Overview of LBNF Target Conceptual Design & Physics Performance

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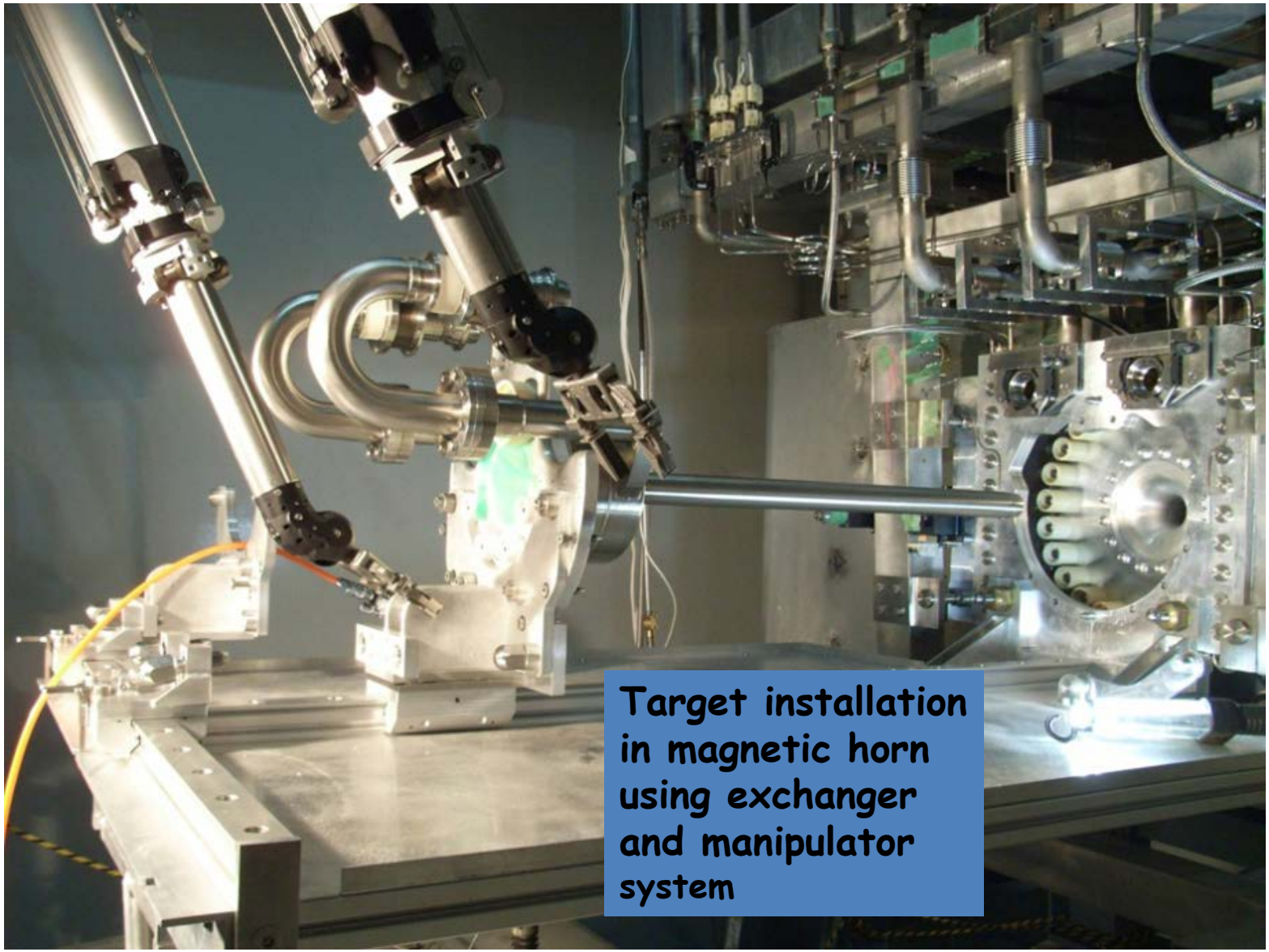
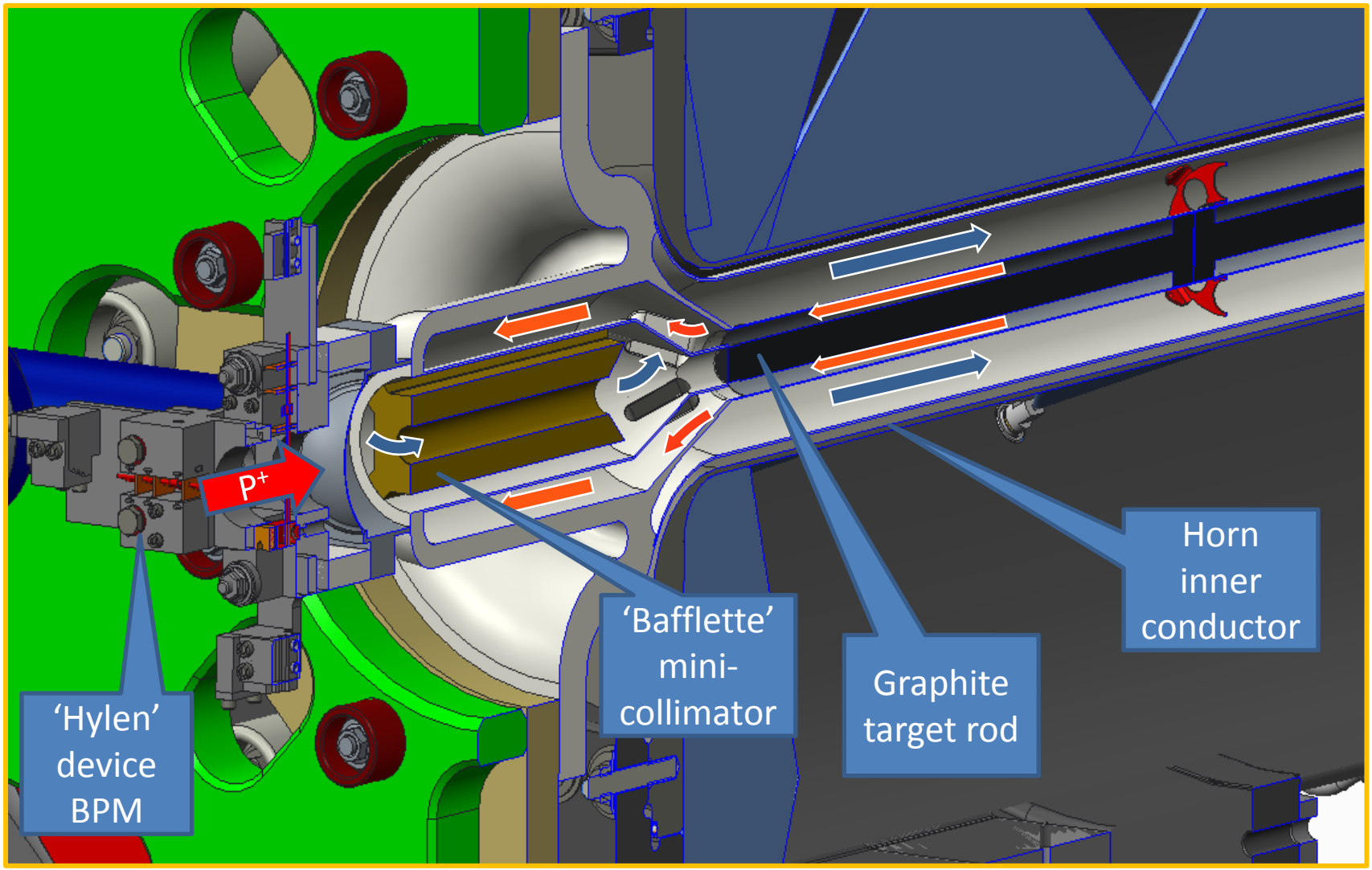
DEEP UNDERGROUND NEUTRINO EXPERIMENT

