Neutron imaging overview and update on the second LOS being implemented (North Pole)

CEA-NNSA Joint Diagnostic Meeting

Neutron Imaging Team

June 29th, 2016

LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

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Outline

- Long term NIS goals
  - 3 LOS, both primary and down scattered neutrons
  - Image plates allow short lines of sight
  - Implementation inside buildings
  - Schedule
- North pole NIS
  - System overview
  - Pinhole assembly
  - Snout body and tube
  - Connection to X-ray LOS
  - Alignment ATLAS
- Conclusions

The team represents a LLNL & LANL collaboration that has been going on since 2009

- LANL
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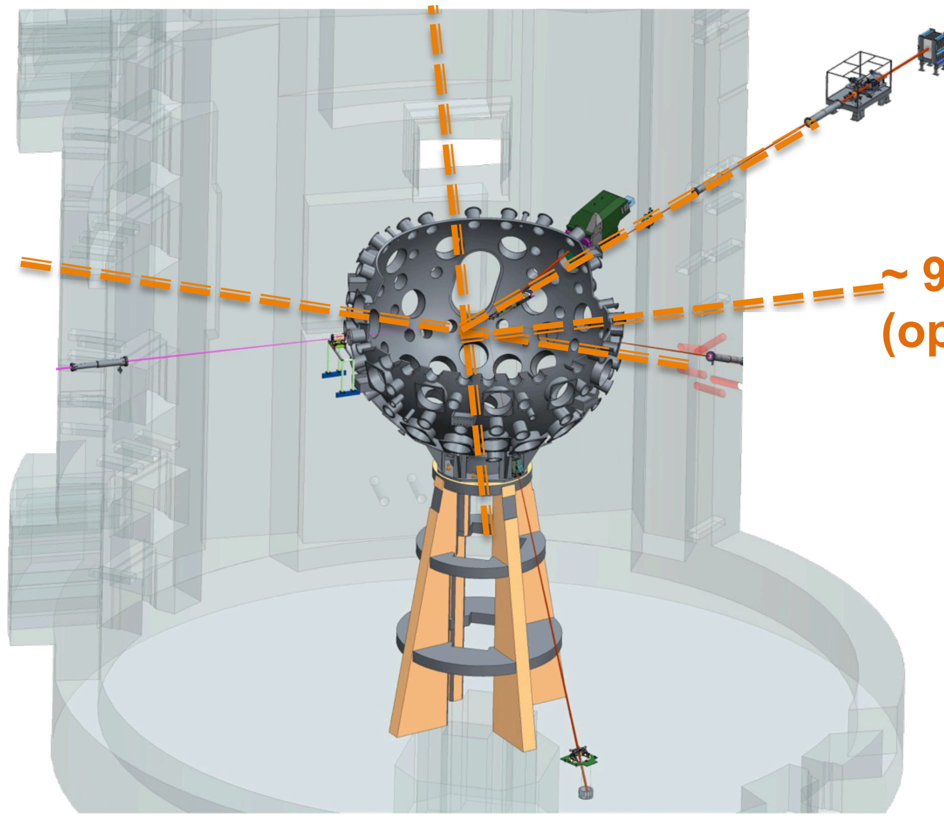
  - Chris Danly
  - Valerie Fatherley
  - Lynne Goodwin
  - Jeffrey Griego
  - Petr Volegov
  - Carl Wilde
  - Adam Wachtor
  - Jim Witt
  - Justin Jorgenson
- LLNL
  - David Fittinghoff, RS
  - Robin Hibbard
  - Robin Benedetti
  - Gary Grim
  - Dave Barker
  - Jay Ayers
  - Don Jedlovec
  - Sabrina Nagel
  - Dan Kalantar
  - Mike Vitalich

…and many others in the past

5 Year plan for Neutron Imaging

Long Term goal is:

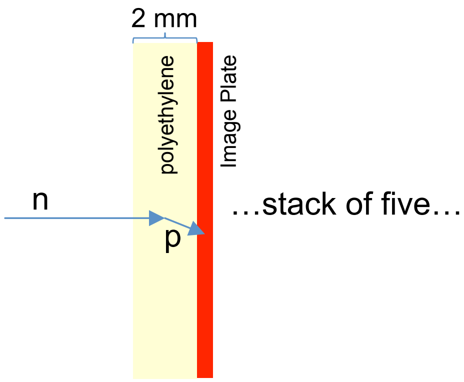
- **3 Orthogonal imaging LOS**
- **All with both primary and down scattered imaging capabilities**



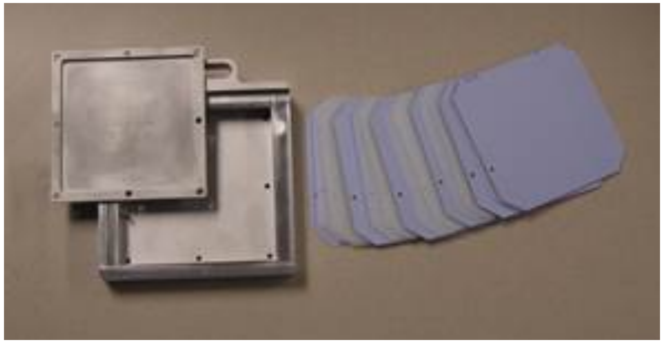
Existing Detectors

Possible Future LOS

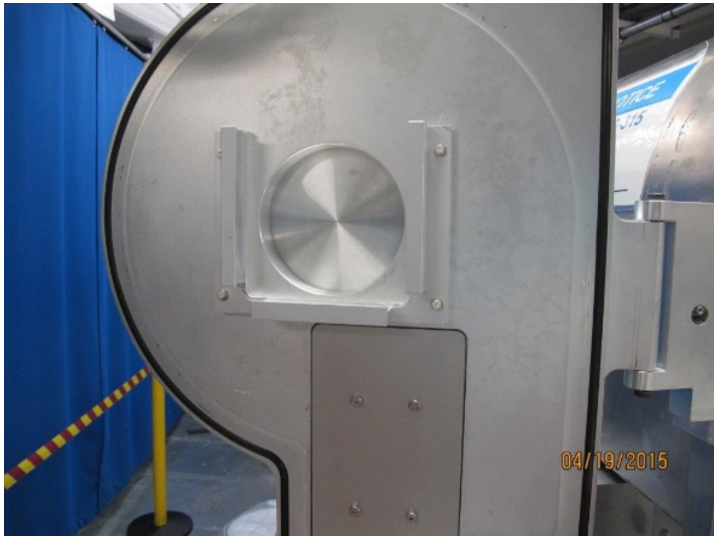
We are implementing a detector system based on image plates, which allows use of a short line of sight, energy-integrated imaging



