Design of a low background cryostat for a 1.3 kg, low-noise, high purity germanium gamma-ray spectrometer

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HAWAII 2014 Presenter – John L. Orrell

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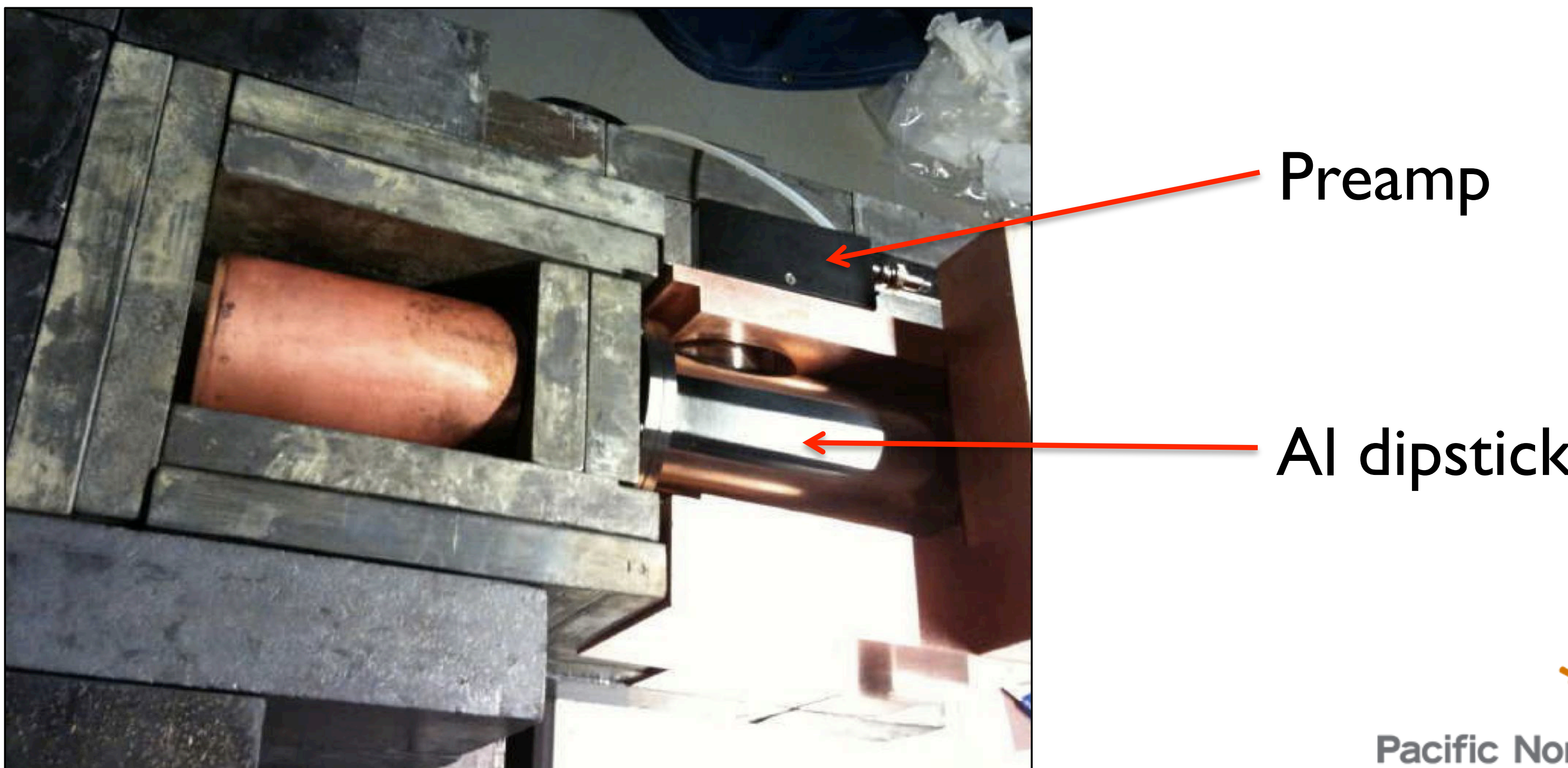
Outline

- Impetus → CoGeNT/Dark Matter
- Background considerations → Front-end sets background
- Initial cryostat design
- Fabrication
- Thermal testing
- Thermal model
- Detector integration
- Preliminary detector performance
- Thoughts on improvements
- Thoughts on low background counter design

