Detector concepts & detector designs at ILC: The Silicon tracking components

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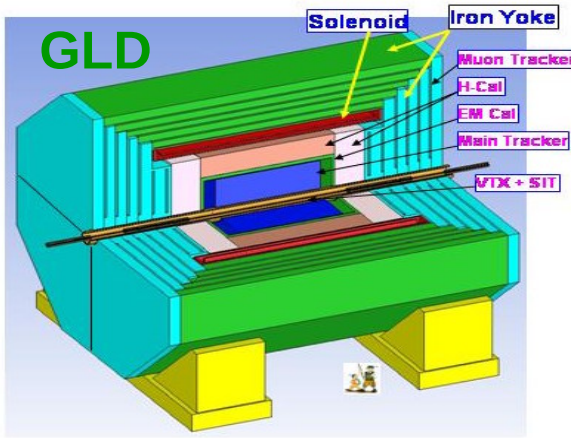
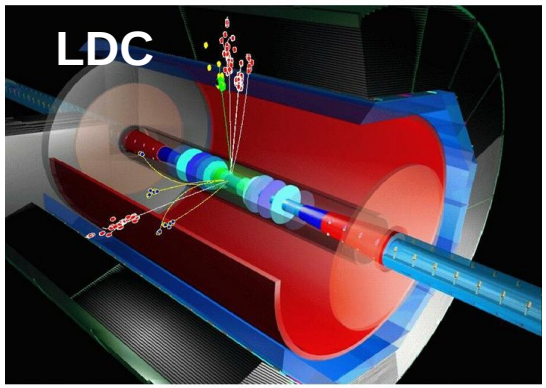
SiLC R&D Objectives

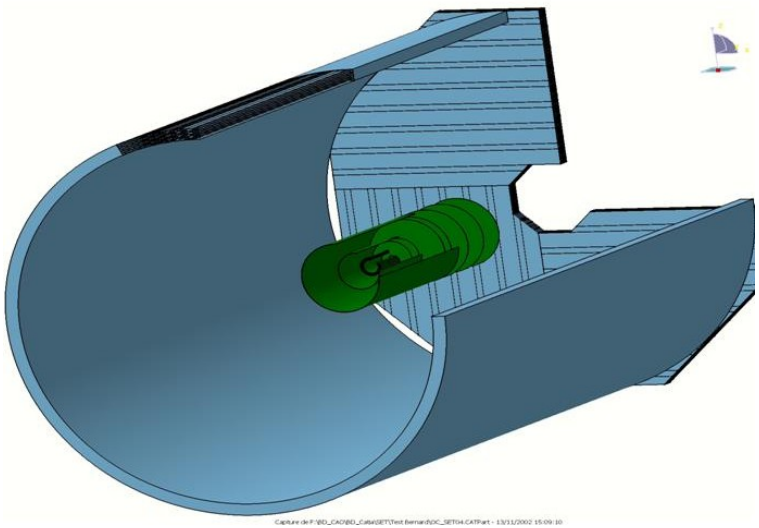
SiLC is a generic R&D aiming to develop the next generation of large area Silicon Trackers for the ILC; It applies to all the detector concepts





- **Very high precision on momentum (10 times better/LEP) & spatial measurements (down to 4μm, in certain regions, average 7-8 μm), large angle coverage.**
- **Low material budget**
- **Tracking redundancy & calibration/monitoring (if TPC)**
- **Robustness**
- **Easy to build and to work with**
- **Low cost**

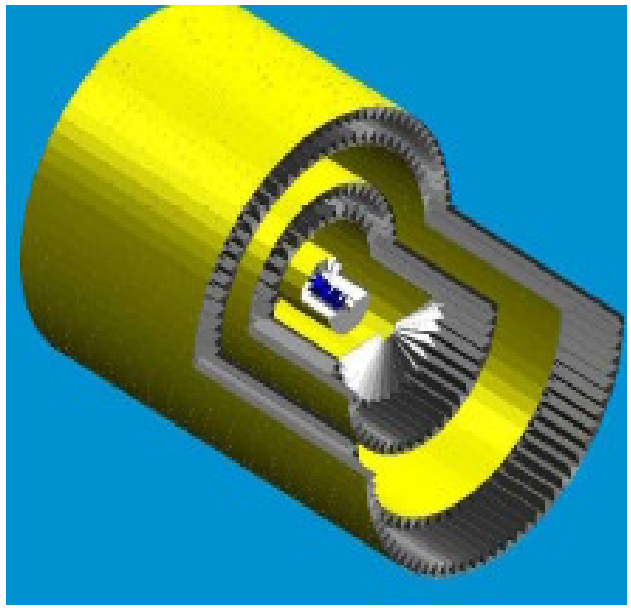
SYNERGY with LHC construction & upgrades



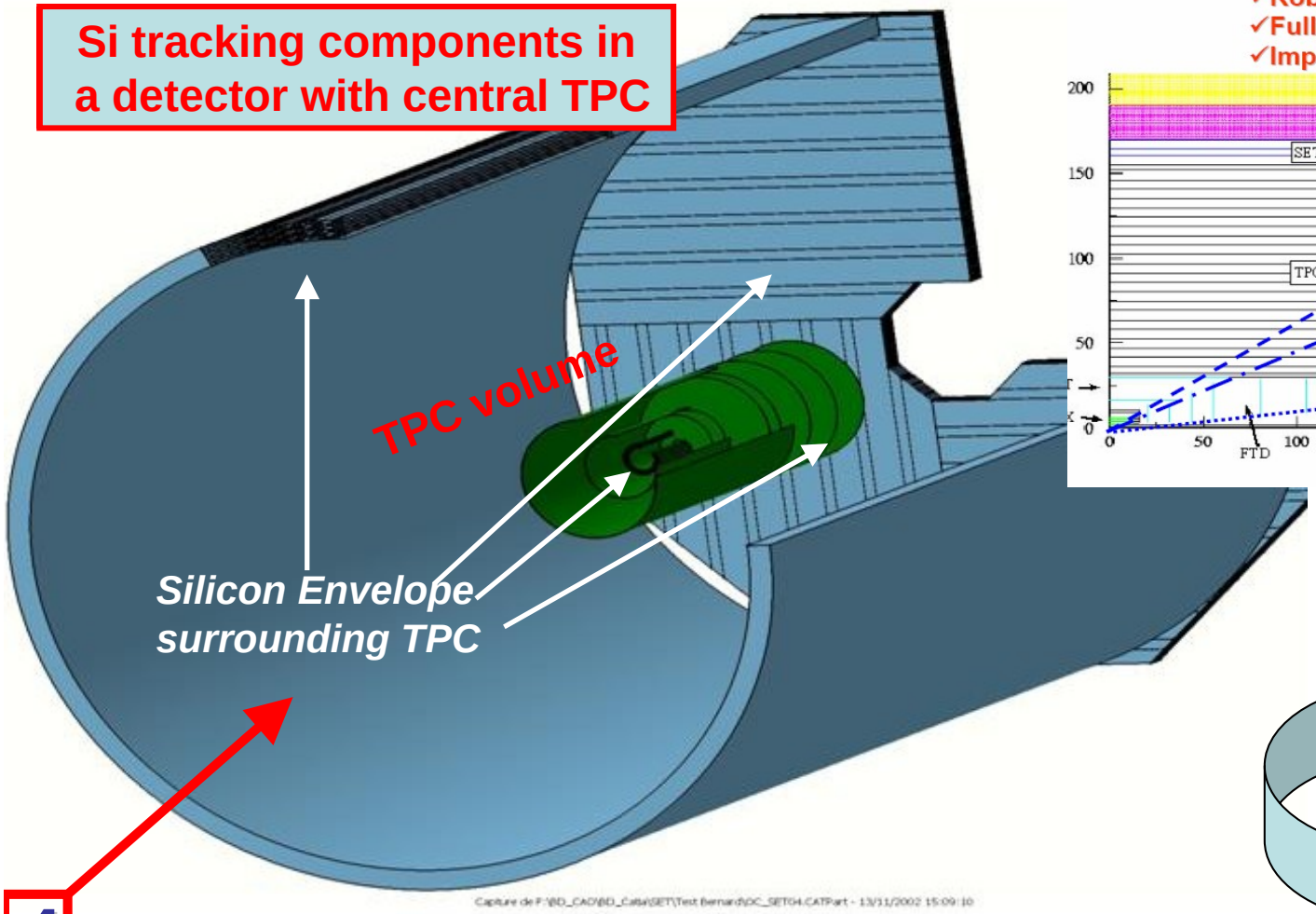
R&D on Mechanics concentrates on:

- CAD design of Si tracking components: essential for baseline design studies of detector concepts
- Elementary module design in close collaboration with FE electronics designers
- Large structure: robust, light, easy to build
- Materials
- Positioning & alignment
- Cooling
- Robotisation & Industry transfer
- Integration issues

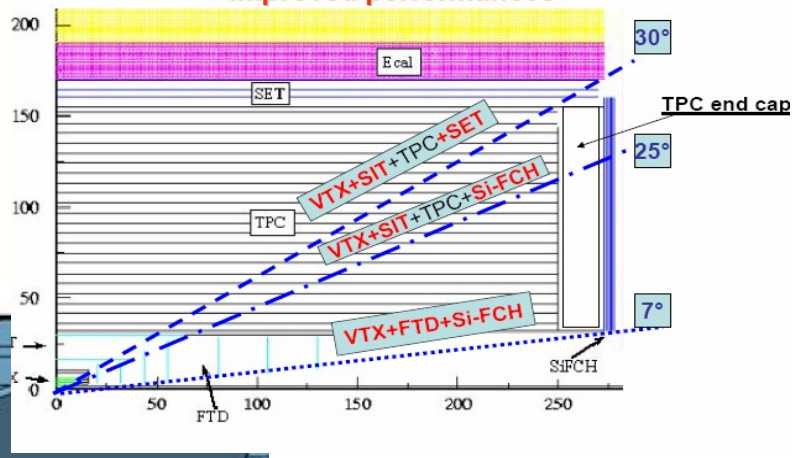
For all these items new solutions must be found



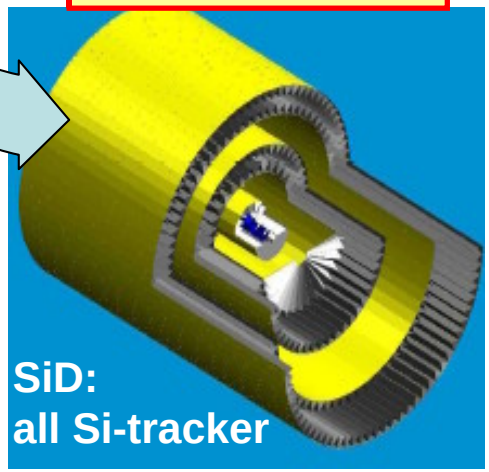
Si tracking components in a detector with central TPC



✓Robustness
✓Full coverage
✓Improved performances



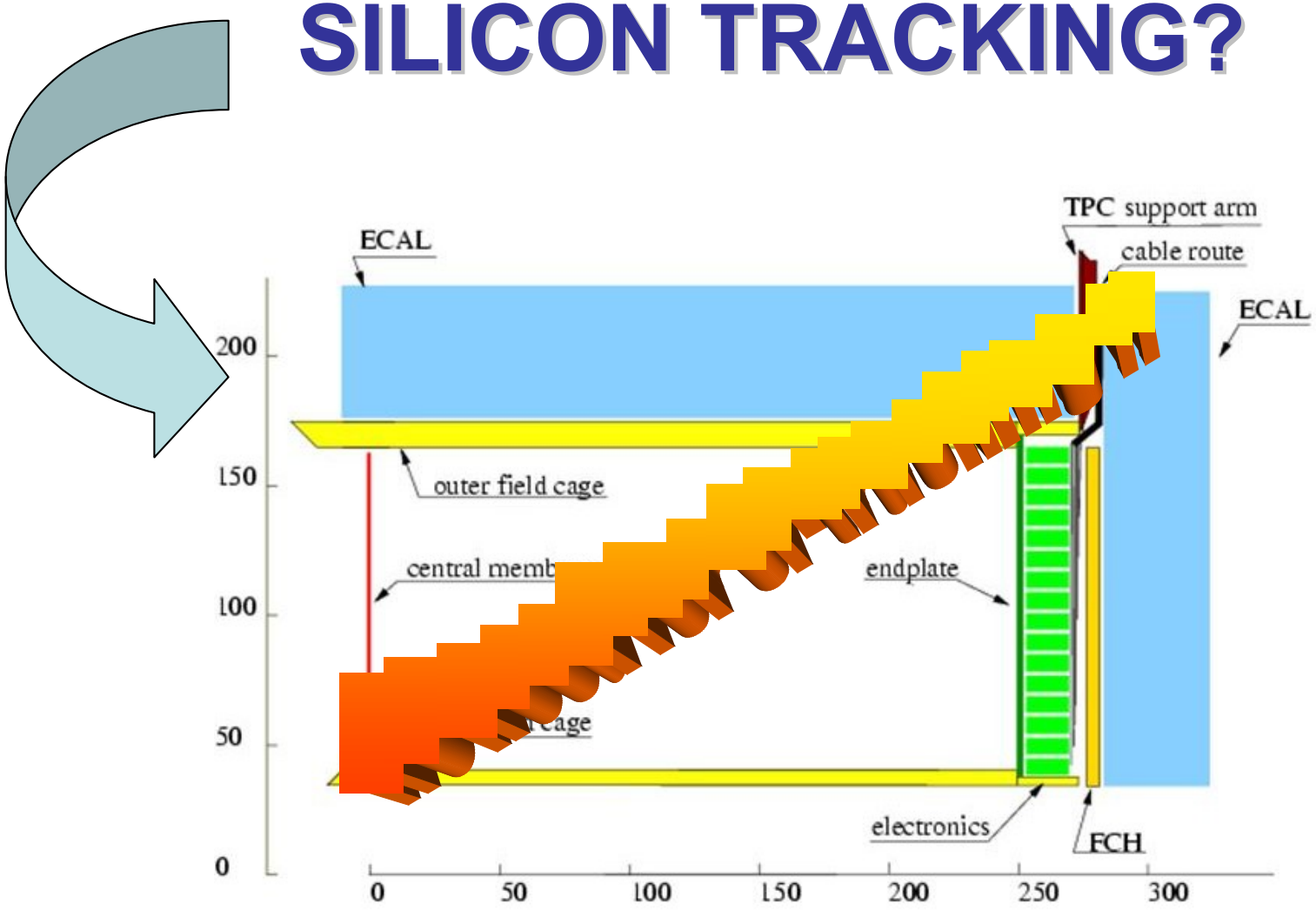
How it compares with SiD tracker?



