CROSS EXPERIMENT:
SIGNAL PROCESSING AND EVENT RECONSTRUCTION

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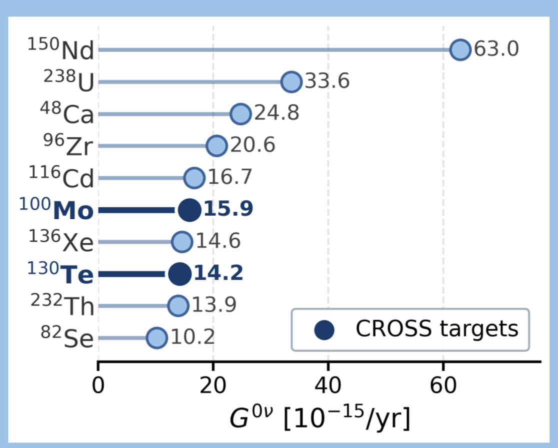
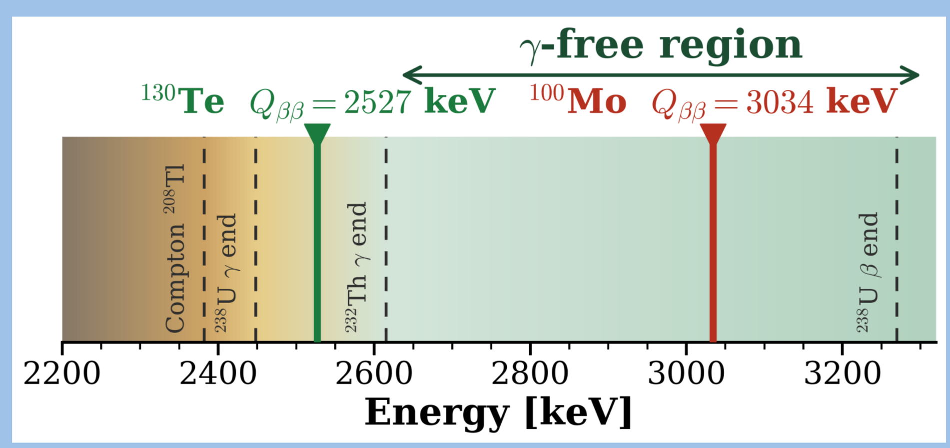
[1]

1. CROSS experiment and experimental setup

a **CROSS** (**C**ryogenic **R**are-event **O**bservatory with **S**urface **S**ensitivity) experiment aims at developing and testing a bolometric technology to search for **neutrinoless double-beta decay**[1], using **^{100}Mo** and **^{130}Te** as target isotopes, embedded respectively in **$Li_2{}^{100}MoO_4$** and **$^{130}TeO_2$** crystals. Each **crystal** is **coupled** to a cryogenic **light detector** for **α/β identification**[3].

$$\frac{1}{T^{0\nu}_{1/2}} = g_A{}^4 G^{0\nu}(Q_{\beta\beta}, Z)\left|M^{0\nu}\right|^2 \left(\frac{m_{\beta\beta}}{m_e}\right)^2$$



