MT Software: From scoping to the TDR (and beyond)

Matthew Needham

Introduction

- Try to give you status and sketch the route to the TDR and beyond for the MT software

- Many slides shown last week in Liverpool MT workshop

- Work of Lucia Grillo, Scott Ely, with Tai-Hua Lin, Donata Osthues, Gary Robertson, Manuel Schiller

"The concept of progress acts as a protective mechanism to shield us from the terrors of the future."

TDR timeline

- Scoping document to be submitted September 2024, approval April 2025?

- (Provisionally) Tracking system TDR submitted to LHCC in Autumn 2026 ?, Approval Spring 2027

Overall plan for Mighty Tracker
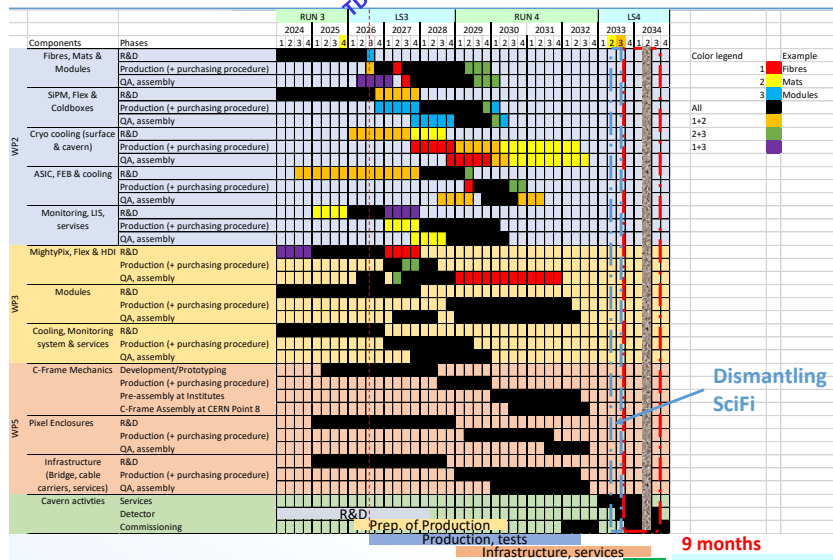
- R&D
  - Proof-of-concept
  - Engineering prototypes
  - ...
- Prep of Prod. & Prototyping
  - Procurement time
- Production, Assembly & Test
  - Production centres:
    - Lab. capacities
    - Resources
    - Sharing
- Infrastructure, Services
- Installation

The constraints
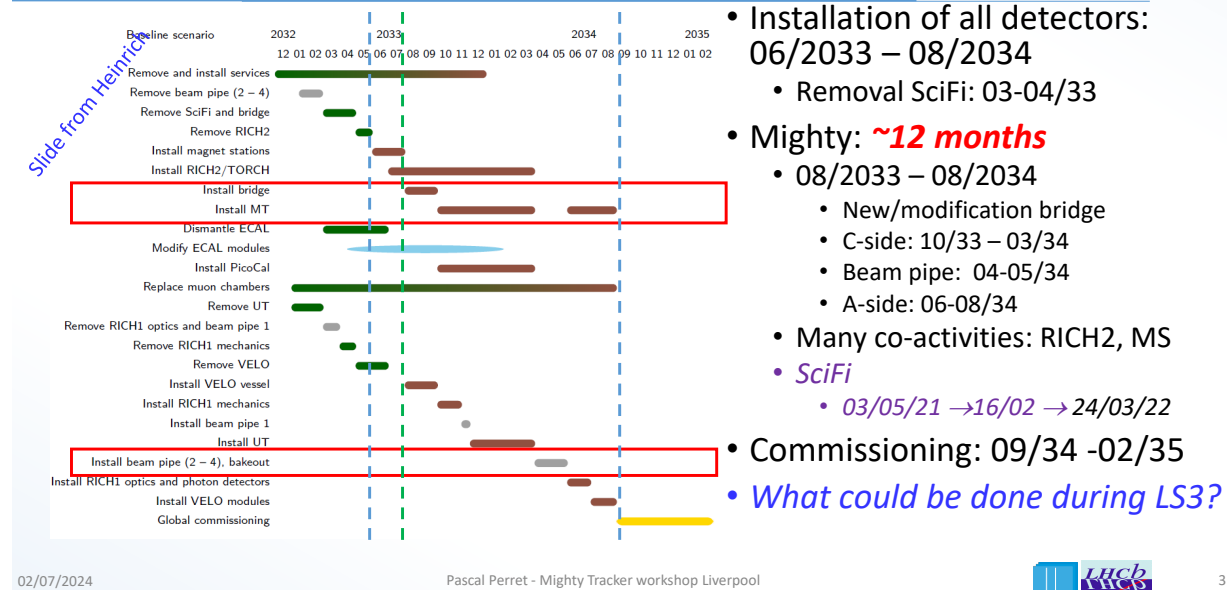
- Installation of all detectors: 06/2033 – 08/2034
  - Removal SciFi: 03-04/33
- Mighty: *~12 months*
  - 08/2033 – 08/2034
    - New/modification bridge
    - C-side: 10/33 – 03/34
    - Beam pipe: 04-05/34
    - A-side: 06-08/34
  - Many co-activities: RICH2, MS
  - *SciFi*
    - *03/05/21 →16/02 → 24/03/22*
- Commissioning: 09/34 -02/35
- *What could be done during LS3?*

"plans are useless, but planning is indispensable"

What do we want in 2034?

