Cosmogenic Backgrounds for ^{76}Ge 0νββ

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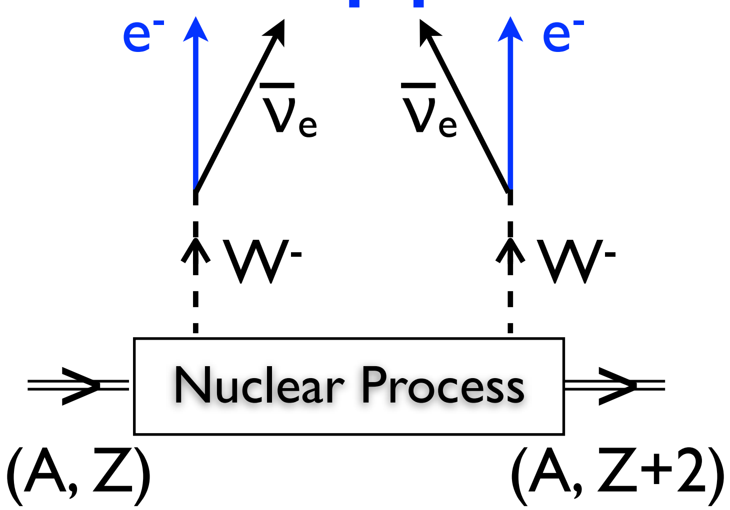
DUSEL AARM Collaboration Meeting

