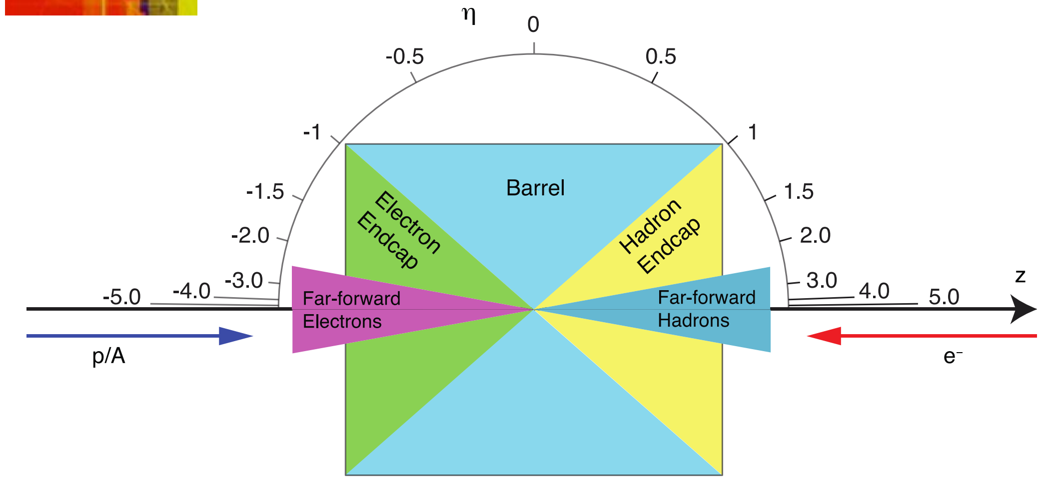
Survey of Gaseous Detector Technologies

1st EIC Yellow Report Workshop @ Temple University

Kondo Gnanvo

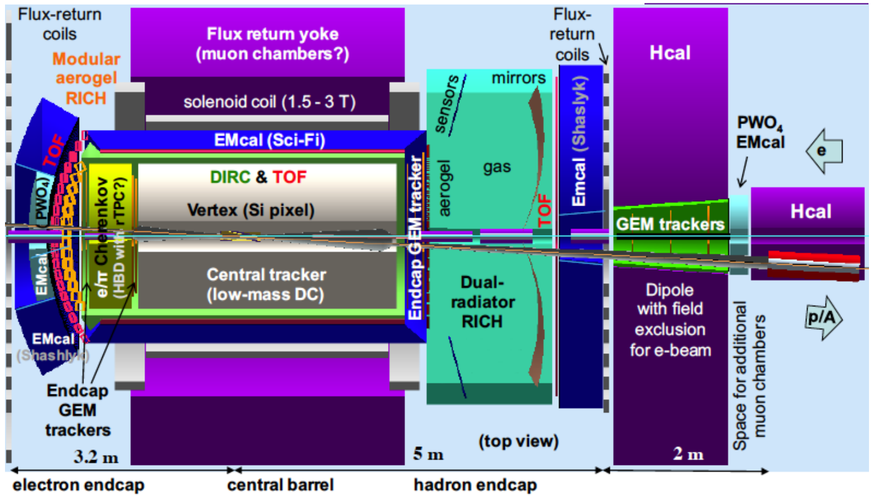
University of Virginia

EIC Detectors Concepts

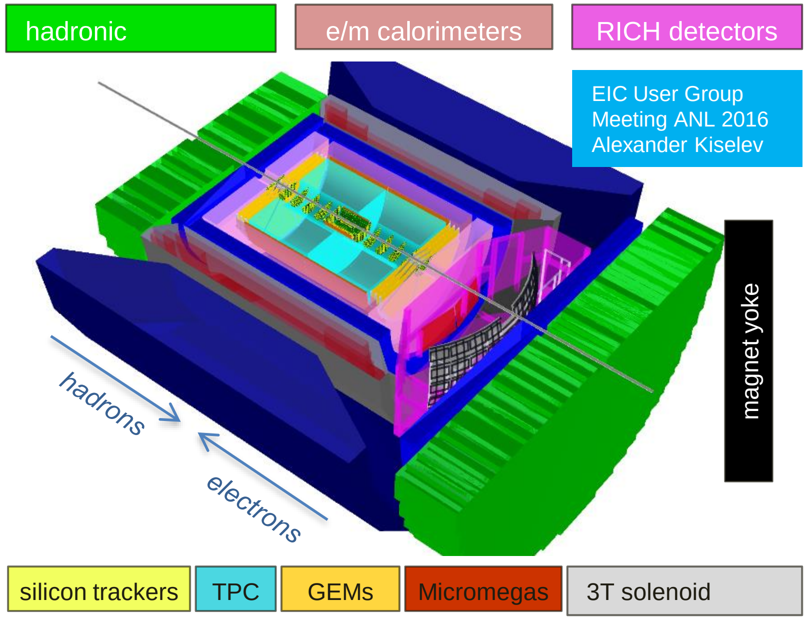


Many baseline EIC detector designs involved various gaseous detectors technologies for tracking in the central as well as end cap region