4 Si tracking components in detector concept with TPC

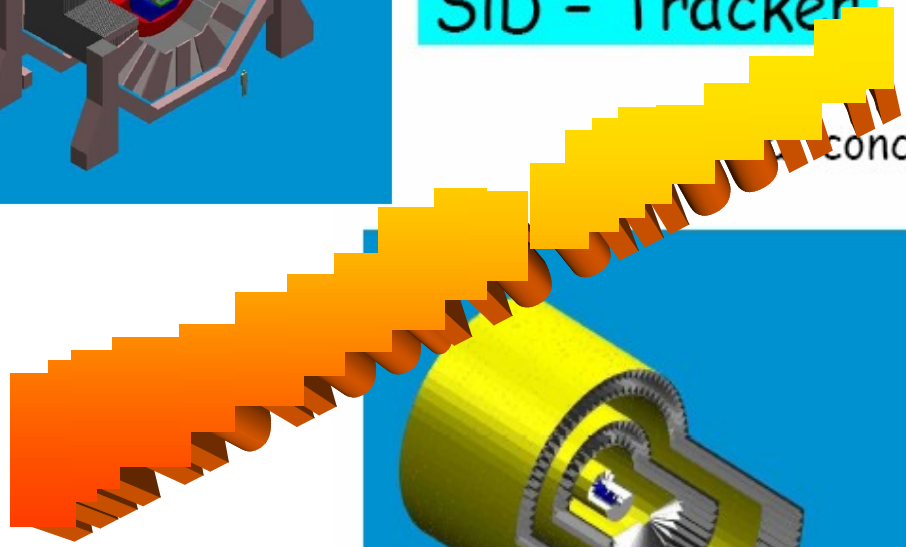
internal and external Si tracking components
in
barrel and large angle (forward/end caps) regions,
acting as intermediate trackers
and forming a complete coverage Si tracking system

CAN WE MAKE IT WITHOUT SILICON TRACKING?

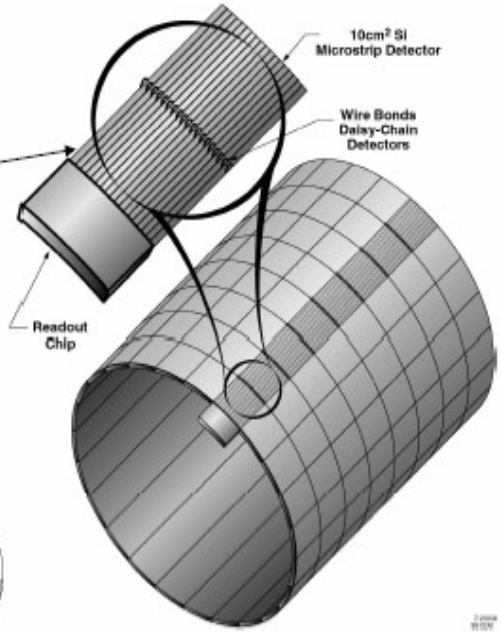


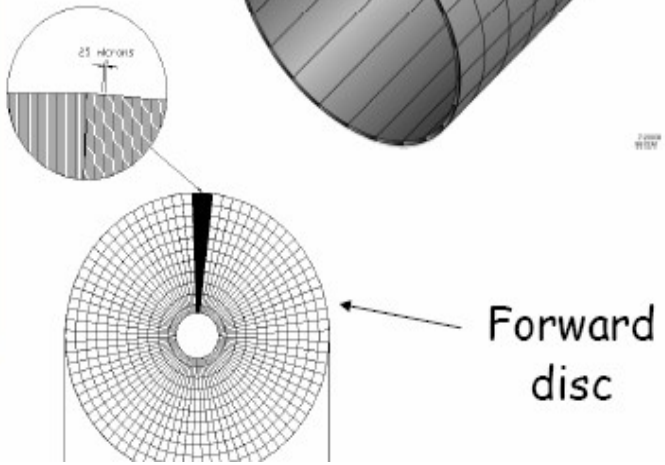
How It compares with ONLY SILICON TRACKING?

SiD - Tracker



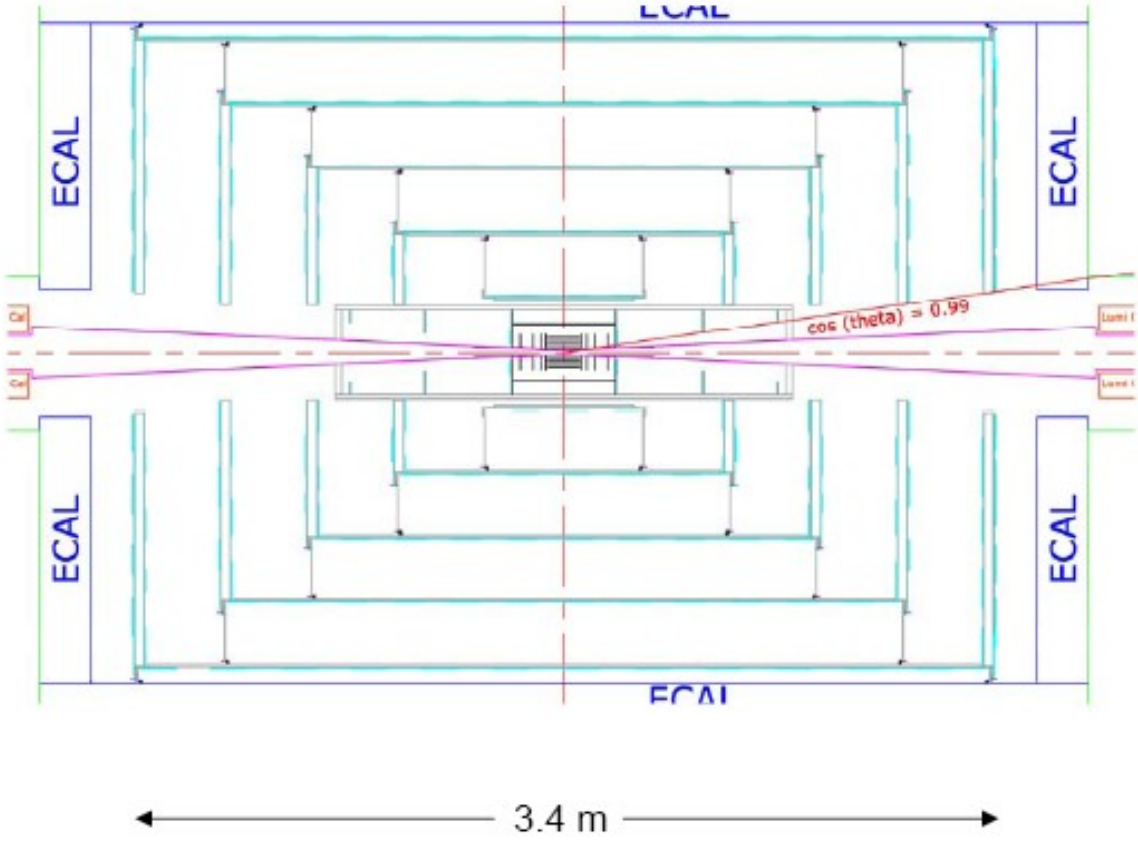
concept

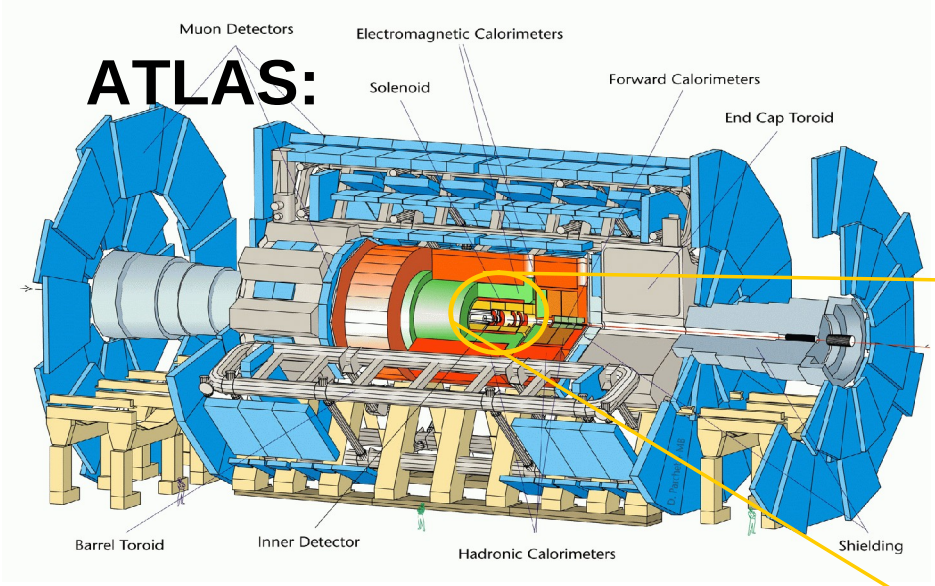


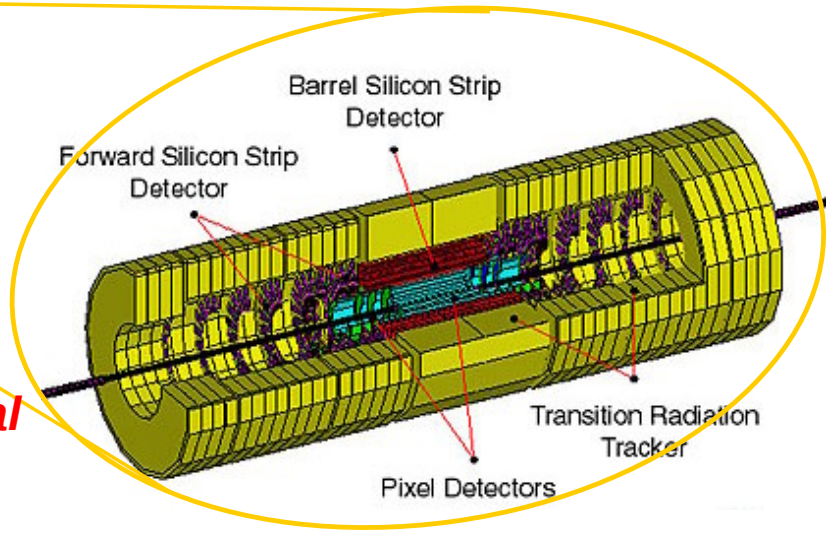


Silicon Tracking Layout

- Outer tracker
  - 5 barrel layers
  - 5 disks per end
  - OR = 1.25 m
  - IR = 0.2 m
    - May need to adjust inner radius to accommodate beam-line elements
  - Supported from ECAL
- Inner detector
  - VXD
    - 5 barrel layers (may increase to 6)
    - 4 disks per end
  - Additional "forward" disks
  - Supported from conical portions of beam pipe







Combining Si-tracking with a central gaseous tracker is proposed/built by several experiments as for instance:

ATLAS: {VTX, SCT, TRT} at LHC

CDF: {VTX, ISL, COT} at Tevatron II

GLD or TESLA: {VTX, SIT/IT tracker, TPC} at ILC.

Main asset:

provides the benefits of both tracking technologies

Inherits in counterpart:

TPC: end caps and bad forward coverage, and for Silicon: material budget.

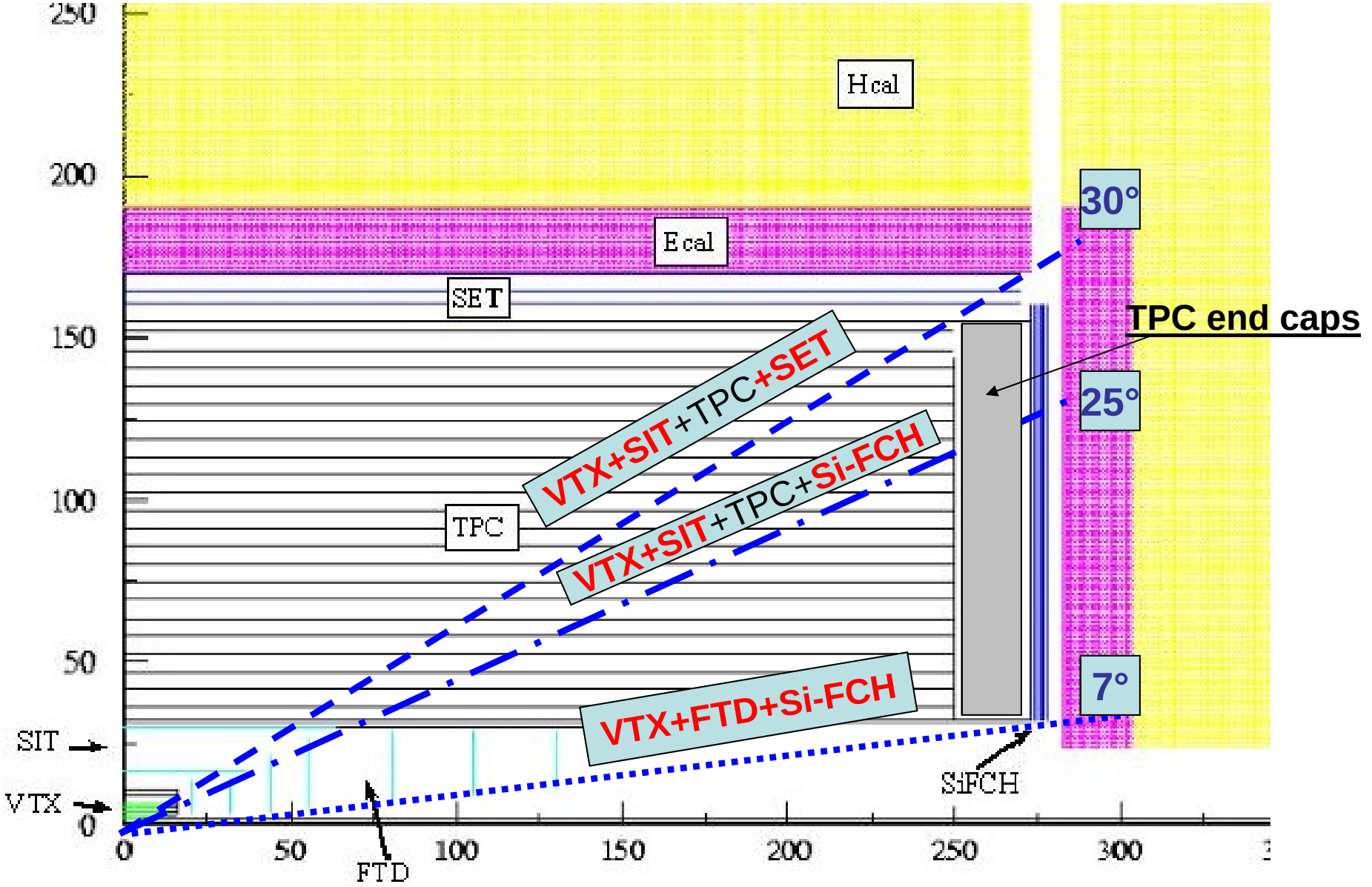
The Si-envelope gives an autonomous tracking system with a coverage down to small angles wrt beam axis (about 7 °) and with full level-arm. It provides:

- **redundancy → reliability (safety)**
- **Independent track finding in TPC and VTX+SIT+SET:** ***Alignement, calibration, distorsions handling***
- **Improvement of the overall tracking system performances:**

Ex: ***dPt/Pt and entry track segments for the fine-grained calorimetry***

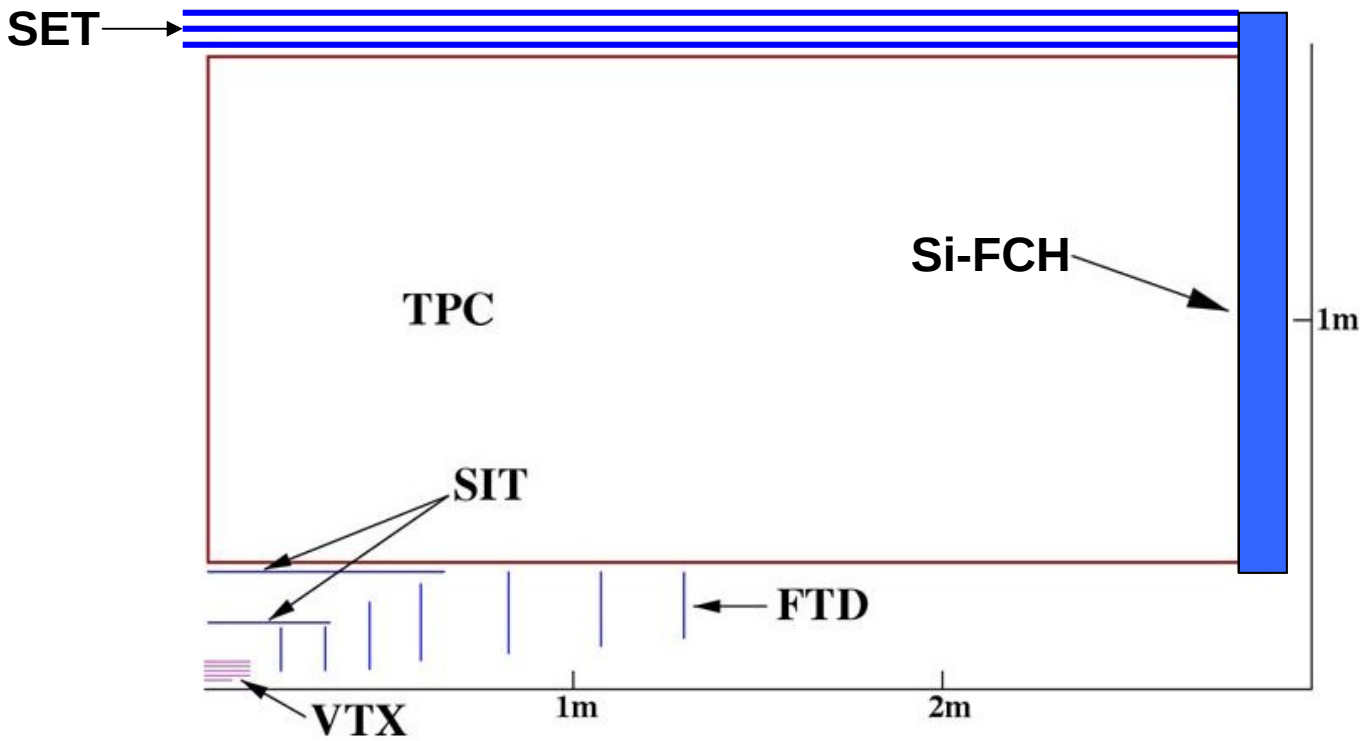
- **Complementarity to the TPC:**
  - **coverage: allows** ***full coverage at large angles and down to small angles wrt beam axis***
  - **Properties:** ***dE/dX (1/β²), spatial resolution, secondary vertex for long lived particles***

Angular coverage of the overall & Si-tracking: quadrant view



Si-tracking components:

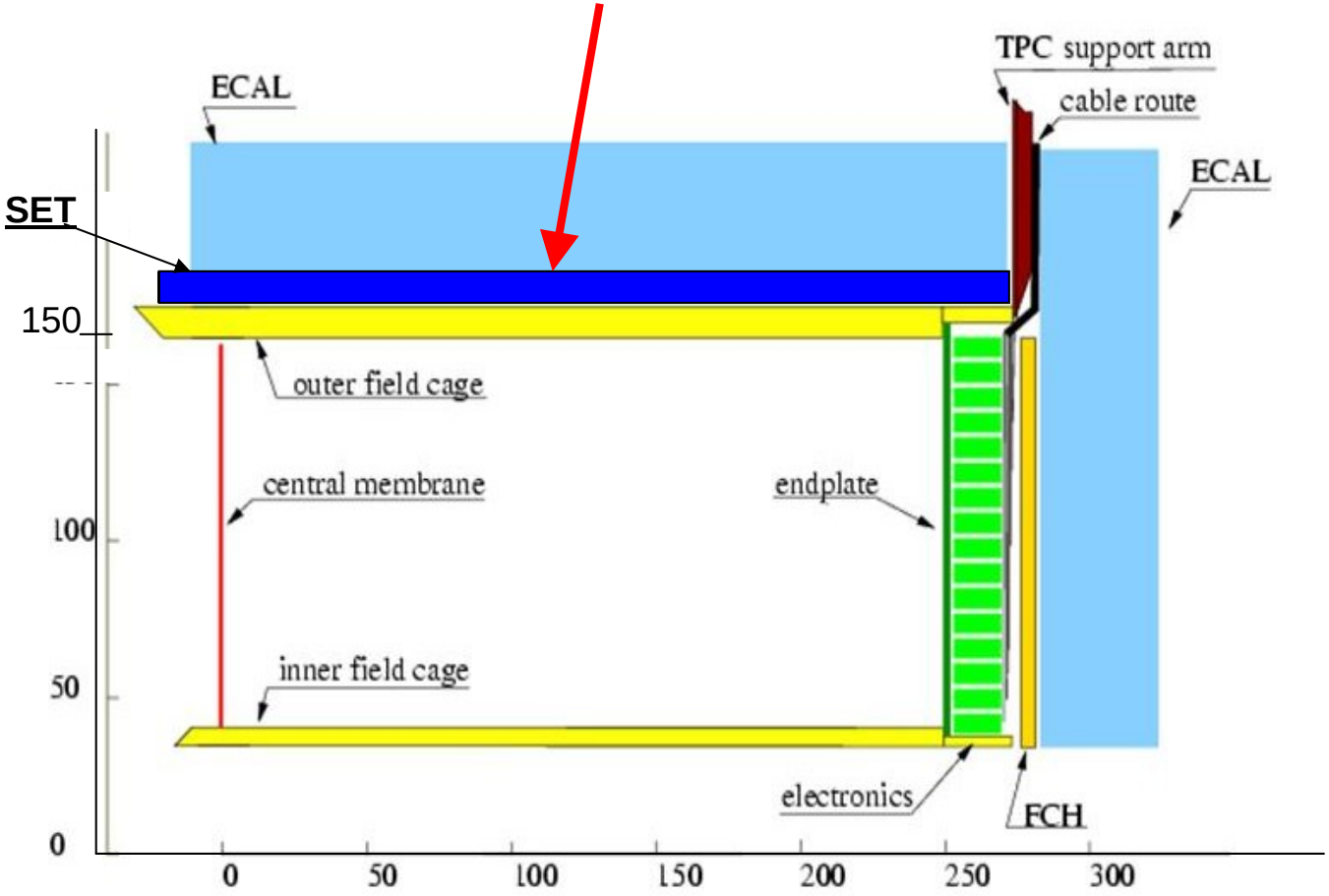
design, role, main issues of each component



Warning:
Note that this presentation starts from the detector design of the TESLA TDR. But this is just to have some basis for the discussion.
Dimensions, values of different parameters are totally opened.

2) The Central Outer Si-Tracker (COSiT)

- **The SET (Silicon External Tracker) proposed in LC-DET-2001-075. Located between the TPC and the e.m. calorimeter occupying about 10 cm space.**
- **Optimized with 3 layers, two single sided external layers, one d.s. intermediate layer and overall alveolar structure.**

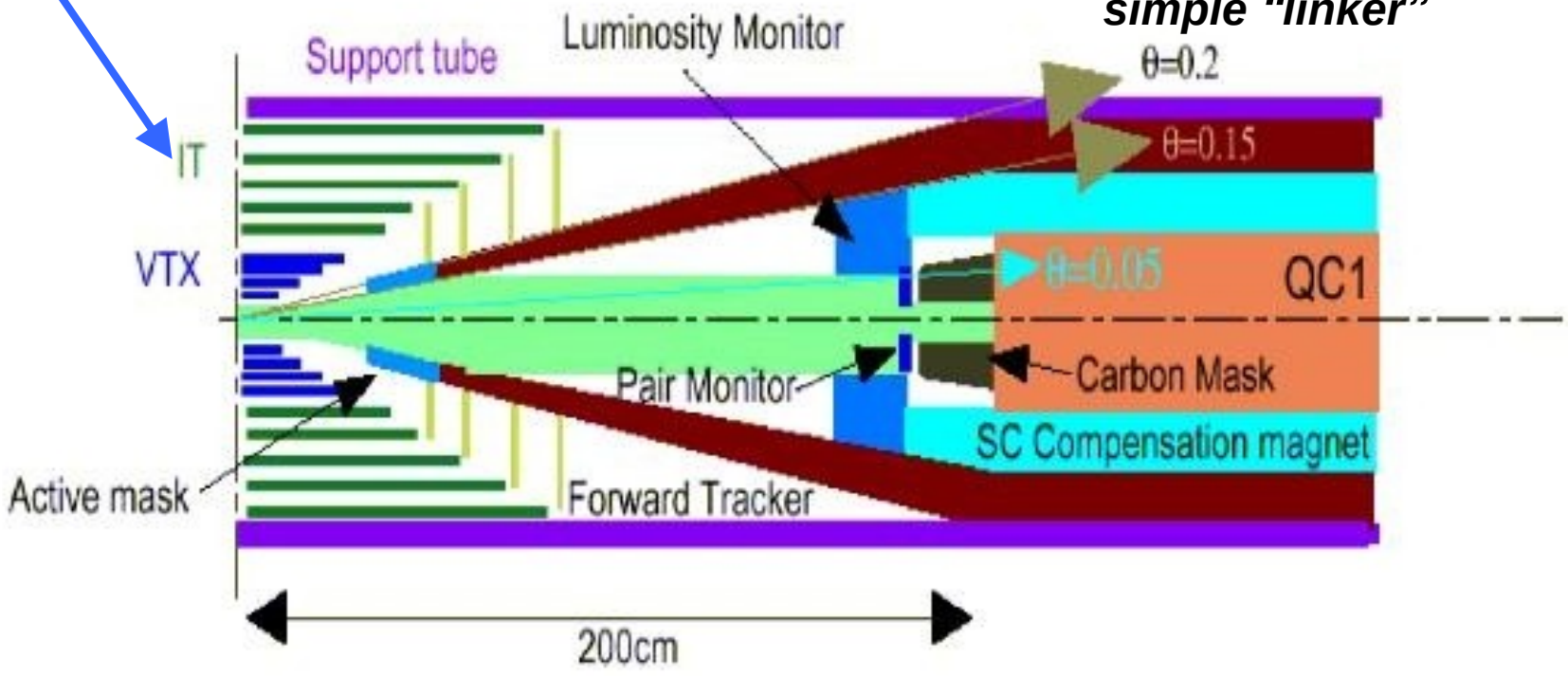


Si tracking components in the central barrel:

1) In the inner part few layers linking the microvertex with the TPC .Two alternative designs:

- **SIT** *(Silicon Internal Tracker) (LC-DET-2001-036) and TESLA TDR, similar to the ISL in CDF*
- **IT** *(Intermediate Tracker), in the GLD design, with 5 Si layers, similar to the SCT in ATLAS. (See presentation of the huge detector)*

More like a real tracker than a simple "linker"

