Giornate Nazionali EIC_NET

Corigliano-Rossano, June 22-23 2023

ePIC Silicon Vertex Tracker and INFN R&D

- ePIC SVT layout and concept
- from EIC Silicon Consortium to ePIC SVT DSC
- activity and plans in the INFN groups

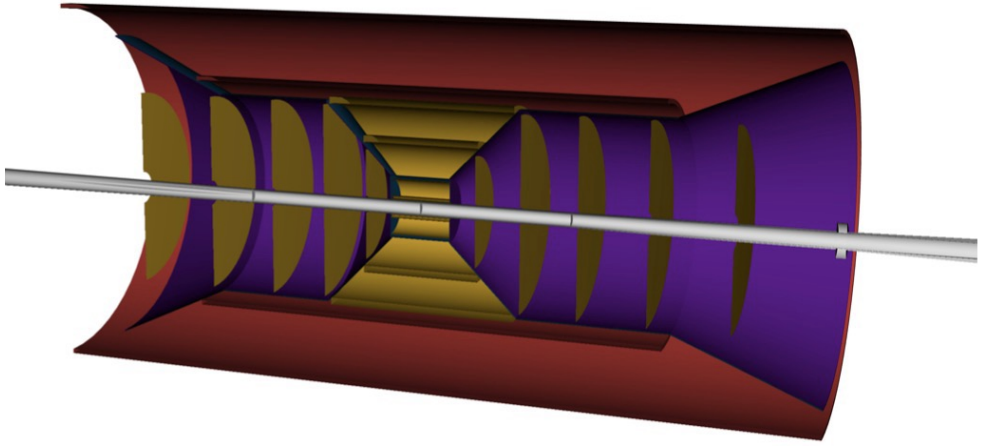
D. Colella and D. Elia (Bari)

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 (E(H)D0-E(H)D4)

October 2022 geometry



Total (active) area: ~8.5 m^2

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

ePIC SVT layout and concept

ePIC SVT concept in a nutshell:

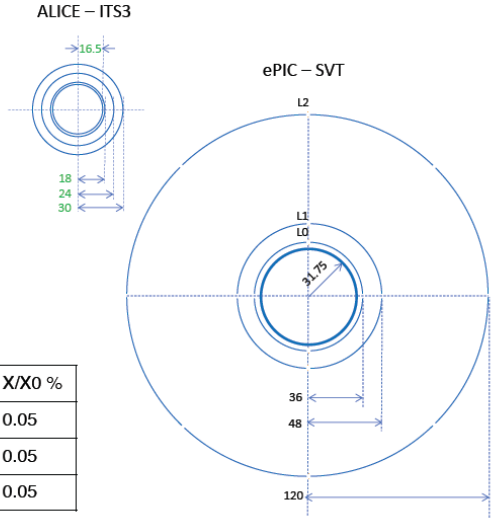
- ITS3-like IB layers:
  - ✓ Use the ITS3 wafer-scale sensor
  - ✓ Adapt ITS3 detector concept to the (larger) EIC radii
    → *Mechanics, services and cooling of ePIC SVT inner barrel layers need specific development*
- OB layers and Disks:
  - ✓ EIC Large Area Sensor (LAS), i.e. ITS3 sensor size optimised 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

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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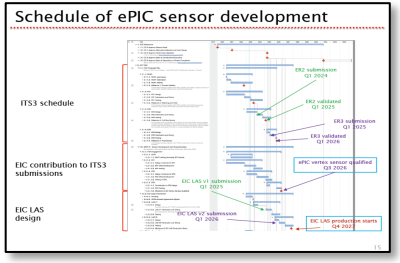
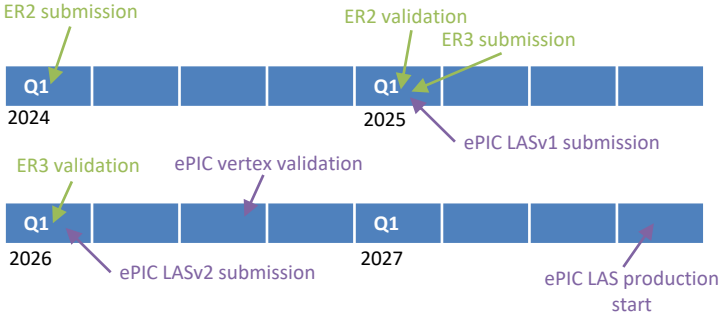
ePIC SVT layout and concept



