Calibration in Hyper-Kamiokande

Neil McCauley

University of Liverpool

Workshop on the Evolution of Advanced Electronics and Instrumentation for Water Cherenkov Experiments

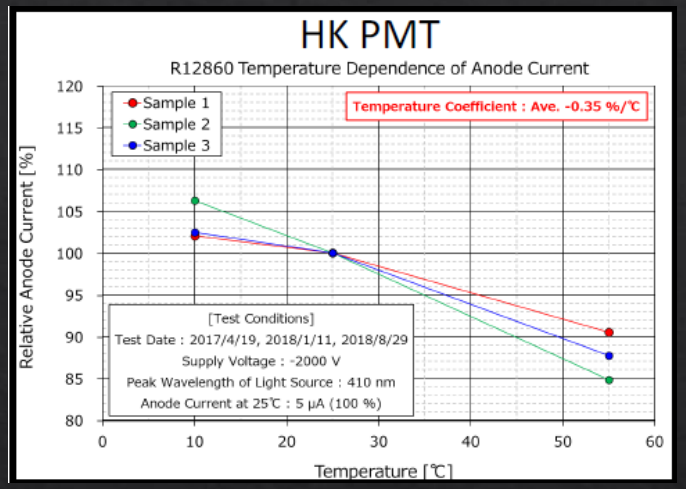
UNIVERSITY OF LIVERPOOL

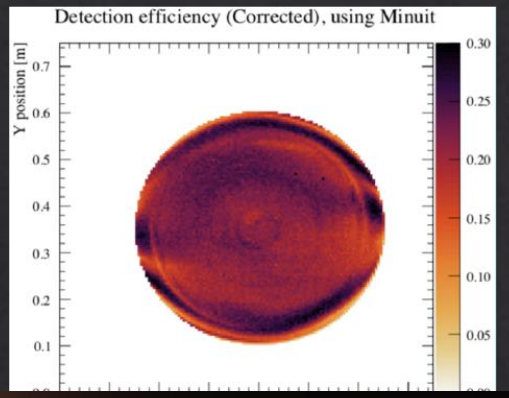
Calibration Strategy

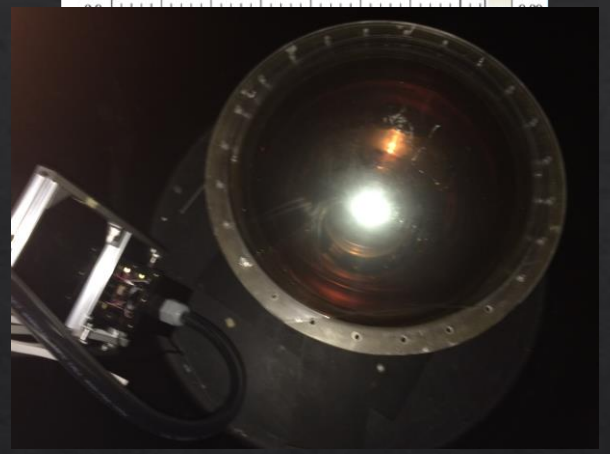
- Improved Calibration is essential to meet the systematic goals of the experimental programme
  - Existing detector systematics must be reduced
- Need to understand underlying detector parameters and high level response
  - Detector model
    - Water Quality: Scattering and Absorption
    - PMT Response: Timing, Efficiency, Gain, Angular Response
    - Geometry
  - Detector Response
    - Energy, Position, Angle, Particle ID : Scale and Resolution
    - High and Low Energy Sources
    - Calibration Sources and Control Samples

PMT Pre-calibration

- PMT Pre-calibration programme under development
- Needs to measure
  - Gain
  - Efficiency
  - Angular response
  - Timing
  - After pulsing
  - Linearity
- Consider effect of
  - Voltage
  - Temperature
  - Magnetic field
- Extensive Pre-calibration programme planned in Japan with extremely detailed measurements in PTF at Triumf

