Silicon tracking for the ILD

A. Savoy-Navarro , LPNHE, UPMC/IN2P3-CNRS

for the SiLC collaboration members participating to ILD:

IMB-CNM/CSIC in Barcelona, University of Barcelona, IEKP Karlsruhe University,
Korean group (Kyungpook Nat. University in Daegu, Yonsei University, Korea National University and Seoul National University all in Seoul), Moscow State University, Obninsk State University, LPNHE-UPMC & CNRS-IN2P3 Paris,
Charles University in Prague, SCIPP & UC Santa Cruz,
IFCA/CSIC & University Santander, Santiago de Compostela University,
Torino University & INFN,
IFIC/CSIC & University Valencia, HEPHY-Academy of Sciences Vienna
and a few more to be convinced…

Third ILD Collaboration Meeting, Ewha Womans University, Seoul, February 16-18, 2009

Topics

- Role of Silicon tracking in ILD
- Silicon system performances
- Calibrations
- Construction and integration issues
- Dedicated R&D on advanced technologies
- Concluding remarks, pending issues

- Role of Silicon tracking in ILD (brief reminder)
- Silicon system performances
- Calibrations
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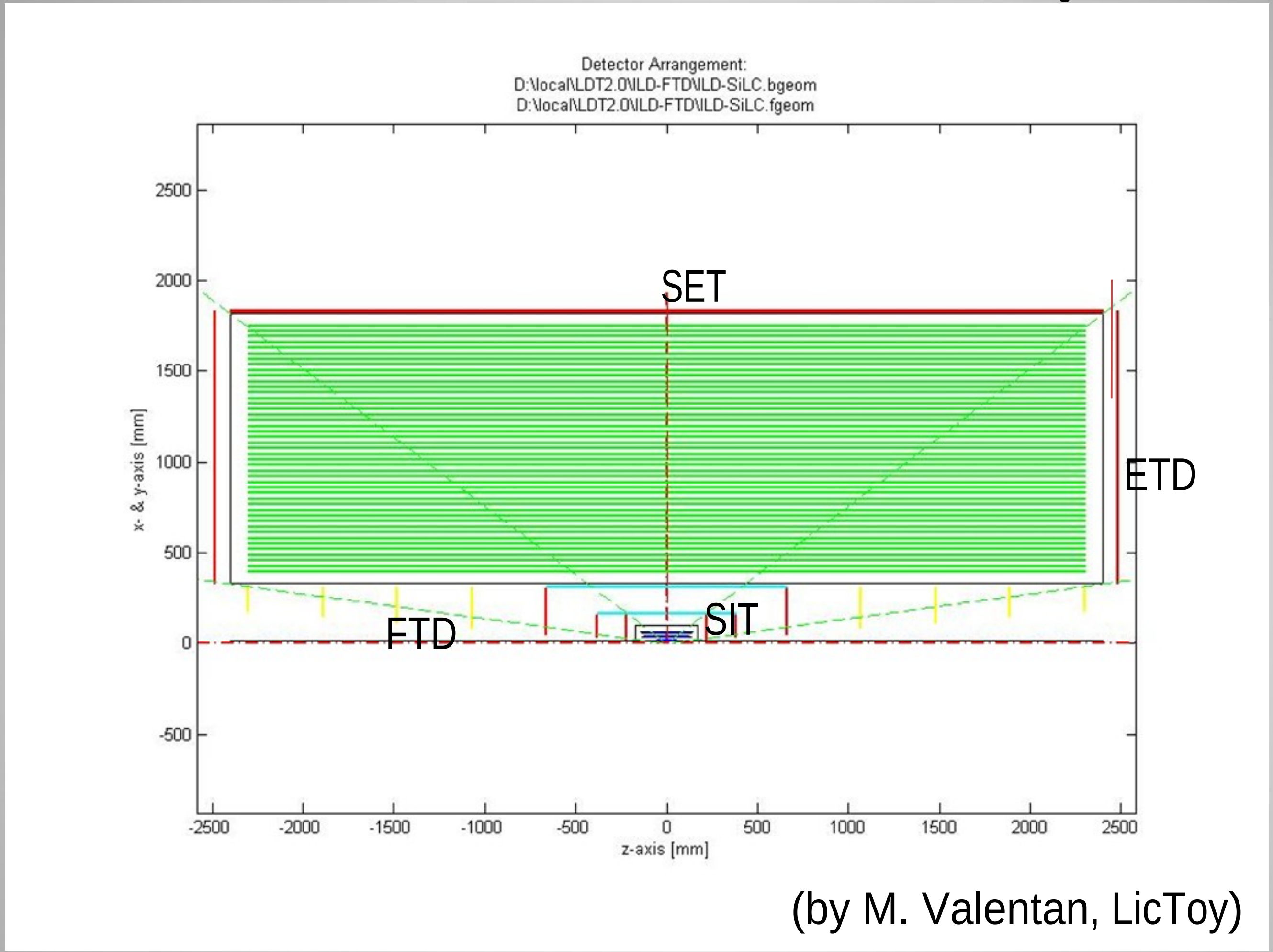
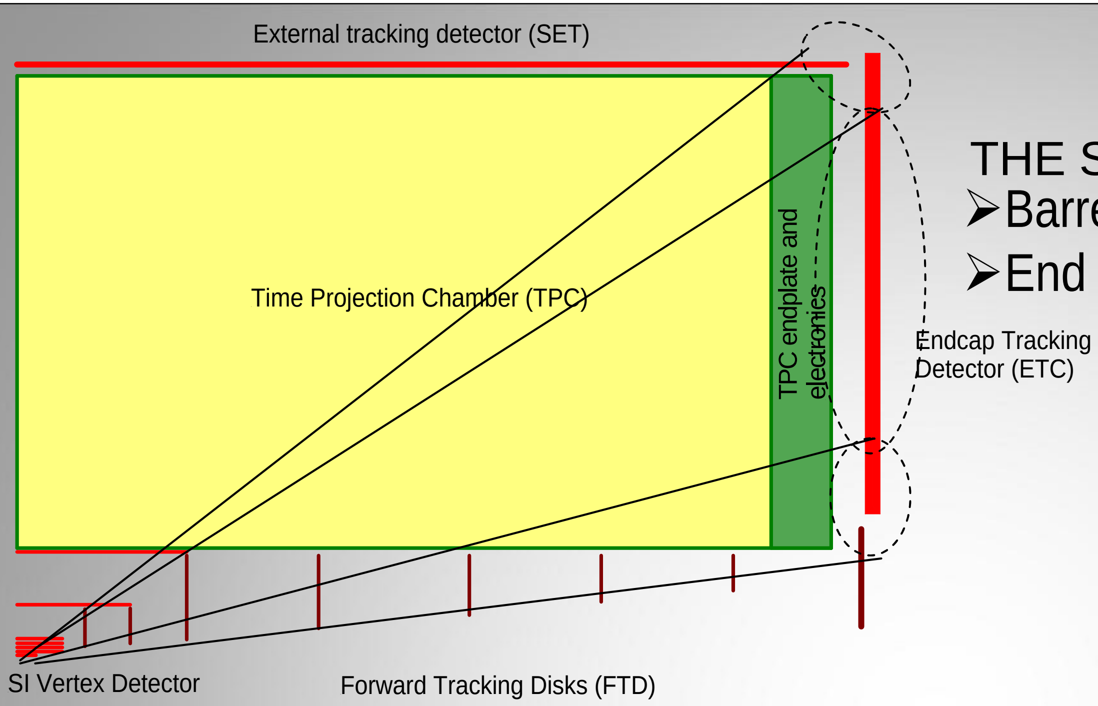
The Silicon envelope



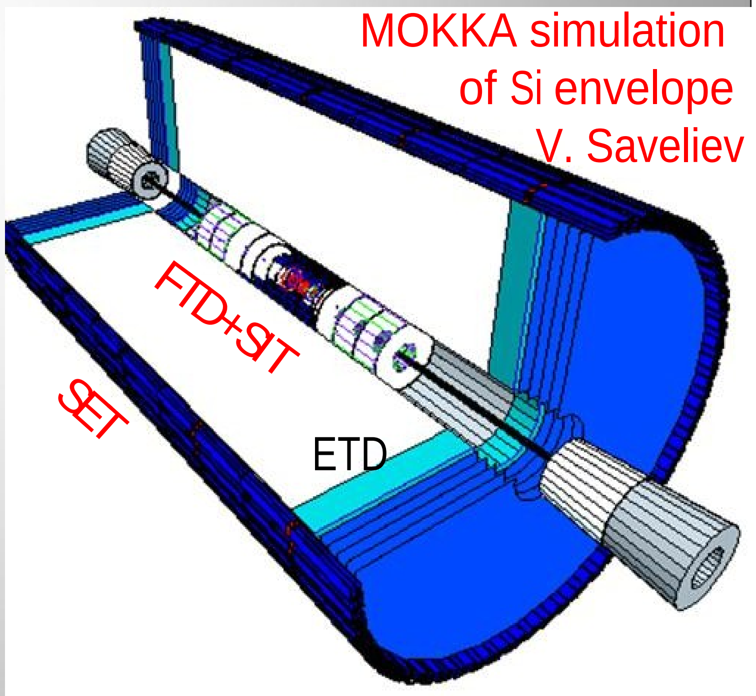
ILD Tracking system is an hybrid system that combines both a central gaseous device with an ensemble of Silicon tracking components all around the TPC.



THE SILICON TRACKING SYSTEM:

- Barrel: SIT+SET (3 2D-layers total)
- End Cap/FWD: FTD(7 disks)+ETD (XUV)

higher tracking performances
tracking hermeticity
alignment
distorsion handling
time stamping
robustness & redundancy

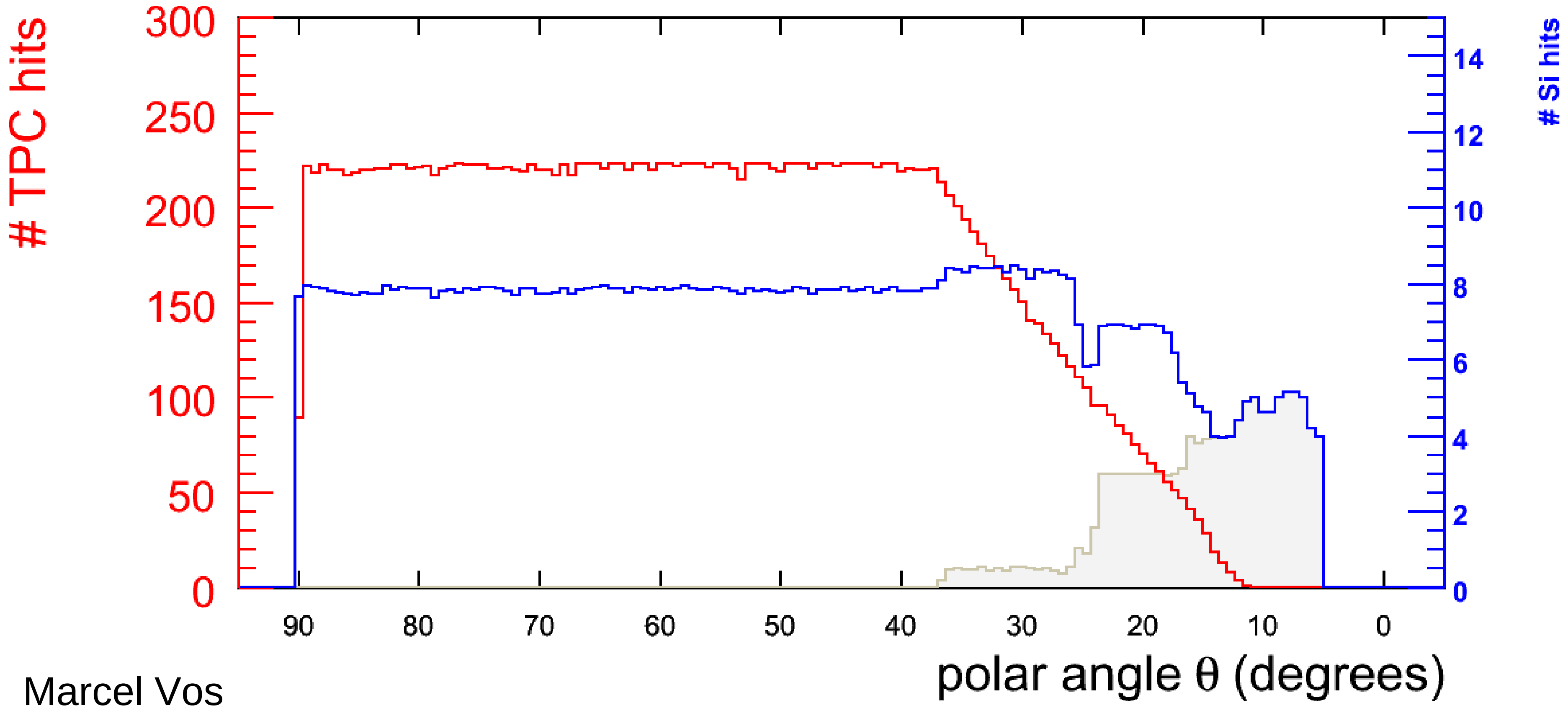


- Role of Silicon tracking in ILD
- **Silicon system performances (some examples)**
- Calibrations
- Construction and integration issues
- Dedicated R&D on advanced technologies
- Concluding remarks, pending issues

M. Vos, J. Duarte, C. Iglesias (Spain), M. Valentan, W. Mitarof, M. Regler (Vienna), V. Saveliev (OSU), Z. Drasal (CU Prague), A. Charpy (LPNHE):

All are focusing on performances and even detailed description of the Si system

Angular coverage Silicon vs TPC



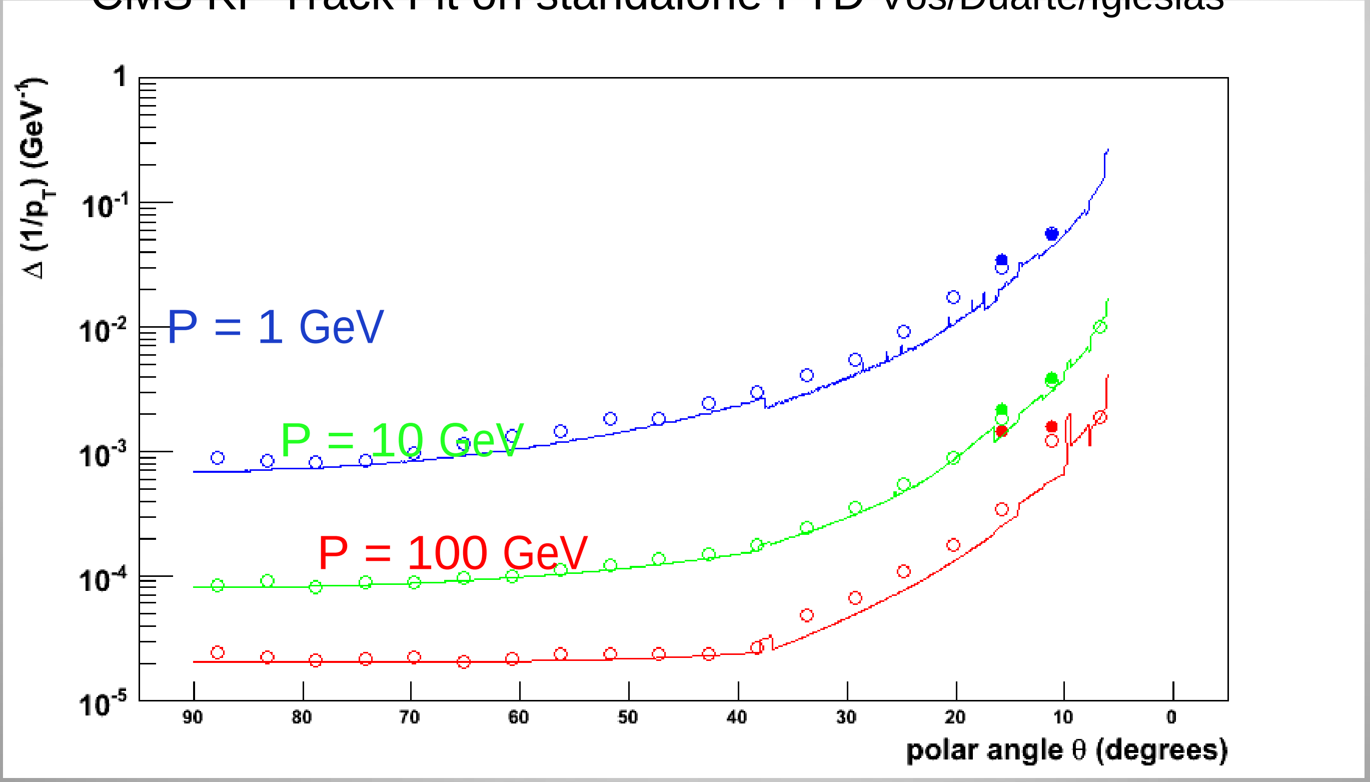
Marcel Vos

Transverse momentum resolution versus polar angle
Measured on three single-muon samples with fixed |p|

LiCToy on ILD00 (full KF fit), M. Valentan, HEPHY Vienna

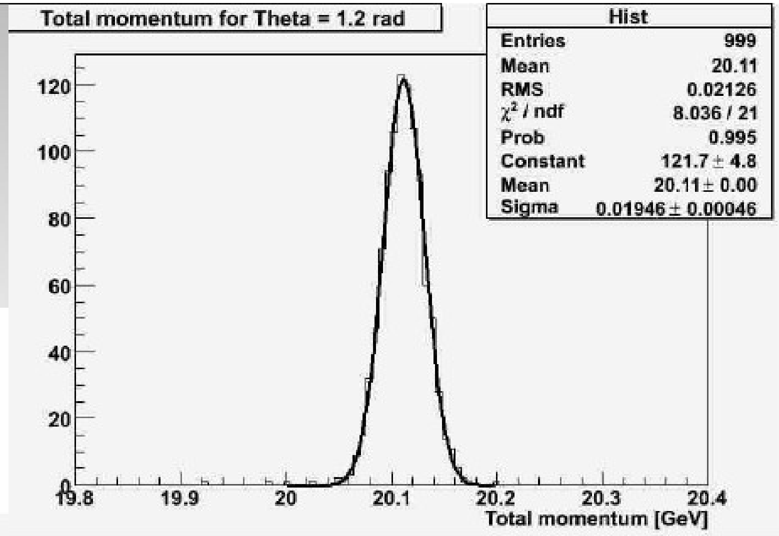
FullLDCTracking on ILD00 (Mokka/MarlinReco) Vos/Duarte/Iglesias

CMS KF Track Fit on standalone FTD Vos/Duarte/Iglesias

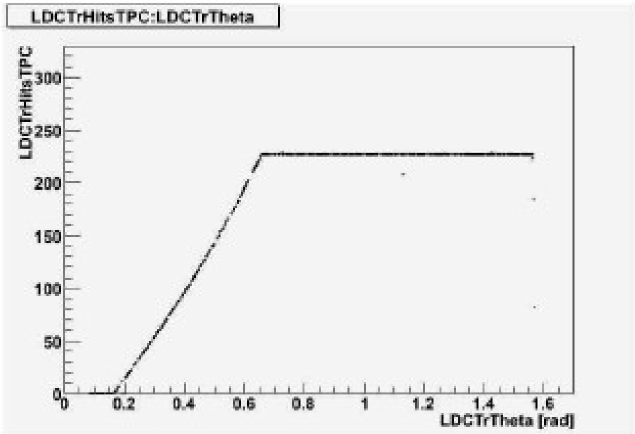


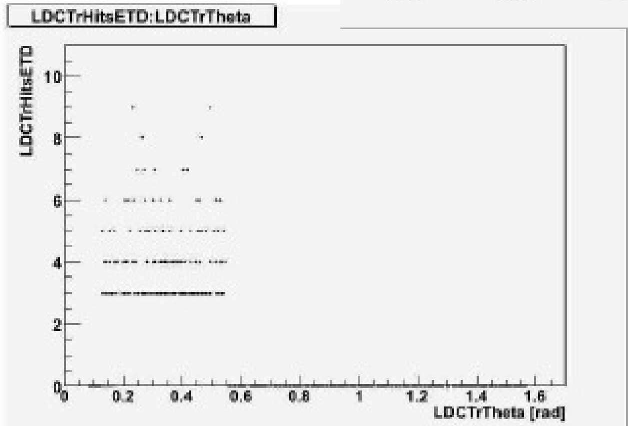
Full MOKA ILD00 Reconstruction

(V. Saveliev)

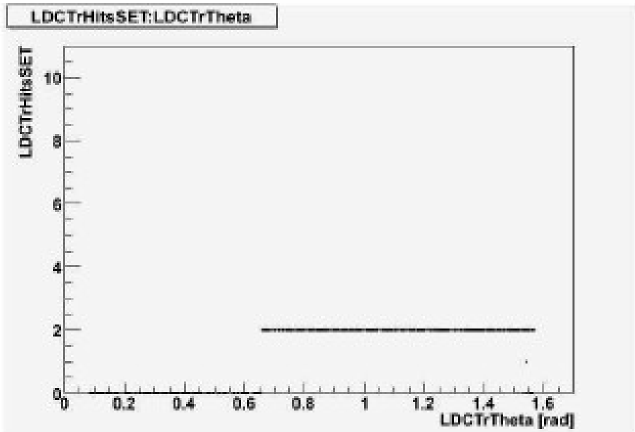


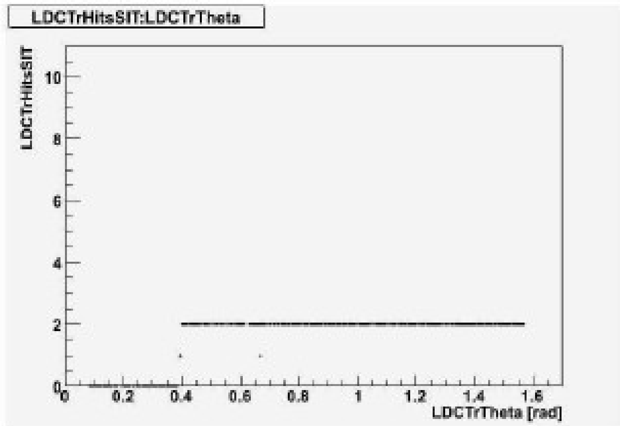
of Hits on TPC, ETD, SIT, SET





Tracking reconstruction of 20 GeV muons at 1.2 rad

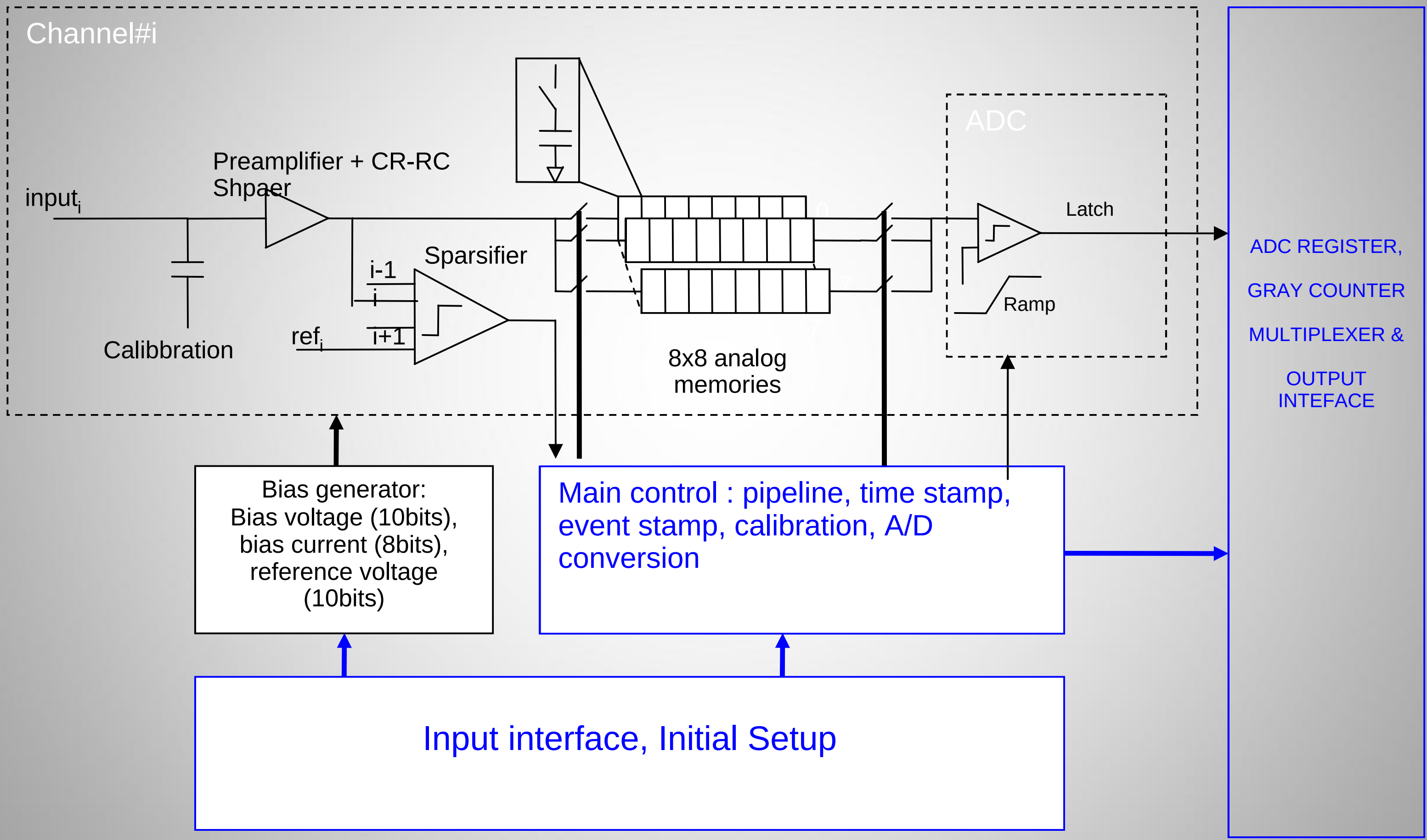




- Role of Silicon tracking in ILD
- Silicon system performances
- **Calibrations**
- Construction and integration issues
- Dedicated R&D on advanced technologies
- Concluding remarks, pending issues

Calibration of the electronic chain

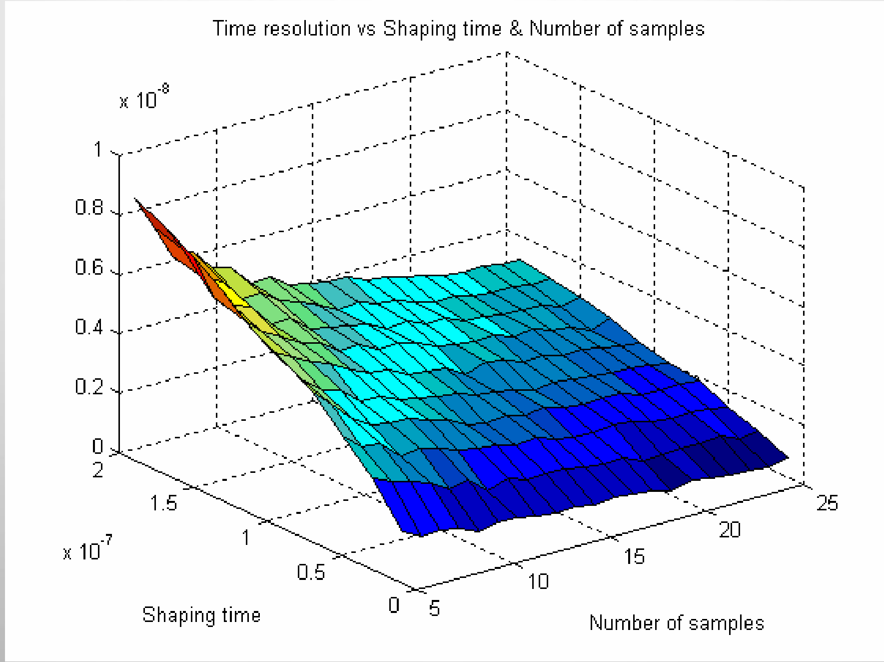
The FE and readout chain includes in its own design a full calibration system fully automatic/programmable through the digital part:



88-channel chip block diagram (Barcelona U. & LPNHE-Paris)

Time stamping

The electronic chain as presently designed and built allows to time stamp with a **precision of 80 nsec.**
Moreover a more detailed estimate is being re-done taking into account the Shaping time, the number of samples in the analogue pipeline. This is based on the algorithm of Cleland and Stern (see here below).



ALIGNMENT *(IFCA & IMB-CNM)*

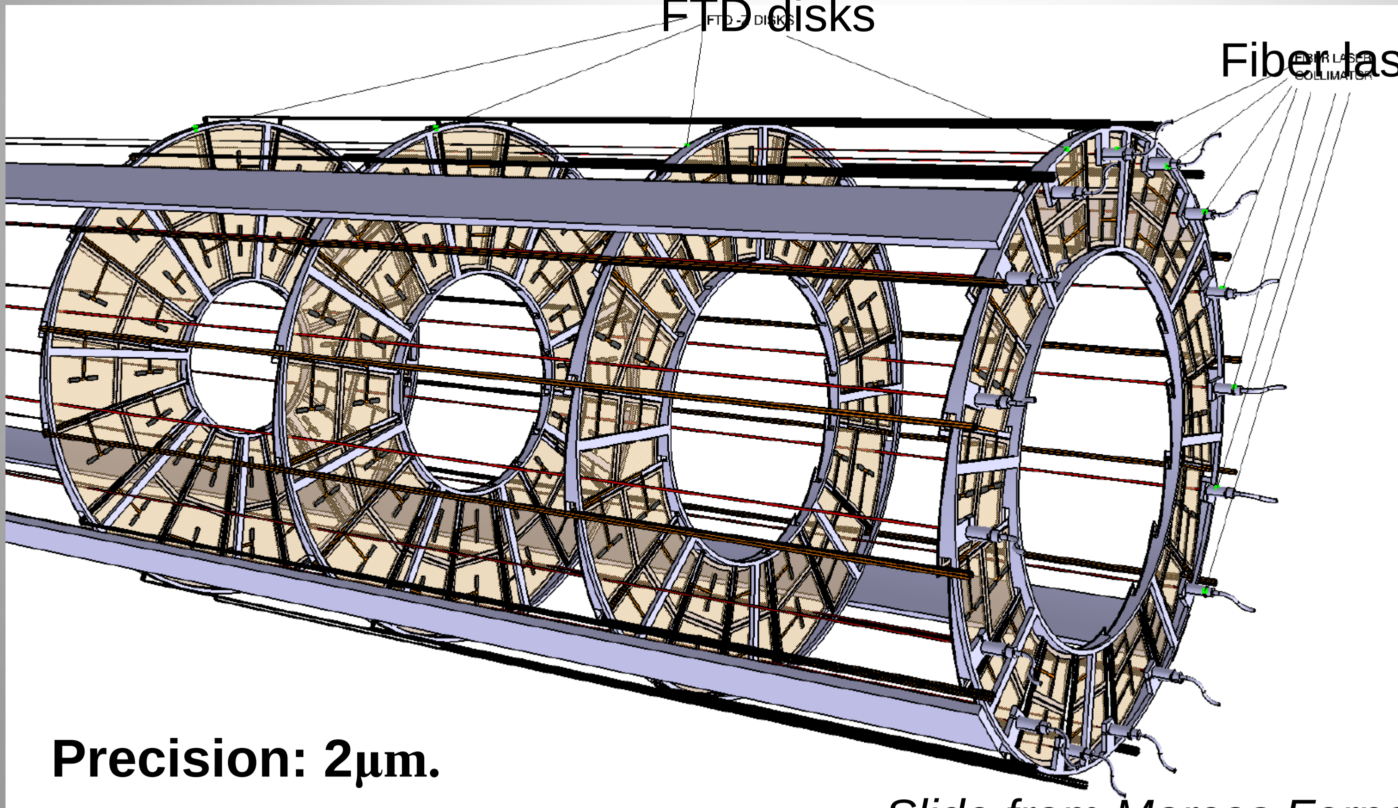
R. Jaramillo, M. Fernandez, M. Lozano, A. Ruiz, I. Vila

Concept of IR alignment system: use IR beams as infinite momentum tracks.(AMS, CMS)

Selected sensors are traversed by IR beams.

These beams are then measured as particle tracks and a first order alignment scenario is obtained.

The rest of sensors are aligned using particle tracks. The transference of coordinates from optical aligned to track aligned modules is done via sensor overlap.



Collimator heads on 1st wheel produce IR-tracks that sequentally cross several Si sensors

Slide from Marcos Fernandez Garcia (IFCA)

- Role of Silicon tracking in ILD
- Silicon system performances
- Calibrations
- Construction and integration issues
- Dedicated R&D on advanced technologies
- Concluding remarks, pending issues

Teams presently involved:
HEPHY(simus), IFCA, IFIC, SCU (FTD), LPNHE and Torino Univ.& INFN (SIT, SET and ETD), Obninsk (simus).
Collaborative efforts with M. Jore and french integration team, MDI and members from LCTPC.

Construction and Integration of a Silicon system into the ILD detector: preliminary ad

The construction and the integration of a Silicon tracking system, part of an hybrid tracking ensemble is much more challenging than an all-Silicon fully integrated system (CMS, SiD and futur s-ATLAS). Among the main challenging issues:

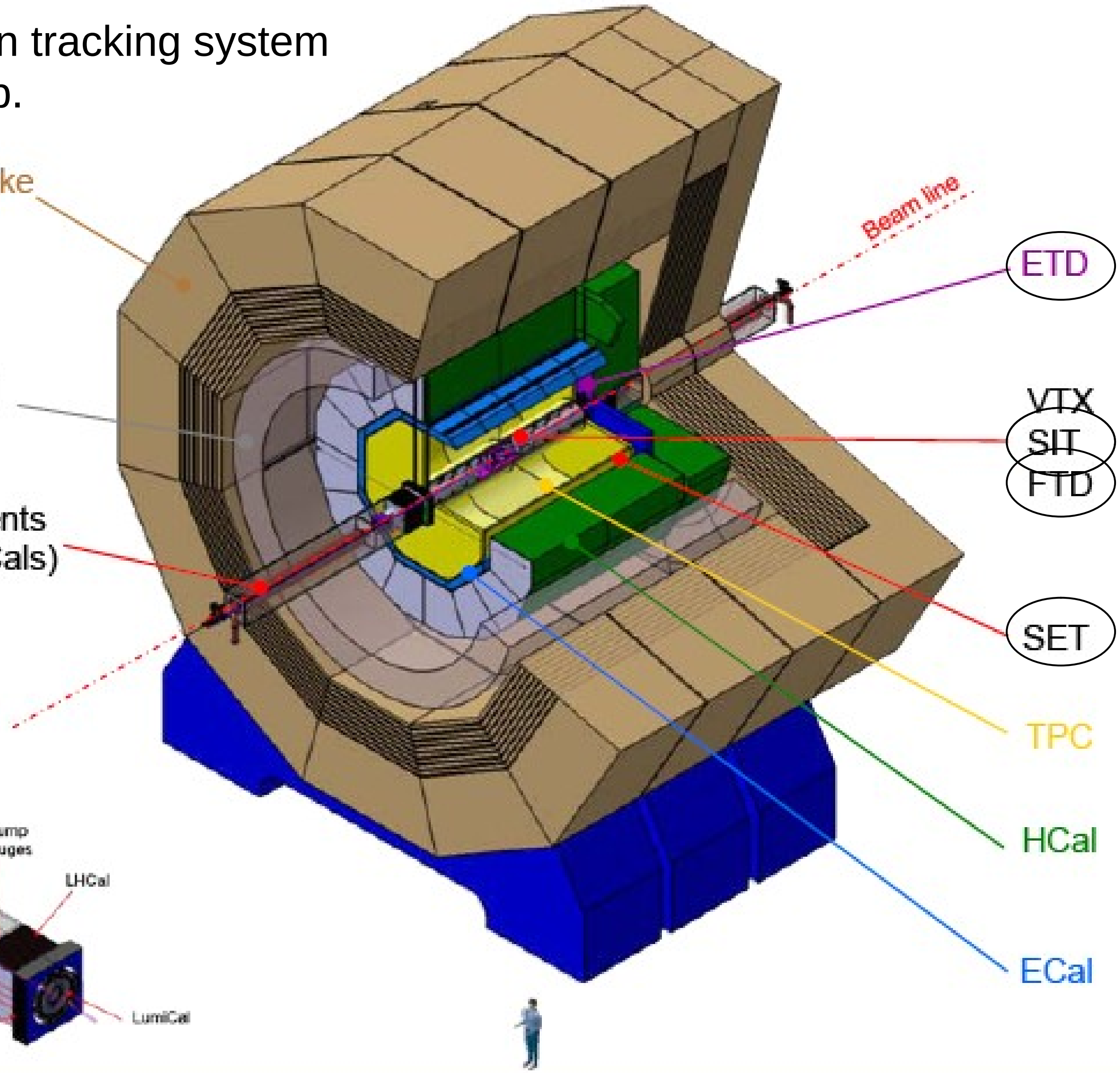
➢ **THE SPACE ALLOCATED**:
All Silicon system has all the tracking space for it alone (1.2m radius or so)
Hybrid: only 2cm for the SET, 4cm for the ETD, 20-25cm for SIT+FTD

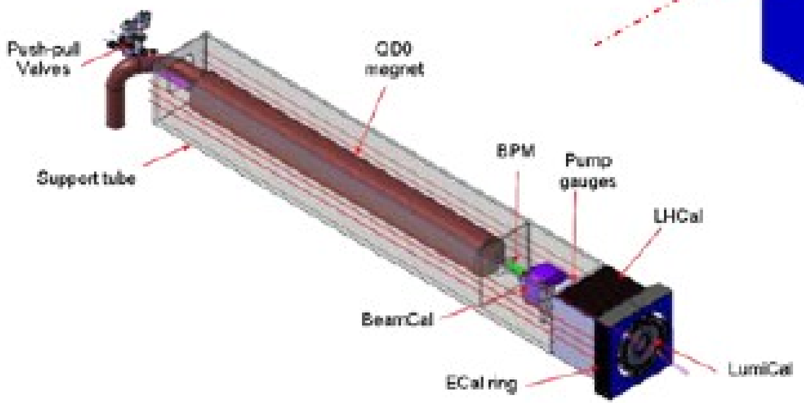
➢**THE FIXATION and SUPPORT STRUCTURE**:
All Si can build the support structure as desired as well as its own fixing system.
Hybrid: the Si device fully depends on the restricted space and the surroundings.

➢**THE ROLE**:
All Silicon system must primarily satisfies the role of the tracker high performance momentum and spatial resolution measurements.
Hybrid case: the Si component must provide additional functions: alignment, time stamping, handling of distortions of the gaseous detector etc.…

➢**COOLING**: here also much more constraining in the hybrid case (much more dependant of the neighbours

Integration of the Silicon tracking system
in the overall ILD set-up.





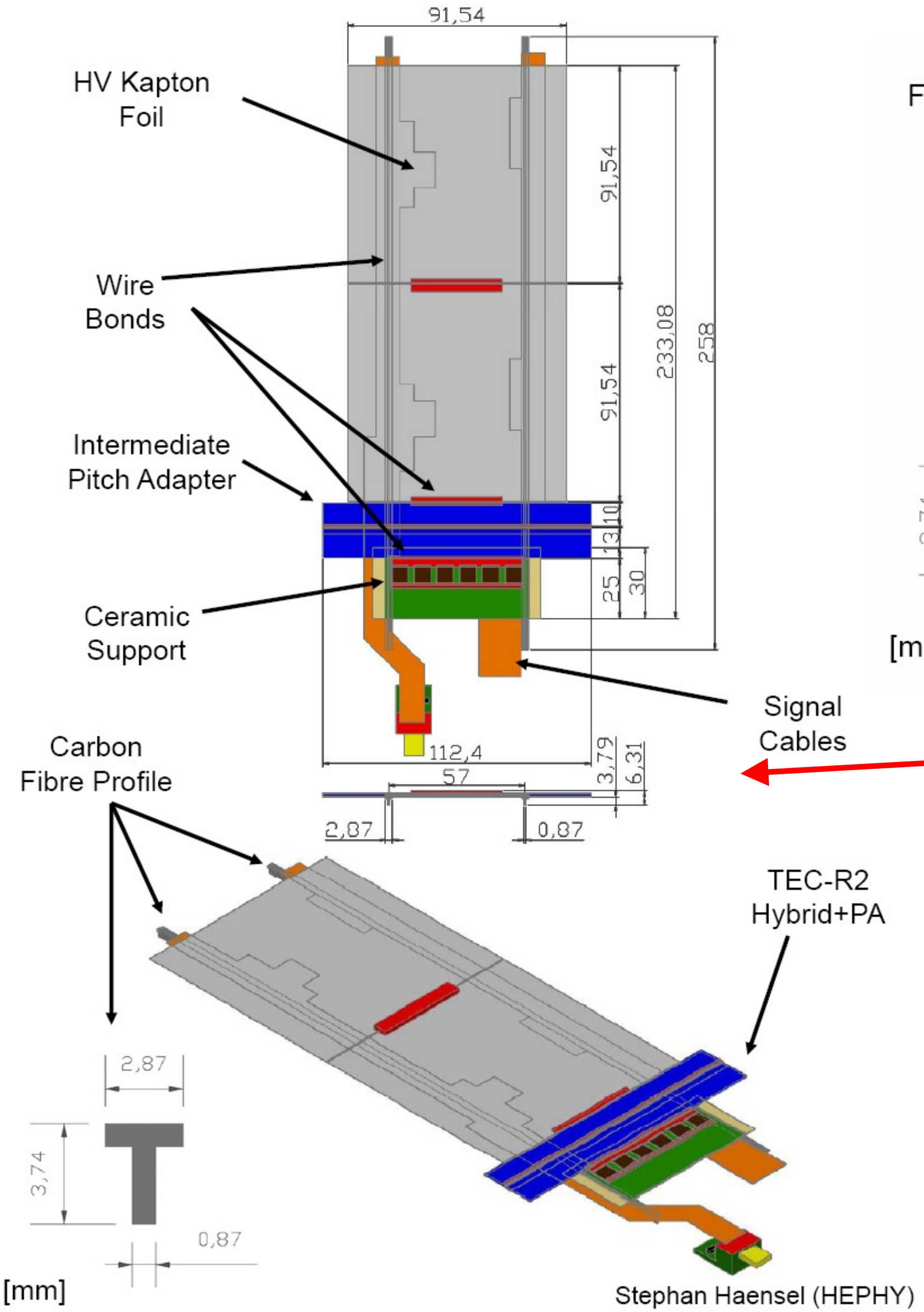
Construction and Integration of a Silicon system into the ILD detector: general philosophy

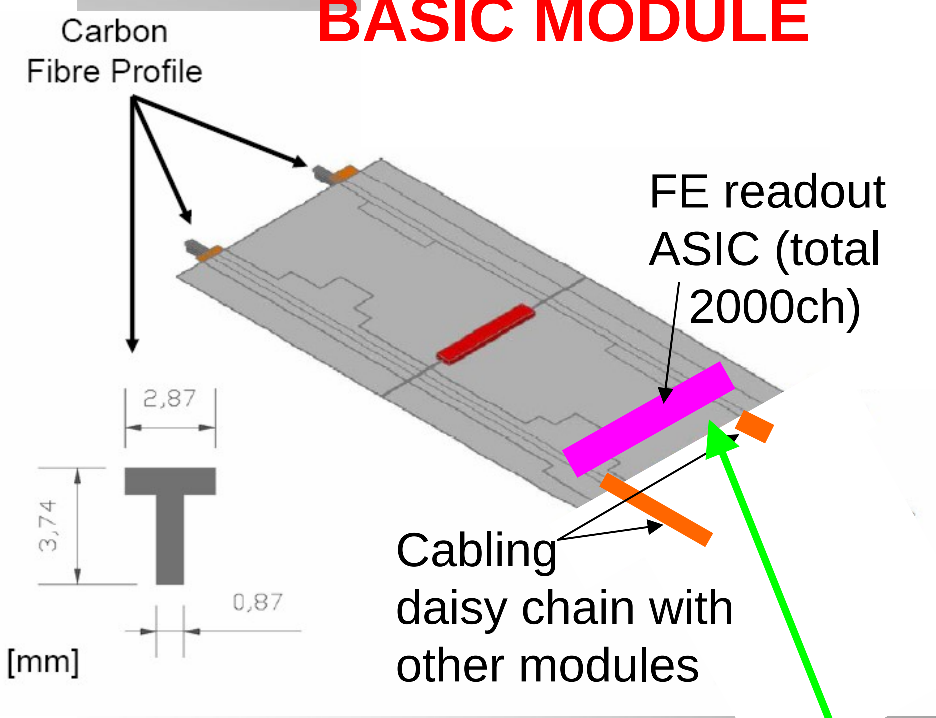
A big step forward has been made by the SiLC collaboration in order to design and build this overall ensemble. Apart from the small FTD disks, the SET, SIT and ETD large Silicon tracking components will be fabricated in the same way:

➢ A **unique sensor**, currently 10x10cm2, edgeless, planar, 200µm thick, 50 µm pitch will be the elementary tile of this ensemble.
➢ False double sided modules will be fabricated: **elementary modules,** and
➢ Assemble into **super-modules** which are modular elements of each main tracking component.
➢The **related electronics and DAQ chain** is being developed consequently as well as the cabling.
This will represent a huge effort and need for further R&D and innovative ideas and novel technologies.

The design studies are currently undergoing (LPNHE and Torino) in collaboration also with
M. Jore, P. Anduze , calorimetry , TPC and MDI teams and with the collaborative efforts of other SiLC teams. This effort is under development.

BASIC MODULE





Present status (left) vs next step

DSM-FE readout into one single unit:

8-256ch chips

Total size: 8x0.5 cm2

Thinned: 50μm

Directly connected onto the sensor

$\Rightarrow$No more pitch adapter,

$\Rightarrow$No more hybrid board

$\Rightarrow$Change in the cabling technology

THE SILICON EXTERNAL TRACKER: SET

Diego Gamba and Paolo Mereu (Torino)

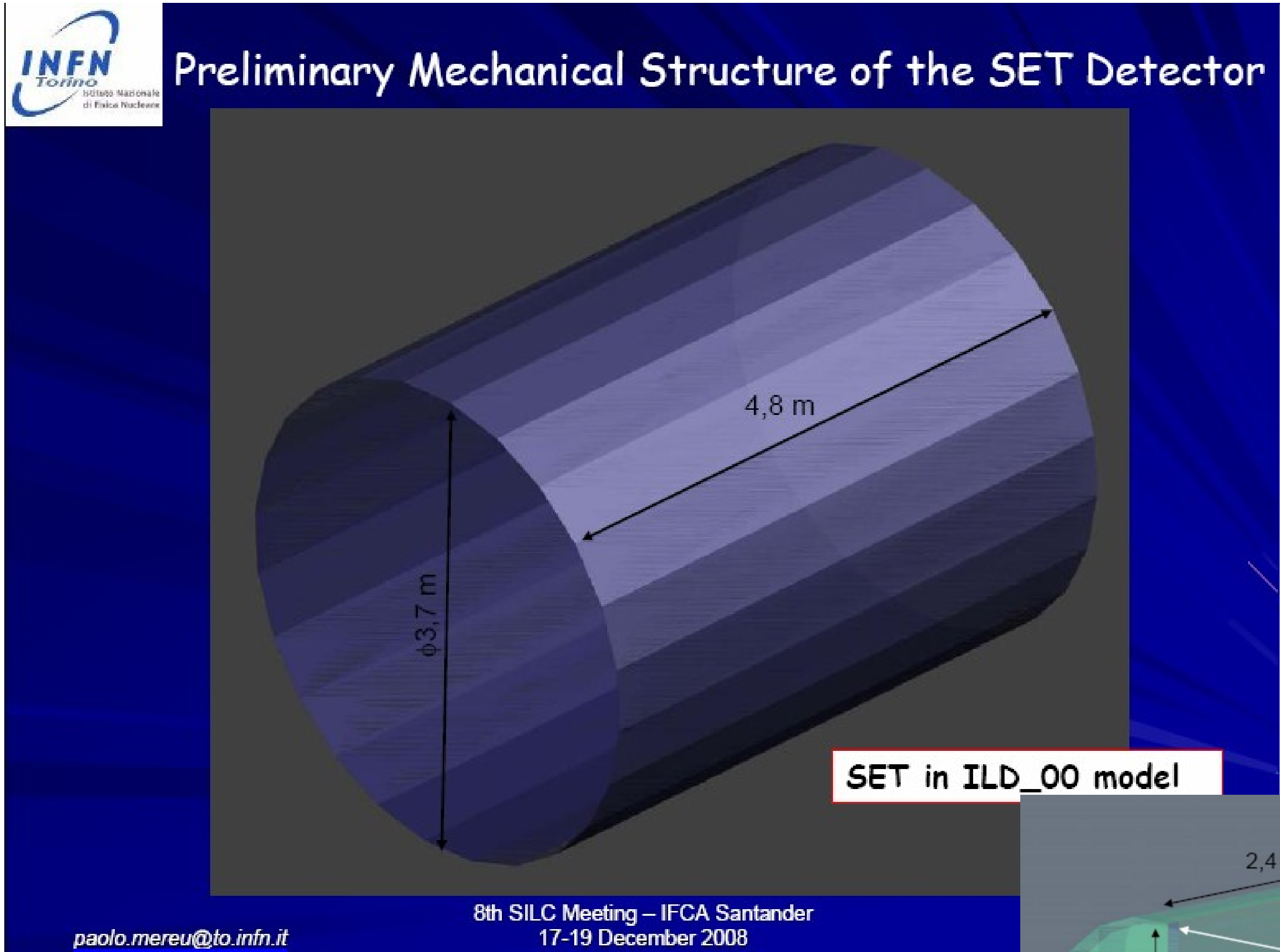
The mechanical structure of the SET is studied in details by the Torino team a real progress was made these last few months.

After a certain number of preliminary designs and studies, P. Mereu and D. Gamba have come to the following basic design:

The mechanical structure of the SET is made by 2 halves composed of 24 panels 2,4x0,48m. Each panel is independently fixed at both short sides to the outer surface of the TPC structure, thus avoiding an additional outer frame and therefore keeping the material budget at its minimum.

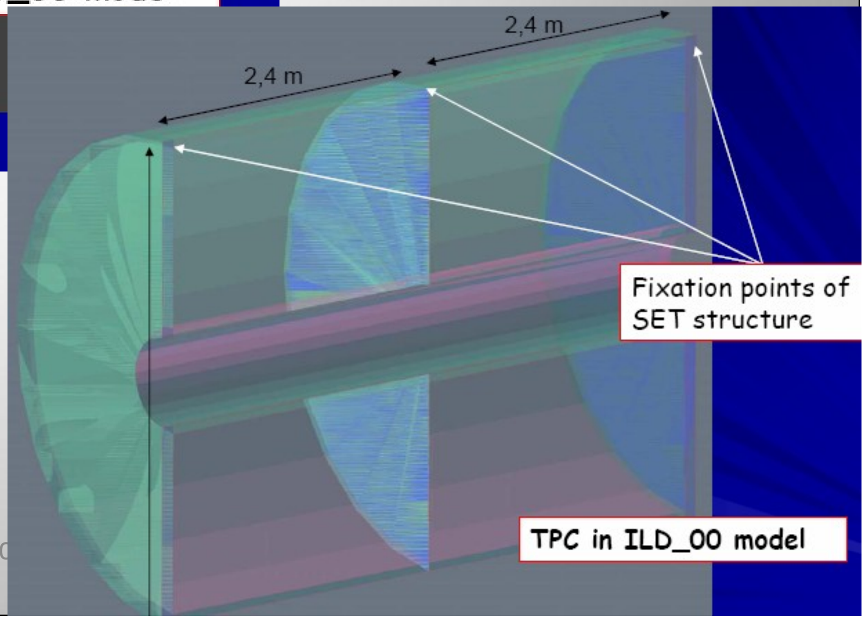
Static deflection with a payload of 1kg/sqm is given in the following slide.

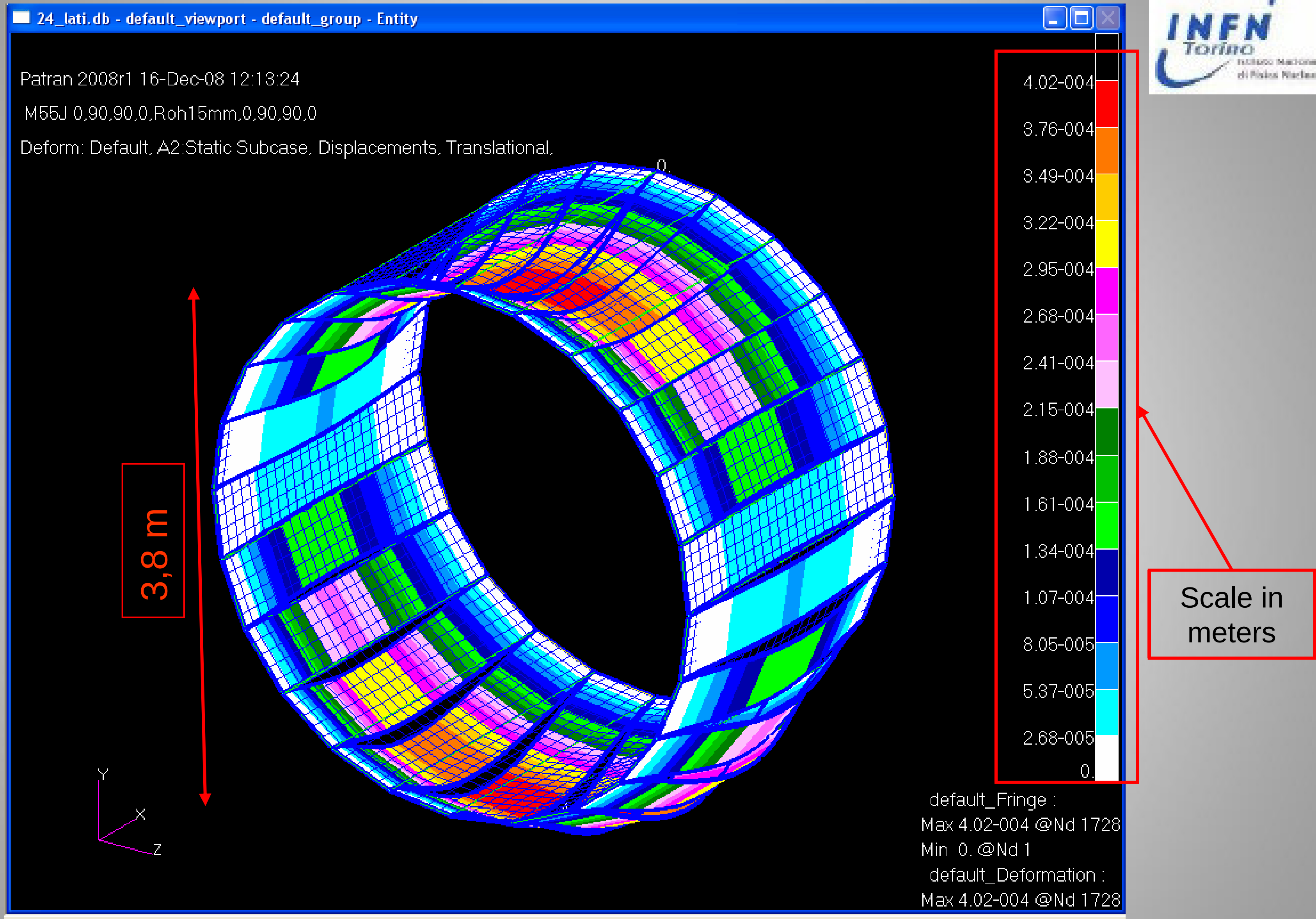
Silicon detectors are fixed on the surface of each panel; details of this fixation have still to be defined….



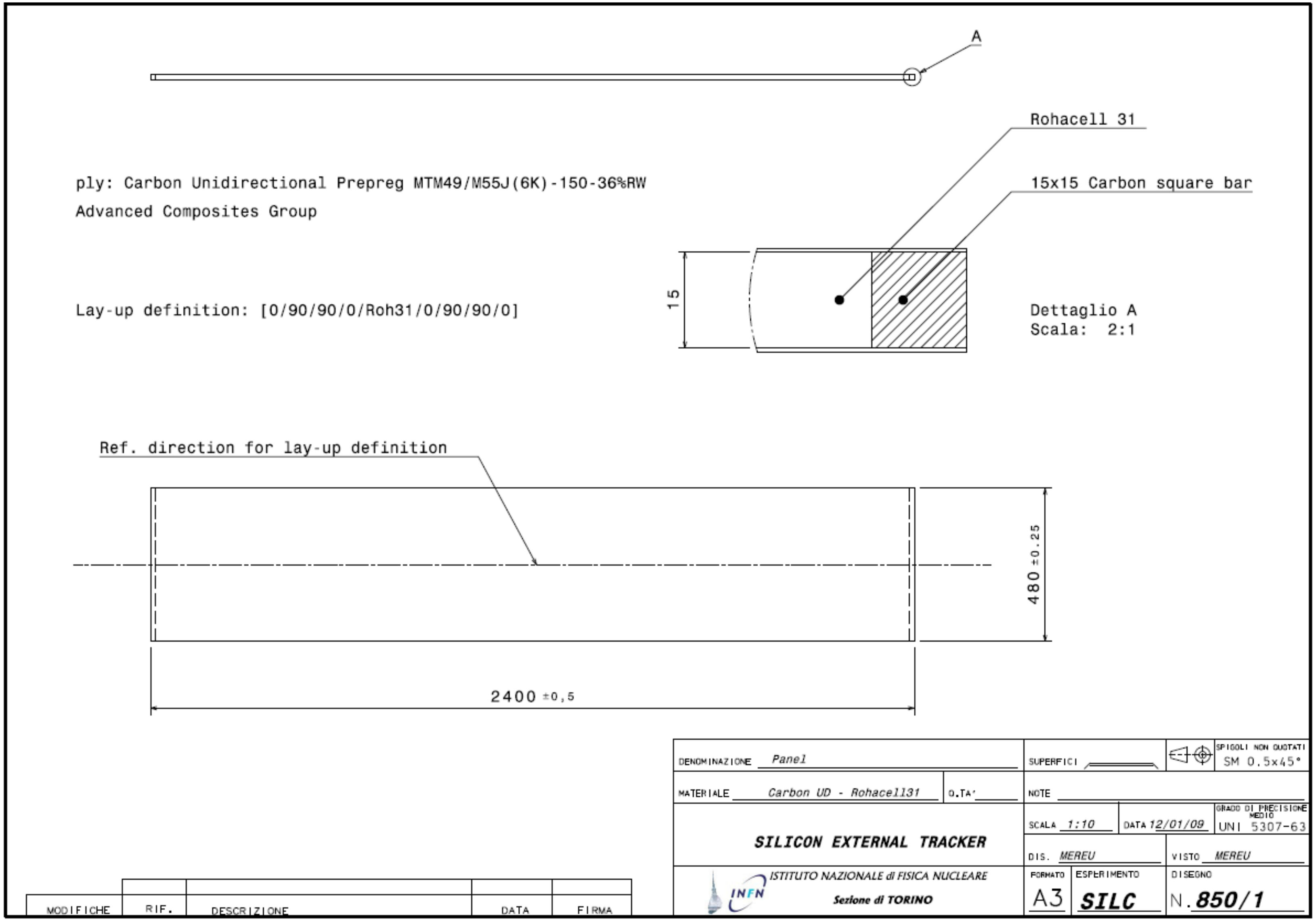
2 halves composed of 24 panels 2,4x0,48m.
Torino will built such a panel as demonstrator and to study all related issues

Each panel is independently fixed at both short sides to the outer surface of the TPC structure





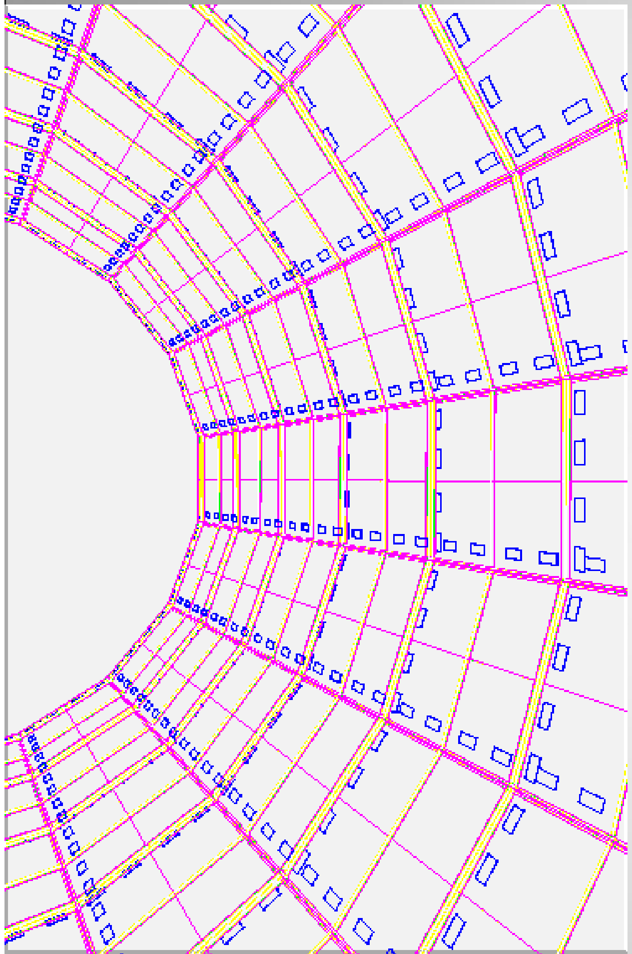
Courtesy of Paolo Mereu (Torino)



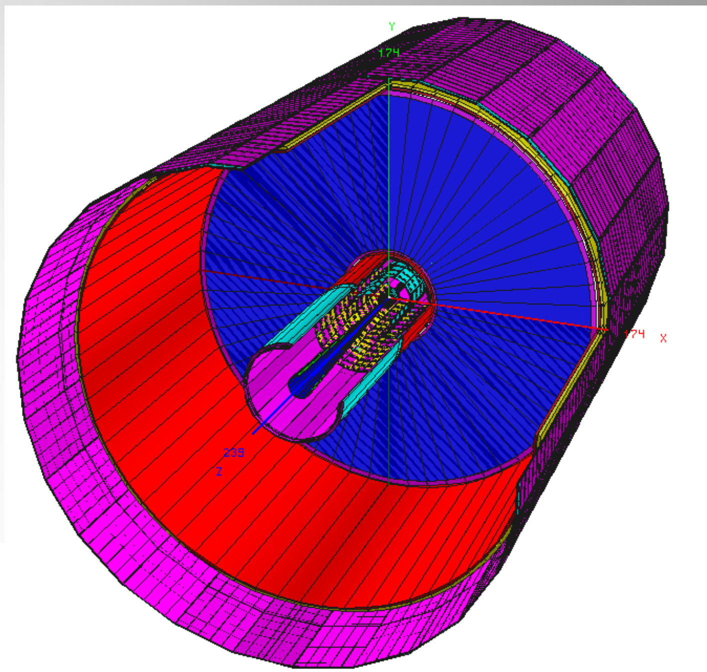
Material budget

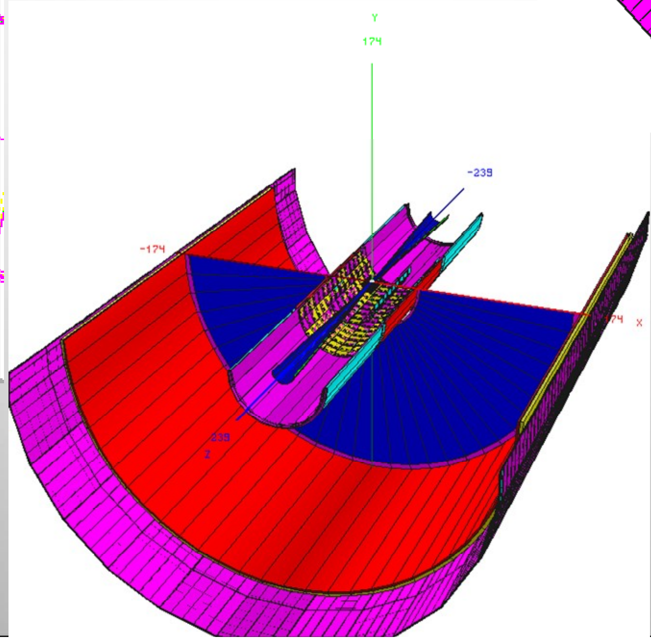
- 8 Unidirectional Carbon-Epoxy Prepreg 0,15mm each: 0,45 % X_0
- 15 mm-thick Rohacell31: 0,135 % X_0
- each panel has 0,585 % X_0

SET: Study of design implementation with detailed simulation *(A. Charpy, LPNHE)*



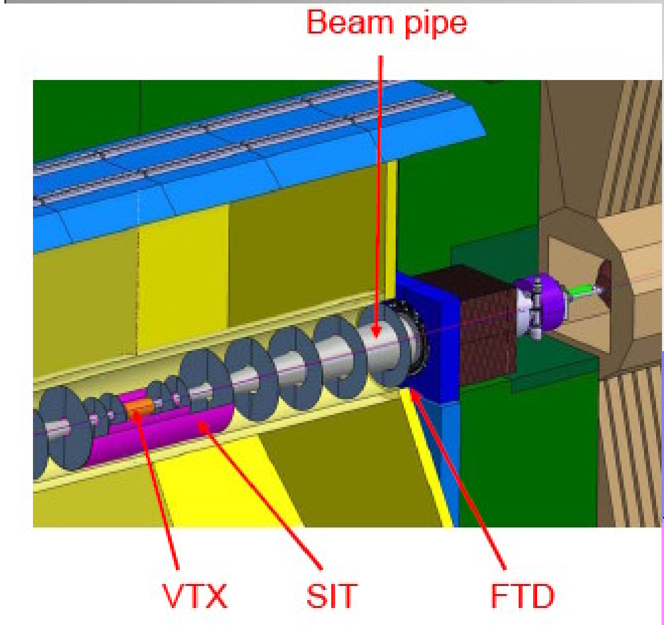
Presently SET is made of false double sided Silicon layers equipped with basic modules made of 5 sensors on both X,Y directions

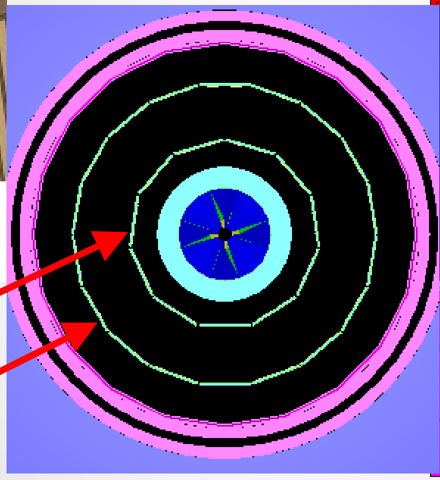


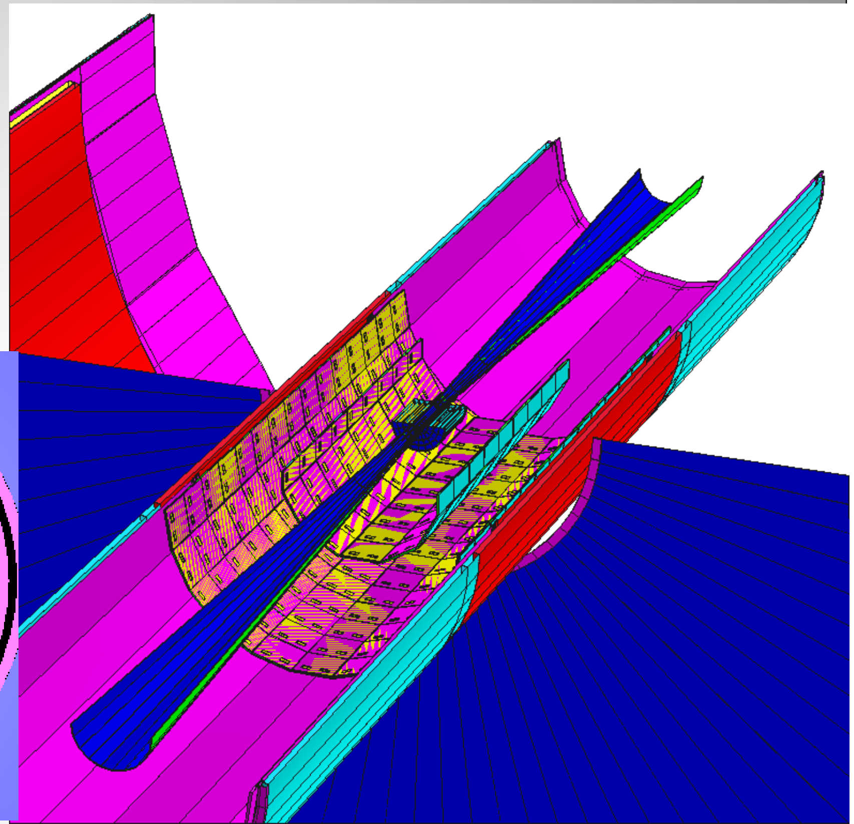


ILCROOT simulation

SIT: Silicon Internal Tracker







SIT1: 11 sectors

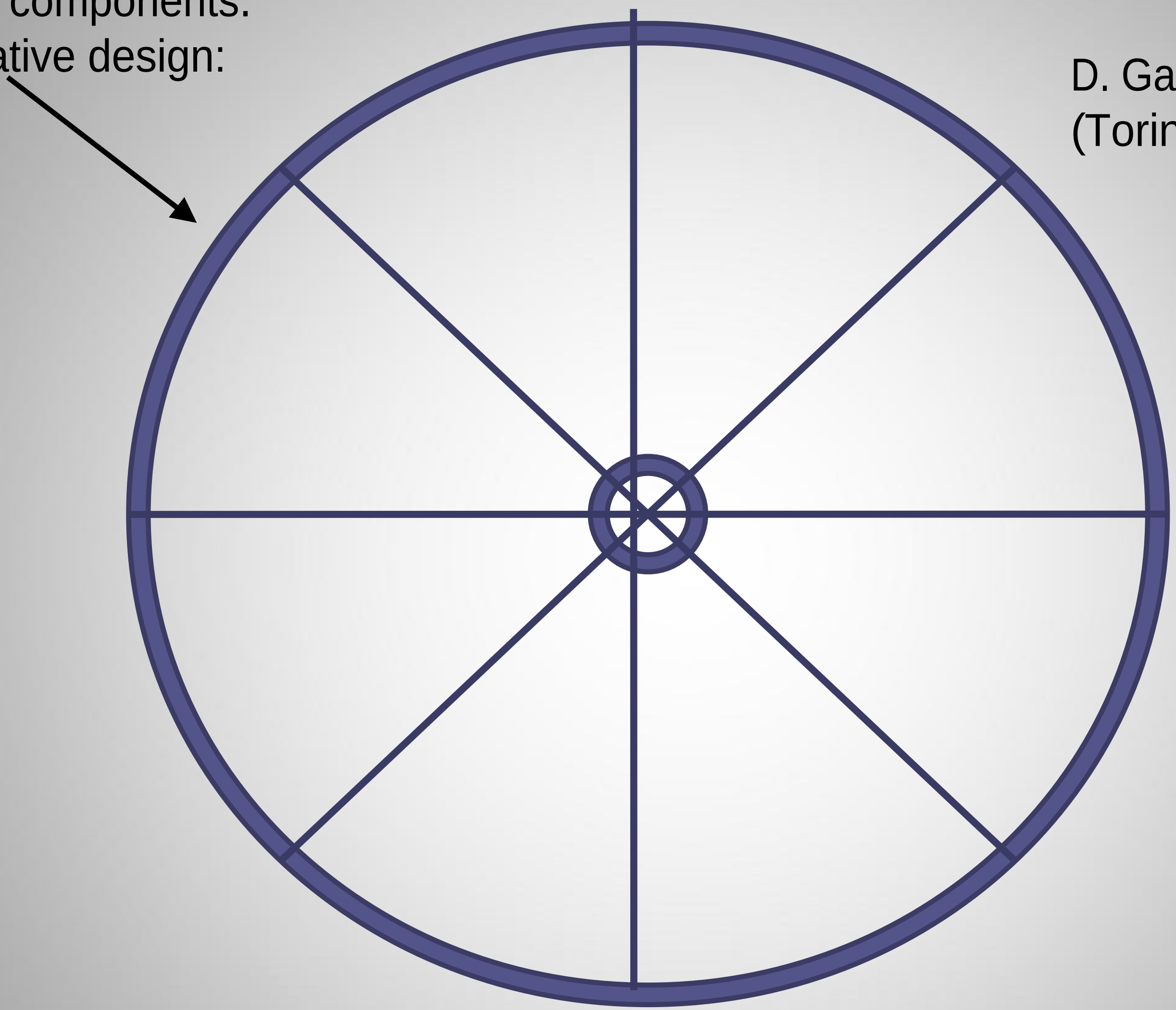
SIT2: 18 sectors

SIT is made of 2 false double sided X,Y layers (built in the same way than SET)
The SIT design as described by A. Charpy with ILCROOT simulation includes:
SIT1: 99 modules made each of a single sensor and 33 modules of 3 sensors each.
SIT2: 270 modules made each of a single sensor and 90 modules of 3 sensors each.

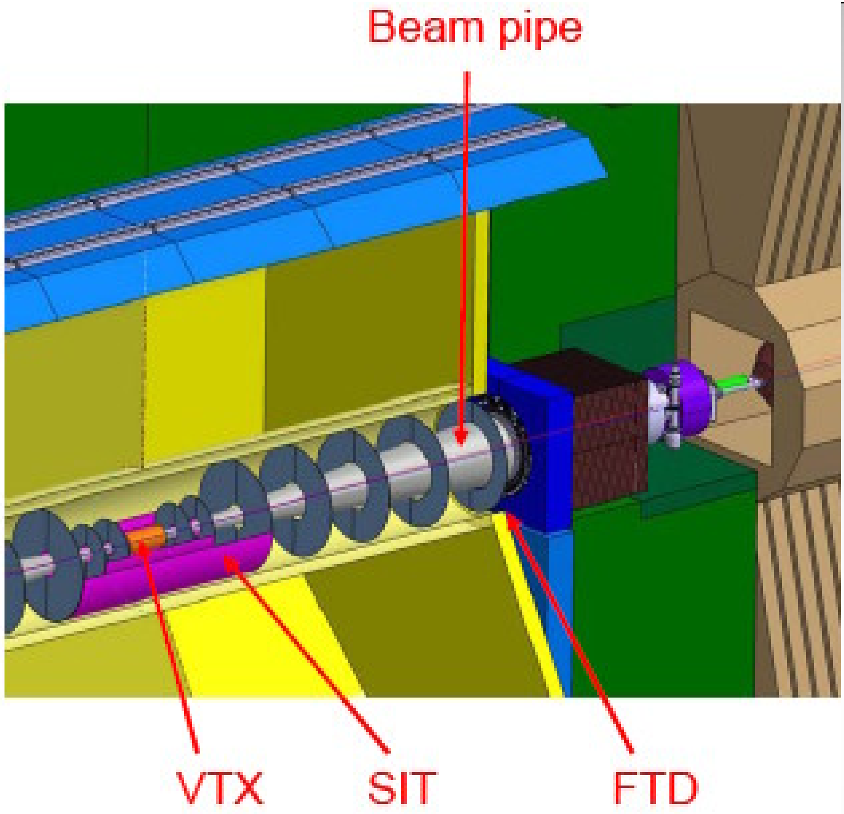
Material budget versus alignment: two options are studied for fixing the central barrel Silicon components.

Alternative design:

D. Gamba & P.Mereu
(Torino U+INFN)



The “bicycle wheel” on each side of the barrel to fix both the SET and (SIT +FTD) envelope independently of the TPC and of other sub-detectors

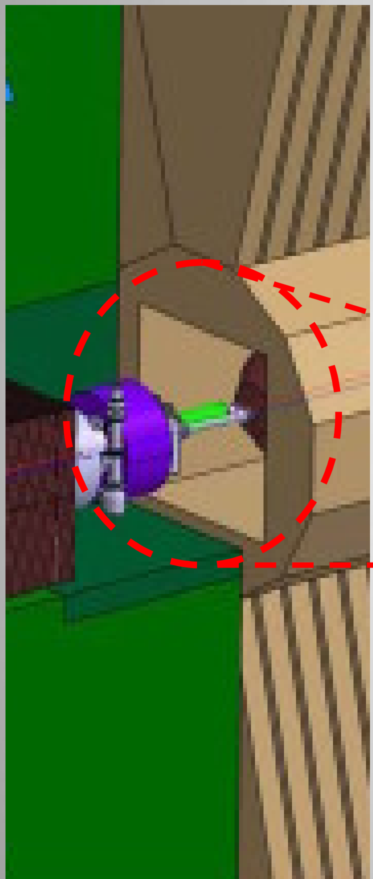


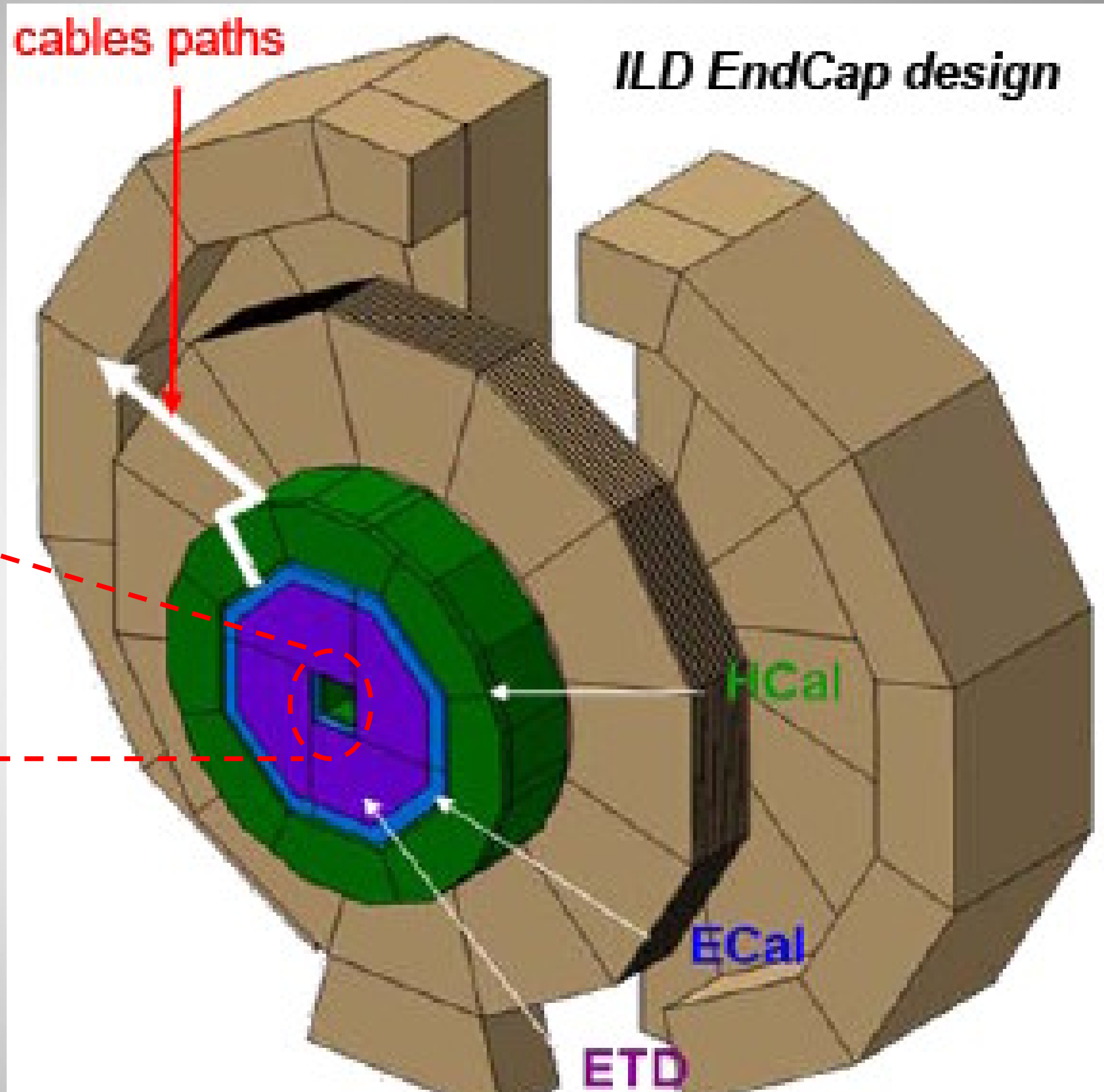
SUPPORT STRUCTURE OF SIT+FTD

The VTX is fixed to the beam pipe and includes its own envelope
The SIT and FTD are fixed to the support structure which itself will be fixed to the TPC: middle plan and on the two edges (unless “bicycle wheel” solution)
There is for ALL the Silicon components only one cable path, i.e. the one along The beam pipe as sketched here below

Courtesy of M. Jore

ETD integration
In the end cap
and Very Forward
calorimeter region

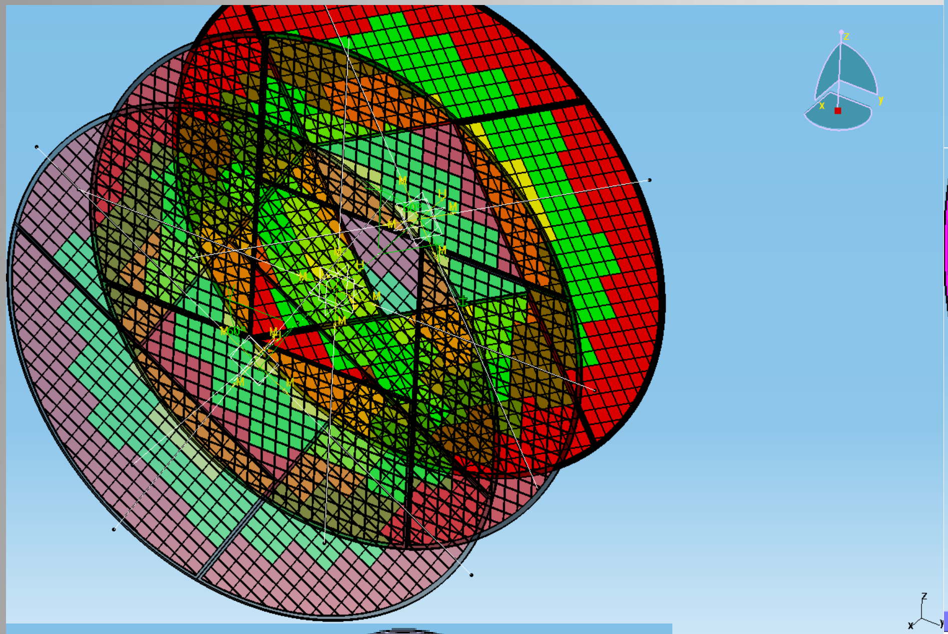


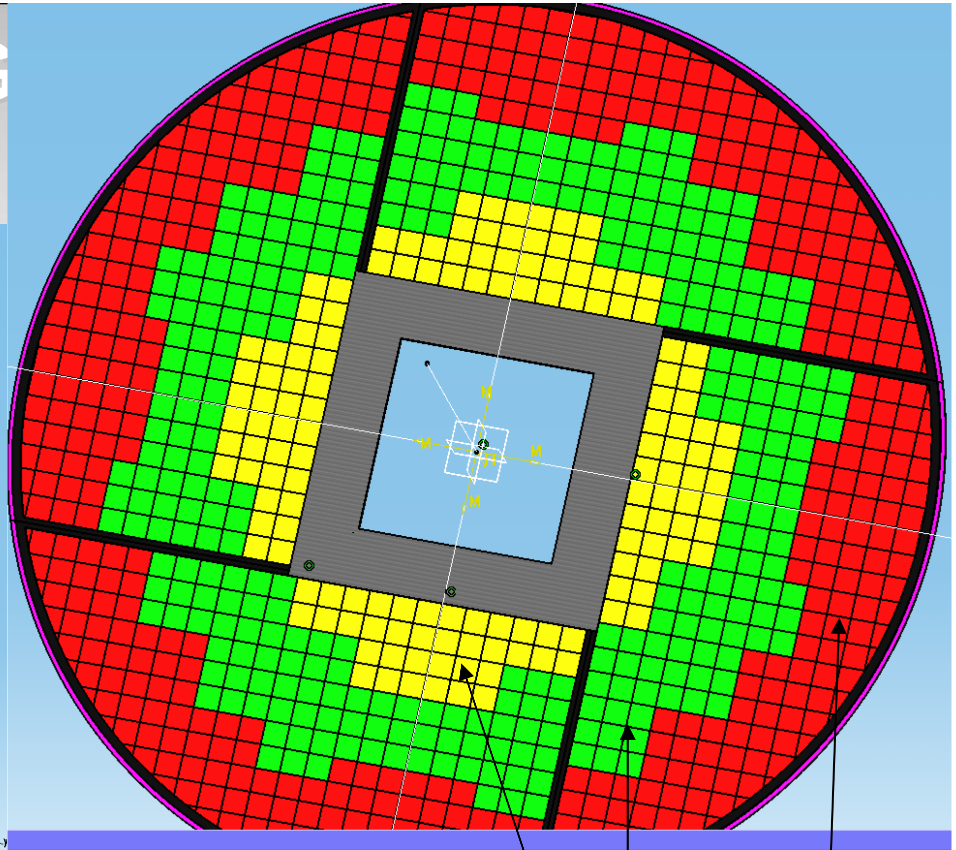


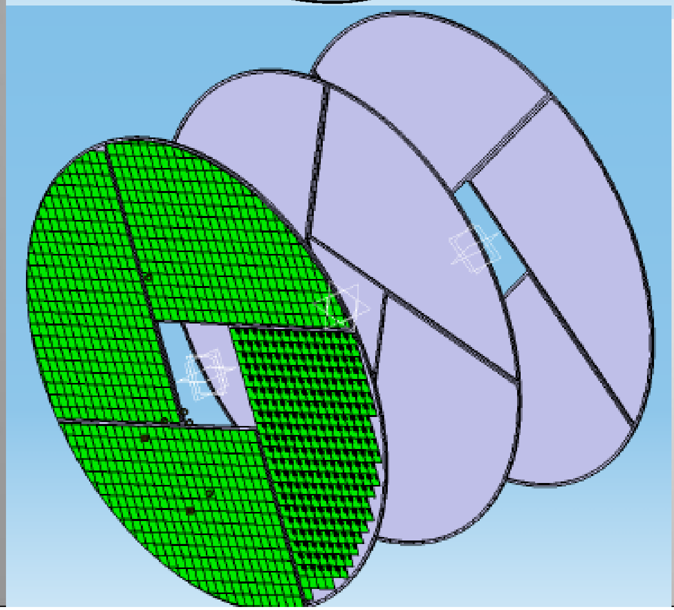
Design courtesy of M. Jore

ETD is studied at LPNHE:
A. Charpy, G. Daubard, P. Ghislain,
D. Imbault, ASN.

ETD: EXTERNAL TRACKING DETECTOR *(LPNHE-Paris)*

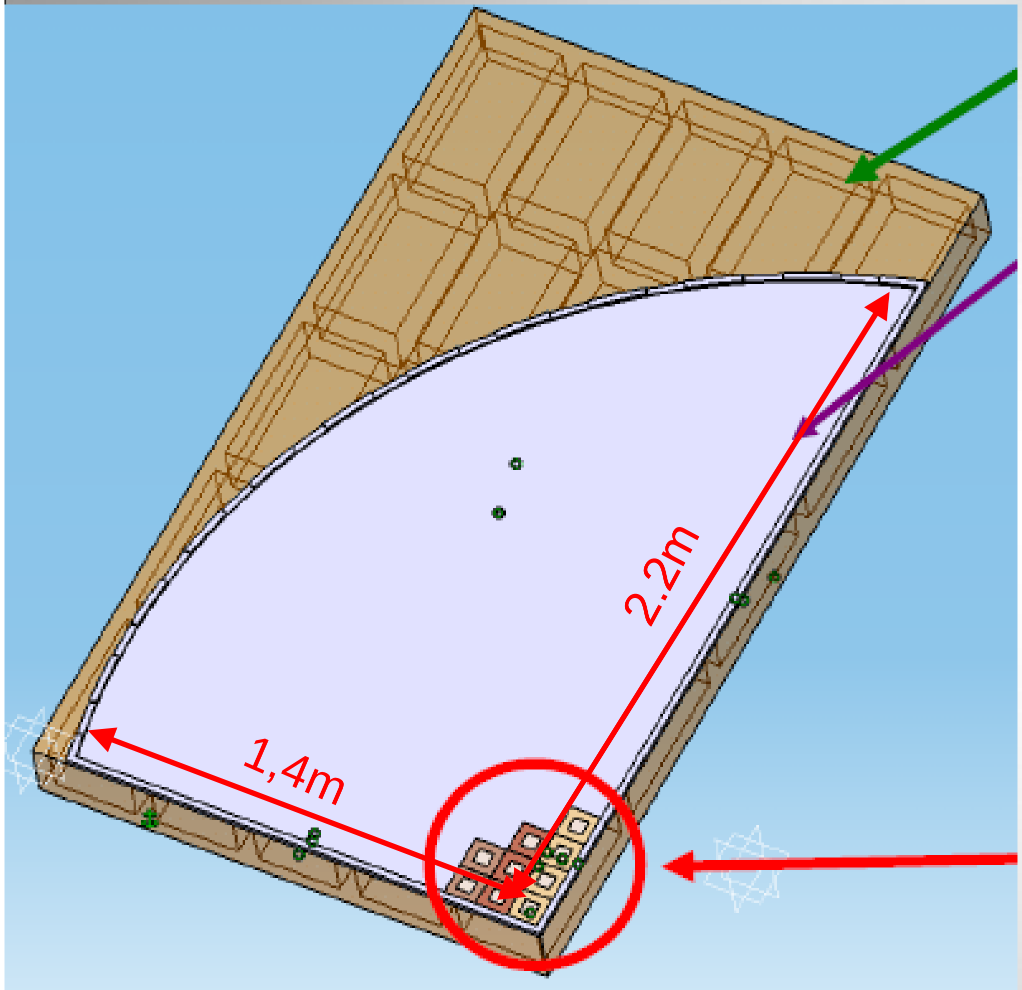






Each ETD is made of 3 single sided XUV plans made each of 4 parts.
Each quadrant is made of modules of 2, 3 or eventually up to 4 sensors (optimization under study)
In the center in order to recover from non squared frame when rotating by 60 degrees each plan a layer of pixels (grey) will be implemented. This pixel area will be just surrounding the square hole of the V.F. (under study)

Manufacturing the ETD components *(LPNHE Paris)*



Quadrant support to mount the overall structure with high spatial precision

Quadrant support structure made in The same way as the SET support structure (C Fiber/Rohacell foam/C fiber).
Paris will build such a quadrant and the related quadrant mounting support as demonstrator and to study all related issues (precise positioning, module integration, cabling, how to proceed to manipulate this large piece from horizontal to vertical, tooling to be developed etc..)

Modules with 2, 3 or eventually up to 4 sensors (to be studied)

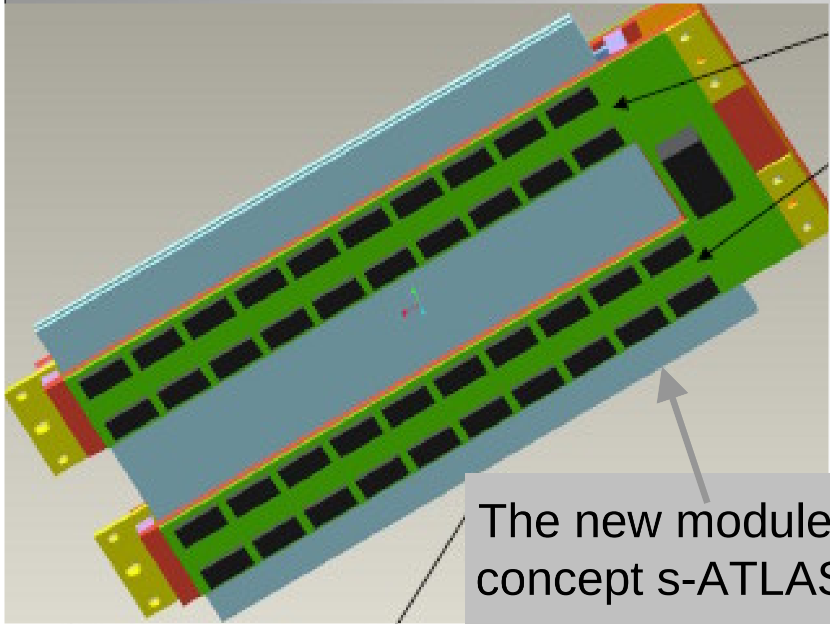
Within this present design the ETDs are made each of 4x3= 12 thus total of 24 quadrants

The SI components in numbers: preliminary

Component	Layer #	# modules	# sensors/ module	# channels	Total surface m2
SIT1	1st layer	33	3	66.000	0.9
	2nd layer	99	1	198.000	0.9
SIT2	1st layer	90	3	180.000	2.7
	2nd layer	270	1	540.000	2.7
SET	1st layer	1260	5	2.520.000	55.2
	2nd layer	1260	5	2.520.000	55.2
ETD_F	X or U or V	82/quad =328/layer =984/ETD	2 or 3 or possibly 4	2.000.000	30
ETD_B	idem	idem	idem	idem	30

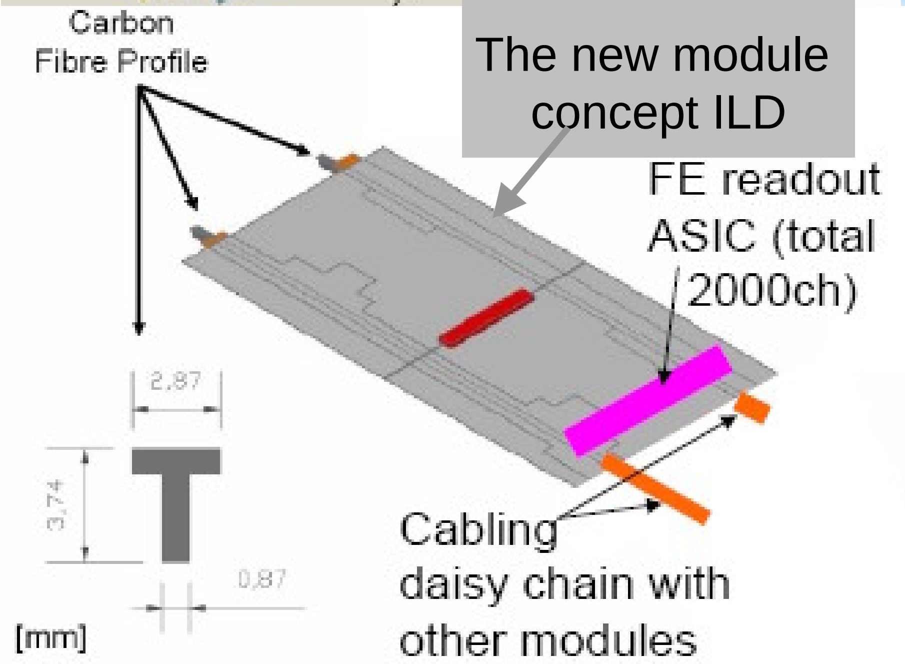
TOTAL: 1.000.000(SIT)+5.000.000(SET)+4.000.000(ETDs)≈10M channels
7 (SIT) + 110 (SET) + 60 (ETDs) ≈ 180 m2 (present SiD: 135m2)
500 (SIT) + 2500 (SET) + 2000 (ETDs) ≈ 5000 modules with unique size sensor

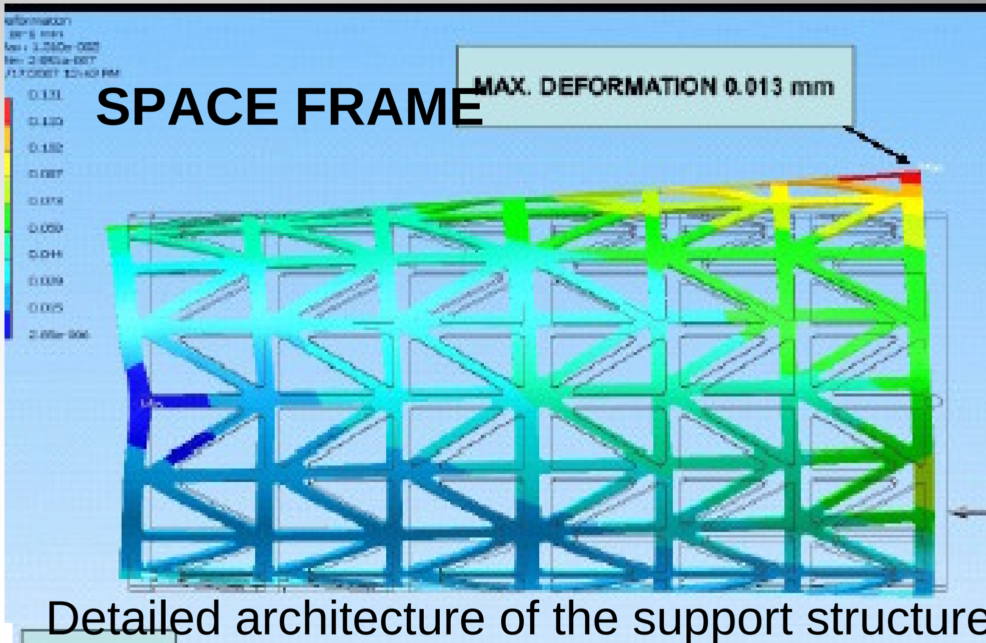
SIT, SET, ETD: Detailed work on structure & modules started



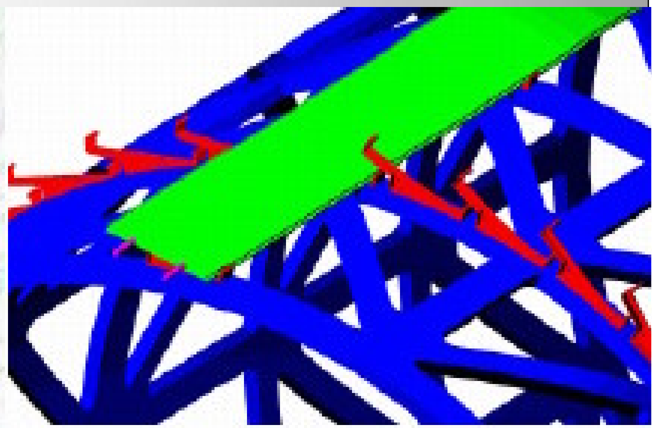
The new module concept s-ATLAS

The new module concept ILD





Detailed architecture of the support structure in progress for SET, SIT, ETD. SuperModule to be built by Torino (SET) & Paris(ETD) for studying all pending issues



s-ATLAS designs by courtesy of Ph. Allport

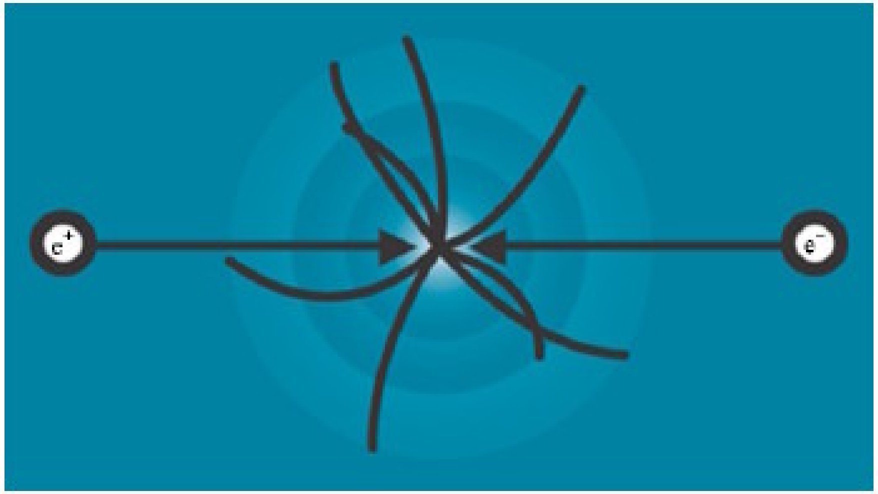
(synergy with LC)

iUT ORSAY
Département Mesures Physiques

CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

Rapport de stage

Etude thermique du système de refroidissement d'un détecteur de traces en silicium



Stage effectué au sein du LPNHE de paris
(Laboratoire de Physique Nucléaire et de Hautes Energies)
Du 5 décembre 2005 au 24 février 2006

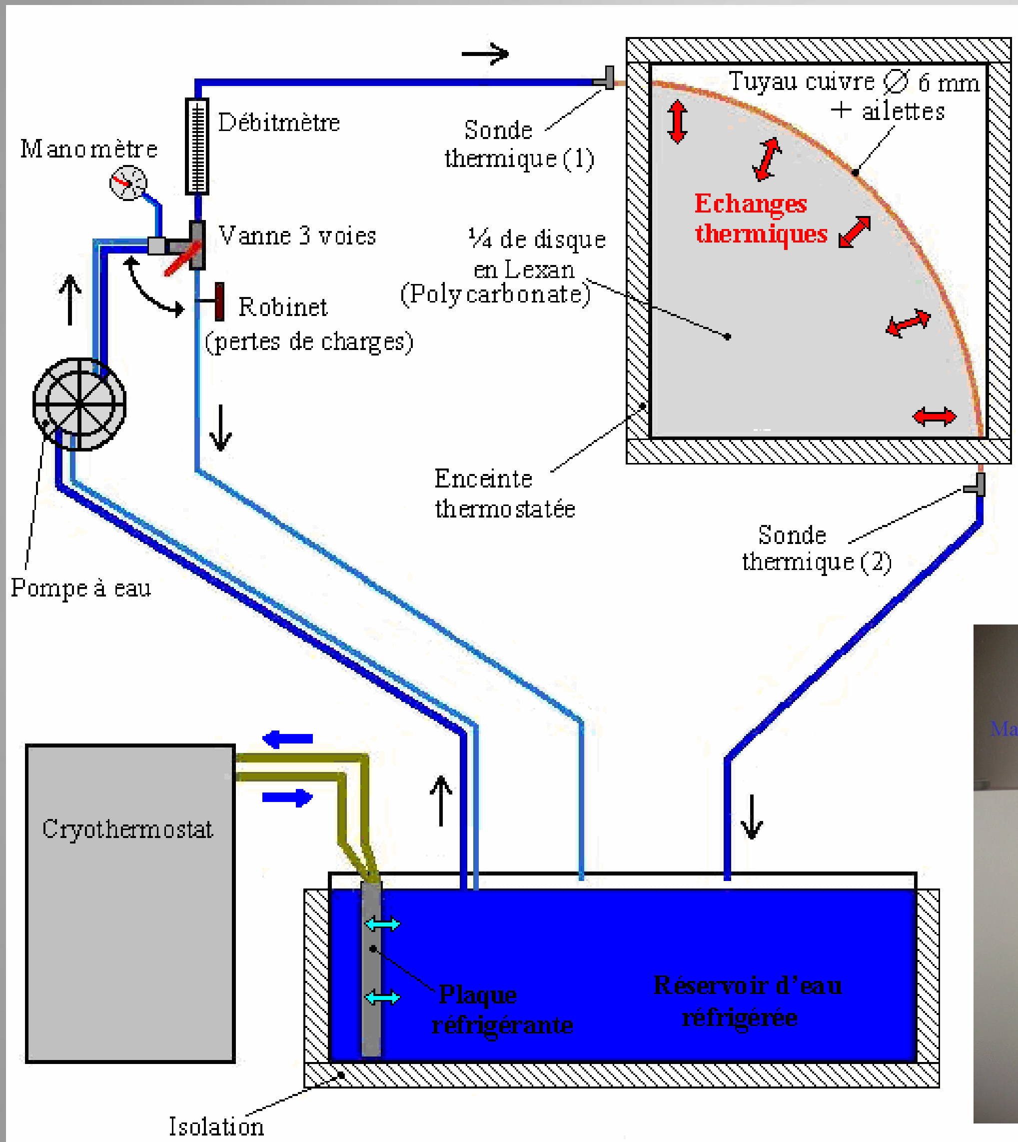
Stagiaire : Guillaume Davée
Maître de stage : Guillaume Daubard
Enseignant responsable : Jay Amrit

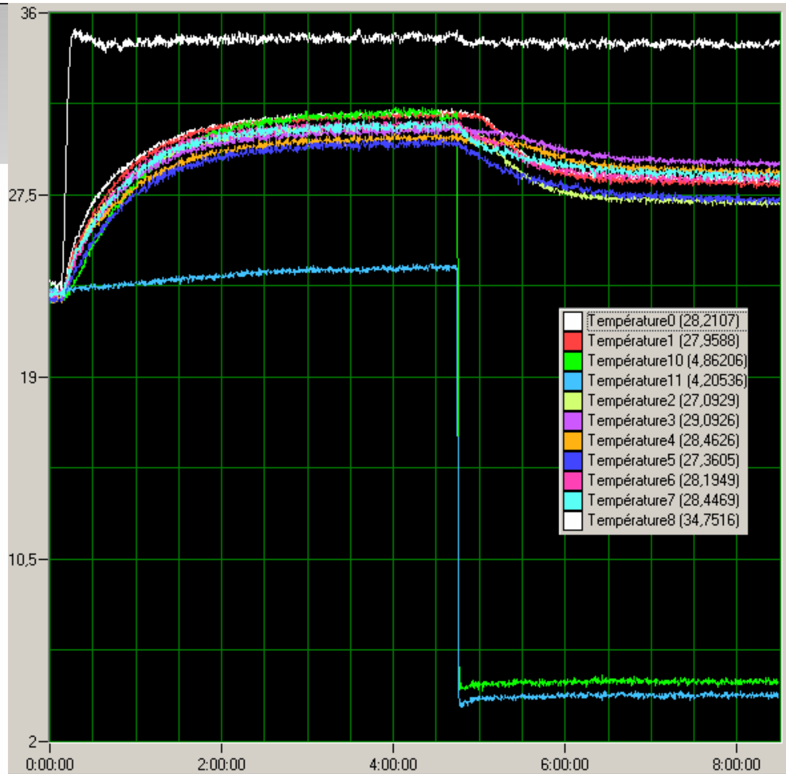
Cooling

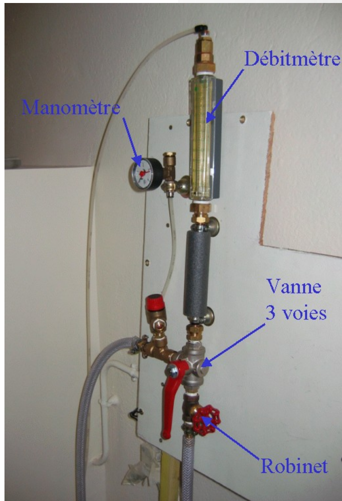
Studies conducted at LPNHE
Here for the ETD

Current FE electronics dissipate
Max 1mWatt/channel.
In addition power cycling is
Included in the last version:
SiTR_130-88

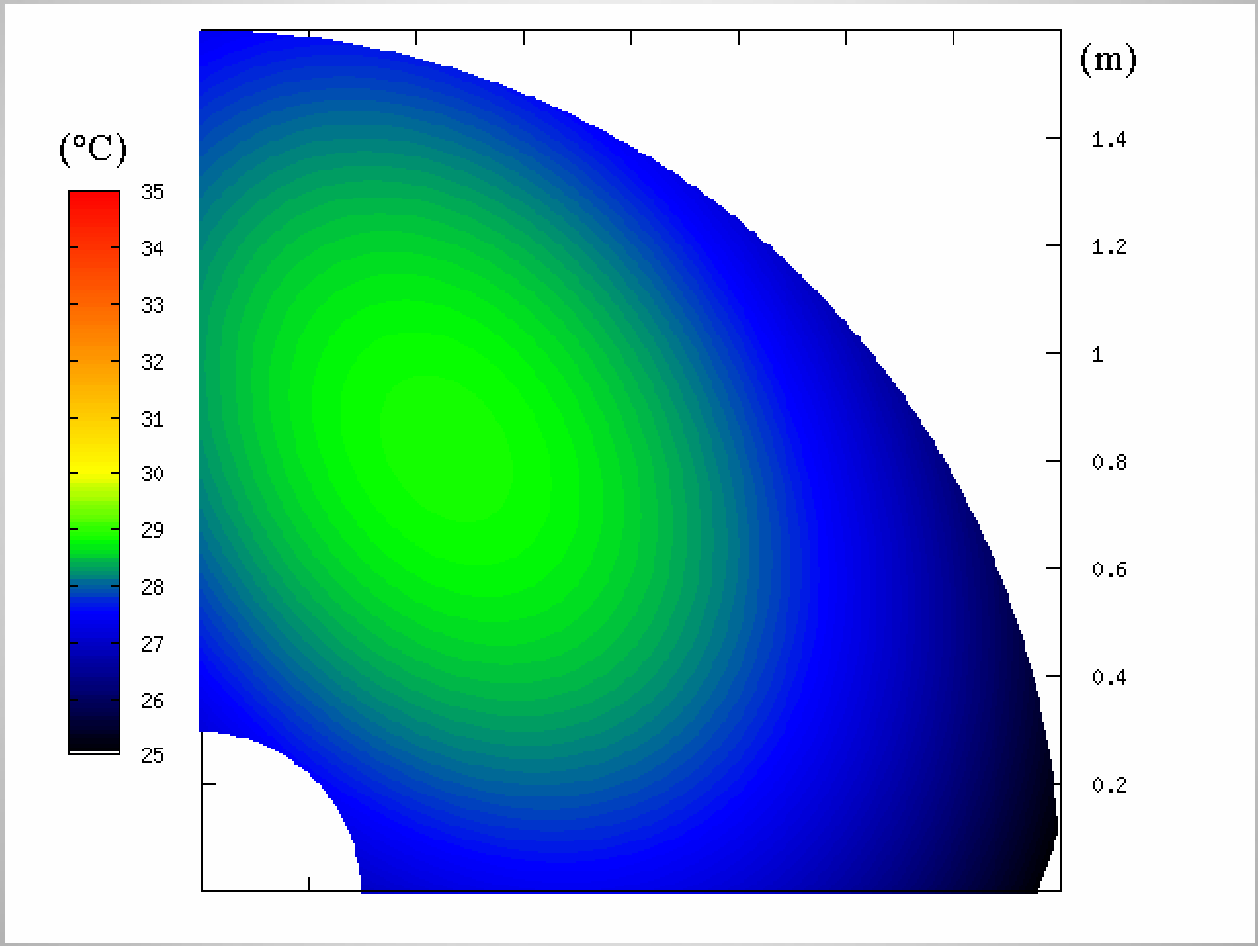
COOLING TEST SET-UP at THE LAB



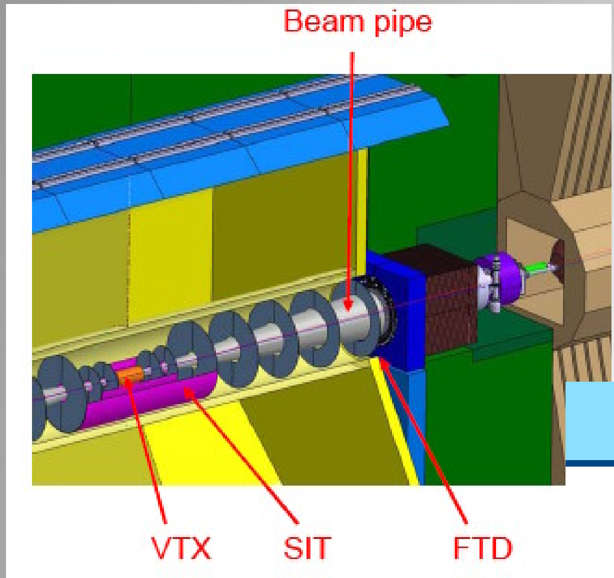




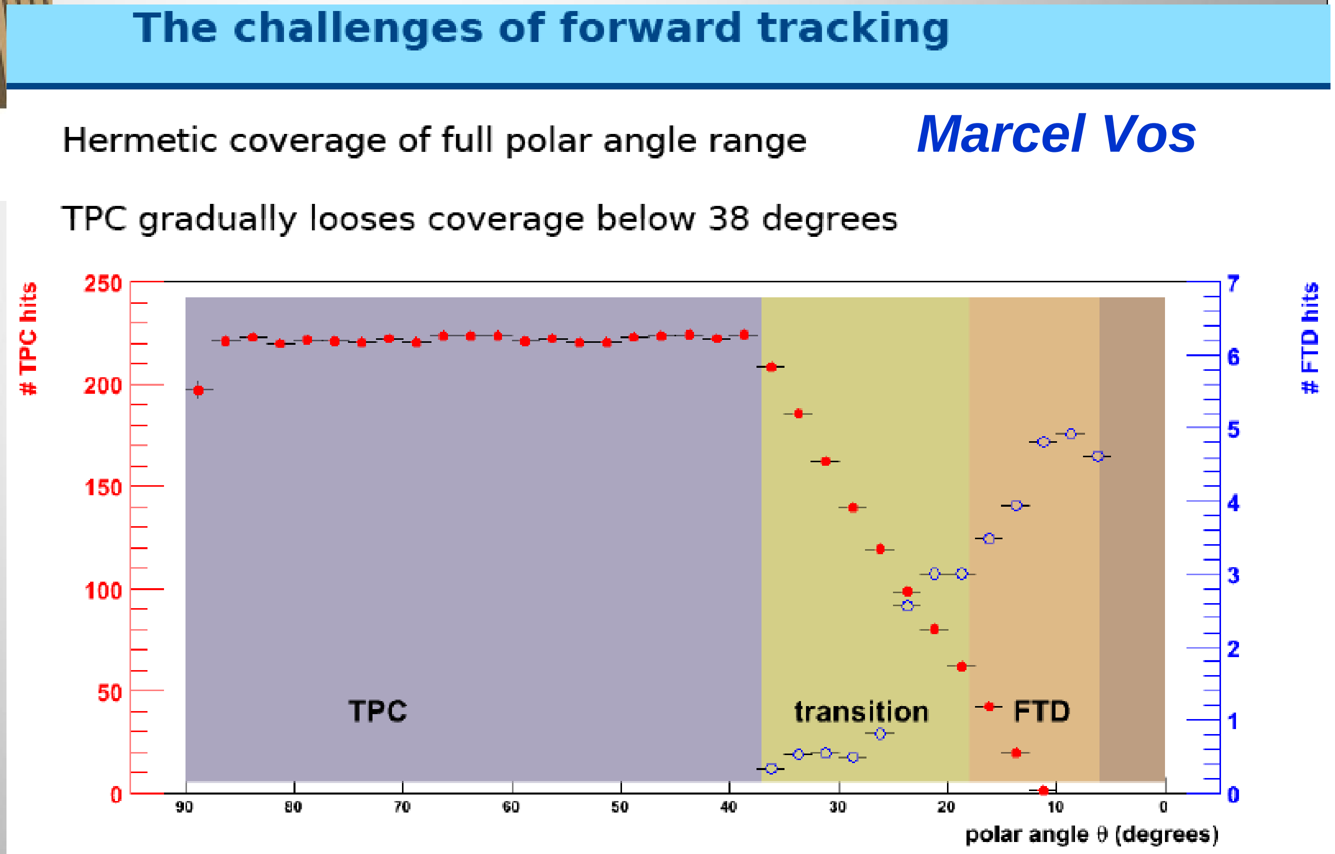
Result of cooling test on ETD quadrant prototype (LPNHE-Paris)



FTD disks: the Spanish team (IFCA, IFIC, USC)



They are performing a complete the FTD disks: detailed simulation studies; development of pixels (first 3 disks): strip detectors (last 4 disks in false DS small angle stereo petals); alignment system (IFCA) including developing new sensors (IMB-CNM), plus engineering to build these disks.



The FTD 4-7 petals design: IFCA+IFIC

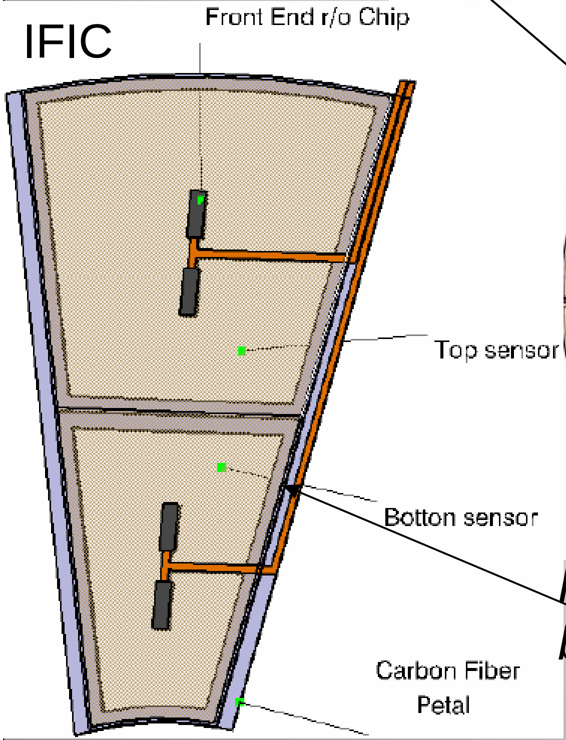
16-petals false double-sided small stereo-angle

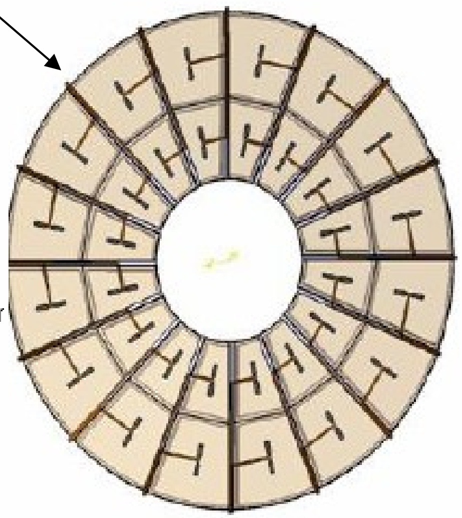
FTD 4: 16 PETALS GEOMETRY

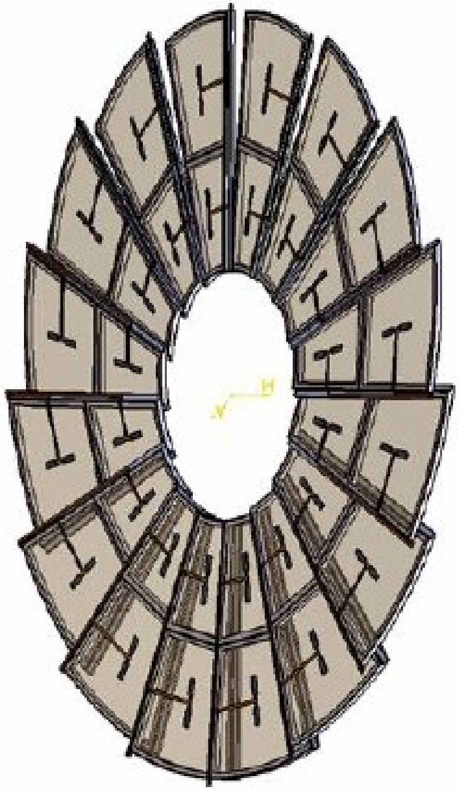
David Moya (IFCA)

- 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.

IFIC

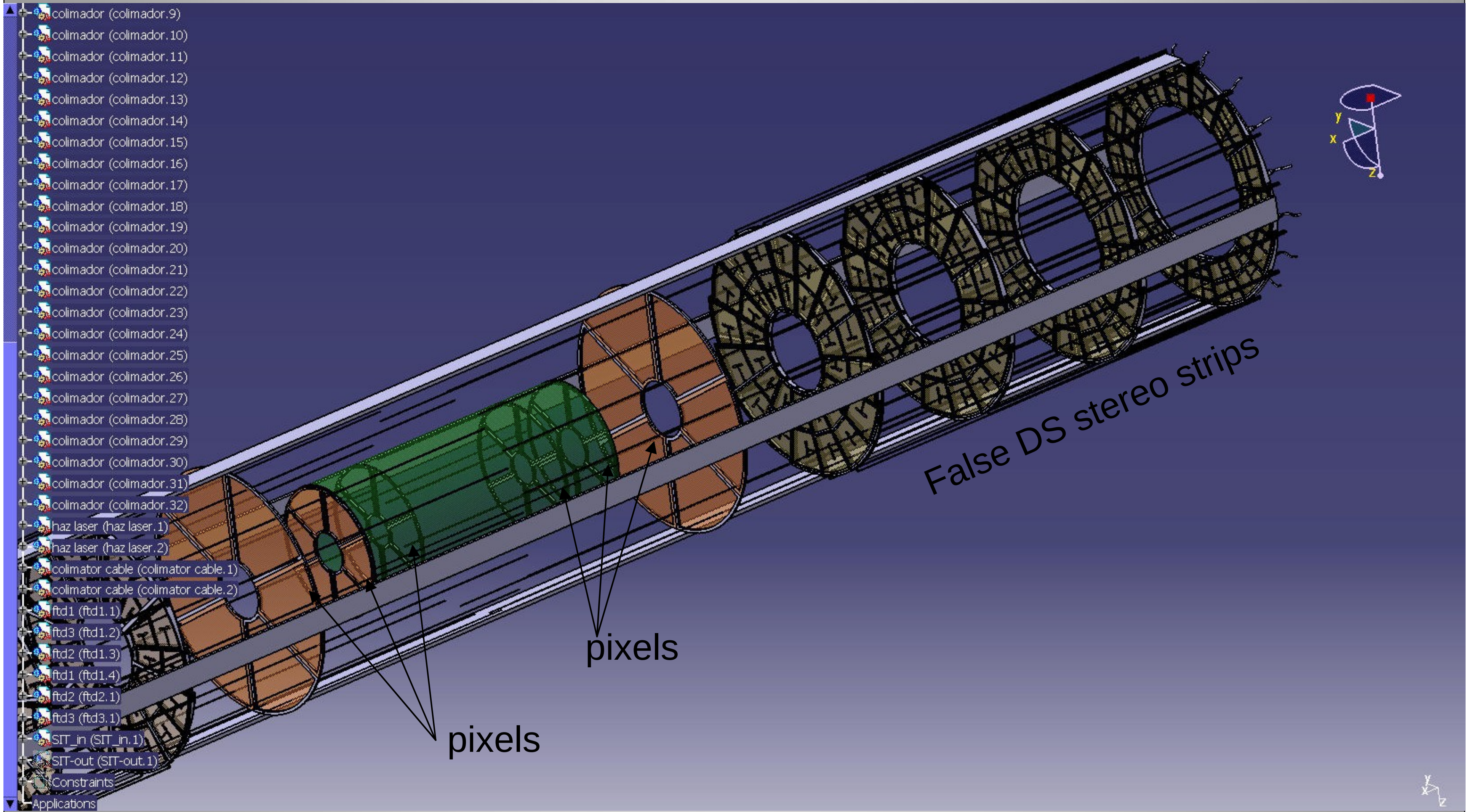






Petal designed by IFIC derived from ATLAS Si End Cap tracker but with new SiLC electronics concept

The FTD system *(The spanish team)*



Study of the hits density in FTD

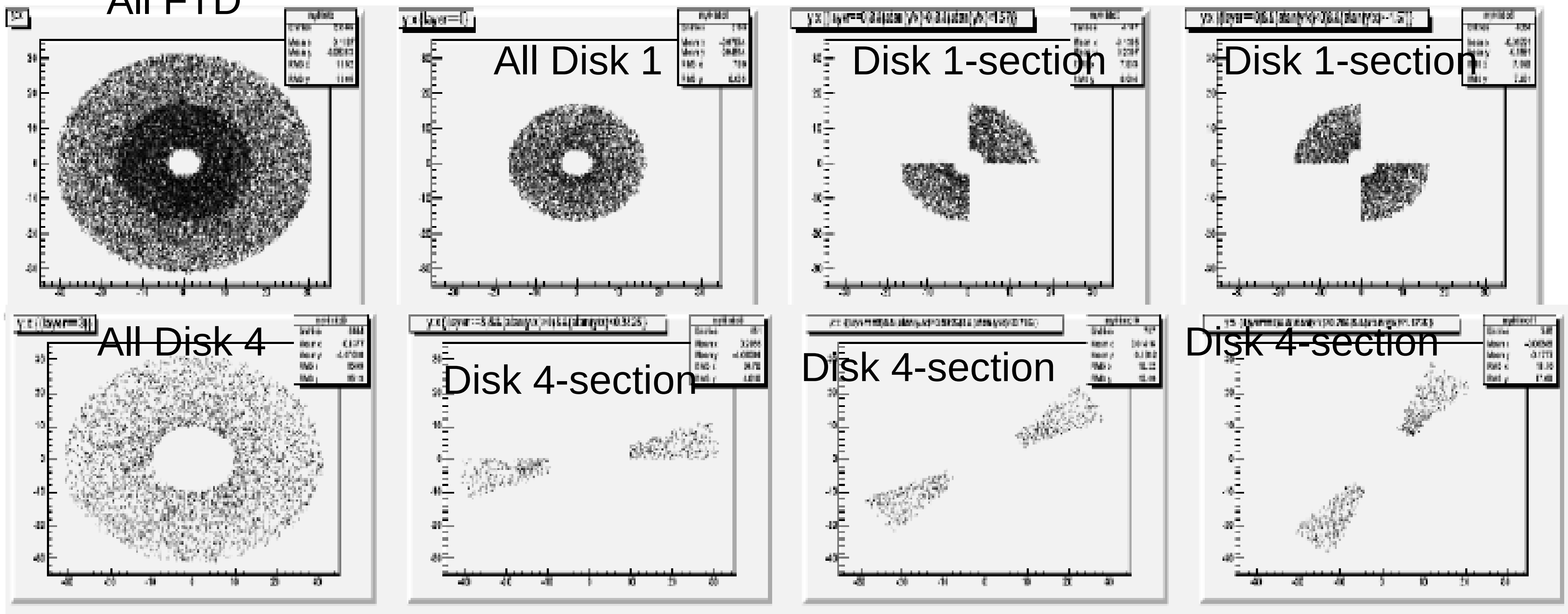
Carmen Iglesias, Bernardo Adeva: USC

The idea is to analyse the hits density in FTD disks dividing them in sections (petals).
In principle, Disks 1-3 in 4 sections and Disks 4-7 in 16 sections (similar to IFCA design), but...

