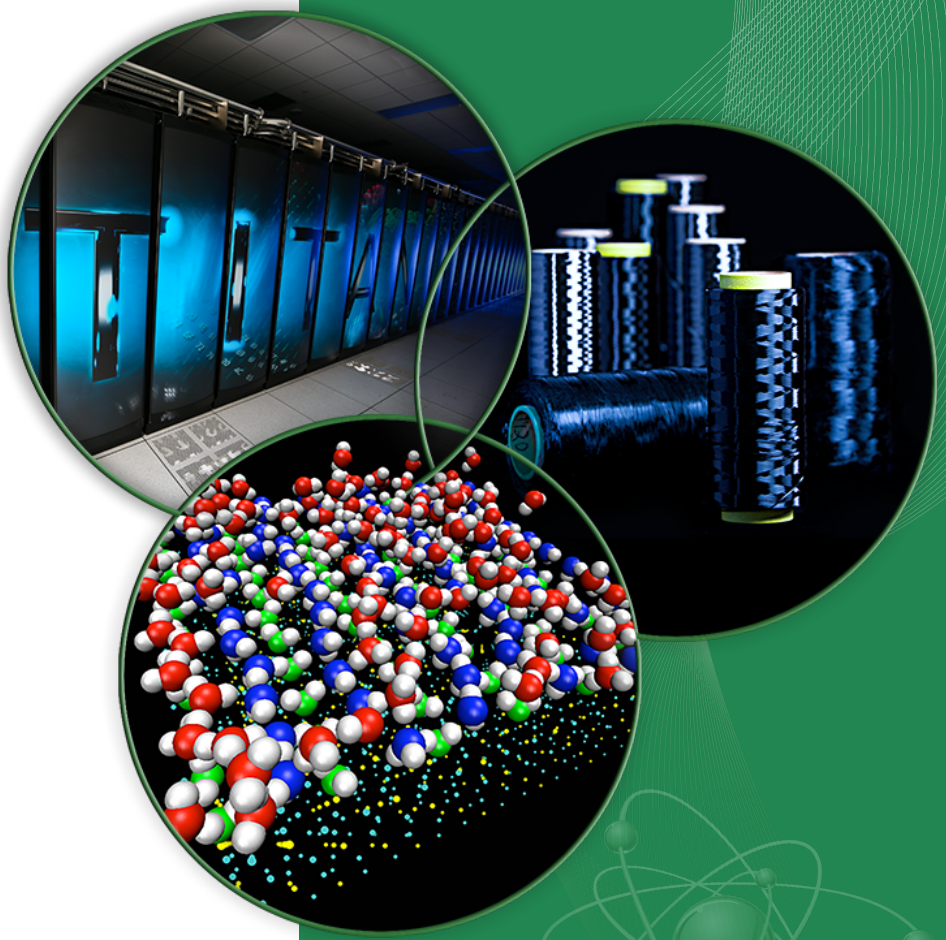
Germanium for COHERENT at the SNS

Matthew Green

ORNL

for the COHERENT Germanium Working Group



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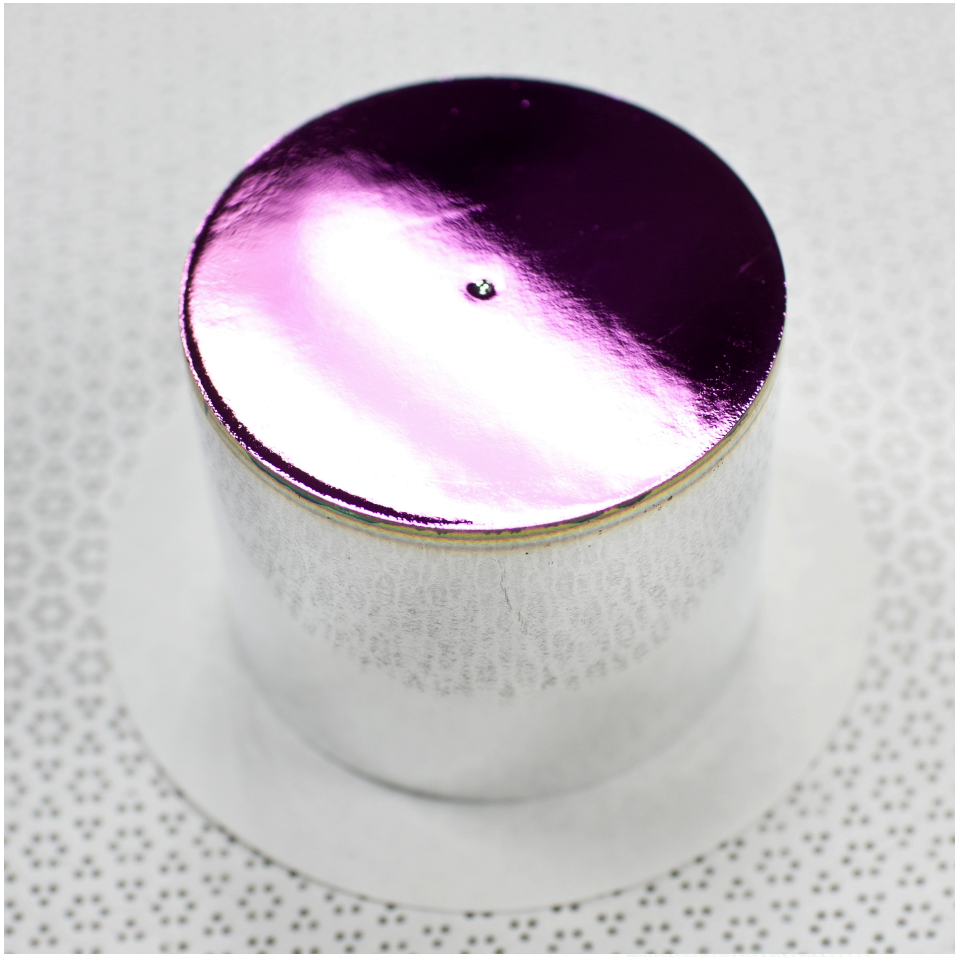
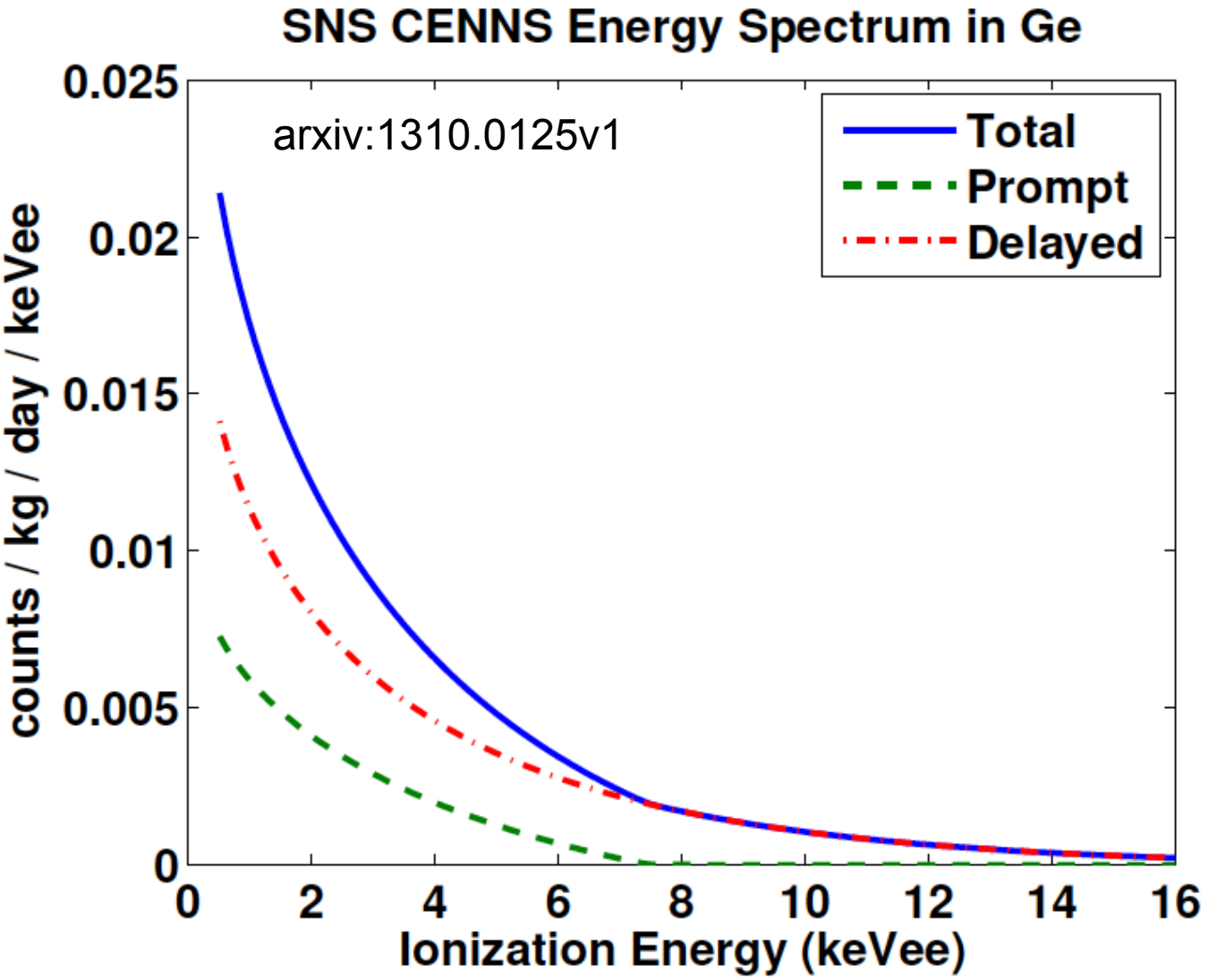
Coherent ν scattering in Ge - PPCs