Detector box mounted on back of DIM



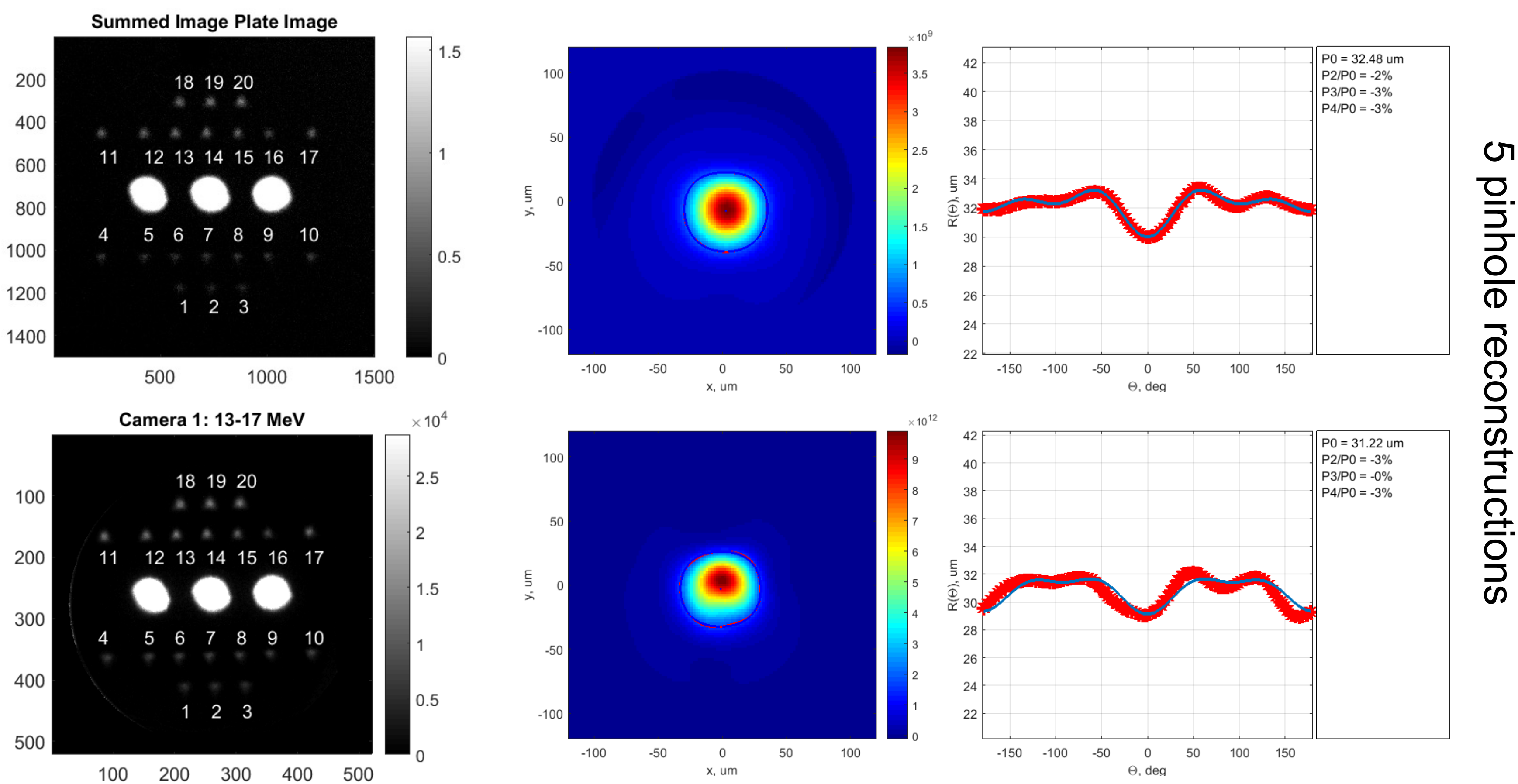
“P” Door at back of 90-315 DIM



An inexpensive neutron detector, consists of a stack of polyethylene converter in front of an image plate. We have been looking at the performance of this system for imaging of high yield experiments.

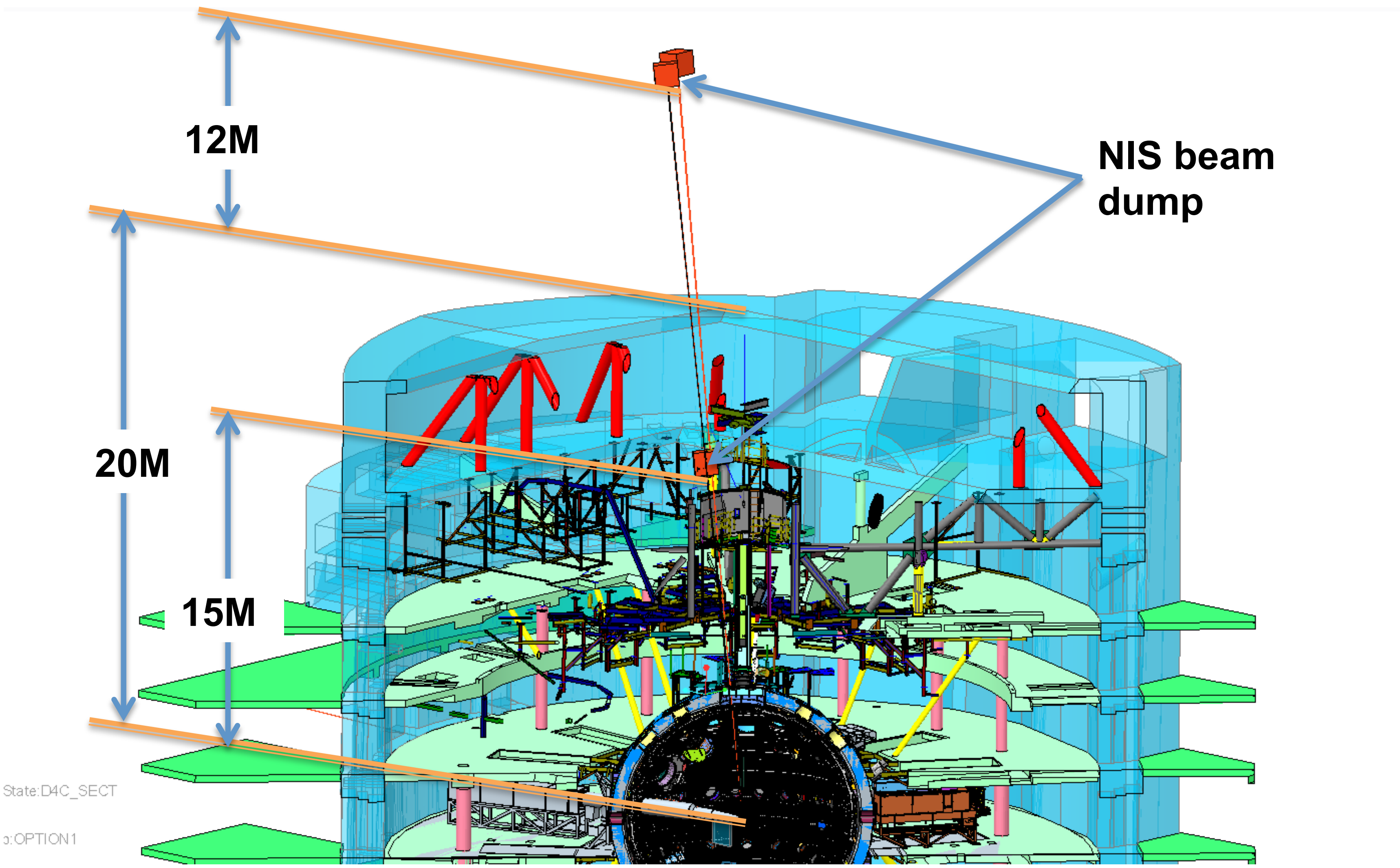
Performance of the short line of sight imaging system allows implementation of the system on the polar axis