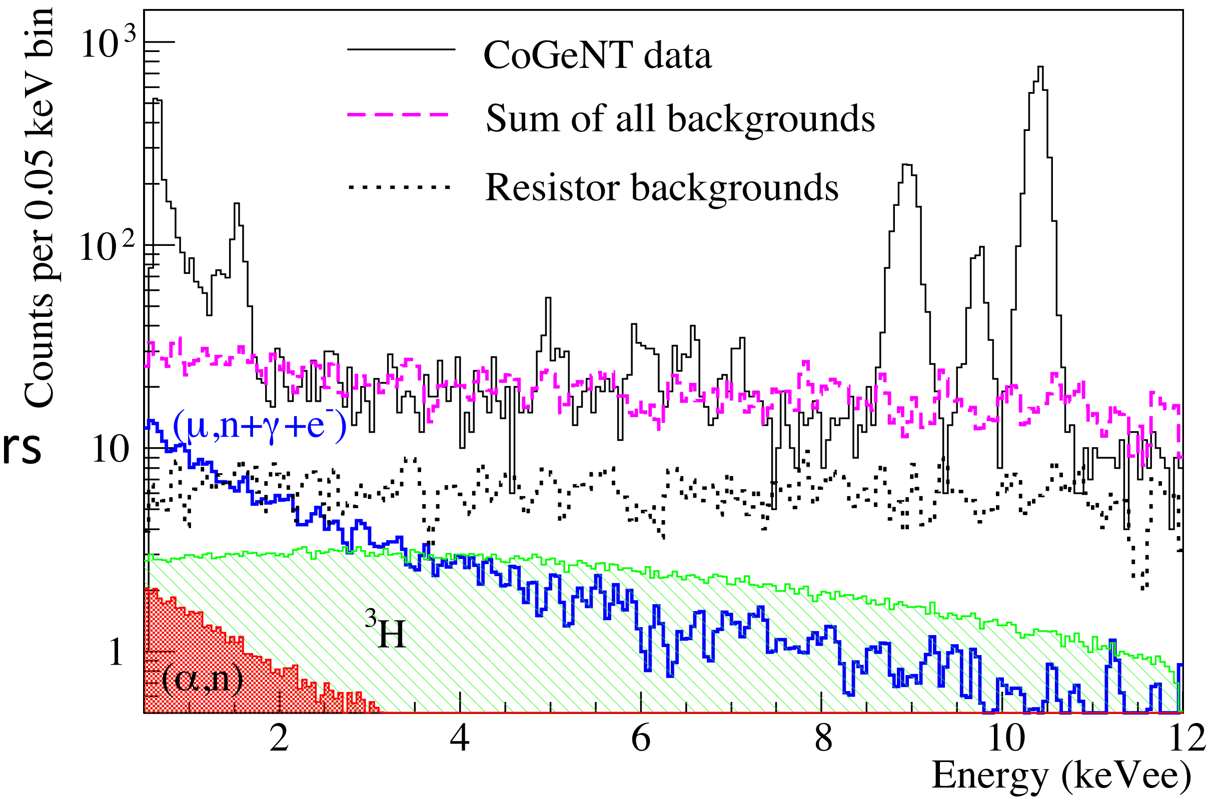
Impetus for a new cryostat design
(circa summer 2012)

- Desire to test CoGeNT dark matter results with new detectors having:
  - Lower background ~5-10× (to ~1 count/keV/kg/day)
  - Lower energy threshold ~2-5× (to ~100 eV)
  - Larger mass ~3× (to 1.25 kg)



Background considerations for new cryostat

- CoGeNT background dominated by front-end read-out
  - Contains multiple resistors
    - 1 for read-out
    - 1 for heating the FET



- New design anticipated using same front-end (for low-energy threshold) but without heater resistor
- Implications:
  - Front-end will still dominate background
  - Use a mixture of OFHC and electroformed copper "as convenient"
  - Otherwise, employ all low-background best practices.

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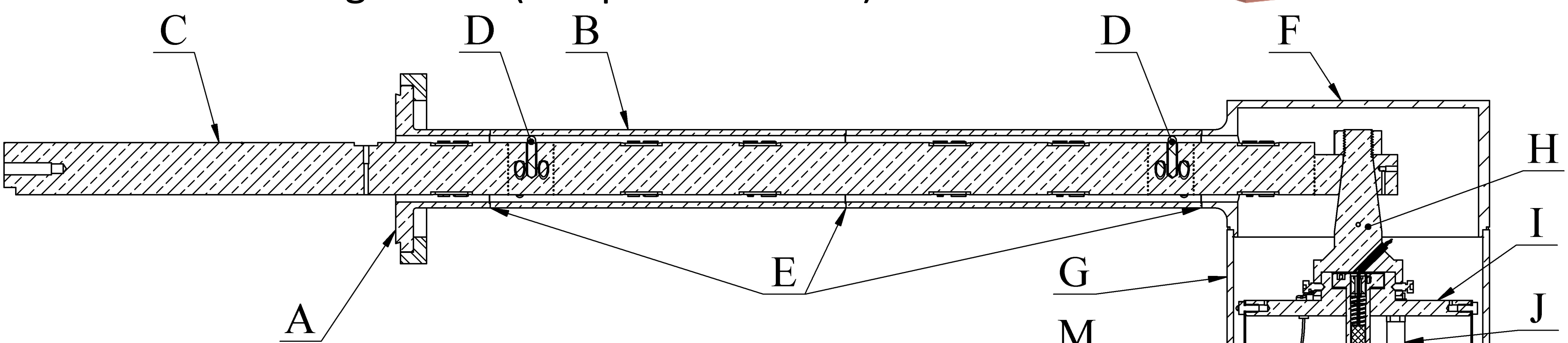
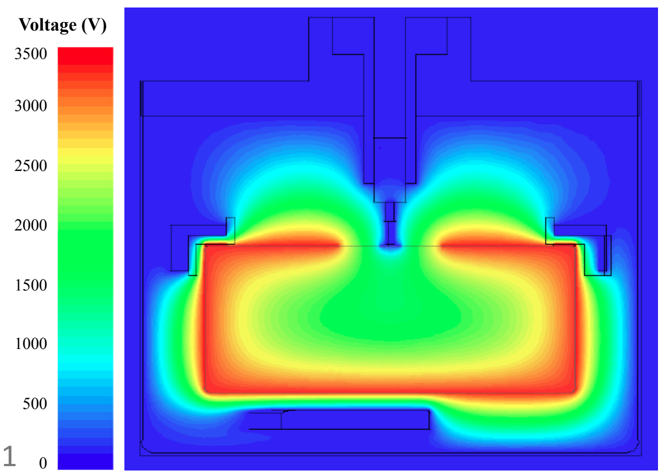
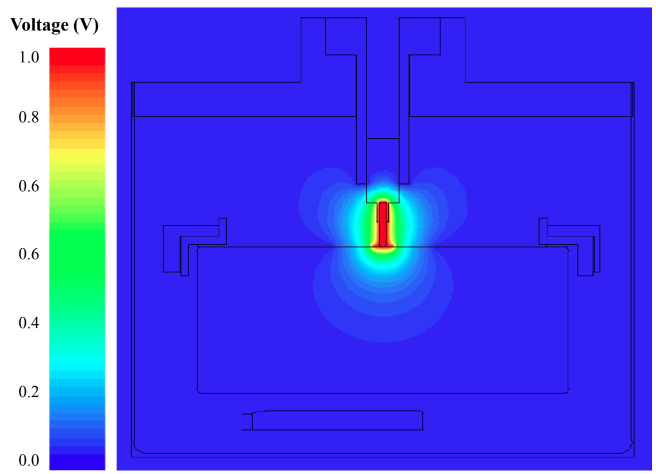
Initial cryostat design and thermal model

