Cryogenic Underground TEst facility

Queen's University

CUTE, an underground test cryogenic facility, a step for SuperCDMS at SNOLAB

- Introduction
- SuperCDMS at SNOLAB
- The CUTE facility
- Short status on scintillating bolometers performances from CRESST and LUMINEU
- Outlook

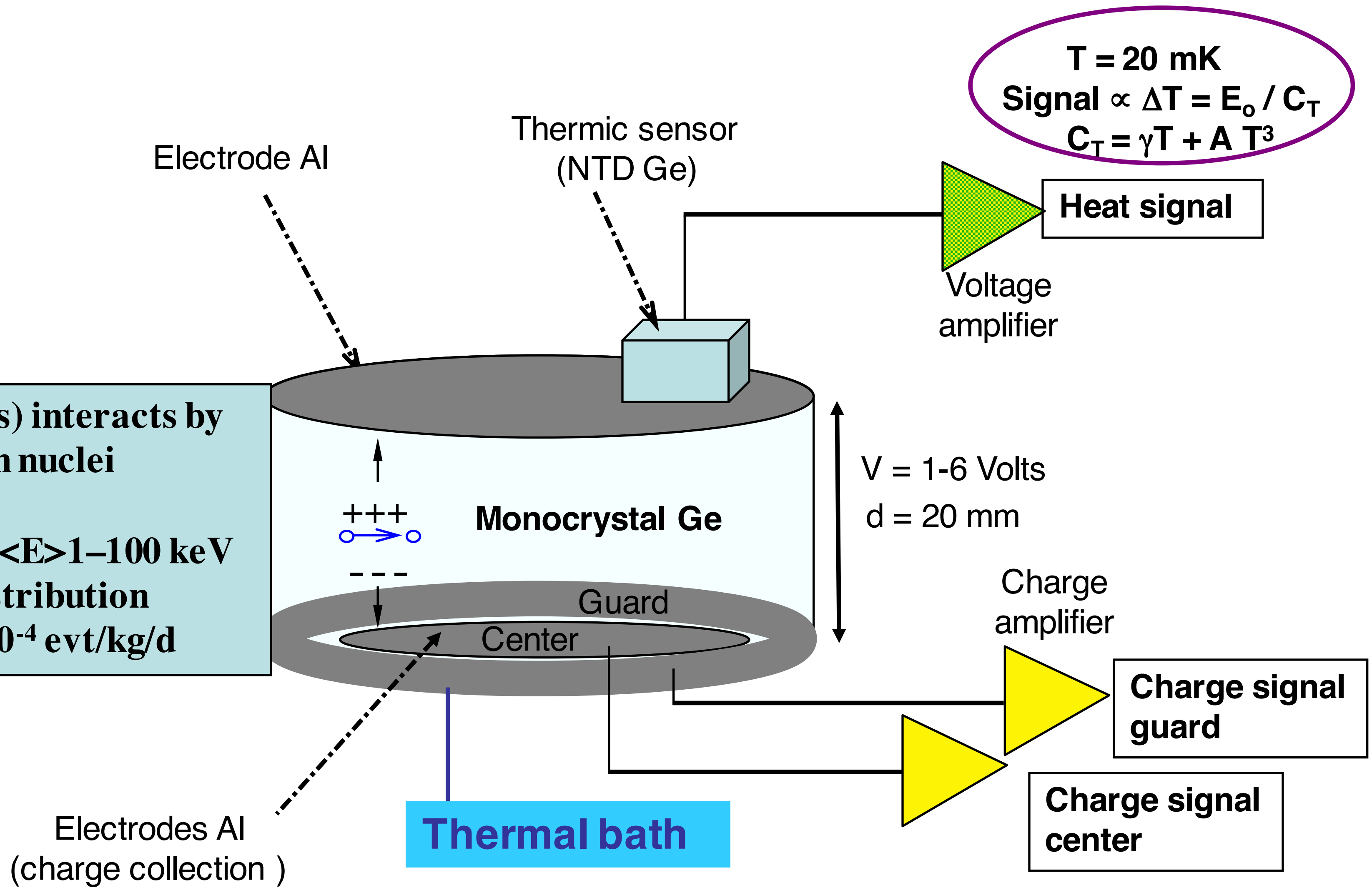
Gilles Gerbier
Queen's University
EDU 2017
Qui Nhon-ICISE– July 27th 2017

