

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

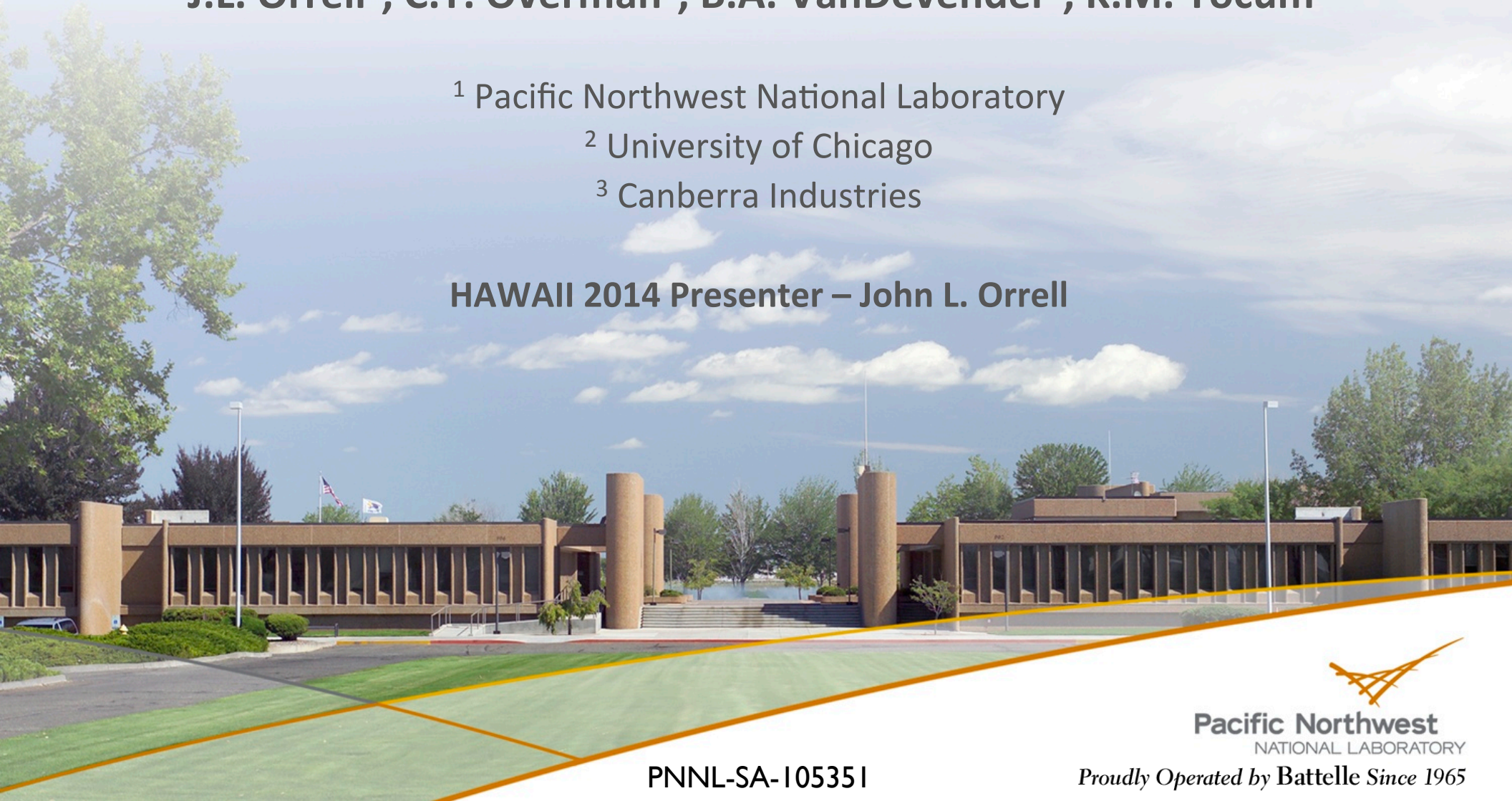
C.E. Aalseth¹, J.I. Collar², J. Colaresi³, J.E. Fast¹, T.W. Hossbach¹,
J.L. Orrell¹, C.T. Overman¹, B.A. VanDevender¹, K.M. Yocum³

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² University of Chicago

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HAWAII 2014 Presenter – John L. Orrell



