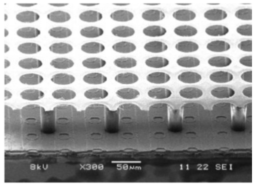
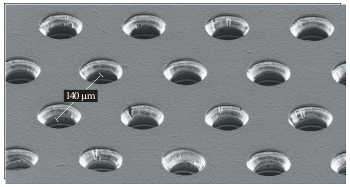




Micropattern Gas Detectors

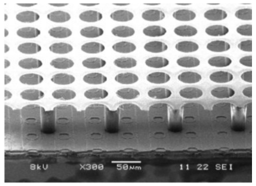
J. Kaminski
Universität Bonn

Vertex 2008, Utö, Sweden

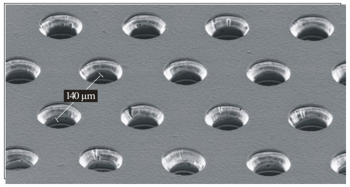
Bundesministerium für Bildung und Forschung

EUDET

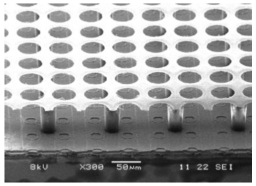
universitätbonn



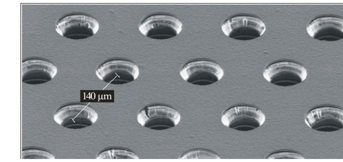
Contents



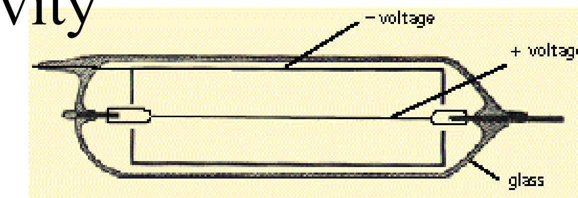
- Short Overview over (Micropattern) Gas Detectors - MPGDs
- Micromegas (MM) & Gas Electron Multipliers (GEMs)
- New Developments and Applications of MPGDs
- CMOS Pixel Readout of GEMs and MMs
- GOSSIP



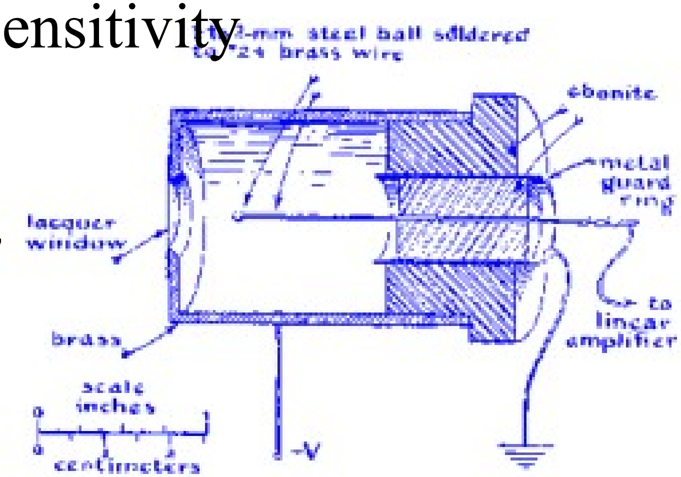
History of Gaseous Detectors



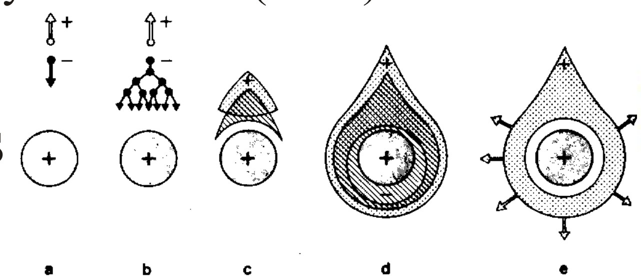
- 1908: First wire Counter
  used by Ruherford in the Study of natural radioactivity
  E. Rutherford and H. Geiger, Proc. Royal Soc. A81 (1908) 141



- 1928: Geiger-Müller Counter - single Electron sensitivity
  H. Geiger and W. Müller, Phys. Zeits. 29 (1928) 839

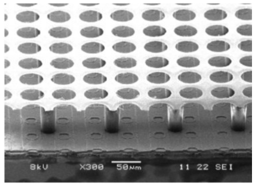


- 1945: Proportional tubes

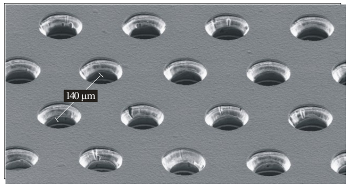


- 1967: Multi-wire Proportional chambers
  G. Charpak, Proc. Int. Symp. Nuclear Electronics (Versailles 10-13 Sept 1968)

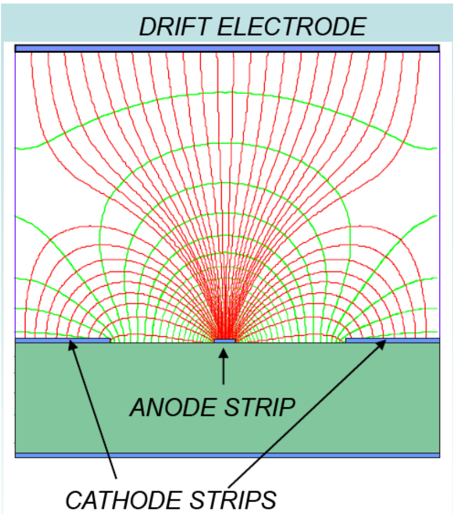
- 1974 Time Projection Chambers
  D. R. Nygren, LBL Internal Report (Feb. 1974)

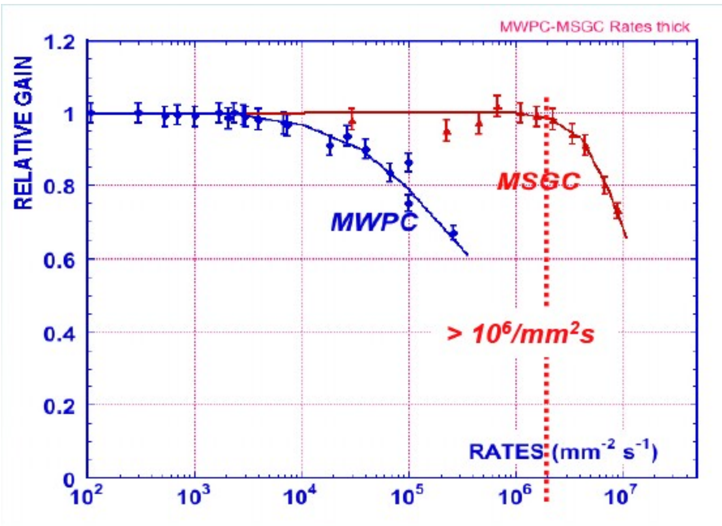


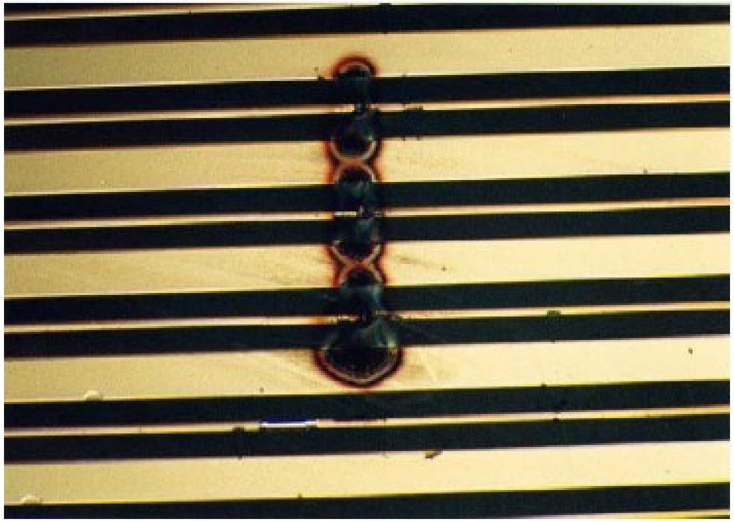
Historic Overview MPGD



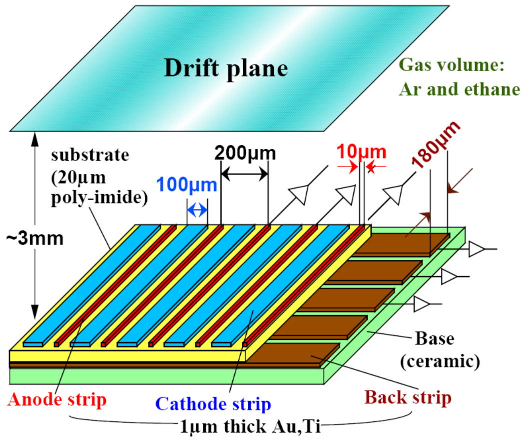
- In 1988 A. Oed introduced the age of micro pattern gas detectors.



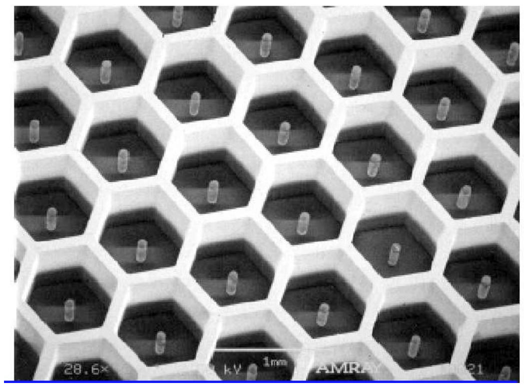




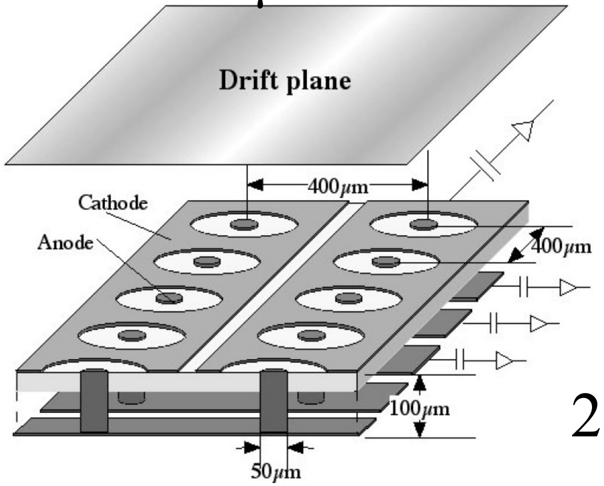
- Many new geometries were tested, …



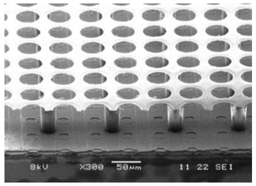
MICRO-PIN ARRAY (MIPA)

