La fuente de Neutrones del CNA: HiSPANoS

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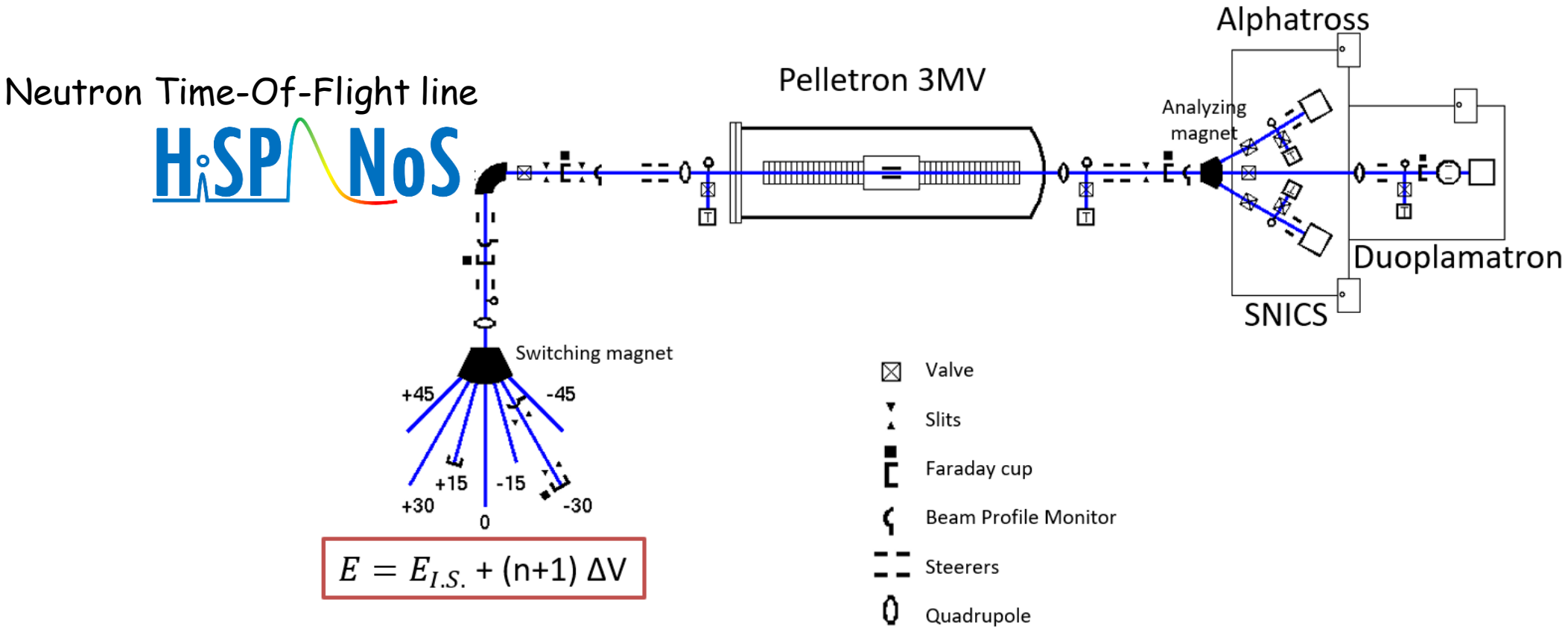
J. Praena (Universidad de Granada)

HiSPANoS
CNA Centro Nacional de Aceleradores
Universidad de Sevilla
CSIC Consejo Superior de Investigaciones Científicas
UNIÓN EUROPEA
FONDO EUROPEO DE DESARROLLO REGIONAL
"Una manera de hacer Europa"
Junta de Andalucía
Consejería de Economía, Conocimiento, Empresas y Universidad

HiSPANoS at the 3 MV Tandem Accelerator

- HiSPANoS is the first Accelerator-based neutron source in Spain and it is installed at the the 3 MV Tandem Accelerator.
- HiSPANoS is working in continuous and pulsed mode



$$E = E_{I.S.} + (n+1)\,\Delta V$$

HiSPANoS en el Acelerador Tandem de 3 MV

HiSPANoS is the first Accelerator-based neutron source in Spain and it is installed at the the 3 MV Tandem Accelerator.

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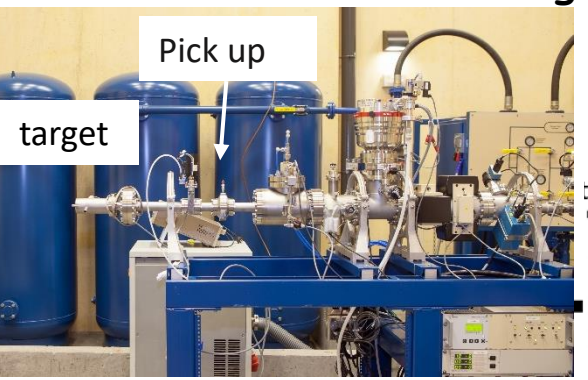
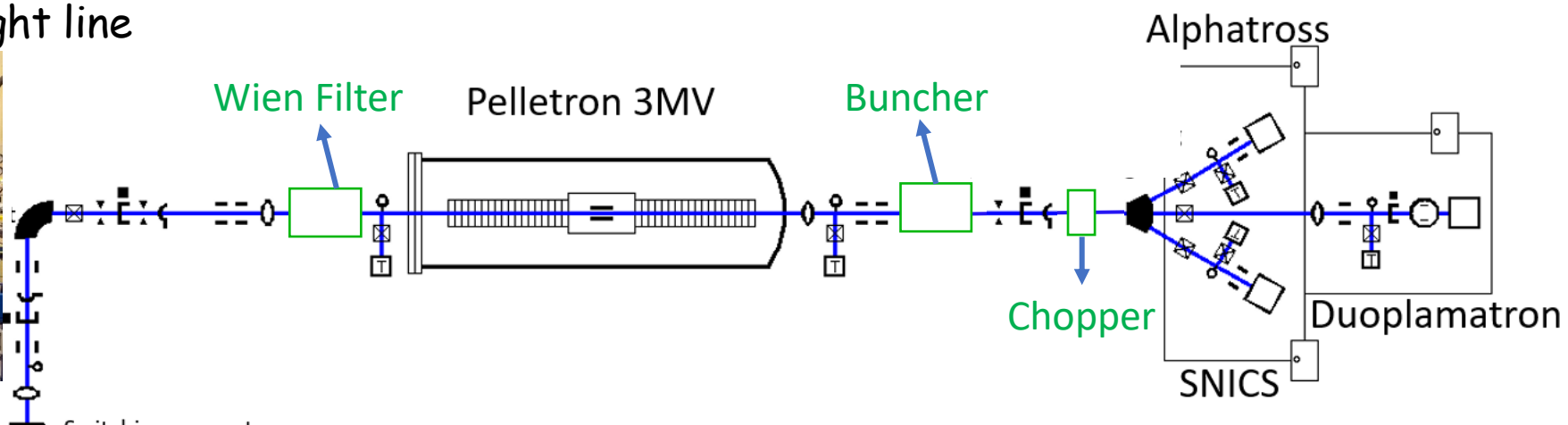
Neutron Time-Of-Flight line

