Instituto de Física

The new facilities and devices at Mexico for low energy nuclear reactions studies.

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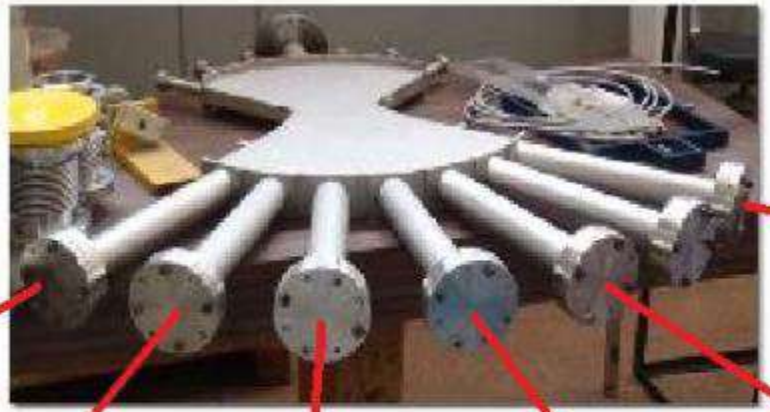
Introduction

- During the last 7 years, the infrastructure related with Experimental Nuclear Physics (basic and applied) at the Instituto de Física, UNAM, has been benefited with an unprecedented injection of resources.
- We have now new facilities and detection systems (ready and in progress).
- The National Laboratory for AMS (LEMA) is one of the most recent facilities installed at IF-UNAM.
- Besides of LEMA, we have a reactor, other accelerators, beam lines, detection systems, DAQ systems and sample preparation labs.
- This presentation will be devoted to show the main characteristics of these new systems and upgrade of previous facilities.
- Some examples of international collaboration will be shown, as well.

Facilities

The 5.5 Van de Graaff LCGF

- The 5.5 MV Van de Graff Accelerator of the Carlos Graef Fernández Laboratory is a 60 years old machine still working.
- p, d, ^{3}He and ^{4}He beams can be produced there with stable currents of 500 μA.
- Since the early 90's the 5.5 was mostly devoted to the IBA studies. More than 100 publications were produced in 25 year period. Eventually, single nuclear measurements were carried out during same period.



- Till 2009 was a single beam line accelerator. Then it became a 7 lines one, with the inclusion of a beam selector.
- The 90º bending magnet was changed as well for a bigger one, in order to improve the beam transmission.

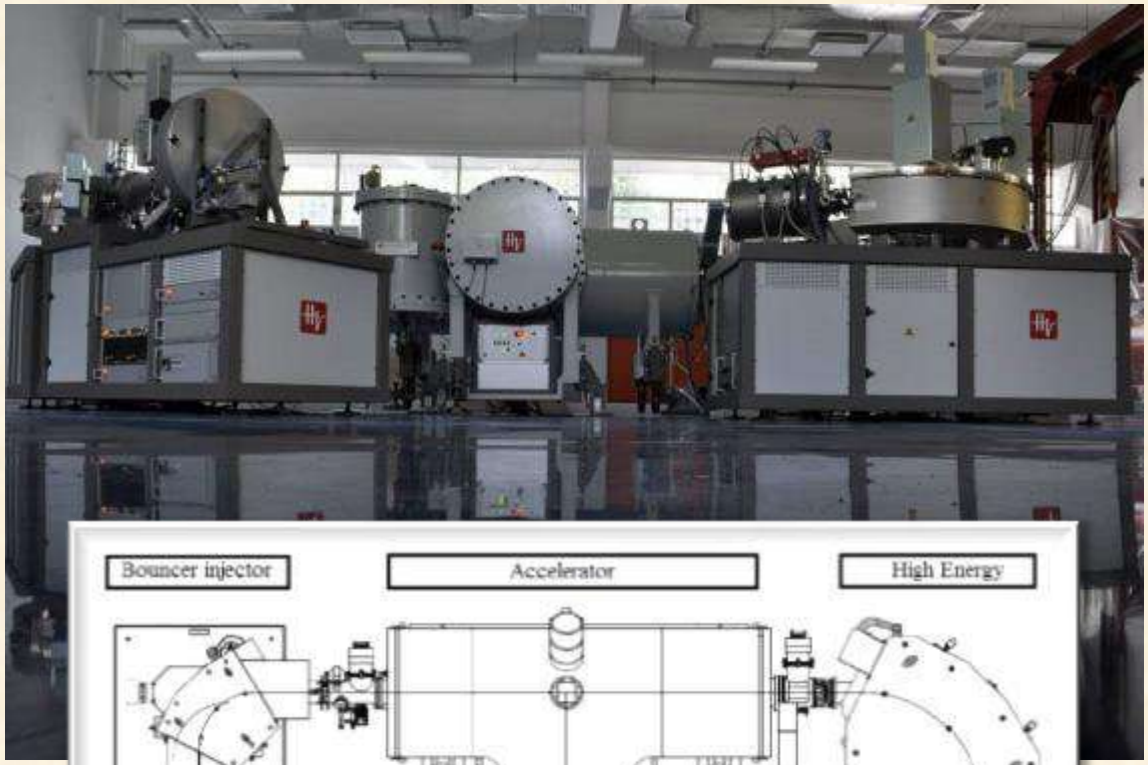
The ININ facilities.

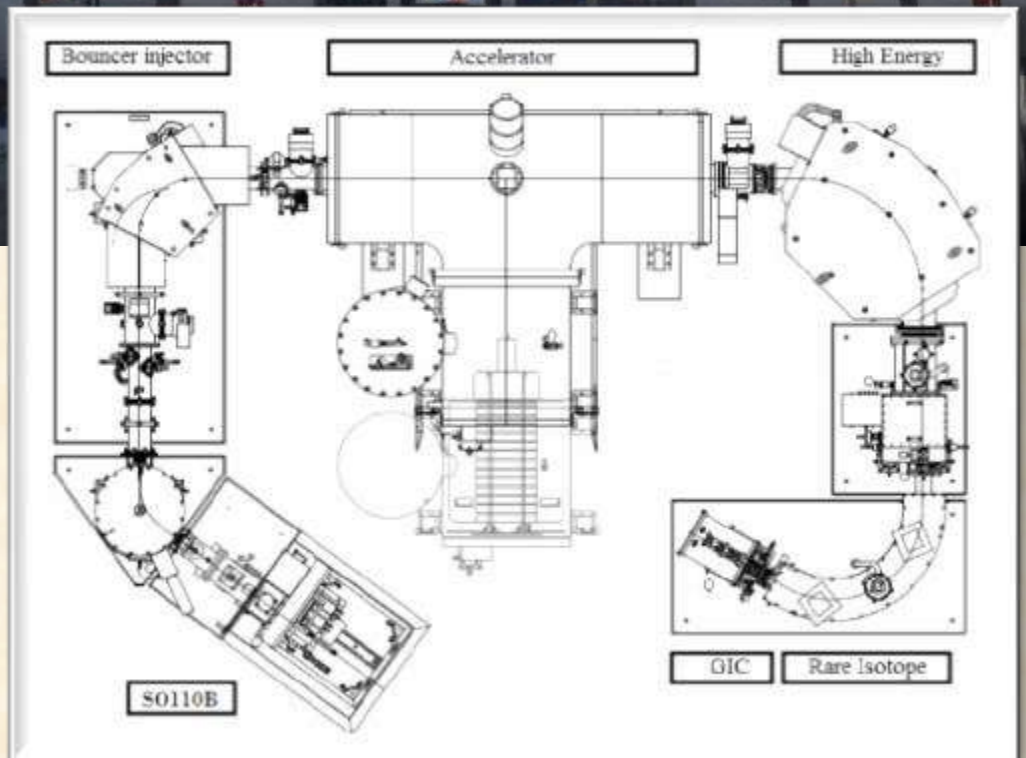
- At 30 km from Mexico City the National Institute for Nuclear Research (ININ) is placed. There we can find a Tandem 6 MV accelerator (most energetic for nuclear studies at Mexico), where many different beams can be produced.

- Recently we start to use also the TRIGA Mark III research reactor, in order to study neutron reactions.

