Office of Nuclear Physics

The MAJORANA Experiment

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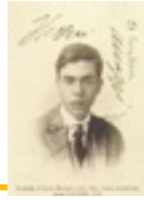
LA-UR-11-11044

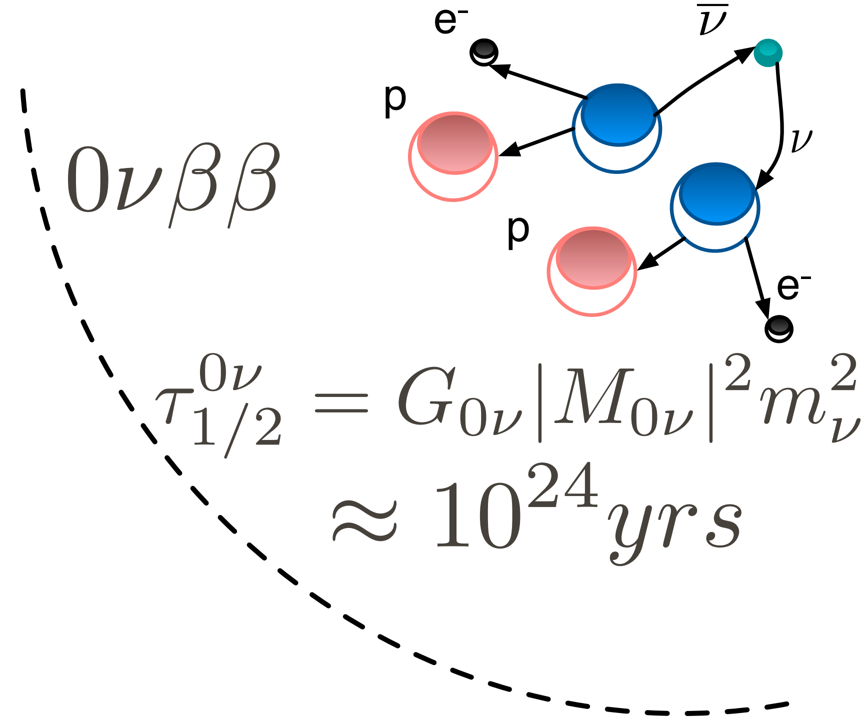


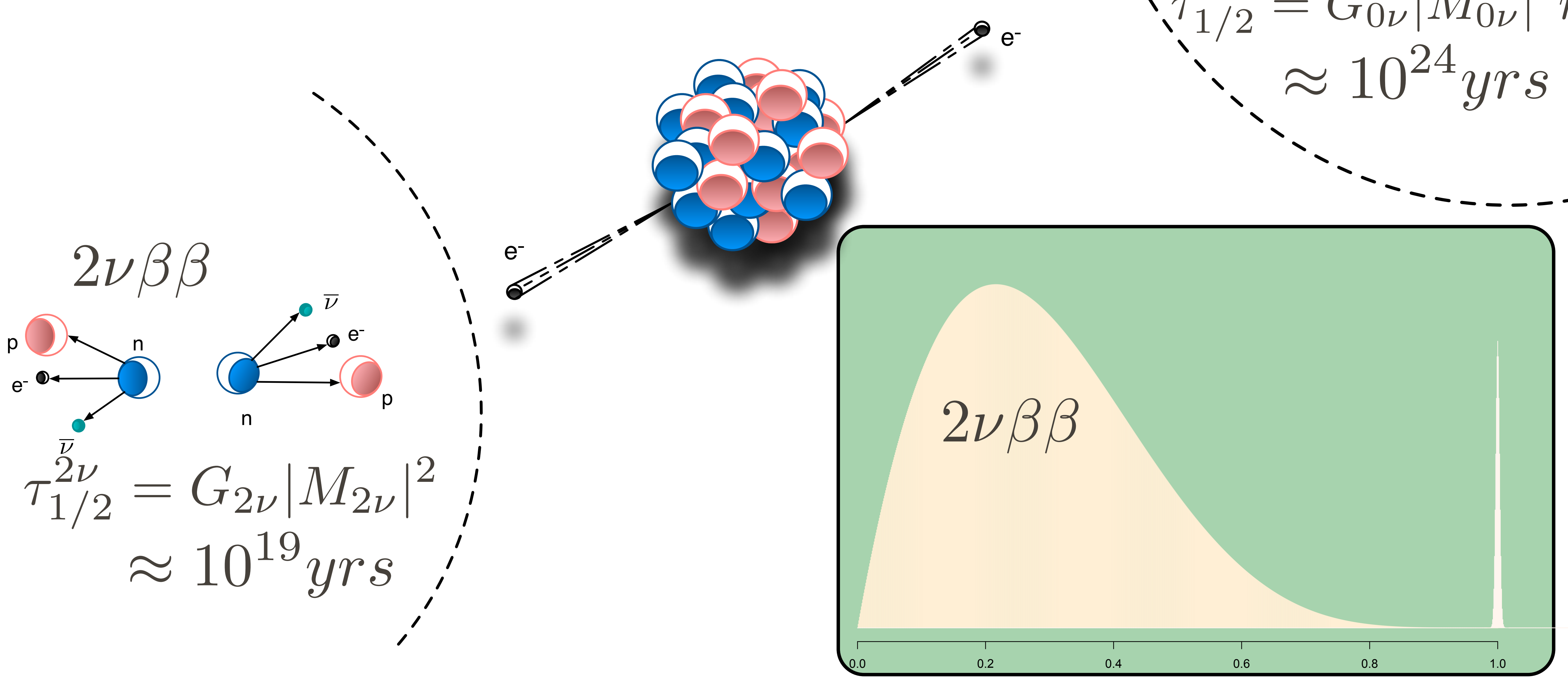
Outline

- Double-Beta Decay
- The MAJORANA Experiment
  - Backgrounds and Background Rejection
  - The DEMONSTRATOR
  - Cosmogenic Backgrounds
  - Recent Progress and Future Plans

Double Beta Decay

- 0νββ decay probes fundamental questions
  - Lepton number conservation
  - Relationship between neutrino and its antiparticle
  - A measure of the effective neutrino mass





Advantages of ^{76}Ge

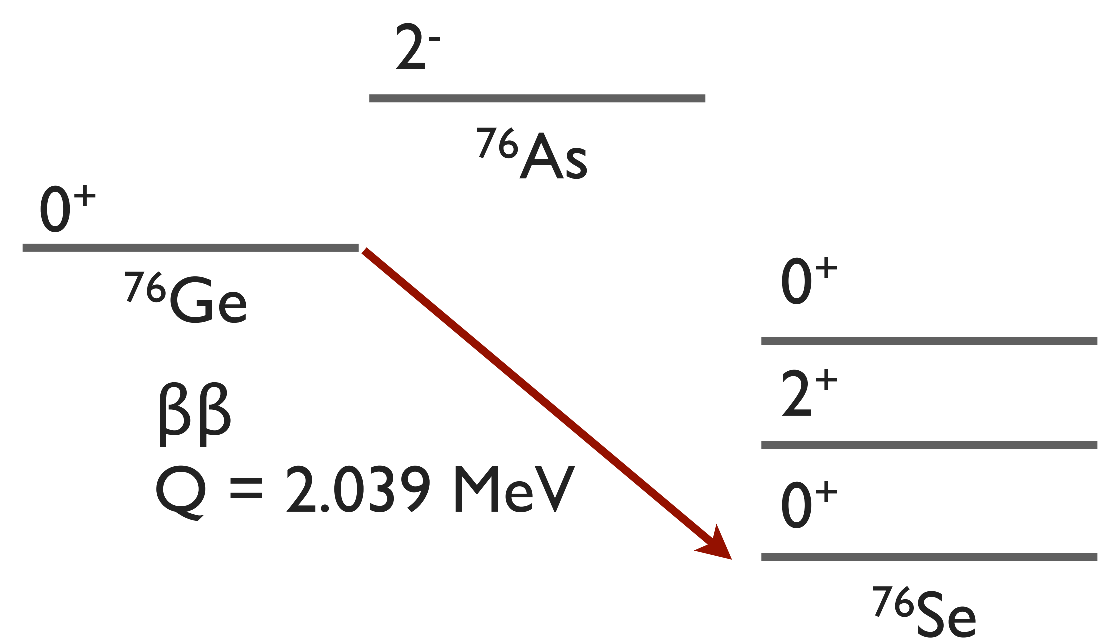
- The source is the detector
- Excellent Energy Resolution
  - 0.16% at 2039 keV (4 keV ROI)
- Powerful background rejection
  - segmentation, timing, pulse shapes
- The best current sensitivity to the neutrino mass
  - $<m_{\beta\beta}> < 300$ meV

$$T^{2\nu}_{1/2} = (1.4 \pm 0.2) \text{ x } 10^{21} \text{ y}$$

$$T^{0\nu}_{1/2} = (G^{0\nu}|M^{0\nu}|^2 < m_{\beta\beta} >^2)^{-1}$$

$$G^{0\nu} = 0.3 \text{ x } 10^{-25}\ y^{-1}\ eV^{-2}$$

$$M^{0\nu} \approx 2.4$$



The MAJORANA Collaboration

the red indicates students

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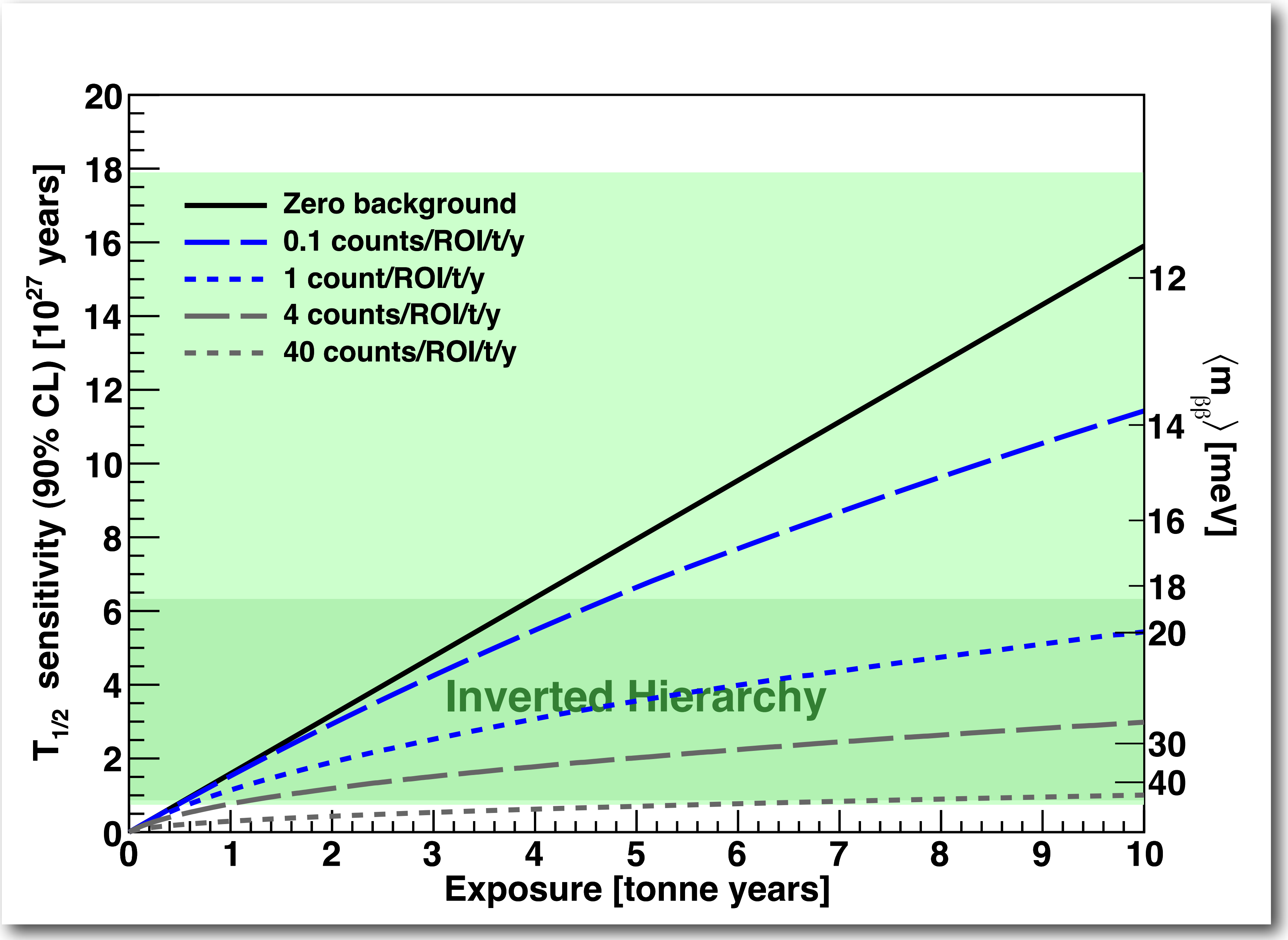
The MAJORANA Collaboration Goals

Actively pursuing the development of R&D aimed at a ~1 tonne scale ^{76}Ge $0\nu\beta\beta$-decay experiment

- **Technical goal:** Demonstrate background low enough to justify building a tonne scale Ge experiment
- **Science goal:** build a prototype module to test the recent claim of an observation of $0\nu\beta\beta$. This goal is a litmus test of any proposed technology.
- Work cooperatively with GERDA Collaboration to prepare for a single international tonne-scale Ge experiment that combines the best technical features of MAJORANA and GERDA
- Pursue longer term R&D to minimize costs and optimize the schedule for a 1-tonne experiment.

Sensitivity of 1-tonne MAJORANA

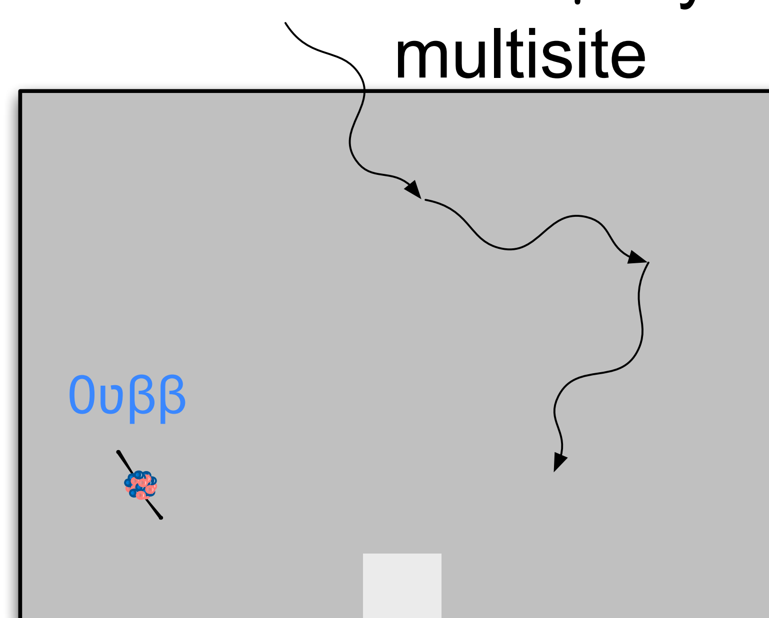
Goal is to achieve ultra-low backgrounds of less that 1 count per ton of material per year in the Region of Interest (ROI) about the 0νββ Q-value energy



MAJORANA Backgrounds

- Goal: < 1 event/ton-year in 4-keV ROI
- Backgrounds:
  - Natural Isotope chains: ^{232}Th, ^{235}U, ^{238}U, Rn
  - Cosmic Rays
    - Surface Activation
    - Hard neutrons from cosmic rays in rock and shield
      - (n,n γ') in Pb, Ge, Cu
  - $2\nu\beta\beta$ decays

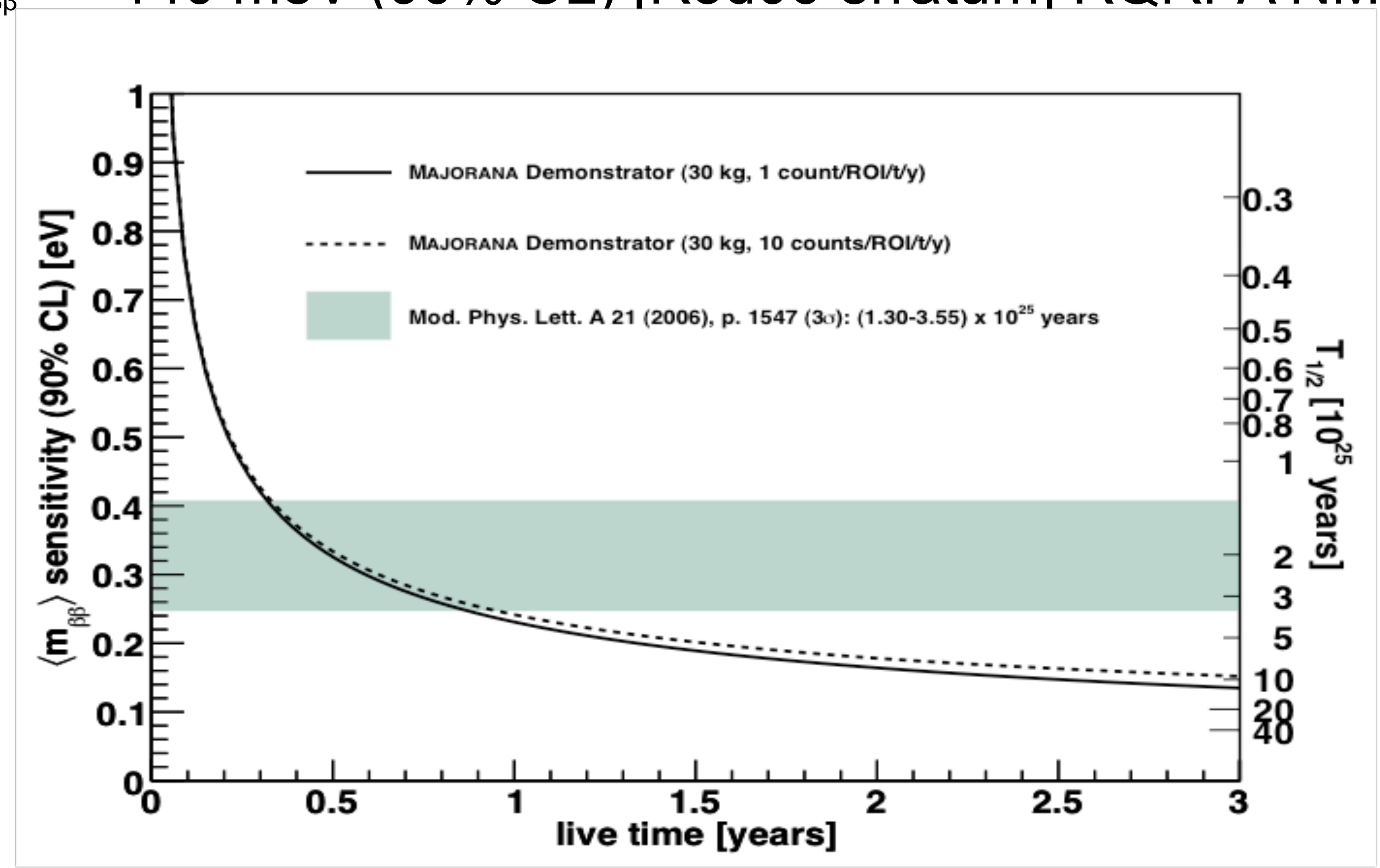
Most γ-rays are multisite



Need a factor of ~100 below whats been demonstrated

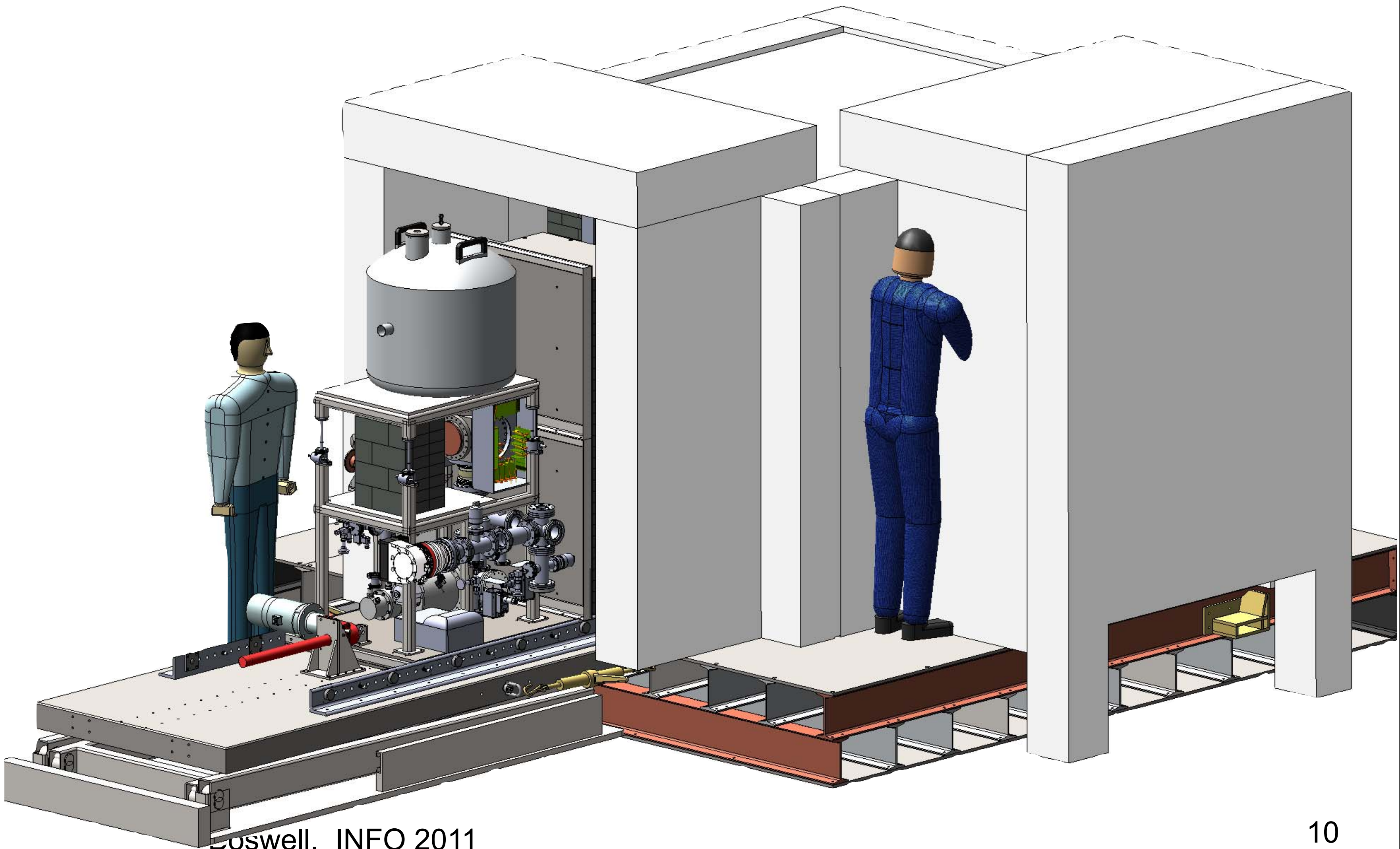
DEMONSTRATOR Sensitivity

- Expected sensitivity to $0\nu\beta\beta$
  - 30 kg of enriched material, running for 3 years, or 0.09 t-year exposure of ^{76}Ge
  - $T_{1/2} \geq 1.0 \times 10^{26}$ years (90% CL)
    - $\langle m_{\beta\beta} \rangle < 140$ meV (90% CL) [Rod06 erratum] RQRPA NME



