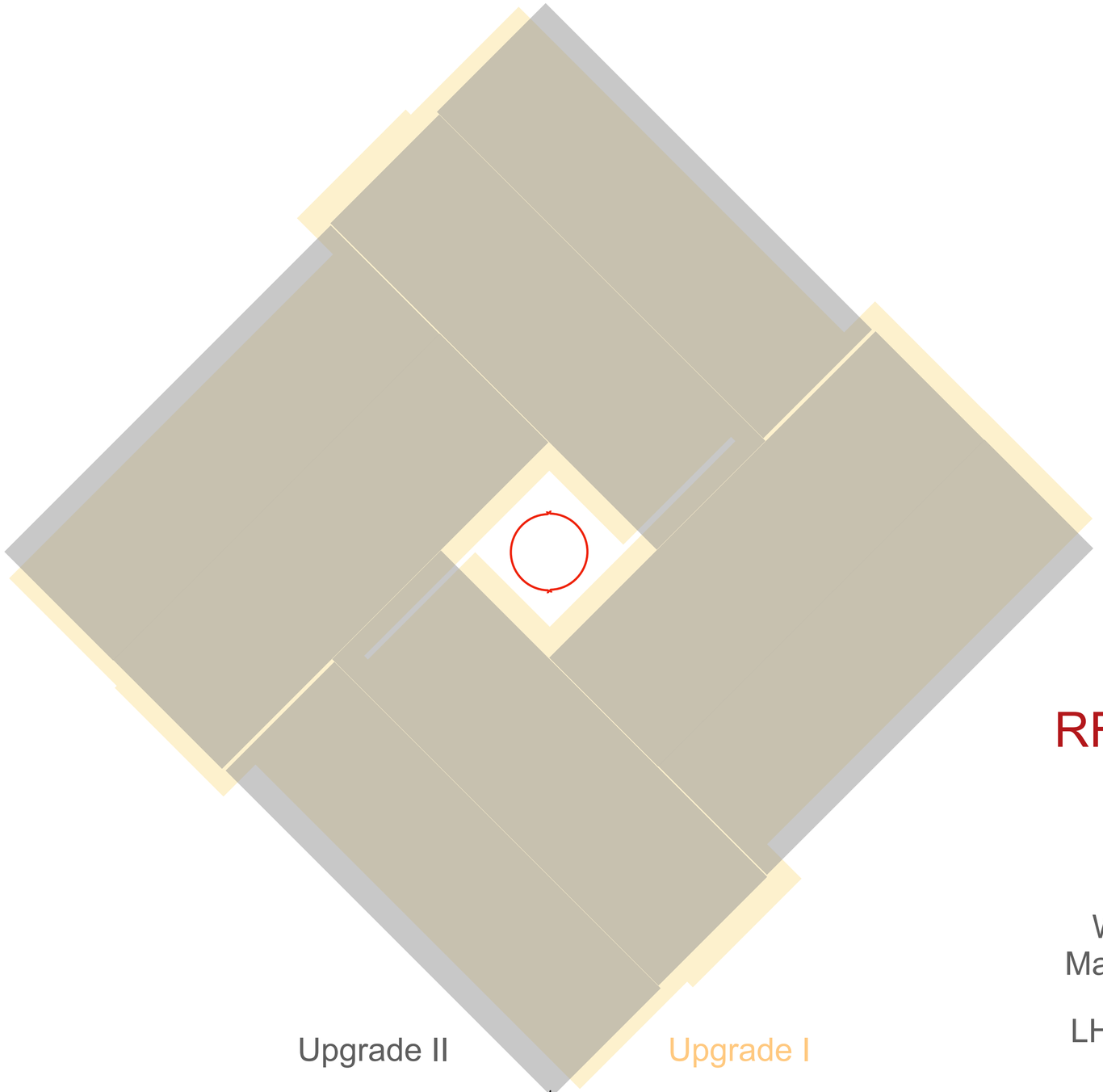

RF shield and VELO mechanics plan

Malcolm John

With input from Liverpool, Manchester, Oxford, Warwick

LHCb-UK July meeting 2024

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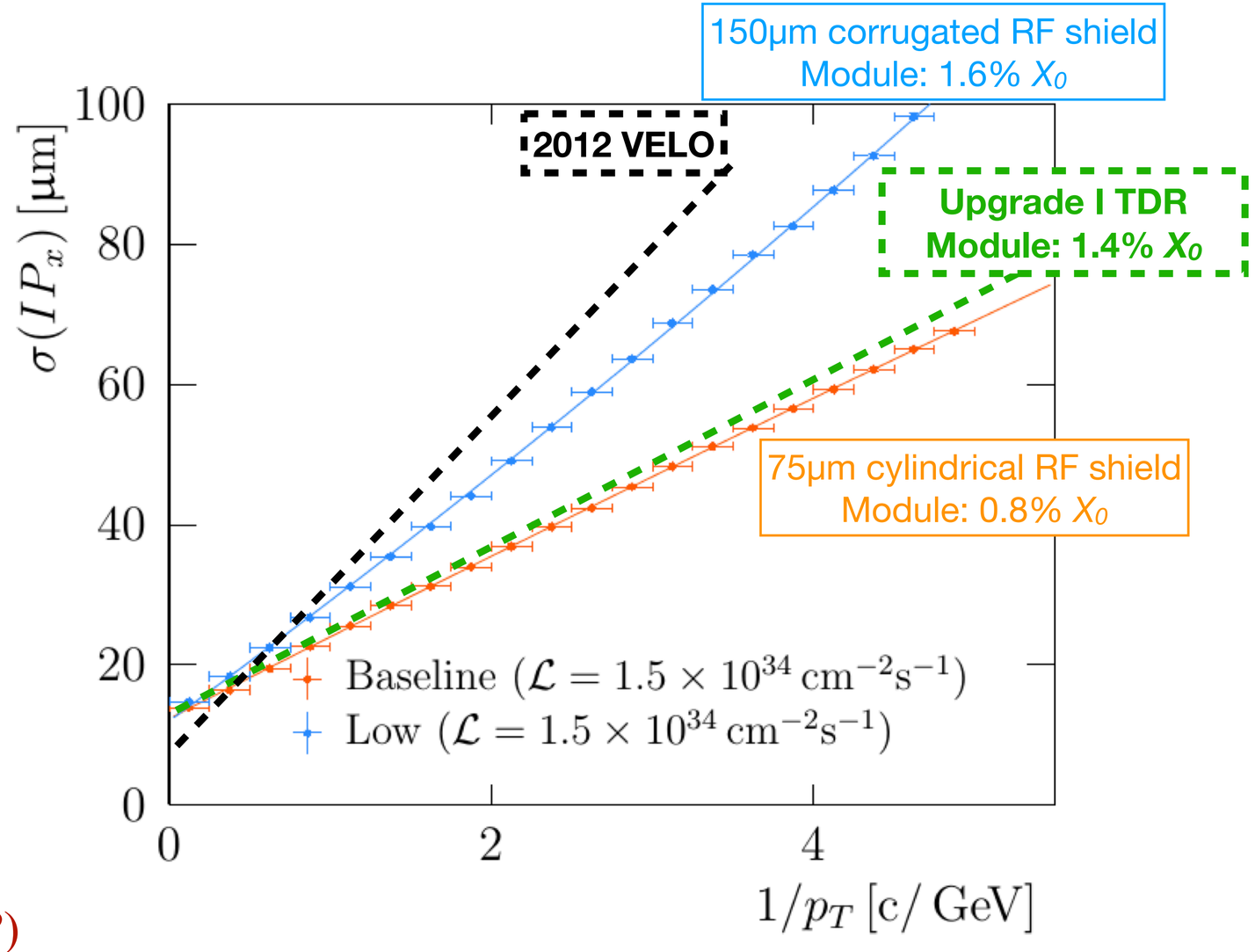
Where we are (summer 2024)

Tim Evans, Manchester

- Despite moving out (5.1mm → 7.2mm), Upgrade I performance is recovered by:
  - Even-thinner silicon detectors
  - Reducing RF-shield material
  - Substrates as thin as the micorchannel substrates of Upgrade I in the primary vacuum
- Most mechanics needs redoing so:
  - Design-in ultra-thin shield
  - Design-in module replacement
  - Challenge the silicon development to up their game (and re-lower r_{min}?)



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Everything (except the tank) must be replaced for Run 5&6

Image: Freek Sanders

Working outwards: a RF-shield reminder

- Vital to minimise material before the first measured point.
  - Scoping document baseline: 75µm [aluminium] cylinder at 3.5mm radius
- RF shield will no longer be a vacuum barrier.
  - Modules/cables/cooling can all sit in the primary vacuum (a big assumption!)
- Still need to guide the mirror charge and minimise the beam impedance
  - Need this when closed and when open
- Despite the blank page for new designed, the severe space and material constraints remain:
  - Upstream: SMOG3/LHCSpin
  - Downstream: minimal material in acceptance.

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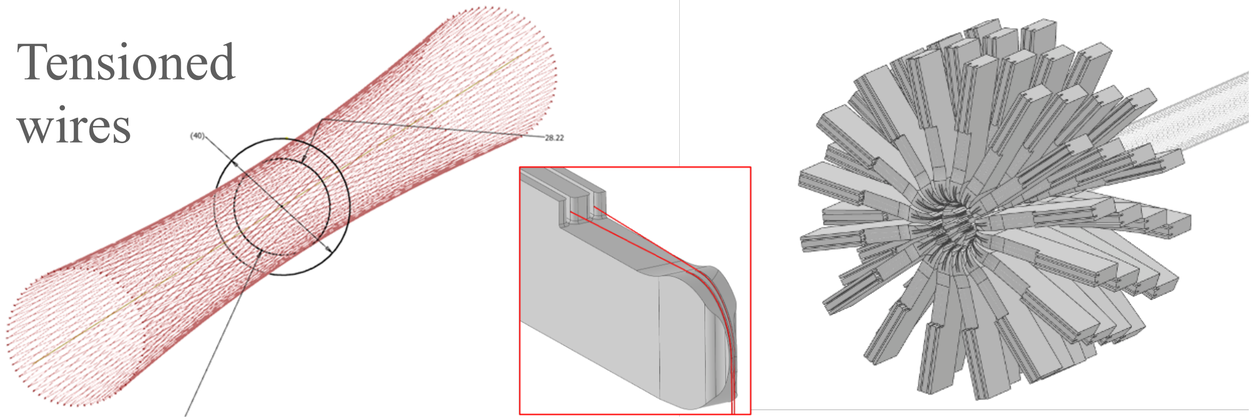
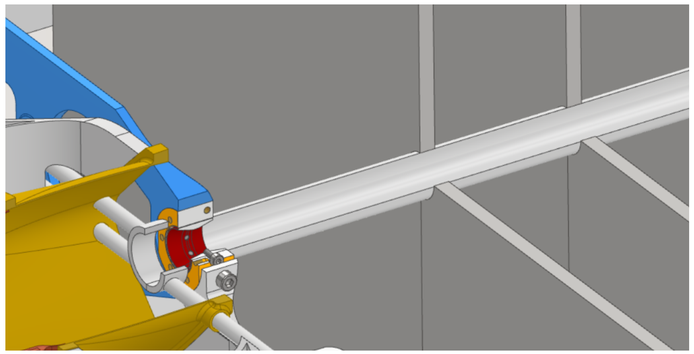
Many concepts have been explored

