$ZnMoO_4$ LUMINEU bolometers at CSNSM

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Outline

- LUMINEU crystals
  - Introduction of LUMINEU
  - First LUMINEU detectors
- The facility at CSNSM
  - RUN #1 at ULISSE cryostat
  - RUN #2 at Moulet Modane cryostat
- Results
- Conclusion and perspectives

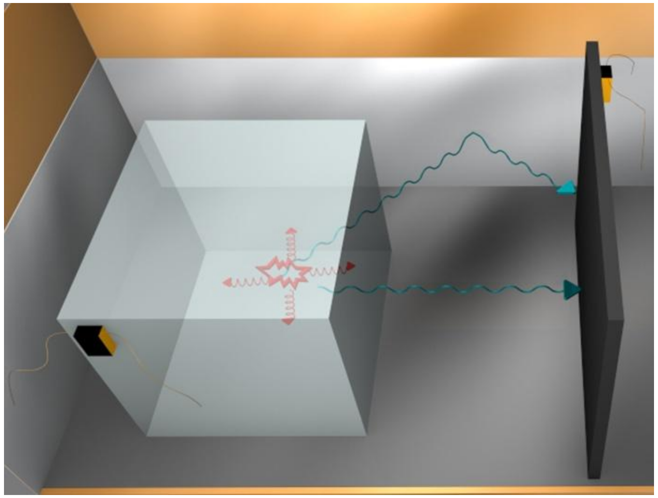
Introduction of LUMINEU

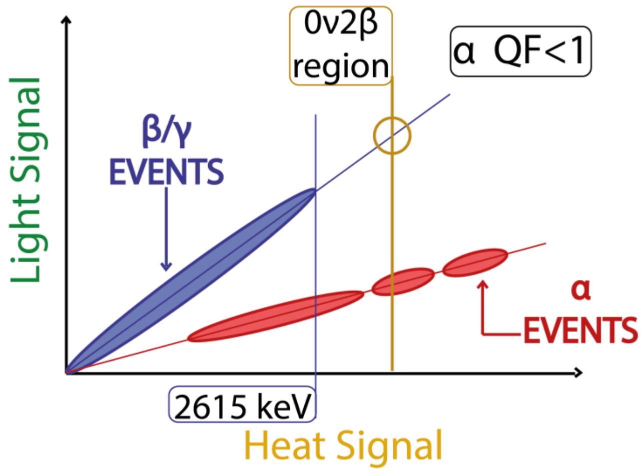
LUMINEU: A pilot experiment to study the 0νββ with the favorable isotope ^{100}Mo embended in $ZnMoO_4$ scintillating bolometers.

- isotope ^{100}Mo (Q=3035 keV, i.a.=9.7%) embedded in $ZnMoO_4$ crystals
- running in underground laboratory

``Zero`` γ backgrounds

- scintillating bolometer technique





$$LY_{\beta/\gamma} \neq LY_{\alpha}$$

Simultaneous detection of heat and light allows to separate γ and β particles form α particles

``Zero`` α backgrounds

Crystal production line for LUMINEU

The production of LUMINEU crystals in **NIIC** (**Novosibirsk, Russia**) is performed in **two dedicated furnaces**, one with crucible ∅ = 40 mm (for R&D), the other ∅ = 80 mm (for final produtcs).

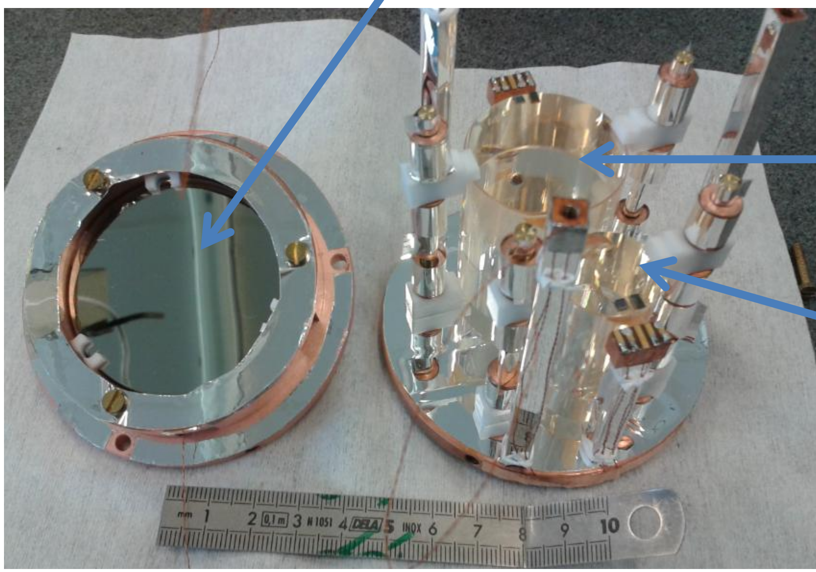
The total LUMINEU production is splitted in **four deliveries:**

① **June 2013**	② **January 2014**	③ **June 2014**	④ **December 2014**
Done	**Expected** **Crystals grown**	**Planned** **Details to be fixed**	**Planned** **Details to be fixed**
2X crystals **∅ 35x40mm** **2X** crystals **∅ 20x40mm**	**2X** crystals **∅ 50x40mm** **1X** enriched **100g**	**4X** crystals **∅ 60x40mm**	Up to **4X enriched** crystals **∅ 60x40mm**
Chemical purification	Chemical purification Physical purification	Chemical purification Physical purification if validated	Chemical purification Physical purification if validated
Presently under test **aboveground** (CSNSM)	They will be tested **underground** (LSM) **February 2014**	To be tested **underground**	**Start pilot experiment underground**