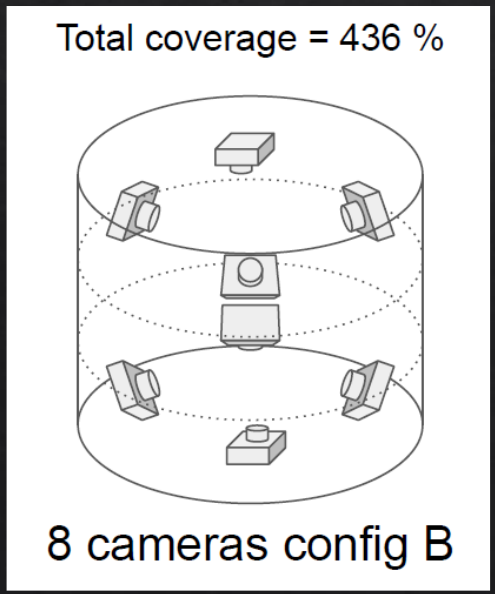


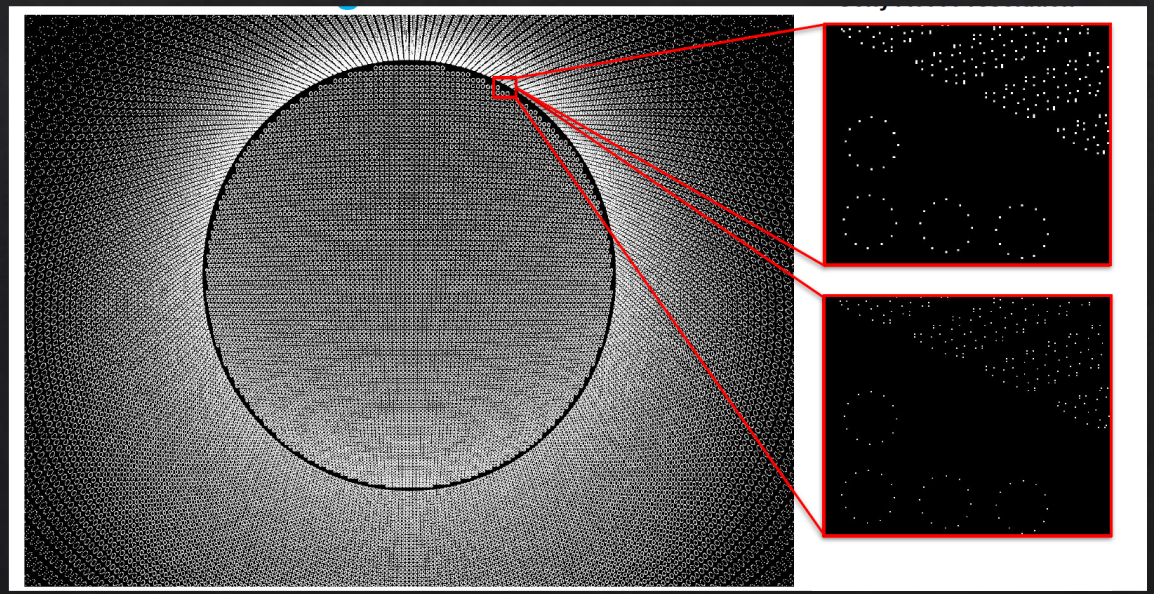




Photogrammetry

- Photogrammetry System to Determine Location of Detector Elements
  - Design → As Built
  - Impact of Stresses and Strains, Buoyancy
  - PMTs, Calibration Source locations
- Inbuilt Camera System and ROV
- Illumination from LED system inside mPMTs

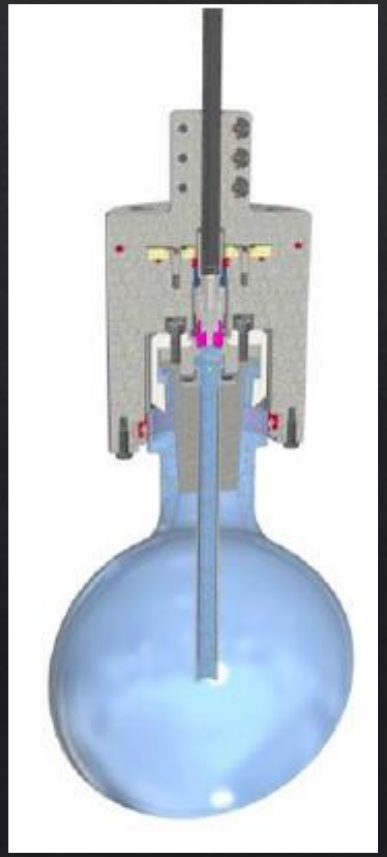




Light Sources

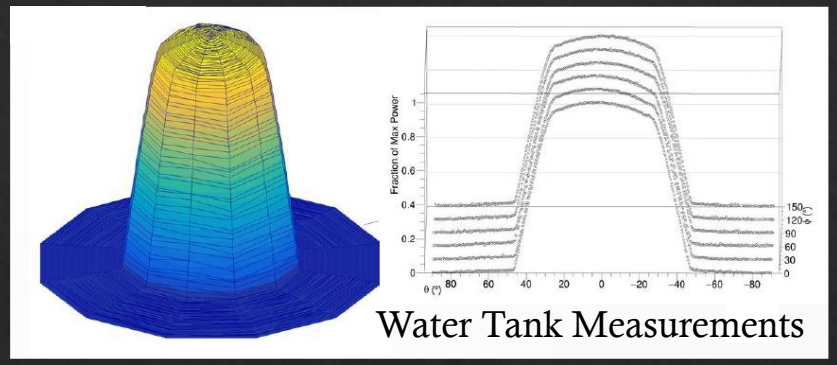
- Light Sources are used to measure the underlying detector parameters
  - Water Scattering and Absorption
  - PMT Properties
- Key Features
  - Well controlled light pulse
  - Shaped light pulse inside detector depending on purpose
- Light Injection and Deployable Light Sources
- Laser and LED Light Sources

