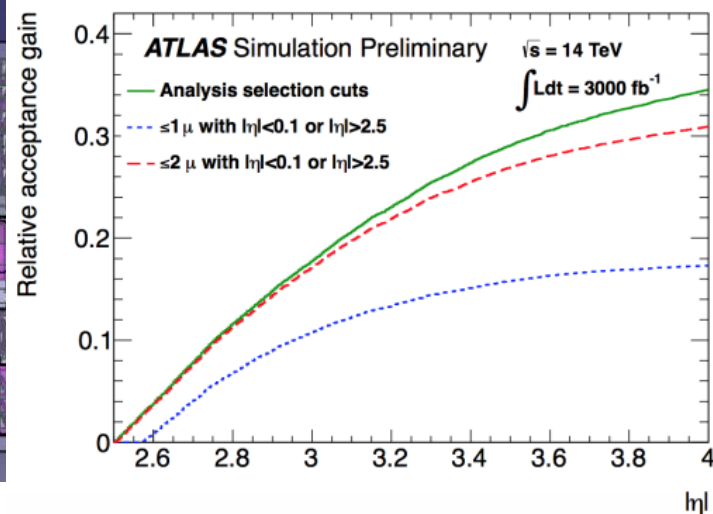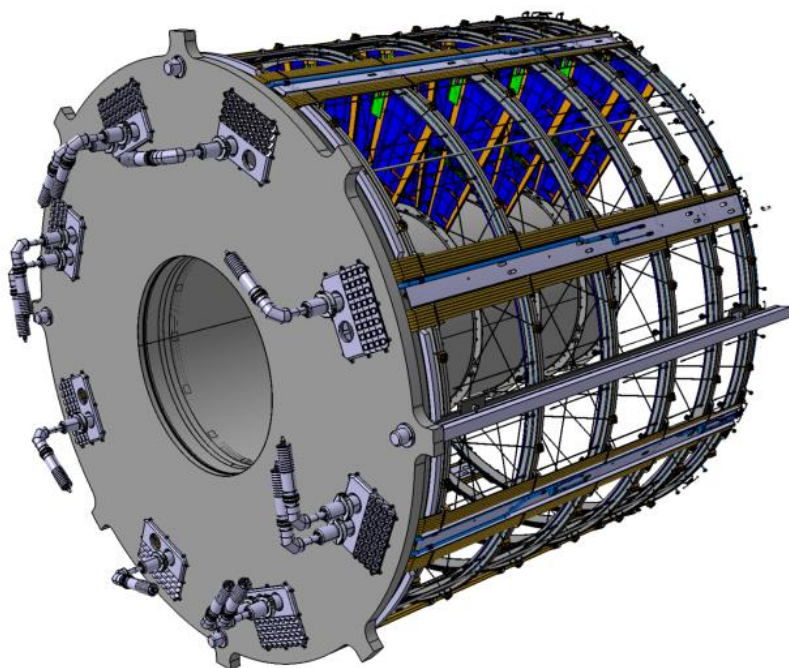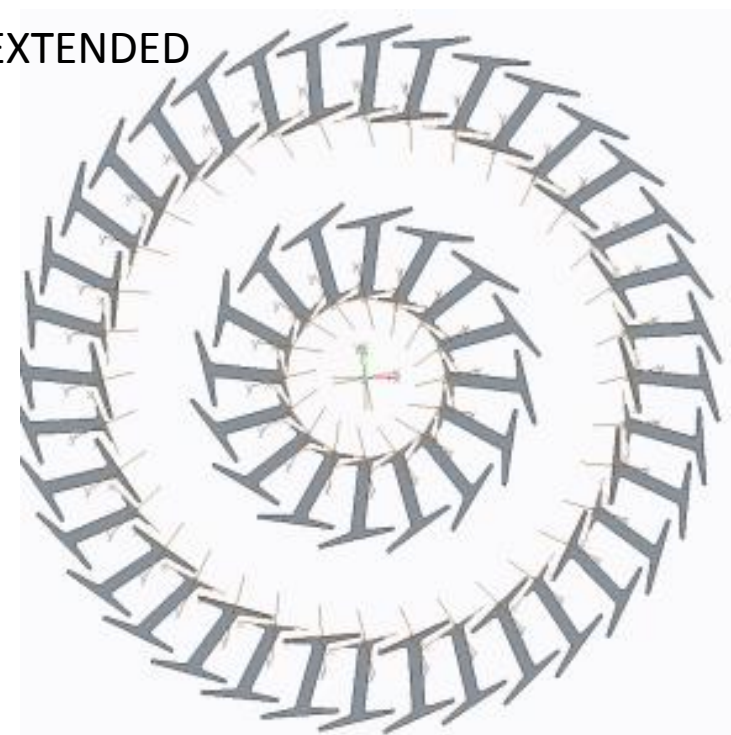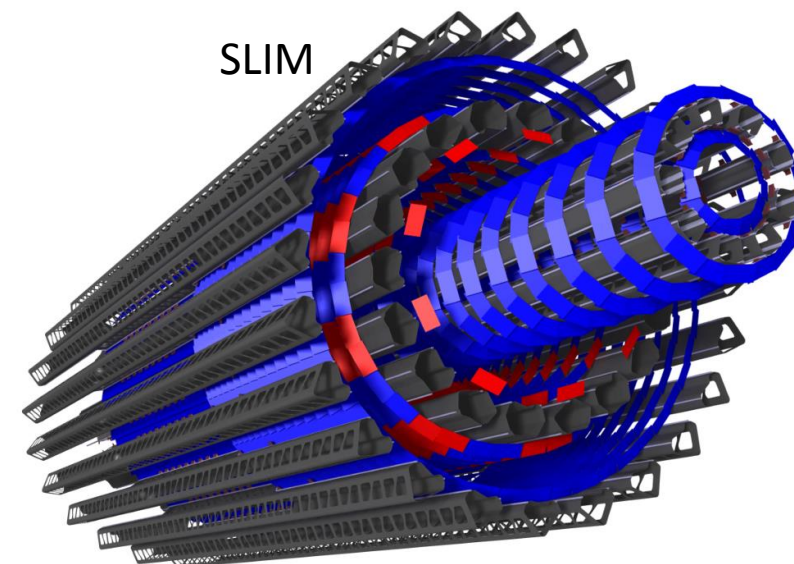ALPINE

EXTENDED

SLIM
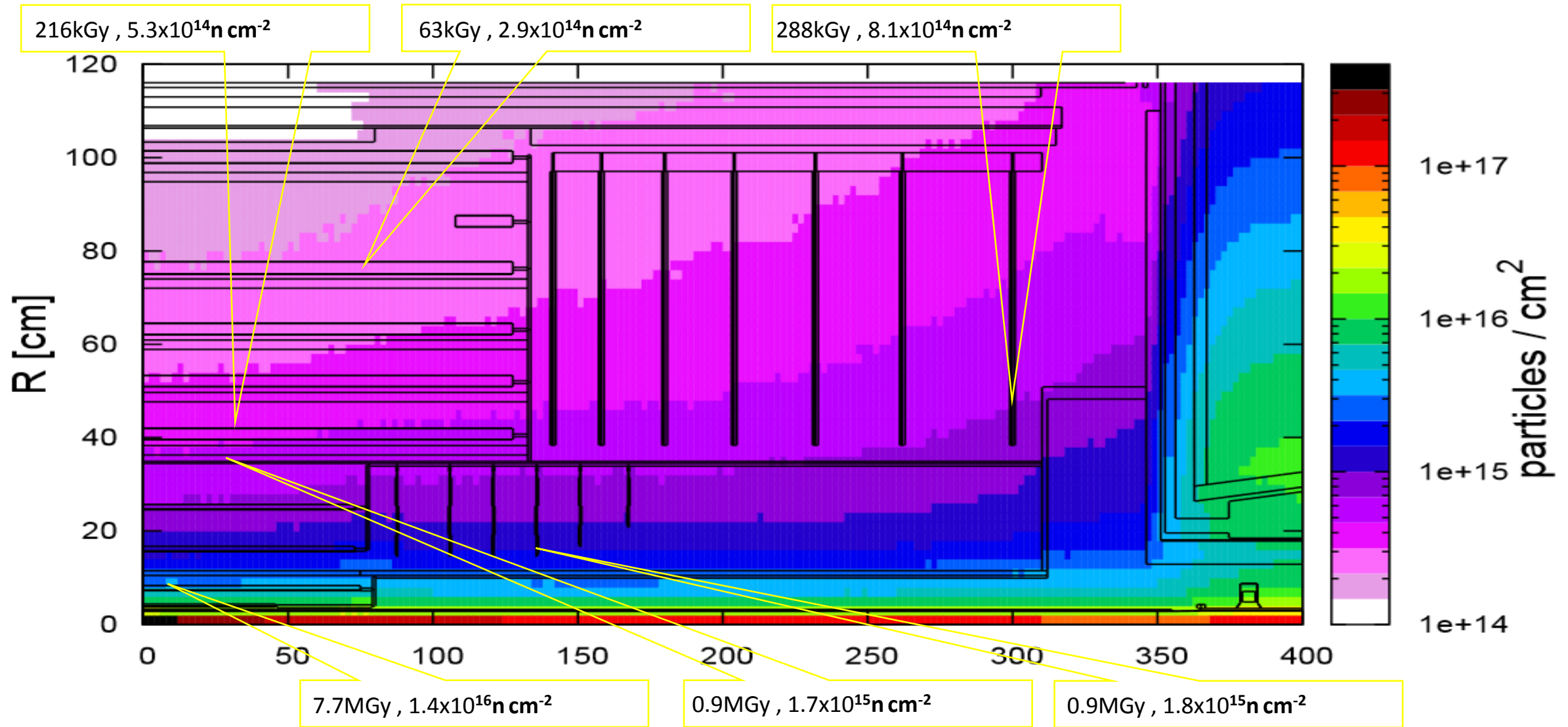
The Layout of the ITk

S. McMahon

RAL/Oxford

on behalf of the ITk project

ACES, CERN, 9th March 2016

Requirements for phase II tracker

- Record a total integrated luminosity of 3,000 fb^{-1}
  - Places stringent requirements on the radiation tolerance of components (particularly sensors).
  - 2×10^{15} 1MeV n_{eq}/cm^{-2} for strips and 10 times this for pixels, TID of 1 GRad
- Maximum instantaneous luminosity of 7.5×10^{34} cm^{-2}s^{-1} ($<\mu> \sim 200$)
- Reconstruct vertices of pile-up events & associate vertex with the hard scatter
- Identify secondary vertices in b-jets with high efficiency and purity
- Measure the tracks in the cores of high energy jets with high efficiency
- Ensure a low rate for reconstruction of fake tracks
- Reconstruct the tracks associated with converted photons
- Be able to reconstruct and trigger on tracks out to the largest pseudo-rapidity
- Minimize the inactive material in the detector volume
- Input to a track trigger run at Level-1 (talk by Nikos yesterday)

ITk - Radiation Fluences : 1 MeV n_{eq} cm^{-2}

216kGy , 5.3x10^{14}n cm^{-2}

63kGy , 2.9x10^{14}n cm^{-2}

288kGy , 8.1x10^{14}n cm^{-2}

7.7MGy , 1.4x10^{16}n cm^{-2}

0.9MGy , 1.7x10^{15}n cm^{-2}

0.9MGy , 1.8x10^{15}n cm^{-2}

Simulations with FLUKA to 3,000 fb^{-1}

ITk Design builds on experience with existing tracker

- However,
  - The pattern recognition, tracking reconstruction and performance requirements at Phase II are more challenging
  - The ITk will be an all silicon design and extend to higher rapidities
  - It will be more radiation tolerant
  - It might use new sensor technologies possibly including CMOS/MAPS (talk by Tobias)
  - It will use <u>lower power electronics</u> (130nm GF-strips and 65nm TSMC-pixels, Alex, Tobias)
  - <u>Exploit DC-DC and Serial Powering</u> for Front-End electronics (talks Laura and Peter yesterday)
  - <u>HV multiplexing</u> (talk by Peter yesterday)
  - <u>Challenges in data transmission at low mass</u> (talk by Martin yesterday)
  - <u>More efficient use of higher bandwidth optical links</u>
  - <u>It will use CO2 cooling</u> (new environmental challenges)
  - ***Lower mass construction***
  - It will use new readout technologies and architecture
  - It has to be installed differently
 - The access and maintenance constraints are more challenging
  - …

