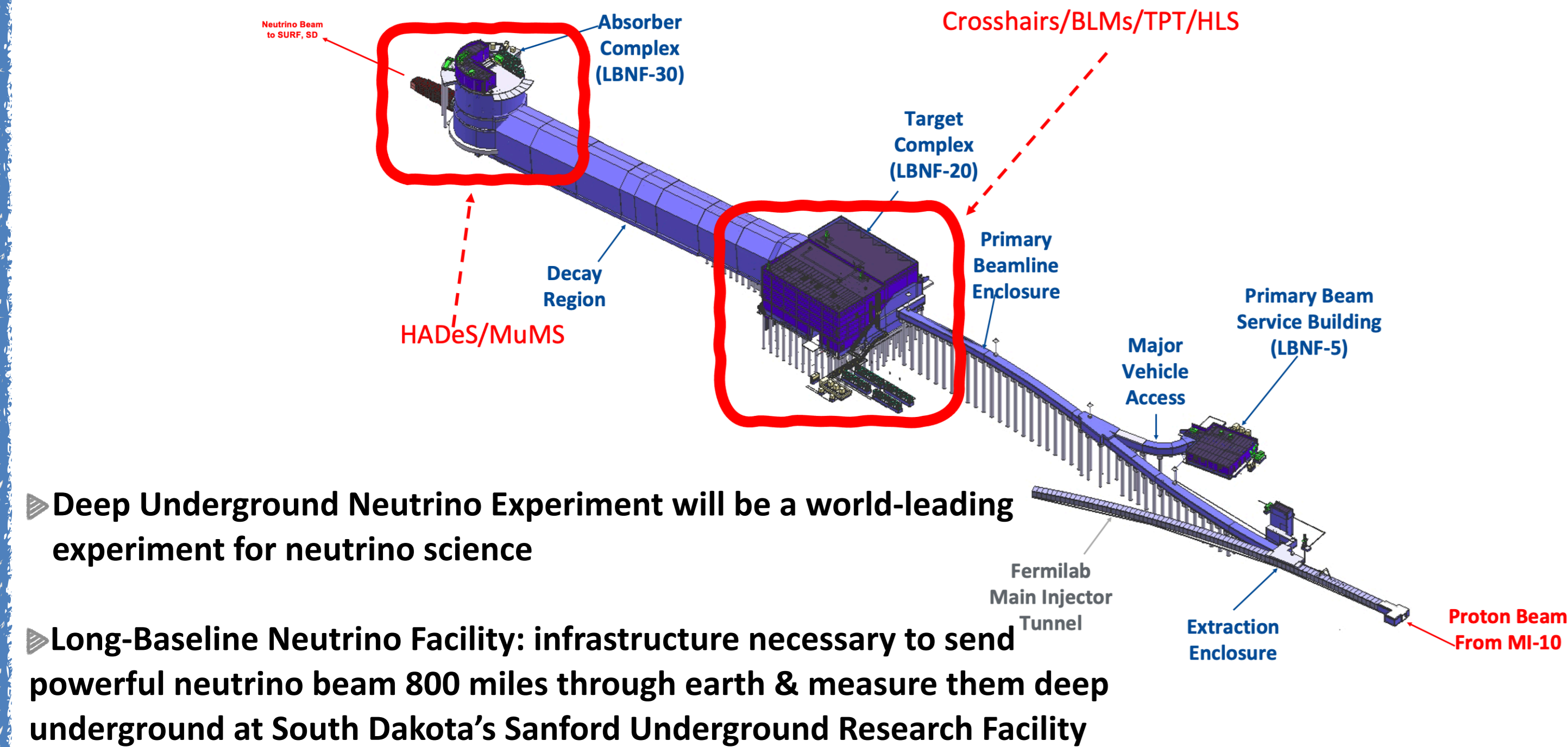


## LBNF Beamline & Locations of NBI

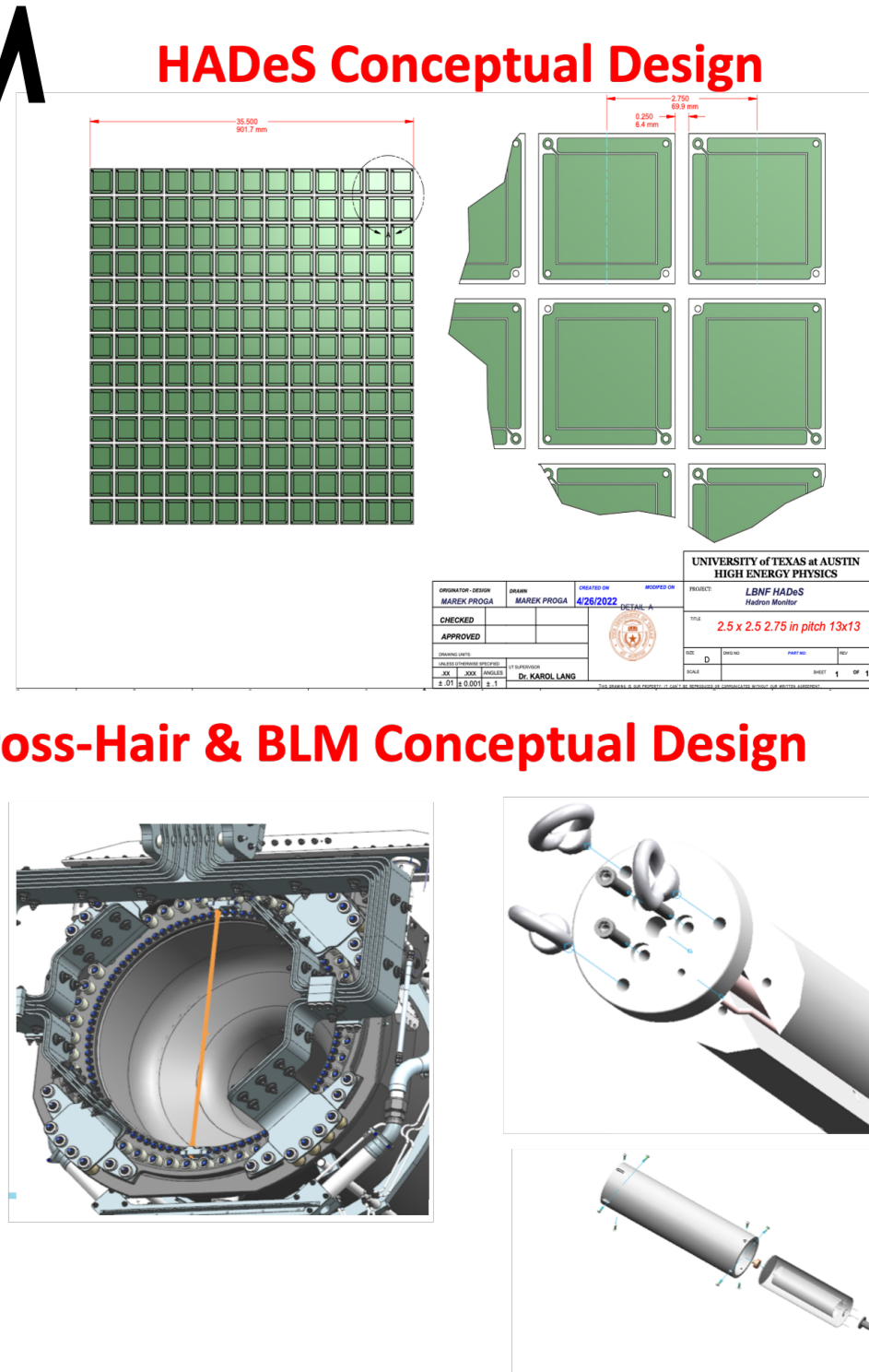


## Requirements & Tolerances

- Require well controlled neutrino beam with minimal systematic errors**
- ▶ No significant contribution to neutrino flux systematic error or impact on physics measurements
  - ▶ Some requirements come from radiation considerations
  - ▶ All instruments designed for 1.2 MW operation & should work at 2.4 MW, easily upgradable
- Tolerances:**
- ▶ Proton beam angle: 70  $\mu$ rad
  - ▶ Proton beam position: 0.5 mm, profile: 10%
  - ▶ Baffle beam scraping: 1%
  - ▶ Target and Horn A/B/C displacement (transverse/tilt): 0.5 mm

