Overview of high precision Gas Detectors

A Cattai – CERN

- Recall the GD working principle
- Example of GD in use
- R&D for future experiments
- Some conclusions …..

ALICE

Pb+Pb @ sqrt(s) = 2.76 ATeV

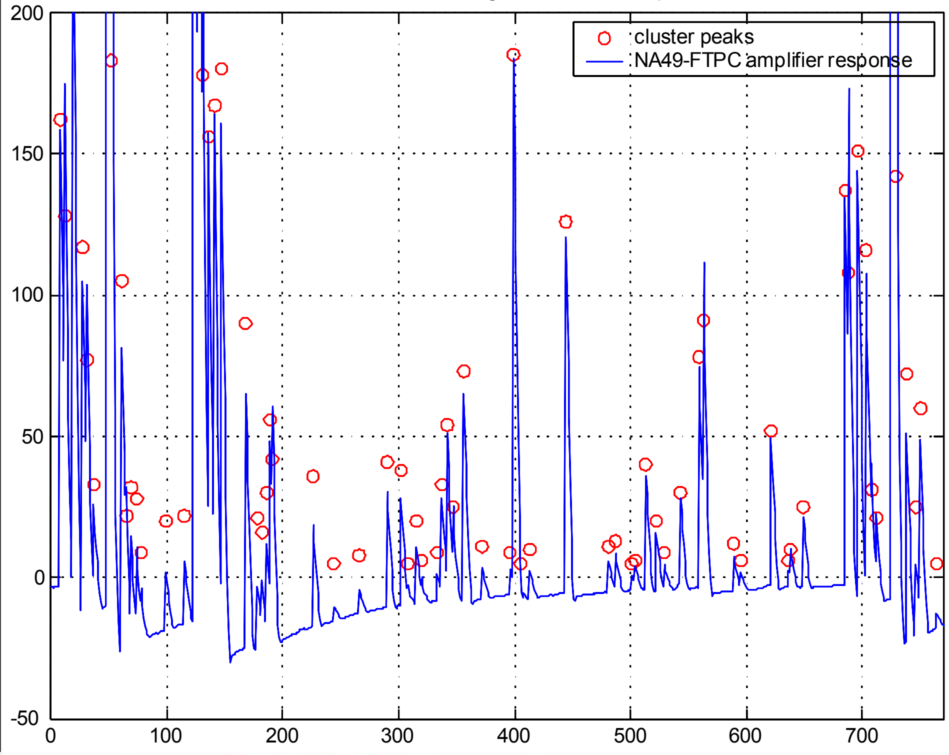
2010-11-08 11:30:46
Fill : 1482
Run : 137124
Event : 0x00000000D3BBE693

Homage to the ALICE TPC

5 m × 5 m
gas purity:
< 5 ppm O_2,
< 10 ppm H_2O

$\Delta T < 0.1\ ^0C$

0.5 M channels
1K samples in time
300 Hz for Pb-Pb



Spatial resolution

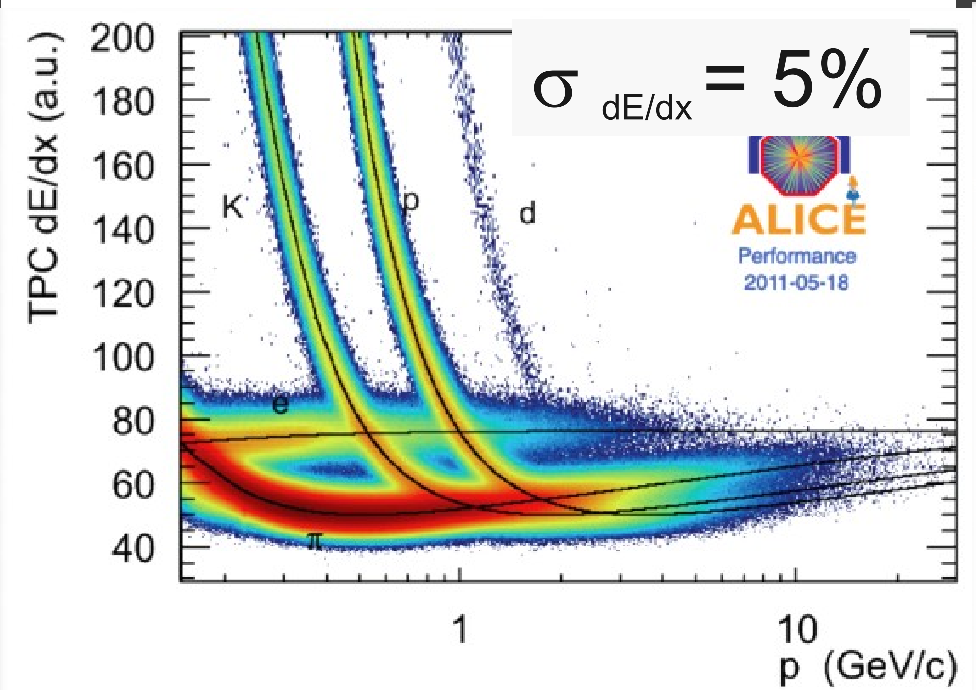
$\sigma_{r\phi}$ & σ_Z = 300 - 800 μm

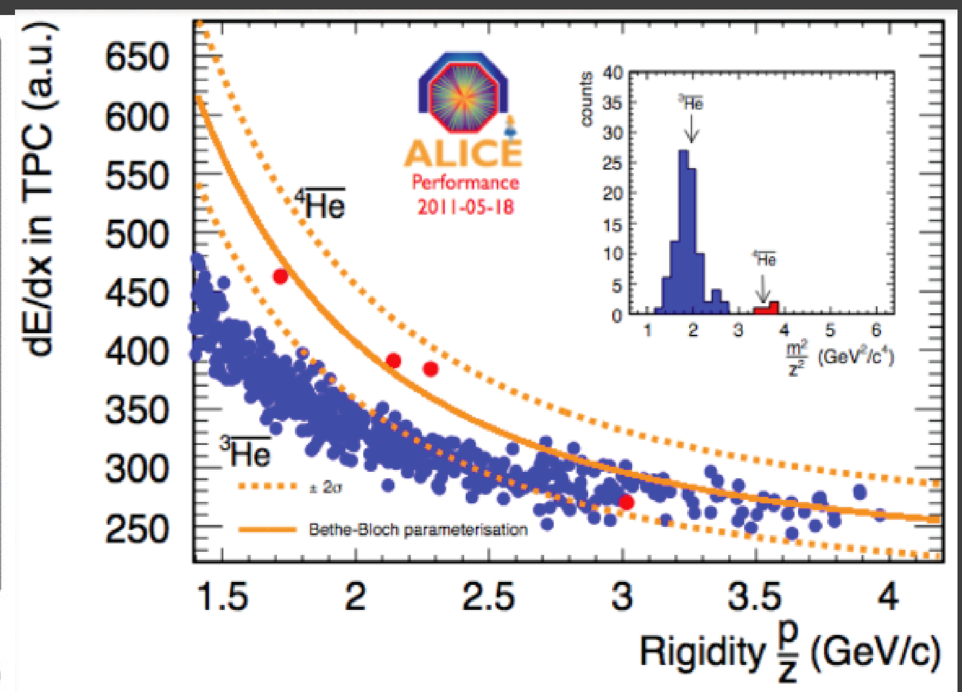
Momentum resolution

~ 7% @ 10 GeV/c

~ 1% below 1 GeV/c

$(\sigma_{p_T}/p_T)^2 = (0.01)^2 + (0.007p_T)^2$





Considerations

Up to some years ago: gaseous detectors were, in large quantities, *mainly* used for “large surface detectors”

ALL muon detectors
Trigger RPC

- Cheap
- “Easy” to produce and handle……

BUT, in general, wires detectors:

- Limited intrinsic spatial resolution → few ten to hundreds μm
- Quite “slow” time response
- Limited rate capabilities due to the space charge effect induced by the time needed to evacuate the ions

SORT OF “RELIABLE” → wires are thin….. sparks are always around the corner…….

In the 80ties, we had a breakthrough in the micro-technologies

→ thin strips, as thin as anodic wires in MWPC could be patterned on various surfaces

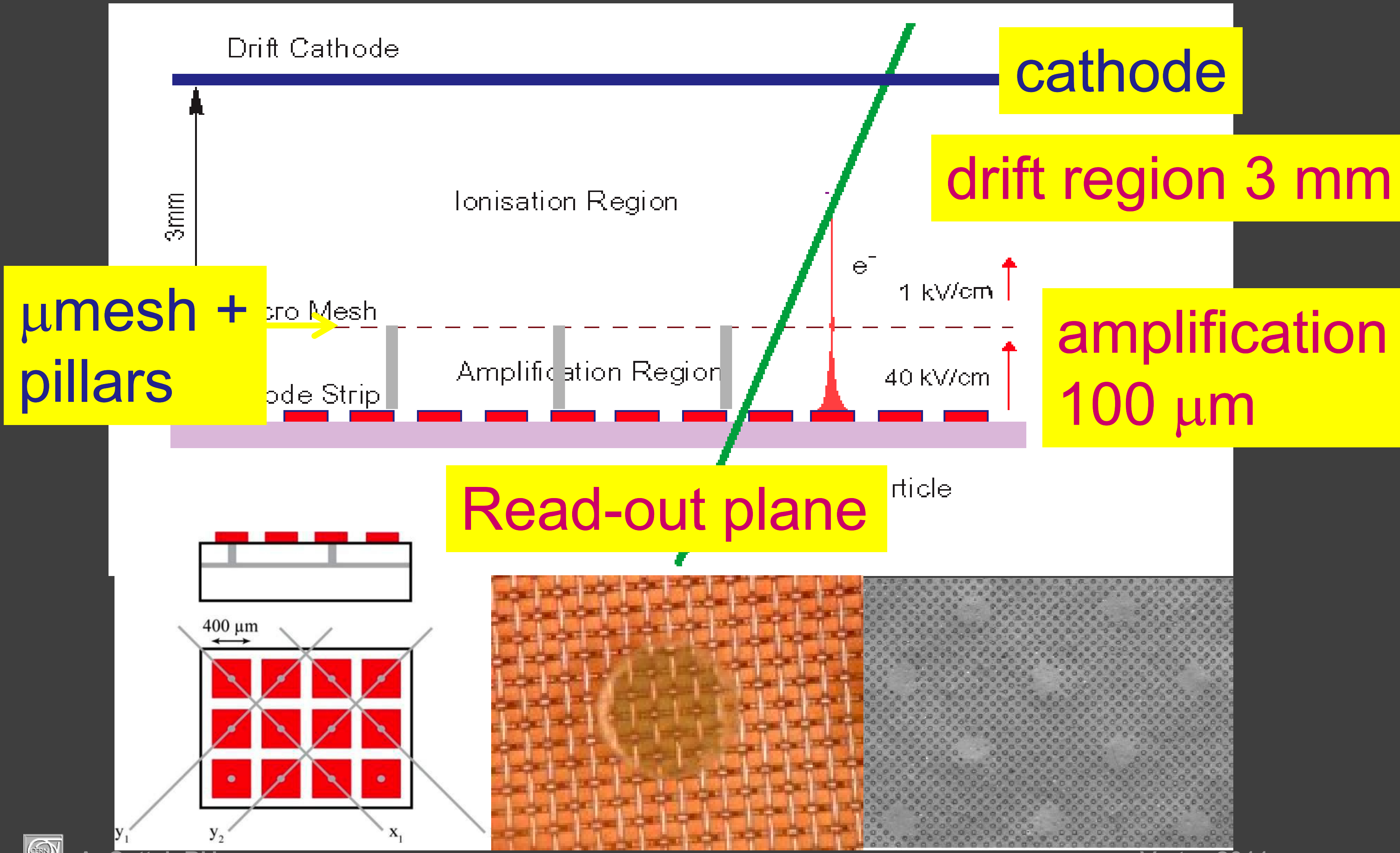
→this allowed major chance "getting rid of wires"

→ increase the rate capabilities (= shorter the ion path)

A large R&D program, fully concentrated on micro-technologies started and produced two detectors, the GEM and the μmegas that are the building blocks of today gaseous detectors