ITk Design builds on experience with existing tracker

- However,
  - The pattern recognition, more challenging
  - The ITk will be an all silic
  - It will be more radiation
  - It might use new sensor
  - It will use <u>lower power</u>
  - <u>Exploit DC-DC and Seria</u>
  - <u>HV multiplexing</u> (talk by
  - <u>Challenges in data trans</u>
  - <u>More efficient use of hig</u>
  - <u>It will use CO2 cooling</u> (
  - ***Lower mass constructio***
  - It will use new readout
  - It has to be installed diff
  - The access and mainten
  - …
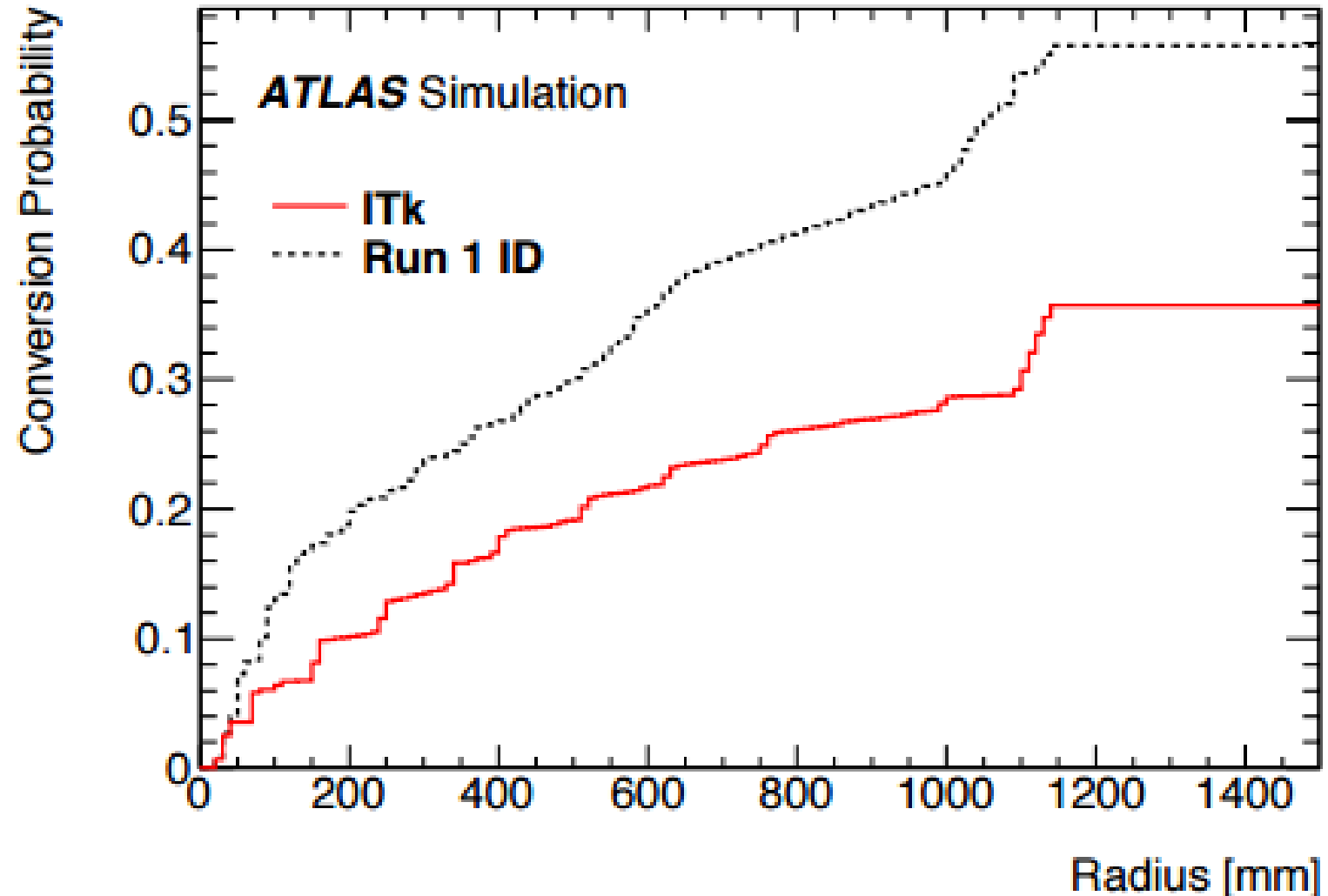
Detector Challenges: cooling at small radius...
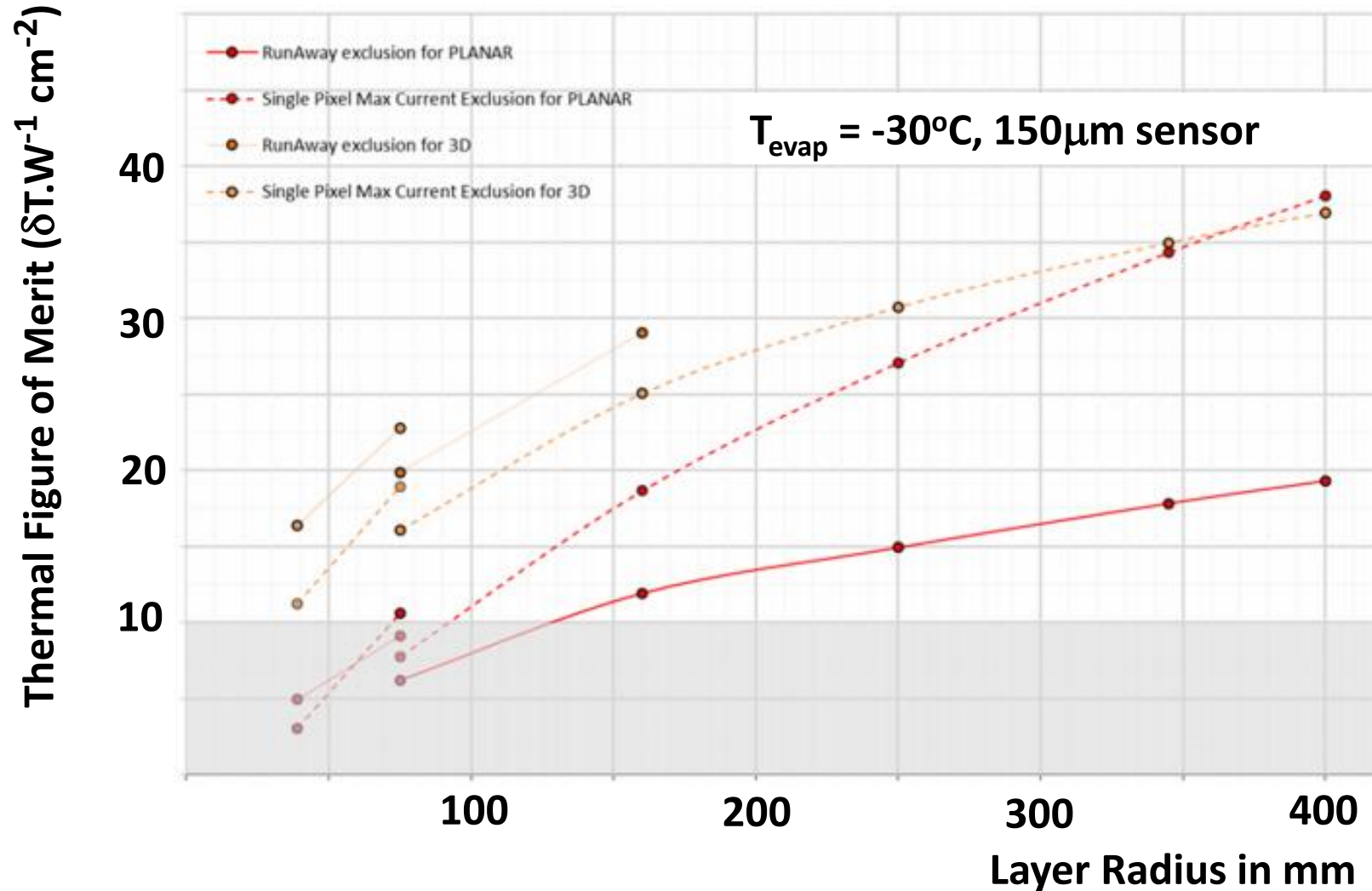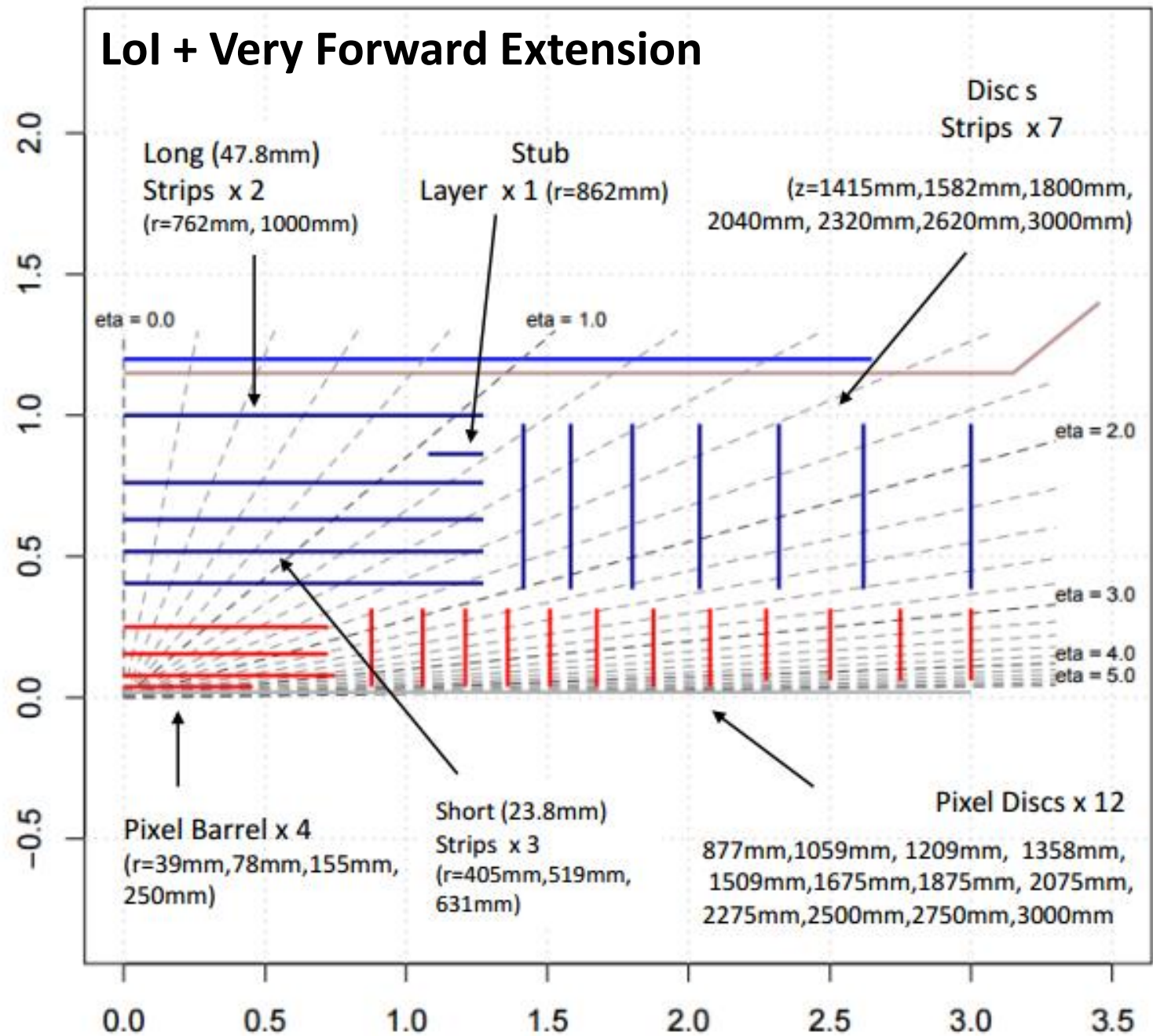
Evolution of ITK including layouts