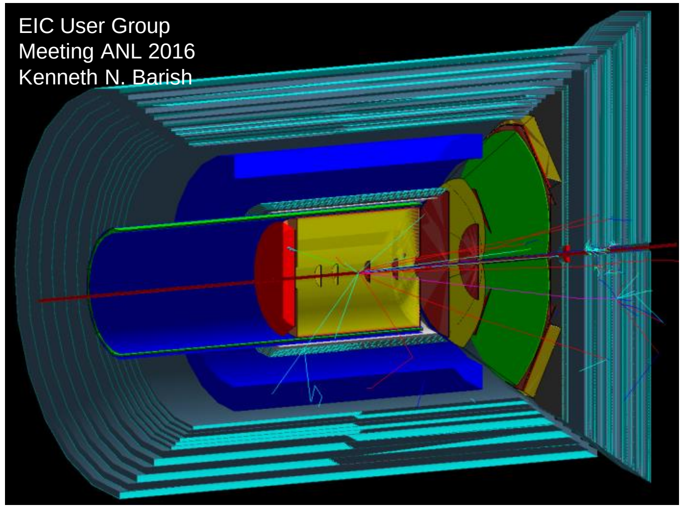
JLEIC Design



BeAST @ eRHIC



ePHENIX @ eRHIC



EIC Detectors Tracking requirements

Barrel Main Tracker

- ❑ Hermetic coverage, close to 4π acceptance
  - ⇨ pseudo-rapidity range up to +/-1)
  - ⇨ Large area detectors
- ❑ Low material budget on the level of 3-5% of X_0/X for the central tracker region
  - ⇨ Gaseous detectors
- ❑ Tracking momentum resolution in few % range