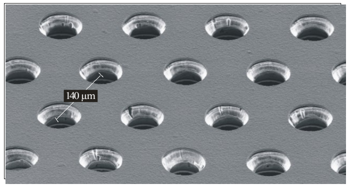


µ-PIC



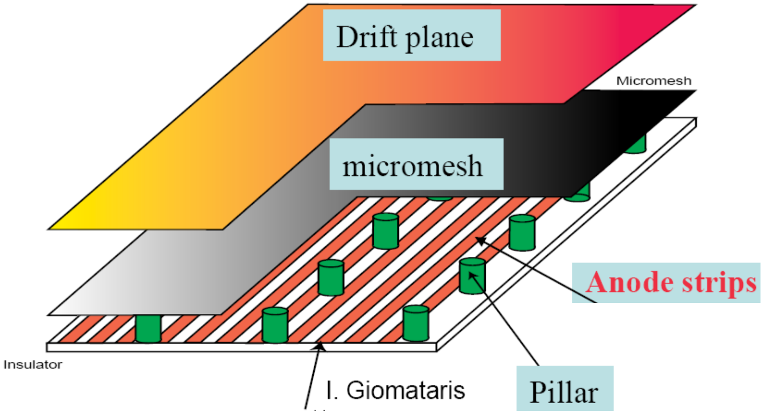
but only
2 prevailed

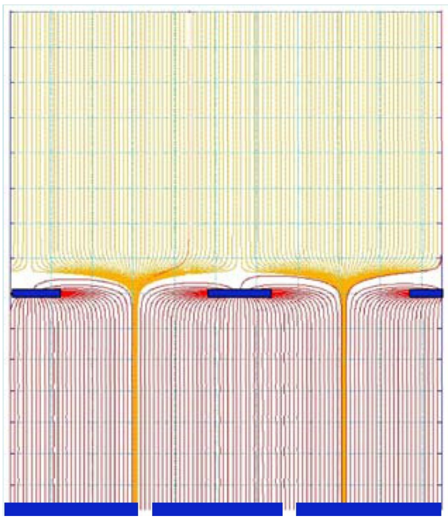




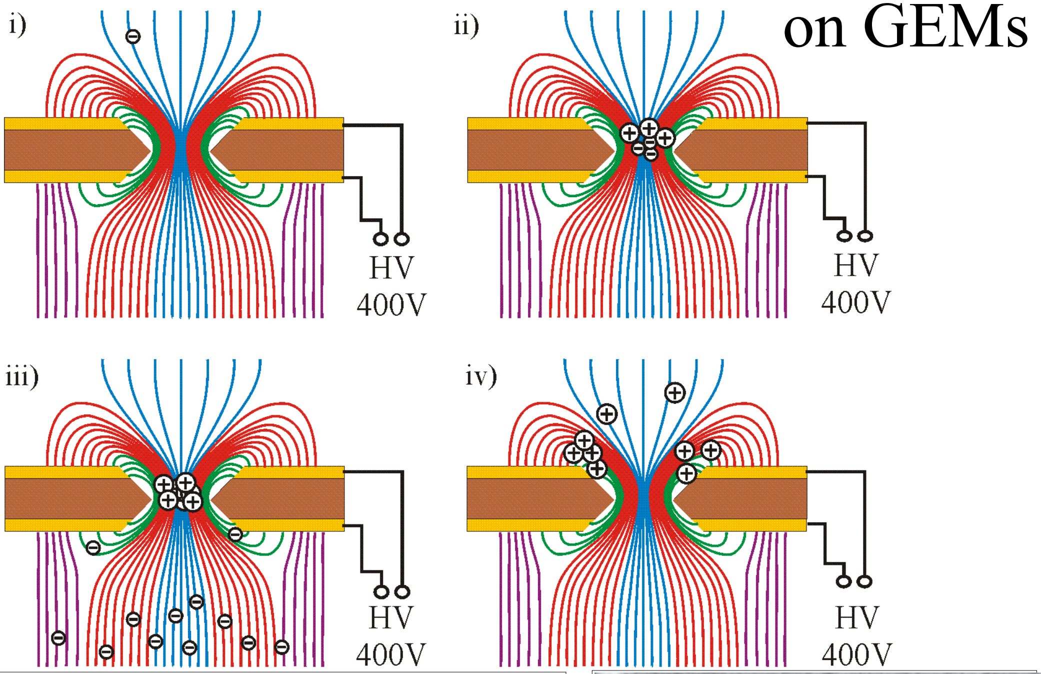
The 2 Favorites: Micromegas & GEMs

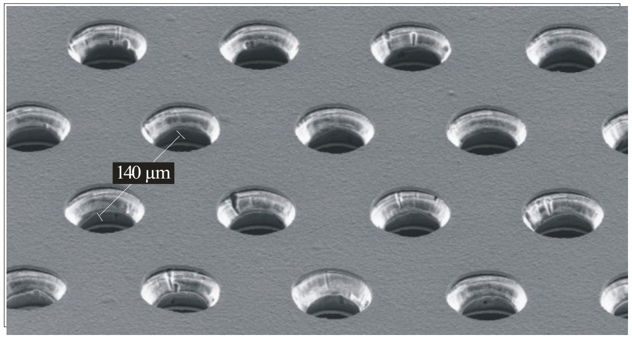
1996 first publication of MM

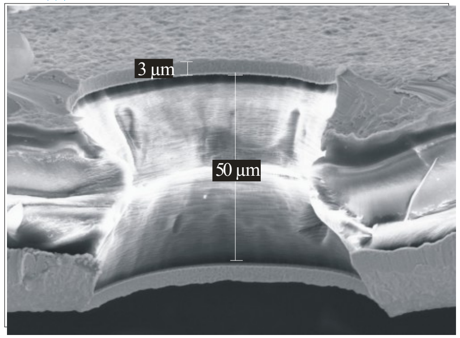


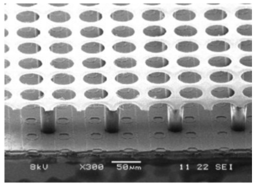


1997 F. Sauli publishes first paper on GEMs

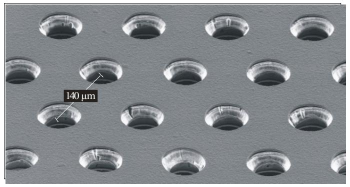




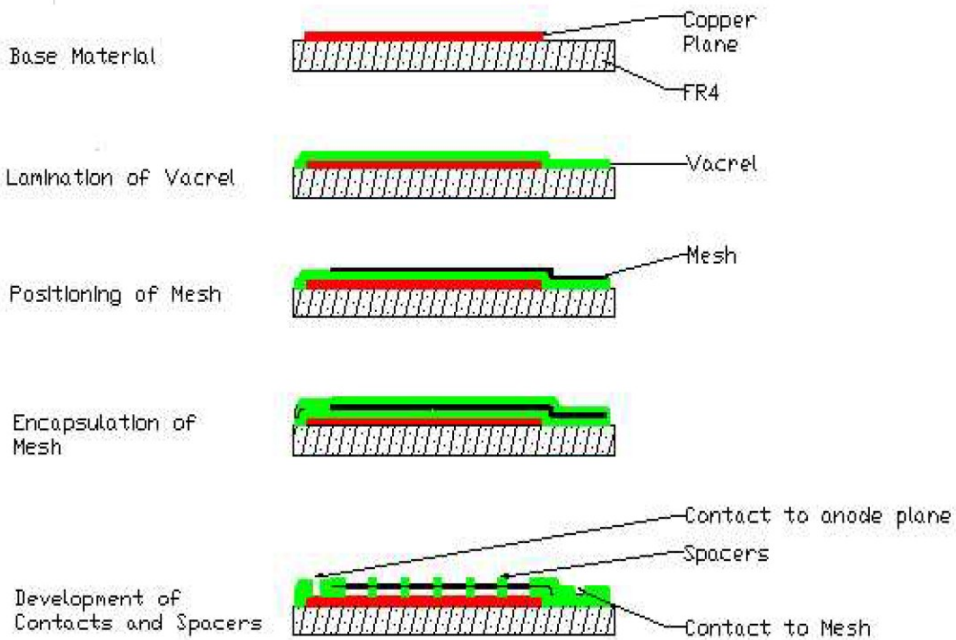




Micromegas



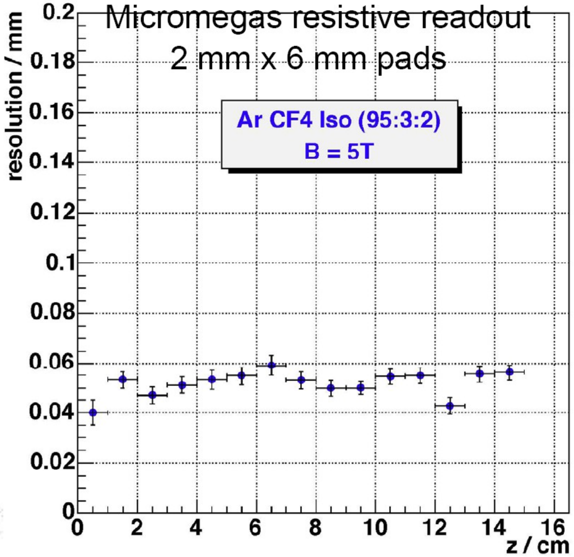
Bulk-Micromegas



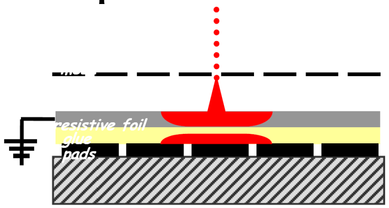
- Bulk Micromegas obtained by lamination of a woven grid on an anode with a photo-imageable film

large area and robustness
easy implementation
low cost
industrial process

B= 5 T D_T= 19 µm/√cm
M. Dixit et al., NIM581(2007)254-257

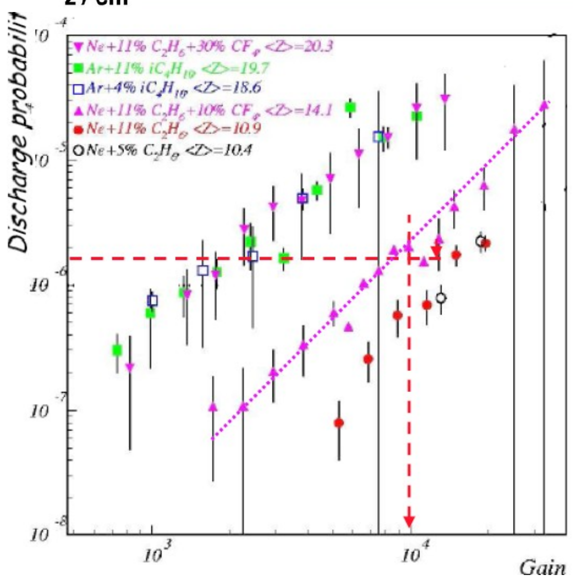


Cover readout pads with resistive foil to broaden signal shape



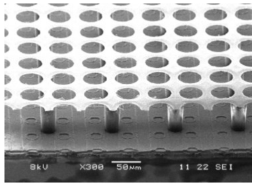
M. Dixit et al., NIM581 (2007)254-257

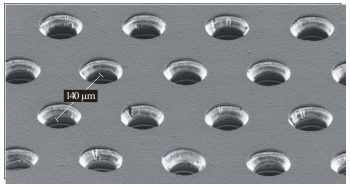
discharge probability at COMPASS tracker: $\sim 10^{-6}$



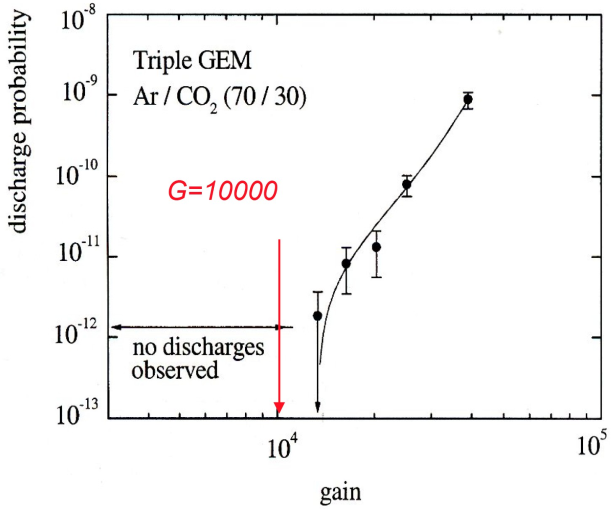
T2K Micromegas TPC:
about 12 m^2 detector surface

GEMs

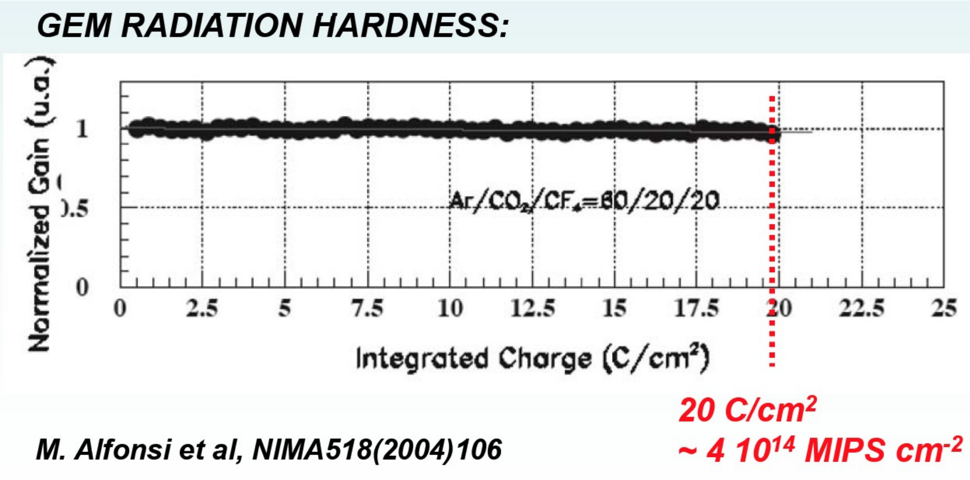




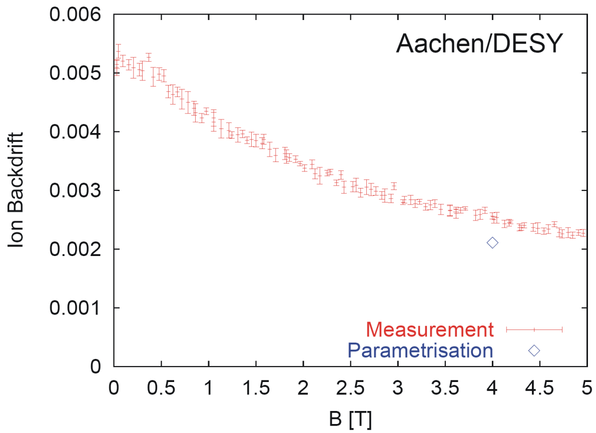
- A large number of experiments have lead to a fair understanding of the enormous parameter space in GEM-detectors.



