The drift chamber of CMD-3 detector

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ABSTRACT

TraPId (**Tra**cking and **P**article **Id**entification), the Central Tracker proposed by the Bari and Lecce INFN groups for the detector for a generic flavour factory is an ultra-light drift chamber equipped with cluster counting/timing readout techniques. Main peculiarities of this design are the high transparency in terms of multiple scattering contributions to the momentum measurement of charged particles and the very promising particle identification capabilities. A drift chamber prototype for TraPId (initially to be used as the central drift chamber of the CMD-3 experiment at VEPP-2000) is going to be developed and tested by groups from INFN Lecce, INFN Bari.

TraPId chamber

The construction of TraPId is driven by two main purposes:

- Maximize the transparency in terms of radiation length.
- Maximize the mechanical stability by reducing to acceptable limits the deformations of the endplates under the total load of the wires.

A significant reduction in the amount of material at the end plates is obtained by separating the gas containment function from the wire tension support function.
The wires are anchored to a self-sustaining light structure ("wire-cage") surrounded by a thin skin ("gas vessel") of suitable shape to compensate for the gas differential pressure with respect to the outside.
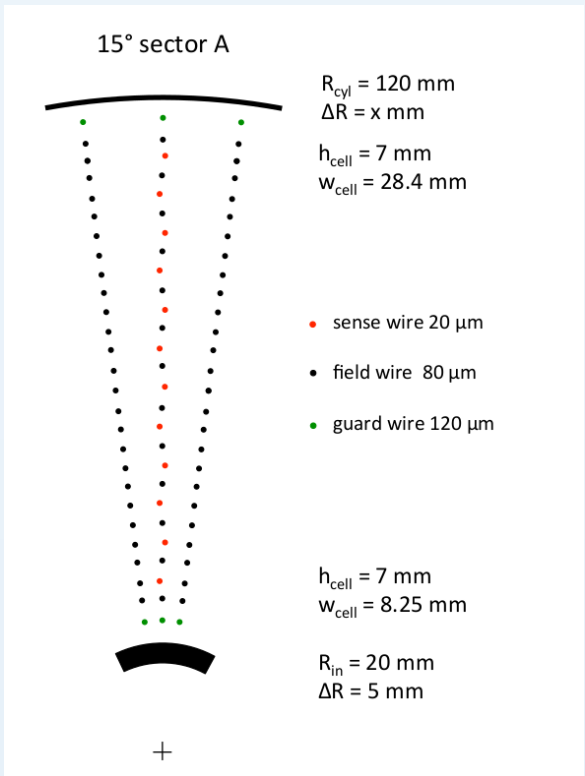Schematically, the wire-cage is made of a set of radial spokes, constrained at their inner ends into a tiny cylinder and extended to the outer endplate rim.
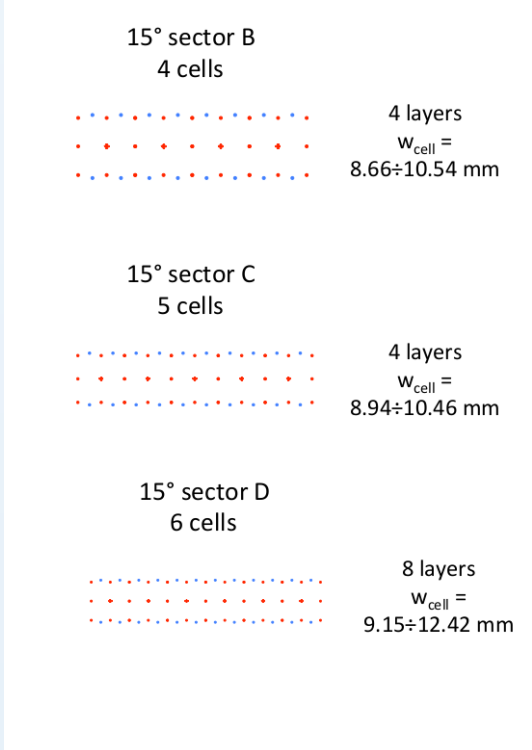

Wire-cage

Gas vessel
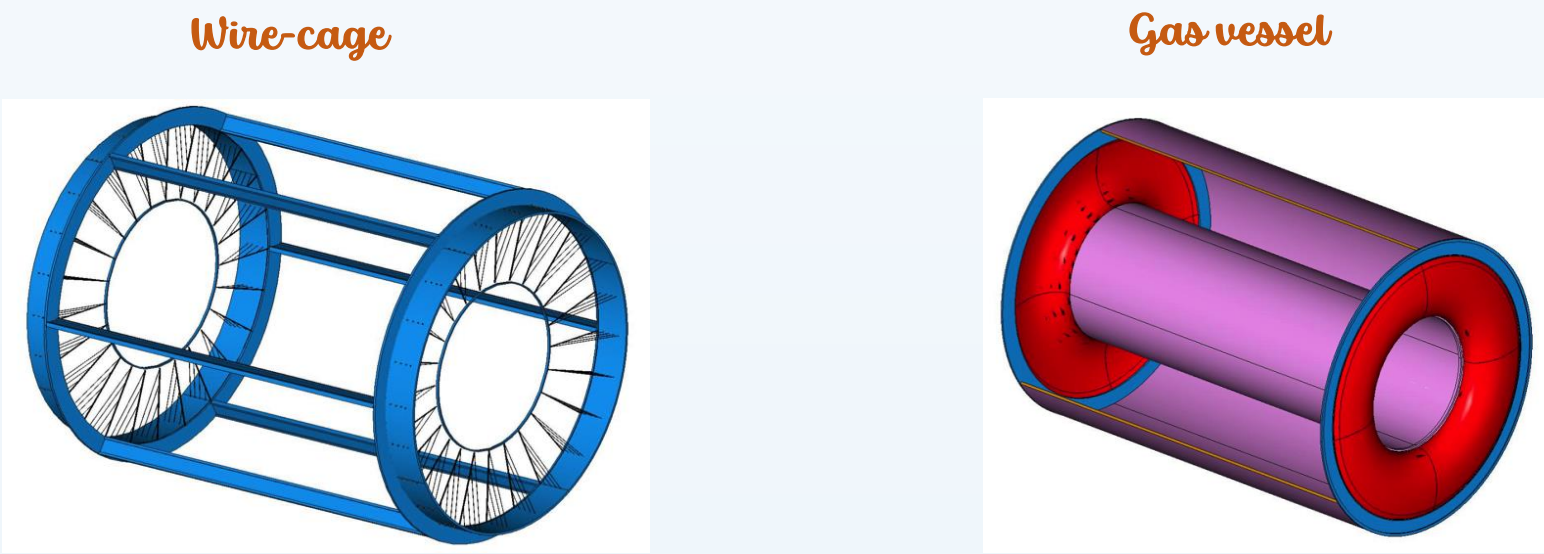
Layout of the CMD-3 drift chamber
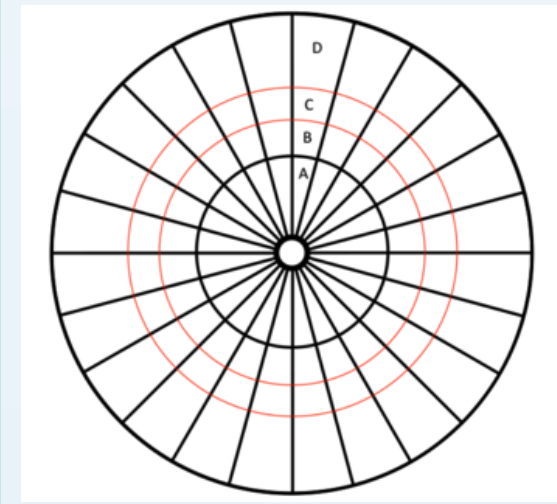
The chamber is divided in 4 concentric super-layers A, B, C and D and 24 identical sectors. Marked with black circles, from the inner to the outer radius, the inner, the middle and the outer cylinders are indicated. The red circles mark the separations between the super-layers boundaries.

15° sector A

R_up = 120 mm
ΔR = x mm
h_cell = 7 mm
w_cell = 28.4 mm

- sense wire 20 μm
- field wire 80 μm
- guard wire 120 μm

h_cell = 7 mm
w_cell = 8.25 mm

R_in = 20 mm
ΔR = 5 mm

Super-layer *A* is made of open jet-cells with wires arranged axially. Each cell defines one of the 24 sectors and includes 12 sense wires (red dots), azimuthally staggered with respect to field wires plane (black dots). The green dots represent two guard wire layers, at the two ends of the super-layer. The cell width increases from the inner to the outer radius up to the value of 28.4 mm.


15° sector B
4 cells
4 layers
w_cell =
8.66÷10.54 mm

15° sector C
5 cells
4 layers
w_cell =
8.94÷10.46 mm

15° sector D
6 cells
8 layers
w_cell =
9.15÷12.42 mm

Super-layers *B, C* and *D* are made of single-wire cells with the wires arranged in an appropriate stereo angle configuration with 4 layers of 4 (5) cells per each sector *B* (*C*) and 8 layers of 6 cells per each sector *D*. The square cell size increases from 8.7 mm at the innermost radius to 12.4 mm at the outermost radius
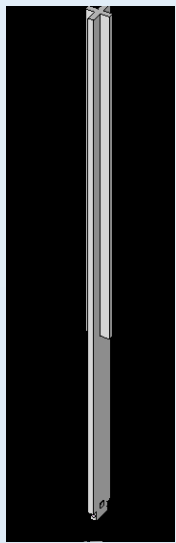
The "missing" end plate

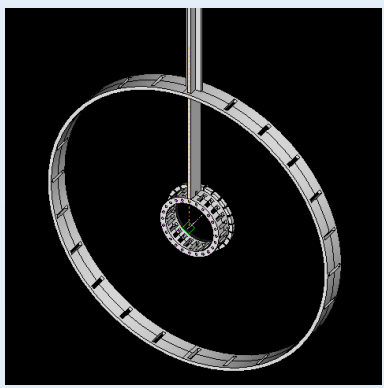The structural parts of the CMD-3 drift chamber mechanics will be built in carbon fibre.
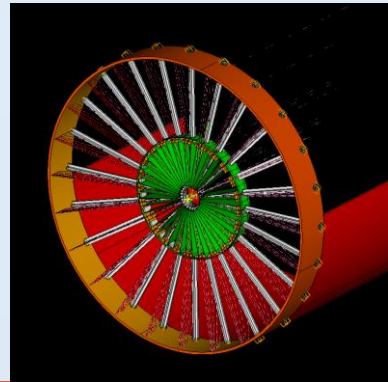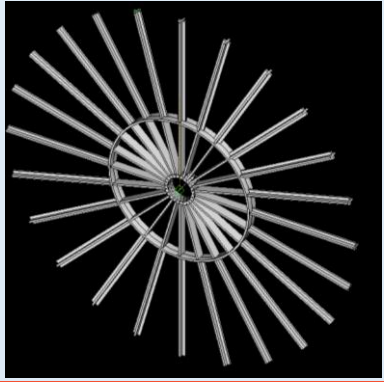
Inner ring
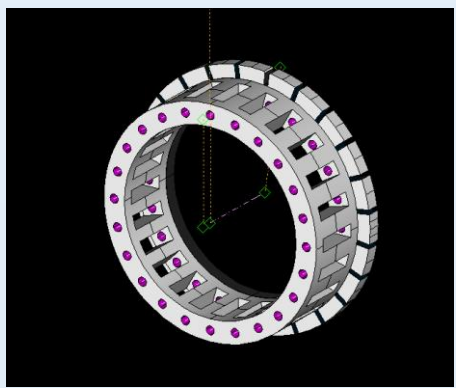
Spoke

Assembly of the spoke with the inner and intermediate rings.

*The outer ring and half of the outer cylinder*

Assembly of the 24 spokes with the inner and intermediate rings
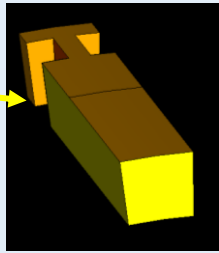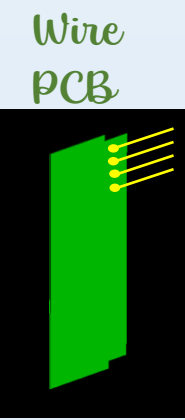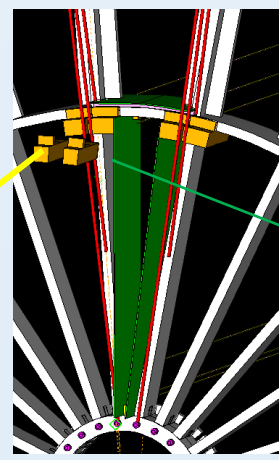

Superlayer A

The wire holding PCB (two per sector), to which the wires are soldered, are inserted on both ends of the chamber, from inside, through the slots of the inner ring and are fixed in position with properly shaped locking blocks This complete the wiring of one sector and the entire procedure is repeated for all 24 sectors to complete the wiring of layer *A*.
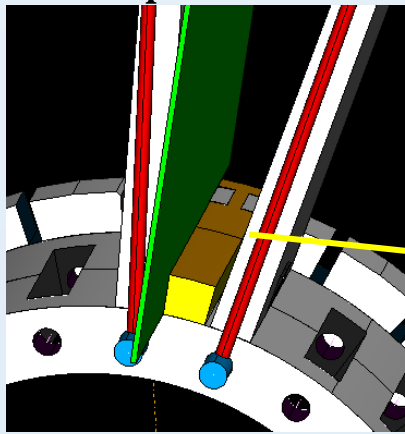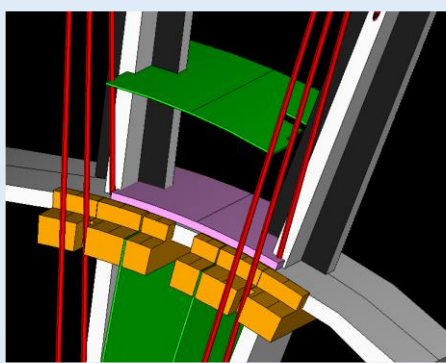

Wedge-shaped locking plate

Supports with a suitable shape to host the PCBs

Wire PCB

Superlayer B,C,D

Superlayers *B*, *C* and *D* are all wired in analogy to the MEG2 drift chamber.

The cell structure in each sub-layer is obtained by overlapping, in the order, inner field wires PCB, spacers, sense wire PCB, spacers and outer field wires PCB, all with the same stereo orientation.
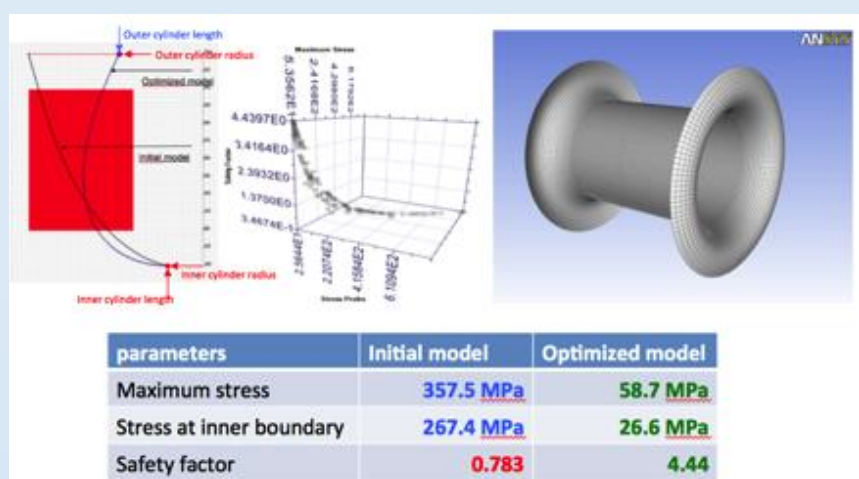The stereo angle is obtained by jumping one sector from one endplate to the other
Successive sub-layers have alternating signs stereo angles.

Tension recovery scheme

In order to limit the spokes deformation, a **set of stays**, the tension of which can be adjusted, are strung between the spokes and the structural outer ring.
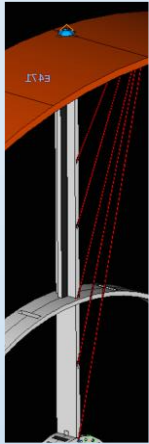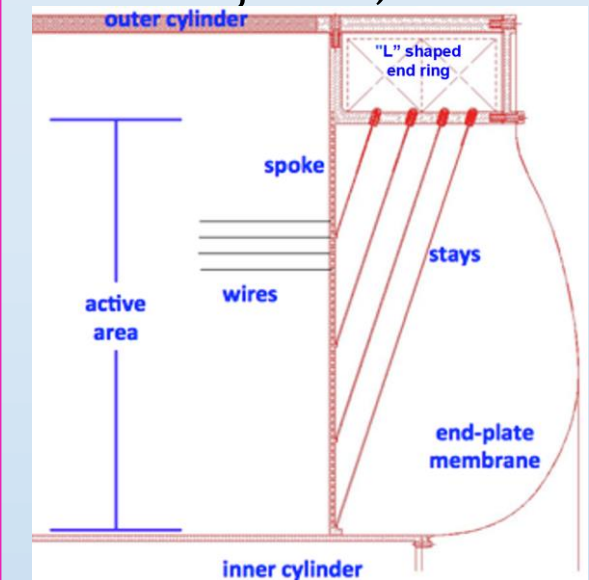

The whole system acts like a "harp cable stayed bridge" structure, with the outer ring acting like the tower (the pylon) and with the spoke representing the bridge deck.

Gas containment

| parameters	Initial model	Optimized model
Maximum stress	357.5 MPa	58.7 MPa
Stress at inner boundary	267.4 MPa	26.6 MPa
Safety factor	0.783	4.44

A structural multivariate analysis to find the optimal shape for the end plates profile by minimizing the total maximum stress and the stress on the inner cylinder.
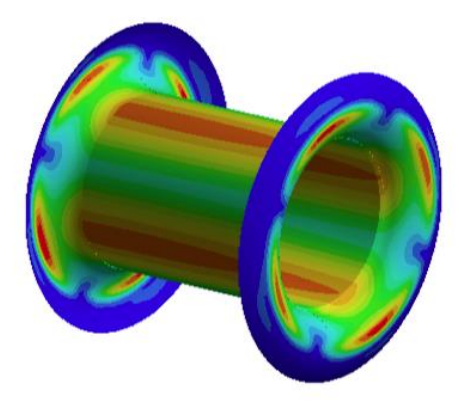

Reduce inner cylinder buckling by increasing the moment of inertia with proper light core composite sandwich
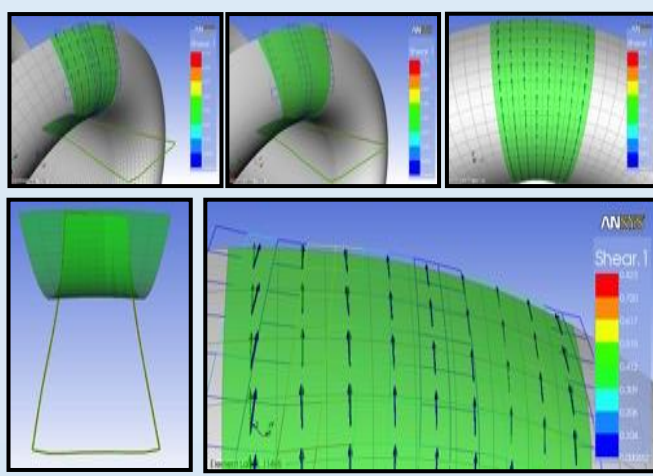

A proper unidirectional pre-preg to form ply draping of the laminates and flat-wrap of the optimized model.

