Neutron background monitoring for the IAXO-D0 detector prototype

Víctor M. Nouvilas[1], Luis Mario Fraile[1,2], Ariel Tarifeño-Saldivia[3], Gloria Luzón[4], Álvaro Quero[6], Cayetano Soneira Landín[1], Max Pallàs i Solís[5], Benedetta Brusasco[5], Víctor Sánchez-Tembleque[1,7], Nil Mont i Geli[5], Guillem Cortes Rossell[5], and José Luis Taín[3].

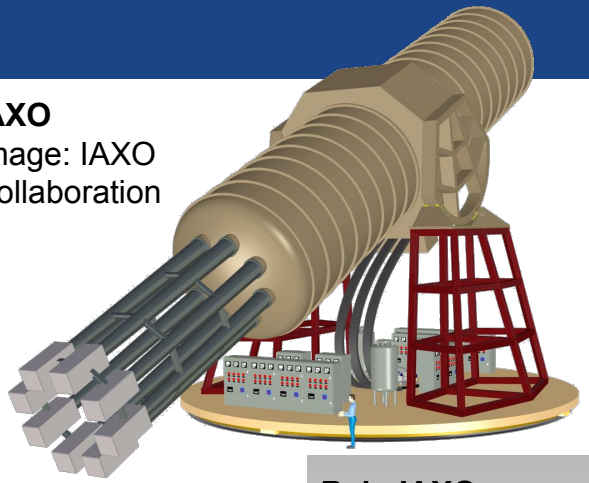
[1]Universidad Complutense de Madrid and IPARCOS, [2]ISOLDE (CERN), [3]Instituto de Física Corpuscular (CSIC-UV), [4]CAPA-Universidad de Zaragoza, [5]Universitat Politècnica de Catalunya, [6]Universidad de Granada, [7]Universidad Carlos III de Madrid

EuNPC 2025 – 22nd September 2025

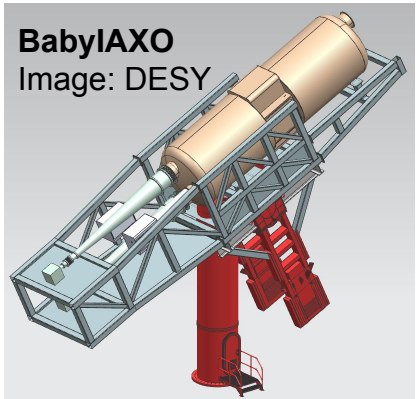
IAXO

- **Axions:**
  - Hypothetical particles
  - Low mass, no charge
  - Proposed as solution to the Strong CP Problem
  - Possible candidates for Cold Dark Matter
- **International Axion Observatory (IAXO):**
  - Axion heliotelescope
  - BabyIAXO in construction at DESY (Hamburg, Germany):
    - IAXO-D0 detector prototype in Zaragoza, Spain
    - One problem: ~100 MeV Neutrons can give false positives