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) ~February 2027



- Construction phase will (mostly) follow R&D:
  - ✓ CD-3 (Approve Start of Construction/Execution) currently anticipated for 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 relationship
  - ✓ 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 mailing list will happen soon)

ePIC SVT DSC

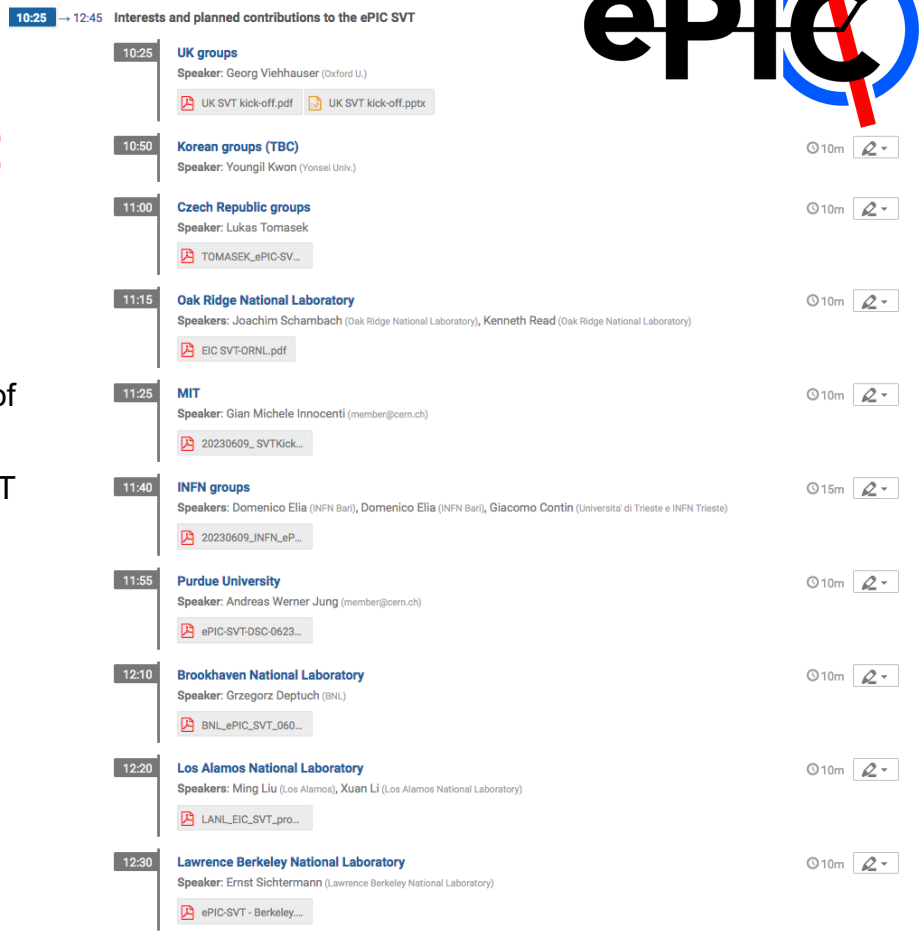
Based on discussions in the EIC SC on ~Jan/Feb:

- SVT DSC coming 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, Laura (*technical coordinator*) and Ernst (*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 DSC

ePIC SVT DSC kickoff meeting:

- June 9: https://indico.bnl.gov/event/19823/
- 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	