Canada Excellence Research Chairs
Chaires d'excellence en recherche du Canada

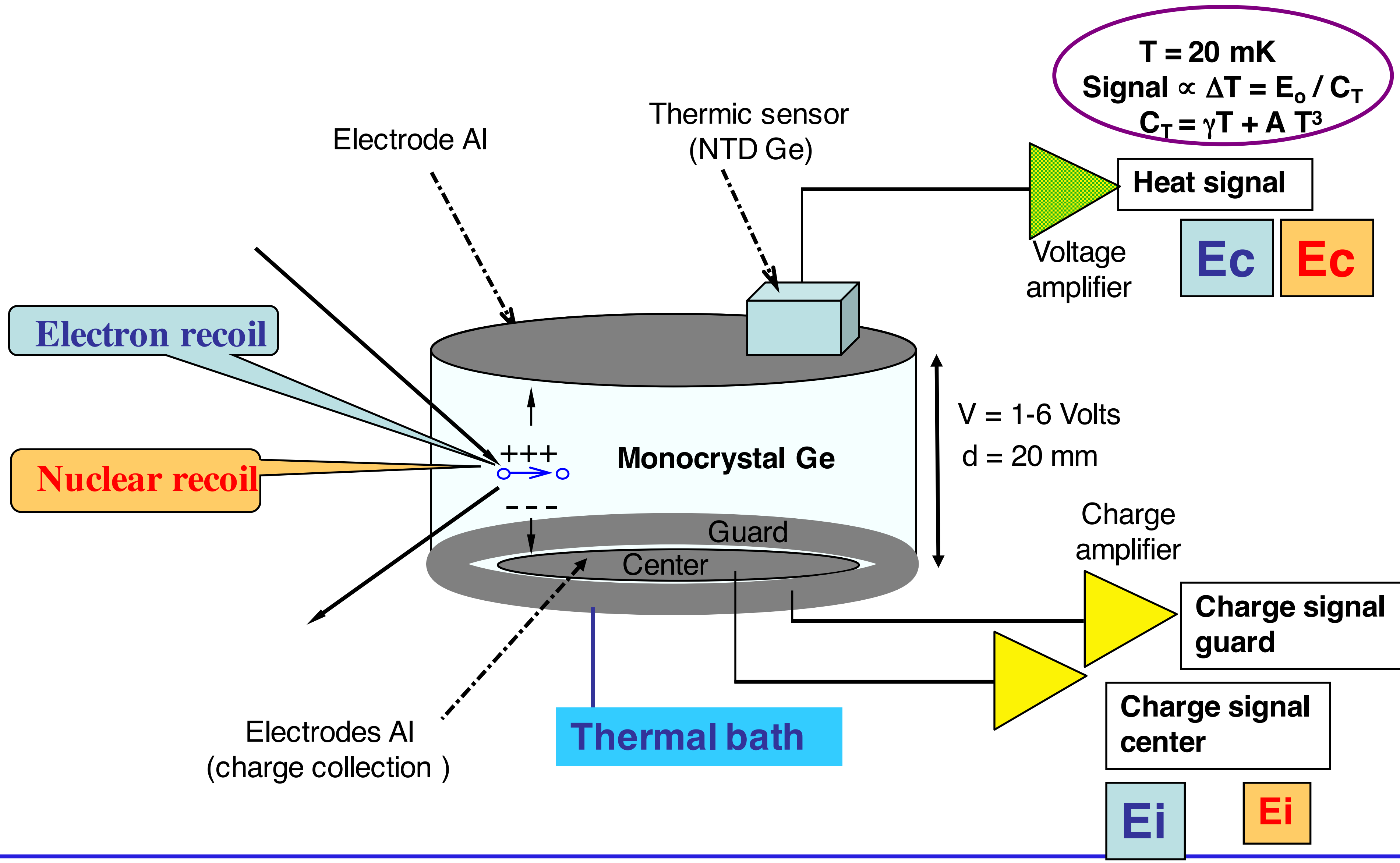
Ionisation-heat (phonon) detectors

WIMP (~ 200 km/s) interacts by <u>elastic diffusion</u> on nuclei

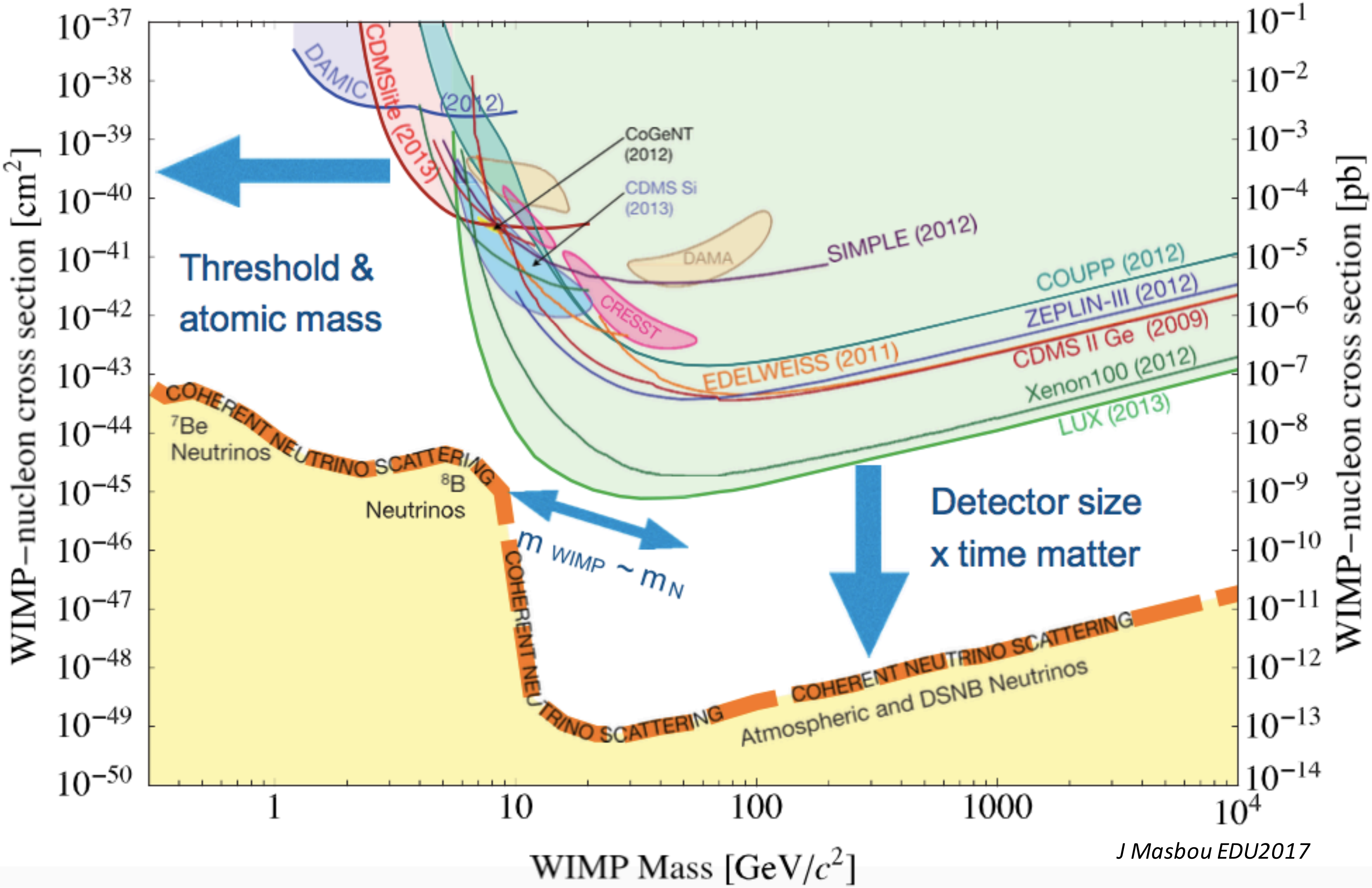
=>Nuclear recoil <E>1–100 keV
=>Exponential distribution
=>Low rate 1-1.10^{-4} evt/kg/d



Ionisation-heat (phonon) detectors

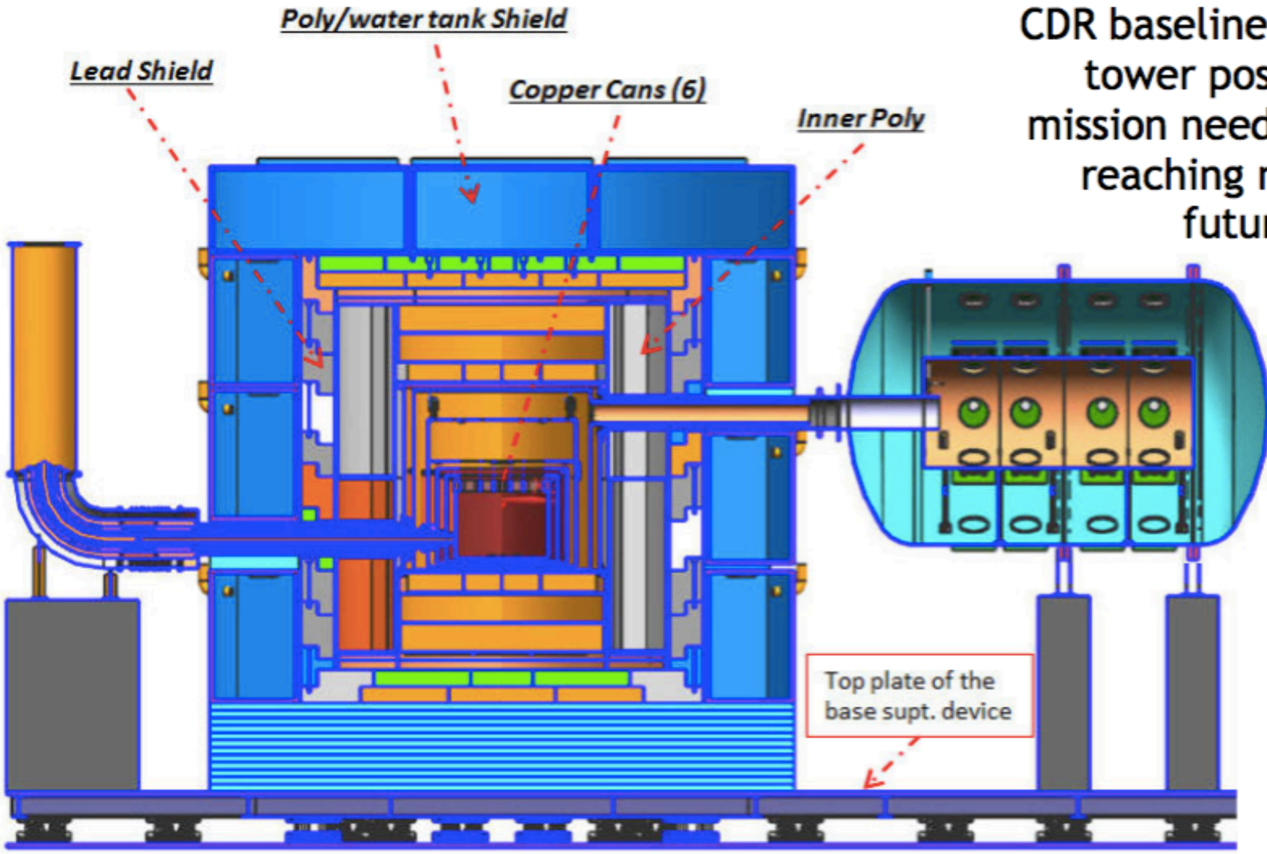


Reminder of situation

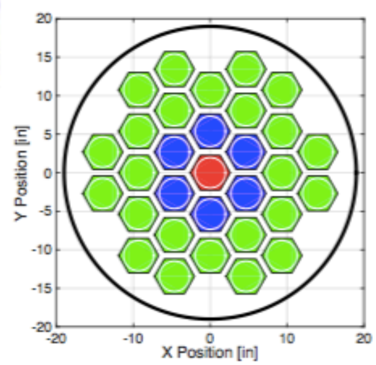


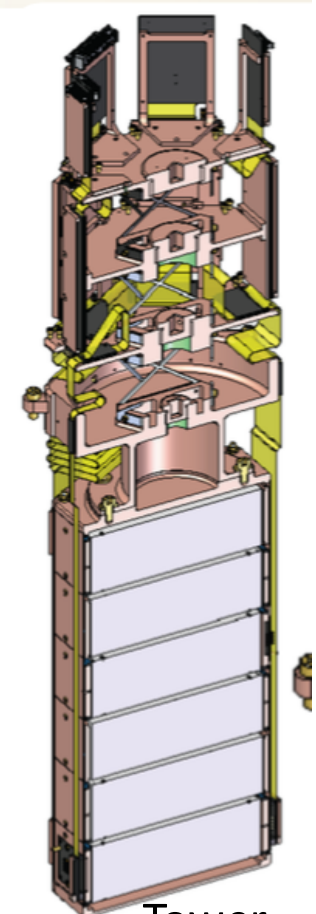
J Masbou EDU2017

SuperCDMS SNOLAB in one slide
Detectors units : "towers"



- CDR baseline design contains 31 tower positions, fulfilling mission need with capability of reaching neutrino floor in future upgrade