e.g., Mike Booth, Amsterdam Workshop, Feb 2023
Adam Lowe, TAG4, Dec 2023

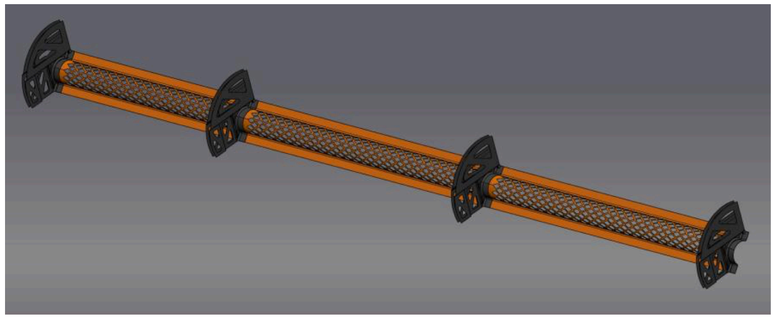
- Tensioned wires



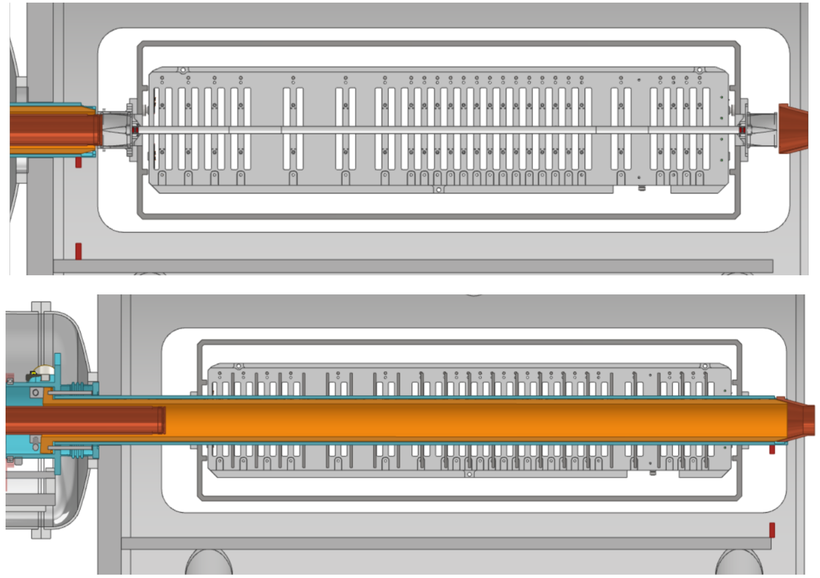
- Tensioned foil



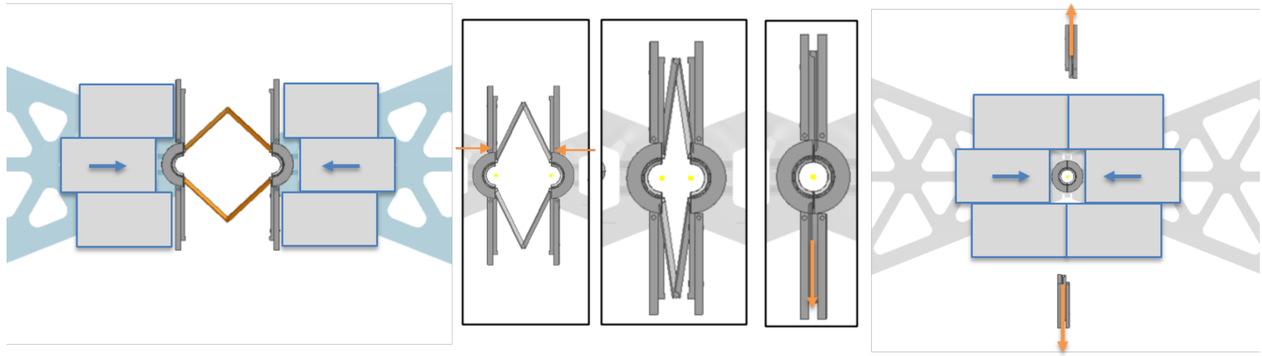
- Module-supported shield(s)



- Issues: Interventions/replacements



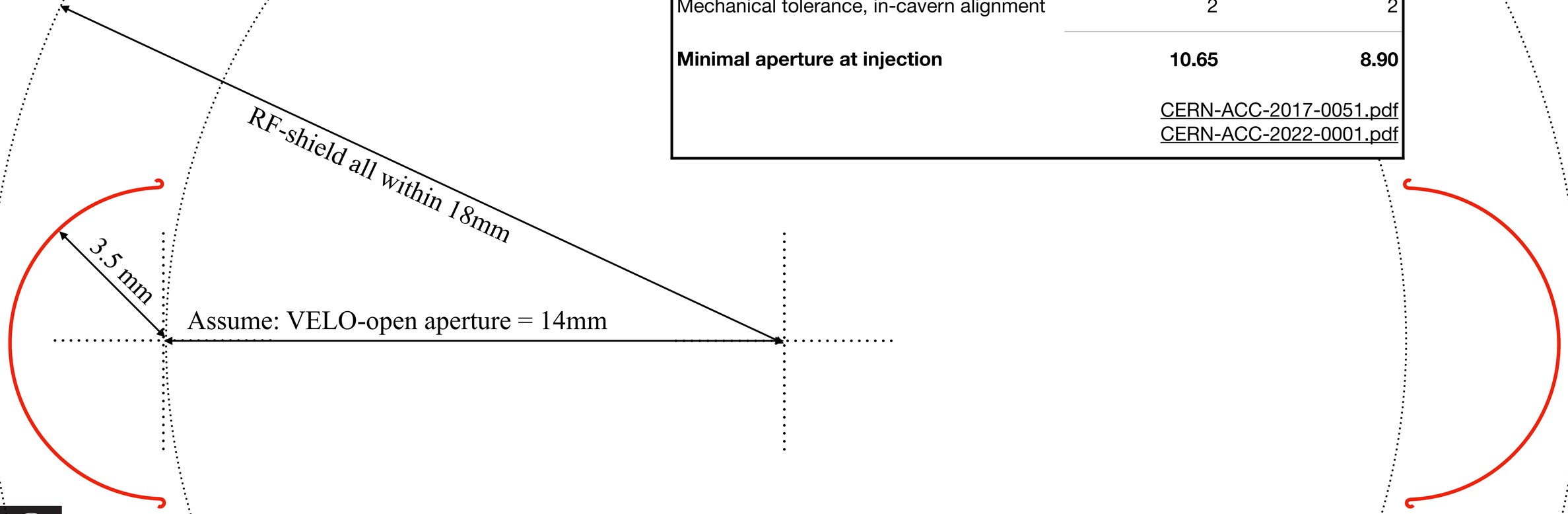
- Issues: VELO-open and closing



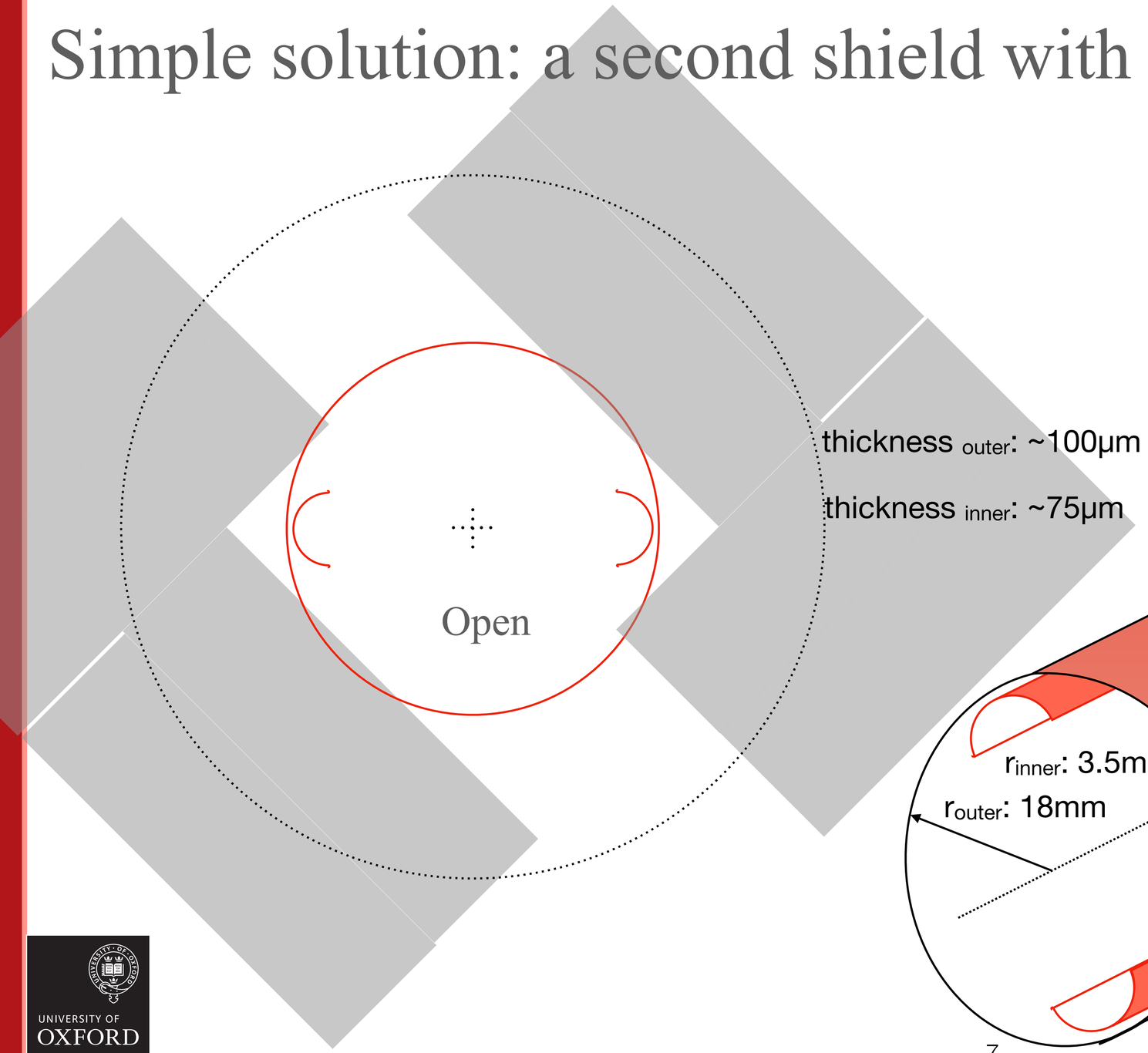
Opening a cylinder

Aperture [mm]	VERTICAL	HORIZONTAL
Beam width (12.6 sigma (IP8) x 230μm)	2.90	2.90
Orbit error (2mm)	2.00	2.00
Crossing angle at 80cm (0.32mrad vert. 2.5mrad hor.)	0.26	2.00
Displacement at injection (3.5mm vertical)	3.5	
Mechanical tolerance, in-cavern alignment	2	2
Minimal aperture at injection	**10.65**	**8.90**

CERN-ACC-2017-0051.pdf
CERN-ACC-2022-0001.pdf

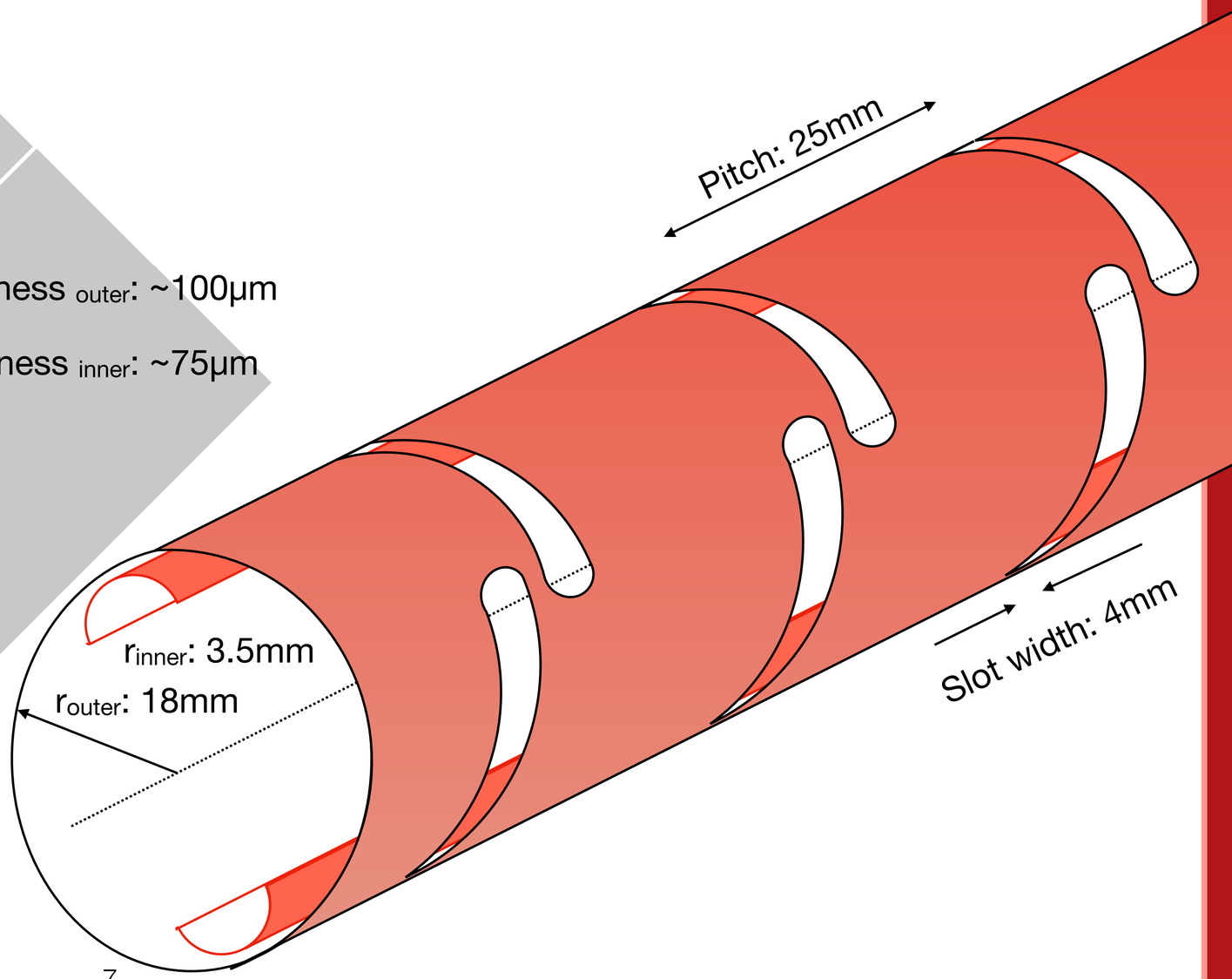


Simple solution: a second shield with slots for the silicon



thickness $_{outer}$: ~100μm

thickness $_{inner}$: ~75μm



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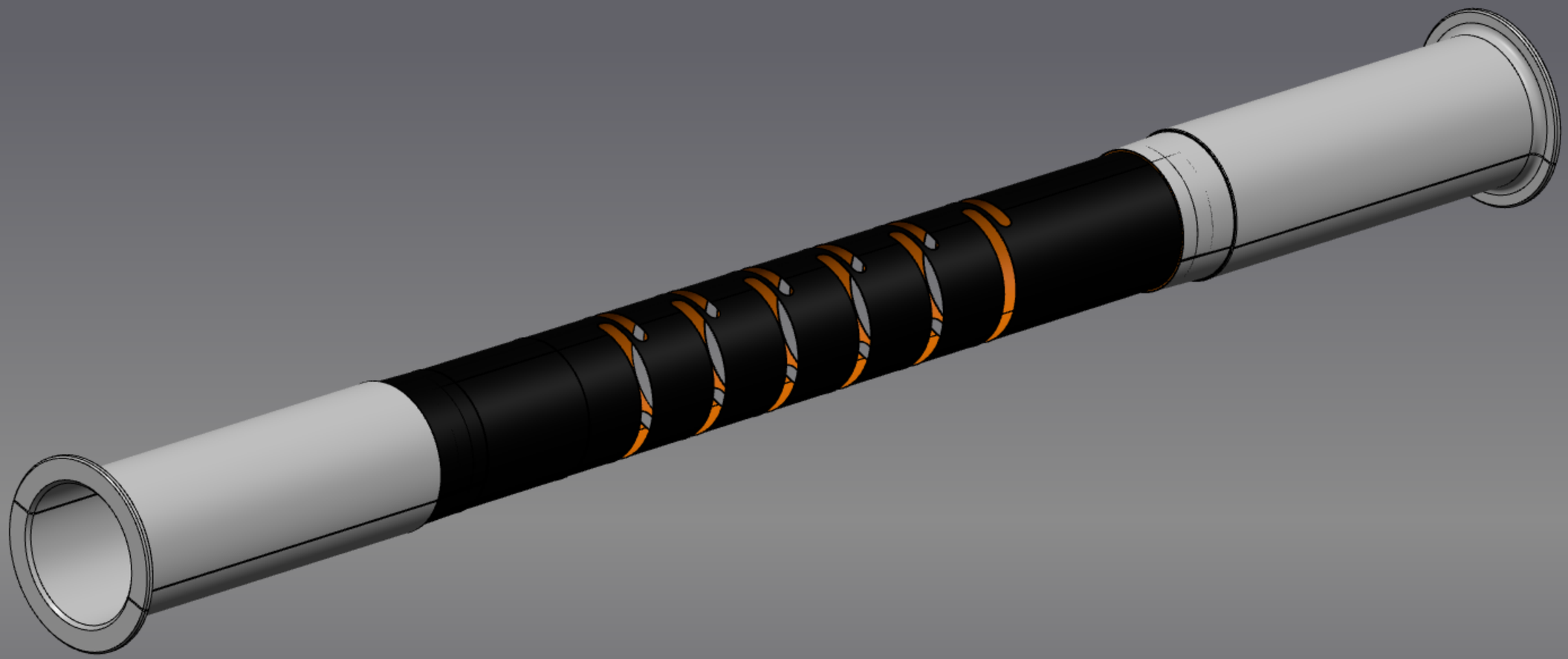
Manufacturability

Adam Lowe, Oxford

- Here: 40µm Copper, 80µm Carbon
- Eventually: 40µm Aluminium, 60µm Carbon



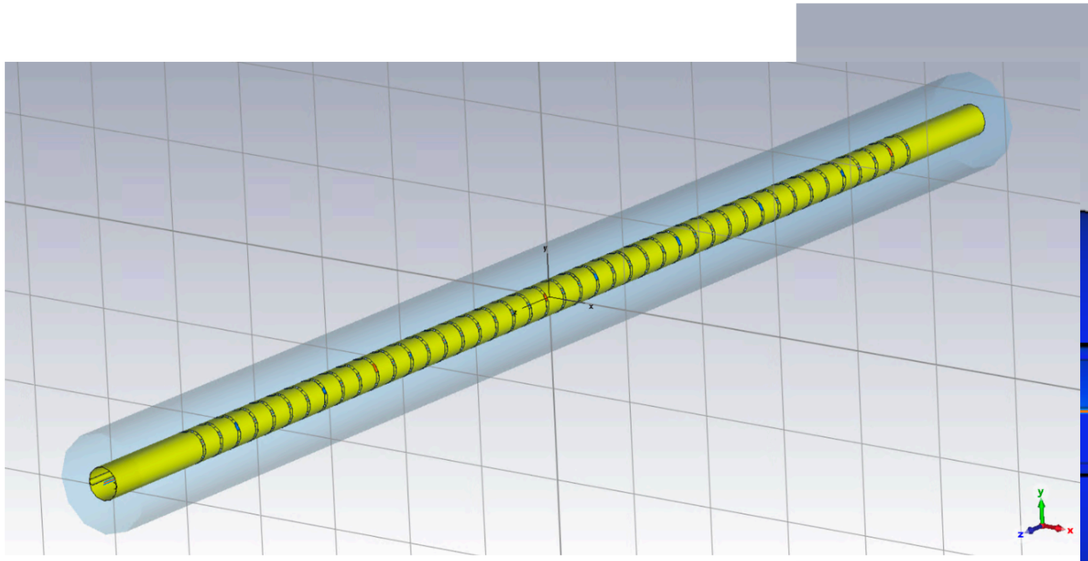
Adam Lowe, Oxford

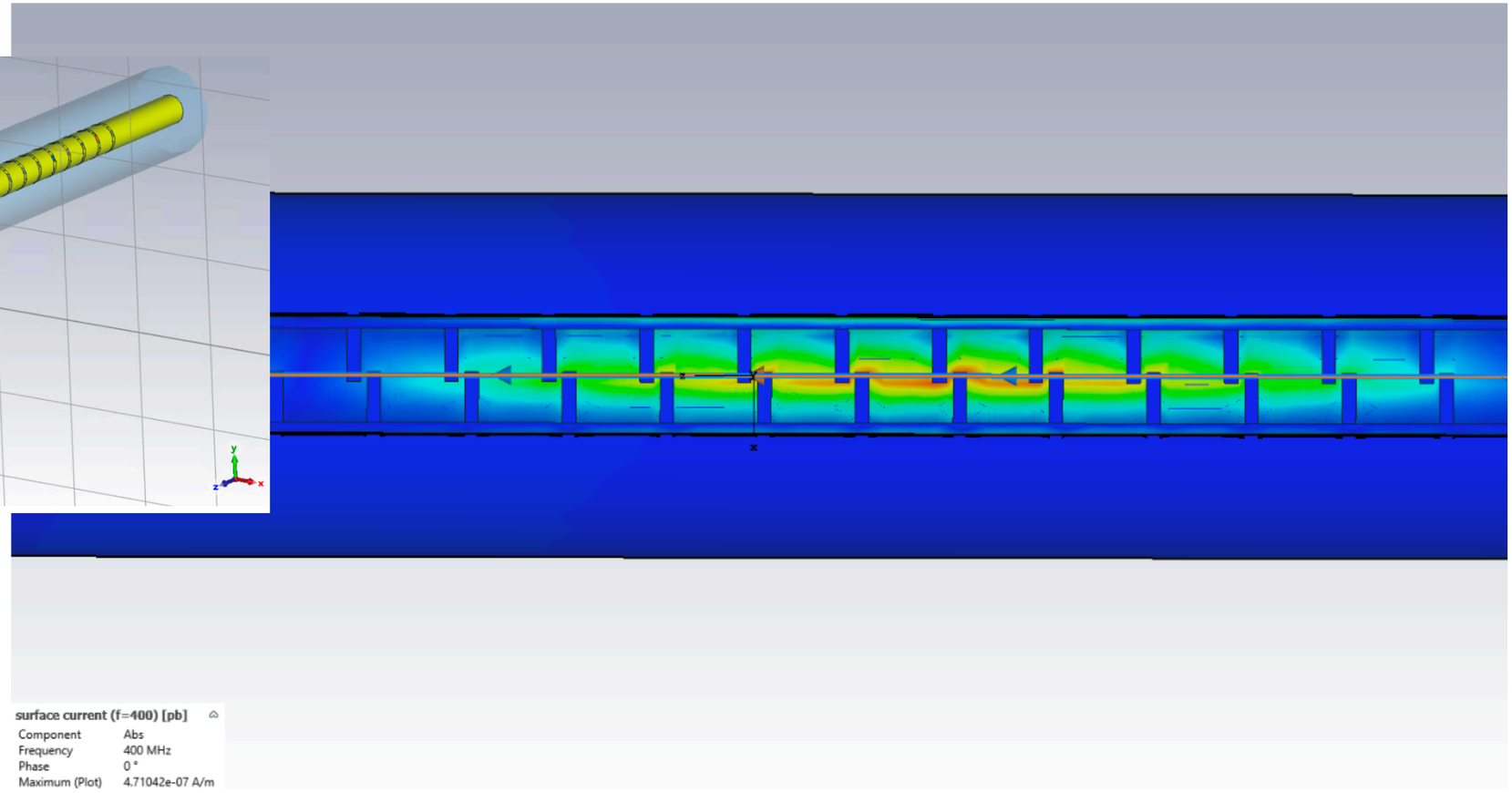
- Here: 40µm Copper, 80µm Carbon
- Eventually: 40µm Aluminium, 60µm Carbon

CST simulation

David Vico Benet, Oxford

- Critical question for slotted foil: how does the mirror charge flow? Are there hot spots?
  - Early development - quantitive results not yet trusted - but no hotspots seen

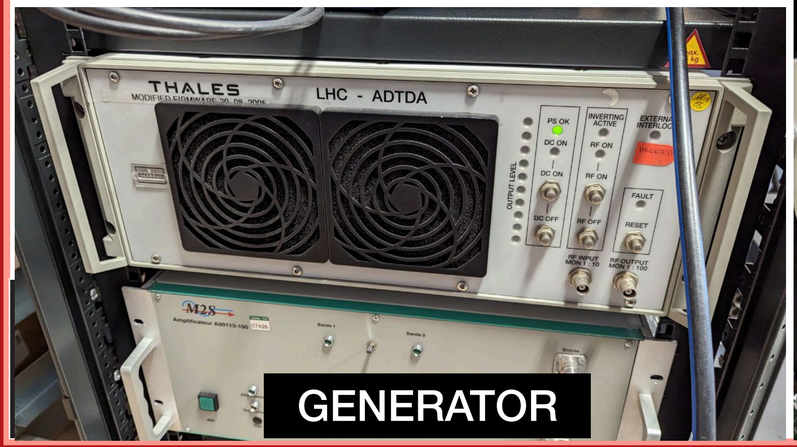


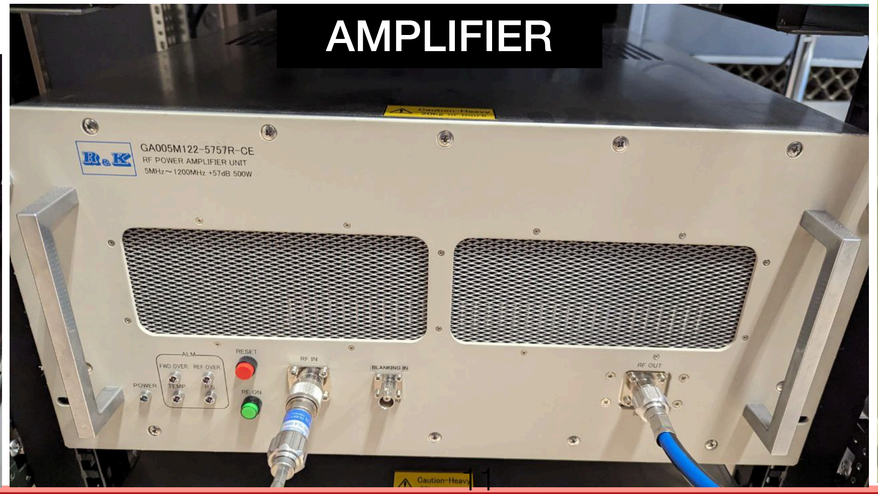


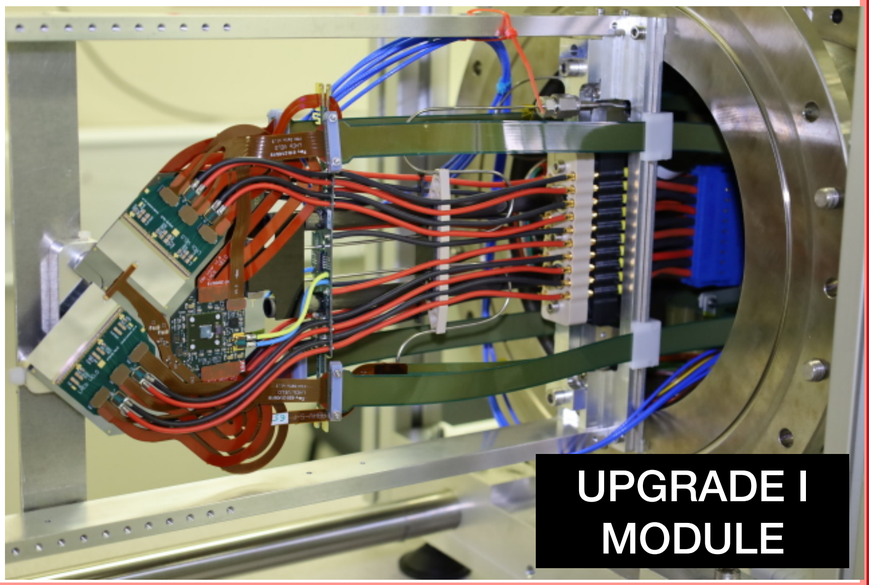
RF shielding and noise pick up

Valeriia Zhovkovska, Warwick

- Possibility to test module and RF foil prototypes in the EMC lab at CERN
  - The lab has powerful amplifiers and generators (up to 500W and 1.2GHz); possible to emulate close-to-LHC beam currents
  - Important to estimate beam impact on the detector and vice versa
- Plan for the lab:
  - Prepare setup simulation
  - Test susceptibility of VeloPix to LHC beam EMI
  - Test RF foil prototypes
- If tests in the lab are successful, proceed to the test in SPS



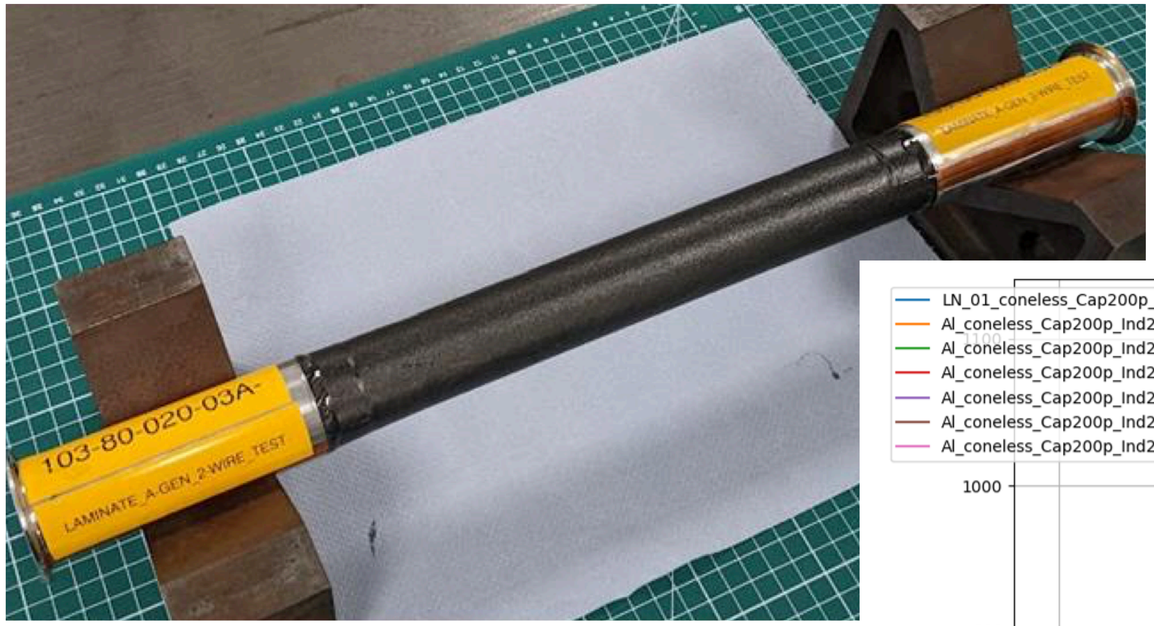


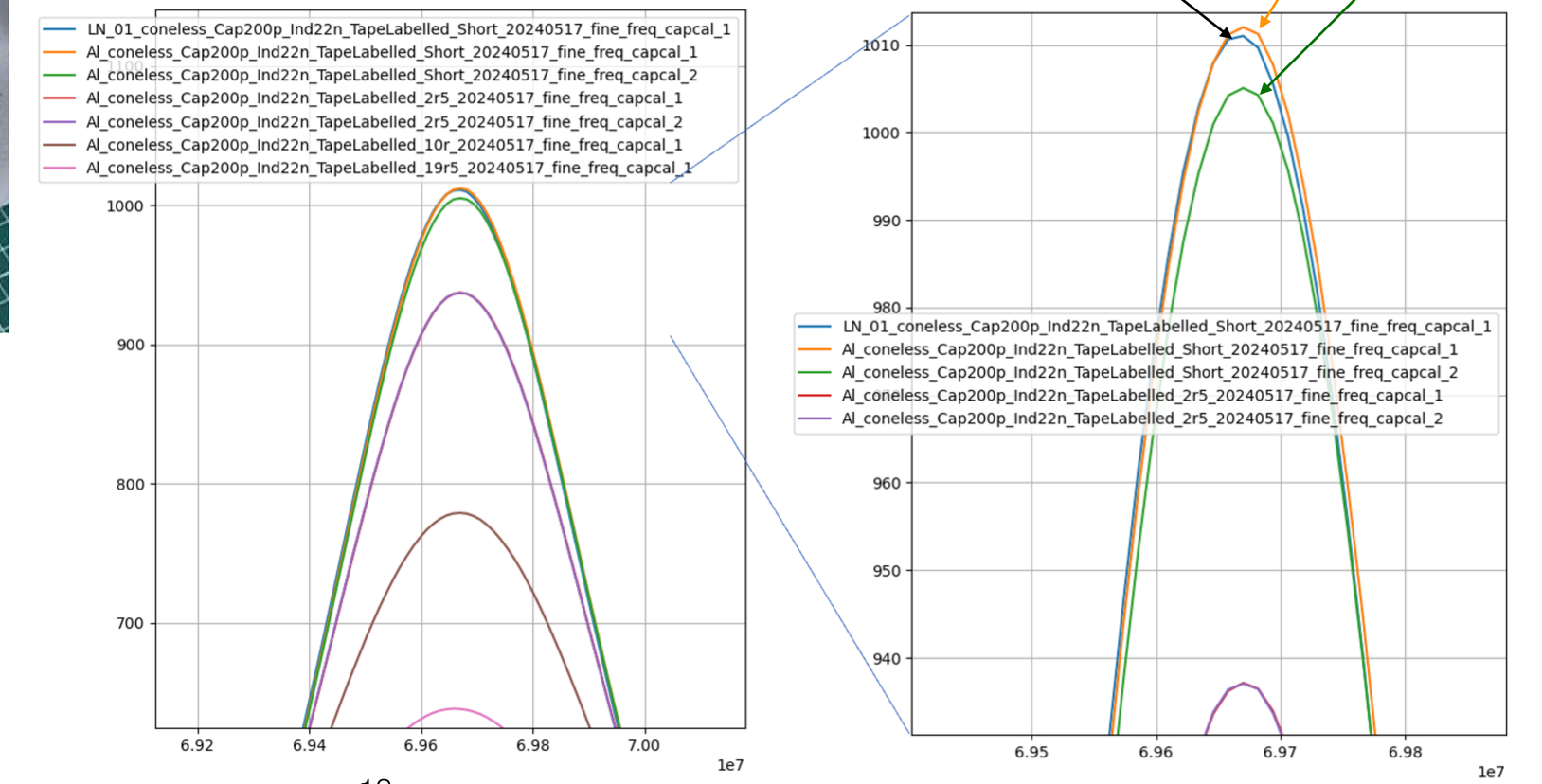


Measure relative impedance of structures

Weida Zhang, Oxford
David Vico Benet, Oxford

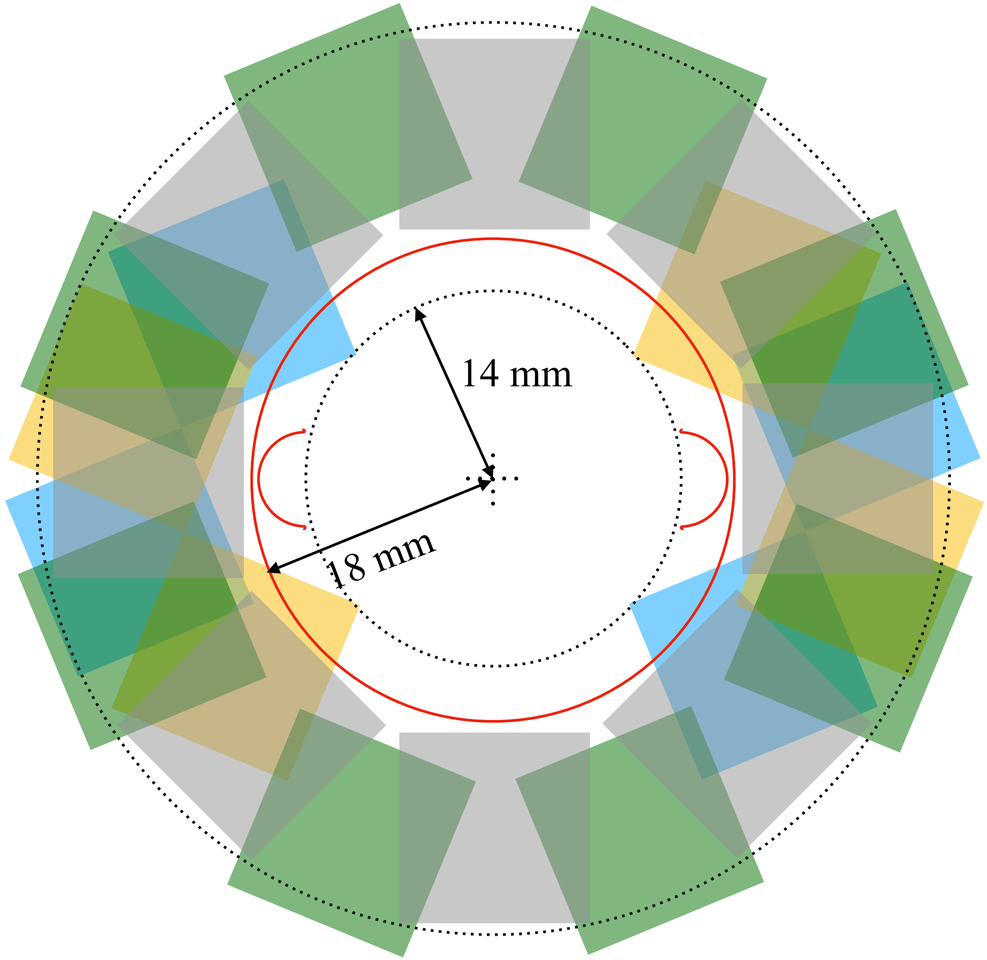
- So far measured a plain Aluminium reference tube and one uniform composite shield



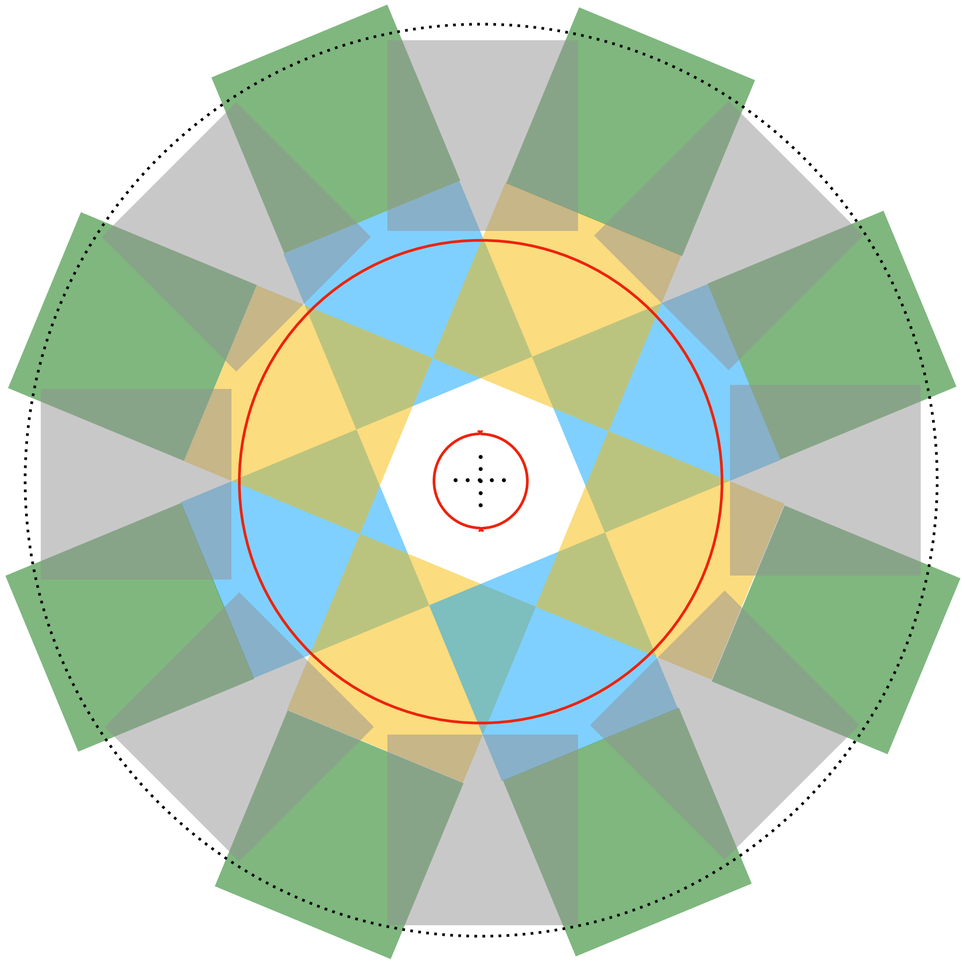


- So far so good… in that negligible difference in impedance seen
- Test slotted shield ASAP

Concentric layout provides static support of the outer ring



Outer ring is behind the outer shield.
Outer shield supported on outer ring.



Only power the outer rings until closed.
Inner shield mounted on, and moves with, inner halves

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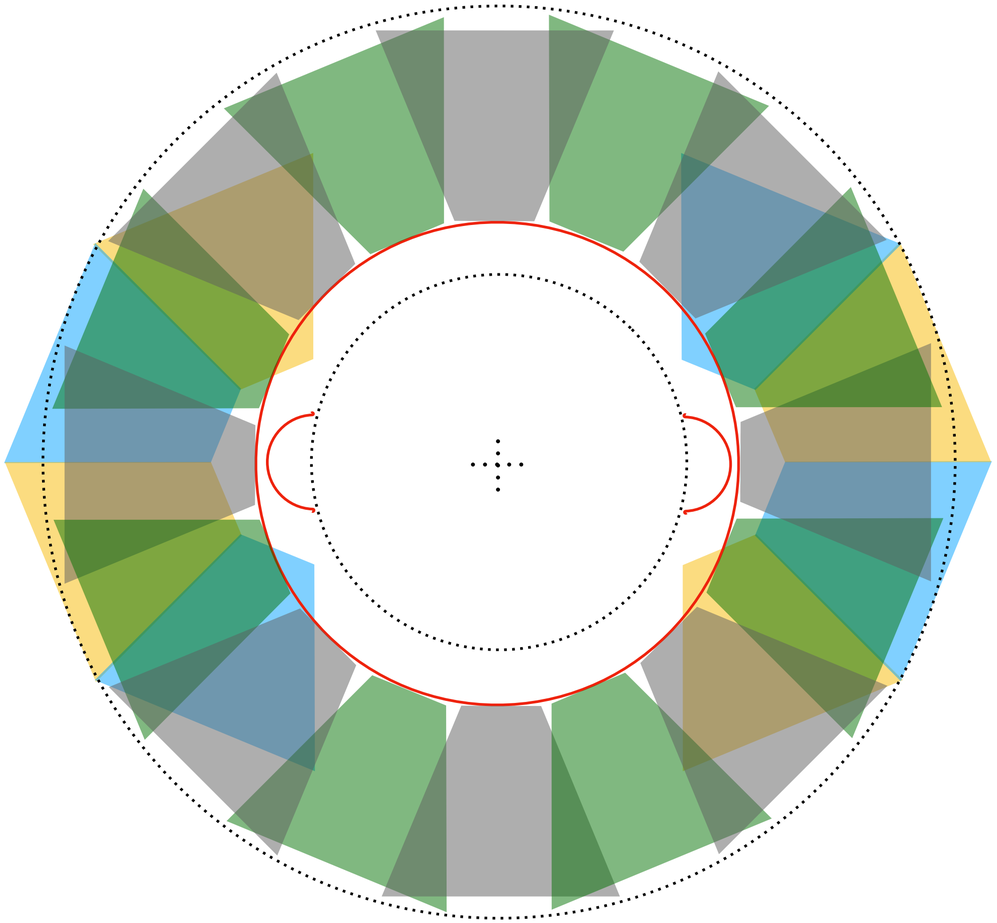
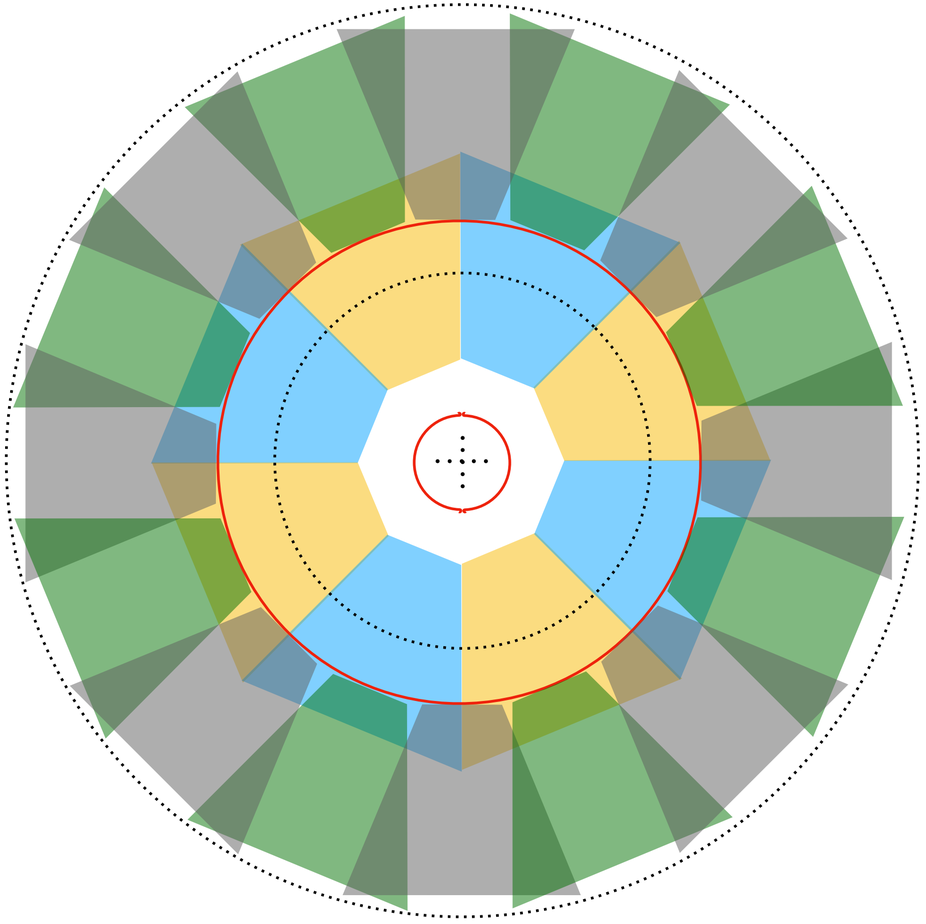
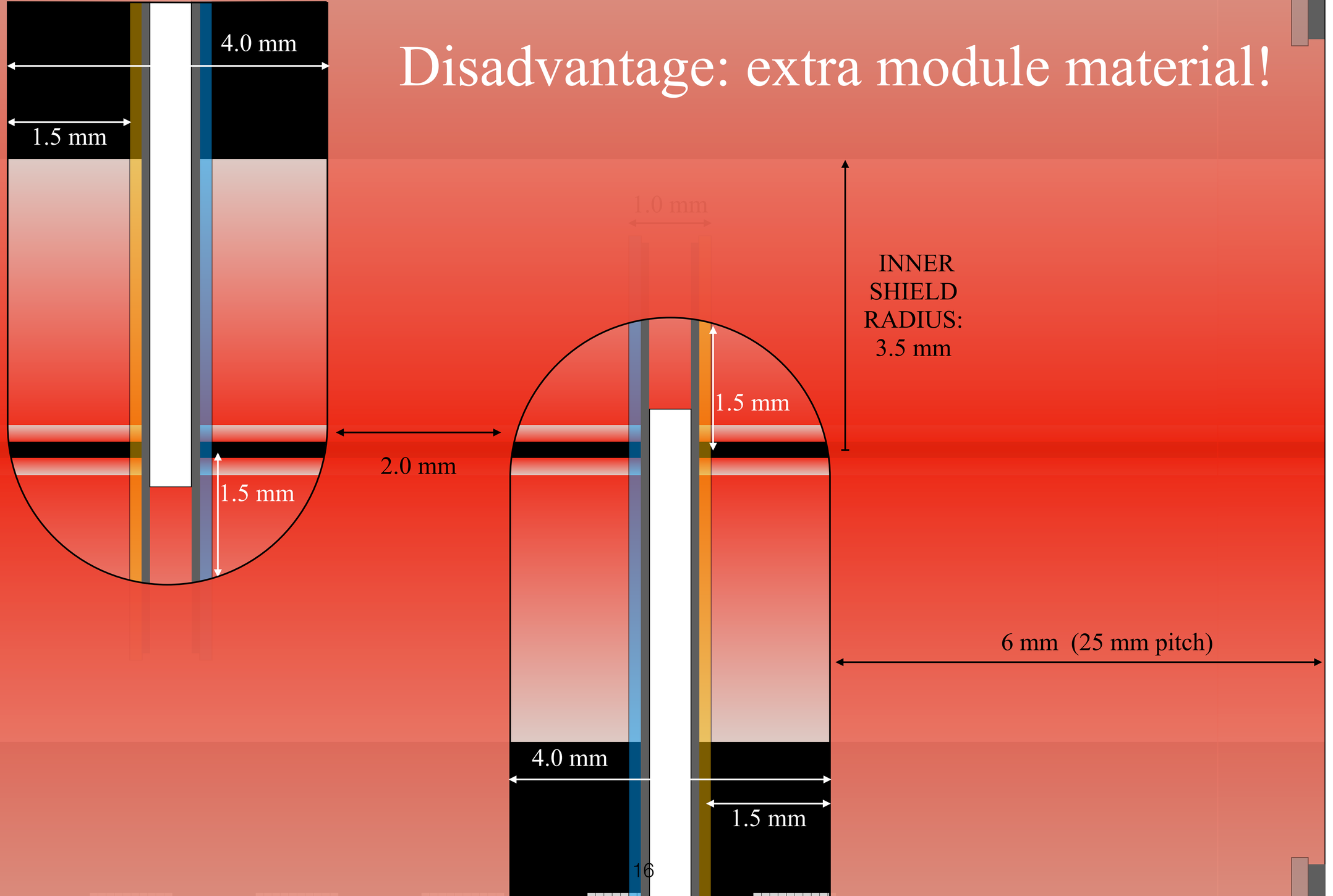
Geometrically advantageous to imaging a trapezium chip





- Very speculative - chip designers need to be willing.

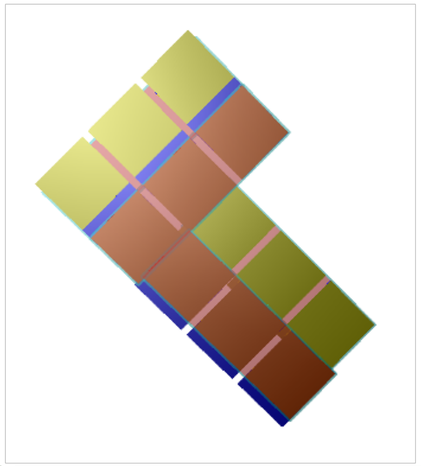
Disadvantage: extra module material!



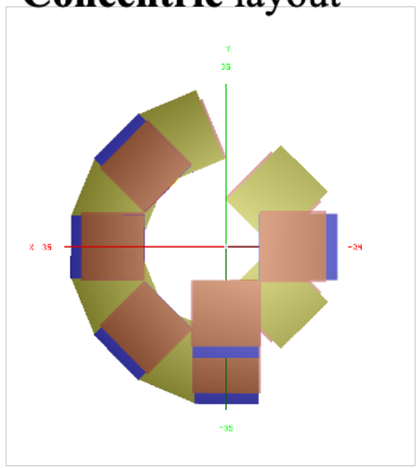
LHCb simulation development of proposals

Guanyue Wan, Warwick
Tom Latham, Warwick

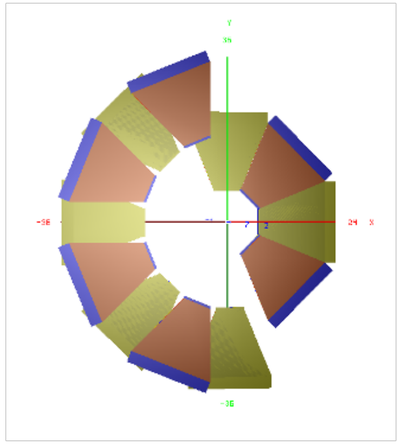
Baseline design



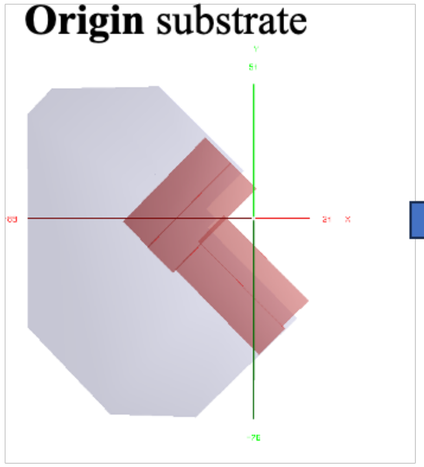
Concentric layout



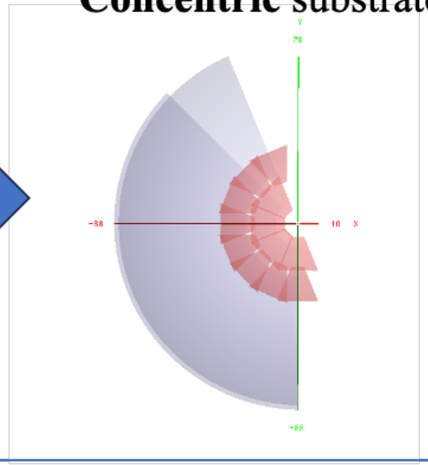
Trapezoid sensor & chips



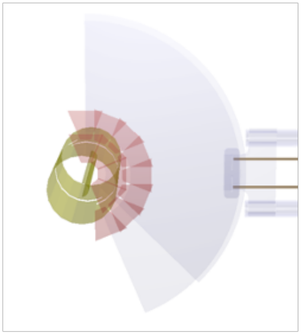
Origin substrate

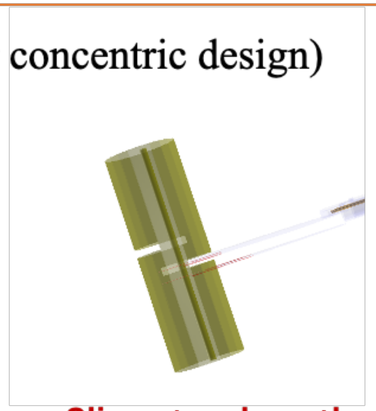


Concentric substrate



Outer pipe (for concentric design)





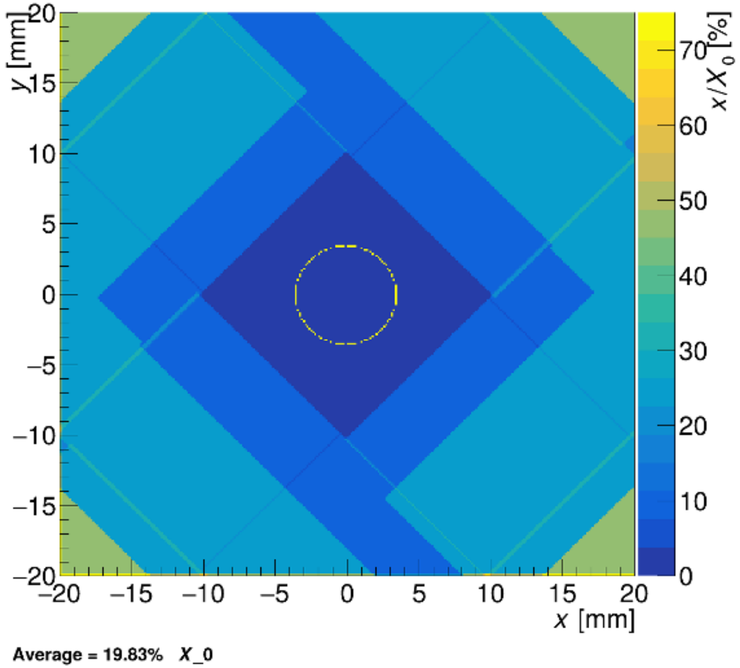
Slices to place the inner modules

LHCb simulation development of proposals

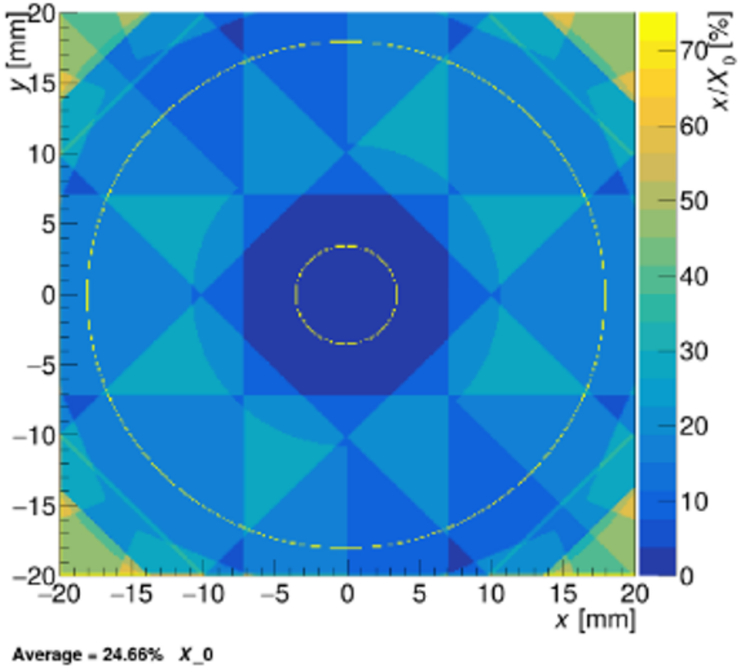
Guanyue Wan, Warwick
Tom Latham, Warwick

- Material scans (for “longitudinal” tracks)
  - Substrate shape/design not optimised at all!

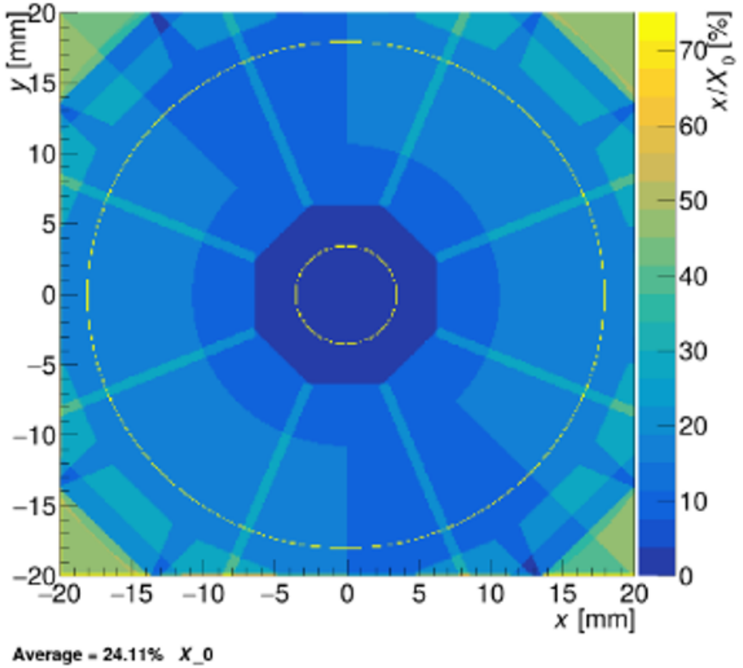
Baseline design



Concentric layout, square sensors



Concentric layout, trapezoid sensors

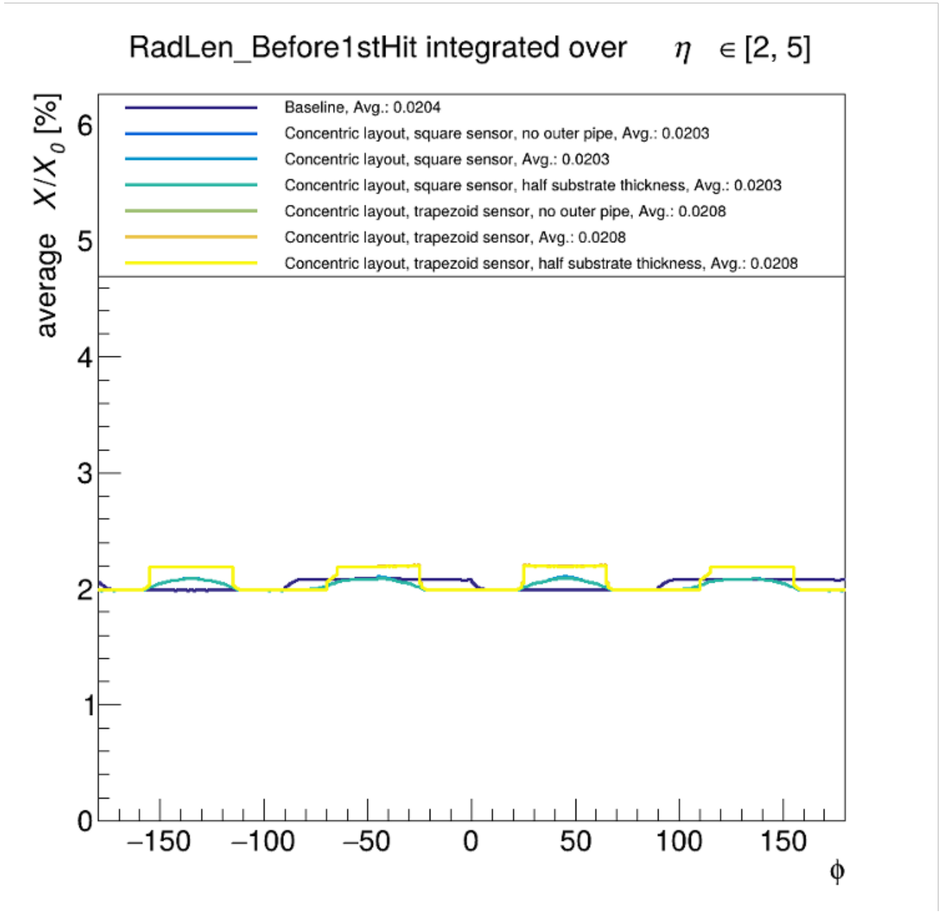


LHCb simulation development of proposals

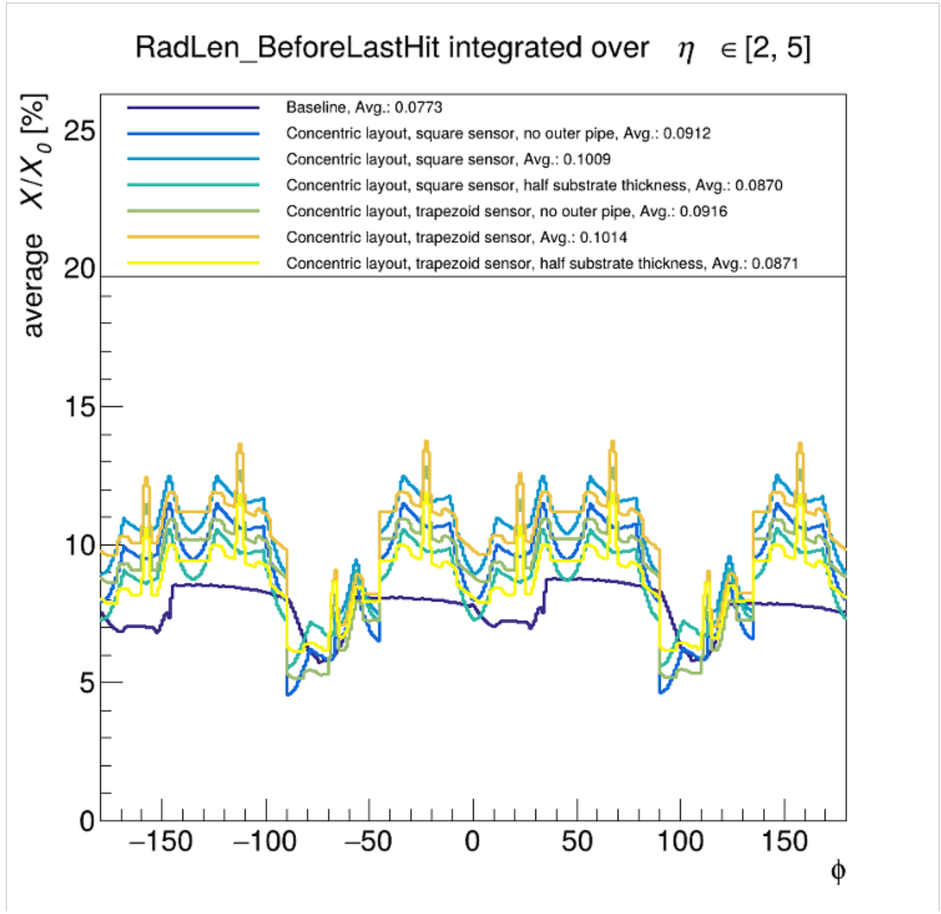
Guanyue Wan, Warwick
Tom Latham, Warwick

- Material scans (for tracks emanating from *pp* collisions)
  - Uniformity in azimuthal angle

Radiation length before 1st hit



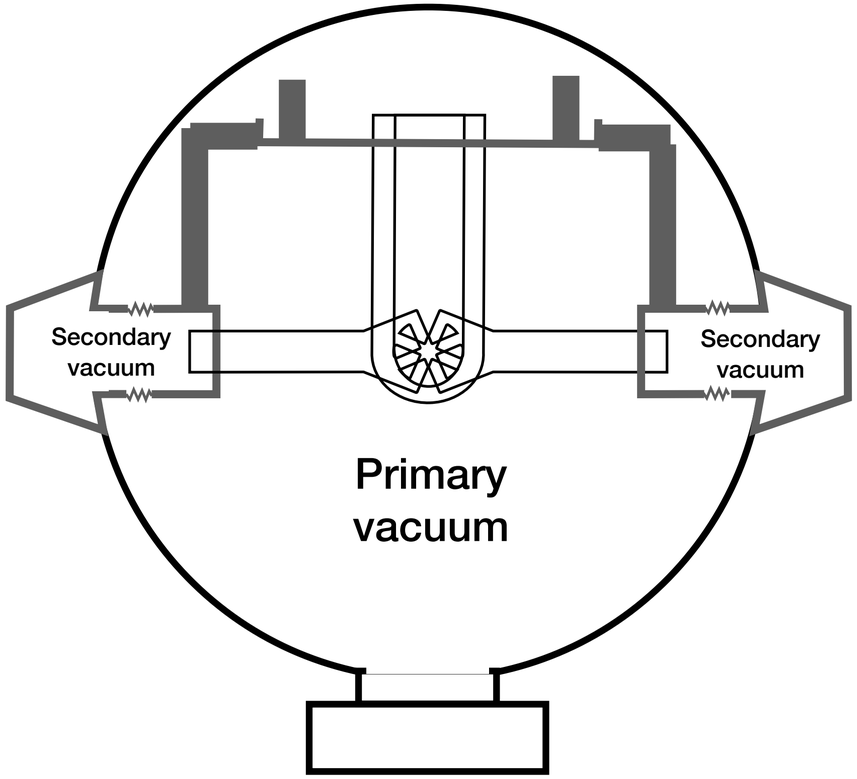
Radiation length before last hit

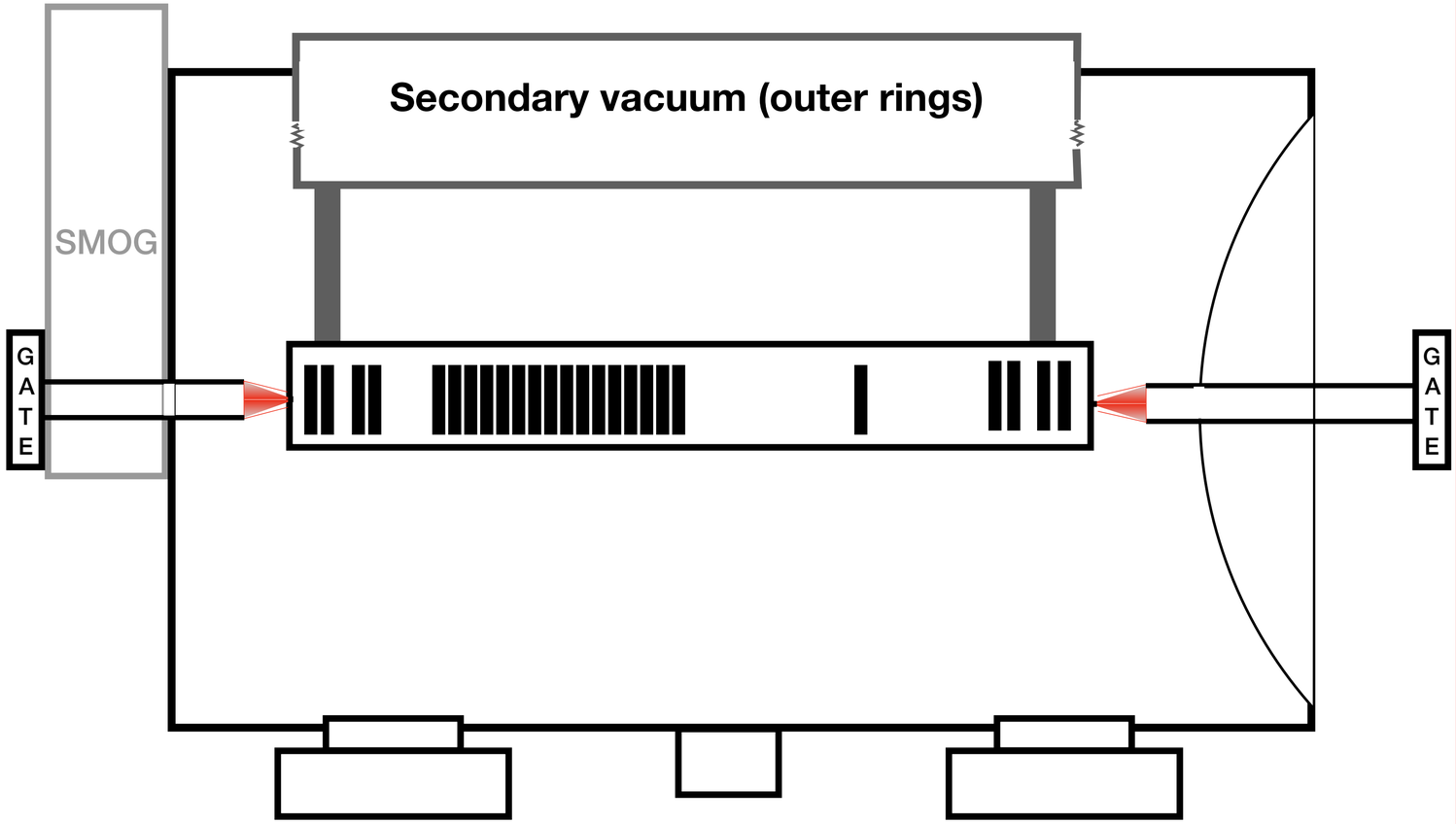


Interplay with module replacement

Kieran Bridges, Liverpool

- Inner modules of a concentric design are smaller, and physically independent of outer modules
- Inner modules receive largest dose



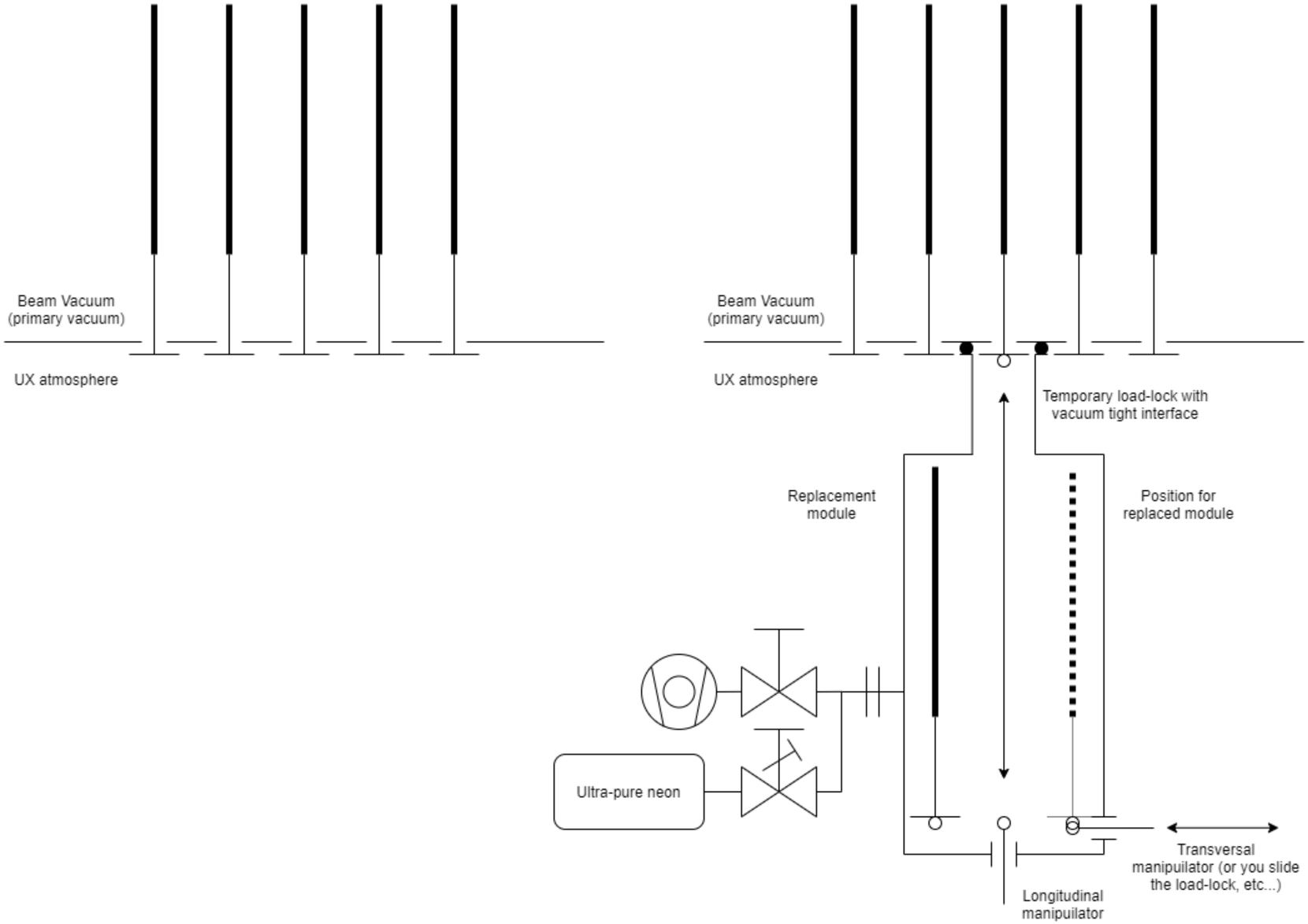


Slotted base is a PV/SV interface. Slots receive inner modules where all services run though the foot.

Module replacement

Kieran Bridges, Liverpool
diagram below: Josef Sestak, CERN

- Slotted base is simple and attractive and has some buy-in from CERN.
  - Detailed development now needed



Plans for the preconstruction project

- Formal deliverable
  - WP2.3-D2 — TDR-ready proposal of VELO4D RF-shield and mechanics
  - TDR preparation: assume summer/autumn 2026
  - However, we need to solidify and cost the UK's construction bid by late spring 2025
- Wish-list of milestones for 2025/2026
  - Demonstrate RF impedance and RF shielding of corrugated and [slotted] cylindrical designs
  - Manufacture full size prototypes of each, refining techniques (e.g. cutting) and materials
  - Be "close-to" achieving CERN sign-off of SEY and vacuum compatibility
  - Have a full design of the module replacement concept
    - Master design necessary too but maybe not a UK job
  - Extensive CST and FEA simulations
  - Detailed study of physics metrics
    - Notably module substrate optimisation for concentric ideas
- And for spring 2025
  - Design work needs to be advanced enough to cost the UK contribution to VELO mechanics

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