The DEMONSTRATOR

- 40-kg Ge array
- Currently under construction
- Funded by DOE Office of Nuclear Physics and NSF Particle and Nuclear Astrophysics

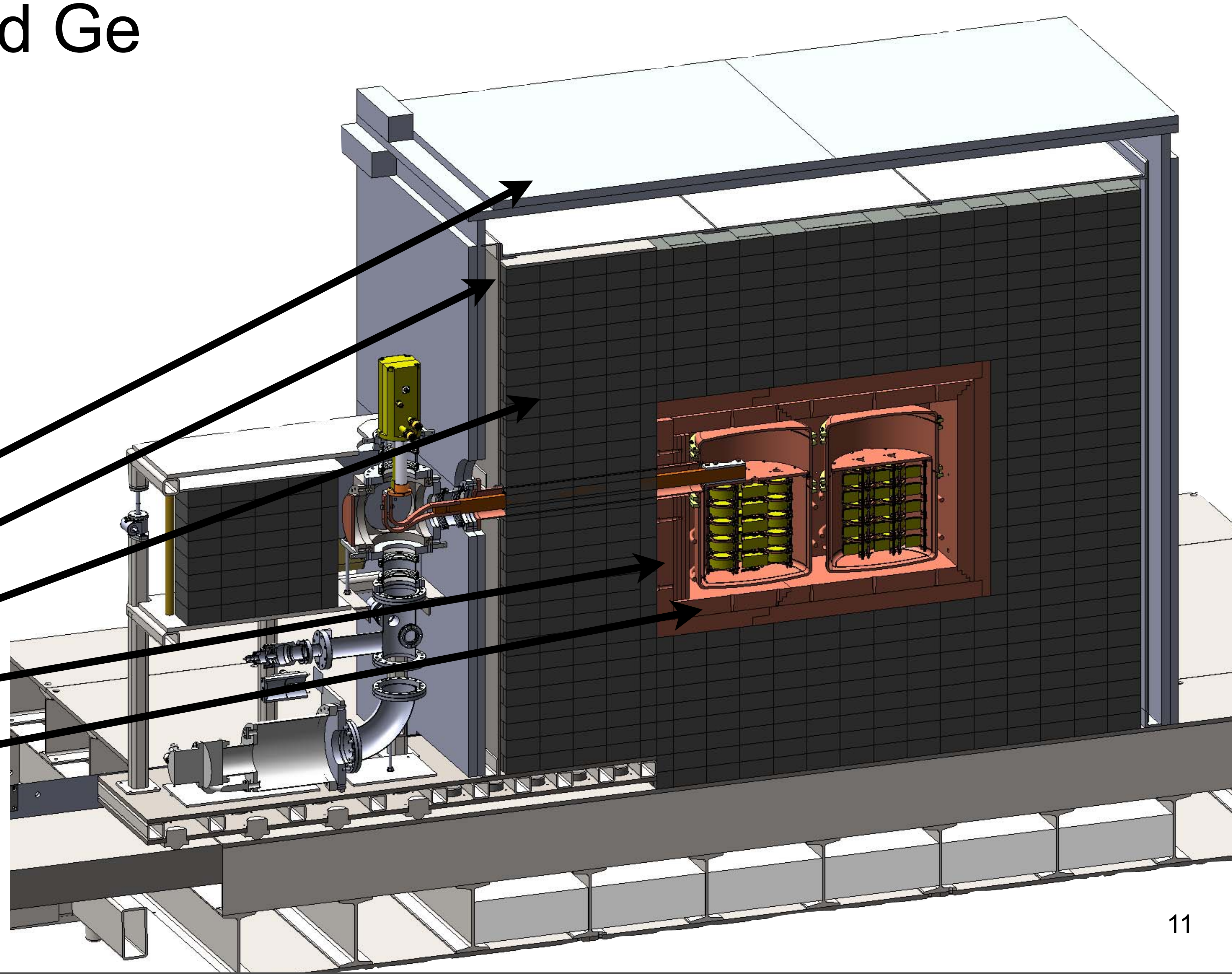


The DEMONSTRATOR

- P-type point contact detectors
- Two independent cryostats, each 20-kg of detectors
- up to 30-kg enriched Ge

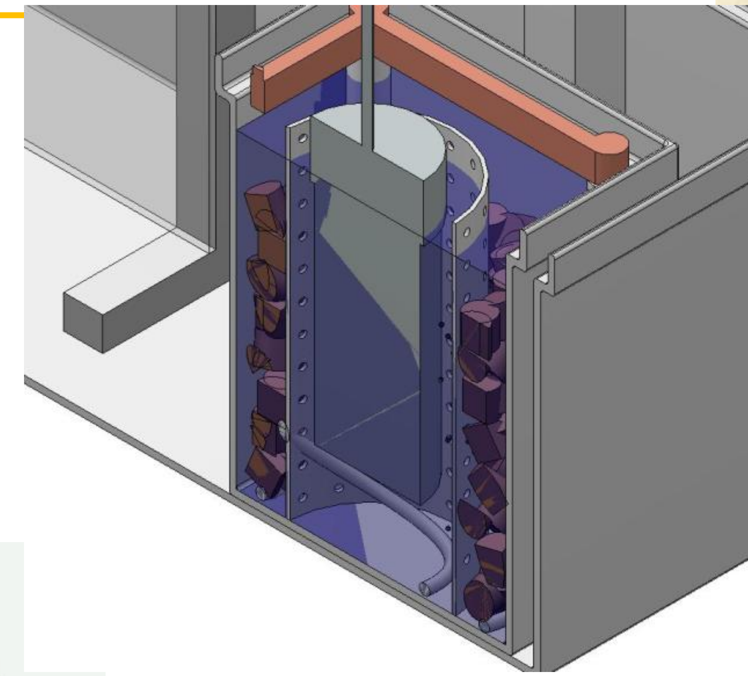
Shielding

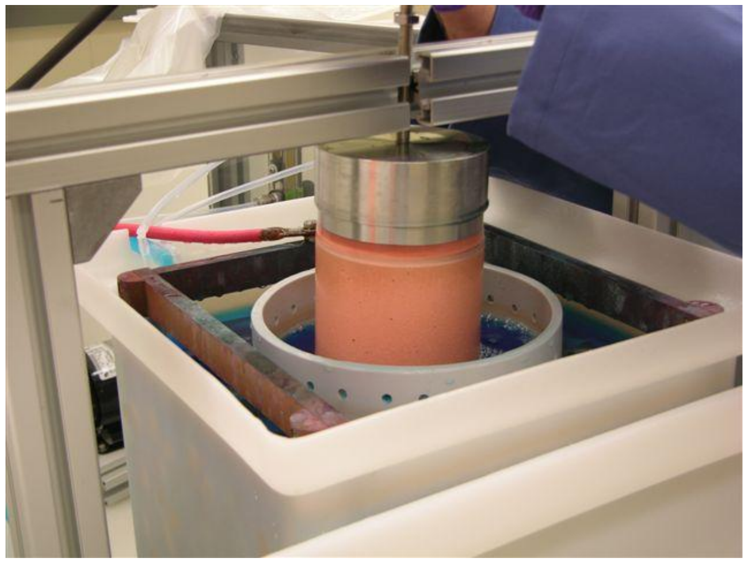
Poly (not shown)
active scintillator veto
radon exclusion box
lead
copper
electroformed copper

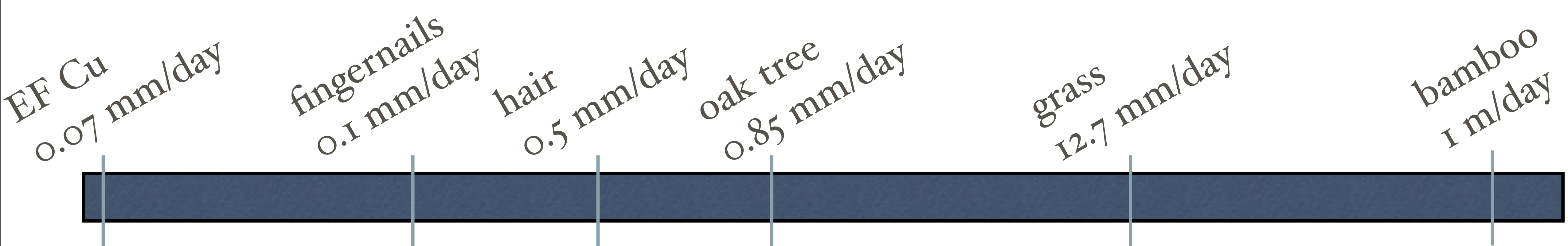


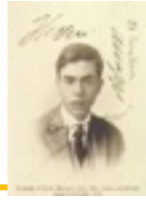
Electro-formed Copper

- Removes impurities (^{60}Co)
- demonstrated purity < 1 μBq/kg
  - –goal is 0.1-0.3 μBq/kg
- Very slow process



