Silicon tracking system for ILD: integration

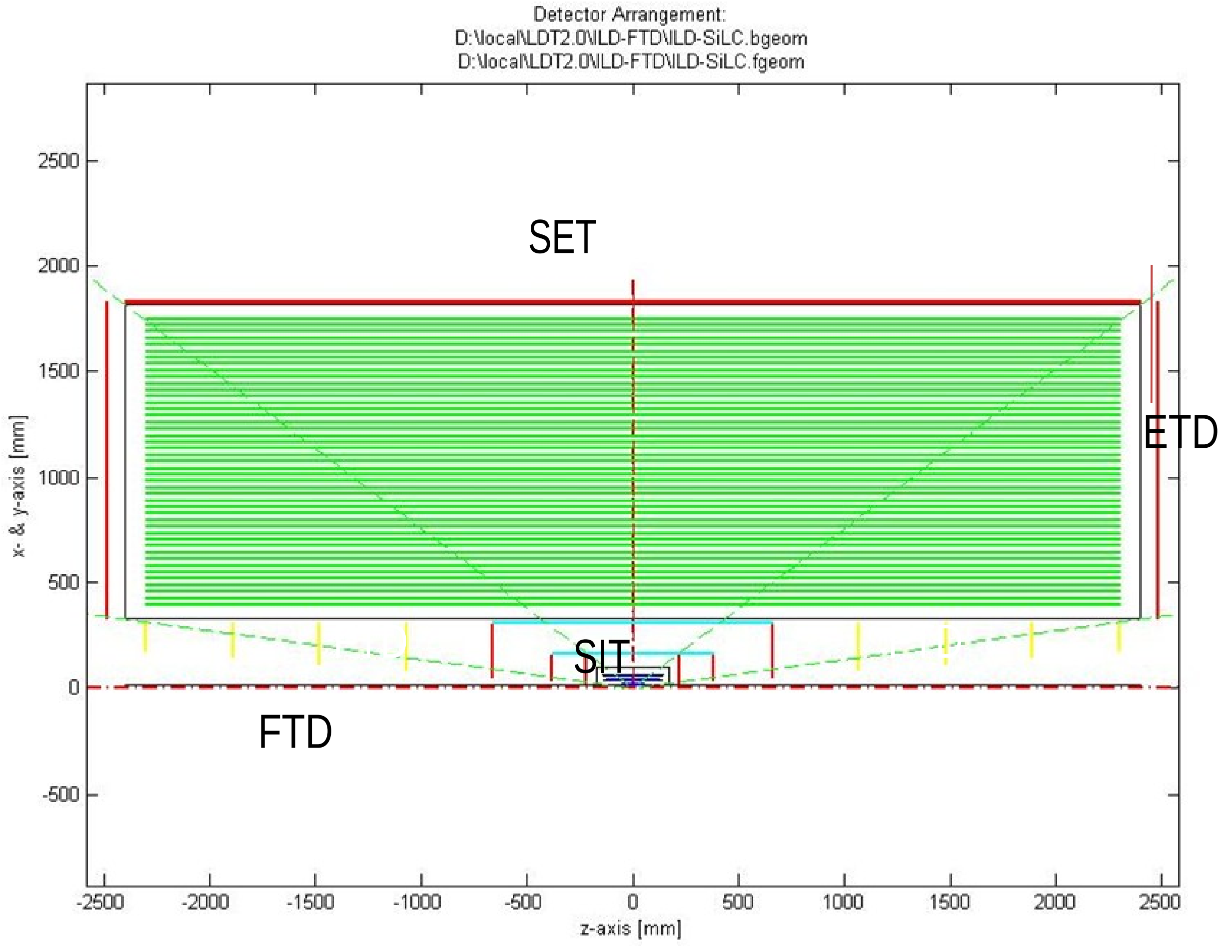
Aurore Savoy-Navarro, LPNHE/CNRS-IN2P3

MDI/Integration Webex meeting January 9, 2009
(in continuation of the MDI/Integration meeting on December 19th)

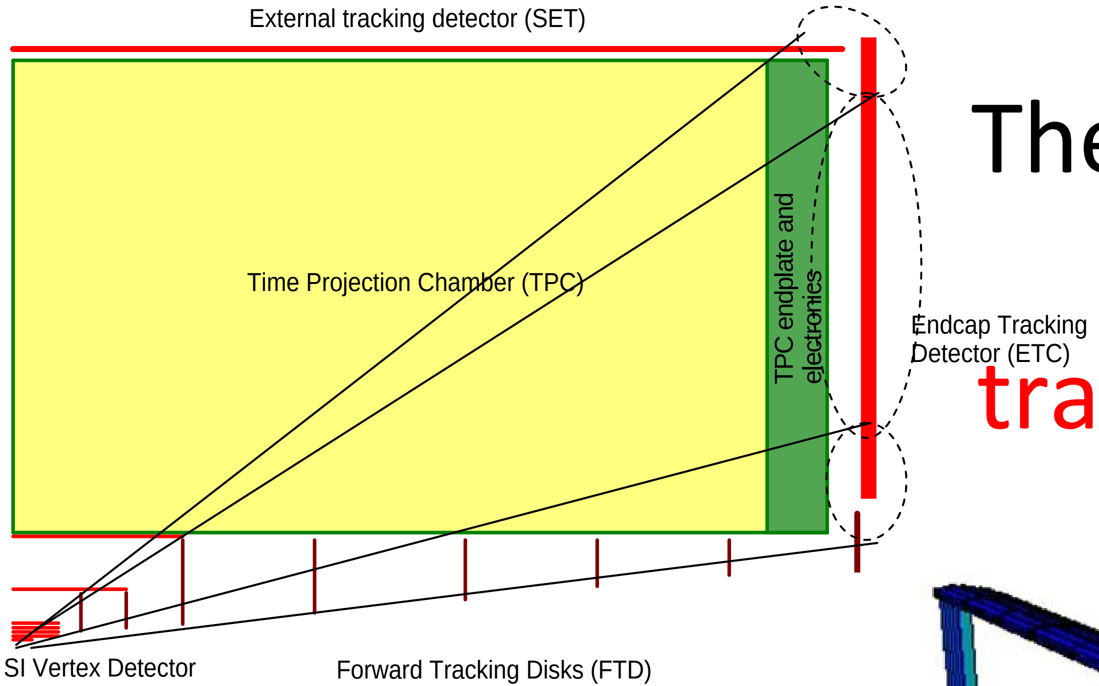
Contributions from especially: Paolo Mereu and Diego Gamba (Torino), Manfred Valentan, Stefan Haensel and Manfred Krammer(HEPHY), David Moya and Alberto Ruiz(IFCA), Bernardo Aveda et al (USC), Alexandre Charpy and A.S.N. (LPNHE)

And from discussions at the session on integration issues for LOI at the 8th SiLC meeting in Santander, 17-19 December 2008.

The Silicon envelope (JE Augustin, M. Berggren, ASN)

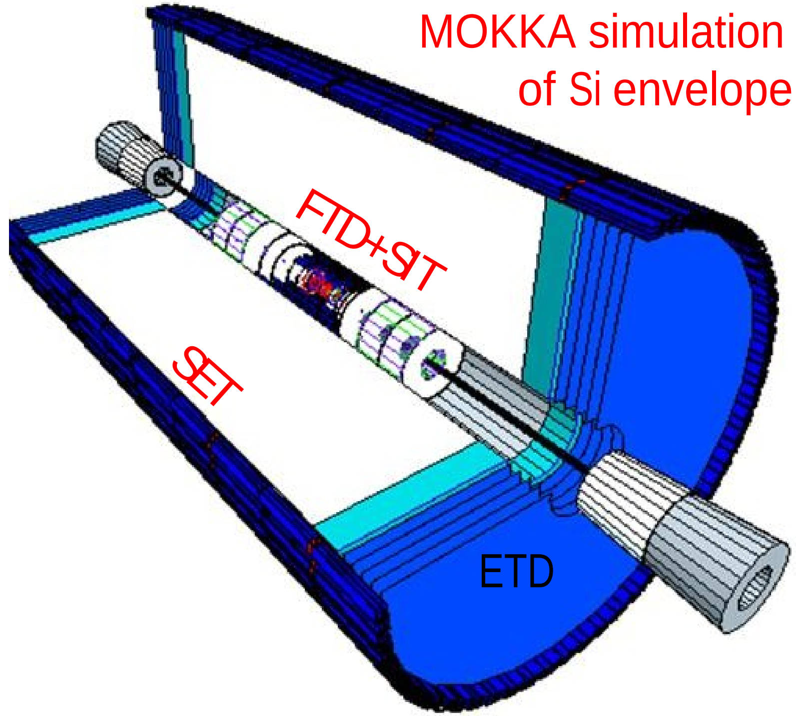


(by M. Valentan, LicToy)



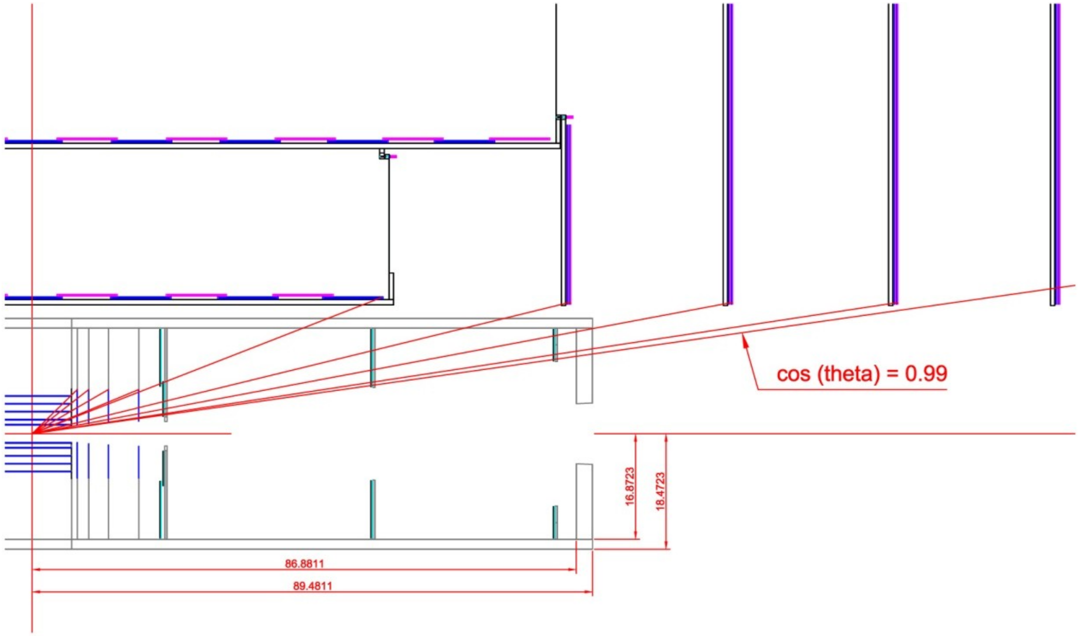
The silicon envelope
or
tracking hermeticity

MOKKA simulation of Si envelope



The Full Silicon tracking system:
Barrel: SIT+SET (3 2D-layers total)
Forward: FTD+ETD
Is included in MOKKA framework
by V. Saveliev

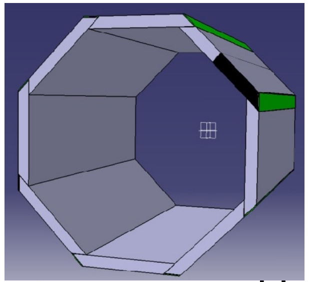
Main integration challenge



All-Silicon tracking system:
fully integrated system =>
Much more easy to integrate.

Compared to an all Silicon tracking system (see SiD design for instance) the ILD Silicon tracking system is much more challenging in terms of integration as it is an hybrid system: gaseous + Silicon and each component is in a LINK region between 2 (at least) sub-detectors.
Thus the SiLC collaboration which is working on this system has to address each case separately this work is undergoing and we are briefly summarizing here the present status.

