Incontro EIC_NET con referee INFN

Bologna, August 31 2023

ePIC Silicon Vertex Tracker (SVT)

- ePIC SVT layout and concept
- from EIC Silicon Consortium to ePIC SVT DSC
- R&D activity in the INFN groups (sinergies with ALICE ITS3)
- plans and financial requests for 2024

Domenico Elia – INFN Bari

for the ePIC SVT INFN groups (BA, PD, PV and TS)

ePIC SVT layout and concept

Current ePIC SVT layout:

- 3 Inner Barrel (IB) layers (curved silicon layers, L0-L2)
- 2 Outer Barrel (OB) layers (stave-based layers, L3-L4)
- 5 Disks on each side of the IP (ED0-ED4)

Well integrated, large acceptance, high granularity, and low-mass subsystem,

New generation MAPS technology to satisfy the requirements — based off the ALICE-ITS3 development.

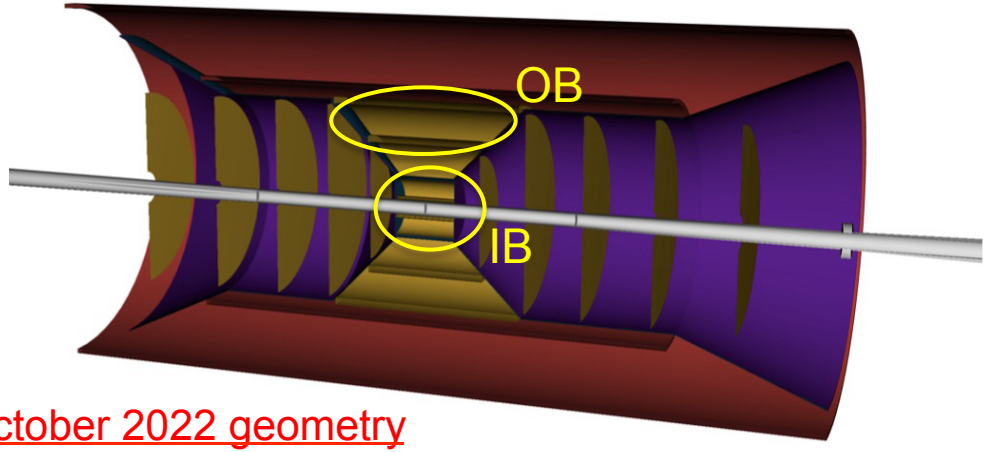
Total (active) area: ~8.5 m^2
Radius ~0.45 m
Length ~ 2.5 m

Updated barrel reference geometry:

- 2 curved silicon vertex layers, r = 36, 48 mm, l = 270mm
- 1 curved silicon dual purpose layer r = 120mm, l = 270mm
- 1 stave-based sagita layer r = 270 mm, l = 540 mm
- 1 stave-based outer layer r = 420 mm, l = 840 mm

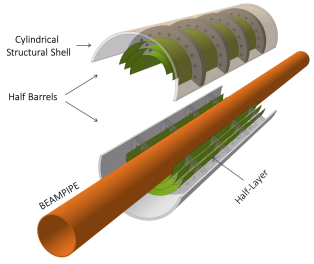
Updated disk reference geometry:

- 5 disks on either side of the nominal IP
  - z = -250, -450, -650, -900, -1150 mm
  - z = 250, 450, 700, 1000, 1350 mm
  - inner radii >= 36 mm, outer radii <= 430 mm



October 2022 geometry

ePIC SVT layout and concept



ePIC SVT concept in a nutshell:

- ITS3-like IB layers:
  - ✓ Use the ITS3 wafer-scale sensor
  - ✓ Adapt ITS3 detector concept to the (larger) EIC radii
    - → *Mechanics, services and cooling of ePIC SVT inner barrel layers need specific development*
- OB layers and Disks:
  - ✓ EIC Large Area Sensor (LAS), i.e. ITS3 sensor size optimised for high yield, low cost, large area coverage
  - ✓ Conventional design of carbon fibre support structures (i.e. staves, disks), with integrated cooling and electrical interfaces

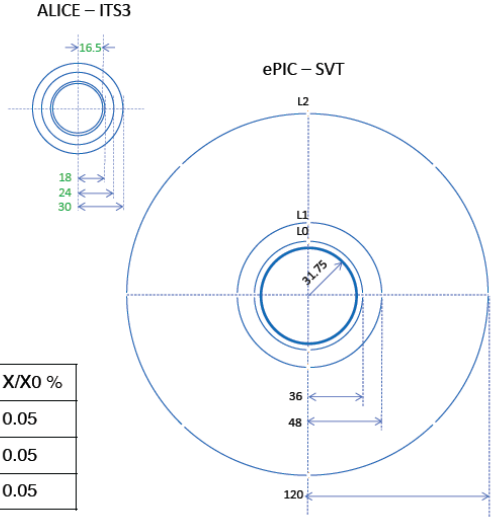
See also **ePIC SVT Wiki pages**: https://wiki.bnl.gov/EPIC/index.php?title=SiConsortium

Meeting EIC/ePIC – CERN/ALICE in April → agreement to share sensor

ePIC SVT layout and concept

ePIC SVT Inner Barrel (IB) layers

- Re-use ITS3 wafer-scale sensor
  - L0: 3x12 RSU + endcaps
  - L1: 4x12 RSU + endcaps
  - L2: 5x12 RSU + endcaps
- Number of sensors per layer
  - L0: 4
  - L1: 4
  - L2: 8



ePIC SVT IB	r [mm]	l [mm]	X/X0 %
L0	36	270	0.05
L1	48	270	0.05
L2	120	270	0.05

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ePIC SVT Outer Barrel (OB) layers and disks

- EIC-LAS sensor = 1 segment with N RSU + endcaps.
- N to be defined based on yield and cost, acceptance and coverage, manufacturing constrains.
- Possibly add some changes in the endcaps.
  - e.g. if needed for powering and data transmission.

ePIC SVT OB	r [mm]	l [mm]	X/X0 %
L3	270	540	0.25
L4	420	840	0.55

Disks nomenclature:
ED0 – ED4 in electron going direction (-z)
HD0 – HD4 in proton going direction (+z)

Disk inner opening:
beam pipe radius + clearance for beam pipe bake out (5 mm);
offset wrt disk center where beam pipe fans out

ePIC SVT Disks	+z [mm]	-z [mm]	r_out [mm]	X/X0 %
Disk 0	250	-250	240	0.24
Disk 1	450	-450	420	0.24
Disk 2	700	-650	420	0.24
Disk 3	1000	-900	420	0.24
Disk 4	1350	-1150	420	0.24