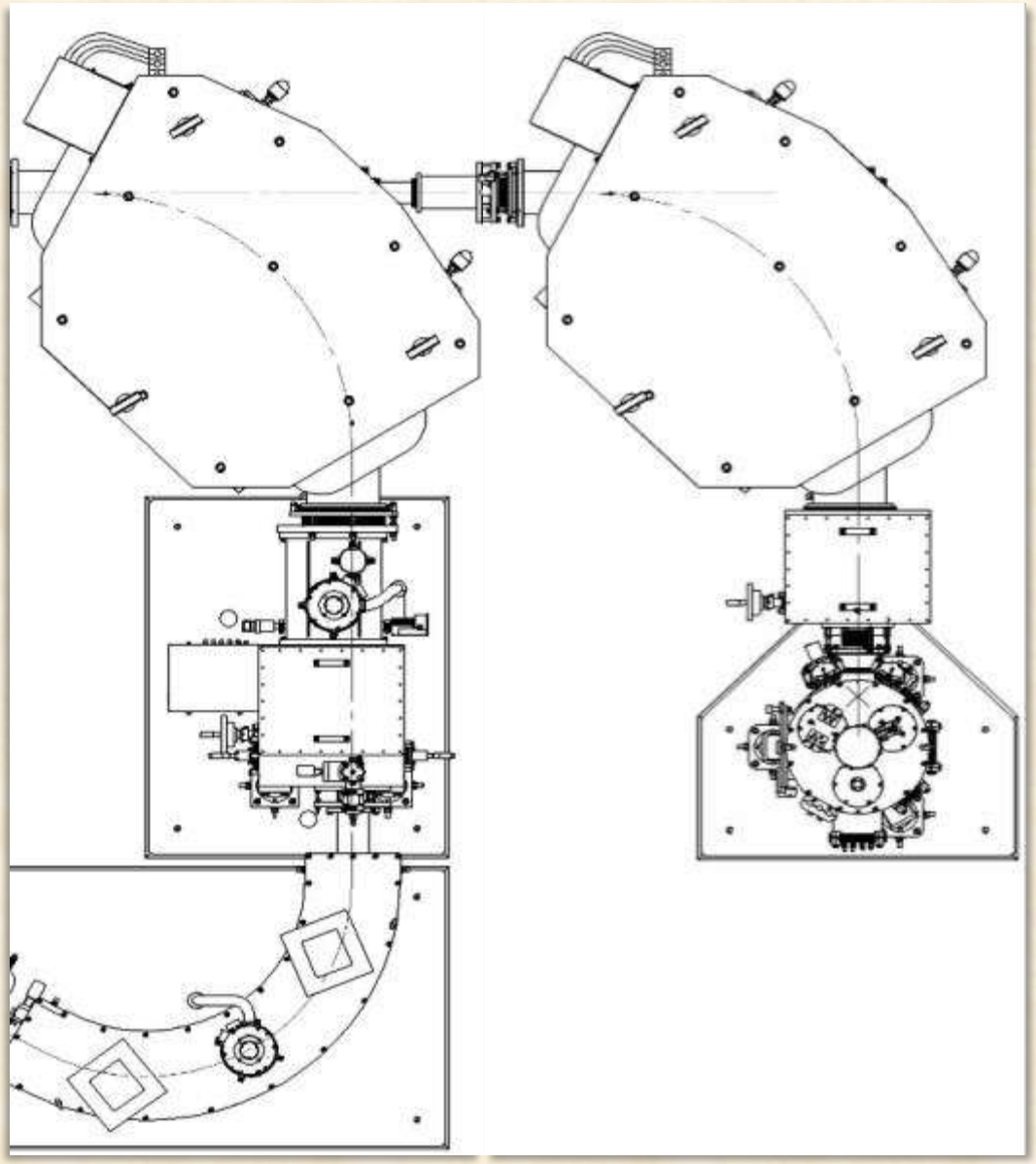
The LEMA facility

- The National Laboratory of Accelerator Mass Spectrometry (LEMA) was commissioned on 2013.
- It was placed at the Physics Institute UNAM along with other previous accelerators.
- A tandetron of 1 MV (HVEE) equipped with peripheral laboratories:
  - for the cleaning and chemical samples preparation;
  - Graphitization of carbon samples.
- Sequential injection makes possible the measurement of isotopes present in concentration ratios from 10^{-10} to 10^{-15}.
- LEMA was calibrated to measured concentrations of ^{10}Be, ^{14}C, ^{26}Al, ^{129}I and Pu isotopes.





The LEMA beam-line



- The system was mounted and commissioned at October 2017.
- Considering the good optics of the Spectrometer, beams as ^{14}C and ^{26}Al at low energies can be produced, as well every stable beam.
- In table are shown the estimations for a ^{197}Au beam.

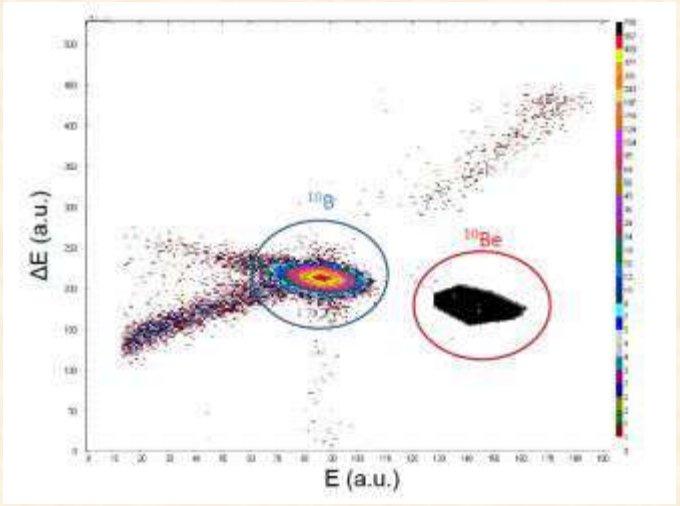
Q	TV(max) MV	E(max) MeV
1	0,185	0,371
2	0,494	1,482
3	0,834	3,335
4	1,000	5,000

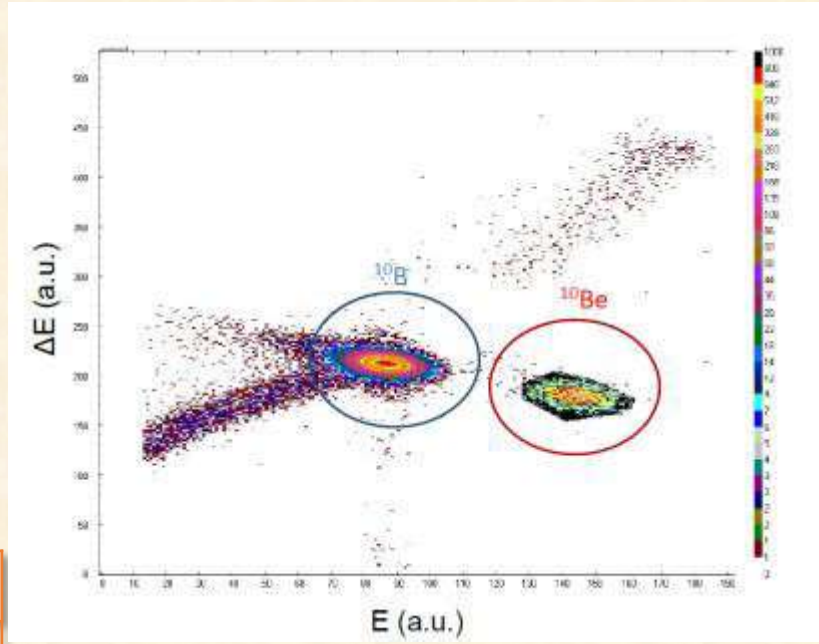
The new line has now a Detection system (detectors, electronics and DAQ).

A radiation chamber was coupled to the end of the line, in order to carry out diverse experiments.

Measurements combining facilities: AMS + reaction production

1. Production of a radioisotope by using an accelerator or a reactor.
2. Radioisotope measurement at AMS-system.
   - $^{28}Si(d,\alpha)^{\mathbf{26}}\mathbf{Al}$ (1.1 MeV, accelerator) $^{9}Be(n,\gamma)^{\mathbf{10}}\mathbf{Be}$ (25 meV, reactor), $^{14}N(n,p)^{\mathbf{14}}\mathbf{C}$ (25 meV, reactor).





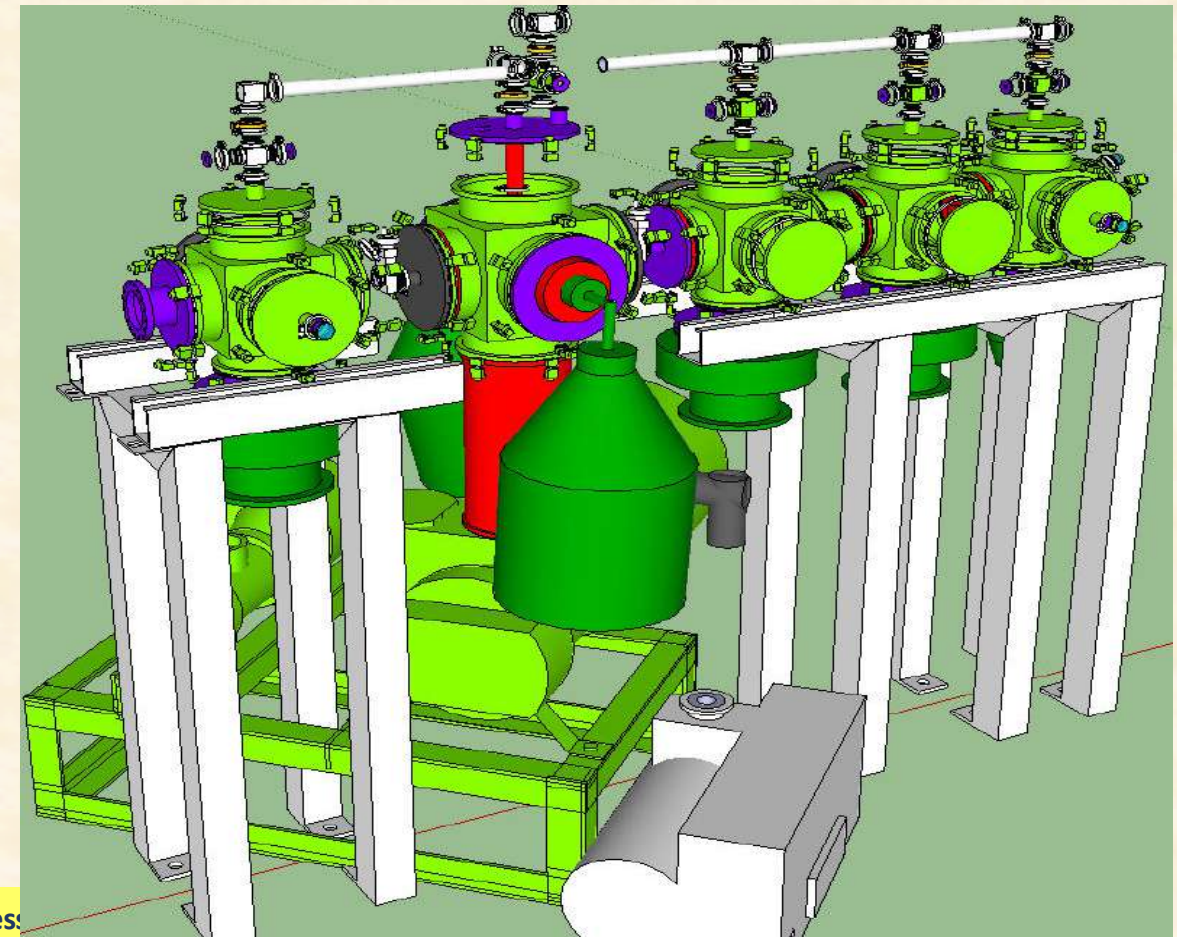
Reaction	σ_{LEMA} [b]	Dσ [b]	σ_{NIST} [b]	σ_{JEFF} [b]
$^{14}N(n,p)^{14}C$	2.0390	± 0.3151	1.9100	1.8292
$^{9}Be(n,\gamma)^{10}Be$	0.0097	± 0.0003	0.0070	-
$^{28}Si(d,\alpha)^{26}Al$	3.9×10^{-6}	$\pm 4\times10^{-7}$	-	-

D. Marín-Lámbarri, et. al. (in progress)
L. Acosta, et. al., EPJ WoC 165, 01001 (2017)

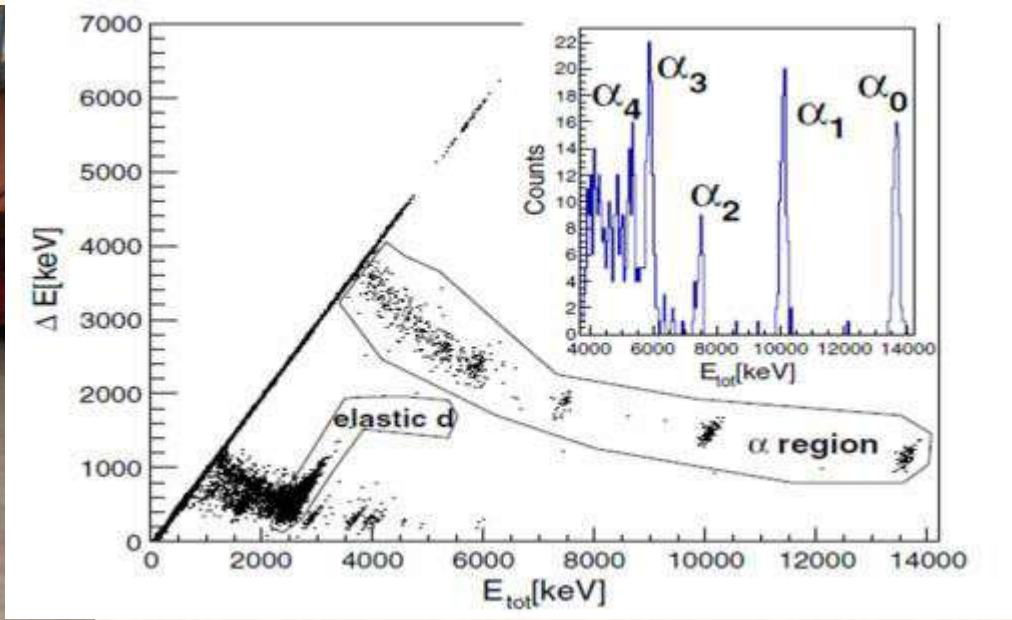
Ancillary Systems

SUGAR

- SUGAR (**SUpersonic GAs jet taRget)**. A windowless gas target at 60º line of Van de Graff accelerator.
- Target thickness = 10^{18} atoms/cm^2
- Projection energy resolution = 200 keV



- For commissioning and characterization was used the following reaction:
  - Deuterium beam @ 2.51 MeV on ^{14}N gas target.
  - E-ΔE Telescope (60 μm + 11 μm) a θ_{lab} = 35°



PHYSICAL REVIEW SPECIAL TOPICS—ACCELERATORS AND BEAMS 18, 123502 (2015)

New supersonic gas jet target for low energy nuclear reaction studies

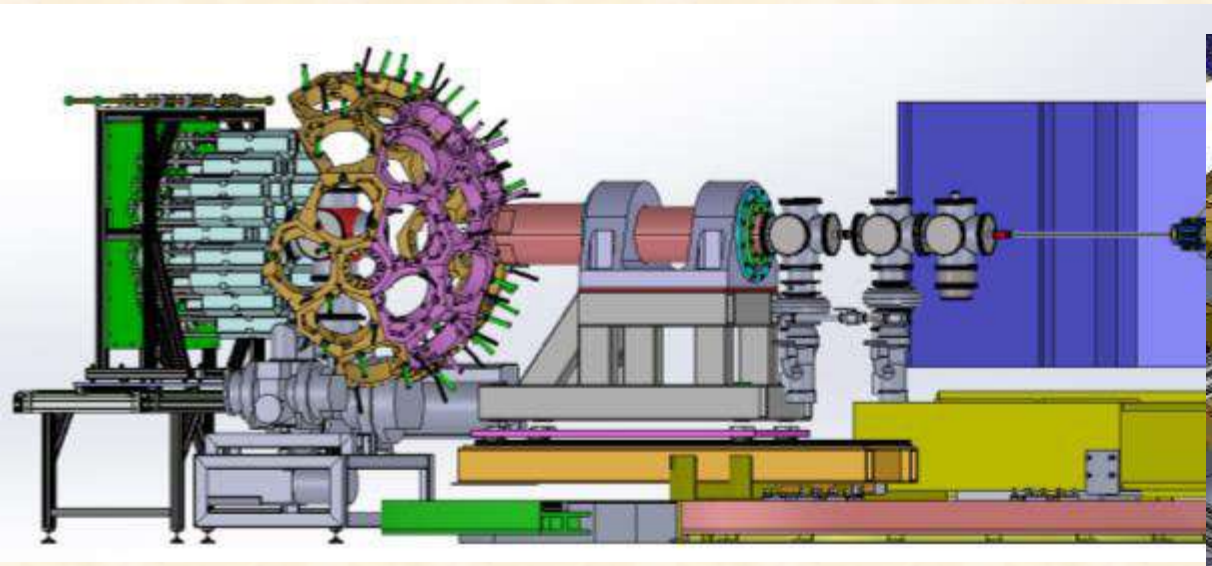
F. Favela,[1] L. Acosta,[1,2] E. Andrade,[1] V. Araujo,[1] A. Huerta,[1] O. G. de Lucio,[1] G. Murillo,[3] M. E. Ortiz,[1] R. Policroniades,[3] P. Santa Rita,[1] A. Varela,[4] and E. Chávez[1]

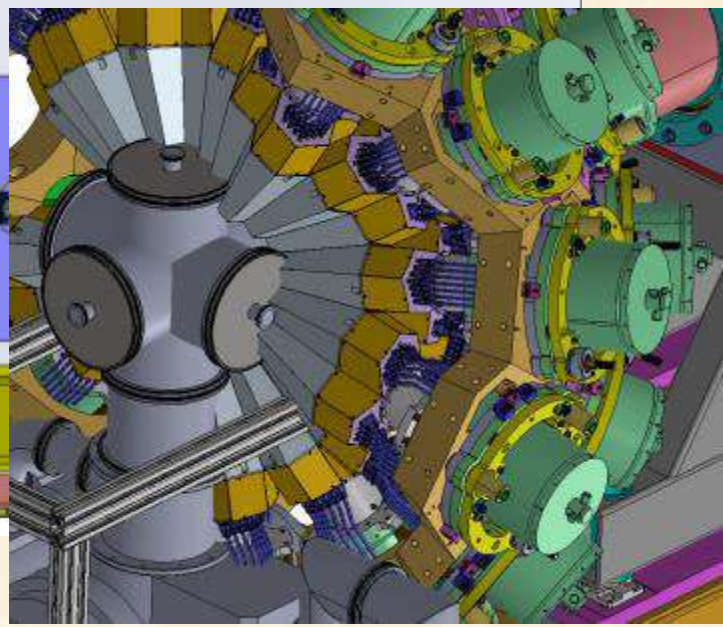
SUGAR @ LNL (AGATA+NEDA)

- Due to the return of AGATA to Legnaro (~ 2021), we are proposing to send SUGAR to LNL.
  - Collaboration agreement INFN-LNL and IF-UNAM

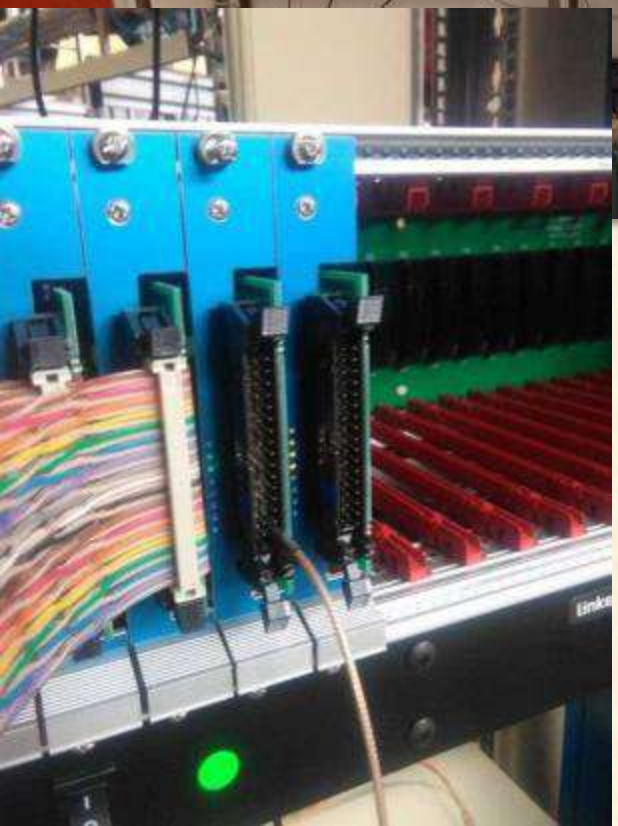
    - $^{16}O+^{16}O$ at 4-6 MeV (oxigen burning during stellar evolution).

    - $^{14}N(d,^{12}C^*)4He$ and $^{12}C(^4He,^3\alpha)^4He$ (rotational band of the Hoyle state as well as high spin excited states in ^{12}C to elucidate its geometric structure).

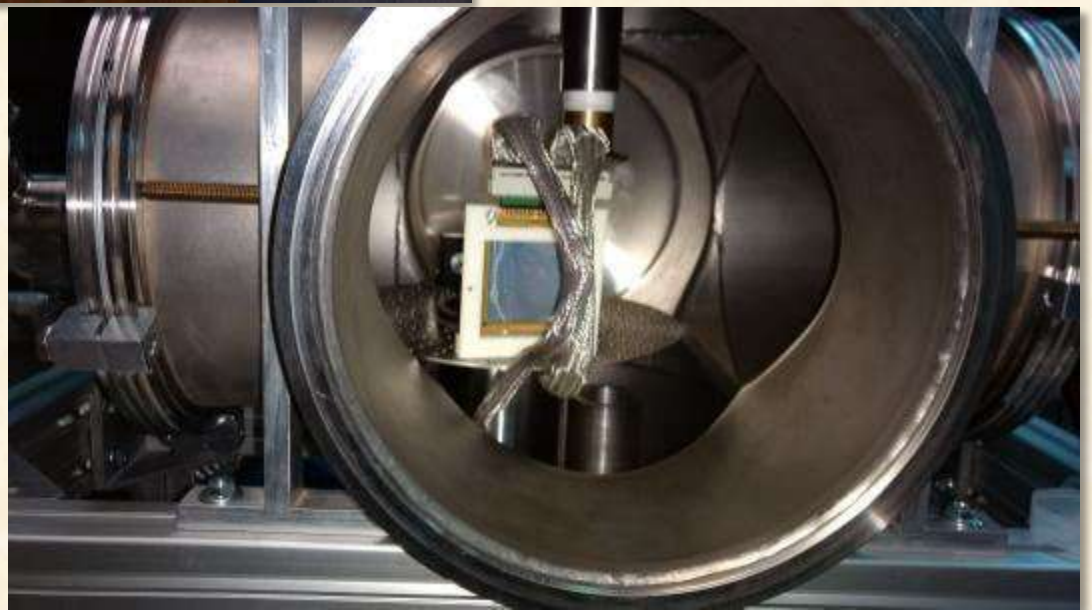




DAQ for SIMAS (FEBEX3-GSI/FAIR).



- The DAQ decided for SIMAS are FEBEX3 cards, performed by N.Kurz team at GSI.
- 16 channel pipeline ADC **Front End Board with optical link EXtension,** 60 MHz, 12 bit, Input -1V to +1V.
- DC sampling rate is max 65 Ms/s.
- Whole system PEXOR3 (Data collection, 600 MB/s FPGA) and TRIXOR (equivalent to TRIVA modules).
- 64 digitalization channels were tested by using a 32 strips of a DSSSD and a triple alpha source. Presently we have 128 operative channels.
- 16 channels Time digitizers (10 ps response).

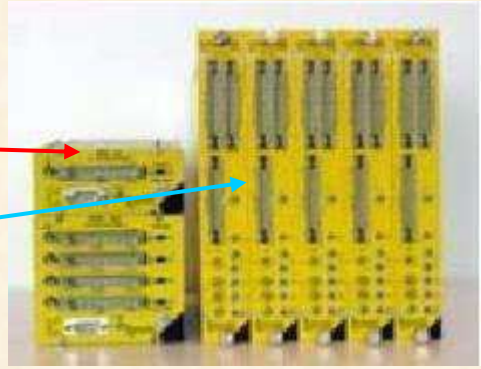


A typical readout and DAQ

Analogical signal is produced by a charge particle in a Detector

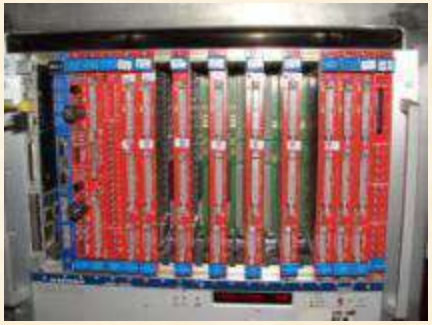
✓Preamplifiers

✓Amplifiers



Logic chain

ADC/TDC converters



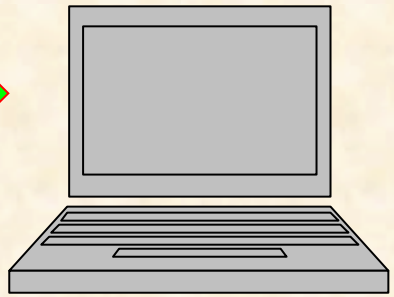
Data acquisition system

✓ADC's and TDC

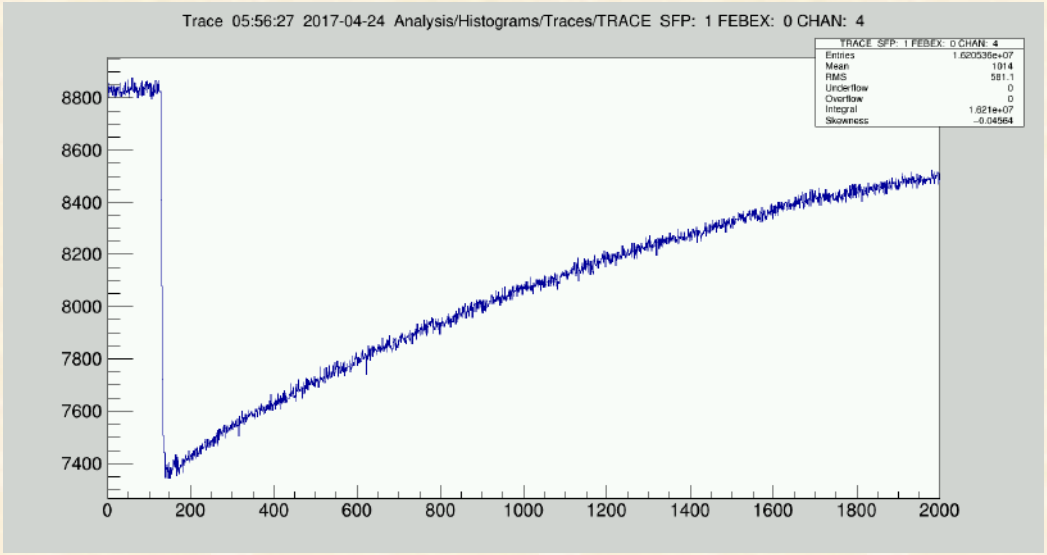
✓Trigger box (TRIVA3)

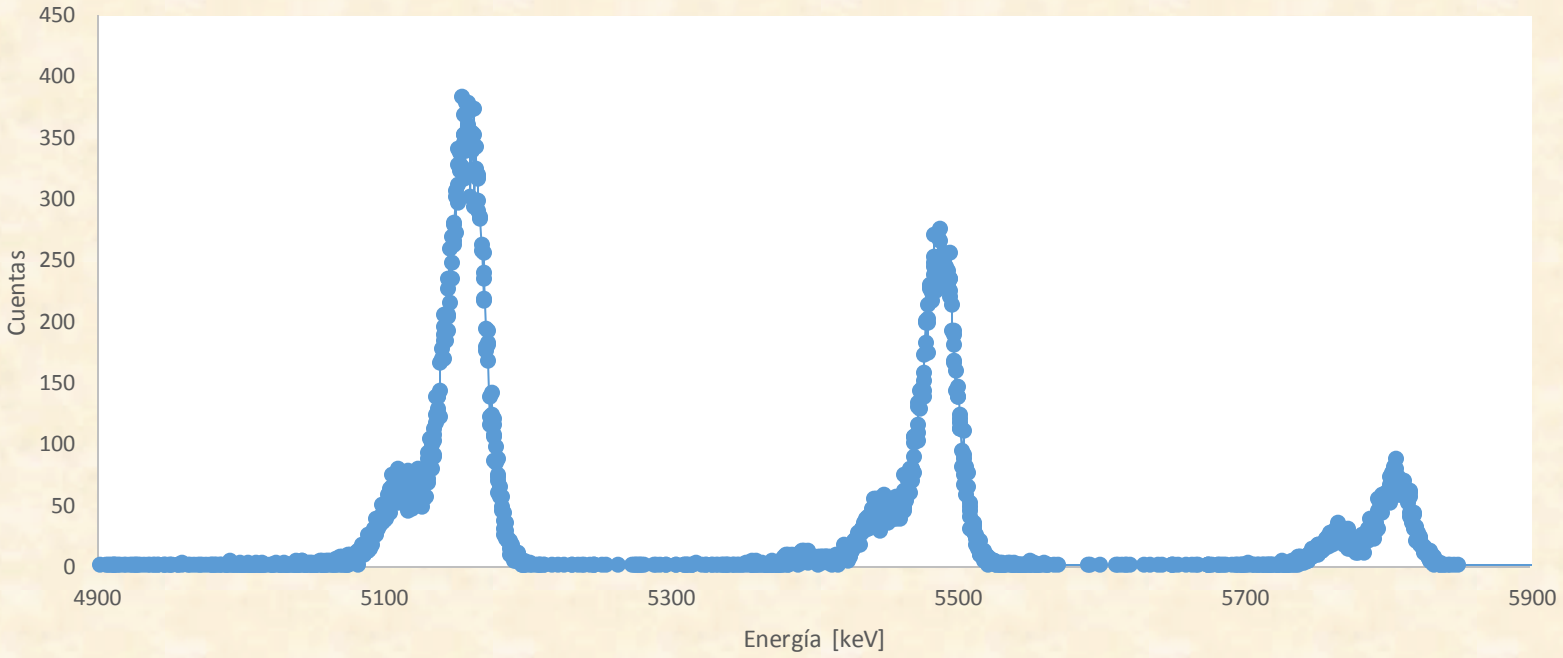
✓Card data processor (CPU-RIO2)

Monitoring and storage

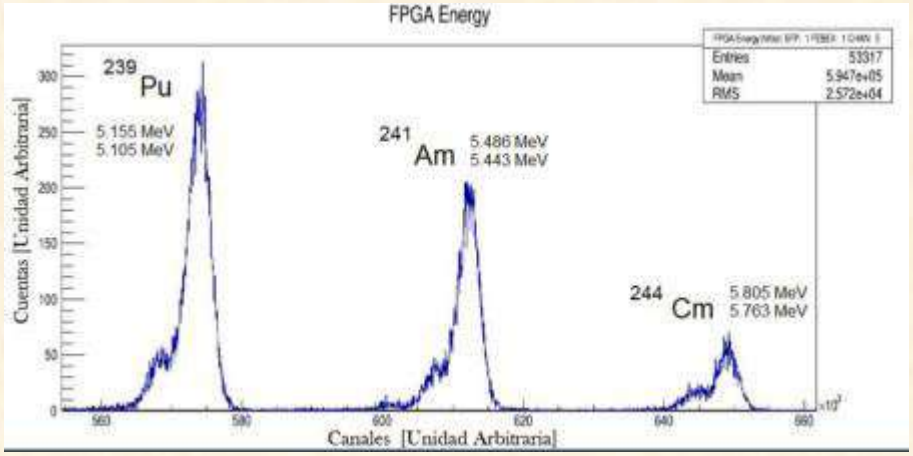


Energy spectra PIP's (using FEBEX-3).

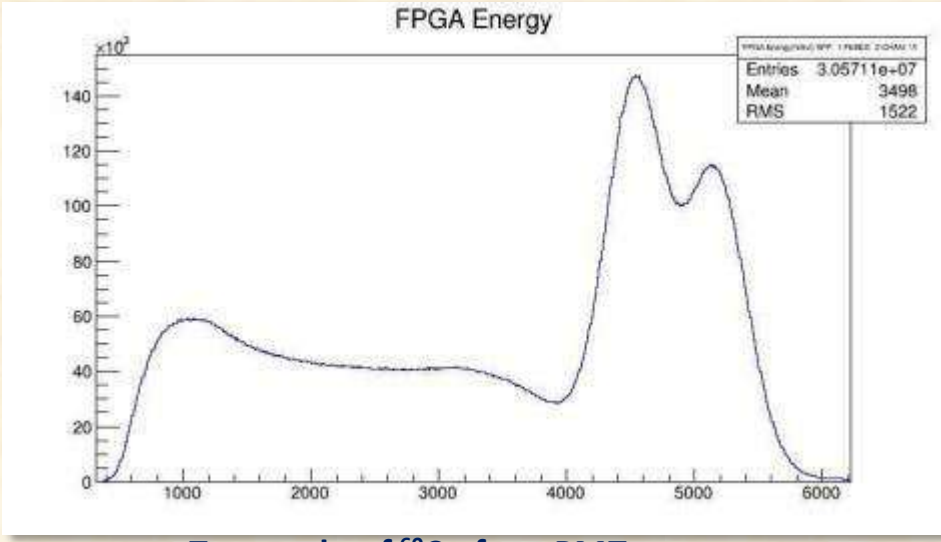




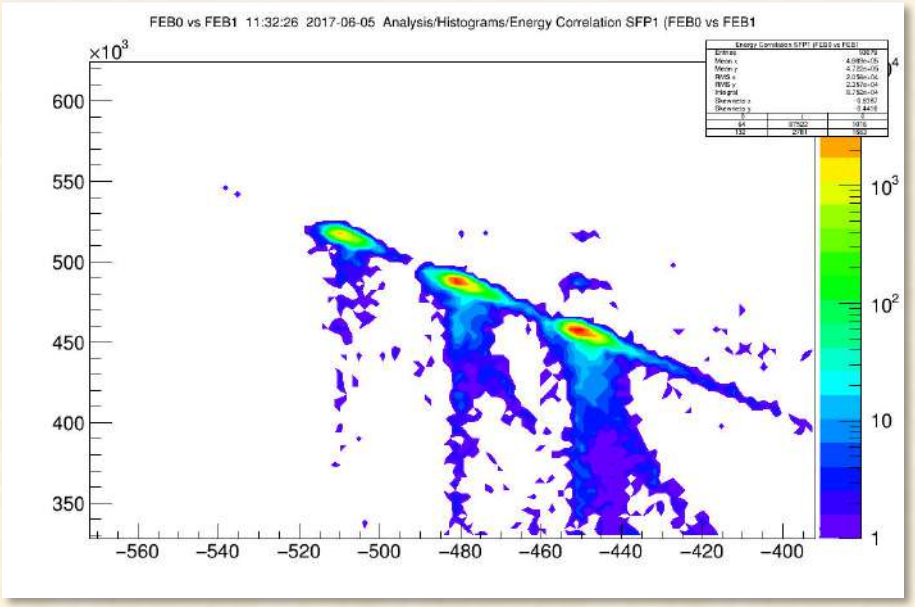
Data taken with different detectors: DSSSD, PMT and Germanium.



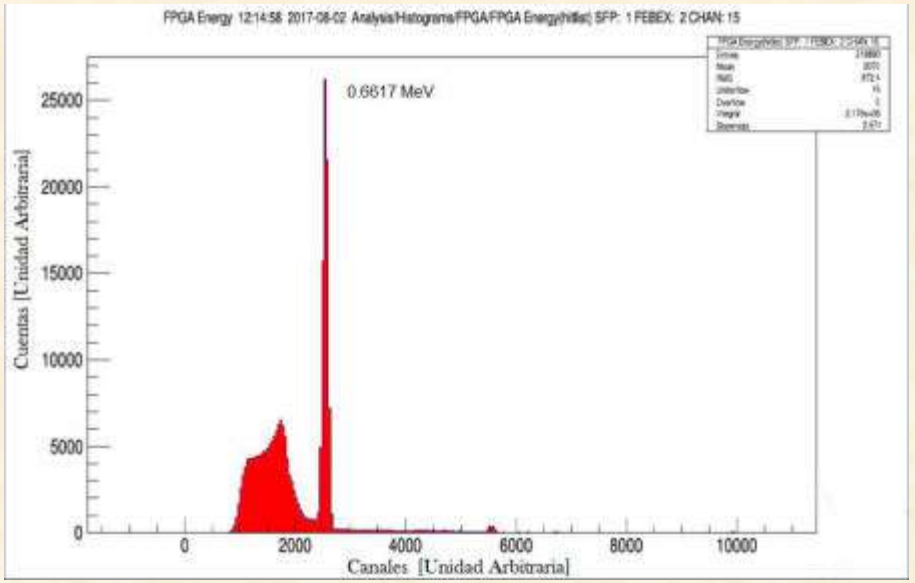
Triple alpha source on one DSSSD backward channel.



Two peaks of ^{60}Co for a PMT



Matrix front-back for alpha source signal



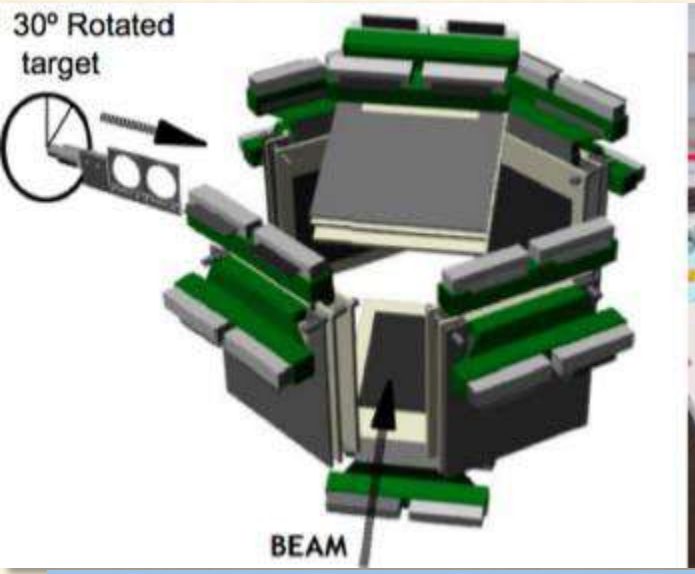
^{137}Cs in a Germanium detector.

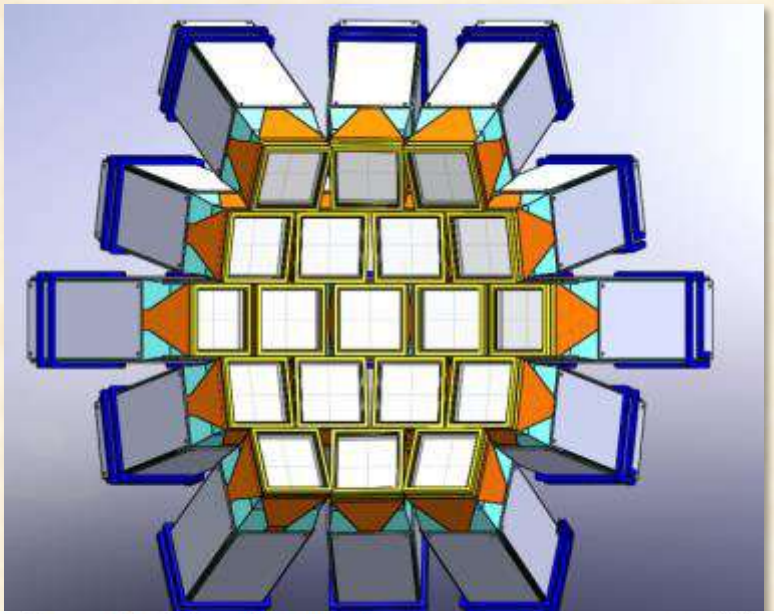
FWHM: DSSSD = 29 keV, PMT = 190 keV, Germanium = 34 keV

Diploma Thesis: L. R. Ríos Álvarez (in progress).

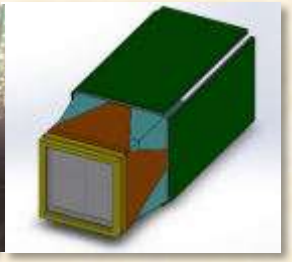
The charge particle array SIMAS

- SIstema Móvil de Alta Segmentación (high segmentation movil system) SIMAS.
- Though to be used principally at LEMA line but also at other facilities.





G. Marquínez-Durán, L. Acosta, R. Berjillos, J.A. Dueñas, J.A. Labrador, K. Rusek, A.M. Sánchez-Benítez, I. Martel. NIM-A 755(2014)69–77

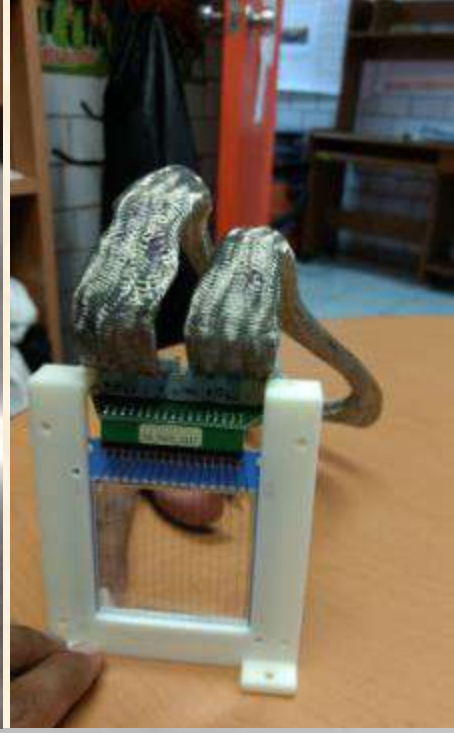


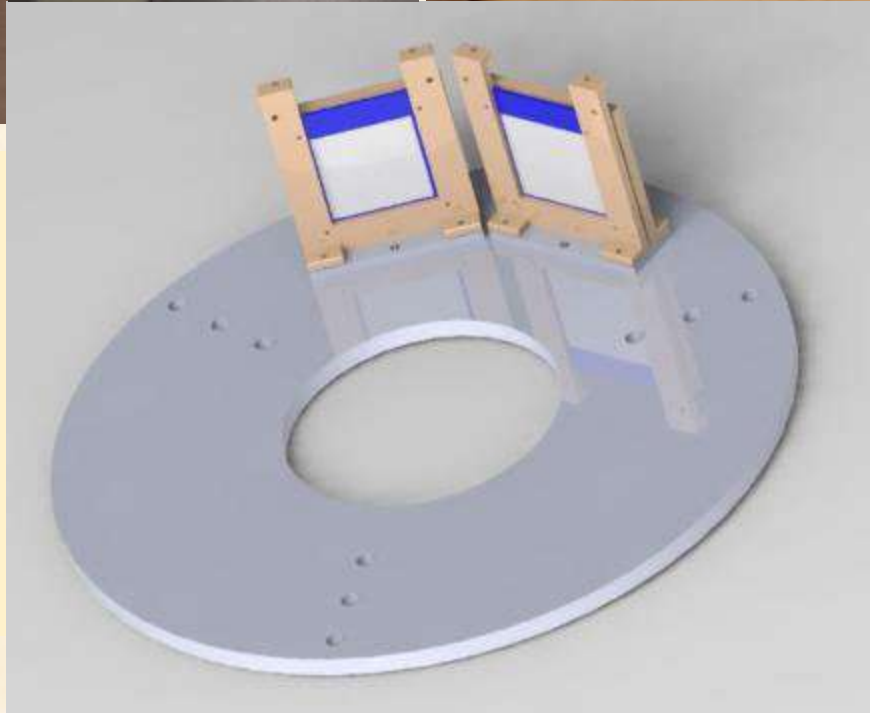
XXXIX Symposium on Nuclear Physics 2016 (Cocoyoc2016) IOP Publishing
Journal of Physics: Conference Series **730** (2016) 012001 doi:10.1088/1742-6596/730/1/012001

Campaign of measurements to probe the good performance of the new array FARCOS for spectroscopy and correlations.

L. Acosta[1,2,*], R. Andolina[3], L. Auditore[4], C. Boiano[5], G. Cardella[2], A. Castoldi[5,6], M. D'Andrea[2], E. De Filippo[2], S. De Luca[4], D. Dell'Aquila[7], L. Francalanza[7], B. Gnoffo[2], C. Guazzoni[5,6], G. Lanzalone[8,9], I. Lombardo[7], N. Martorana[3,9], T. Minniti[4], S. Norella[4], A. Pagano[2], E.V. Pagano[3,9], M. Papa[2], T. Parsani[5,6], S. Pirrone[2], G. Politi[2,3], F. Porto[3,9], L. Quattrocchi[4], F. Rizzo[3,9], P. Russotto[2], G. Saccà[2], A. Trifirò[4], M. Trimarchi[4], G. Verde[2,10], M. Vigilante[7] and P. Zambon[5,6,11]

SIMAS detectors





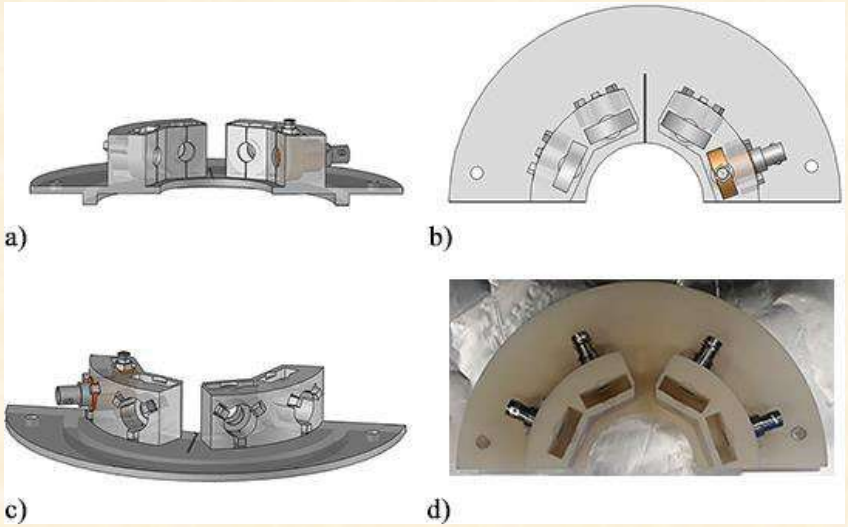
2 (of 4) Double-sided silicon strip detectors (DSSSD) 20 micron. 16x16 strips, 5x5 cm active area.

2 PAD (of 4), 130 micron. 5x5 cm active area

Resolution FWHM ~ 20 keV.

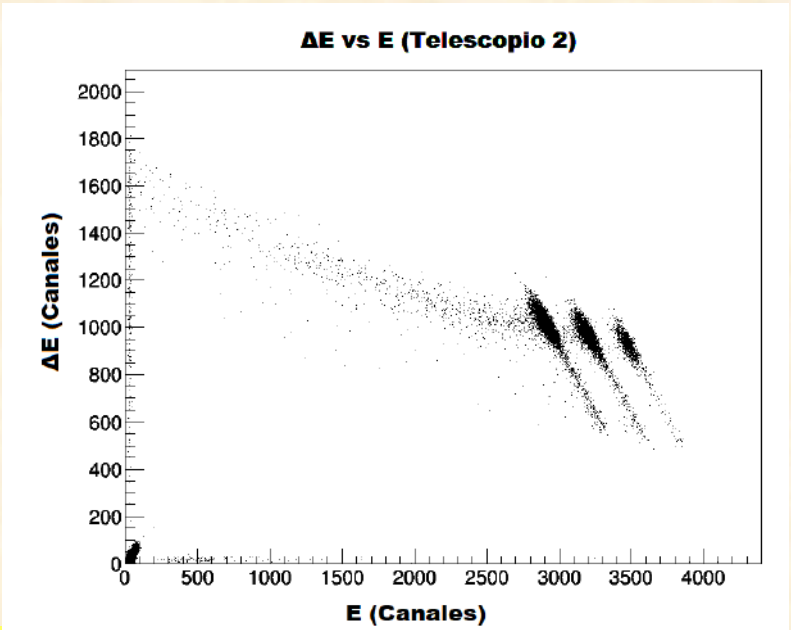
4 single telescopes: ΔE = SB detector 15 µm (1x1 cm^2 active area). E = PIPS detector 300 µm (1x1 cm^2 active area) .

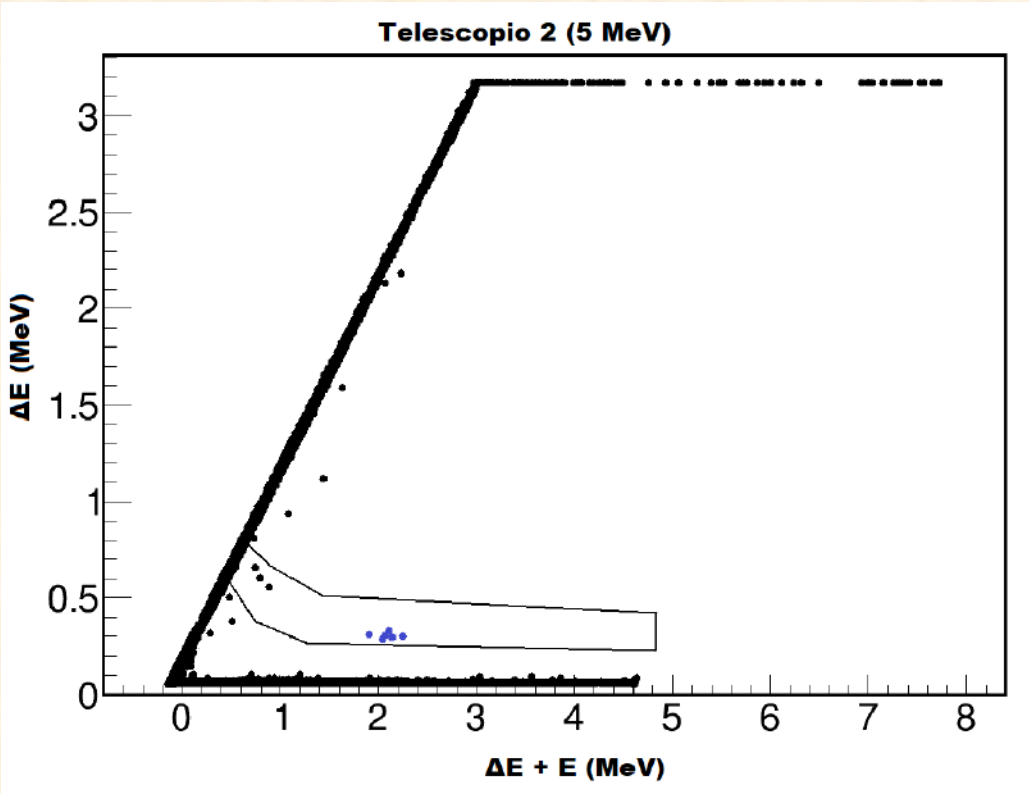
SIMAS commissioning (SB+PIPS)



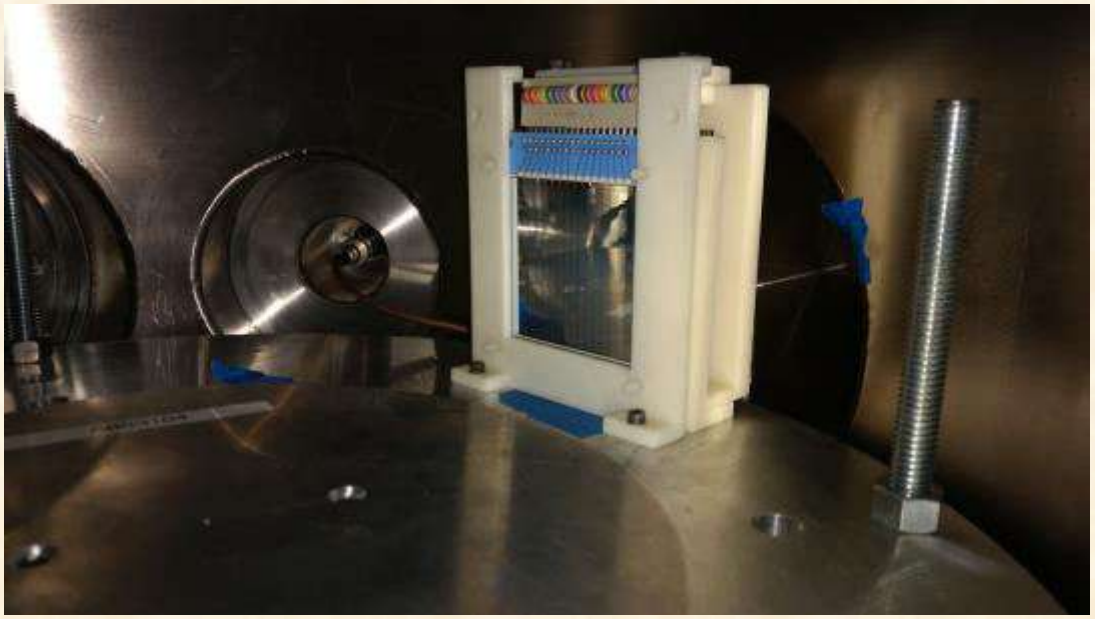
$^{12}C+^{12}C$	$^{20}Ne+\alpha$	Q=4.62 MeV
$^{12}C+^{12}C$	$^{23}Na+p$	Q=2.24 MeV

4 energies 7 days = 21 BTU.

