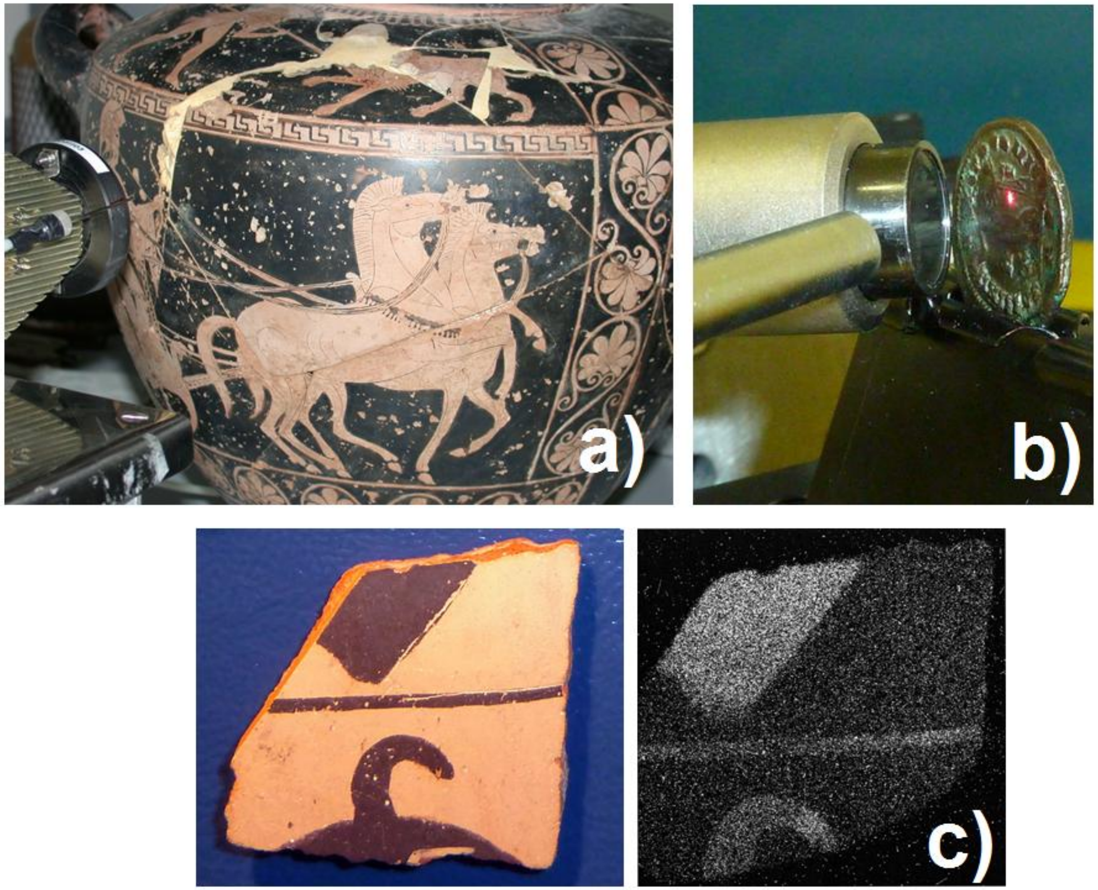
350 patients treated (Feb. 2002-Jul 2012)

- **336 uveal melanomas**
- **8 conjunctival melanoma**
- **6 other malignancies (orbital RMS, non-Hodgkin Lymphoma, various metastases)**

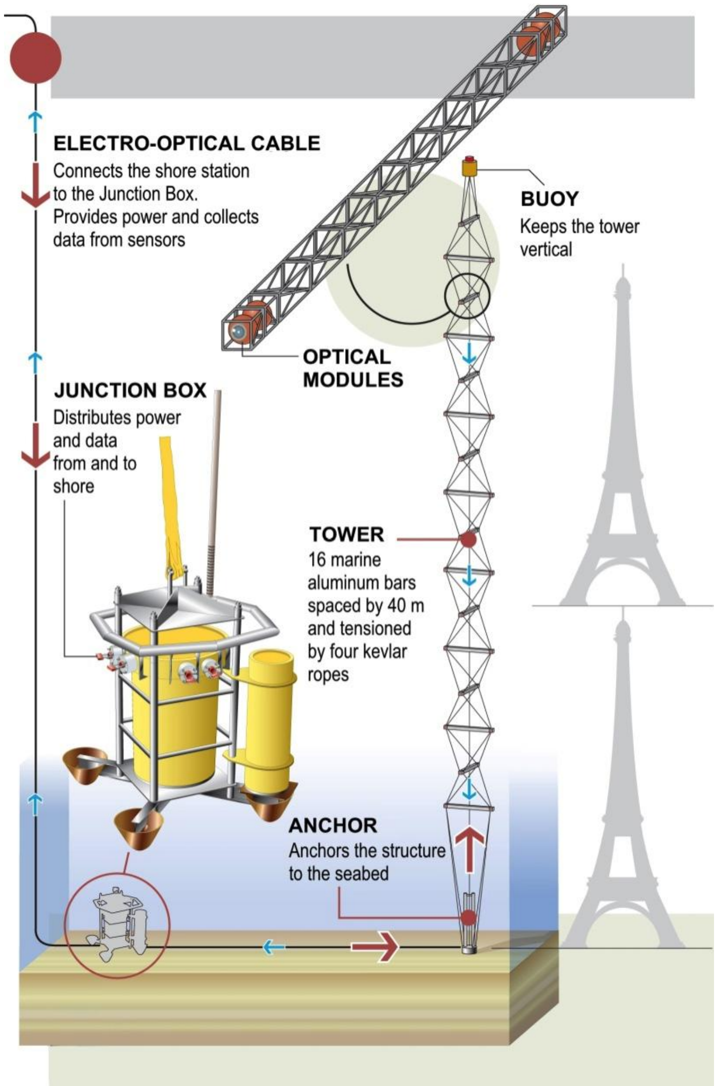
Follow-up on 220 patients: 95% of success