## HADeS, Cross-Hair, BLM

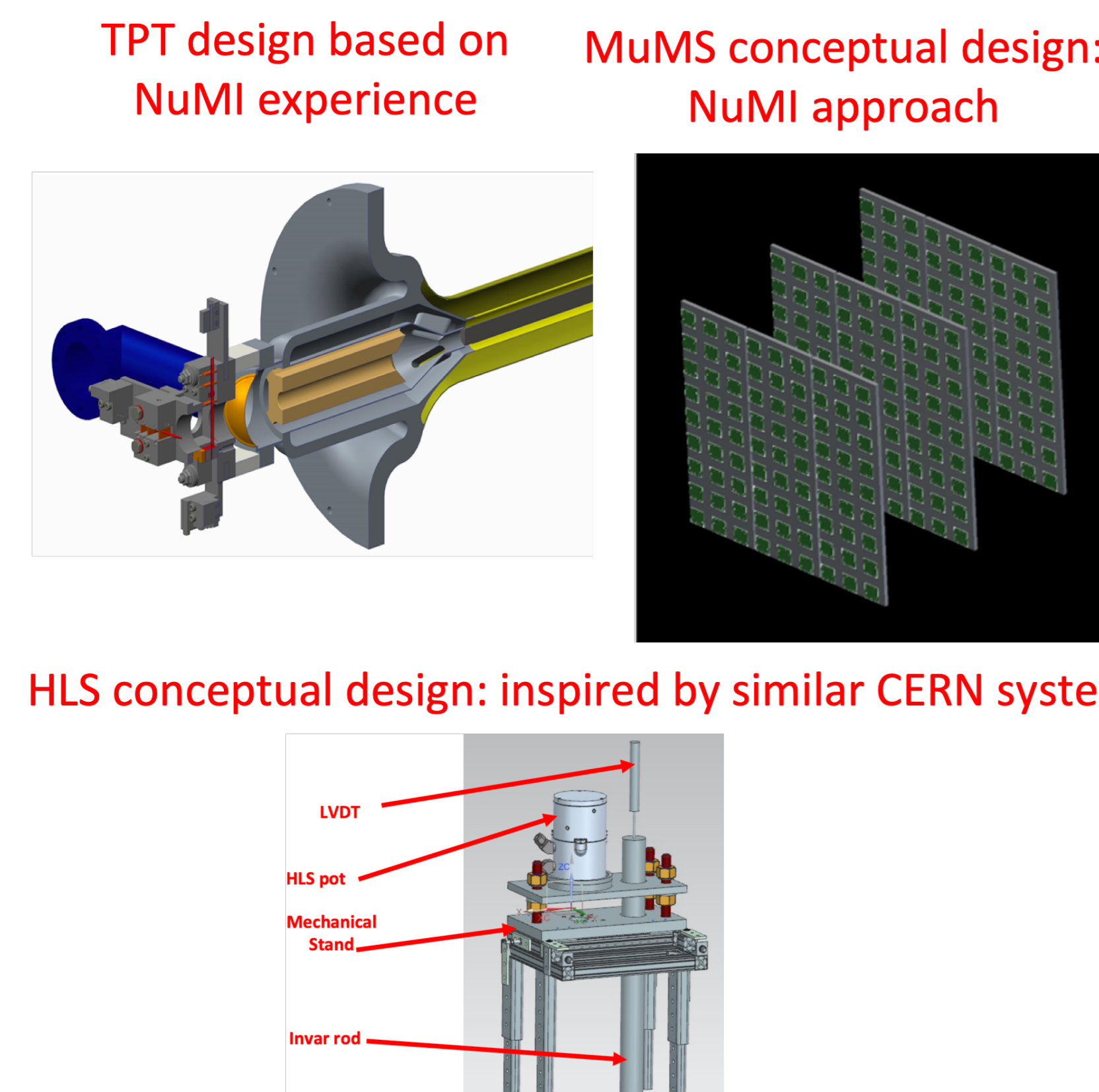
- Align beamline elements within tolerance**
- ▶ Beam-Based Alignment requires:
    - ▶ Beam Position Monitors (BPMs, upstream of target)
    - ▶ Hadron Alignment Detector System (HADeS), in front of absorber, at end of decay pipe)
    - ▶ Horn cross-hairs, beam-loss monitors (BLMs)
    - ▶ Heavily rely on NuMI experience



