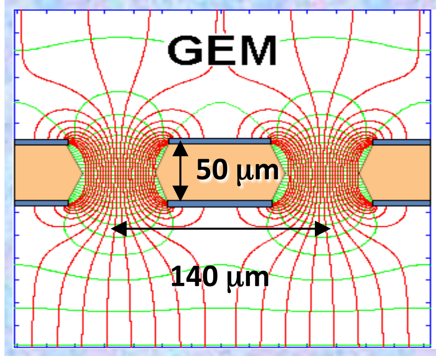
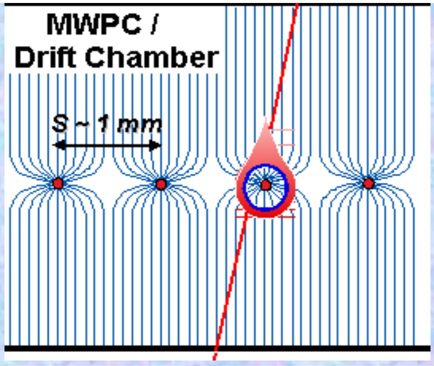
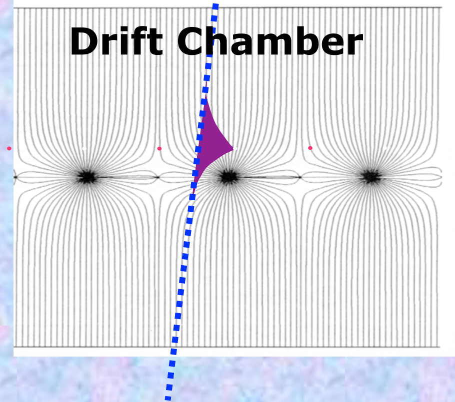
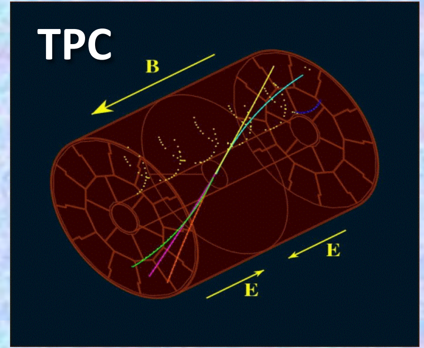
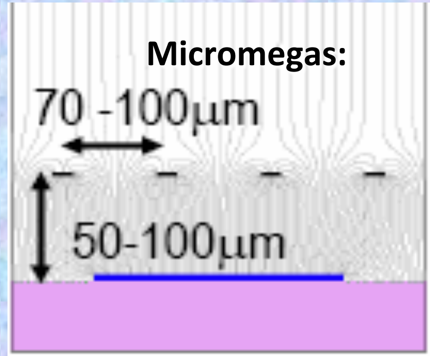




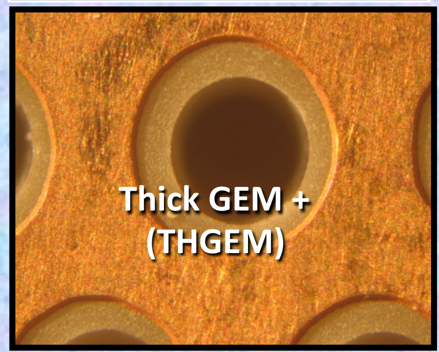


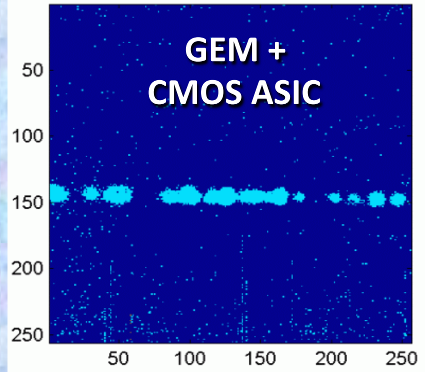




Gaseous Detectors: Poster Review

Maxim Titov, CEA Saclay, France





12th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba (Italy) May 20 - 26, 2012

Summary of Gas Detector Posters:

20 posters contributions to the session (a few more in other ones):

- **3 posters - Basic studies & Multiplication & Gas Mixture Properties**
- **2 posters – Low-mass tracking detectors for operation in vacuum**
- **1 posters – Transition Radiation Tracker in Space (AMS)**
- **3 posters – Resistive Drift Chambers (sLHC and R&D for LC)**
- **1 posters – Drift Tubes (sLHC)**
- **10 posters – Micro-Pattern Gas Detectors (sLHC, future projects)**

List of gas detector posters in other poster sessions (* not complete):

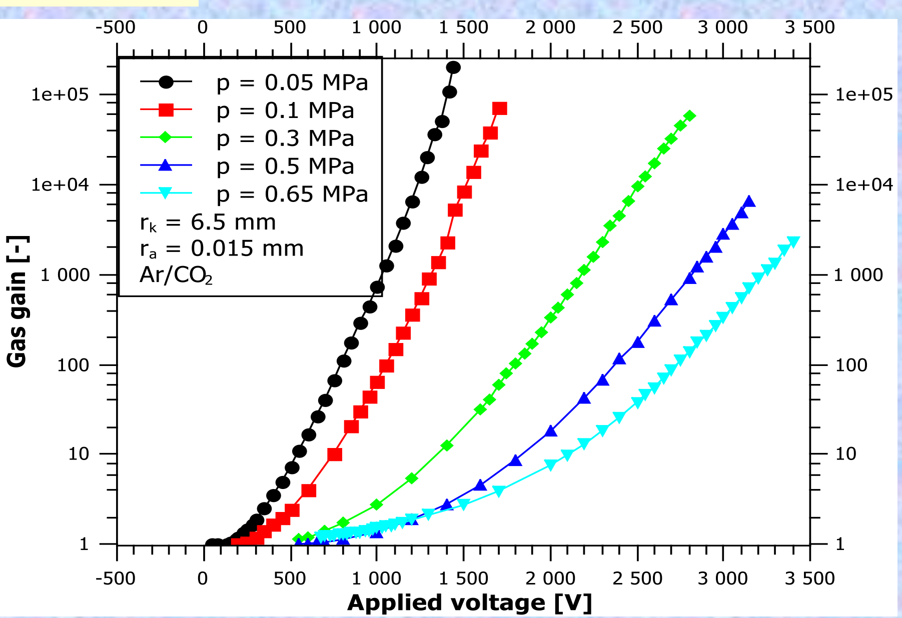
- **S. Biswas, "Development of Multi-Gap RPC for Medical Imaging (Applications)**
- **K. Pushkin, "R&D for the EXO-GAS experiment to search for neutrinoless double beta decay (Exp. Systems without Accelerators)**
- **S. Jowzaee, "Particle identification using the time-over-threshold measurements in straw tube detectors (PID and Photodetectors)**
- **Fulvio Tessarotto, Progress on THGEM-based photon detectors for COMPASS RICH-1 (PID and Photodetectors)**

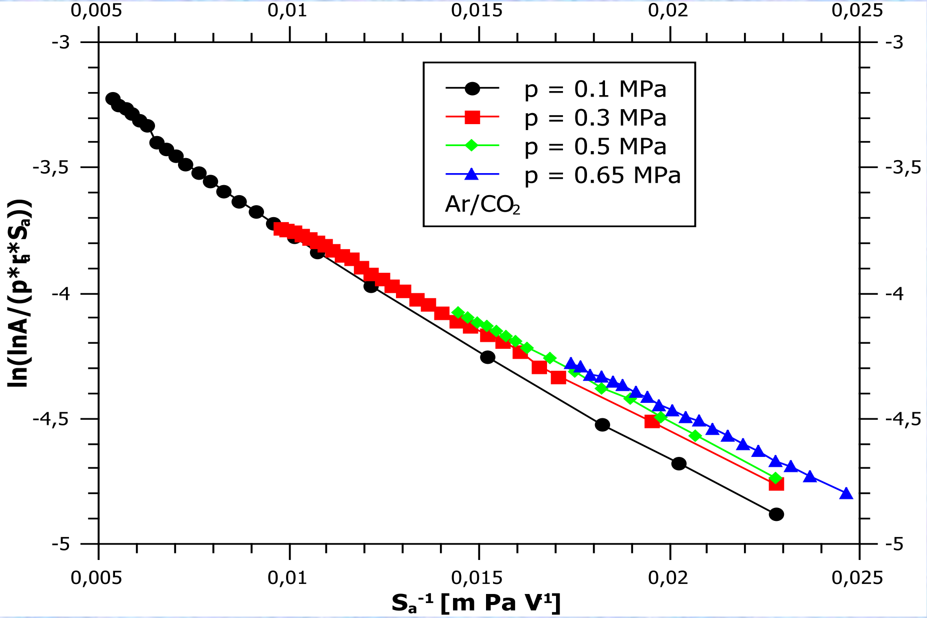
Gas Multiplication in High Pressure Proportional Counter

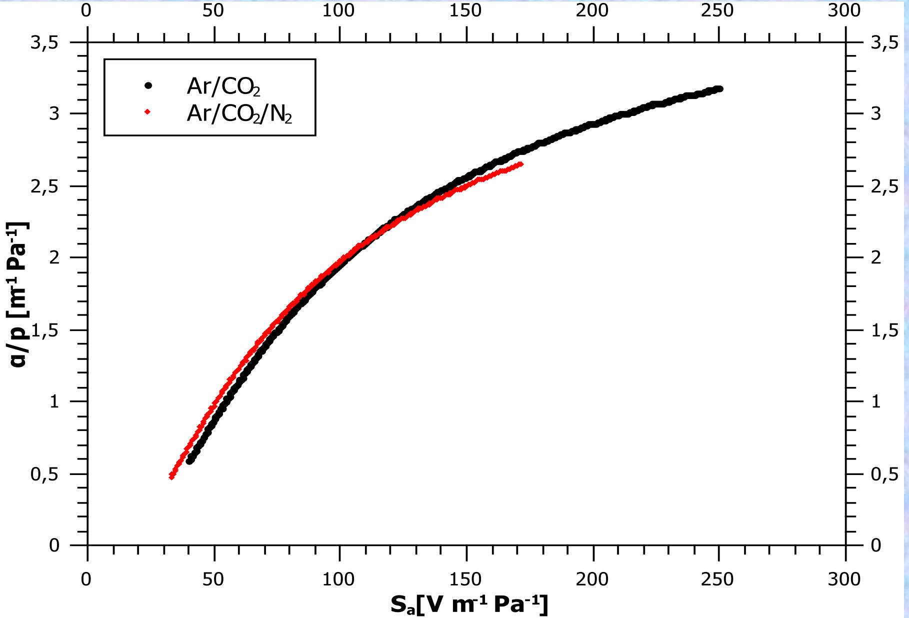
S. Koperny, T.Z. Kowalski

- **Study of gas gain parametrization (e.g. formula of Williams & Sara) in wide range of gas pressure and counter dimensions**

- **Determination of the first Townsend coefficient, which is the main parameter describing avalanche development, as a function of electrical field**







Secondary Avalanches in Gas Mixtures

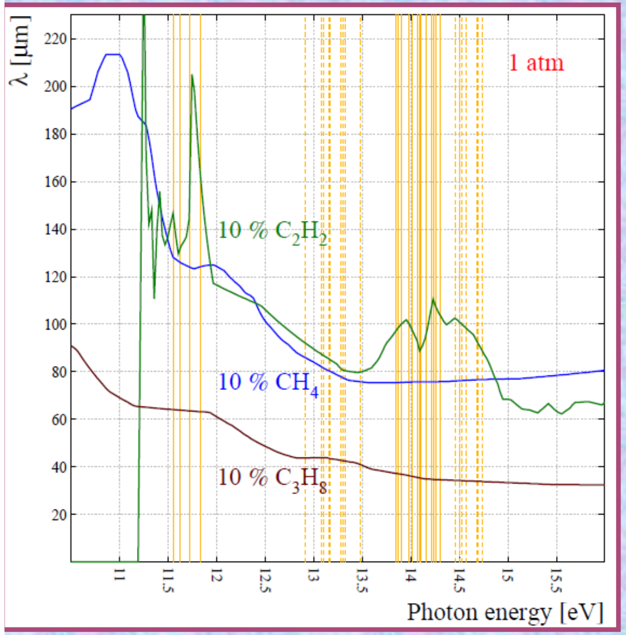
Ö. ŞAHİN, İ. TAPAN and R. VEENHOF

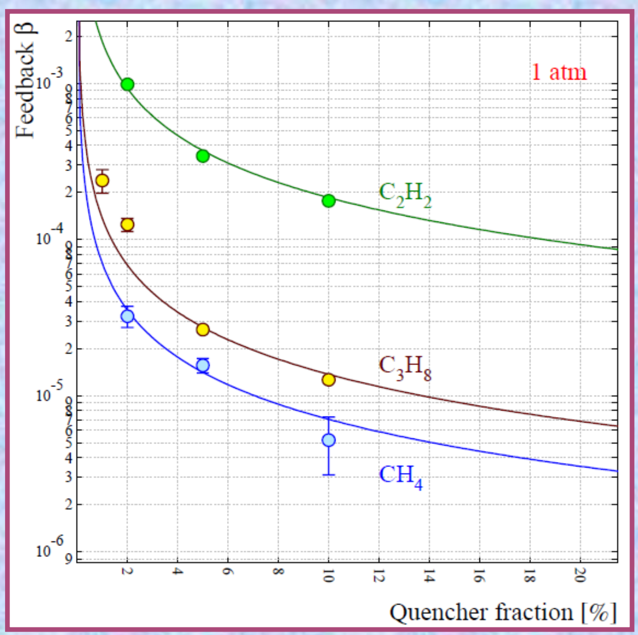
Photon feedback → over-exponential increase of gas gain because of secondary avalanches

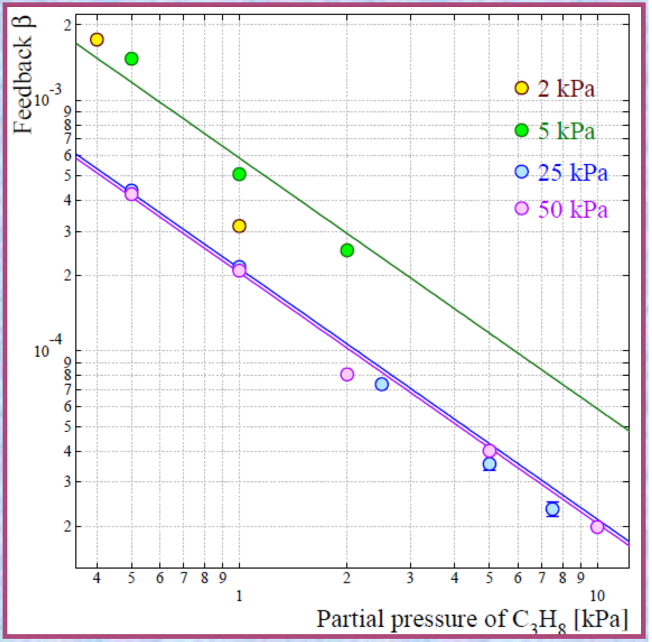
$$G_T = G + \beta G^2 + \beta^2 G^3 + \ldots = \frac{G}{1 - \beta G}$$

Derive photon feedback from published gain measurements
→ fit these parameters in a model (function of the quencher concentration and the pressure)

→Relation between feedback β (number of secondary avalanches) and quencher fraction is not exponential



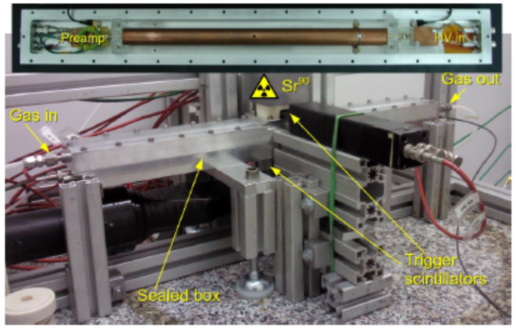


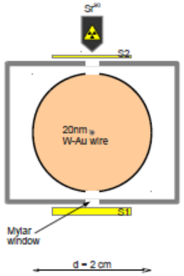


Ultra-Light Gas Mixtures for Drift Chambers

Michele Cascella et al

Studies of drift velocity, diffusion, ionization, gas gain below the atmospheric pressure, down to 100 mbar

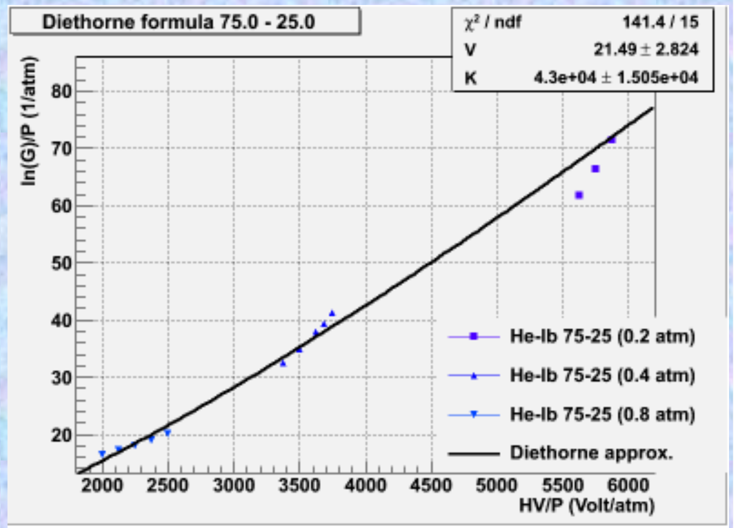




The test tube is hosted in a vacuum proof aluminum box with two thin mylar widows to allow beta electrons from a Sr90 source and X-rays in.

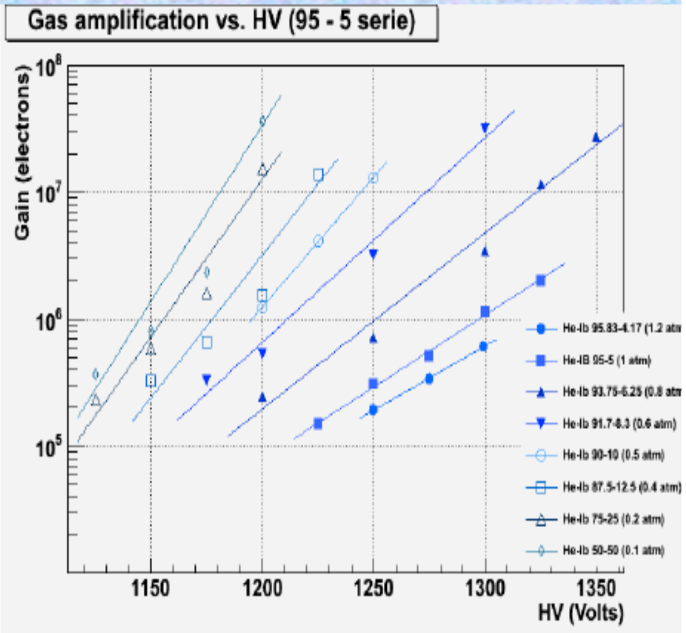
Interesting for experiments like Mu2e at Fermilab, where the tracking detector is immersed in vacuum

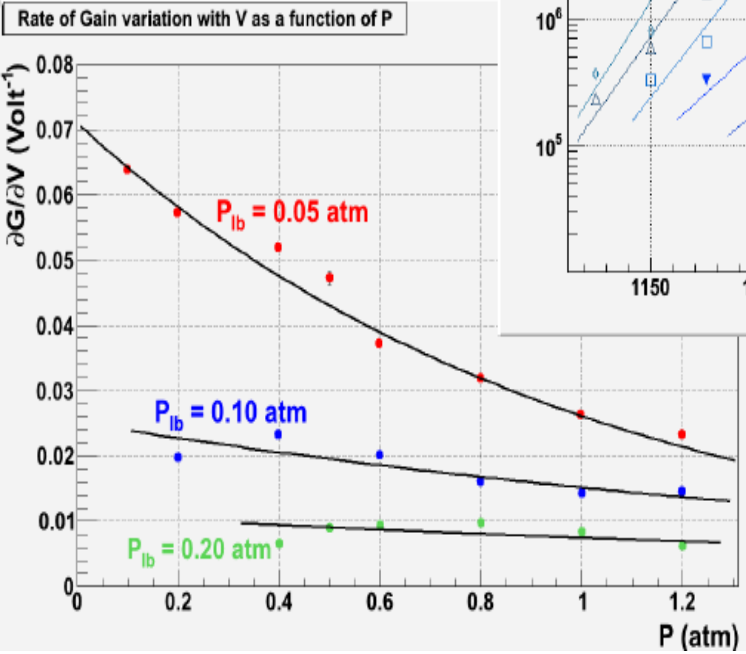
Study of gas gain parametrization:



Gain

(right) Gain variation vs V for different P at P_{Ib}= 0.05 atm





(left) Rate of gain variation with V as a function of P for different He/Ib mixtures.

Ultra-Low Mass Drift Chambers

Giovanni Francesco Tassielli et al

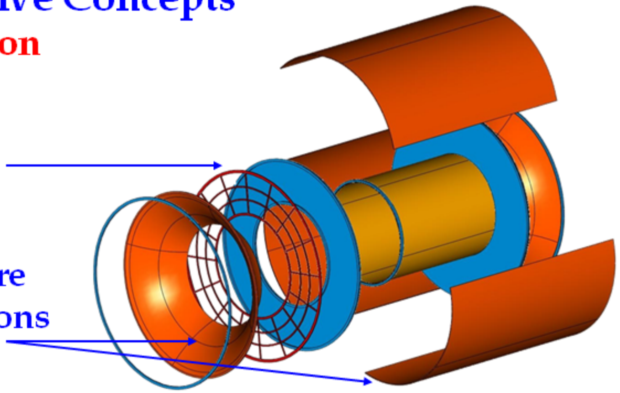
Techniques for assembling low mass drfit chamber

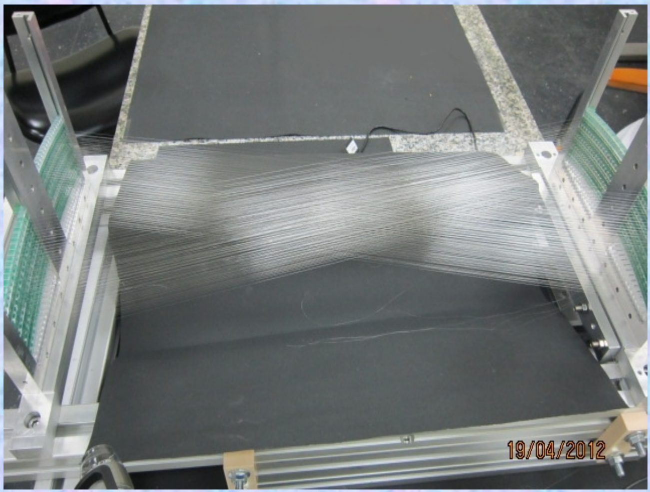
The Mu2e tracker is immersed in vacuum and its gas envelope must withstand a differential pressure of 1 bar, and to keep at minimum both multiple scattering and energy loss straggling for conversion electrons →
optimize the shape of the gas envelope and to minimize the amount of material

Innovative Concepts

separate the wire supporting function from gas tightness:

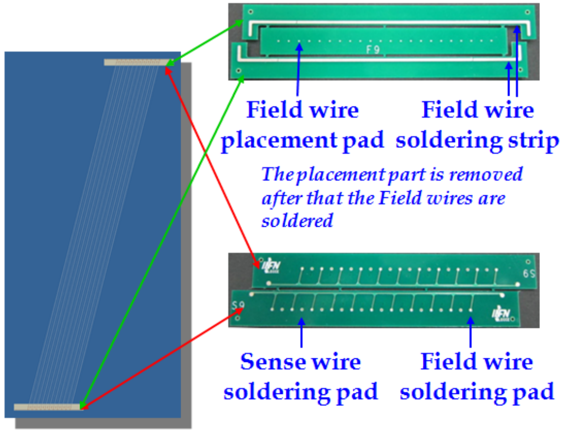
- wire holding structure must be undeformable, but not necessarily gas tight;
- gas envelope must withstand pressure but is free to sustain large deformations




19/04/2012

wire anchoring system without feed-through:

- lay, in a single operation, a large number of parallel wires, at any angle, within a layer with a well defined pitch, by gluing and soldering the wires on thin FR4 (G10) supports. Two types of them are needed, one wired with only field wires and a second one wired with both sense and field wires;



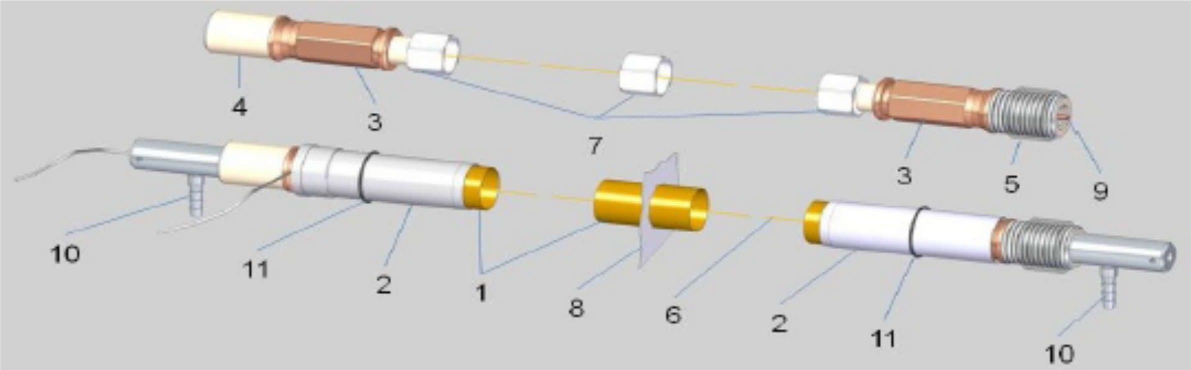
The placement part is removed after that the Field wires are soldered

The Thin Wall Drift Tube Chamber Operating in Vacuum

Levan Glonti et al

Proposed as a candidate for the NA62 tracker

Design drift tube operating in vacuum and to develop technologies for tubes independent assembly and mounting in the chamber → rigid vacuum-tight structure with minimum mechanical distortion of the tube geometry

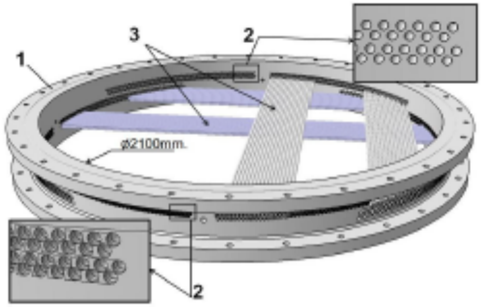


Completely assembled drift tube with end plugs: Drift tube, 2. sleeve, 3. hexagonal bushes, 4. insulating inserts, 5. nut, 6. anode wire, 7. hexagonal spacers, 8. film strip support, 9. copper pin, 10. gas connections, 11. O-rings

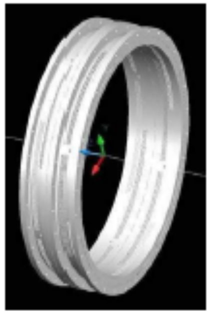
Tubes are made of flexible mylar film (wall thickness 36 μm, diameter 9.80 mm, length 2160 mm)

Independent assembly of drift tubes:

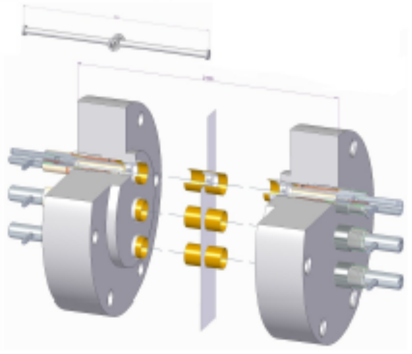
"Self-centering" spacers and bushes are used for precise setting of the anode wires and tubes.



The two-coordinate round chamber design.
(1) Chamber, (2) holes for end plugs, (3) drift



Round for 4ˣ coordinates chamber



3D view of the chamber prototype

The prototype and tubes working characteristics

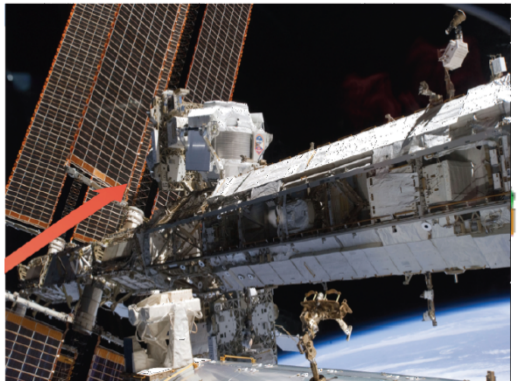
Operation of the AMS-02 TRD in Space

Francesca Spada

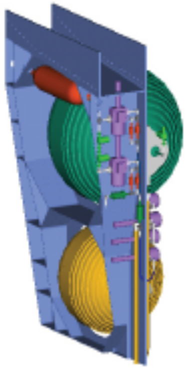
GASEOUS DETECTOR at the International SPACE Station

The AMS-02 detector was installed on May 2011 on board of the International Space Station and has since collected billions of Cosmic Ray events. AMS will measure with high precision Cosmic Ray spectra up to the TeV energy scale.
The Tranisiton Radiation Detector, filled with a Xe/CO_2 mixture, is used to reach the sensitivity to positron identification needed for the detection of a neutralino dark matter candidate.

Radiatior material: 22 mm fleece of polypropilene fibers
Detecting material: 5,248 Ø 6 mm straw tubes filled with a [80:20] Xe/CO_2 mixture
Gas supply: > 20 years

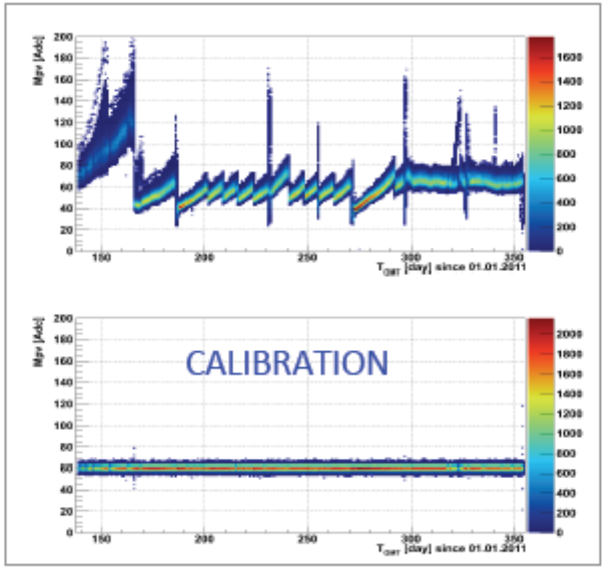


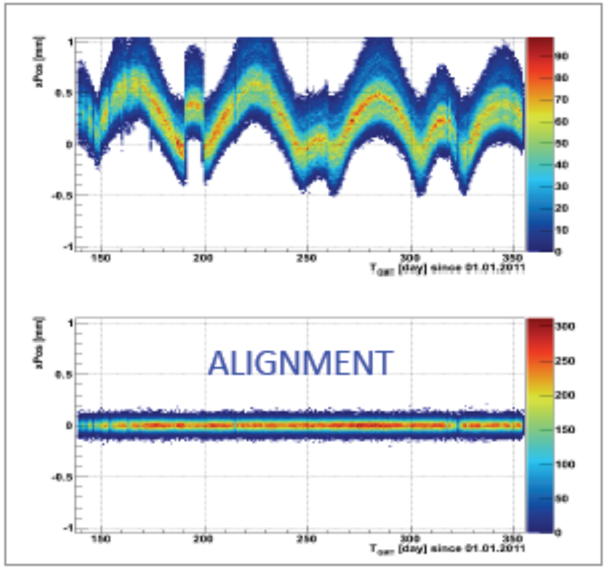
TRD: 5,248 Pulse Heights
Precision TRD Gas System:
482 Temperature Sensors,
8 Pressure Sensors
Onboard processing:
30 computers



Xe storage [48 kg]

CO_2 storage [5 kg]





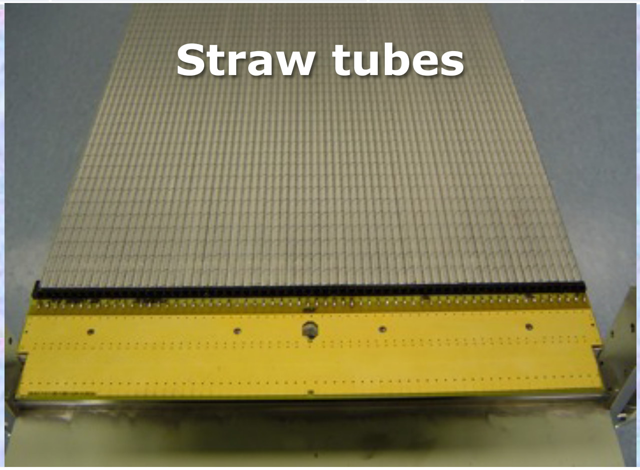
Due to temperatue, pressure, gas composition and HV changes, the TRD detector response is changing too.
Due to temperature variations, the TRD is moving on top of the inner tracker by up to 1 mm.

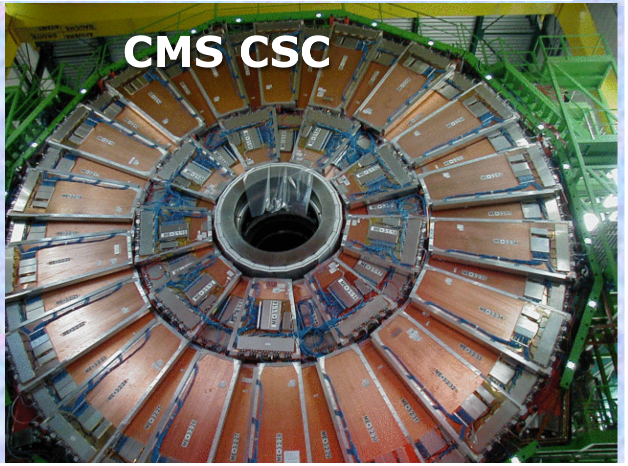
We use CR protons to equalize the TRD response to homogeneity within 3%, and align each straw module with an accuracy of 0.04 mm.

Gaseous Detectors in LHC Experiments

	Vertex	Inner Tracker	PID/ photo-det.	EM CALO	HAD CALO	MUON Track	MUON Trigger
ATLAS	-	TRD (straws)	-	-	-	MDT (drift tubes), CSC	RPC, TGC (thin gap chambers)
CMS ----- **TOTEM**	-	-	-	-	-	Drift tubes, CSC ----- GEM	RPC, CSC ----- GEM
LHCb	-	Straw Tubes	-	-	-	MWPC	MWPC, GEM
ALICE	-	TPC (MWPC)	TOF(MRPC), PMD, HPMID (RICH-pad chamber), TRD (MWPC)	-	-	Muon pad chambers	RPC


ALICE TPC

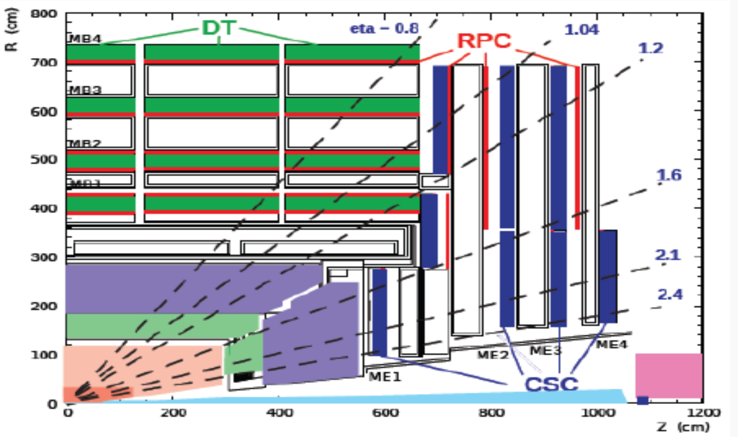

Straw tubes


CMS CSC

Operations and Performance of the CMS RPC Muon System at LHC

Anna Cimmino et al.

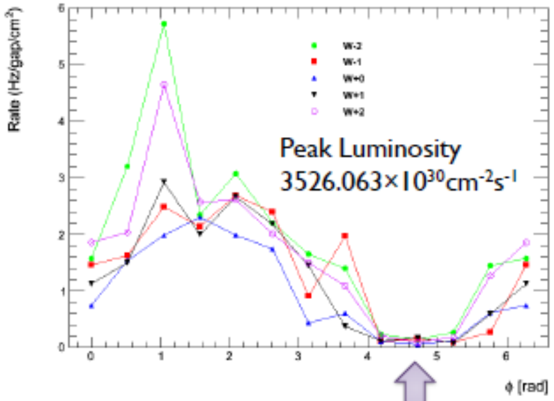
Muon reconstruction in CMS detector



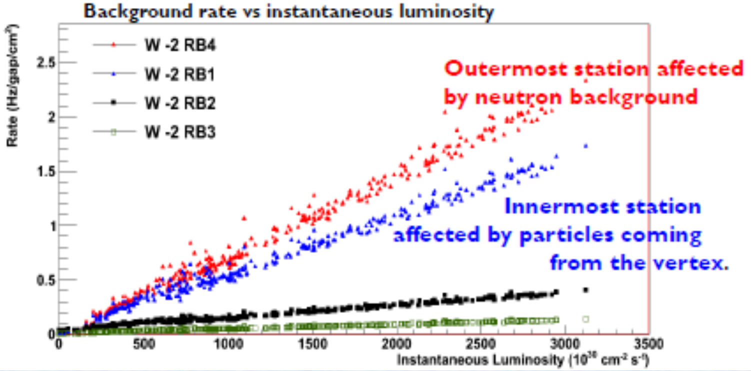
A schematic view of the CMS detector

Radiation Background

Radiation background levels are an important parameter for the overall performance of the system. High background levels could affect negatively RPC trigger performance Radiation background is studied as function of R, Z and ϕ as well as function of increasing luminosity. Results are in good qualitative agreement with the other two muon subsystems (DT and CSC).



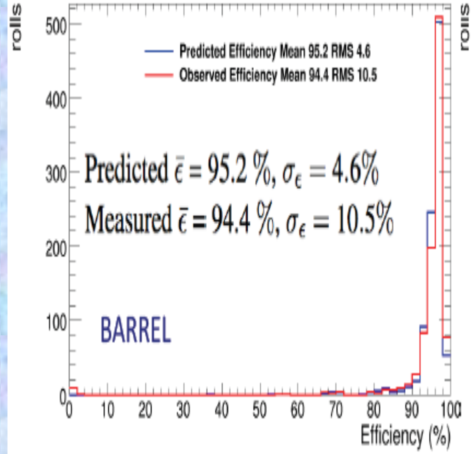
Radiation background, for a given run, as function of ϕ, for all Barrel wheels (W-2 - W+2.) Bottom sectors are less affected by neutron background due to the cavern floor shielding.

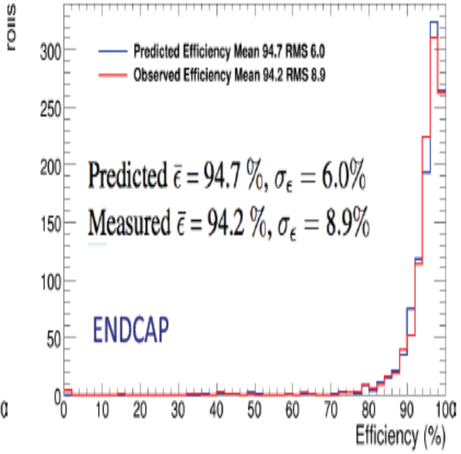


Outermost station affected by neutron background

Innermost station affected by particles coming from the vertex.

Performance using 2011 data:





Conclusions: Overall Performance in 2011

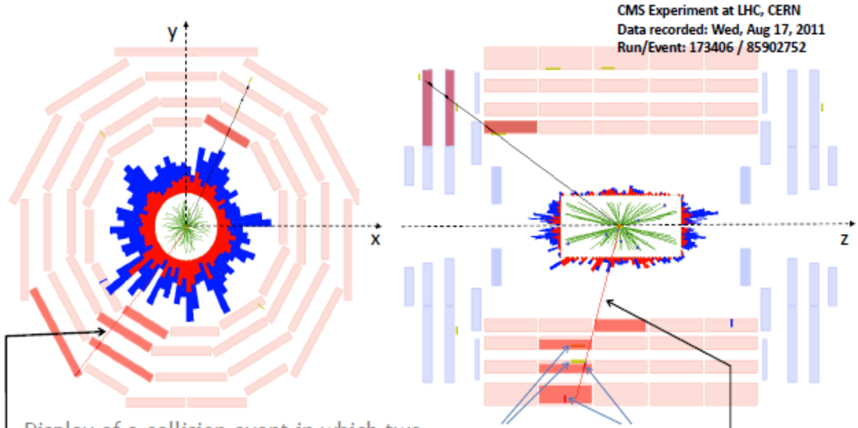
Data loss for RPC	19 pb^{-1} – 0.37%
Overall operating channels	98.4%
Average efficiency	95%
Average cluster size	< 2
Average rate ($3 \cdot 10^{33}$ cm^{-2} s^{-1})	1.3 Hz/cm^2
Average intrinsic noise (no-beam)	~ 0.1 Hz/cm^2
Average current (no-beam)	~ 1 μA
Average current (with beam)	~ 1.5 μA
Temperature	< 21.5 °C

RPC Hits Contribution to CMS Muon Reconstruction at LHC

Hyunkwan Seo et al.

RPC is used as dedicated trigger detector in both barrel and endcap regions of the CMS experiment together with **DT** and **CSC**. This redundancy of the muon system in CMS is used also to improve the muon identification including the RPC hits in the muon identification and reconstruction algorithms.

Example of muon recovered by RPCs

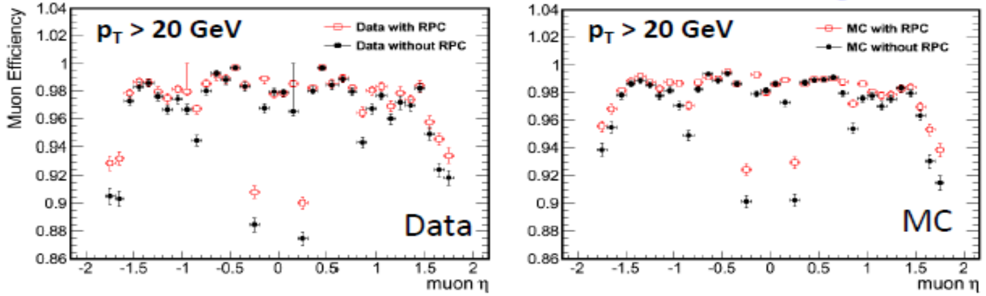


Display of a collision event in which two muons were reconstructed

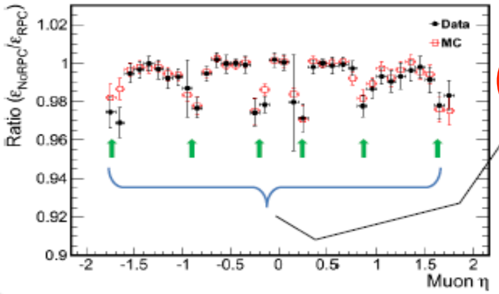
The red track have two DT segments and two RPC hits. This track, however, will fail in reconstruction when the RPC hits are removed in track fitting because one of the two DT segments have no Z coordinate.