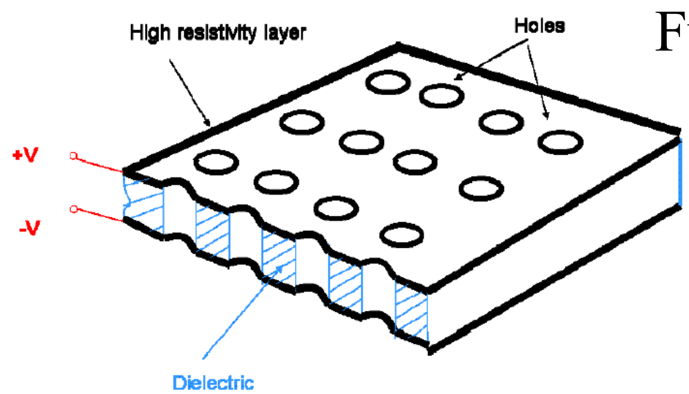
discharge probability at COMPASS tracker: $<10^{-12}$



low ion backflow

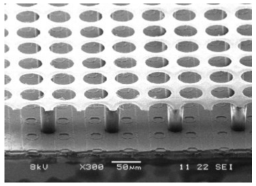


There are many modifications e.g. the RETGEMs

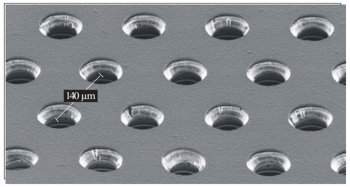


Fully spark protected detector

geom. and elec. characteristics:
0.3-0.8 mm, pitch 0.7- 1.2 mm, thickness 0.5-2 mm.
Resistivity:200-800kΩ/cm
Kapton type: 100XC10E

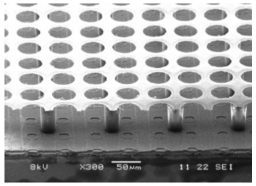


Advantages of MPGD

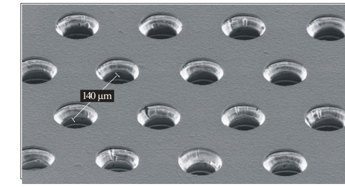


- ion backflow can be reduced significantly
  => continuous readout is possible
- small pitch of gas amplification regions (i.e. holes)
  => strong reduction of ExB-effects
- no preference in direction (as with wires)
  => all 2 dim. readout geometries can be used
- no ion tail => very fast signal (O(10ns))
  => good timing and double track resolution
- no induced signal, but direct e^--collection
  => small transverse width
  => good double track resolution

<u>Applications in</u> thin tracking devices - e.g. COMPASS
photon detection – e.g. CAST, Weizmann Institute
large volume drift chambers – e.g. TPC



COMPASS Upgrade

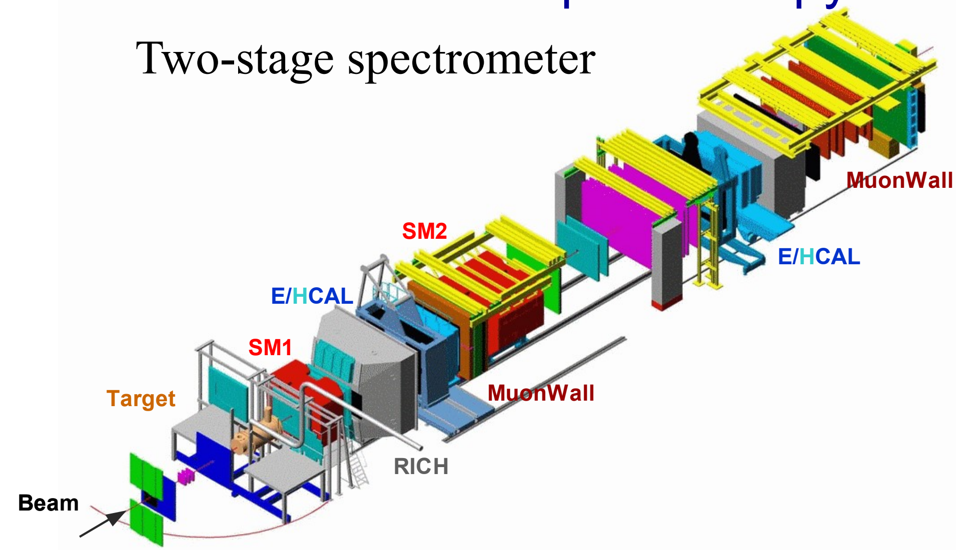


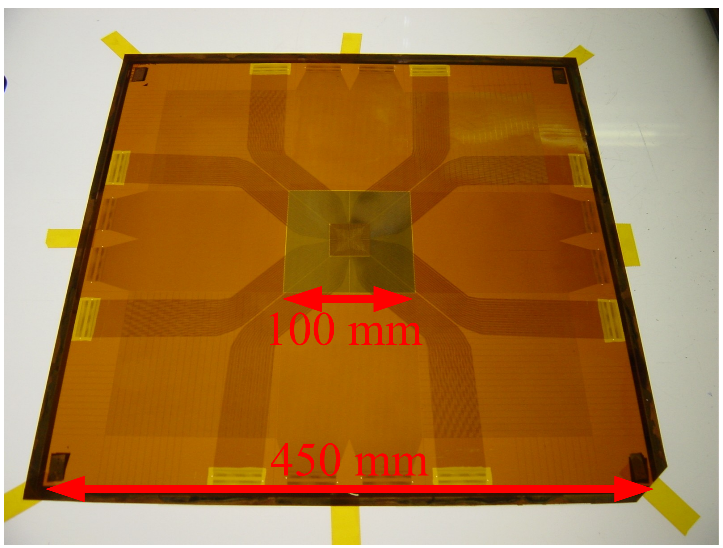
COmmon Muon and Proton Apparatus for Structure and Spectroscopy

Plans to upgrade the detector for 2008 beam tracking with GEM detectors:

- GEM material budget 0.4% X_0
- beam rate $2*10^7$ s^{-1}
- rate capability > 10^5 $mm^{-2}s^{-1}$

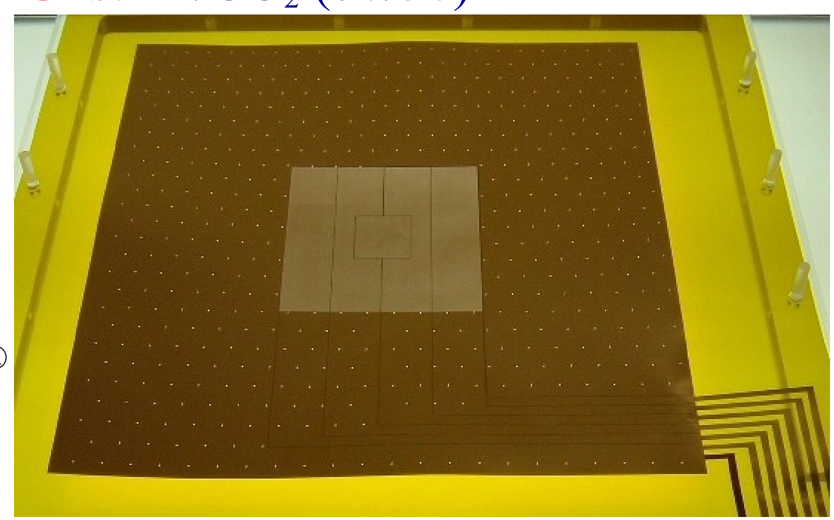
Two-stage spectrometer





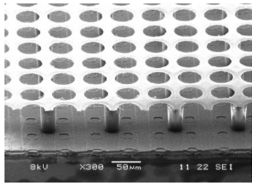
- 3-layer PCB, 100mm APICAL®
- center: 32×32 pixels, 1 mm^2
- periphery: 2×512 strips (2D)

Gas: Ar/CO_2 (70/30)

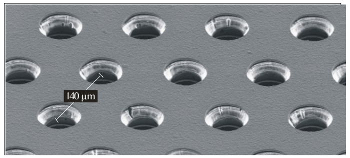


discharge prevention:

- triple GEM
- asymmetric gain sharing
- segmented GEM foils



COMPASS Beam Test Results



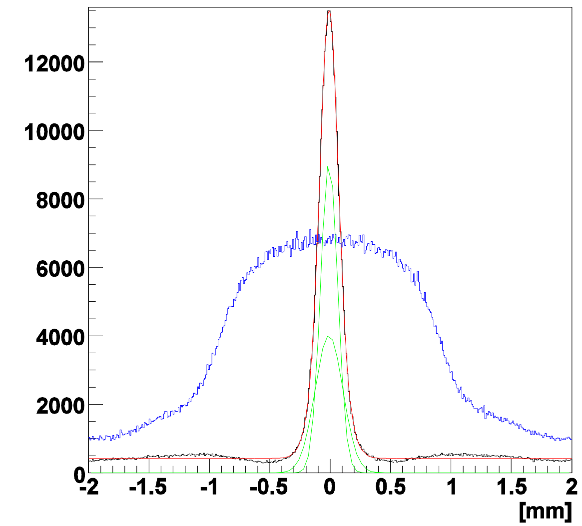
- beam test at CERN
- 160 GeV/c muons
- intensity $4.2 \cdot 10^7$/s
- up to $1.2 \cdot 10^5$ /mm^2/s
- 190 GeV/c π
- intensity 10^6/s
- up to $1.2 \cdot 10^4$ /mm^2/s

spatial resolution:

low intensity ($4*10^6$ µ/s): 90µm

high intensity ($5*10^7$µ/s): 135µm

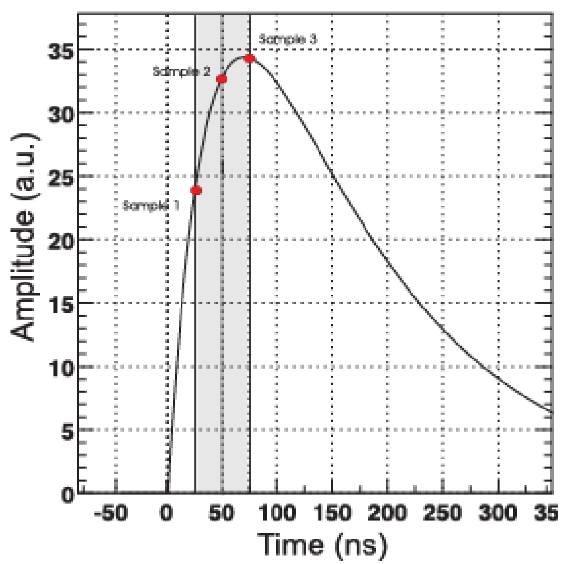
efficiency: 96% -98.5%

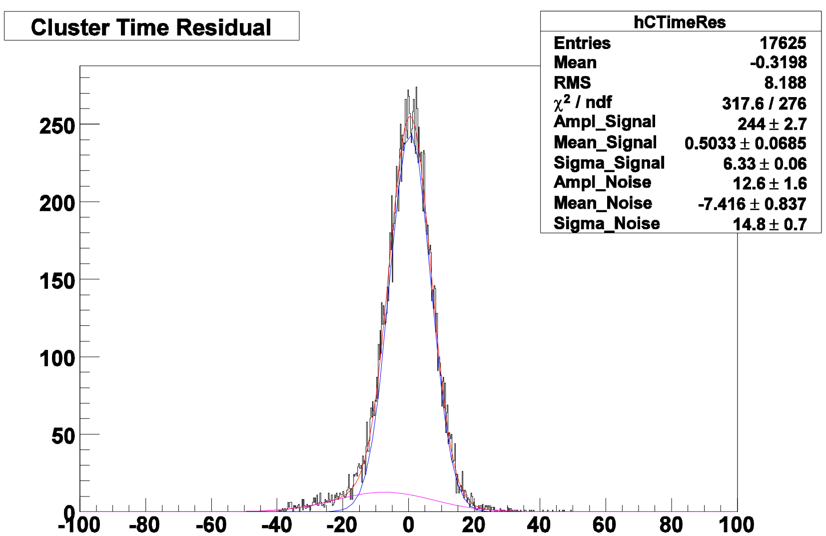


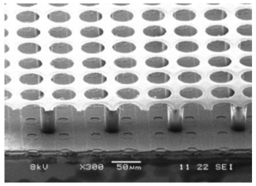
- time residuals:
- 3 samples of rising edge
- t_0 reconstructed from known pulse shape