First LUMINEU detector

Light detector LT7

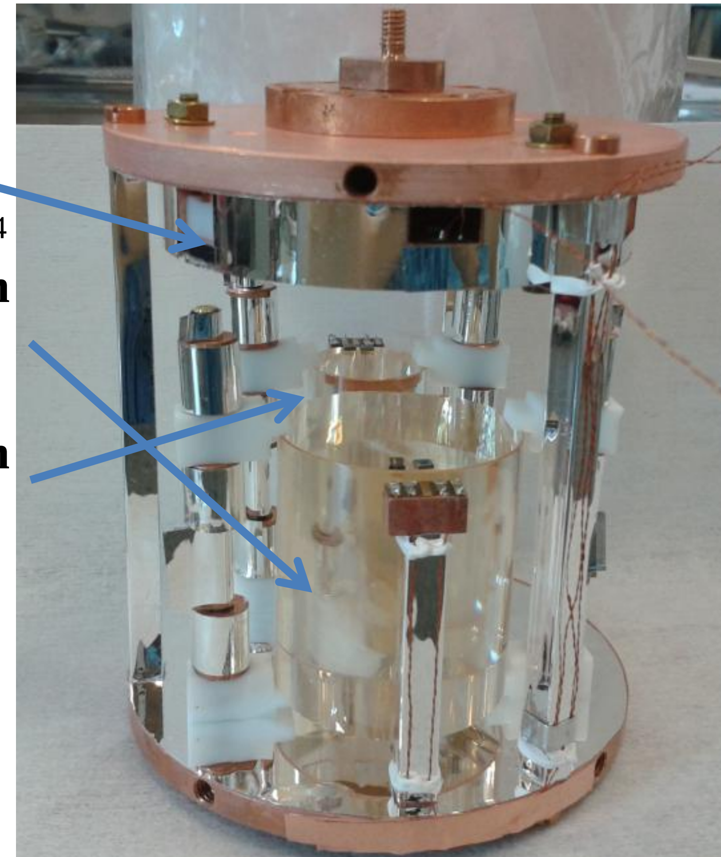
Hyper-pure Ge slab ∅**50mm**



X $ZnMoO_4$

∅ 35x40mm
~165 g

∅ 20x40mm
~55 g

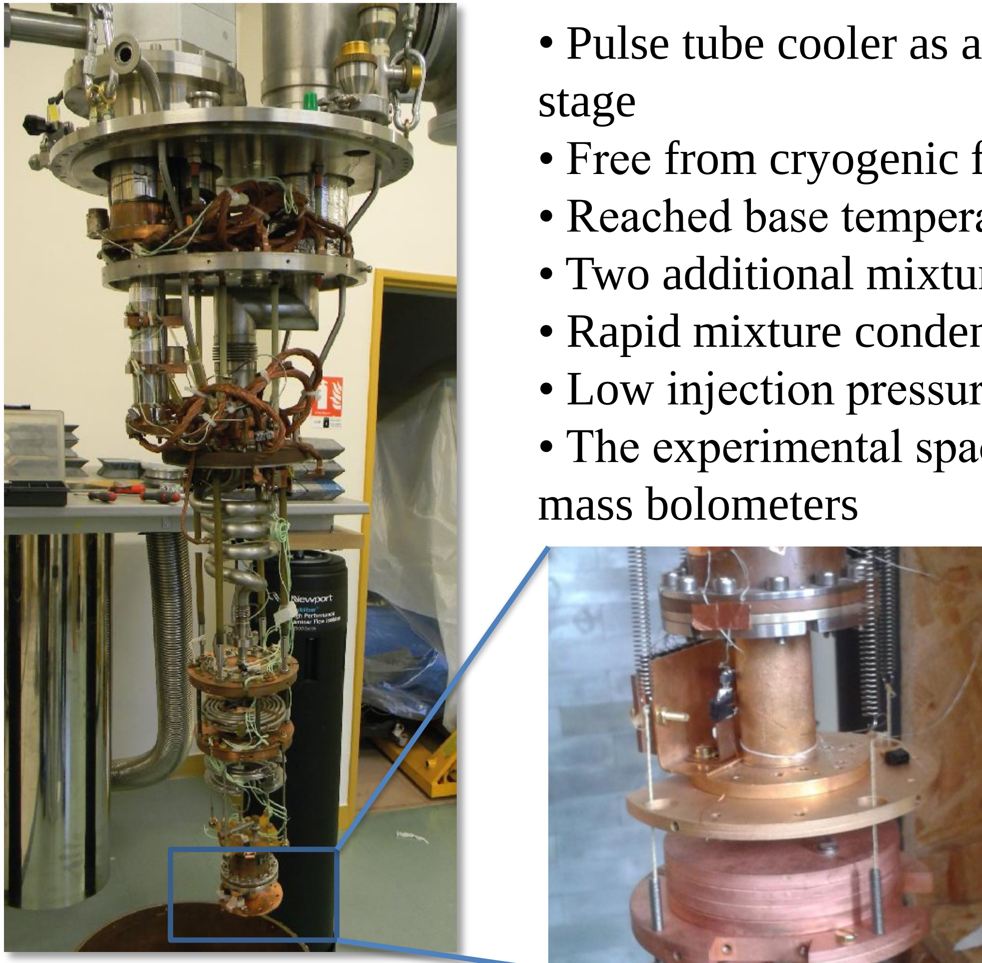


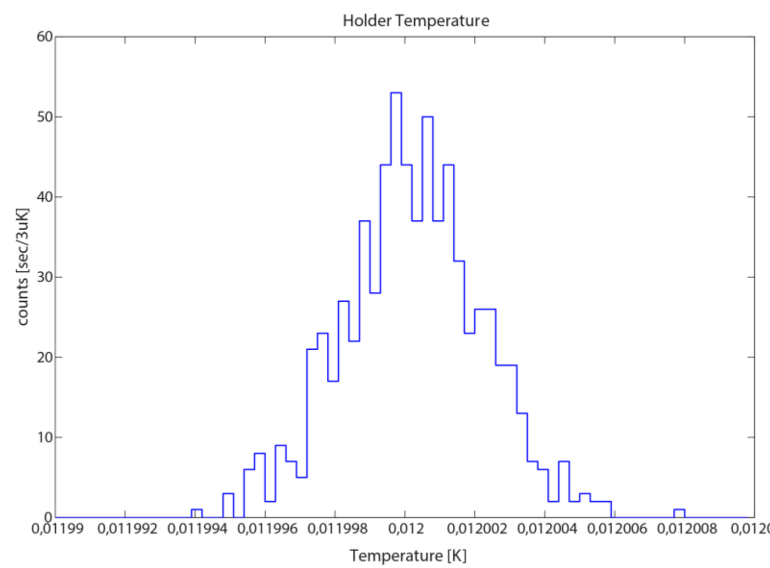
- OFHC copper holder
- Detectors equiped with NTD Ge thermistors R_0=1.09 T_0=3.83
- PTFE clamps provide the thermal coupling

All the assemble is then surrounded by reflective foil (3M VM2000/2002)

RUN#1 @ ULISSE

- Pulse tube cooler as a first cryogenic stage
- Free from cryogenic fluids
- Reached base temperature below 12 mK
- Two additional mixture precooling stages at pulse tube level
- Rapid mixture condensation
- Low injection pressure→ ^{3}He compressor OFF
- The experimental space of 5 l allows measurement several large mass bolometers





❖ The temperature of the holder can be stabilized very well: at T=12 mK FWHM =6 μK over 3 hours

The Orsay facility

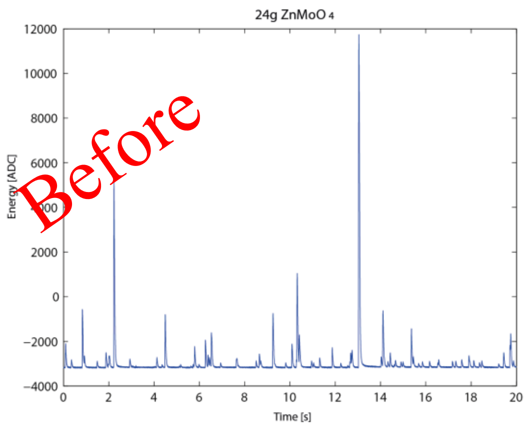
Measurement aboveground of large mass bolometer:

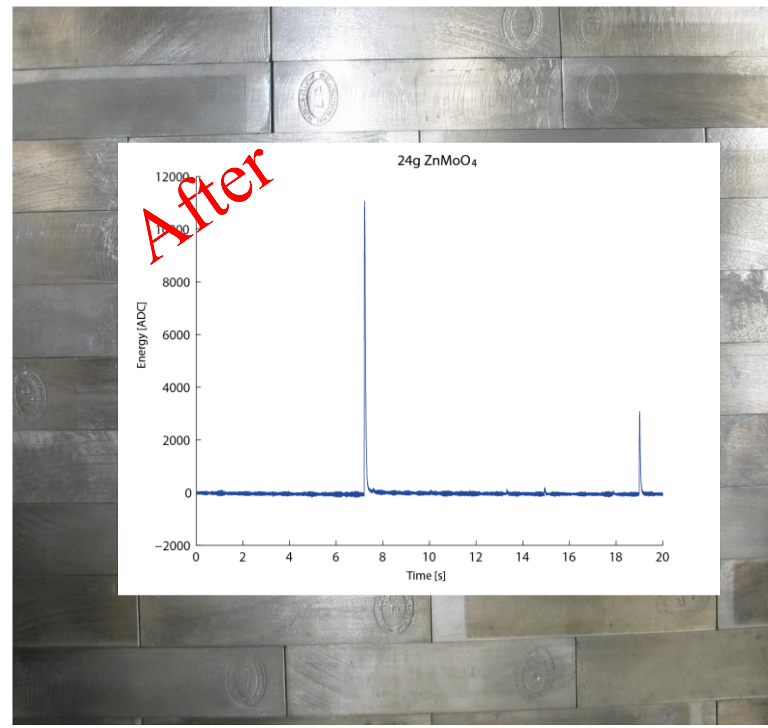
the slow decay time of the pulse (≈100 ms) +high interaction rate+enviromental radioactivity → pileup

→high purity lead shield (minimum thickness 10 cm) containing less than 30 Bq/kg of 210 Pb

❖Effect of the Pb shield on the BKG of a 24 g ZMO detector

energy range keV	without lead counts/sec	with lead counts/sec	Reduction factor
100-500	1.840	0.084	0.046
500-1000	0.309	0.0156	0.050
1000-1500	0.114	0.0064	0.056
1500-2000	0.027	0.0034	0.126
2000-2500	0.014	0.0021	0.15
2500-3000	0.005	0.0016	0.32





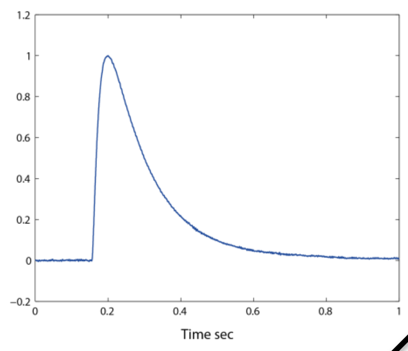
Analysis

- ❑ Triggered and analysed with optimum filter

The optimum filter: Is the transer function wich maximize the amplitude to noise ratio.

$$H(j\omega) = K' \frac{S_1^*(\omega)}{N(\omega)} e^{-j\omega\tau_M}$$

$H(j\omega) =$ [F (



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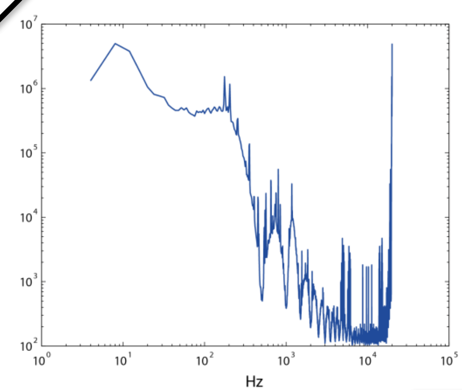
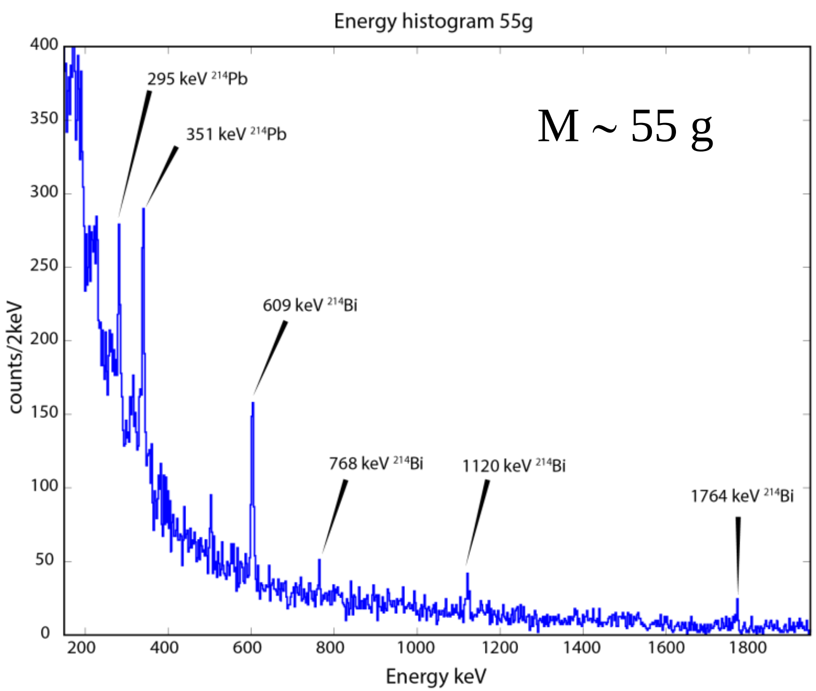
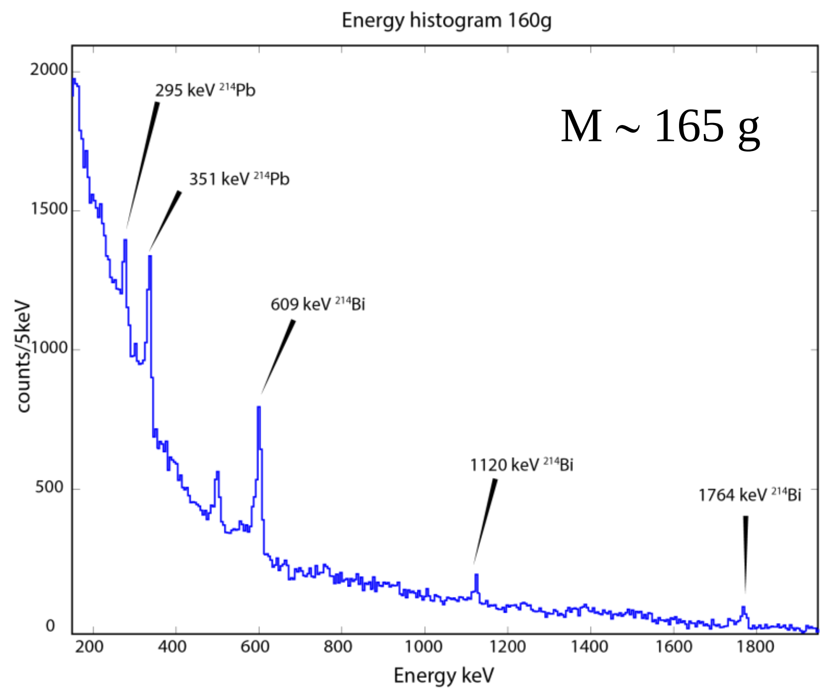