Muon reconstruction efficiency vs. η

For Medium-Tight Muon



Ratio = $\varepsilon_{NoRPC} / \varepsilon_{RPC}$ (for both MC and data)



3-4 % of muons are lost at the cracks between adjacent wheels if **RPC** hits are not used in muon identification and reconstruction

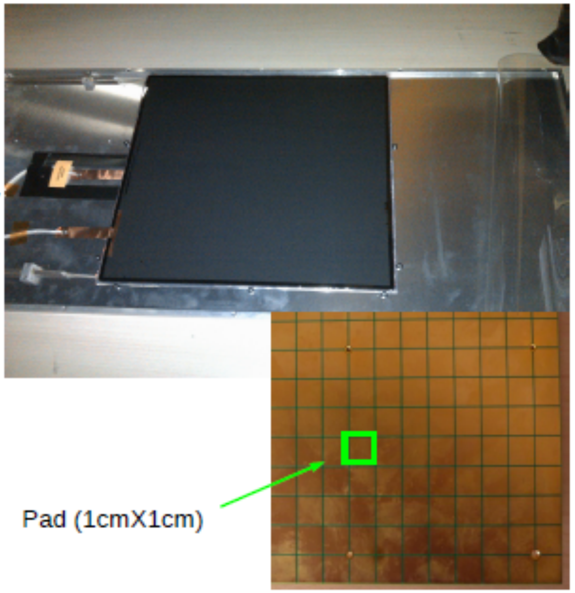
Similar studies are being performed for J/Ψ candidates to investigate RPC contribution to low pT muons

High Rate Glass RPC

Yacine Haddad et al.

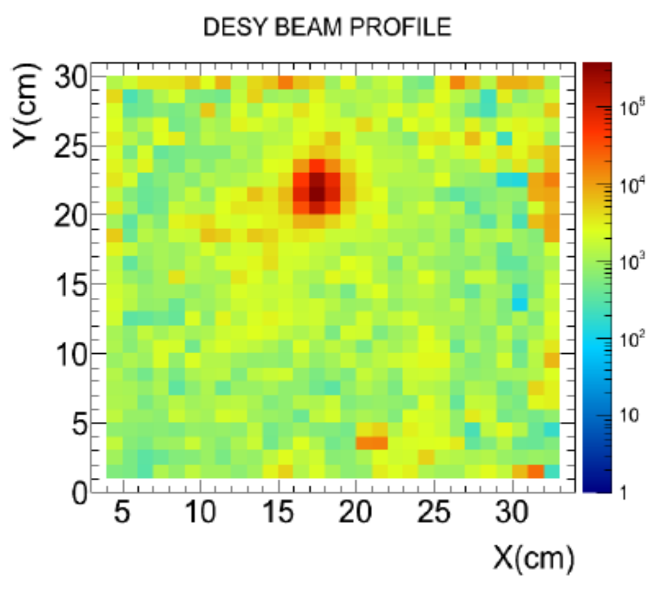
Semi-conductive Glass

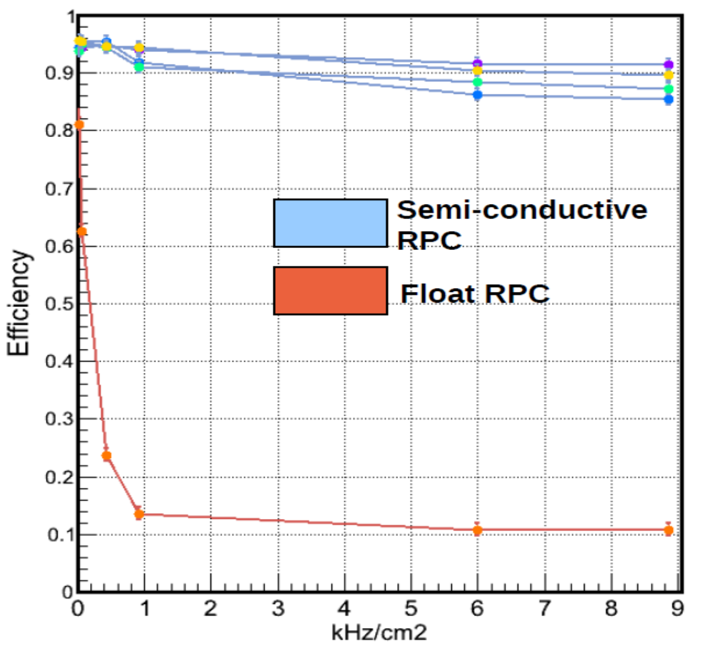
- Resistive material coatings:
  Colloidal graphite : ≈ 1 MΩ/□
- Glass plates: doped glass, low resistivity: 10^{10} Ω.cm to be compared with the resistivity of float glass currently used : 10^{13} Ω.cm
- Plates thickness:
  Cathode 1.1 mm/ Anode 0.7 mm
- Gas distribution: Capillary tubes drive gas into channeled inlet.
- Spacers: 1.2 mm ceramic balls for spacers.
  GRPC size : 30X30 cm2
- GRPC thickness : 6 mm
- Spatial resolution: 4 mm

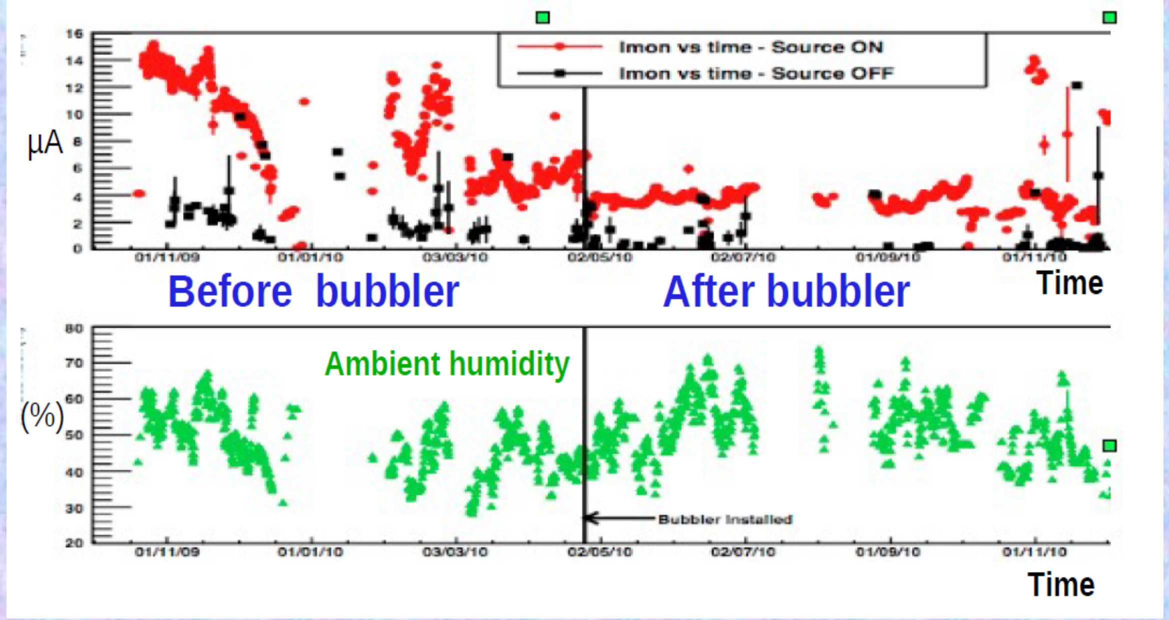


Pad (1cmX1cm)

Studies at 6 GeV electrons:







Production and Test of a Full Prototype Drift-Tube Chamber for the Upgrade of the ATLAS Muon Spectrometer at High LHC Luminosities

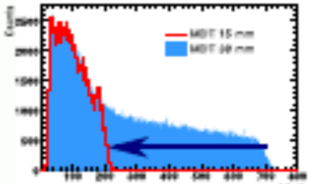
Hubert Kroha et al.

How to improve the rate capability of drift tubes?

Reduce the tube diameter!

ATLAS MDT:
⌀ 30 mm

sMDT:
⌀ 15 mm

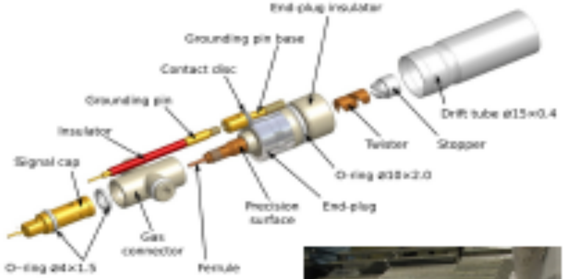


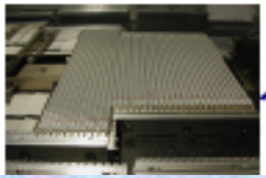
much shorter drift time

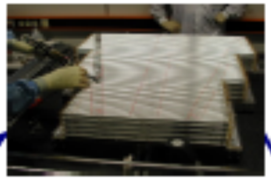
Advantages of smaller drift tubes: The highlights

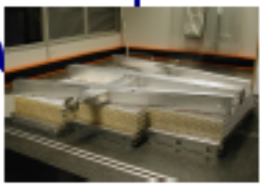
- 7.8× lower occupancy
- 8/16× less space charge for gammas and charged hadrons.
- Higher granularity: Twice the number of tube layers possible
- Easy to integrate into the existing systems.

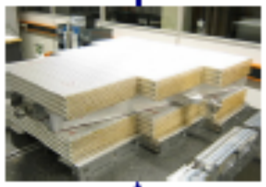
Design and Assembly





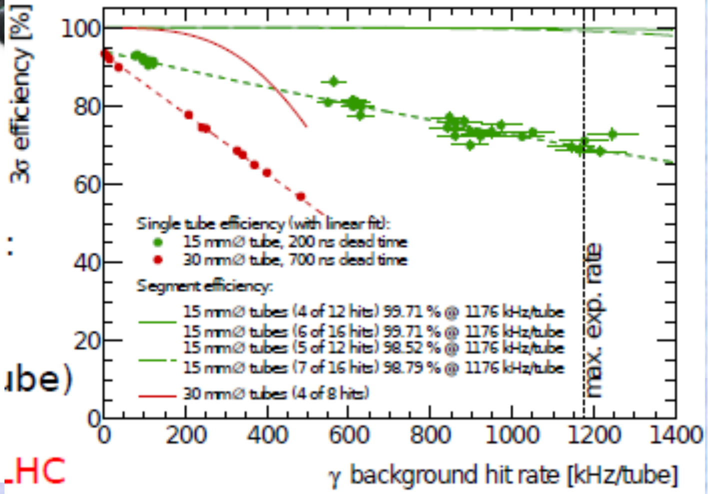




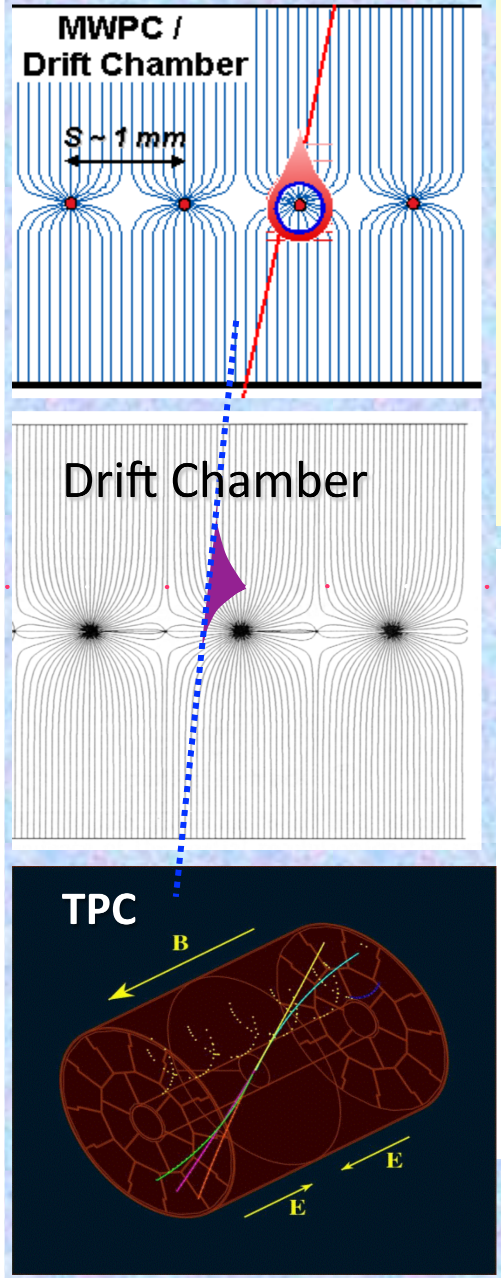


Method allows positioning of wires with 20 µm precision

Results: Efficiency



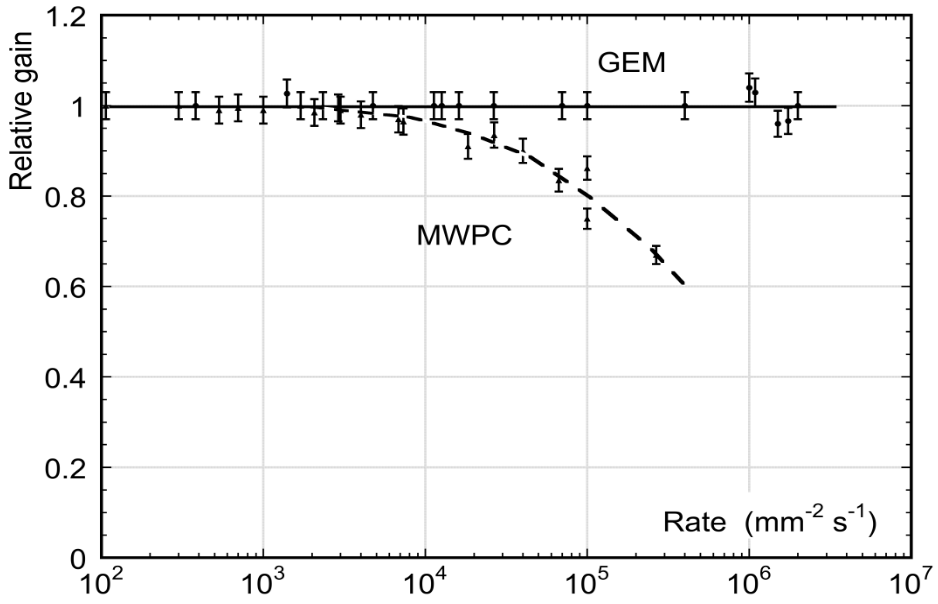
Advanced Concepts: Detectors @ High Luminosity

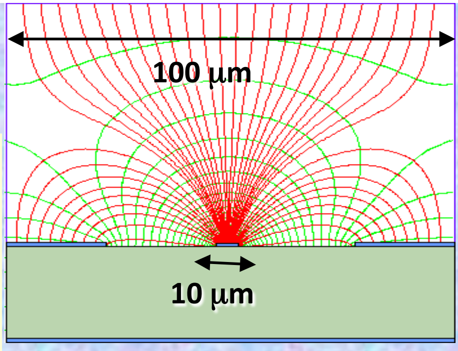


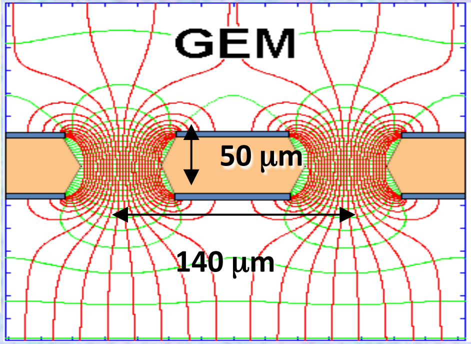
Higher Rate, enormous occupancy:
1D easily saturated → 2D → 3D

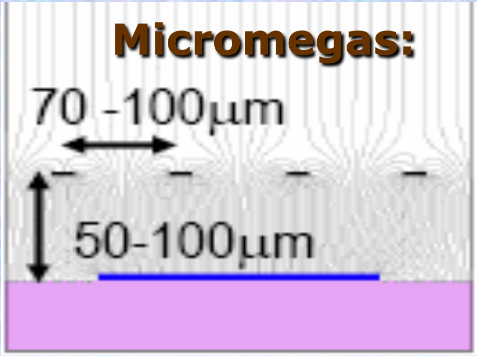
- **Silicon detectors:**
  Strips →Pixels (2D)→ 3D-Si det.
  & 3D electronics integration

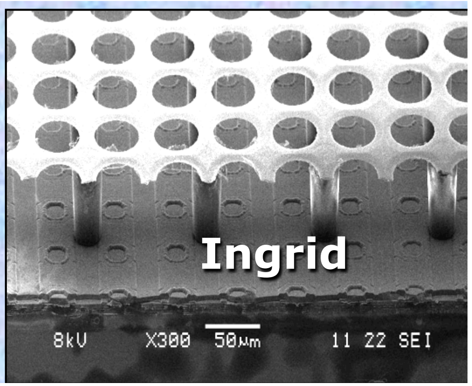
- **Gaseous detectors**
  Wire Chamber → Wireless MPGD (2D)
  → InGrid/Timepix (3D)







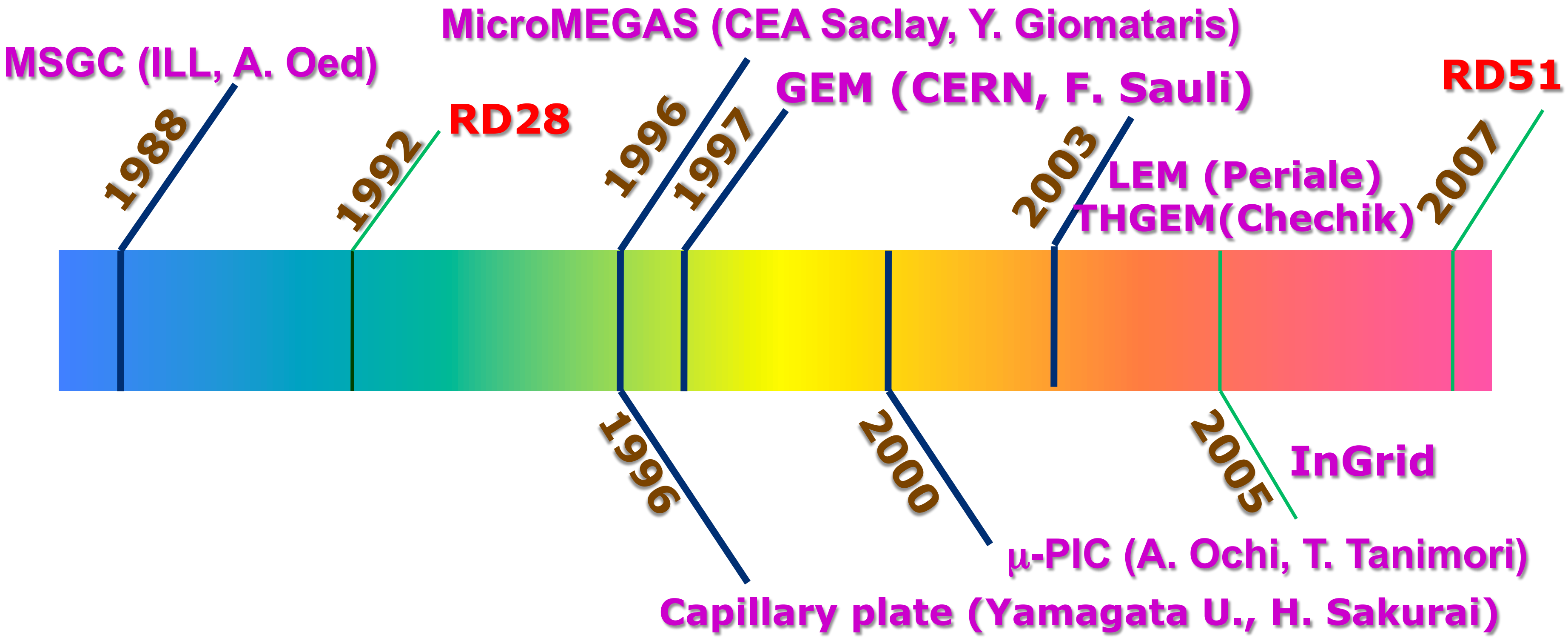




Advances in Micro-electronics & Etching Technology → Micro pattern Gaseous

MPGD Developments: Historical Roadmap*

(*Many more micro-pattern structures were developed; only widely spread technologies are shown)



1988
MSGC (ILL, A. Oed)

1992
RD28

1996
MicroMEGAS (CEA Saclay, Y. Giomataris)

1996
Capillary plate (Yamagata U., H. Sakurai)

1997
GEM (CERN, F. Sauli)

2000
μ-PIC (A. Ochi, T. Tanimori)

2003
LEM (Periale)
THGEM(Chechik)

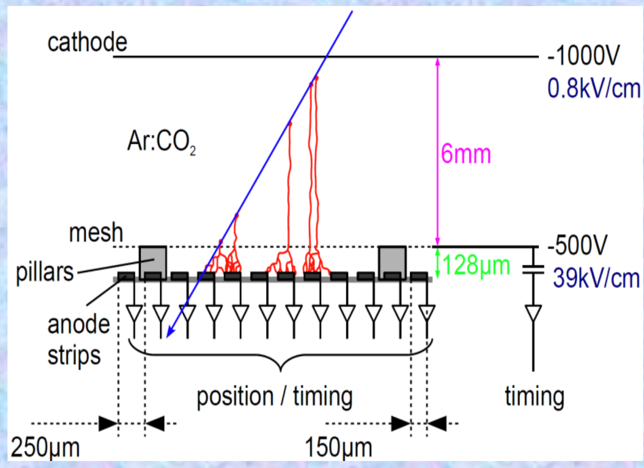
2005
InGrid

2007
RD51

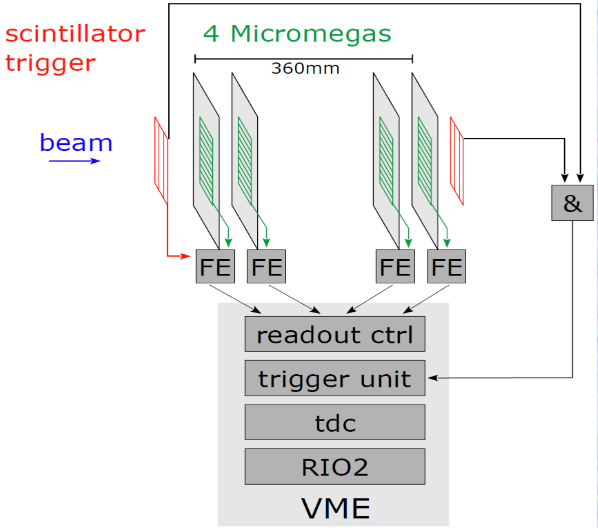
From A.Ochi ADA2012@Kolkata (updated)

High-Resolution Micromegas Telescope for Pion- and Muon- Tracking

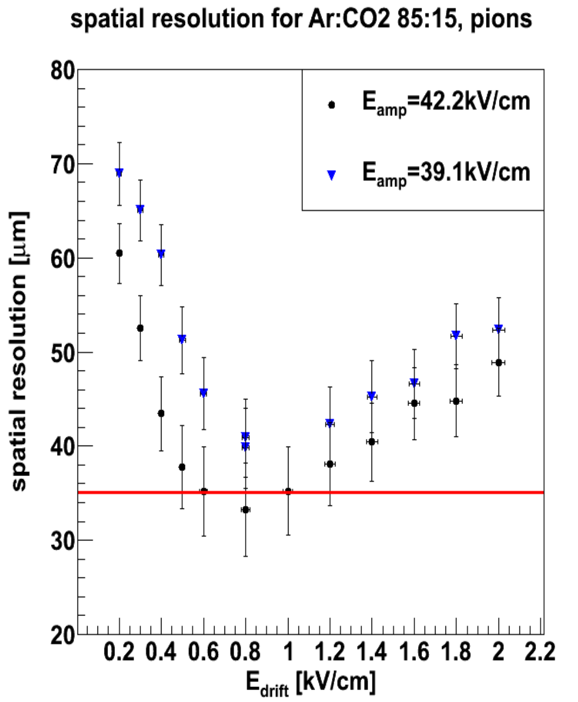
Jonathan Bortfeldt et al.

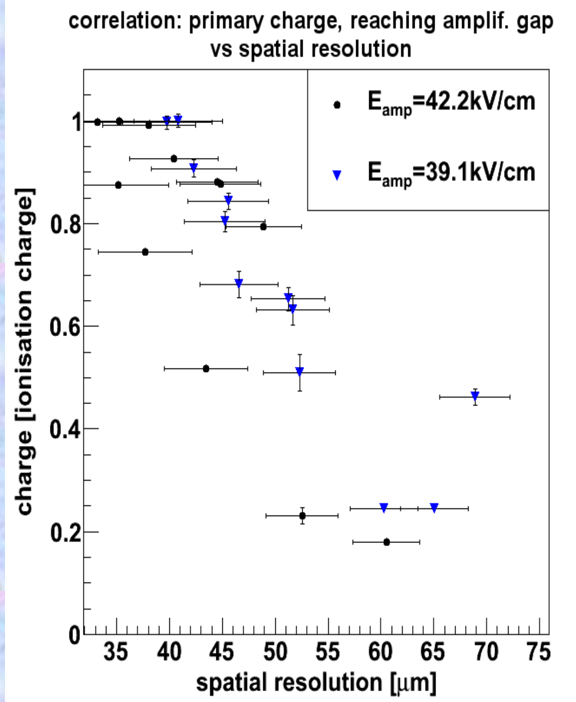


- **Goal: track reference system with < 20µm resolution for tests with high-energy pions and muons**
- **4 Micromegas Detectors (9 cm x 10cm area, 250µm pitch), Gassiplex electronics**



- detector efficiency: 98.5%
- discharge probability: 1.5 x 10^{-5}
- best value of single detector spatial resolution: 35µm → track resolution <20µm with 2 x 2 detectors


spatial resolution for Ar:CO2 85:15, pions


correlation: primary charge, reaching amplif. gap vs spatial resolution

Advancing MPGD Technologies for Energy Frontier (sLHC, LC)

Experiments are challenging, demanding aggressive focused detector R&D*

	Vertex	Inner Tracker	PID/ photo-det.	EM CALO	HAD CALO	MUON Track	MUON Trigger
ATLAS	**GOSSIP**	**GOSSIP**				**Micromegas**	**Micromegas**
CMS						**GEM**	**GEM**
ALICE		**TPC (GEM)**	**VHPMID (CsI-THGEM)**				
Linear Collider		**TPC (MM,GEM, InGrid)**			**DHCAL (MM,GEM)**		

(*ongoing R&D projects using MPGD detectors in the framework of HEP collaborations)

Development of Large-Area Resistive-Strip Micromegas Chambers for the ATLAS Muon System Upgrade

Marcin Byszewski et al.

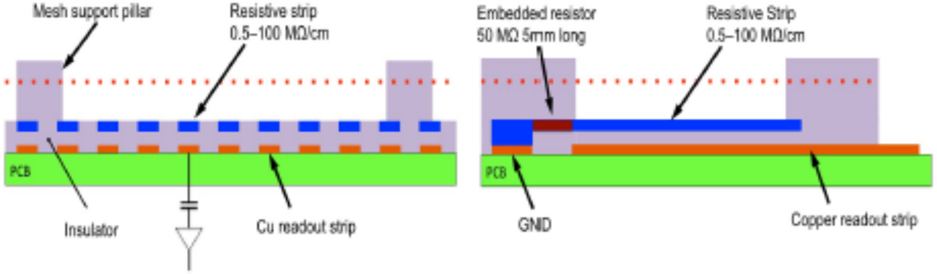
MAJOR BREAKTHROUGH SINCE 2009 ELBA CONFERENCE

In 2018 it is foreseen to replace the existing small wheels to cope with the expected high luminosity. Resistive-strip micromegas have been chosen as precision chambers as the baseline for the upgrade of the Small Wheels.