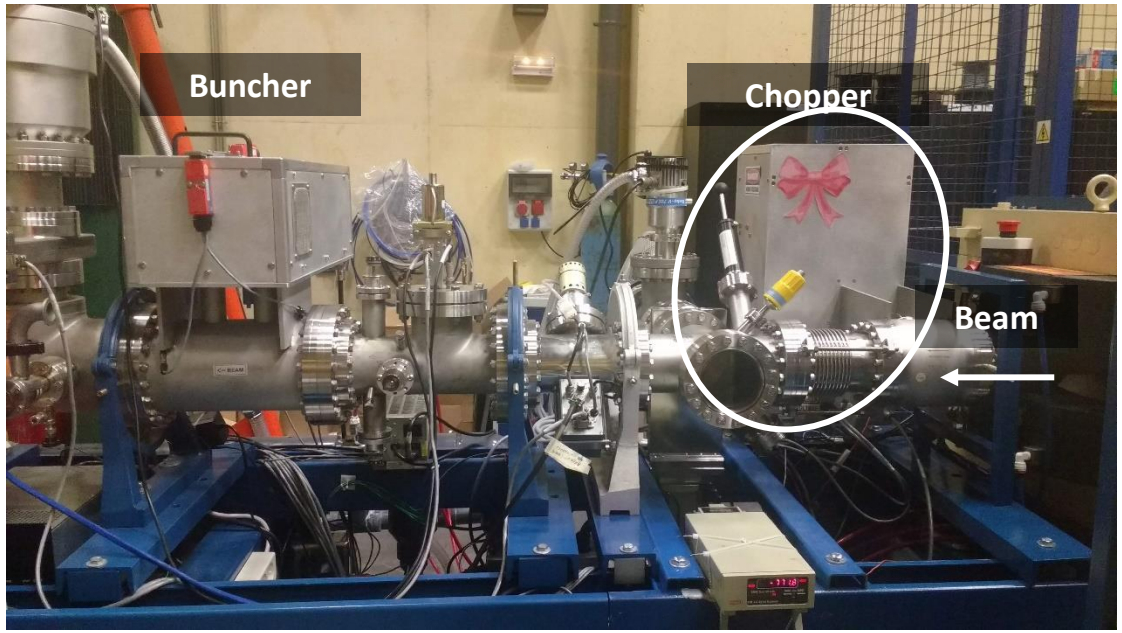




$$E = E_{I.S.} + (n+1)\,\Delta V$$

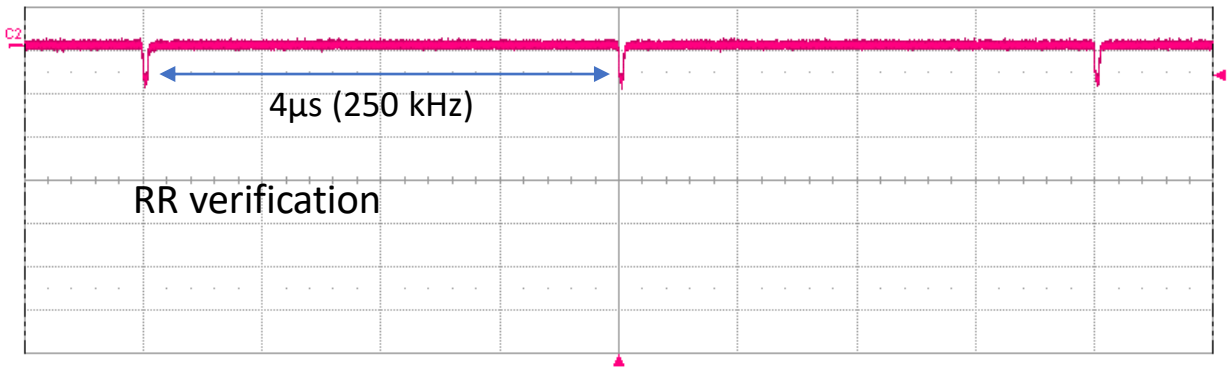
Valve
Slits
Faraday cup
Beam Profile Monitor
Steerers
Quadrupole

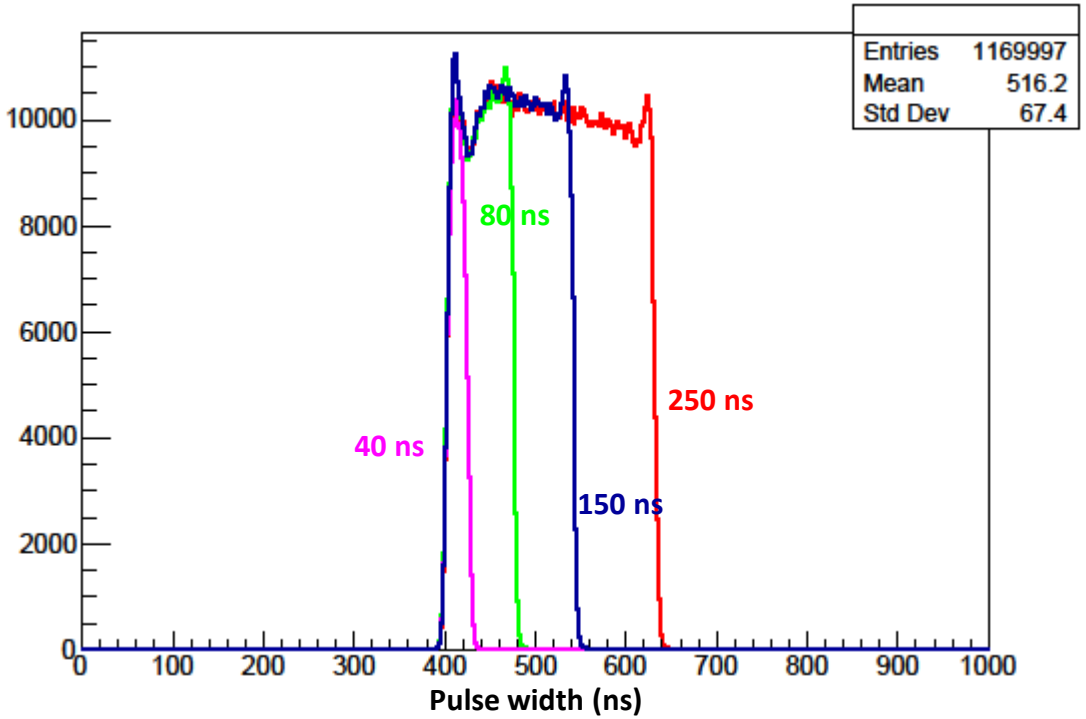
Pulsing system: p,d & α



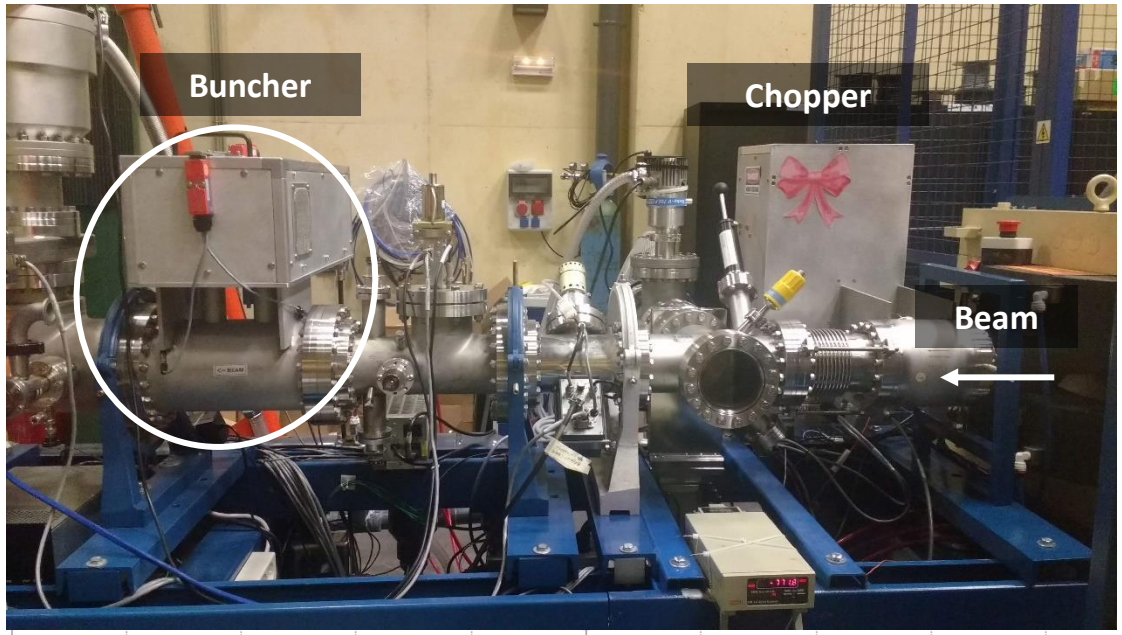
Chopper:

- Variable width: 40 ns-250 ns
- RR: 31.25 kHz-2MHz
- Switcher Voltage: 650 V





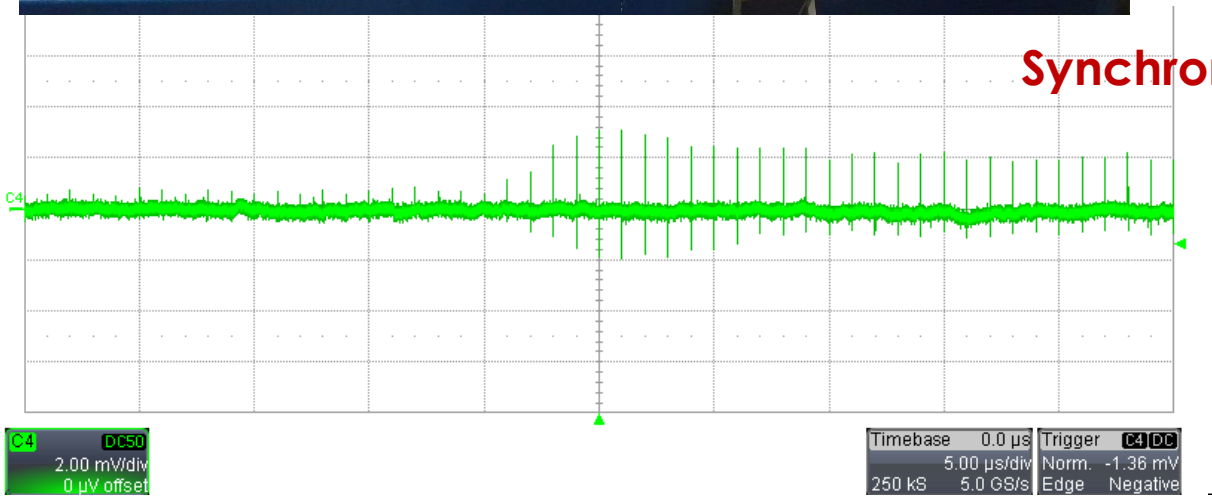
Pulsing system: 1-2 ns p,d & a beams

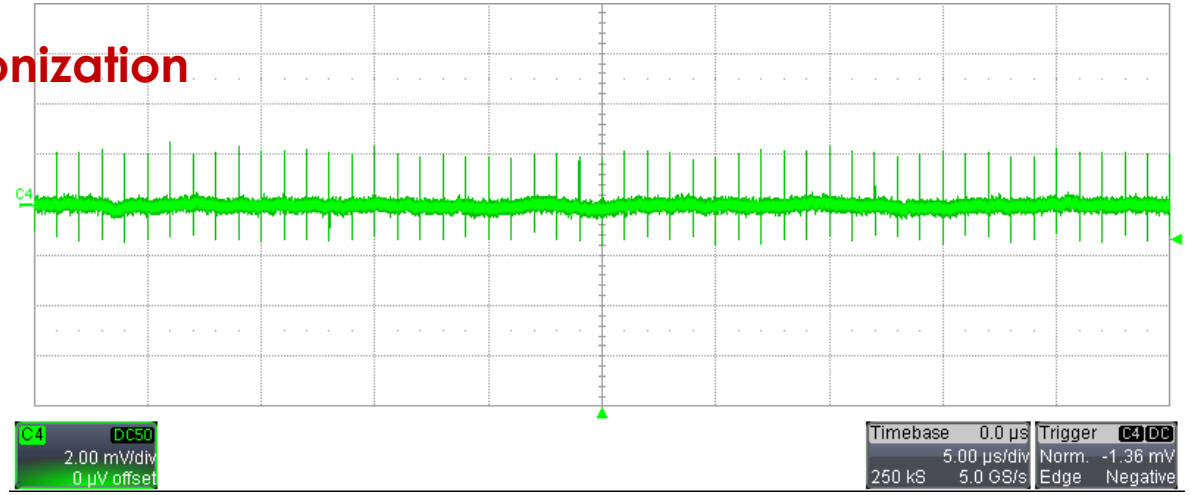


Buncher:

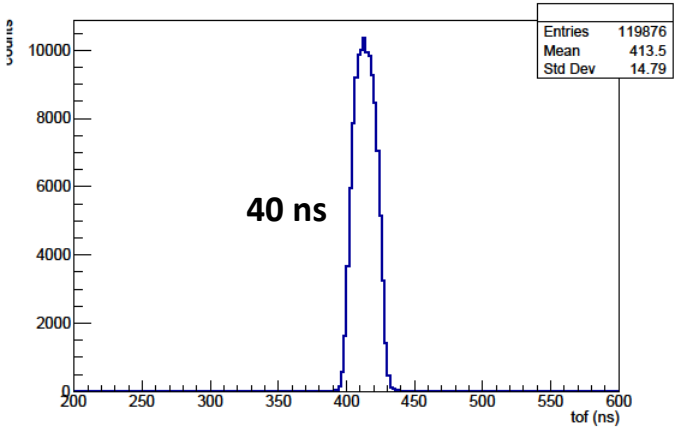
Needs tuning (delay & power) for synchronization

