Giornata Nazionale EIC_NET 2022

Catania, June 30 – July 1

Update on Silicon vertex

- EIC Silicon Consortium
- eRD104 and eRD111 projects
- synergies with ALICE ITS3
- connection with Det-1 tracking WG

Domenico Elia (INFN Bari)

EIC Silicon Consortium

Mission and Organizational issues:

- coordinating effort towards the EIC silicon tracker
  - ✓ supporting the three detector proposals (ATHENA, ECCE, CORE) and now Det-1
  - ✓ 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)
- monthly General meetings (eic-rd-silicon-l@lists.bnl.gov):
  - ✓ indico: https://indico.bnl.gov/category/386/
  - ✓ SC activity progress reports
  - ✓ involving participants and presenters by the different groups
  - ✓ next meeting: July, 11

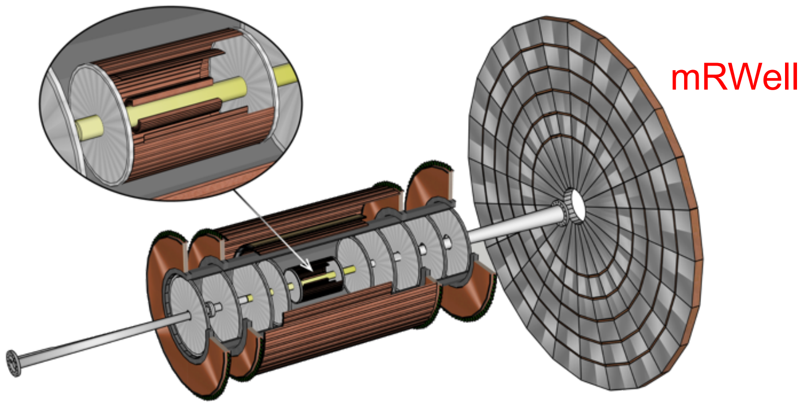
EIC Silicon Consortium

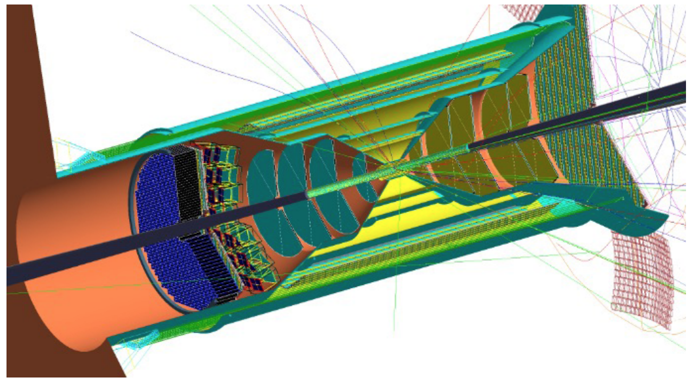
Basics of the design choices:

- 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)

