Mighty Tracker project overview and plans

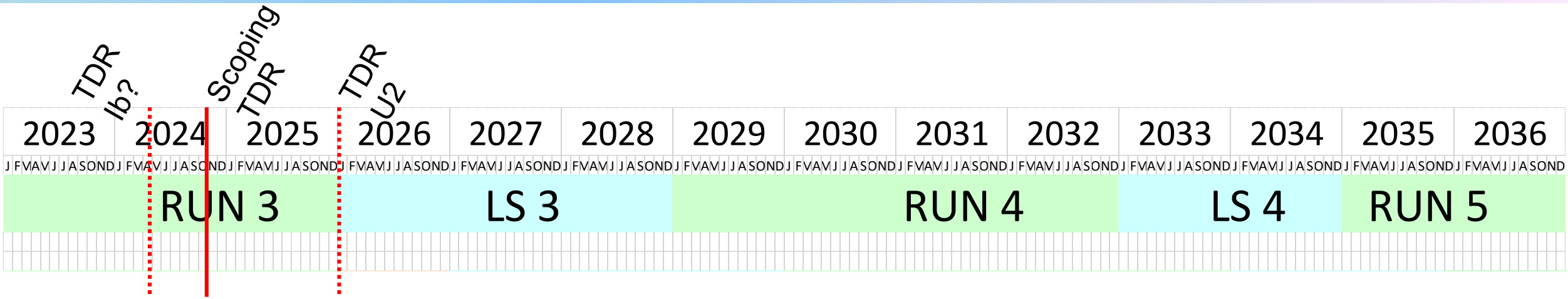
6th Workshop on LHCb upgrade II
Barcelona

30 March 2023

Pascal Perret

On behalf the Mighty Tracker Project

Overview



- A lot in front of us:
  - Up to 3 TDR to prepare
    - Run 4: «Opportunities for the detector at LS3»
      - LHCb Tracker TDR: early 2024?
    - Run 5:
      - Descoping TDR: 2024
      - U2 TDRs: 2025-2026
  - 1st Mighty tracker workshop organised at CERN March 7-8 https://indico.cern.ch/event/1251283/

Run 4: which tracking detector?

- SciFi **is the baseline solution.** It was designed to run efficiently up to 50 fb^{-1}
  - ~<3% loss expected in pattern recognition performance
    - Some studies on-going (cf talk from Lennart)
    - But possibility to increase SiPM HV to compensate (partially?) this aging (cf Guido)
  - Is it valid?
    - SiPM aging?
      - DCR comparison between expectation and measurements after 1 fb^{-1} agrees very well (talk SciFi meeting: Federico)
    - Fibers aging
      - Oxidation ?
        - Test samples: continuing monitoring of 29 samples (5 year): average aging rate < 1% (talk SciFi meeting: Jan, Sonia)
      - Radiation?
        - To be checked, need of additional data (running at nominal lumi …)

    Not in time for a TDR early 2024
  - Replacement of SciFi central modules is a first option in case of needs (aging).
  - Replacement of SiPM inner modules with new SiPM development (cf Blake) ?

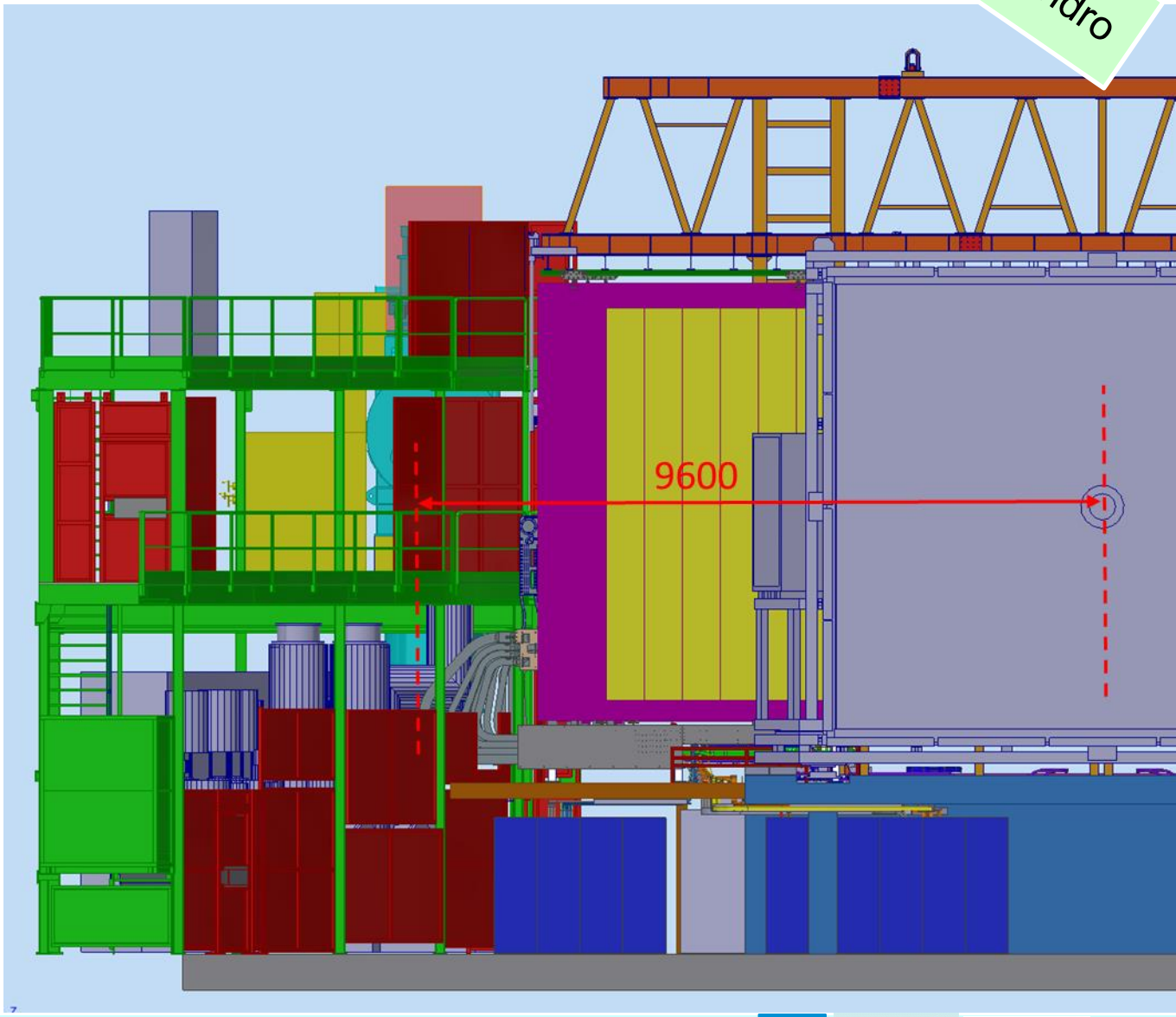
Run 4: which tracking detector?

