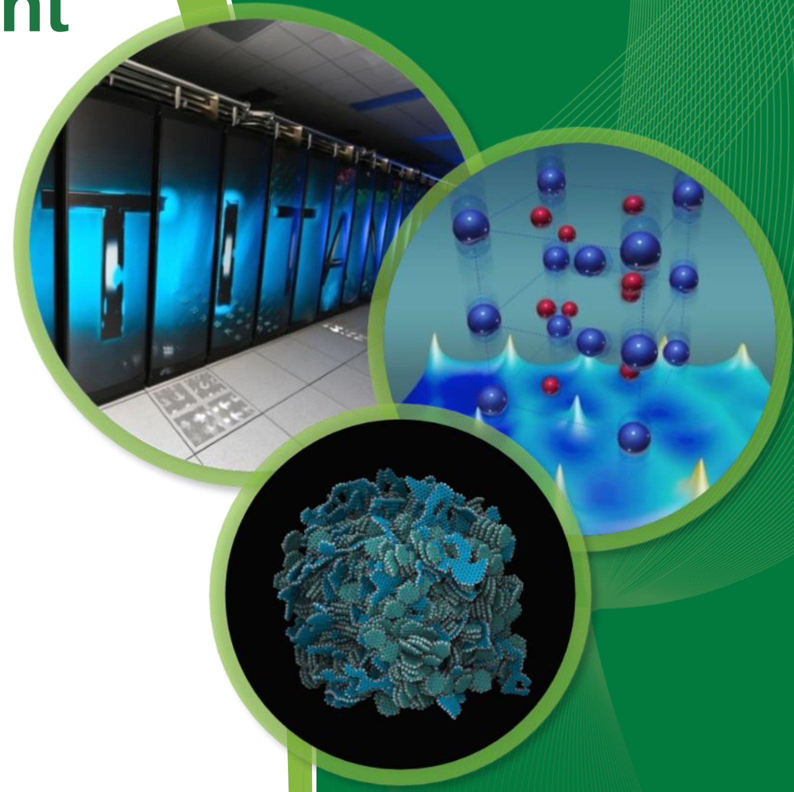
The New High-Angle Detector for the Bio-SANS Instrument at HFIR



Kevin Berry

DENIM

Lund, Sweden

September 19, 2016

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OAK RIDGE National Laboratory | HIGH FLUX ISOTOPE REACTOR

Outline

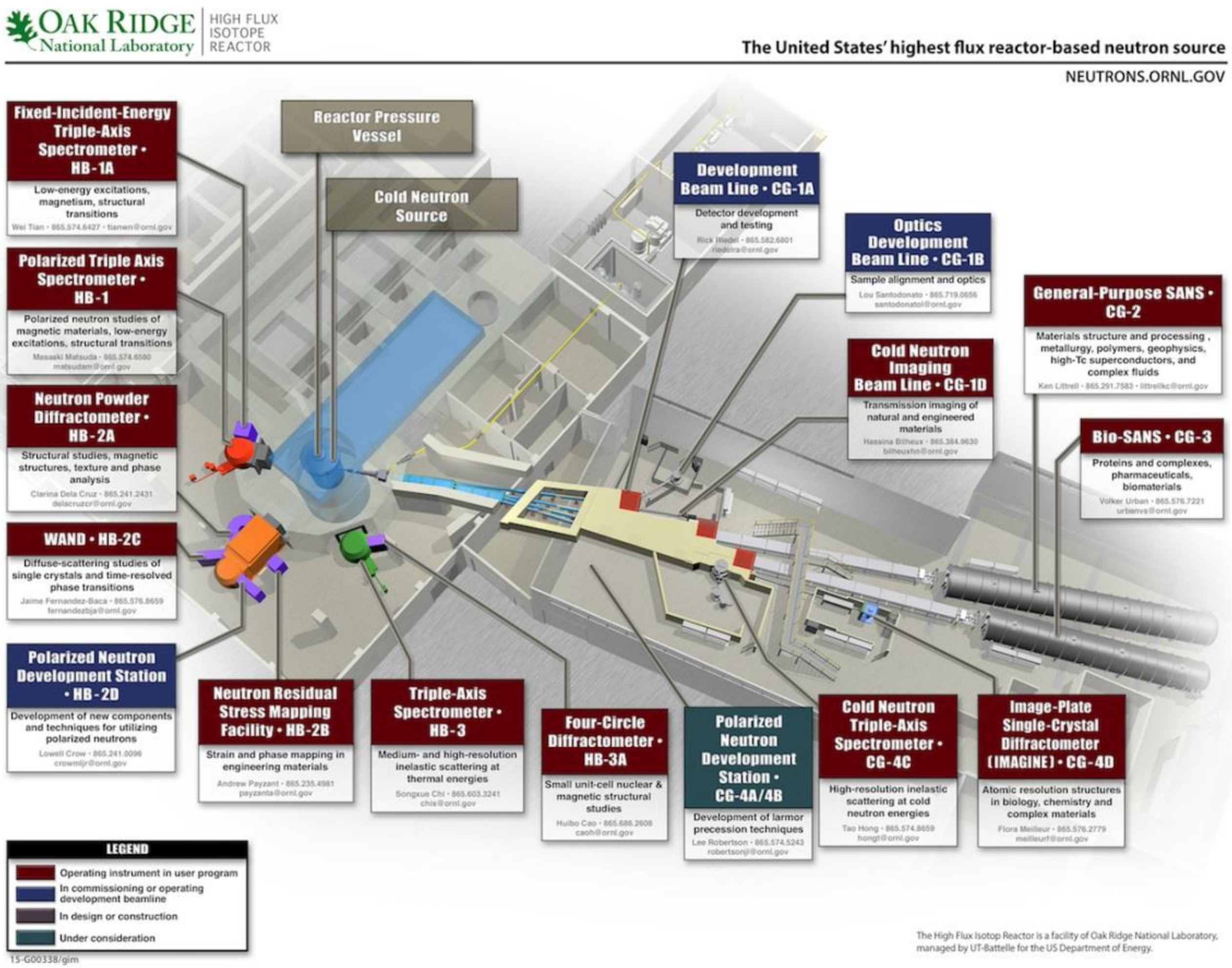
- Introduction to the Bio-SANS Instrument at HFIR
- The Main Detector (since 2012)
  - Design and Performance
  - Pros and Cons
- The New High Angle Detector Project (2016)
  - Design and Construction
  - Installation and Performance
- Final Comments

Two neutron sources at ORNL

- **High Flux Isotope Reactor (1965)**
- 85 MW, peak thermal flux >2x10^{15}/cm^2-s
- Thermal and cold neutron beam lines
- Cold neutron source, guide hall commissioned in 2007
- 7 cycles/year (~ 24 days per cycle)
- 12 instruments in user program, 2 development beam lines

- **Spallation Neutron Source (2006)**
- > 1 MW continuous operating power
- 60 Hz rep rate, peak flux >1x10^{14}/cm^2-s
- Plans for power upgrade to 2.8 MW
- 17 instruments in user program
- Plans for 2nd target station with up to 22 new instruments

HFIR – 12 instruments in user program



- 4 triple axis spectrometers
- 5 diffractometers
- 2 SANS
- 1 imaging beam line
- 2 development beam lines

Bio-SANS (instrument CG-3 at HFIR)
- operated by the Center for Structural Molecular Biology

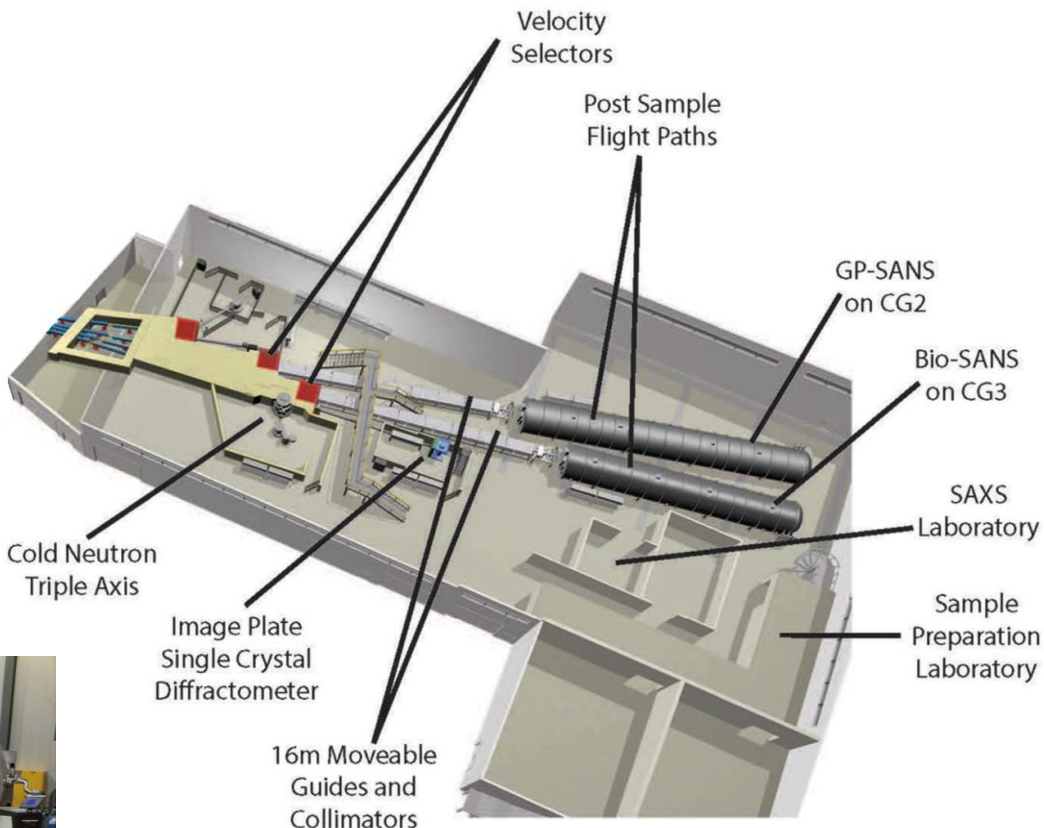
Specifications

Wavelength	6< λ <25 Å
Wavelength resolution	Δλ/ λ = 9–45%
Q range	0.0009–0.8 $Å^{-1}$
Sample-to-detector distance	1.1–15.3 m
Detector	2–D linear position-sensitive detector
Detector size	1 x 1 m^2
Detector resolution/ pixels	192 x 256