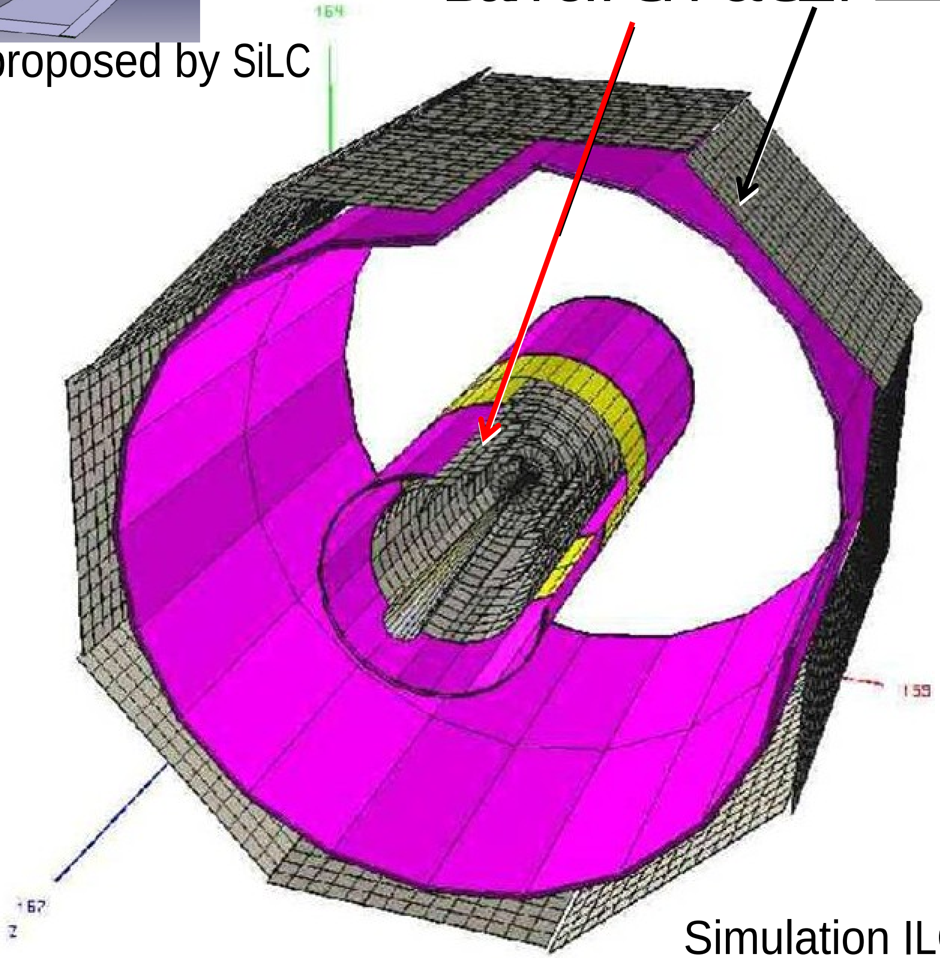
ILD Silicon tracking: the barrel components



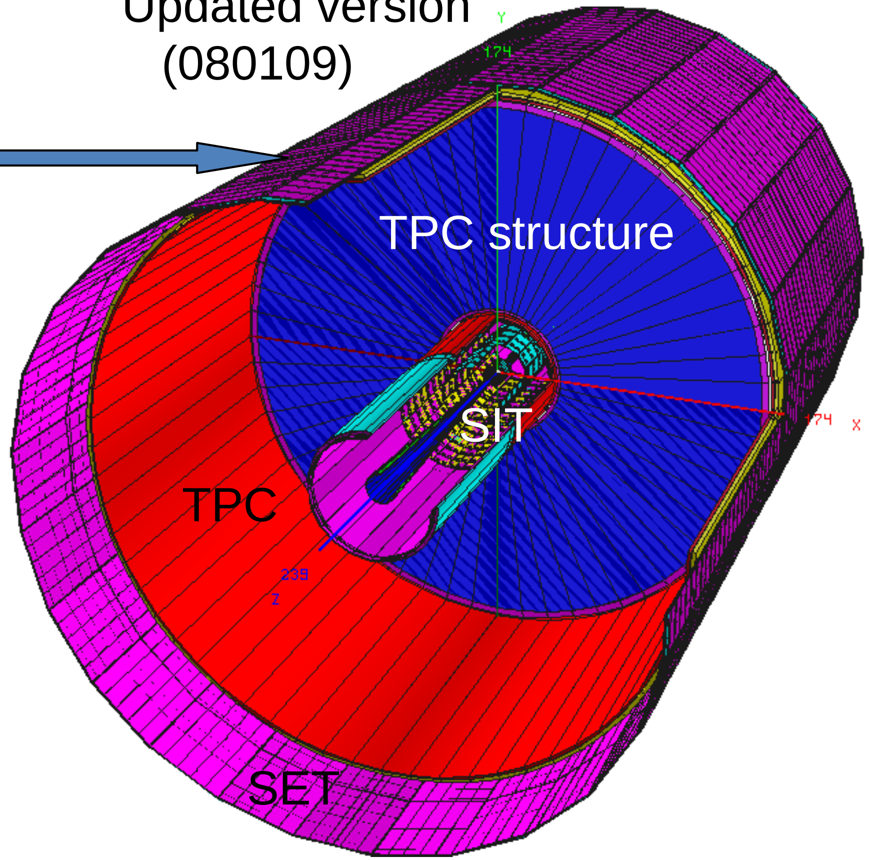
Starting from
Calorimeter shape

As proposed by SiLC

Barrel: SIT & SET



Updated version
(080109)



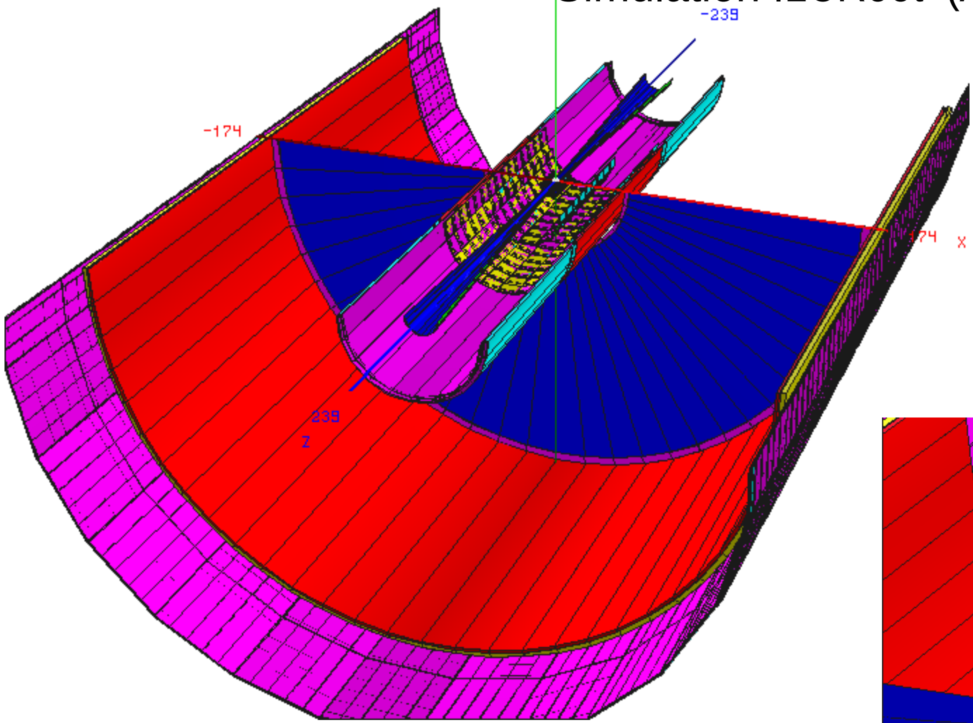
False double sided strip sensors
for both SET and SIT

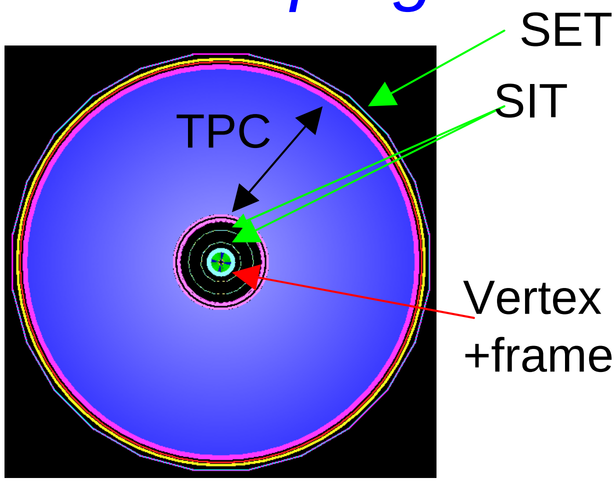
Simulation ILCRoot (A. Charpy)

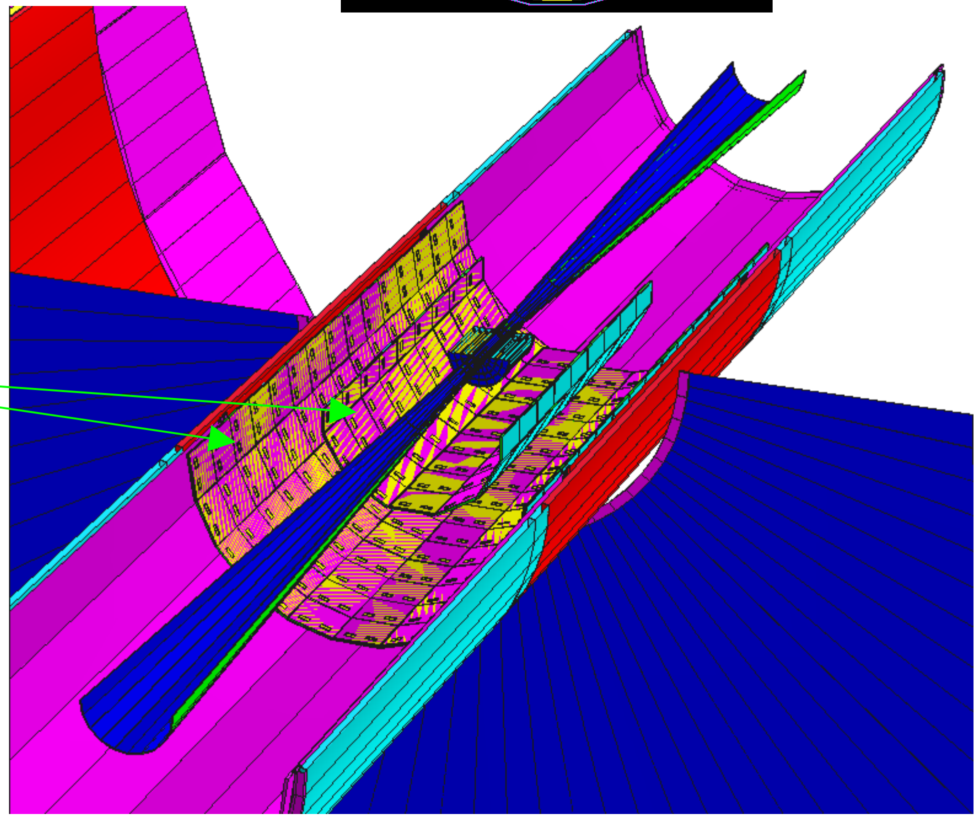
Updated barrel components *(see mechanical study later)*

introduced in the ILCROOT, simulation work in progress

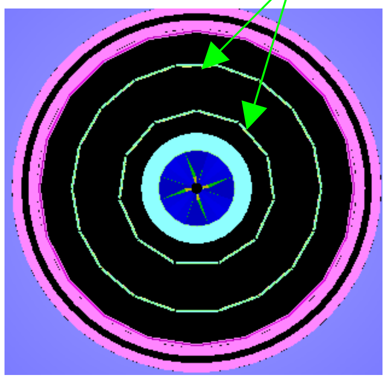
Simulation ILCRoot (A. Charpy)







Zoom on the two SIT layers



ILD's tracking performance (in the barrel region)

and the effect of the silicon enevelope

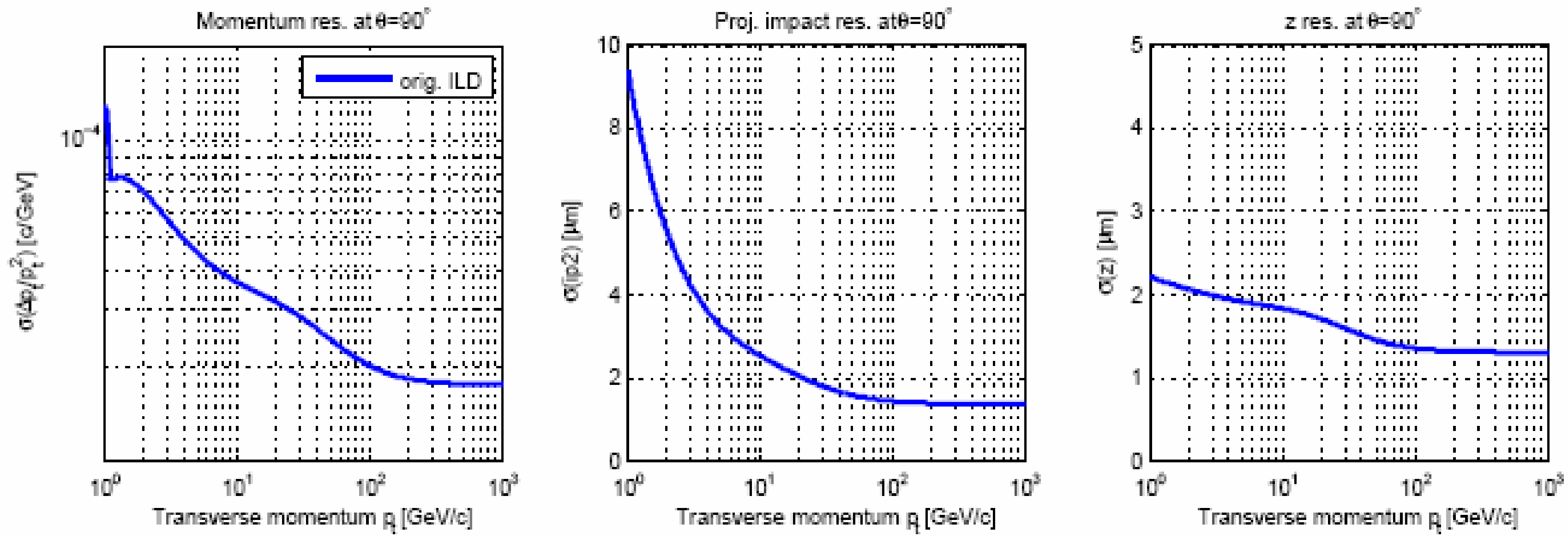
By Manfred Valentan (HEPHY) based on LicToy studies