] $e^{-j\omega\tau_M}$

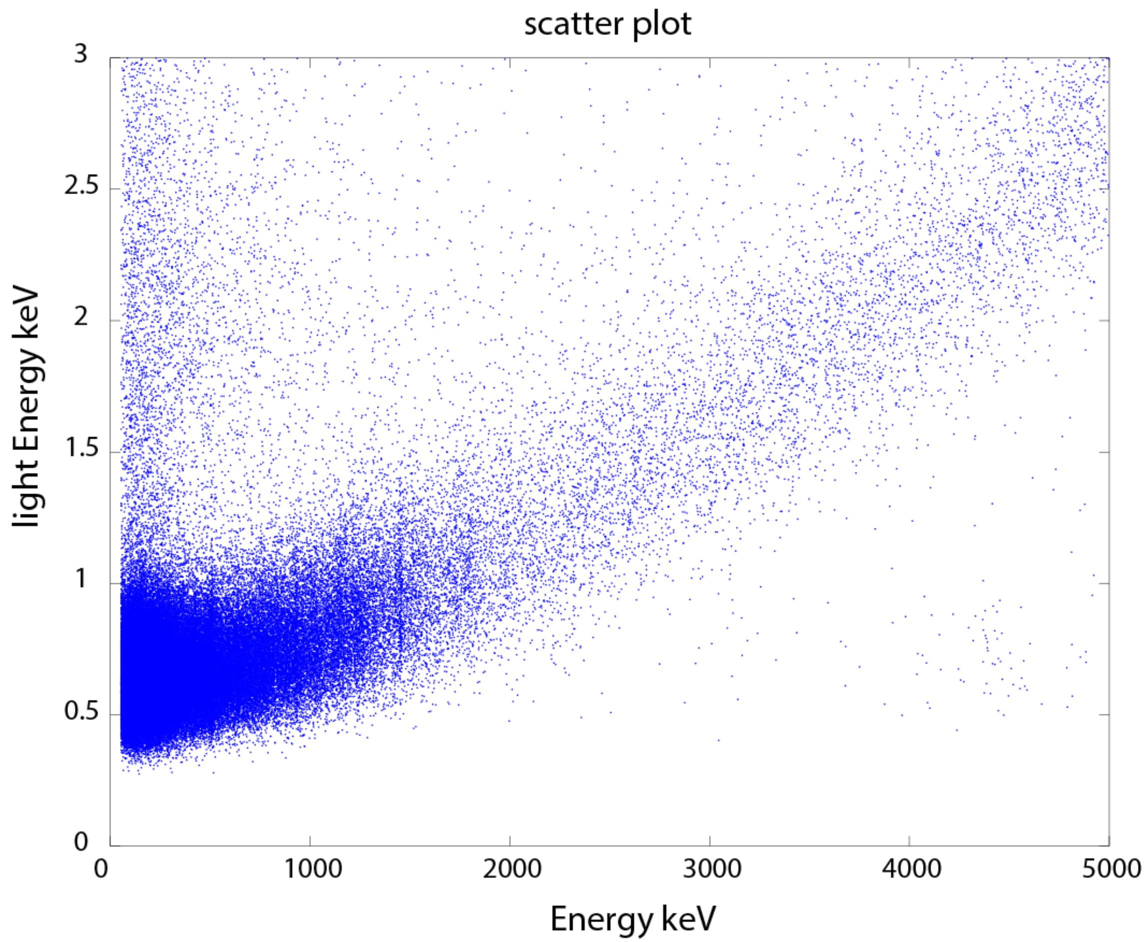
RUN#1

	Signal μV/MeV	Rise Time ms	Decay Time ms
• Light detector	850	3.8	32
• 55g $ZnMoO_4$	104	17.2	130
• 160g $ZnMoO_4$	134	15.2	104





RUN#1



The high noise wich affected the light detector doesn't permit a good discrimination

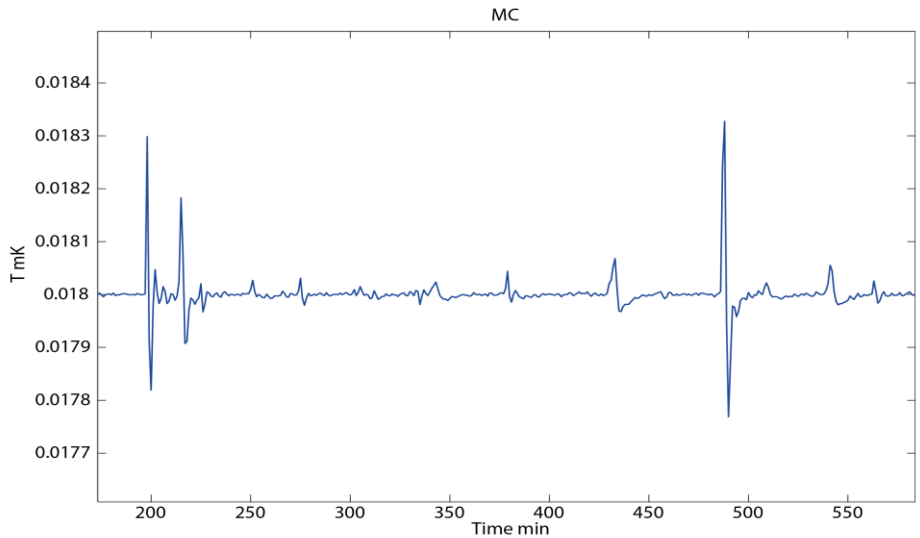
RUN#2 @ Mulet MODANE

- Dilution cryostat with LHe
- Reached base temperature below 15 mK
- Cold preamplifier
- AC bias polarization