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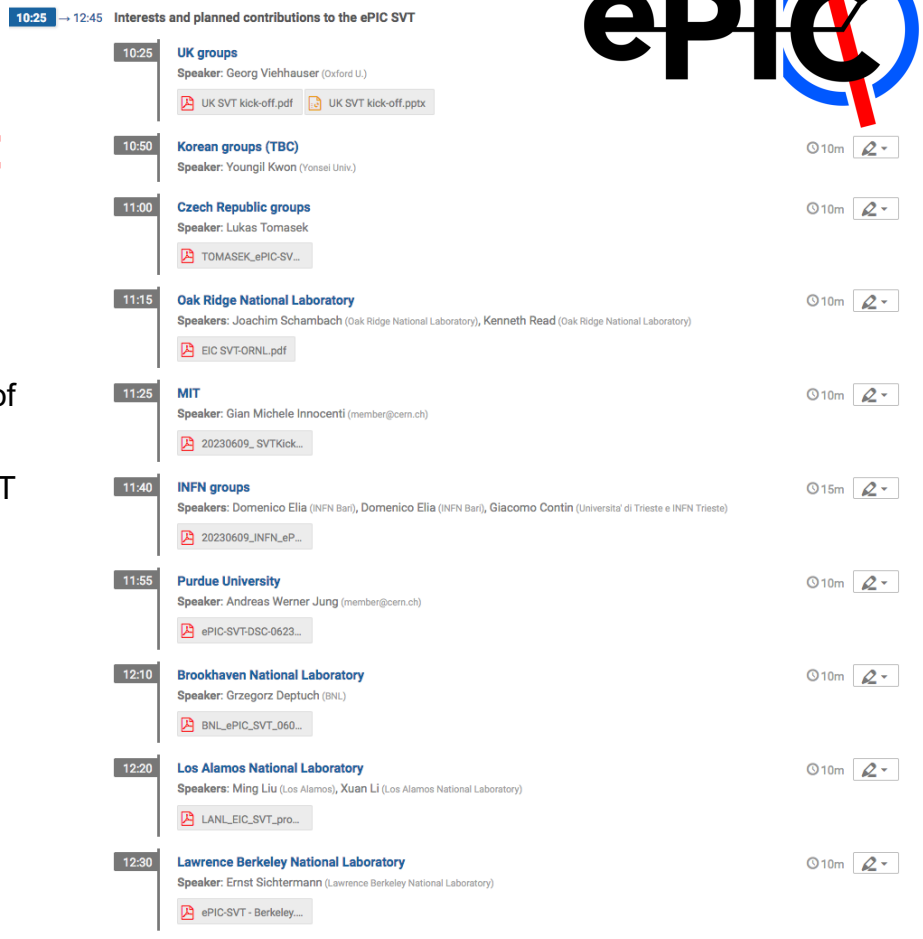
- INFN contribution here:
  - ✓ planned contributions: next slide
  - ✓ ongoing R&D activities: following slides



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):

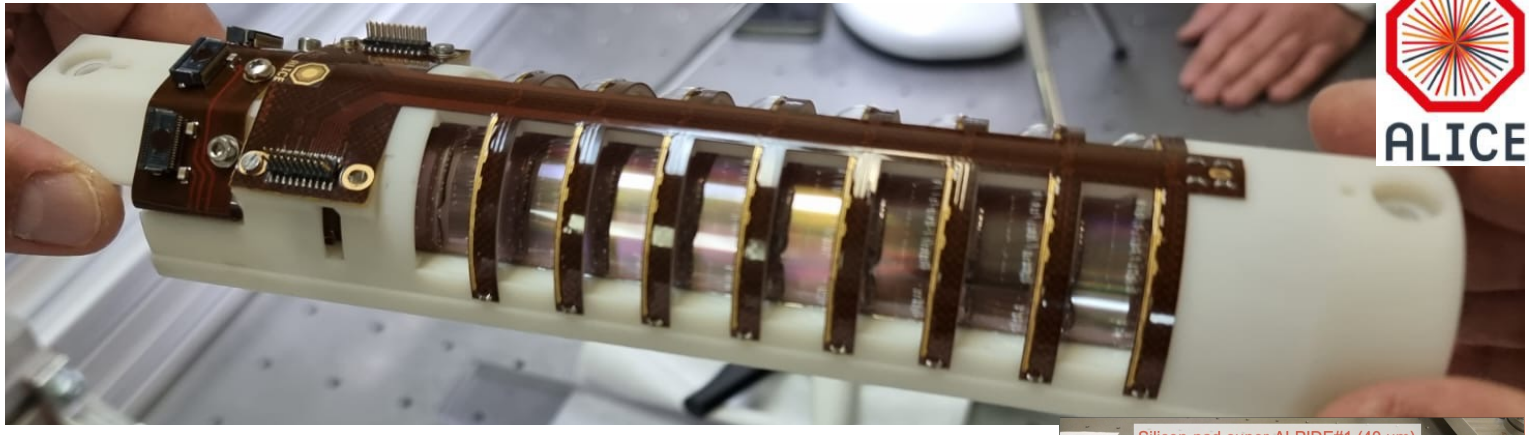
- status of administrative procedures:
  - ✓ approved by INFN CD, contracts (INFN-JLab/DOE sides) signed
  - ✓ status for the corresponding positions:
    - BA: call for a post-doc position (1y+1), expected to be out in July
    - PD: co-funding of a PhD position with Phys. Dept. (contact: P. Giubilato)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

