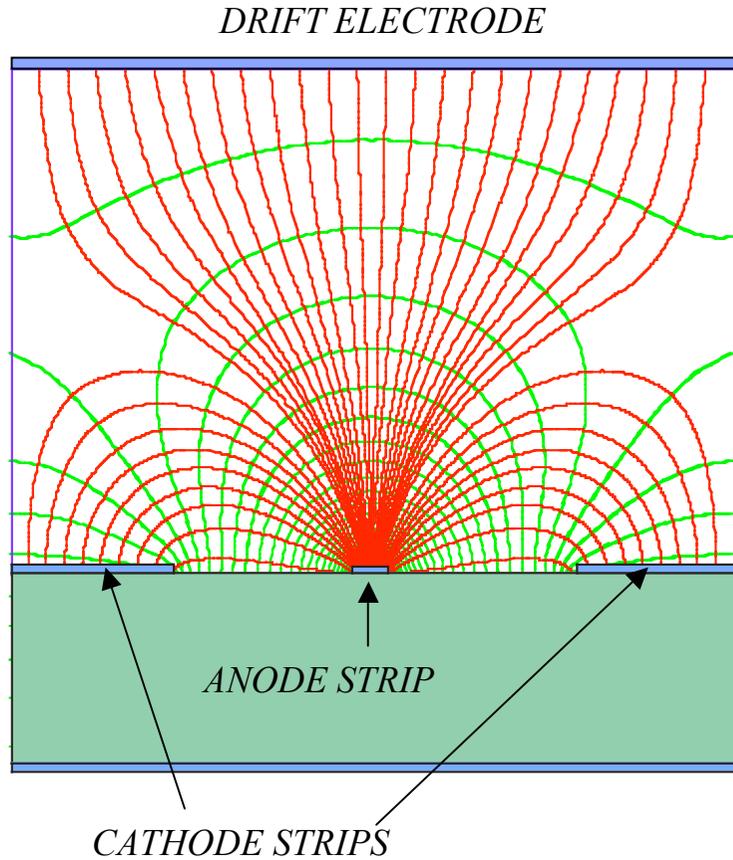


7

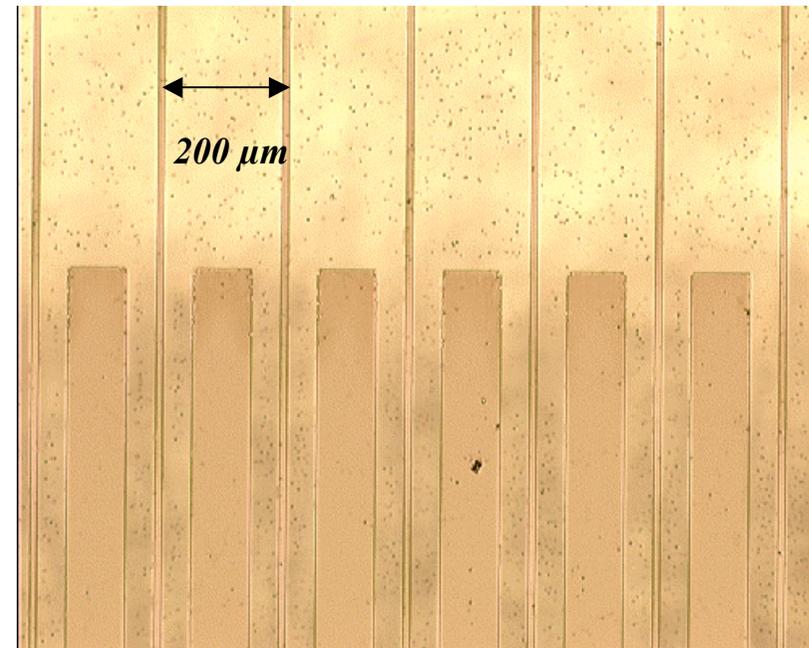
MICRO-PATTERN GAS DETECTORS

MICROSTRIP GAS CHAMBERS (MSGC)

Anton Oed (1988)

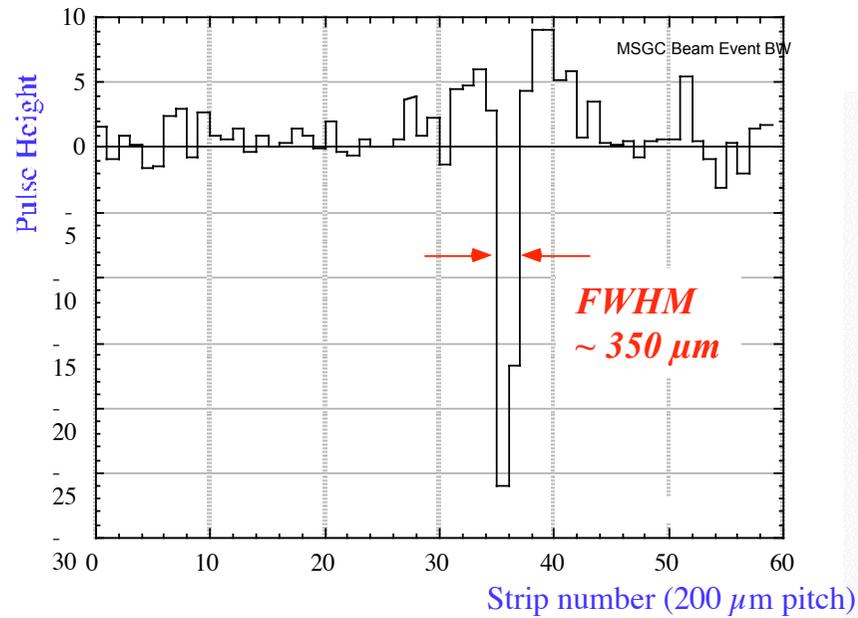
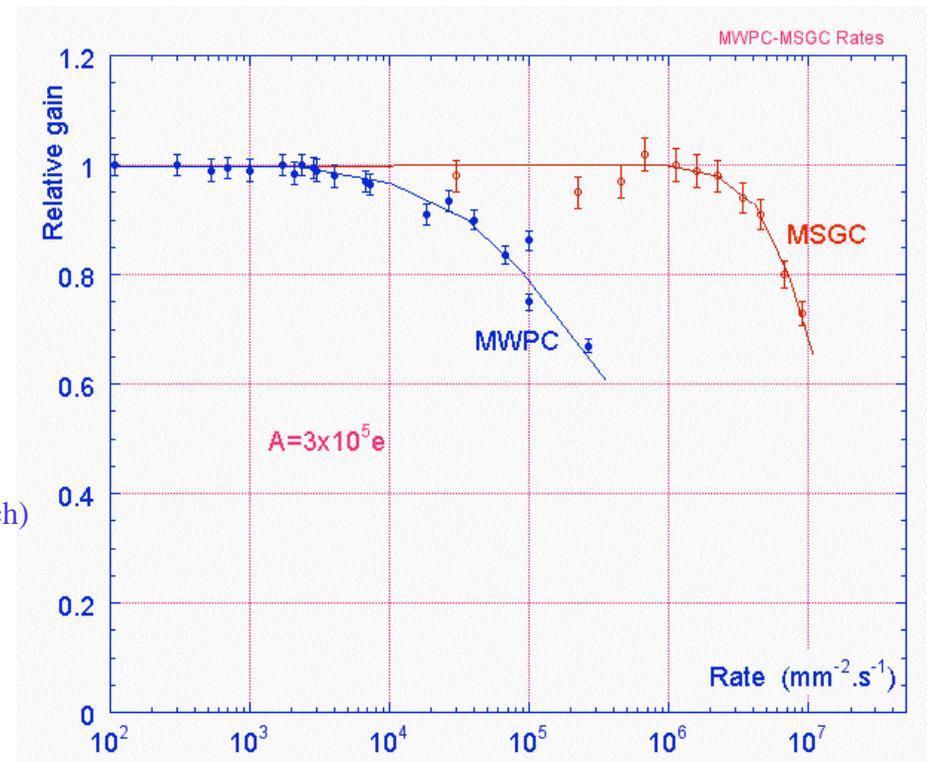


THIN METAL STRIPS ETCHED ON GLASS



A.Oed, Nucl. Instr. and Meth. A263(1988)351

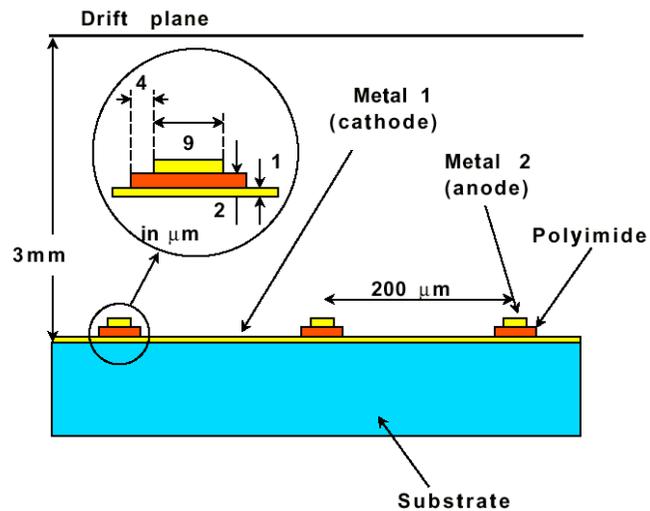
TWO-TRACK RESOLUTION:

RATE CAPABILITY
MSGC on high-resistivity glass:

A. Barr et al, Nucl. Instr. and Meth. A392(1997)99

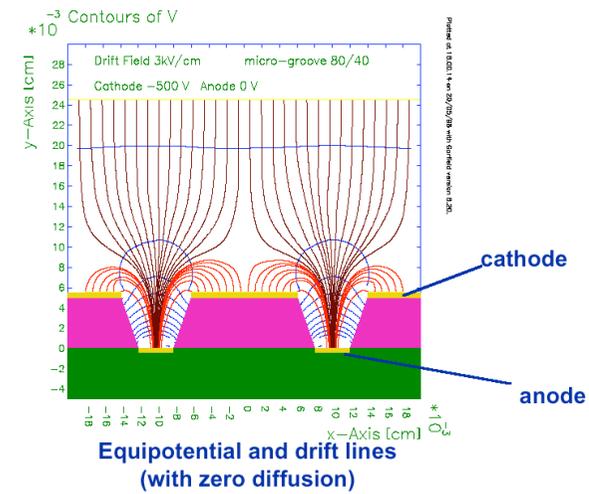
Fabio Sauli - CHIPP Winter School 2010

MICRO-GAP CHAMBER



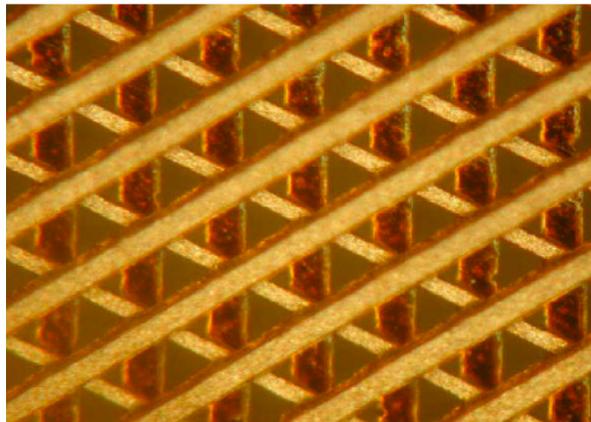
R. Bellazzini et al, Nucl. Instr. and Meth. A335(1993)69

MICRO-GROOVE CHAMBER



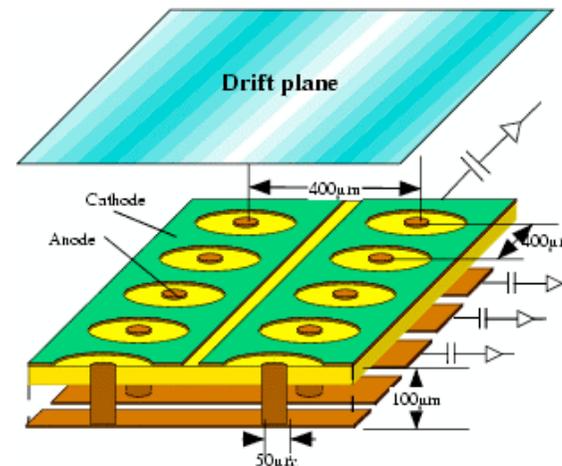
R. Bellazzini et al, Nucl. Instr. and Meth. A424(1999)444

FIELD GRADIENT LATTICE DETECTOR (FGLD)



L. Dick et al Nucl. Instr. and Meth. A535(2004)347

MICRO-PIXEL CHAMBER

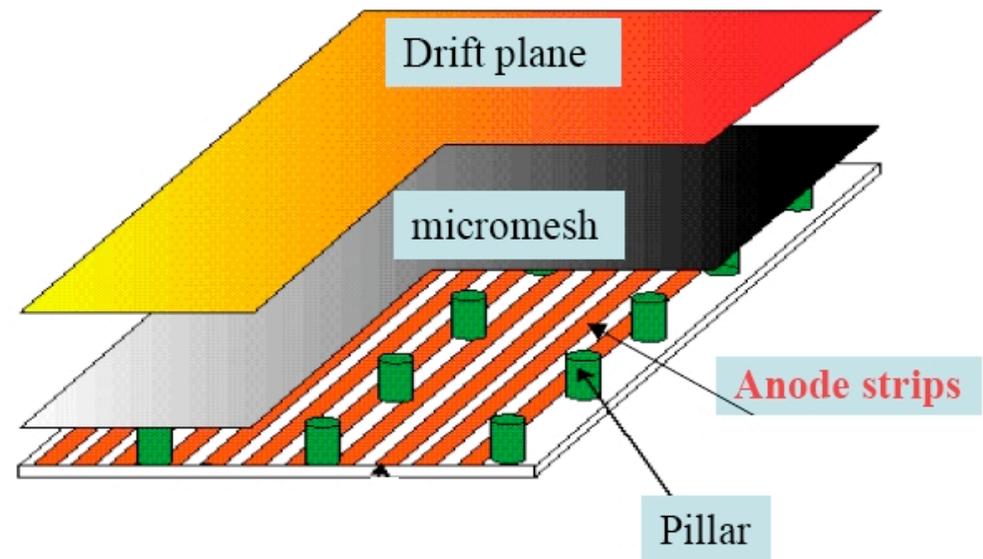
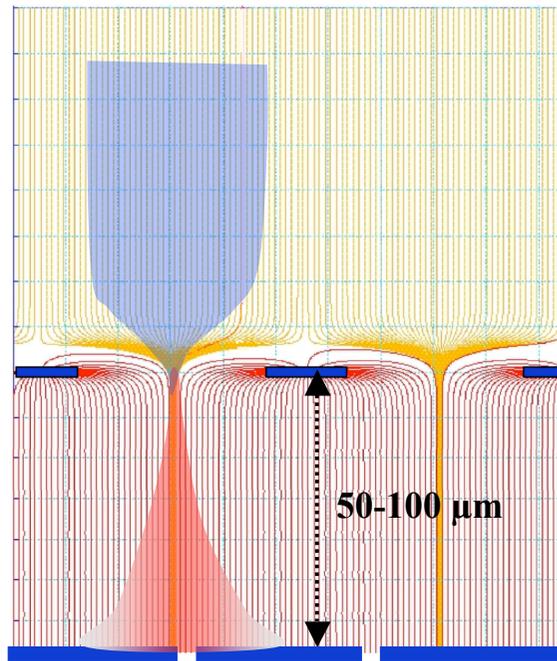


A. Ochi et al, Nucl. Instr. and Meth. A471(2001)264

MICRO MESH Gaseous Structure

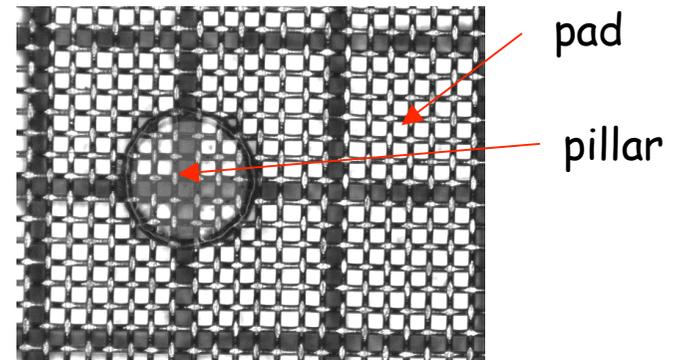
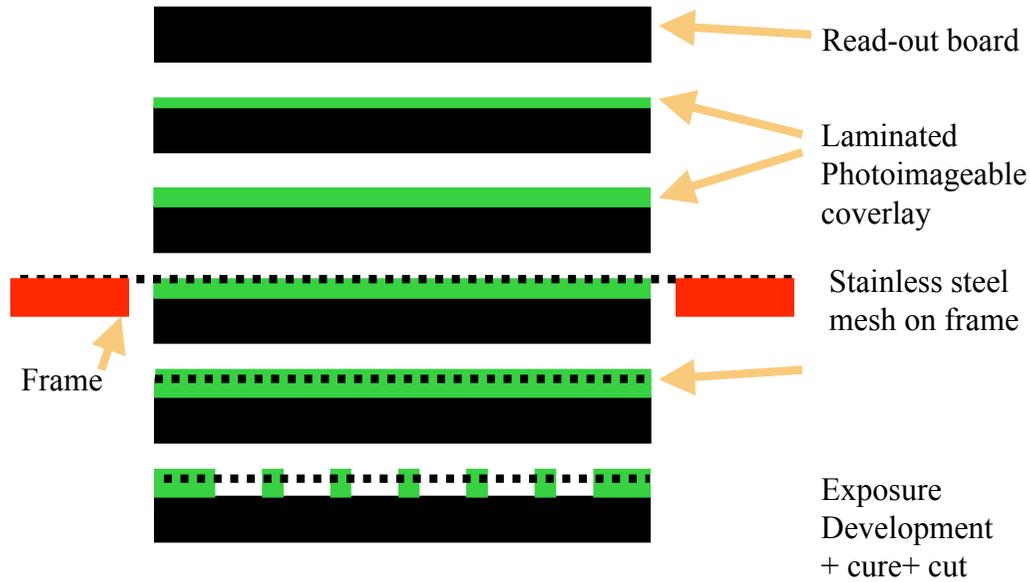
Ioanis Giomataris (1996)