Provides better performances in terms of vibration and electric noise

Lower lead shielding quality

Temperature oscillation issue at MC level due to residual He

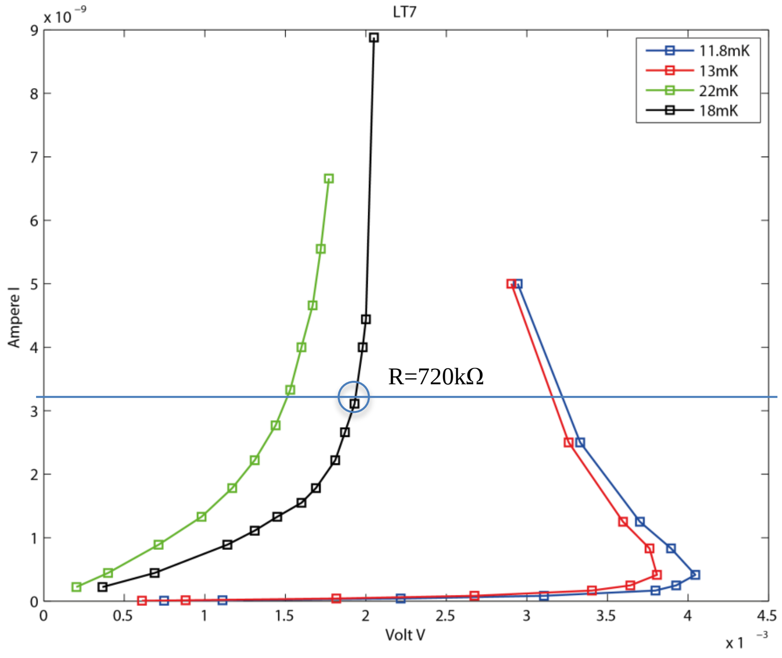


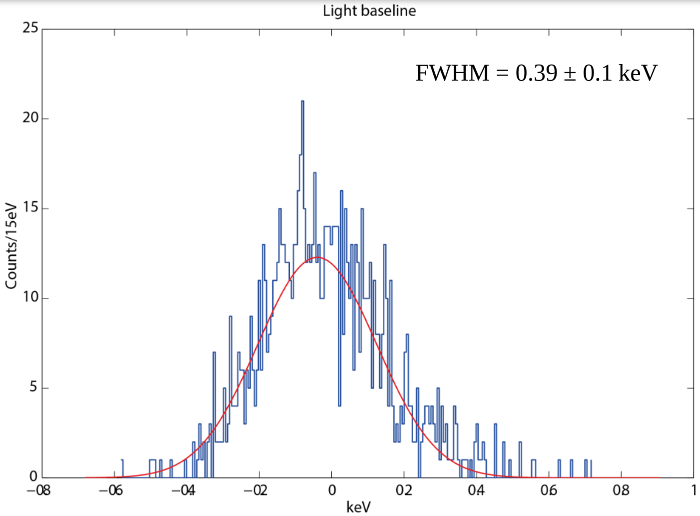
Light detector RUN#2

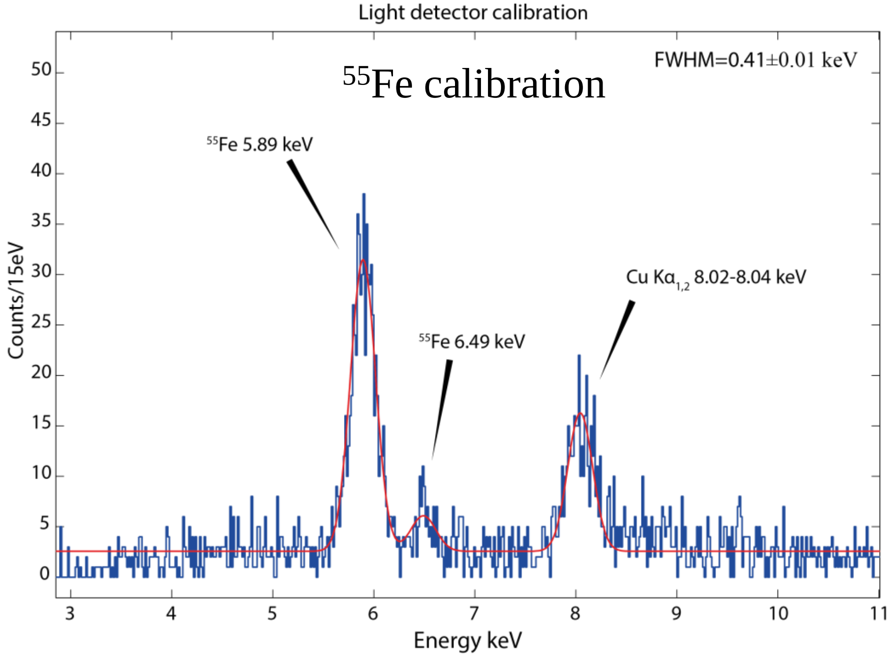
FWHM = 0.39 keV

AC polazization → R ≈ 1 MΩ

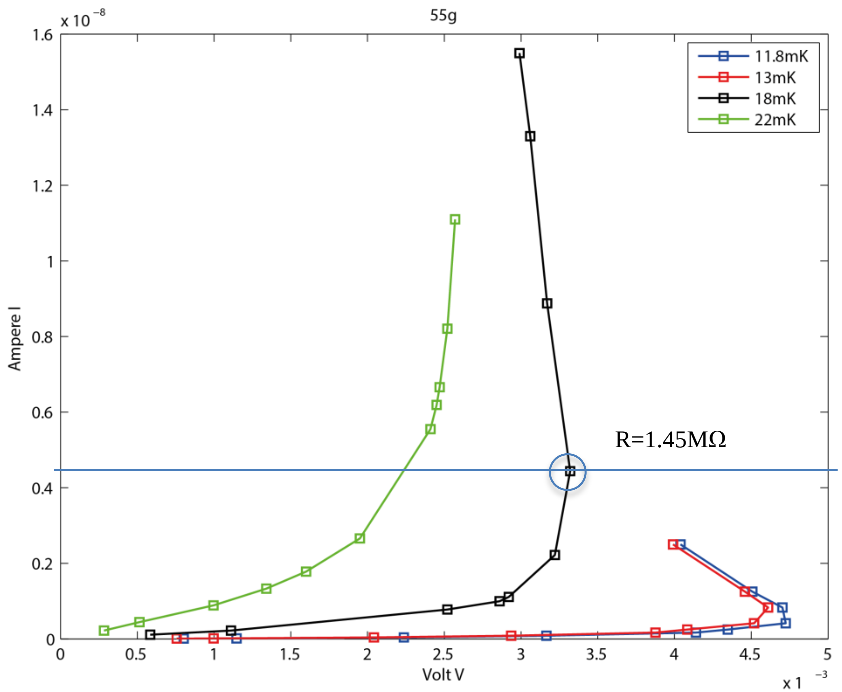
Sensitivity = 269 nV/keV

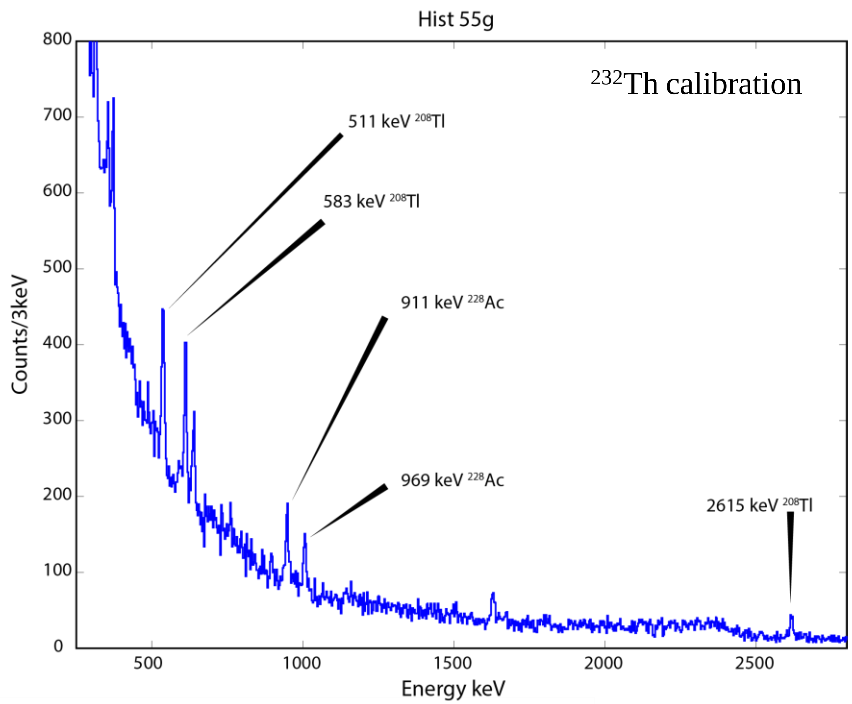


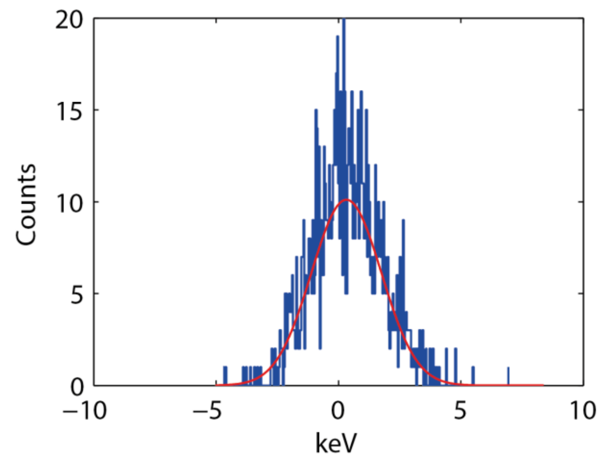