Outline

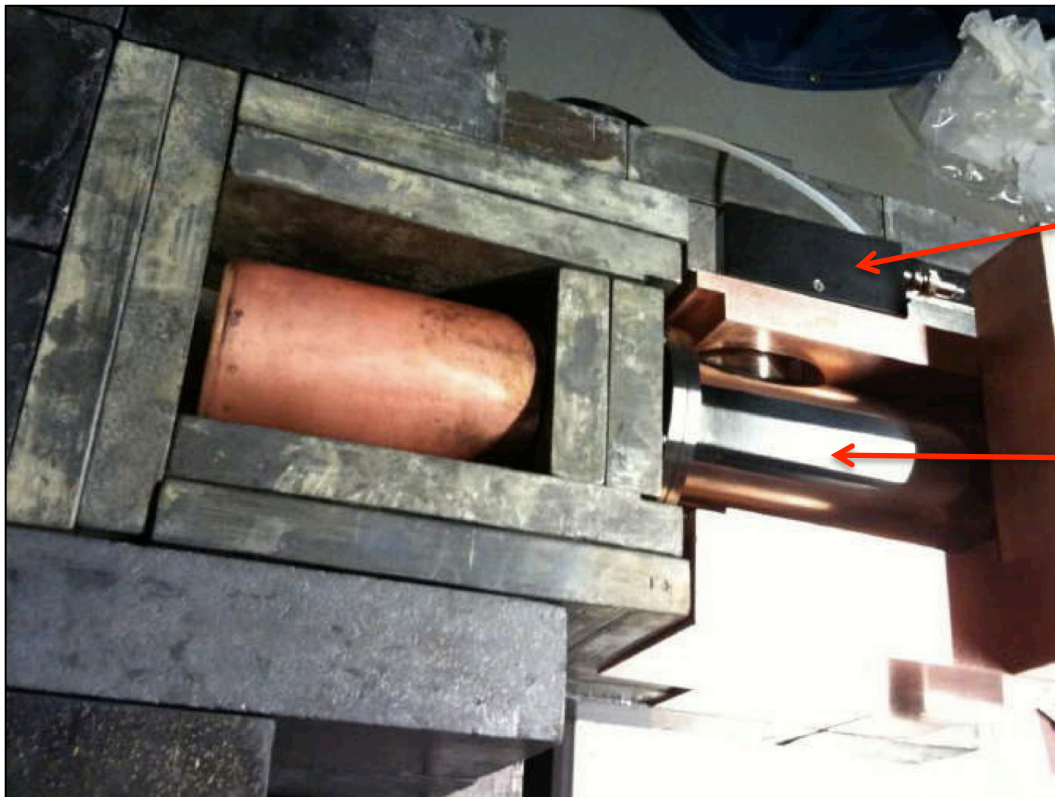
- ▶ Impetus → CoGeNT/Dark Matter
- ▶ Background considerations → Front-end sets background
- ▶ Initial cryostat design
- ▶ Fabrication
- ▶ Thermal testing
- ▶ Thermal model
- ▶ Detector integration
- ▶ Preliminary detector performance
- ▶ Thoughts on improvements
- ▶ Thoughts on low background counter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



Impetus for a new cryostat design (circa summer 2012)

► Desire to test CoGeNT dark matter results with new detectors having:

- Lower background $\sim 5\text{-}10\times$ (to ~ 1 count/keV/kg/day)
- Lower energy threshold $\sim 2\text{-}5\times$ (to ~ 100 eV)
- Larger mass $\sim 3\times$ (to 1.25 kg)



Preamp

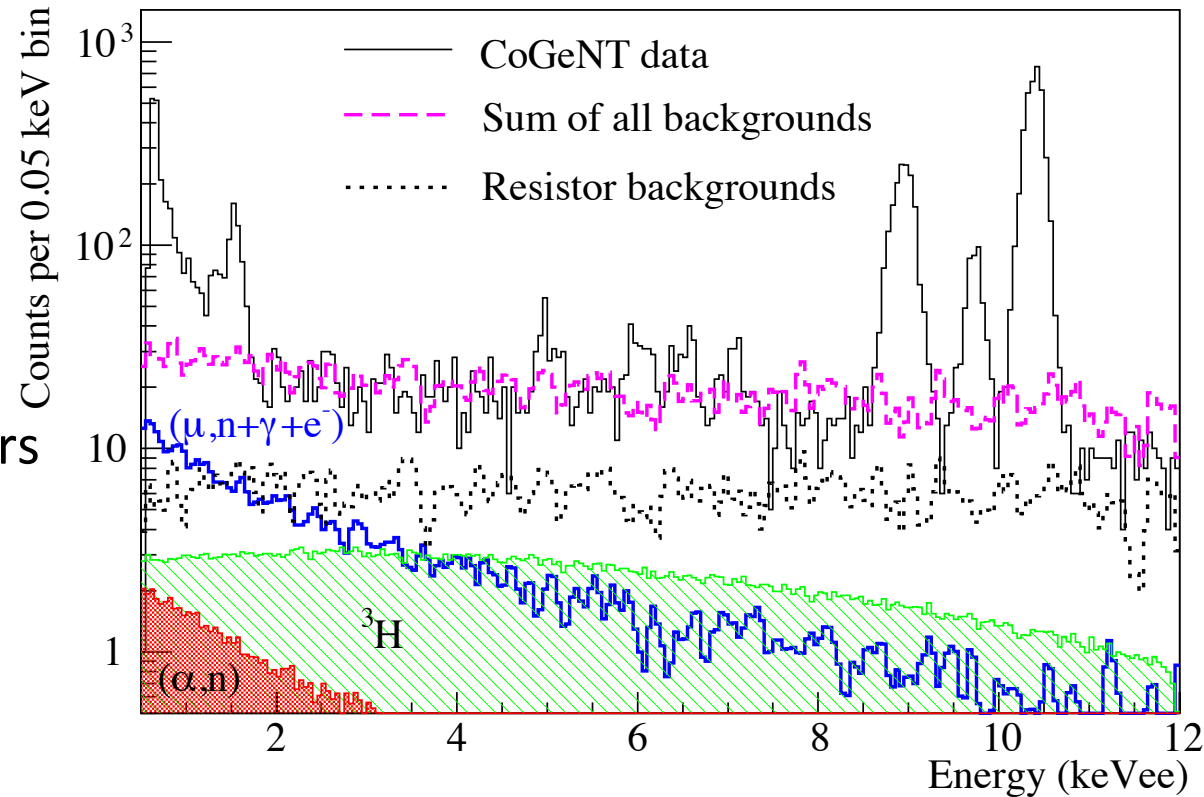
Al dipstick



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:

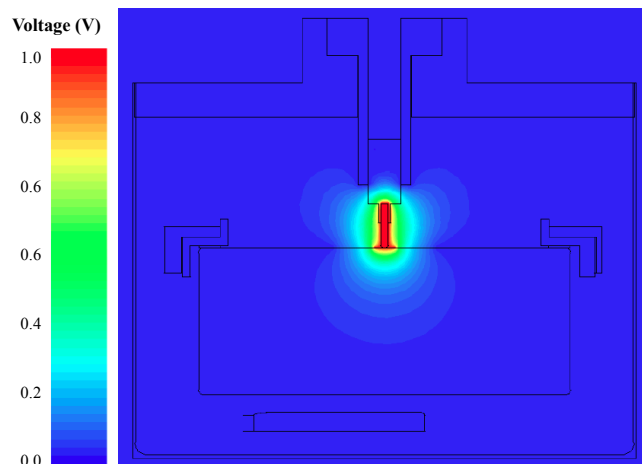
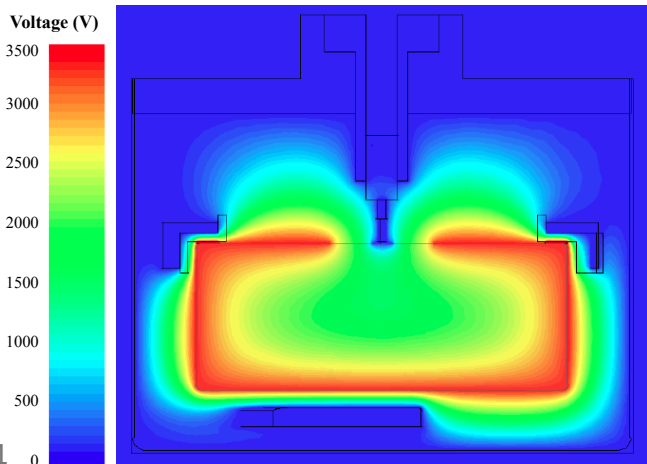
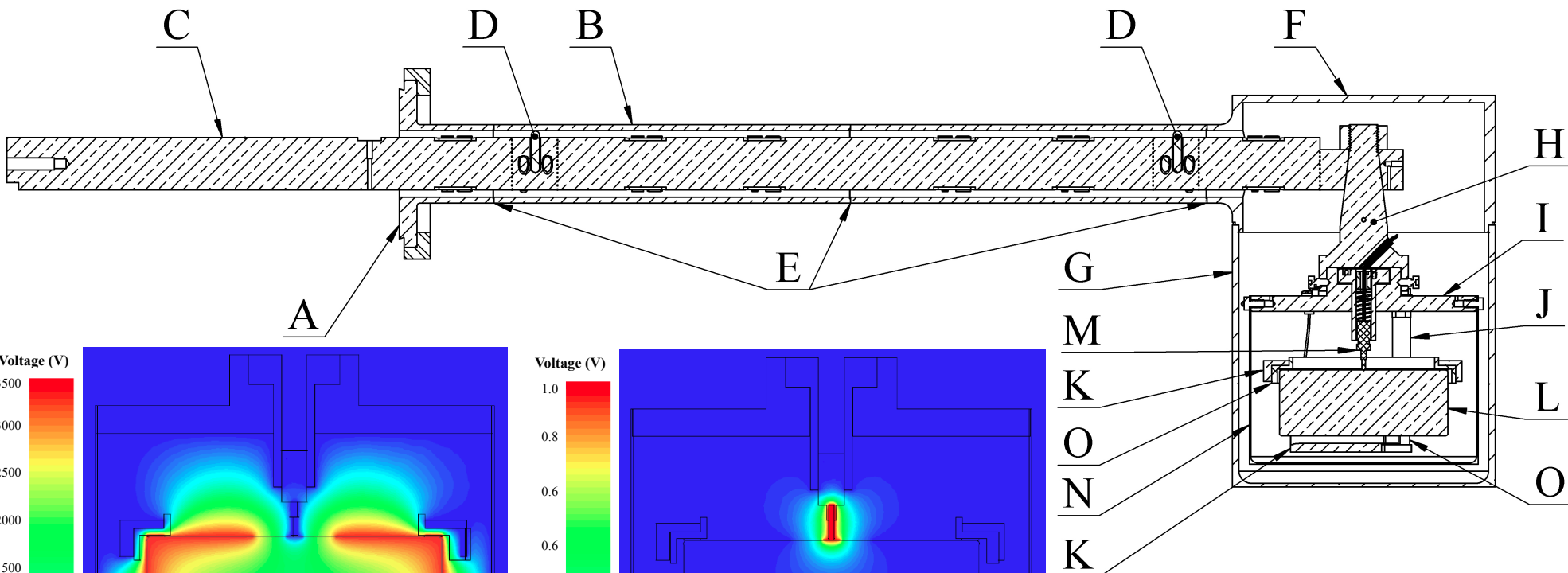
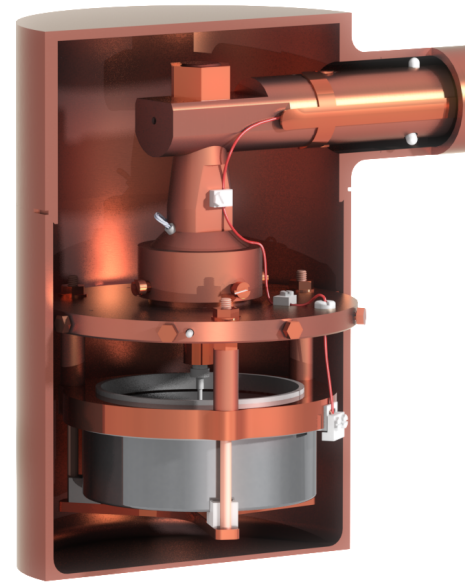
- Front-end will still dominate background
- Use a mixture of OFHC and electroformed copper “as convenient”
- Otherwise, employ all low-background best practices.