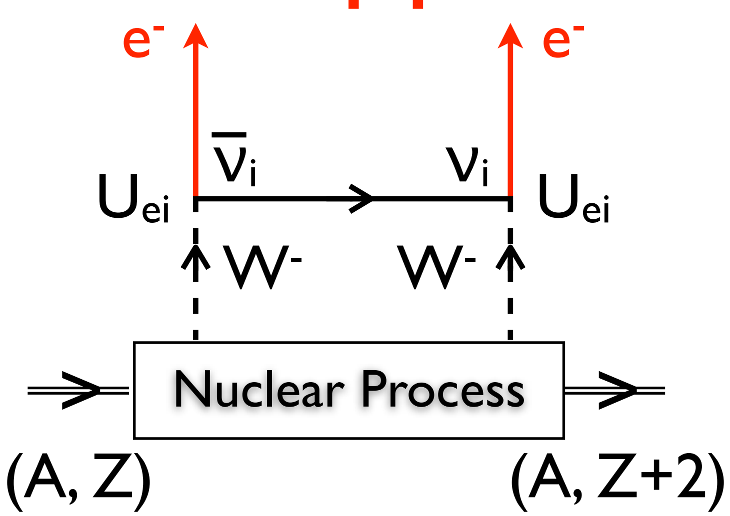
Minneapolis, MN, Feb 25, 2011

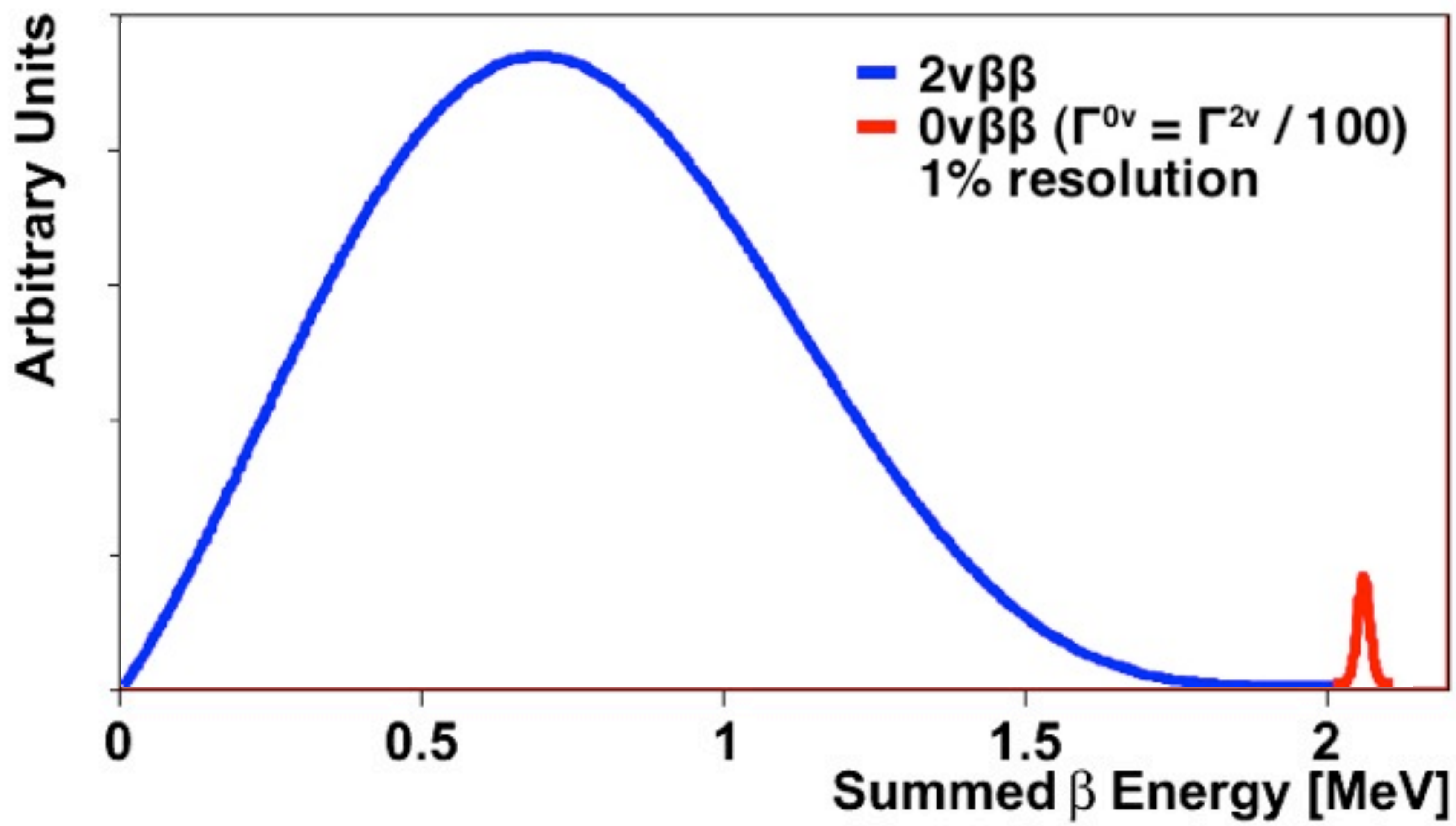
Double-Beta Decay

2νββ



0νββ



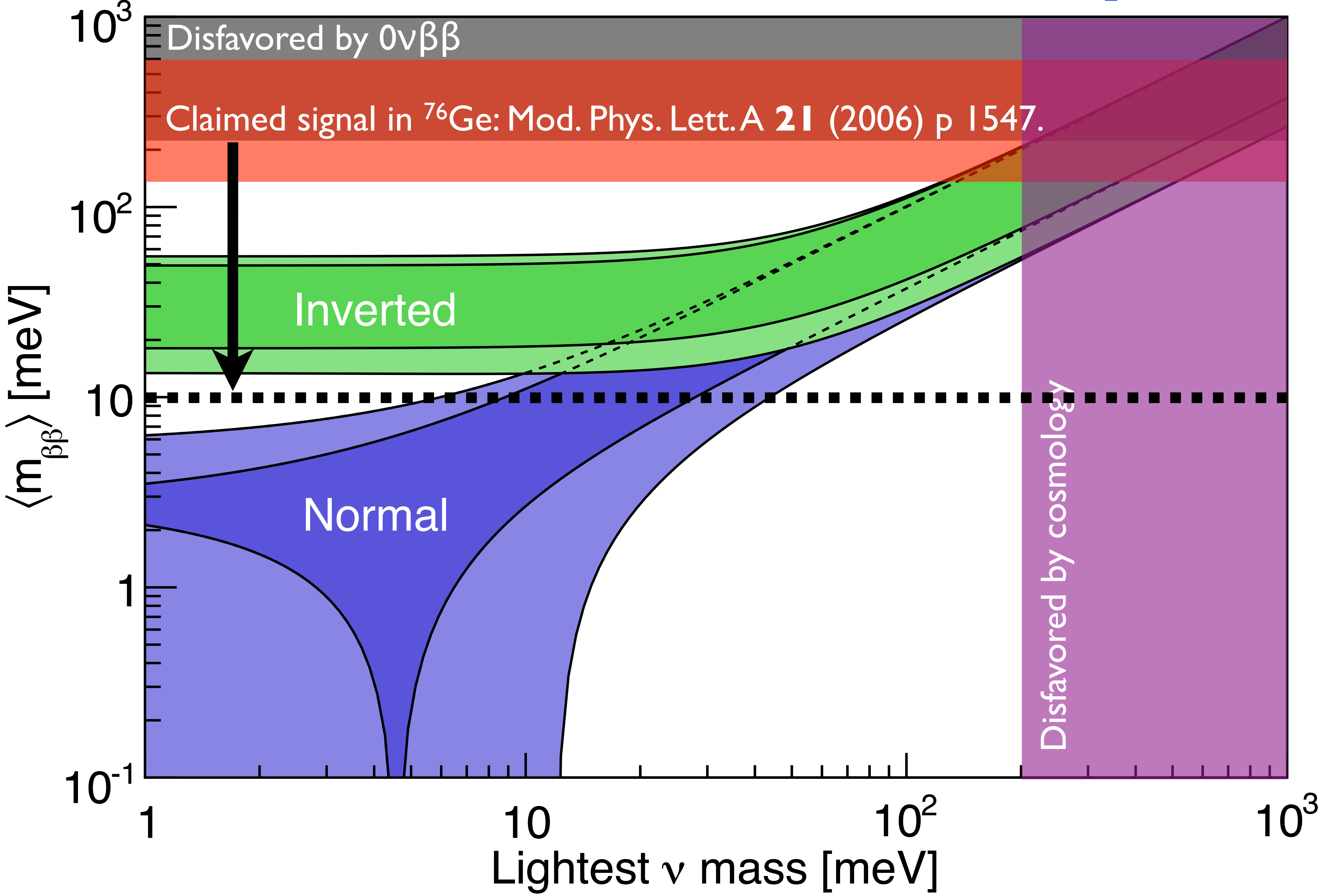


$$\Gamma_{1/2}^{0\nu} = G^{0\nu} \, |M^{0\nu}|^2 \, \langle m_{\beta\beta} \rangle^2$$

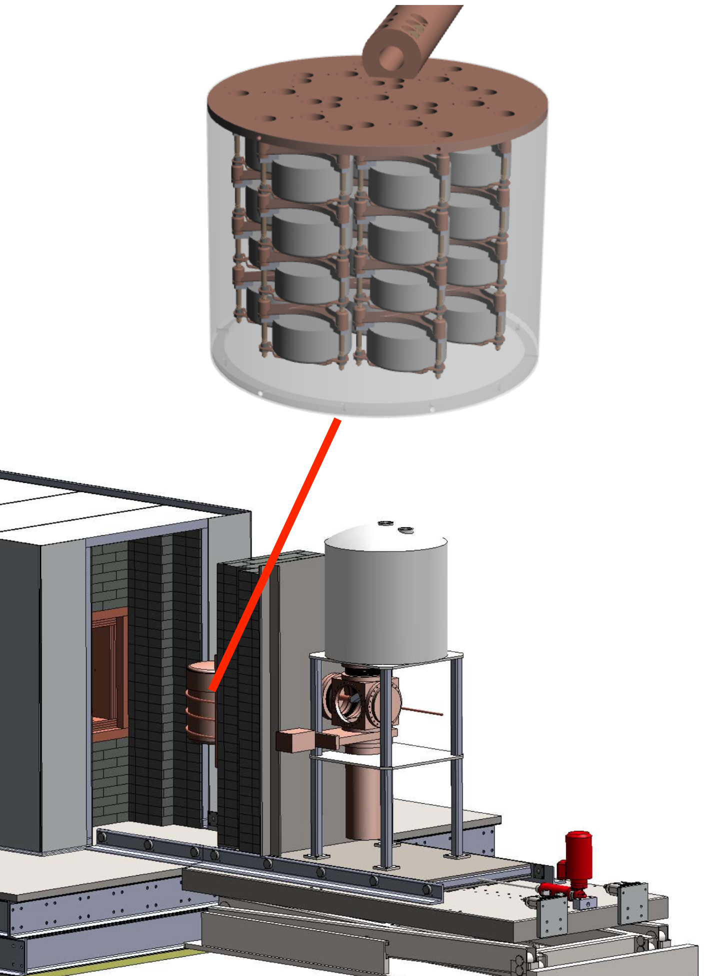
$$\langle m_{\beta\beta} \rangle \equiv \Sigma \, m_i \, U_{ei}^2$$

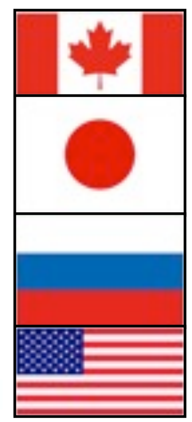
ν = ∇ → Lepton number violation → Leptogenesis

