Incontro EIC_NET con referee INFN

Bologna, August 31 2022

Status R&D e richieste vertex

- EIC tracking: basic design and strategy
- INFN involvement and contribution:
  - ✓ EIC Silicon Consortium, R&D synergies with ALICE ITS3
  - ✓ activity in the EPIC Tracking WG
- plans and financial requests for 2023

Domenico Elia per BA, PD e TS

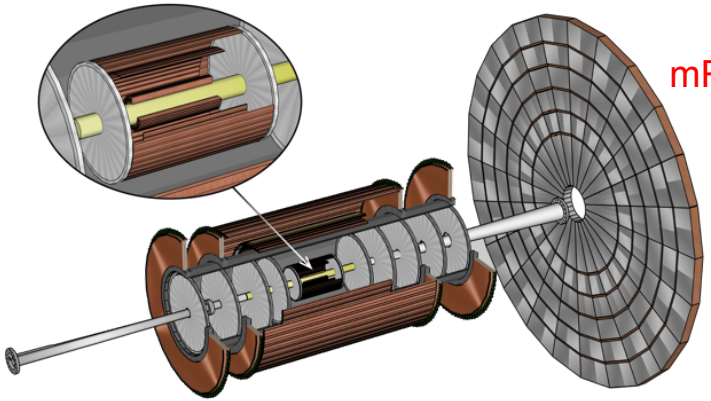
EIC vertex and tracking

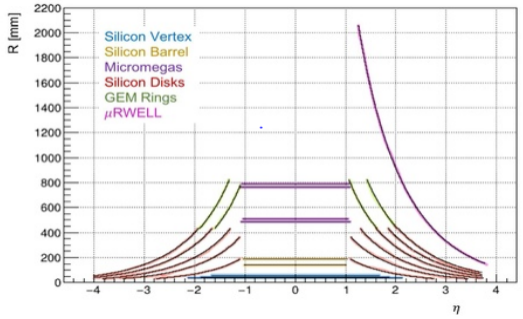
Basics of the design choices:

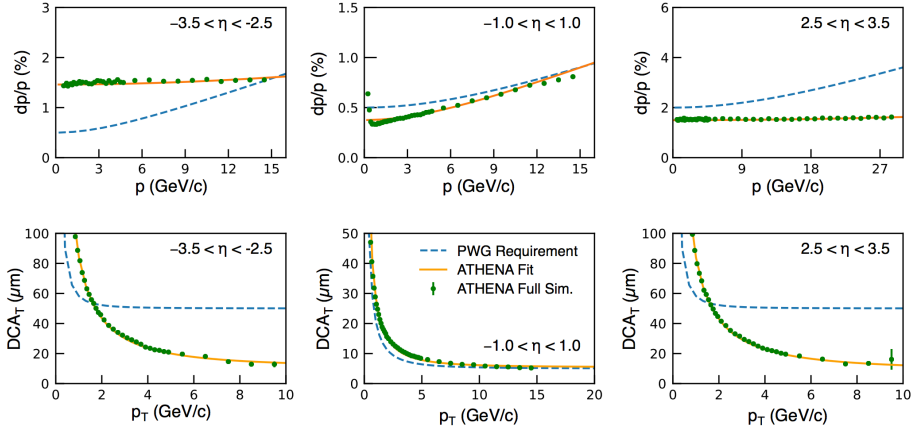
- mostly independent of the detector proposals

ATHENA

- Si Vertex Tracker: 3 layers (R_0~33mm)
- Si inner barrel Tracker: 2 layers
- 5+6 Si Tracker disks (including GEMs)







EIC vertex and tracking

Basics of the design choices:

- mostly independent of the detector proposals
- since April (**ECCE** selected as reference detector from DPAP):
  - ✓ working to optimize ECCE configuration: reference → baseline for TDR
    ongoing within the EPIC Tracking WG (more later in this presentation)

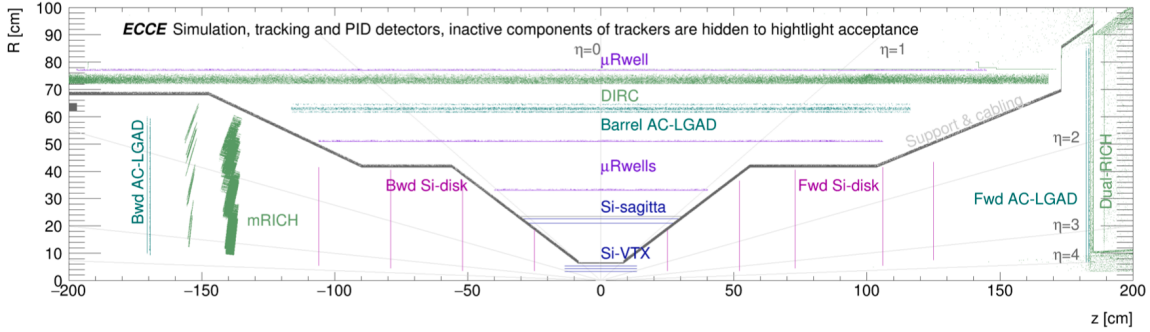


Figure 2.5: Schematic view of the ECCE tracker, including silicon, μRWELL, AC-LGAD, DIRC, mRICH and dRICH detector systems.

EIC vertex and tracking

Basics of the design choices:

- mostly independent of the detector proposals
- since April (ECCE selected as reference detector from DPAP):
  - ✓ working to optimize ECCE configuration: reference → baseline for TDR
- based on the main constraints → ALICE ITS3
  - ✓ vertex layers:
    adopt ALICE ITS3 65 nm CMOS monolithic sensors and ITS3 detector concept
    → crucial interaction with ALICE ITS3 Project to access the technology
  - ✓ sagitta layers and disks:
    create a smaller version of the ITS3 sensor
    develop EIC-dedicated support structures and cooling infrastructure

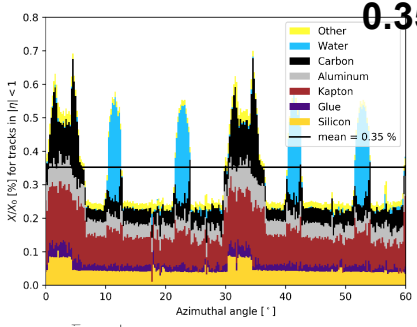
EIC vertex and tracking

ALICE ITS3 sensor and detector concept:

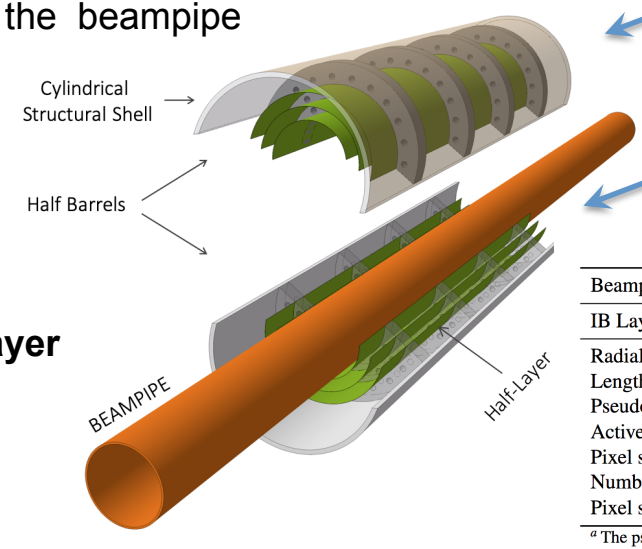
- three layers vertex detector with 0.05% X_0 per layer

Wafer-scale, low-power sensor design in 65 nm CMOS technology, thinned and bent around the beampipe

0.35% X_0 /layer



0.05% X_0 /layer



One sensor on the top half

One sensor on the bottom half

Table 1: Geometrical parameters of the upgraded ITS.