Tracking performance in the barrel region of the present ILD setup, in terms of

- Momentum resolution $\sigma\left(\frac{\Delta p_{\mathrm{T}}}{p_{\mathrm{T}}^2}\right)$
- Projected impact parameter resolution $\sigma(ip2)$
- z resolution $\sigma(z)$
- evaluated at the inner side of the beamtube
- with LiC Detector Toy 2.0

Tracking performance as function of p_T, at $\vartheta = 90^\circ$

By Manfred Valentan (HEPHY) based on LicToy studies



(Evaluation at the inner side of the beamtube)

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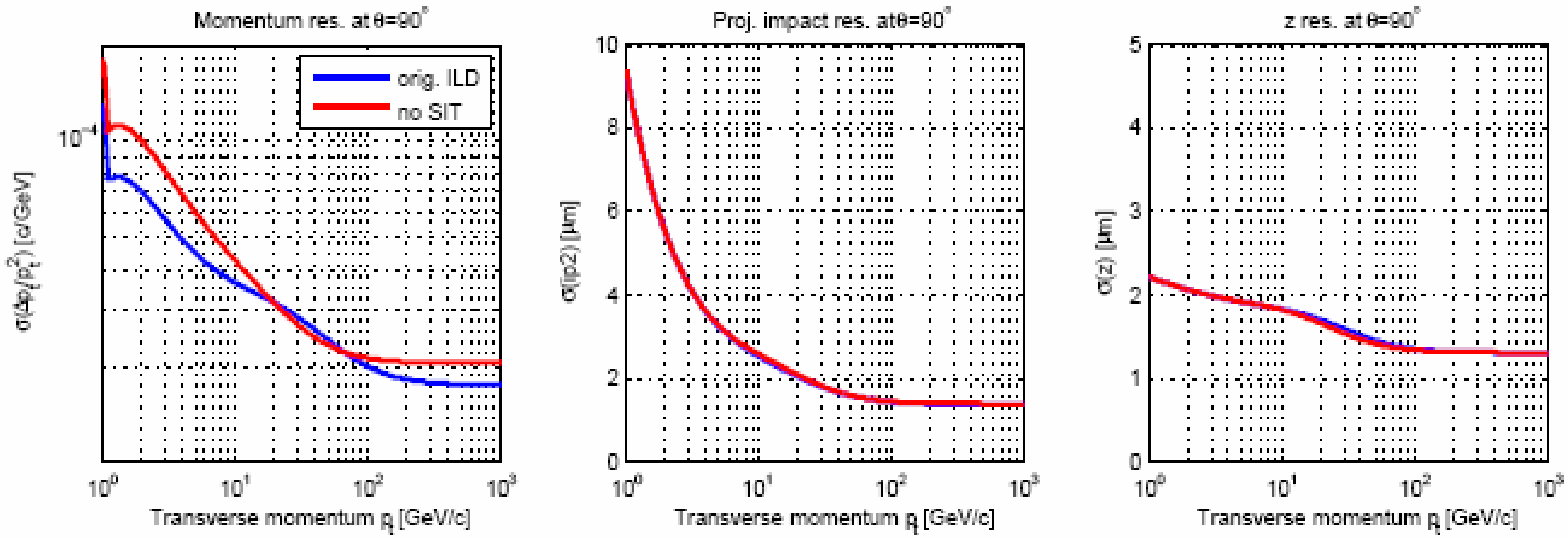

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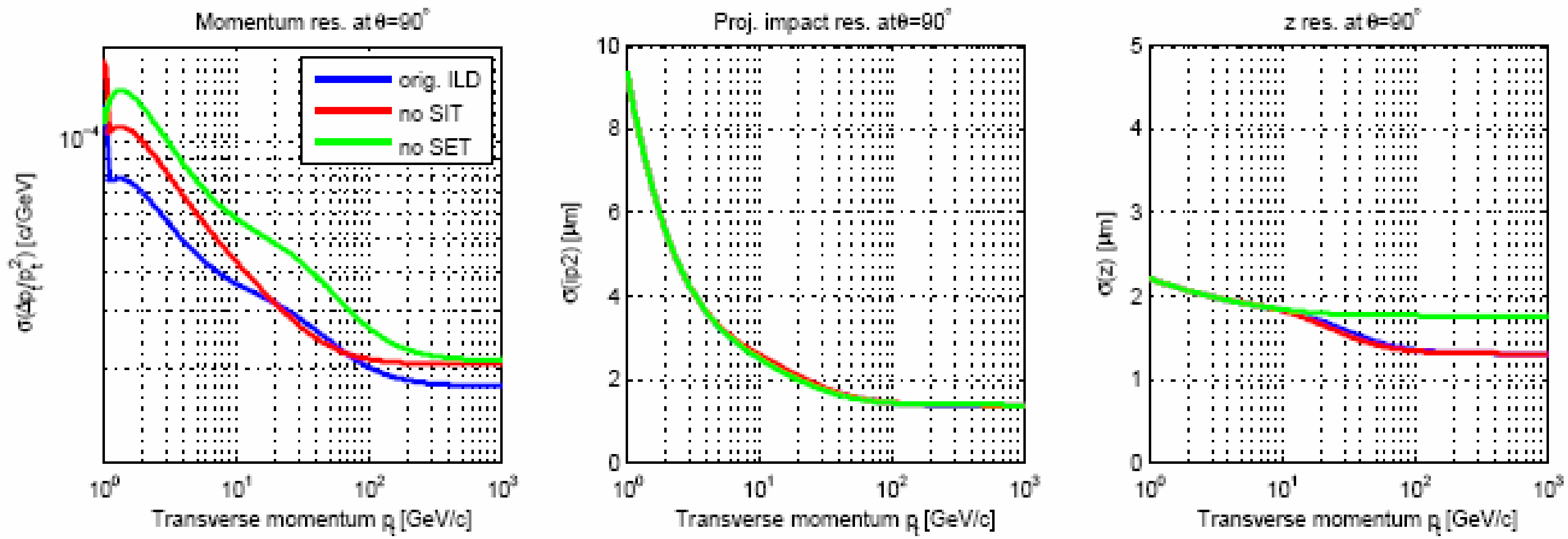
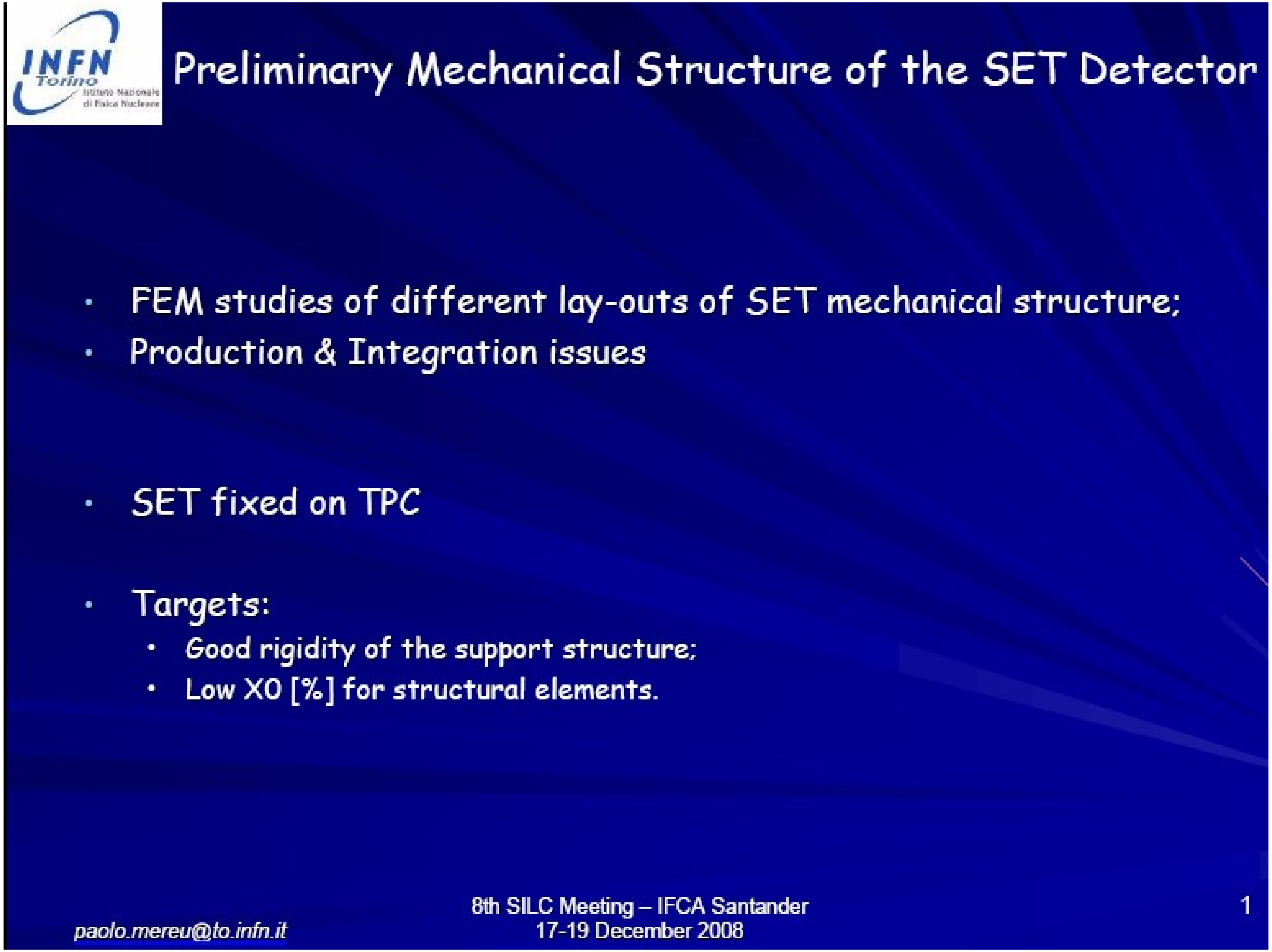


(Evaluation at the inner side of the beamtube)

The SET provides a precise z measurement at large lever arm!