Neutron Monitor as veto

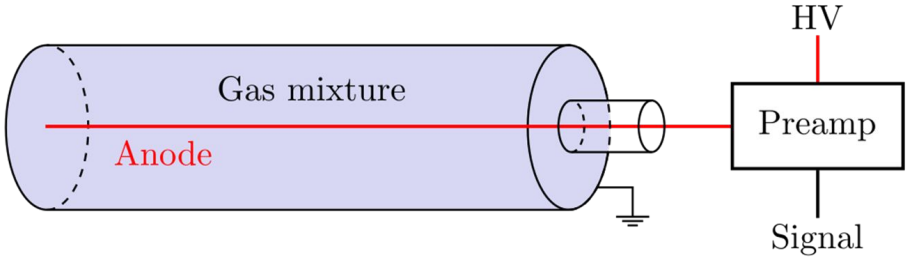


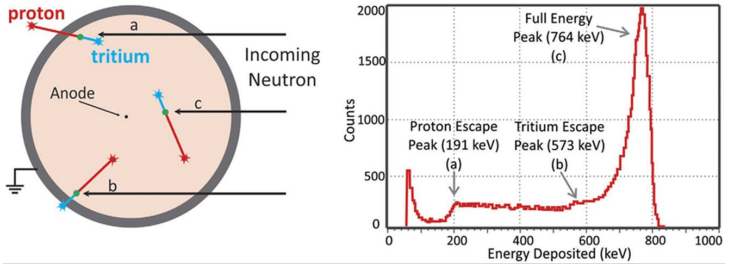
IAXO
Image: IAXO Collaboration



BabyIAXO
Image: DESY

Neutron Monitors

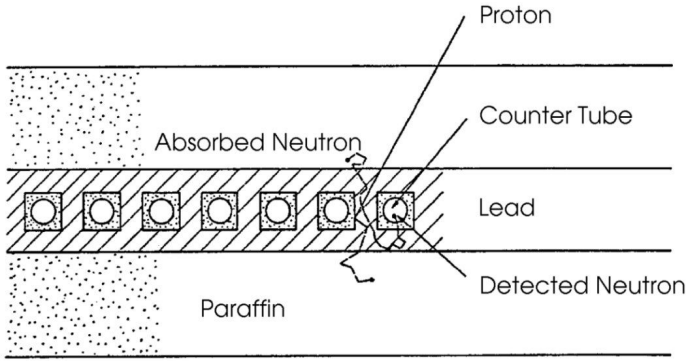


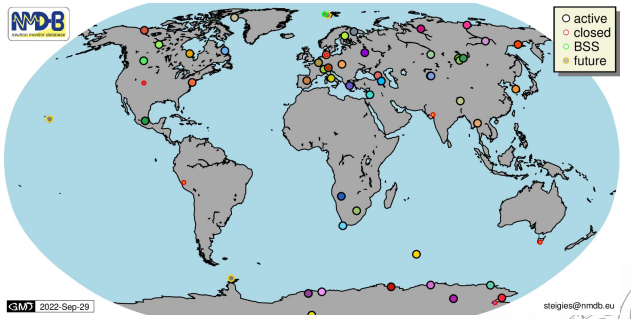


(F. D. Amaro et al., Feb. 2017)

$^{3}He + n\ (thermal) \rightarrow p^{+} + {}^{3}H + Q$

$Q = 764\ keV$





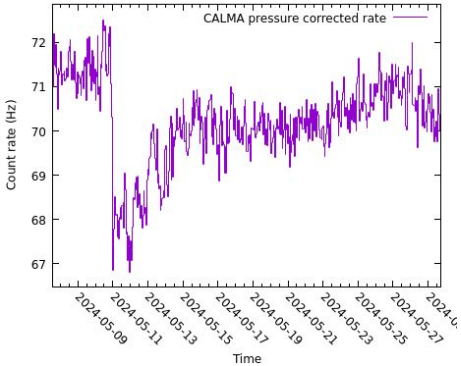
Neutron Monitor Database (NMDB): nmdb.eu