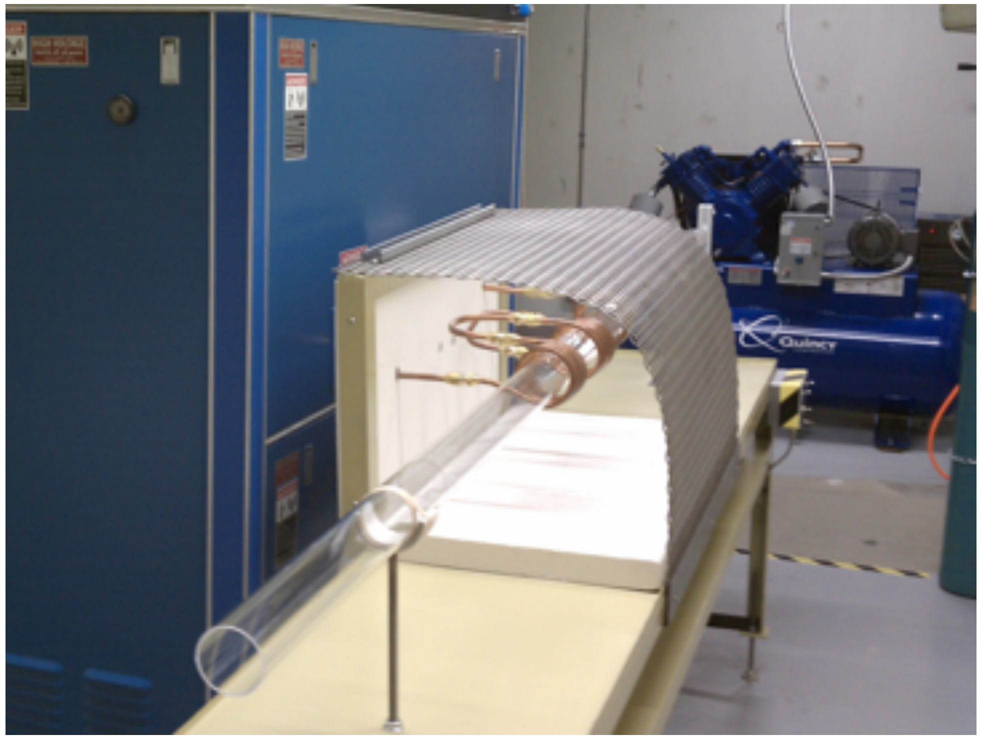






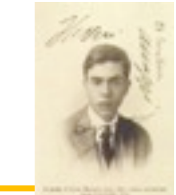
Germanium Processing

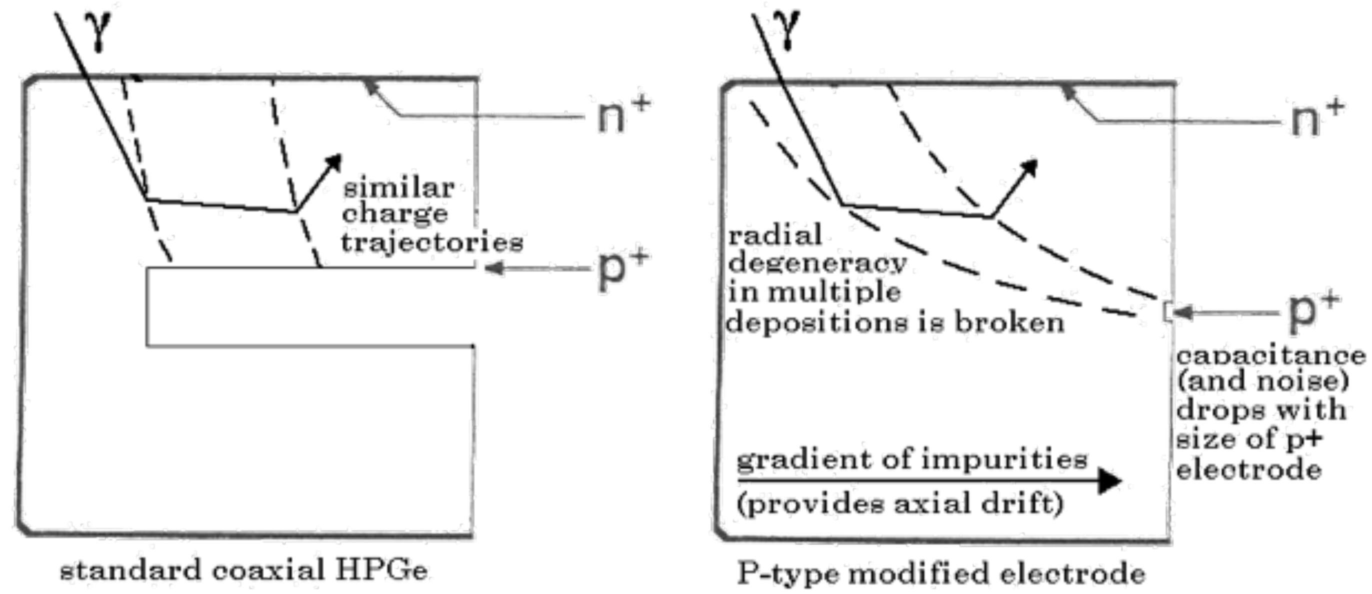
- 20 kg of ^{76}Ge ordered
- Refinement facility constructed
- Storage facility under preparation in Cherokee Caverns

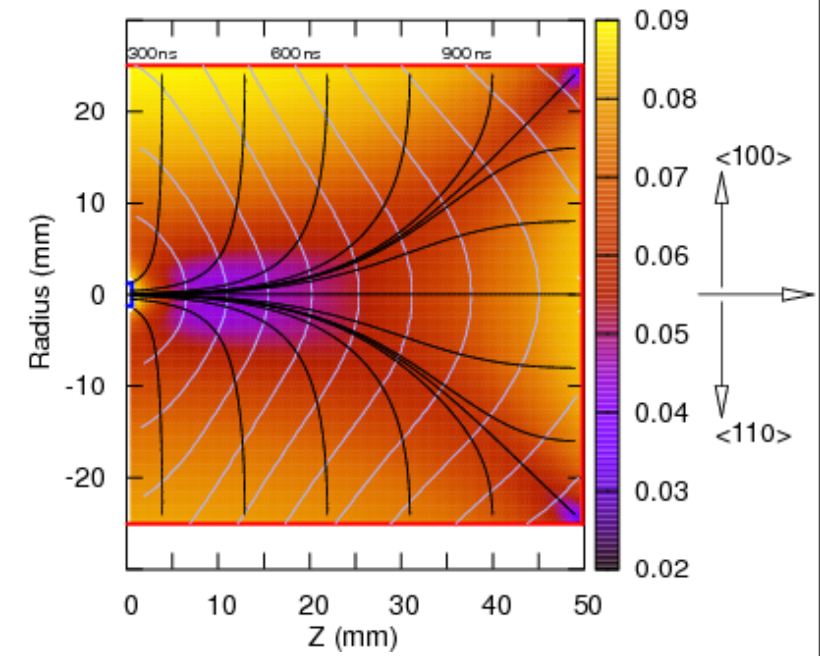


Isotope	Fractional Composition
^{70}Ge	0.00006(1)
^{72}Ge	0.00011(1)
^{73}Ge	0.00033(3)
^{74}Ge	0.086(5)
^{76}Ge	0.914(5)

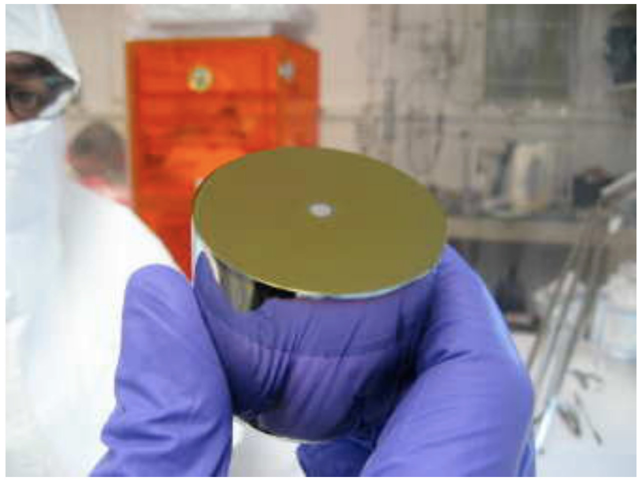
P-type Point Contact Detectors



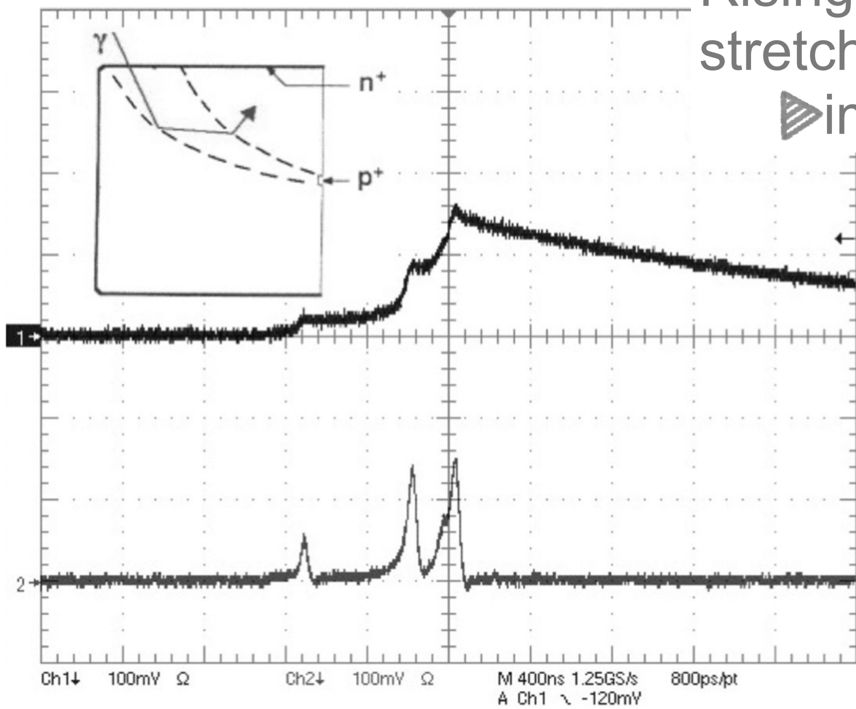




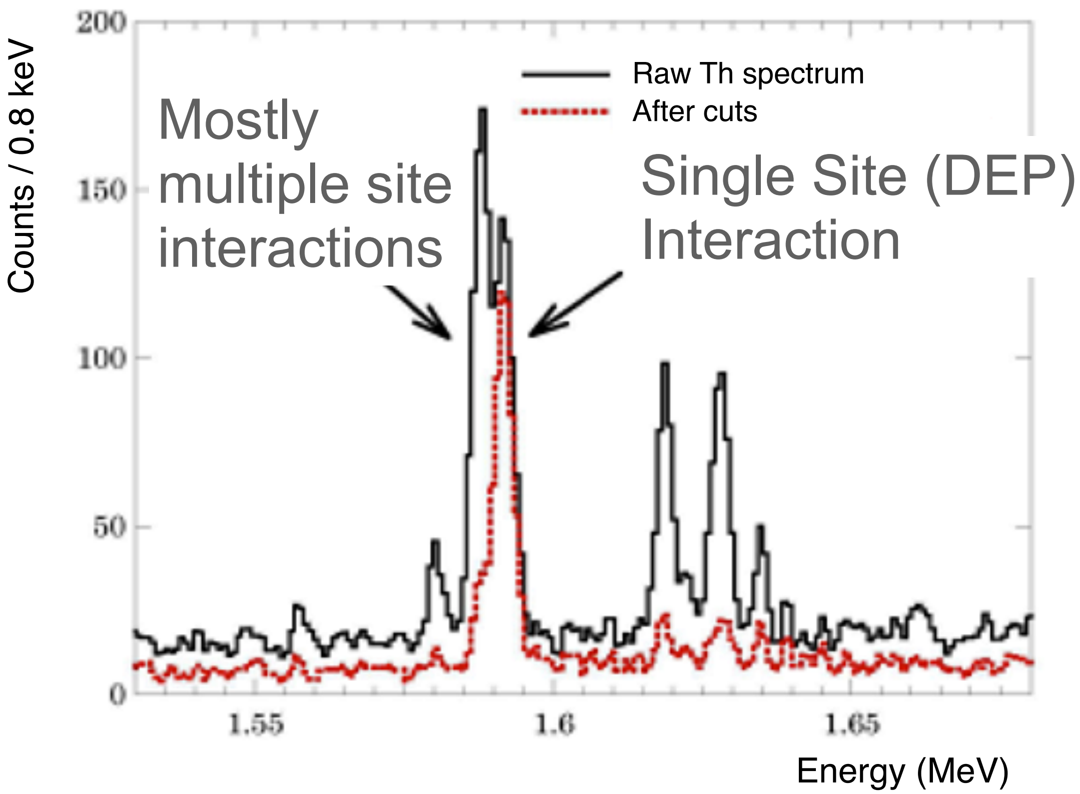
- Solid p-type detector are easier to fabricate and handle
- Lower capacitance which means less noise, and a lower energy threshold
- Longer drift times stretch out the pulses, and allow for easier identification of background-related multisite events