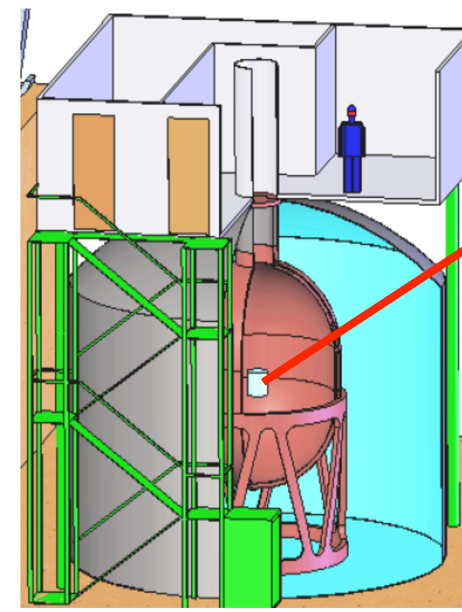
Double-Beta Decay

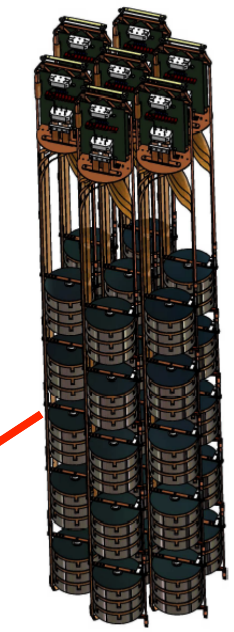


MAJORANA and GERDA









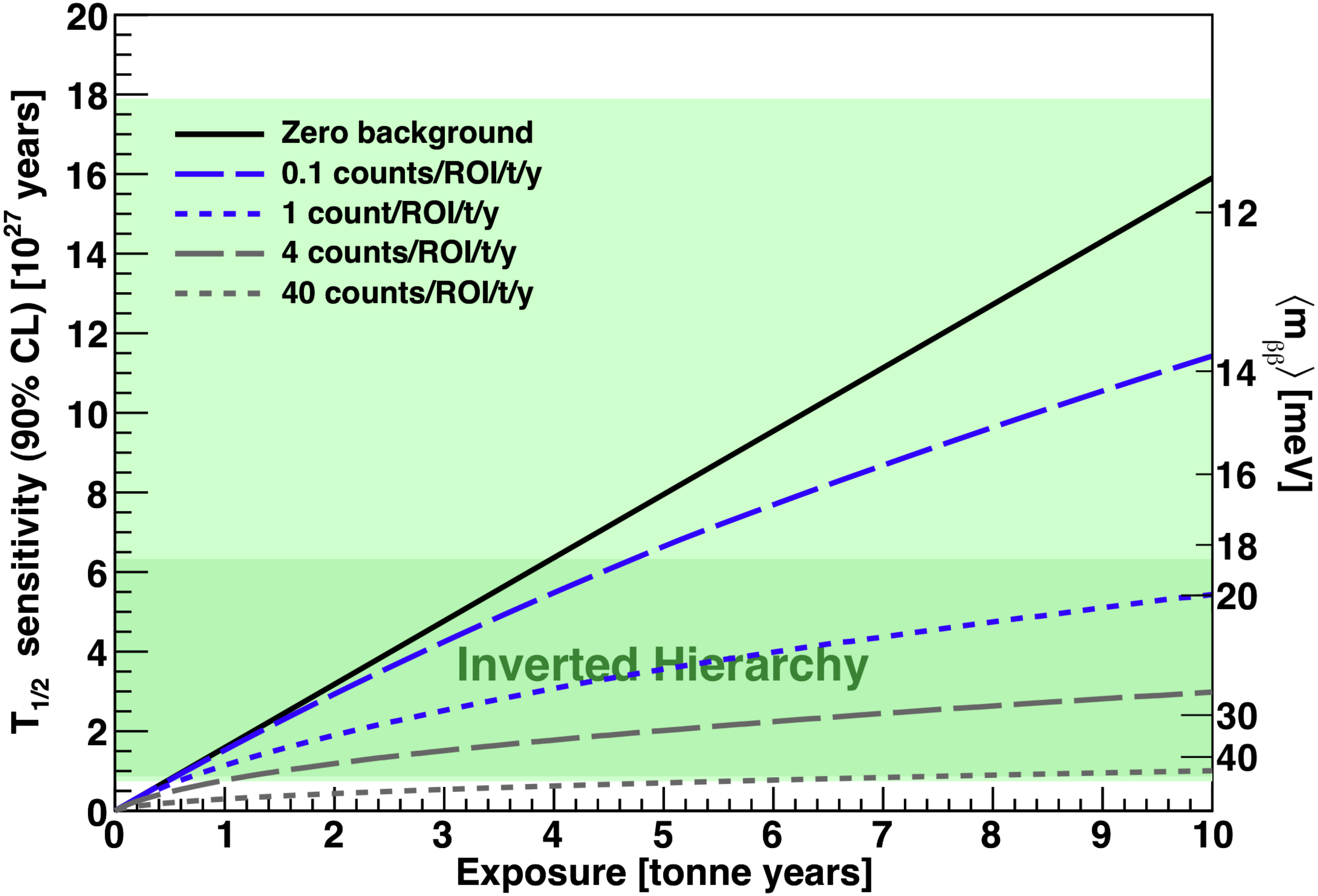
MAJORANA DEMONSTRATOR

- Modular ^{enr}Ge arrays in electroformed Cu cryostats
- E-formed Cu / Pb passive shielding
- 4π plastic scintillator μ veto

- ^{enr}Ge array submersed in LAr
- Water cherenkov μ veto
- Phase I: ~18 kg (H-M/IGEX xtals)
- Phase II: +20 kg segmented xtals

- Open exchange of knowledge and ideas (e.g. MaGe MC)
- Intend to merge for ton-scale experiment using the best techniques

Sensitivity

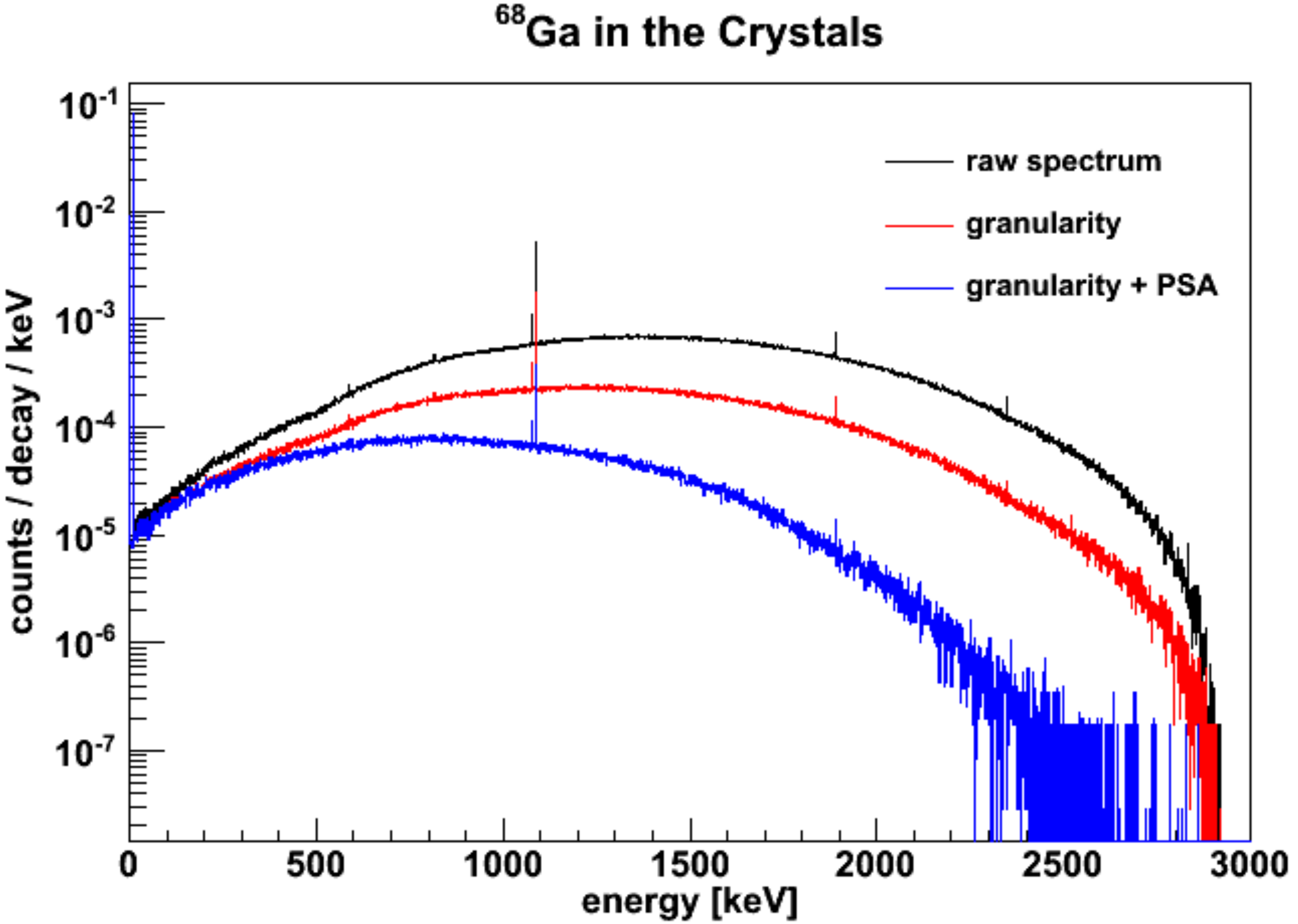


Cosmogenic Backgrounds

- Any event with $E > Q_{\beta\beta}$ is dangerous
- Long-lived isotope production
  - On surface in crystals: ^{68}Ge, ^{60}Co, ...
  - On surface in structural material: ^{60}Co ...
  - In situ production: ^{77}Ge, ...
- Muon-induced activity: spallation, ..