- A detector that gives good physics from Day 7 of beam, within 100 days?
  - A bigger challenge than Upgrade I/original LHCb – limited commissioning time, HV-CMOS technology a lot more complicated the strips, need intellectual innovation/investment in reconstruction (e.g. incorporating timing into Kalman fit, exploiting all the new info we have), and port our understanding to run real-time on a "GPU"

- This can only be achieved with well understood and ready software
  - Iron out the bugs
  - Software should support the commissioning
  - Tools to calibrate the detector
  - A detector that we know is easy to align
  - Clear interfaces with tracking/RTA

"It is impossible to live in the past, difficult to live in the present and a waste to live in the future"

(Some) Questions we need to address

- Does the detector fit within the z envelope ?
  - Not just a mechanical question, physics/reconstruction should also drive layer layout
- Why 6 layers not 5 ?
  - Answering this needs detailed module geometry (dead areas) + realistic digitization
- What is the material budget of the detector ?
  - This will determine the mass resolution and performance for electrons
  - If it is too high mitigations (e.g. lighter foam/cooling) need to be considered
- Can we align the detector ?
  - Experience from IT/OT times - split inhomogeneous system will be much harder to align than SciFi alone
  - Layers are close together – limited lines of sight when closed
  - Build in alignability: overlaps, define production tolerances, BCAM?, understanding how to survey

Simulation strategy

Lucia Grillo, Matt Needham

4th Mighty Tracker workshop

2nd July 2024

▸ Not only geometry and material for full simulation samples

  ▸ Detector geometry and material description for full simulation

  ▸ Digitisation for fibre and pixel (pixel more relevant towards TDR and beyond)

  ▸ Track reconstruction and Performance studies (using full simulation or shortcuts)

▸ Constraints for full simulation samples production:

  ▸ Multiple software projects involved - difficult to draw up a timeline without accounting for the status of projects involved & undesirable to stick to private versions

  ▸ Progress on other software projects (Gauss, LHCb, Detector) and detector projects (TV, UP) steered by Scoping document plans:

    ▸ A roughly correct description of MT was needed yesterday to give the people studying the reconstruction something to work with - approximations made, positions/dimensions as we knew at the time etc

    ▸ More accurate descriptions being worked on in parallel, for next round of full simulation samples production, and towards the TDRs

    ▸ Updates can and will be done periodically, but do not expect a change in design will necessarily end up in a Detector MR the day after

- Not only geometry and material for full simulation samples
    - Detector geometry and material description for full simulation
    - Digitisation for fibre and pixel (pixel more relevant towards TDR and beyond)
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end of January

Technical test of Gauss-on-Gaussino on grid

Submitted 21st Feb

early March

Production campaign for Scoping document with default full detector

Delayed - by end of April?

Production campaign for Baseline Scoping scenario tracking system by mid July?

Medium and low 1-2 weeks later?

Dec '23 first U2 samples

M. Whitehead U2 workshop

Directly after Easter

Production campaign for Scoping document with default tracking detectors

early February

Production campaign for Scoping document with alternative detector layouts

**April**

New production campaign with updates End of summer?

Upcoming MC samples for Scoping document (short timescale)

▸ Baseline geometry of the Scoping document: reduced MP area wrt FTDR   DetectorMR!556

▸ Update (with March estimates) on **material budget for the silicon**   DetectorMR!463

    ▸ Cooling ? Operation temperature of the pixels? ($-10°$ chip temperature? K. Padeken MightyPix rad damage)

    ▸ Services (power, and optical fibres) - depending a lot on off-chip electronics design choices, support structure

Ta-Hua Lin 12.03.24

	Thickness	Layers	X0	X/X0	Filling factor	With Scifi	Density	Mass	Mass fraction
Silicon	200	1	9.37	0.213	1				
Cooling tube	50	2	28.6	0.004	0.12		1.43	0.002	0.003
Carbon form	4200	1	185.65	0.226	1		0.23	0.097	0.142
Carbon fibre	300	2	23.70	0.253	1		2.2	0.132	0.194
Flex tape	340	1		0.356	1		1.71	0.058	0.085
Glue	120	1	35.49	0.034	1		1.17	0.014	0.021
Armacell	18800	2	801.27	0.469	1	20.238	0.08	0.301	0.442
PCB	1570	1	17.0	0.185	0.2	6.746	2.44	0.077	0.113
SUM	44730			1.74			0.152	0.681	1

    ▸ Update last T-station position to fit the envelope (and add material on last MP layer)

▸ Scifi "cut-out", leaving 2cm overlap between fibres and pixels   DetectorMR!531

As of 1st July we are just waiting for DetectorMR!531 and Gauss!1032 to be merged to have a reasonable MT Baseline for the Scoping!