The SET detector integration



Preliminary Mechanical Structure of the SET Detector

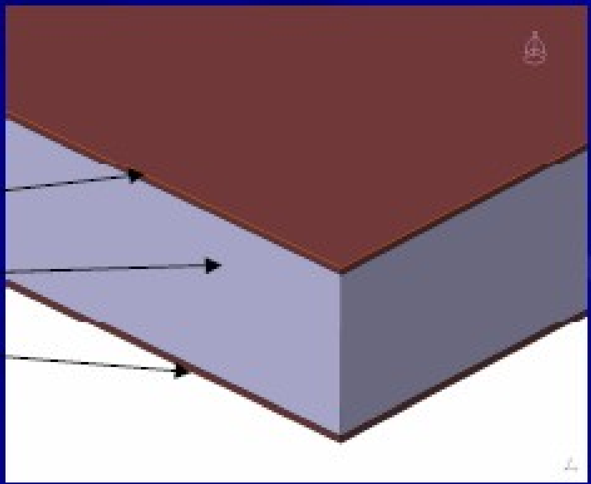
BASIC STRUCTURAL ELEMENT

- sandwich panel
  - 4 High Module UD Carbon-Epoxy 0,16 mm (0,64 mm) prepeg plies per side
  - 15 mm Rohacell 31 core (PMI) polymethacrylimide rigid foam;
  - approx. 2,5 kg/m^2

MATERIAL BUDGET

0,24 X0 [%] 4 UD C plies
0,135 X0 [%] 15 mm ROHACELL
0,24 X0 [%] 4 UD C plies

TOTAL 0,615 X0 [%]



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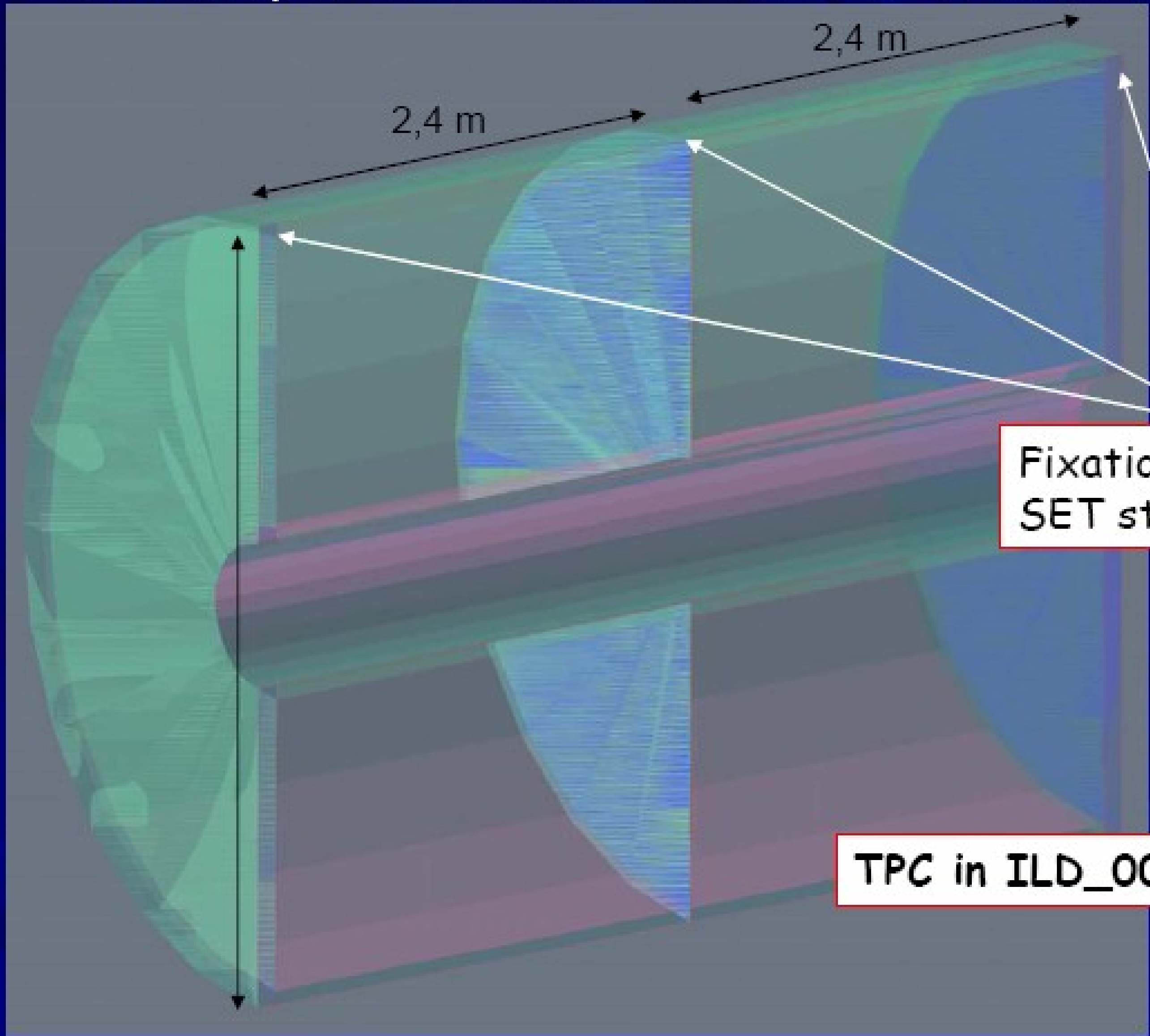
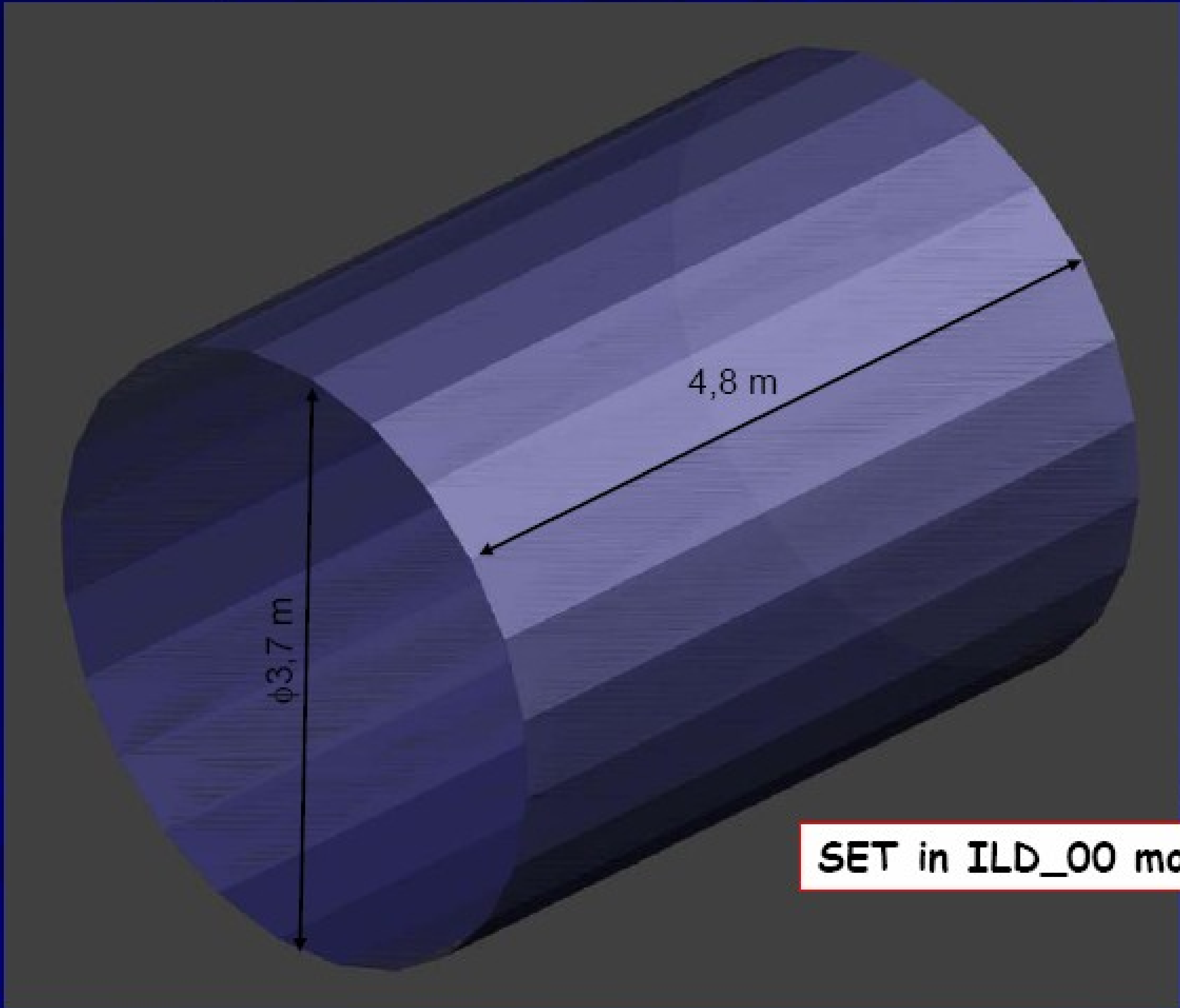


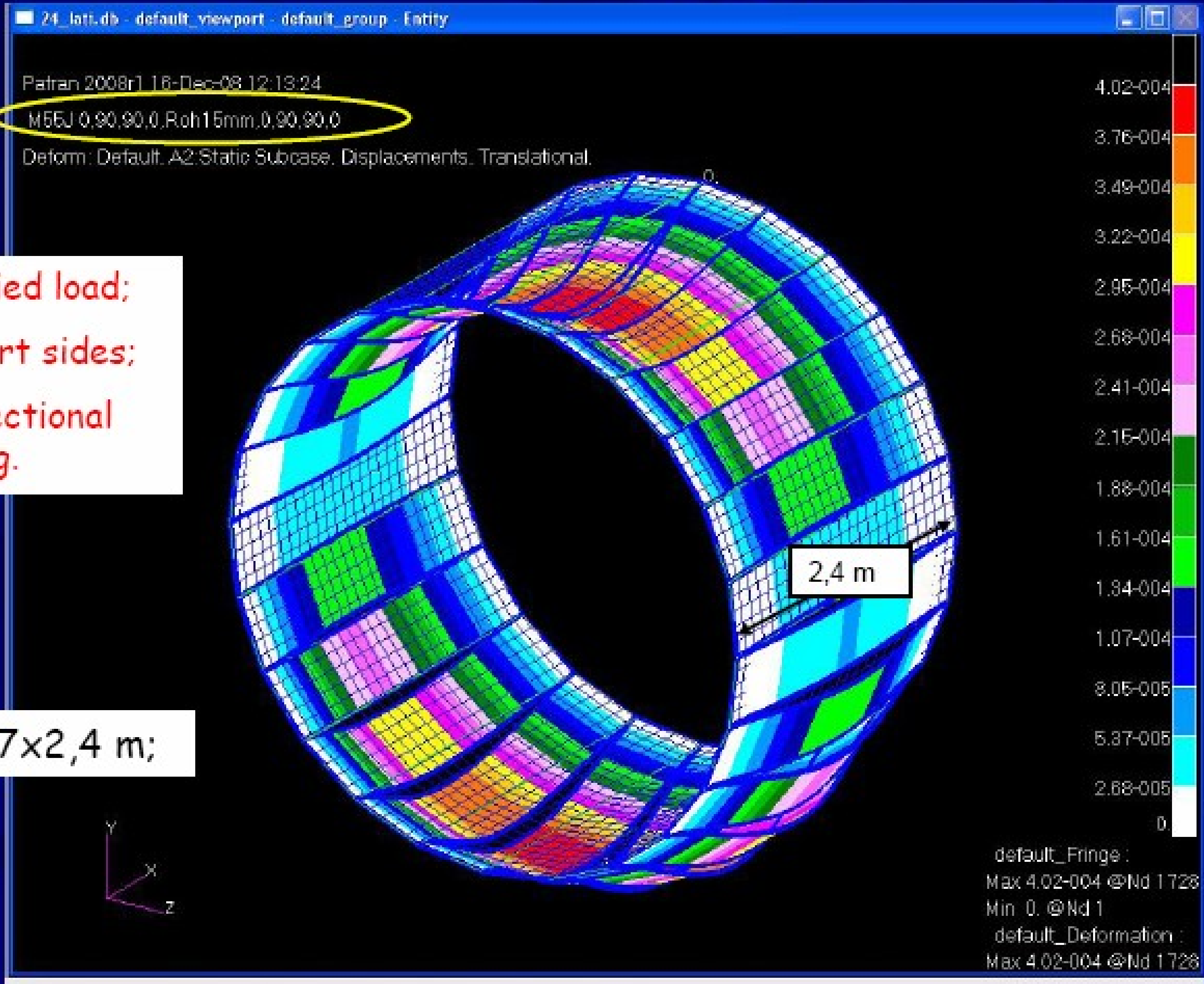
Preliminary Mechanical Structure of the SET Detector



SET in ILD_00 model

paolo.mereu@to.infn.it

Preliminary Mechanical Structure of the SET Detector



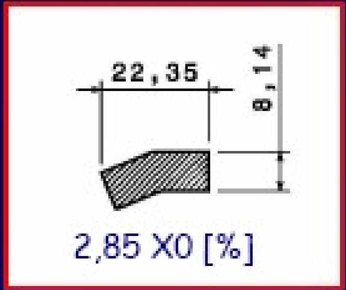
10 N/m2 applied load;

