Searching for neutrinoless double beta decay With AMoRE

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On behalf of AMoRE collaboration

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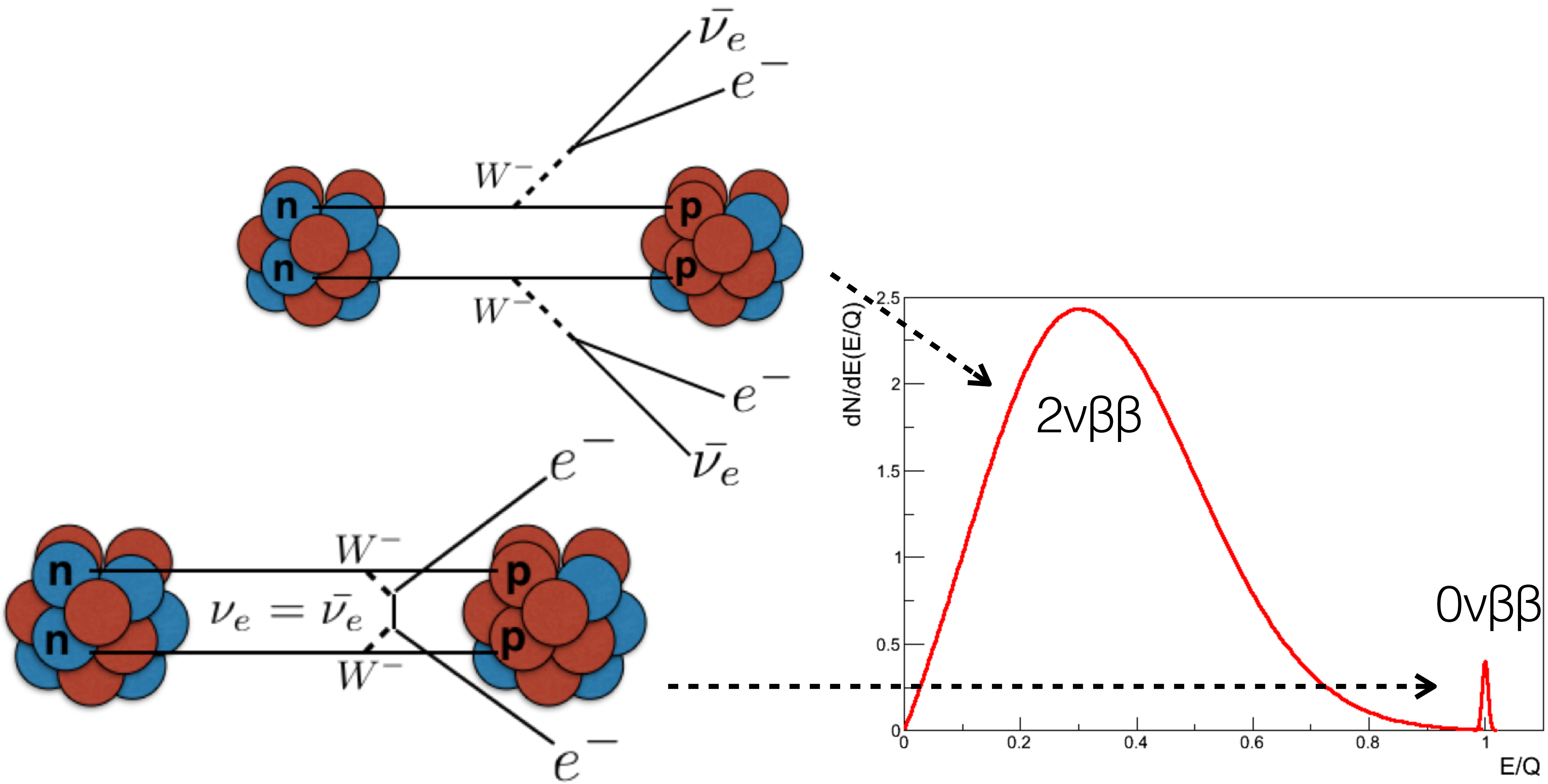
Neutrinoless double beta decay (0νββ) ?

Double β decay

=> In most even-even nuclei, single β decay forbidden

But, for a large number of them, double β decays allowed.

=> Two modes : 2νββ (T~10^{18}-10^{22} yrs), 0νββ (T>10^{26} yrs)



Why 0νββ ?

Lepton number non-conserving process
=> Process beyond the standard model
=> Leptogenesis / Baryon asymmetry

Revealing unknown properties of neutrinos
=> Unambiguous signature for Majorna nature of neutrinos
=> Absolute Neutrino mass

$$[T^{0\nu}_{1/2}]^{-1} = G^{0\nu}|M_{0\nu}|^2\langle m_{\beta\beta}\rangle^2$$

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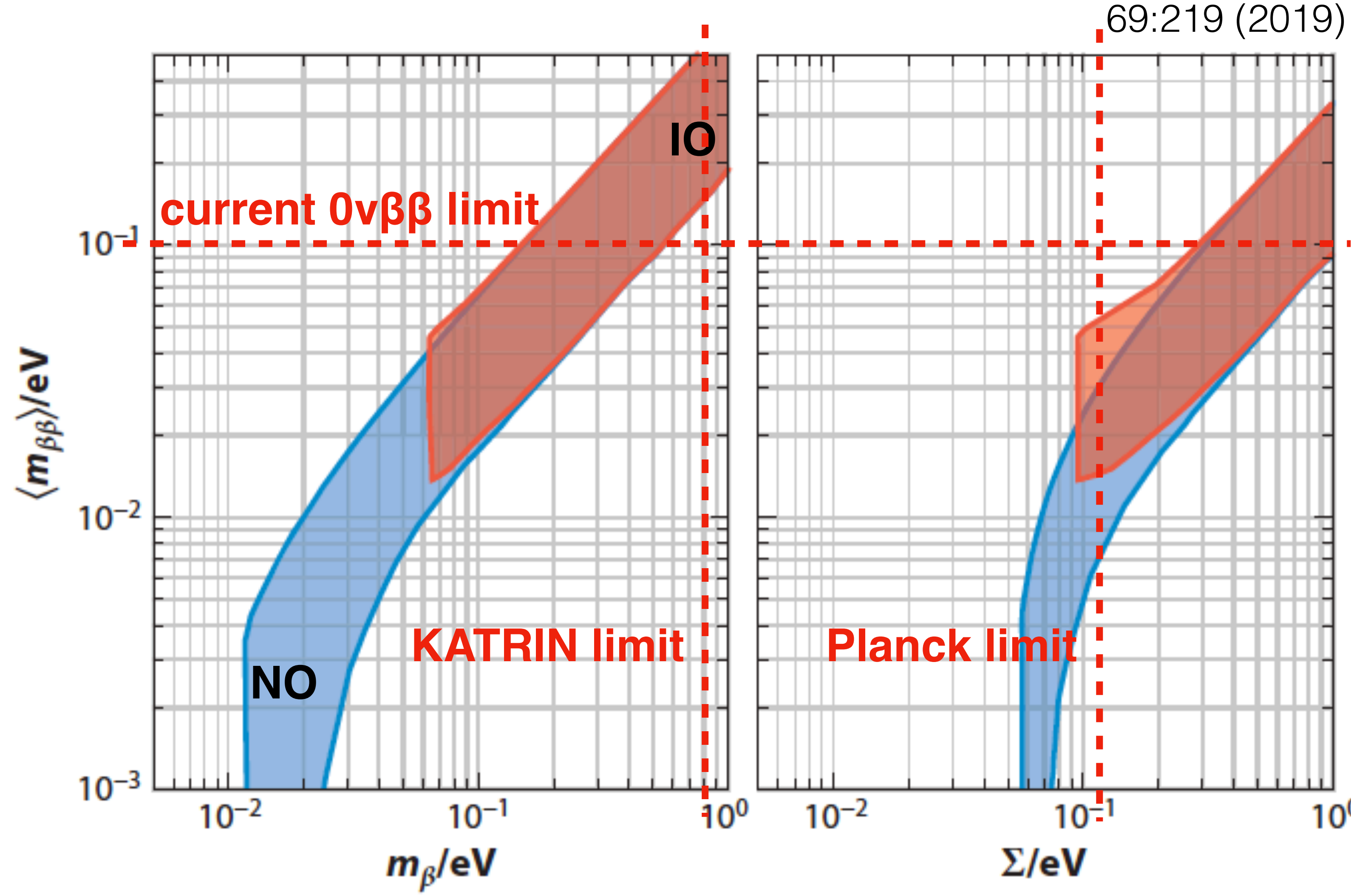


AMoRE experiment

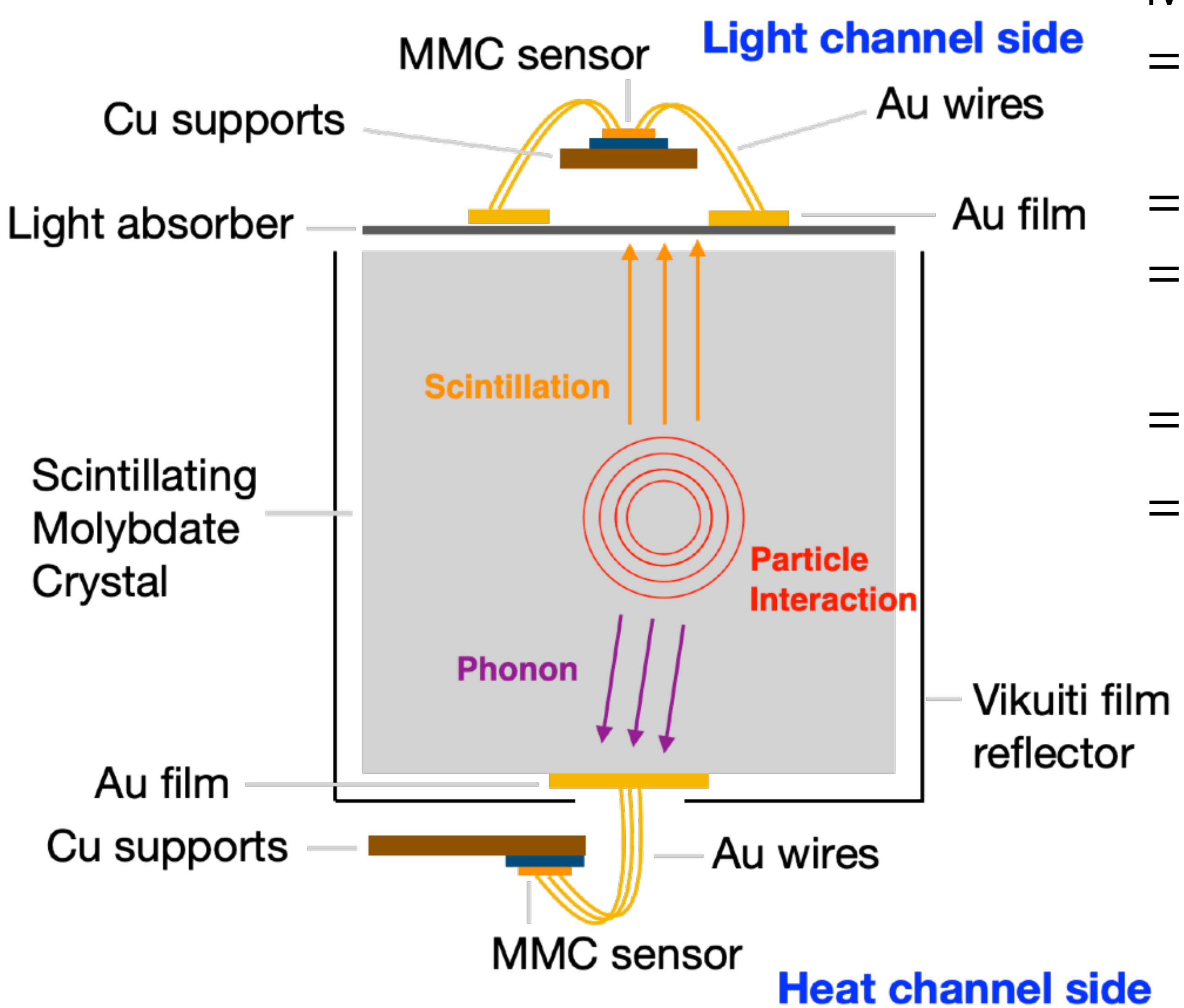
0νββ source : ^{100}Mo isotope

=> relatively high Q-value : 3034 keV
shorter half-life expected
=> high natural abundance of 9.8 %
=> Isotope with long DBD search history

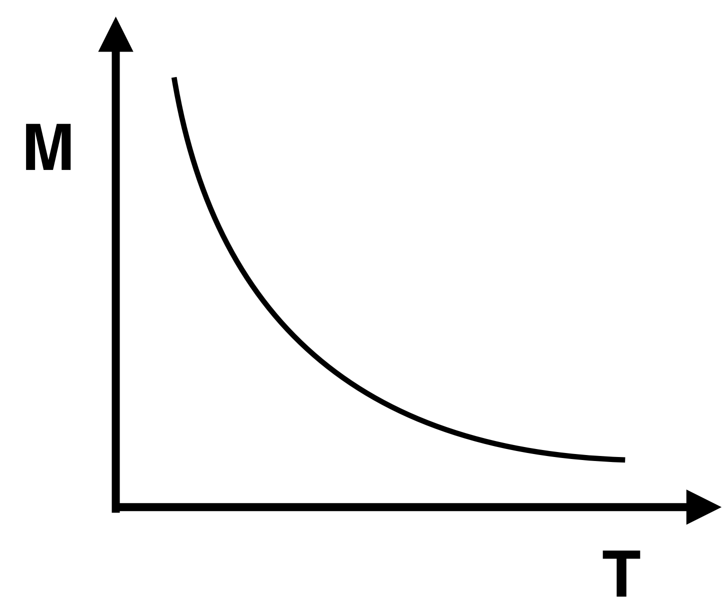
Detector : cryogenic calorimeter
with scintillating molybdate crystal

=> Cryogenic calorimeter with massive crystal absorber:
Source equals detector
Excellent energy resolution
=> Scintillating crystal:
Alpha signal rejection in ROI
Simultaneous light signal depending on the particle type
Different pulse shape

