Design update for the Cymbal detector

ePIC / EIC Collaboration meeting

July 18th 2025

Audrey on behalf of CEA Saclay

What is Cymbal?

Cylindrical Micromegas Barrel Layer

Part of the tracking system

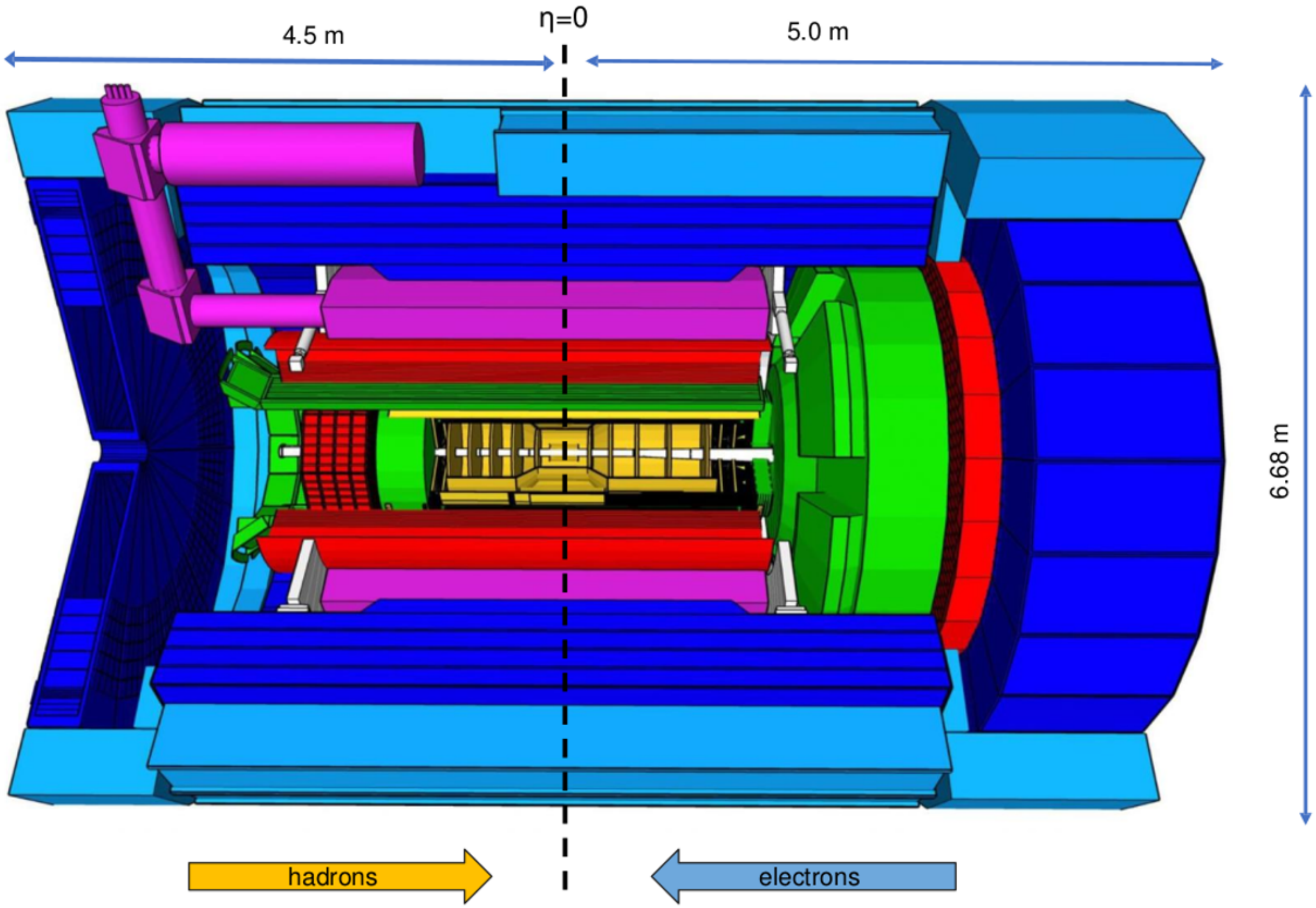
Magnet
- New 1.7 T SC solenoid, 2.8 m bore diameter

Tracking
- Si Vertex Tracker MAPS wafer-level stitched sensors (ALICE ITS3)
- Si Tracker MAPS barrel and disks
- Gaseous tracker: MPGDs (μRWELL, MMG) cylindrical and planar

PID
- high performance DIRC (hpDIRC)
- dual RICH (aerogel + gas) (forward)
- proximity focussing RICH (backward)
- ToF using AC-LGAD (barrel+forward)

EM Calorimetry
- imaging EMCal (barrel)
- W-powder/SciFi (forward)
- $PbWO_4$ crystals (backward)

Hadron calorimetry
- FeSc (barrel, re-used from sPHENIX)
- Steel/Scint – W/Scint (backward/forward)



Who is Cymbal?

Francesco Bossù

Fabien Janneau

Maxence Vandenbroucke

Audrey Francisco

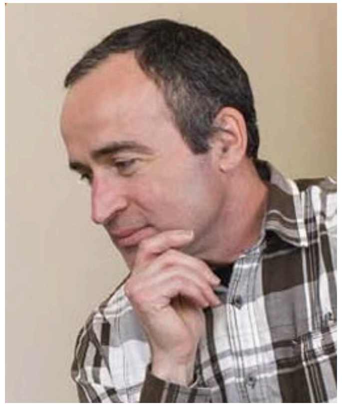
Dylan Neff

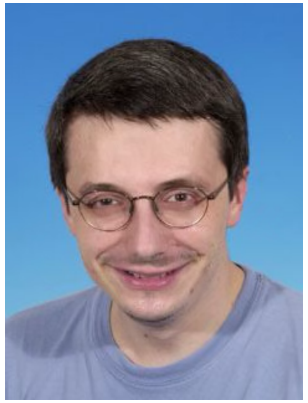
Samy Polcher Rafael

Alain Delbart

Seraphin Vetter

Irakli Mandjavize





Damien Neyret

Yann Bedfer

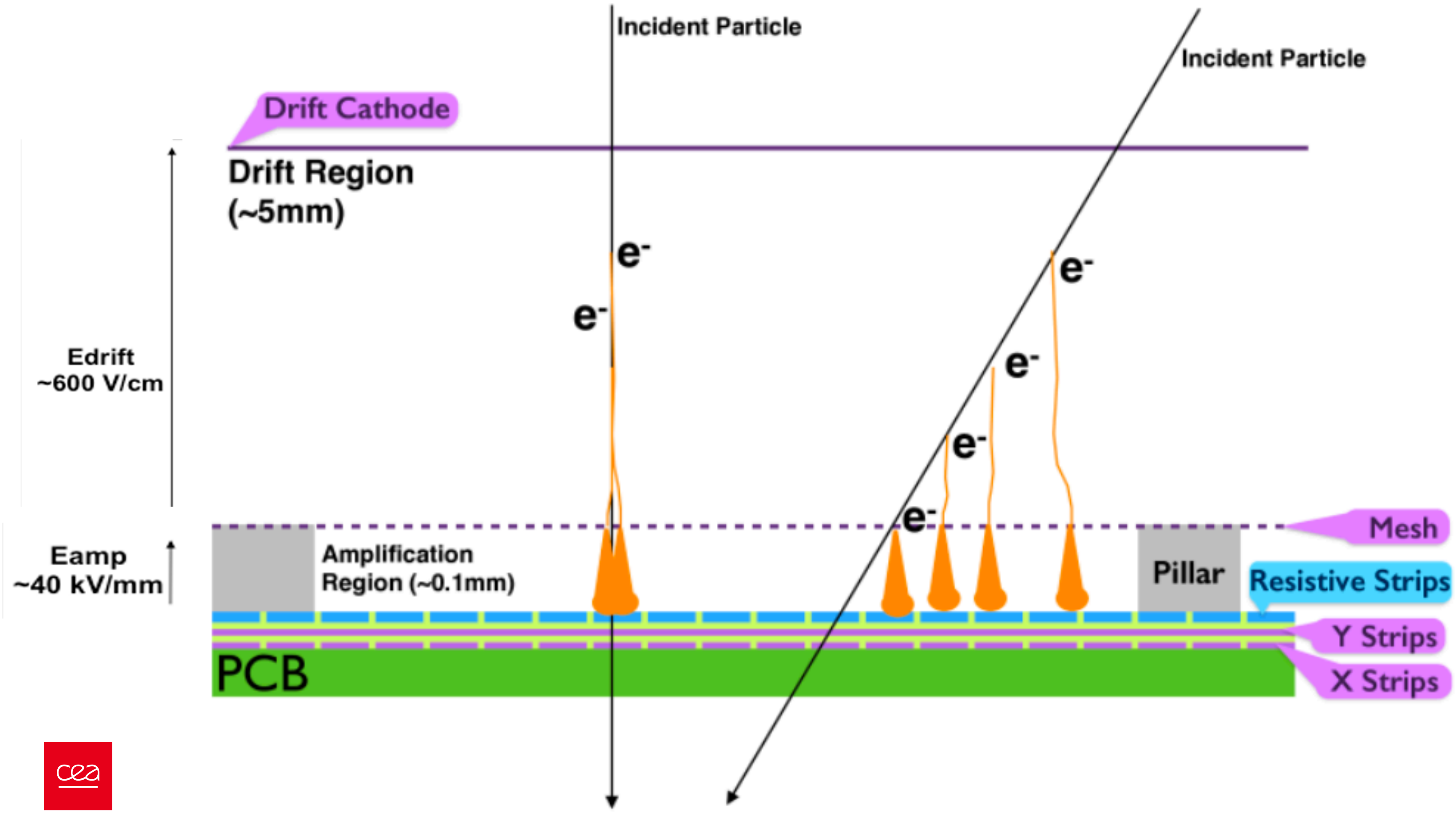
Pierre Chatagnon

+ SALSA team

Anatomy of a micromegas detector

Type of gaseous detector (MPGD family)

Intermediate spatial and timing resolutions



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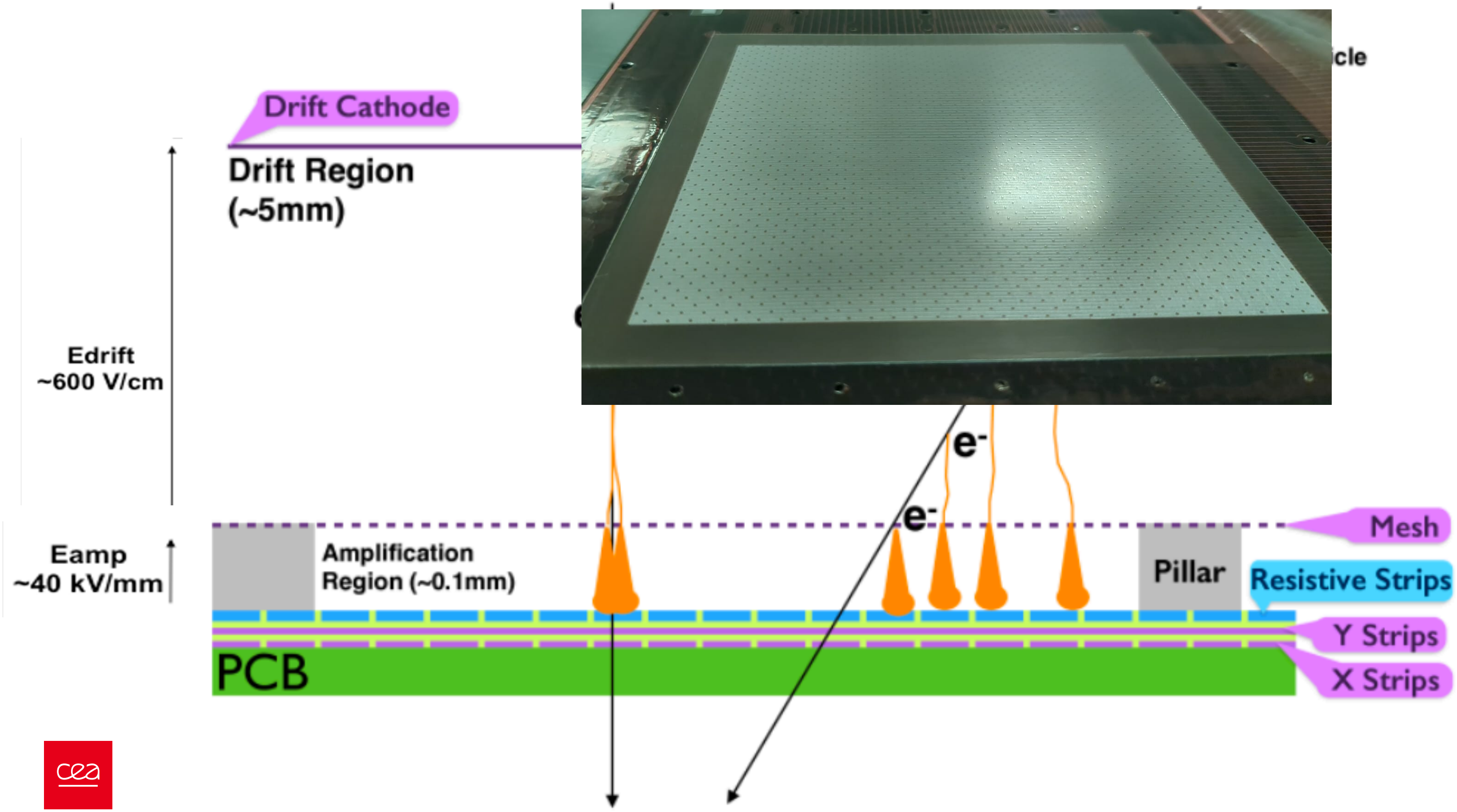

