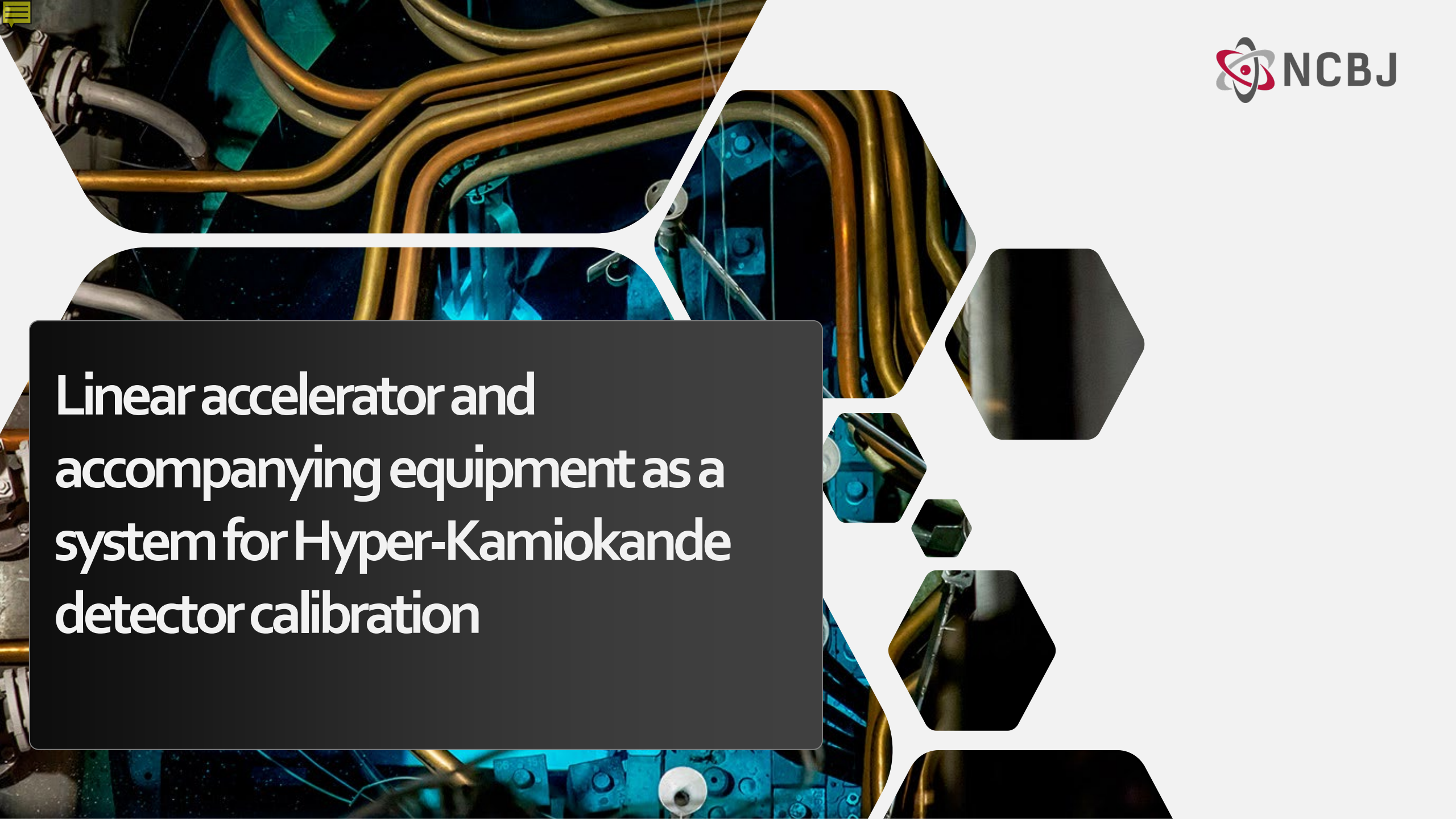
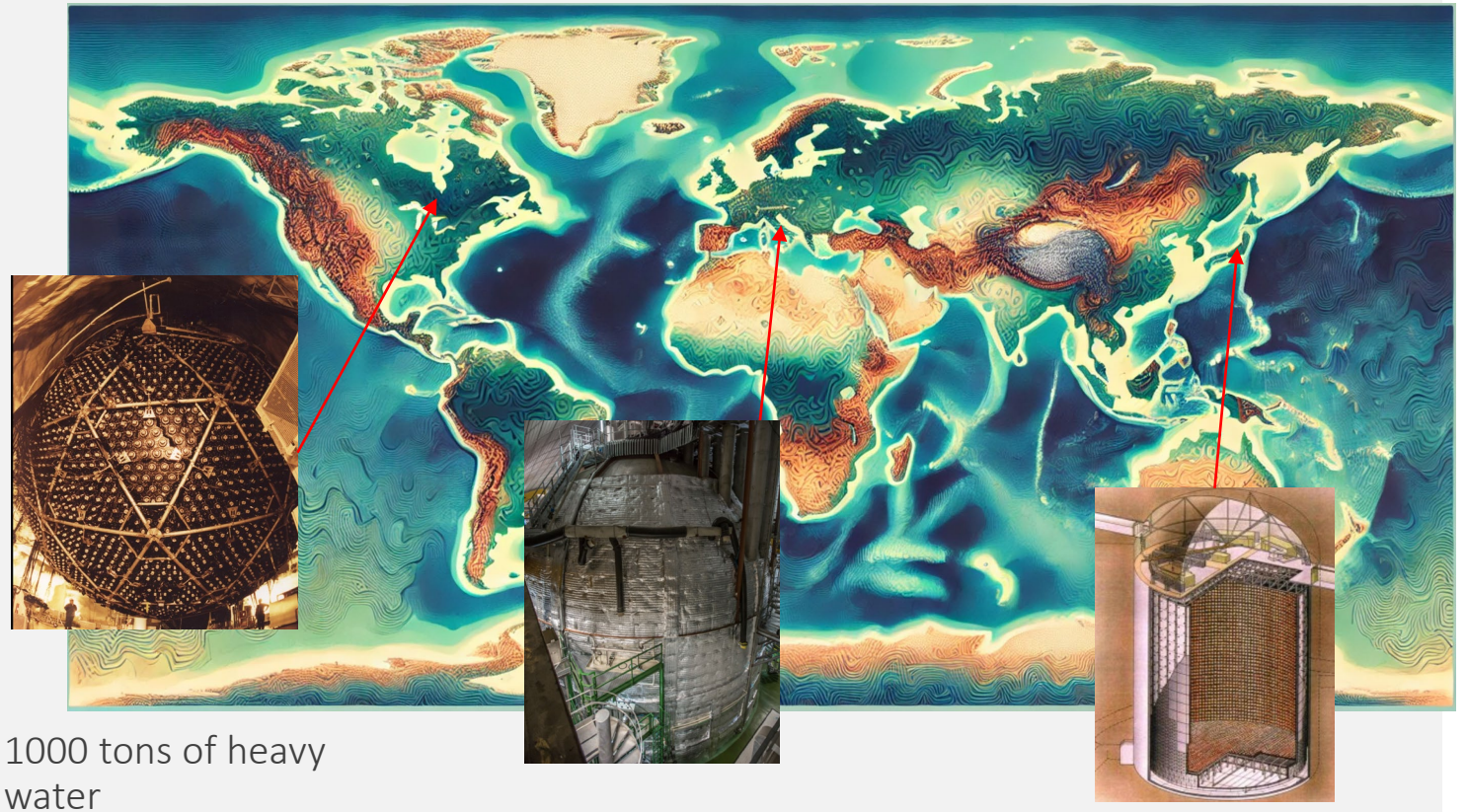


