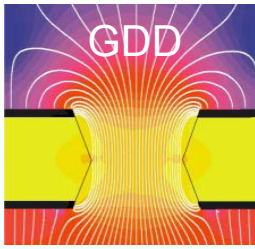
GEM



SVILUPPO E APPLICAZIONI DEL MOLTIPLICATORE GASSOSO DI ELETTRONI (GEM)

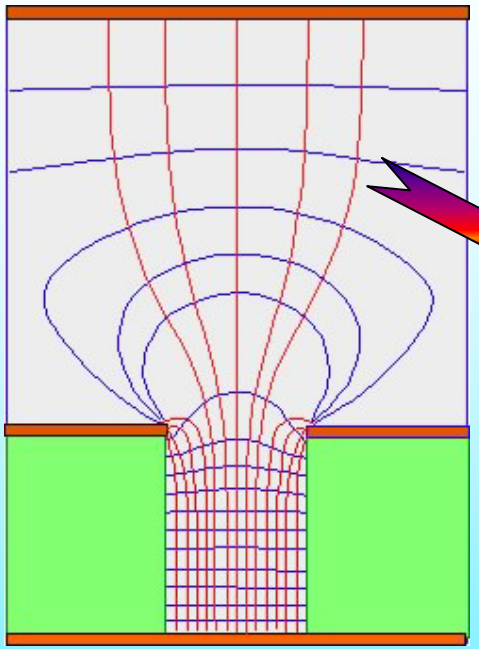
Fabio SAULI
Gas Detectors Development

CERN - Geneva - Switzerland

Seminario
Università di Napoli
17 maggio 2005

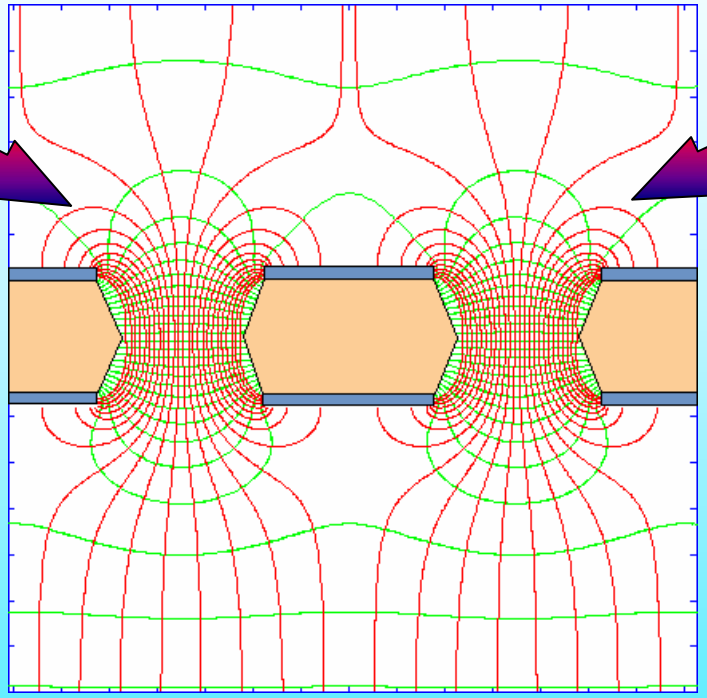
SEARCH FOR ALTERNATIVE MICRO-PATTERN STRUCTURES

Compteur a trous
Single hole in PC board:



F. Bartol, M. Bordessoule, G. Chaplier, M. Lemonnier, S. Megtert, J. Phys. III (1996) 337

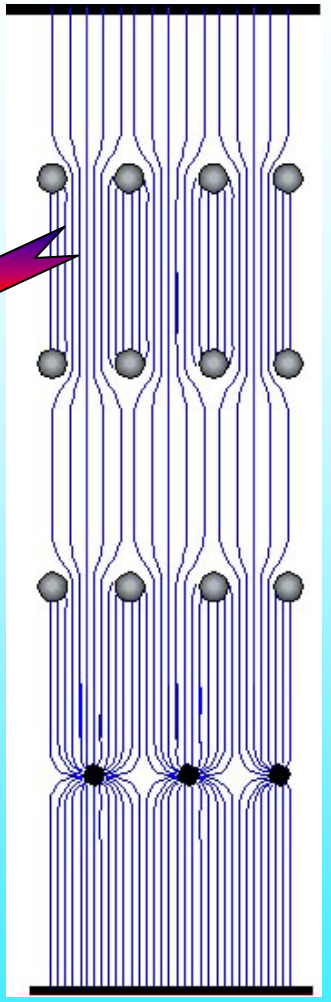
Gas Electron Multiplier (GEM)
Metal-coated thin foil with holes:



- Sturdier mechanical structure
- Separate amplifying (HV) and read-out electrodes

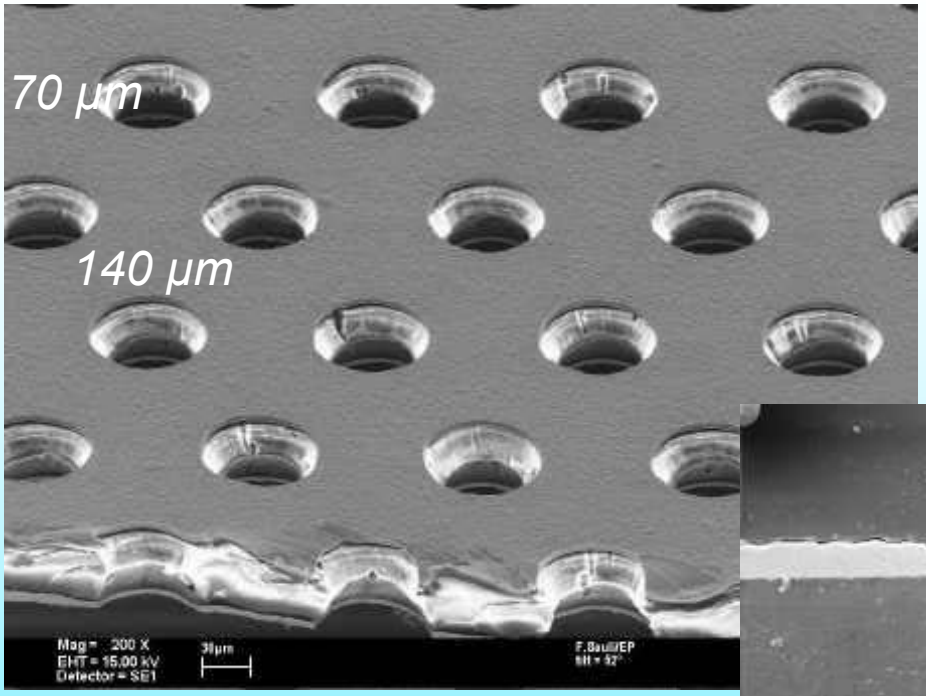
F. Sauli, Nucl. Instr. and Methods A386(1997)531

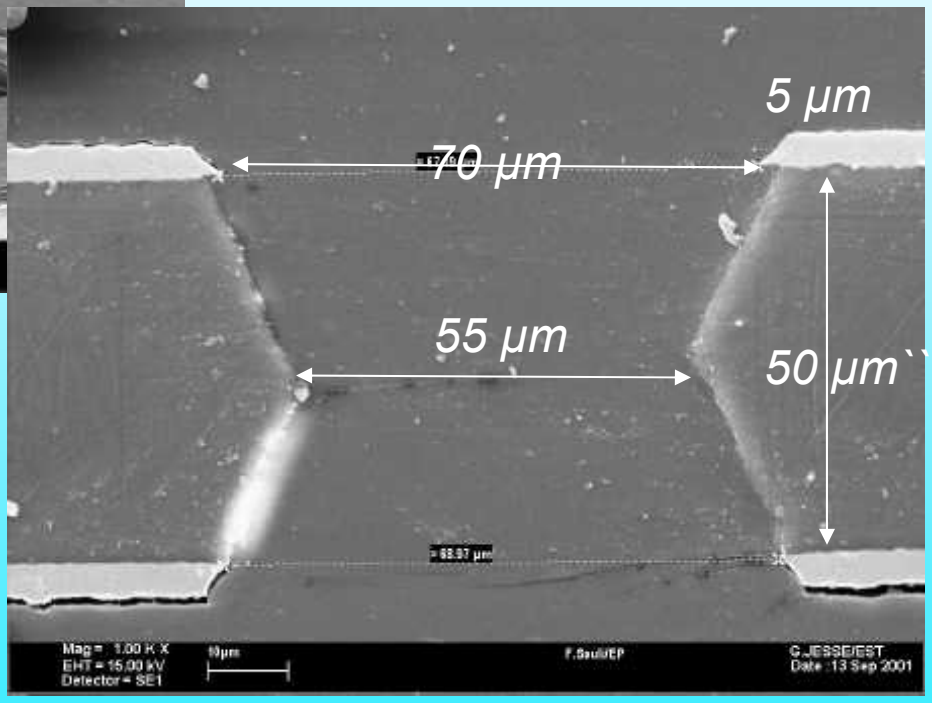
Multistep Chamber
Multiwire structure:



G. Charpak and F. Sauli, Phys. Letters 78 B (1978) 523

Typical GEM geometry: 5 μm Cu on 50 μm Kapton, 70 μm holes at 140 mm pitch





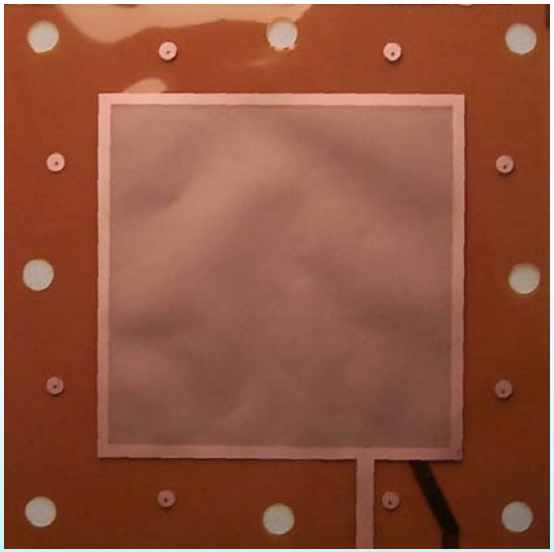
Chemical etching

Manufacturing technology developed by R. De Oliveira (CERN-EST)

GEM FOR HERA-B

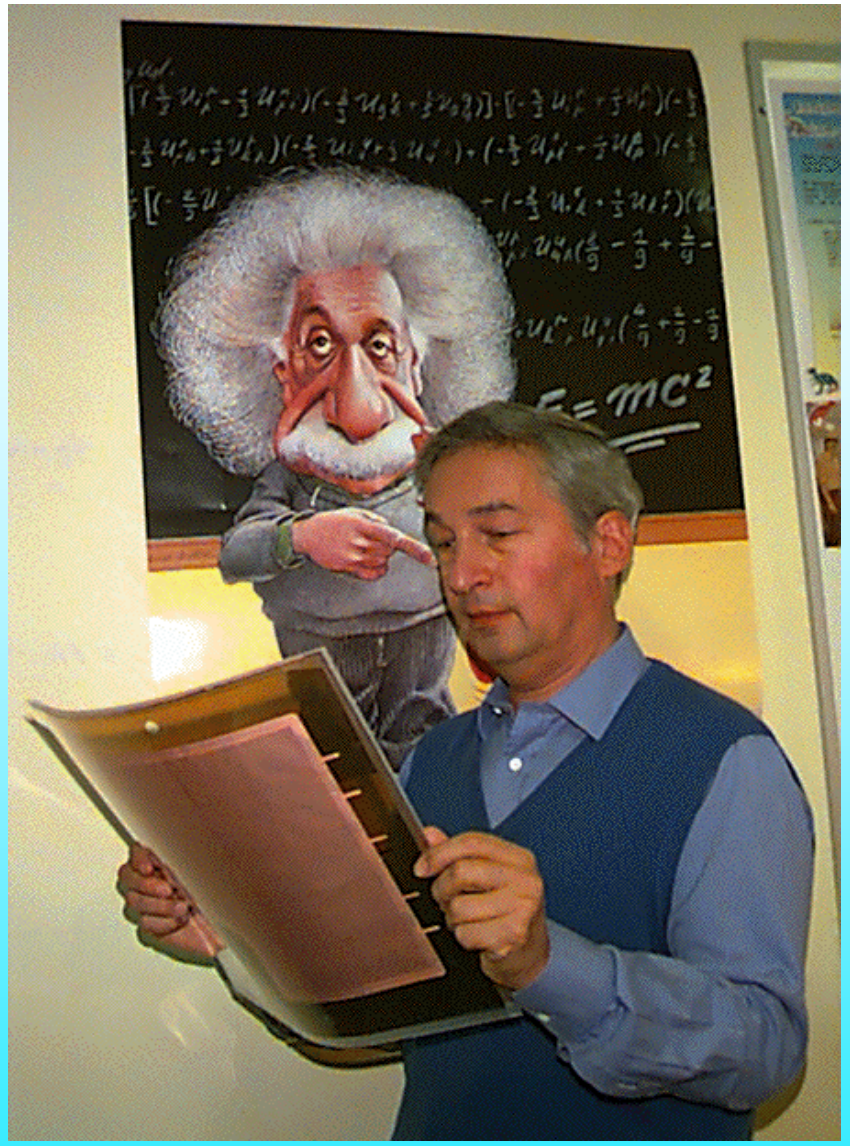
Round GEM for INTEGRAL

"Standard" small GEM: 10x10 cm^2

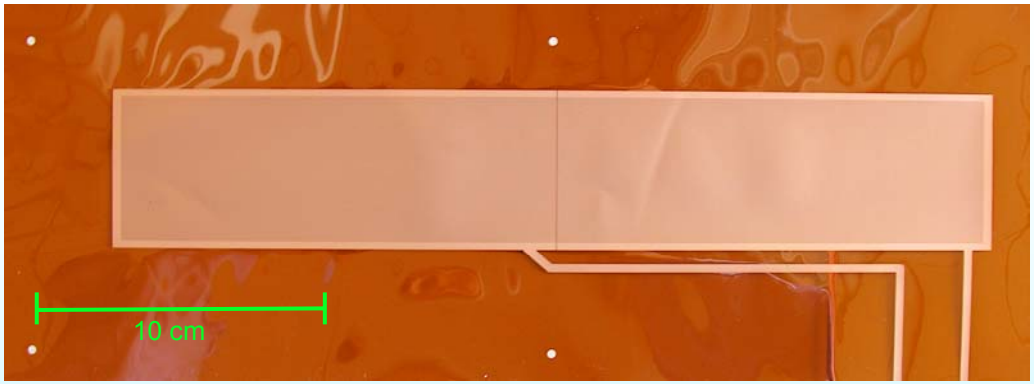


4-segments GEM 10x10 cm^2 :

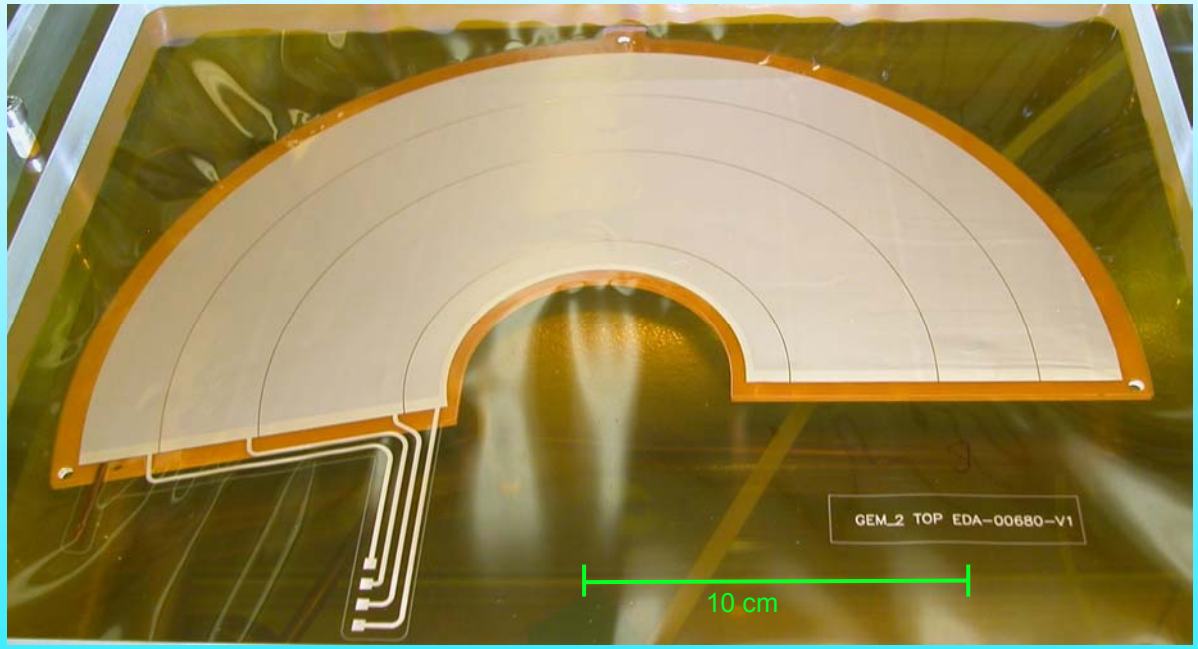
COMPASS GEM 31x31 cm^2



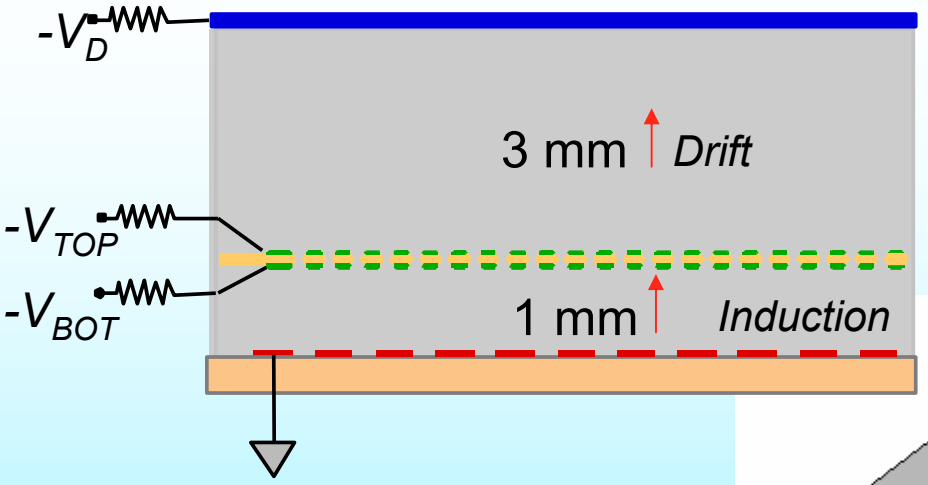
Nuclear Magnetic Spectrometer (Osaka Univ.)



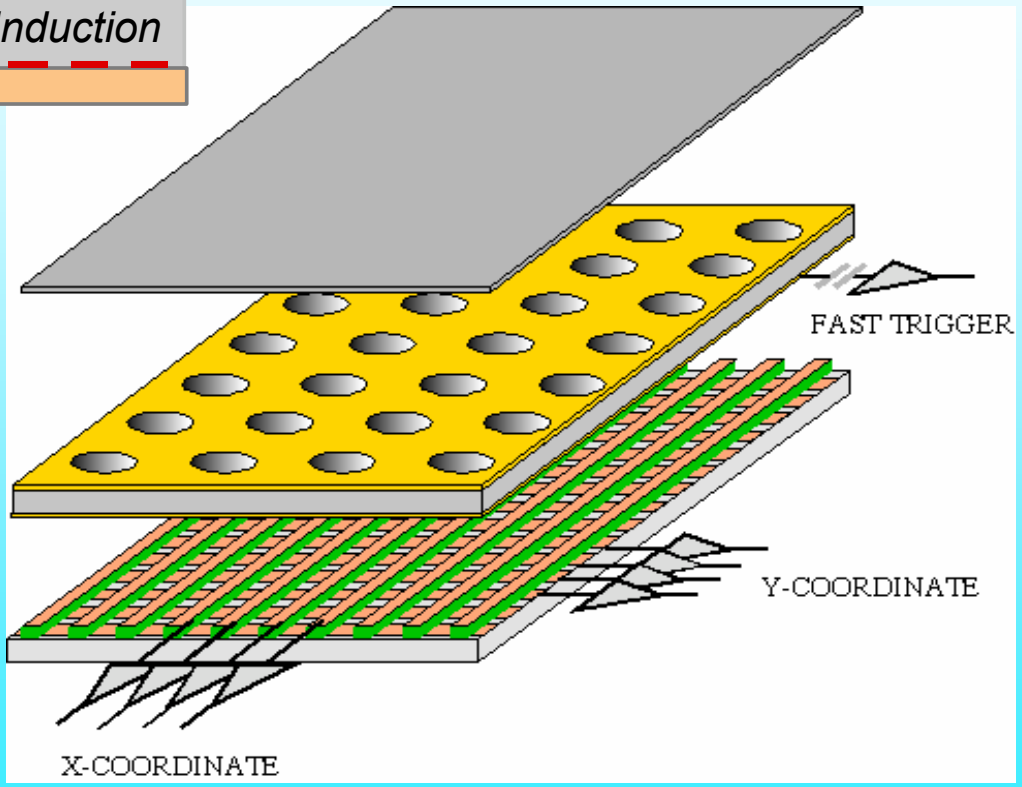
TOTEM tracker (CERN-CMS)



Single GEM detector



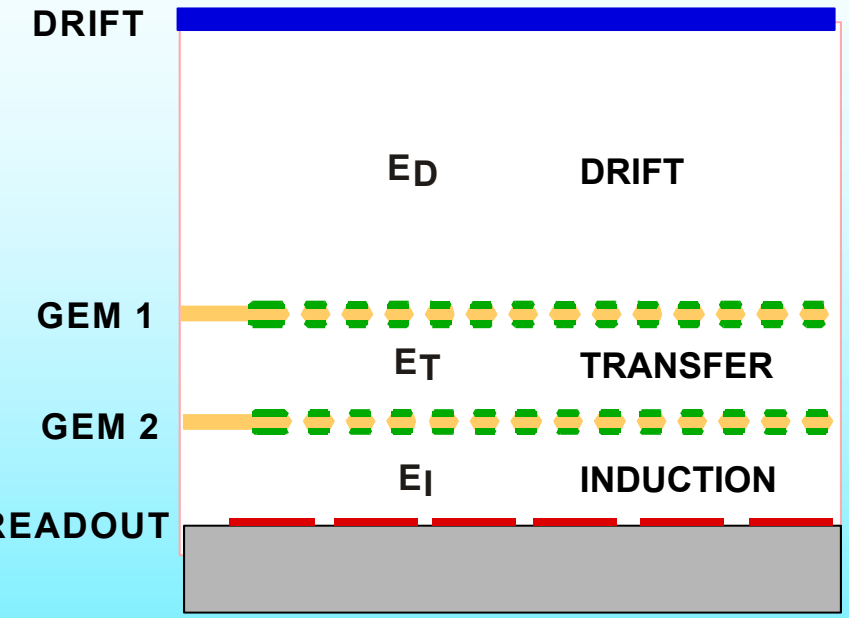
ADVANTAGES OF GEM DEVICES:
-Readout planeseparated from multiplying electrode
-Arbitrary readout pattern (1D or 2D strips, pads)



