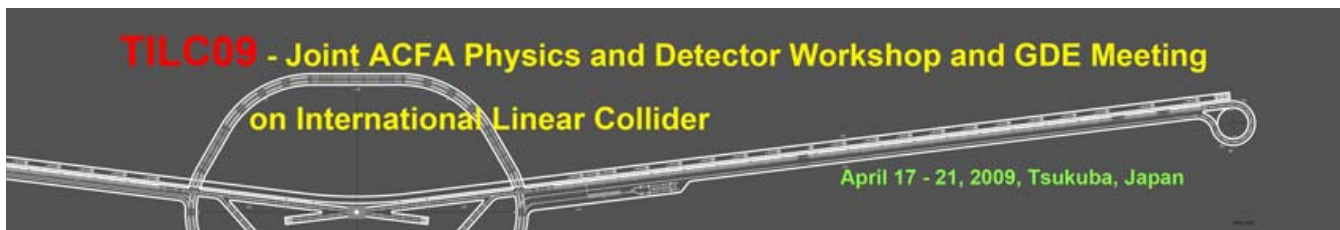


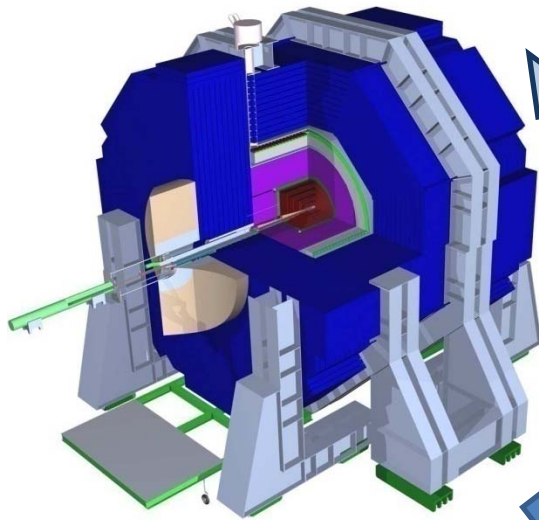
# Integrating Silicon tracking in ILC detector concepts: solutions & challenges

Aurore Savoy-Navarro, LPNHE-Universite Pierre et Marie Curie/IN2P3-CNRS

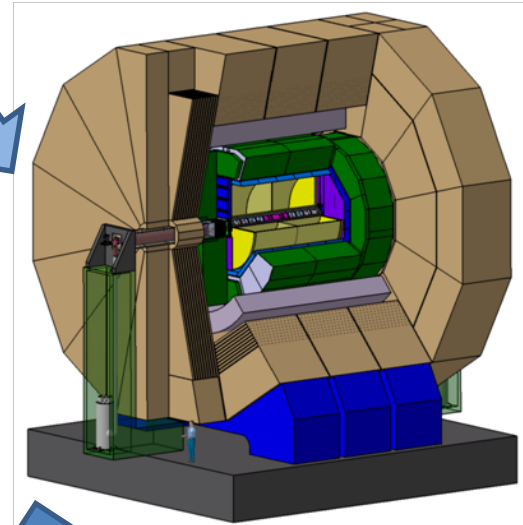
*The work reported here is done within the SiLC R&D collaboration and EUDET project and the ILD concept plus collaborative contacts with SiD.*



# Two tracking strategies



All Silicon tracking



Combined Silicon &  
gaseous tracking

Two integration solutions:  
Differences but still many common issues

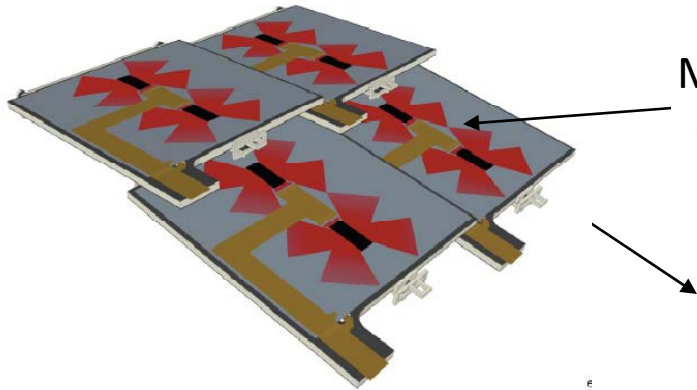
*The LOIs submission triggered a lot of activities & progress in this field that must be pursued!*

# An All Silicon tracking case



~100 m<sup>2</sup> Si Strips: Barrel single sided (r- $\phi$ ); endcaps double sided

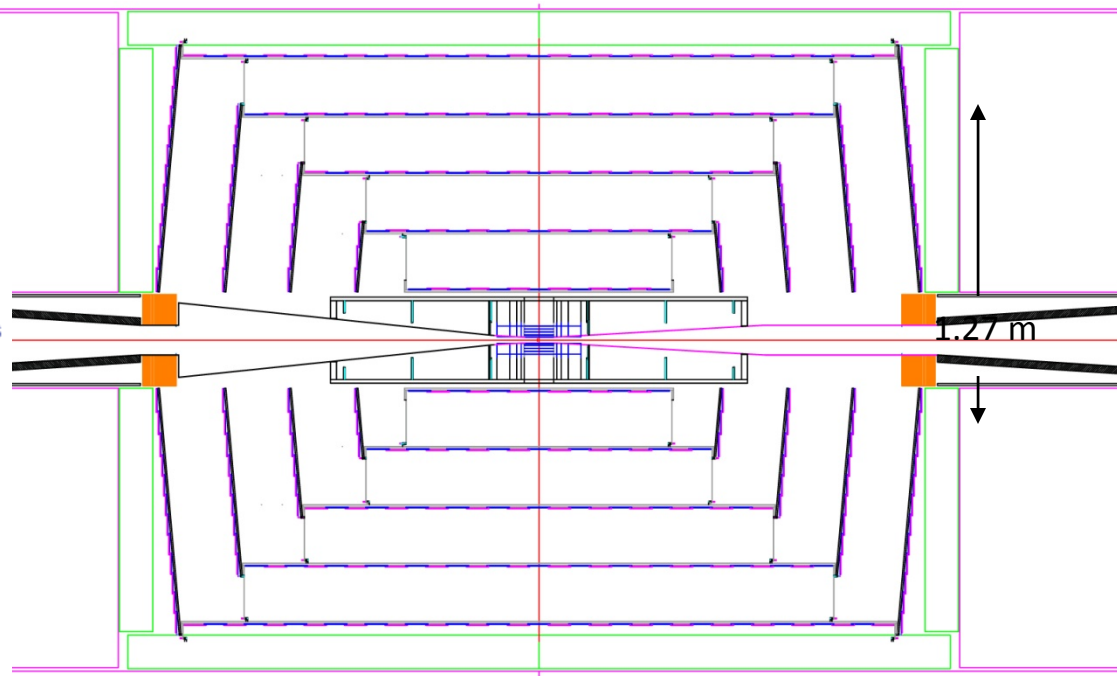
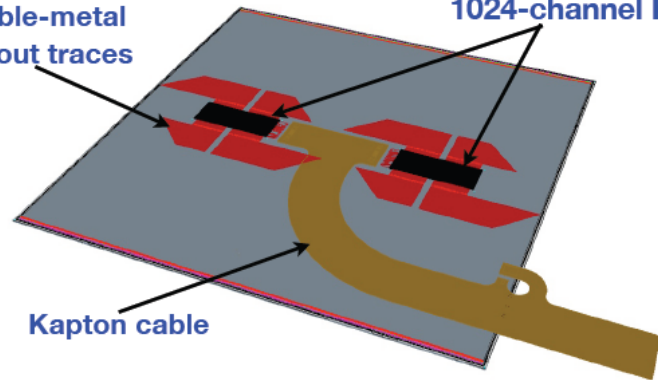
Modular low mass sensors tile CF cylinders



Double-metal  
readout traces

1024-channel KPixs

Kapton cable



~10 cm x 10 cm; 320  $\mu$ m thick; 25  $\mu$ m sense pitch; 50  $\mu$ m readout (prototype fabricated);  
S/N > 20; <5  $\mu$ m hit resolution

Bump bonded readout with 2 KPix chip; no hybrid

KPix measures amplitude and bunch # in ILC train, up to 4 measurements per train

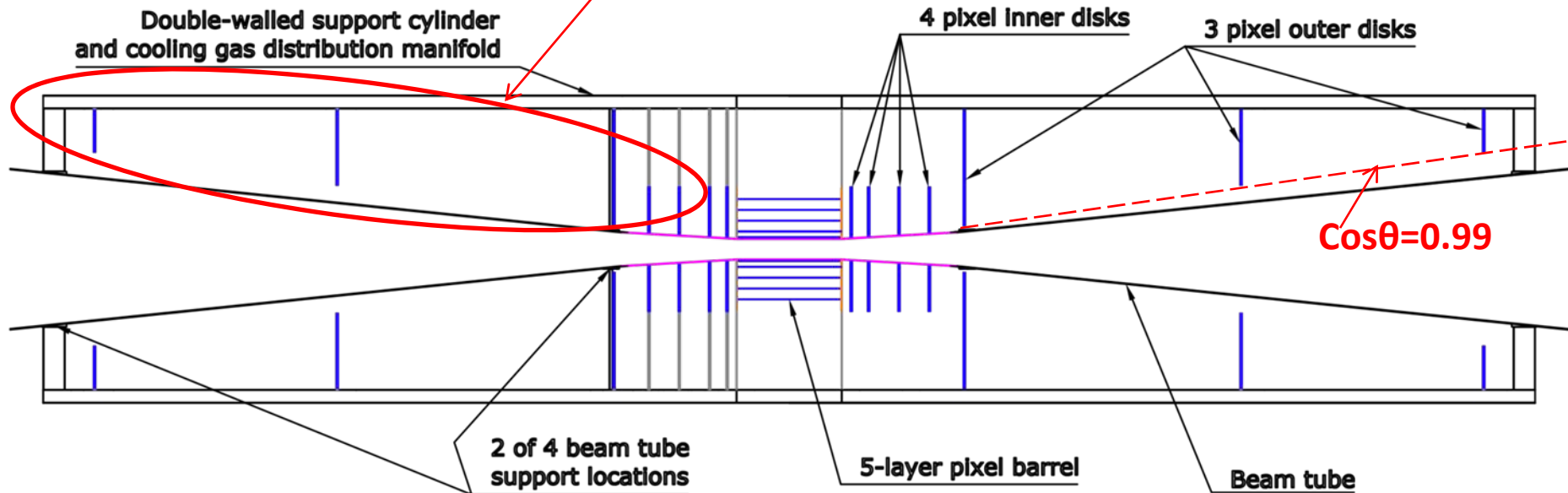
Pulsed Power: 20  $\mu$ W/channel avg; ~600 W for 30 M channels; gas cooling

(From SiD LOI talk)