- Phase II - Letter of intent (December 2012)
  http://cds.cern.ch/record/1502664?ln=en

- ATLAS ITk Initial Design Report (Internal-October 2014)
  Internal

- ATLAS Scoping document (September 2015)
  https://cds.cern.ch/record/2055248?ln=en
  Cost vs performance of tracker studied in detail
  Compare 3 tracking detectors

The reference tracking detector presented in the scoping document : https://cds.cern.ch/record/2055248?ln=en

LoI + Very Forward Extension

Long (47.8mm)
Strips x 2
(r=762mm, 1000mm)

Stub
Layer x 1 (r=862mm)

Disc s
Strips x 7

(z=1415mm,1582mm,1800mm,
2040mm, 2320mm,2620mm,3000mm)

eta = 0.0

eta = 1.0

eta = 2.0

eta = 3.0

eta = 4.0
eta = 5.0

Pixel Barrel x 4
(r=39mm,78mm,155mm,
250mm)

Short (23.8mm)
Strips x 3
(r=405mm,519mm,
631mm)

Pixel Discs x 12

877mm,1059mm, 1209mm, 1358mm,
1509mm,1675mm,1875mm, 2075mm,
2275mm,2500mm,2750mm,3000mm

McMahon : Layout of the ITk; ACES 16

8

Motivations for the extension in acceptance
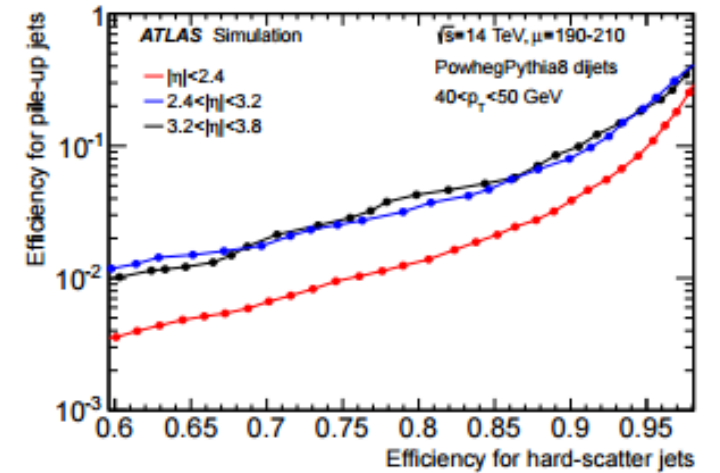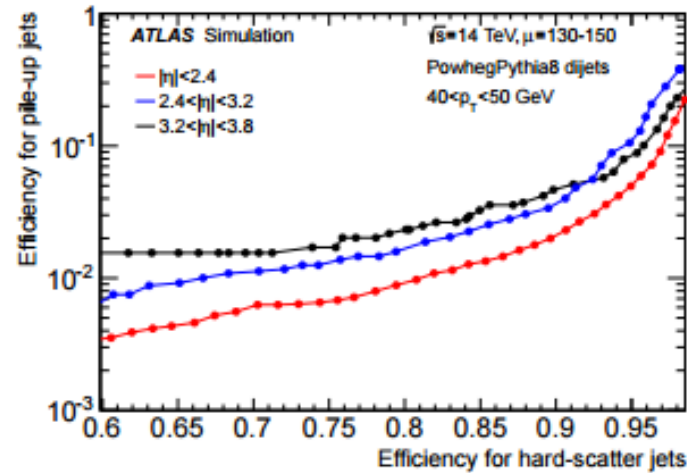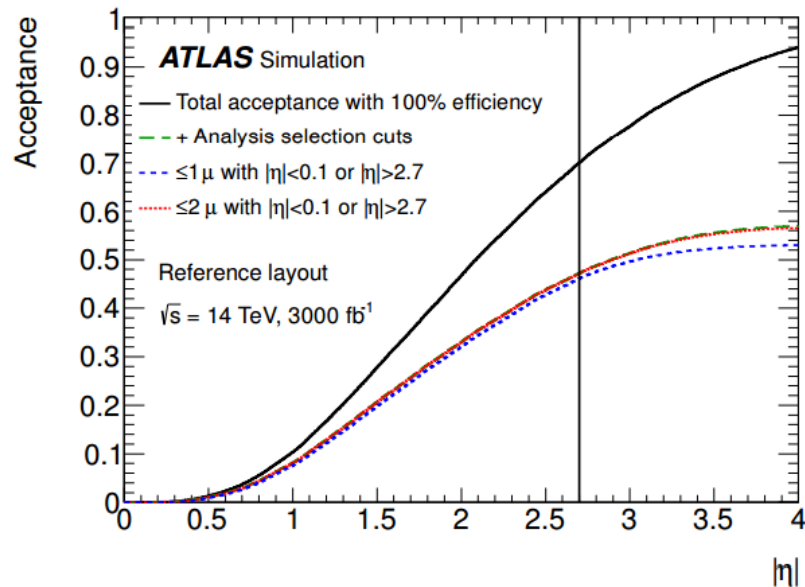
Figure 87. The efficiency for pile-up jets as a function of the efficiency for hard-scatter jets with $40 < p_T < 50$ GeV using a track-matching algorithm for $\mu = 140$ (left) and $\mu = 200$ (right). The algorithm can be applied in $|\eta| < 2.4$ the Low scenario, $|\eta| < 3.2$ in the Middle scenario and $|\eta| < 3.8$ in the Reference scenario.

https://cds.cern.ch/record/2055248?ln=en

New Layouts : Extended 4.0 (3.2 also under study)
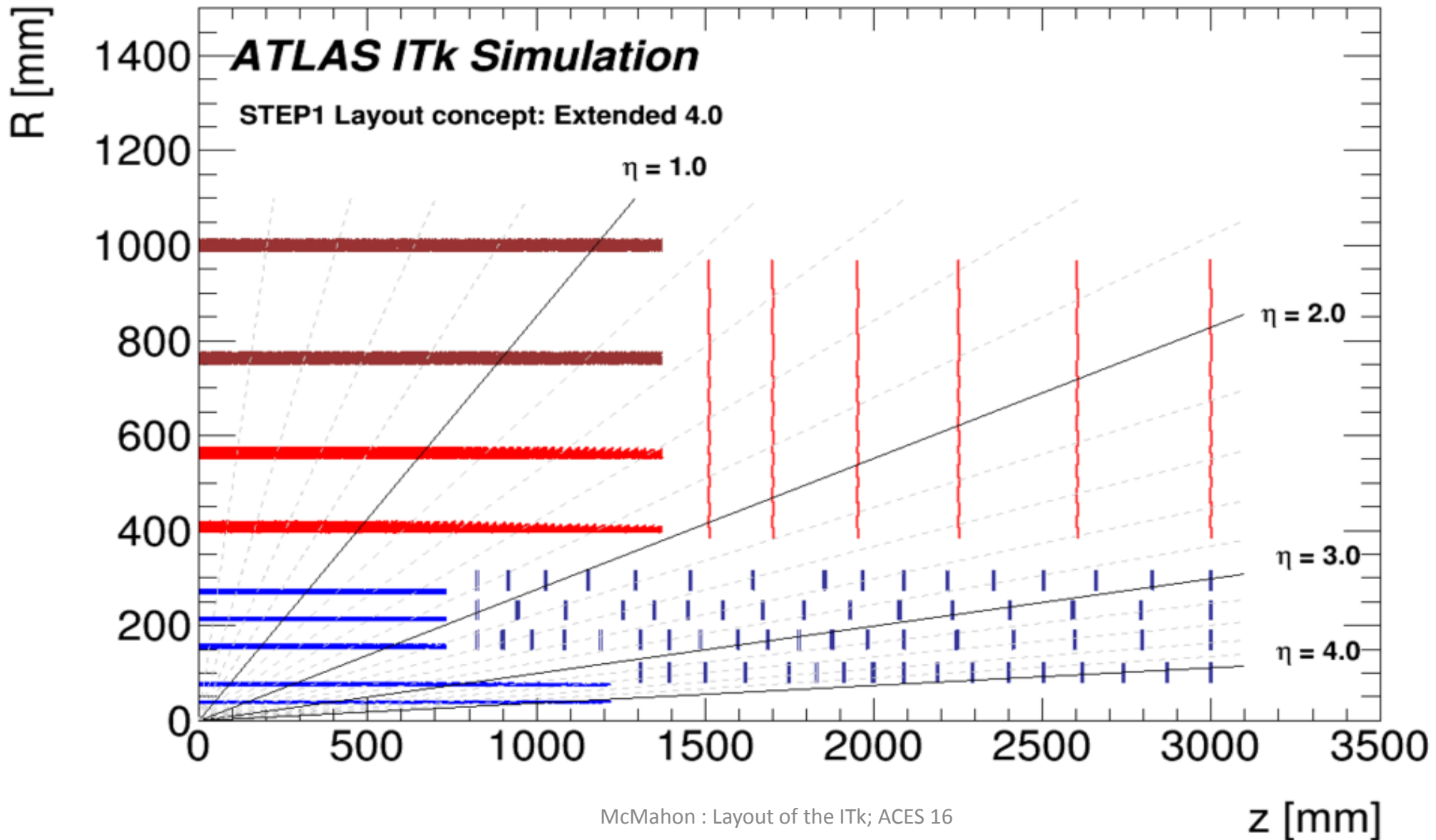
New Layouts : Inclined 4.0 (3.2 also under study)
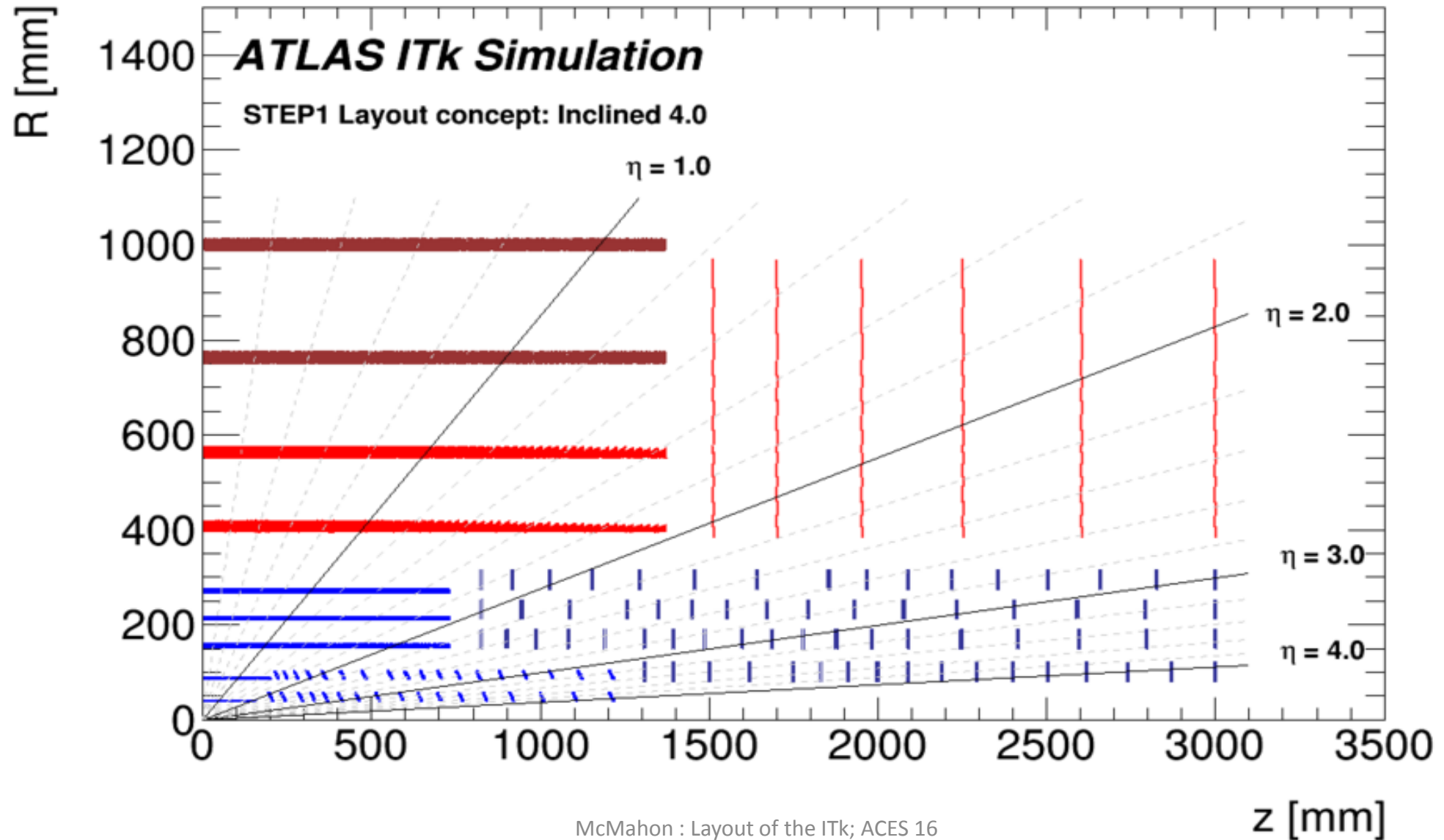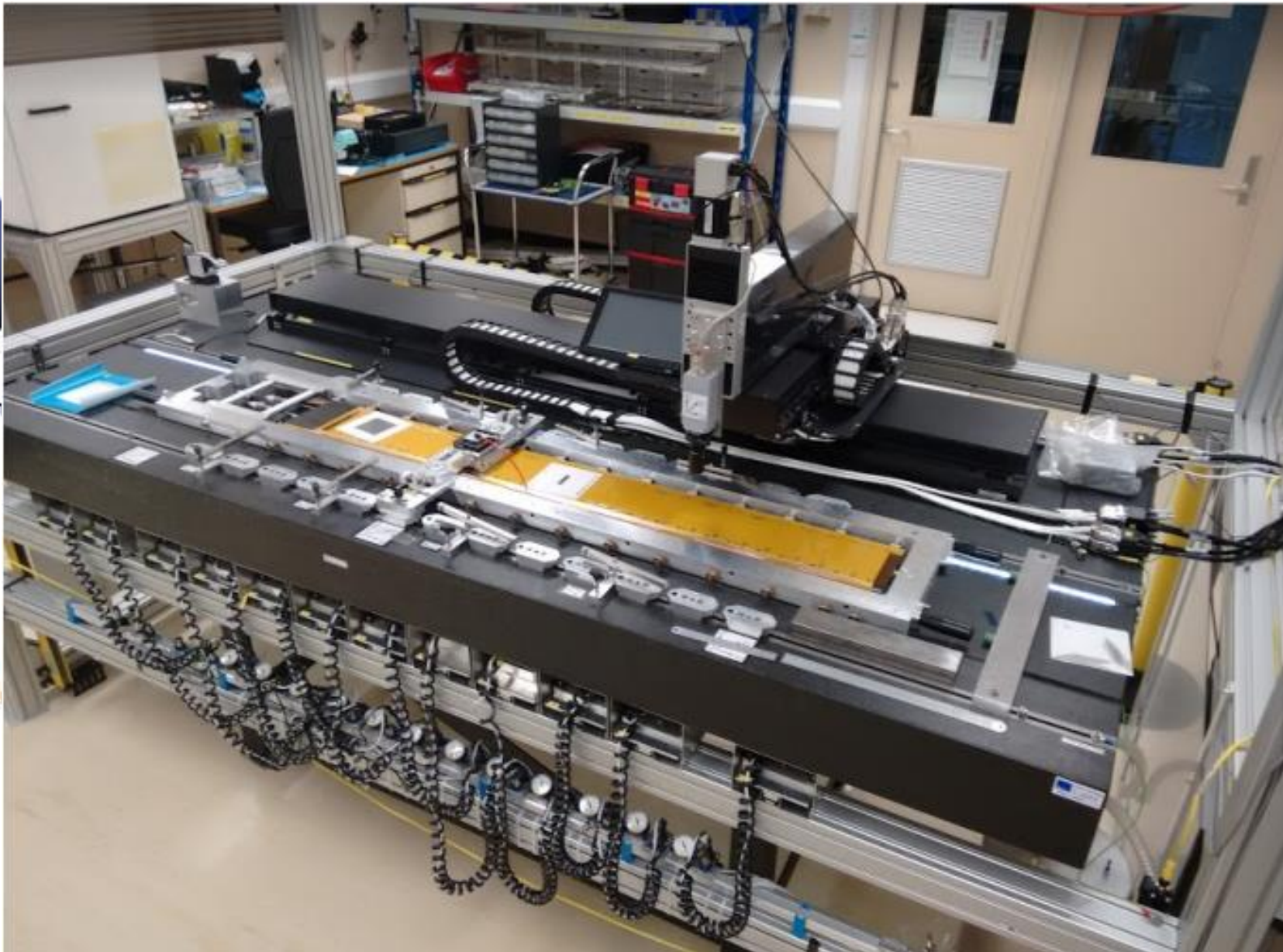
ITk Strips

