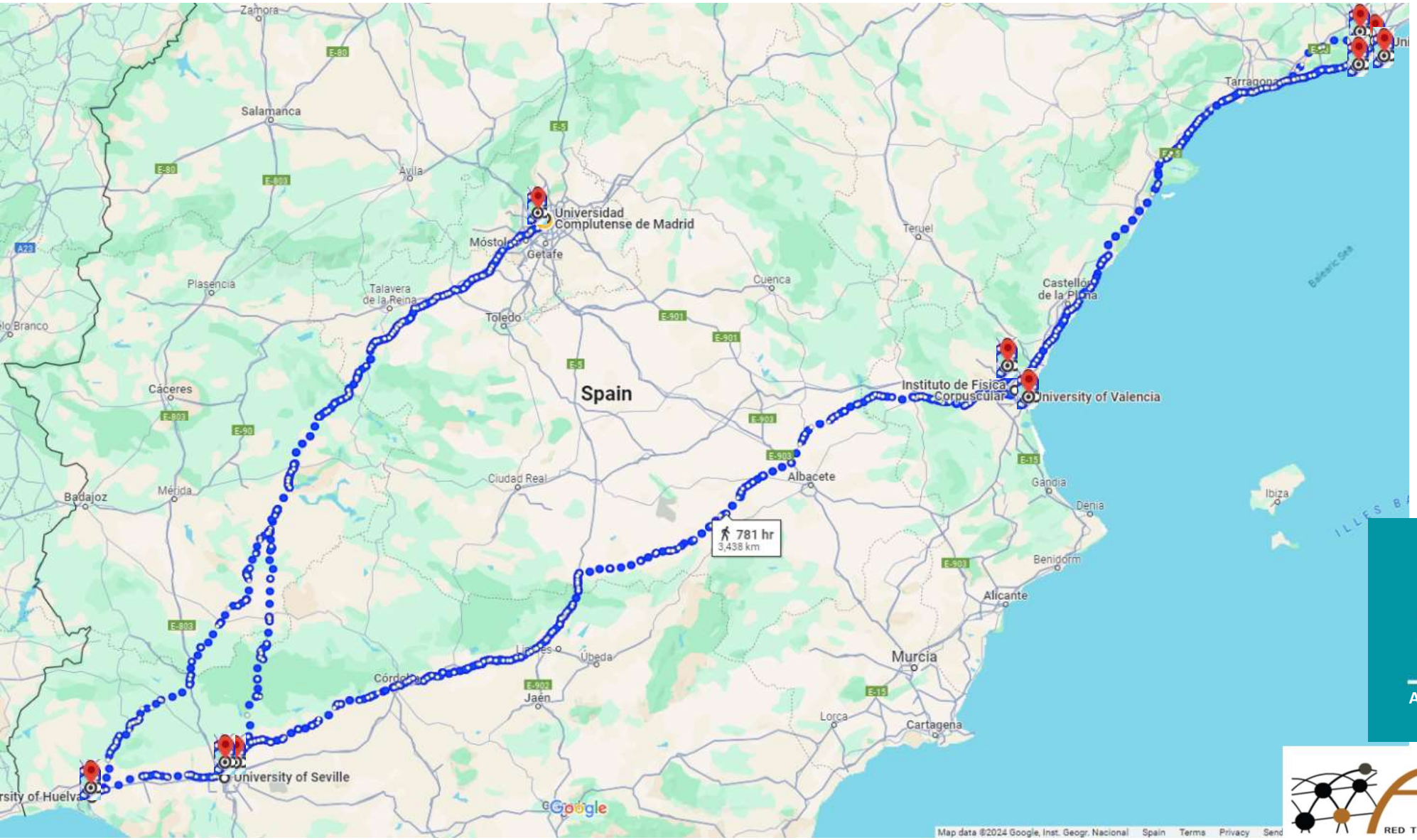
Advanced radiation detectors and instrumentation for nuclear physics and applications

LA1: Desarrollo de instrumentación de vanguardia para futuros experimentos de Física de Partículas y Nuclear

JM Udías (GFN@IPARCOS for FNUC)

Astrofísica y física de altas energías

FNUC RED TEMÁTICA DE FÍSICA NUCLEAR



Astrofísica y física de altas energías

RED TEMÁTICA DE FÍSICA NUCLEAR

CA ANDALUCÍA

1.1 sub-line: 500 k€, 1.2: 500 k€, 1.3: 250 k€, 1.4: 200 k€, 1.5: 156 k€

Junta de Andalucía
Consejería de Universidad, Investigación e Innovación

GOBIERNO DE ESPAÑA

Financiado por la Unión Europea
NextGenerationEU

LA1: Desarrollo de instrumentación de vanguardia para futuros experimentos de Física de Partículas y Nuclear

CSIC

CNA
Centro Nacional de Aceleradores

Universidad de Huelva

Activity 1.1: Detector irradiation with accelerators

IP: Javier García López. Univ. de Sevilla

Goal: Improvement and updating of the equipment of the 3 MV Tandem accelerators and National Accelerator Center cyclotron for radiation detector studies

Total Funds: 496.082€

Personnel: 160.065,60 € 1 Technician + 1 Predoc + 1 Postdoc (incorporated)

Equipment: 296.000€ + 40.016,40 € = 336.016,40 € (on-going bid)

- **Buncher** for pulsed beams of H, D and He: 94.000 €
- **Charge Preamplifiers**: 34.240 €
- 3 sets of **slits micrometrics**: ~ 184.000 €
- **X-ray SDD high resolution detector**: ~ 24.000 €

Activity 1.2: Mass spectroscopy with accelerators

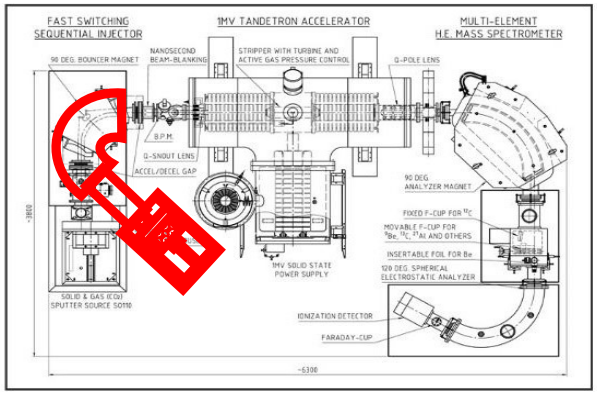
IP: José María López Gutiérrez.