- Areas of design focus:
  - Field modeling for low capacitance
  - Thermal modeling for low crystal temperature
  - “Low-background” (see previous slide)

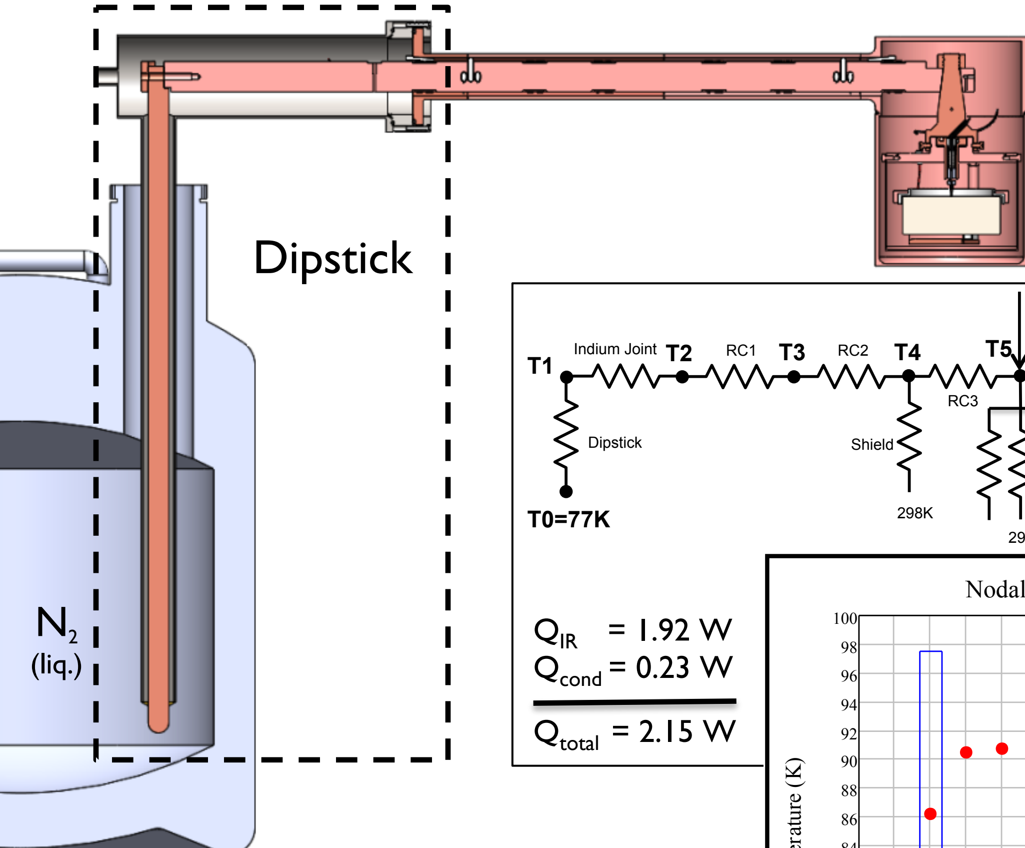


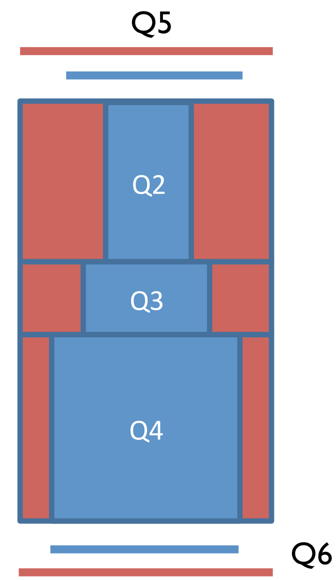


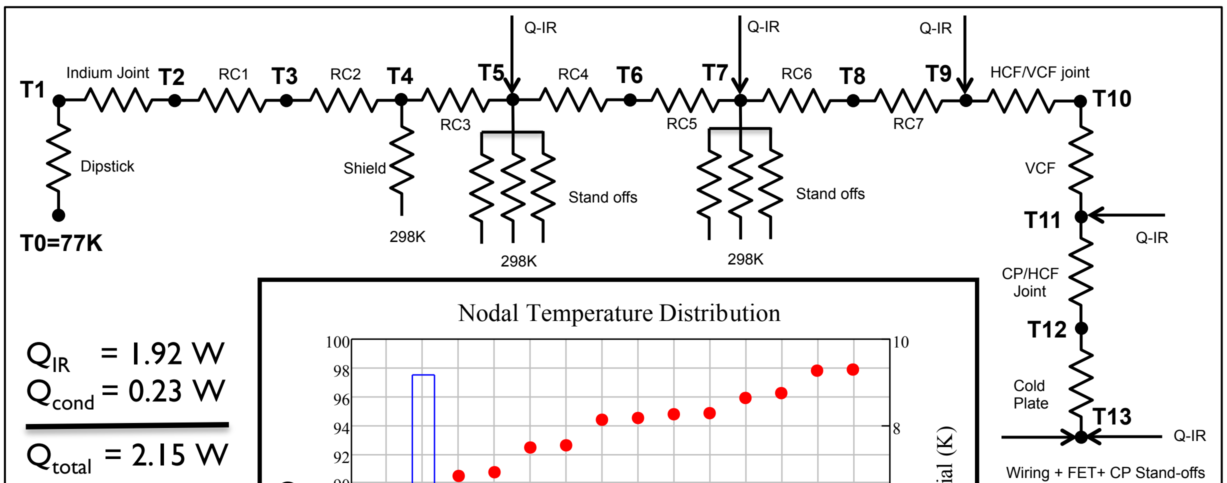


Initial cryostat thermal model