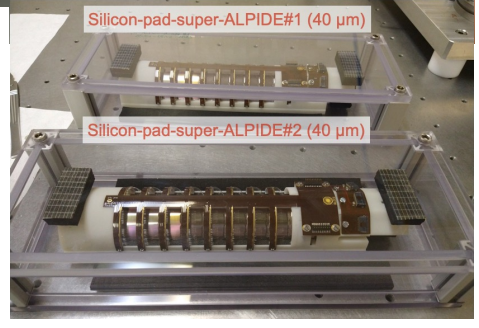
Plans for FY24:

- eRD104, eRD111, eRD113: call is out, proposal deadline July 7, 2023
- generic R&D: call is out, proposal deadline July 14, 2023
- INFN aim: get a similar second-year funding, in continuation to FY23

R&D activity in the INFN groups

ITS3 super-ALPIDE project in Bari:



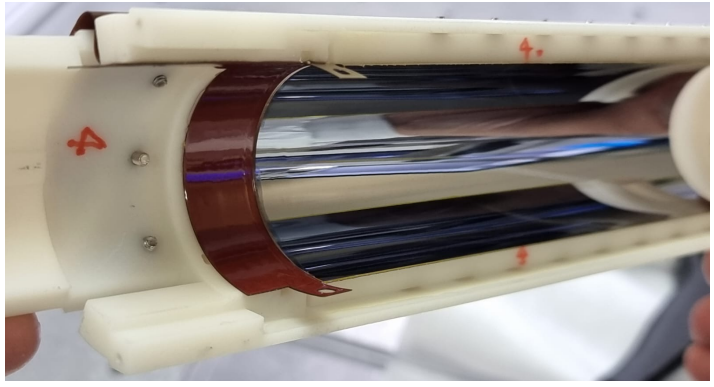


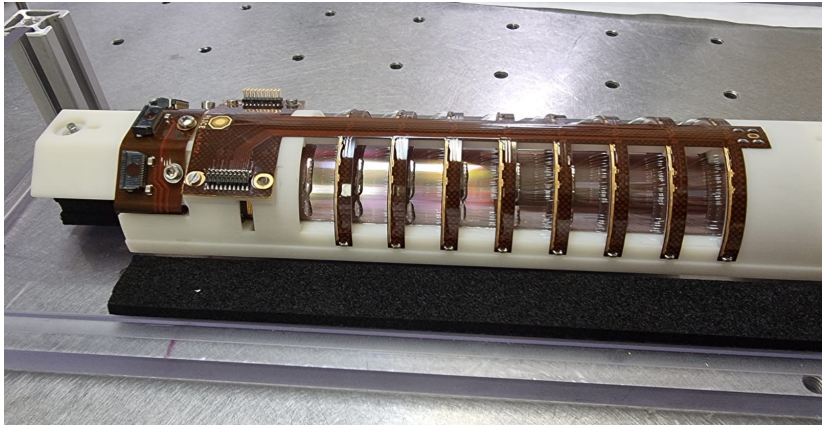
Dummy-pad-super-ALPIDE#1 (40 µm)
First complete assembly of a super-ALPIDE prototype based on real blank silicon (not electronics integrated) with metallic pad for bonding → Completed on 8/2/23

