

ePIC Silicon Vertex Tracker (SVT)

- detector layout and concept
- SVT DSC: institutions, interests, organization
- SVT project timeline
- INFN involvement: recent R&D activity and construction plans
- proposed funding profile

Domenico Elia

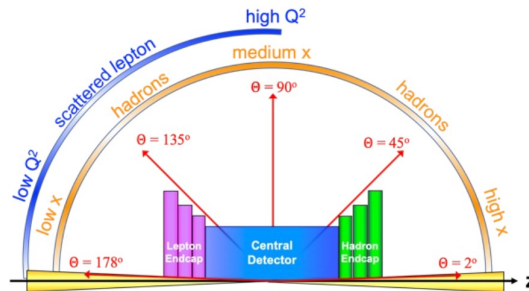
for the SVT INFN groups (BA, PD, PV and TS)

SVT layout and concept

Performance requirements:

- <https://eic.jlab.org/Requirements/index.html>
- based on physics in the [Yellow Report](#)

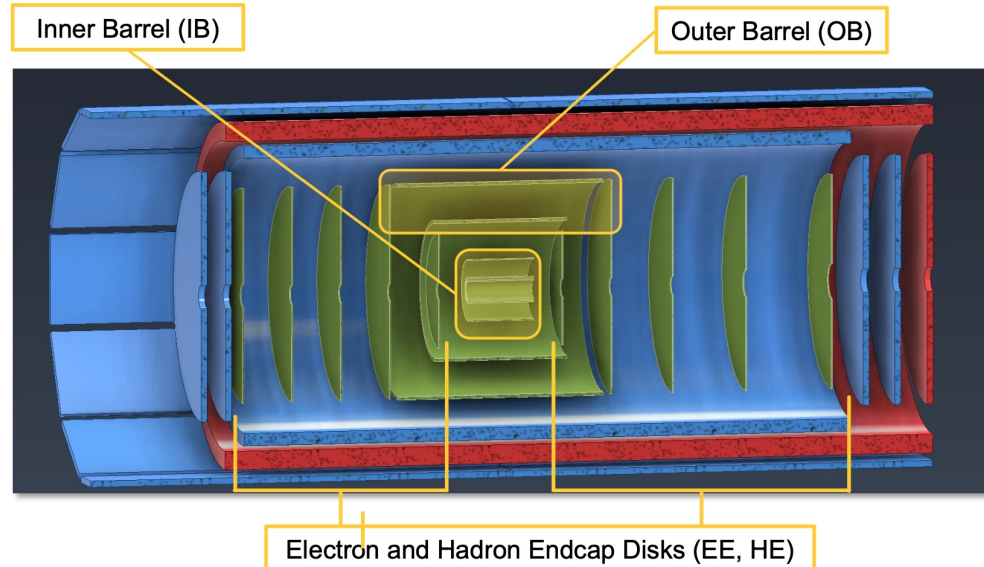
	Momentum Resolution	Spatial Resolution
Backward (-3.5 to -2.5)	$\sim 0.10\% \times p \oplus 2.0\%$	$\sim 30/pT \mu\text{m} \oplus 40 \mu\text{m}$
Backward (-2.5 to -1.0)	$\sim 0.05\% \times p \oplus 1.0\%$	$\sim 30/pT \mu\text{m} \oplus 20 \mu\text{m}$
Barrel (-1.0 to 1.0)	$\sim 0.05\% \times p \oplus 0.5\%$	$\sim 20/pT \mu\text{m} \oplus 5 \mu\text{m}$
Forward (1.0 to 2.5)	$\sim 0.05\% \times p \oplus 1.0\%$	$\sim 30/pT \mu\text{m} \oplus 20 \mu\text{m}$
Forward (2.5 to 3.5)	$\sim 0.10\% \times p \oplus 2.0\%$	$\sim 30/pT \mu\text{m} \oplus 40 \mu\text{m}$



SVT layout and concept

Three main sub-systems:

- **Inner Barrel (IB)**
 - ✓ 3 layers: L0, L1, L2
 - ✓ Radii of 36, 41, 120 mm
 - ✓ Length of 27 cm
 - ✓ $X/X_0 \sim 0.05\%$ per layer
 - ✓ Curved, thinned, wafer-scale sensor
- **Outer Barrel (OB)**
 - ✓ 2 layers: L3, L4
 - ✓ Radii of 27 and 42 cm
 - ✓ $X/X_0 \sim 0.25\%$ and $\sim 0.55\%$
 - ✓ More conventional structure w. staves
- **Electron/Hadron Endcaps (EE, HE)**
 - ✓ 2 arrays with 5 disks each
 - ✓ $X/X_0 \sim 0.25\%$ per disk
 - ✓ More conventional structure



Lengths L2 \rightarrow L4 increase so as to project back to $z = 0$; disk radii adjust accordingly

SVT layout and concept

Basic assumptions for the IB:

- use the ALICE ITS3 wafer-scale sensor
- adapt ITS3 detector concept to the (larger) ePIC radii