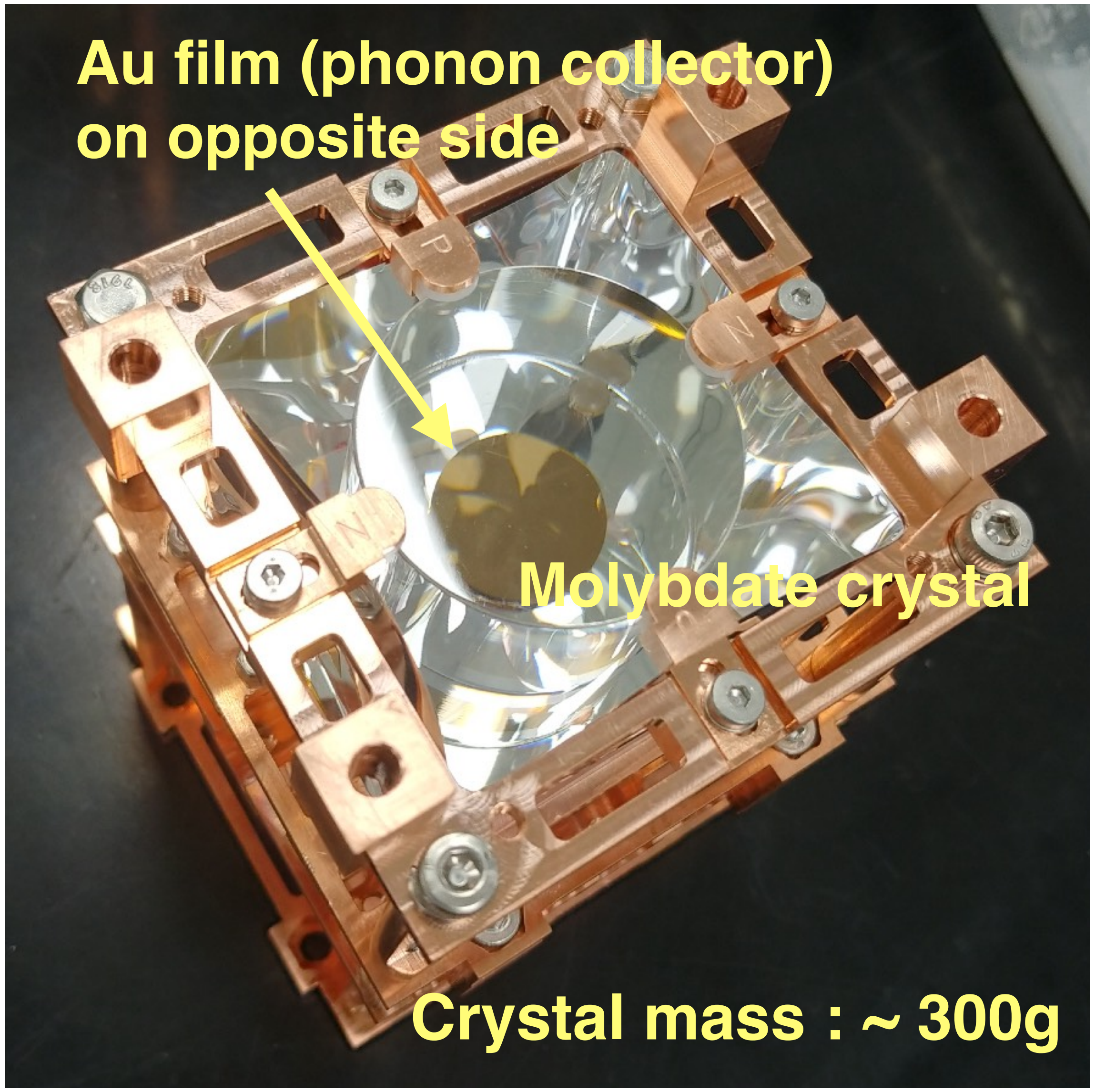
Principle of AMoRE detector

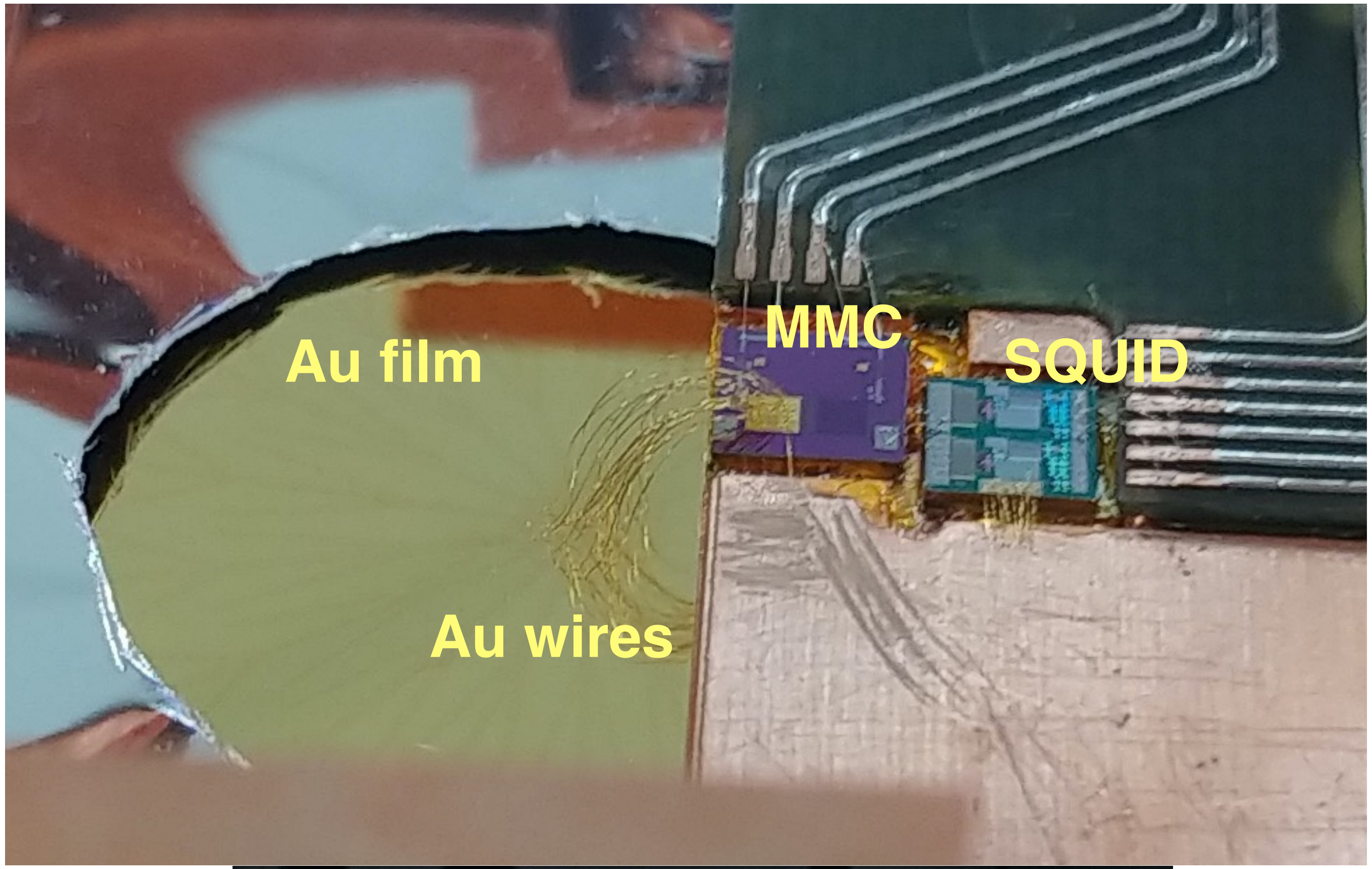


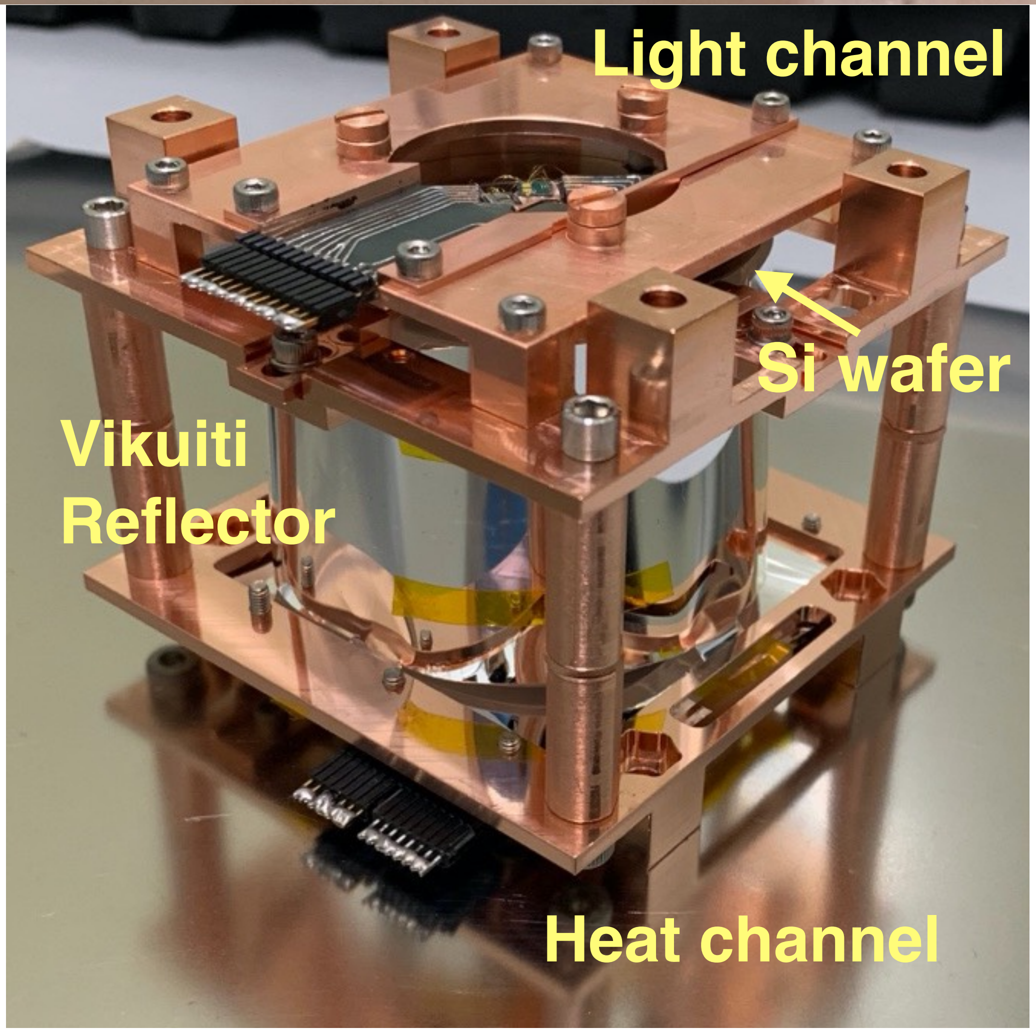
MMC (Metallic Magnetic Calorimeter)
=> Paramagnetic material
Metallic host (Au or Ag) + Magnetic ions (Er)
=> Magnetization (**M**) very sensitive to **T**
=> MMC implemented with superconducting current (**I**) loop to provide B-field
=> Δ**I** induced by Δ**M** as a function of Δ**T**
=> SQUID measures Δ**I** as signal



AMoRE detector







Details keep changing…

Scintillating Molybdate crystals

Calcium molybdate crystal ($CaMoO_4$), “CMO”

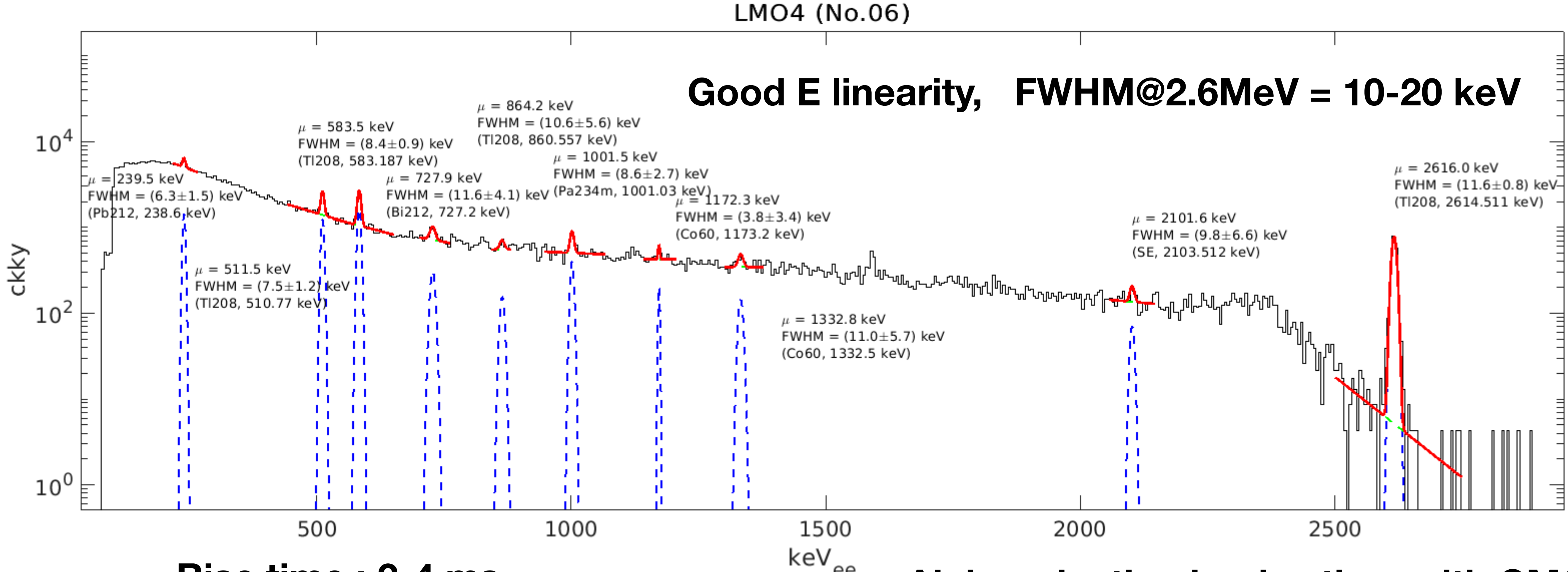
=> Highest light output molybdate
=> Easy crystal handling
=> Good energy resolution / Particle identification demonstrated
=> Annealing necessary for the optical quality
=> ^{48}Ca depletion required

Lithium molybdate crystal (Li_2MoO_4), “LMO”

=> High molybdenum content
=> Simple crystal growth : low melting point, no need of annealing
=> Low radioactive background
=> Good energy resolution demonstrated
=> Small light output
=> Hygroscopic surface