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▸ *Updated z position of the layers?* (If we manage to open the MR in the next few days should be OK)
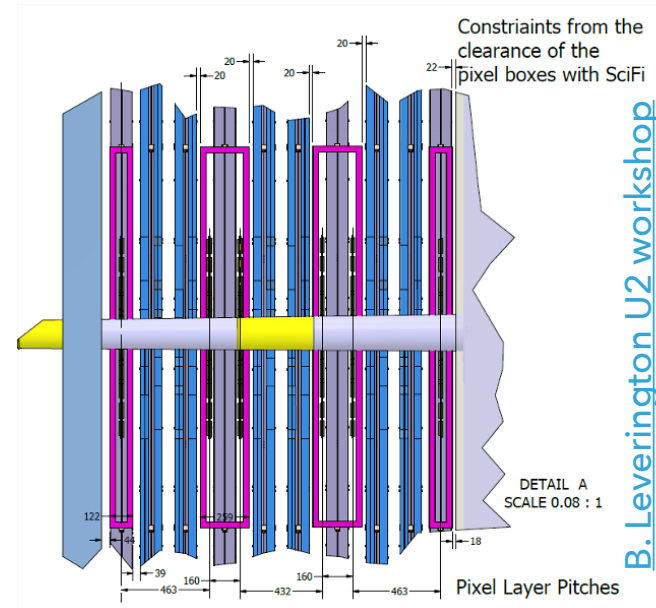
B. Leverington U2 workshop

Where are we now?

Organization

❏ Work tracked in two CodiMDs:

- Set up geometry and track open & merged MRs:

https://codimd.web.cern.ch/QEUbRMs9SqupKjMQjhCWEA#

- List of tasks and timeline, grouped in priority:

https://codimd.web.cern.ch/FV20taPkQc-No_NsXudPAg#

❏ Central branch stores updates to our geometry:
MT_backup

- Commits made to this branch
- Create MRs to wider simulation effort from this branch
- Allows us to be consistent with one another
- Check for conflicts/overlaps with the rest of the detector

Short (for next sample deadline)

- **Tai-Hua**: new layer placements
- **Gary**: Merge MP geometry options (specifically to include Low geometry) and new position to Gary's/upgrade branch
- **Gary**: ~~Reduce FT size 10cm – this is something Lucia spotted is written in the FTDR and we then confirmed with Matt, so we need to shave 5cm off of the top and bottom of FT. –~~ Detector!579
- **Gary**: Make the hole code work better with differing geometries
- **Tai-Hua**: Change .cpp part of the FT to co-exist with current running version and upgrade version - Will we need the new FT upgrade detector or will we using the flag to switch between runs?
- **Tai-Hua**: Sync or merge the geometry options (medium, low, high) between MP and FT
- **Gary**: ~~Fix the FT overlaps that are left – these are overlaps that FT has with itself, believe these were introduced when the FT hole was added.~~

Medium (for next to next sample deadline?)

- **Scott/Donata**: add in chips and services
  - Services Added (MP Data fibers, LV, HV + Monitoring)
- **Gary**: Merge Scott and Donata's implementation into current MP geometry when ready
- **Tai-Hua**: Detector element naming, numbering, channel ID and hierarchy. - Needed for digitisation
- **Scott/Donata/Tai-Hua**: re-structure a bit on current MP script. We are currenting working on the same file which makes it quite difficult to sort it out and merge. It would be great to have some header or new class for different part of the geometry like VP/TV)
- **Scott**: Adding cooling pipe in the silicon region
  - Done

Long

- Adding sensor properties, e.g HV
- Adding electronics part of the geometry, e.g. adding DC-DC convertor

Where are we now?

Current Status of Merge Requests

❑ **Detector:**

- ~~https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/463 - add in baseline MP geometry.~~ **(MERGED)**

- ~~https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/556 - change FT volume to an assembly.~~ **(MERGED)**

- ~~https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/560 - change z-position of last FT station.~~ **(MERGED)**

- https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/531 - implement hole in FT geometry.

- ~~https://gitlab.cern.ch/lhcb/Detector/-/merge_requests/579 - reduce y-size of FT by 10cm.~~ **(CLOSED)**

❑ ~~LHCb: https://gitlab.cern.ch/lhcb/LHCb/-/merge_requests/4372~~ **(MERGED)**

❑ Gauss: https://gitlab.cern.ch/lhcb/Gauss/-/merge_requests/1032

❑ ~~CondDB: https://gitlab.cern.ch/lhcb-conddb/lhcb-conditions-database/-/merge_requests/113~~ **(MERGED)**

Where are we now?