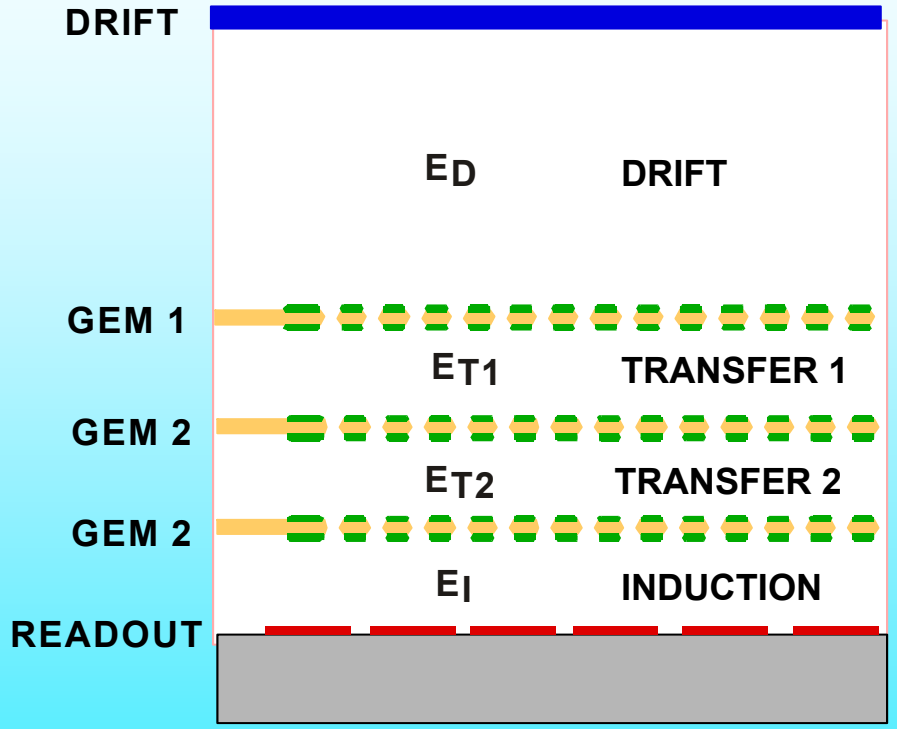
A. Bressan et al, Nucl. Instr. and Meth. A425 (1999) 254

GEMs CAN BE CASCADED FOR HIGHER/SAFER GAIN:

Double GEM



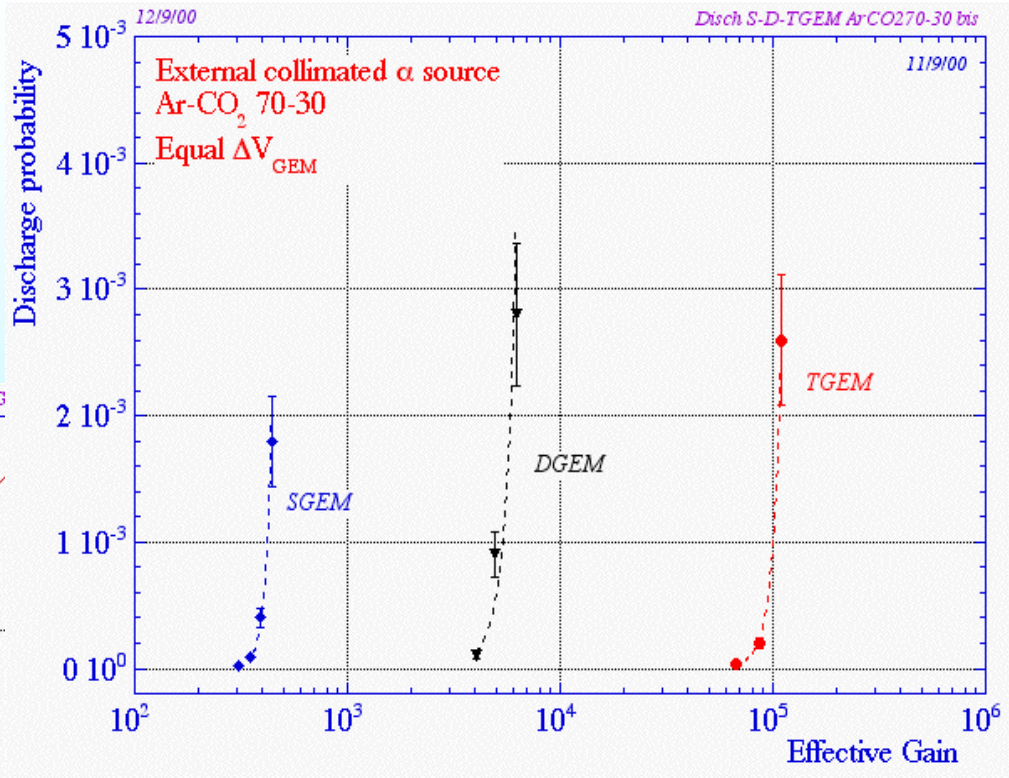
Triple GEM



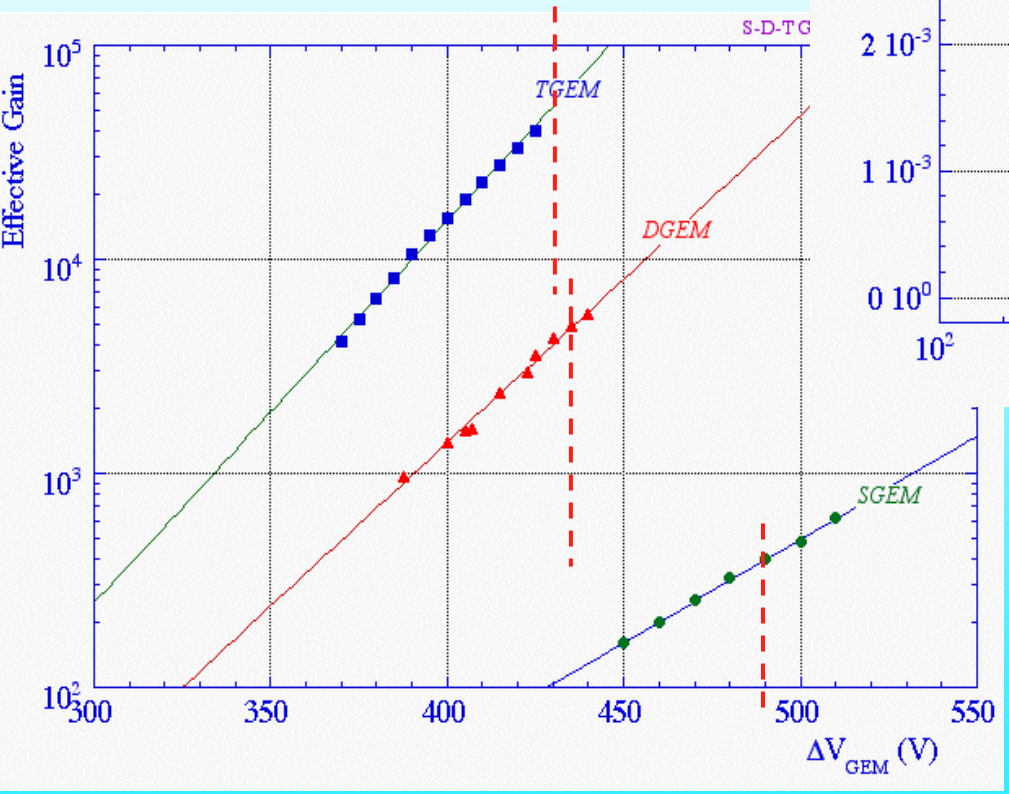
C. Buttner et al, Nucl. Instr. and Meth. A 409(1998)79
S. Bachmann et al, Nucl. Instr. and Meth. A 443(1999)464

MULTIGEM GAIN/DISCHARGE

Discharge probability exposed to 5 MeV α:



Proportional Gain:

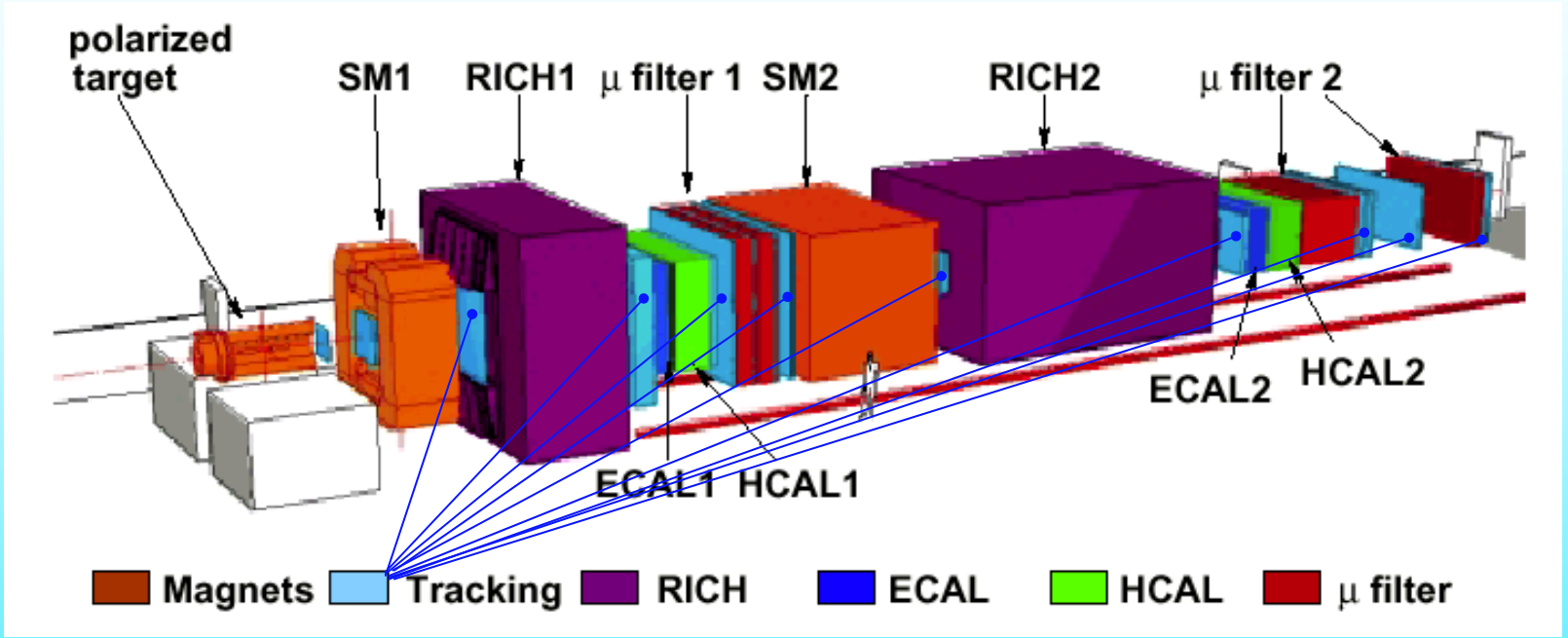


S. Bachmann et al Nucl. Instr. and Meth. A479(2002)294

TRIPLE GEM TRACKER FOR COMPASS AT CERN (NA58)

Common Muon and Proton Apparatus for Structure and Spectroscopy

High rate forward spectrometer: ~ 5.10^7 polarized 160 GeV μ^+/s on polarized ^{6}LiD target

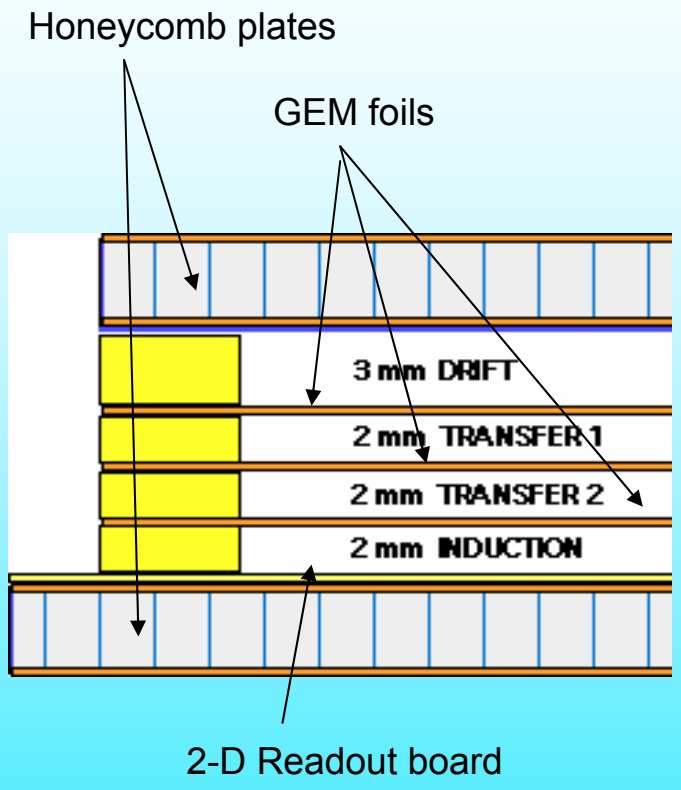


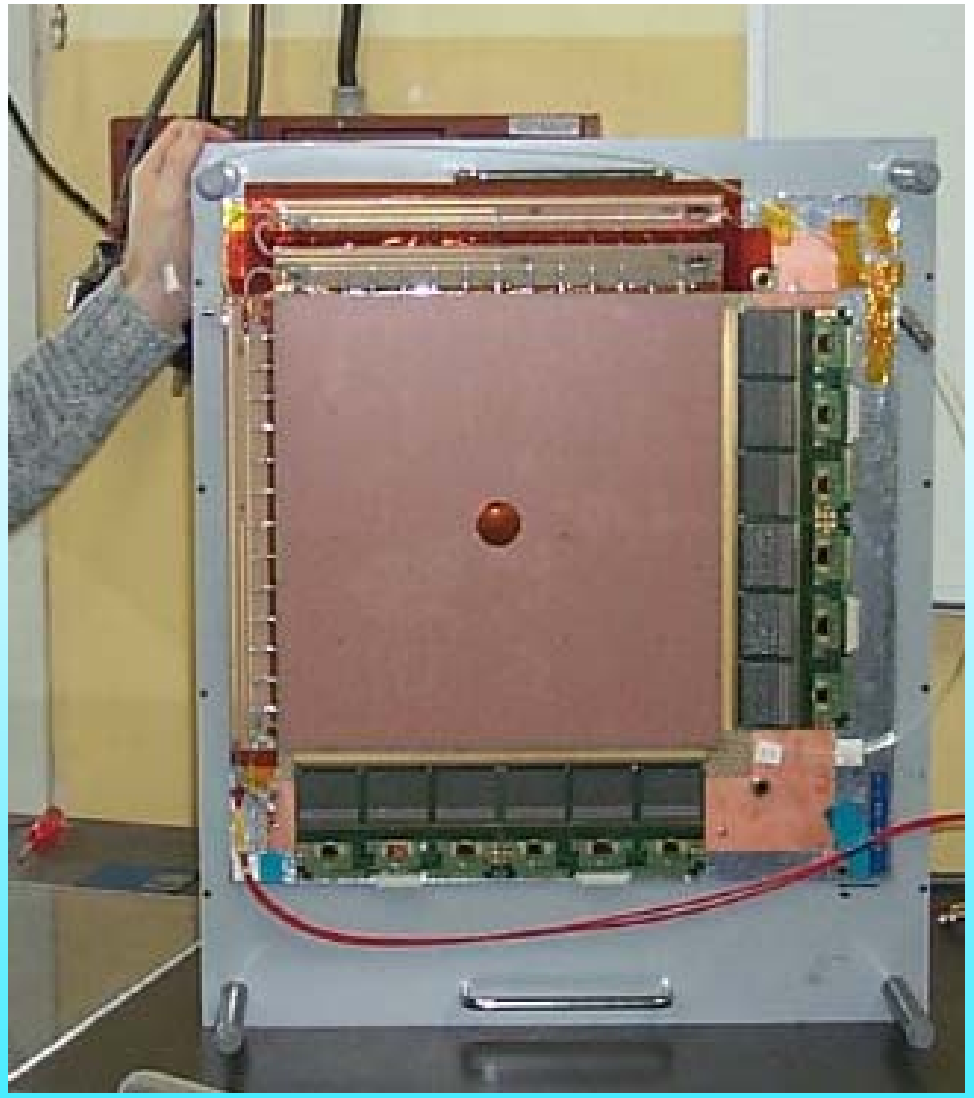
22 Triple-GEM detectors, mounted in pairs on 11 stations
Data taking since 2001

http://wwwcompass.cern.ch/

COMPASS Triple-GEM detectors

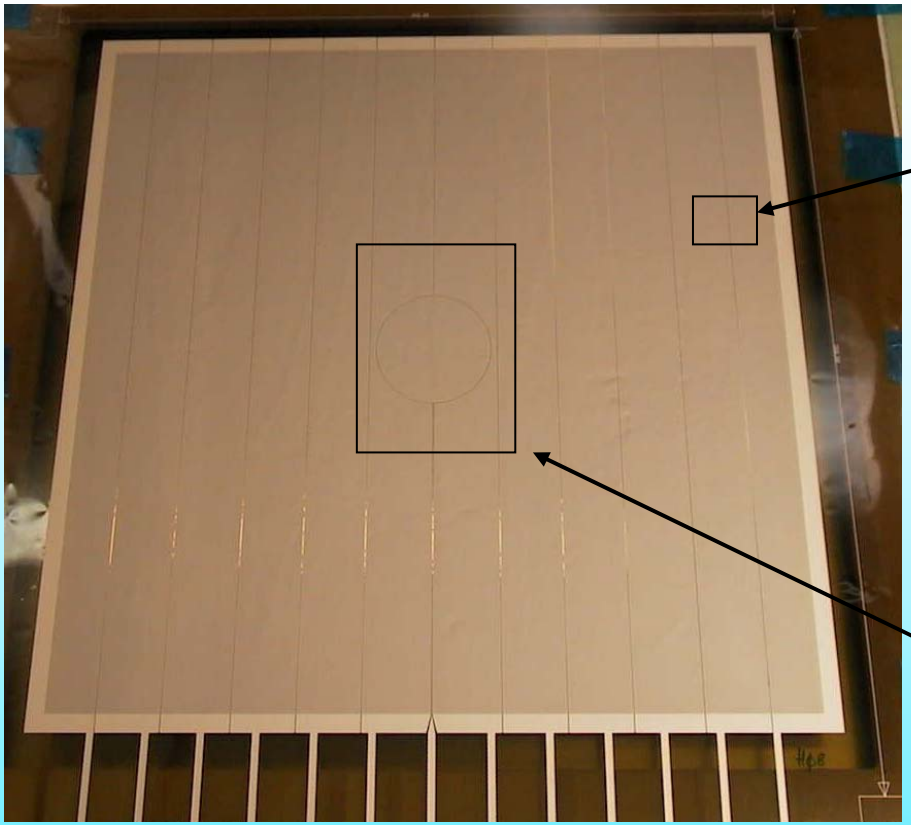
Light all-glued construction:
0.7% X_0 in active area

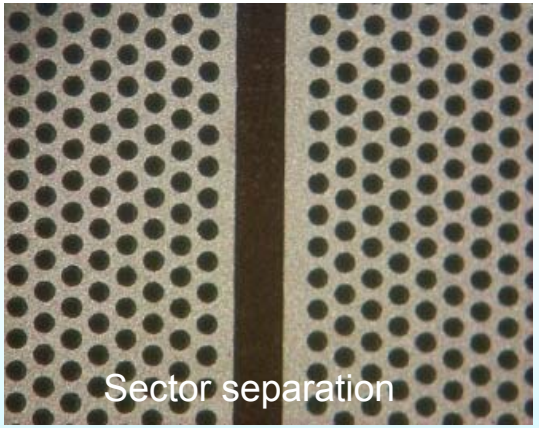


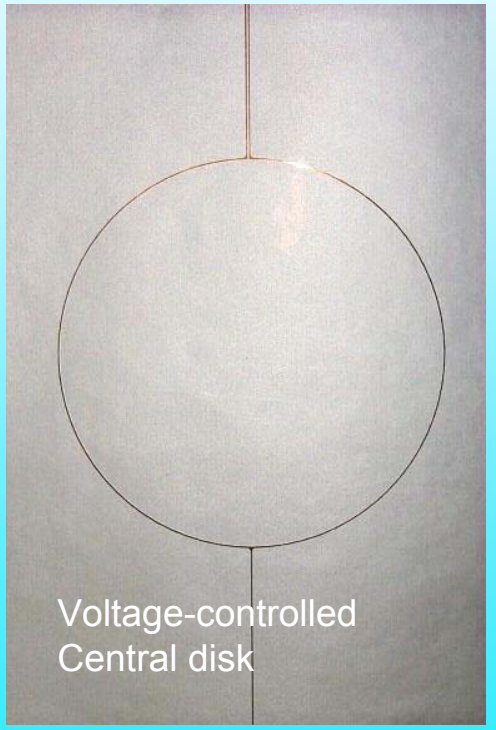


C. Altumbas et al, Nucl. Instr. Methods A490(2002)177

GEM foils for COMPASS (31x31 cm^2), 12-sectors + beam killer

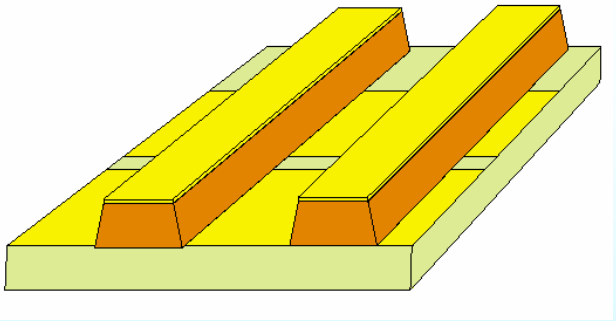


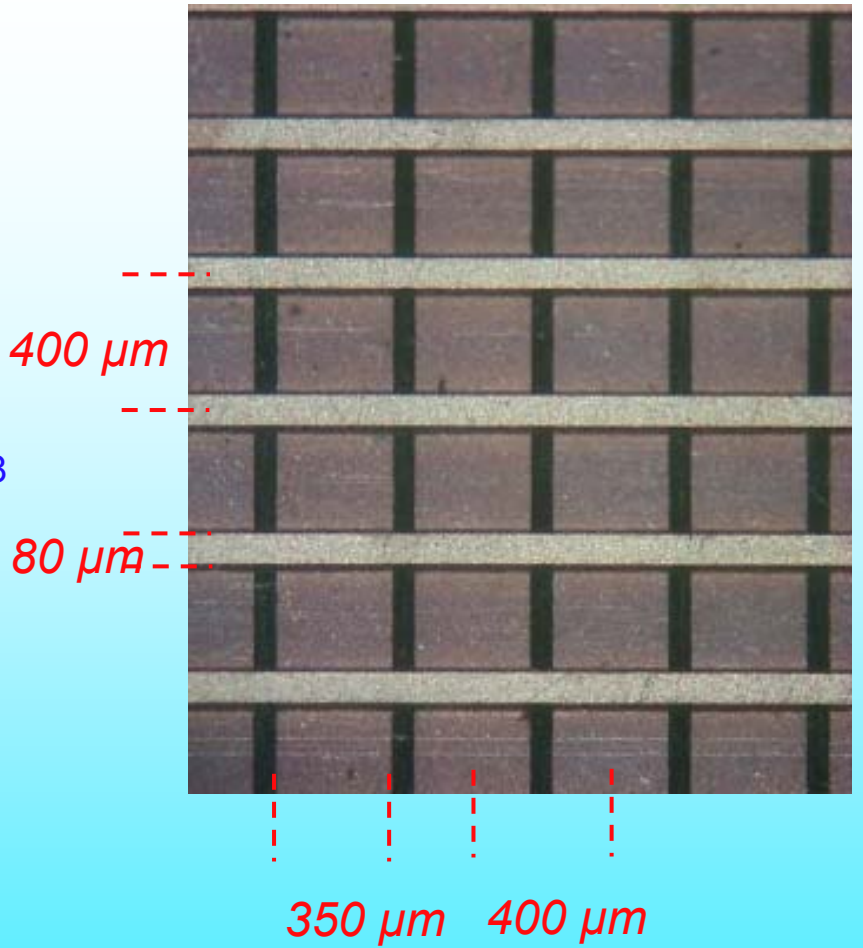




~ 100 foils produced
22 Triple-GEM detectors running

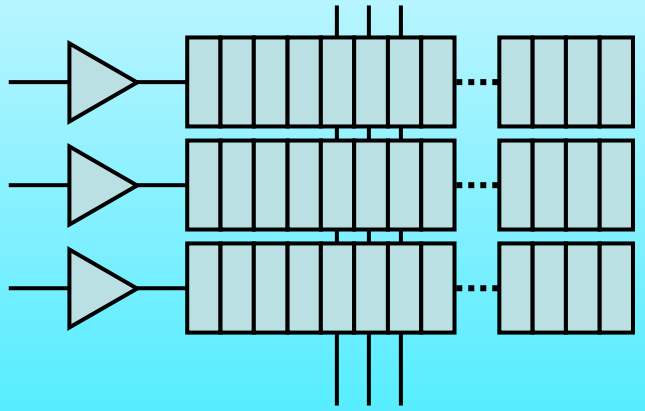
2-D READOUT: perpendicular strips at 400 μm pitch