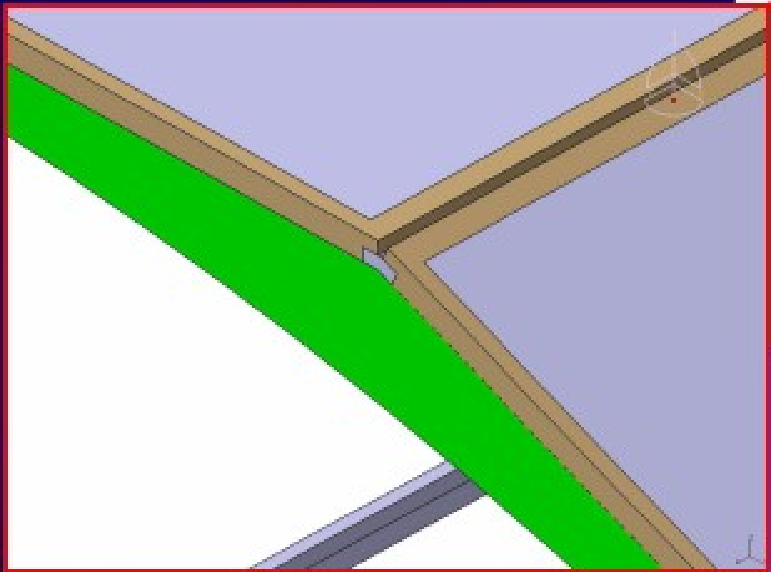
Clamps at short sides;

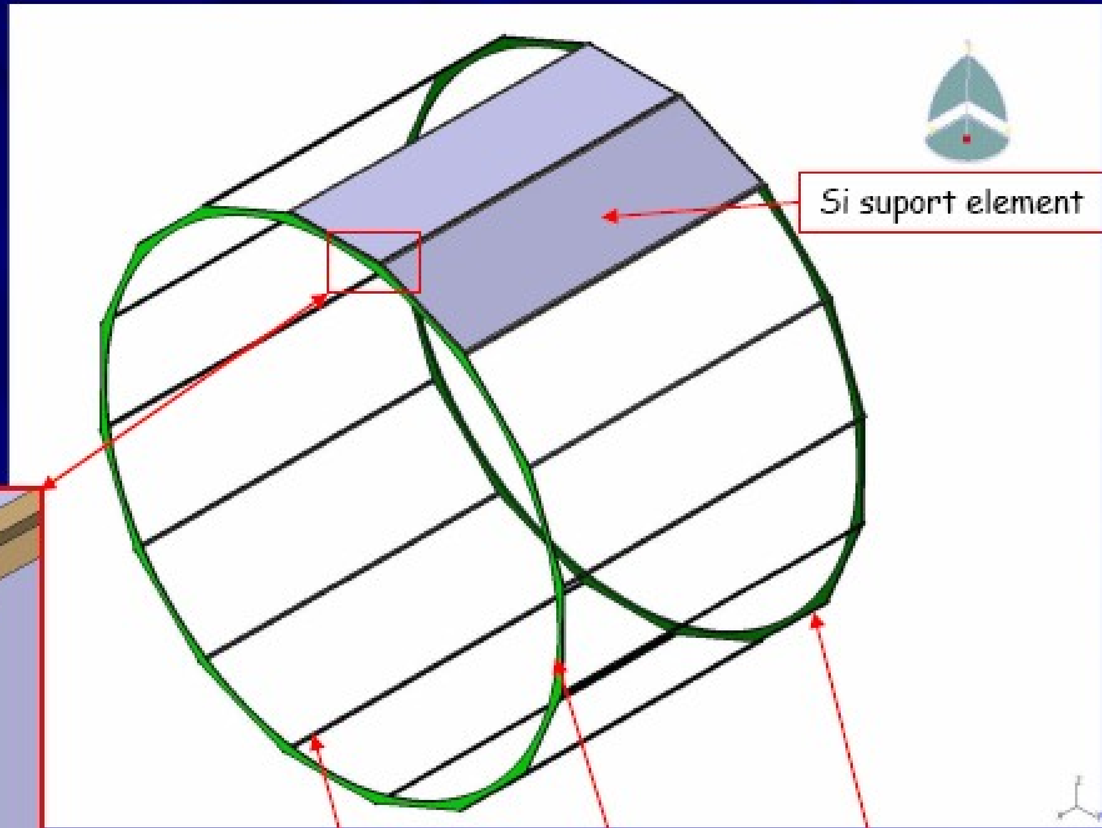
M55J Unidirectional Carbon prepeg.

24 panels 0,47x2,4 m;

Preliminary Mechanical Structure of the SET Detector







CFRE: Carbon Fiber Reinforced Epoxy

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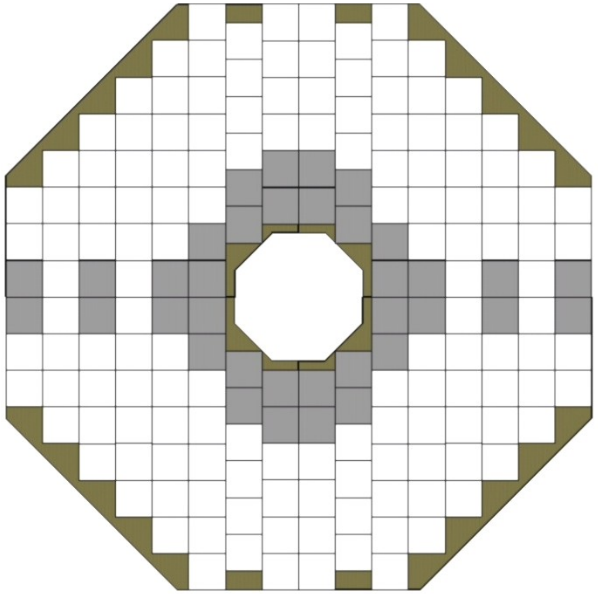
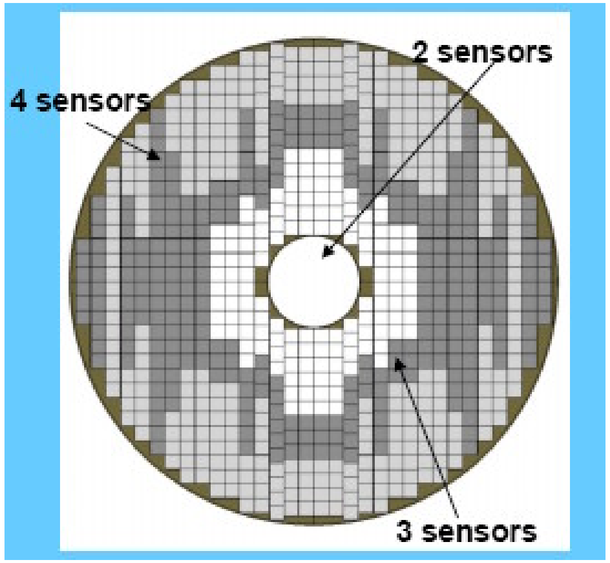
Preliminary Mechanical Structure of the SET Detector

Flat panel solution

- 2,4 meter-long sandwich panels (THREE FIXATION DISCS ON THE TPC, end caps + mid plane);
- modularity: very good for production, Si positioning, assembly and maintenance;
- more panels, better solution...
- minimization of material (NO LONGITUDINAL ELEMENTS, each panel is constrained at 2 short sides): max deflection ~0,4 mm;
- minimization of deflection (WITH LONGITUDINAL ELEMENTS, each panel is constrained at 4 sides): max deflection ~0,4 mm.

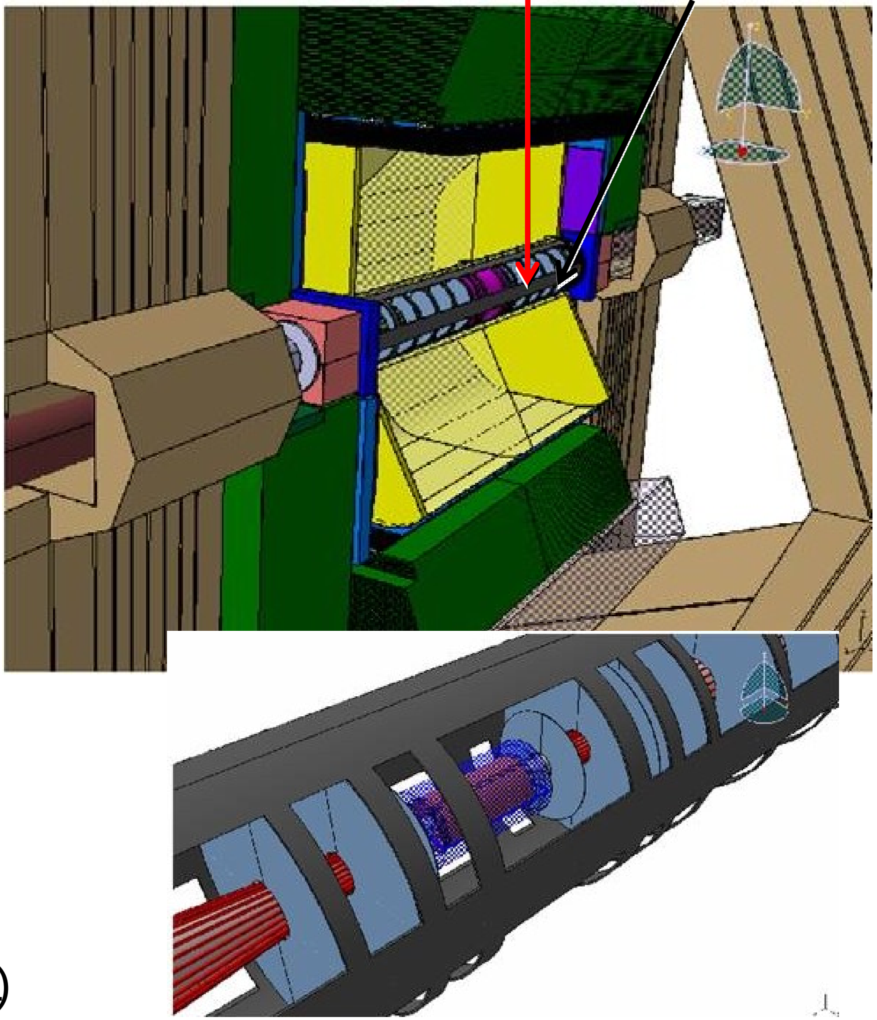
ILD Silicon tracking: the forward components





ETD: XUV design instead of projective (LPNHE)

Very preliminary mechanical design



SIT, SET and ETD present design

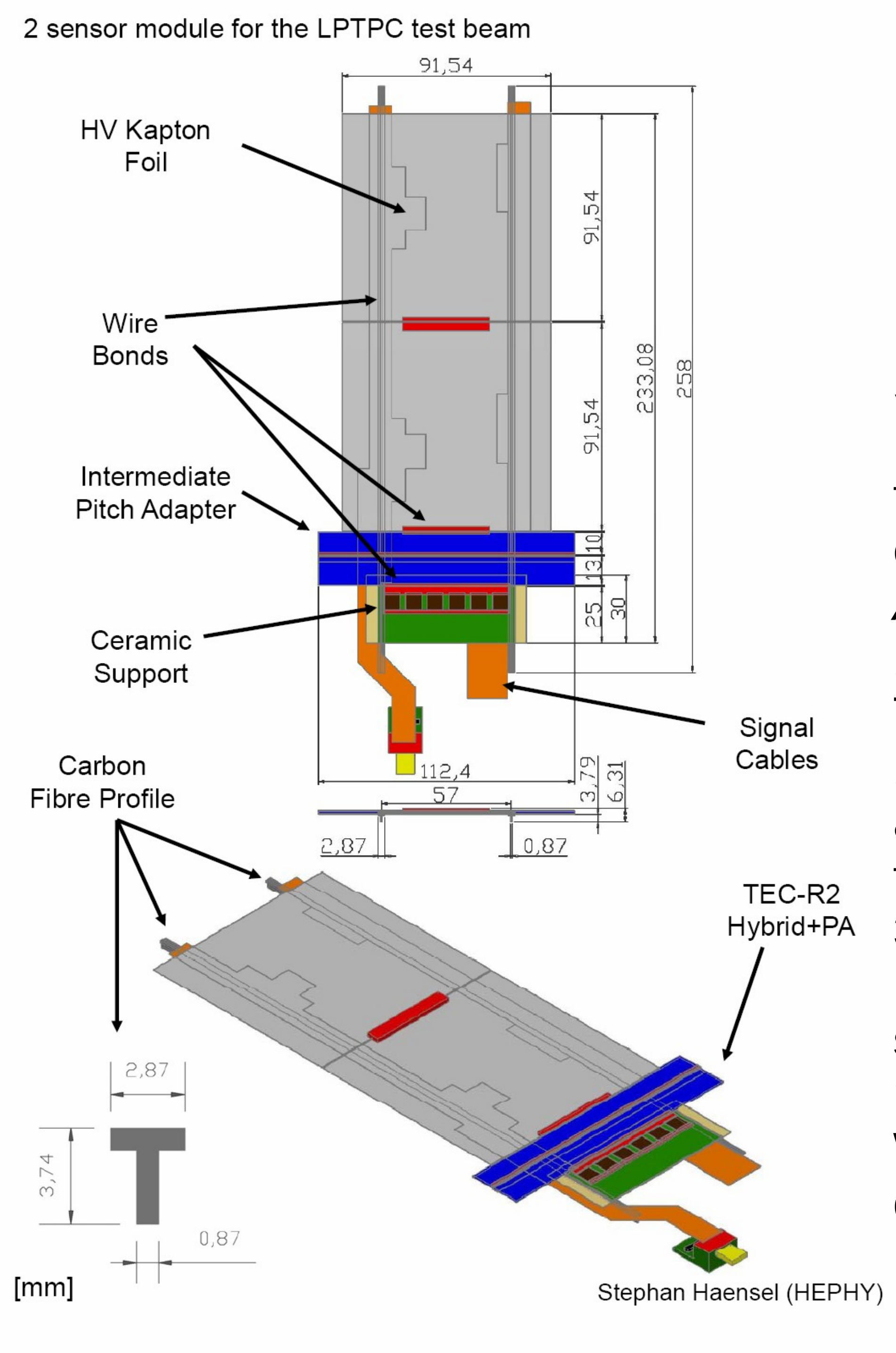
- We are working on a common support structure and module design with unique type of microstrip sensors for these 3 Silicon tracking components.