- SciFi consolidation?
  - Critical points:
    - SiPM cooling liquid (using of C_6F_{14}): in case of leak?
    - Heating wires and CPS
    - Electronics: VTRx, Cluster FPGA reprogramming after radiation
    - Detector access is an issue:
      - Pilars
      - RICH2

Run 4: which tracking detector?

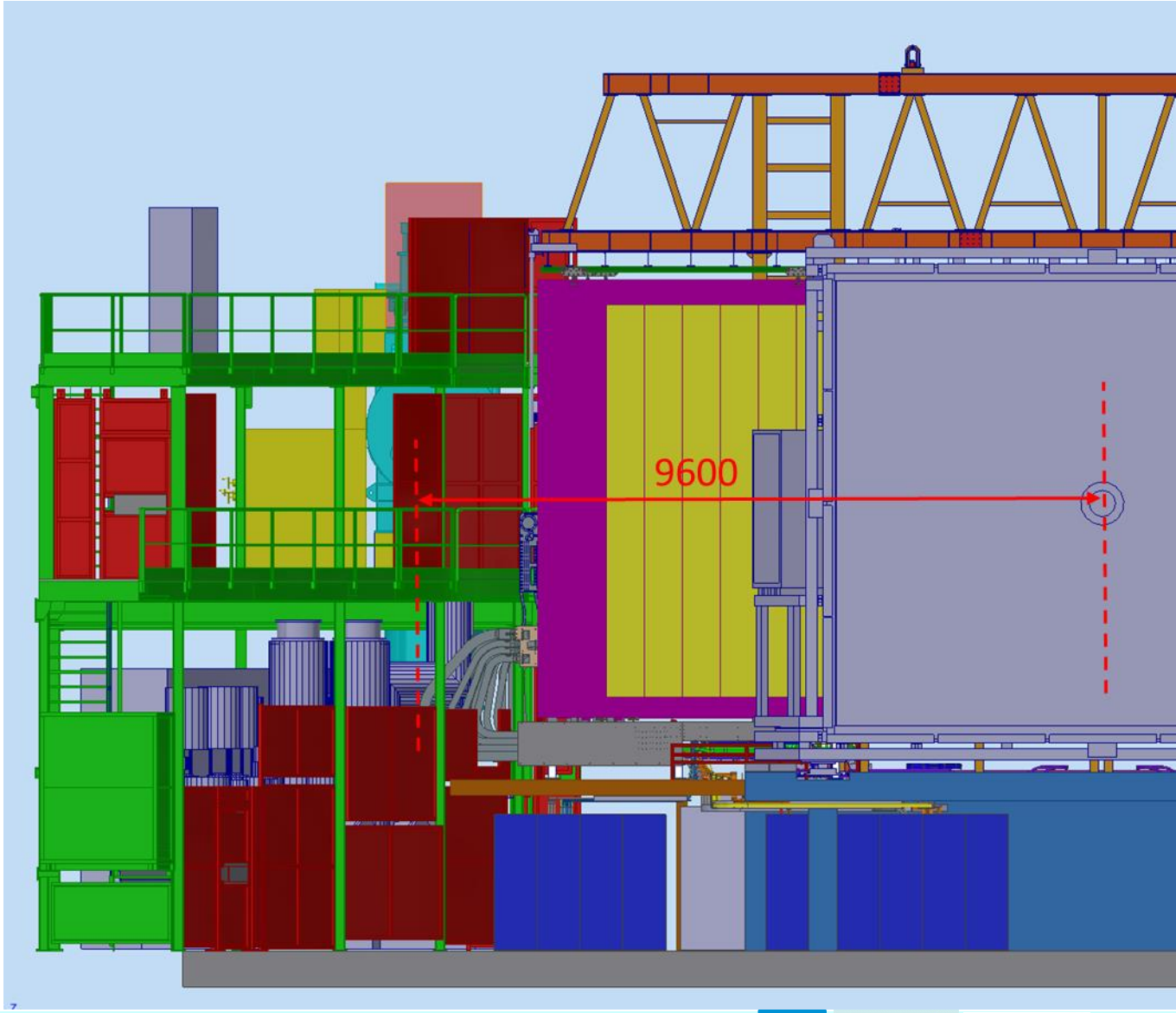
Alessandro

- SciFi consolidation?
  - Critical points:
    - Detector access is an issue
      - Pilars
      - RICH2
    - We need some extra space on cryo side in order to open completely C-side, going out of RICH2