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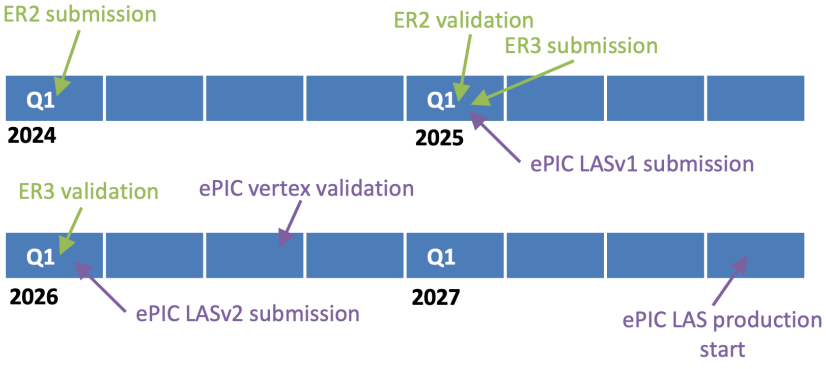
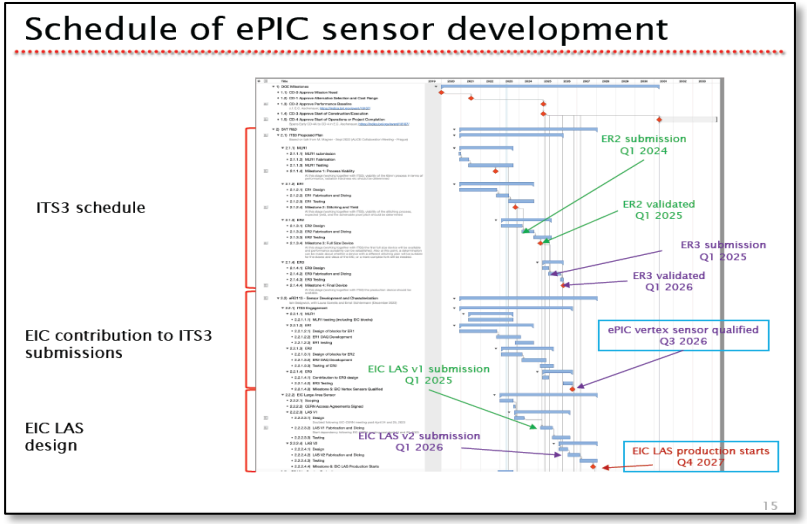
ePIC SVT layout and concept

ePIC SVT relevant timeline:

- R&D phase ongoing:
  - ✓ EIC vertex sensor qualification expected in September 2026, concurrent with ALICE-ITS3
  - ✓ EIC Large Area Sensor production start (not before) ~Q4 2027





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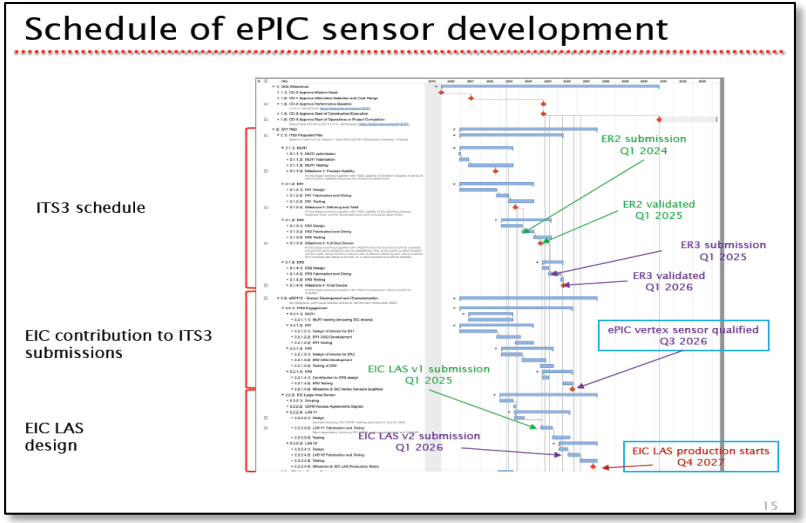


- Construction phase will (mostly) follow R&D:
  - ✓ CD-3 (Approve Start of Construction/Execution) currently anticipated to Spring 2025
  - ✓ SVT construction estimated ~3-4 years in a technically driven schedule

EIC Silicon Consortium

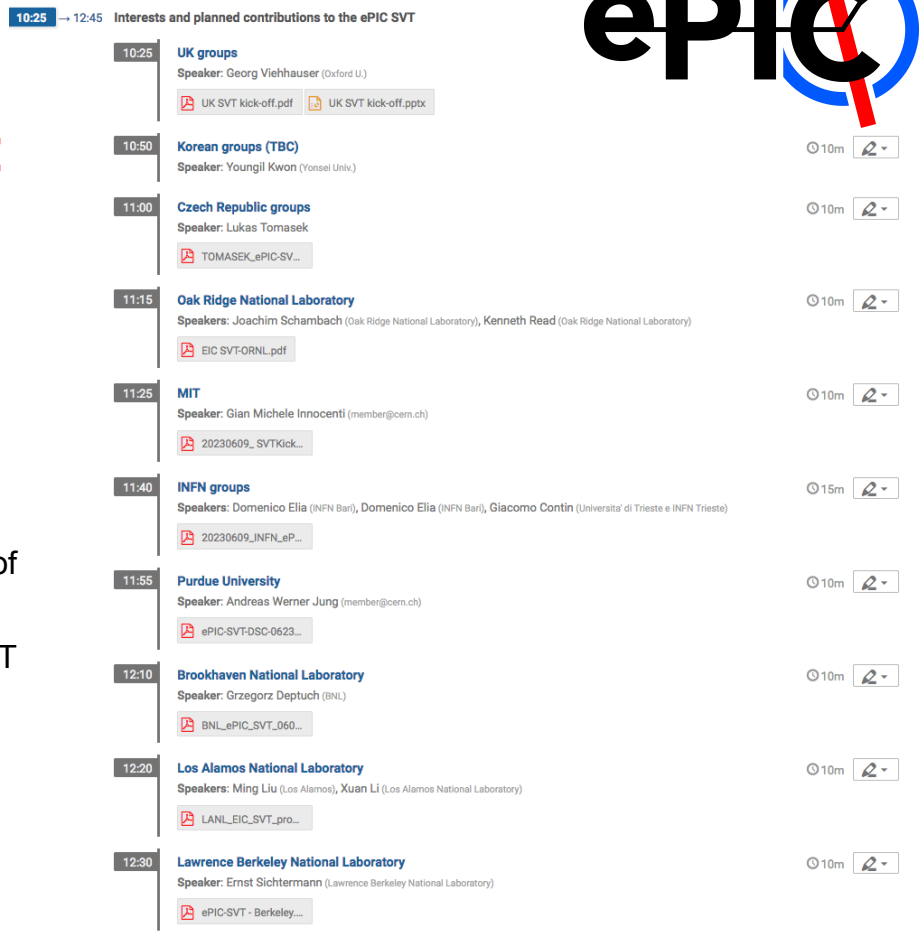
Past and ongoing activities:

- coordinating effort towards the EIC silicon tracker:
  - ✓ supporting the ePIC Tracking WG and R&D activities on the silicon detectors
  - ✓ moving to the **ePIC Si-Vertex Tracker DSC,** open to additional groups and institutions
- weekly Coordination meetings, on Monday @12pm EDT:
  - ✓ indico: https://indico.bnl.gov/category/387/
  - ✓ promoting activity progress and coordinating institutional relashionship
  - ✓ people: N. Apadula (LBL), **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)
- bimonthly General meetings, on Tuesday @12pm EDT:
  - ✓ indico: https://indico.bnl.gov/category/386/, mailing list: eic-rd-silicon-l@lists.bnl.gov
  - ✓ SC activity progress reports (eRD104, eRD111 and eRD113 projects, in rotation)
  - ✓ now becoming **"ePIC SVT DSC meetings"** (change in the mailinig list will happen soon)

ePIC SVT DSC

ePIC SVT DSC kickoff meeting:

- June 9: https://indico.bnl.gov/event/19823/
- leadership:
  - ✓ L. Gonella (Birmingham, UK) technical coordinator
  - ✓ E. Sichtermann (LBNL, US) DSC leader
- main goals:
  - ✓ agreed-on work packages
  - ✓ how the work will be shared during the remainder of the R&D phase and during construction
  - ✓ create common understanding of the current SVT baseline to facilitate efficient collaboration



ePIC SVT DSC

WP1	Sensor development	Design •Contribution to ITS3 ER2 and ER3 •EIC LAS v1, v2, production Characterisation •Lab, test beam, irradiations	(Most closely related to eRD113 project R&D)
WP2	Mechanics and cooling	•Mechanics of bent vertex layers •Air cooling for vertex layers •Support structure for sagitta layers and disks •Cooling for sagitta layers and disks	(eRD111 project R&D)
WP3	Sensors electrical interfaces	•FPC from sensors to end of layers/disks •Wire bonding (sensor to FPC) •Connection to services (FPC to services)	(Aspects within eRD111 project R&D scope)
WP4	Readout and powering	•Power regulator; SP architecture (data transmission, current source, grounding) •On-/off-sensor data handling, full chain until FELIX	(eRD104 project R&D)
WP5	Integration	•Overall mechanical support and integration •Detector cabling (i.e. cables and routing) •Power supplies and cooling plant •Close collaboration with project engineers	(Aspects within eRD111 project R&D scope)
WP6	Simulations	•Link to tracking working group •(Detailed) SVT detector description	
WP7	Interlocks, slow control, run control, monitoring	To be activated later on	

ePIC SVT DSC

Planned contributions to the ePIC SVT

- Funding and labor force
  - ✓ Project not officially funded yet, ~1M$ in-kind contribution to SVT is foreseen for construction phase
  - ✓ Scientific staff ramping up to 3-5 FTE during R&D phase + technical personnel. Expected to grow for construction, to be defined
- R&D for vertex layers
  - ✓ **Bending and interconnections** based on bending/interconnection/prototyping activites for ITS3
  - ✓ General contribution on **sensor test and characterization** (also connected to the eRD111 targets for this year)
  - ✓ Contribution to **FPC development and testing**
    - ➔ overall effort **to be better defined** based on effective dedicated labor force growing in the groups
- Construction of vertex layers
  - ✓ Possible **in-kind** contribution to **silicon production runs, thinning and dicing**
  - ✓ Considering specific construction items compatible with ongoing R&D and available labor force, for example:
    - ✓ On-wafer large-area **sensor probe testing**
    - ✓ **FPC** production and integration
    - ✓ Participation in **chip bending and layer integration**
      - ➢ **To be decided** based on the other groups' interests and the available resources

June 9th 2023 ePIC SVT DSC kickoff meeting 6

ePIC SVT DSC

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June 9th 2023 ePIC SVT DSC kickoff meeting 6

10:25 → 12:45 **Interests and planned contributions to the ePIC SVT**

10:25	**UK groups** Speaker: Georg Viehhauser (Oxford U.) UK SVT kick-off.pdf, UK SVT kick-off.pptx	**Sensor development Barrel layers**
10:50	**Korean groups (TBC)** Speaker: Youngil Kwon (Yonsei Univ.)	10m
11:00	**Czech Republic groups** Speaker: Lukas Tomasek TOMASEK_ePIC-SV...	**Barrel layers** 10m
11:15	**Oak Ridge National Laboratory** Speakers: Joachim Schambach (Oak Ridge National Laboratory), Kenneth Read (Oak Ridge National Laboratory) EIC SVT-ORNL.pdf	**DAQ** 10m
11:25	**MIT** Speaker: Gian Michele Innocenti (member@cern.ch) 20230609_ SVTKick...	**Vertex layers** 10m
11:40	**INFN groups** Speakers: Domenico Elia (INFN Bari), Domenico Elia (INFN Bari), Giacomo Contin (Universita' di Trieste e INFN Trieste) 20230609_INFN_eP...	15m
11:55	**Purdue University** Speaker: Andreas Werner Jung (member@cern.ch) ePIC-SVT-DSC-0623...	**Disks** 10m
12:10	**Brookhaven National Laboratory** Speaker: Grzegorz Deptuch (BNL) BNL_ePIC_SVT_060...	**Sensor development** 10m
12:20	**Los Alamos National Laboratory** Speakers: Ming Liu (Los Alamos), Xuan Li (Los Alamos National Laboratory) LANL_EIC_SVT_pro...	**Disks** 10m
12:30	**Lawrence Berkeley National Laboratory** Speaker: Ernst Sichtermann (Lawrence Berkeley National Laboratory) ePIC-SVT - Berkeley....	**Vertex layers** 10m

R&D activity in the INFN groups

INFN participates in the following projects for FY23:

- generic R&D:
  - ✓ INFN: ~0.4 Post-doc FTE = 34 kUSD, material = 15 kUSD
    - *Additive manufacturing of power and data redistribution layers on thin large-area silicon*
  - ✓ contact: G. Contin (TS)
- eRD111 – Silicon vertex (sensors excluded)
  - ✓ INFN: 0.25 Post-doc FTE = 20 kUSD, material = 10 kUSD
    - *Forming modules from stitched sensors*
  - ✓ contact: R. Turrisi (PD)
- eRD113 – Sensor development and characterization
  - ✓ INFN: 0.25 Post-doc FTE = 20 kUSD, material = 10 kUSD
    - *Progress in testing and characterization*
  - ✓ contact: D. Elia (BA)

R&D activity in the INFN groups

INFN participates in the following projects for FY23 (cont'd):

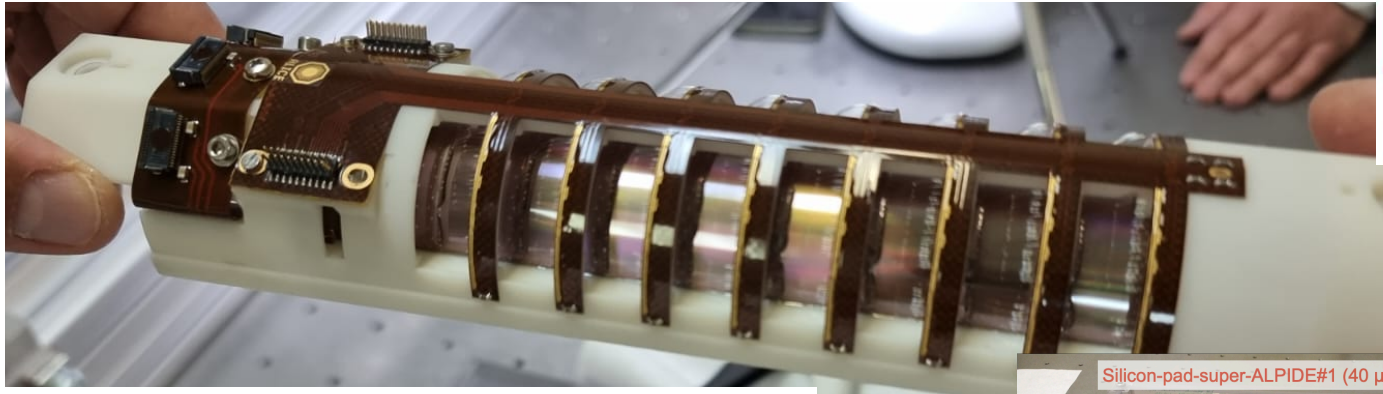
- status of administrative procedures:
  - ✓ approved by INFN CD, contracts (INFN-JLab/DOE sides) signed
  - ✓ status for the corresponding positions:
    - BA: call for a post-doc position (1y+1), will be out in the next week
    - PD: co-funding of a PhD position with Phys. Dept. (contact: P. Giubilato)
    - TS: looking for co-funding of a post-doc position, call expected to be out in Sept