Current MP, plus geometry options

❑ Four geometry options available:
- 0: FTDR
- 1: Medium
- 2: Low
- 3: High

❑ Selection by setting corresponding flag in:
Detector/compact/components/MP/trunk/parameters.xml
<constant name="MP:geometryOptions" value="1"/> *<!--"0":FTDR; "1":Baseline; "2":Low-->*

Medium

FTDR

Low

High
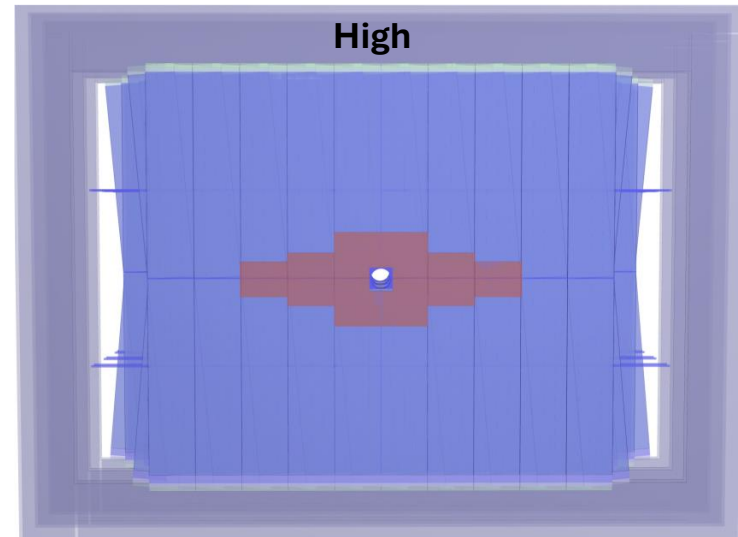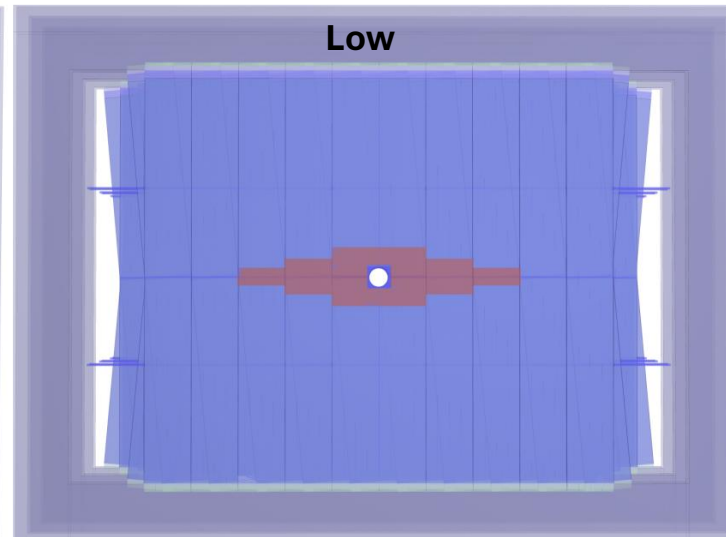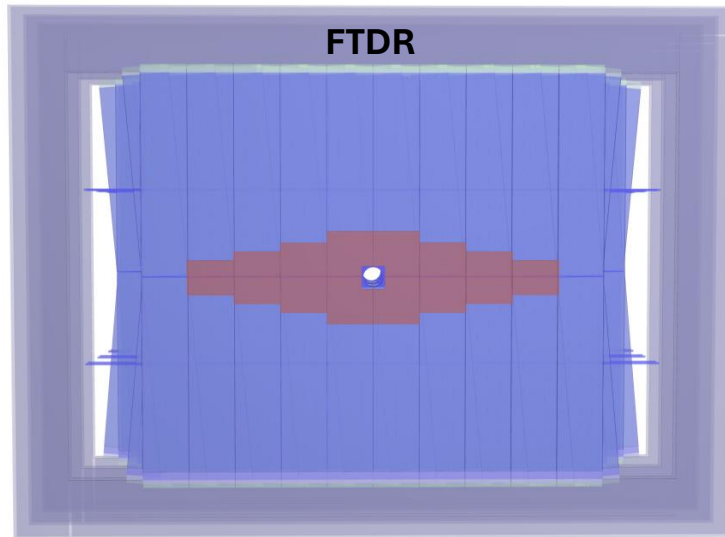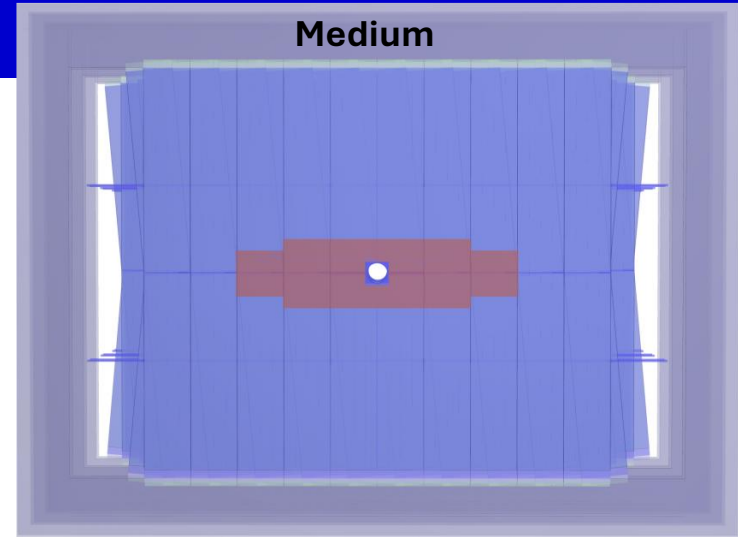
Where are we now?