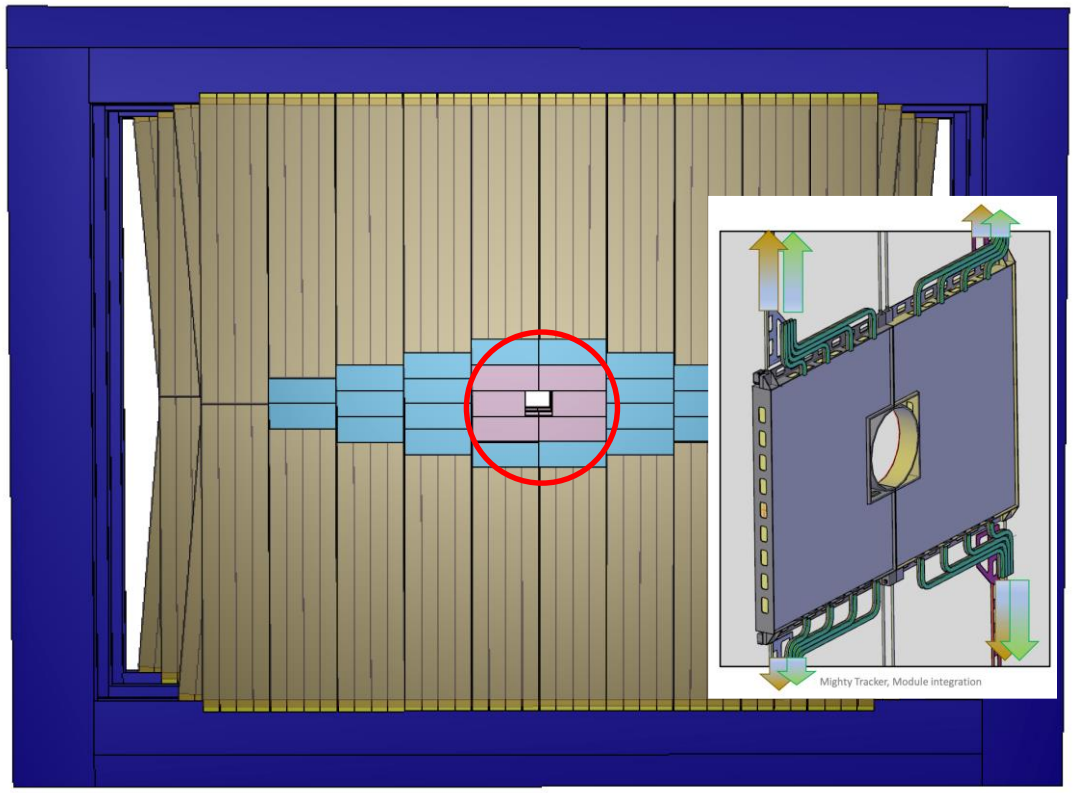
Run 4: which tracking detector?

- SciFi consolidation?
  - Critical points:
    - Detector access is an issue
    - We need some extra space on cryo side in order to open completely C-side going out of RICH2
    - Others?
  - Need more running experience to identify possible point of failures that will have to be fixed



Run 4: which tracking detector?

- Do we want/need to go above the baseline?
  - **Some boundary conditions**
    - Any additional part should not affect the reliability of the SciFi
      - SciFi detector access for maintenance has to be granted
    - Additional material budget should not degrade the tracking (and LHCb) performances
    - Should not compromise U2
      - Resources dispersion/availabilities
        - Manpower, budget
  - Mpix is an option
    - What could be available?
      - Inner part (6 modules)
      - 2 layers (after T2, front of T3)?
    - Is the time scale realistic?
    - What could be re-used for Run 5?
      - Installation of complete cooling system?
    - Financial agency support? (~10% - 20% of U2?)



Run 4: which tracking detector?

- What are the motivations to go above the baseline?
  - Do we plan to collect more than 50 fb^{-1} before LS4?
  - Physics performance enhancement?
    - Heavy ion run program in Run 4
      - How many pixel layers needed, which area? → *What will bring 2 Si layers?*
    - Other physics channel?
      - Is SciFi enhancement needed/ enough?
  - **We need some guidelines**

- Installation of new infrastructure during LS3 for LS4/Run 5?
  - Or for a “pilot detector” that could be installed during 1 EYETS in ~2031?

- **Internal review Q4 2023 to preparing a decision on LS3/Run 4**

U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

-14% -32%

Table 3.8: Cost for the Upgrade II Mighty Tracker detector.

Component	Cost [kCHF]
Outer region: SciFi	
Scintillating fibre mats	4250
SiPMs	2500
Electronics	6300
Infrastructure	9300
Inner and Middle regions: Silicon	
MightyPix	8950
Electronics	5850
Infrastructure	4700
Total	41850

Detector	Baseline (kCHF)
VELO	14800
UT	8900
Magnet Stations	2300
MT-SciFi	22400
MT-CMOS	19500
RICH	15600
TORCH	9900
ECAL	34800
Muon	7100
RTA	17400
Online	8900
Infrastructure	13500
Total	175100

U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

-14% -32%

Table 3.8: Cost for the Upgrade II Mighty Tracker detector.

Component	Cost [kCHF]	
Outer region: SciFi		22,350
Scintillating fibre mats	4250	
SiPMs	2500	
Electronics	6300	
Infrastructure	9300	
Inner and Middle regions: Silicon		19,500
MightyPix	8950	
Electronics	5850	
Infrastructure	4700	
Total	41850	

FTDR:
Reducing the number of fiber layers from 6 to 4 will have a small impact (~3%)

Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)

U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

-14% -32%

Table 3.8: Cost for the Upgrade II Mighty Tracker detector.

Component	Cost [kCHF]
Outer region: SciFi	
Scintillating fibre mats	4250
SiPMs	2500
Electronics	6300
Infrastructure	9300
Inner and Middle regions: Silicon	
MightyPix	8950
Electronics	5850
Infrastructure	4700
Total	41850

22,350

42%!