Beampipe inner/outer radius (mm)	16.0/16.5		
IB Layer parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	270	270	270
Pseudo-rapidity coverage[a]	±2.5	±2.3	±2.0
Active area (cm^2)	305	408	508
Pixel sensors dimensions (mm^2)	280×56.5	280×75.5	280×94
Number of pixel sensors / layer	2		
Pixel size (μm^2)	$O(15 \times 15)$[b]		

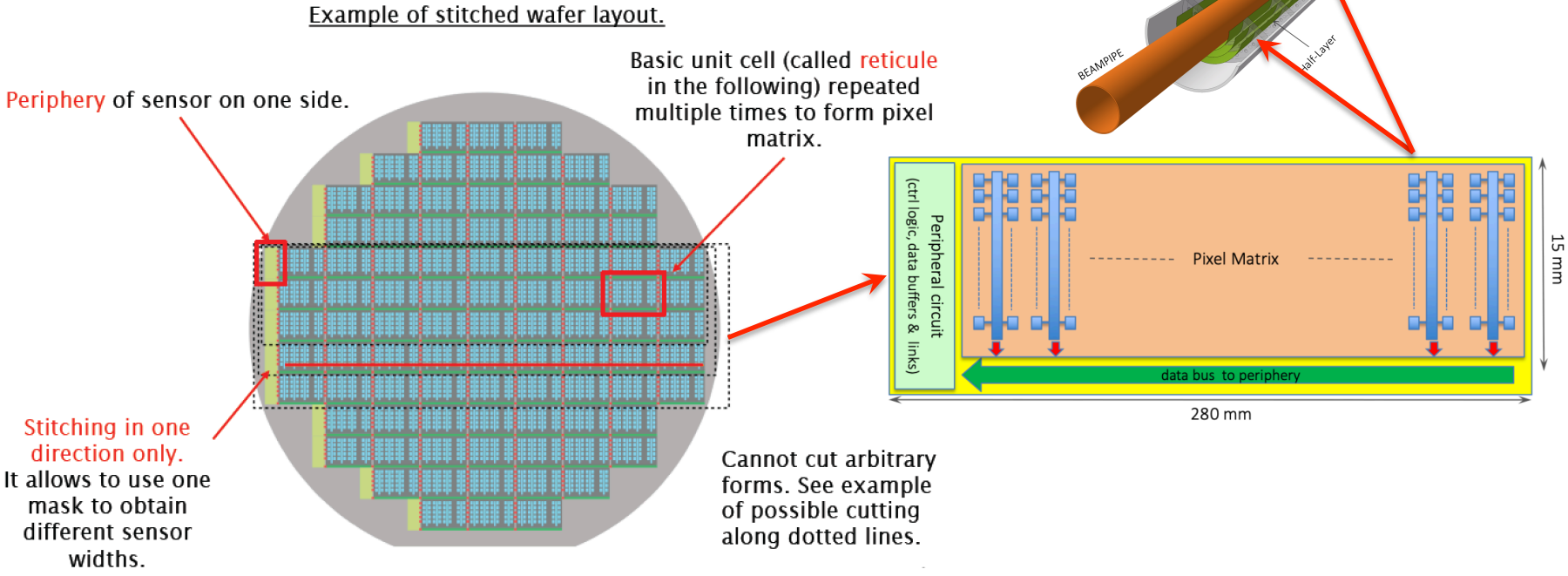
[a] The pseudorapidity coverage of the detector layers refers to tracks originating from a collision at the nominal interaction point ($z = 0$).
[b] For the fallback solution the pixel size is about a factor two larger ($O(30 \times 30)$ μm^2).

https://cds.cern.ch/record/2703140

EIC vertex and tracking

Stitching for the ITS3 sensor:

- deployed to design a wafer scale sensor



EIC Silicon Consortium

Mission and Organizational issues:

- coordinating effort towards the EIC silicon tracker
  - ✓ supported the three detector proposals (ATHENA, ECCE, CORE), now for EPIC
  - ✓ open to all the EIC interested groups and institutions
- weekly Coordination meetings, on Monday @1pm EDT:
  - ✓ indico: https://indico.bnl.gov/category/387/
  - ✓ promoting activity progress and coordinating institutional relashionship
  - ✓ people: **G. Contin** (INFN Trieste), G. Deptuch (BNL), L. Greiner (LBL), **D. Elia** (INFN Bari), L. Gonella (Birmingham), P. Jones (Birmingham), I. Sedgwick (RAL), E. Sichtermann (LBL)
- bi-weekly General meetings (eic-rd-silicon-l@lists.bnl.gov):
  - ✓ indico: https://indico.bnl.gov/category/386/
  - ✓ SC activity progress reports (including activity for projects eRD104 and eRD111 so far)
  - ✓ involving participants and presenters by the different groups
  - ✓ latest meeting: August, 29 (discussion of eRD proposals for FY23, incoming deadline)

EIC Silicon Consortium

Main lines of actions:

- promoting institute's participation in the ITS3 activities
  - ✓ sensor design: participation partially started (only RAL)
  - ✓ sensor characterization: test systems requested, shadowing other groups
  - ✓ ITS3 project leaders and conveners well aware of the SC interests
    → formalization depends on higher level agreements, work ongoing
- promoting MoU between ALICE/CERN and EIC/DOE
  - ✓ contacts with Luciano Musa, Elke Aschenauer and Rolf Ent started last summer
  - ✓ progress with recent meetings @ CERN (last one at beginning of June)
  - ✓ finally relashionships should be regulated by CERN/DOE agreements
- funding and planning resources
  - ✓ contribute to the ALICE ITS3 developments of common interest
  - ✓ support EIC-specific developments
  - ✓ more on EIC R&D program → next slides

EIC tracking R&D program

SC participates in the following eRD for FY22:

- eRD104 – Silicon services reduction
  - ✓ Powering & readout (Birmingham, RAL, ORNL)
- eRD111 – Silicon vertex (sensors excluded)
  - ✓ **Forming modules from stiched sensors** (**INFN Bari and Trieste**, UK groups)
  - ✓ Staves and Disks (LBNL, LANL, UK groups)
  - ✓ Mechanics, integration and cooling (LBNL, LANL, JLAB)
- funding and plans:
  - ✓ delayed a few months by US budget continuing resolution
  - ✓ requests fully awarded in April: eRD104 → 48 kUSD, eRD111 → 241 kUSD
  - ✓ **INFN Bari and Trieste** participating with their own resources so far
    - mostly intellectual work and synergies for FY22
  - ✓ status reports and new proposals for FY23 due by October 1

EIC tracking R&D program

eRD111 – Forming modules from stitched sensors:

- ongoing activities:
  - ✓ size options for ITS3 and EIC-specific sensors studied by Birmingham
    https://indico.bnl.gov/event/15486/contributions/62590/attachments/40656/67919/EIC-Sensors-Jones.pdf
    https://indico.bnl.gov/event/16261/contributions/65122/attachments/41722/69887/20220623-EIC-SC-updates.pdf
  - ✓ tiling options for disks studied by LBNL:
    https://indico.bnl.gov/event/15486/contributions/62591/attachments/40661/67928/20220425%20-%20EIC%20Silicon%20Consortium%20mtg.pdf

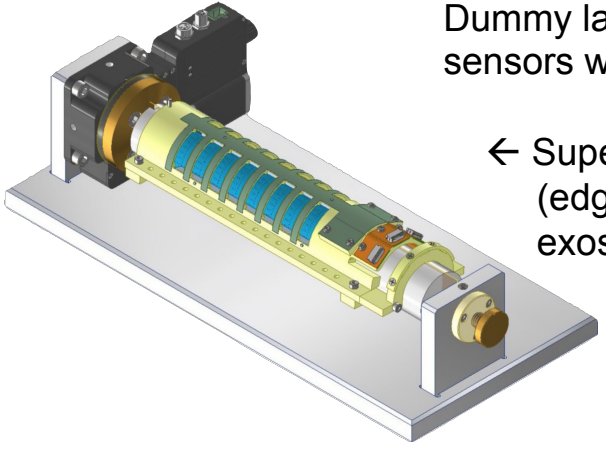
ON THE INFN SIDE:

- ✓ bending and wire-bonding on curved silicon (ITS3, lower radii)
  - large-area sensors bending being mastered at INFN Bari
  - wire-bonding on curved silicon already well exercised at INFN Bari and Trieste

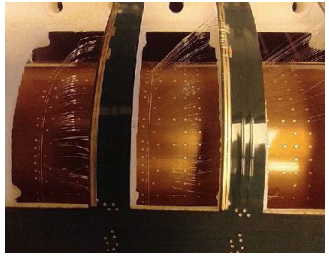
EIC tracking R&D program

eRD111 – Forming modules from stitched sensors:

- ongoing activities (INFN):

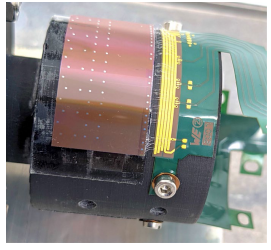


Dummy large-area sensors wire bonding →

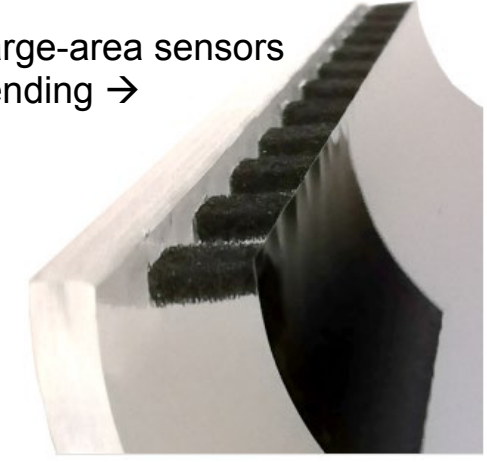


← SuperALPIDE (edge-FPC like in ITS3, exoskeleton mimiking mechanics etc)

Bent 50 μm ALPIDE wire bonding →



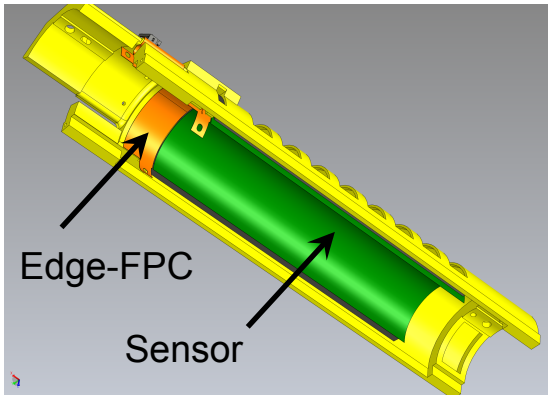
Large-area sensors bending →

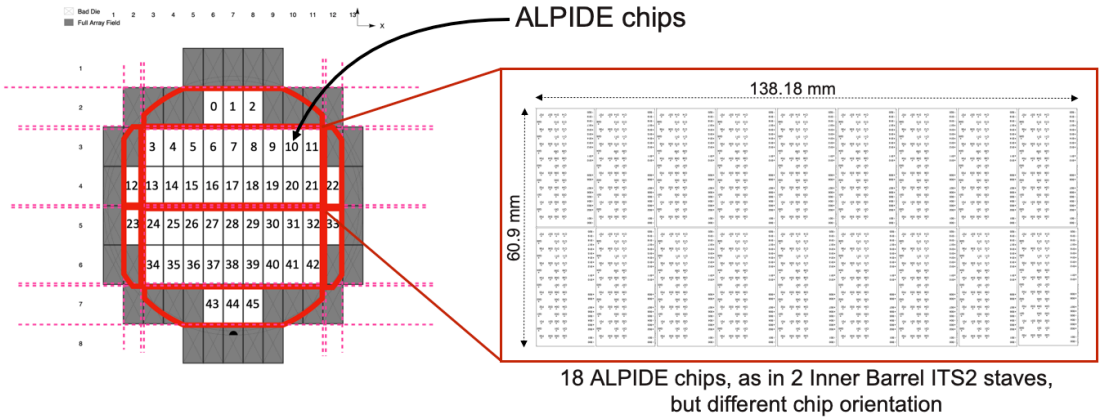


R&D for ITS3/EIC in Bari and Trieste (I)

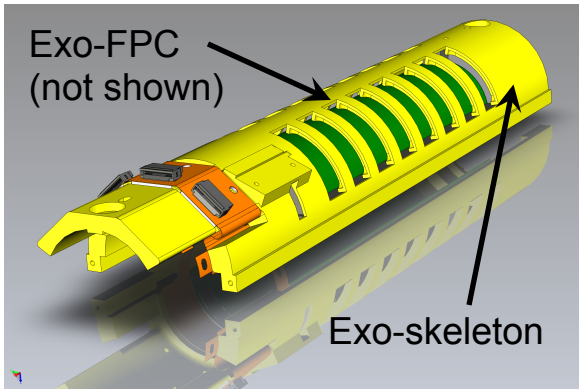
SuperALPIDE motivation and goal:

- proof concept for large dimension bent silicon sensor detector
  - ✓ while waiting for large-dimension ITS3 sensors
  - ✓ learn how to handle large dimension chips
  - ✓ explore wire-bonding interconnection to flex (for data/control/powering) and encapsulation
  - ✓ explore edge-flex solutions towards final detector





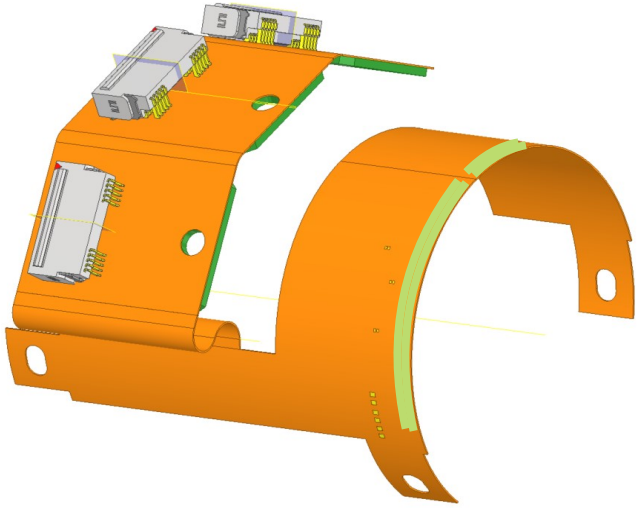
18 ALPIDE chips, as in 2 Inner Barrel ITS2 staves, but different chip orientation

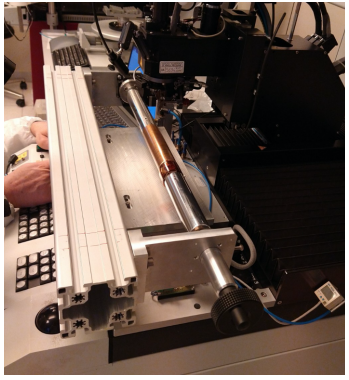


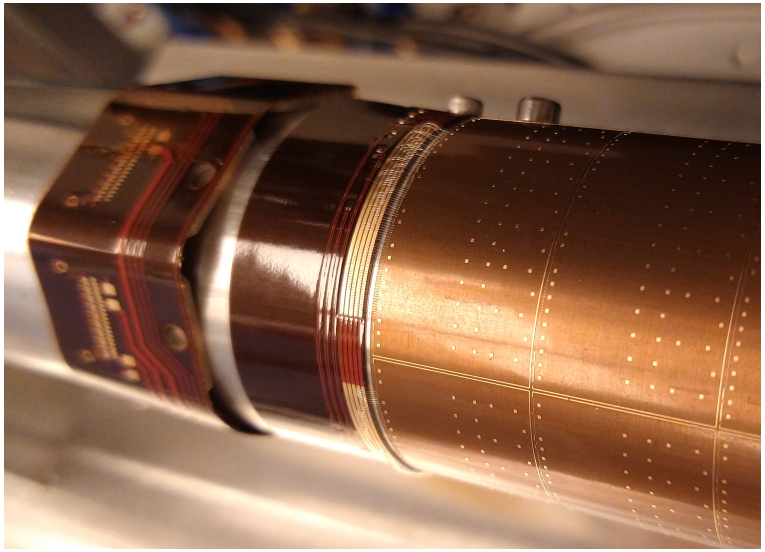
R&D for ITS3/EIC in Bari and Trieste (II)

Edge-FPC:

- final detector FPC prototype



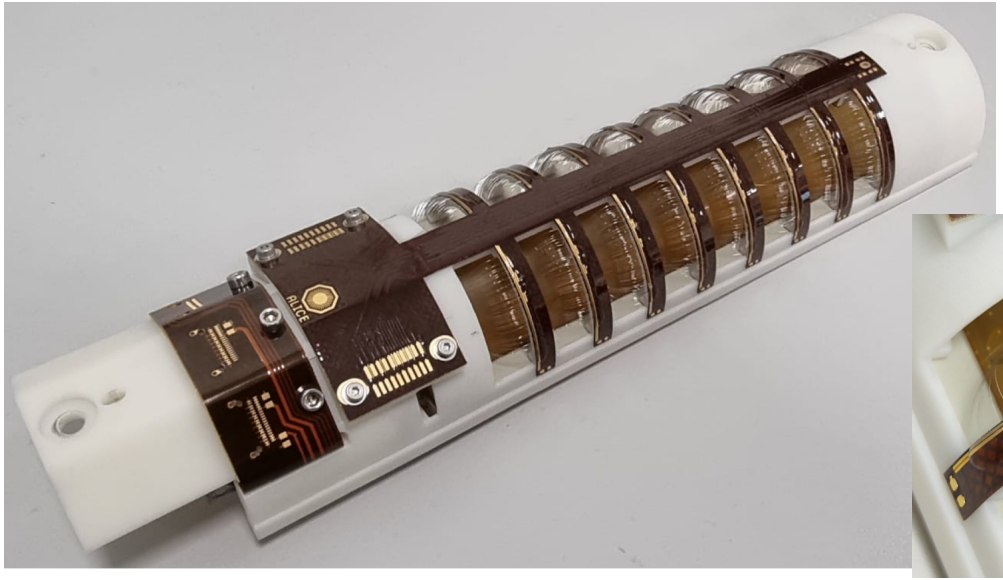




R&D for ITS3/EIC in Bari and Trieste (III)

Assembly procedure:

- done using dummy sensors so far

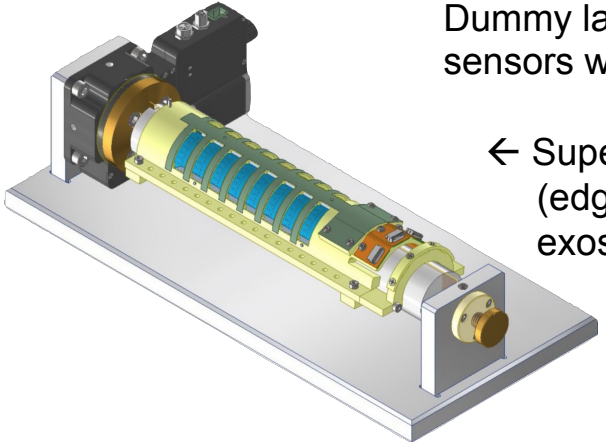


→ assembly with working sensor in September-October

EIC tracking R&D program

eRD111 – Forming modules from stitched sensors:

- ongoing activities (INFN):