Center Capabilities

Bio-deuteration
Protein production + analysis
HFIR Bio-support lab
Computational tools (Tools for GI SANS analysis)
Small-angle x-ray scattering (Available at SNS/CNMS, alignment in progress on pin-hole instrument at HFIR)
Light scattering (Available at the JINS lab)

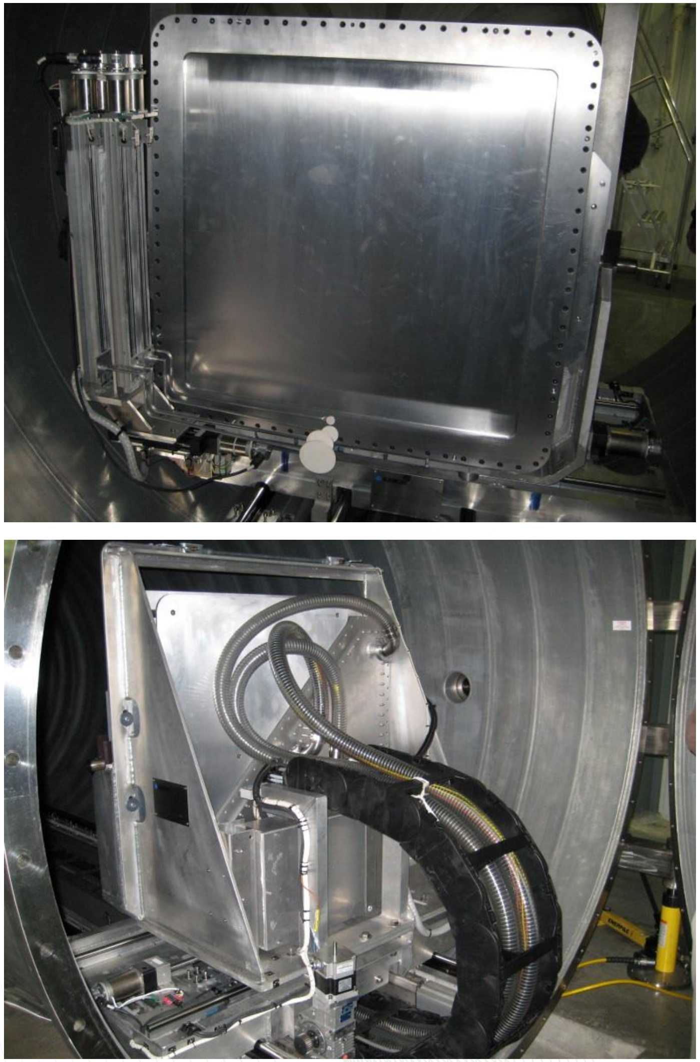
Status: Available to users



Urban, et al., J. Appl. Cryst. (2014), **47**, 1238-1246

Original Bio-SANS detector (2007-2012)

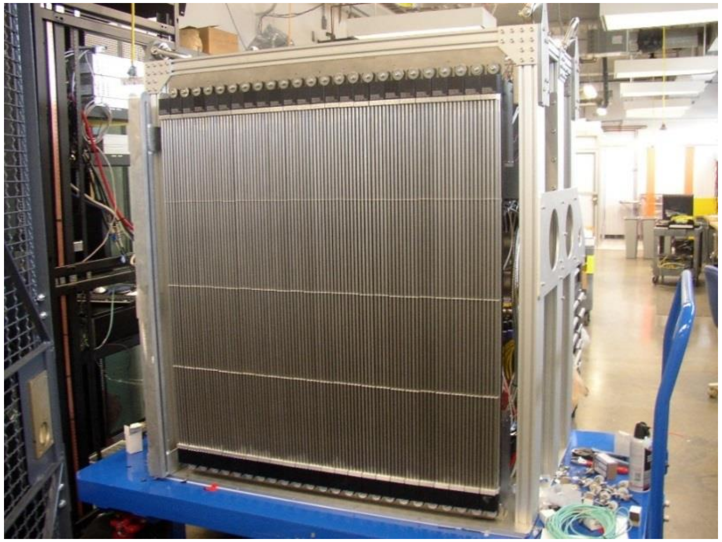
- commissioned in 2007
- ^{3}He filled multi-wire proportional chamber
- 1 m x 1 m active area, 6.4 cm thick
- 192 x 192 cathode wires
- pixel size 5.1 mm x 5.1 mm
- electronics enclosure on back plane, vented to atmosphere
- translates full 15 m length of tank, also 45 cm lateral movement for higher Q
- rate limited to 20 cps/pixel, 18 kcps global to prevent damage
- detector repair removed instrument from user program for months at a time

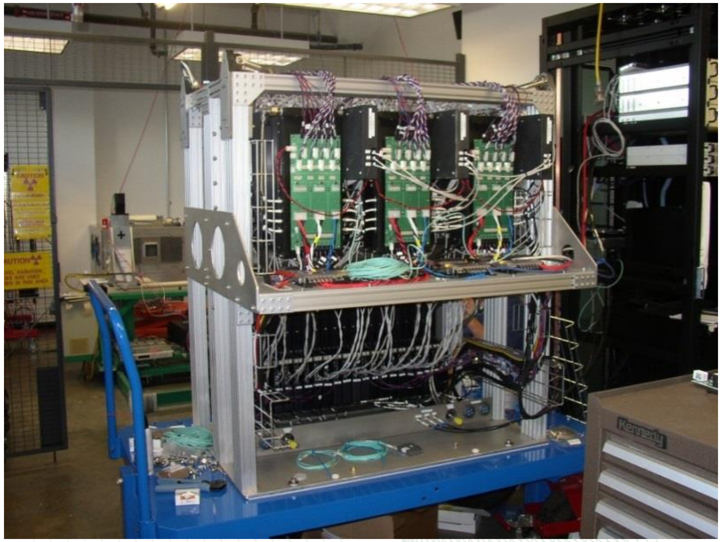


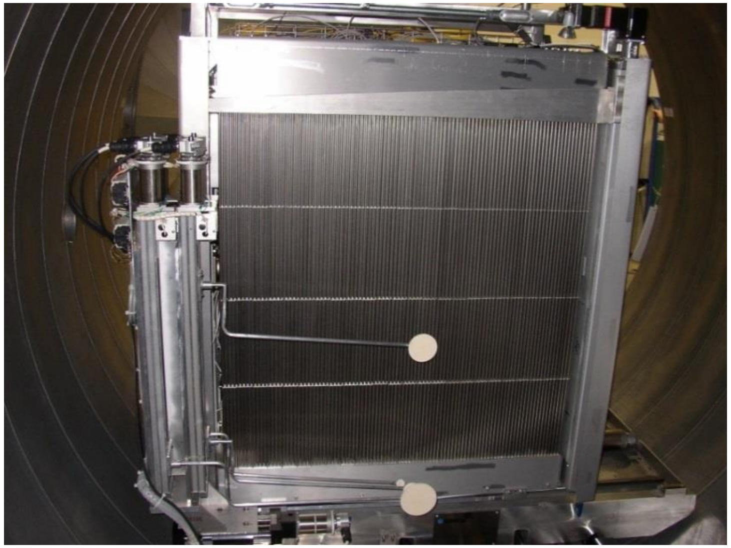
ORDELA Model 21000N

Detector replaced with LPSDs in 2012

- helium-3 filled linear position sensitive detectors (LPSD)
- 192 tubes assembled into 24 ‘8-packs’ (GE Reuter-Stokes)
- 1 m x 1 m active area
- two row design, front and back rows offset, each row contains 96 tubes
- tubes 0.8 cm diameter x 1 meter length
- identical to GP-SANS detector (2011)
  very similar to EQ-SANS at SNS (2008)