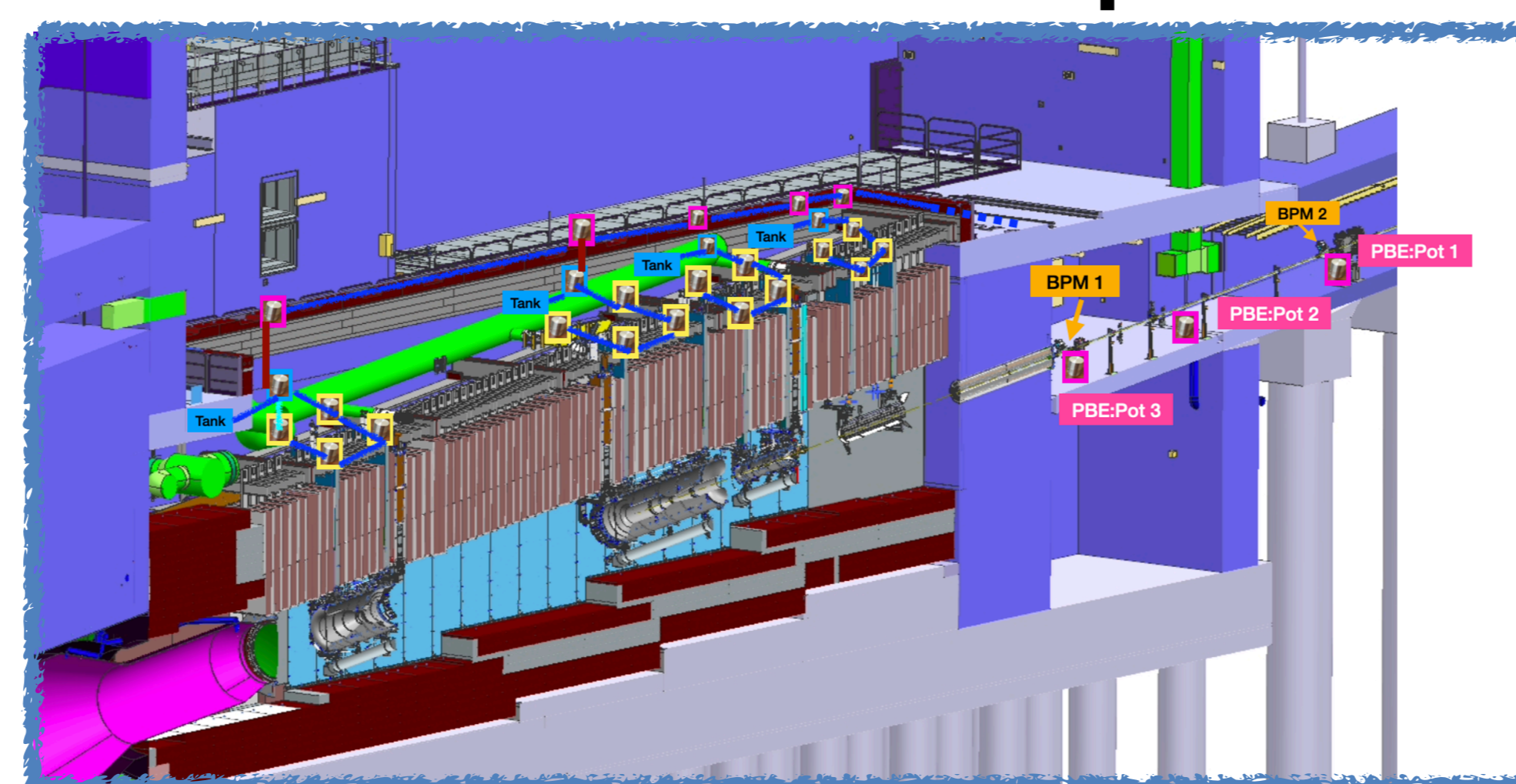
## TPT, MuMS, HLS

Monitor neutrino beam intensity & direction during operation

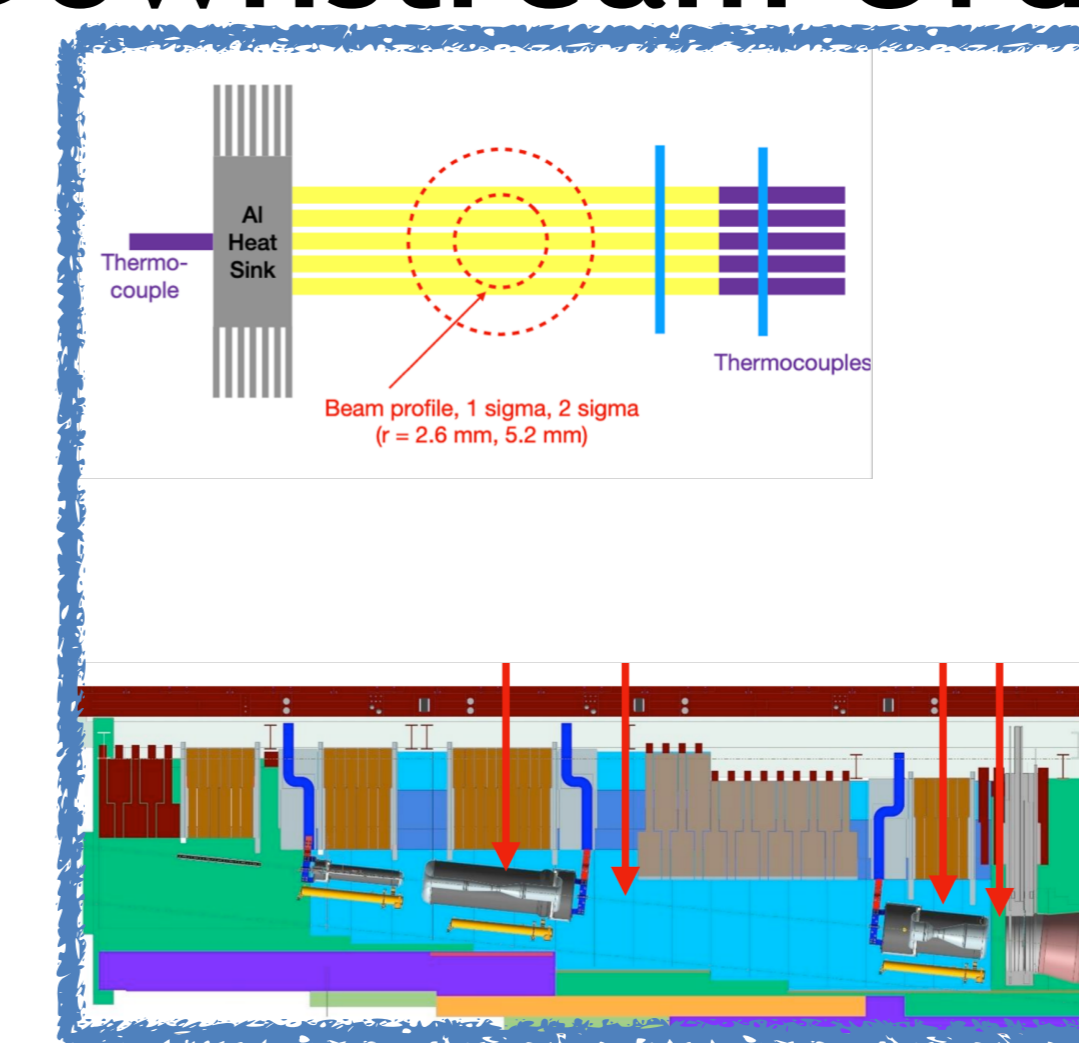
- ▶ Target position thermometer (TPT): indicates target movement if position of beam on target changes w/ no corresponding change in position on BPMs
- ▶ Muon monitor system (MuMS): tracks intensity, beam center & width on a spill-by-spill basis
- ▶ Horn-leveling system (HLS): independent measurement of positions of focusing horns