Deployable Diffuser Ball

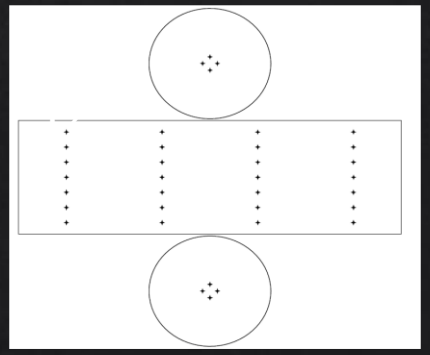


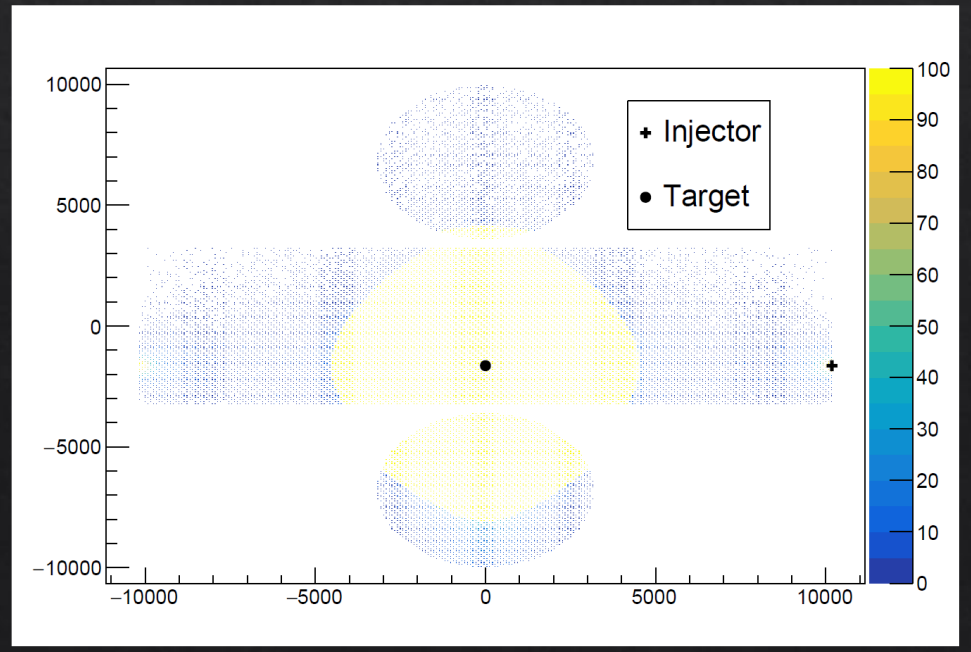
Light Injection System

- Fibre Coupled Light Injection System
- Dual Injectors
  - Diffusers
    - 40º Half Angle Uniform Source
    - Illuminate large fraction of the PMTs
  - Collimators
    - 3.5º Beam
    - Dedicated for scattering measurements
- Light Source
  - Multi Wavelength Fibre Coupled Laser
  - Commercial Fibre Switches to distribute pules
- Requires graded index fibre to minimise pulse dispersion