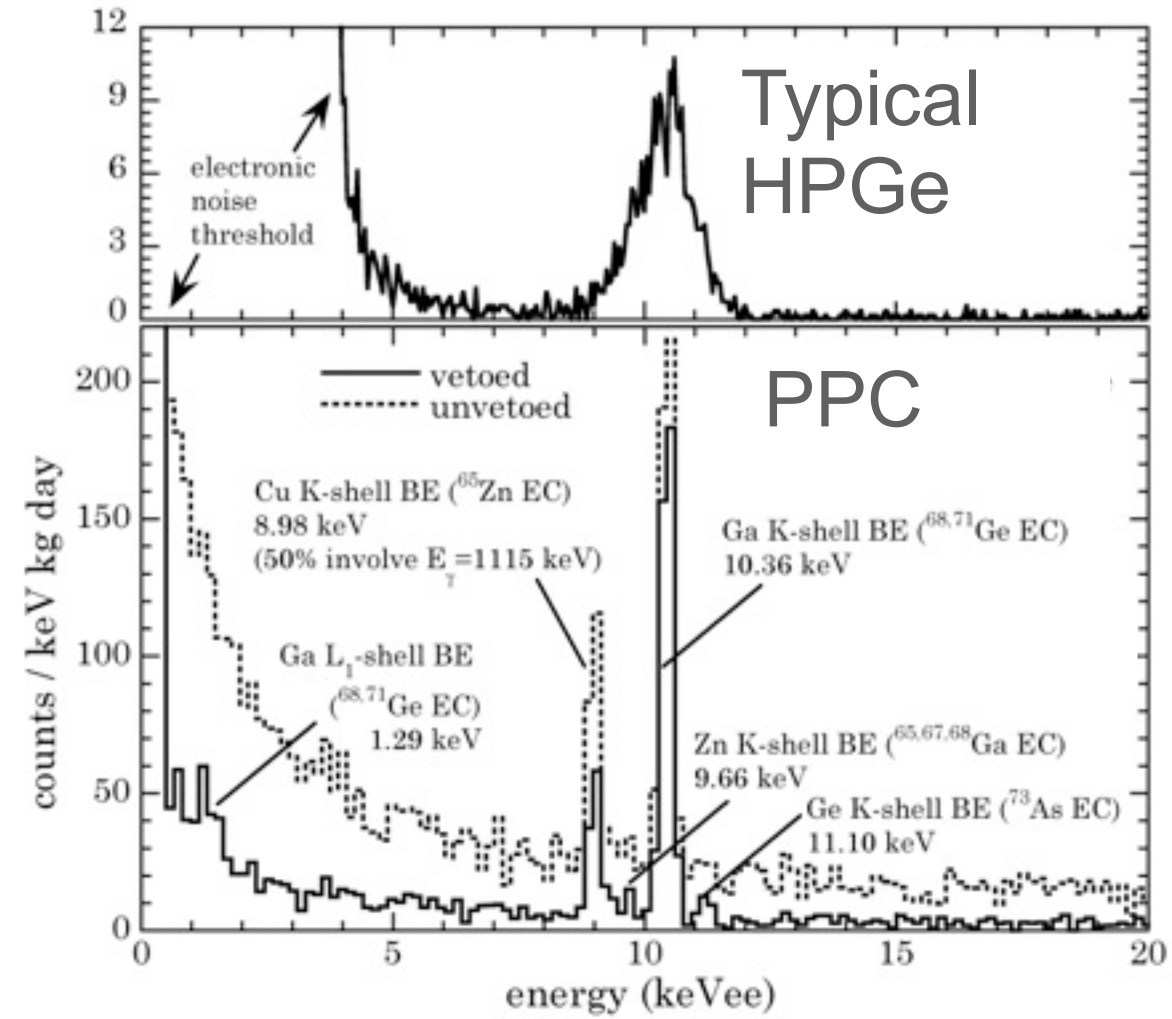


P-type Point Contact Detectors



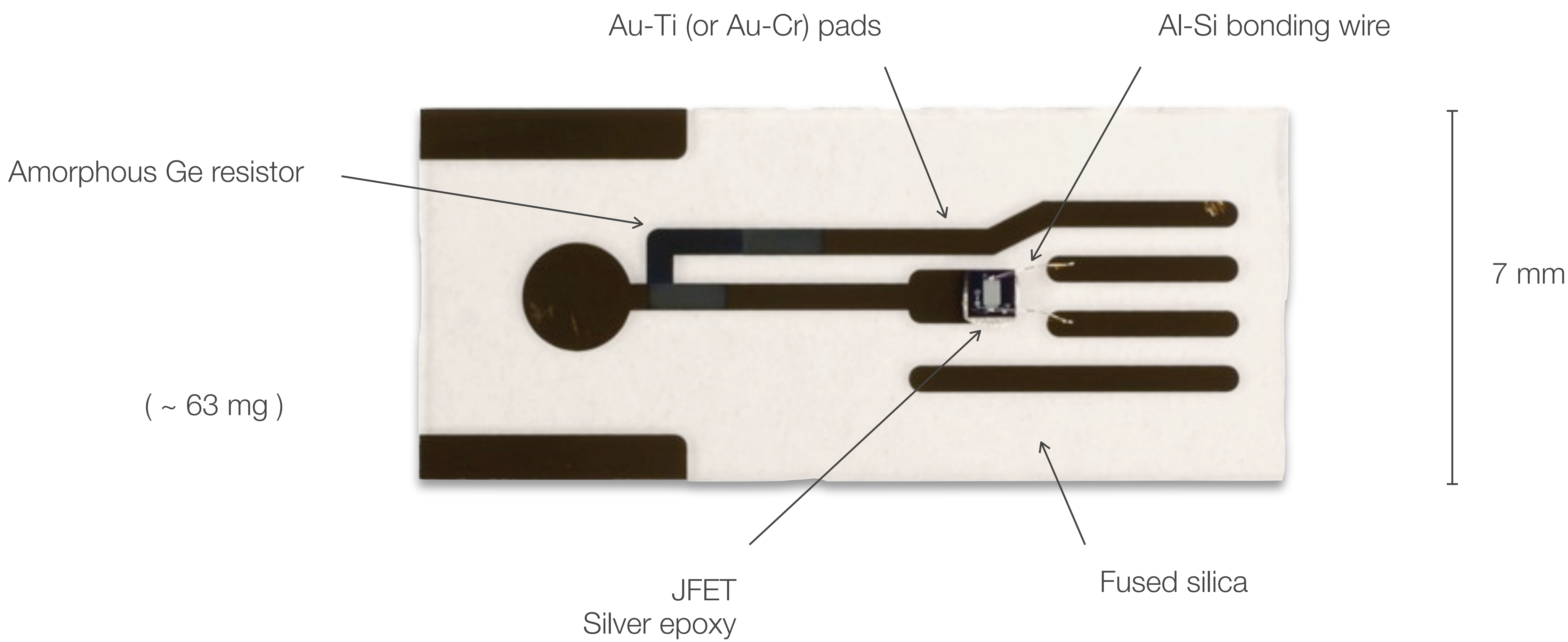
Rising edge is stretched in time
⇒improved PSA!

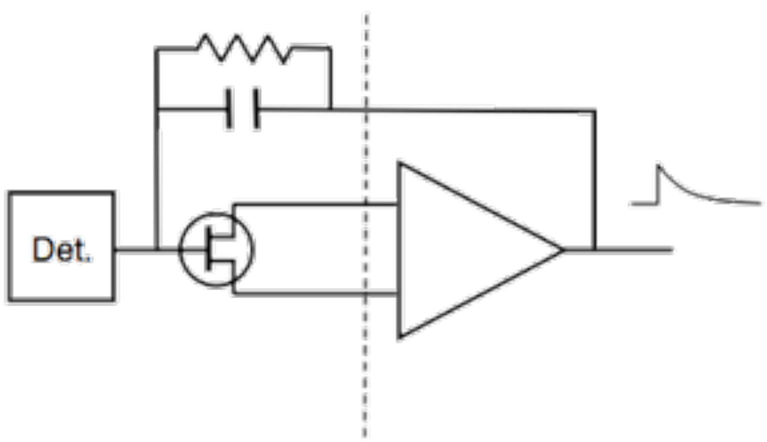




Barbeau et al., JCAP 09 (2007) 009;
C. E. Aalseth *et al.*, Phys. Rev. Let. **101**, 251301 (2008);
Luke et al., IEEE trans. Nucl. Sci. 36 , 926(1989).

Front End Electronics





Fused silica (*high purity, low dielectric losses, low thermal conductivity*)
Amorphous Ge film for R_f (*high purity, low noise)*
Stay capacitance for C_f

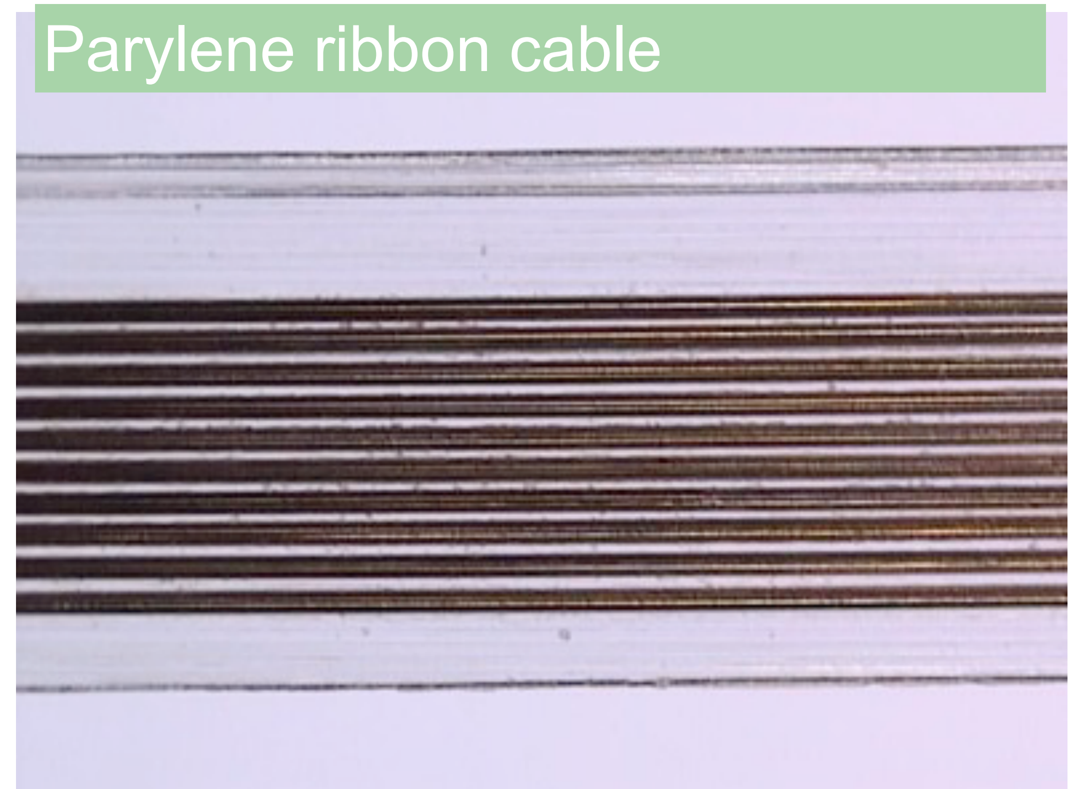
MX-11 JFET
$R_f \sim 1$ GΩ
$C_f \sim 0.2$ pF