End cap Trackers

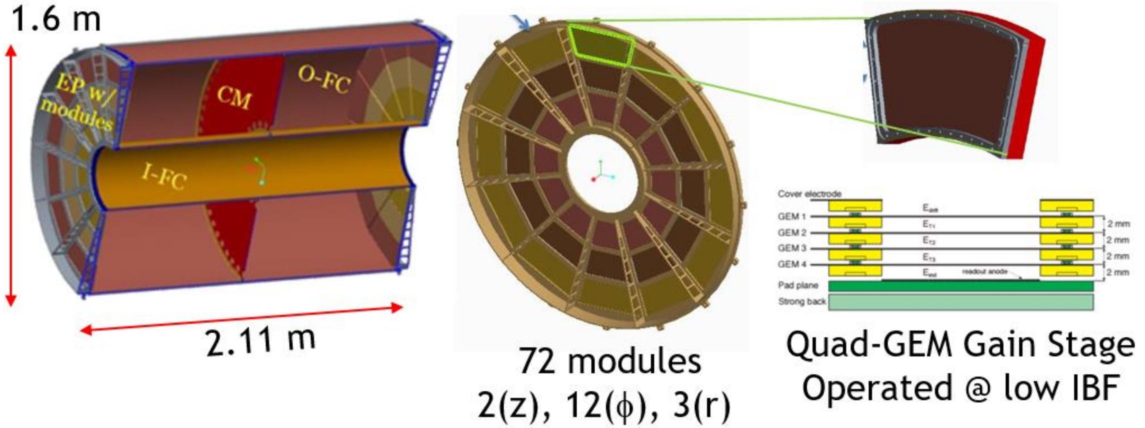
- ❑ Coverage in the end cap
  - ⇨ pseudo-rapidity range up to +/-1 to +/-3.5
  - ⇨ Large area detectors
- ❑ Low material budget specially for the electron endcap
  - ⇨ Gaseous detectors
- ❑ Tracking momentum resolution in few % range
  - ⇨ 50 μm space point resolution **desirable** for high P (> 50 GeV) in the hadron end cap

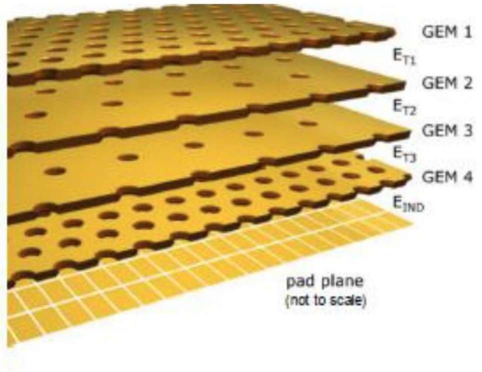
EIC Detector Requirements

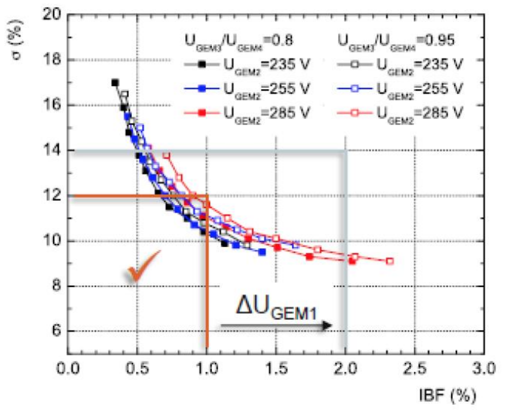
η	Nomenclature			Tracking			Electrons		π/K/p PID		HCAL	Muons
				Resolution	Allowed X/X_0	Si-Vertex	Resolution σ_E/E	PID	p-Range (GeV/c)	Separation	Resolution σ_E/E	
-6.9 — -5.8	↓ p/A	Auxiliary Detectors	low-Q^2 tagger	$\delta\theta/\theta < 1.5\%$; $10^{-6} < Q^2 < 10^{-2}$ GeV^2								
…												
-4.5 — -4.0			Instrumentation to separate charged particles from photons				2%/√E					
-4.0 — -3.5												
-3.5 — -3.0		Central Detector	Backwards Detectors	$\sigma_p/p \sim 0.1\% \times p + 2.0\%$	~5% or less	TBD		π suppression up to 1:10^4	≤ 7 GeV/c	≥ 3σ	~50%/√E	
-3.0 — -2.5												
-2.5 — -2.0				$\sigma_p/p \sim 0.05\% \times p + 1.0\%$								
-2.0 — -1.5							7%/√E					
-1.5 — -1.0												
-1.0 — -0.5			Barrel	$\sigma_p/p \sim 0.05\% \times p + 0.5\%$		$\sigma_{xyz} \sim 20$ μm, $d_0(z) \sim d_0(r\phi) \sim 20/p_T$ GeV μm + 5 μm	(10-12)%/√E		≤ 5 GeV/c		TBD	TBD
-0.5 — 0.0												
0.0 — 0.5												
0.5 — 1.0												
1.0 — 1.5			Forward Detectors	$\sigma_p/p \sim 0.05\% \times p + 1.0\%$		TBD			≤ 8 GeV/c		~50%/√E	
1.5 — 2.0												
2.0 — 2.5									≤ 20 GeV/c			
2.5 — 3.0				$\sigma_p/p \sim 0.1\% \times p + 2.0\%$								
3.0 — 3.5									≤ 45 GeV/c			
3.5 — 4.0	↑e	Auxiliary Detectors	Instrumentation to separate charged particles from photons									
4.0 — 4.5												
…												
> 6.2			Proton Spectrometer	$\sigma_{intrinsic}(\|t\|)/\|t\| < 1\%$; Acceptance: $0.2 < p_T < 1.2$ GeV/c								