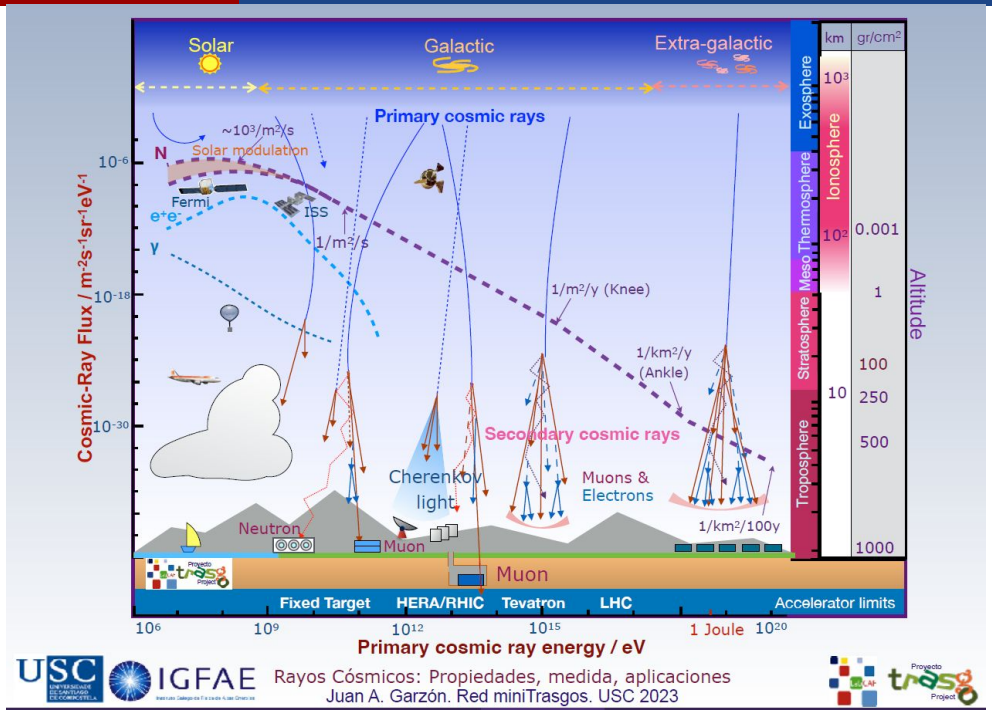
Cosmic Rays: Forbush Decrease

Cosmic rays:

- Primary rays: High energy particles:
  - γ, e, p, n, nuclei
- Different origins
- Primary rays interact with atmosphere → Secondary rays:
  - γ, e, μ, n

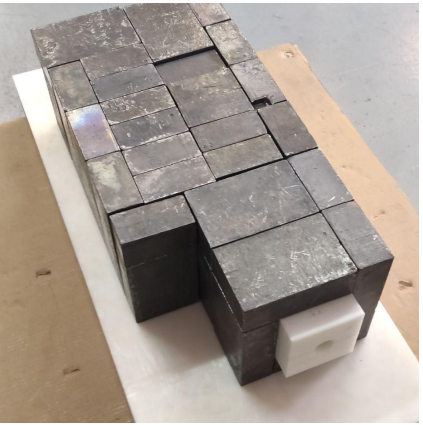
Forbush Decrease:
Coronal Mass Ejection (CME) → Earth:
Cosmic ray rate reduced

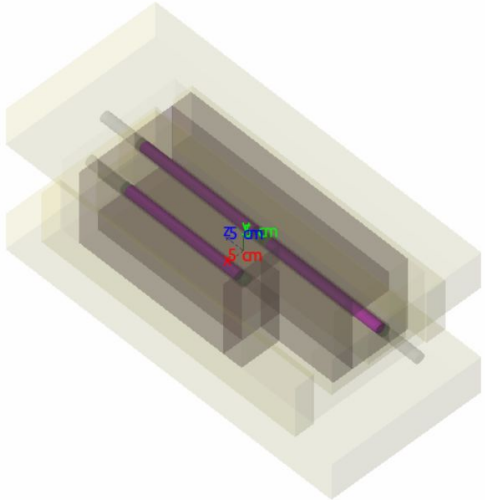


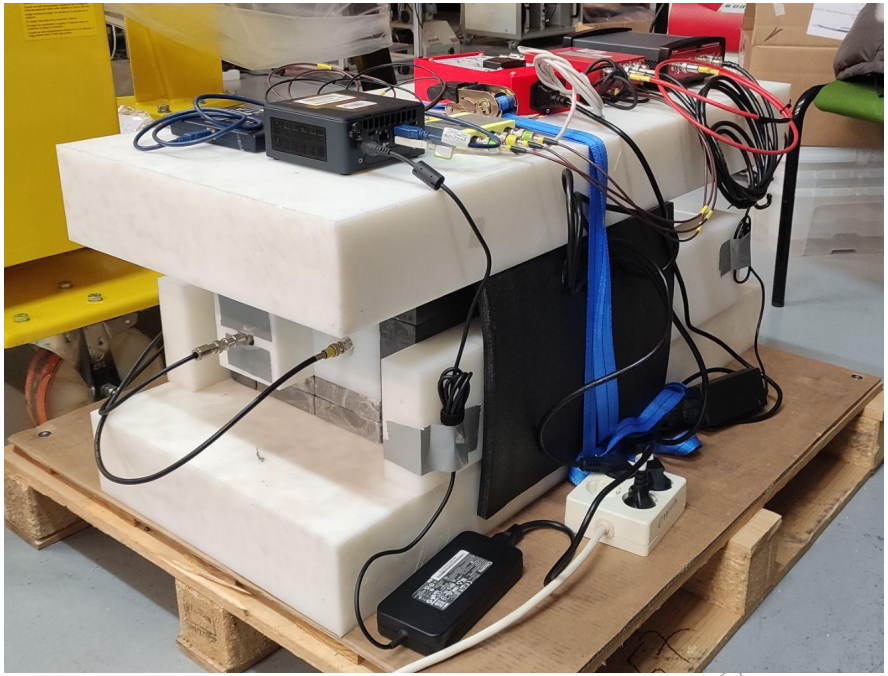


“Sandwich” Neutron Monitor

- 3 Neutron 3He counter tubes;
  - LND 252189 (10 bar, 280mm)
- Several layers of HDPE and lead as reflector, multiplier and moderator.
- CAEN A1422B090F2 preamplifier
- Picoscope Series 2000 digitizer:
  - 100 MS/s (10 ns/S)
  - 15 bits