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





EIC Silicon Consortium

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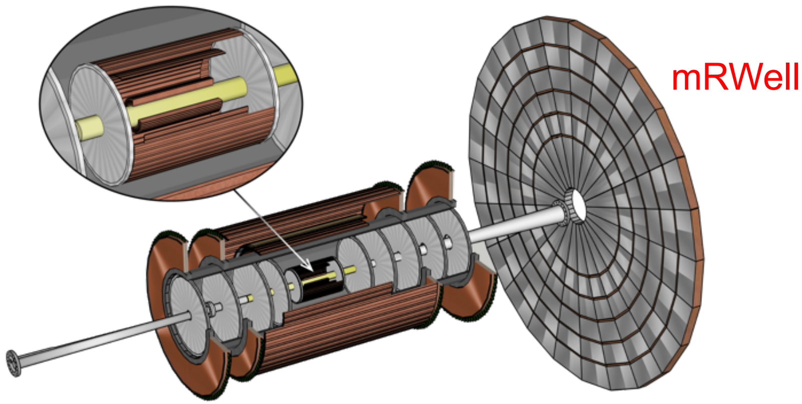
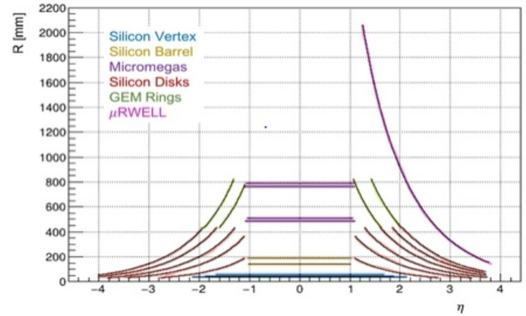
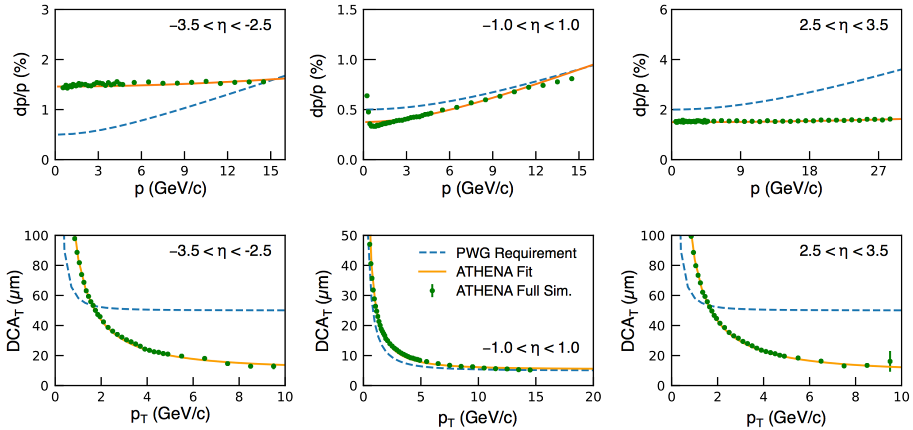






EIC Silicon Consortium

Basics of the design choices:

- mostly independent of the detector proposals
- same idea, same 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

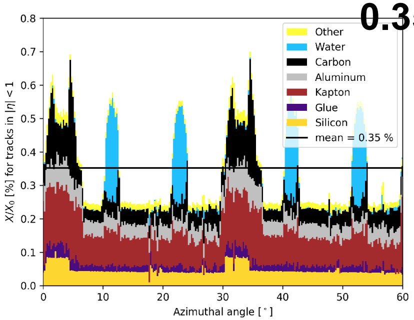
EIC Silicon Consortium

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



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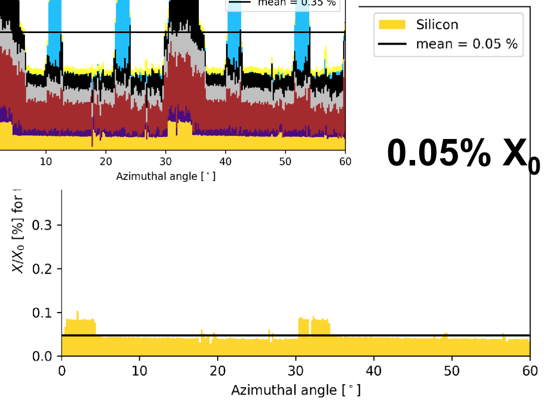
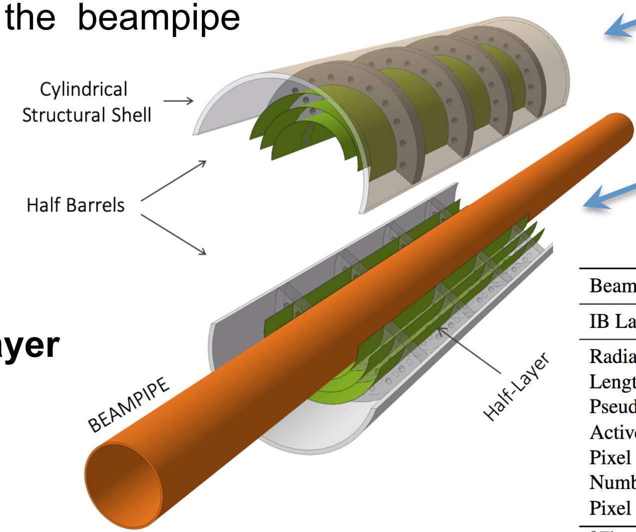




One sensor on the top half

One sensor on the bottom half

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

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 ($O(30 \times 30)\ \mu m^2$).