- A ~ 73, Z = 32
- Crystalline semi-conductor
- LN-temp operation
- Low-background
- Detector masses: ~0.5-1kg
- Small readout contacts
  - Low noise ➔ < 1keV energy threshold
  - Good energy resolution
- Well-measured quenching factor: 20±1%
- ~10ns/mm drift velocity ➔ Δt_{drift} ~ 1μs

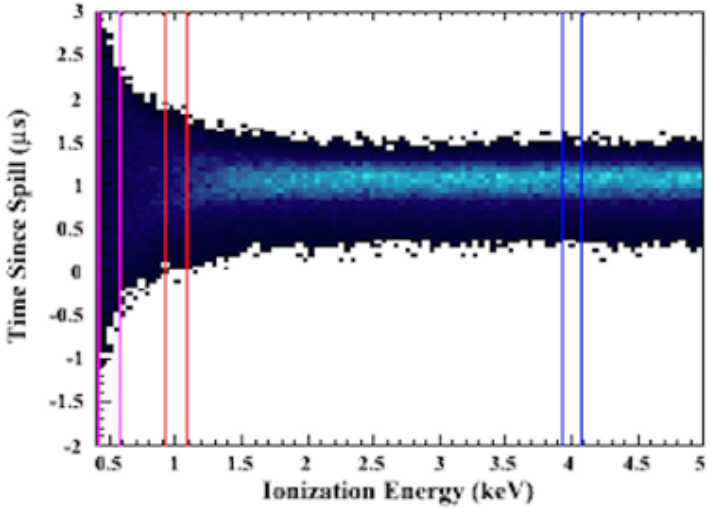


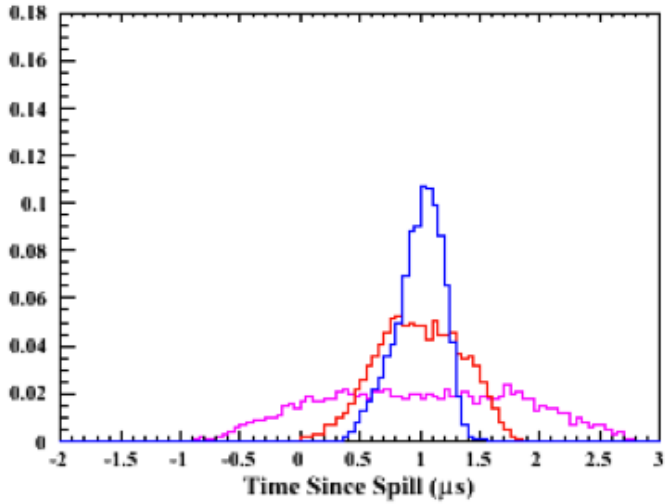
LBL PPC Detector

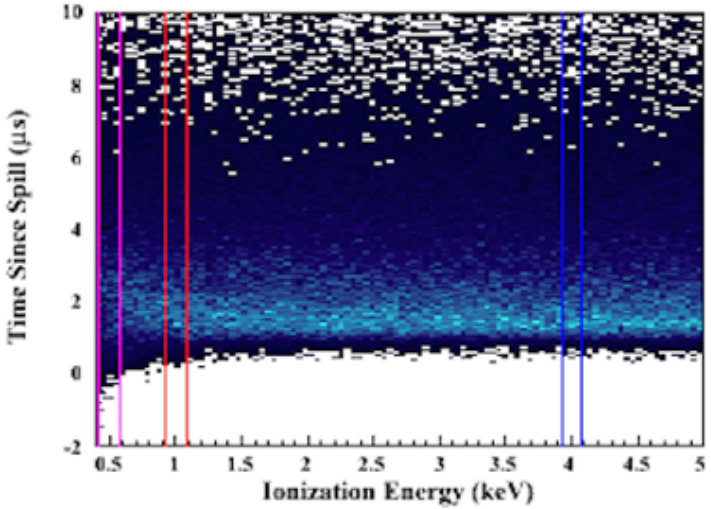
Coherent ν scattering in Ge - PPCs

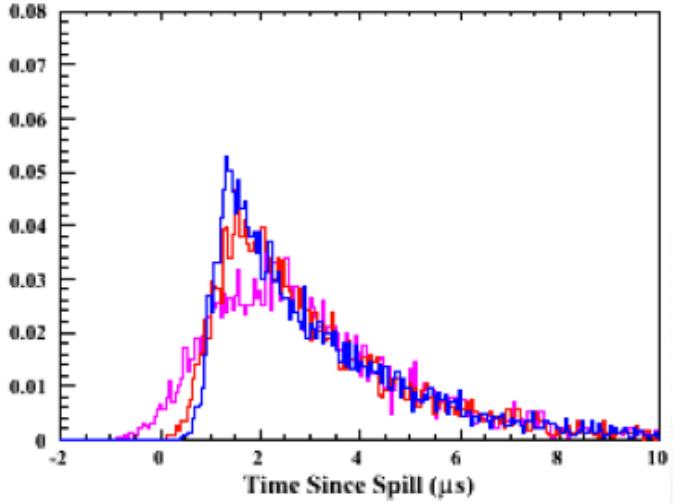


