Neutron background monitoring for the IAXO-D0 detector prototype

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

[1]Universidad Complutense de Madrid, [2]Instituto de Física Corpuscular (CSIC-UV), [3]CAPA-Universidad de Zaragoza, [4]Universitat Politècnica de Catalunya, [5]Universidad de Granada

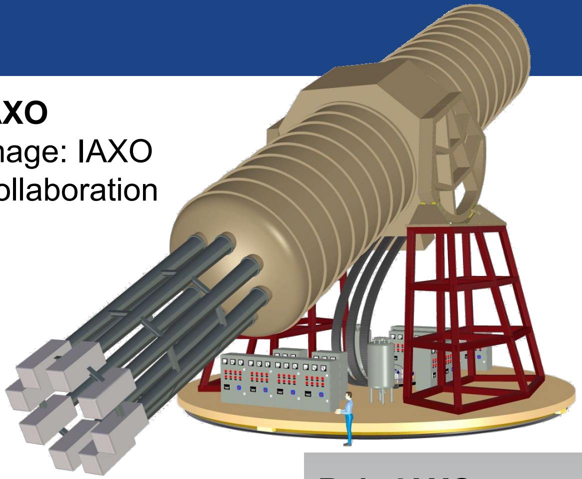
XVI CPAN Days Madrid – 19th November 2024

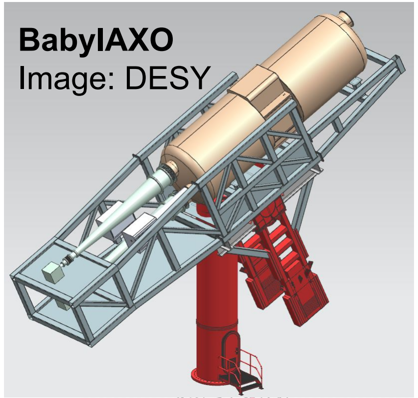
IAXO

- **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 (Germany):
    - IAXO-D0 detector prototype in Zaragoza
    - One problem: ~100 MeV Neutrons can give false positives