→ *mechanics, services and cooling of the SVT IB need specific development*

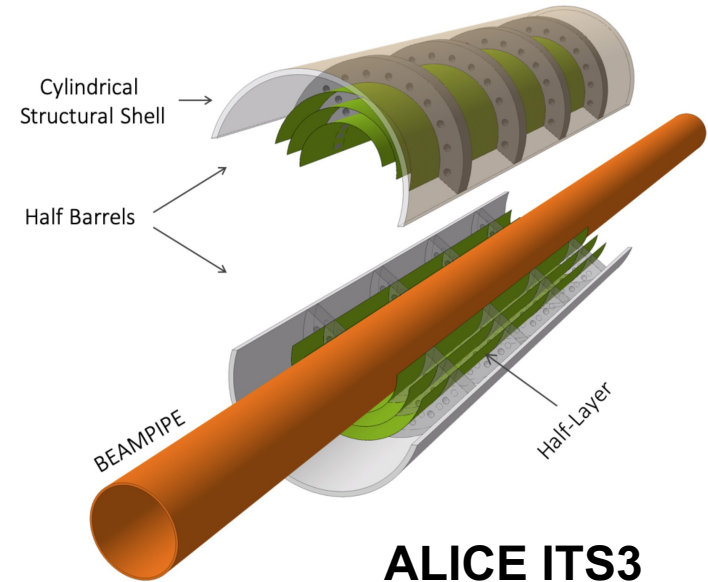
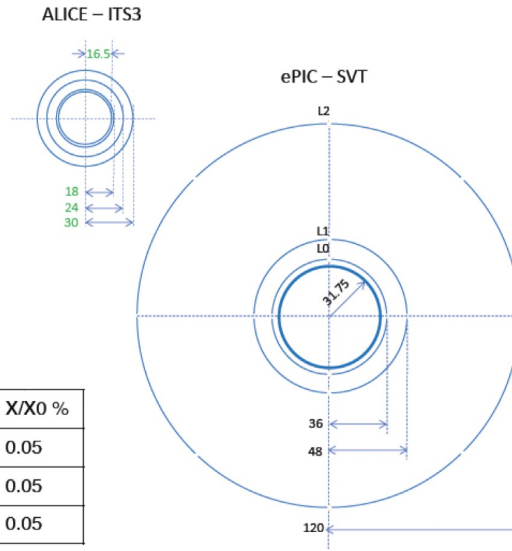
• Re-use ITS3 wafer-scale sensor

- L0: 3x12 RSU + endcaps
- L1: 4x12 RSU + endcaps
- L2: 5x12 RSU + endcaps

• Number of sensors per layer

- L0: 4
- L1: 4
- L2: 8

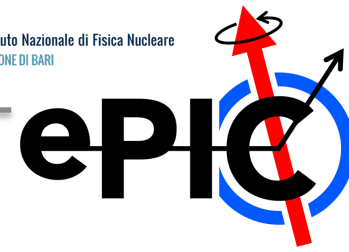
ePIC SVT IB	r [mm]	l [mm]	X/X0 %
L0	36	270	0.05
L1	48	270	0.05
L2	120	270	0.05



Detector Subsystem Collaboration



Istituto Nazionale di Fisica Nucleare
SEZIONE DI BARI



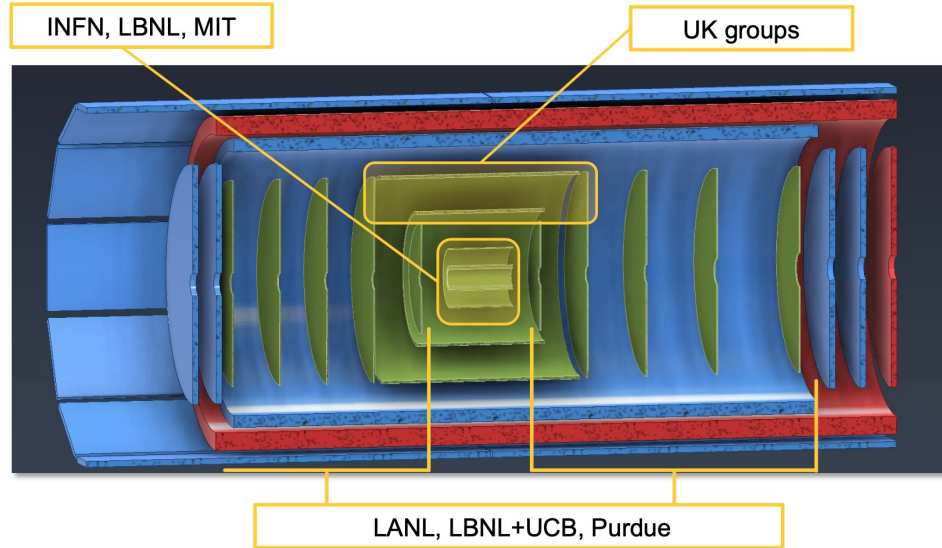
SVT DSC participating institutions:



Extensive Si-detector experience in the ALICE, ATLAS, CMS, sPHENIX, STAR collider experiments

Detector Subsystem Collaboration

SVT DSC institutional interests:



Subsystem coordination:

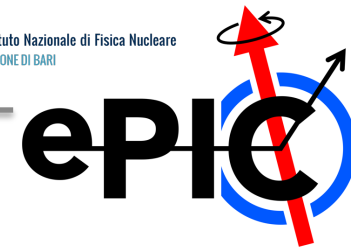
- IB: INFN (D. Elia)
- OB: Oxford (G. Viehhauser)
- HE/EE: LBNL (N. Apadula)