Micromegas in the Small Wheels

- Replace the muon chambers of the Small Wheels with 128 micromegas chambers of 0.5 m^2 to 2.5 m^2 area, each
- Micromegas provide precision, 2nd coordinate measurement and trigger functionality in a single device
- Each chamber comprises eight active layers, arranged in two multilayers: a total of about 1200 m^2 of detection layers; 2M readout channels (30k trigger channels)

Resistive chamber design



R&D Reached milestones

- Large area chambers
- 2D readout (x-y, x-u-v)
- Inverted HV scheme (mesh on GND)

Short-term plans

- Summer 2012 1x1 m^2 chamber
- End of 2012 1x2 m^2 chamber
- Readout integration to ATLAS DAQ

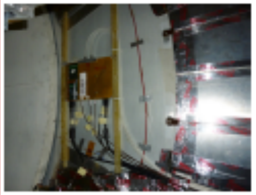
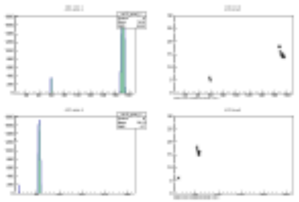
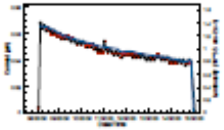
Performance

- Spatial resolution ~30µm (Ar:CO_2 93:7)
- Single plane efficiency 98%
- Gains above 10^4
- Clean signals up to >1 MHz/cm^2, with some loss of gain
- Stable response over duration of neutron irradiation equivalent to 20 years LHC (5×10^{34} cm^{-2}s^{-1})

Prototypes in ATLAS

Installed during winter shutdown 2011

- Chamber 9x4.5cm^2 at MBTS z=3.5m r=1
- 4 Chambers on SW CSC s.9


Advancing MPGD Technologies for Nuclear and Hadron Physics

… MPGD are used/proposed for high-rate tracking and photodetectors

… MANY POSTERS are presented AT ELBA 2012 …

- **COMPASS Upgrade:**
  - Micromegas and GEM detectors for high-rate tracking
  - Photon Detectors Using THGEM technology for RICH 1

- **KLOE2 Upgrade:**
  - Large-area cylindrical GEMs for Inner Tracker

- **RHIC Upgrades:**
  - GEM Tracking for STAR Experiment
  - GEM Tracking for PHENIX Experiment(+ drift micro-TPC); development of Ring Imaging version of HBD for particle ID

- **Future JLAB Projects:**
  - Thin-Curved Micromegas for JLAB/CLAS12
  - GEM Tracker for JLAB/Hall A High Luminosity (SBS) experiments

- **Future FAIR Facility:**
  - GEM Tracker and GEM TPC for the PANDA Experiment
  - GEM/Micromegas tracking in CBM Muon Chamber (MUCH)

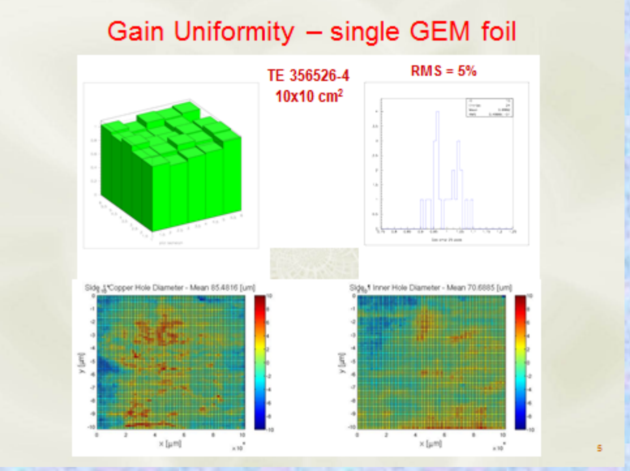
- **Future Electron - Ion Collider Facility:**
  - Tracking and particle ID detectors based on MPGD-technology

Development of 2d and 3d coordinate single plane readout for GEM

Richard Majka, Nikolai Smirnov

Commercial manufacture

Tech-Etch (USA)



Gain Uniformity – single GEM foil

TE 356526-4
10x10 cm^2

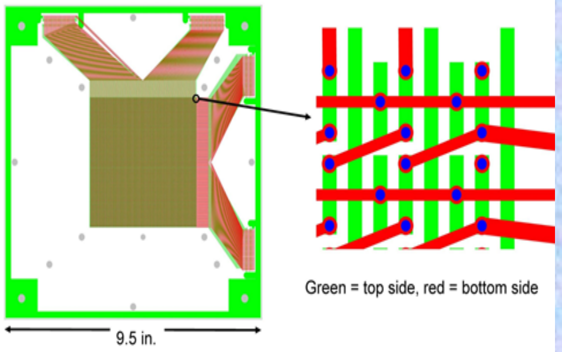
RMS = 5%

New approach for GEM readout:

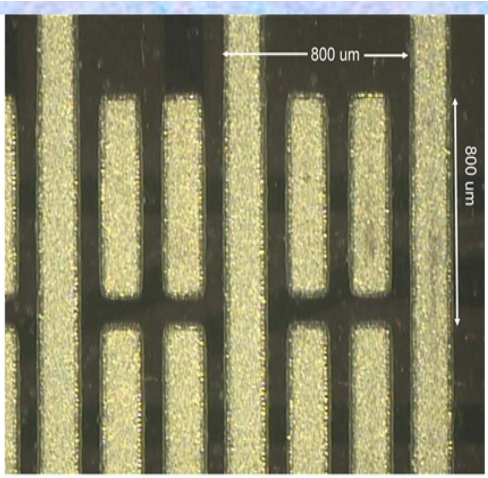
-- using the same Kapton foils as for GEM production → low mass

-- one side etching to prepare strip – pad(s) pattern

-- using other side for pads via-connection → “one side” technology, low cost



Green = top side, red = bottom side



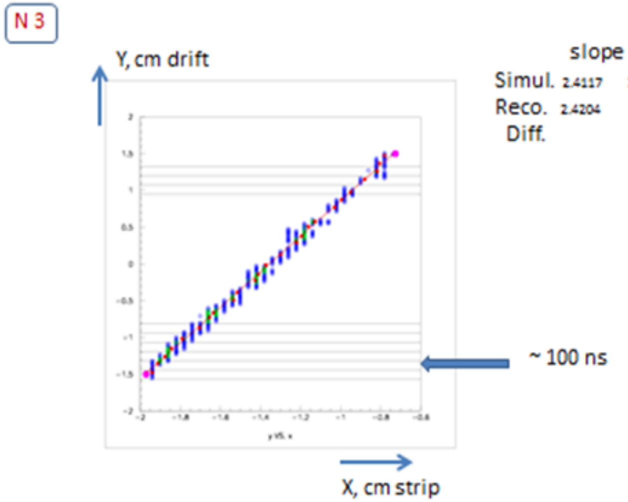
Finished board – detail in circled area above

GEMs for PHENIX and STAR Upgrade and detector R&D for an Electron-Ion Collider:

+ Developing short drift TPC with GEM readout to improve tracking resolution at larger angles

+ Developing a Ring Imaging version of the HBD using dual radiators for particle ID in the forward direction

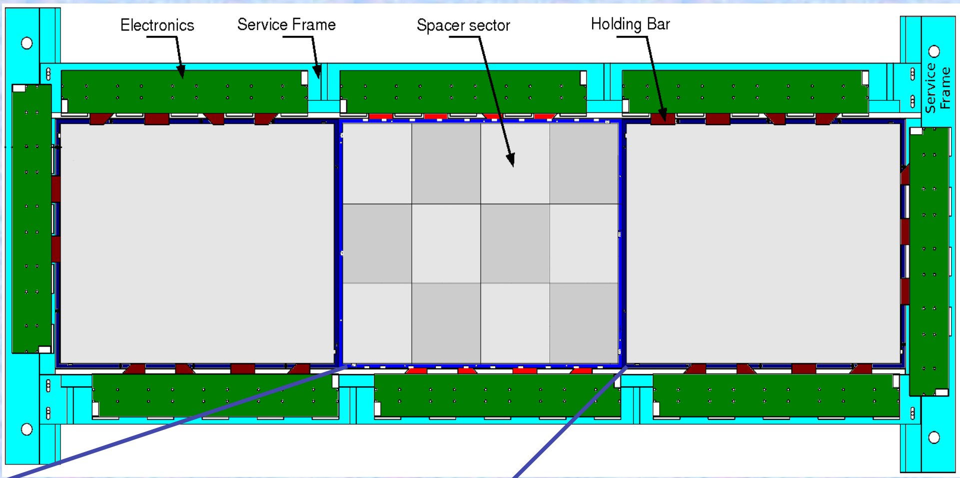
GEM Detector Response Simulation:

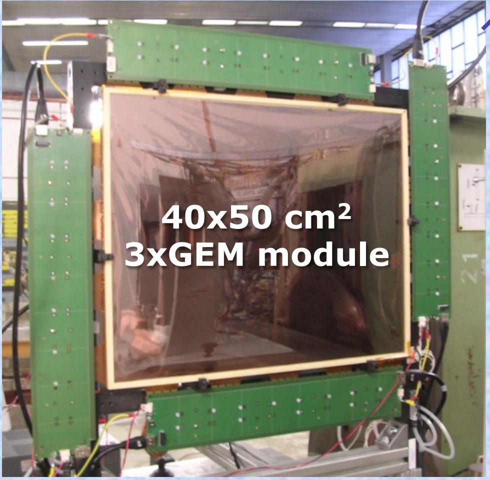


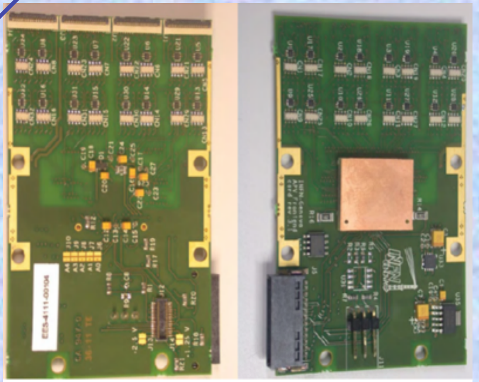
	slope	alpha	offset
Simul.	2.4117	22.5 deg	-1.9696
Reco.	2.4204	22.45 deg	-1.9749
Diff.		0.05 deg	0.0053

Production Status of the JLAB HALL-A GEM and Si-microstrip Tracker

S. Minutoli and P. Musico







Front-end readout cards based on APV25

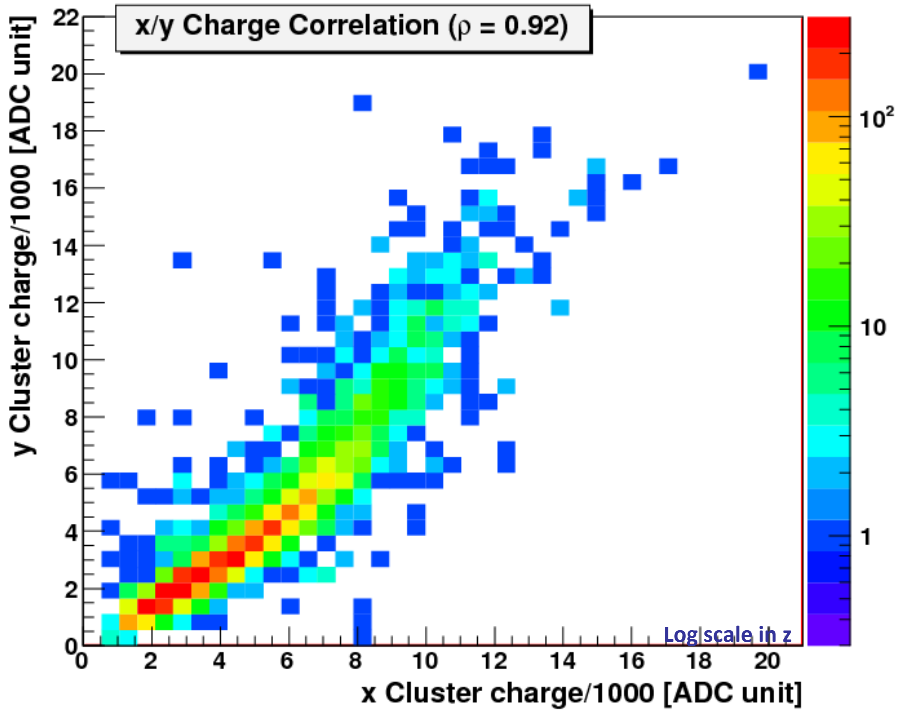
GEM and fine pitch Si micro-strip Share the same electronics (APV25)

Requirements:

- **Able to operate in photon flux up to 250 MHz/cm^2**
- **Active area larger than 120x40 cm^2**
- **Spatial resolution at the level of 70 μm**

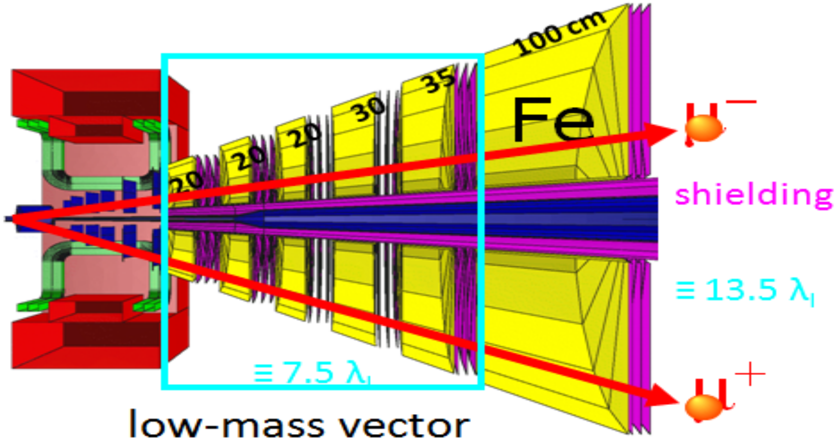
Implementation:

- **Large chambers made of 3 identical 40x50 cm2 triple GEM modules with x/y strip readout – 0.4 mm pitch**



GEM Detector Development for CBM Experiment at FAIR

Anand Dubey et al.



