Study of (alpha,n) reactions in Spain

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On behalf of the
MANY collaboration

(alpha,n) reactions

Scientific motivation

Nuclear data on (alpha,n) reactions are important for:
- **Nuclear astrophysics**. Source of neutrons for the s-process, “light” r-process.
- **Rare-event experiments**. Neutron-induced background in underground experiments (dark matter, neutrinos, neutrinoless double beta decay).
- **Nuclear technologies**. Fission and fusion reactors, spent fuel management and nonproliferation. Neutron-induced background in particle accelerators.

MANY collaboration: **M**easurement of **A**lpha **N**euntron **Y**ields
A joint effort with the aim to carry out measurements of (α,xn) reactions using existing facilities in Spain

Detection techniques:
- Direct neutron counting
- Neutron Time-of-Flight Spectroscopy
- Activation
- Gamma spectroscopy

Physical magnitudes:
- Reaction Yields
- Cross sections
- Neutron spectra
- Angular distributions

The MANY Collaboration

Two Spanish facilities

Infraestructuras Científicas y Técnicas Singulares

CMAM

HiSPANoS

CNA Centro Nacional de Aceleradores

UPC

Universidad de Sevilla

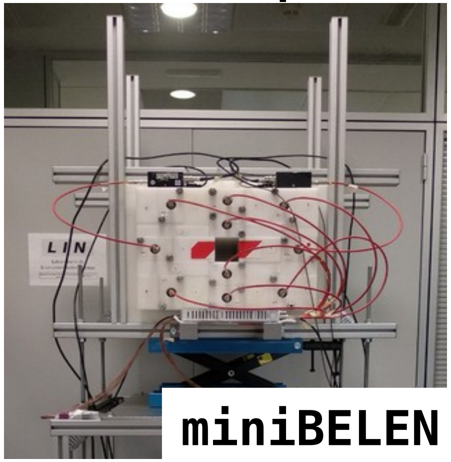
IFIC Institut de Física Corpuscular

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

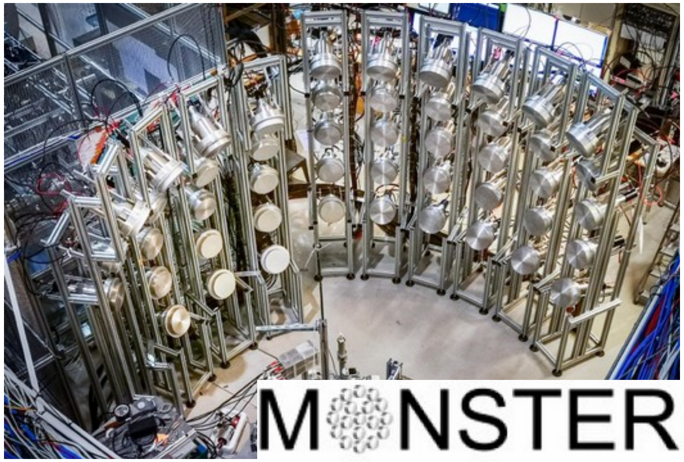
Universidad Complutense Madrid

IEM Instituto de Estructura de la Materia

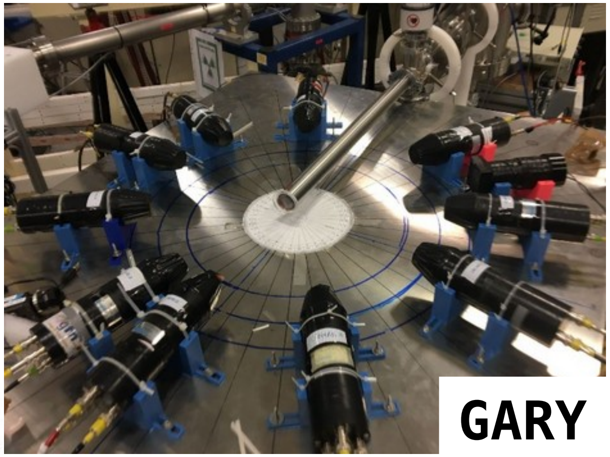
Three Spanish detectors



miniBELEN



MONSTER

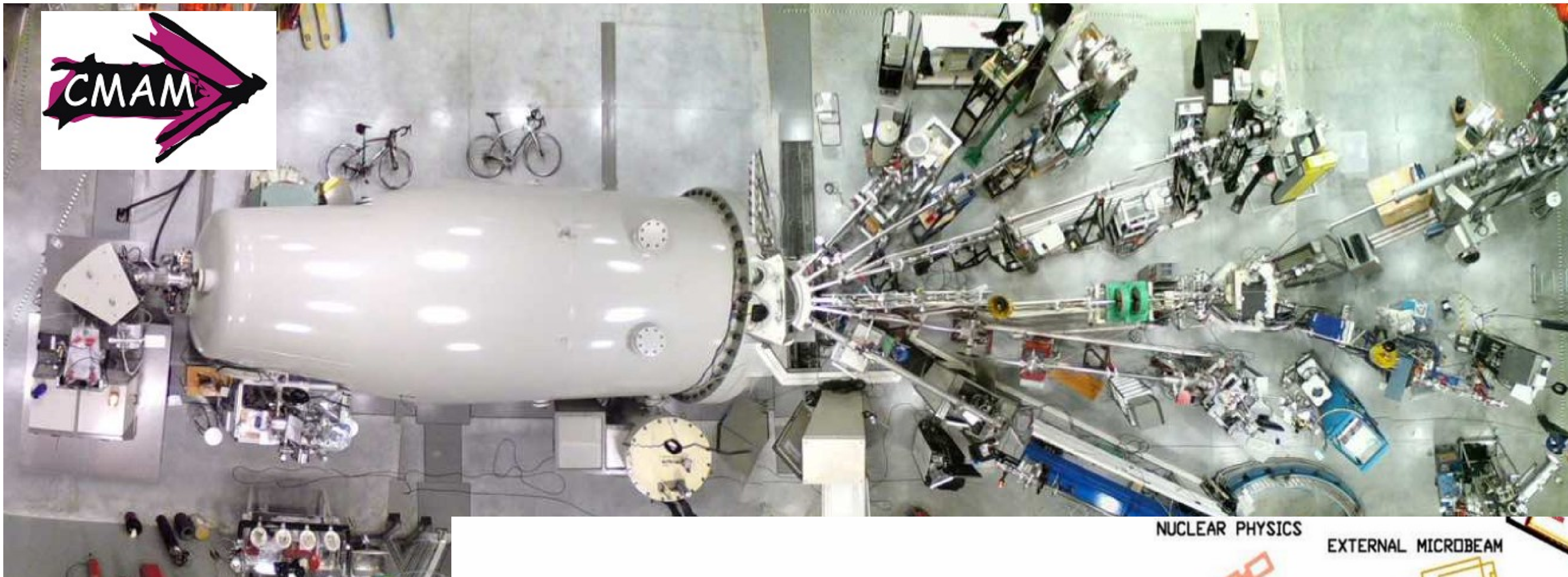


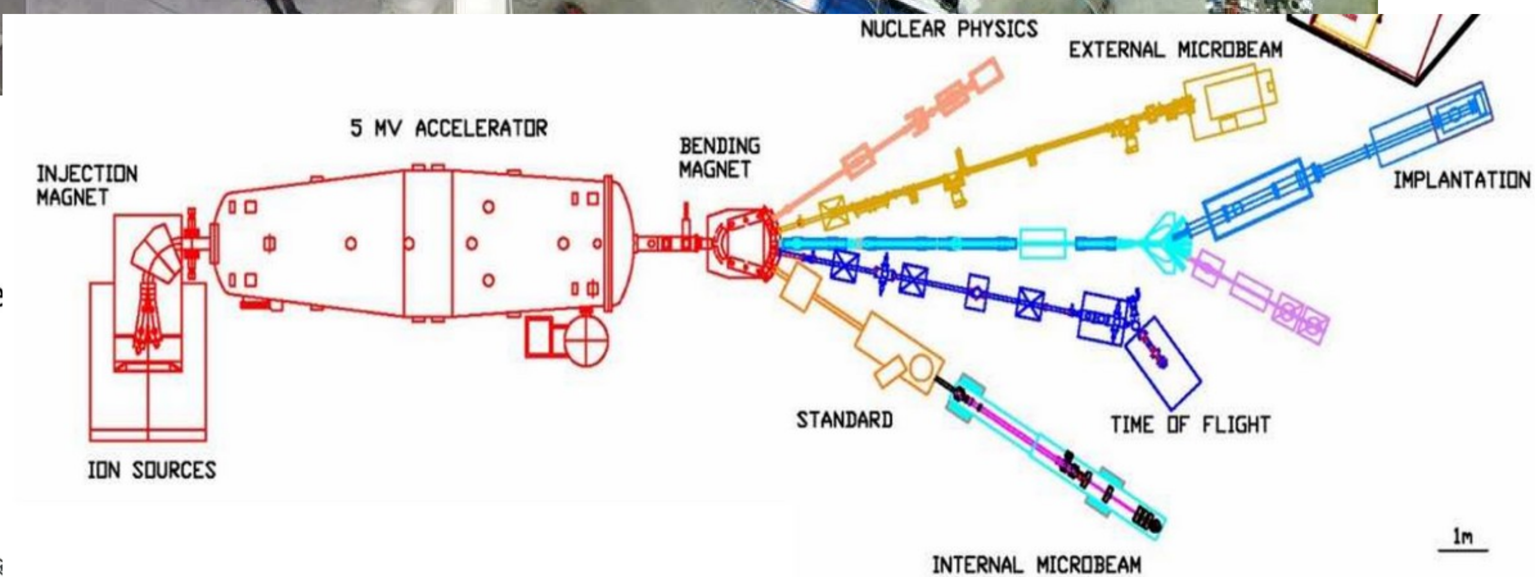
GARY

Facilities: Centre for Micro Analysis of Materials (CMAM)

Maximum of (Z+1) x 5 MeV beams, minimum energy below 300 keV with decent ripple.

Terminal voltage was originally calibrated using 11 different nuclear reactions. Recalibration was required after replacement of faulty diodes (2013), about 0.3% deviation found.



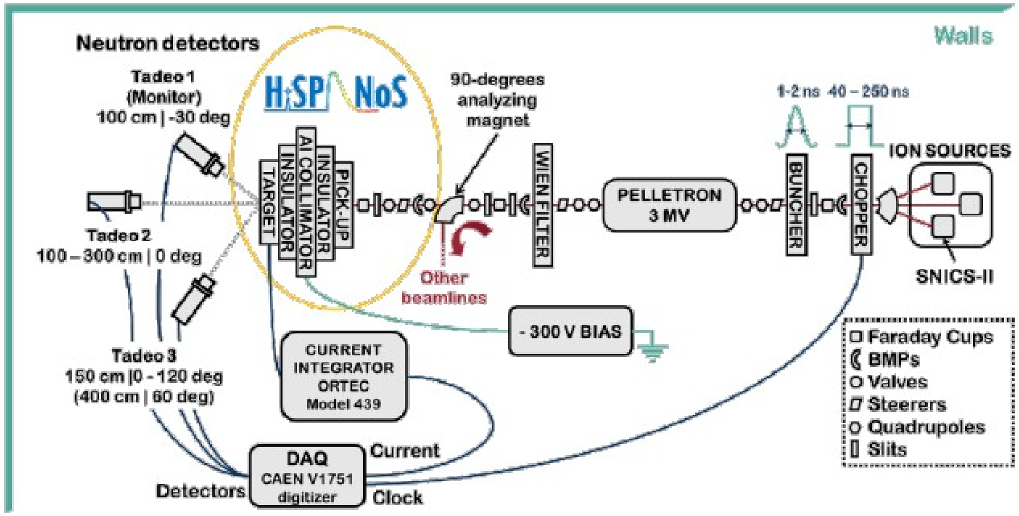


HVee tandem
5 MV maximum terminal voltaje
Cockroft-Walton acceleration

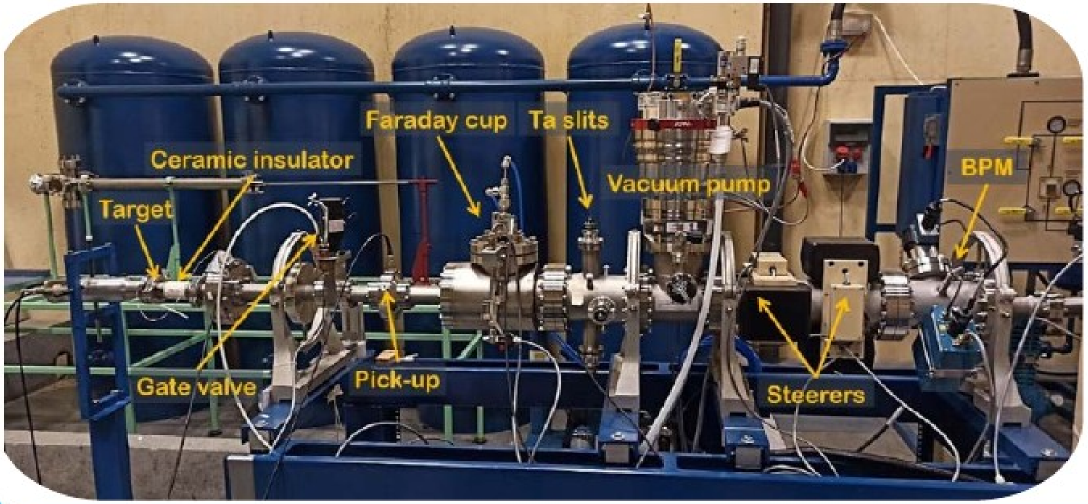
Courtesy of LM Fraile

The HiSPANoS neutron source @CNA

- HiSPANoS is **the first Accelerator-based neutron source** in Spain and it is installed at the the 3 MV Tandem Accelerator.
- Operates since:
    - **2013** in continuous mode
    - **2018** in pulsed mode