Science & Technology Facilities Council
Rutherford Appleton Laboratory

Our starting point: Helium Cooled T2K Target



LBNF helium cooled target conceptual design



Target Concept Selection Criteria

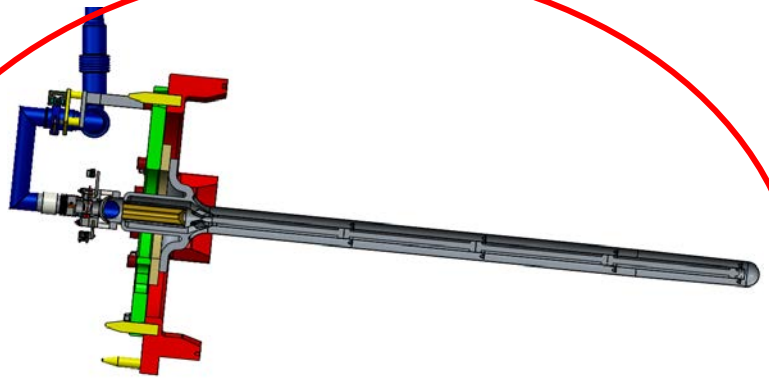
1	Physics performance	Instantaneous physics performance Upgradeability to 2.4 MW Flexibility re optimisation (materials, beam size etc) Compatibility with beam alignment (hadron vs muon?)
2	Engineering performance	Safety factor = f(stress, temperature) Lifetime, resilience to radiation damage Resilience to off-normal conditions Resilience to beam trips Potential for diagnostics
3	Impact on other systems	Impact on horn/stripline design Ease of integration with horn Ease/reliability of alignment with horn axis Impact on services/plant Ease of remote handling/disposal Impact on TS design Impact on absorber design
4	Cost	Cost & resource for design/prototyping Cost & resource for manufacture Cost of RH equipment Disposal cost
5	Schedule	Time to design Time to prototype Time to manufacture Schedule impact on other systems
6	Risk	Design complexity Ease of manufacture Remote handling complexity Departure from known technology Schedule risk ES&H / ALARA issues