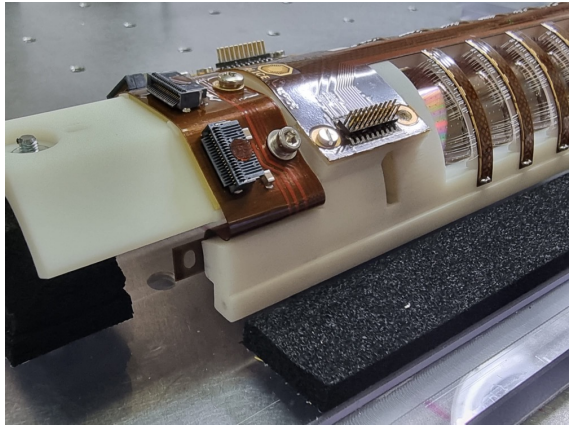
Dummy-pad-super-ALPIDE#21 (40 µm)
Second complete assembly of a super-ALPIDE prototype this time using carbon foam support structures → Completed on 14/3/23

Super-ALPIDE#11 (30 µm)
Assembly with working sensor failed (28/3) → Mandrel with improved quality surface under production

R&D activity in the INFN groups

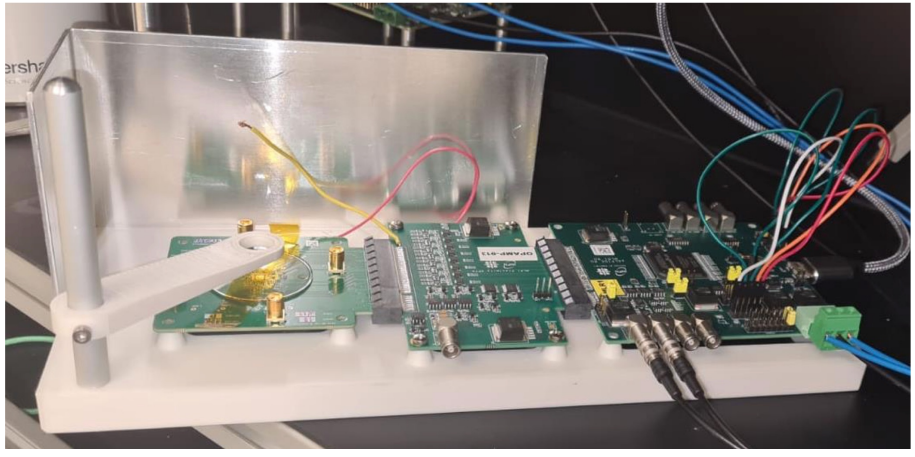




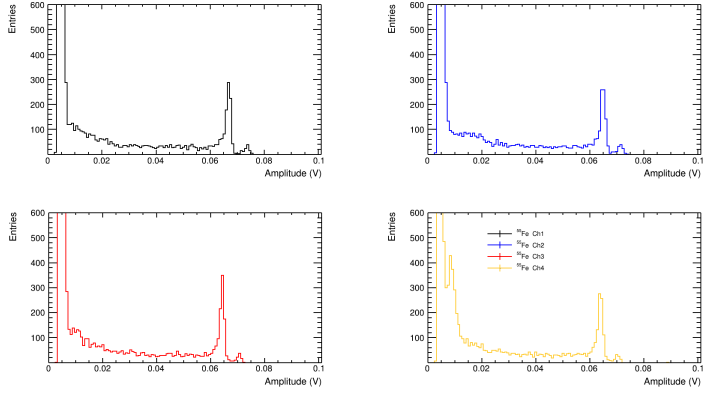


R&D activity in the INFN groups

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 (S. Kumar, A. Mastroserio):