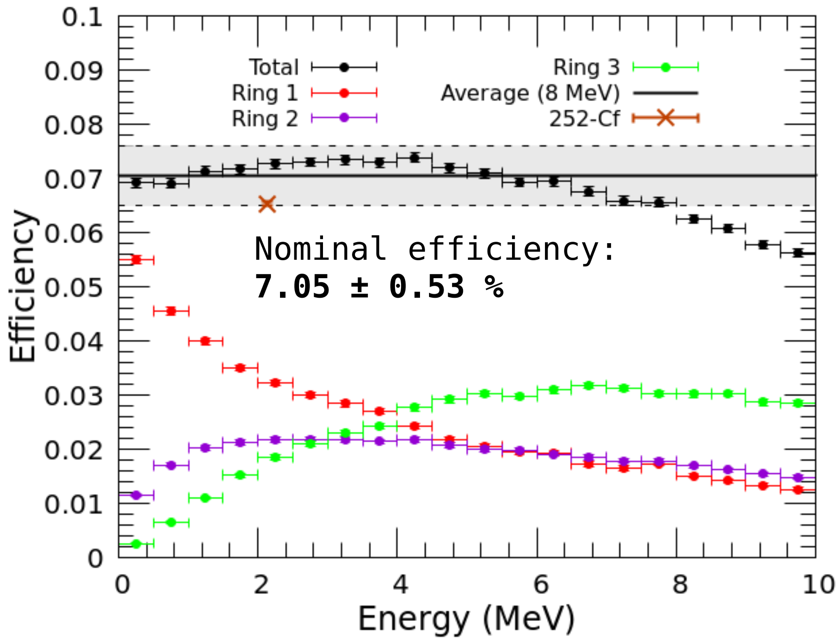


Courtesy of C Guerrero

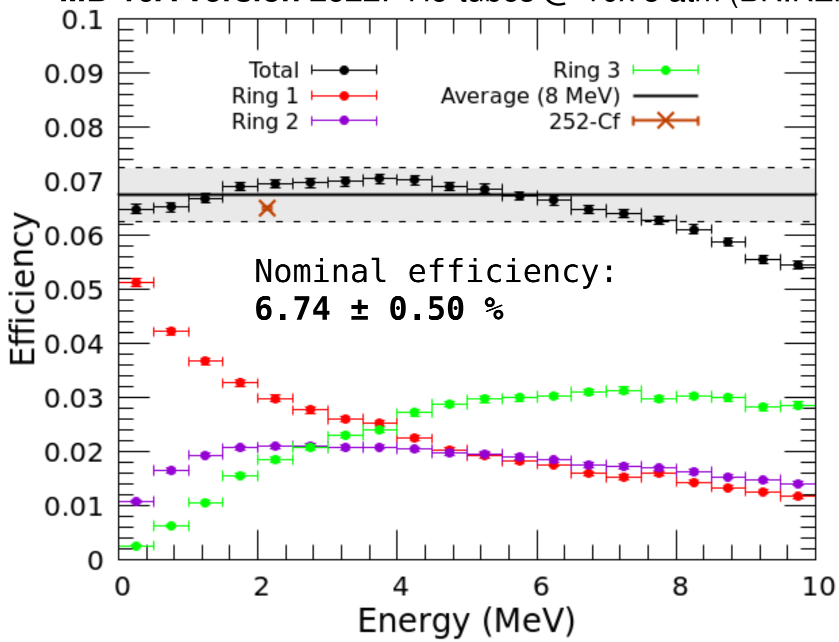


Detection systems: MiniBELEN-10A

MB-10A version 2021: ^{3}He-tubes @ 7x 10 atm, 1x 4/8/20 atm

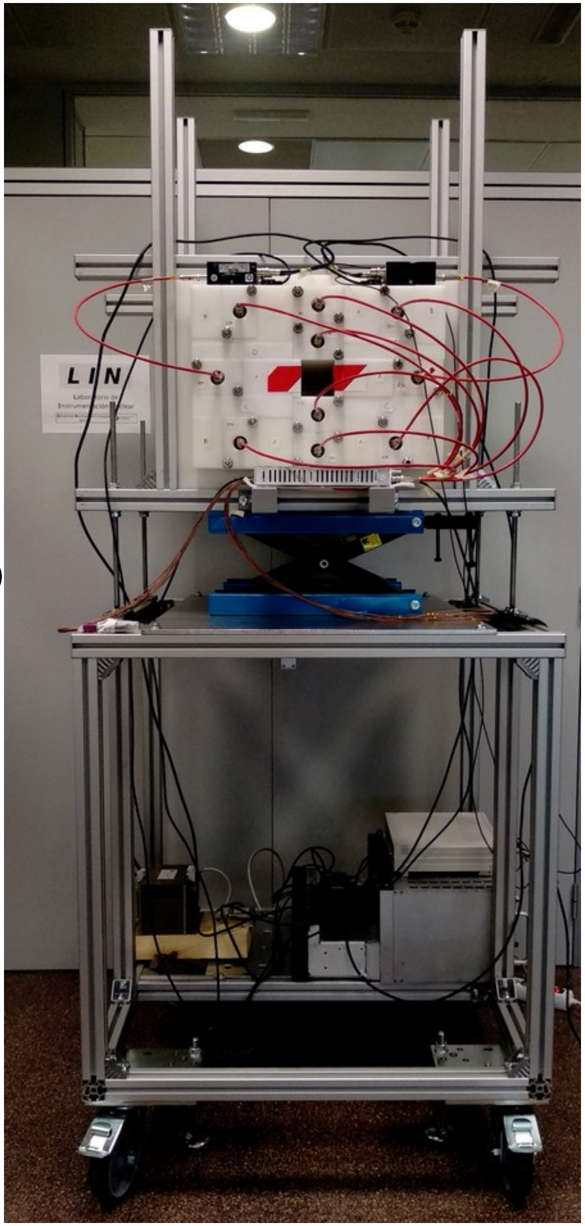


MB-10A version 2022: ^{3}He-tubes @ 10x 8 atm (BRIKEN)



MC simulations by the Geant4 application ***ParticleCounter***.

Particle Counter



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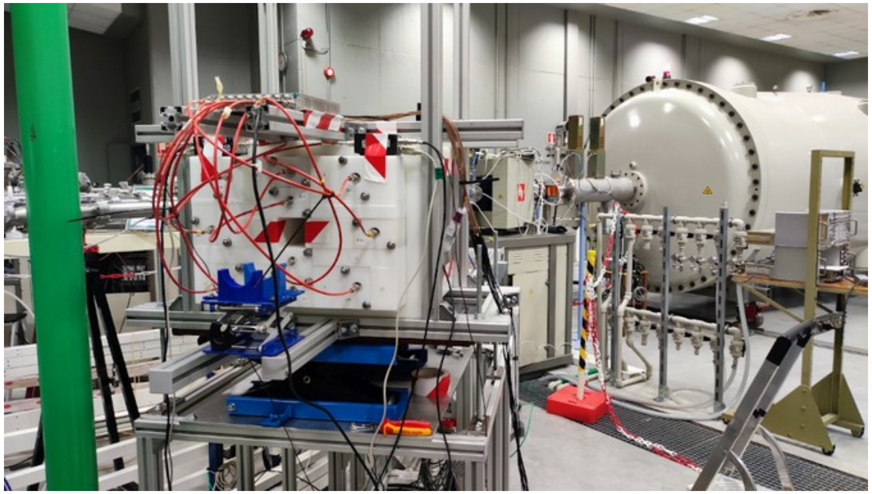
Institut de Tècniques Energètiques

