SuperB Drift Chamber: workshop summary

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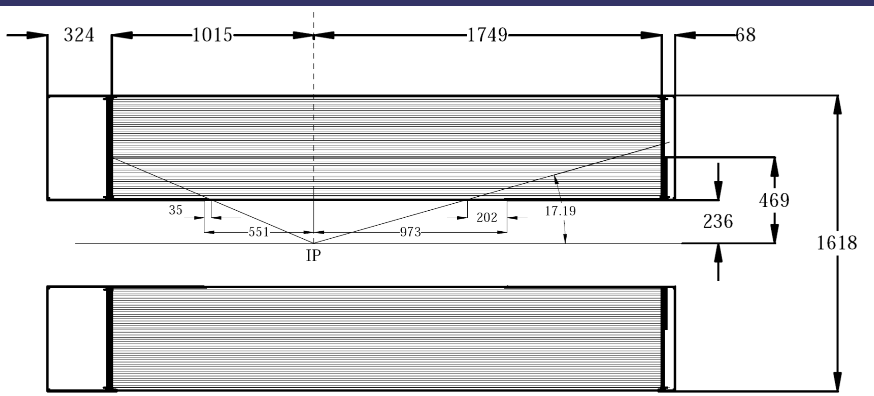
on behalf of the SuperB-DCH group

Intro – Baseline design

Single cell drift chamber à la *BABAR* appears the most natural choice:

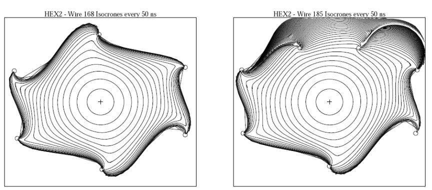
- result of a careful design optimization
- Performances in terms of momentum and dE/dx resolution have met design requirements



Dimensions in mm

24 cm inner radius	Be & Al inner cylinder
81 cm outer radius	Carbon fiber/Nomex outer
2.8 m length	2.5 (1.2) cm Al end plates
IP 37 cm behind center	All electronics on rear

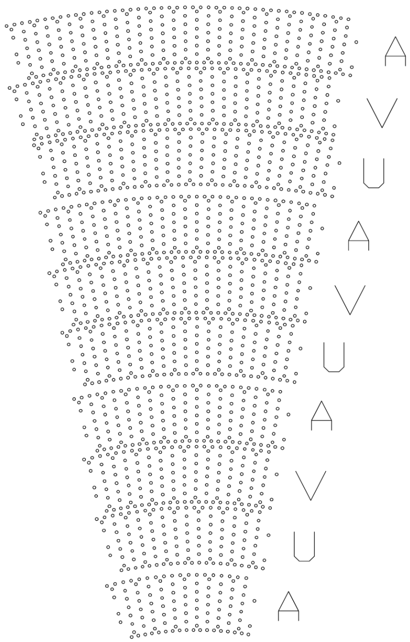
Small hex cells (1∼2 cm)



10 superlayers of 4 layers each
Axial and stereo (∼ 4°)

96–256 cells/superlayer

Sense wires 20 μm W-Rh (Au)
Field wires 120 μm Al (Au)
Guard wires 80 μm Al (Au)



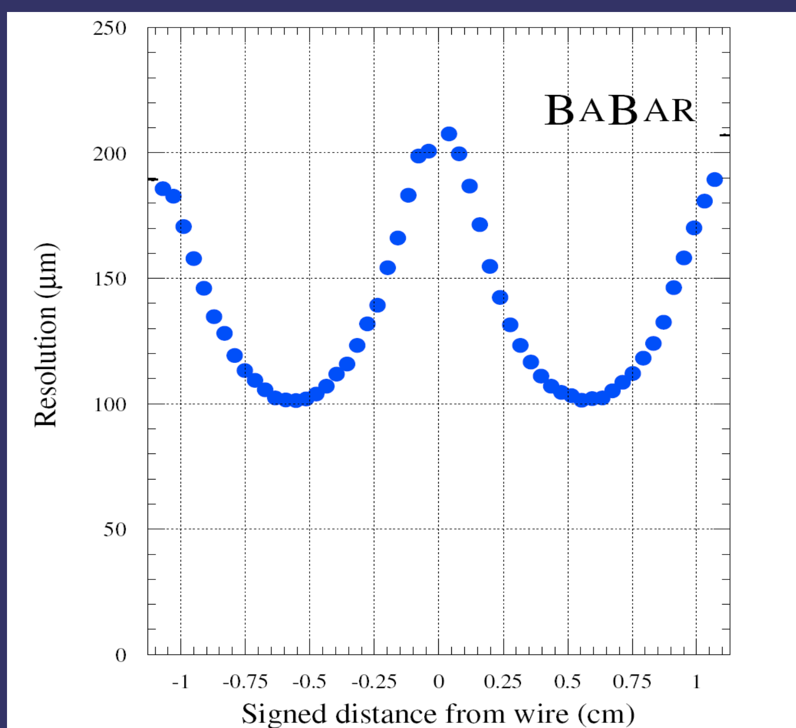
The BABAR Drift Chamber - performances

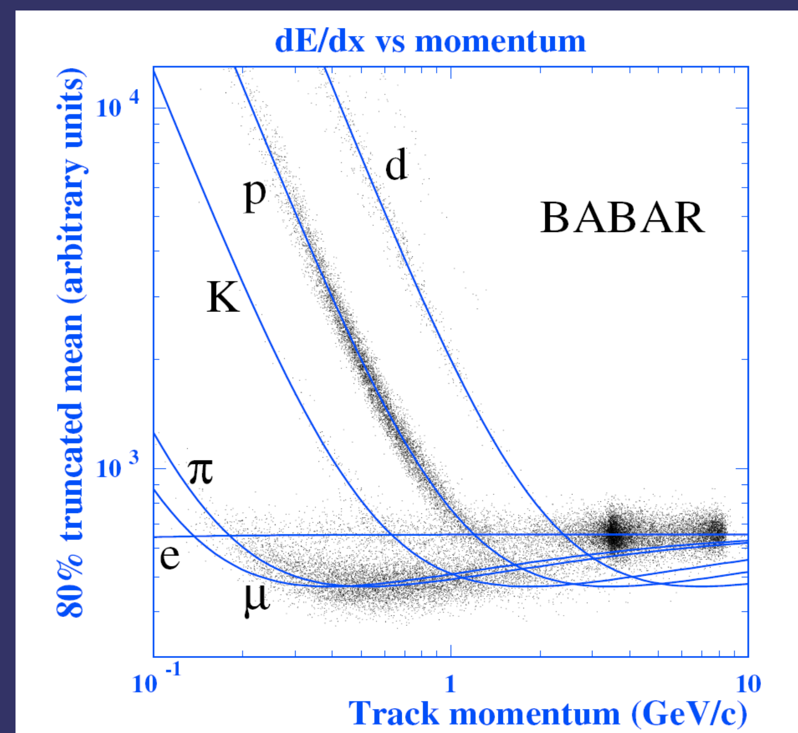
Hit resolution: σ~125μm (target: 140μm)

Momentum: $\sigma(p_T)/p_T=0.45\%+0.13\%p_T$ GeV/c

Tracking efficiency > 95% (fraction of tracks matched with STV)

dE/dx resolution ~ 7.5%





So, why build a new chamber?

1. Despite the excellent aging performance of the BABAR DCH, it would not live 10-15 years more in the *BABAR* environment

Experiment	Gas Mix	[mC/cm] Charge	[%/(mC/cm)] $\Delta G/G$ Aging
CDF (Run 2)	Ar:Eth:Alc 50:50:1	130	$<1 \sim 20$
ZEUS	Ar:Eth:CO_2 83:5:12	100	$\lesssim 0.1$
H1	Ar:Eth:H_2O 50:50:0.1	< 10	$\gtrsim 1$
HERA-B (test)	Ar:CF_4:CO_2 65:30:5	2300	$\sim$ none
BaBar	**He:i-C_4H_{10}:H_2O 80:20:0.4**	**33.6**	**0.3**

2. The SuperB environment will be tougher
   - Luminosity x 100
   - Backgrounds probably not 100 time worse than BABAR, but hardly predictable at this point

Required/desired/possible design improvements

1. Design a faster detector

- in *BABAR* ~500ns ionization collection time

- Faster gas mixture – Smaller cells - Both
- Gas mixture
  - Ideally, want a faster gas mixture with more primary clusters (smaller cells), but still light a with small Lorentz angle
- Smaller cells → more wires
  - make stringing more painful
  - increase load on end-plates
  - increase multiple scattering

  → use small cells only in innermost layers?
- Since we are at it: optimize cell packing?
  - A stereo-only structure would minimize dead space
    - more measurement points/unit length
    - consider implications on L1 trigger
    - Is it really worth?