N150528, 5.7x10^{15} neutrons

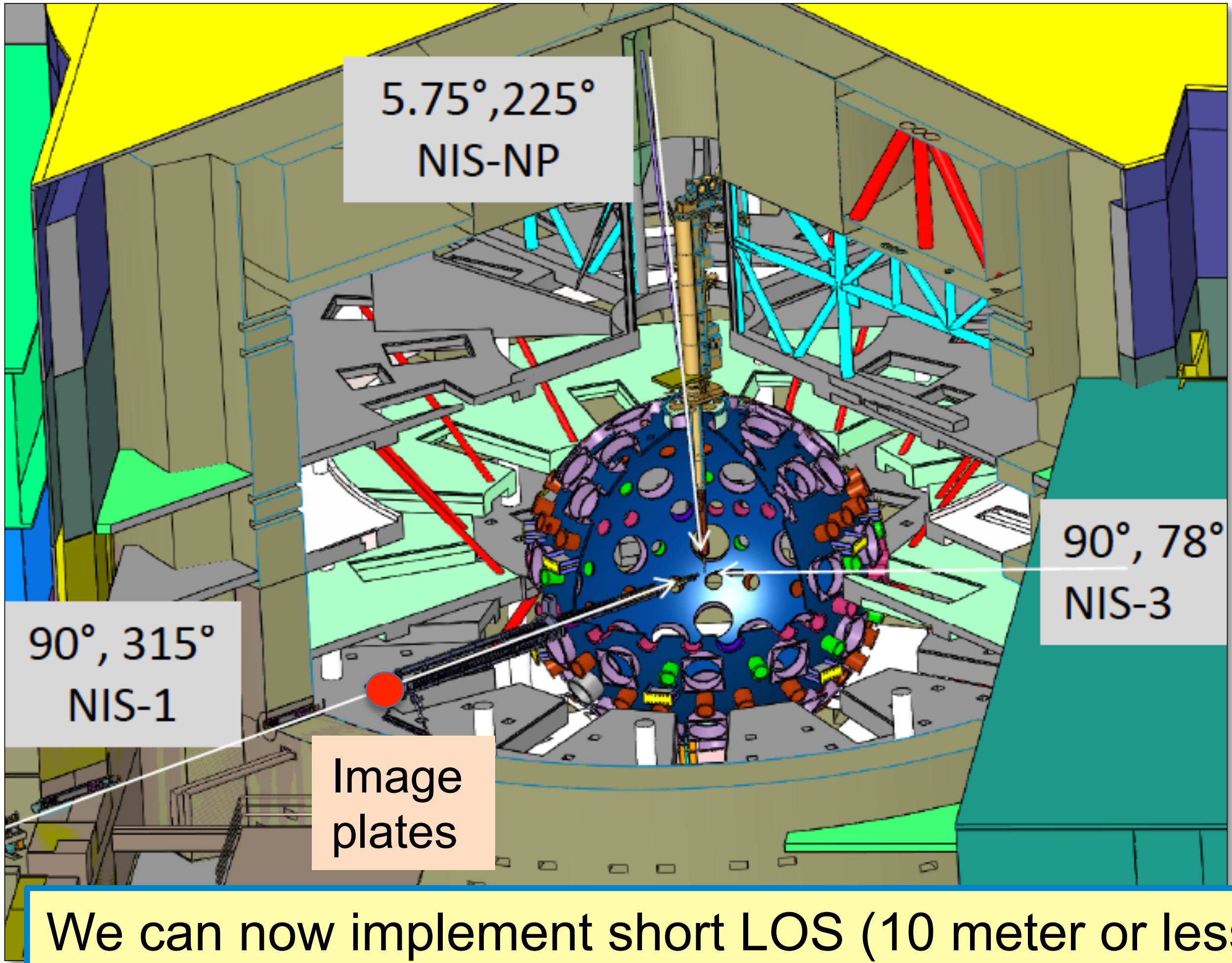


This allows moving inside the building and saves time and costs. It also facilitates the implementation of a second equatorial LOS inside the Target Bay

18 months ago we thought NIS had to be above the Target Bay on the roof



Short LOS allow north pole and a second equatorial LOS to be inside the Target Bay

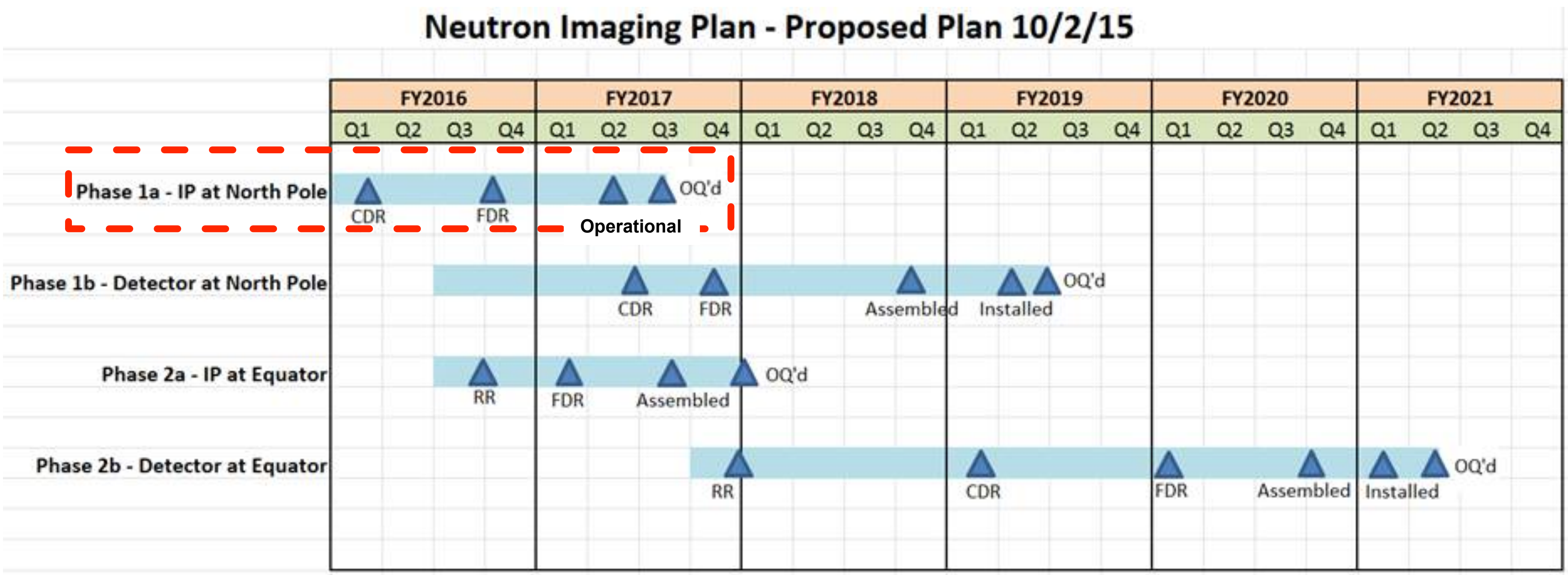


- Existing 90-315 NI LOS is 23 meters
- Image plates developed at 11 meter LOS

90-45 or 90-225 would be closer to orthogonal

We can now implement short LOS (10 meter or less) systems without expensive building modifications

The Neutron Imaging Plan as of October, 2015



- Phase 1: Polar View
  - Phase 1A: Energy integrated polar view - Dec 201
  - Phase 1B: Energy resolved polar view - 2019
- Phase 2: 2nd Equatorial View
  - Phase 2A: Energy integrated equatorial view - 20
  - Phase 2B: Energy resolved polar view - 2021

Opportunity:
Need new detectors for down scattered neutrons on short LOS.