Barrel support points
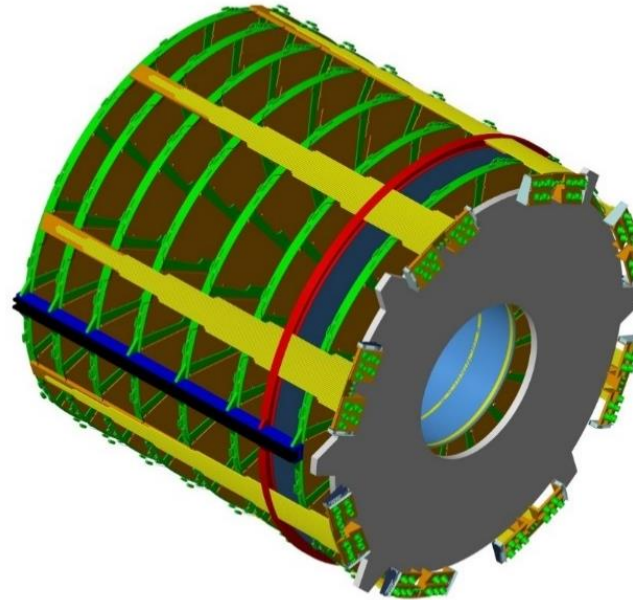
Barrel end flange
(size varies)

Interlinks, one per
stave all identical

Barrel reinforcement
rings not shown
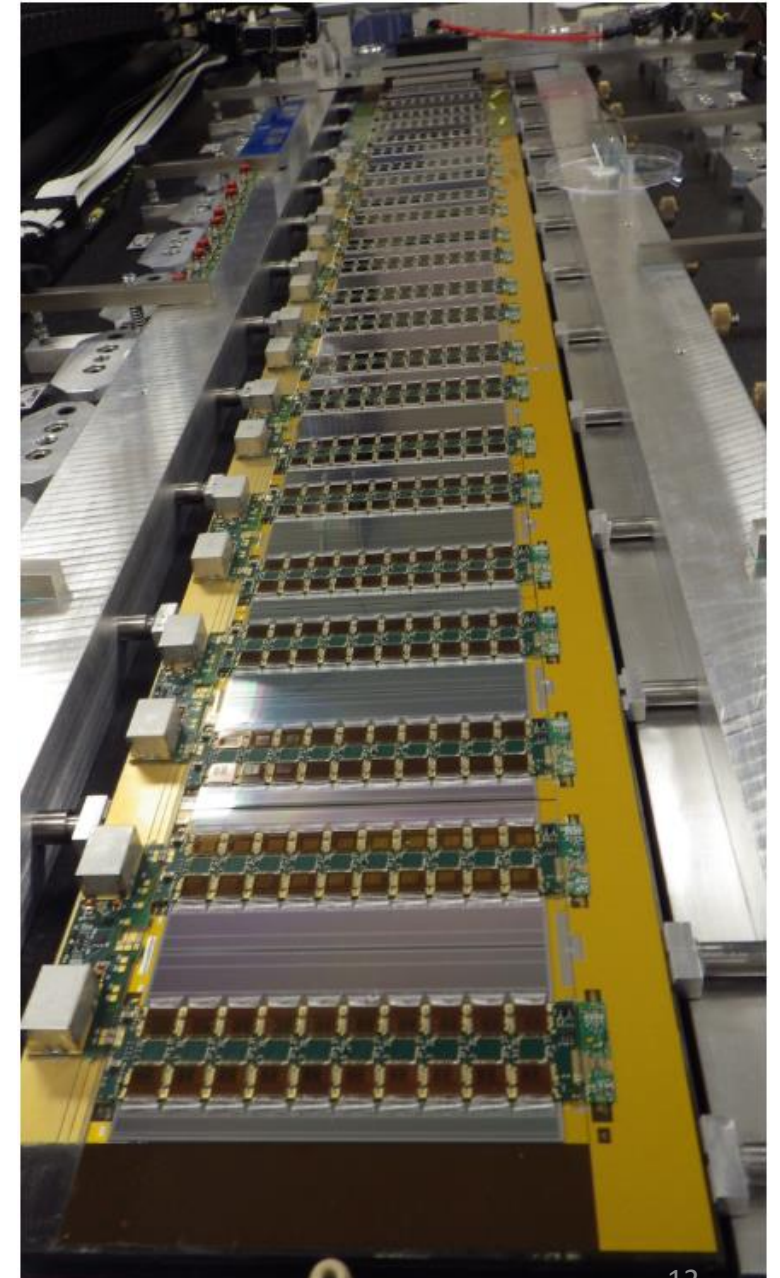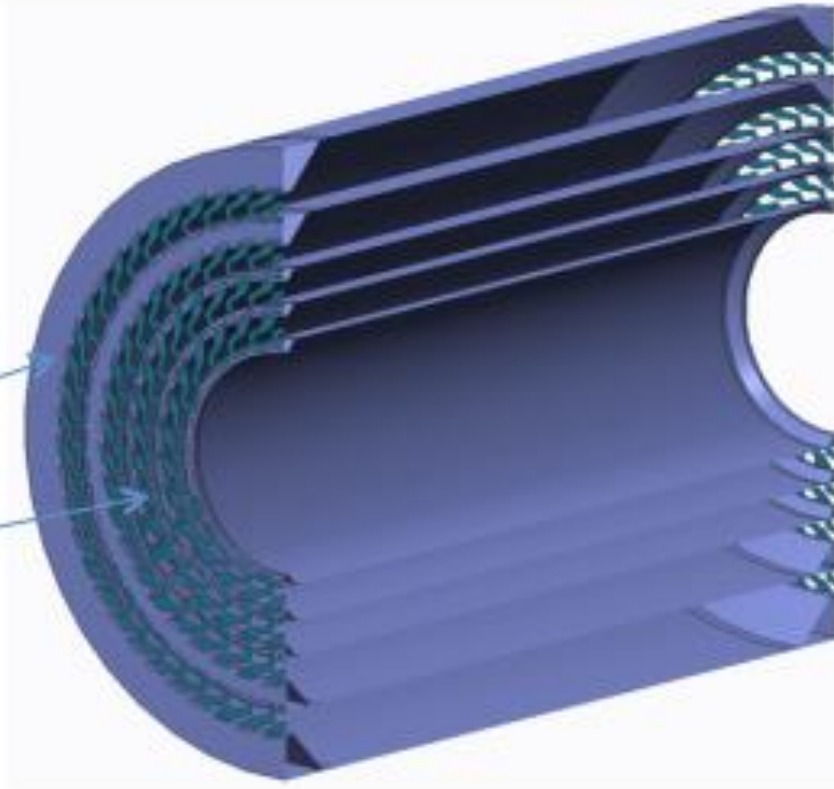
See talk by Alex Grillo later this morning