Micro-pattern detector 1: μMEGAS

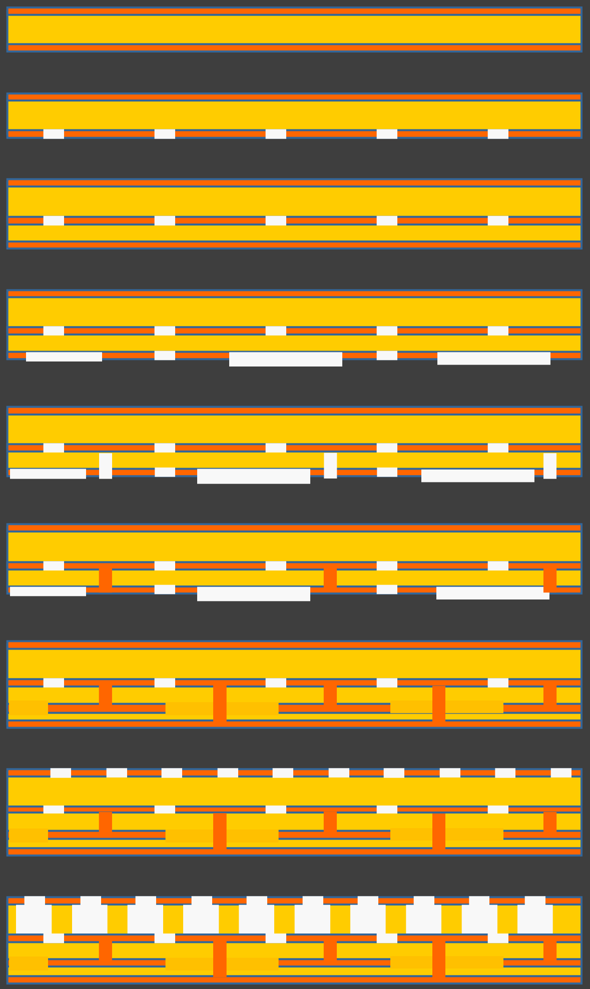
Y. Giomataris, Nucl. Instr. and Meth. A419(1998)239



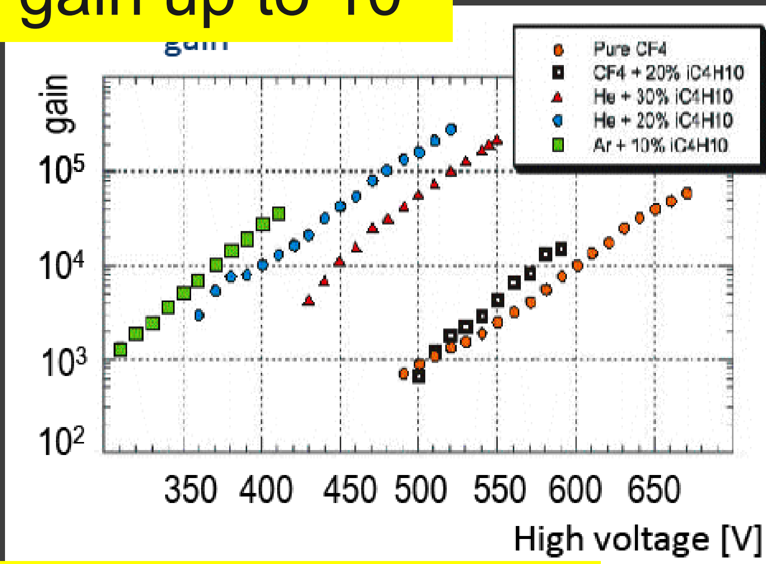
Building a microbulk μmegas

Photolithography on Kapton

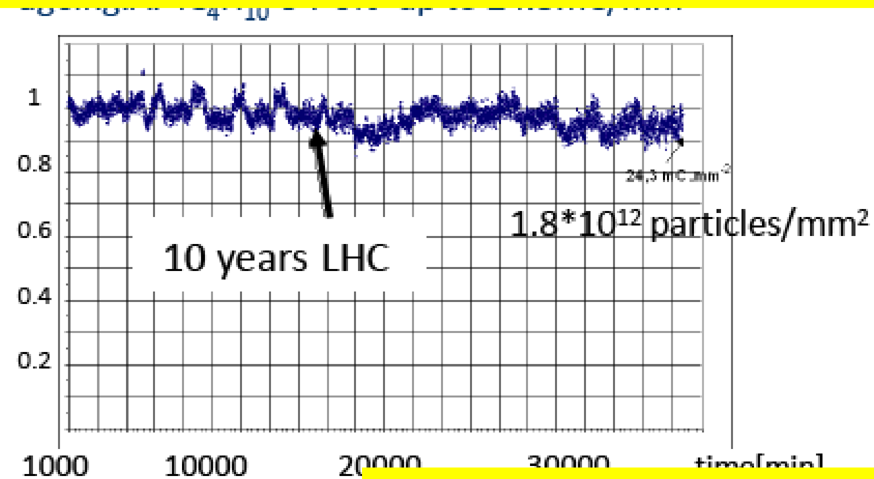
- Kapton foil (50 μm), both side Cu-coated (5 μm)
- Construction of readout strips/pads (photolithography)
- Attachment of a single-side Cu-coated kapton foil (25/5 μm)
- Construction of readout lines
- Etching of kapton
- Vias construction
- 2nd Layer of Cu-coated kapton
- Photochemical production of mesh holes
- Kapton etching
- Cleaning