Initial cryostat design and thermal model

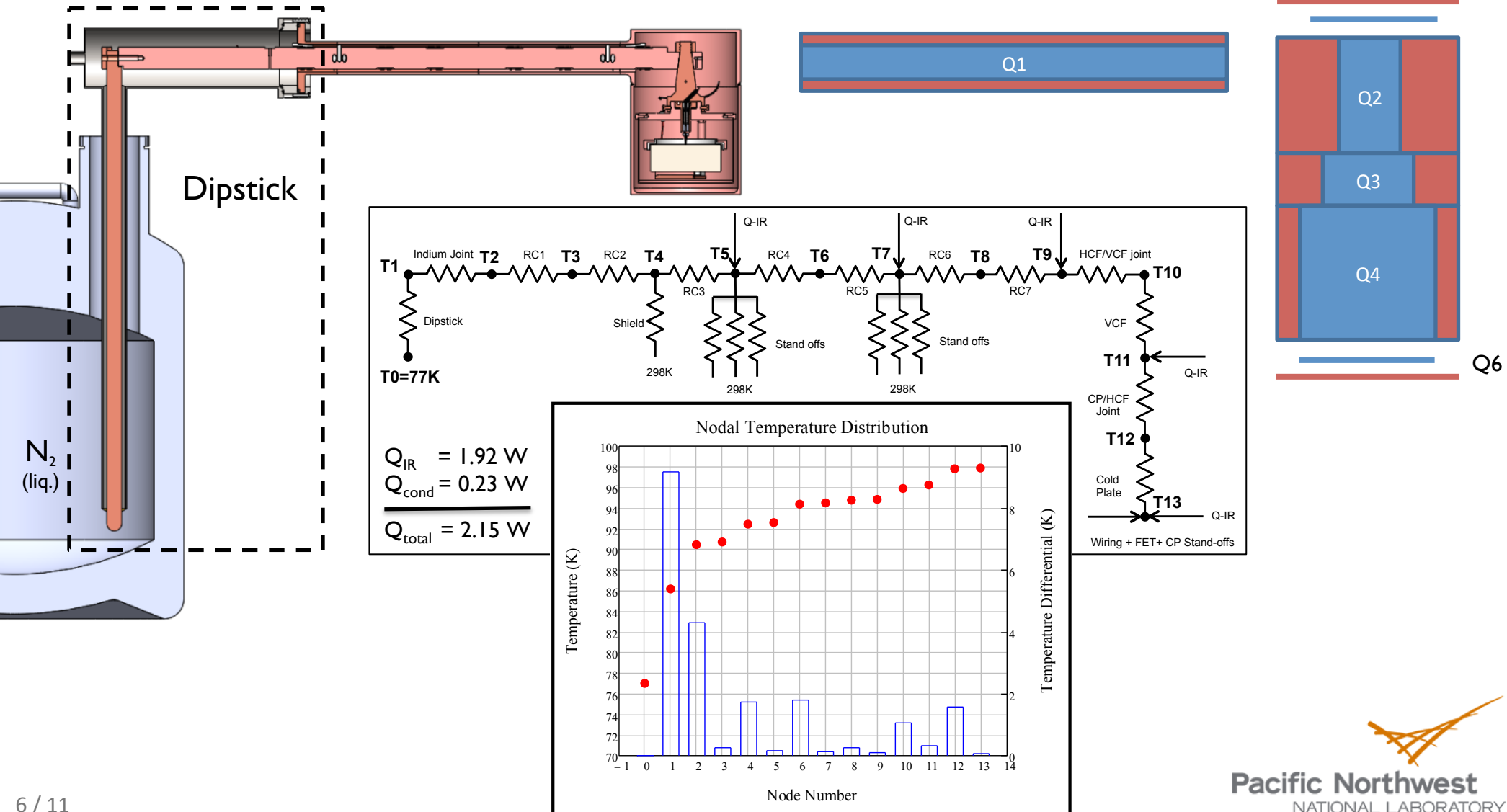
► Areas of design focus:

- Field modeling for low capacitance
- Thermal modeling for low crystal temperature
- “Low-background” (see previous slide)



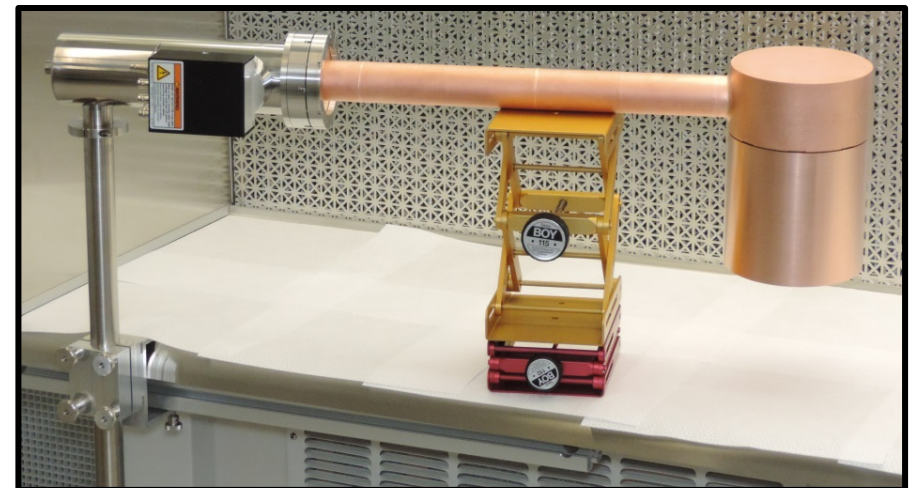
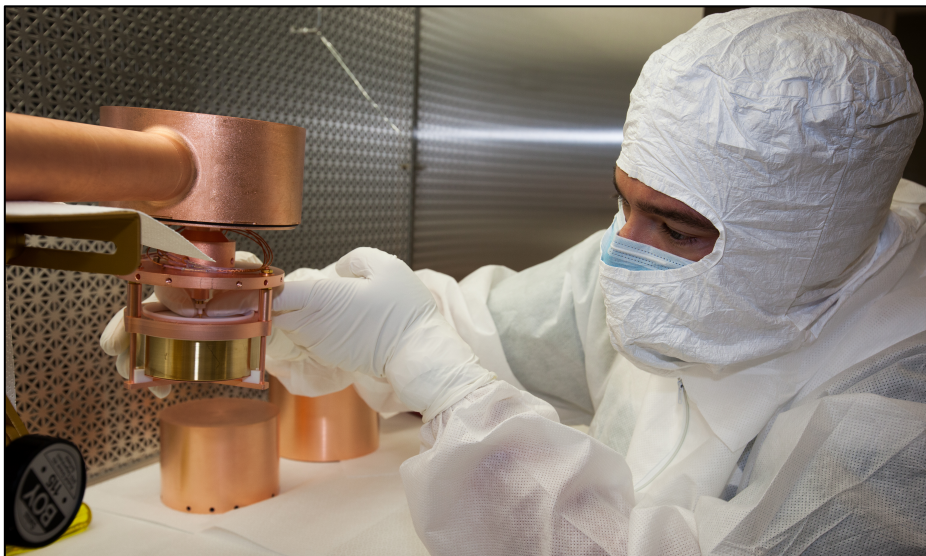
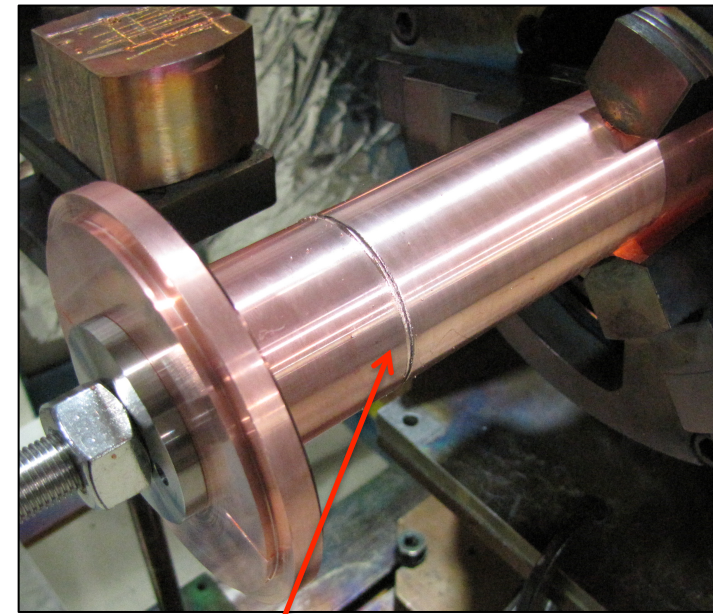
Initial cryostat thermal model