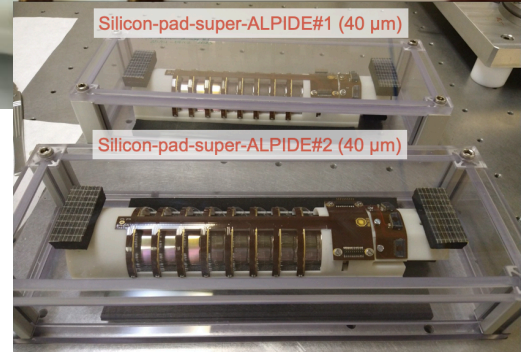
Plans for FY24:

- eRD call deadline on July 7, 2023:
  - ✓ INFN proposal: 45 kUSD each for eRD111 and eRD113, total of 90 kUSD
  - ✓ aim to get 3 additional positions (years) funded
  - ✓ no further requests from INFN for FY24 within the generic R&D programme

R&D activity in the INFN groups

ITS3 super-ALPIDE project in Bari:



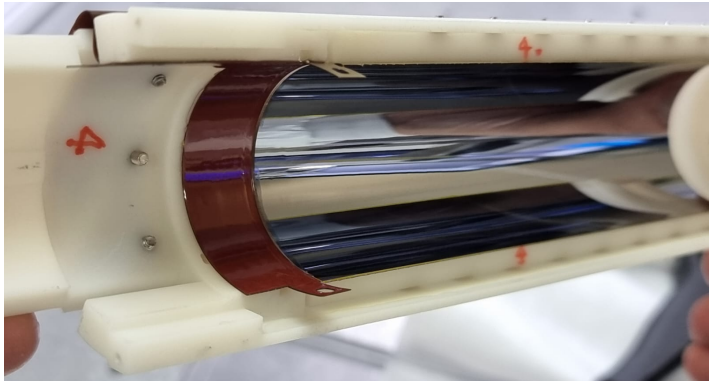


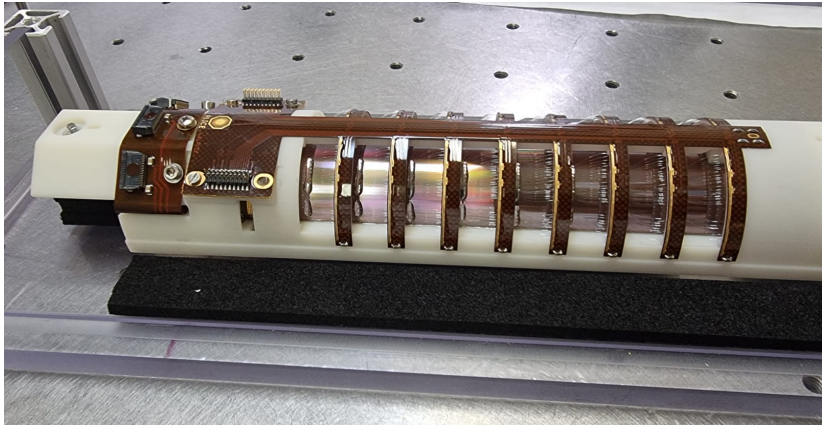
Dummy-pad-super-ALPIDE#1 (40 µm)
First complete assembly of a super-ALPIDE prototype based on real blank silicon (not electronics integrated) with metallic pad for bonding → Completed on 8/2/23

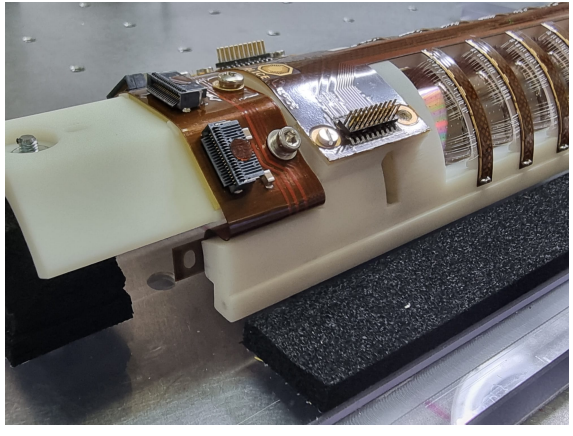
Dummy-pad-super-ALPIDE#2 (40 µm)
Second complete assembly of a super-ALPIDE prototype this time using carbon foam support structures → Completed on 14/3/23

Super-ALPIDE#1 (30 µm)
Assembly with working sensor is the next step → mandrel with improved quality surface needed (currently under production)

R&D activity in the INFN groups

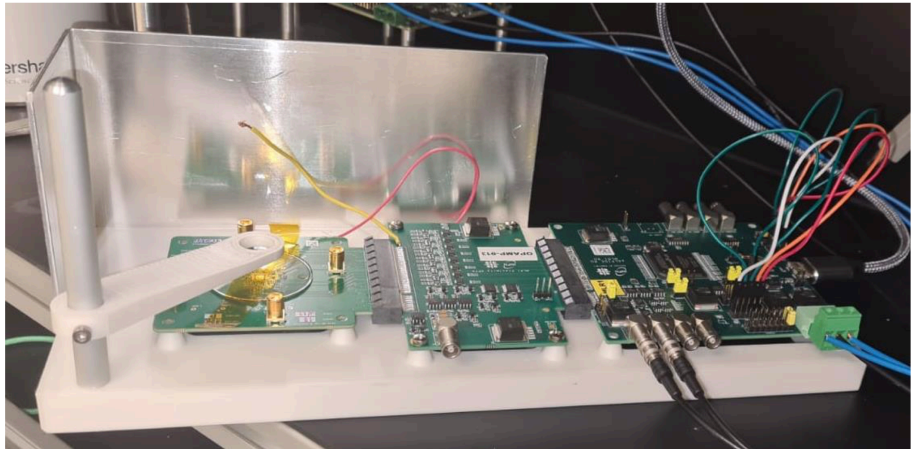




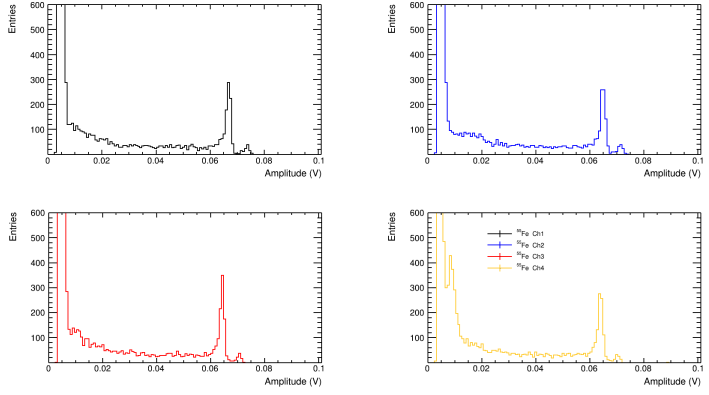


R&D activity in the INFN groups

MLR1 APTS OP-AMP characterization in Bari:



Low stat. ^{55}Fe spectrum



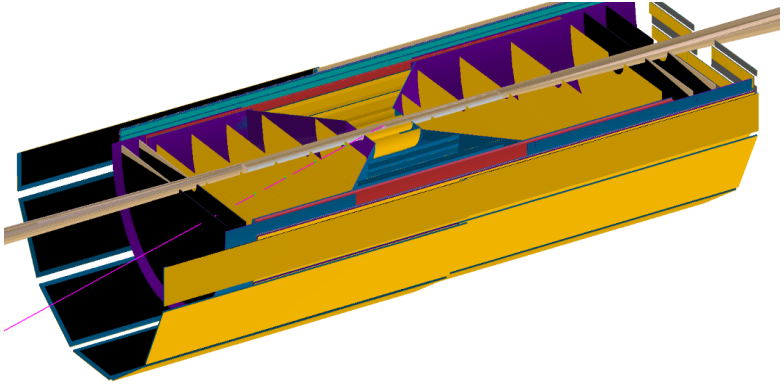
- Setup configured and verified
- Very first ^{55}Fe spectrum with low statistics, using the central 4 pixels of the matrix (acquired using an oscilloscope)
- Higher activity ^{55}Fe source under procurement
- Data acquisition software development

R&D activity in the INFN groups

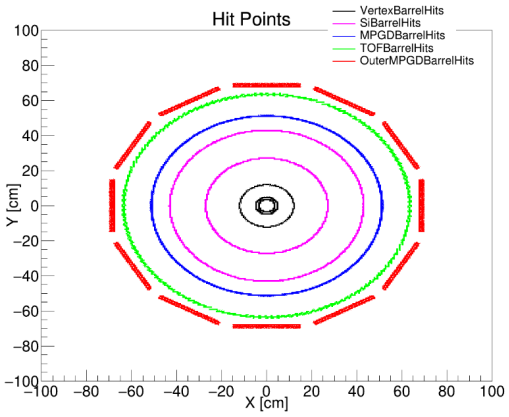
Simulation activities in Bari within the Tracking WG:

- Fast Simulation Studies with the EPIC Detector
  https://indico.bnl.gov/event/17750/contributions/71187/attachments/44843/75637/EPIC_Tracking_Meeting_Shyam1Dec2022.pdf
- Event Display Tutorial (ROOT Based)
  https://indico.bnl.gov/event/18213/contributions/73480/attachments/46166/78396/EventDisplay_ShyamKumar23Feb2023.pdf
- Study of angular resolutions with the Smearing of Truth Parameters
  https://indico.bnl.gov/event/19910/contributions/77891/attachments/48158/81759/EPIC_Meeting_Shyam_June22_23.pdf
- Tracking Studies with New Geometry
  https://indico.bnl.gov/event/20073/contributions/78629/attachments/48575/82607/EPIC_Tracking_Meeting_Shyam13July2023.pdf
- Study of “Crater Lake” geometry Material and Coverage
  https://indico.bnl.gov/event/20126/contributions/78818/attachments/48715/82936/EPIC_Tracking_Meeting_Shyam20July2023.pdf
- Photon simulation (in DD4hep and FLUKA)
  https://indico.bnl.gov/event/20218/contributions/79344/attachments/49019/83526/EPIC_Background_Meeting_Shyam8August23.pdf
- Compile ACTS updates with EICrecon (ongoing effort)

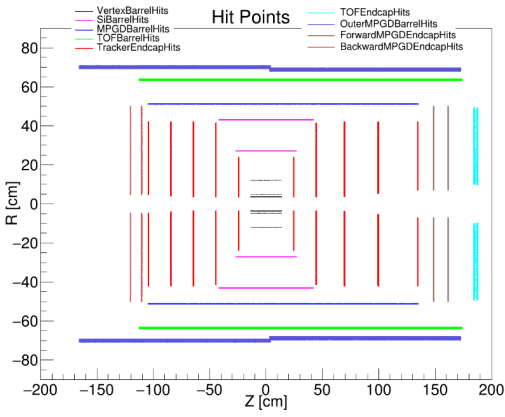
Event-display (epic_craterlake_tracking_only)