- Simplified “by hand” calculation

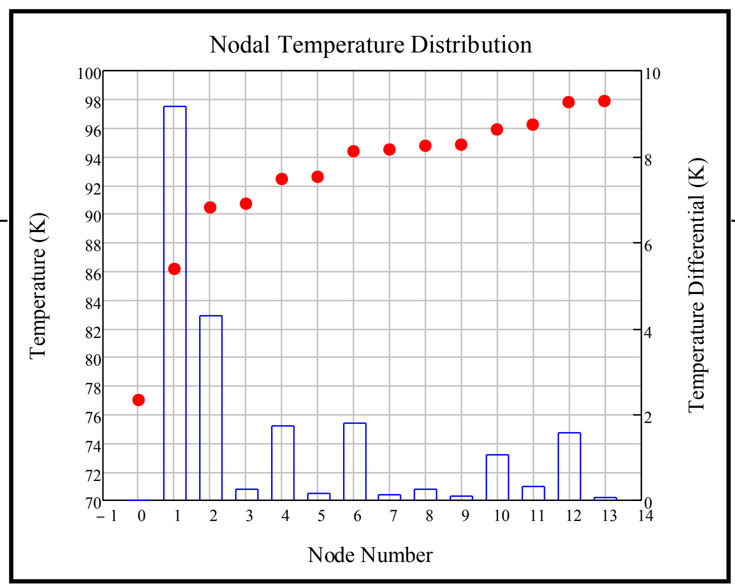






Q_{IR} = 1.92 W
Q_{cond} = 0.23 W

Q_{total} = 2.15 W



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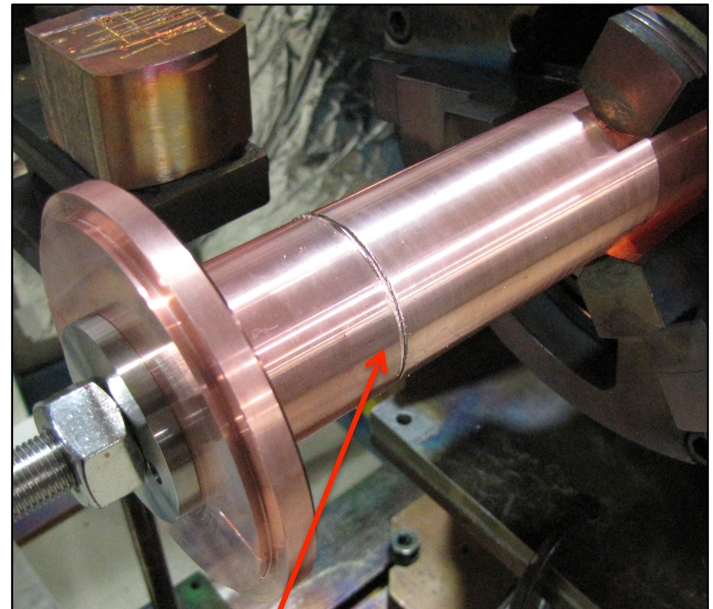
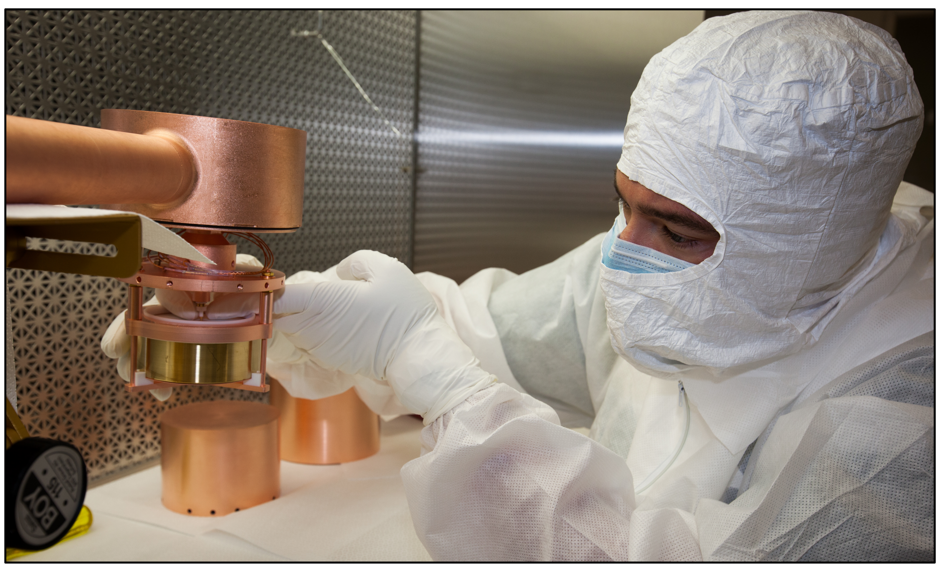
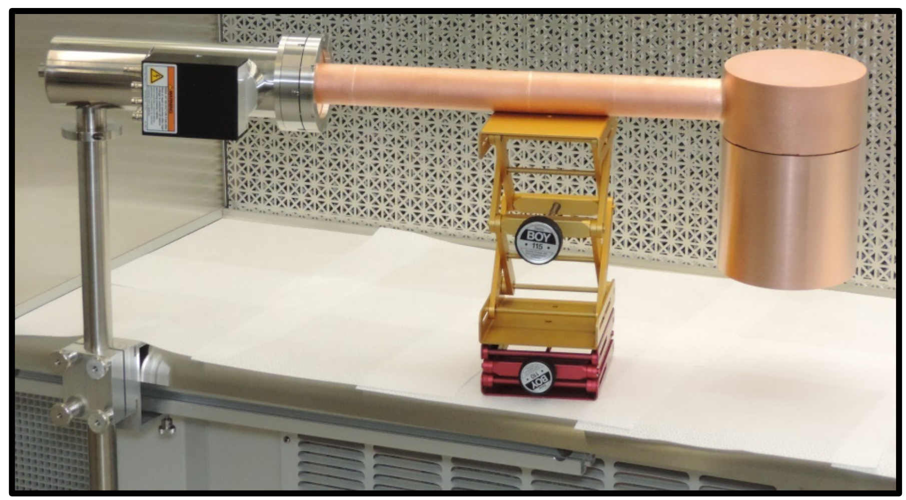
Fabrication