19,500

24%

FTDR:
Reducing the number of fiber layers from 6 to 4 will have a small impact (~3%)

Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)

Infrastructure is a large part
- Bridge modification/replacement not costed

Uncertainty on cost estimate

Currency exchange rate: €/$/£/¥/ CHF: large fluctuations

U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF
    -14% -32%
  - Mighty Tracker
    - Reduce the number of channels
      - Reduce the acceptance
        - Change of B field (magnet)
      - Increase the granularity (fibre diameter, pixel size or combine electronics/readout channel)
    - Reduce the number of layers/station
    - New technologies
    - Revisit the cost estimate

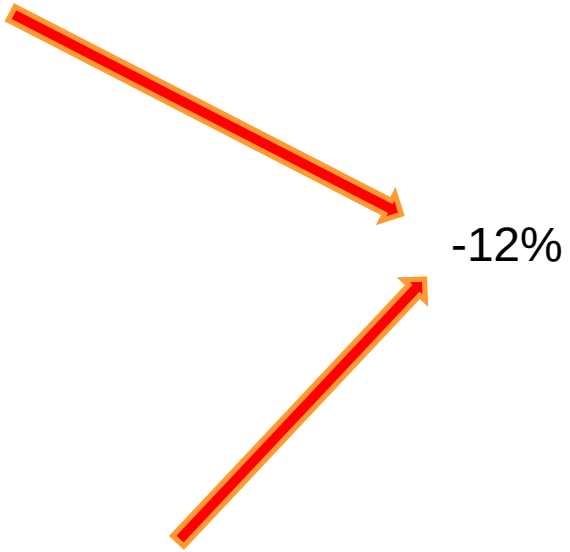
U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF
    -14% -32%
  - SciFi tracker
    - Reducing the number of fibre layers will have a small impact (3%)
      - Remove outer part (24/128) (assuming same infrastructure) ⇒ - 6%
      - Reduce the height of the modules?
    - Increase radiation hardness of fibres and/or SiPM
      - Alternative to cryogenic cooling?
    - Infrastructure: 42%. How to reduce the cost?
  - Pixel tracker
    - Reduce the detector area (impact on SciFi (radiation?))
      - Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)
      - Reducing by a factor 2 Pix + Electronics (assuming same infrastructure) ⇒ - 18% …

U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

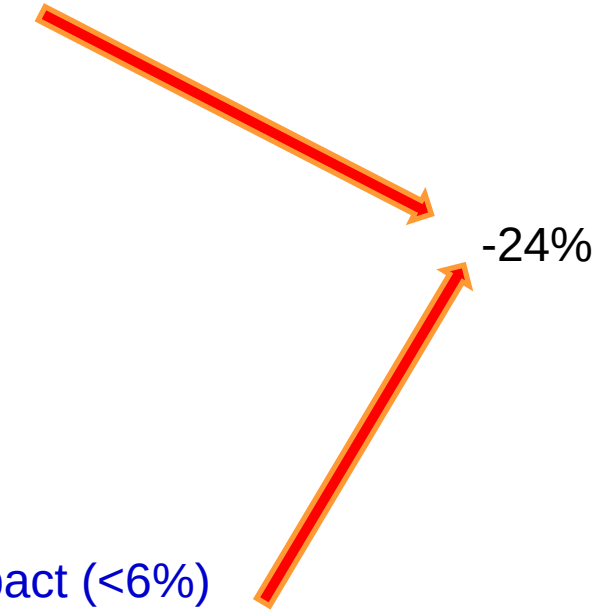
    -14% -32%
  - SciFi tracker
    - Reducing the number of fiber layers will have a small impact (3%)
      - Remove outer part (24/128) (assuming same infrastructure) ⇒ - 6%
      - Reduce the height of the modules?
    - Increase radiation hardness of fibres and/or SiPM
      - Alternative to cryogenic cooling?
    - Infrastructure: 42%. How to reduce the cost?
  - Pixel tracker
    - Reduce the detector area (impact on SciFi (radiation?))
      - Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)
      - Reducing by a factor 2 Pix + Electronics (assuming same infrastructure) ⇒ - 18% …



U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

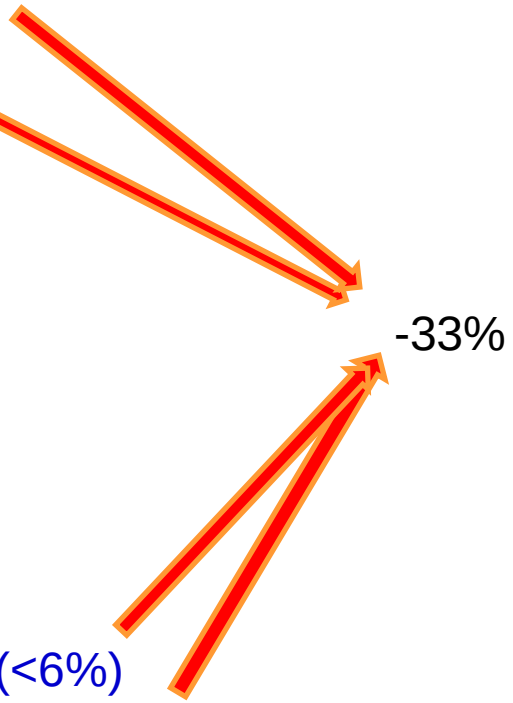
    -14% -32%
  - SciFi tracker
    - Reducing the number of fiber layers will have a small impact (3%)
      - Remove outer part (24/128) (assuming same infrastructure) ⇒ - 6%
      - Reduce the height of the modules?
    - Increase radiation hardness of fibres and/or SiPM
      - Alternative to cryogenic cooling?
    - Infrastructure: 42%. How to reduce the cost?
  - Pixel tracker
    - Reduce the detector area (impact on SciFi (radiation?))
      - Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)
      - Reducing by a factor 2 Pix + Electronics (assuming same infrastructure) ⇒ - 18% …