► Simplified “by hand” calculation



Fabrication

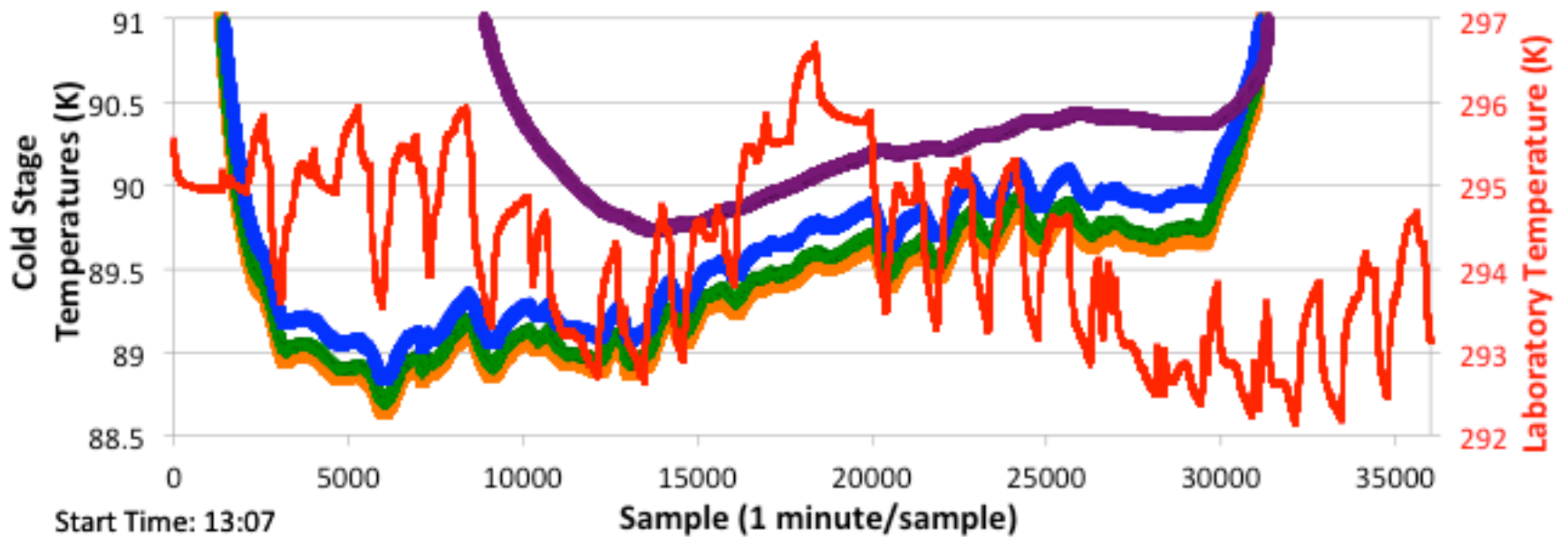
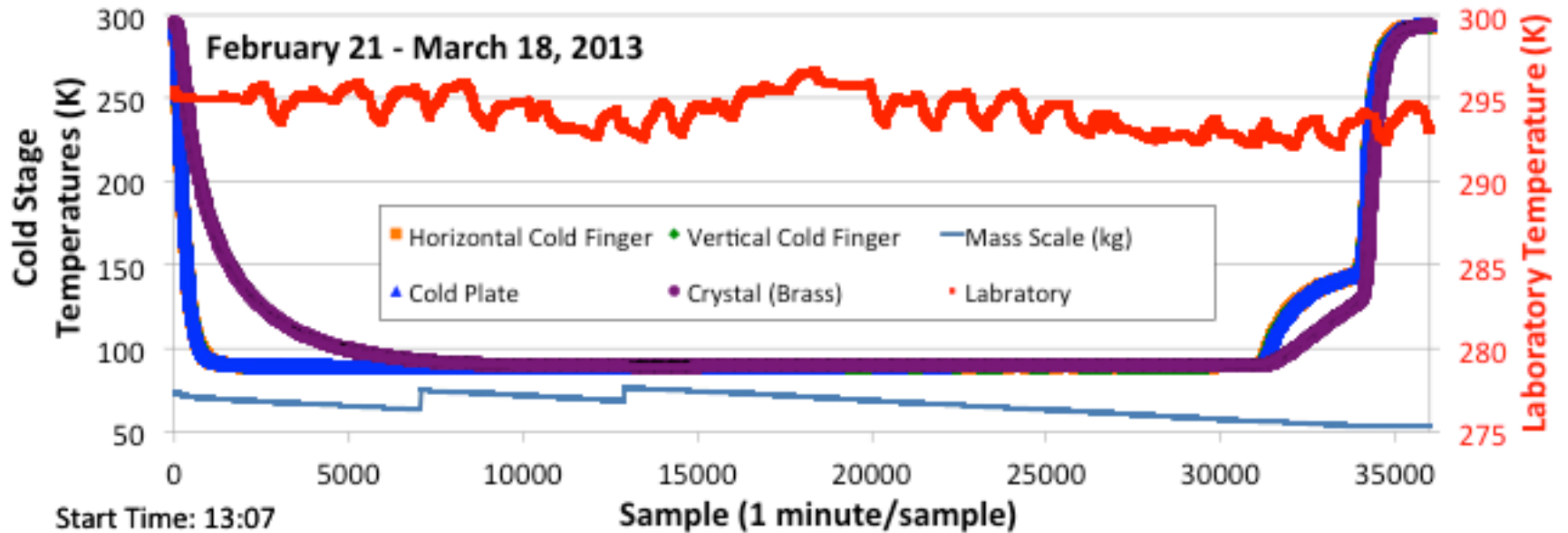
- ▶ Electroformed copper:
 - End cap and crystal IR shield
- ▶ OFHC copper everywhere else
- ▶ E-beam welds to make cross-arm vacuum jacket
- ▶ All copper etched and passivated
- ▶ Limited use of PTFE as crystal mount/HV stand-off



Thermal testing

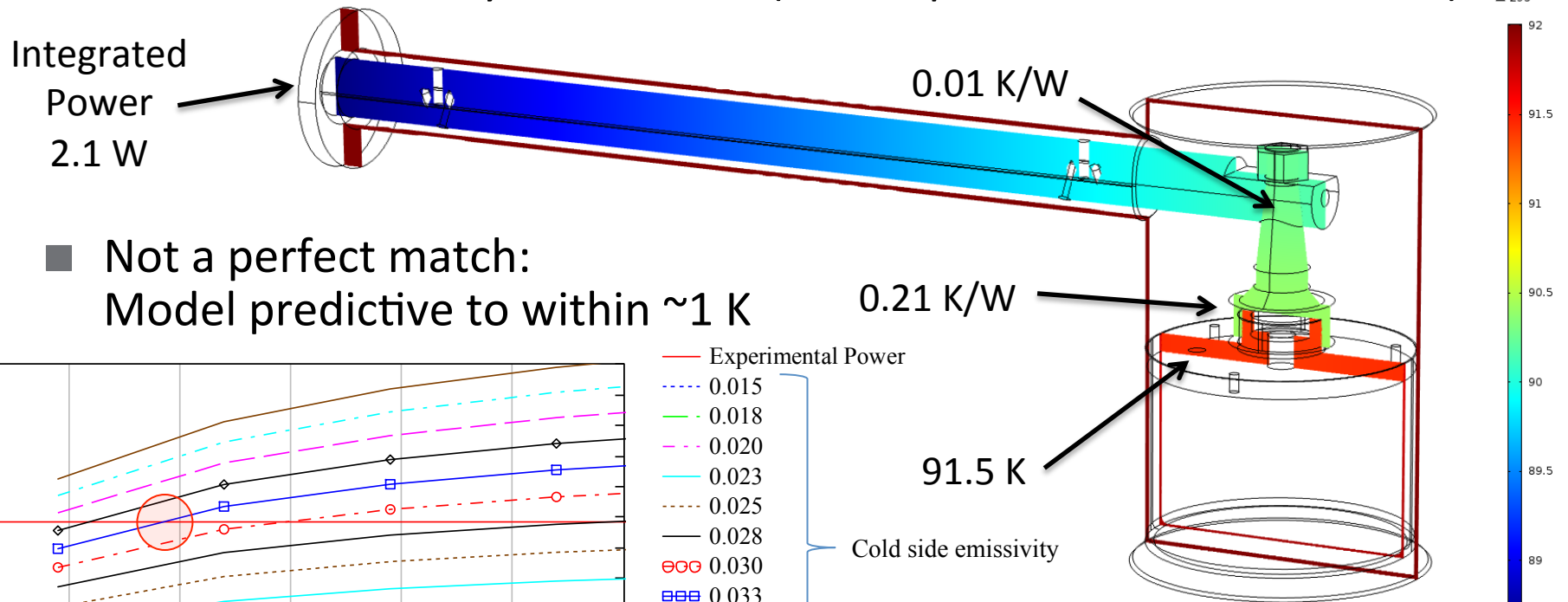


Thermal testing

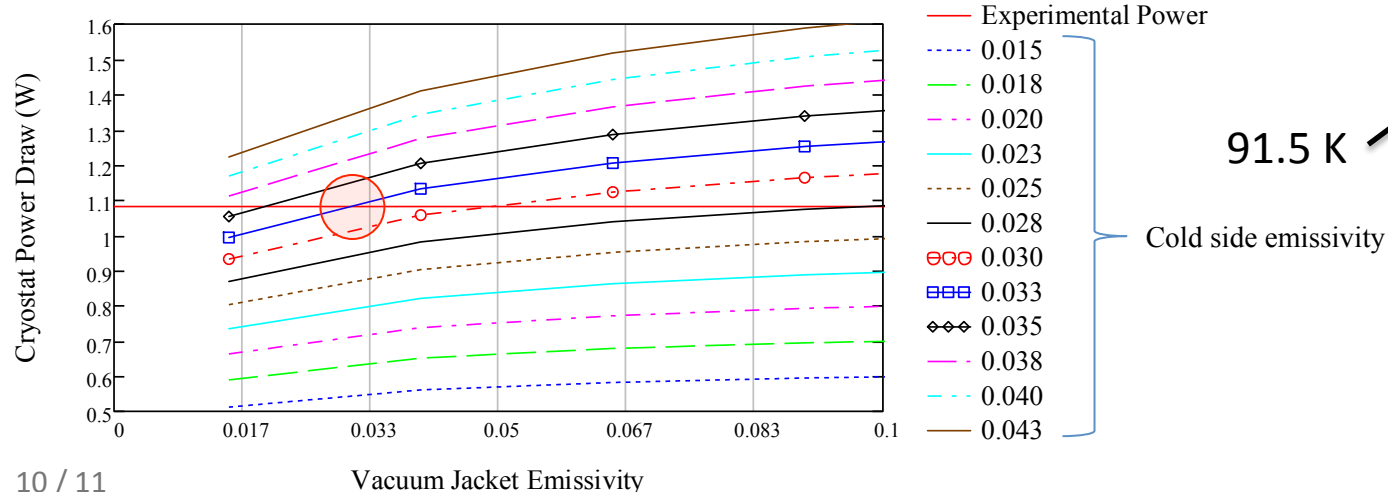


Thermal model (COMSOL)