Sensor and IC design: BNL, LBNL, MIT, RAL – further groups in characterization

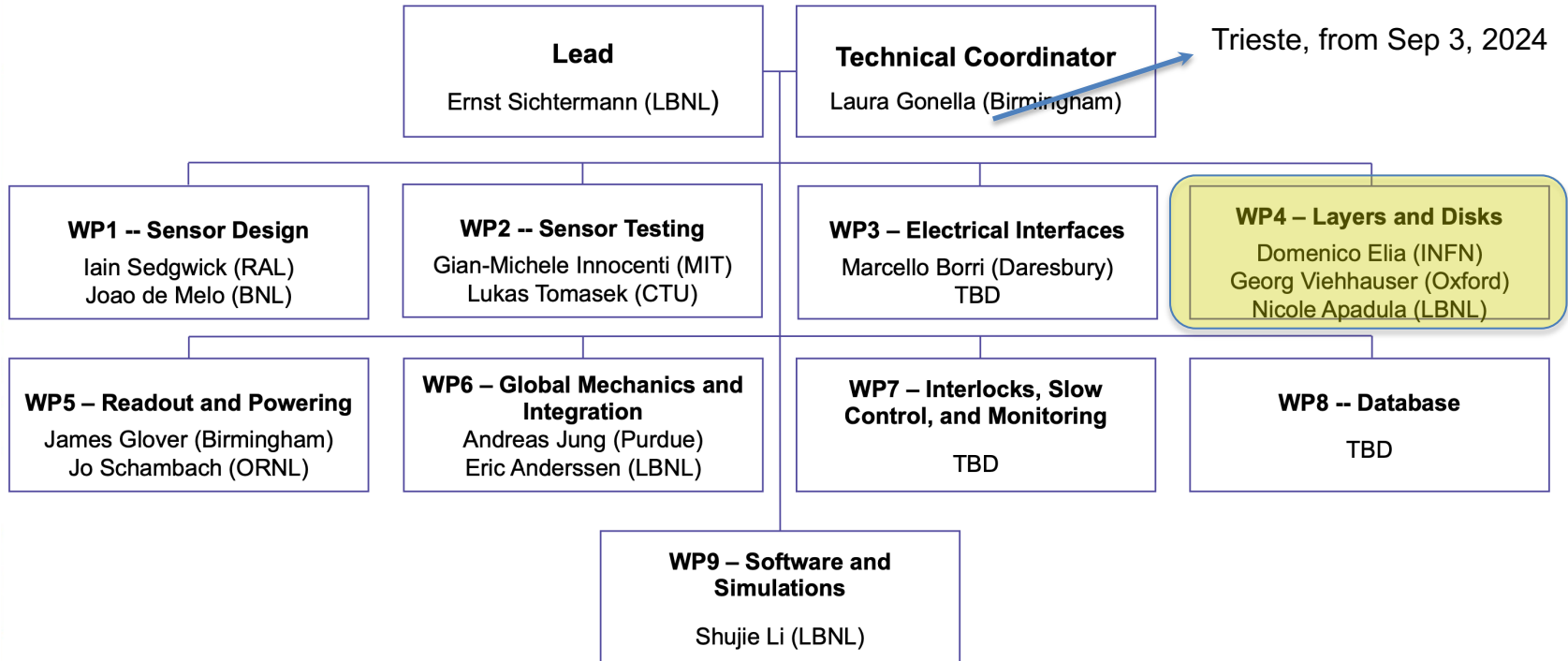
Readout: ORNL, MIT

Additional groups expressed interest

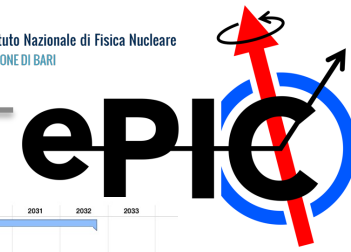
Detector Subsystem Collaboration



SVT DSC organization:

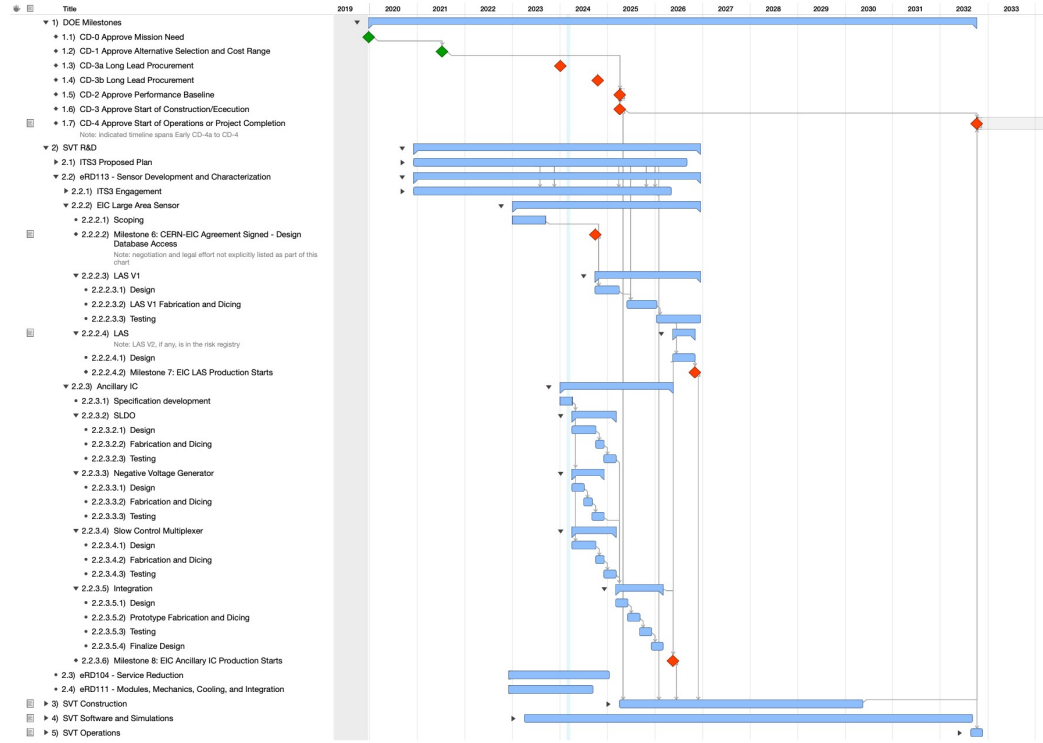


SVT project timeline



E. Sichtermann @PTDR March 2024

- Sensor development:
 - ITS3 wafer scale sensor development (ER2, ER3) for IB 2024 – 2026,
 - EIC-LAS development for OB and Disks complete and ready for production start in calendar Q4 2026,
 - Ancillary IC development for EIC-LAS complete and ready for production start in calendar Q2 2026.