Mighty Pix Geometry Development

❑ **New Milestone: Expand upon the baseline Mighty Tracker (MP) geometry**

❑ In April: discussions to get major MP components added into the simulation

- Add MP material that's *closer-to-reality*
    - Get a baseline design, then iterate on this design moving forward
- Produce sim files & study tracking, material budget
- In addition to Gary and Tai-Hua:
    - Donata: Module level components
    - Scott: MP Mechanics + Services

❑ Goal was to have this ready by this summer (now)

❑ Estimates of services, structures, MT weight also needed by LHCb technical team

- Understand to what extent cavern & existing structures can be modified
- Especially current SciFi bridge

❑ Consider different silicon footprints in the geometry.

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Design is still evolving(module layout + size, chip,cooling) – trying to track a moving target

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Pixel Module Hierarchy

❑ Map placed on both upstream & downstream face of sheet via rotation

❑ Maps are then stacked onto Module Columns

❑ Full detector is then built in a hierarchal fashion, following Tai Hyun's initial method

❑ Still FTDR geometry

• Updated geometry is WIP
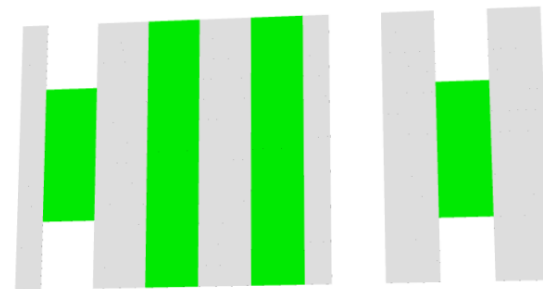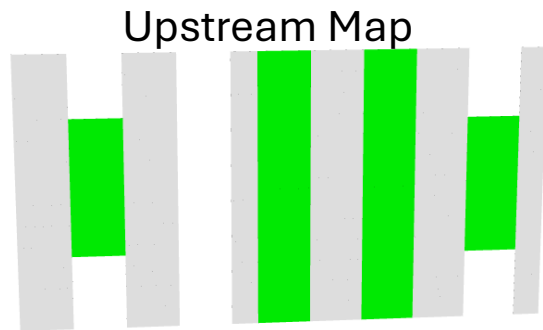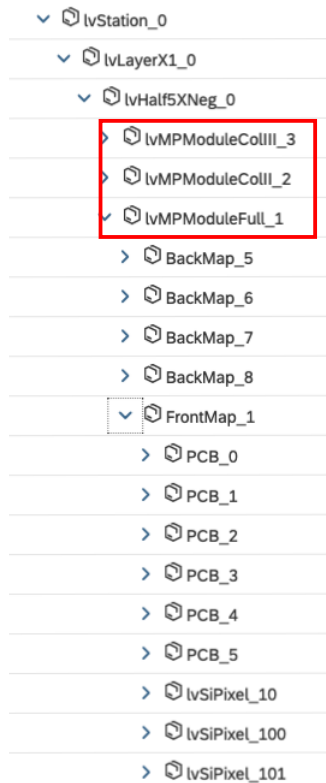
Multiple maps built into Module Column
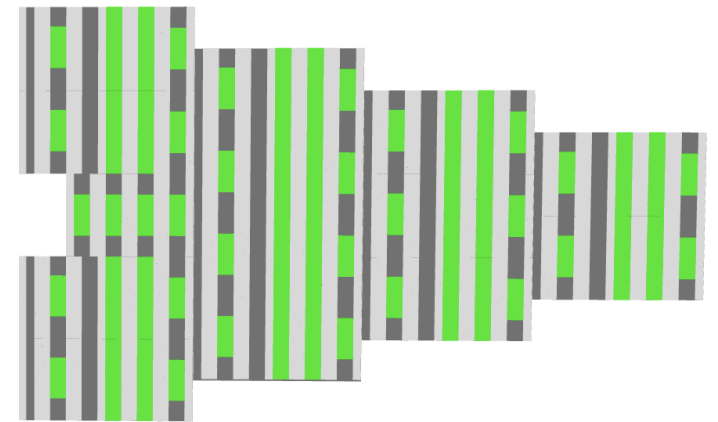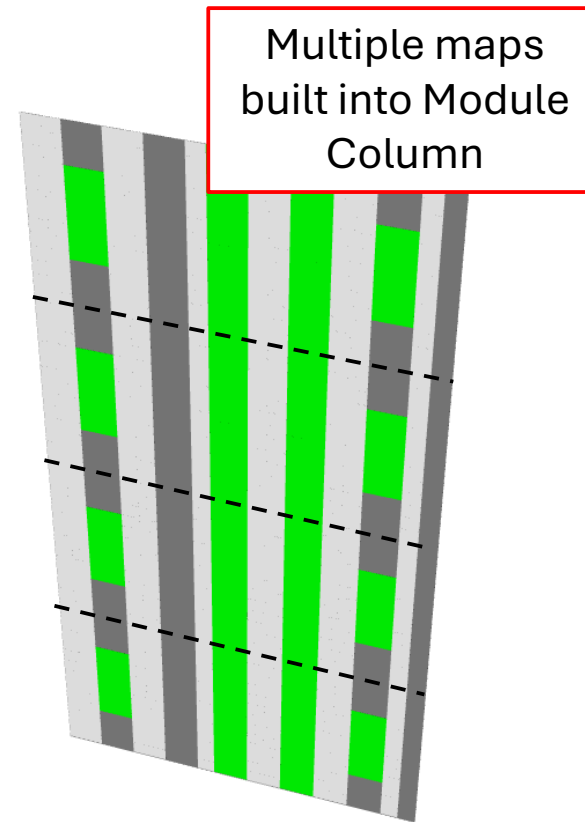
Mechanics Workflow