Neutron Monitor as veto

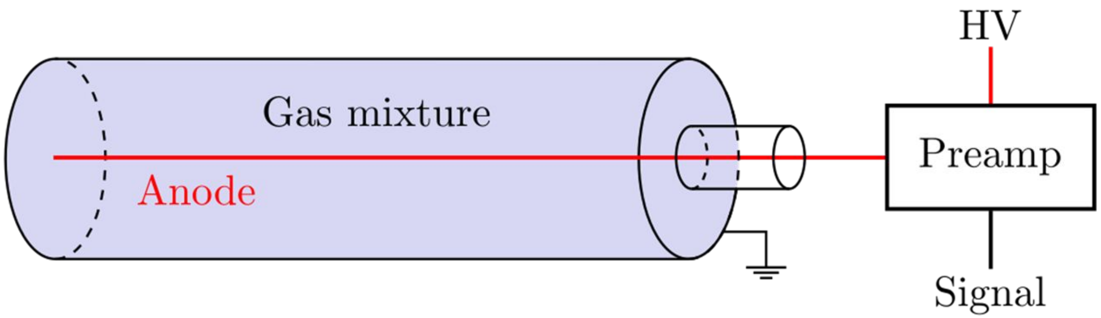
IAXO
Image: IAXO Collaboration

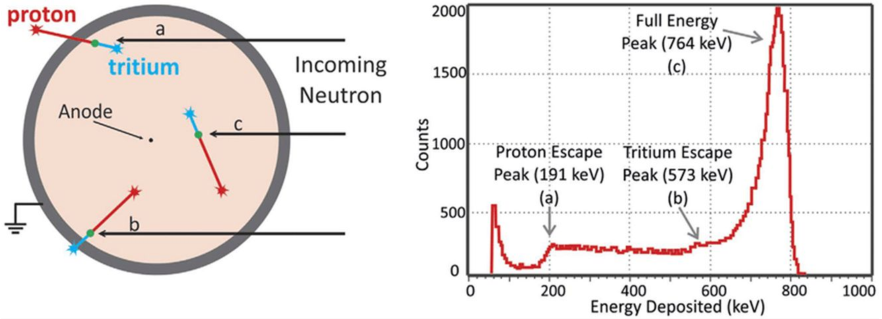




BabyIAXO
Image: DESY

Neutron Counters





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

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

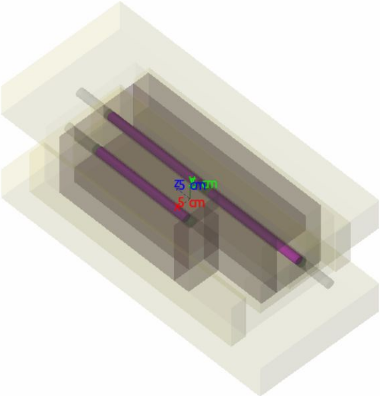
$$Q = 764\ \text{keV}$$

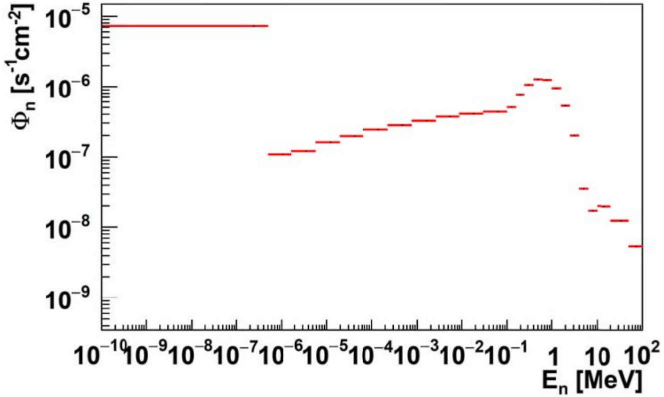
Neutron Counters

Neutron counter array data ✚ **Monte Carlo simulations** $\xrightarrow{\text{Deconvolution}}$ **Energy Spectrum**

Examples:

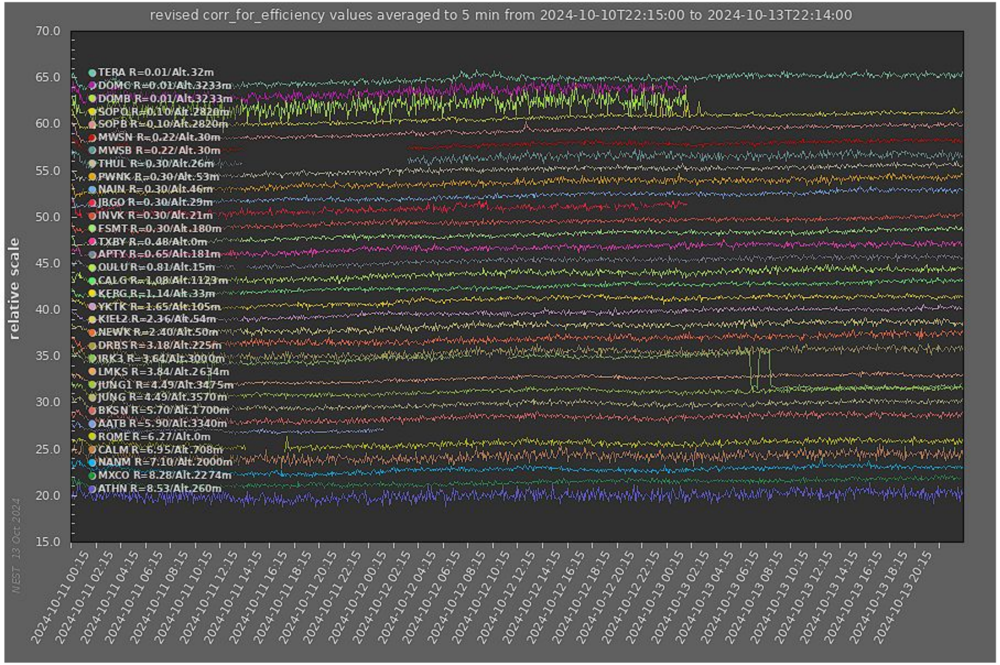
HENSA++
Ariel Tarifeño, Álvaro Quero, et al.
(IFIC, UPC, UGr)