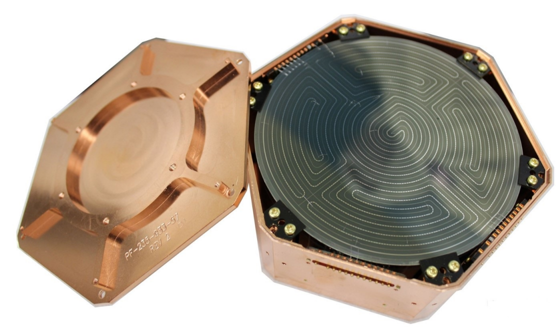




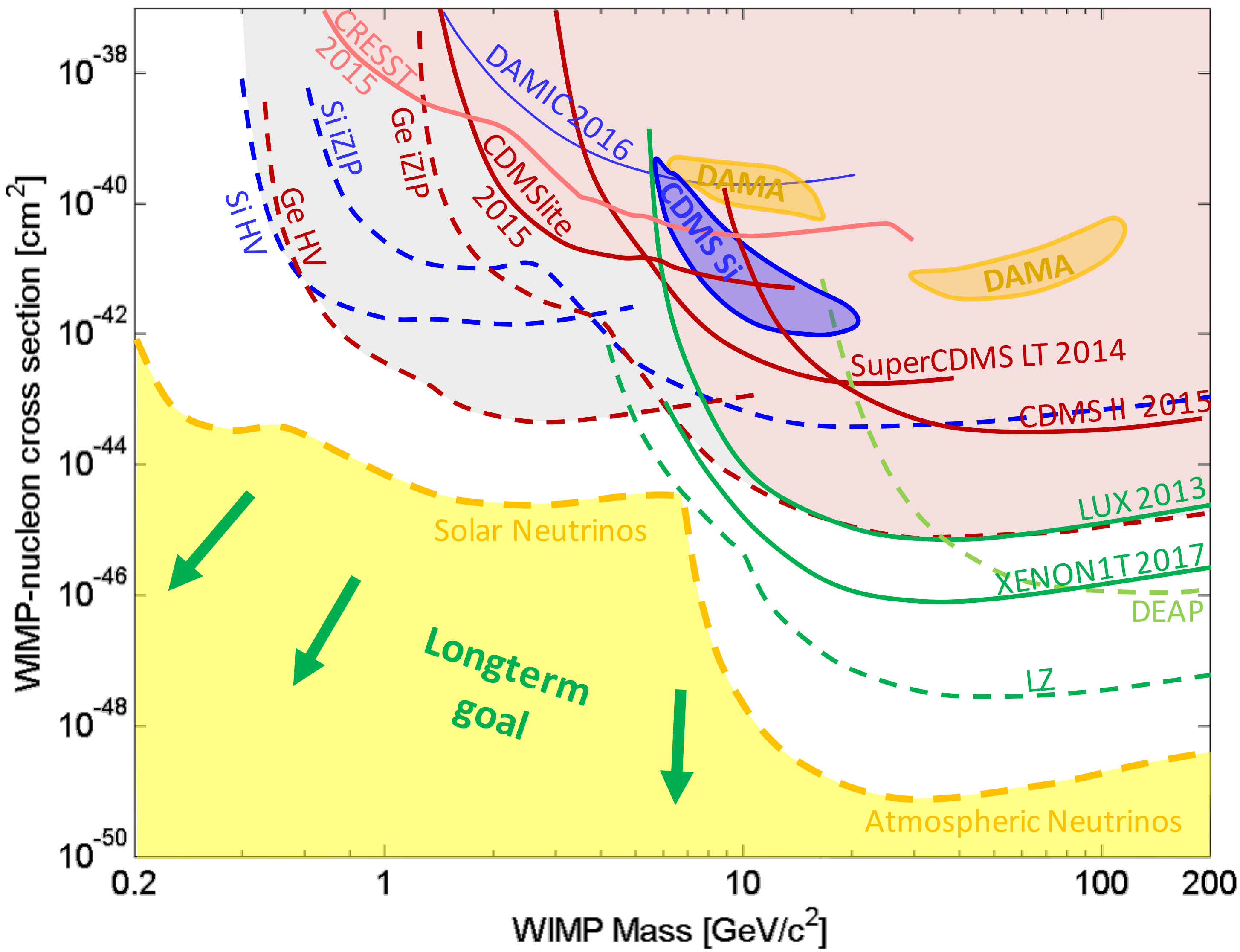
Tower

Large duty cycle : month

Detector
1 kg Germanium

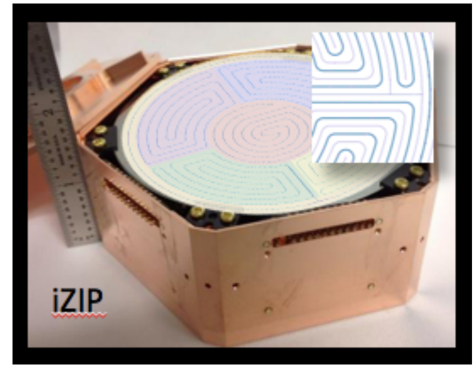


Expected sensitivity of SuperCDMS @ SNOLAB

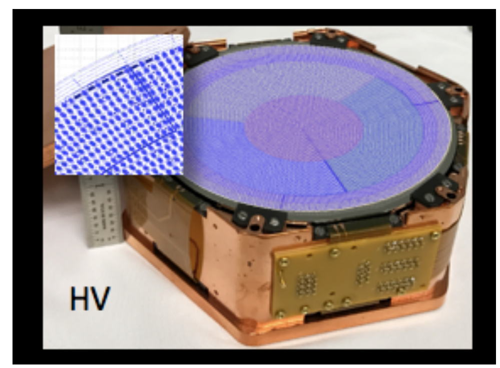


arXiv:1610.00006

"iZIP" detectors
Higher threshold
Discrimination



"HV" detectors
Low threshold
No discrimination



Luke-Neganov effect in CDMSLite -2: use phonons to read charge

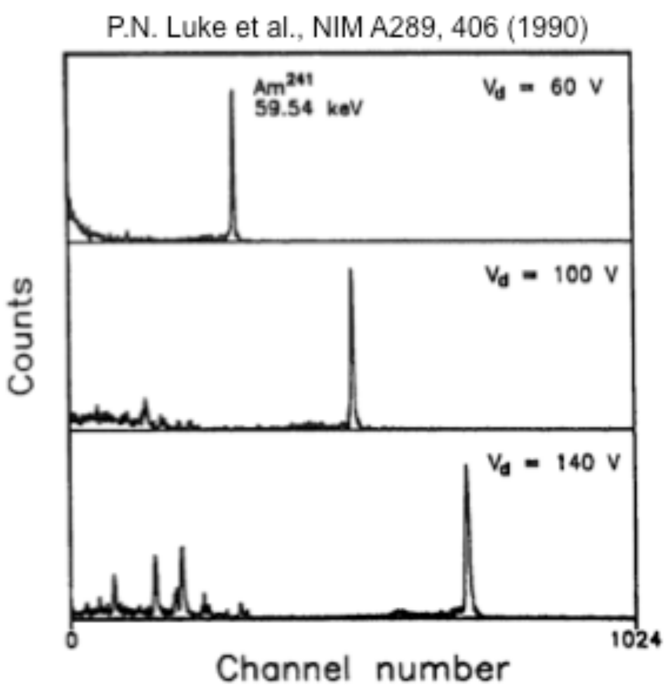
- Bias a standard SuperCDMS 600 g iZIP detector at 69 V (rather than 4 V)
- Phonon amplification proportional to charge, bias voltage