http://eicug.org/web/sites/default/files/EIC_HANDBOOK_v1.1.pdf

Central Tracking: TPC with MPGD-based readout structure







Minimization of ion back flow with quad-GEM (ALICE TPC)

PROs

- Cost effective way to instrument large volume
- High tracking efficiency in high backgrounds
- Minimize material (X0) including new ideas on endcap construction
- Works nice in large B-field (drift || B)
- Good V0 detection and reconstruction
- Good dE/dx for particle ID
- Continues readout option (no gating grid) with MPGD as a gain stage -> high rate detector (but "needs" fast tracking detectors in front and behind (in R))
- Good charge particle momentum reconstruction (But if Space Charge Distortions can be minimized and "calibrated")
- A lot of experiences in construction and utilization (ALICE TPCs …)

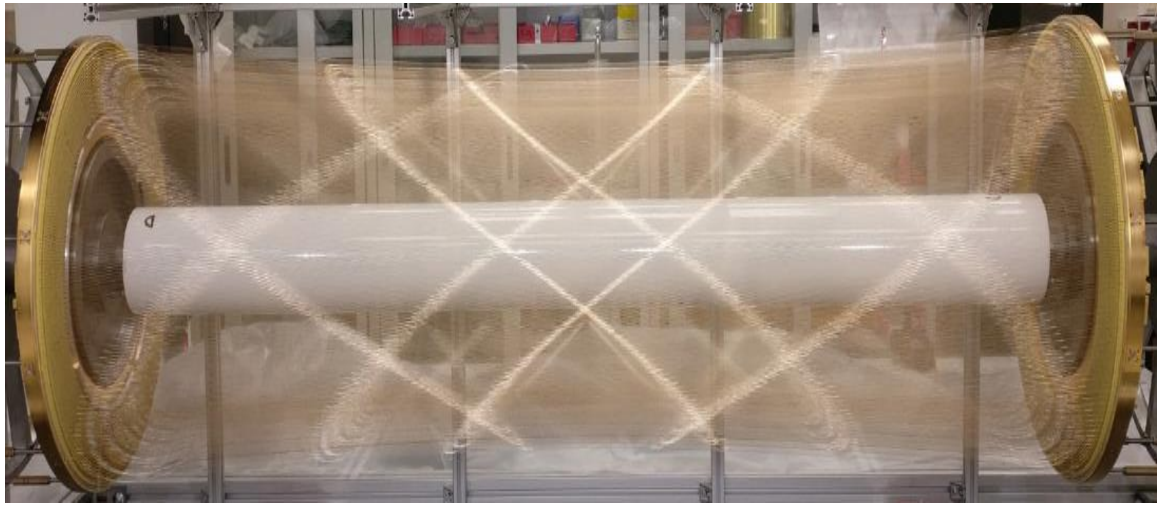
CONs

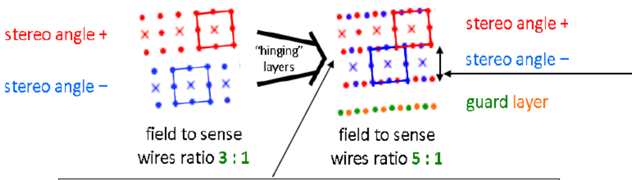
- Electron drift time ⇨ A lot of events overlap
- Ions Back Flow ⇨Space Charge Distortions
- TPC Readout ⇨ Lots of materials (mechanical structures, electronics, cables, cooling) in Endcap
- Needs Laser to calibrate & control some crucial parameters.