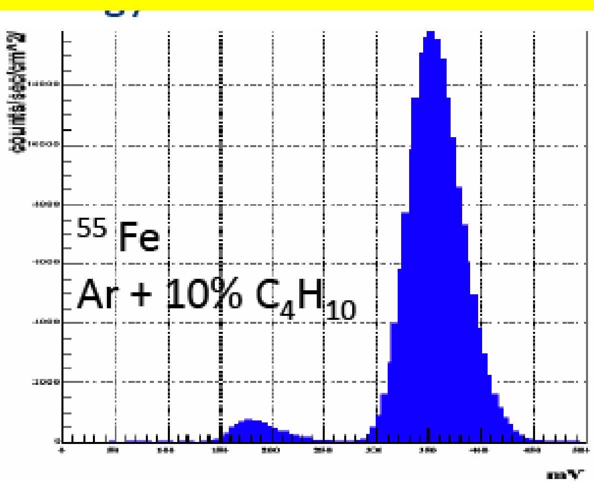
gain up to 10^5

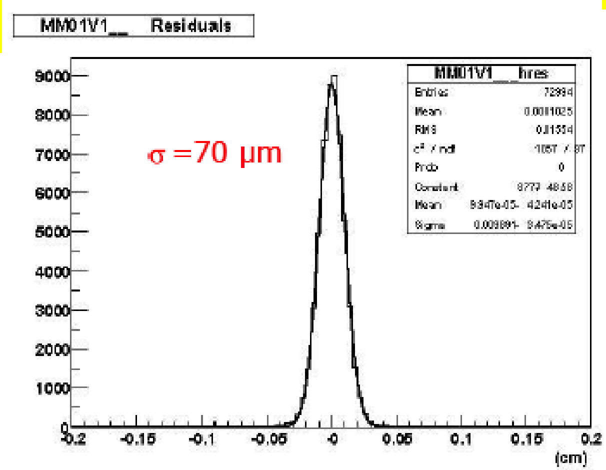


ageing: stand easily 10 LHC y



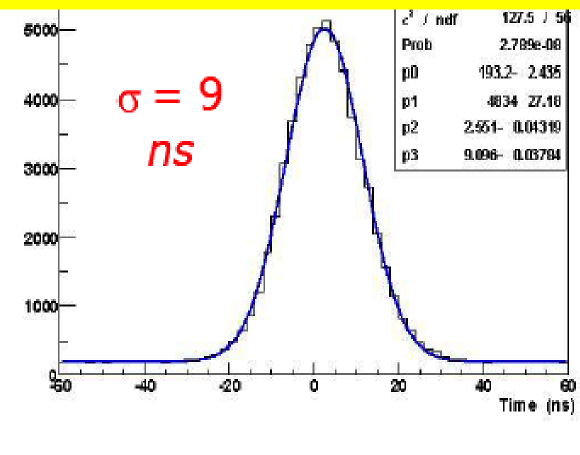
Energy resolution10%





spatial resolution 70 μm

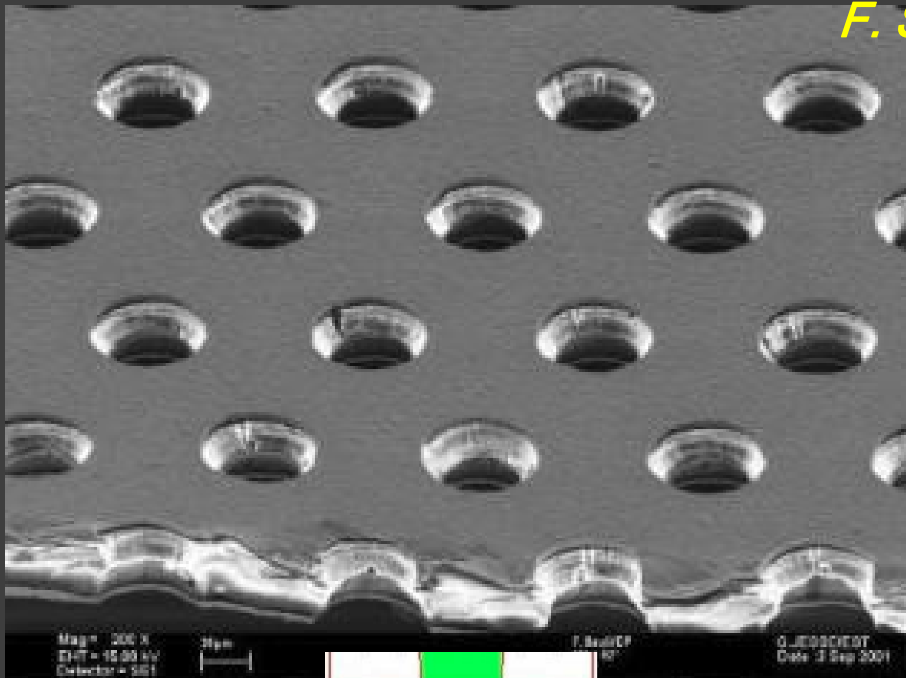
time resolution 9 ns

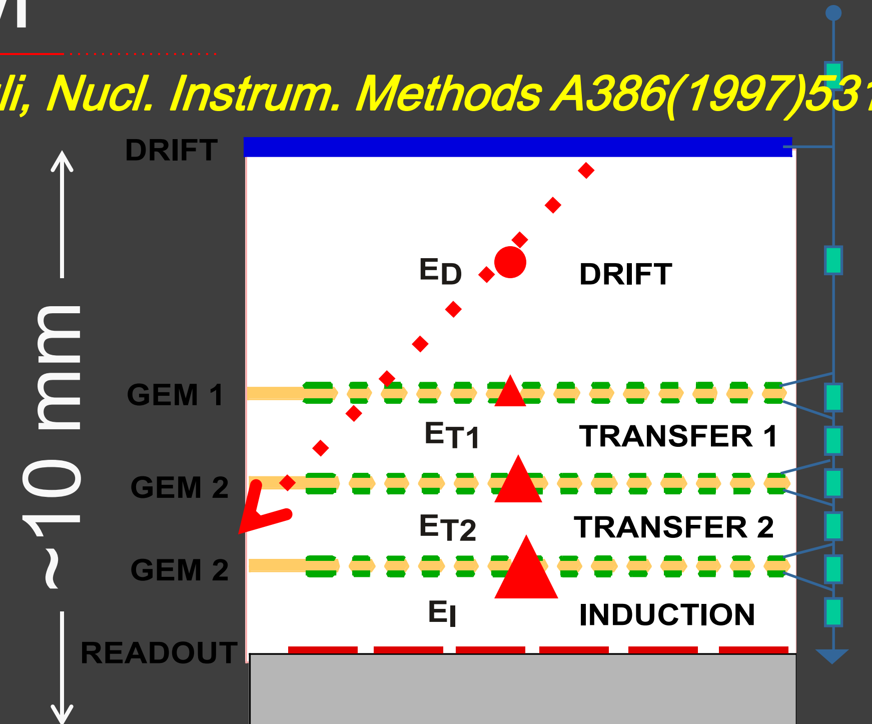


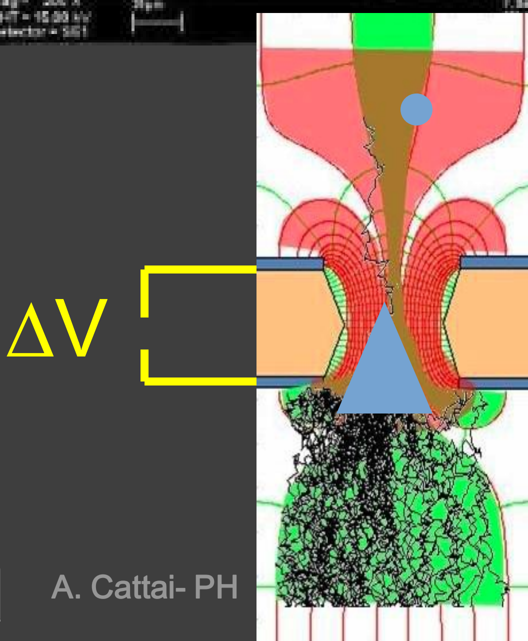
Time resolution : 9 ns

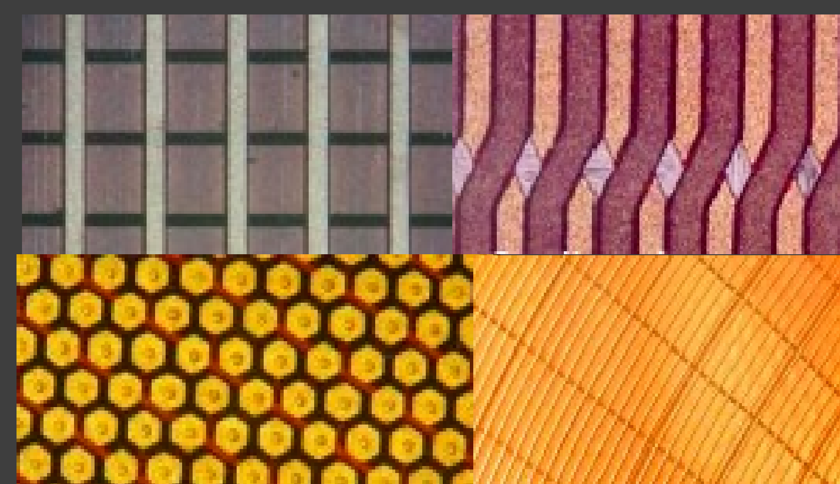
Micro-pattern detector 2: GEM

F. Sauli, Nucl. Instrum. Methods A386(1997)531

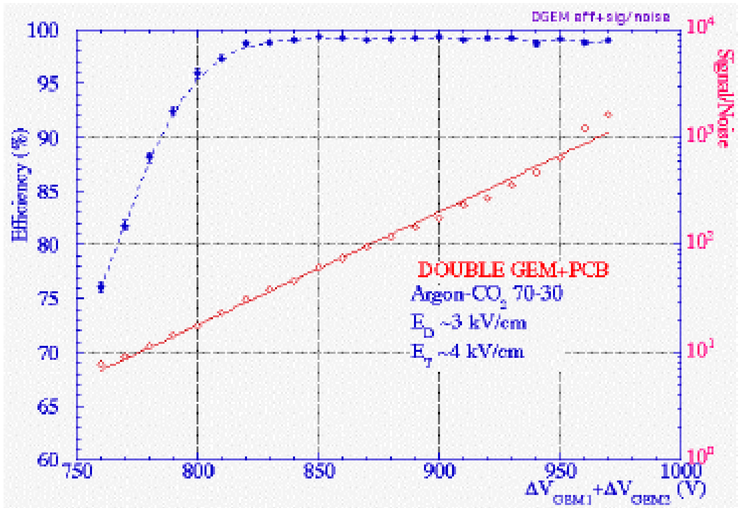




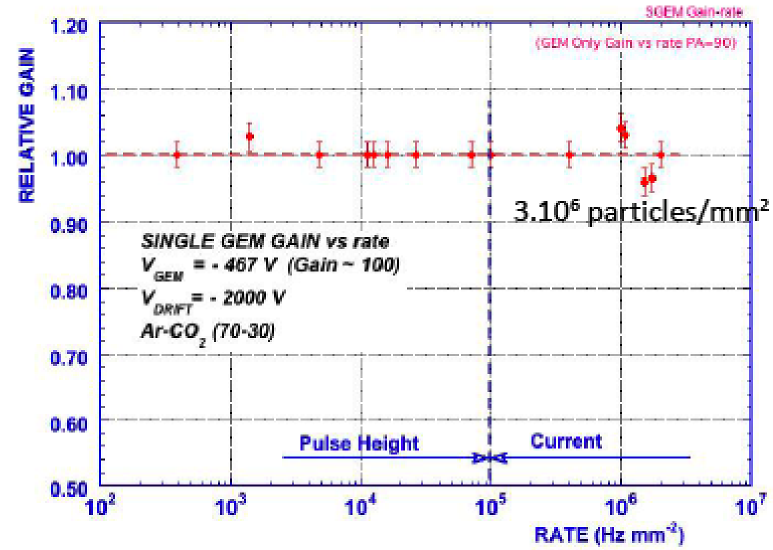




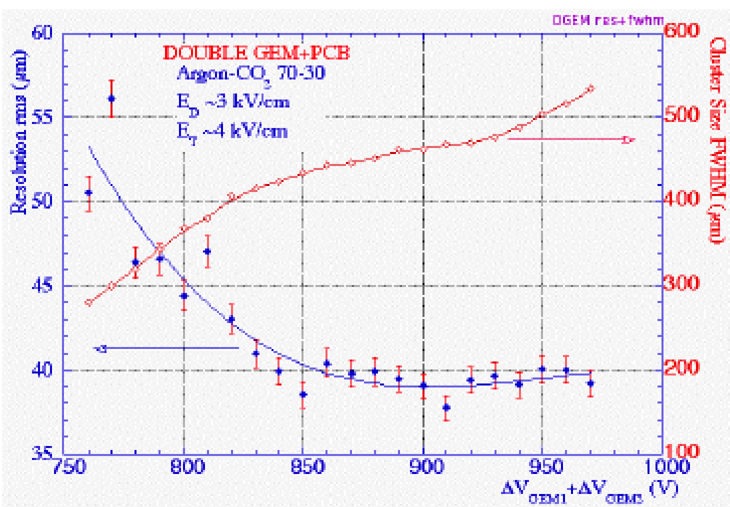
GEM characteristic parameters



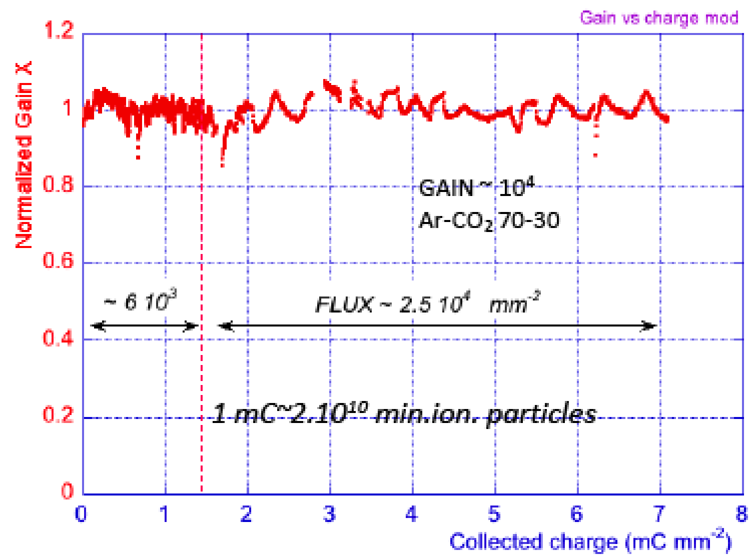
Efficiency for minimum ionizing particles with 3 mm gap



Rate capability > 10^6 Hz mm^{-2}

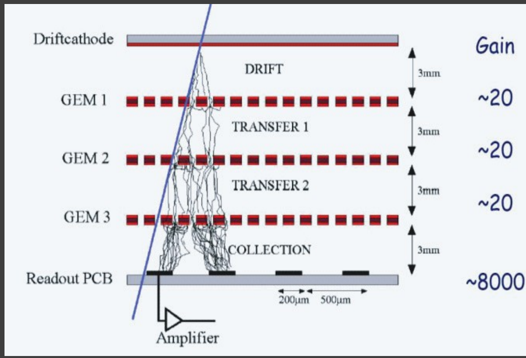


Space resolution ~ 40 μm rms
Cluster size ~ 500 μm FWHM



C. Altunbas et al, DESY Aging Workshop (Nov. 2001) Nucl. Instr. and Meth. A
J. Benlloch et al, IEEE NS-45(1998)234

From μMEGAS and GEM to exotica -1-



Gas detectors keep on having limited "gain"

→ use more amplification steps

…… many GEMs layers is complicated!

* stretch Kapton foils (30 * 30 cm)

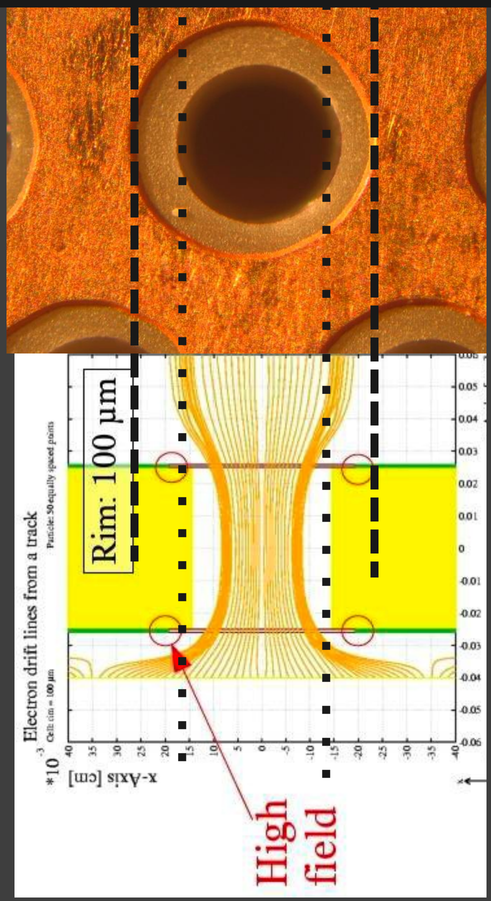
* keeping them flat

How about building a self-supporting structure?

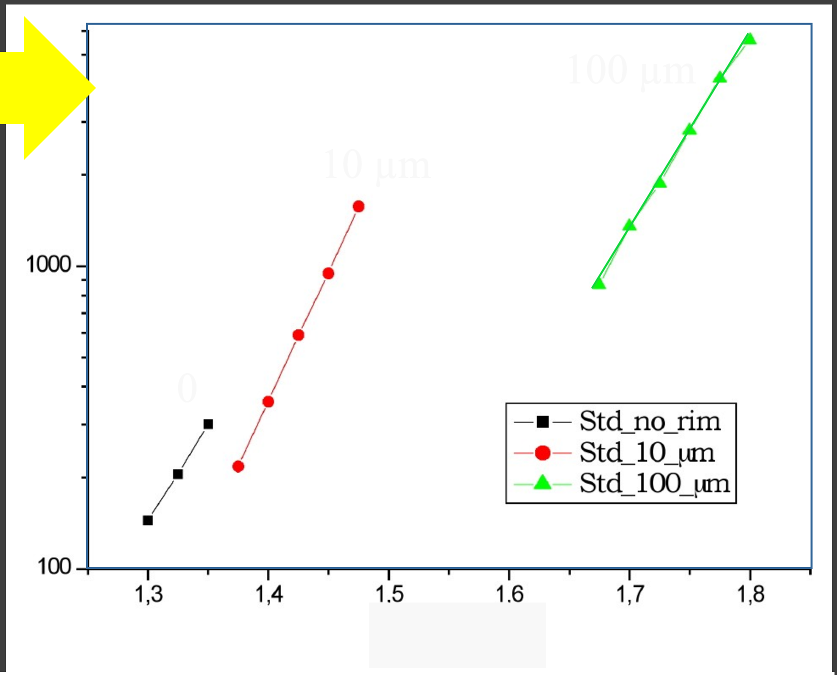
R.Chechik et al, Nucl. Instr. and Meth. A535(2004)303

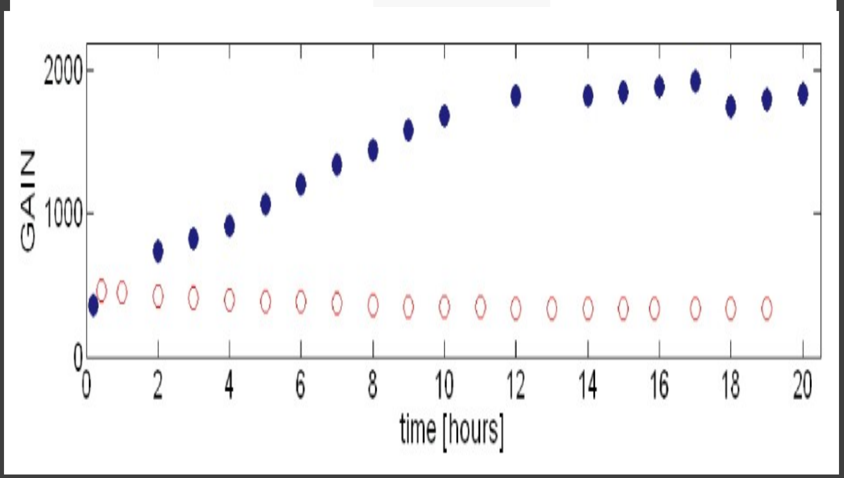
Thick GEM: drill holes in metal clad PCB