PPC Timing Considerations



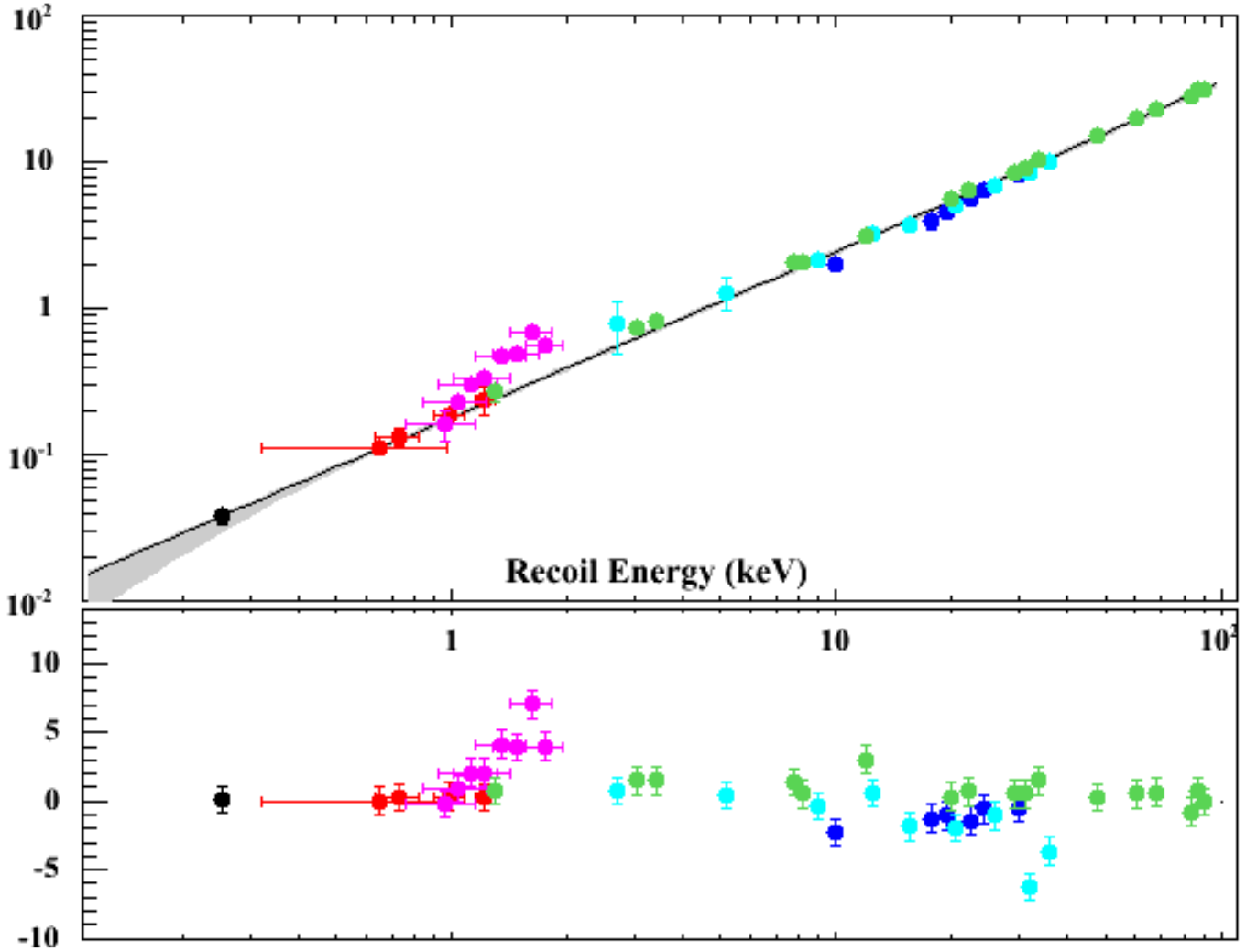






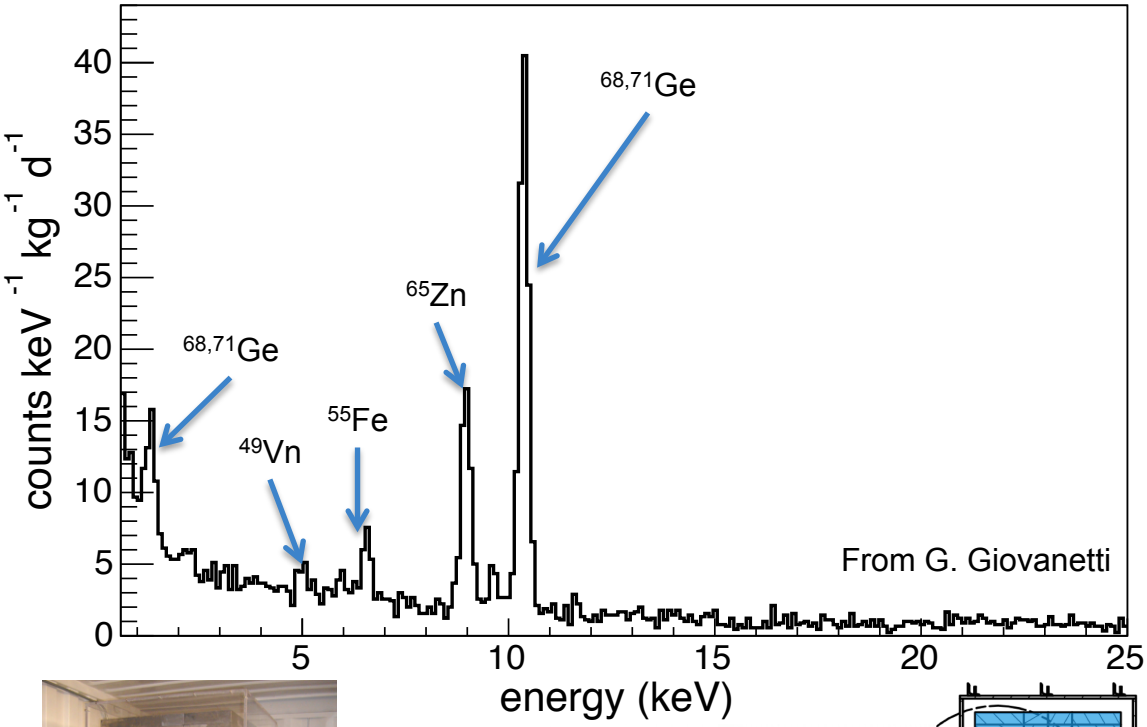
From P. Barbeau

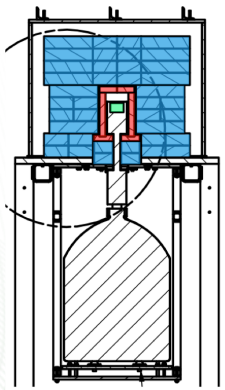
Ge Quenching Factor Measurements



PPC Low-Energy Performance - MALBEK

- Low-background PPC detector at KURF
- 1450 mwe overburden
- Layered shielding
  - 1” ancient lead
  - 8” low-background lead
  - 2” plastic scintillator μ veto
  - 10” polyethylene
- 240eV FWHM @ 10keV
- 600eV analysis threshold
- ~2 cnts/keV/kg/day continuum background