low intensity ($4*10^6$ µ/s): 6.3 ns

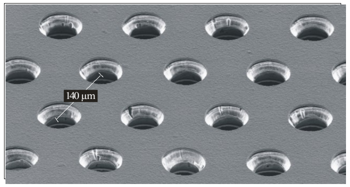
high intensity ($5*10^7$µ/s): 7.3 ns



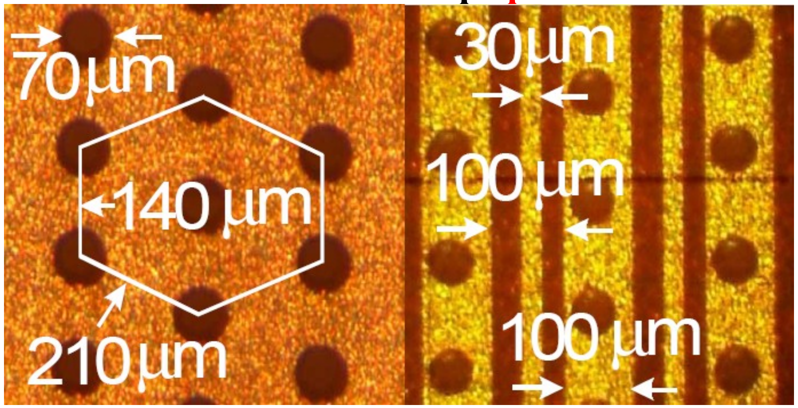


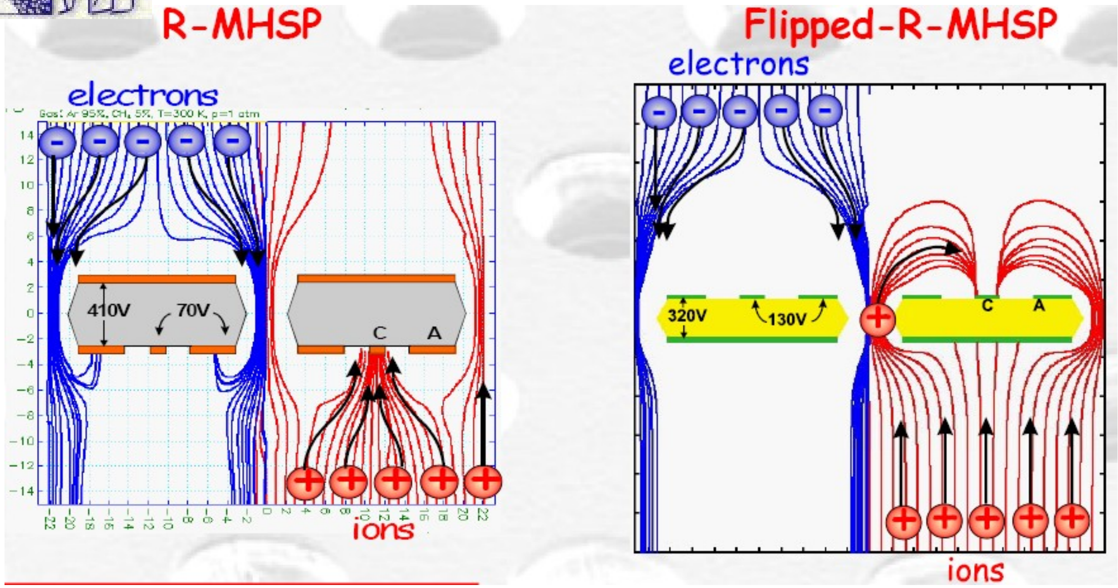


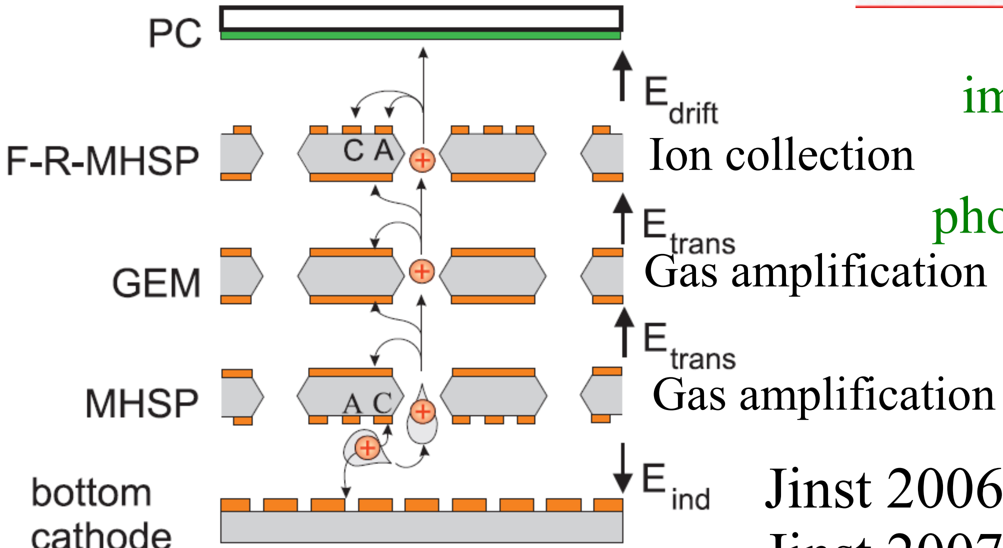
Reduction of Ion Backflow



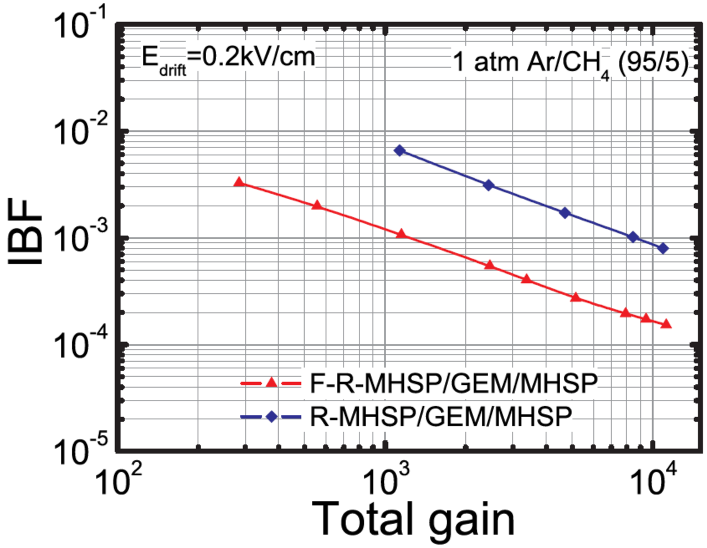
Microhole & Strip plate





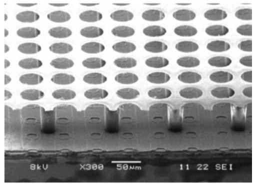


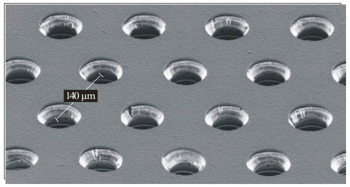
important for TPC and photon detectors



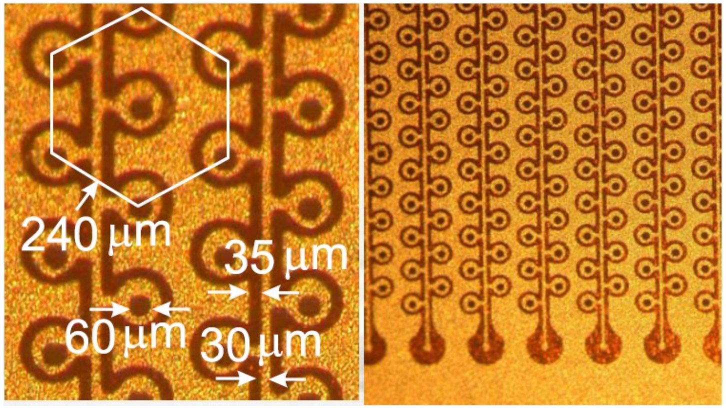
Jinst 2006 10 P10004
Jinst 2007 08 P08004

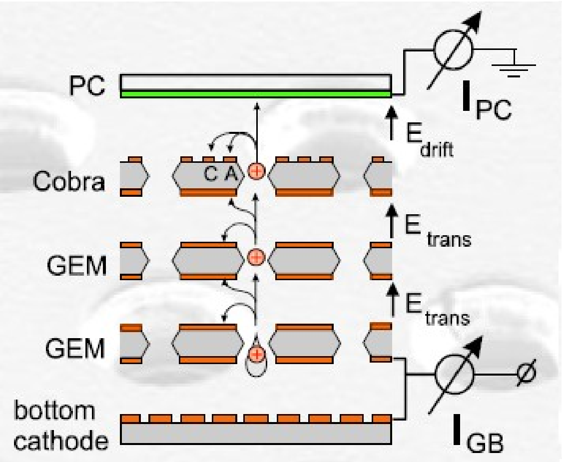
More on Reduction of Ion Backflow

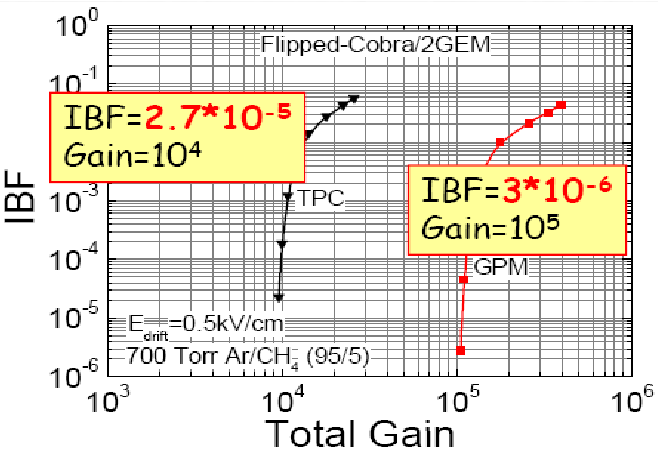




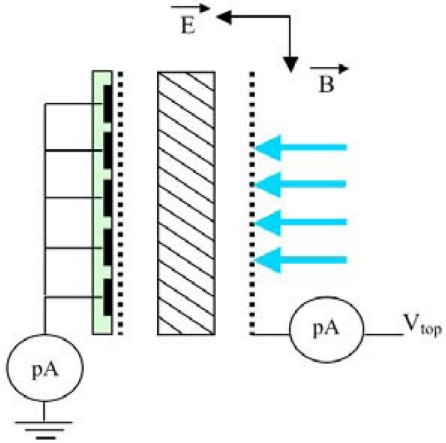
- COBRA

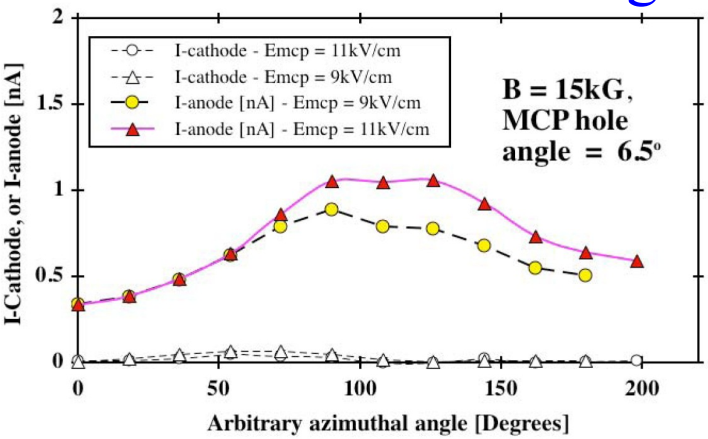






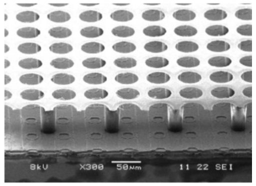
- Ion backflow = 0.0027%
  electron collection efficiency is only 20 %
- Microchannel Plates with inclined holes in magnetic fields



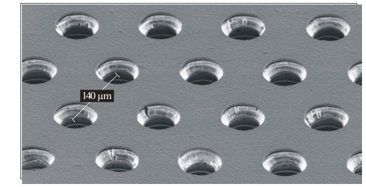


Lorentz-angle is used to neutralize ions

J. Va'vra, T. Sumiyoshi, NIM A 553 (2005) 76-84



TPC with MPGDs

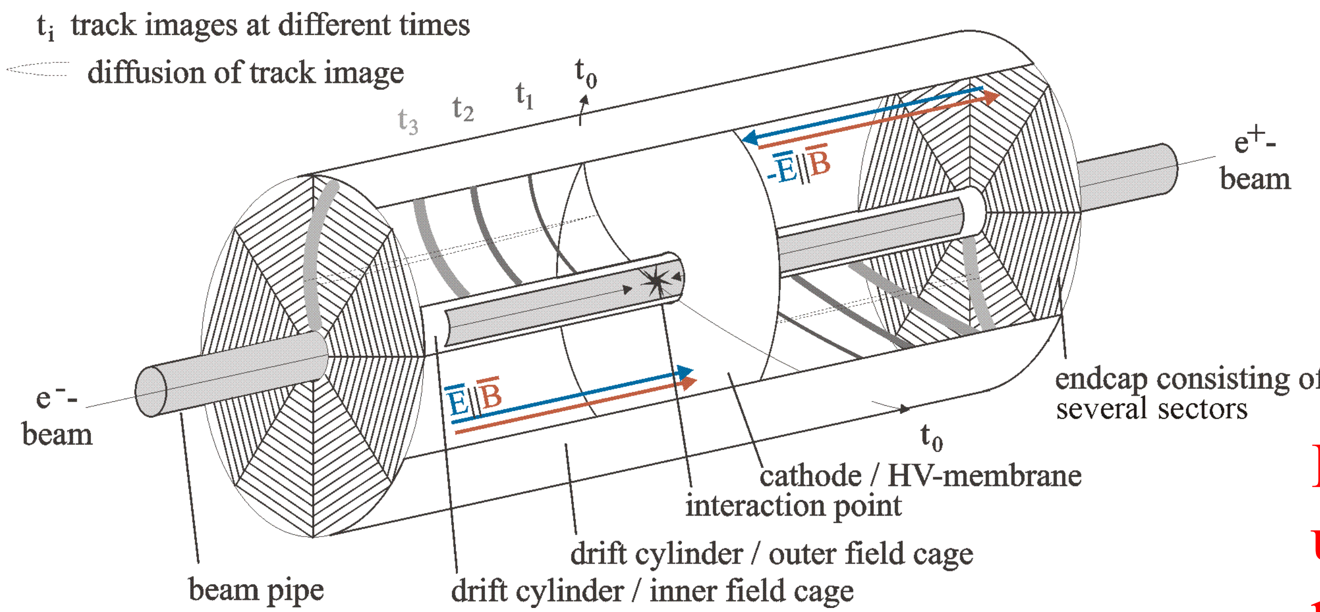


- good spatial resolution (O(100µm))
- large number of measurements (200)
- good energy resolution with dE/dx (5%)
- true 3-dimensional detector (no ambiguities)
- high granularity (10^9 voxels)
- low material budget ($3\%X_0$)
- very homogeneous (only gas)
- comparably cheap

Large number of experiments are designing and constructing TPCs with MPGD:

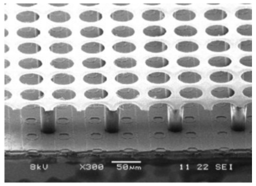
GEM: FOPI, PANDA, Crystal Barrel, ILC, MICE

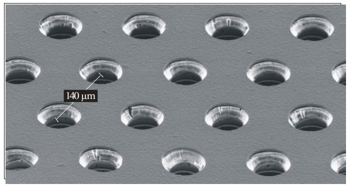
MM: T2K, ILC



Disadvantages:
- long drift times (40µs)
- ions have to be neutral-ized after gas amplification
- diffusion and pad size limits spatial resolution