^{68}Ge in Crystals

^{68}Ge (EC, $T_{1/2}$ = 270 d) → ^{68}Ga (90% 1.9 MeV β^+, $T_{1/2}$ = 68 min)

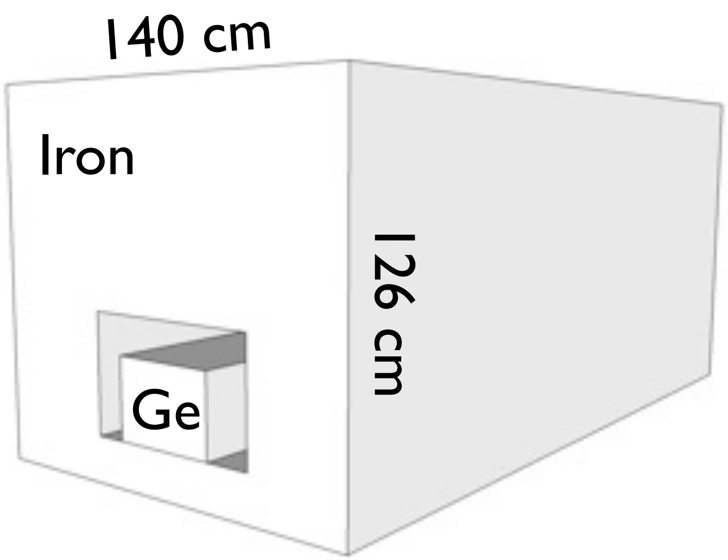


^{68}Ge in Crystals

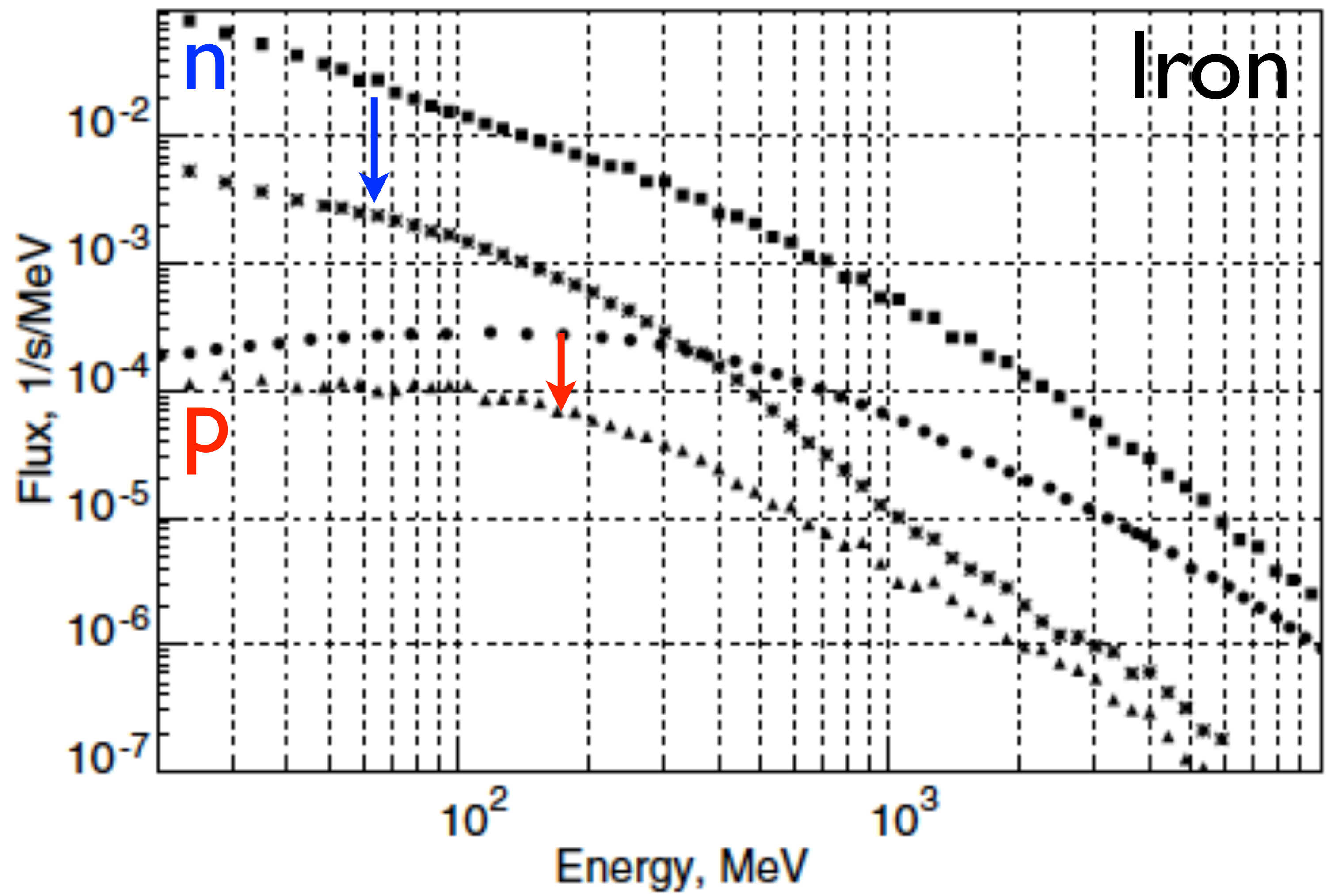
- Sea-level activation rate: 2.1* (30**) atoms/kg/day for ^{enr}Ge (^{nat}Ge), driven by hadronic component
- Shield for storage and transport. But with what material?***
  - Interaction cross-section $\sigma \sim A^{0.66}$-$A^{0.8}$
  - Attenuation length $\lambda \sim A/\sigma\rho$
  - Mass of box with sides of length λ: $m \sim A^{0.8}/\rho^2$

* S.R. Elliott *et al.*, PRC **82**, 054610 (2010).
** H.S. Miley *et al.*, J. Rad. Nucl. Chem. **160**, 371 (1992).
*** From I. Barabanov *et al.*, NIMB **251**, 115 (2006).