Electron-Ion Collider

Tracking Detectors Review, March 20-21, 2024

SVT project timeline

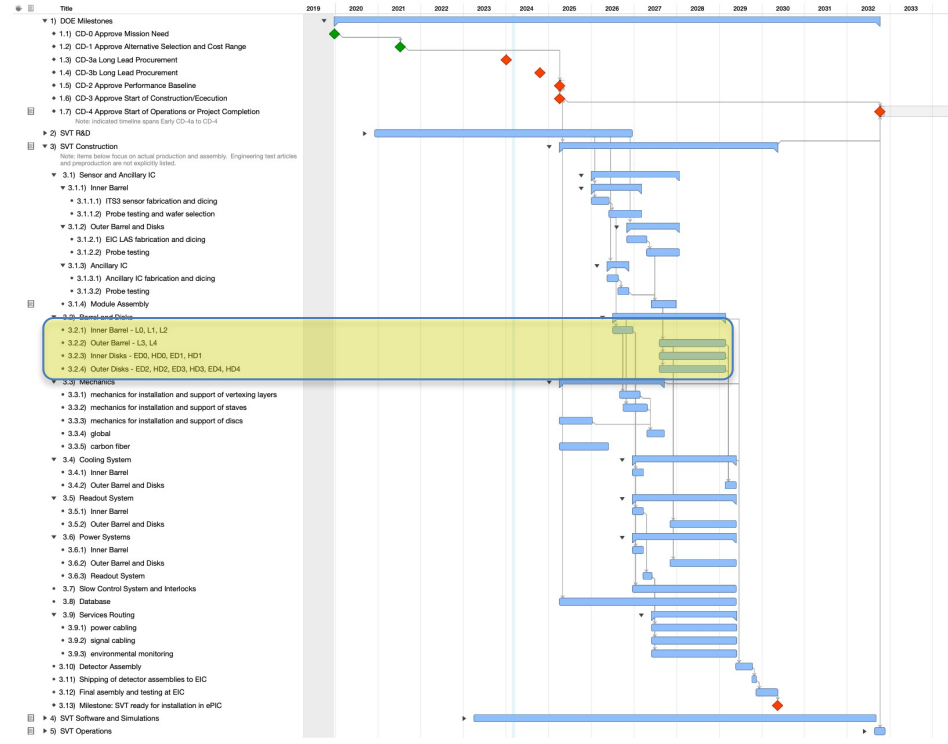


E. Sichtermann @PTDR March 2024

• Construction:

- Engineering test articles following R&D in 2025—2026,
- Pre-production phase of about 1 year for IB; 2 years for OB,
- Production and QA through calendar Q2 2029 followed by assembly,
- Current plan is shipment of surveyed and assembled half barrels and disks to BNL in calendar Q4 2029,
- Final assembly and testing at BNL through calendar Q1 and Q2 2030, prior to installation in ePIC.

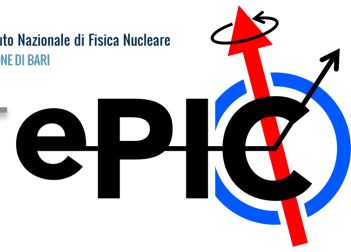
- SVT schedule is compatible with Project requirements, being finalized.



Electron-Ion Collider

Tracking Detectors Review, March 20-21, 2024

INFN involvement in SVT



Participation and main interests:

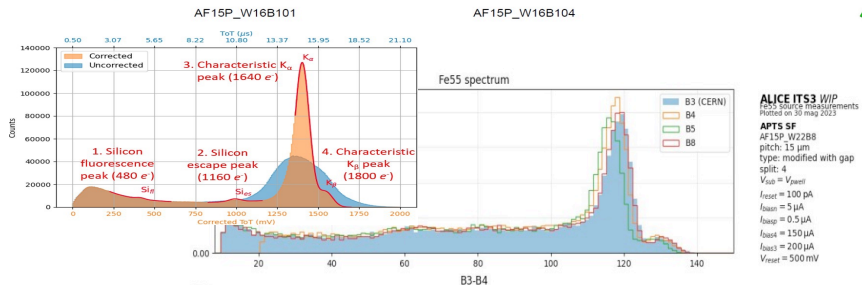
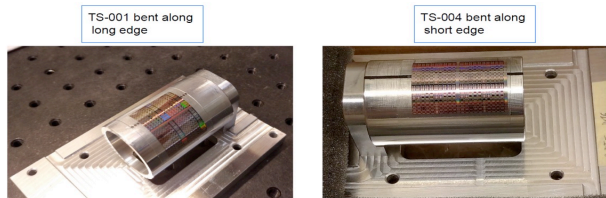
- currently involved groups: BA, PD, PV and TS
- interest focused on the IB (overlap/synergies with ALICE ITS3)
- main R&D activities along the last 2-3 years:
 - ✓ bending and interconnection issues (BA, TS)
 - ✓ test of MLR1 (APTS and DPTS) structures (BA, PD, TS)
 - ✓ start development of IB concept design, local and global mechanics (BA, PD)
 - ✓ investigate thermal chamber test and transport issues (PV)
 - ✓ tracking/vertexing simulation (BA)