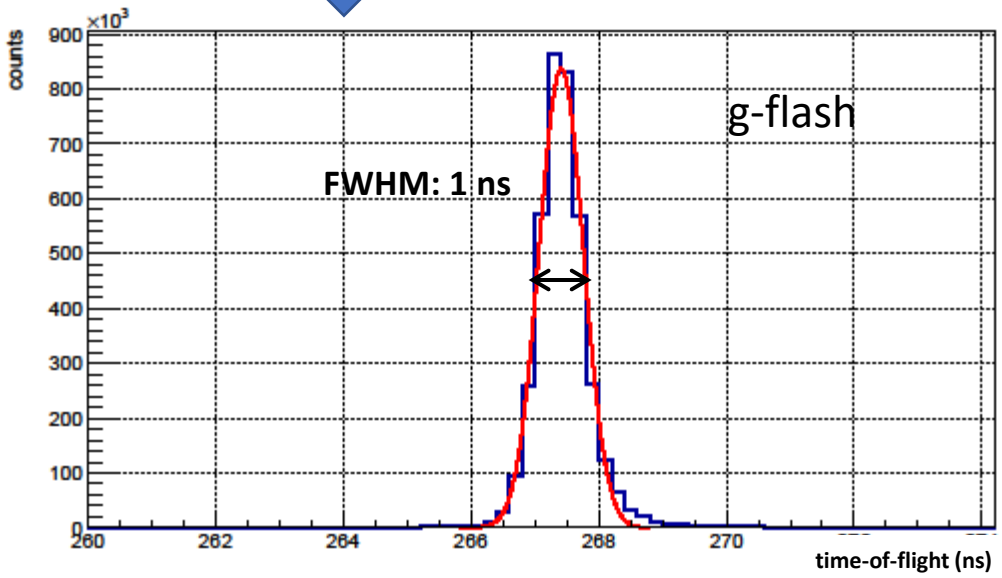
Synchronization

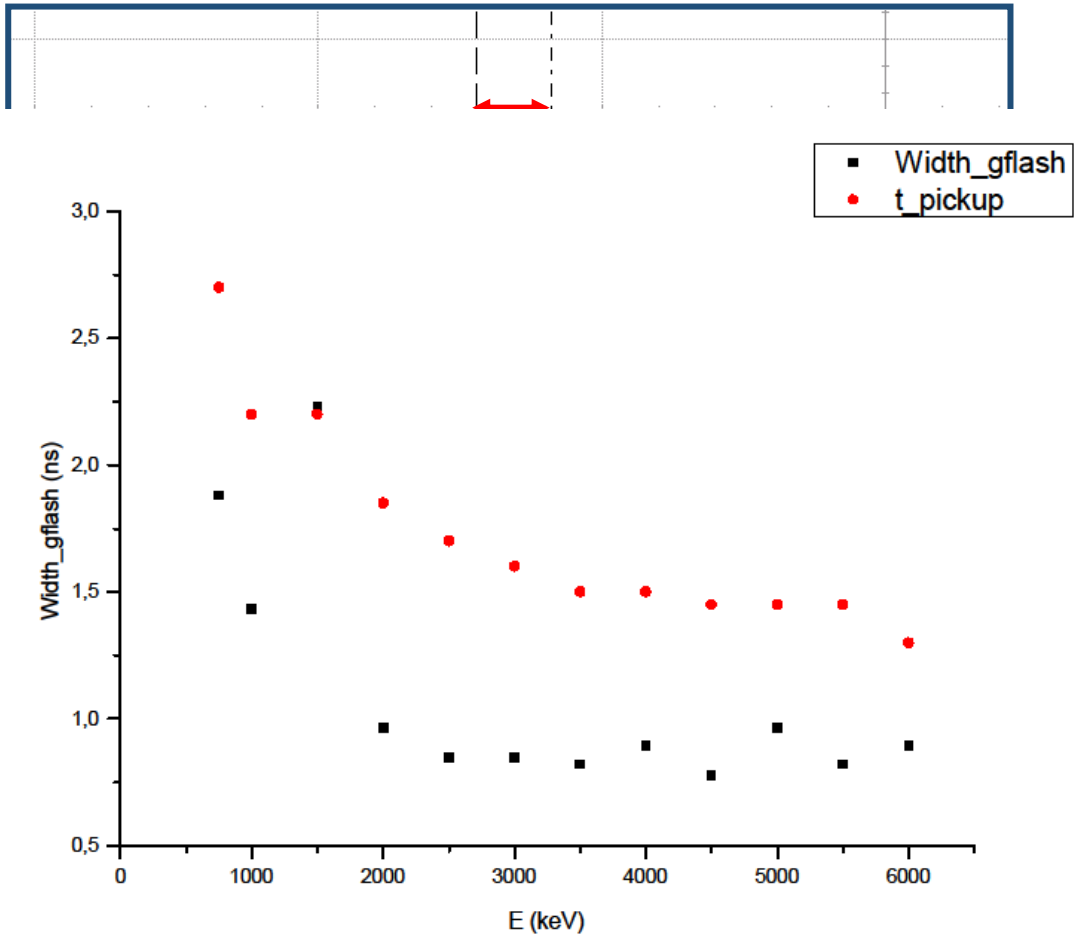




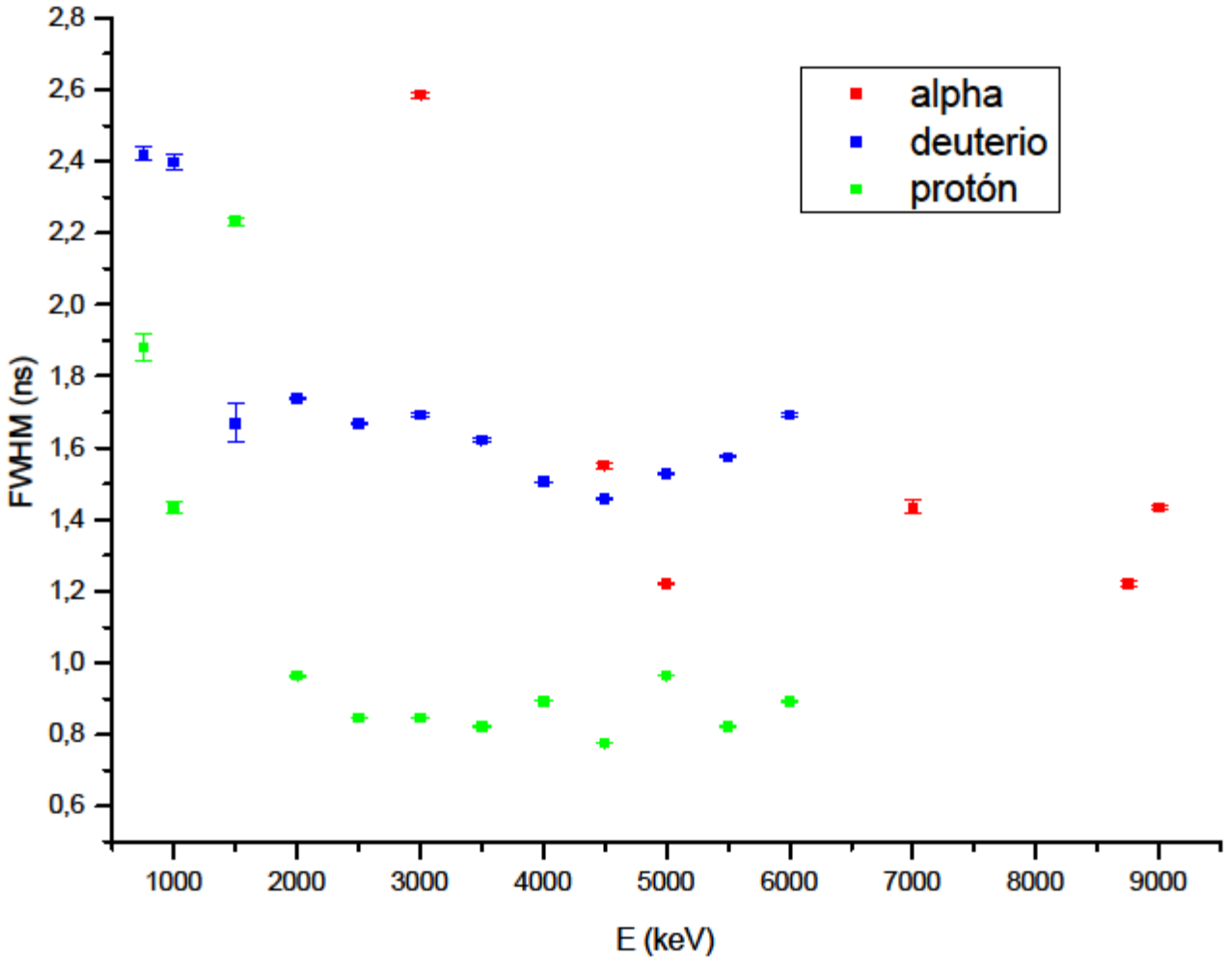
Pulsing system: 1-2 ns p,d & a beams







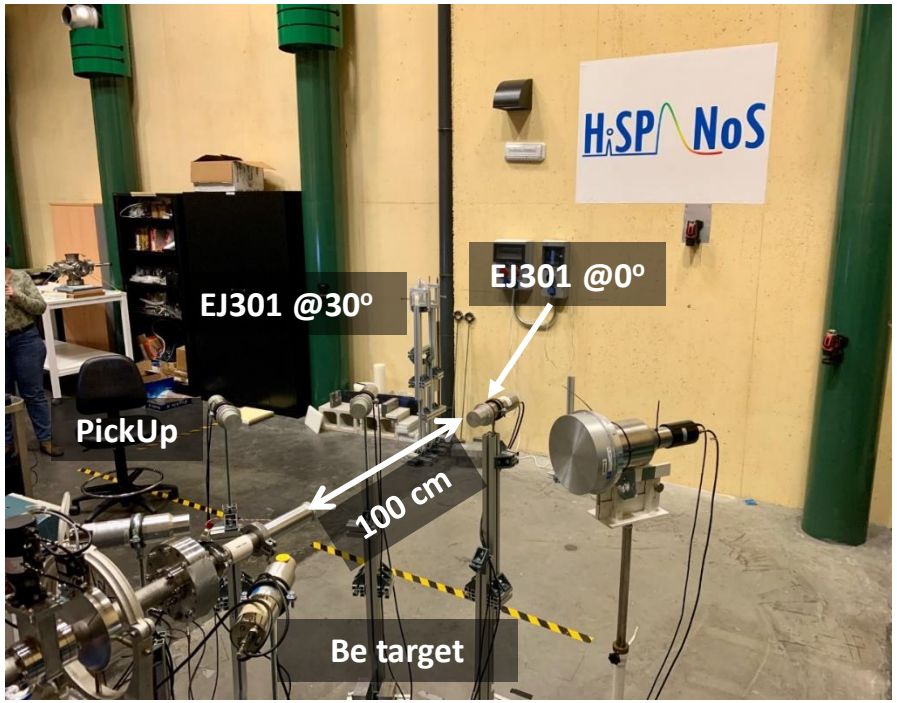
Pulsing system: 1-2 ns p,d & α beams



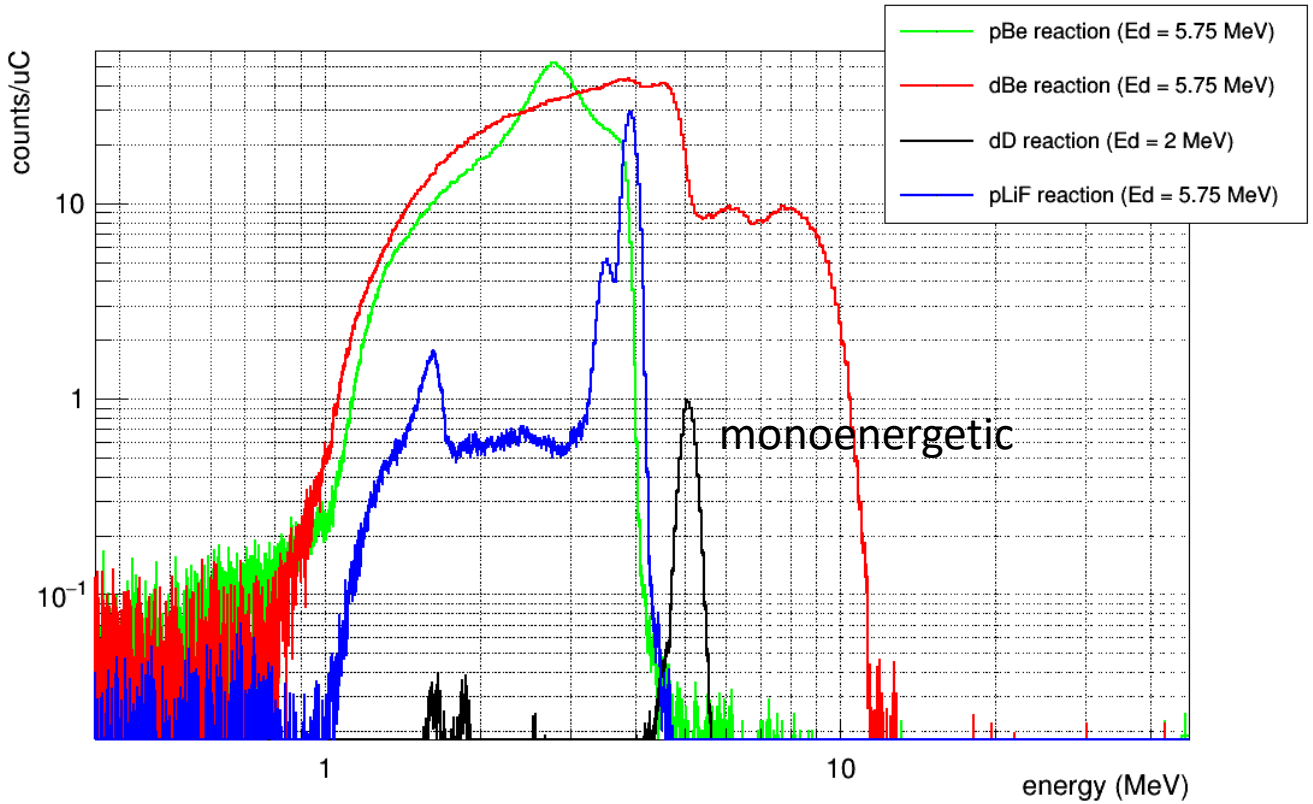
Nuetron production targets/mechanism

Target	Geometry	Reaction [Q value]	E_{beam} (MeV)	Neutron spectra
Li (metallic)	Ø 10 mm Thickness < 1mm	^{7}Li(p,n) [-1.7 MeV]	E_p=1.912	quasi-Maxwellian@kT=30keV Thermal by means of moderation
LiF (Evaporated on Cu)	Ø 30 mm Thickness: 16 µm			
D:Ti >1.5	Ø 30 mm D/Ti (500 µg/cm^2)	D(d,n) [3.3 MeV]	E_d=0.5-6	Quasi-monoenergetic between 3-9 MeV
Be	Square: 25 mm Thickness: 3 mm	^{9}Be(p,n) [-1.9 MeV]	E_p=2.1-6	Continium from keV to E_n~E_p-2.1MeV
		^{9}Be(d,n) [4.4 MeV]	E_d=0.5-6	Fast between 4 and 10 MeV

