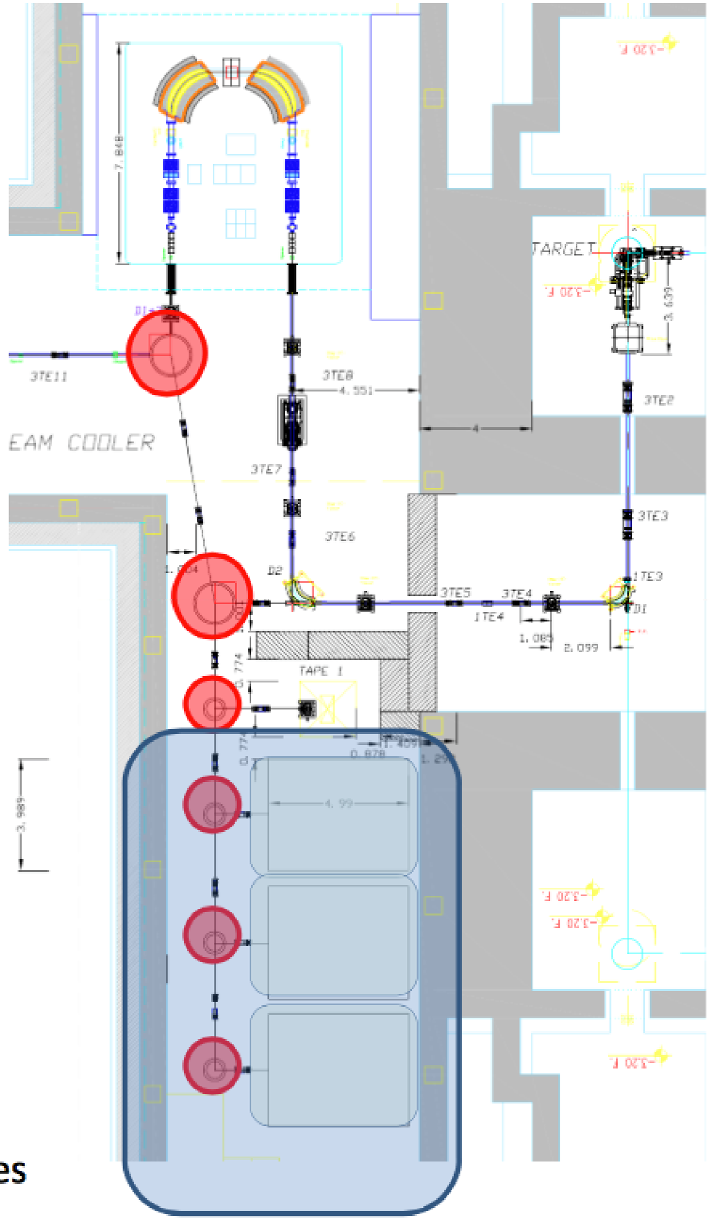
Experimental area for non re-accelerated RIBs

According to the Scientific Advisory Committee advise, an area for non re-accelerated RIBs experiments was defined. Preliminary design was performed to evaluate general layout and cost.

Working group:
F.Gramegna, (coordination)
M.Cinausero (physics)
A.Mendez (ORNL, electrostatic design)
A.Monetti (engineering and beam transport)
L.Bellan (beam transport)

- Three experimental areas available (20m² each)
- Evaluated additional cost for installation (1M€)
- Proposal for construction to be submitted to INFN management



Electrostatic dipoles

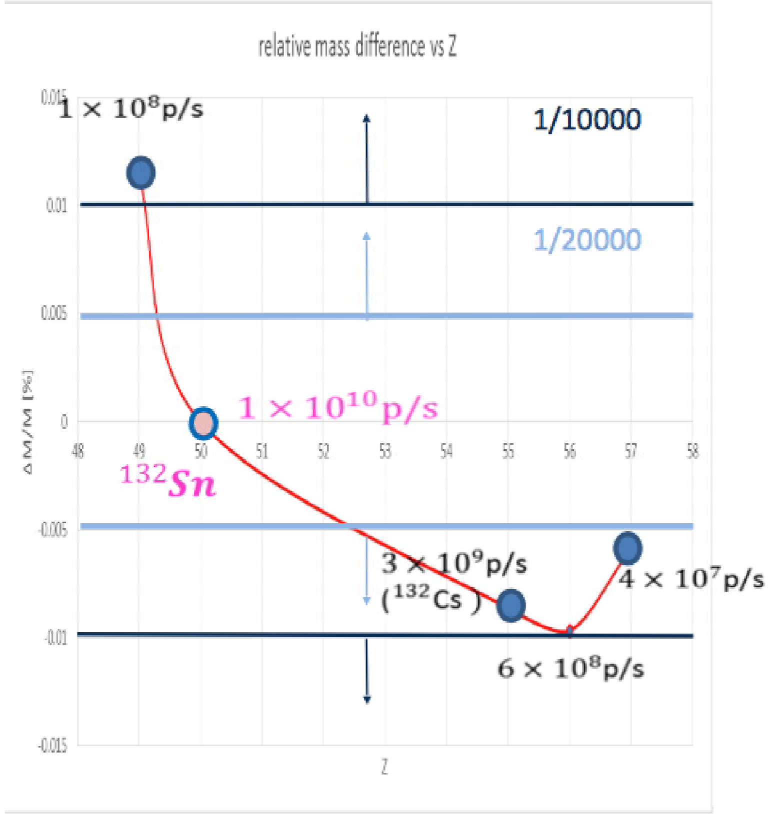
Why 1/20000? An example

Ref case: ^{132}Sn produced by LIS

Zoom of the nuclide chart

Z\A	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
42	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	0.00E+00	0.00E+00	0.00E+00								0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	0.00E+00	0.00E+00	0.00E+00								0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45	0.00E+00	0.00E+00	0.00E+00								0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	0.00E+00	0.00E+00	0.00E+00								0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49	3.60E+09	2.52E+09	4.20E+09	3.85E+09	4.19E+09	2.98E+09	2.52E+09	1.72E+09	1.26E+09	3.03E+08	1.73E+08	9.94E+07	2.31E+07	1.93E+06	1.96E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50	9.96E+09	1.84E+10	1.29E+10	2.10E+10	1.57E+10	2.36E+10	1.85E+10	2.42E+10	2.03E+10	2.43E+10	1.63E+10	1.30E+10	2.60E+09	2.52E+09	1.25E+09	2.09E+08	2.79E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55	0.00E+00	3.15E+06	1.55E+07	2.23E+07	1.24E+08	1.88E+08	5.05E+08	7.47E+08	1.40E+09	2.06E+09	3.75E+09	3.15E+09	7.56E+09	8.11E+09	1.29E+10	1.31E+10	1.87E+10	1.10E+10	1.44E+10	1.10E+10	1.33E+10	7.78E+09	1.13E+10
56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+06	1.51E+06	1.66E+07	6.34E+07	1.01E+08	2.93E+08	3.98E+08	5.74E+08	1.05E+09	2.01E+09	2.14E+09	4.07E+09	4.33E+09	6.79E+09	4.82E+09	6.24E+09	4.48E+09	6.78E+09	3.08E+09
57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+06	1.13E+07	3.62E+07	4.22E+07	1.33E+08	2.09E+08	4.46E+08	5.68E+08	1.03E+09	1.40E+09	2.23E+09	1.66E+09	2.41E+09	1.96E+09	2.32E+09
58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

- HRMS selected species
- 1/200 selected species
- WF selected species
- Nominal beam

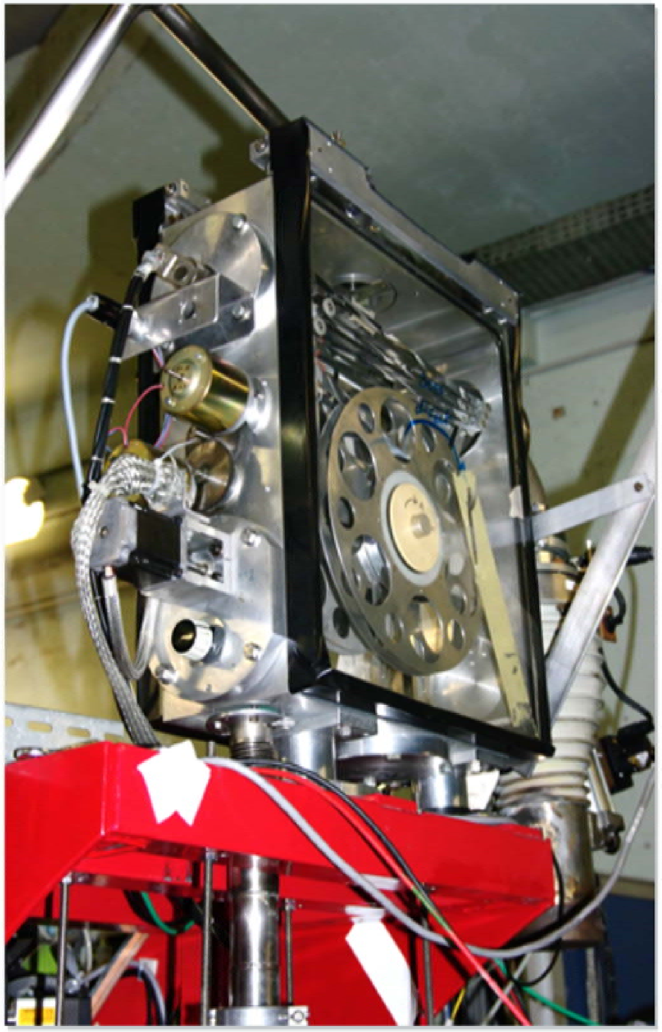


If mass separation is 1/10000, we can separate just one isobar from the nominal beam. Instead, a separation in mass of over 1/20000 ensures a “clean selection”, in particular versus ^{132}Cs.

Diagnostics for radioactive beams

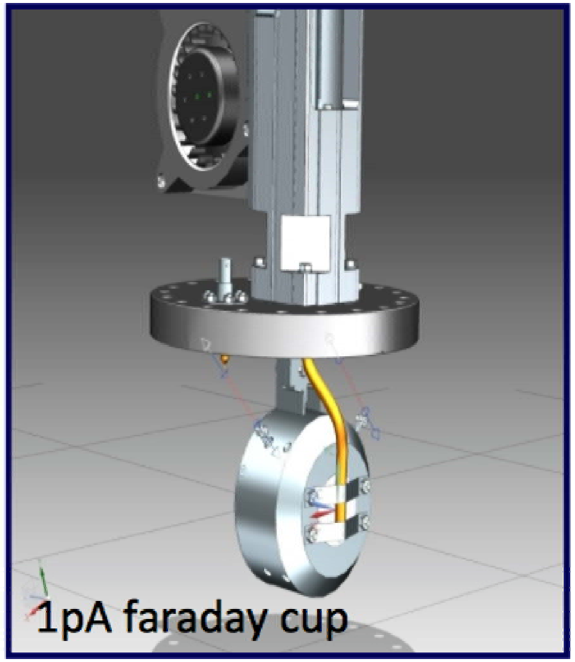
Study group (mainly physics researchers) to define instrumentation to be implemented for SPES (report at end 2015)

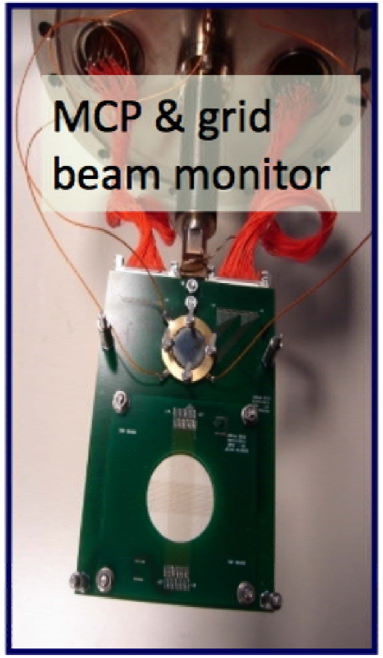
E.Fioretto (coordinator)
D.Fabris, G.Montagnoli, D.Mengoni, G.Collazuol, M.Poggi, R.Cherubini and collaboration with LNS



Tape station based on Orsay design

Low intensity beam monitors





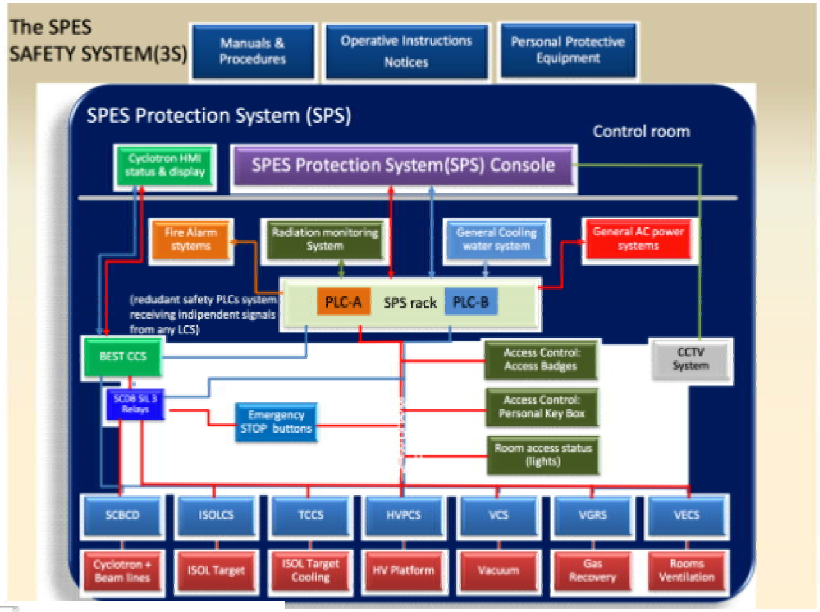
SPES safety system

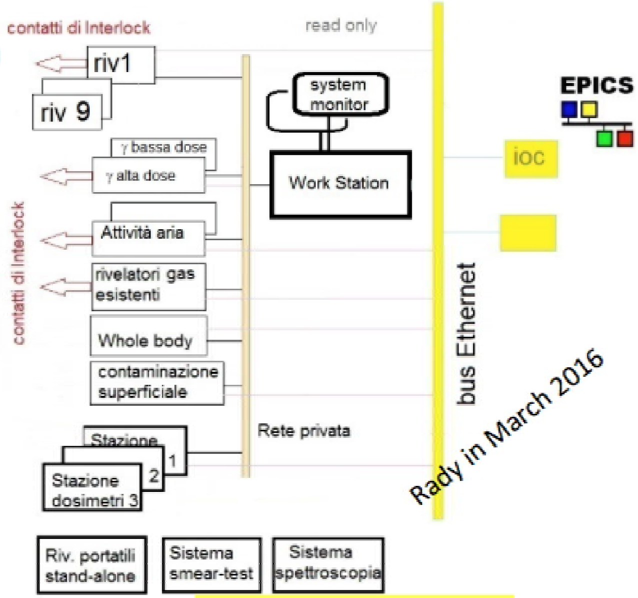
A SIL3 safety system is under development (tender launched)