Linear accelerator and accompanying equipment as a system for Hyper-Kamiokande detector calibration

Liquid Cherenkov Detectors

Three the most famouse detectors:

- Super-Kamiokande – Japan, Gifu Prefecture (1996)
- Sudbury Neutrino Observatory (SNO) – Canada, Ontario (1999)
- Borexino - Italy, Grand Sasso (mountain) (2007)



- 1000 tons of heavy water
- 6-metre-radius (20 ft) acrylic vessel

- 278 tons of mixed scintillation materials: pseudocumene and PPO

- 50,000 tons of ultra-pure water
- Currently: water mixed with gadolinium

New Liquide Cherenkov detector: Hyper Kamiokande

Dimensions (5 time bigger than SK):

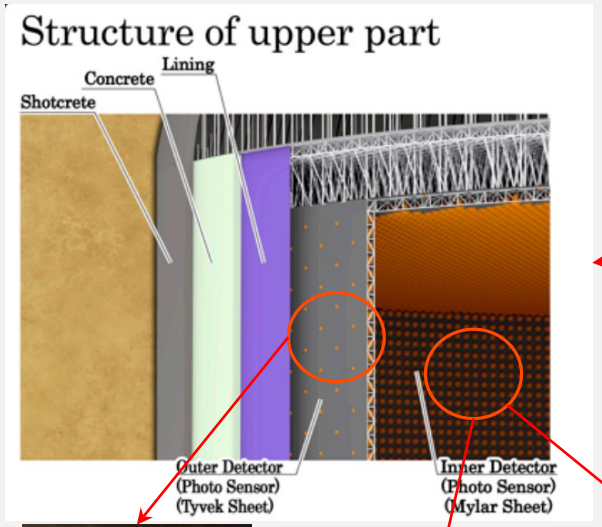
- ø 68m
- height 71m
- Water total amount: 250 000 tons

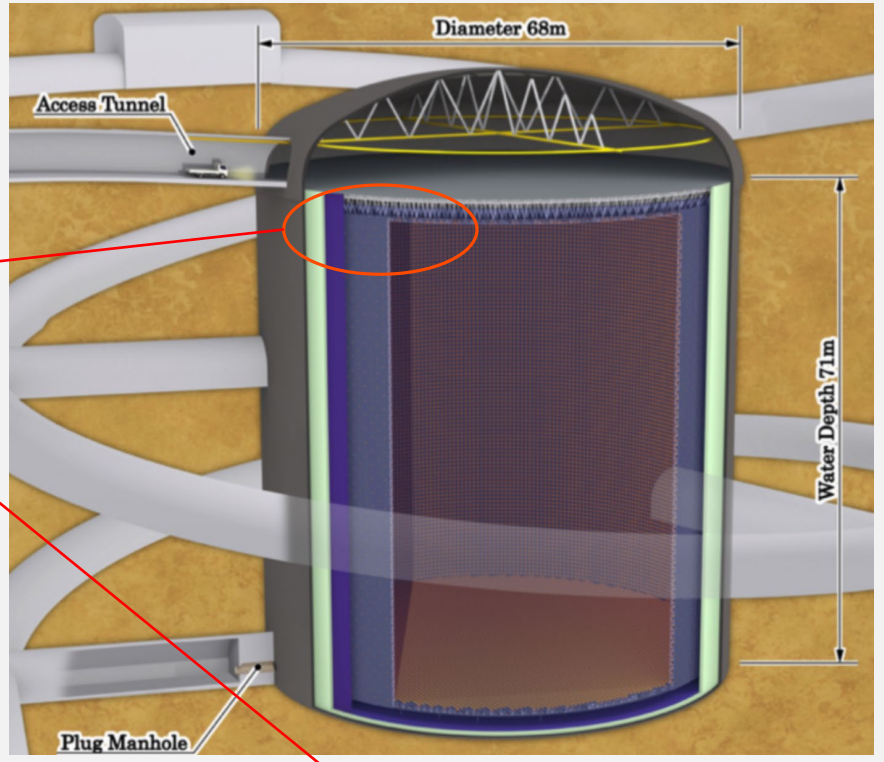
Two detectors:

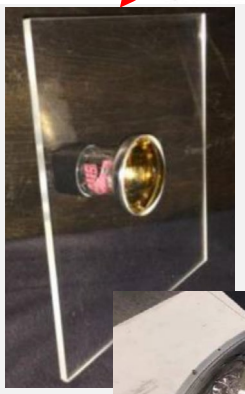
- ID – Inner detector
- OD – Outer Detector

Photomultipliers

- ID part: 20 000 PMT (ø 50 cm) + 1 000 mPMT
- OD part: 7 200 (ø 8 cm) with wavelength shifting plate







Detector calibrations systems

Light-Based Calibration System:

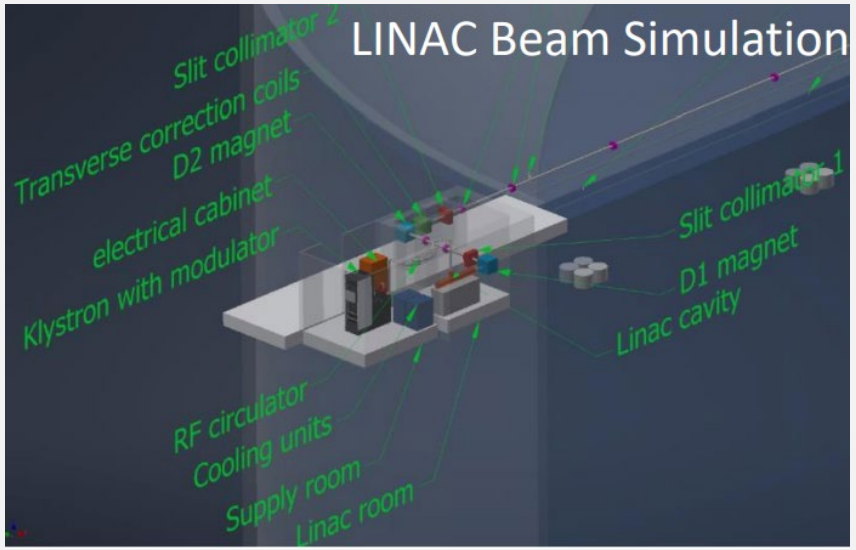
- Diffusers and collimators
- mPMT system
- OD injectors

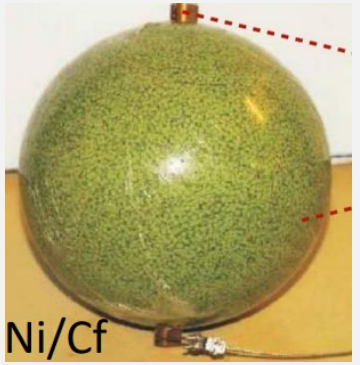
Isotope-Based Calibration System:

