Status of the RICOCHET experiment at ILL

RENCONTRES DE MORIOND – EW+U 2026 SESSION

SERRA Renaud on behalf of the RICOCHET collaboration

17/03/2026

Physical process: CEνNS

Coherent **E**lastic **N**eutrino-**N**ucleus **S**cattering

- Theorized in 1974 by Daniel Z. Freedman
- First measurement in 2017 by COHERENT

Cross section predicted by the Standard Model:

$$\frac{d\sigma_{\nu/N}}{dE_R} = \frac{G_F^2}{4\pi} Q_w^2 \, m_N \left(1 - \frac{m_N \, E_R}{2 \, E_\nu^2}\right) F^2(E_R) \sim N^2$$

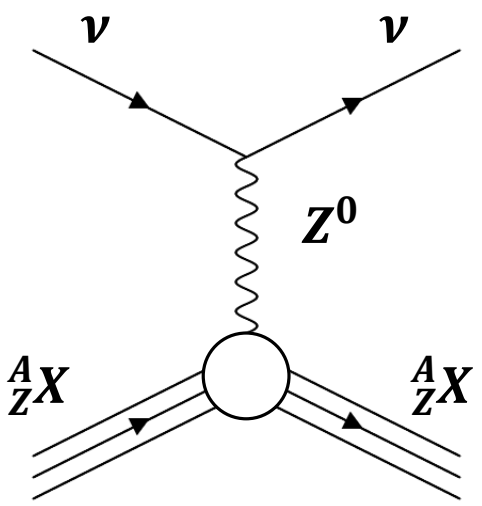
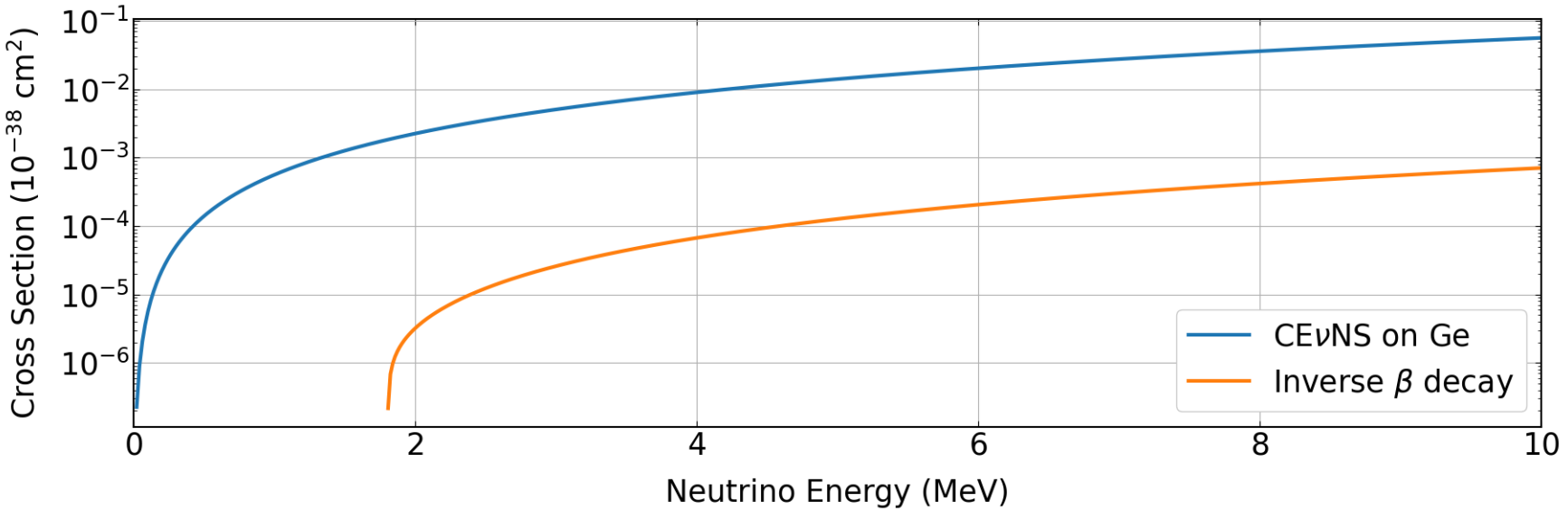


Diagram of CEνNS



Interactions cross-sections for various processes [L. Bailly-Salins, EPS-HEP 2025]

Physical process: sensitivity

1. Standard Model: **Weinberg angle**
2. Sensitivity to **new physics**:

- non-standard ν-quark interaction
- neutrino magnetic moment μ_ν
- new mediator boson Z'

3. Background for **dark matter**:

- same signature and inevitability
- experimental threshold

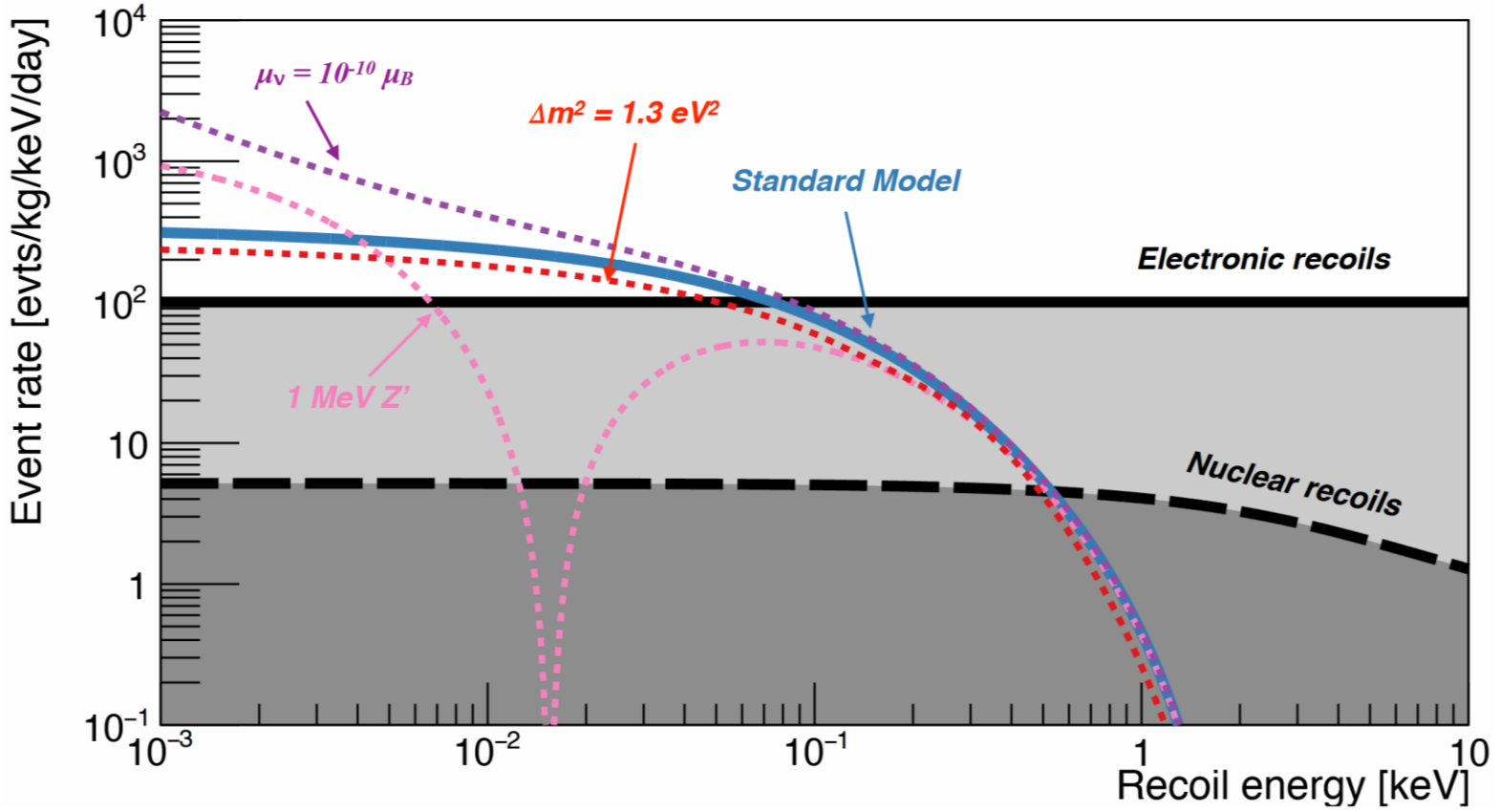
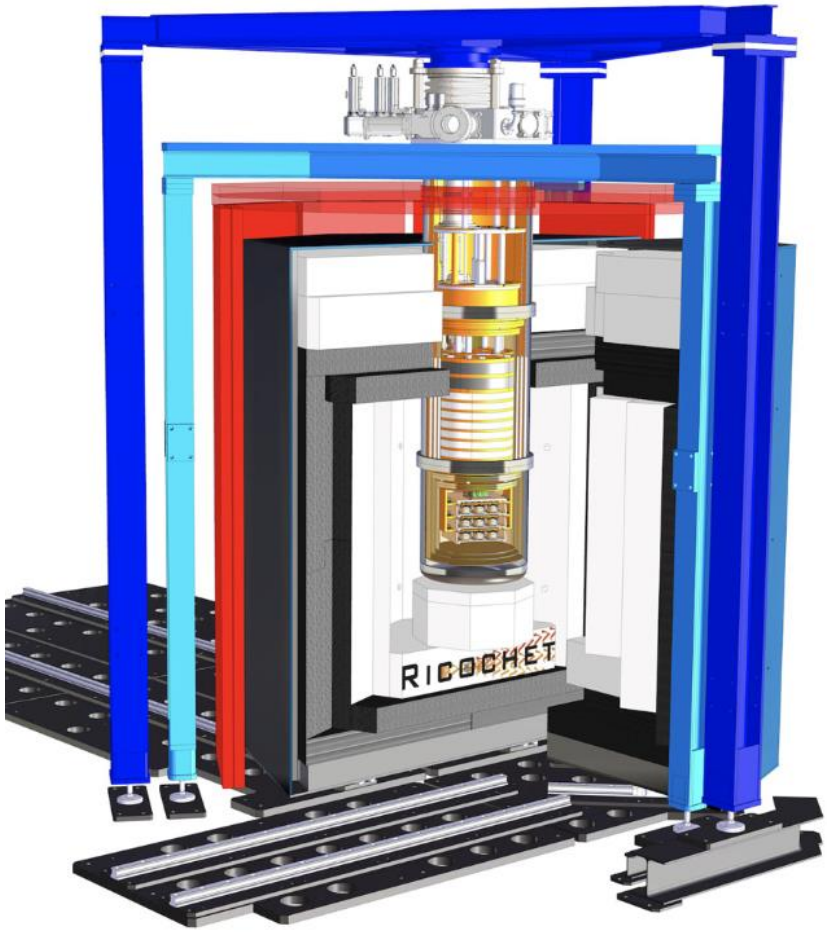