McMahon : Layout of the ITk; ACES 16

ITk Strips

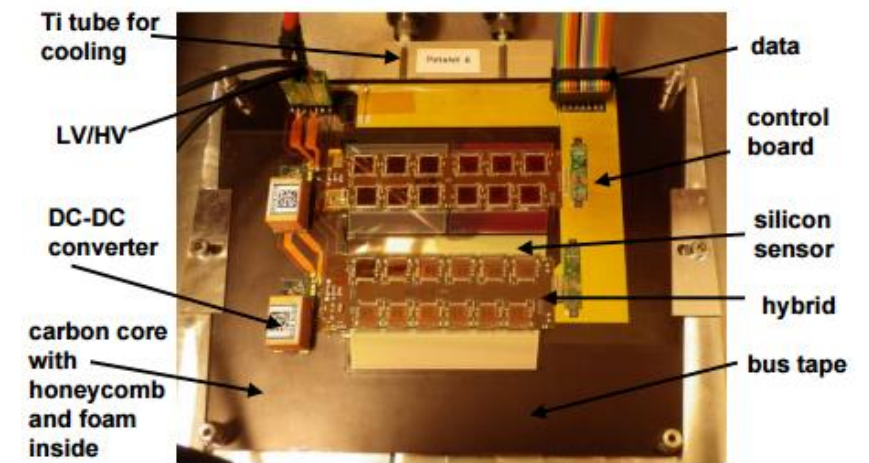

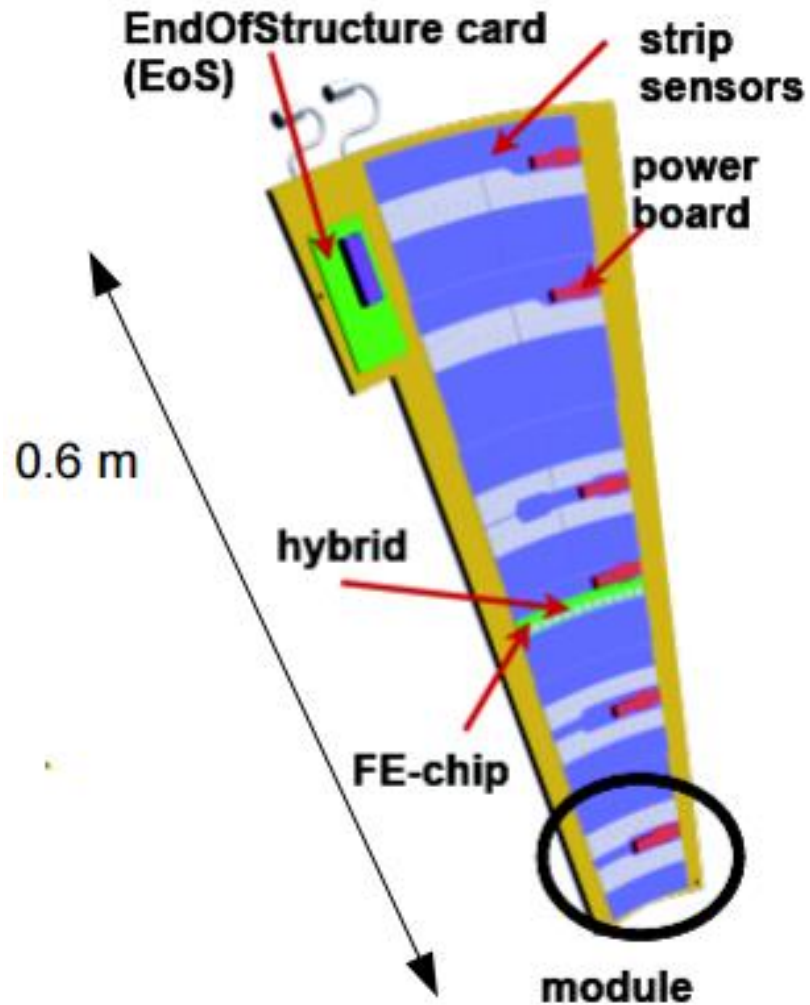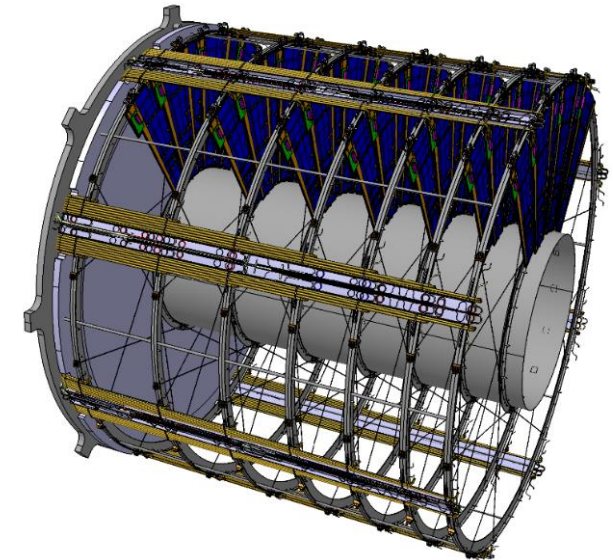Barrel support poin

Barrel end flange
(size varies)

Interlinks, one per
stave all identical

Barrel reinforceme
rings not shown

See talk by Alex Grillo later this morning

ITk Strips

EndOfStructure card (EoS)

strip sensors

power board

0.6 m

hybrid

FE-chip

module

Ti tube for cooling

LV/HV

DC-DC converter

carbon core with honeycomb and foam inside

data

control board

silicon sensor

hybrid

bus tape

CF blades are single units.
CF structure to hold blades.

CF wheels with spokes are single units.
Wheels are put on inner tube.
Petals are mounted on wheels.

See talk by Alex Grillo later this morning

The Extended Pixel Barrel Option

ATLAS ITk Simulation
STEP1 Layout concept: Extended 4.0
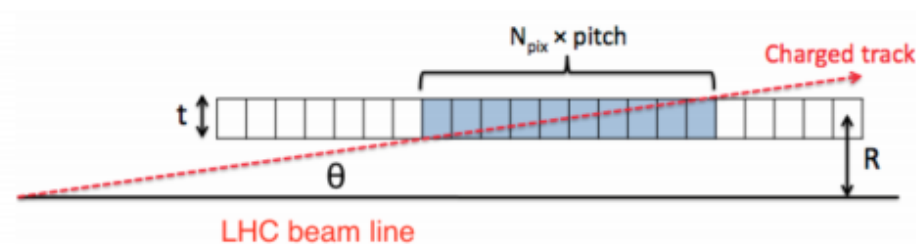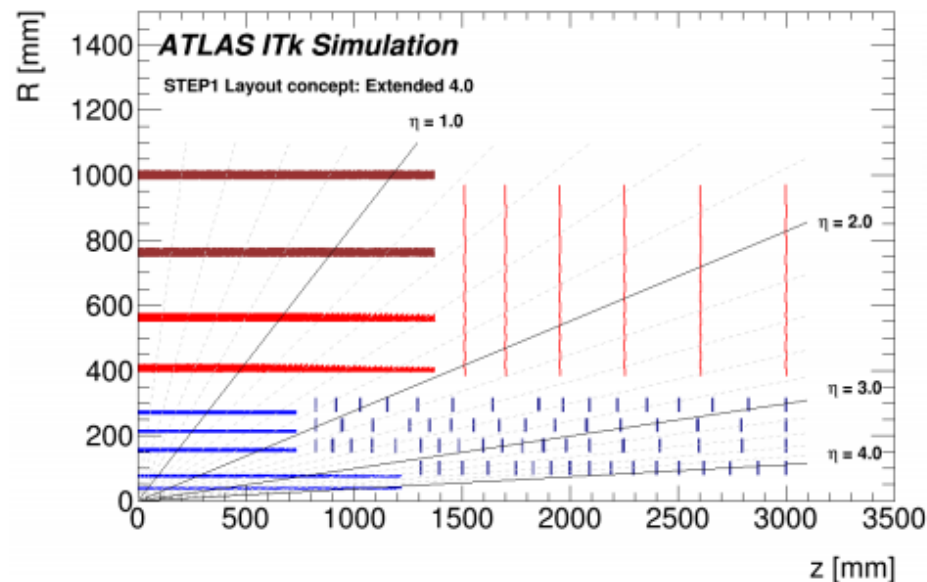
$$\tan\theta = \frac{t}{\left(N_{pix} - \delta\right) \times p}, \quad \delta \approx 1$$

- **Main idea:** long clusters = "tracklets", providing initial precise estimates of θ and z_0
  - Seed pattern recognition
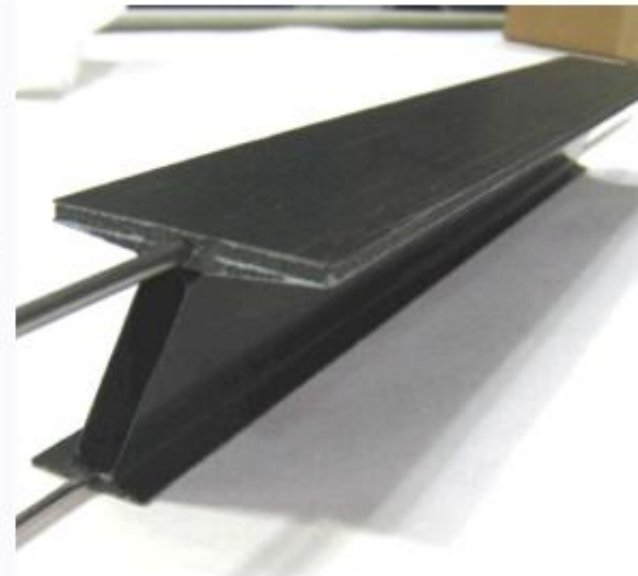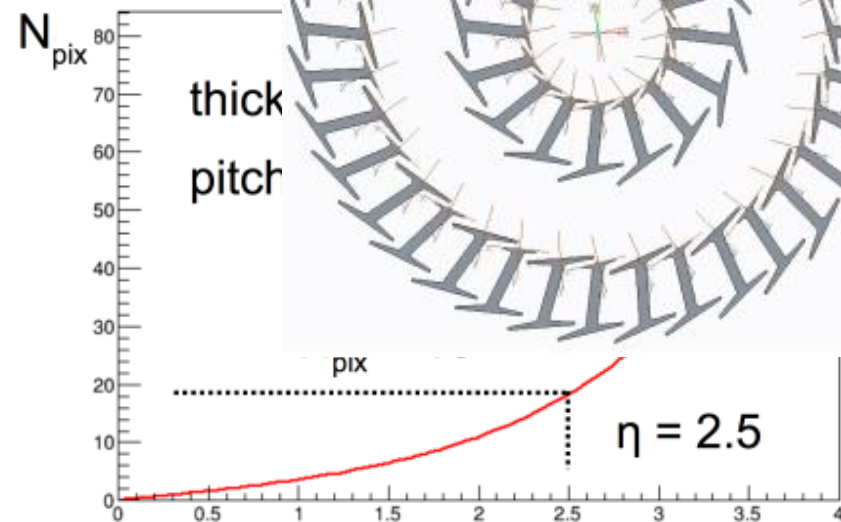 - Potential to reduce fake rate
  - Potential to reduce CPU time
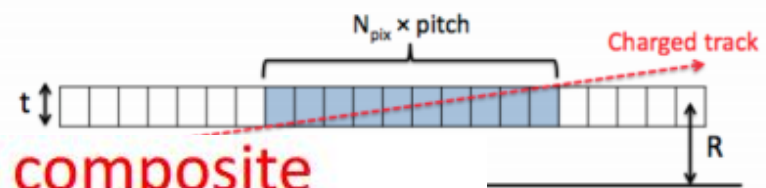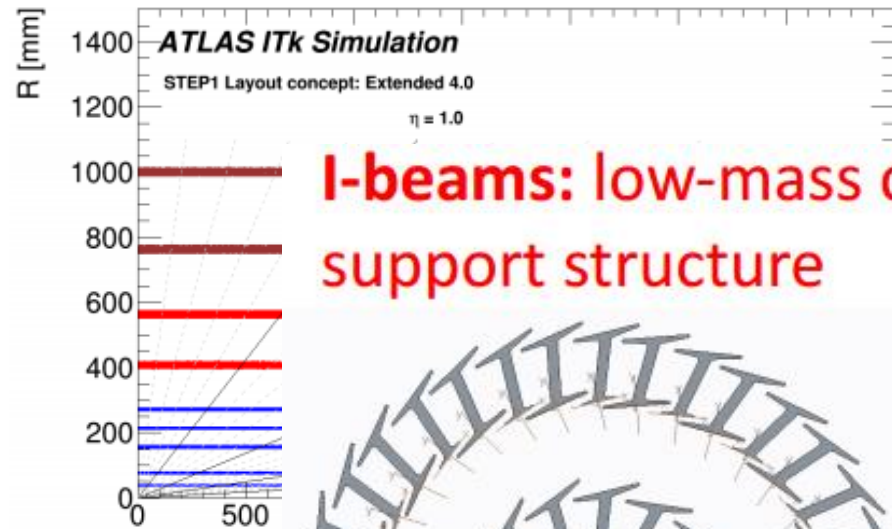
thickness = 150 μm