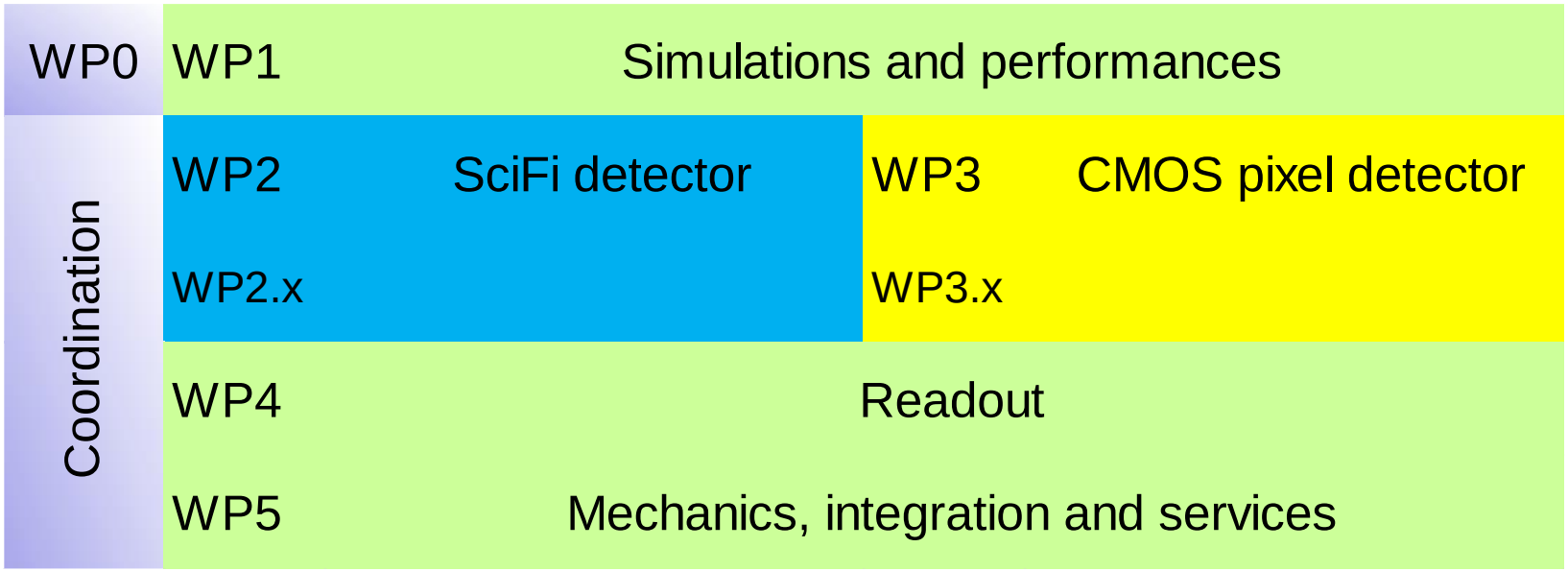
U2: descoping options

- How to decrease the cost (impact on performances?)?
  - Descoping: FTDR ~ 175 MCHF ; MEDIUM ~ 150 MCHF ; LOW ~ 120 MCHF

    -14% -32%
  - SciFi tracker
    - Reducing the number of fiber layers will have a small impact (3%)
      - Remove outer part (24/128) (assuming same infrastructure) ⇒ - 6%
      - Reduce the height of the modules?
    - Increase radiation hardness of fibres and/or SiPM
      - Alternative to cryogenic cooling?
    - Infrastructure: 42%. How to reduce the cost?
  - Pixel tracker
    - Reduce the detector area (impact on SciFi (radiation?))
      - Reducing the number of Si layers from 6 to 5 will have a small impact (<6%)
      - Reducing by a factor 2 Pix + Electronics (assuming same infrastructure) ⇒ - 18% …



Organisation



Work Package breakdown structure under discussion

- 2 coordinators for each WP
- Institute interests

Institutes have to be involved in the decision process: extended IB

Some work packages exist already and are very active!

To help to answer all these questions, each WP will have to provide

- A roadmap
- Milestones
- Estimated (needed/available) FTE
- SciFi is a new project!

New collaborators welcome: plenty of tasks not covered

Open questions

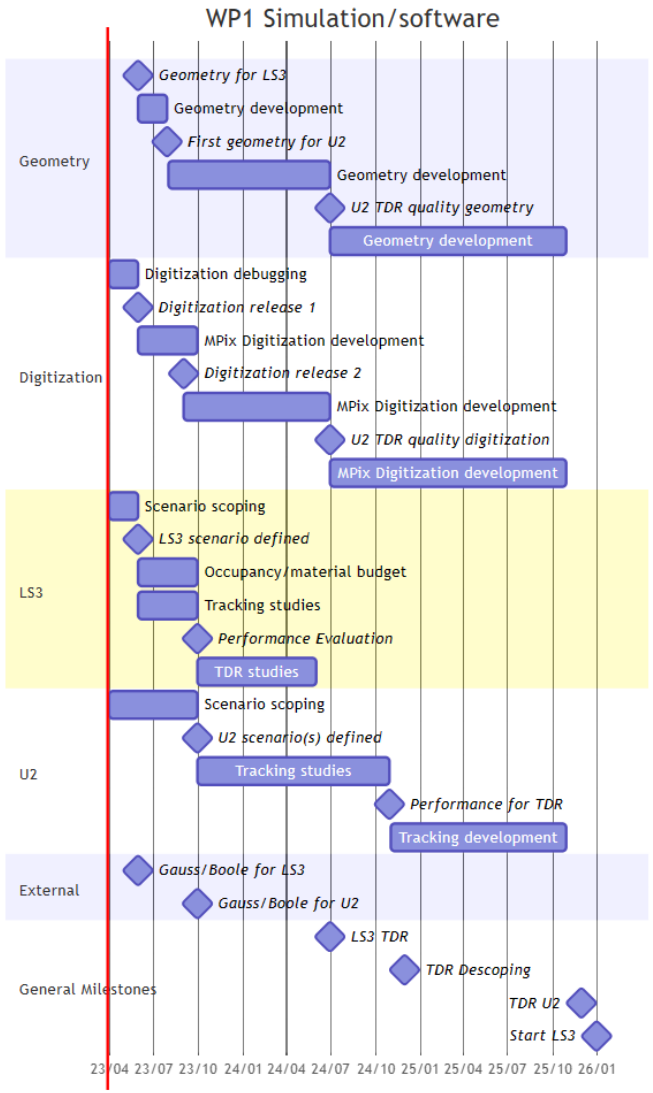
- R&D detector choices
  - HV-CMOS
    - Radiation damage
    - Low material budget
    - Operating temperature
  - SciFi: this is a new detector
    - Radiation damage (Impact of new ECAL on radiation?)
      - Improvement in fibre radiation tolerance
      - Neutron shielding
    - Cryogenic cooling, vacuum insulation
    - Fibre mirroring
    - Could timing information be useful?
    - FE electronics architecture
  - **Detector integration**

- Tracking algorithm improvements (Retina, Graphical Neural Network, etc.)