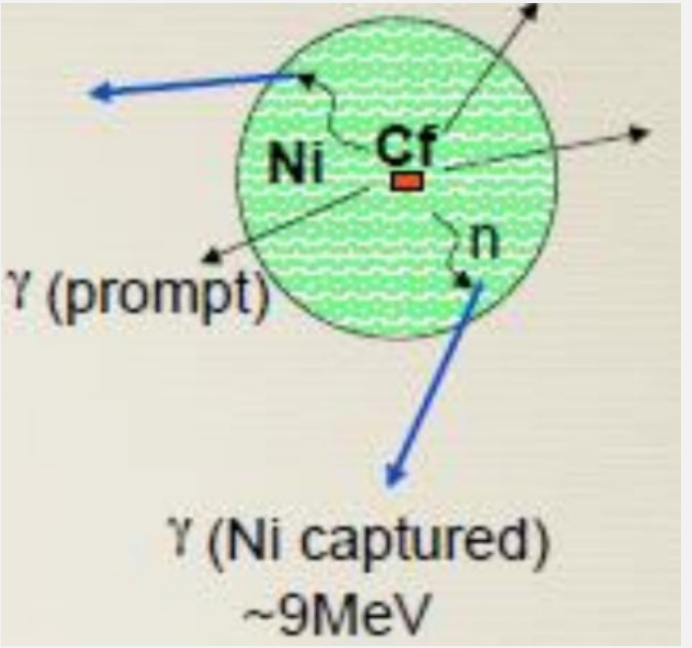
- AmBe + BGO – tagged neutrons
- Ni/Cf – 9 MeV γ cascade

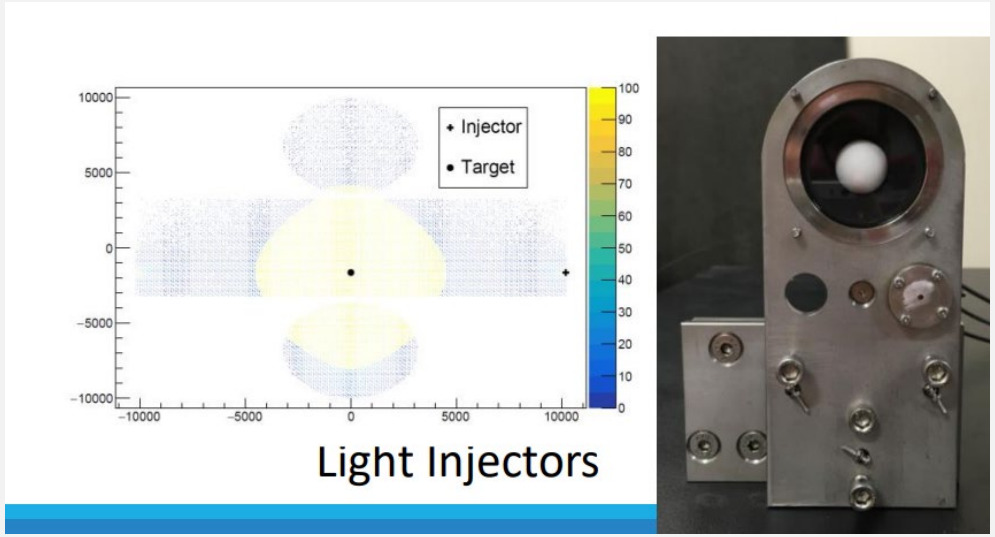
Linear Accelerator Calibration System:

- 3-24 MeV electrons









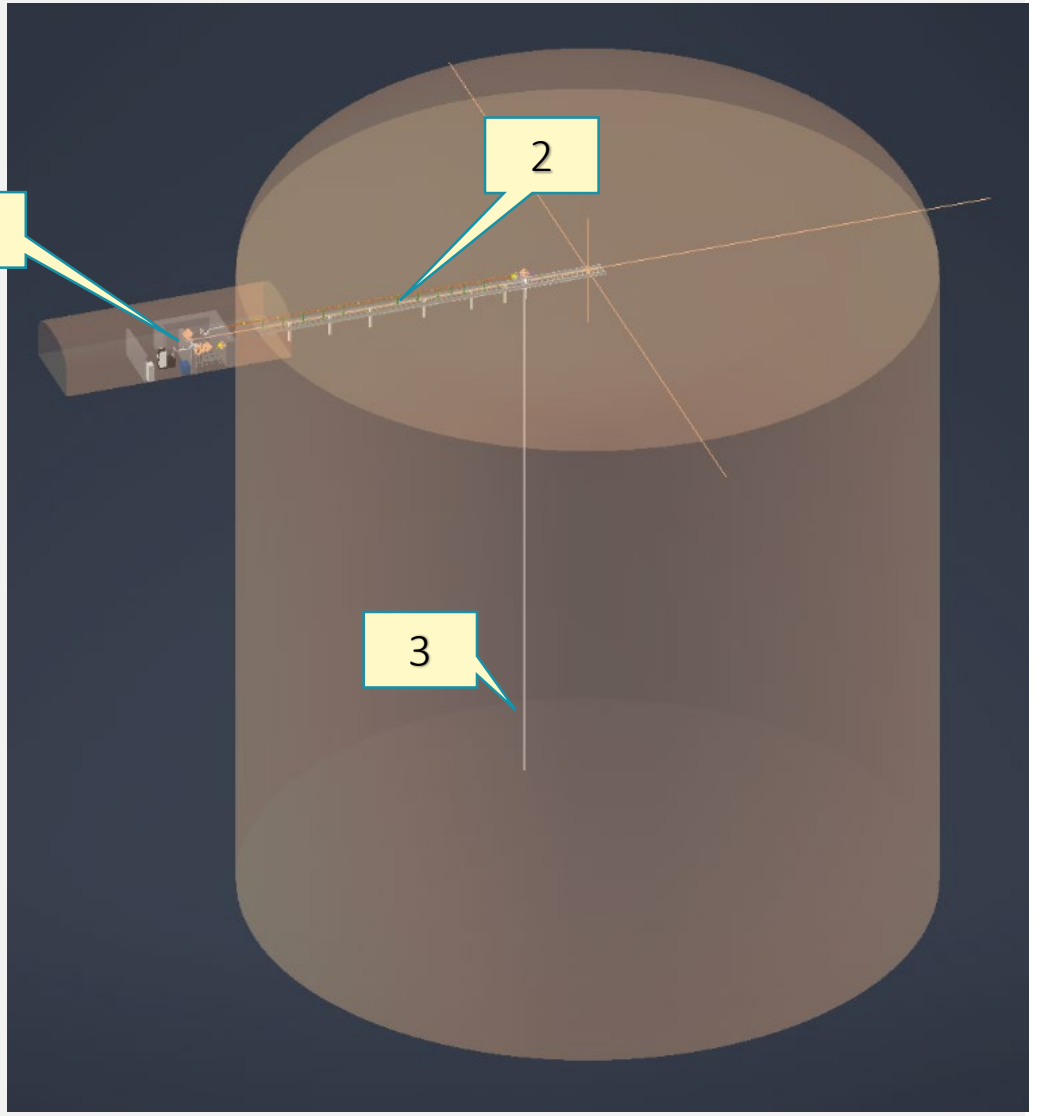
Calibration System Based on the Linear Accelerator

The system can be divided into three main groups:

1. Linac
2. Horizontal beam transport system and D3 magnet trolley
3. Vertical beam transport system

Main goals:

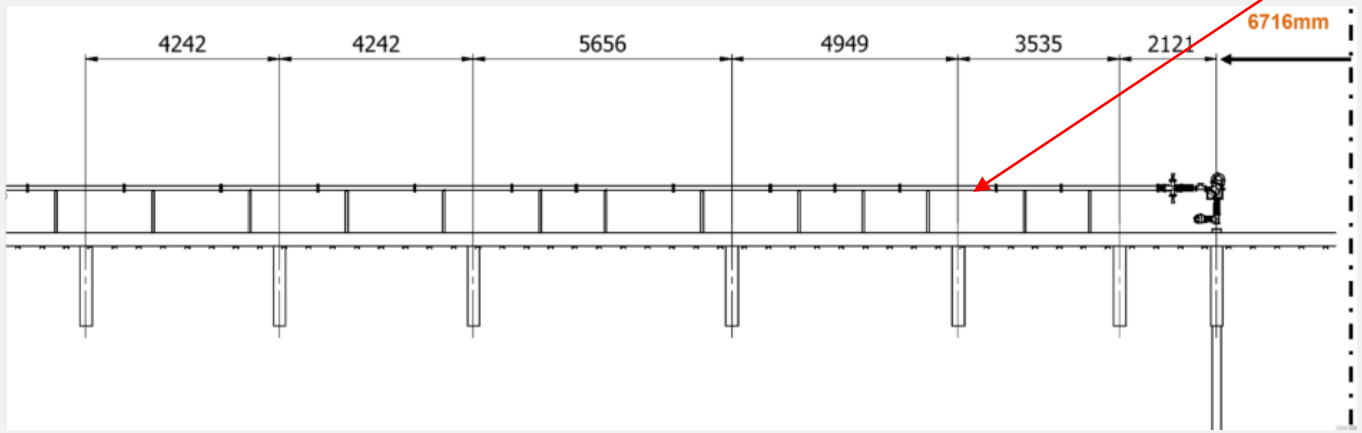
- Produce a beam with a selected energy in the range of 3 to 24 MeV
- Reduce the number of electrons to reach a safe level of radiation
- Transport electrons from the linac room to the tank cavern
- Adjust the beam orientation and deliver it to the selected depth of the tank
- Achieve an exact number of electrons at the final depth in the tank: ~ 1 e^- per pulse

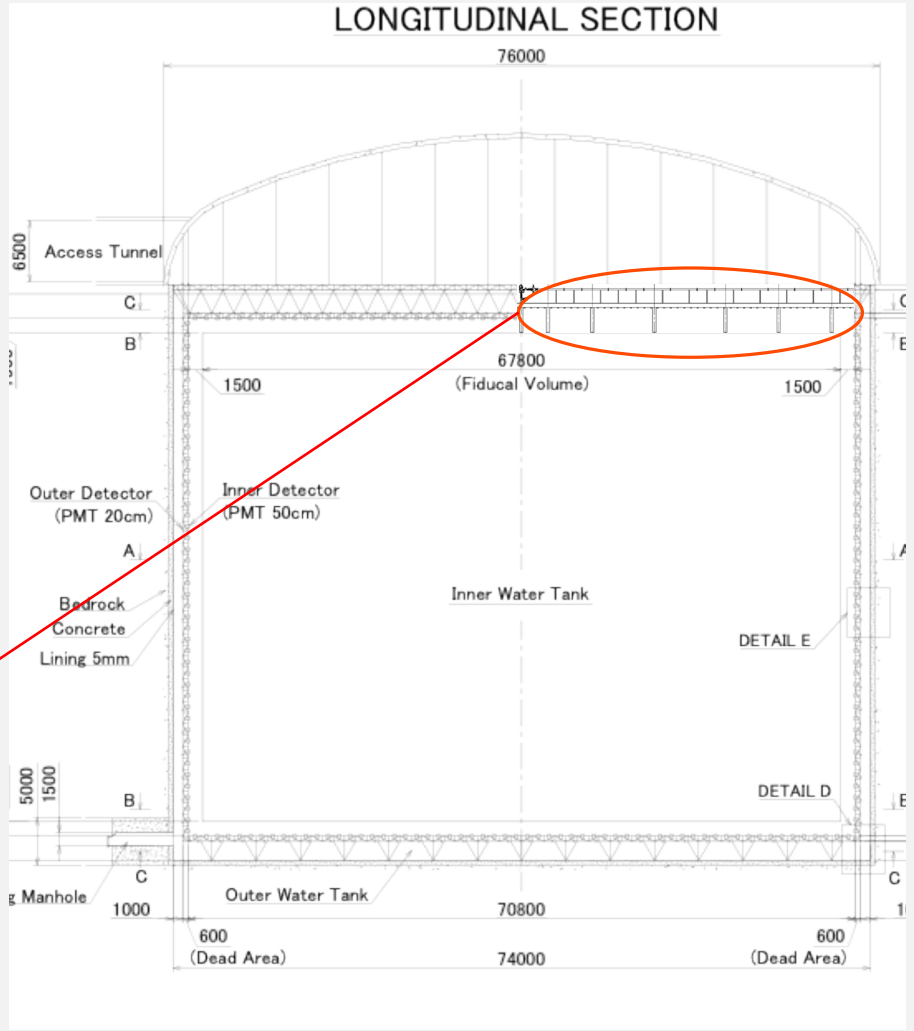


Calibration with linear accelerator

Preparing for calibration:

- Select the calibration port
- Connect the horizontal pipe to achieve the required length
- Install the output chamber
- Install vertical pipes to achieve the required depth
- Connect the D3 magnet trolley
- Create a vacuum
- Open all valves on the beam path
- Start calibration