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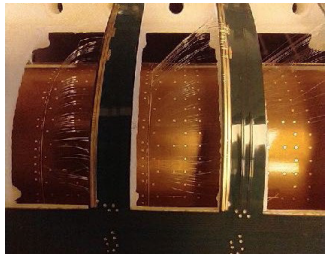
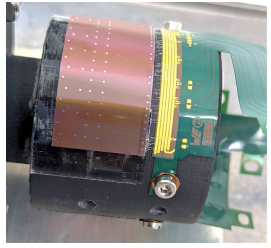
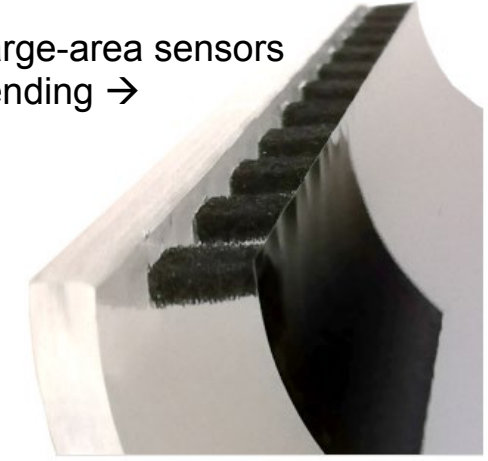




Large-area sensors bending →



- next steps and milestones:
  - ✓ adapt to EIC radii (once defined) and optimize bending and interconnections
  - ✓ study how to configure sensors in staves/disks based on reticle size on a 12” wafer

Further synergies with ALICE ITS3

Sensor development and characterization:

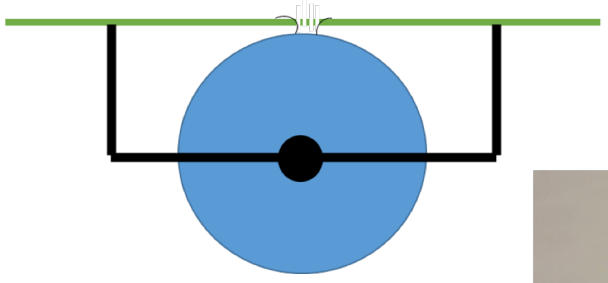
- items not included in the EIC R&D program for FY22
  - ✓ will be included in the eRD program for FY23 (eRD113), proposal by October 1
- contribution to the ITS3 sensor design
  - ✓ RAL well integrated with a specific SEU structure
  - ✓ BNL and LBNL going to start soon, too late for the ER1 submission (these days)
- contribution to the ITS3 sensors characterization
  - ✓ participation in meetings and training sessions
  - ✓ test system available in TS (digital structures), being initialized in BA (analog)
  - ✓ services like mass production wire-bonding and fabrication/assembly of the test systems have been offered
- **Bari and Trieste active** as ALICE institutes
  - ✓ testing digital structures (DPTS) in TS, preparing for analog (APTS OPAMP) in BA

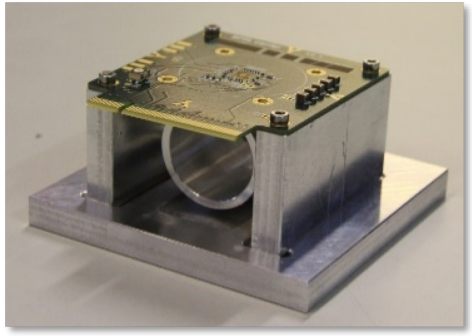
R&D for ITS3/EIC in Bari and Trieste (IV)

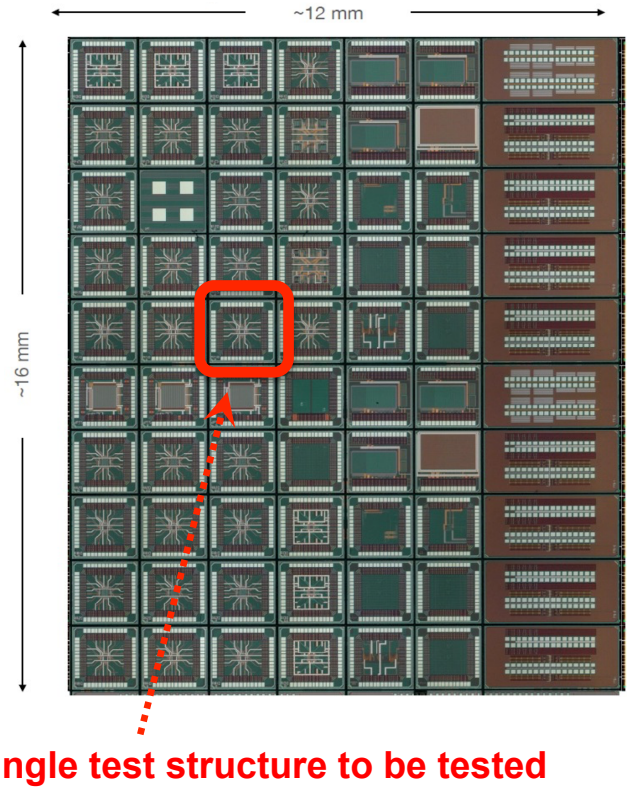
MLR1 test structure characterization:

- MLR1 bending tool development in Trieste

Bent chip support tool





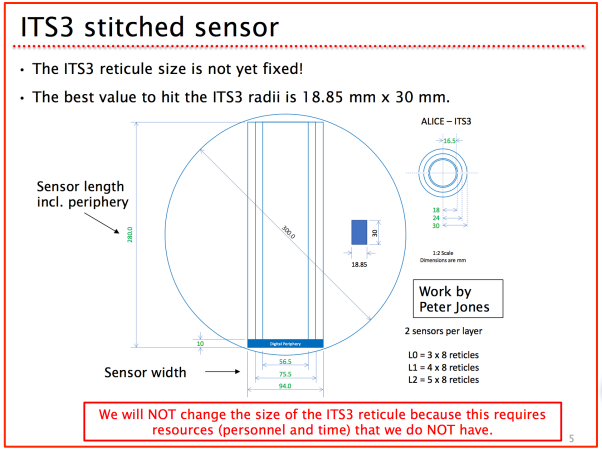


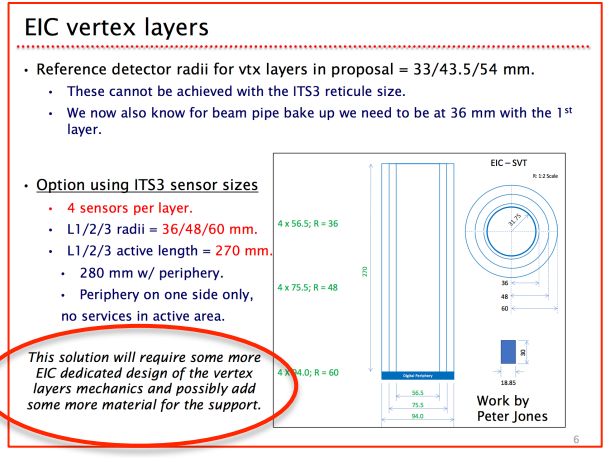
Single test structure to be tested

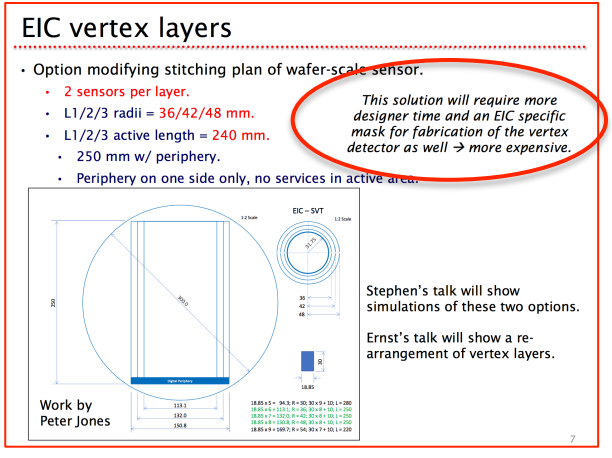
Activity in the EPIC tracking WG

Main lines of interaction with the SC:

- tracking WG working to the optimization of the reference design
- SC helping to fold in technology constraints, eg
  - ✓ ITS3 stitching and implications for the EIC vertex layer layout
  - ✓ check alternative stitching options and consequences (layout, cost etc)





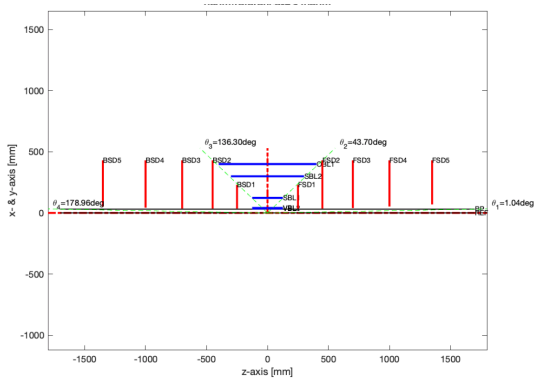


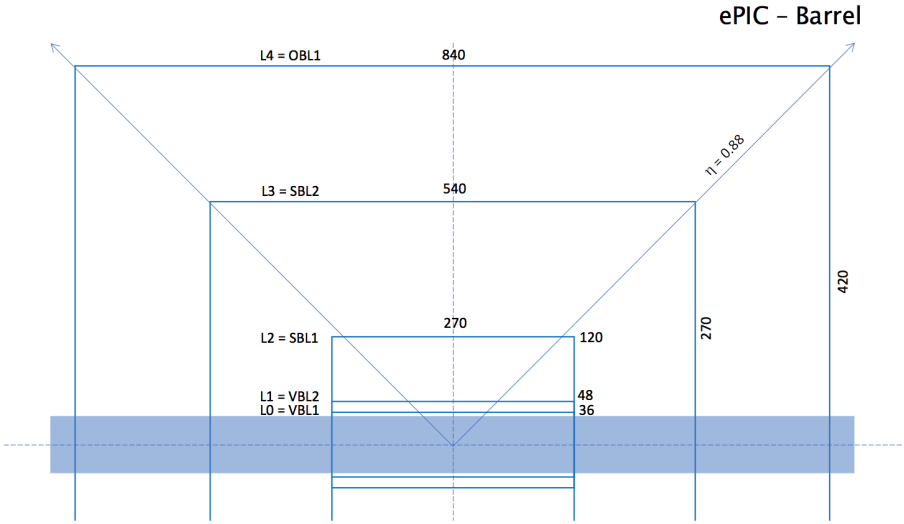
Activity in the EPIC tracking WG

Current (barrel) configuration:

Barrel:

	r [mm]	l [mm]	X/X0 %
Layer 1	36	270	0.05
Layer 2	48	270	0.05
Layer 3	120	270	0.05
Layer 4	270	540	0.25
Layer 5	420	840	0.55





Note: radii and lengths work with a reticle size of 18.85 x 30.00 mm^2.
Length of L0, L1 and L2 is made of one 270 mm sensor: read out at ONE end.
Length of L3 is (or can be) made of two 270 mm sensors: read out at BOTH ends.
Length of L4 is (or can be) made of four 210 mm sensors: read out at BOTH ends + services along the staves to reach 2nd and 3rd sensor.

Activity in the EPIC tracking WG

Simulation activity in Bari:

more in Salvatore Fazio's talk

- started with the YR (2020), then along ATHENA and now in EPIC
- contributing to performance studies in different configurations
- main tools, allowed comparisons/cross-checks:
  - ✓ fast simulation tool (developed in Bari, S. Kumar)
    - first (quick) analytical check of different configuration varying layer number/ position/resolution, material budget, magnetic field etc
    - disentangle different contributions to the final performance (eg multiple scattering vs spatial resolution)
  - ✓ Fun4All (used for the YR, also ECCE implementation for the proposal)
    - full simulation, including the WG implementation of the detector
  - ✓ DD4HEP (selected framework in ATHENA, also for EPIC)
    - initial exercises, going to be used for the next studies within the WG

Plans for 2023

R&D activity:

- continuing effort within the EIC-SC coordination and eRD projects:
  - ✓ bending and interconnection at the EIC vertex radii
  - ✓ sensor configuration in staves/disks based on reticle size
  - ✓ contribution to the characterization of the new structures in 65 nm
- milestone end of 2023 (Appendix C EIC_NET 2022 Annual Report):
  - ✓ "Misura della resa di produzione e ottimizzazione delle dimensioni dei sensori CMOS 65 nm stitched per Detector 1 (==EPIC) tracker"

Simulations within the Tracking WG:

- continuing contribution to the optimisation of the EPIC baseline
- start performance studies on physics benchmarks (HF decay)

Financial requests for 2023

Mostly covered by requests for ALICE ITS3:

- based on agreed synergies: https://cernbox.cern.ch/index.php/s/C7QUuny57ibvmxJ
  (also Appendix A to the EIC_NET 2022 Annual Report)
- within ALICE:
  - ✓ requests for “CONSUMO” and “INVENTARIO”
  - ✓ “MISSIONI”: only for participation to beam test periods at CERN

	Consumo*	Inventario	Missioni TB	Totale
BA	30.5	2.5 sj	5.0	35.5 + 2.5 sj
PD	11.0	0	2.0	13.0
TS	22.0	6.5	5.0	33.5
	63.5	**6.5 + 2.5 sj**	**12.0**	**82.0 + 2.5 sj**

*In addition (TO): 250 k€ per “sottomissione ER2, produzione TS di grande area, contributo Alice Italia a thinning and dicing dei wafer. Attivita' SYN. EIC_NET e NA60+”