Illustration of theoretical interaction rates for the Ricochet experiment

[RICOCHET Collaboration, J Low Temp Phys 212 (2023), 127]

RICOCHET at ILL reactor

[RICOCHET Collaboration, EPJ 83 (2023), 20]



RICOCHET's shielding and cryostat

Only **8.8 m** to the reactor → $\boldsymbol{\phi_\nu \sim 10^{12}\ cm^{-2}.s^{-1}}$

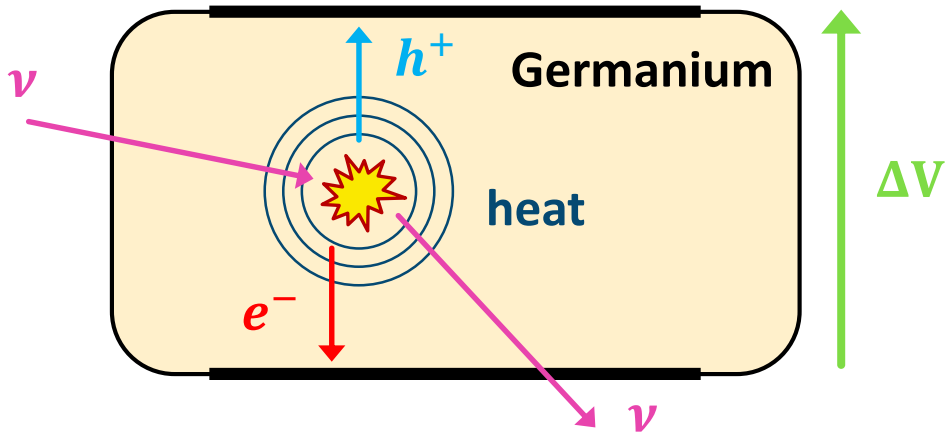
Radioactive **background** divided into 3 categories

- **Cosmogenic**: from cosmic particles (μ, n, etc.)
- **Reactogenic**: isotopes activated by reactor neutrons
- **Radiogenic**: natural background of the environment

Four-part background **mitigation** strategy

- **Passive** shielding: borated PE, lead and soft iron
- **Active** shielding: muon veto
- **Discrimination** based on recoil type: $\mathbf{ER/NR}$
- $\mathbf{ON–OFF}$ reactor cycle data subtraction

CryoCube detectors principle



Planar detector operating diagram

Mini-CryoCube: 3 cryogenic bolometers

CryoCube: 2×3 mini-CryoCube

Full payload: 18×42 g $\Rightarrow$ kg-scale

Technologies: PL & FID detectors

Strategy: ionization & heat signals

Discrimination: ionization yield or quenching $\boldsymbol{Q = \frac{E_{ion}}{E_{recoil}}}$

- Electronic Recoil (**ER**): from γ & e^- $\Rightarrow$ $\boldsymbol{Q = 1}$
- Nuclear Recoil (**NR**): from ν & n $\Rightarrow$ $\boldsymbol{Q \approx 0.2}$
- Low-Energy Excess (**LEE**) or Heat-Only (**HO**): $\boldsymbol{Q = 0}$

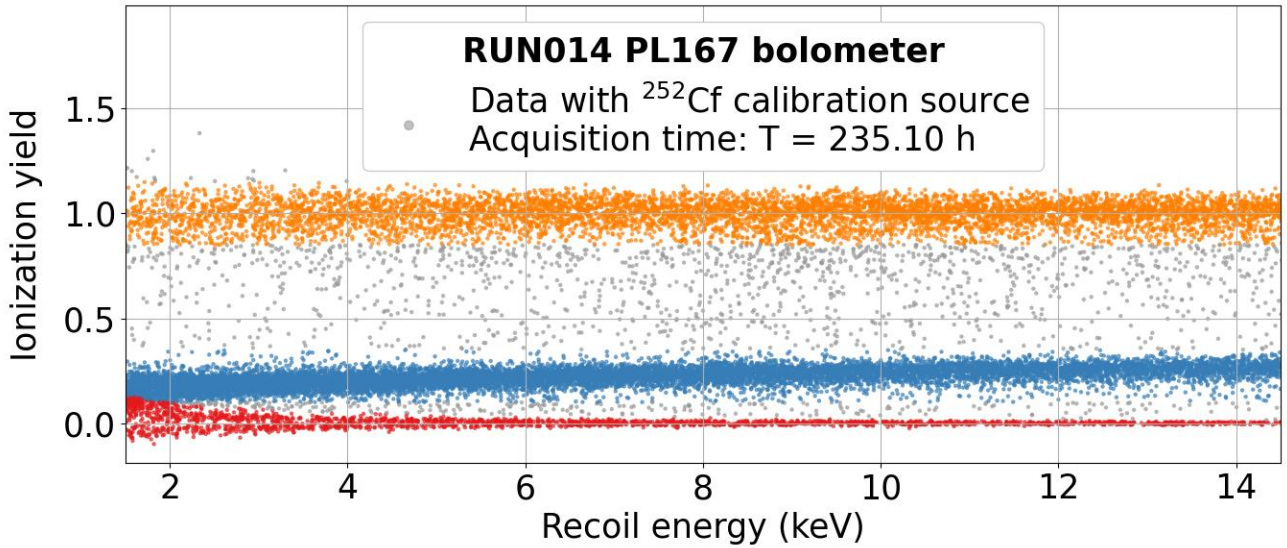


Illustration of ionization yield as a function of recoil energy

[Adapted from Phys. Rev. D 112 (2025), 112019]

Gamma background

[RICOCHET Collaboration, Phys. Rev. D 112 (2025), 112019]