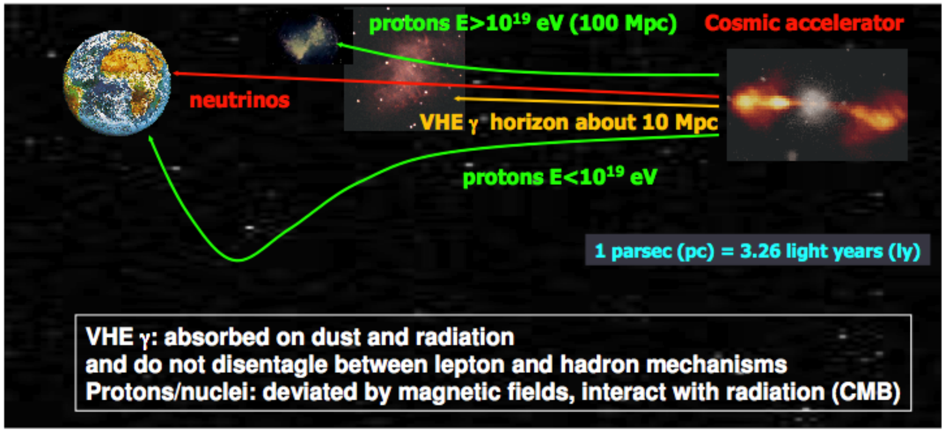
Follow-up: PT Center at Cannizzaro Hosp. in Catania. Tender in progress (120 M€). INFN is part of the game having on this item a dedicatd MoU with Regione Sicilia

LANDIS: Applications of nuclear physics in the field of cultural heritage



LANDIS collaboration: *innovative IBA (Ion Beam Analysis) and XRS (X-ray Spectrometry) non-destructive methods for in-situ applications in the Cultural Heritage field. The figure shows some complementary techniques – the PIXE-alfa, the LE-micro-XRF (low energy micro-XRF) and the X-ray imaging and space resolved spectroscopy – recently commissioned at the LANDIS laboratory for the analysis of surfaces in Arts and Archaeology.*

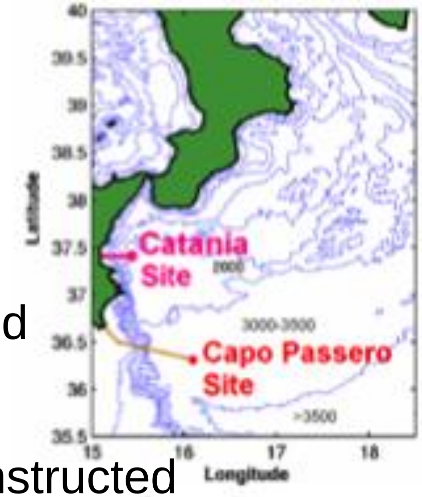




Neutrinos will provide unique pieces of information on the High Energy Universe. Detection possible by tracking the secondary muons in a km-cube size array of photosensors in deep sea waters

20.8 M€(PON Funds) are at LNS for the realization of 25 towers at LNS-Porto Palo Lab

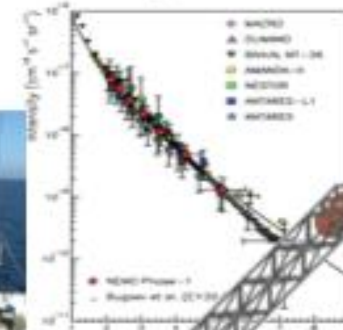
Status of the KM3NeT-Italia Project



1998-2012: NEMO R&D, NEMO, ANTARES
2006-2009: Km3Net Consortium Design Study
2009-2012: Km3Net Consortium Preparatory Phase (INFN)
2012-2015: Km3Net Italia (22 M€ funding regione Siciliana and MIUR)

Catania Test Site, 2100 m water depth (25 km)

NEMO Phase 1: test of key deep-sea technologies, muon flux reconstructed
First Cabled node of EMSO: geo-hazard and (bio-)acoustic monitoring

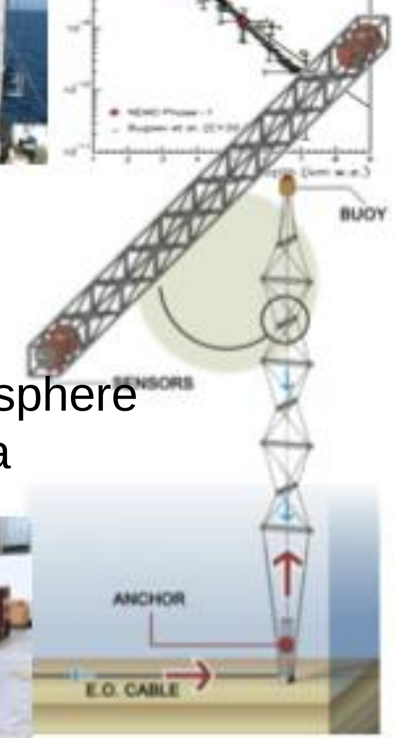


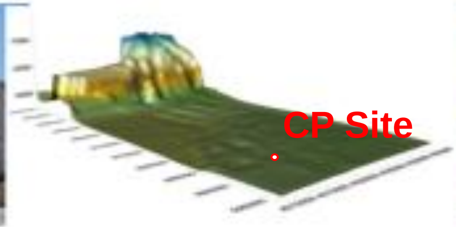




Capo Passero Km3Net-Italia Site, 3500 m water depth (100 km)