❑ Develop structures in a flexible manner

- Easily update as overall footprint changes
- Accommodate mechanics design changes
- Detailed CAD for mechanics developed by Trevor

- Simplified CAD provided for rough dimensions, placement
- Add structures to MP_geo.cpp

❑ Strategy:

- Define material
- Build structure for quadrant/half as needed
- Replicate to build up detector in a hierarchal manner
- Add components to stations
  - **Single or double layers controlled with flag in MPBuild:: functions**
- Repeat for all objects

CAD

Simplified CAD

Simulation
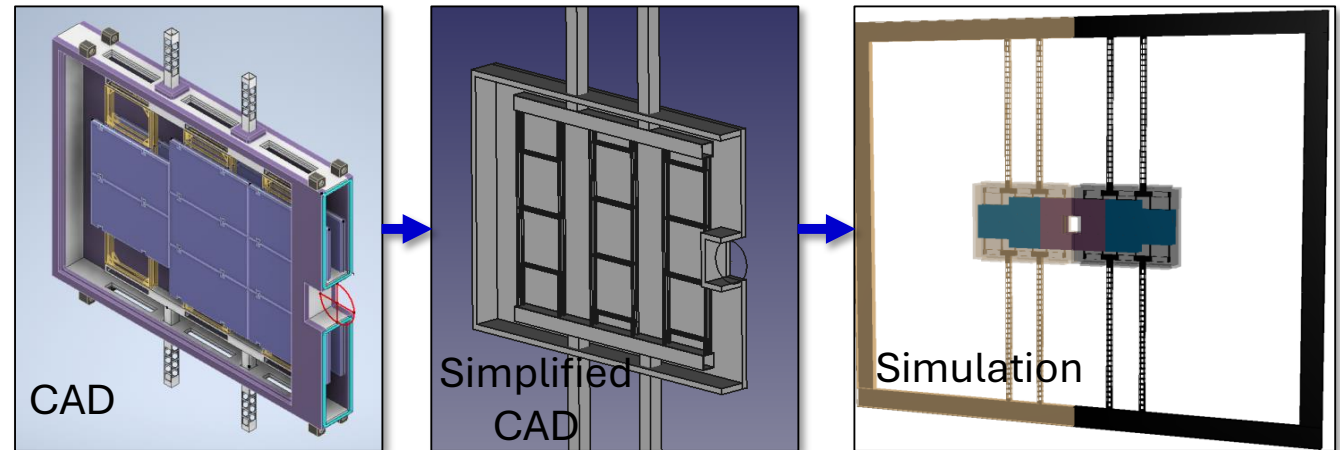