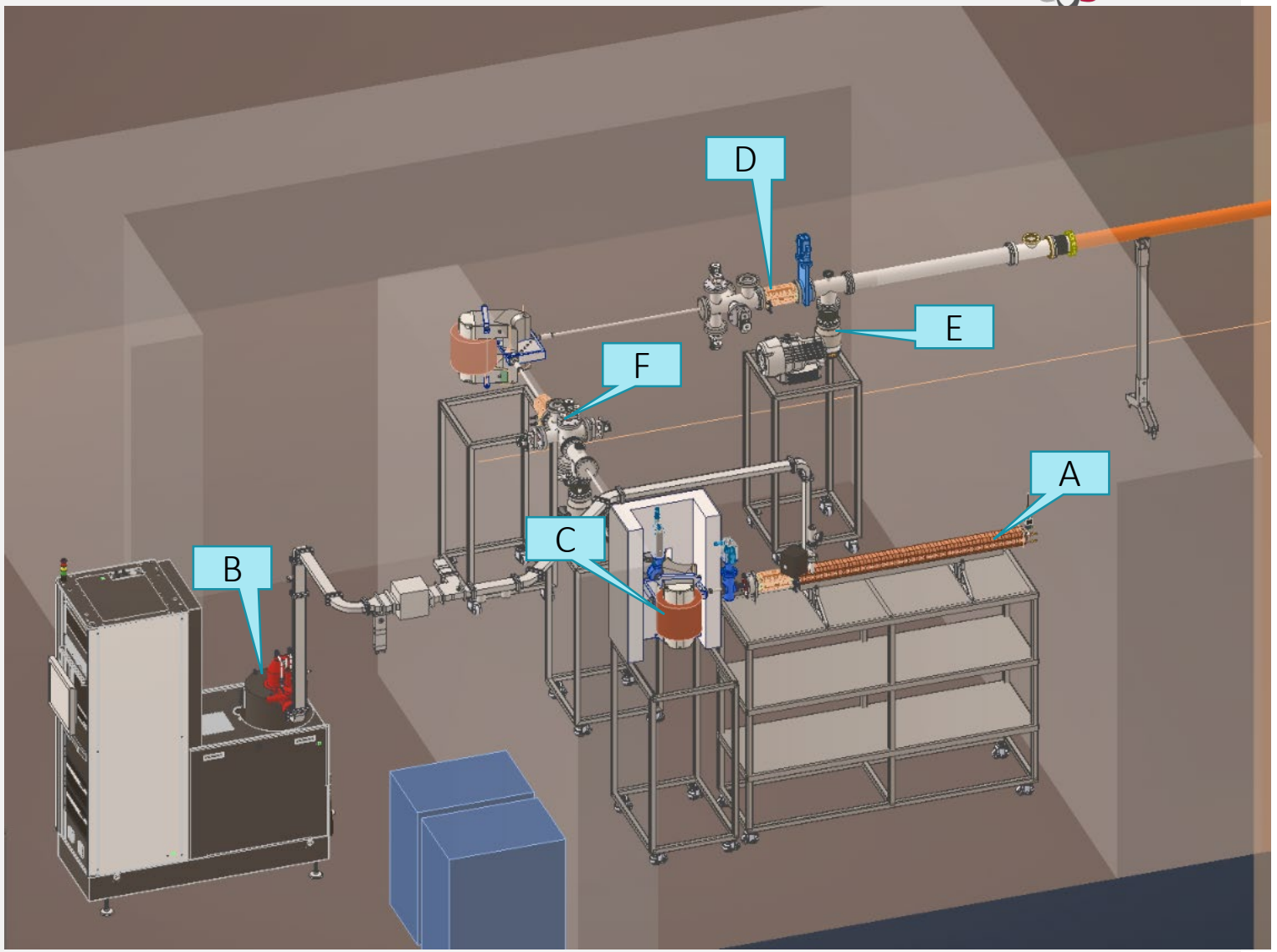




1. Linac

Electron linear accelerator

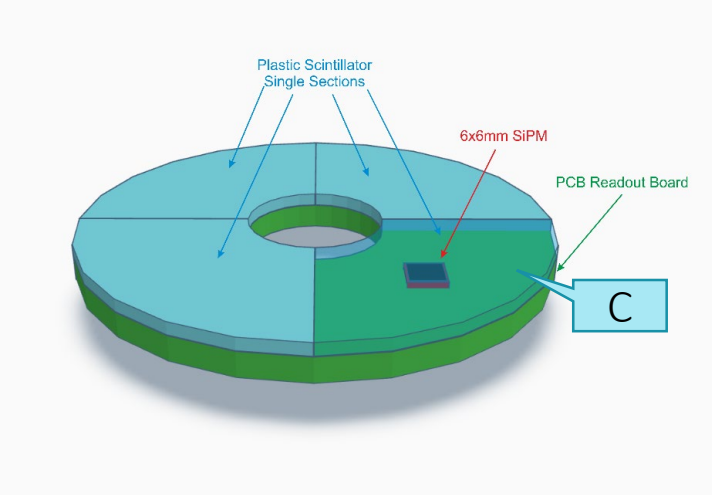
A. Accelerating cavity: 3 – 24MeV
B. RF source – 10 MW klystrons
C. Dipole magnet: 90°
D. Beam steering components
E. Vacuum pumps
F. Detection system components



Beam line components

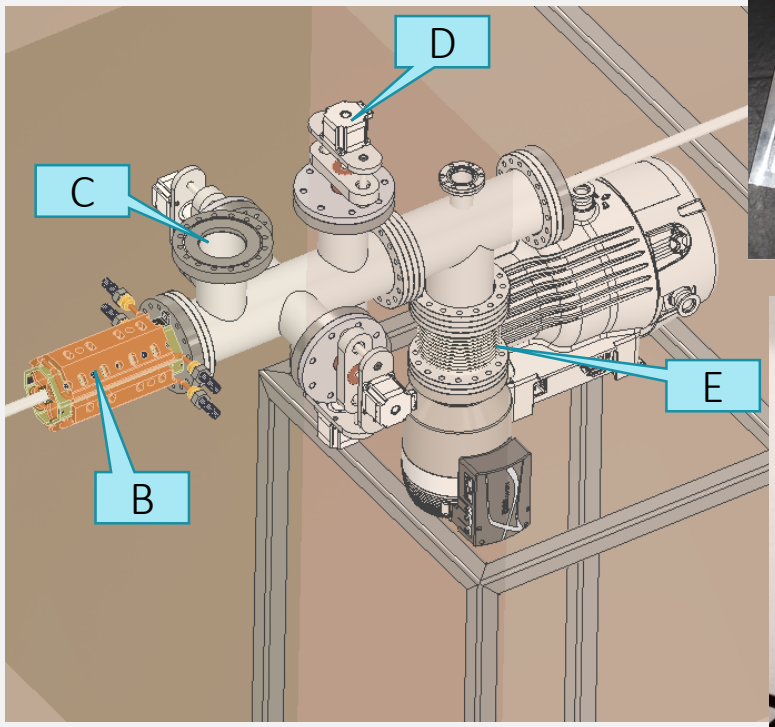
To optimize costs and future maintenance expenses, a process of standardization has been implemented.

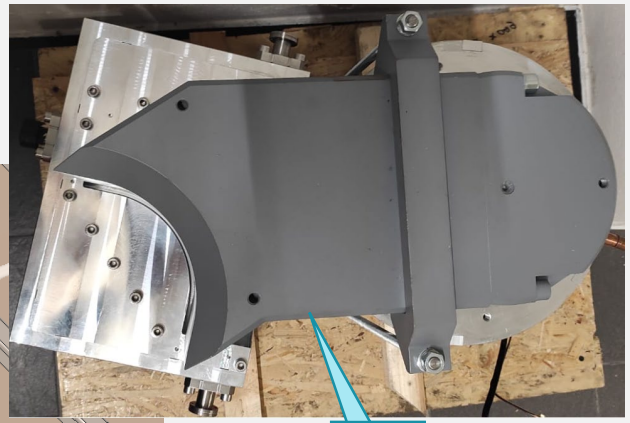
A. Dipole magnet: 90°
B. Triplet coils
C. Beam diagnostics
D. Collimators
E. Vacuum pumps

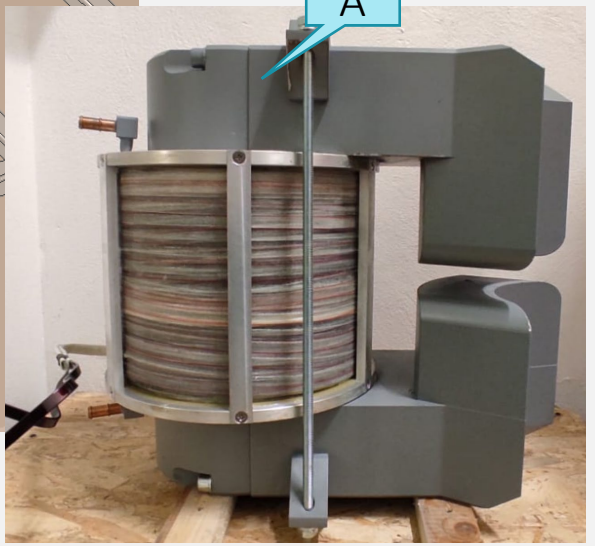


The aim of the Beam Monitor is to detect and verify the number of electrons outside of the beam axis.