EIC Silicon Consortium

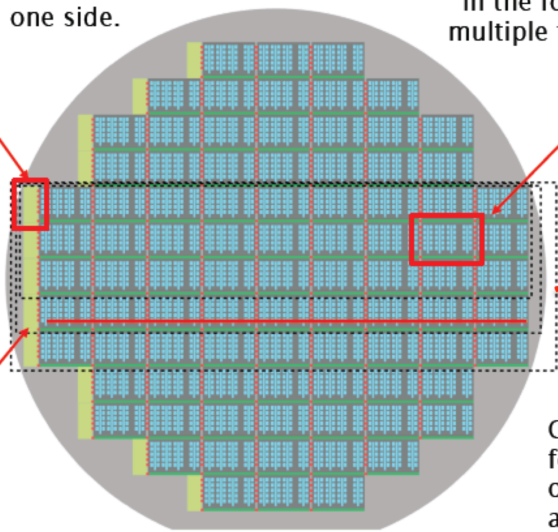
Stitching for the ITS3 sensor:

- deployed to design a wafer scale sensor

Example of stitched wafer layout.

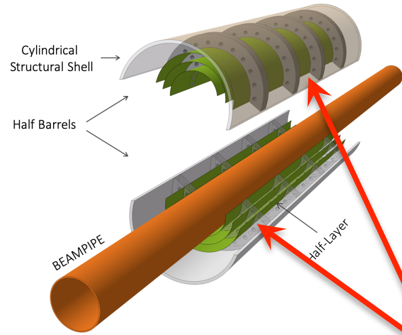
Periphery of sensor on one side.

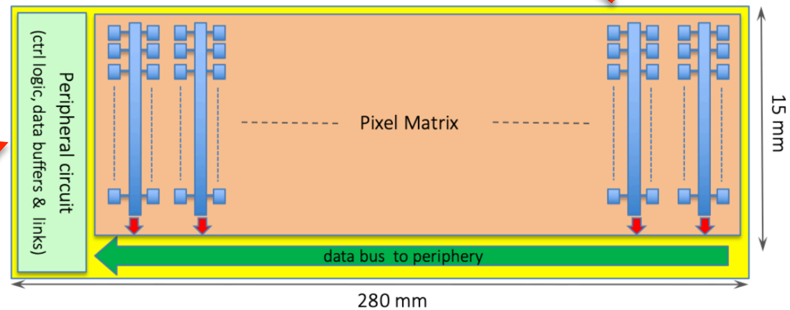
Basic unit cell (called reticule in the following) repeated multiple times to form pixel matrix.



Stitching in one direction only.
It allows to use one mask to obtain different sensor widths.

Cannot cut arbitrary forms. See example of possible cutting along dotted lines.





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
- promoting MoU between ALICE/CERN and EIC/DOE
  - ✓ contacts with L. Musa, Elke and Rolf 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 FY2022:

- 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 desig
  - ✓ Staves and Disks (LBNL, LANL, UK groups)
    - conceptual designs
  - ✓ Mechanics, integration and cooling (LBNL, LANL, JLAB)
    - support structures, study of air cooling

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  - ✓ Staves and Disks (LBNL, LANL, UK groups)
  - ✓ Mechanics, integration and cooling (LBNL, LANL, JLAB)
- funding and plans:
  - ✓ delayed until now by US budget continuing resolution
  - ✓ finally, requests fully awarded: eRD104 → 48 kUSD, eRD111 → 241 kUSD
    - groups still preparing SoW (LBNL done, LANL almost done, BNL and ORNL coming)
  - ✓ INFN Bari and Trieste participating with their own resources
  - ✓ mostly intellectual work and synergies for FY2022