INFN involvement in SVT

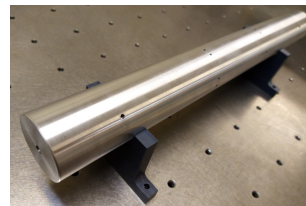
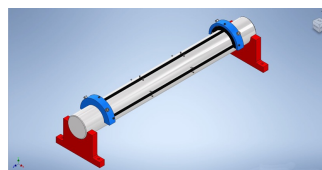
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Bending and test of APTS/DPTS @PD, TS



SVT L0-1 local mechanics design

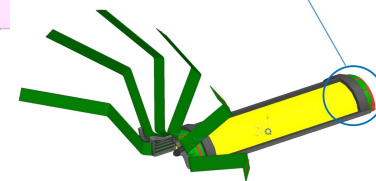
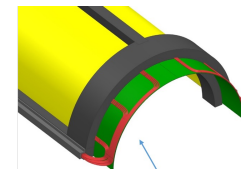
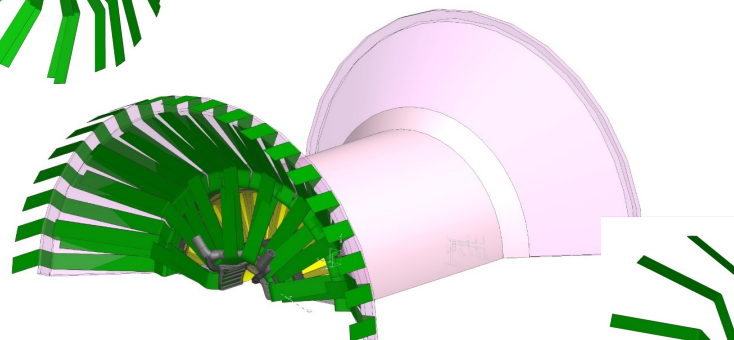
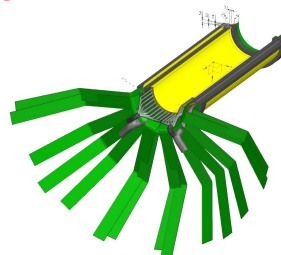


@BA

Bending/interconnection ITS3 super-ALPIDE



SVT IB global mechanics design @PD

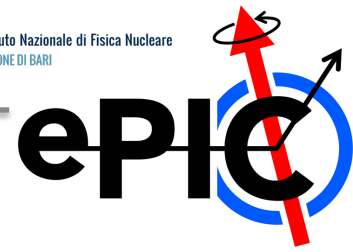


INFN involvement in SVT

Participation and main interests:

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- main R&D activities along the last 2-3 years:
 - ✓ bending and interconnection issues (BA, TS)
 - ✓ test of MLR1 (APTS and DPTS) structures (BA, PD, TS)
 - ✓ start development of IB concept design, local and global mechanics (BA, PD)
 - ✓ investigate thermal chamber test and transport issues (PV)
 - ✓ tracking/vertexing simulation (BA)
- participation to the DOE-funded eRD projects in FY23 and 24:
 - ✓ eRD111 – Silicon vertex (sensors excluded), INFN contact: D. Elia
 - 30 kUSD for FY23, 45 kUSD for FY24 (75 kUSD, all groups)
 - ✓ eRD113 – Sensor development and characterization, INFN contact: R. Turrisi
 - 30 kUSD for FY23, 45 kUSD for FY24 (75 kUSD, all groups)
 - ✓ generic RD – Additive power&data redistribution layers, INFN contact: G. Contin (50 kUSD, TS)

INFN involvement in SVT



Plans for construction:

- INFN IKC for SVT IB (overall 900 k€):
 - ✓ sensors, including characterization and test
 - ✓ design, prototyping and construction of the two innermost layer barrels (L0-L1)
 - ✓ design, prototyping and production of the IB global mechanics
 - ✓ qualification, test and production of the FPCs
- sharing of the responsibilities within the INFN groups:
 - ✓ **BA**: leading IB project, main assembly centre of the two innermost layers
 - ✓ **PD**: development and production of the global SVT IB mechanics and backup assembly/production centre for the two innermost layers
 - ✓ **PV**: test of the special gluing of the sensors with support structure (climatic chamber), development of dedicated transport boxes and shipping/handling to BNL
 - ✓ **TS**: qualification, test and production of the SVT IB FPC

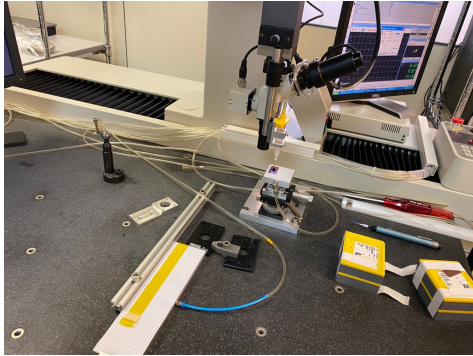
INFN involvement in SVT

Group infrastructures and resources:

Group	Infrastructure	Resources	FTE/year
Bari	Camera pulita CAD e officina meccanica Servizio elettronica	Electronic technician: Mechanical engineer: Mechanical designer: Mechanical technician:	0.1 0.2 0.2 0.3
Padova	Camera pulita CAD e officina meccanica Servizio elettronica	Electronic technician: Mechanical engineer: Mechanical designer: Mechanical technician:	0.3 0.2 0.3 0.3
Pavia	CAD e officina meccanica Servizio elettronica	Electronic technician: Mechanical engineer: Mechanical designer: Mechanical technician:	0.1 0.2 0.2 0.2
Trieste	CAD e officina meccanica Servizio elettronica	Electronic engineer: Electronic technician: Mechanical technician:	0.1 0.2 0.1

INFN involvement in SVT

Group infrastructures and resources:

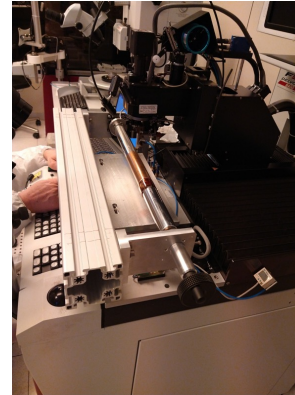


@INFN BA

Mitutoyo with alignment vacuum tools

Sensor bending setup

Delvotec G4 wirebonder



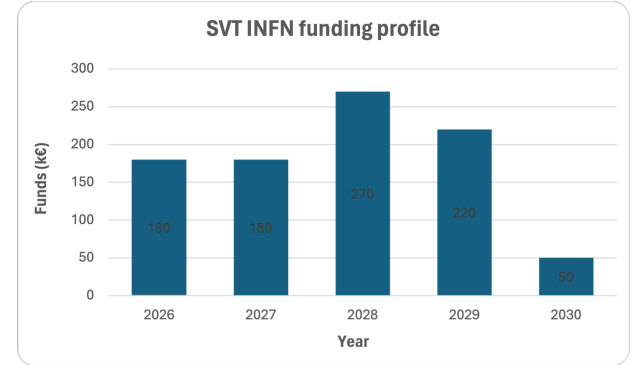
@INFN PV

Climatic chamber Galli, Genviro-030LC

INFN funding profile for SVT

Based on following assumptions:

- prototyping till 2026, construction ~2027 (2028?)
 - ✓ strongly dependent from ER2-ER3, sensor testing etc
 - ✓ some contingency for spares (may extend to 2029)
- spread of funding for sensors and FPC till 2030
 - ✓ project buffering may help overall INFN funding for ePIC



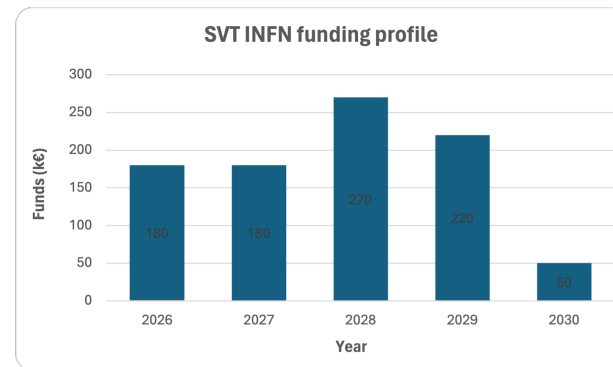
Profilo spesa SVT 2026-2030						
Item	2026	2027	2028	2029	2030	Tot
Design e produzione tool sensor bending setup	15	10	10			35
Design e produzione local support structure L0-L1, carbon foam etc	10	10	10			30
Produzione e test prototipi, assembly finale e spare L0-L1	20	10	10			40
Design e produzione prototipi e soluzione finale global mechanics IB	10	20	20	20		70
Design e produzione prototipi e soluzione finale box trasporto	5	10	10			25
Test e produzione prototipi e soluzione finale FPC	20	20	60	50		150
Contributo run di produzione sensori	100	100	150	150	50	550
Profilo	180	180	270	220	50	900

INFN funding profile for SVT

Comparison:

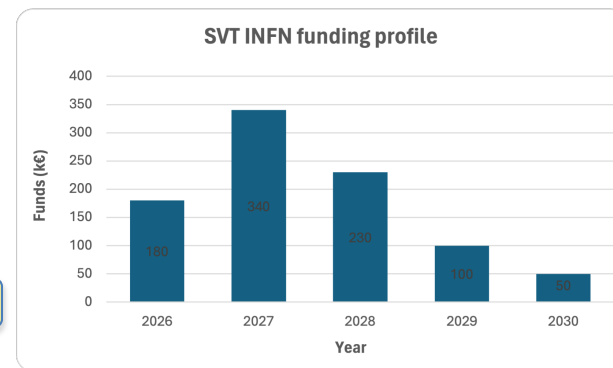
1) assumed with buffering from project

Profilo spesa SVT 2026-2030						
Item	2026	2027	2028	2029	2030	Tot
Design e produzione tool sensor bending setup	15	10	10			35
Design e produzione local support structure L0-L1, carbon foam etc	10	10	10			30
Produzione e test prototipi, assembly finale e spare L0-L1	20	10	10			40
Design e produzione prototipi e soluzione finale global mechanics IB	10	20	20	20		70
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Test e produzione prototipi e soluzione finale FPC	20	20	60	50		150
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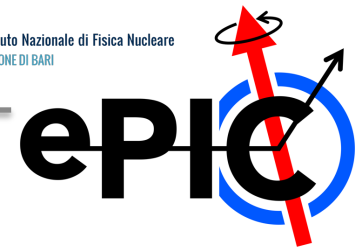