THIN GAP PARALLEL PLATE AVALANCHE CHAMBER



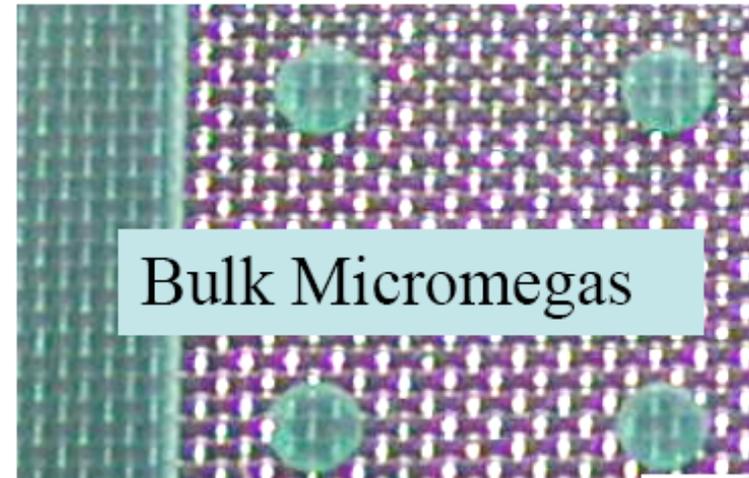
Y. Giomataris et al, Nucl. Instr. and Meth. A376(1996)29

BULK MICROMEAS MANUFACTURING

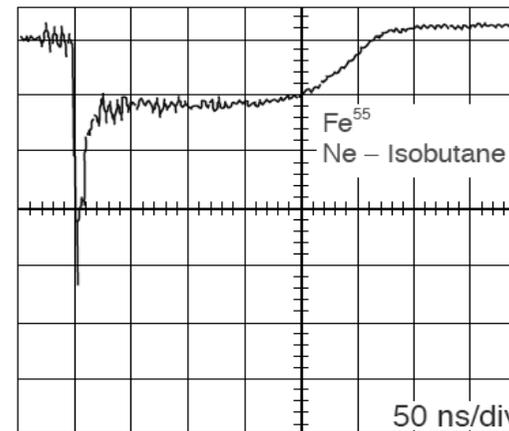


I. Giomataris et al, Nucl. Instr. and Meth. A560(2006)405

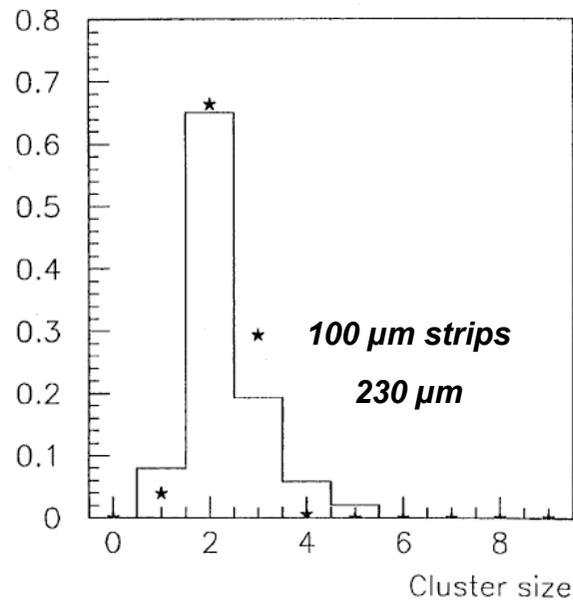
J. Bouchet et al, Nucl. Instr. and Meth. A574(2007)425



FAST ELECTRON SIGNALS WITH SLOW ION TAIL:

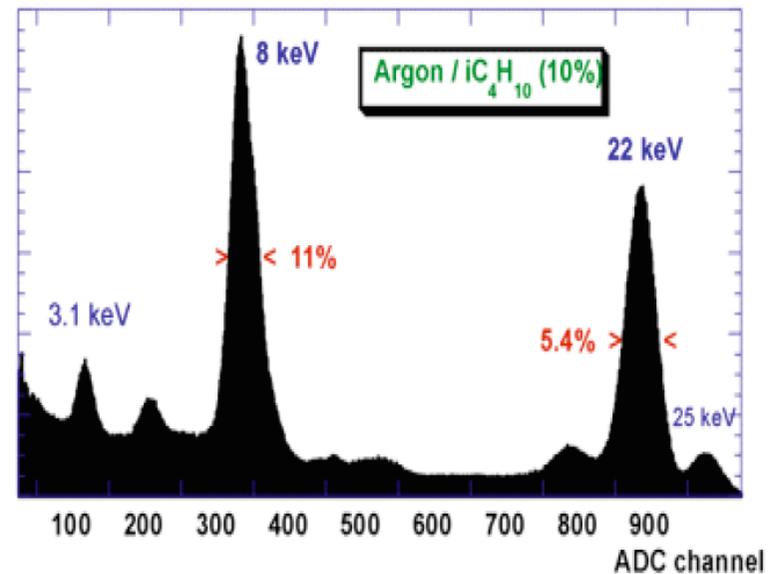


SIGNAL CLUSTER SIZE



*J. Derré et al,
Nucl. Instr. and Meth. A459(2001)523*

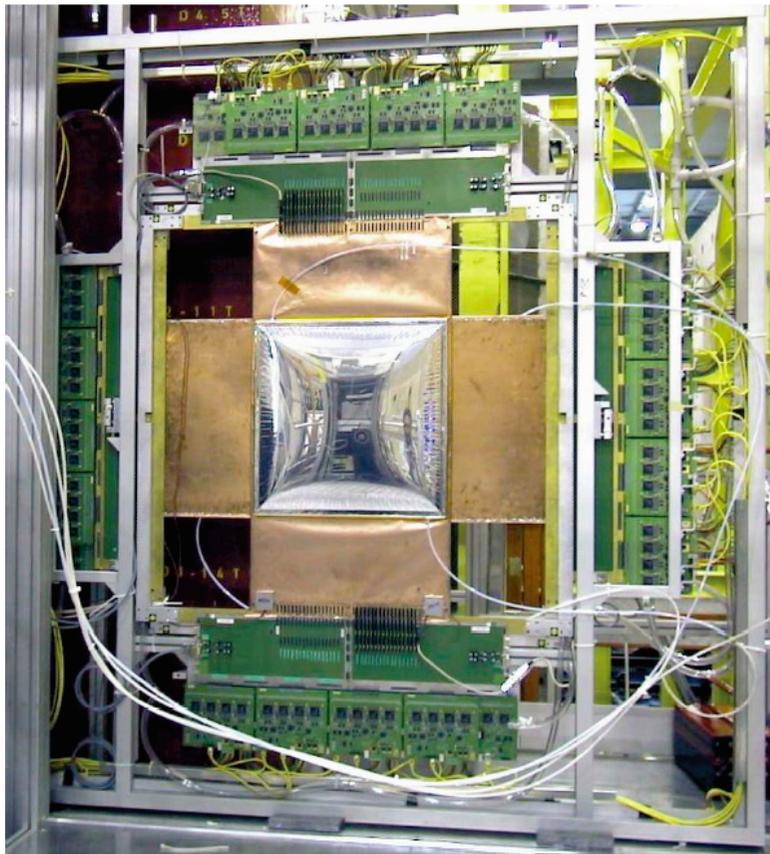
ENERGY RESOLUTION



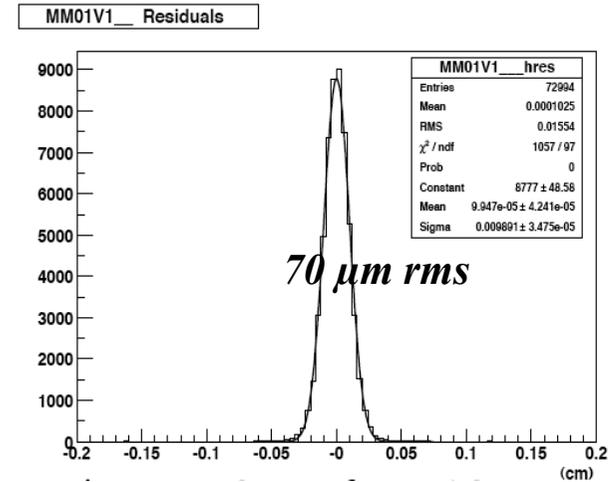
A. Delbart et al, Nucl. Instr. and Meth. A461(2001)84

COMPASS MICROMEAS:

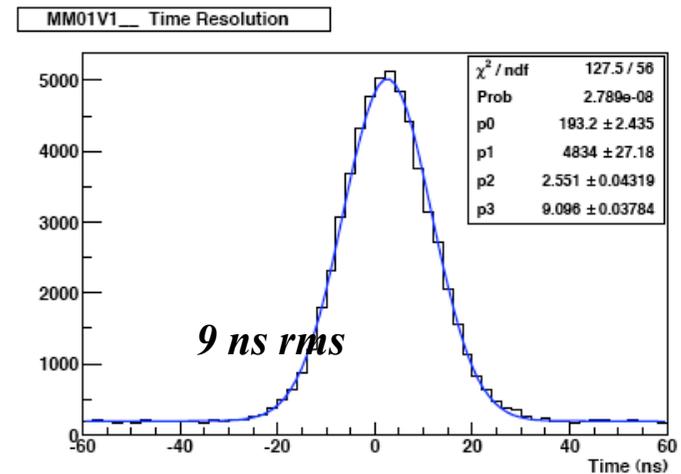
12 PLANES IN 3 STATIONS X,Y, U, V
 40x40 cm² active
 350 μm strips with digital readout



SPACE RESOLUTION



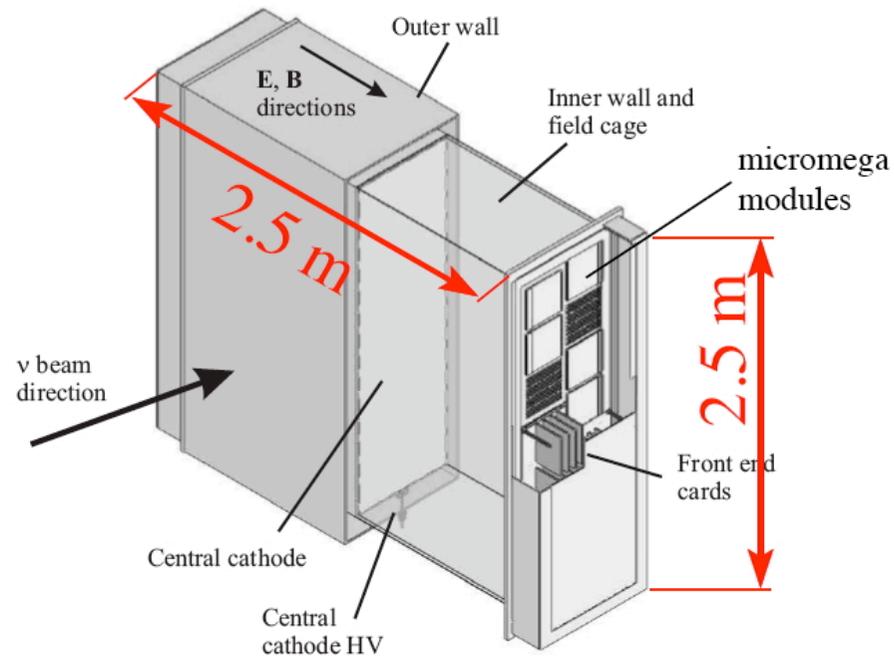
TIME RESOLUTION



C. Bernet et al, Nucl. Instr. and Meth. A536(2005)61

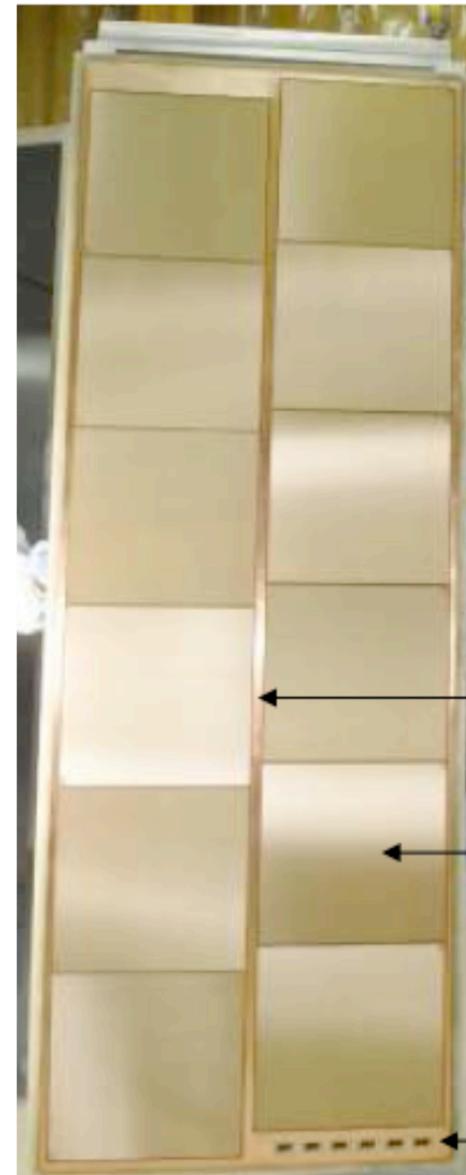
Fabio Sauli - CHIPP Winter School 2010

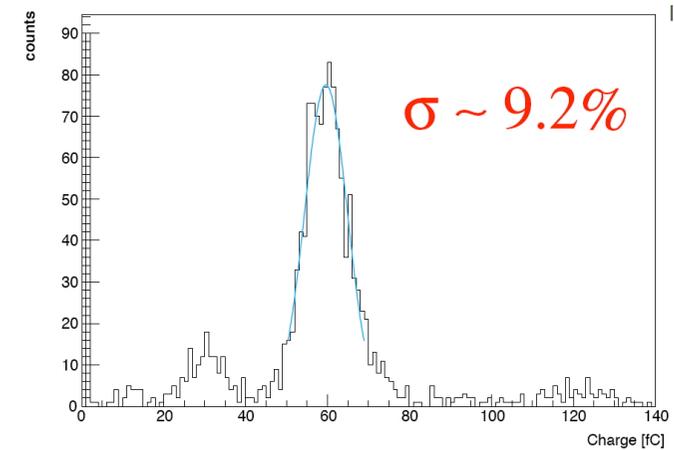
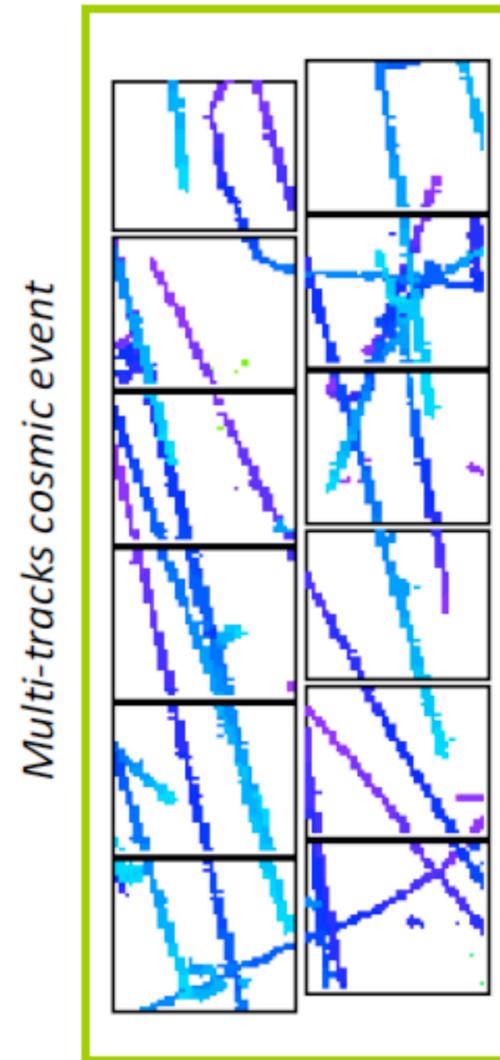
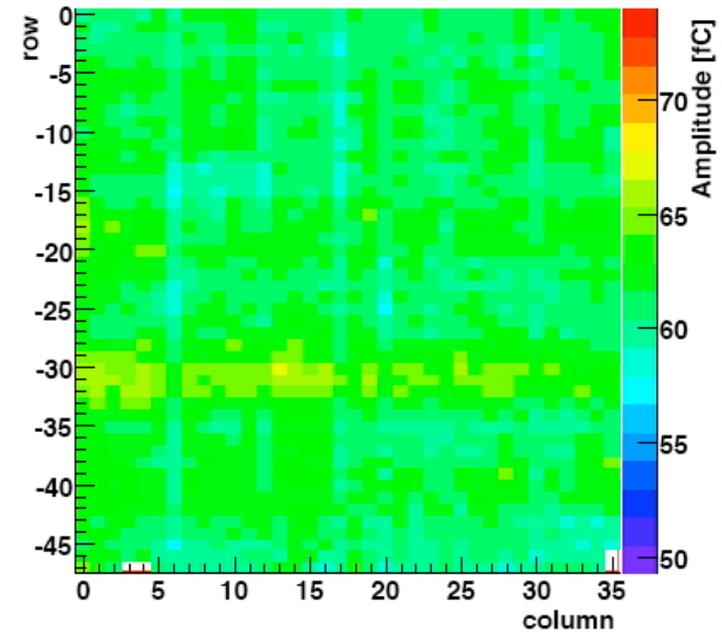
T2K TIME PROJECTION CHAMBER (KEK)