- Event Display Tutorial (ROOT Based)
  - ✓ https://indico.bnl.gov/event/18213/contributions/73480/attachments/46166/78396/EventDisplay_ShyamKumar23Feb2023.pdf
- Smearing of Parameters in the Truth Seeding
  - ✓ https://indico.bnl.gov/event/18272/contributions/72753/attachments/45921/77608/EPIC_Meeting_Shyam9Feb23.pdf
- Studies of Number of Hits/Lever Arm
  - ✓ https://indico.bnl.gov/event/17924/contributions/72265/attachments/45681/77134/EPIC_Tracking_Meeting_Shyam26Jan2023.pdf
- Fast Simulation Studies with the EPIC Detector
  - ✓ https://indico.bnl.gov/event/17750/contributions/71187/attachments/44843/75637/EPIC_Tracking_Meeting_Shyam1Dec2022.pdf

R&D activity in the INFN groups

ITS3/ePIC activities in Padova and Trieste:

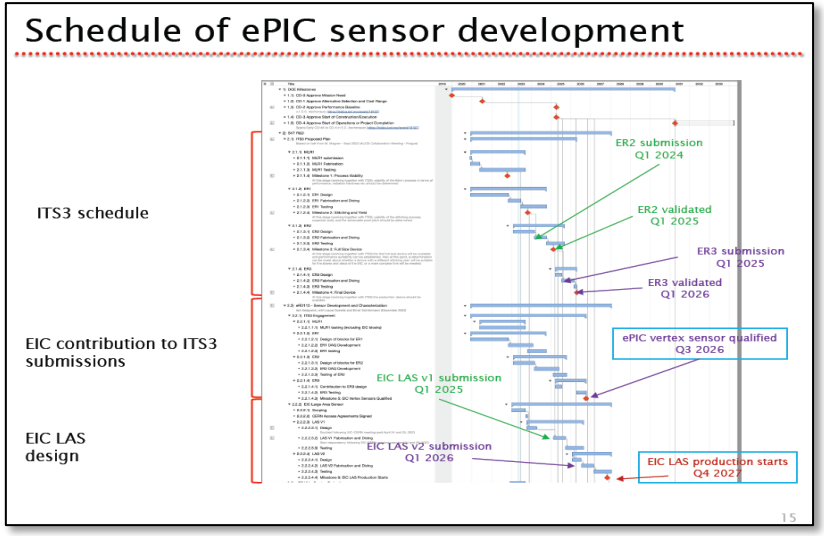
- Joint effort for MLR1 characterization after bending
- Two APTS were bent in Trieste along two different axis
- Tested in Padova with an X-ray source (^{55}Fe) for different depletion voltages and a comparison with a flat chip was performed
- More details in Rosario's presentation