Required/desired/possible design improvements (cont.)

2. Novel method: cluster counting

   see later

3. Make lighter mechanical structure

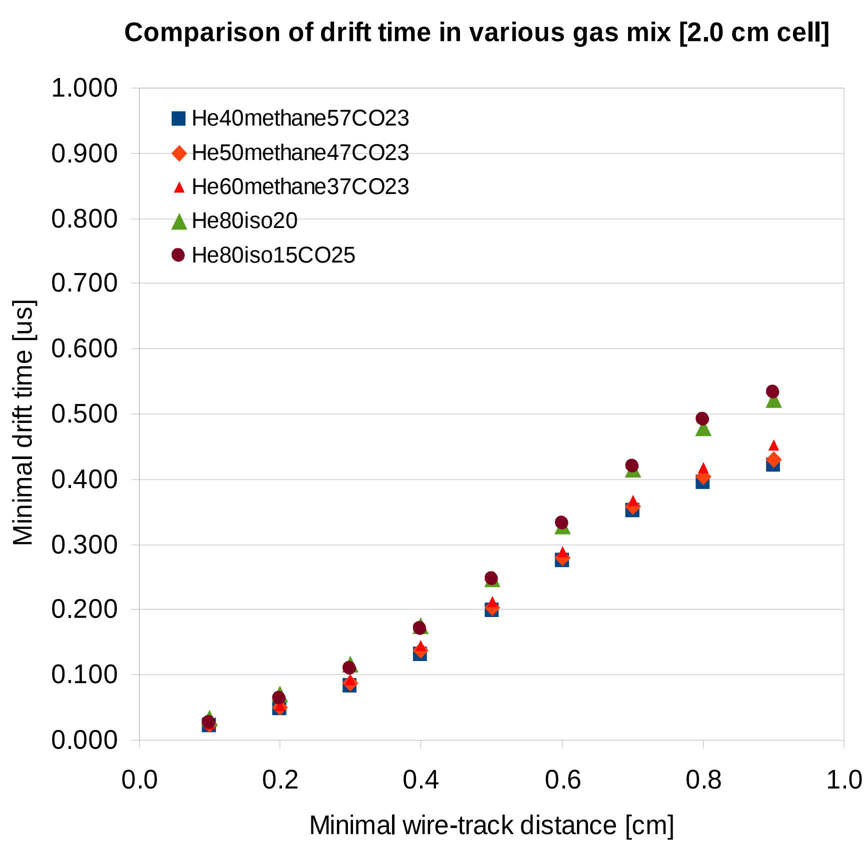
   minimize material in front of outer detectors – see later

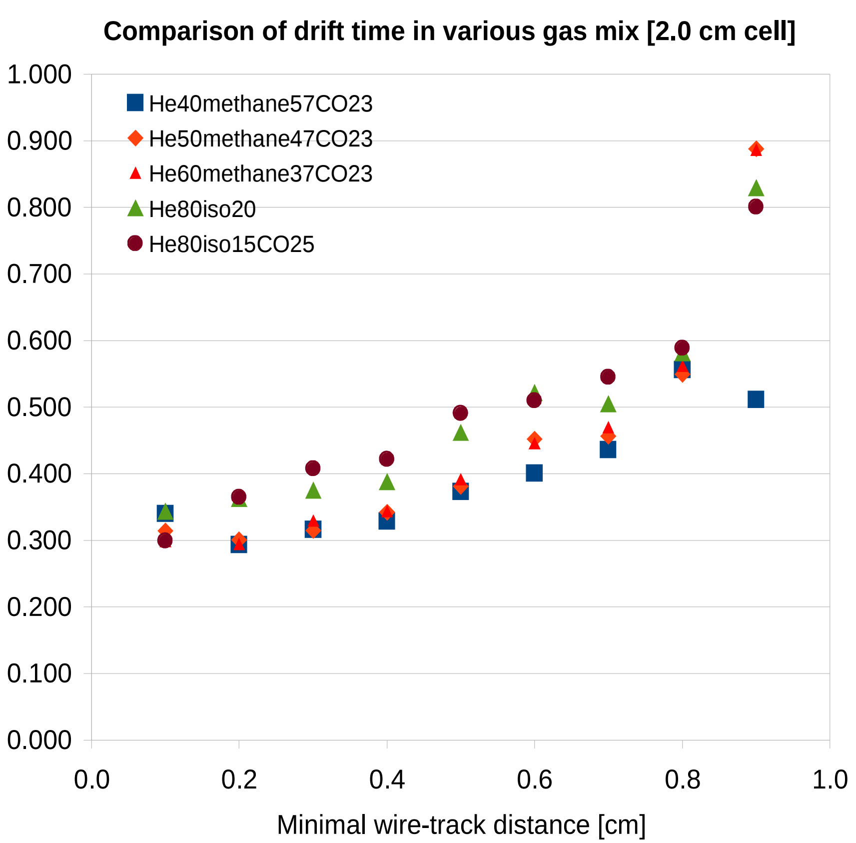
4. Review design of F.E. Electronics
   - must cope with increased rates
   - Keep to a minimum amount of material
     - presently rather massive design of the whole package (mainly e.m. shielding)
     - there might be room for substantial improvements
   - Use of current technologies on original BABAR design should already allow a substantial reduction of dissipated power and material budget

1. Design a faster detector

- Quantify how faster the collection time should be
  - Need detailed simulation of expected backgrounds
- Fast simulation to study detector performance vs. number of cells and spatial resolution
- Garfield simulations
- Prototypes with different cell shapes/sizes/gas mixtures
- External tracking telescope with sufficient resolution (≤ 100μm/point)
- Beam Test (BTF Frascati/other)

Garfield simulations



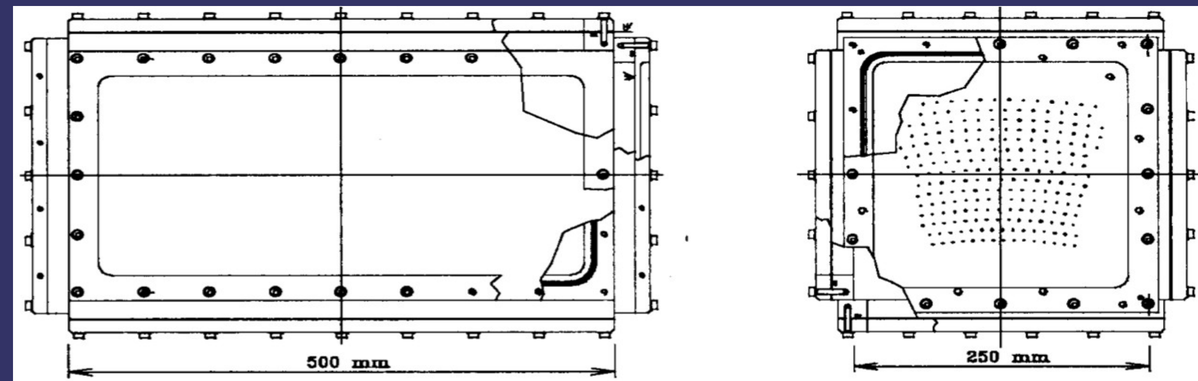


t_{min} and $t_{90\%}$ in various gas mixtures (standard BABAR cell)