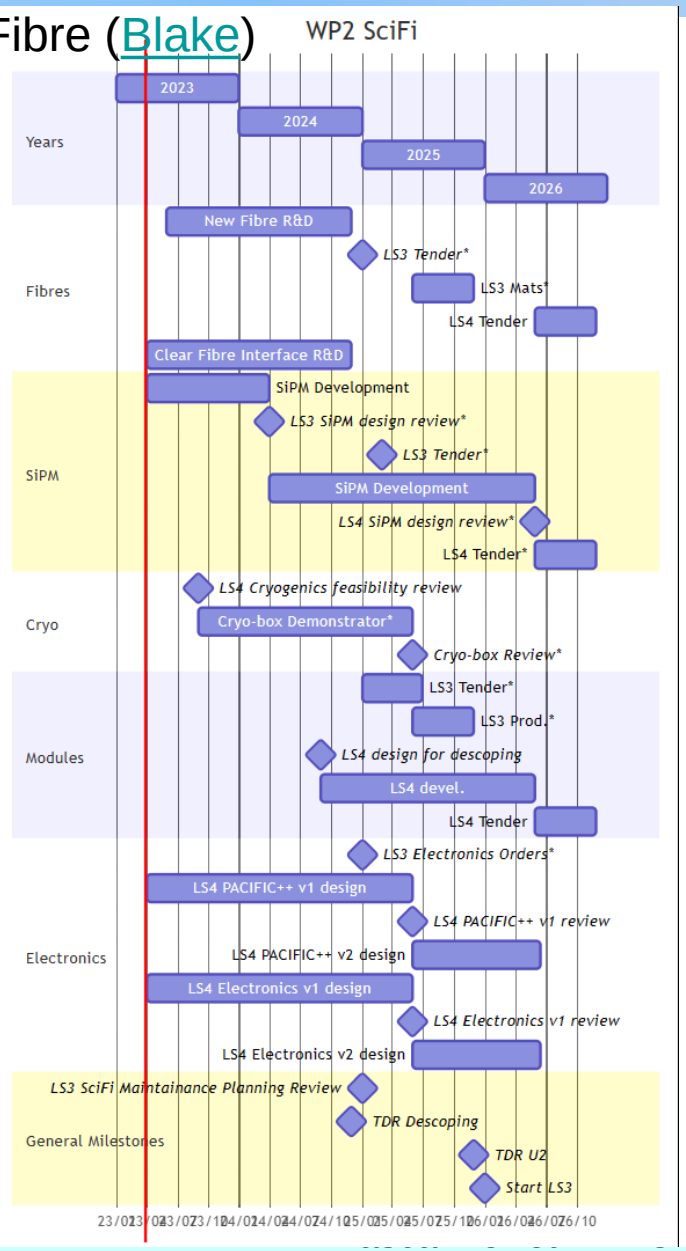
First step: Project Timeline

Preliminary

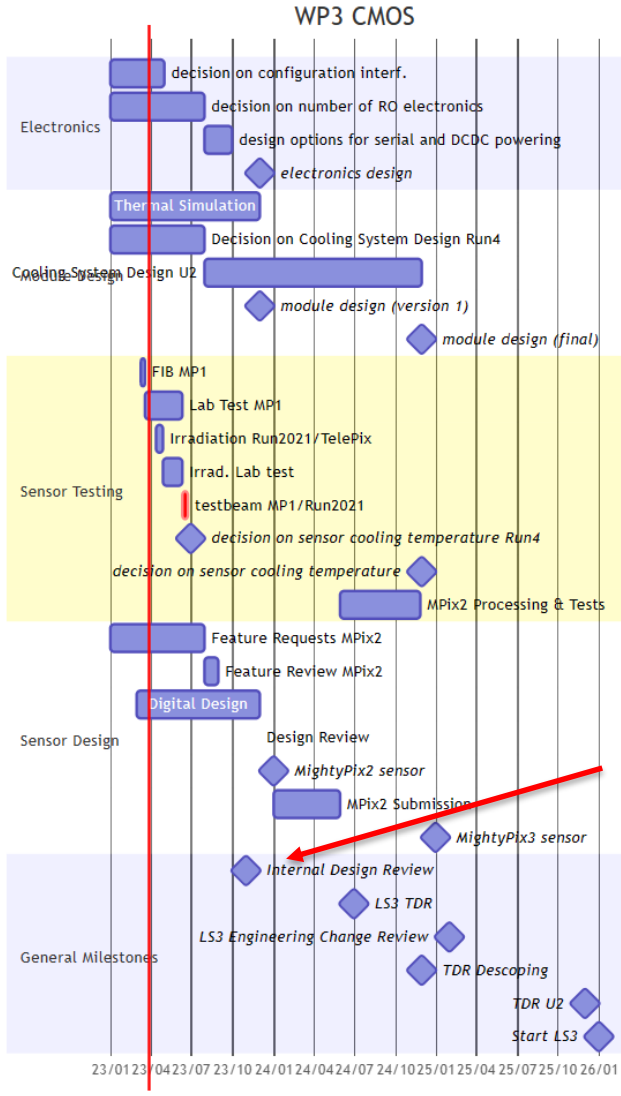
Simulation (Matt)



Fibre (Blake)



Pixel (Klaas)



To be reviewed.

Next steps:

- Manpower estimation (needed/available)
- Define priorities

Internal review Q4 2023
To preparing a decision on LS3

What next

- We have to identify commonalities with other projects
  - Pixel: UT
    - Common meetings to present our progress and to identify possible common R&D
      - Pre-meeting next week
    - cooling
  - SiPM/cooling : RICH?
  - Fibres: ECAL ?
      - Meeting mid-April
  - Others?

