Report from the LNL and LNS PAC (ENSAR meeting, CERN November 2014)

Laboratori Nazionali di Legnaro (near Padova)

LNL: two PAC meetings
- 23-24 January 2014
- 7-8 July 2014

in the following composition

D. Ackermann	GSI
B. Back	Argonne
G. Colo'	Milano
A. Del Zoppo	LNS
S. Lunardi	Padova (Chair)
O. Sorlin	GANIL
R. Wadsworth	York

Two new PAC members have been recently nominated to substitute A. Del Zoppo and R. Wadsworth.
They are G. Cardella (Catania) and C. Fahlander (Lund)

Legnaro accelerators

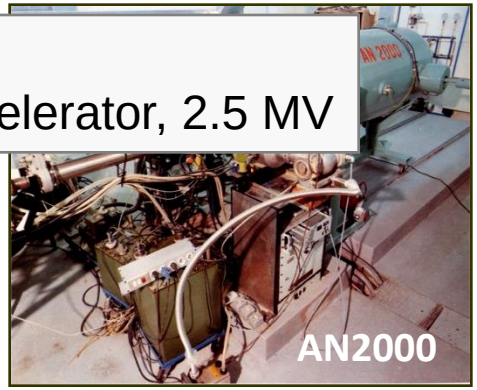
TANDEM-XTU
Elettrostatic accelerator, 15 MV

Mainly used for fundamental heavy-ions nuclear physics experiments (discussed and approved by the Nuclear Physics PAC)

ALPI
Linear superconducting accelerator. Injection from Tandem or ECR source and PIAVE

Part of the beam time also to applied physics experiments (the beam time division between nuclear and applied physics experiments is decided by the Lab. Director)

AN2000
Elettrostatic accelerator, 2.5 MV

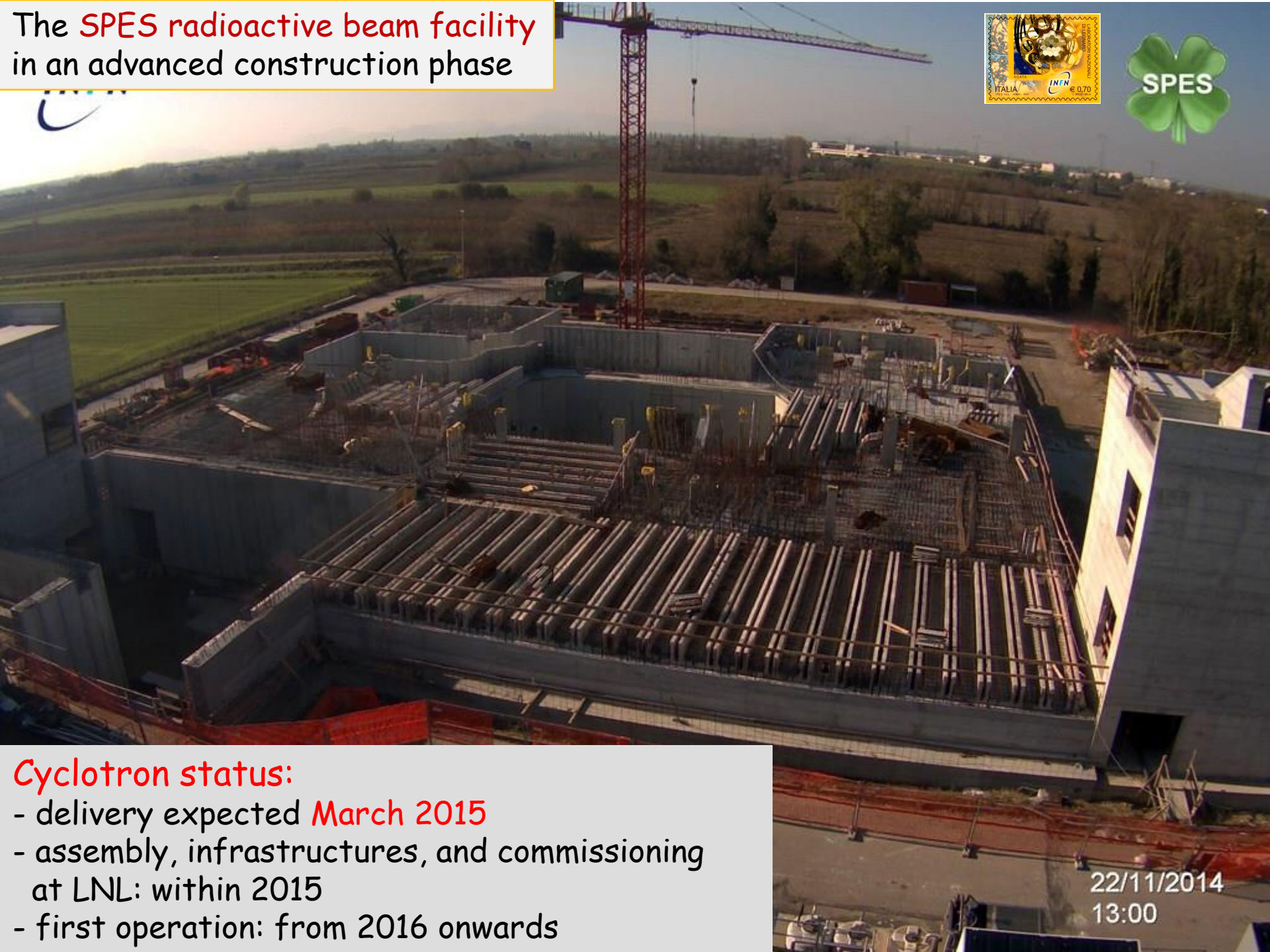


CN
Elettrostatic accelerator, 7 MV

Mainly used for interdisciplinary research, applied physics, solid state physics, neutron physics research and advanced educational purposes.

The interdisciplinary, applied physics experiments are discussed and approved by a dedicated PAC (USIP)

The SPES radioactive beam facility in an advanced construction phase



Cyclotron status:

- delivery expected March 2015
- assembly, infrastructures, and commissioning at LNL: within 2015
- first operation: from 2016 onwards

The PAC meeting is held usually twice a year
in 2014 the two meetings were held on

- January 23-24 (beam time April-July 2014)

- July 7-8 (beam time October 2014-March 2015)

The proposals presented were mainly in the field of nuclear reaction mechanism (transfer reactions, sub-barrier fusion, hot nuclei, nuclear astrophysics, clustering in nuclei, etc..)

- next meeting will be in January 22-23, 2015

- before the meeting, each proposal is assigned to two members of the PAC for a more detailed analysis
- at the meetings each proposal is presented orally (10 minutes + 5 discussion) by the spokesperson
- in the closed PAC meeting, there is an open discussion of each proposal. The proposals are not ranked individually by each member but a consensus is reached after the discussion
- the criteria for ranking are strictly based on scientific merits and on the feasibility of the experiment. Attention is given also on results and publications from past experiments

Total number of proposals: 37

Number of PAC proposals (Nuclear Physics): 20

USIP proposals : 17

Total requested PAC days : **177 (71%)**

USIP days : 72 (29%)

Total time available	208 days
Carry over:	11 days (5%)
Accelerator tests, etc..	27
Time allocated to new proposals (NP):	122 days (69% of the request)
Time allocated for Applied Physics (USP) :	48 days (67% of the request)

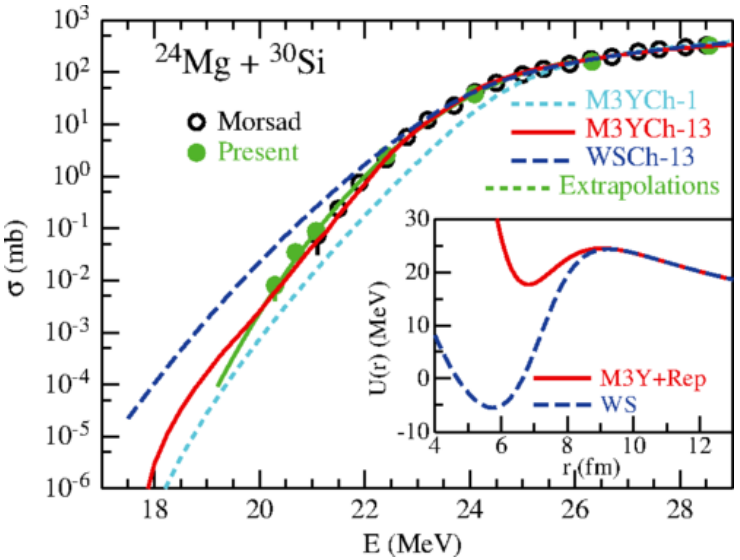
the 20 NP experiments : 9 approved for the total amount of beam time
6 approved with reduced beam time
5 not approved

Some physics results

From the PISOLO set-up
Fusion hindrance for a positive-Q-value system $^{24}Mg+^{30}Si$

Physical Review Letters 113, 022701 (2014)

σ measured down to 8 μb

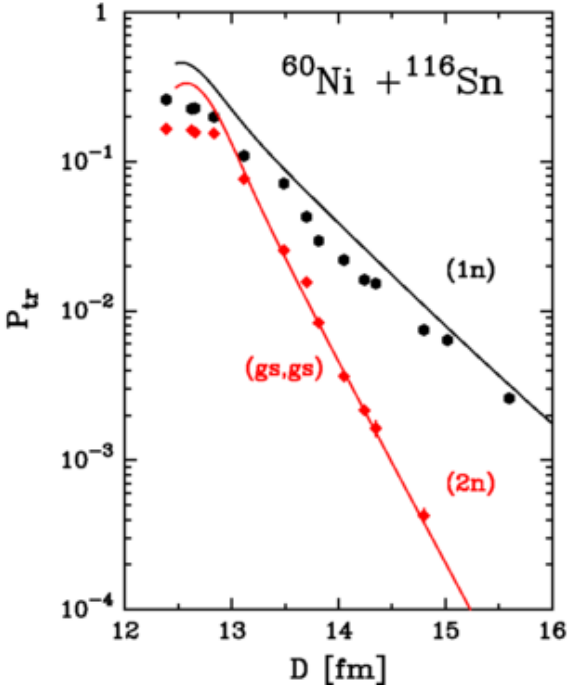


The S-factor maximum observed in this large, positive-Q-value system is the most pronounced among such systems studied thus far. This result would strongly impact the extrapolated cross sections and reaction rates in the carbon and oxygen burnings and, thus, the study of the history of stellar evolution.