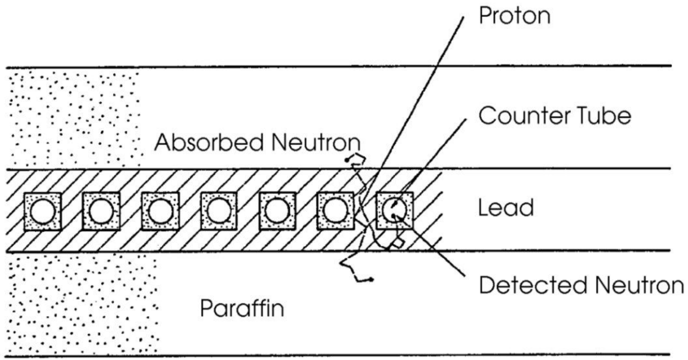


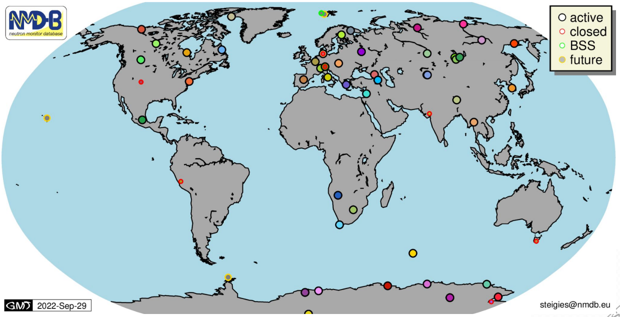


S E A Orrigo et al 2021 J. Phys.: Conf. Ser. 2156 012169

Neutron Monitors





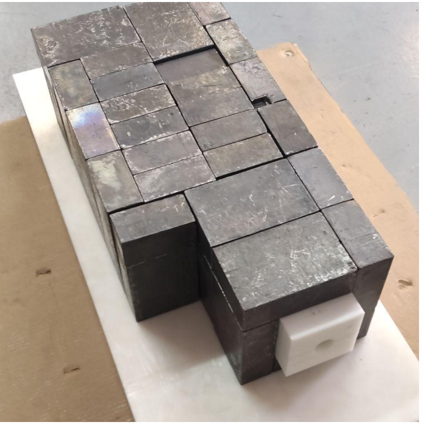


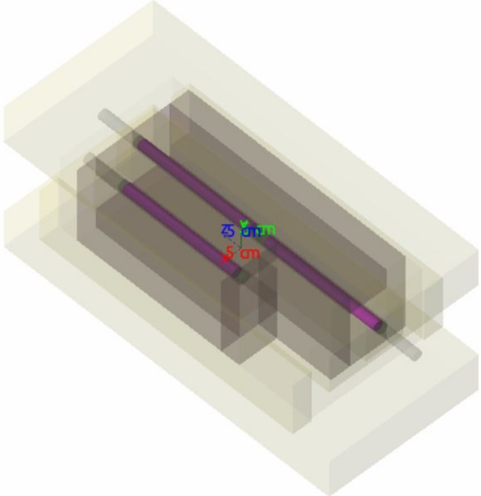
Neutron Monitor Database (NMDB)

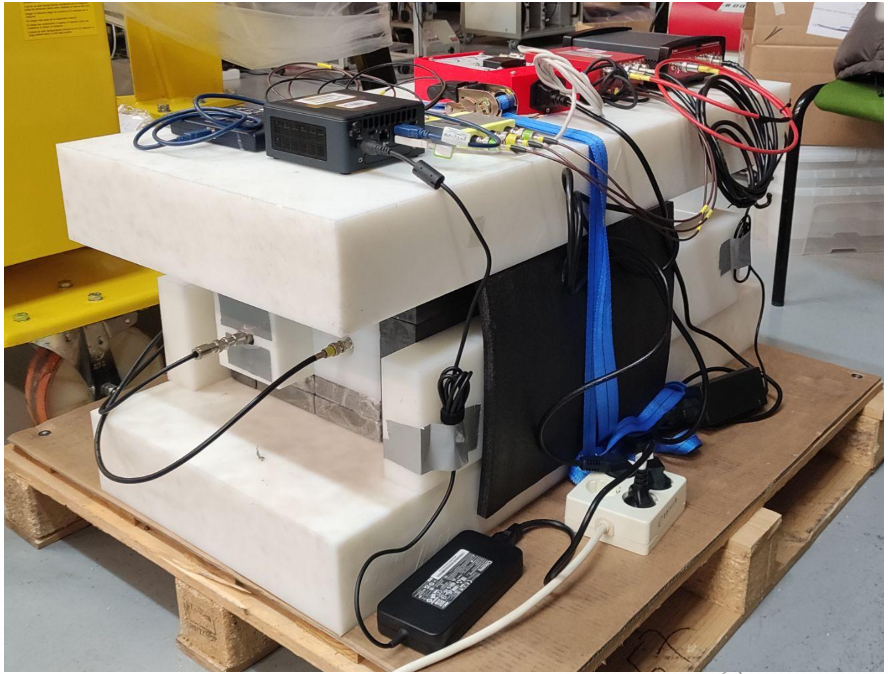
Grupo de Física Nuclear

“Sandwich” Neutron Monitor

- 3 Neutron 3He counter tubes:
  - LND 252189
  - 10 bar
- Several layers of HDPE and lead moderators
- CAEN A1422B090F2 preamplifier
- Picoscope Series 2000 digitizer:
  - 100 MS/s (10 ns/S)
  - 15 bits