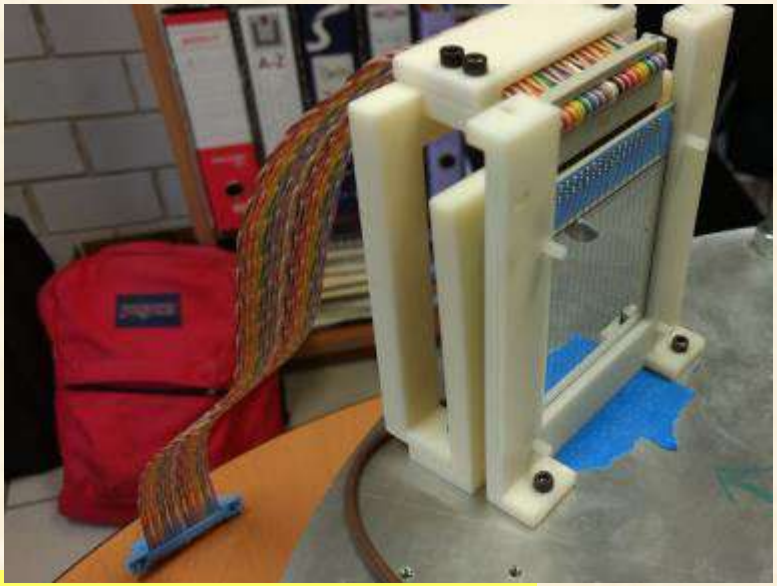




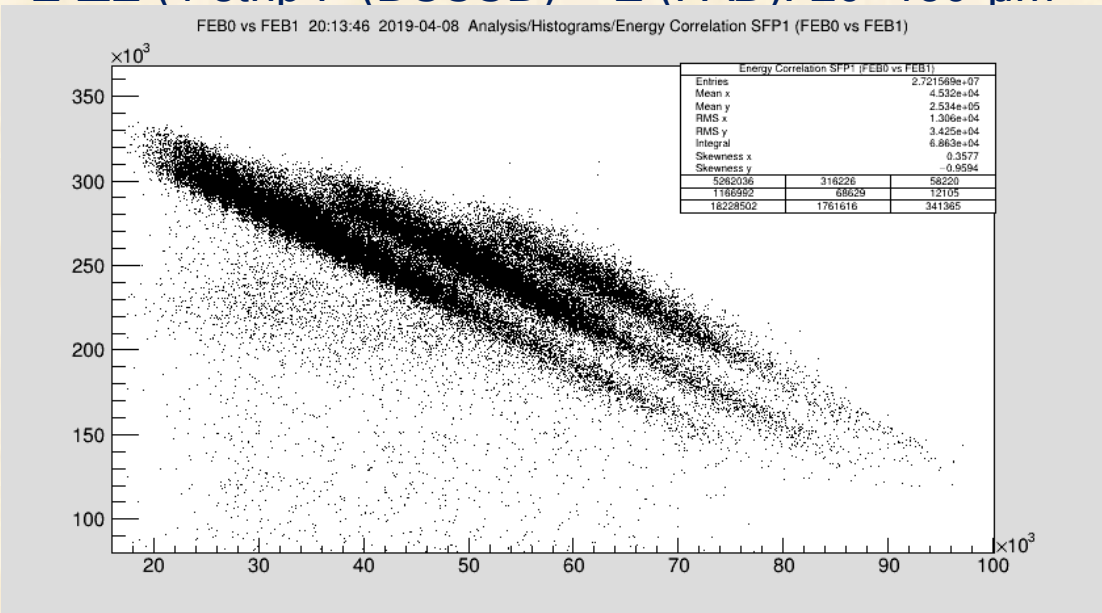
SIMAS commissioning (DSSSD+PAD)



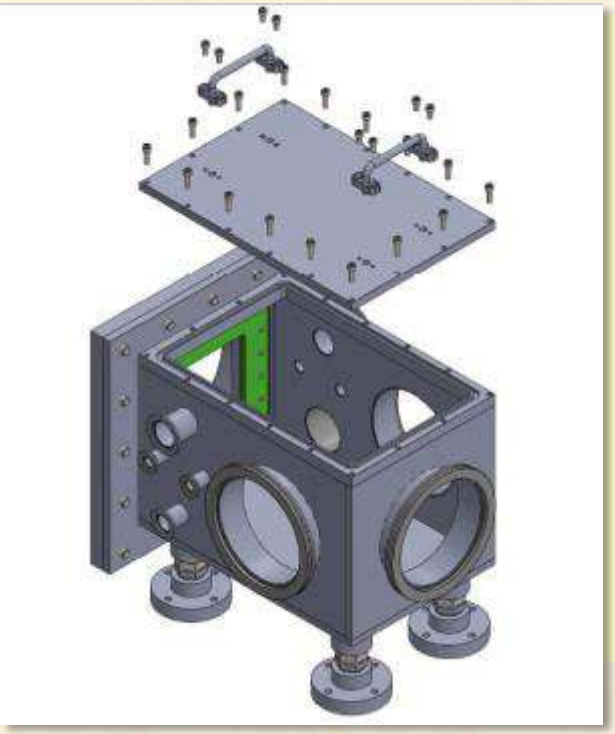
- To continue the $^{12}C+^{12}C$ experiment (solid angle increased substantially).
- Fusion hindrance at sub-barrier energies for weakly bound nuclei on heavy targets: the $^{8}B + ^{208}Pb$ case. A. Pakou, J. Kolata, L. Acosta et. al., (TwinSol, Notre Dame, August'19)



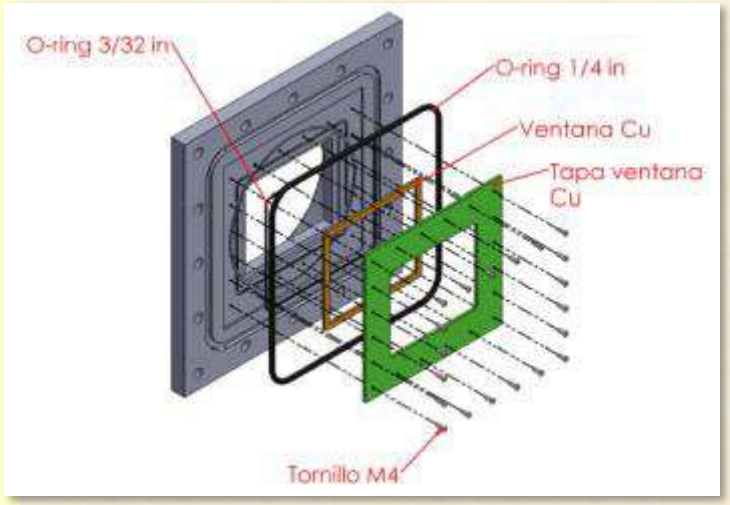
E-ΔE (1 strip P (DSSSD) + E (PAD). 20+130 μm

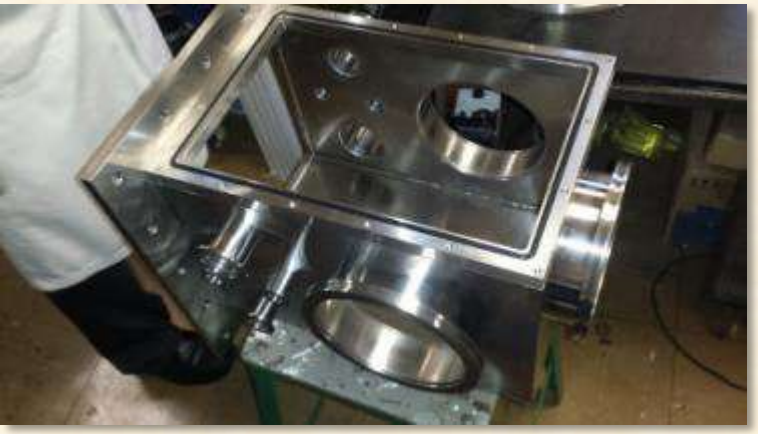


Other capabilities: IF-UNAM workshop



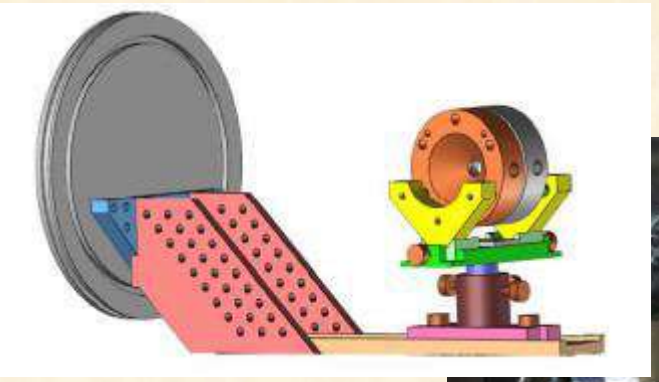
- As part of NUMEN collaboration (F. Cappuzzello talk). It was performed a chamber for a tracker detector prototype
- It was designed and manufactured totally at IFUNAM workshop.