Financial requests for 2023

Mostly covered by requests for ALICE ITS3:

- based on agreed synergies: https://cernbox.cern.ch/index.php/s/C7QUuny57ibvmxJ
  (also Appendix A to the EIC_NET 2022 Annual Report)
- within EIC_NET:
  - ✓ requests for “MISSIONI” (dedicated networking, EIC-SC meeting etc)
    - crucial to keep INFN role in the SC, help connection to ITS3, support PD to join

	EIC-SC* in US	EIC-SC/ITS3 @CERN	Altre sedi in IT	Totale
BA	2.5	2.0	0	4.5
PD	2.5 sj	0	1.0	1.0 + 2.5 sj
TS	2.5	2.0	0	4.5
	5.0 + 2.5 sj	**4.0**	**1.0**	**10.0 + 2.5 sj**

*BA and TS members of the EIC-SC coordination

Summary

- EIC vertex and tracking project
  - ✓ moving from the ECCE reference to the (EPIC) baseline within the Tracking WG
  - ✓ EIC SC coordinating R&D effort and supporting the WG optimisation studies
  - ✓ participation in ITS3 crucial: needs to be formally regulated by DOE/CERN and EIC/ALICE agreements (ongoing)
- INFN contribution:
  - ✓ **Bari and Trieste contributing to the EIC-SC coordination and R&D effort**
  - ✓ working on the vertex (and stave/disk layout) development within eRD1111
  - ✓ fully exploiting synergies with the ITS3 activities (bending & interconnection, characterization of the 65 nm structures)
- INFN plans for 2023
  - ✓ continuing effort within SC and eRD111 (eventually eRD113) for FY23
  - ✓ **good news: Padova also joining!**

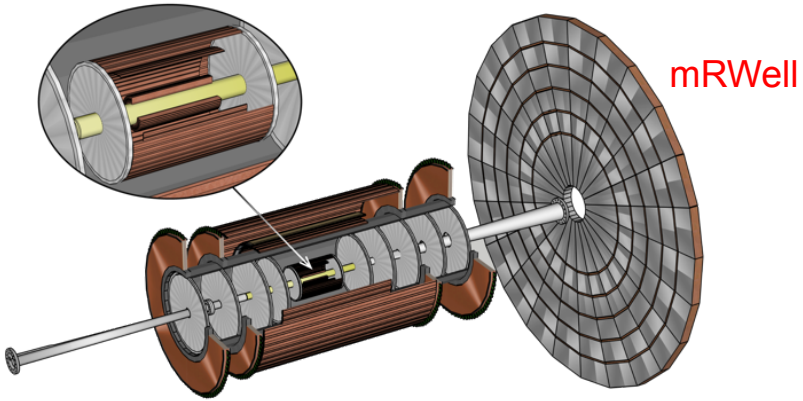
Backup

EIC vertex and tracking

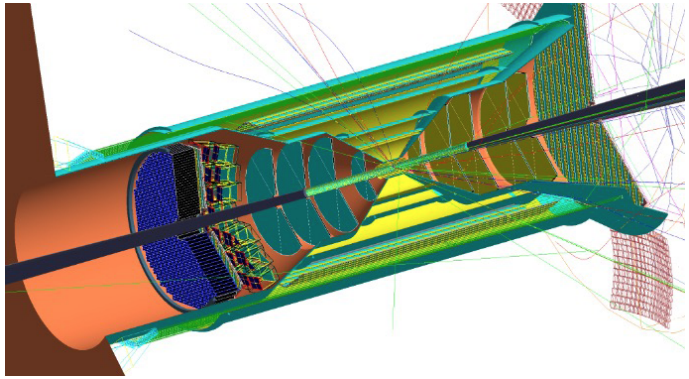
Basics of the design choices:

- mostly independent of the detector proposals: **ATHENA** vs **ECCE**

ATHENA
- Si Vertex Tracker: 3 layers (R_0~33mm)
- Si inner barrel Tracker: 2 layers
- 5+6 Si Tracker disks (including GEMs)



ECCE
- 3-layers silicon vertex (R_0~33mm)
- 2-layers silicon sagitta tracker
- 4+5 Si disk endcaps



Detector configurations

ATHENA

Silicon Tracker (3 Vertex + 2 Barrel Layers)

R (cm)	Length (cm)	Resolution	Active Area Material (X/X0 %)
3.3	28.0	10 um pixel pitch	0.05
4.35	28.0	10 um pixel pitch	0.05
5.4	28.0	10 um pixel pitch	0.05
13.34	34.34	10 um pixel pitch	0.55
17.96	46.68	10 um pixel pitch	0.55

Micromegas Barrel (4 barrel layers)

R (cm)	Length (cm)	Resolution	Active Area Material (X/X0 %)
47.72	127.47	150 um (r-phi) x 150 um (z)	0.4
49.57	127.47	150 um (r-phi) x 150 um (z)	0.4
75.61	201.98	150 um (r-phi) x 150 um (z)	0.4
77.46	201.98	150 um (r-phi) x 150 um (z)	0.4

ECCE

Region	Layer index	technology	radius	minimum z	maximum z	pixel pitch
barrel	1	MAPS	3.3 cm	-13.5 cm	13.5 cm	10 μm
⋮	2	⋮	4.35 cm	-13.5 cm	13.5 cm	10 μm
⋮	3	⋮	5.4 cm	-13.5 cm	13.5 cm	10 μm
⋮	4	⋮	21.0 cm	-27 cm	27 cm	10 μm
⋮	5	⋮	22.68 cm	-30 cm	30 cm	10 μm
Region	Layer index	technology	radius	minimum z	maximum z	strip pitch
barrel	1	μRWELL	33.14 cm	-40 cm	40 cm	400 μm
⋮	2	⋮	51 cm	-106 cm	106 cm	400 μm
⋮	3	⋮	77.0 cm	-197 cm	145 cm	400 μm
Region	Disk index	technology	z location	inner radius	outer radius	pixel pitch
e-endcap	1	MAPS	-25 cm	3.5 cm	18.5 cm	10 μm
⋮	2	⋮	-52 cm	3.5 cm	36.5 cm	10 μm
⋮	3	⋮	-79 cm	4.5 cm	40.5 cm	10 μm
⋮	4	⋮	-106 cm	5.5 cm	41.5 cm	10 μm
Region	Disk index	technology	z location	inner radius	outer radius	pixel pitch
h-endcap	1	MAPS	25 cm	3.5 cm	18.5 cm	10 μm
⋮	2	⋮	49 cm	3.5 cm	36.5 cm	10 μm
⋮	3	⋮	73 cm	4.5 cm	40.5 cm	10 μm
⋮	4	⋮	106 cm	5.5 cm	41.5 cm	10 μm
⋮	5	⋮	125 cm	7.5 cm	43.5 cm	10 μm

EIC tracking R&D program

SC participates in the following eRD for FY22:

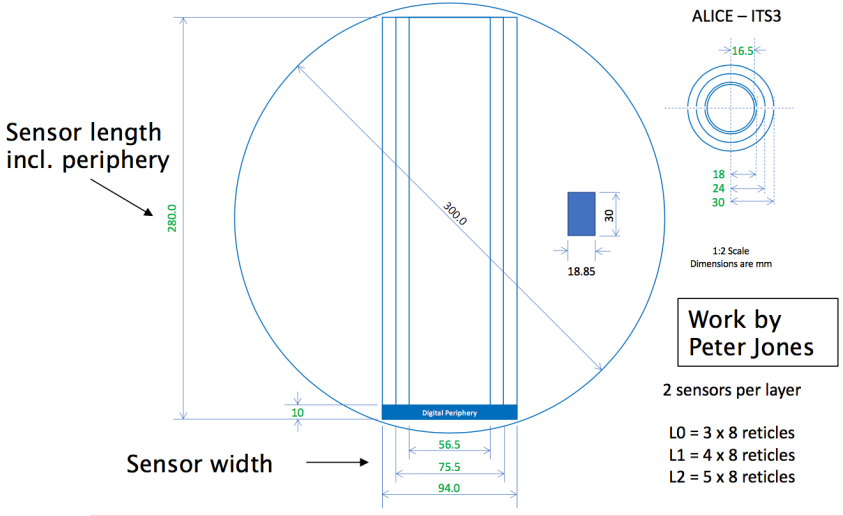
- eRD104 – Silicon services reduction
  - ✓ Powering & readout (Birmingham, RAL, ORNL)
- eRD111 – Silicon vertex (sensors excluded)
  - ✓ **Forming modules from stiched sensors** (**INFN Bari and Trieste**, UK groups: Birmingham, Daresbury, Lancaster, Liverpool)
    - optimizing the module size & design to meet mechanical requirements and take advantage of the new sensor design
  - ✓ Staves and Disks (LBNL, LANL, UK groups)
    - conceptual designs
  - ✓ Mechanics, integration and cooling (LBNL, LANL, JLAB)
    - support structures, study of air cooling

Activity in the EPIC tracking WG

L. Gonella @ Det1 Tracking WG 23.6.2022

ITS3 stitched sensor

- The ITS3 reticule size is not yet fixed!
- The best value to hit the ITS3 radii is 18.85 mm x 30 mm.



We will NOT change the size of the ITS3 reticule because this requires resources (personnel and time) that we do NOT have.

5

Activity in the EPIC tracking WG

L. Gonella @ Det1 Tracking WG 23.6.2022

ITS3 stitched sensor

- The ITS3 reticule size is r
- The best value to hit the

Sensor length incl. periphery

280.0

10

Sensor width

We will NOT chan
resources

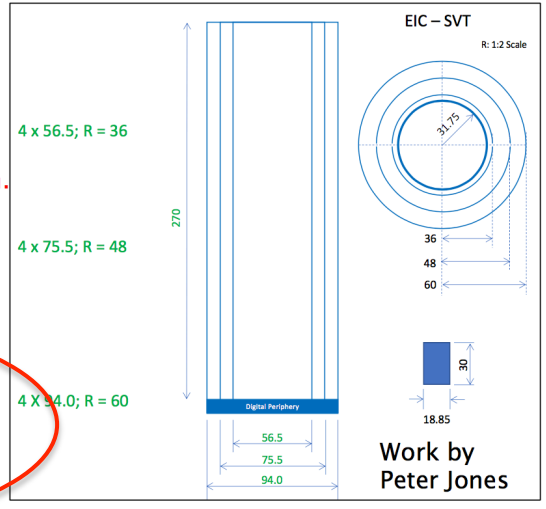
EIC vertex layers

- Reference detector radii for vtx layers in proposal = 33/43.5/54 mm.
  - These cannot be achieved with the ITS3 reticule size.
  - We now also know for beam pipe bake up we need to be at 36 mm with the 1st layer.

- Option using ITS3 sensor sizes
  - 4 sensors per layer.
  - L1/2/3 radii = 36/48/60 mm.
  - L1/2/3 active length = 270 mm.
    - 280 mm w/ periphery.
    - Periphery on one side only,

  no services in active area.

This solution will require some more EIC dedicated design of the vertex layers mechanics and possibly add some more material for the support.



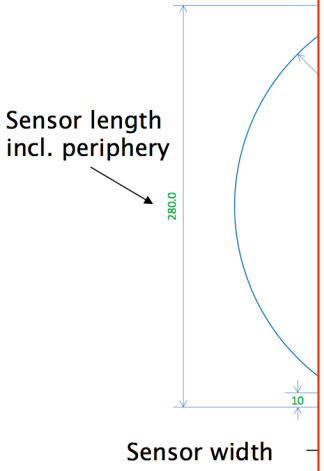
6

Activity in the EPIC tracking WG

L. Gonella @ Det1 Tracking WG 23.6.2022

ITS3 stitched sensor

- The ITS3 reticule size is r
- The best value to hit the



We will NOT chan
resources

EIC vertex layers

- Reference detector radii fo
  - These cannot be achieved
  - We now also know for be
    layer.

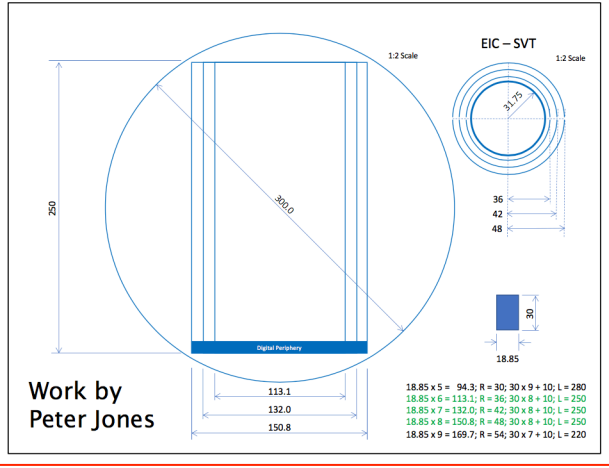
- Option using ITS3 sensor s
  - 4 sensors per layer.
  - L1/2/3 radii = 36/48/60
  - L1/2/3 active length = 27
    - 280 mm w/ periphery.
    - Periphery on one side o
      no services in active area.

This solution will require some
EIC dedicated design of the ve
layers mechanics and possibly
some more material for the sup

EIC vertex layers

- Option modifying stitching plan of wafer-scale sensor
  - 2 sensors per layer.
  - L1/2/3 radii = 36/42/48 mm.
  - L1/2/3 active length = 240 mm.
    - 250 mm w/ periphery.
    - Periphery on one side only, no services in active area.

This solution will require more designer time and an EIC specific mask for fabrication of the vertex detector as well → more expensive.



Work by
Peter Jones

Stephen's talk will show simulations of these two options.

Ernst's talk will show a re-arrangement of vertex layers.