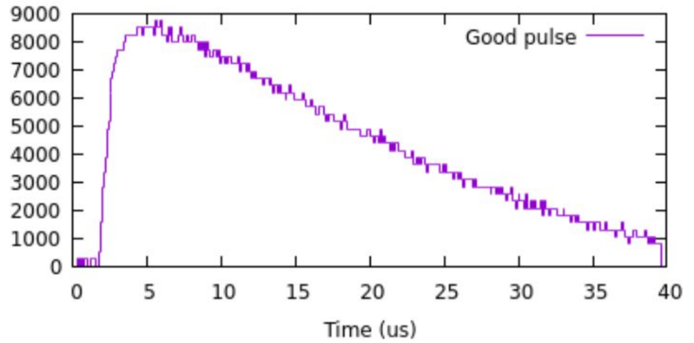


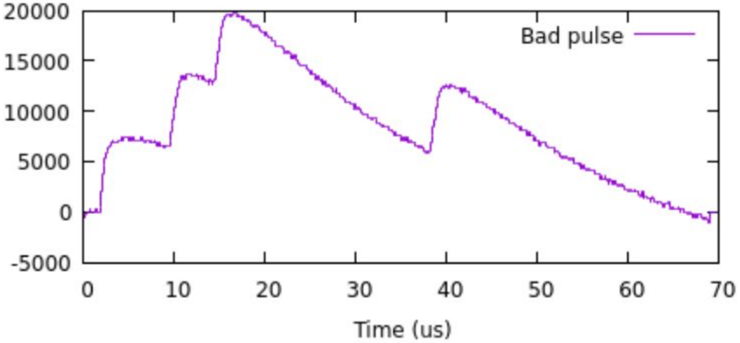


Taking data since March 2024
(some stops due to electricity cuts)

Data 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.