- ▶ 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



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



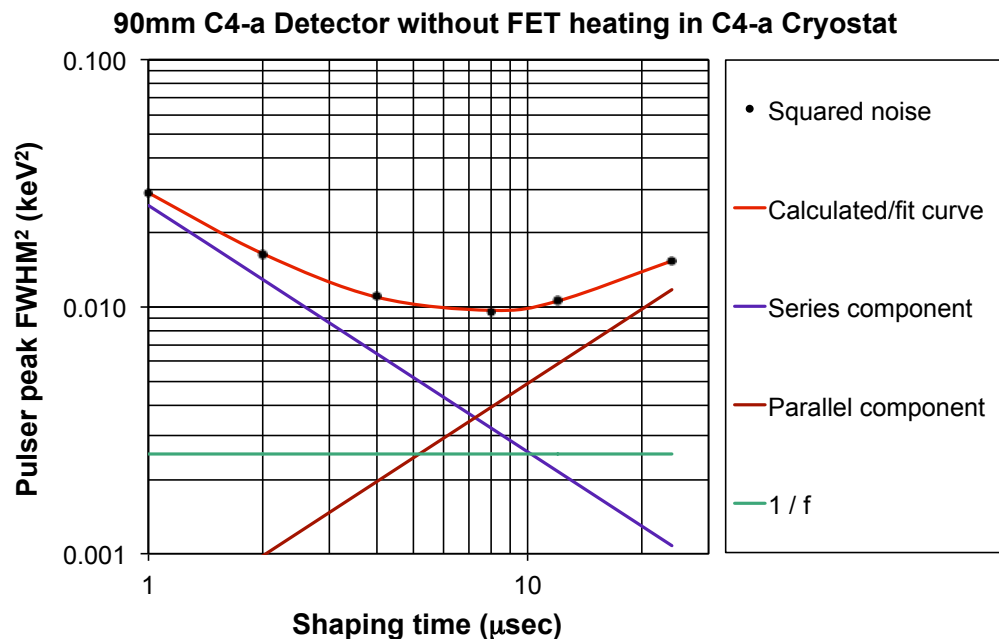
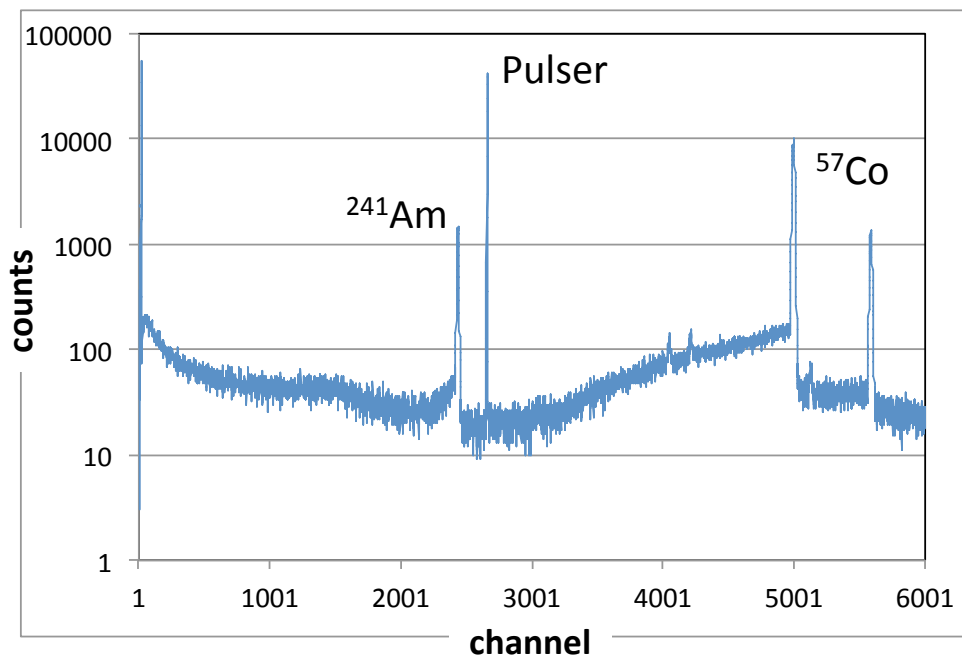
Integration performed by:
Todd Hossbach (PNNL)
Mike Yocum (CANBERRA)



Preliminary performance

Shaping time during measurement	8 μ s (Day 2)	4 μ s (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!*



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?



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The LRT workshop examines topics in low radioactivity materials and techniques, a fundamental aspect of rare event searches, including dark matter, solar neutrinos, double-beta decay, and long half-life phenomena.

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Abstract Submission and Registration Opens
November 1, 2014

Abstract Submission Closes
January 16, 2015

Registration Closes
March 3, 2015

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