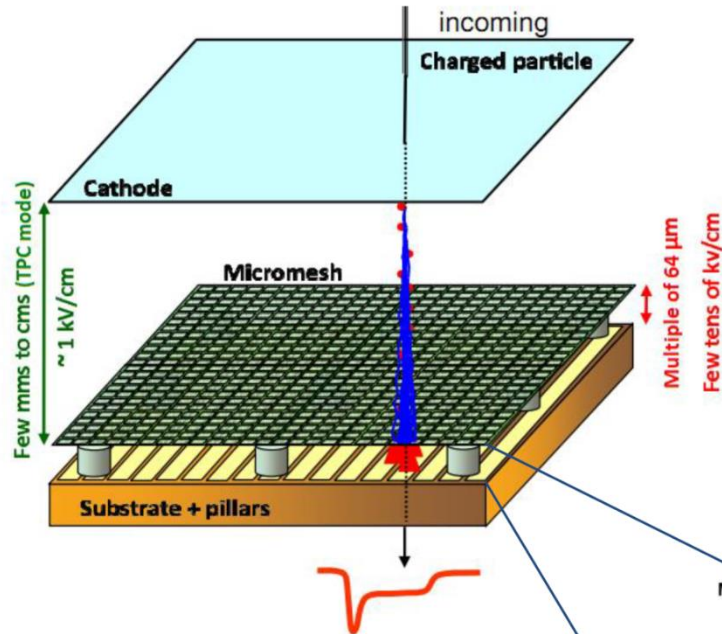
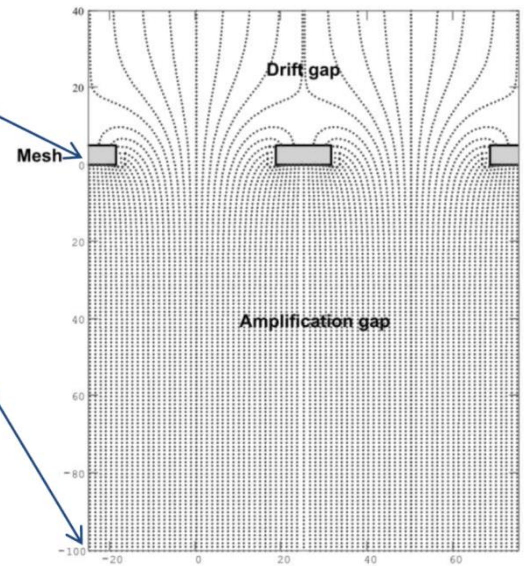
Proposal of vertex detector based on MicroMegas technology

Aims and background

- MM vertex detector is planned to be used first few years of data taking, and will be replaced by silicon vertex detector later.
- First years of data taking NICA/SPD will operate at C.M. energy bellow nominal, and steel or aluminum vacuum tube will be used instead of beryllium one. So far forward region will be less important
- There is no task to reconstruct secondary vertices with high accuracy
- Proposal is based on experience of CLAS12 MM tracker developed by Saclay group NIM A957(2020),12

- **MicroMegas (MicroMeshGaseousStructure)** – double- gap parallel plate counter with ionization/drift(2-5mm) and amplification(~125µ) gaps, separated by fine mesh (typically -18x40µ)



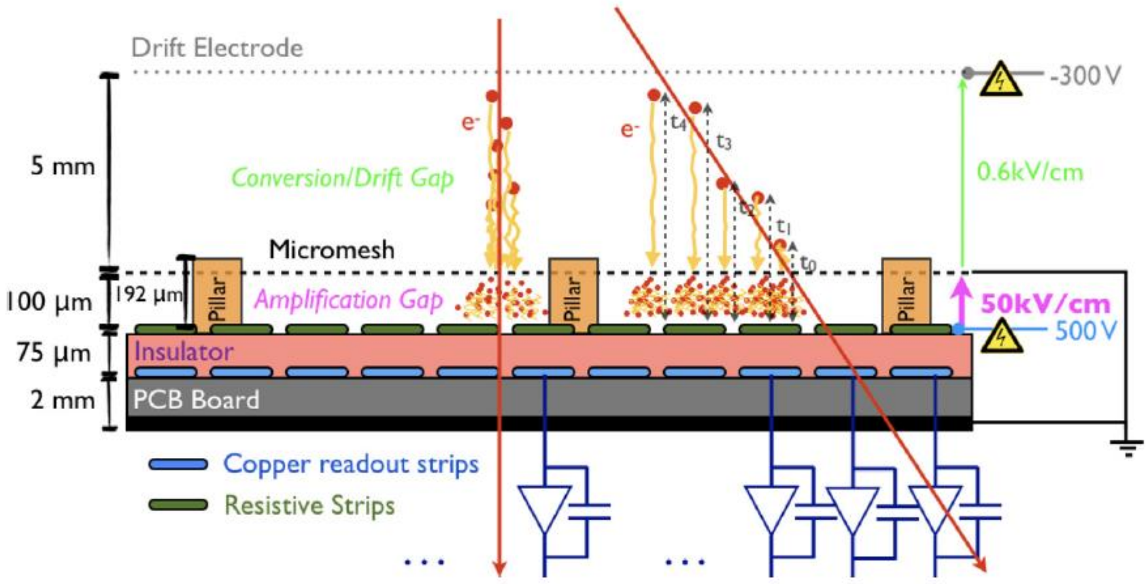


- operation gain is $G \leq 10^4$
- Signal is dominated by ion component
- Ion collection time <150 ns
- Full signal lenght is defined by electron drift time(up to 150us) and ion collection time
- Amplifier shaping time is 100/200 us (VMM3)

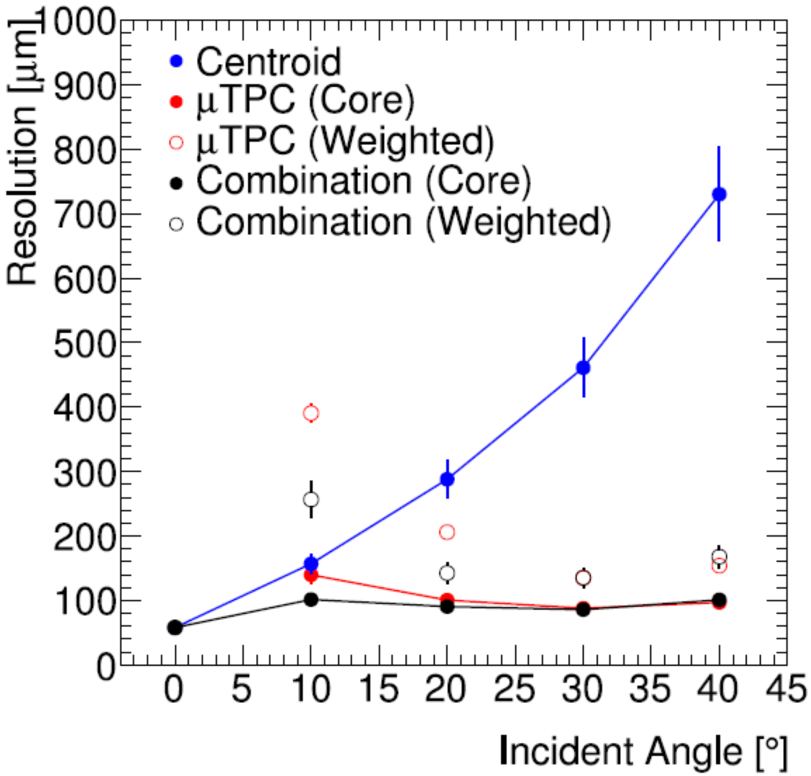
- Electric field in ionization gap $E \approx 600\,V/cm$
- Amplification gap field $E \approx 50\,kV/cm$
- Mesh transparency for primary electrons is ~99%

Hit position reconstruction in MM

- There are 2 main method of hit position reconstruction
  - **Charge centroid** (charge weighting) – excellent for perpendicular tracks, accuracy degrade fast if track is inclined
  - **µTPC** method. Utilize strip time information to reconstruct track angle and position. Good for inclined track, but require good timing, higher amplitude and lower noise.



Hit position reconstruction in MM

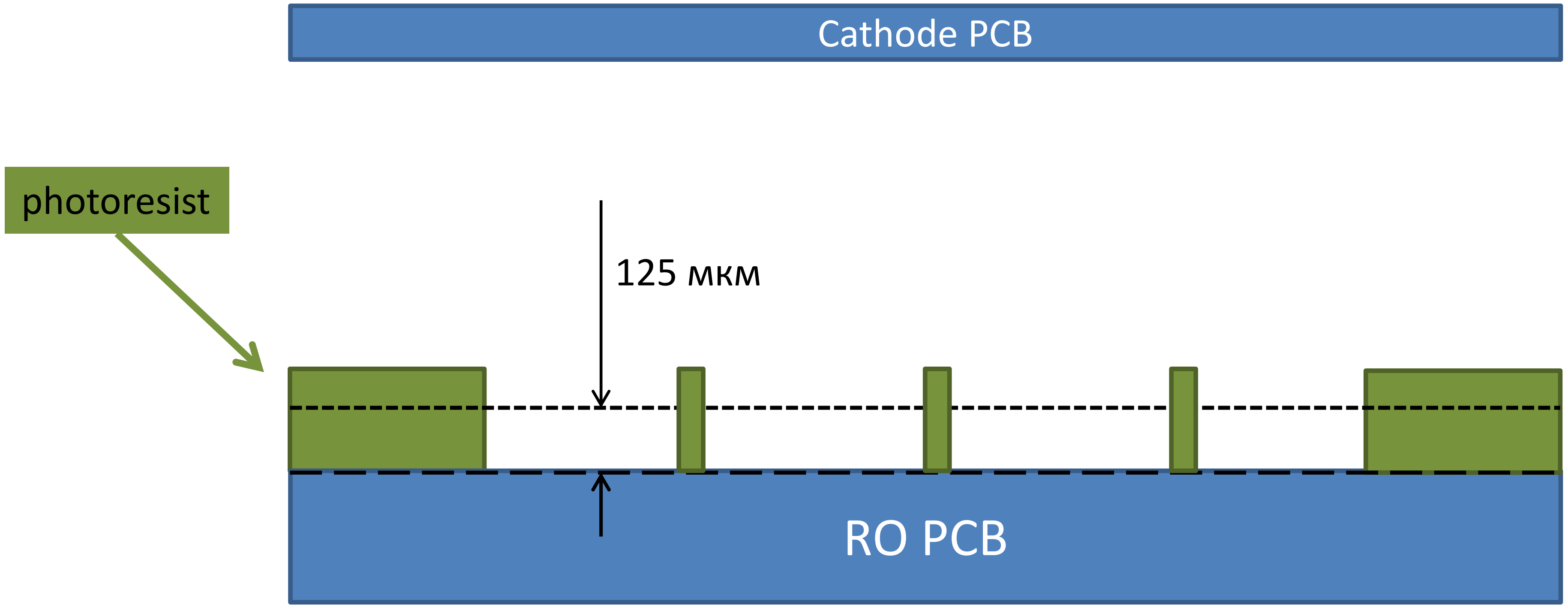


Atlas MM prototype test results

- In magnetic field non-negligible Lorentz angle result in inclined drift line, so perpendicular track looks like "effectively inclined" for reconstruction
- Typical Lorentz angle is 30-40°.
- To have accuracy better then 150μ we need either
  - μTPC, which apply strong limitation on strip capacity(length)
  - Gases/field configuration with very low Lorentz angle

Micromegas for SPD VD

- MM for SPD will be produced using “Bulk” technology
- RO PCB, mesh and amplification gap form entire module produced by photolithography



Micromegas for SPD VD

- “bulk” module and cathode pcb are glued together on cylindrical template. Gas gap and detector shape are defined by carbon longbeam and end-face arcs.
- After gluing MM chamber can not be disassembled

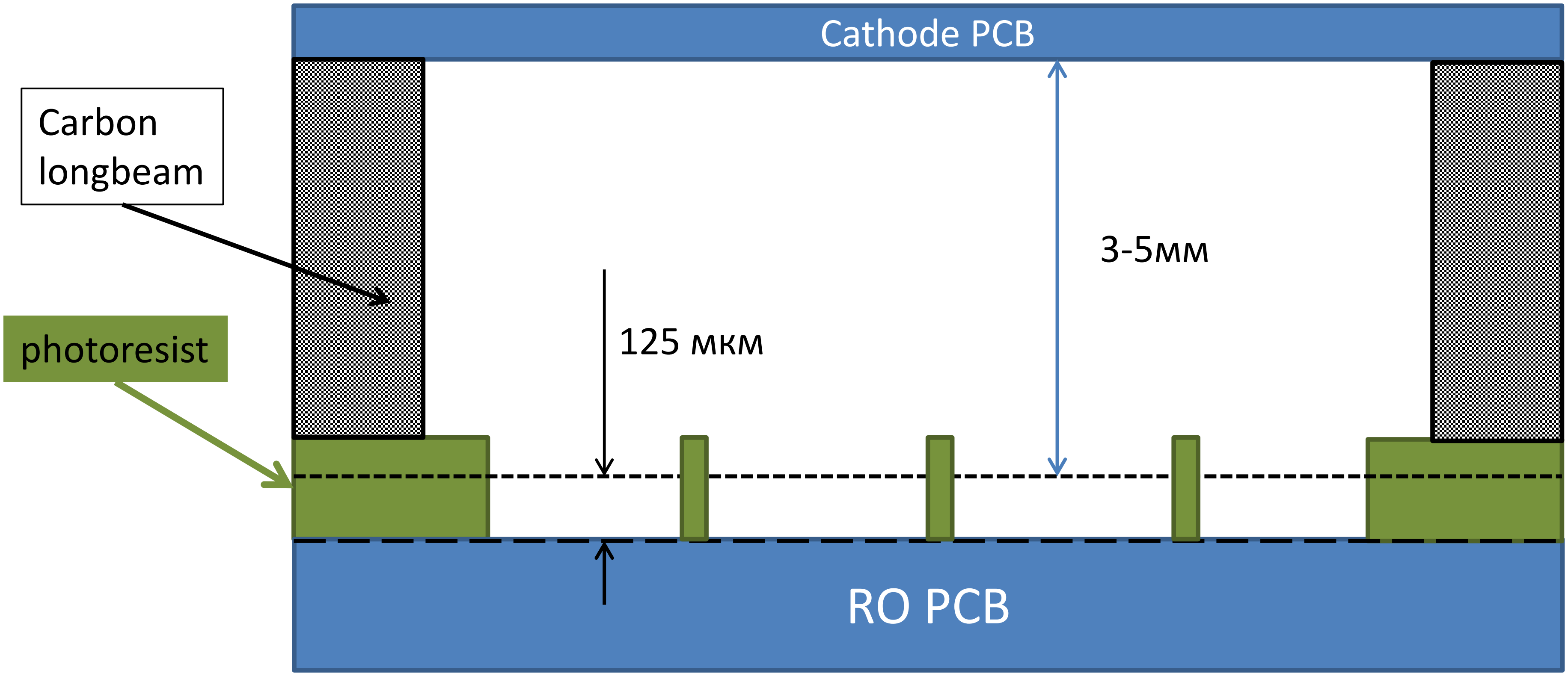
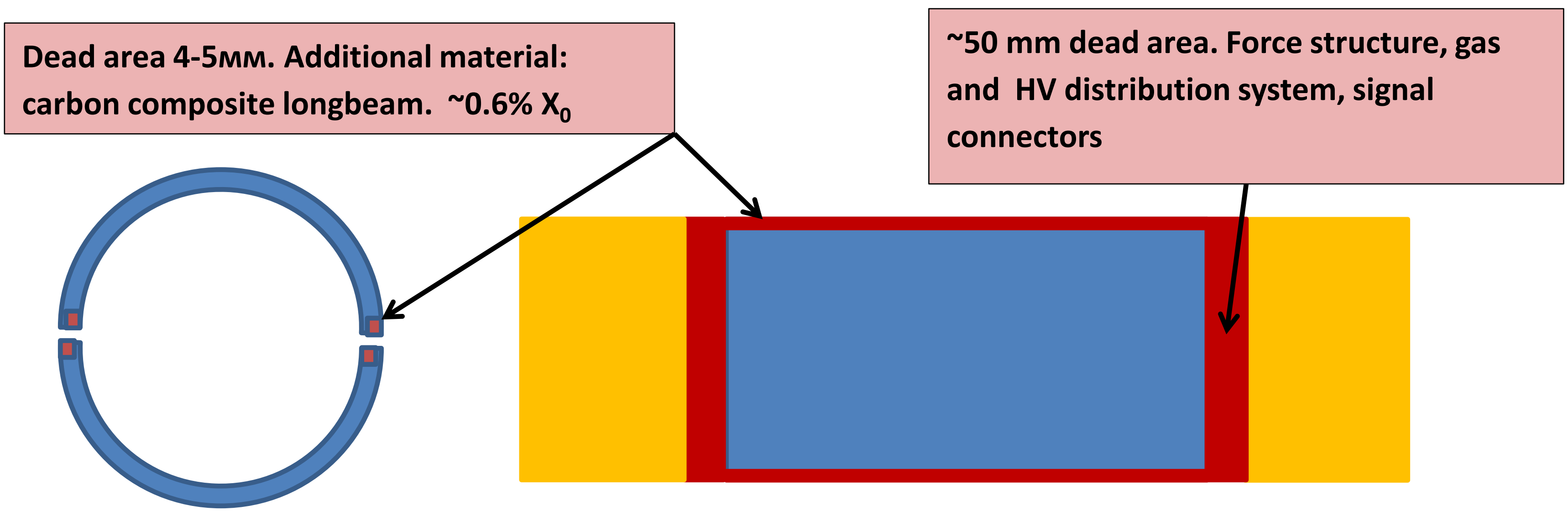


Рисунок для плоской геометрии. Не в масштабе.

Barrel layers

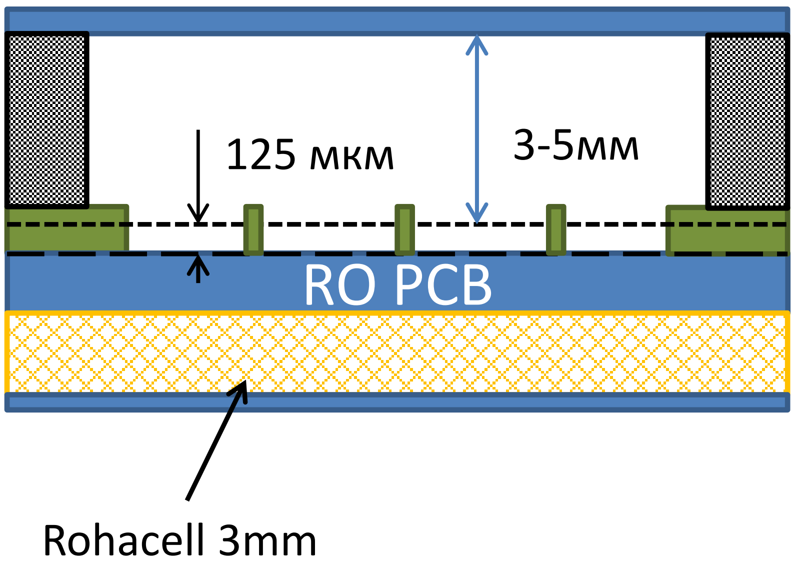
- Barrel detectors look like half-cylinder. Every single layer is independent 1-coordinate detector. Minimal layer radius $R_{min} \cong 50mm$. Layer thickness ~4mm. Material budget is about $0.4\% X_0$ per layer.
- MM design need reasonable dead space at detector edge for mesh fixation, force elements, gas end electrical connections etc. Expected dead area along pcb side parallel to beam is 4-5mm and 50mm at end-face

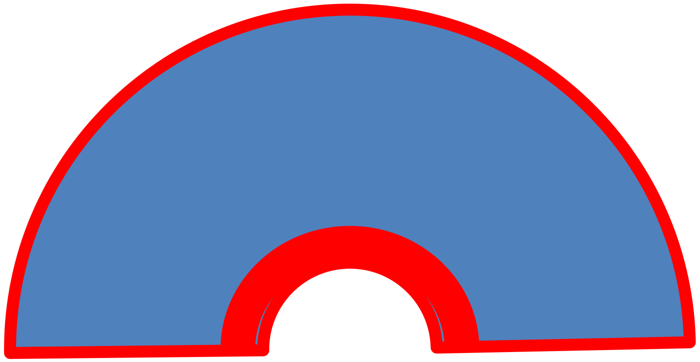


NOT at scale

End-caps

- End-cap detector need sandwich structure to be rigid enough





Technical limitations:

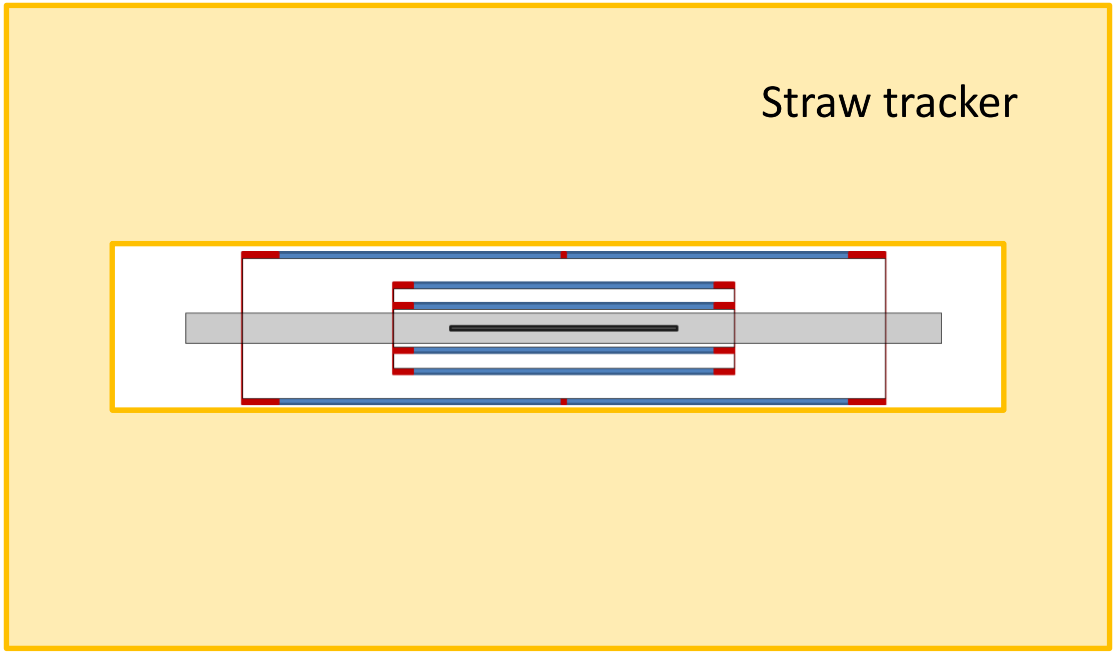
- Maximum active area size for single detector is 800x600 mm^2, limited by photolithography equipment in JINR and Saclay

- Signal strip and cable capacitance
  - FE electronic noise grows linearly with signal electrode capacitance. Existing experience with VMM3 chips shows that capacitance $C_d \approx 150\ pf$ is close to limit of operation and $C_d \leq 100\ pf$ is desirable. For typical strip and cable capacitance 100 pf/m it is highly recommended to keep total length of strip and cable bellow 1m

Detector layout(barrel)

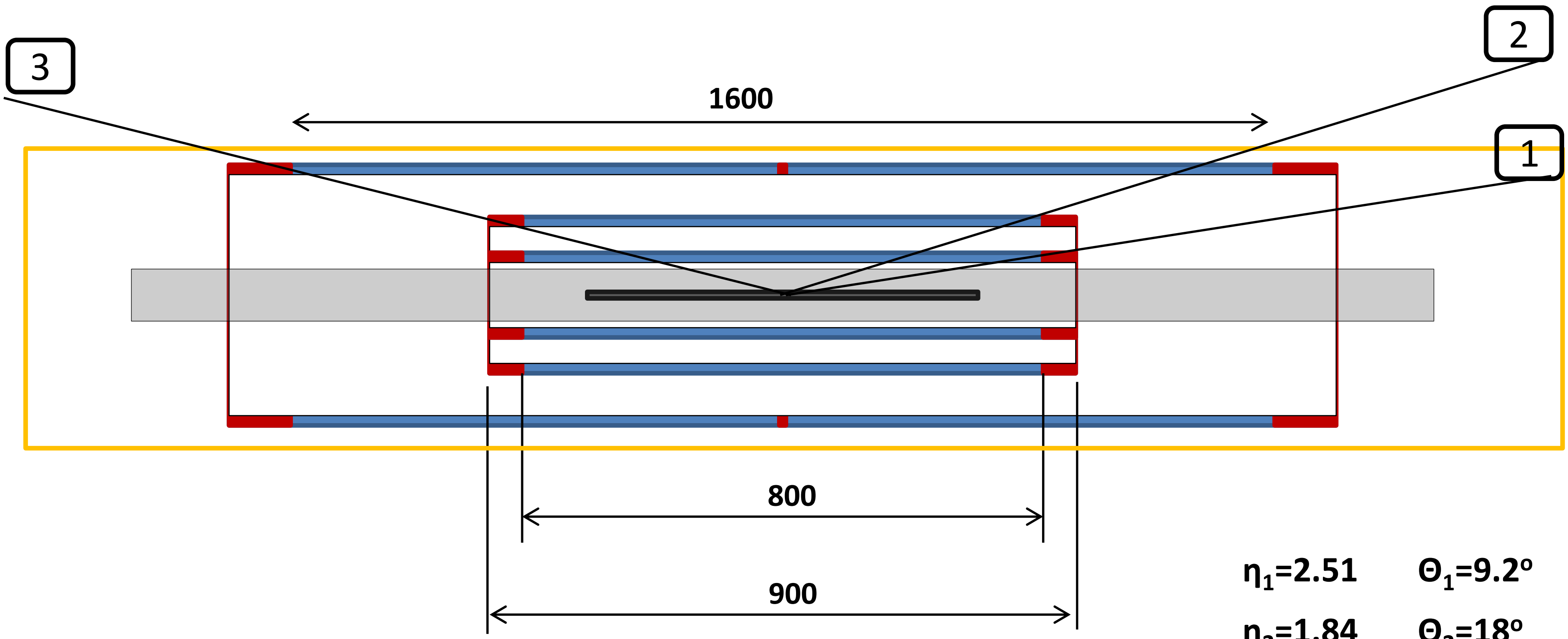
- PCB with almost any strip geometry can be produced
- As Z coordinate accuracy is less important then rϕ, strips inclined slightly toward beam axis is effective.
- We offer group layer into 3 superlayers, 2 or 3 layers in each; Strip angle is (+α, - α , 0) or (+ α , - α), where $\alpha=2\text{-}5^{o}$. (3 layer in innermost superlayer, 2 layer in outer layers)
- Superlayer structure simplify mechanical support, and and make it easier to find tracks
- Half-cylinder junction plane rotated 60^{o} from layer to layer to avoid dead zone

MM vertex detector inside straw tracker



In scale

MM vertex detector layout



$\eta_1=2.51$ $\Theta_1=9.2^o$

$\eta_2=1.84$ $\Theta_2=18^o$

$\eta_3=2.09$ $\Theta_3=14^o$

Straw tracker
Inner space

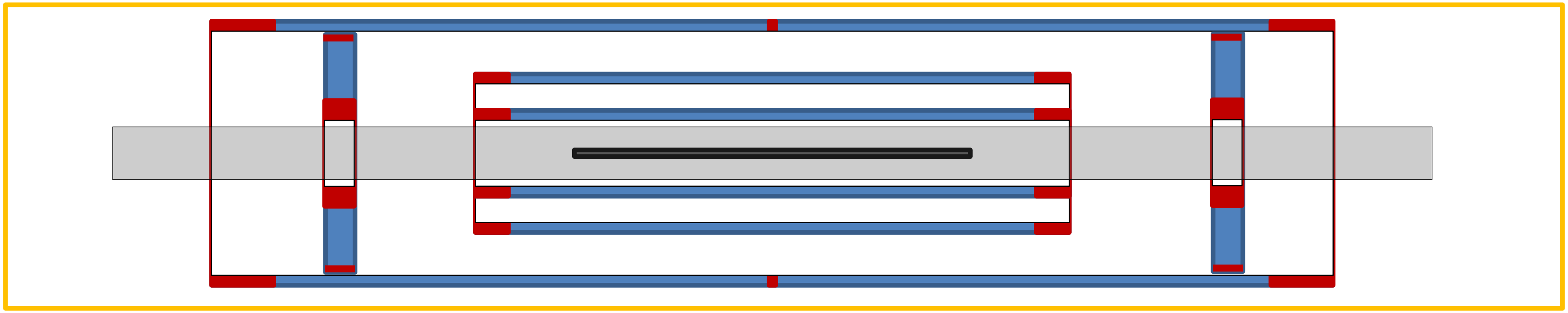
Inner superlayer:
3 layers, +5°,-5°,0°
R=50-65mm

Medium superlayer:
2 layers, +5°,-5°
R=120-130mm

Outer superlayer:
2 layers, 4 MM each
+5°,-5° , R=190-200mm

MM vertex detector layout

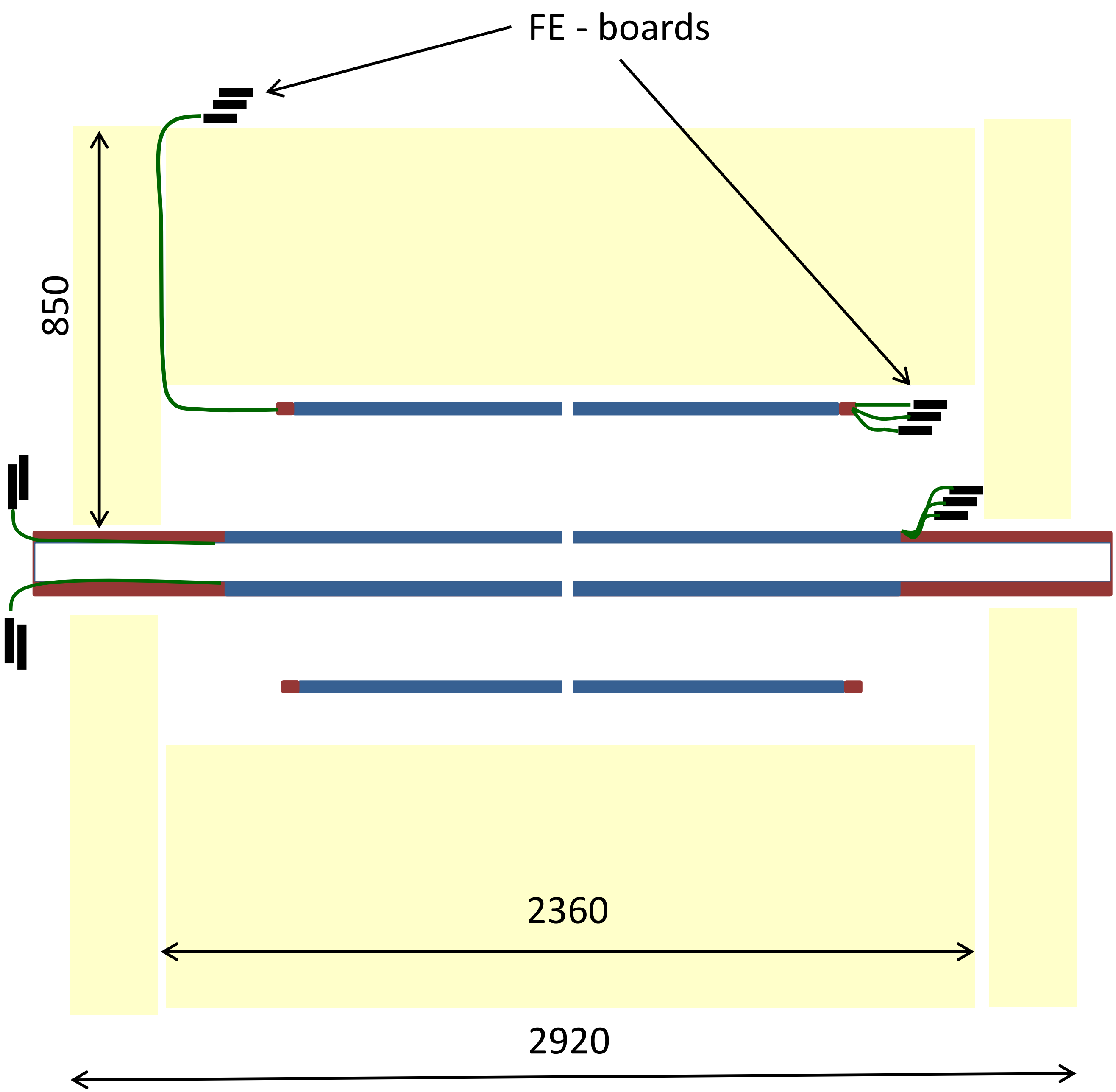
Possible option with end-cap



3 plane(6 half-disc) in each end-cap

FE electronic

- The only FE board available now is Hybrid128 – VMM3-based board, developed by RD51 collaboration to use as part of SRC.
  - Possible option is FE for MM @ EIC (is under development now)
- Board size is 50x80mm, 128 channels/board, channel density is 1/390µ – well fit MM needs
- Boards may be located
  - Inside straw tracker, in end-cap region
  - Outside straw tracker, in barrel part of detector (assuming no PID detector for 1st stage of SPD operation
  - Outside straw tracker, end-cap part of detector
- Main criteria to choose FE boards location is capacitance attached to FE channel and material inside tracker
- For both variants with board position outside straw tracker total strip+cable length is about 2 m
- **We offer to locate FE board inside straw tracker as close to tube as possible**



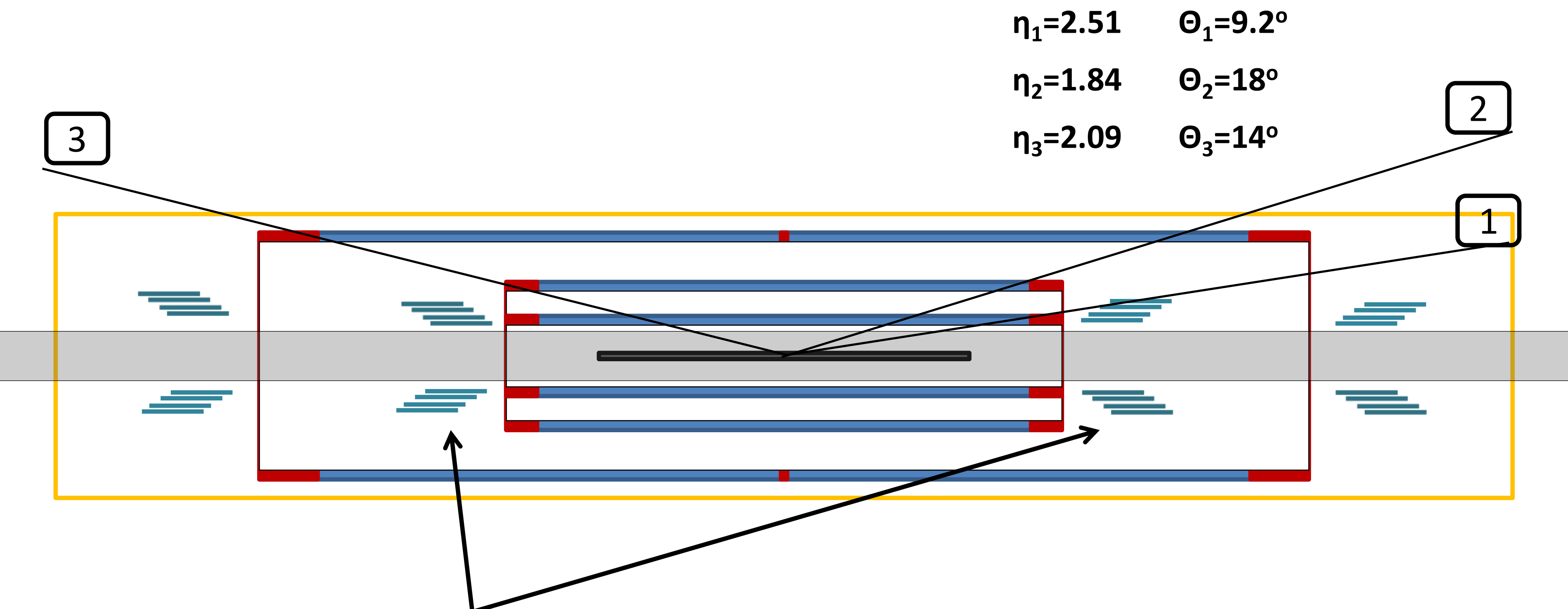
ATLAS MM experience.
VMM3 noise:

- **Short strip ~0.2 fCl**
- **1.8 м strips ~1.2 fCl**
- **Noise grow lineally with strip length**

Number of FE channels

Super Layer	Pitch, mm	Strip Lenth,mm	Layer R,mm	Strip angle	Nch	Nch Total	N boards
1	0.4	800	50-55	+0^o	733		6
			55-60	+5^o	1065		9
			60-65	-5^o	1144		9
2	0.5		120-125	+5^o	1597		13
			125-130	-5^o	2145		13
3	0.5	2x800	210-215	+5^o	2x2477		40
			215-220	-5^o	2x2540		40

FE boards location

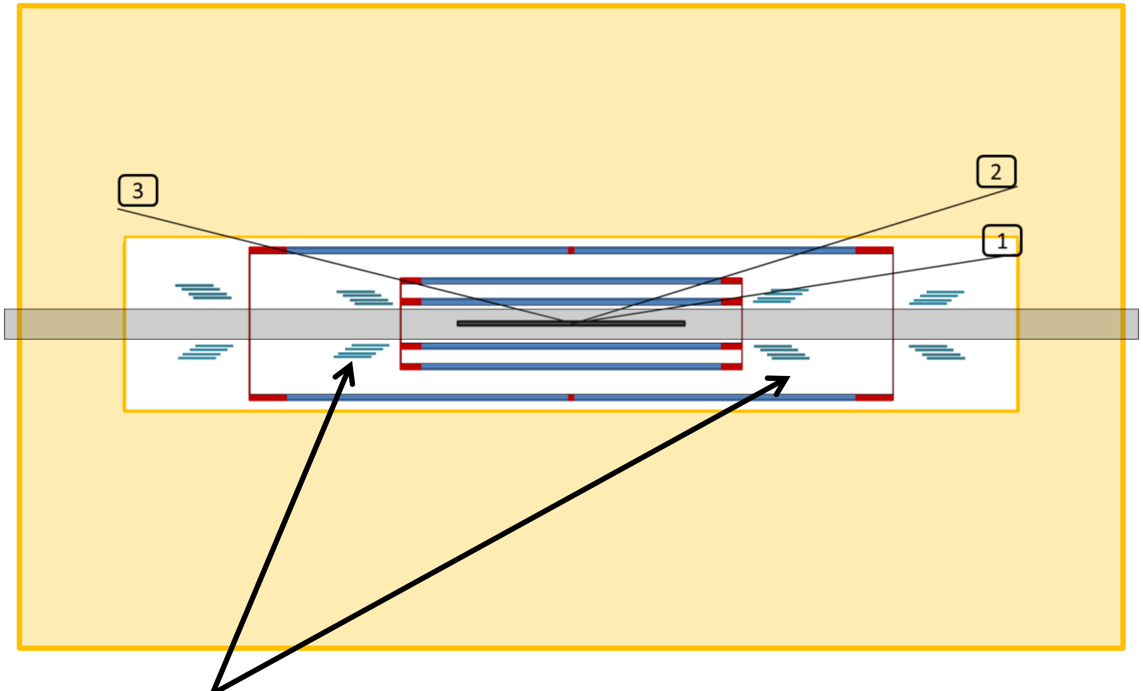


Up to 2x30 boards in 5 rings within R=100 mm
$Z = \mp(500 - 550)mm$, η=2.41, θ=10.3°