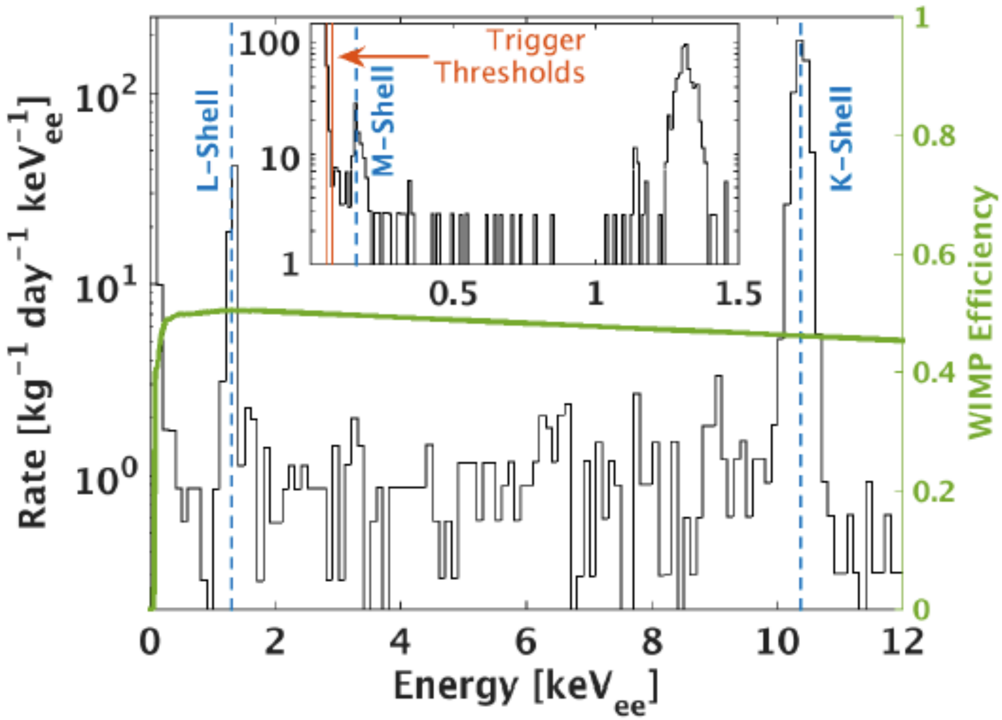
Single detector : exposure 70 kg.d

Threshold : 75 eVee = 350 eVNR on Ge

Loss of background discrimination

BG diluted with respect to signal

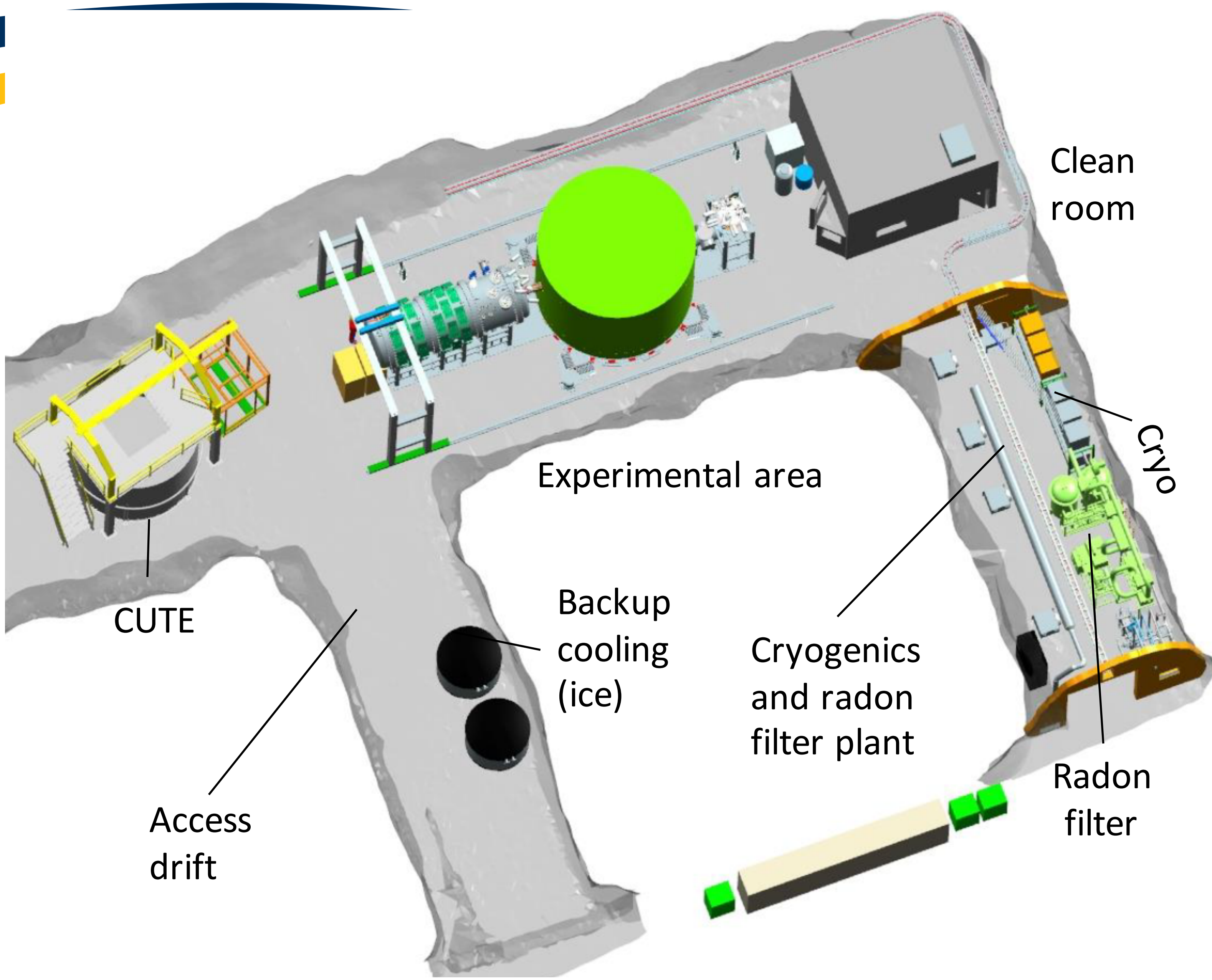




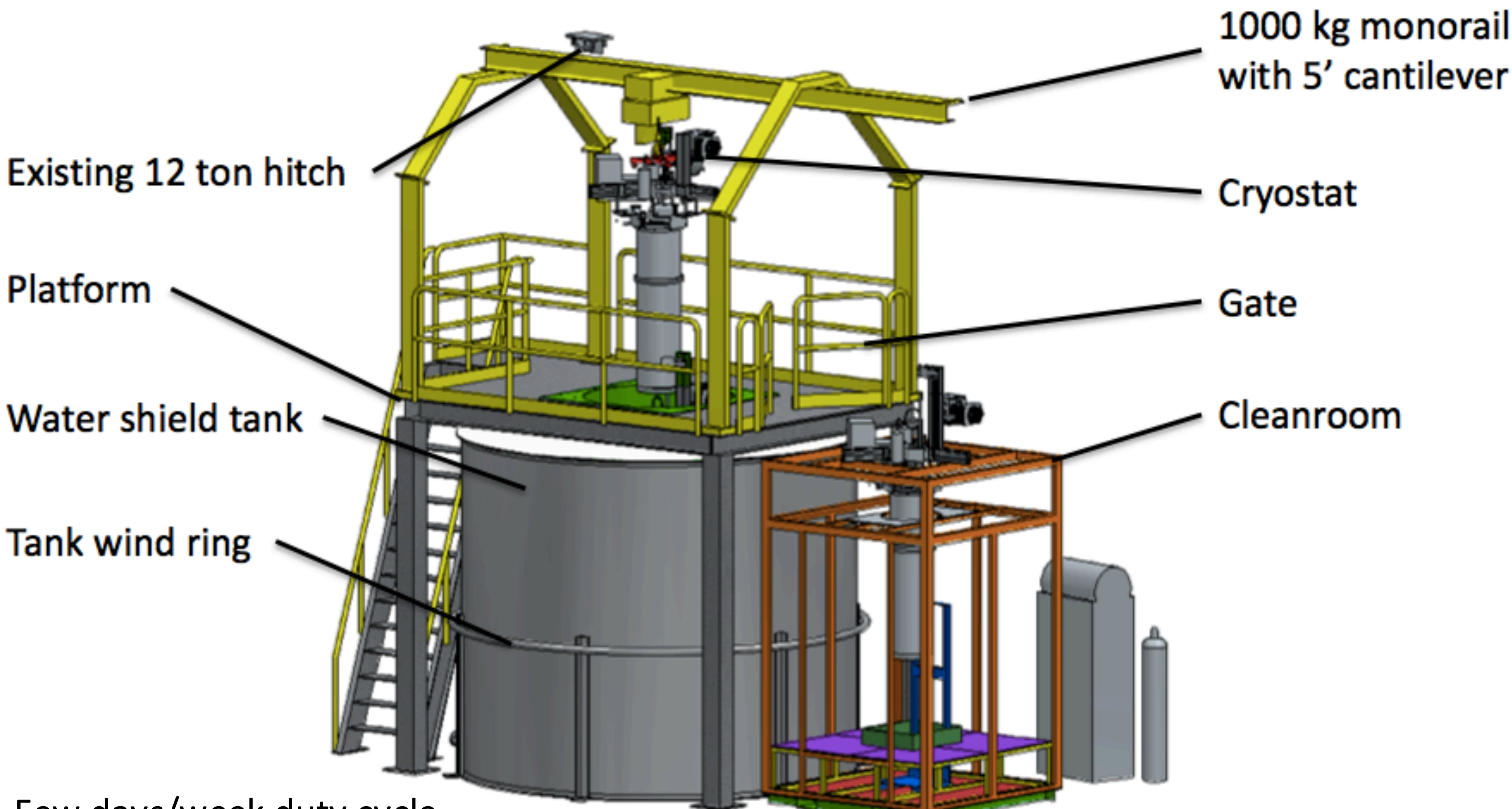
Scope of CUTE

- Goal : provide handy low activity test facility for "tower" type detector unit
- Motivations
  - SuperCDMS detector performance and background studies
    - Detector integrity after transportation
    - Background discrimination
    - Noise performance (impact of background)
    - Confirm screening program and handling procedures
    - Study cosmogenic backgrounds (3H, 32Si)
  - Opportunity for early science ! (BG $\mathcal{O}$ (few evt/keV/kg/d below 10 keV)
  - Available for testing of other cryogenic detectors for rare event searches (e.g. EURECA detectors for integration with SuperCDMS)
- Proponents of CUTE = Queen's (Kingston/Canada) team
  - GG, Wolfgang Rau, Philippe Camus
  - Mostly based on CERC funding