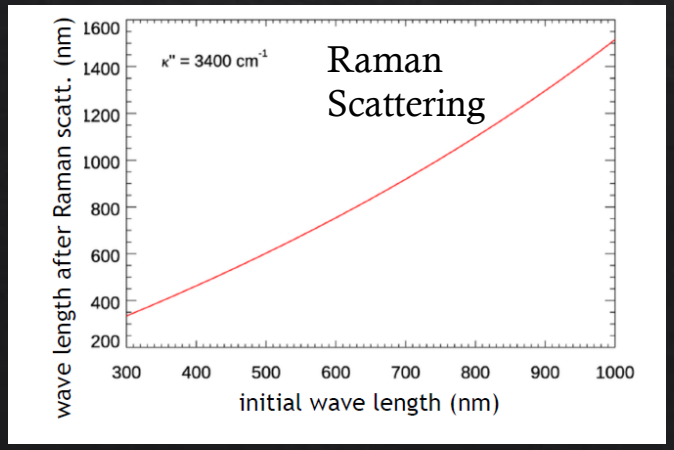
Water Tank Measurements

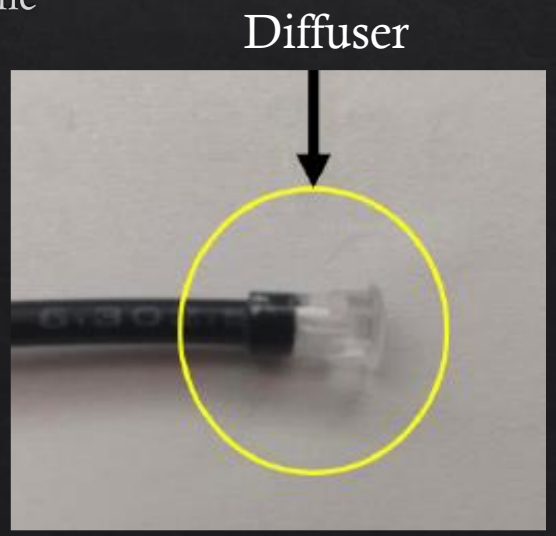




Light Injectors in mPMTs

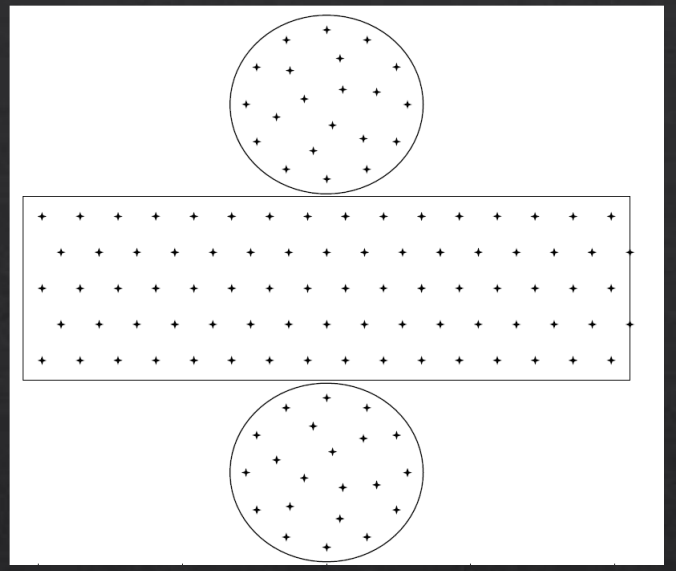
- mPMTs are important devices for calibration
  - They can provide key information for analysis
  - They can also house calibration devices
- LED light sources for Photogrammetry System
- Pulsed LED source for calibration
- One option to include 300 nm LEDs
  - Measure Raman scattering as only sensitive to scattered light after wavelength shifting
  - Improvement to optical model, monitored for the first time