^{68}Ge in Crystals



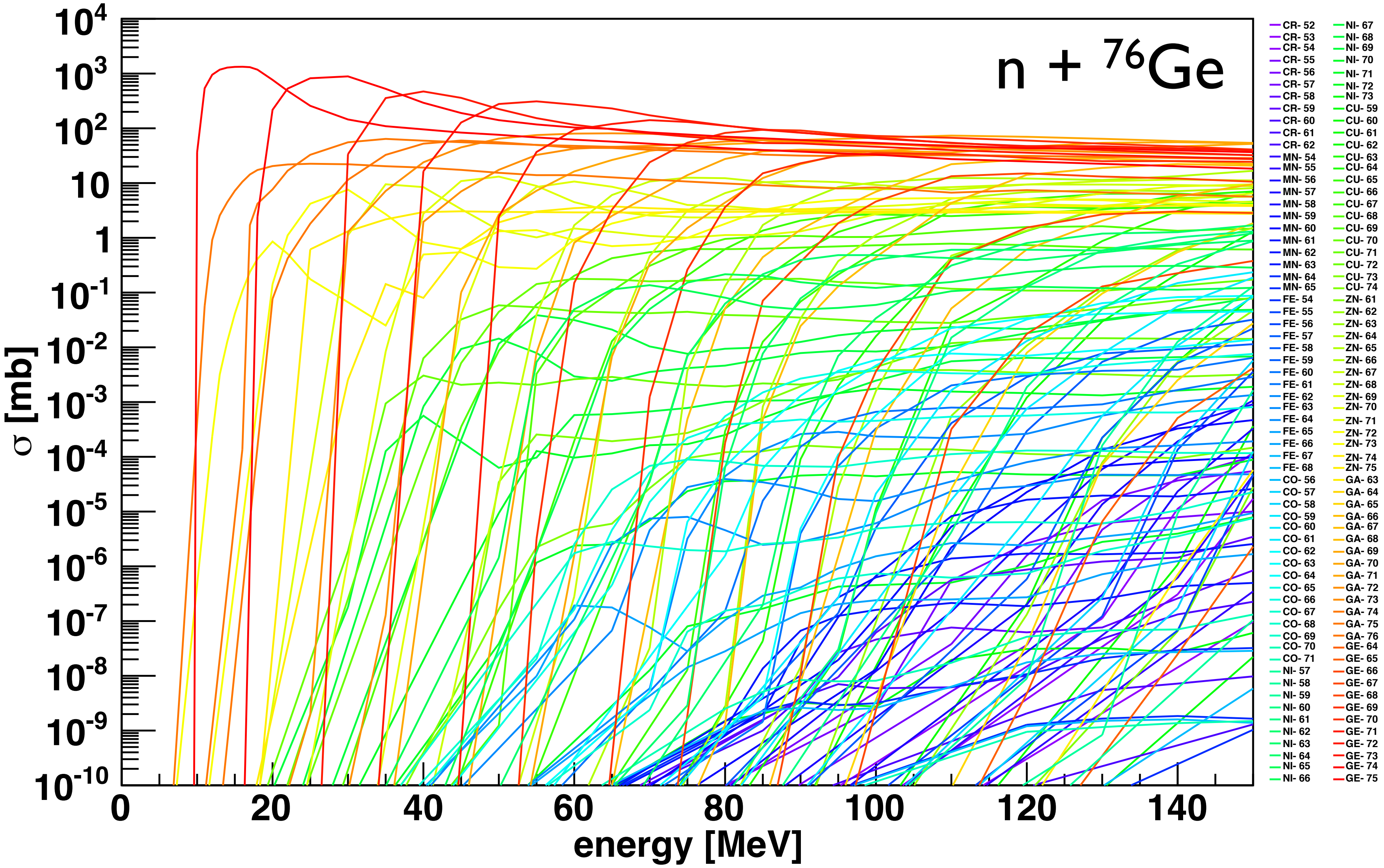
Material	$A^{0.8}/\rho^2$
Polyethylene	7.5
Aluminum	2
Iron	0.4
Lead	0.6



I. Barabanov *et al.*, NIMB **251**, 115 (2006).

^{68}Ge in Crystals

- High-Z material can multiply the hadrons, but secondaries are lower energy
- Evaluating this in within Majorana



Data from ACSELAM Library, available at http://wwwndc.jaea.go.jp/ftpnd/sae/acl.html

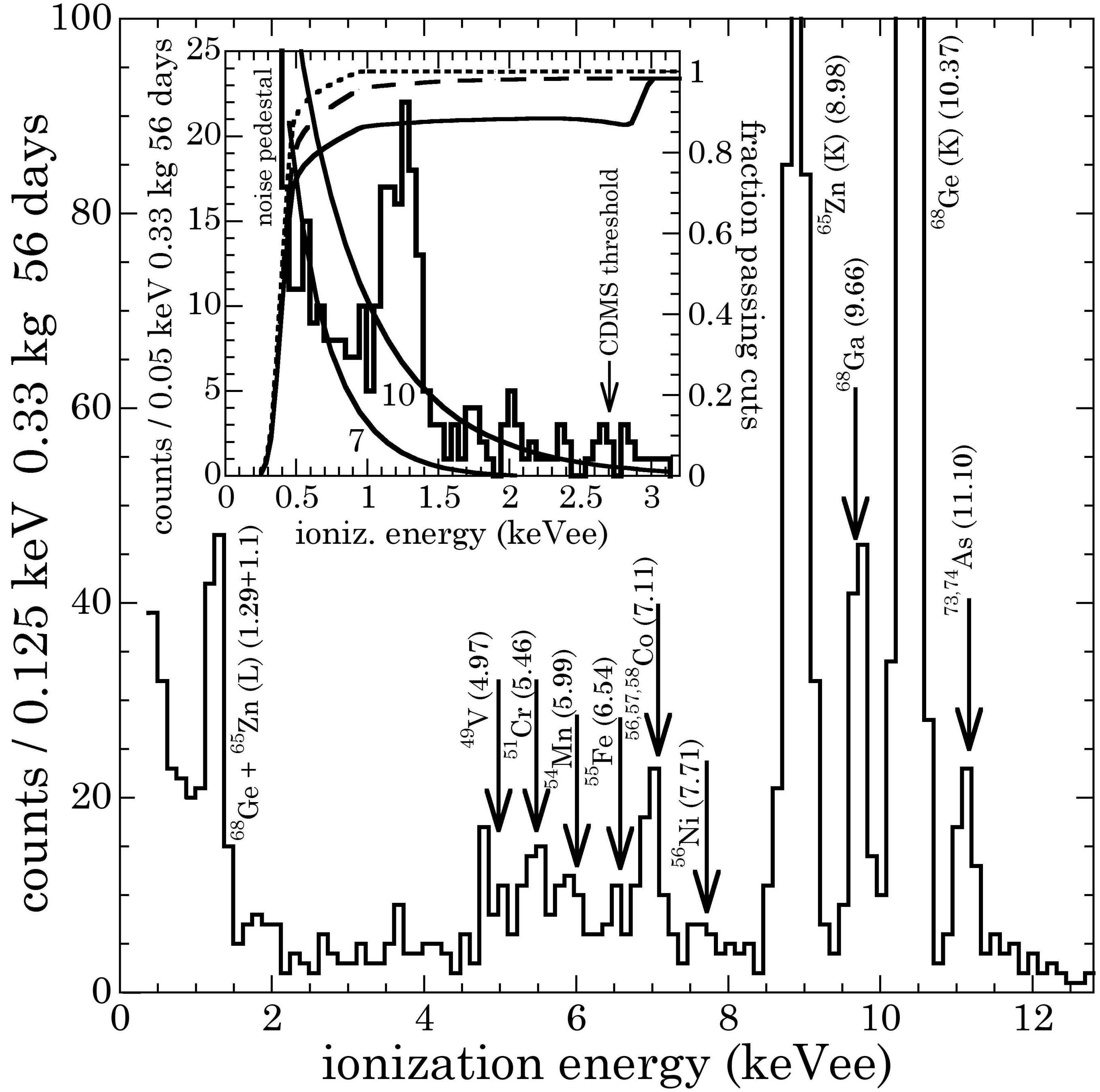
Single-Site Time Correlation

- Tag ^{68}Ge K-shell (~10 keV, 86.4%), L-shell (~1 keV, 11.5%) de-excitations
- Veto detector for several ^{68}Ga half-lives; set duration to maximize sensitivity
- Requires low rate in tag window(s)

Low-E Backgrounds

- Ge, Ga, Zn, As, etc.
- Tritium
- Affects:
  - SSTC capability
  - DM sensitivity
  - Other physics