Implementation at SNOLAB



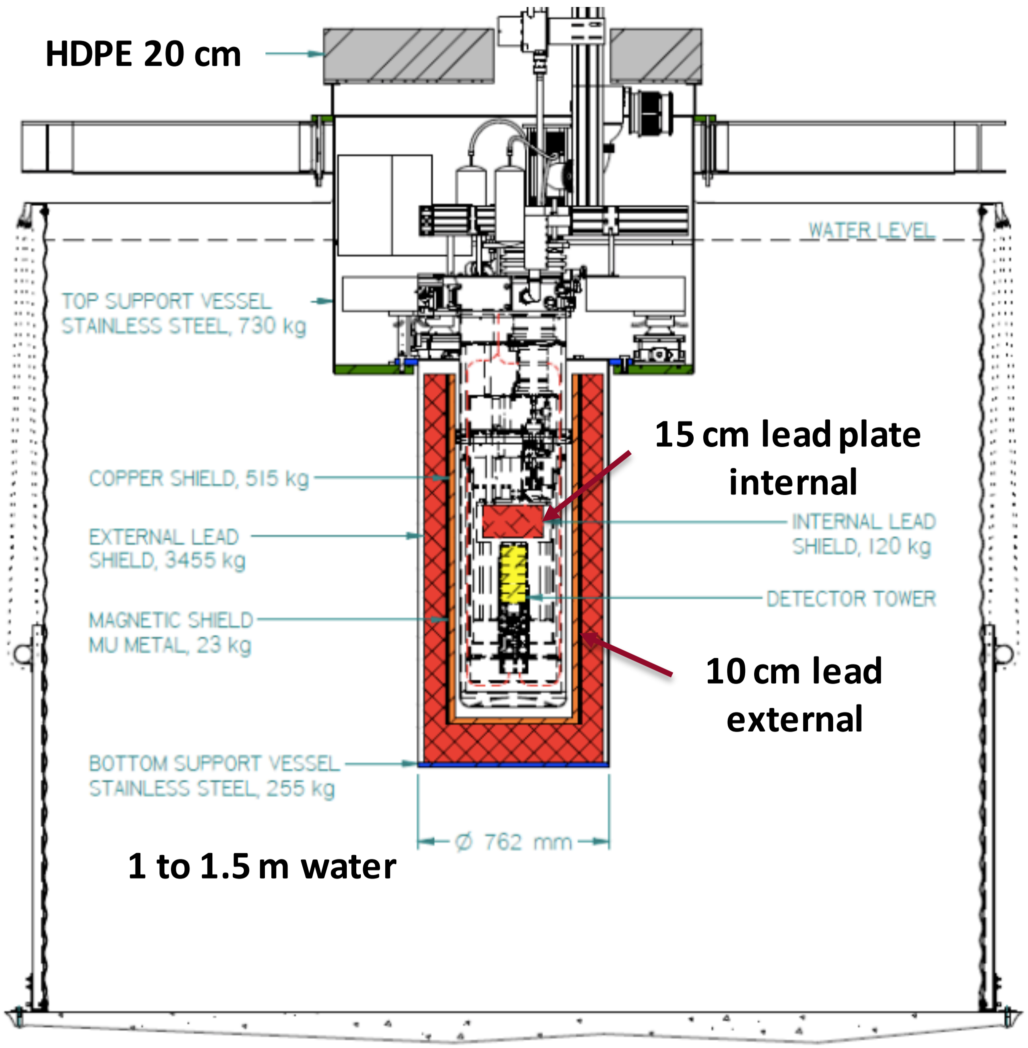
Cute set-up



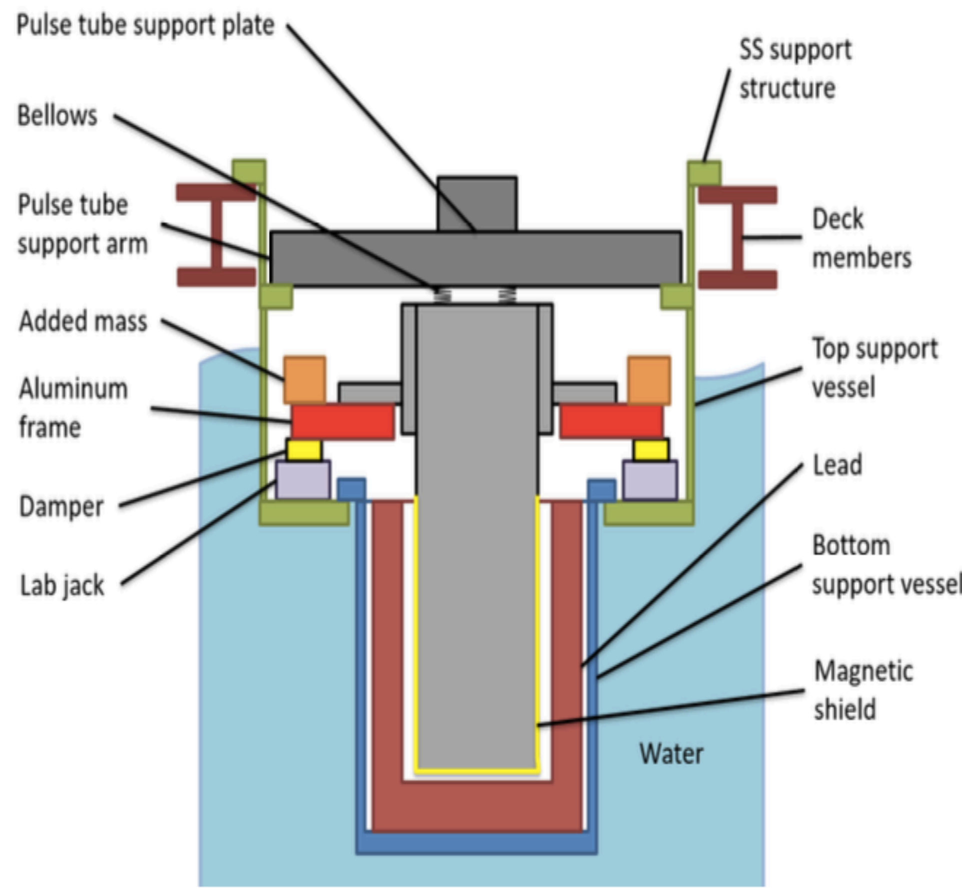
Few days/week duty cycle

Cute shields and vibration isolations

"Dry" dilution refrigeratot (Pulse tube)
Pb/water/PE shields



Double system for vibration decoupling of cryostat from Pulse tube and from environment



Background budget in first keV's

Source	Material	Radionuclides	*dru* (0-1 keV)
Cryostat inner shields	Copper CuC2	U/Th, ^{60}Co	0.10
Brazing	AgSn	^{210}Pb	0.25
Cryostat vacuum can	S/S 316L	U/Th, ^{60}Co	0.58
Lead shield (int.)	Low Act. Lead	U/Th, ^{210}Pb	0.10
Radon in air gap	Water	^{222}Rn	0.04
Lead shield (ext.)	Low Act. Lead	U/Th, ^{210}Pb	0.65
Radon in water	Surface air	^{222}Rn	0.05
External environment	Cavern walls	^{208}Ti, ^{40}K, n	1.10
TOTAL			**2.82**