# The inner tracking part of SiD



In their latest designs, all ILC detector concepts are introducing a few more forward disks in order to ensure the tracking coverage down to very low angle w.r.t beam axis (see also 4<sup>th</sup>)

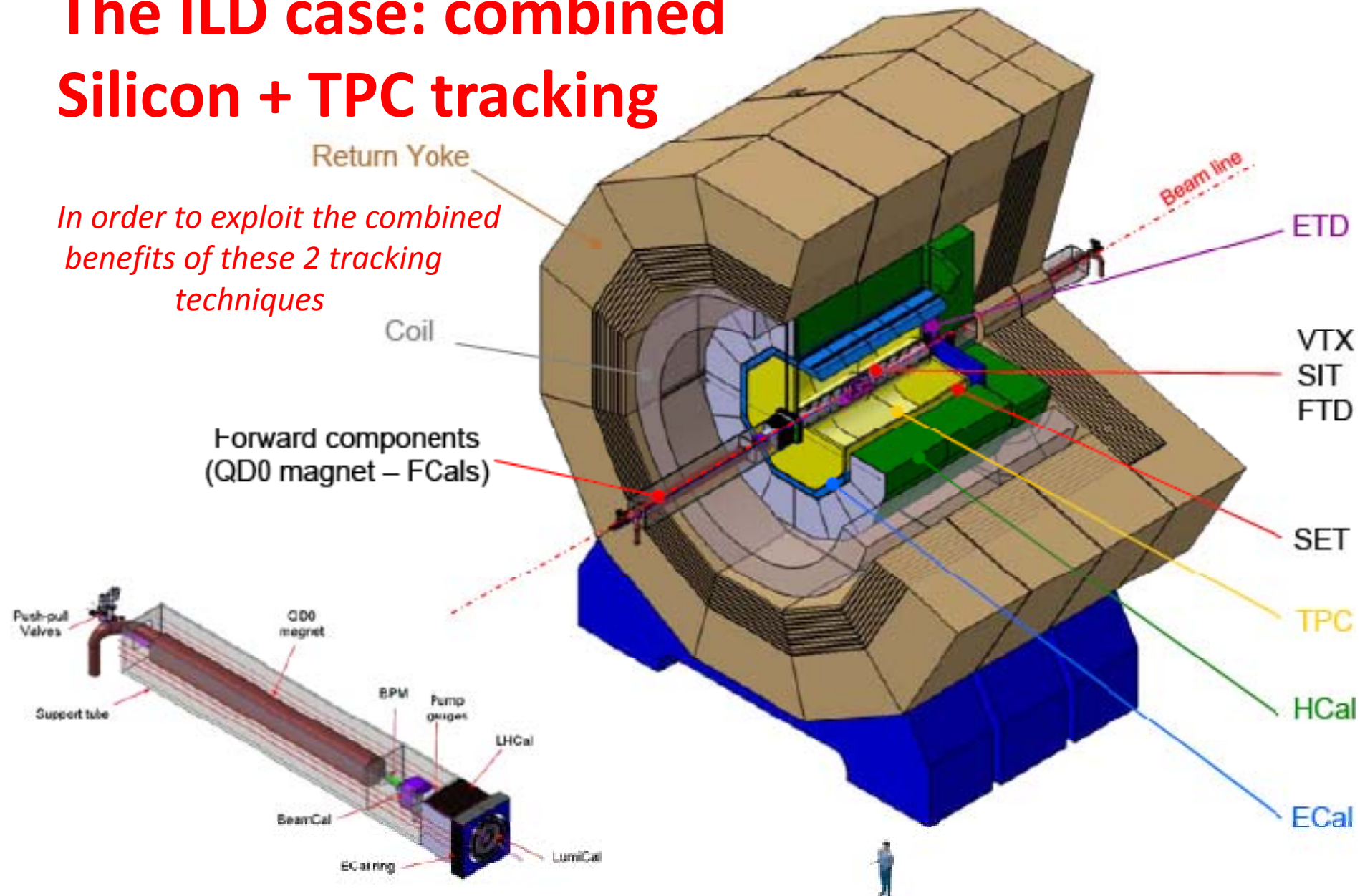


- Around the beam pipe two 4-plane end disk assemblies and three additional disks per end for extended coverage.
- All elements are supported indirectly from the beam tube via double-walled, carbone fiber laminate half cylinder.
- Sensor thickness of 75  $\mu\text{m}$  assumed, with 20 x 20  $\mu\text{m}^2$  pixel size

(Courtesy M. Demarteau)

# The ILD case: combined Silicon + TPC tracking

*In order to exploit the combined benefits of these 2 tracking techniques*





# Integration of a Silicon system into the ILD concept: remarks

The construction and the integration of a Silicon tracking system, part of an hybrid tracking ensemble (CDF, ATLAS) 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:**

An 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 fulfill the role of a highly performing tracker i.e. in 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....

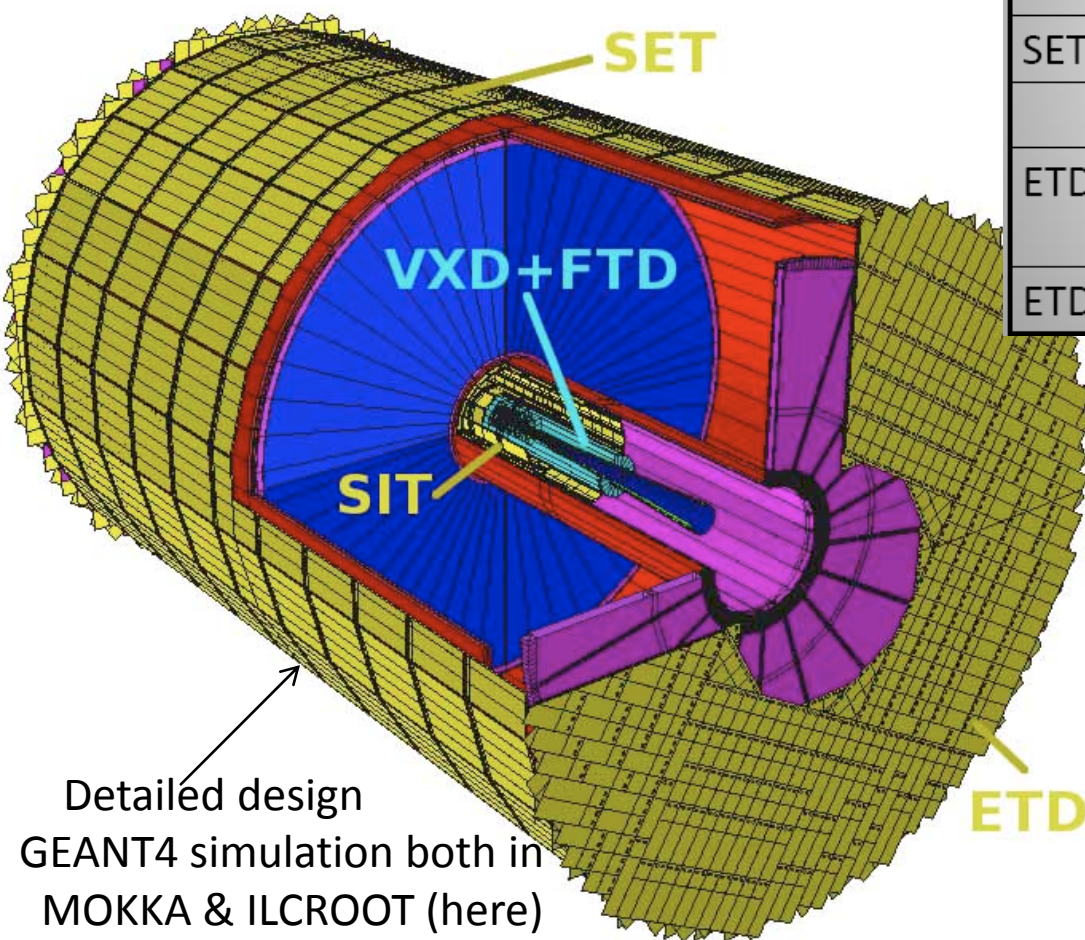
➤ **ALIGNMENT:** “global” in the all Si case, “mixed-mode” in the hybrid case.

➤ **COOLING:** here also much more constraining in the hybrid case (much more dependant on the neighbors)



# The Silicon Envelope in numbers (current scheme)

**ILD**



Component	Layer #	# modules	# sensors/ module	# channels	Total surface m2
SIT1	1 <sup>st</sup> layer	33	3	66.000	0.9
	2 <sup>nd</sup> layer	99	1	198.000	0.9
SIT2	1 <sup>st</sup> layer	90	3	180.000	2.7
	2 <sup>nd</sup> layer	270	1	540.000	2.7
SET	1 <sup>st</sup> layer	1260	5	2.520.000	55.2
	2 <sup>nd</sup> 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 number of channels:**

$$10^6 \text{ (SIT)} + 5 \times 10^6 \text{ (SET)} + 4 \times 10^6 \text{ (2 ETD)} \\ = \mathbf{10 \times 10^6 \text{ channels}}$$

**Total area:**

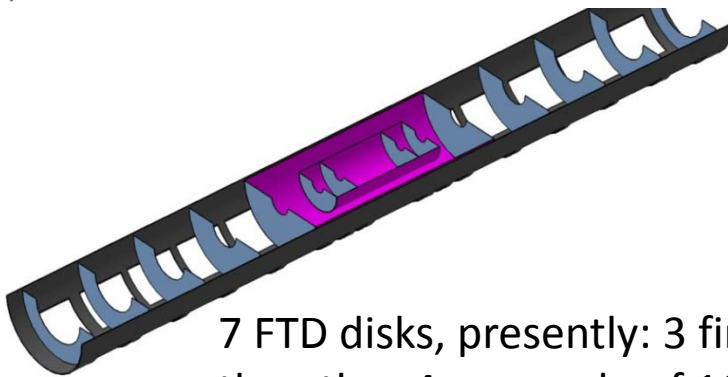
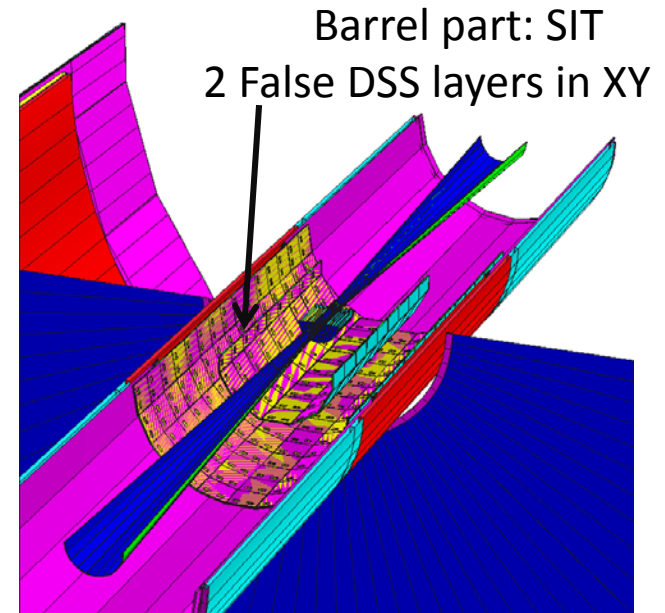
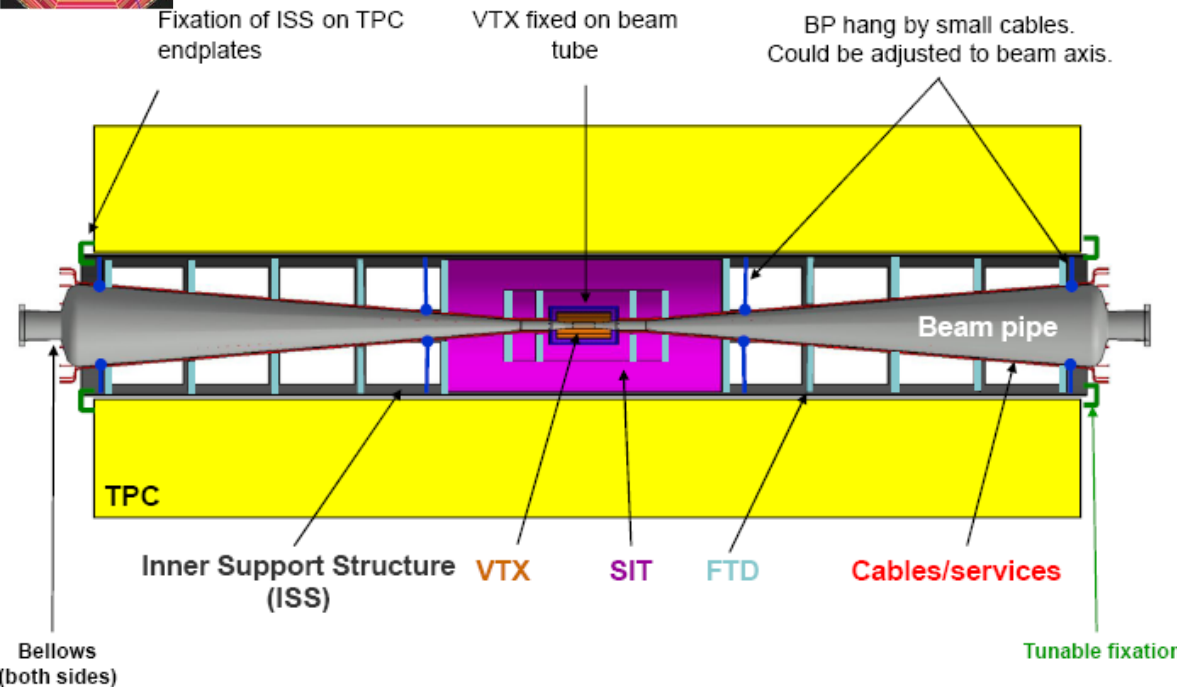
$$7 \text{ (SIT)} + 110 \text{ (SET)} + 2 \times 30 \text{ (ETDs)} = \mathbf{180 \text{ m}^2}$$

**Total number of modules:**

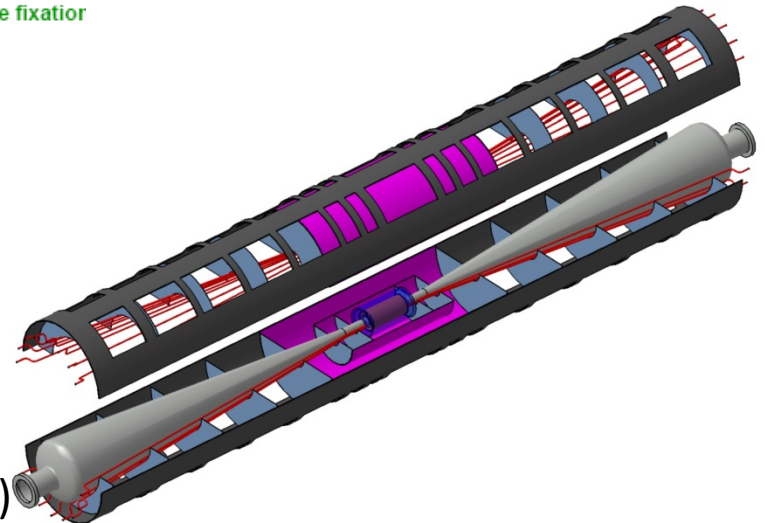
$$500 \text{ (SIT)} + 2500 \text{ (SET)} + 2000 \text{ (ETDs)} = \\ \mathbf{5000 \text{ modules with unique size sensors}}$$



# ILD inner Si tracking system

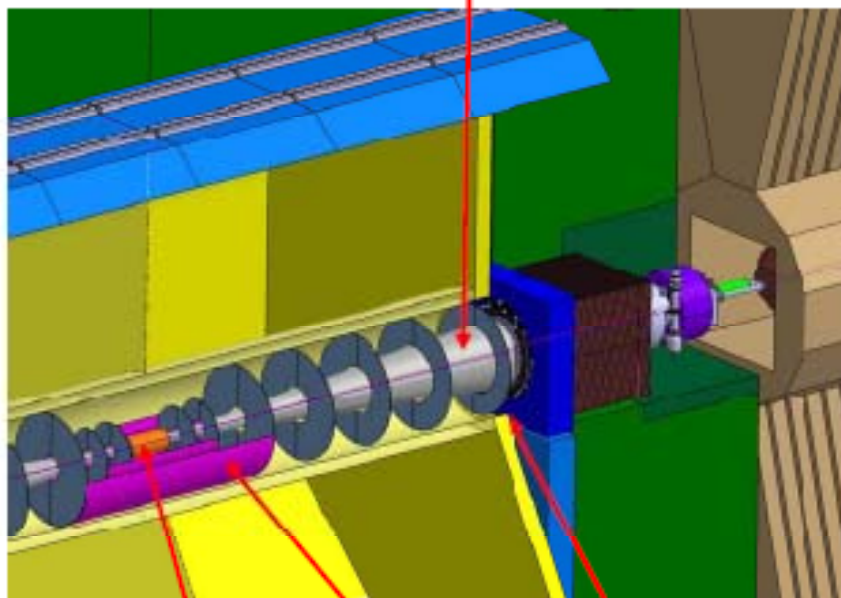


7 FTD disks, presently: 3 first = pixels,  
the other 4 are made of 16 petals with  
DSS strip sensors (similar to FWD ATLAS)  
*Possibly later: all pixels (?)*





Beam pipe



VTX

SIT

FTD

## 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

There is for ALL the Silicon components only one cable path, i.e. the one along the beam pipe as sketched here below

Cables



Support structure

Courtesy of M. Jore



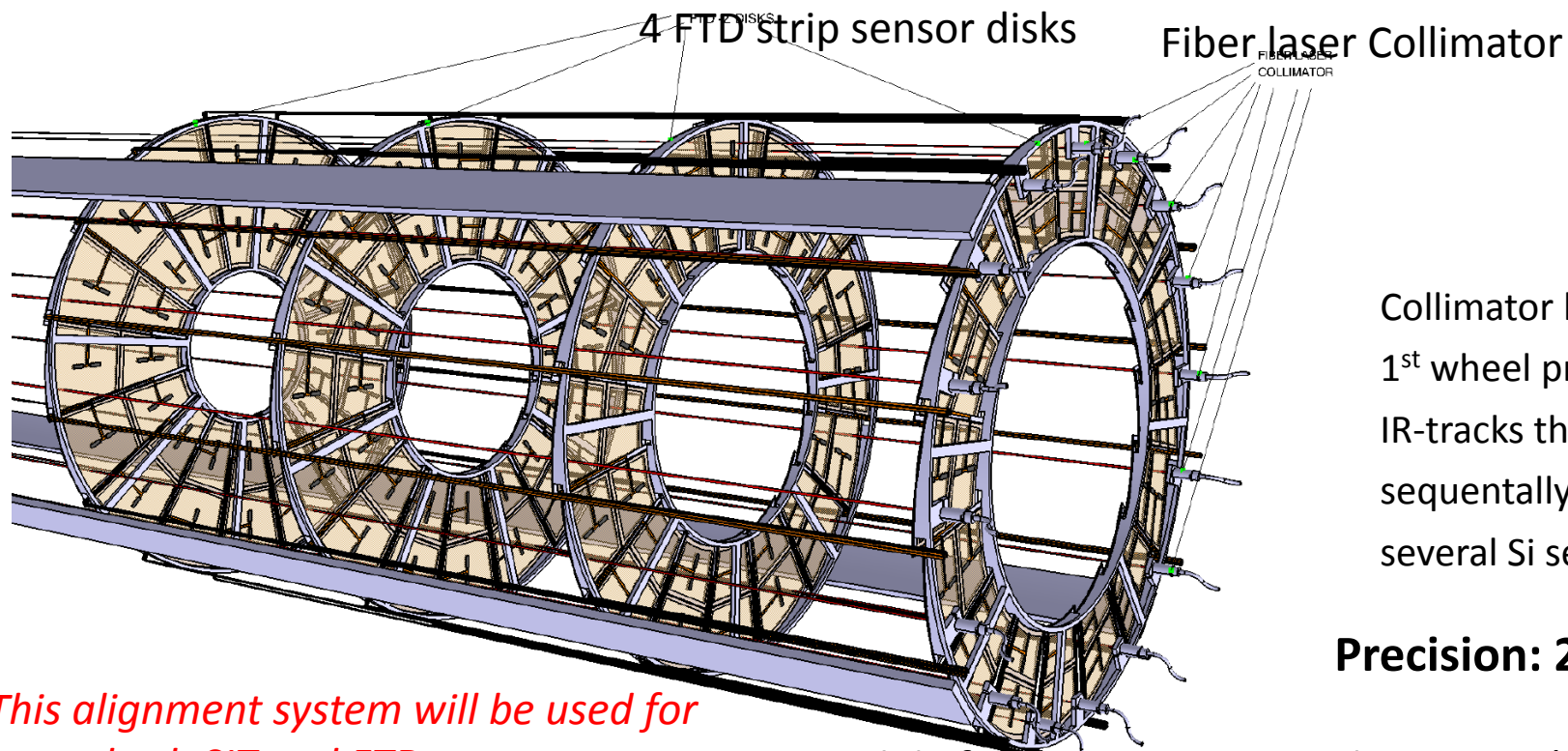
# ALIGNMENT (IMB-CNM & ICFA)



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

Selected sensors are traversed by IR beams.

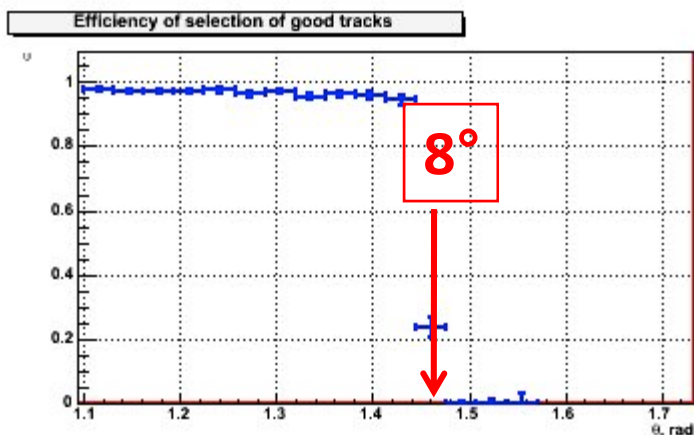
These beams are then measured as particle tracks and a first order alignment scenario is obtained. The rest of sensors are aligned using particle tracks. The transference of coordinates from optical aligned to track aligned modules is done via sensor overlap.



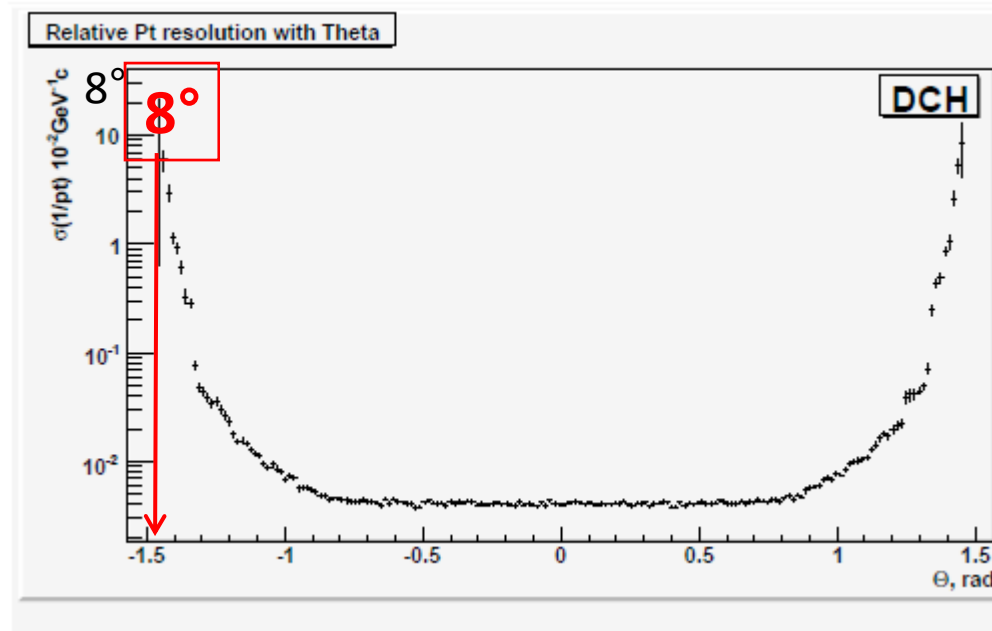
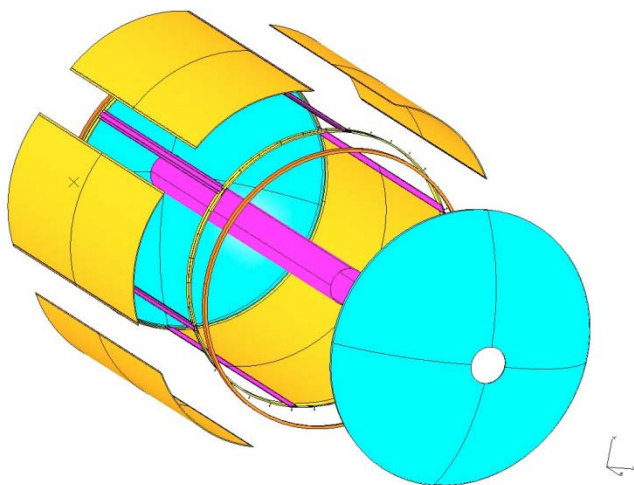
*This alignment system will be used for both SIT and FTD*

*Slide from Marcos Fernandez Garcia (IFCA)*

# Nobody is perfect ....



Drift chamber efficiency vs theta



Momentum resolution vs theta

Courtesy F. Grancagnolo (CLUCOU in 4<sup>th</sup>)



**Need also further forward coverage**



# *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.

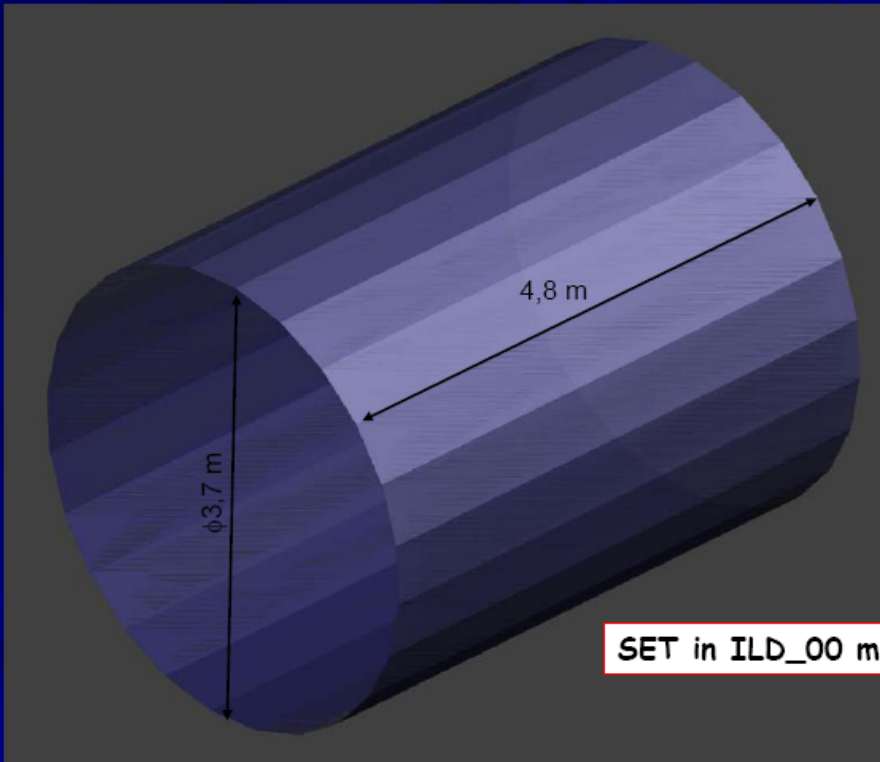
After a certain number of preliminary designs and studies, P. Mereu and D. Gamba have come to the following basic design:

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 are being studied.



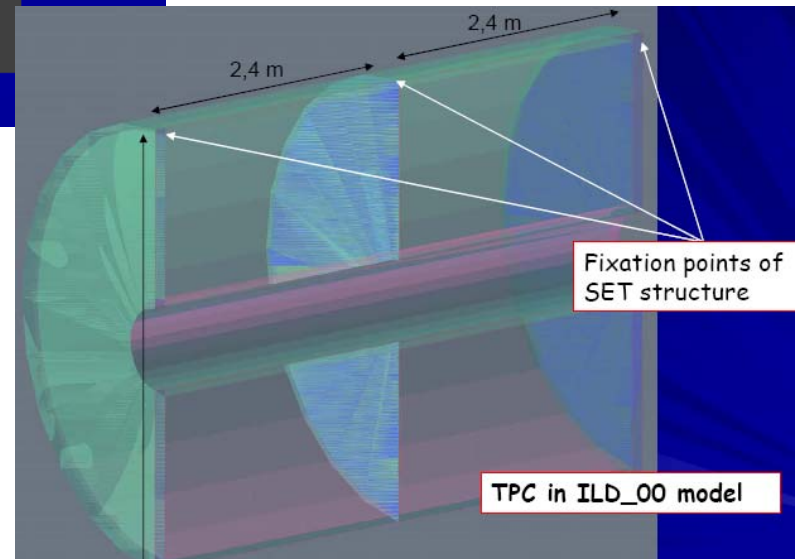


SET in ILD\_00 model

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

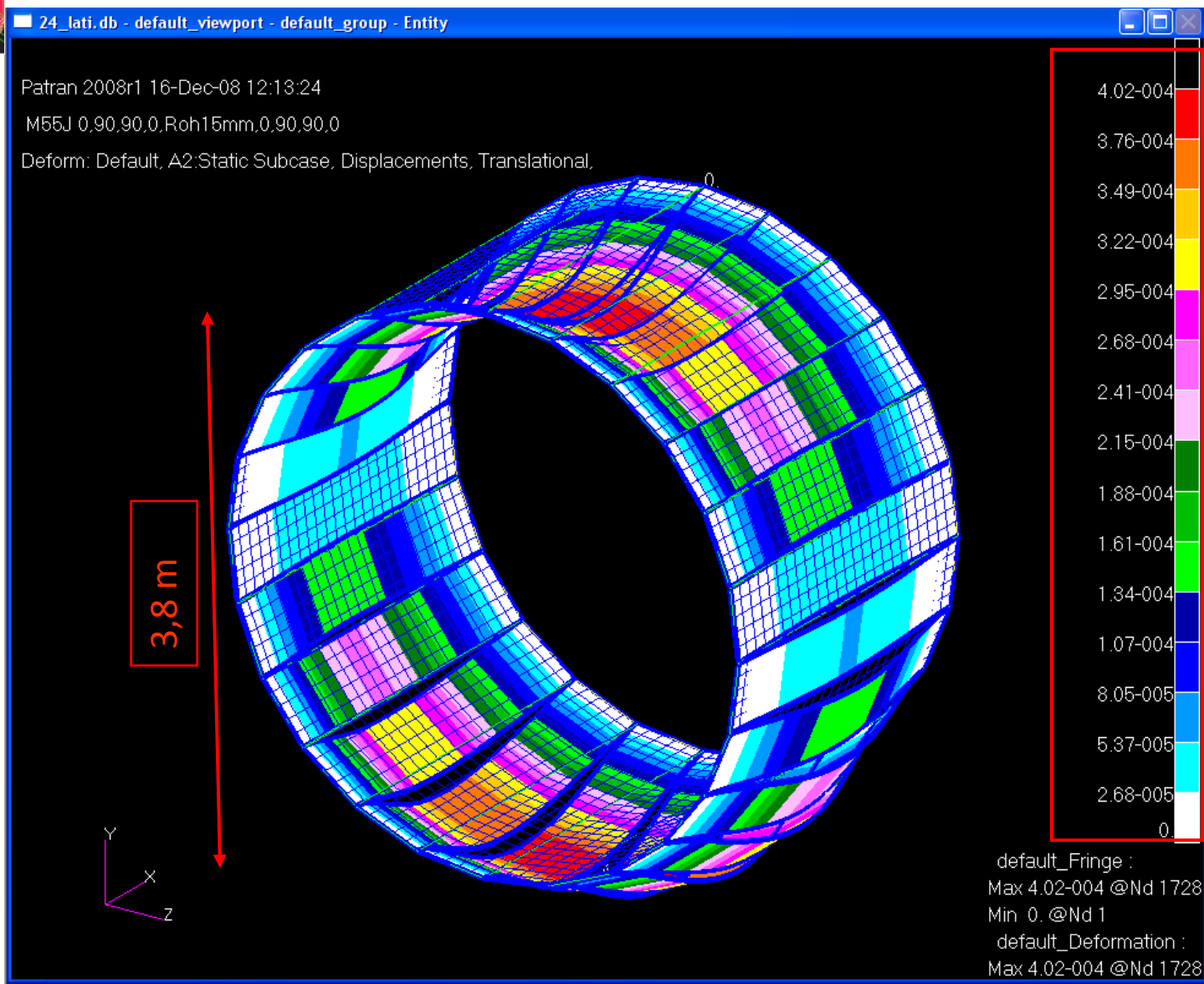
paolo.mereu@to.infn.it

8th SILC Meeting – IFCA Santander  
17-19 December 2008

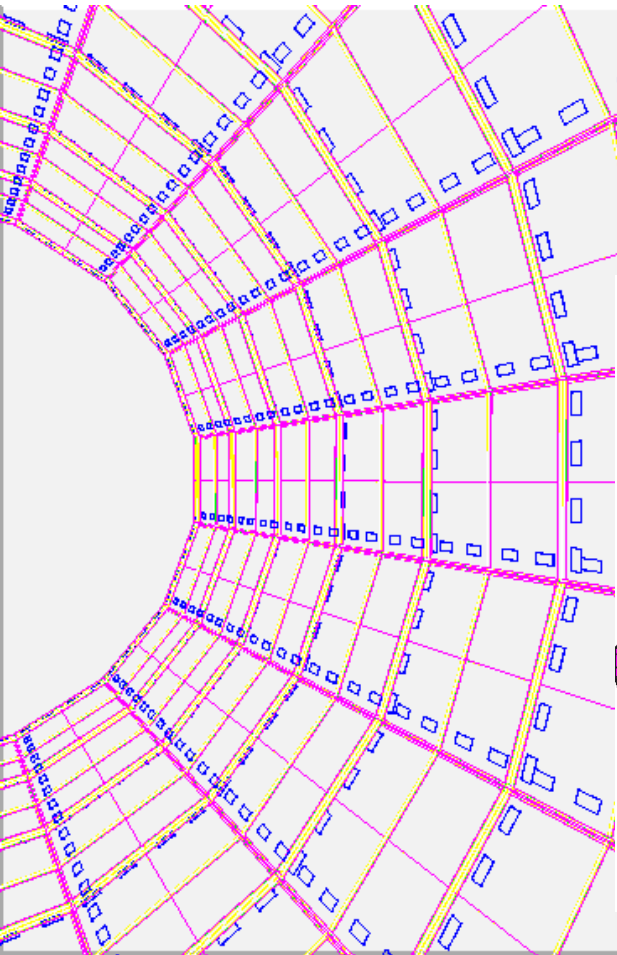


TPC in ILD\_00 model

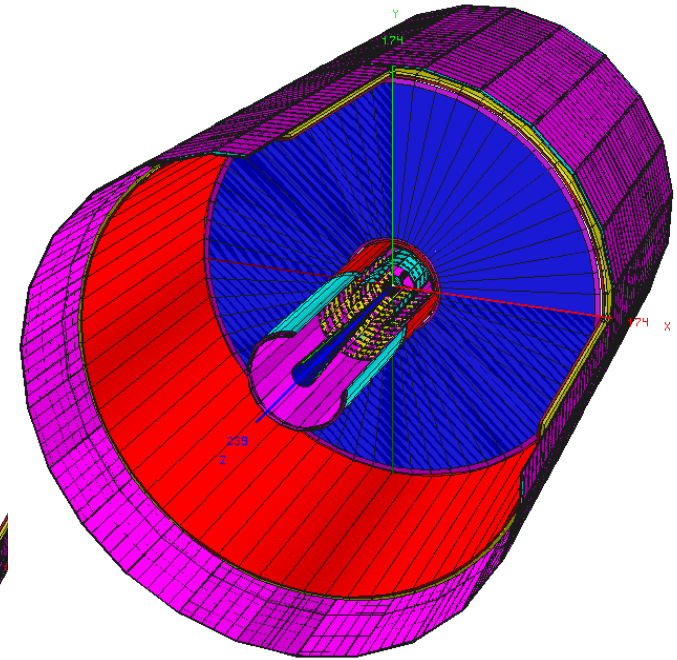
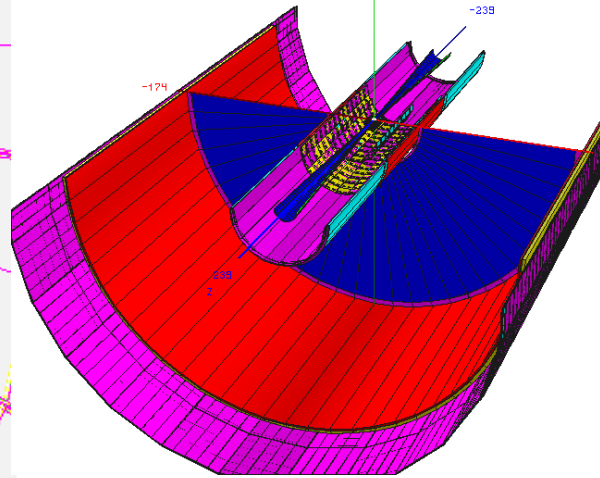
Each panel is independently fixed at both short  
sides to the outer surface of the TPC structure



# 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

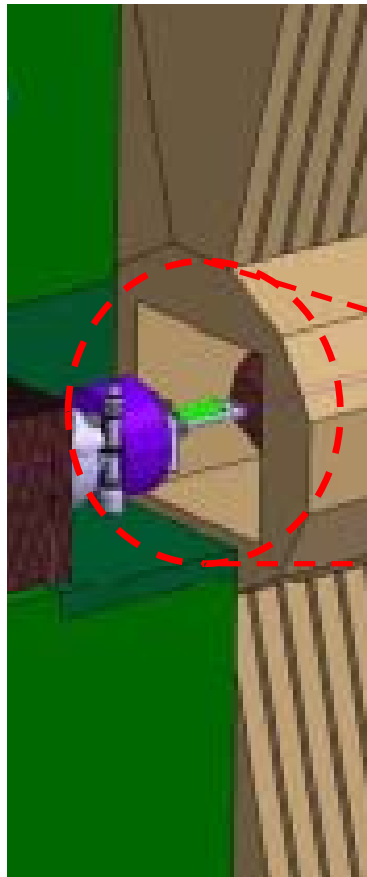


ILCROOT simulation

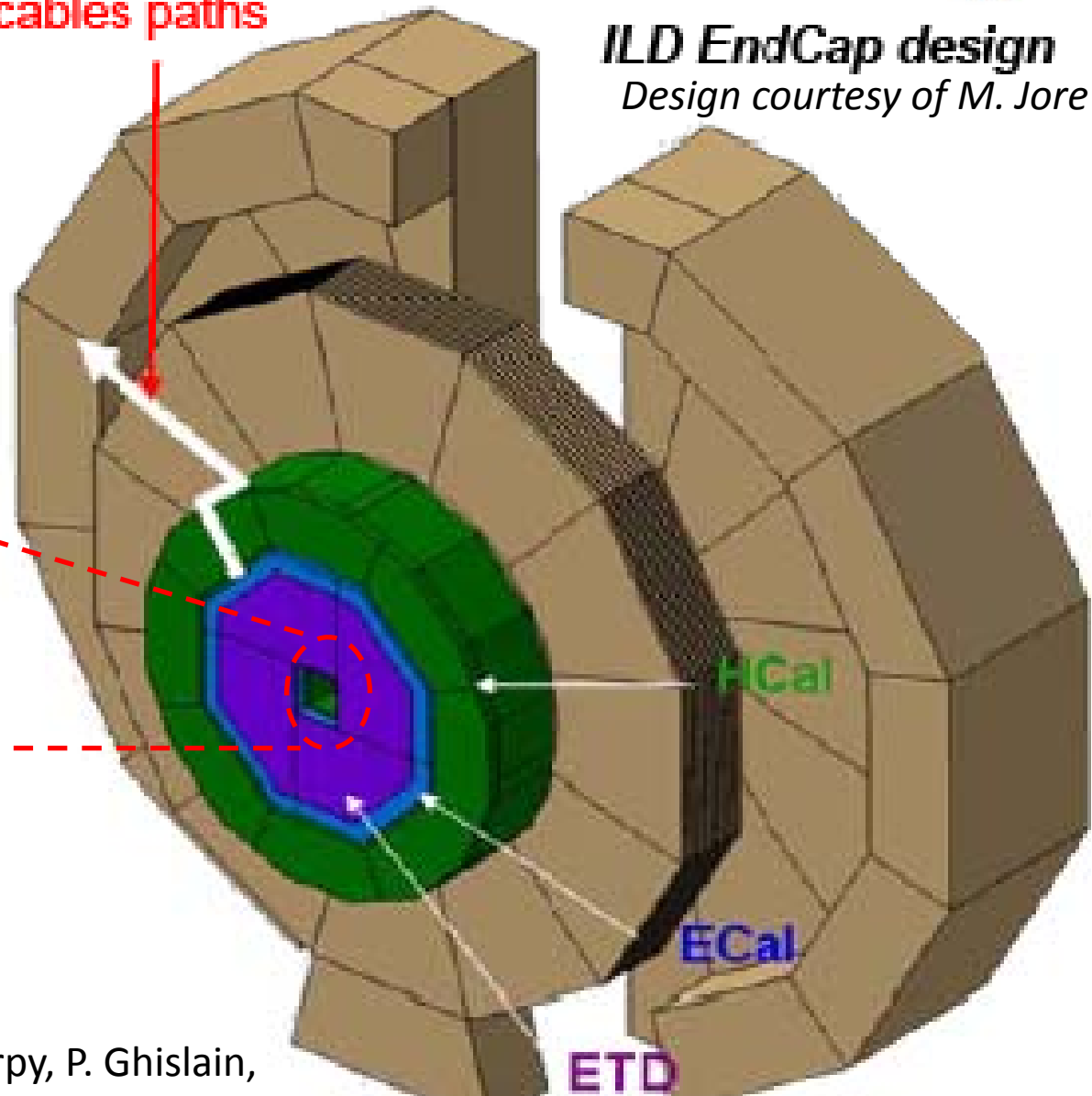
**Challenging issues: alignment** (the positioning on the TPC wall must be precise at  $100\mu\text{m}$ ) well monitored wrt SIT could/should be refined with a few tens of  $\mu\text{m}$  (under study). Power dissipation from calorimeters? Vibrations? Etc... Issues to be studied.

# ETD integration in the end cap and Very Forward calorimeter region

**ILD EndCap design**  
*Design courtesy of M. Jore*



**cables paths**



**ETD**

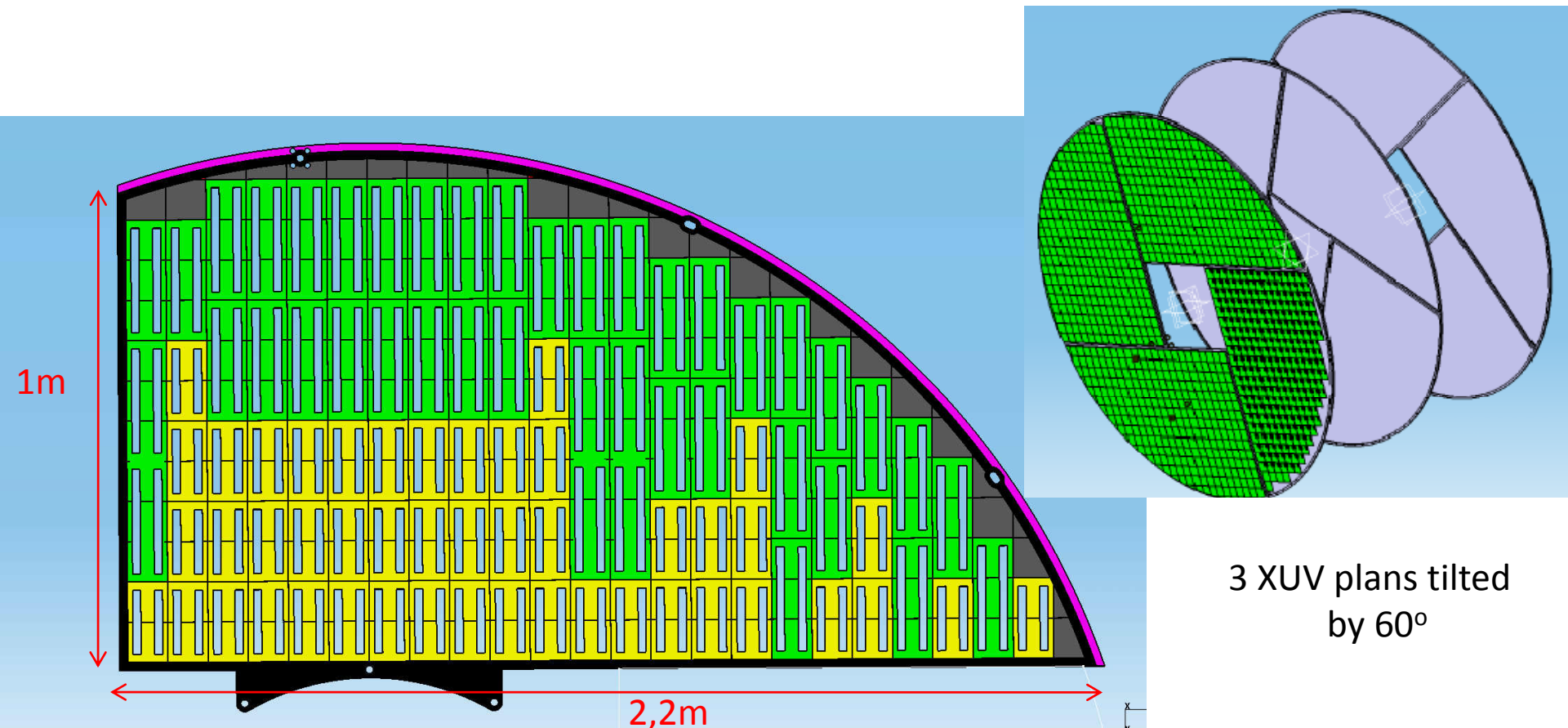
**ECal**

**HCal**

ETD studied at LPNHE: A. Charpy, P. Ghislain,  
 D. Imbault, ASN and with M. Jore, R. Poeschl (LAL), P. Anduze (LLR) & D. Grondin(LPSC)



# One quadrant of XUV end cap: present design



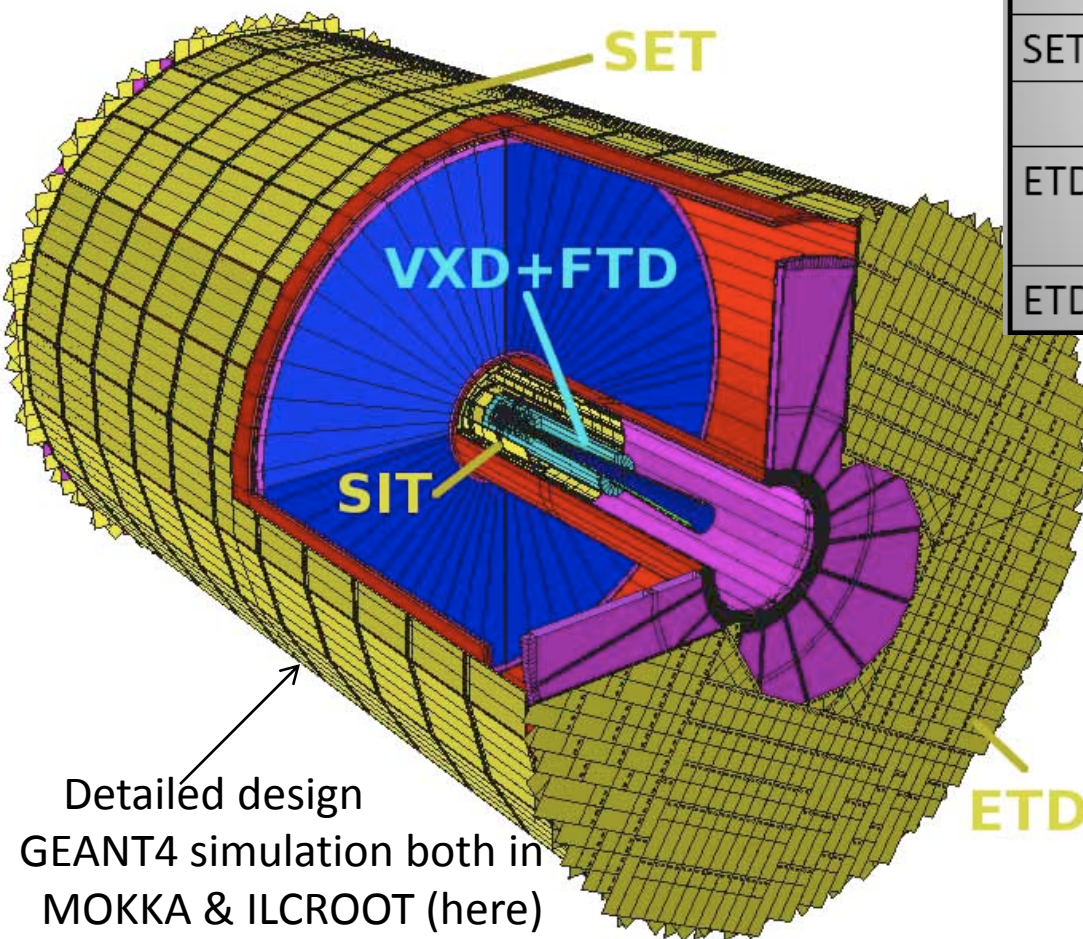
3 XUV plans tilted  
by  $60^\circ$

Made of modules with 2 (yellow) or 3 (green) sensors. (current design, rapidly evolving)  
12 quadrants per XUV triplets. Thus 24 in total. Fixed via a C fiber membrane to the e.m. calorimeter; Positioning screw with precision of the order of  $100\ \mu\text{m}$ , light but very precise. A mechanical prototyped quadrant will be built and tested with mechanical proto of e.m.



# The Silicon Envelope in numbers (current scheme)

**ILD**



Component	Layer #	# modules	# sensors/ module	# channels	Total surface m2
SIT1	1 <sup>st</sup> layer	33	3	66.000	0.9
	2 <sup>nd</sup> layer	99	1	198.000	0.9
SIT2	1 <sup>st</sup> layer	90	3	180.000	2.7
	2 <sup>nd</sup> layer	270	1	540.000	2.7
SET	1 <sup>st</sup> layer	1260	5	2.520.000	55.2
	2 <sup>nd</sup> 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 number of channels:**

$$10^6 \text{ (SIT)} + 5 \times 10^6 \text{ (SET)} + 4 \times 10^6 \text{ (2 ETD)} \\ = \mathbf{10 \times 10^6 \text{ channels}}$$

**Total area:**

$$7 \text{ (SIT)} + 110 \text{ (SET)} + 2 \times 30 \text{ (ETDs)} = \mathbf{180 \text{ m}^2}$$

**Total number of modules:**

$$500 \text{ (SIT)} + 2500 \text{ (SET)} + 2000 \text{ (ETDs)} =$$

**5000 modules with unique size sensors**  
**=> Achieved: a unified and simple design**  
**for all components (except FTD)**

Detailed design

GEANT4 simulation both in  
MOKKA & ILCROOT (here)  
& mechanical design (CATIA) in progress

# Common issues and challenges

- The basic module (*see next slides*)
  - The sensors (*see next slides*)
  - The forward Si tracking (converging scheme) ✓
  - The FEE and direct connection to the sensor (*see next talk*)
  - Power cycling (*next talk*)
  - Effect of high B-field (vibrations) : **NOT YET (will be tested with new chips)**
  - The support structures ✓
  - The modularity: ✓
    - => towards a unique sensor type in the present ILD design for all components but FTD and repetitive elements of construction (super-modules) : ✓
    - => or a unique module size (SiD) at least in the central barrel (the End Caps:??) : ✓
  - The cooling (*studies ongoing since a few years on Si prototypes –SiLC- need combined tests with other sub-detectors mechanical prototypes (foreseen)*)
  - The alignment techniques ✓
  - The stability, robustness, reliability (*under study*)
  - Calibrations, monitoring, push pull issues (*under study or development*)
- Even if alternatives are looked for by the different detector concepts, the issues and often the solutions to them are rather similar. A lot of work underway within SiLC.*
- A few examples have been already shown and a few more here after.*



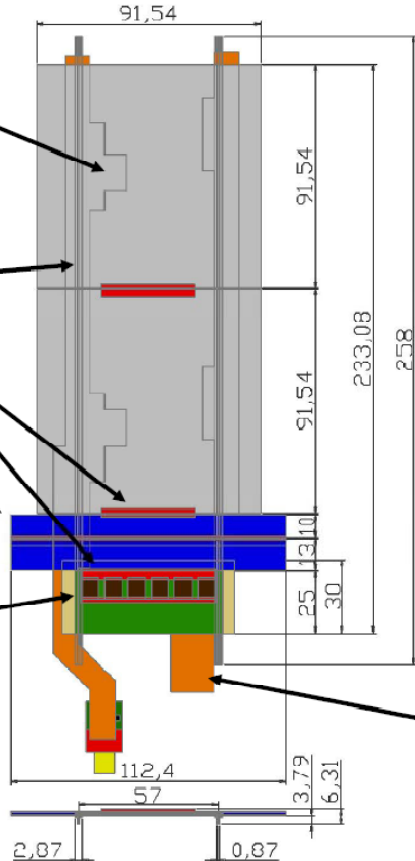
HV Kapton Foil

Wire Bonds

Intermediate Pitch Adapter

Ceramic Support

Carbon Fibre Profile



Signal Cables

TEC-R2 Hybrid+PA

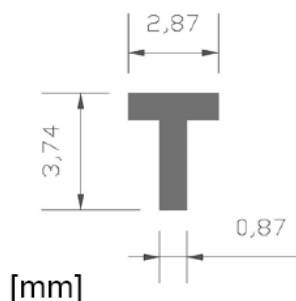
Stephan Haensel (HEPHY)

## KEY-PIECE of Si tracking: THE BASIC MODULE

Carbon Fibre Profile

FE readout ASIC (total /2000ch)

Cabling daisy chain with other modules



Present status (left) vs next step:

DSM-FE readout into one single unit:

8-256ch chips

Total size:  $8 \times 0.5 \text{ cm}^2$

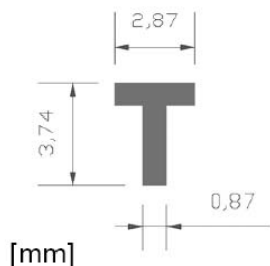
Thinned:  $50 \mu\text{m}$

Directly connected onto the sensor

⇒ No more pitch adapter,

⇒ No more hybrid board

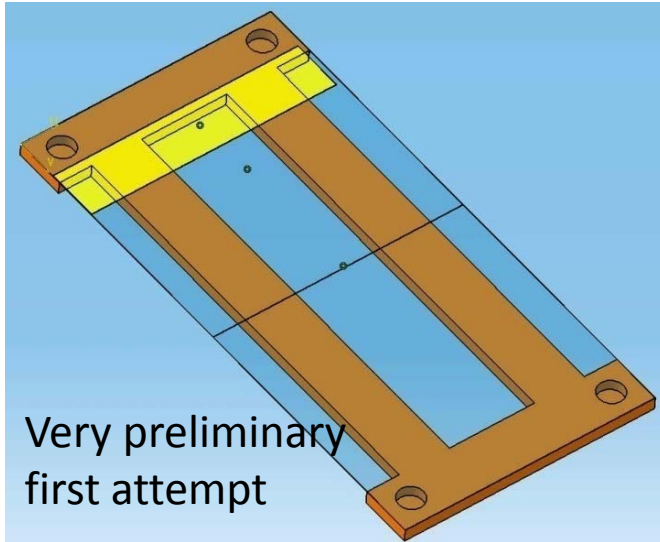
⇒ Change in the cabling technology



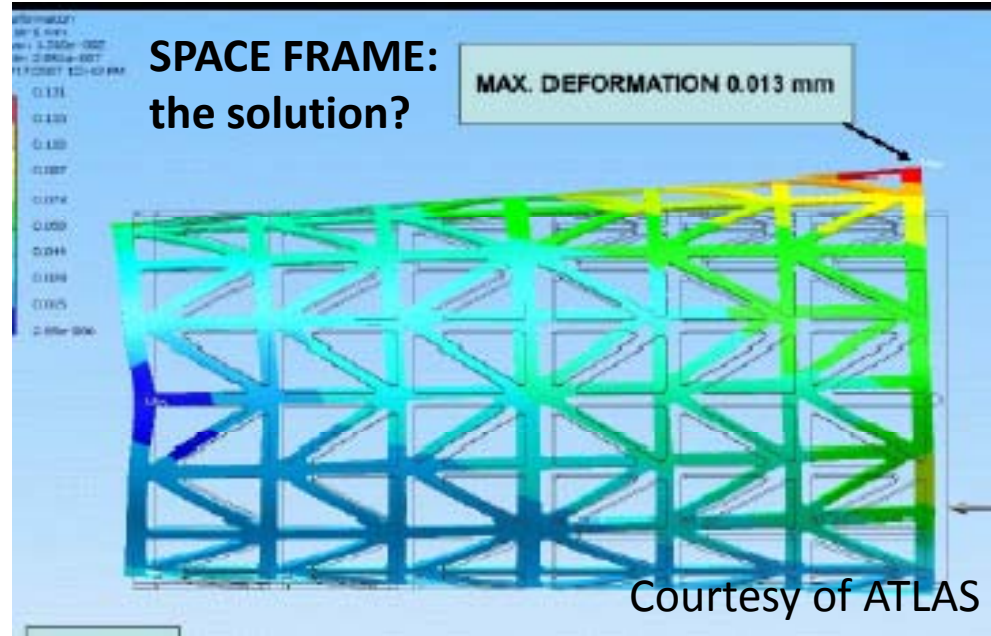
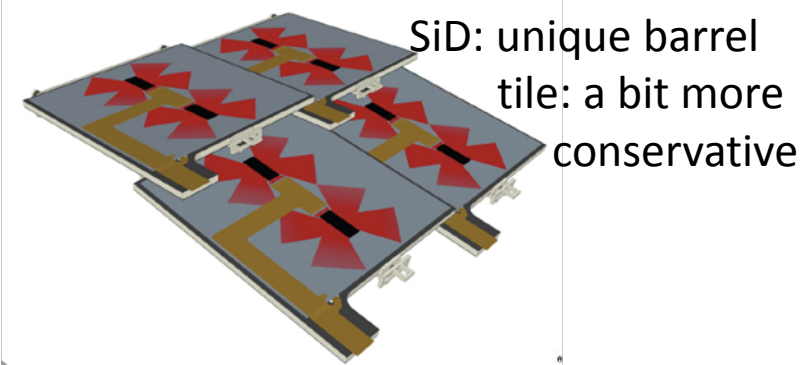
[mm]



# Light modules and supports: the diet...

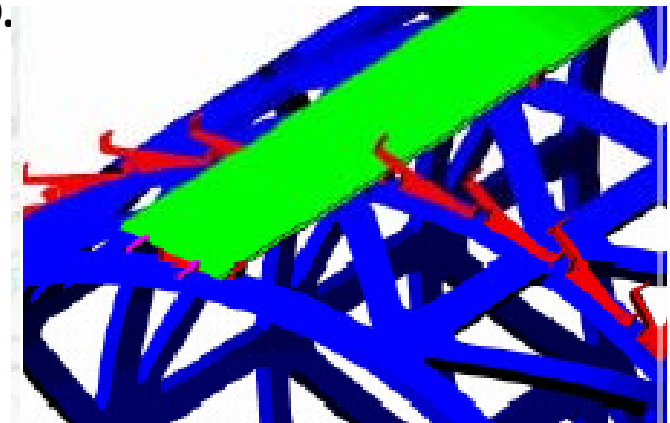


**SiLC (ILD) develops very light modules, with edgeless sensors (no overlay => challenging alignment btw modules) & variable strip length (exploit ILC cycle) thus reduction of electronic channels.**



**Detailed architecture of the support structure in progress at ILD.**

Super-module to be built by Torino (SET) & Paris(ETD) for studying the pending issues





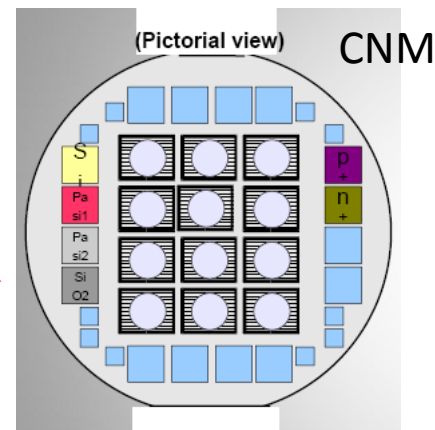
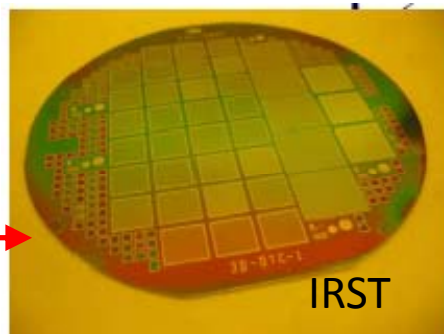
# R&D on sensors roadmap

## ➤ *Strip sensors: in progress*

“Standard strips” but: larger wafers 6” → 8”,  
thinner: 300 → 200 μm, pitch: 50 μm

## Edgeless:

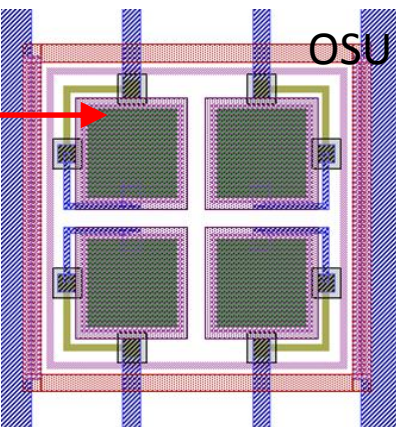
Planar 6”, 50 μm pitch,  
≤ 200 μm thick and 3D Planar



## ➤ *Strip sensors for alignment: in progress*

Standard specially treated

Novel technology



## ➤ *Smaller sensors granularity* (also wrt CLIC)

follow SLHC developments ex: strixels

**Pixels:** 3D technology based (Low Material Budget  
& High Gain Pixels by OSU) & joining the worldwide effort

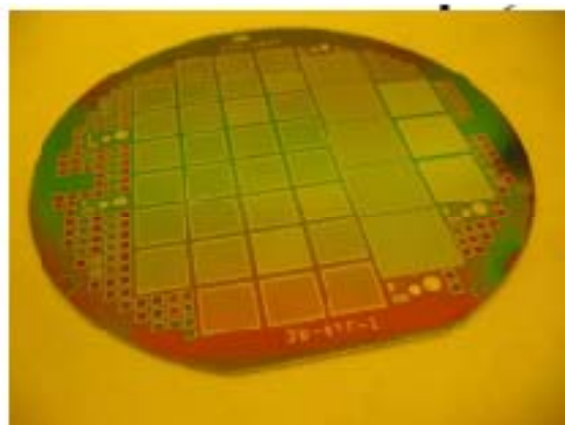
## ➤ *Inherited expertise* on detailed testing: *test structures*