Simplified system will be ready for cyclotron test

Cyclotron and beam lines

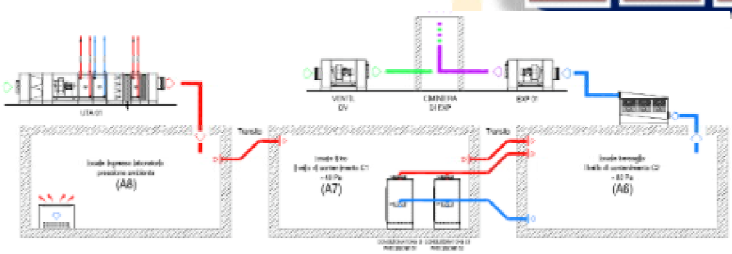
ISOL target



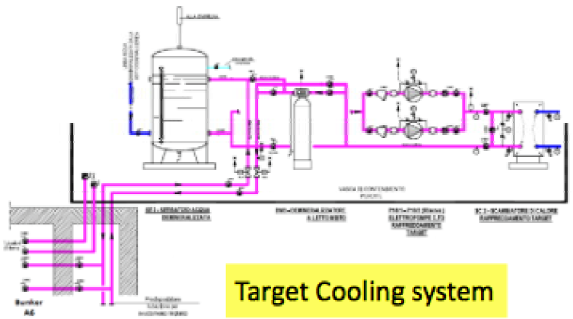


Radiologic survey system

Access Control System

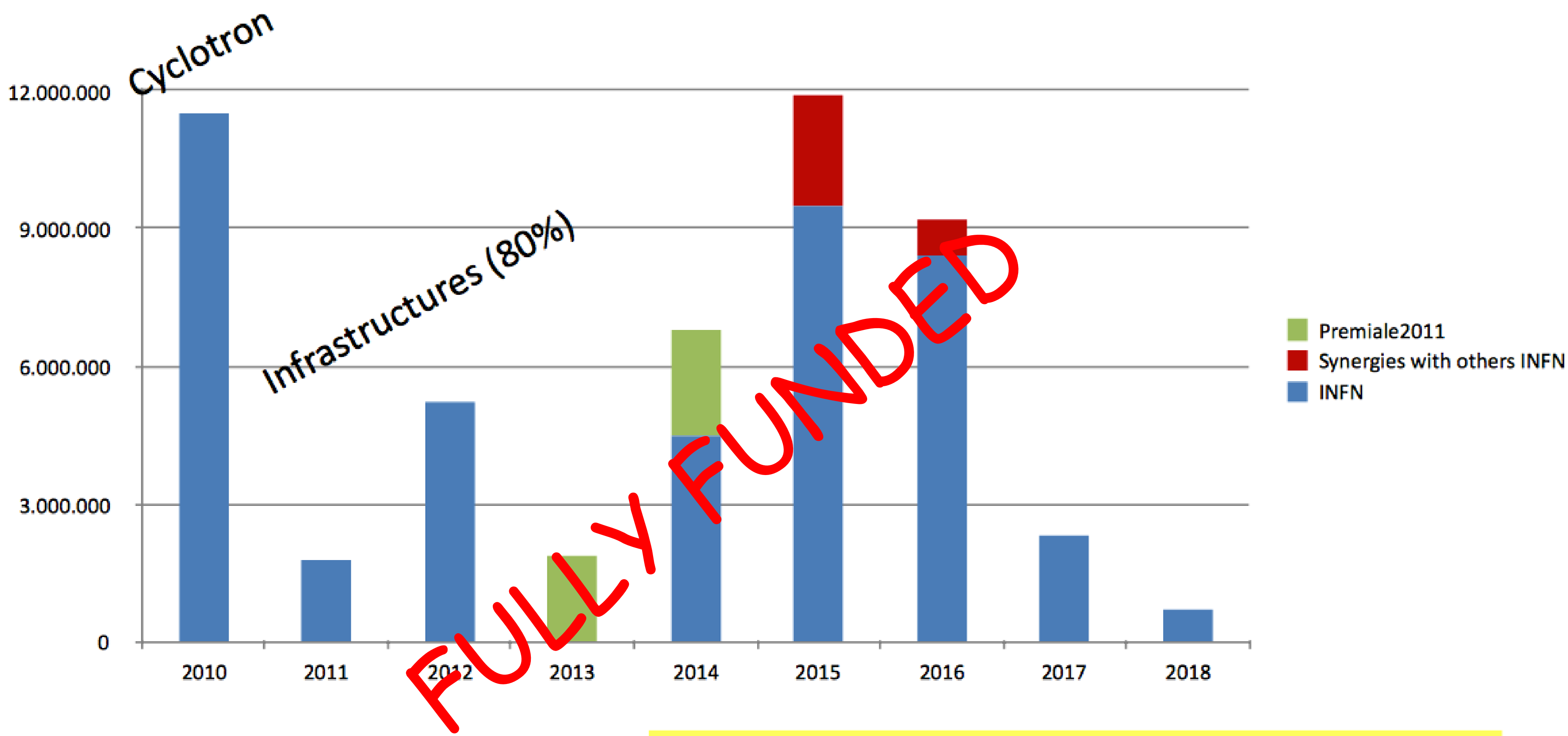


ventilation



Target Cooling system

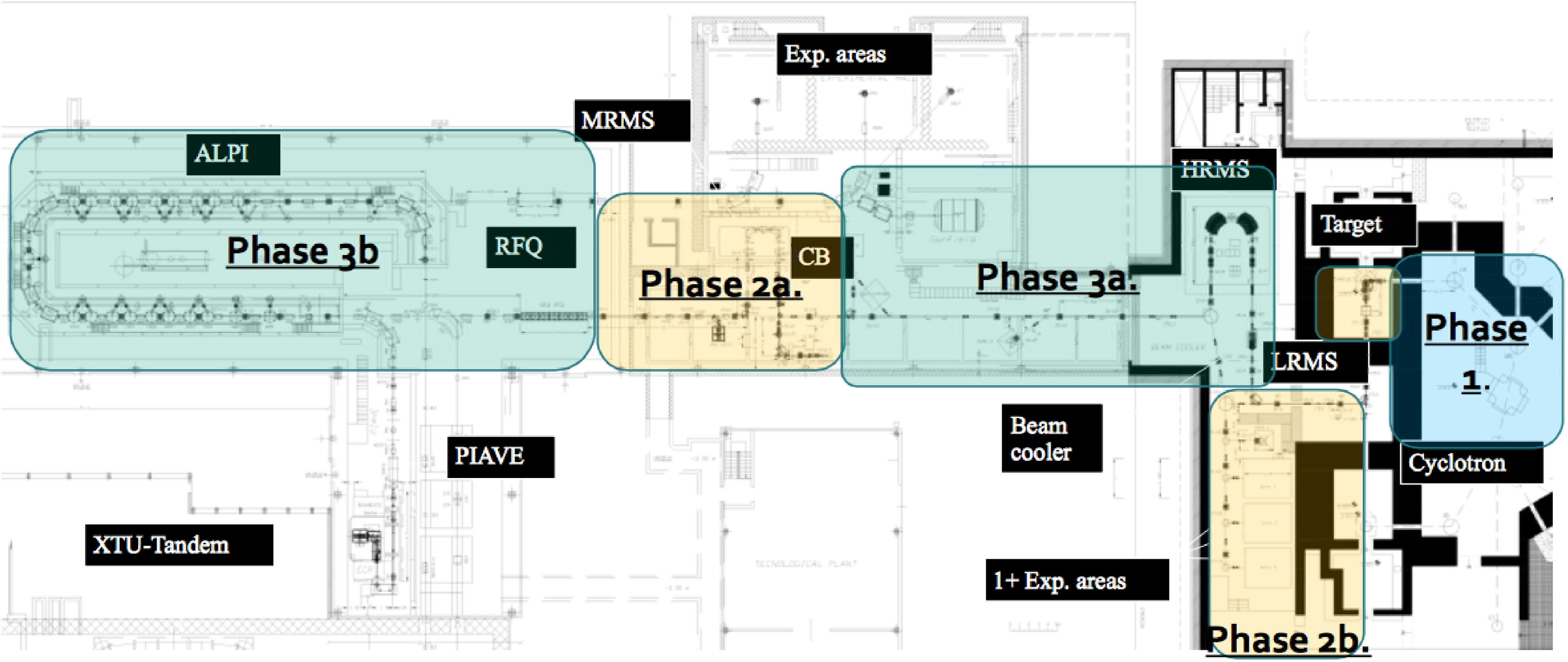
Economic planning for SPES construction 2010-2018



Approved project funding for ompletion: Nov 2014

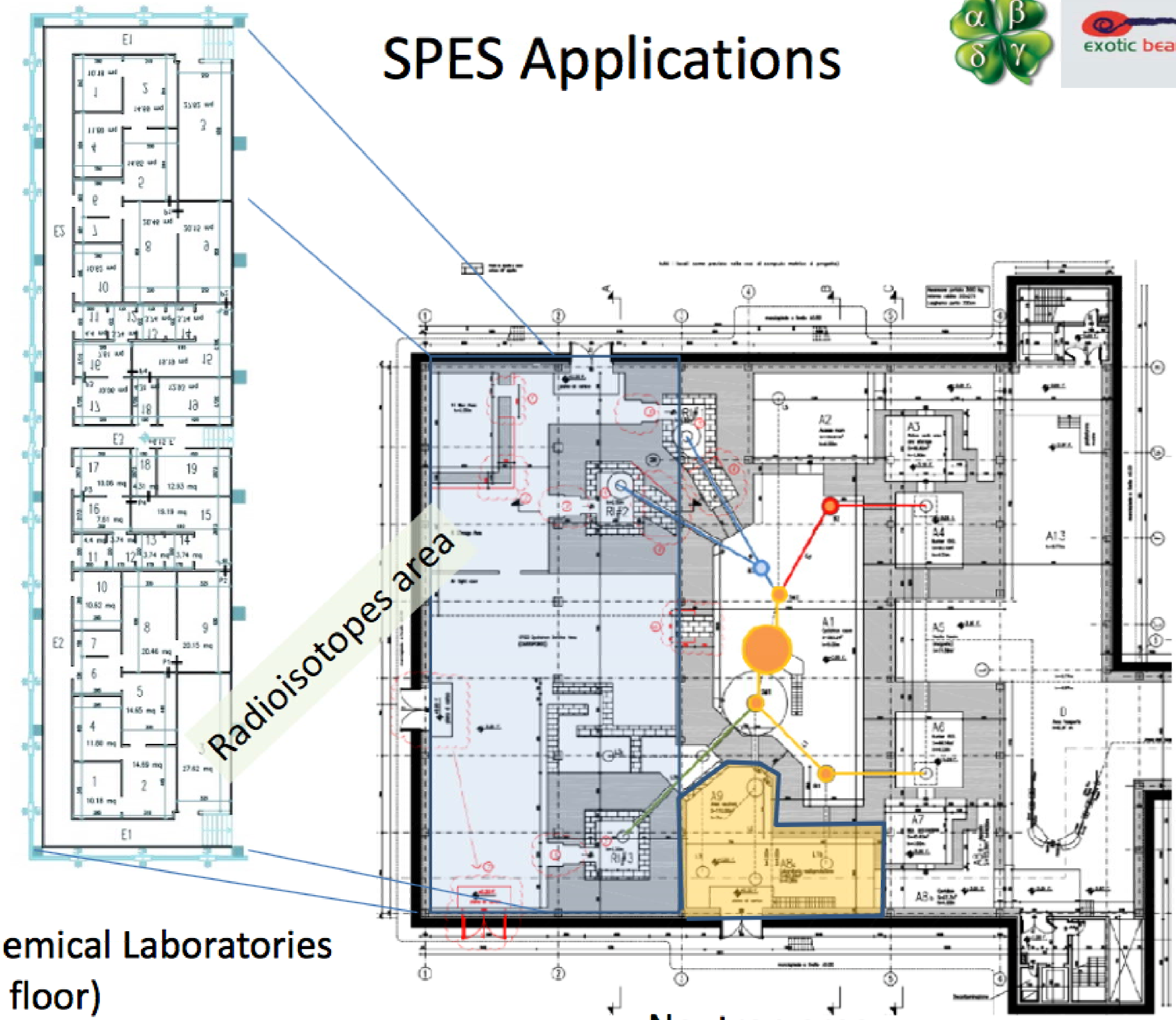
Total SPES construction 2010-2018 (51.200 kEuro)	2010	2011	2012	2013	2014	2015	2016	2017	2018	Grand Total
Estimate (2013)	11,500	1,800	5,200	1,900	6,700	12,900	8,200	2,300	700	51,200
Invested (June 2015)	11,500	1,800	5,200	1,900	2,900	8.400 (+1.500)				