EIC tracking R&D program

eRD111 – Forming modules from stiched 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)

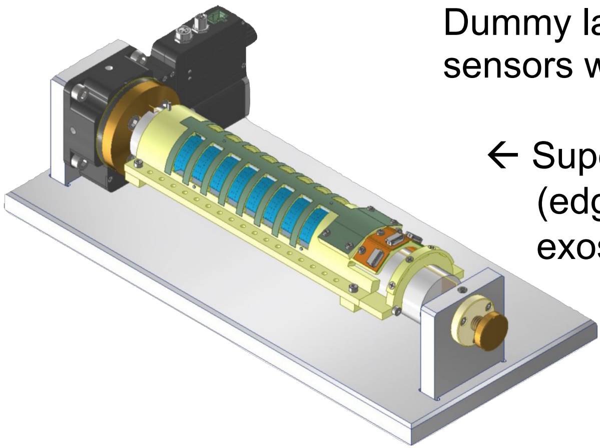
- large-area sensors bending being mastered at INFN Bari
- wire-bonding on curved silicon already well exercised at INFN Bari and Trieste

EIC tracking R&D program

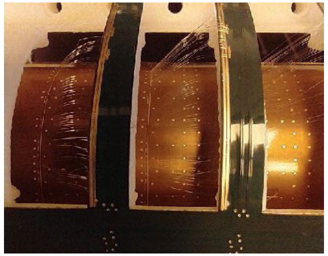
eRD111 – Forming modules from stiched sensors:

- ongoing activities (INFN):

more in D. Colella's talk

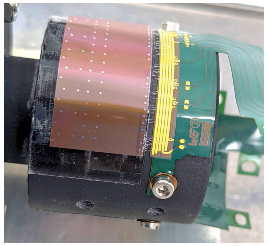


Dummy large-area sensors wire bonding →

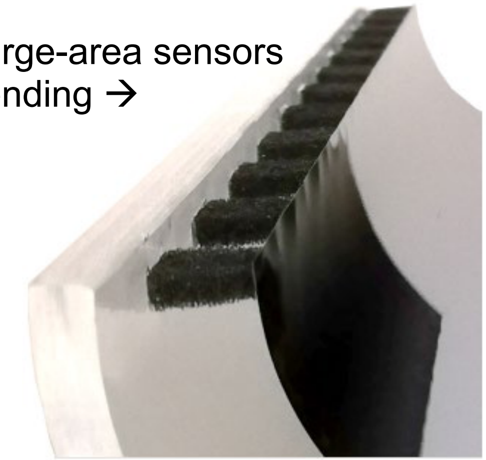


← SuperALPIDE (edge-FPC like in ITS3, exoskeleton mimiking mechanics etc)

Bent 50 μm ALPIDE wire bonding →



Large-area sensors bending →

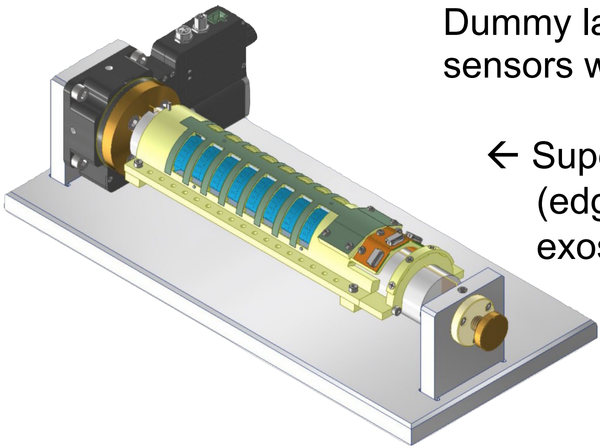


EIC tracking R&D program

eRD111 – Forming modules from stiched sensors:

more in D. Colella’s talk

- ongoing activities (INFN):