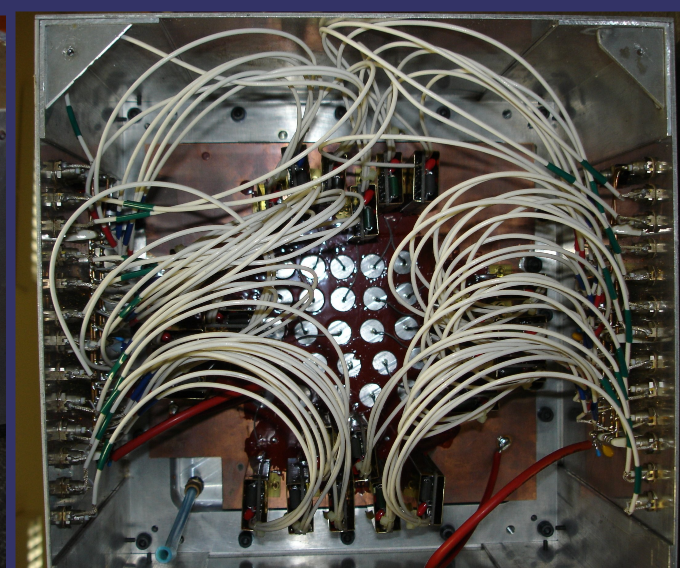
KLOE prototypes

- In Frascati our group designed and built the KLOE DCH
  - largest drift chamber built to date!
  - 52k wires, all stereo square cell, 3:1field/sense wire ratio
- Built threes small prototypes to test the various layouts
- Built a precision tracking telescope
- Very good news is that we have been able to recover this equipment

The KLOE prototype

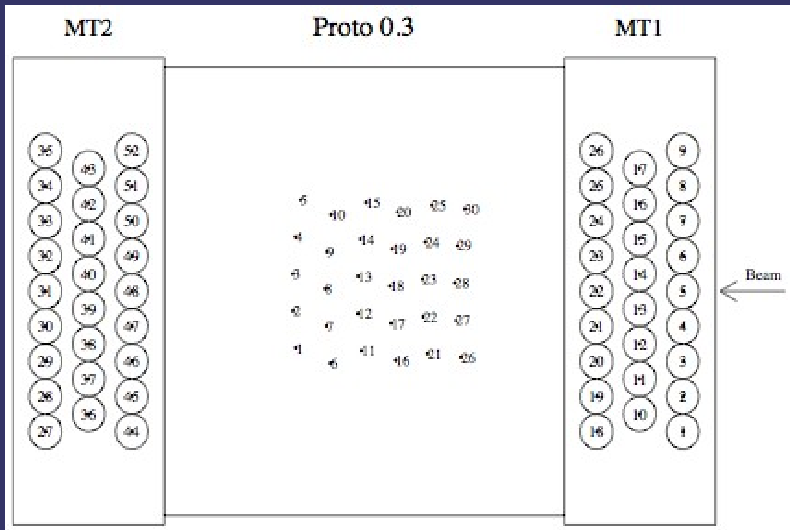


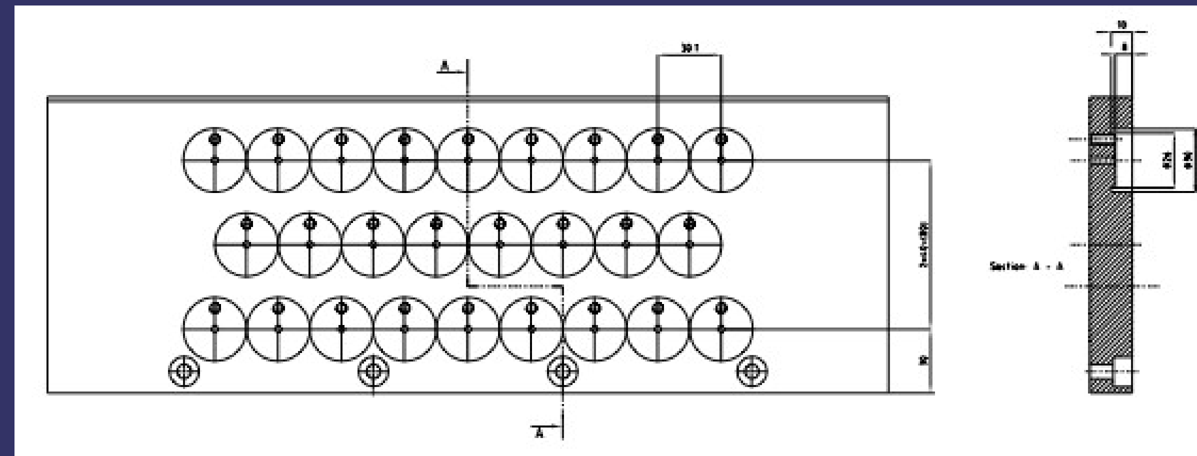
See “KLOE Central Drift Chamber – Addendum to the KLOE Technical Proposal”, LNF 94-028 (IR), June 1994



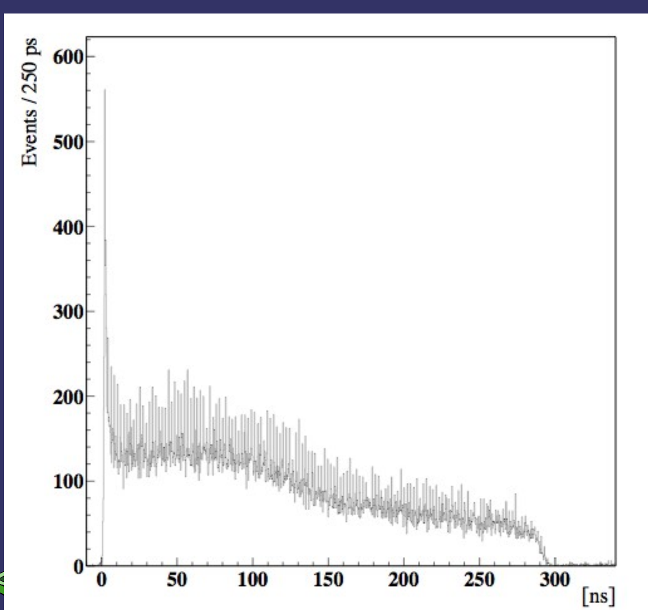
Mechanical structure perfectly reusable – only need to drill new hole pattern on the end-plates, and restring

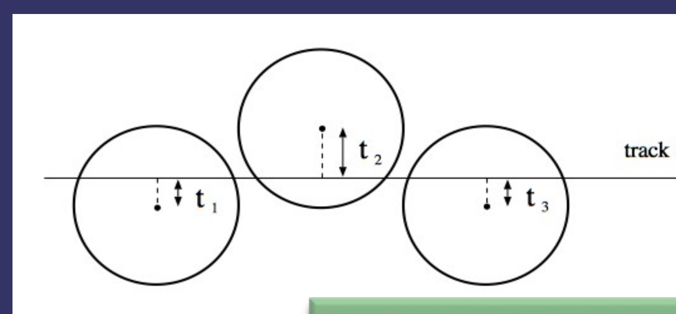
The KLOE “mini-trackers”