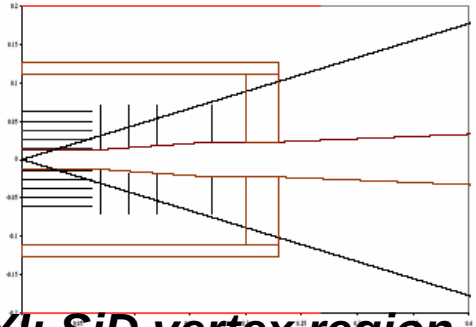


Si tracking components in Forward region

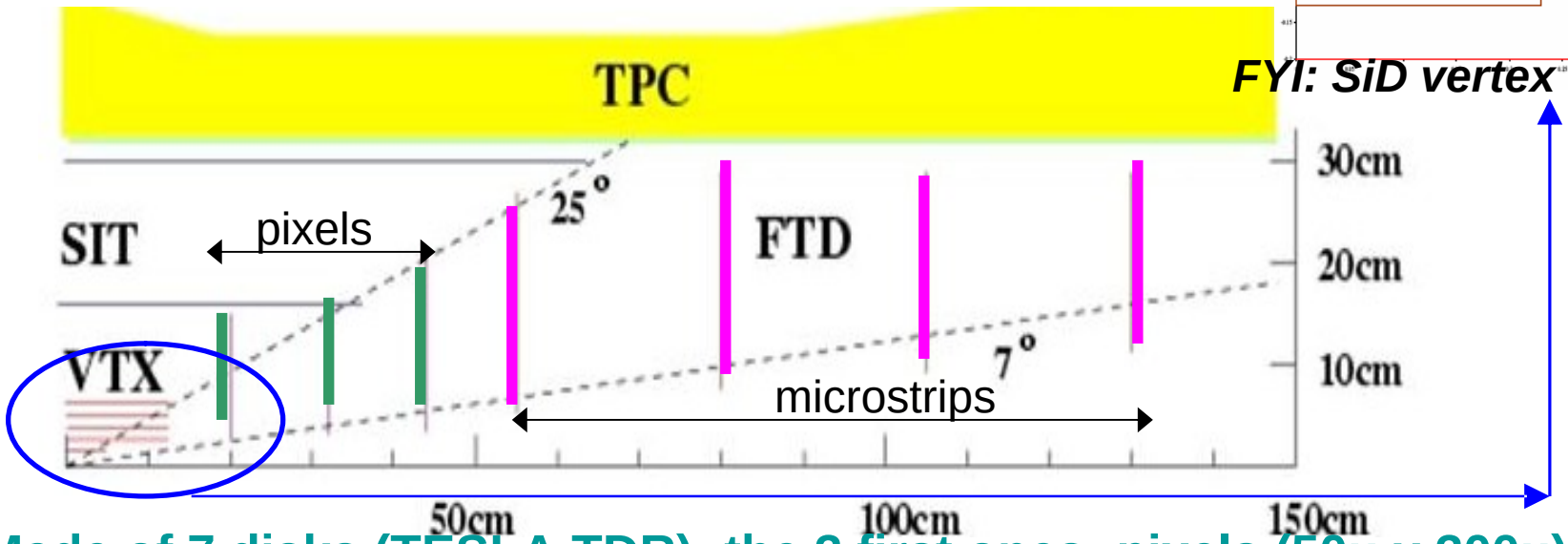
The forward region is a key-region for Physics at the ILC c.m. To have highly performing tracking system at large angle is therefore mandatory. Its design is actively addressed. It also implies optimising the overlap between the central and the forward tracking.

3) The inner forward Si tracker FTD:

covers between 25° to 7° wrt beam axis. No TPC. Links VTX to the forward outer tracker with TPC end cap in between.

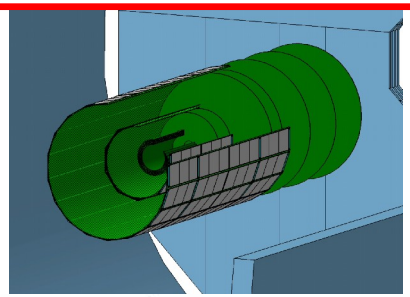


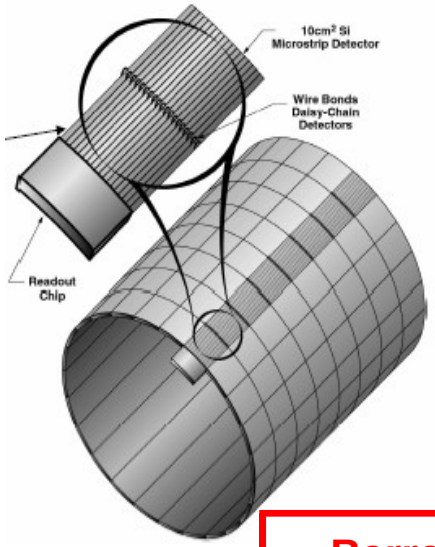
FYI: SiD vertex region



Made of 7 disks (TESLA TDR); the 3 first ones: pixels (50μ x 300μ) the 4 next ones with microstrips

CAD & main issues for Si components: detector design & performances

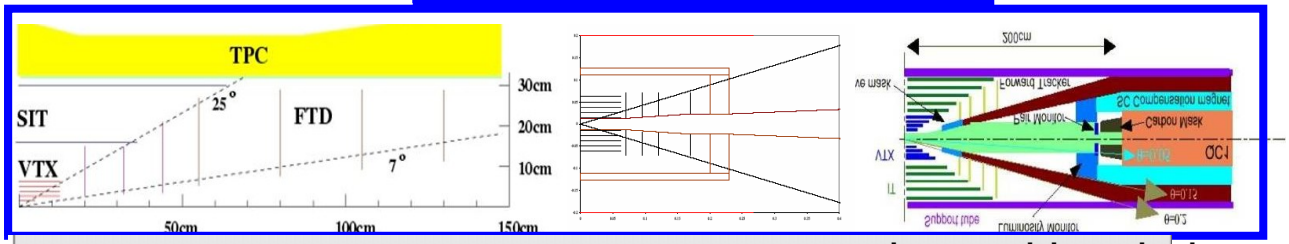


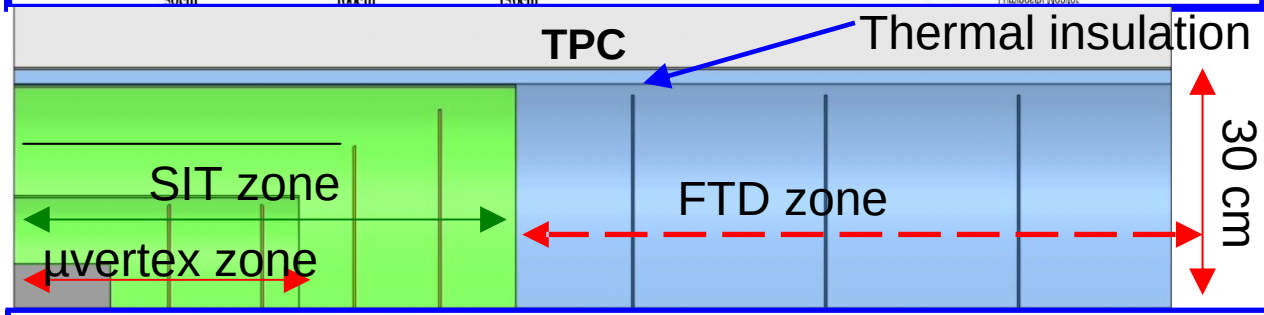


Barrel

Tiles vs Ladders ?
SET if TPC ?
How?

Internal barrel + forward





Microvertex zone includes: µvertex + 2 disks with same pixel technology

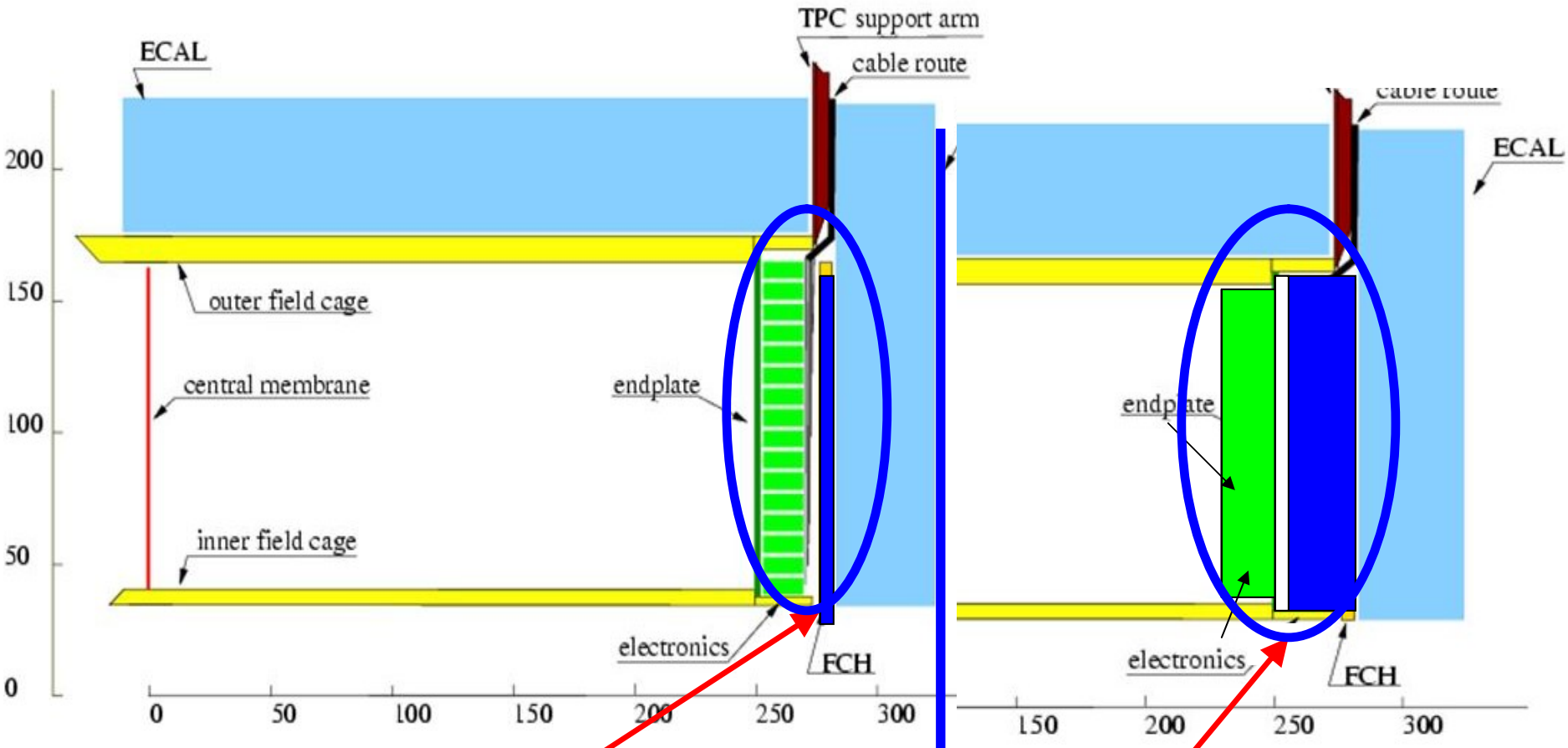
SIT zone includes: 2 or 3 Si layers + 2 disks strips and /or pixel techno

FTD zone includes: at least 3 more disks extending from 60cm to 150cm or up to the end of TPC length with eventually more disks

The ensemble {µvertex + SIT +FTD} is inside a thermal insulation (under study)

Nb of layers and disks & preferred techno are being studied (preliminary simulations studies: M. Berggren)

4) The Forward Outer Si tracker: 2 possibilities



The external forward Si-tracker is compressed between TPC endplate and the calorimetry. Thus it is more a linker than a real tracker.

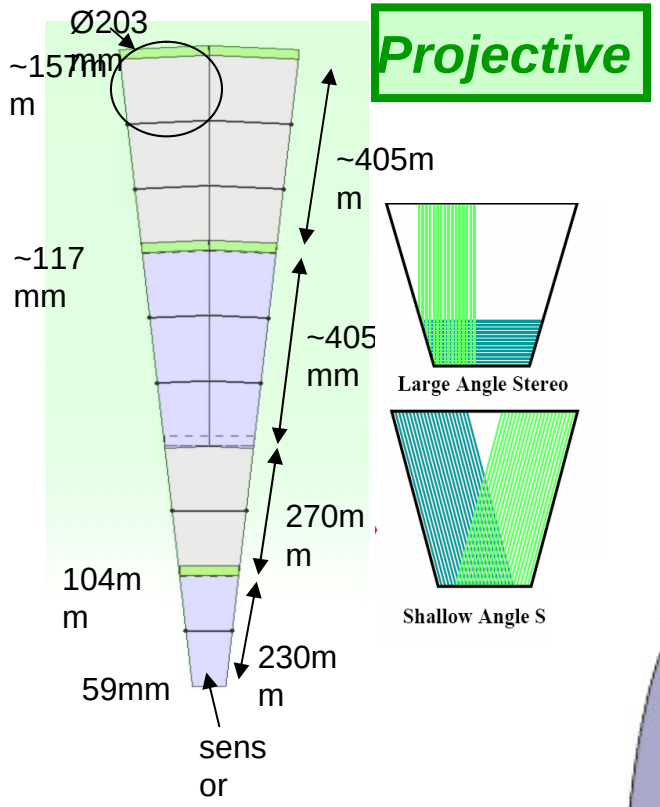
The external Si- tracker is extended over about 40 cm thus it provides a real tracking (level-arm)
(this means a shorter TPC)

Simulation studies needed !!

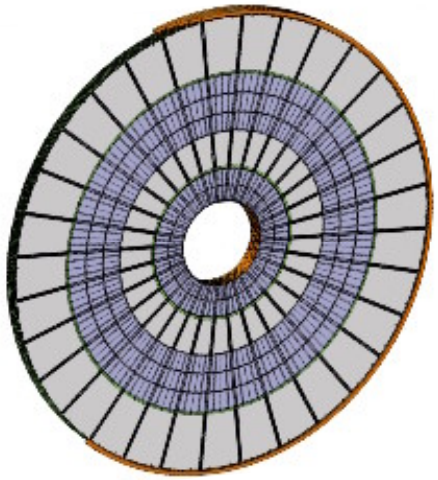
EndCapTracker

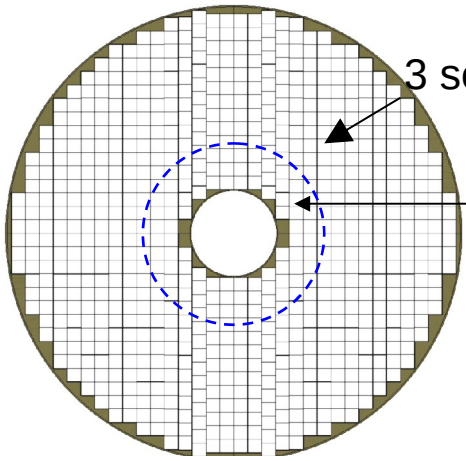
Nb of layers? Projective vs XUV ?
How to arrange them? (simu studies)

Mechanical team
LPNHE-Paris

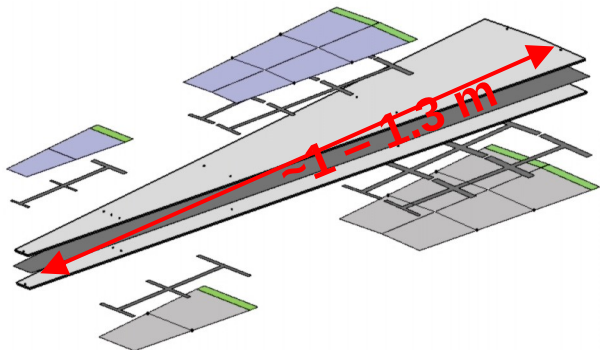


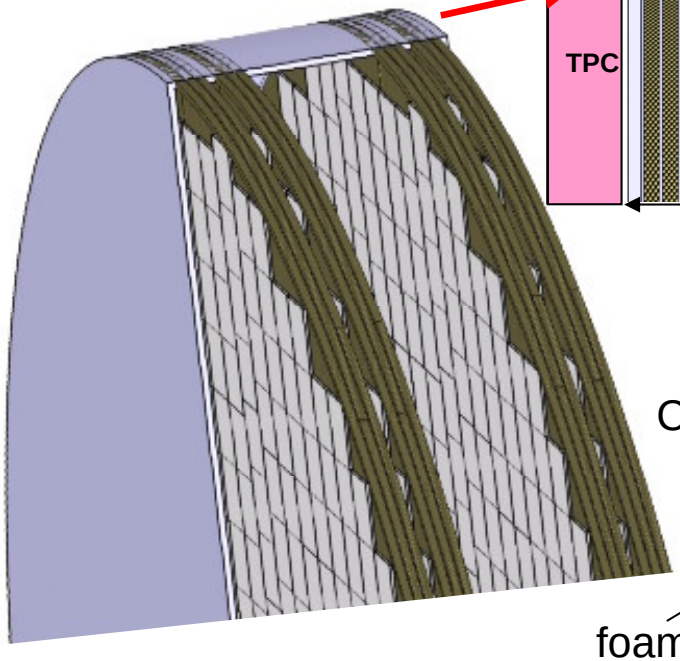
Projective

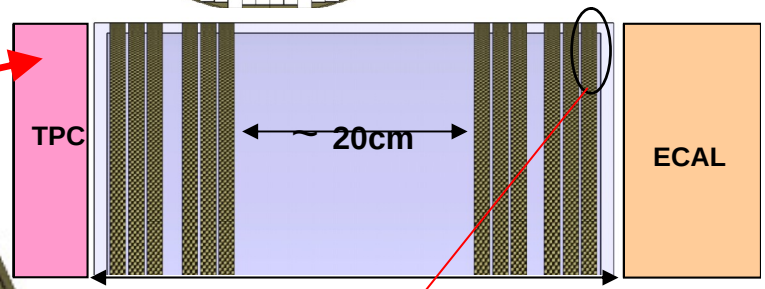


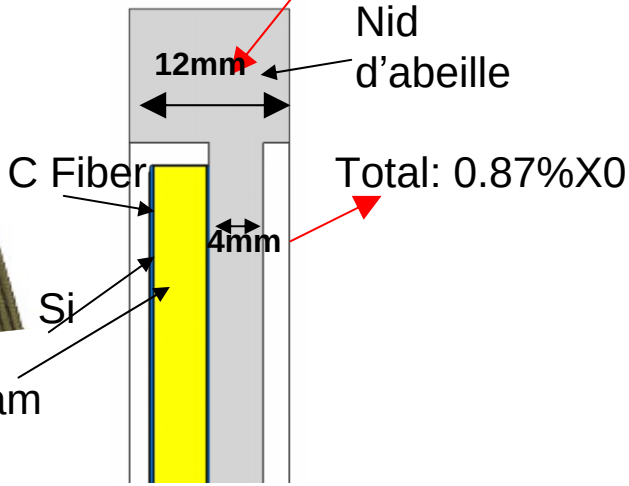


XUV

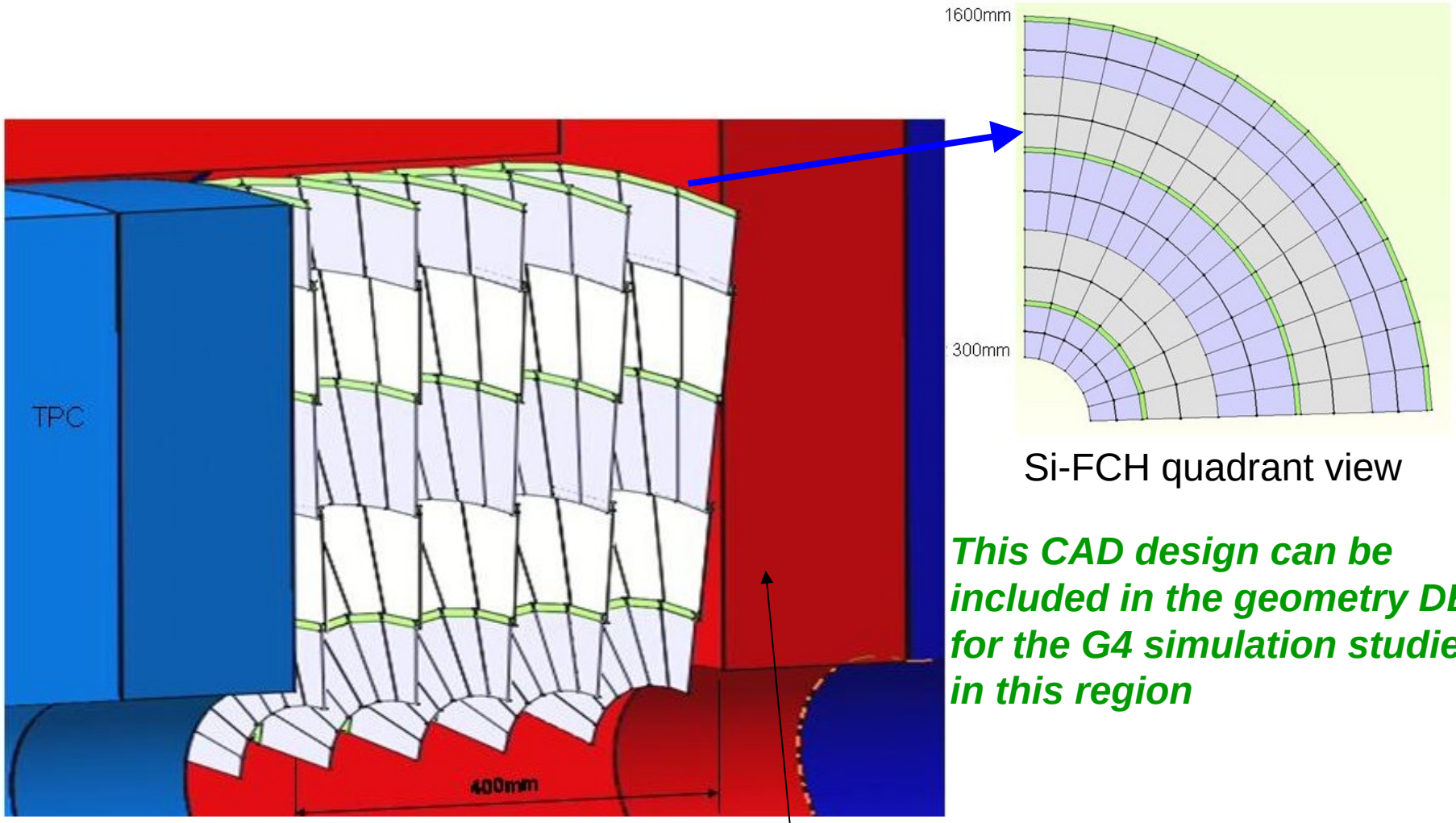






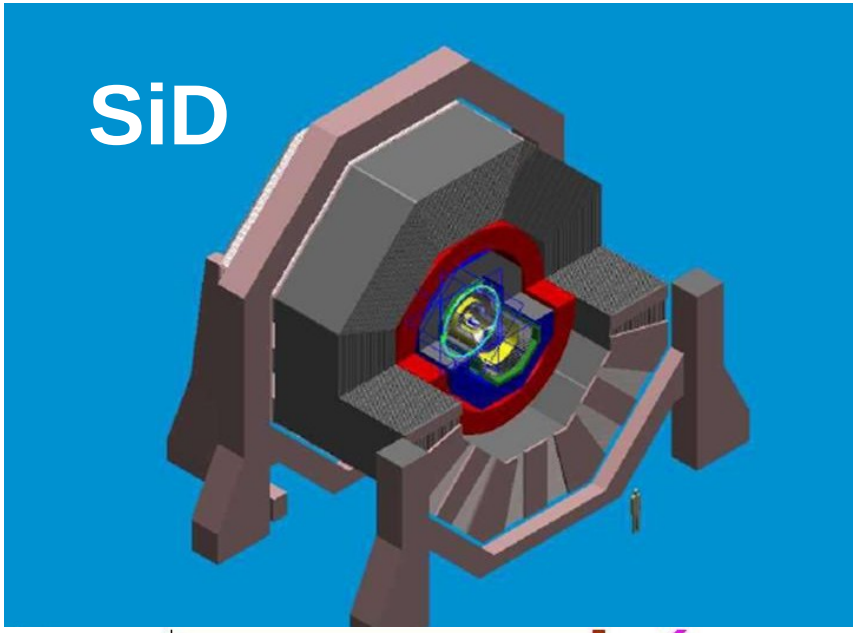


Si-FCH detector: overall view integrated in the experiment



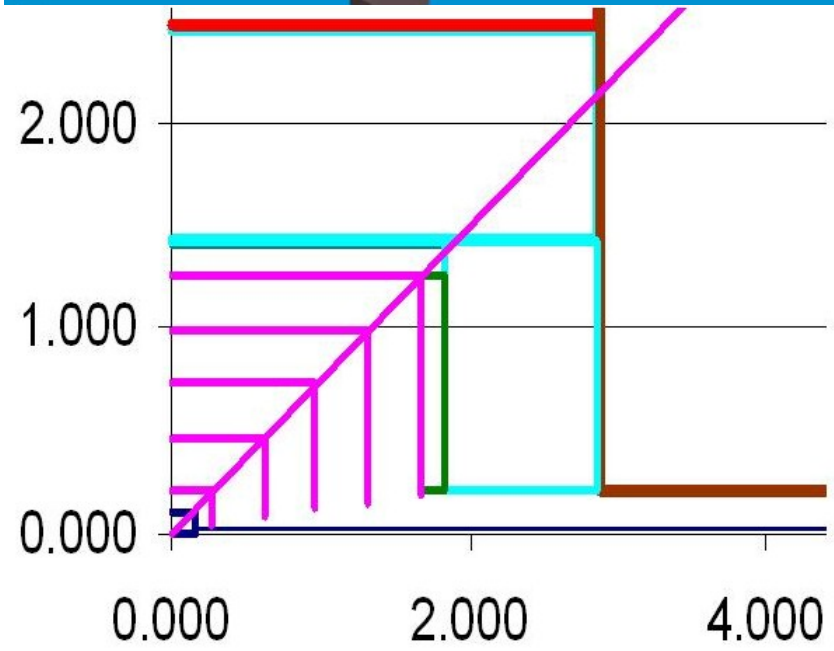
Si-FCH quadrant view

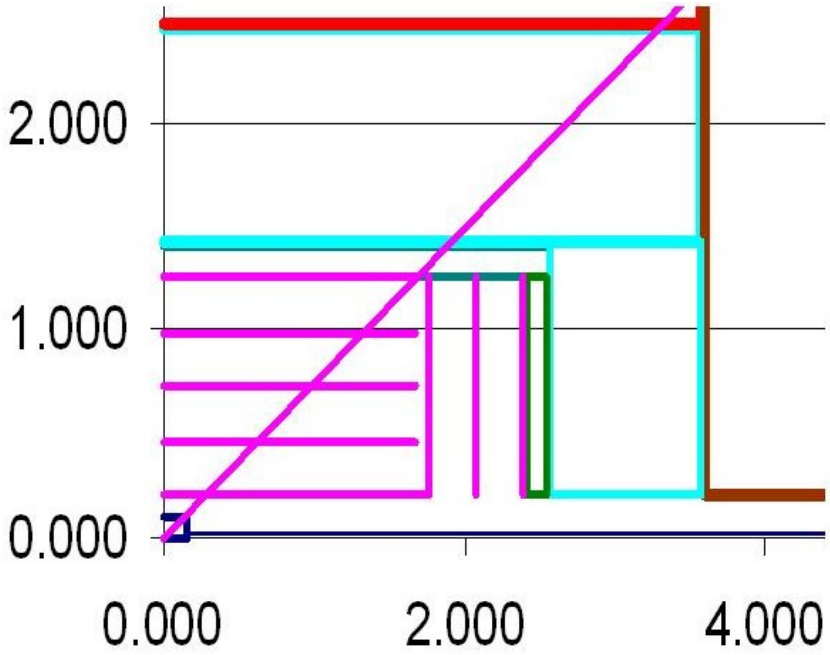
This CAD design can be included in the geometry DB for the G4 simulation studies in this region



How it compares with the SiD Forward tracking ?

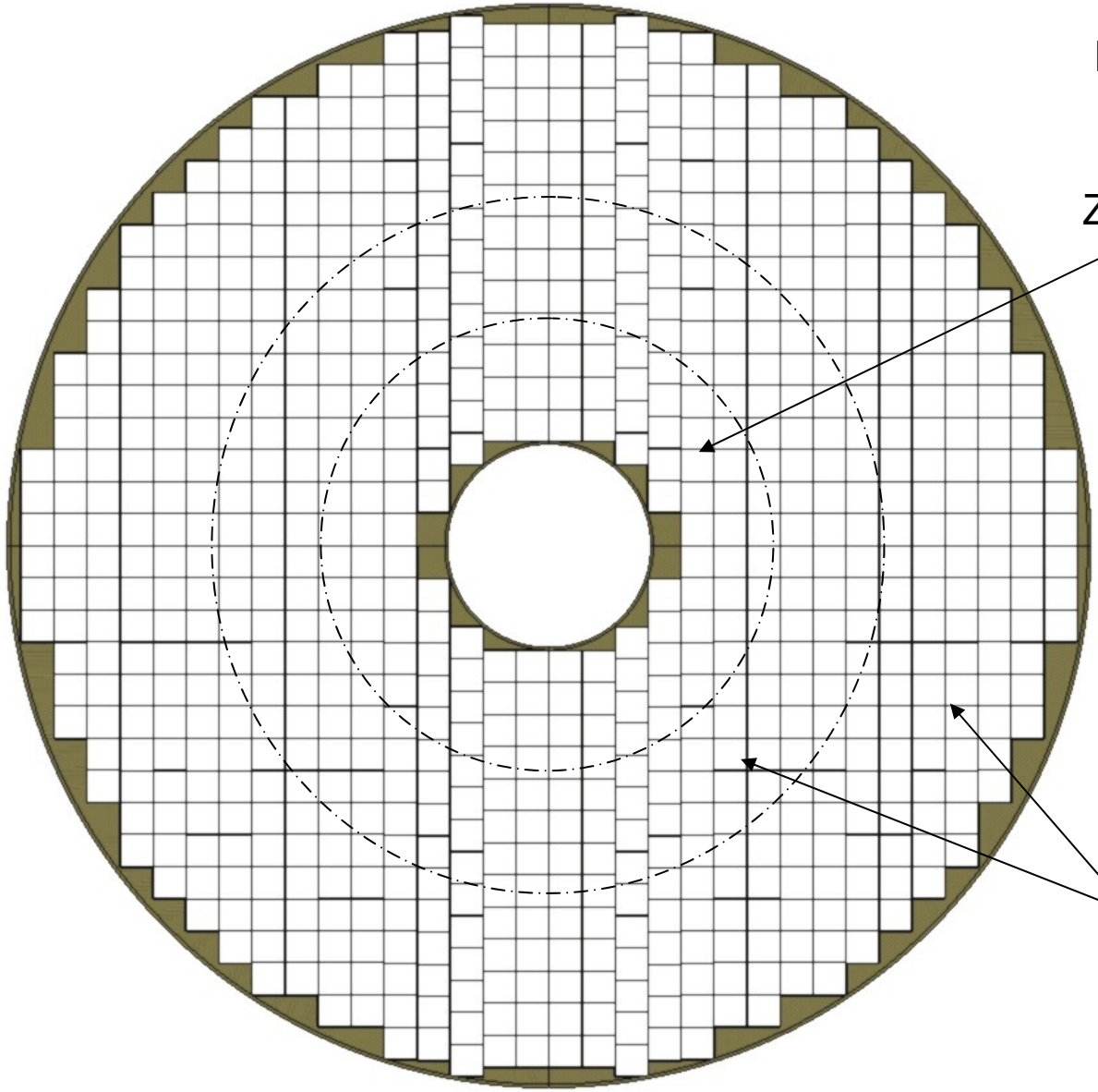
The all-Si-tracking system a la CMS of SiD is under active design. It is important to compare tracking performances with SiD. (started within SiLC collaboration)





The All-Si-tracking: two studied possibilities

Un disque X, U ou V

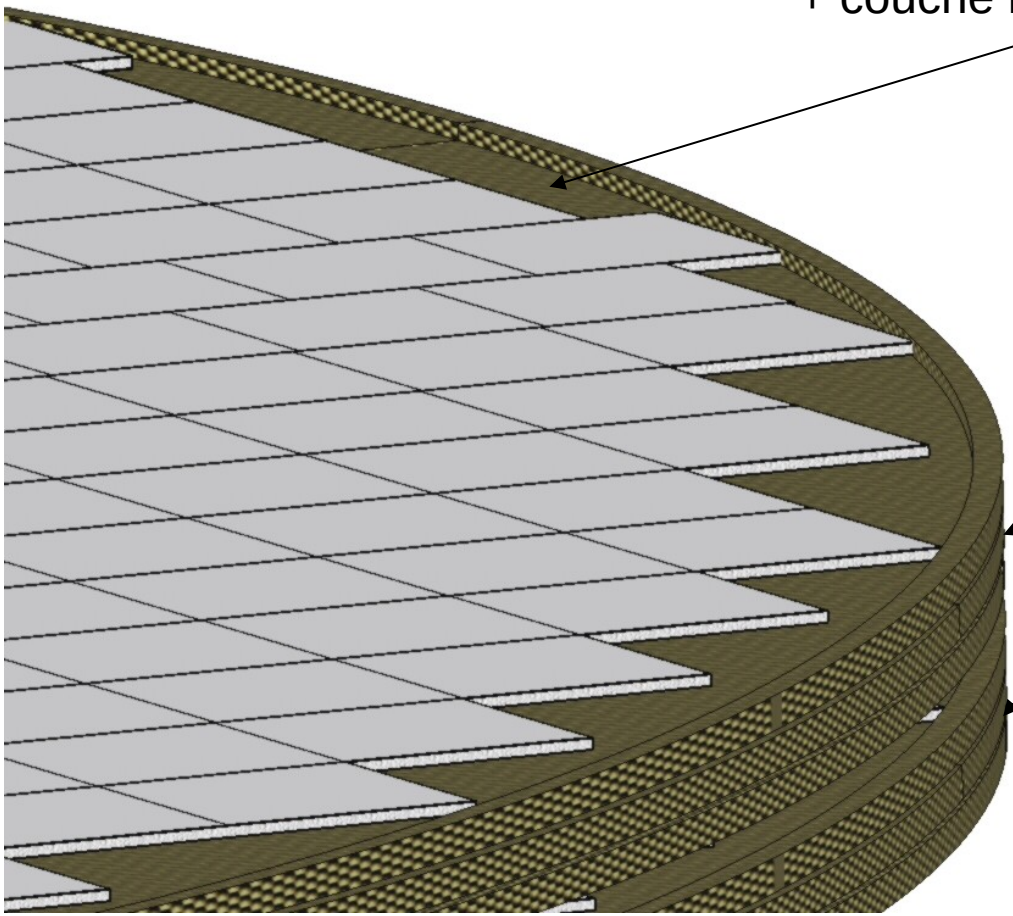


Répartition des Si :

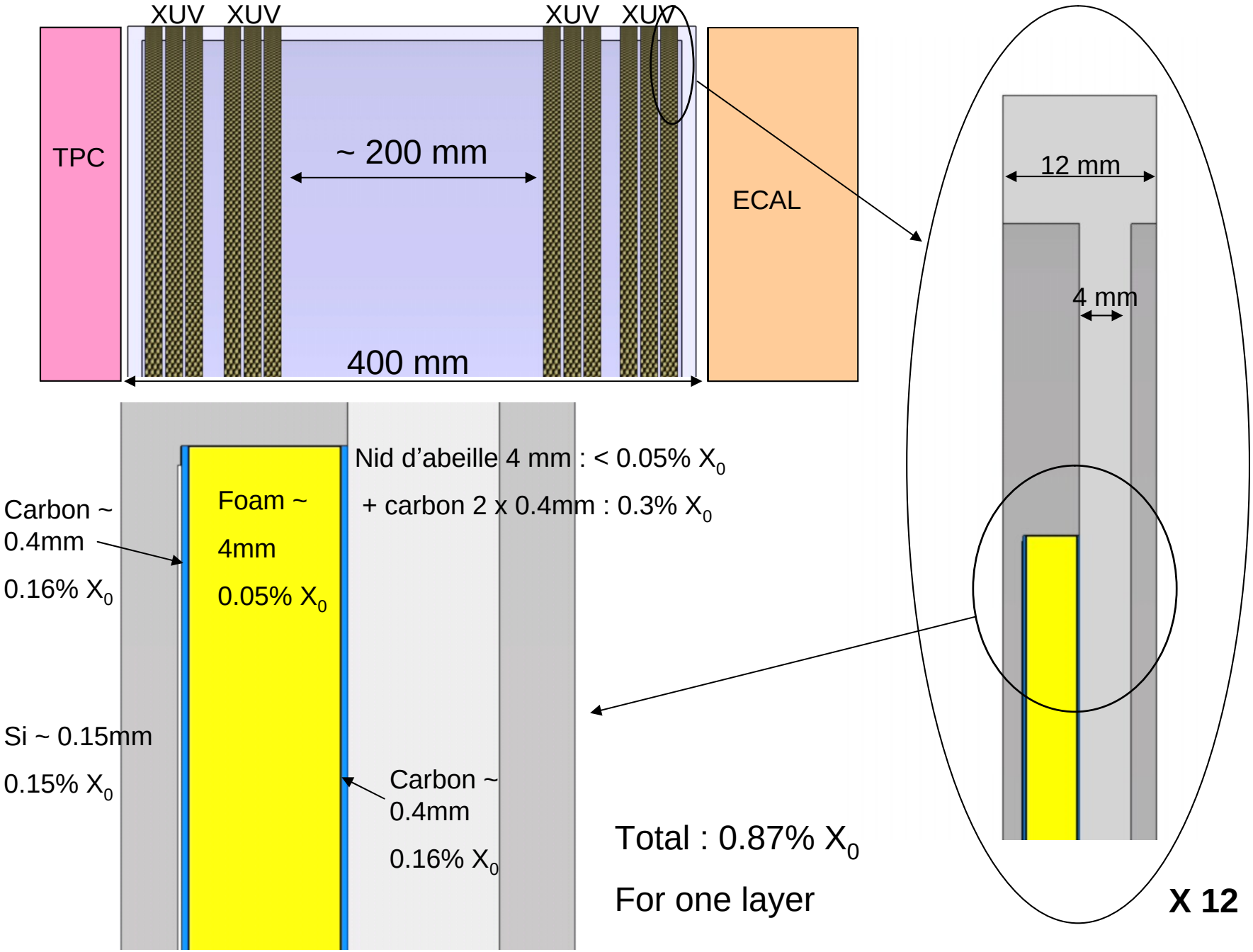
Zone de raquettes 2 Si
vers le centre

Zone de raquettes
3 ou 4 Si

Structure de soutien des raquettes en nid d’abeille
+ couche mince de carbone



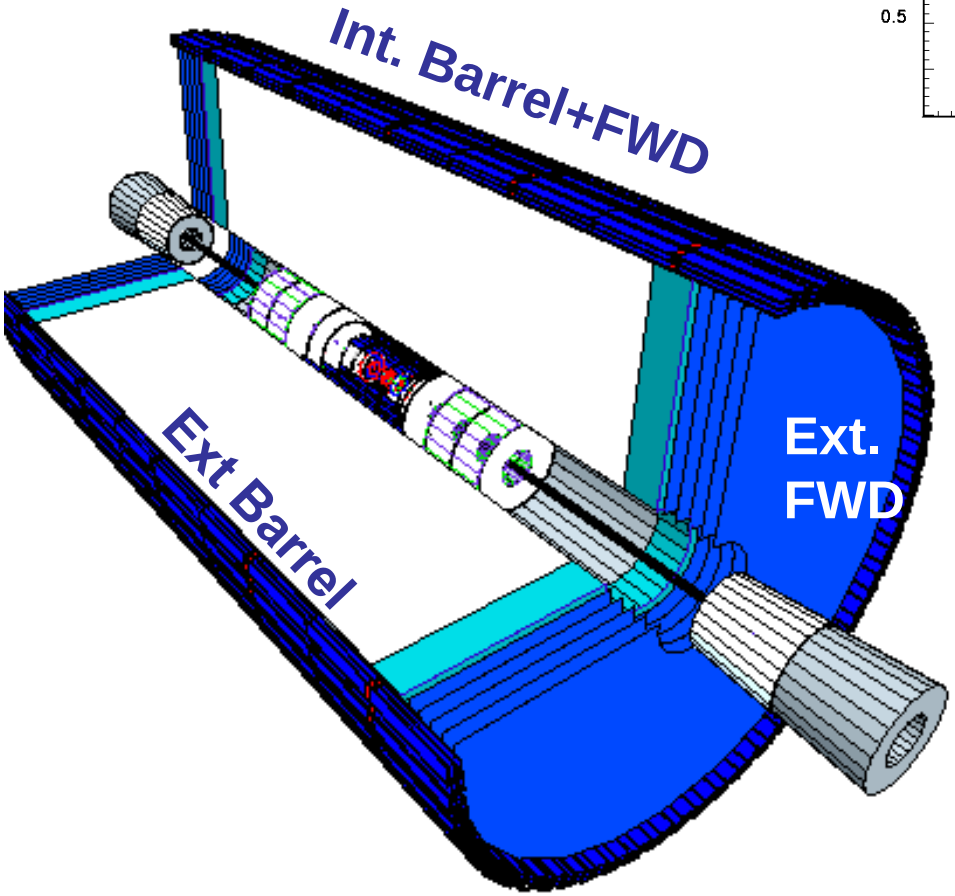
2 couches XUV

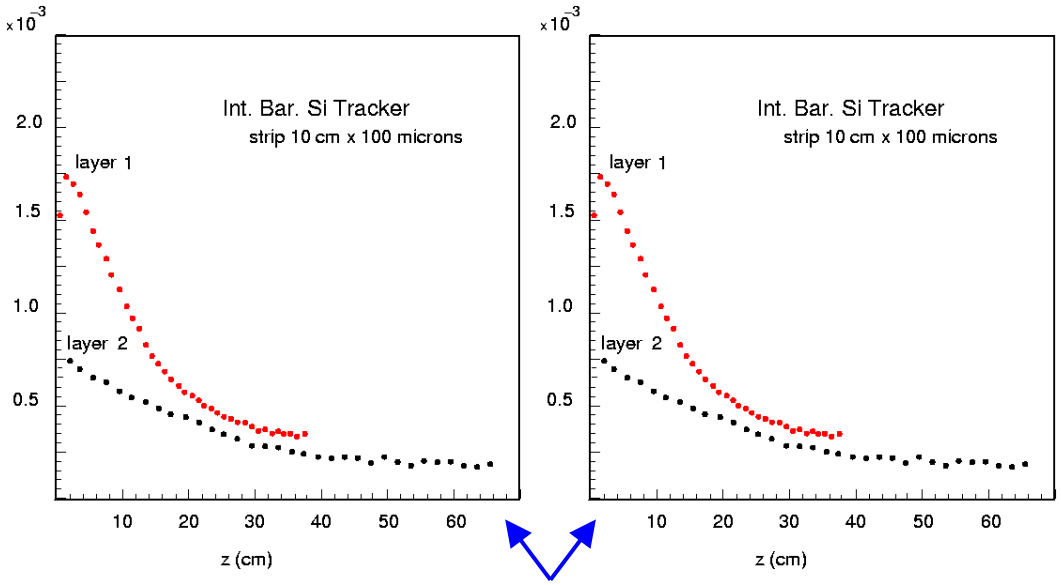

XUV
XUV
XUV
XUV
TPC
~ 200 mm
ECAL
400 mm
12 mm
4 mm
Nid d'abeille 4 mm : < 0.05% X_0
+ carbon 2 x 0.4mm : 0.3% X_0
Carbon ~ 0.4mm
0.16% X_0
Foam ~ 4mm
0.05% X_0
Si ~ 0.15mm
0.15% X_0
Carbon ~ 0.4mm
0.16% X_0
Total : 0.87% X_0
For one layer
X 12

SIMULATIONS

G4 geometry of the Si Envelope (V. Saveliev, Obninsk St U.)

DB description in G4 thanks to the detailed CAD





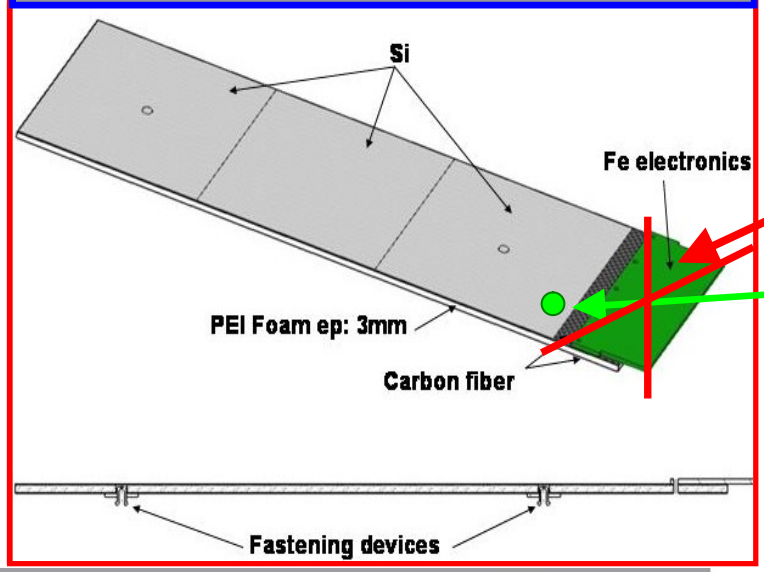
Occupancies calculated with BRAHMS full simulation (Si-Envelope+TPC), Higgstrahlung HZ with bbbar and q qbar at Ecm=500 GeV

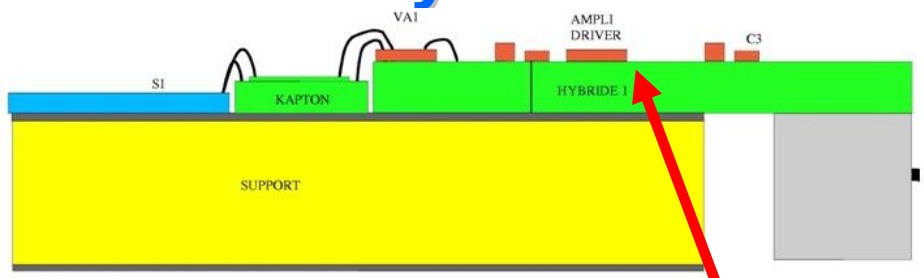
Values at most of order a few% for the hotest places in the detector!

Thus medium size ladder looks to be appropriate.

Elementary modules: to be totally revisited!

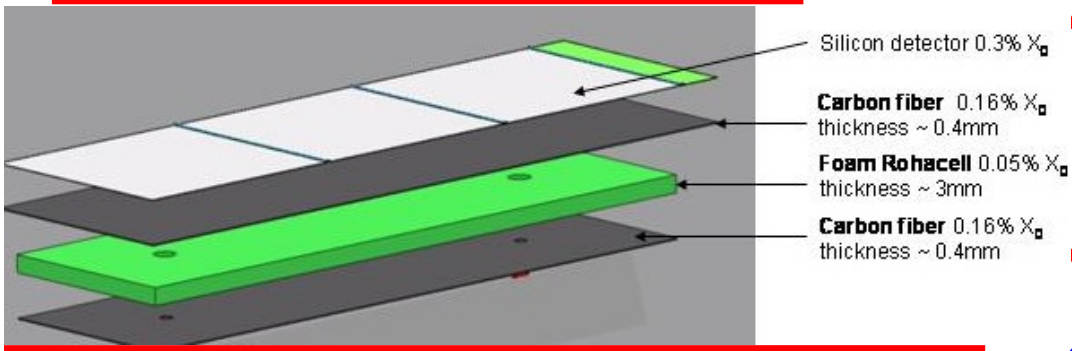
Ladder with 1 to 3 sensors





Old fashioned FE electronics!!

Next step = chip inserted onto the detector:
connectics/VDSM/cabling issues
(study starting: see SiLC meeting)



0.7%X0

N.B. This is just a very first ladder prototype:
just a very preliminary exercise…
By no means what will be the final one!!

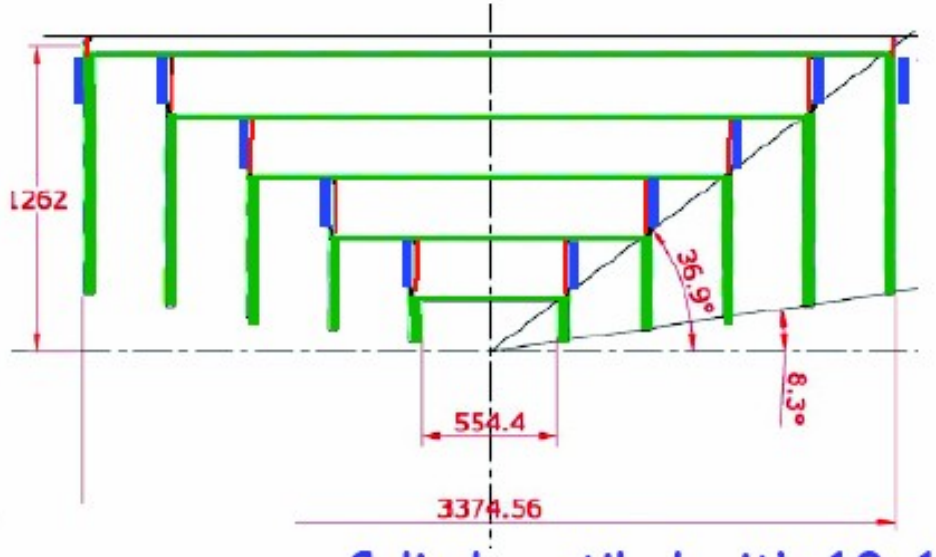
Modules: light, precise, robust, easy to build & assemble

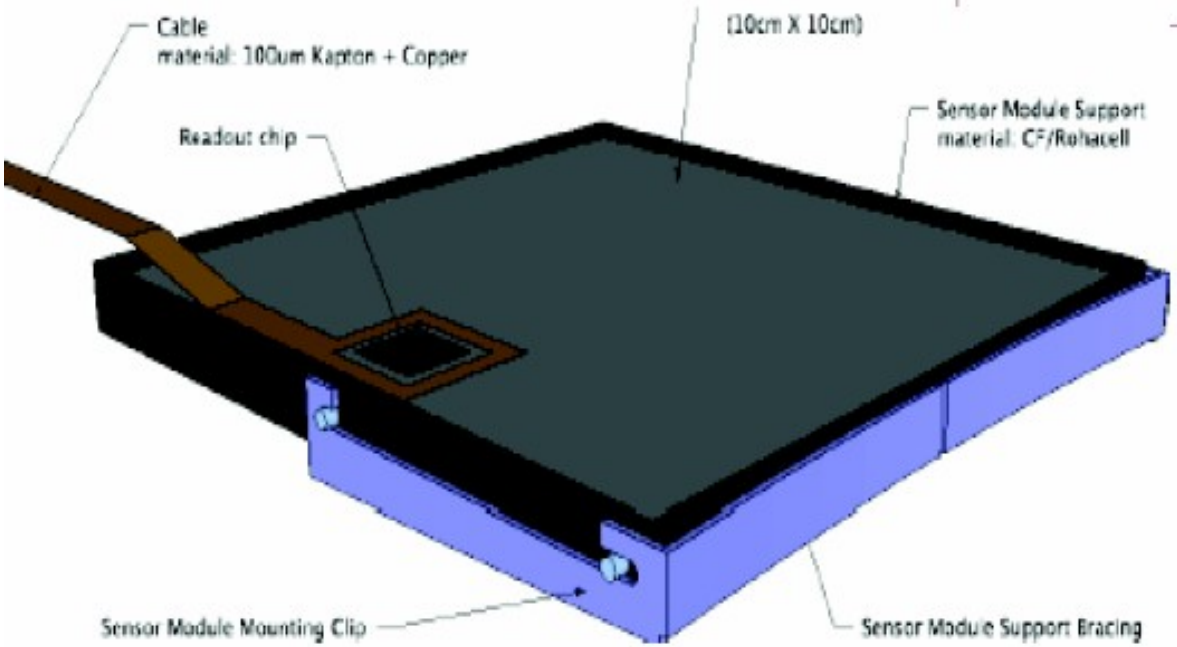
- ✓***New sensors (next generation)***
- ✓***Support: materials & design***
- ✓***FE electronics connectics, packaging and cabling***
- ✓***Module positioning on large size support structure***
- ✓***Easy to build (robotisation ?)***
- ✓***Industry Transfer (large #)***
- ✓***Universal sensor vs diff. types***

Be innovative!

Outer Tracker as Modeled in SiD_{00}

- Closed CF/Rohacell cylinders
- Nested support via annular rings
- Power/readout motherboard mounted on support rings



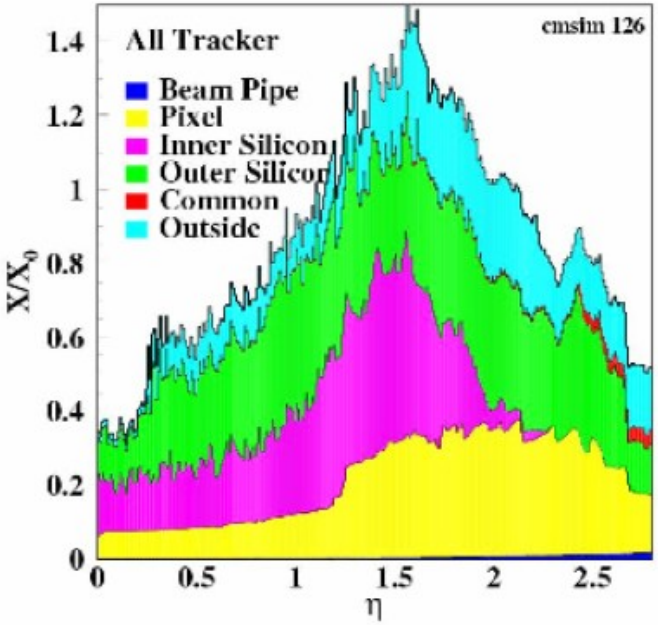


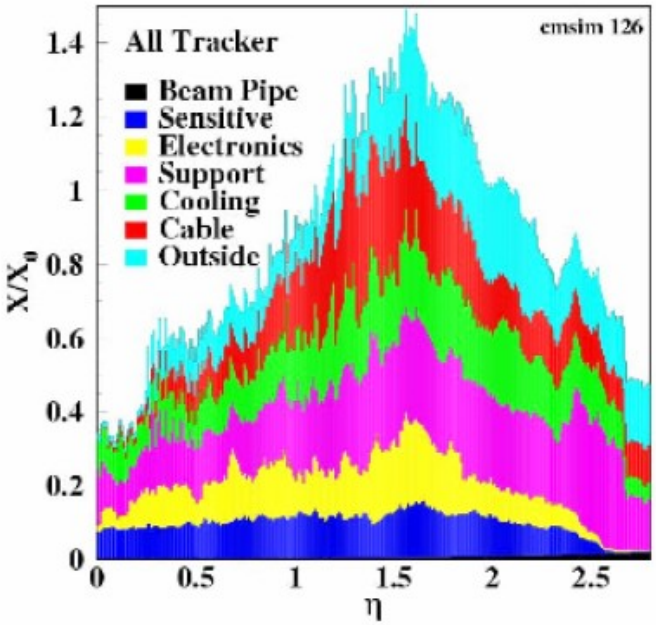
- Cylinders tiled with 10x10cm sensors with readout chip
- Single sided (ϕ) in barrel
- R, ϕ in disks
- Modules mainly silicon with minimal support (0.8% X_0)
- Overlap in *phi* and *z*