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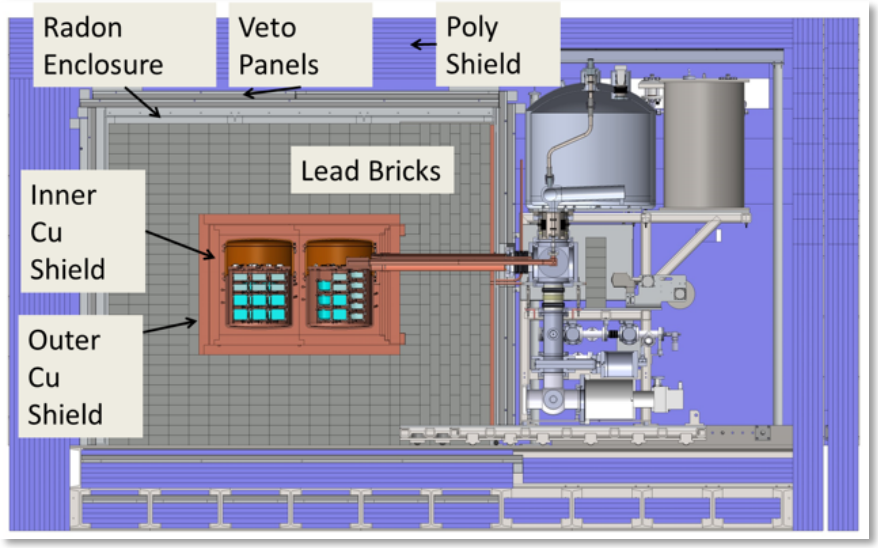
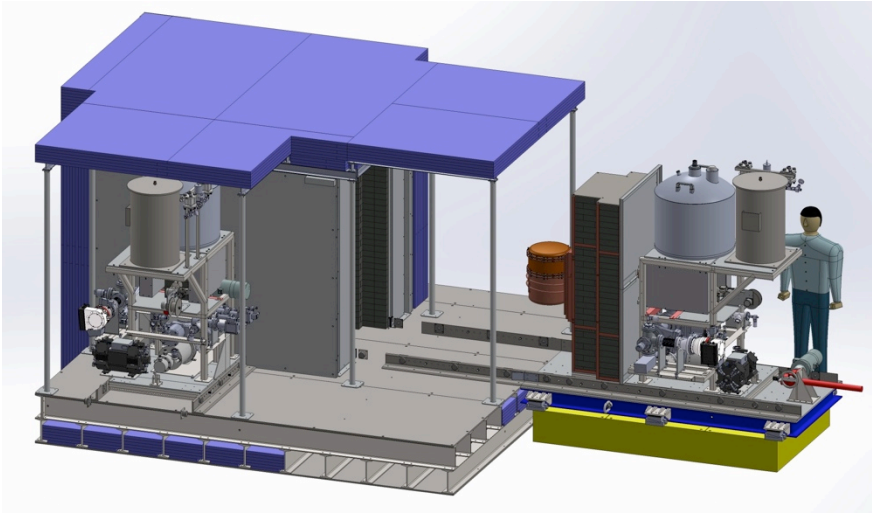
The MAJORANA DEMONSTRATOR: Modular Germanium Detector Arrays

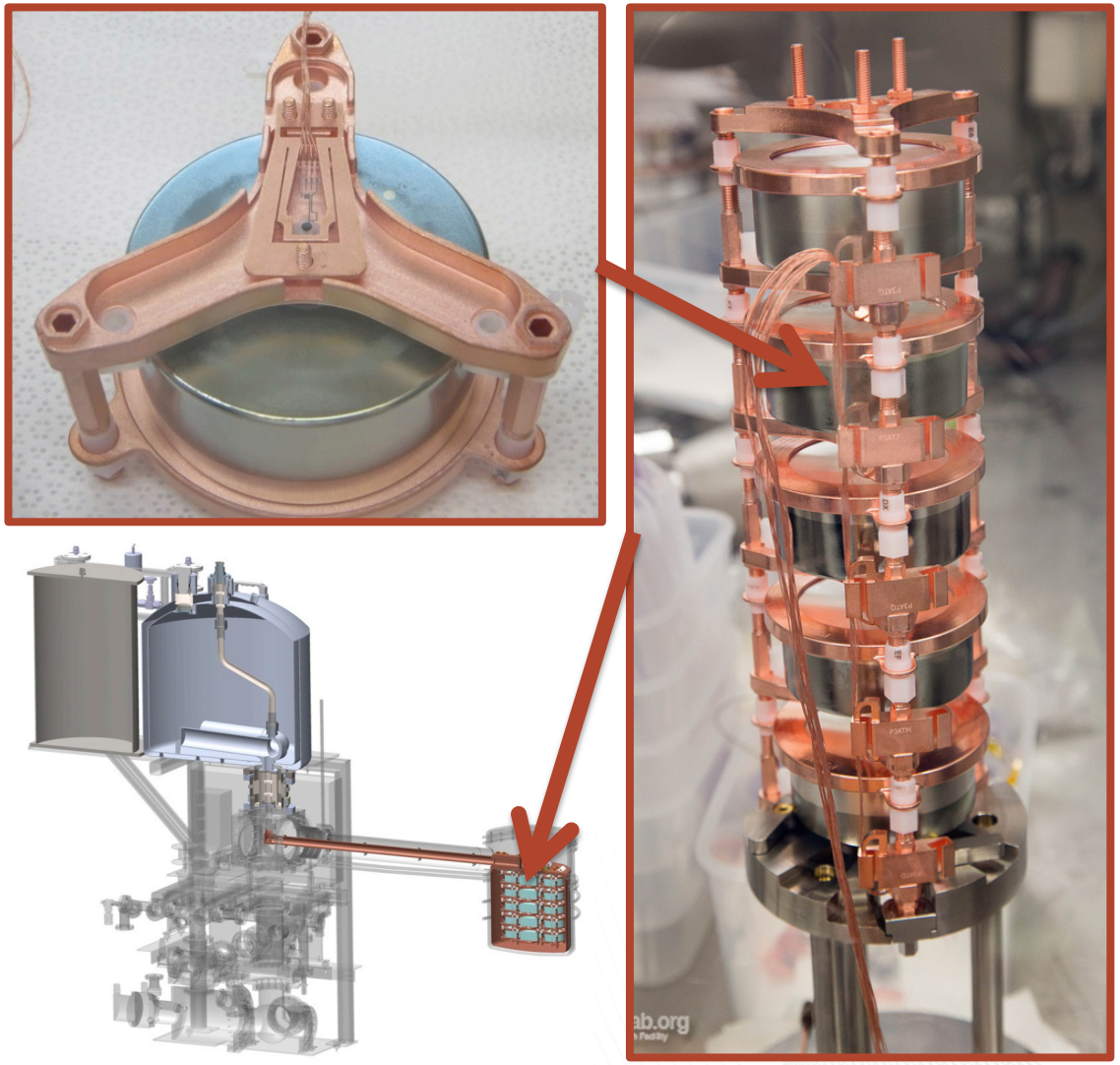
- Search for 0νββ in ^{76}Ge.
- Designed to demonstrate modular, scalable, ultra-low-background Ge array deployment.
- P-type Point-Contact (PPC) detectors
  - Low thresholds enable Single-Site Time Correlated event cut for backgrounds with associated x-ray emission (^{68}Ge K, L-shell).
  - Built upon experience of CoGeNT, MALBEK to search for low-mass WIMPs.