pitch = 50 μm

N_{pix} = 18

η = 2.5
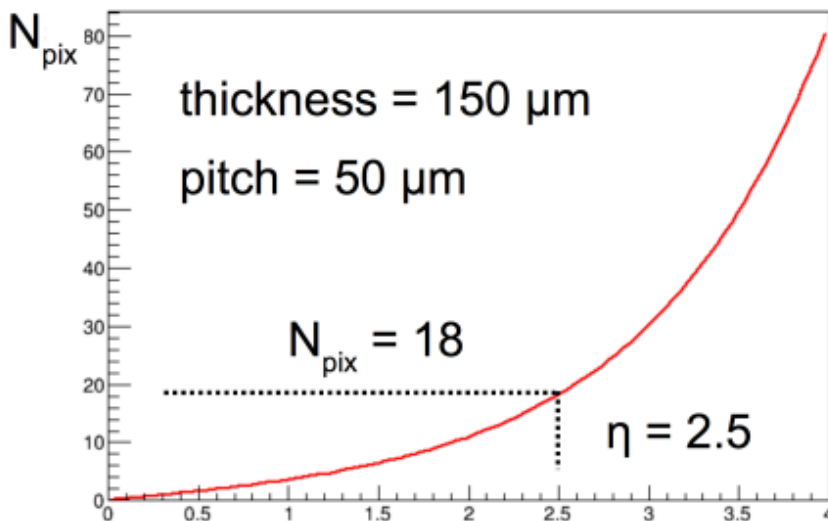
Basic information about sensors:
Barrel Layer-0,1 & inner end-cap ring: $50 \times 50 \times 100$ μm^3
Barrel Layer-2,3,4 & end-cap: $50 \times 50 \times 150$ μm^3

Courtesy Sasha Pranko

See talk by Tobias Flick later this morning

The Extended Pixel Barrel Option

I-beams: low-mass carbon composite support structure

ATLAS ITk Simulation
STEP1 Layout concept: Extended 4.0
$\eta = 1.0$

$N_{pix} \times$ pitch

Charged track

≈ 1

"tracklets", timates of θ

rate
time

thick

pitch

$\eta = 2.5$

$0 \times 50 \times 100$ μm^3

Barrel Layer-2,3,4 & end-cap: $50 \times 50 \times 150$ μm^3
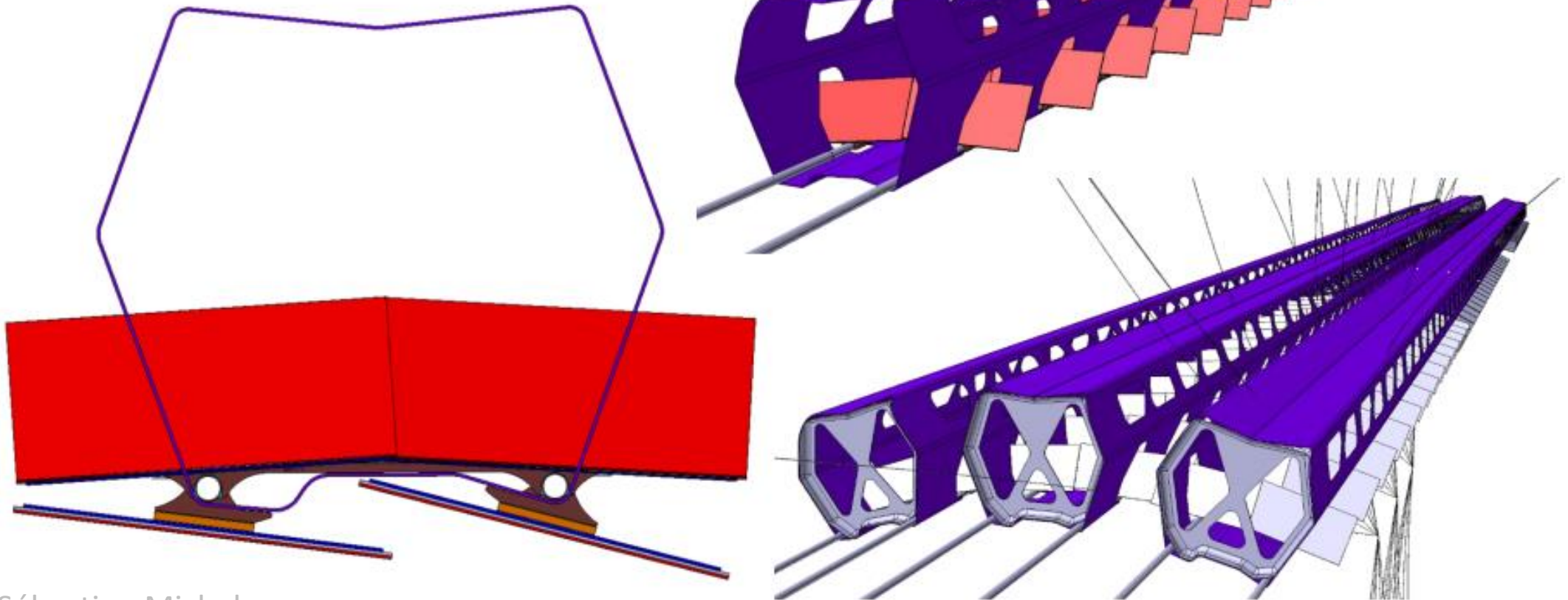
Courtesy Sasha Pranko

The Extended Pixel Barrel Option
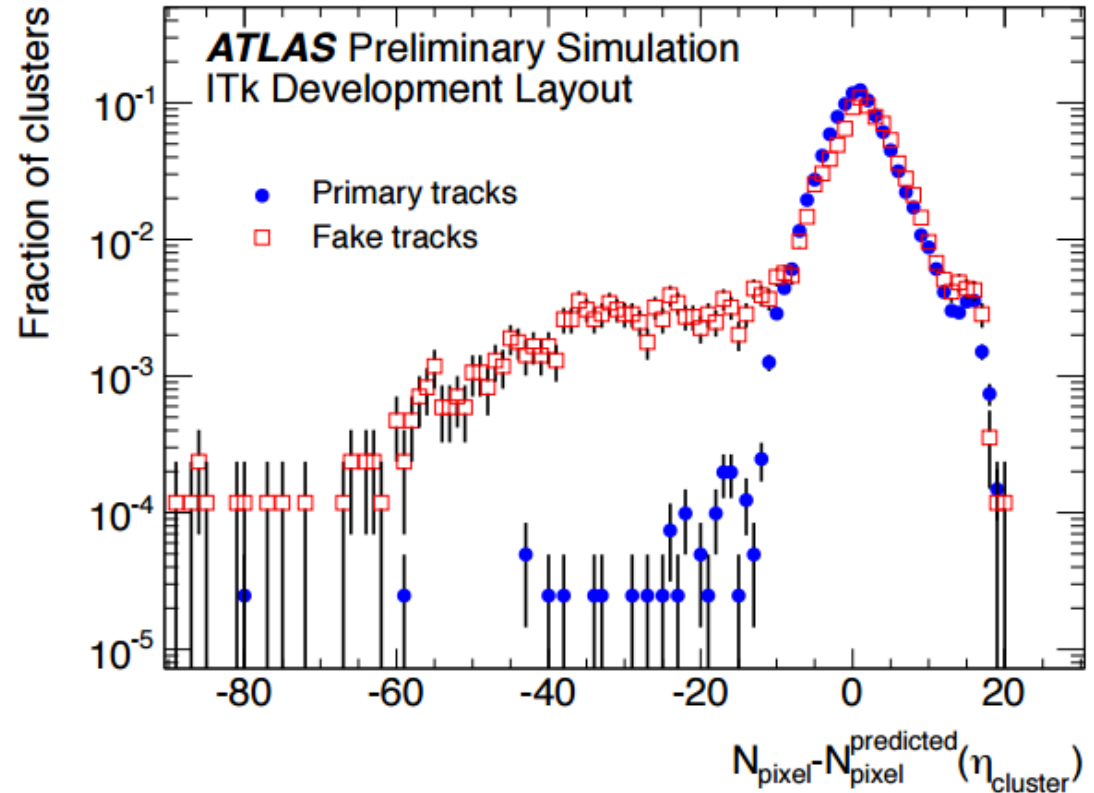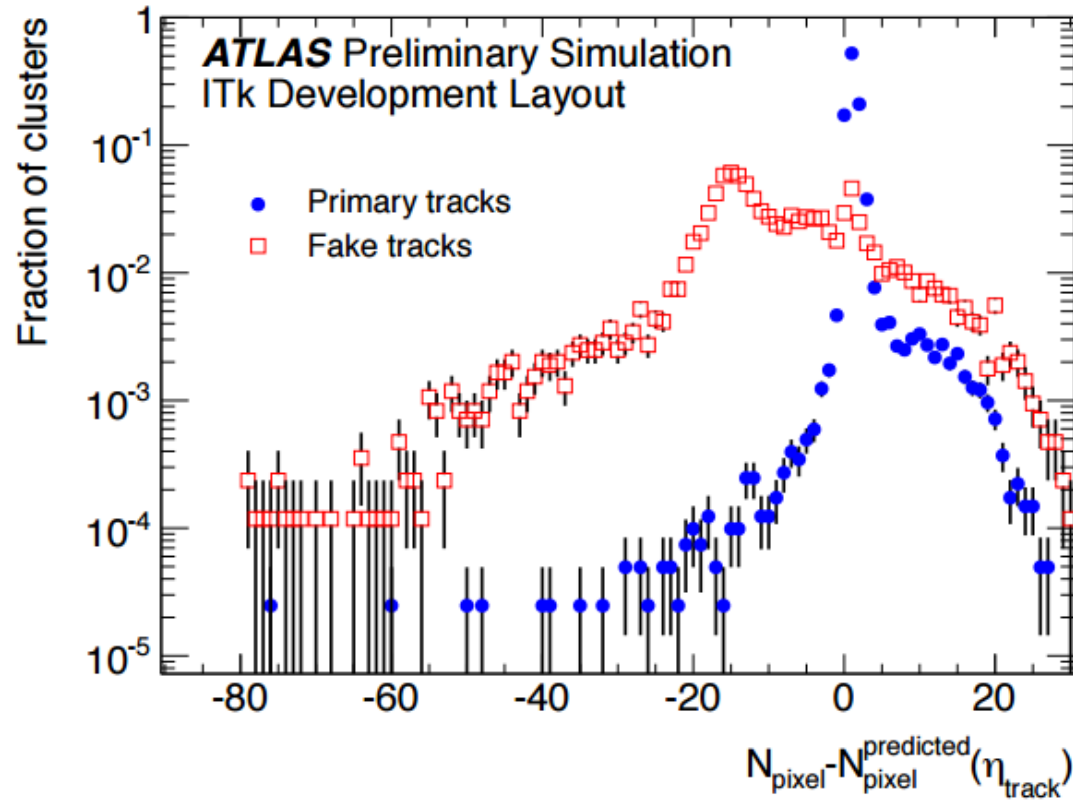
Courtesy Sasha Pranko