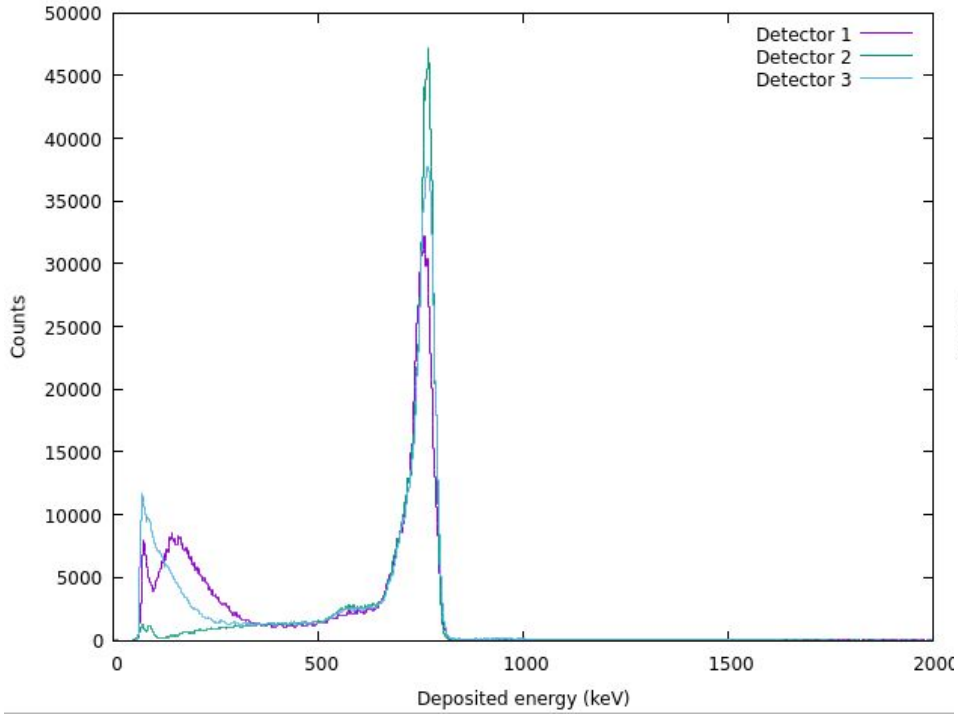


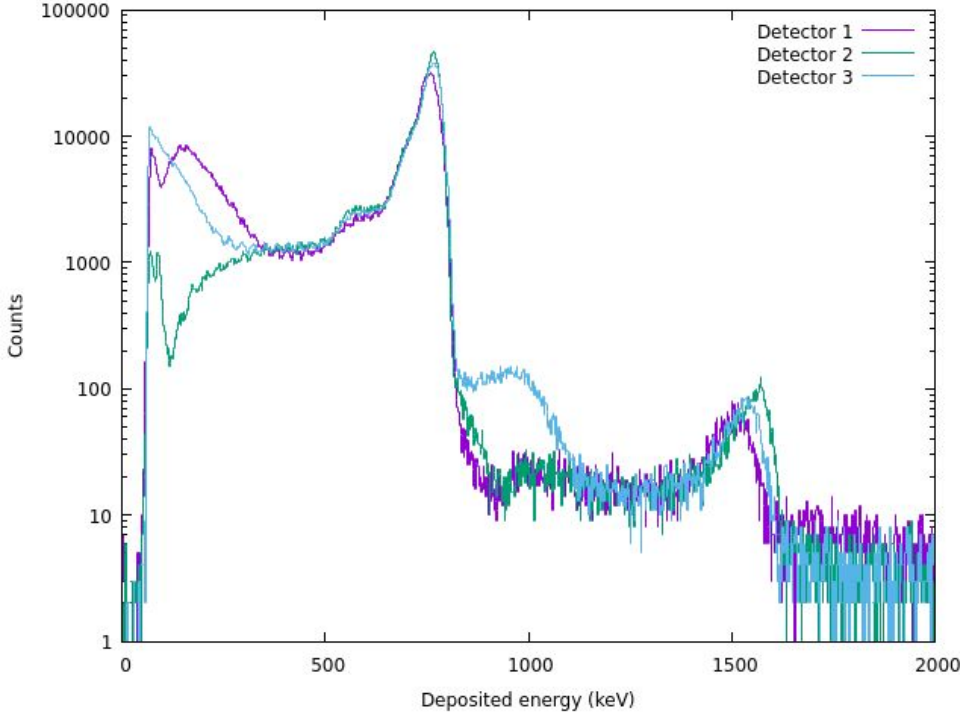
Taking data since March 2024
(some stops due to electricity cuts)

Data: Energy histograms

RUN1:

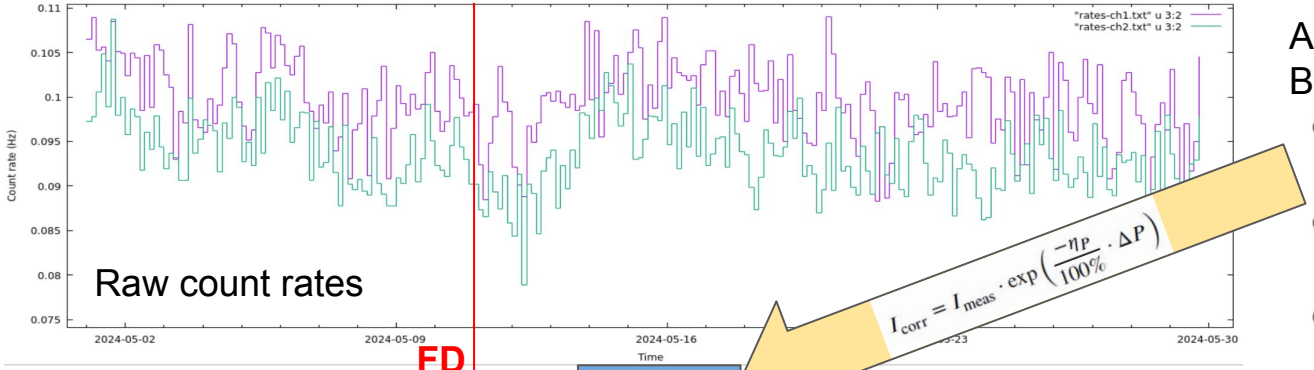
- Start: 2024-03-15
- End: 2024-07-24





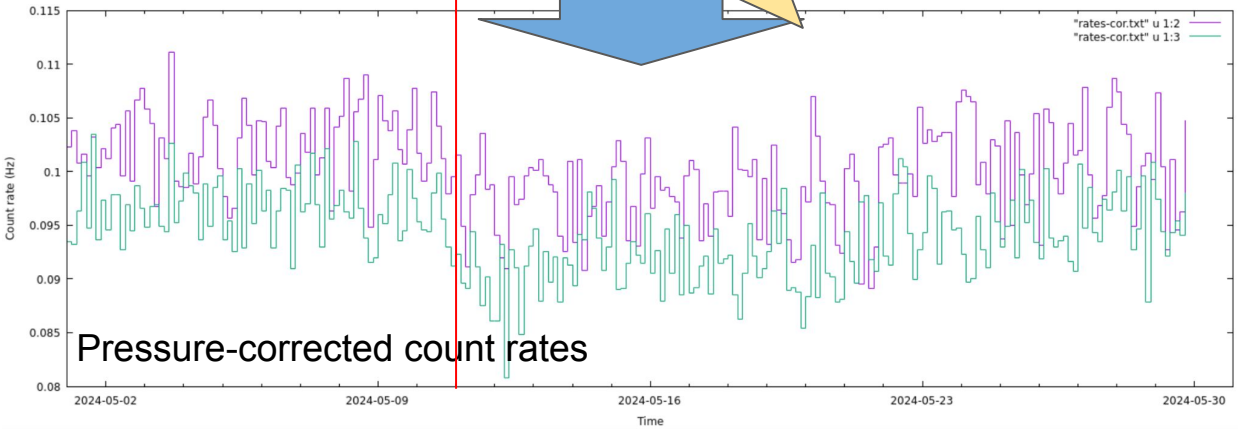
Data: Count Rates

Intense CME in May 11th 2024 → Forbush Decrease observed throughout NMDB

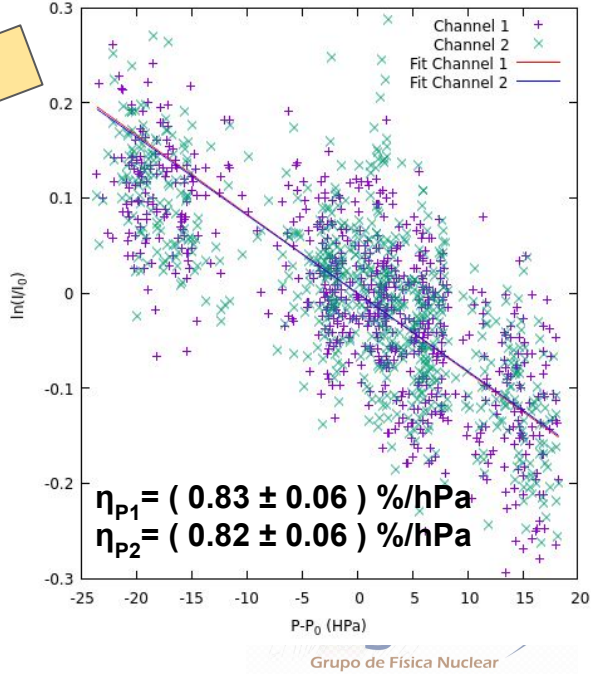


FD

$$I_{corr} = I_{meas} \cdot \exp\left(\frac{-\eta_P}{100\%} \cdot \Delta P\right)$$



Atmospheric pressure correction:
Barometric coefficient η_P



Grupo de Física Nuclear

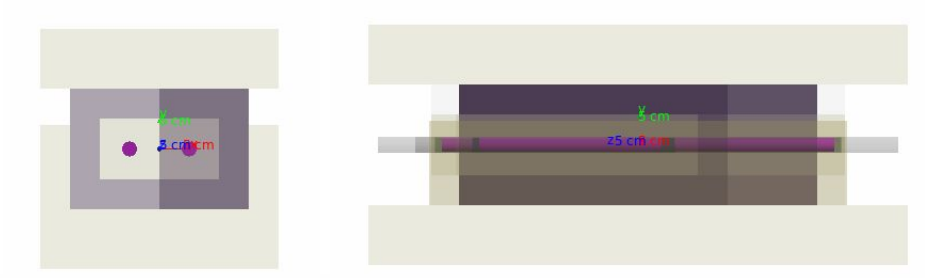
Data: Count Rates

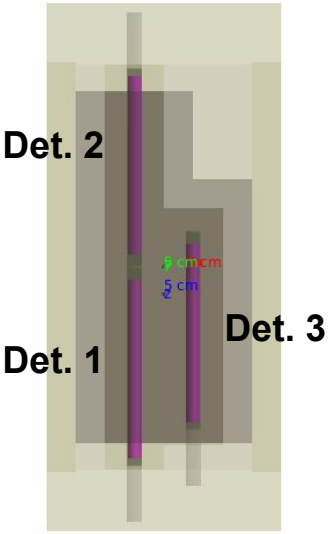
Intense CME in May 11th 2024 → Forbush Decrease observed throughout NMDB ⇒ **We see it!**

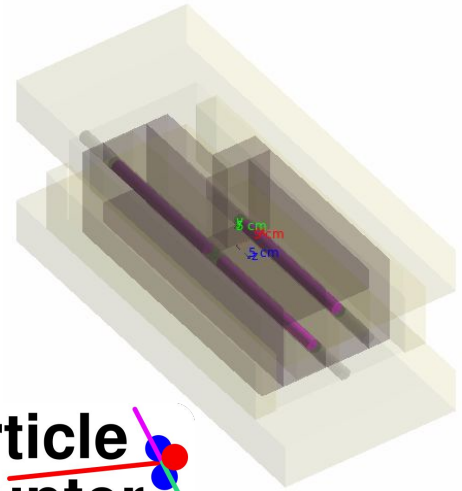
CaLMa data (pressure corrected and *1/300) (Guadalajara, Spain)

Sandwich data (pressure corrected) (Zaragoza, Spain)

Monte Carlo Simulations





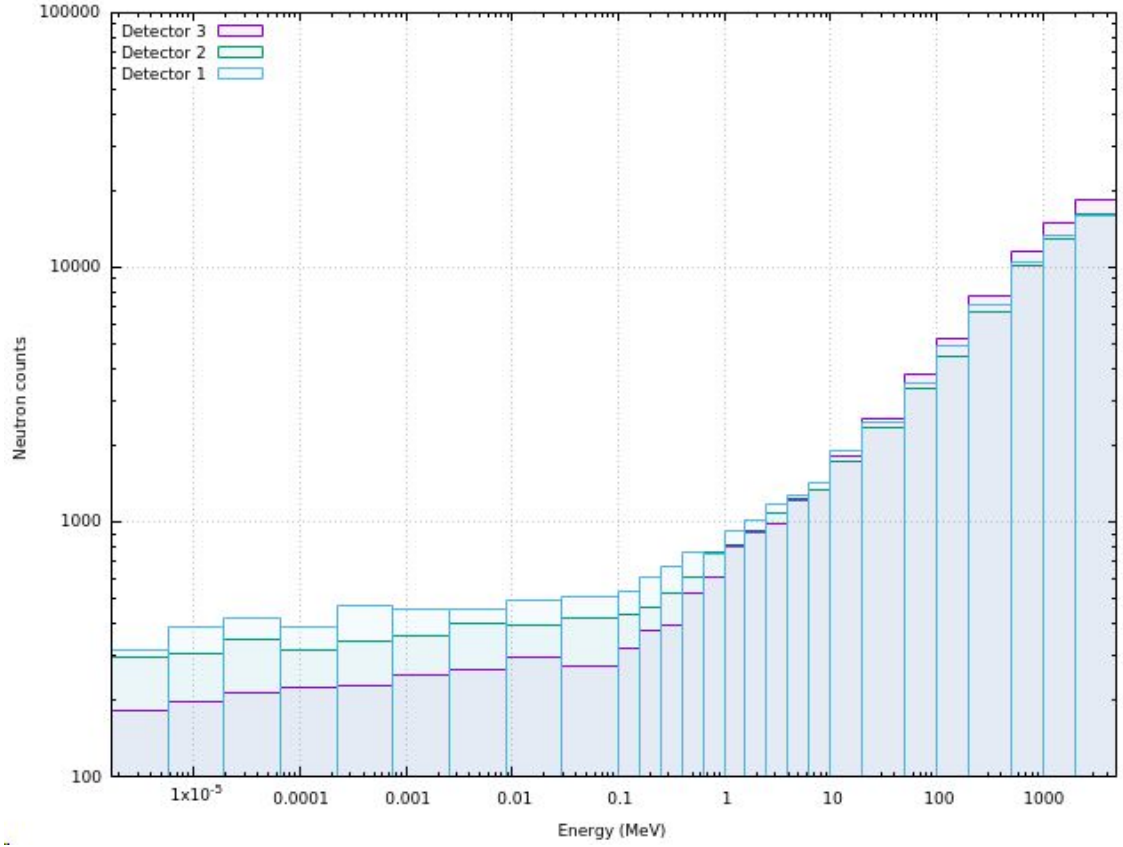


Particle Counter

- GEANT4-based ParticleCounter (A.Tarifeño et al.)
- 27 bins from $1.7 \cdot 10^{-6}$ MeV to $5 \cdot 10^{3}$ MeV
- 10^{8} neutrons generated
- 4π homogeneous neutron distribution

gfn UCM
Grupo de Física Nuclear

Monte Carlo Simulations



- Response increases with neutron energy
- Detector 3 slightly more efficient at high energies

Future work

- Obtain Energy spectrum using the NM's response and HENSA++ deconvoluted spectrum measured at the same location (Ariel Tarifeño, Álvaro Quero et al.)
- Study pile-up pulses: energy, multiplicity, time distribution
- Obtain long-time background neutron rates
- Analyse the neutron rates for the Forbush Decrease on June 2025
- New optimized Neutron Monitor:
  - 5 new 3He tubes:
    - VacuTec 70 063
    - 1,95 bar
    - 253 mm
  - Moderator optimization ongoing