See eRD6 talk in this session
M. Posik

Central Tracking: Drift Chambers

MEGII Drift Chamber





The wire net created by the combination of + and – orientation generates a more uniform equipotential plane

Full stereo cylindrical DC with large stereo angles (102÷147 mrad)
Small square cells
(5.8÷7.8 mm at z=0, 6.7÷9.0 at z=±L/2)
(~ 12 wires/cm^2)

sense wires: 20 μm diameter W(Au) => 1728 wires
field wires: 40 μm diameter Al(Ag) => 7680 wires
f. and g. wires: 50 μm diameter Al(Ag) => 2496 wires
11904 wires in total

Active length L	1932	mm
N. of layers	9	
N. of stereo sectors	12	
N. of cells per layer	192	
N. of cells per sector	16	
Cell size (at z=0)	5.8 ÷ 7.8	mm
Twist angle	±60°	
Stereo angle	102 ÷ 147	mrad
Stereo drop	35.7 ÷ 51.4	mm

High wire densities, anyway, require complex and time consuming assembly procedures and need novel approaches to a feed-through-less wiring

Giovanni Francesco TASSIELLI, INSTR20, Feb 24, 3030 Novosibirsk

PROs

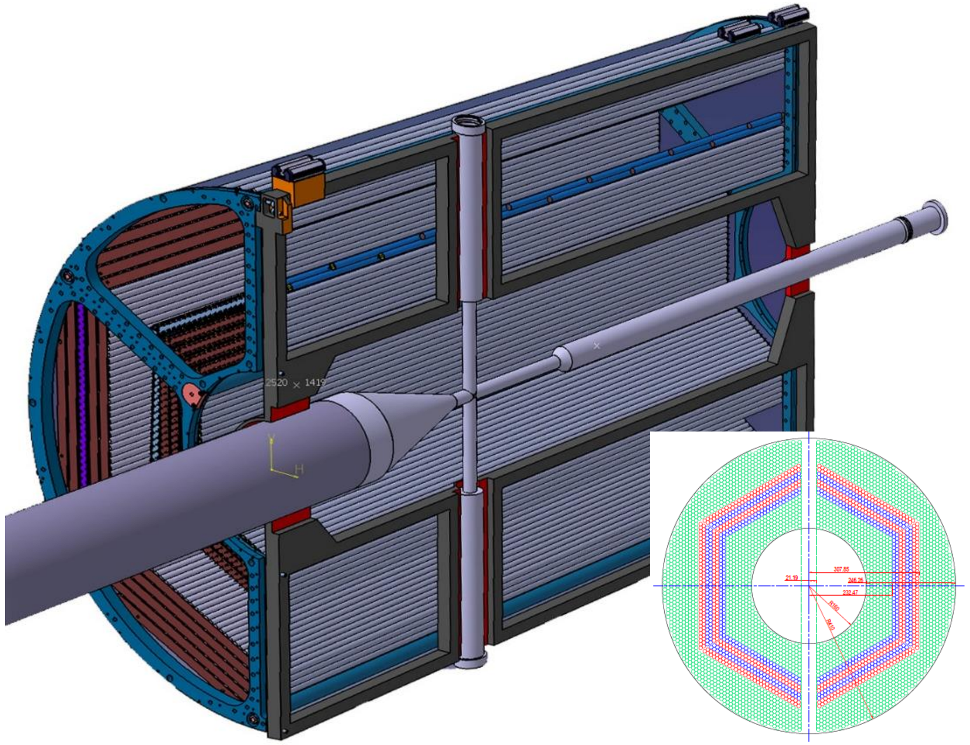
- Cost effective way to instrument large volume
- Good 1D spatial resolution in the radial-to-wire direction (~150 μm)
- Small overall material budget (X0)
- Good dE/dx for particle ID capability
- Good charge particle momentum reconstruction capabilities
- Experiences in construction and utilization (MEGII Drift Chambers)

CONs

- Poor spatial resolution along the wire direction
- Issue with mechanical stabilities of the wires and impact on the operation of the detectors
- Large material budget in the End Cap region

See talk on Drift Chambers and Straw Tube in this session
F. Grancagnolo

Central Tracking: Straw Tubes



PROs

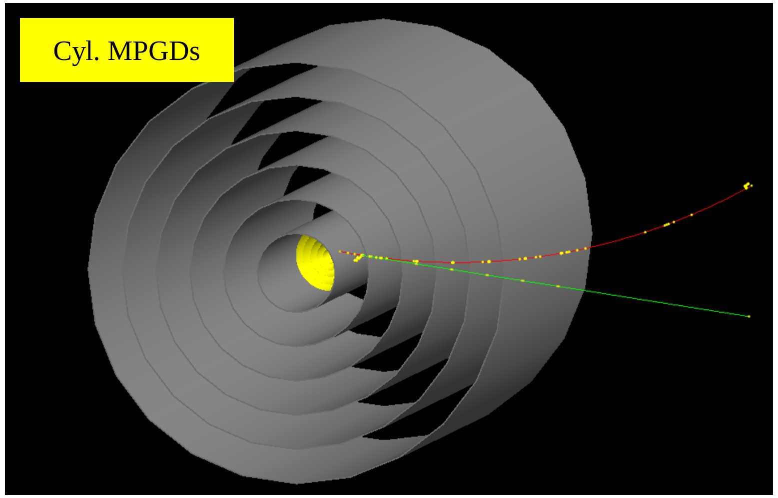
- Cost effective way to instrument large volume
- Good 1D spatial resolution in the radial-to-wire direction (~150 μm)
- Small overall material budget (X0)
- Good dE/dx for particle ID capability in high pressure operation mode
- U-V straw tubes layers configuration improve resolution in beam direction and /or mitigate the left and right ambiguity
- Good charge particle momentum reconstruction capabilities
- Experiences in construction and utilization (PANDA @ FAIR, or GLUeX@ JLab)

CONs

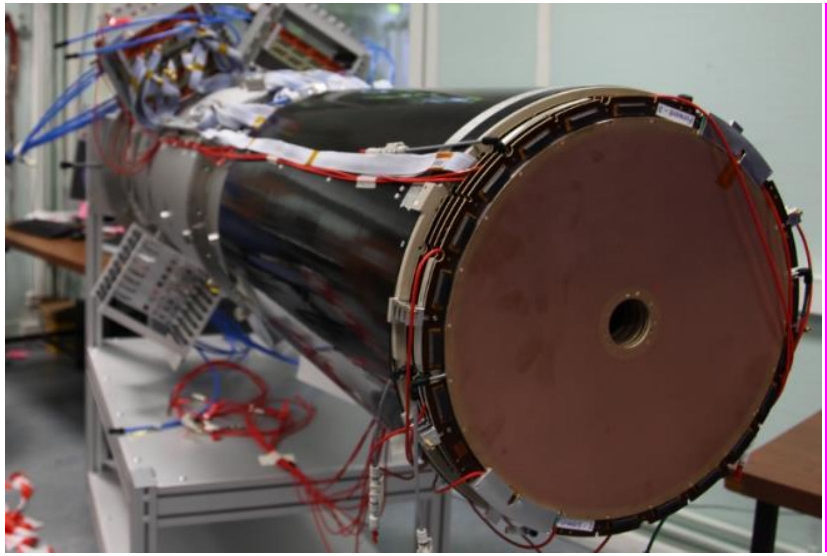
- Left and wire ambiguity issues
- Poor spatial resolution along the wire direction (~ 1cm)
- Need for U-V layers configuration limitation on the geometric acceptance of the detector (so lower geometric efficiency)