From the PRISMA spectrometer
Neutron pair transfer in $^{60}Ni+^{116}Sn$ far below the coulomb barrier

Physical Review Letters 113, 052501 (2014)

transfer products detected down to ~10^{-4} with respect to elastic yeld

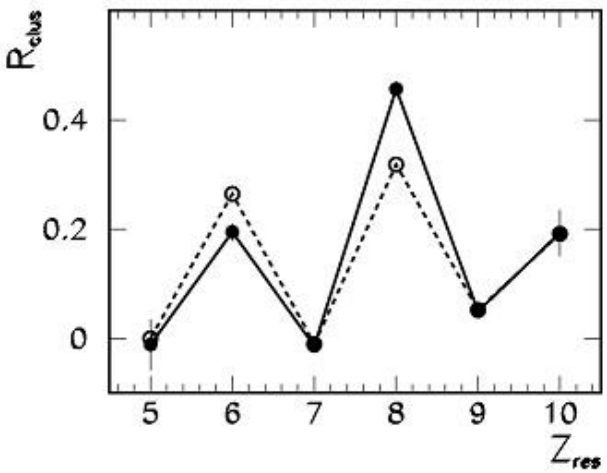


Measurements performed from the Coulomb barrier to far below it. The experimental transfer probabilities are well reproduced, for the first time with heavy ions, in absolute values and in slope by microscopic calculations which incorporate nucleon-nucleon pairing correlations.

from the GARFIELD apparatus

Clustering in highly excited light nuclei:

Unexpected α-particle structures in $^{12}C+^{12}C$ reactions

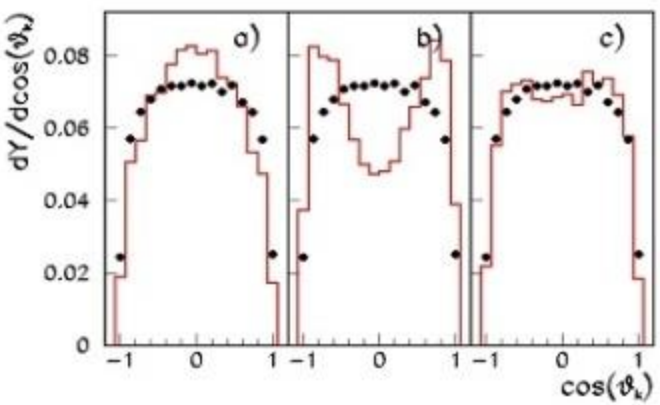


Emission channels involving multiple α-particles are 20% to 40% more probable than expected from a purely statistical behavior.

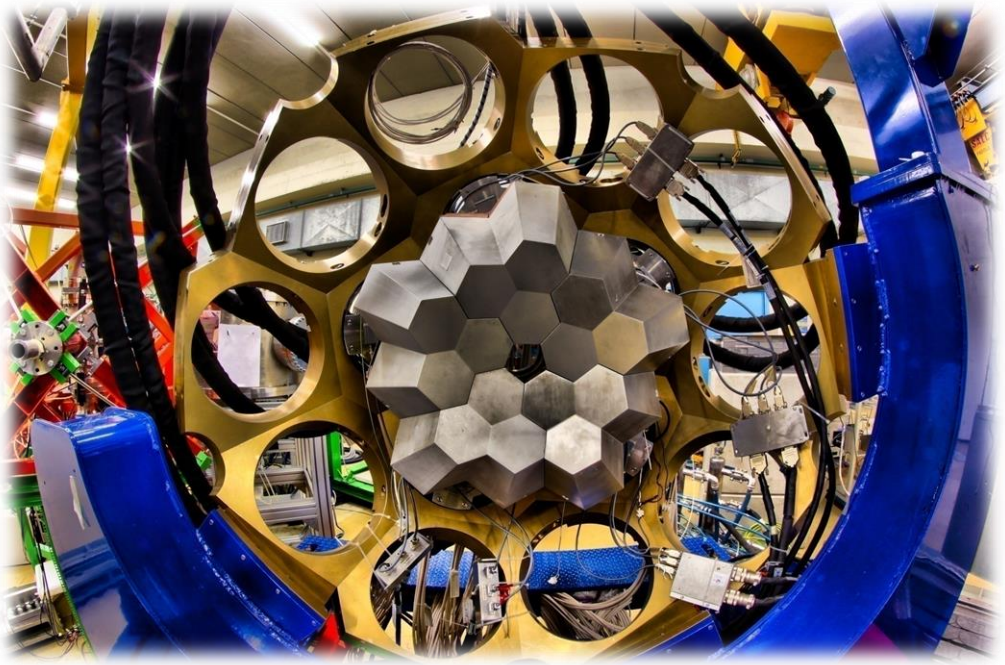
α correlations indicates a sequential process with a clear hierarchy in the emission sequence.

The results show that cluster structures persist for ^{24}Mg and/or ^{20}Ne, at excitation energies well above the energy threshold for disintegration into α's.

n-α-α α-n-α α-α-n



L. Morelli et al., 2014 J. Phys. G: Nucl. Part. Phys. 41 075107
L. Morelli et al., 2014 J. Phys. G: Nucl. Part. Phys. 41 075108

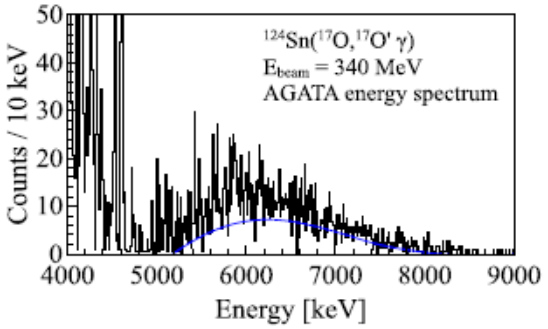


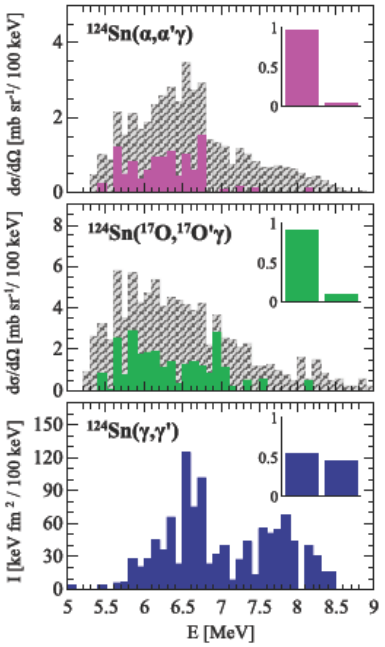
Results from the AGATA demonstrator campaign of 2010-2011 are (slowly) coming out.

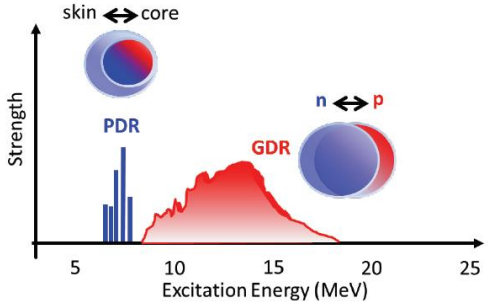
1 PRC in 2012
3 PRC, 1 EPJA in 2013
1 PRL, 1 PLB , 1 PRC in 2014