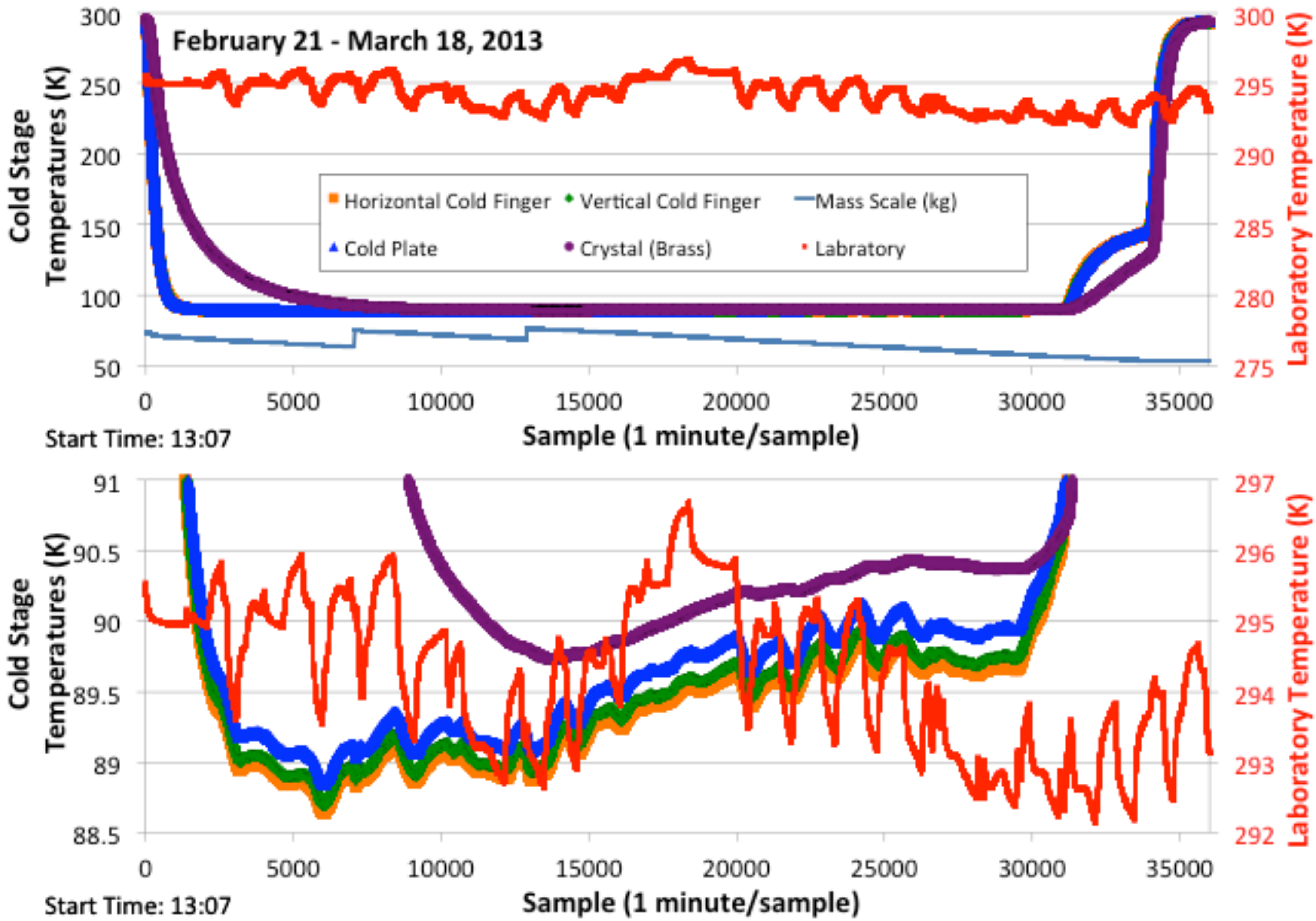
- Electroformed copper:
  - End cap and crystal IR shield
- OFHC copper everywhere else
- E-beam welds to make cross-arm vacuum jacket
- All copper etched and passivated
- Limited use of PTFE as crystal mount/HV stand-off