Nuetron production targets/mechanism

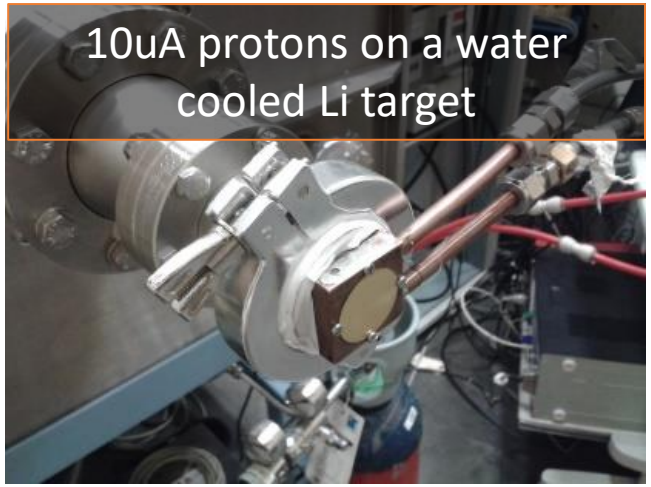


Some HiSPANoS neutron fluxes



What can we do at HiSPANoS???

MACS measurements for astrophysics



Praena et al., NIM-A 727 (2013)

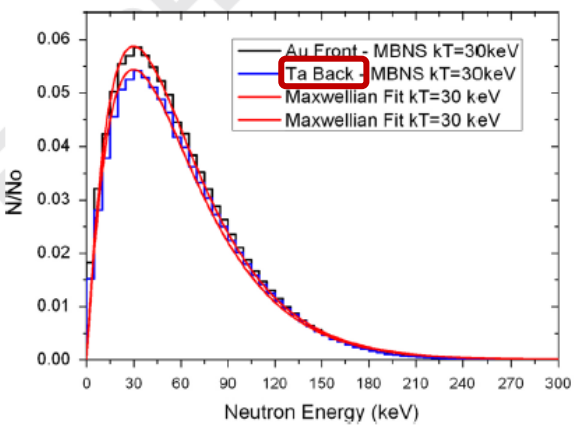


Fig. 3. Neutron spectra obtained with SIMPRO crossing the front surface of the Au sample for the activation at kT=30 keV (black histogram) and back surface of Ta (blue histogram); Maxwellian fits at kT=30 keV are shown by red lines. N is the number of neutrons crossing the samples and N_0 is the total number of neutrons generated in the simulation. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this article.)

Praena et al., NDS 120 (2014)

TABLE I. Summary of corrections and uncertainties (upper panel). The MACS of ^{159}Tb(n,γ) at kT = 30 keV vs experimental data and selected evaluations (lower panel).

Corrections	Value ± Uncertainty(%)
Counting statistics	– ± 0.1
Au self-absorption [9],[23]	0.988 ± 0.2
Tb self-absorption [24]	0.956 ± 0.4
I_γ (Au) [25]	95.6 ± 0.2
I_γ (Tb) [26]	26.6 ± 0.2
Efficiency HPGe	– ± 5.8
$T_{1/2}$ Au (days) [25]	2.6947 ± 0.1
$T_{1/2}$ Tb (days) [26]	72.3 ± 0.1
Fluence ratio	1.02 ± 0.2
MACS Au reference [11]	(582 ± 1.5) mb
Fitting procedure	– ± 0.1
Total	– ± 8.3
	MACS (mb) at kT = 30 keV
This work	2166 ± 181
Bokhovko 1992 [19]	1471 ± 66
Mizumoto 1978 [20]	1800 ± 100
Lépine 1972 [27]	1850 ± 250
Allen 1971 [16]	2200 ± 200
KADoNiS [5]	1580 ± 150
ENDF/B-VII.1 [17, 18]	2080 ± 250

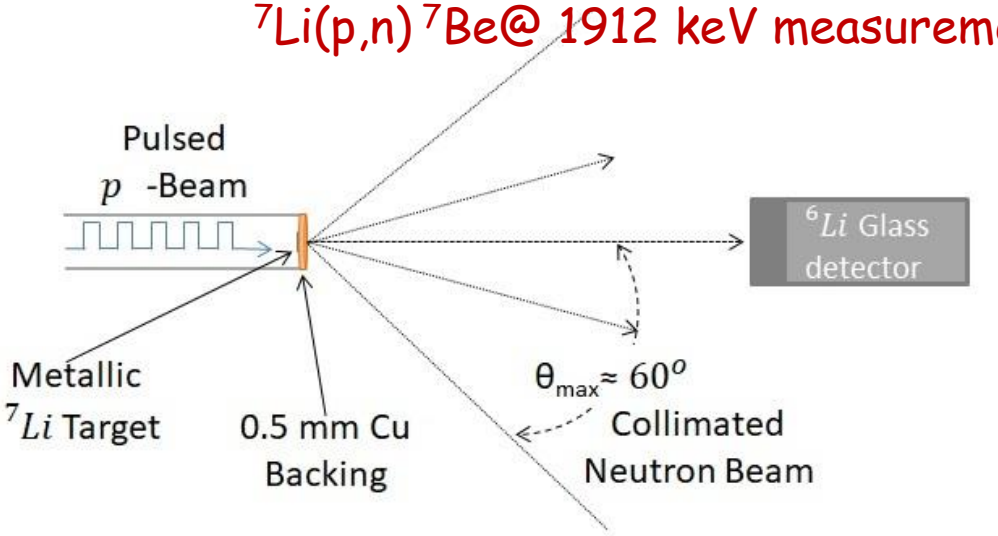
In the future….

Plans for MACS on ^{242}Pu & ^{50}Cr as complement to n_TOF experiments

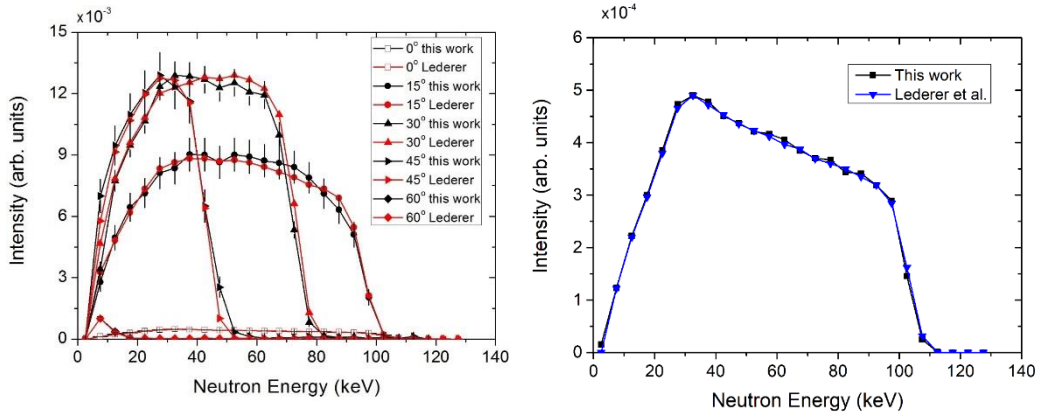
Neutron field measurements for…

Astrophysics applications

$^{7}Li(p,n)^{7}Be$@ 1912 keV measurement

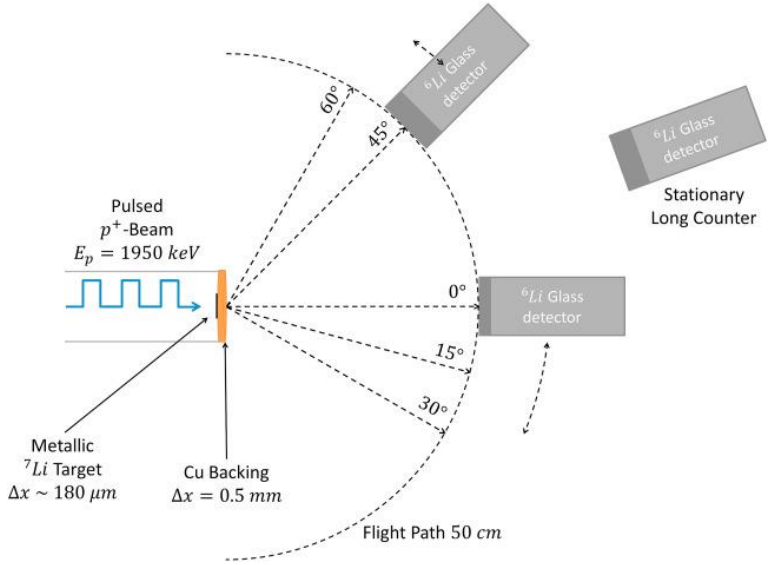


Macias et al., RPC 168 (2020)