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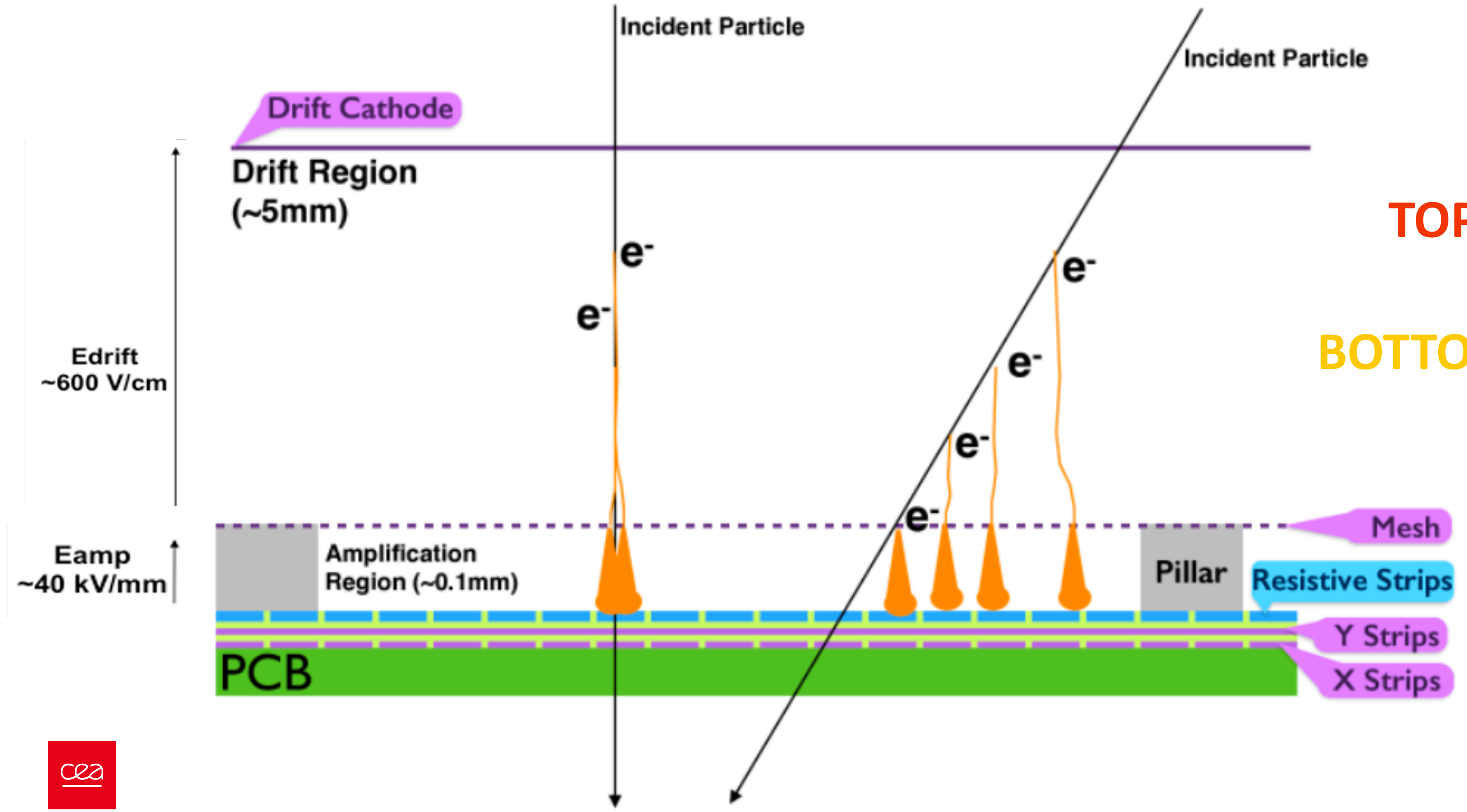

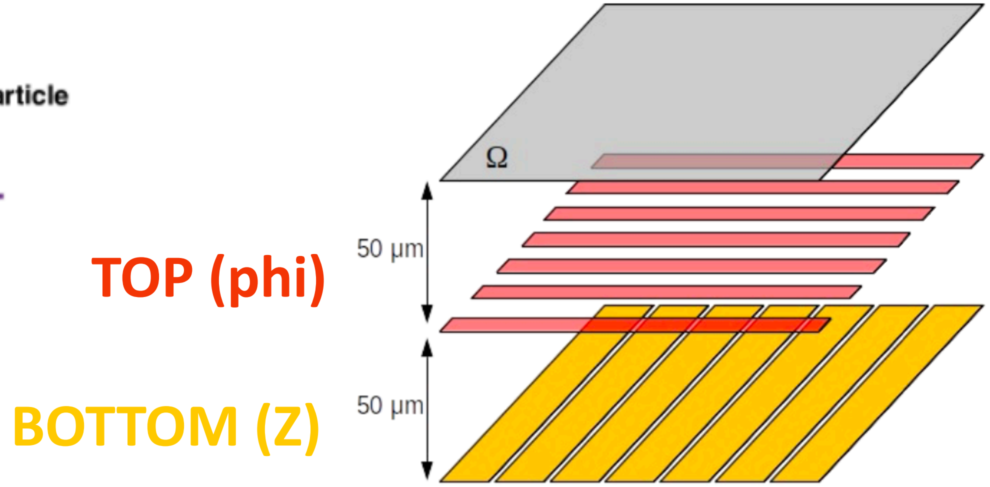

For Cymbal: 2D readout

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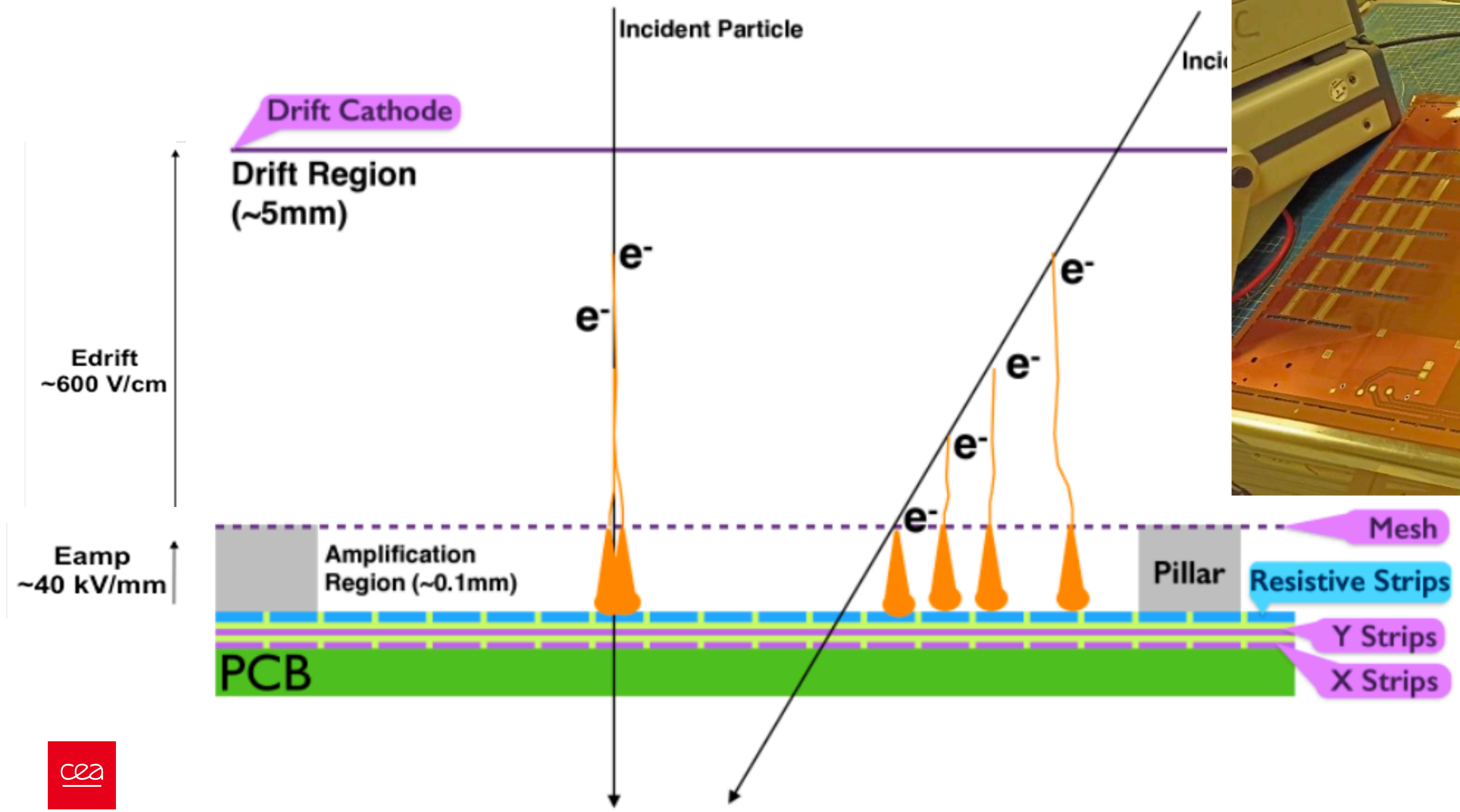
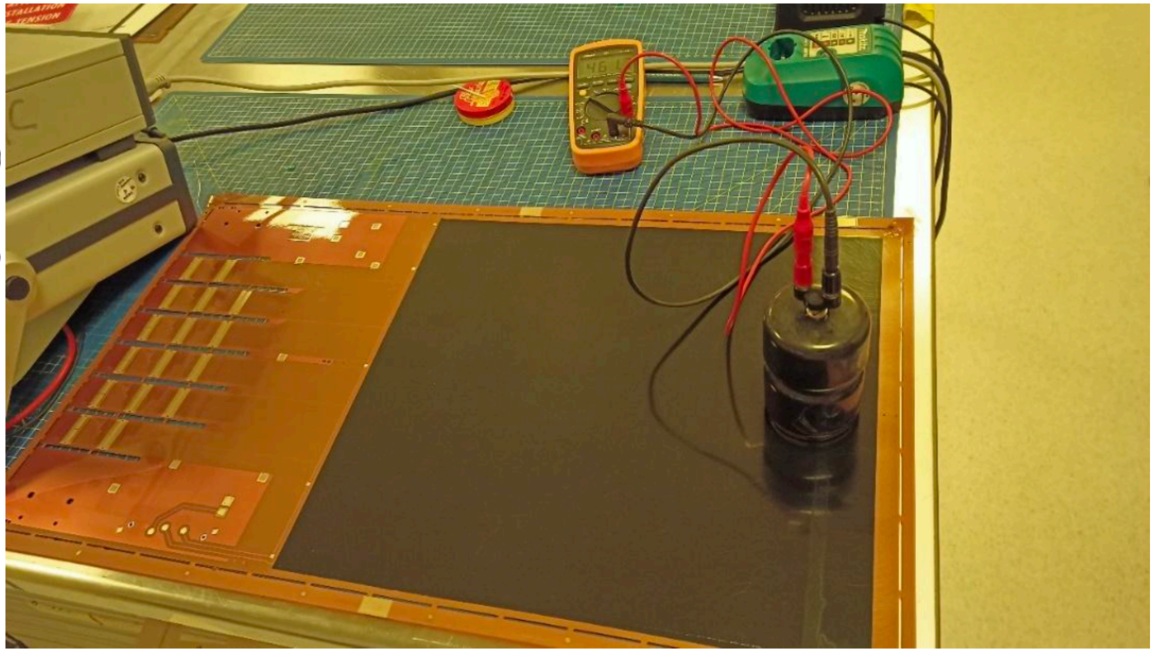
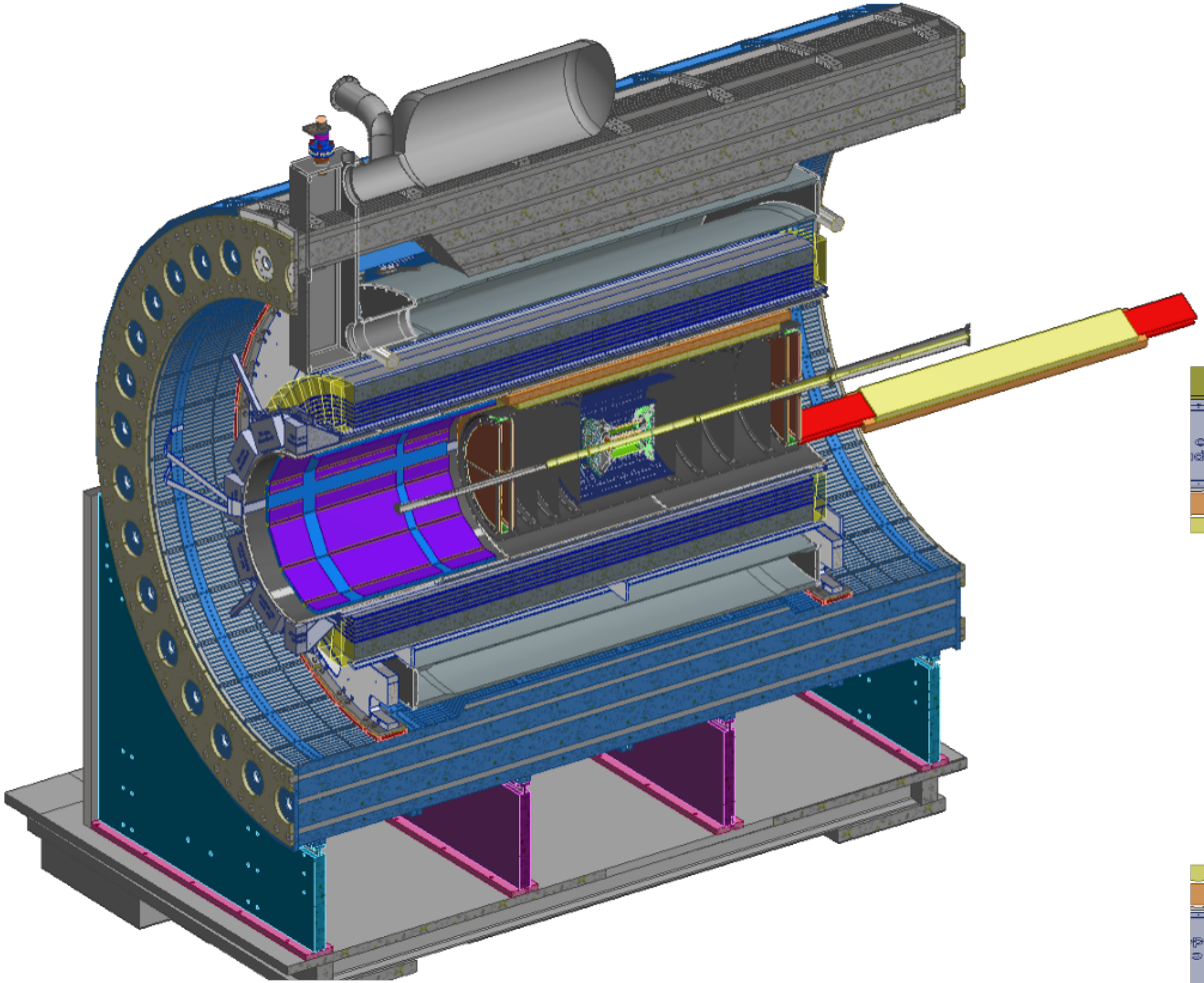