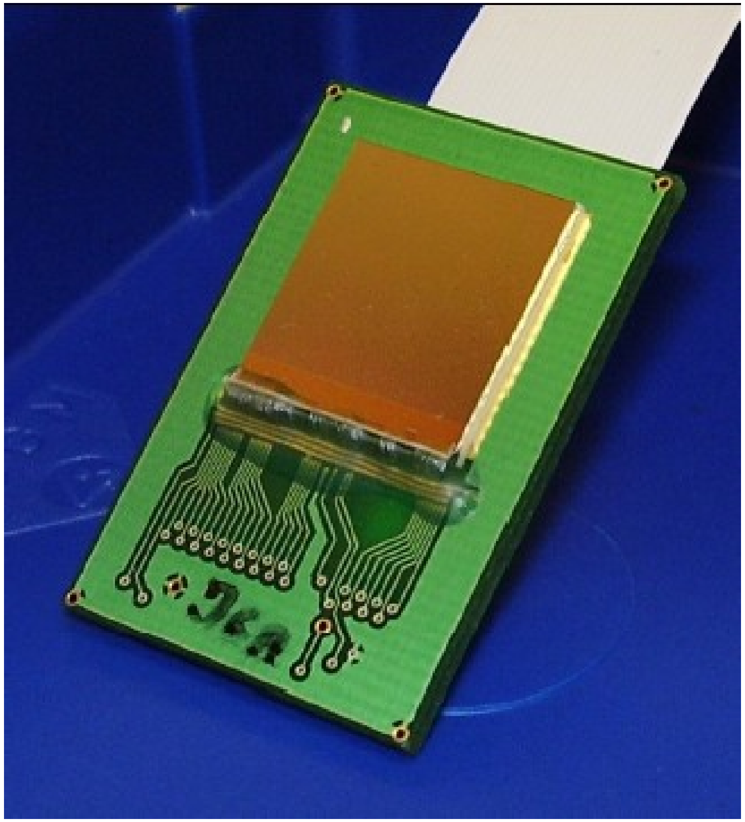
Improve spatial resolution: use 'naked' CMOS pixel readout chip as anode





TimePix

Timepix chip (1st version) derived from MediPix-2



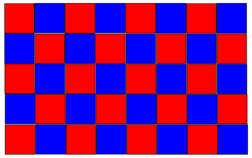
Available for detector tests since Nov. 2006

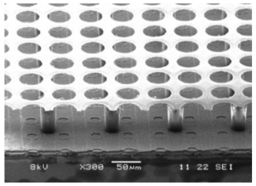
256 * 256 Pixel
Pixel size: 55 * 55 μm^2
chip dimensions: 1.4 * 1.4 cm^2

Each pixel can be set to one of these modes:

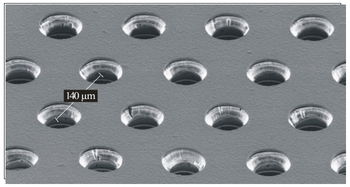
- Hit counting
- TOT = time over threshold
  gives integrated charge
- Time between hit and shutter end
- Hit/no-Hit

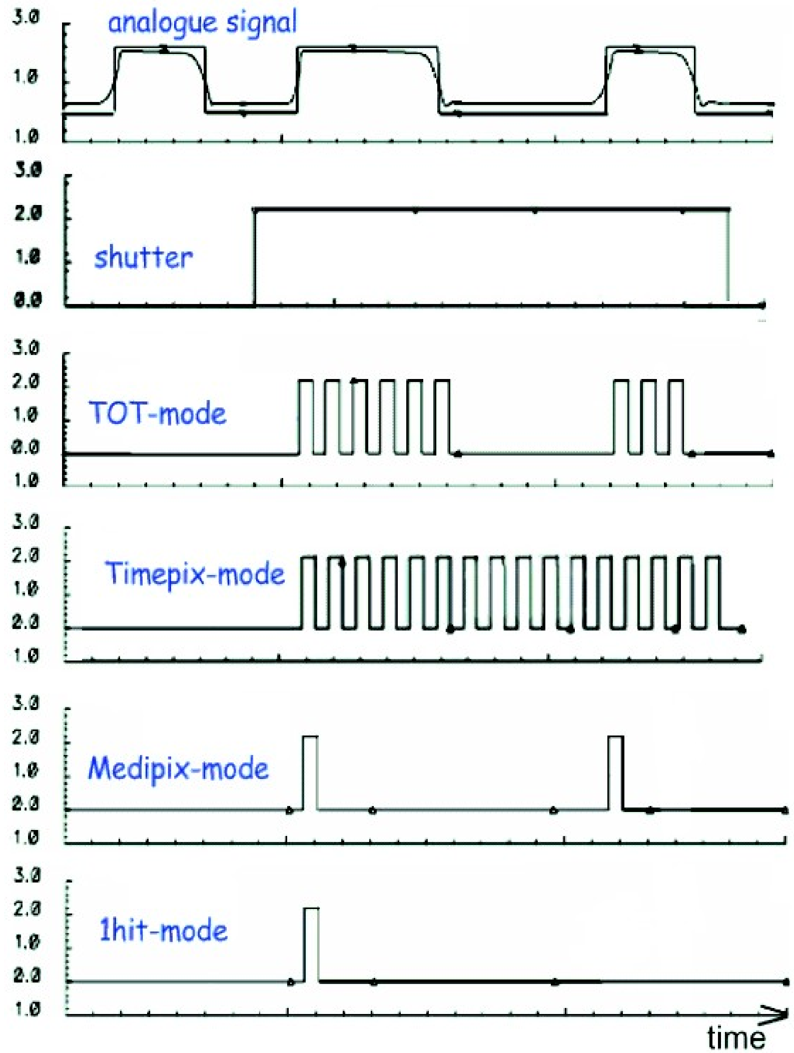
<u>current running condition</u>:
checker-board pattern of TOT and Time





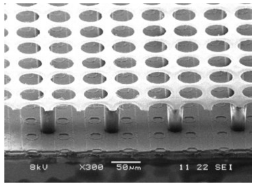
TimePix working principle



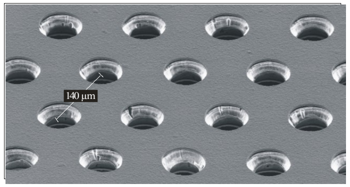


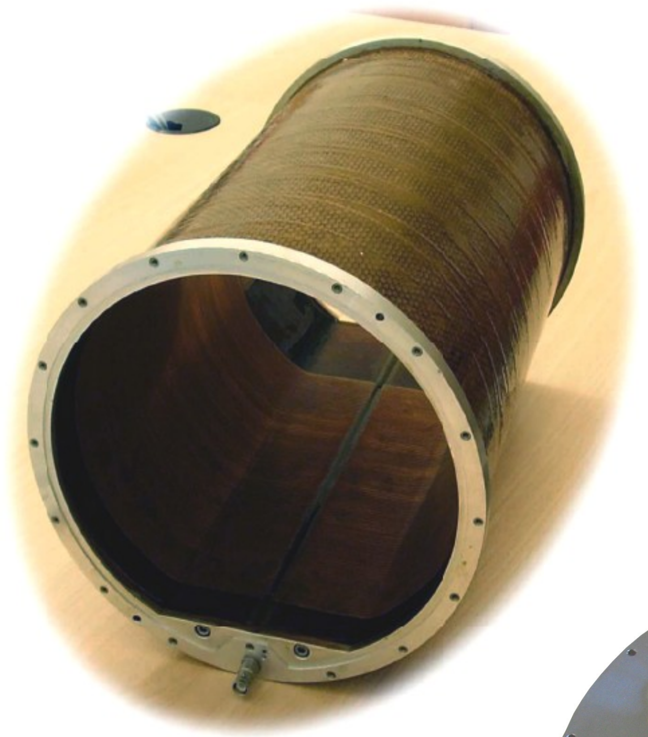
- output of analogue circuit
- shutter: activates digital readout
- time-over-threshold: charge measurement => integrates over all hits
- time-mode: measures time from first hit to end of shutter
- MediPix-mode: number of hits
- 1-hit mode: hit/no hit

Disadvantage: not multi-hit capable

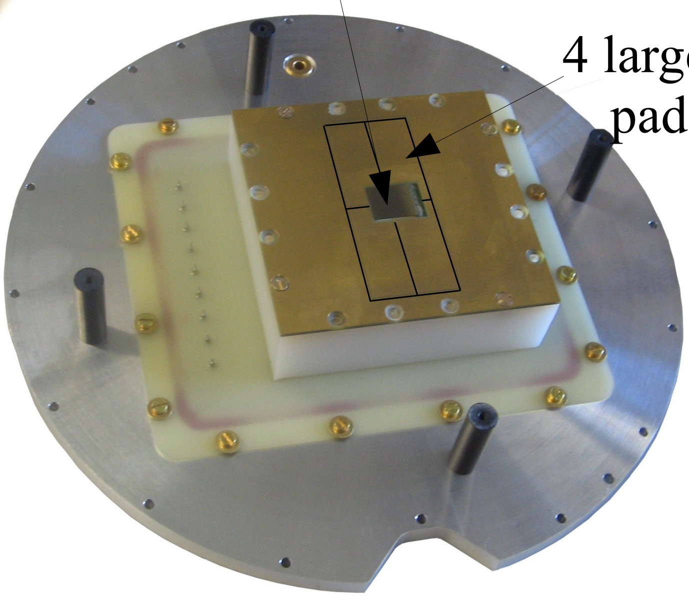


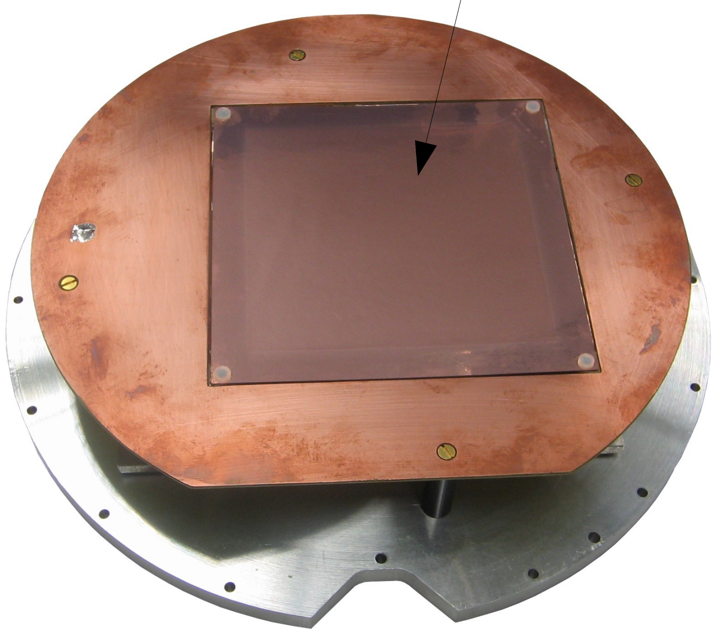
Test Detector at Bonn





Field cage designed and produced at Aachen
- drift distance: 26 cm
- inner diameter: 23 cm
- double layer field cage with ~200 field strips
- material budget: 1 % X_0
- up to 30 kV => drift field of 1 kV/cm

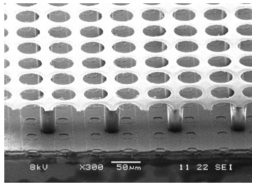




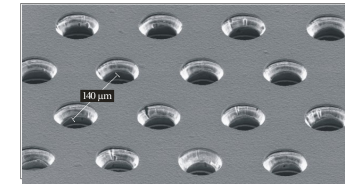
<u>For now:</u>

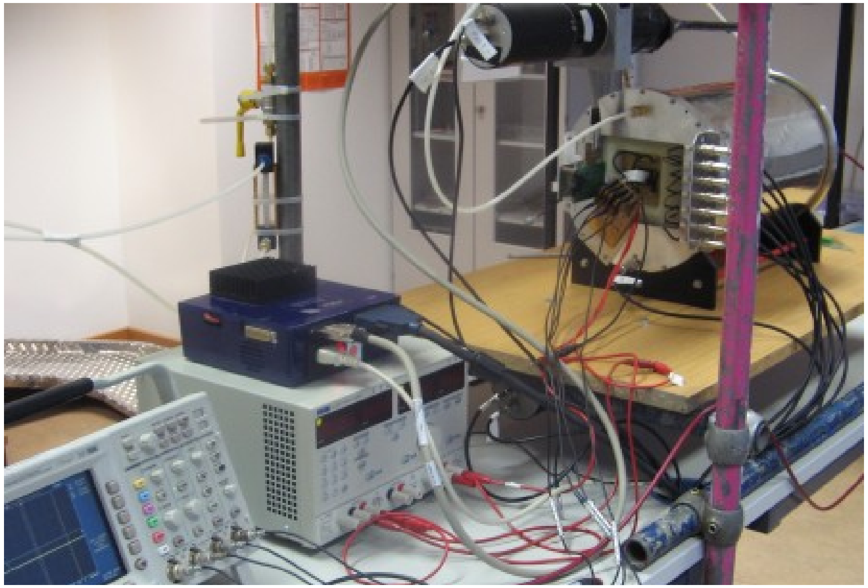
Ar : CO_2 70:30

E_{drift}: 500 V/cm



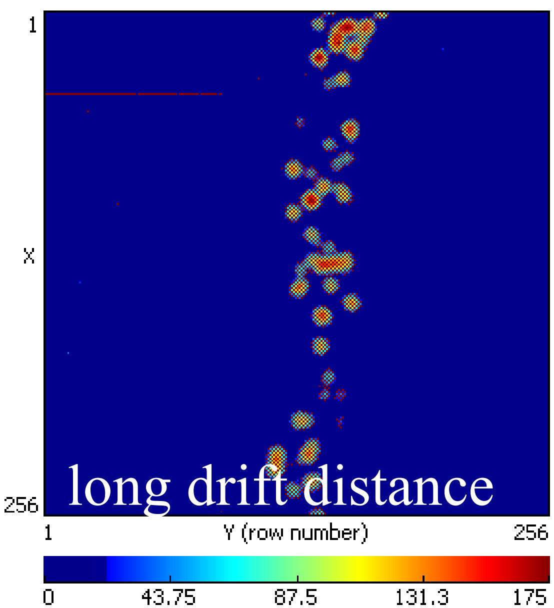
Cosmic Ray Setup

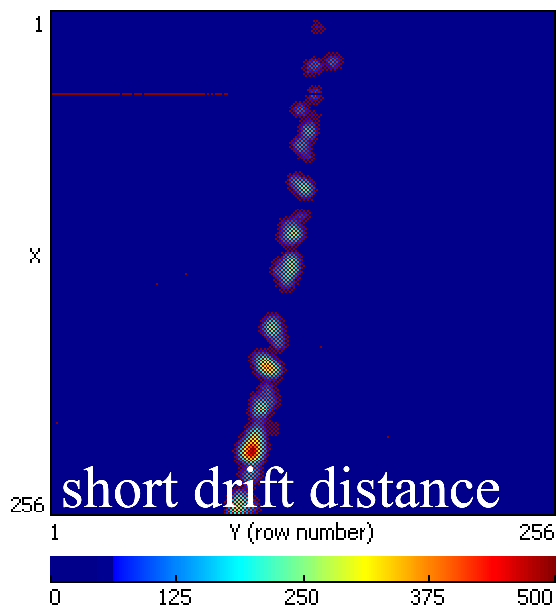




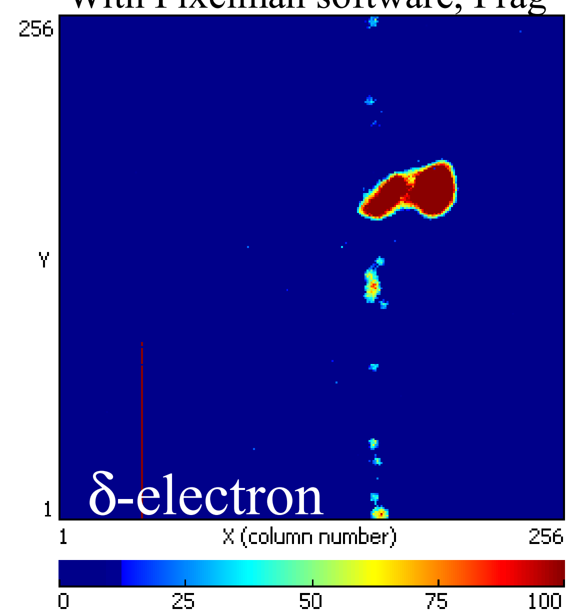
coincidence of 2 scintillators
(2 * 23 cm², 4.5* 35 cm²)
gives external start signal

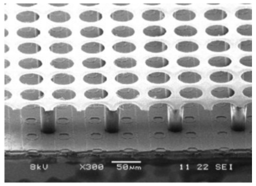
=> 40,000 tracks collected

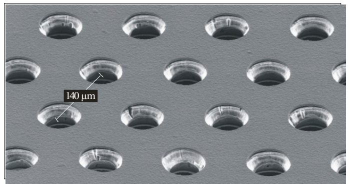




With Pixelman software, Prag

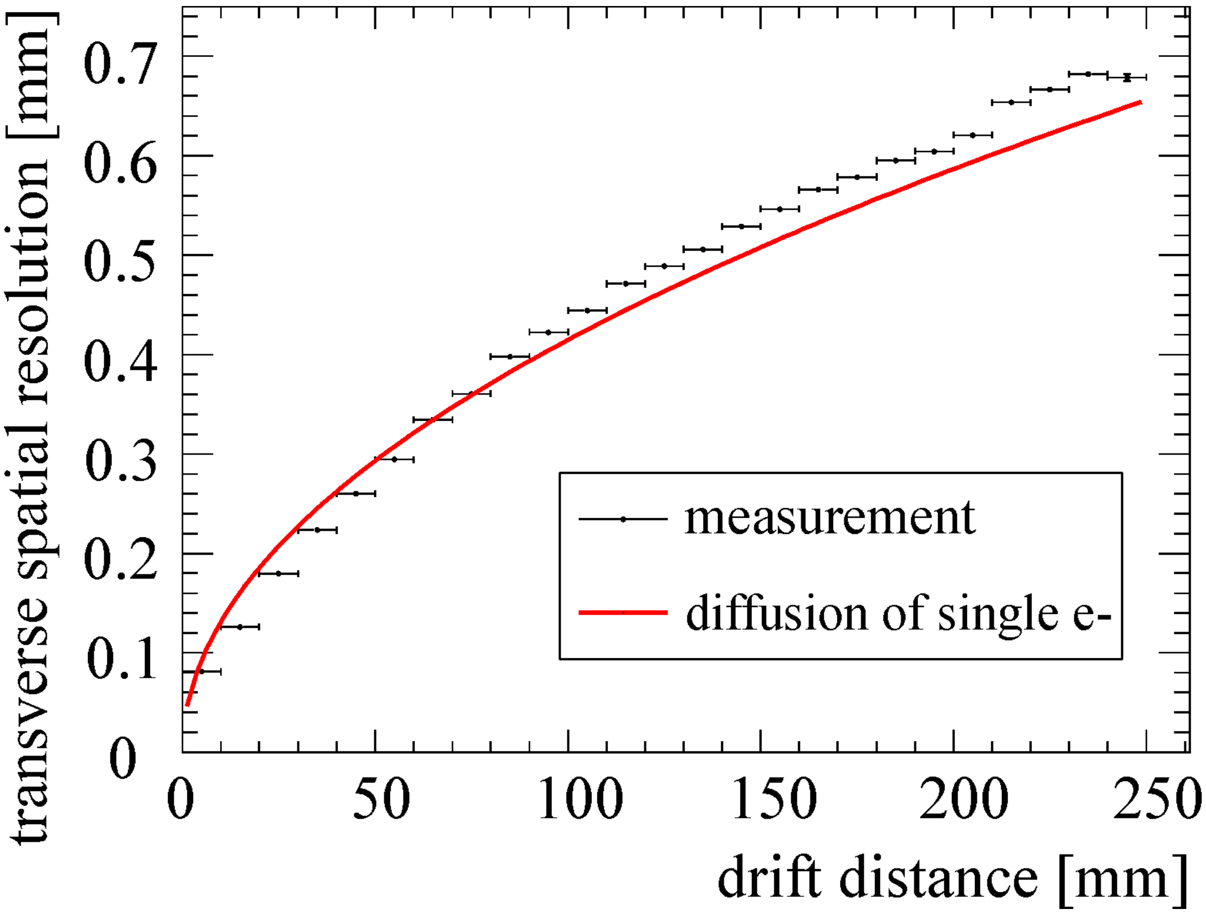






Cosmic Ray Results

preliminary !

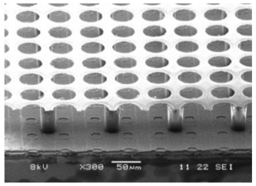


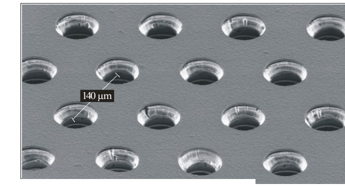
diffusion of single e^-:
$\sigma = D_T * \sqrt{x}$

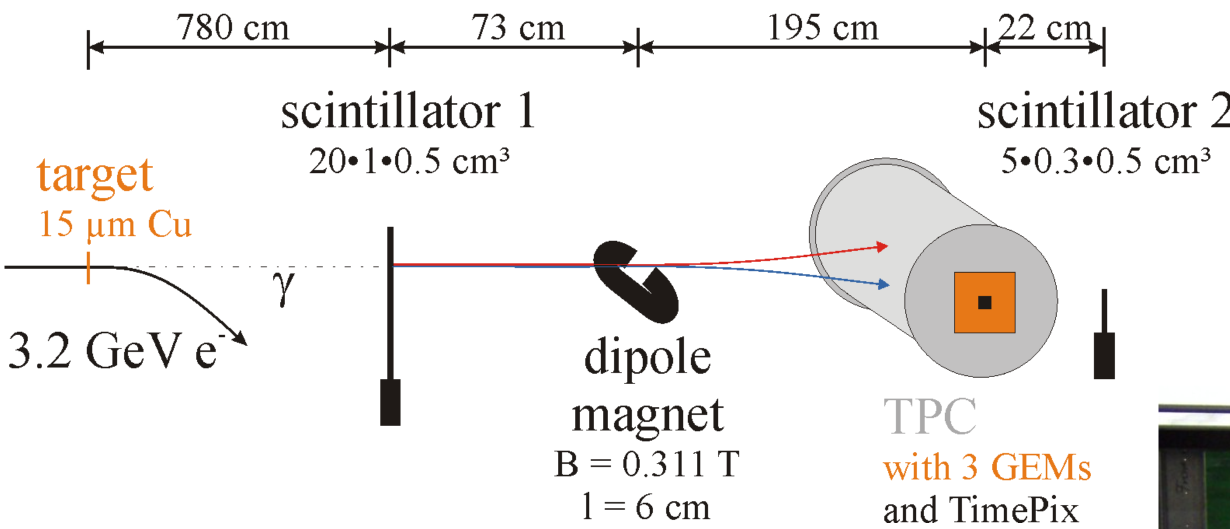
note: $n_{eff} = 1$

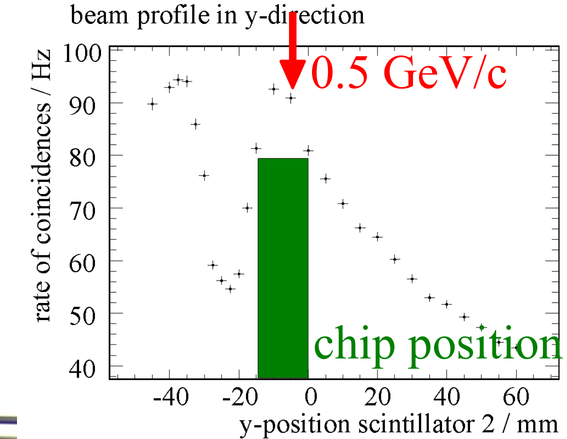
Only selection criteria:
tracks with more than 5 hits

Test Beam Setup

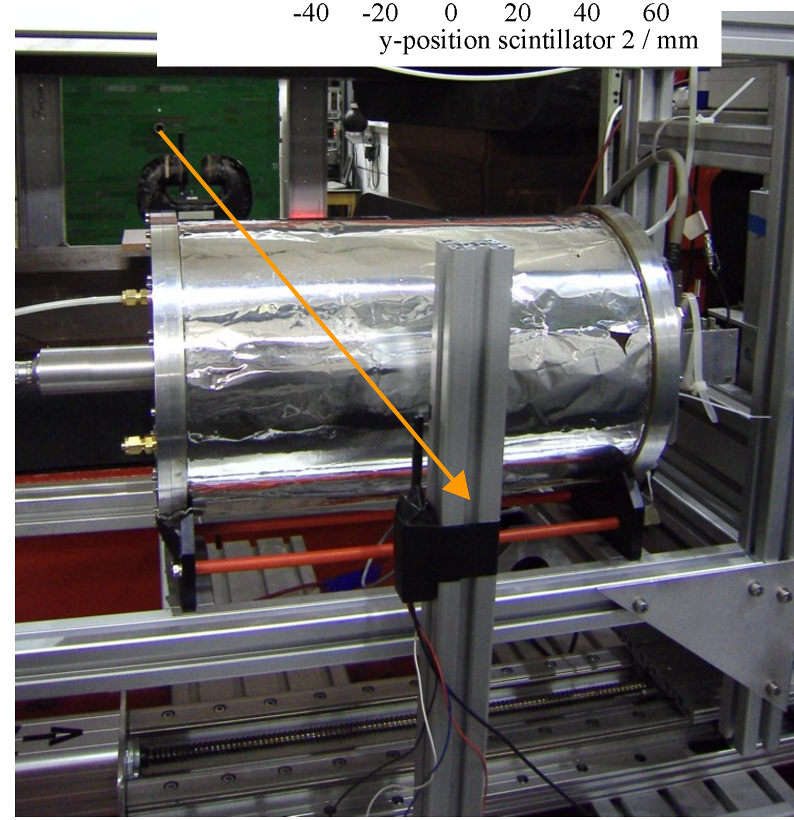








- γ were created at a target
- primary e^--beam was dumped
- photons converted in scintillator 1
- dipole separated e^+e^-
- Coincidence of scinti 1 and 2 select single particle events



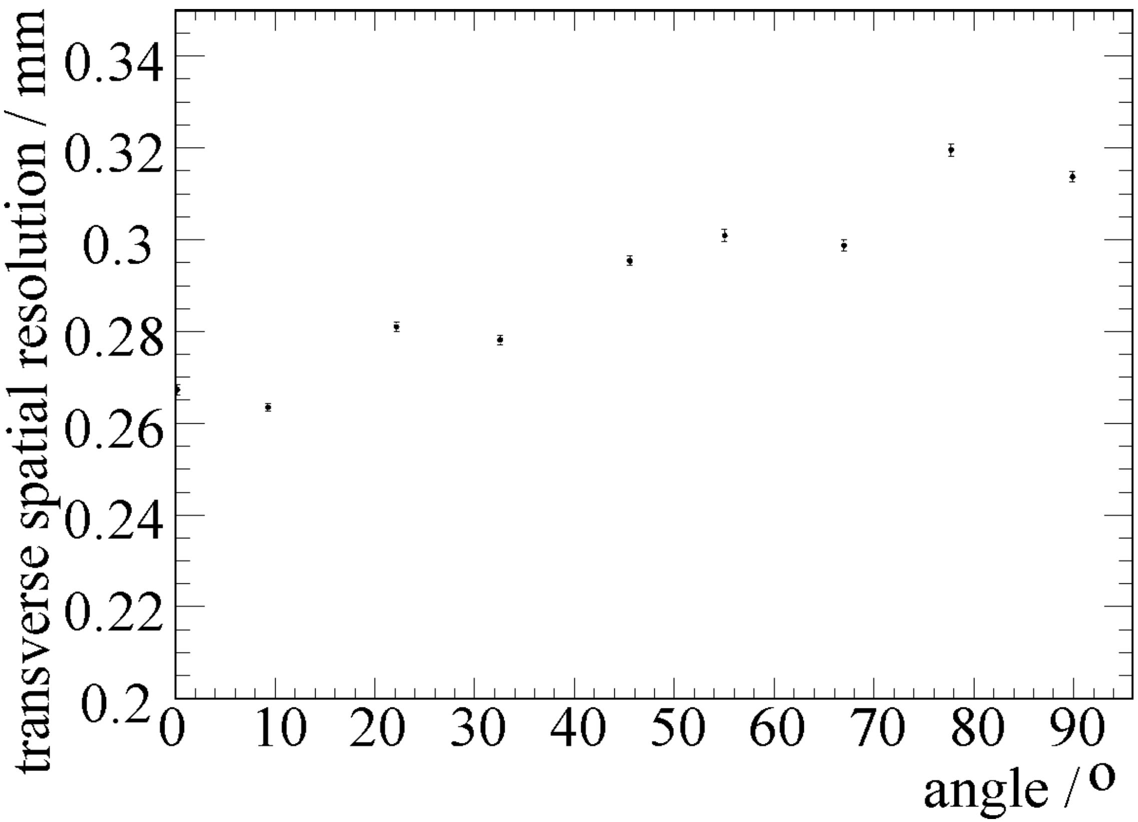
begin of this month

universitätbonn

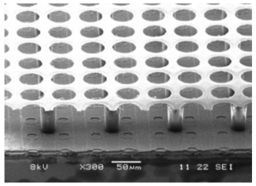
Test beam Results

Very preliminary!!!

