Optical Calibration and Scintillator Plant Construction on the SNO+ experiment

Christmas 2014

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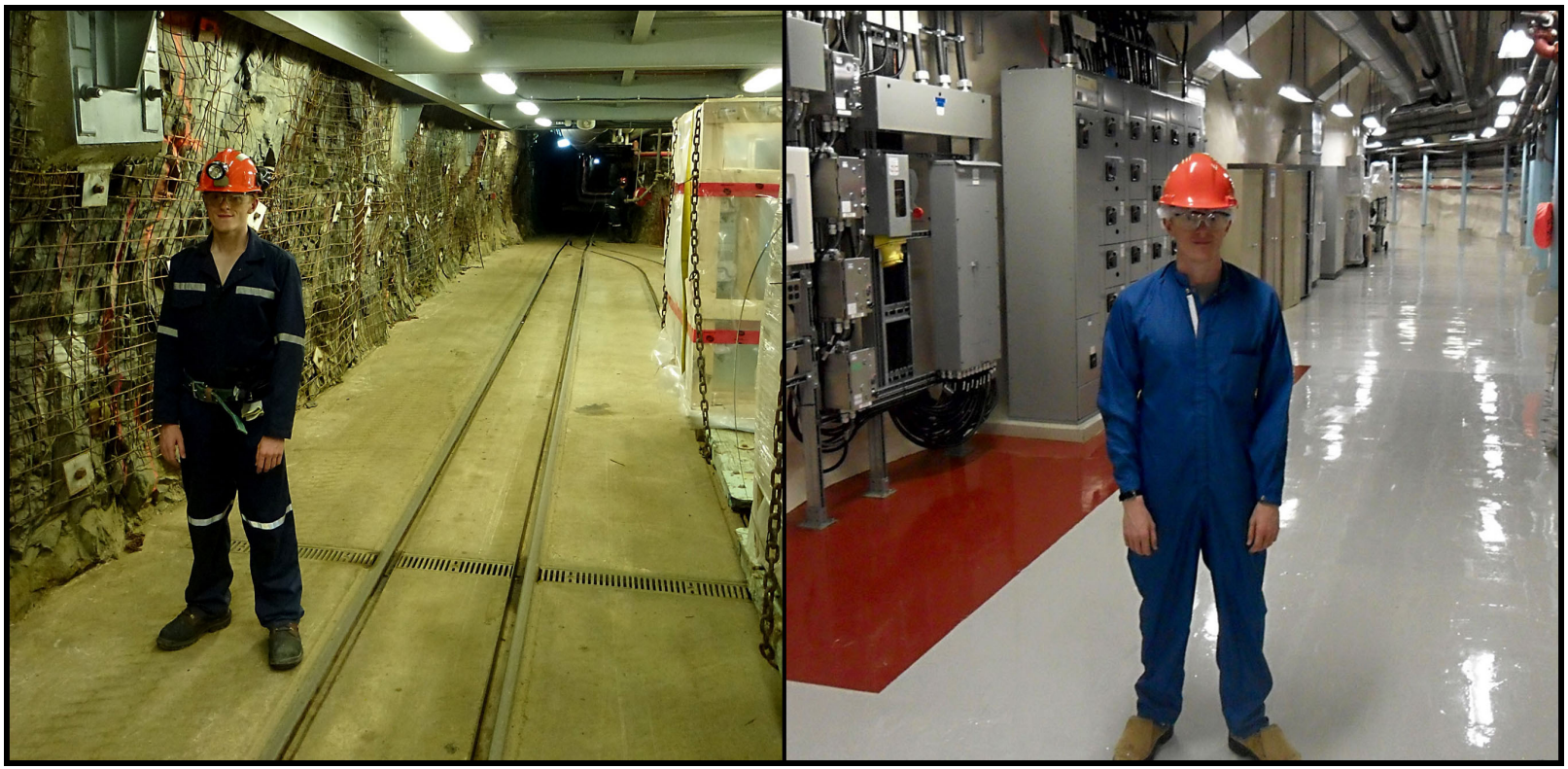
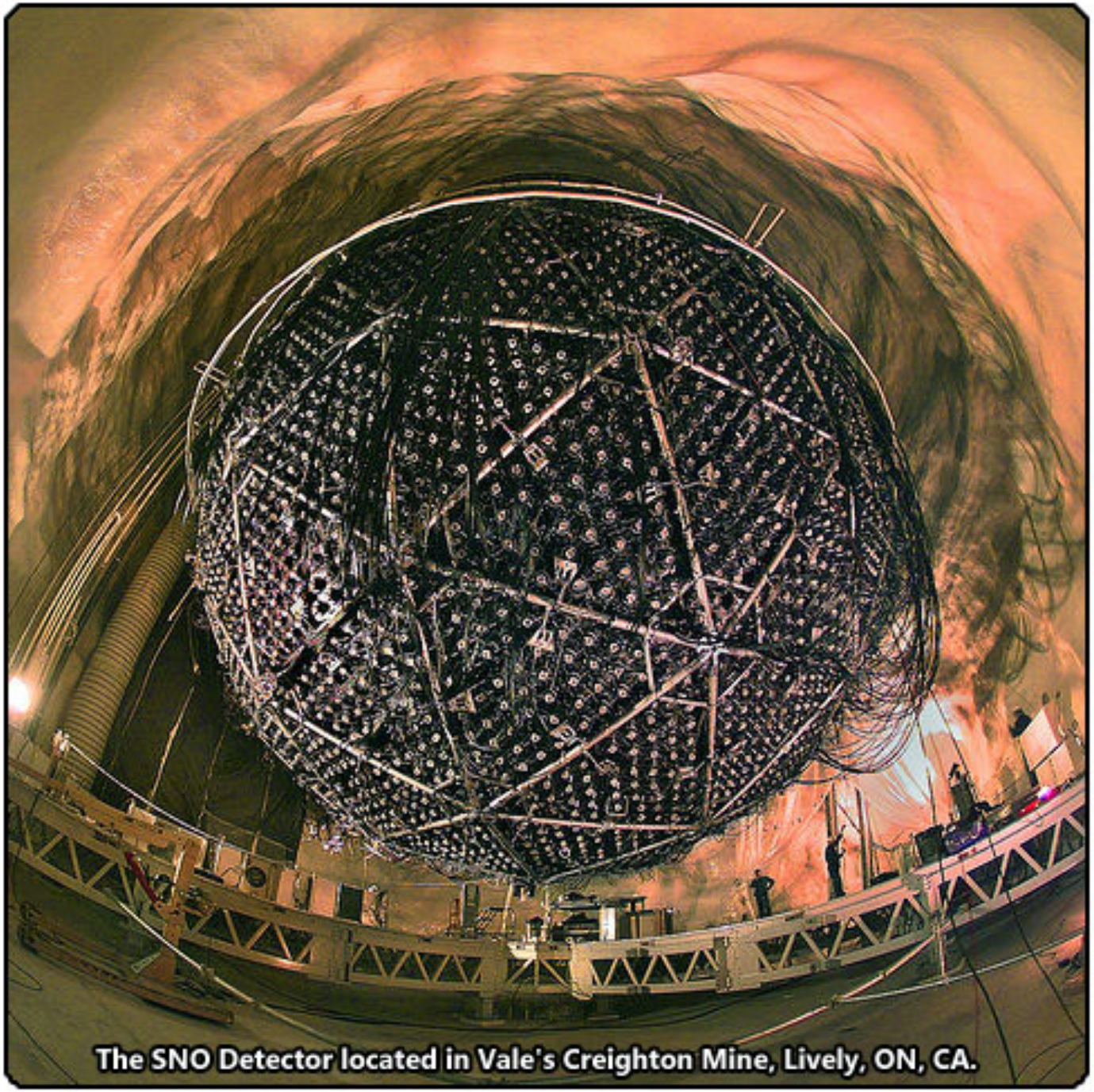
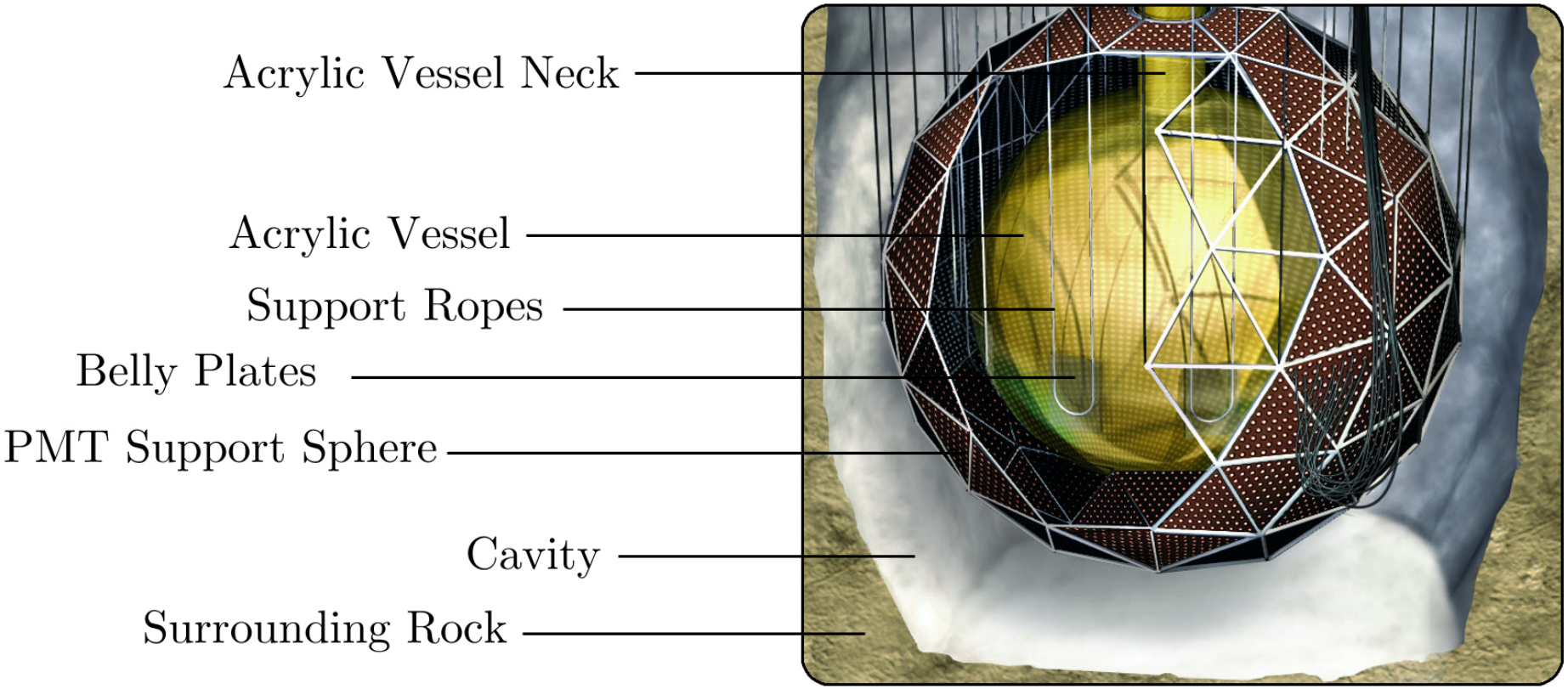
Future Work - LAST YEAR [2013]