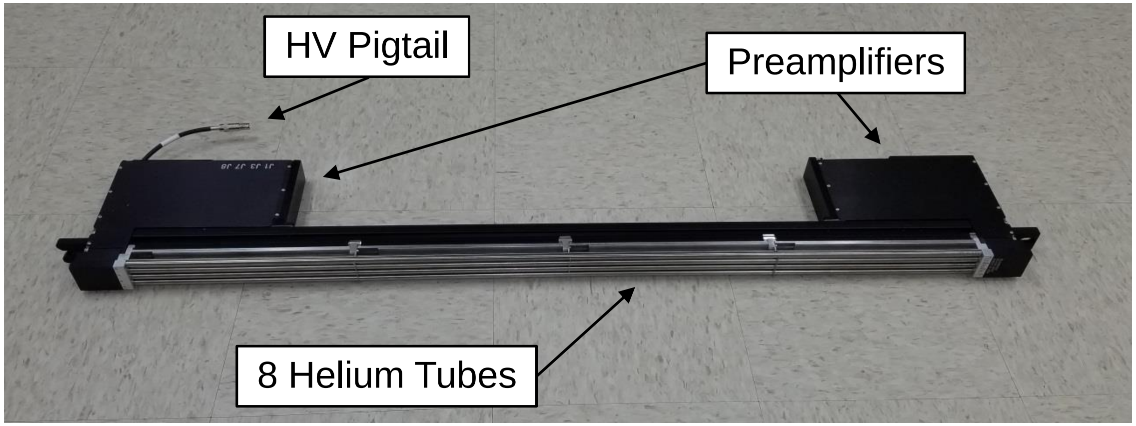


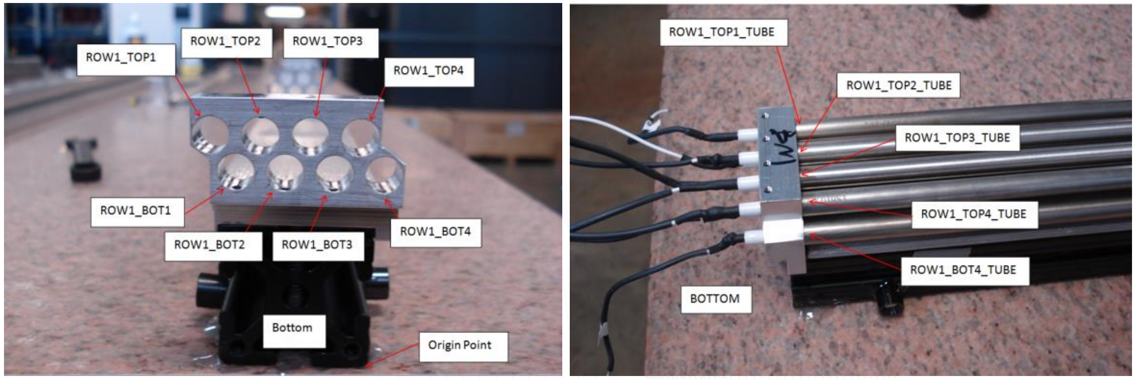


Berry, et al., NIM A 693 (2012) 179-185

LPSD 8-pack module design

- 8 tubes per module, assembled into two rows of four tubes each
- front and back rows offset
- modular design facilitates maintenance, problem modules can be replaced individually
- shorter gas depth (8 mm) reduces parallax compared to original detector
- improved rate capability 150 cps/pixel (minimum)

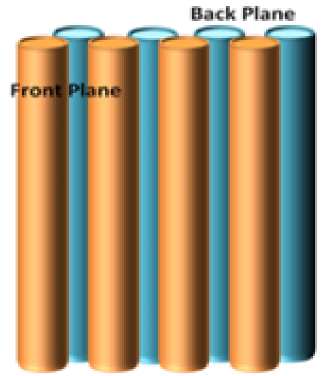


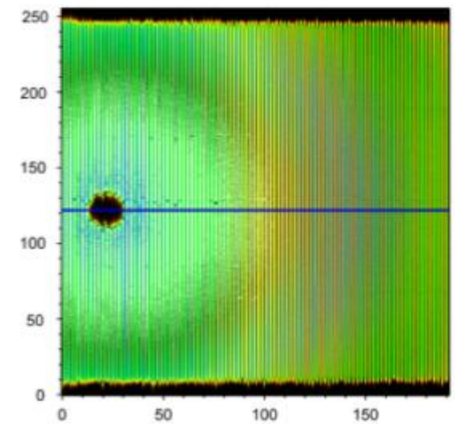


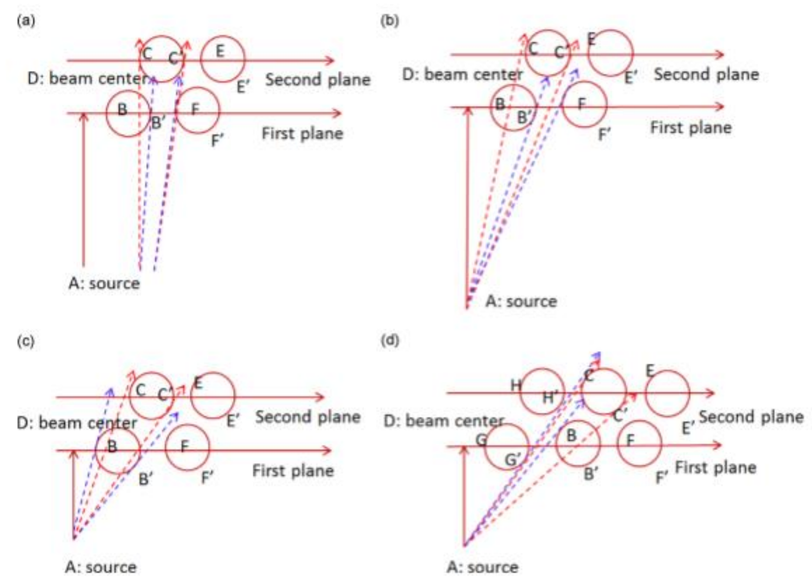
photos showing offset, two row configuration of tubes

Two row construction - shadowing at high angles which varies with angle

- front/back tube intensity banding occurs as expected
- beyond ~ 7 m sample to detector distance (SDD) front to back intensity is reasonably stable
- shorter than 7 m SDD, front to back intensity varies with angle
- normalization problematic
- at SDD shorter than 7 m, occasionally have to disregard back row data
- front to back intensity also wavelength dependent