Aalseth *et al.*, arXiv:1002.4703

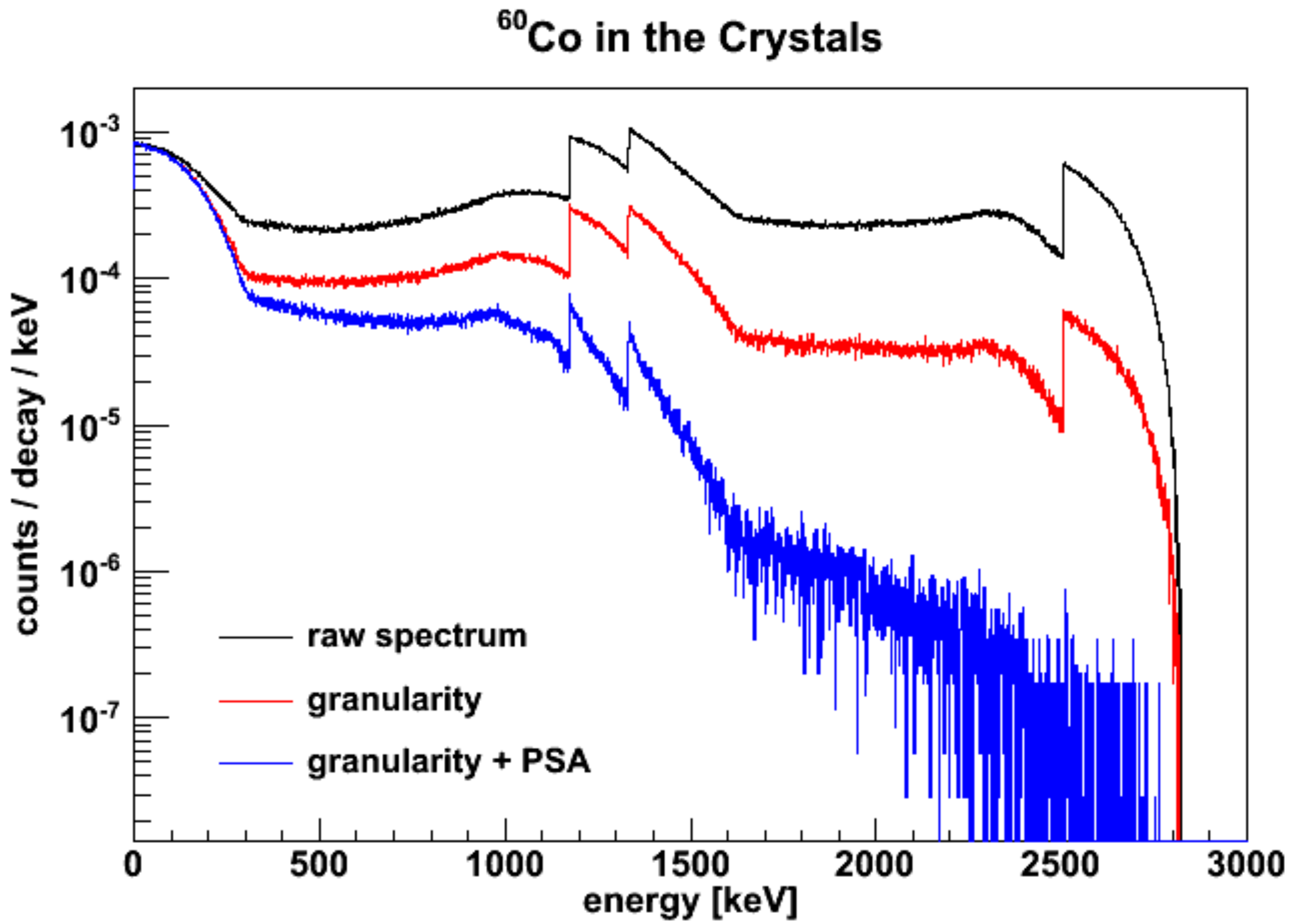


Study in MJD

^{60}Co in Crystals

^{60}Co (β^- + γ's, Q = 2.8 MeV, $T_{½}$ = 5.3 years)

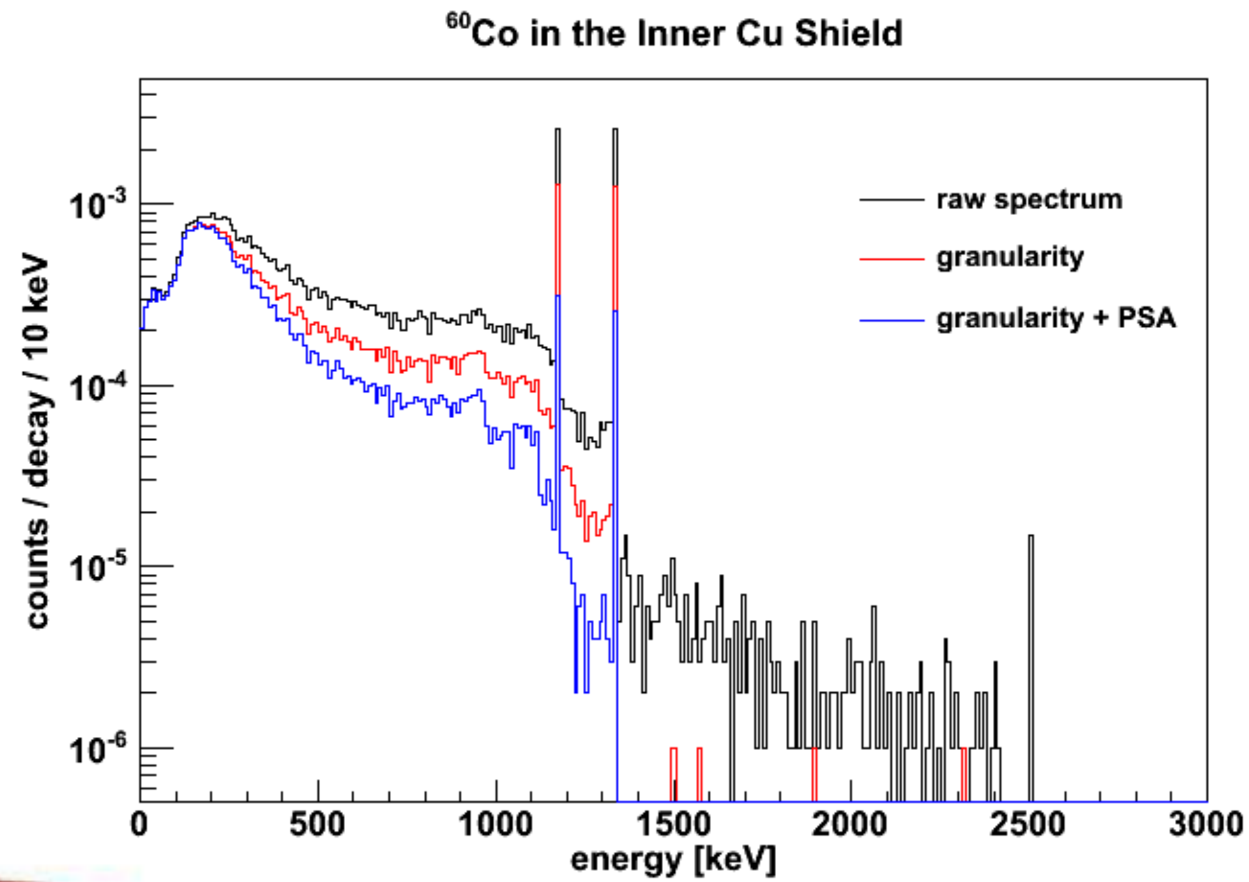
- Sea-level activation rate: 2.6* (5**) atoms/kg/day for ^{enr}Ge (^{nat}Ge)
- Reset at crystal pulling
- Minimize exposure