BACKUP

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) ~February 2027



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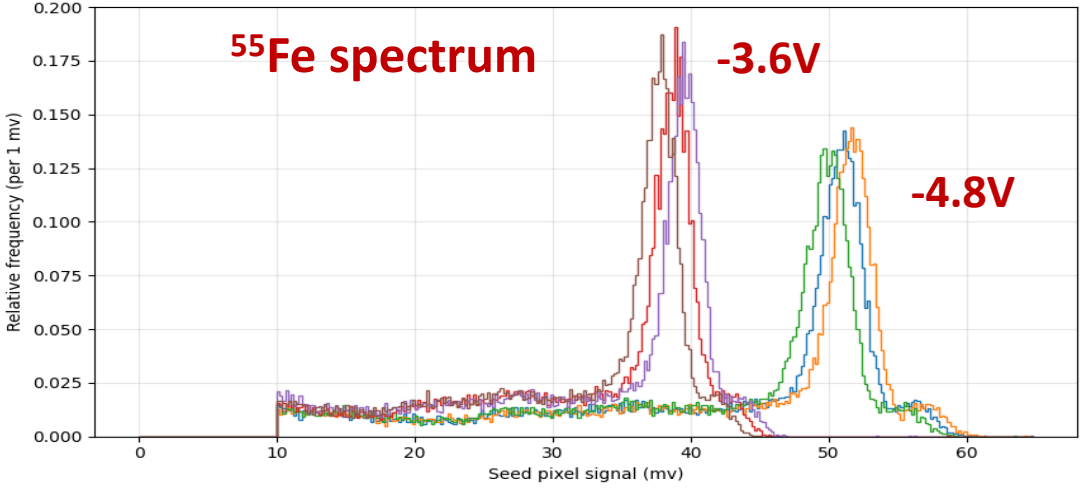
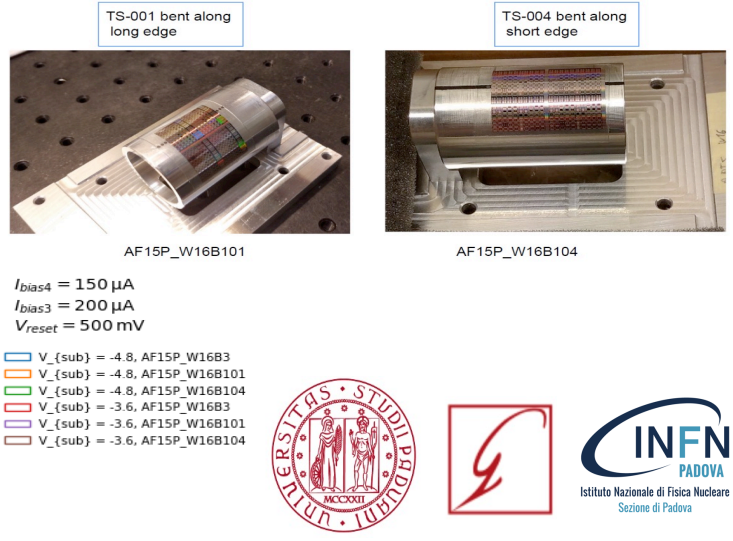
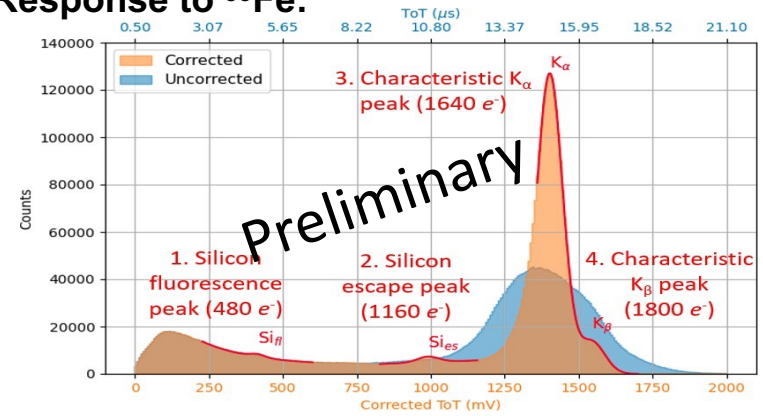


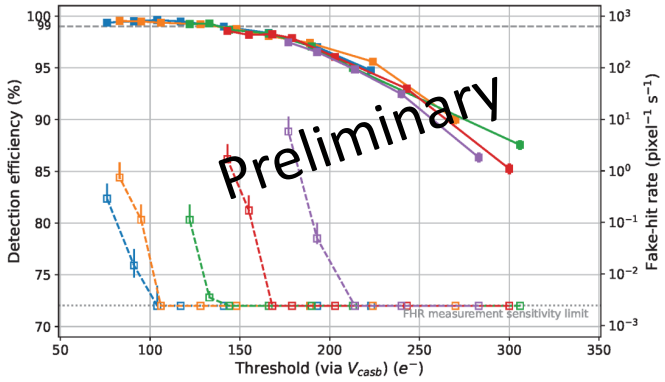


R&D activity in the INFN groups

Bending and testing 65 nm CMOS chips in Trieste:

Response to ^{55}Fe:





Bending: