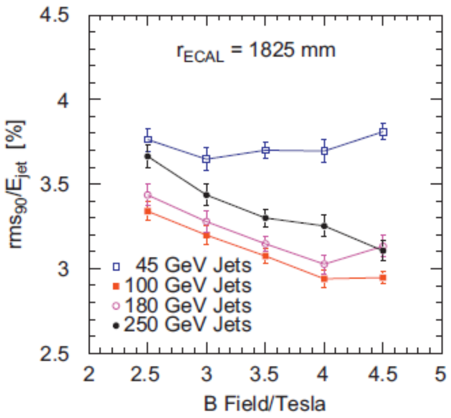
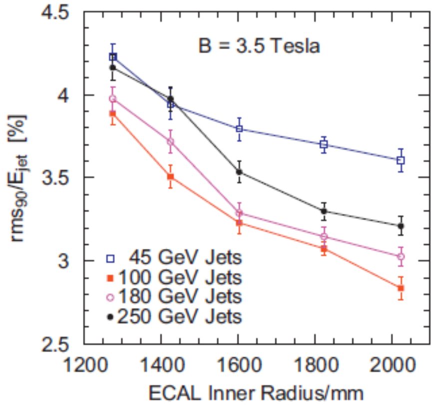
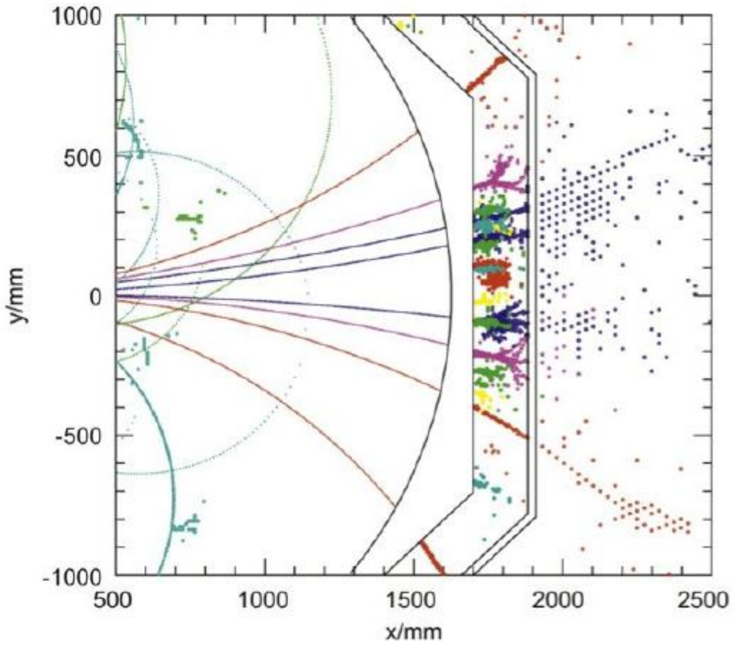
The ILD detector: Design optimization and TPC R&D

Paul Colas

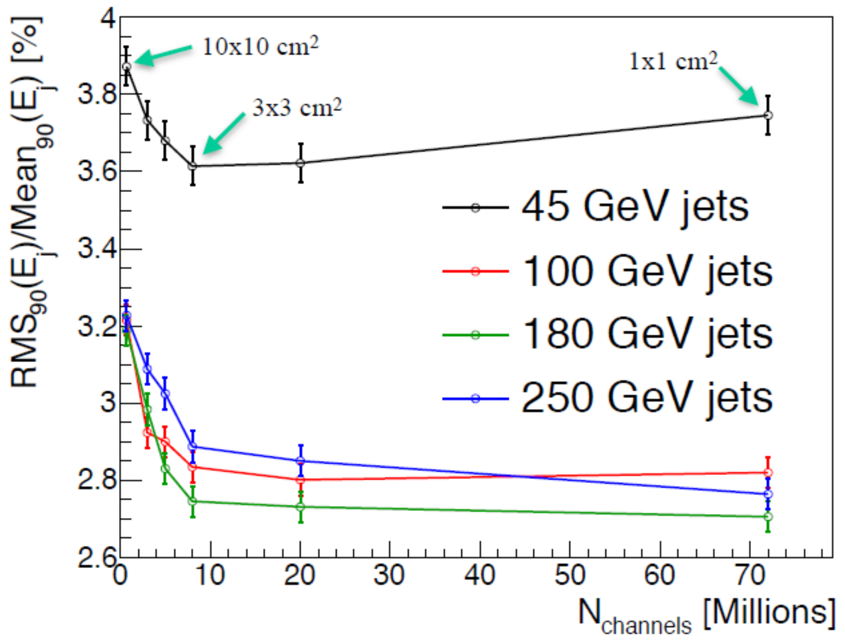






The ILD concept

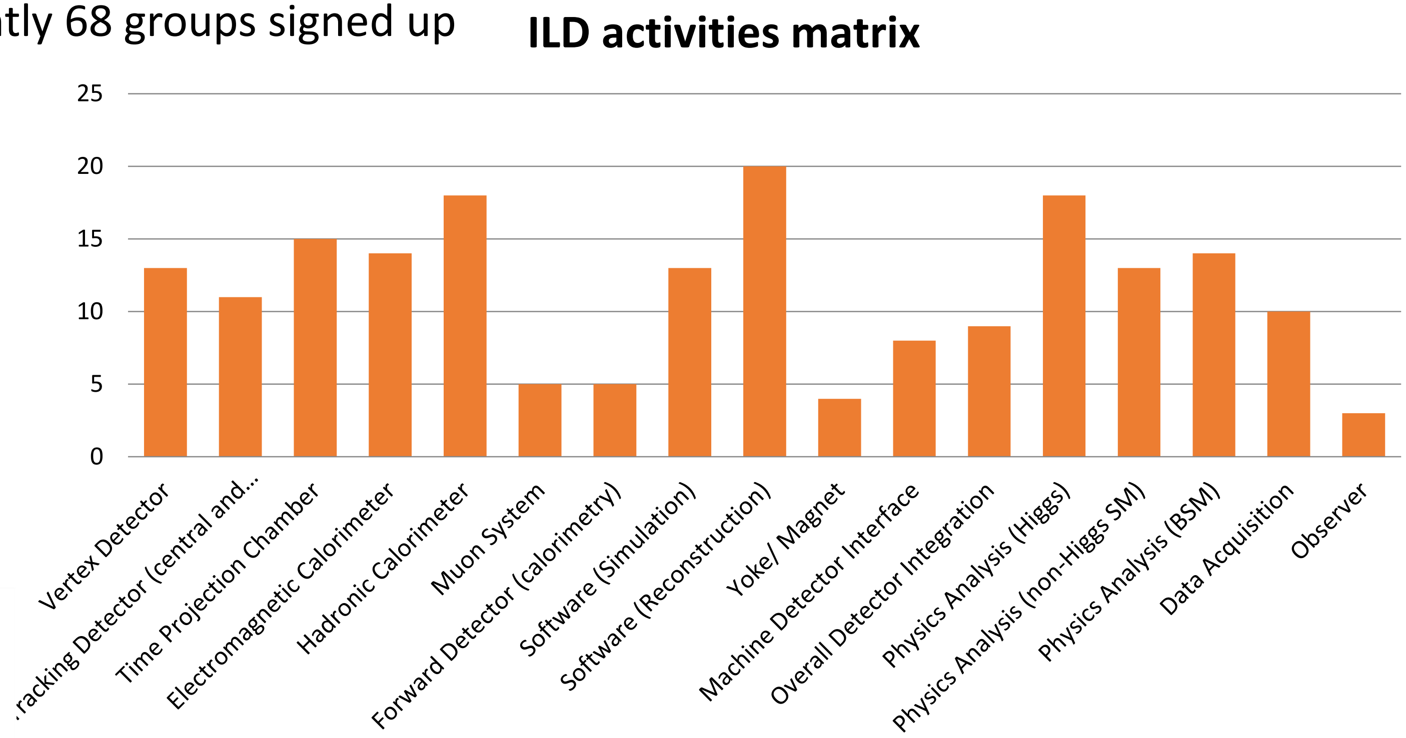
- Based on Particle Flow: reconstruct the event by matching calorimeter objects with charged tracks (use the most precise E-p determination, avoid double count between tracks and E objects
- Continuous tracking (TPC) and highly segmented calorimeters
- Optimize jet energy resolution .vs. B, R_{TPC} , ECAL cell size : 3.5T, 1.7 m or 1.4 m, 1cm or less (MIP subtraction)

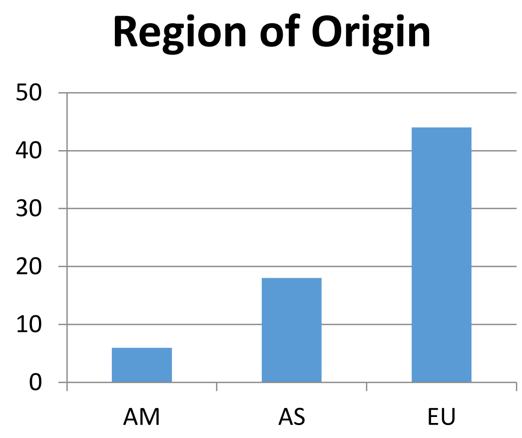


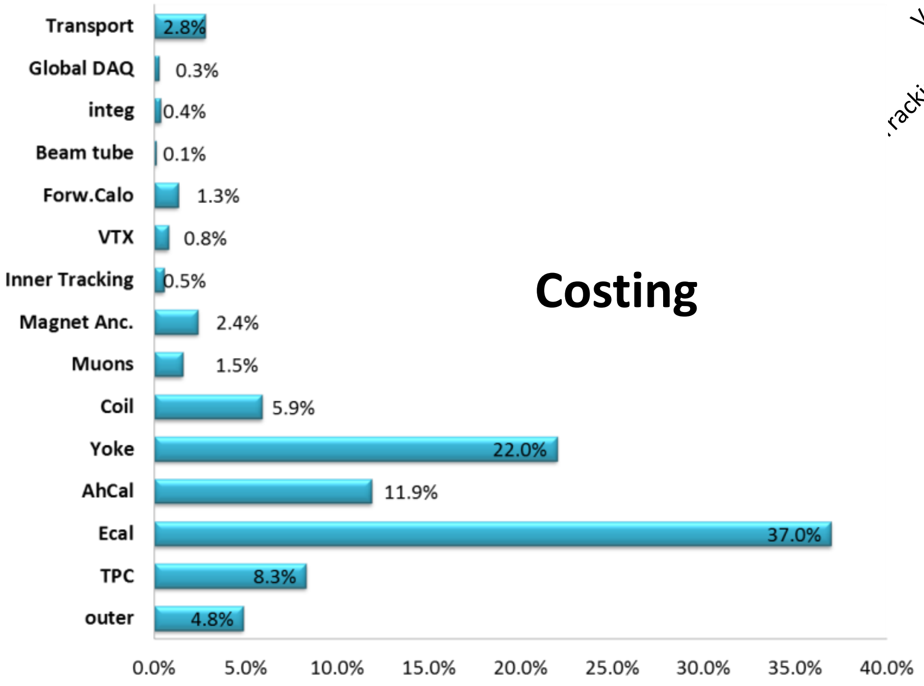
- Vertex detector for b and c hadron recon-struction (jet charge) : 4 µm resolution

The ILD Group

Currently 68 groups signed up



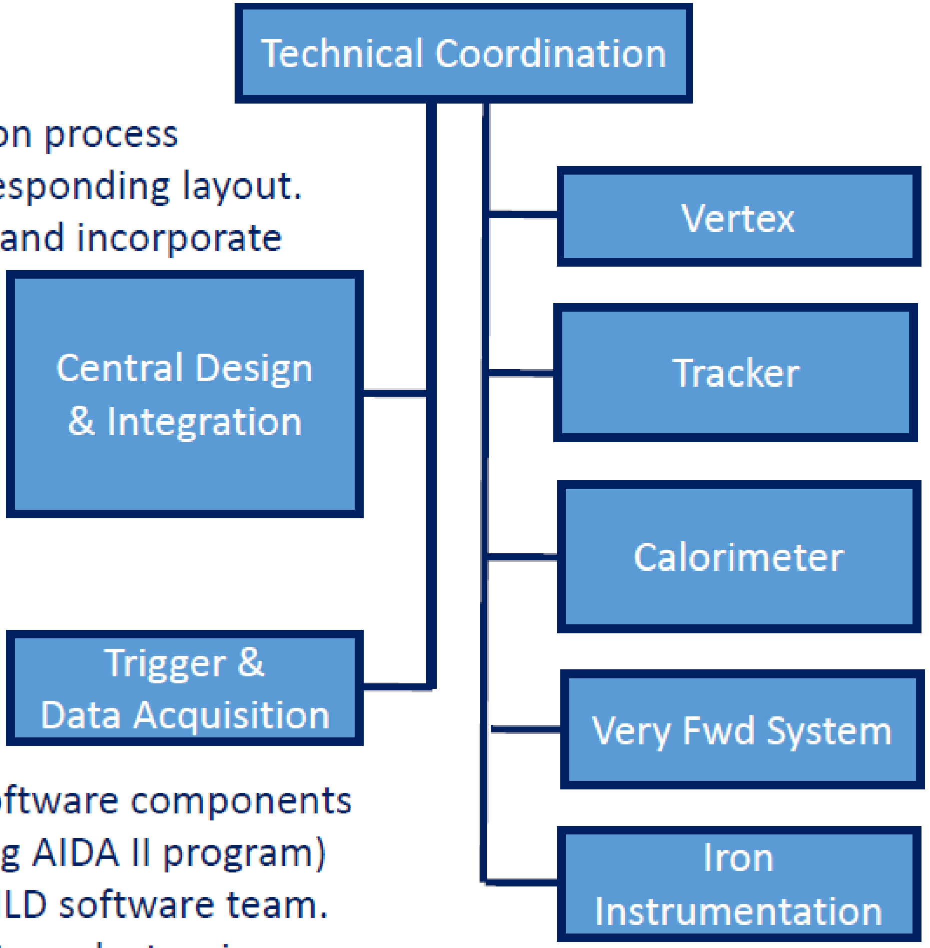




The ILD Organization

- Born from the fusion of GLD (mainly Asian) and LCD (mainly EU)
- LOI in March 2009, ‘Detector Baseline Document’ in 2013
- One spoke (Ties Behnke, elected in 2015)
- One deputy spoke (Kiyotomo Kawagoe, nominated in 2016)
- An Institute Assembly (68 members, one per institute)
- An Executive Team
- A Technical Board, chaired by the Technical Coordinator (Claude Vallée nominated in 2016)
- A Physics Group (Physics Coordinator Keisuke Fujii)
- A Software Group (Software Coordinator Frank Gaede)

The ILD Technical Organization



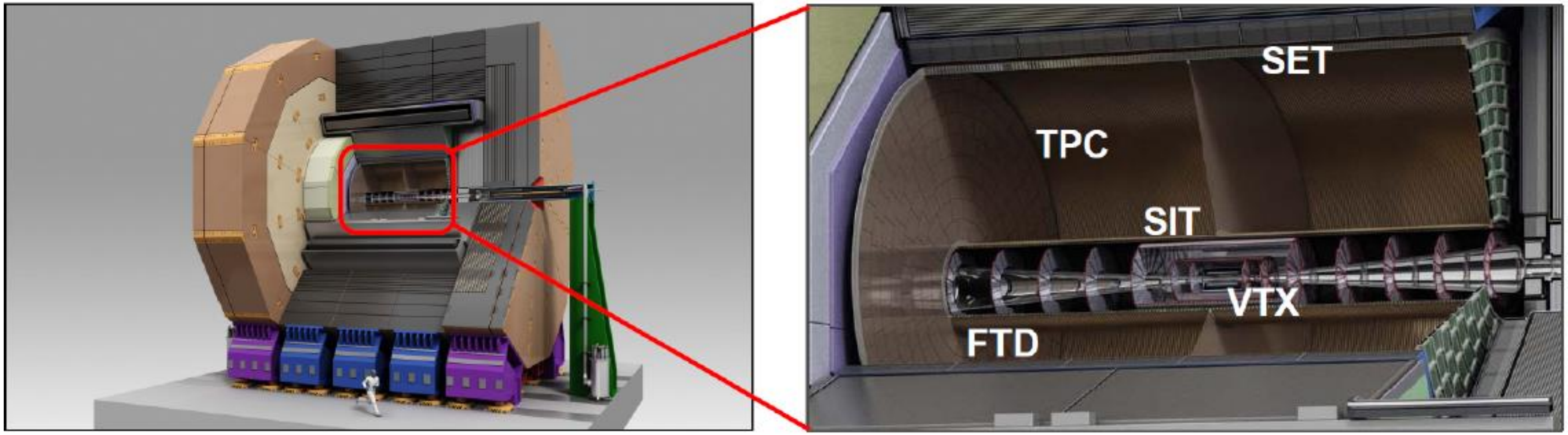
- Interact with physics optimization process to design the best possible corresponding layout.
- Design overall services strategy and incorporate subdetectors services.
- Update detector costing.
- Interact with ILC and SiD for beam&hall integration and assembly procedures.

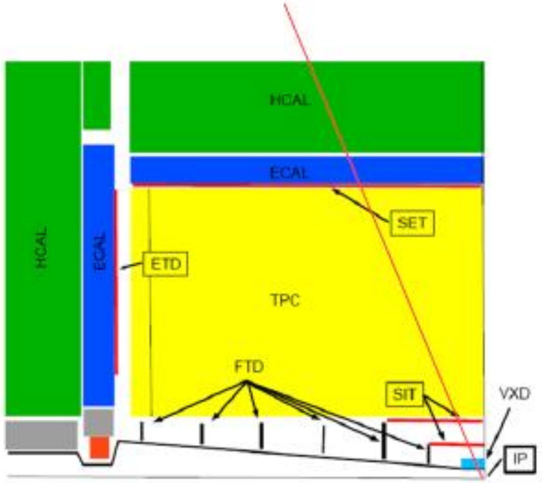
- Foster use of common hard/software components in combined test beams (along AIDA II program) in close cooperation with the ILD software team.
- Ensure that evolving subdetectors electronics complies with ILC specifications.

<u>For each subdetector</u> :

- For current technology options, follow progress on engineering prototypes developed by the R&D Collaborations or implemented in future projects like LHC upgrades.
- Follow also emergence of possibly new promising technologies.
- For each technology option, gather information on services, infrastructure etc... relevant for its integration in the global ILD detector.
- For each technology option provide realistic and validated simulation and digitization code within the overall ILD software environment.

ILD tracking





Increasing radius

Tracker sub-systems

Beam pipe

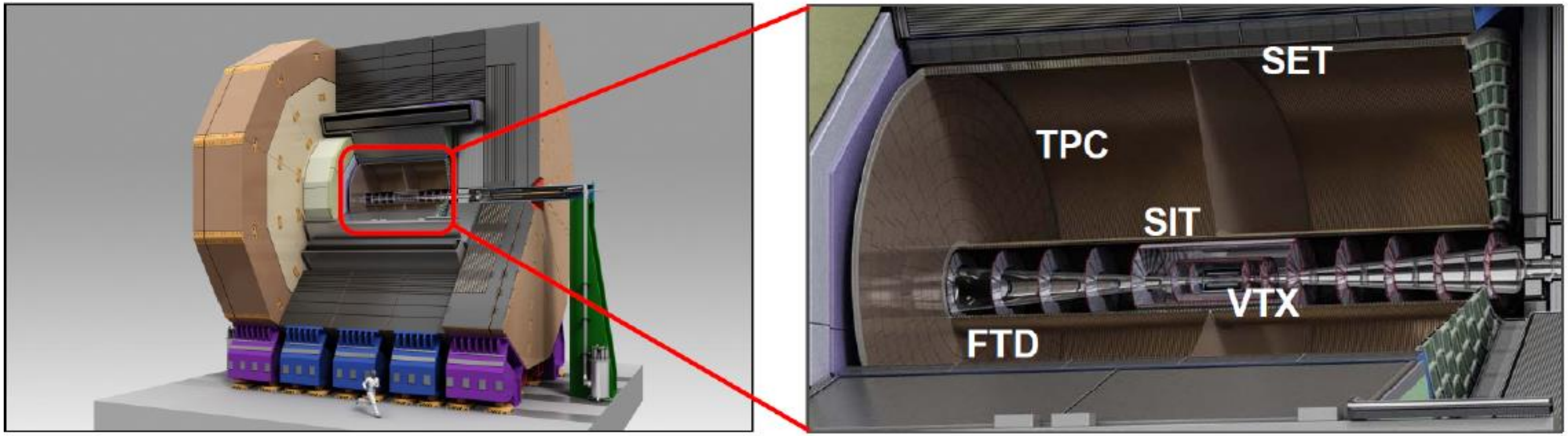
Vertex Detector (VXD)

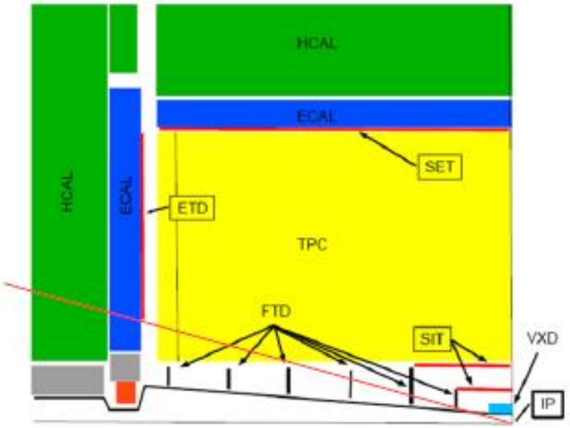
Silicon Intermediate Tracker (SIT)

Time Projection Chamber (TPC)

Silicon Envelope Tracker (SET)

ILD tracking





Increasing z

Tracker sub-systems

Beam pipe

Vertex Detector (VXD, $\theta > 15^{o}$)

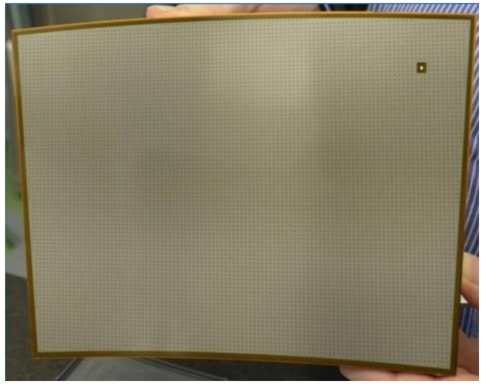
Forward Tracking Disks (FTD)

Time Projection Chamber (TPC, $\theta > 12^{o}$)

TPC Readout Technologies

MPGDs suffer less from ExB effects than MWPCs. They require less heavy mechanics. Panels with each technology have been made and tested.

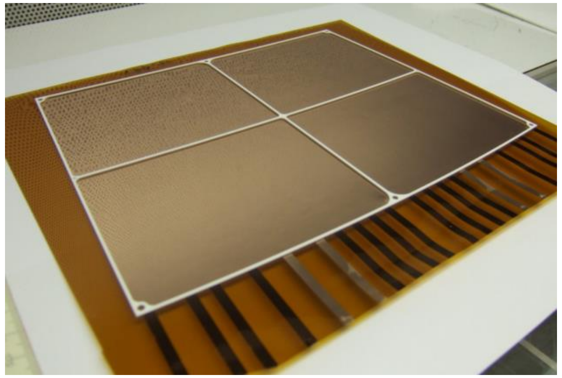
Micromegas



Mesh on top of a charge-dispersing resistive anode

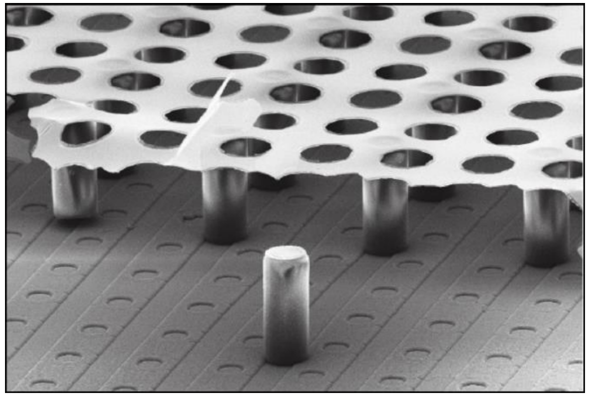
European GEMs

Standard kapton triple GEM with ceramic spacers

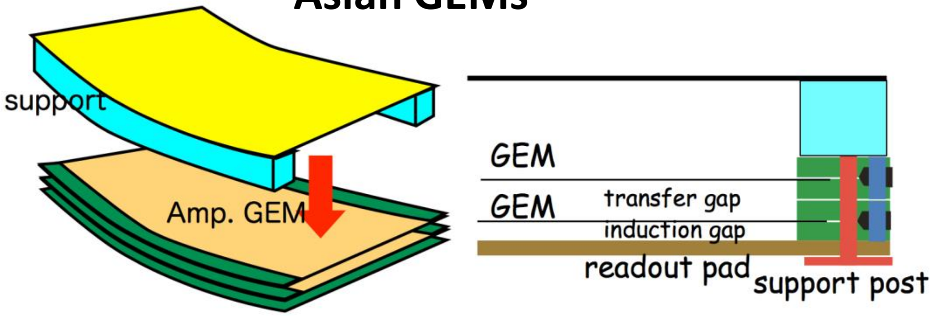


GridPix

Integrated grid on 55 µ digital pixels



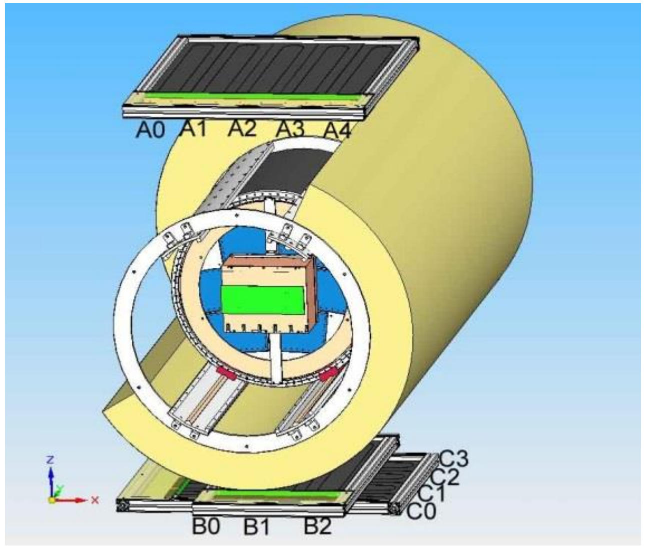
Asian GEMs

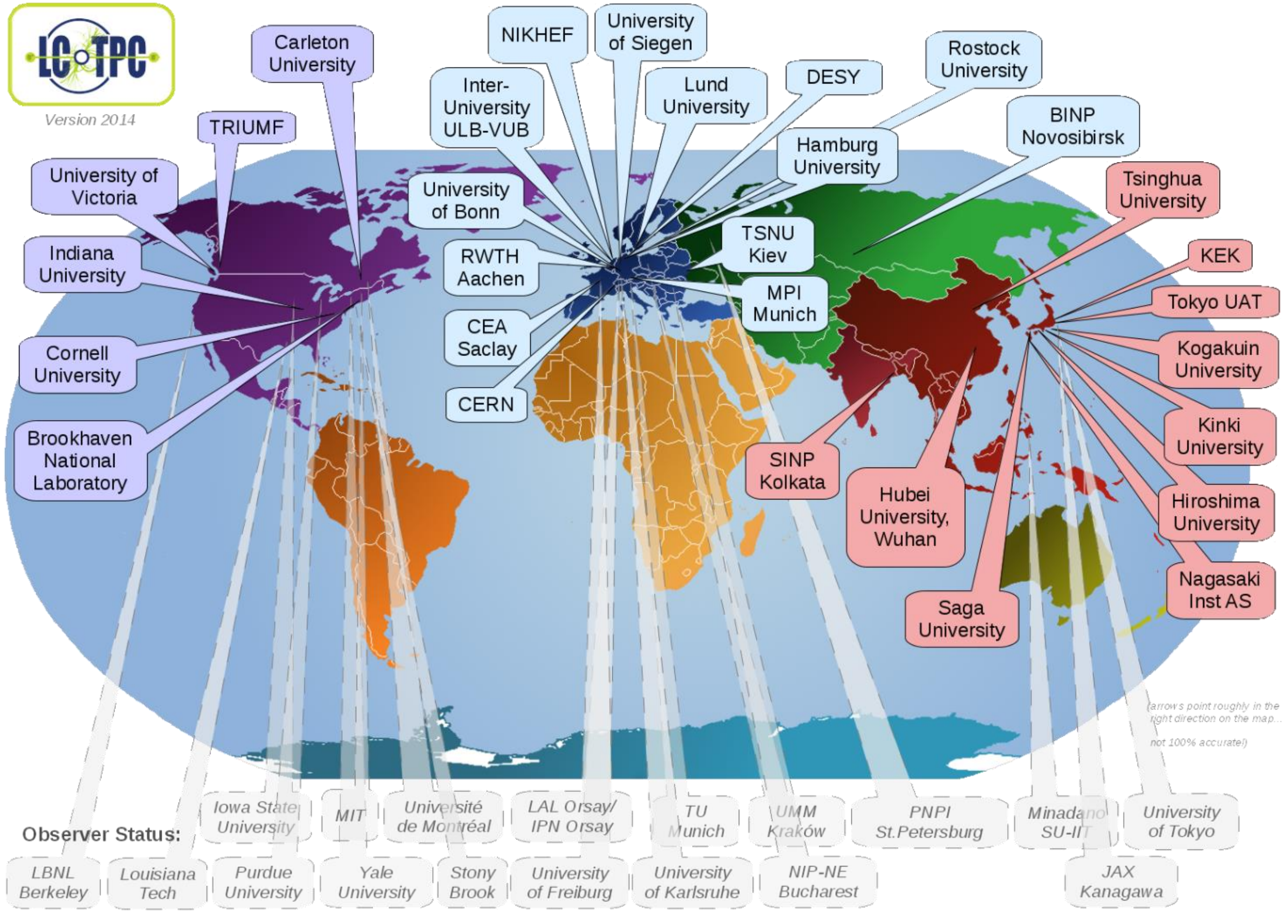


TPC R&D: The LCTPC collaboration and the DESY test setup

All the TPC R&D is gathered.
www.lctpc.org

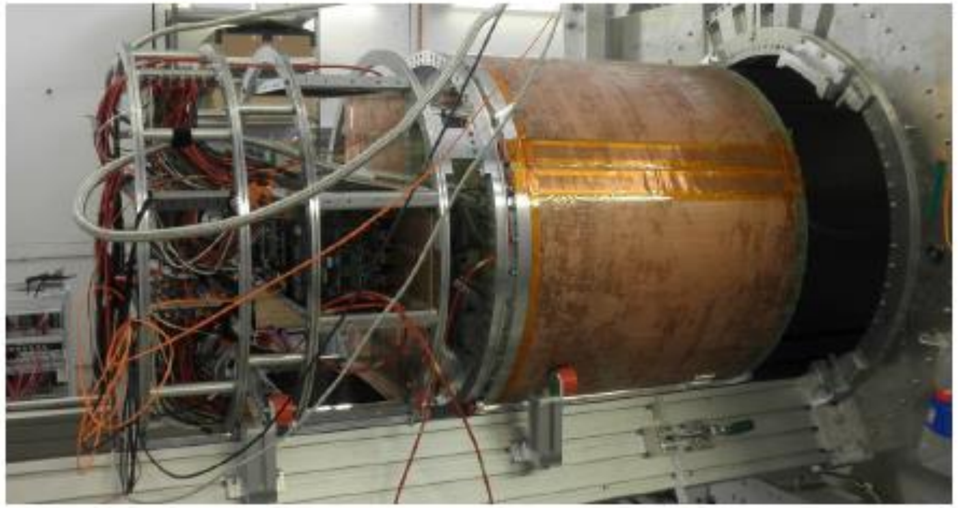
The collaboration shares a test facility (Field cage, magnet, endplate, cosmic-ray trigger, ancillaries)



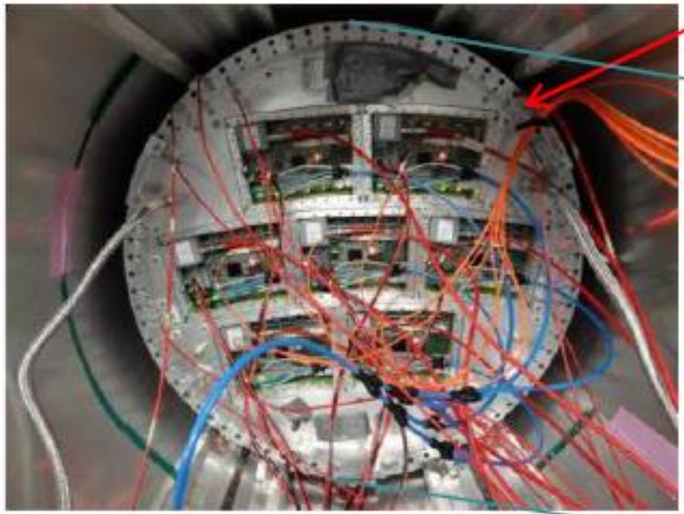


Allows testing/comparing several technologies/ideas with cost-awareness

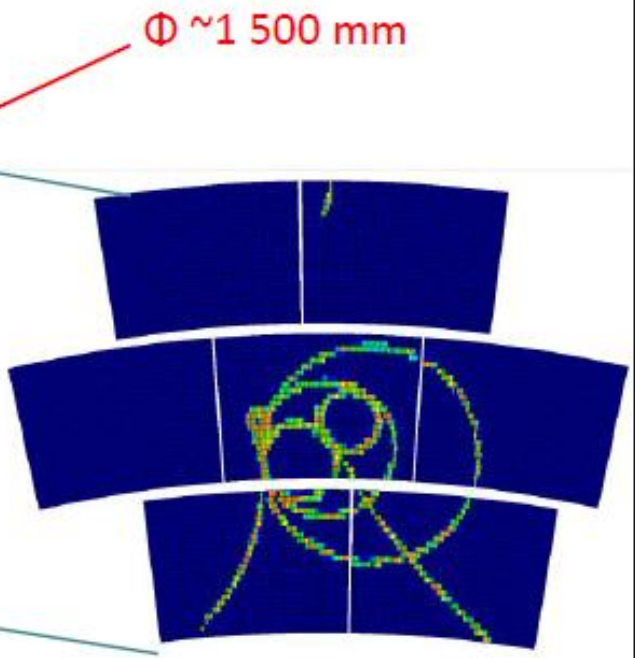
Beam and cosmic-ray tests



with 3 GEM modules



with 7 MM modules

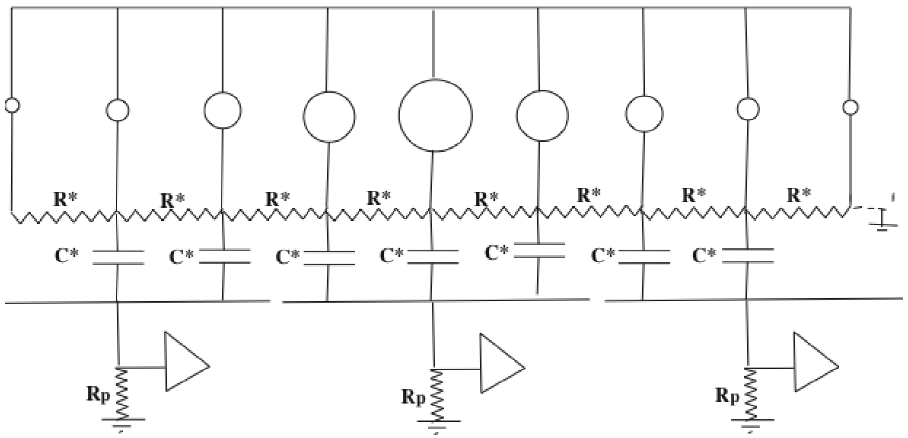


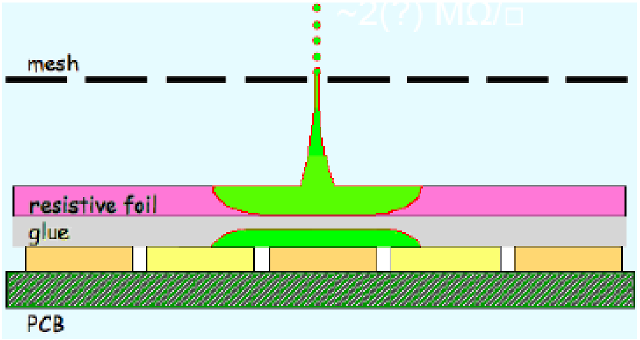
Beam test in DESY magnet

Cosmic-ray test at Saclay

Charge spreading by resistive foil

Resistive coating on top of an insulator:
Continuous RC network which spreads the
charge: improves position sensitivity





M. Dixit, A. Rankin, NIM A 566 (2006) 28

Various resistive coatings have been tried: Carbon-loaded Kapton (CLK),
Diamond-like Carbon (DLC) and resistive ink (3-5 MΩ/sq)

In addition the resistive foil suppresses sparks.

Charge spreading by resistive foil

$$\rho(\mathrm{r},\mathrm{t}) = \frac{\mathrm{RC}}{2\mathrm{t}} \exp\left[-\frac{-\mathrm{r}^2\mathrm{RC}}{4\mathrm{t}}\right]$$

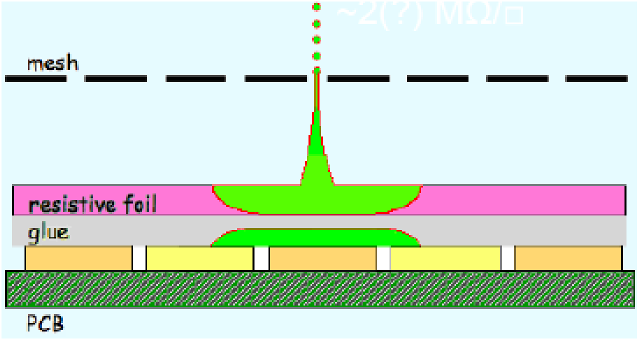
R- surface resistivity
C- capacitance/unit area

Gaussian spreading as a function of time with σ_r = sqrt(2t/RC)

t~shaping~few 100 ns
RC = 180 R(MΩ) /(d/175μ) ns/mm²

For R= 2 Mohm/sq, shaping 200 ns, 200 μ insulation in addition to the 50 μm kapton, one obtains sigma = 1.3 mm

(For 0.2 Mohm/sq, we would have sigma= 3.16 mm)



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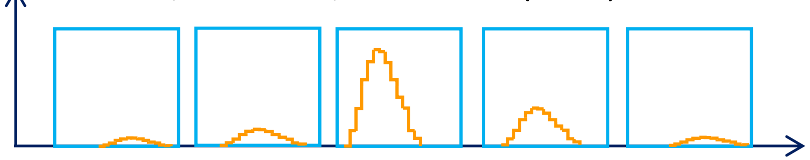
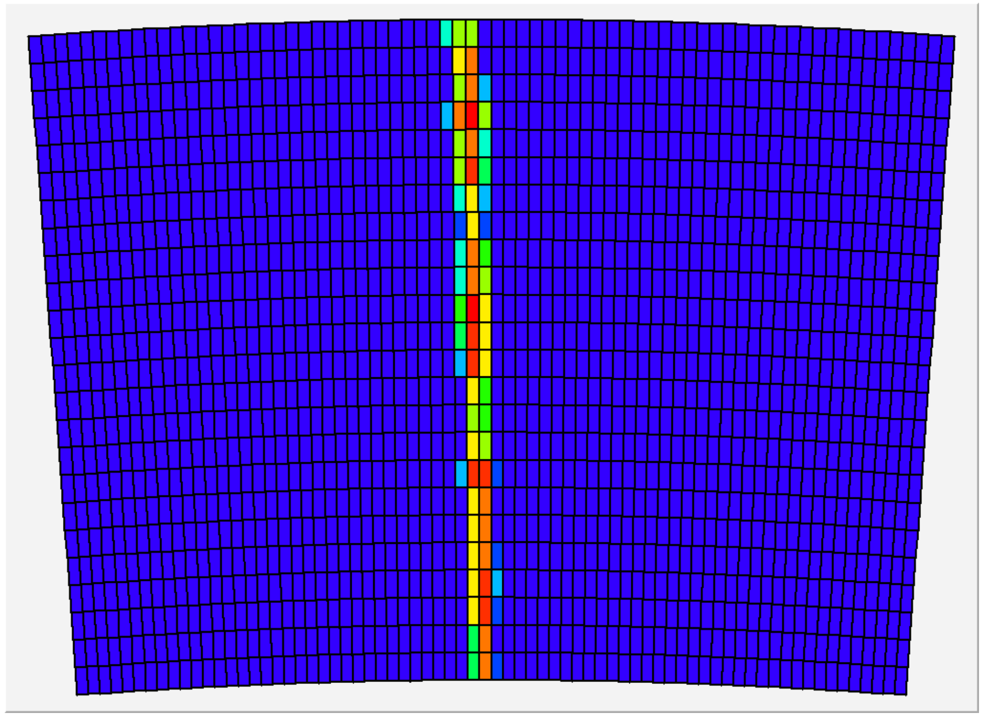


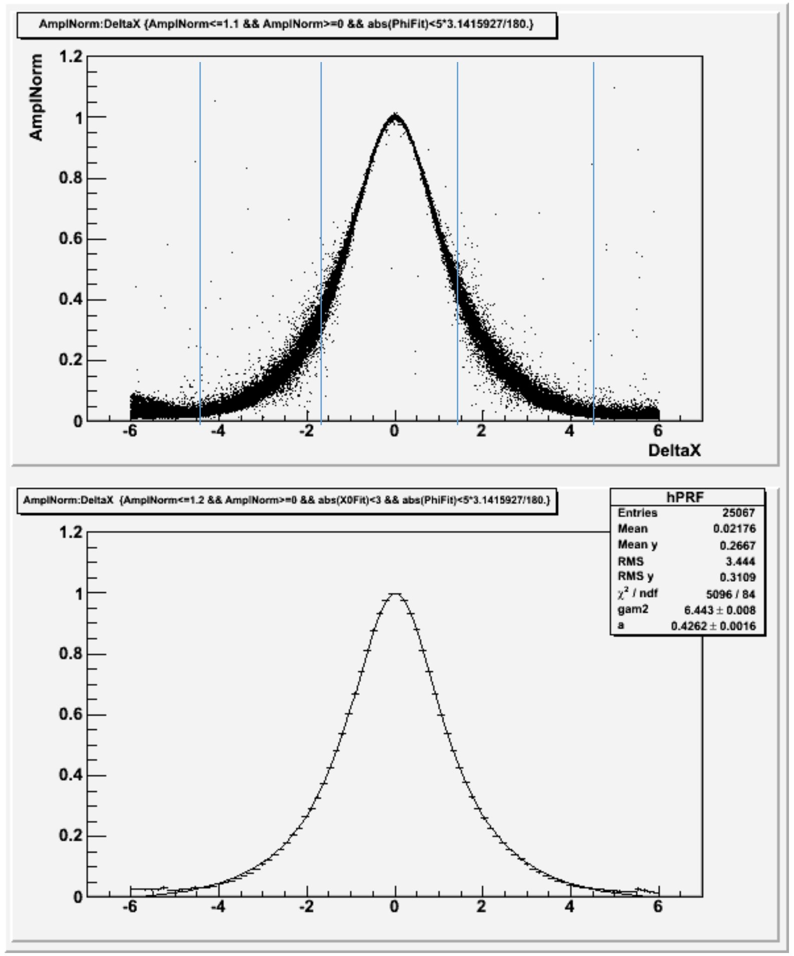
Pad response

Relative fraction of 'charge' seen by the pad, vs x(pad)-x(track)



24 rows x 72 columns of 3 x 6.8 mm² pads

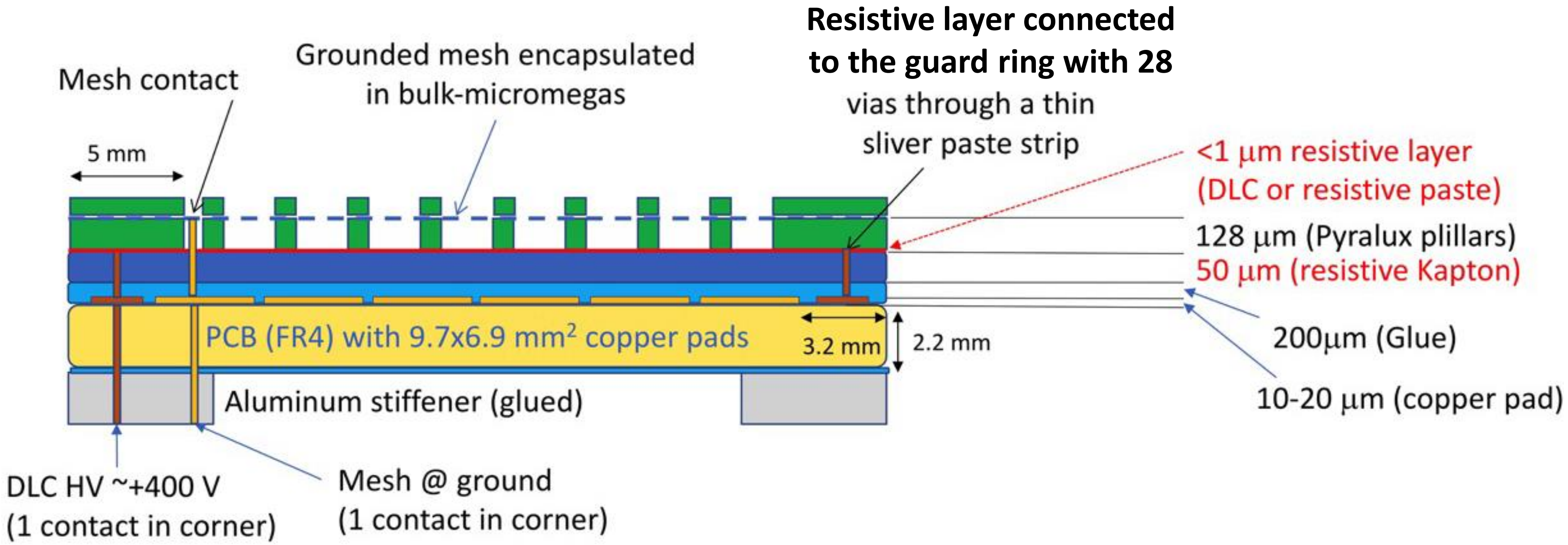
Z=20cm, 200 ns shaping



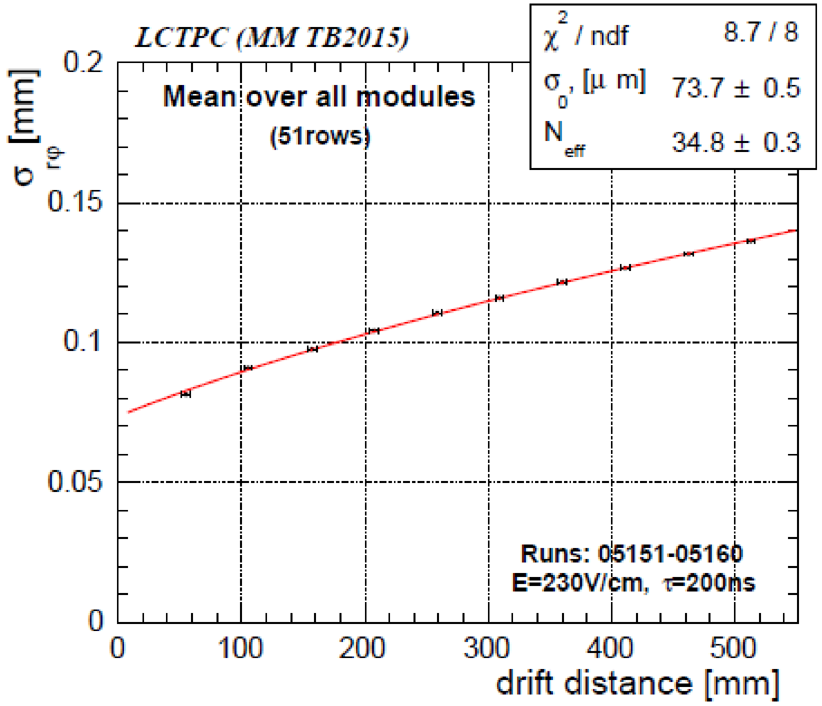
x(pad) – x(track) (mm)

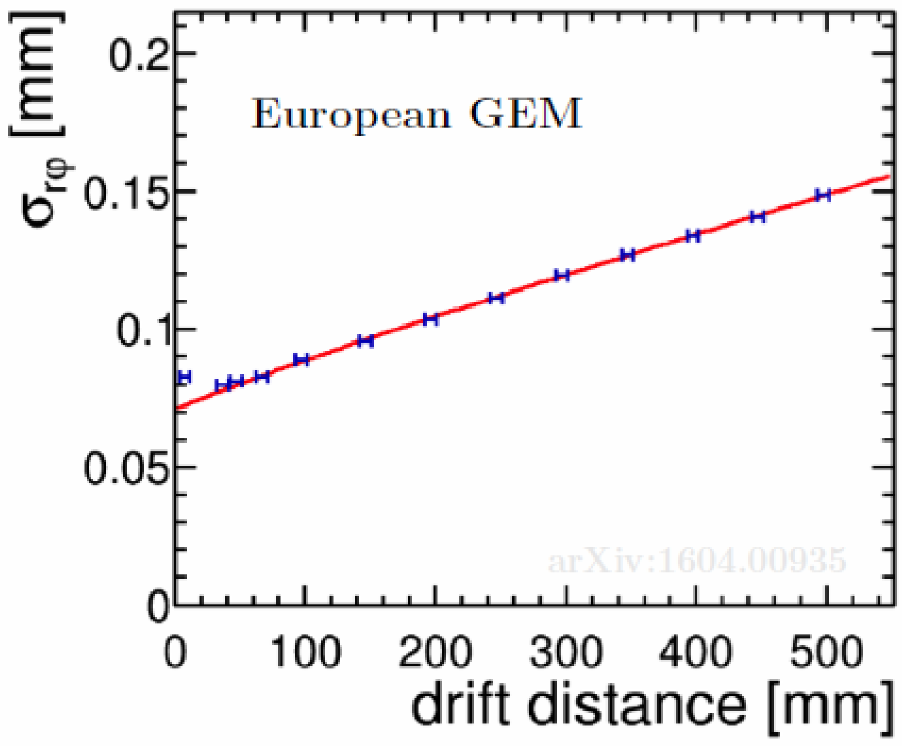
ENCAPSULATED RESISTIVE ANODE DESIGN

Spreading :



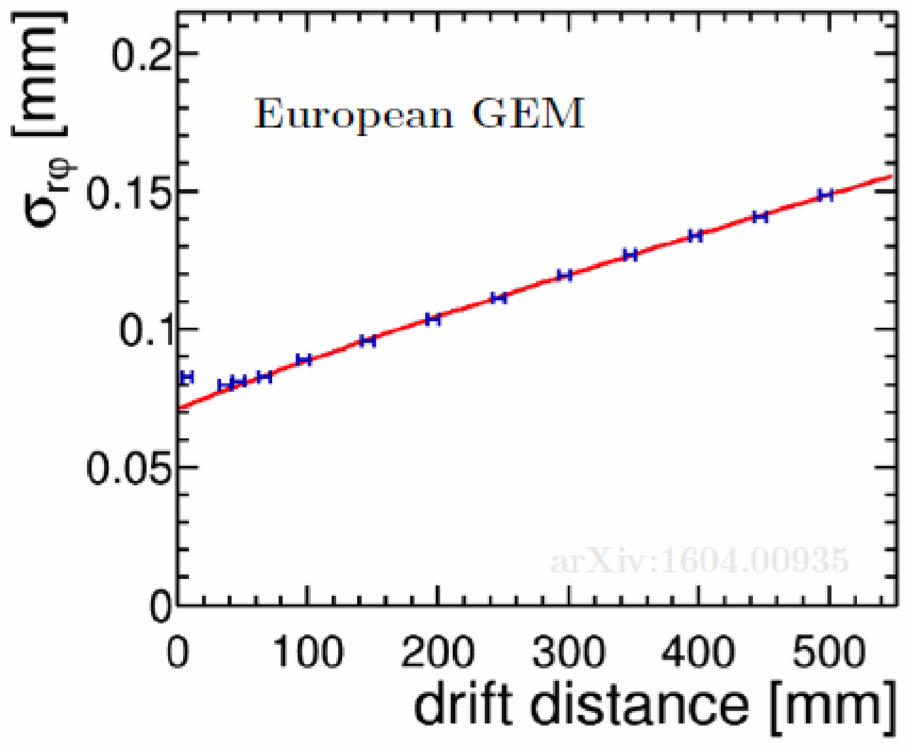
Results on resolution

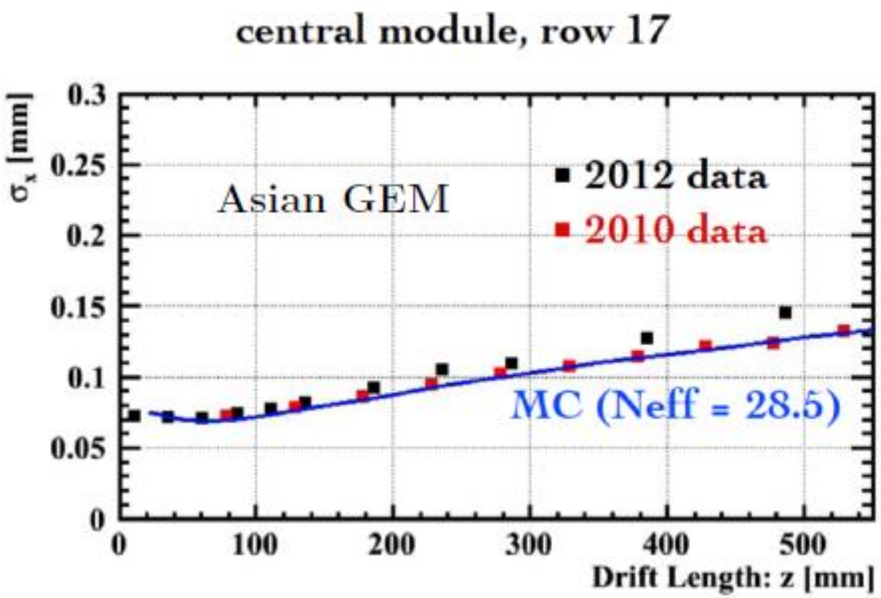




All pad TPC technologies give similar results
(but with 3mm pads for MM and 1.2mm pads for GEMs)

Results on resolution





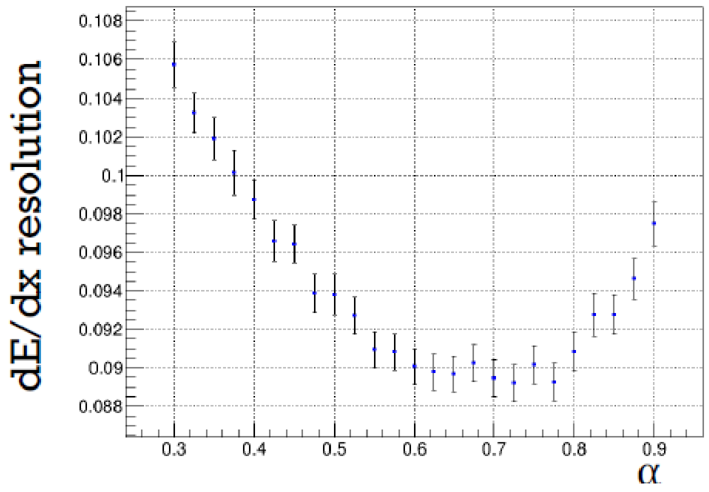
All pad TPC technologies give similar results
(but with 3mm pads for MM and 1.2mm pads for GEMs)

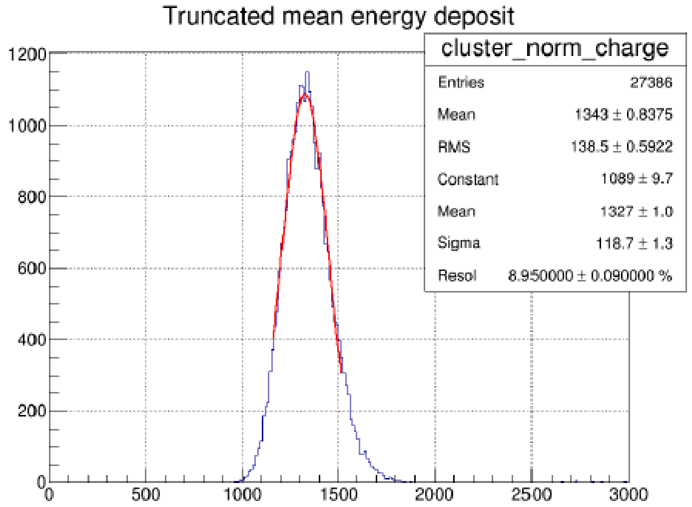
S. Voronov, M. Zito, PC

dE/dx resolution of a resistive-anode TPC

- Apply multi FEM selection
- Vary α to reach the best resolution
- T2K value is 0.7 → still make sense
- Use 20+19+21=60 clusters, 42.5 cm - 8.95 ± 0.09 %
- Approximating to T2K vertical 72 clusters 80 cm - 6.48 ± 0.07%

OK for T2K2
OK for ILD TPC : 5.0%



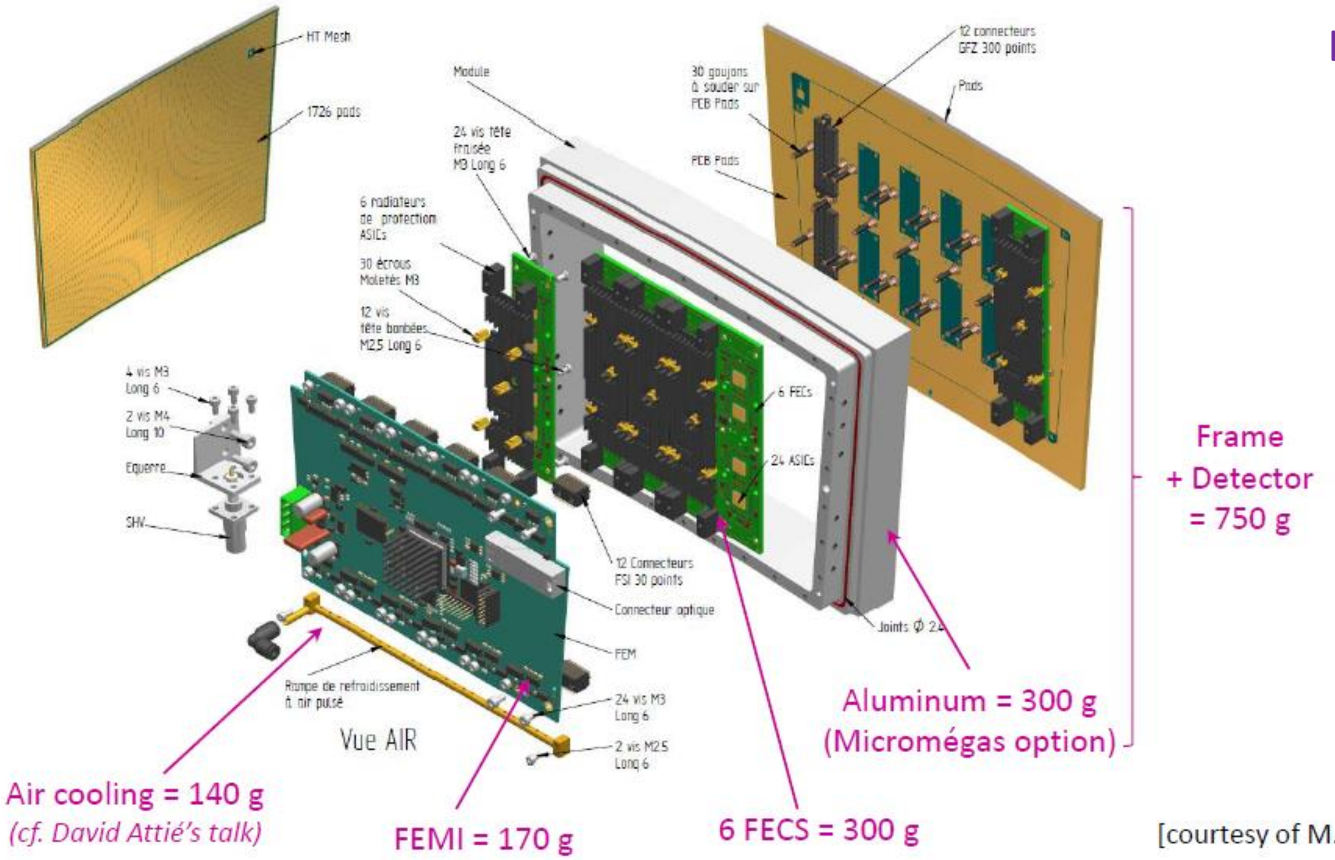


TPC design and integration :electronics integration

- 374 cm²
- ~1 500 g

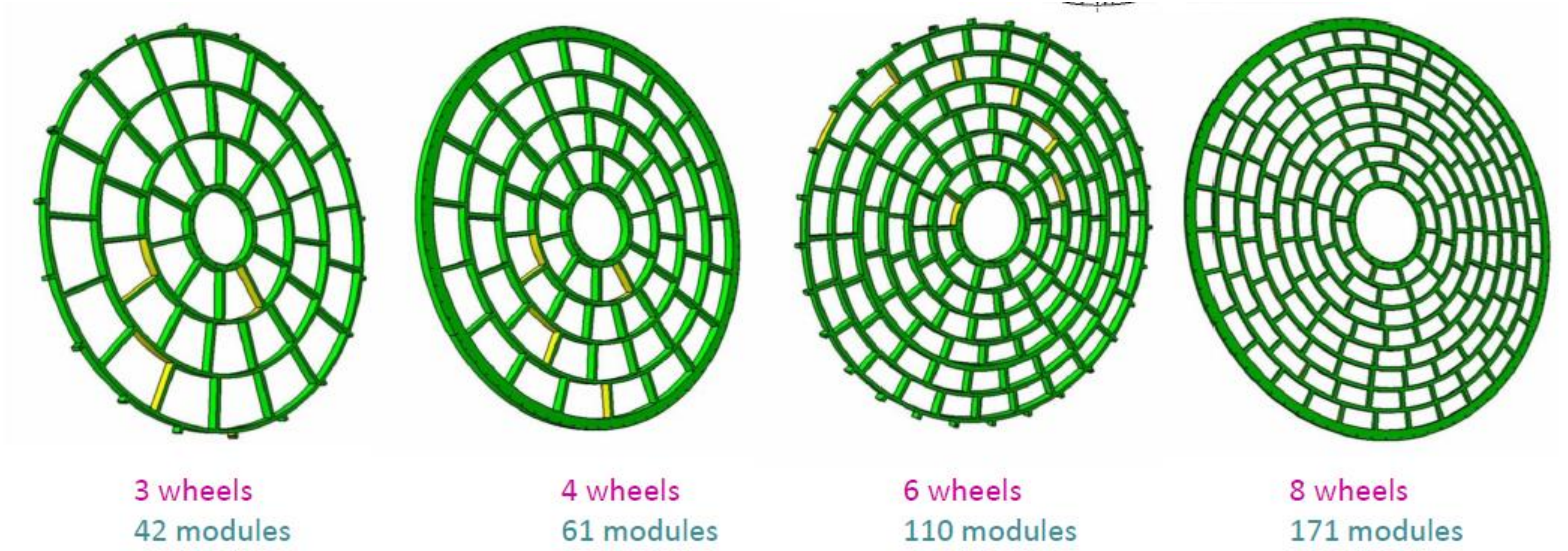
4 g/cm² on Si/Al → < 25% X_0

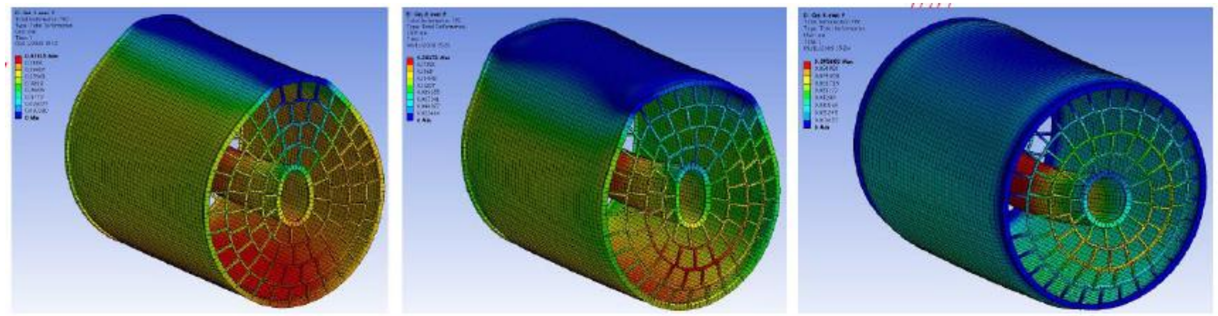
D. Calvet et al., IEEE trans.