• Goal: Upgrade of the injector system of the CNA Accelerator Mass Spectroscopy system

Total funds: 496.082€

New injector magnet: 422.000 € => on-going

Personnel: 74.082 €, researcher hired



New injector for SARA

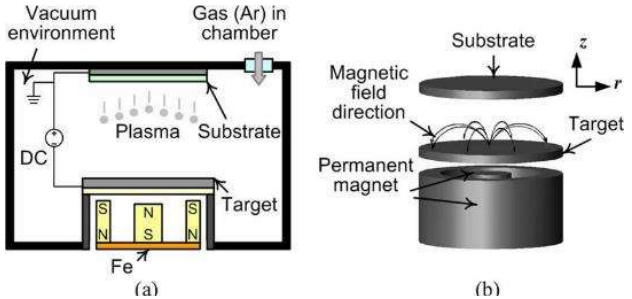
• **Activity 1.3: Exploitation of European Nuclear Physics Facilities**

IPs: Joaquín Gómez Camacho and Carlos Guerrero

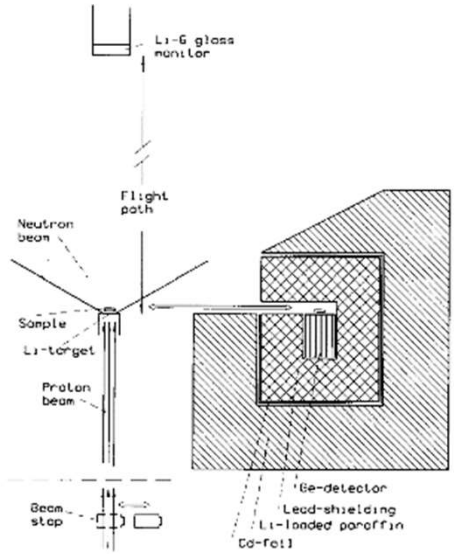
• Goals: Acquisition and development of equipment that allows consolidating and improving the participation of Andalusian researchers in nuclear physics experiments carried out at the n_TOF (CERN), ISOLDE (CERN) and LNS (INFN) facilities.

• Total Funds: 251.000€

- Magnetron-sputtering chamber and target support: 128.000 € => ongoing
- Linear stage + shieldings for ciclic activation station: 80.000€ => design phase
- Personnel: 43.000 € => Done



magnetron-sputtering system



Cyclic activation system (FZK. Karlsruhe, Germany)

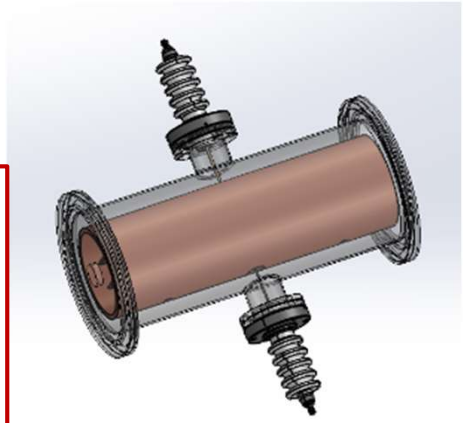
1.4 Protontherapy applications

Cyclotron 18/9 MeV

IP M. C. Jiménez-Ramos (CNA)

Design and manufacture of a new beam pulsed system for the external line of the CNA cyclotron (US, CSIC, Junta de Andalucía) for radiobiology studies in FLASH regime

Total funds: 196k€, personnel 96k€ (done), equipment 100 k€ (design phase) + IFIC & CERN



Preliminary design of the beam deflector chamber

1.5 Phenomenology development in Hadronic and Nuclear Physics

IP José Rodríguez-Quintero (UHU)

Total funds: 156k€, all in personnel, done

Non-perturbative calculations of hadronic structure functions (PDAs, PDFs, GPDs, TDAs) to describe phenomenology in EIC (Electron Ion Collider), EicC (Electron Ion Collider in China) and JLab

CA VALENCIANA

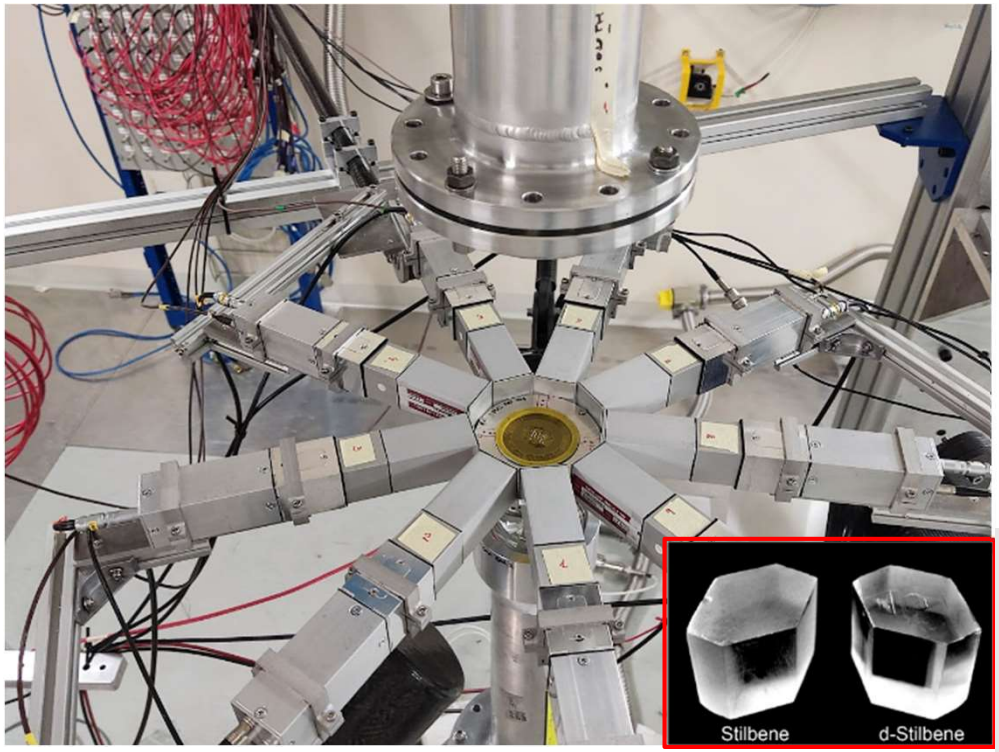
ASFAE projects.