Particle Production Target 'Optimum' Performance

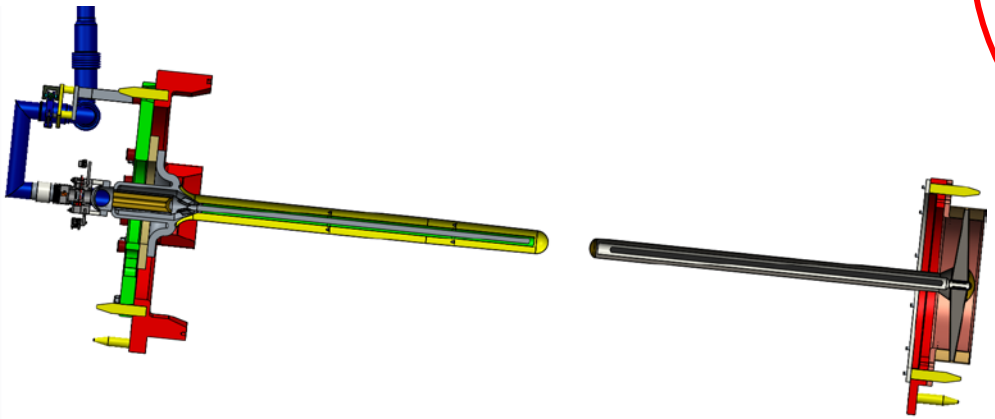
- $\lambda_{overall} = \lambda_{physics} \times \lambda_{reliability}$, *where* $\lambda_{reliability} = fn(I,\sigma,L\ldots)$
- For CP sensitivity – small beam σ is favoured
- For target lifetime – bigger σ is better.
  - Lower power density – lower temperatures, lower stresses
  - Lower radiation damage rate
  - Lower amplitude 'violin' modes (and lower stresses)
- For CP sensitivity – long target (c.2m) is better
- For max lifetime – short and *simple* target is better
- For **integrated** optimum performance, need to take both *instantaneous* performance and *reliability* into account
  - E.g. How to achieve best physics performance possible for a target lifetime of a minimum of 1 year?
  - Answer will depend on beam parameters & power, changeout time etc