North Pole System Overview

CEA-NNSA Joint Diagnostic Meeting

Neutron Imaging Team

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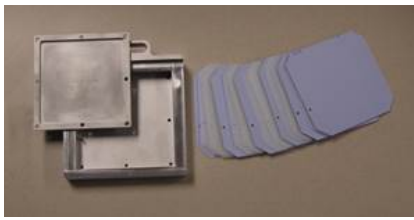
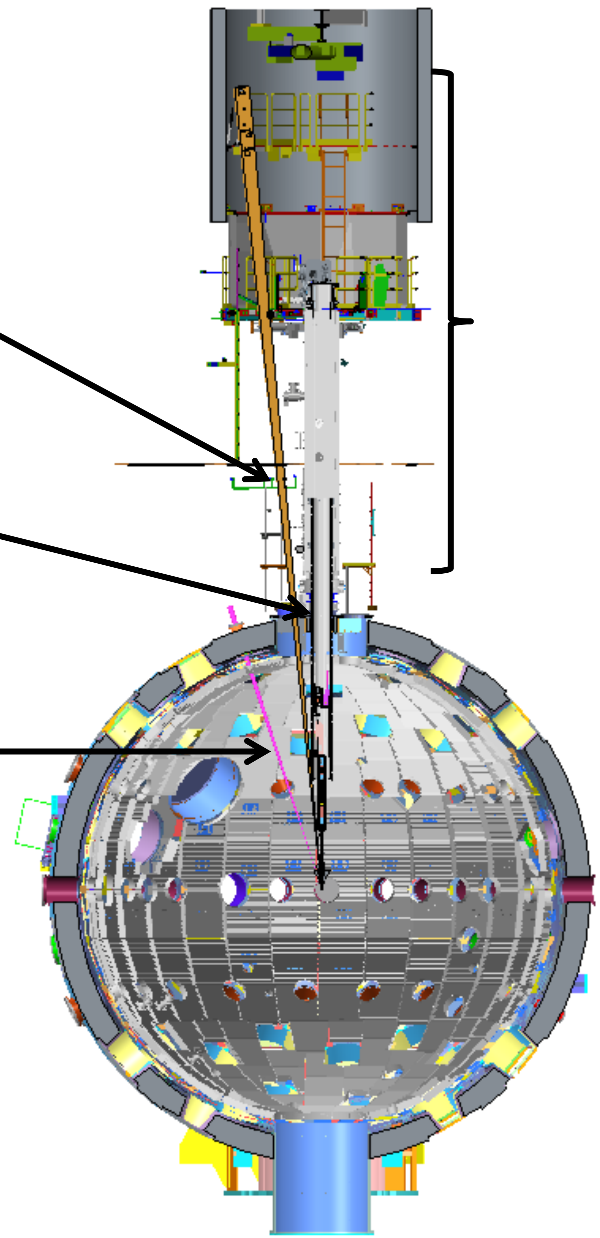
NIS-NP Top Level

Detector - Stacked Image Plate on X/Y stage (Now at 8.6 m)

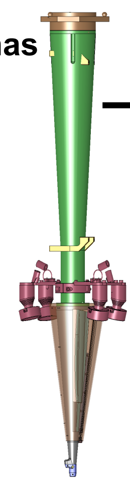


Polar Dim carries the NIS snout assembly



NIS-NP Snout Assembly has to maintain three LOS

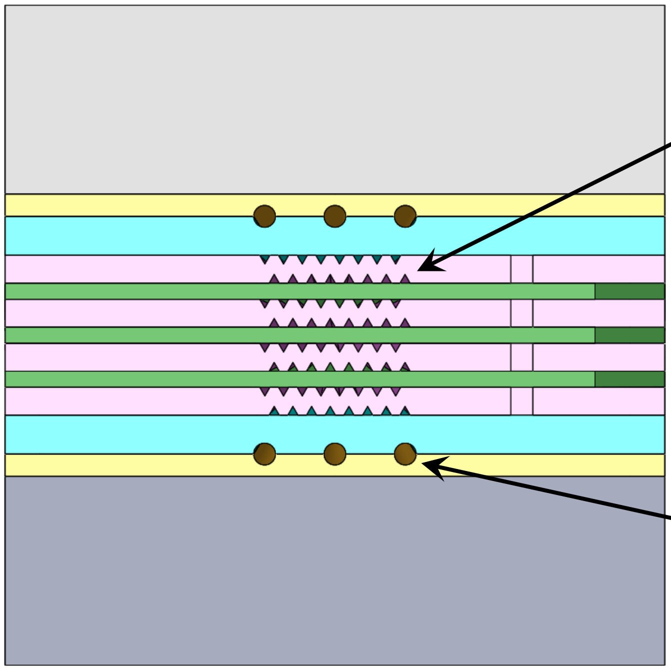
- NIS PHA
- PHA Mounting Bracket
- DIXI/HGXD pinholes
- SRCs



Big picture operations

- Image plate detector at 8.6 M
- Polar DIM inserts NIS snout
- Maintains the x-ray imaging at 0-0
- Big change is precision built snout that is metrologized and fixed. No active alignment of the PH during shots.
- ATLAS aligns this LOS to TCC
- The detector can be moved onto this LOS

The pinholes will be scribed in gold as in the current design



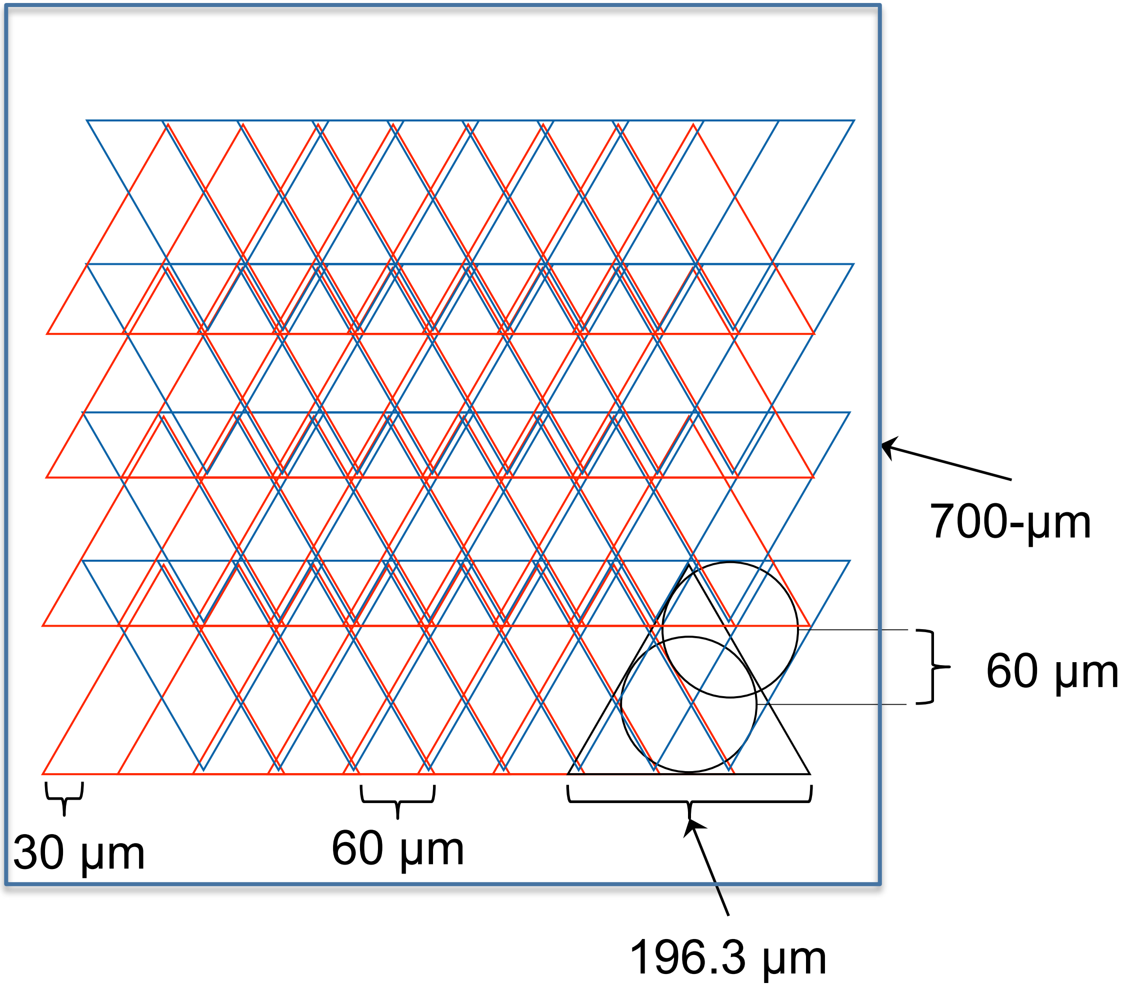
- Minimum pinhole spacing determined by 178um minimum working layer thickness of gold.
- Number of pinholes per layer limited by size of image plate.