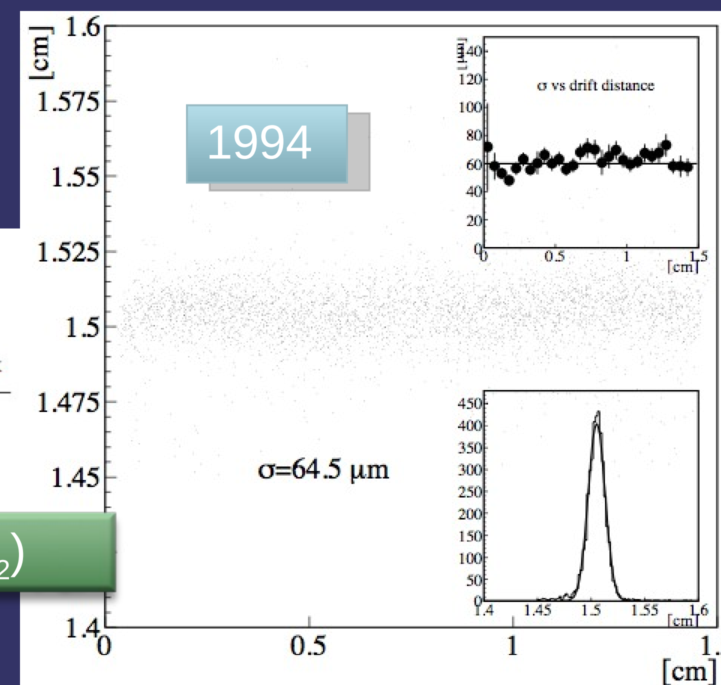


See: NIM A367, p154-158, 1995
Point resolution < 70 micron

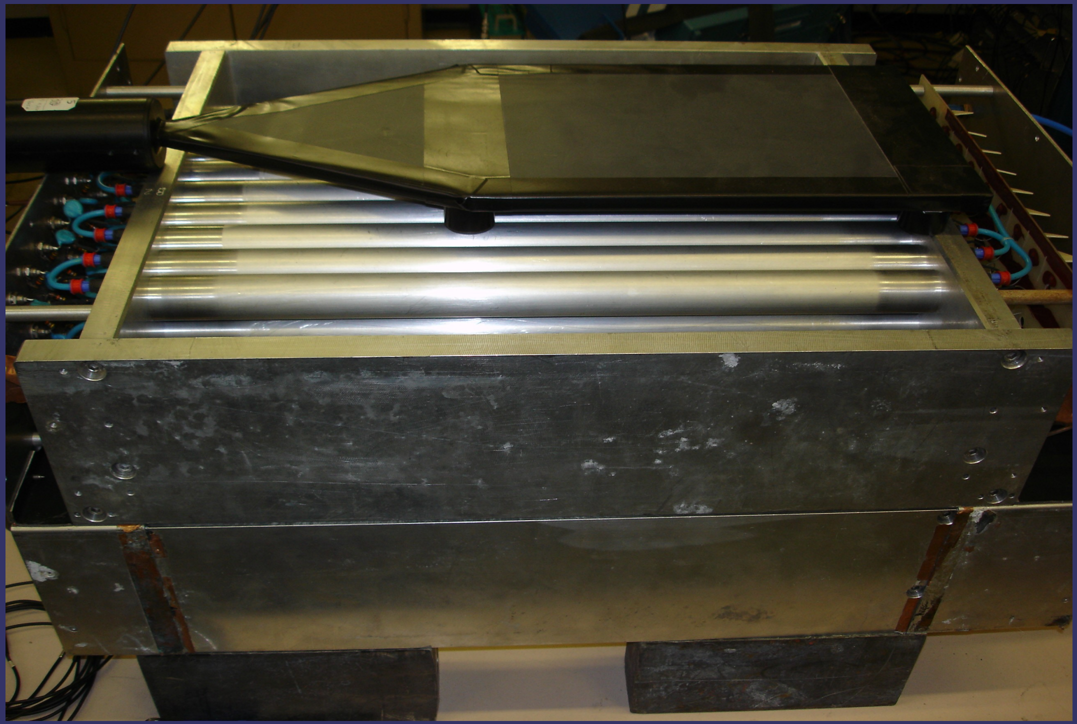


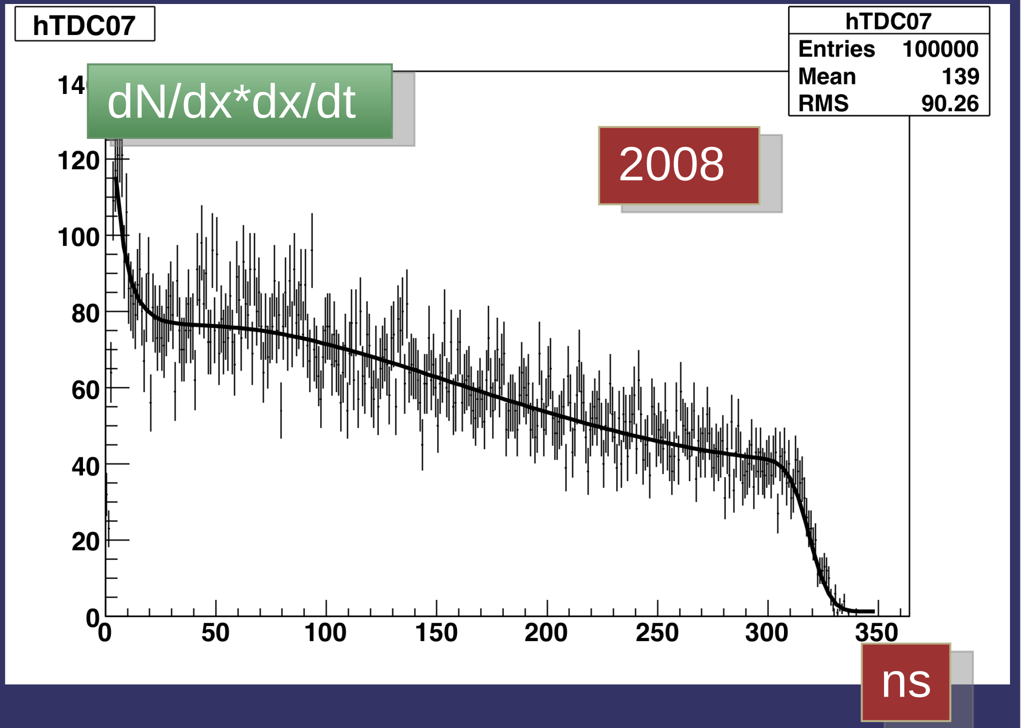


$(x(t_1)+x(t_3))/2+x(t_2)$



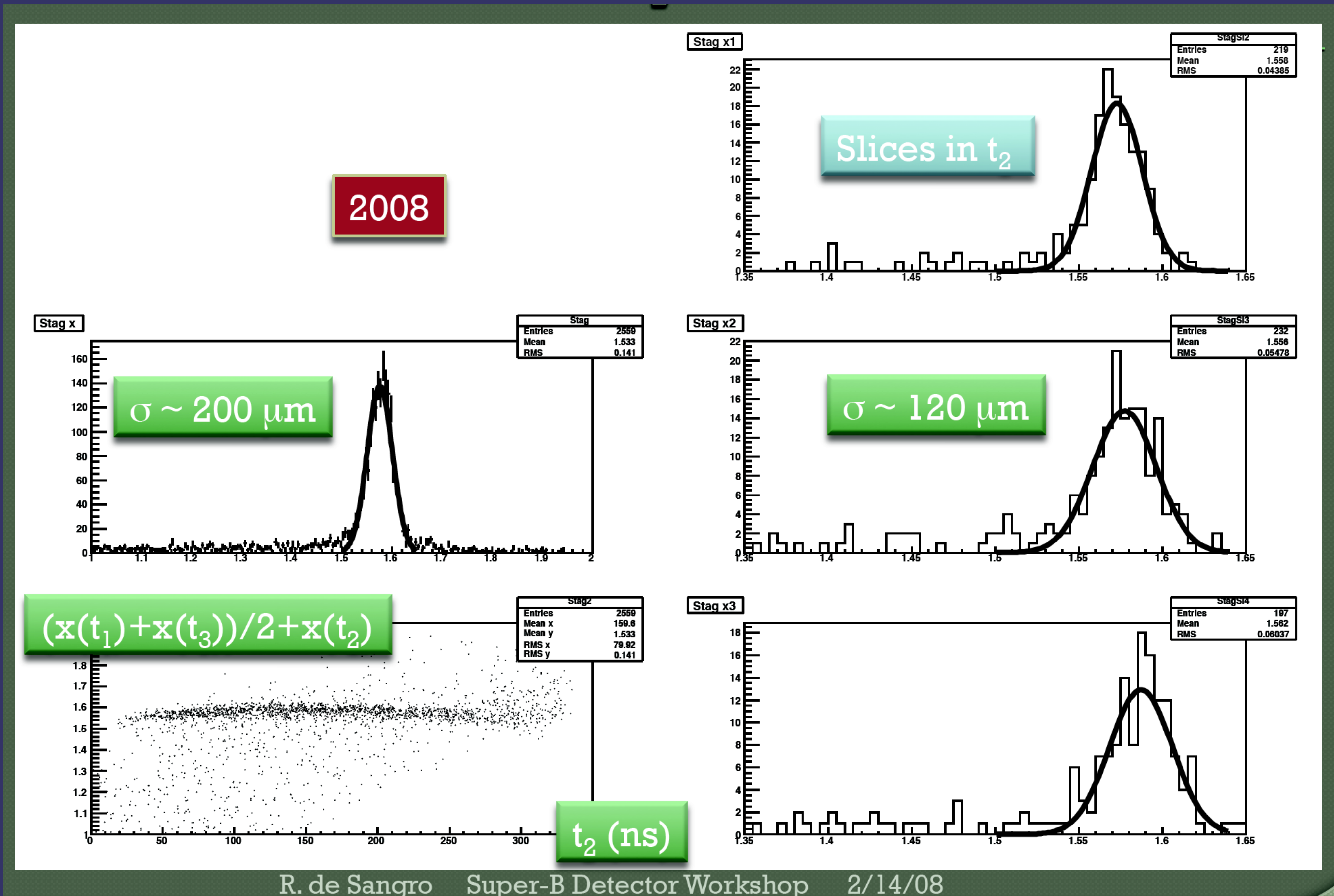
The KLOE "mini-trackers" - preliminary performances 2008