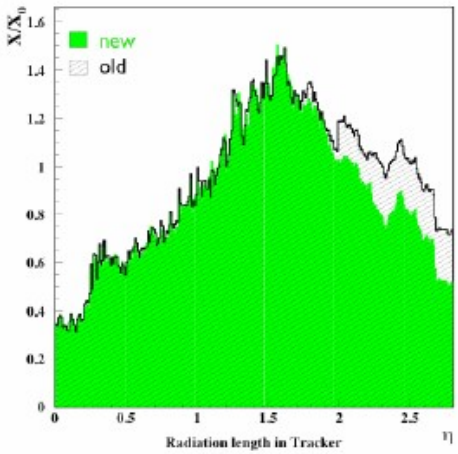
T. K. Nelson, SLAC

Material budget

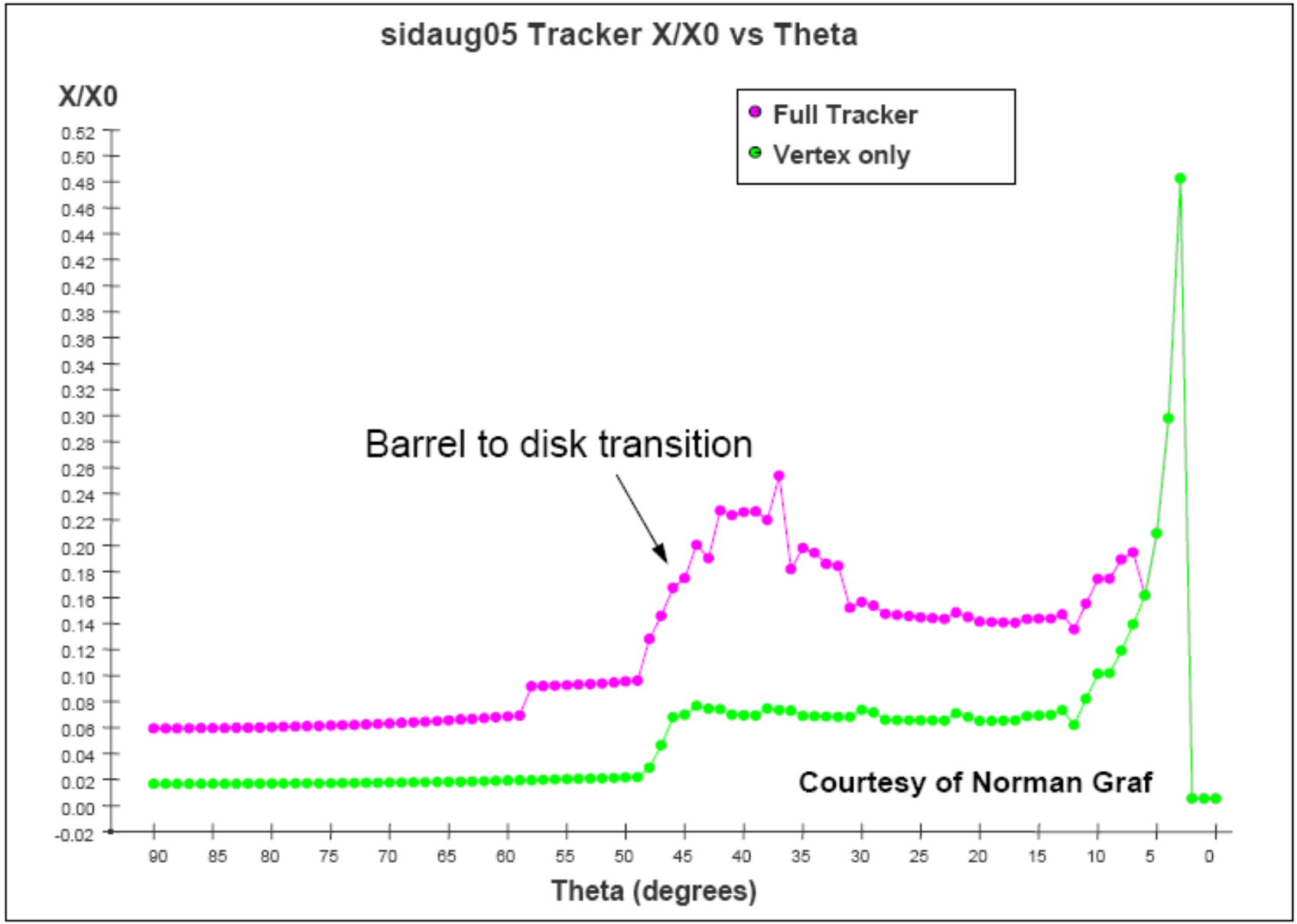
- *Design goal in 1999: $X/X_0 < 1$*
- *Most of the material is electronics related (electronics, cooling, cable, ...)*
- *New description (with most importantly a better description of the bulkheads collecting the services behind the endcaps) predicts less material in the forward region*





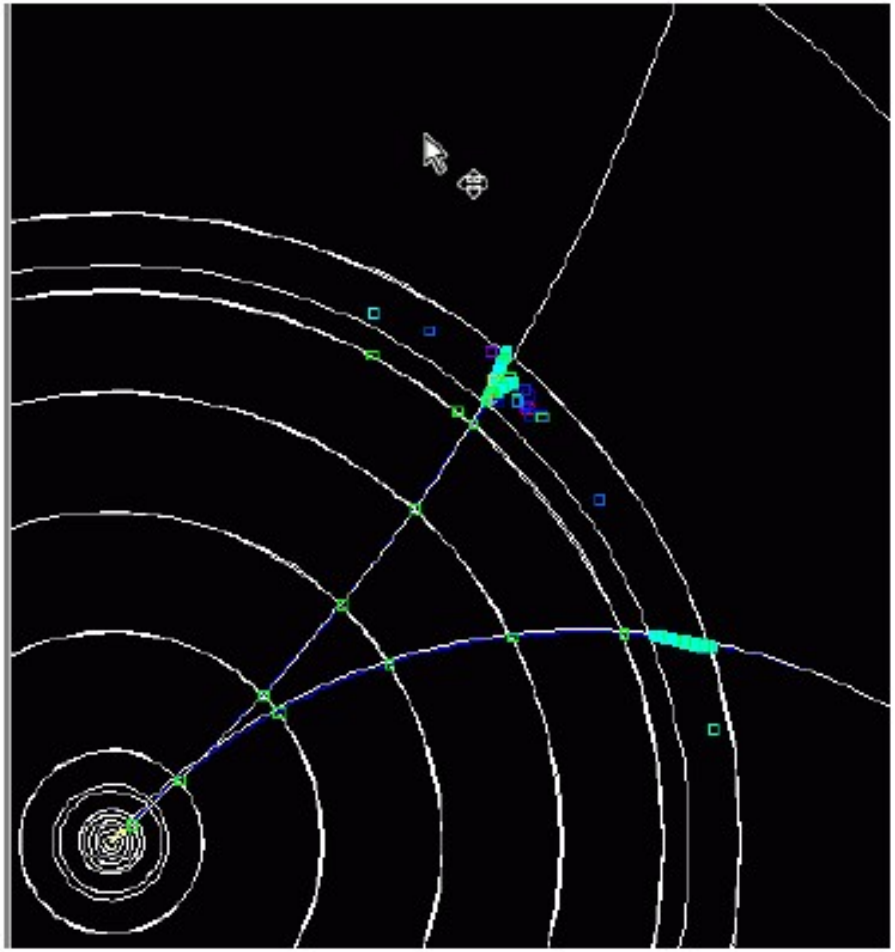


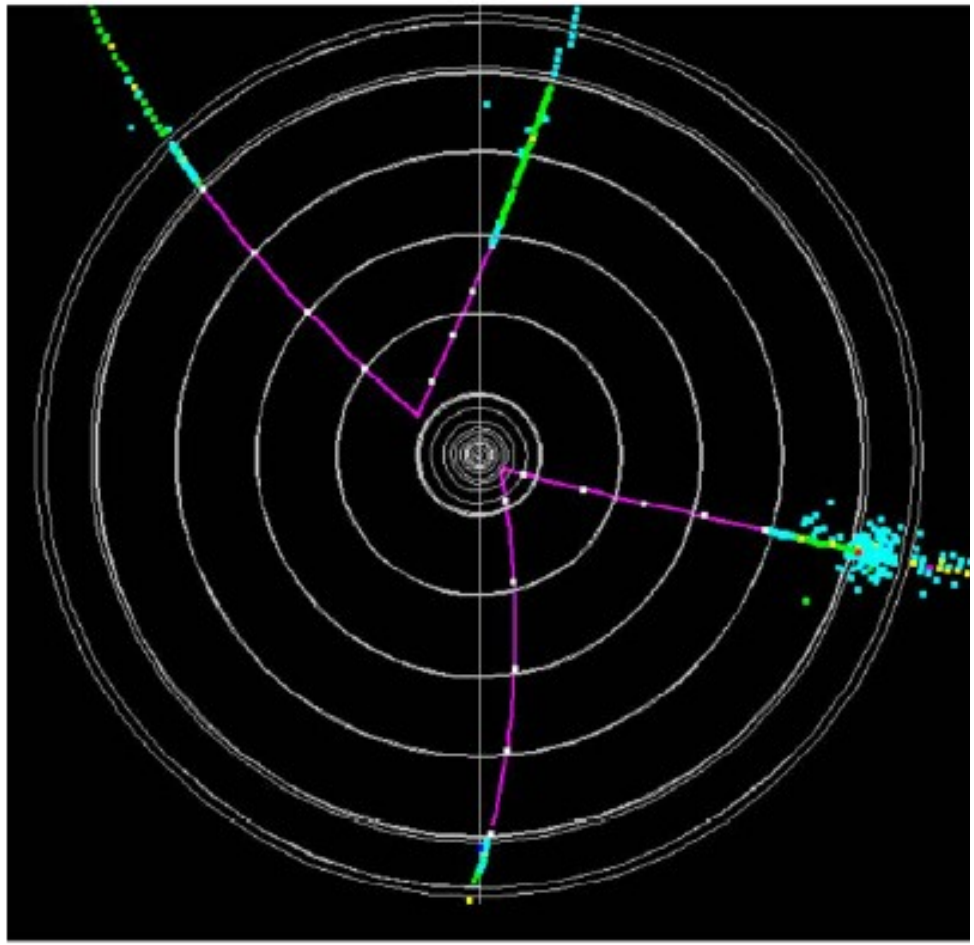
August 2005 SiD Simulation

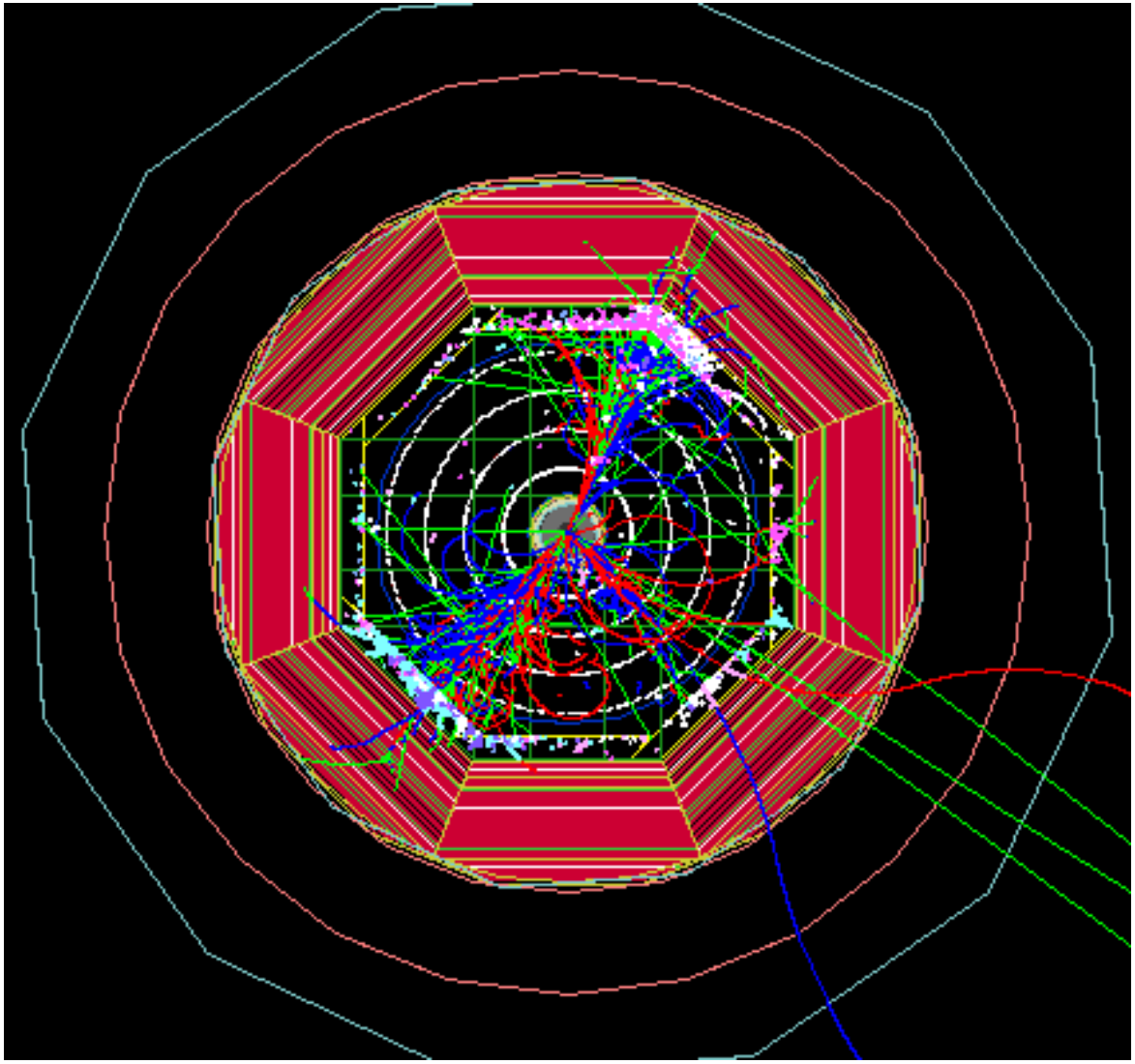


Tracking from Outside Inward

- Dmitry Onoprienko has been developing algorithms for finding track starting from ECAL.
- Particularly helpful for decays outside VXD







Higgs event in the SiD detector design, using MOKKA G4 framework
SiD detector included in geometry DB
(V. Saveliev)

Work on detailed simulations x CAD designs must be pursued
Needed for the DOD and forthcoming documents
Important to really compare performances of detectors