55g $ZnMoO_4$ RUN#2





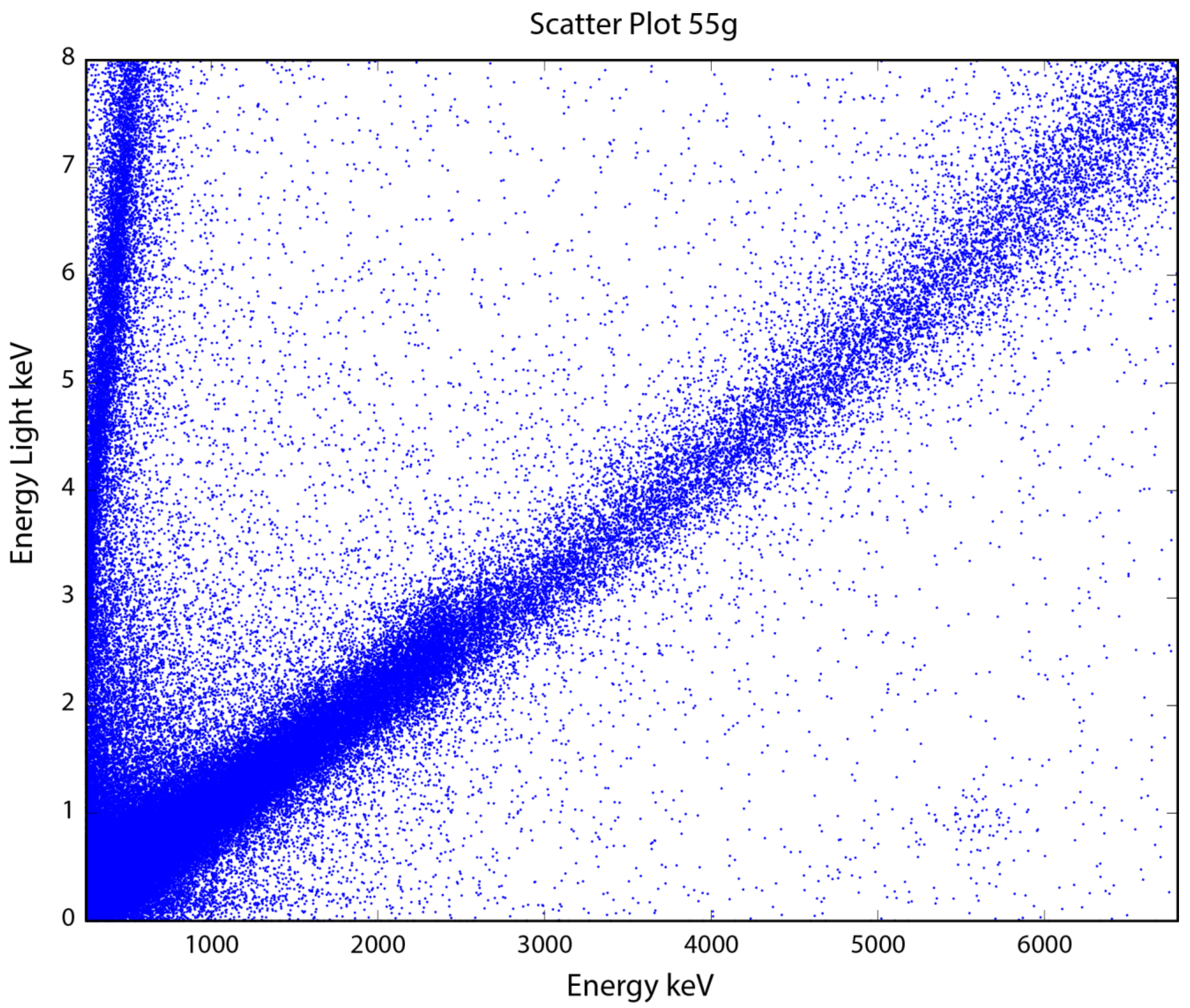


Baseline analysis

FWHM = 3.7 ± 0.1 keV

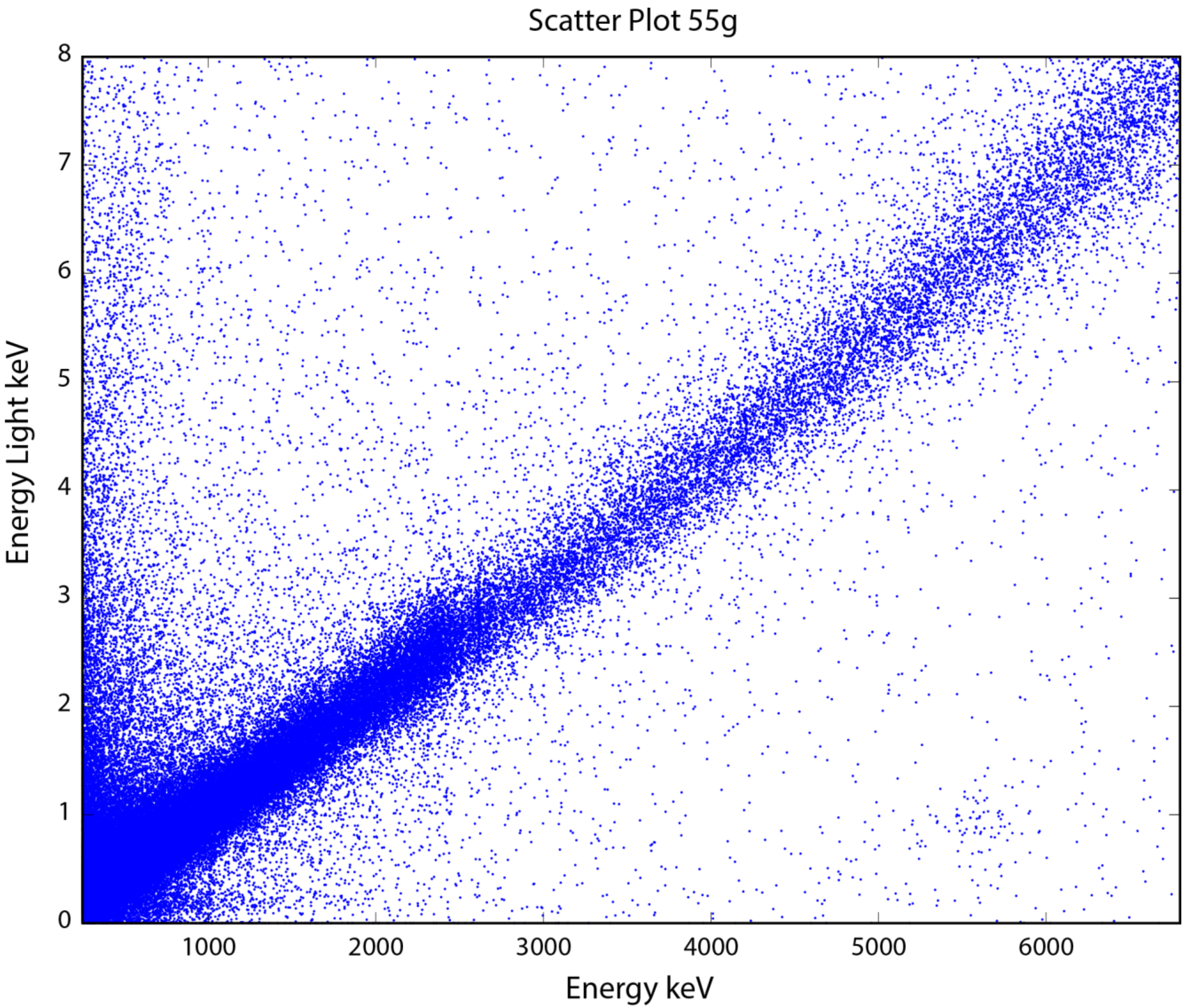
Sensitivity = 121 nV/keV

55g $ZnMoO_4$ RUN#2



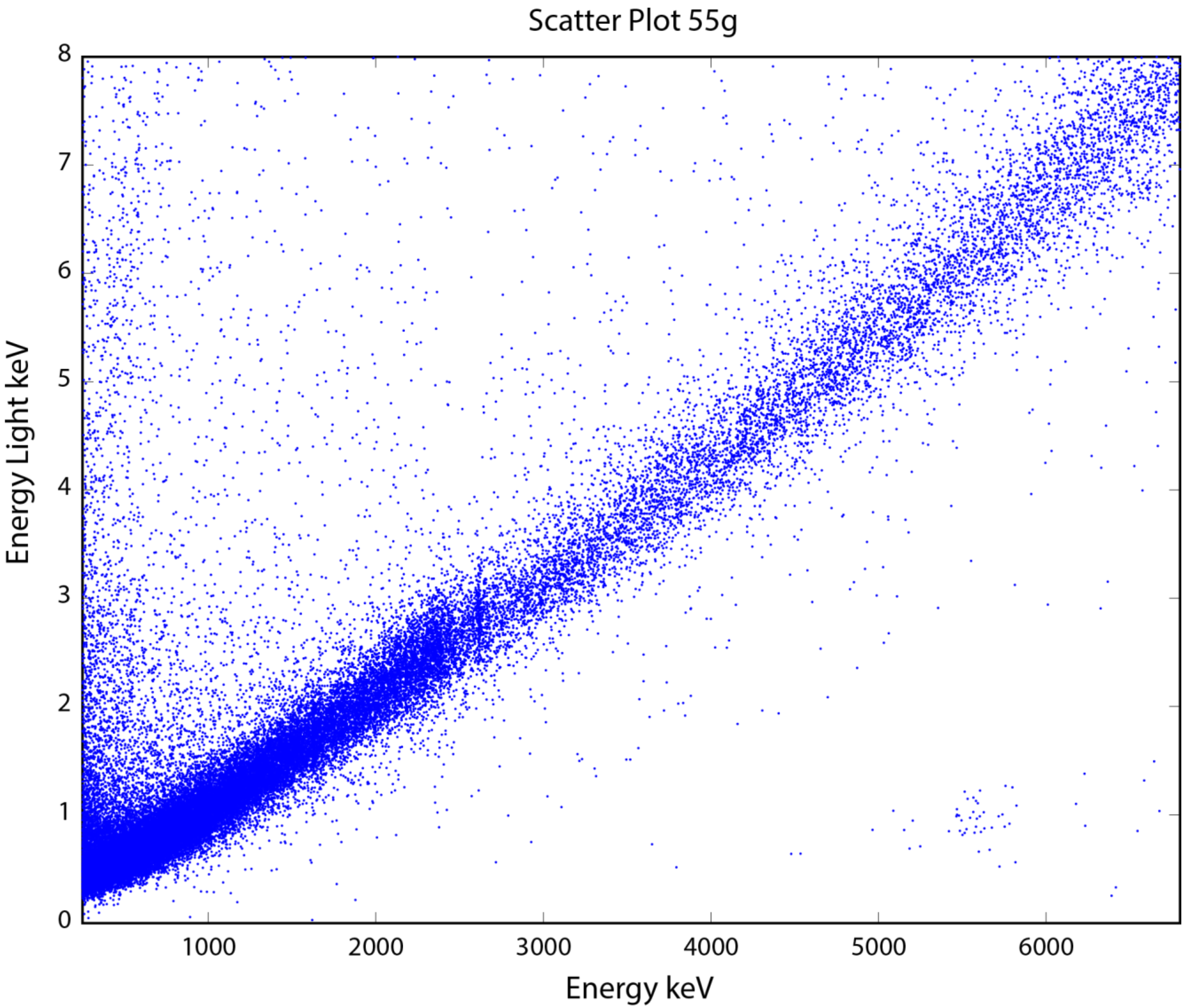
- No cuts

55g $ZnMoO_4$ RUN#2



- Selection of good heat events

55g $ZnMoO_4$ RUN#2



- Selection of good heat events
- Selection of good light events

LYalpha = 0.00015
Lybeta = 0.00098
QF = 0.153

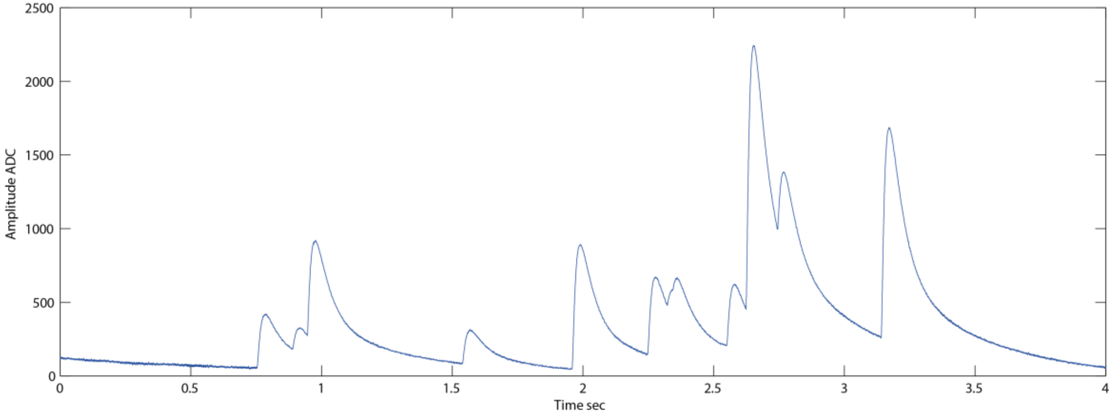
160g $ZnMoO_4$ RUN#2