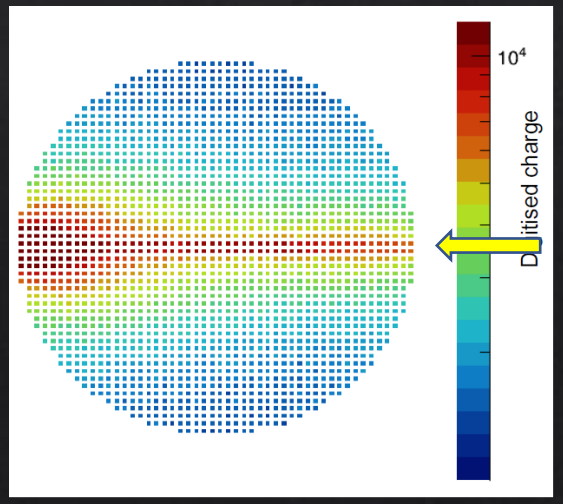




Outer Detector System

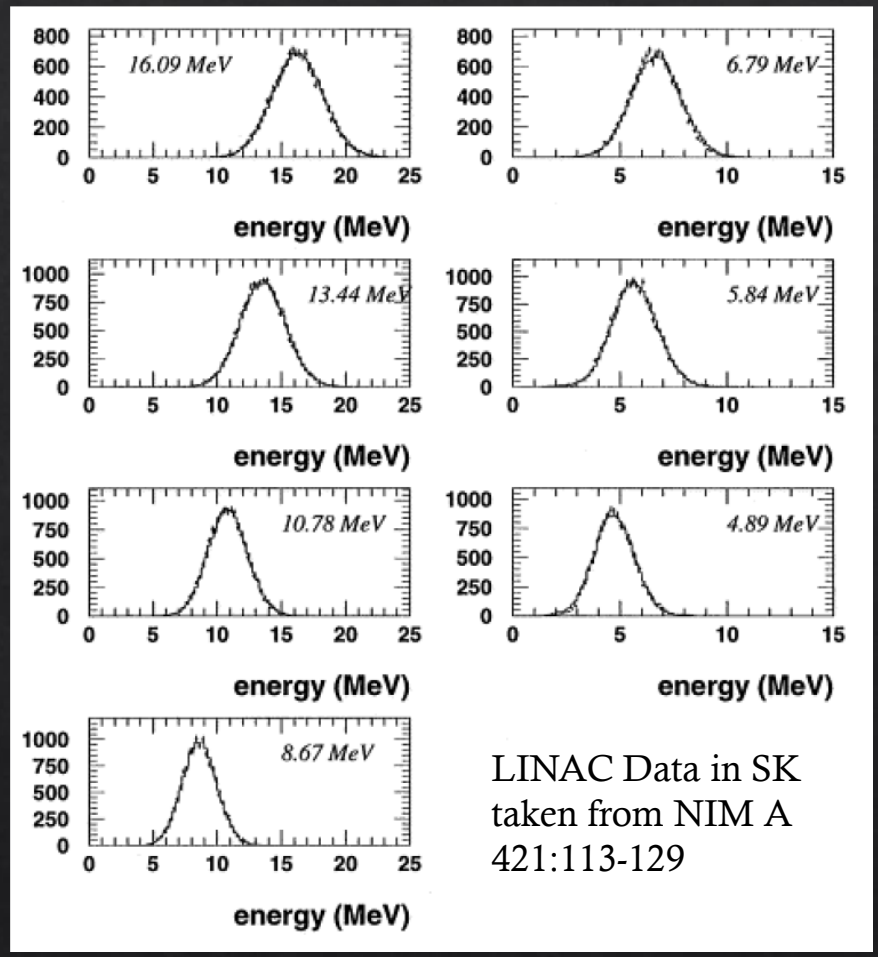
- OD Light Injection System to measure PMT performance and OD optics
- Diffusers as in ID to distribute light
- Collimators allow measurements of OD Optics
  - Water Quality and Tyvek performance
  - Collimators installed parallel to OD walls
- Pulsed LED light sources
  - ID Laser source for collimator channels





LINAC

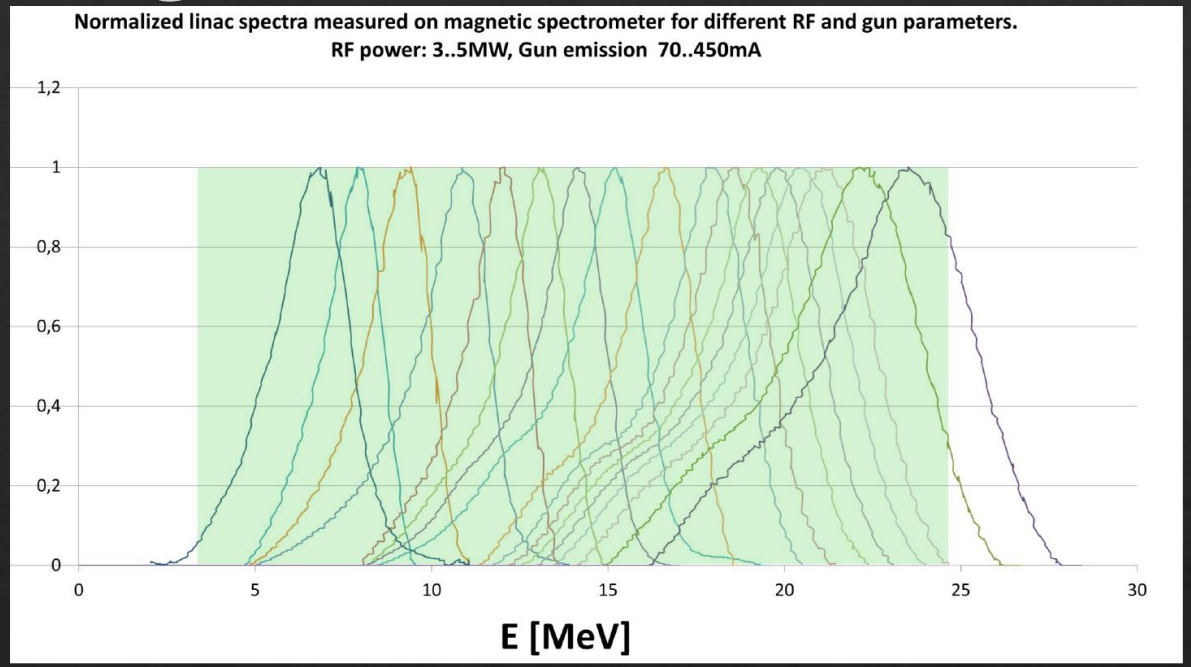
- While at high energy we use control samples to measure detector response, at low energy we use sources.
- The LINAC provides full coverage of the energy range to measure energy response of detector
  - Essential to meet systematic requirements for solar upturn search
- Angular Resolution is also obtained from LINAC data
- Other sources needed to complete map across detector and angular variations