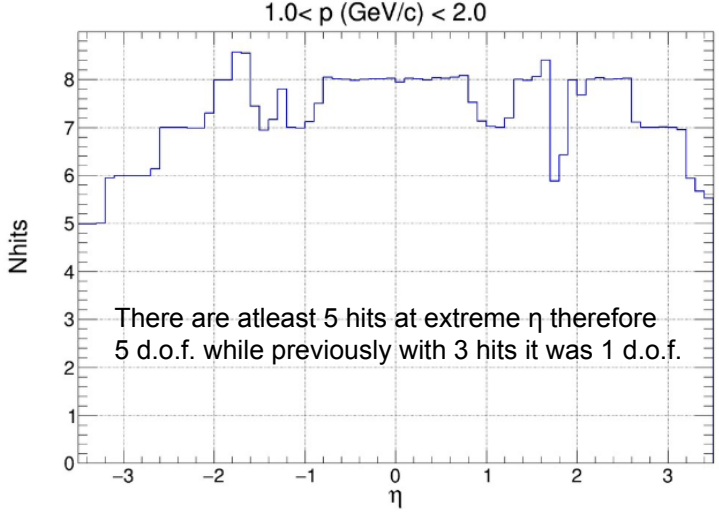
X-Y Points



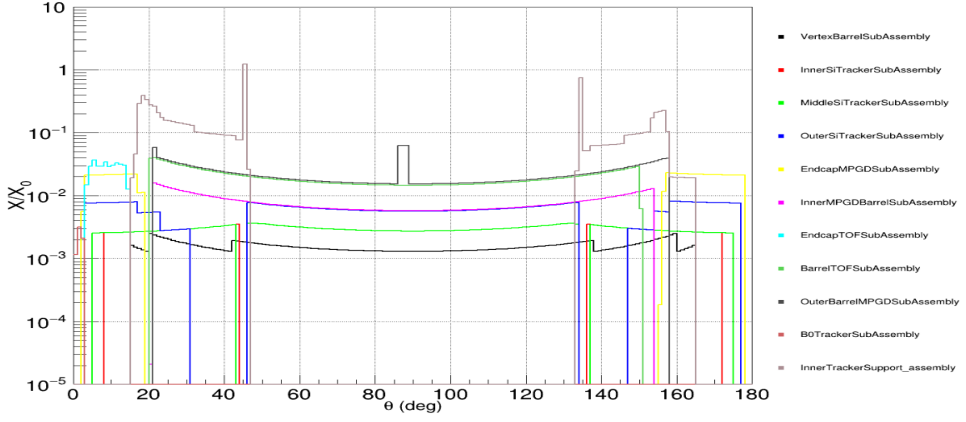
R-Z Points



Number of hits vs η



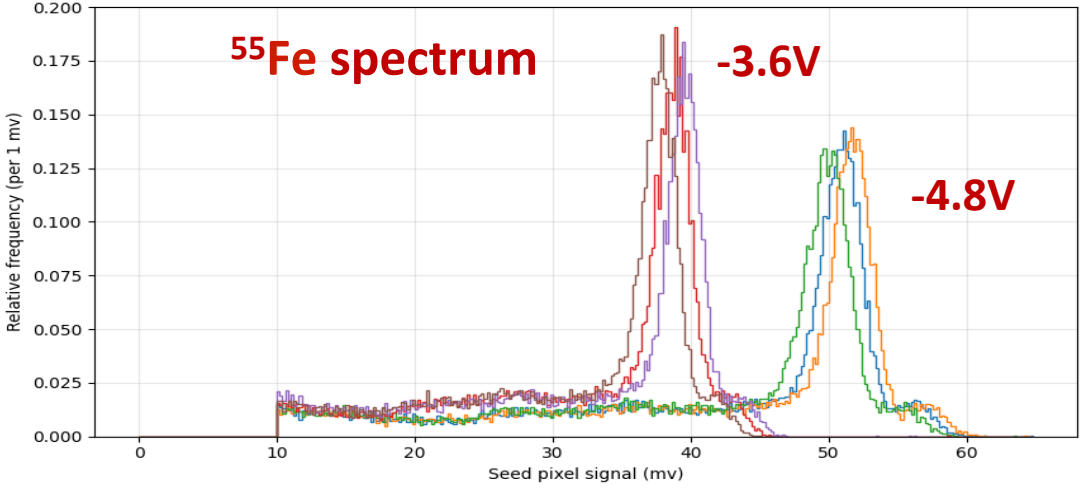
Material map
(epic_craterlake_tracking_only)

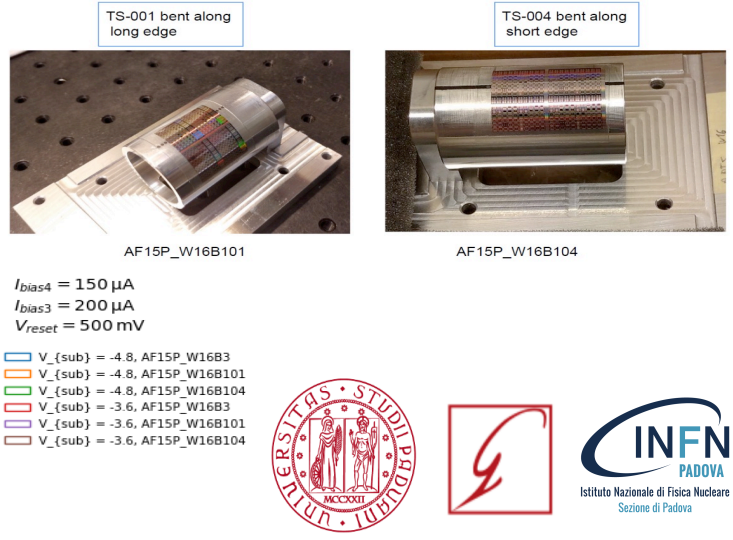


R&D activity in the INFN groups

MLR1 bent APTS SF characterization in Padova:

- two APTS were bent in Trieste along two different axis
- tested in Padova with an X-ray source (^{55}Fe) for different depletion voltages and a comparison with a flat chip was performed

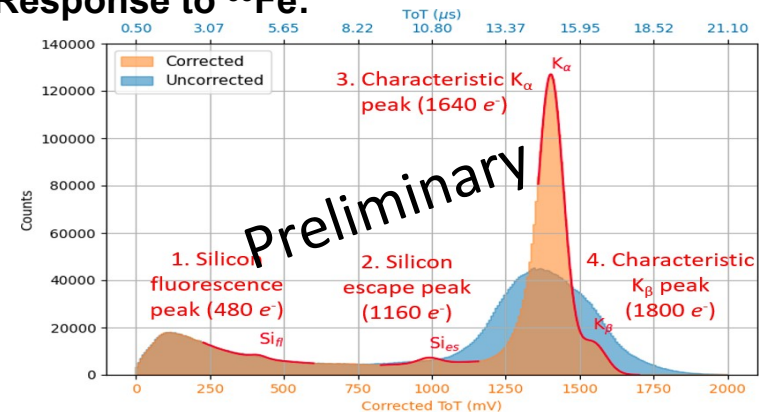


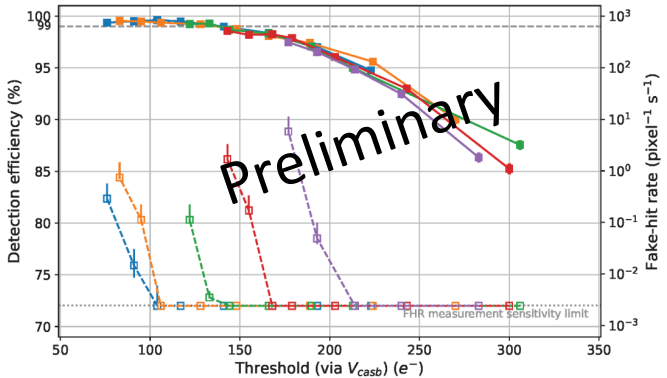


R&D activity in the INFN groups

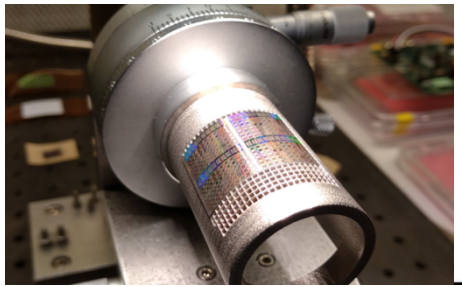
Bending and testing 65 nm (DPTS) chips in Trieste:

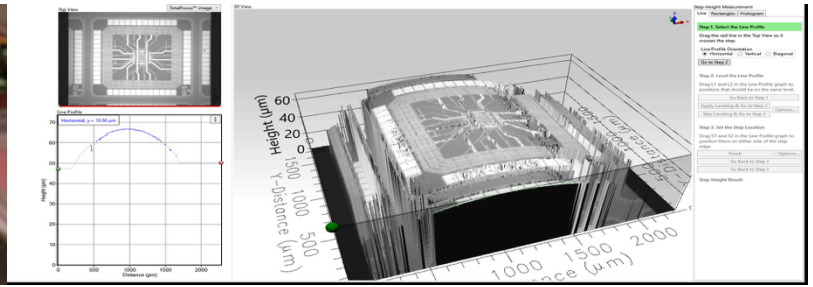
Response to ^{55}Fe:





Bending:





Plans and requests for 2024

Planned activity:

- sensor test and characterisation within SVT WP1 (and eRD113):
  - ✓ BA, PD and TS already well involved in prototype sensor tests from MLR1
    - plan to continue activities (including test beams @CERN) exploiting synergies with ITS3
  - ✓ sensor tests will also focus on EIC-specific measurements
    - eg configuration settings to minimise integration time and noise hit level
  - ✓ plan to contribute to test of the ER1 stitched prototype (@CERN)
    - targeting stitching yield → also crucial for the definition of size/layout of barrel layers (eRD111)