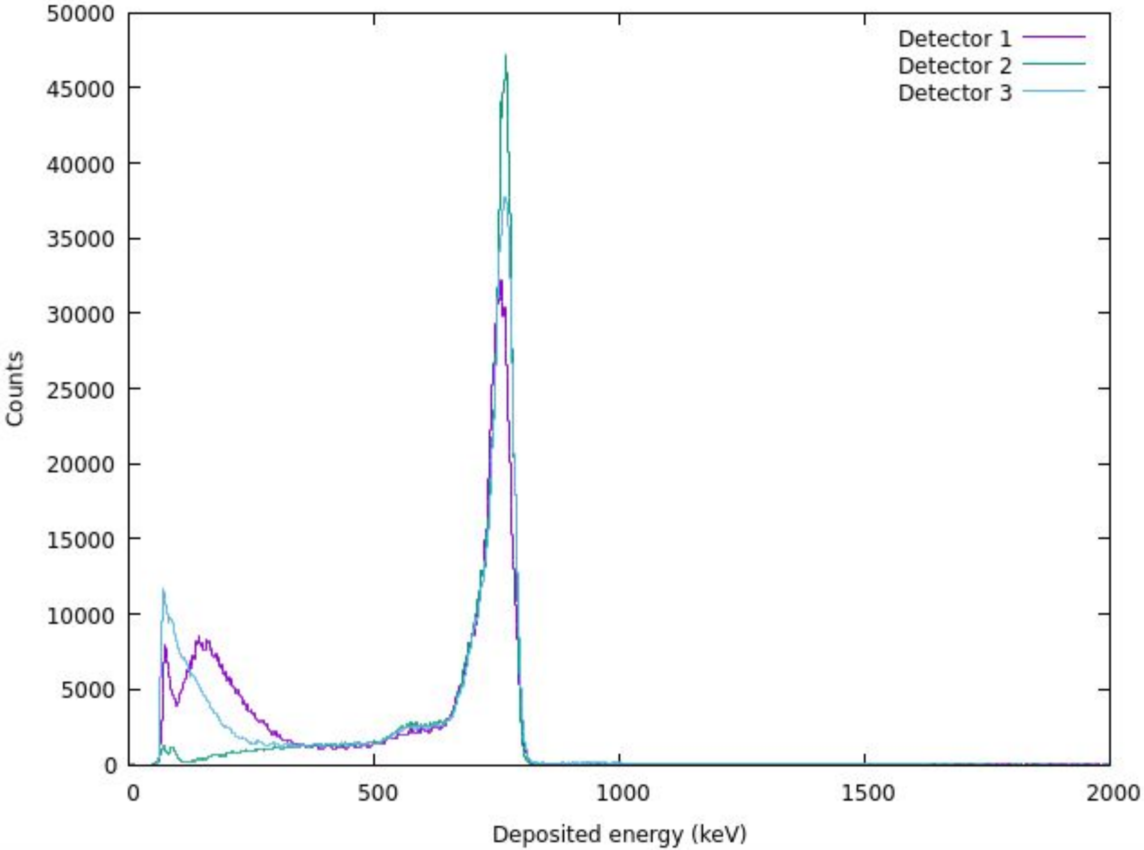




Grupo de Física Nuclear

Data: RUN1

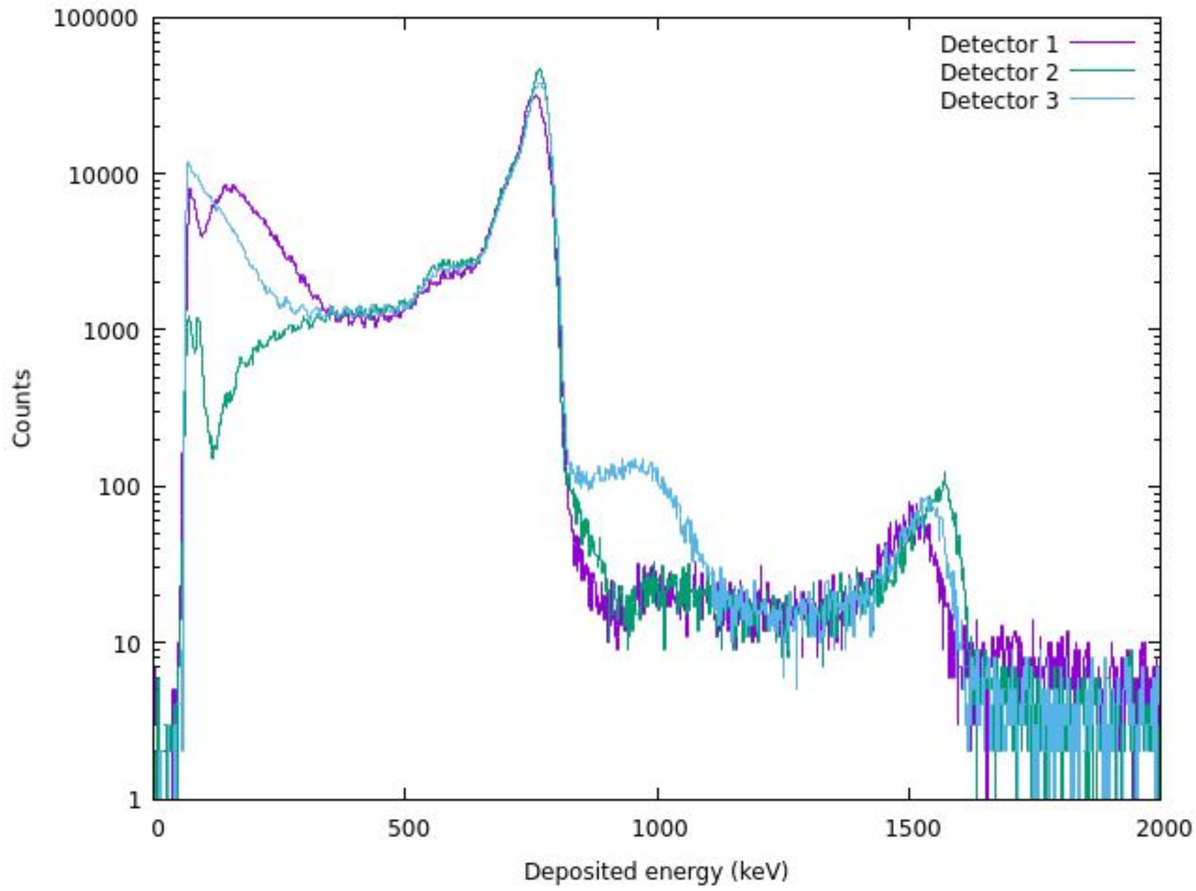
Energy histograms



RUN1:

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

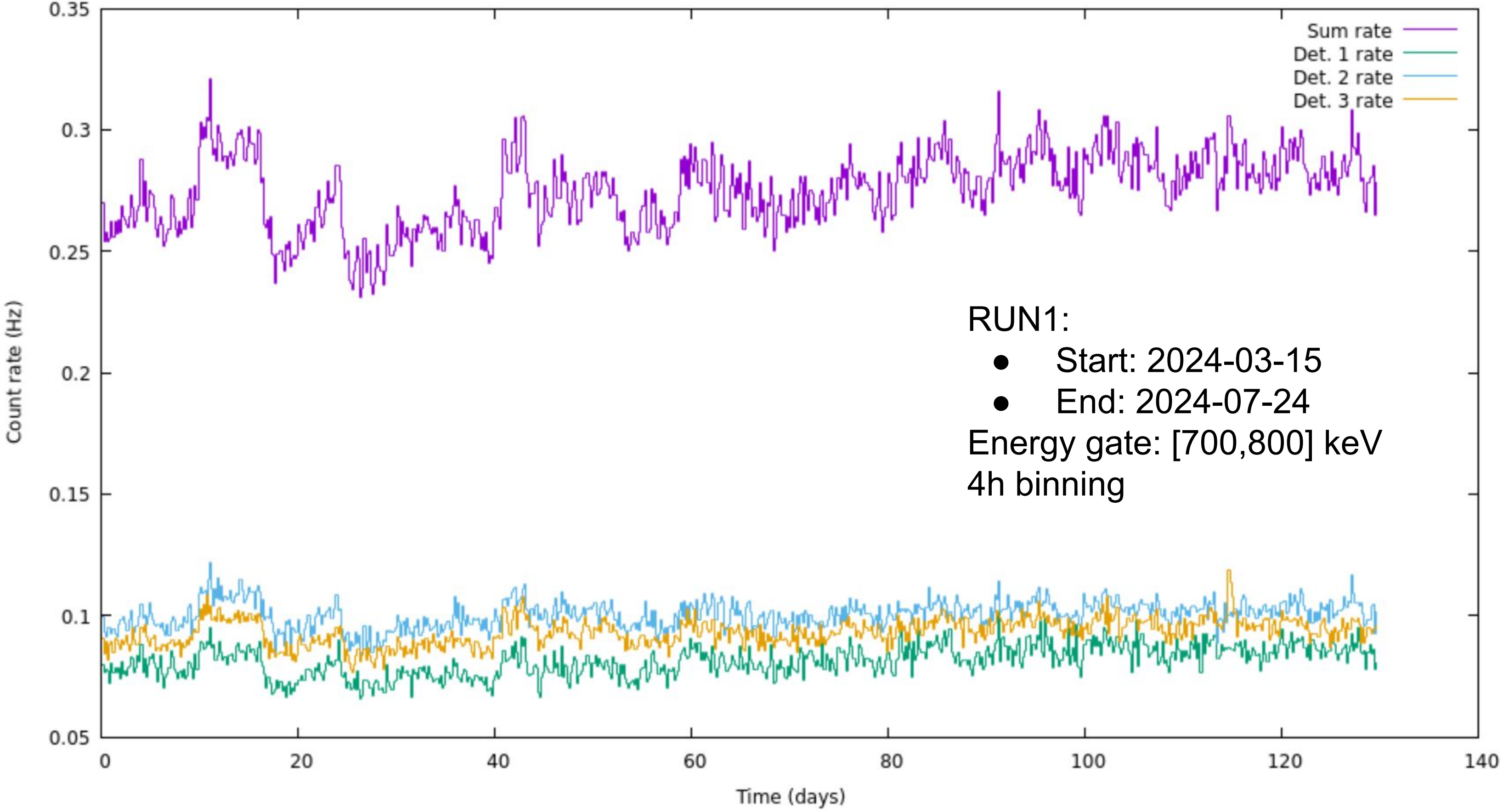
Data: RUN1



RUN1:

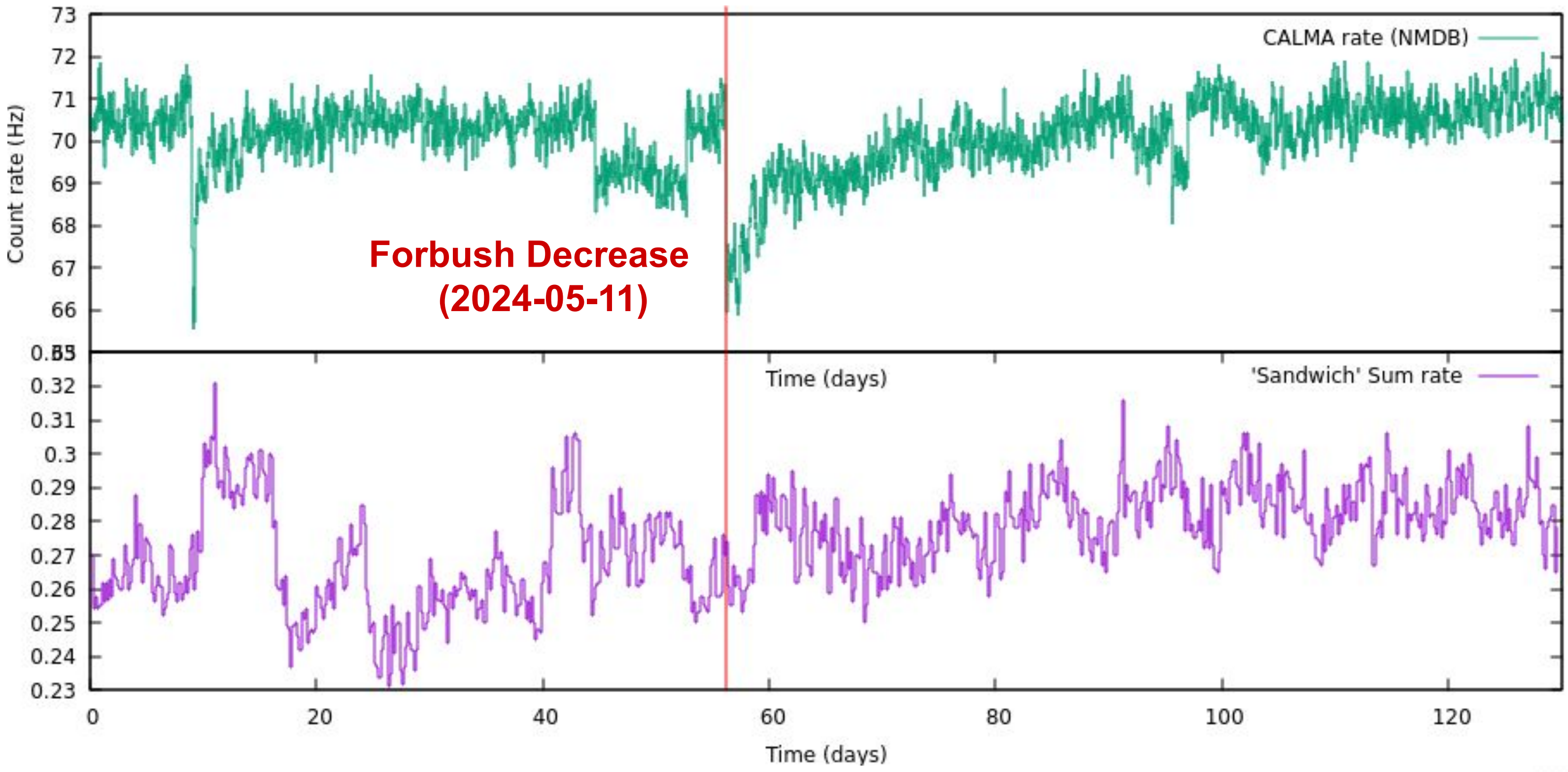
- Start: 2024-03-15
- End: 2024-07-24

Data: RUN1



RUN1:
- Start: 2024-03-15
- End: 2024-07-24

Energy gate: [700,800] keV
4h binning

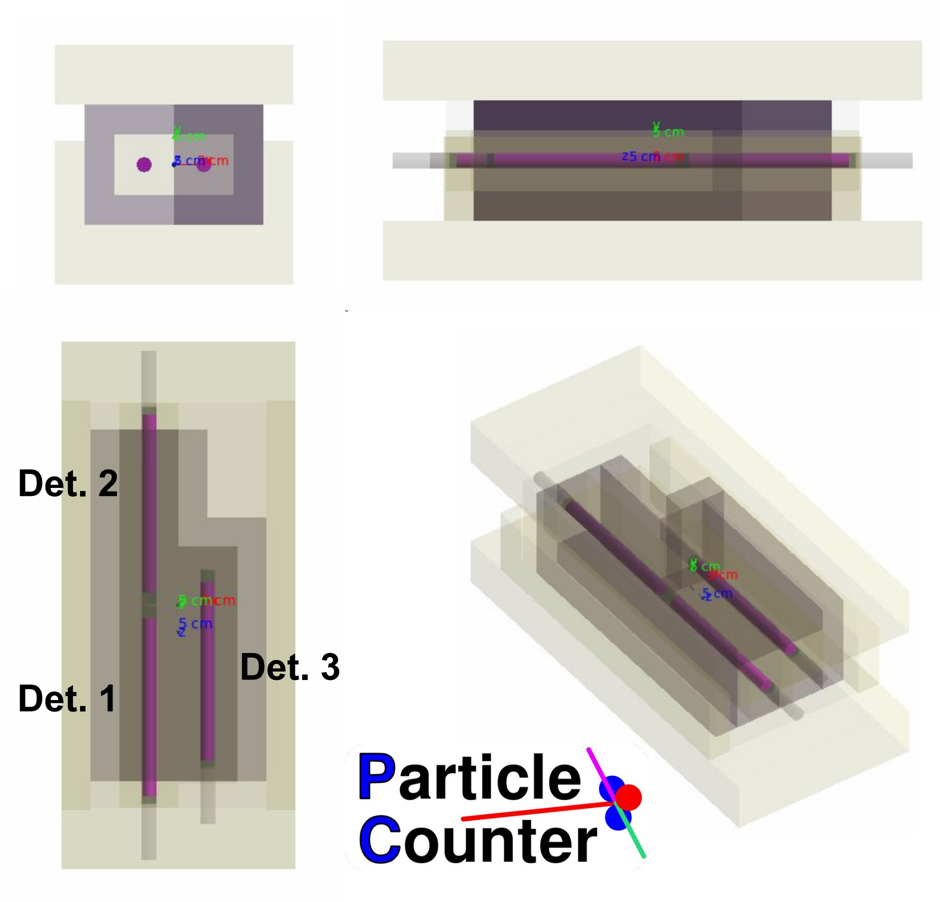


Start: 2024-03-15 → End: 2024-07-24

CaLMa data (Guadalajara, Spain)
- Efficiency and atmospheric pressure corrected

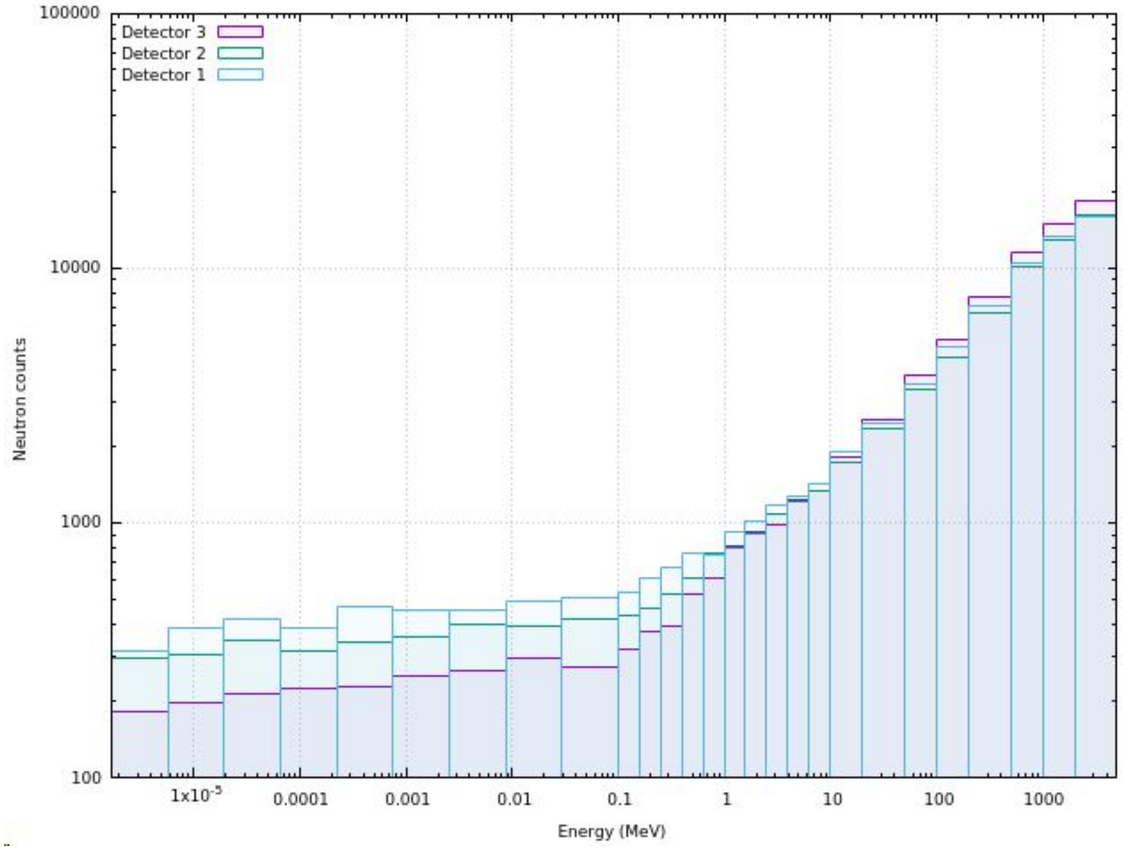
'Sandwich' RUN1:
- Energy gate: [700,800] keV
- 4h binning
- **Not** corrected by efficiency nor atm. pressure (yet)

Monte Carlo Simulations



- 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

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.)

- Correct count rate by efficiency and atmospheric pressure (barometric coefficient)

- Study pile-up pulses: multiplicity and time distribution

- New optimized Neutron Monitor:
  - 5 new 3He tubes:
    - VacuTec 70 063
    - 1,95 bar
    - 253 mm
  - Moderator optimization ongoing

Grupo de Física Nuclear

Thank you for your time

References:

- The IAXO Collaboration, “Conceptual design of the international axion observatory (IAXO),” Journal of Instrumentation, vol. 9, no. 05, p. T05002–T05002, May 2014, doi: 10.1088/1748-0221/9/05/t05002.