Thermal testing

Thermal testing



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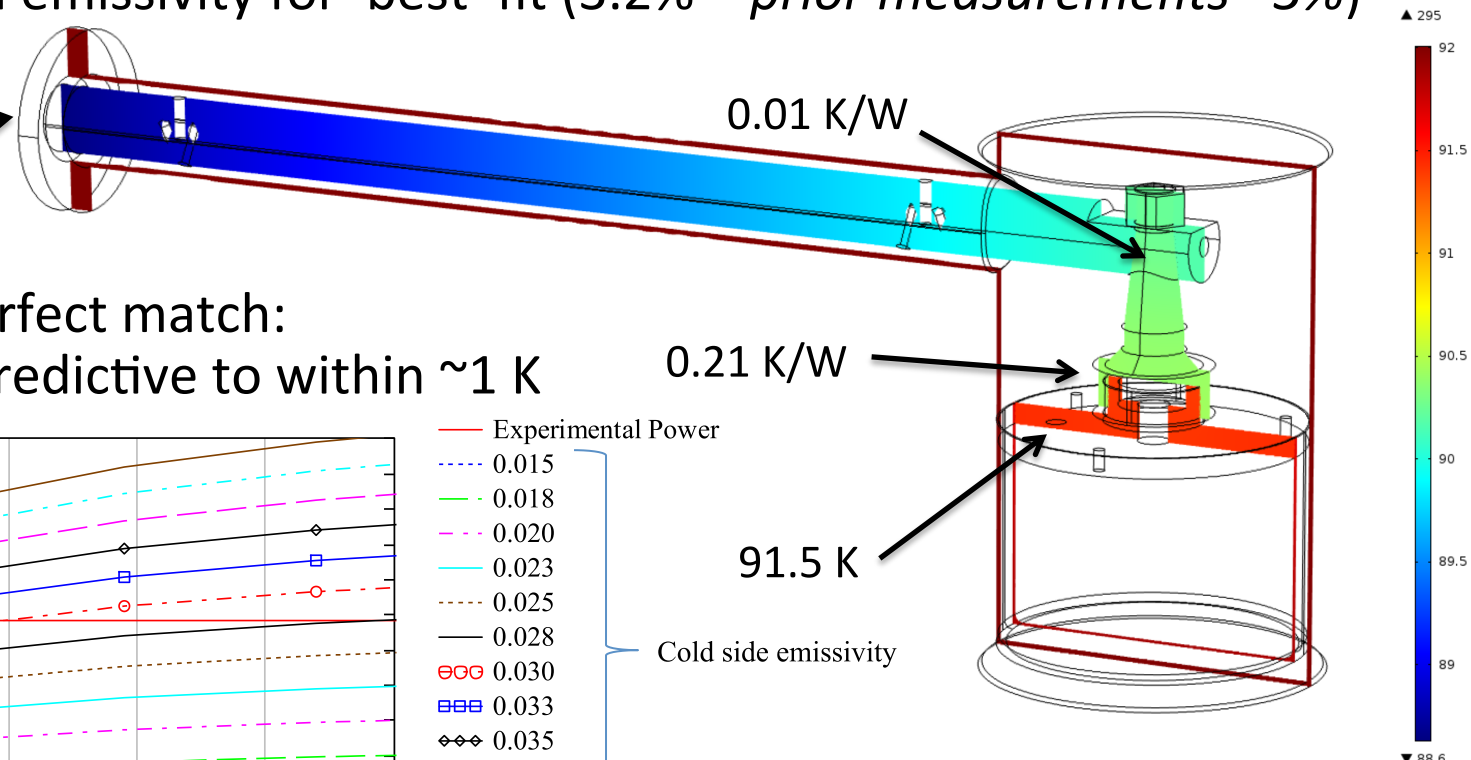
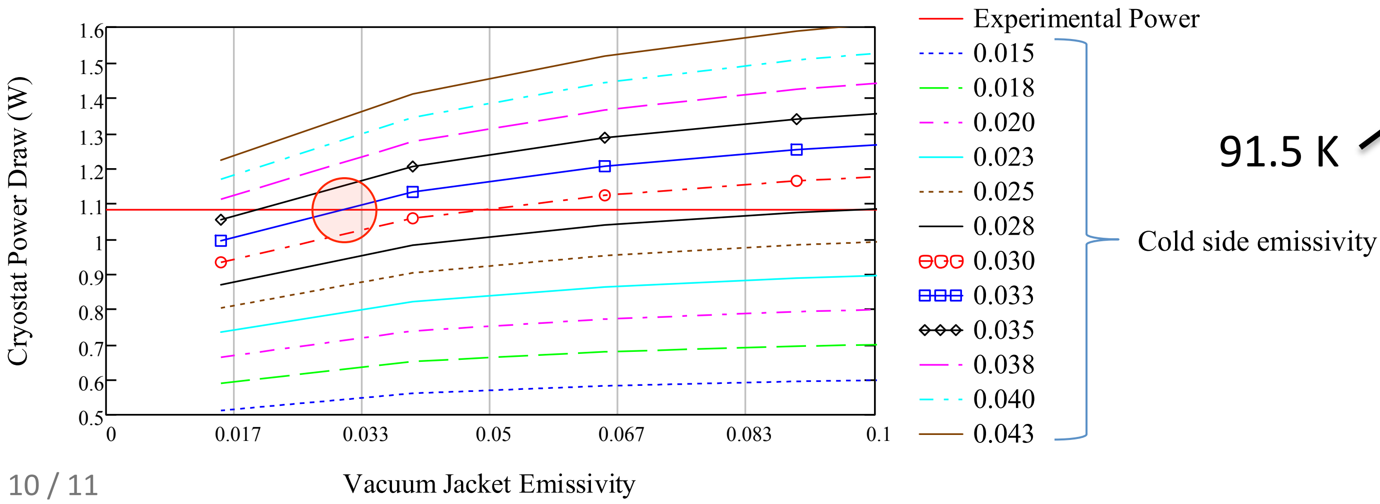
Thermal model (COMSOL)

- Largest uncertainty in initial thermal model: Joint resistance
- COMSOL model developed to extract joint resistances from measured temperatures (previous page)