READOUT ELECTRONICS

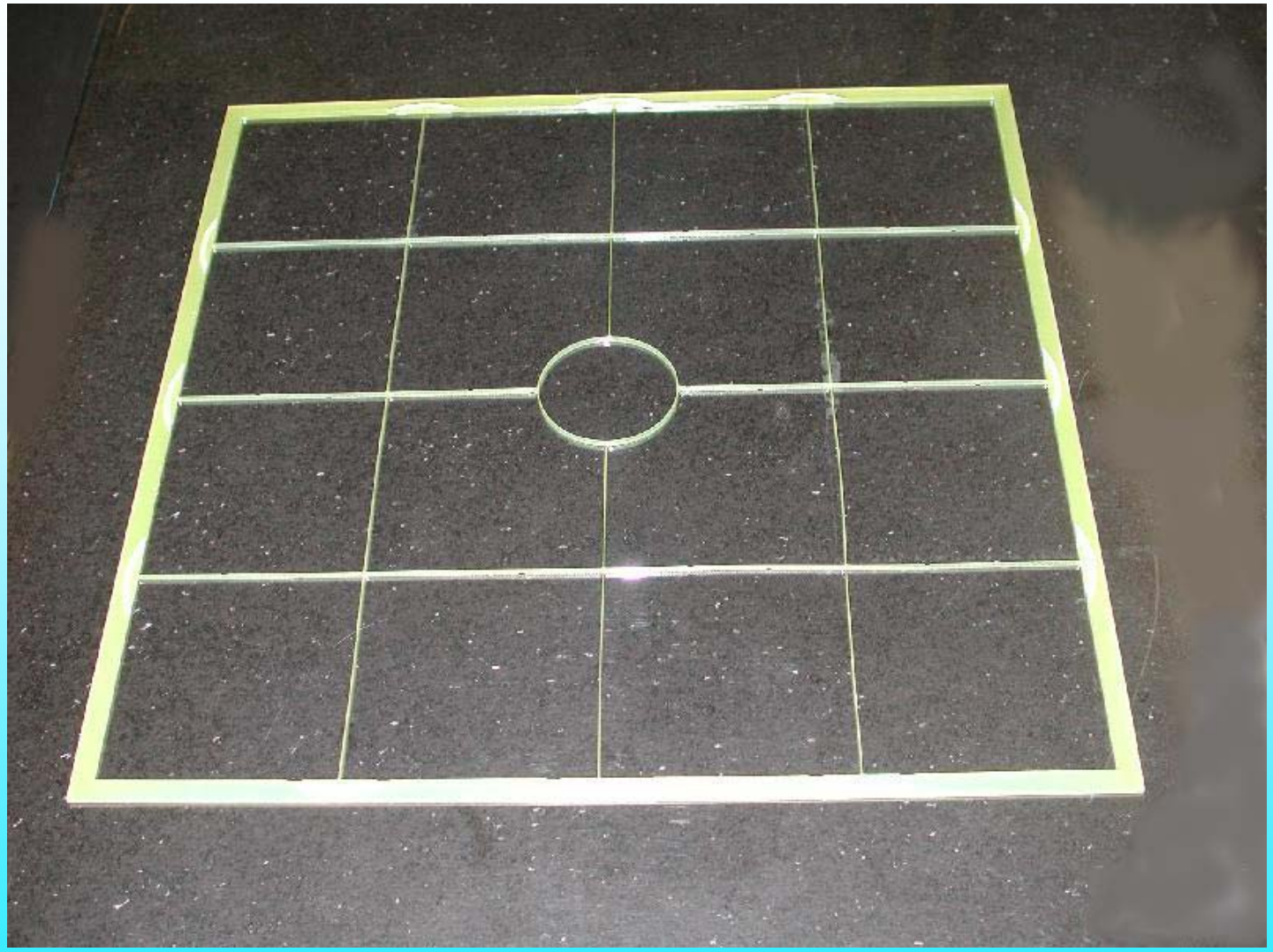
Recording of charge on each strip with the APV25 128 channels analogue pipeline (25 ns sampling)



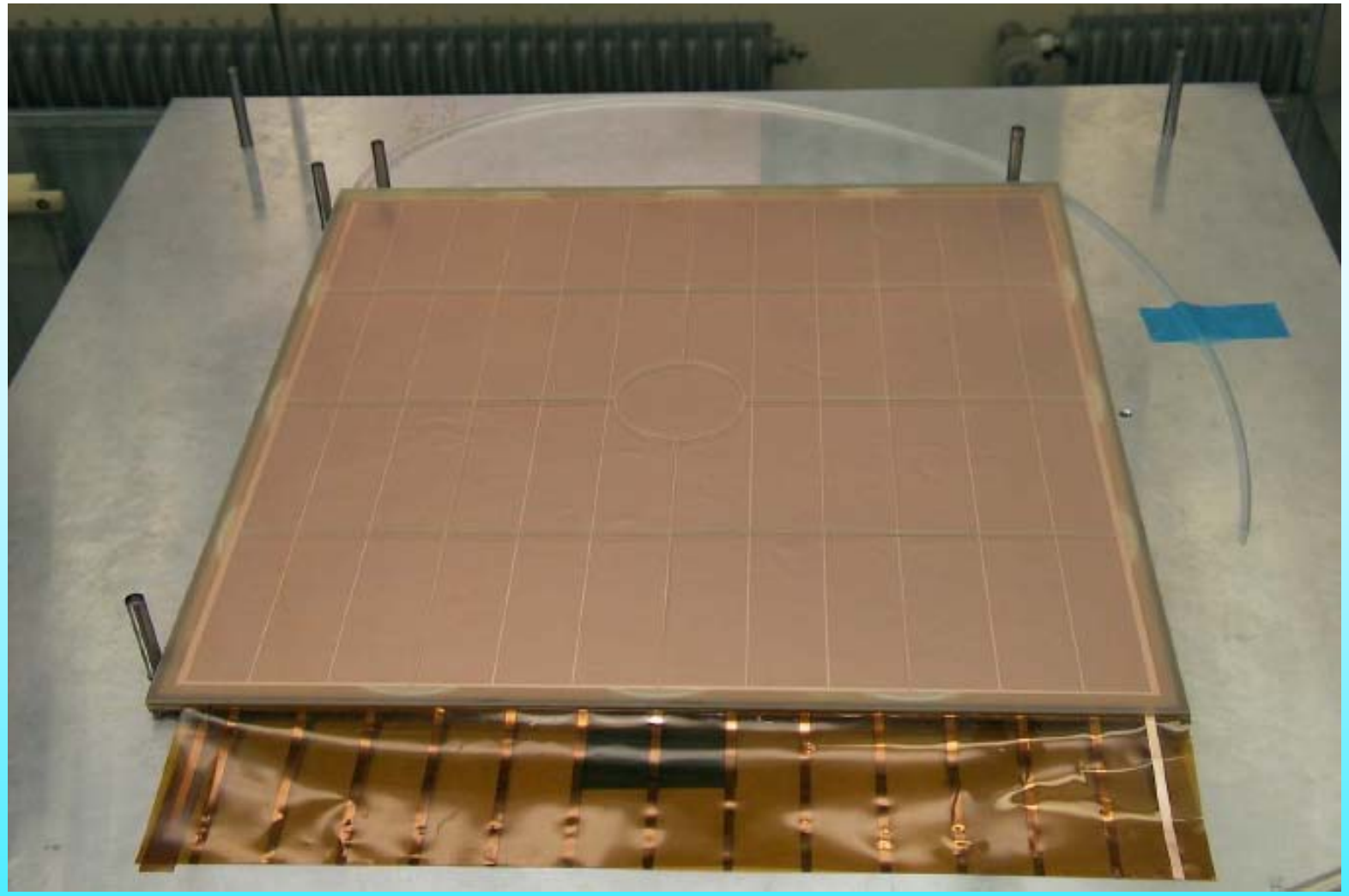
Charge recorded on 3hree adjacent bins (10 bit ADC)

M. J. French et al, Nucl. Instr. and Meth. A466(2001)359

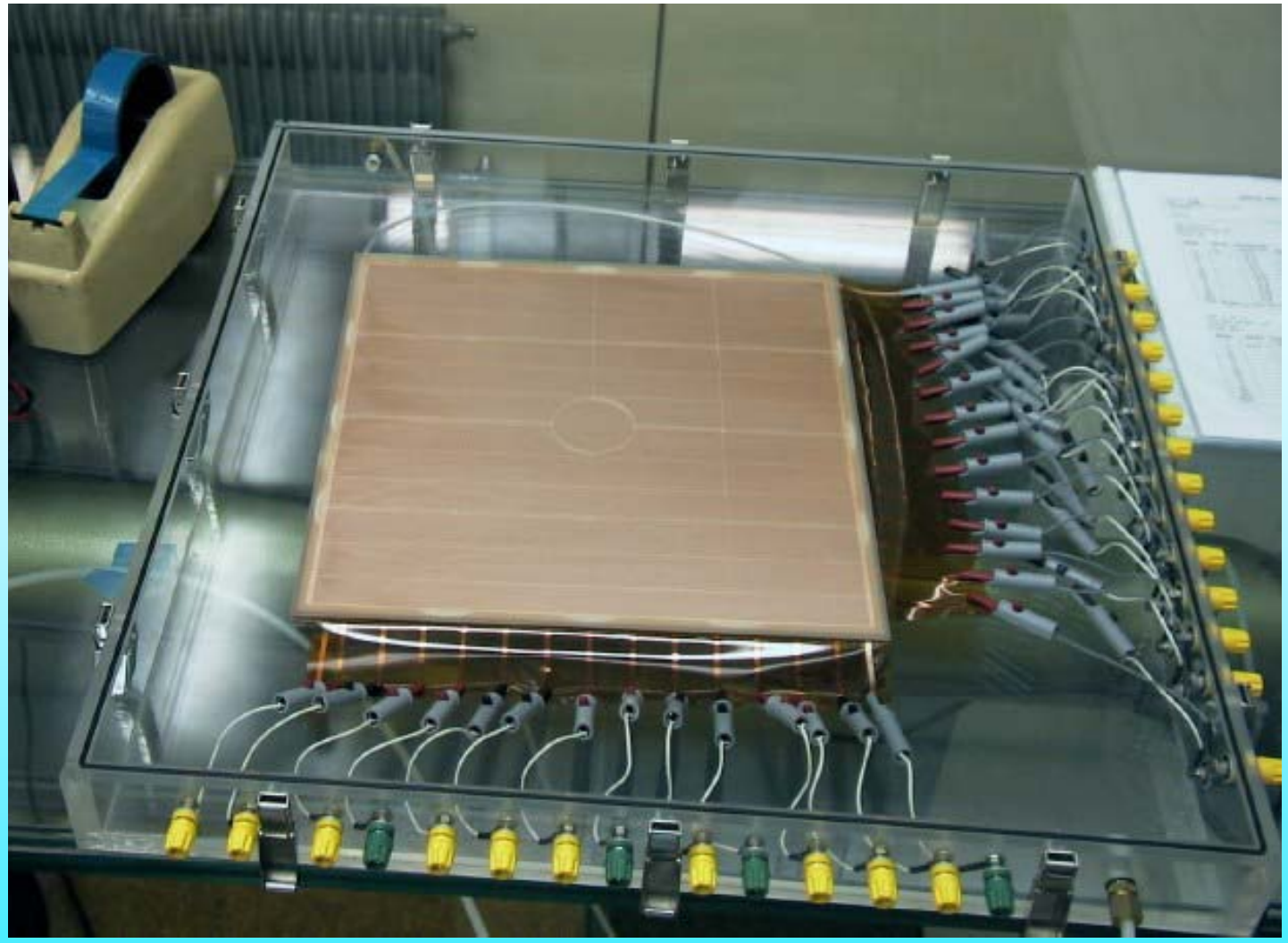
GEM FRAME AND SPACER:



First GEM stretched and glued on frame:

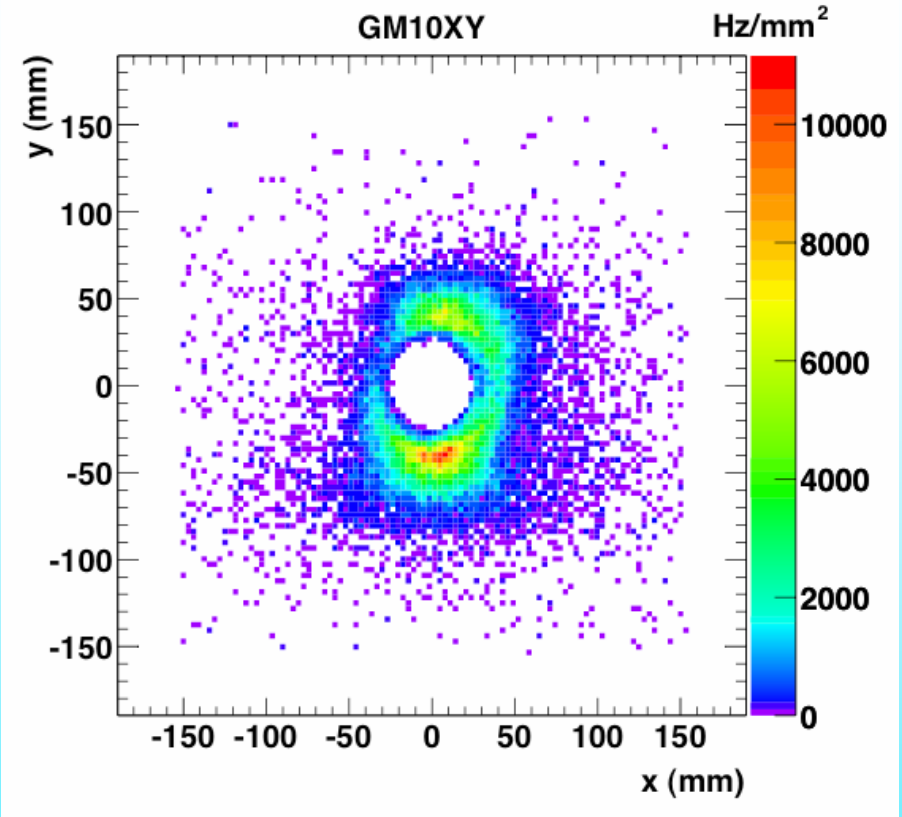


HV TESTING DURING CONSTRUCTION

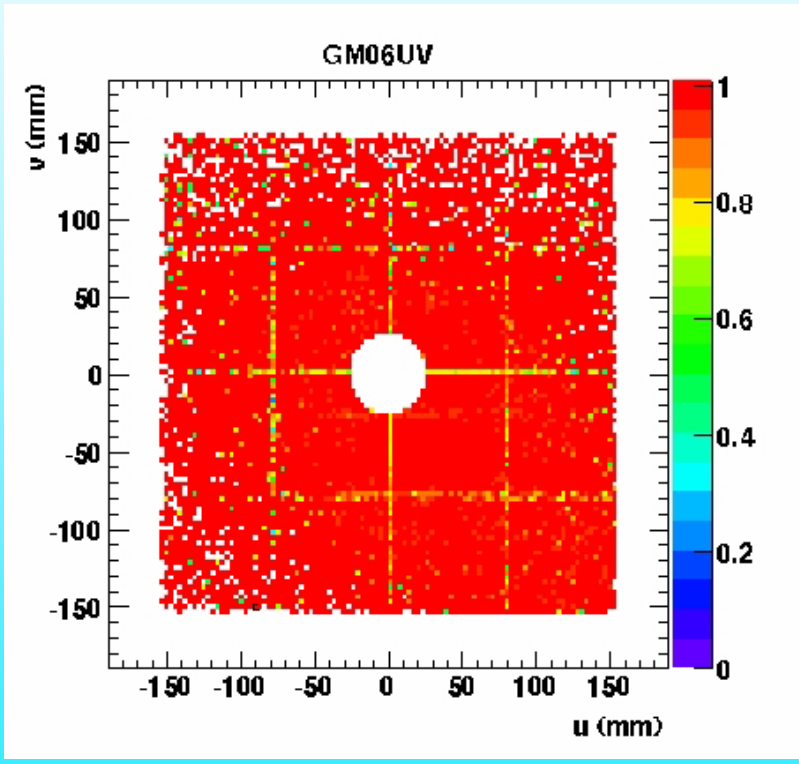


HIGH-RATE RUNNING PERFORMANCE

Reconstructed tracks density:

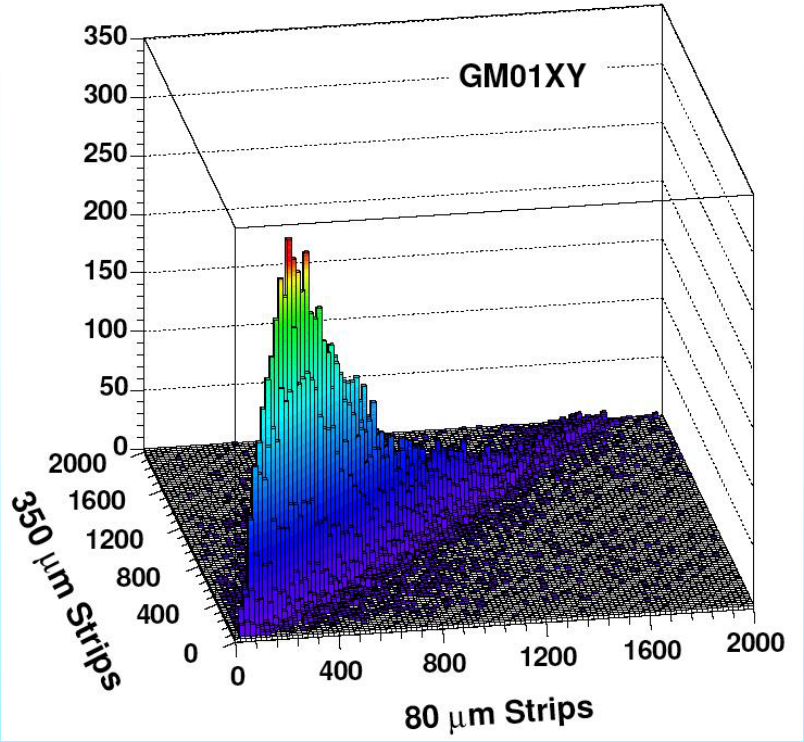


Efficiency uniformity:

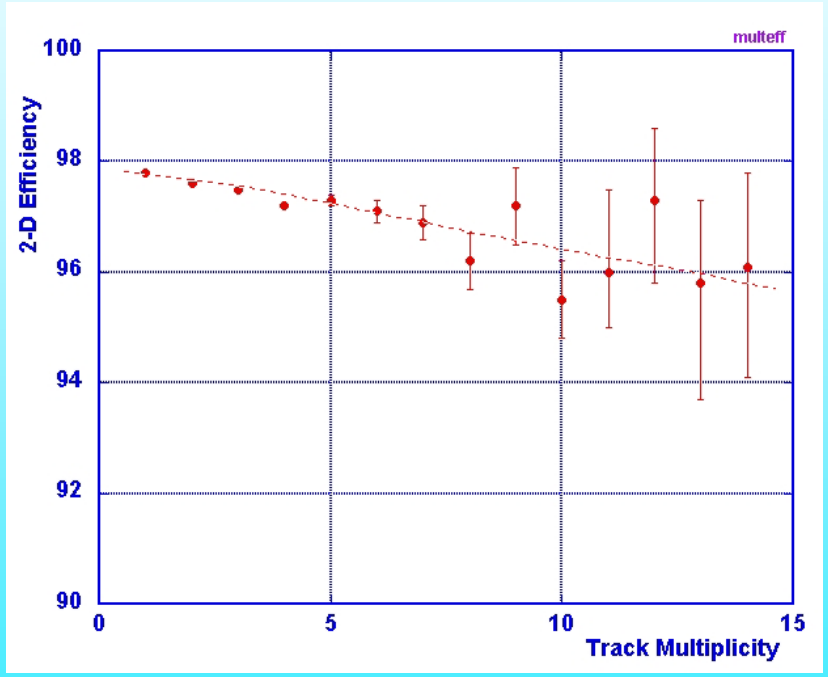


B. Ketzer et al, Nucl. Instr. And Meth. A535(2004)314

Charge correlation between the two projections:



Efficiency vs track multiplicity:



SUMMARY OF RUNNING PERFORMANCES:

Max rate 10 kHz mm^{-2}

Space accuracy $\sigma_x \sim \sigma_y \sim 70$ μm

Efficiency: 97.2% (single)

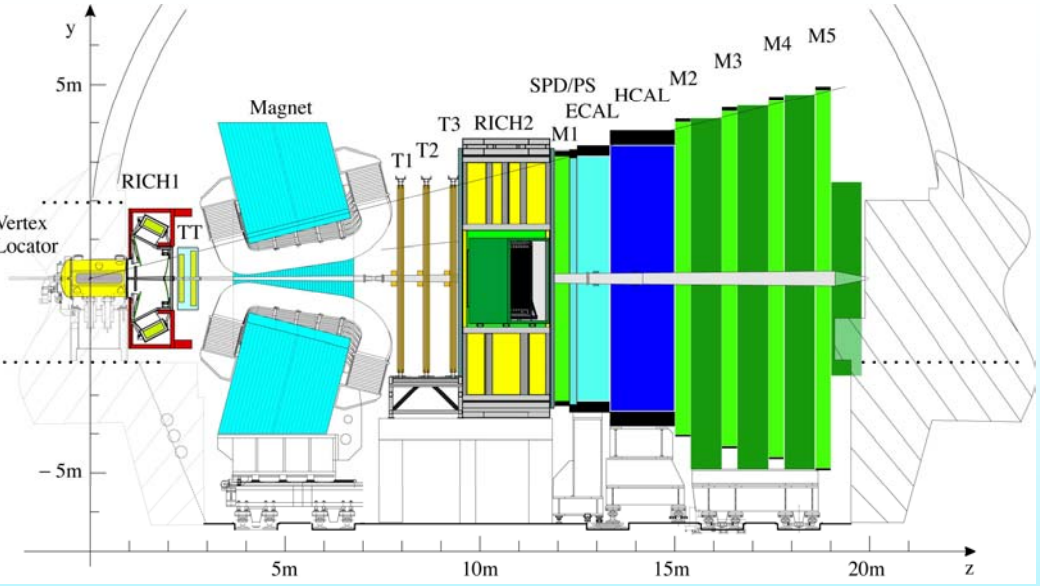
95.6% (2D)

X-Y Charge correlation: 10% rms

Time resolution: $\sigma_t = 12$ ns (from 3-sample fit)

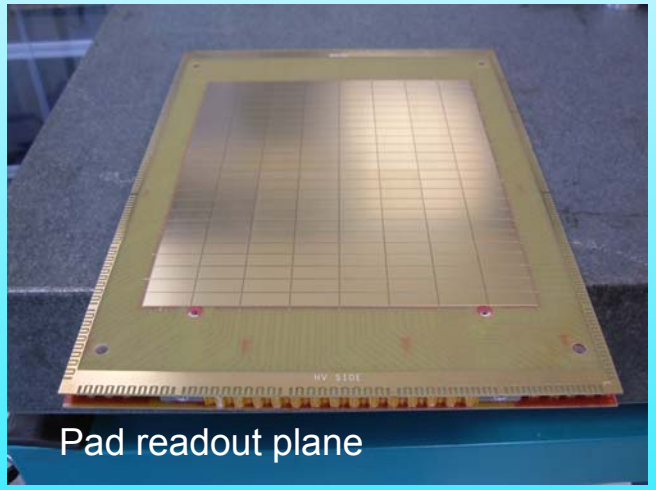
B. Ketzer et al, Nucl. Instr. And Meth. A535(2004)314