Support Structure & C-Frames

- Carbon Fiber support for:
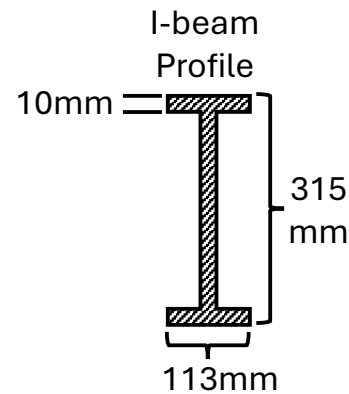 - Modules
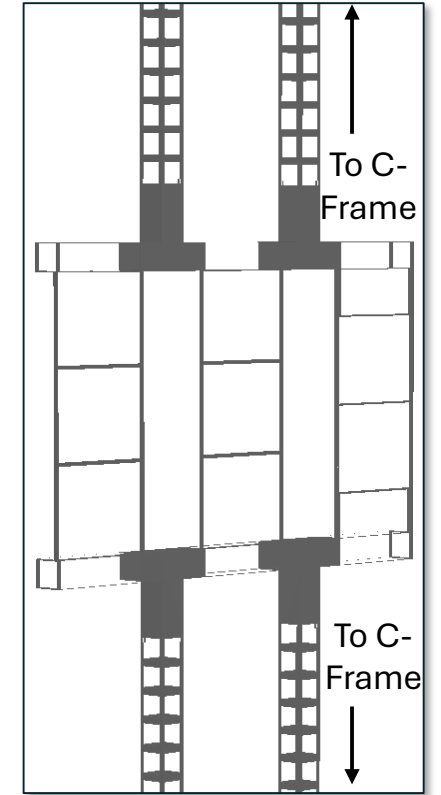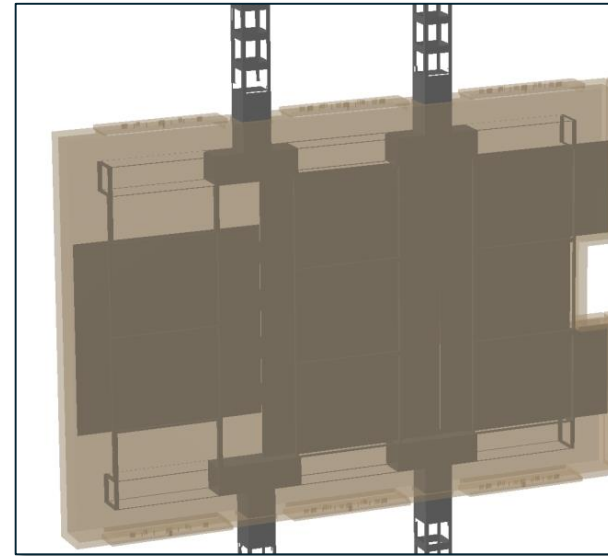 - Mechanics
- Removed material in a uniform fashion
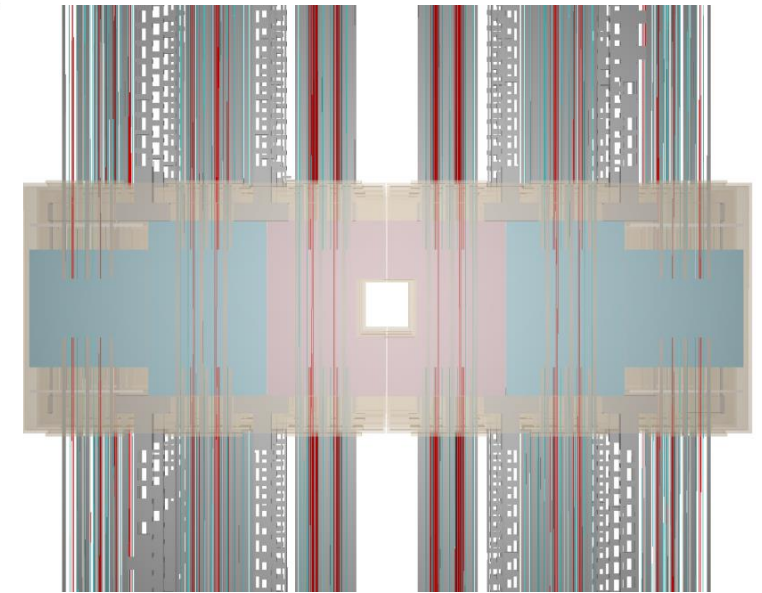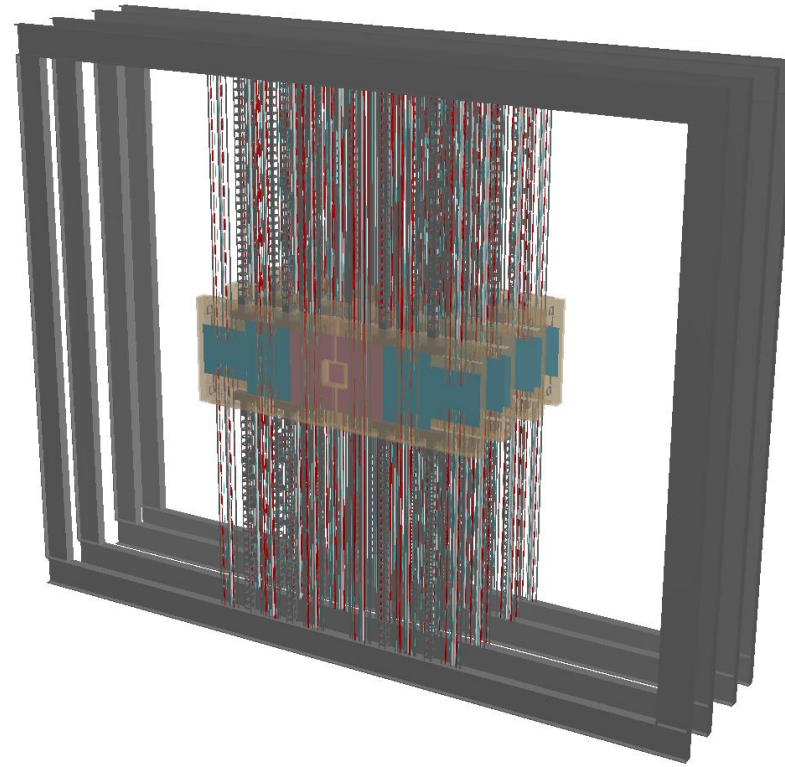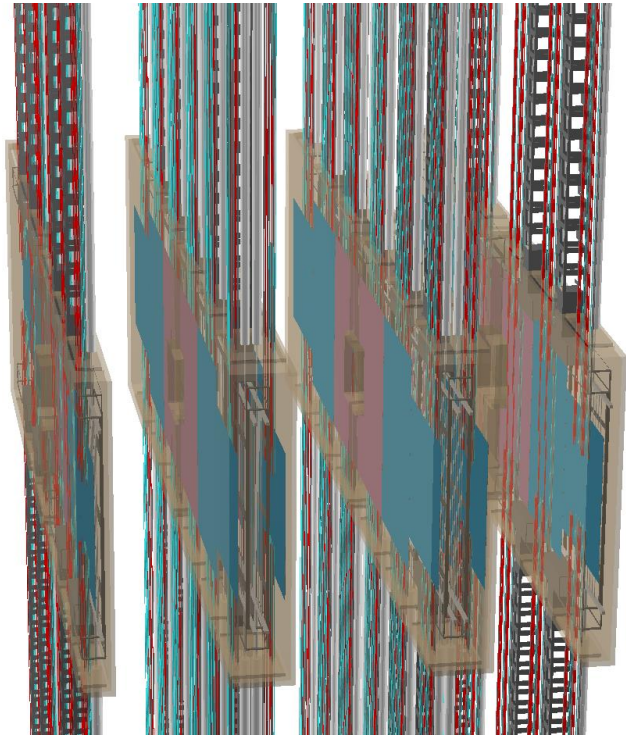 - Solid CF at enclosure interface
- Lacking some details:
  - Module to frame fixation
  - Panel installation/extraction mechanics
  - Enclosure box fixation
- C-Frames:
  - Stainless Steel 316 I-beam