- This will provide simplicity, modularity and easy construction

- A new idea is being study now to support the SET and SIT layers in an independent way from the other subdetectors (TPC and calorimeters). And the three double sided layers formed by the SIT and SET will be on the other hand part of a same light support. This fits well with the alignment function to be fulfilled by the SIT+SET couple. (work in progress).

SIT, SET and ETD present design

- One crucial topic under study: the detailed structure of the supports (not just plans as sketched in the present Paolo's study but a more complex structure were the modules, services and cables are being included)
- Another crucial point: the detailed design of the modules: we are presently following designs such as the one used for the Si modules for the LPTPC test = very light structures



Developing light module structure

SiLC is working on a new way to build light Silicon modules easy to include in the overall support structure of the component.

As a guideline here is the presently built module for the LPTPC tests in DESY. The next generation will not include hybrid boards for the FEE electronics or picth adapters. This will be part included onto the module itself (bump bonding then 3D vertical interconnect)

But the concept of light bars to sustain the sensors as in this drawing will be further pursued.

Work in progress with the prototypes we are developing for the beam tests.

Some important features:

- The FEE readout electronics is proven to give:

  1mWatt per channel and will be power cycled (factor: 70:1)

  (already existing prototype in 130mn technology)

  => NO COOLING

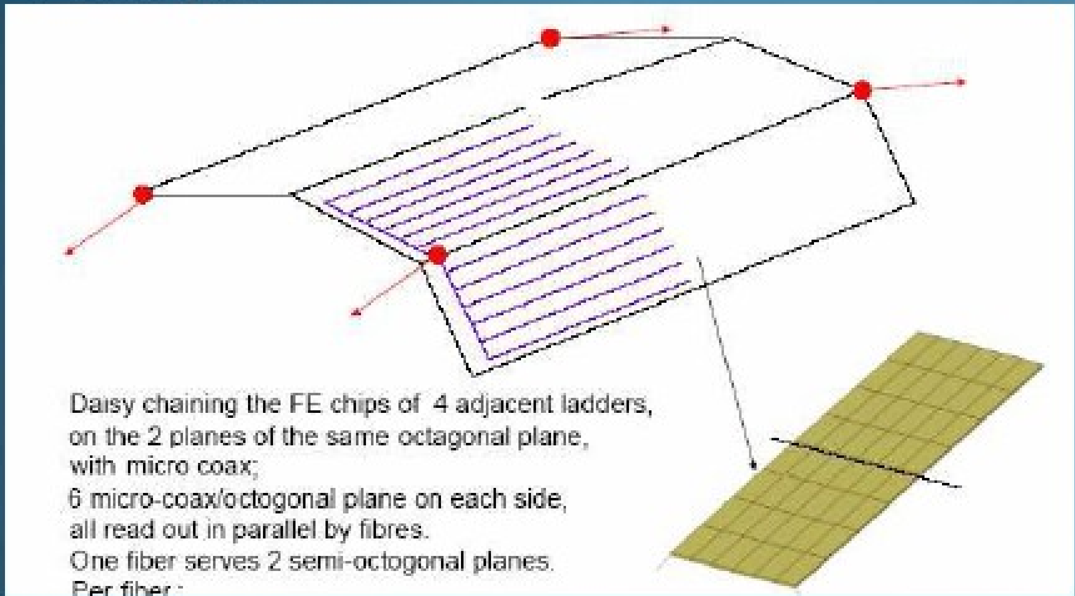
  Cooling is really not an issue in the ILC case contrary to the LHC case. The Si detectors can works with T up to 30 degrees and a temperature gradient of 10 degrees. Many studies performed by SiLC with realistic mechanical prototypes.

  WHAT IS NEEDED is to know what is the power dissipation of the neigbours (TPC, vertex or calorimeters??)

  The strips sensors will be edgeless technology, thus a "flat structure".
- The FEE readout will be on detector (bump bonding first then 3D vertical interconnect): high multiplexing in the FEE electronics architecture and NO FE-boards
- The processed data are daisy chained (micro-coax) on the detector and sent outside of the detector to the C.R. with digital fibers

Level 2: FE-on detector edges, interface detector with external world

Example

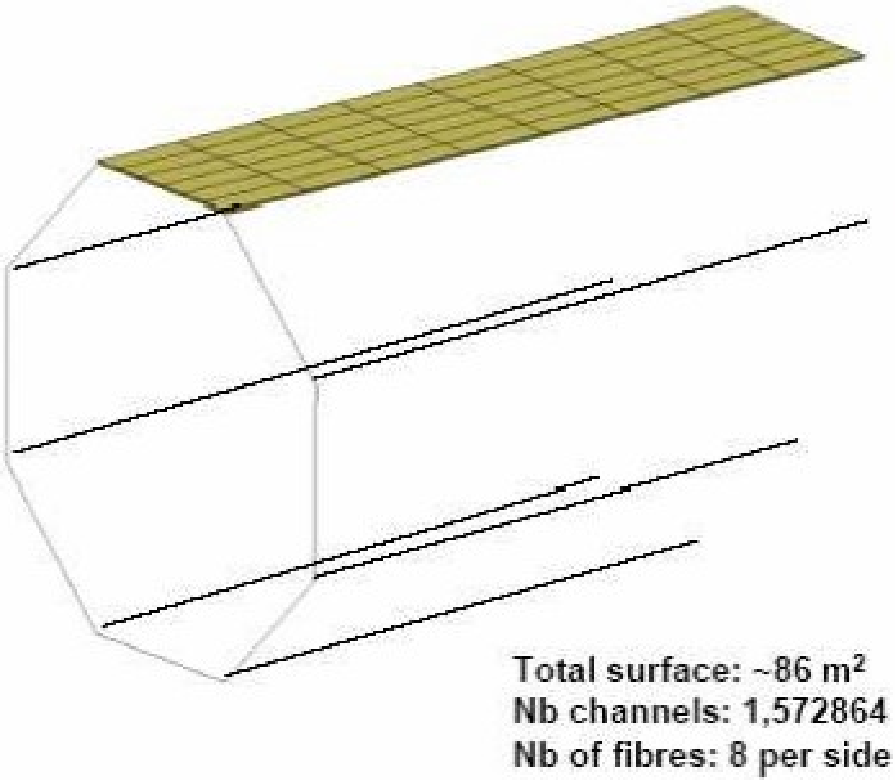


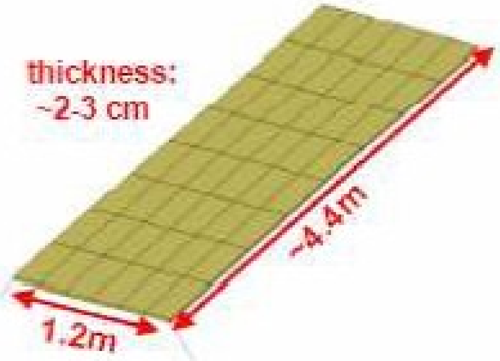
Cabling:
Level 1 to Level 2: microcoax
Level 2 to Level 3: digital fibers

Number of issues related to cabling:
Follow industrial advances
High rates and high speed, reliability, fault tolerance, robustness
Common for all sub detectors

Each red points = buffer + pre-processing 2 (re-ordering & compressing data), transceiver (digital fiber to external world = Control Room)
Sends pre-digested data at CR and get slow control and distributes it on detector

Just an example





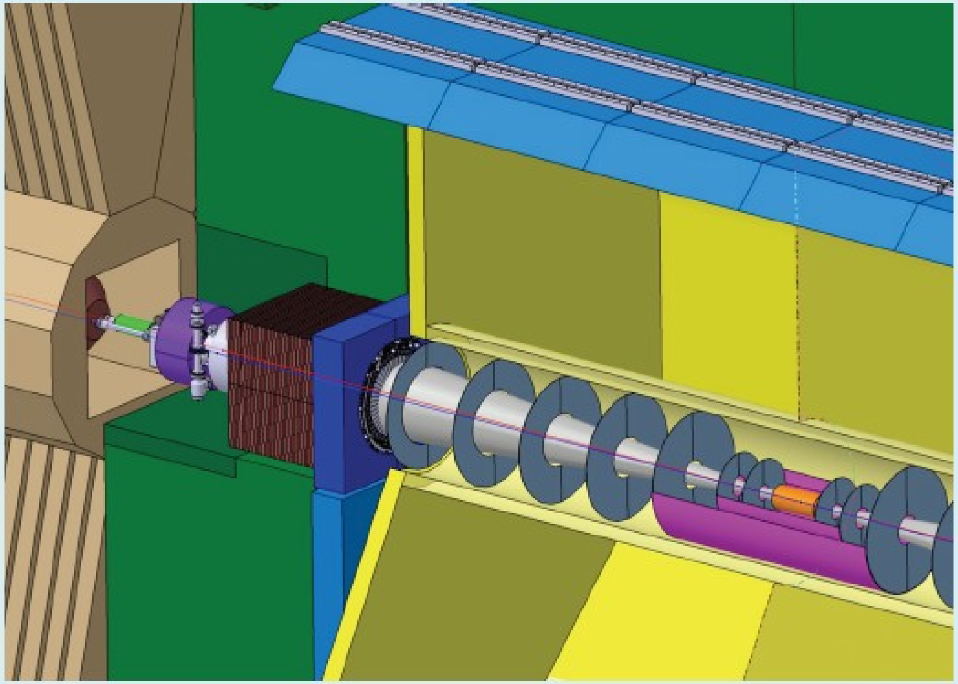
# ladders/octagone	96
# sensors/octagone	288
# channels/octagone	196608
# µchips/octagone	192
# µcoax/octagone	192
# fibres/octagone	2
# µchips/fibre	96
# channels /fibre	98304

Outer Silicon tracking layer : false double sided sensors

The FTD integration case

Inner Detector Support

- No study of the inner detector support yet
- Important to understand the support of the beam pipe, stability, vibrations, etc.