The triplet coils contain: 3 sets of focusing coils and 2 pairs of Y and X deflecting coils.

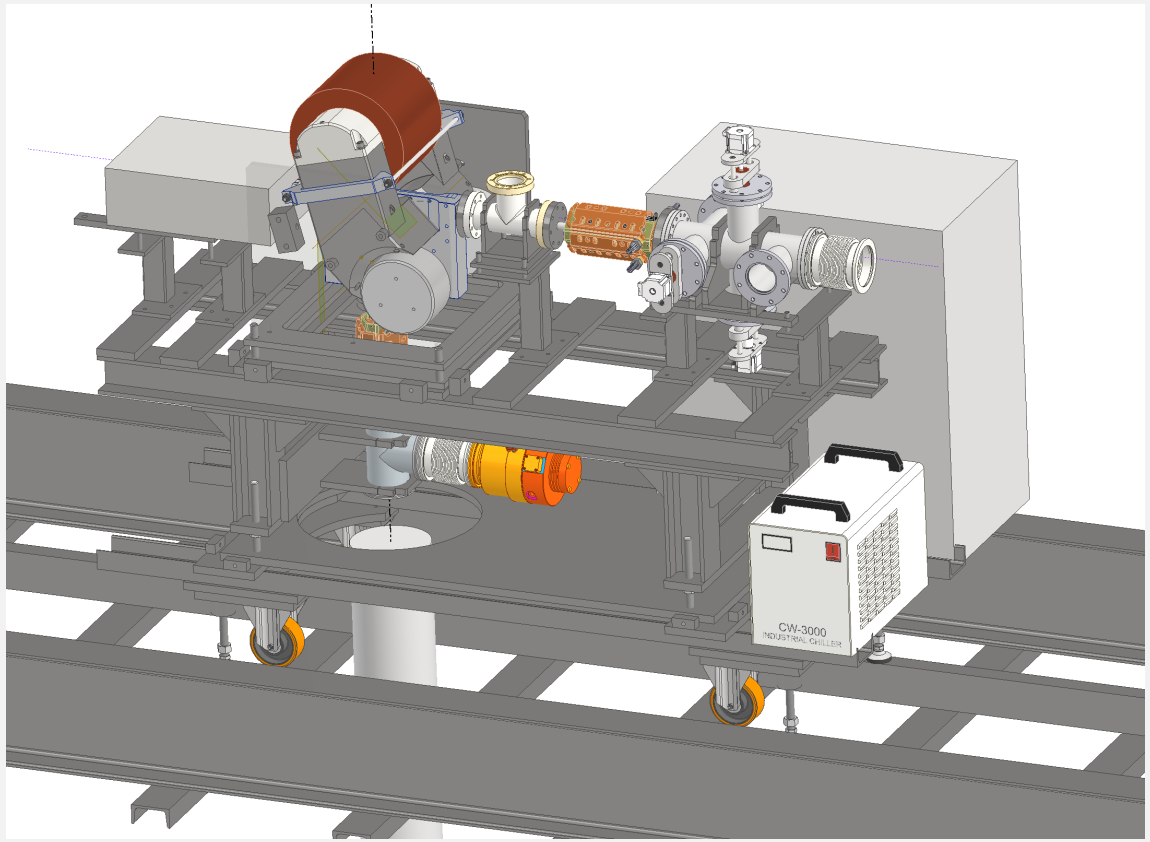






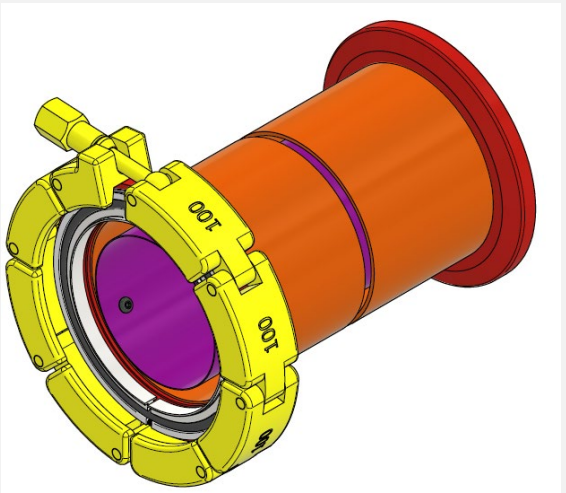
The dipole magnet shape was tailored to reduce the level of radiation produced by deflected electrons.

2. Horizontal beam transport system and D3 trolley



D3 magnet trolley, acts as a hub, allowing the linac to be connected to the selected calibration port,

- Modify the beamline.
- Maintain a vacuum for the D3 magnet chamber and the vertical beamline.



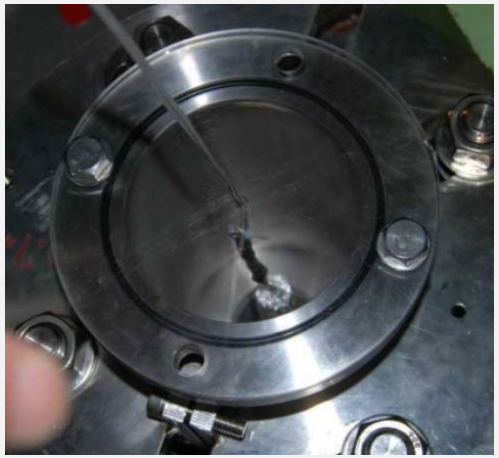
Horizontal line:

- KF flanges for vacuum (Viton on stainless steel ring)
- Fastening based on a chain system
- Dedicated tool for achieving same torque force
- The miu-metal insert is placed inside the pipe

3. Vertical beam pipe system

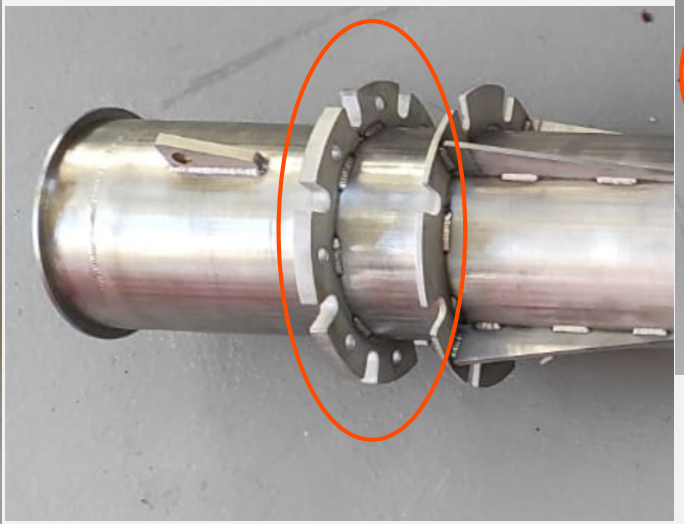
The new solution is based on the Super-Kamiokande design with important changes.

- Originally, the fastening system used flanges secured by four screws.
- During assembly, cables and protective cones were installed separately.
- Cables were secured using plastic zip ties.