- The IAXO Collaboration, “Conceptual design of babyiaxo, the intermediate stage towards the international axion observatory,” Journal of High Energy Physics, vol. 2021, no. 137, May 2021, doi: 10.1007/JHEP05(2021)137.
- J.A. Simpson, “The cosmic ray nucleonic component: The invention and scientific uses of the neutron monitor – (keynote lecture),” Space Science Reviews, no. 93, pp. 11–32, 2000, doi: 10.1023/A:1026567706183.
- A. Tarifeño-Saldivia et al., “Conceptual design of a hybrid neutron-gamma detector for study of -delayed neutrons at the rib facility of riken,” Journal of Instrumentation, vol. 12, no. 04, p. P04006, apr 2017, doi: 10.1088/1748-0221/12/04/P04006
- S E A Orrigo et al, “Measurement of the neutron flux at the Canfranc Underground Laboratory with HENSA”, J. Phys.: Conf. Ser. 2156 012169, 2021. DOI 10.1088/1742-6596/2156/1/012169

Acknowledgements:

-
- Part of the calculations of this work were performed in the “Clúster de Cálculo para Técnicas Físicas” funded in part by UCM and in part by EU Regional Funds.
- We acknowledge the NMDB database www.nmdb.eu, founded under the European Union's FP7 programme (contract no. 213007) for providing data. CaLMa neutron monitor data were kindly provided by the Space Research Group (SRG-UAH), University of Alcala, Spain.