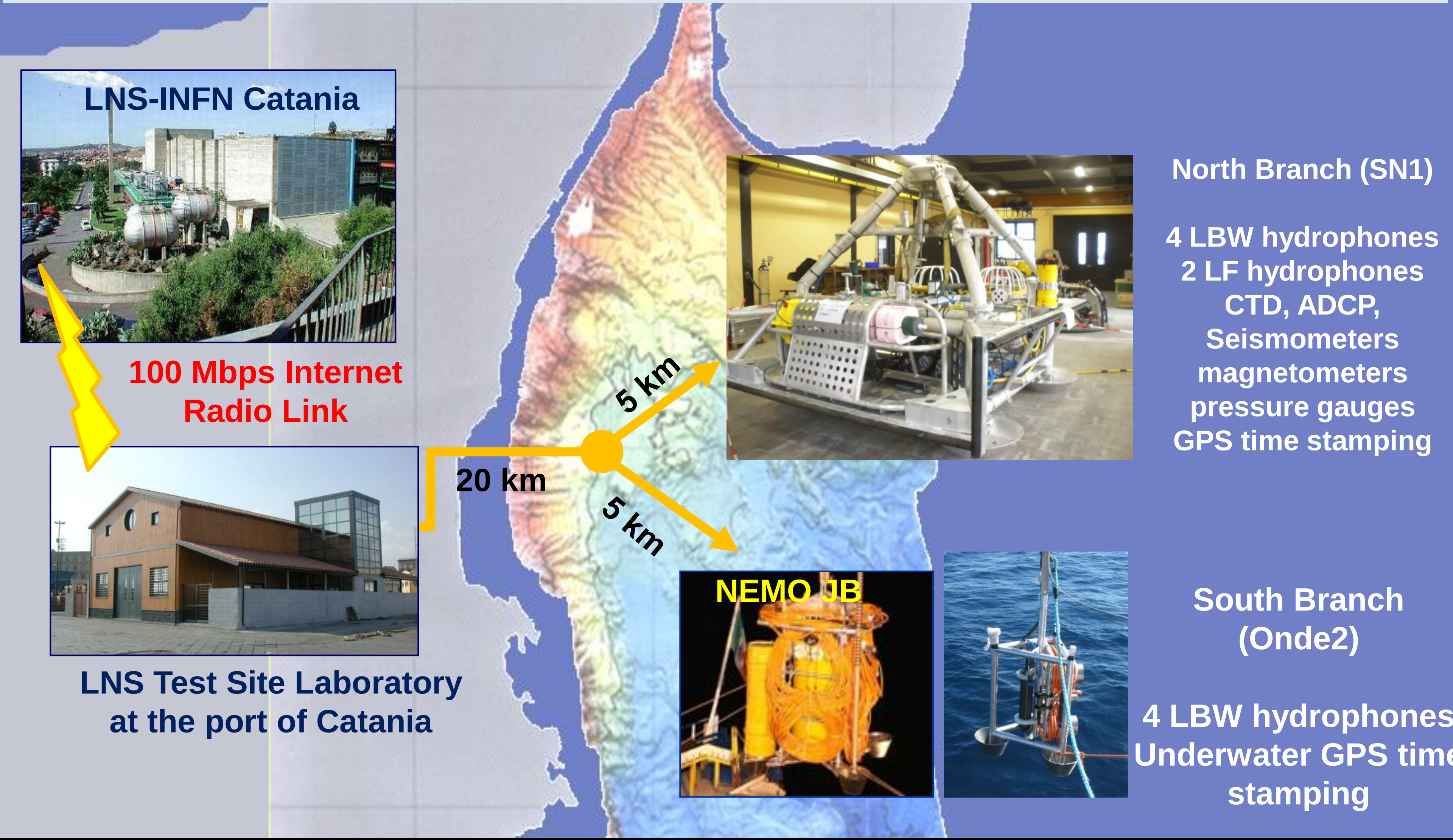
Optimal deep-sea Conditions: site search and monitoring activity
NEMO Phase 2: demostrator for the tower-shape detection unit
20 Detection Units in 2015: the largest telescope in the Northern Hemisphere
Seabed network and GARR-X: An open Science Gateway to deep sea




The Catania Test Site: a multidisciplinary deep sea-lab

LIDO demo mission of ESONET-EMSO: Refurbishment of SN1 and OnDE observatories
Goals: Bioacoustics, ocean monitoring,Tsunami warning.



Infrastructure requested by UCL and CSIC for installation of deep-sea stations in 2013

the structure of the 'NEMO' tower

Ready for Deployment Oct 22-26

- 8 floors in Al bars
- 8 m length
- Vertical distance of the floors = 40 m
- Total height = 450 m

- 4 Optical Modules on each floor : 32 OMs
- 18 hydrophones+ oceanographic instruments
- LED , laser beacon

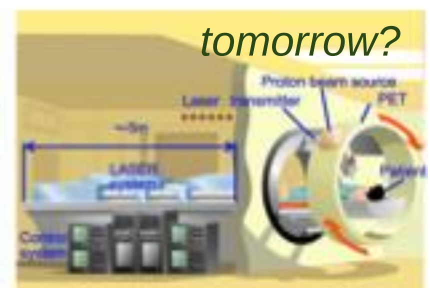
ELI-Beams and the ELIMED idea

ELI (Extreme Light Infrastructure)

new type of European large scale laser infrastructure specifically designed to produce the highest peak power (10 PW) and focused intensity;

- ELI-Beamlines (Czech Rep.)
  - ELIMED
  - X-ray sources
  - Exotic physics
  - ...
- Hungary
- Romania
- ...