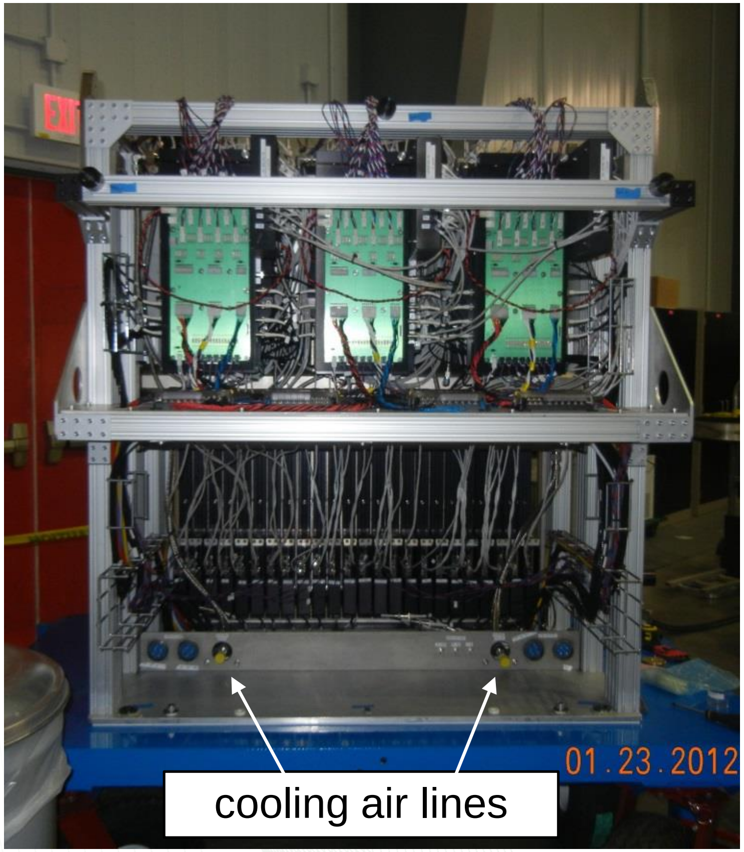




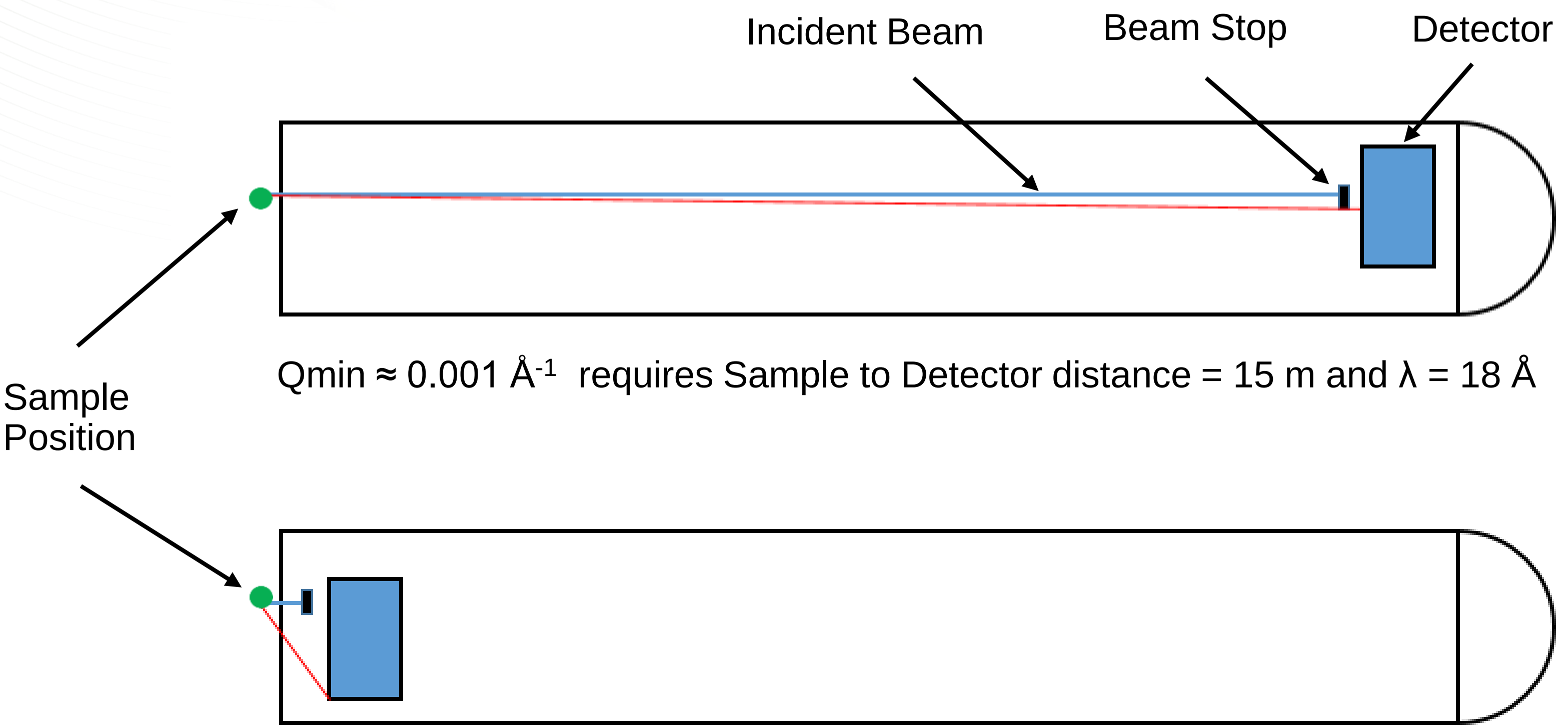
He, et al., NIM A 775 (2015) 63-70

Additional requirements – improved vacuum, cooling, and interlocks and controls

- **Vacuum upgrade** < 2 mTorr to prevent arcing
  - HV components now in vacuum space
- **Cooling air lines** to control electronic circuit board temperatures to < 50 ^{o}C
  - circuit boards in vacuum, densely packed
- **Interlock system** to control interplay between high voltage, detector motion, air flow
  - high voltage dropped if vacuum goes bad (arcing, damage to electronics)
  - high voltage dropped while motion enabled (anode wires short out, damage to tubes)
  - low voltage dropped if cooling air flow too low (overheating, damage to electronics)



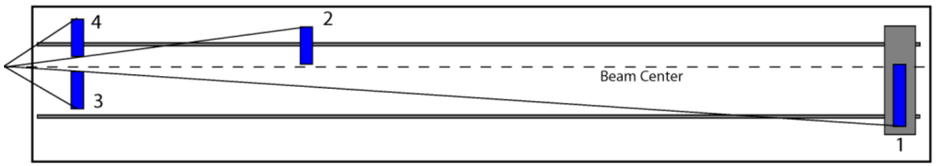
Accessing full Q range required acquisitions at two different detector positions



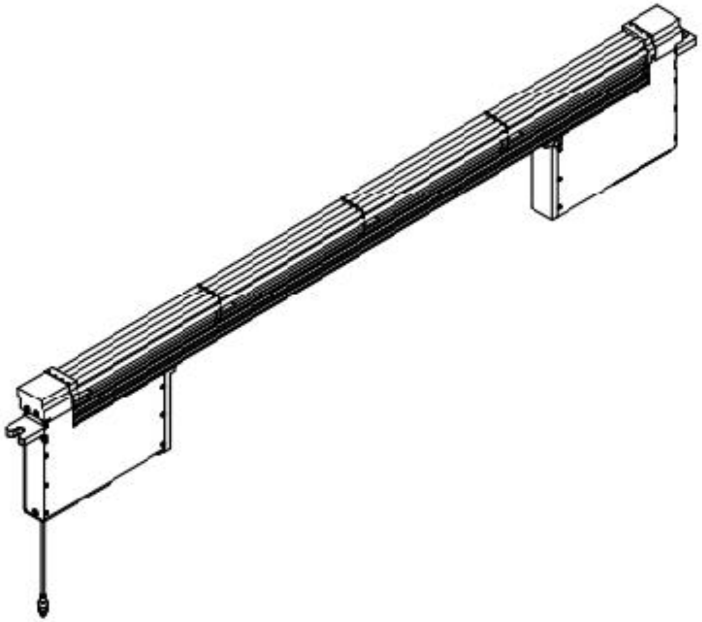
Qmax ≈ 0.7 Å^{-1} requires Sample to Detector distance = 1.2 m and λ = 6 Å

Plans for new high angle detector banks

- plans for some form of increased high angle detector coverage discussed back in 2012
- detector procurements each year in preparation (GE Reuter-Stokes)
- purchased same detector type used in main detector, so as to have spares in the interim
- by the time project began (2015) 11 assembled 8-packs plus 112 individual tubes were available



Early diagram of proposed new detector locations



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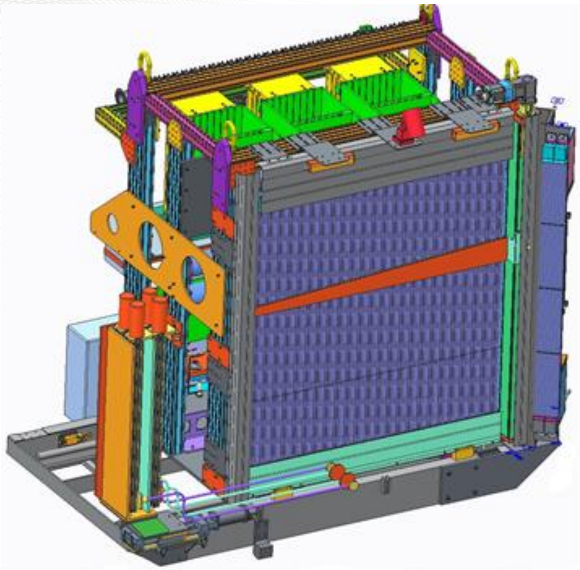
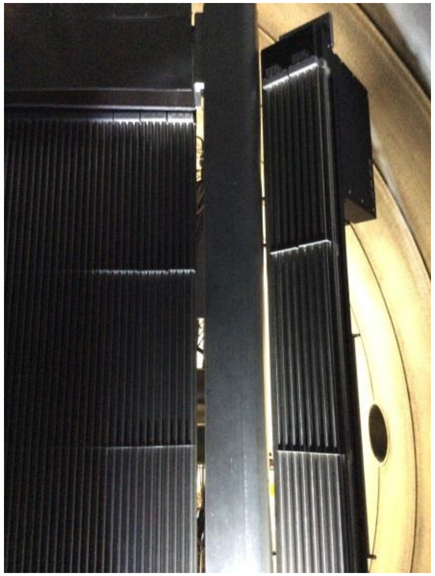
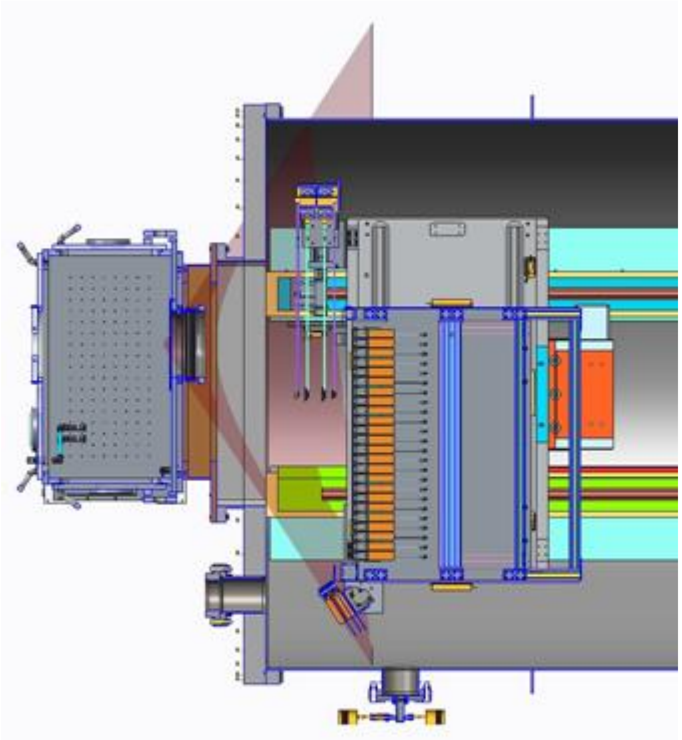
Two high angle detectors installed temporarily for proof of concept (2014)







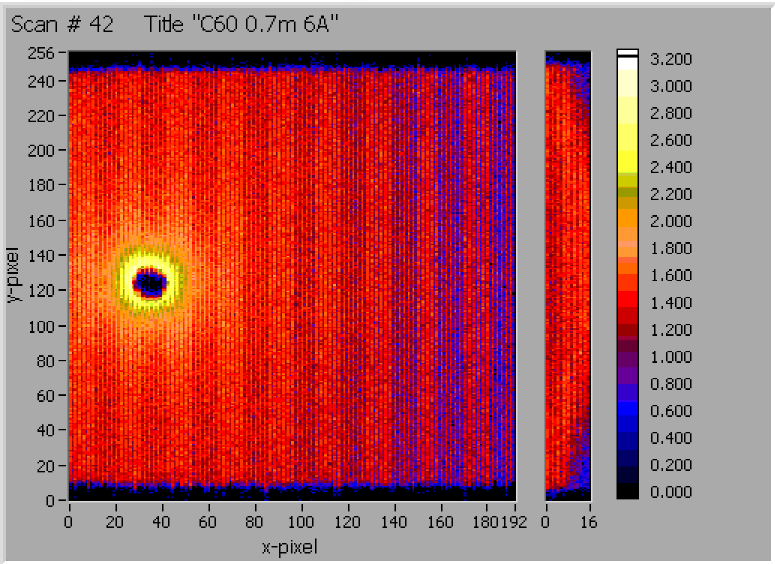
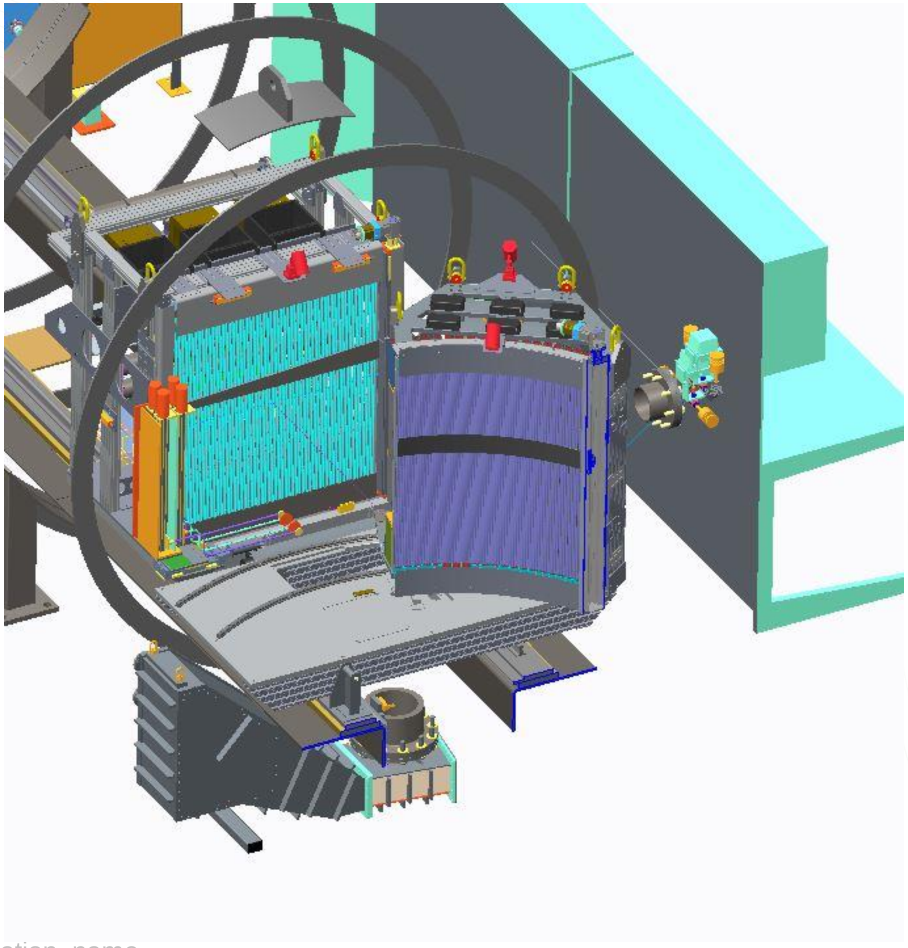


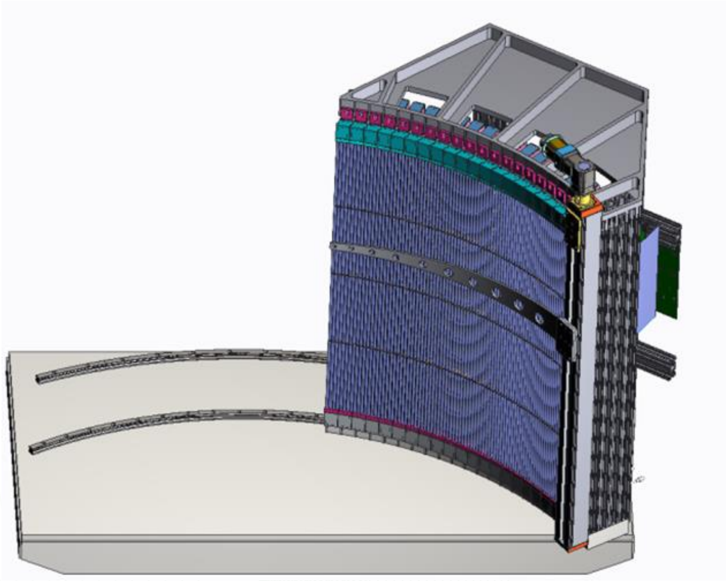
Photo and models above show location of the two high angle detector modules.

Detector response in SpICE shown at left.

Based on proof of concept results, curved detector design chosen

- 20 detector modules on curved frame
- fixed upstream radius (equal to sample to detector distance)
- translational motion on curved rails





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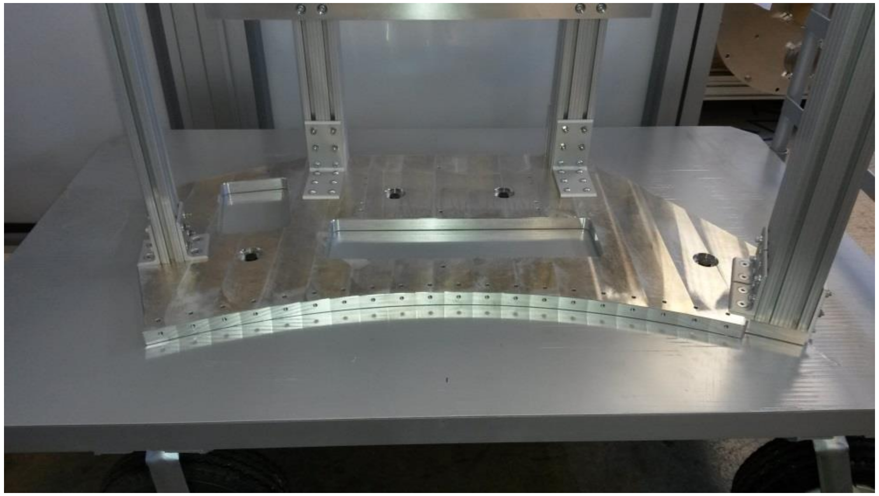
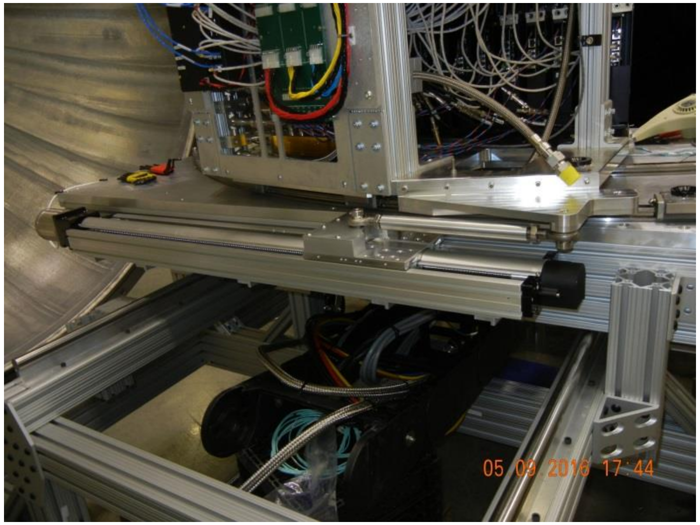
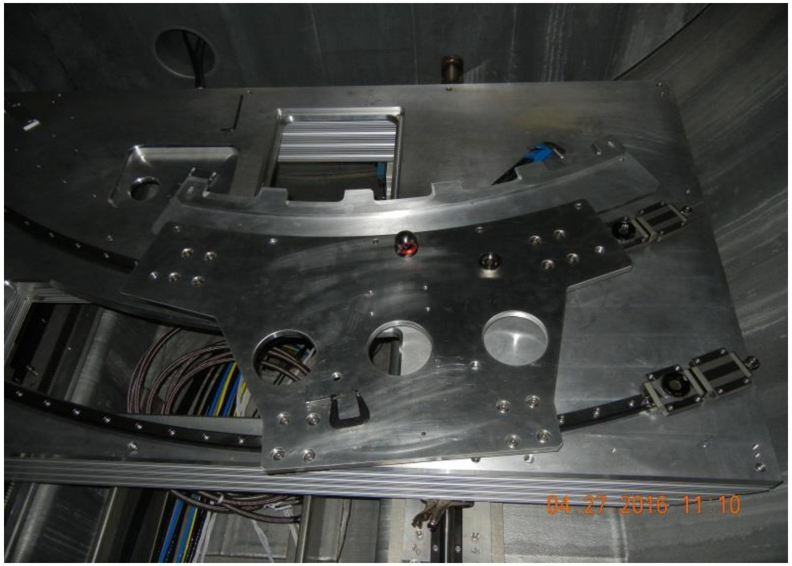
Curved mounting frame built to hold the 20 new detector modules