Gamma background: electronic recoil band

Major contribution: $^{41}_{18}\mathrm{Ar}$ decay during ON

Experimental result in region of interest*

- RUN014: $\boldsymbol{R^{PL167}_{ON-OFF} = (980 \pm 174)\ DRU}^{\dagger}$

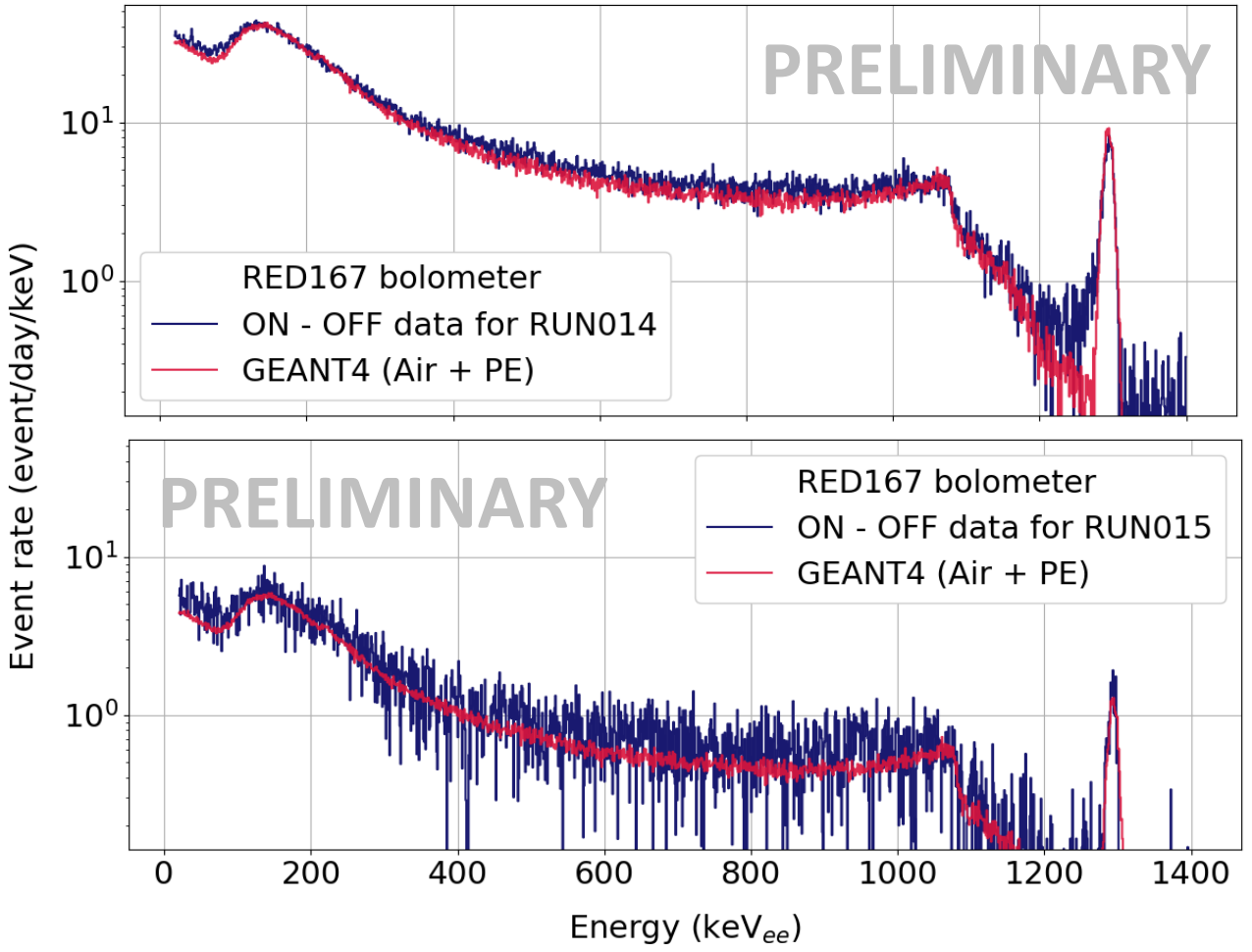
GEANT4 simulations: in air and shielding§

- RUN014: $\boldsymbol{R^{PL167}_{GEANT4} = (839 \pm 69)\ DRU}$
- RUN015: $\boldsymbol{R^{PL167}_{GEANT4} = (117 \pm 14)\ DRU}$

86% reduction in event rate between RUNs

Due to improvements in **shielding sealing**

* from 2 to 7 keV & † 1 DRU = 1 event/day/kg/keV & § used in MCMC reconstruction



Reconstruction of ionization spectra with simulations

Summary & outlook

RICOCHET successfully operating at ILL

2024

- **RUN012**: cryogenic test at ILL

2025

- **RUN013:** first test of PL detectors
- **RUN014:** background validation test
- **RUN015:** first test with FID detectors

2026

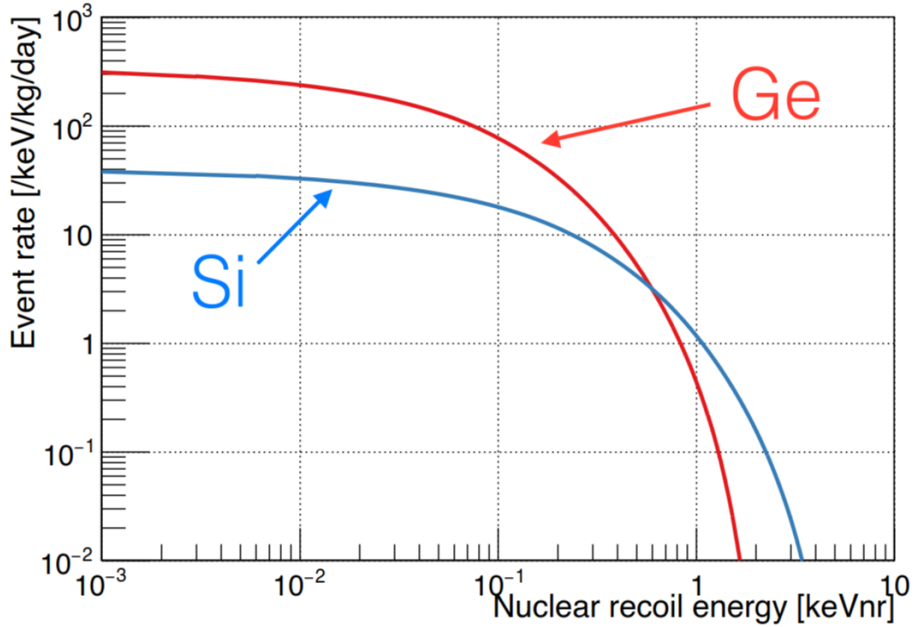
- **RUN016:** first science run with full payload
- **RUN017:** second science run

Baseline resolutions RUN014:

- 40 eV_{ee} ionization
- 50–80 eV_{ph} phonon

Development in progress

- **Q-Array:** superdconducting crystals
- **Silicon detector:** complementary targets



CEνNS event rate spectra in Ge and Si crystals

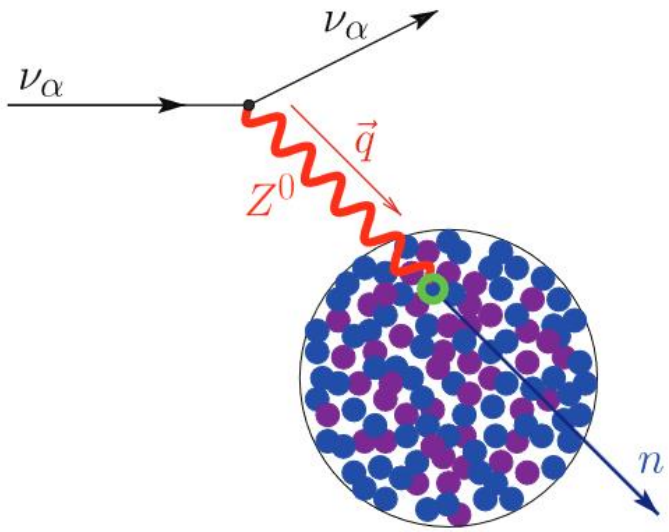
[Julien Billard *et al*, JCAP11(2018), 016]

Thank you for your attention!

Back-up

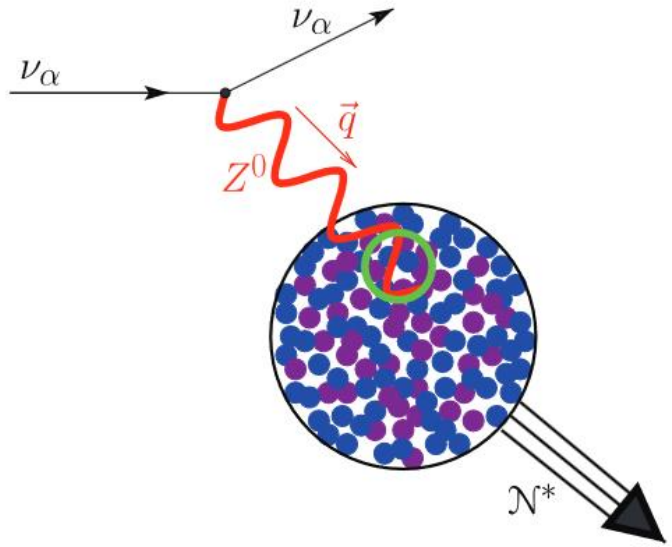
Neutrino-nucleus interactions

[M. Cadeddu *et al*, EPL 143 (2023), 34001]