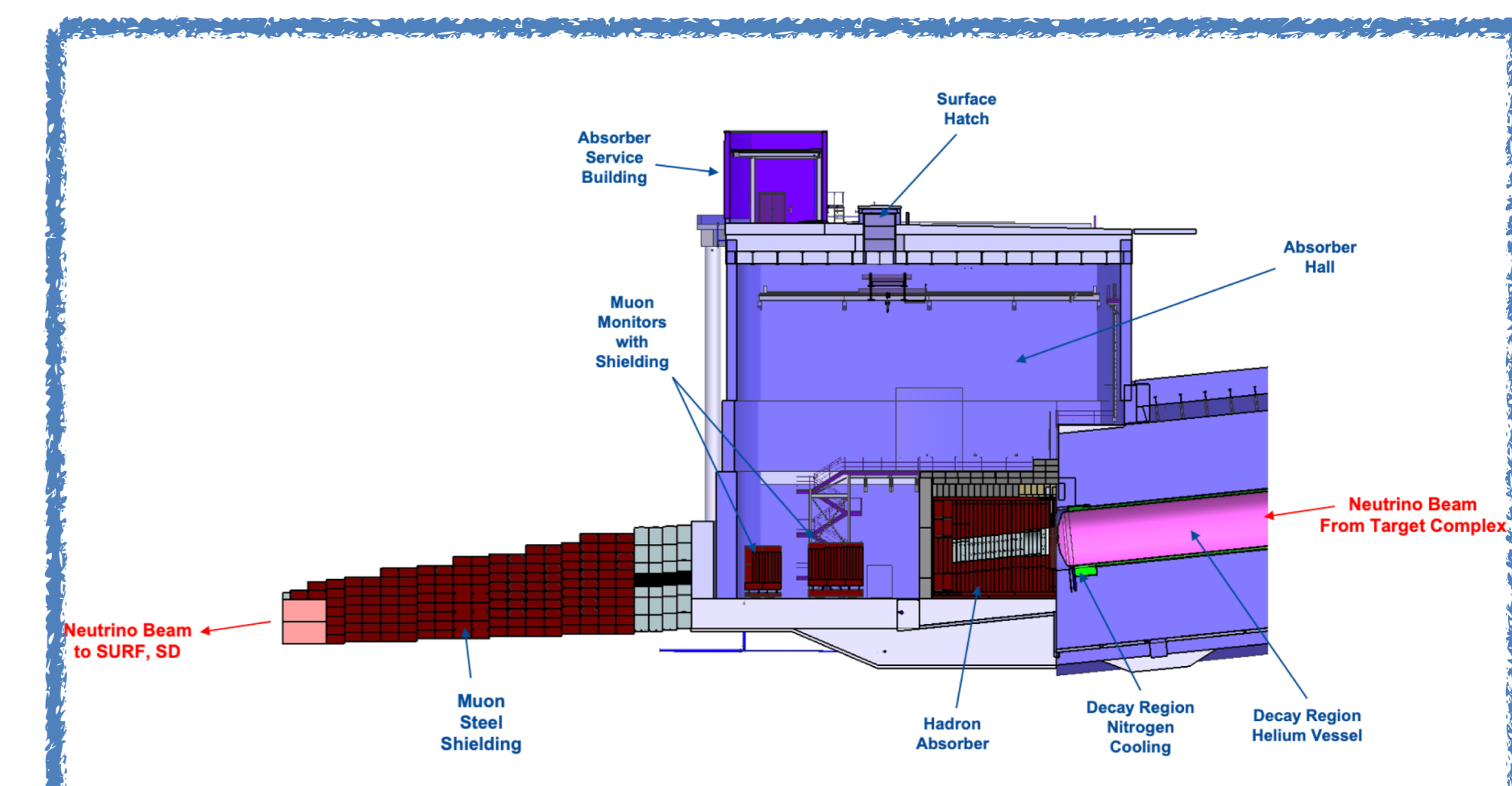
## Instrumentation in Upstream to Downstream Order