I-beam Profile

10mm

315 mm

113mm

To C-Frame

To C-Frame

Support Profile

3.2 mm

80mm

Full Detector

S. Ely - 4th Mighty Tracker Workshop
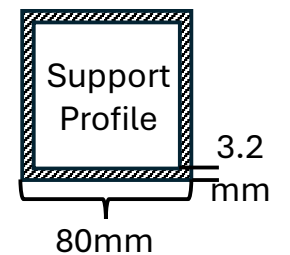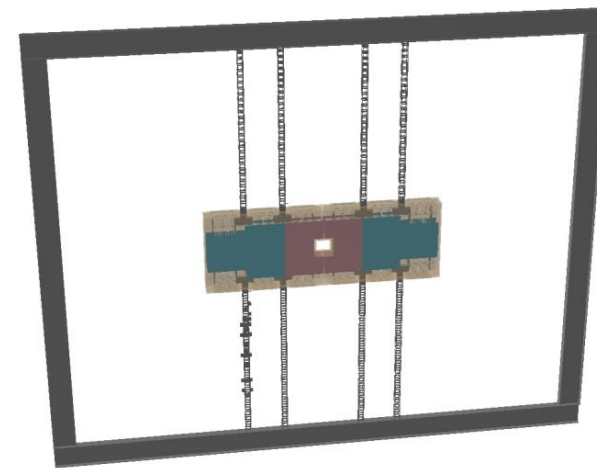
Summary and Outlook

❑ Only 2 MR needed for baseline MP description in simulation
- Detector!531
- Gauss!1032

❑ Lots of progress made in developing the MP geometry description in simulation
- Big thank you to Tai-Hua and Gary for all their help!

❑ First iteration of module components in place, ready to be merged with MT_backup

❑ First iteration of major mechanics components are written, ready to be merged with MT_backup
- All local overlaps resolved
- Will need to check with silicon footprint, updated geometries

❑ Check MP overlaps of MT_backup with FT, LHCb

❑ Very close to submitting MRs for simulation with updated MP geometry

❑ Continue to iterate the description as more detector components are finalized
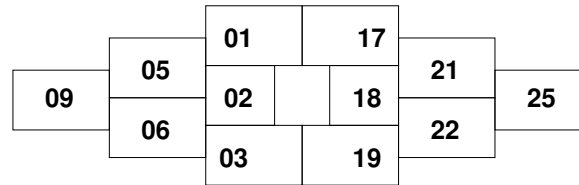- DCDCs, Panel installation, Services support, ...

Channel Numbering

proposal
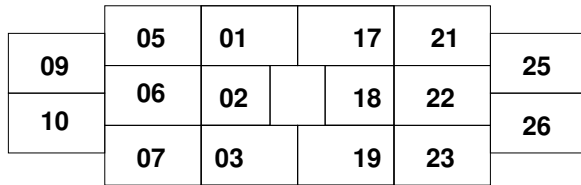
medium

low

First ideas about numbering schemes

- this is for the medium/low options
- distance from top of row can be identified from remainder mod 4
- moving up/down is +/-1
- A/C side differ in bit 4 (i.e. < 16 vs. ≥ 16)
- numbering is A/C side mirror symmetric

What do need for the TDR?

- Best guess of the material budget (for IT/OT at TDR we were within 10-20 % of reality)
  - Means need detector geometry including services and mechanics (in progress)

- Understanding of dead areas
  - Detailed module layout (in progress)
  - First set of digitization algorithms

- Understanding of how to align the detector
  - Overlaps, survey, system (e.g. BCAM) needs

- Mature tracking algorithms, ready to optimize for RTA
  - Full chain from digitization to 'raw data' to tracks running
  - Robustness checks

Summary

- UK efforts have been key in developing the MT simulation for the scoping document

- Critical the effort continues to the TDR and beyond to ensure detector able to deliver excellent physics
  - Good detector needs working hardware and software

- Many challenges
  - Detector is still evolving fast – moving target (it was ever thus)
  - Lowering the bar to getting involved

*"This is the time
Because there is no time"*

"Lanark said irritably, "You seem to understand my questions, but your answers make no sense to me."
"That's typical of life, isn't it?"