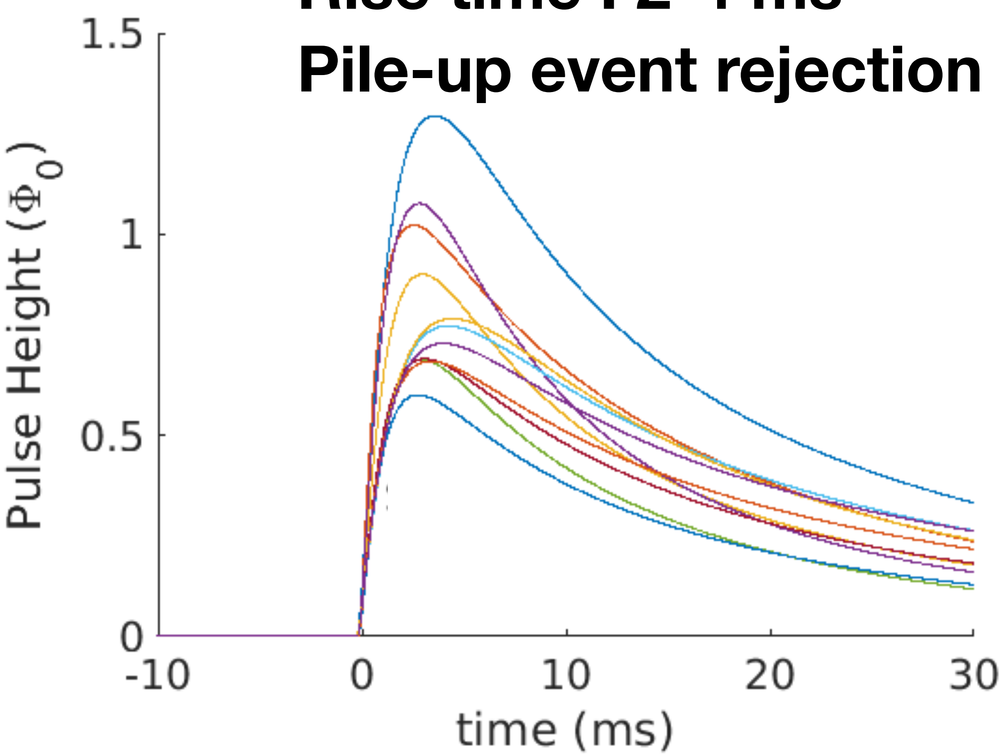
Detector performance

operation T = 10 ~ 20 mK

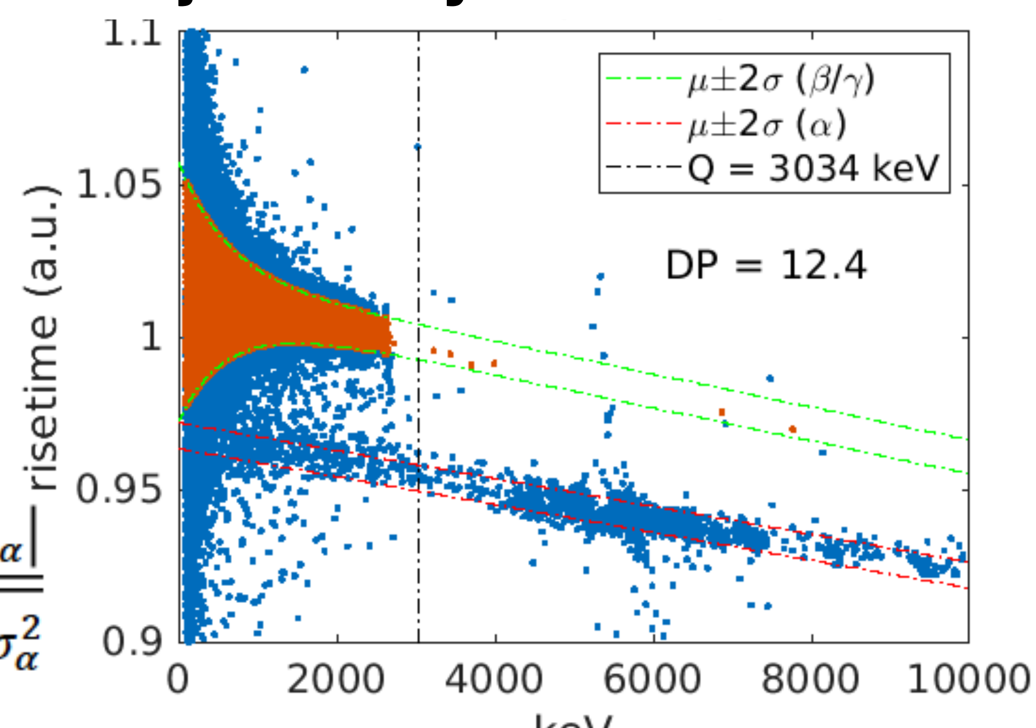


Rise time : 2-4 ms

Pile-up event rejection up to 500μs



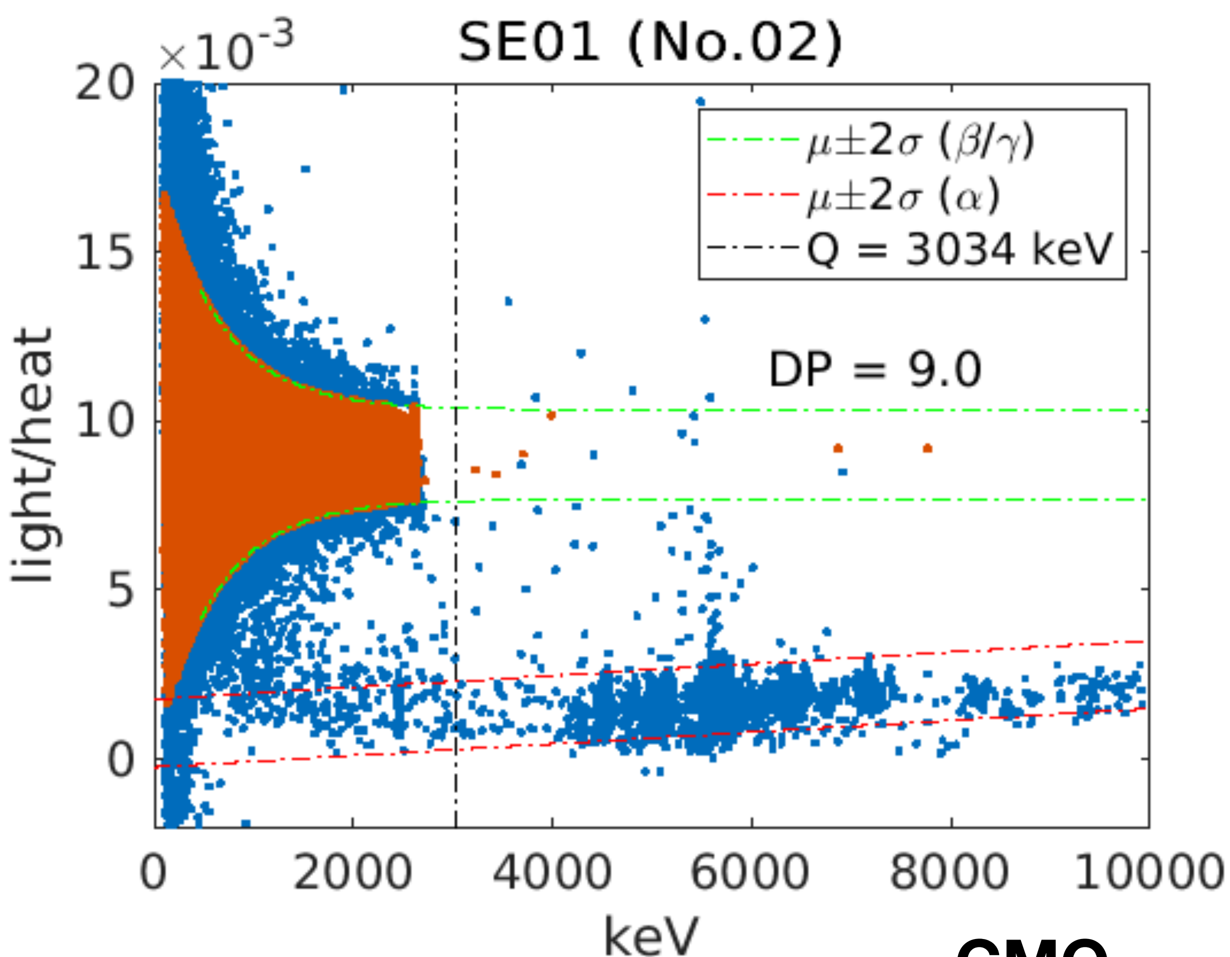
Alpha rejection by rise time with CMO



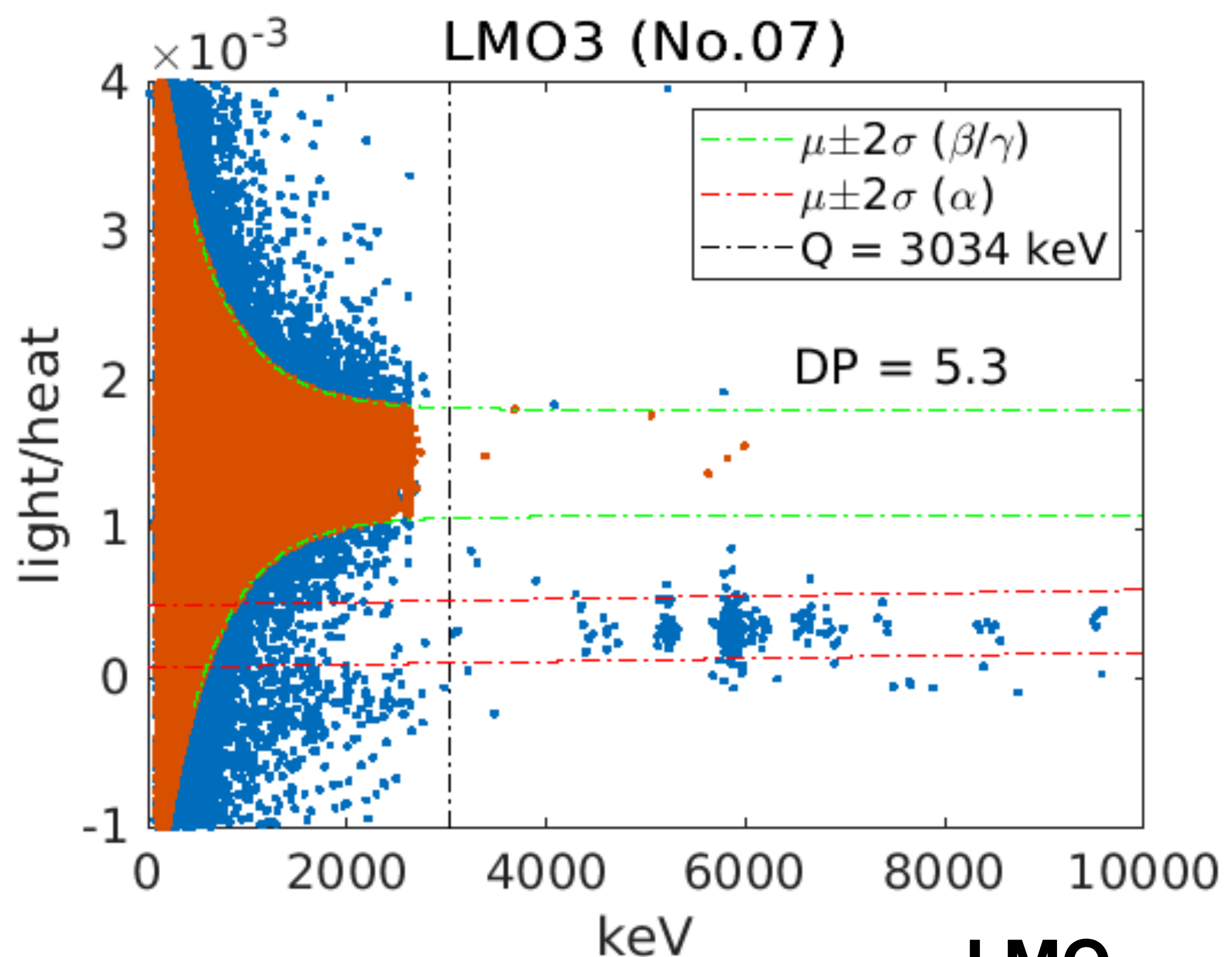
$$DP = \frac{|\mu_{\beta/\gamma} - \mu_{\alpha}|}{\sqrt{\sigma_{\beta/\gamma}^2 + \sigma_{\alpha}^2}}$$

Detector performance

Alpha particle rejection based on light/heat ratio



CMO



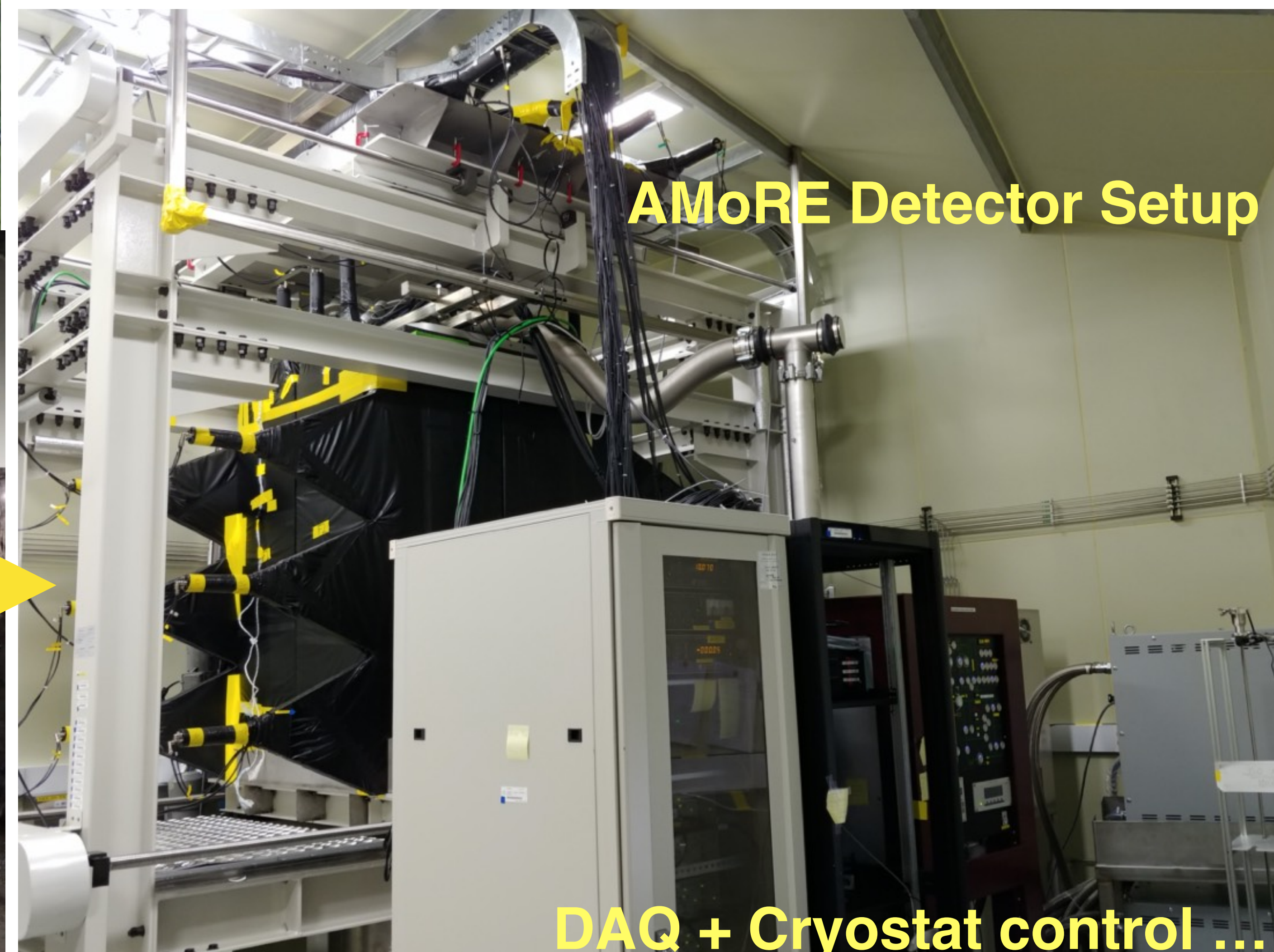
LMO

Experimental site : Yangyang (Y2L) underground lab

700 m minimum vertical depth (2000 m.w.e)