- Workshop in Bonn 31/05 – 02/06: https://indico.cern.ch/event/1266905/
  - Wider audience
  - Attract new collaborators
    - **Every one is welcome to join and participate**
  - Prepare our roadmap

Summary

- Run 4
  - SciFi is the baseline
    - Detector access is an issue
      - Benefit of LHC cryo displacement to extend a bit available space
  - Internal review Q4 2023: to prepare a decision (needs, Mpix readiness, resources, impact, etc.)
- Run 5 & Descoping
  - Revisit the cost
  - New technologies (fibres, cooling, etc.)
  - Decrease of the number of channels ⇒ Reduce detector acceptance
- We need new collaborators: you are welcome
- **Mighty Tracker Workshop in Bonn 31/05 – 02/06** https://indico.cern.ch/event/1266905/

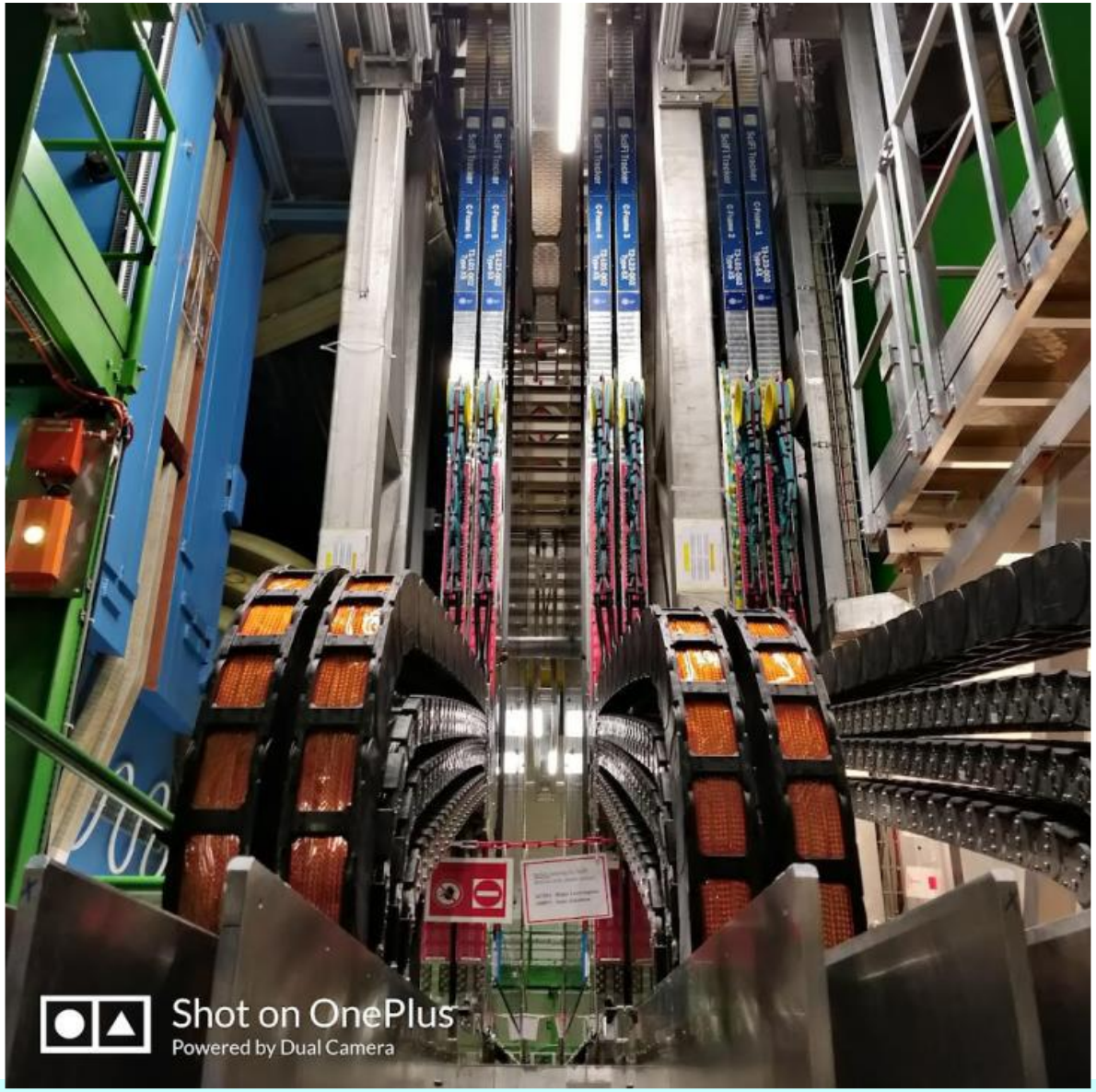
We need some guidelines
+ Global optimisation

- More information: Simulation (Matt), Fibre (Blake), Pixel (Klaas)