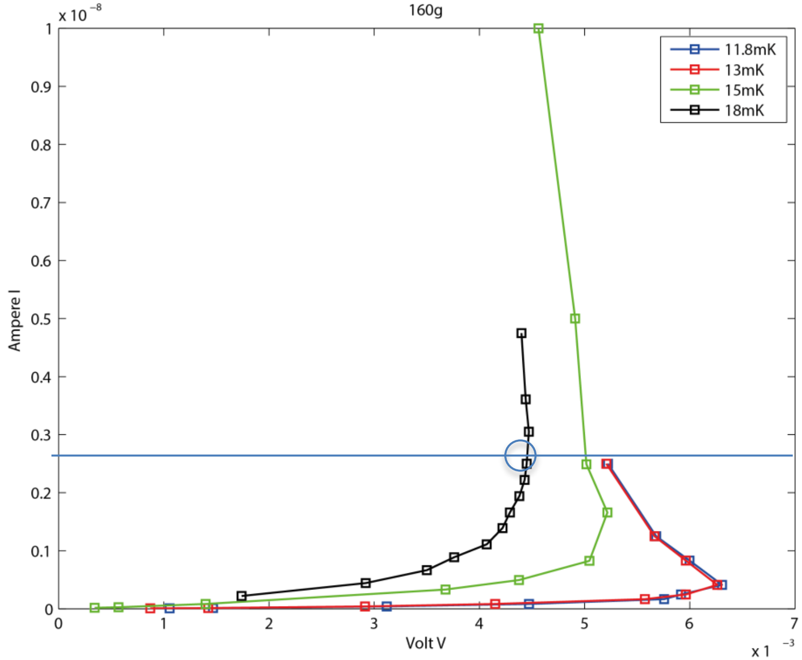
❖ 4 sec output of 160g

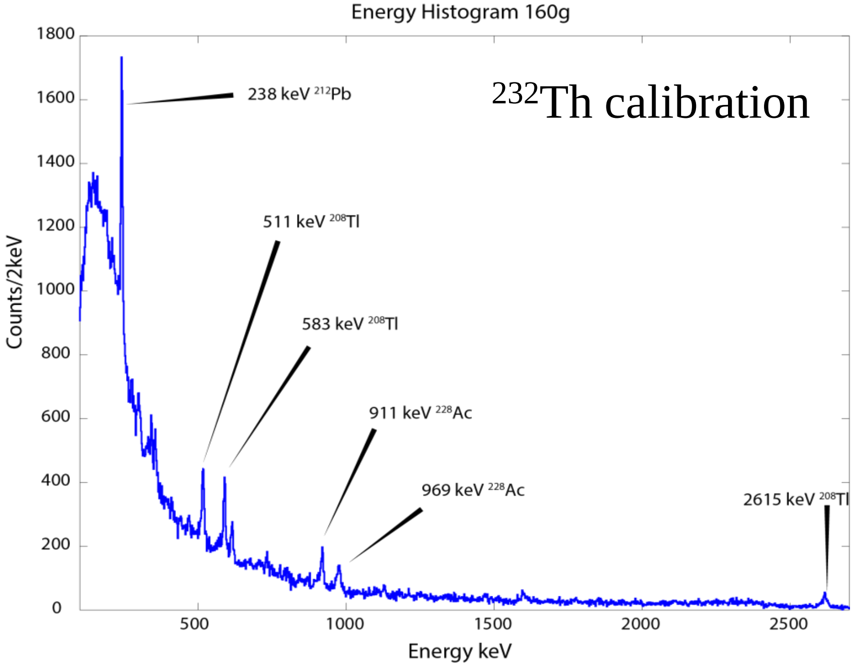
Huge pile-up

No baseline available for analysis
Analitic FWHM =5.97 keV

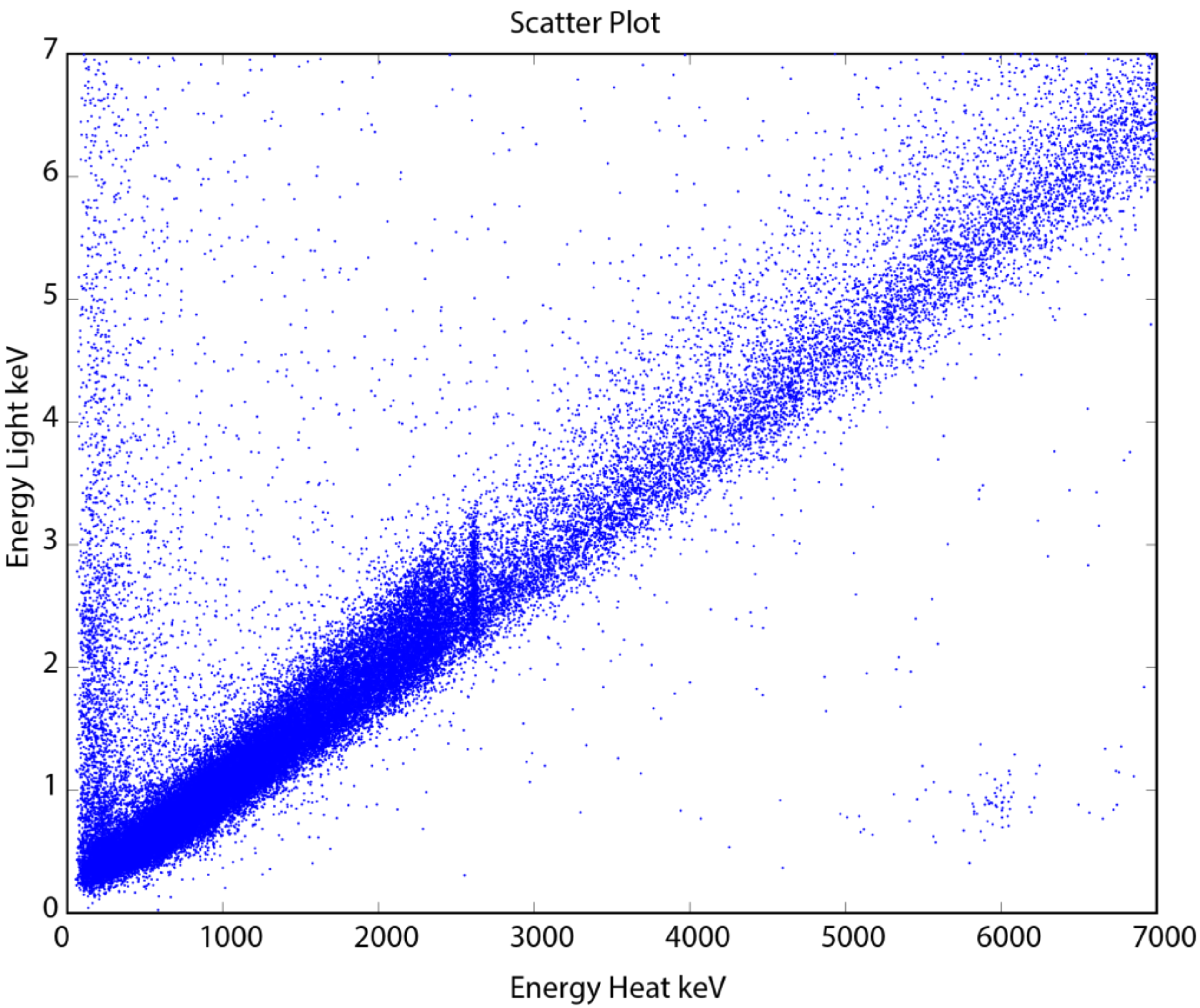
Sensitivity = 212 nV/keV







160g $ZnMoO_4$ RUN#2



- Selection of good heat events
- Selection of good light events

LYalpha = 0.00015
Lybeta = 0.00096
QF = 0.156

Conclusion

The LUMINEU program aims at performing a pilot experiment on neutrinoless double beta decay of ^{100}Mo using radiopure $ZnMoO_4$ crystals operated as scintillating bolometers.

A first LUMINEU crystals grown by LTG CZ technique. Thermal and bolometric properties were tested at CSNSM.

The energy resolution is good

The alpha/beta separation is excellent in the scatter plot: no alpha background is expected underground in the DBD region

An algorim for good pile-up treatment will be developed

The ULISSE facility is under upgrade and will be soon ready to successfully test the ISOTTA crystals