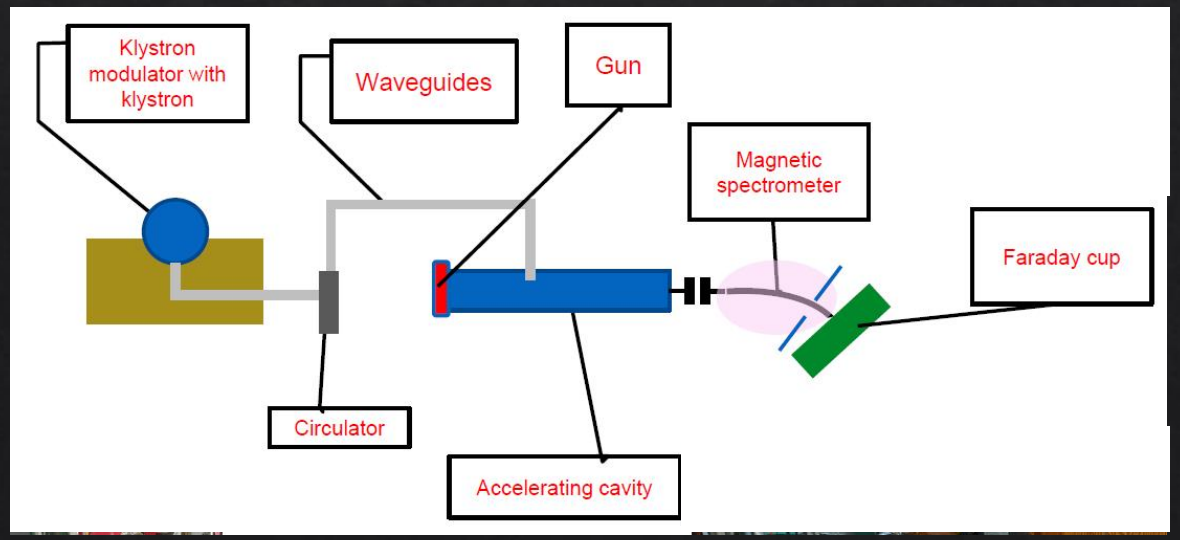


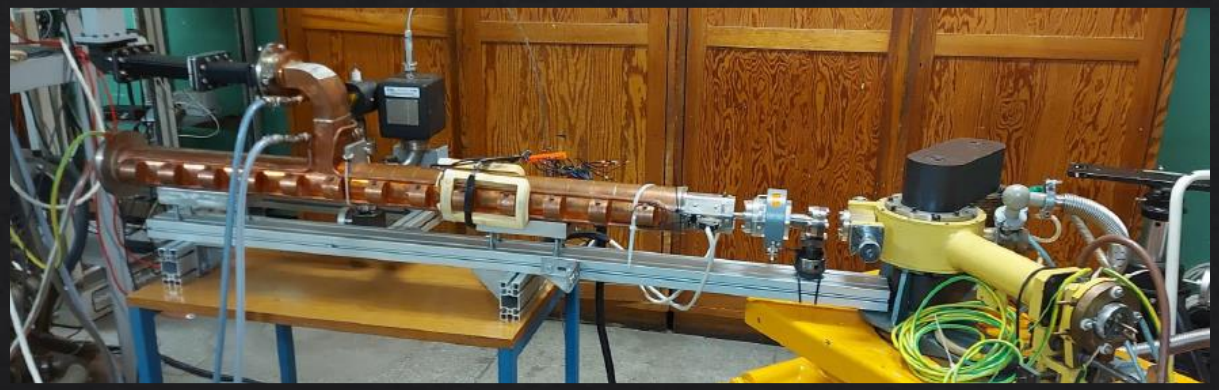
LINAC Data in SK taken from NIM A 421:113-129

Electron LINAC Testing

- LINAC setup at NCBJ
- Measurement of wideband output for different LINAC settings
  - Confirms coverage from 3-24 MeV
  - Detailed beam characterisations underway
- Narrow beam energy through beam transport system