Inclined Sensor Option for Pixels: SLIM

- Single skin CFRP 0.325 mm thick [0, 45, 90, -45, 0]
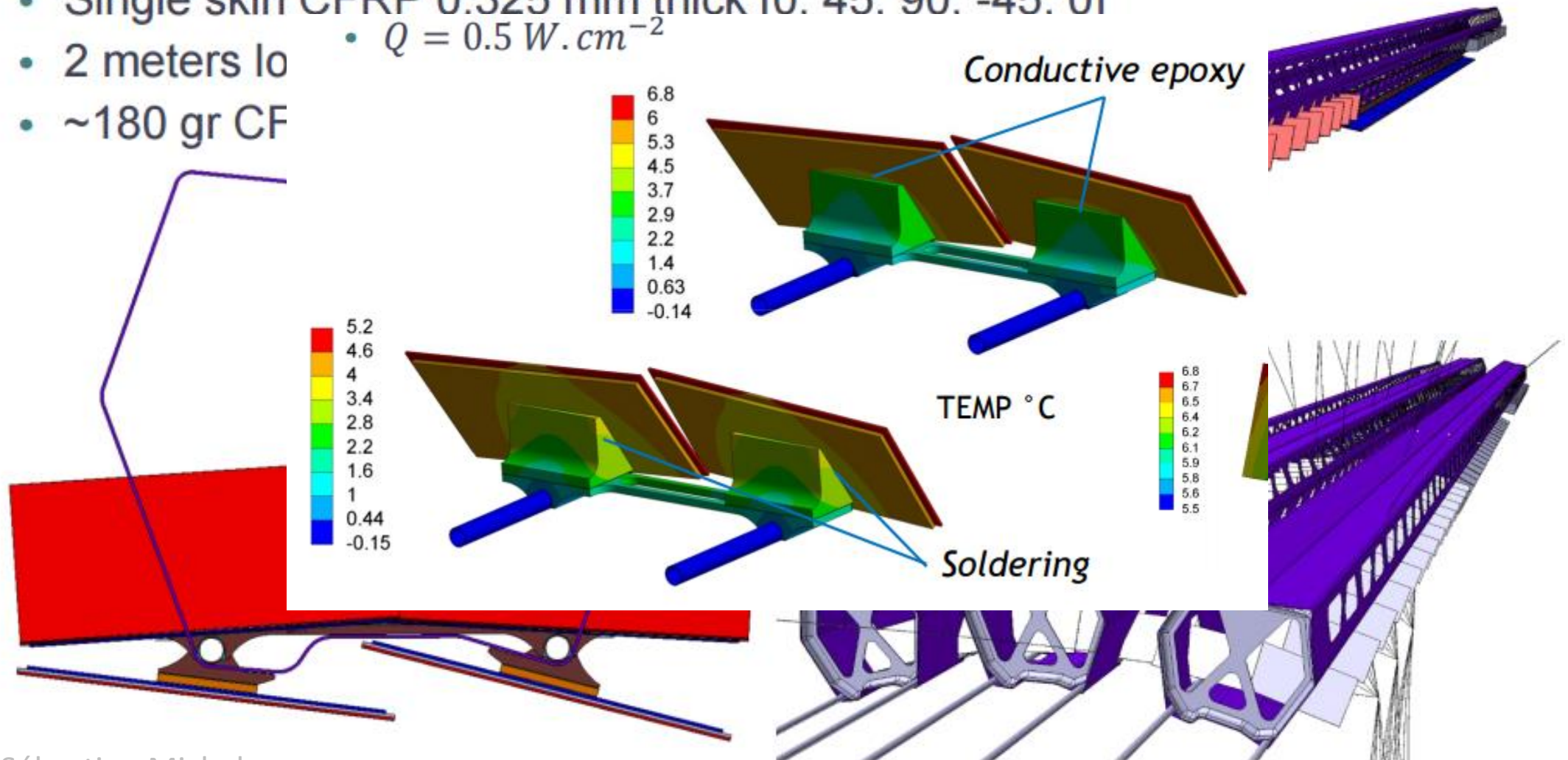- 2 meters long (5th layer)
- ~180 gr CFRP skin

Inclined Sensor Option for Pixels: SLIM

- Single skin CFRP 0.325 mm thick [0. 45. 90. -45. 0]
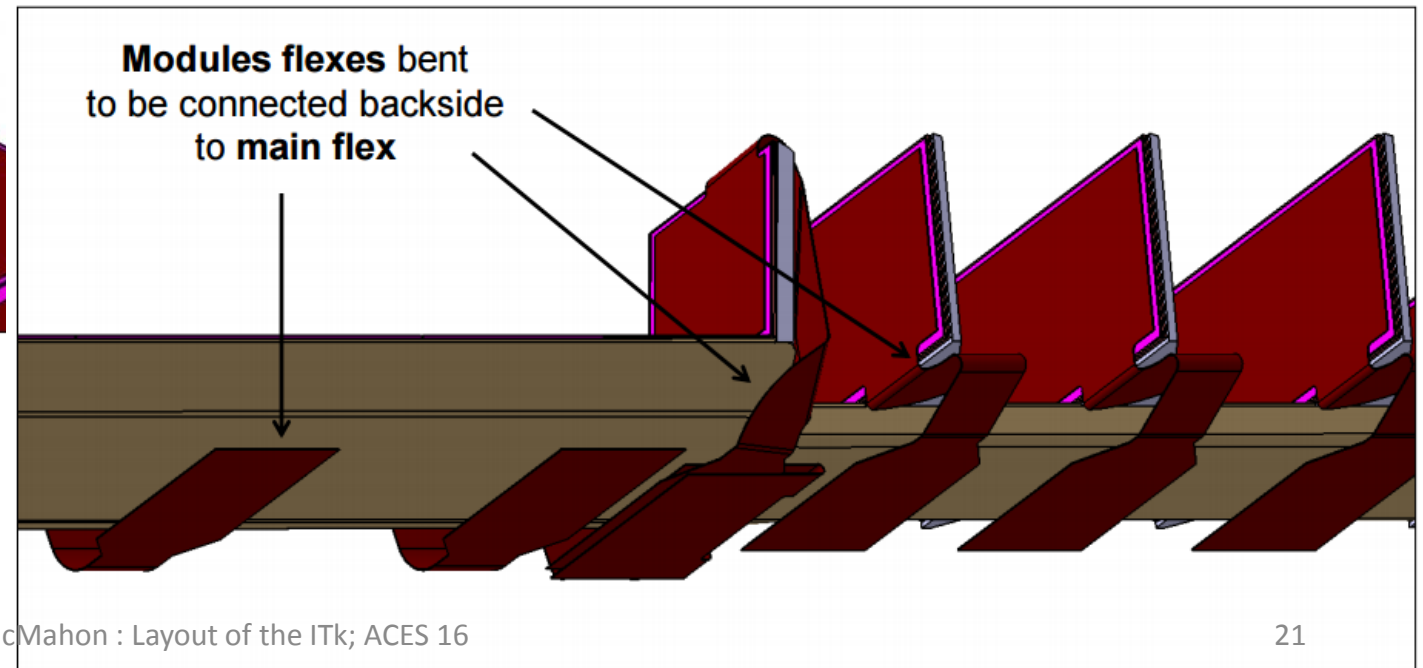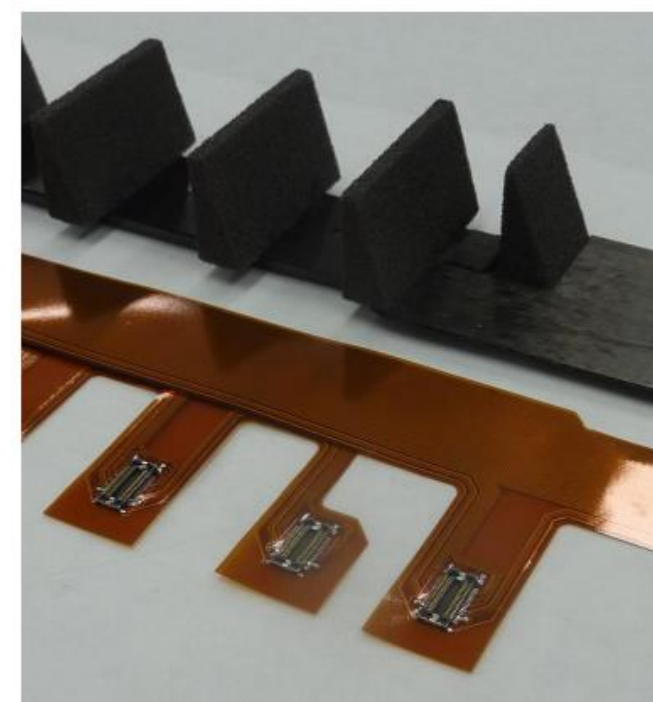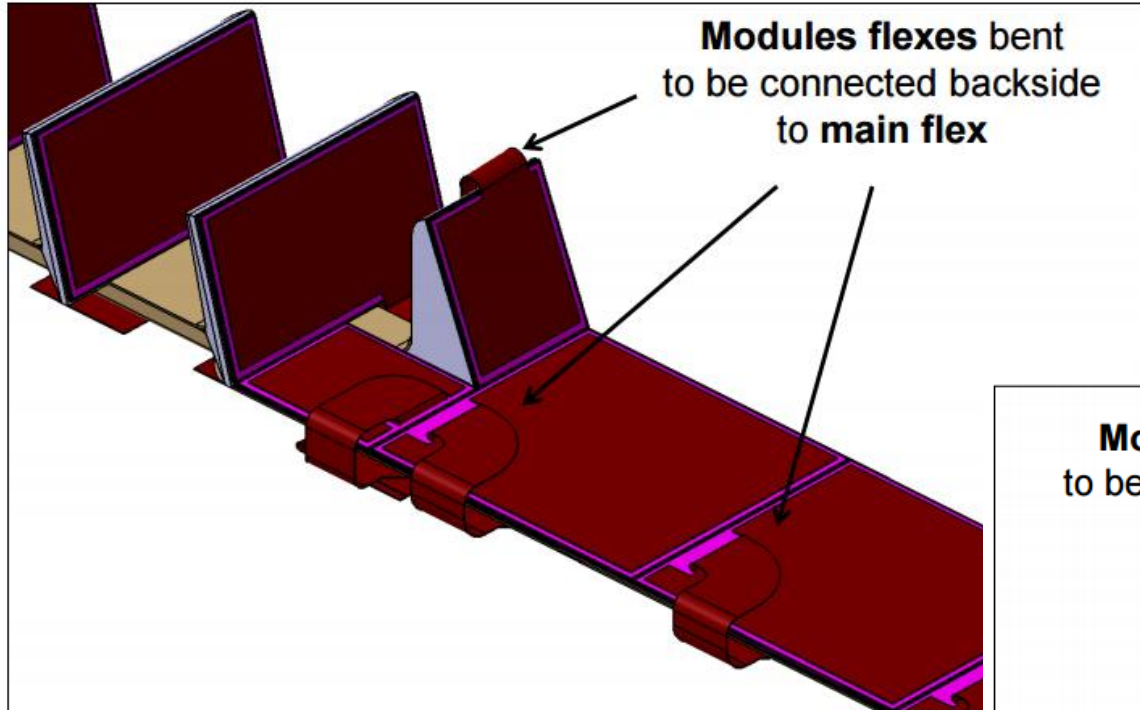- 2 meters lo
- ~180 gr CF