72 MICROMEAS MODULES (35x36 cm²)READOUT: 36x48 PADS of 9.7x6.9 mm²

A. Delbart, Int. Conf. on Technology and Instrumentation in Particle Physics (TIPP09, Tsukuba March 12-17, 2009)

J. Beucher, MPGD Int. Conf. (Crete, June 12-15, 2009)

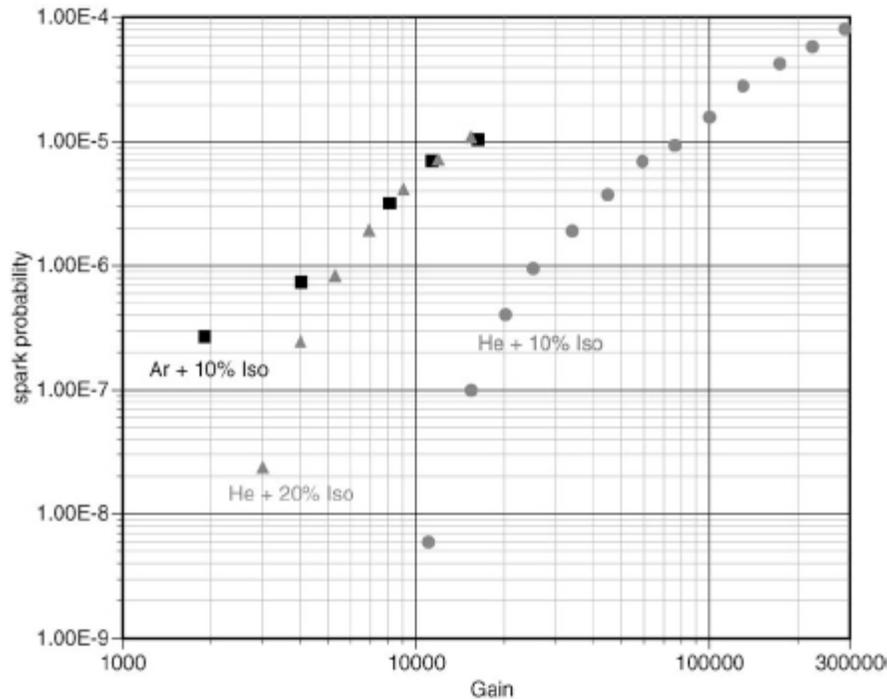


ENERGY RESOLUTION ON ^{55}Fe :GAIN UNIFORMITY: $\sim 2\%$ RMS

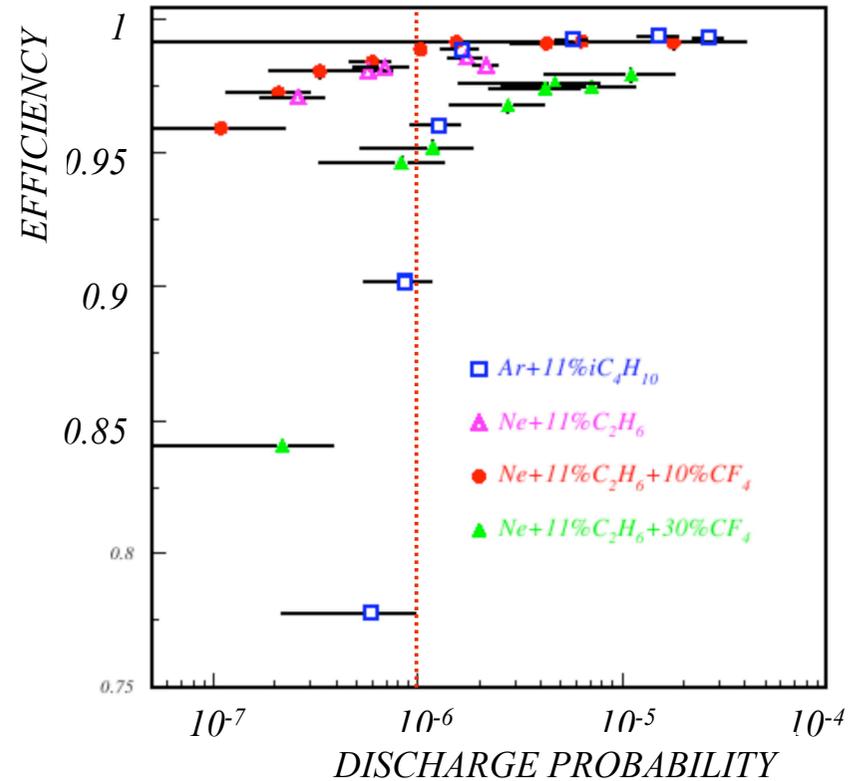
J. Beucher, MPGD Int. Conf. (Crete, June 12-15, 2009)

Fabio Sauli - CHIPP Winter School 2010

SPARK PROBABILITY IN HADRON BEAM



COMPASS MICROME GAS:

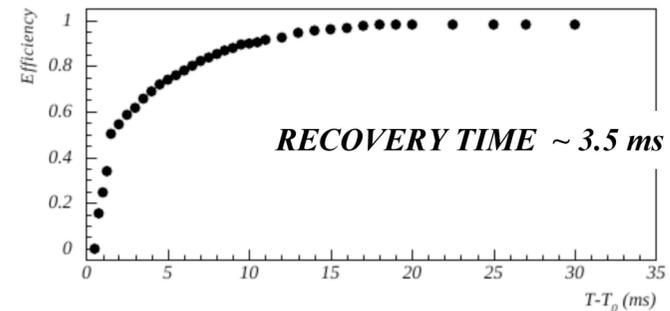


A. Delbart et al, Nucl. Instr. and Meth. A478(2002)205

A. Bay et al, Nucl. Instr. and Meth. A488(2002)162

For a gain of $5 \cdot 10^3$, 10^6 particles s⁻¹:
one discharge per second

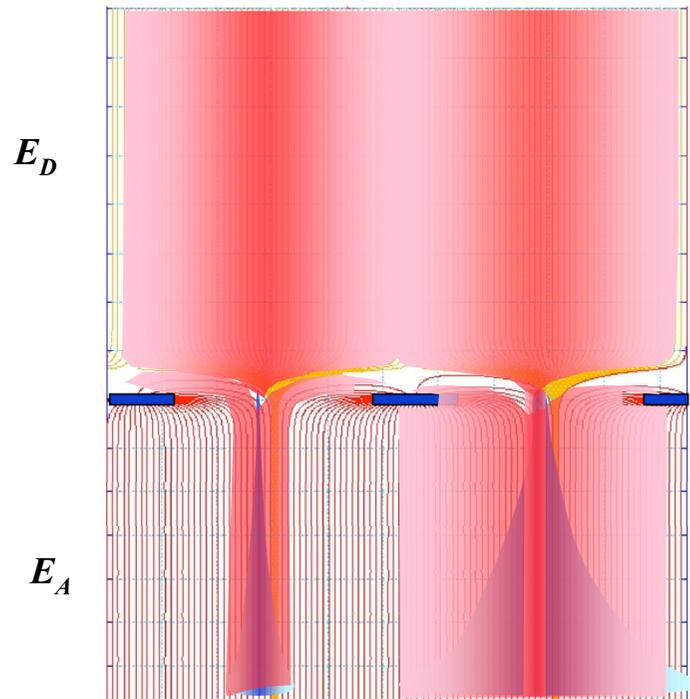
ROBUST DETECTOR AND ELECTRONICS



D. Neyret, MPGD2009 (Crete, June 12-17, 2009)

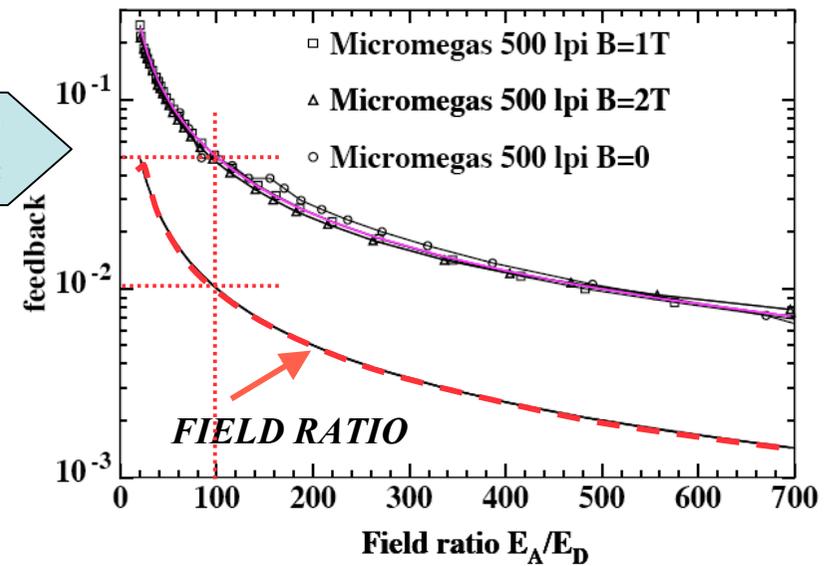
MICROMEGAS

The fractional ion feedback depends on avalanche spread, but cannot be smaller than the field ratio:

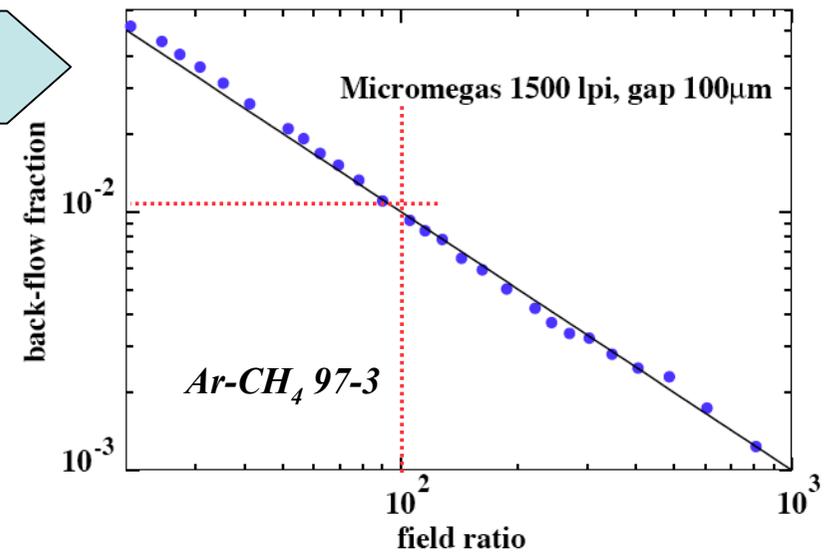


P. Colas et al, Nucl. Instr. and Meth. A535(2004)226

100 μm gap
50 μm pitch



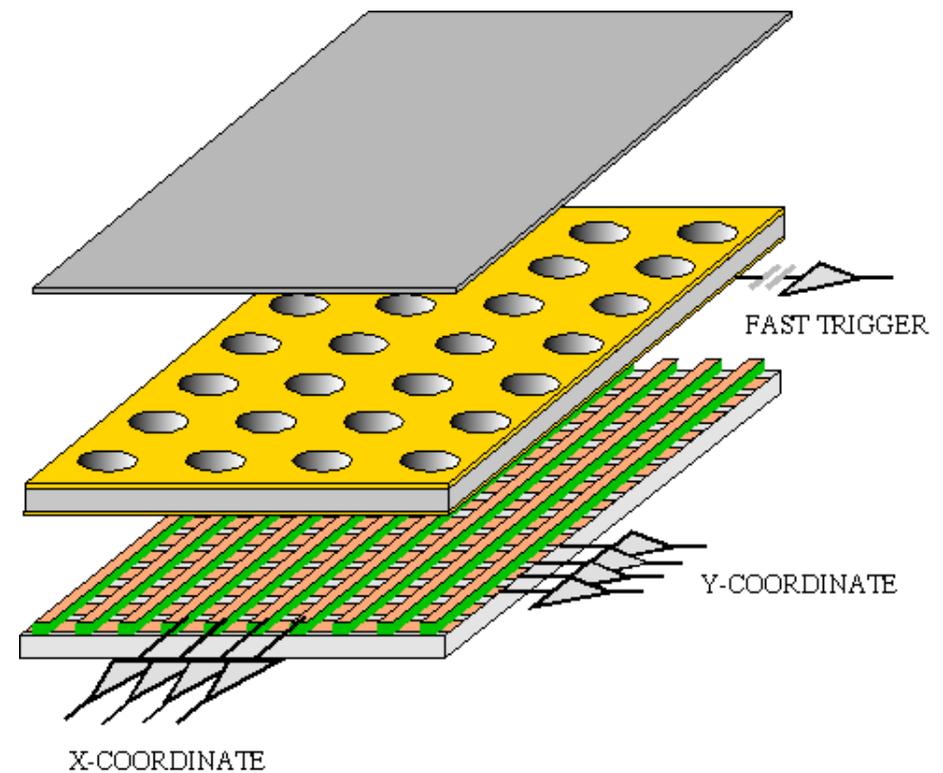
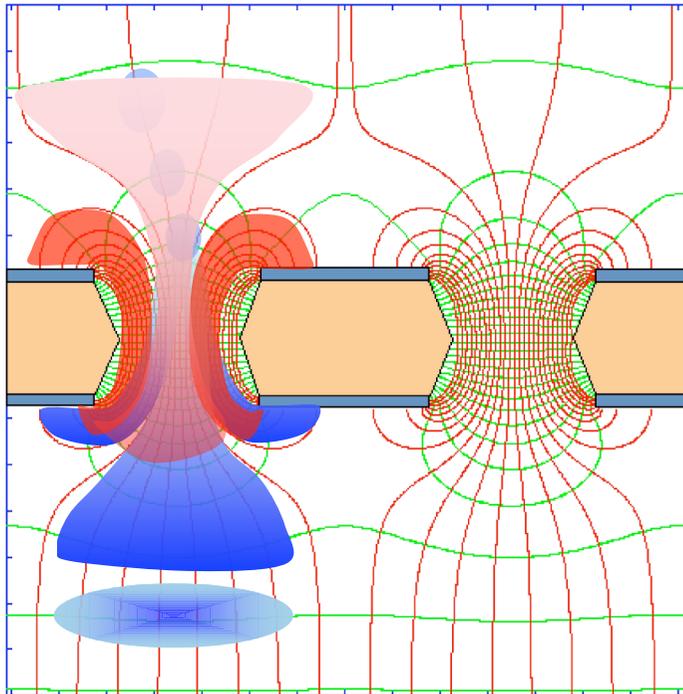
100 μm gap
17 μm pitch



GAS ELECTRON MULTIPLIER (GEM):
HOLES THROUGH THIN METAL-PLATED POLYMER FOIL

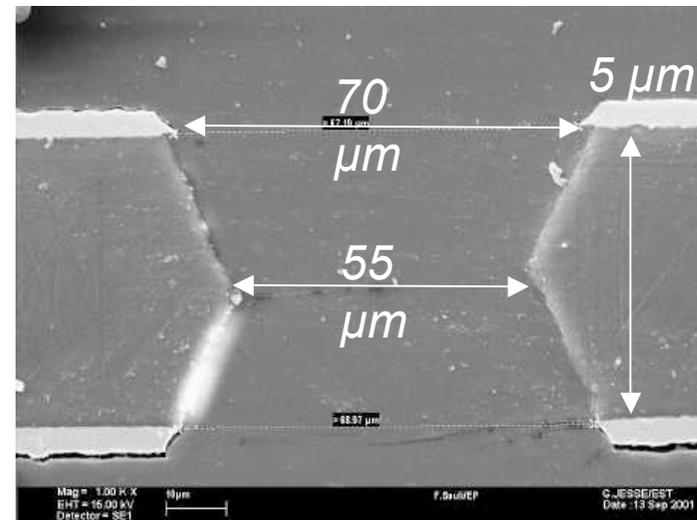
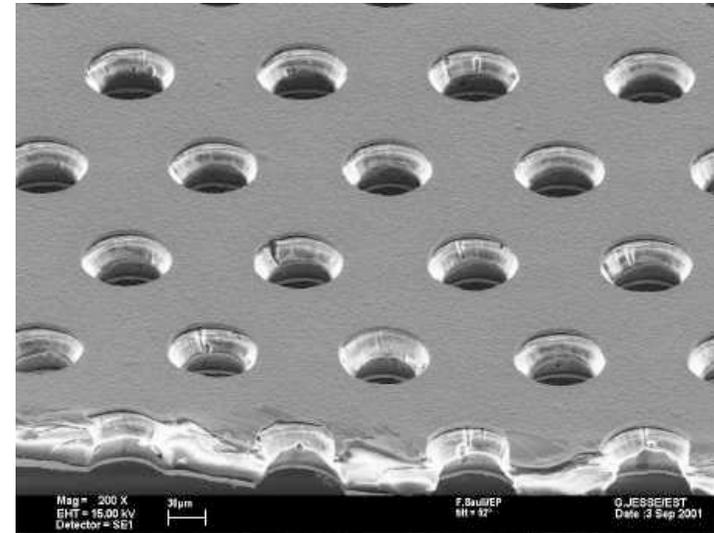
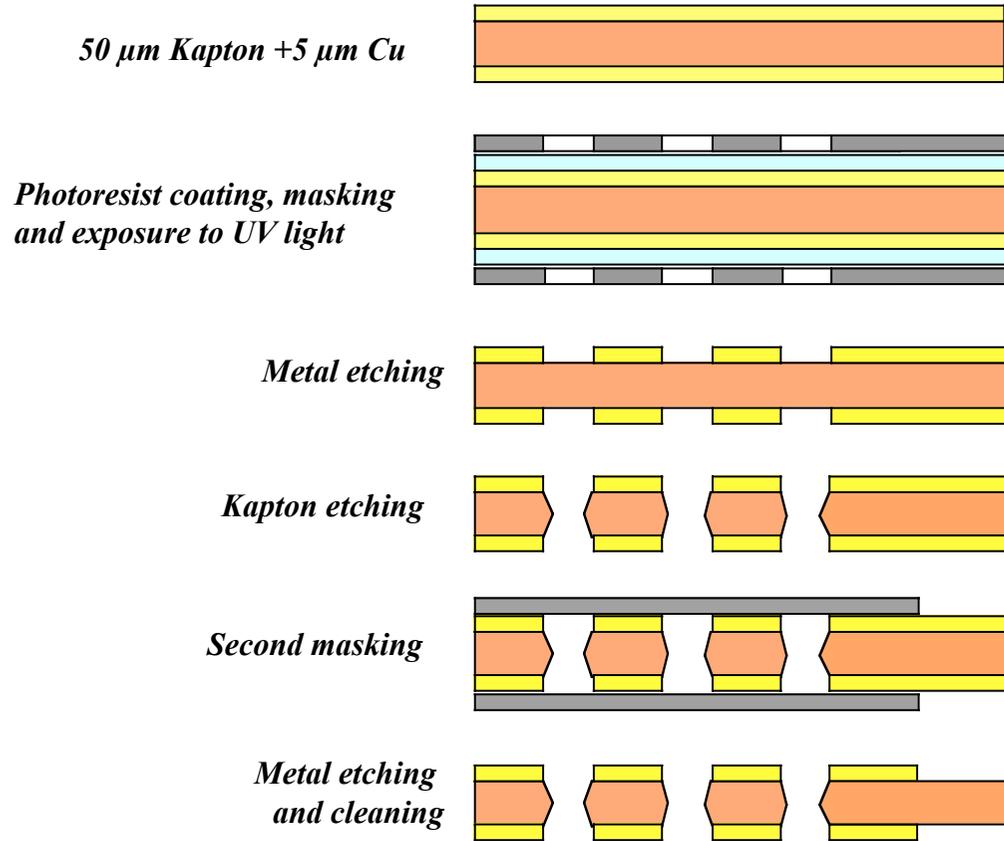
Fabio Sauli (1997)