Inelastic and incoherent :

$$\lambda_{Z_0} \ll 2R$$



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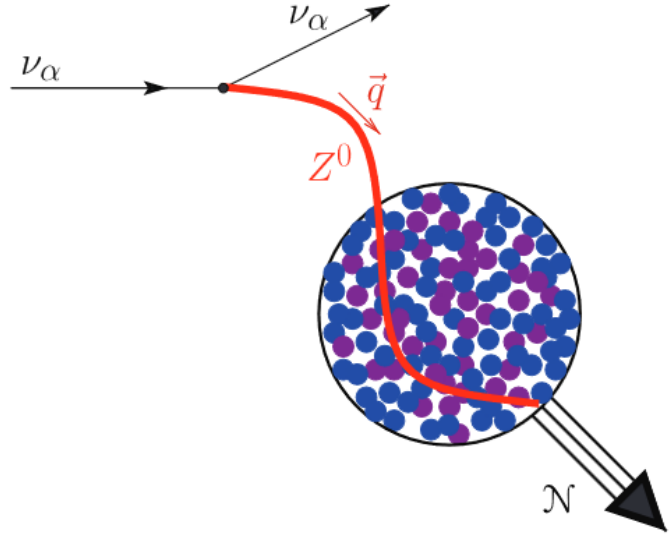


Elastic and coherent :

$$\lambda_{Z_0} \geq 2R$$

Standard Model probe

E_R : recoil energy

E_ν : neutrino energy

G_F : Fermi's constant

m_N : nucleus mass

$F(E_R)$: form facteur

Q_w : nucleus weak charge

N : number of neutrons

Z : number of protons

$\boldsymbol{\theta_W}$: weak mixing angle

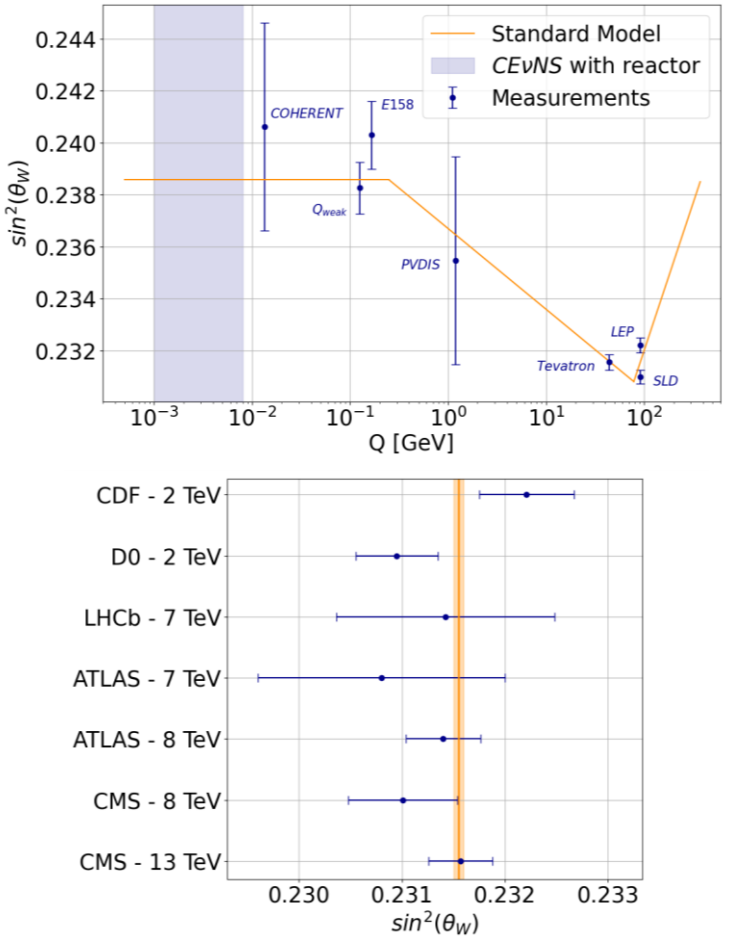
Cross section predicted by the Standard Model :

$$\frac{d\sigma_{\nu/N}}{dE_R} = \frac{G_F^2}{4\pi} Q_w^2 m_N \left(1 - \frac{m_N E_R}{2 E_\nu^2}\right) F^2(E_R)$$

With : $Q_w = N - \left(1 - 4\sin^2 \boldsymbol{\theta_W}\right) Z$

Unification of the electromagnetic force and the weak interaction :

- Represents the rotation caused by spontaneous symmetry breaking
- Proportion of weak and electromagnetic interactions in particle interactions



$sin^2\theta_w$ experimental measurements

Beyond the Standard Model

Standard Model prediction :

$$\frac{d\sigma_{SM}}{dE_R} = \frac{G_F^2}{4\pi} Q_w^2 \, m_N \left(1 - \frac{m_N \, E_R}{2 \, E_\nu^2}\right) F^2(E_R)$$

Non-zero magnetic moment :

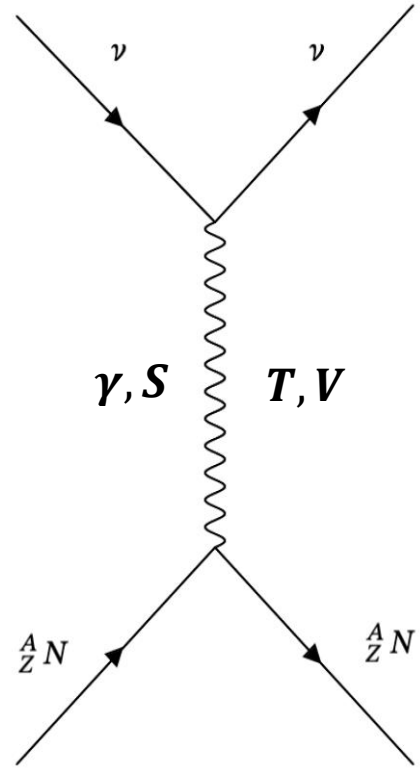
$$\frac{d\sigma_\mu}{dE_R} = \frac{\pi \, \alpha^2 \, \mu_\nu^2 \, Z^2}{m_e} \left(\frac{1}{E_R} - \frac{1}{E_\nu} + \frac{E_R}{4E_\nu^2}\right) F^2(E_R)$$

Scalar boson :

$$\frac{d\sigma_S}{dE_R} = \frac{Q_S^2}{4\pi} \frac{m_N^2 \, E_R}{E_\nu^2 \, (q^2 + m_S^2)^2} F^2(E_R) \qquad Q_S = g_{\nu,S} \, g_{q,S} \, (15.1 \, Z + 14 \, N)$$

Tensor boson :

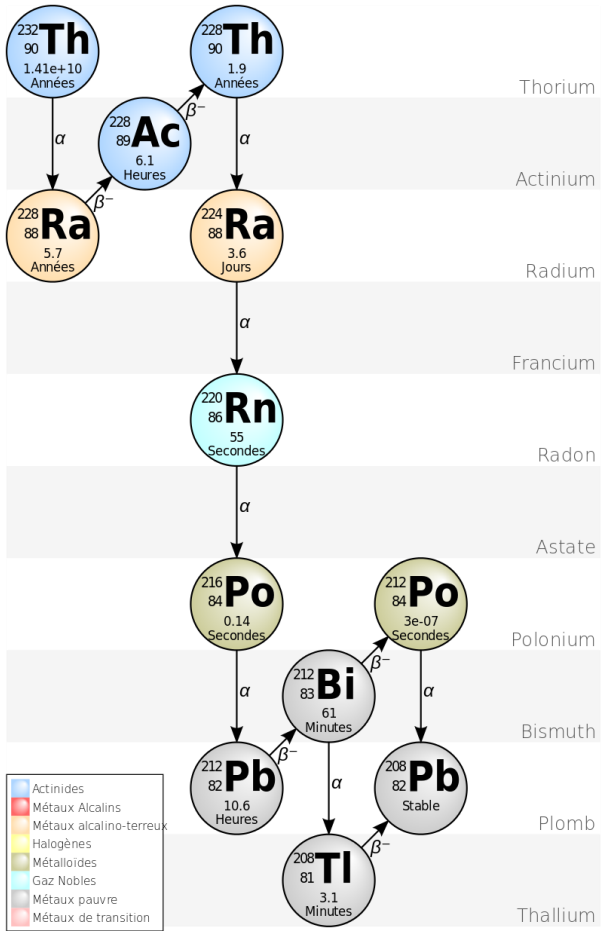
$$\frac{d\sigma_T}{dE_R} = \frac{Q_T^2}{2\pi} \frac{m_N \, (4 \, E_\nu^2 - m_N \, E_R)}{E_\nu^2 \, (q^2 + m_T^2)^2} F^2(E_R) \qquad Q_T = g_{\nu,T} \, g_{q,T} \, (0.85 \, Z + 0{,}08 \, N)$$

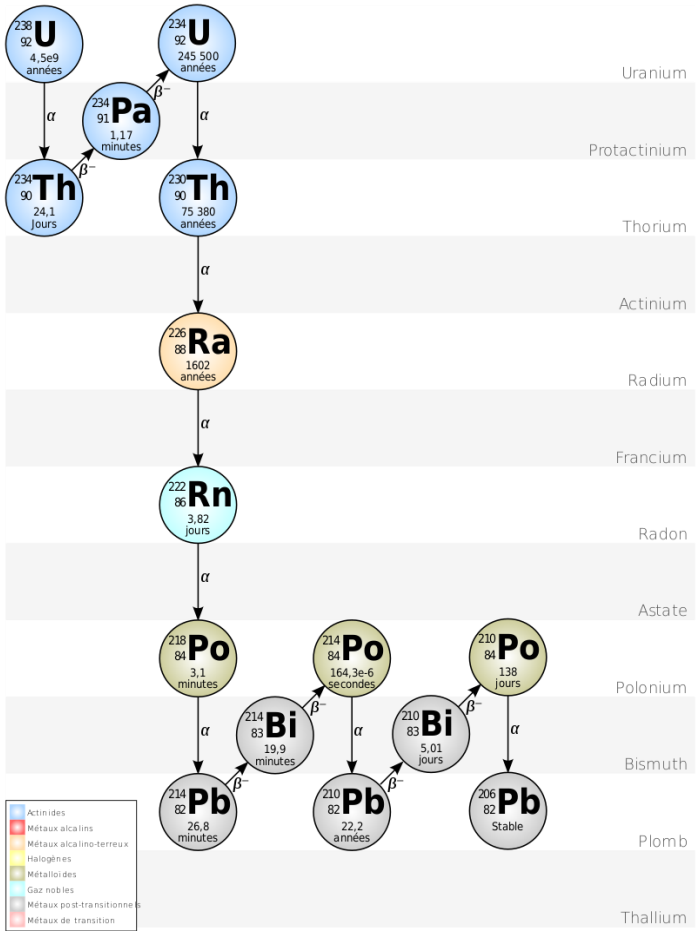


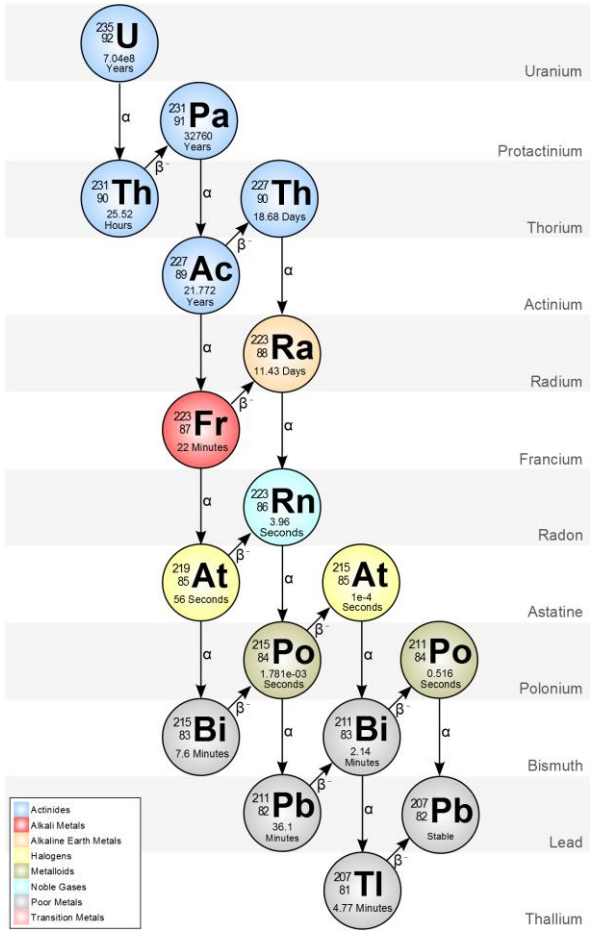
Vector boson :

$$\frac{d\sigma_V}{dE_R} \propto \frac{d\sigma_{SM}}{dE_R} \qquad Q_W \rightarrow Q_{tot} = Q_W - \frac{\sqrt{2}}{G_F \, q^2} \frac{g_{\nu,V} \left[Z \left(2 \, g_{u,V} + g_{d,V}\right) + N \left(g_{u,V} + 2 \, g_{d,V}\right) \right]}{q^2 + m_V^2}$$

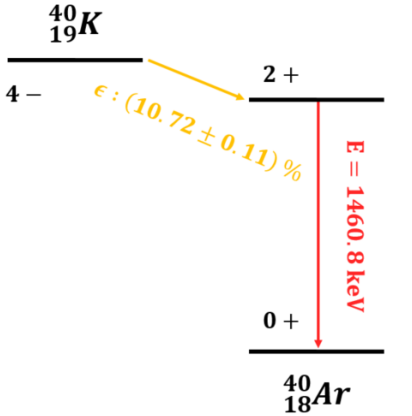
Gamma background sources

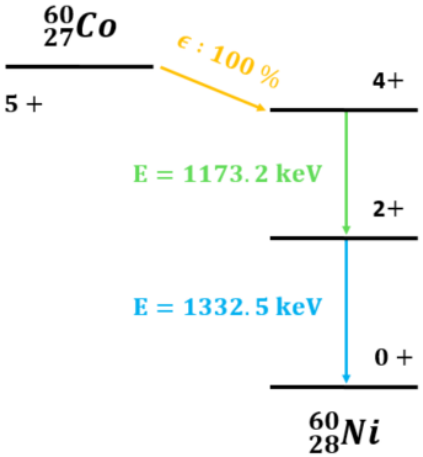






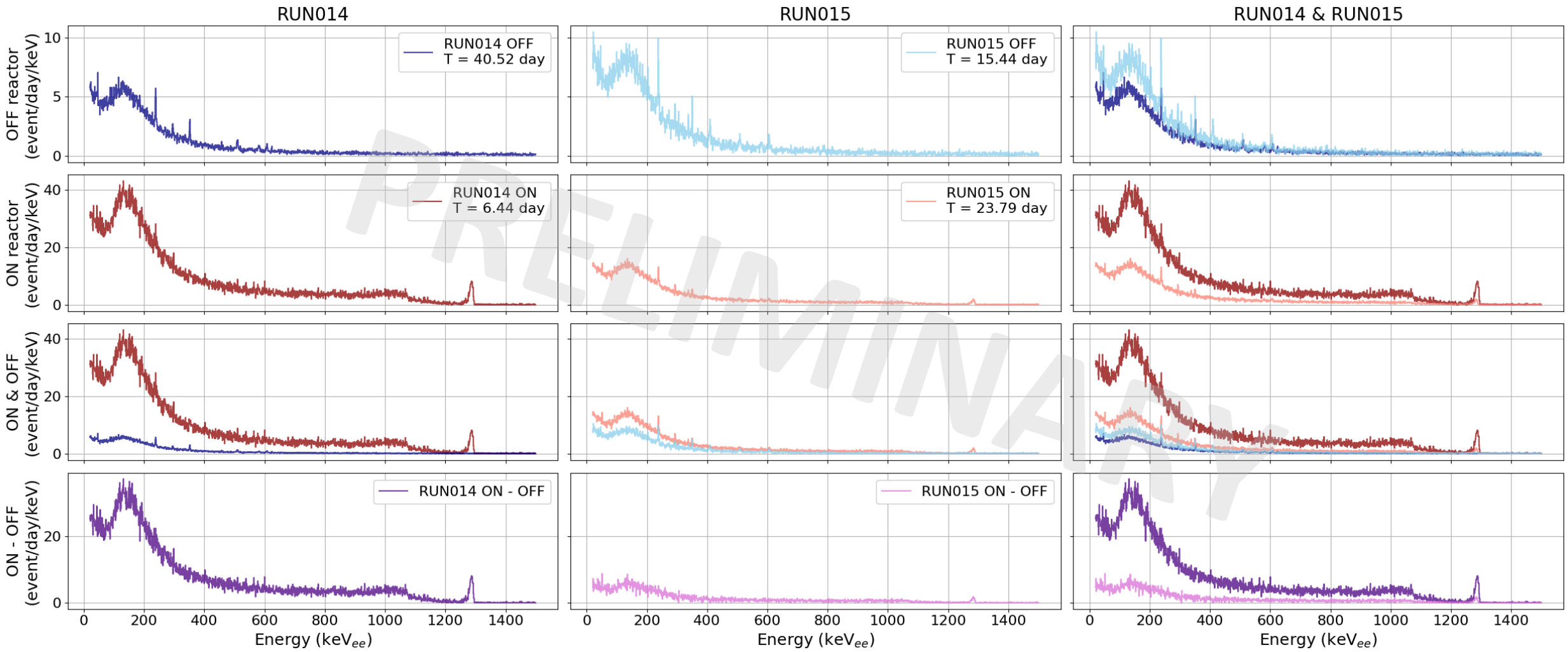
From top to bottom :
40-K and 60-Co



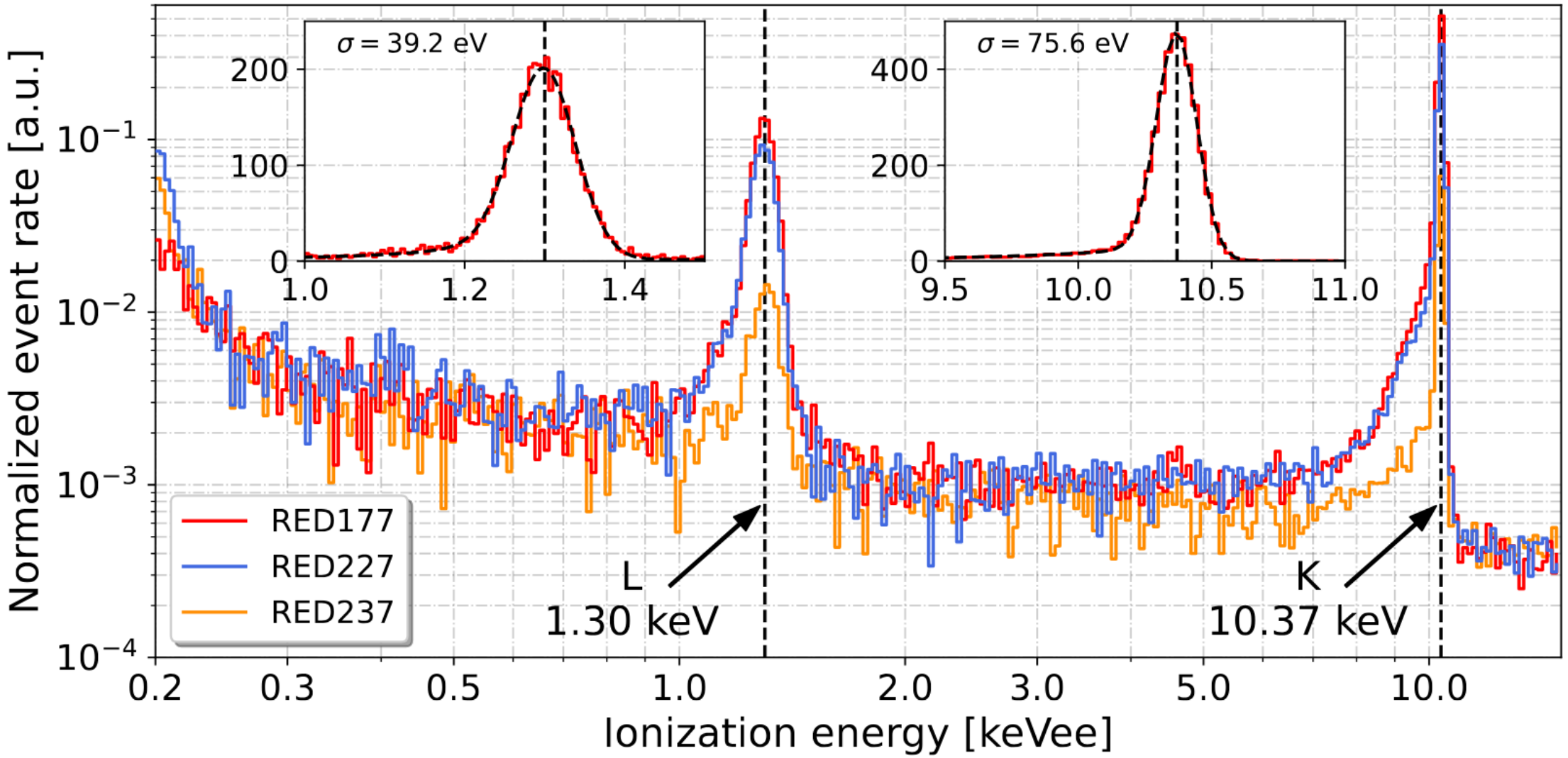


From left to right : 232-Th, 238-U and 235-U chains

Ionization spectra comparison

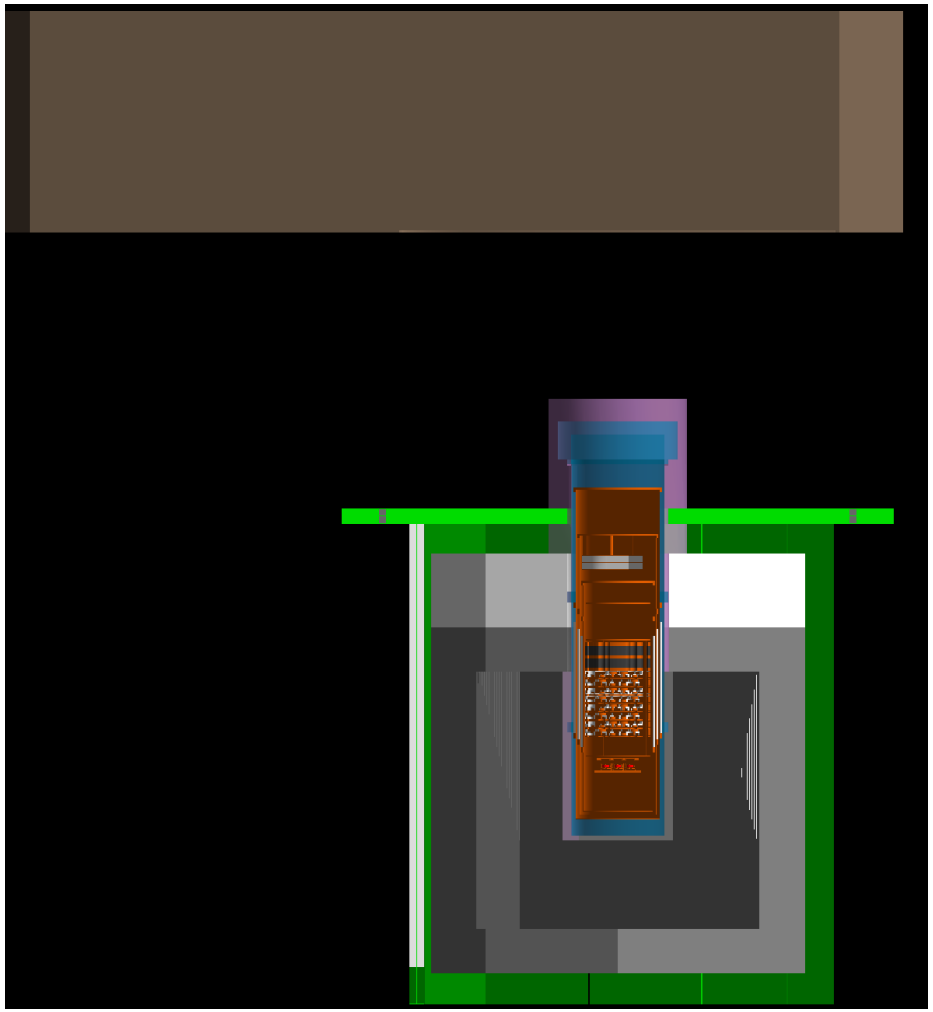


Bolometer energy calibration



[RICOCHET Collaboration, EPJC 84 (2024), 186]

RUN014/015 GEANT4 simulations



Contents of the **RUN014/015** GEANT4 simulation :

- two-part lead shielding : save calculation time
- transfer channel slab
- Cable (electronics)

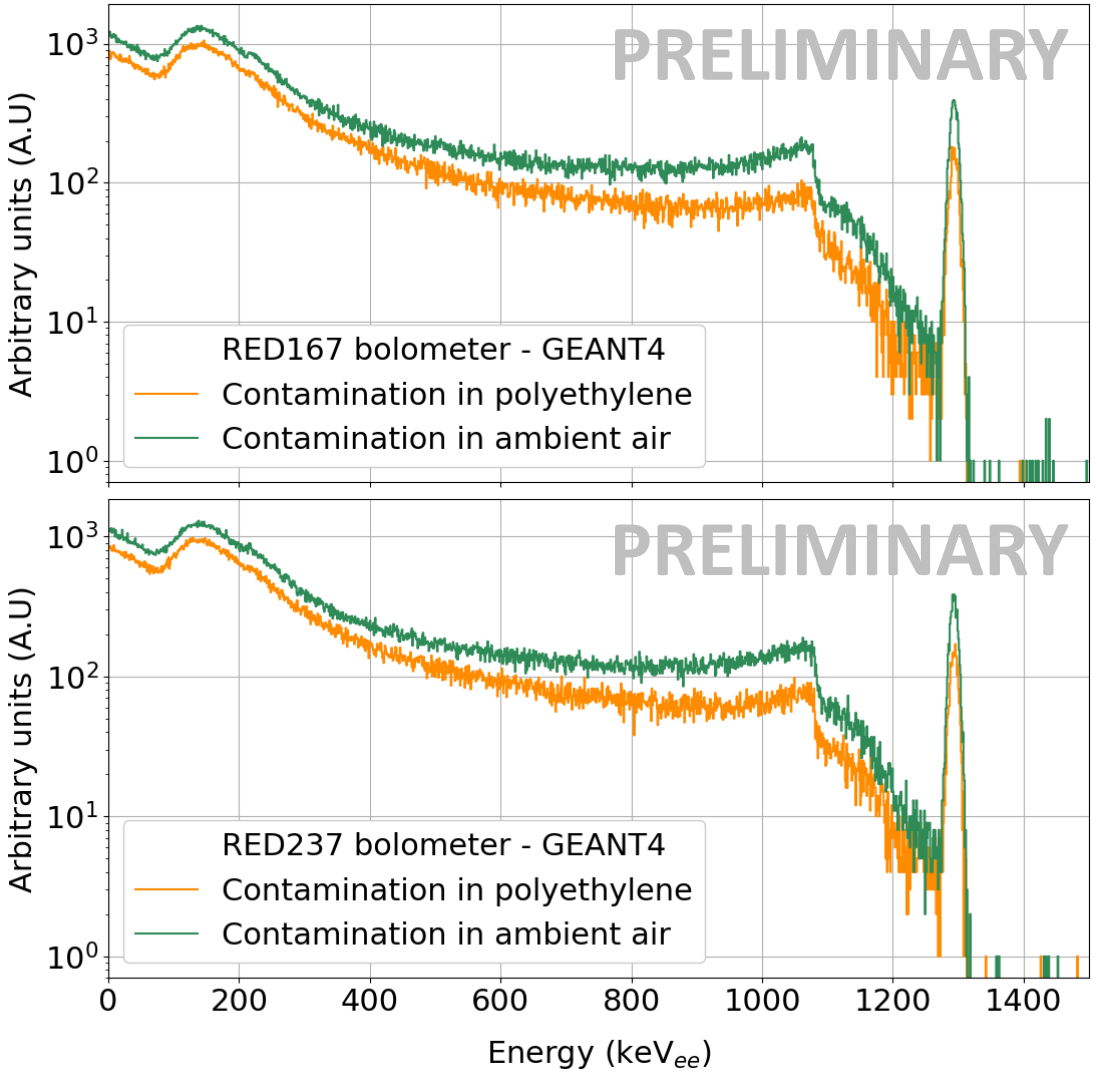
} radiogenic contamination

- ambient air near cryostat
- polyethylene shielding

} ^{41}Ar **contamination**

- N active detectors (only planar for the moment)
- detector mass : $m_{Bolo} = 42.038\ g$

GEANT4 spectra examples



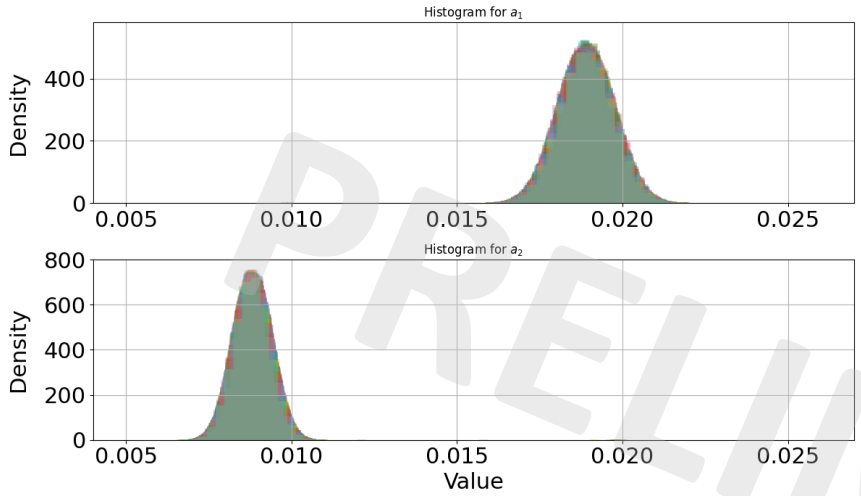
Markov chain Monte Carlo algorithm :

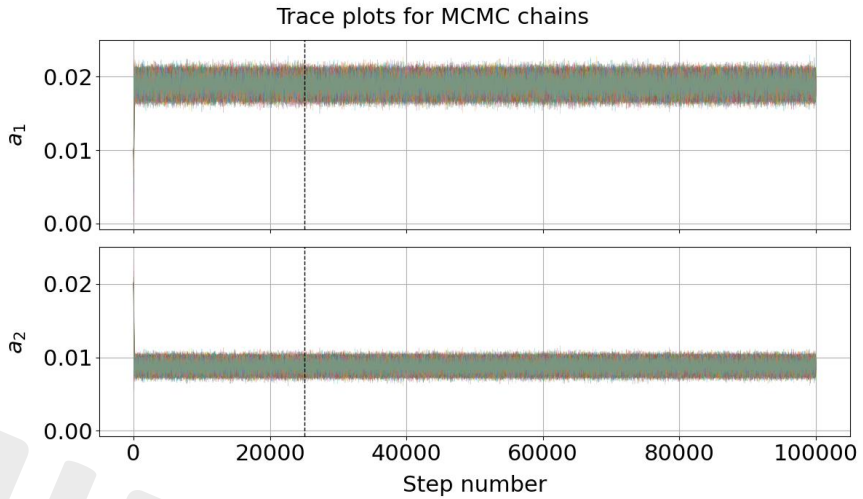
$$\mathcal{L}(\vec{\theta}) \propto \exp\left(-\frac{1}{2}\chi^2\right) \Rightarrow \log[\mathcal{L}(\vec{\theta})] \propto -\frac{1}{2}\chi^2$$

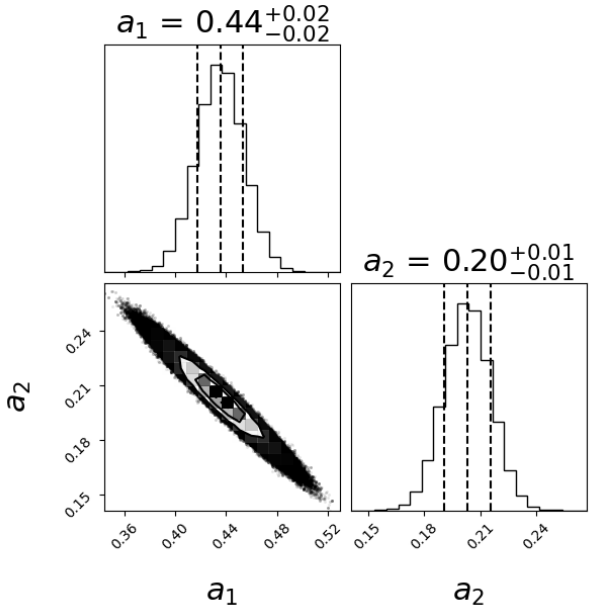
$$\chi^2 = \sum_{i=1}^{N_{bin}} \left[w_i \times \frac{S_i^{exp.} - S_i^{sim.}(s_k^{mat.}, a_k^{mat.})}{\sigma_i} \right]^2$$

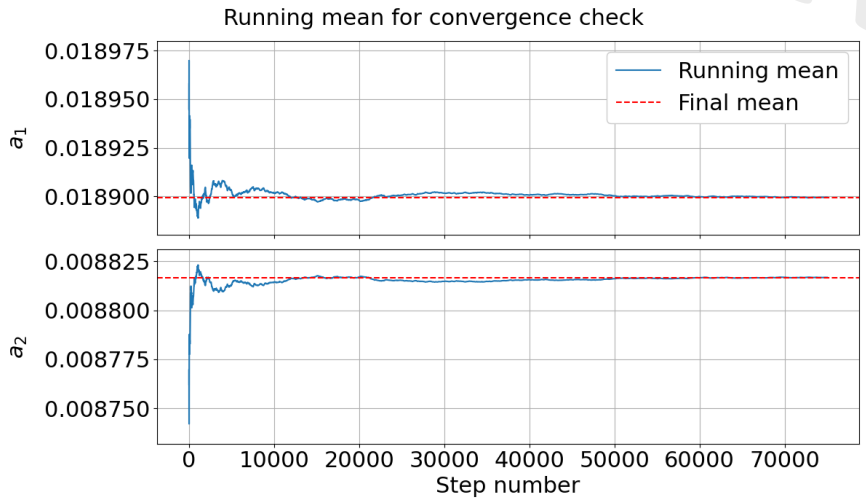
- $S_i^{exp.}$: experimental spectrum (RED167 & RED237)
- $S_i^{sim.}(s_k, a_k) = \sum_k a_k\, s_k$: simulated spectra model
- $\sigma_i = \sqrt{N_i}$: Poissonian errors on spectra
- w_i : weight function to constrain the model