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    - eg configuration settings to minimise integration time and noise hit level
  - ✓ plan to contribute to test of the ER1 stitched prototype (@CERN)
    - targeting stitching yield → also crucial for the definition of size/layout of barrel layers (eRD111)
- bending and interconnection within SVT WP2 (and eRD111):
  - ✓ BA and TS involved in bending and interconnection activities for ITS3
    - super-ALPIDE assembly with working sensors within ITS3 to be completed in BA by end 2023
  - ✓ following step: exercise bending/interconnection at the ePIC SVT innermost radius
  - ✓ PV joining (thermal cycles and ageing test using a climate chamber)
    - contribution to long term stability tests on sensor assemblies, support structures and interconnections

Plans and requests for 2024

Corresponding requests:

- partly covered by requests for ALICE ITS3:
  - ✓ based on agreed synergies (ALICE, EIC_NET, NA60+) defined in June 2022* (see https://cernbox.cern.ch/index.php/s/C7QUuny57ibvmxJ)
    - CONSUMO/INVENTARIO: only specific developments for ePIC funded within EIC_NET
    - MISSIONI: only participation to test beams funded within ALICE

*A total of 300 k€/year for three years were granted to the CSN3 budget as additional funds following this submission. The additional funds are being used to cover mainly the cost of 65 nm test structures and aerogel studies.

Plans and requests for 2024

Corresponding requests (EIC_NET):

- sensor test and characterisation within SVT WP1 (and eRD113):
  - ✓ “INVENTARIO” PD: 10 k€
    - “box termostato test rivelatori silicio irraggiati”

    Offerta: non ancora disponibile, richiesta basata su ragionevole stima

    Test di chip irradiati a diversi livelli di radiazione e poi portati a temperatura ~10° C
- bending and interconnection within SVT WP2 (and eRD111):
  - ✓ “CONSUMO” BA: 24 k€
    - “mandrino per piegamento sensori a raggio ePIC” 1 k€
    - “motorino per rotazione controllata e automatica sensore” 2 k€
    - “stampe 3D per strutture supporti meccanici per test incollaggi” 1 k€
    - “silicio dummy (10 wafer), incluso di taglio e assotigliamento” 20 k€

    Offerte: https://cernbox.cern.ch/index.php/s/gDZQQIkFe6OvN9C

Milestone:

Sviluppo procedura di curvatura e interconnessione per prototipizzazione ePIC vertex layer (31.12.2024)

Plans and requests for 2024

Corresponding requests (EIC_NET cont'd):

- sviluppo rete distribuzione alimentazioni e dati (generic R&D):
  - ✓ "INVENTARIO" TS: 5 k€
    - "vasca bagno ultrasuoni ad alta potenza pulizia stampati e componenti macchina AJP"

    Offerta: https://cernbox.cern.ch/index.php/s/uktRe8SGO3Hng5e

    Attività dedicata a sviluppo rete distribuzione alimentazioni e dati su silici di grandi dimensioni (eventualmente anche curvi) attraverso esplorazione di tecnologia Aerosol Jet Printing (AJP):
    - si utilizzano stampanti 3D ad alta precisione su qualsiasi supporto e forma con un aerosol di materiale conduttivo o dielettrico all'occorrenza
    - l'idea è di testare materiali diversi per ottenere resistività giusta, dopo ogni "stampa" è necessario pulire le componenti della macchina con bagno a ultrasuoni.

Plans and requests for 2024

Corresponding requests (EIC_NET cont'd):

- supporting in-person participation to ePIC SVT activities:
  - ✓ "MISSIONI": 18 k€
    - international travelling: SC and SVT DSC meetings in US, link with ITS3 (mostly @CERN)
    - national travelling: collaboration among the INFN groups

	EIC-SC/SVT in US	link with ITS3 @CERN	national travelling	Total
BA	5.0	2.0	2.0	9.0
PD	2.5	0	0.5	3.0
PV	2.5	0	1.0	3.5
TS	0	2.5	0	2.5
	10.0	**4.5**	**3.5**	**18.0**

Plans and requests for 2024

Corresponding requests (EIC_NET cont'd):

- supporting in-person participation to ePIC SVT activities:
  - ✓ "MISSIONI": 18 k€
    - international travelling: SC and SVT DSC meetings in US, link with ITS3 (mostly @CERN)
    - national travelling: collaboration among the INFN groups

Summary table SVT-dedicated requests:

	CONSUMO	INVENTARIO	MISSIONI	Total
BA	24.0	0	9.0	33.0
PD	0	10.0	3.0	13.0
PV	0	0	3.5	3.5
TS	0	5.0	2.5	7.5
	24.0	**15.0**	**18.0**	**57.0**

BACKUP

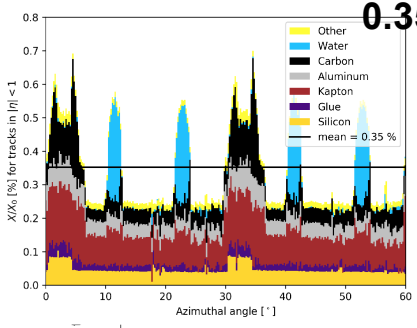
EIC vertex and tracking

ALICE ITS3 sensor and detector concept:

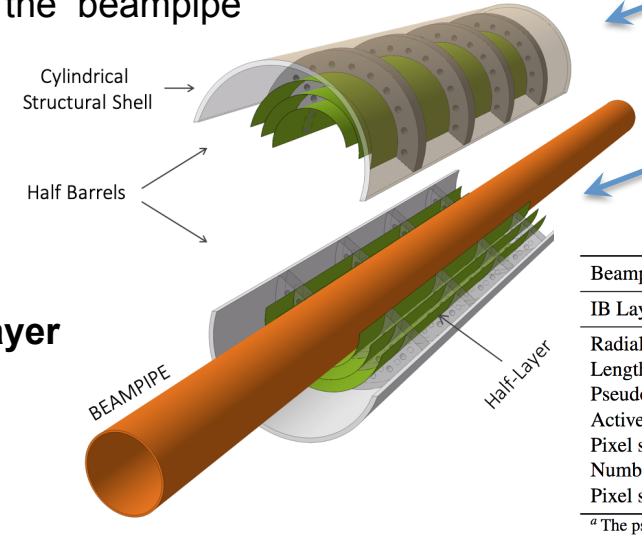
- three layers vertex detector with 0.05% X_0 per layer

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]		