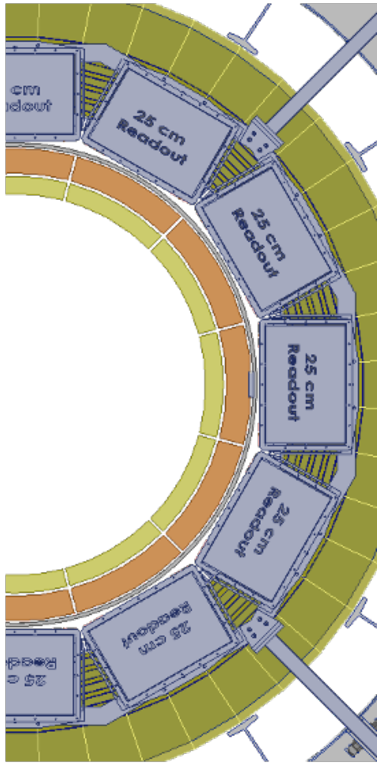


For Cymbal: 2D readout

Maintenance access

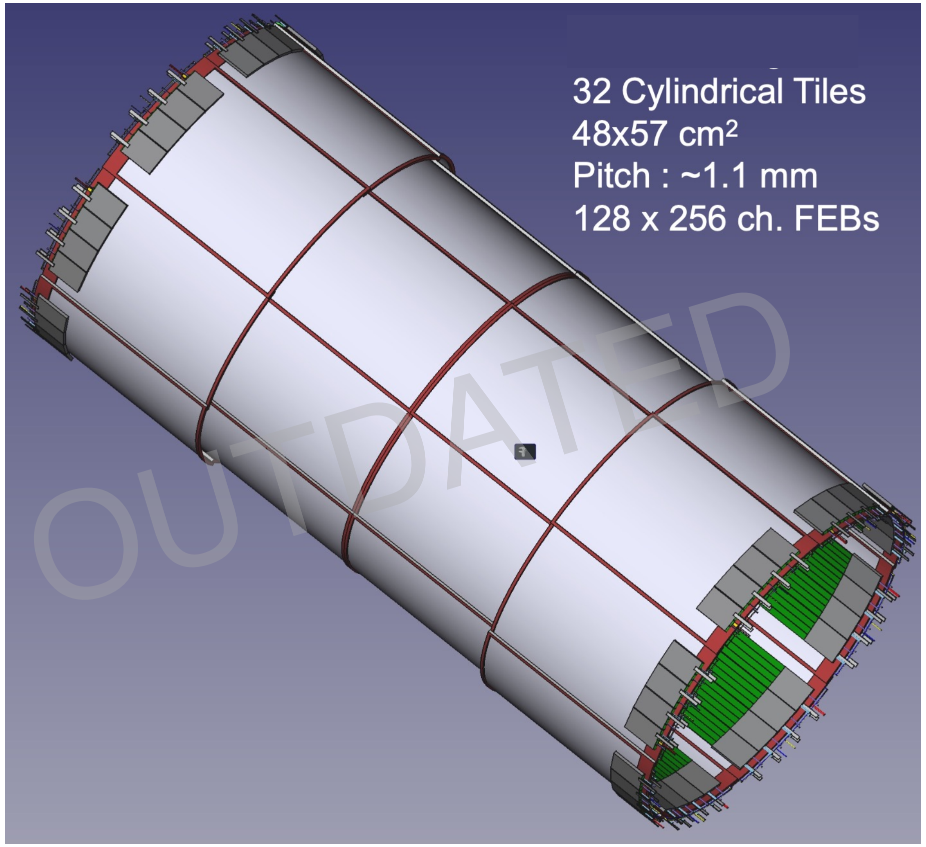


From Roland's talk on Tuesday
Go see his slides for animation!