SPES installation Phases



- Phase 1. 2016- First Operation with the cyclotron
- Phase 2a. 2017- RNB ALPI Injector
- Phase 2b. 2018- SPES target, LRMS, experimental 1+ Beam Lines
- Phase 3a. 2019- HRMS and beam line to the CB
- Phase 3b. 2019- RFQ and ALPI

SPES Applications



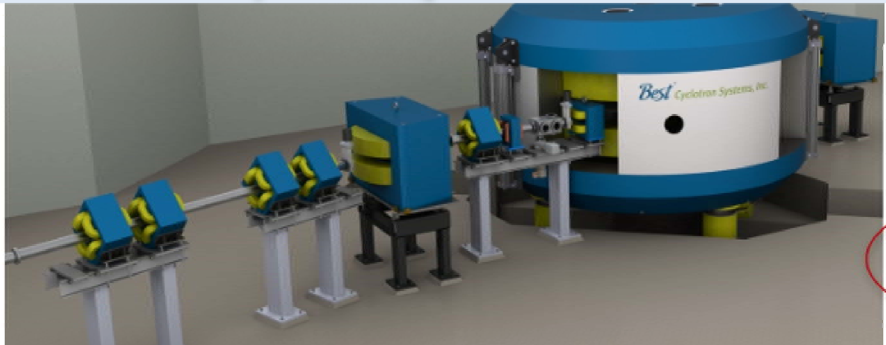
Radiochemical Laboratories (second floor)

Neutron area

SPES γ: Radio-isotopes for medicine

«LARAMED» project

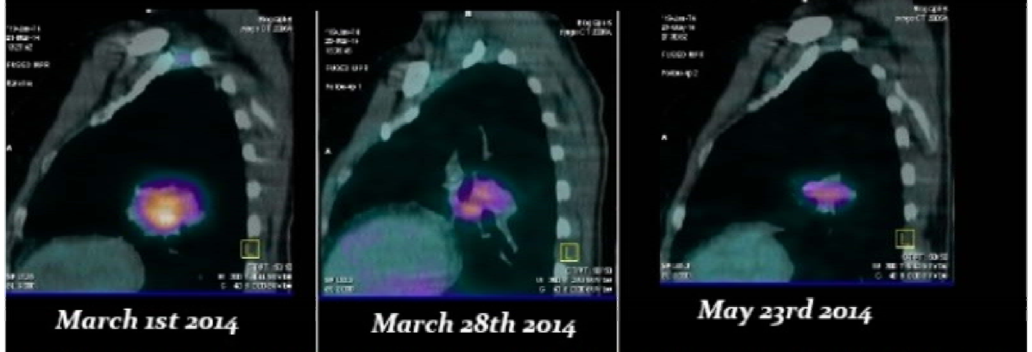
Production of radionuclides for medicine using the SPES cyclotron (production&research)



ARRONAX – SPES collaboration:
Isotopes and high-Power target developments

Effect of cancer treatment with ^{64}Cu produced with proton beam at cyclotrons. Better result expected with ^{67}Cu.

$^{64}CuCl_2$

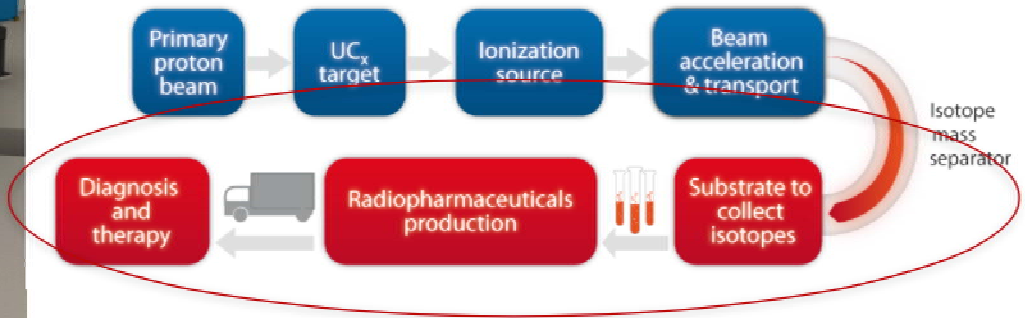


patient: male, 55 y, pulmonary hilar adenopathy (left lung)

ISOLPHARMA*

* INFN Patent pending

Use of ISOL technique for Direct isotope on-line separation : very high specific activity (4-5 order of magnitude than standard)



Radiopharmaceutical	Targeted organs	Half-life	Specific Activity (GBq/mg)	
			SPES production	Neutron capture reaction
^{89}Sr-$SrCl_2$	Bone	50.5 d	≥ 597	≥ 0,004
^{90}Y-YCl_3	Liver and endocrine system	64.1 h	≥ 9480	≥ 0,8
^{125}I-NaI	Prostat, brain, lung, pancreas, liver	59.4 d	≥ 552	≥ 6
^{131}I-NaI	Thyroid	8.02 d	≥ 3911	≥ 0,7
^{75}Se-H_2SeO_3	Liver	119.6 d	≥ 323	≥ 3,7

LARAMED Project

Funded with 6.8 Meuro

Joint Research lab of INFN, CNR, Universities and external companies:

- Measurement of cross section through targets activation
- High power targets tests
- Radioisotopes/radiopharmaceuticals Production test facility (^{99m}Tc, ^{64}Cu, ^{67}Cu, ^{82}Sr, ...)

STATUS:

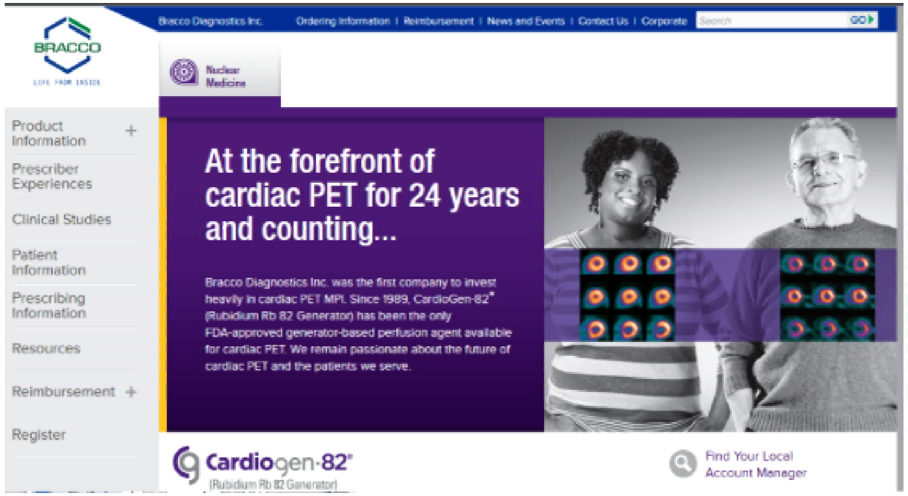
- Building and infrastructures under development
- Design of radiochemistry labs
- Design of beam line and target management
- Contract with company for radioisotopes production to be finalized

Production laboratory in join. venture with external companies:

Selected isotopes of medical interest

Sr-82/Rb-82 generator

T1/2: 25.6 d EC 100% / 1.3 min photons 511keV, 776keV



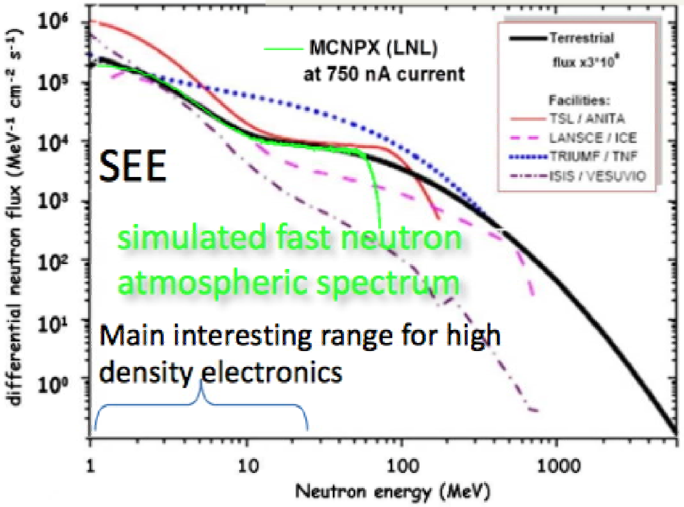
NEPIR: Neutron production at SPES

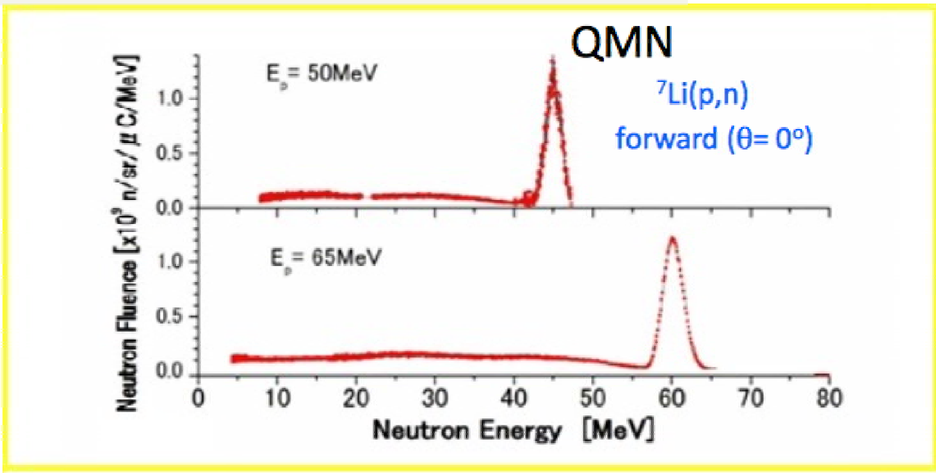
Design study

Integral neutron production at SPES Cyclotron Proton beam= 70 MeV, 500 μA Target = W 5mm			
Energy region (MeV)	Sn (n/s) $\sim 6 \cdot 10^{14}\ s^{-1}$	Φ_n @ 2.5 m ($n\ cm^{-2}\ s^{-1}$)	Φ_n @ 1 cm ($n\ cm^{-2}\ s^{-1}$)
1 < E < 10	$\sim 5 \cdot 10^{14}\ s^{-1}$	5×10^{8}	3×10^{13}
10 < E < 50	$\sim 1 \cdot 10^{14}\ s^{-1}$	1×10^{8}	6×10^{12}

Continuum and Quasi Mono Energetic fast neutron spectra

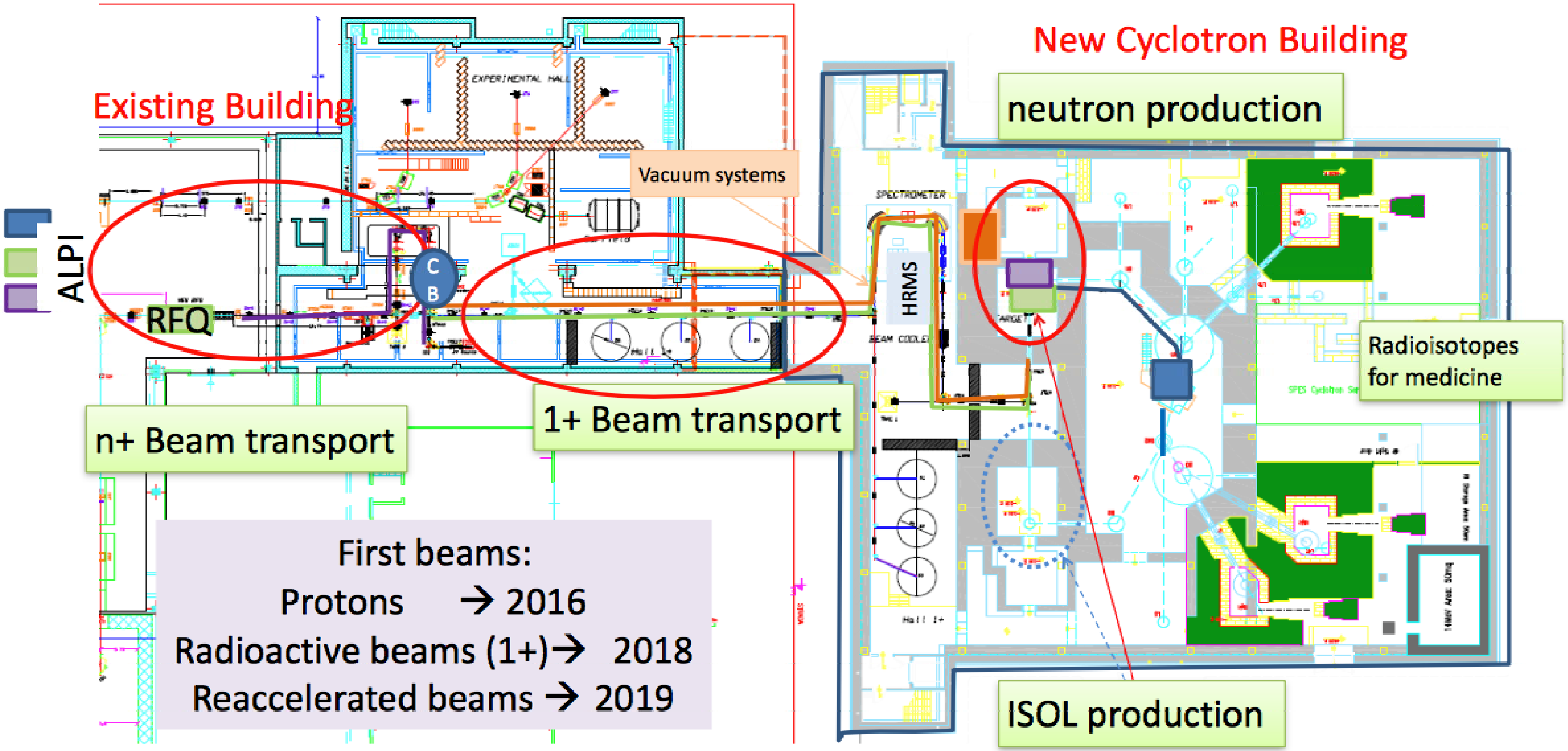
- Cross section data for basic science and astrophisics
- Oncology studies
- Calibration of radiation instrumentation
- Radiation protection studies (shielding-benchmarks)
- Radiation hardness studies (Single Event Effect)