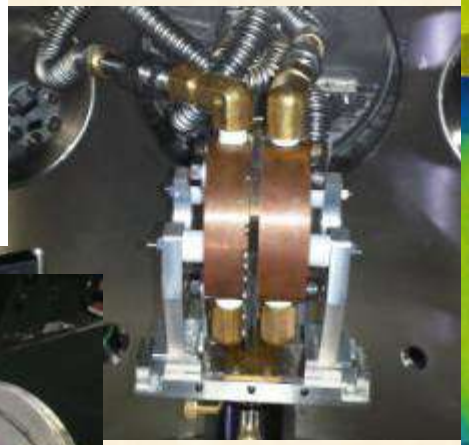


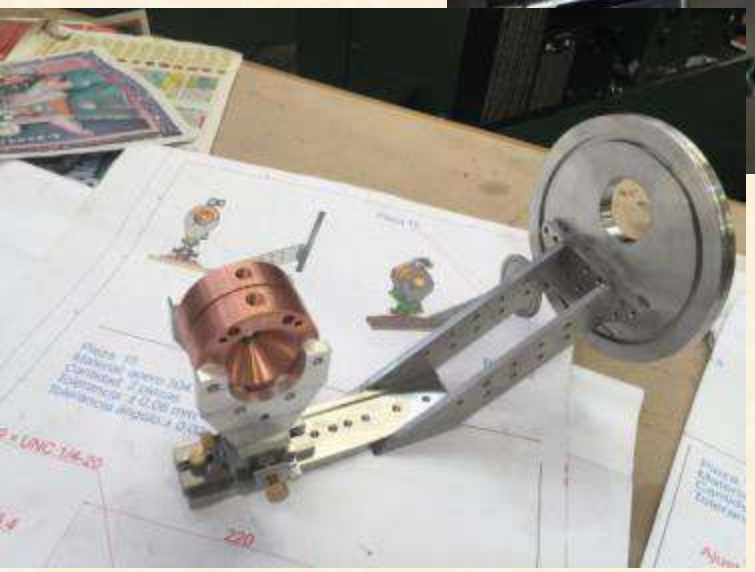


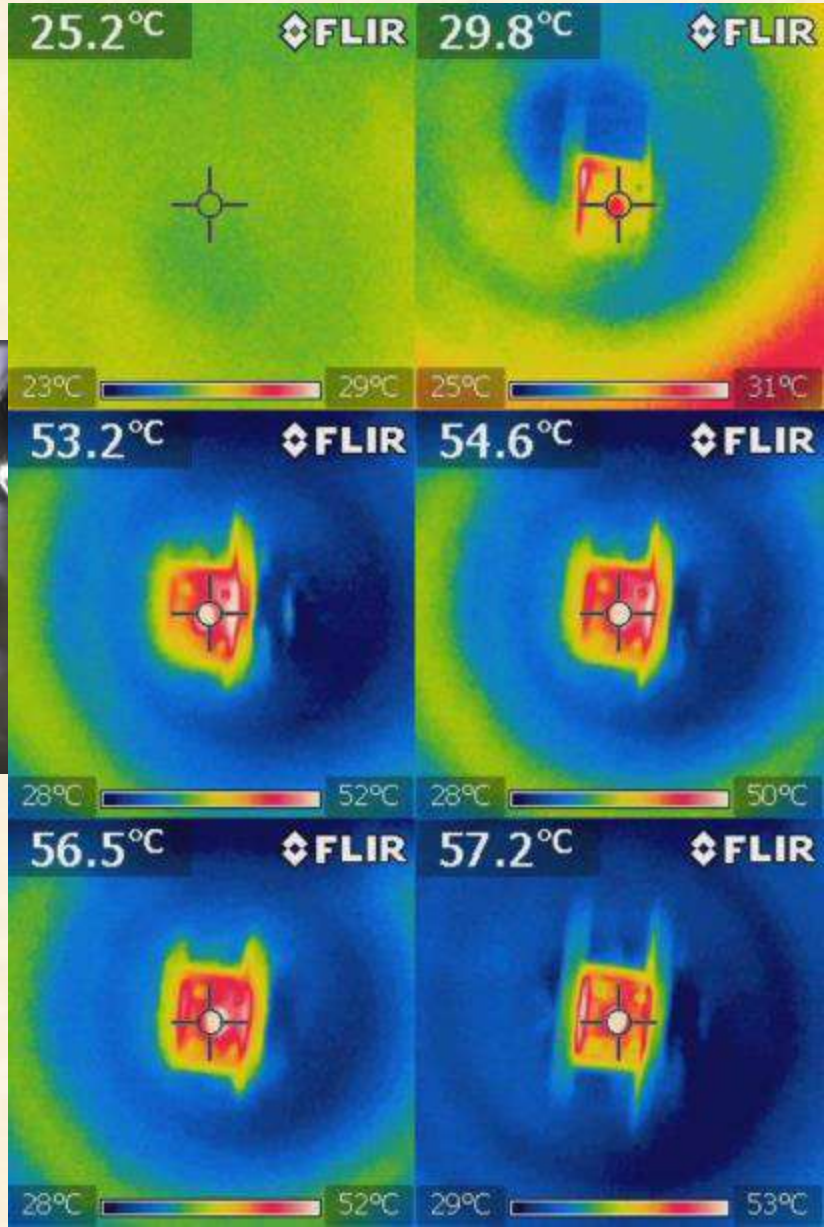
Target test for NUMEN Project (LEMA-ININ)

- The main idea was to evaluate the resistance to high beam intensity of prototype targets for the NUMEN Project.
- The first of this experiment was developed at LEMA and ININ facilities (Jun 2018 in collaboration with INFN-Torino and LNS-INFN.
- 3 and 16 MeV ^{12}C beams (1-7 μA) in Sn and Te targets.



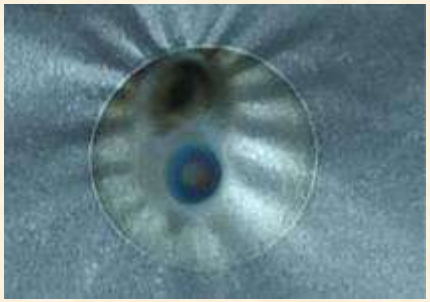


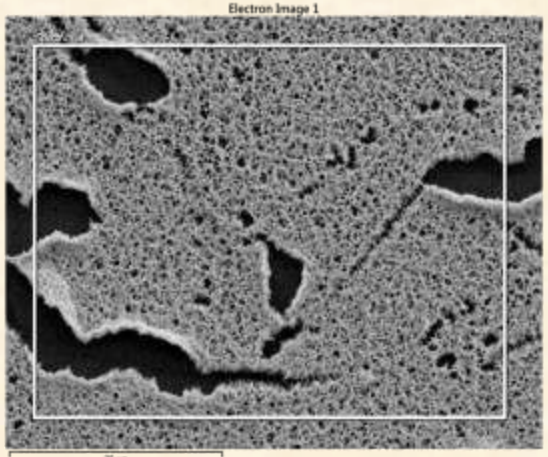


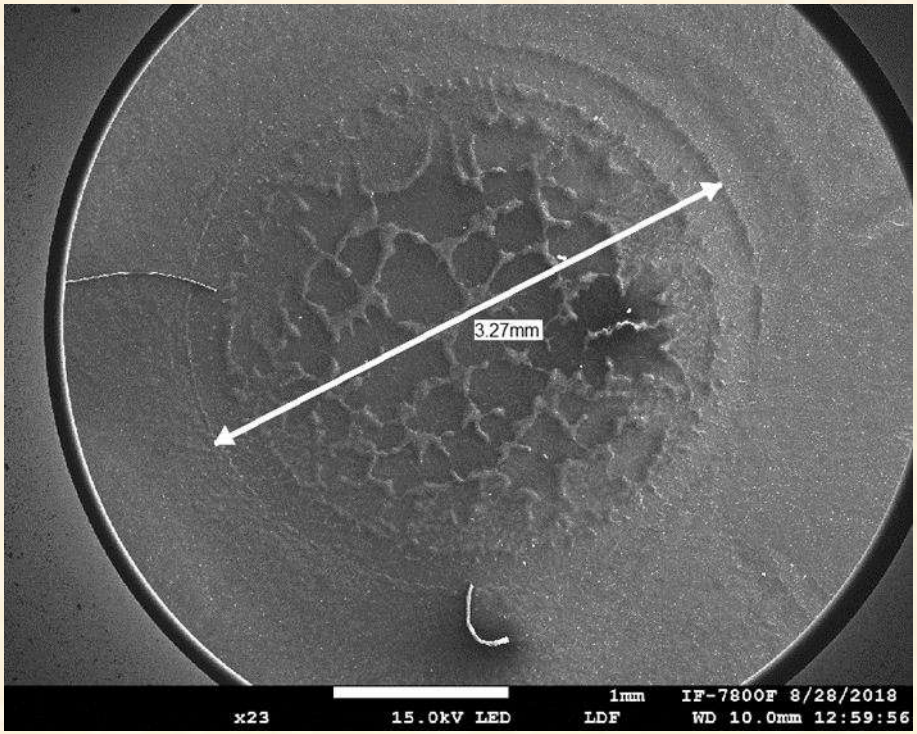


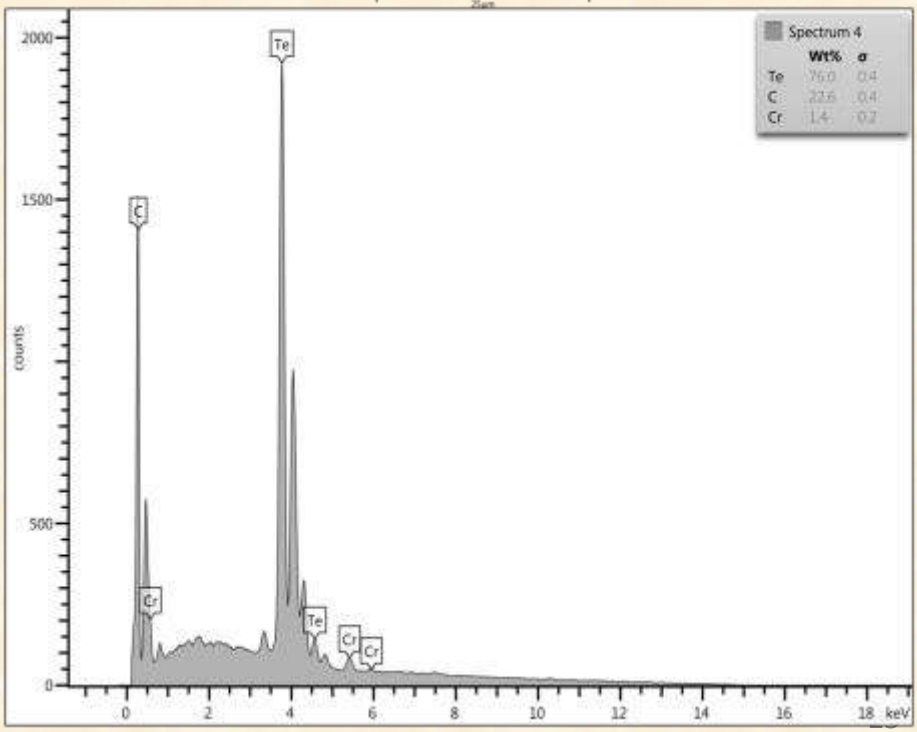
Analysis after irradiation: Central Microscopy Lab (IF-UNAM).

- By mean of EDX-SEM (energy disperse X ray spectroscopy; Scanning electron microscopy) is possible to make a further analysis of the irradiated targets where may be identified the elements that compose the sample









Summary.

- In this talk were described the facilities for nuclear physics studies (low energies) presently working at Mexico (IF-UNAM, ININ).
  - Van de Graaff Accelerator (5.5 MV).
  - Tandem Accelerator (6 MV).
  - Research reactor.
  - Mass Spectrometry Accelerator (LEMA-1 MV).
  - Low-energy LEMA-line.
- Thanks to an important economical injection (by Mexican Council CONACYT, DGAPA-UNAM, PIIF-IFUNAM), all these facilities are been complemented with modern systems to improved measurements and to open new possibilities.
- The cited systems were:
  - New beam-lines.
  - Gas target.
  - A novel array for charge particle identification at low energies SIMAS.
  - 128 channels of a digital data acquisition system (FEBEX3).
  - other detectors and workshop capabilities.
  - Central Laboratory of Microscopy.
- Some examples of research developed in collaboration was as well presented.
- Searching for new ideas and studies, we are totally open to establish new collaborations.

Instituto de Física

Thank you for your attention

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