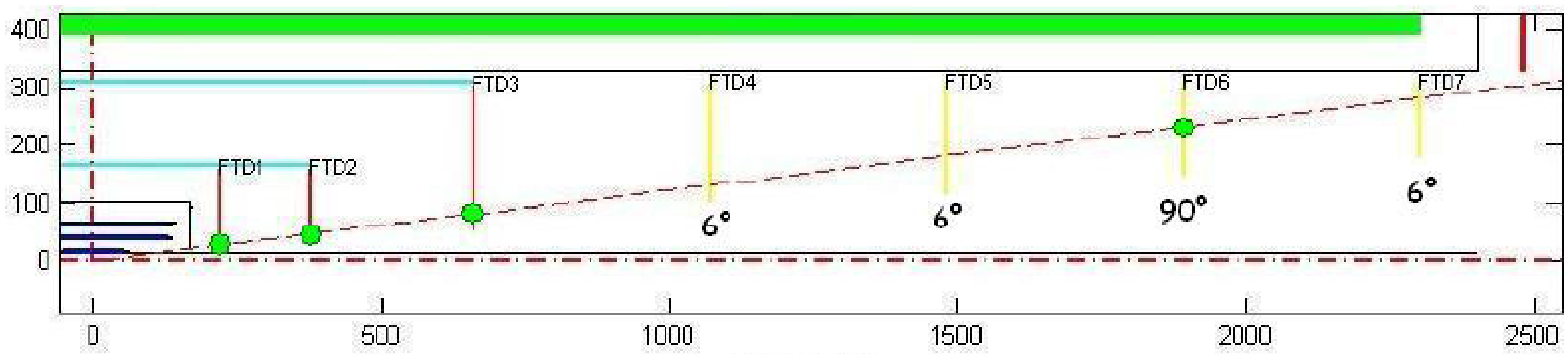


Preliminary idea: the FTD small disks 7x2 and the 2 DS SIT layers will be included in a single envelope made of rohacel l foam included into 2 foils of C-fiber

Finding a feasable optimized setup

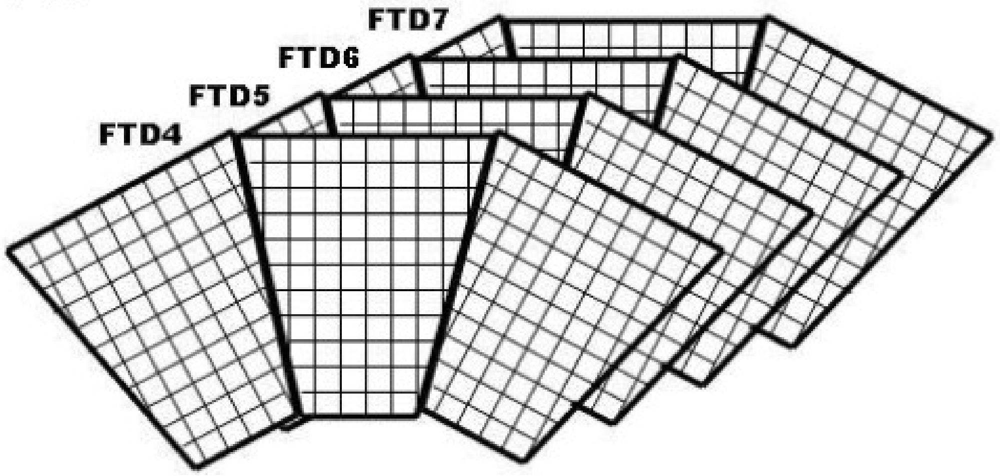
By Manfred Valentan (HEPHY) based on LicToy studies

- Optimal tradeoff is academic:
  - Hardware people prefer small stereo angles
  - CMS uses $\alpha = 100\mathrm{mRad} \approx 6^\circ$
- High energies: track is a straight line in the (y,z)-projection
  - Already three good *R* measurements in *FTD*1-*FTD*3
  - One additional good *R* measurement in one of the strip disks *FTD*4-*FTD*7 sufficient to fix the *z* resolution
  - $\Longrightarrow$ Three disks with $\alpha = 6^\circ$, one with $\alpha = 90^\circ$



Remaining optimized setups

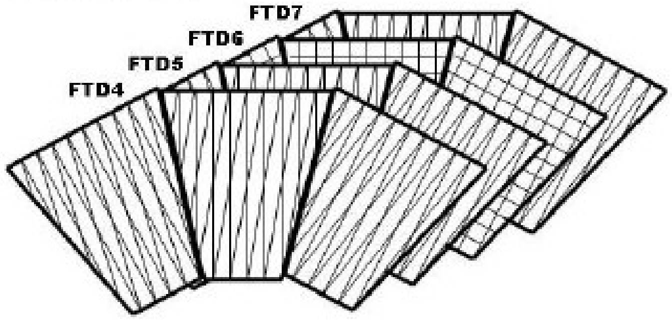
ILD:



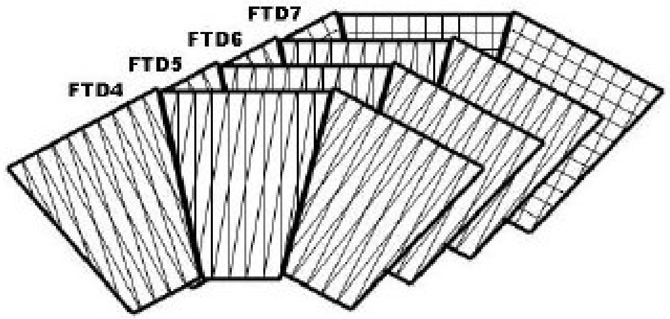
Compare original ILD ("+ + + +") with

- 1: $\alpha_6 = 90^\circ$, $\alpha_{4,5,7} = 6^\circ$ ("|| || + ||")
- 2: $\alpha_7 = 90^\circ$, $\alpha_{4,5,6} = 6^\circ$ ("|| || || +")
- *FTD*6 hardly contributes to $\sigma(\Delta p_\mathrm{T}/p_\mathrm{T}^2)$!
  $\Longrightarrow$ Sensors of *FTD*6 rotated by 90°
  3: $\alpha_6 = 6^\circ$, $\alpha_{4,5,7} = 6^\circ$ ("|| || = ||")

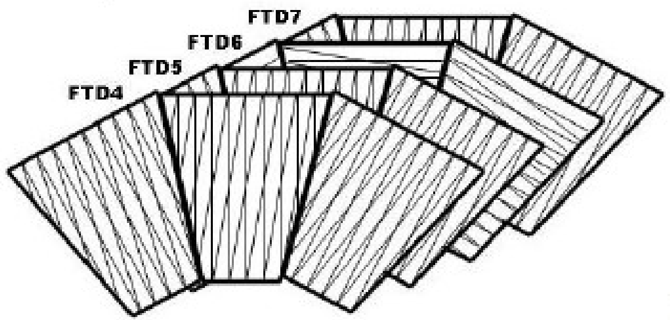
Setup 1:



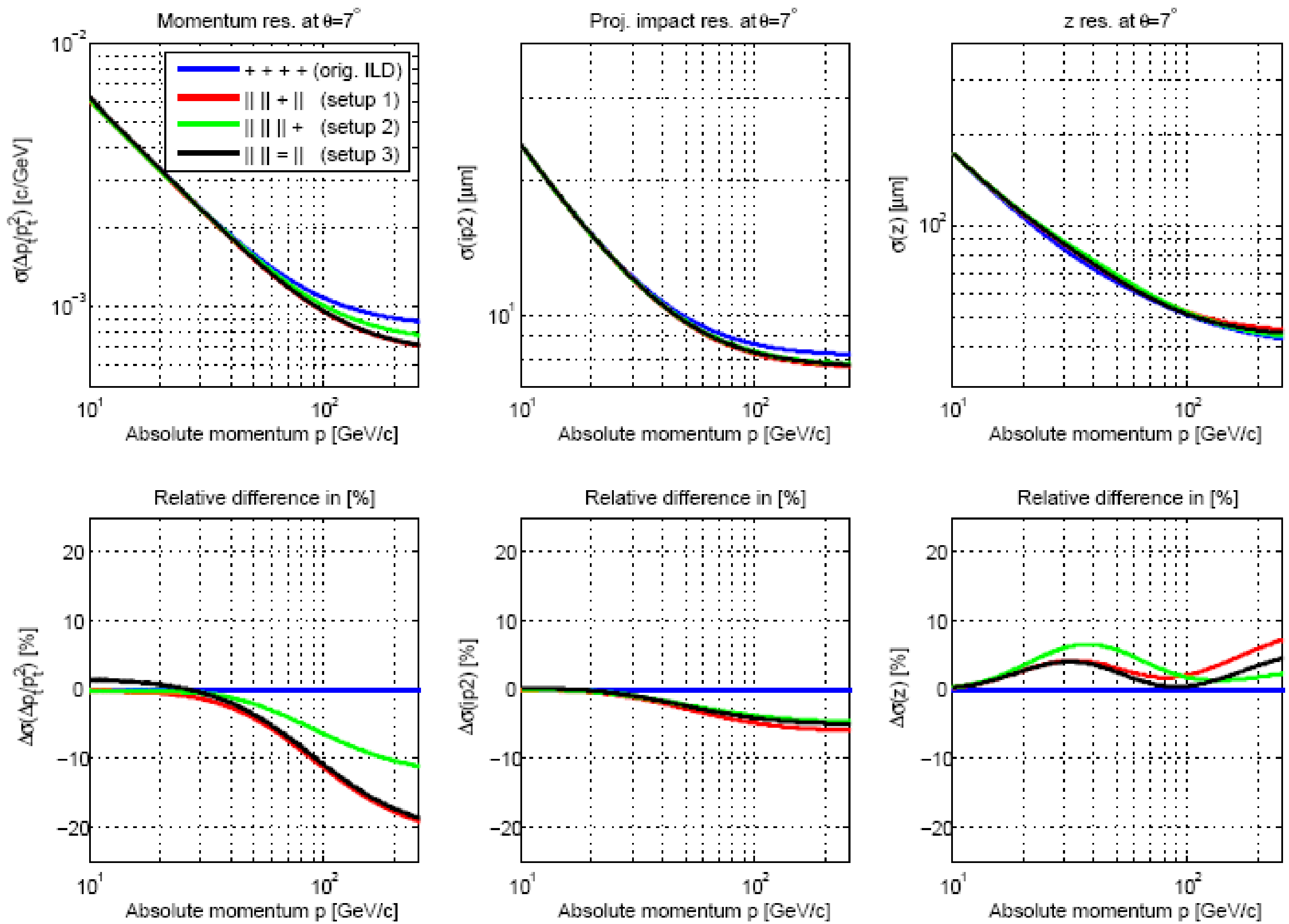
Setup 2:



Setup 3:



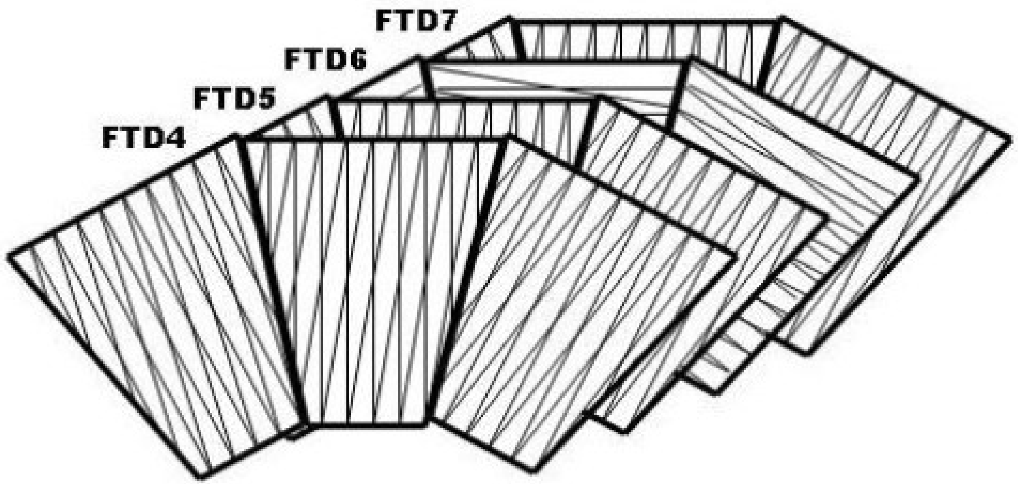
Comparison of the optimized setups, as function of *p*



Summary

- The ILD reference design is already well configured. However, there is some potential for improvement.
- Proposal for an optimized forward tracker (with minimal diversity of sensors):

Layer	R [mm]	|z| [mm]	RL [%]	σ [μm]	d_{strip} [μm]	α [$^\circ$]	Type
FTD1	24.5-160	220	0.25	7	-	-	Pixels
FTD2	39.9-160	380	0.25	7	-	-	Pixels
FTD3	52.0-304	660	0.25	7	-	-	Pixels
FTD4	84.4-309	1070.6	0.65	-	25	6	Strips
FTD5	116.7-309	1481.2	0.65	-	25	6	Strips
FTD6	149-309	1891.8	0.65	-	25	6 (rot. by 90°)	Strips
FTD7	181.4-309	2302.5	0.65	-	25	6	Strips