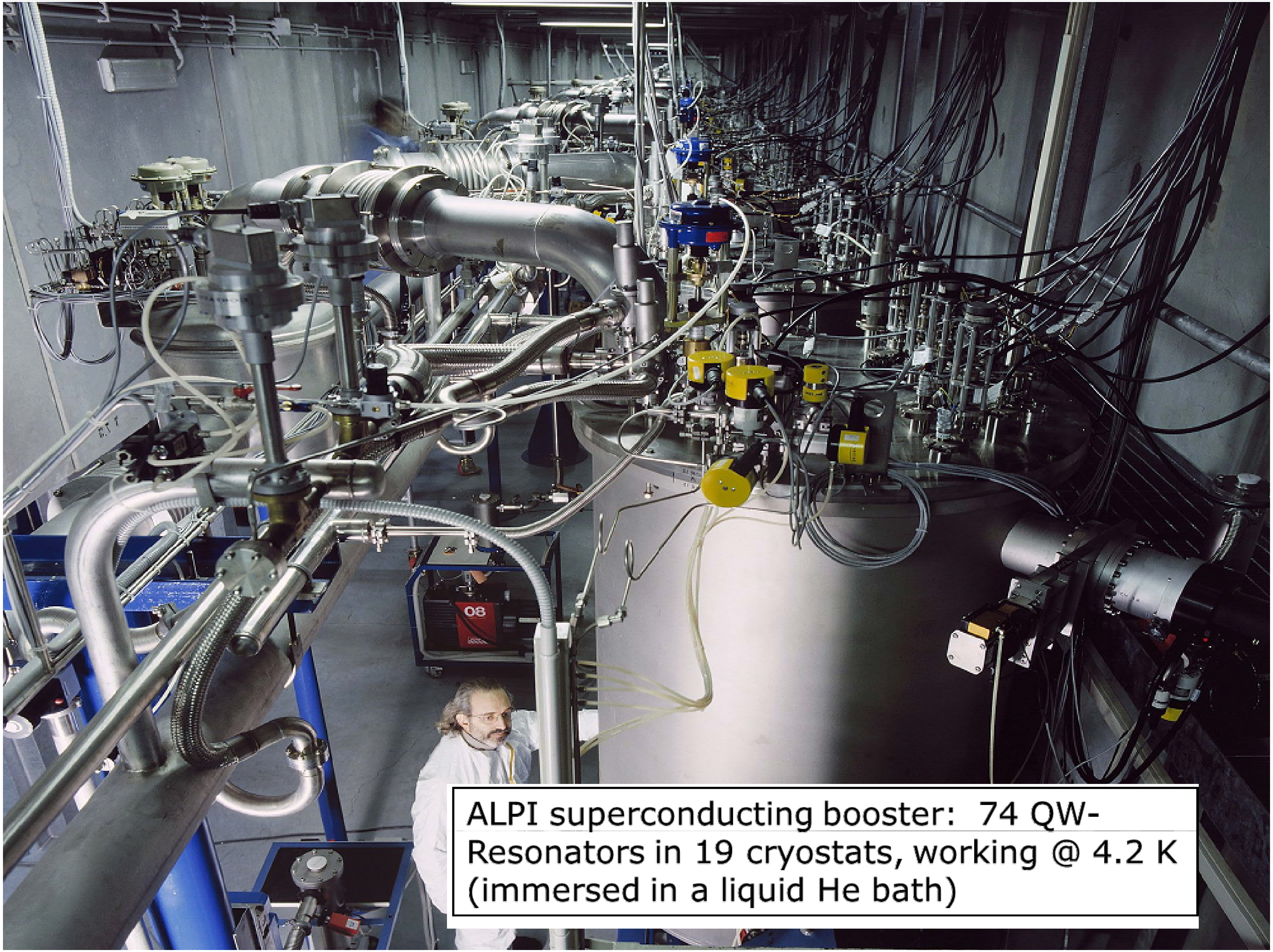




Construction phase: MAIN TENDERS

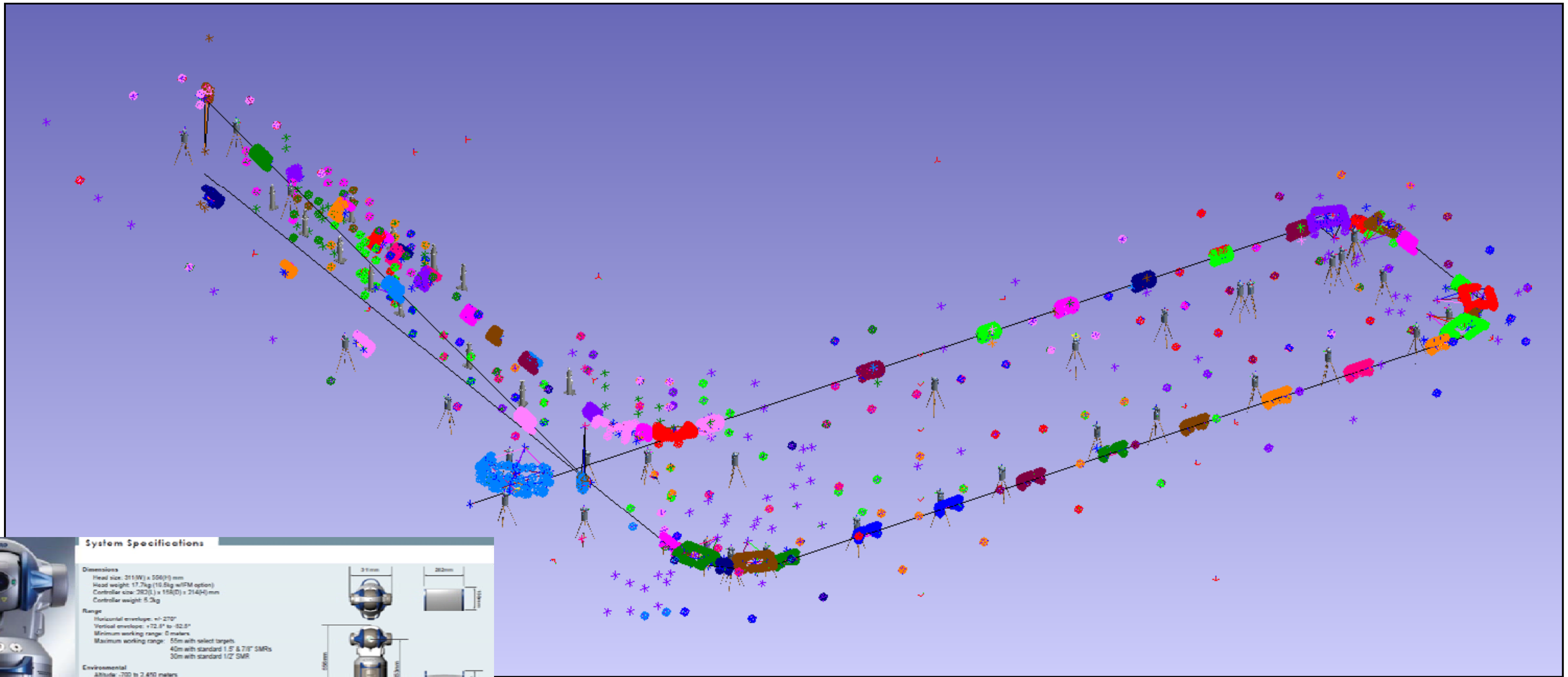
2010-2012	2013-2014	2015	2016	2017
ISOL target Cyclotron and Building	Laser source Vacuum systems Charge Breeder n+ beam transport	Safety, RFQ, HVPlatform, UCx Lab design, Plant upgrade	UCx Lab, 1+ line, Vacuum systems, ISOL installation, Hot cell, RFQ	High Resolution Mass Separator

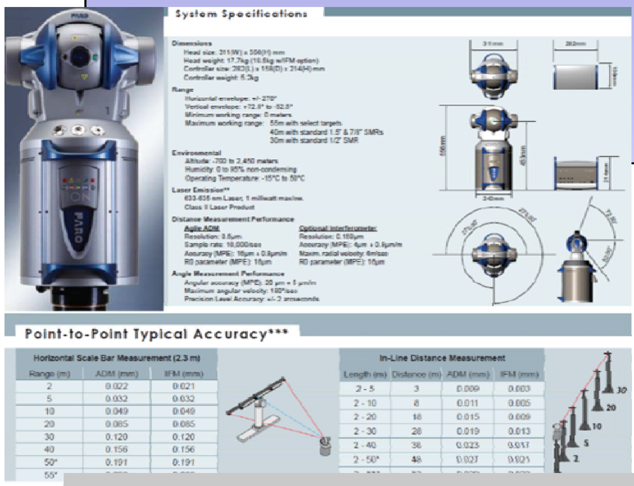




ALPI superconducting booster: 74 QW-Resonators in 19 cryostats, working @ 4.2 K (immersed in a liquid He bath)

OUTPUT OF Fiducialization OF ALL MAGNETS IN ALPI





System Specifications

Dimensions
Head size: 311(W) x 556(H) mm
Head weight: 17.7kg (18.5kg w/IFM option)
Controller size: 392(L) x 158(D) x 314(H) mm
Controller weight: 5.3kg

Range
Horizontal envelope: +/- 270°
Vertical envelope: +72.8° to -52.8°
Minimum working range: 0 meters
Maximum working range: 55m with select targets
40m with standard 1.5" & 7/8" SMRs
30m with standard 1/2" SMR

Environmental
Altitude: -700 to 2,450 meters
Humidity: 0 to 95% non-condensing
Operating Temperature: -15°C to 50°C

Laser Emission**
633-635 nm Laser, 1 milliwatt max/cw.
Class II Laser Product

Distance Measurement Performance

Agile ADM
Resolution: 0.5μm
Sample rate: 10,000/sec
Accuracy (MPE): 16μm + 0.8μm/m
R0 parameter (MPE): 16μm

Optional Interferometer
Resolution: 0.158μm
Accuracy (MPE): 4μm + 0.8μm/m
Maxim. radial velocity: 4m/sec
R0 parameter (MPE): 16μm

Angle Measurement Performance
Angular accuracy (MPE): 20 μm + 5 μm/m
Maximum angular velocity: 180°/sec
Precision Level Accuracy: +/- 2 arcseconds

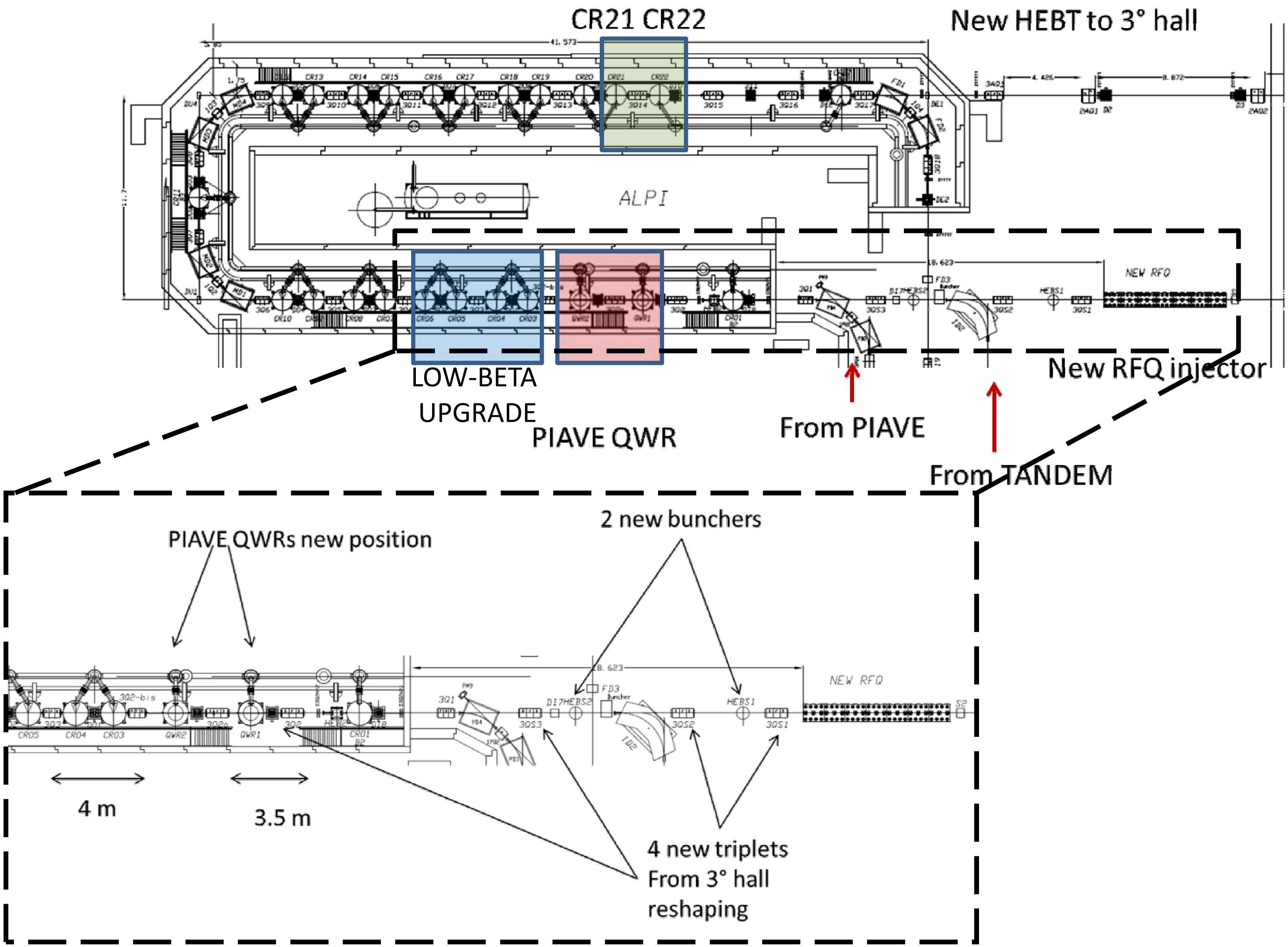
Point-to-Point Typical Accuracy***

Horizontal Scale Bar Measurement (2.3 m)		
Range (m)	ADM (mm)	IFM (mm)
2	0.022	0.021
5	0.032	0.032
10	0.049	0.049
20	0.085	0.085
30	0.120	0.120
40	0.156	0.156
50*	0.191	0.191
55*	[illegible]	[illegible]

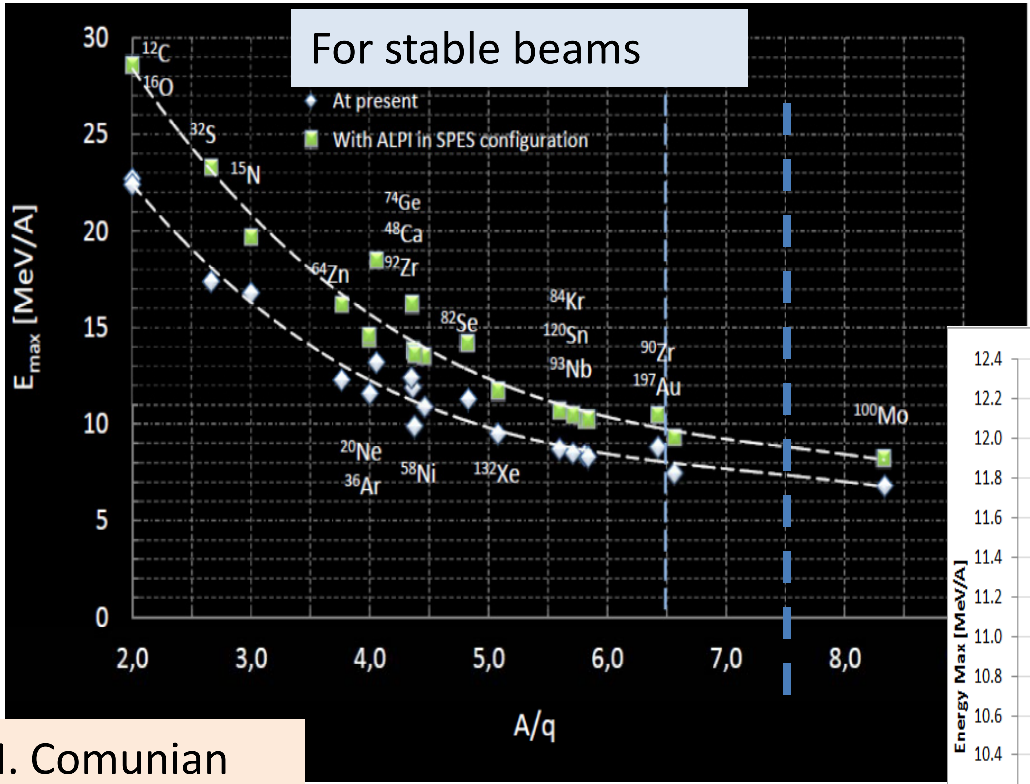
In-Line Distance Measurement			
Length (m)	Distance (m)	ADM (mm)	IFM (mm)
2 - 5	3	0.009	0.003
2 - 10	8	0.011	0.005
2 - 20	18	0.015	0.009
2 - 30	28	0.019	0.013
2 - 40	38	0.023	0.017
2 - 50*	48	0.027	0.021
[illegible]	[illegible]	[illegible]	[illegible]

E. Fagotti et al.

SC Resonator Improvements on ALPI



The Upgraded Alpi post-accelerator

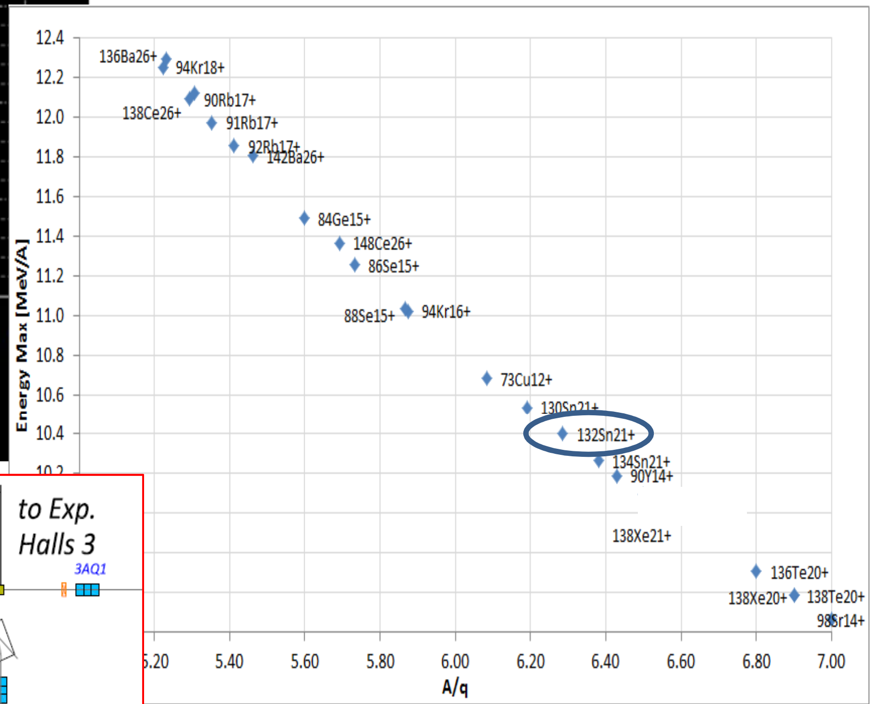


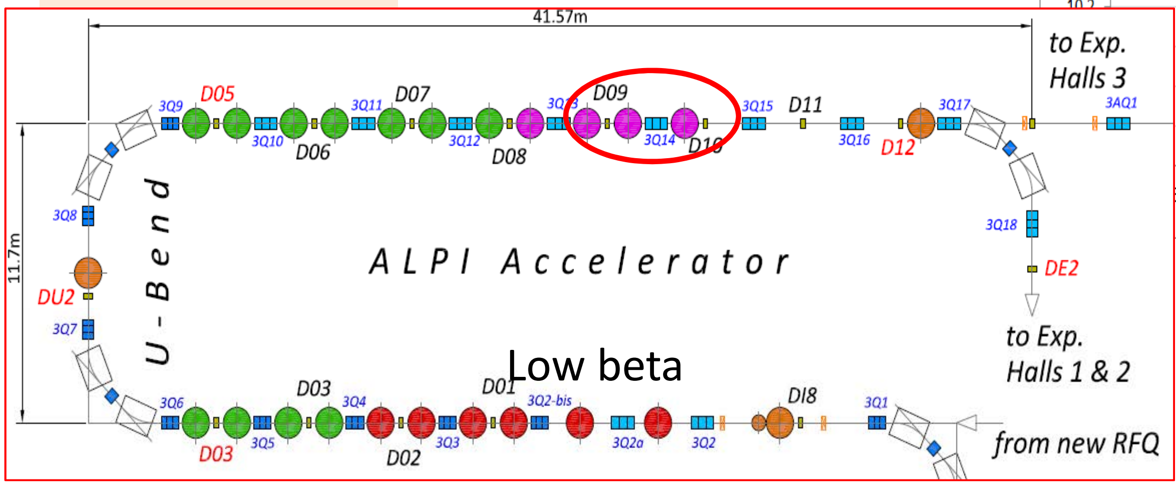
M. Comunian

For exotic beams

Low Beta=5 MV/m, Medium Beta=4.3 MV/m, High Beta=5.5 MV/m

Conservative value: 2 cavities off in the calculation.

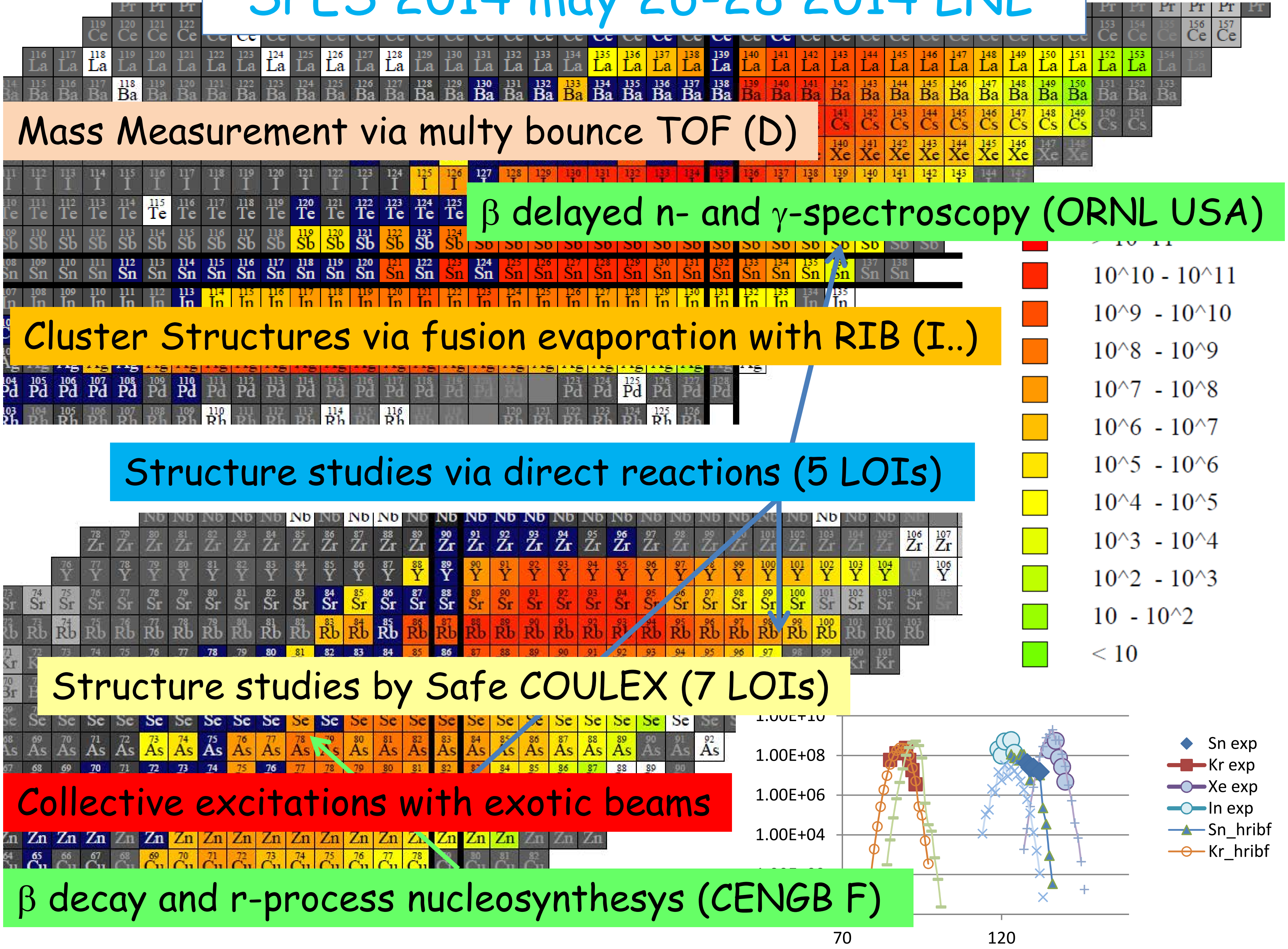




Reshape and improvement of low beta cavities.

Added high beta cryostats to improve the final energy.

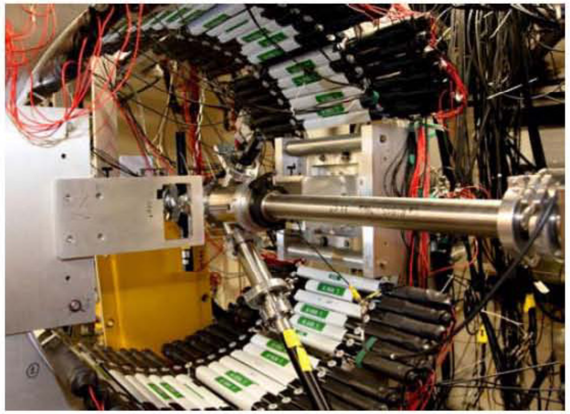
SPES 2014 may 26-28 2014 LNL



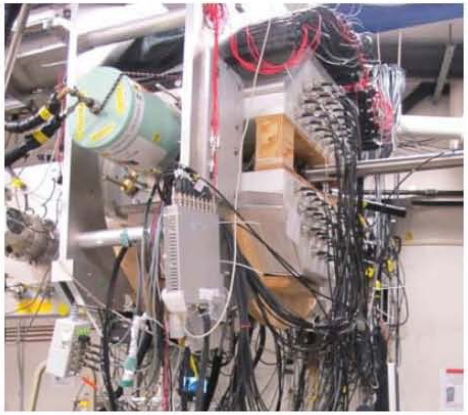
Decay spectroscopy techniques to study neutron-rich fission fragments at SPES

Krzysztof P. Rykaczewski, Robert Grzywacz, Carl J. Gross, Daniel W. Stracener, Yuan Liu
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831-6371, USA
in collaboration with
C. Mazzocchi, A. Korgul, M. Karny, K. Miernik, U. of Warsaw, Warsaw, Poland
W. Krolas, Institute of Nuclear Physics PAN, Krakow, Poland

MTAS = Modular Total Absorption Spectrometer



VANDLE = Versatile Array of Neutron Detectors for Low Energy

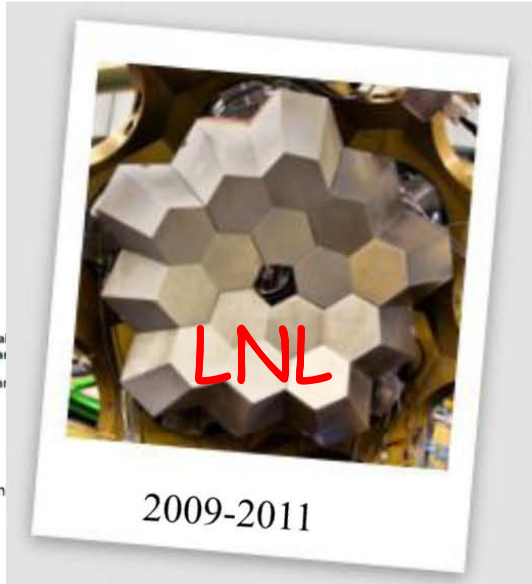


3Hen = Helium-3 Neutron Detectors
Hybrid-3Hen = 3Hen + Clover Ge

The physics of neutron-rich fission fragments

- nuclear structure evolution as N >> Z
- spectroscopy near and above the neutron separation energy
- rapid-neutron capture half-lives and beta-delayed neutron branchings
- societal impact in better data for modeling neutron-rich environments such as nuclear reactors
- more detailed understanding of the anti-neutrino spectra from reactors

INFN
Istituto Nazional
di Fisica Nuclear
Laboratori Nazionali di Legnar



To Prof. Giovanni Fiorentin

Director of LNL

Dear Gianni,

Let us first convey to you, on behalf of the AGATA Steering Committee (ASC) and AGATA Collaboration Council (ACC), the message that the full scientific community around AGATA has appreciated the interest of the LNL laboratory in the AGATA physics program and in particular in the scientific potential of the AGATA detector in combination with the exotic radioactive ion beams of the SPES facility. In view of the wide scientific program of AGATA at SPES, already envisaged by the scientific community through the presentation of 15 LOIs, the AGATA Steering Committee has agreed to install the AGATA detector at LNL-SPES for running an experimental campaign in the period 2019-2020.

Therefore the AGATA Steering Committee has decided for a commitment of the detector until 2020 (GANIL 2017-2018, LNL 2019-2020).

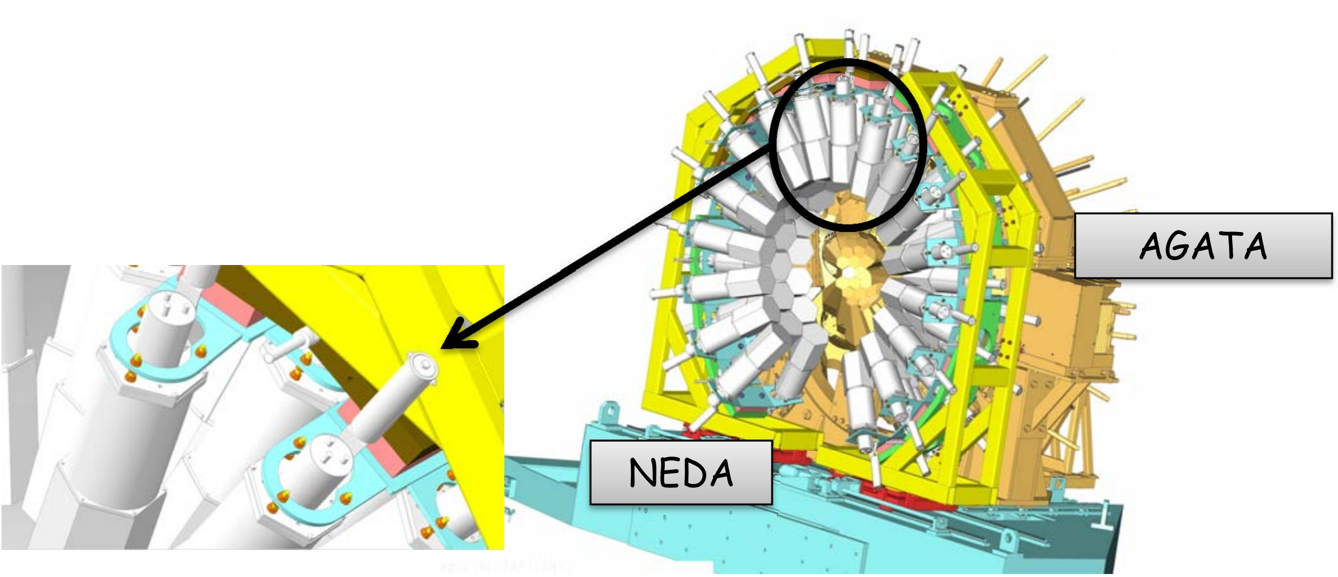
Best Regards,

G. de Angelis (ASC Chair) and J. Nyberg (ACC Chair)

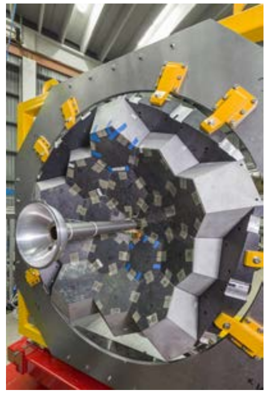
AGATA @ SPES
2019-2020

Neutron Detector Array

- Versatile neutron detector to be coupled to gamma-ray arrays
- Neutron detection is based on the liquid scintillator EJ301 with good neutron-gamma discrimination capabilities.
- Single hexagonal detector FEE fully digital system:
  - 200 MHz and ENOB 11,3
  - Global Trigger System - GTS



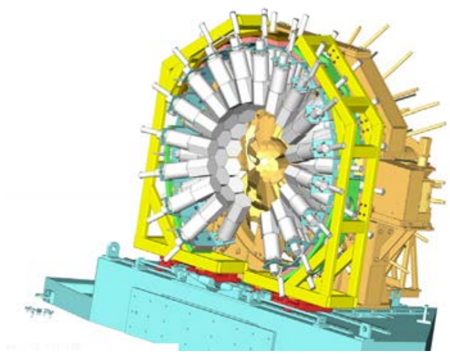
Predecessor Neutron Wall

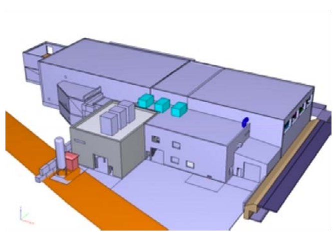


Time line of NEDA

2016	2017	2018	2019	2020	2021

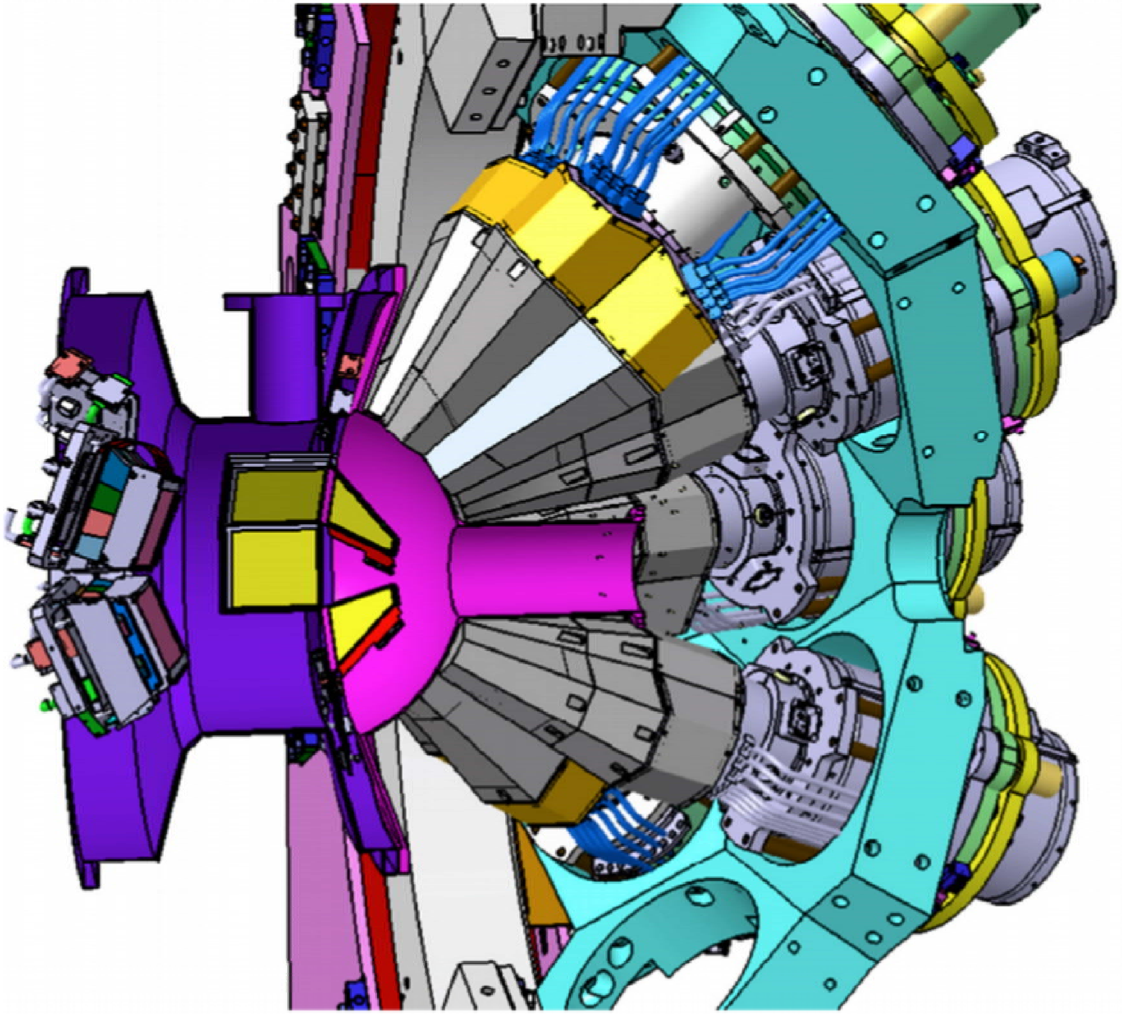
Production of NEDA	NEDA/AGATA@ GANIL	NEDA HIE-ISOLDE??	NEDA SPES





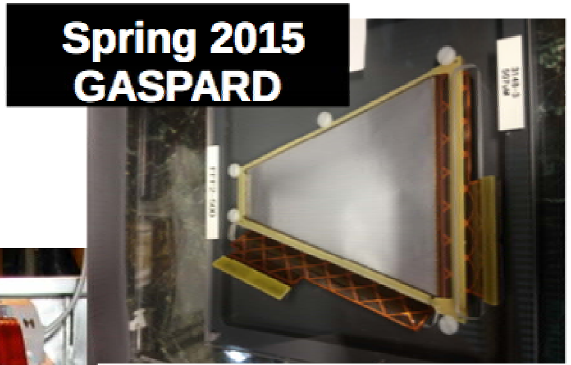
SPES
exotic beams for science

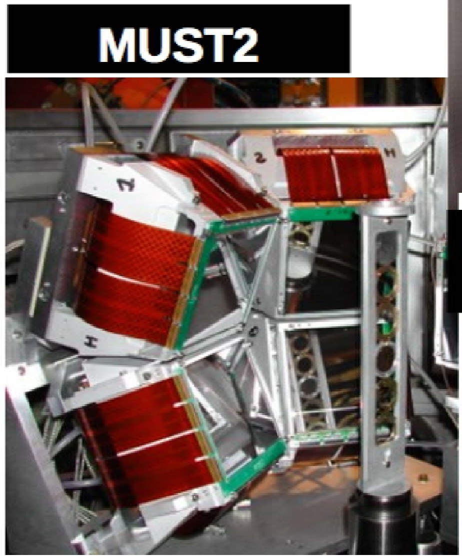
MUST2+GASPARD+TRACE: MUGAST

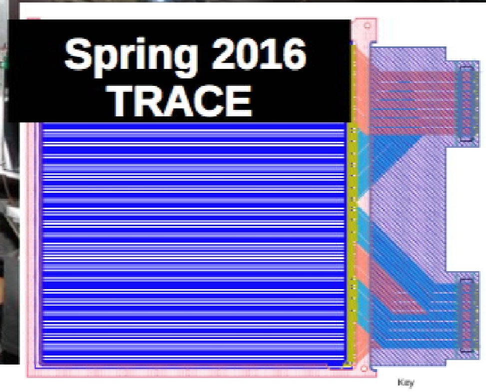


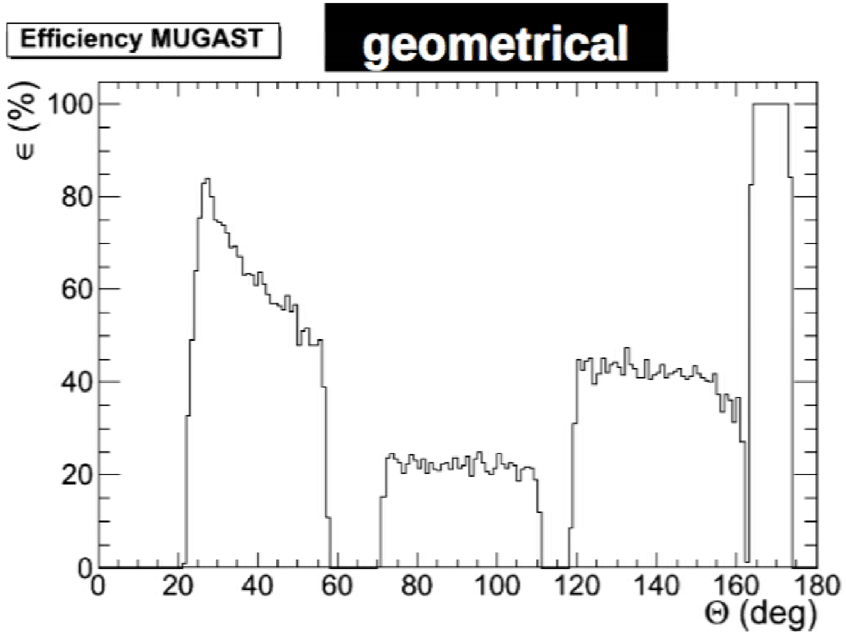
- Structure and reaction studies
- AGATA+MUGAST +VAMOS, ...
- LoI@GANIL PAC

NEW TRACE GASPASRD PROTO + MUST2





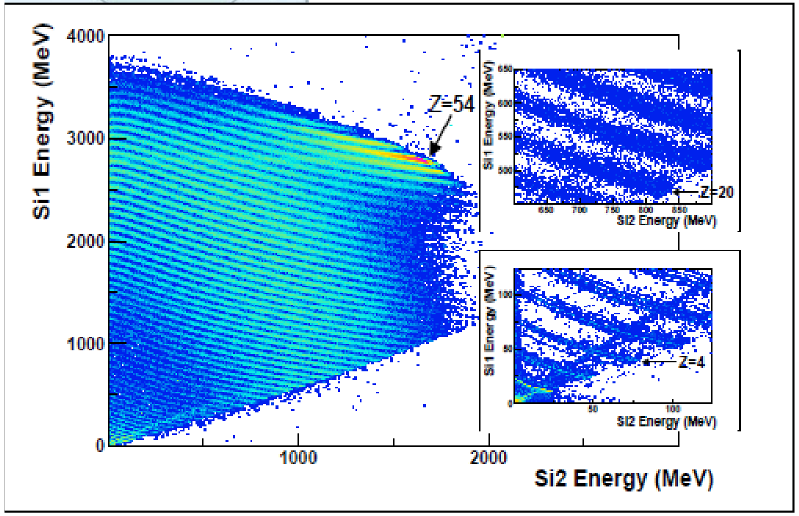


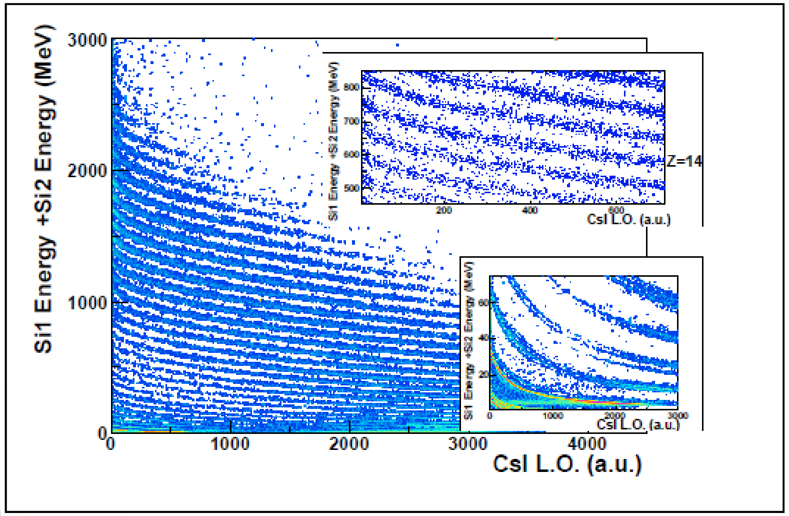


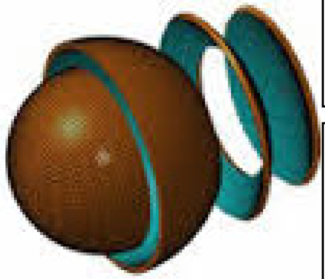
- Forward: 4 Must2 telescopes
- Backward: 4 Trape DSSD 500um
- 2 square DSSD 500um
- 1 Annular (back or forward)

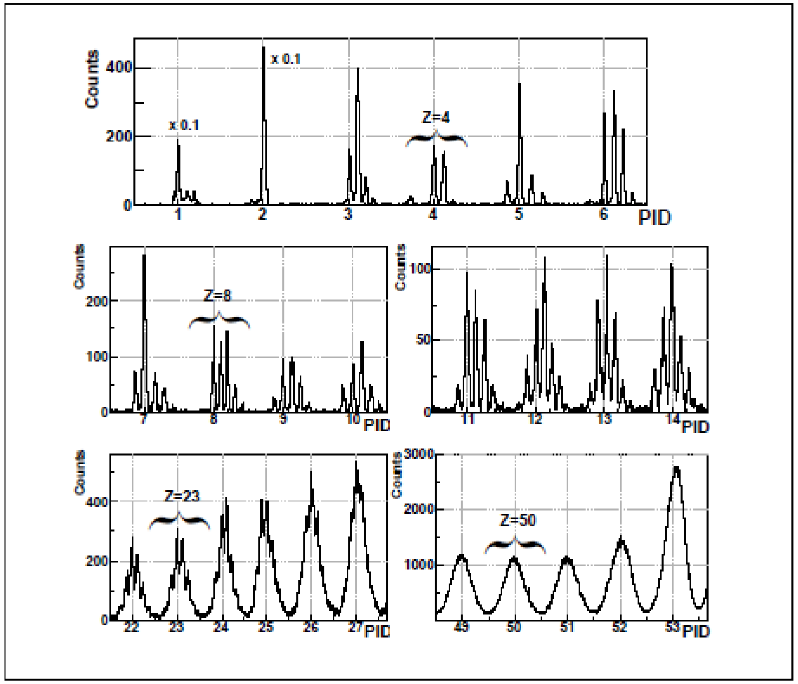
- Large Area
- Large Eff
- NTD

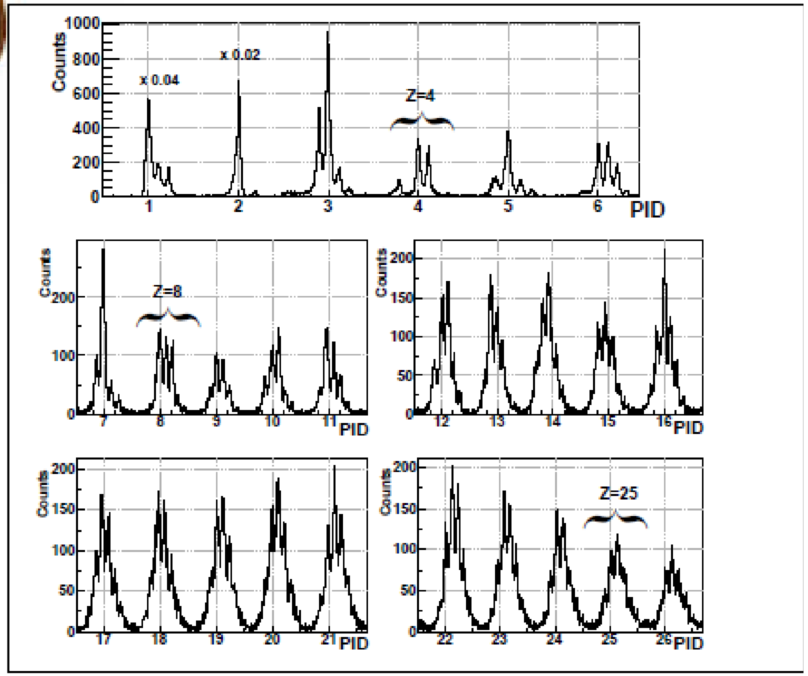
The FAZIA project

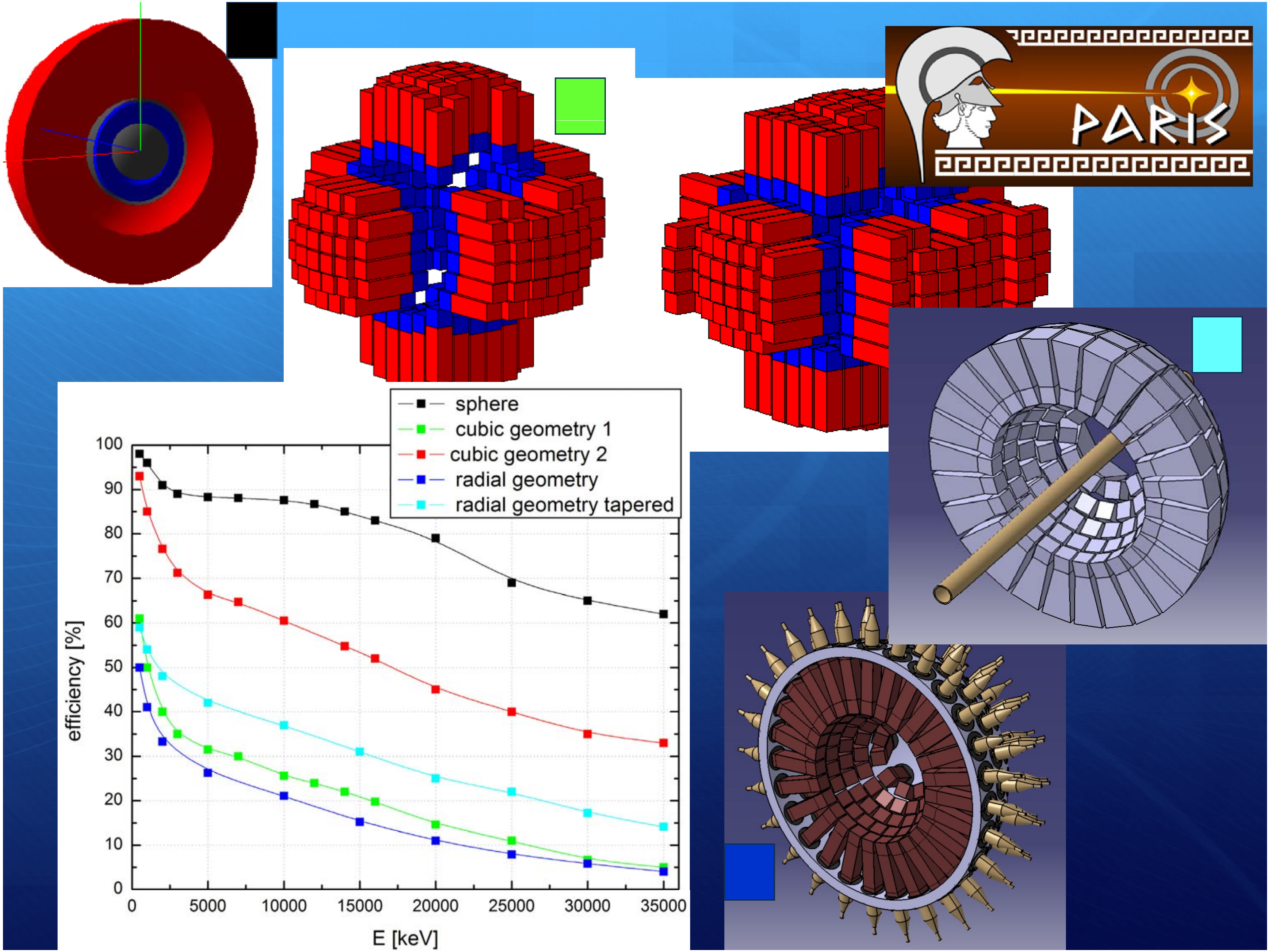











PARIS
sphere
cubic geometry 1
cubic geometry 2
radial geometry
radial geometry tapered
efficiency [%]
E [keV]
0
10
20
30
40
50
60
70
80
90
100
0
5000
10000
15000
20000
25000
30000
35000

Active Target Detectors: ACTAR

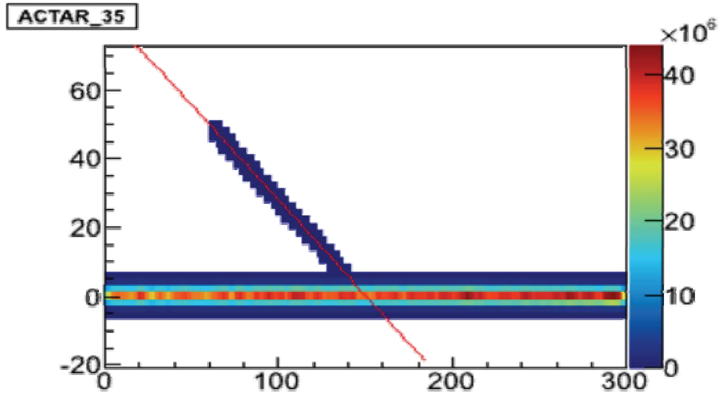
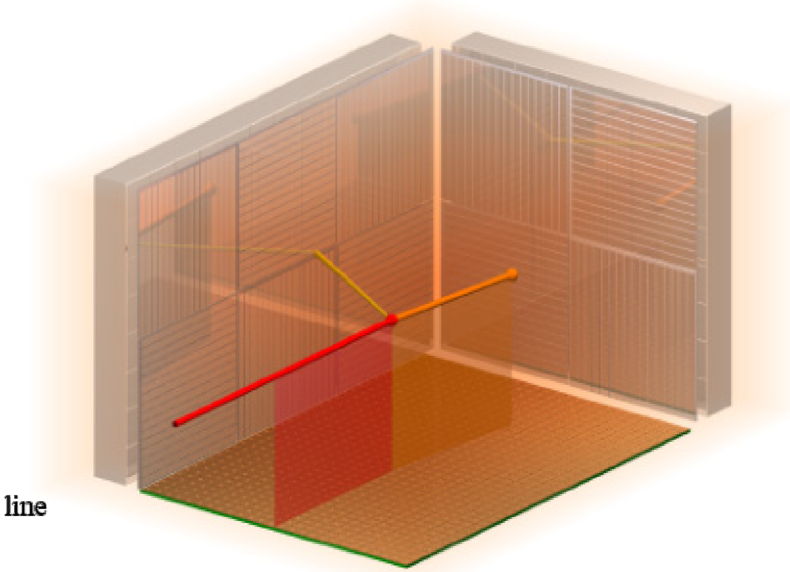
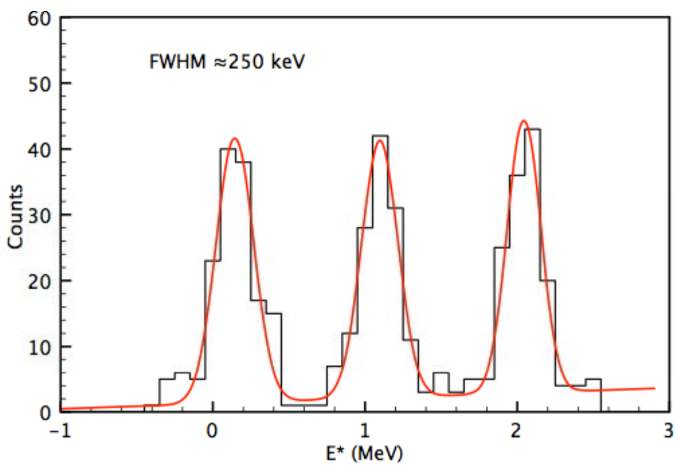
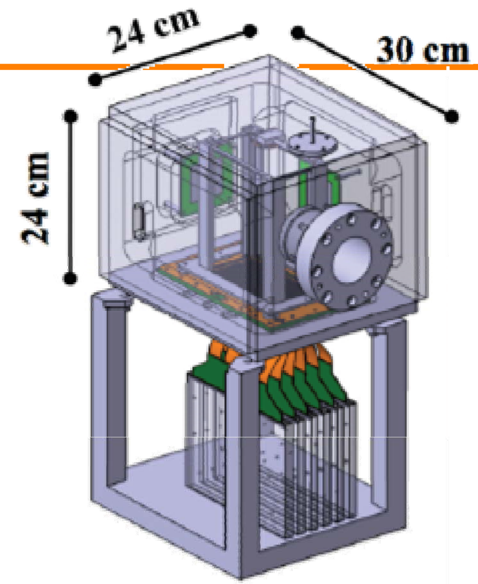


Fig. 4: Sample digitized trace for a ^{132}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.

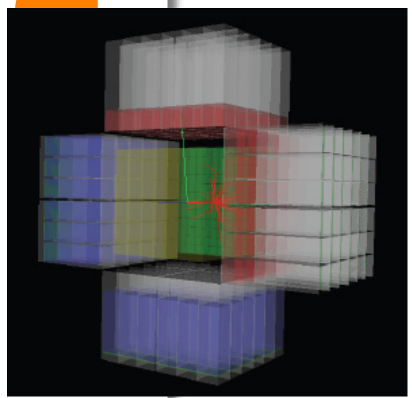




Proton energy resolution for the ^{78}Ni(d,p) reaction at 8 AMeV with 4x4 mm^2 pads



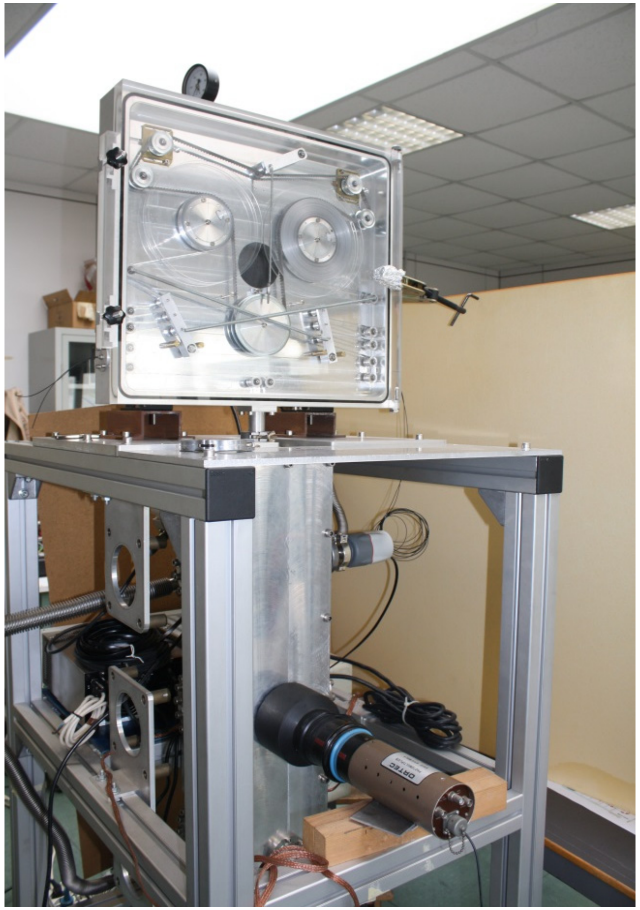
ACTAR + γ-ray array

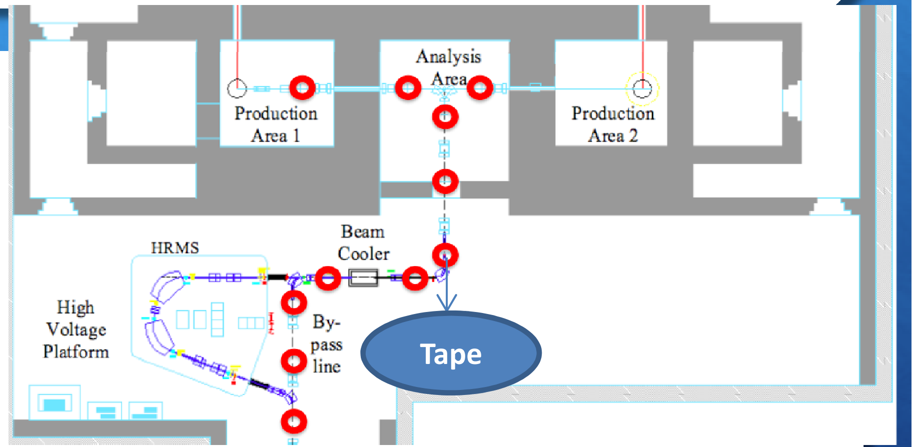


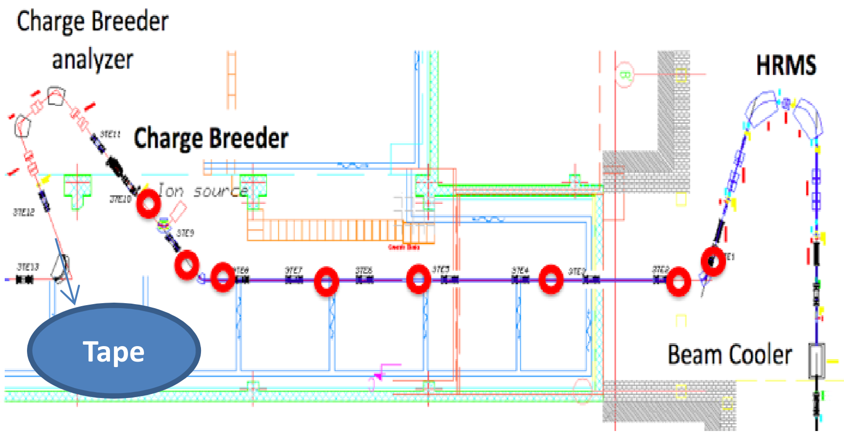
ERC: ACTAR TPC - G. Grynier - GANIL
ERC: SpecMAT - R. Raabe - K.U. Leuven

[ACTAR collaboration: http://pro.ganil-spiral2.eu/spiral2/instrumentation/actar-tpc]

Decay Station at SPES: LOI Mi ,.....



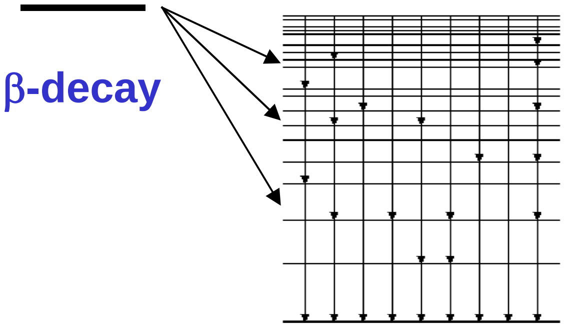




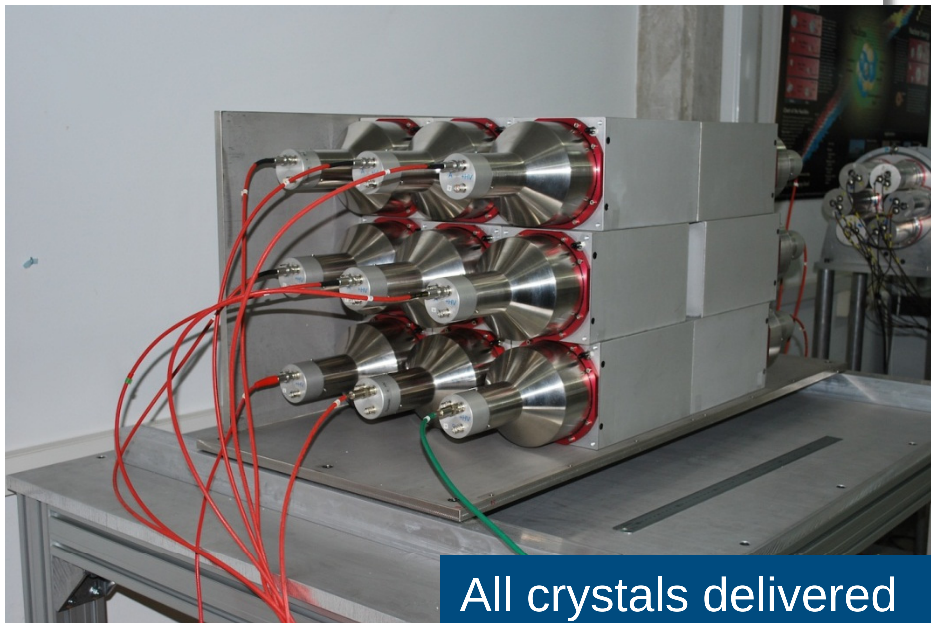
Total Absorption Spectrometer (TAS) or MTAS (ORNL)

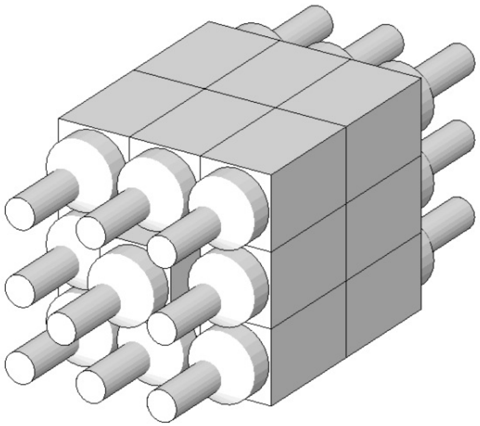
Courtesy of B. Rubio

β-decay

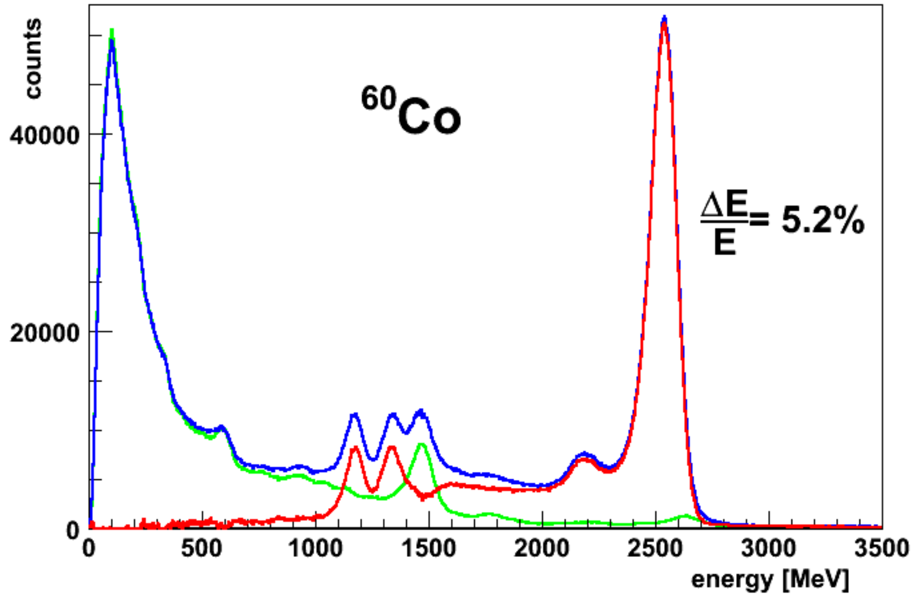


Information on the **multiplicity of the gamma cascade**





TDR submitted in 2012 and accepted!



16 × NaI(Tl) crystals:

- 15×15×25 cm^3
- Minimum dead-material
- 5" PMT: ETL9390

CONCLUSIONS

- The SPES project is financed by INFN up to the completion
- The cyclotron is under installation
- The proton beam is expected to be extracted in december 2015 for the Site Acceptance Test
- ISOL:
  - The ISOL sistem will be installed in 2016
  - First radioactive beam in 2018 (no reacceleration)
- Applications:
  - A program for study and production of radioisotopes for medical use is started
  - First beams available for medicine and neutrons in 2016
  - A neutron facility for fast neutrons is under design

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Third SPES international workshop
LNL   -   10-12 October 2016

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