	R_inner (mm)	R_outer(mm)	Z(mm)	Area_disk(cm²)	Area_Section(cm²)
FTD_1	39	164	220	797.17	199.29 (1/4)
FTD_2	40.6308	164	371.309	793.09	198.27 (1/4)
FTD_3	70.1393	308	644.906	3318.57	**829.64 (1/4) o 207.41 (1/16)**
FTD_4	100.298	309	1046.12	2683.58	167.72 (1/16)
FTD_5	130.372	309	1447.33	2466.07	154.12 (1/16)
FTD_6	160.447	309	1848.54	2190.87	136.92(1/16)
FTD_7	190.54	309	2250	1859.05	116.19 (1/16)

....It's seems better divide the 3 Disk in 16 sections instead of only 4.

Plots show the x-y positions of hits in Forward Disk, for the whole FTD and for Disk 1 and 4, and their sections:



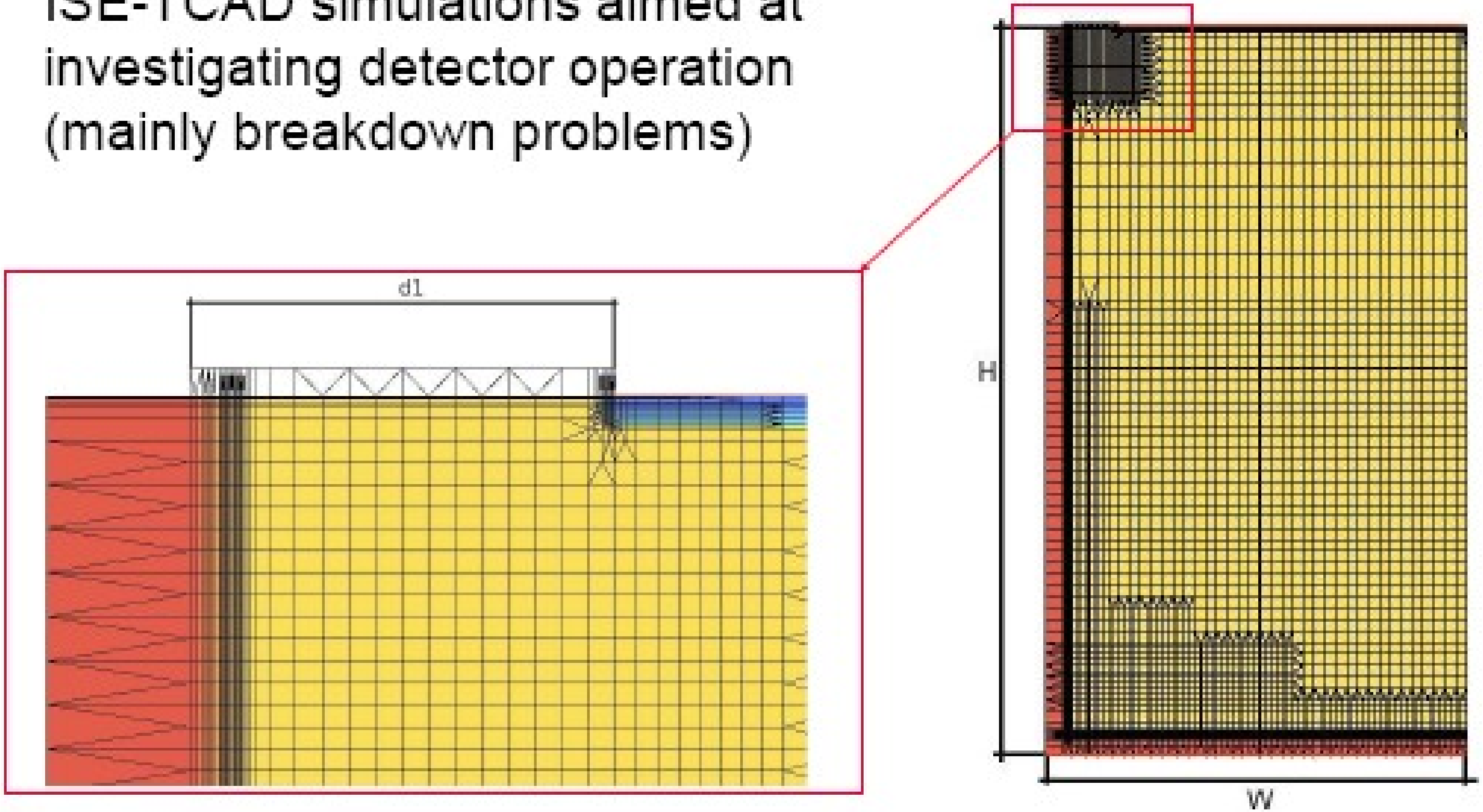
- Role of Silicon tracking in ILD
- Silicon system and performances
- Calibrations
- Construction and integration issues
- Dedicated R&D on advanced technologies
- Concluding remarks, pending issues

In order to make adequatly the elementary modules a series of related R&Ds are undertaken on:

- Novel sensors: edgeless planar microstrip sensors
  Go to 3D planar microstrips (?)
  Purpose: go to thinner, lower voltage sensors, lower power dissipation, radhard
- VDSM FE readout electronics
- Direct connection of electronics on sensor:
  bump bonding (underway with present ASIC)
  3D interconnection
- Cabling and transmission of data out of the detector
- A lot of challenges also on the mechanics side in order to have 1) the lightest possible modules
  2) the lightest possible structure

Simulation of planar detectors with active edge

ISE-TCAD simulations aimed at investigating detector operation (mainly breakdown problems)



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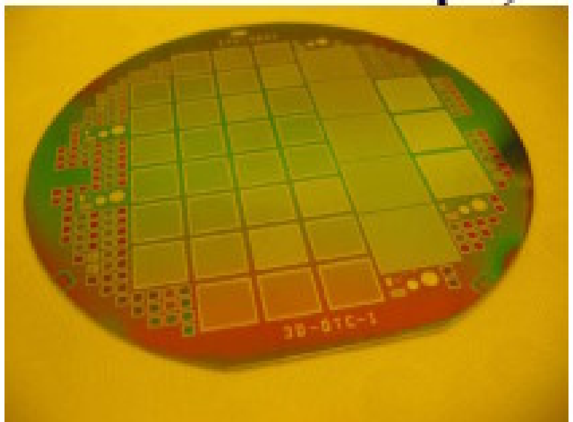
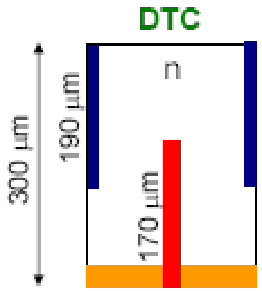
G.-F. Dalla Betta

3D-DTC-1 batch

- N-type substrate
- (Mostly) microstrip detectors
  useful to ease characterization and investigate process yield



Column overlap not optimized: about 60um



Courtesy G. F. Dalla Betta

Silicon ILD Tr

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Fabrication

- 2 batches under fabrication at FBK

1) Recycle of 3D-DTC-2: n-on-p, 200-µm thick substrate, non-passing-through columns (180 µm)
   Currently at 2nd DRIE etching, to be completed by 02/09.

2) 3D-DTC-3: n-on-p, 250-µm thick substrate, full 3D detectors (passing-through) columns.

New double-sided process defined, no need for support wafer, also suitable for dual read-out pixel/strip.
   Just started, to be completed by 04/09

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G.-F. Dalla Betta LPNHE, Paris, Jan. 16, 2009

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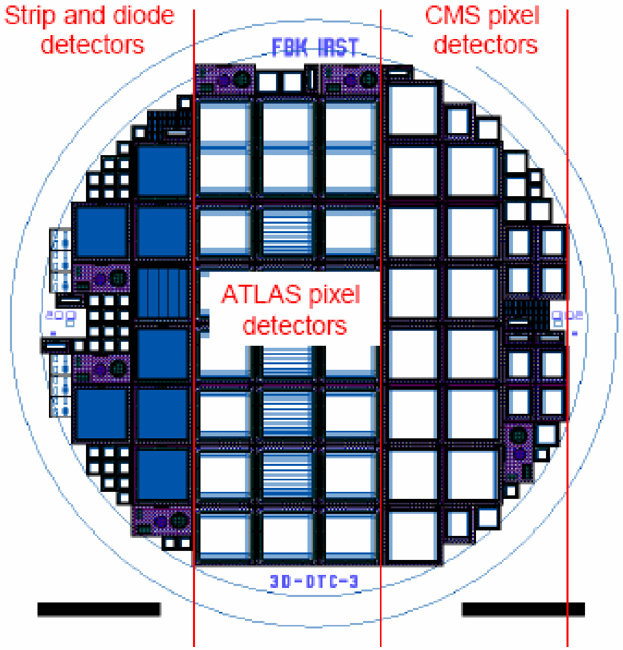
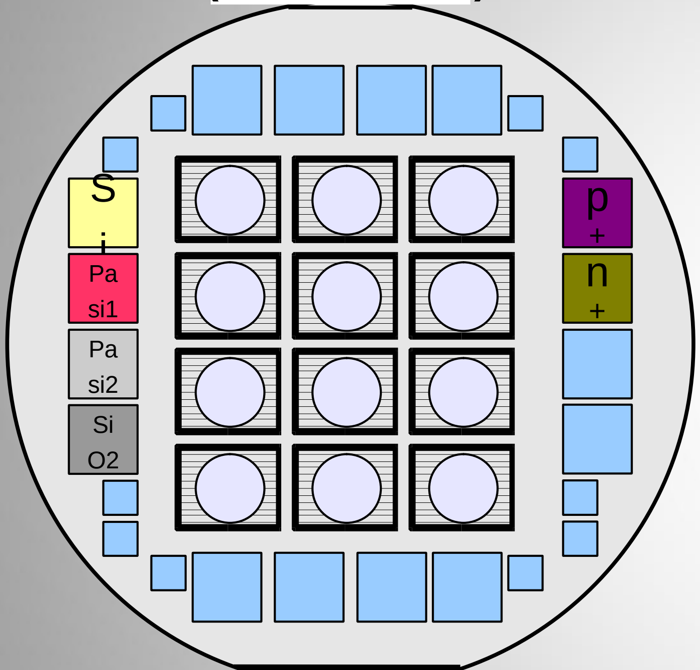
New layout (3D-DTC-3)

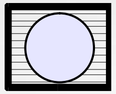


NOVEL SENSORS SPECIAL FOR ALIGNMENT

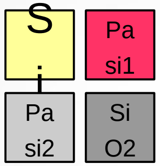
IMB-CNM (Barcelona) is producing the first sensor prototypes with multigeometry and optimum thickness.

(Pictorial view)

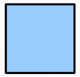




Alignment sensor 1.5×1.28 cm^2 (256 strips → 2 Alibava)
(Likely to become 1.5×1.5 cm^2 with guard rings...)
Al hole in the back ⌀~1 cm
Strip width is the same along the full strip
Slightly larger area to mount on PCB



Optical test structure (TS)
No Al in the back
1 per layer of material
Ellipsometry?



Electrical TS
See poster by M. Dragicevic at INSTR08, Novosibirsk
All SiLC TS are valid here

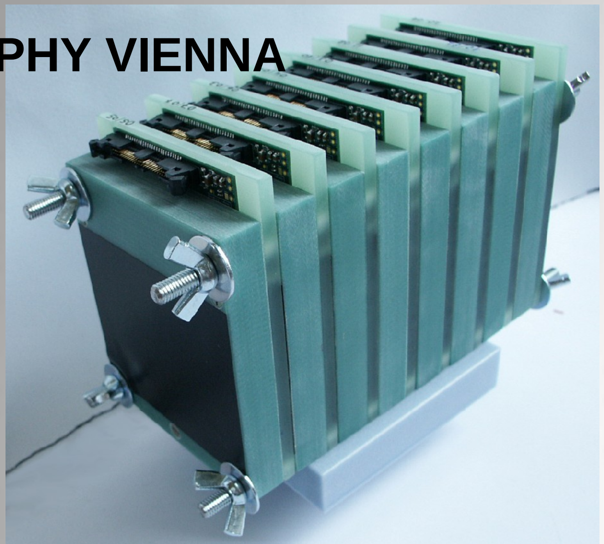
Pitch=50 µm
Metal width=3, 5, 10, 15 µm

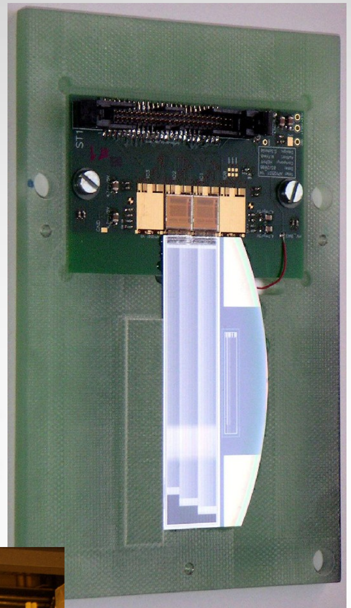
Granted by GICSERV08
AC sensors
– Al strips (3 wafers)
– Al strips&Al backside (1 wafer)

Slide from Marcos Fernandez Garcia (IFCA)

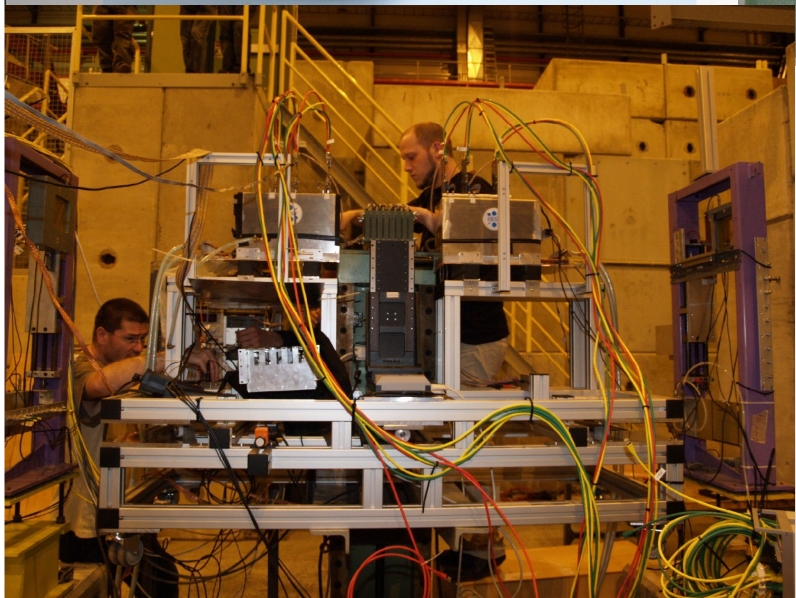
Ongoing R&D activities: example test bench to measure the sensor detailed performances

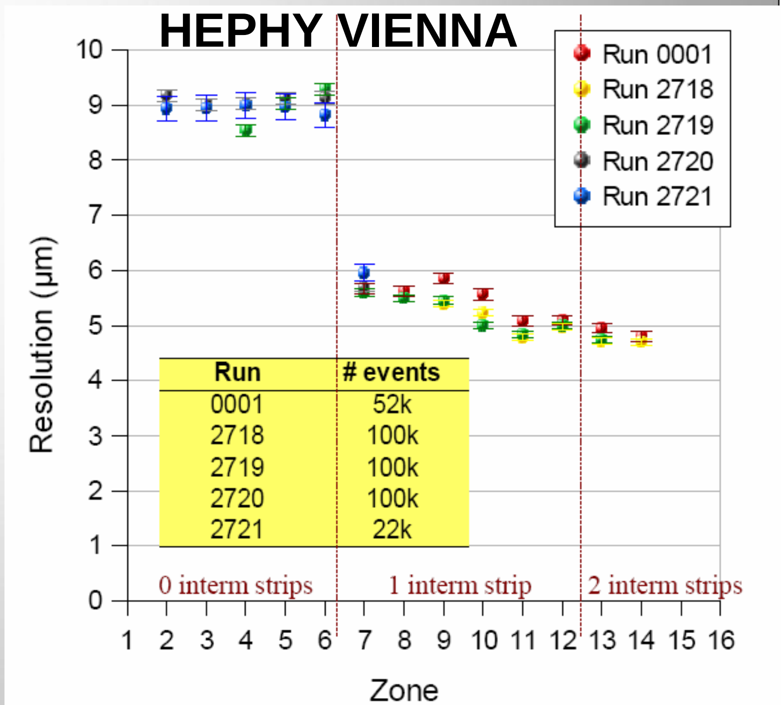
HEPHY VIENNA





New series of tests this year at CERN with novel sensors from IMB-CNM and from Poland with wire bonded chips.
Expertise and well experienced teams = asset





Run	# events
0001	52k
2718	100k
2719	100k
2720	100k
2721	22k

(CU Prague)

Th. Bergauer, S. Haensel, M. Krammer et al.(HEPHY)

Concluding remarks

- Based on the SiLC R&D activities and the contribution of a large number of its members, a detailed design of the Silicon tracking system for ILD is achieved.
- The construction and integration issues are addressed in a more and more realistic way (supported by more and more detailed performance simulation studies),
- As well as the needed advanced technology to be pursued for achieving the requested performances.
- It also opened a new phase of larger scale prototypes (realistic) and of even more aggressive R&D challenges especially in sensors, electronics and mechanical issues
- The SiLC collaboration is dedicating a large effort to achieve these goals, very demanding in person-power, high expertise and financial support.

With many thanks to all the SiLC collaborators