R&D plans for the drift chamber in 2025

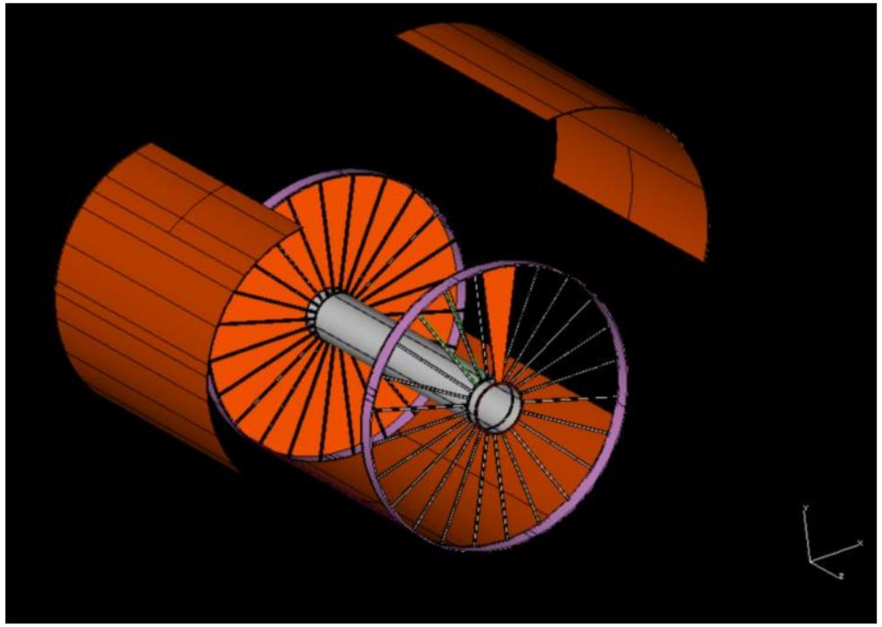
6st IDEA Study Group meeting
March 25th 2025

M. Primavera (INFN Lecce) on behalf of the IDEA DCH Groups:

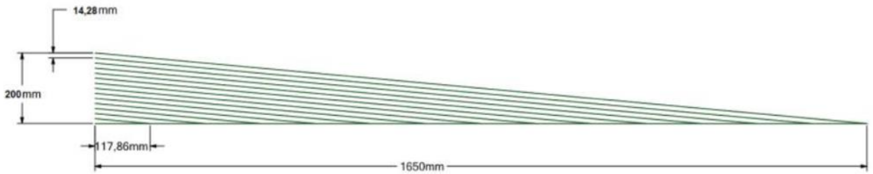
Bari: **M. Abbrescia , M. Numan Anwar , N. De Filippis, W. Elmetenawee, M. Louka, F.M. Procacci**
Lecce: **A. Corvaglia, F. De Santis, E. Gorini, F. Grancagnolo, S. Grancagnolo, F.G. Gravili, A. Miccoli, F. Paladini, M. Panareo, A. Ventura, C. Veri**
Pisa: **M. Chiappini**

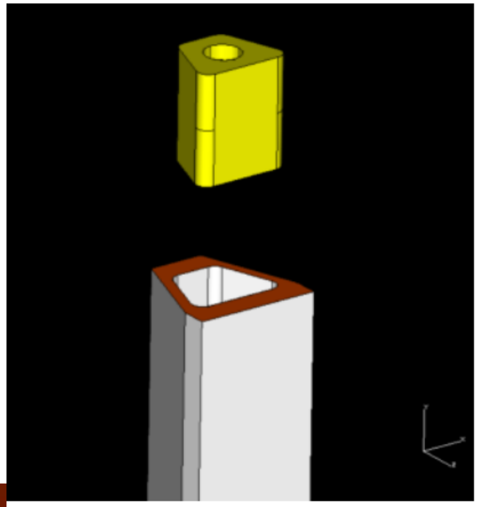
Other collaborators expressed their interest in joining the project → BNL (G. Iakovidis, A. Sciandra), IJCLAB (G. Charles), Purdue (A. Jung)

DCH mechanical design → updates and plans/1



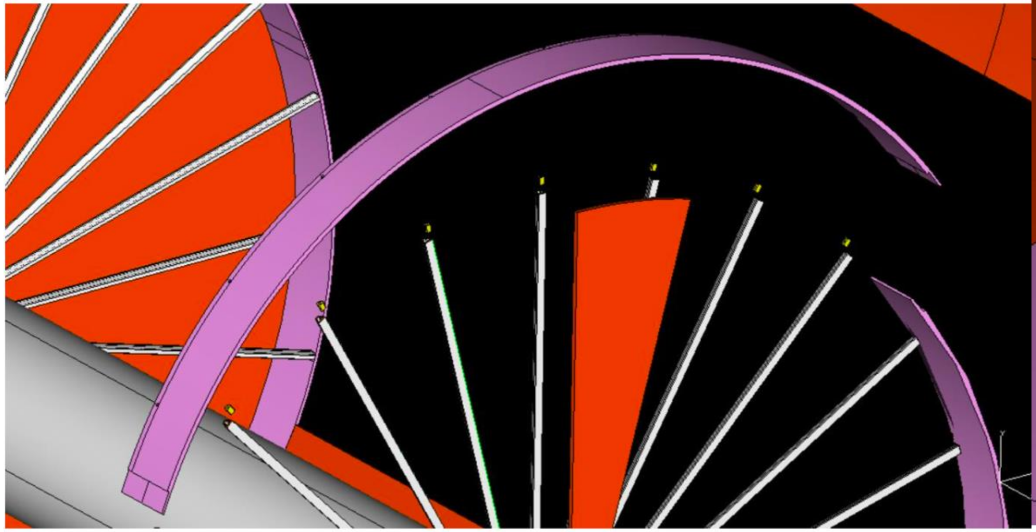
- **Outer cylinder** made of 3 panels **2 cm** thick →3 layers (2 monolithic CF with Al honeycomb structure in the middle)
- **External and internal ring** in monolithic CF
- **Endplates** made of 48 **Spokes** (24 per endcap), defining 24 azimuthal sectors.
- Each **spoke** (length **l = 165cm)** is supported by 15 **Stays.**
- **Inner cylinder** thickness **200 μm** CF – not structural

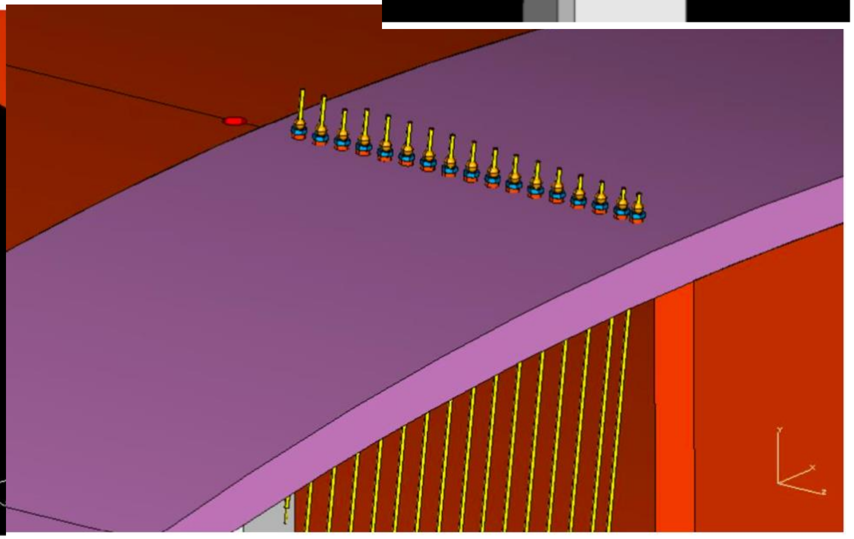




Outer ring/spoke details

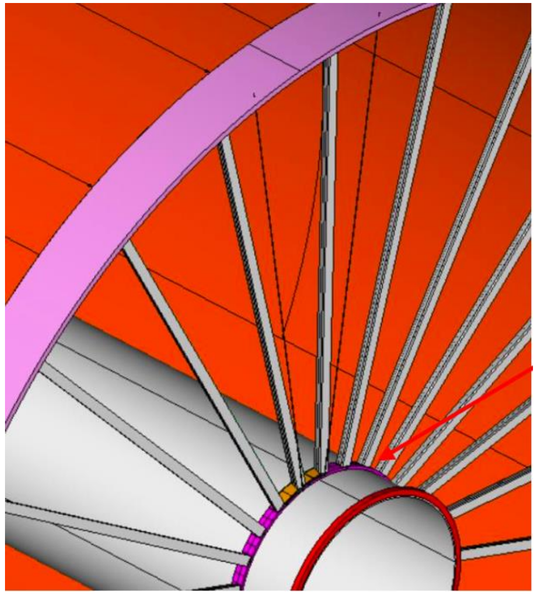
On the outer part the spoke has an internally glued female joint (yellow) which locks the spoke to the outer ring (pink)

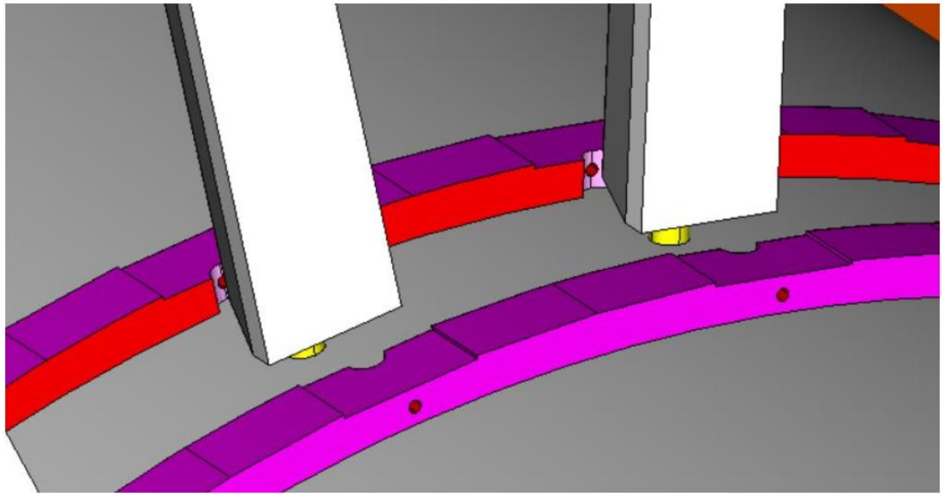


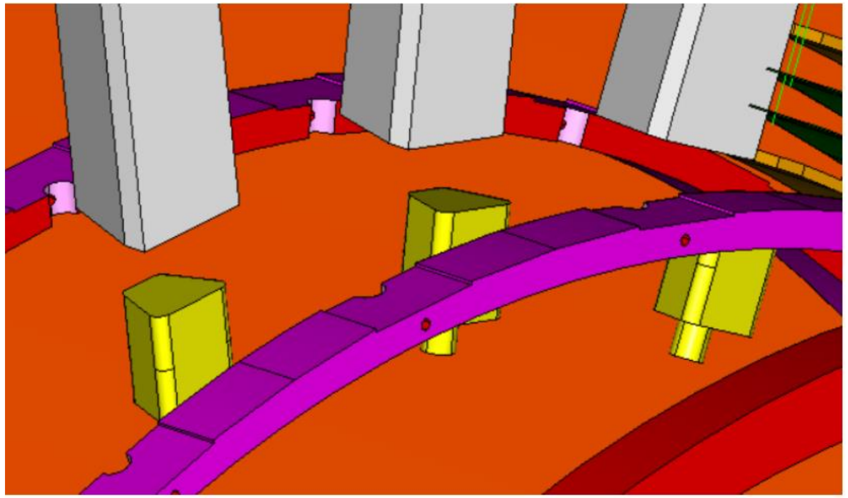


DCH mechanical design → updates and plans/2

Inner ring details

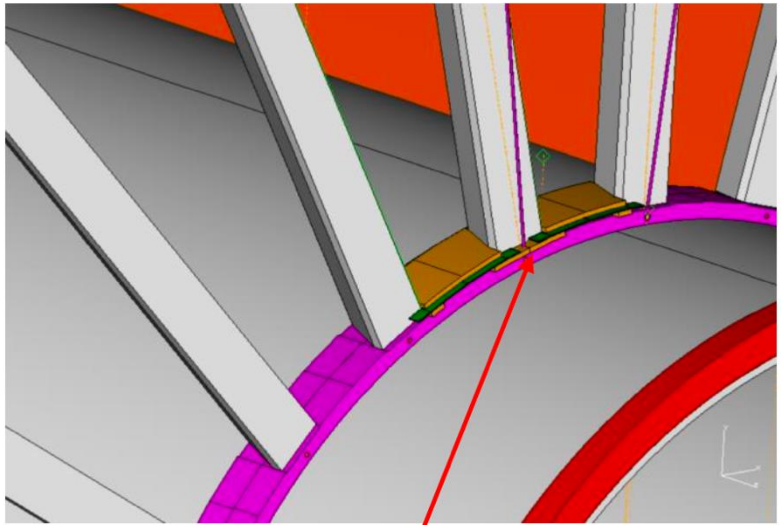






Two interlocking rings (violet) lock the spokes (grey)

Each spoke has an internally glued male joint (yellow) that fits into the rings

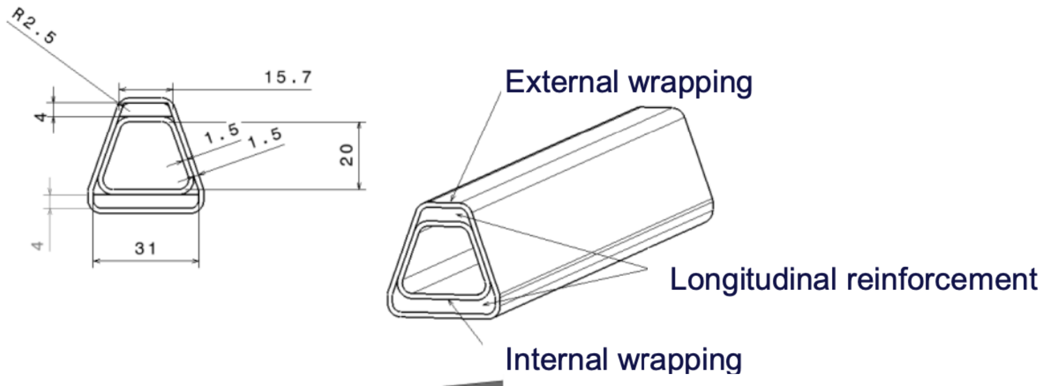


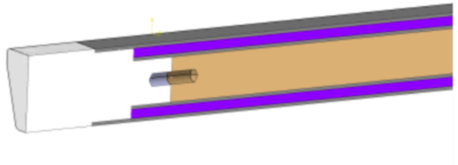
Spacers (yellow) and PCBs (green) are inserted between the spokes. The spacers have holes for the gas distribution

The edge of the PCB acts as a stop on the spoke, providing a reference.

The supporting cables of the spokes are anchored to some spacers appropriately shaped

DCH mechanical design → updates and plans/3





Carbon foam core **6x** lighter than aluminum (FOAM ROHACELL® 35 HTC)

Spoke prototype (50 cm long):

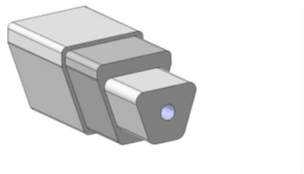
✓ The core was milled with a numerically controlled machine.

✓ The winding foils were manually cut into strips of the sizes above.

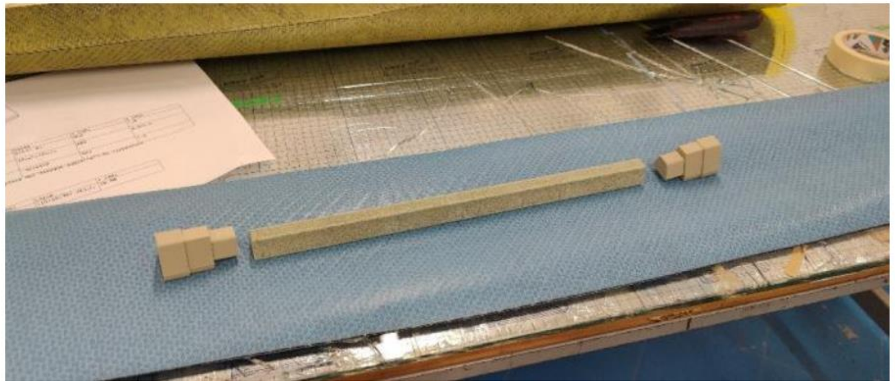
✓ The PEEK side inserts were glued with acrylic adhesive

Item	Material	CPT (mm)	Layup	T (mm)
Internal wrapping	Prepreg Tissue 430g/m2	0.5	(0)3	1.5
Longitudinal reinforcement	Prepreg Tissue 800g/m2	0.86	(0)4	4
External wrapping	Prepreg Tissue 430g/m2	0.5	(0)3	1.5

CF thickness # of CF layers total thickness



Peek side inserts



- ✓ **Simulation plans:**
  - Study the stability of the outer and inner rings with all the connections
  - Study the best solution for connect the stays at the spokes
  - Buckling analysis on outer cylinder
- ✓ **Production plans:**
  - More spokes prototypes
  - Mechanical test with torsion, compression, bending
  - Internal and external rings with the connections
- ✓ **Plans for test to be done in parallel:**
  - Characterize the wires we have (micrometer positioning stages)

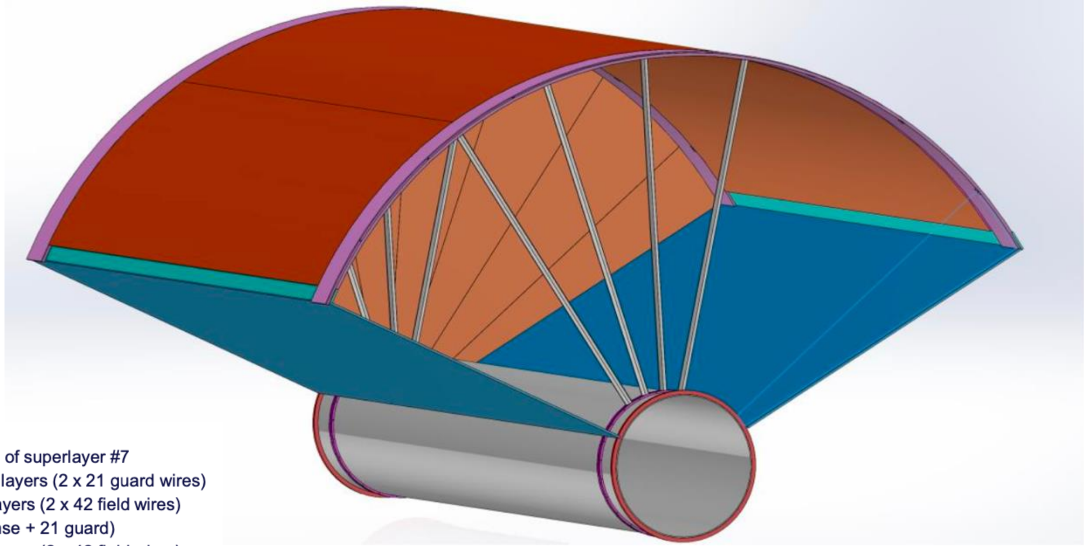
DCH prototype → updates and plans/1

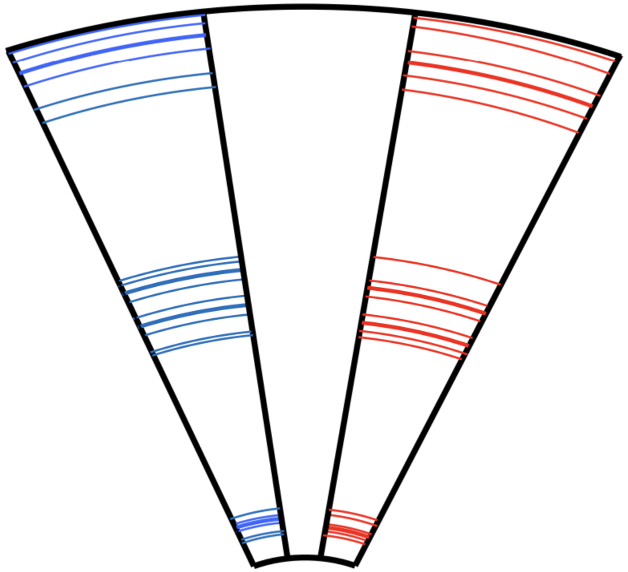
- ✓ Activities to start the construction of a **full-scale prototype** → to test the chamber mechanical and electrostatic stability

- ✓ Goal: construction a full length DCH prototype with 3 sectors per endcap:
  - 8 spokes (4 per endcap)
  - Internal ring
  - 1/3 outer ring
  - 1/3 cylindrical panel

- ✓ Collaboration with **CETMA composites**

- ✓ ***A clean room is needed for wiring the prototype!***



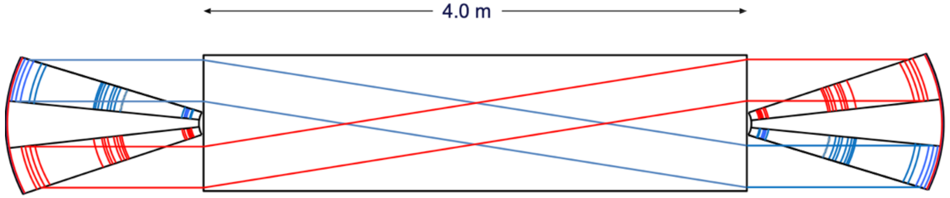


First two layers of superlayer #1
V and U guard layers (2 x 9 guard wires)
V and U field layers (2 x 18 field wires)
U layer (8 sense + 9 guard)
U and V field layers (2 x 18 field wires)
V layer (8 sense + 9 guard)
V and U field layers (2 x 18 field wires)
V and U guard layer (2 x 9 guard wires)

Last two layers of superlayer #7
V and U guard layers (2 x 21 guard wires)
V and U field layers (2 x 42 field wires)
U layer (20 sense + 21 guard)
U and V field layers (2 x 42 field wires)
V layer (20 sense + 21 guard)
V field layer (42 field wires)

First two layers of superlayer #8
U field layer (46 field wires)
U layer (22 sense + 23 guard)
U and V field layers (2 x 46 field wires)
V layer (22 sense + 23 guard)
V and U field layers (2 x 46 field wires)
V and U guard layer (2 x 23 guard wires)

Last two layers of superlayer #14
V and U guard layers (2 x 35 guard wires)
V and U field layers (2 x 70 field wires)
U layer (34 sense + 35 guard)
U and V field layers (2 x 70 field wires)
V layer (34 sense + 35 guard)
V and U field layers (2 x 70 field wires)
V and U guard layer (2 x 35 guard wires)



TOTAL LAYERS: 8
Sense wires: 168
Field wires: 965
Guard wires: 264
~1400 wires in total

PCBoards wire layers: 42
Sense wire boards: 8
Field wire boards: 22
Guard wire boards: 12
HV values: 14

Readout channels: 8+8 + 16+16+16+16 + 16+16 = 112

DCH prototype → updates and plans/2

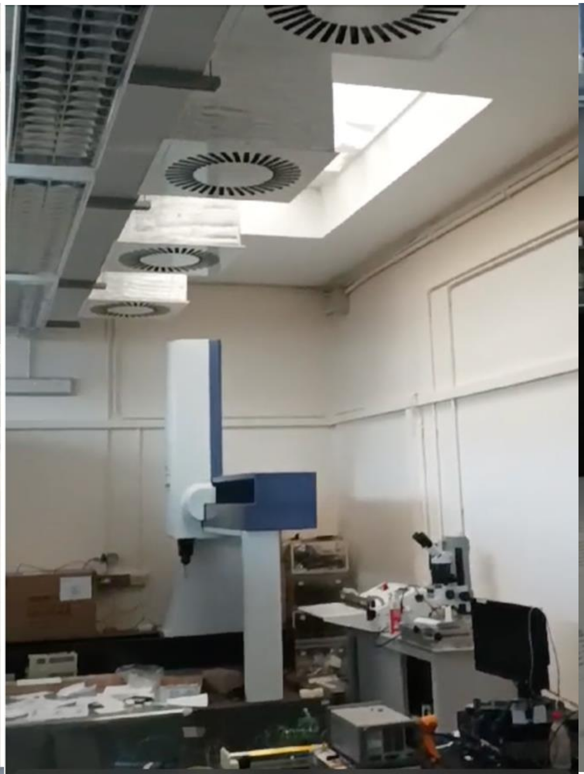
- ✓ Several options evaluated for the clean room, but dimensions need to be large (~5m x ~8m) and it must not be already occupied, so there are not many possibilities. Recently (on March 4th) we visited the ex-``ALICE’’ clean room in Bari, together with Paolo.

- ✓ Dimensions are fine (even if not ``fully comfortable’’ to host the wiring machine + prototype + additional test desks)

- ✓ Status is fine: interventions of the clean room functionality recovery and further safety adaptations should be carried out

- ✓ *Other possible options are still under evaluation (a CNR clean room in Lecce…)*






DCH prototype → updates and plans/3

Plans

✓ Reply to the requests (before to ask INFN funds for the clean room):

- A map of the layout needed for the operation
- Simulation with CAD of the dimensions and the movements of the prototype, e.g. to be extracted from the clean room
- Realistic estimate of the costs to: restore the functionality of the clean room, ensure safety operations (e.g. Safe access to the air recirculation system), ensure maintenance and daily consumption
- Realistic estimate of the person power needed for the clean room management

✓ First attempt (an exercise) to have a time schedule to realize the prototype → main steps, supposing T0 = OK from INFN to the clean room:

2025 *OK from INFN to give funds to make the clean room operational*
2026 *carry out the bureaucratic steps for entrusting the contract to a company*
2026 *Procurement of the needed materials/mechanics for the prototype*
2027 *clean room ready and operational*
2027 *prototype wiring in the clean room*
2027 *Procurement of the needed electronics for the prototype readout*
2028 *Test the prototype on cosmics*
2029 *Test the prototype on a beam facility*

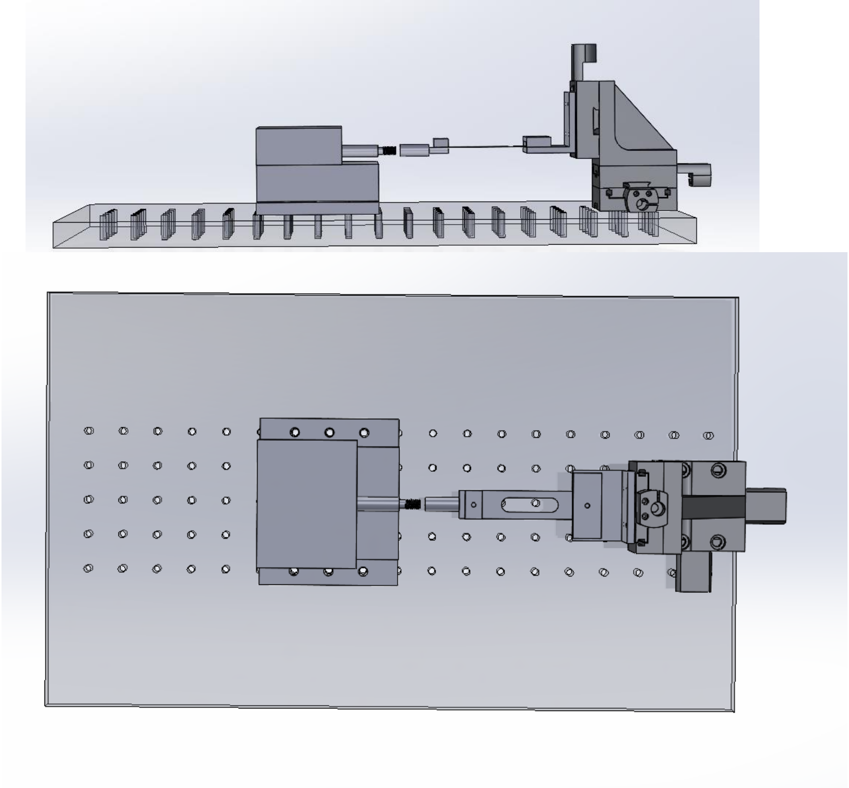
DCH prototype → updates and plans/4

✓ Wire tests starting just now in a Bari clean room, mechanical components of the setup are under preparation.
For the moment:

- 1 Km Gold plated W wire, 20 μm diameter, Luma Metal (US), to be tested through traction following ASTM 3379 (Standard Test Method for Tensile Strength and Young's Modulus), then analised looking at the breaking points with Scanning Electron Microscope (SEM).

- ~ 1 Km of CF monofilament is also available (Alessandro M.), 33.5 μm diameter, Specialty Materials (US), and could be also tested, but the problem remains the metallization

Testing samples

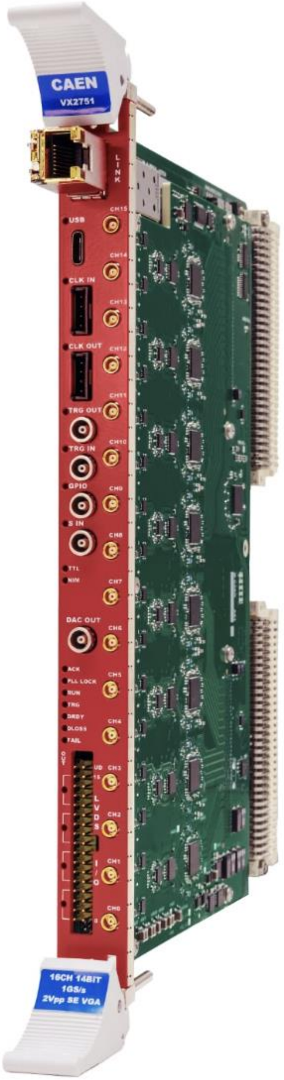


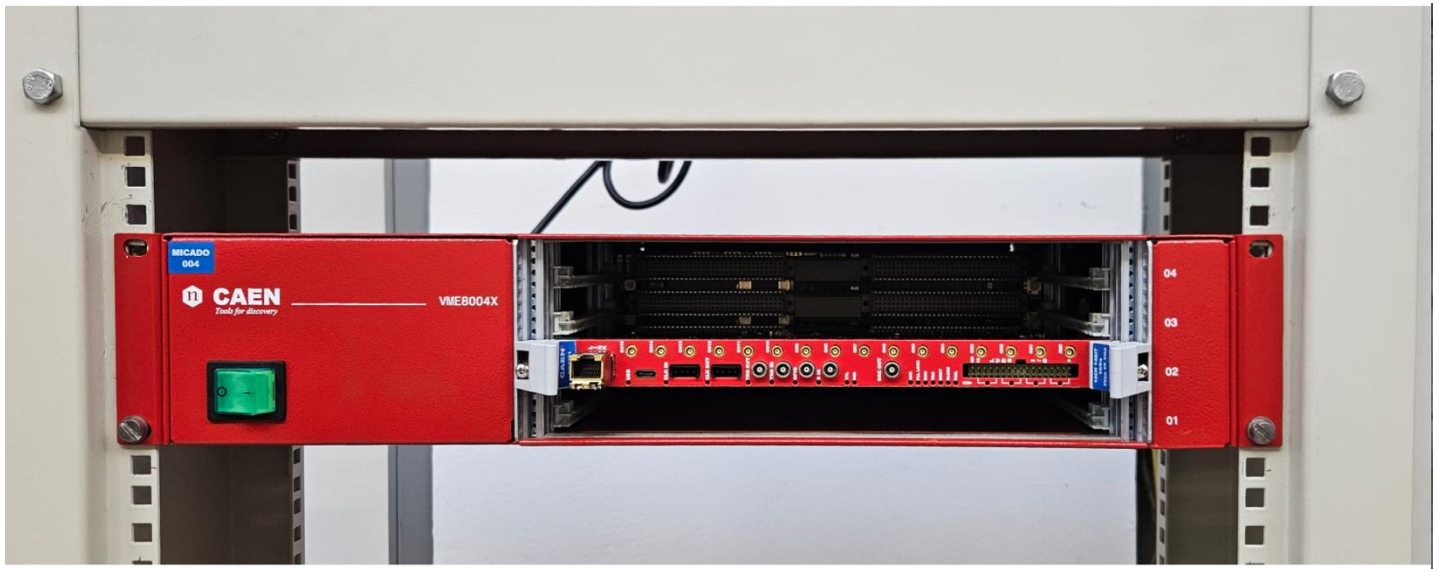
Design of the tensioning machine

DCH prototype → updates and plans/5

- ✓ **Lecce**: CAEN sent us the VX2751 module (to be used on loan), which has been located in the crate VME64X and it's ready to be operated and tested

16 Channel 14 bit 1 GS/s Digitizer with programmable Input Gain





- ✓ Meanwhile: collaboration with SLAC (Julia Gonski), where they are developing embedded FPGAs (integrated into a system on a chip (SoC)) which could offer a way to design a front-end readout ASIC running a configurable ML algorithm for the drift chamber. Peak finding algorithm might be adapted for the eFPGA target.

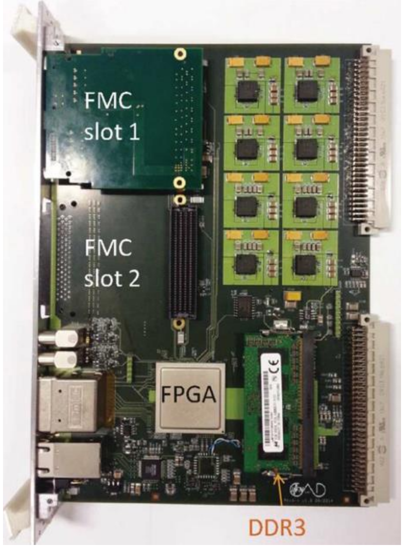
- ✓ Our Chinese colleagues Guang/Linghui, who developed a ML peak finding algorithm, RNN based, provided the code to Julia

DCH prototype → updates and plans/6

Bari: Enable testing of the HDSoC v1 (Naluscientific) waveform digitizer → starting to develop a dedicated communication block to interface MOSAIC with HDSoC v1.

✓ **MOSAIC Board Key Features**

- Designed for detector testing in high-energy physics.
- Supports 10 high-speed serial links (up to 6.6 Gbps) and 126 slower LVDS channels.
- Xilinx XC7A200T FPGA with:
  - 215,360 Logic Cells, 730 Block RAMs (12.8 Mb)
  - 16 Low-Power Gigabit Transceivers (up to 6.6 Gb/s)
  - High-speed data transfer via DDR3
  - Gigabit Ethernet interface with 120 MB/s transfer rate
  - Integrated 8-bit microprocessor for configuration & monitoring

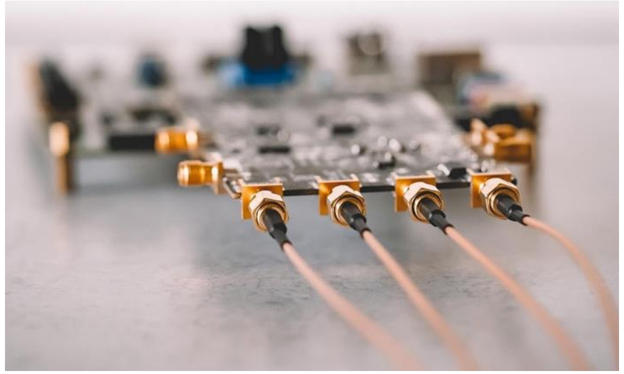


✓ **Waveform Digitizer HDSoC v1 Features**

- Sampling Rate: 1 GSa/s
- 32 channels
- 2k Sample Buffer
- > 600MHz Analog Bandwidth
- < 100 ps Timing Resolution
- Internally configurable triggering schemes

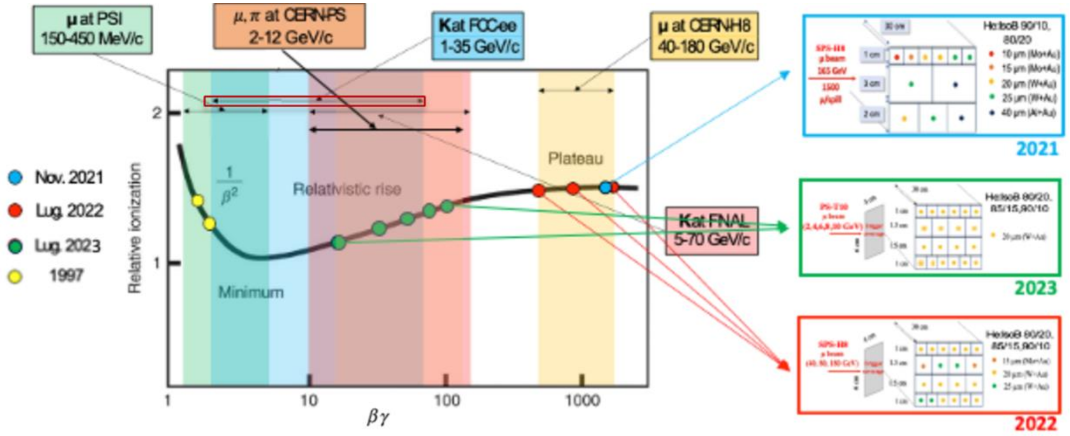
Plans

- Final design and implementation of the MOSAIC-HDSoC interface block.
- Initial firmware test with simulated data.
- Full integration and testing with the HDSoC waveform digitizer.



Test beam → updates and plans/1

- ✓ New results from the 2021/2022 beam tests at CERN H8 ($\beta\gamma$ > 400) [ICHEP 2024]

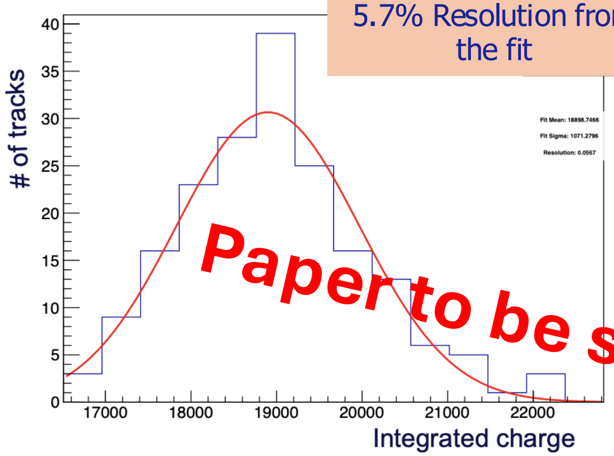


- ✓ Landau distribution for the charge along a track
- ✓ Selected the distribution with 80% of the charges for the dE/dx truncation to be compared with dN/dx. There is still margin for improvements in CC efficiency!
- ✓ **Further improvements in the RTA algorithm ensuring that the applied cuts now adjust automatically when changing the template or the sampling rate.**

Study done using same tracks (2 m track length) made of the same hits. 180 GeV/c muons

dE/dx Resolution (remove 20% higher charges)

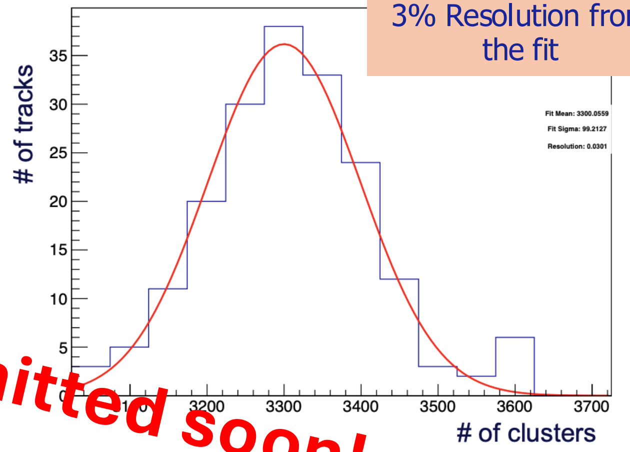
5.7% Resolution from the fit



@2m long track we have dE/dx resolution 5.7%

dN/dx Resolution

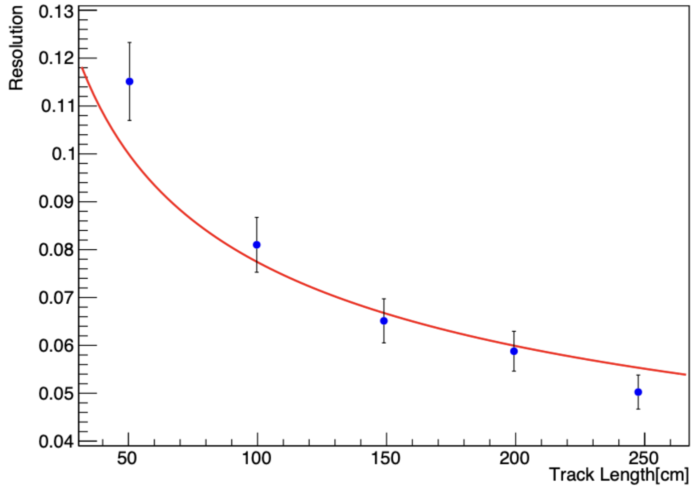
3% Resolution from the fit



@2m long track we have dN/dx resolution 3%

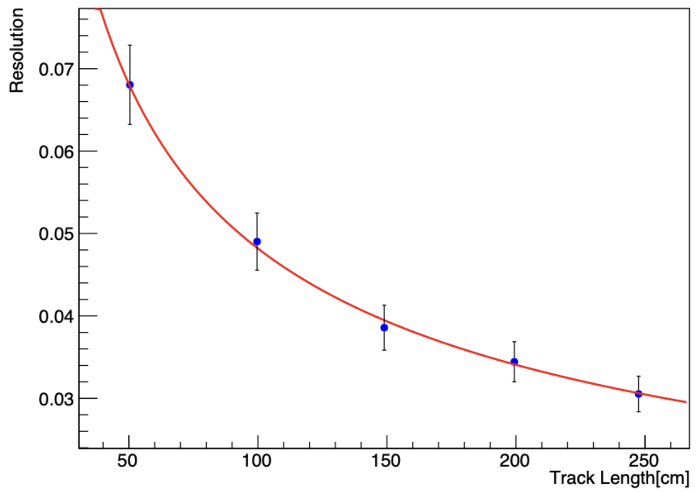
Paper to be submitted soon!

dE/dx Resolution scan vs track lenght



dE/dx resolution dependence on the track length $L^{-0.37}$

dN/dx Resolution scan vs track lenght



dN/dx resolution dependence on the track length $L^{-0.5}$

~ **2 times** improvement in the resolution using dN/dx method

Test beam → updates and plans/2

Plans

✓ Finalize data analysis of the two test beams at CERN T10 performed in July 2023 and July 2024 with muons (1-12 GeV)

✓ Original plan for 2025: test beam at **FNAL-MT6** with **π** and **K (βγ = 10–140)** → important to fully exploit the relativitic rise. **This option does not seem feasible at the moment** (TB facility at FNAL is closed at least until the end of the year, due to an accident occurred), then we are exploring the option to perform the test beam at CERN. **Franco requested** to the responsibles at CERN:

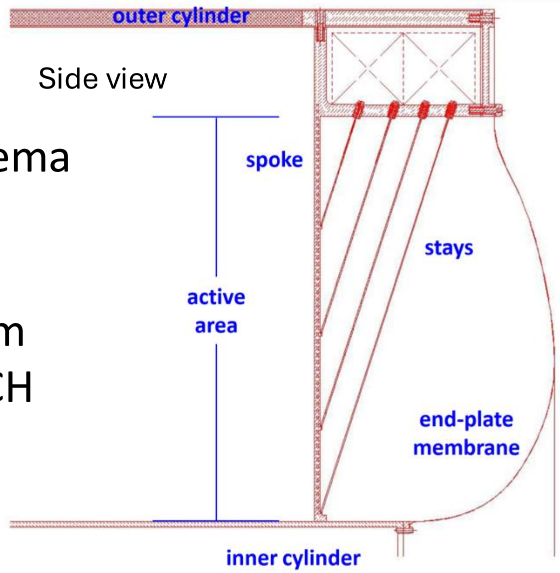
- We are interested in a beam of π and K in the range between 1 and 30 GeV/c.
- Any wide interval contained in this range will suits us.
- Momentum spread up to a few % is acceptable.
- Beam intensity of the order of $1e^4$ over a 10x10 cm^2 is our target.
- A π/K discrimination is necessary (Cherenkov)
- We could probably sort out a muon veto and/or an electron filter.
- It looks like that positive beam at T9 might be the best option with K identified in the range 4.5 to 16 GeV/c, but T10 could also be ok.

Reply from the PS/SPS Physics Coordinator: currently the T9 beam line is fully booked for 2025, there is some possibility to have some late minute cancellations, but staying in a waiting list.

Backup

DCH mechanical structure

- New tension recovery schema
- Experience inherited from the MEG2 DCH

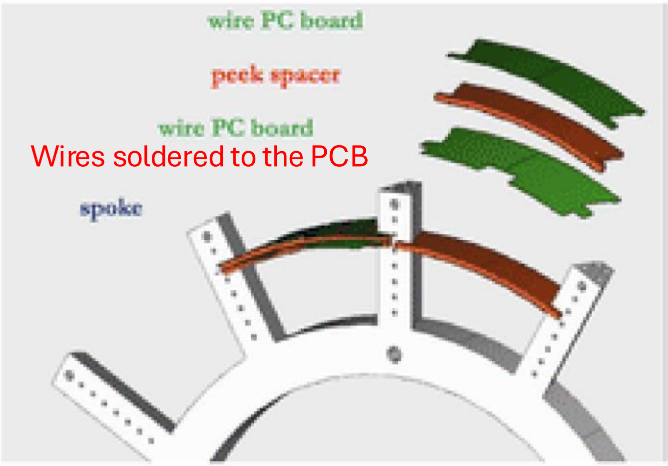


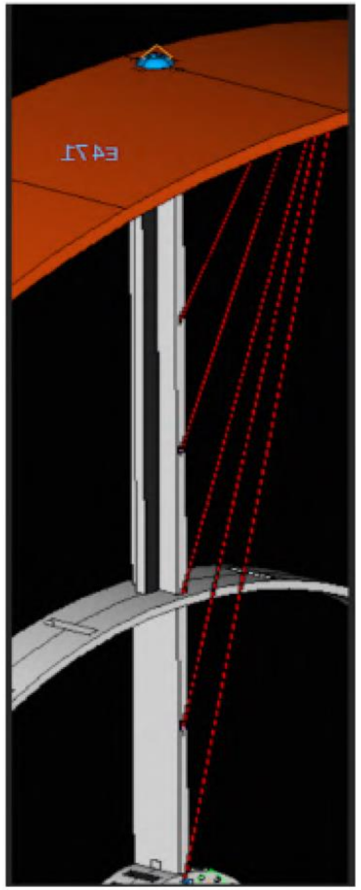
Inner cylinder and Outer cylinder connected with 48 Spokes (24 per Each side) forming 24 azimuthal sectors.

Each spoke supported by 15 Cables/Stays.

Spoke length = 160cm

Material: Epoxy Carbon Prepeg for cylinders and spokes, Structural steel for the cables.





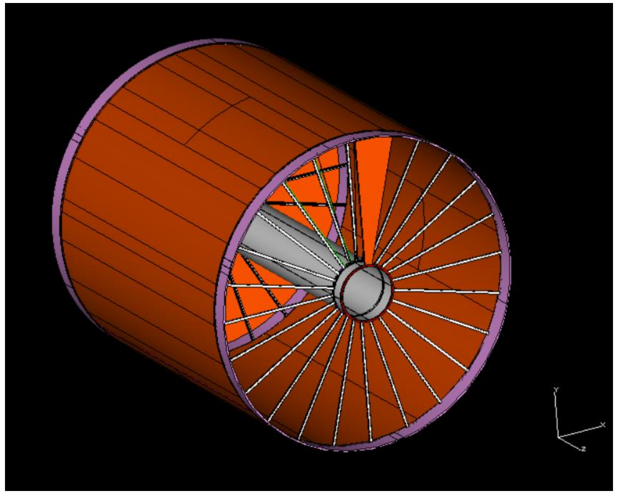
Our **main goal** was to limit the deformation of the spokes to **200 µm** while ensuring the structural integrity.

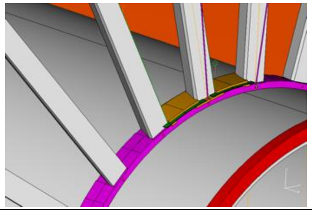
FEM Parametric Design exploration → varying input parameters in some possible ranges in order to see how the system responds - Response Surface Methodology (RSM) is used.

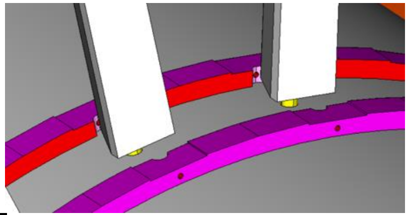
A realistic complete model ready:

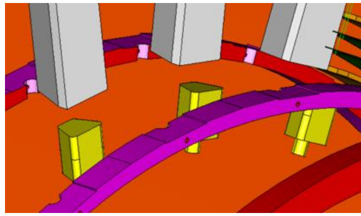
- mechanically accurate
- precise definition of the connections of the cables on the structure
- connections of the wires on the PCB
- location of the necessary spacers
- connection between wire cage and gas containment structure

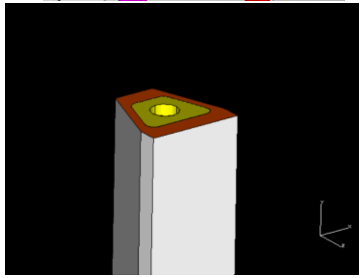
Plan to start the construction of a DCH prototype full lenght, three sectors per EC

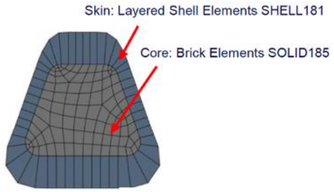


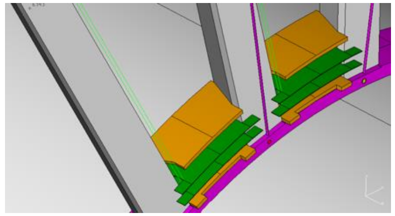












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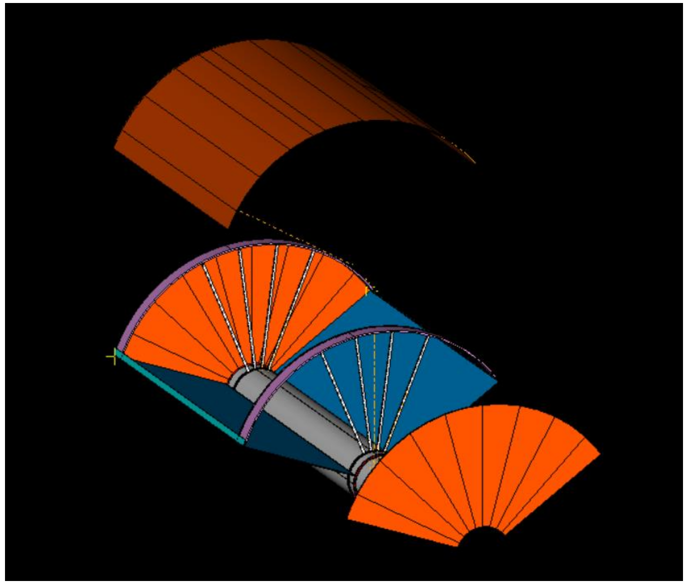
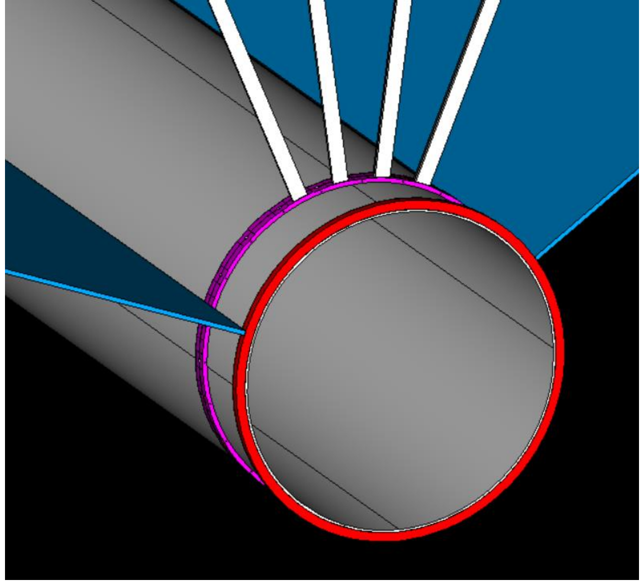


DCH full length prototype

- 8 spokes (4 per endcap)
- Internal ring
- part of the outer ring
- part of the cylindrical panel

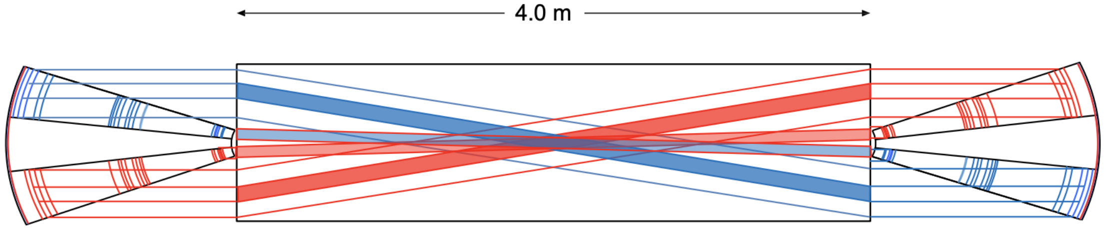
TOTAL LAYERS: 8
Sense wires: 168
Field wires: 965
Guard wires: 264



PCBoards wire layers: 42
Sense wire boards: 8
Field wire boards: 22
Guard wire boards: 12
HV values: 14

Readout channels: 8+8 +16+16+16+16 + 16+16 = 112

ELECTRONICS COVERAGE



Minimum stereo angle 50 mrad
Maximum stereo angle: 250 mrad

- Check the limits of the wires' electrostatic stability at full length and at nominal stereo angles
- Test different wires, different wire anchoring procedures (soldering, welding, gluing, crimping, …) to the wire PCBs, different materials and production procedures for spokes, stays, support structures and spacers, compatibility of proposed materials with drift chamber operation (outgassing, aging, creeping, …)
- Validate the concept of the wire tension recovery scheme with respect to the tolerances on the wire positions, optimize the layout of the wires' PCBs (sense, field and guard), according to the wire anchoring procedures, with aim at minimizing the end-plate total material budget
- optimize the wiring strategy, the High Voltage and signal distribution, test performance of different versions of front-end, digitization and acquisition chain