$$Q = 0.5 \, W.cm^{-2}$$

Conductive epoxy

TEMP °C

Soldering

Inclined Sensor Option for Pixels: SLIM

ITk Pixel Inclined Sensor Option: ALPINE

Modules flexes bent to be connected backside to main flex

ITk Pixel Inclined Sensor Option: ALPINE
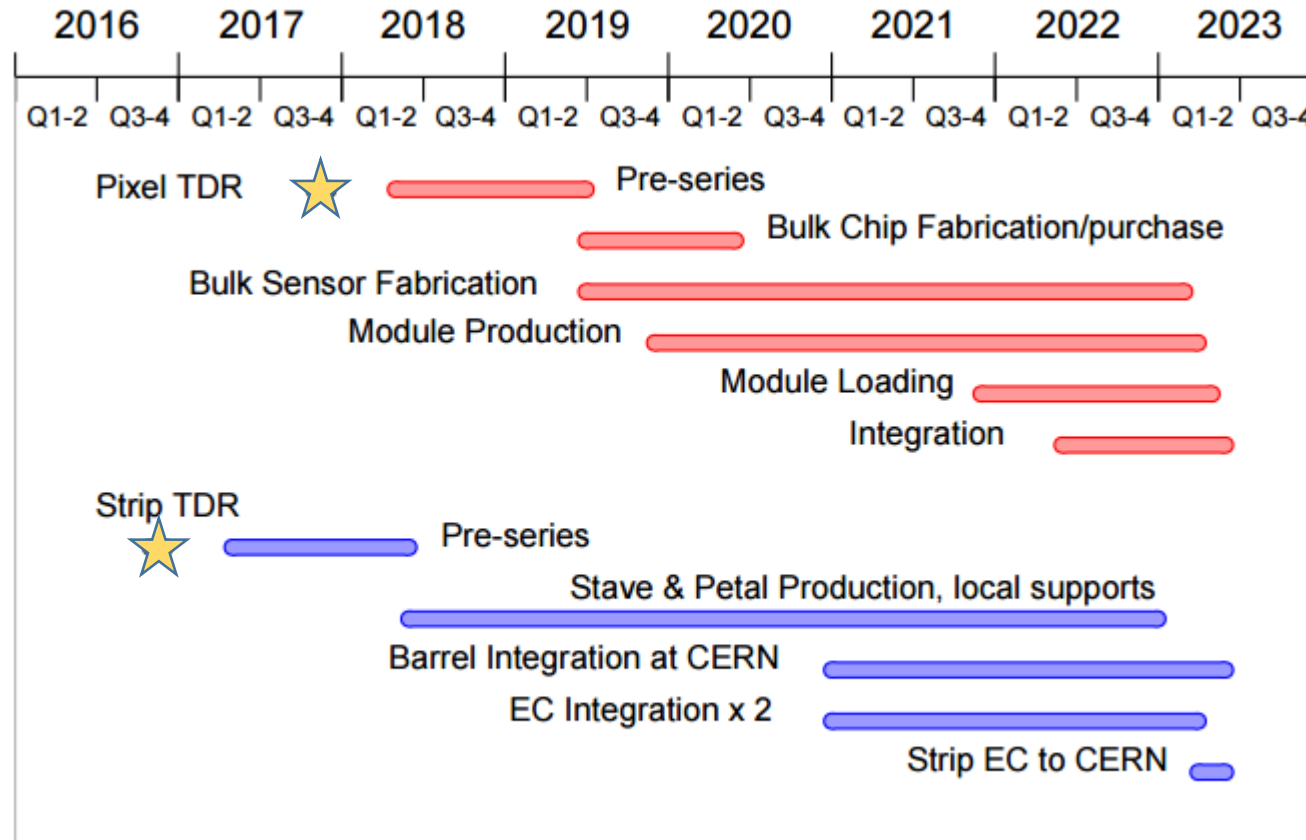

Courtesy ALPINE team
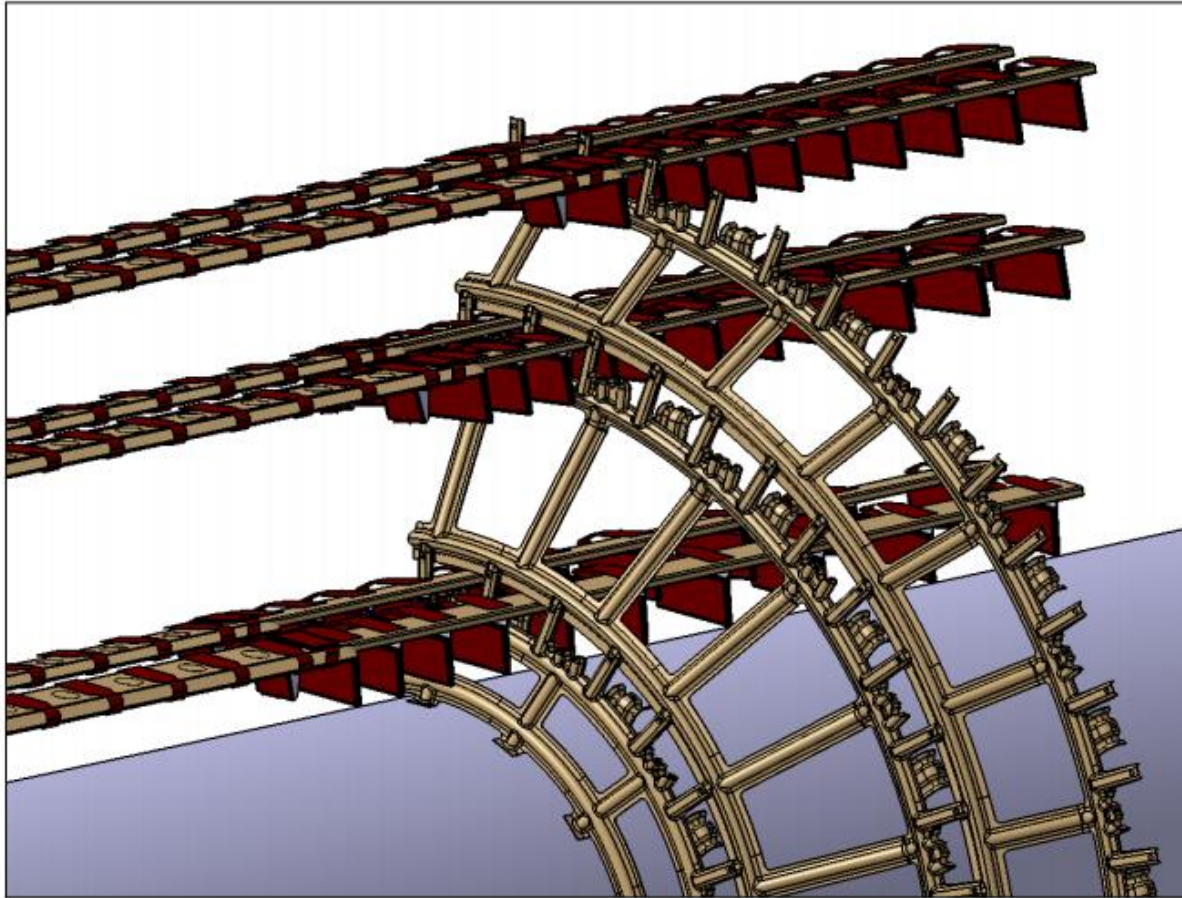
ITk Timeline

- Timeline : End-Game
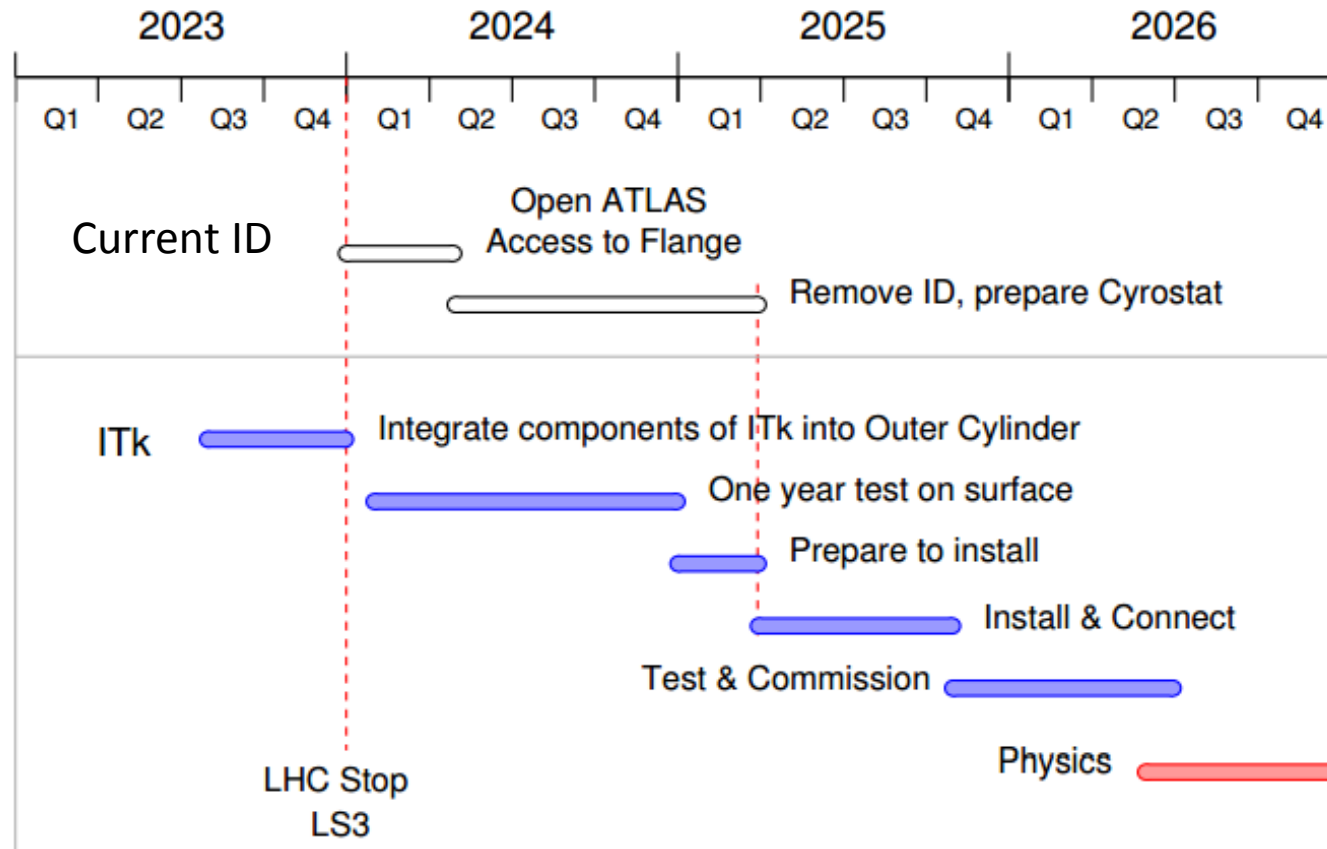
ITk Timeline

- Timeline : TDRs and into production …

Conclusion

- ITk design builds on the positive experience accumulated in the construction of the existing Inner Detector and its operation in Run-1

- However, the new design responds to the unique new challenges that are presented for a tracker to exploit the physics at Phase II

- Development is going very well
  - See talks of Alex and Tobias

- First stage of layout decisions will take place in 2016 (ahead of strip TDR)

- Preparing for TDRs in 2016 and 2017

- Will also deliver an ID decommissioning report at the end of 2017