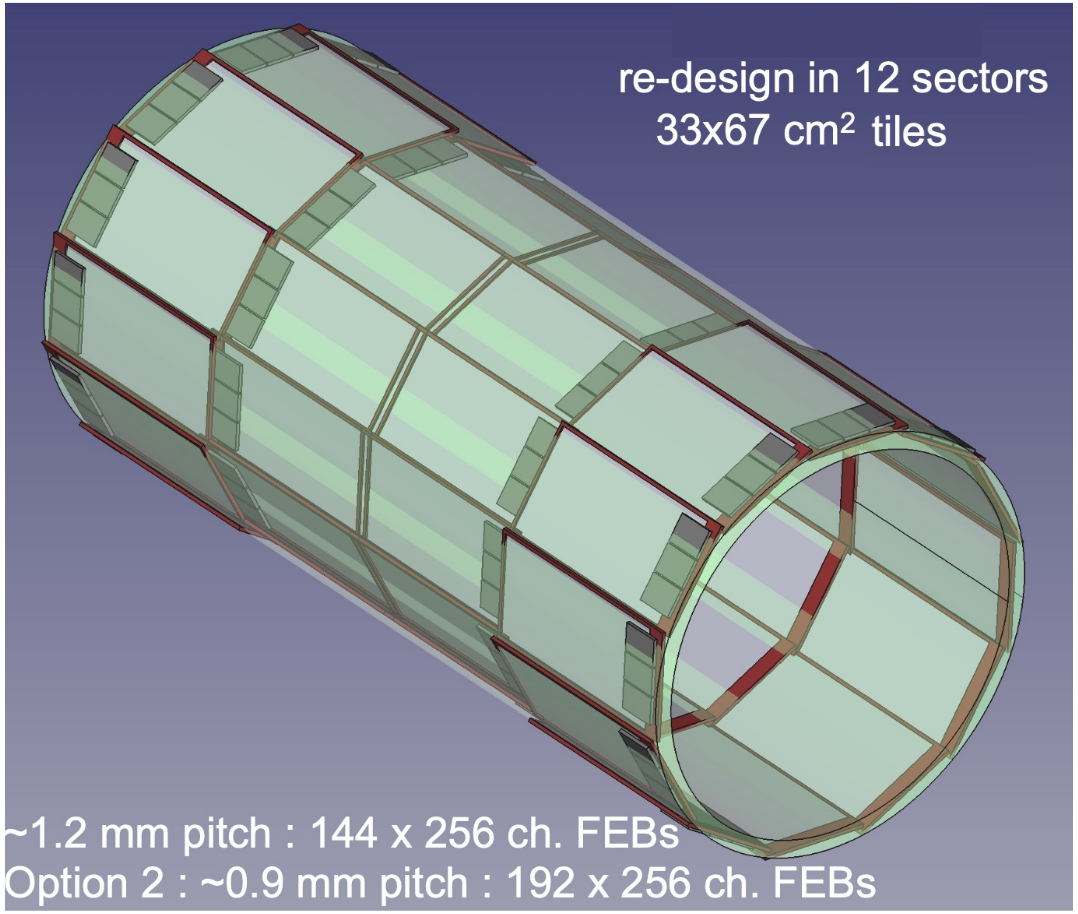


Design evolution to accommodate maintenance needs

Initial layout



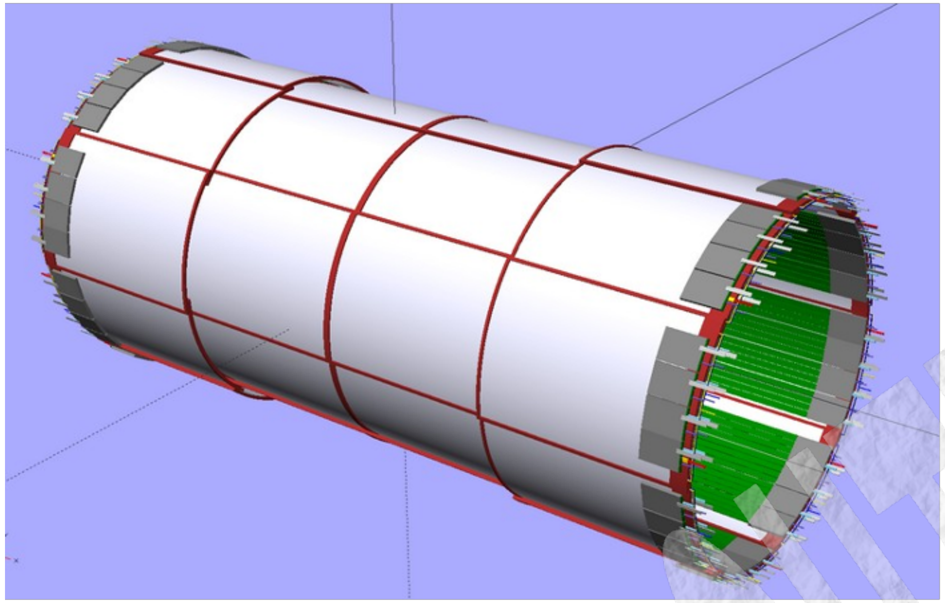
Recent update

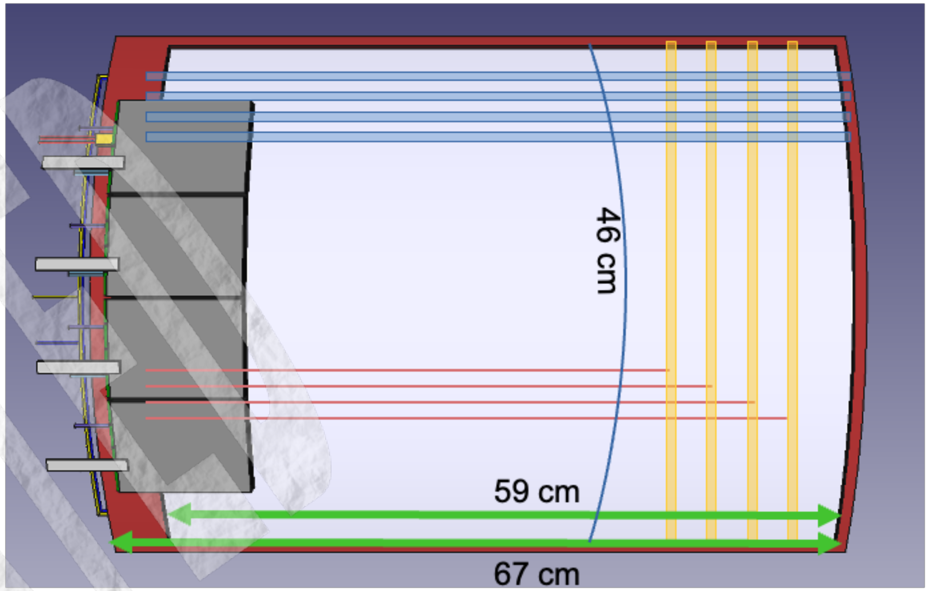


Coupled to TOF

12 radial sections, individually removable and independent of GST and PST

Previous design





32 module: 8 modules in ϕ × 4 modules in z

- R_{min} = 55 cm; R_{max} = 60.5 cm
- Overlaps in ϕ and in z for hermeticity
- 1024 readout channels/module
- **32K readout channels**

Module dimensions

Z = 67 cm

R*phi = 48 cm

Active zone dimensions

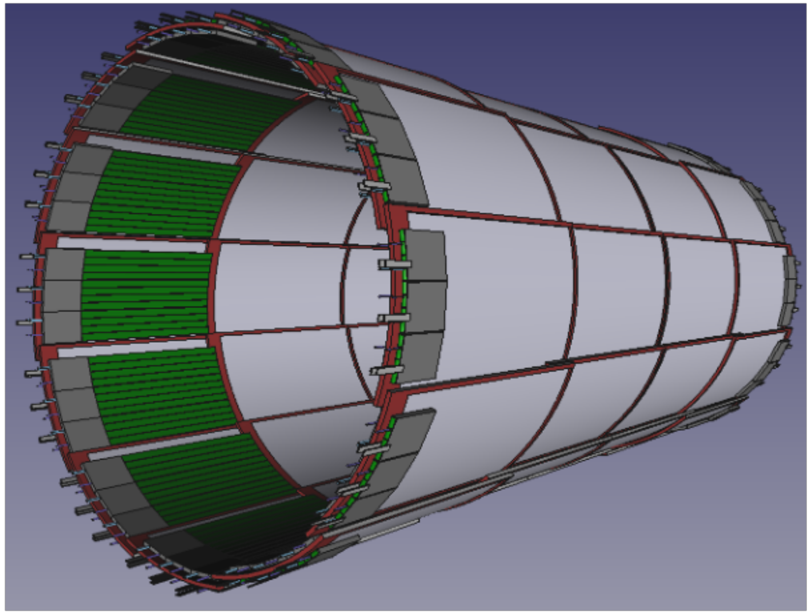
Z = 59 cm

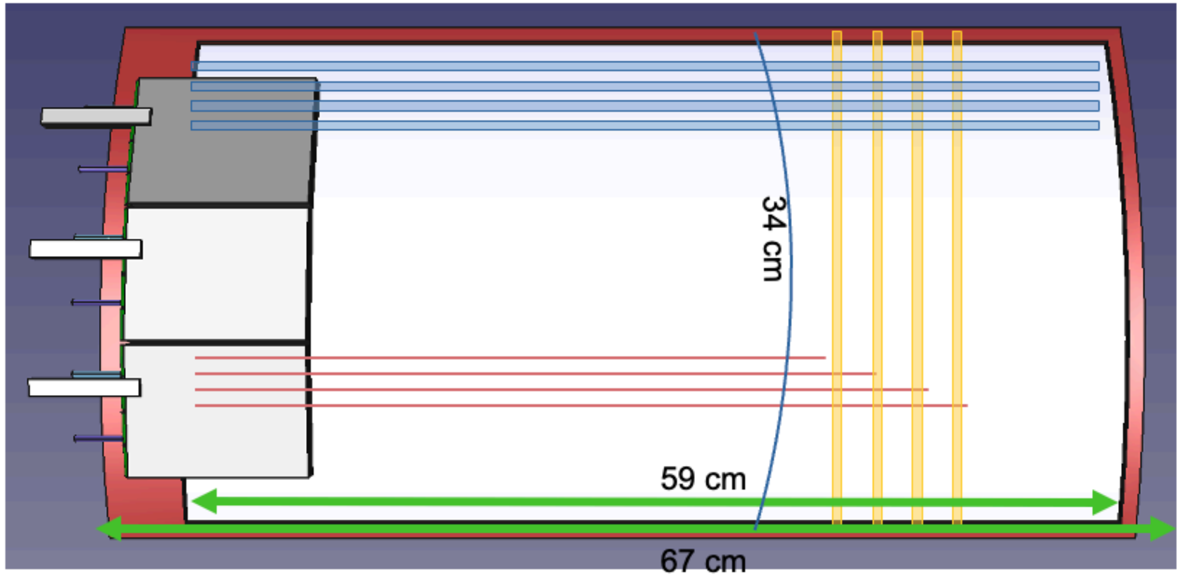
R*phi = 46 cm

Expected performances

- Spatial resolution: < 300 (500) μm in Z (r*phi)
- Time resolution ~20ns
- Efficiency ≥ 98%
- Material budget ~0.5% X0

Updated design





48 module: 12 modules in ϕ × 4 modules in z

- R_{min} = 56 cm; R_{max} = 61.5 cm
- Overlaps in ϕ and in z for hermeticity
- 768 readout channels/module
- **36K readout channels**

Module dimensions

Z = 67 cm

R*phi = 34 cm

Active zone dimensions

Z = 59 cm

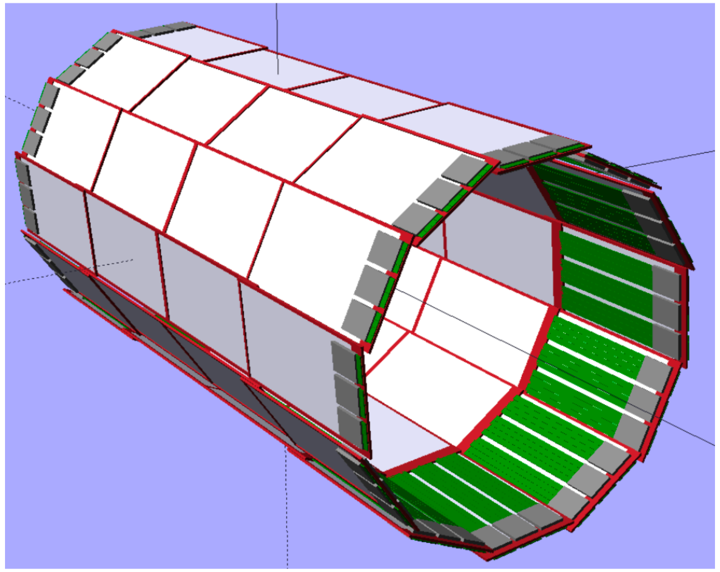
R*phi = 32 cm

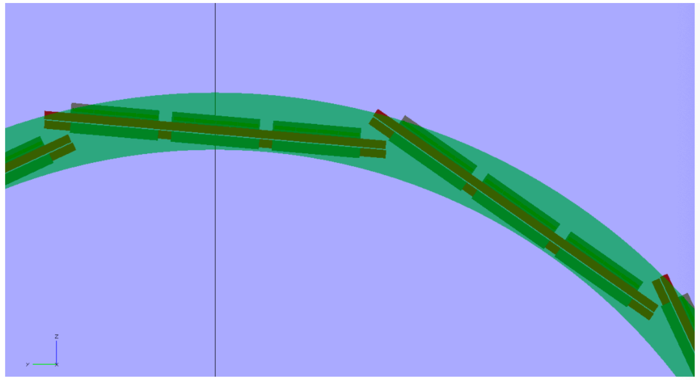
Expected performances

- Spatial resolution: < 300 (500) µm in Z (r*phi)
- Time resolution ~20ns
- Efficiency ≥ 98%
- Material budget ~0.5% X0

Considered layouts

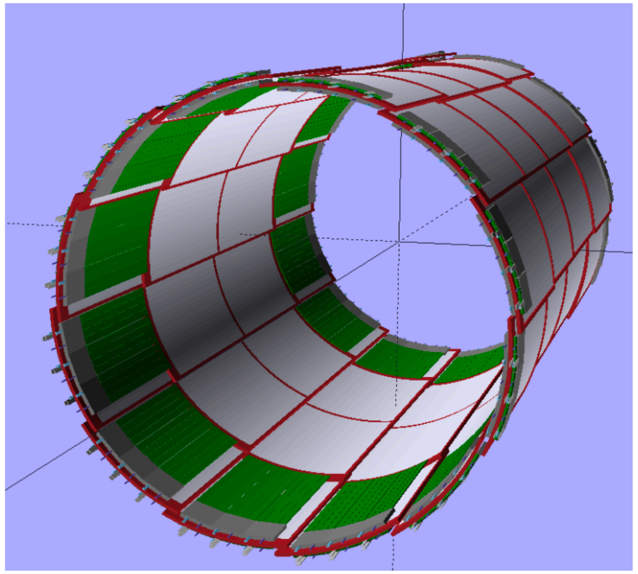
Slats

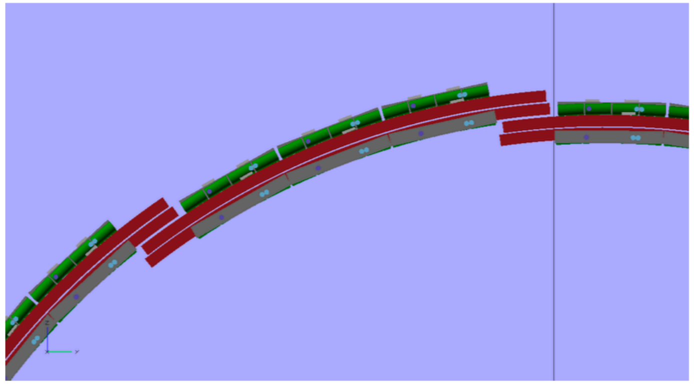




Keeping zone: [560,615] mm
Flat modules (slats)
Slat thickness: 8 mm
Delta radius in-out modules: 9 mm
Tiles tilt angle = 5 degrees
Tile dimensions= 330x670 mm^2

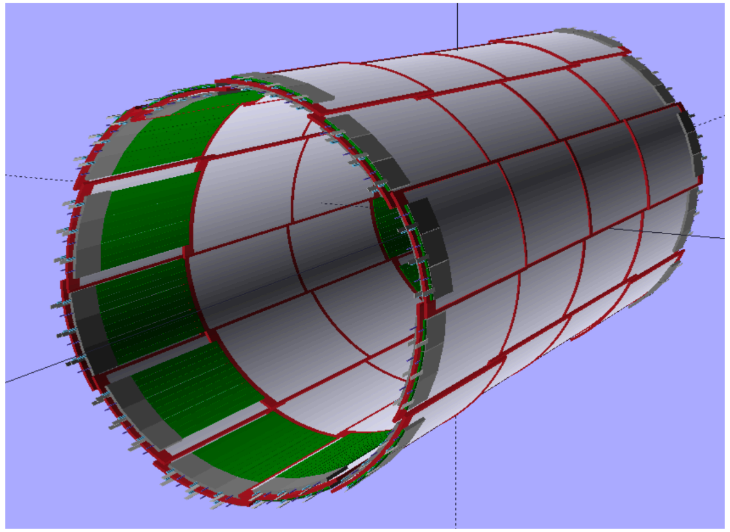
Fish scale

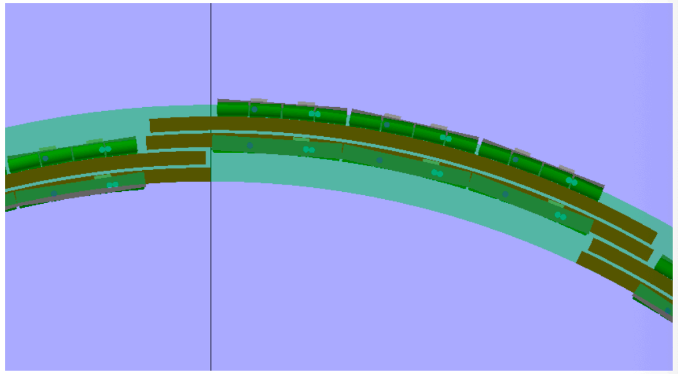




Keeping zone: [560,615] mm
Tile curvature radius: 572 mm
Tile thickness: 9 mm
Delta radius in-out modules: 10 mm
Tiles tilt angle = 4 degrees
Tile dimensions= 340x670 mm^2