- Triangular Pinholes:
  - — 64 individual pinholes
  - — 200um FOV (as defined by the height of the triangle at the back of the PHA)
  - — 15-µm opening at the front of the PHA body
  - — 60-µm spacing at target plane
- Penumbra:
  - — 6 penumbral openings
  - — 300-µm at front, 300-µm at center, 500-µm at back
  - — 160um x 350um spacing at target plane

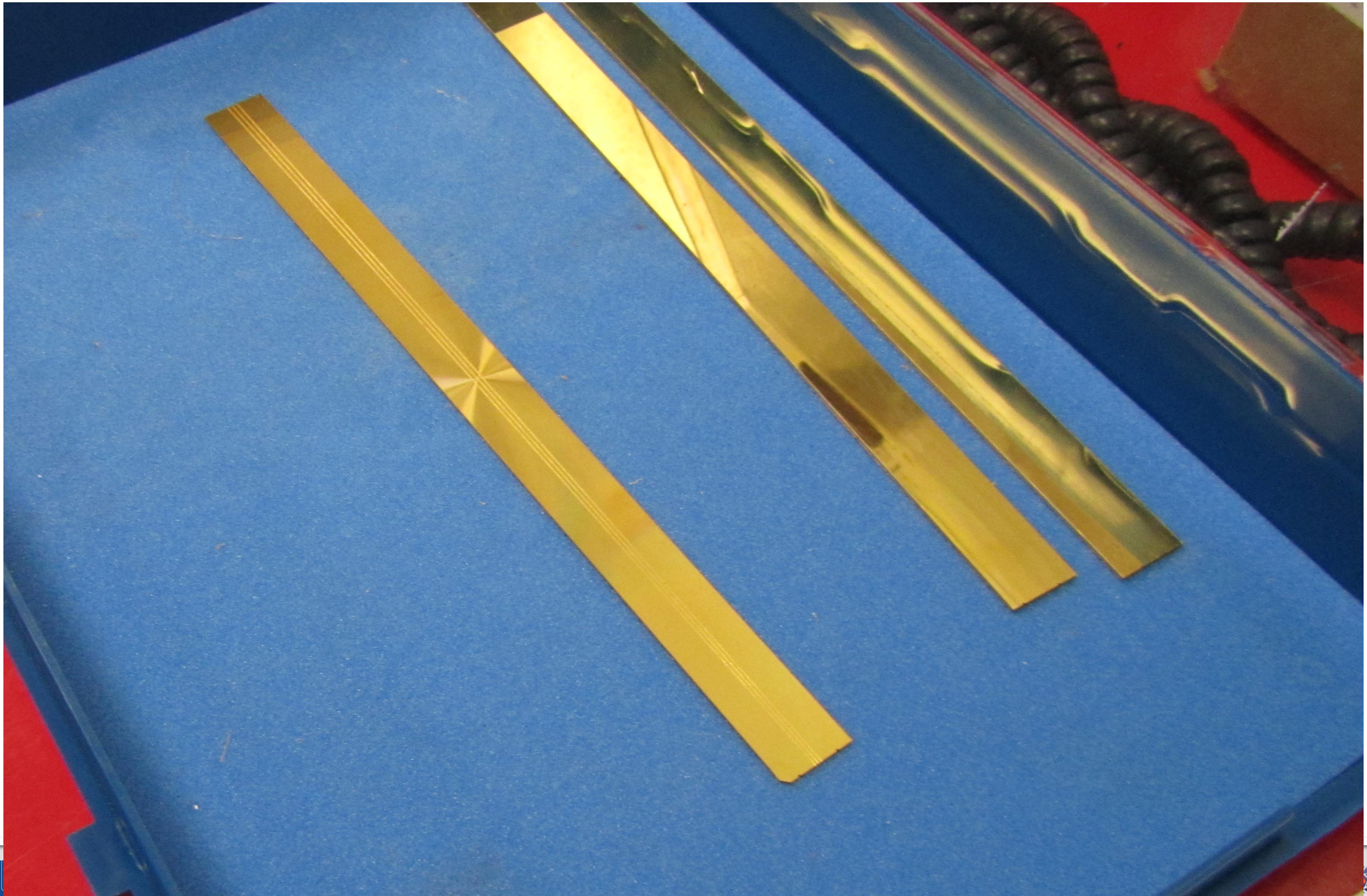
Pinholes shown at the back of the 20-cm long array.

A 700-μm total FOV will require overlapping the coverage at the target plane

- 64 Triangular pinholes
  - 8 pinholes across
  - 8 layers vertical
- Spacing
  - In-row : 60 μm
  - Vertical: 60 μm
  - Row offset: 30 μm
- Geometric FOV
  - Projection of pinhole to the source.
  - Neutron penetration increases the overall FOV.