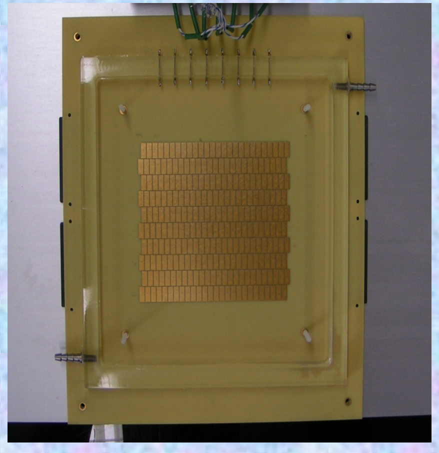
low-mass vector meson measurements (compact setup)

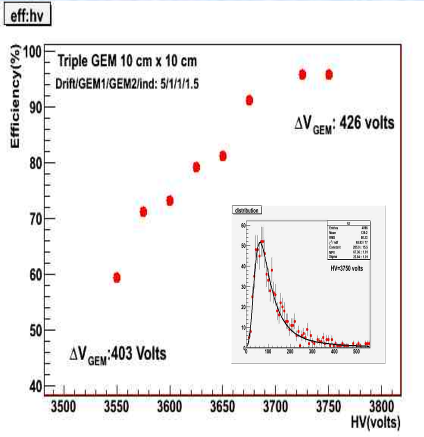
Muon Detection System:

- ✓ high rate capability (up to 1MHz/cm2)
- ✓ high granularity (up to 1 hit/cm2 in central Au-Au colisions)
- ✓ Good position resolution
- ✓ Radiation resistant
- ✓ Data to be readout in a self triggered mode

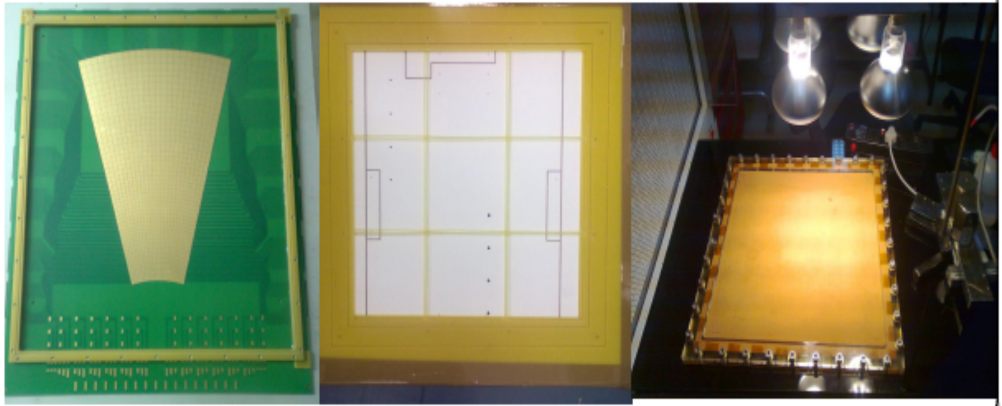
GEM for the first few stations and straw tubes and Micromegas for the latter stations

3GEM ($10*10cm^2$) at VECC, Kolkata:





Towards building a 30cm x 30 cm chamber



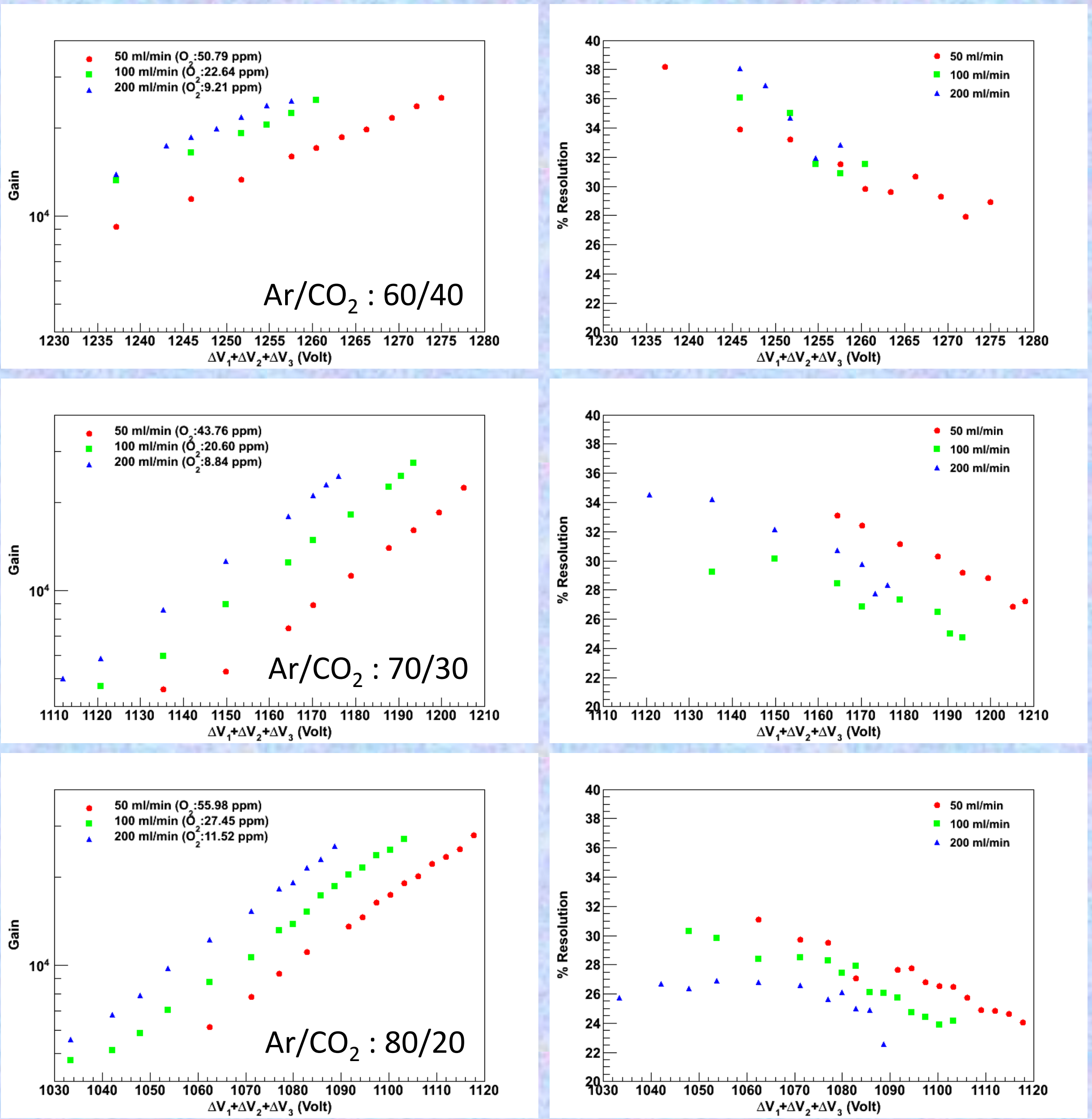
readout pcb with sector layout

Thermal stretching mechanism of foils

Study of the Characteristics of GEM detectors for CBM Experiment at FAIR

Saikat Biswas et al.

- Decrease of gas gain as a function of increased oxygen content (10 – 60 ppm) in the mixture
- Energy resolution was studied as a function of gas flow
- In an initial long-term test, variations of gain and energy resolution were observed. Further studies will be performed to take into account changes in T and P.



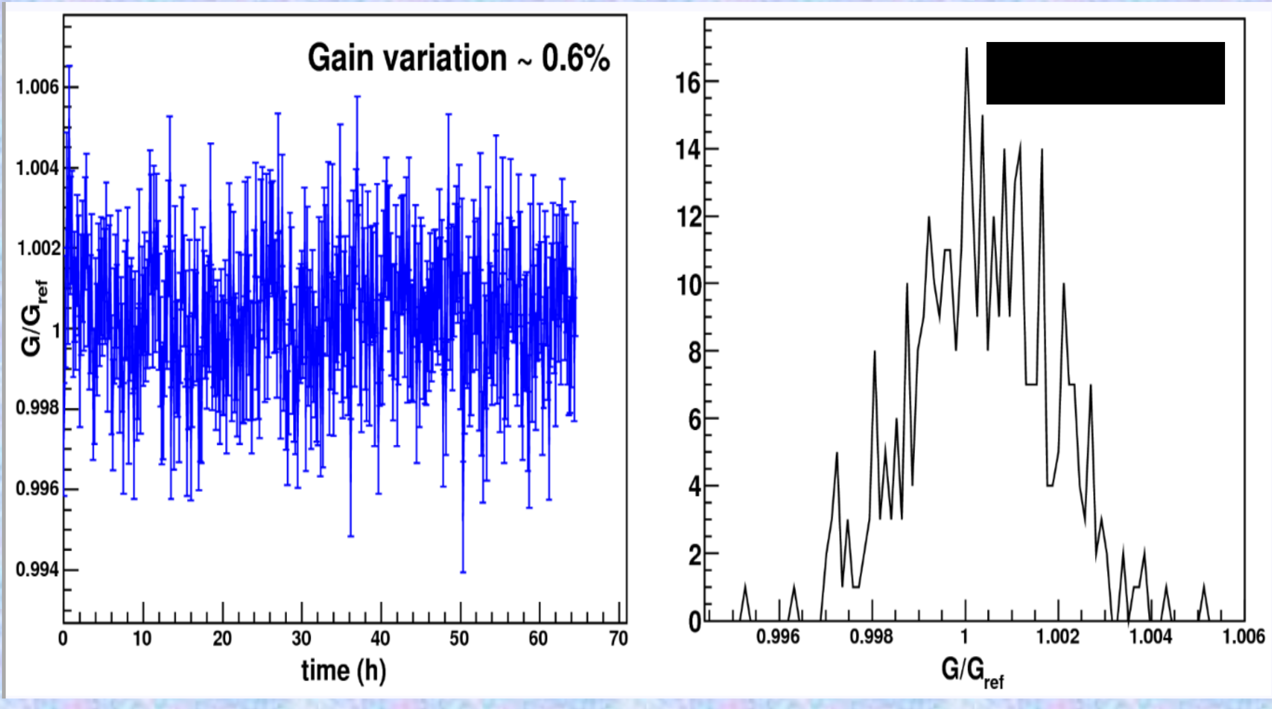
Setup Optimization toward accurate aging studies of gas filled detectors

Allhussain Abuhoza et al.

Radiation hardness ("aging") studies of gaseous detectors is of a primary importance

A dedicated aging setup (to test different construction materials) is being constructed in GSI DetLab to perform ageing tests

Several improvements of the setup have been implemented to obtain high precision of gain measurements and to correct for pressure and temperature variations

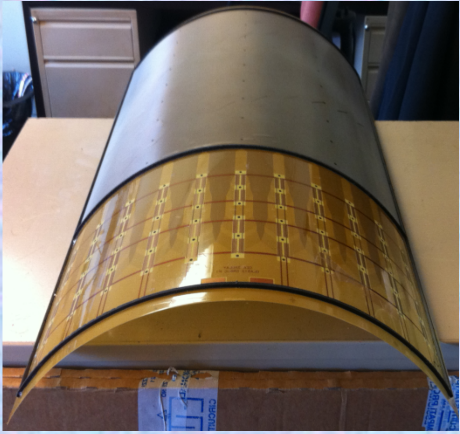


[redacted]

Advancing Concepts: Cylindrical Tracking Detectors

Thin Curved Micromegas for CLAS12

Curved Micromegas

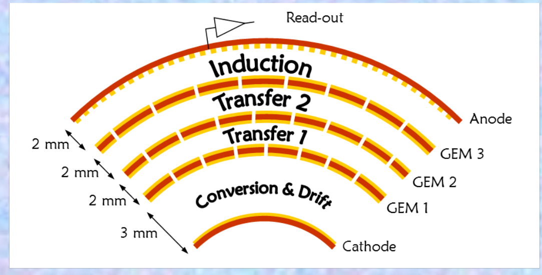


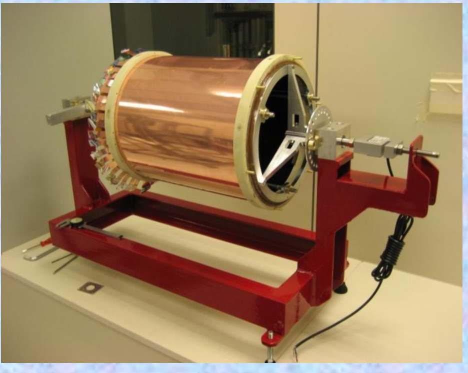
New techniques are developed to curve the detector, keep it curved and bring the gas to the active area with the requirement that the quantity of material must be as low as possible.

Cylindrical GEM for KLOE2 Inner Tracker Upgrade:

The KLOE experiment at the DAFNE Φ-factory will be upgraded with a new Inner Tracker composed by 4 tracking layers with radii of 130 / 155 / 180 / 205 mm around the Interaction Point

Each layer is a Cylindrical Triple-GEM detector





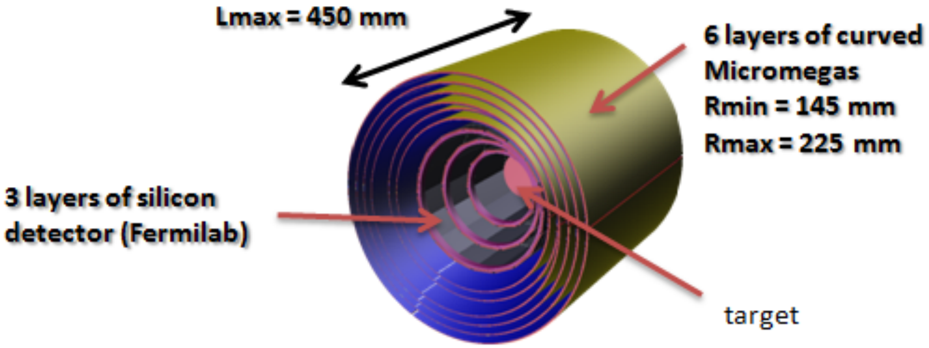
D. Domenici et al., "Production and test of the first 2 layers of the KLOE-2 Inner Tracker

G. Charles et al, "Micromegas Detectors for CLAS12 at Jefferson Lab"

→ Curved MPGD can be used as light, fast and high resolution, vertex and/or central tracker for high luminosity experiments

Micromegas detectors for CLAS12 at Jefferson Lab

Central vertex tracker

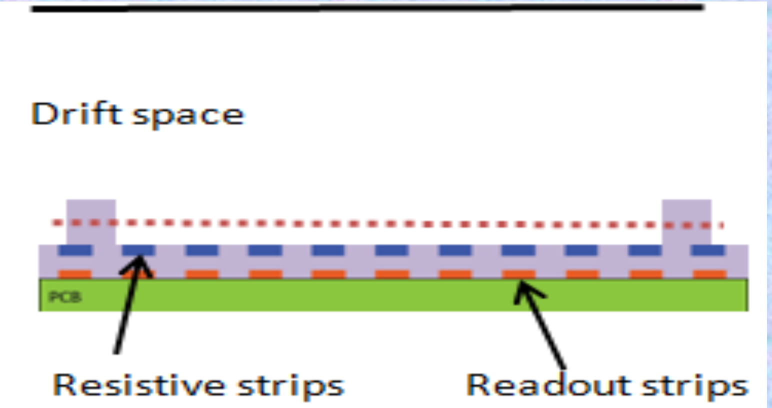


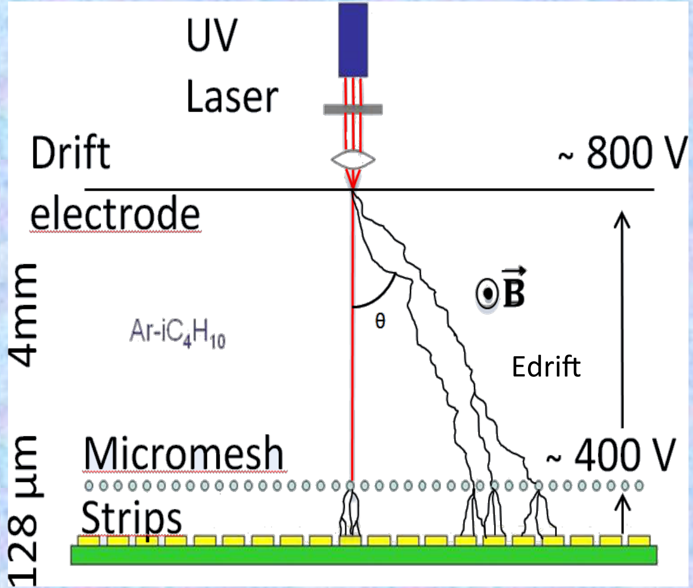
Many challenges :

- **strong magnetic field**
- **curved Micromegas**
- **high spark rate**
- **new electronics**
- **large area**

Gabriel Charles et al.