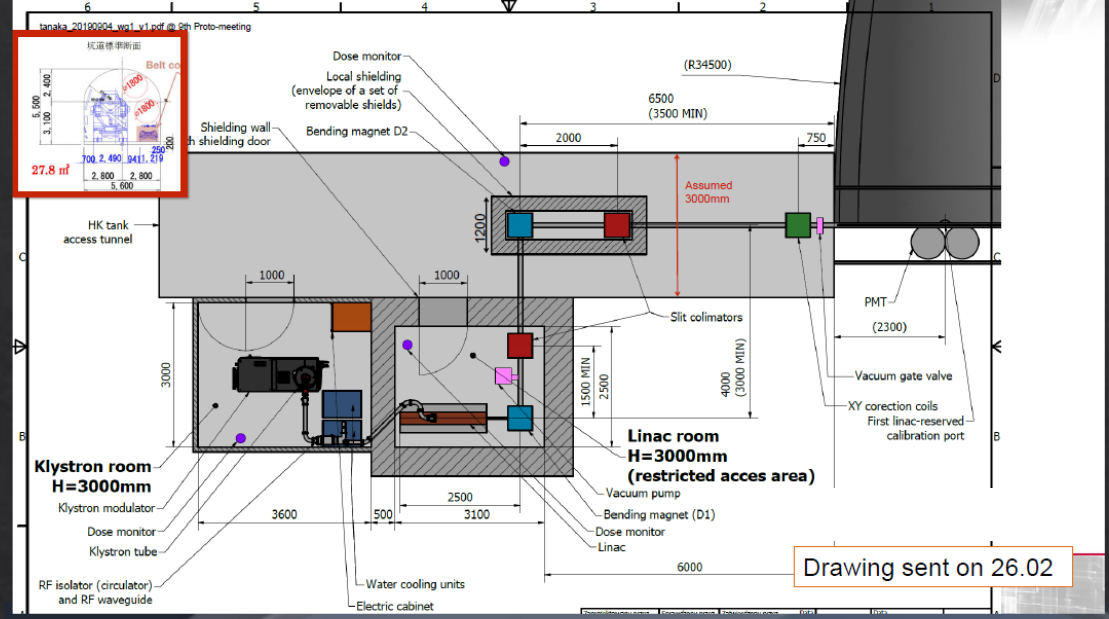


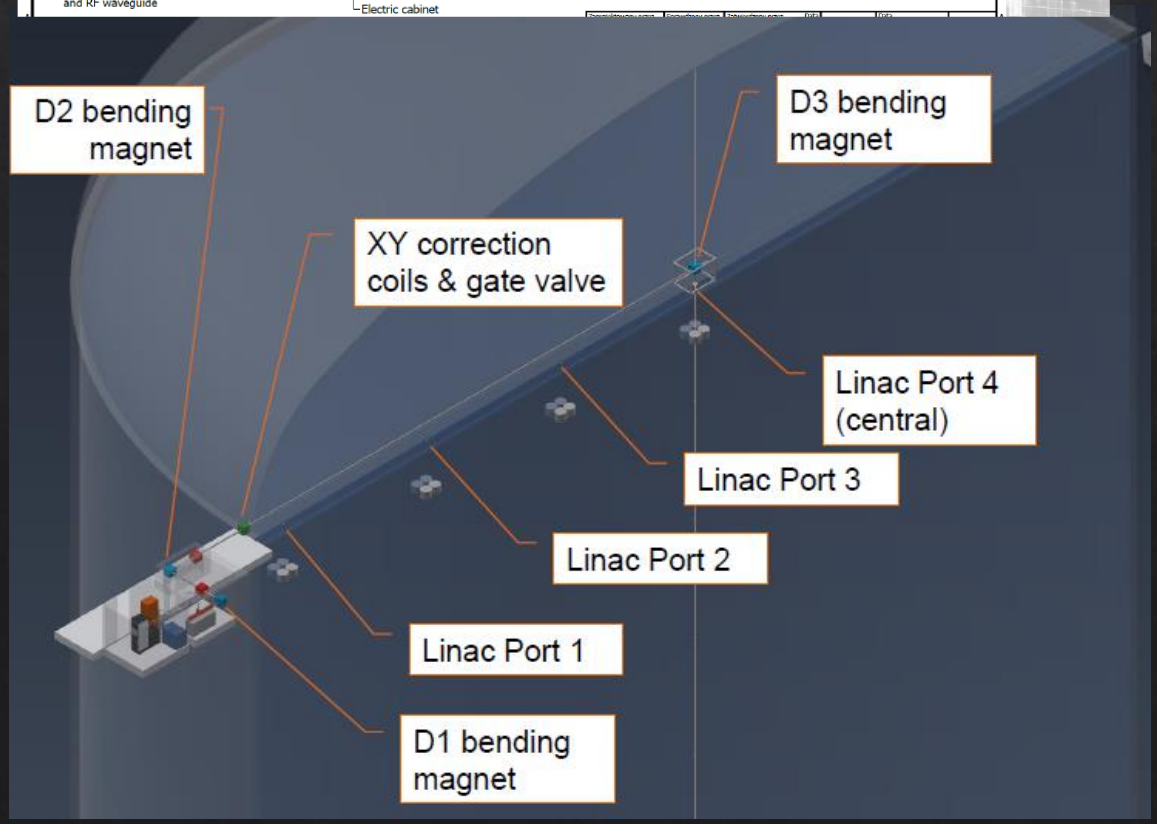




Beam Transport System

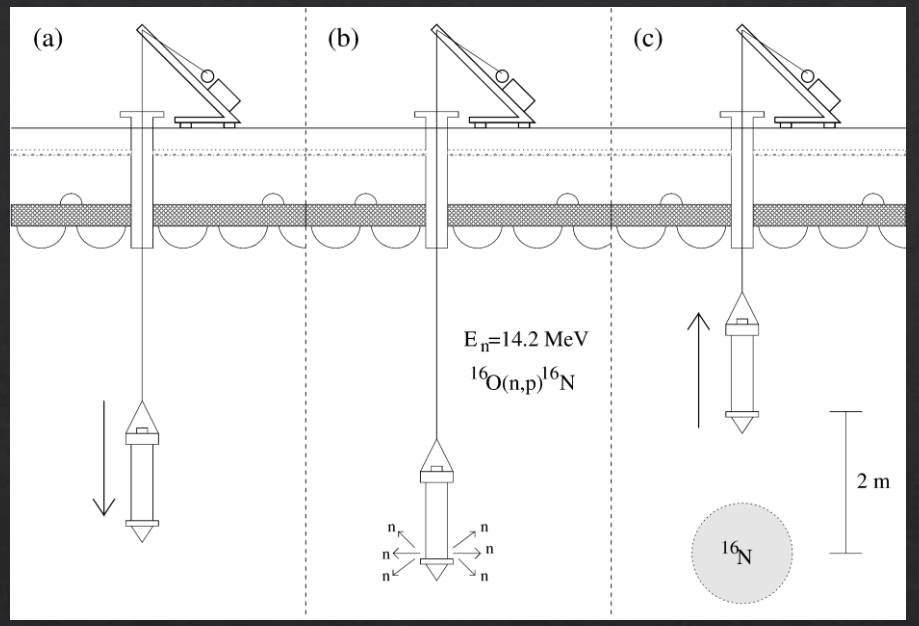
- Beam transport system must
  - Select very narrow energy
  - Attenuate to 1 electron per event
- Horizontal alignment selected with two right angle turns
- Double tower system
  - Allows running at edge of fiducial volume with smaller tower
- Mechanical tolerances of beam pipe critical
  - Bending
  - Oscillation

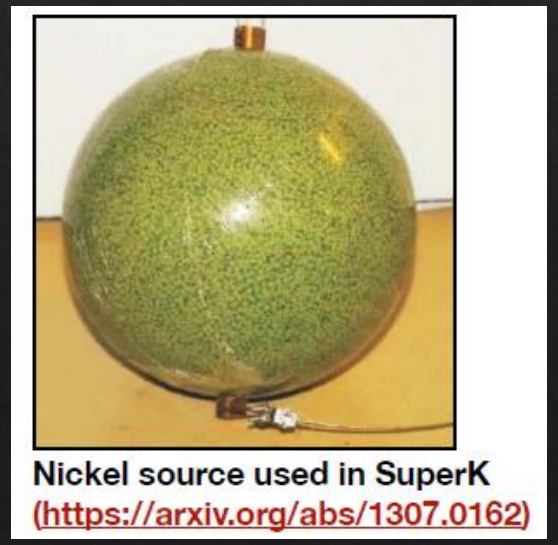




Radioactive Sources

- Use DT generator to make ^{16}N
  - $\beta\gamma$ source with well understood spectrum
  - Used to measure energy response across detector and in all directions
- NiCf Source
  - Neutron capture on ^{58}Ni
  - ~9 MeV gamma cascade
  - Monitoring and uniform Cherenkov light source
- AmBe – BGO
  - Tagged neutron source
  - Use BGO crystal to detect 4 MeV photon




Nickel source used in SuperK
(https://arxiv.org/abs/1307.0162)

Summary

- Hyper-Kamiokande will deploy a number of calibration sources to fully understand the detector
- Detector Model
  - Pre-calibration
  - Photogrammetry
  - Light Injection
- Physics Sources
  - LINAC
  - DT and Radioactive Sources