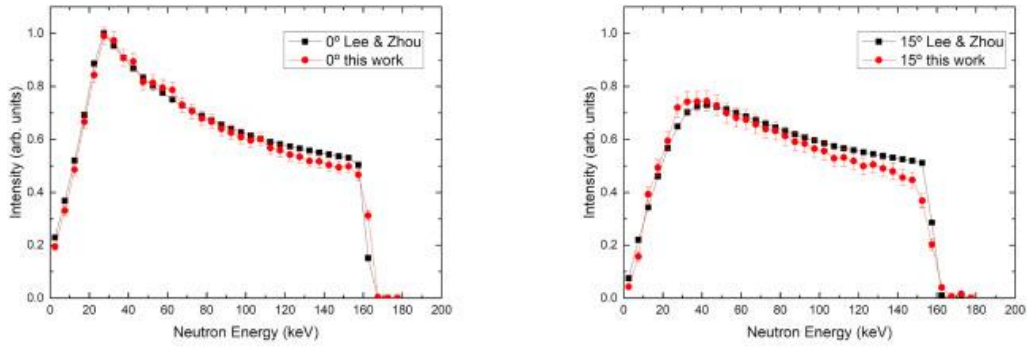


Medical Physics application

$^{7}Li(p,n)^{7}Be$@ 1950 keV measurement for BNCT evaluation



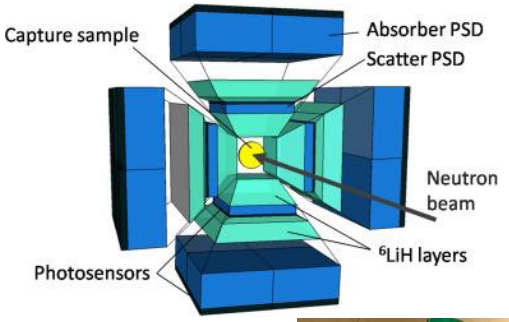
Macias et al., RPC 181 (2021)



Detectors Characterization

Neutron sensitivity of i-TED for neutron capture at CERN n_TOF (with CSIC-IFIC)

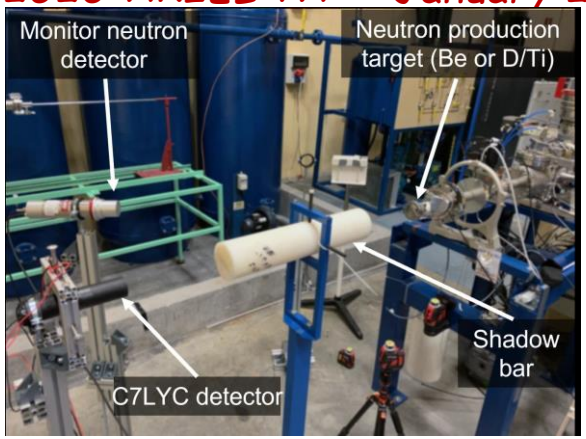
+ CERN n_TOF: s(n,g) measurements by ToF
+ Scattered neutrons: main background
⇒ Carachterization of detector response to epitermal neutrons => ^{7}Li(p,n) + time-of-flight



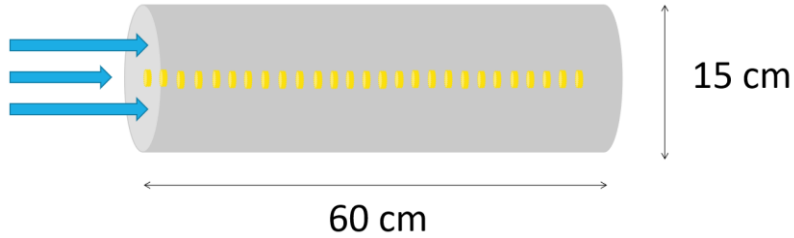
May 2021

Characterization of C7LYC for neutron diagnostic in fusion (with INFN-MIB)

@HISPANOS: Be(d,n) + time-of-flight
H2020-ARIEL TA => January 2022



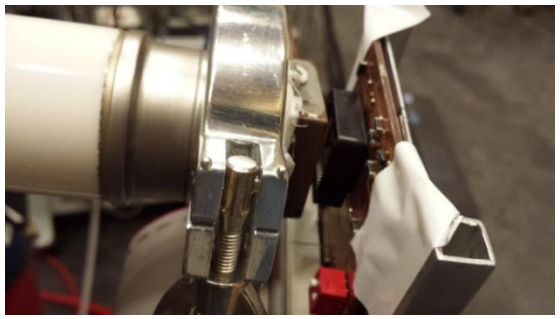
Development of the ANTILOPE detector (with CIEMAT & n_TOF)



P. Perez Maroto talk tomorrow @ 13:00 pm !!!

Fast neutron irradiations & dosimetry

Electronic damage by irradiation with protons and fast neutrons



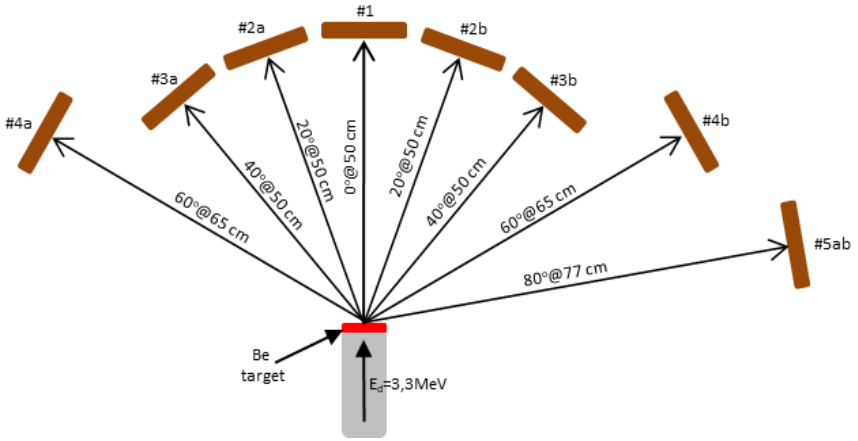
Dosimetric mapping & dosimeter intercomp. with fast neutrons (with UPM)

@100 cm & 0º:
+ LUPIN (UPM): 77(1) mSv/h/μA
+ BIOREM (CNA): 88(1) mSv/h/μA

} 13% agreement

Buds irradiation with fast neutrons

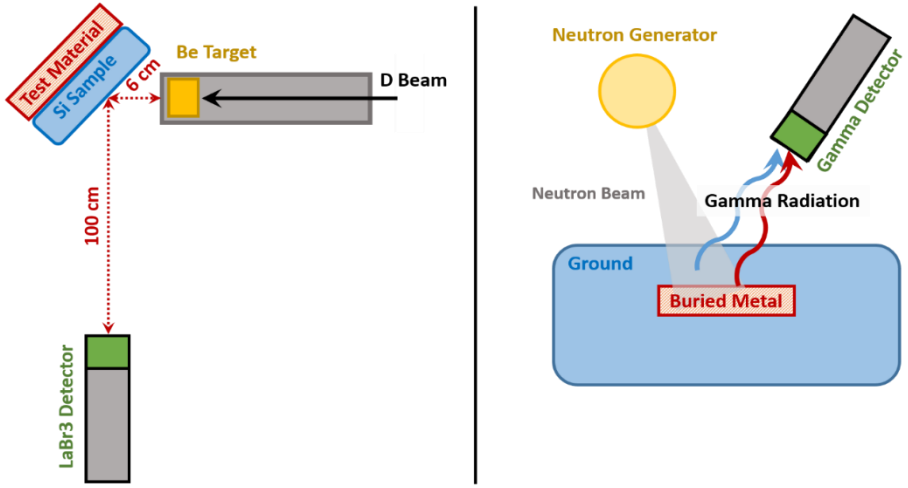
(Colab. ANECOOP & Irradiation@CNA)