A single TH-GEM has enough gain for full efficiency

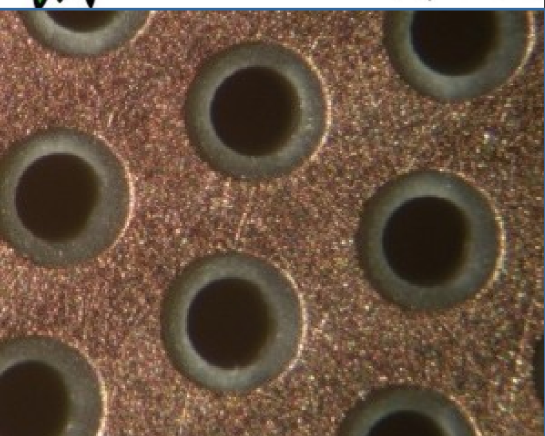


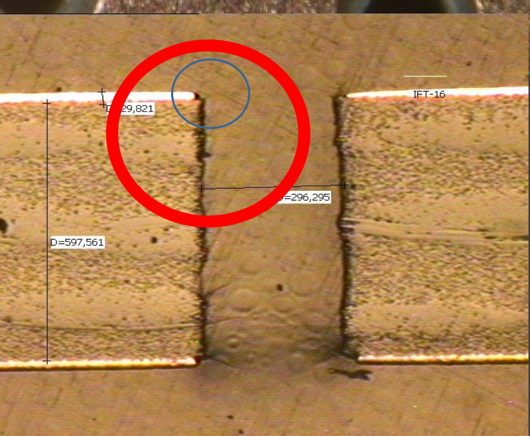
1 mm thick

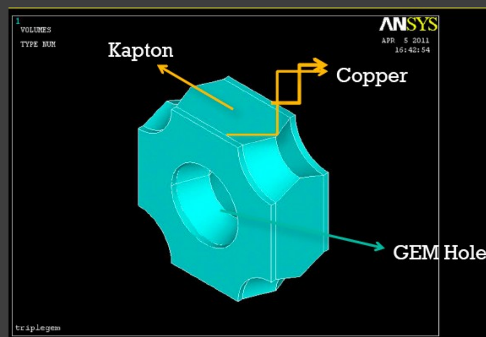


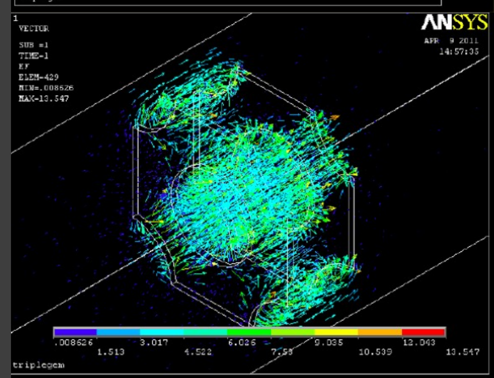


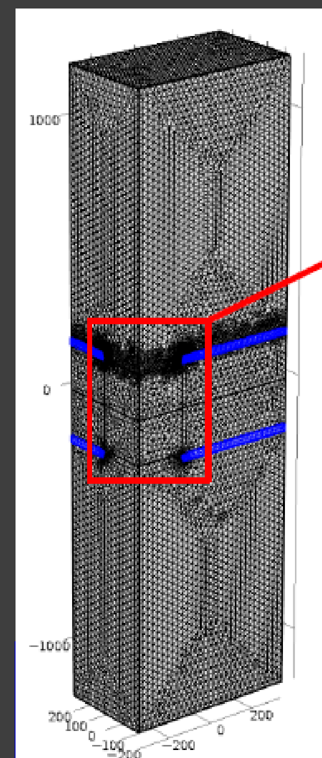
Why do I care about instability problems in the thick-GEM????

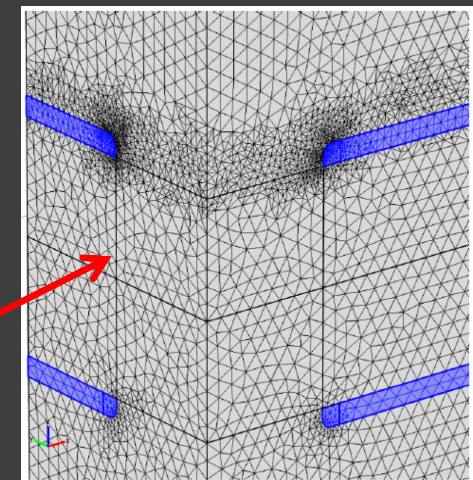


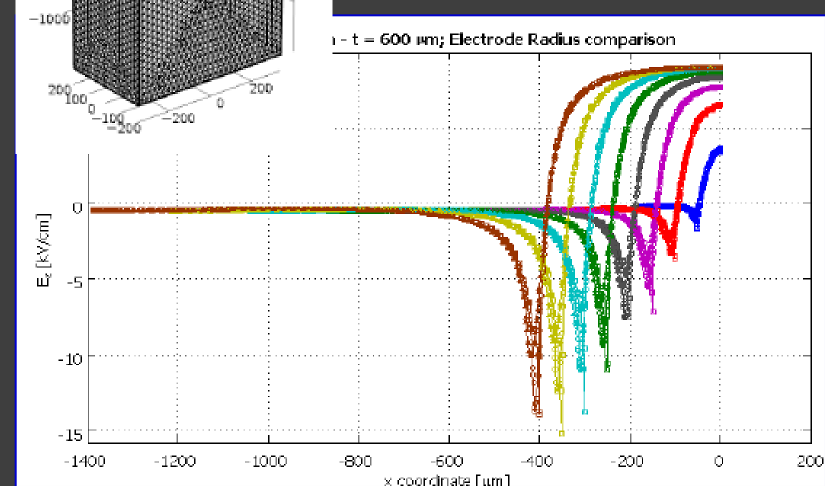




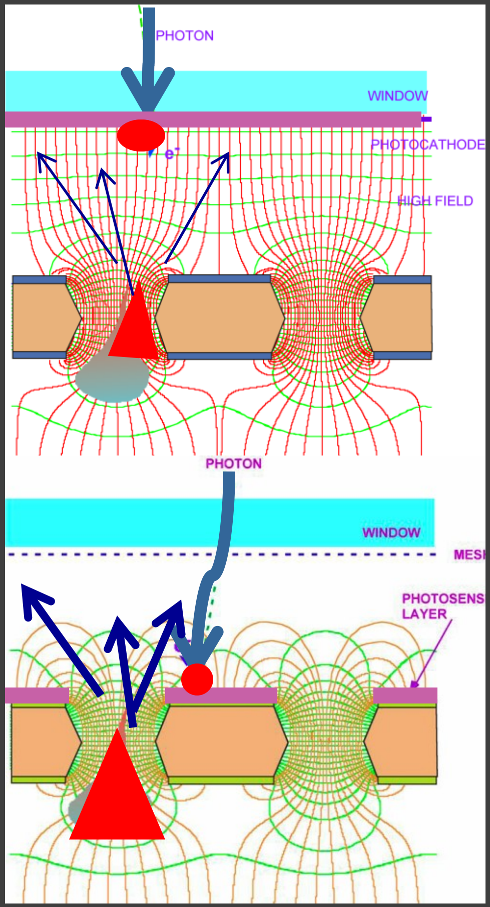








THGEM as photodetectors

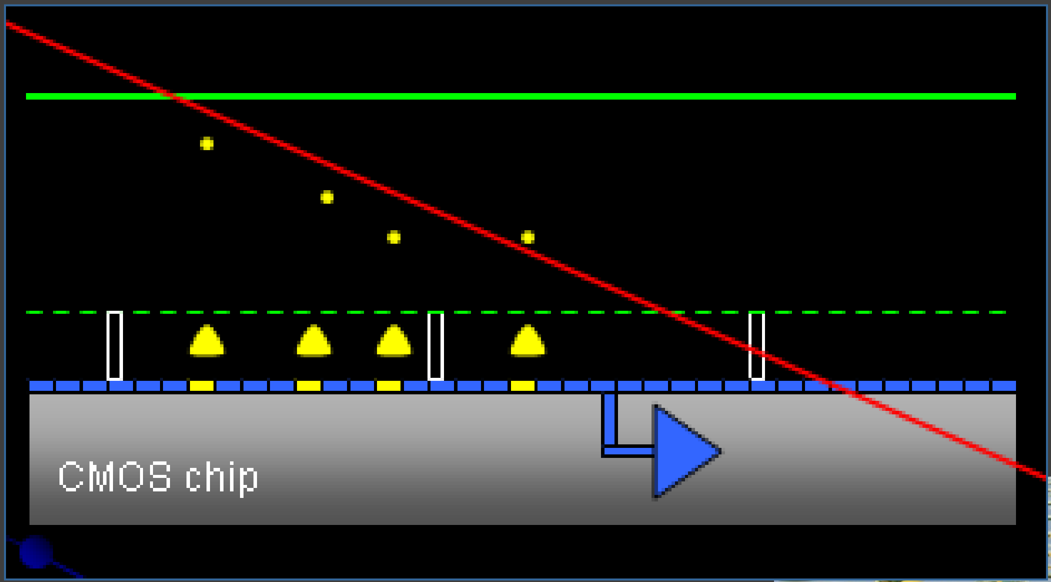


- Eliminate the drift region
- deposited a CsI layer on the top electrode
- γ will extract e^-
- e^- is highly amplified → 10^5
- closed geometry suppress the photons feedback

→ Good efficiency for γ detection

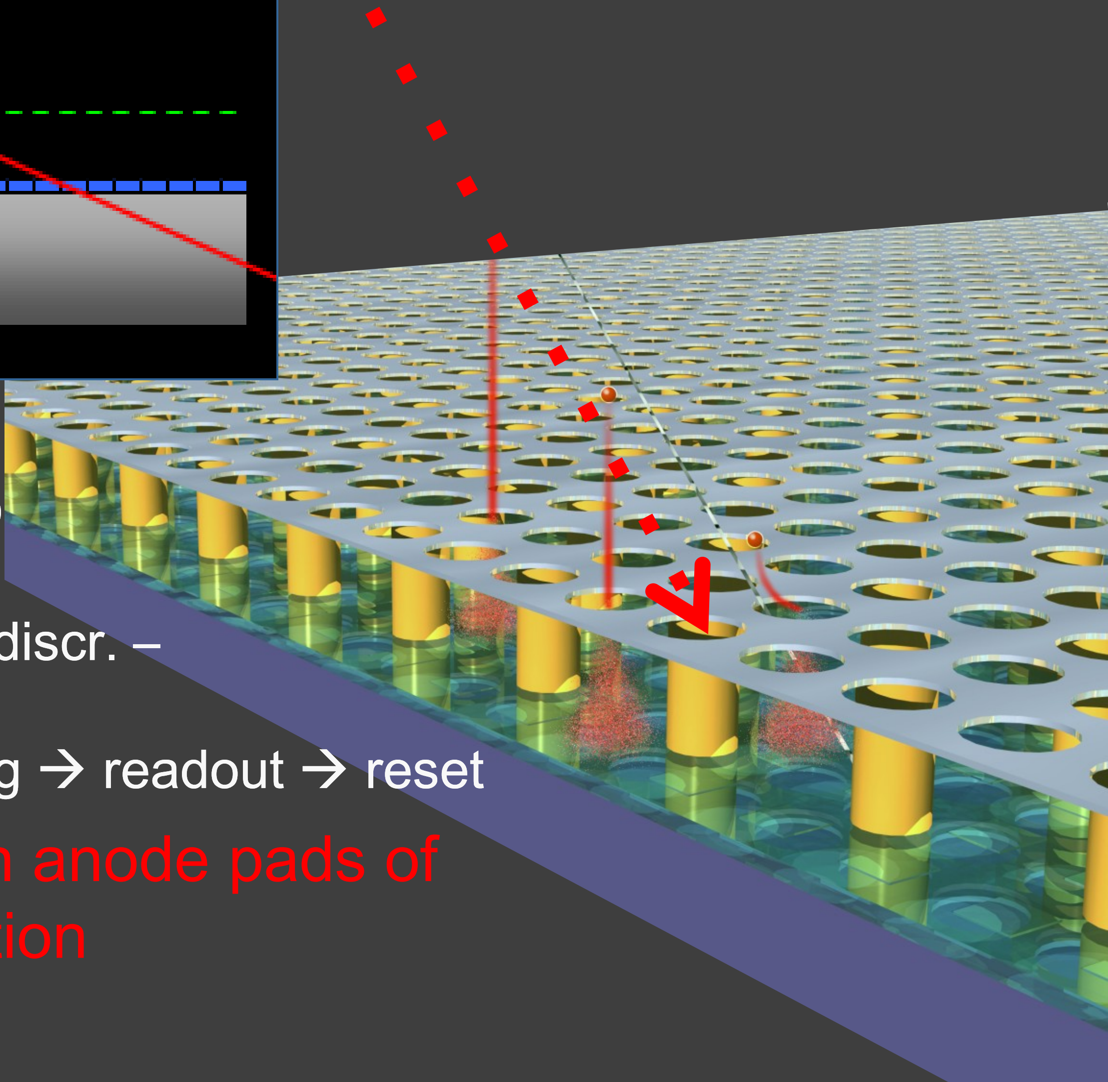
TH-GEM good candidate for RICH counters → COMPASS already adopted