- ▶ HLS monitors vertical shifts of beamline components (pre-target BPMs, Baffle, Horns)
  - Uses water level to transfer height between sensors, system based on Frequency Scanning Interferometry (FSI)
  - Simultaneously compares multiple interferometers to same reference
  - Can sustain radiation on top of LBNF module (5 – 50 kilo-rad/year)
- ▶ BPMs steer beam on target
  - Beam-based alignment finds target & other elements within BPM coordinates

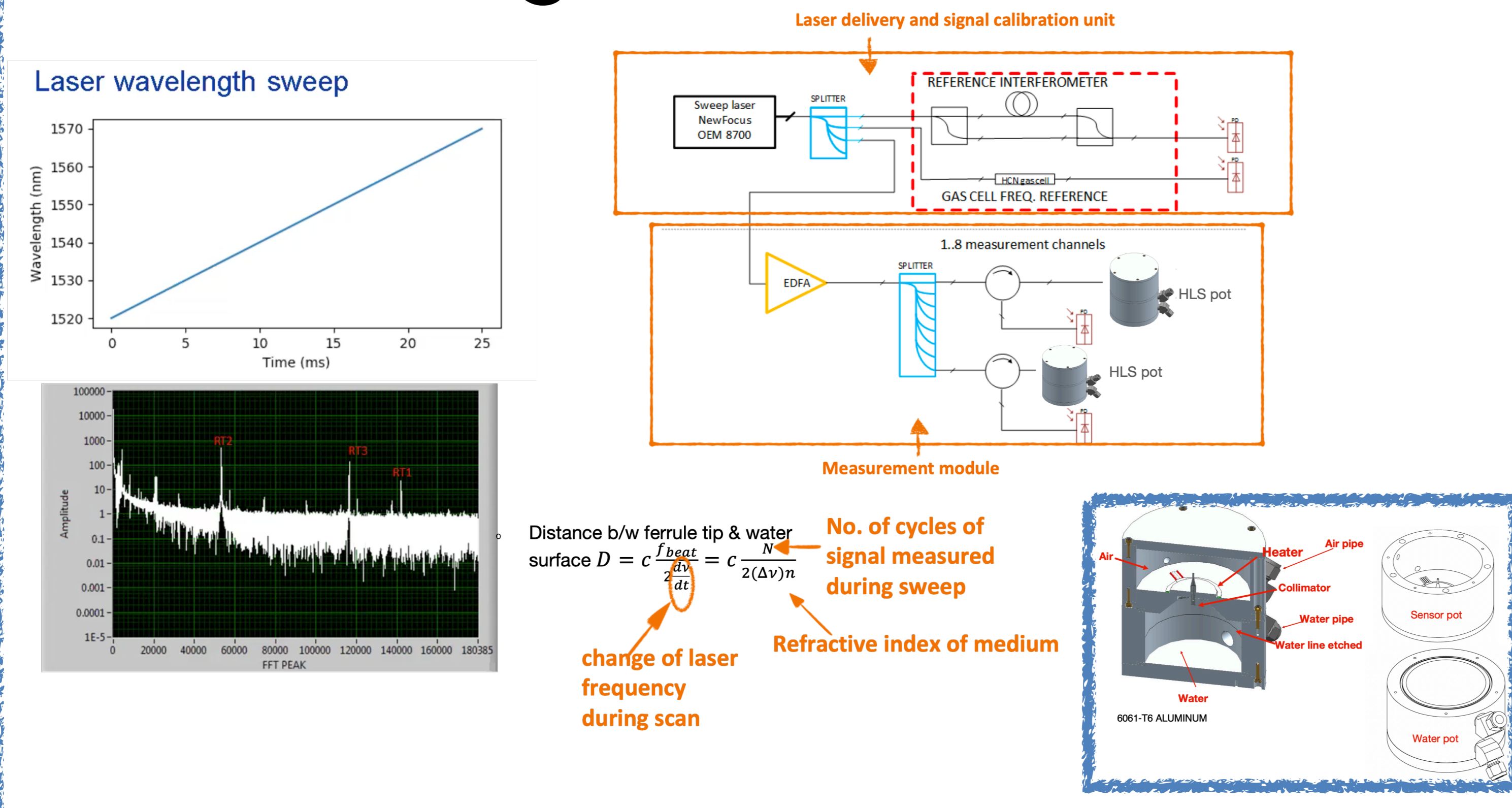


- ▶ TPT measures beam on target with full intensity
- ▶ Cross Hairs/ BLMs
  - ▶ Horn B & C aligned as part of BBA
  - ▶ Scan beam across known physical features to locate each element
  - ▶ Use Cross Hairs at upstream & downstream ends of Horns B & C
  - ▶ Beam loss monitors to detect beam scatter from Cross Hairs



- ▶ HADeS: array of ionization chamber
  - ▶ Measure centroid position, integrated intensity, RMS change
  - ▶ Inserted only for alignment, retracted during normal operation
- ▶ MuMS
  - ▶ Sensitive to beam focusing problems, measure beam centroid
  - ▶ Same technology as HADeS
  - ▶ 3 Stations with muon thresholds at 5, 11, and 15 GeV

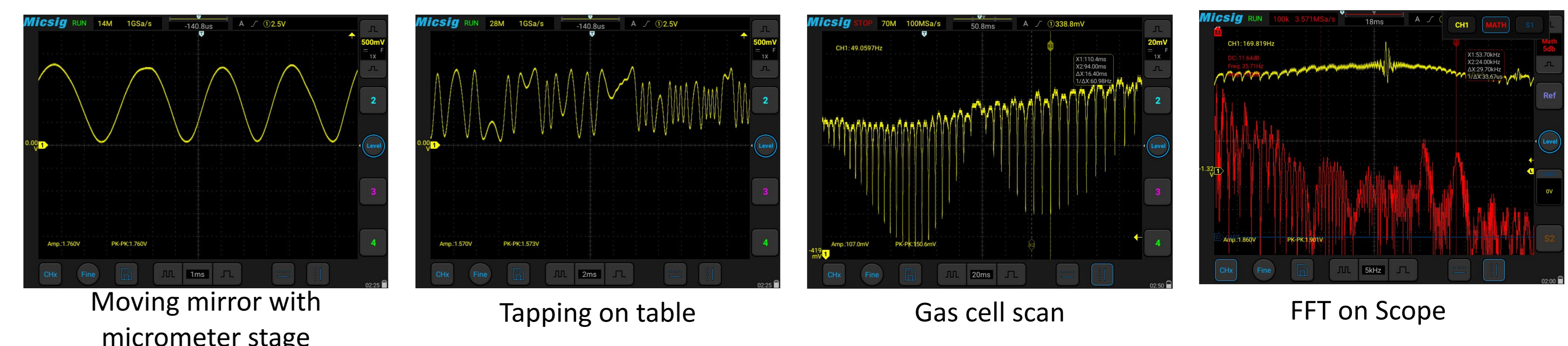
## Horn Leveling System (HLS)



- Main components:**
- ▶ Tunable laser source with range: 1530 – 1625 nm
  - ▶ Reference interferometer → constant length interferometer of 2 fibers.
  - ▶ Hydrogen Cyanide (HCN) absorption gas cell → track “true” frequency of sweeping laser
  - ▶ Erbium-Doped Fiber Amplifier (EDFA) → amplify laser signal before transmitting it to measurement channels
  - ▶ Measurement channels → each consists of C-band optical circulator, measurement optics with a pot, photodetector.
- Measurement steps:**
- ▶ Photodetectors data linearization
  - ▶ Sweep speed calculation
  - ▶ Detection of the “beat” frequency peaks

## Prototype Test

- ▶ Recently began at Lab 6
- ▶ Will evaluate individual components of overall design
- ▶ Will test mechanical design and manufacturing feasibility
- ▶ Gain assembly, installation, and operational experience



## Conclusion:

- ▶ NBI Preliminary Design Review held b/w May 11 – May 12, 2022, currently preparing for final design
- ▶ On track to have NBI installed and commissioned by 2031, in line with rest of project

Reference - <https://indico.fnal.gov/event/53964/contributions/249793/>