Radon free air supplied

Neighbor of COSINE experiment



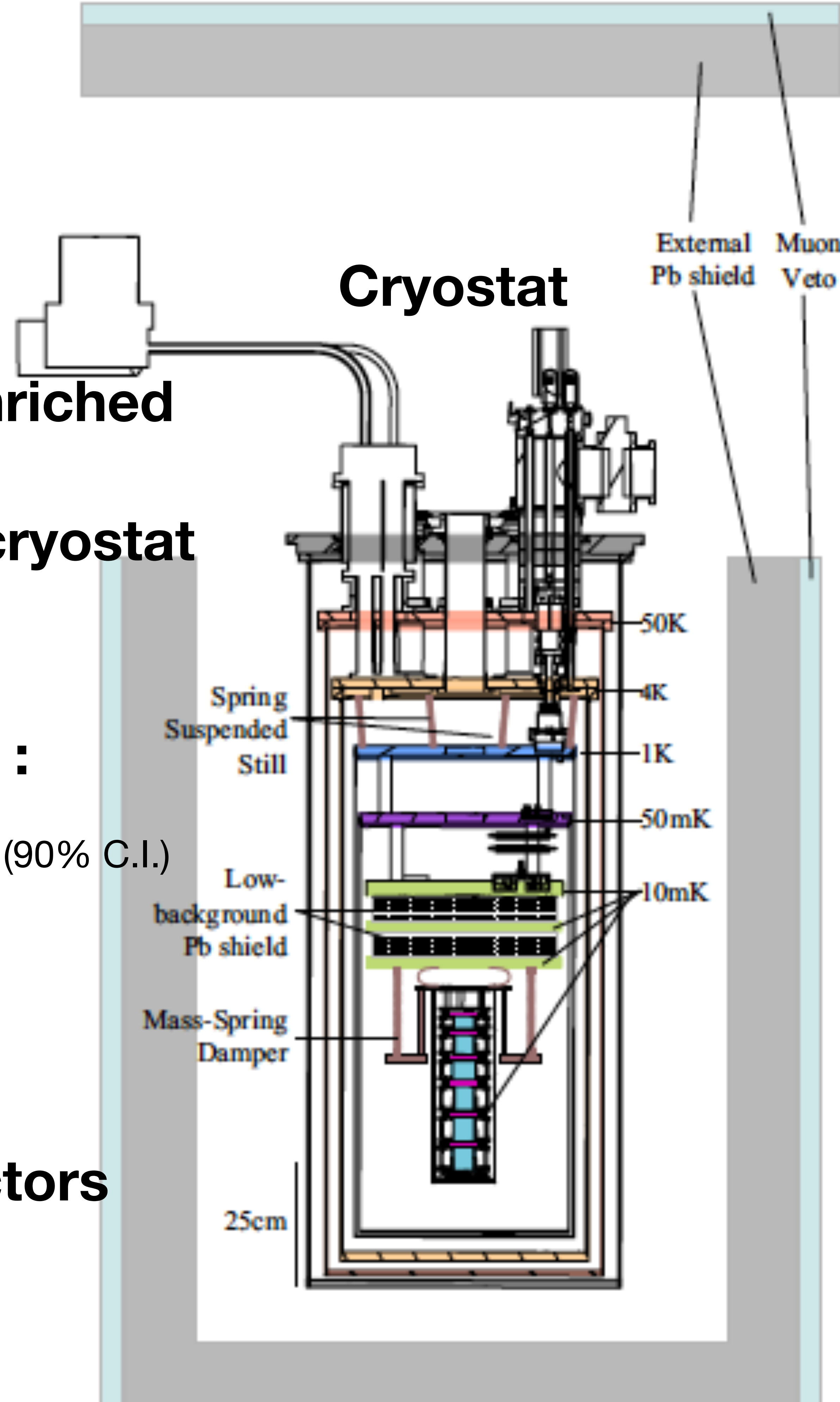
AMoRE pilot

Period : 2015 - 2018
6 CMO (FOMOS)
^{48}Ca depleted, ^{100}Mo enriched
Total mass : 1.9 kg
Vibration damping for cryostat

First results (2019)
with 0.3 kg yr exposure :
$T^{0\nu}_{1/2} > 9.5 \times 10^{22}\mathrm{yrs}$ (90% C.I.)

Bkg at ROI ~ 0.2 ckky

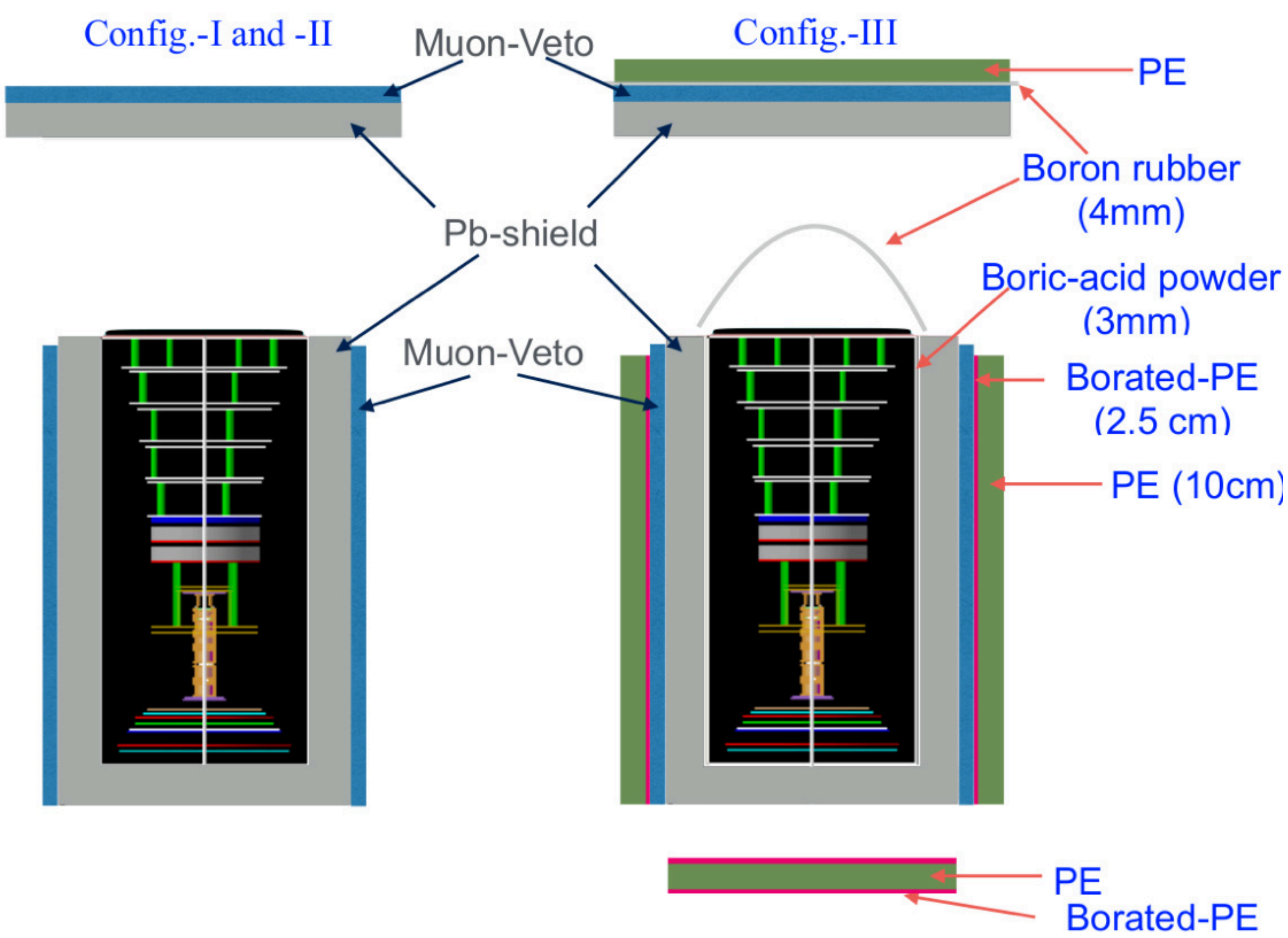
Demonstration of detectors
for 0νββ search

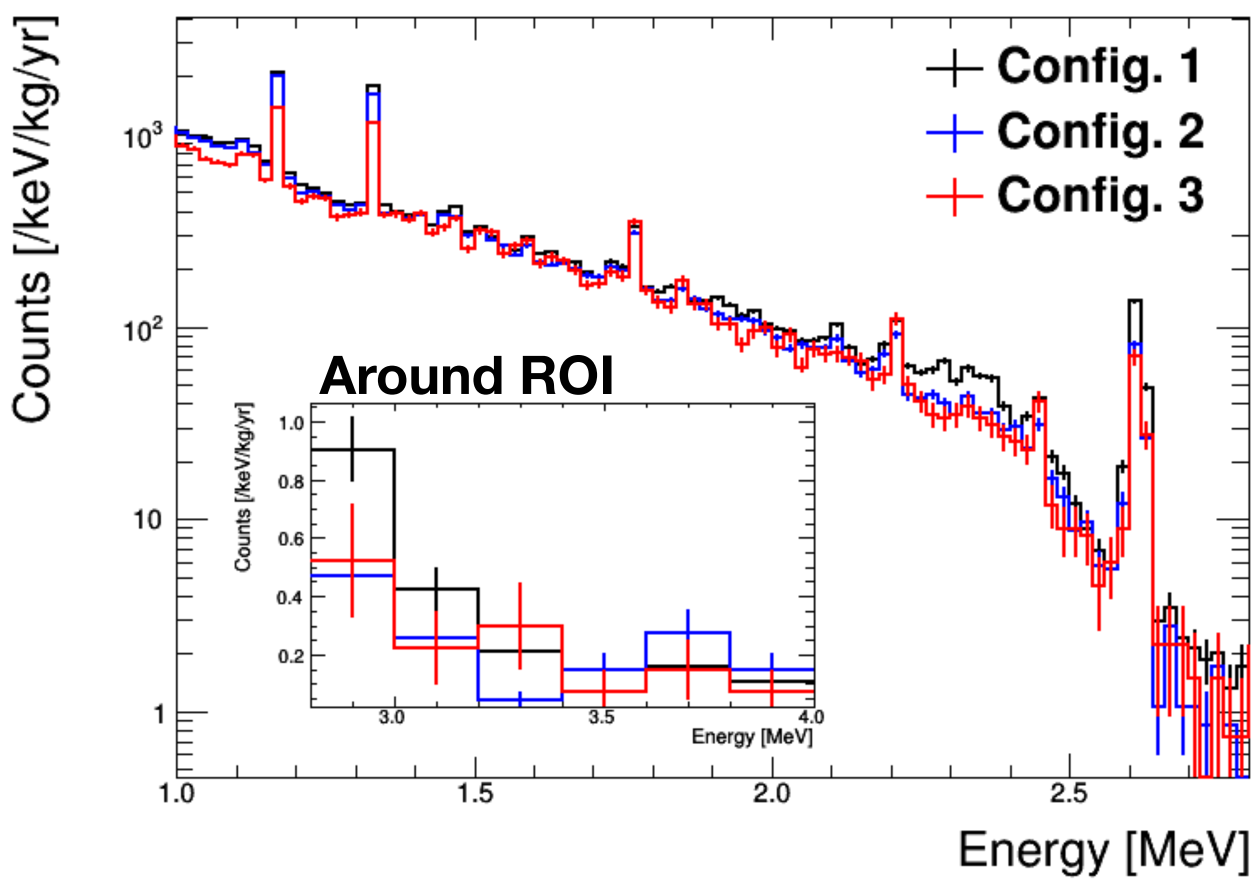


* ckky = cnts/kg/keV/yr

AMoRE pilot

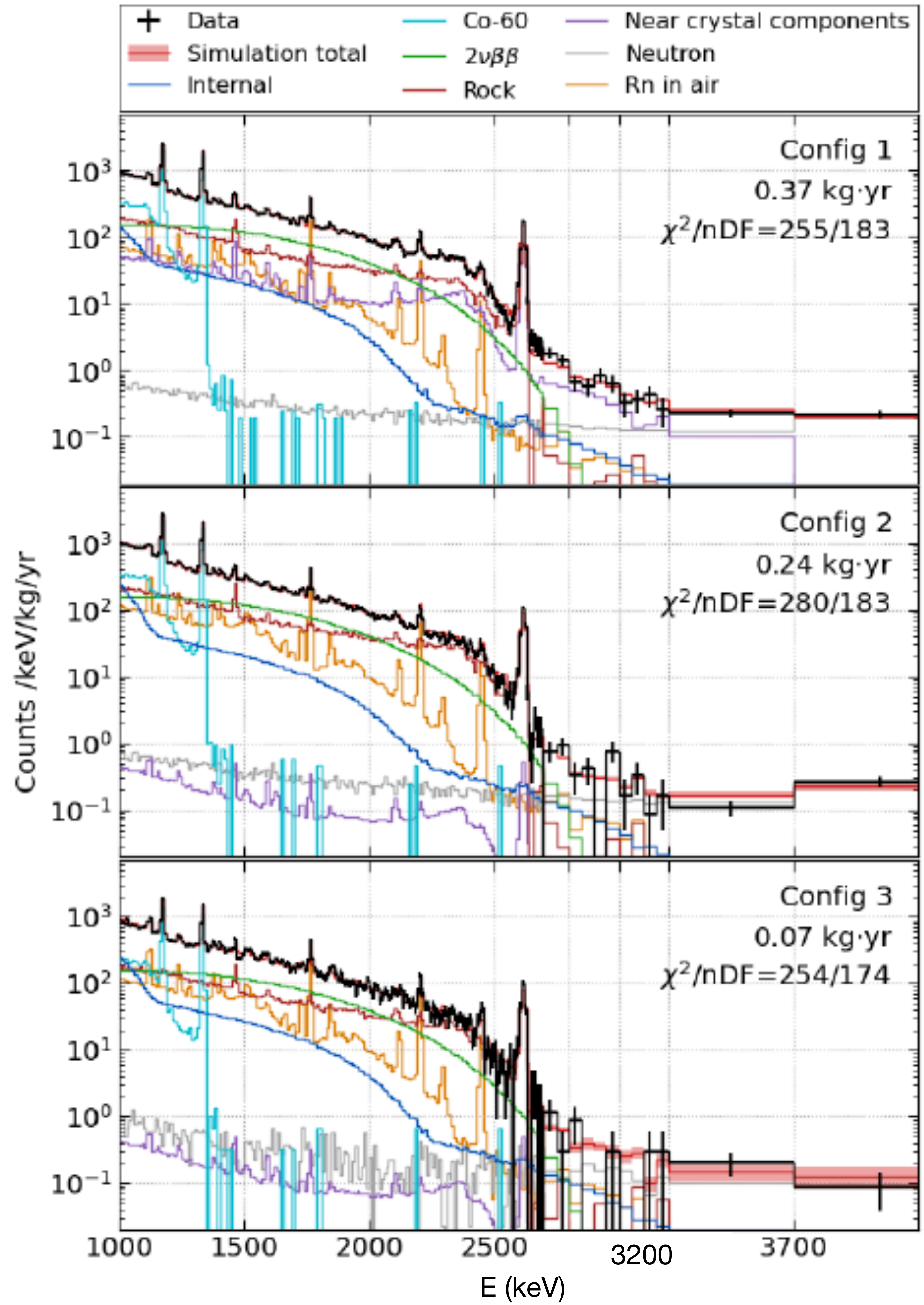
A lot of learnings about the background control





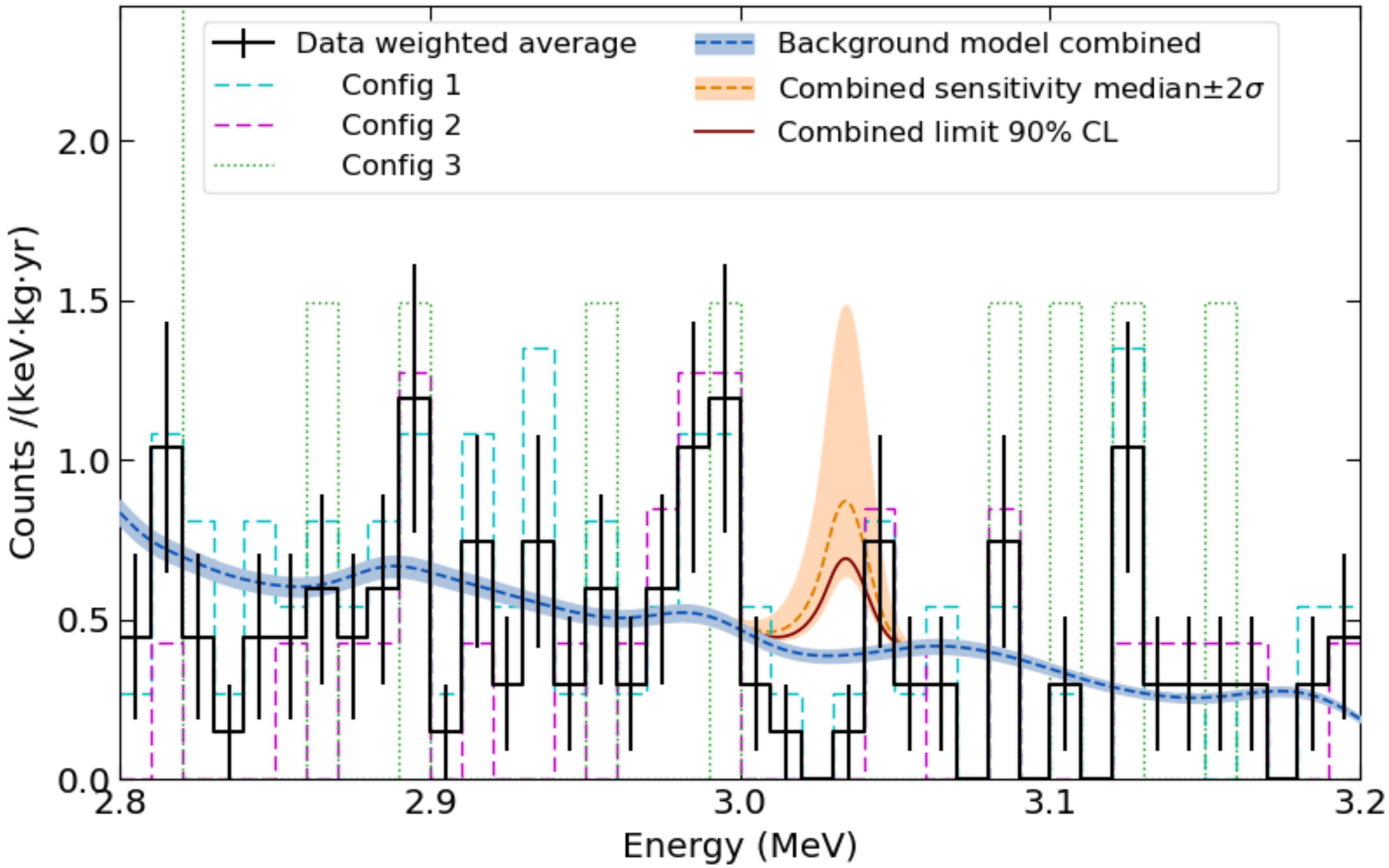
Config. 2 : Removing “hot” radioactive components (epoxy, pin connector, holder…)
Config. 3 : Neutron shielding

AMoRE pilot
Background Modeling

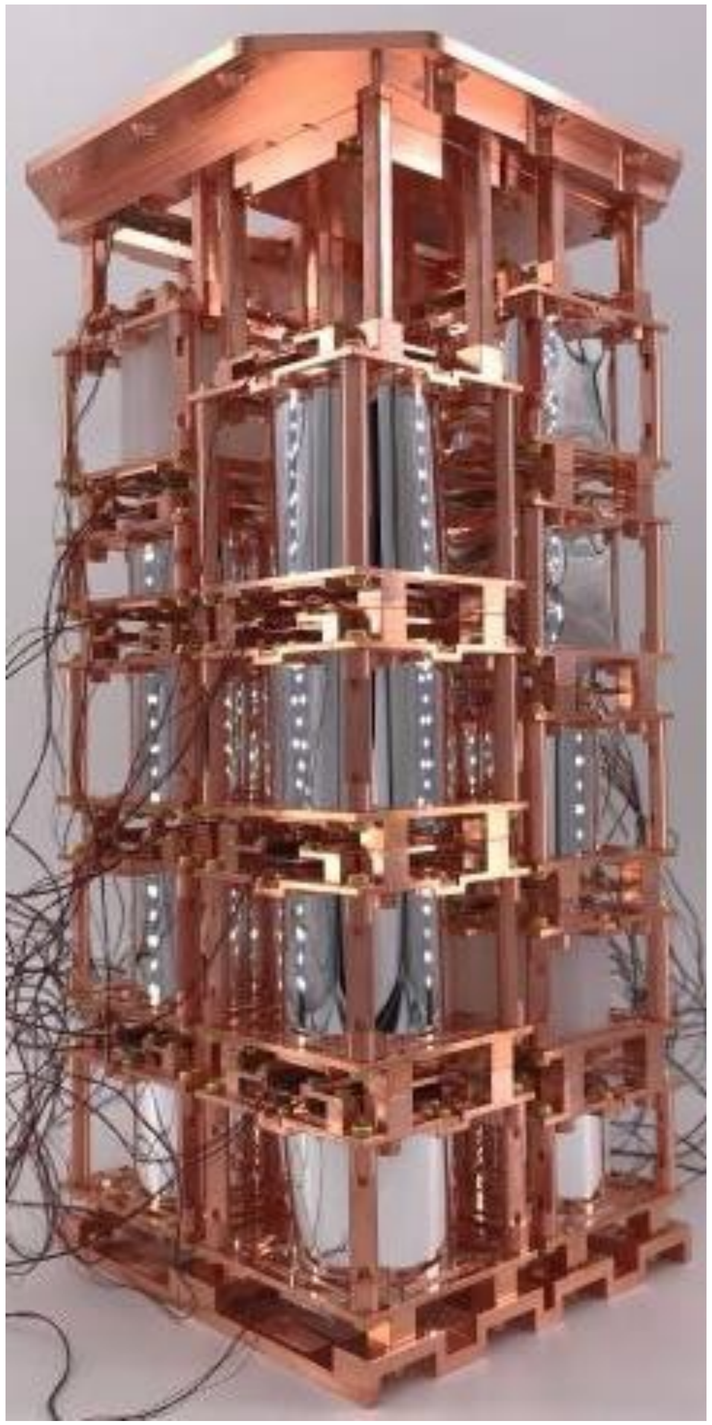


Results with 0.68 kg yr exposure :

$$T_{1/2}^{0\nu} > 3.4 \times 10^{23} \text{yrs}$$ (90% C.I.)



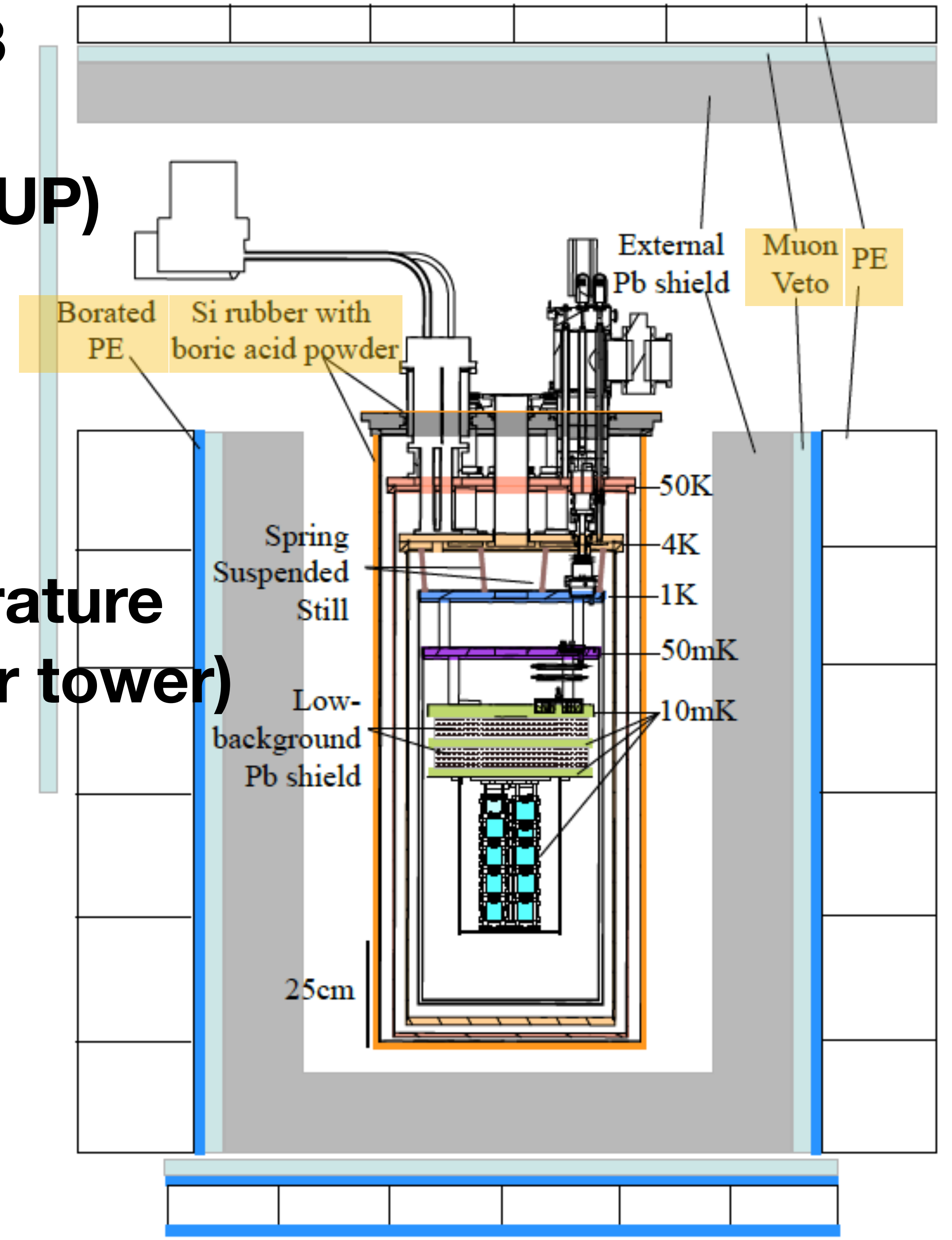
AMoRE-I



Period : 2020 - 2023
13 CMO + 5 LMO
(FOMOS + NIIC + CUP)
Total mass : 6.2 kg

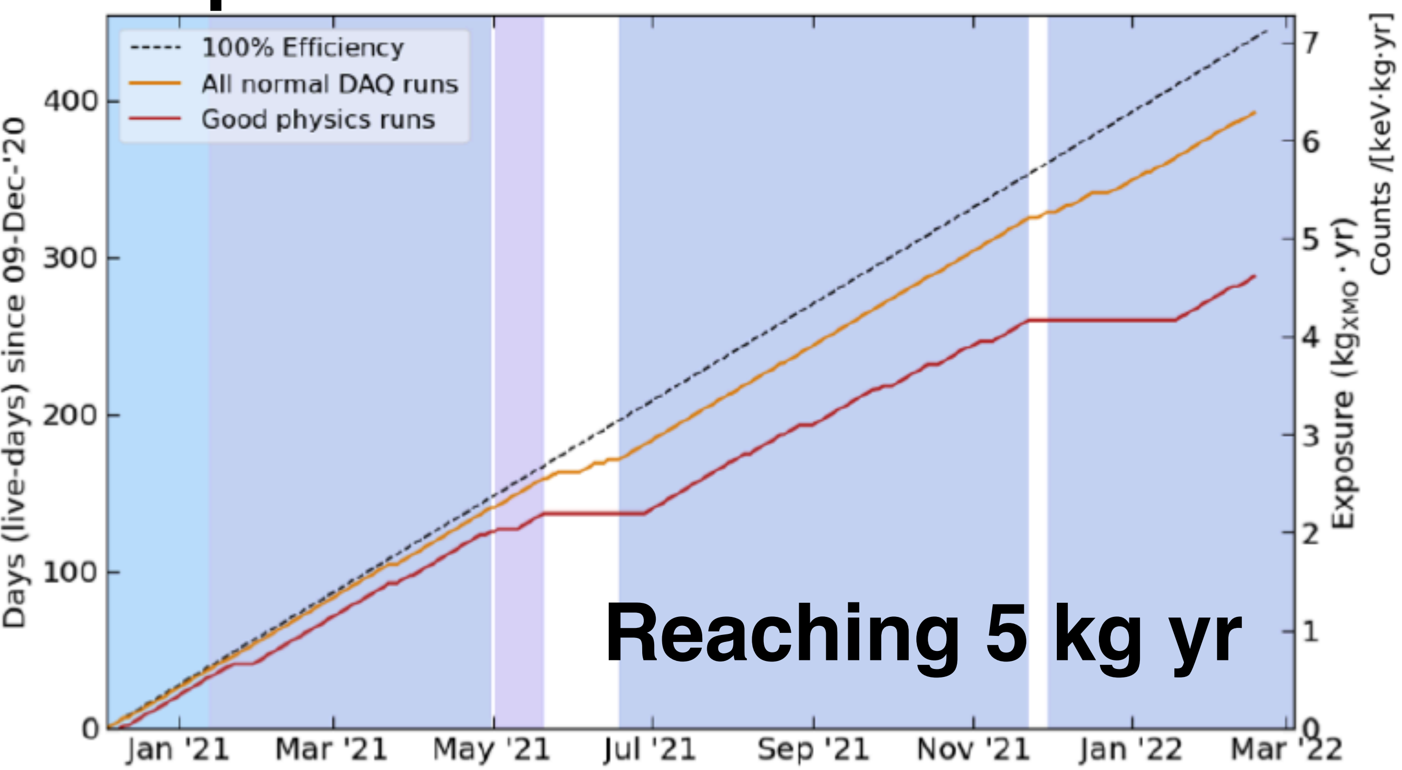
Upgraded shielding

More stable temperature
(2nd PID at detector tower)

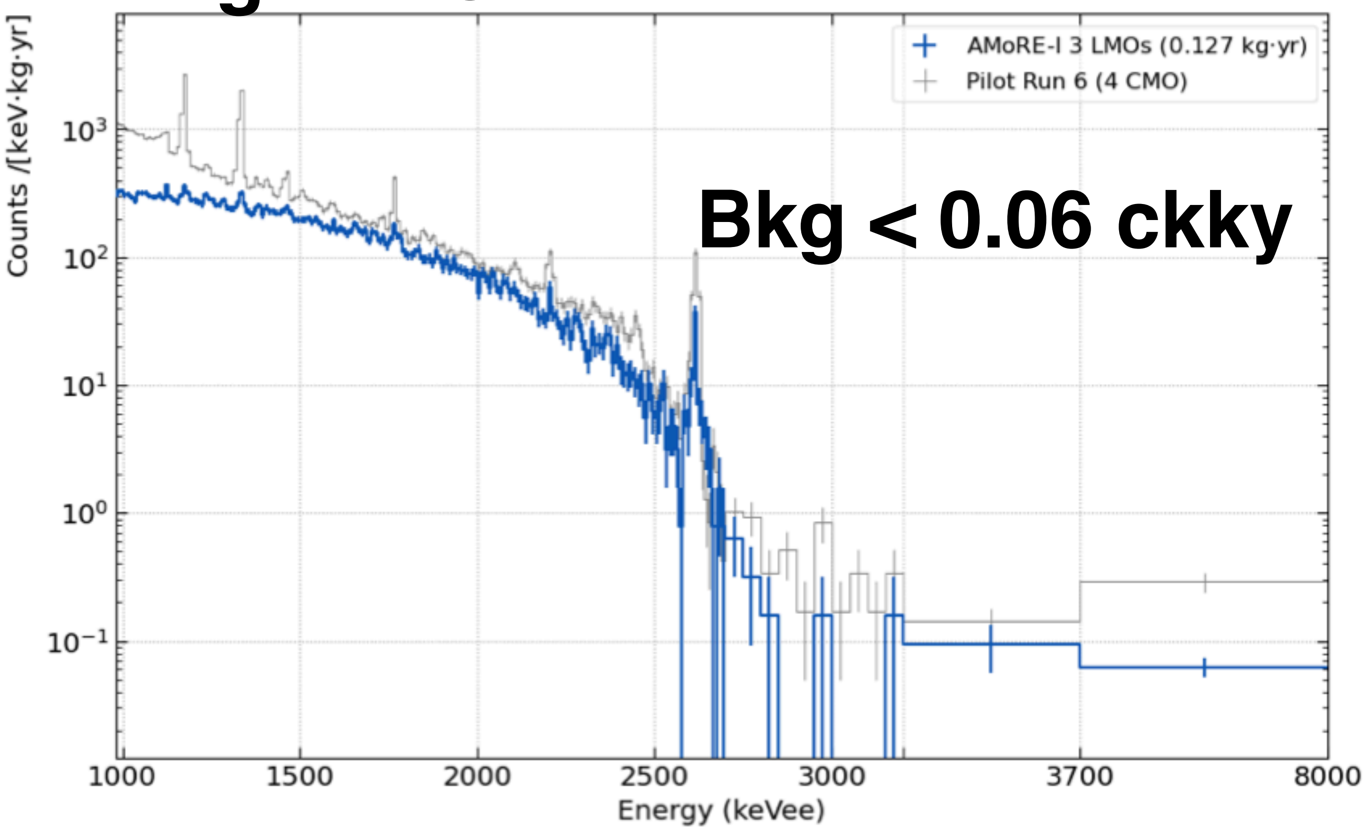


AMoRE-I status

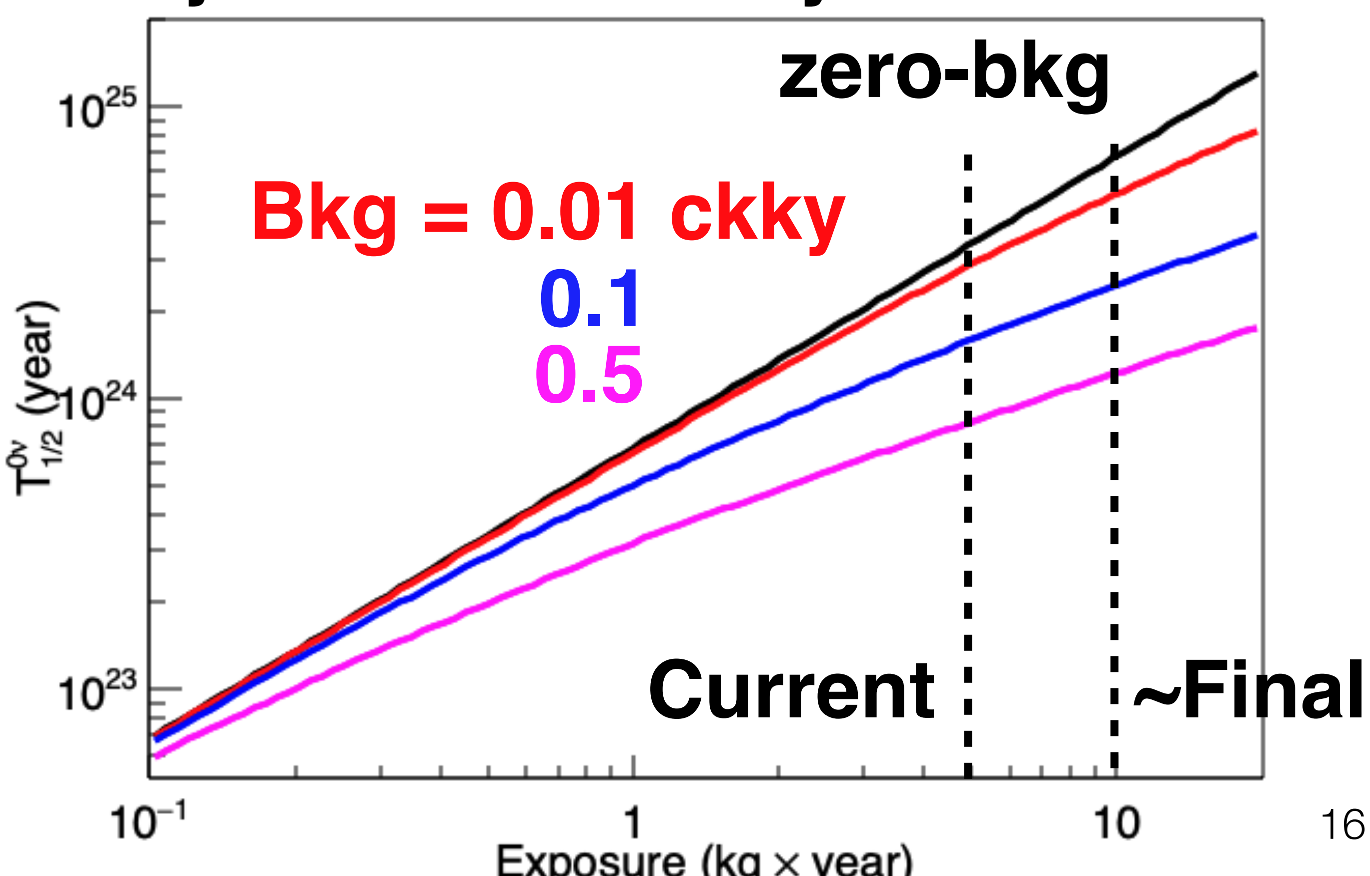
Exposure



Bkg in ROI



Projected Sensitivity

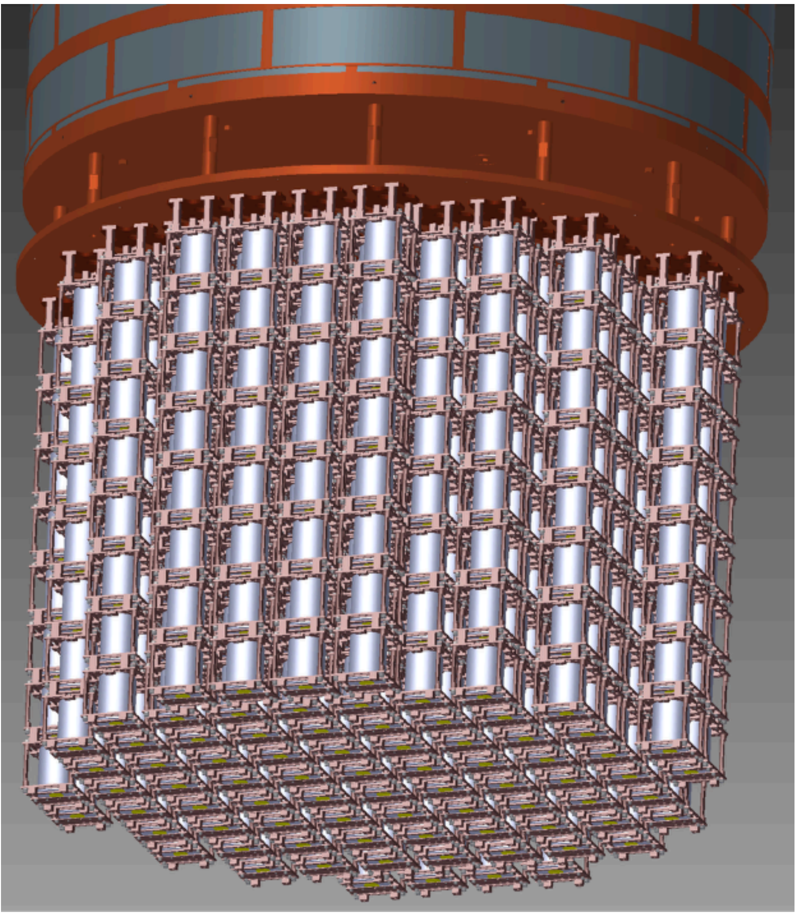


FWHM@2.6 MeV : 10 ~ 20keV

Full analysis underway

First results coming soon

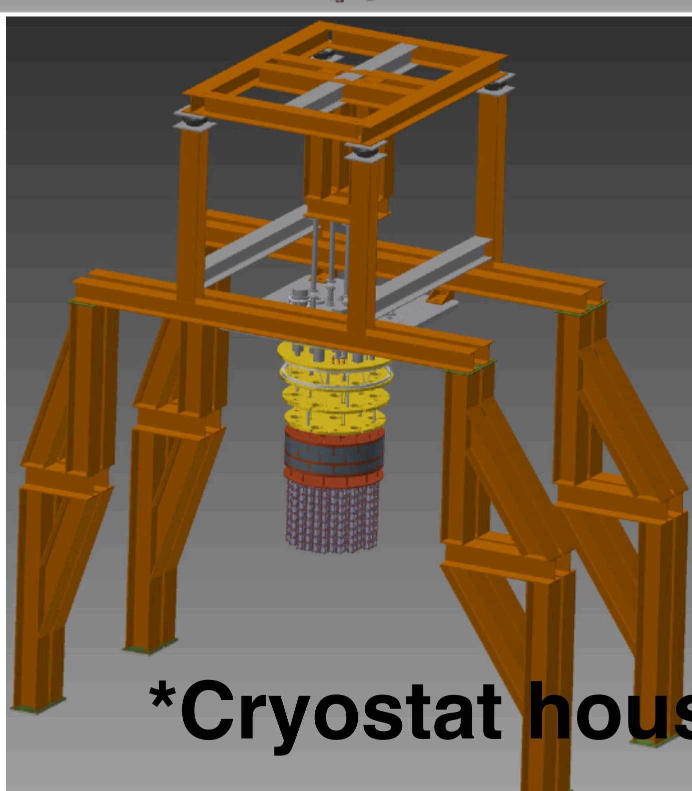
AMoRE-II



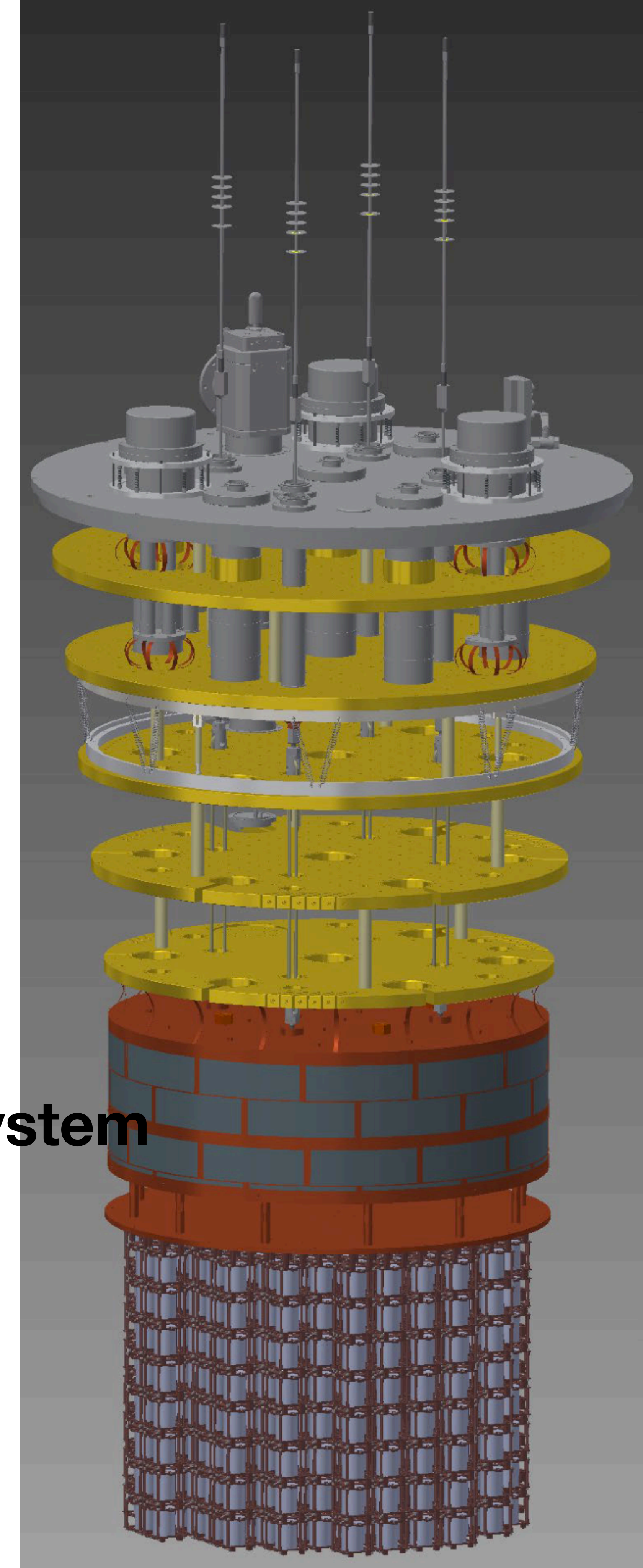
Period : 2022 - 2027
100 kg of ^{100}Mo
Hundreds of detectors
Total mass : ~200 kg
Mostly, LMO (NIIC + CUP)
Aiming at 10^{-4} ckky at ROI

Built in two phases
Located in new lab (Yemilab)

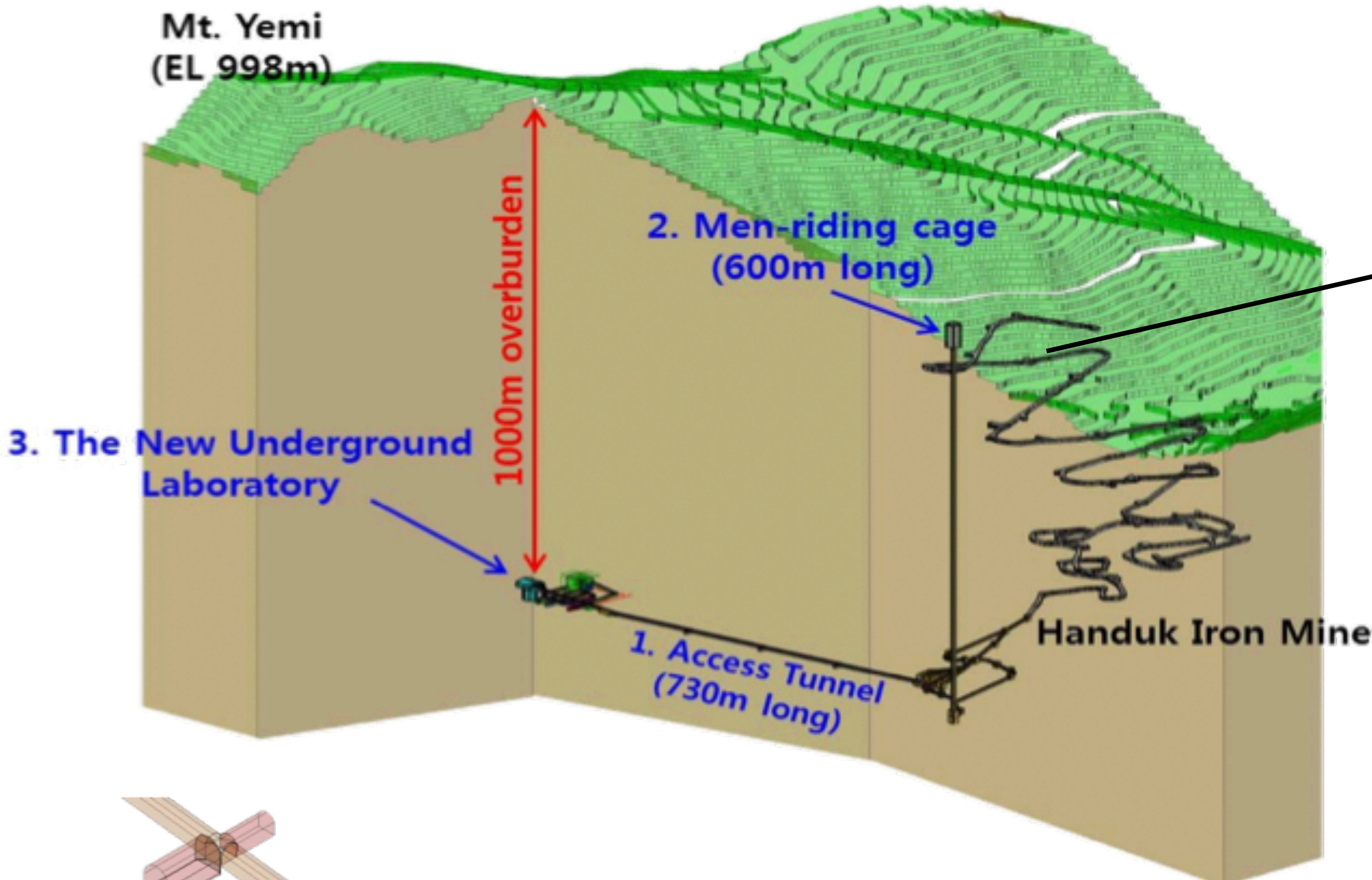
New vibration damping
=> Hanging by kevlar wire system
=> suspending ~3.4 tone

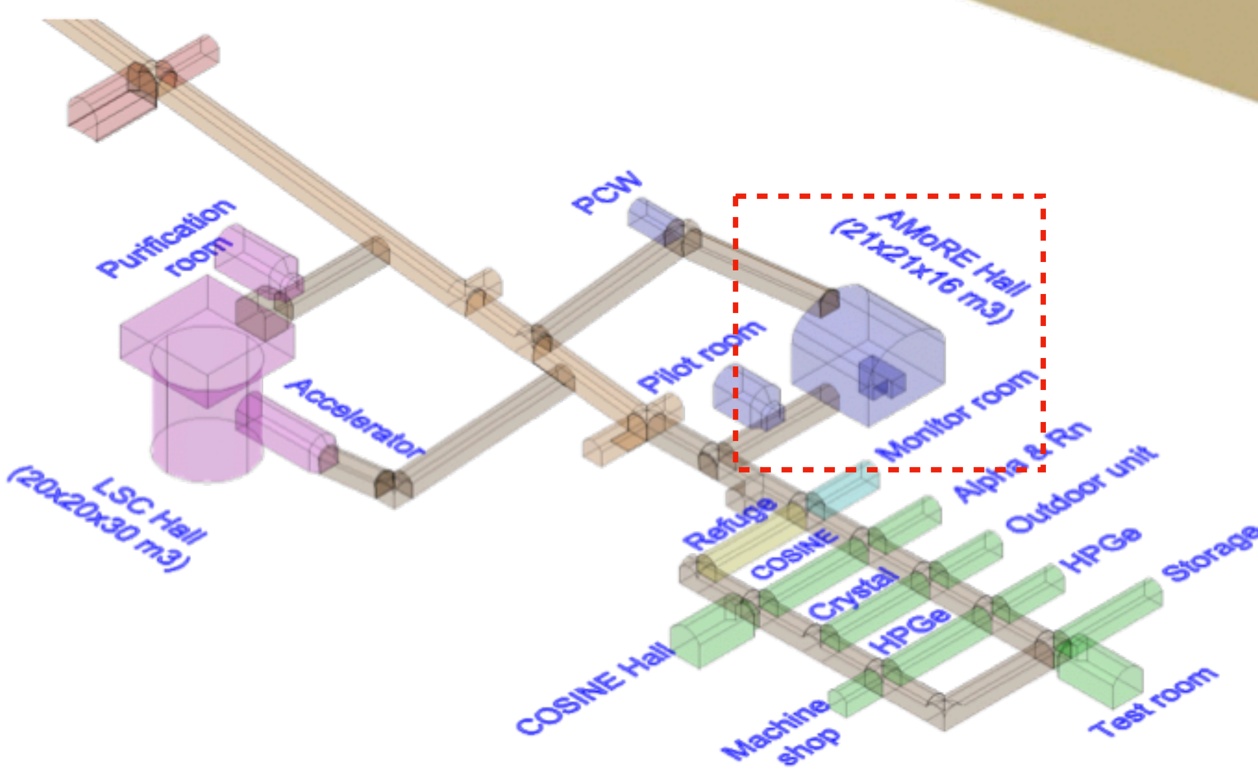


*Cryostat housing not drawn



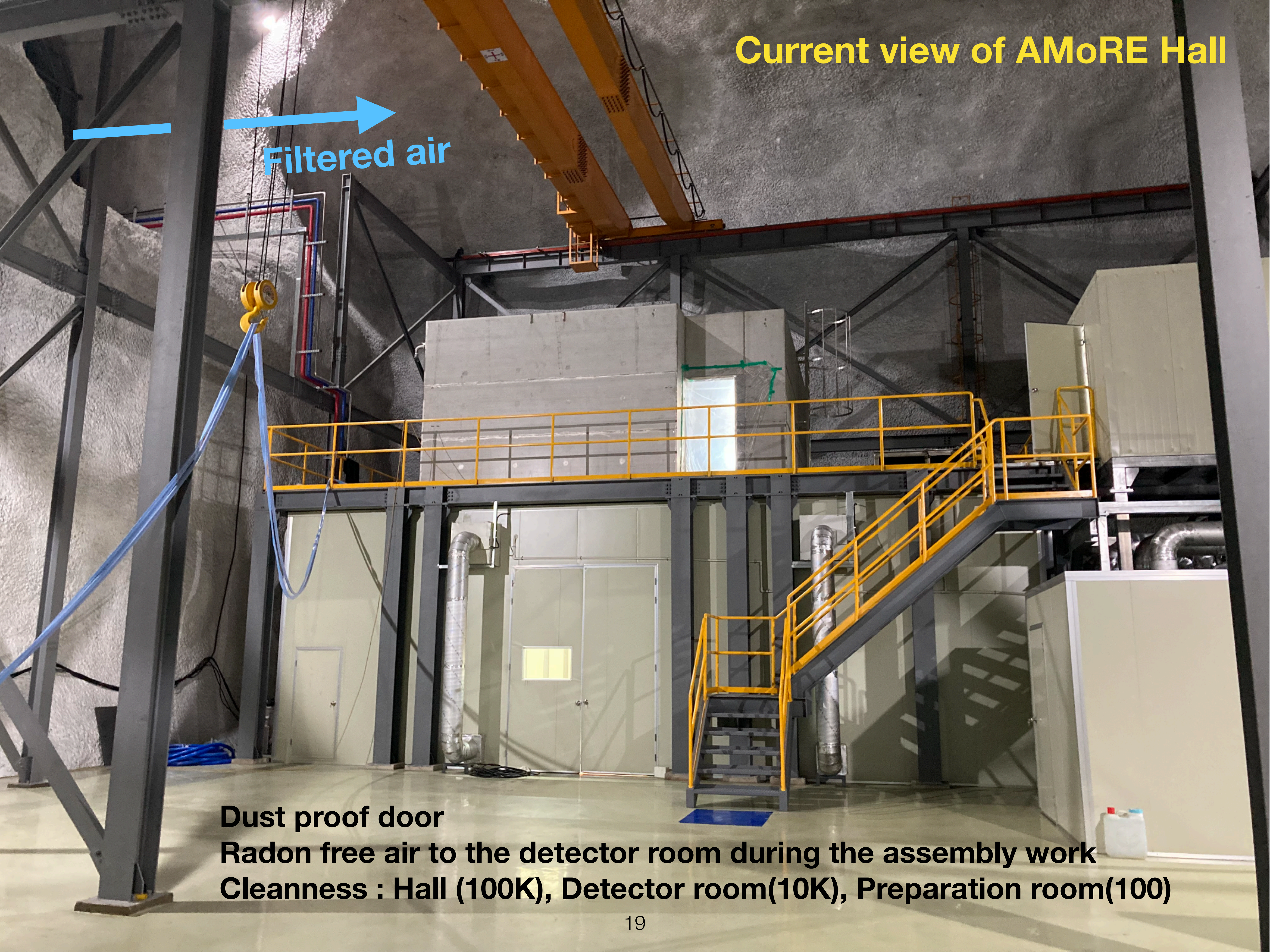
Yemilab





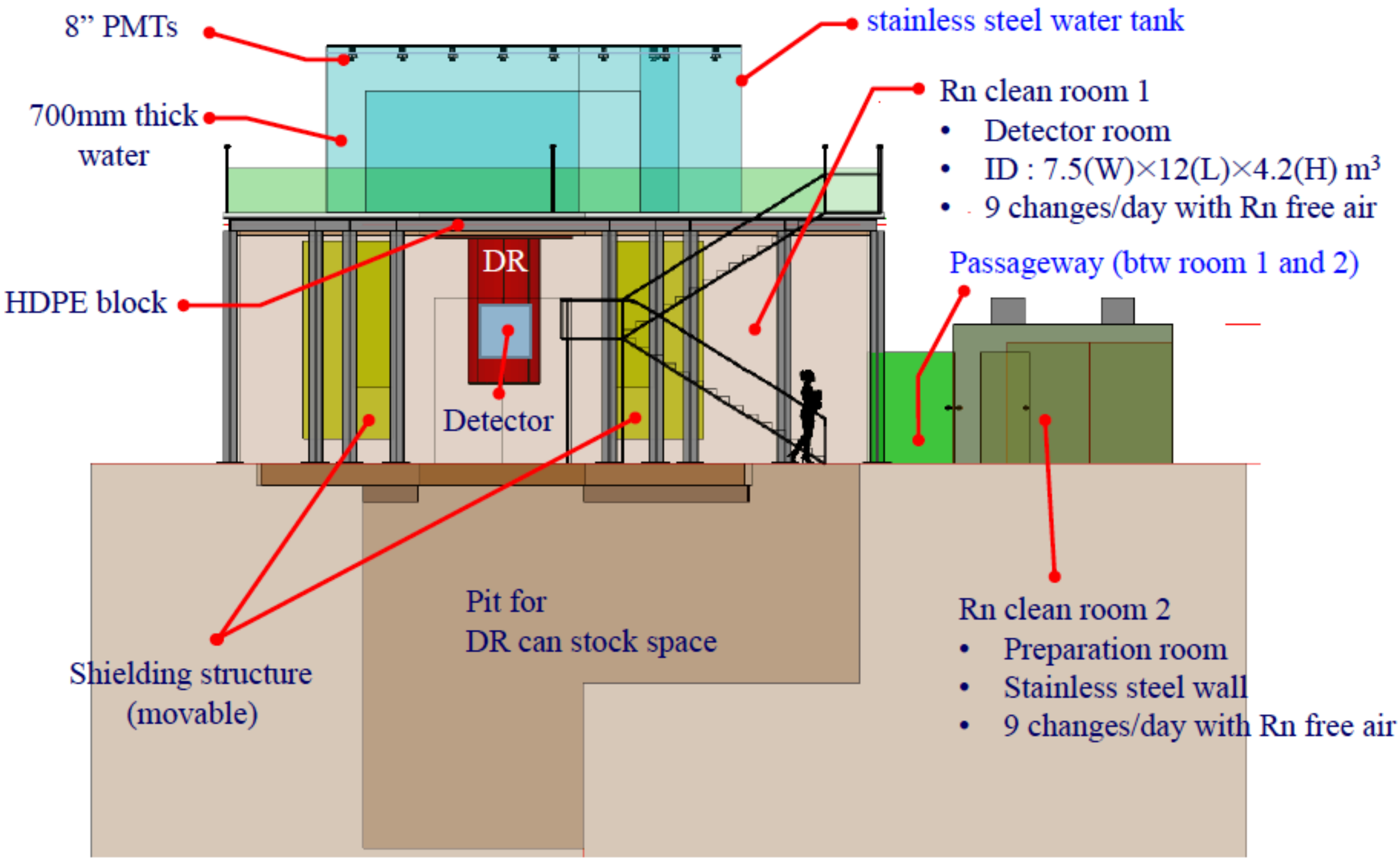
Jeongseon, Korea
1000 m vertical depth
Underground lab with $2600\ m^2$
Open in October this year!

Current view of AMoRE Hall



Dust proof door
Radon free air to the detector room during the assembly work
Cleanness : Hall (100K), Detector room(10K), Preparation room(100)

Detector room

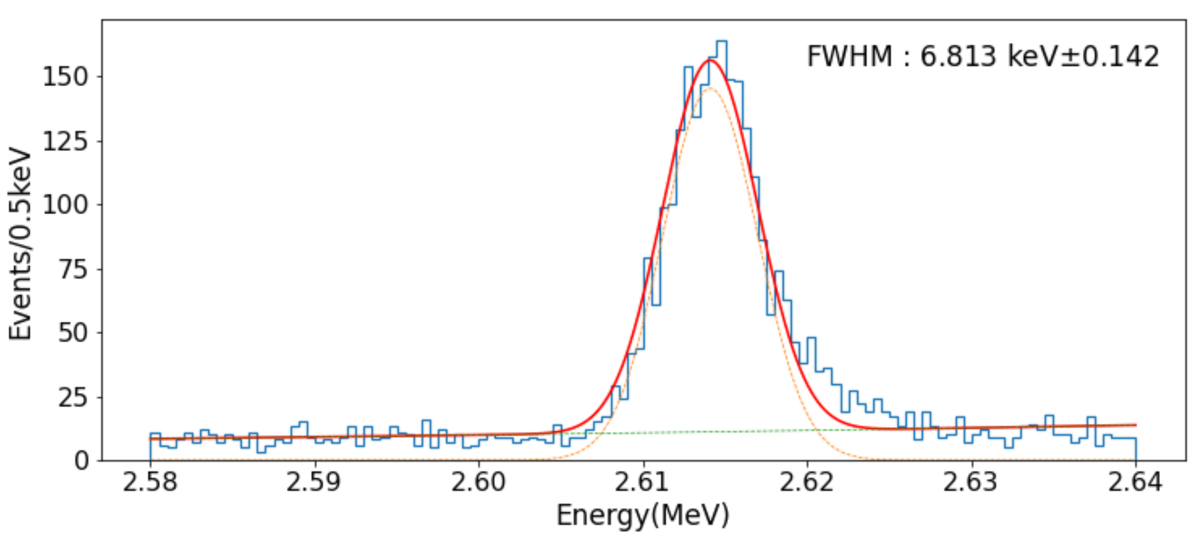


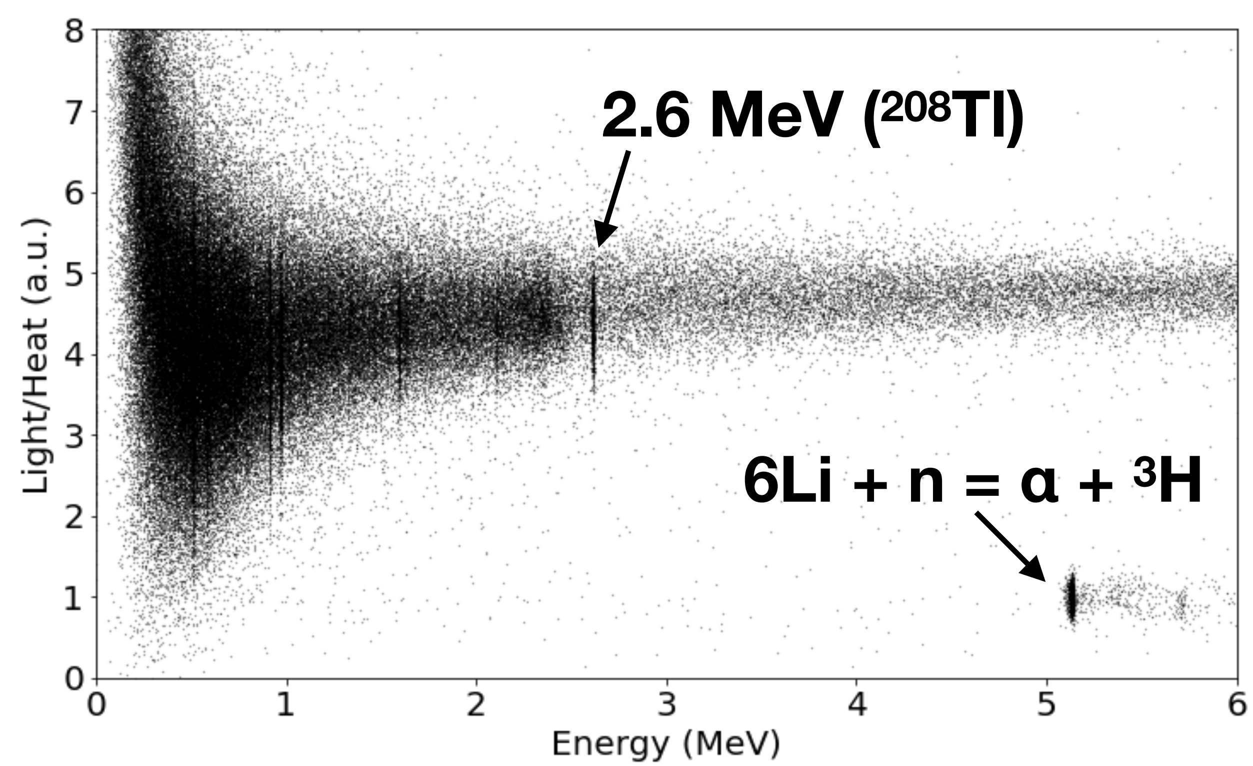
Detector R&D for AMoRE-II

Optimization : Performance, A lot of detectors in time

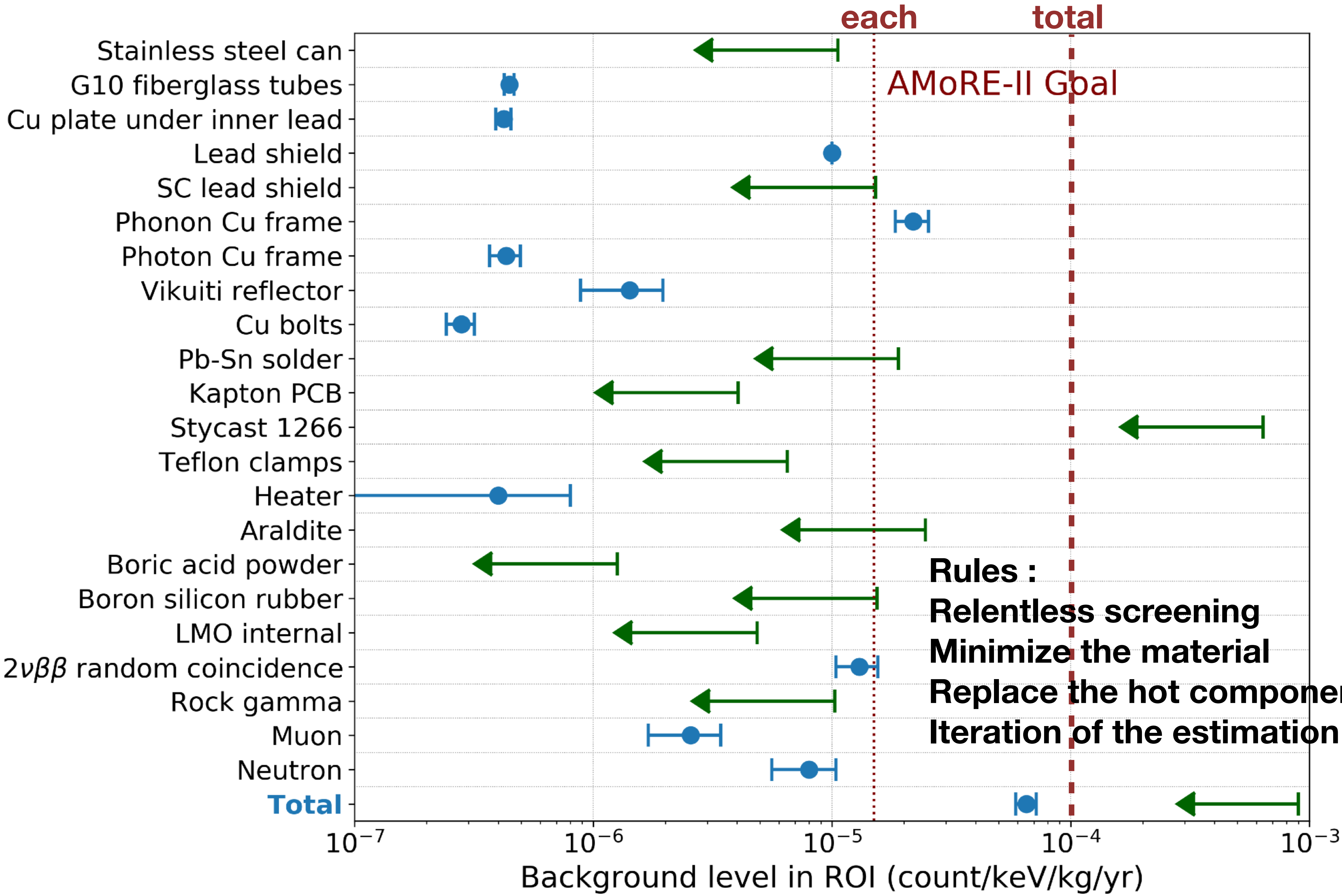
Mainly, LMO :
humidity, large crystal, surface treatment, thermal connection …

Currently, demonstrating :
=> FWHM < 7 keV at 2.6 MeV with a crystal of 516 g
=> DP = 14 at 5-6 MeV by light/heat ratio (~10 at ROI)



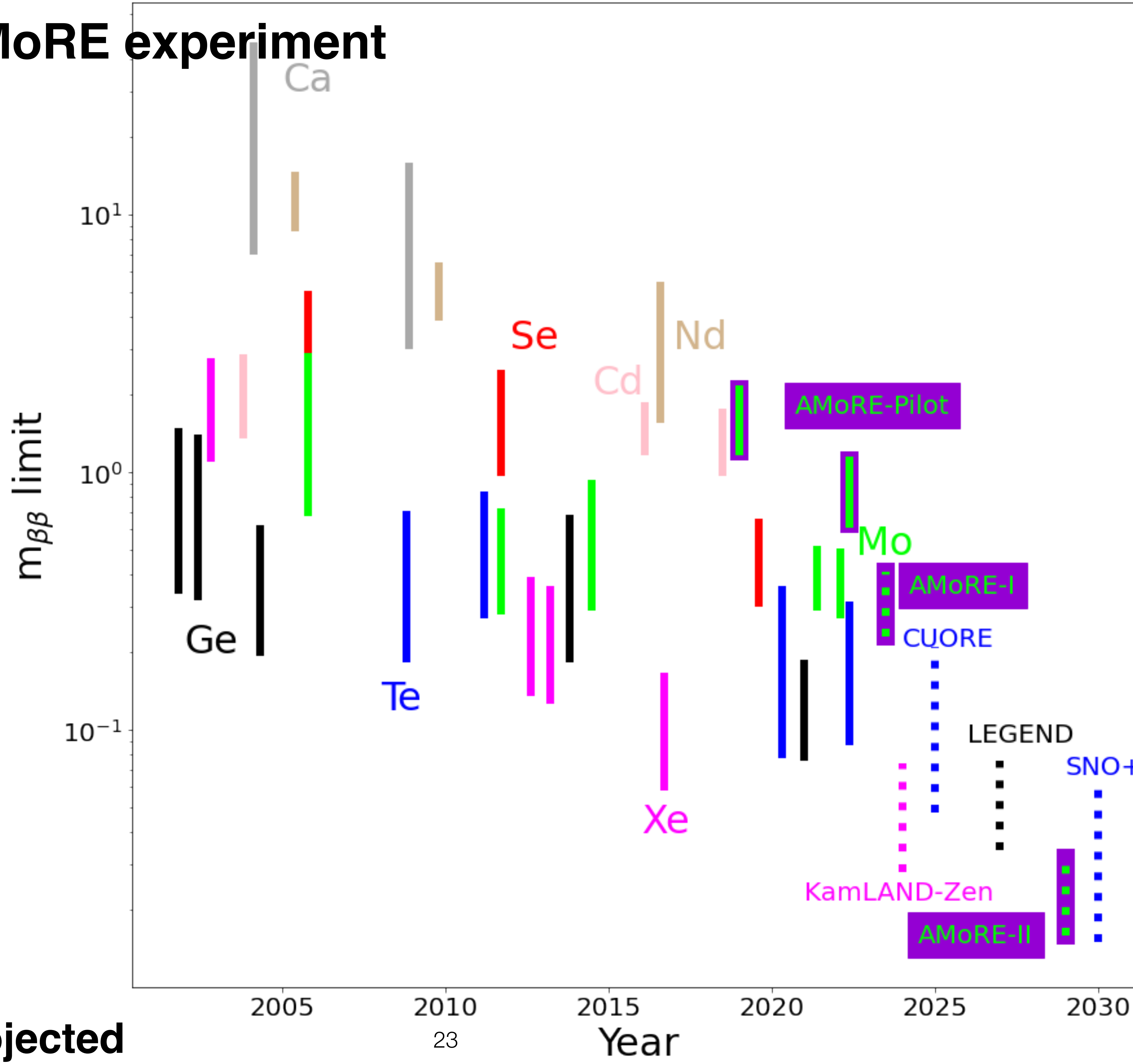


Expectation of AMoRE-II Backgrounds



Rules :
Relentless screening
Minimize the material
Replace the hot component
Iteration of the estimation

Goal of AMoRE experiment



- - - - - **Projected**

Conclusion

Search for 0vββ from ^{100}Mo using CMO/LMO crystals

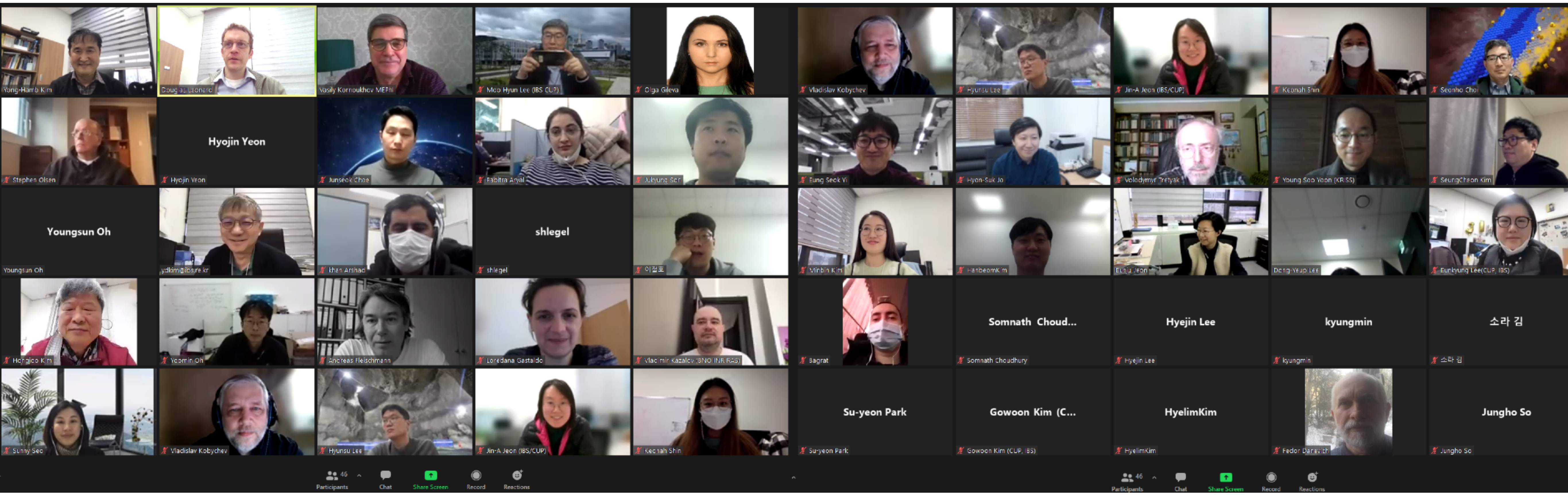
Cryogenic calorimeter with simultaneous light detection using MMC

AMoRE-pilot demonstrated the potential for 0vββ probe
=> $T^{0\nu}_{1/2} > 3.4 \times 10^{23}\mathrm{yrs}$, 90% C.I. with the exposure of 0.68 kg yr
=> Opportunity to identify background in ROI

AMoRE-I experiment is currently running with 6.2 kg detector mass
=> Reaching 5 kg yr, Bkg level < 0.06 ckky
=> Expecting competitive sensitivity as other ^{100}Mo based search

Preparing for AMoRE-II with 100 kg of ^{100}Mo
=> Built in two phases, Early phase start at the end of this year
=> R&D improvement : FWHM@2.6MeV <7 keV, DP@5-6MeV = 14
=> New experimental hall at Yemilab, Better material screening
=> Aiming at $T^{0\nu}_{1/2} > 10^{27}\mathrm{yrs}$ by 2030

Acknowledgement :
AMoRE collaboration



~107 members, 25 institutes, 9 countries

Back up