From μMEGAS and GEM to exotica -2-



GOSSIP

By H. van der Graaf



MediPix2 pixel CMOS chip

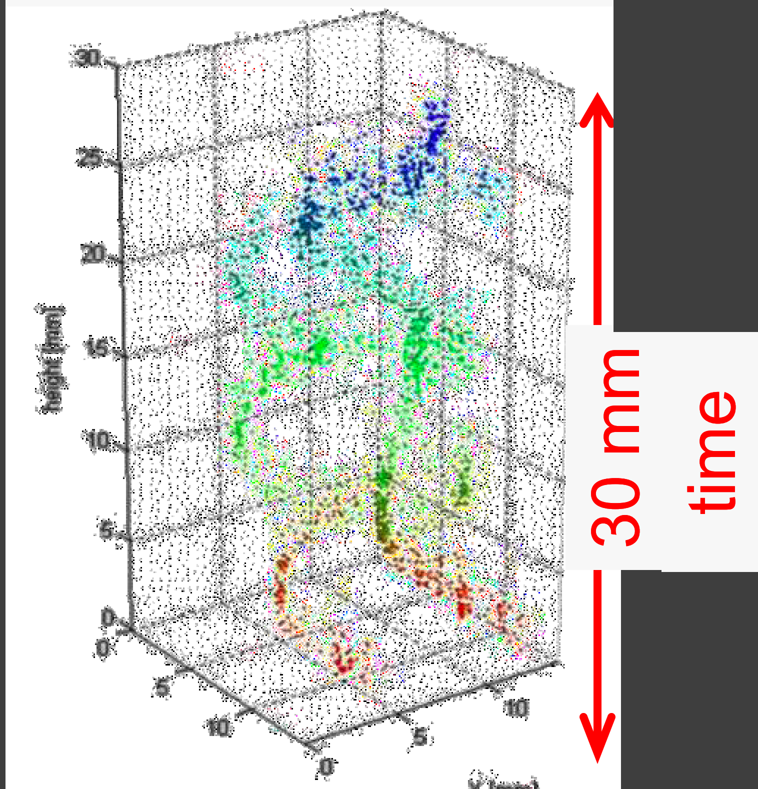
pixel: 55 x 55 μm^2

per pixel: preamp – shaper – 2 discr. – Thresh. DAQ - 14 bit counter

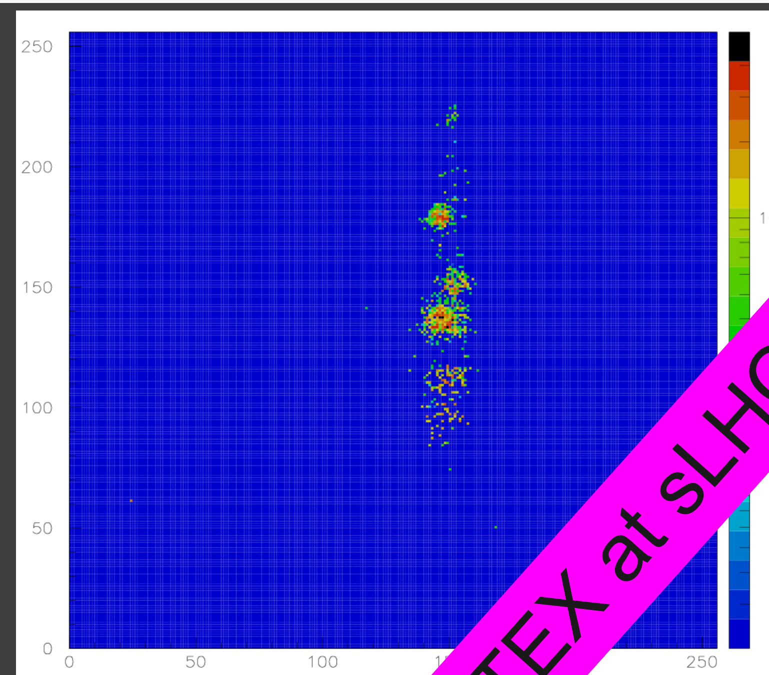
enable counting → stop counting → readout → reset

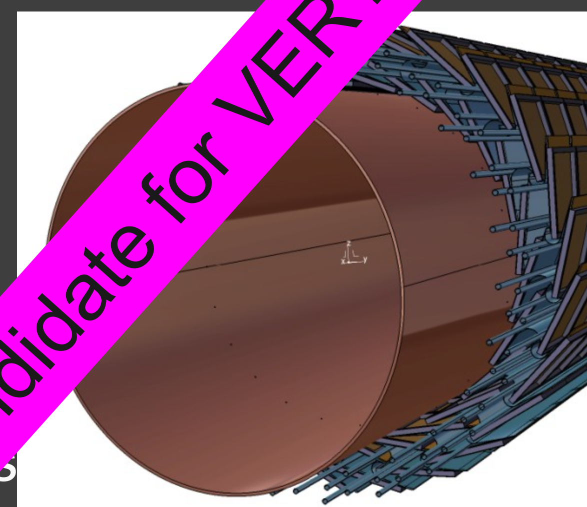
7μm thick layer of **Si_3N_4** on anode pads of pixel chip for spark protection

Sr 90 tracks in 2 T field



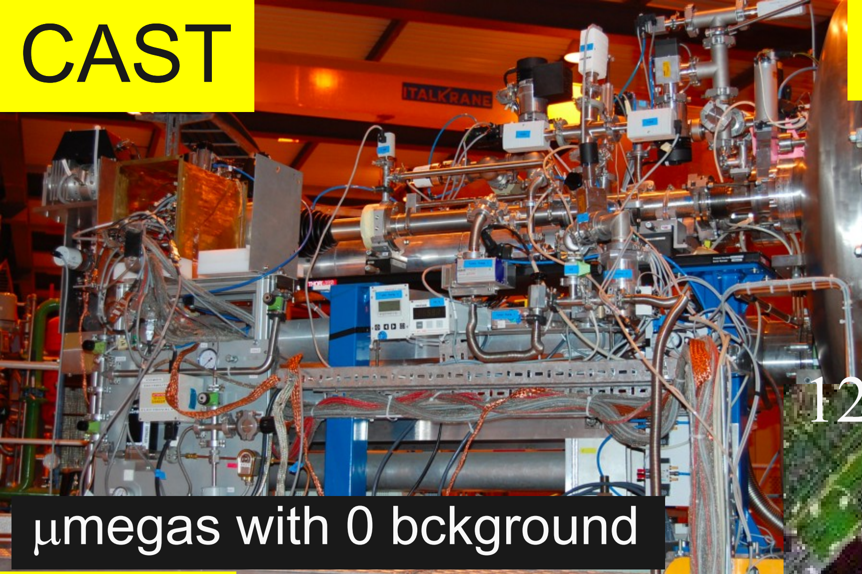
Track in test beam: cluster counting

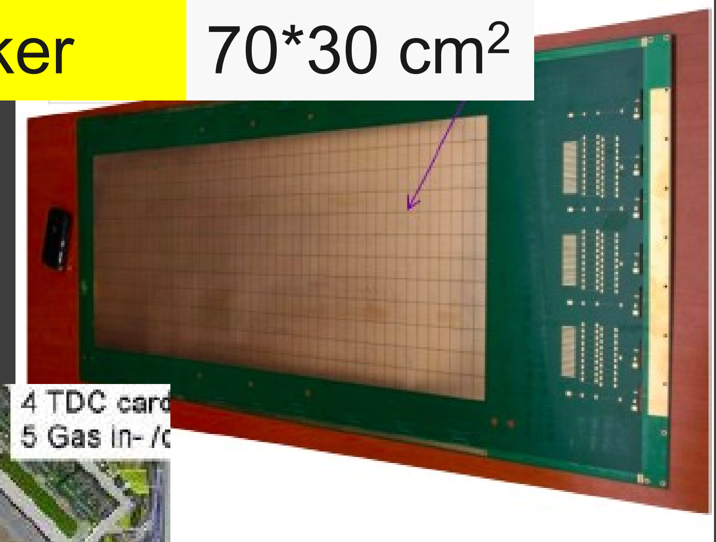


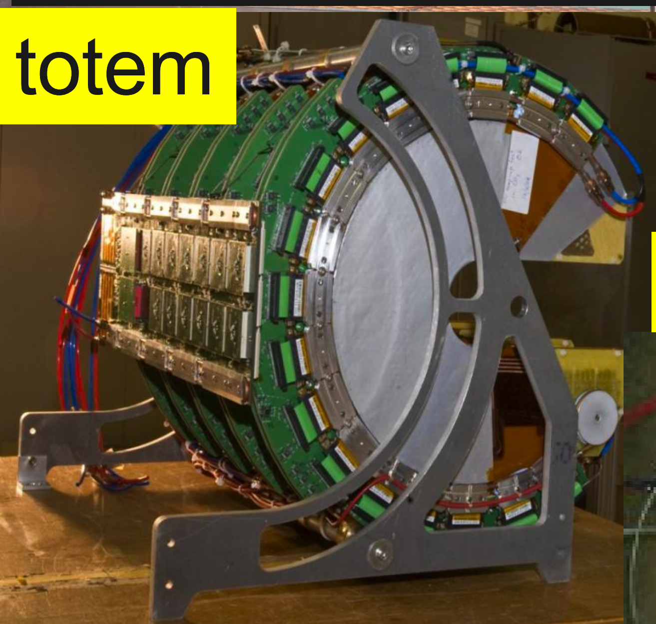


Candidate for VERTEX at sLHC?

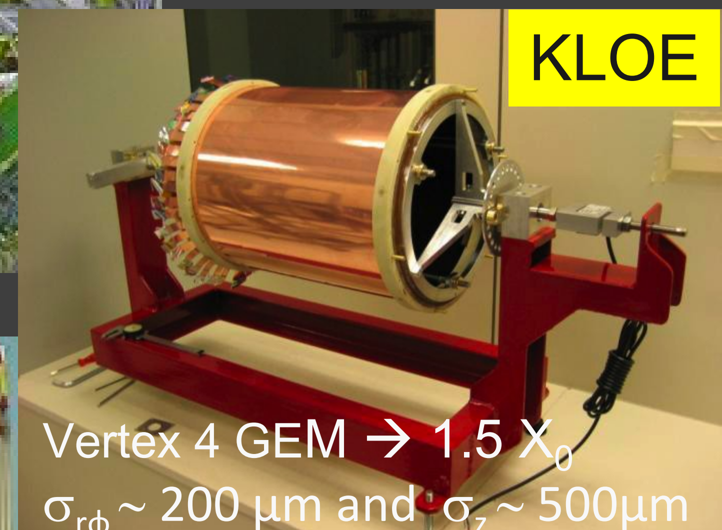
1. Precise coordinate measurements.
2. Vector track reconstruction.
3. Very good multi-track resolution.
4. dE/dX measurements
5. L1 trigger possibilities for high Pt

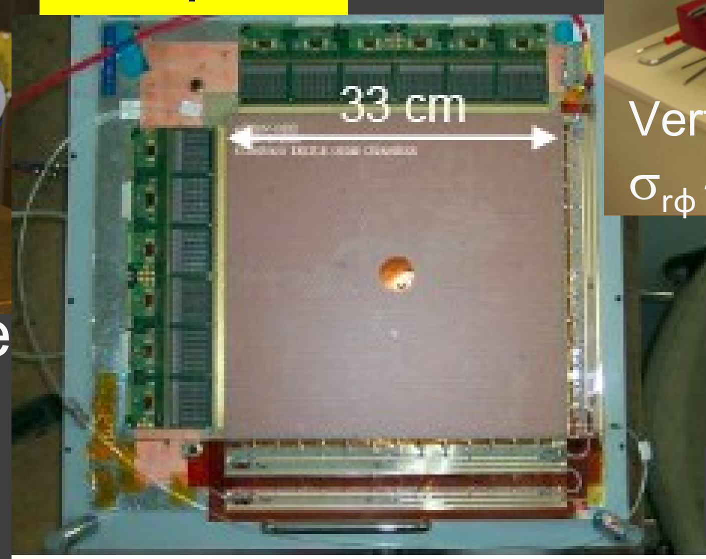






GEM 30 cm diamete





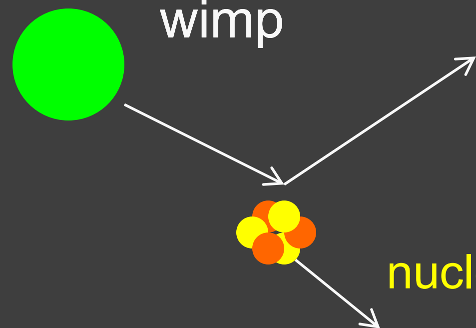
33 GEM 25 KHz/mm^2

Dark matter searches

candidates: WIMPs, axions, gravitinos.......