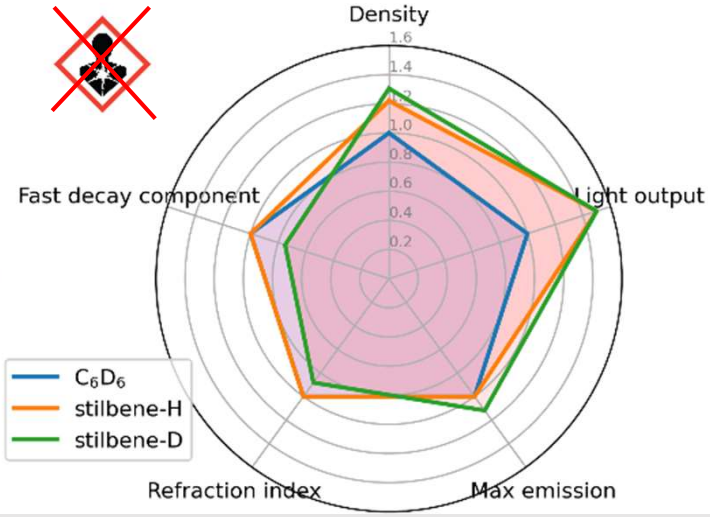
ASFAE/2022/027 (300 k€),

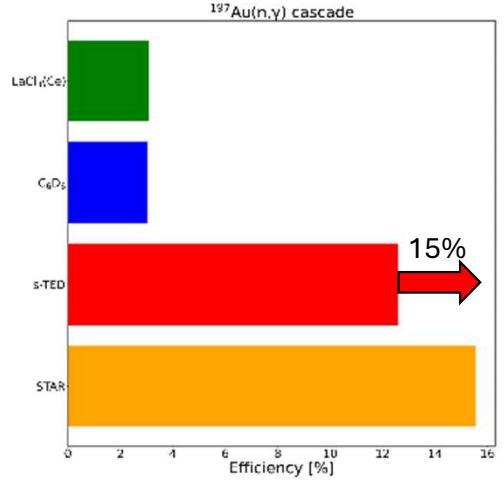
ASFAE/2022/031 (300 k€),

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Total Energy Detectors for (n,γ) @ n_TOF







ASFE goal: Develop the new generation of **high sensitivity TED** array detector for **(n,ɣ)** measurements @ CERN-**n_TOF**, **STAR** (Stilbene-d12 deTector ARray) :

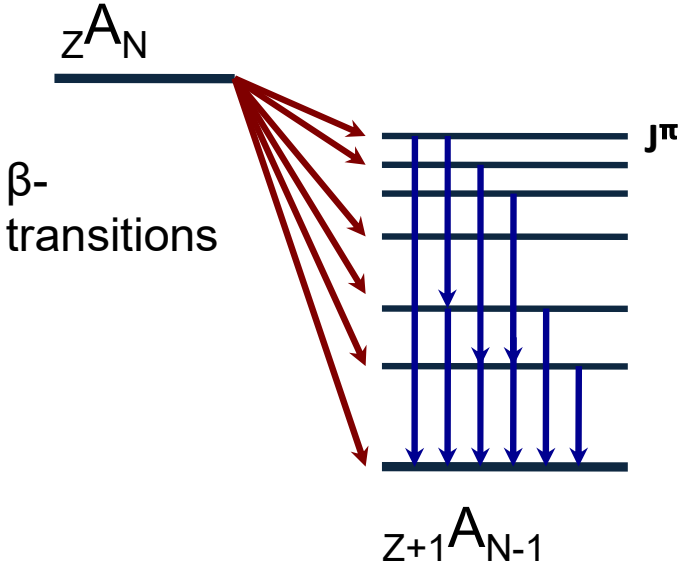
- **Worldwide Unique** detection array made of **solid Stilbene-d12** (very expensive material).
- **Improved s/b** ratio (Small volume/Larger efficiency)
- Better deposited **energy resolution**.
- **New** detector **reading** systems (**SiPM**, Fast PMT..)
- **PSD** n/ɣ Stilbene/C6D6~**x3**

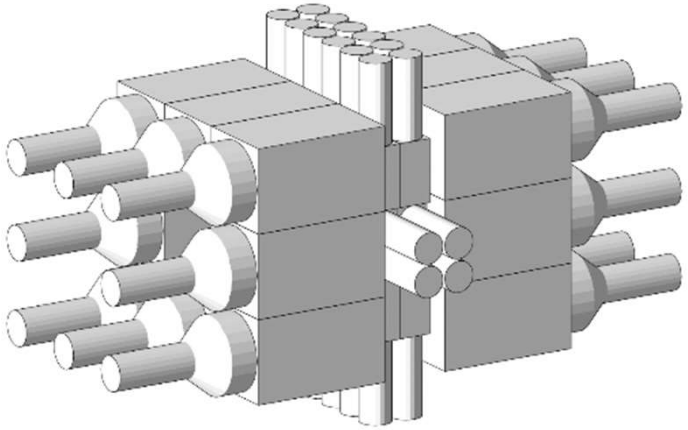
Development fund
ASFAE/2022/027 & **MRR-CERN-IFIC**

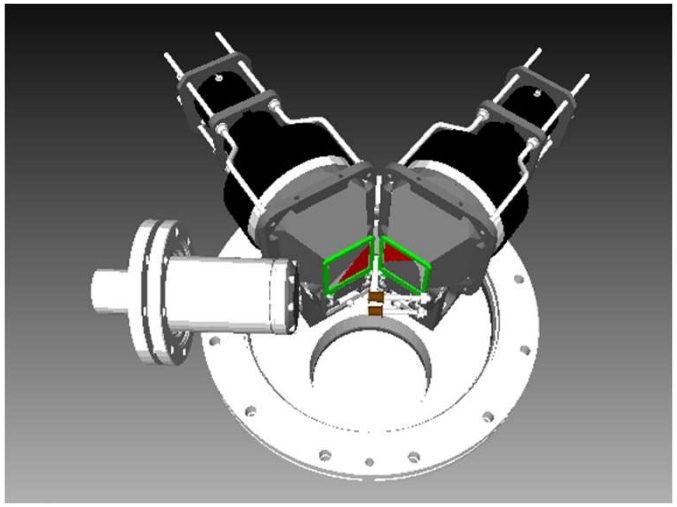
The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

Financiado por la Unión Europea NextGenerationEU
Plan de Recuperación, Transformación y Resiliencia
GENERALITAT VALENCIANA
GVANEXT

Advanced technology for challenging β decays







Accurate description of β decay requires primary information on:

- Decay half-life
- Involved masses (Q values)
- Beta decay probabilities (feedings)

ASFAE: study of **Advanced TAS geometries** and improvement of light readout of **$LaBr_3$** detectors

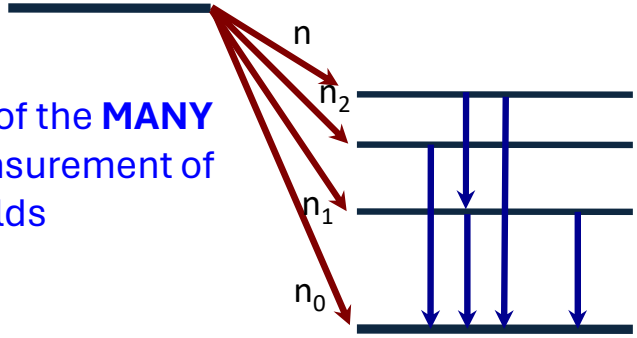
ASFAE: Development of **compact ΔE-E**, **low noisy β** detectors to be **combined** with **TAS detectors**

Developments fund **ASFAE/2022/027**

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

(α,n) reactions of nuclear astrophysics interest

MiniBELEN is part of the **MANY** collaboration: **M**easurement of **A**lpha **N**eutron **Y**ields

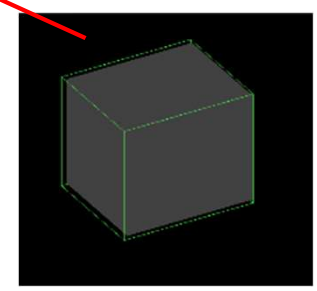


(α,n) reactions can populate excited levels!

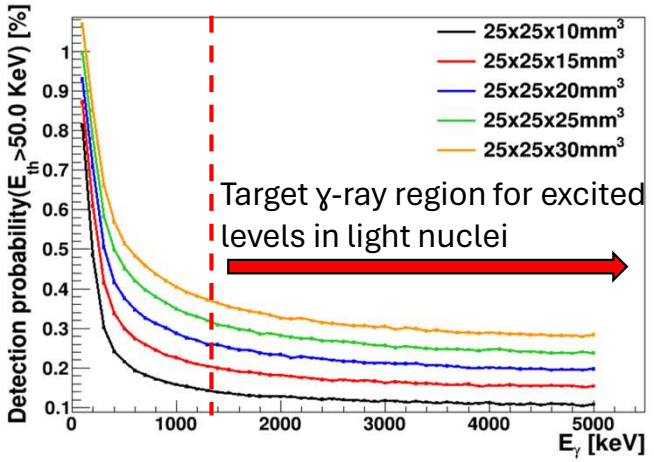
ASFAE **Goal**: **Replace** a **small fraction of the moderator** by **small $LaCl_3$(Ce)** in order to **tag n_0,n_1,n_2,...**

MiniBELEN-10A: A modular detector for study of (α,n) reactions by direct neutron counting

- Provides a response almost independent of the neutron energy up to 8 MeV.
- Nominal detection efficiency: 7% (up to 8 MeV)
- Allows for measurements of (α,n) yields and reaction cross sections from thin and thick targets.