Only equipped with 3+3 electronics channel at the moment

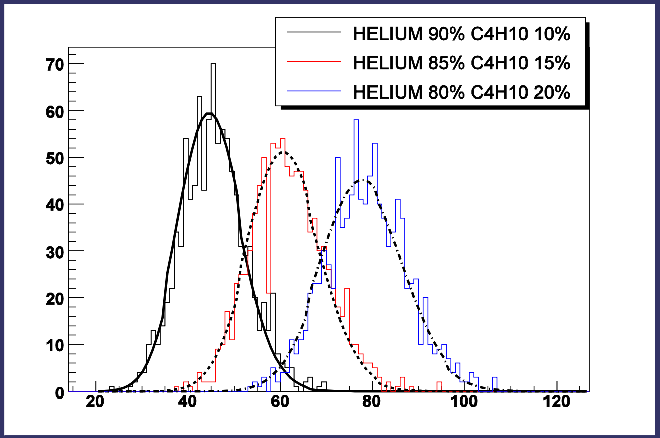
The KLOE "mini-trackers" - preliminary performances 2008



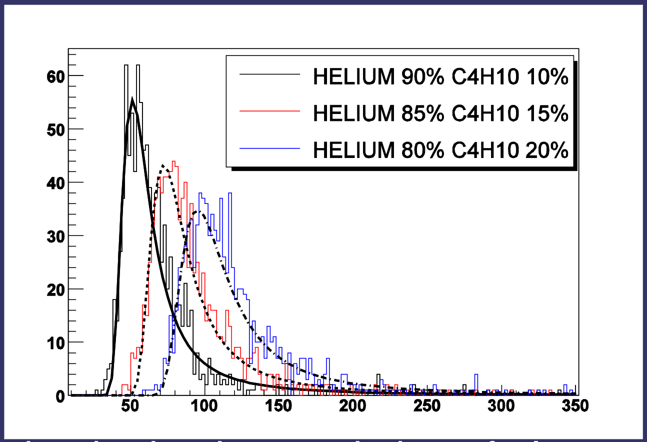
2. Cluster Counting

Gabriele Chiodini - INFN-Le

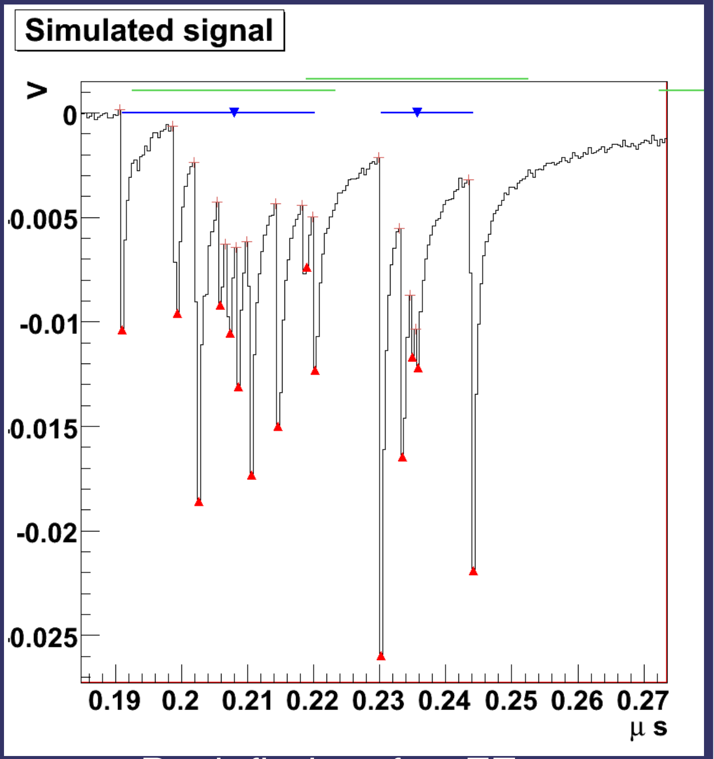
- Poisson statistics from counting would allow substantially better PID performances than dE/dx with conventional truncated mean (3% vs 7% resolution)
- Use of all clusters (as opposed to only 1st one) in the time measurement would allow spatial resolutions O(50μm)
  - Would that be useful in SuperB (multiple scattering)?
- This method generates huge amount of data (2Gsample/s, 6-7bit)
  - feature extraction capabilities badly needed



Poisson ionization statistics of clusters

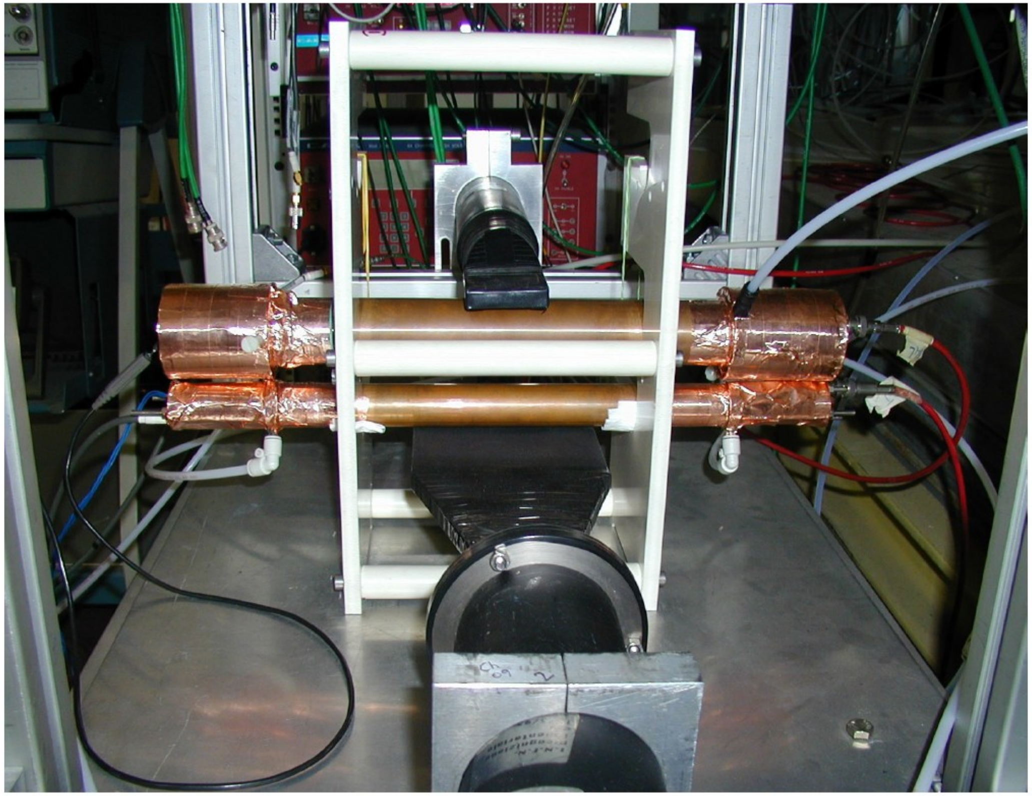


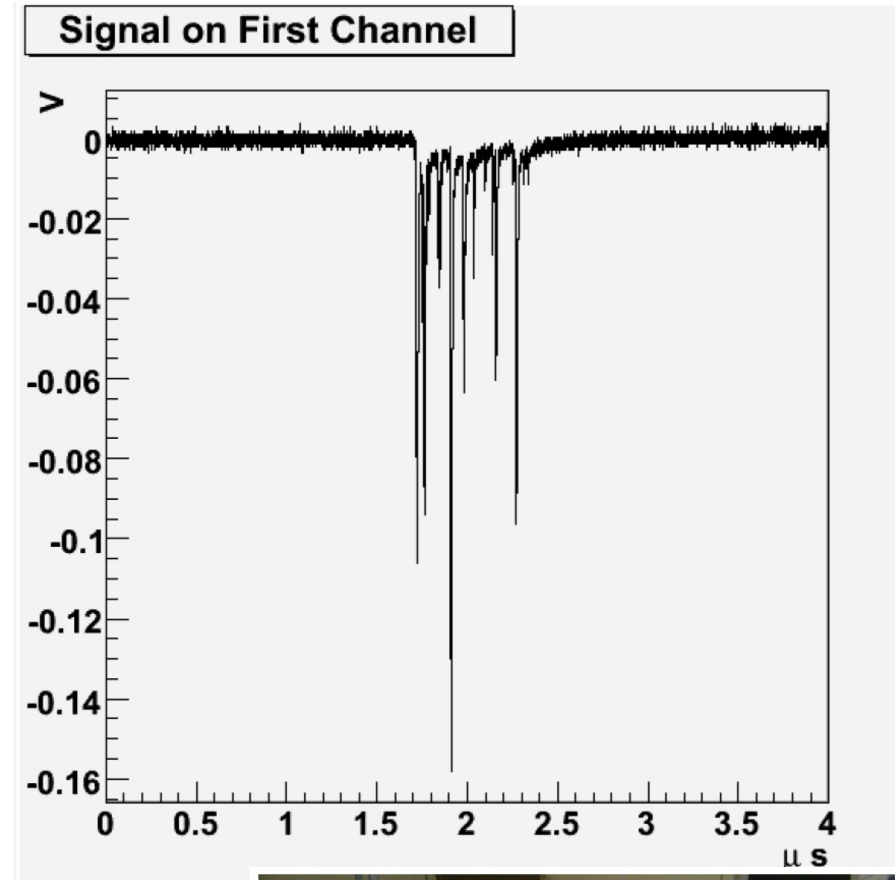
Landau ionization statistics of electrons