signal

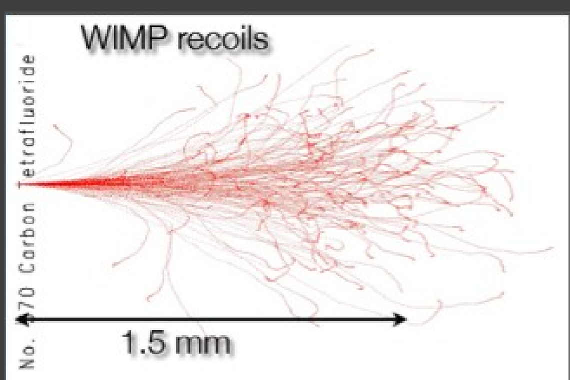
wimp

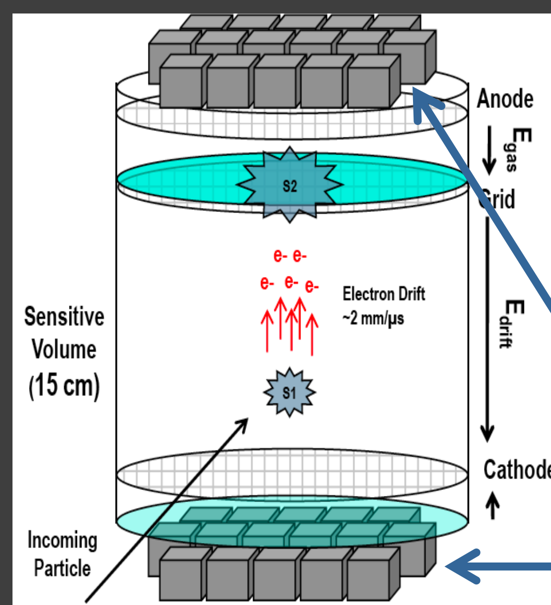


nuclear recoil E~O(10kev)

ArDM

TPC filled with liquid Xe, Ar





~GEM

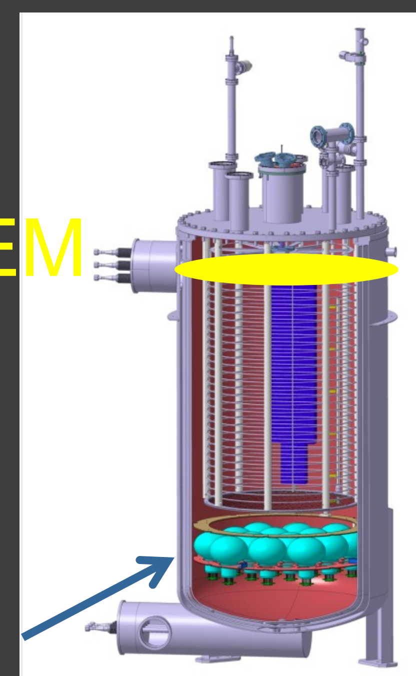
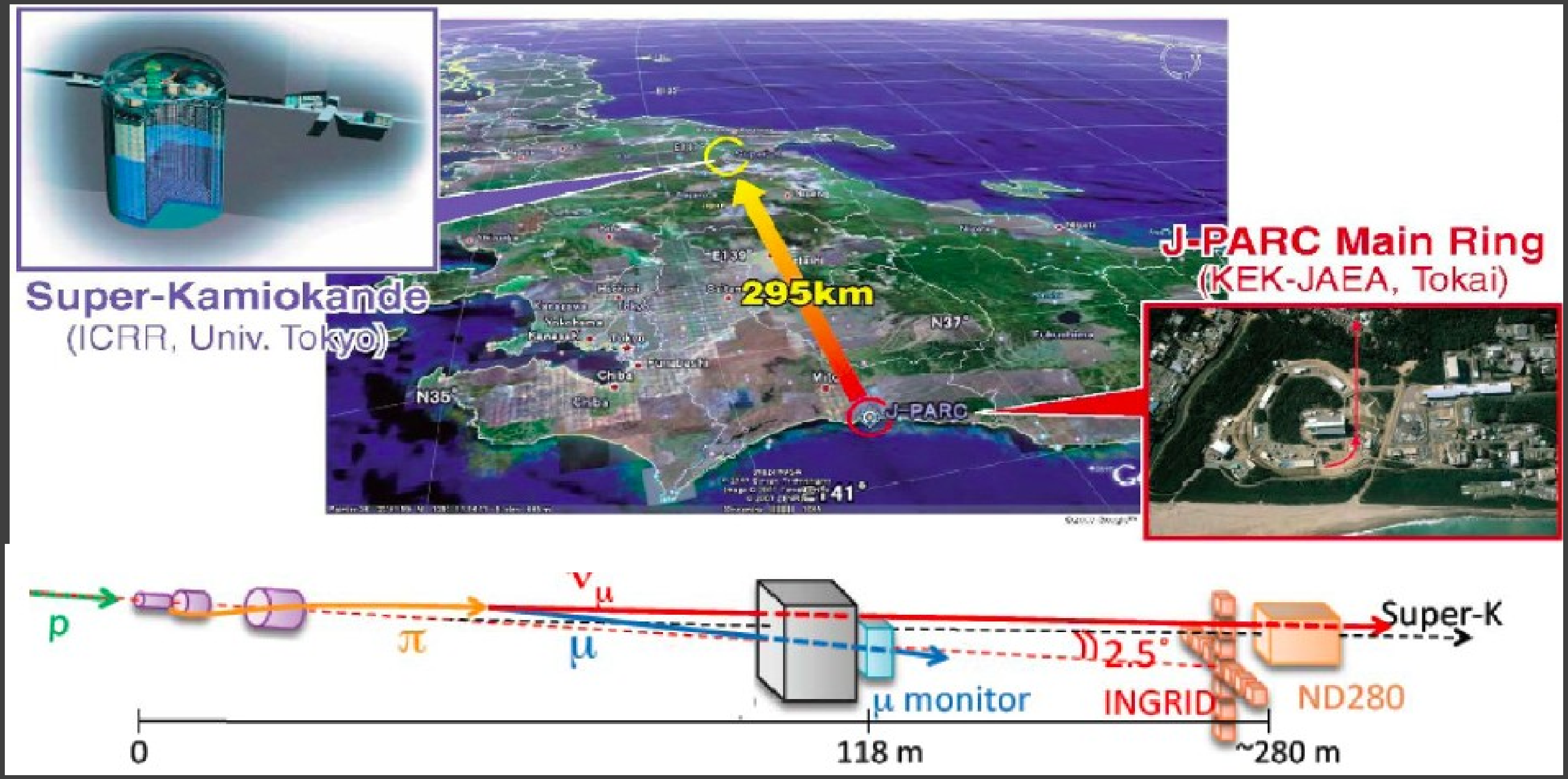


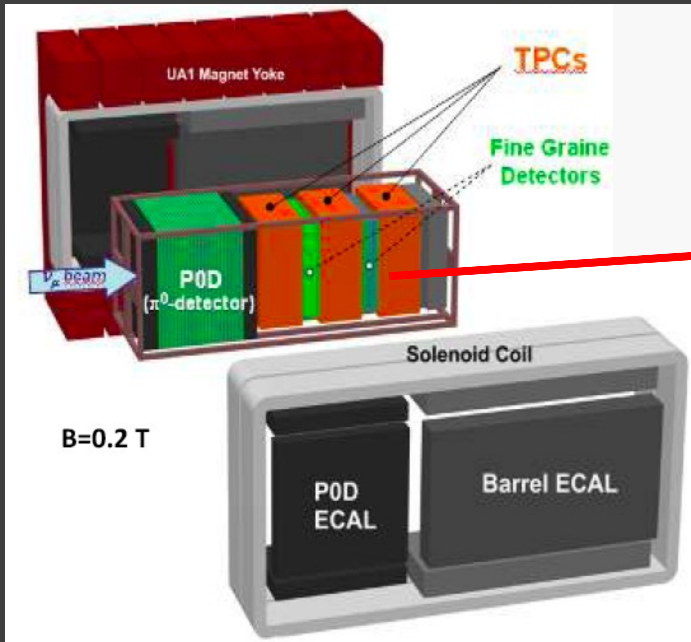
Photo multipliers

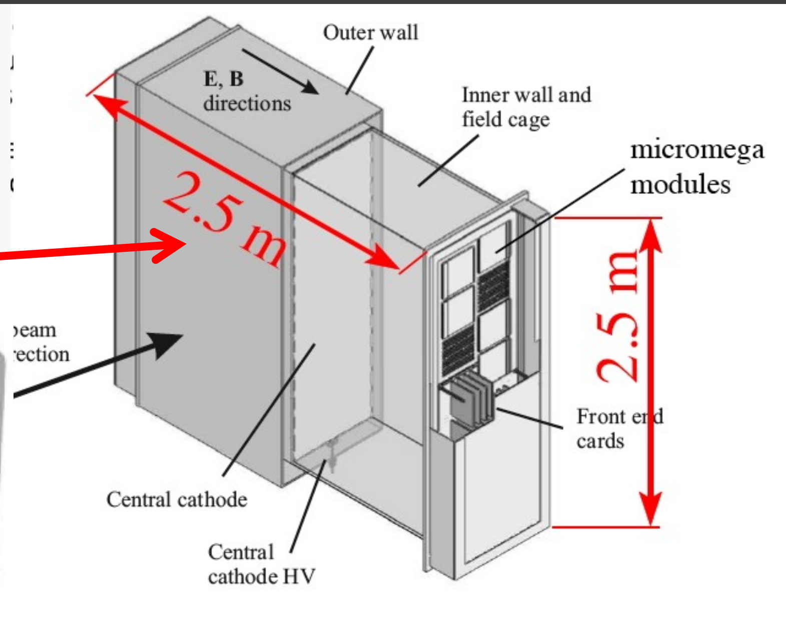
ν oscillation experiments

T2K look for $\nu_\mu \rightarrow \nu_e$ appearance

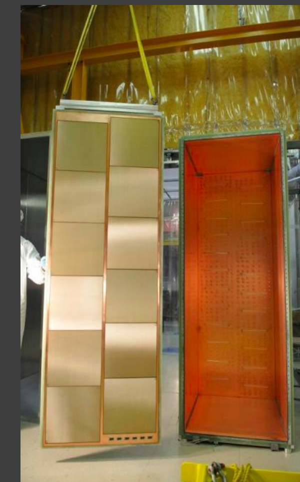


Comparisons of the spectra collected in the two apparatus allows for precise extraction of ν⌠ disappearance

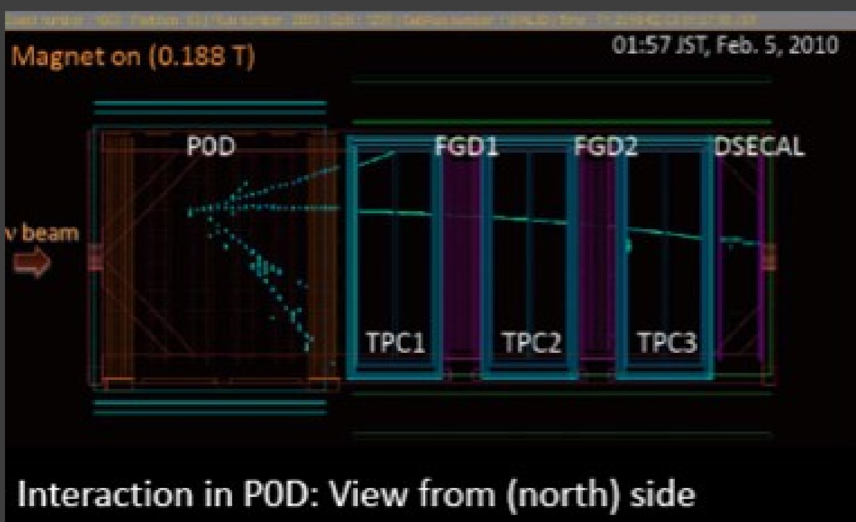


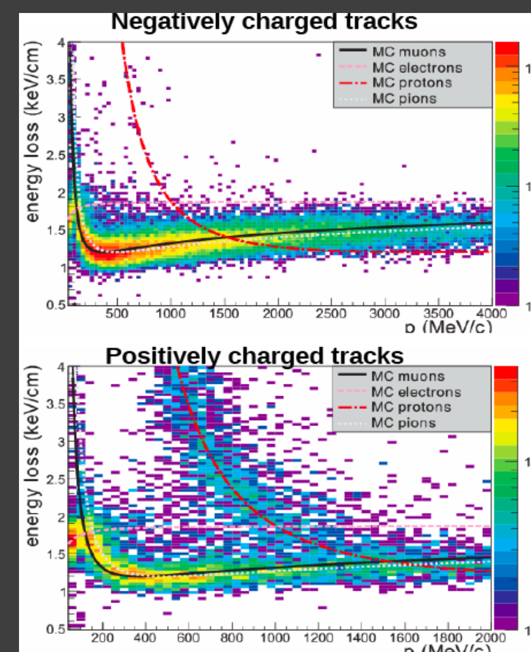


72 μmegas
35*35 cm²



dE/dx < 10% δp/p < 10% @ 1GeV/c

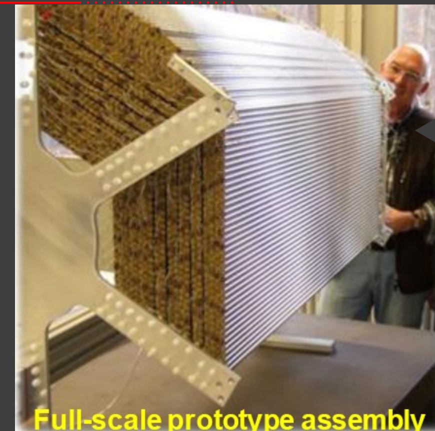




PANDA: TPC+GEM or straw tubes?