[courtesy of M. Riallot]

TPC design and integration : mechanical integration





Deformations under weight and inner pressure

M. Carty, P. Manil *et al.*
Resuming : Zhihong Sun *et al.*

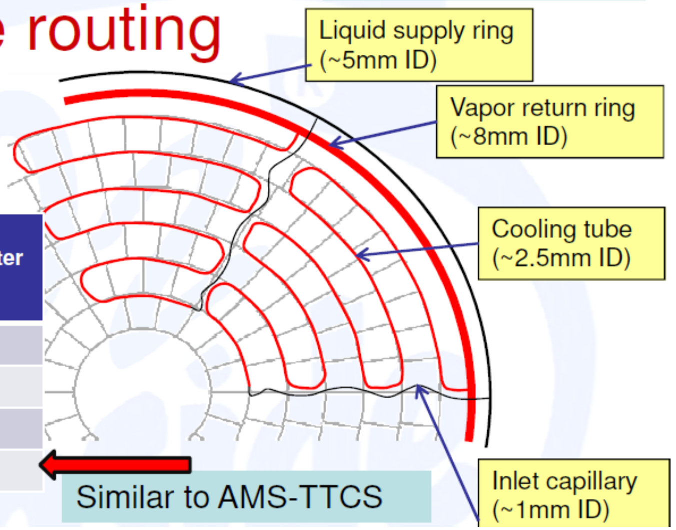
TPC design and integration : 2-phase CO_2 cooling

Advantages:
Specific heat 4 x water
Latent heat for evaporation : 80 x water
Boiling point at room temperature at 60 bar
Inexplosive, non-conductive, vapors instantly at 1 atm.

Tested in our test beam in 2014 and 2015

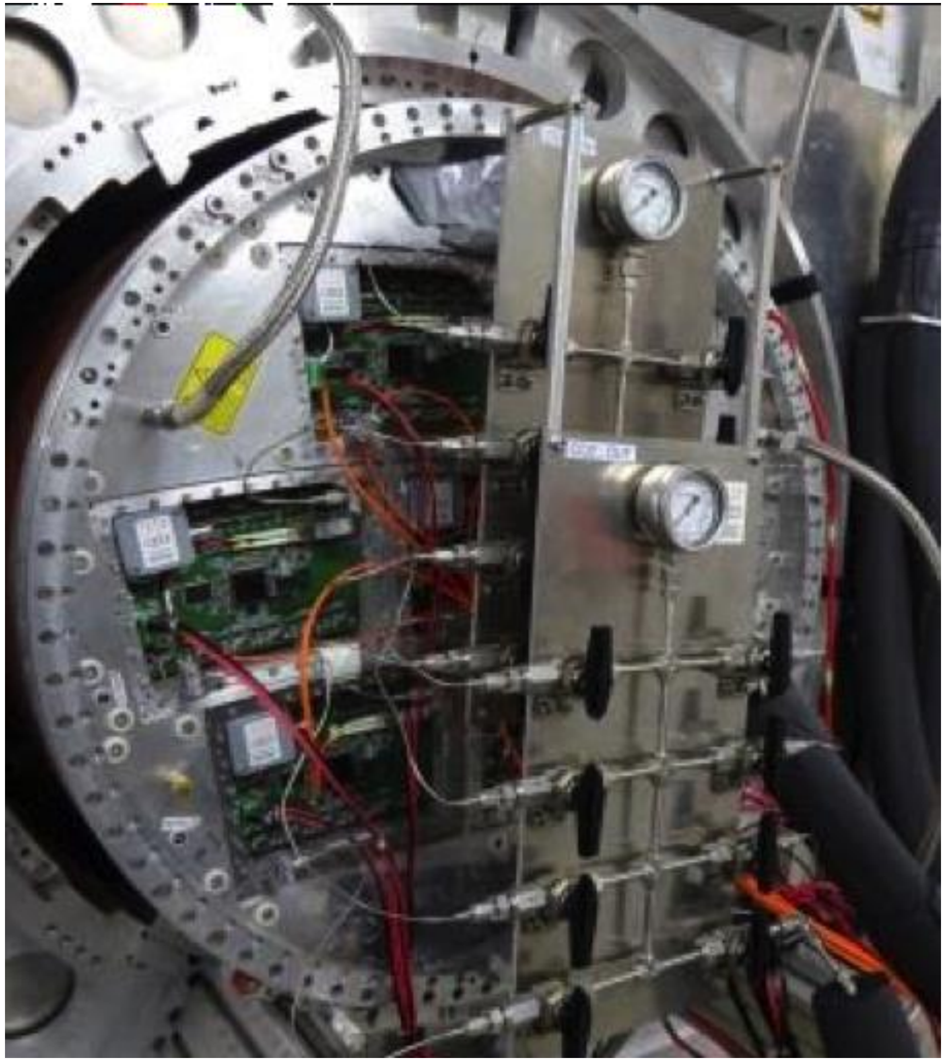
TPC end plate cooling tube routing

Possible layout of the 6 loops option



	Qty Frames / loop	Heat load per loop (W)	Tube length (m)	Inner diameter (mm)
1 loop	200	1000	48m	6.2
2 loops	100	500	24m	4.3
4 loops	50	250	12m	3
6 loops	34	171	8m	2.2

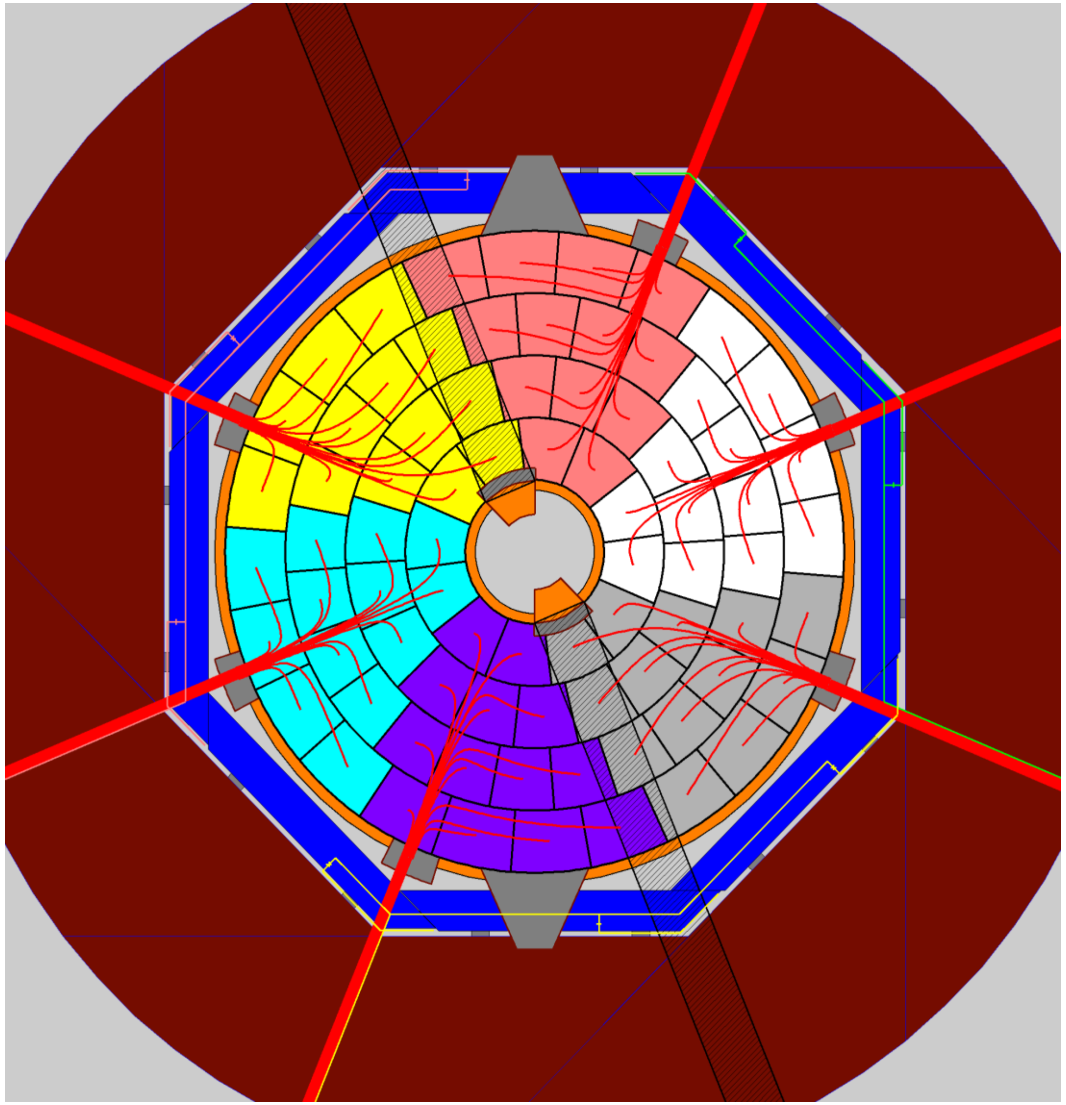
Similar to AMS-TTCS



Cables, services, power consumption,…

All details are written in a TPC Interface Control Document.

Serious issues from push-pull operation.



Ion back-flow, Gating

IBF naturally suppressed in Micromegas.
However a gating might be necessary, under study.
One possibility demonstrated: large opening GEM, could be integrated to the modules.

Conclusions

The ILD collaboration is coming to life

Proof-of-principle of a Micromegas TPC done (GEMs have similar performances, the difference will be in complexity/reliability)

Getting ready for the technology choice (S. Ganjour, K. Fujii et al., TYL)

Solutions for integration demonstrated, but still lots of studies in progress to make the detector a reality

ILD members from Irfu:
ATTIE David; BERRIAUD Christophe; Besancon Marc; COLAS Paul; FOURCHES Nicolas; GANJOUR Serguei; Giomataris Ioannis; NAPOLY Olivier; SHARYY Viatcheslav; TITOV Maksym; Tuchming Boris;