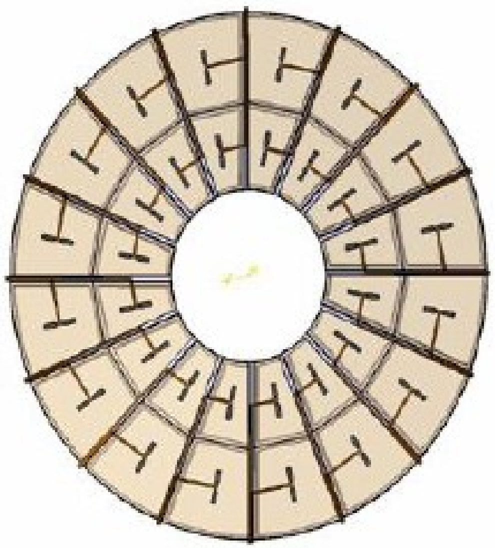


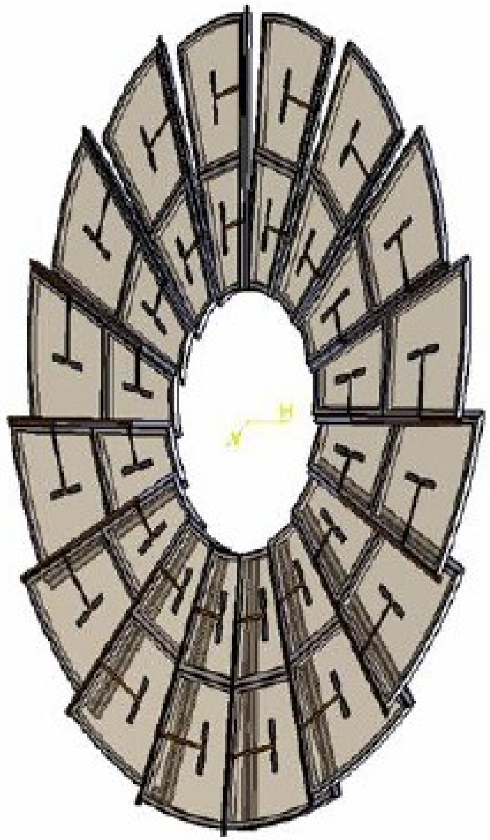
FTD disks: mechanical studies

By David Moya (IFCA) based on LicToy studies

4th FTD DESIGN

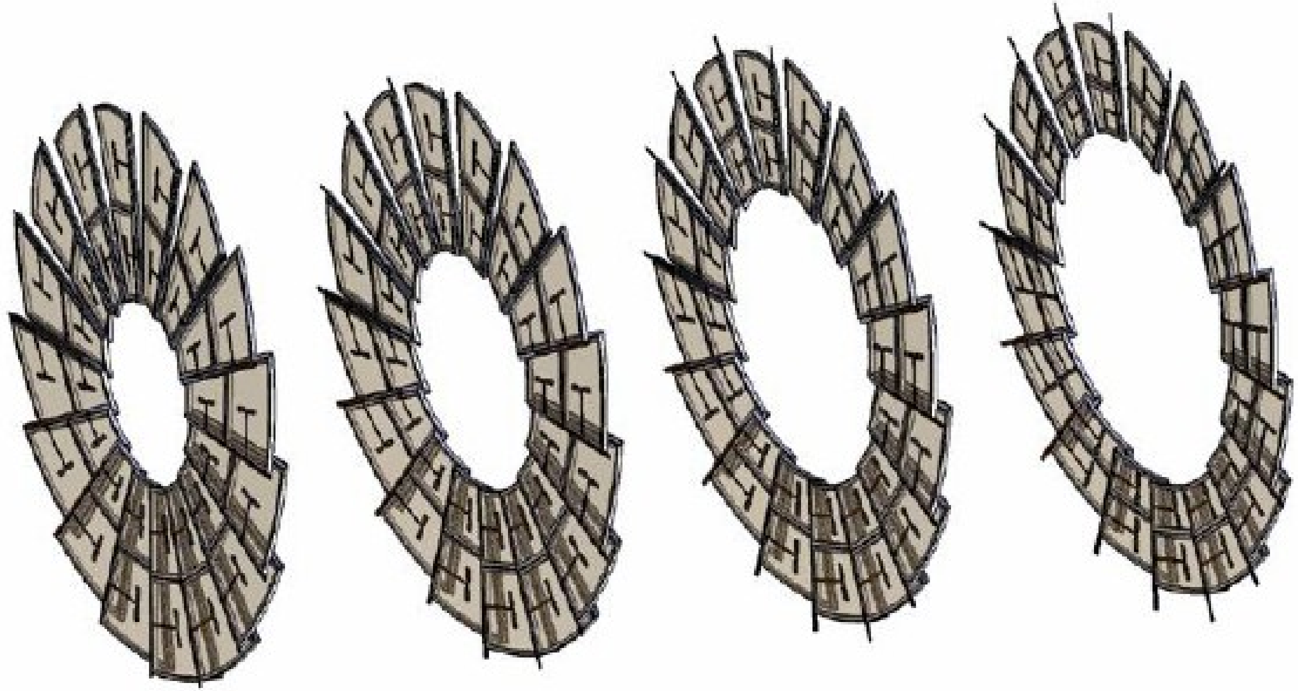
- Applying the design to all the petals of the FTD
- In the right picture we can see the rotation of the petal respect to the bean pipe axis
- In the bottom picture we can see the 4th FTD perpendicular projection to the beam pipe.

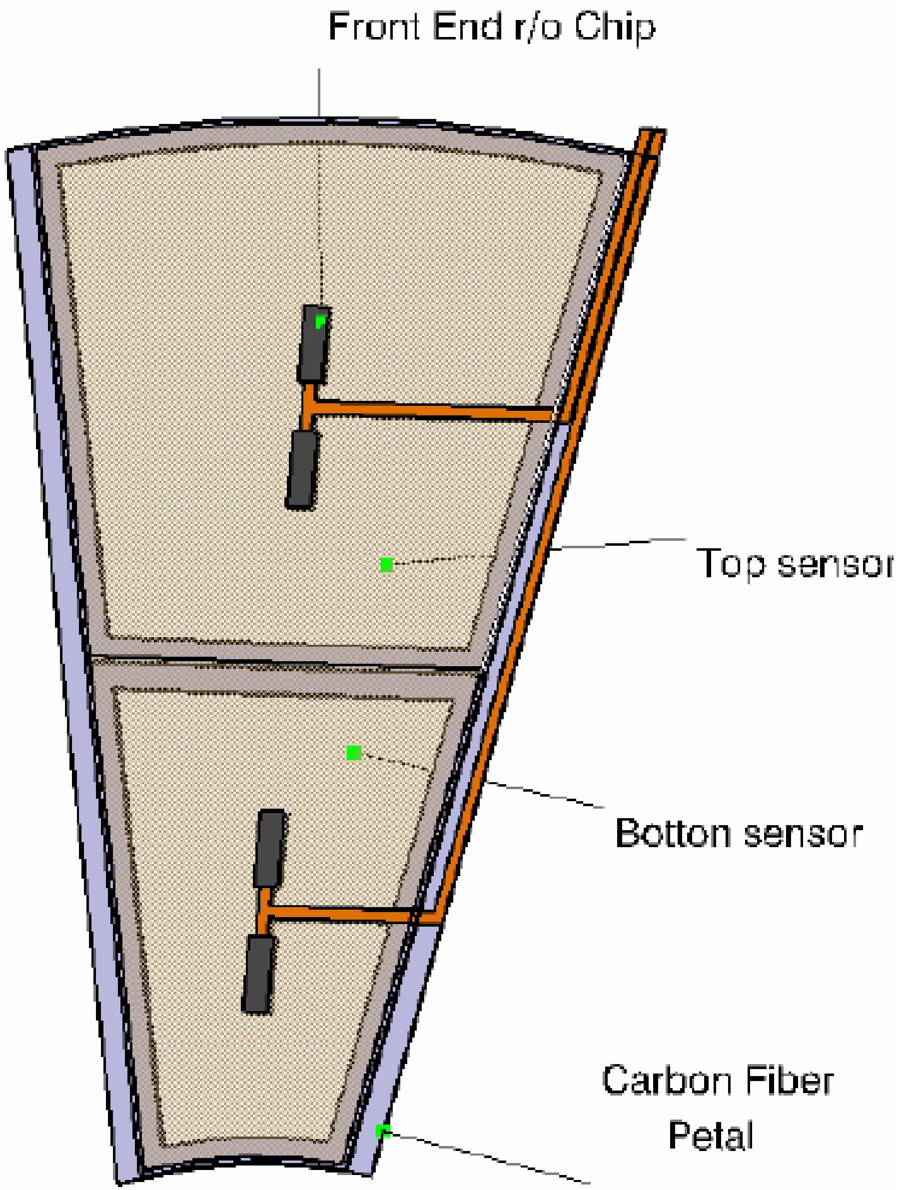




DISK 5,6,and 7 DESING

- Once the FTD 4 geometry and design is defined, we apply this to the 5,6 and 7 forward tracking disk.





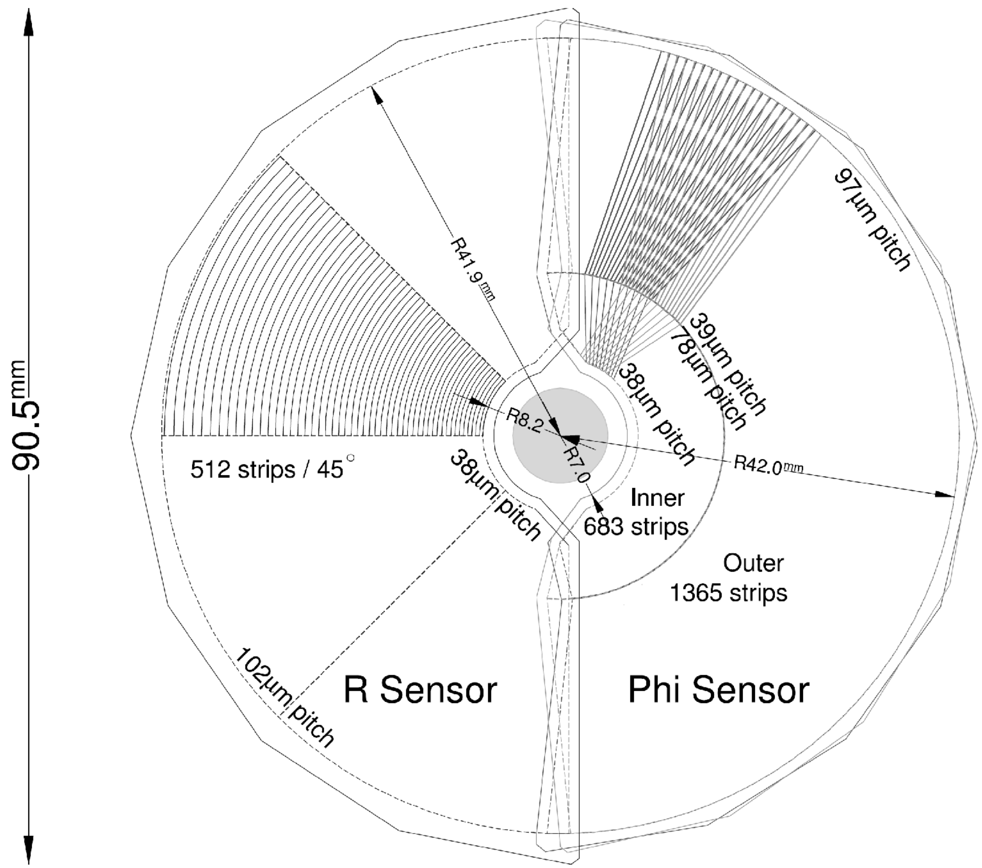
Reasons to use smart structures in the tracker

- Advantage of using smart structure:
  - Allow measuring mechanical properties of the structure in different points
  - Is embedded in the structure. The integration in the design would be easy
  - We can calculate the strain, temperature and deformation distribution on the structure as well as the deformation shape.
  - With a single optical fiber we could take the strain and temperature in different points of the structure

Some details about
the petals modules
in one of the FTD designs
(IFIC+IFCA)

Another option for the FTDs: use the R-Phi strip sensors a la VELO (LHCb) for all the 7 disks

Courtesy of B. d'Adeva et al (USC)



	R sensor	ϕ-sensor
number of sensors	42 + 4 (VETO)	42
readout channels per sensor	2048	2048
sensor thickness	300 μm	300 μm
smallest pitch	40 μm	38 μm
largest pitch	102 μm	97 μm
length of shortest strip	3.8 mm	5.9 mm
length of longest strip	33.8 mm	24.9 mm
inner radius of active area	8.2 mm	8.2 mm
outer radius of active area	42 mm	42 mm
angular coverage	182 deg	$\approx$ 182 deg
stereo angle	-	10–20 deg
double metal layer	yes	yes
average occupancy	1.1%	1.1/0.7% inner/outer

USC team is adapting this geometry to the design and dimensions of the FTDs and simulations will compare the performances between both strips designs

The integration of the Silicon components in the innermost part of the ILD barrel

SIIC is discussing an overall envelope where both SIT and FTD detectors would be included and also how to fix the FTD disks and the SIT.

We need to get the proper informations from all the other parties, i.e:

=> MDI and beam pipe

=> vertex detector

=> TPC

Alignment is being worked out by the IFCA team (more to come soon)

This is a proposed set up to align the innermost Silicon system (FTDs) based on the use of an IR laser and transparent especially developed sensors. Interesting deature of this system: it does not bring additional material and use the same readout system

Concluding remarks

- Works on integration of the Si components is udertaken by SiLC collaboration
- No show-stoppers
- ***But need to have collaborative effort with other subdetectors and MDI team to achieve a first reliable integration schema for all the components.***