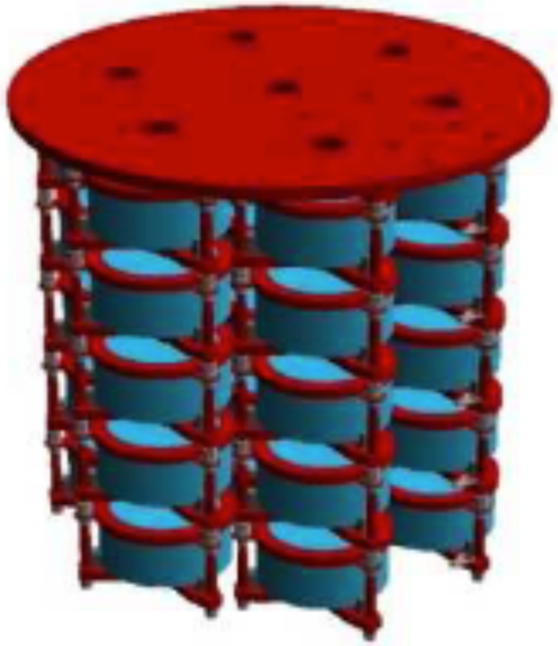


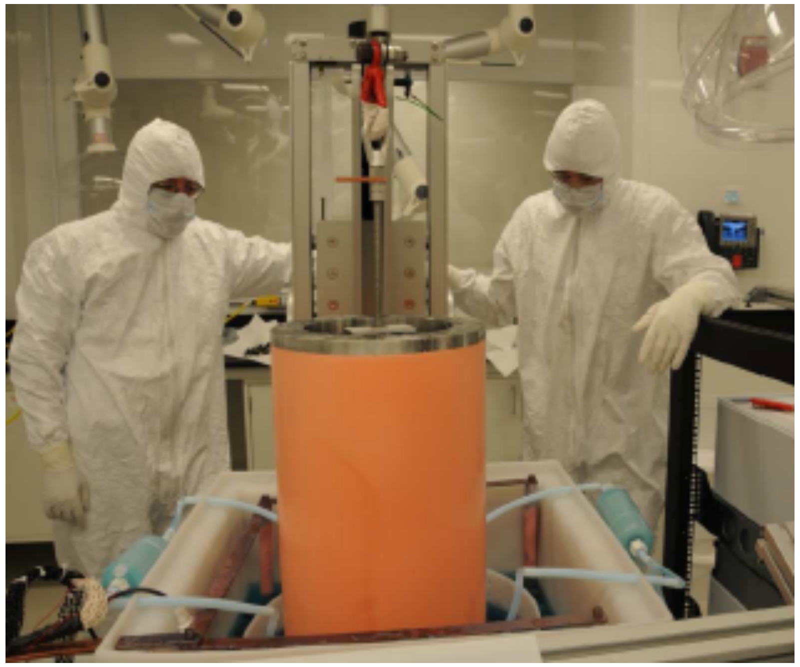
* S.R. Elliott *et al.*, PRC **82**, 054610 (2010).
** H.S. Miley *et al.*, J. Rad. Nucl. Chem. **160**, 371 (1992).

^{60}Co in Structural Cu

- Surface production rate: ~200 atoms/kg/day*
- BG is summed γ/β
- Minimize internal Cu mass
- Electroform Cu underground
- Minimize surface exposure

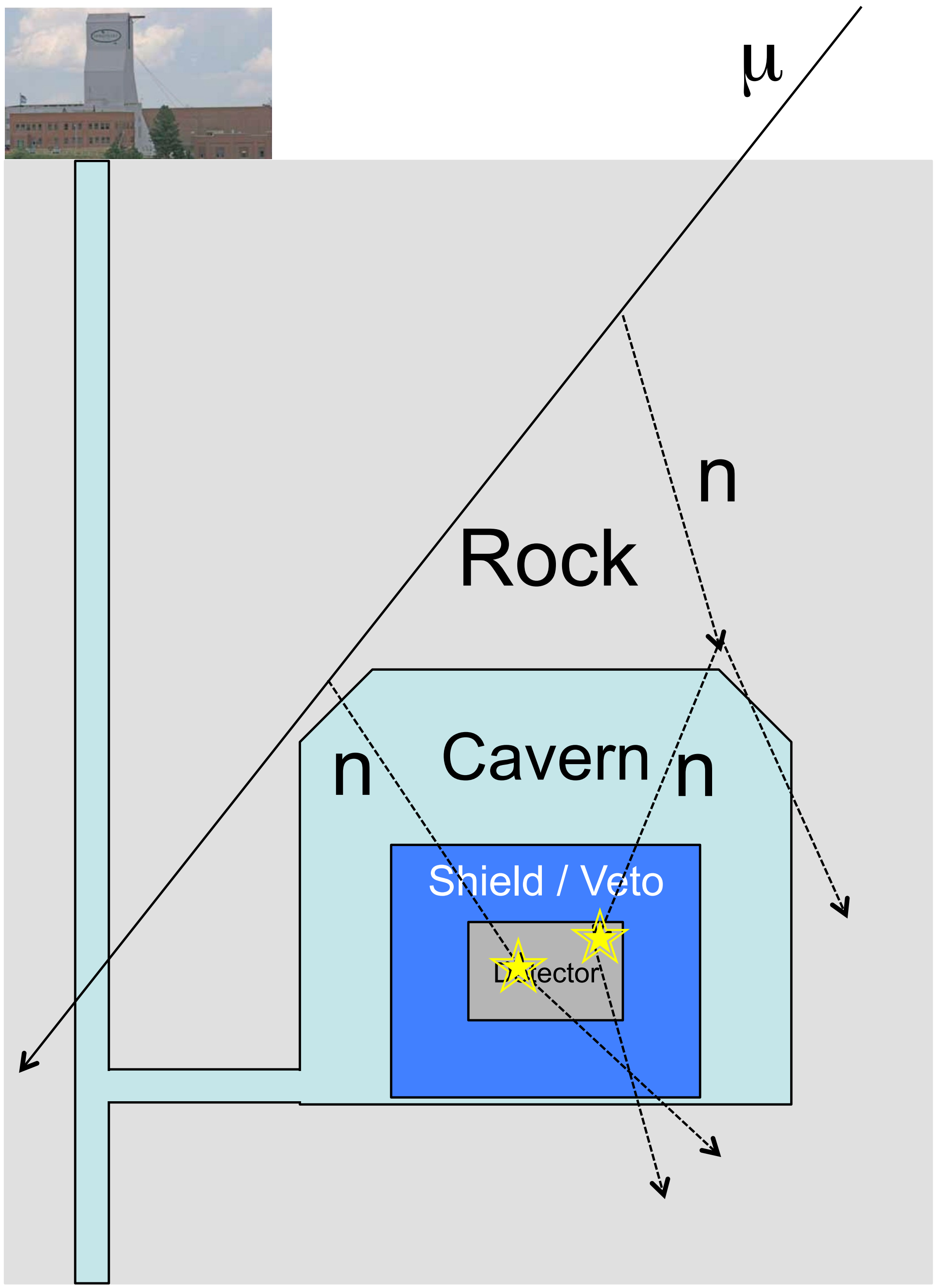






* M. Laubenstein and G. Heusser, Appl. Radiat. Isotopes **67**, 750 (2009).

Prompt Muon Activity



Primary danger: spallation n scattering on detectors and shielding material

Reaction	BG in Mei & Hime (2006)
^{76}Ge$(n, n'\gamma)$	40
$^{74}Ge(n, n'\gamma)$	8.0
$Cu(n, n'\gamma)$	7.6
$^{208}Pb(n, n'\gamma)$	14
$Ge(n, n)$	14
μ hits	10
Others	9.6
Total	100 c/ROI/t/y

Prompt Muon Activity

Mei & Hime → MJD:

- Gran Sasso → Sanford Lab (4850L)
- n moderator 10 cm → 30 cm
- $\varepsilon_{veto}(\mu)$ 90% → 99%
- $\varepsilon_{veto}(n)$ 20% → 80% (need to verify)