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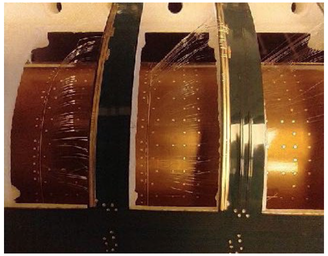

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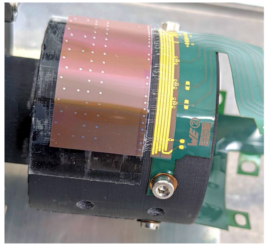

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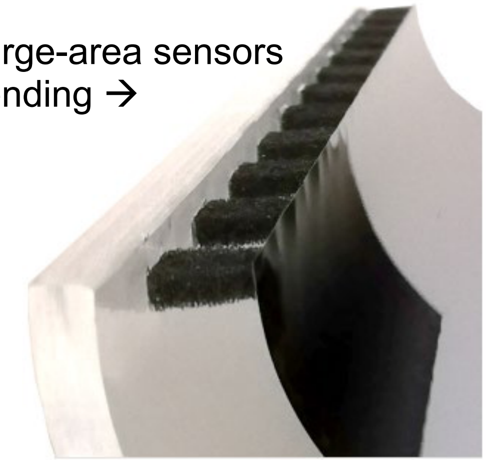


- next steps and milestones:
  - ✓ adapt to EIC radii (once defined) and optimize bending and interconnections
  - ✓ study how to configure sensors in staves/disks based on reticle size on a 12” wafer

Further synergies with ALICE ITS3

Sensor development and characterization:

- items not included in the EIC R&D program
  - ✓ signs that they will become soon Project R&D items (would be very important!)
- 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 systems requested
  - ✓ services like mass production wire-bonding and fabrication/assembly of the test systems have been offered
- Bari and Trieste active as ALICE institutes

Connection to Det-1 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
  - ✓ alternative stitching options and consequences (layout, cost etc)

    → simulations studies ongoing to check impacts on performance (contributions also from S. Kumar in Bari)

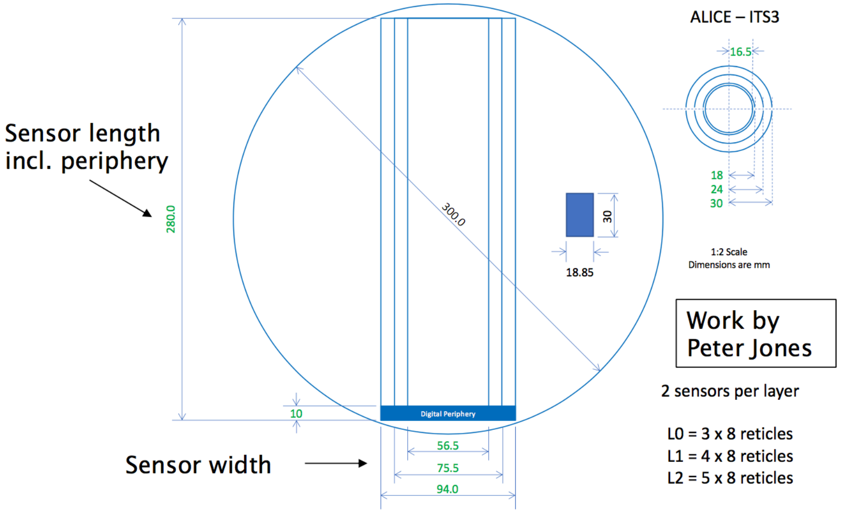
more in A. Mastroserio's talk

Connection to Det-1 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.