Peak finder after FE

CLUCOU measurements: Setup





Gax Mixture = 90 % He 10 % iso-C_4H_{10}
Drift tube ray = 1.4 cm
Wire diameter = 25 micron
Tube lenght = 30 cm
High Voltage = 1750 V
Amplifier Gain = 10
Amplifier BW = 500 MHz

3. Drift chamber mechanical structure:

preliminary considerations

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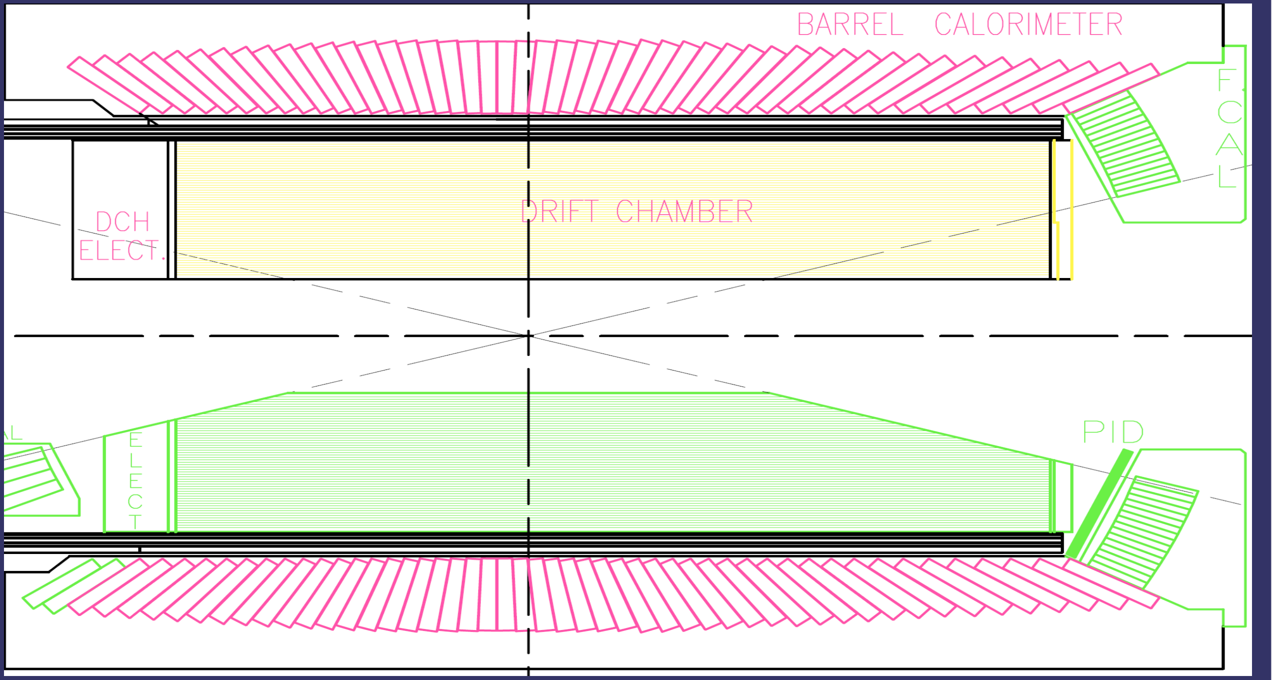
Servizio Sviluppo e Costruzione Rivelatori

3 options considered for the end-plates

- Flat
- Spherical
  - Reduce thickness
- Conical
  - Reduce occupancy in forward direction



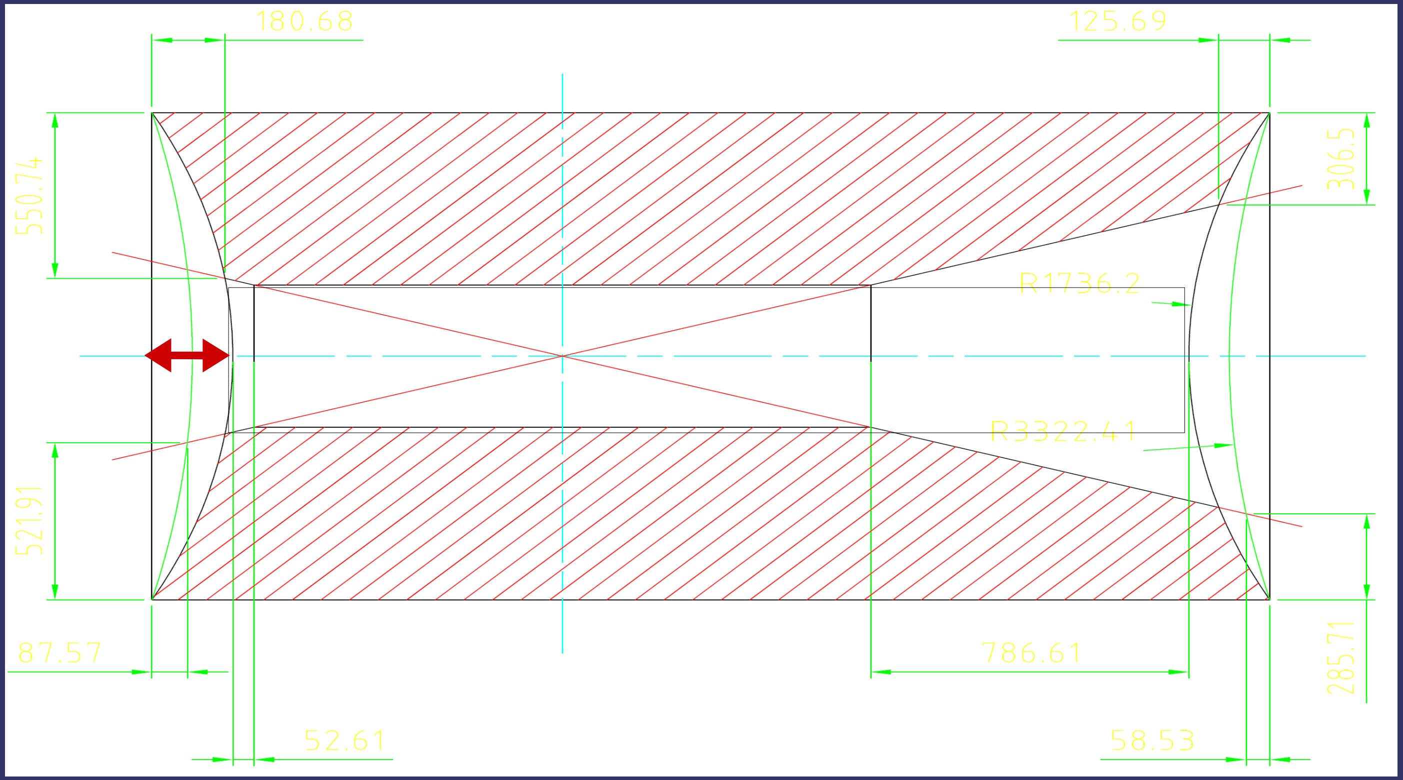
For all options, the E.P.'s are only constrained at the OUTER radius