GEM DETECTOR: MULTIPLICATION AND CHARGE
COLLECTION ON SEPARATE ELECTRODES



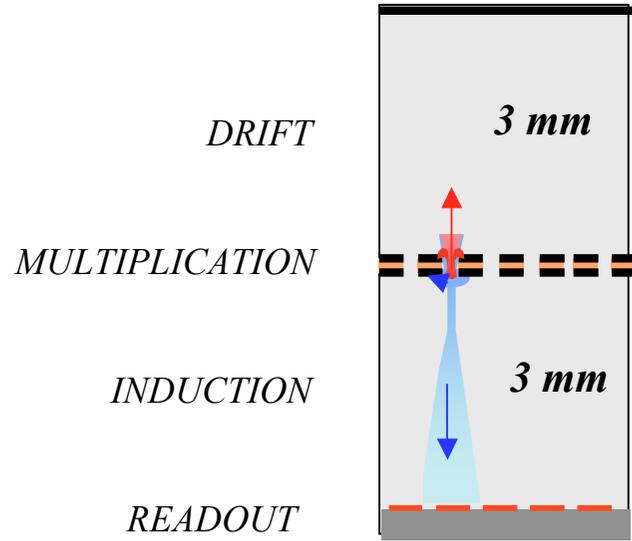
F. Sauli, Nucl. Instrum. Methods A386(1997)531

DOUBLE MASK PHOTOLITHOGRAPHY PROCESS



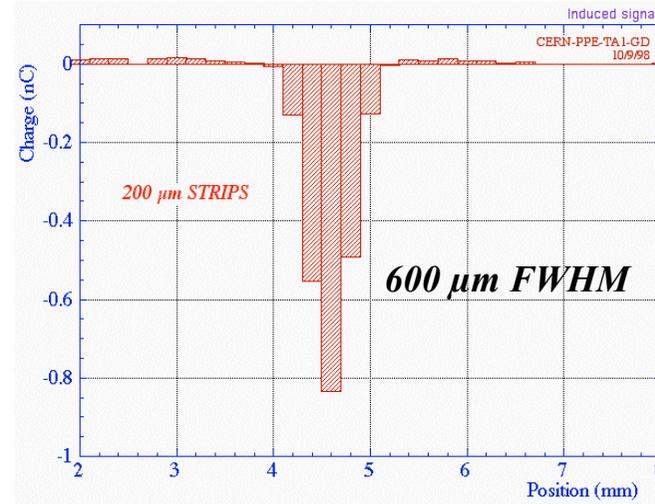
F. Sauli, Nucl. Instr. and Meth. A386(1997)531

SINGLE GEM DETECTOR:

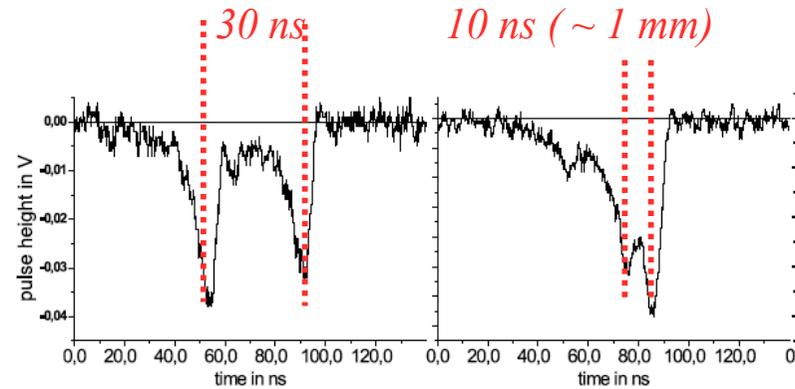


VOLUME RESOLUTION
 $\Delta V \sim 1 \text{ mm}^3$

SIGNAL CHARGE DISTRIBUTION

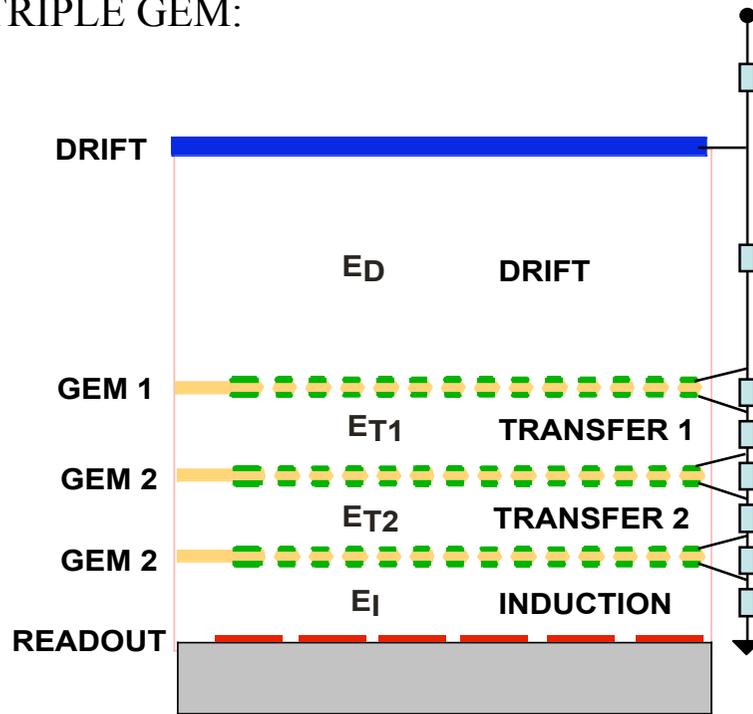


TIME SEPARATION (electron signal only):

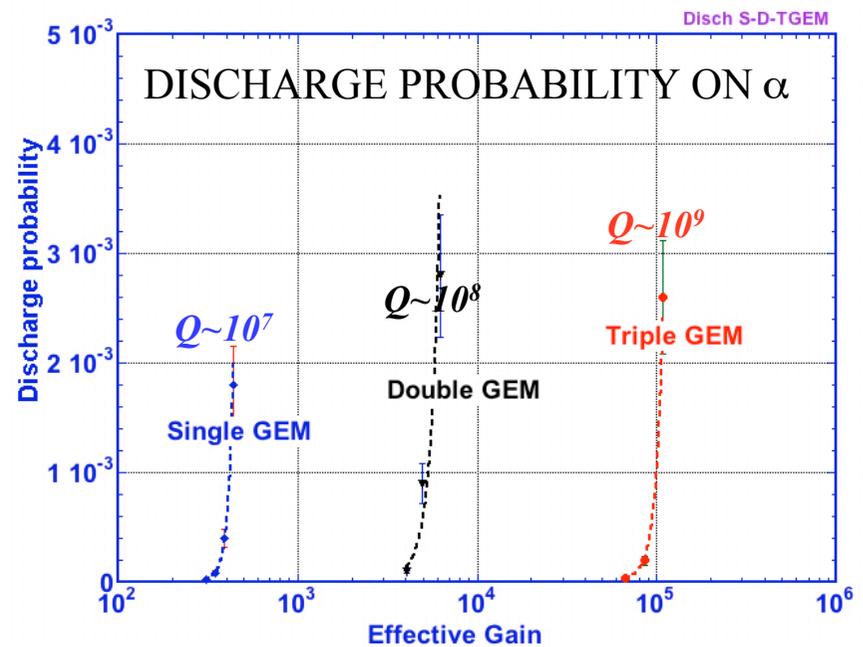
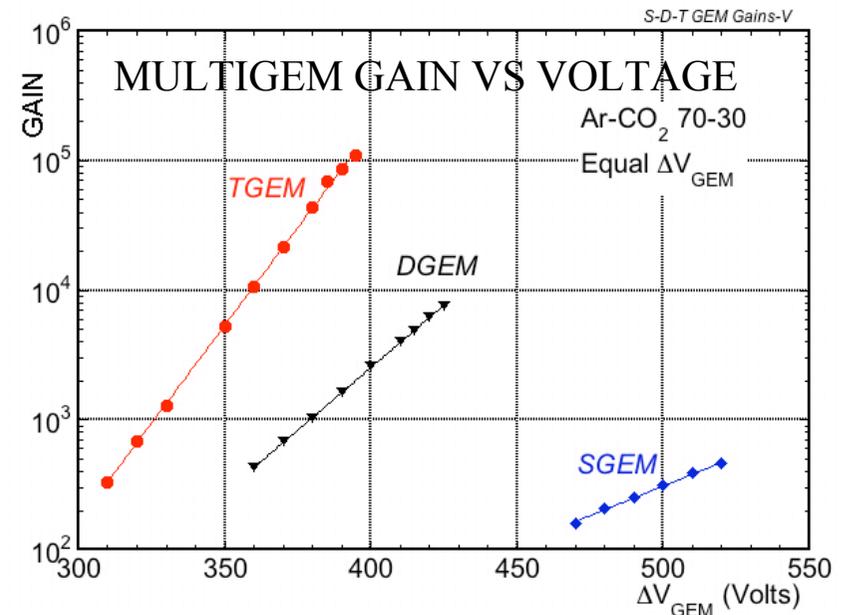