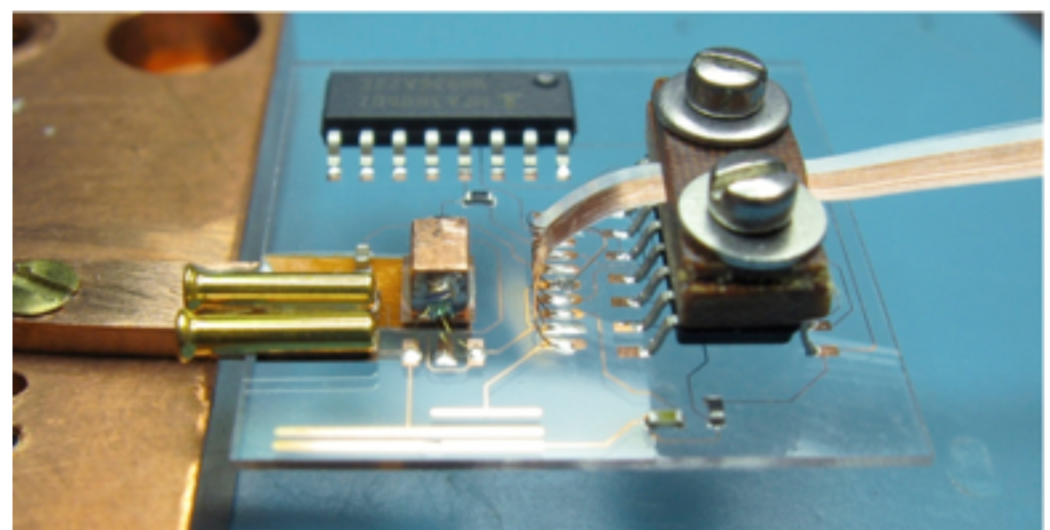
Signal Cables

Parylene cable production

Parylene ribbon cable

3 mm





prototype front-end electronics

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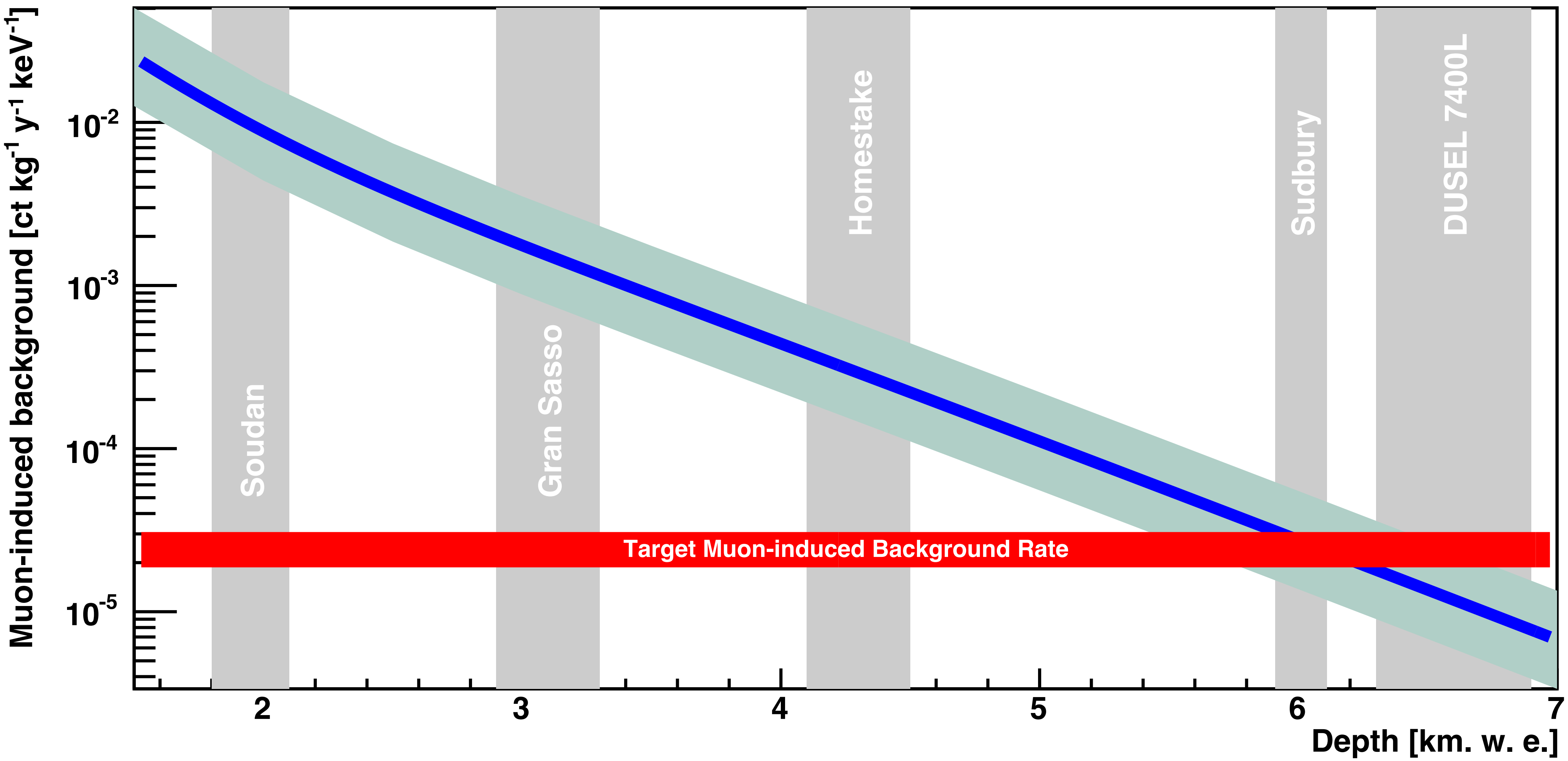
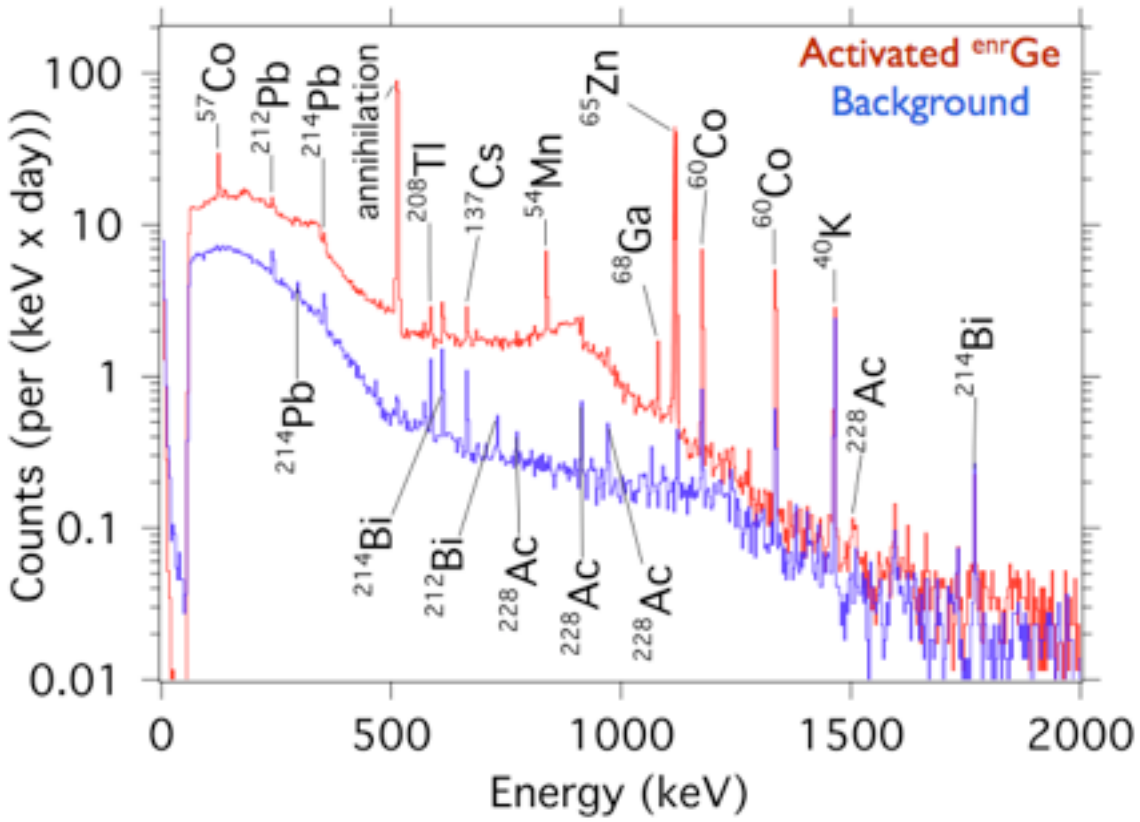
Cosmogenic Backgrounds

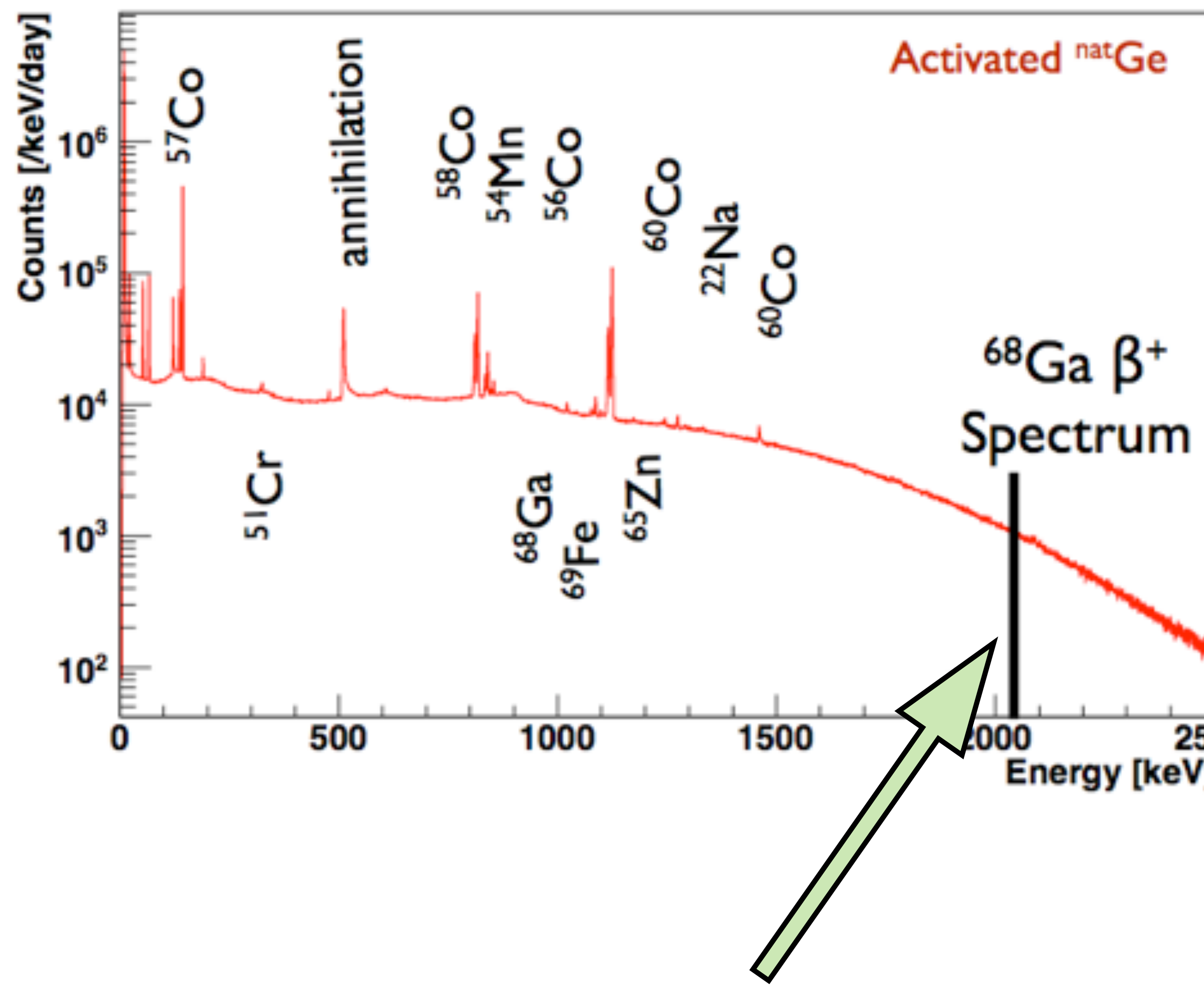
Majorana Depth Requirement



Cosmic-Ray Activation

Activation rate measured by placing a ^{76}Ge sample and a HPGe detector in a high intensity neutron beam (LANSCE)