Helium cooled target concept selection

1: Single 2.2m long target with remote-docking downstream support

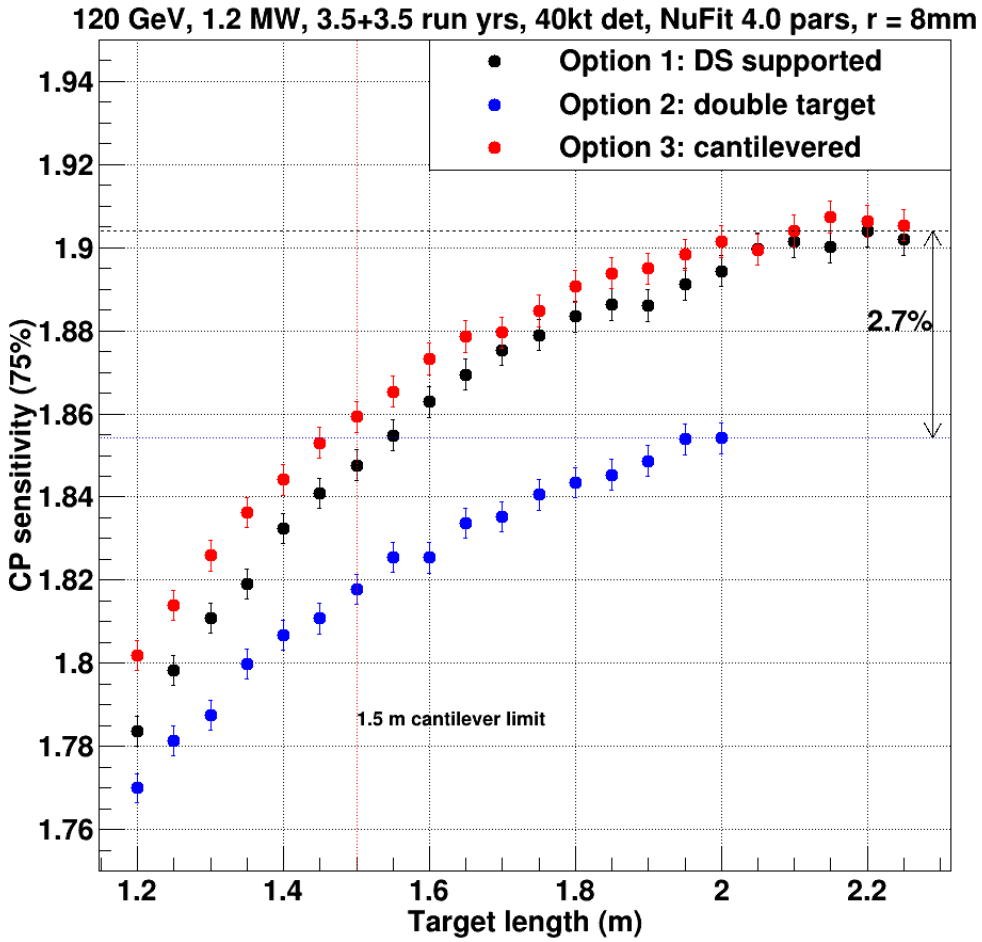


3: Single intermediate length (c.1.5 m) target supported as a simple cantilever



2: Two ~1m long cantilever targets, one inserted at either end of horn

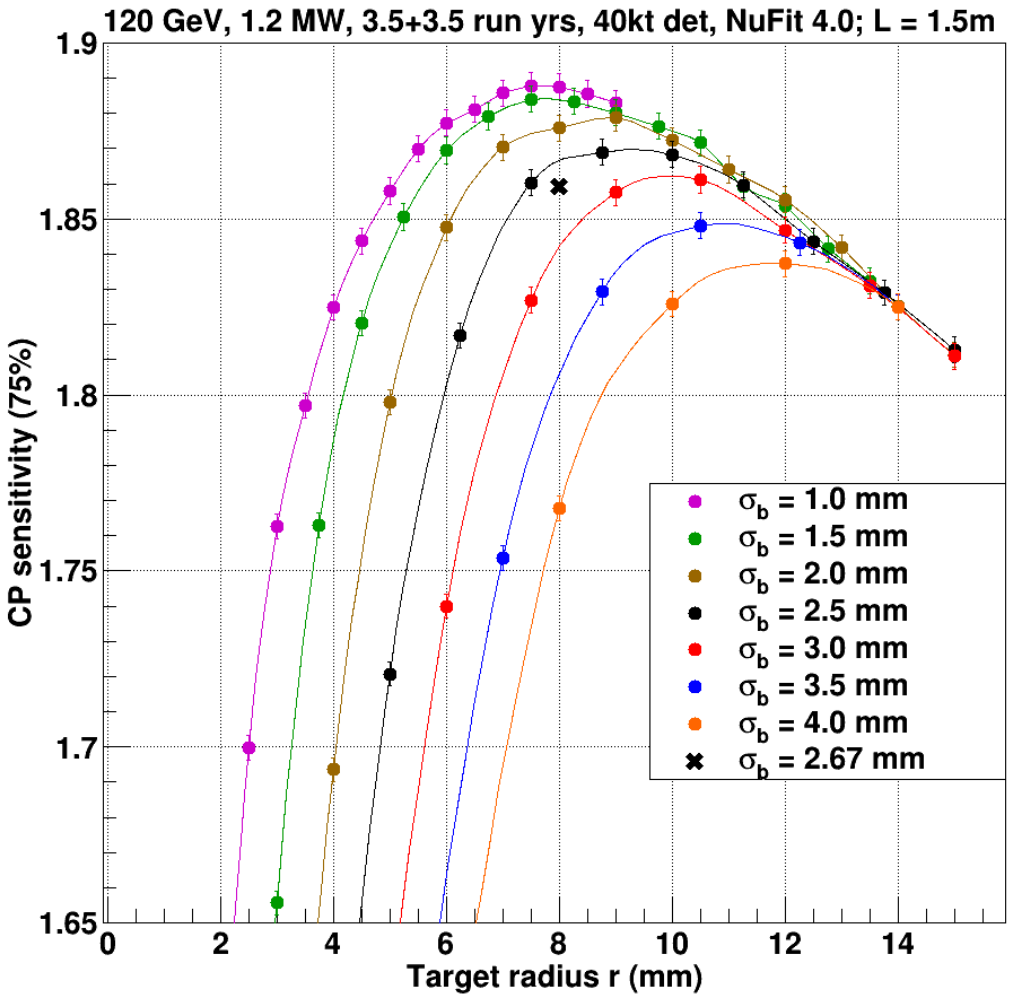
Comparison of CP sensitivity for 3 options considered (all r = 8 mm, σ = r/3



To achieve same 3σ exposure for CP sensitivity as 2.2 m long target:

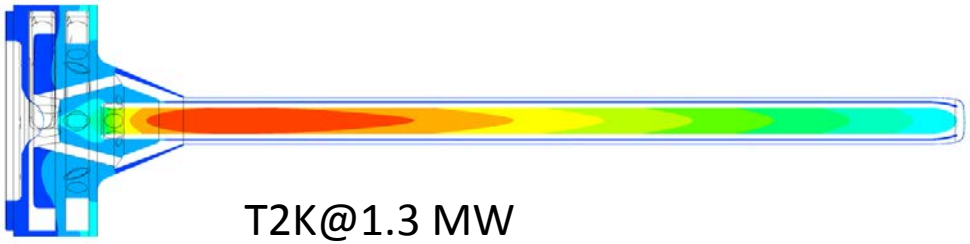
- 1.5 m cantilever needs to run extra 19 days/year
- 1.6 m cantilever needs to run extra 13 days/year
- Ultimate objective: 'As Long As Realistically Achievable' cantilever target