BACKUP

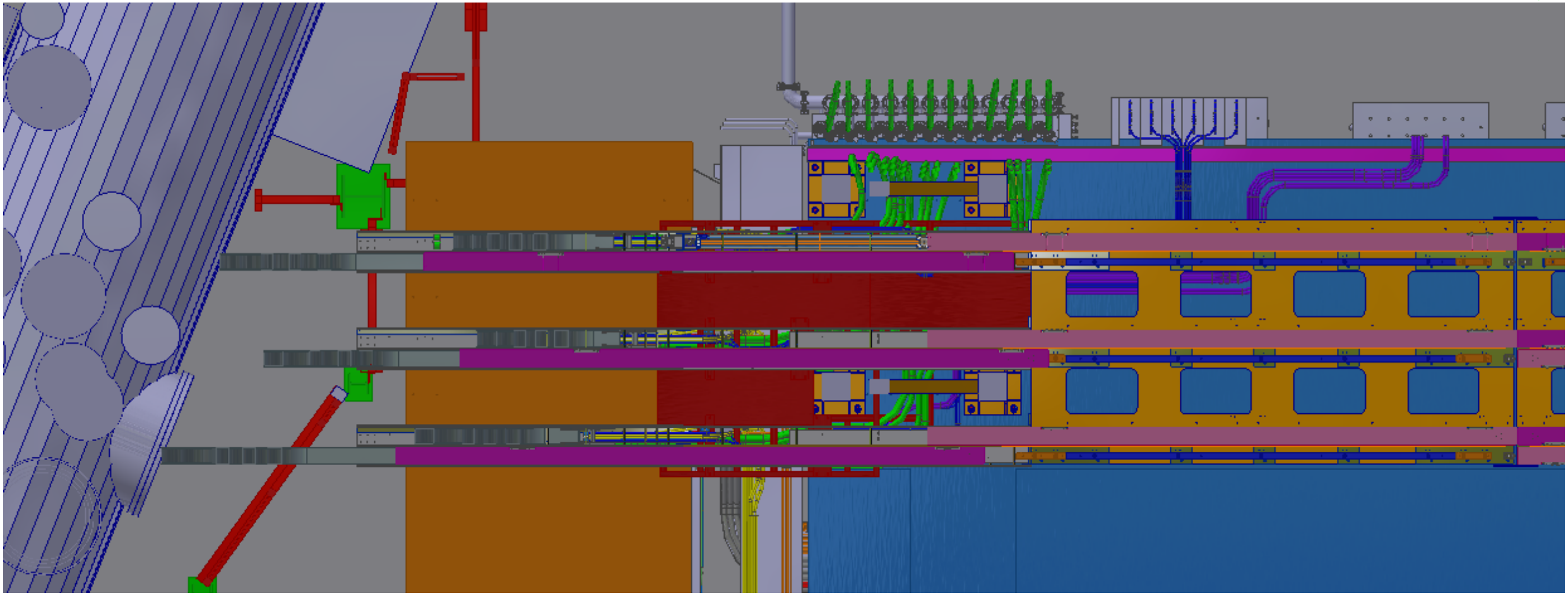
SciFi view from C-side

Blake



SciFi top view C-side

Alessandro



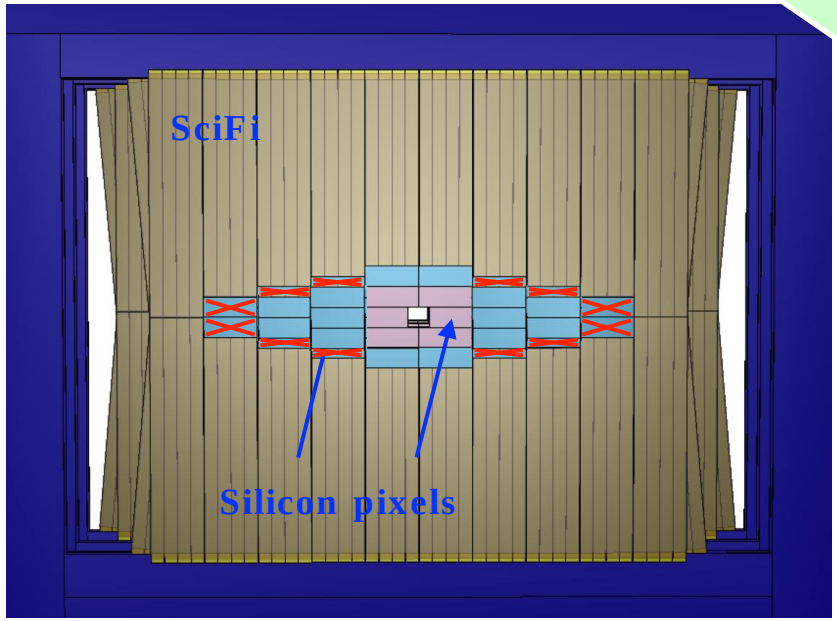
Descoping roadmap

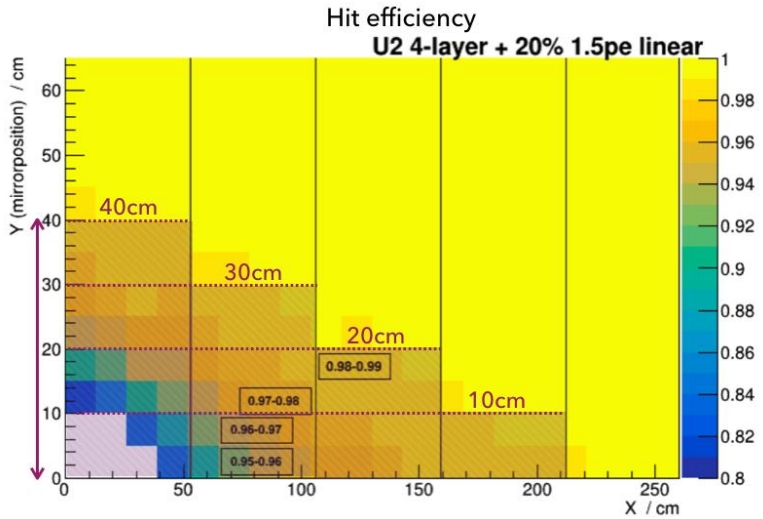
- Descoping
  - Revisit the cost estimate
  - Global detector optimisation process needed:
    - Reduce peak luminosity (integrated luminosity?), reduce detector futures
    - Reduce detector acceptance $\Rightarrow$ Impact on physics performances
  - Reduce Si size
    - 6 $\rightarrow$ 5 layers: impact on tracking performances?
    - Reduce Si area:
      - SciFi radiation hardness?
      - Could timing information be useful?
  - SciFi
    - Reduce the number of layers?
    - Remove outer modules (flexibility: no design changes, decision could be take at the construction time)
    - Have shorter modules?

Downscoping: A modest tracker

Matt

- In FTDR main descope option discussed is reducing the silicon area: assume we gain from cryo cooling on the SciFi side.
- Also reduce to 5 silicon layers
- Silicon area reduces to 11 m^2
- Reduces cost of Silicon by 40 %
- With 4 fiber layers for SciFi total system cost also reduces





Acceptance

Tim