Active volume LaCl3 25x25x**XX**mm^3

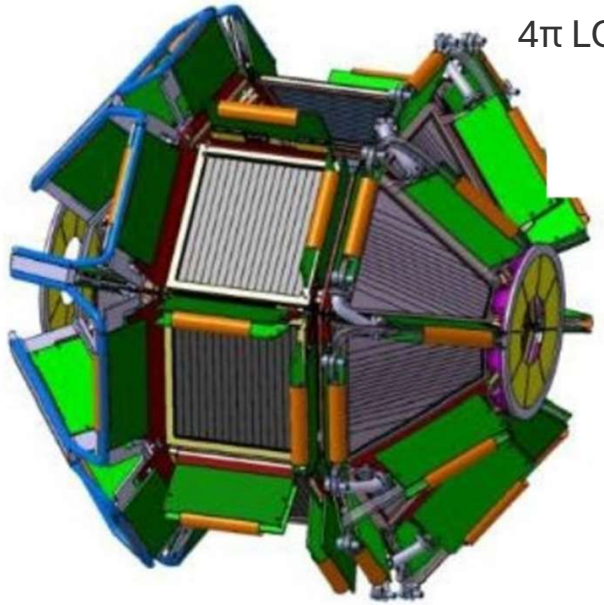


Development fund
ASFAE/2022/027

The ASFAE's research projects acknowledge funding from the Spanish Agencia Estatal de Investigación MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

GRIT detector for inverse kinematic reactions

GRIT (Granularity, Resolution, Identification, Transparency)
4π LCP Silicon array for low energy nuclear physics



Objective

- Direct reactions of nuclear structure and/or nuclear astrophysics in inverse kinematics
- Designed to be coupled with gamma arrays like AGATA

Structure

- 16 trapezoidal telescopes: 8+8 front/rear
- 8 square telescopes in the ring at 90º
- 1 annular telescope at 0º
- Telescopes built with DSSD: good spatial (~1 mm) and energy resolution (<1% @ 5MeV)
- 128 channels/telescope => 3000+ channels to read out

ASFAE 2022/031 Objectives

- PLAS ASIC design completion
- Front-end distributor design
- Trigger interface design based on MicroATC
- Contribution to GRIT construction

Developments fund
ASFAE/2022/031

The ASFAE's research projects acknowledge the financial support from the MCIU with funding from the European Union NextGenerationEU and Generalitat Valenciana.

CA CATALUÑA

Tecnologías avanzadas para la exploración del universo

Planes Complementarios en el área de Astrofísica y Física de Altas Energía
Componente 17 del Plan de Recuperación, Transformación y Resiliencia

IFAE Institut de Física d'Altes Energies · CSIC · IEEC Institut d'Estudis Espacials de Catalunya · Universitat de Barcelona · Universitat Politècnica de Catalunya BarcelonaTech

ANT – Advanced Nuclear Technologies Research Group

UPC – Universitat Politecnica de Catalunya
AGAUR – Agencia de Gestió de d'Ajuts Universitaris i de Recerca, Generalitat de Catalunya
Grup de Recerca Consolidat: 2021 SGR 00217

ENPAI – Experimental Nuclear Physics, Applications and Instrumentation

https://ant.upc.edu/en/enpai
Contact: F. Calviño (francisco.calvino@upc.edu)

Financiado por la Unión Europea NextGenerationEU

Generalitat de Catalunya Departament de Recerca i Universitats · Next Generation Catalunya · Pla de Recuperació, Transformació i Resiliència · Gobierno de España Ministerio de Ciencia e Innovación

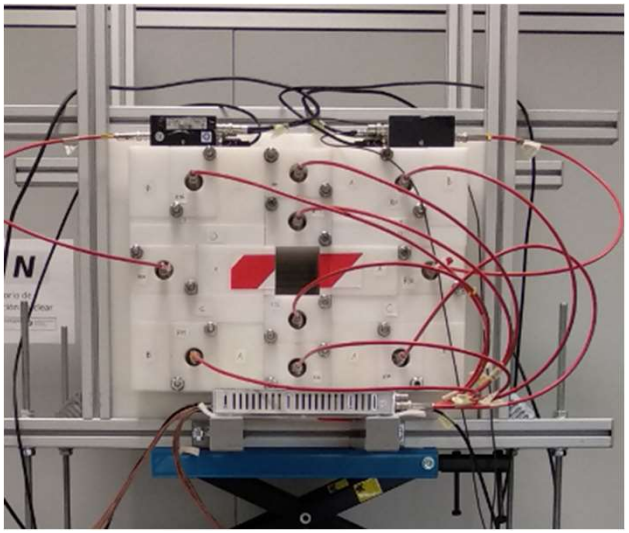
MANY Measurement of (Alpha,N) Yields

Goal: improve the nuclear data on (α,xn) reactions

Design of a new modular neutron moderated counter, (mini-BELEN) with a flat efficiency up to 8 MeV. Commissioning with thick-target (alpha,n) yield measurements on ^{27}Al

Future plans: design and commissioning of a new **hybrid detector for neutron and gamma detection**

Nil Mont
PhD thesis.



HENSA High Efficiency Neutron Spectrometry Array

Goal: characterization of neutron flux

Underground labs: long-term characterization of n flux in Hall B of the LSC since March 2021. Setup upgraded in August 2022. Background characterization for ANAIS.

Current/future plans

Construction of a replica of the setup at LSC for a new collaboration at LNGS (Gran Sasso, Italy). Since late April 2024 the new HENSA is being used at LNGS. Future plans include also the development of new setups for a long-term monitoring of the neutron flux in multiple locations.

The HENSA concept has been used for Environmental Monitoring, Cosmic Ray Studies – Space Weather, and Underground Laboratories. NESTA - the Nested Neutron Spectrometry Array, is a portable version of HENSA Optimized for the **n_TOF facility at CERN**

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

IFIC

UNIVERSIDAD COMPLUTENSE MADRID

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat

UNIVERSIDAD D SEVILLA 1505

IEM

CMAM

CNA Centro Nacional de Aceleradores

CMAN
CNA

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

Experimental Nuclear Physics, Applications and Instrumentation – ENPAI – ANT. UPC (https://ant.upc.edu/en/enpai)

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ELECTRONICS

Development of Electronics for Nuclear Instrumentation

Charge preamplifiers

- More than 20 units built.
- Patent pending.
- 6 preamplifiers for He-3 proportional counters at the Centro de Estudios Nucleares La Reina (Chile)

High voltage Power Suppliers

- Possibility of remote management.
- Used in various experiments and teaching laboratory

Under development

- Compact Multi-Channel Analyzer and digital pulse analysis systems.
- Light-weight neutron dosimeter prototype by event counting.
- Neutron dosimeter prototype by charge integration (Grant: Producte-24, AGAUR).