  - Tweaked emissivity for 'best' fit (3.2% – *prior measurements ~3%*)



  - Not a perfect match:
    Model predictive to within ~1 K



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Detector integration at CANBERRA (Meriden, CT)

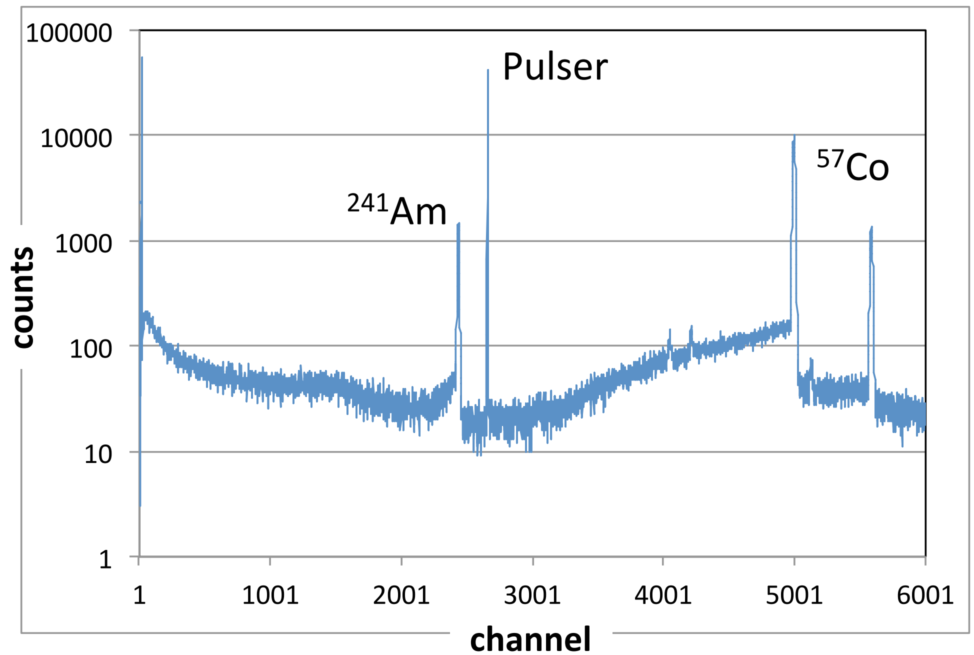
- HPGe crystal (SAGE design – See CANBERRA poster)
  - 1.268 kg, 92 mm diameter, 36.5 mm height
- Pulser peak FWHM in CANBERRA cryostat = 87 eV