Preliminary Finite Element Analysis

Preliminary investigations, using Finite Element Analysis, have been performed under much simpler conditions, just to establish the feasibility of the concept.
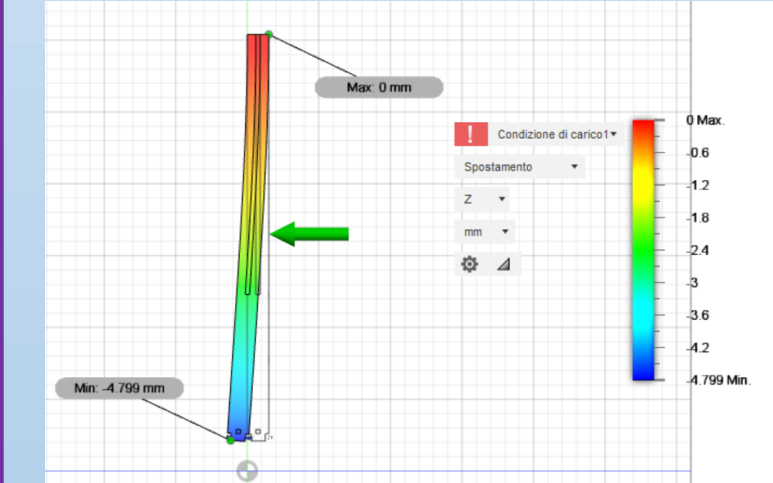
Assuming a uniformly distributed load around 20 kg along the spoke length, with the spoke solidly constrained on one end to the non-deformable outer ring and free to flex at the other end and using a 133 GPa low modulus carbon fiber, one get a spoke deflection of 4.8 mm.
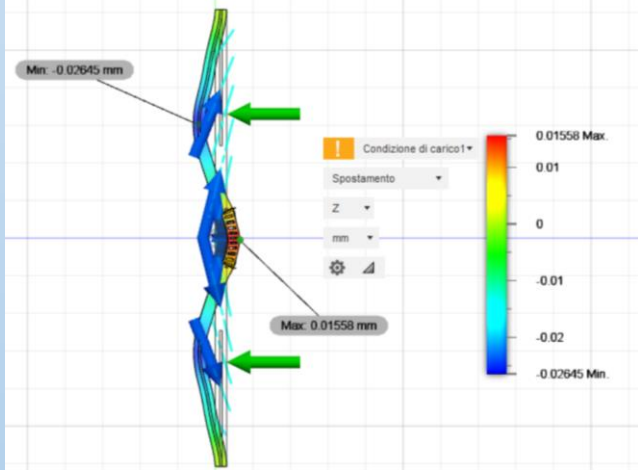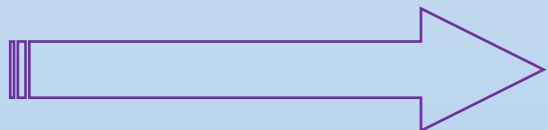
Three stays per spoke, loaded with 14 Kg placed at 10° at the inner ring, 24 Kg at 14° at the intermediate ring and 20 Kg at 21° midway between the intermediate and the outer rings, reduce the maximum deflection within ±25 μm

- **An ultra-low mass drift chamber for** a generic flavour factory with a material budget **<1.5x10⁻² X/X₀** in the radial direction and **<5x10⁻² X/X₀** in the forward and backward directions (including HV and FEE services) **can be built** with the novel technique adopted for the successful construction of the MEG2 drift chamber.
- Δpt/pt = 2.0×10-3, Δθ = 0.70 mrad, Δφ = 0.78 mrad at p = 1 GeV/c.
- Particle identification at the level of 3.6% with cluster counting allowing for π/K separation ≥ 3σ over a wide range of momenta.