- Why ELIMED?
  - Realization of a facility at ELI-Beamlines, to *demonstrate the clinical applicability of the laser-driven protons*
  - **Compactness, cost-reduction**, new pioneering treatment modalities



- Why ELIMED at INFN?

-The project we are proposing is related to the preparatory phase of ELIMED (2013-2015): optimisation of the proton beams, transport, diagnostic dosimetric and radiobiologic studies.

ELIMED MoU

- It was born by an idea of FZU of Prague and INFN-LNS researchers

- A MoU (Memorandum of Understanding) between INFN-LNS and ELI has been signed and officially started the activity


Fyzikální ústav
Akademie věd ČR, v. v. i.
INFN

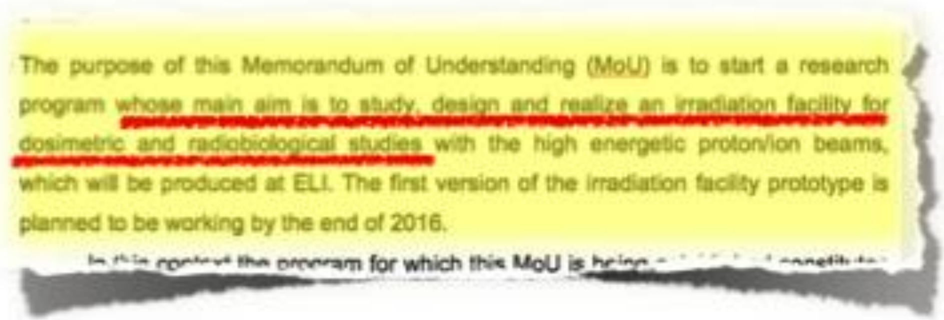
Memorandum of Understanding for a scientific and technologic collaboration towards medical applications at ELI Beamlines

Between the

Eli-Beamlines, Institute of Physics of AS CR, public research institution (FZU),
Prague, Czech Republic

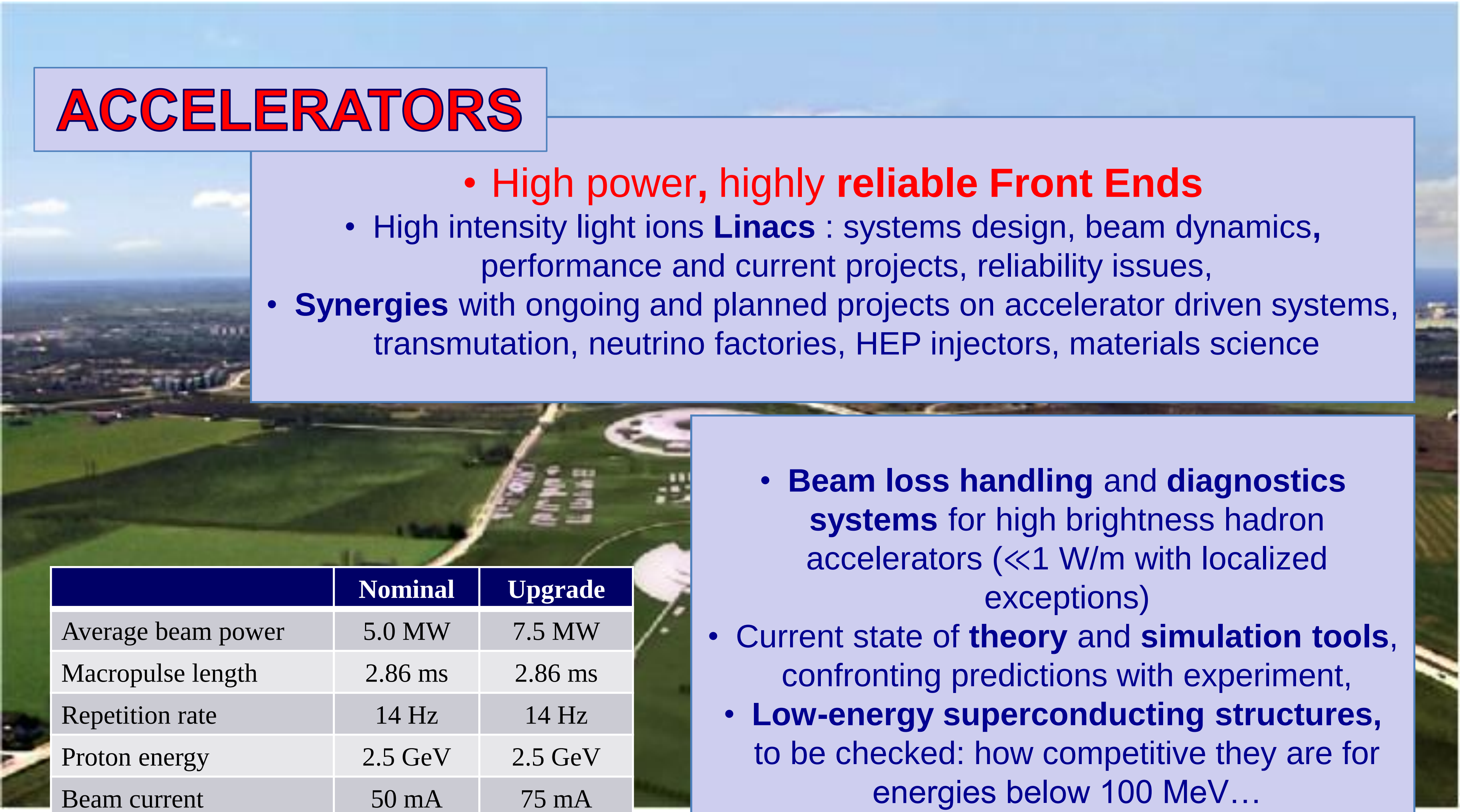
And

Laboratori Nazionali del Sud (LNS), of INFN, public research institution,
Catania, Italy


The purpose of this Memorandum of Understanding (MoU) is to start a research program whose main aim is to study, design and realize an irradiation facility for dosimetric and radiobiological studies with the high energetic proton/ion beams, which will be produced at ELI. The first version of the irradiation facility prototype is planned to be working by the end of 2016.