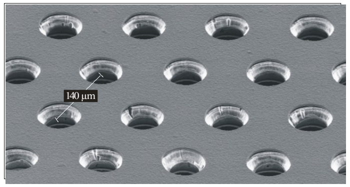
data was taken only 2 weeks ago



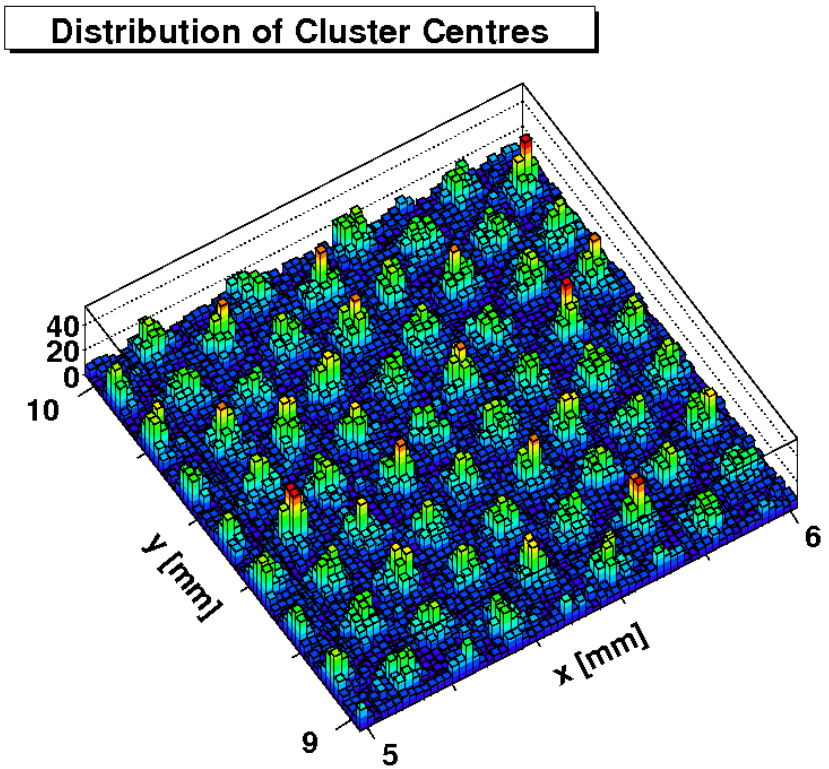
transverse spatial resolution in dependence on track inclination

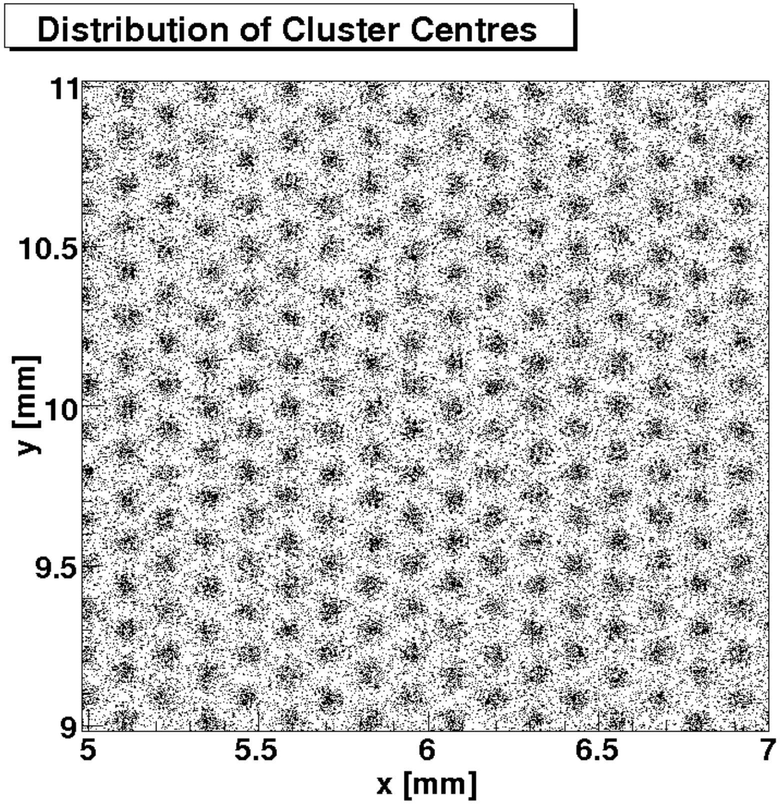


'Electron-tomography' of a GEM

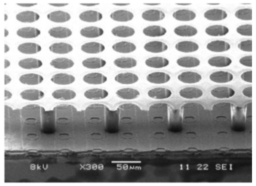


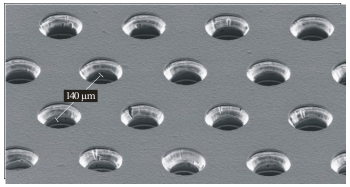
- ^{90}Sr placed at a drift distance of 25 cm
- untriggered data taking
- reconstruction of hit positions

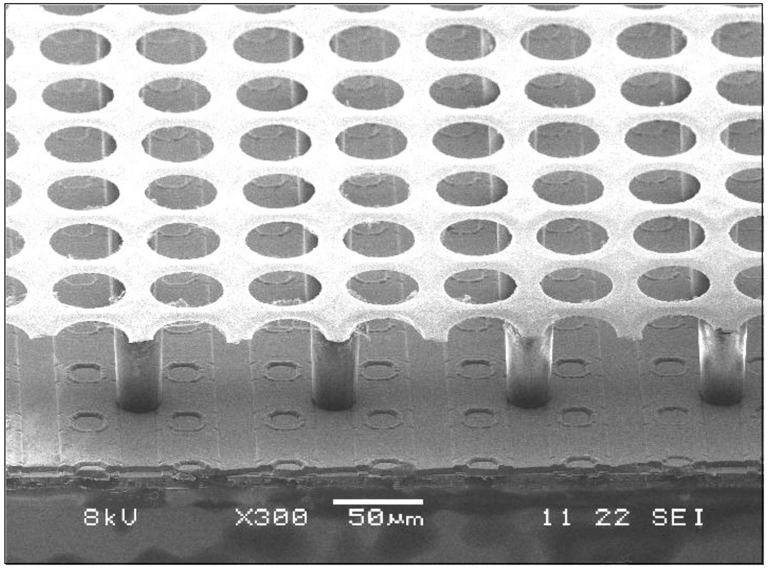


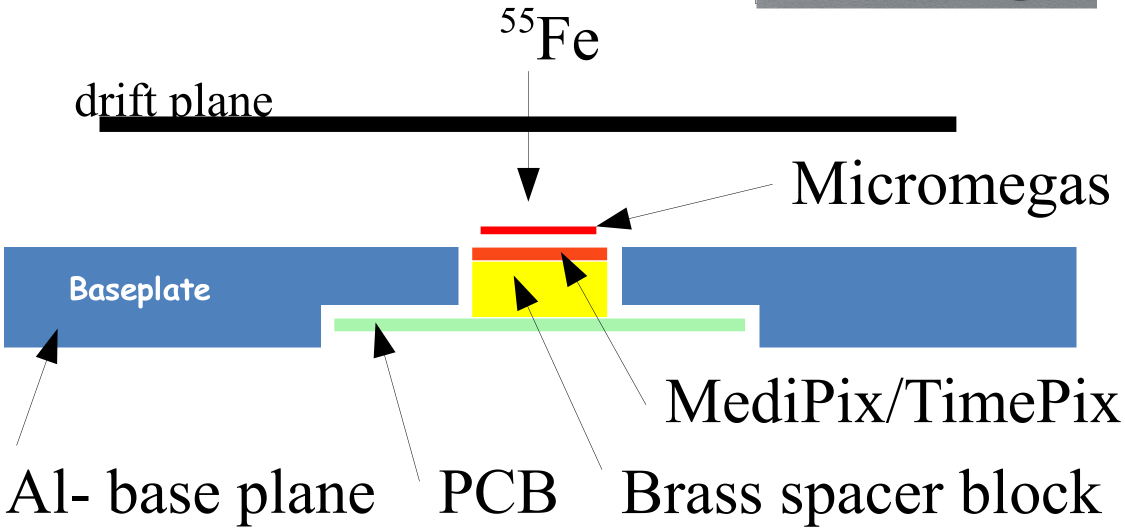


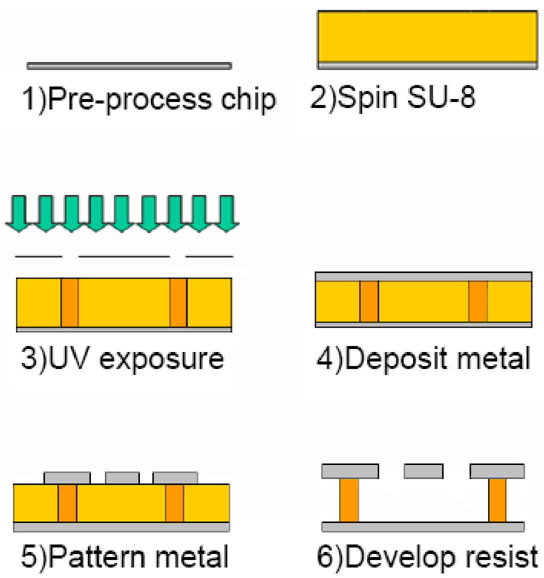
InGrid



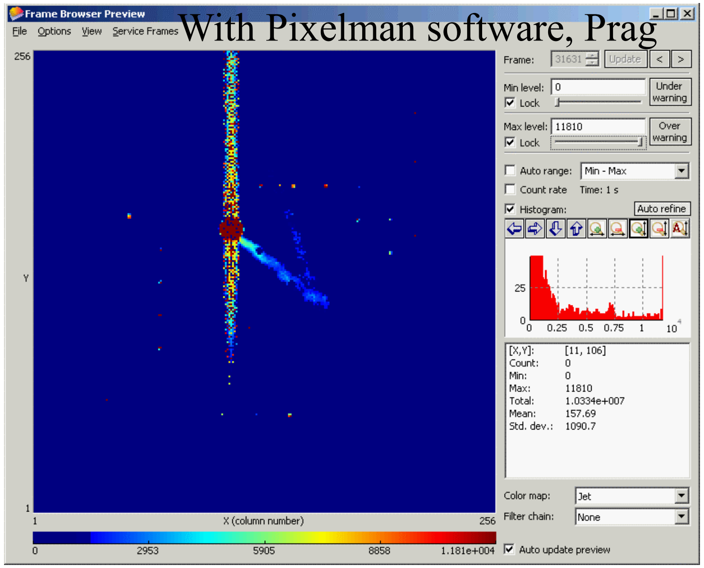




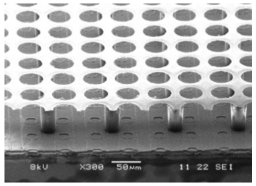




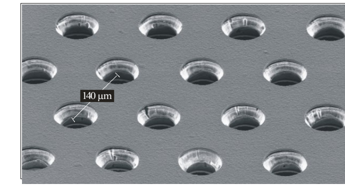
IMT Neuchatel:
15 or 20 μm highly resistive aSi:H protection layer (~10^{11} Ω·cm)
MESA+: InGrid