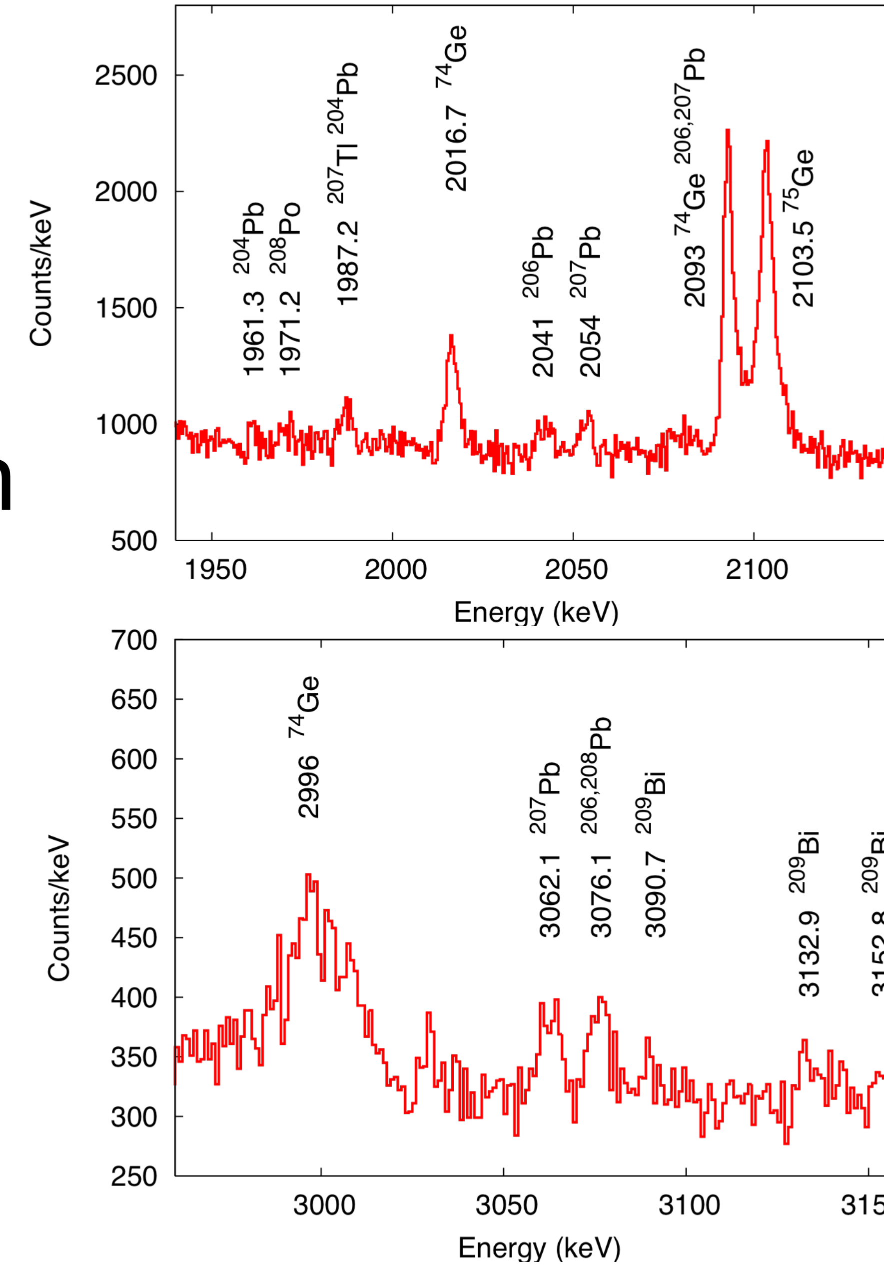


Region of interest for $2\nu\beta\beta$

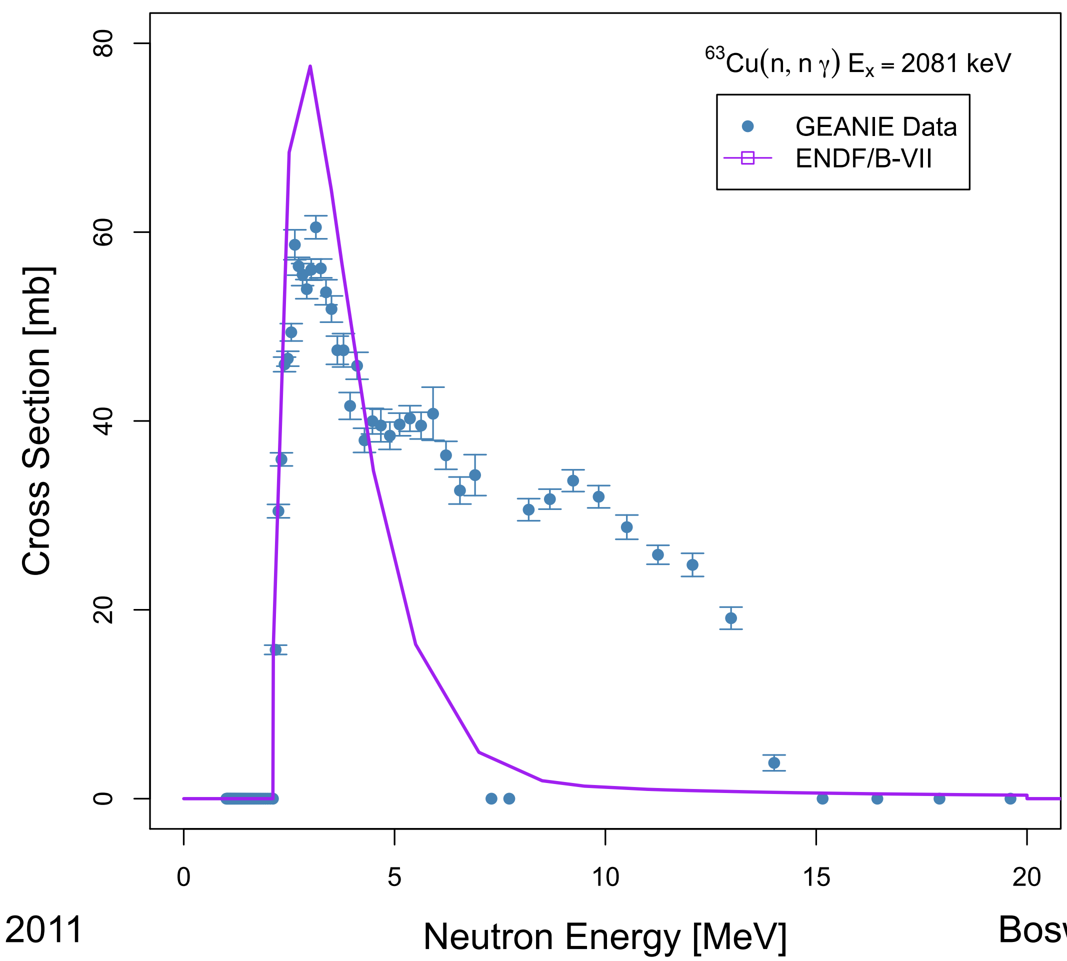
Elliott, S. R., Guiseppe, V. E., Laroque, B. H., Johnson, R. A., & Mashnik, S. G. (2010). Fast-Neutron Activation of Long-Lived Isotopes in Enriched Ge. *Physical Review C*, *82*, 054610.

(n,nγ') Measurements

- Identified specific Pb γ-rays as problematic backgrounds
- Examine the ENDF/B-VII evaluation for Cu
  – Excitation function is overestimated in regions where there is no experimental data

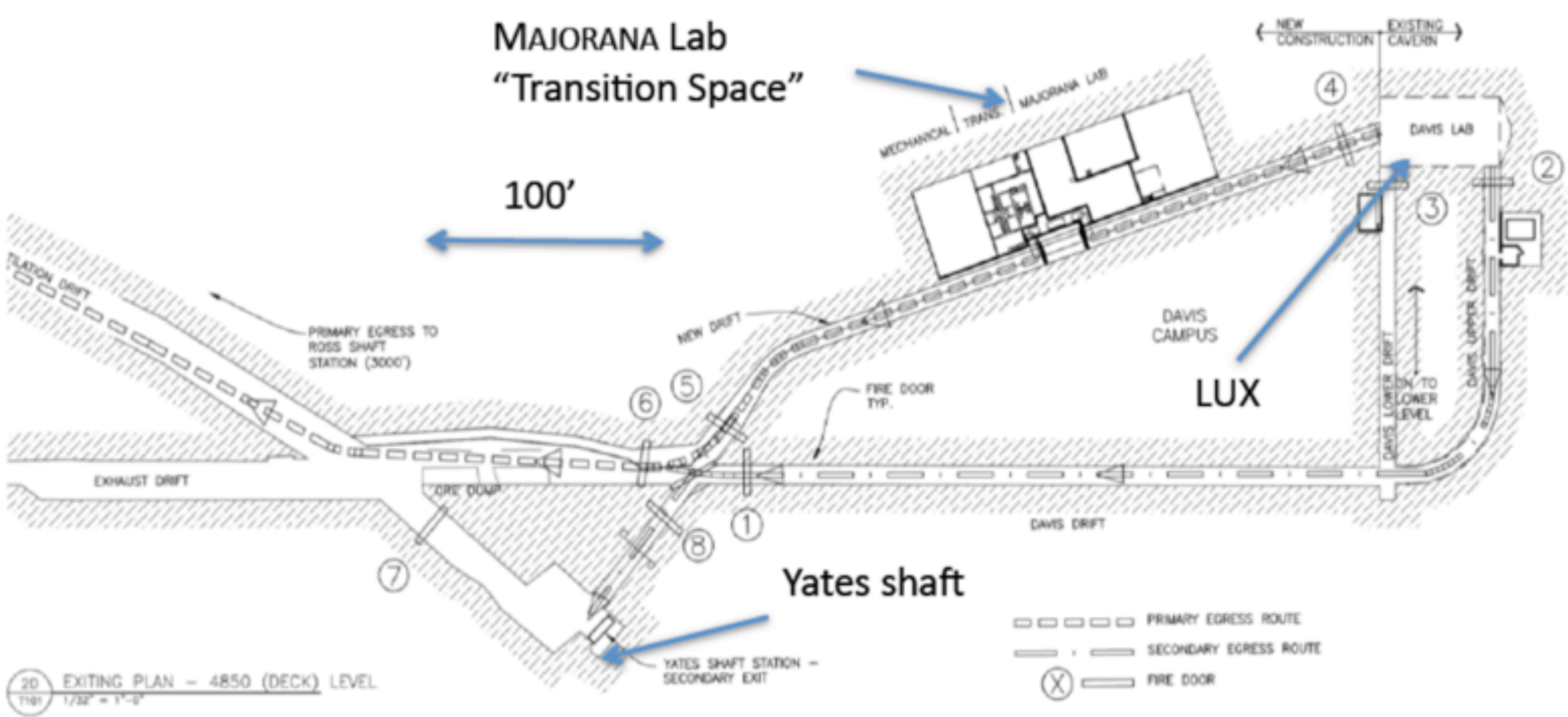


Guiseppe, V. E., Devlin, M., Elliott, S. R., Fotiades, N., Hime, A., Mei, D.-M., et al. (2009). *Physical Review C*, *79*, 054604.