ELI Tender in progress for ELIMED

European Spallation Source – Lund (Sweden)



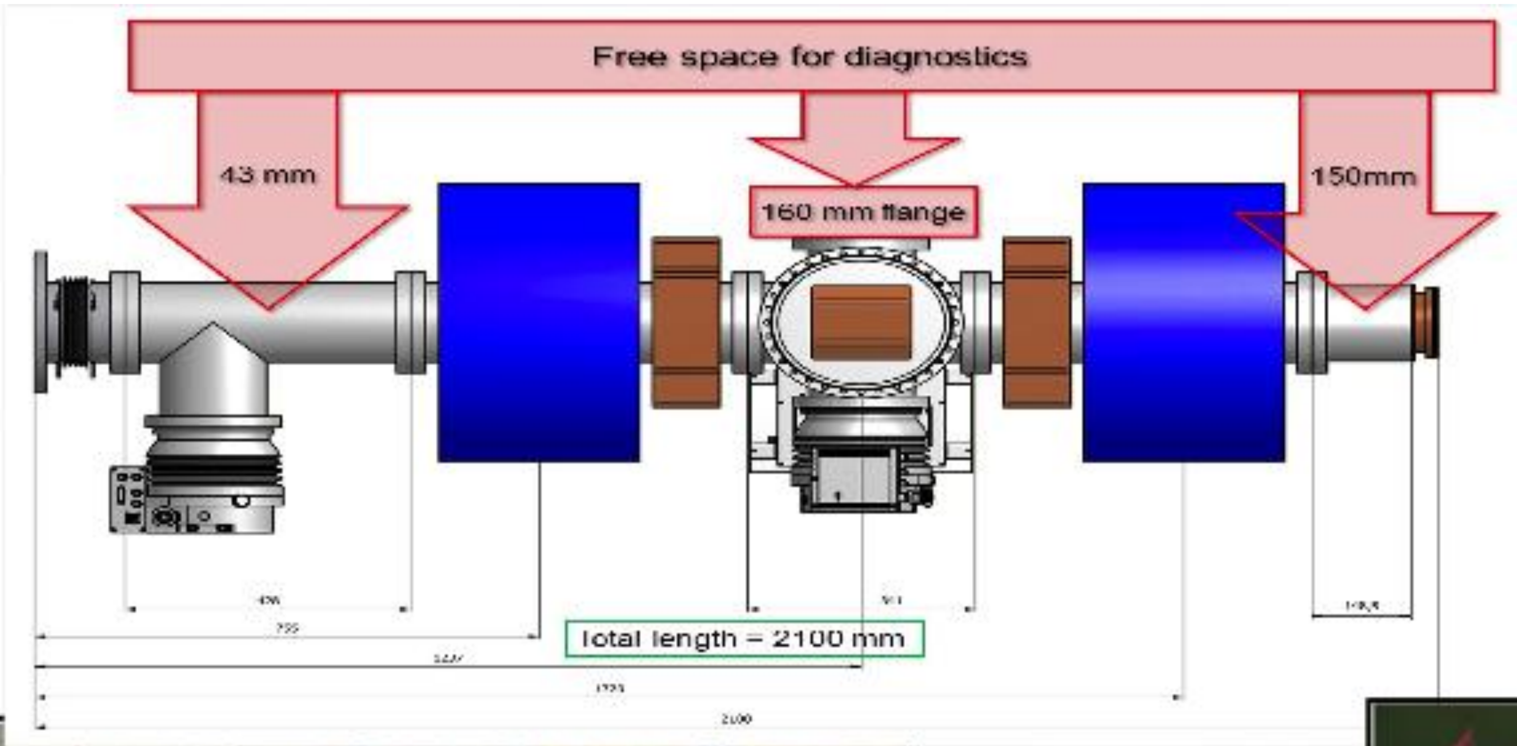
ACCELERATORS

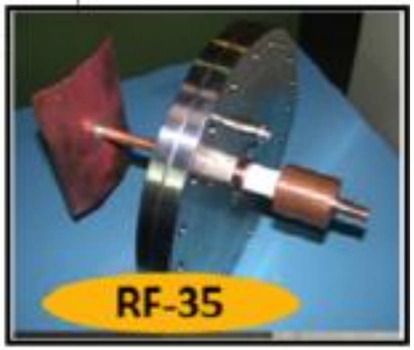
- **High power, highly reliable Front Ends**
  - High intensity light ions **Linacs** : systems design, beam dynamics**,** performance and current projects, reliability issues,
- **Synergies** with ongoing and planned projects on accelerator driven systems, transmutation, neutrino factories, HEP injectors, materials science

	Nominal	Upgrade
Average beam power	5.0 MW	7.5 MW
Macropulse length	2.86 ms	2.86 ms
Repetition rate	14 Hz	14 Hz
Proton energy	2.5 GeV	2.5 GeV
Beam current	50 mA	75 mA
Duty factor	4%	4%
Beam loss rate	< 1 W/m	< 1 W/m

- **Beam loss handling** and **diagnostics systems** for high brightness hadron accelerators (≪1 W/m with localized exceptions)
- Current state of **theory** and **simulation tools**, confronting predictions with experiment,
- **Low-energy superconducting structures,** to be checked: how competitive they are for energies below 100 MeV…