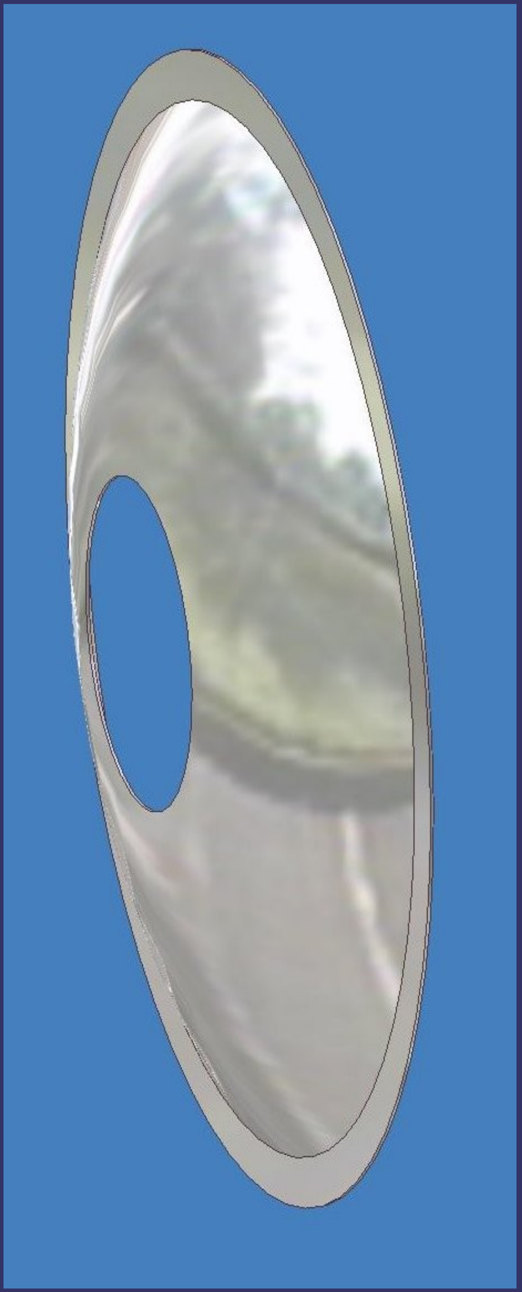
Disclaimer: what follows is VERY preliminary

Option(s) #1: flat CF end-plates

- 25mm thick CF sandwich of
  2mmCF + 21mm honeycomb + 2mm CF
  - ➔ ~0.015X_0, max deformation δ_{max}~1 mm
- 10mm thick CF sandwich of
  2mmCF + 6mm honeycomb + 2mm CF
  - ➔ ~0.015X_0, δ_{max}~7 mm
- 20mm thick CF
  - ➔ ~0.075X_0, δ_{max}~1 mm
- 10mm thick CF
  - ➔ ~0.04X_0, δ_{max}~6 mm

Option #2: spherical end-plates





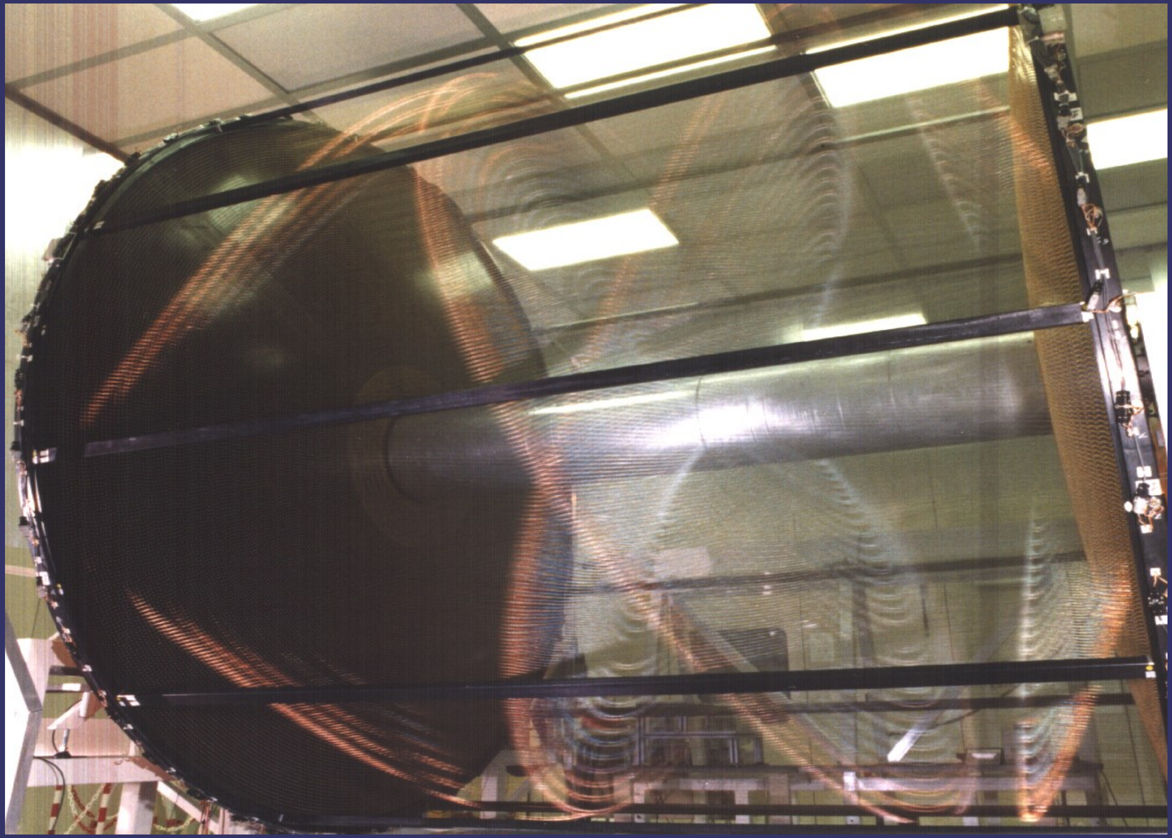
Thickness O(4mm), or *0.015* X_0

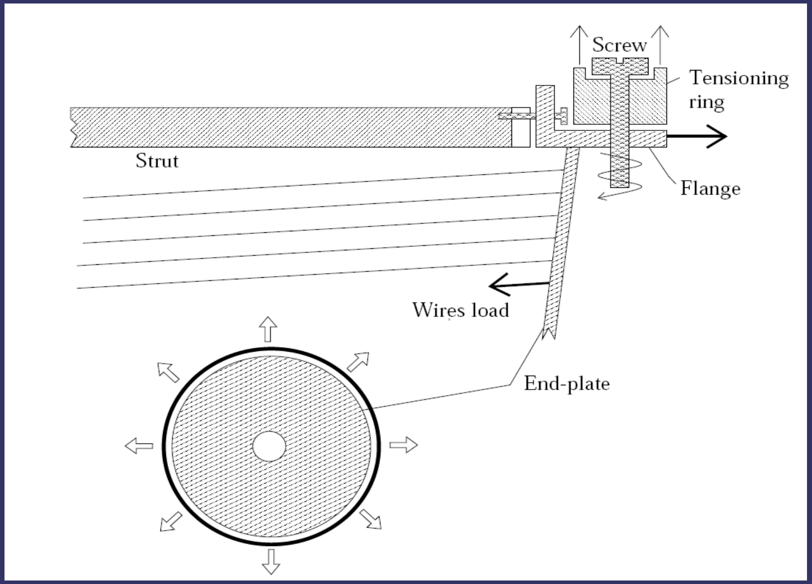
sagitta=200 mm ➡ $\delta_{max200} \leq 0.5mm$

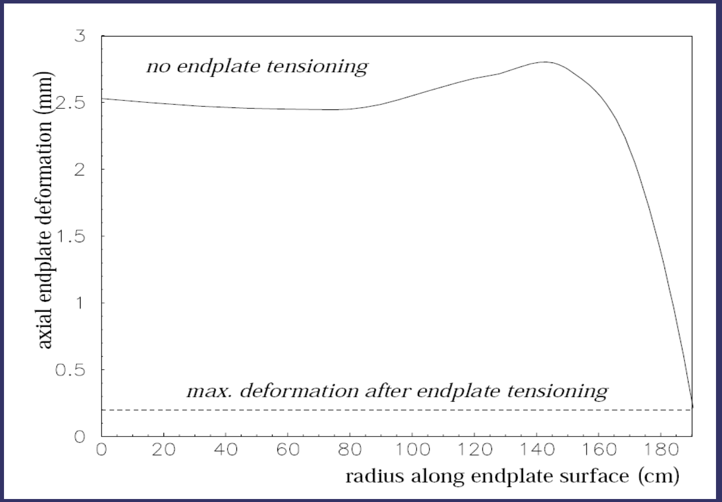
sagitta=100 mm ➡ $\delta_{max100} \sim 2x\delta_{max200}$