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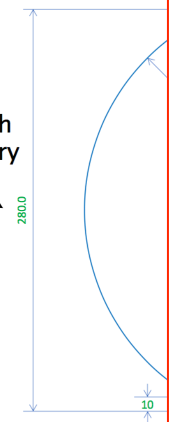
Connection to Det-1 tracking WG

[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

Sensor width

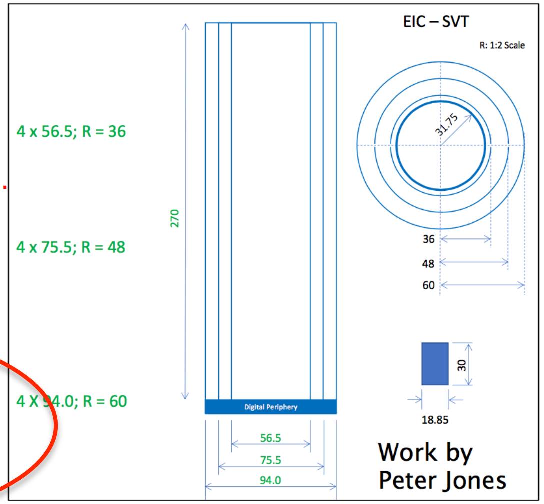
We will NOT chan
resources

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.
- <u>Option using ITS3 sensor sizes</u>
  - 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.



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Connection to Det-1 tracking WG

L. Gonella @ Det1 Tracking WG 23.6.2022

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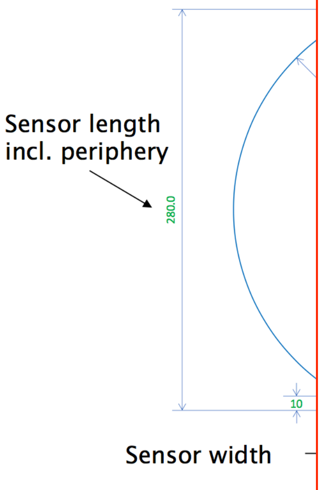

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EIC vertex layers

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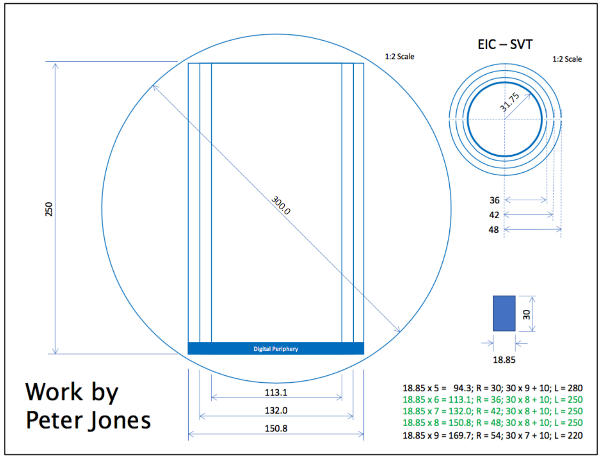
- Option using ITS3 sensor s
  - 4 sensors per layer.
  - L1/2/3 radii = 36/48/60
  - L1/2/3 active length = 27
    - 280 mm w/ periphery.
    - Periphery on one side o
  no services in active area.

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.



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

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

Connection to Det-1 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
  - ✓ alternative stitching options and consequences (layout, cost etc)
    → simulations studies ongoing to check impacts on performance
- but also for the barrel layers:
  - ✓ more conservative support structures and cooling → increase material
  - ✓ stitched wafer-scale sensor yield → design, cost
  - ✓ radius vs length → L5 might need more than 2 sensors in z (> 54 cm)
    → services need to run along the stave → material increase ...
  - ✓ ...

Summary

- EIC Silicon Consortium key role
  - ✓ coordinating the effort towards building the EIC silicon tracker
  - ✓ provided valuable and common input to all the detector proposals
  - ✓ now supporting Detector-1 tracking WG optimization studies
  - ✓ effort to include all interested EIC Institutions
- EIC SC participation in ITS3 crucial
  - ✓ needs to be formally regulated by DOE/CERN, EIC/ALICE agreements
  - ✓ work in progress ...
- EIC and R&D projects
  - ✓ funding to eRD projects now available (needed by US Institutes)
  - ✓ **INFN participation limited to Bari and Trieste so far**

Backup

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