Mounting frame delivered to detector lab at SNS

Radial motion - curved rails, linear translation stage, pivoting drive arm





Detectors, electronics, and cabling all coming together in the detector lab

Rear view

Top view

Front view

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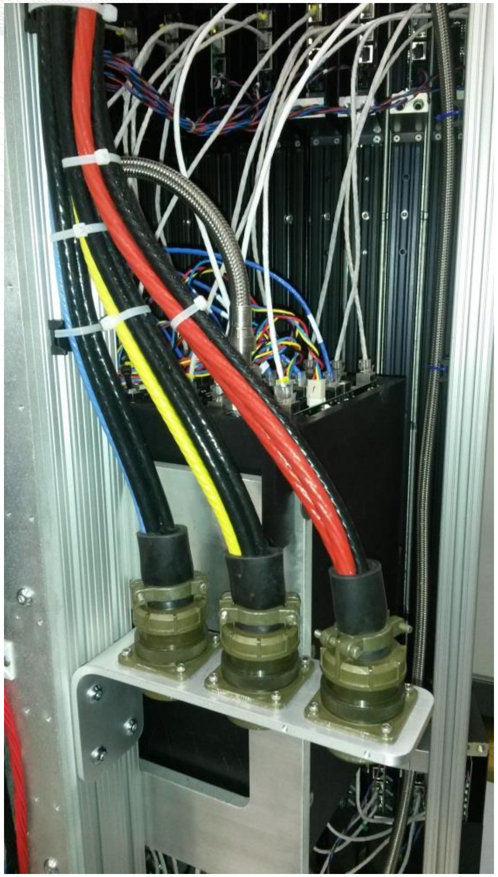
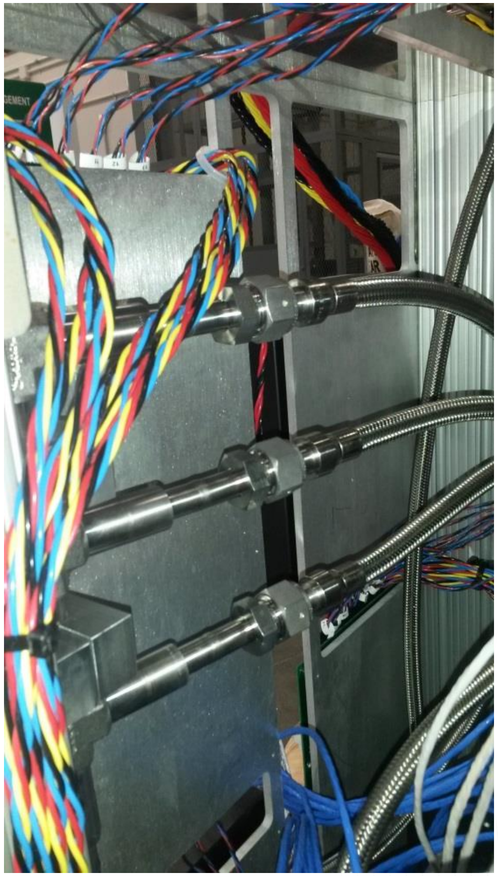
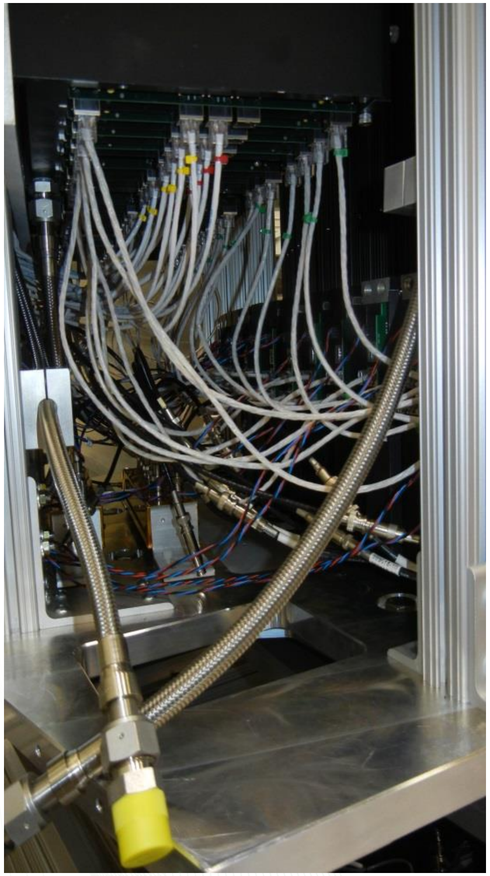
Connections for power, cooling air





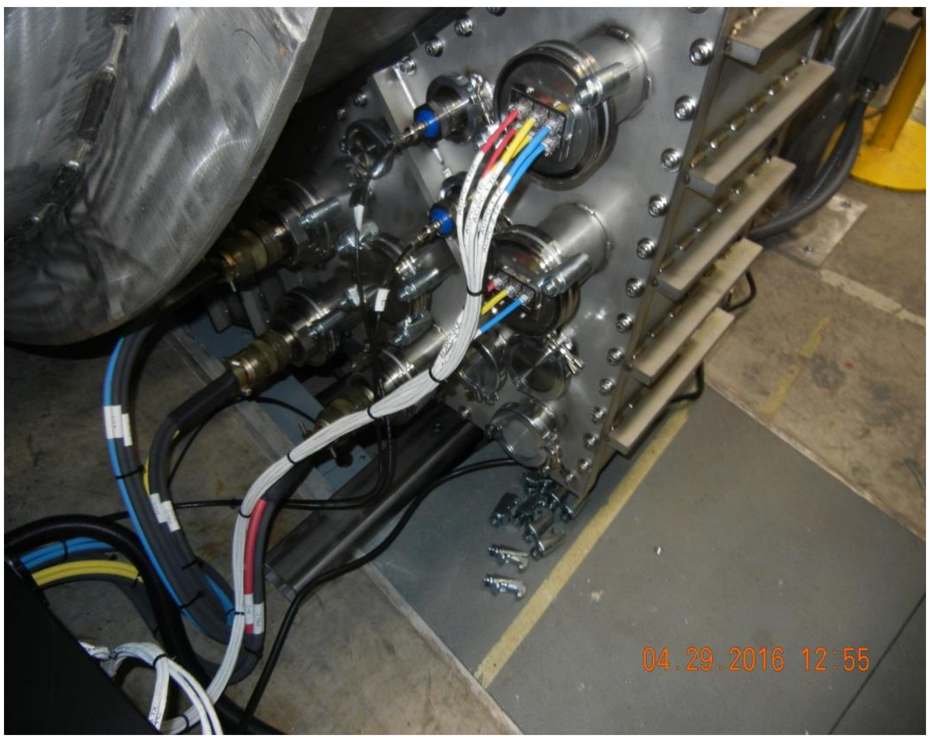


Low voltage connectors, cooling air manifold, and VCR fittings for attaching air lines

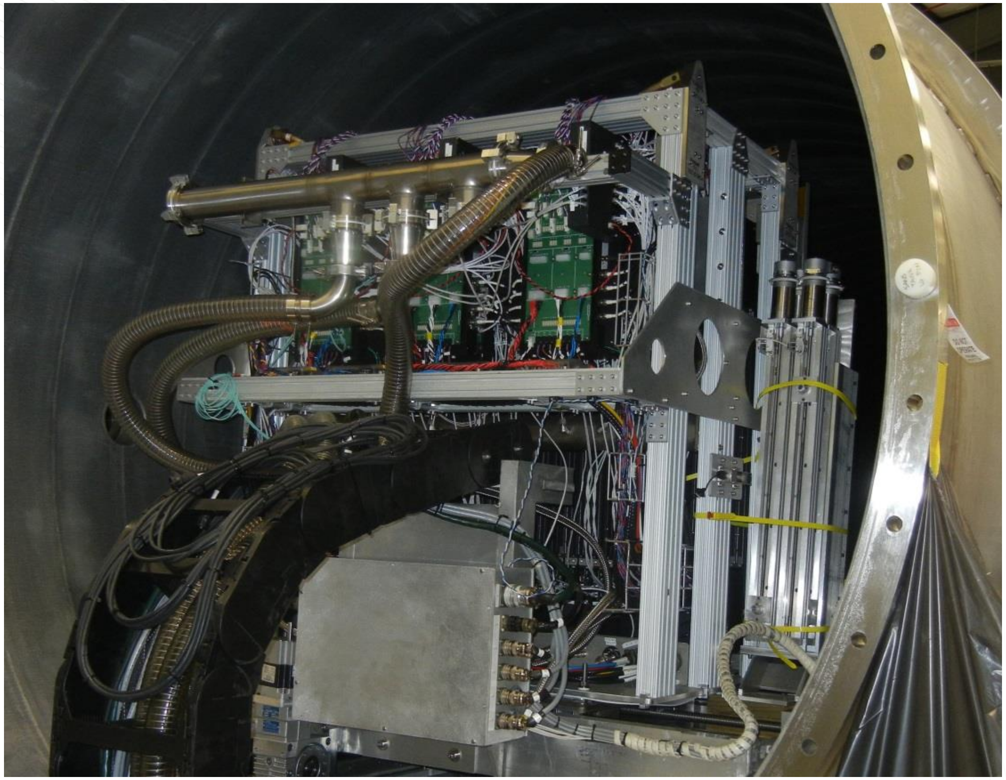
Feedthrough expansion chamber was installed during a previous outage to maximize resource availability during installation outage