CA MADRID

TAU Project. Funded during second call. 150 k€ in Nuclear Activities of LA1.

"**Tecnologías Avanzadas para la Exploración del Universo y sus Componentes**" (PR47/21 TAU-CM-PRTR), with EU Resilient and NextGeneration funds.

Financiado por la Unión Europea
NextGenerationEU

Astrofísica y física de altas energías

IP: Ignazio Scimemi (director of IPARCOS). Luis Mario Fraile (Nuclear Activities in LA1)

Total funds: 150 k€, 90 k€ for personnel (one electronic engineer, one electronics technician, supported until Dec 2024), 60 k€ equipment (20 Gs/s, 6 GHz bandwidth, 4 channels scope + other fast digitizers), already executed.

Goals: Develop compact **trigger detectors based on sipm+plastic**, and large inexpensive area detectors for $LaBr_3(Ce)$ Scintillators, **optimize time-pickup for fast timing detector**, with **DL** algorithms. Pave the way for **smart fast timing detectors based on modern microcontrollers** (MCU). Explore **translation to PET electronics.**

IPARCOS

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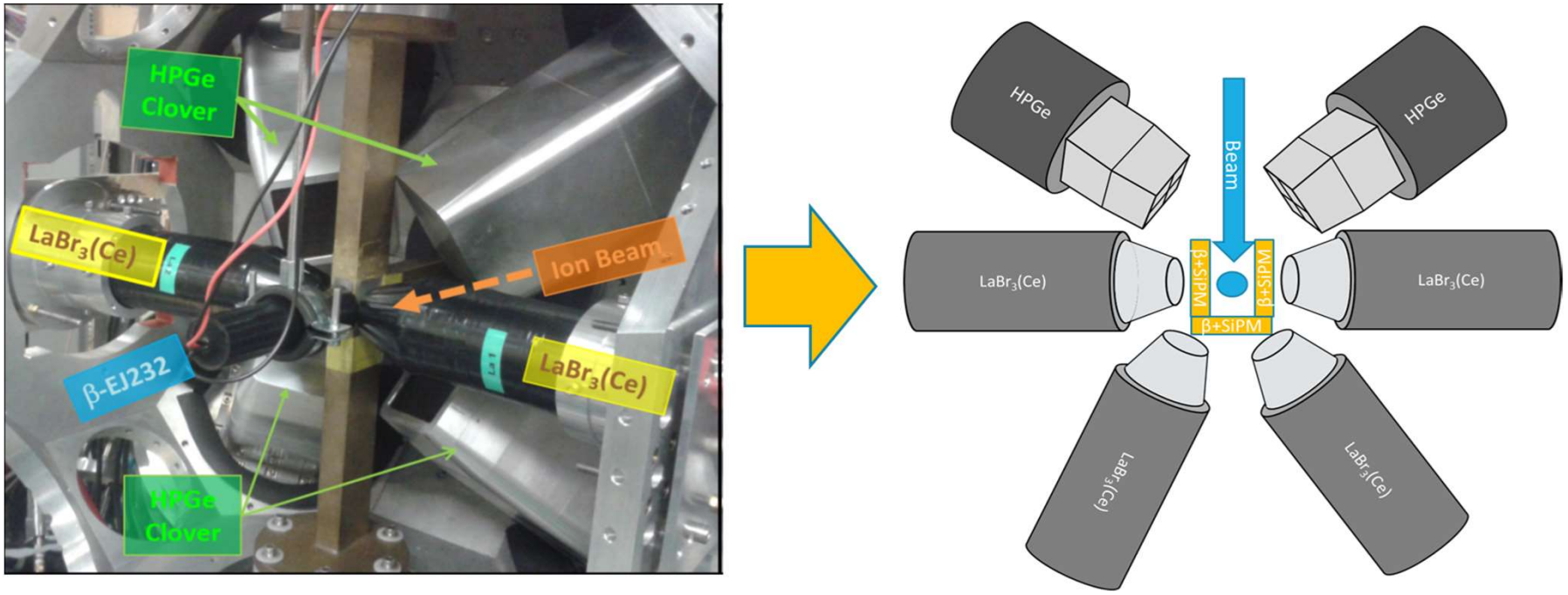
1.1 SiPM + plastic for trigger with fast timing capabilities (IP L.M. Fraile)



Left: Example of a fast-timing setup at ISOLDE used for βγγ(t) spectroscopic measurements.
Right: Possible alternative configuration using beta-SiPM detectors