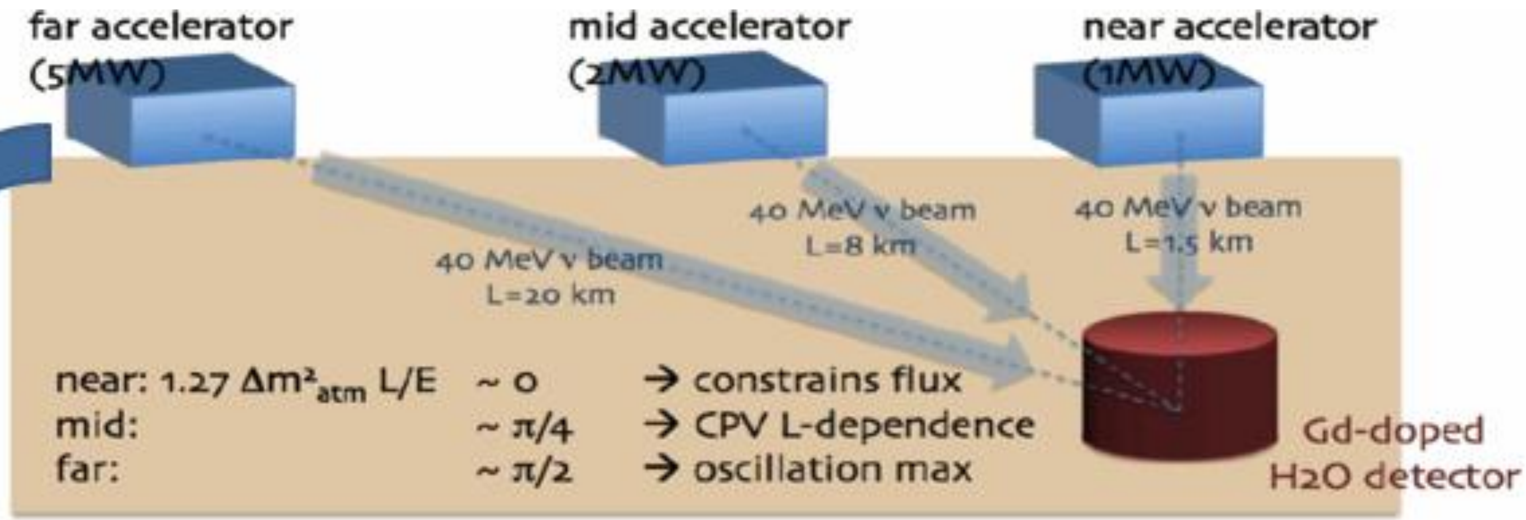
LEBT



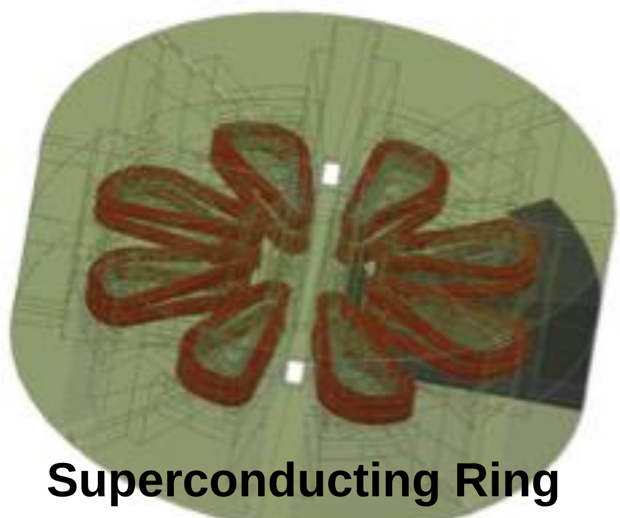


- **Chopper built at INFN-LNS and already delivered to GANIL for SPIRAL 2**

DAEδALUS: experiment overview



Accelerator Complex designed by LNS



The scientists of LNS are member of the DAEdALUS collaboration. The main contribution of our scientists is to design an accelerator complex based on cyclotron accelerator able to accelerate the H2+ beam, to deliver proton beam at 800 MeV with an average power about 2 MW! The injector cyclotron (Emax=60 MeV/n) can be used also to perform the experiment ISODAR to investigate the existence of sterile neutrinos

The anomalies that have been observed in the data from LSND, MiniBooNE, short-baseline reactor studies, and gallium source calibration runs, are often interpreted as due to sterile neutrinos and have motivated the development of the IsoDAR (IsotopeDecay-At-Rest) concept