See talk on Drift Chambers and Straw Tube in this session
F. Grancagnolo

Central Tracking: Cylindrical MPGDs (µRWELL, Micromegas)



Cyl. Micromegas – MVT CLAS12 (Hall B, JLab)



M. Vandenbroucke, MPGD2015
Trieste, Italy

PROs

- Cost effective way to instrument large volume
- High tracking efficiency in high backgrounds and High rate capabilities
- Typical 2D space point resolution 100 µm achievable
- Works nice even in large B-field
- No issues with Ion Back Flow
- Good charge particle momentum reconstruction possible in µTPC (or mini-drift) operation mode
- Minimization of the material budget in the End Cap region
- Ideal as fast signal tracking layer the Si + TPC central tracking option
- Experiences in construction and operation with CLAS12 Micromegas vertex Tracker

CONs

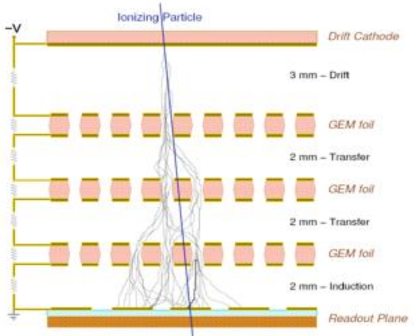
- Require several layers (6 layers) to achieve the required momentum resolution
- Overall material budget will be higher than other options
- Construction on large volume (2 m diameter) is challenging
- Not obvious to have good dE/dx capability

See talk on Cylindrical Micromegas in this session
F. Bossu

End Cap Tracking: MPGDs (GEMs, µRWELL, Micromegas)

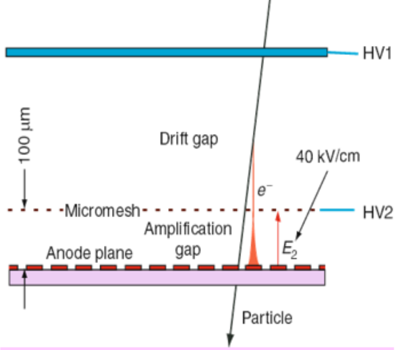
See eRD6 talk in this session
M. Posik

GEM: Gas Electron Multipliers



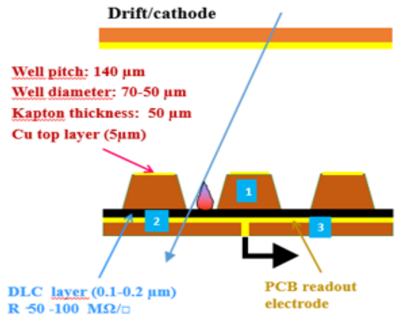
F. Sauli, Nucl. Instr. and Meth. A386 (1997) 531