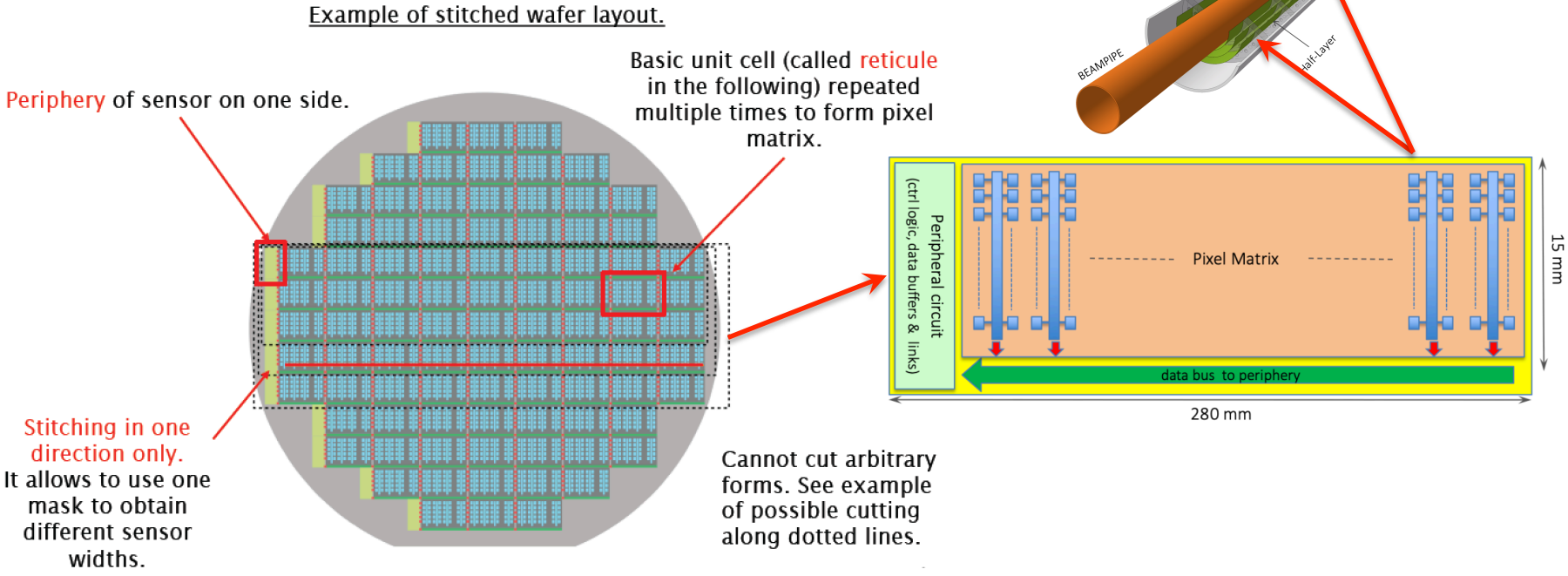
[a] The pseudorapidity coverage of the detector layers refers to tracks originating from a collision at the nominal interaction point ($z = 0$).
[b] For the fallback solution the pixel size is about a factor two larger ($O(30 \times 30)$ μm^2).

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

EIC vertex and tracking

Stitching for the ITS3 sensor:

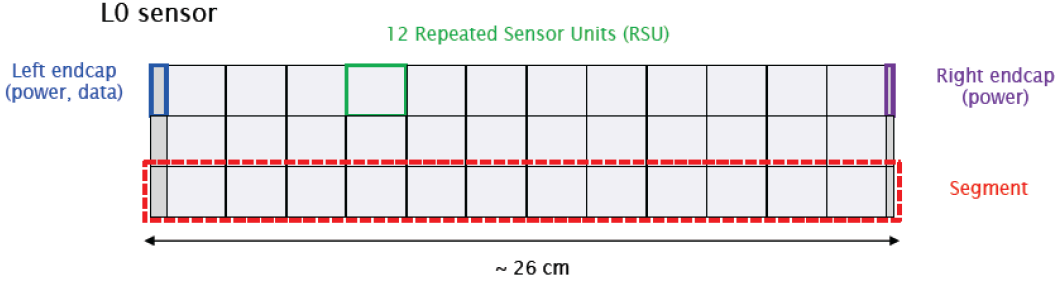
- deployed to design a wafer scale sensor



ePIC SVT layout and concept

ER2 and ePIC IB sensor

- ER2 segment = 12 RSU, left and right endcap
  - Note: ER2 design evolving rapidly; design specifications can still change (RSU and pixel size, power distribution scheme, on/off-sensor data transmission, etc.)
  - Direct impact on the overall ePIC SVT design (powering, readout, mechanics, cooling)
  - Design to converge in the next few months
- ITS3 and ePIC SVT IB sensor
  - L0: 3 segments, L1: 4 segments, L2: 5 segments



Laura Gonella | ePIC collaboration meeting | 27 July 2023 7

ePIC SVT DSC

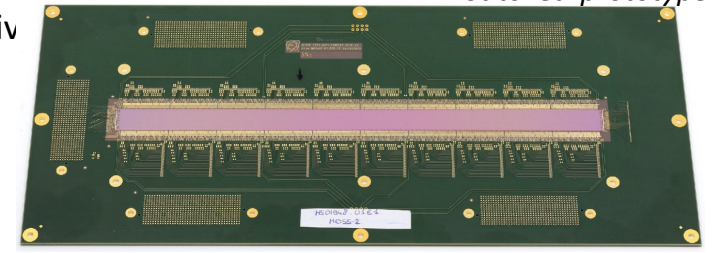
Based on discussions in the EIC SC on ~Jan/Feb:

- SVT DSC caming together "*to develop, construct and operate a well-integrated, large-acceptance, low-mass, high resolution tracking and vertexing solution for ePIC based on Monolithic Active Pixel Sensors (MAPS) in 65 nm technology*"
- by consensus of the initial membership, L. Gonella (*technical coordinator*) and E. Sichtermann (*DSC leader*) will serve in the startup phase
- imperative to advance earlier initial discussions in the EIC SC on:
  - ✓ who will participate (R&D phase, and during construction)?
  - ✓ who will do what?
  - ✓ what resources are available to / within the SVT-DSC?
  - ✓ what is not covered or missing?

ePIC SVT sensor risk mitigation: conductive layer deposition

- EIC Generic R&D FY23 program awarded 49k$ for R&D based on additiv manufacturing to mitigate possible risks on vertex detectors for EIC

Stitched prototype

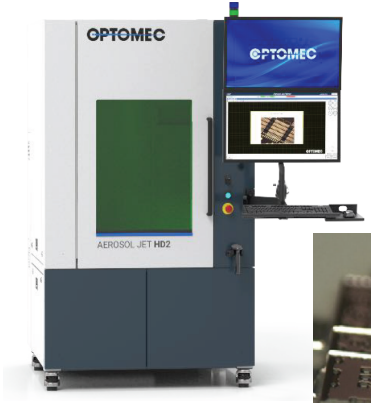


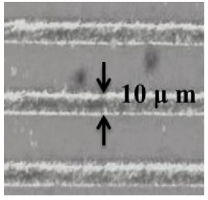
- In-silicon power distribution over long distances not yet validated
  - If *stitching* yield is sub-optimal for excessive voltage drop across the chip, **processing** of the sensor is needed (measurements are ongoing)

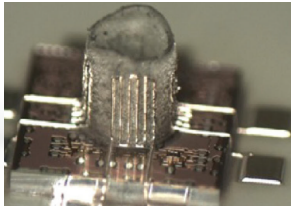
a **post-**

AJP – conductive traces

- Application of a **Re-Distribution Layer** (RDL) with additive manufacturing
  - Additional copper and polyamide layer(s) added to the wafer where needed
  - Trade-off between resistance and material budget
  - ***Aerosol Jet Printing (AJP)*** machine available at INFN TS – UniTS:
    - 10 µm spatial resolution, on planar and bent substrate







- **EIC_NET request for 2024**: ultrasound bath device to clean parts after ink deposition with AJP