ISODAR

To be published on PRL

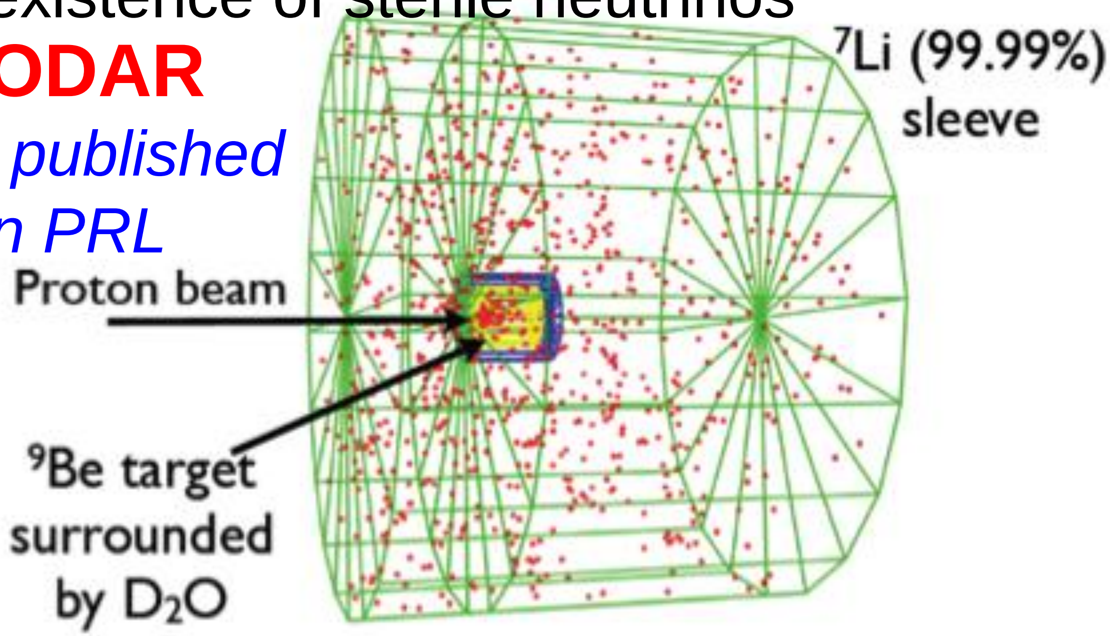


FIG. 1: A schematic of the IsoDAR target and surrounding volume design. The dots represent ^{8}Li ($\overline{\nu}_e$) creation points, obtained with 10^5 protons on target simulated. The surrounding graphite neutron reflector and shielding are not shown.

CONCLUSIONS

LNS can have a key role in the european framework:

- **In this decade for stable and RIBs at intermediate energy**
- **Leading role for Nuclear astrophysics (with FRIBs & Excyt beams and Trojan Horse Method)**
- **Strong contribution at the development of the European/Int. projects: ESS, ELI, Eurisol, DAEδALUS**
- **Advanced applications of Nuclear Physics: Hadronteherapy, Novel Imaging, Cultural Heritage, Radiobiology.**
- **An international Research Infrastructure for neutrino astrophysis and deep see applications (The site for KM3Net).**

LNS is becoming a lab for astrophysics (from KeV to TeV), never forgetting accelerators & interdisciplinary applications.

LNS with their accelerators can have a key role in the european framework:

At least in the next 5 yrs for stable and RIBs at intermediate energy *<u>NN2015 will be held in Catania</u>*

Nuclear astrophysics with Excyt beams and Troian Horse Methods

Strong contribution at the development of the European projects: ESS, ELI, Eurisol

Advanced applications of Nuclear Physics: HT, Radioisotope prod. Cultural Heritage, Radiobiology.

MIT-BEST-LNS MoU for Daedalus

Catana: eye tumours protontherapy facility (10 yrs after)

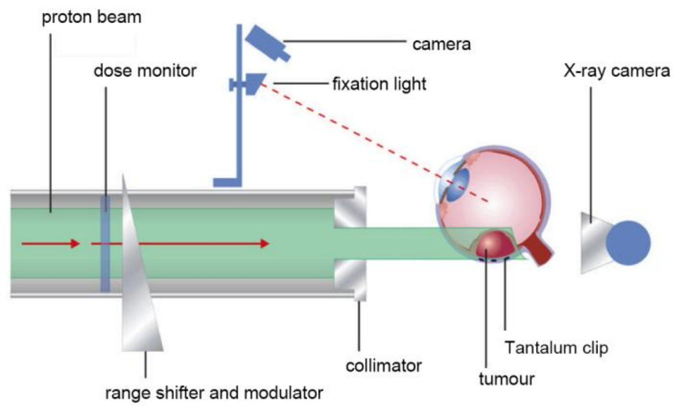
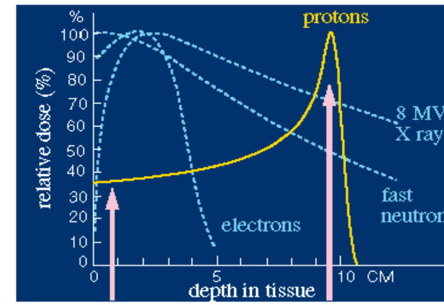


Figure 6: Principle of the irradiation The range shifter and the modulator wheel are represented by the range modulator.