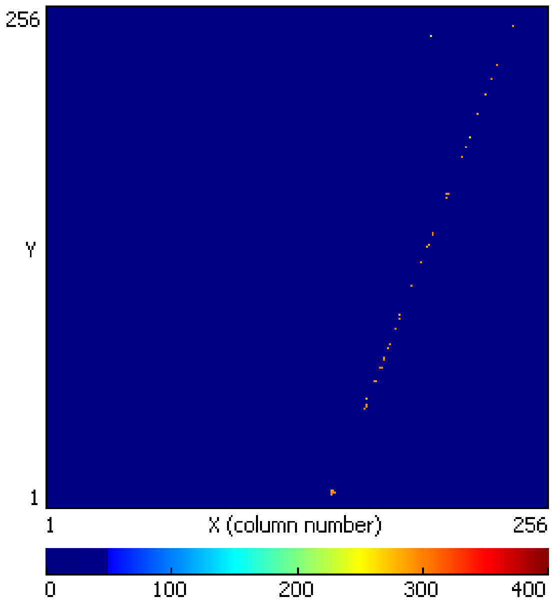


chip survives several 1000 discharges induced by Thorium



InGrid – some Event Pictures

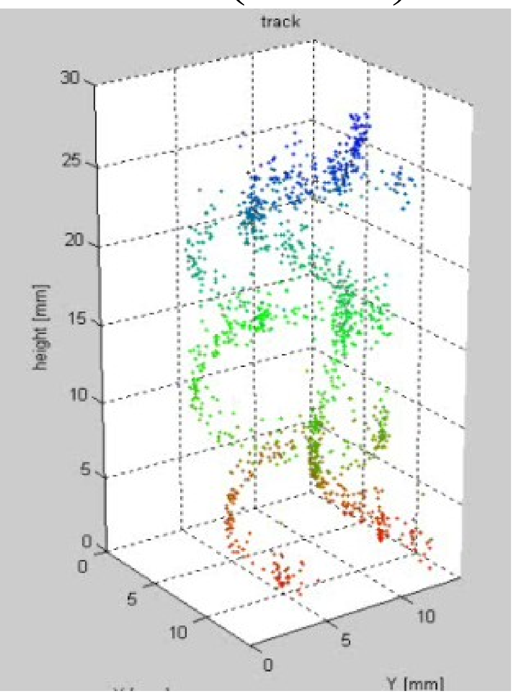




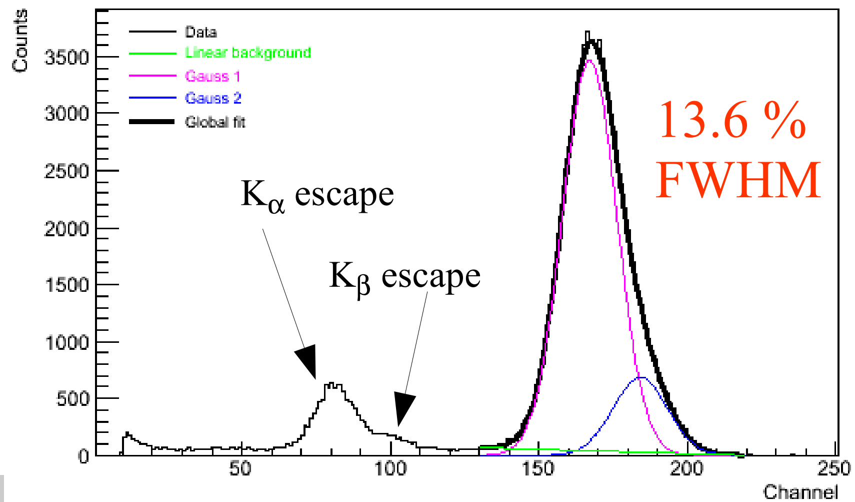
With Pixelman software, Prag

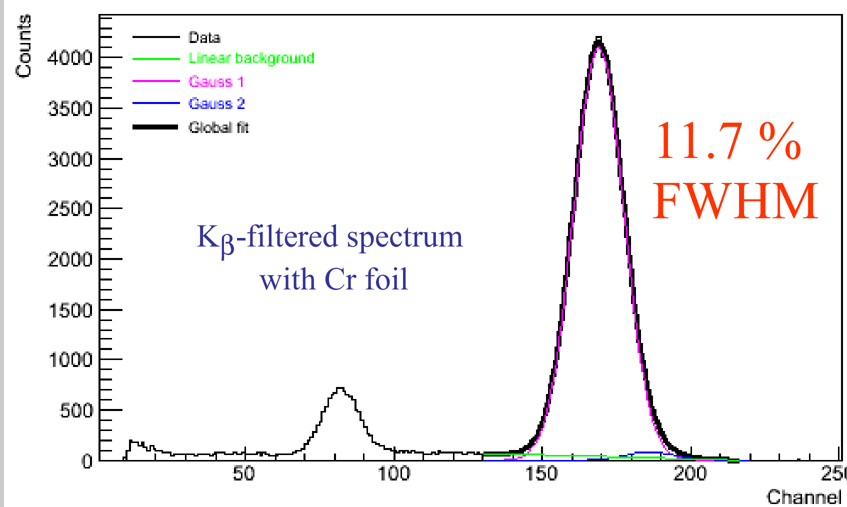
NIKHEF

5 GeV negative hadron beam at CERN
- $ArCO_2$ (70/30)



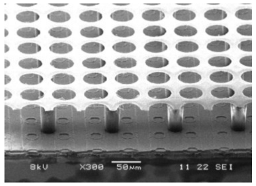
2 electrons from ^{90}Sr in B=0.2T



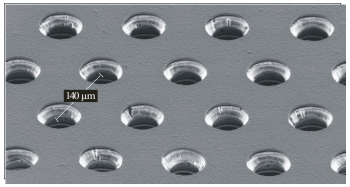


^{55}Fe spectrum in Ar:CH_4 90-10

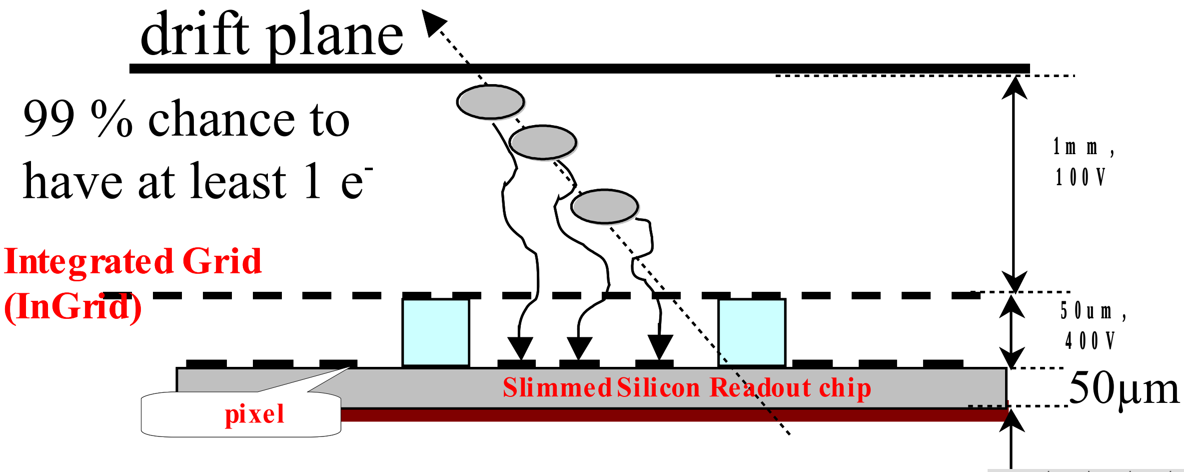
universitätbonn



Gossip

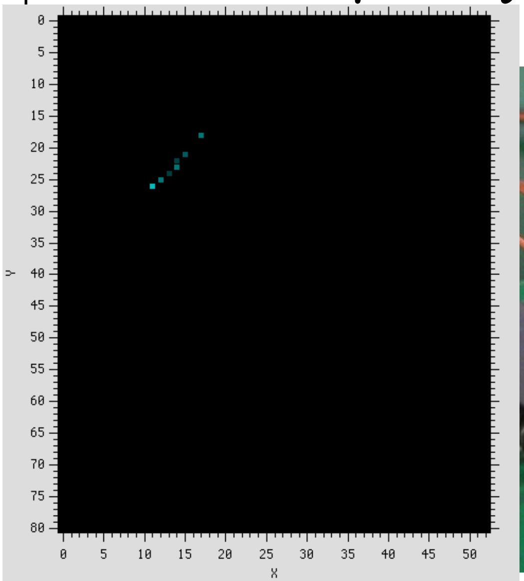


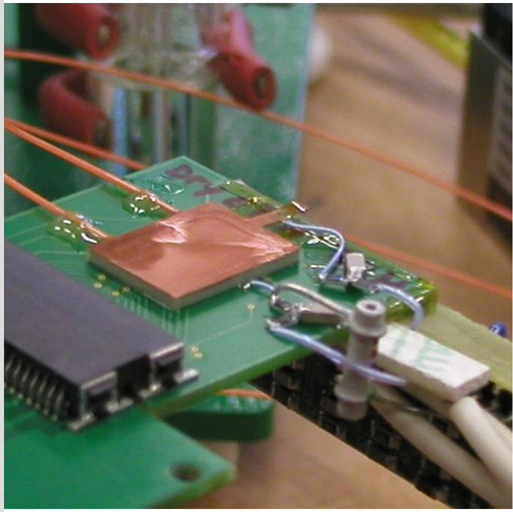
Gas On Slimmed Silicon Pixel



First prototype of GOSSIP on a PSI-46 (CMS Pixel FE chip) is working:

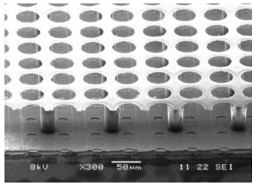
- 1.2 mm drift gap
- Grid signal used as trigger
- 30 µm layer of SiProt



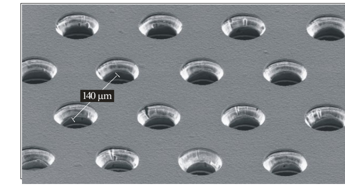


<u>Some advantages: gas versus Si</u>

- it is light and cheap
- gas amplification, no bias current
  => low power & simple FE circuits
- gas can be exchanged:
  => no radiation damage of sensor
- no temperature requirements
- gas has a low ε_r: -> low capacitance
  => fast, low-noise, and low-power preamps

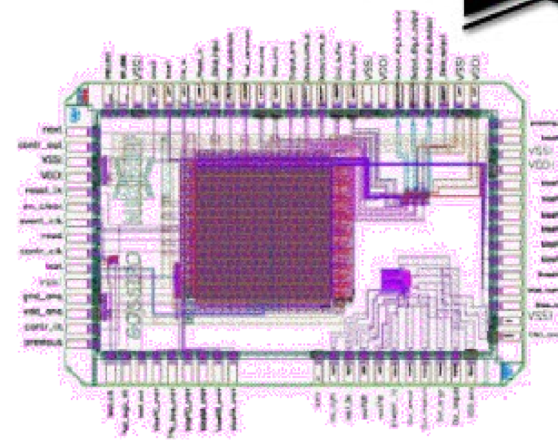


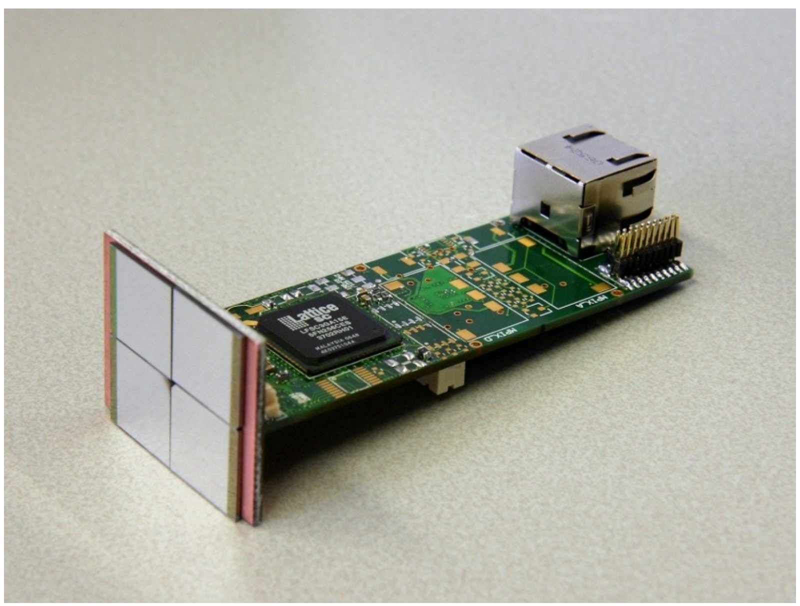
Gossip & InGrid



Gossip and InGrid based TPC face very similar challenges:

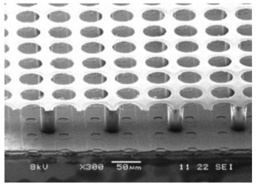
- spark protection solved by aSi:H – layer
- aging must be tested/ under control
- diffusion limits max. drift length
  => test low diffusion gases (e.g. Ar:CF_4)
- enlarging surface (currently only 2 cm²)
- development of new readout chips



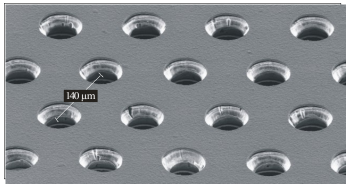


Development of new readout chips:

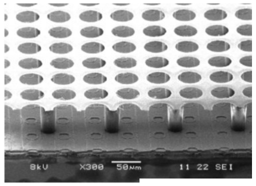
- GOSSIPO-2 at NIKHEF
  16*16 Pixel, 0.13µm CMOS technology
  low noise σ_n=70e^- ENC
  low power consumption (2µW/channel)
  1.8 ns time resolution
- TimePix-2 at CERN/NIKHEF/Bonn/...
  design will start soon



Conclusion & Outlook



- Development of micropattern gas detectors is a very active field.
- This is underlined by the formation of a new collaboration at CERN: RD51. Joining the forces to cover the needs of the community: test beams, irradiation facilities, electronics, industrialization, develop simulation tools,...
- Some very promising ideas have been made to work in the last years.
- Especially the readout with CMOS chips with very small pixels shows interesting results in a number of new applications.
- New post-processing steps of readout chips are planned. e.g. pad enlarging, through-silicon-vias, ...



Modern Particle Identification