Needed more feedthrough area than existing flanges could provide

Similar to what was installed for main array in 2012



Prior to installing the new detector, first needed to disassemble and remove the main detector from the tank



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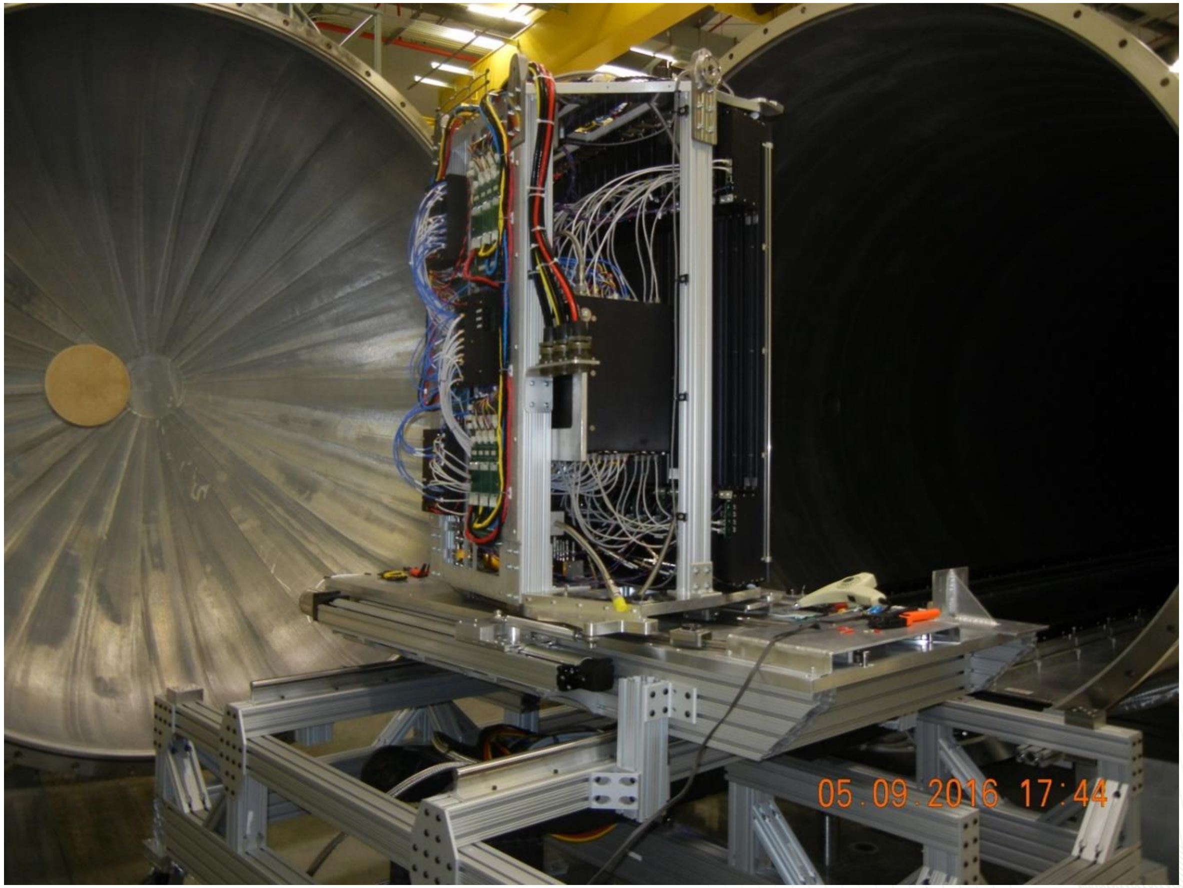
Special cart built to lift new high angle detector to the height of the tank rails



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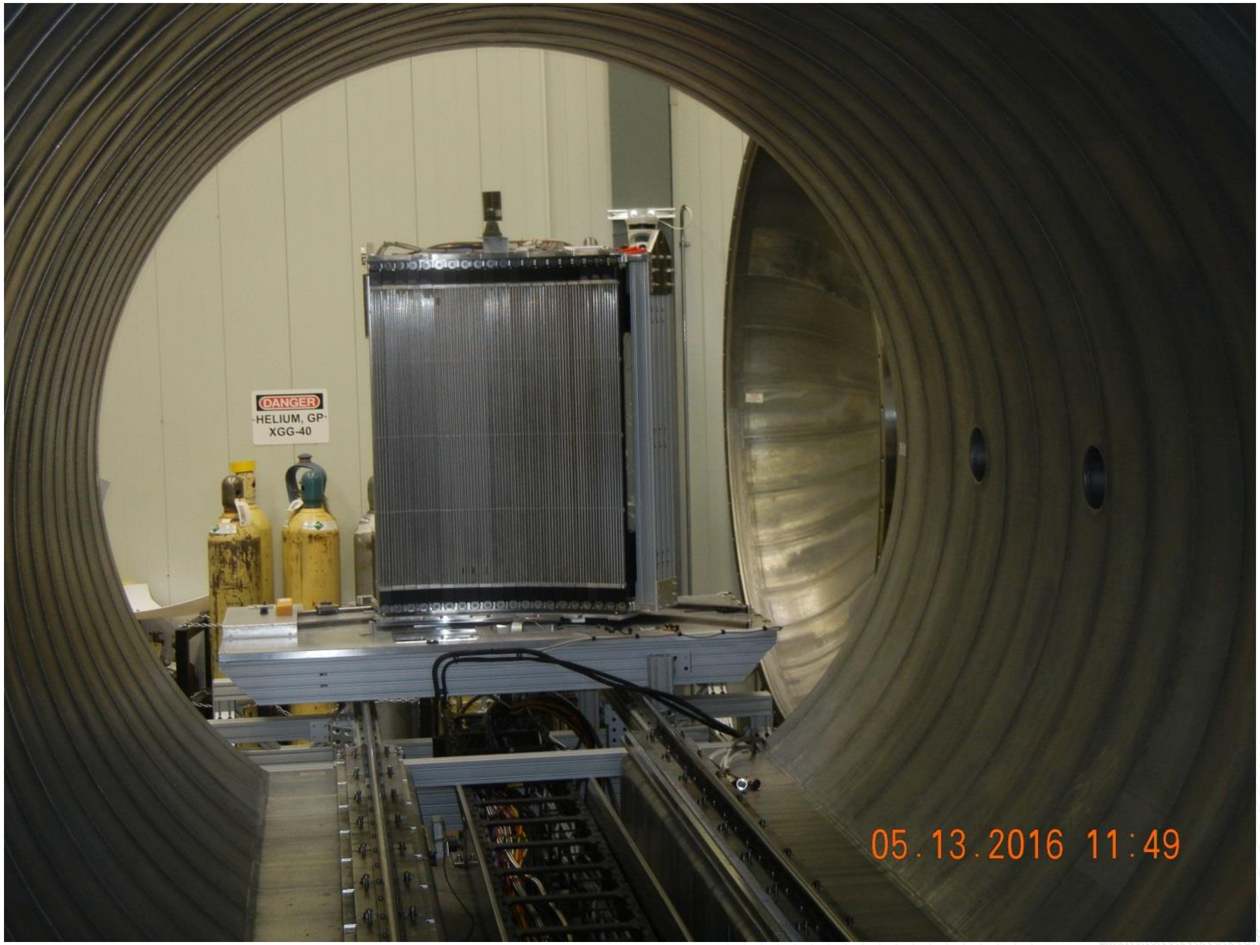
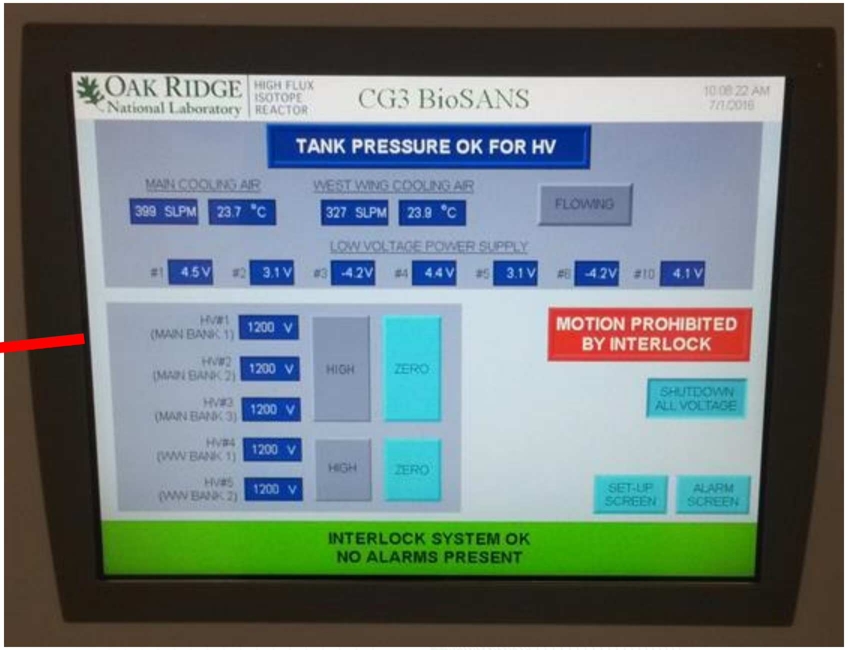
Test fit before detector moved into position at front of tank