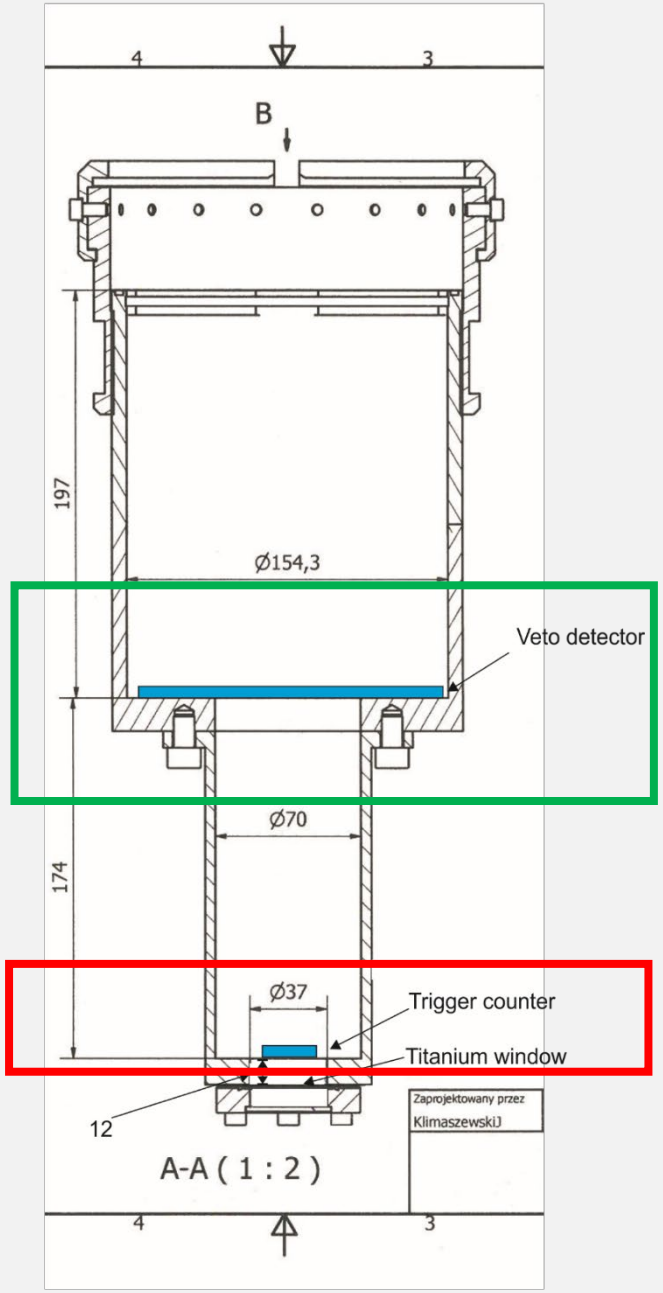


HyperK solution:

- Fastening based on a nut-thread system.
- Infinite pipe positioning options.
- Integrated cable holders.
- Integrated protective cones and pipe sliders.

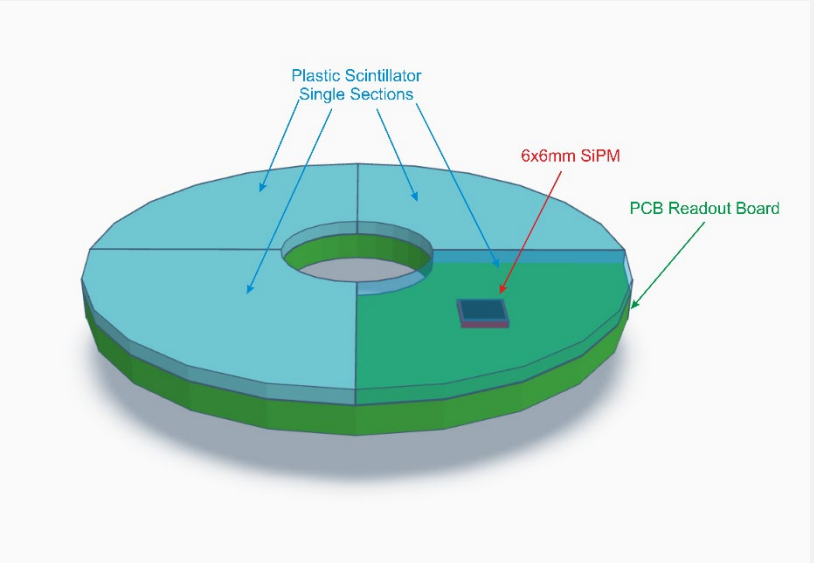


3. Vertical beam pipe system – output chamber

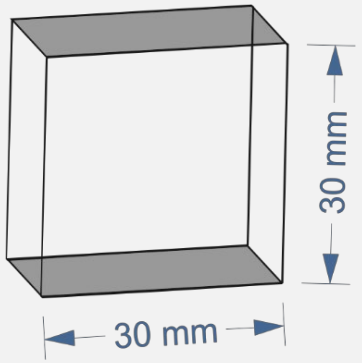


Last element on the vertical beam line:

- Titanium output window
- Trigger detector
- Veto detector.



The Veto Detector must detect and verify the number of electrons outside of the beam axis in 4 directions (4 sections of a donut-like scintillator)

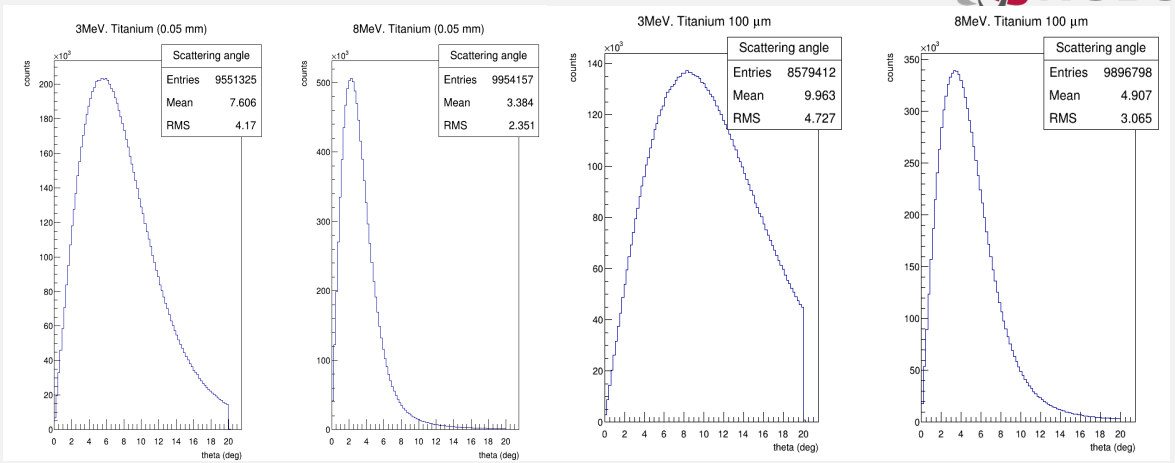


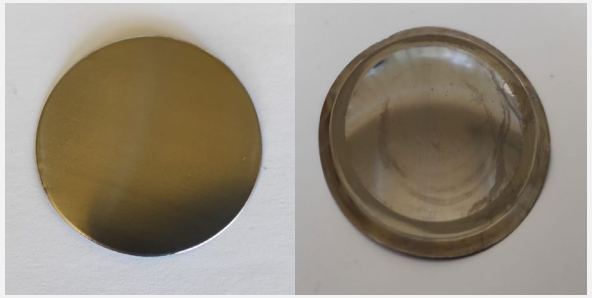
The aim of The Trigger Counter is to detect and confirm, that such single electron was present and entered into the tank.