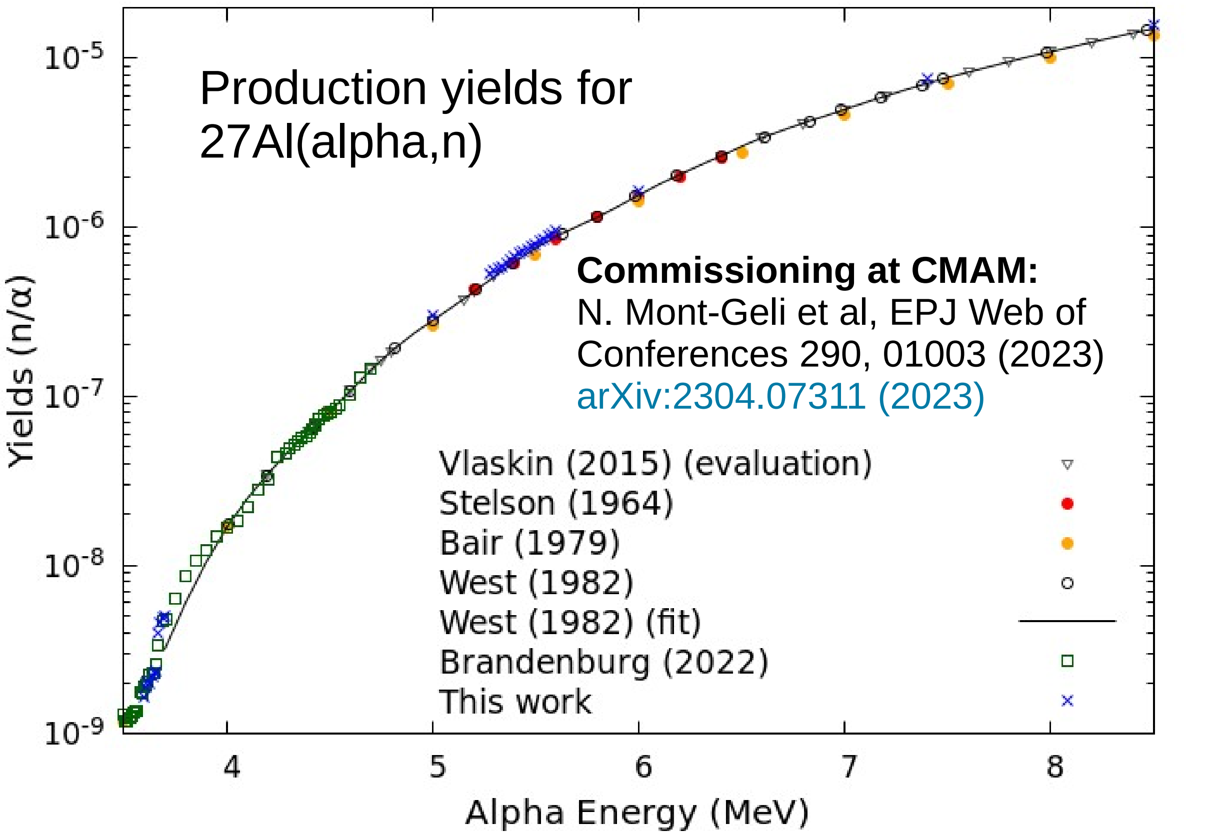
IFIC INSTITUT DE FÍSICA CORPUSCULAR

- Detector assembled and operative since Jan 2021.
- Nominal efficiency fully determined by MC simulations (GEANT4).
- Experimental characterization by means of NMC with ^{252}Cf source. ***Good agreement with G4 simulations.***
- Detector table designed to be compatible with beamlines at CMAM and CNA.

N. Mont, PhD thesis (UPC)

MiniBELEN commissioning 45º beamline @ CMAM (Madrid)





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Universidad de Sevilla
GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
IEM
CMAM

Detection systems: MONSTER

MONSTER

MOdular Neutron time-of-flight SpectromeTER is a detection system designed for DESPEC

MONSTER TDR, (2013)

It's the result of an international collaboration between CIEMAT, JYFL-ACCLAB, VECC, IFIC, and UPC

Main characteristics:

- Low neutron energy threshold
- High intrinsic neutron detection efficiency
- Discriminates between detected neutrons and γ-rays by their pulse shape
- Good time resolution
- The energy of the neutrons is determined with the TOF technique