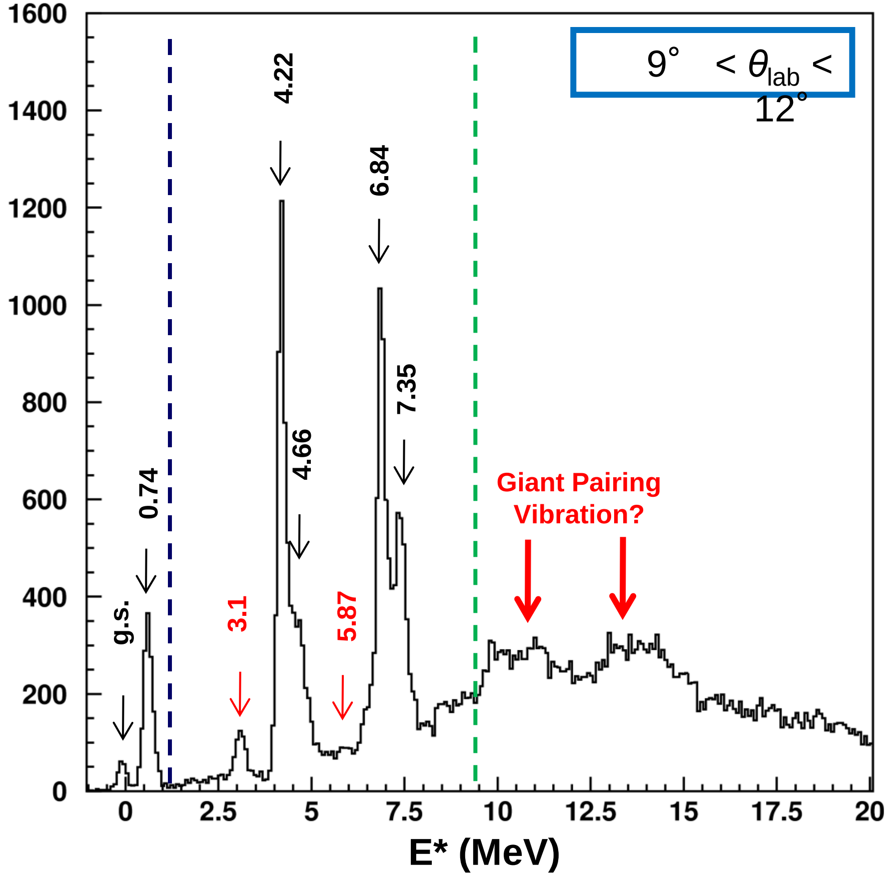


2002:	750 h	23 patiets
2003:	600 h	34 patients
2004:	350 h	19 patients
2005:	420 h	16 patients
2006:	492 h	31 patients
2007:	197 h	18 patients
2008:	290 h	32 patients
2009:	330 h	15 patients
2010:	220 h	19 patients
2011:	360 h	25 patients
2012	2600 h	45 patients

Total : 277 patients

5 sessions on average per year

$^{13}C(^{18}O,^{16}O)^{15}C$ at 84 MeV

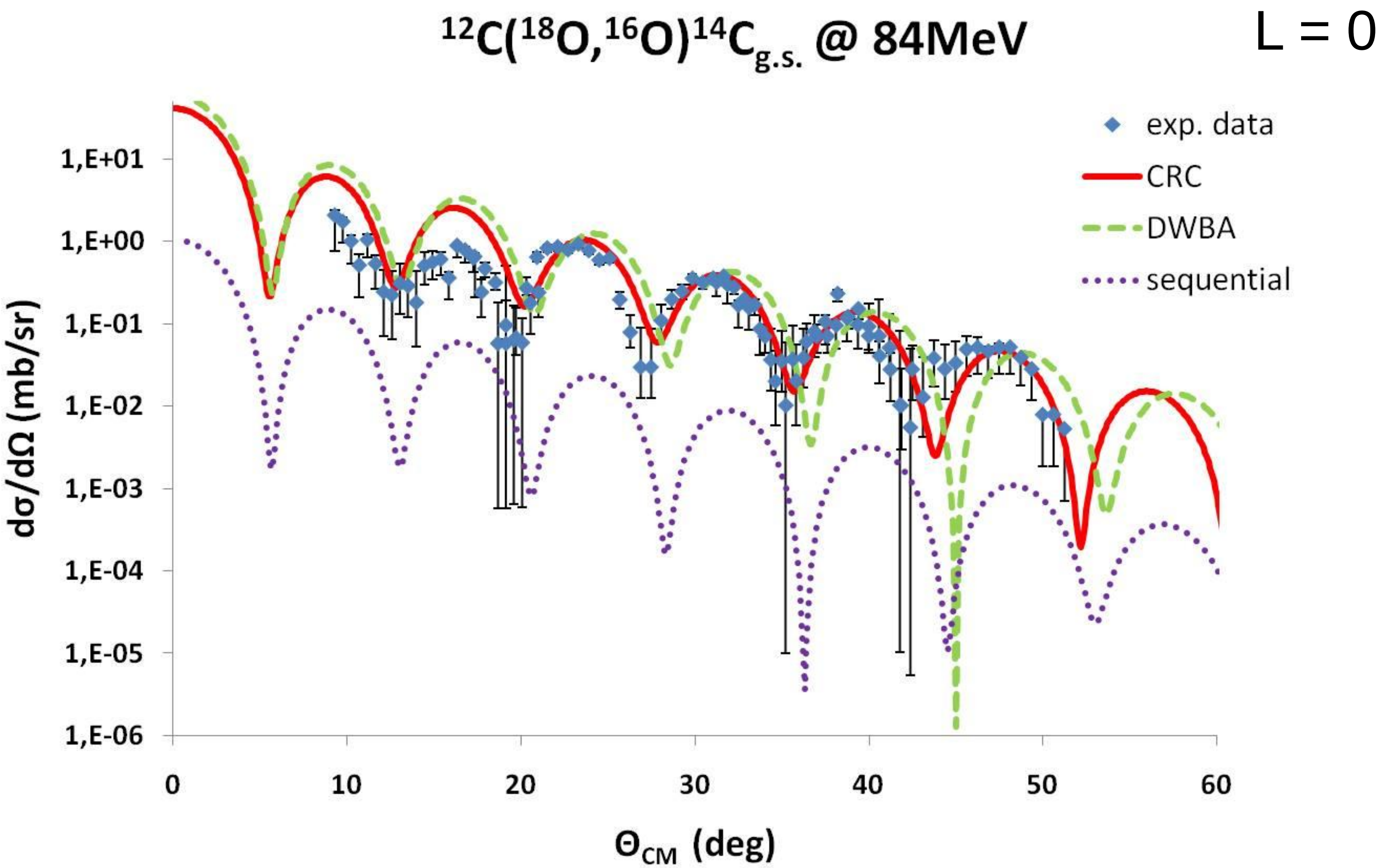


S_n = 1.2 MeV

S_{2n} = 9.4 MeV

MAGNEX

Study of two-neutron transfer mechanism



MAGNEX

Presentazione di Casini: facilities per fasci esotici
FRIB @ MSU NSCL fino a 400 kW

ISOLDE CERN: moltissimi fasci ma a bassa energia 3 MeV/u – in programma uno sviluppo ad alta energia