Pigmy Dipole Resonance in ^{124}Sn populated by inelastic scattering of ^{17}O

L. Pellegri et al. PLB738, 519 (2014)

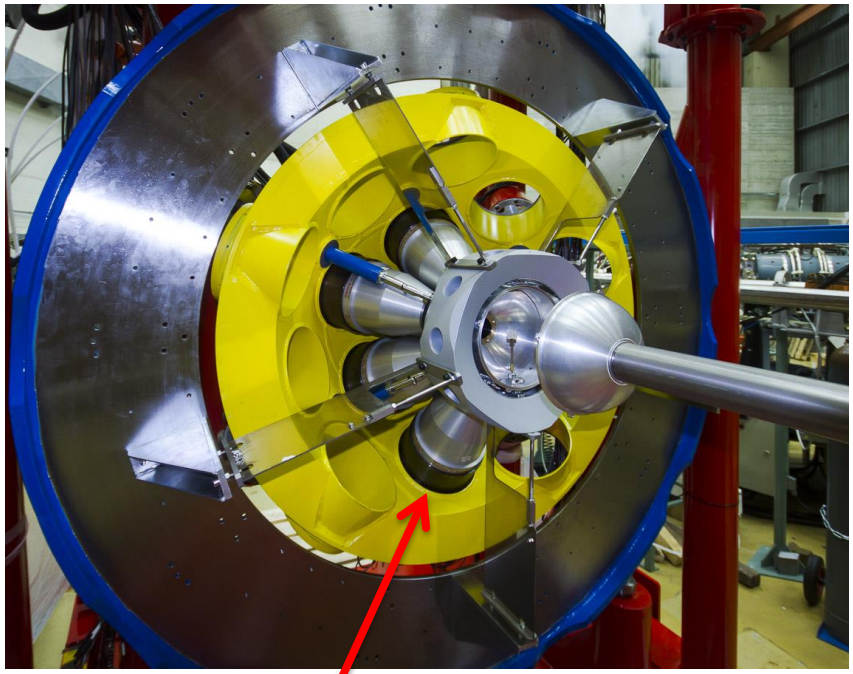






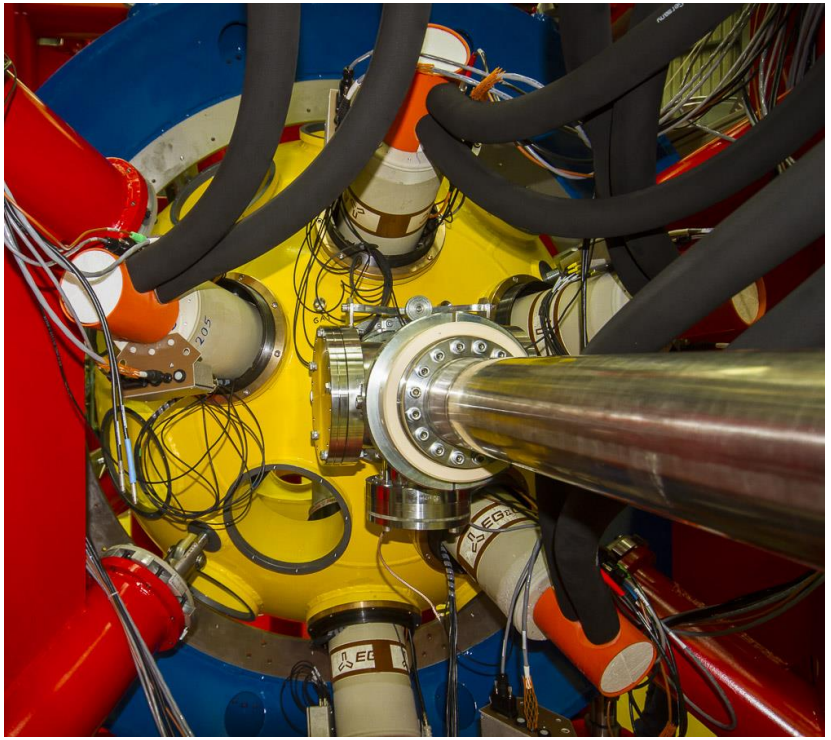
As in the case of the α probe, also with ^{17}O, one populates mostly the low energy component, the real PDR related to an excess of neutrons (neutron skin) which oscillates against an N = Z core

First commissioning runs approved and performed for the new large γ-ray spectrometer GALILEO



Gasp Ge-detectors + AC shields mounted

In 2015 the N-Wall from GANIL will be installed



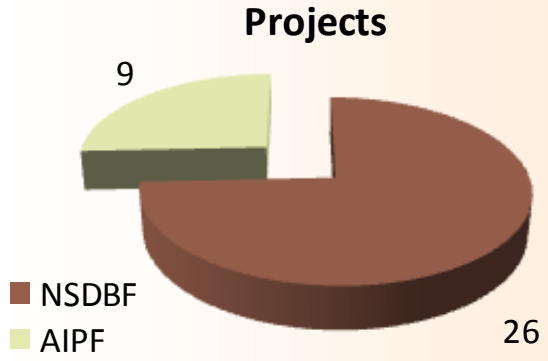
Accelerators plan at LNL for 2014-2017

- September 2014 – July 2015 – Tandem
- September 2015 – February 2016 – Tandem, ALPI, PIAVE
- March 2016 – July 2016 – Tandem
- September 2016 – February 2017 – Tandem, ALPI, PIAVE

(ALPI-PIAVE operating only 6 months per year to save money for SPES)

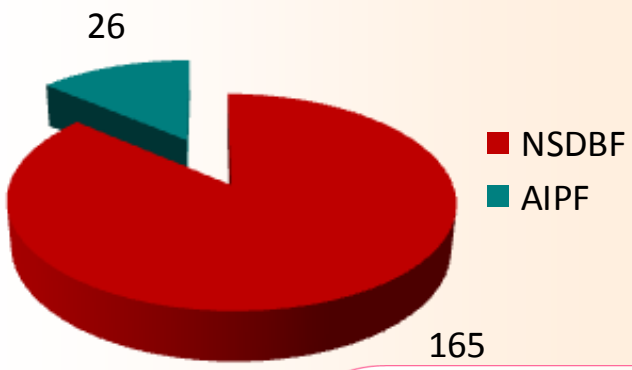
According to the present schedule of SPES, from spring 2017 for 12 months: SPES assembly with (likely) no beams at all.

TNA03 – Activity at LNL up the end of Oct 2014



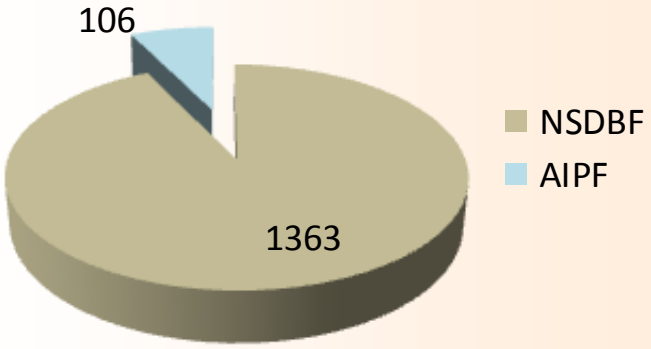
28 projects / 4y (20 @ **NSDBF**, 8 @ **AIPF**)

35 projects (**26 NSDBF**, 9 **AIPF**)



124 users / 4y

191 users



1104 person-days / 4y

1469 person-days

Report from the LNL and LNS PAC (ENSAR meeting, CERN November 2014)

Laboratori Nazionali del Sud (Catania)

LNS PAC composition:

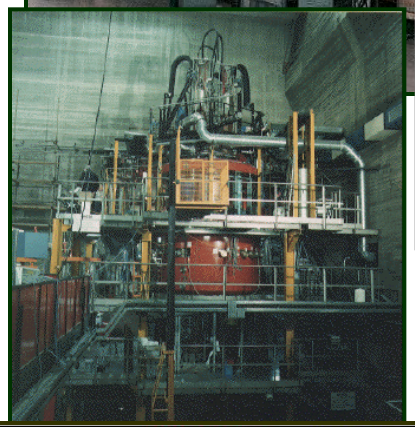
R. Bougault	Caen (Chair)
P. Descouvement	Bruxelles
M. J. Borge	Madrid/CERN
F. Gramegna	LNL
A. Kacperek	Clatterbridge Hospital (UK)
Thomas Aumann	(GSI)
R. Tribble	Texas

No PAC meetings in 2014 because of problems with accelerators (see below).

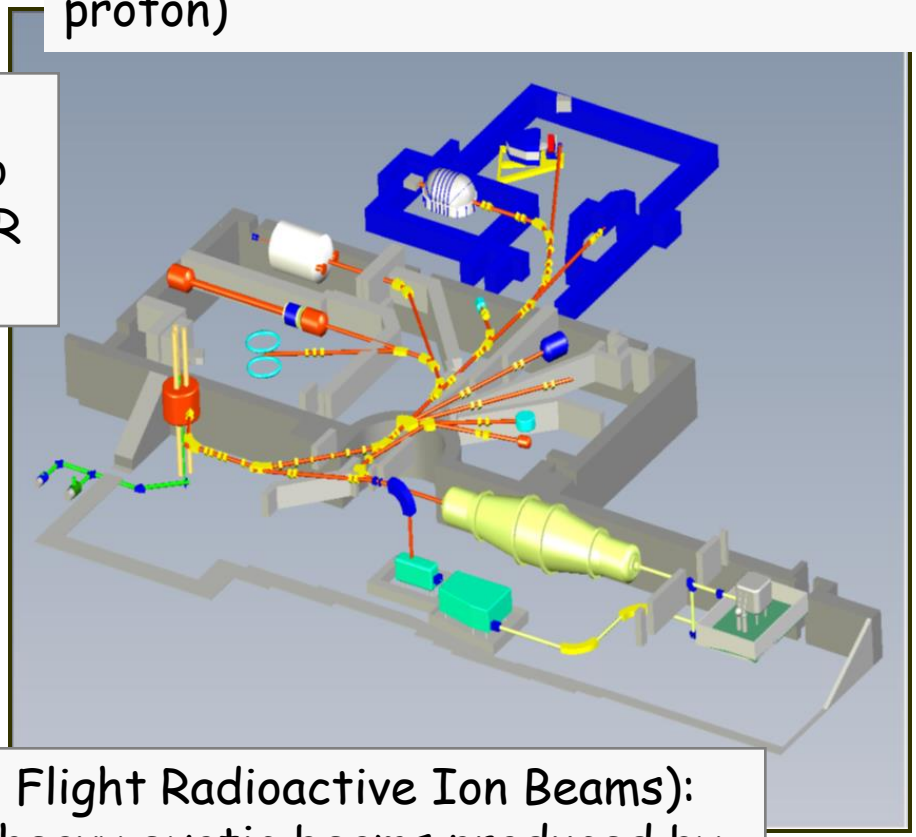
LNS (Catania) accelerators

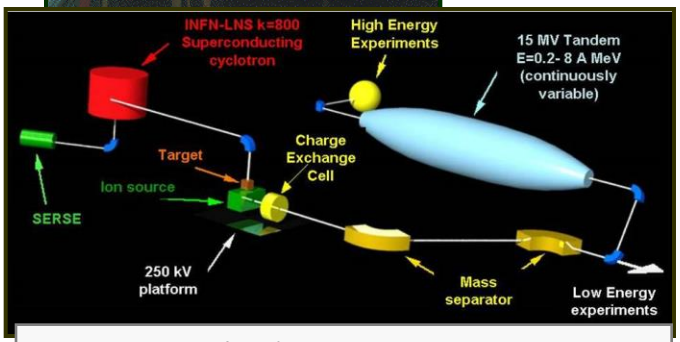
TANDEM Elettrostatic accelerator, 15 MV

Mainly used for fundamental heavy-ions nuclear physics experiments, interdisciplinary research, solid state physics, radiobiology, applied physics and proton therapy (K800 62 MeV proton)



K800: superconducting cyclotron. Energy up to 80 MeV/AMU. Two ECR sources.





EXCYT light exotic beams (0.2 up to 8 MeV/AMU).

FRIBS (in Flight Radioactive Ion Beams): Light and heavy exotic beams produced by projectile fragmentation of stable beams accelerated by the LNS-Cyclotron.

LNS Tandem upgrade: Belt -> Pelletron conversion

Charging system

HVEC does not produce belts any longer. The insulating material of belts, different from the original ones does not resist to temperature and discharges.

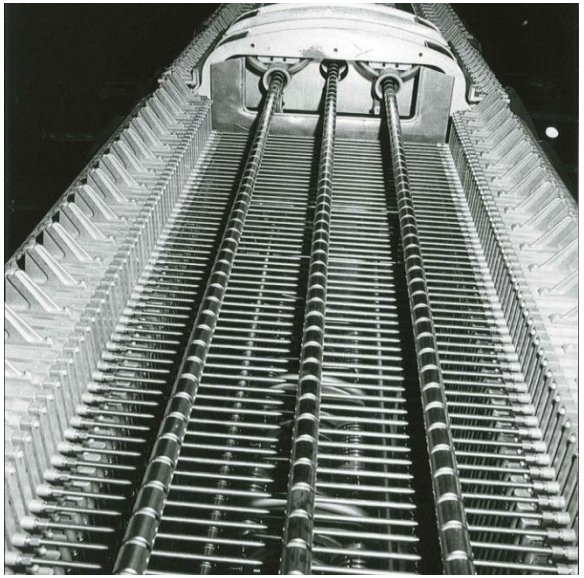
Belts must have good mechanical and electrical characteristics – No Company is available to improve them.

Alternative to the belt: Pelletron by NEC

Order to National Electrostatic Corporation (NEC, USA) issued in July 2013: 598.845 US$ - Time needed for installation: 2 months – Delivery in January 2015

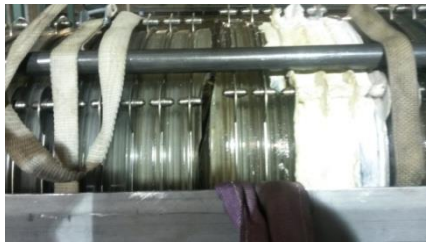
From the belt

to the Pelletron

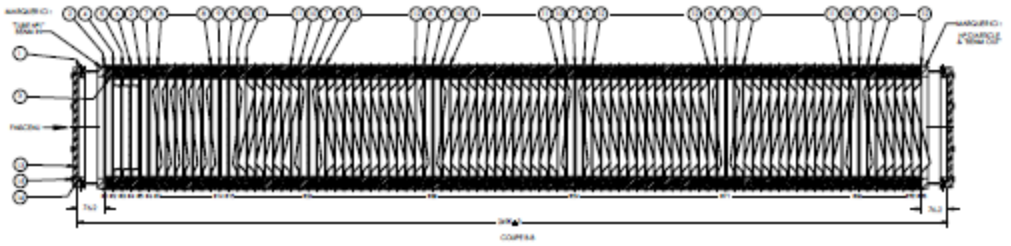


LNS Tandem upgrade: a new Accelerator Tube n.1

Tube n. 1 damaged : high residual pressure in the Low energy section due to vacuum losses



Order to VIVIRAD, France, dated December 20th 2013: 237.000,00 € for 2 accelerator tubes - Delivered in May 2014



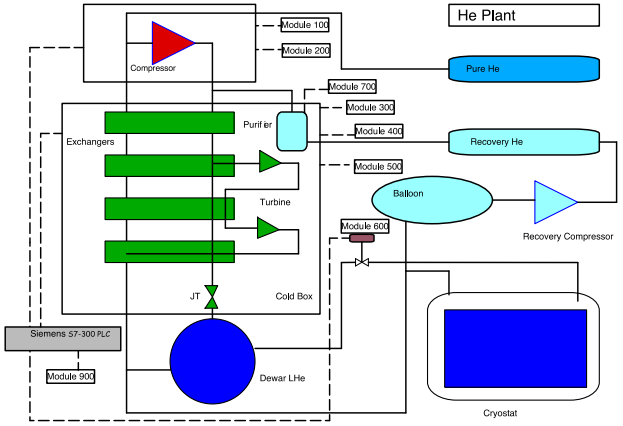
Replacement from the L.E. side

Dedicated system manufactured to remove the old tube and assemble the new one

July 9 2014 – The new tube positioned inside the Tandem

Superconducting Cyclotron: Helium liquefier revamping

- **January 1st 2013** Breakdown of the helium liquefier: turbine found broken due to impurities (Air Liquide diagnosis) – restart on January 15 - Cyclotron operating on January 25
- **May 2nd 2013** a new failure! Air Liquide inspection: again problems at the turbine - extraordinary maintenance and upgrade (revamping) needed to restore the reliability grade of the past 20 years



- **July 8th 2013** Economical offer for the revamping operation produced by Air Liquide after a heavy interaction
  Estimated time: **6 months** from the order
- **July 20th 2013** Contract approved by the INFN Executive Board – performance bond and declarations requested to Air Liquide
- **October 8th 2013** Air Liquide documents ready
- **October 15th 2013** order issued

Helium liquefier revamping

Three planning documents received from Air Liquide since the order issue (October 15)

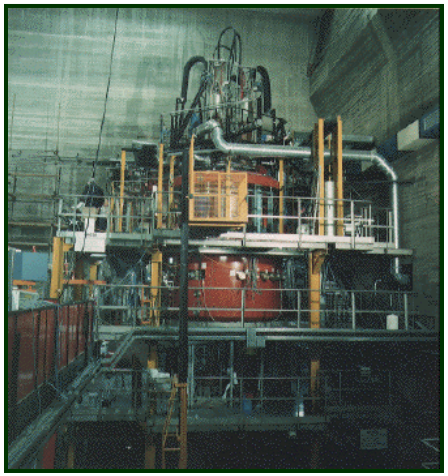
1) : end of revamping in March 2014
turbines not repaired, software not ready

2) : end of revamping in May 2014
software malfunctioning

3) : end of revamping in July 2014
problems of vacuum tightness in the turbine

LNS was kept open in August
The Cyclotron cryostat was full of LHe on September 23

Proton beam extracted on October 2, 2014



Beam time: Superconducting Cyclotron

The experimental activity re-started in October 2014 after the liquefier revamping.

In June 2013 beam time was assigned for 1 year. Therefore, there are approved experiments until the end of 2015.

The backlog is of 130 days

Few months before the end of 2015, a new call for proposals will be sent.

Experiments supported by ENSAR, scheduled before the end of 2014: HADMAC and DNA-BRAGG (it has been impossible to schedule also the last experiments approved for the ENSAR support)

Beam time: Tandem

After the replacement of Tube n.1, tests are in progress in view of the Pelletron conversion, that will be accomplished in January 2015, as scheduled.

After the Pelletron installation, the already approved experiments will be performed and a call for proposals will be sent.

The backlog is 28 days

Recent experiments supported by ENSAR: LIPMAGNEX

Some physics results

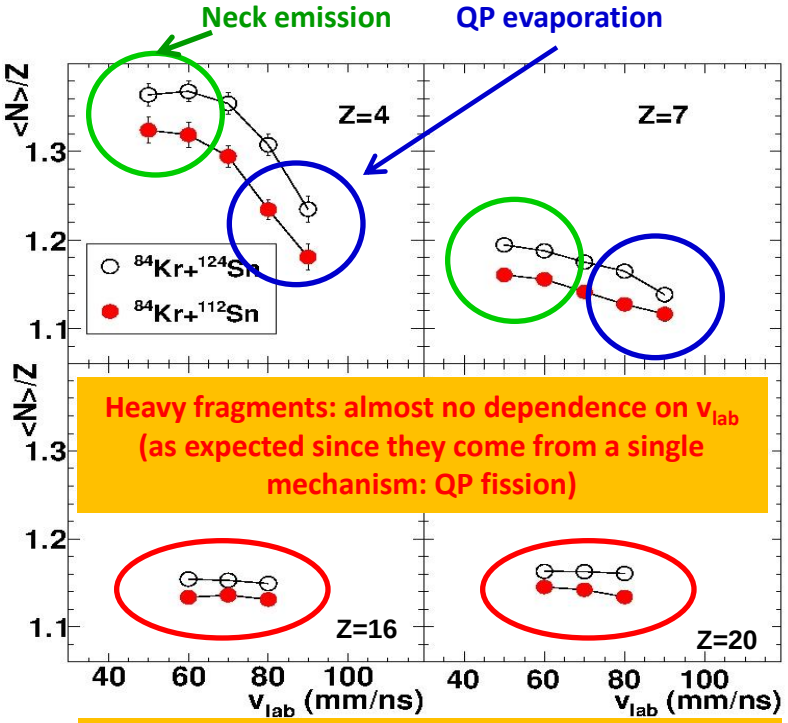
from FAZIA (first prototipes)

$^{84}Kr + ^{112,124}Sn$@35AMeV

Isospin transport phenomena

Light fragments: strong dependence on v_{lab}. Two production mechanisms: neck emission (with higher <N>/Z) and QP evaporation (smaller <N>/Z)

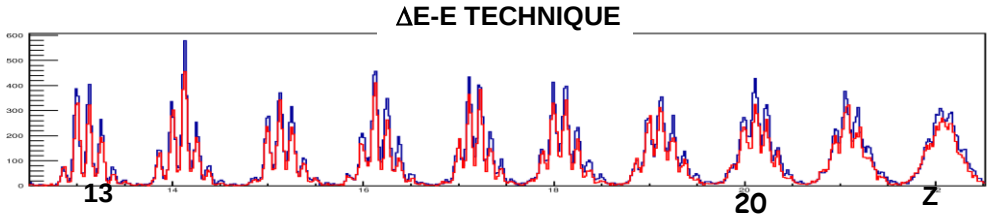
Isospin drift effect



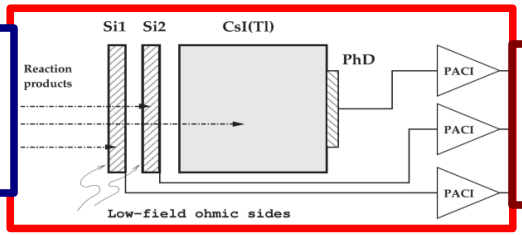
Heavy fragments: almost no dependence on v_{lab} (as expected since they come from a single mechanism: QP fission)

<N>/Z of n-rich case sistematically higher at all v_{lab} values: Isospin diffusion effect

S. Barlini et al., PRC87 (2013)054607

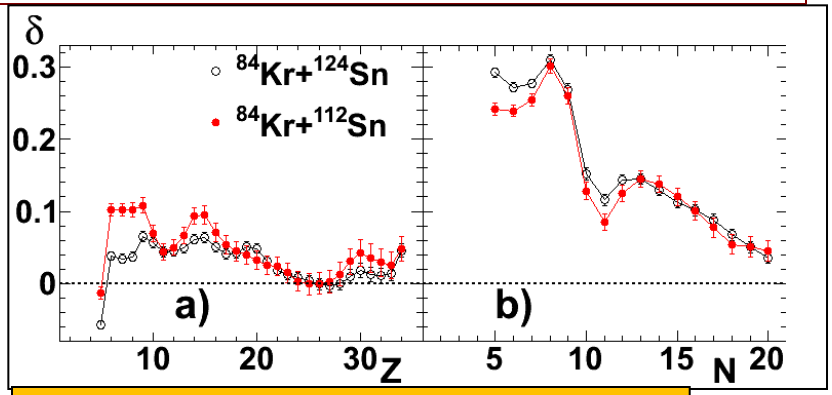


2 20x20mm^2 nTD type **Silicon detectors** 300 and 500 μm



20x20mm2 tapered 10 cm thick **CsI(Tl)** 1500-2000ppm Tl-uniform doping

N and Z odd-even staggering in Kr+Sn collisions at Fermi energies



δ gives a quantitative evaluation of the staggering amplitude

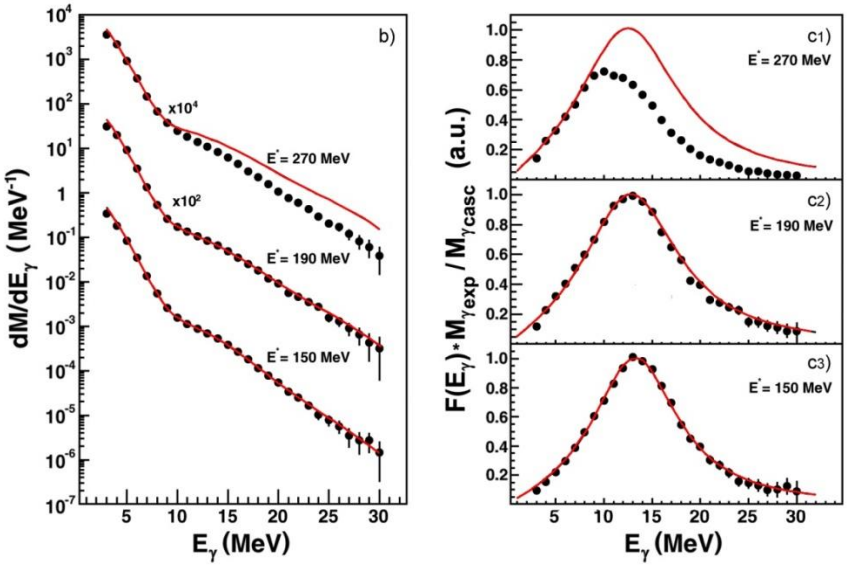
S. Piantelli et al., PRC88 (2013) 064607

- N staggering greater than Z staggering for our systems
- Z staggering greater for n-poor system
- N staggering more similar for both systems
- The staggering decreases when the size of the fragments increases, with some bumps e.g. around Z=30

from MEDEA

Hot GDR study in nuclei in the mass region A~120-132

	E*	A_{res}
^{116}Sn+^{12}C 17*A* MeV	150	124
^{116}Sn+^{12}C 23*A* MeV	190	123
^{116}Sn+^{24}Mg 17*A* MeV	270	132



Evidence of a quenching of the GDR gamma yield was found at 270 MeV excitation energy. A limiting excitation energy for the collective motion of **E*/A ~ 2 MeV/A** was extracted.

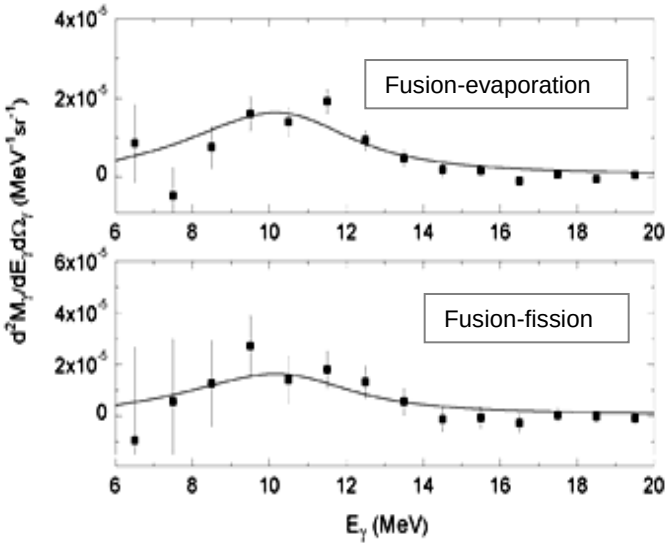
D. Santonocito et al. Phys. Rev. C 90 (2014) 054603

Study of Dynamic Dipole emission in ^{192}Pb

^{40}Ca + ^{152}Sm @ 11 *A* MeV
^{48}Ca + ^{144}Sm @ 10.1 *A* MeV

Comparison of gamma spectra measured in the decay of ^{192}Pb populated using both charge symmetric and asymmetric reactions.

Extra yield ascribed to DD emission found in the charge asymmetric reaction



Dynamic Dipole mode survives also in heavy systems

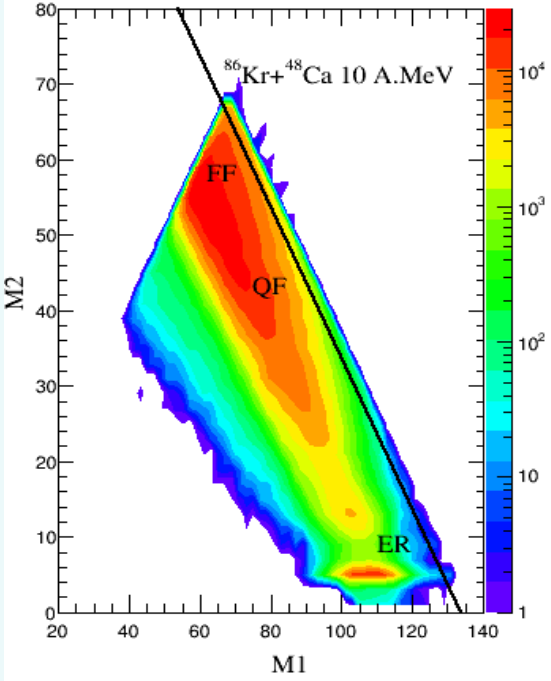
C. Parascandolo et al. Acta Phys.Pol. B44(2013)605
C. Parascandolo et al. EPJ Web of Conferences 66 (2014) 03069

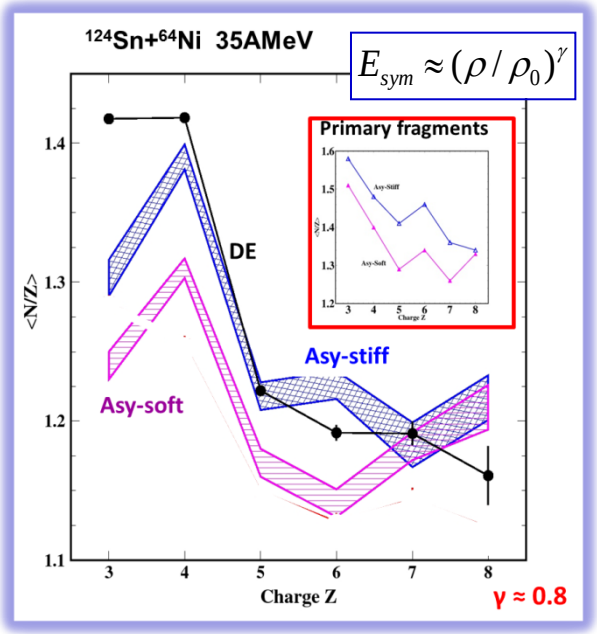
from CHIMERA

Physics themes

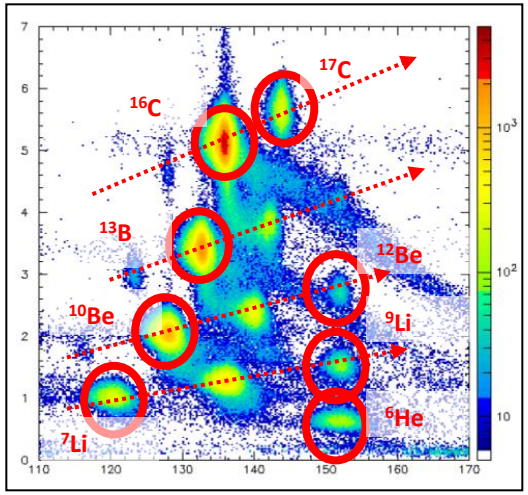
- ✓ Reaction Dynamics at Fermi energy
- ✓ EOS - density dependence of the symmetry term
- ✓ Reactions and Structure with Radioactive beams
- ✓ Correlations and interferometry with FARCOS

Study of **density dependence of EOS symmetry** term in the reaction ^{124}**Sn** +^{64}**Ni** at 35 A.MeV





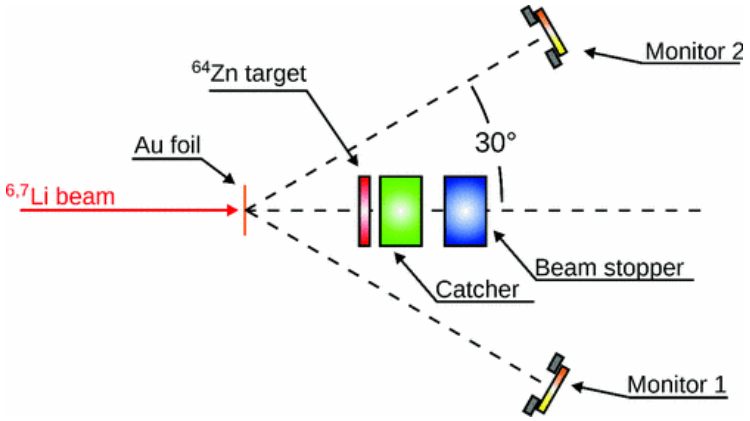
In-flight RIB production at LNS and CHIMERA **tagging system**



ISODEC: Decay modes and isospin effects in reactions ^{86}**Kr**+^{48}**Ca** and ^{78}**Kr** + ^{40}**Ca** at 10 A.MeV

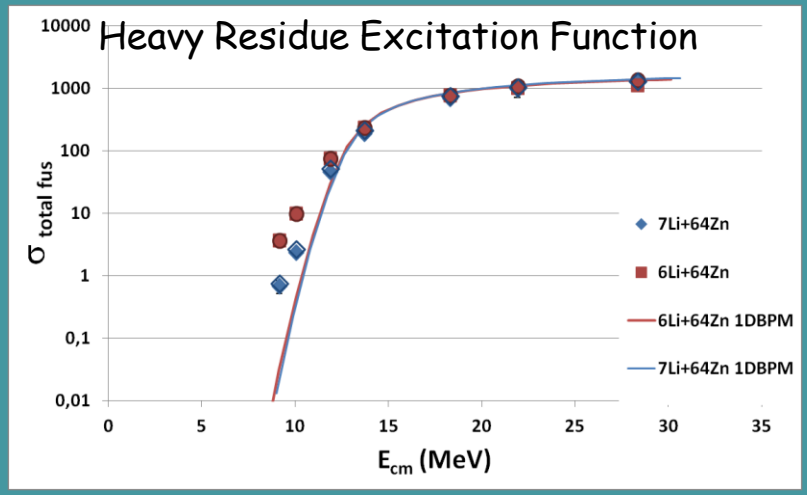
For a recent review see:
E. De Filippo and A Pagano, EPJA 50, 32 (2014)

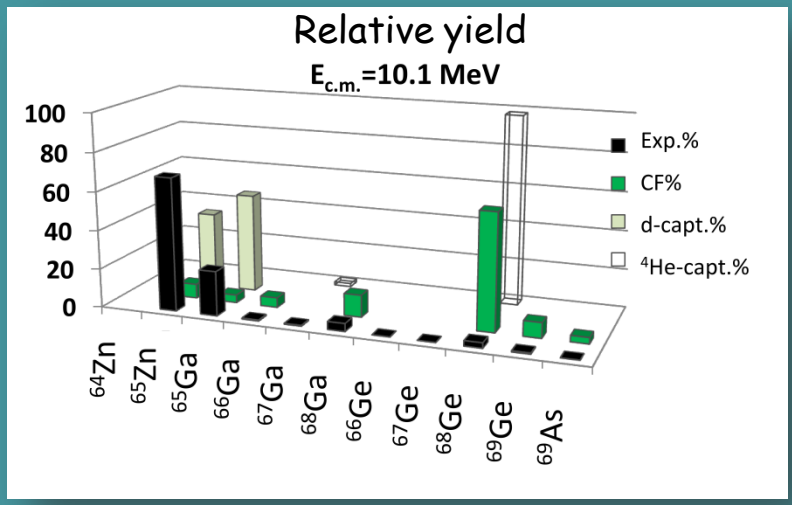
Study of structure effects on reaction processes: the case of sub-barrier fusion.



Enhancement of sub-barrier total fusion induced by weakly bound projectiles on medium mass targets was previously attributed to coupling effects to the continuum.

This work shows that complete fusion dominates heavy residue production cross-section above the barrier.
On the contrary, below the barrier, reaction channels other than complete fusion dominate the measured cross-section.