A. R. Garcia *et al.*, JINST, **7**, (2012) C05012
T. Martinez *et al.*, Nuclear Data Sheets, **120**, (2014) 78

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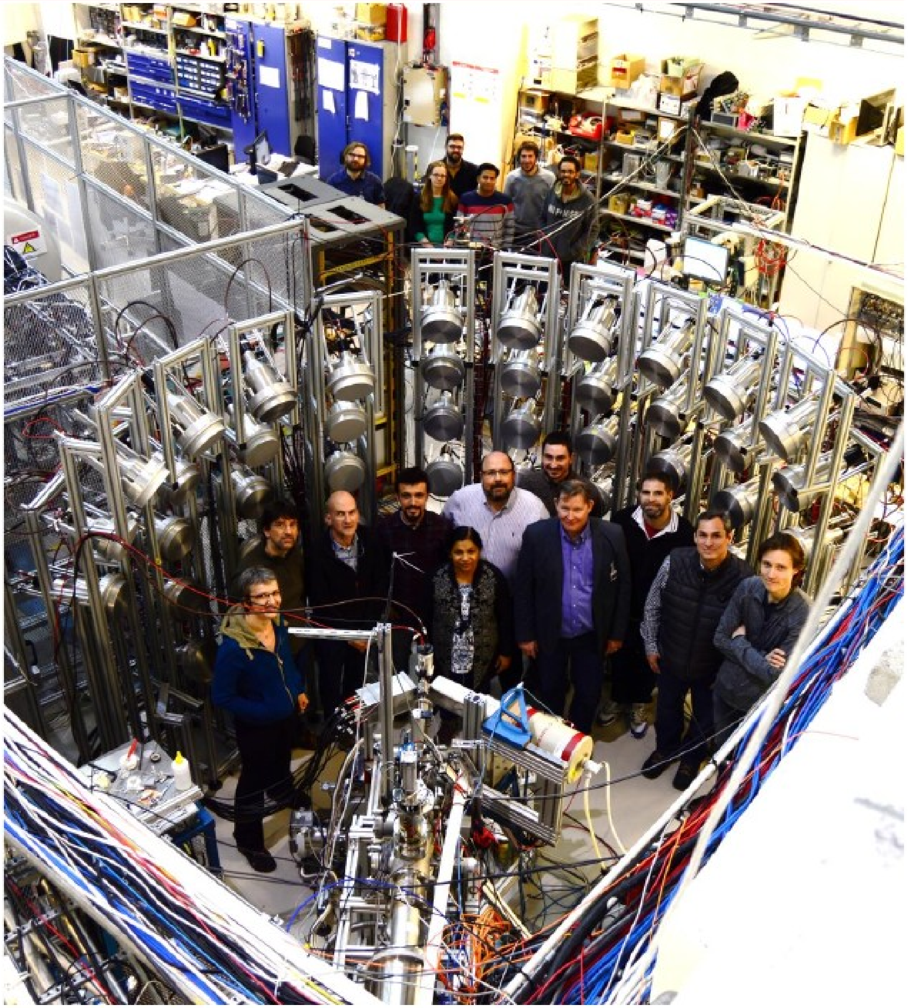
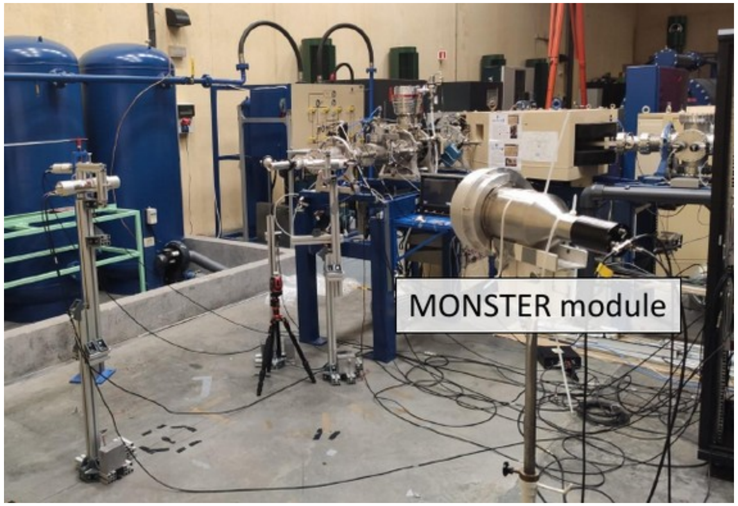
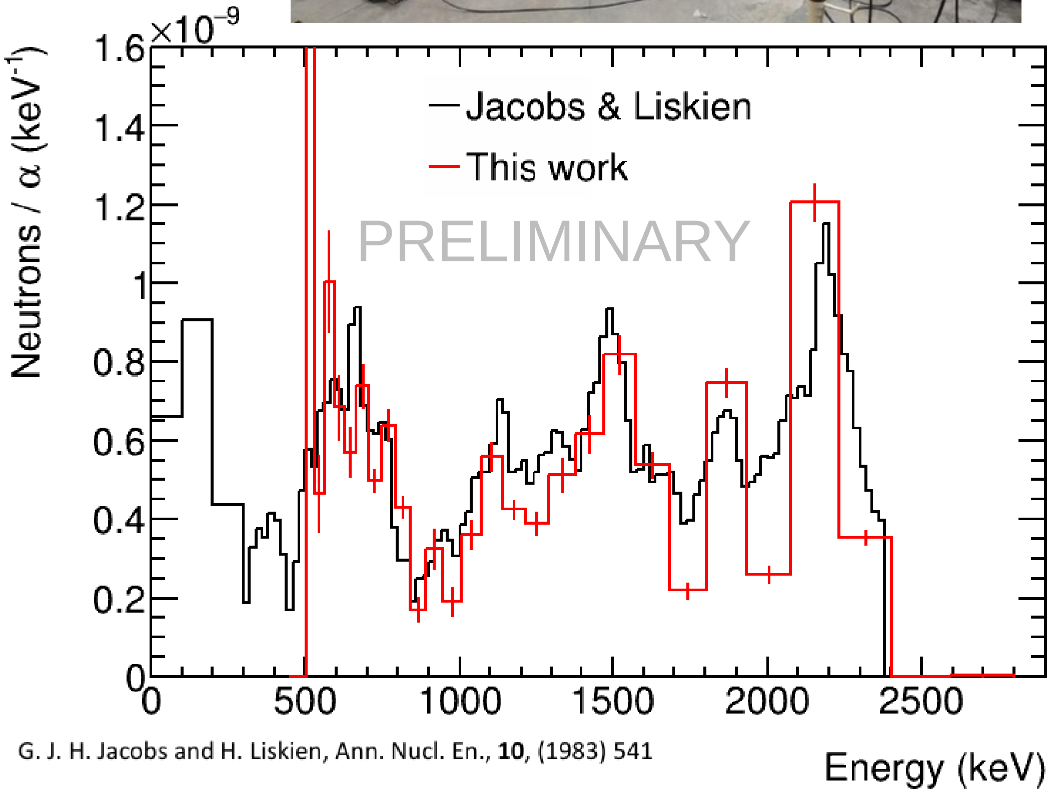