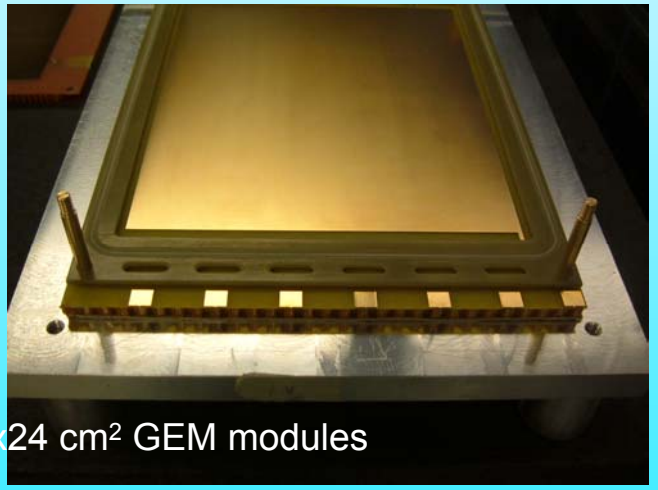
FAST TGEM DETECTORS FOR LHCb MUON TRIGGER



12 double TGEM detectors operated with fast gas mixture (Ar-CO_2-CF_4)

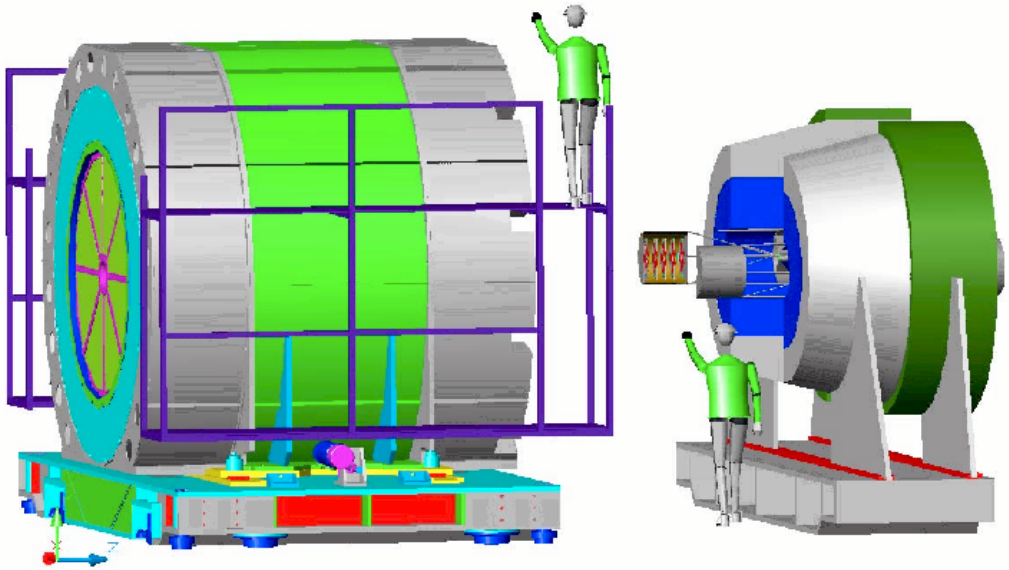
Rate - 5 kHz mm^{-2}
Time resolution 4.5 ns rms
No aging up to integrated charge of 20 mC mm^{-2} (15 LHCb years)


Pad readout plane


20x24 cm^2 GEM modules

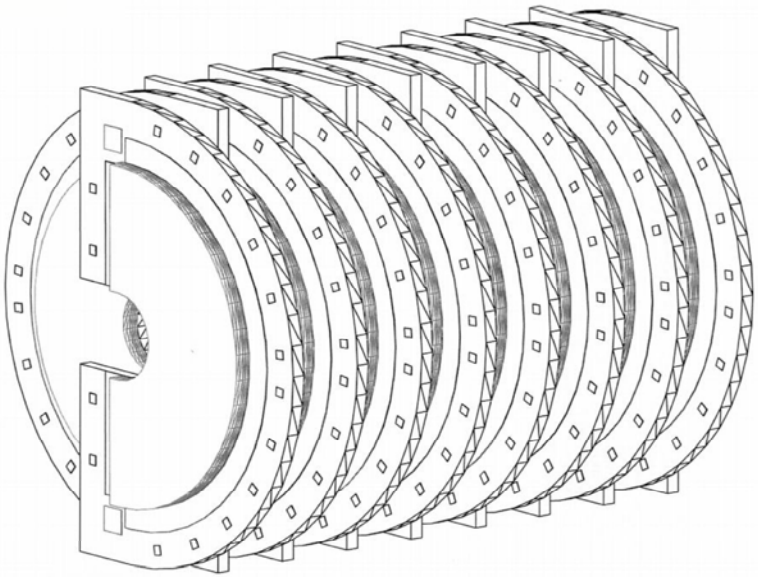
M. Alfonsi et al, Nucl. Instr. And Meth. A535(2004)319
W. Bonivento, IEEE Nucl. Sci. Symposium (Rome 2004)

TOTEM: Total Cros Section, Elastic Scattering and Diffraction Dissociation at LHC



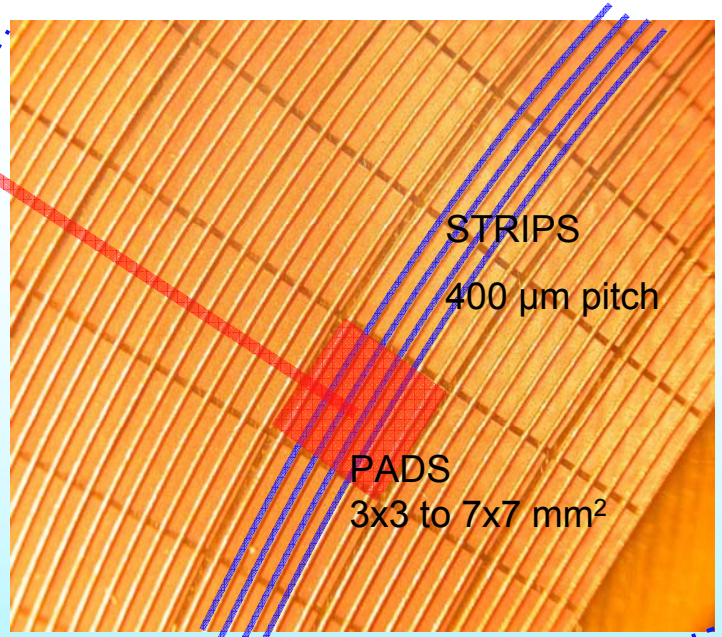
TGEM Tracker in the open plug of the CMS forward shielding

2x10 Semicircular TGEM detectors on each arm:

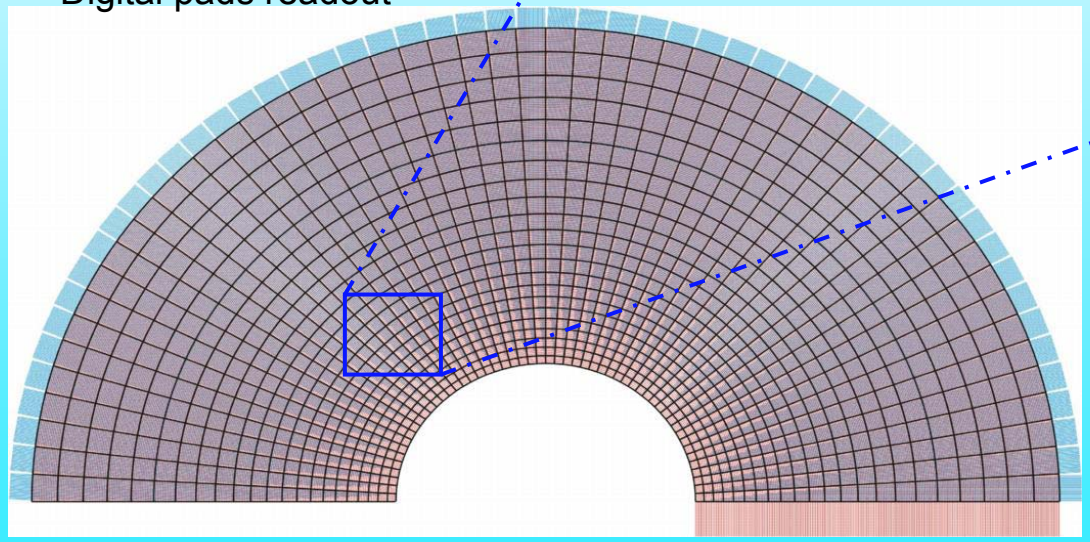


http://totem.web.cern.ch/Totem/

TOTEM tgem READOUT BOARD:
- Radial strips (accurate track's angle)
- Pad matrix (fast trigger and coarse coordinate)

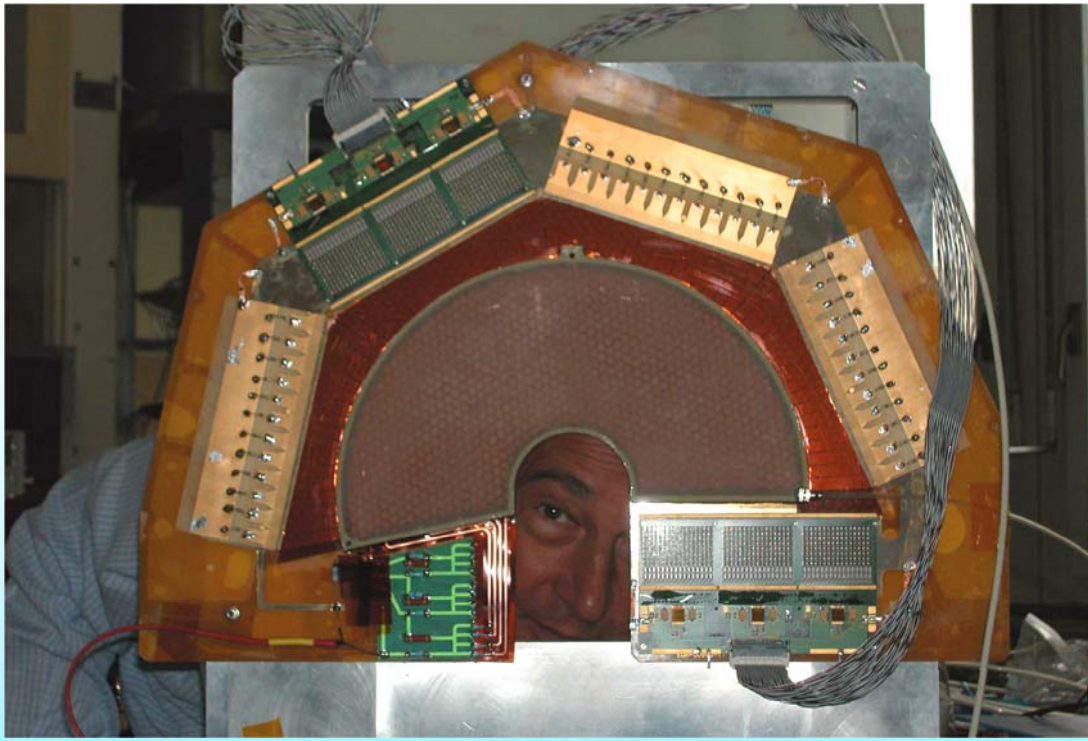


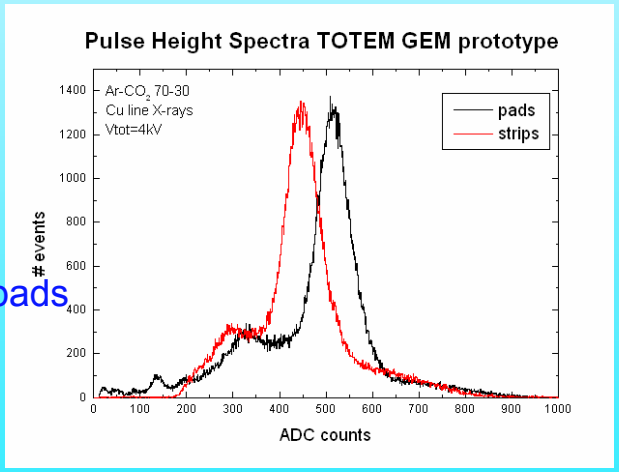
Digital pads readout



Analogue strips readout

FIRST TOTEM TGEM PROTOTYPE
Beam tested (end 2004)

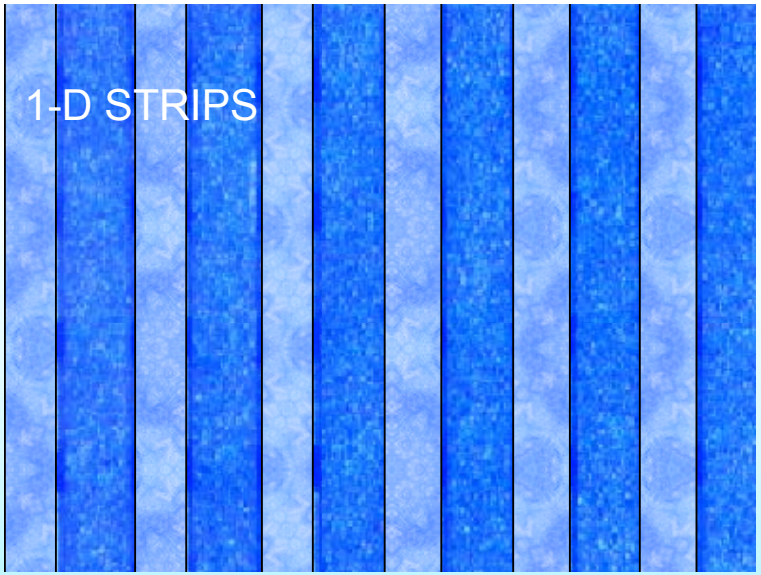


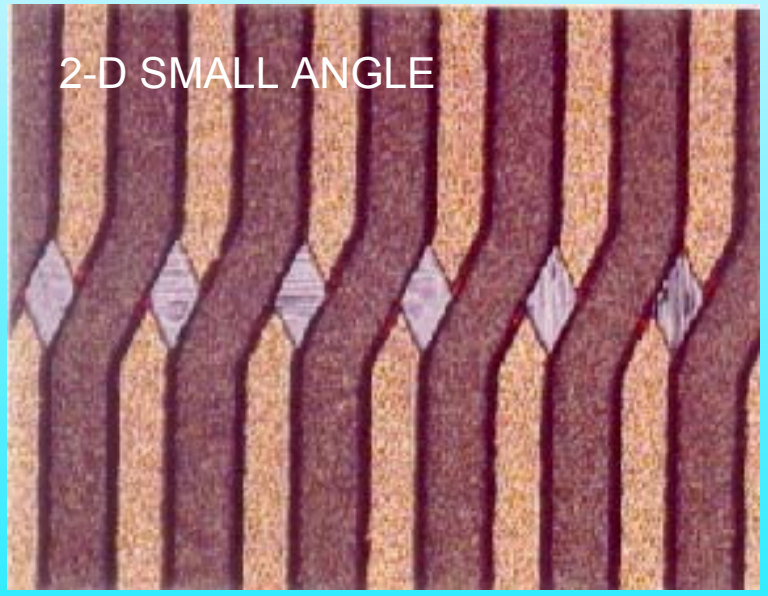


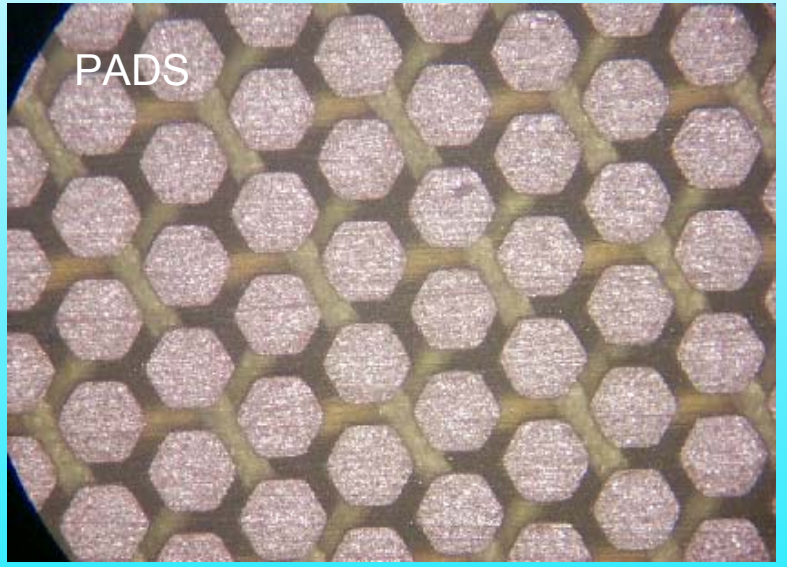
Charge sharing strips/pads

M. Bozzo et al, subm. IEEE Nuclear Science Symposium (Rome, Oct. 16-22, 2004)

READOUT PATTERNS:

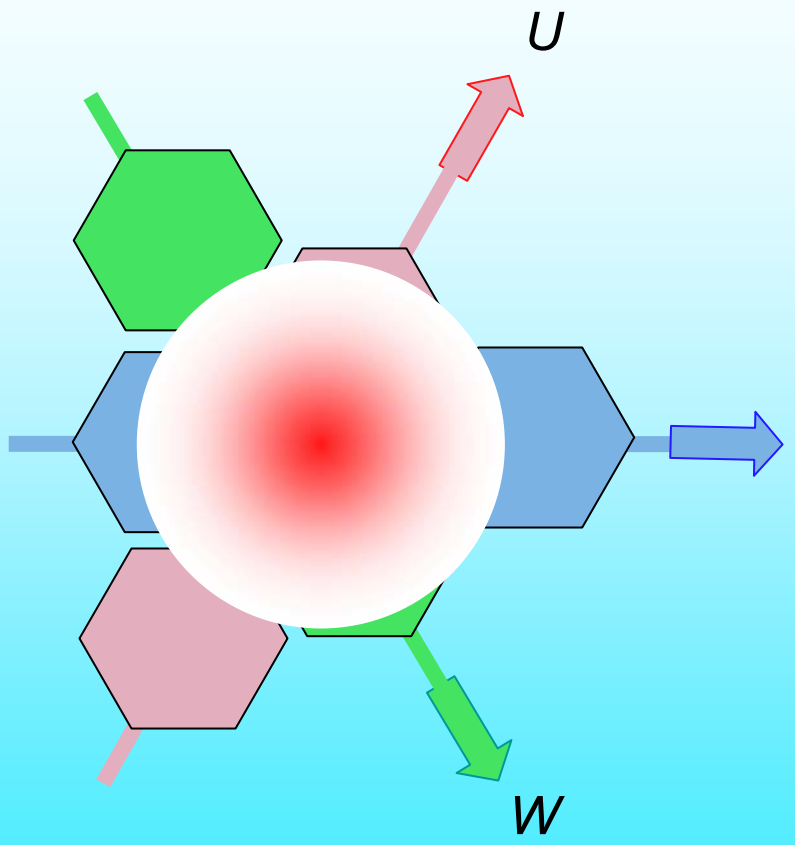


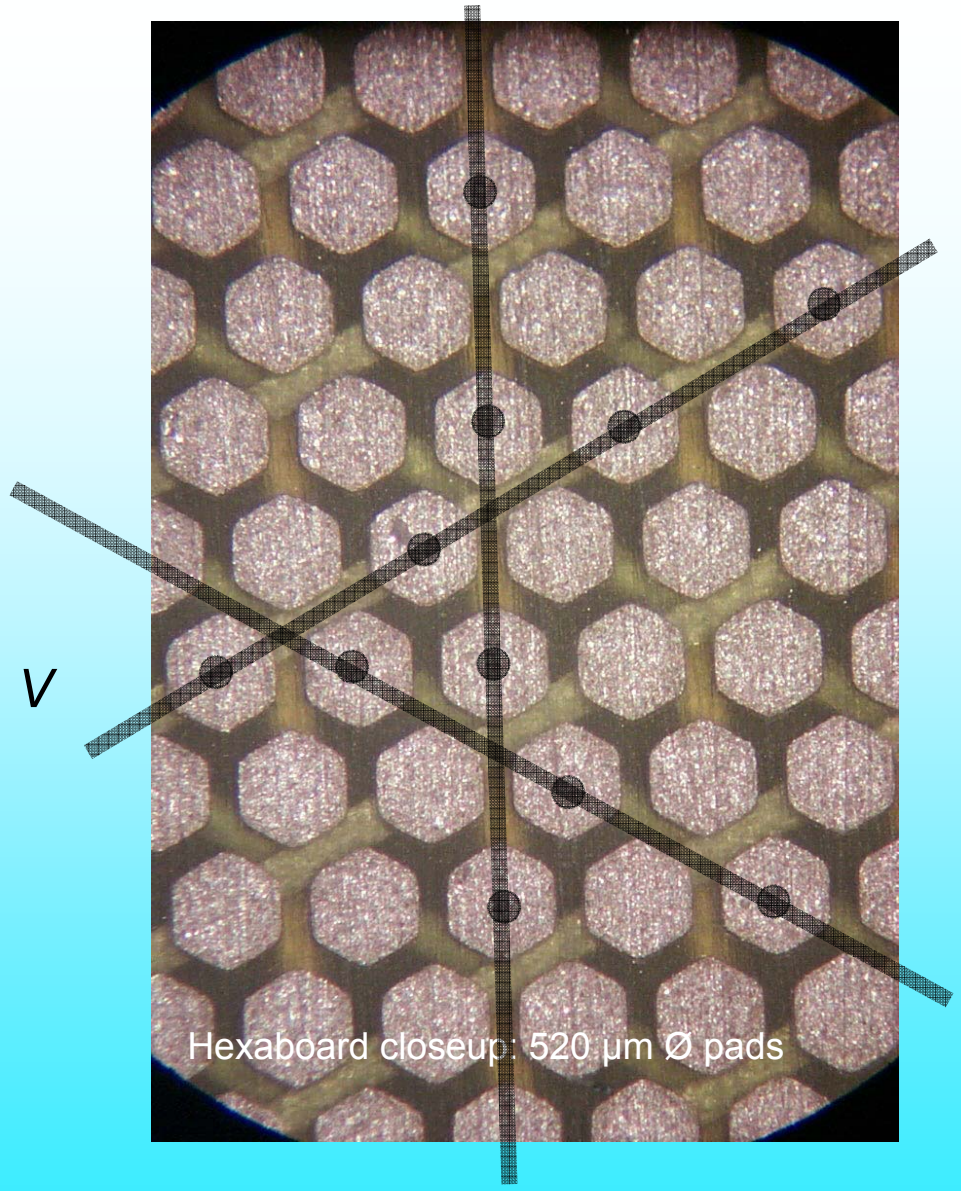




HEXABOARD READOUT: 3D

Hexagonal pads interconnected along three projections at 120º:

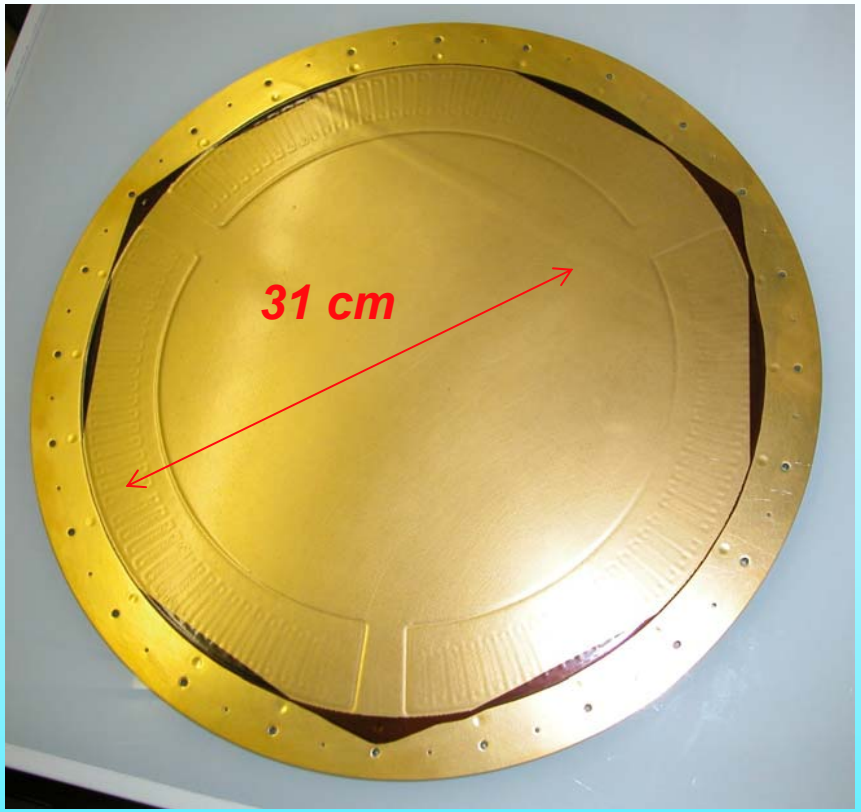


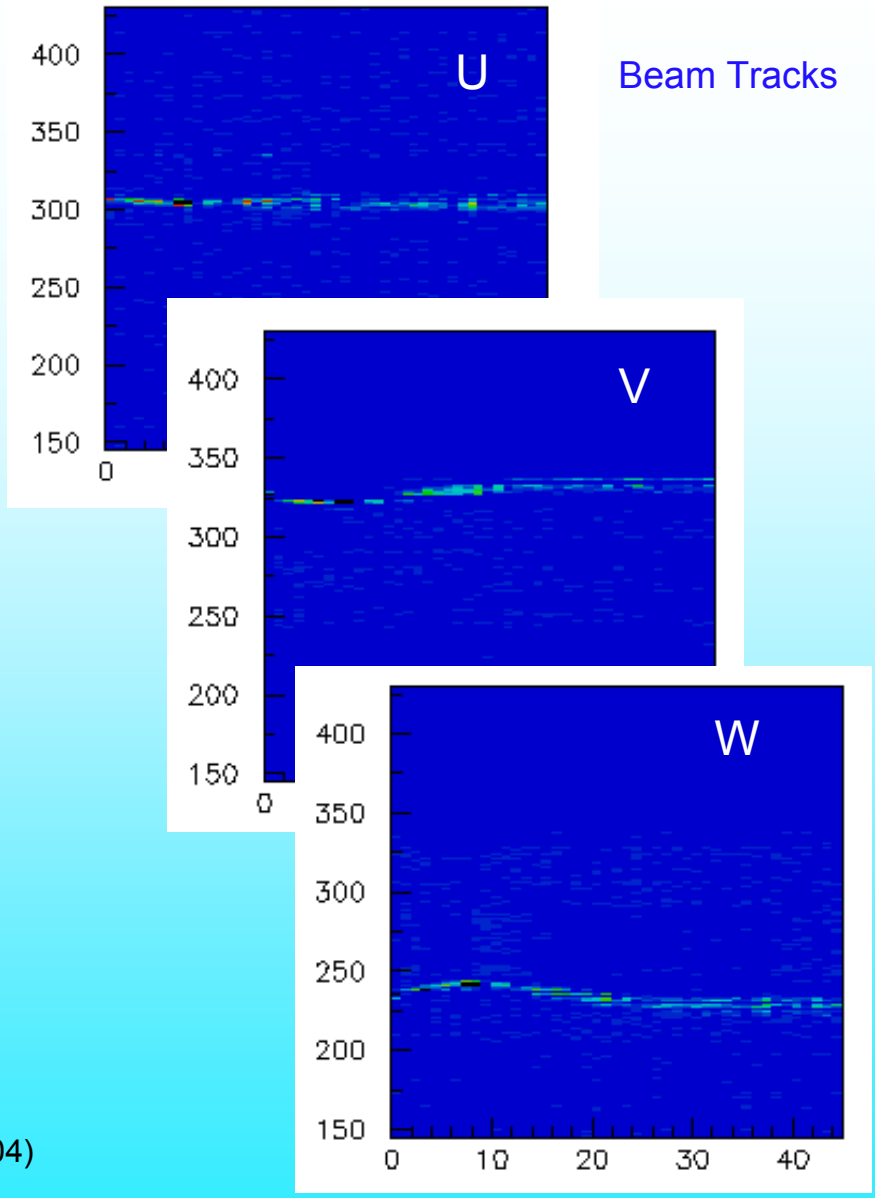


S. Bachmann et al, Nucl. Instr. and Meth. A 478 (2002) 104

MICE: Muon Ionization Cooling Experiment

HEXABOARD GEM TPC Prototype

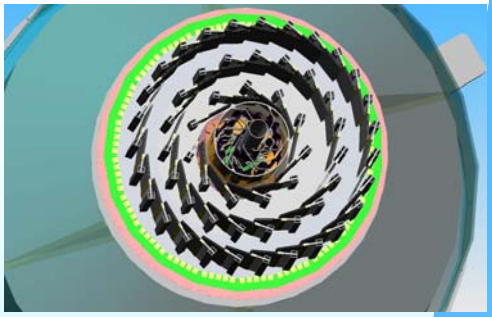


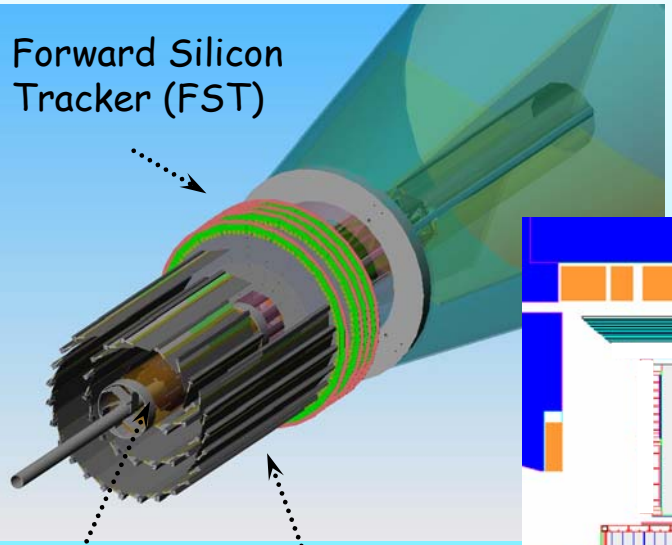


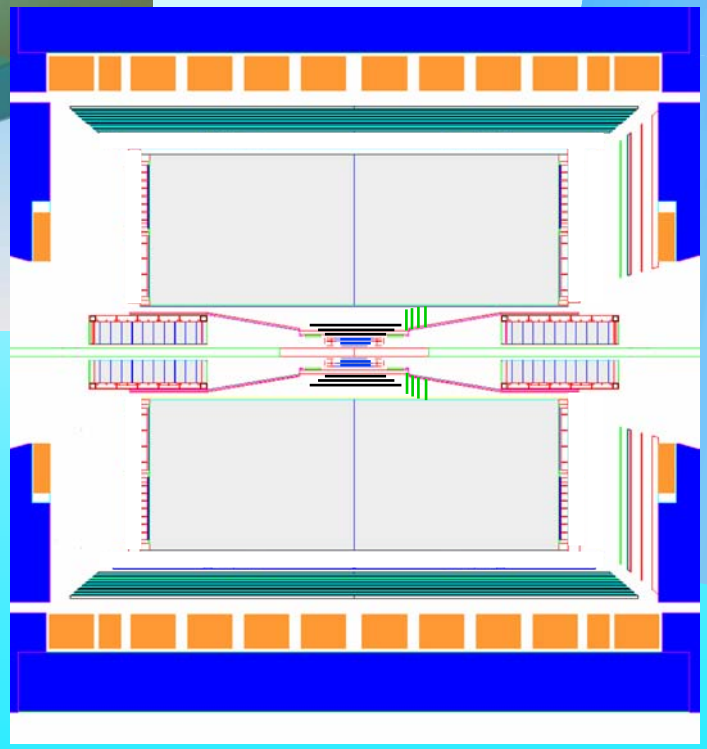
V. Ableev et al, Nucl. Instr. and Meth. A518(2004)113

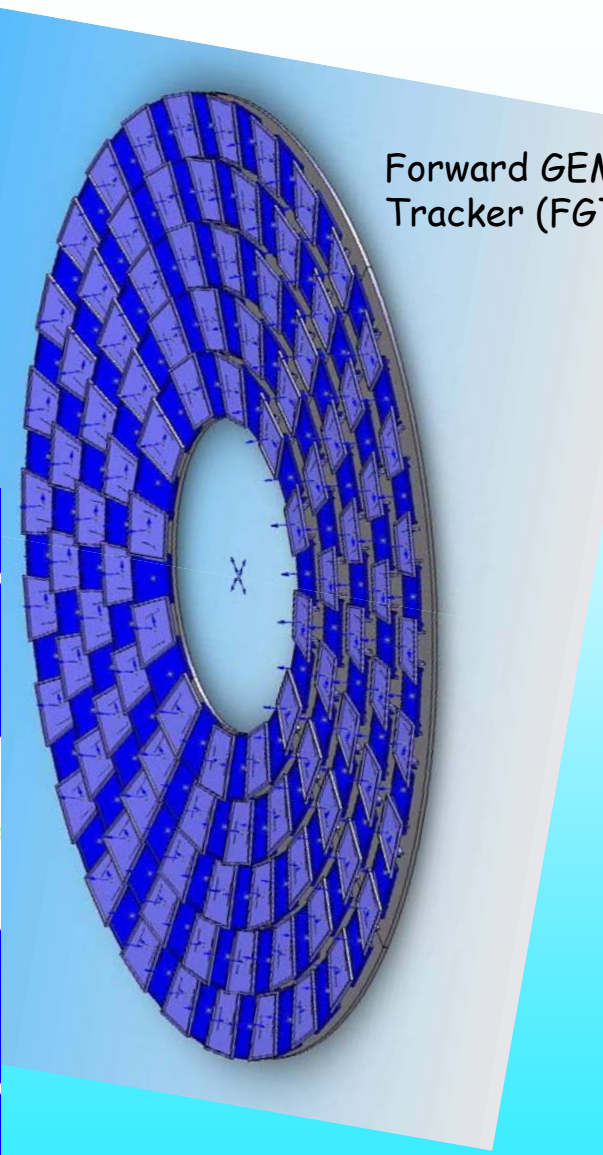
Pietro Chimenti, IEEE Nuclear Science Symposium (Roma 2004)

- Solidworks design





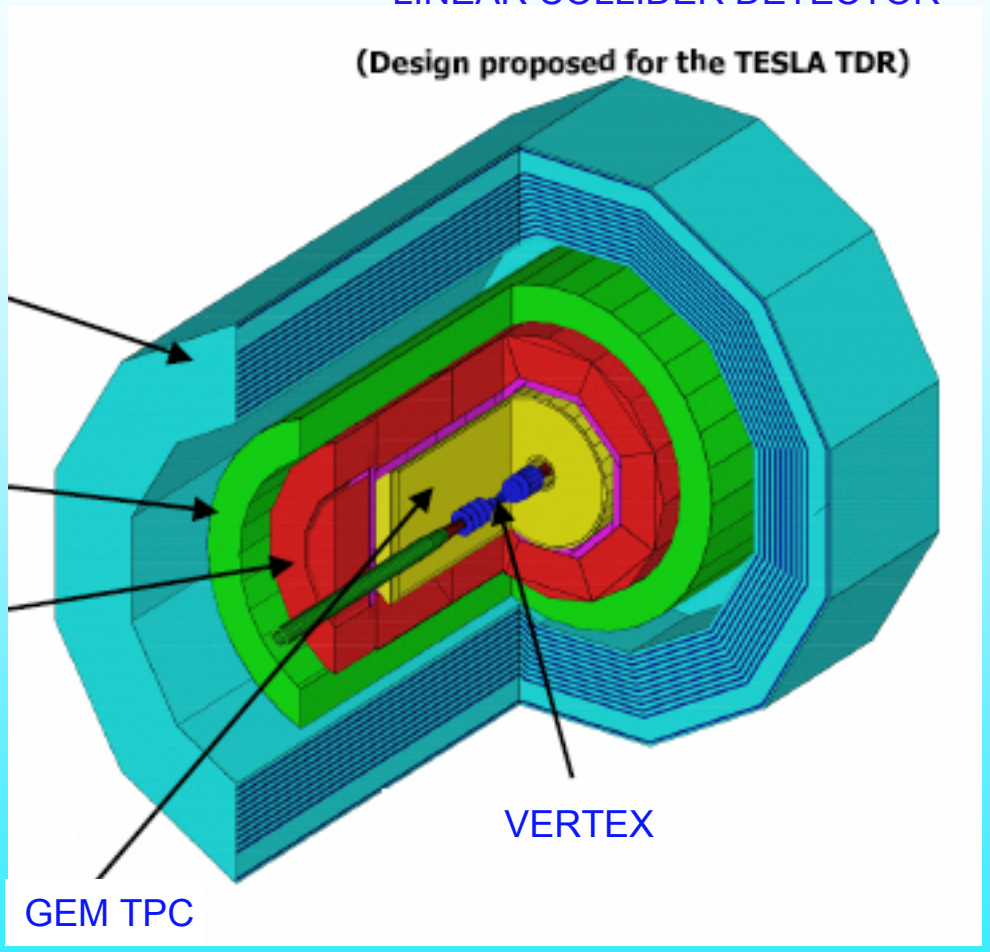




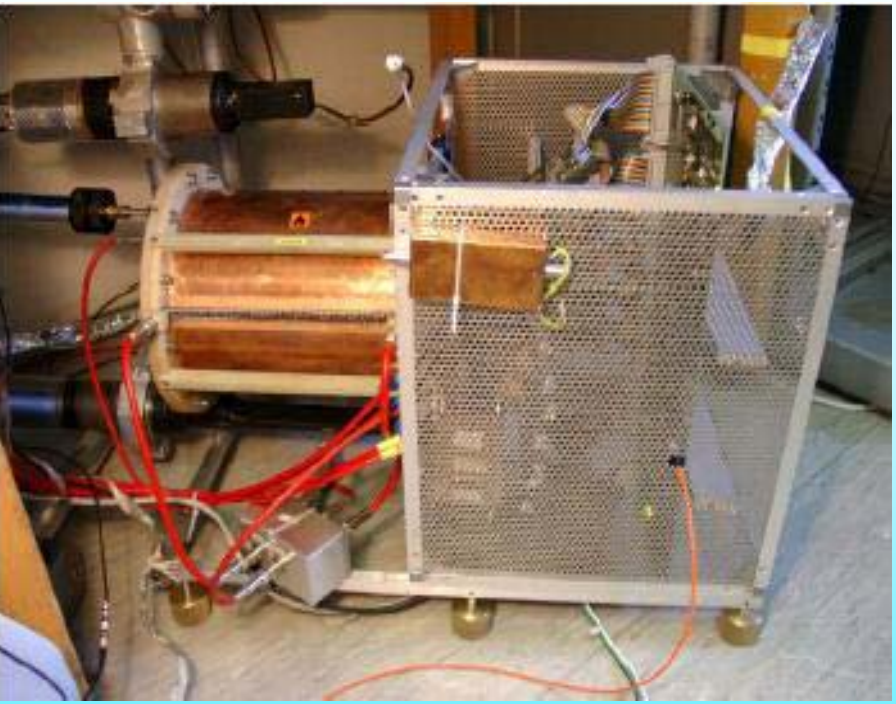
GEM READOUT FOR THE TIME PROJECTION CHAMBER

- Narrow pad response function: $\Delta s \sim 1$ mm
- Fast signals (no ion tail): $\Delta T \sim 20$ ns
- Very good multi-track resolution: $\Delta V \sim 1$ mm^3 (Standard MWPC TPC ~ 1 cm^3)
- Ion feedback suppression: $I^+/I^- \sim 0.1\%$
- No ExB distortions
- Freedom in end-cap shapes
- Robustness

LINEAR COLLIDER DETECTOR



GEM-TPC PROTOTYPE
LBL-KARLSRUHE-CERN



QuickTime™ and a
GIF decompressor
are needed to see this picture.

QuickTime™ and a
GIF decompressor
are needed to see this picture.

Test beam results:

Efficiency 99.3 %

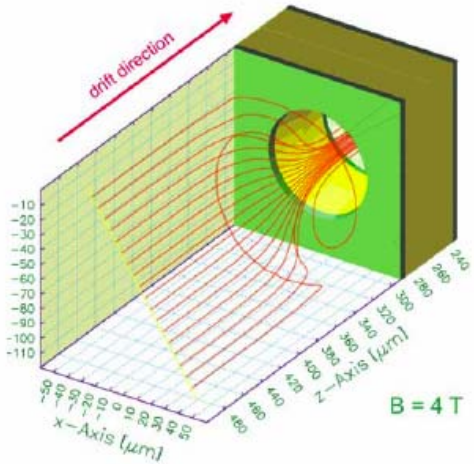
Position accuracy $\sigma_x \sim \sigma_z \sim 100$ μm

PAD ROWS: 1.27 x 12.5 mm

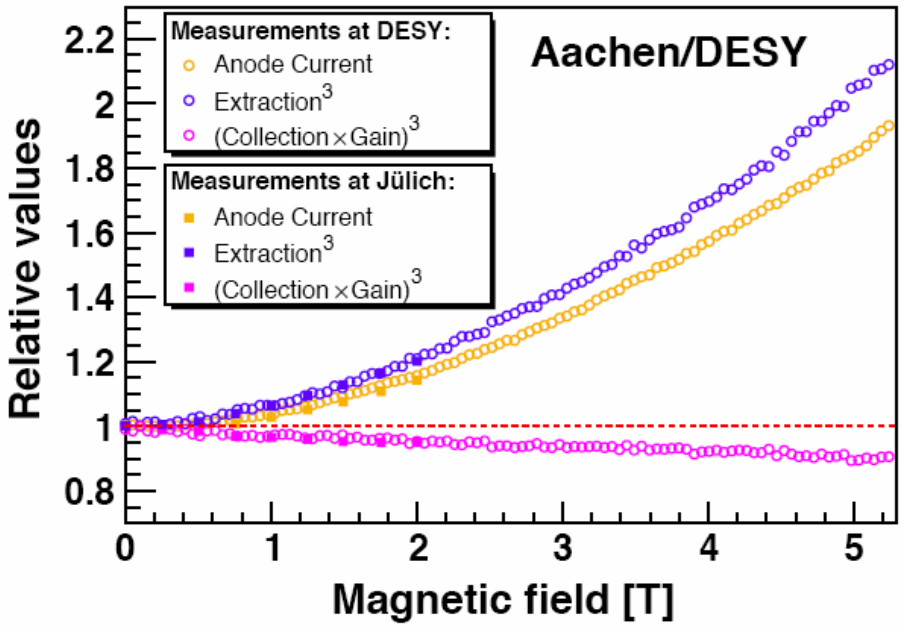
S. Kappler et al, IEEE Trans. Nucl. Sci. NS51(2004)1039
J. Kaminski et al, Nucl. Instr. and Meth. A535(2004)201

GEM TPC STUDIES

Charge transport in high magnetic fields:

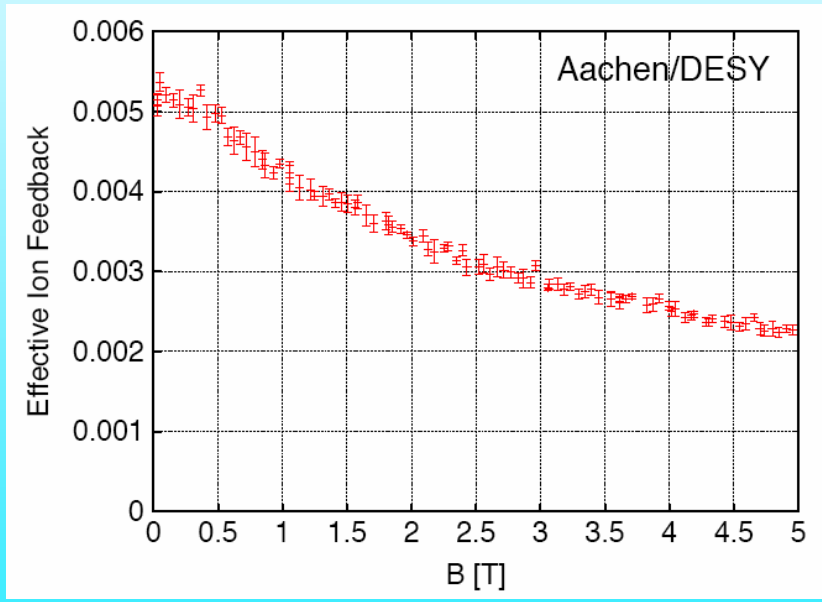


Electron signal:



M. Killenberg et al,
Nucl. Instr. and Meth. A530(2004)251

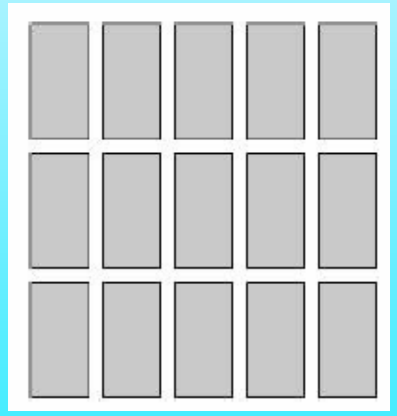
Ion feedback:

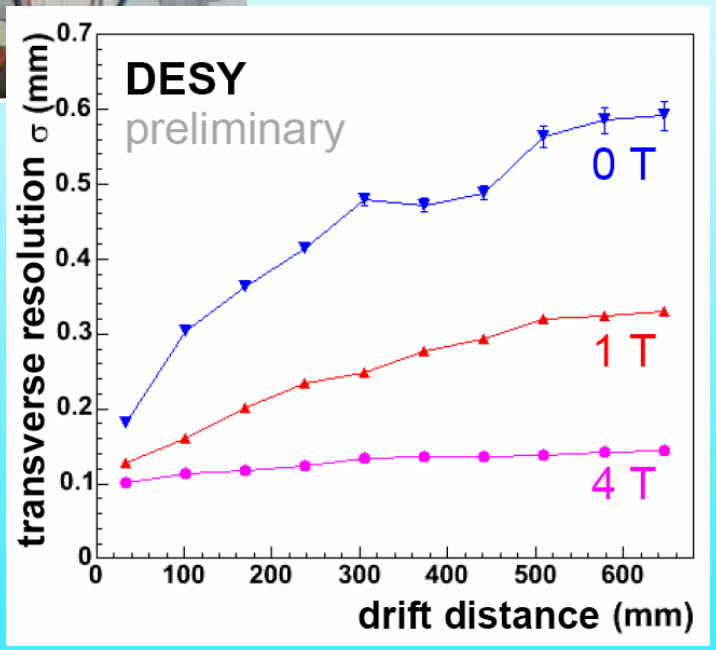


GEM-TPC studies in high magnetic field at DESY:

80 cm drift - Triple GEM detector

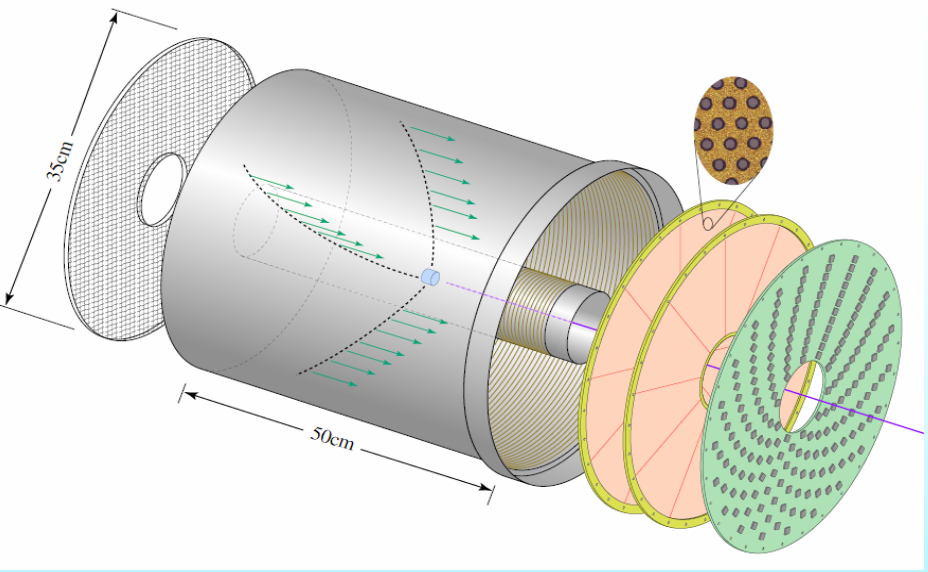
2.2x6.2 mm² pads

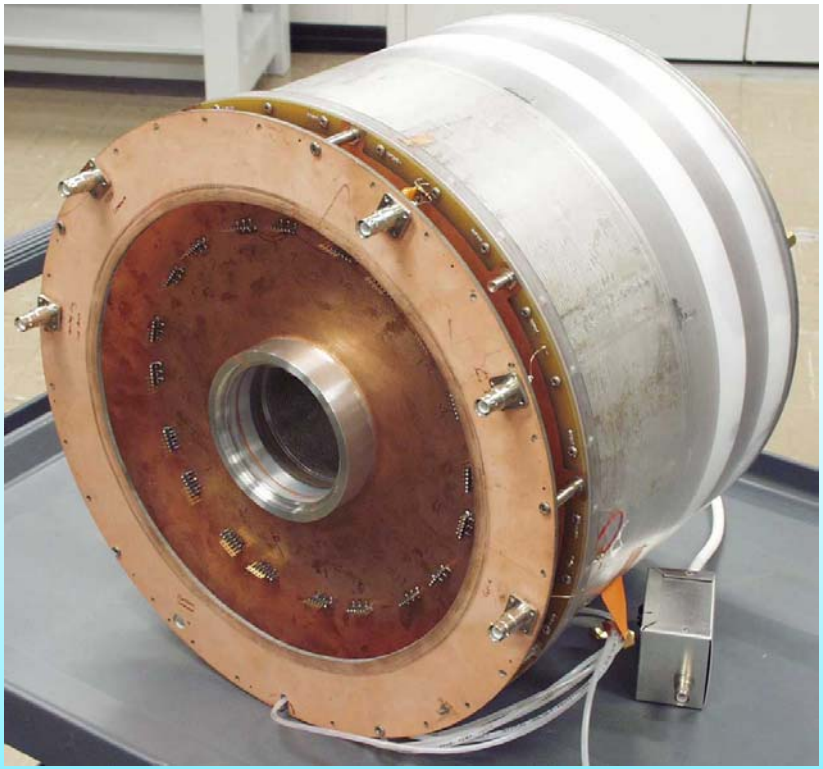


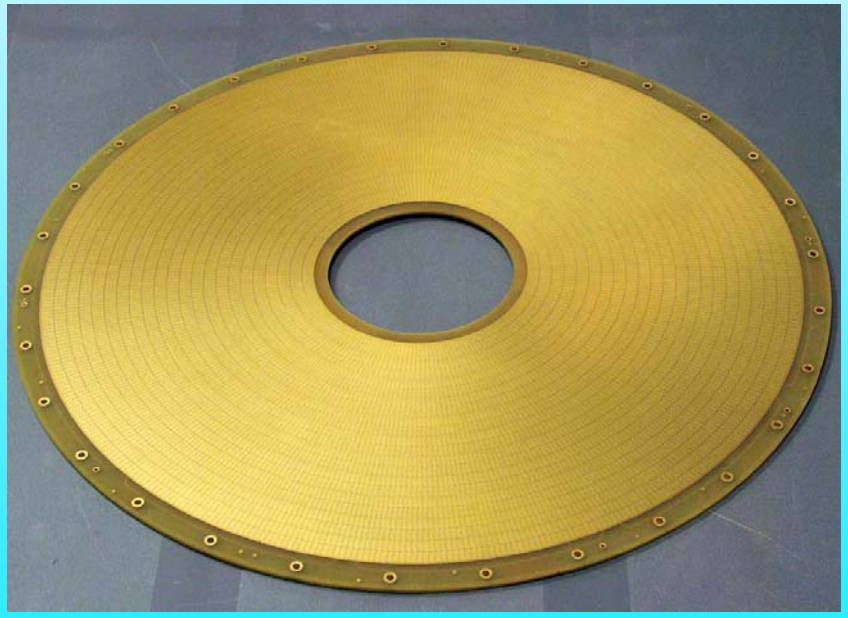


P. Wienemann, Int. Linear Collider Workshop, SLAC March 18-22, 2005

GEM-TPC FOR LEGS (LASER ELECTRON GAMMA SOURCE) AT BNL







Bo Yu, personal communication

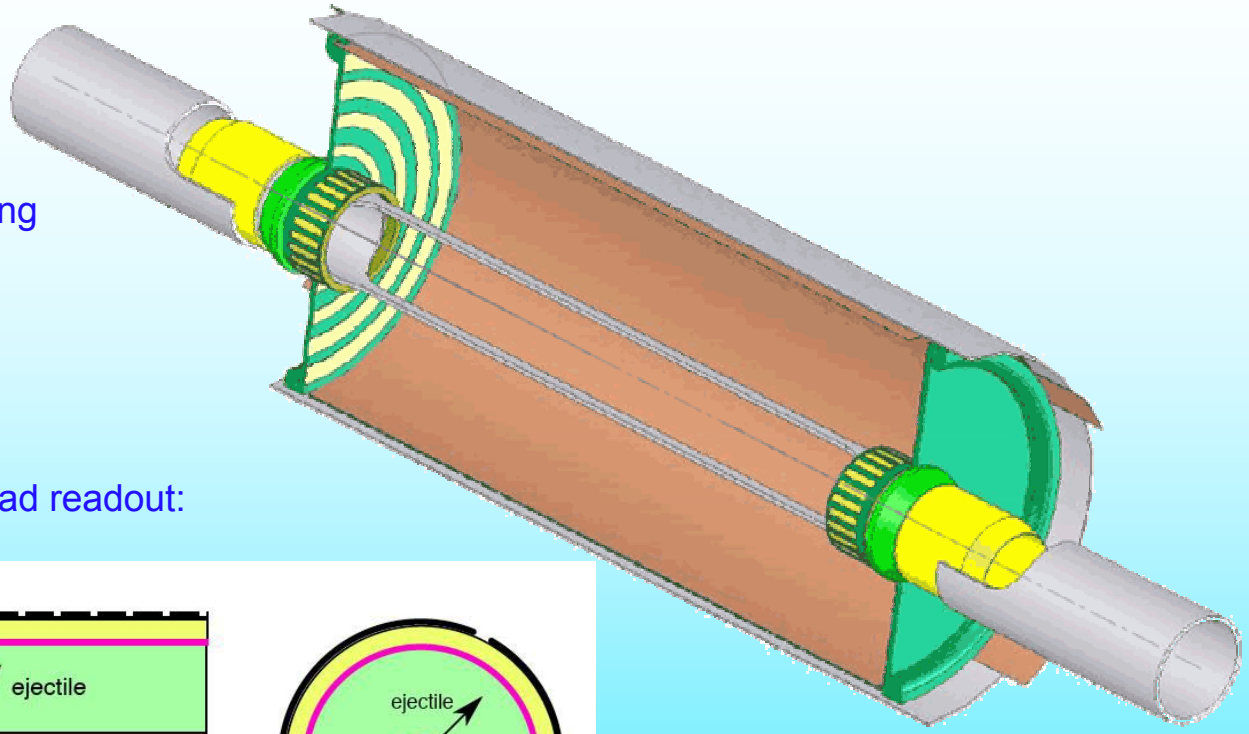
TACTIC

TRIUMF Annular Chamber for the Tracking and Identification of Charged particles

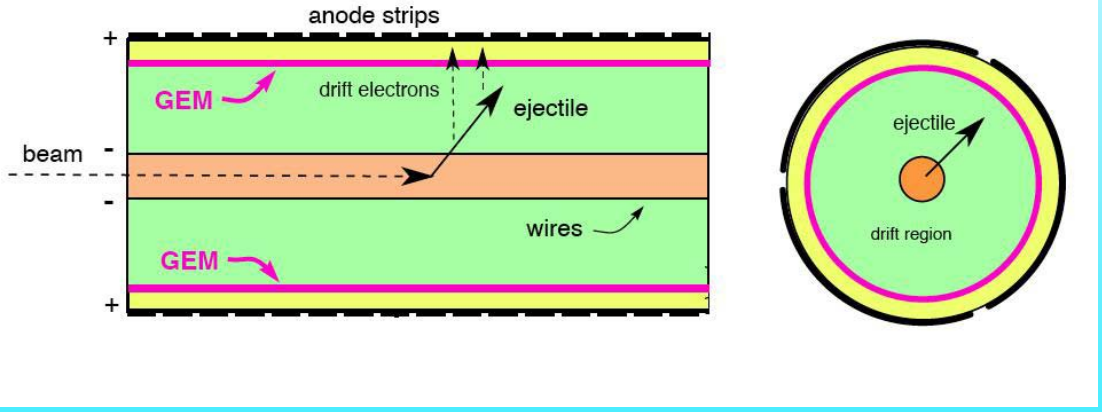
Measurement of nuclear cross sections for astrophysics

$^{8}Li(\alpha,n)\ ^{11}B$

^{8}Li ions (90-220 keV/u) interacting in He gas



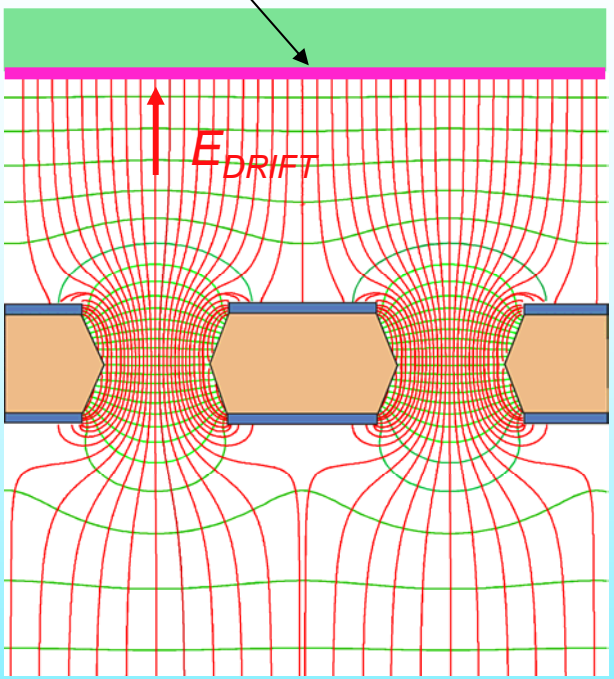
Cylindrical GEM detector with pad readout:



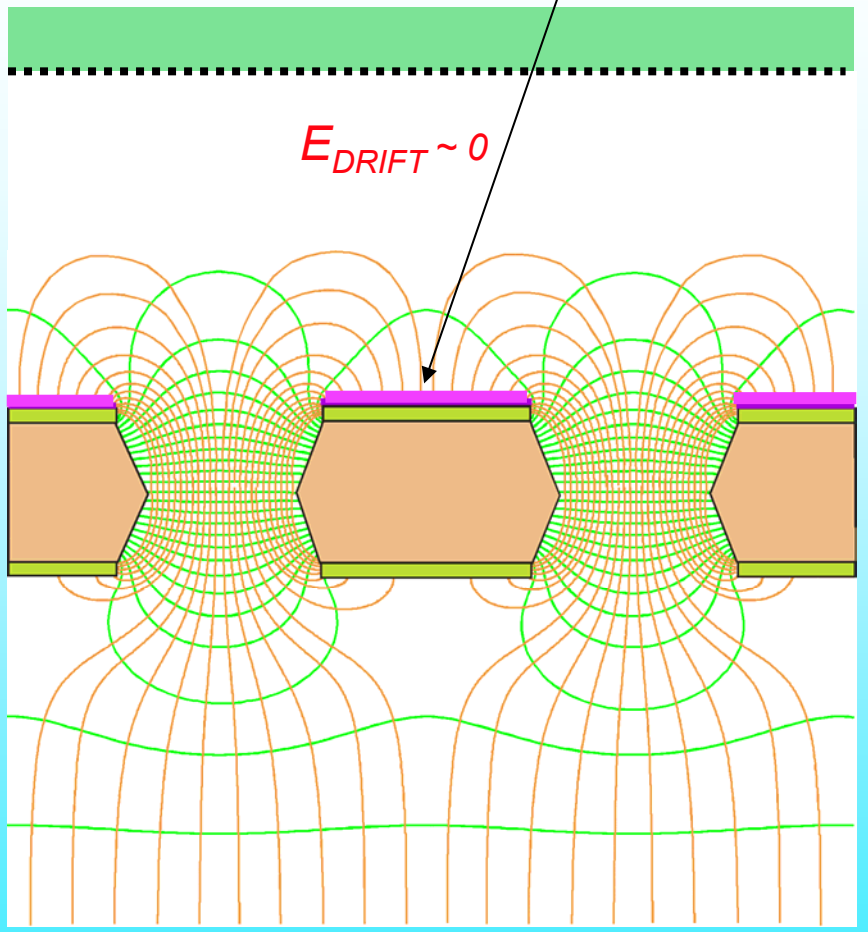
http://tactic.triumf.ca/about.html

PHOTON DETECTION WITH GEM

Semi-transparent photocathode:



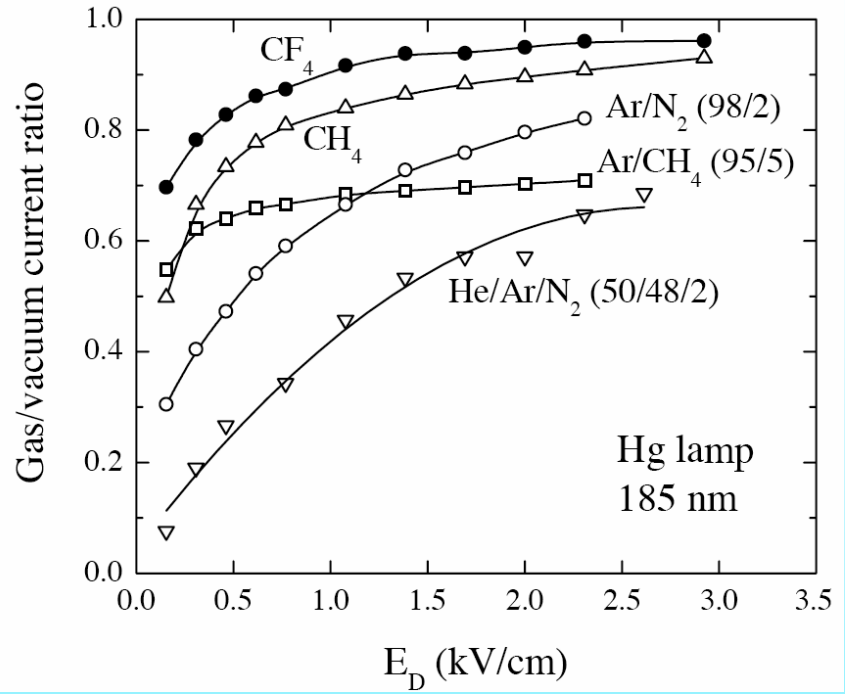
Reflective photocathode:



R. Bouclier et al, IEEE Trans. Nucl. Science NS-44(1997)646

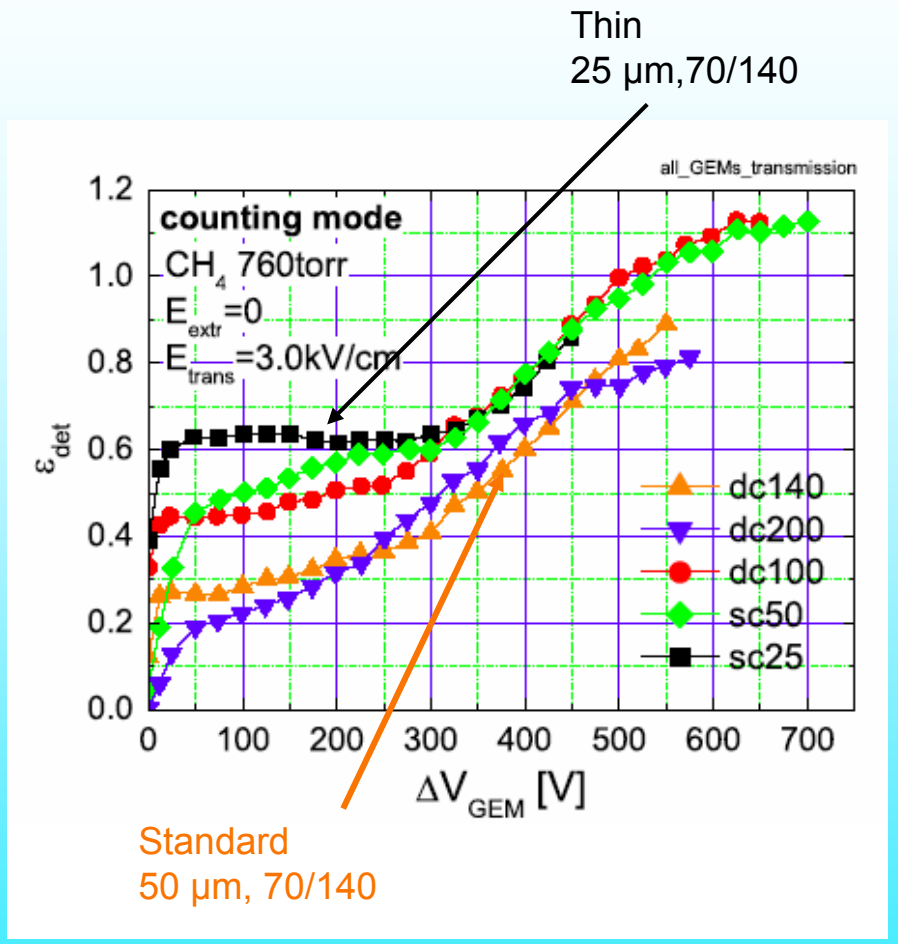
D. Mormann et al, Nucl. Instr. and Meth. A478(2002)230

CsI QUANTUM EFFICIENCY (relative to vacuum):



A. Breskin et al, Nucl. Instrum. and Methods A483(2001)670

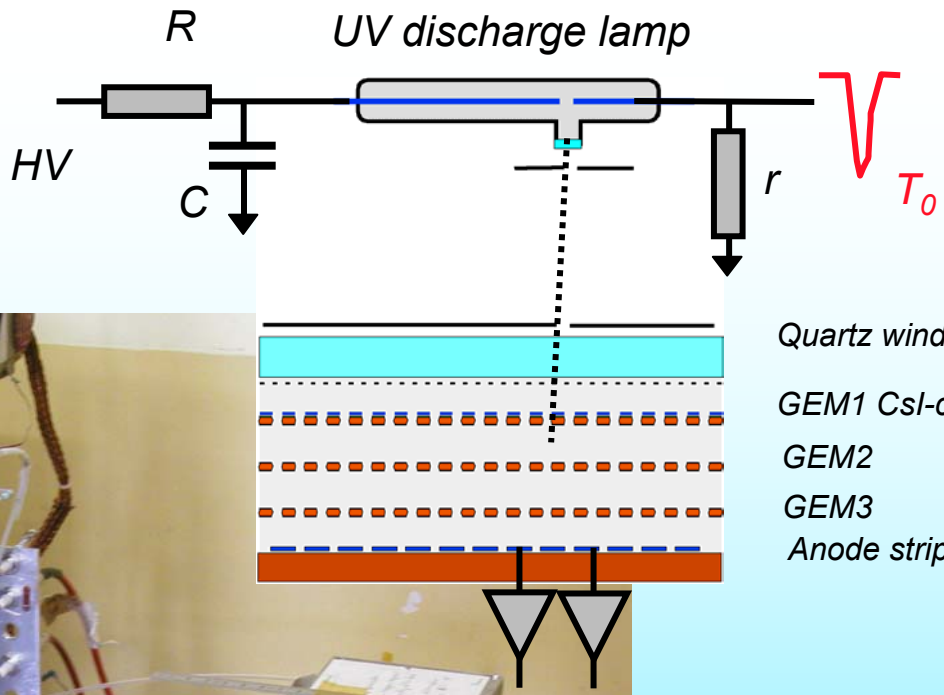
Efficiency vs GEM geometry:

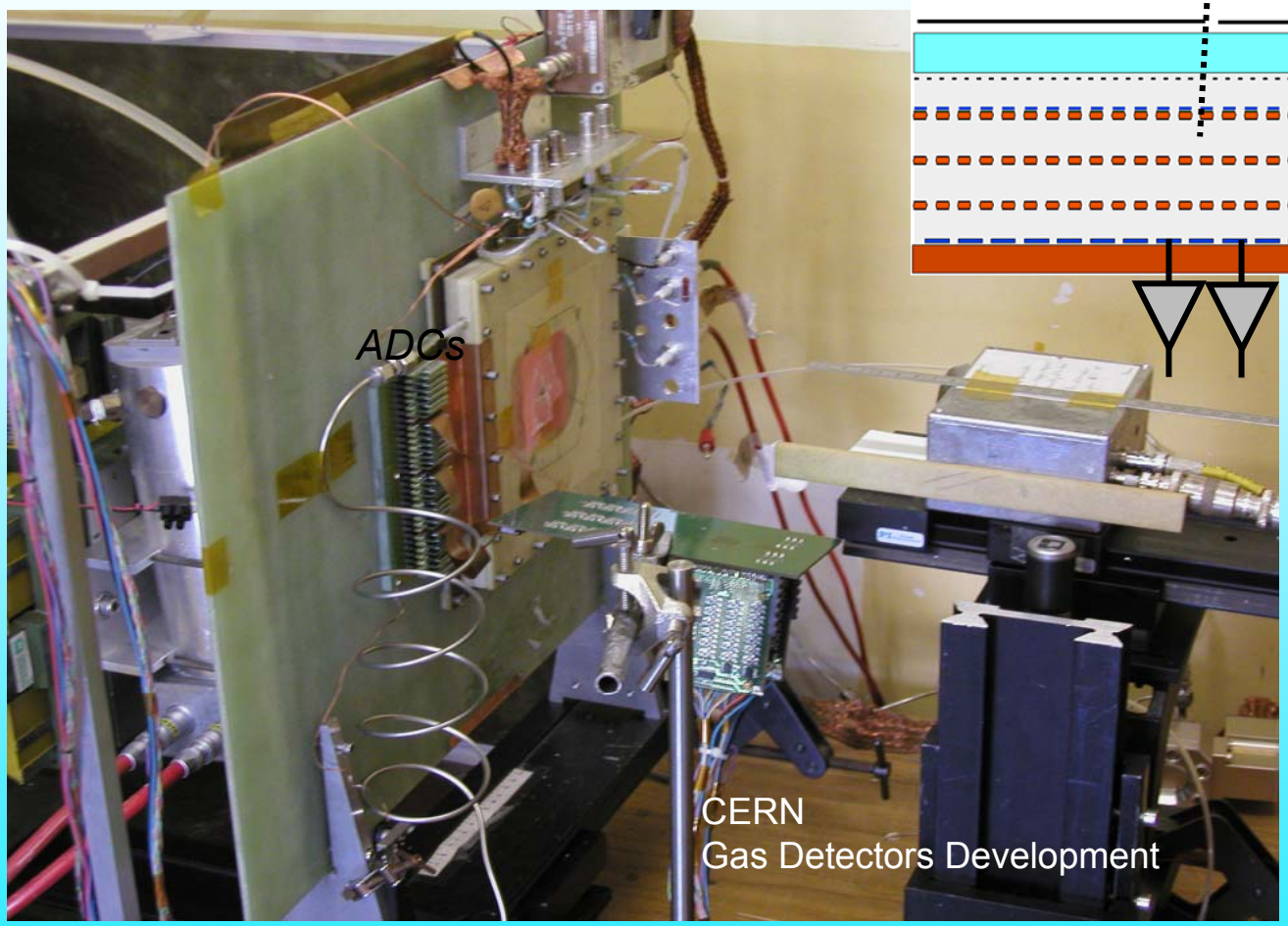


D. Mörmann et al, Nucl. Instr. and Meth. A530 (2004)258

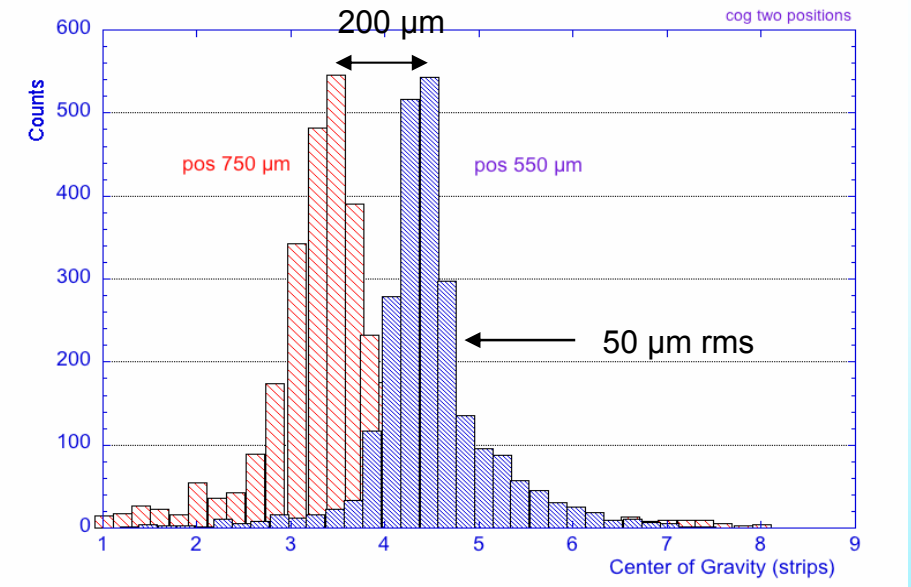
Lab measurements with collimated UV photon source