MJD Detector Array Overiew

- Detectors mounted in individual “Detector Units”
- Stacked into “Strings” of 4-5 detectors
- Up to 7 strings installed in Modular cryostats
- MJD to operate 2 modular arrays inside of compact Cu / Pb / Poly shield



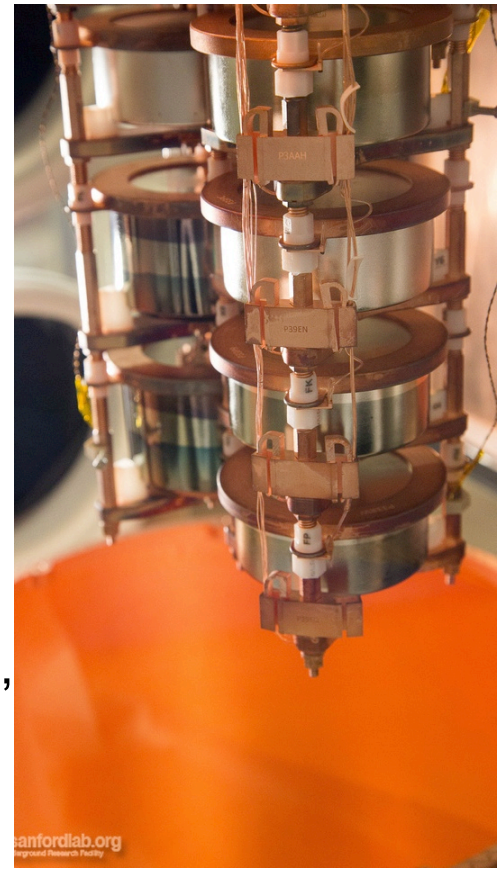
MJD Detector Units

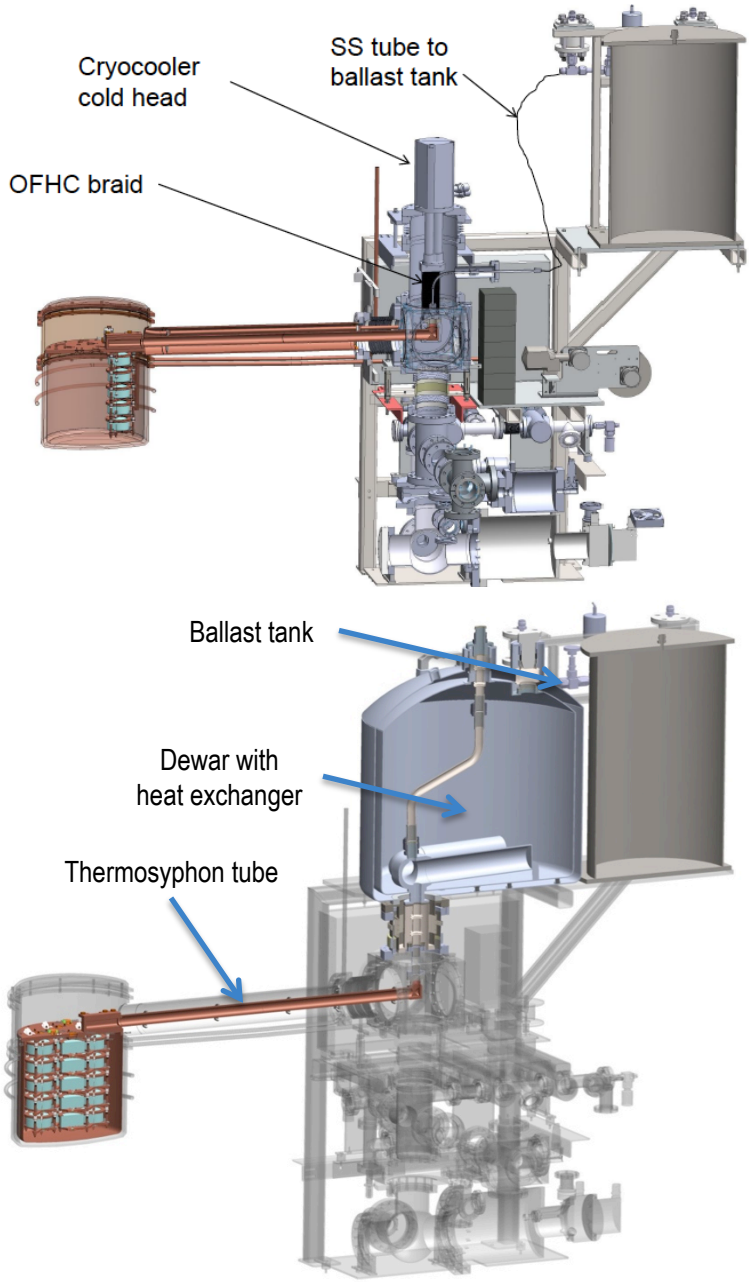
- Low mass PPC detector mounting structure
- Copper and PTFE construction
- Low-Mass Front End (LMFE) electronics assembly
- Adaptable to a range of form factors:
  - Diameters: 25 – 65mm
  - Heights: 50 – 77mm

Canberra BEGe PPC detector

MJD Modules

- Capacity: 7 strings, up to 22.5kg
- Form factor driven by compact shielding capability
- Remotely operable
- UHV vacuum system
- Demonstrated operation in 2 cooling configurations:
  - Pulse-tube cooler: relatively inexpensive, tunable, electrically-powered
  - Thermosyphon: low vibration, inherently stable, LN-driven