Courtesy of A Perez de la Rada

Detection systems: MONSTER





G. J. H. Jacobs and H. Liskien, Ann. Nucl. En., **10**, (1983) 541

Courtesy of A Perez de la Rada

Thick (300 μm) 27Al (99 % purity) target
Eα = 5.5, 7, and 8.25 MeV
(Buncher not optimized for α-particles)

Uncertainties

Jacobs and Liskien:

- Target stability, charge measurement: 2.0 %
- Neutron detection efficiency: 3.2 - 5.2 %
- Integration procedure: 2.6 %
- Statistics: 2.0 %
- Neutron energy determination:
  - 0.5 % @ 200 keV
  - 1.7 % @ 7 MeV

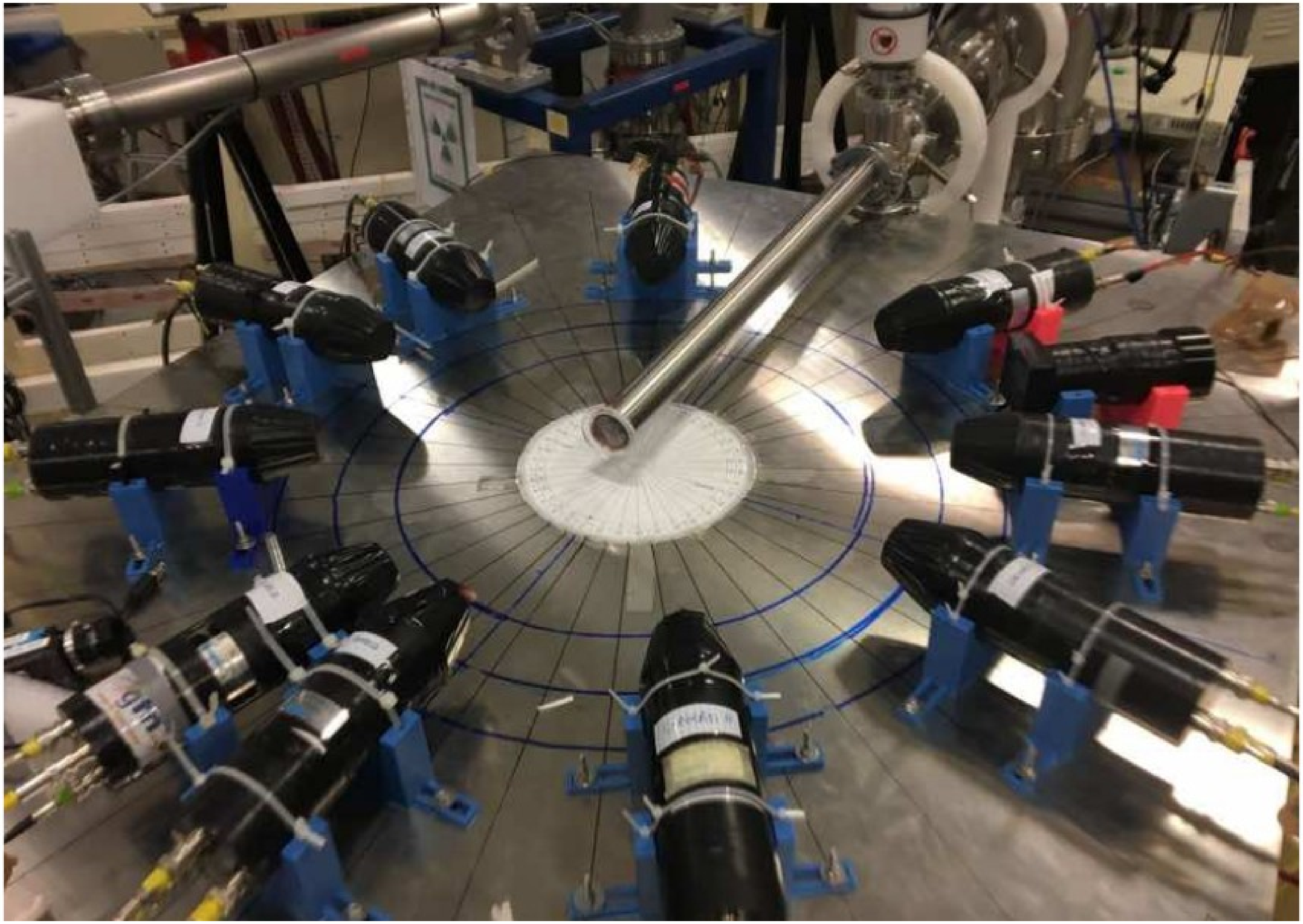
This work:

- Statistical
- Systematic (only):
  - Efficiency
  - Flight path
  - TOF resolution