Triple GEM with CsI coating

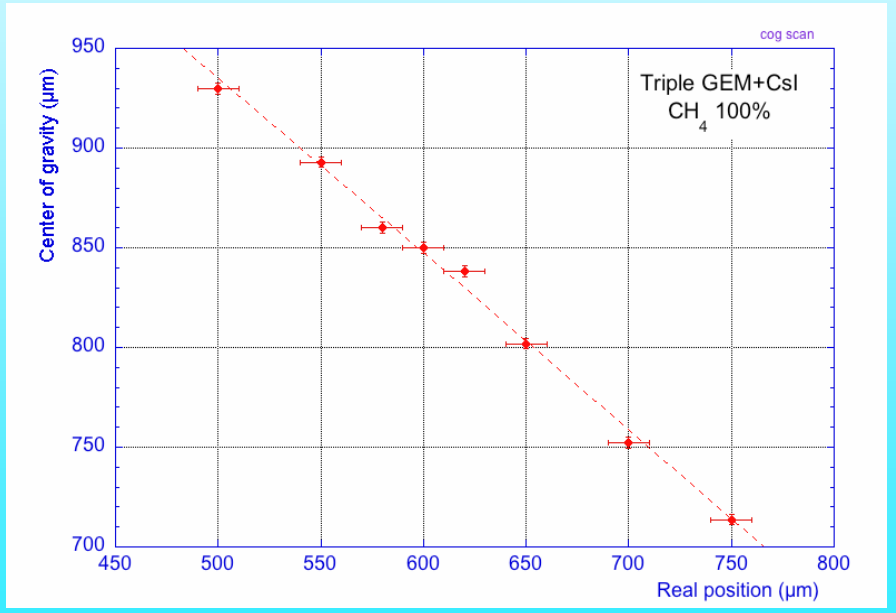




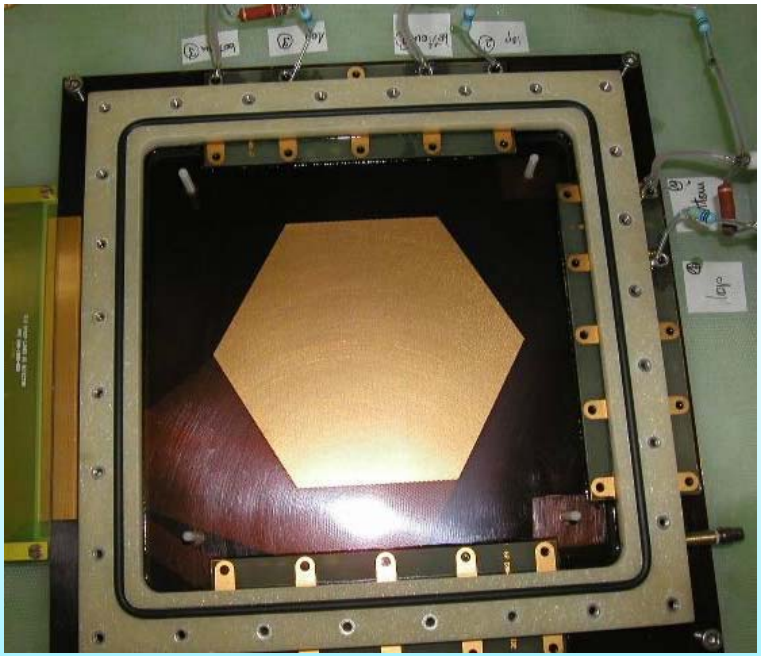
SINGLE PHOTOELECTRON POSITION ACCURACY (1-D READOUT STRIPS):
Two positions of collimated beam 200 μm apart:



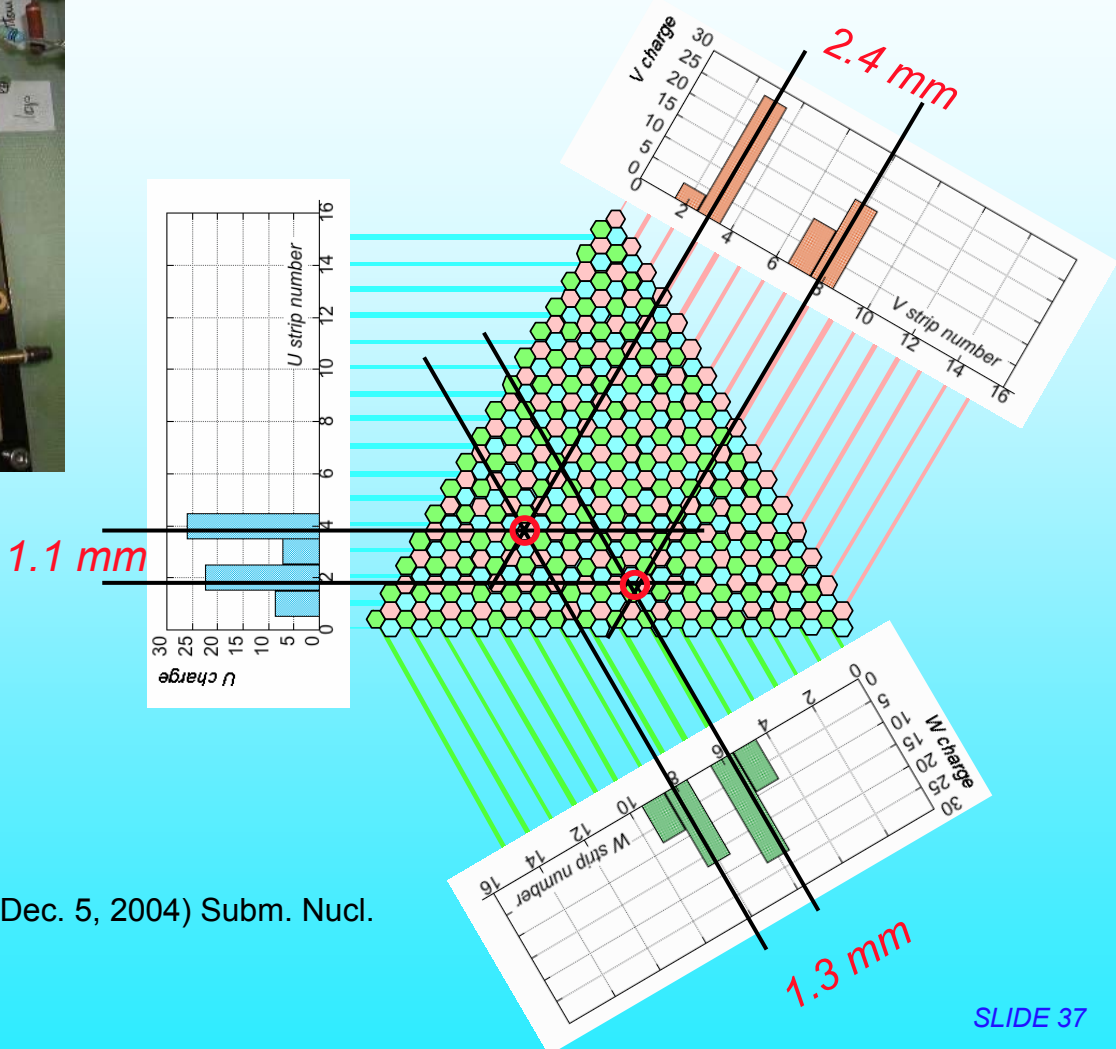
Linearity of response (real vs measured position)



GEM-CsI DETECTOR WITH HEXABOARD READOUT

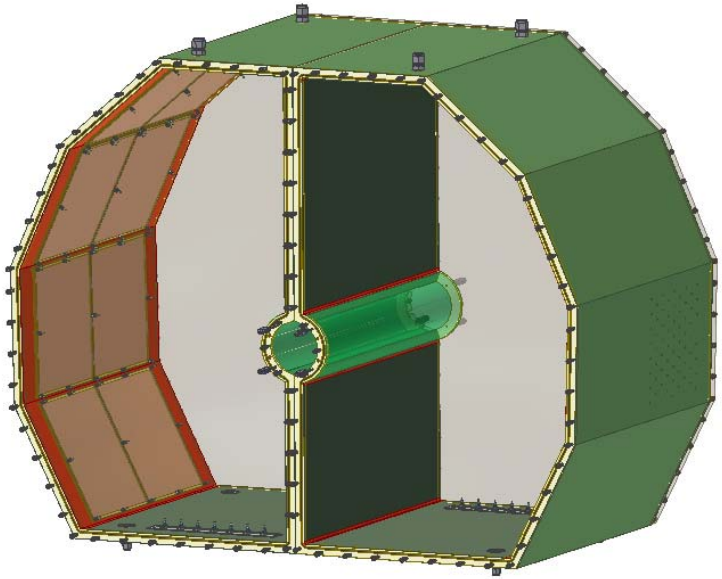


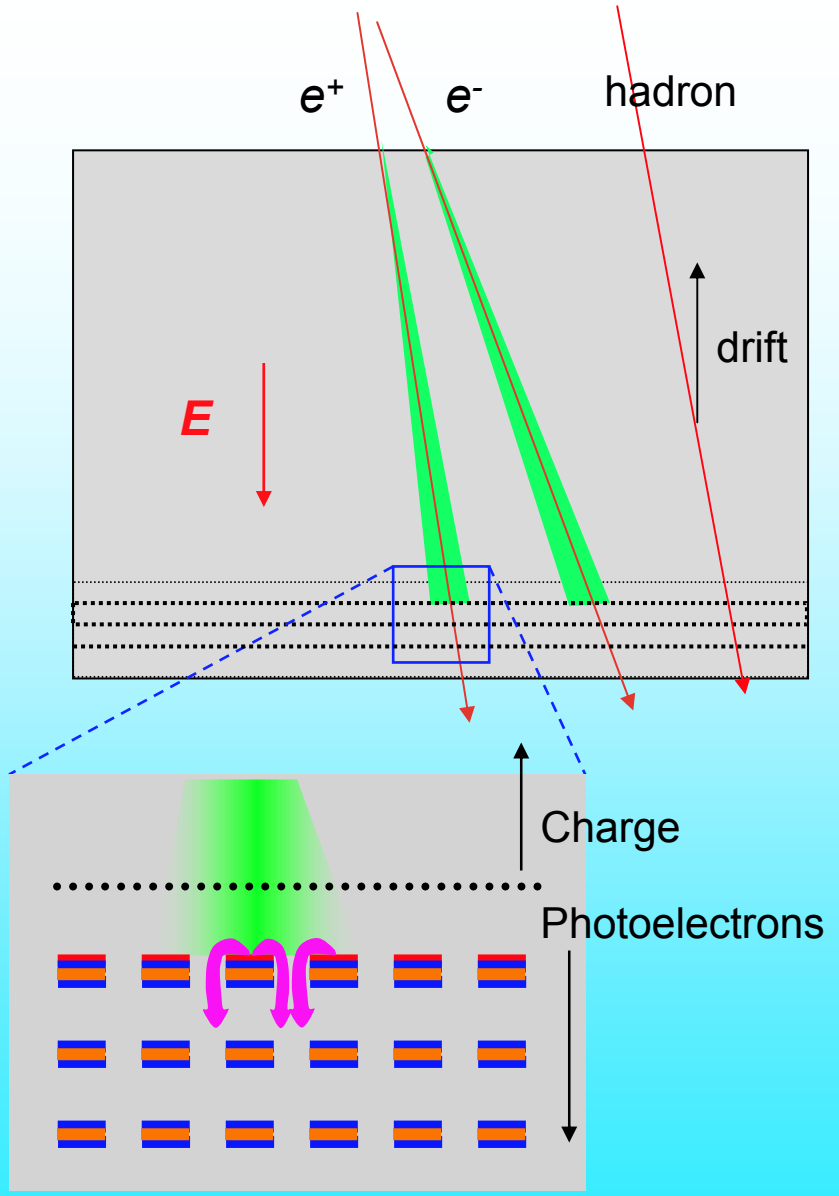
Charge recorded on each projection
(with ALICE ALTRO ADC)



F. Sauli, RICH04 (Playa del Carmen, Nov. 30-Dec. 5, 2004) Subm. Nucl. Instr. And Meth.

PHENIX UPGRADE AT BNL
Hadron-blind GEM-TPC-RICH





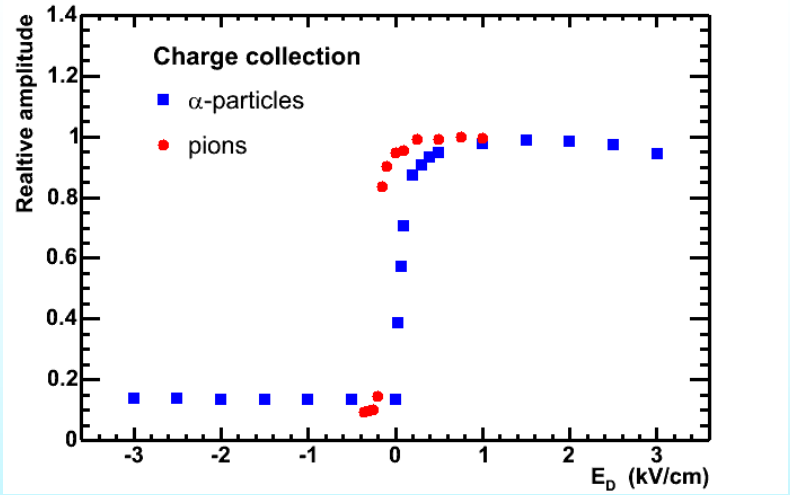
Windowless Cherenkov detector
(inverted field TPC)
CF_4 gas radiator
Triple-GEM chamber
CsI photocathode on first GEM

C. Aidala et al,
Nucl. Instr. and Methods A502(2003)200

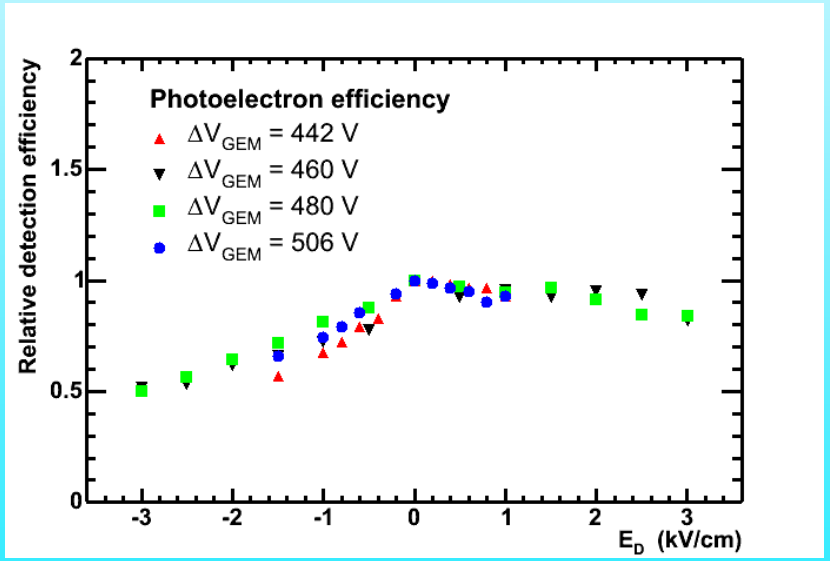
A. Kozlov et al,
Nucl. Instr. and Meth. A523(2004)344

Prototype measurements

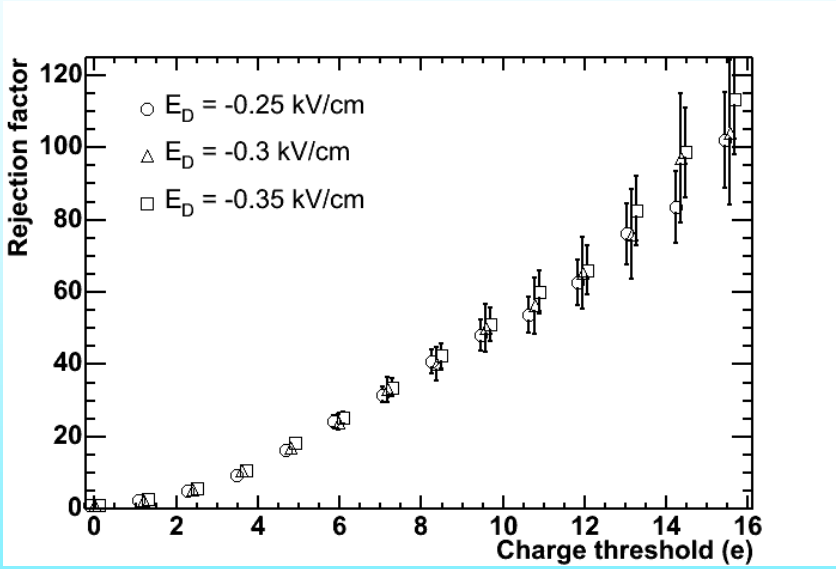
Response for hadrons:



Response for electrons:

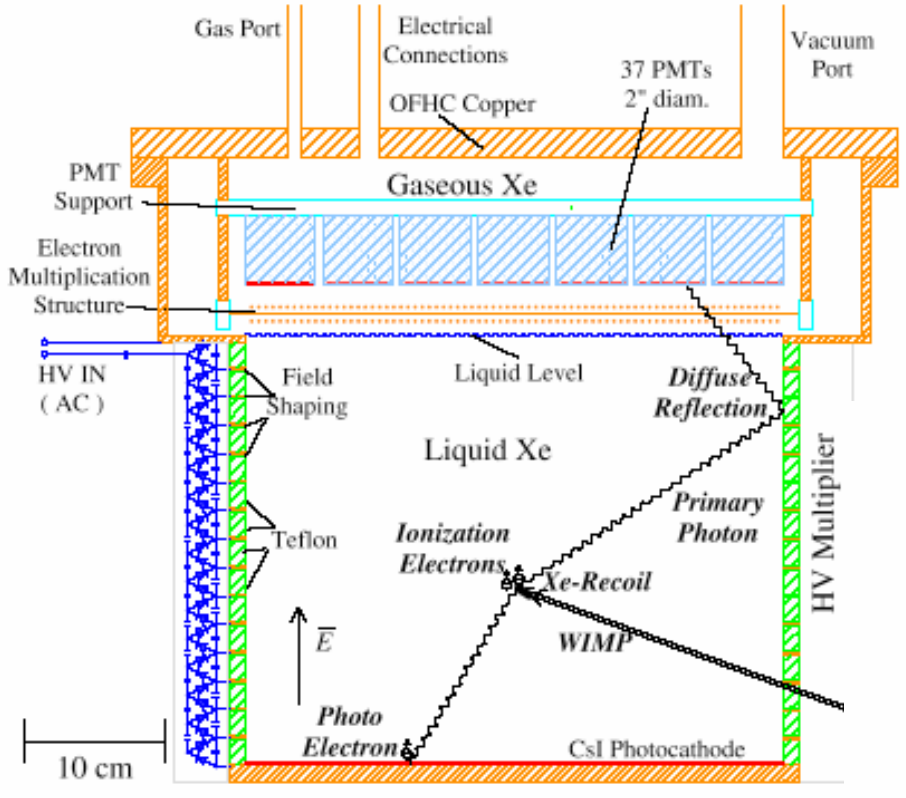


Rejection factor:

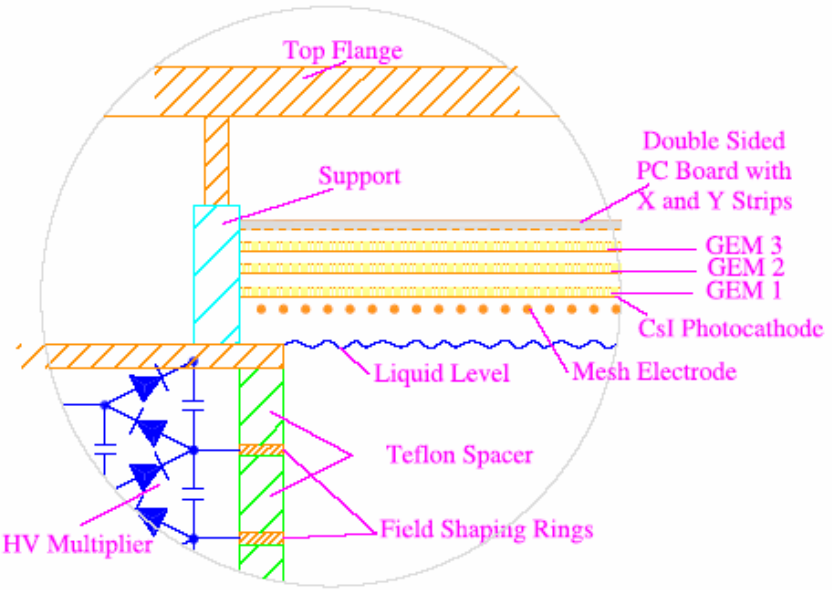


I. Tserruya, RICH04 (Playa del Carmen, Nov. 30-Dec. 5, 2004)

TWO-PHASE DETECTOR:
Electrons produced in Liquid Xe are extracted and multiplied in the gas phase



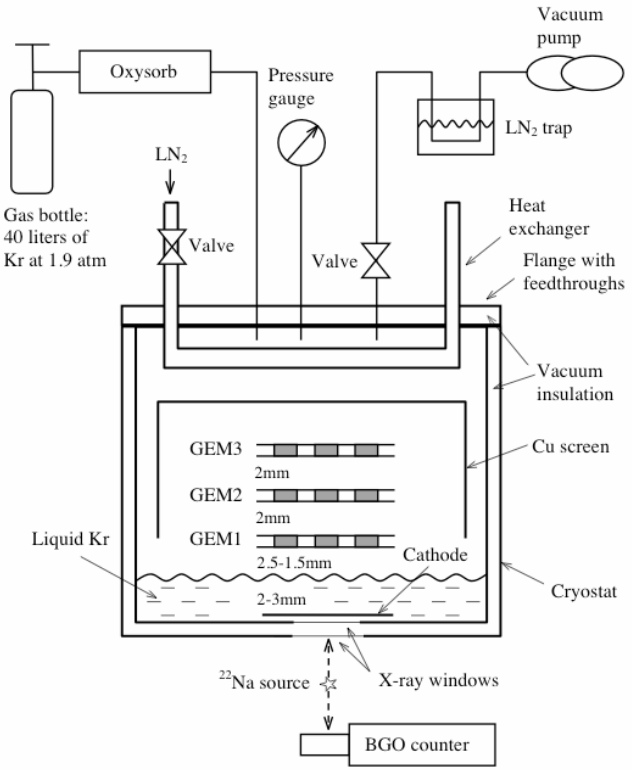
Multi-GEM detector

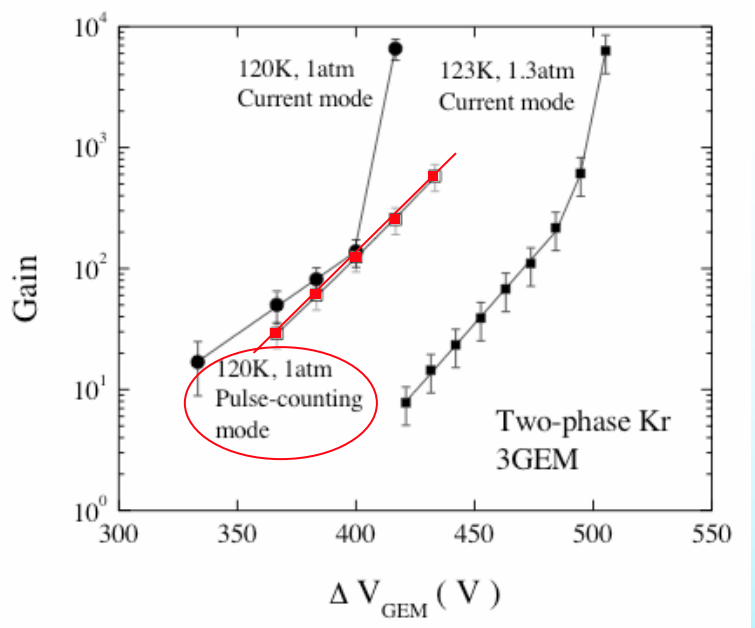


XENON: Dark Matter and WIMPs search

Columbia - Rice - Princeton Univ.