The pinhole is starting to appear ☺

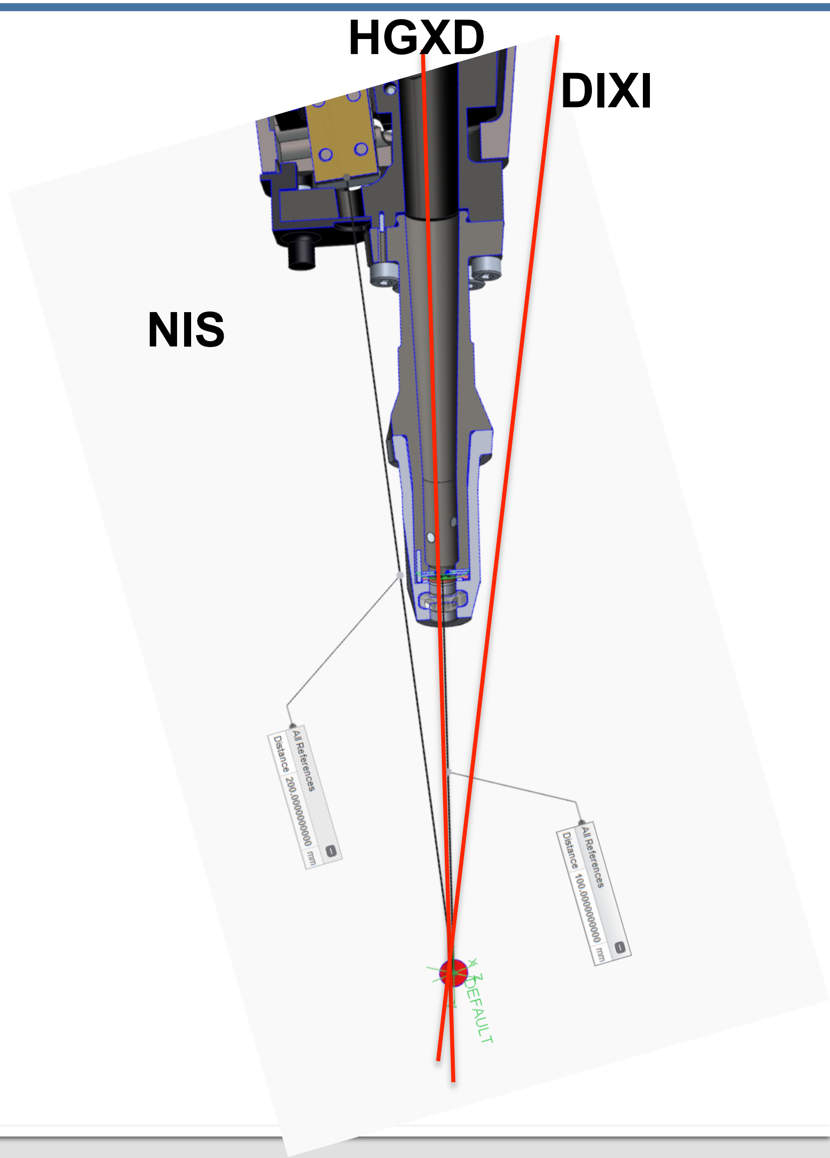


The NIS snout alignment is based on the requirements and the pinhole assembly design

- **NIS Pinhole FOV = 700 um, the PHA is designed for up to 3.9 mrad of angular error**
  - **The pointing required of the NIS LOS to TCC aim point is +/- 275 um**
  - **This is within the ATLAS and manufacturing capabilities**

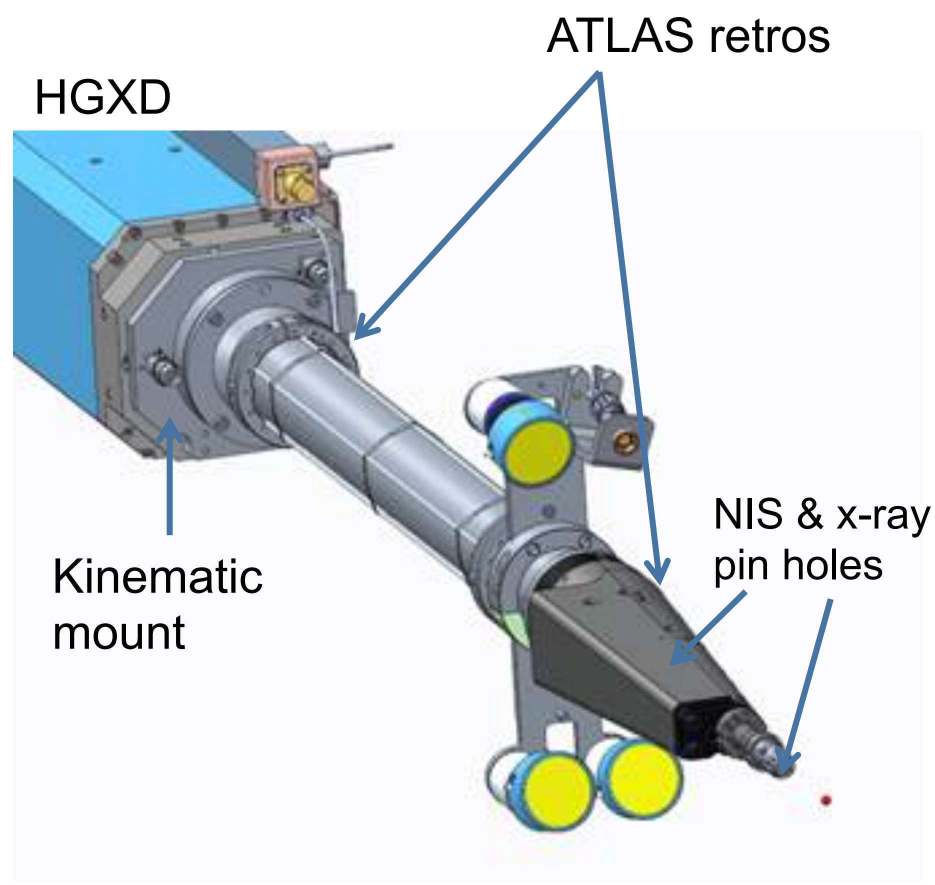
- **HGXD (Ross Pairs) and DIXI alignment tolerance +/- 500 um**

- **The NIS detector need to be aligned to +/- 1.0 mm (surveyed into place)**



The NIS system is mounted in PDIM on the front of the standard x-ray imaging systems

- Polar DIM and the typical X-ray imaging system holds the NIS “snout”
- The “snout” is modified and holds the NIS pinhole
- NIS is the primary LOS for alignment
- HGXD rides along
- Precision built into the snout makes this work
- There are ATLAS retros on the snout extension tube and the snout body
- ** CMM data from the snout body and NIS LOS is correlated with ATLAS coordinates



NIS snout and kinematic base mounted on HGXD

The NIS detector is oversized and fixed in place

50 foot floor

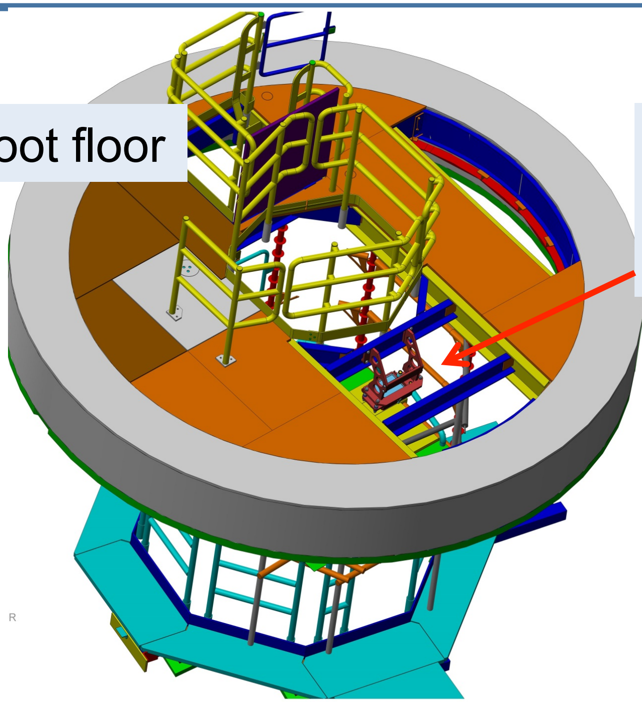
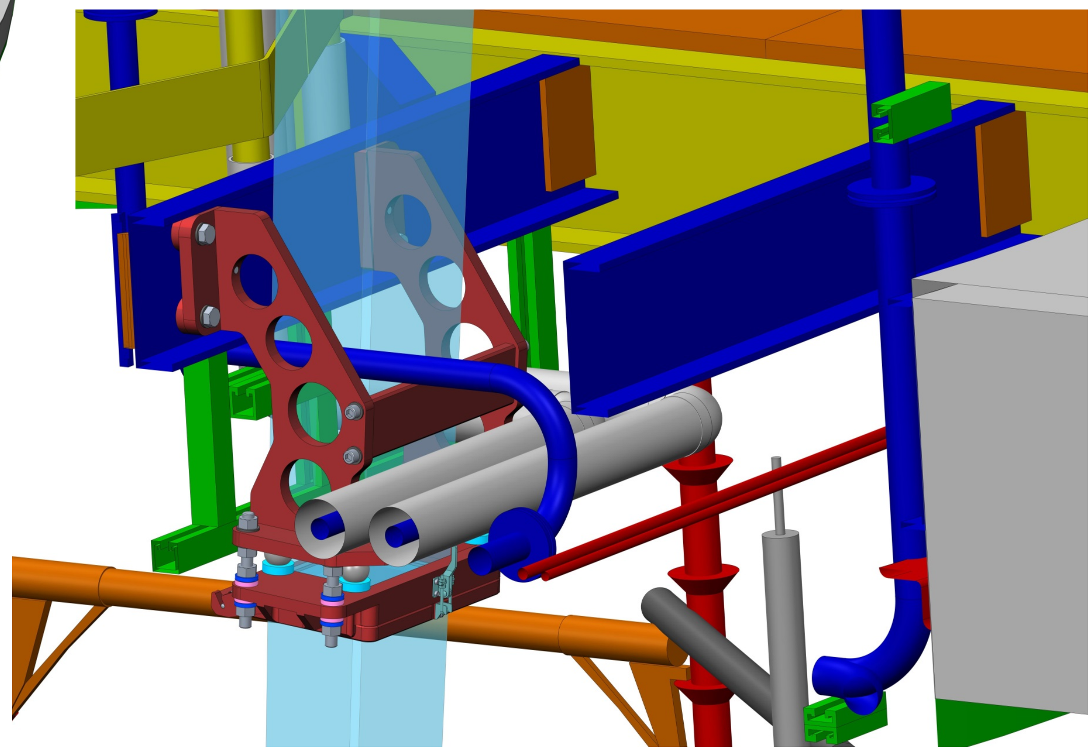


Image plates is tucked under the floor

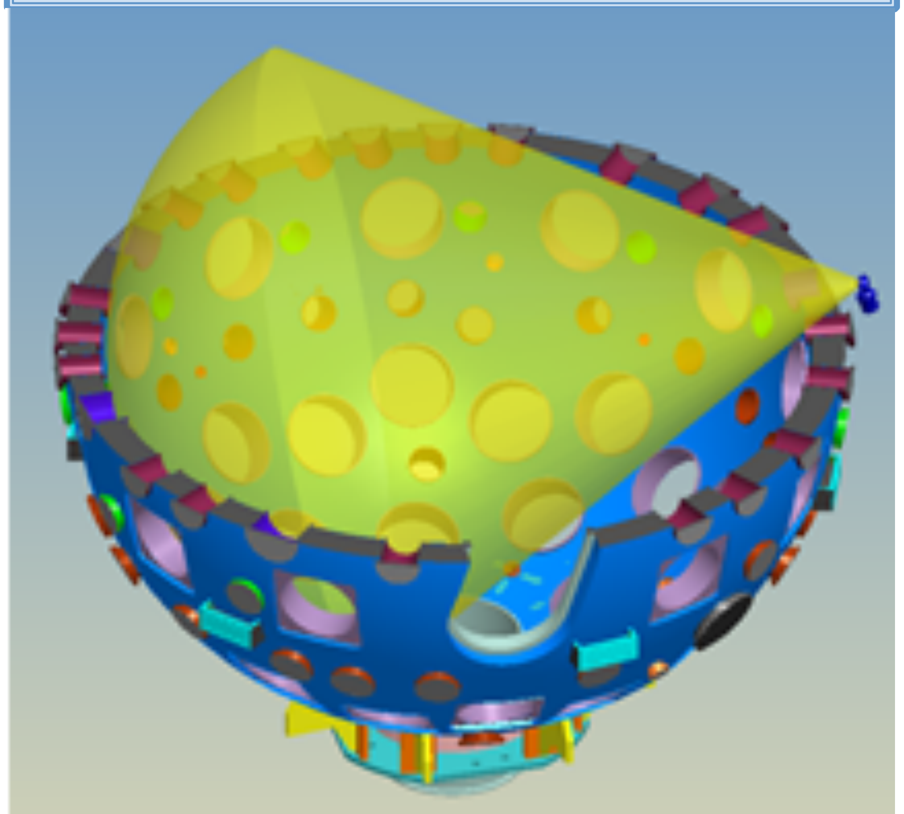
Note: A lot of stuff in the way

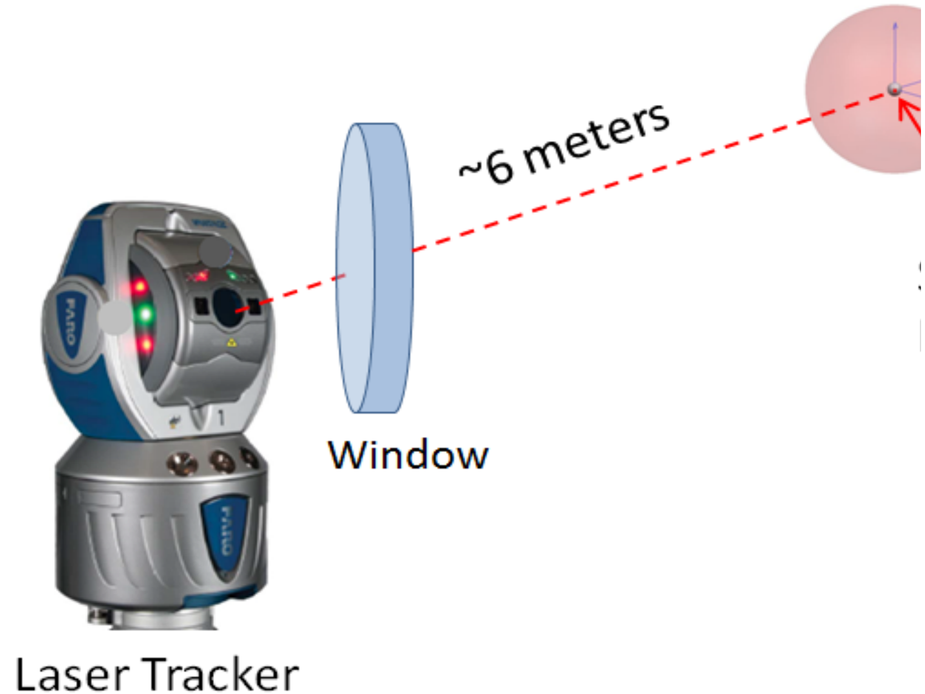


- **Image is ~ 10 x 20 cm^2**
- **Image plates are 20 x 40 cm^2 and there is enough margin to fix them in palce**

ATLAS new laser tracker alignment system being commissioned on NIF

ATLAS Alignment System





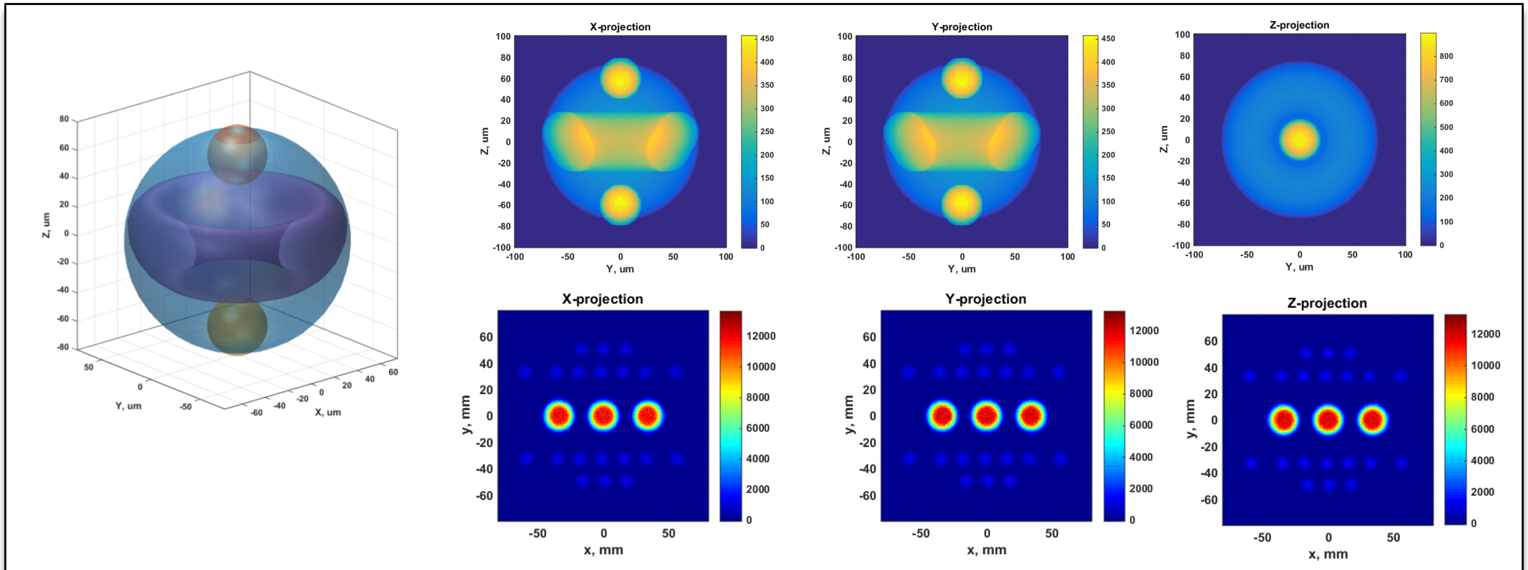
Conclusions

- 5 year goal – three orthogonal LOS all with primary and down scattered neutrons
- Image pales have allowed us to consider short LOS
- Now the challenge is to find detectors that can do the down scattered neutrons at a short LOS
- North pole neutron imaging system is expected to start taking data in December 2016 (primary neutrons only)

Back ups?

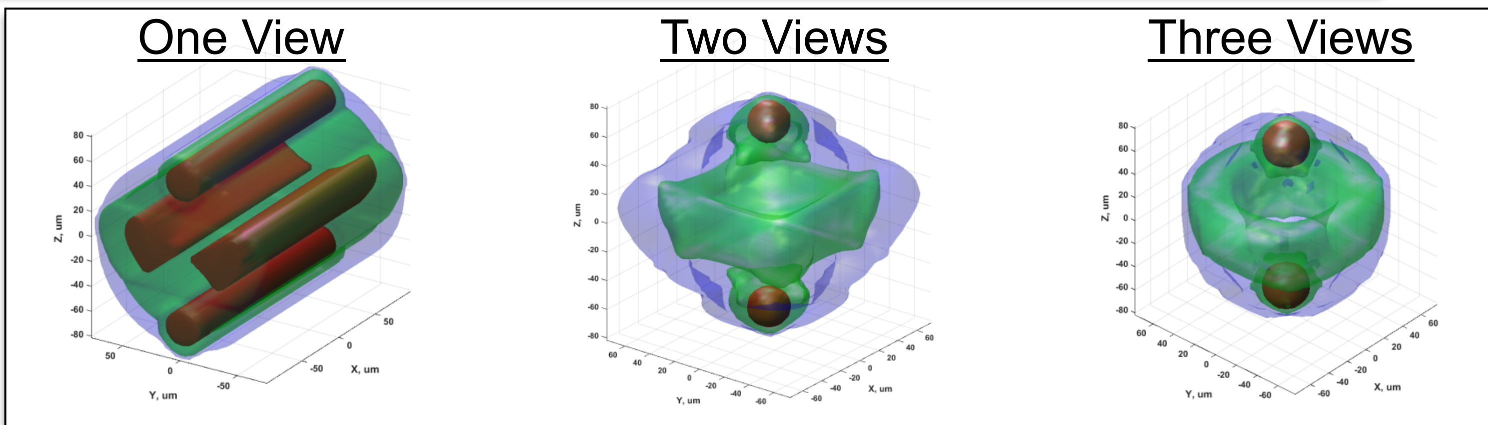
Simulations show that multi-axis neutron imaging can provide useful 3D burn information

Motivation



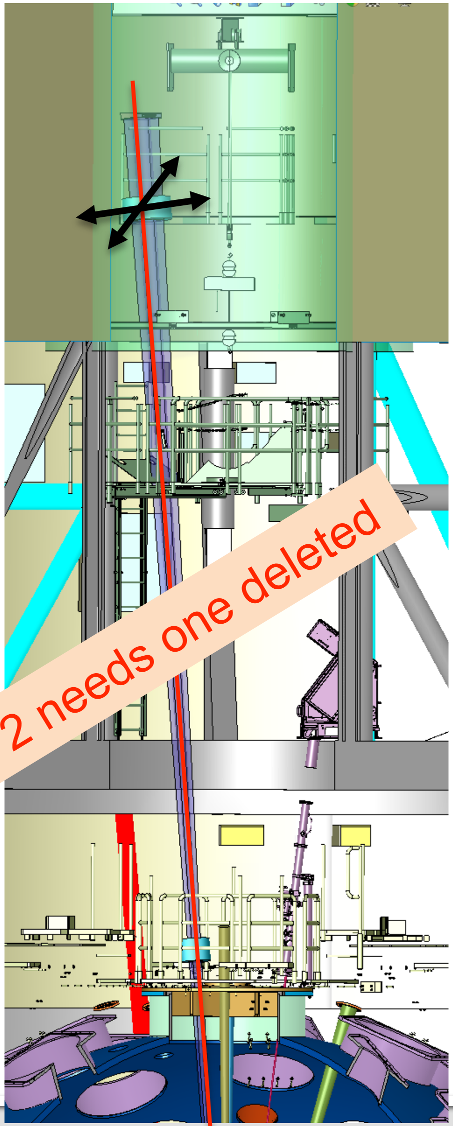
Generate projections

Forward model through pinholes with 10^{14} neutrons.



The NIS detector alignment is simple, ATLAS sets a NIS LOS, then ICCS moves the detector onto it

- **ATLAS points the front of the NIS pinhole assembly to TCC**
- **The vector orientation is known in NIF global coordinates**
- **The detector center is moved to that coordinate**
- **The detector need to be aligned to +/- 1.0 mm**



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