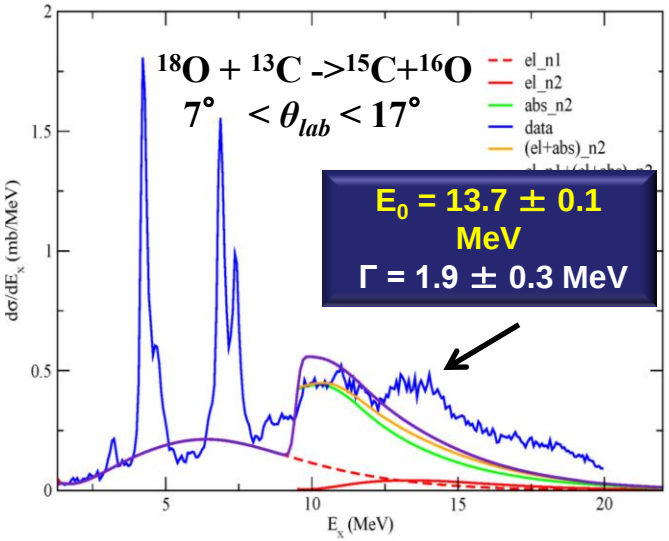


A. Di Pietro et al. Phys. Rev. C87, 064614 (2013)

Study on the Giant Pairing Vibration (GPV) with MAGNEX

Light nuclei

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



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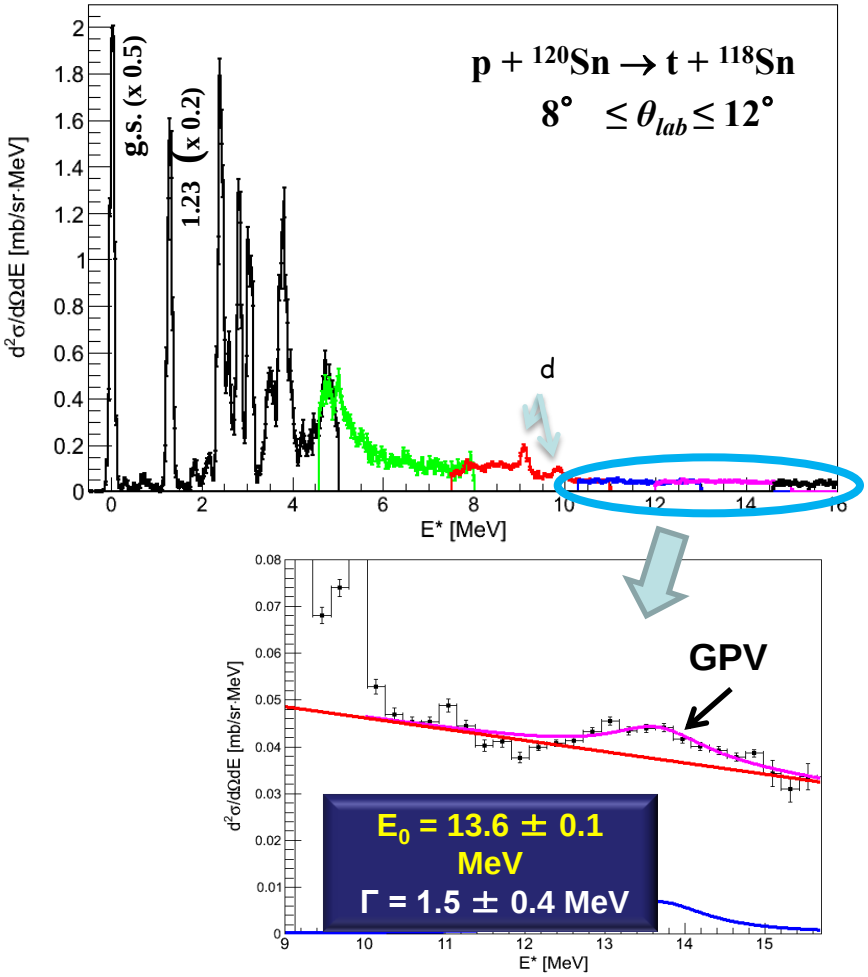
The GPV has been populated via two-neutron transfer reactions in different nuclei.
The GPV is much more excited in light nuclei due to favoured matching conditions.

Heavy nuclei

$^{120}Sn(p,t)^{118}Sn$ at 35 MeV



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Nuclear Astrophysics

$^{12}C + {}^{12}C \rightarrow \alpha + {}^{20}Ne$

$^{12}C + {}^{12}C \rightarrow p + {}^{23}Na$

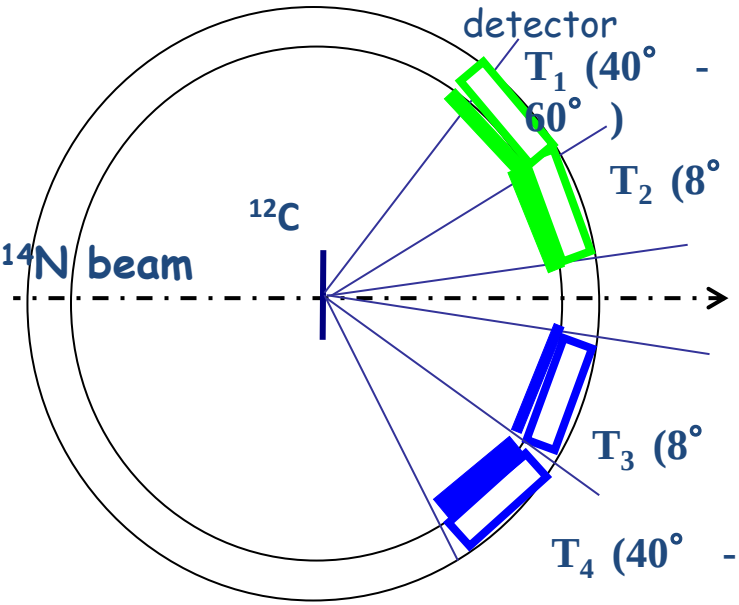
Troyan Horse Method experiment for C-burning:
$^{12}C(^{14}N,\alpha^{20}Ne)^{2}H$ and $^{12}C(^{14}N,p^{23}Na)^{2}H$ reactions at 30 MeV

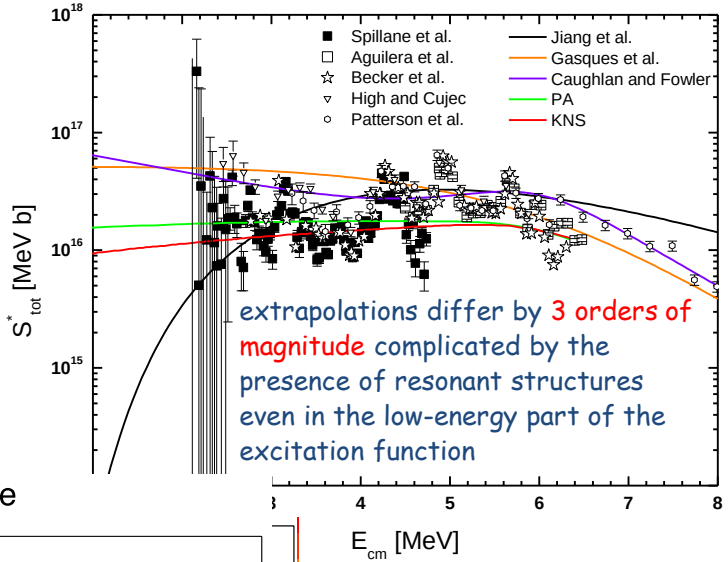
importance: evolution of massive stars

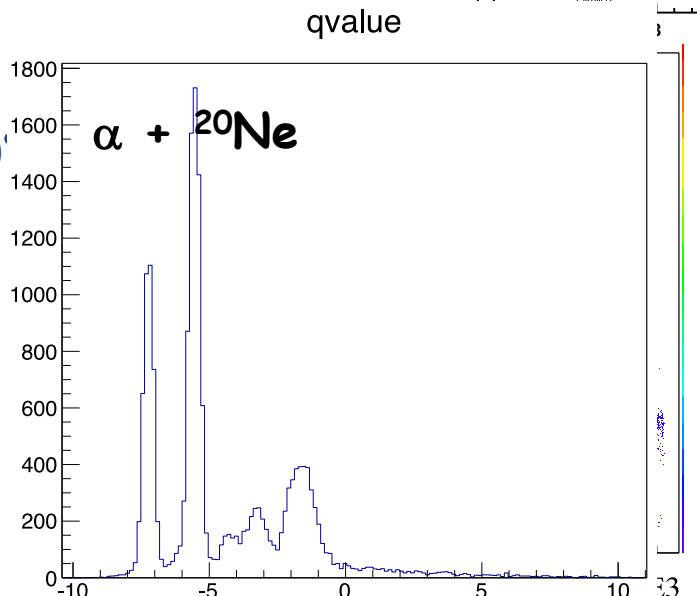
astrophysical energy: 1 – 3 MeV

Status of art: minimum measured E: 2.1 MeV (by γ-ray spectroscopy)

Experimental setup: d-a and d-p coincidence measurement
Particle identification supplied by silicon telescopes: 40 μm as ΔE- and 1000 μm Position Sensitive Detector (PSD) as E-detector







Analysis being undertaken: several levels of ^{24}Mg are populated; next step angular correlation analysis to determine J^{π}

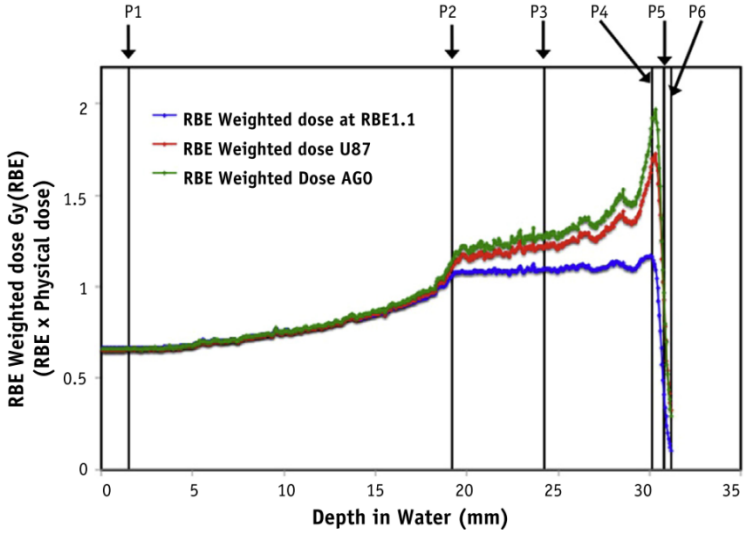
Experiment performed last year, only preliminary results

DNA-BRAGG project

Spokesperson: Dr. G. Schettino
Queen's University Belfast, UK

Aim: characterizing biological effectiveness along the proton Bragg curve

Glioblastoma (U87) and Fibroblasts (AG01522) have been exposed to different depth positions along a clinical proton beam with unprecedented ~50 μm accuracy. By comparison with X-ray, the Relative Biological Effectiveness (RBE) has been estimated as a function of dose, depth and intrinsic cellular sensitivity.
Data have been used to evaluate shortfall of current clinical practice employing a fix RBE value of 1.1 and to develop a parameterized RBE model.