Up to 2x60 boards within R=130mm
$Z = \mp 900 - 1000\ mm$,

FE boards position

η_1=2.51 Θ_1=9.2°
η_2=1.84 Θ_2=18°
η_3=2.09 Θ_3=14°



Up to 2x30 boards in 5 rings within R=100 mm
$Z = \mp(500 - 550)mm$, η=2.41, θ=10.3°

Up to 2x60 boards within R=130mm
$Z = \mp 900 - 1000\ mm$,

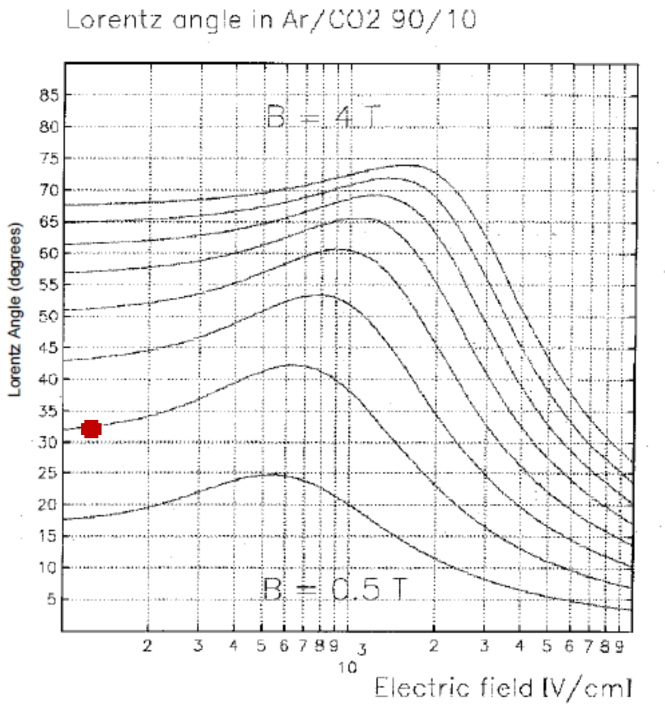
Cost estimate

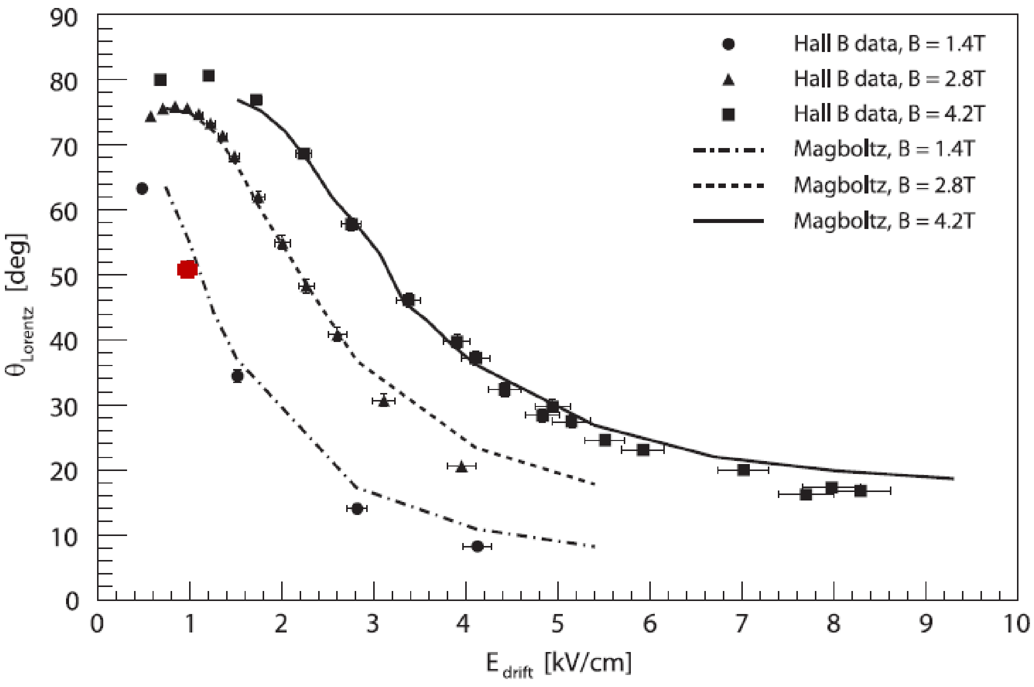
	Cost per unit, kEuro	N units	Cost, kEuro
MM detectors materials	8	18	144
FE electronic, SRC, cables	1.5	150-250	375
HV PS, HV cable			20
Gas system			20
Carbon support structure, cooling etc.			?
Assembling tools production			?

600+ kEuro

Backup slides

Lorentz angle for Ar-CO_2(10%) and Ar-iC_4H_{10} (Clas12)mixtures





Lorentz Angle and drift speed for $Ar\text{-}CO_2\text{-}iC_4H_{10}$ mixtures