Alternating tiles



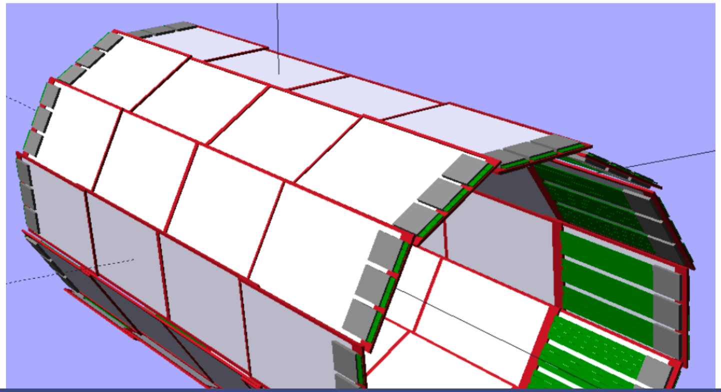


Keeping zone: [560,610] mm
Cylindrical modules (tiles)
Tile thickness: 9 mm
Delta radius in-out modules: 11 mm
Sectors delta radius 23 mm
Tile dimensions= 340x670 mm^2

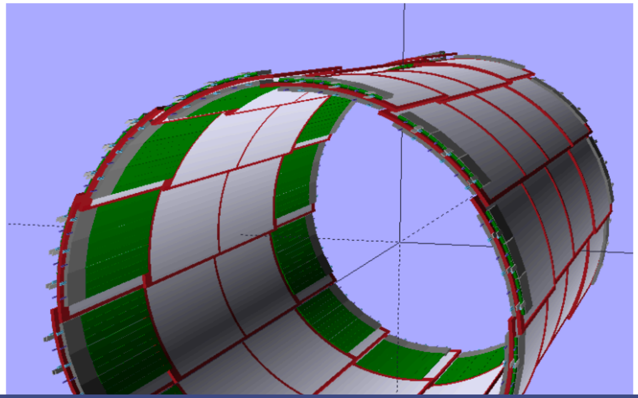
Considered layouts

Slats | **Fish scale** | **Alternating tiles**

Slats



Fish scale



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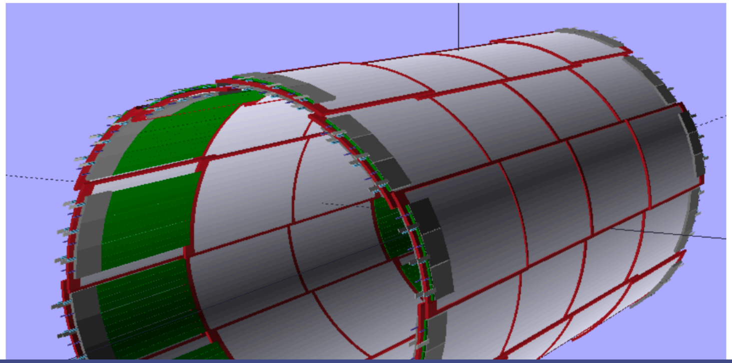
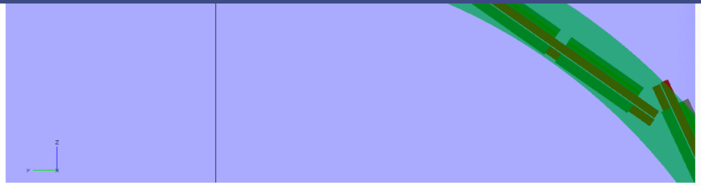
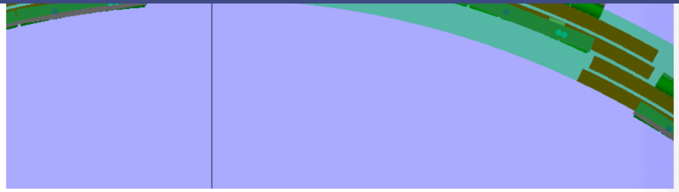


Many options are possible and we have several design propositions
Mechanical support constrain is required to converge towards a final configuration





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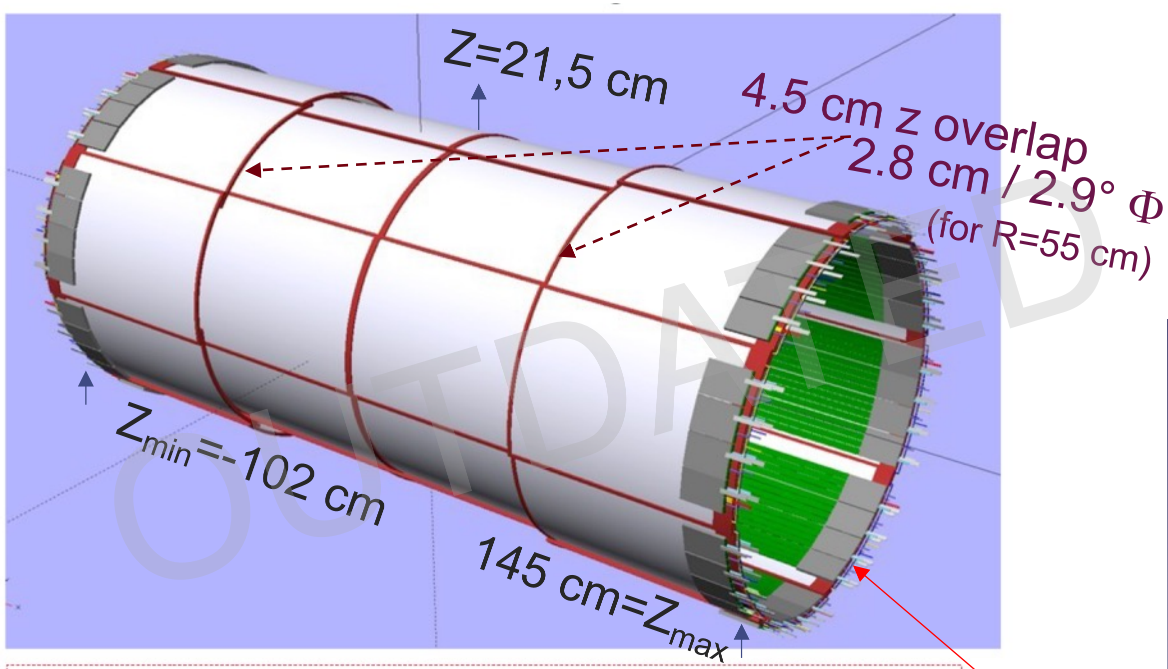
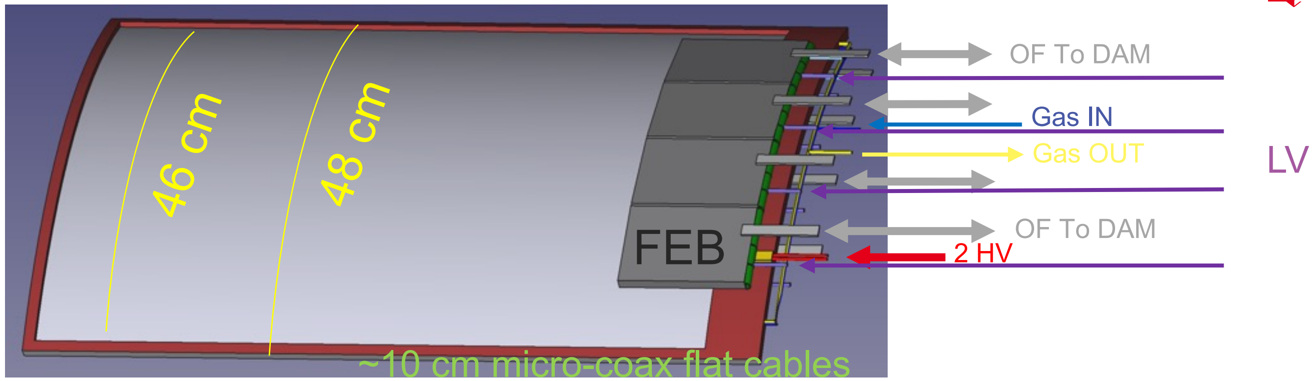
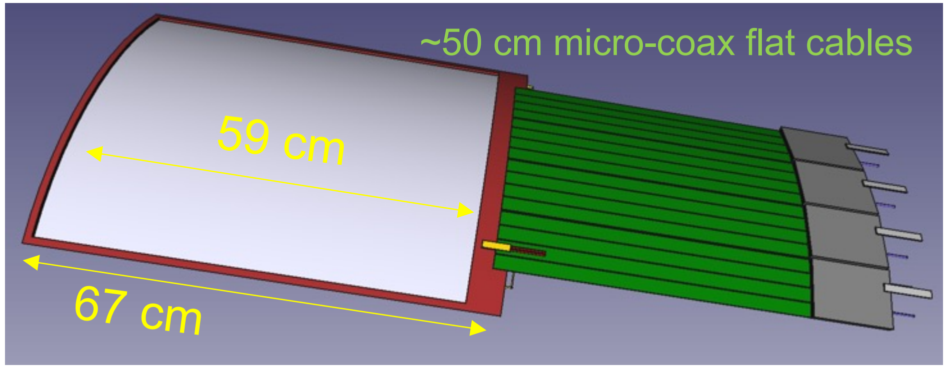
Services and FEB

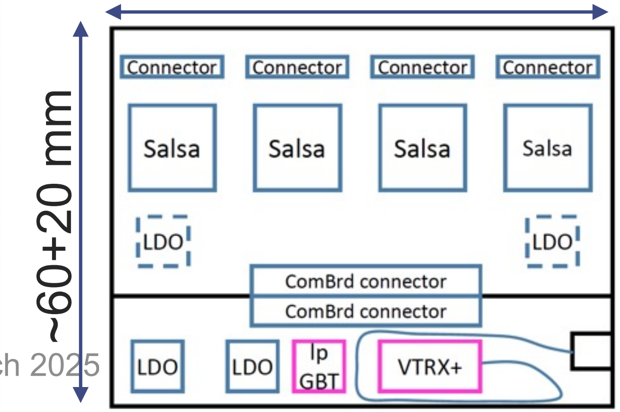






- 32 module: 8 modules in ϕ times 4 modules in z
- Overlaps in ϕ and in z for hermeticity
- 1024 readout channels/module
- 32K readout channels
- 128 FEBs (2x32 on each side - 4/tile)

FEB+cooling plate (15 mm thick ?)