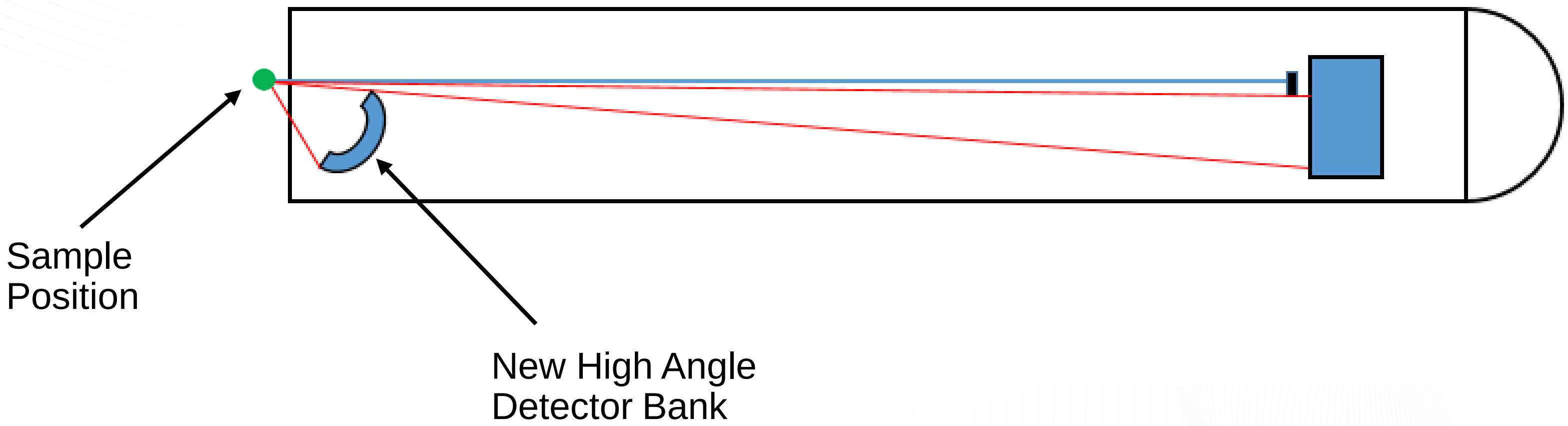


Additional aspects of project required by detector upgrade

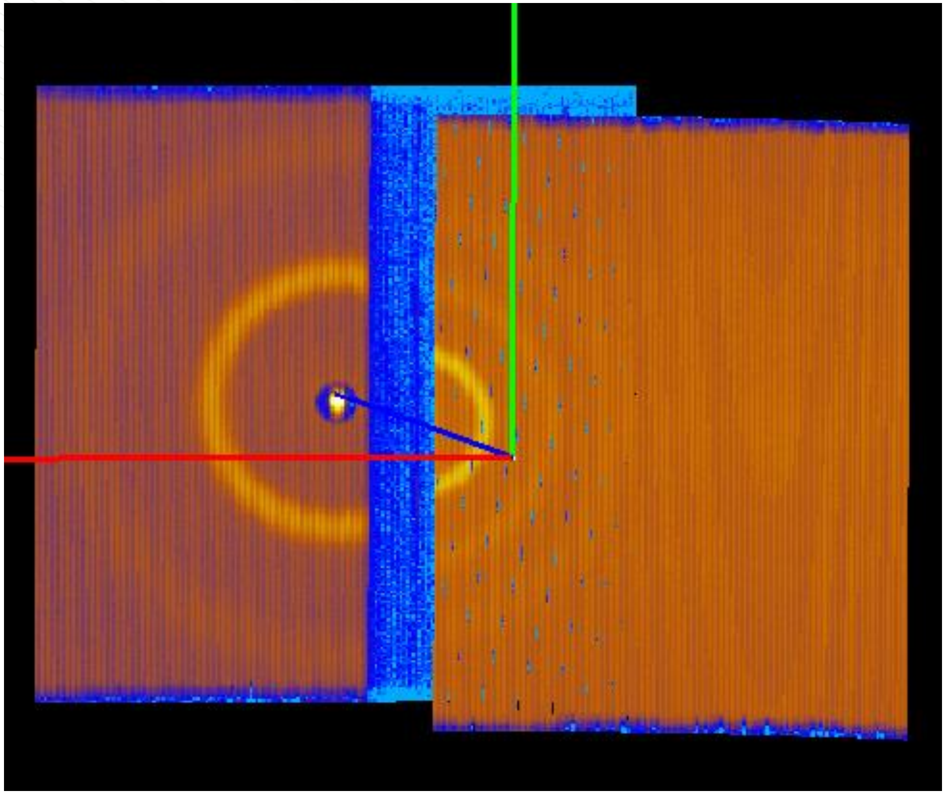
- new touchscreen interlock PLC, rebuild of motor control and detector power supply racks



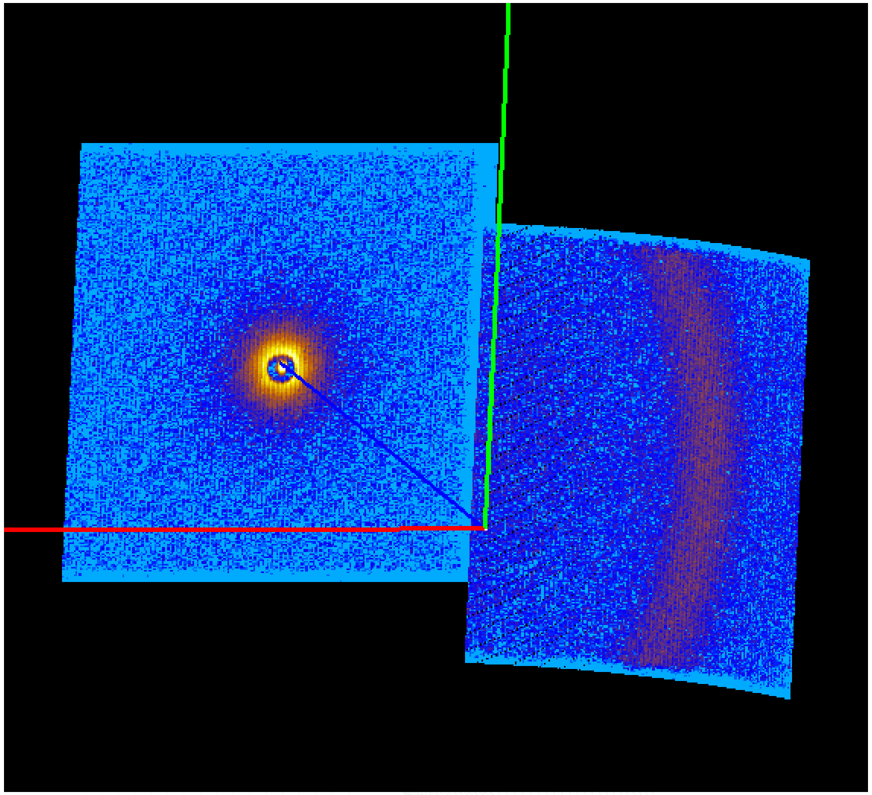
Full Q range now accessible with single acquisition utilizing both detector banks



Simultaneous images from both detector banks show previously inaccessible Q range



Silver Behenate



C-60 Fullerene

Final Comments

- Some preliminary work was completed in previous outages
  - rebuild of motor control rack
  - installation of feedthrough expansion chamber
- Detector and frame assembly built and fully tested offline
- Installation during long (88 day) outage 3/18 - 6/14, 2016
- Began commissioning at start of next run cycle (June 14), able to take friendly users toward end of the run cycle

Thank You for your Time and Attention

Amy Jones – Engineering Lead and Project Management

Engineering and Design

Amy Jones
Barton Bailey
Randy Summers
Larry Davis
Steve Hamblen
Mike Costa

Installation Support

Ron Conaway
John Stout

Instrument Staff

Venky Pingali
Shuo Qian
Volker Urban
Lakeisha Walker
Ryan Oliver

DAS Team

Steve Kulan
Mike Harrington
Ray Gregory
Larry Senesac

Detector Team

Kevin Berry
Justin Beal
Loren Funk
Will Reynolds