Spherical EP concept proved in the KLOE DC

- R_{max} ~ 2m
- 52,140 wires
- total load ~ 3.5 tons
- EP thickness 9 mm
- Plate deformations recovered with CF "stiffening ring"
  - Given the smaller radius of the SuperB DCH, we can probably avoid this complication

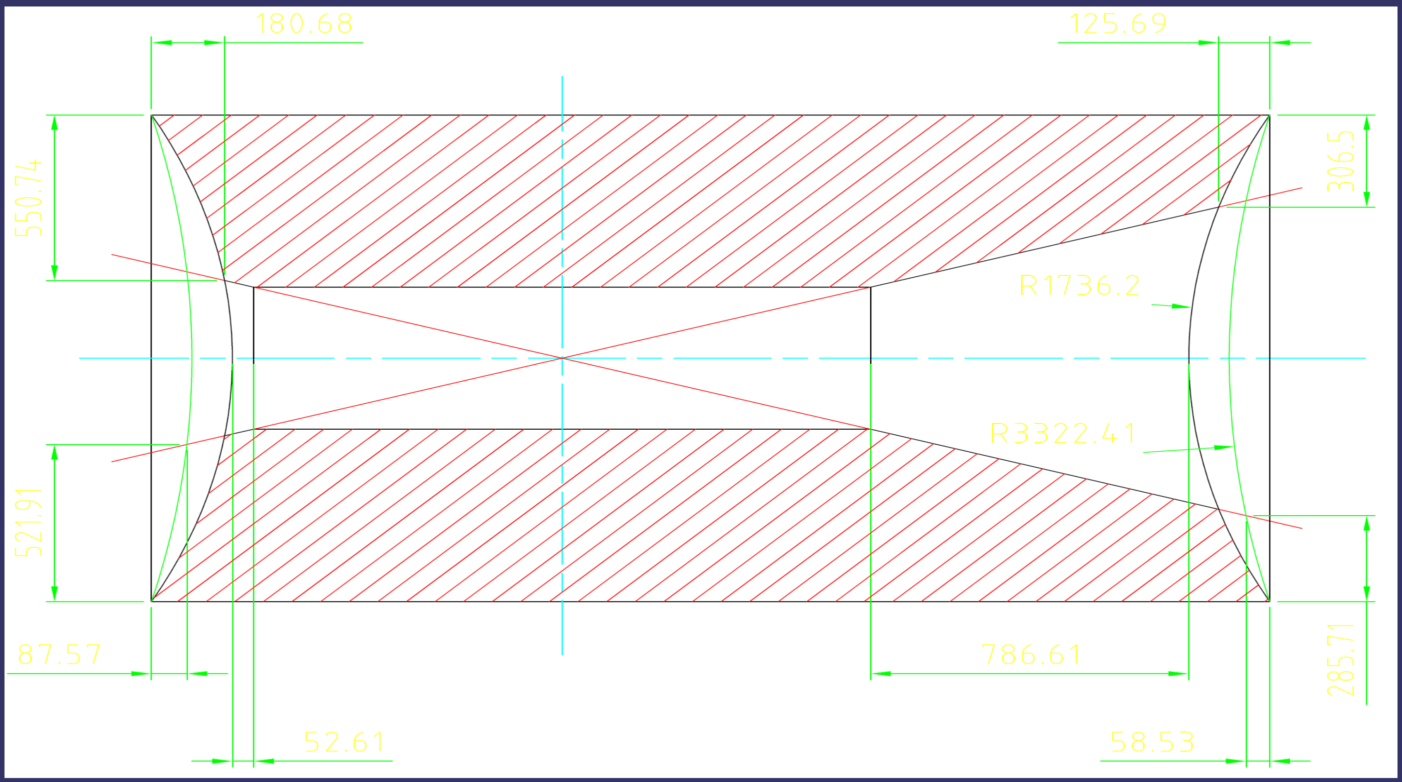


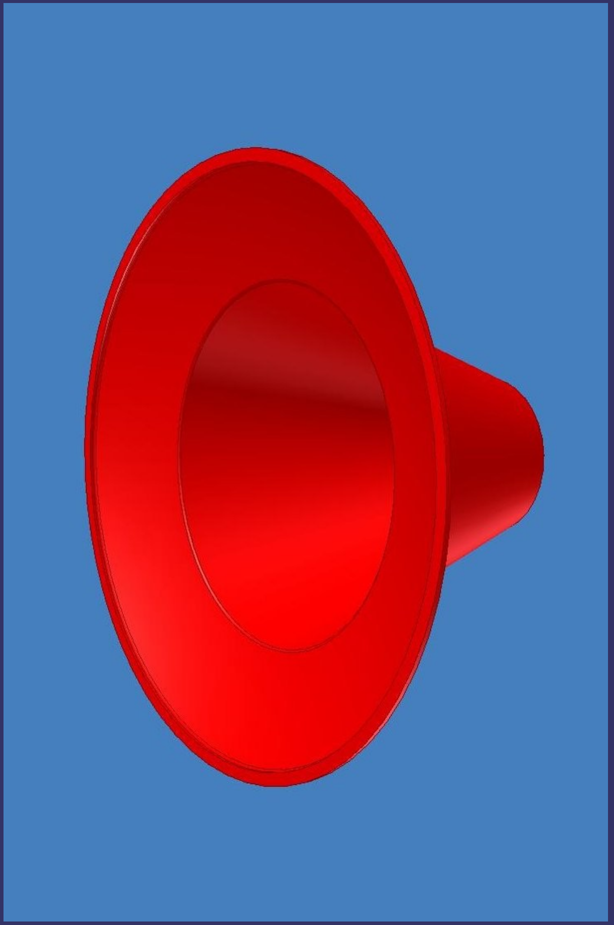




Option #3: conical end-plates

Expect high particle flux in forward direction. Conic-shaped EP's might help reducing occupancy in inner layers.

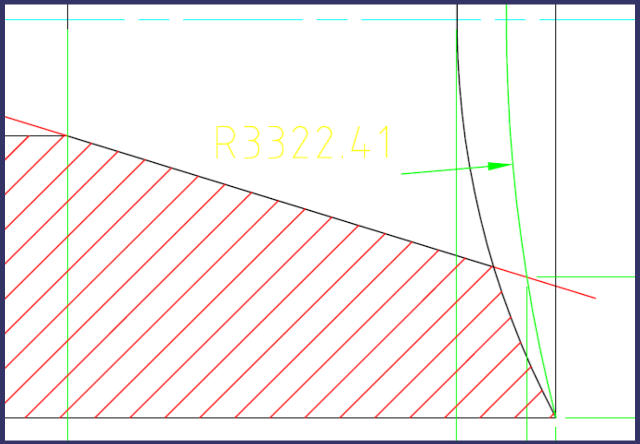




Thickness O(4mm), or *1.5%* X_0 (perp. to walls)

δ_{max}~0.5mm

Option #3: conical end-plates (cont.)



- Besides the trickier structural analysis, conical end-plates would pose several problems though:
  1) drilling the holes at a very small angle
  2) ensuring a flat seat for the feed-throughs
  3) stringing the wires in the conical section
  4) a lot of material seen by electrons tangential to the cone ⇨ a lot of background produced
- None of the above (excluding 4), which needs careful investigation) looks unsurmountable, but we should be aware that conic end-plates are not exempt from issues.

Summary and outlook

- Assuming the present BABAR DCH performances, and taking into account increase in occupancy foreseen in *SuperB*, we identified various areas of intervention and a tentative R&D program to meet the requirements.
- To finalize this R&D program crucial information is missing:
  - What is the maximum expected background rate
- Good progress in the procurement of the hardware necessary for the cell studies (tracking telescope + KLOE prototype)
- Working hypothesis is to keep total thickness < e.g. PID system
- Preliminary studies of the mechanical structure have been started by LNF engineers.
  - Conical/spherical Carbon Fiber end-plates seem feasible, with thickness O(few %X_0) and deformations < 1mm.
- Adjustments of length and position of DCH from interplay with other detector systems