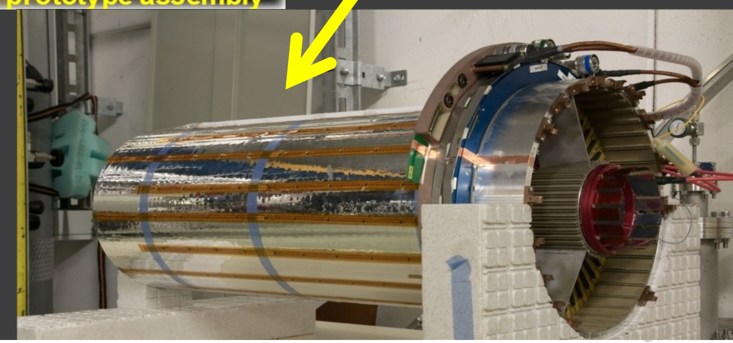
pp annihilation at antiprotonbeams at FAIR -GSI

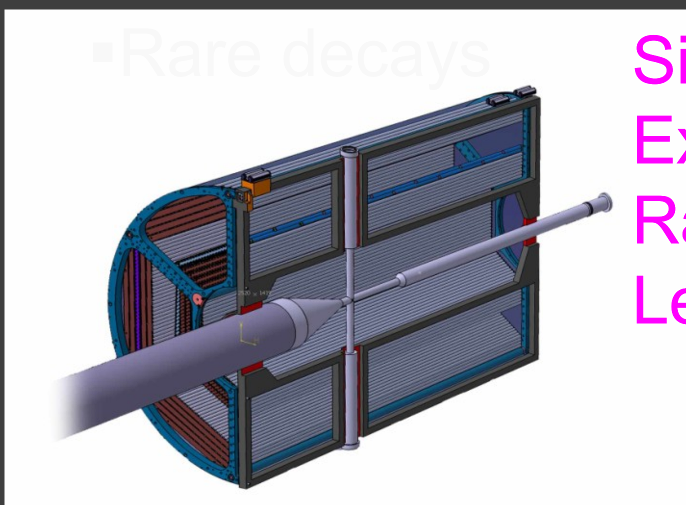
- Hadron spectroscopy
- Nucleon structure
- CP violation
- Rare decays



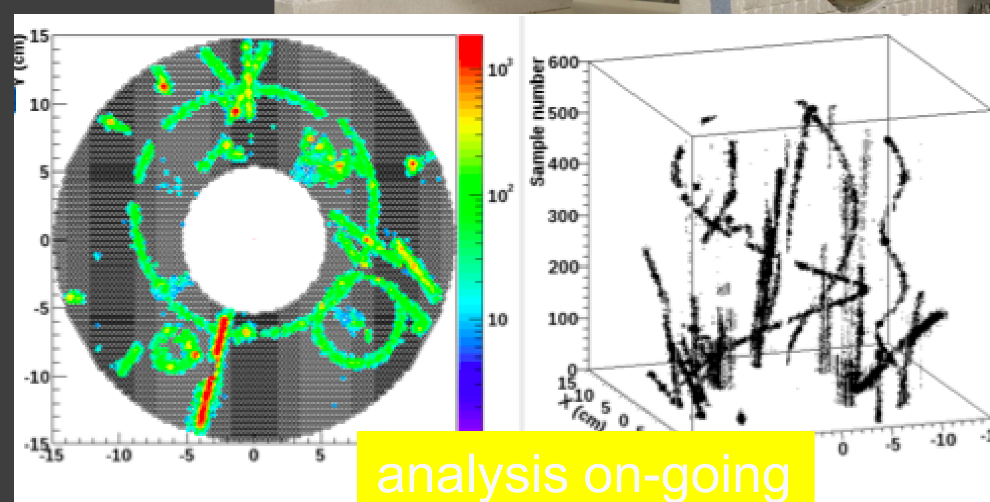
Straw

TPC





Si vertex
External Tracker
Radius = .5 m
Length = 1.5 m

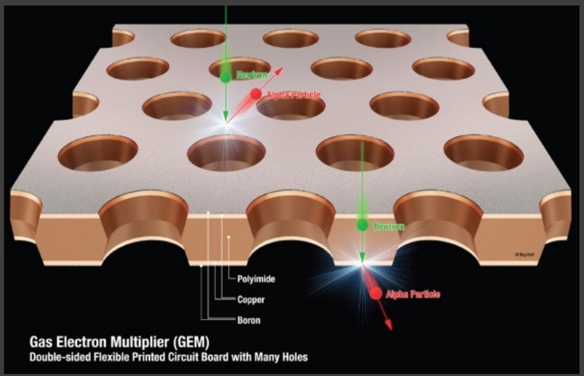


analysis on-going

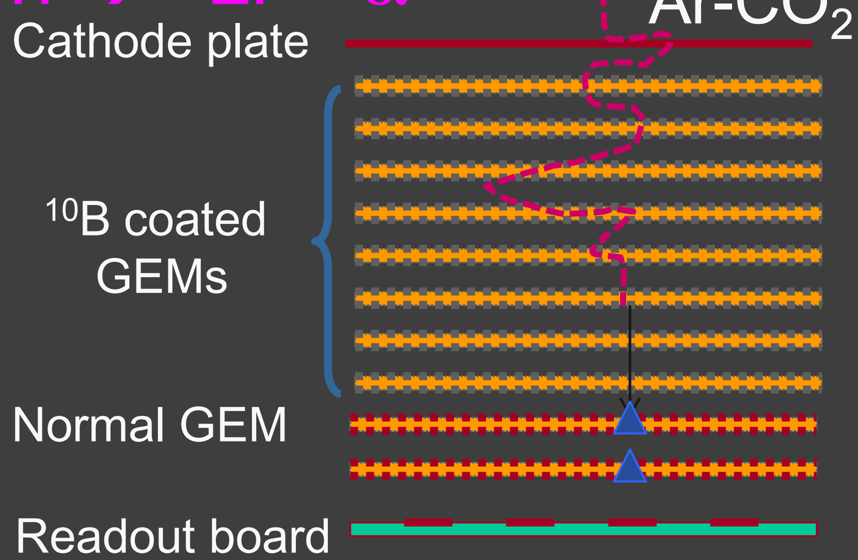
- High rate capability: $2x10^7$ interaction/s
- Momentum $\Delta p/p$ ~ 1%
- $\sigma_{r\phi}$ ~ 150 μm σ_z ~ 1mm

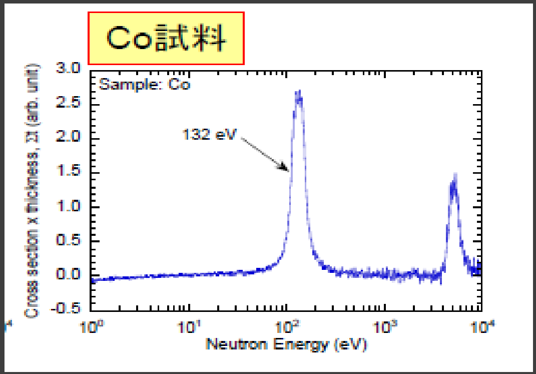
GEMs for neutron detection

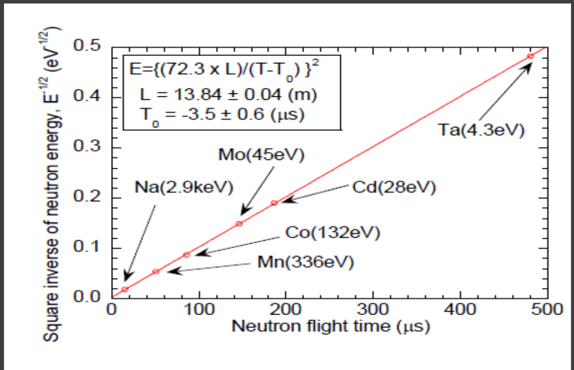
Basic reaction: $^{10}B + n \rightarrow {}^{7}Li + \alpha$



Both sides of a GEM are coated with few μm of ^{10}B



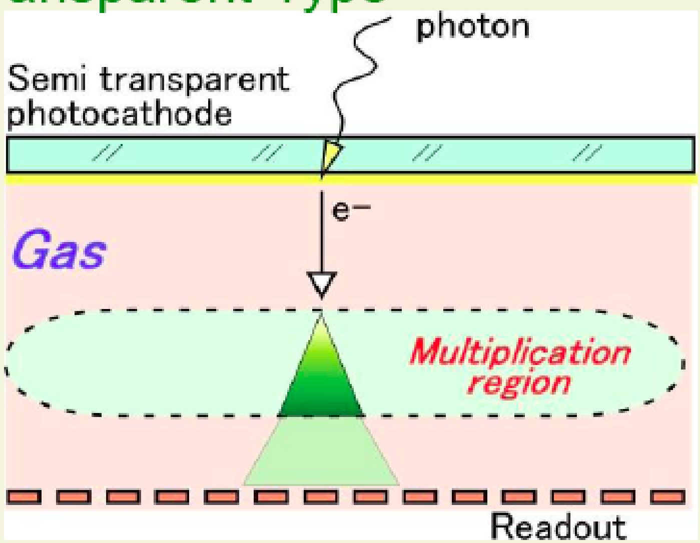




Implemented for radiography of materials

Gas PM with MPGD

Transparent-Type



Photons are converted to electrons by photoelectric effect .

Photoelectrons are multiplied in a high electric field in the gas.

Signals are formed on the anode pads.

- Can be operated in a high magnetic field (~1.5T)
- Can achieve a very large effective area
- Low cost per channel

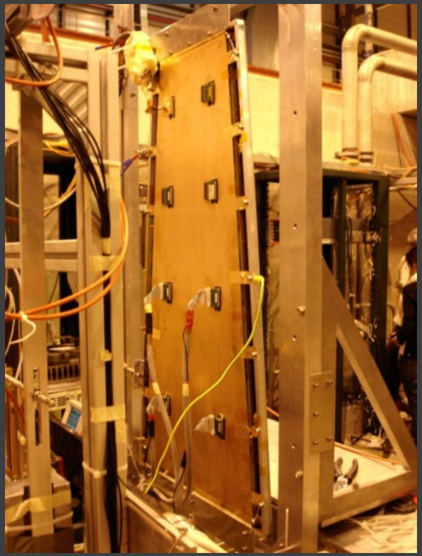
-- feedback problem almost solved

Implemented for PET and MRI at industrial level

Consideration on size and industrial production

Achieving large sizes with “in-house” production open the road for the use of MPGD in future colliders detector

μmegas mesh
for ATLAS
1.2 * 0.6 m^2



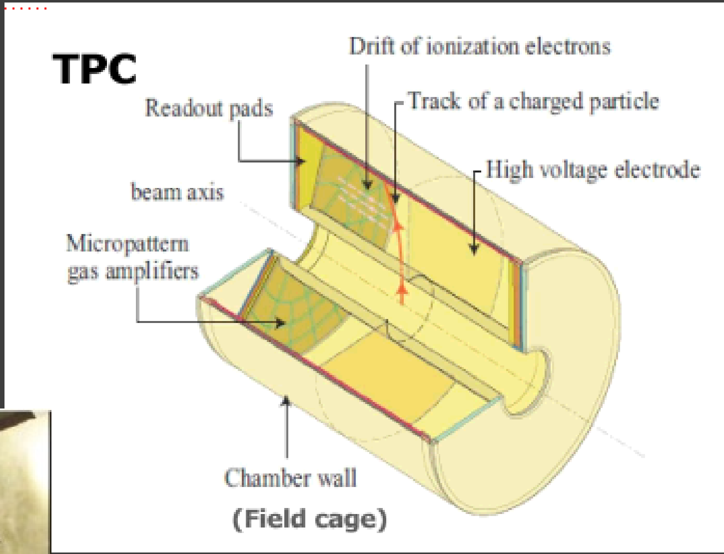
3 stage GEM
for CMS
1.2 * 0.6 m^2

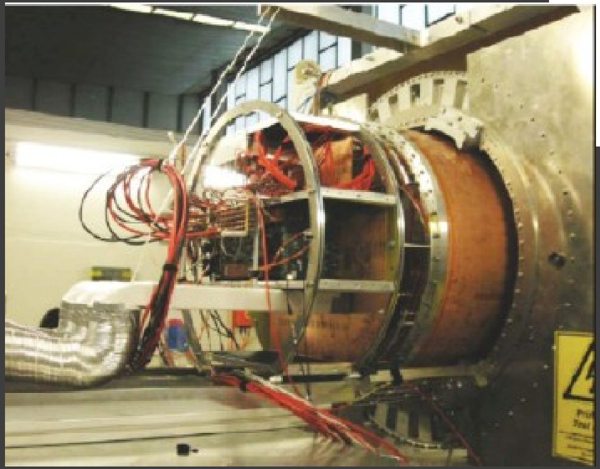
TH-GEM
for COMPASS
0.6 * 0.6 m^2

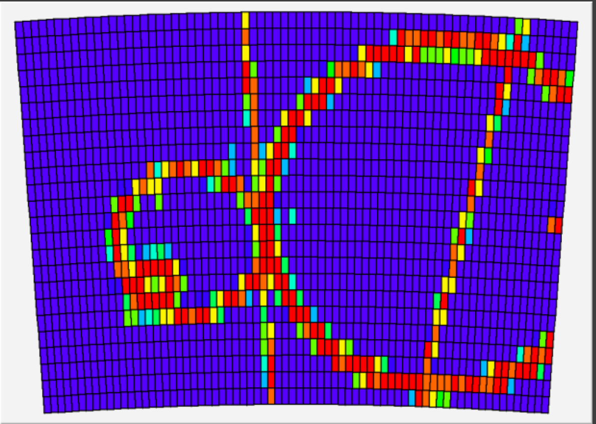
8 industries are looking into serial production → run in 2011