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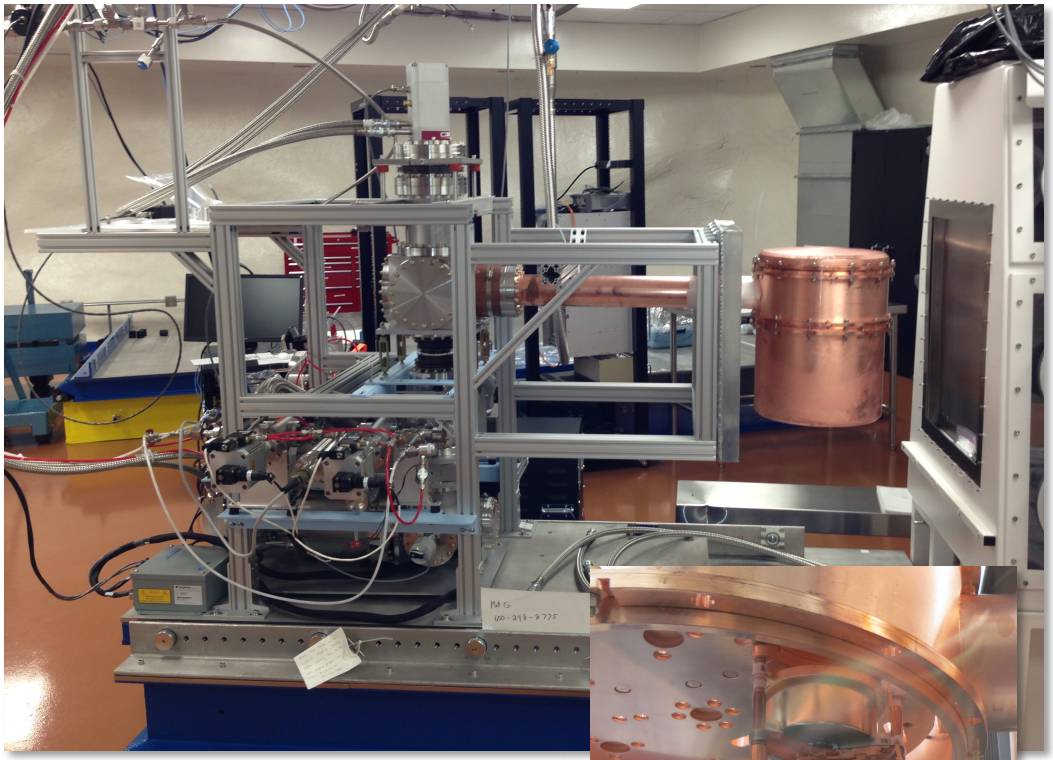
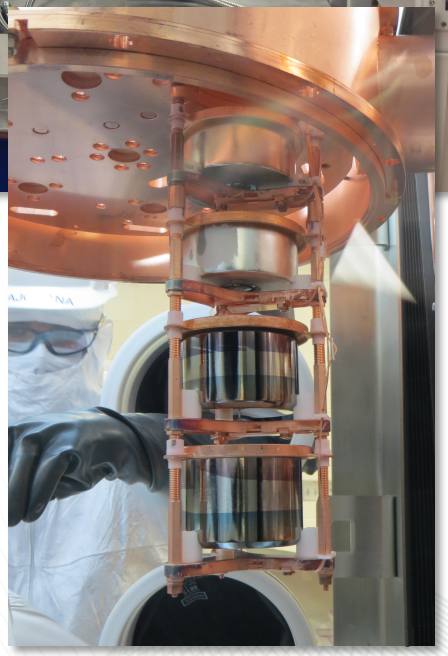
The MAJORANA DEMONSTRATOR Prototype Module

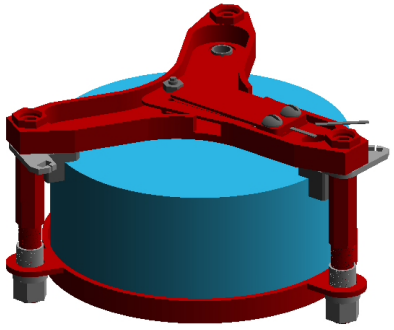
- Full-scale, operational prototype of MJD Modules.
- Commercial copper cryostat, underground since 2012.
- Testbed for MJD:
  - mechanical systems
  - fabrication processes
  - assembly procedures
- Currently operating with 10 installed ^{nat}Ge detectors.
- Internal backgrounds measured
- To be decommissioned Spring 2015.
- Opportunity to redeploy MJD PM at SNS for CEvNS

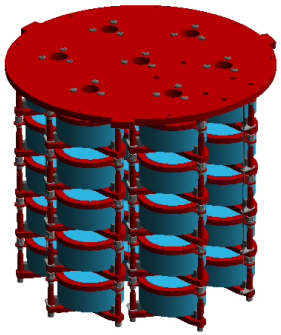


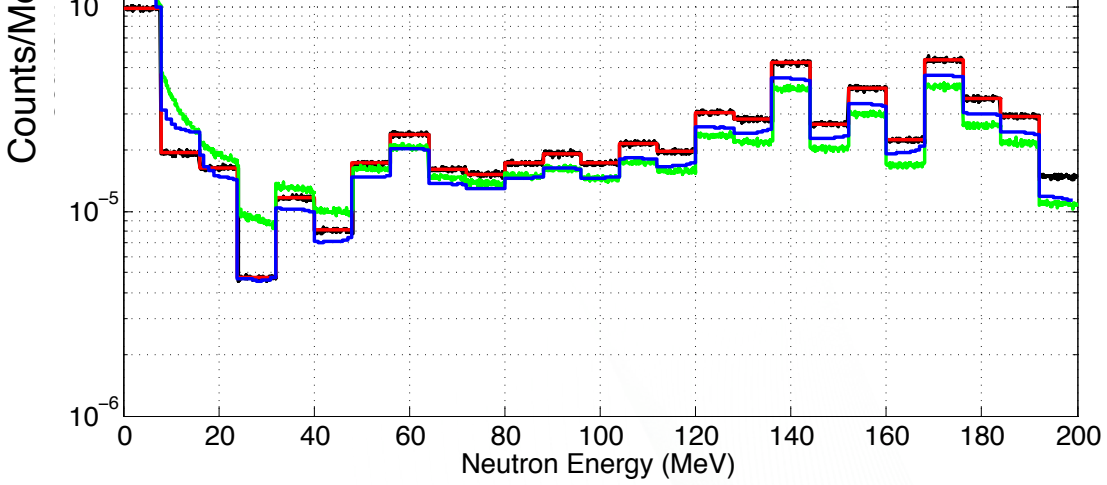


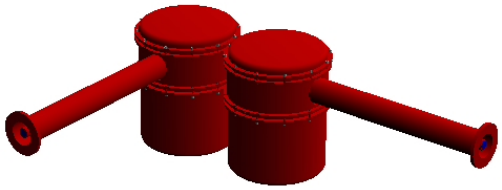
Simulation Tools

- Geant4
- MaGe
  - Jointly developed by MJD/ Gerda
  - Built on G4
  - MJD Cryostats, components already modeled, internal backgrounds estimated.
- MCNP
- Currently performing cross-checks of MCNP / G4 for fast neutron & shielding simulations