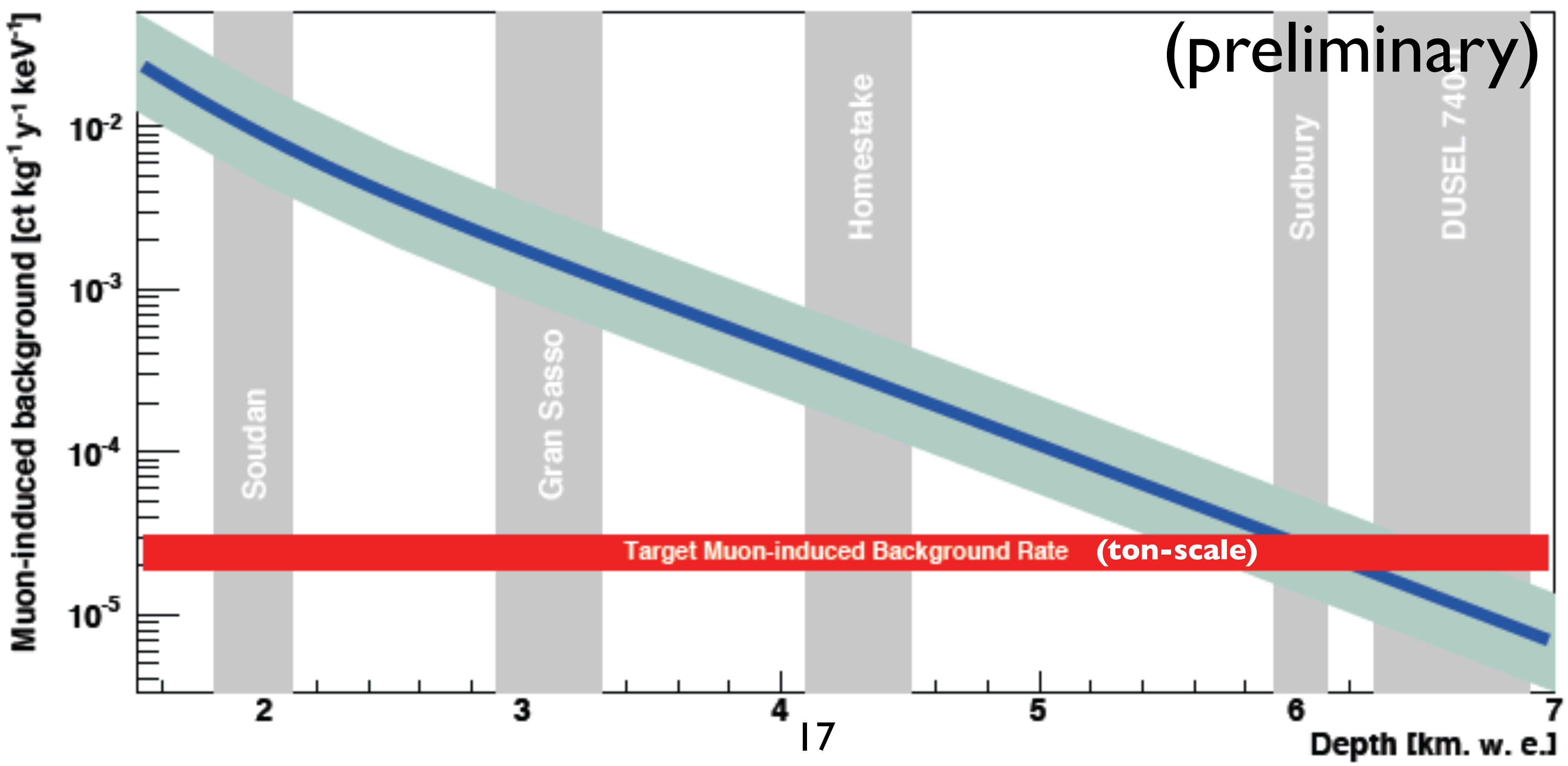
Scaling Factor Summary (preliminary):

Background	Depth	n Moderator	μ/n Veto	Total
$(n, n'\gamma)$	5.6	2	7.2	81
$Ge(n, n)$	5.6	2	7.2	81
μ hits	5.9		10	59
Others	5.3	2	7.2	76

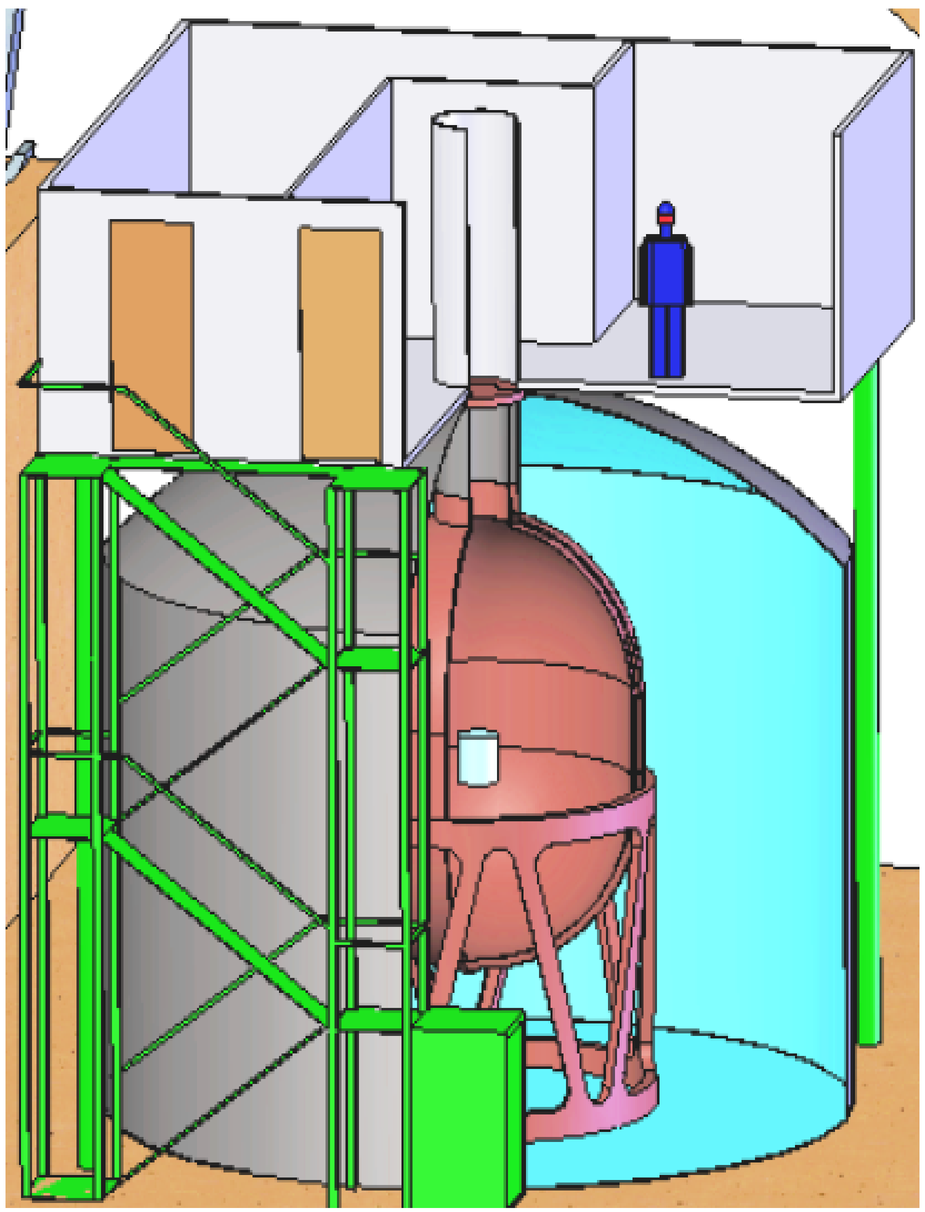
Prompt Muon Activity

Reaction	BG in Mei & Hime (2006)	BG in MJ Dem.
^{76}Ge$(n, n'\gamma)$	40	0.49
$^{74}Ge(n, n'\gamma)$	8.0	0.10
$Cu(n, n'\gamma)$	7.6	0.094
$^{208}Pb(n, n'\gamma)$	14	0.17
$Ge(n, n)$	14	0.17
μ hits	10	0.17
Others	9.6	0.13
Total	**100** c/ROI/t/y	**1.3** c/ROI/t/y

(preliminary)



Shielding Options for 1TGe



Active Veto:

- LAr (a la GERDA)
- Water cherenkov
- Liquid scintillator

Under evaluation

Summary

- Chief cosmogenic problems for $0\nu\beta\beta$: long-lived isotopes and fast neutrons
- Produce pure materials, minimize surface exposure
- Reject with event multiplicity, SSTC, veto cuts
- MJD-style 1TGe requires depth > 5500 mwe. Investigating other shielding options.