## ➤ *Newly developed* refined tests at the *test beams*

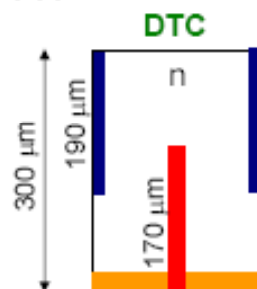


## 3D-DTC-1 batch

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



Column overlap not optimized:  
about 60μm



**NEW SENSORS R&D:**  
**R&D on 3D planar strips**

## 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 2<sup>nd</sup> DRIE etching, to be completed by 02/09.**

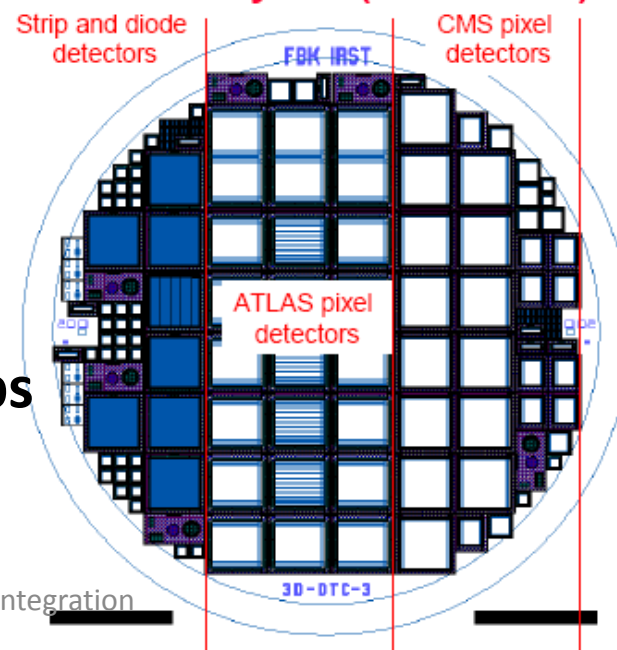
2) 3D-DTC-3: n-on-p, 250-μm thick substrate, full 3D detectors (passing-through) columns.

New double-sided process defined, no need for support wafer, also suitable for dual read-out pixel/strip.

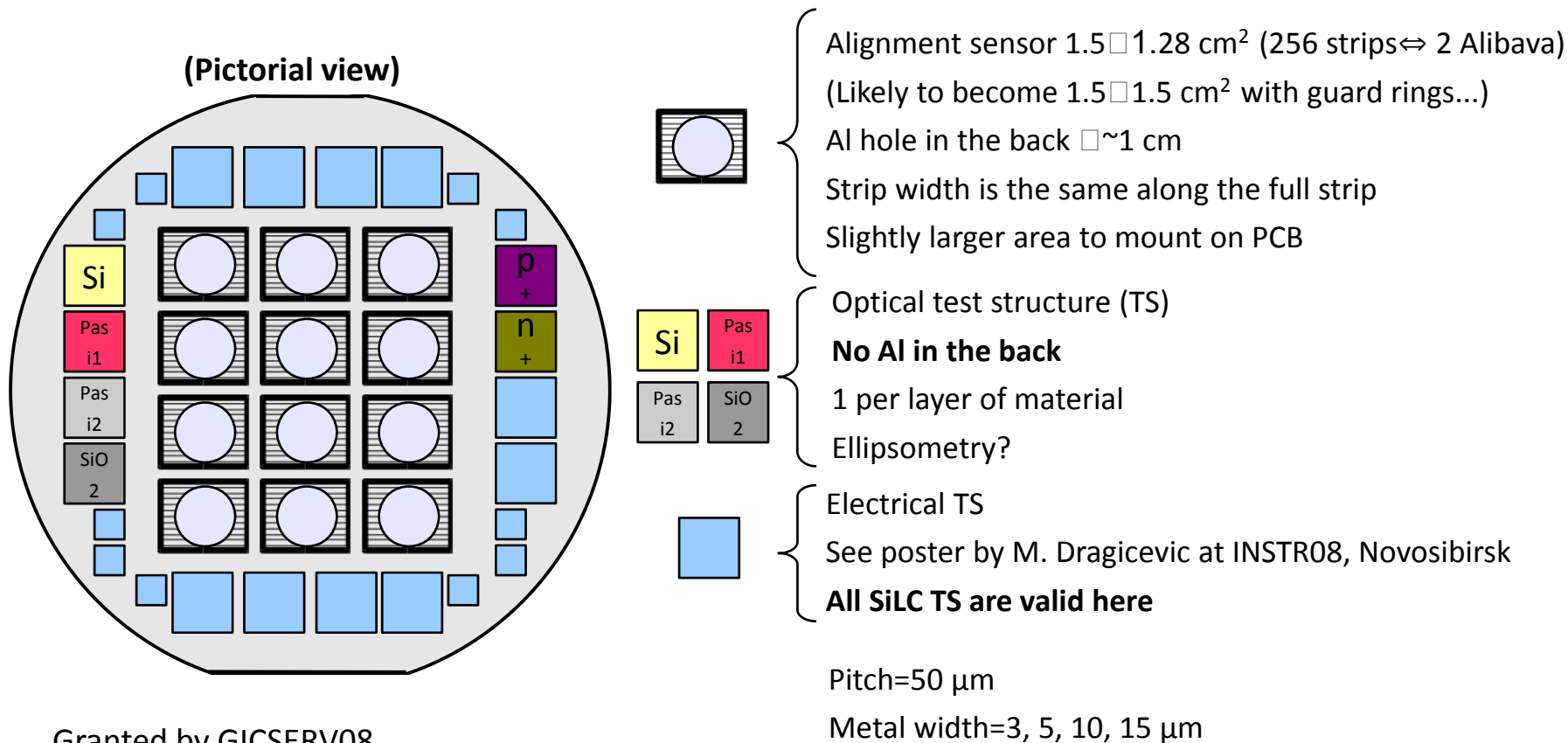
**Just started, to be completed by 04/09**



## New layout (3D-DTC-3)



**IMB-CNM (Barcelona) is producing the first sensor prototypes with multi-geometry and optimum thickness.** *Tentatively scheduled for test beam in August 2009 (?)*



Granted by GICSERV08

AC sensors

– Al strips

(3 wafers)

– Al strips&Al backside

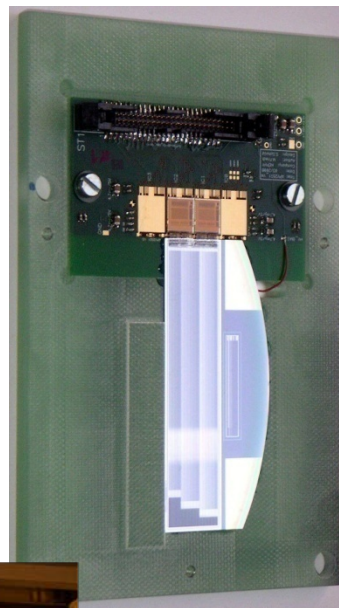
(1 wafer)





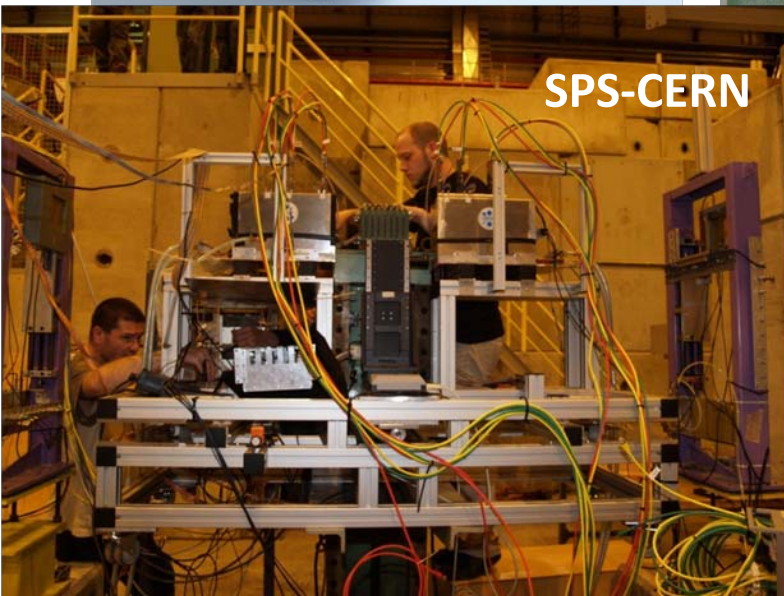
# Test bench to measure sensor detailed performances

HEPHY VIENNA

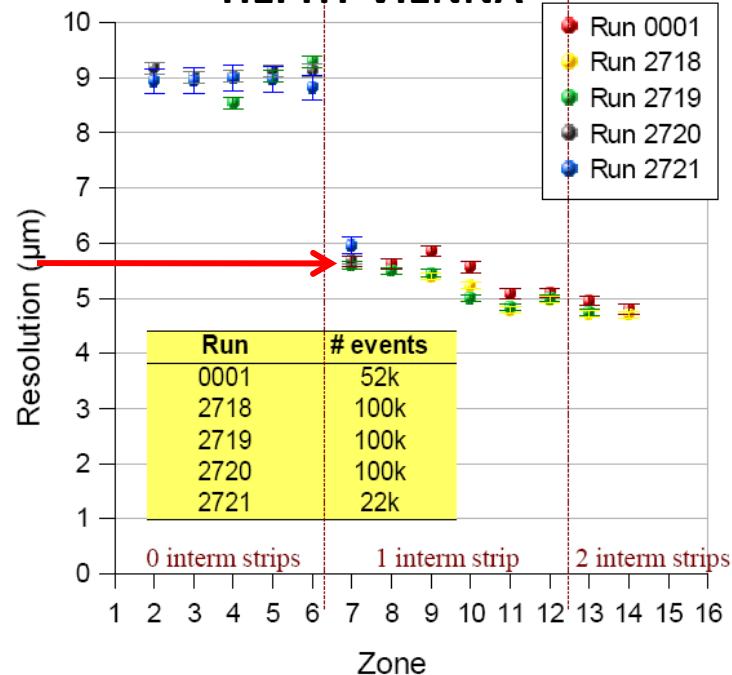


New series of tests in 2009 at CERN with novel sensors from IMB-CNM and from Poland with wire bonded chips. Expertise & experienced teams: asset

SPS-CERN



HEPHY VIENNA



(CU Prague)

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

# Concluding remarks

- The LOI gave a serious boost in developing realistic scenarios for integrating the Si tracking in the various detector concepts.
- Two Si tracking scenarios: with or without gaseous detector;  
The all-Si case is much simpler for integrating than the hybrid or combined case.
- But there are many common issues with often similar solutions in both schemes.
- This reinforces the interest of having an horizontal R&D that addresses these issues on common basis and gather the efforts of many teams to work on the best possible solutions.
- Moreover the test beams and prototypes developments are instrumental as well as the combined tests with other sub-detectors. There also an horizontal R&D helps in merging the efforts.
- The dynamics created with the LOIs should not be lost!!