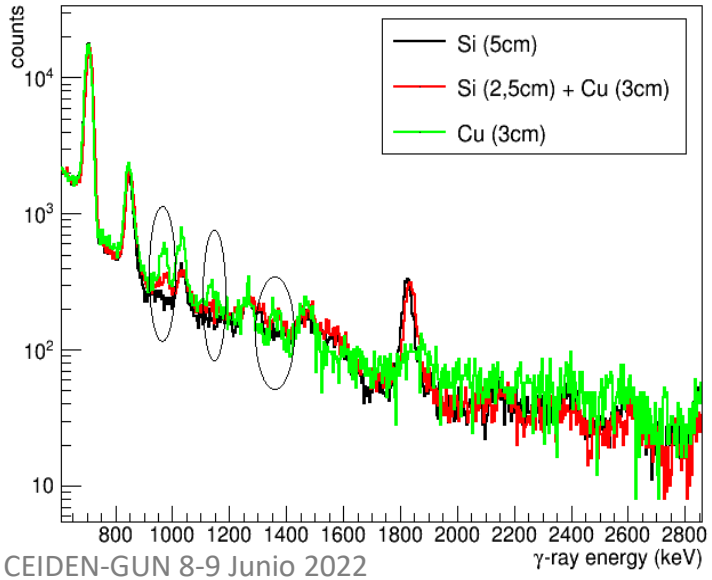


Anecoop

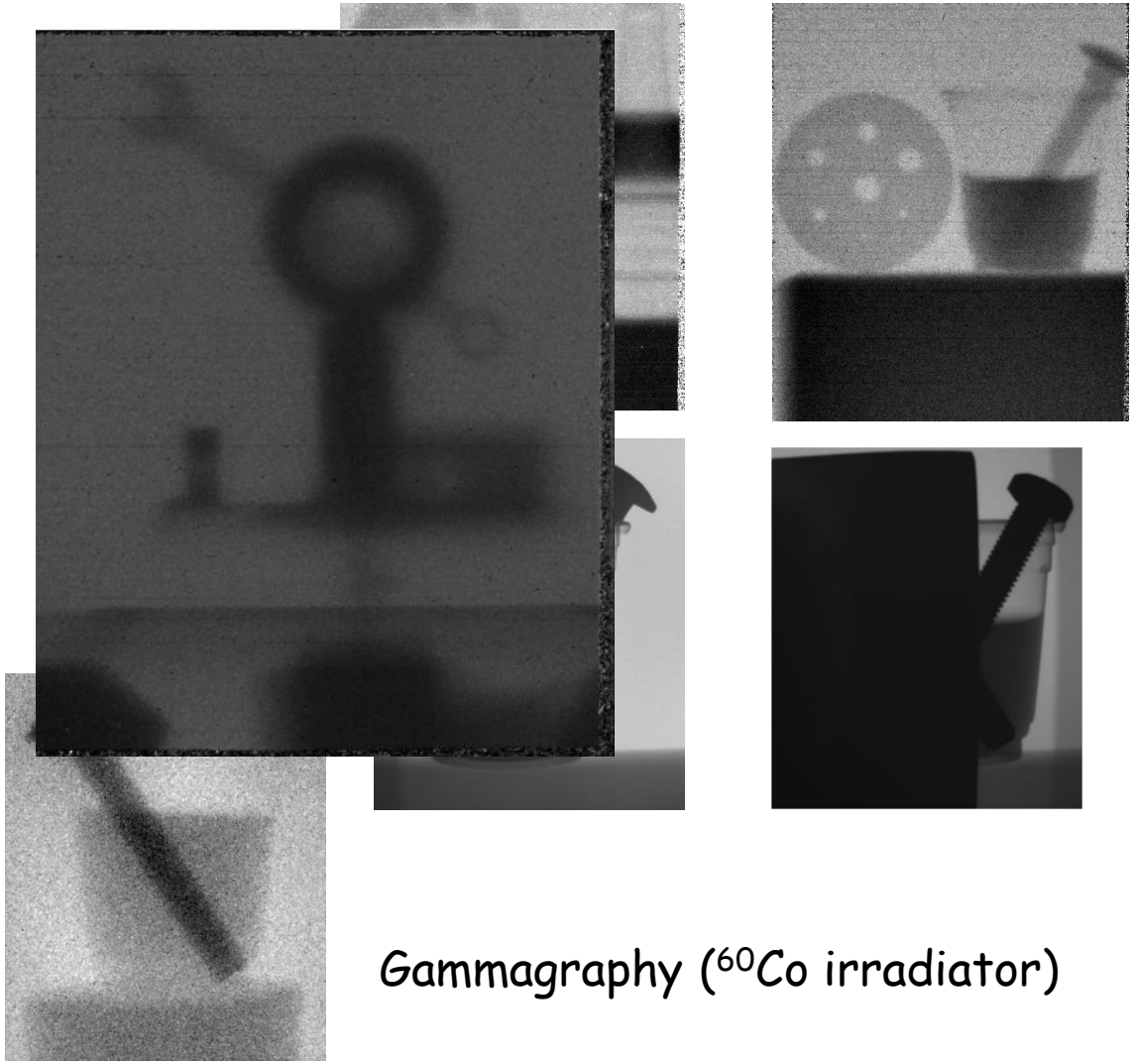
Imaging and material inspection

Identification of elements in large samples by PGA (with UPV & IDOM)



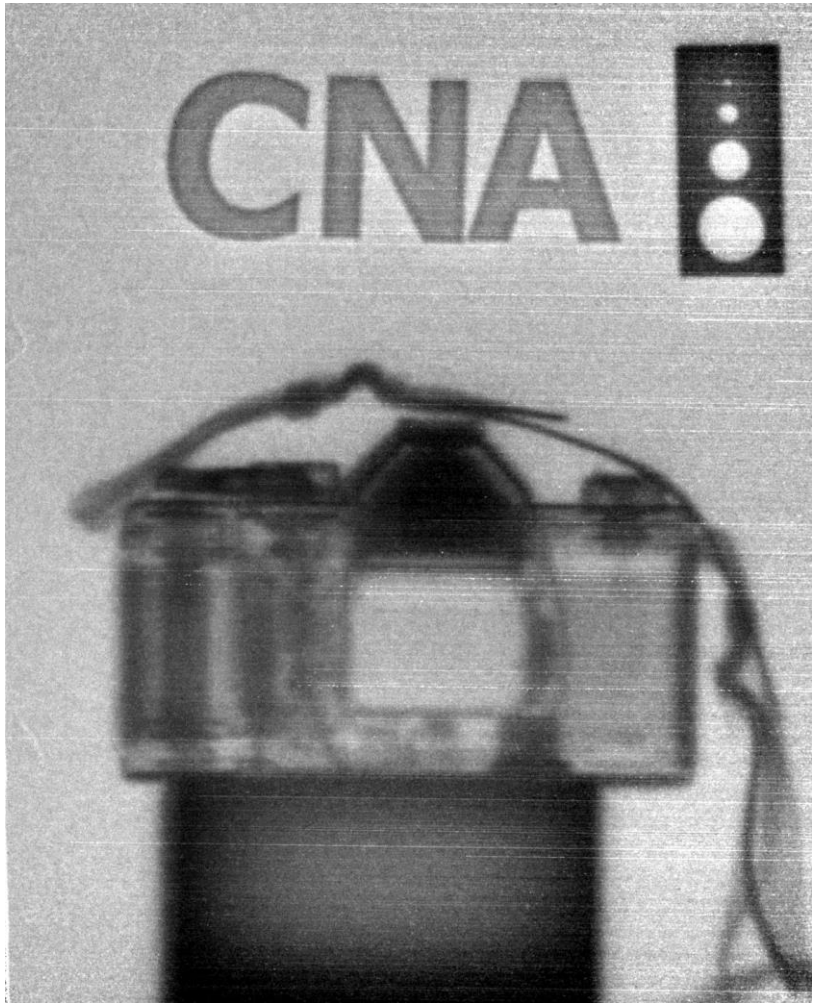


Neutron, gammas and x-ray imaging



Gammagraphy (^{60}Co irradiator)