Plot showing the underestimated effective dose delivered using a fixed RBE

$$RBE = \frac{\left(\sqrt{\left(\alpha_x^2 + 4\beta_x D_p\left(\alpha_x + \lambda LET + \beta_x D_p\right)\right)} - \alpha_x\right)}{\left(2\beta_x D_p\right)}$$

Developed parameterised RBE model expressing the relative effectiveness of proton beam compared to established X-ray treatments.
aand β are intrinsic cell radiosensitivity parameters, D is the proton dose and LET is the radiobiological equivalent of the stopping power

Chaudhary et al. "Relative Biological Effectiveness Variation Along Monoenergetic and Modulated Bragg Peaks of a 62-MeV Therapeutic Proton Beam: *A Preclinical Assessment", (2014) Int J Radiat Oncol Biol Phys. 90(1); p.27-35.*

Future work will be aimed to investigate the impact of treatment fractionation on the RBE in order to support clinical decision for hyper- or hypo-fractionation regimes

TNA03 – Activity at LNS up to the end of Oct 2014

Projects

24 projects / 4y (16 @ **NSDBF**, 8 @ **AIPF**)

10 projects (5 **NSDBF**, 5 **AIPF**) → **~ 42%**

Users

80 users / 4y

44 users → **~ 55%**

Person-days

712 person-days / 4y

300 person-days → **42%**

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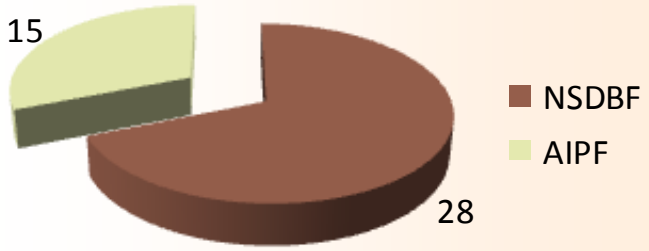
TNA03 – Activity at LNL-LNS up the end of Oct 2014

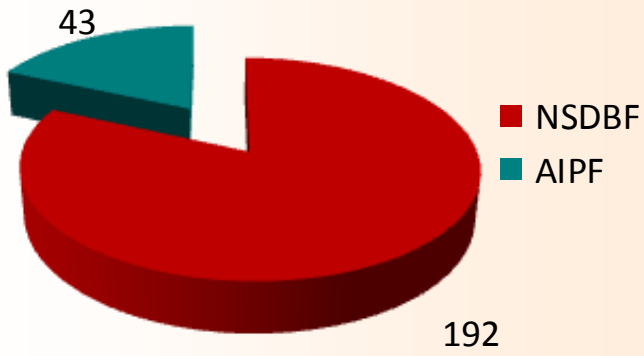


52 projects / 4y (36 @ **NSDBF**, 16 @ **AIPF**)

45 projects (31 **NSDBF**, 14 **AIPF**) → **~ 88%**

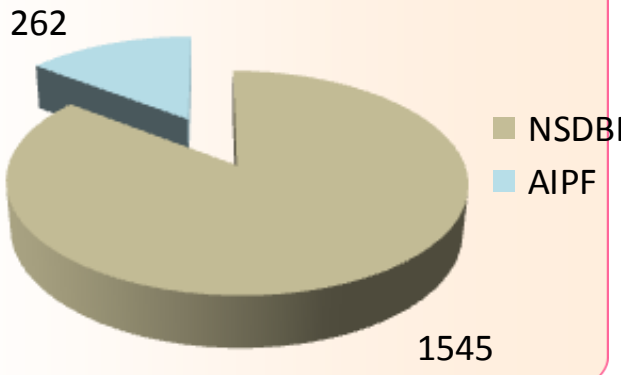
204 users / 4y

235 users



1816 person-days / 4y

1769 person-days → **~ 97%**



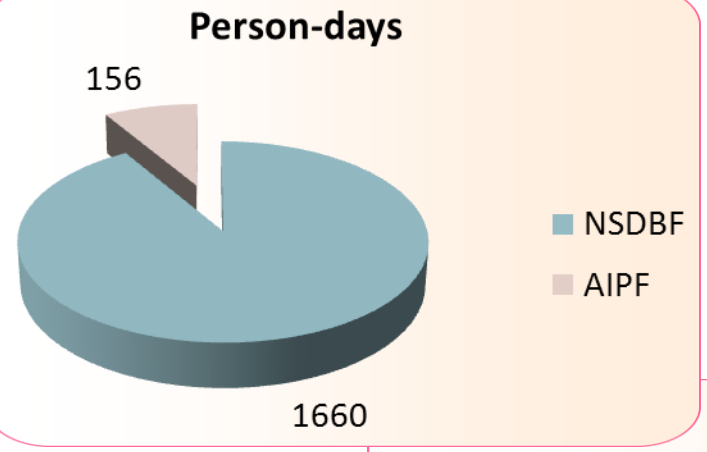
TNA03 – Deliverables

Nuclear Structure and Dynamics Based Facilities (**NSDBF**)

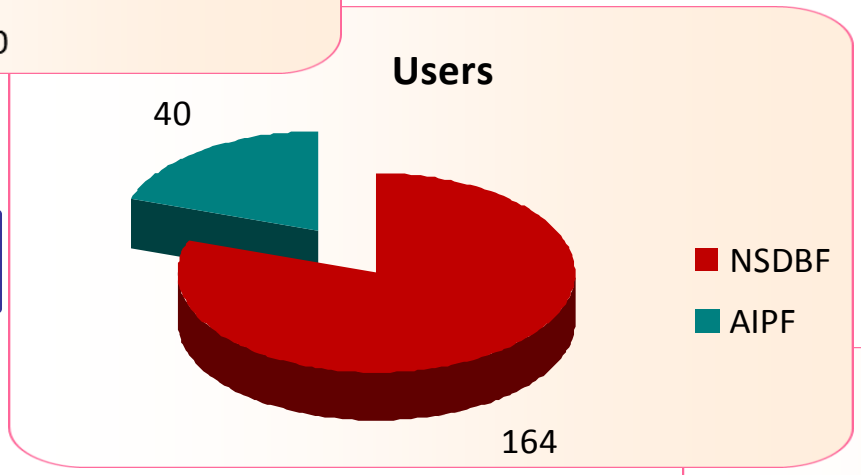
Applied and Interdisciplinary Physics Facilities (**AIPF**)

Min. quantity of access to be provided

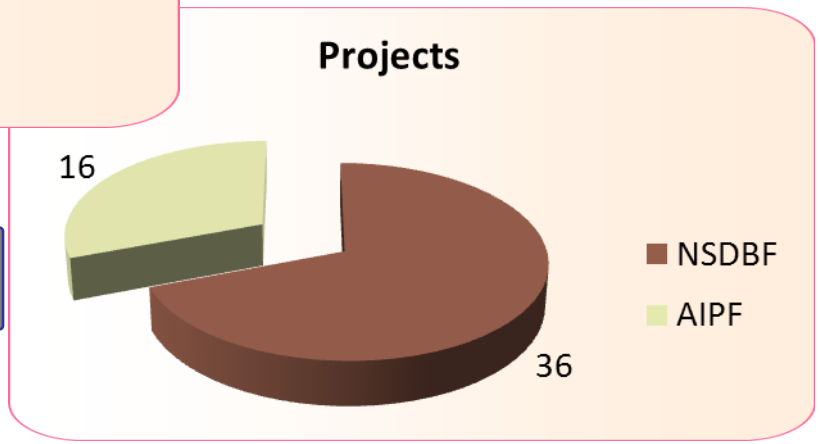
4424 h / 4y



204 users / 4y



52 projects / 4y



TNA03 – USP meetings and approved projects

	LNL	LNS
13 July 2011 at LNL	4 experiments at NSDBF	4 experiments at NSDBF
12 October 2011 via e-mail	5 experiments at NSDBF 2 projects at AIPF	2 experiments at NSDBF 2 projects at AIPF
11 July 2012 at LNS 4 October via e-mail	4 experiments at NSDBF 4 projects at AIPF	2 experiments at NSDBF 3 projects at AIPF
24 Jan 2013 at LNL	4 experiments at NSDBF 1 project at AIPF	
19 July 2013 at LNS August via e-mail	4 experiments at NSDBF 5 project at AIPF	2 experiments at NSDBF 3 project at AIPF
24 Jan 2014 at LNL	3 experiments at NSDBF 3 projects at AIPF	
10 Jul 2014 at LNL	3 experiments at NSDBF 2 projects at AIPF	

End of October 2014

44 35 experiments already performed

18 10 experiments already performed

E. Fioretto

TNA03 – Deliverables at the end of October 2014

	Deliverables for the full duration of ENSAR	October 2014
Number of beam-on-target hours	4424	5910
Estimated number of users	204	235
Estimated number of days	1816	1769
Estimated number of projects	52	45
AGATA costs	63.542	63.501
Travel & Subsistence	234.320 €	151.472 €

Some experiments performed in 2014
not yet reimbursed

Five experiments
(not included in this table and in the previous graphs)
will be performed by November 2014
278 beam-on-target hours; 92 person-days; 16 users