3. Vertical beam pipe system – titanium window

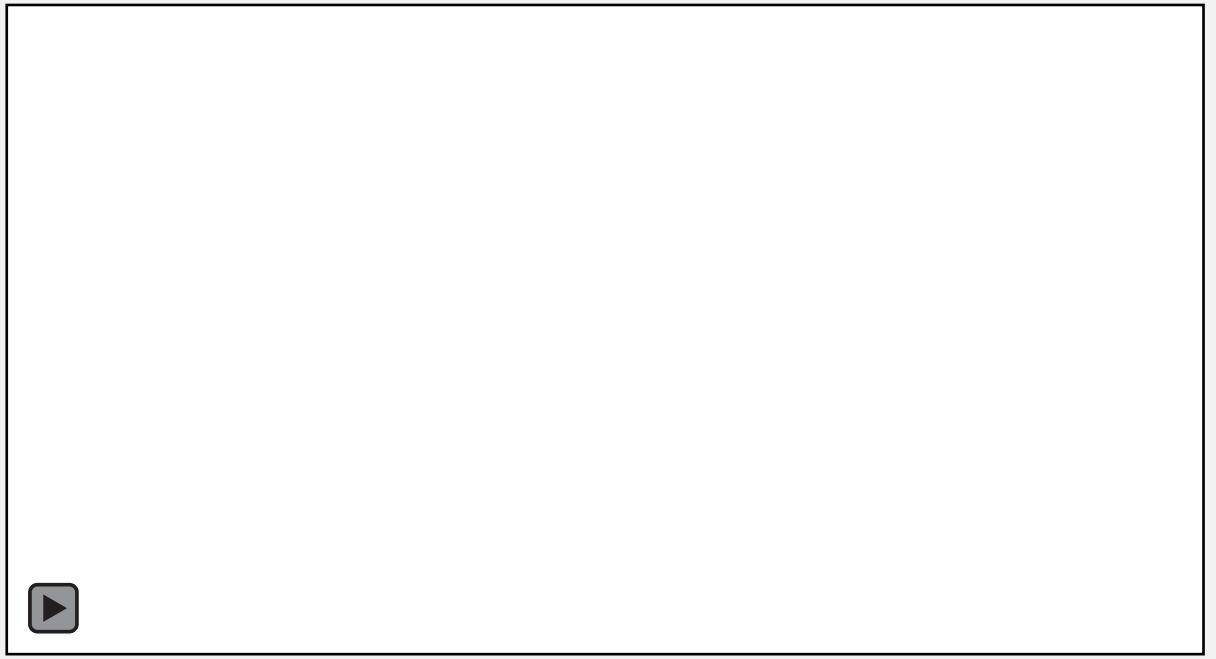
The titanium window is the last barrier between the water and the vacuum.

- Titanium is an approved material for use in the HK water tank.
- The thickness of the titanium foil determines the dispersion angle.
- No bremsstrahlung radiation occurs when passing through the titanium window.



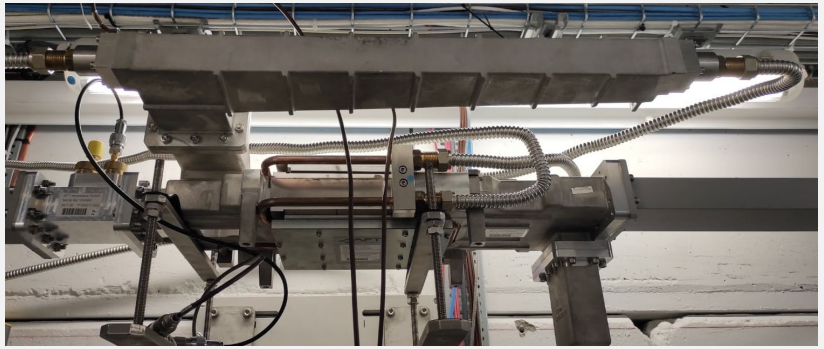


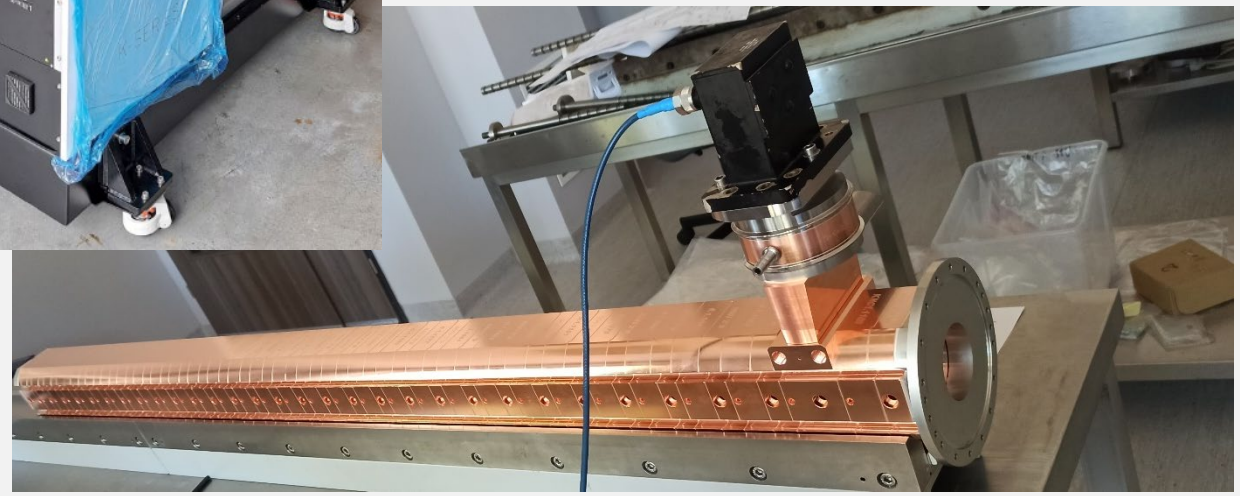
Before After



Summary

- The design and prototyping of components have been completed.
- The first prototype components were tested.
- The results of the tested components were sent for verification and approval by the experiment committee.
- Key components such as the RF source, accelerating cavity vacuum components and 4-port circulator have been ordered and delivered.
- The accelerating cavity has undergone the final brazing process, and the assembly process will start soon.





2. NCBJ Linac group:

- Prof Sławomir Wronka – head of project
- MSc Mariusz Chabera – electronic engineer
- MSc Zbigniew Chmieliński – mechanical engineer
- MSc Magdalena Dobrzyńska – physicist
- PhD Martyna Grodzicka-Kobyłka – physicist
- MSc Jan Klimaszewski – mechanical engineer
- Eng. Tymoteusz Kosiński – electronic engineer
- MSc Natalia Kozak – PLC specialist, programmer
- MSc Michał Matusiak – electronic engineer
- MSc Krzysztof Mazurek – PLC specialist, electronic engineer
- PhD Tomasz Szcześniak – physicist
- MSc Marcin Wiktorowicz – physicist
- MSc Marcin Wojciechowski – mechanical engineer
- PhD Tomasz Zakrzewski – IT specialist, programmer

ThankYou

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