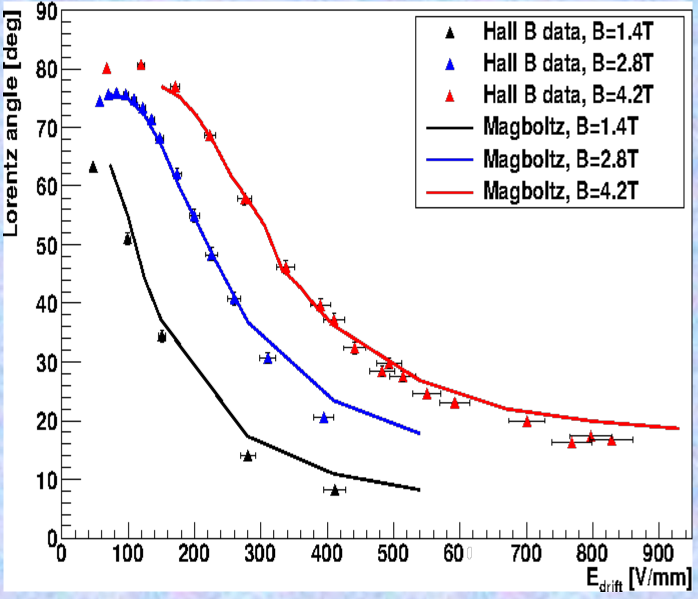
Resistive Micromegas: major recent breakthrough to eliminate sparks





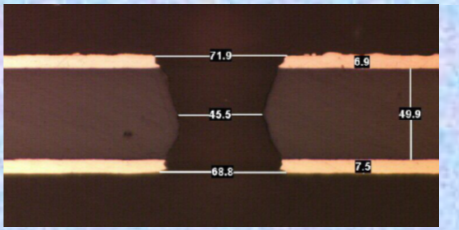
First effect studied : the strong magnetic field (4T at the level of the target).

These tests strongly suggest that the Lorentz angle can be reduced to 20° at 5T if the drift field is set to about 8 kV/cm.

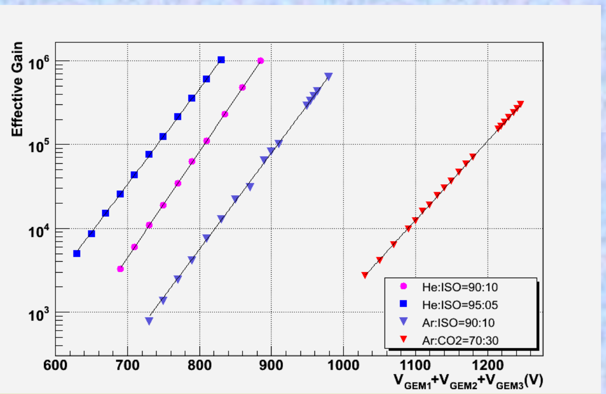


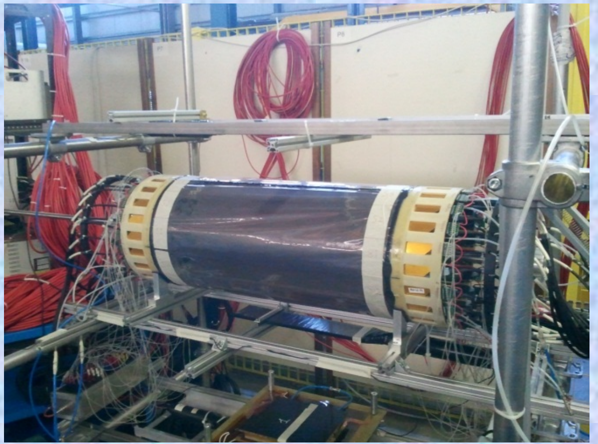
Production and test of the KLOE-2 Inner Tracker

Danilo Domenici et al.

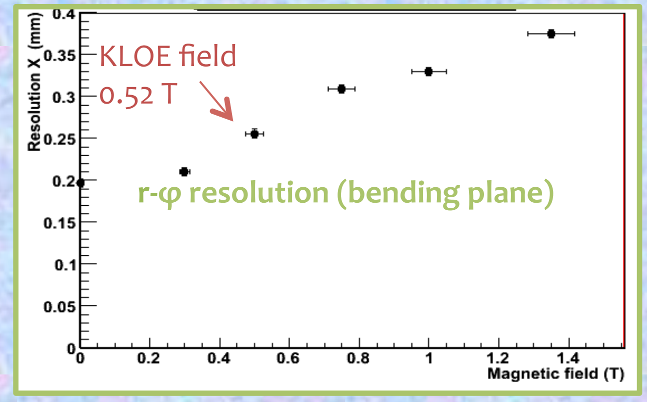


GEM foils are produced with a single-mask etching. We measured the gain of 4 different gas mixtures.
The final choice is Ar/Iso : 90/10.



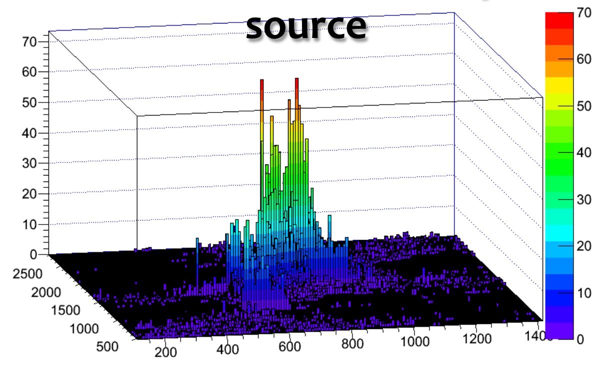


Spatial resolution as a function of the Magnetic field



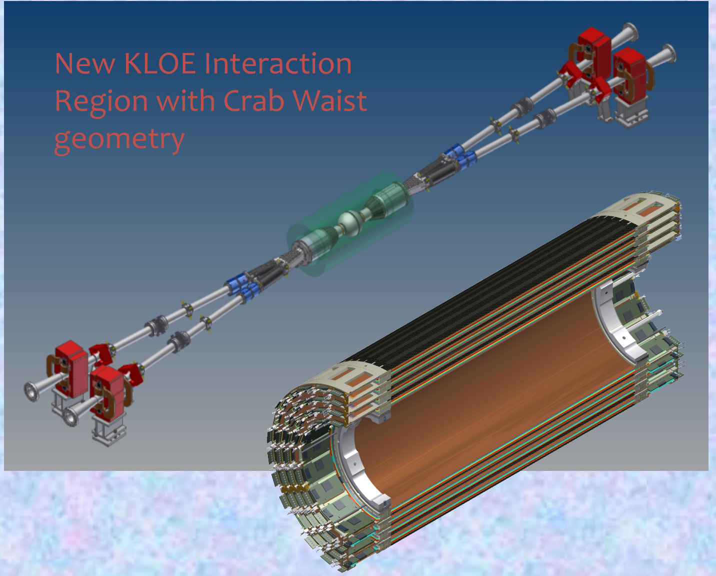
FEE is based on GASTONE: a charge amplifier, shaper, discriminator chip developed for the KLOE-2 Inner Tracker

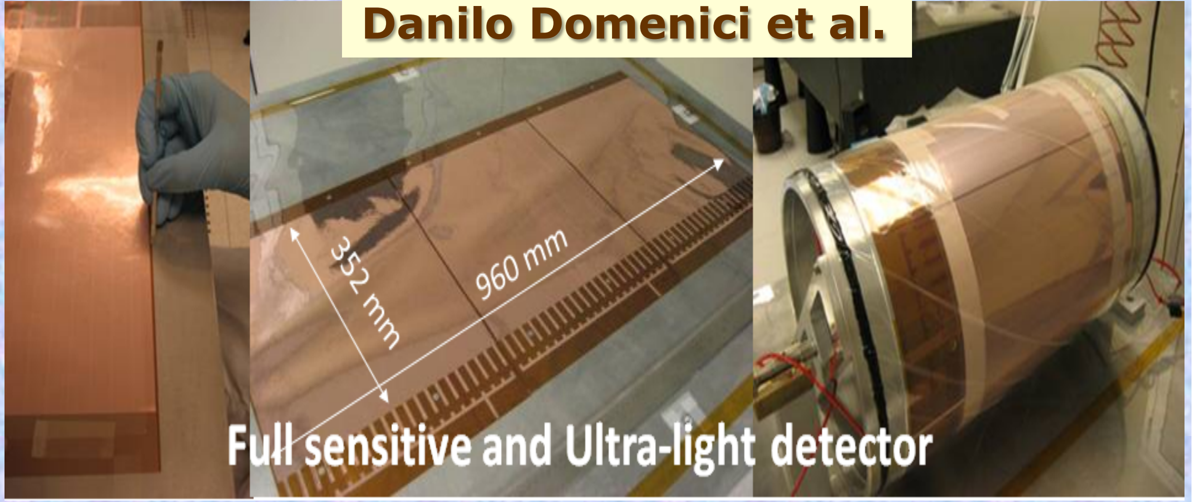
Hit distribution of a β source



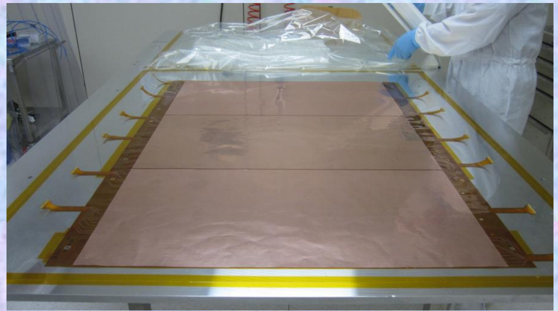
Production and test of the KLOE-2 Inner Tracker

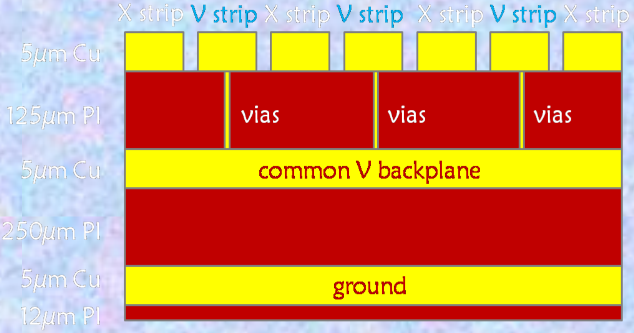
Danilo Domenici et al.





The 5 electrodes (Cathode, 3 GEMs and Readout) are realized as cylindrical polyimide foils without frames in the active area. The overall material budget is below 2% of X_0





The readout is a multilayer flexible circuit on a polyimide substrate providing a 2-dim point with XV strips at 650 μm pitch

NEXT Prototypes based on Micromegas Readouts

Laura Segui et al

NEXT EXPERIMENT

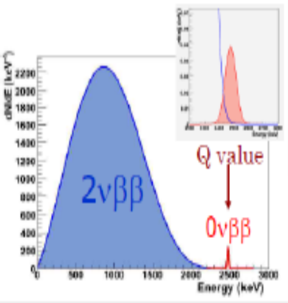
(for more details see D. Lorca's talk)

- A high-pressure, 100 kg gaseous Xe TPC to look for the 0νββ decay of ^{136}Xe → $Q_{\beta\beta}$ at 2.46 MeV

- **Baseline**: an EL TPC, energy measured by PMTs and tracking with SiPM.

R & D studies

Microbulk Micromegas with pixelized anode to study gas mixtures and tracking.



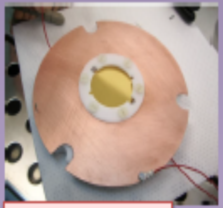
Requirements:

- ☐ Good energy resolution to separate ββ0ν from ββ2ν signal
- ☐ Ultra low background (~10^{-4} counts/keV/kg/yr for m_ν ~ 50 meV)
- ☐ High masses of isotope
- ☐ Pattern recognition

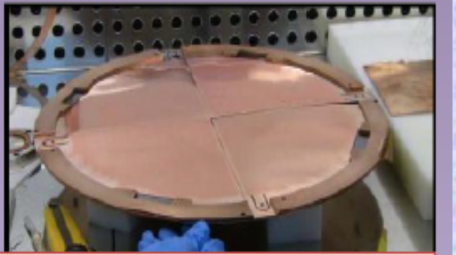
→ advantage using **pixelized detectors + gas TPC**

MicroBulk Technology

- ☐ Made from a single Cu-Kapton foil
- ☐ High homogeneity
- ☐ Radiopure low mass-constructed [S. Cebrian et al, Radiopurity of Micromegas readout planes, Astropart.Phys. 34 (2011) 354-359]

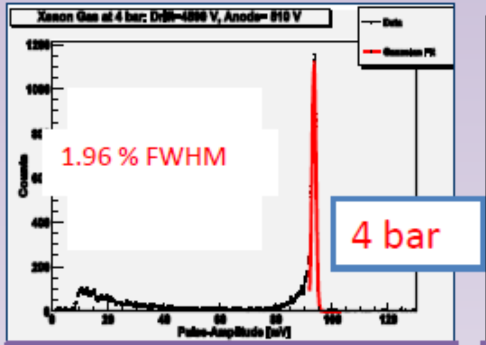


Ø = 35 mm
50 μm gap



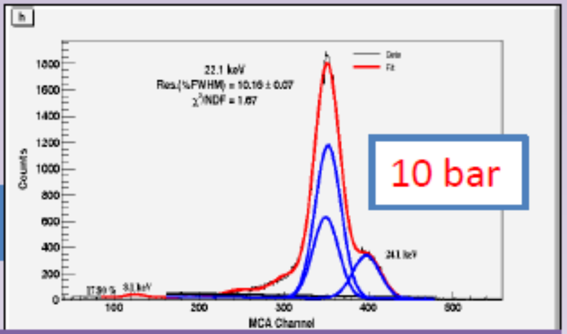
Largest area with μbulk technology
Each sector radius = 14 cm
1252 pixels independently read
0.8 cm pixel
50 μm gap

- **Pure Xe**



Am–241 source, 5.5 MeV
ΔE = 1.96 % FWHM
@ 4bar

- **Xe-TMA** (Penning Mixture)



Cd-109 source 22.1 keV
ΔE = 10.16% FWHM **@ 10bar**
→ ΔE = 1.02 % FWHM @ $Q_{\beta\beta}$

Studies with large NEXT-MM prototype ongoing

HP TPC: 74 l, 35 cm drfit