From
B. Cabrera-Palmer

Redeployment of MJD PM at SNS

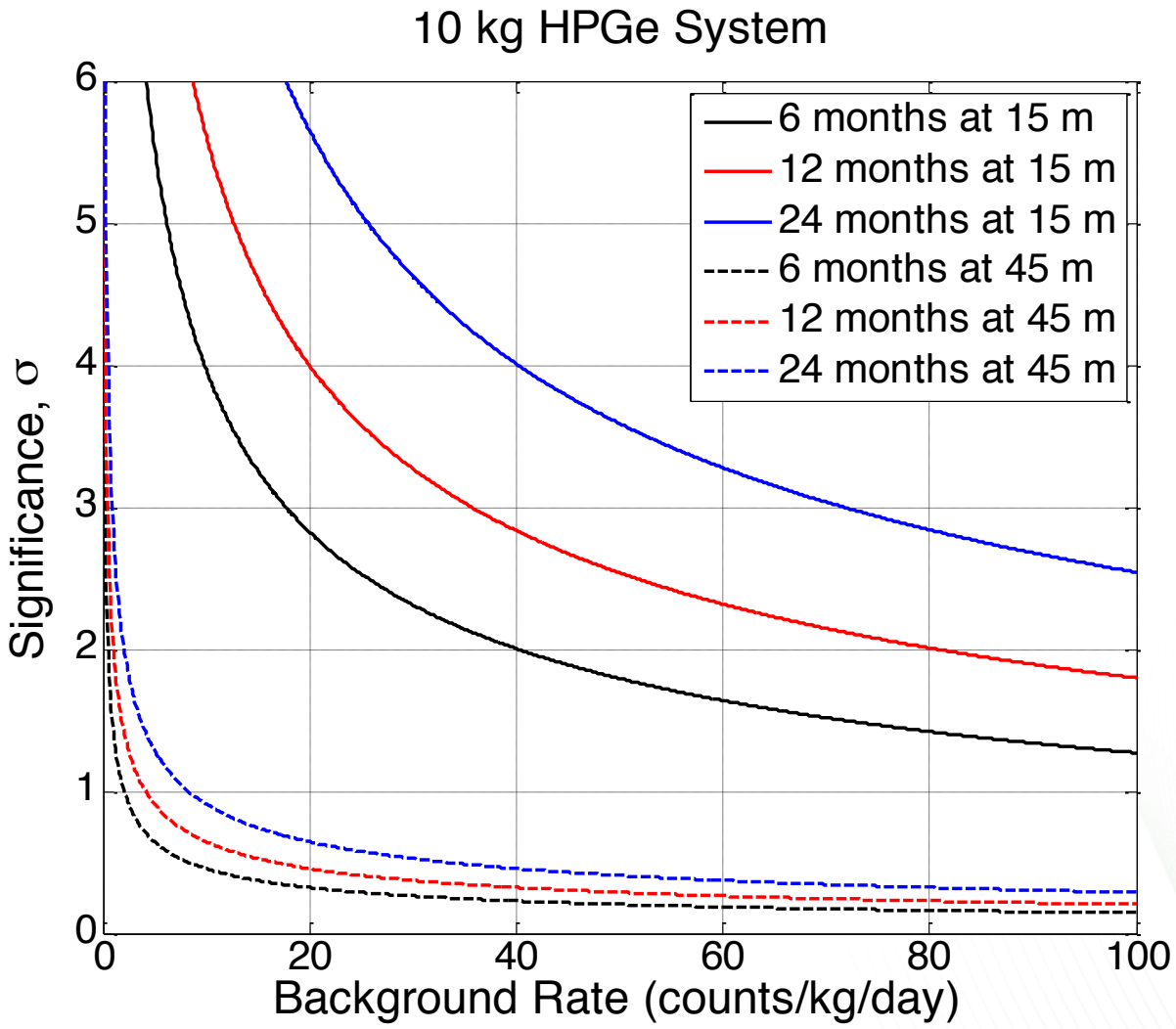
Advantages

- Available cryostat with well-measured internal backgrounds.
- MJD in possession of ~10kg of Ge detectors which could be used.
- Adaptable MJD detector unit design can accommodate detectors from community.
- Little engineering / design work. Can use existing CNC machine code to fabricate new components.
- Can leverage MJD simulation tools.

Drawbacks

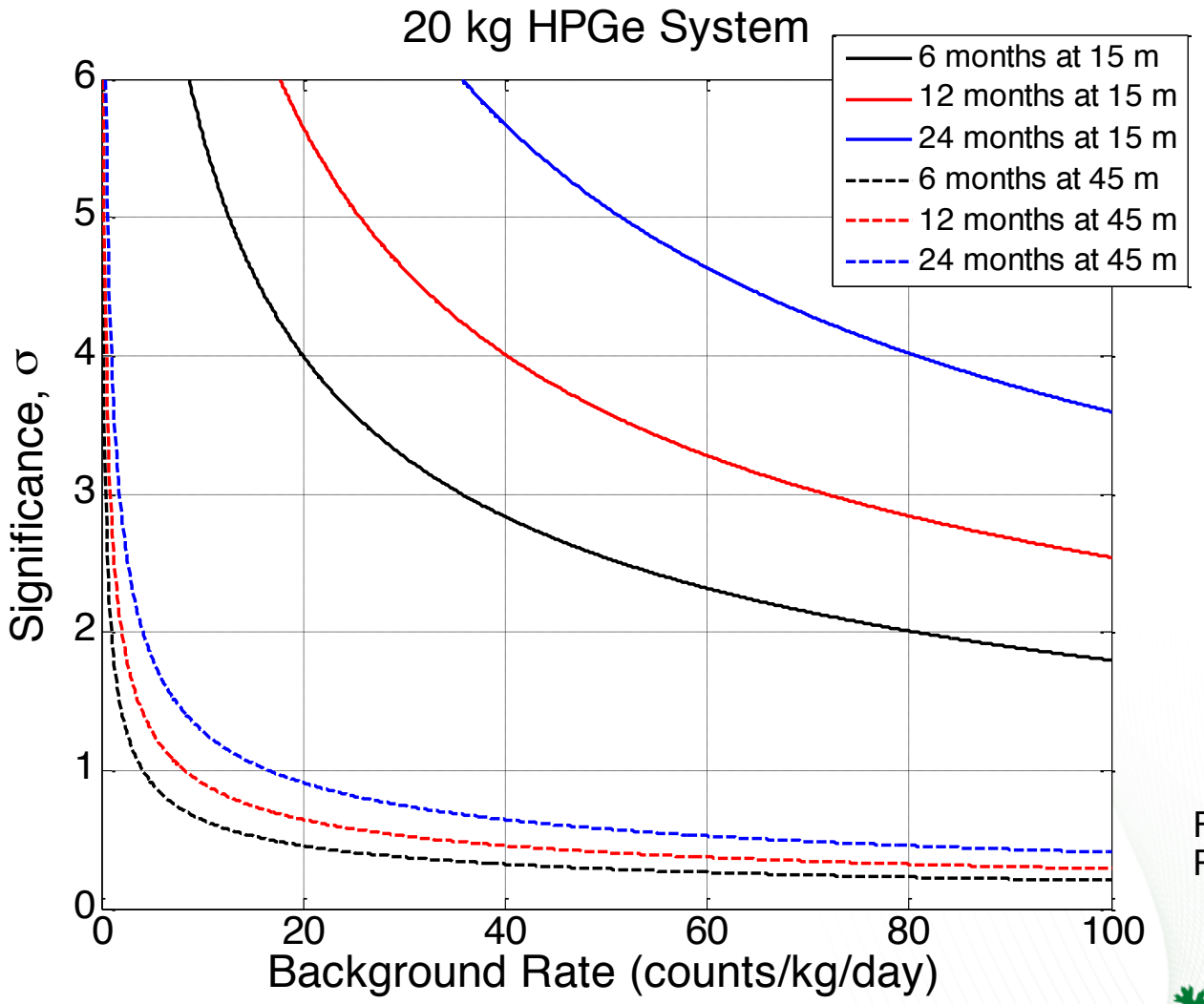
- Significant cost:
  - Vacuum & cryogenic system replacements
  - Detector mounting hardware fabrication
  - Additional Ge detectors?
- Complicated assembly / too fragile to transport ➔ assembly infrastructure required at/near deployment site.
- Ge detectors susceptible to ^{68}Ge and ^{71}Ge activation in high neutron flux environments.