CP sensitivity for 1.5 m cantilever target vs target & beam rms radius



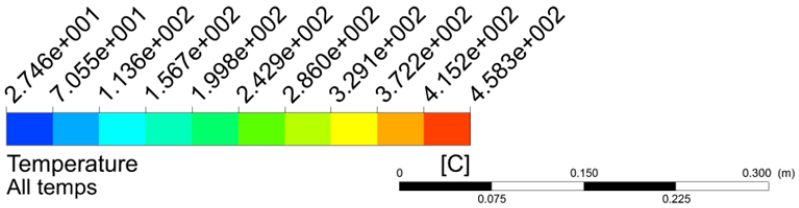
- Comprehensive study of physics performance for range of beam and target radii
- Need to compromise between physics and engineering performance
- Some scope to improve CP sensitivity for given beam rms radius

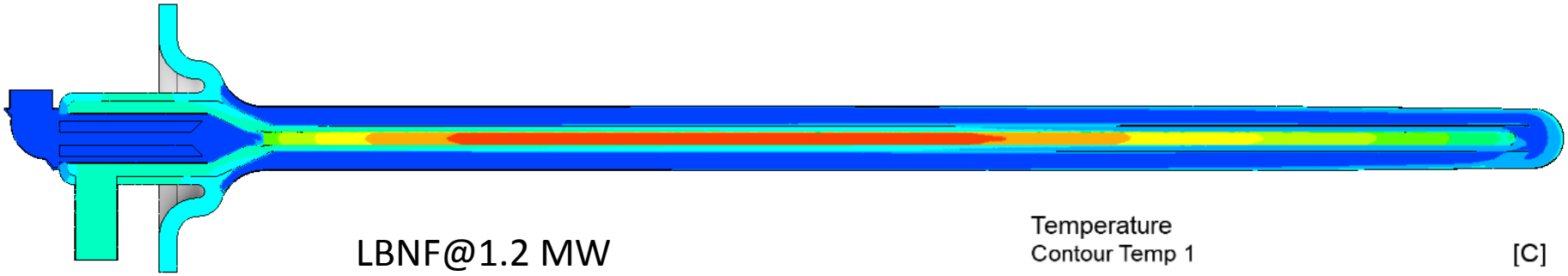
LBNF conceptual design compared with current 'state-of-the-art'



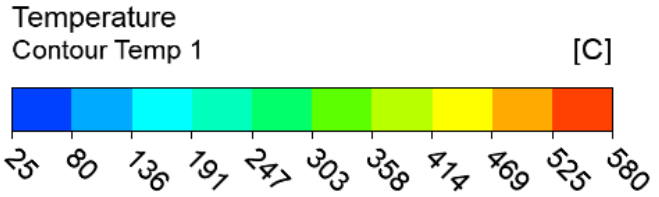
T2K@1.3 MW

NB current experience up to 500 kW

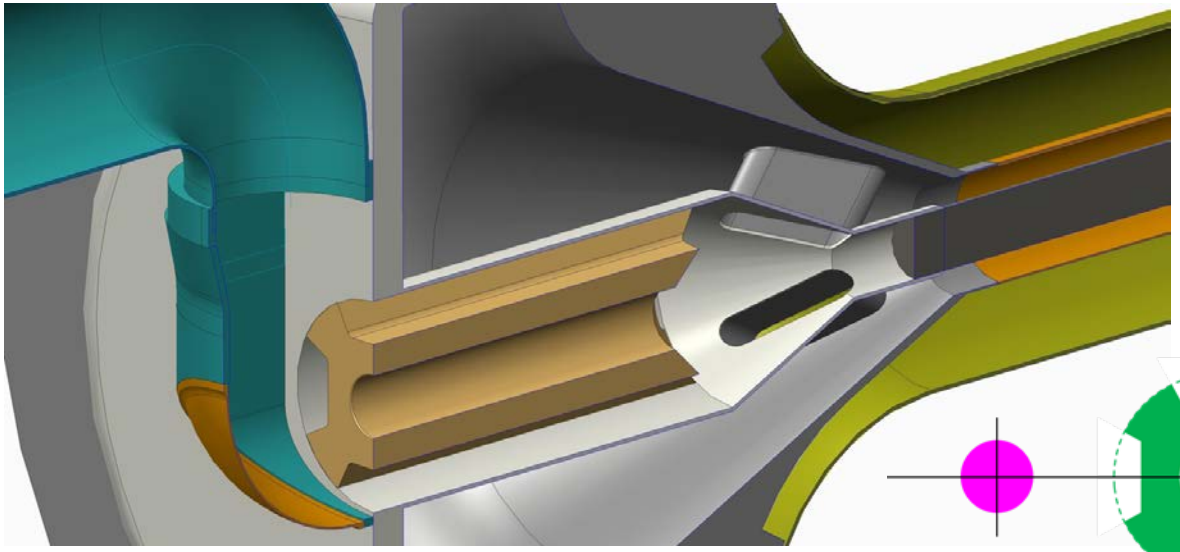


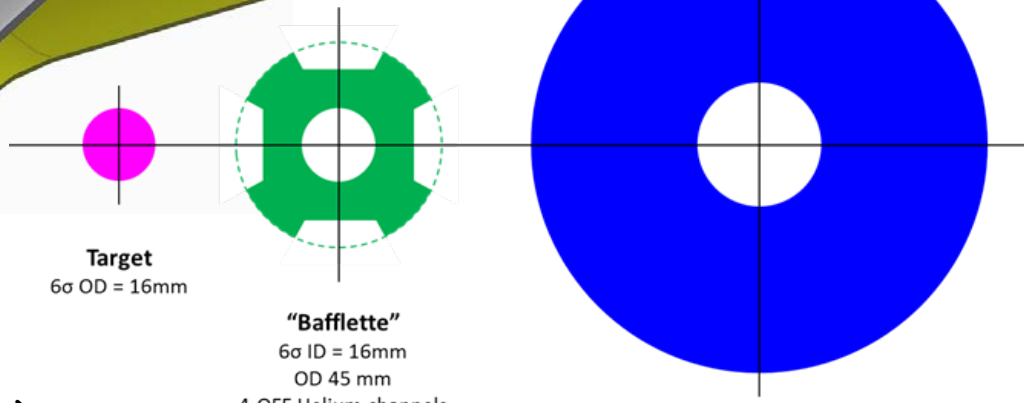


LBNF@1.2 MW



Beam based alignment



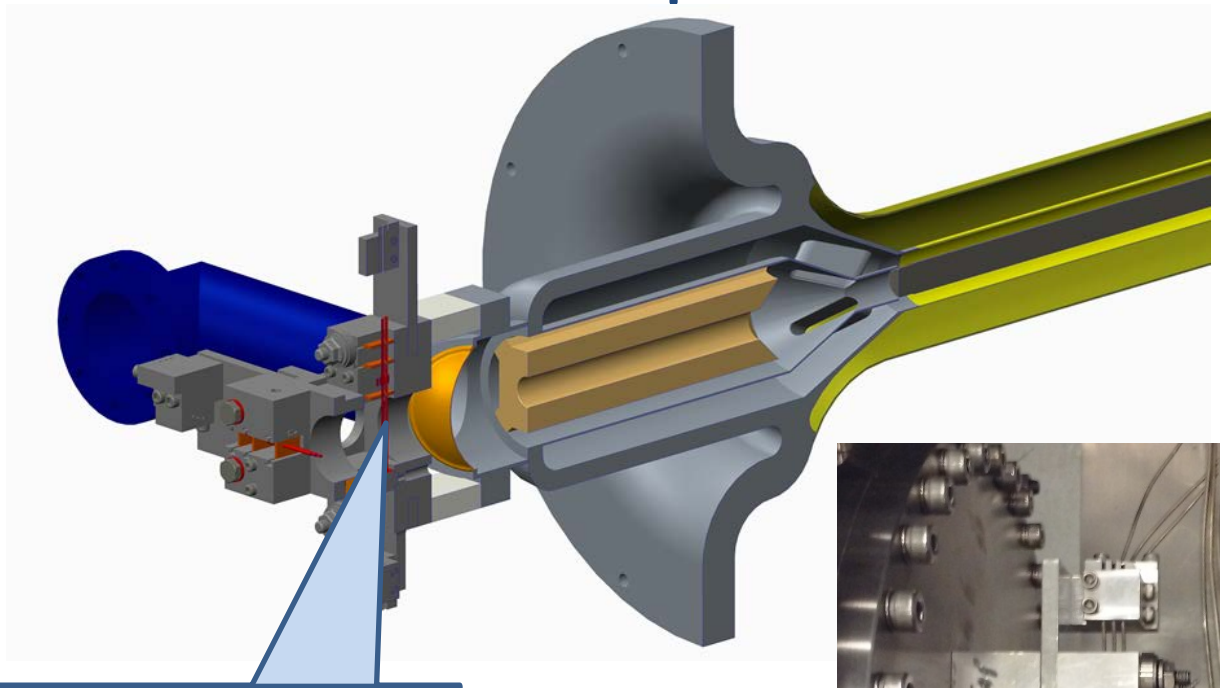


During initial alignment (without baffle):

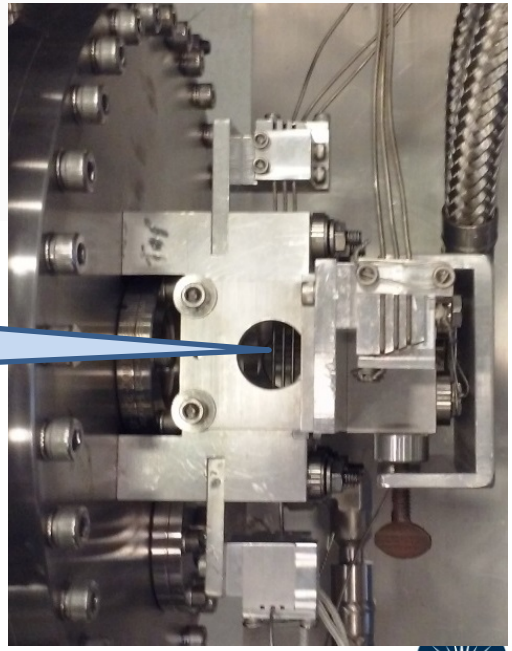
Use low intensity beam scans (horizontal and vertical) to:

1. Find outer edges (therefore centre) of bafflette
   - (25% interaction through bafflette)
   - Bafflette easily distinguishable from target
2. Find outside edges (therefore centre of mass) of target
   - (75% transmission vs 2% transmission through 4λ target)
3. Bafflette centre and target centre gives target angle

Incorporation of 'Hylen device' (beam position monitor)



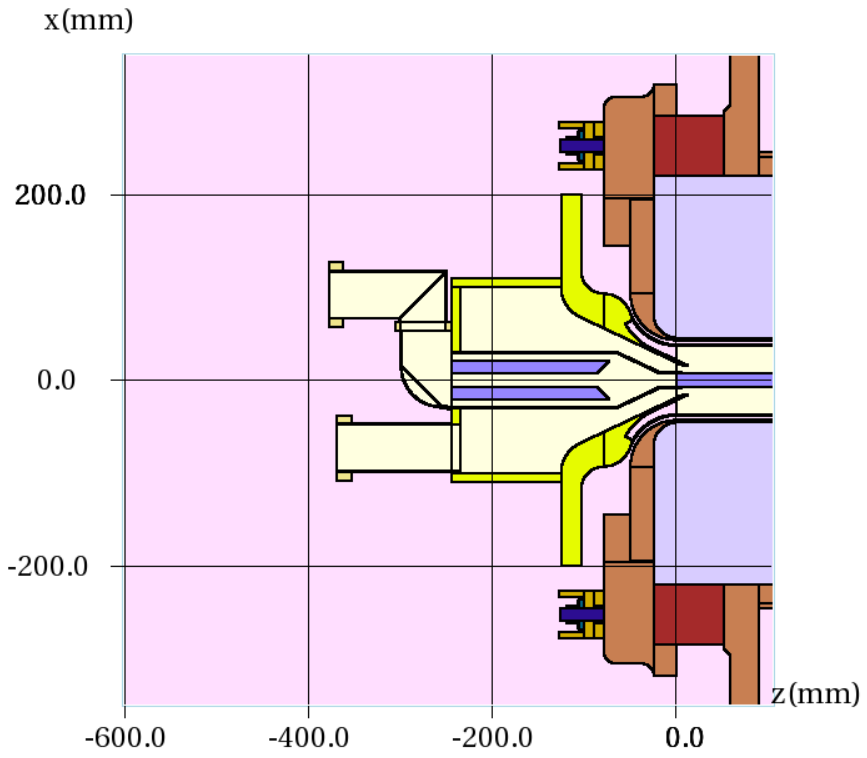
Thermocouples attached to ends of 3x3 array of beryllium rods serves as online Beam Position Monitor

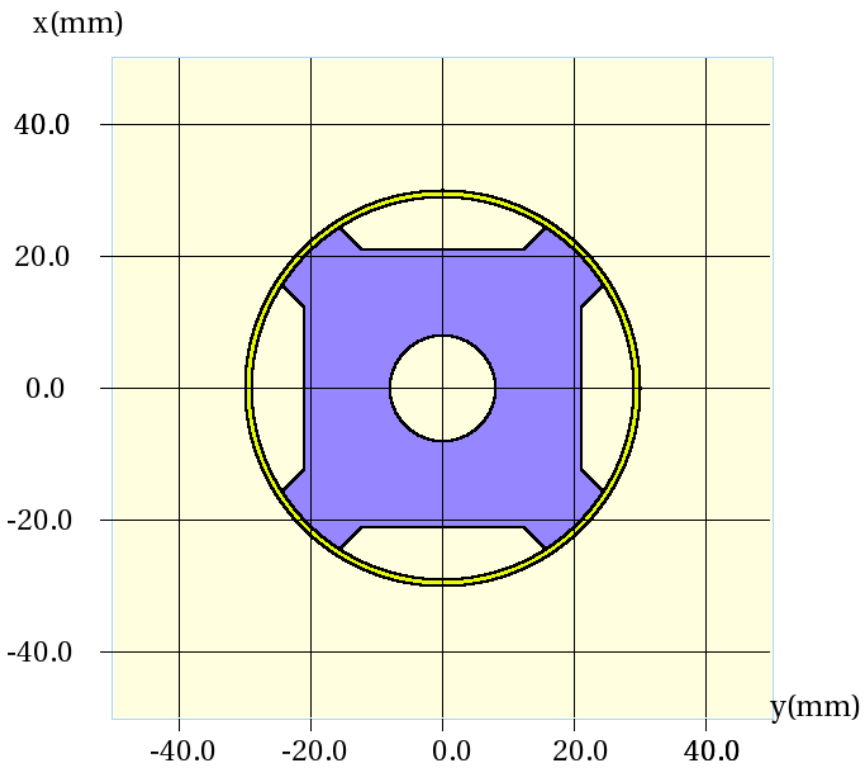


Existing NuMI design

- Provides target upstream location at full beam intensity
- Fermilab to supply physics design and Be components
- RAL to supply engineering design and other mechanical parts
- RAL to integrate with target and remote handling

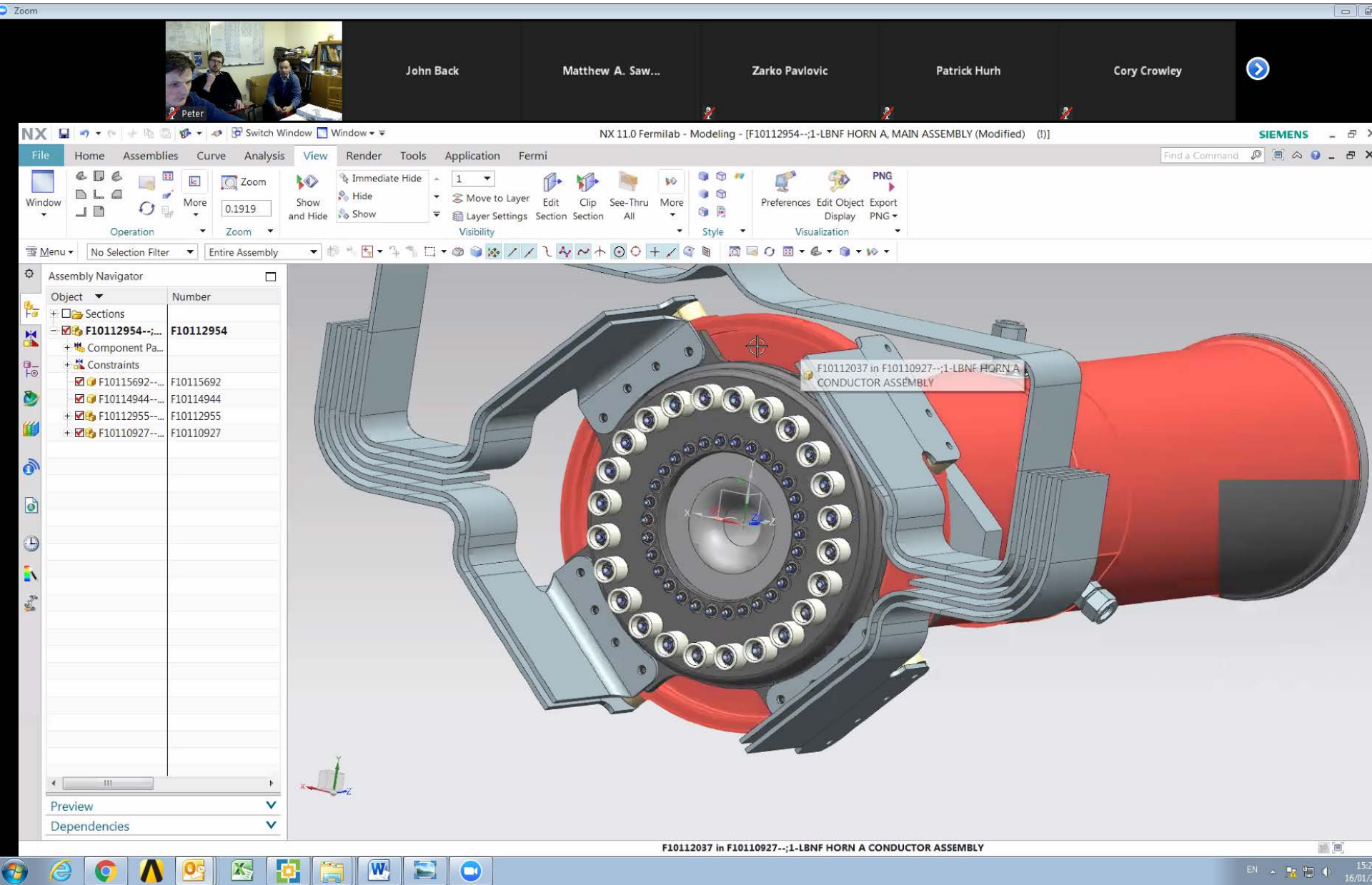
Charge Q3: Integration of target and baffletteinMARSLBNF





Impact of target on other systems (e.g. Hadron Absorber) well understood by LBNF project team at Fermilab (Reitzner, Mokhov, Striganof)

Charge Q3 (contd): Screenshot of a bi-weekly Technical Coordination Meeting on Zoom



Target system: outline work plan (charge Q2)

1. Develop preliminary design for 1.5 m long helium cooled graphite target system
   - Develop 3D CAD design informed by FLUKA, ANSYS CFX and thermal/mechanical FEA in iterative process
   - Identify realistic manufacturing and joining methods
   - Carry out critical feature prototyping
2. Generate outline specification for helium cooling circuit (with some overhead for longer target)
   - Develop helium circuit conceptual design (Fermilab have already started)
3. Preliminary design of target support, services & horn integration
4. Preliminary design of target exchanger (for up to 1.84 m long)
5. Final design for 1.5 m long target (c.2022)
6. Construct 1st full prototype ~1.5 m long target (ideally a viable backup)
7. R&D towards construction of first operational 'As Long As Realistically Achievable Cantilever Target' (c. 2026)

Charge Q1

- Onto the rest of the talks…