Table 1: Facility main contributions to the background in Ge detectors

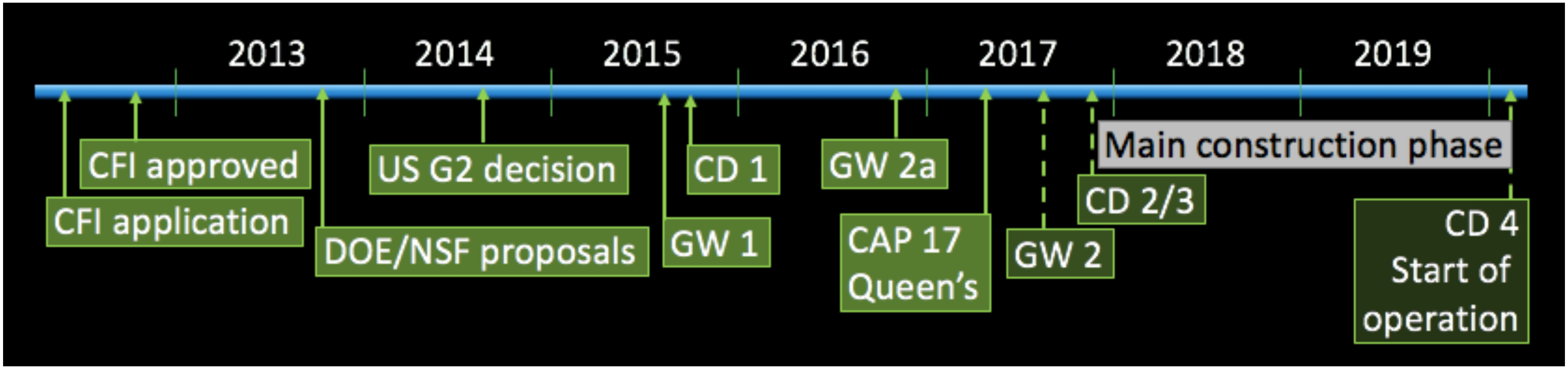
dru = evts/keV.kg.d

NB : benchmarks

- residual rate in CDMS lite 2 spectrum at threshold = 7 dru
- rate due to Tritium from cosmogenics in SuperCDMS = 0.1 dru

Schedules

SuperCDMS



2020

CUTE

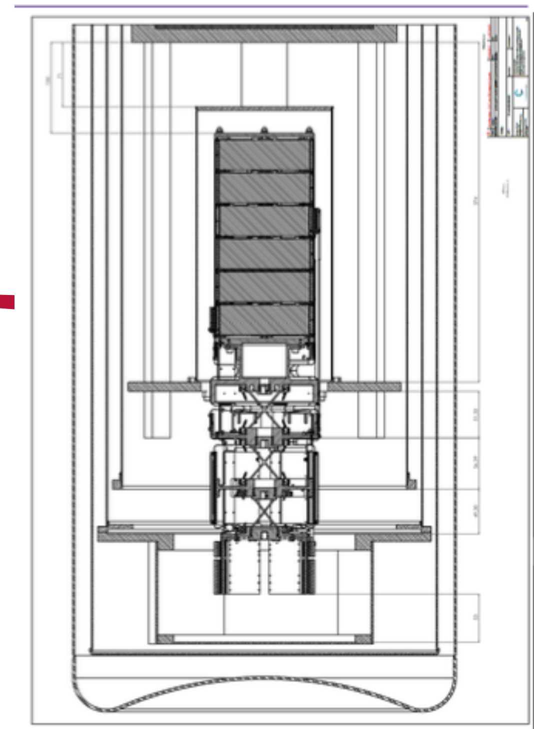
oct 2017 : delivery of refrigerator at Queen's

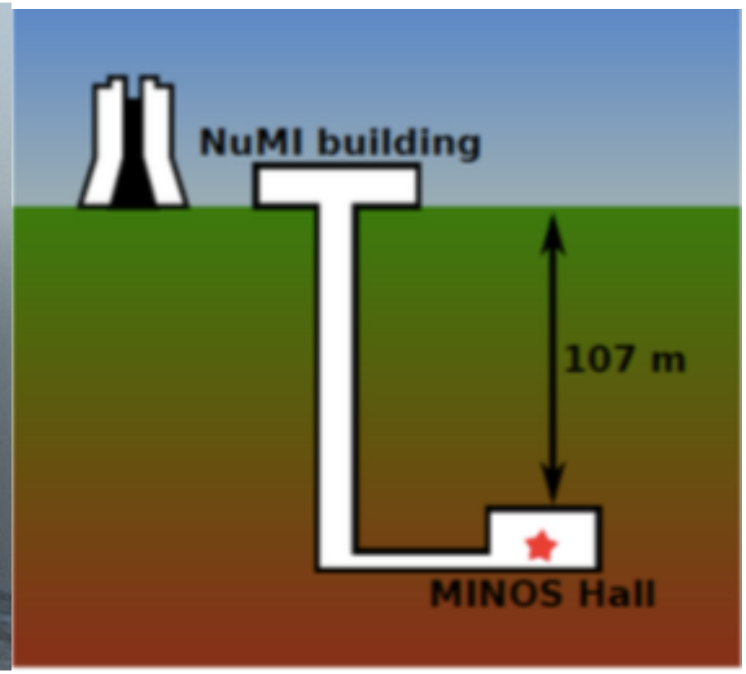
dec17-jan18 : delivery and installation of all systems at SNOLAB

march-june 2018 : commissioning

NEXUS

- NEXUS @ Fermilab : similar set up as CUTE
- "Tower" compatible
- Operated by E Figueroa et al. at Northwestern (Chicago)
- Same base cryostat
- Backgrounds ~100 dru (evnt/keV/kg/day)
- Designed for preliminary tests





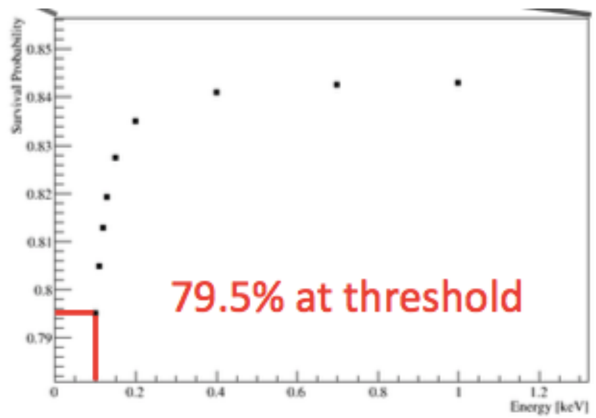
Some illustrations of cryogenic detectors performances

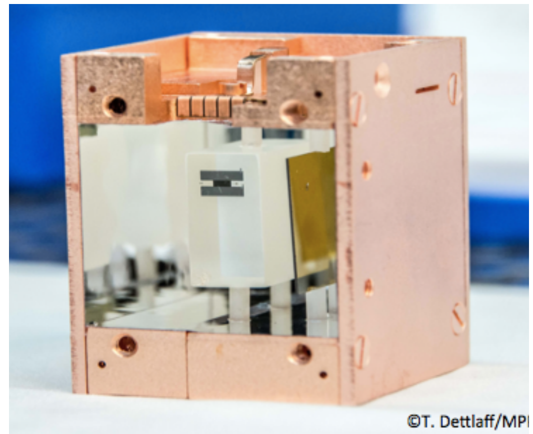
- CRESST : results shown @ TAUP, on behalf of F Petricca
- LUMINEU: recent results on behalf of A Giuliani