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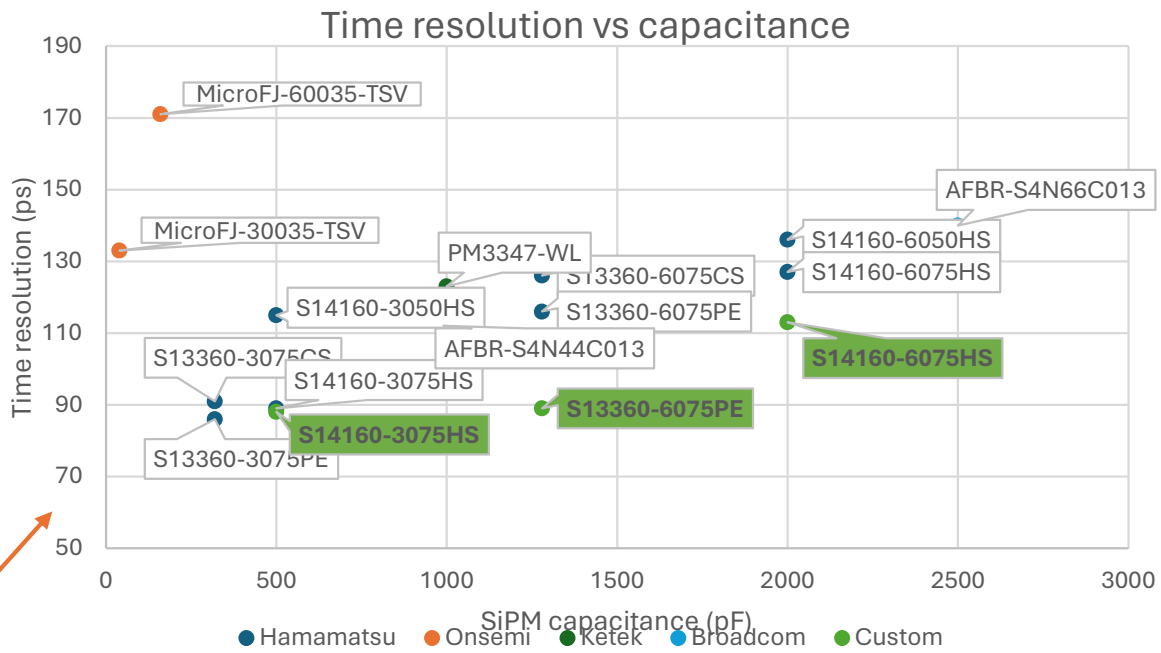
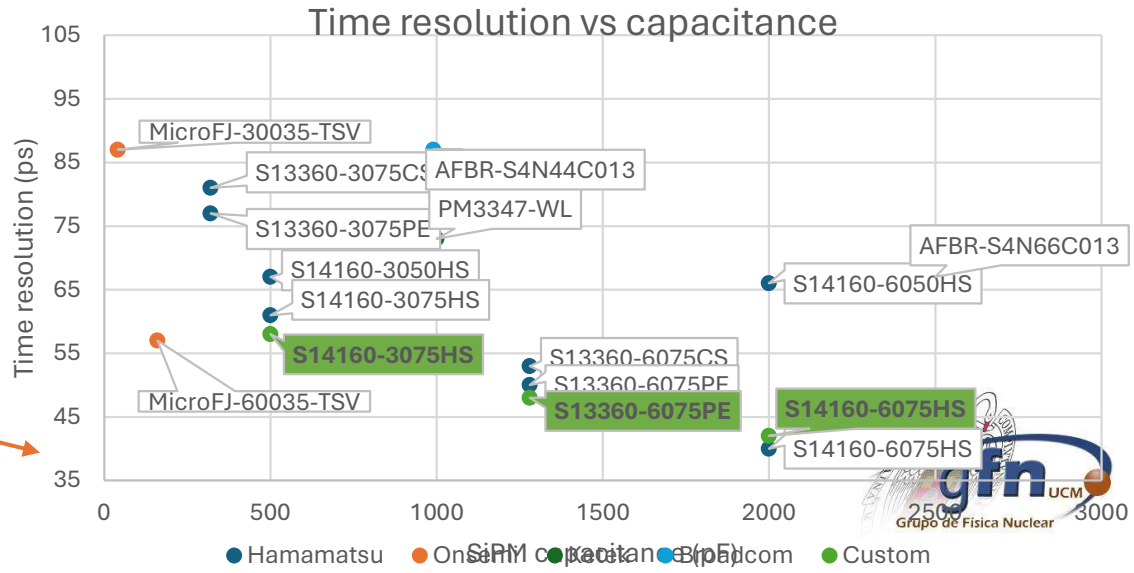
Brand	Serie	Model	Size (mm^2)	Pixel pitch (µm)	PDE (%)
Hamamatsu	S13360	3075CS	3x3	75	50
Hamamatsu	S13360	3075PE	3x3	75	50
Hamamatsu	S13360	6075CS	6x6	75	50
Hamamatsu	S13360	6075PE	6x6	75	50
Hamamatsu	S14160	3050HS	3x3	50	50
Hamamatsu	S14160	6050HS	6x6	50	50
Hamamatsu	S14160	6075HS	6x6	75	57
Onsemi	MicroFJ	30035-TSV	3x3	35	38
Onsemi	MicroFJ	60035-TSV	6x6	35	38
Broadcom	AFBR	S4N44C013	4x4	30	43
Broadcom	AFBR	S4N66C013	6x6	30	44
Ketek	WL	PM3347	3x3	47	47

Scintillator	Light yield (photons/keV)	Decay time (ns)	Size (mm^3)
LYSO	29	42	3x3x5
EJ-232Q	2,9	0,7	6x6x5

· Inorganic **Scintillator LYSO**: Na-22 source and three SiPMs+LYSO detectors in coincidences

· **Plastic EJ-232Q** with Eu-152 source in coincidence against PMT R9779 (HPK) with $LaBr_3$(Ce) 1x1".