Tracker: TPC for ILD detector at ILC

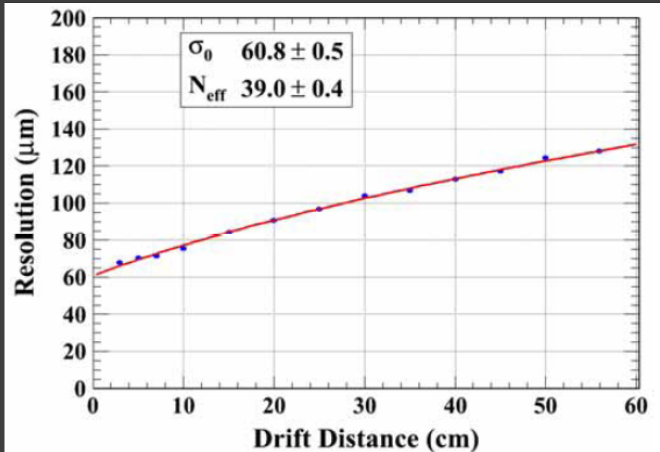
'Large' prototype made
- D = 0.7 m, L=0.6 m
- Beam test under 1T
- Both GEM and μMEGAS
    - ion feedback
    - thin endplates





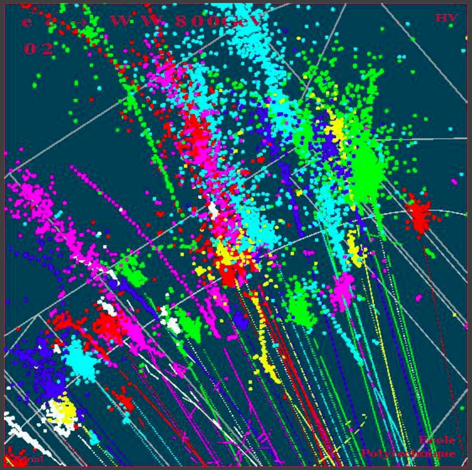


μmegas: 60 μm resolution at 0 drift with 3 mm pads !



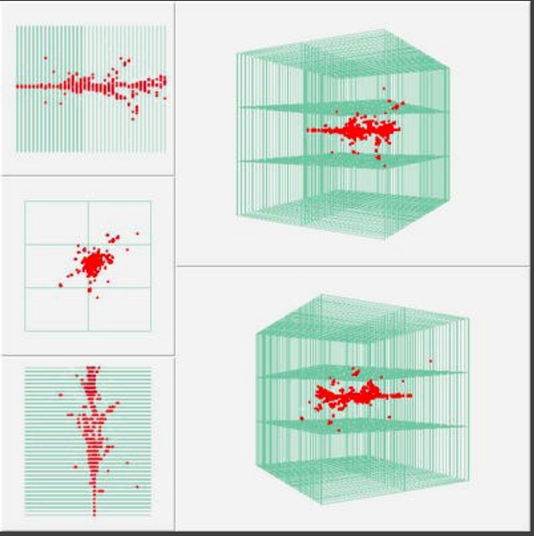
Calorimeters for future accelerators

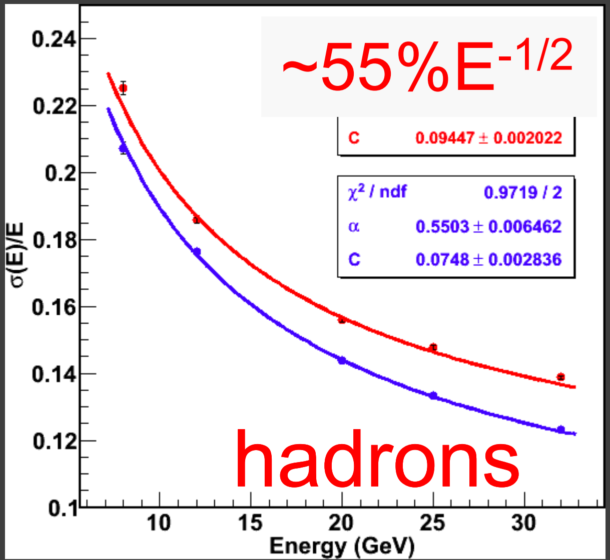
Current hadron calorimeters for LC: sampling of absorbers and scintillators, RPC, glass RPC

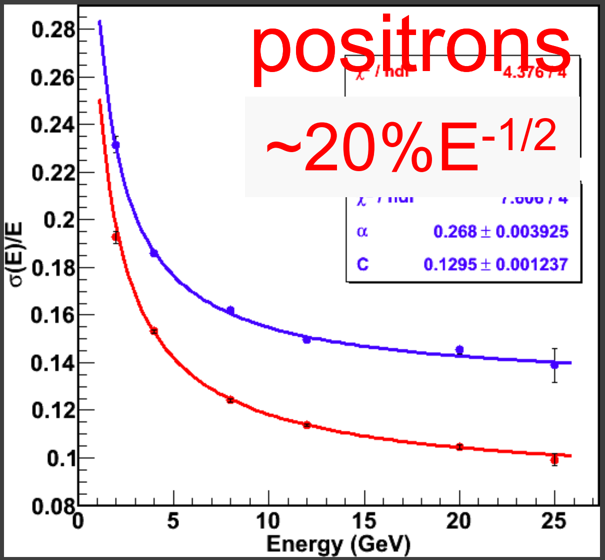


Read out will be digital or semi-digital with pad size 1*1 cm^2

Calice DHCAL with RPC



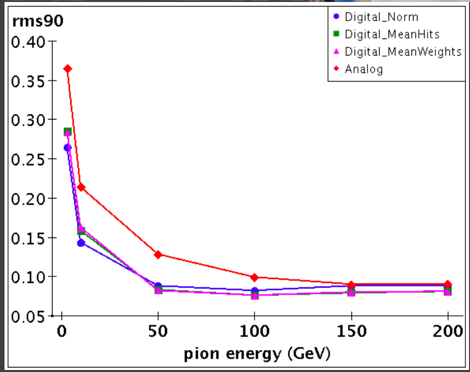




Calorimeters for future accelerators

Within CALICE collaboration, two digital calorimeters will be constructed and tested in the test-beam in August

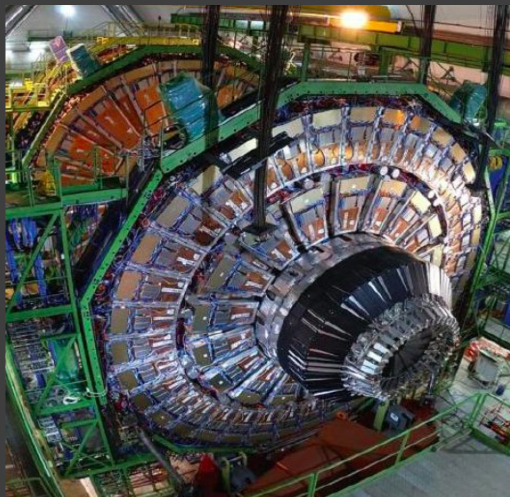
6 μmegas cover 1 m^2



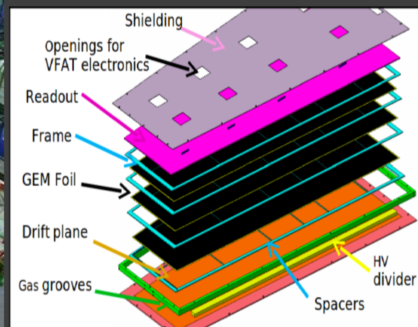
Expected from MC calculation $.28\text{-}.38E^{-1/2}$

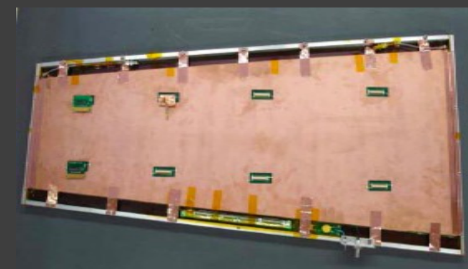
3 GEMs cover 1 m^2

Upgrades in LHC detectors at high-η



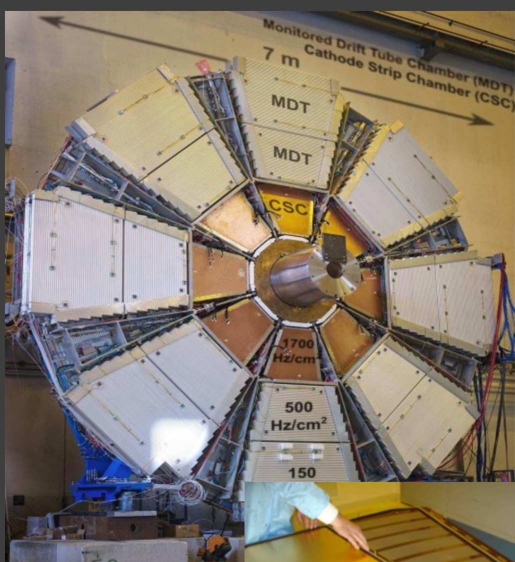
CMS →
thin RPC or large triple GEM??

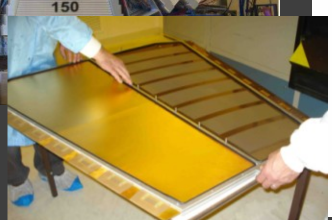




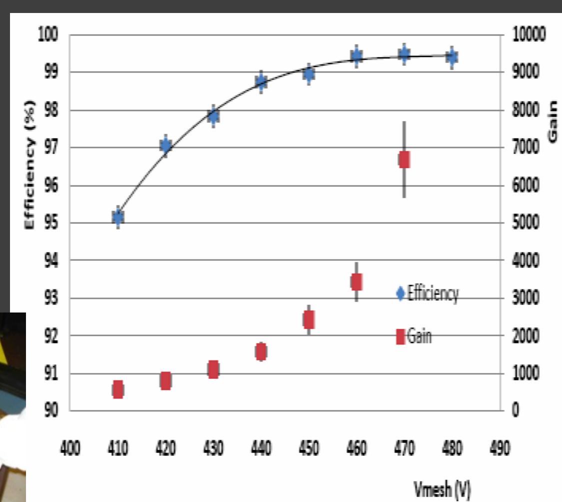
← 1 m →

σ_{sp}=300 μm
eff=98%

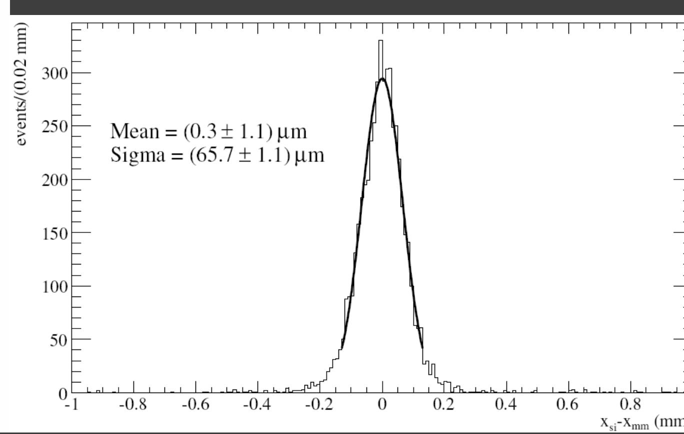




ATLAS CRC →
small r MDT, ThGC or μmegas



$\sigma_{\mu M}$ = (24±7) μm .25 mm pitch



Conclusions

- Micro Pattern Gaseous Detectors – GEM THGEM μmegas – have become established and reliable detectors
- They all have pros and cons → choosing one or the other is also a question of taste and philosophy
- Production of large size detectors by the industry is around the corner
  → excellent candidate for next generation digital calorimeter and tracking devices

SHALL I DO A BET ON THE NEXT TRACKER FOR CLIC???

TPC with a GOSSIP detection plane

Thanks to:

Alfonsi, Akimoto, Aprile, Arora, Attie', Beucher, Blaha, Bilki, Budnik, Cascade coll. Colas, Cushman, dalla Torre, de Oliveira, Epprecht, Giomataris, Hamamatsu, Iguaz, Jamieson, Karchin, Lippmann, Loomba, Matsumoto, Moulik, Musa, Peskov, Retiere, Ropelewski, Sauli, Smirski, Tessarotto, Titov, Uno,Van der Graaf, Veenhof, Wotschack, Yamaoka, Yu

Radon detection in air

homage to George C.

Rn can be found in basements and “can be emitted in air before an earthquake” → TH-GEM and other wire chamber operating in air can detect Rn concentration