2) no buffering

Profilo spesa SVT 2026-2030						
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Design e produzione prototipi e soluzione finale box trasporto	5	10	10			25
Test e produzione prototipi e soluzione finale FPC	20	30	70	30		150
Contributo run di produzione sensori	100	250	100	50	50	550
Profilo	180	290	280	100	50	900



Backup

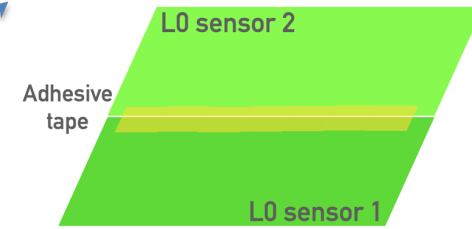


INFN involvement in SVT

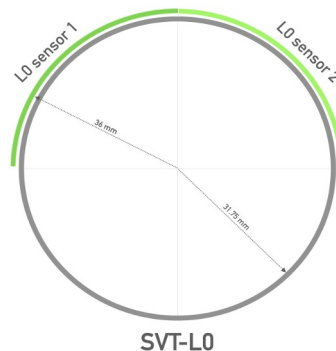
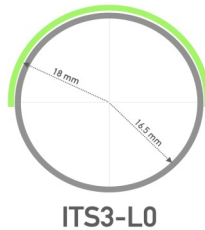
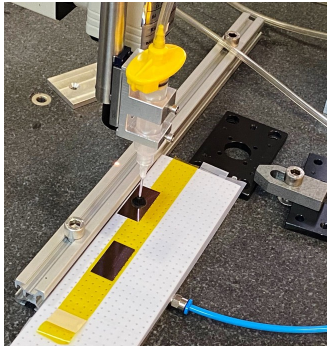
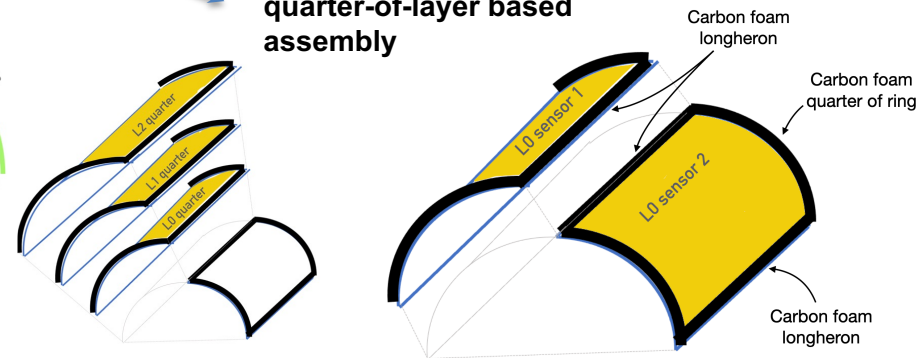
BARI:

- Design, prototyping and construction of SVT L0-L1 barrel:
 - ✓ exploiting experience with bending and interconnection for ITS3
 - ✓ investigating two possible bending/assembly strategies:
 - ✓ **2-sensor bending**: try to exploit “connect” the two sensors with kapton tape and bend them as a single object
 - ✓ **independent bending**: bend each of the two sensors separately and glue them on independent support structures

half-layer based
assembly (a la ITS3)



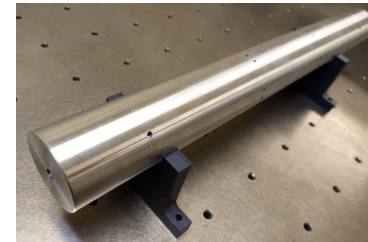
quarter-of-layer based
assembly



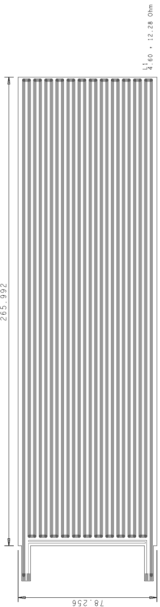
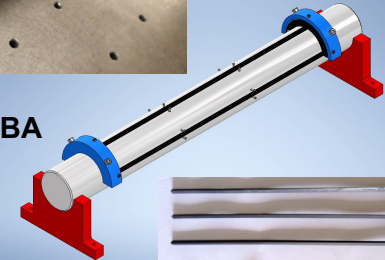
INFN involvement in SVT

BARI:

- Design, prototyping and construction of SVT L0-L1 barrel:
 - ✓ exploiting experience with bending and interconnection for ITS3
 - ✓ investigating two possible bending/assembly strategies
 - ✓ preliminary SVT-dedicated setup assembled:
 - all components already available (procurements + local production)
 - external contact for high-quality mandrels already in place
 - ✓ first ideas on local support structure being developed
 - based on the assumption of 2-sensor bending works
 - ✓ prototype campaigning planned for the coming months
 - starting with dummies in kapton 50 um tick
 - will proceed soon with dummy silicon ordered to DISCO
 - will also include thermo-mechanical prototypes (CERN)



CAD @INFN BA

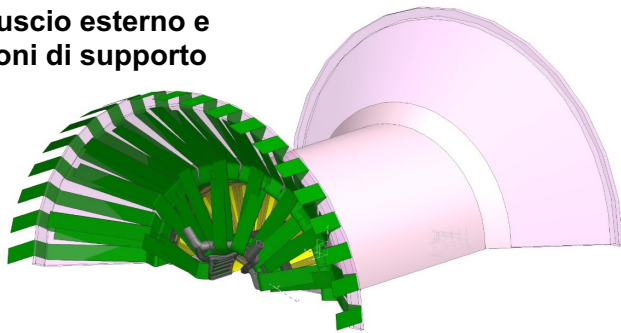


INFN involvement in SVT

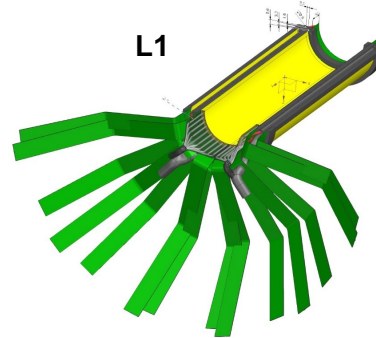
PADOVA:

- Costruzione meccanica globale SVT:
 - ✓ responsabilità disegno e realizzazione meccanica globale Inner Barrel SVT:
 - realizzazione mock-up necessari alla qualificazione della procedura di integrazione sensori e servizi
 - realizzazione prototipo/i supporto finale
 - ✓ In fase di indagine:
 - studio vibrazioni indotte da flusso aria per raffreddamento sensori con utilizzo galleria del vento (dotazione UniPD?) e sensori confocali cromatici per rilevamento posizione con risoluzione (sub)micrometrica

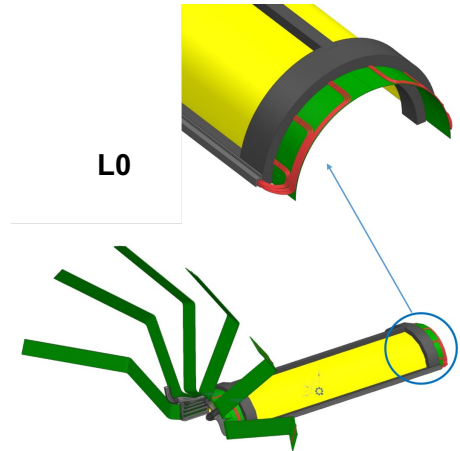
guscio esterno e
coni di supporto



CAD design
by M. Turcato



L0



INFN involvement in SVT

PADOVA:

- Costruzione meccanica globale SVT:
- Secondo punto di produzione layer interni L0-L1 di SVT:
 - ✓ possibilità di produzione tooling per piegamento sensori MAPS
 - mandrini prodotti in OM INFN-Pd
 - lavorazione superficie per rugosità <0.1 ai LNL (plasma) o ditta esterna (rettifica e doratura), da verificare la qualità e convenienza dei due processi
 - ✓ processo completo (piegamento, wire-bonding FPC, posa/incollaggio supporto, etc.) dipende da disponibilità macchina wire-bonder (gli FPC devono essere fissati prima di rimuovere il sensore dal mandrino):
 - la particolare operazione (bonding su superficie curva), le dimensioni del supporto e la procedura di fissaggio FPC e fissaggio su supporto definitivo pongono condizioni sul tipo di macchina bondatrice (bore, manovrabilità testa, non necessariamente automatica)
 - market survey in corso
 - contatti per coinvolgimento altri progetti interessati per acquisto condiviso con limitato contributo INFN

INFN involvement in SVT

PAVIA:

- Testing in climatic chamber Galli Genviro-030LC:
 - ✓ used in the past for ageing tests of ALPIDE chips assemblies for ALICE ITS2
 - ✓ plan to use it for checking possible deterioration of the SVT inner layer assemblies (including prototypes) in conditions of controlled/high temperature and/or humidity



inner volume	30 liters
inner dimensions	330 x 280 x 330
temperature range	-70 °C ÷ +180 °C
humidity range	10% ÷ 98%
temperature precision	± 0.1 °C ÷ ± 0.3 °C
temperature uniformity	± 0.5 °C ÷ ± 1.5 °C
humidity precision	± 1 ÷ ± 3 %
temperature gradient	± 3 °C/min
internal heat dissipation	100 W
power	1.4 ÷ 2.4 kW

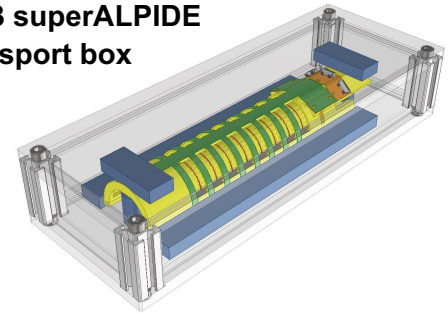
INFN involvement in SVT

PAVIA:

- Testing in climatic chamber Galli Genviro-030LC:
- Design and production of transportation boxes:
 - ✓ to be used for transport of SVT inner layer assembly prototypes in Italy and final detector assemblies in US → different prototypes will be needed along the various phases
 - ✓ two options currently under discussion:
 - plexiglass box where detectors are kept still by foam sponge
 - box similar to that for ALICE ITS2 OB staves, smaller in size



ITS3 superALPIDE
transport box



ITS2 OB stave
transport box:

- wire ropes recommended to achieve about 10 Hz cut-off frequency
- arbitrary low acceleration can be achieved at the cost of space: about linear in average acceleration

INFN involvement in SVT

TRIESTE:

- Activity on SVT IB FPC:
 - ✓ collaboration with Daresbury LAB and SVT WGs for FPC design adaptation from ITS3 version to the SVT constraints and characteristics
 - ✓ SVT FPC prototyping and qualification tests
 - ✓ production quality control
- Existing expertise from ITS2 OB FPCs:
 - ✓ definition of production specifications
 - ✓ vendor search and production tendering
 - ✓ qualification tests
 - ✓ final integration with power bus
 - ✓ vendor search and quality assurance

ITS TDR: [CERN-LHCC-2024-003](#)