- Continue work on LOCAS in time for laserball runs (early 2014)
  Optical Calibration
- Work onsite with other members of the collaboration in 2014 in Sudbury.
  Construction




The SNO Detector located in Vale's Creighton Mine, Lively, ON, CA.



Acrylic vessel to be filled with scintillator in 2015/6. Scintillator loaded (0.3 % g/g) with Tellurium [Telluric acid in solution] sometime during 2016.

SNO+ Cavity Access

SNO+ Cavity Access


SNO+ Cavity Access

Optical Calibration

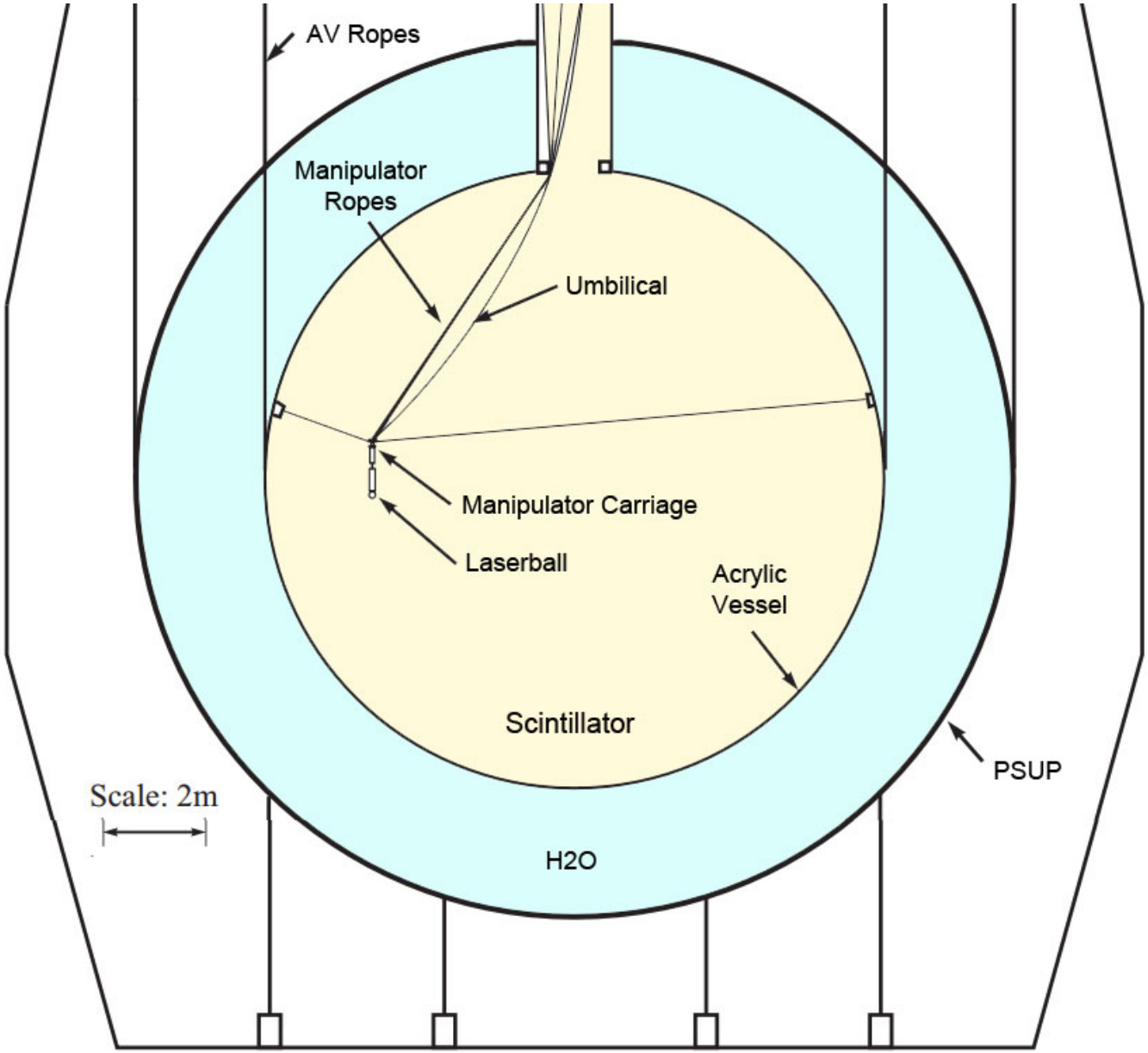
- **An optical calibration of the SNO+ detector:**
  - In-situ measurements from a controlled source to calibrate detector
  - Characterise the optical response of the detector. i.e. How the scintillator, acrylic of the AV, water and PMT response affect scintillation light and its detection.

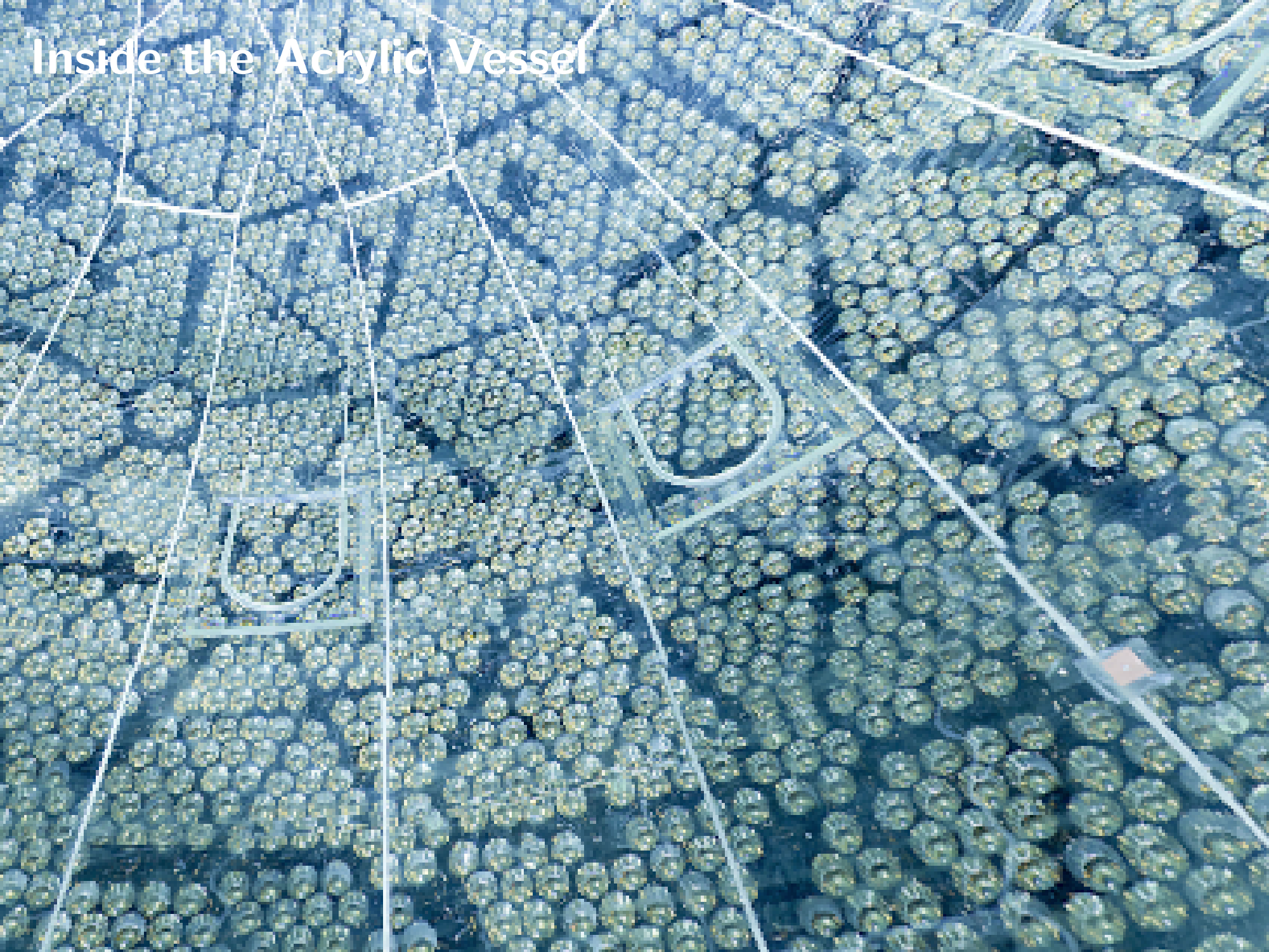
Controlled: [**position, intensity, wavelength**] light source, ideally isotropic . . .

Calibration data collected using an in-situ light source; the **Laserball**.

Perform many runs with the laserball in different positions and at different intensities and wavelengths.

The Laserball




Inside the Acrylic Vessel

Optical Model

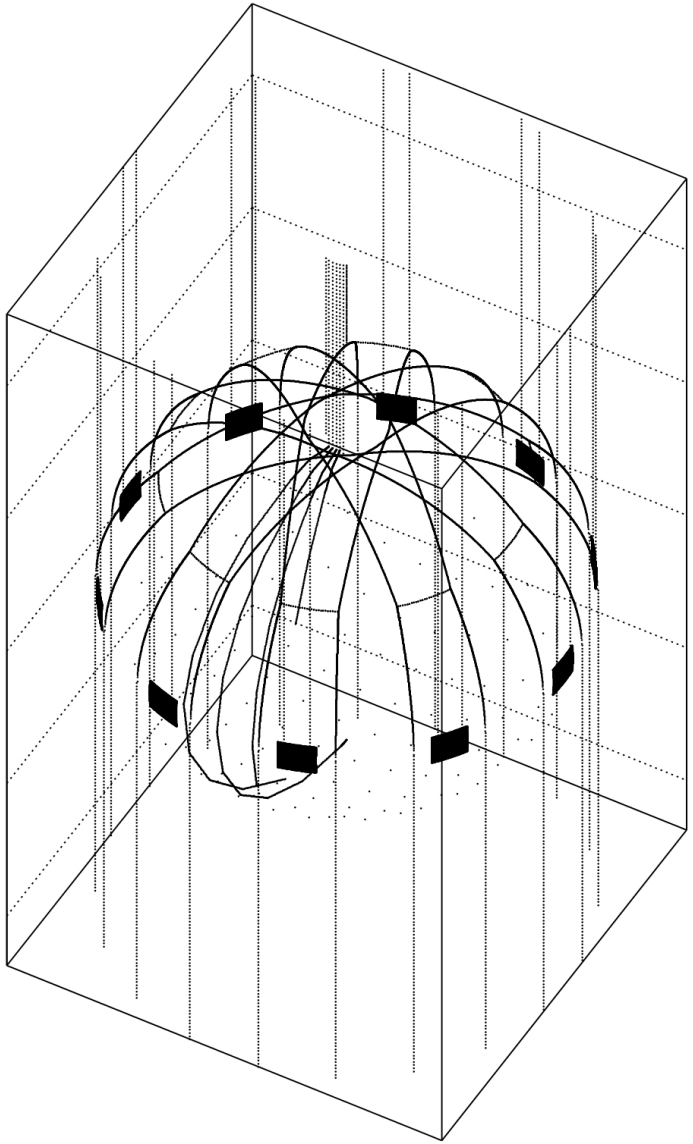
Occupancy at PMT j from laserball run i relative to central laserball run, modelled as follows:

$$\mathbf{R_{Occ,ij}} = \frac{\mathbf{Occ_{ij}}}{\mathbf{Occ_{0j}}} = \frac{\mathbf{\Omega_{ij} R_{ij} T_{ij} L_{ij}} e^{-(\mathbf{d_{ij,scint}}/\alpha_{\mathrm{scint}} + \mathbf{d_{ij,av}}/\alpha_{\mathrm{av}} + \mathbf{d_{ij,H2O}}/\alpha_{\mathrm{H2O}})}}{\mathbf{\Omega_{0j} R_{0j} T_{0j} L_{0j}} e^{-(\mathbf{d_{0j,scint}}/\alpha_{\mathrm{scint}} + \mathbf{d_{0j,av}}/\alpha_{\mathrm{av}} + \mathbf{d_{0j,H2O}}/\alpha_{\mathrm{H2O}})}}$$

- $\mathbf{\Omega_{ij}}$: - Solid angle subtended by the PMT
- $\mathbf{R_{ij}(\theta_{PMT})}$: - PMT angular response beyond the solid angle
- $\mathbf{T_{ij}}$: - Transmission coefficient for material boundaries
- $\mathbf{L_{ij}(\theta_{LB}, \phi_{LB})}$: - Isotropy distribution
- $\mathbf{d_{scint}}$,$\mathbf{d_{av}}$,$\mathbf{d_{h2o}}$: - Light distance in scintillator, acrylic vessel and water
- $\alpha_{\mathbf{scint}}$,$\alpha_{\mathbf{av}}$,$\alpha_{\mathbf{h2o}}$: - Attenuation lengths

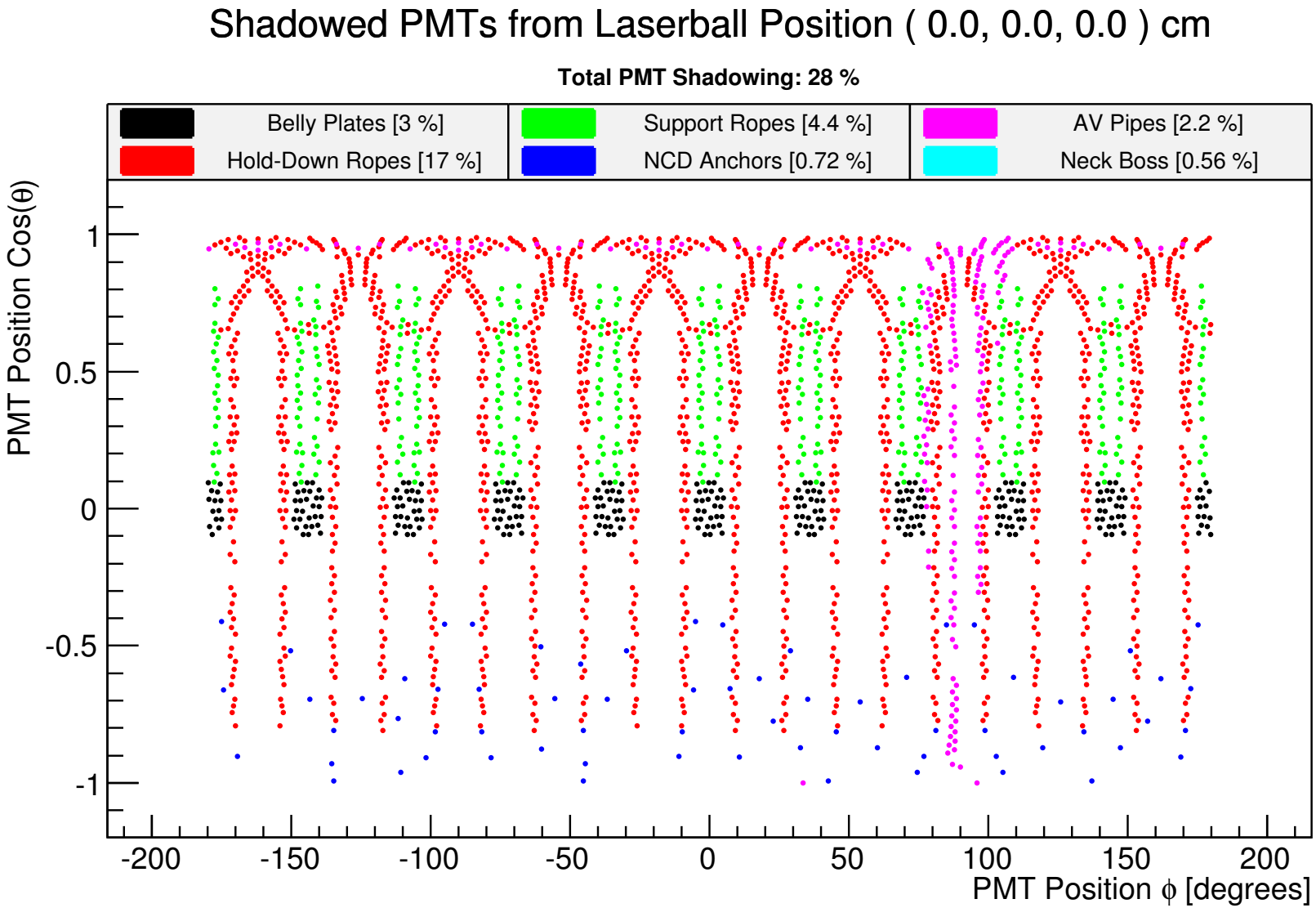
black: calculated values **red: fitted values**

Revised PMT Shadowing Calculation



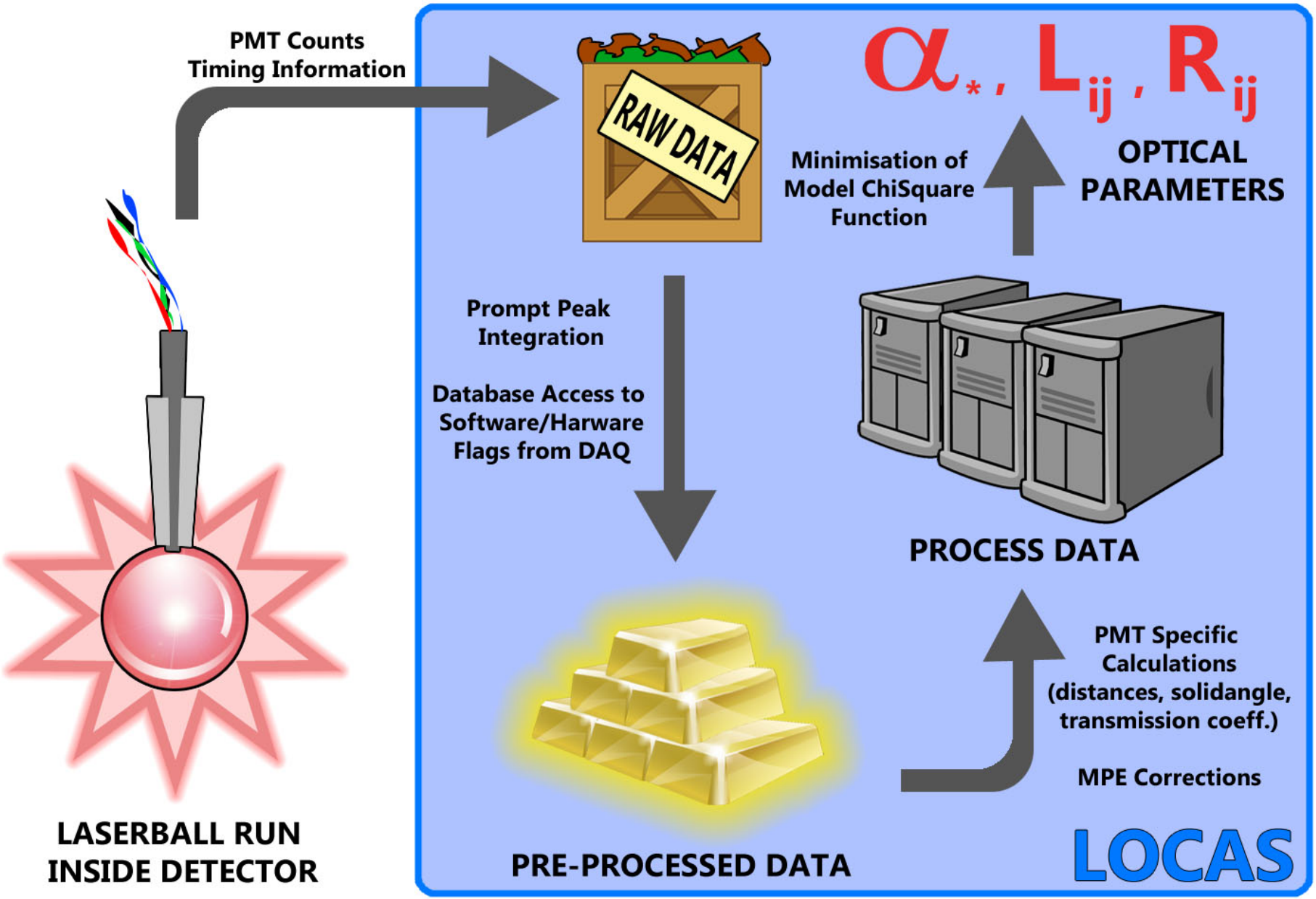
LightPathCalculator extrapolated geometry positions.

Revised PMT Shadowing Calculation



Example output of **new** PMT shadowing calculation technique.

LOCAS: **L**isbon, Liverpool, **O**ptical **C**alibration **S**ussex



LOCAS: Optics Fit with original SNO data

- October 2003, 420 nm laserball waterfill data set.
- 27 off-axis (i.e. not central) runs. All using the same normalising central run.
- Fit using aforementioned occupancy ratio method as input data points.

LOCAS: Optics Fit

Minimise over the chi-square function:

$$\chi^2 = \sum_{i=1}^{N_{\text{runs}}} \sum_{j=1}^{N_{\text{pmts}}} \frac{\left(R^{\text{data}}_{\text{Occ, ij}} - R^{\text{model}}_{\text{Occ, ij}} \right)^2}{\sigma^2 + \sigma^2_{\text{PMT}}},$$

using Levenberg-Marquardt algorithm.

- $R^{\text{data}}_{\text{Occ, ij}}$, $R^{\text{model}}_{\text{Occ, ij}}$ - Observed and respective model predicted occupancy ratios.
- σ - Statistical error on measured occupancies from off-axis and central run.
- σ^2_{PMT} - PMT variability correction based on θ_{PMT}.

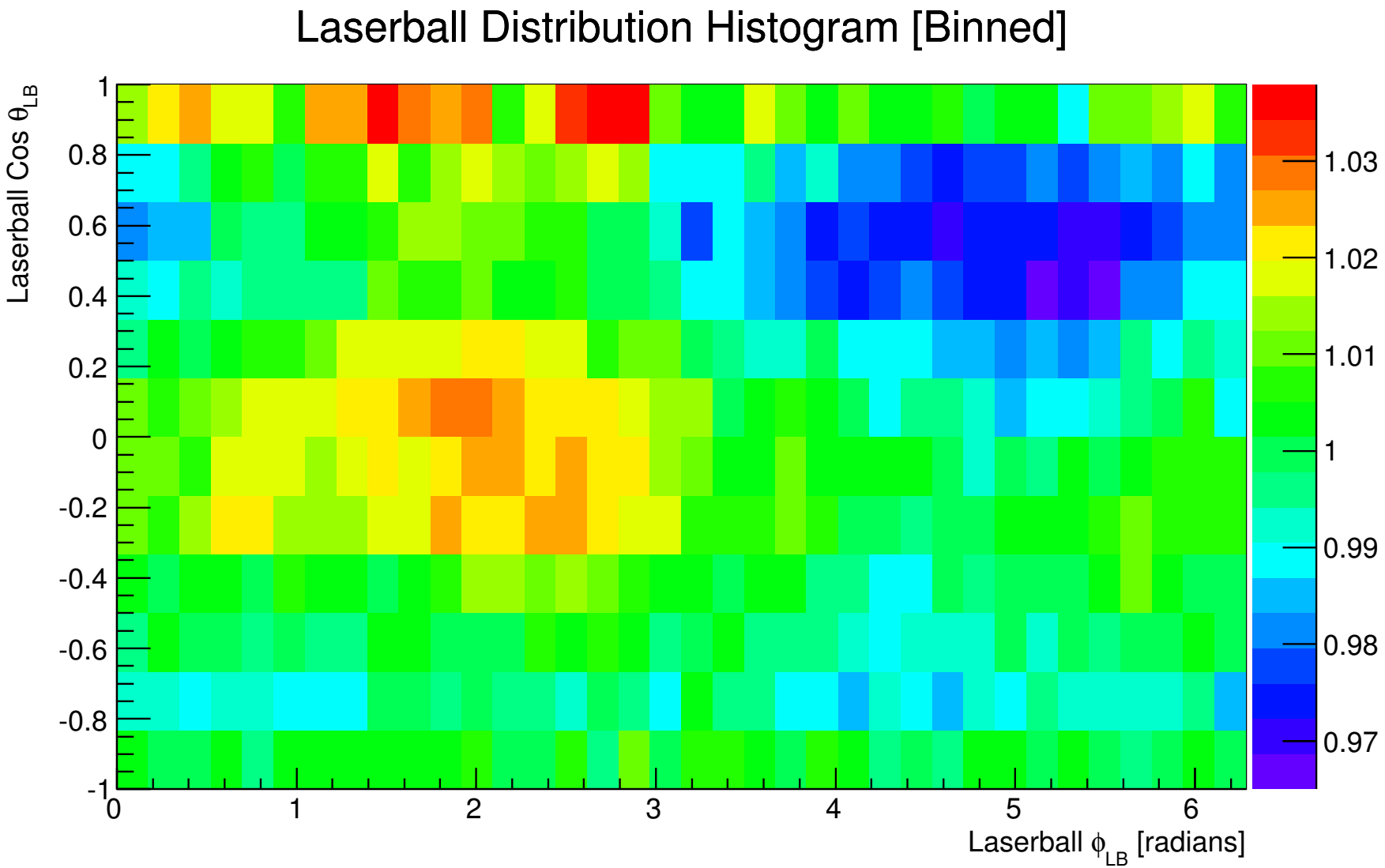
LOCAS: Optics Fit - Minimisation and Results

Perform 4 fits + 1 nominal fit using following chisquare limits for each data point at the top-level of each fit:

$$\chi^2_{\text{max}} : 1000, 100, 25, 16 + 16$$

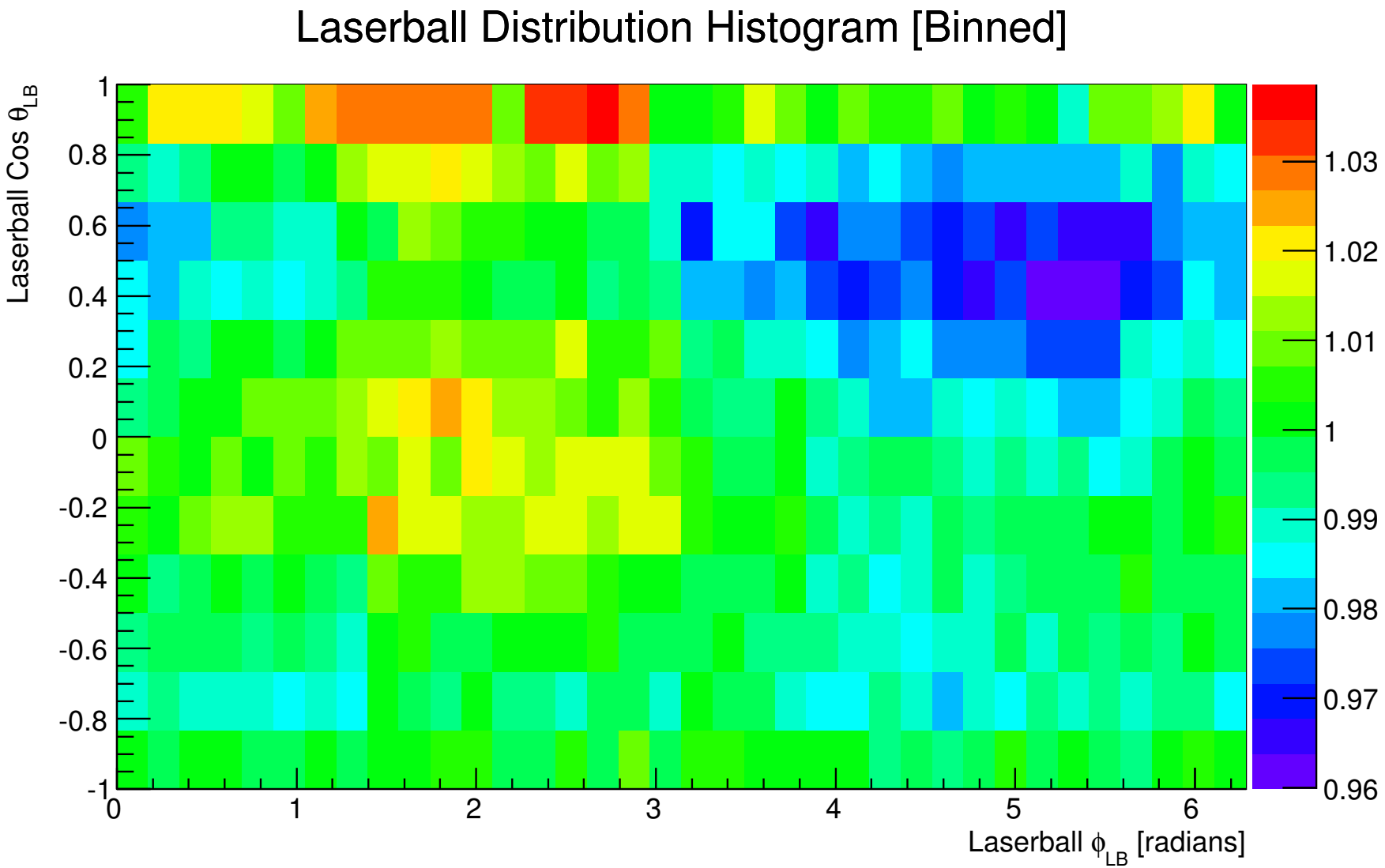
- **LOCAS (SNO)**
  - $\chi^2_{\text{reduced}} = 108259.1016/(144364 - 510) = 0.7526$
  - $\alpha_{D_2O} = (6.72 \pm 0.01) \times 10^{-5}\ \text{cm}^{-1}$
  - $\alpha_{H_2O} = (1.50 \pm 0.29) \times 10^{-4}\ \text{cm}^{-1}$
- **LOCAS (SNO+)**
  - $\chi^2_{\text{reduced}} = 165855.1719/(171059 - 510) = 0.9725$
  - $\alpha_{D_2O} = (6.20 \pm 0.01) \times 10^{-5}\ \text{cm}^{-1}$
  - $\alpha_{H_2O} = (2.20 \pm 0.25) \times 10^{-4}\ \text{cm}^{-1}$

LOCAS: Optics Fit - Results



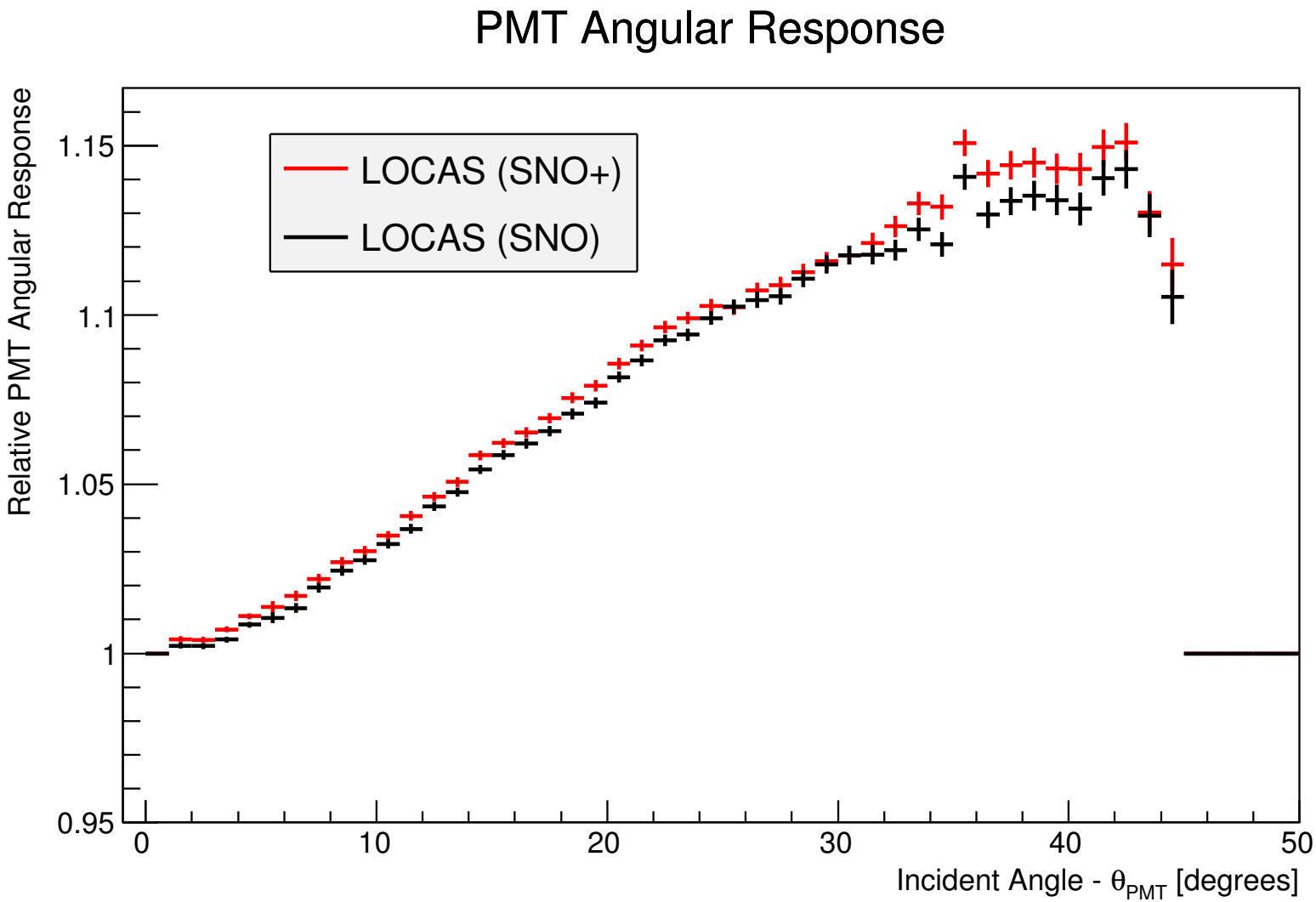
LOCAS (SNO) laserball distribution histogram

LOCAS: Optics Fit - Results



LOCAS (SNO+) laserball distribution histogram

LOCAS: Optics Fit - Results



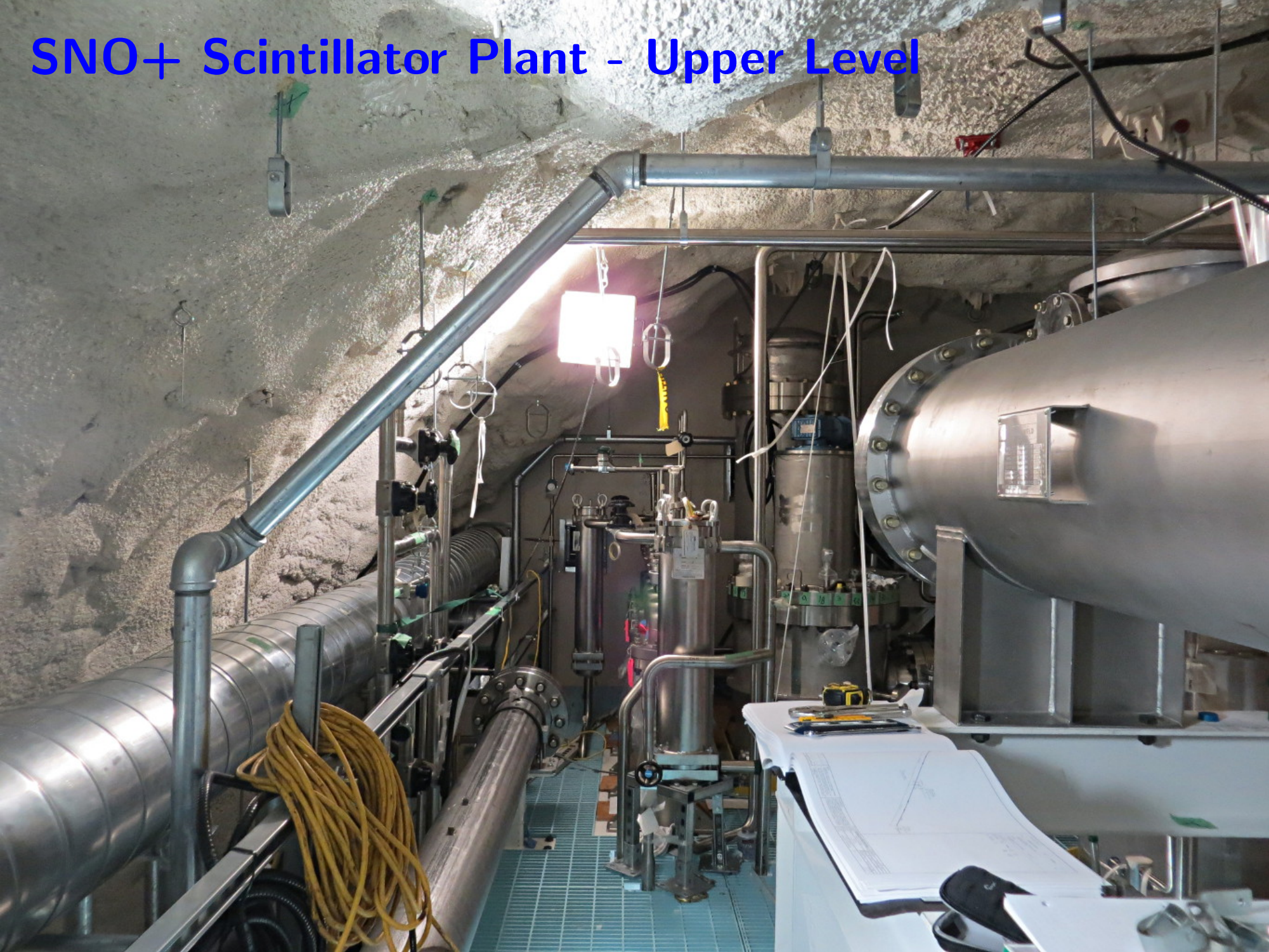
Comparison of the fitted PMT angular response (histogram) distributions from LOCAS (SNO) and LOCAS (SNO+) using the same shadowing values.

Long Term Stay in Sudbury

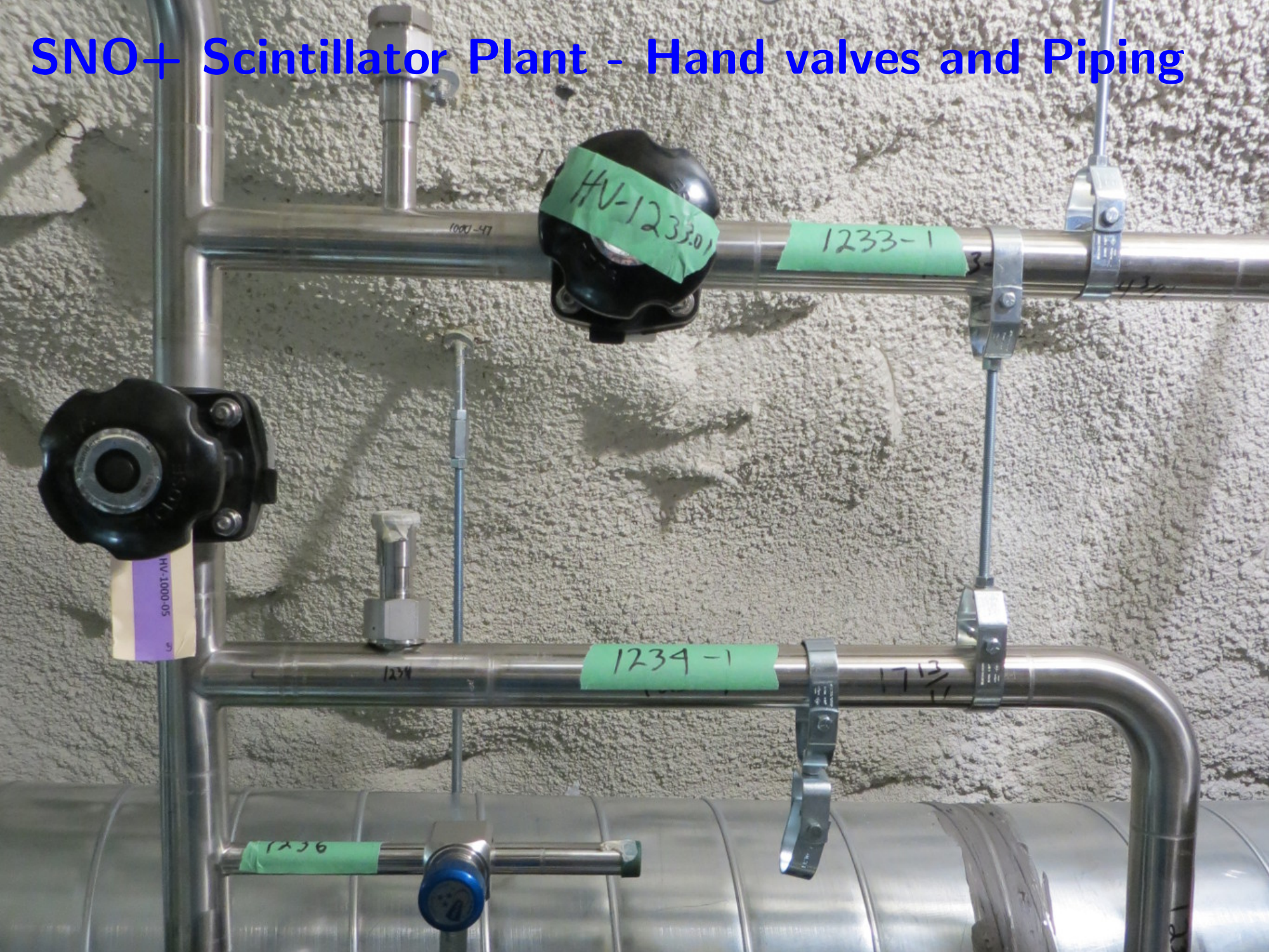
- 8 months on site working with various members of the collaboration.
- Gained valuable experience and skills from a variety of tasks.

Working with John Walker

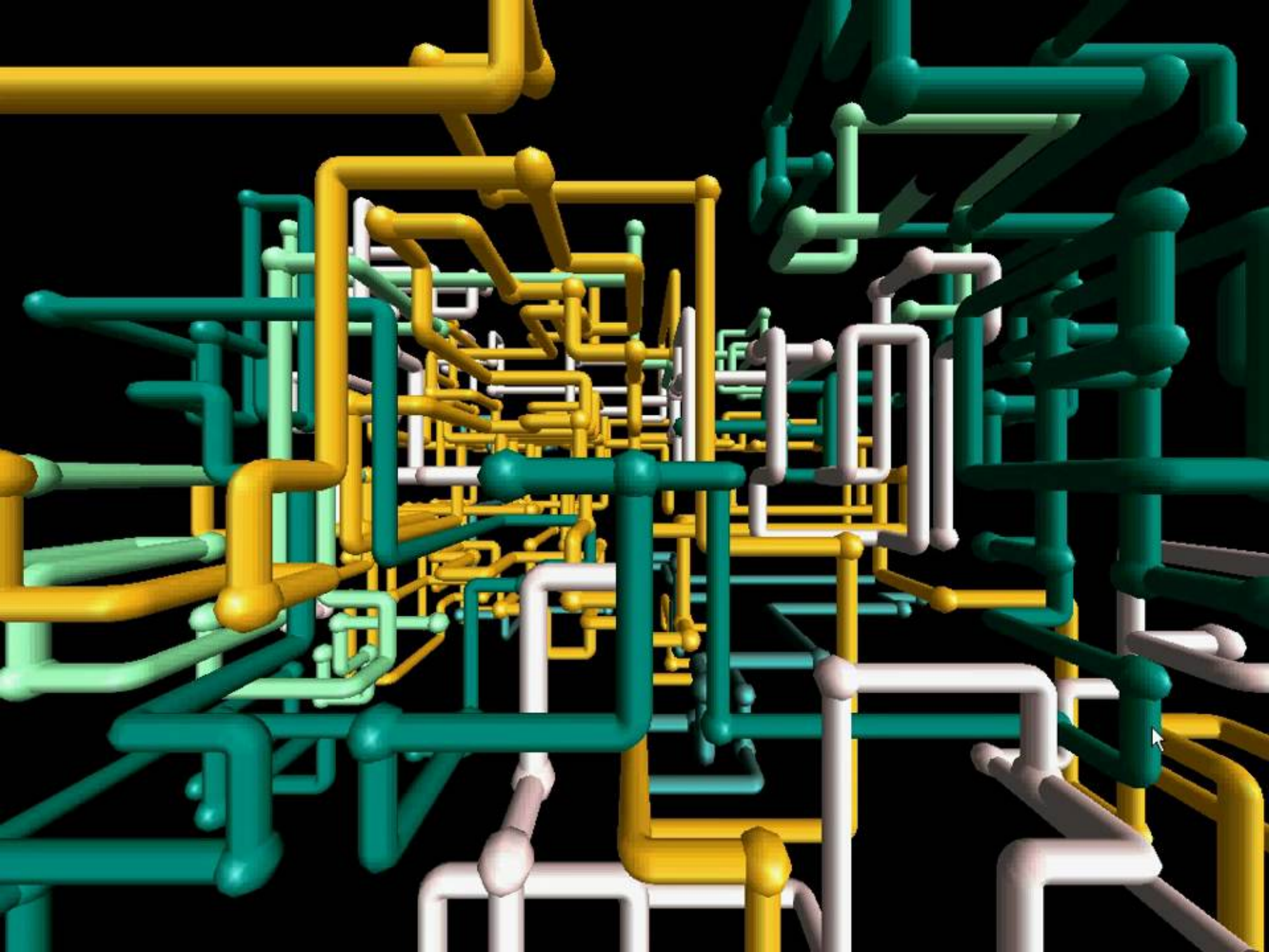
SNO+ Scintillator Plant - Upper Level



SNO+ Scintillator Plant - Hand valves and Piping

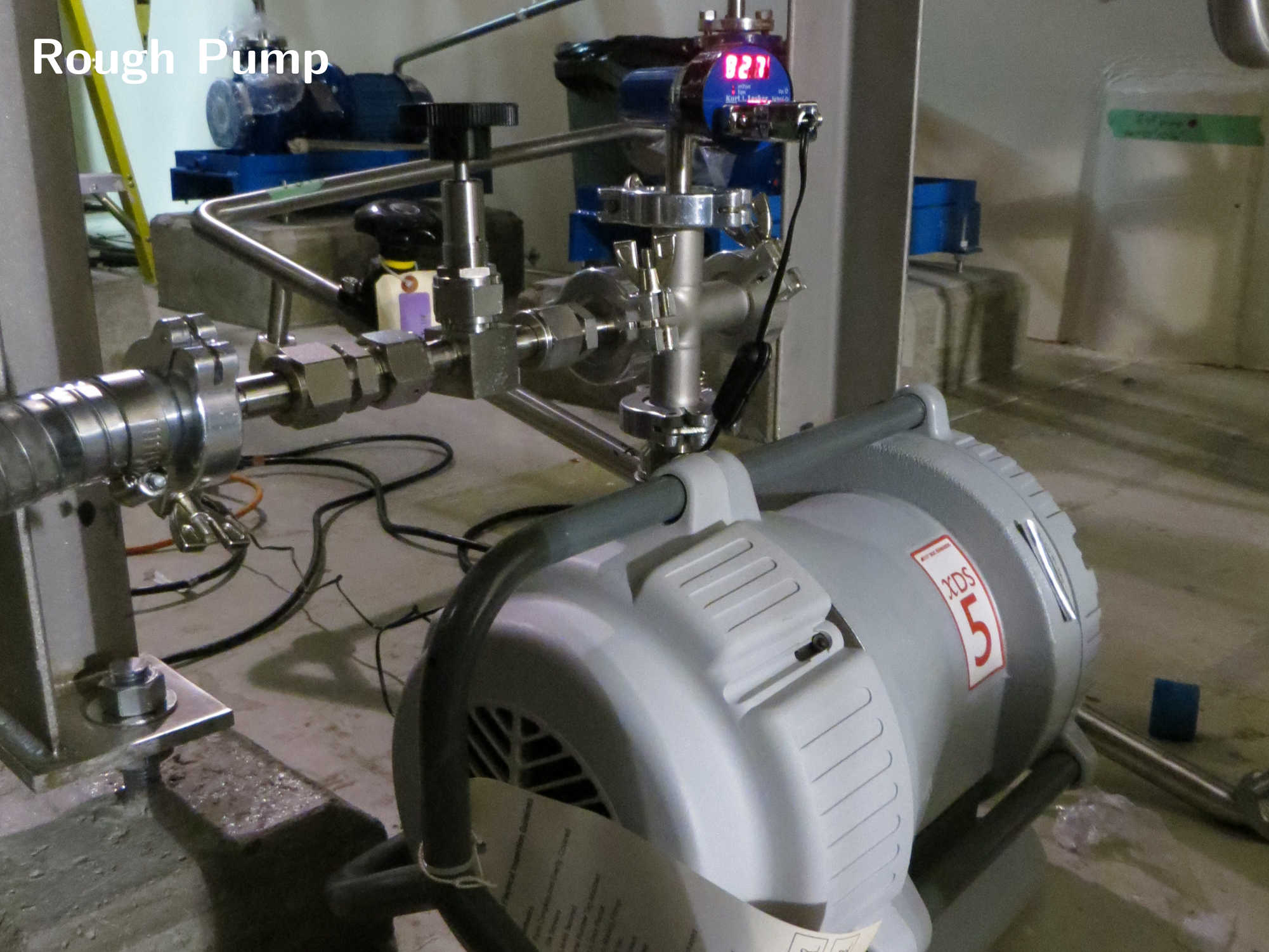


SNO+ Scintillator Plant - Lower Level



Helium Leak Checking and Construction

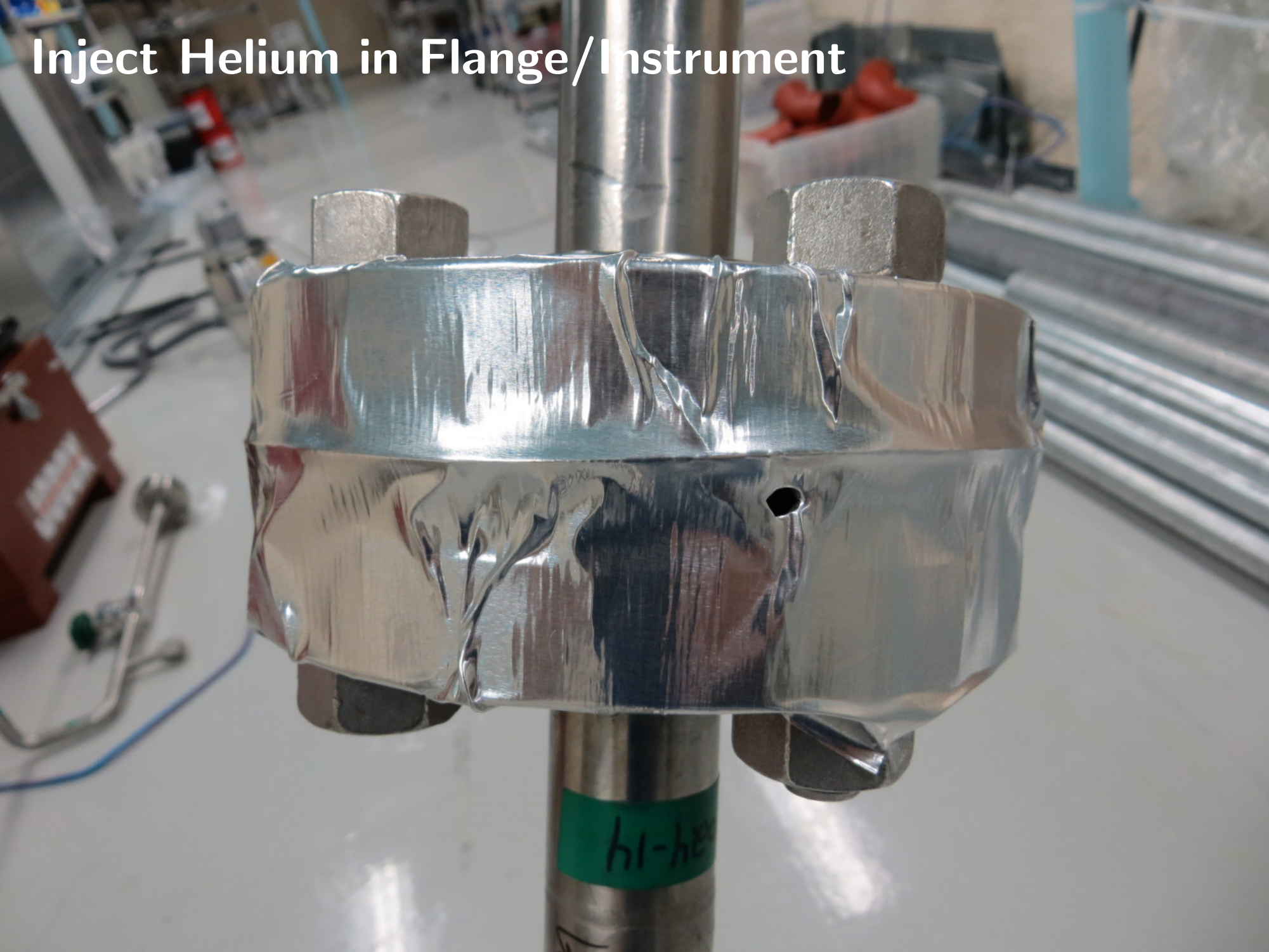
- Plant consists of 13 Vessels, 17 Kettles, 9 Columns and $\sim$ 2 km of piping.
- Purpose is to test seal/weld integrity of all volumes in the plant.
- SNO+ requires $< 10^{-9}$ mBar.l.s^{-1} leak rate to beat naturally occuring Radon background levels in the mine.


Rough Pump
XDS
5

Helium Leak Detector

Helium Source

Inject Helium in Flange/Instrument



Helium leak checking crew - November

Helium leak checking crew November

Future Work

- Continue work on LOCAS in time for laserball data runs (mid-late 2015).
- Write thesis.

Moose

END.