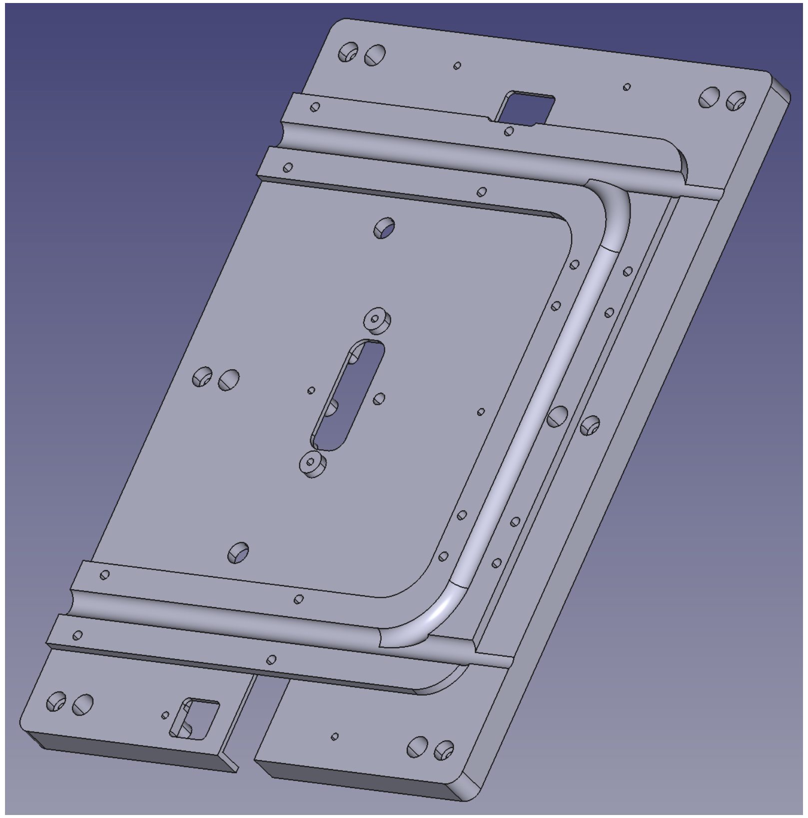
weight estimates

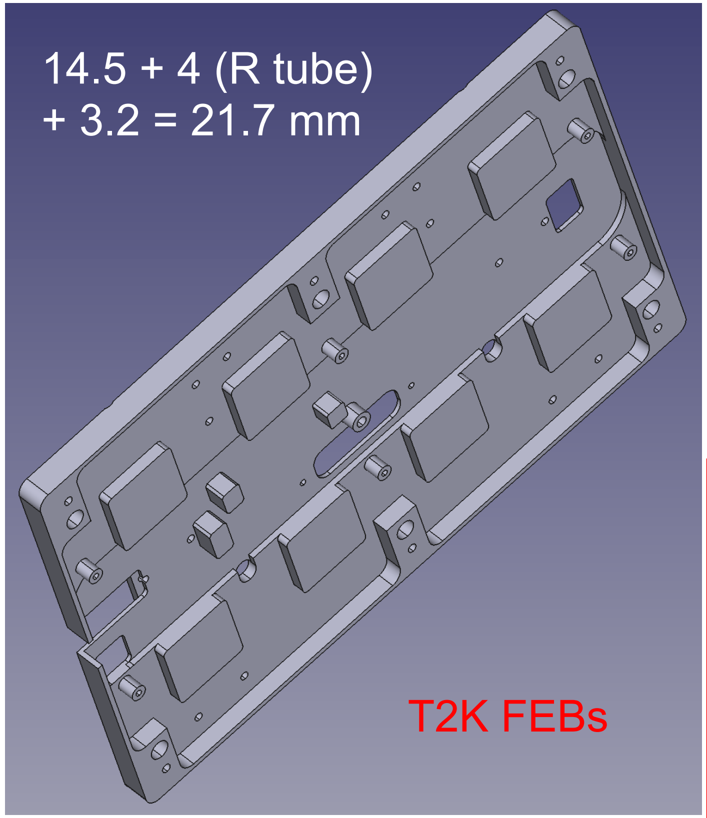
- Raw tile	~1 kg
- FEB PCB	~0.3 kg
- Cooling plate+fluid tube	~0.3 kg

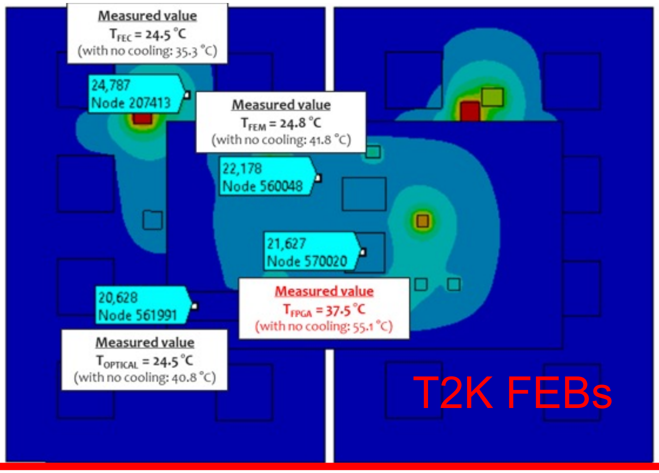
(*rough estimate for 3 mm Al cooling plate + copper tubes, thermal simulations to be done*)

On each side of the barrel	**~40 kg**
Cymbal	**~110 kg**

Started the design of the cooling plate (T2K- HA TPC)







- Negative pressure water cooling system
- 7 W/FEB (**8.5 for CyMBaL**), cooled at ~25°C +/- 0.2 °C with ~3 l/minute 18°C water flow in 6 ID/8 OD copper tubes
- Confirmed with complete thermal simulations (heat dissipation, steady state temperatures, pressure drops, water flow, …)

More compact design for CyMBaL
Minimal figures (?) to be confirmed for / by simulations **(mm)**

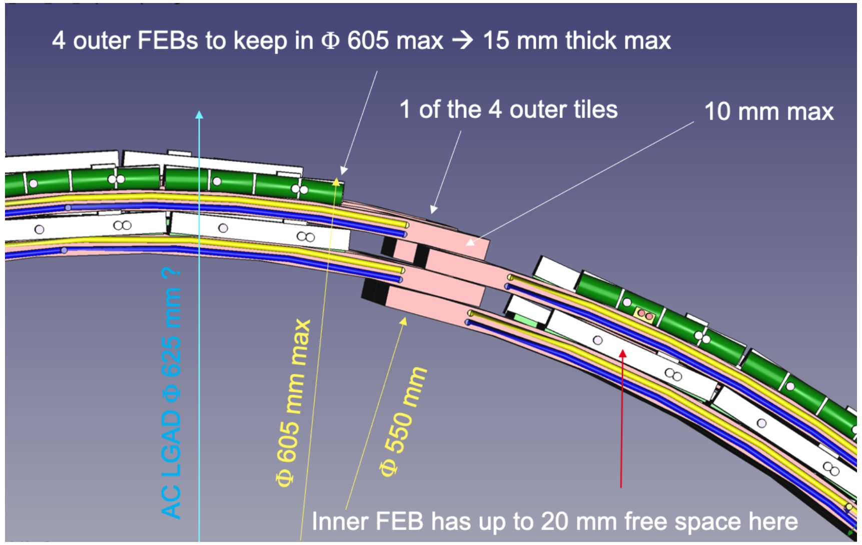
- FEB PCB : 3.2
- Component height : 3
- Compressed thermal foam : 1
- Plain cooling plate : 3
- Pipe outer radius (enough flow ?) : 3

minimal FEB+cooling plate thickness 13.2 mm ?

Mechanics + services

Space enveloppe for Cymbal?

- How much space is there for **services**?
- How much space for **FEB** at the edge?
- How do we support the FEBs

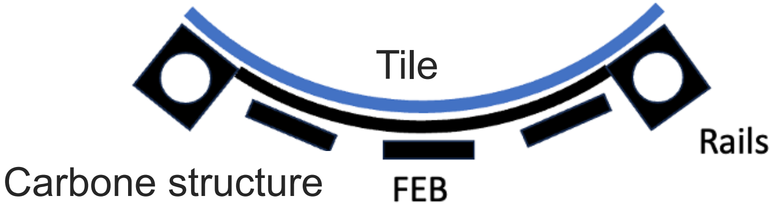


Maintenance:

- How do we slide each section? How do we deal with **services** (cable chains?)?

Coupling to TOF:

- How are we attached to TOF?



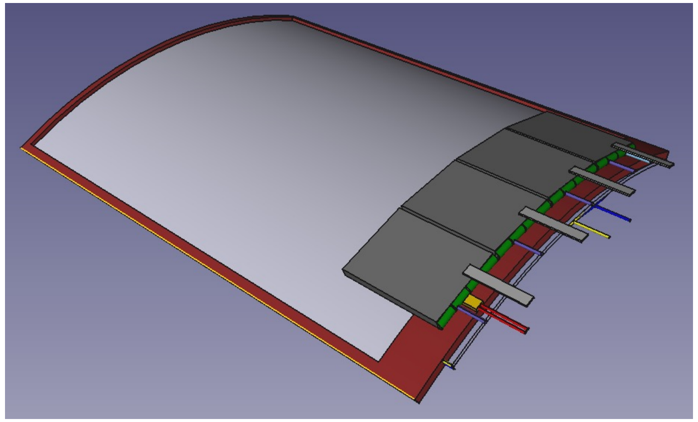
New design → **new mechanical interface and service routing** (and electronics cooling?) from Cymbal coupled to TOF

Need to clarify **who is responsible for which part of these designs**

→ Need for a close collaboration CyMBAL-TOF- mechanical design (BNL and Purdue) for the new support structure design

Impact of size modification on readout design

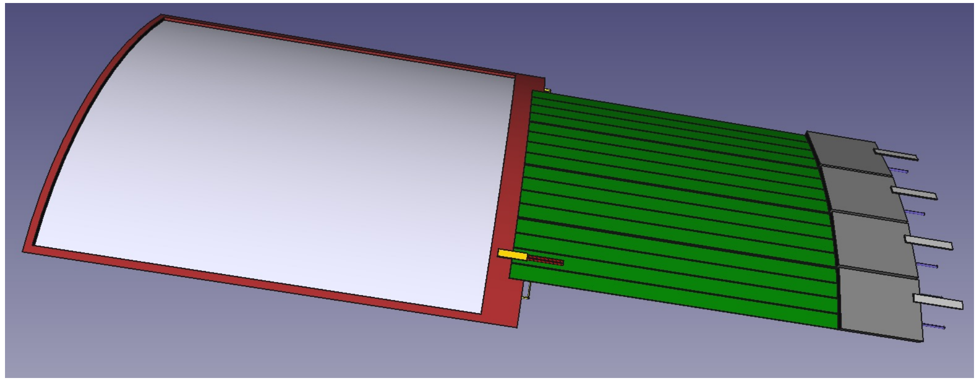
Initial design	Z	Phi
Ext. dimensions (cm)	67	48
Active area. dimensions (cm)	59	46
#channels / pitch (cm)	576 / 1,02	448 / 1,02
# SALSA	9	7
# FEB	4	



Not enough space for 4 FEB in the updated design

Space for front-end cards is limited
→ Limit on the number of electronic channels
Several options:

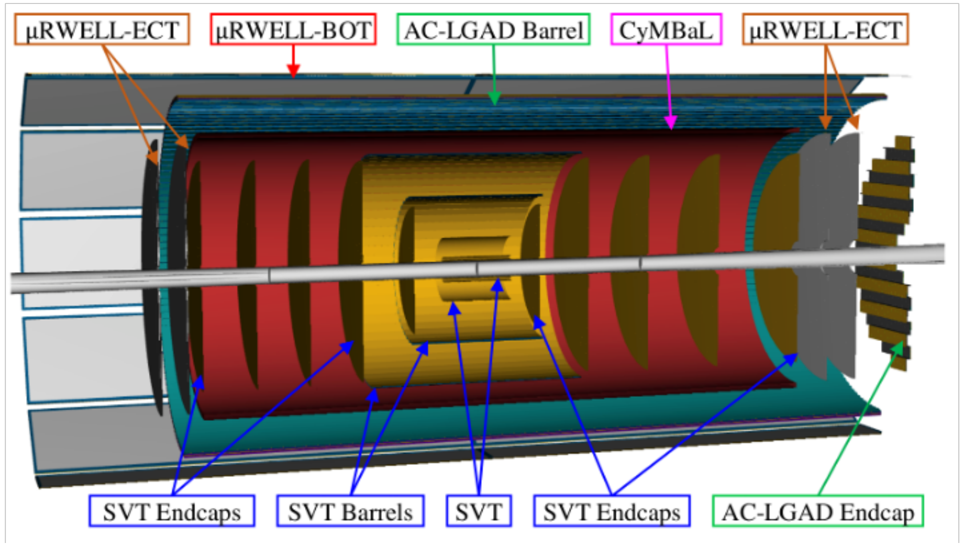
Updated design (same pitch)	Z	Phi
Ext. dimensions (cm)	67	33
Active area. dimensions (cm)	59	31
#channels / pitch (cm)	512 / 1,15	256 / 1,2
# SALSA	8	4
# FEB	3	



Updated design (Z precision)	Z	Phi
Ext. dimensions (cm)	67	33
Active area. dimensions (cm)	59	31
#channels / pitch (cm)	576 / 1,02	192 / 1,6
# SALSA	9	3
# FEB	3	

Tiles: 32 → 48 (+50%)
FEB: 128 → 144 (+12,5%)
SALSA: 512 → 576 (+12,5%)

Role of Cymbal



MPGD's role:

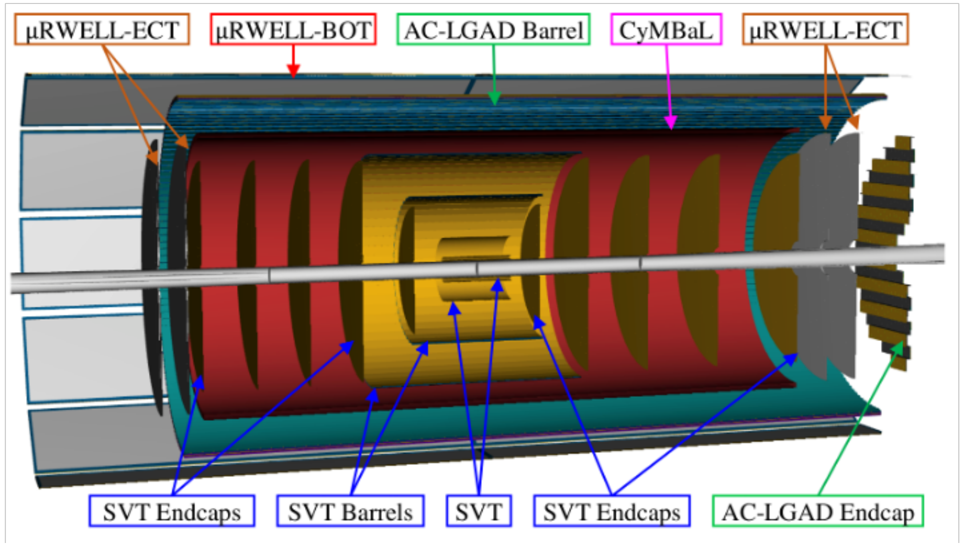
- Provide redundancy hit points for track reconstruction
- Provide "fast" hits for pattern recognition. Challenges:
  - streaming readout
  - High backgrounds
  - Long MAPS integration time

Latest performance requirements (@Frascati)

Envelopes	Defined: 5 cm radial space Module dimension set	
Space resolution	R*phi ≤ 500 µm Z ≤ 300 µm	- Constraint: 1k ch/module - Optimisation of pitch for the z coordinate. - Select hits in time
Time resolution	~ 20 ns	Optimize drift field, gas, hit selection,...
Efficiency	≥98%	For MIPs
Material budget	~0.5% X0	Similar to CLAS12 technology

Plots to support these numbers?

Role of Cymbal



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Time resolution	~ 20 ns	Optimize drift field, gas, hit selection,...
Efficiency	≥98%	For MIPs
Material budget	~0.5% X0	Similar to CLAS12 technology

Plots to support these numbers?

* spatial resolution -> on which coordinate?

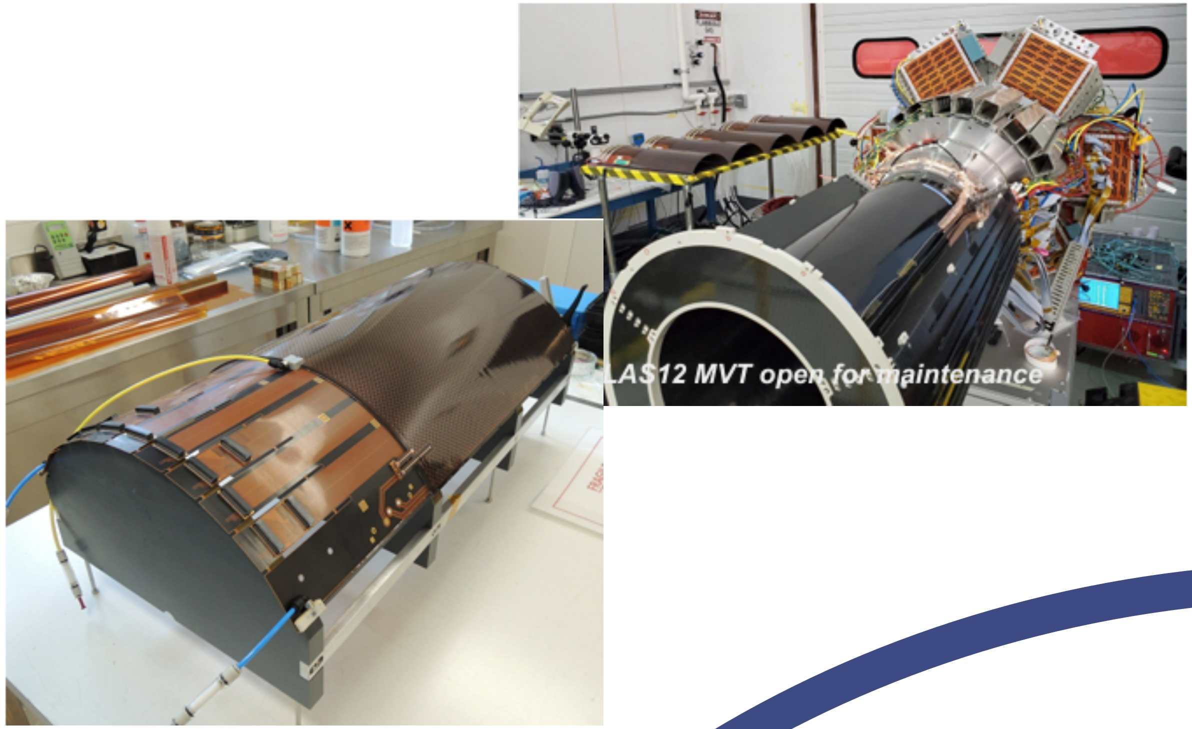
* timing resolution -> what's the impact of going higher than 20ns?

* How much degradation is acceptable at large angle (Lorentz angle)?

* precise occupancy, background levels?

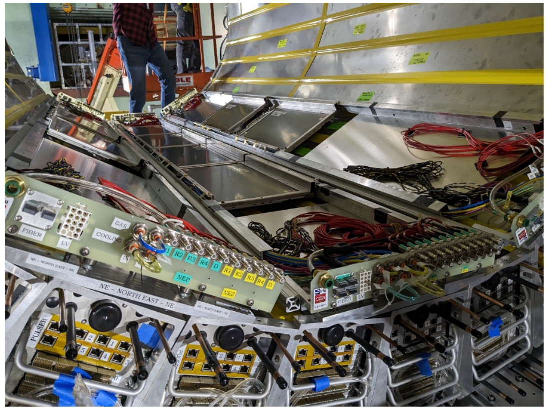
* Any interest in having 2 layers instead of 1?

Examples of other micromegas detectors

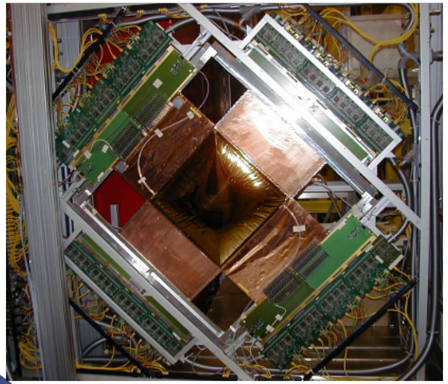


Curved tiles on CLAS 12 (resistive strips, 0.5% X0)

TPOT (2 x1D-MM)



Pixelised MM on COMPASS with GEM pre-amplification



Also **ATLAS NSW**, **MCube**, **PicoSec, P2**, etc…

Lever manoeuvres

Readout pattern: pitch and pattern
Resistive layer: resistivity and pattern
Size of the drift gap
Gas
Pre-amplification
…

Electronics

Tile configuration

Number of layers
System layout, access

Need to consider the whole detector system: Micromegas module + readout + environment (allocated mechanical space, services and maintenance needs)

Conclusion

CyMBAL: Cylindrical micromegas tracking layer

So far our R&D focused on the 2D design
Reaching a stage where we need to take critical decisions

Recent change in configuration (12 sectors + TOF coupling)

→ opportunity to rethink the required performances for Cymbal

Configuration change is the opportunity to rethink the required performances for Cymbal

Inputs are needed:

- from **mechanics** to design the module structure and layout

- from **physics and tracking simulations** to steer our focus towards relevant performances

Many different options are possible and considered - experience of several detector designs with very large array of focuses → **tailor the detector to ePIC needs**

We need inputs and to collaborate more closely with :
mechanical engineers and reconstruction + physics WG

Back-up

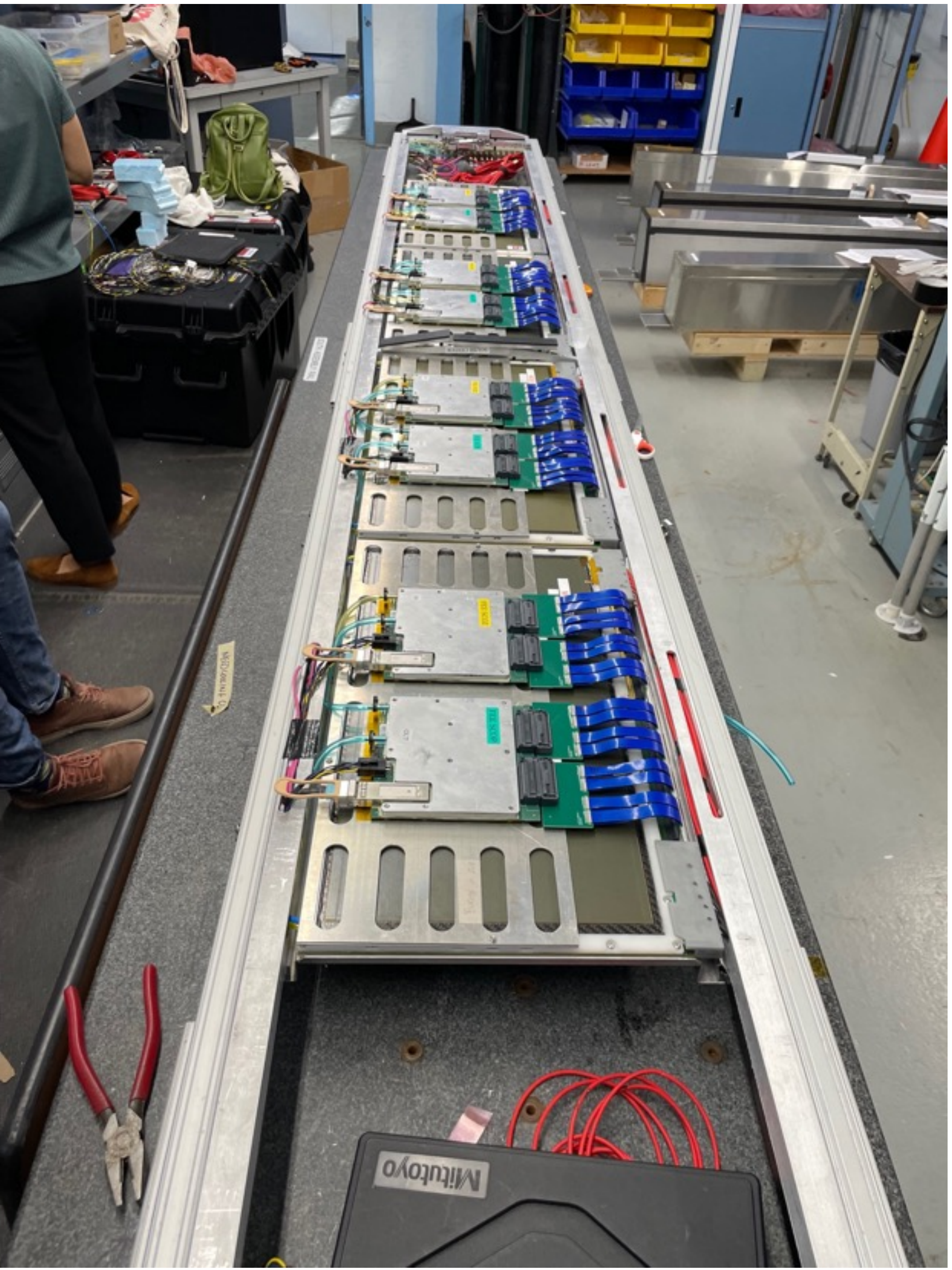
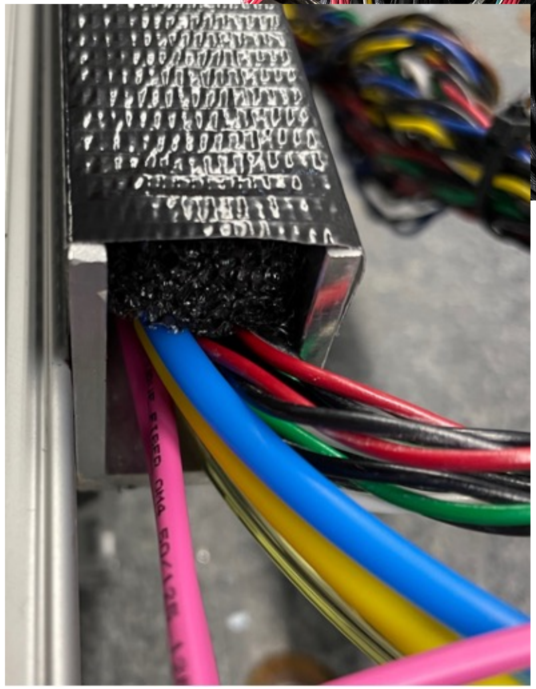
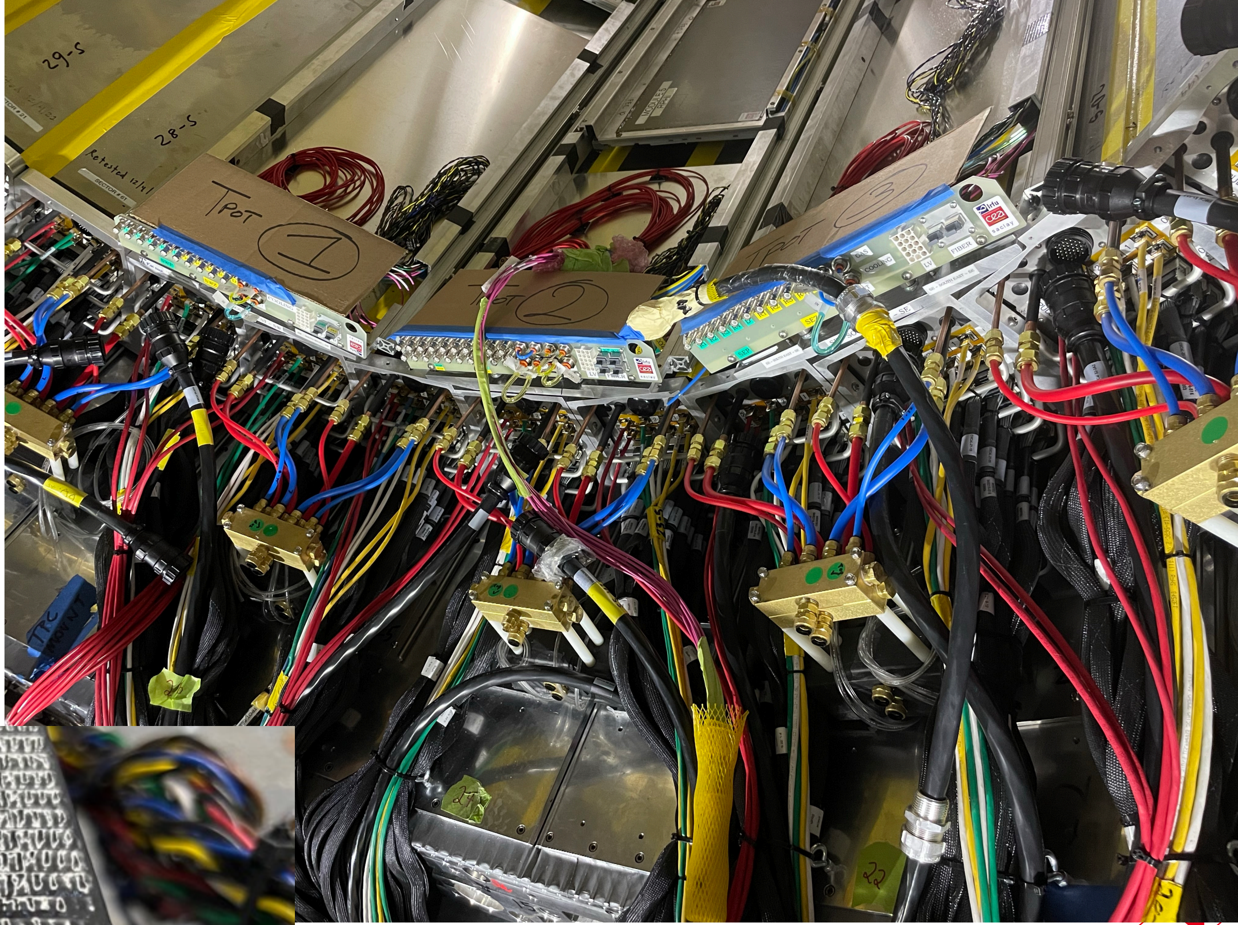
Micromegas performances

Gas	Ar-iC_4H_{10}	Ar-iC_4H_{10}	Ne-C_2H_6	Ne-C_2H_6	Ne$C_2H_6CF_4$	Ne$C_2H_6CF_4$
%	96-4	89-11	95-5	89-11	79-11-10	59-11-30
n_{ep}	28.4	36.9	13.5	14.6	19.7	19.6
G_0	4100	3700	14500	14000	6400	7400
cluster size cl_{sz}	3.0	2.4	3.4	2.9	2.1	2.2
TOT (ns)	210	195	187	182	171	179
RESOLUTIONS:						
Position(μm)	70	62	80	80	50	50
Timing (ns)	17.1	12.3	17.9	16.5	8.8	8.6

when adding 10 % CF_4. Adding 30 % does not improve it anymore since the contribution of the SFE16 starts to dominate.

Performances of a Micromegas detector, at full eeciency for various gas mixturess read out electronics : SFE166 beam conditions: 10 GeV or p.

Role of steps in deposition rate in silane chemical vapor deposition on Si(111), Franck Thibaudau, Physical Review B 71

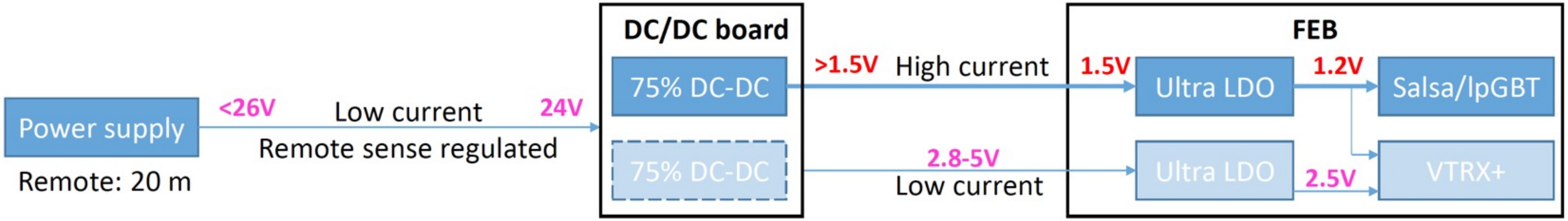

Mitutoyo


TPOT 1
TPOT 2

LV powering the Front-End readout electronics

Contact: Irakli Mandjavidze (Irfu)

Same location
As a patch panel ?

128 FEB



As close to FEB as
possible : 1 cm - 3 m

FEB components and their power consumption

Component	Vin V	Current mA	Power mW	Comment
Salsa 1	1.2	1 000	1 200	15 mW/ch
Salsa 2				
Salsa 3				
Salsa 4				
lpGBT	1.2	420	500	Overestimated
VTRX+	1.2	20	25	
	2.5	70	175	
LDO Salsa 1-2	1.5	2 000	600	LDO / Salsa to avoid hotspots ?
LDO Salsa 3-4				
LDO lpGBT/VTRX+	1.5	440	130	
LDO VTRX+	2.8	70	20	

Total ~6.8 W (8.5 W with 25% safety margin)

→ CyMBaL Barrel total power of **~1.1 kW** (+ extra from DC/DC)

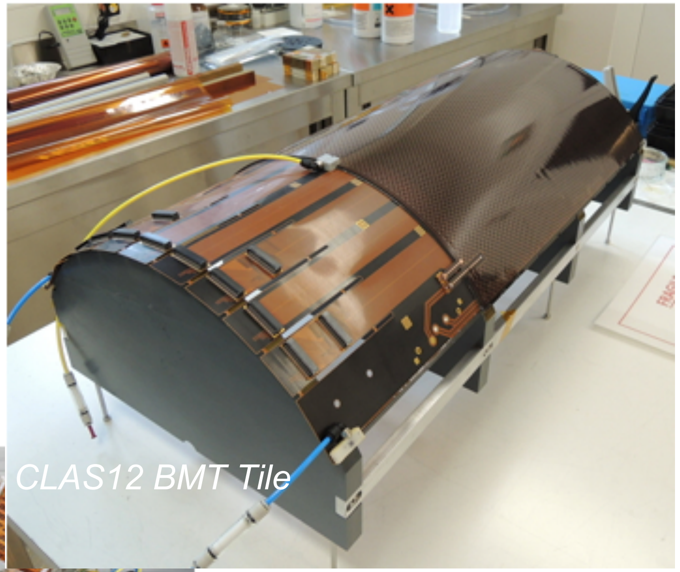
Tim Camarda & Gerard Visser

50-70% Power efficiency of DC/DC converters

Circuit	V_{IN}	I_{IN}	Reg	V_{OUT}	I_{OUT}	P_{OUT}	P_{LOSS}	P_{EFF}
SALSA ASIC	3.0	2A	LT3033 (1)	1.2V	2A	2.4W	3.6W	50%
SALSA ASIC	3.0	2A	LT3033 (2)	1.2V	2A	2.4W	3.6W	50%
LpGBT	3.0	700mA	LT3033 (3)	1.2V	700mA	850mW	1.3W	53%
VTRX	3.0	50mA	LT3033 (3)	1.2V	50mA	60mW	90mW	50%
VTRX	3.0	105mA	LT3042 (4)	2.5V	105mA	275mW	60mW	78%
Input Reg	24V	870mA	bPOL48V	3.0V	4.86A	14.6W	4.38W	70%

CyMBaL tiles à la CLAS12

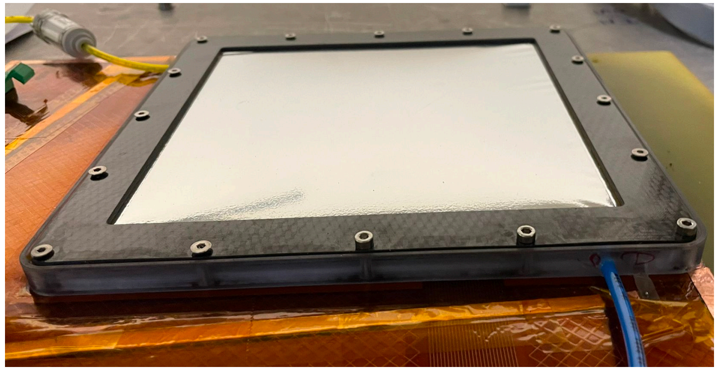
- Design of the tile **very similar to CLAS12 BMT detector** (project led by CEA and taking data since 2017)
  - B=5T solenoid, total active area ~4m^2
  - Light cylindrical tiles (~0.4% X_0 per layer)
- **Build on past experience** by upgrading CLAS12 design for ePIC needs
  - **Bending** of the tile (larger radius)
  - Upgrade from **1D to 2D** readout


CLAS12 BMT Tile


CLAS12 MVT open for maintenance

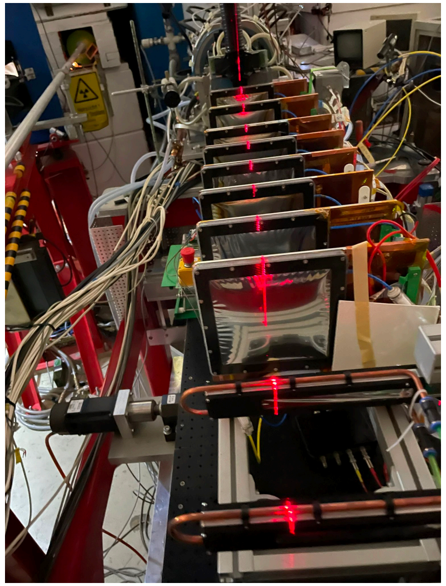
Low-X_0 2D micromegas R&D

- **R&D for very-low material budget** (0.2% X_0) 2D Micromegas
- Replacing FR4 (PCB) with **light kapton foil** stretched over carbon frame
- **Investigating optimal 2D readout and resistive patterns** + combinations
  - Varying resistivity, shape, pitch, etc..
- Less support = stronger constraints for production
- Testing **small flat prototypes** (12x12 cm²)



Testing of low-X_0 micromegas

- Tested several small Micromegas and µRWELL prototypes
- Looking for optimal performances (cluster size, uniformity of charge sharing, resolution)
- Beam test of about one week in June ‘23 in Mainz at MAMI
- Results from TB dominated by multiple scattering but 1mm strips design shows interesting performances
- Testing of updates for the serigraphy/bulk processes



Ex. for straight strips readout