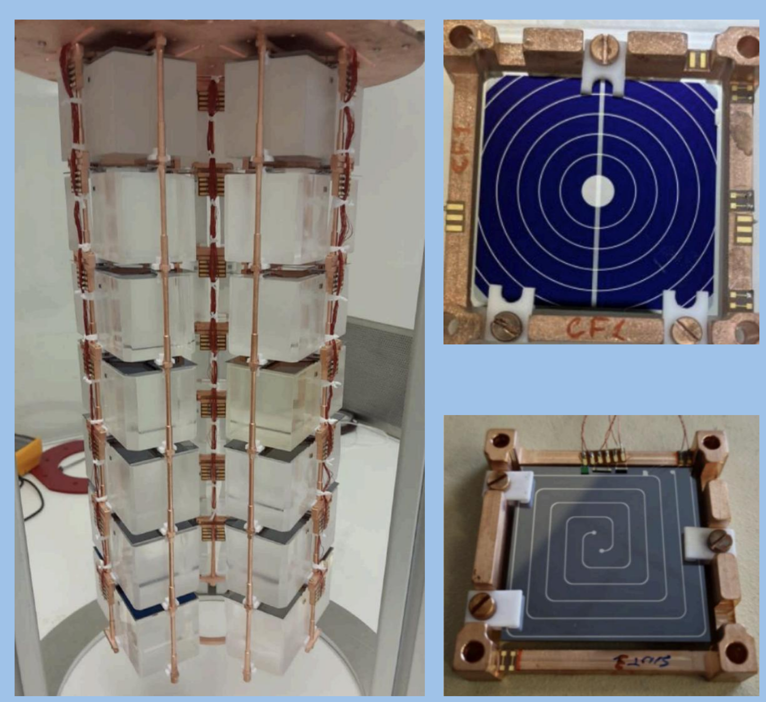


[2] Kotila & Iachello, Phys. Rev. C 85, 034316

[3] D. Auguste et al. (CROSS Coll.), arXiv:2607.26732

b Experimental Setup[3]

- **42 modules** with **dual heat–light readout** (36 Li_2MoO_4, 6 $^{130}TeO_2$ crystals)
- **Neutron Transmutation Doped-Ge thermistors** on crystals and wafers
- **Si-based resistive heater** glued on each crystal for **gain-stabilization pulses**
- **Ge/Si light detectors** (45×45 mm²) with **Neganov-Trofimov-Luke signal amplification** *via* Al electrodes
- **"Warm"** NTD working point:
  - R≈0.9 MΩ → fast response (0.54 ms)
- **Operational temperature 17-27 mK**



c Sensitivity to ^{100}Mo 0v2β decay: MC background and projection[3]

- A 0v2β decay would show up as a **peak at 3034 keV**, the **$Q_{\beta\beta}$ value** of **^{100}Mo**
- **Background under the peak:** Geant4 MC of cryostat, shields and array with **BI = 3.2(5)×10^{-3} counts/(keV·kg·year)**, in the **$Q_{\beta\beta}$ ± 50 keV band**
- **Result: $T_{1/2}$ > 6×10^{24} yr (90% C.L.) in 2 years (Exclusion Sensitivity)**
- **More conservative case: BI ~ 10^{-2} counts/(keV·kg·year) ($T_{1/2}$ ≳ 5×10^{24} yr)**

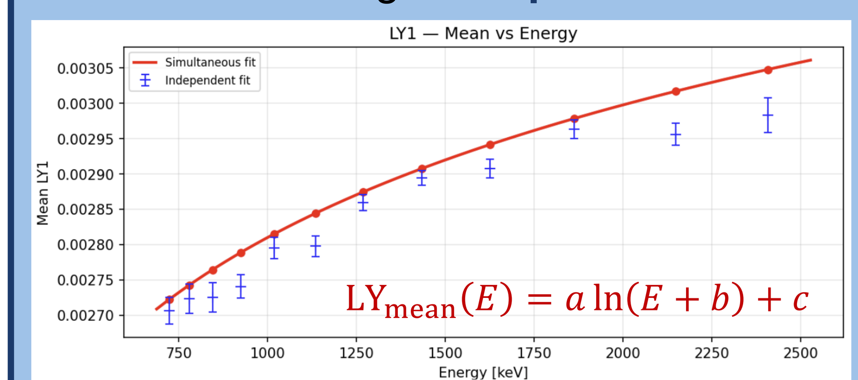
3. Light Detector data and alpha discrimination

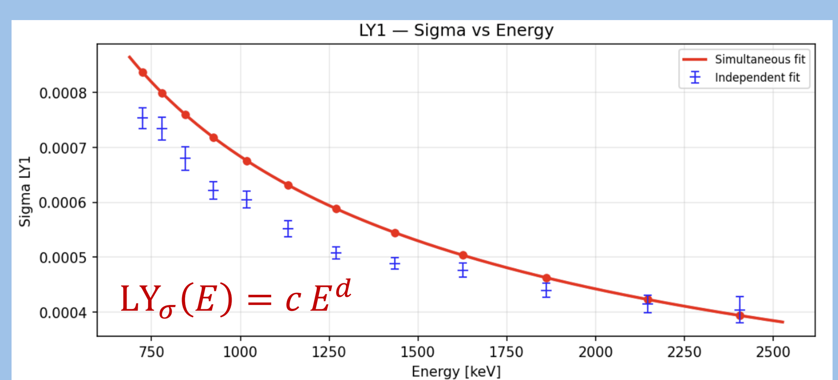
Light channels processing and Light Yield

Light channels follow the **same reconstruction stream** as the heat channel. The trigger is **not** generated on the light pulse but **propagated from the heat channel**: the light OF amplitude is evaluated in a window synchronous with the phonon event, so weak pulses below the LD self-trigger threshold are not lost.

Light Yield vs energy – Gaussian slices and simultaneous fit[4, 5]

The light channels build a **PSD variable based on the Light Yield**: events are divided into **heat-energy intervals** and in each one mean and sigma of the LY distribution are extracted through **independent** and **simultaneous** fits.



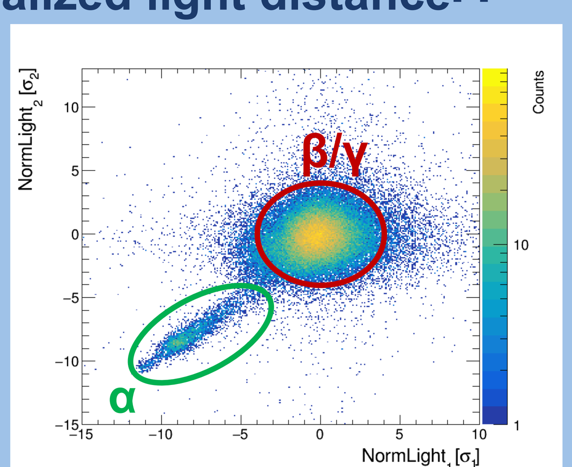


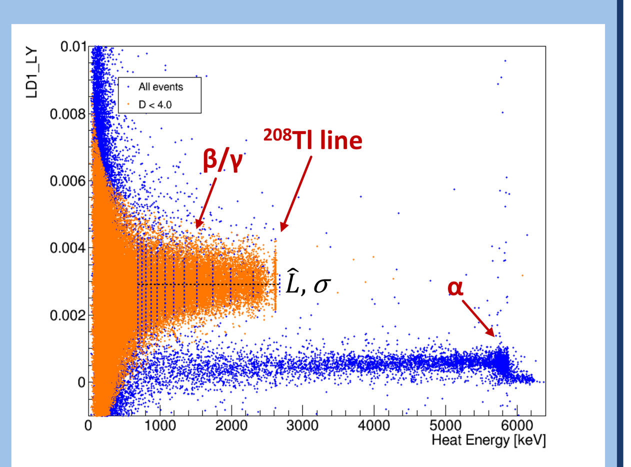
α/β discrimination – normalized light distance[5]

$$n_{c,s,d} = \frac{L_{c,s,d} - \hat{L}_{c,s,d}(E)}{\sigma(E)_{c,s,d}}$$

$$D = \sqrt{\left(n_{c,1}^2 + n_{c,2}^2\right)}$$

α background removed with the cut: **D < 4**

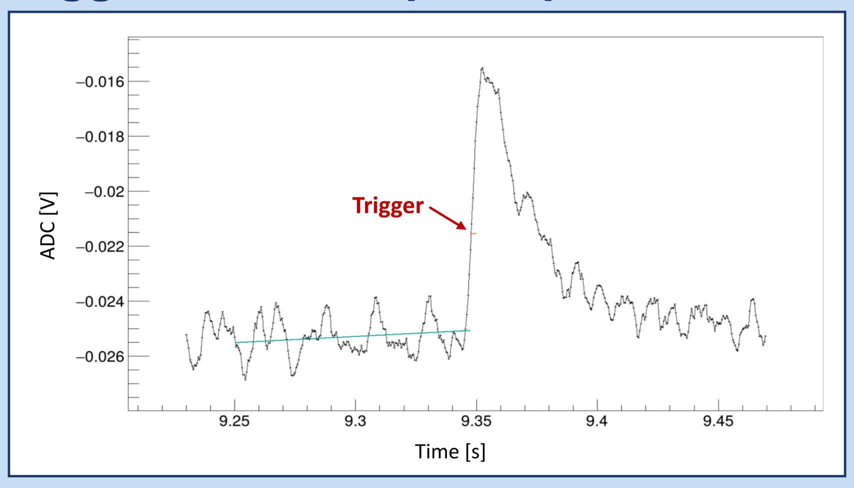




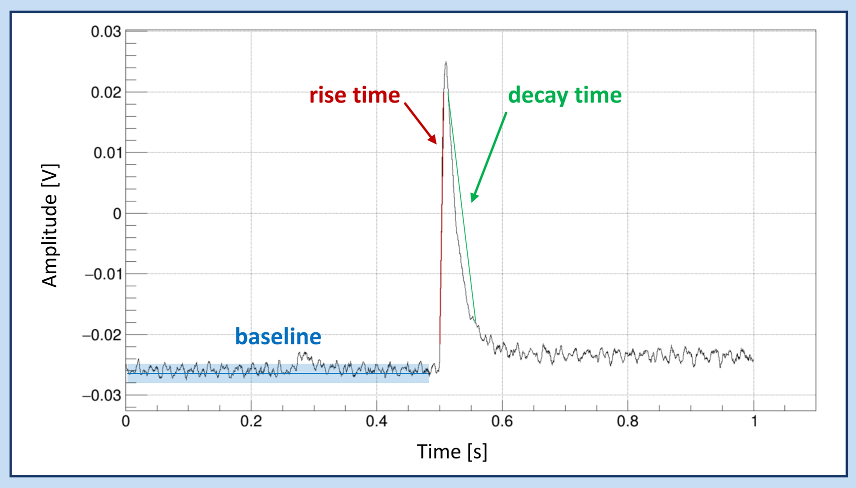
[4] Developed by R. Serino [5] C. Augier, et al., Eur. Phys. J. C 83, 675 (2023)

2. Li_2MoO_4 data reconstruction

Trigger and basic pulse parameters

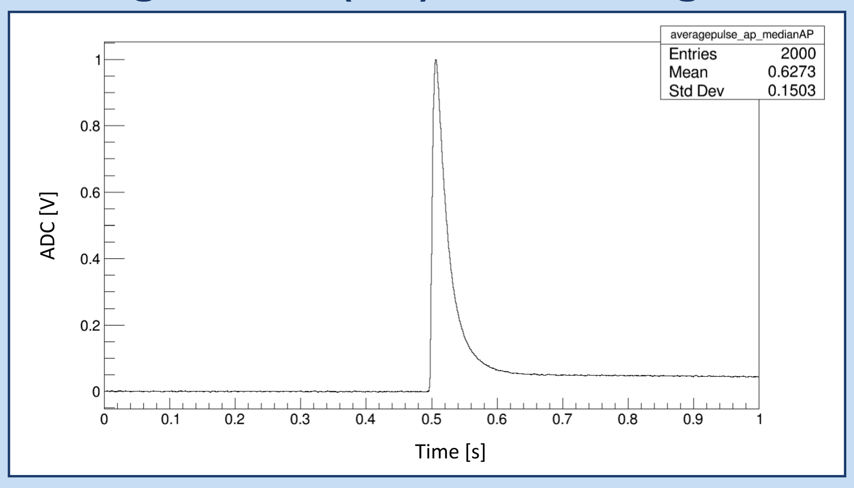


Linear interpolation trigger

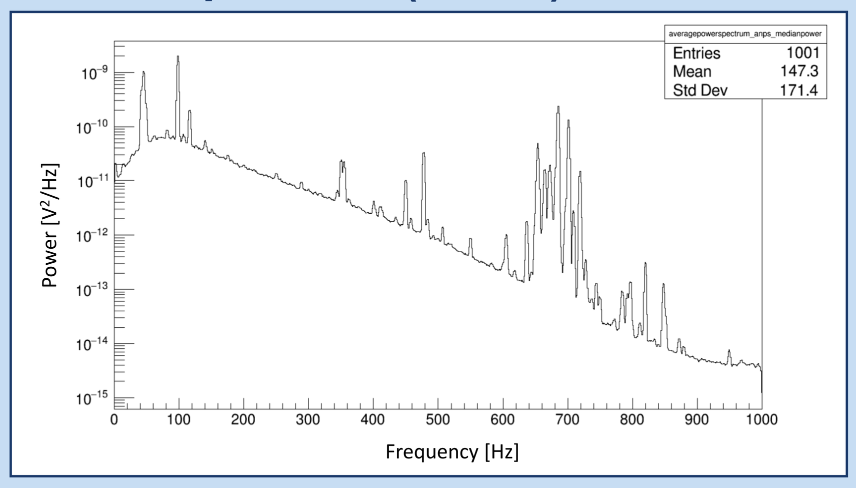


Baseline, rise time and decay time

Average Pulse (AP) and Average Noise Power Spectrum (ANPS)

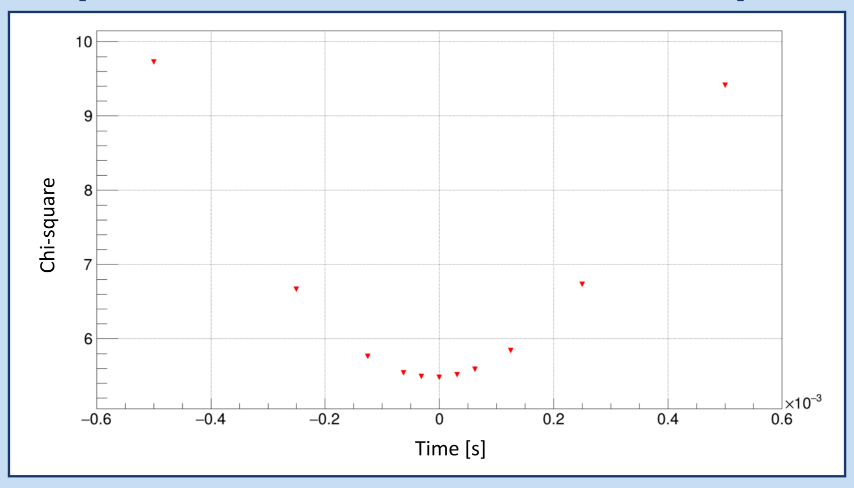


AP

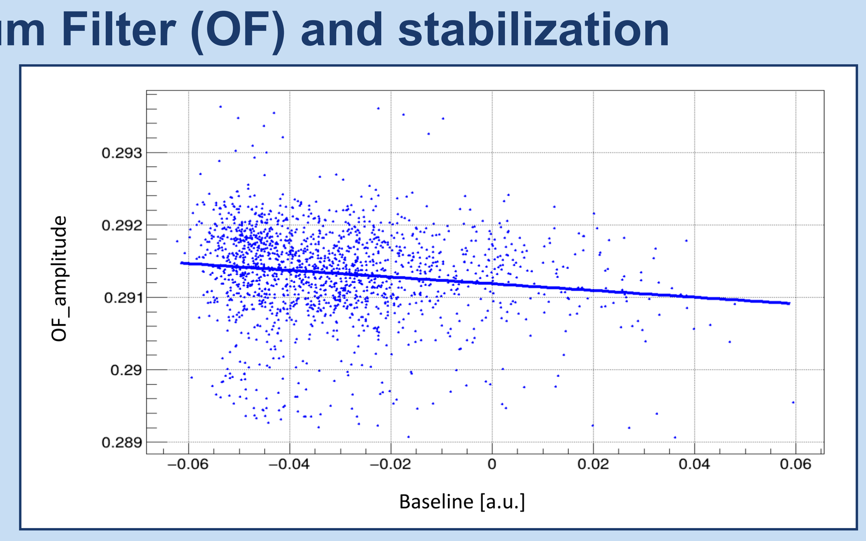


ANPS

Amplitude reconstruction with Optimum Filter (OF) and stabilization



OF χ^2 minimization



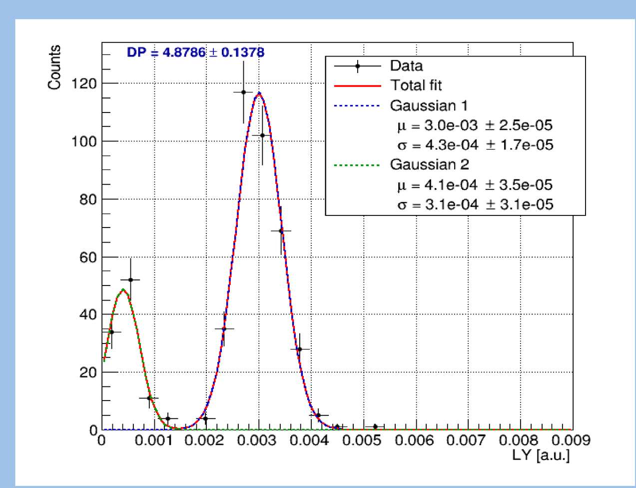
Stabilization

$$\chi^2 = \sum_f \mathrm{Re}\left[\frac{S(f) - \boldsymbol{A}\bar{S}_f e^{-\omega\delta t}}{N_F^2}\right]$$

χ^2 minimized over δt → best-fit amplitude $\boldsymbol{A}$

4. Preliminary analysis

Light Yield Discrimination Power



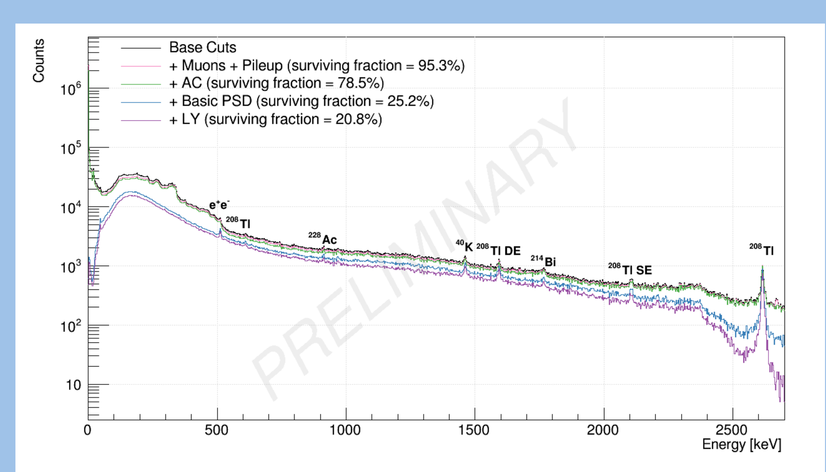
Light Yield Discrimination Power (DP) @ ^{208}Tl peak (2614.5 ± 100 keV) quantifies the **separation** between **β/γ** and **α events**

$$DP = \frac{|\mu_1 - \mu_2|}{\sqrt{\sigma_1^2 + \sigma_2^2}}$$

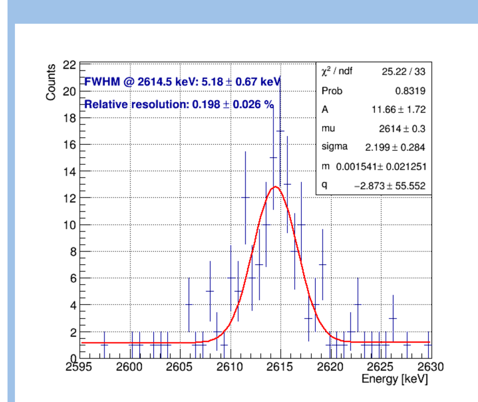
Summed calibrated spectrum – background runs (971.9 hours ~ 41 days)

The **background spectrum** is built with **36 Li_2MoO_4** crystals, 4.9 kg of ^{100}Mo[6, 7]:

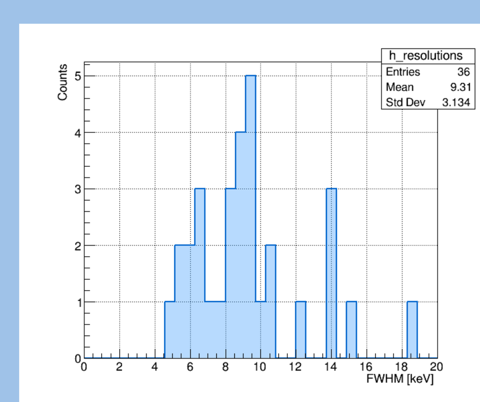
- **32 crystals enriched in ^{100}Mo (97.7(3)%)** — light output **~0.3 keV/MeV**, internal **^{228}Th/^{226}Ra activity < 1 µBq/kg** — provide the ^{100}Mo exposure for the 0v2β search
- **2 crystals from Mo depleted in ^{100}Mo**
- **2 from natural-abundance Mo**



Individual LMO energy resolution @ ^{208}Tl peak (calibration run)



Distribution of energy resolution (calibration run)



Quantity	Value
$FWHM_{Tl}$ (24/32 $^{100}Mo_{enr}$)	8.2 ± 0.2 keV
$FWHM_{baseline}$ (24/32 $^{100}Mo_{enr}$)	~ 3.2 keV
NTL_{gain}	~ 9 @ 80V[3]
$FWHM_{baseline}$ (LD)	~ 10 eV[3]
DP (30/36 LDs)	4.4 ± 0.6

Dedicated runs:

- Calibration run with a ^{232}Th source
- Background run
- Contamination and efficiency studies are planned

[6] K. Alfonso, et al., JINST 18, P06018
[7] I. Bandac, et al., Sensors 23, 5465