Sensitivity with detectors on-hand: 10kg



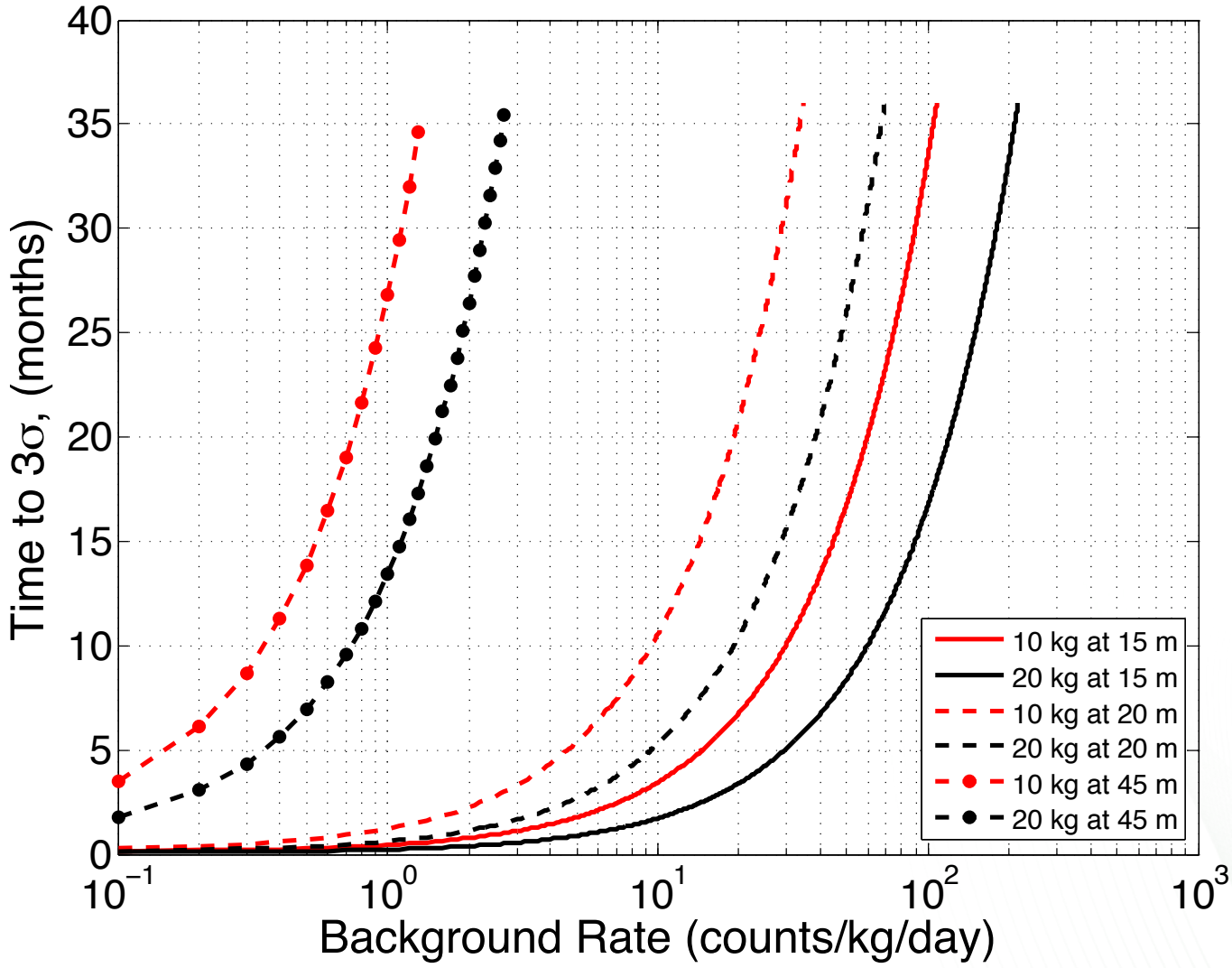
From
R. Cooper

Sensitivity with full MJD Cryostat: 20kg



From
R. Cooper

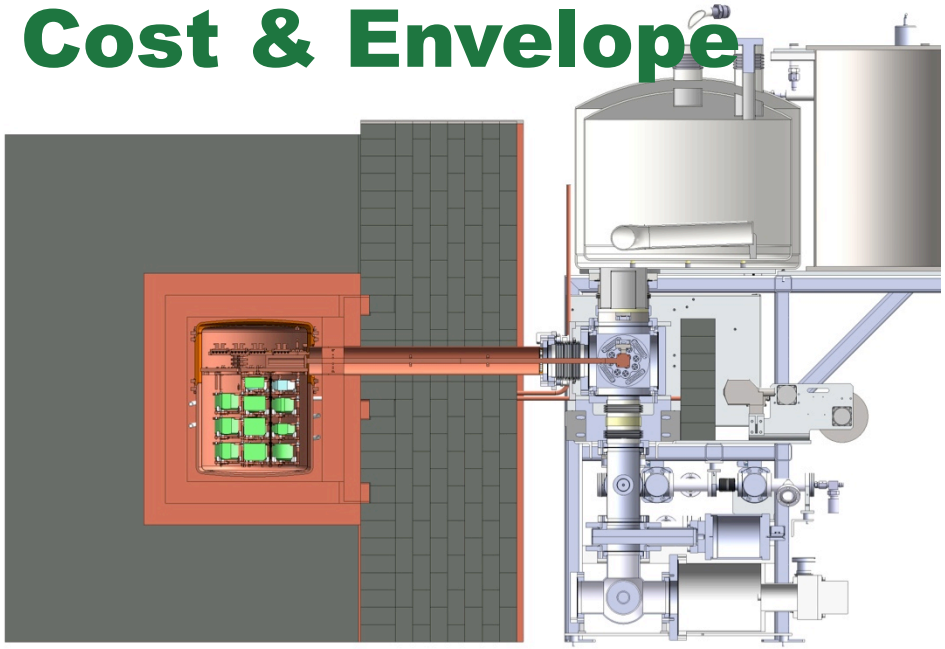
Time to 3σ

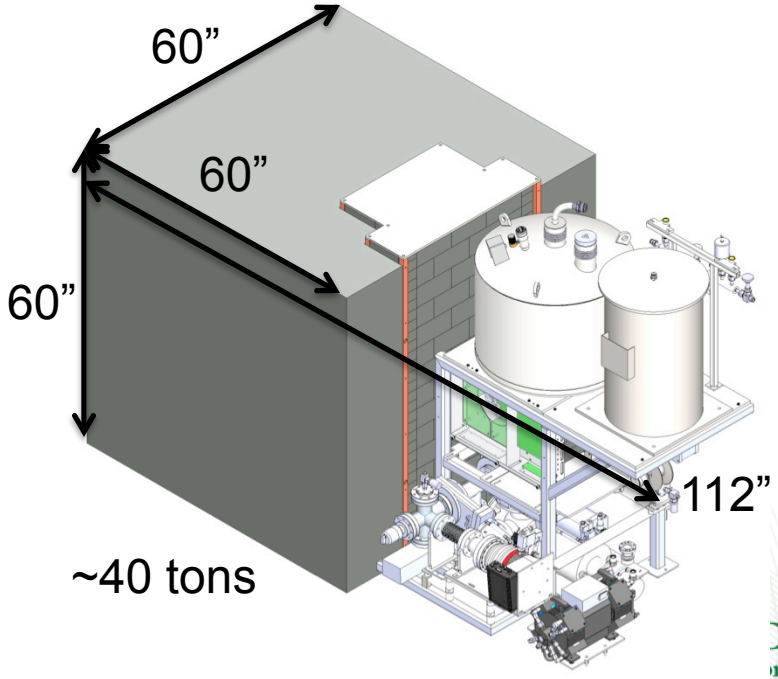


From
R. Cooper

20kg in MJD Module Cost & Envelope

- Detectors: 35 for $1.05M
- String hardware: $200k
- Back-end electronics: $52k
- Power supplies: $4k
- Front-end electronics: $50k
- DAQ / Digitizers: $150k
- Module vacuum: $190k
- Pulse-tube cooler system: $32k
- -or- Thermosyphon system: $85k
- Assembly glovebox: $140k
- Shielding: 5” Cu + 16” Pb -> $230k (material) + $25k machining





Time to 3σ