Micromegas:
Micro Mesh Gaseous Structure



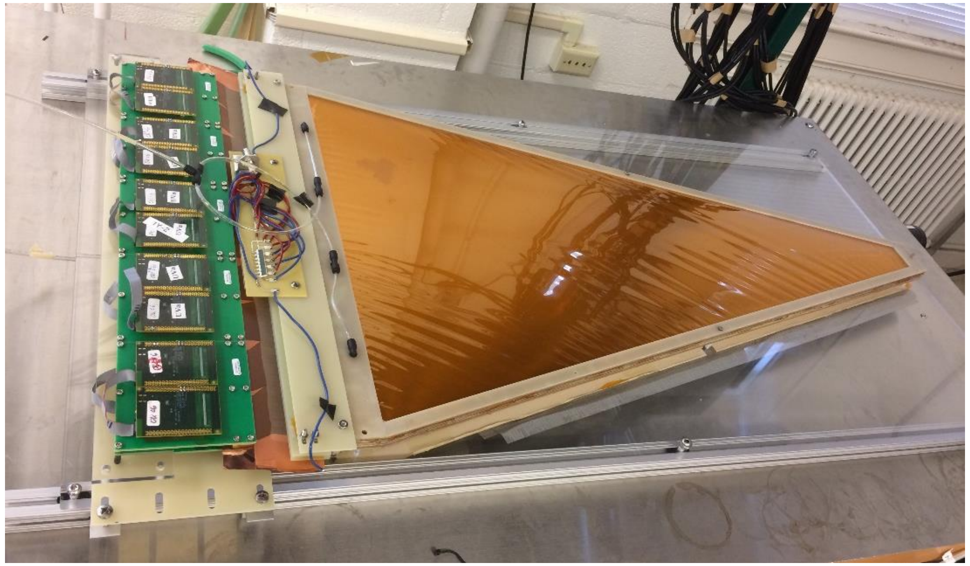
Giomataris, Nucl. Instr. and Meth. A419 (1998) 239

µRWELL:
Resistive micro-WELL Detector



G. Bencivenni et al., 2015_JINST_10_P02008

eRD6: Large & Low Mass End Cap GEM prototype



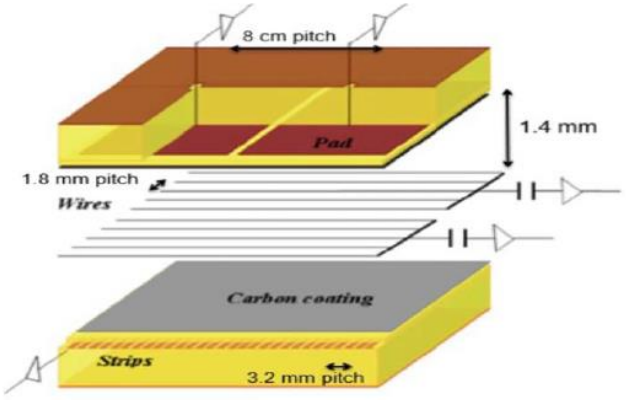
PROs

- Several MPGD technologies are mature enough
- Cost effective for large area coverage in the end cap region
- Excellent space point resolution (~ 50 to 100 µm)
- High rate capability (MHz /cm^2)
- Good timing performances (15 ns) fast signal detector
- Minimize material (X/X0 ~ 0.4%)
- Robustness of the technologies (spark free detector with resistive layer technologies)
- MPGD-based TRD to provide tracking and e/π PID in End Cap region
- Vast experiences in construction and utilization (LHC detector upgrade, JLab, BNL experiments ..) But Some R&D still needed for Resistive MPGDs technologies (uRWELL, Micromegas)

CONs

- Not so much really for EIC End Cap Trackers

End Cap Tracking: Small-Strip Thin Gap Chambers (sTGCs)



Denis Pudhza, INSTR20, Feb 25, 3030 Novosibirsk

PROs

- Cost effective for large area coverage in the end cap region
- Good space point resolution (~ 100 µm)
- High rate capability (100kHz /cm^2)
- Good timing performances (15 ns)
- Experiences in construction and utilization (ATLAS small Wheel Detector and STAR Forward Tracker.)

CONs

- Material budget higher than MPGDs
- Spatial resolution not as good as MPGDs

See talk on sTGCs in this session
D. Brandenburg

Summary

- Many baseline EIC detector designs involved various gaseous detectors technologies for tracking in the central as well as end cap region
- A few technologies are mature for EIC Detectors and would require only limited R&D
- Some of these technologies seems more natural options for some subdetectors
- There is still a need for small level of R&D to fully satisfy the EIC requirements
- The anticipated simulation work within Tracking WG will help select the best technologies for EIC