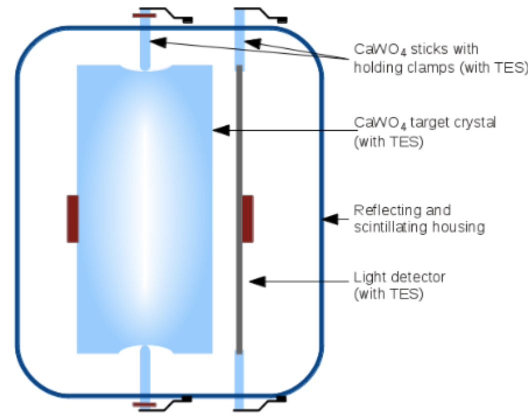
CRESST

Detector A — Scintillating $CaWO_4$ crystals as target

Analysis started (of course) from detector A

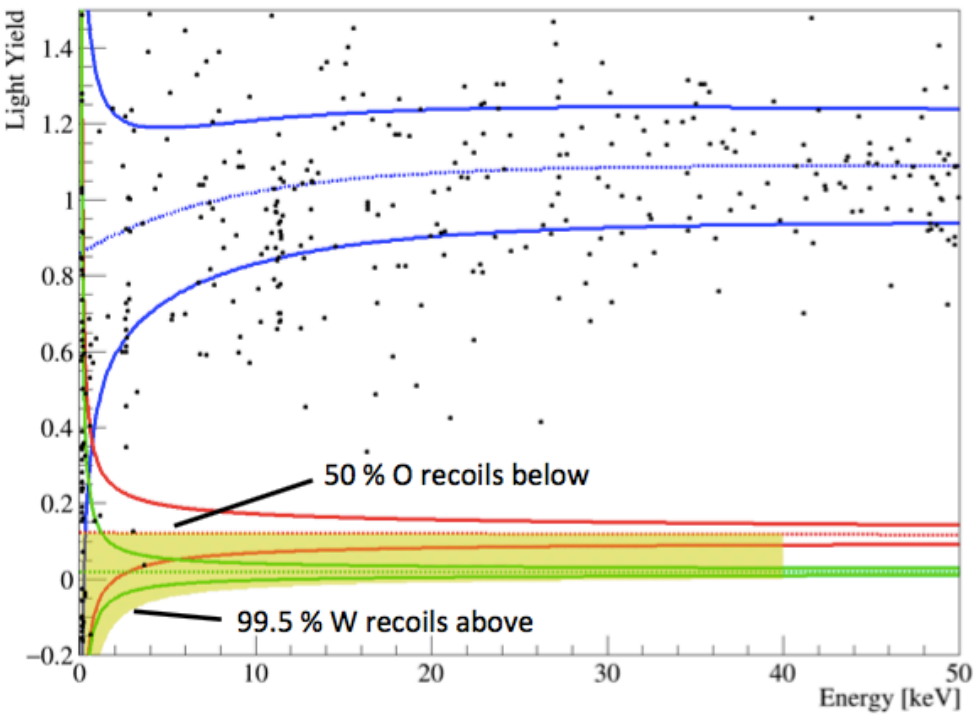




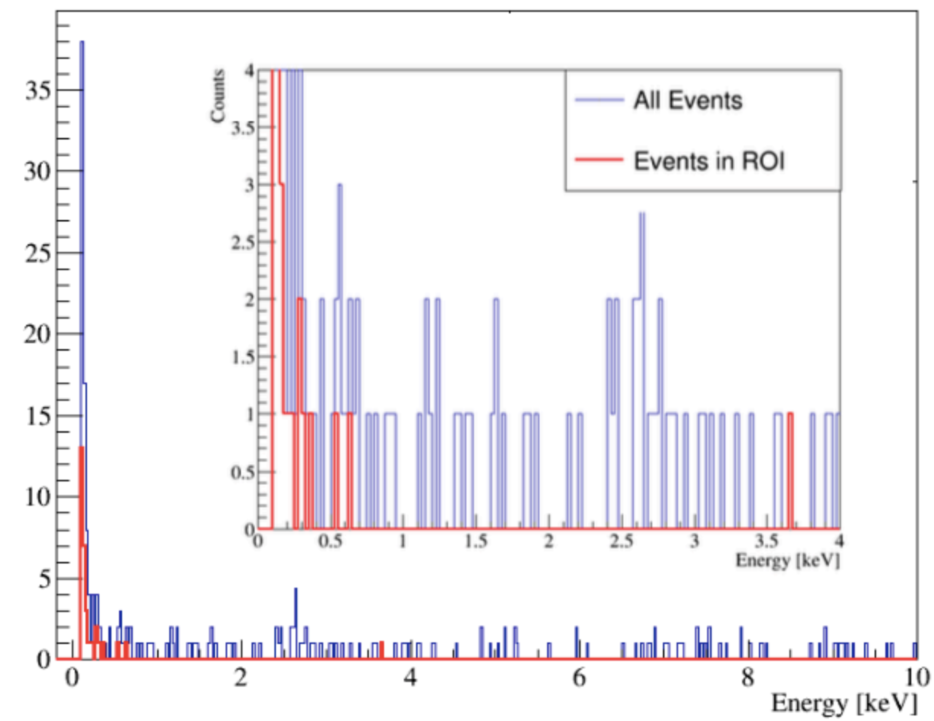


Data taking period:	31.10.16 - 05.07.17
Non blind data (dynamically growing):	20% randomly selected
Detector mass:	24g
Total exposure:	2.39 kg days
Net exposureafter rate/stability cut (control of operating point and noise conditions):	2.21 kg days
Analysis threshold:	100 eV

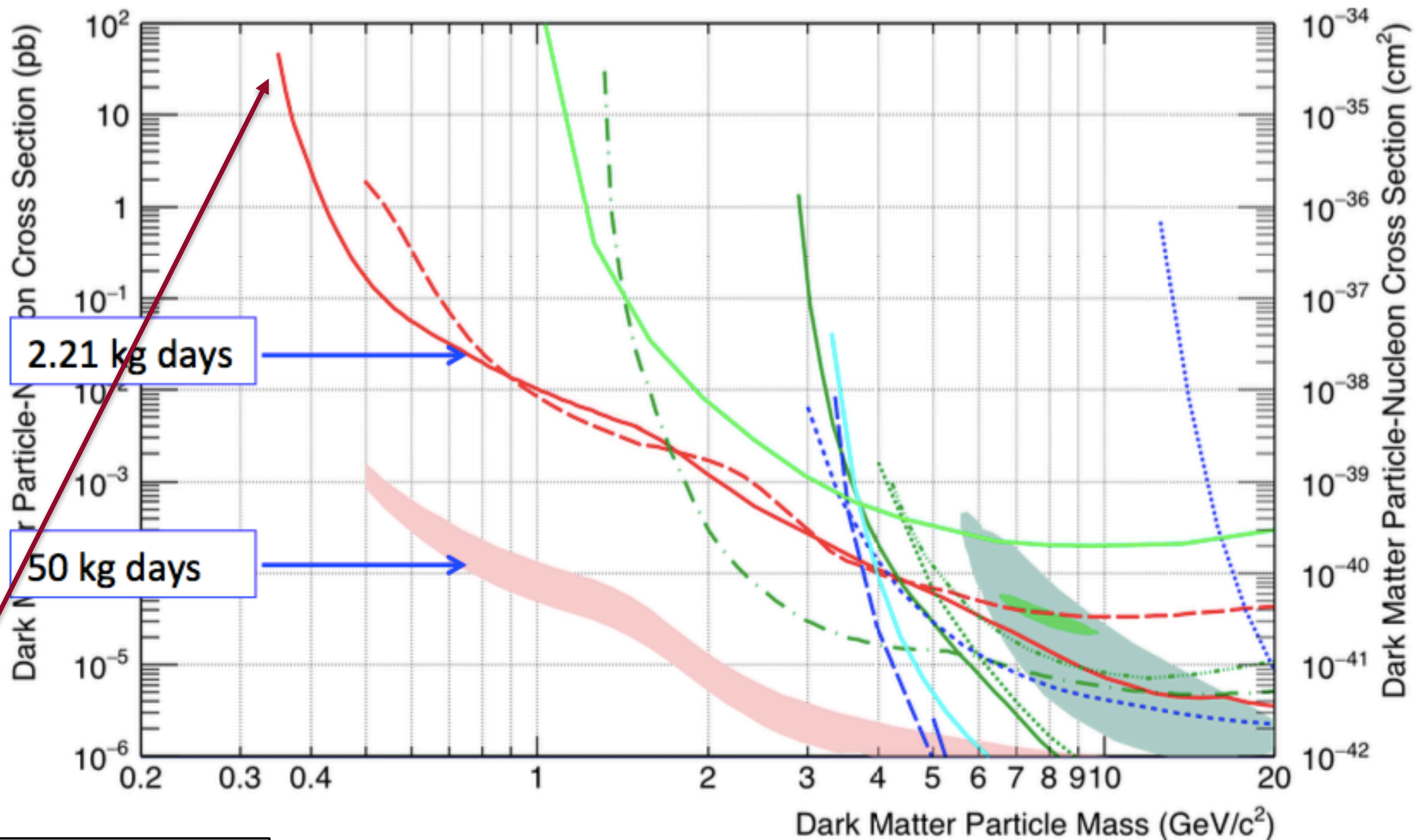
Spectrum of detector A



Zoom low energy



The exclusion limit - improvements



0.35 GeV lower bound
on WIMP Mass
but high backg level

3 times lower optimum threshold (than 100eV analysis threshold) for detector A

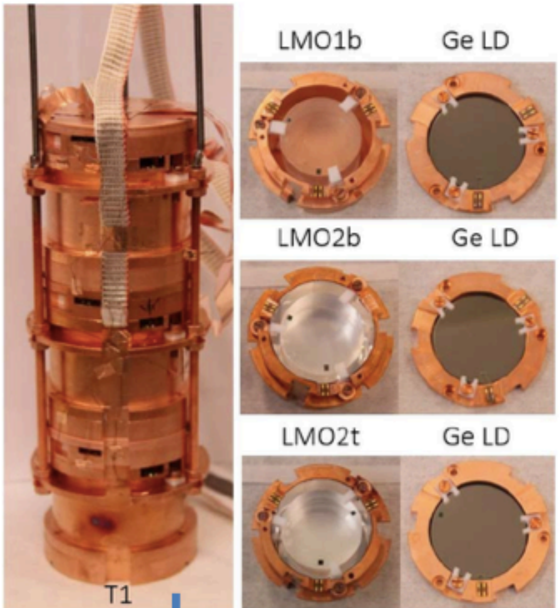
3 other detectors with thresholds << 100eV