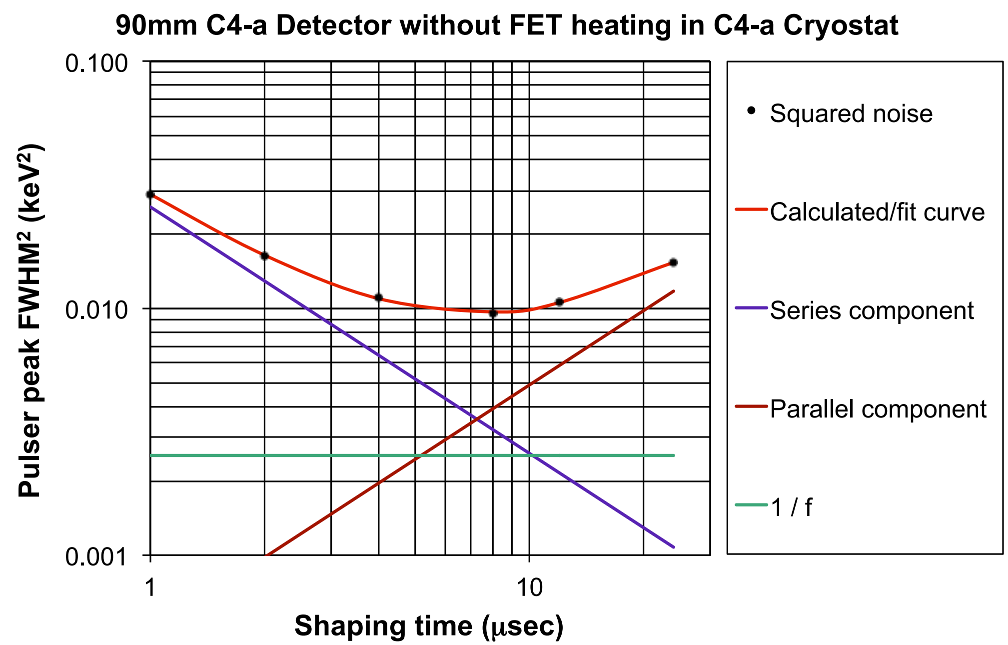
Integration performed by:
Todd Hossbach (PNNL)
Mike Yocum (CANBERRA)

Preliminary performance

Shaping time during measurement	8 μs (Day 2)	4 μs (Day 2)
Pulser FWHM	98 eV	105 eV
FWHM @ 59 keV (^{241}Am)	342 eV	336 eV
FWTM @ 59 keV (^{241}Am)	628 eV	625 eV
FWHM @ 122 keV (^{57}Co)	477 eV	481 eV
FWTM @ 122 keV (^{57}Co)	873 eV	876 eV
FWHM @ 1332 keV (^{60}Co)	1905 eV	2107 eV
FWTM @ 1332 keV (^{60}Co)	3525 eV	3912 eV

- 96 hour cool down
- Operated at expected bias (3000 V)
- 98 eV pulser peak FWHM





- *Further characterization underway at University of Chicago!*

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Thoughts on design improvements

- Larger diameter vertical dipstick
  - Improved cooling
- Additional instrumentation ports on dipstick portion
  - Additional feed-throughs across from preamp for thermal testing
- Super-insulation around the horizontal cold finger
  - Reduce the IR heat load
- Remove: vertical cold finger *to* cold plate joint
  - Feature wasn't used
- More attention to crystal-end wiring routing
  - Wiring worked, it was just very tedious to work with

- *Plan a design for 2+ kg p-type point contact HPGe crystal!*

Thoughts on low-background counter design

- Design intended for dark matter research…
- However, result appears like a good low-background counting system design
- Some changes needed:
  - Design as an "Up-looker"
    - This is not difficult
  - Reduce thicknesses of end-cap and crystal IR shield
    - Tunable with electroforming
  - Design an appropriate low background shield
    - CoGeNT shield wasn't difficult to design or make… but CoGeNT didn't have a sample counting chamber & door

Thank you!

Questions?