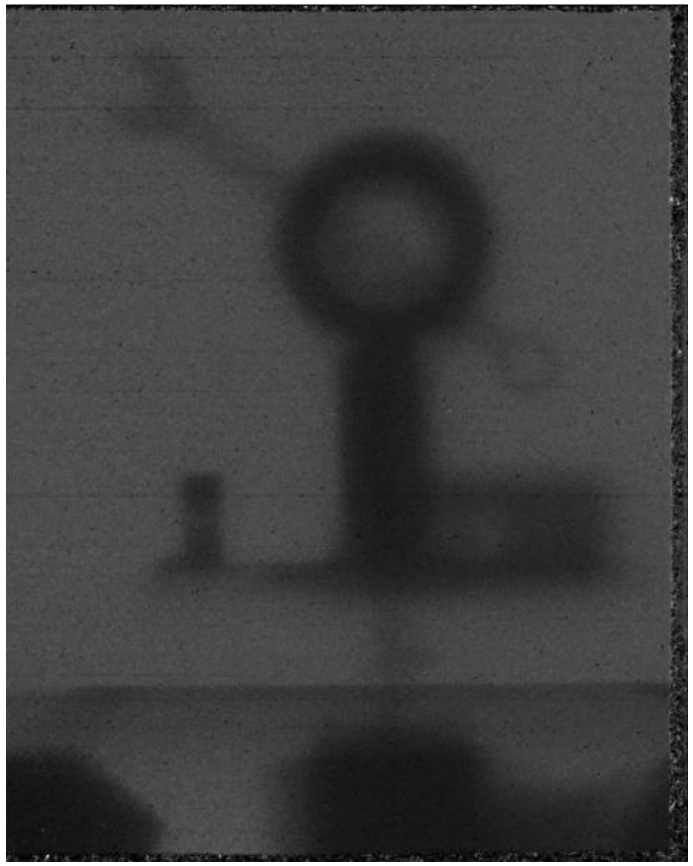
Thermal Neutron Imaging



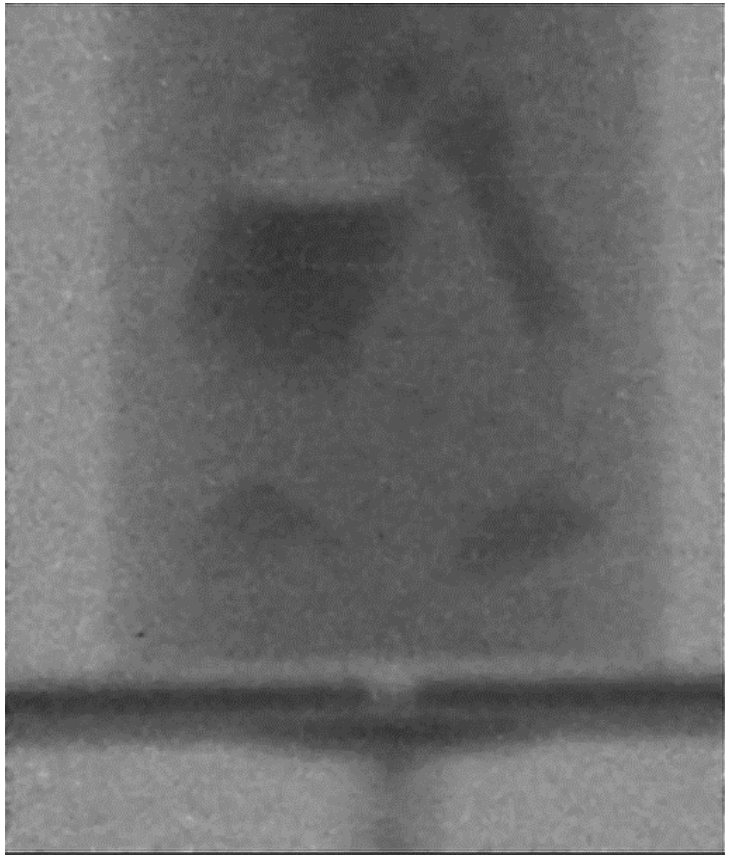
5 exposures,
120 s each one.

10 min
Total exposure

Neutron Tomography



Thermal Neutron Tomography



First Fast Neutron Tomography!!

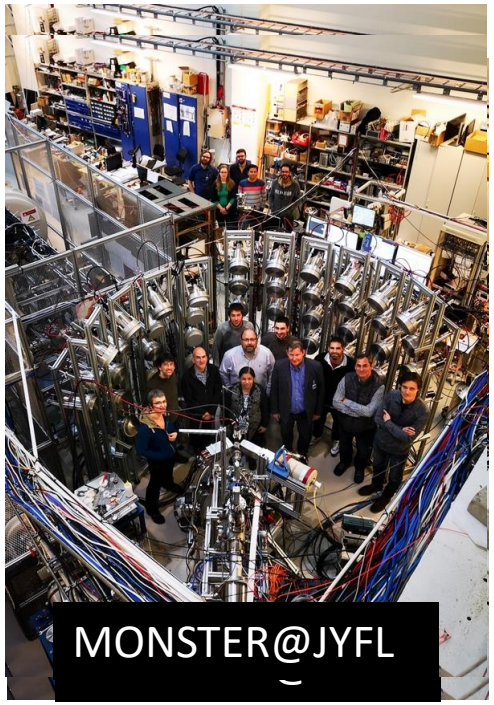
Cross sections measurements

Neutron production from (a,n) reactions for dark matter searches and astrophysics

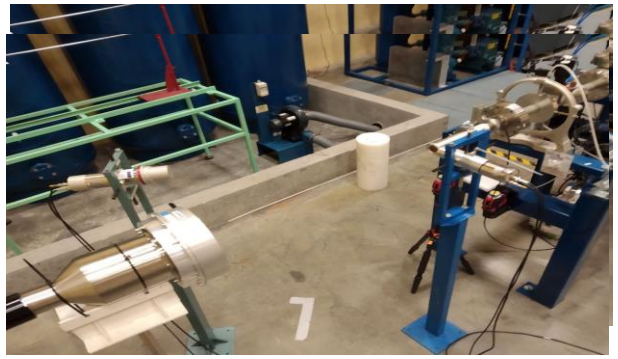
(*The MANY Collaboration*: CNA, CMAM, CIEMAT, UPC, IFIC, UPM)

Measurements at CNA (cont.& pulsed) and CMAM (cont. only) with the detectors:

- miniBELEN
- MONSTER

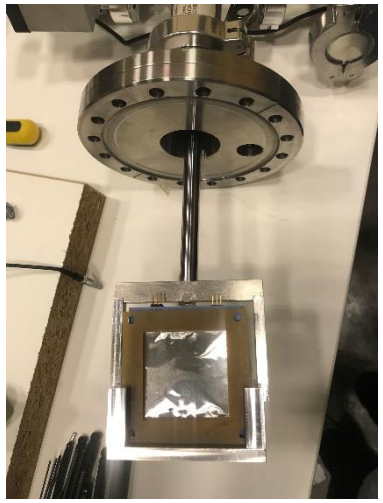


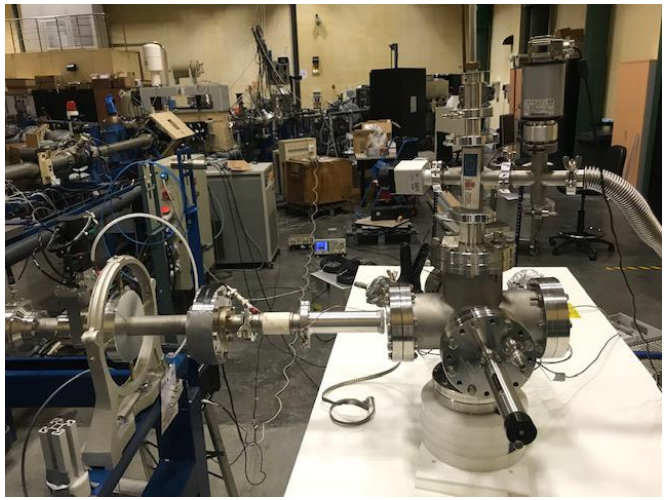
MONSTER@JYFL

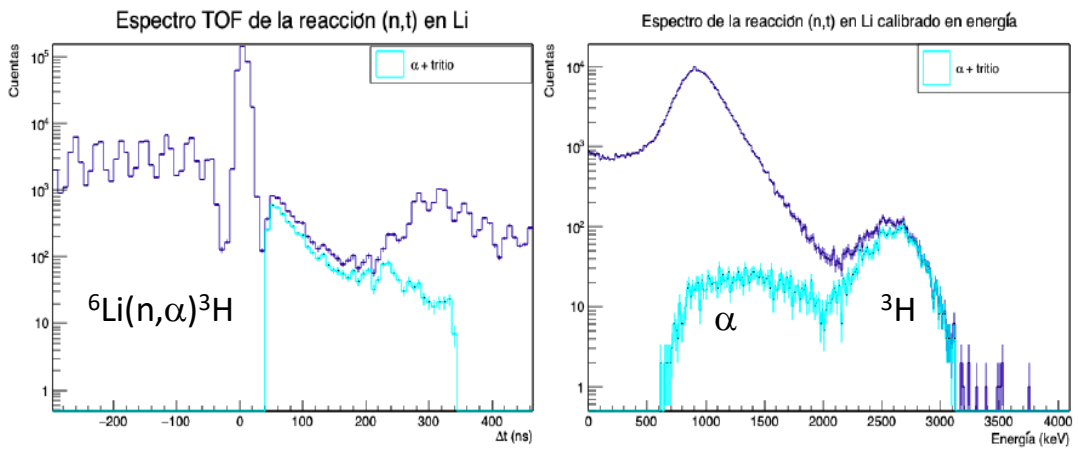


MONSTER module@HISPANOS

Development of the capabilities to measure (n,cp) reactions by ToF







Summary and Conclusions

- HiSPANoS is the first accelerator based neutron source in Spain (continuous and pulsed mode)
- A new experimental line for n ToF measurements was installed at the 3 MV tandem accelerator at CNA
- The new buncher & chopper can deliver 1-2 ns protons, deuterons and alpha pulsed beams
- Several measurements have been carried out at HiSPANoS for different applications: detector characterization, nuclear technology, neutron dosimetry, medical physics,imaging, etc, in collaboration with different research groups.
- We are opened to collaborations to exploit our neutron facility
- HiSPANoS is elegible in ARIEL H2020 Project as TA

Thank you!!

This work is supported by Junta de Andalucía-Fondos FEDER through the Project US-1261006