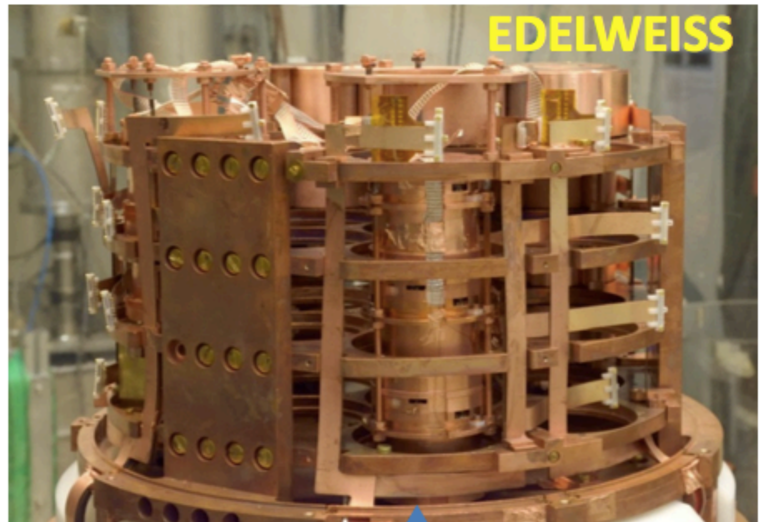
3 times more statistics → deeper understanding of backgrounds

Scintillating bolometers : LUMINEU

$Li_2{}^{100}MoO_4$ 210 g detector

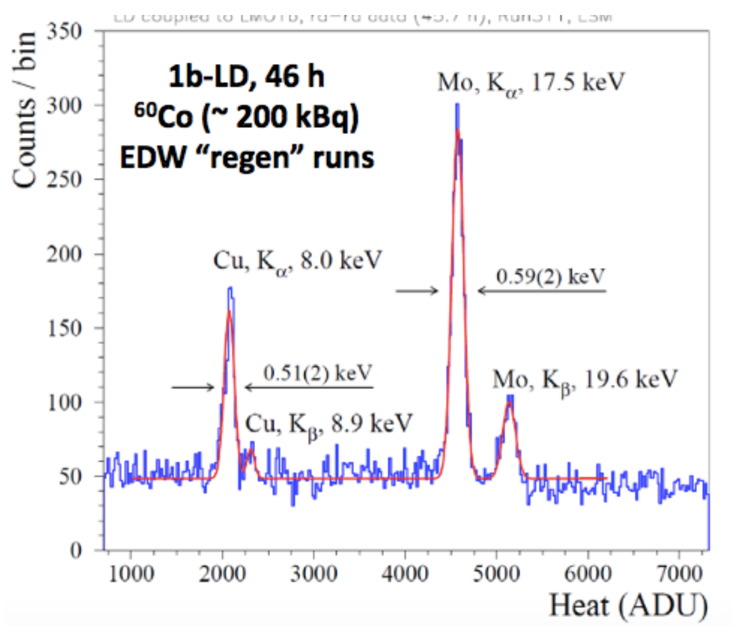
For double beta decay search

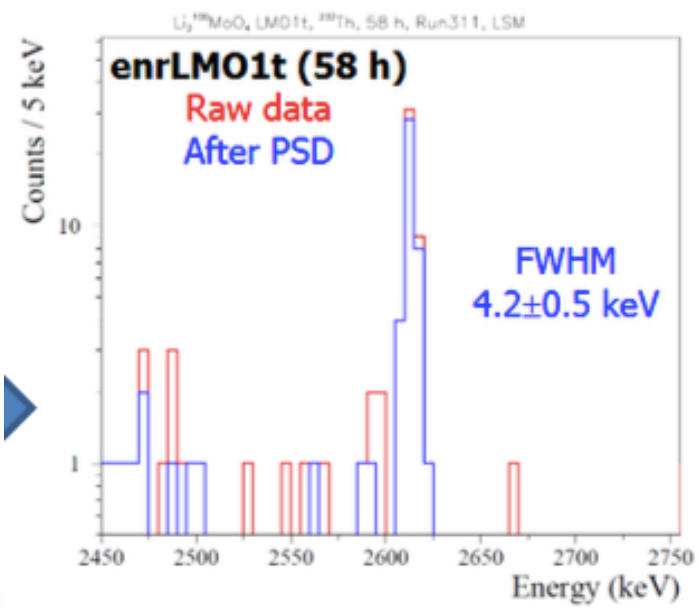




Light detector

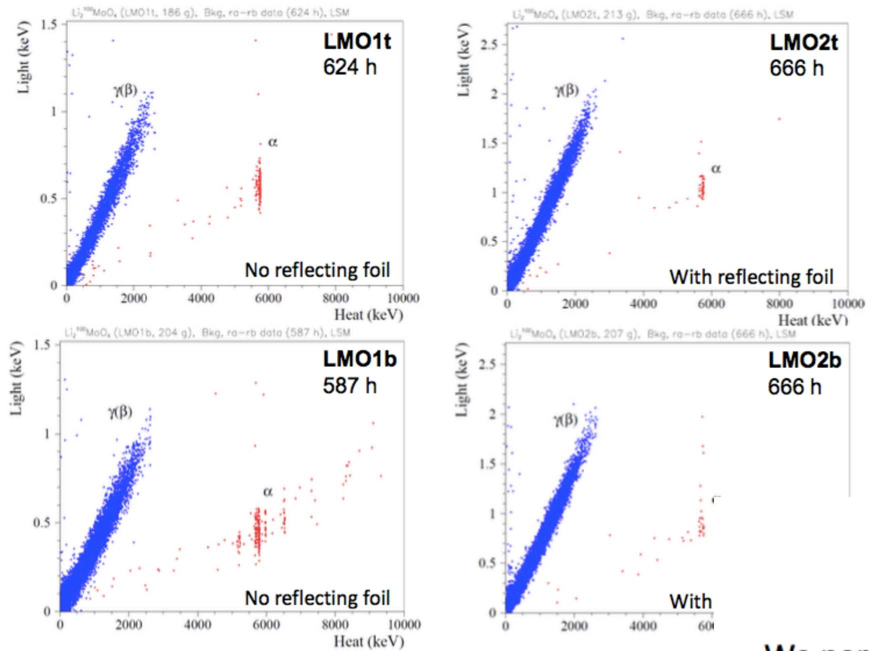
Absorber crystal





α rejection

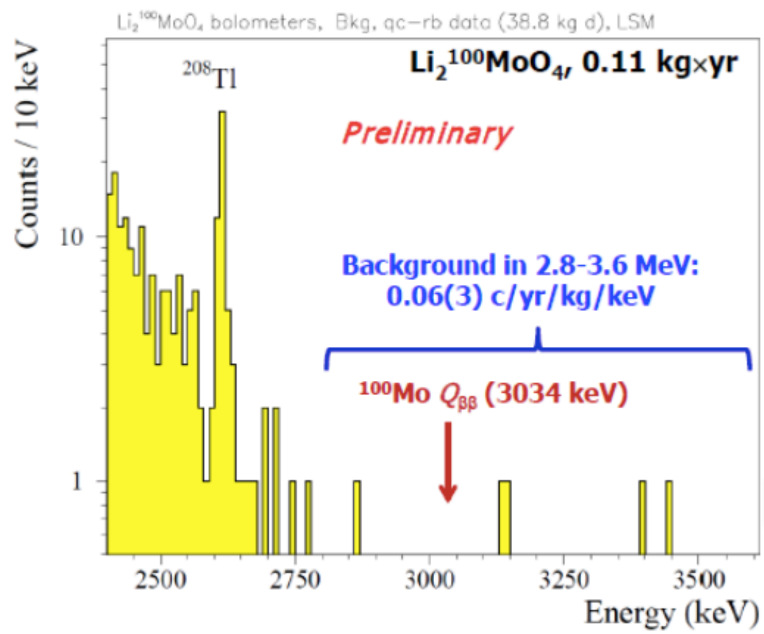
99.9% α rejection with > 99 % β acceptance



$Li_2{}^{100}MoO_4$

Investigation of ^{100}Mo 0ν2β decay

We performed 0ν2β search joining the two runs where enriched crystals were operated



Sensitivity to ^{100}Mo 0ν2β:

- $Q_{\beta\beta}$(^{100}Mo) = 3034 keV
- ROI = 10 keV window @ $Q_{\beta\beta}$
- $eff_{0\nu2\beta}$ = 73% in ROI
- eff_{PSD} = 97%
- Enrichment = 96.9% of ^{100}Mo
- Exposure = 39 kg×d
- BI: 0.06 cnts/yr/kg/keV
  ⇒ Bkg: 0.064 counts
- 90% CL sensitivity (by F.-C.):
  lim*S:* 2.49 counts

⇓

lim $T_{1/2}$ = 0.67x10^{23} y @ 90% C.L.

lim<$m_{\beta\beta}$> = 1.2-2.1 eV

NEMO-3 (34.3 kg×yr):
$T_{1/2} \geq 1.1 \times 10^{24}$ yr @ 90% CL
PRD 92 (2015) 072011

Outlook

- CUTE operational in 2018
- Will allow validation and first measurements of performance of SuperCDMS detectors
- Open to other new innovative cryogenic detectors requiring low activity environment
- Complementary set-ups : NEXUS/CUTE/SuperCDMS @ SNOLAB provide comprehensive progression for validation and operation of cryogenic (15 mK) detectors