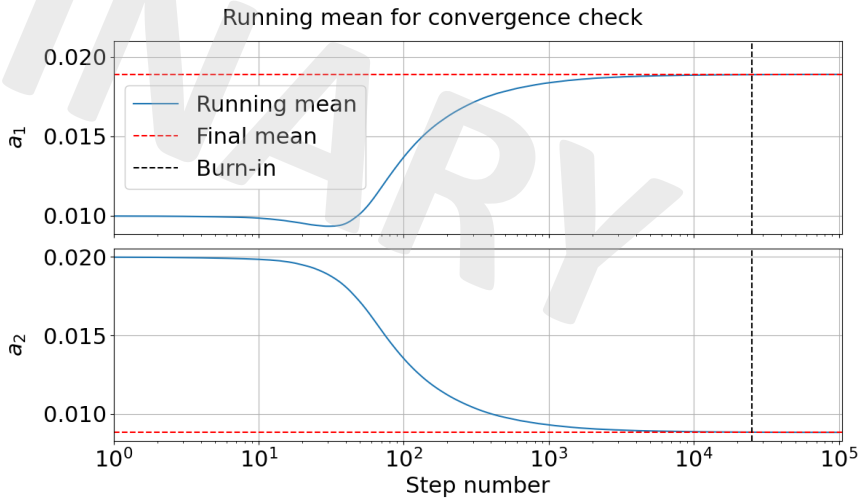
PL167 MCMC convergence











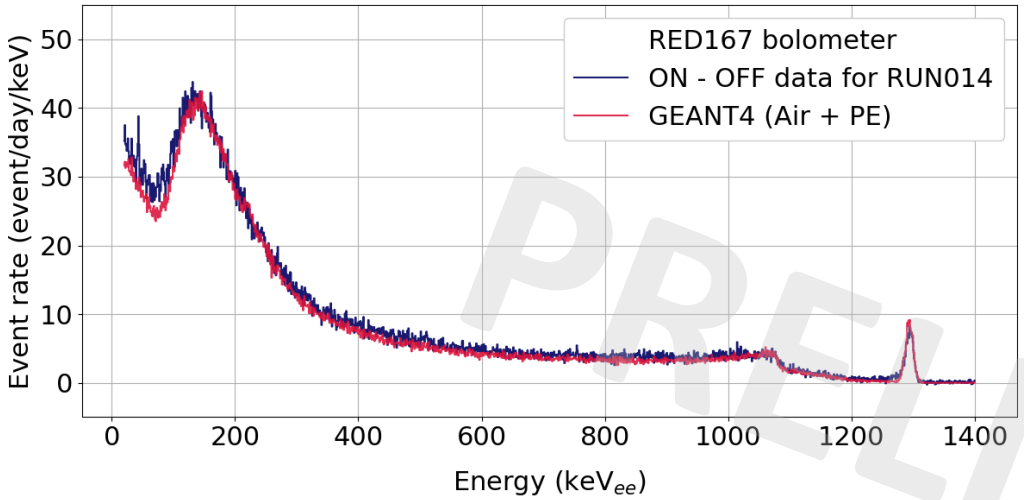
Gelman-Rubin coefficient :

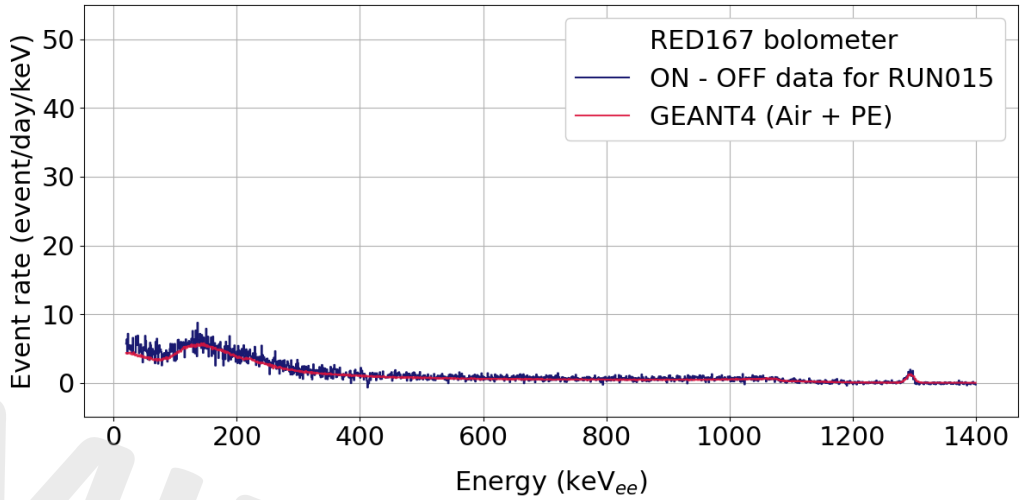
$$\hat{R}_1 = 1.0033 \approx 1$$

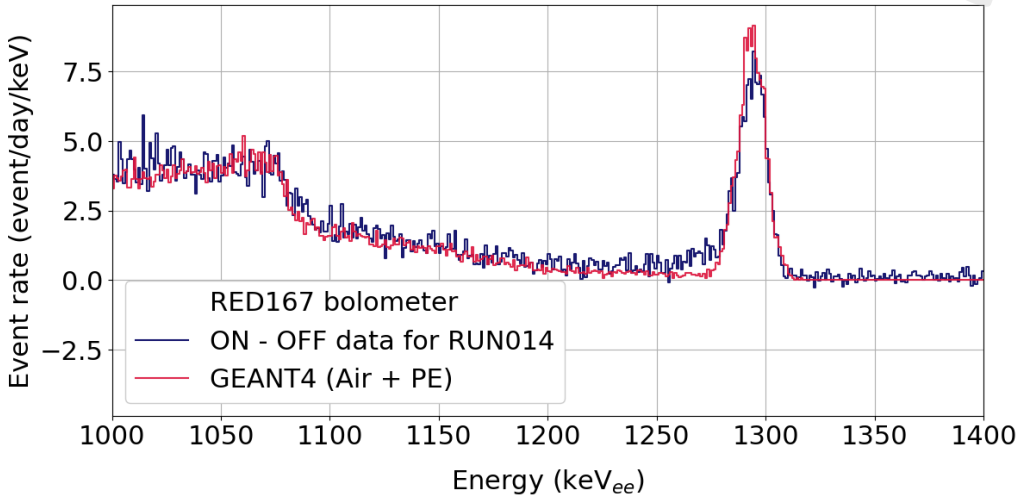
$$\hat{R}_2 = 1.0031 \approx 1$$

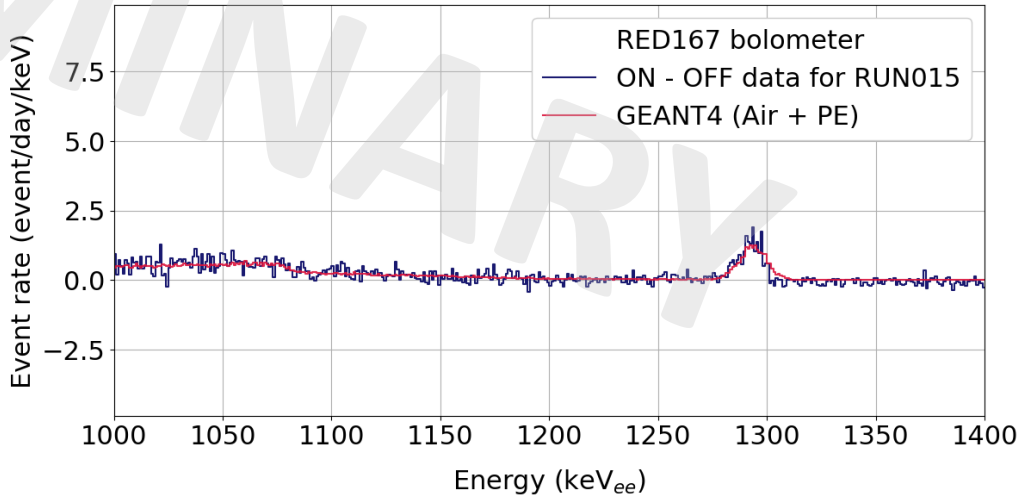
PRELIMINARY

Gamma background reconstruction









PRELIMINARY