IPARCOS

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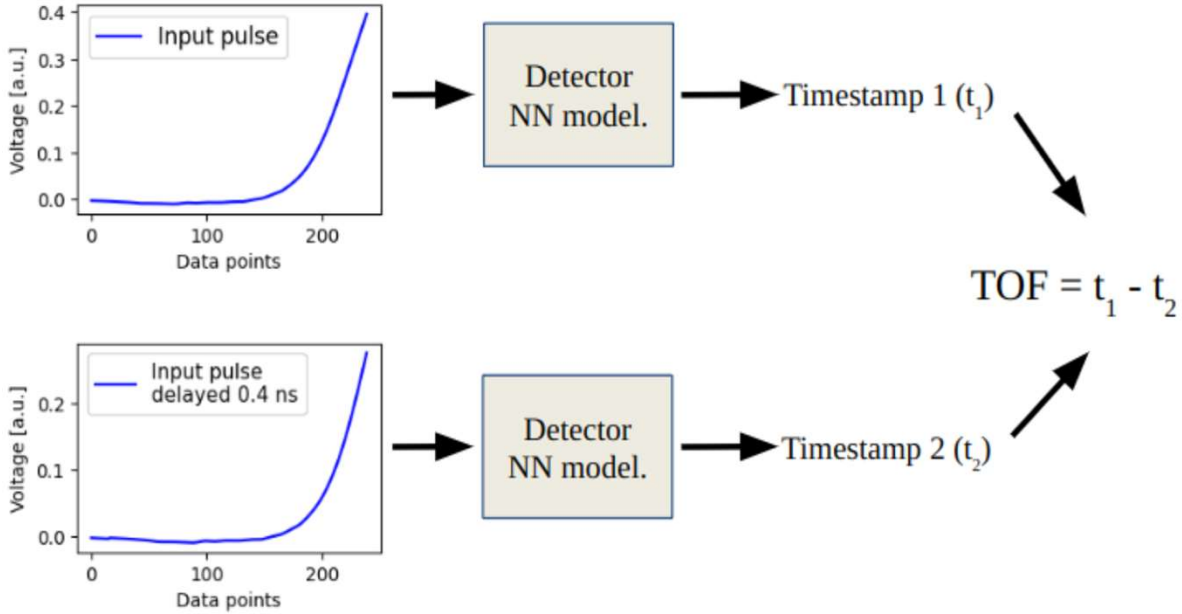
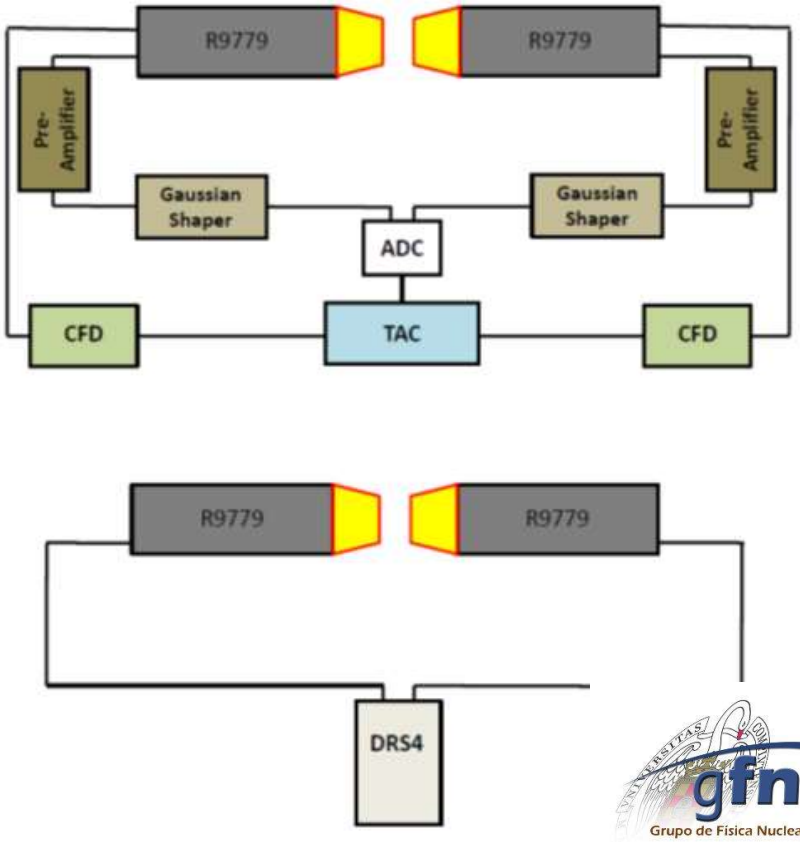
1.2 DL algorithms for timing, IP JL Herraiz.

Three layer fully-connected architecture with 32 neurons per layer ending in a fourth output single-neuron layer using a MSE loss. Benchmark against conventional optimized CFD +TAC which yields **156 ps** (Co-60, CRT, FWHM)





Position	Centroid	CRT
8cm - 2cm	0.174 ns	148 ps
5cm - 5cm	0.003 ns	146 ps
2cm - 8cm	-0.185 ns	152 ps

IPARCOS

Grupo de Física Nuclear

1.3 Inexpensive electronics DAQ for timing and Smart detectors, IP JM Udías.

		ARM family of MCU		
FAMILY	STM32	NXP	NXP	Raspberry Foundation
MCU MODEL	STM32H747	i.MX RT1060	i.MX RT1170	RP2040
# cores	2: M7+M4	1	2:M7+M4	1
freq.	480 MHz / 240 MHz	600 MHz	800 MHz / 400 MHz	133 MHz
Board example	Portenta-lite	Teensy 4.1	several vendors	Raspberry Pico Pi
eth	100 Mbit	100 Mbit	Gbit	10 Mbit
flowtensor ready	YES	?	YES	?
Power (W)	2	0,4	0,5	0,2
Price per TIME+ENERGY channel at max rates (€)	75	50	60	20
Events per second to computer (8 bytes	1 Mcps	1Mcps	2,5 Mcps (3 MS/s ADCs)	100 kcps

Widely available, very low jitter (<20ps) comparators designed for LIDAR (3 €), and high quality ADCs (real 12 bits, up to 10 MS/s, <3€ per channel) designed for automotive applications. Inexpensive MCUs (ST32, NXP, Raspberry Pi PICO), used in a **'from analog detector to ethernet'** DAQ. GI or GS for energy, TAC for time.

Take advantage of additional tensor cores in multi-core MCUs.

We demonstrated >1 Mcps per detector, **25 ps time jitter in the TAC, 4096 useable channels** in energy histograms. More tan 70 Mevents per second aggregated in a 40 cores PC, with our parallel, scalable software.

IPARCOS

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Summary

LA1 related to Nuclear Physics present in Four Autonomous Regions

Focus on international facilities (ISOLDE, nToF, others) with support and contribution of local facilities (CNA, CMAM)

Strong inter-region / inter-group collaboration

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