Neutron yields

Threshold (keV)	Y_n^{JL}/Y_n
500	1.05
900	1.09
1750	1.01

Detection systems: GARY



Gamma-detector array for Alpha-induced Reaction Yield measurements

$LaBr_3(Ce)$ based array

HPGe detectors

Monitoring neutron detectors

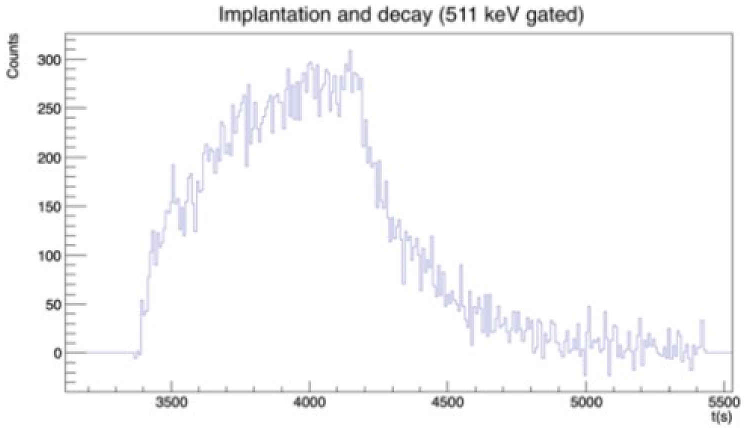
Courtesy of LM Fraile

UNIVERSIDAD COMPLUTENSE MADRID

Activation measurements at CMAM

thick-target yields in 27Al(alpha,ng)

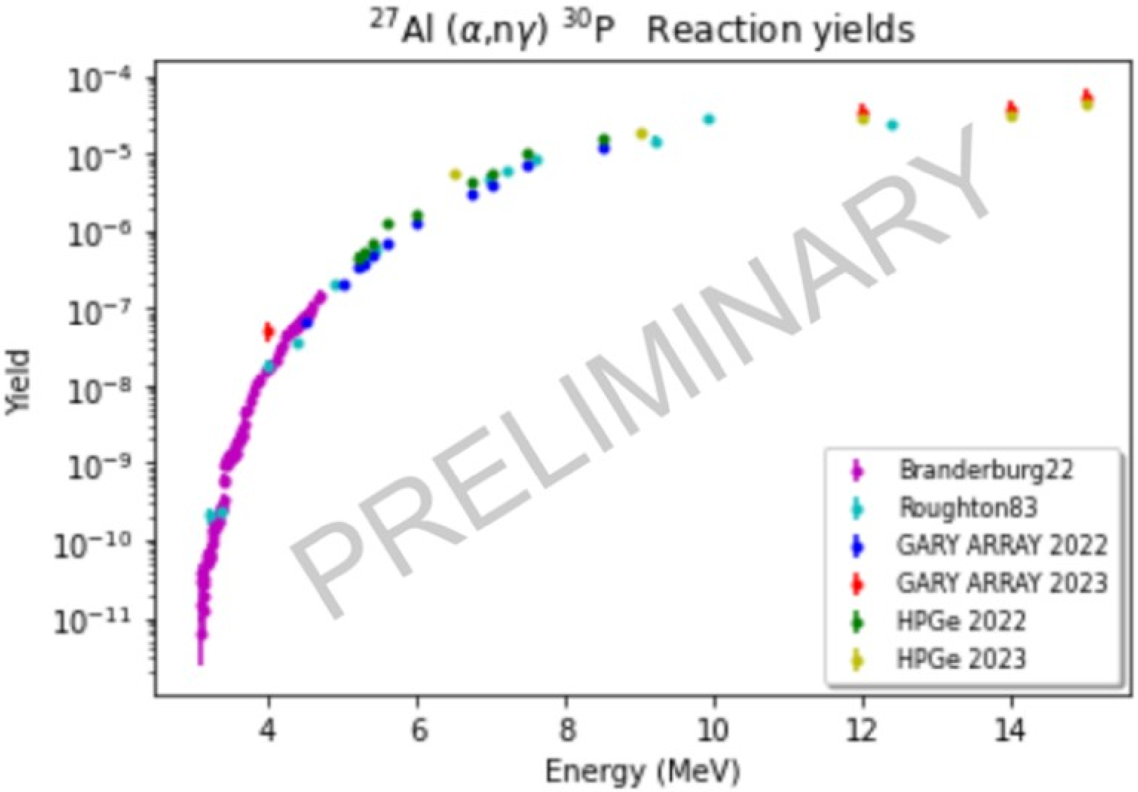
Activation measurements



- Using decay of 511 keV when possible
- Using total rate (activation + decay)
- Using activation time

HPGe seems to work fine

$LaBr_3(Ce)$ array



Courtesy of LM Fraile

The MANY collaboration:

V. Alcayne[6], A. Algora[2], O. Alonso-Sañudo[3], J. Balibrea-Correa[2], J. Benito[3], M. J. García-Borge[5], J. A. Briz[3], F. Calviño[1], D. Cano-Ott[6], G. Cortés[1], A. De Blas[1], C. Domingo-Pardo[2], A. Espinosa[3], B. Fernández[7], L. M. Fraile[3], G. Garcia[4], R. García[1], V. García-Tavora[4], J. Gómez-Camacho[7], E.M. González-Romero[6], C. Guerrero[7], A. Illana[3], J. Lerendegui-Marco[2], M. Llanos[3], T. Martínez[6], V. Martínez-Nouvilas[3], E. Mendoza[6], N. Mont-Geli[1], JR. Murias[3], E. Nácher[2], A. Nerio-Aguirre[5], V. V. O. Onecha[3], S. Orrigo[2], M. Pallàs[1], A. Perea[5], A. Pérez de Rada[6], V. Pesudo[6], J. Plaza[6], J.M. Quesada[7], A. Sánchez[6], V. Sánchez-Tembleque[3], R. Santorelli[6], J.L. Tain[2], A. Tarifeño-Saldivia[2], O. Tengblad[5], J.M. Udías[3], D. Villamarín[6] and S. Viñals[4]

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THANKS!