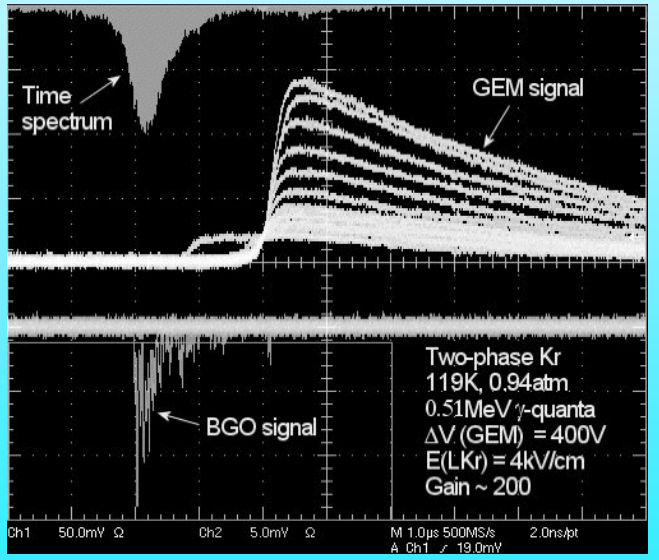
TWO-PHASE KRIPTON DETECTOR





^{22}Na e$^+$

511 keV γ

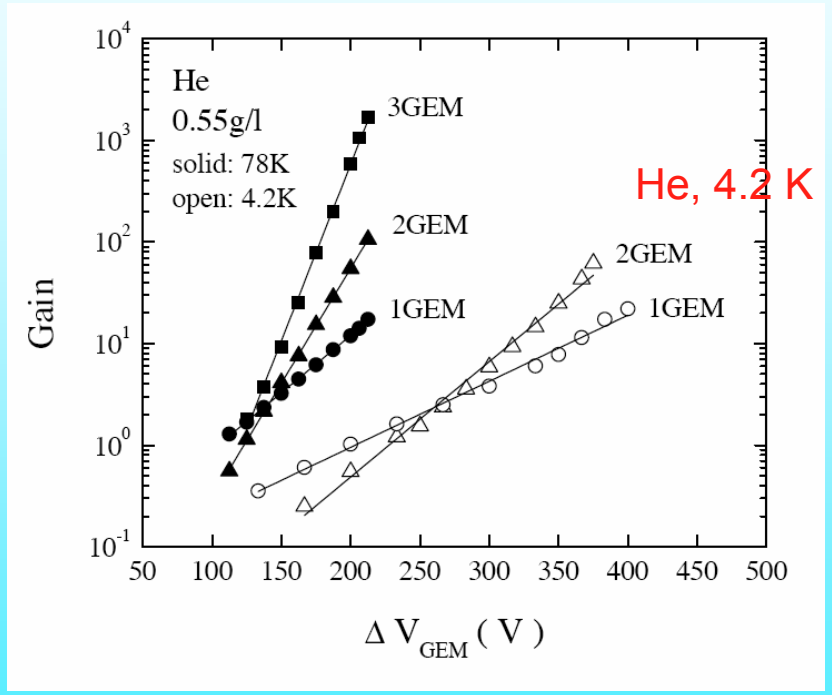


A. Bondar et al, Subm. Nucl. Instr. And Meth. (31.3.2005)

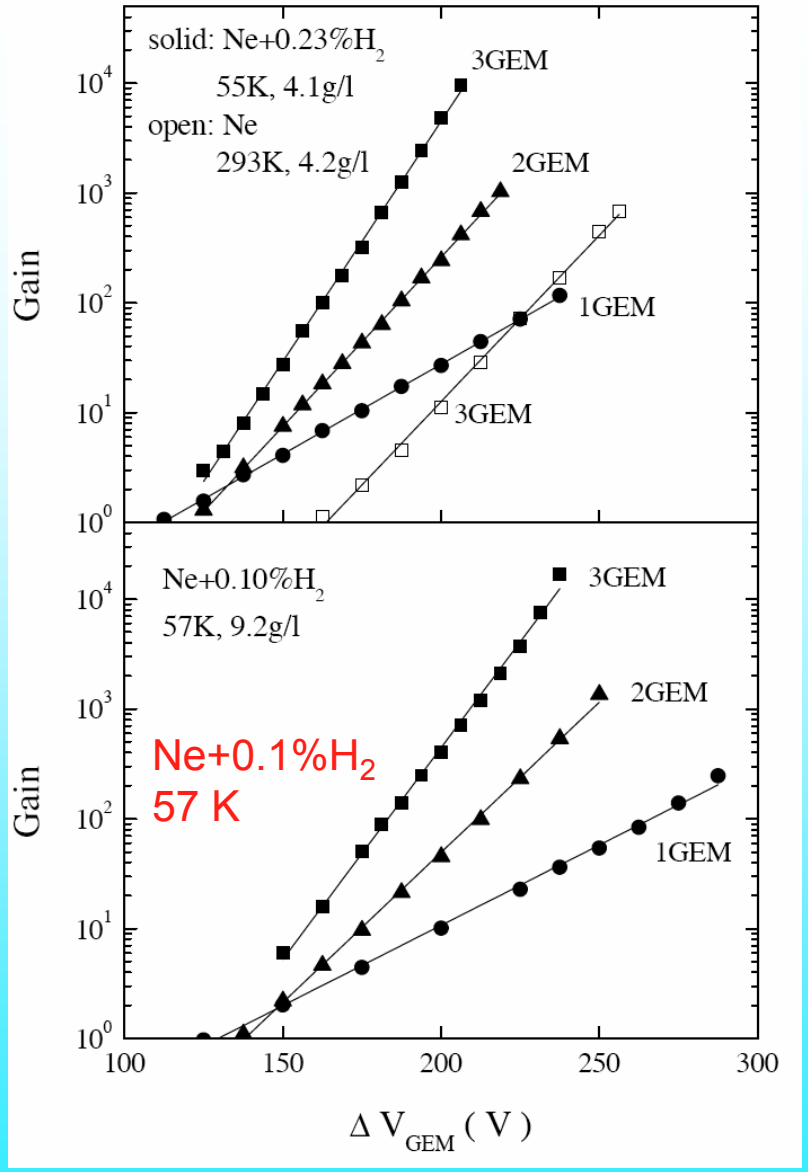
GEM operation in low temperature He and Ne

NEVIS, BNL, BINP Novosibirsk

--> e-bubble chamber for solar neutrino detection (Bill Willis)

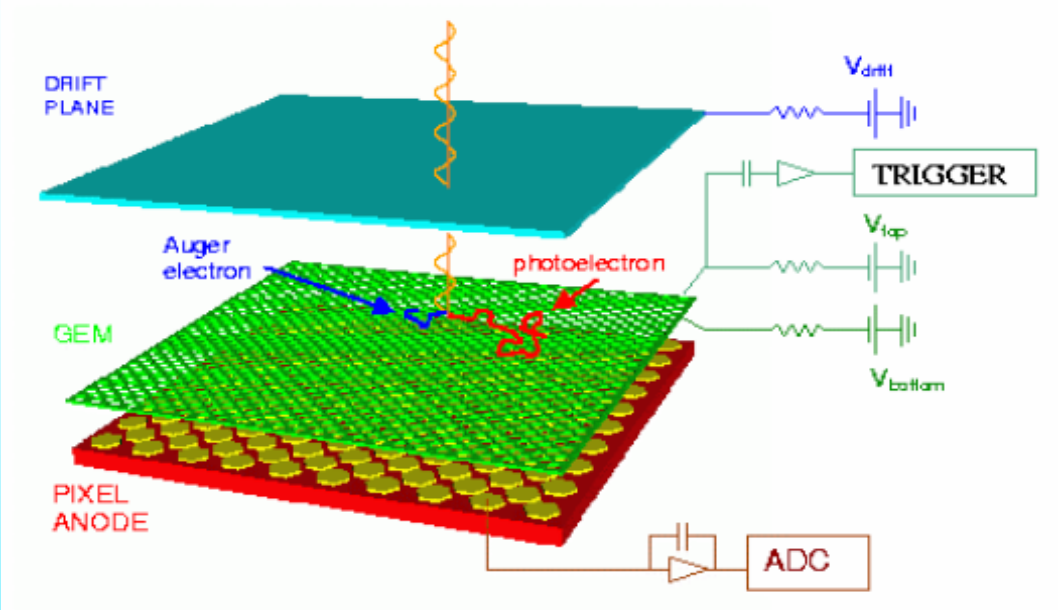


A. Buzulutskov et al, Subm. Nucl. Instr. And Meth (April 2005)

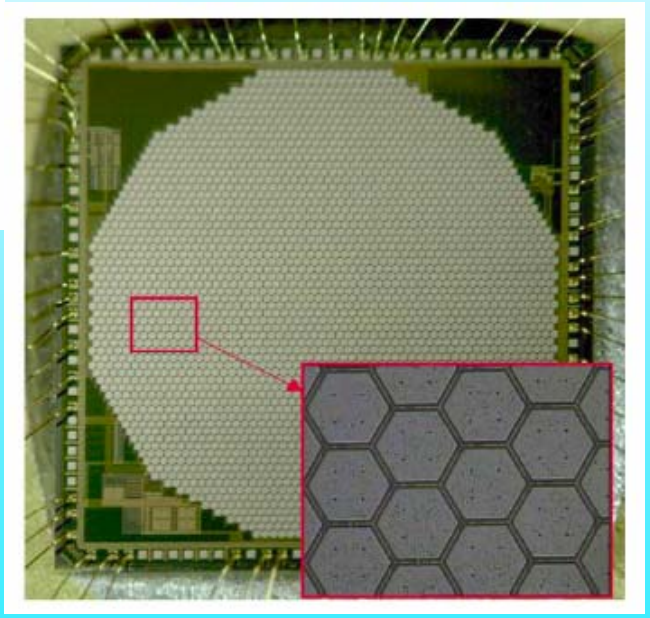


X-RAY POLARIMETER

Micro-GEM detector with pad readout: tracking the direction of the photoelectrons

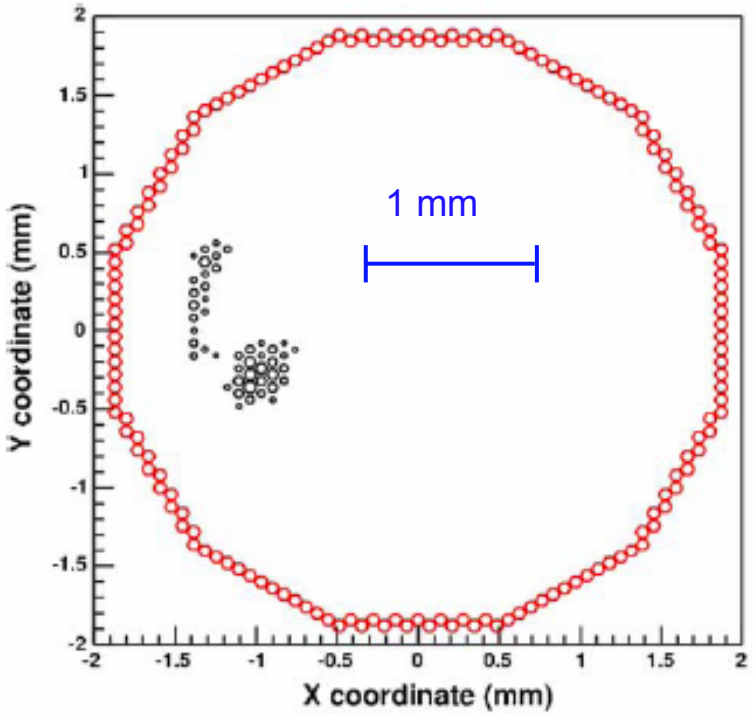


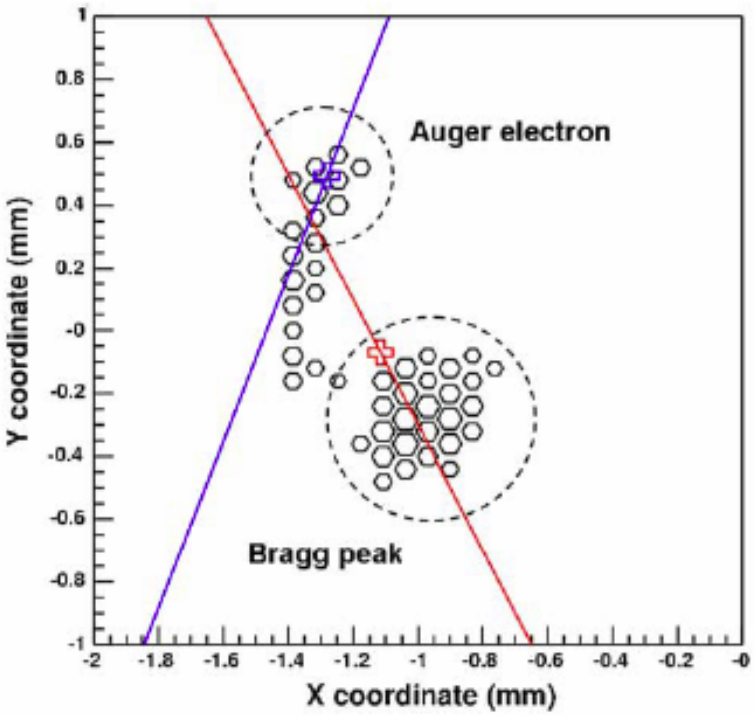
CMOS ASIC readout with 2101 hexagonal pixels at 80 μm pitch



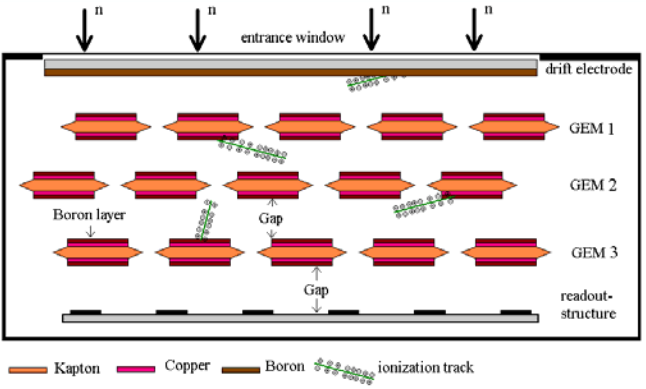
E. Costa et al, Nature 411(2001)662
R. Bellazzini et al, Nucl. Instr. Methods A435(2004)477

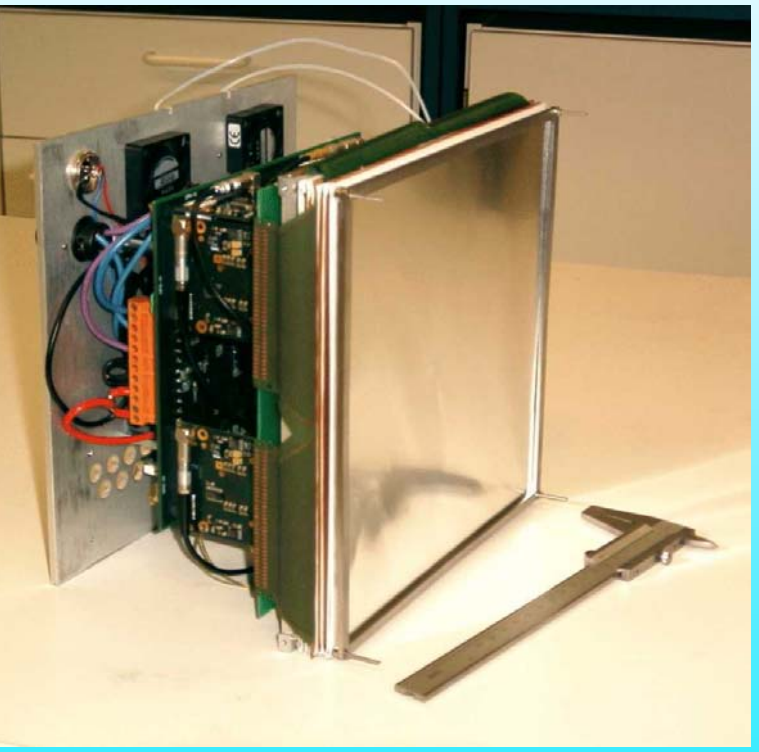
Reconstruction of a 5 keV photoelectron:





CASCADE (Heidelberg University)

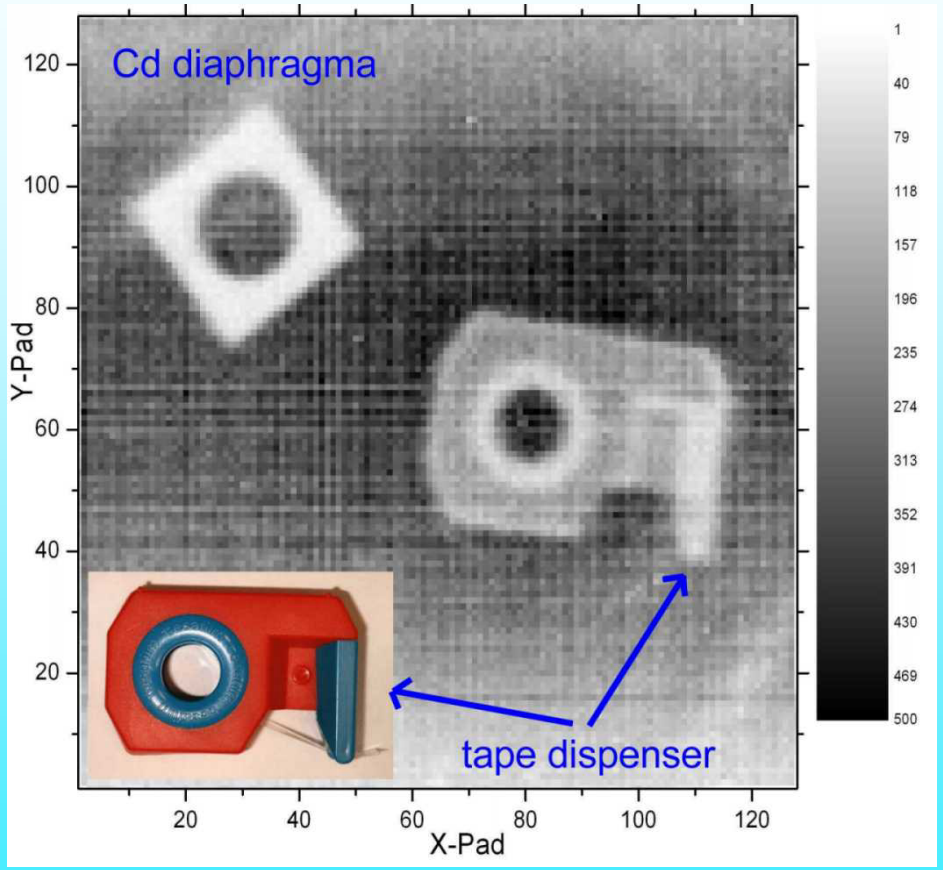




^{10}B - COATED GEMS FOR THERMAL NEUTRON DETECTION

$^{10}B(n,\alpha) \rightarrow {}^{7}Li$

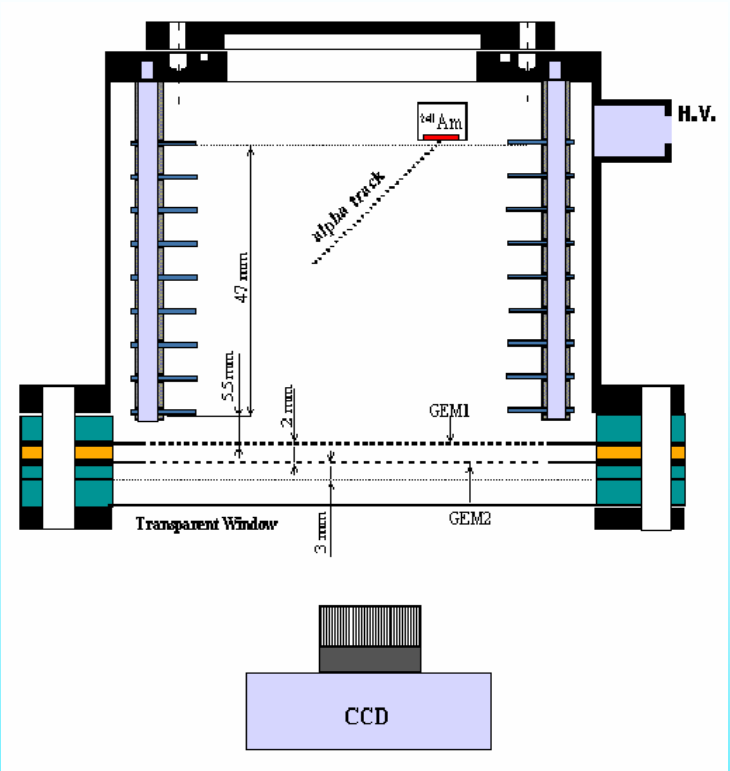
^{252}Cf neutron radiography:



http://www.physi.uni-heidelberg.de/physi/cascade

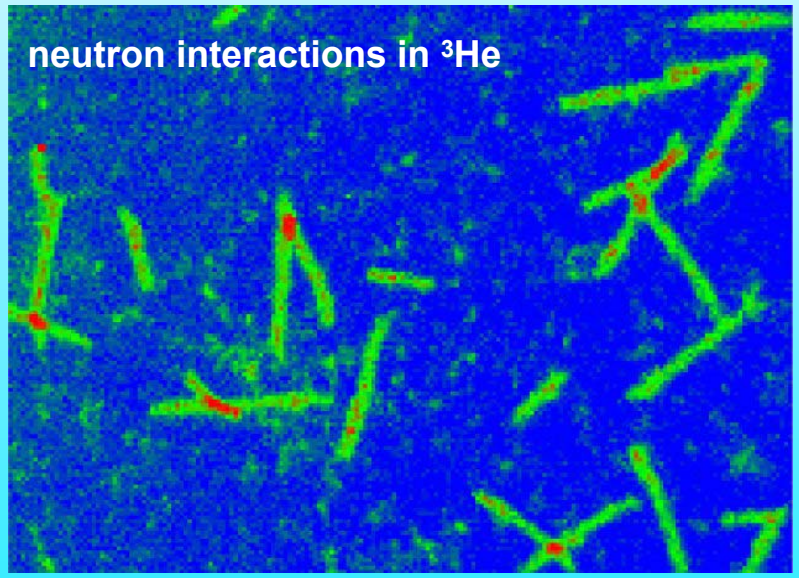
DETECTION OF SCINTILLATION LIGHT FROM GEM

Low rate continuous imaging



QuickTime™ and a
Video decompressor
are needed to see this picture.

a PARTICLES



F.A.F. Fraga et al, Nucl. Instr. and Meth. A478(2002)357
L.M.S.Margato et al, Nucl. Instr. and Meth. A535(2004)231

FINE