MAJORANA at Sanford

- Copper Electro-forming, detector facilities, and machine shop in one campus at 4850' level (new drift to Davis cavity for LUX)
- Excavation finished--beneficial occupancy soon!
- Temporary lab for Copper Electro-forming near Ross Shaft



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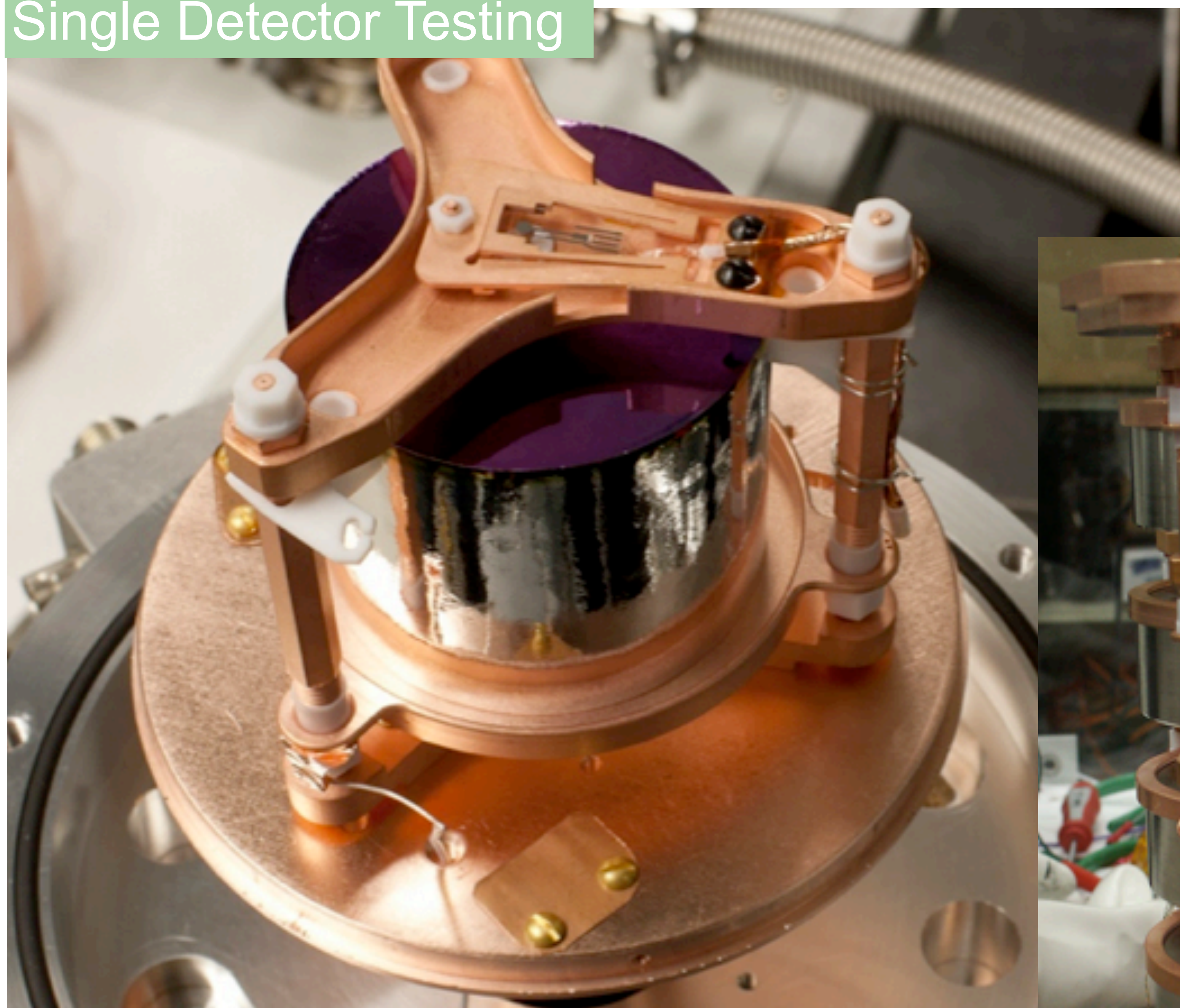
Recent Progress

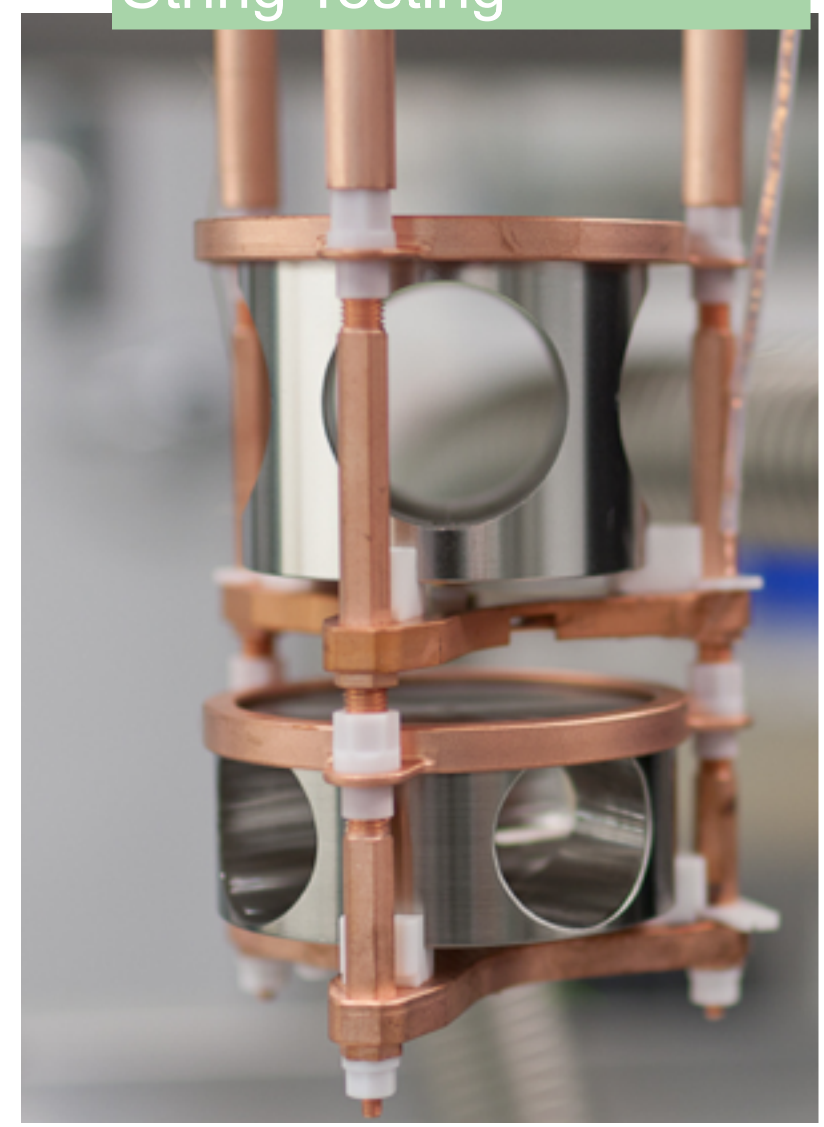
String and detector mounting testing

Single Detector Testing



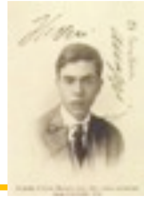
Thermal Test

String Testing



Temporary Clean Room

Underground Detectors



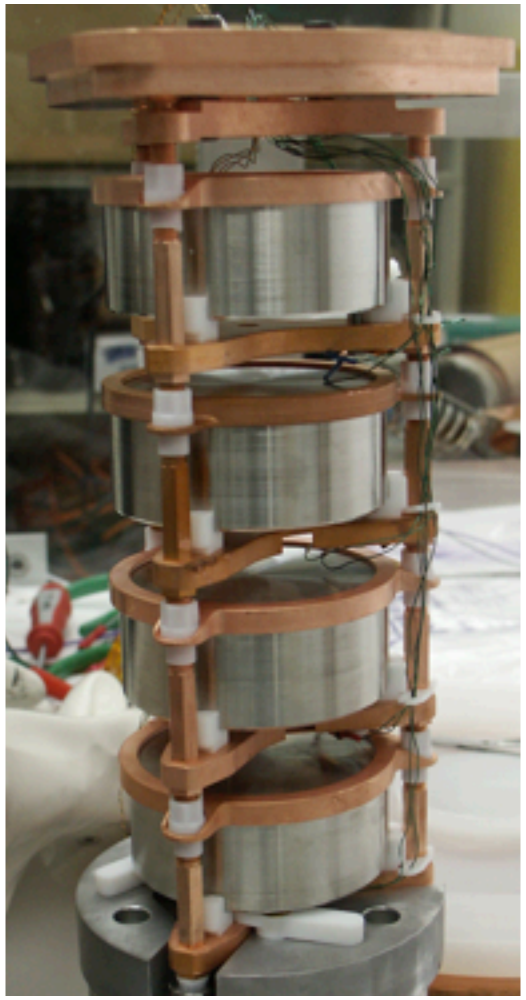
MAJORANA Status

- MAJORANA is an experiment searching for $0\nu\beta\beta$ with an array of Ge detectors
- Construction of the first phase of MAJORANA, the DEMONSTRATOR, is underway
  - Beneficial occupancy of DEMONSTRATOR lab before the early 2012
  - Prototype cryostat by mid 2012
  - First module of enriched detectors by mid 2013

The MAJORANA Collaboration

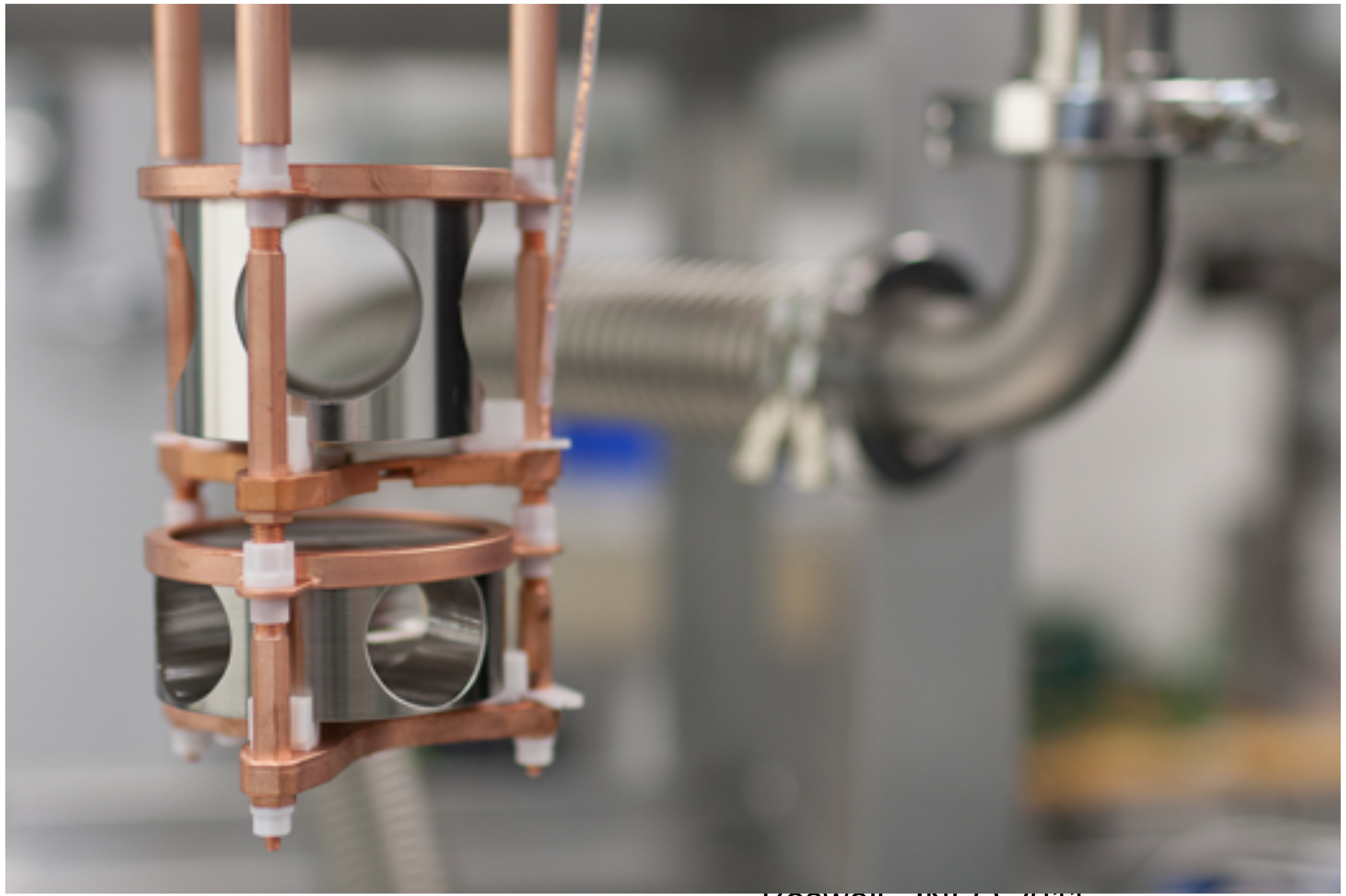
Thermal Tests

- Heat load model has been created
- Thermal and mechanical tests of detector string design are ongoing



Electronics String Test

- Test electronics in a detector string configuration



Mass Sensitivities