Thank you for your time

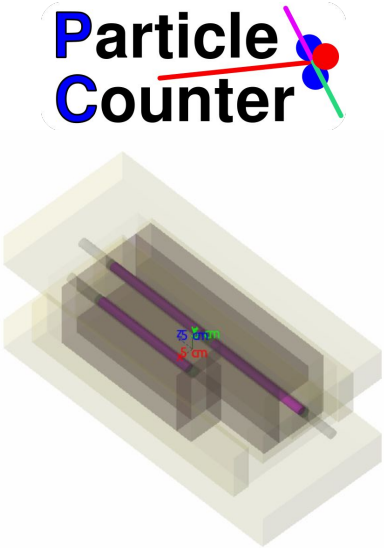
~ Backup slides ~

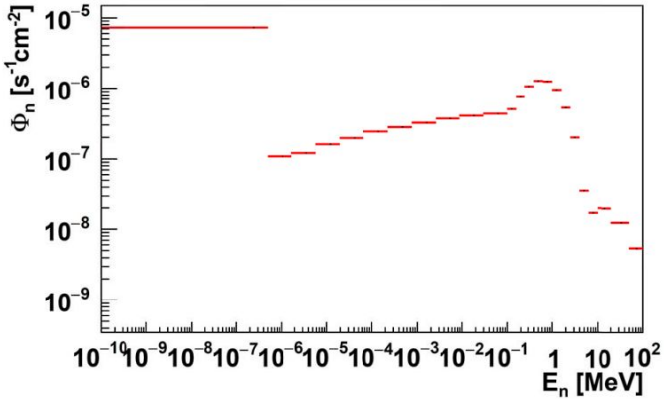
Neutron Monitors

Neutron counter array data + **Monte Carlo simulations** —Deconvolution→ **Energy Spectrum**

Examples:

HENSA++
Ariel Tarifeño, Álvaro Quero, et al.
(IFIC, UPC, UGr)

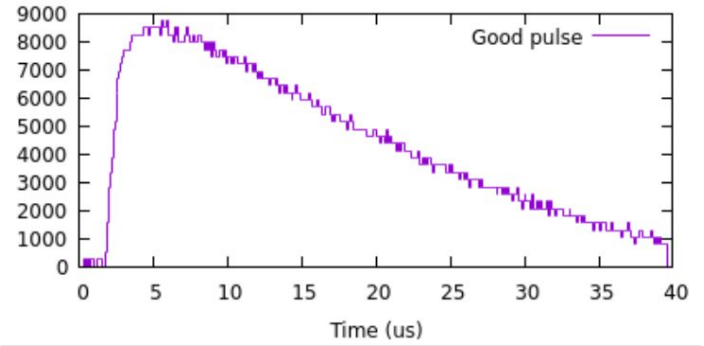


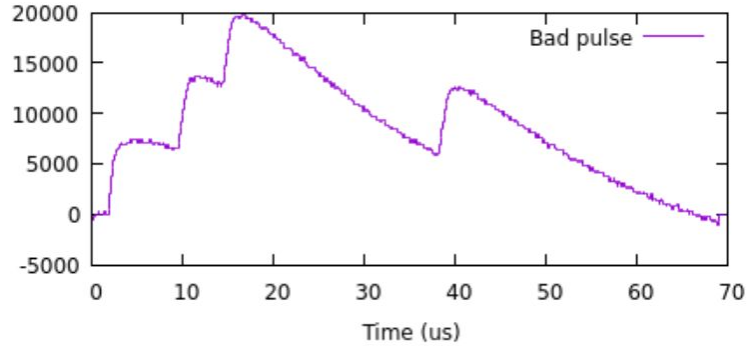


S E A Orrigo et al 2021 J. Phys.: Conf. Ser. 2156 012169

Data processing

- Picoscope C program:
  - Streaming mode acquisition
  - Output:
    - List file
    - Pulse traces
  - Threshold triggering
  - Discards pulses shorter than a chosen length
- Pile-up identification program (finds pulse local maxima):
  - At each sample it checks within a 4 μs radius whether it is a maximum.
  - If it finds at least 2 local maxima, we have pile-up: The pulse gets discarded.
  - If any of the maxima is located at sample ≥ 10μs, it's categorized as pile-up.





Data: Energy vs Time plot