GEM ELECTRODES CAN BE CASCADED FOR HIGHER GAIN AND LOWER DISCHARGE PROBABILITY

TRIPLE GEM:

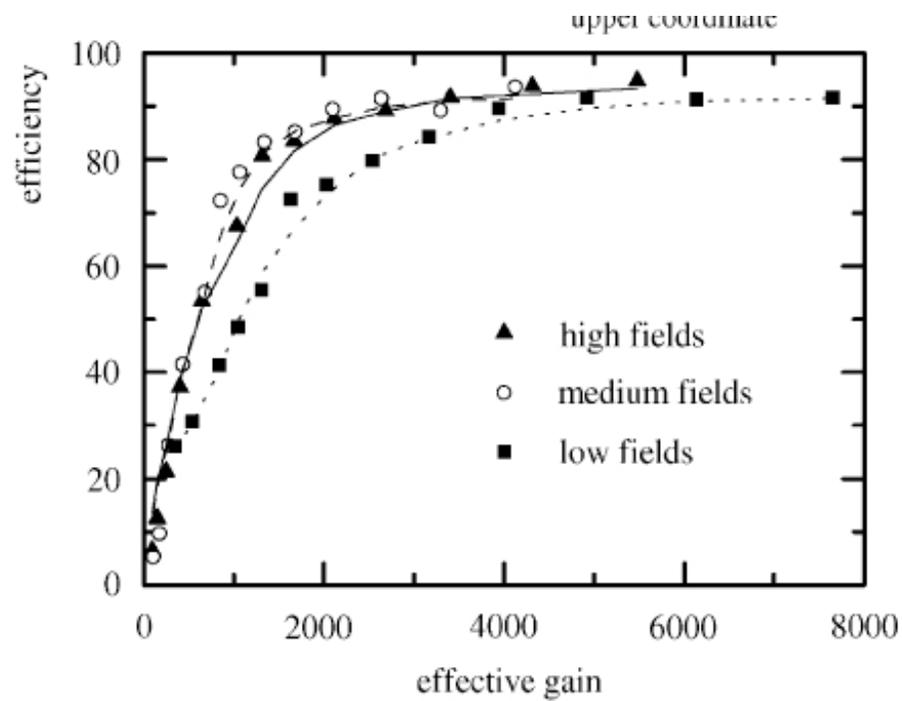


C. Büttner et al,
*Nucl. Instr. and Meth. A*409(1998)79
 S. Bachmann et al,
*Nucl. Instr. and Meth. A*479 (2002) 294



COMPASS TRIPLE-GEM IN HADRON BEAM

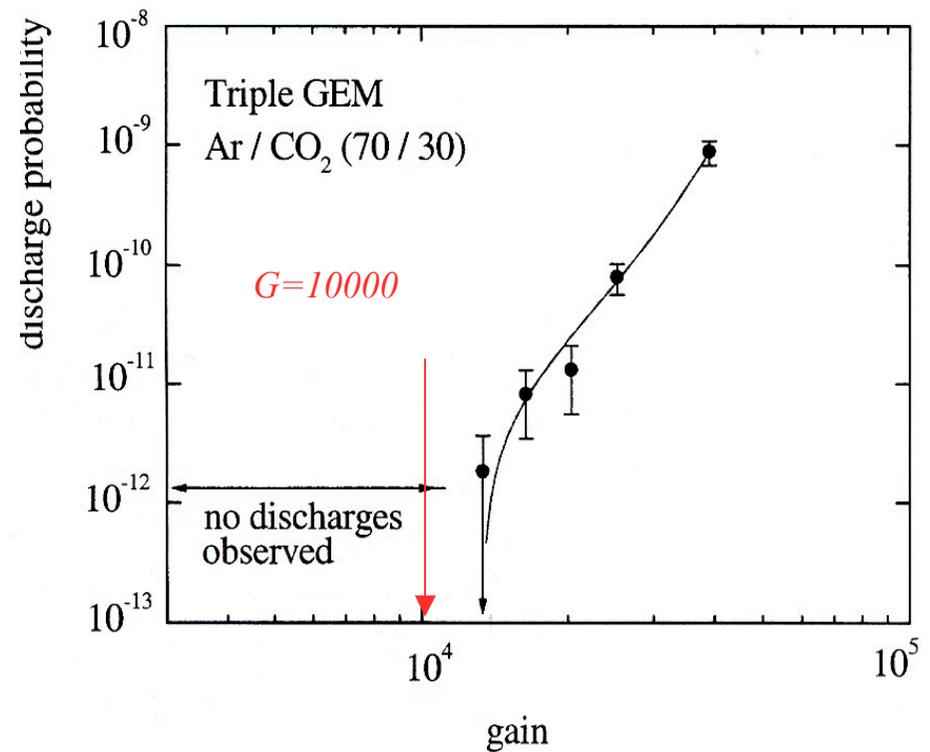
EFFICIENCY



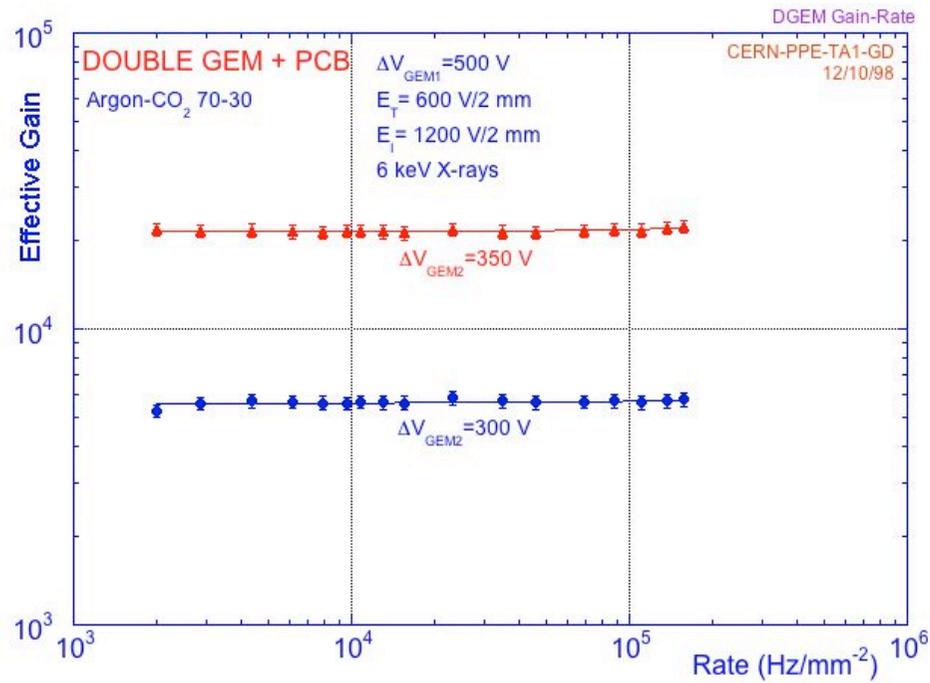
S. Bachmann et al,
Nucl. Instr. and Meth. A470(2001)548

DISCHARGE RATE VS GAIN

No discharges in 12 hrs of operation at gain 10^4

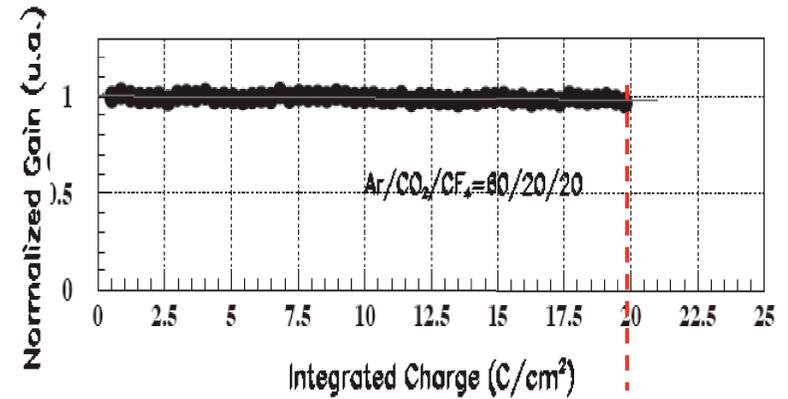


RATE CAPABILITY:



J. Benloch et al, IEEE NS-45(1998)234

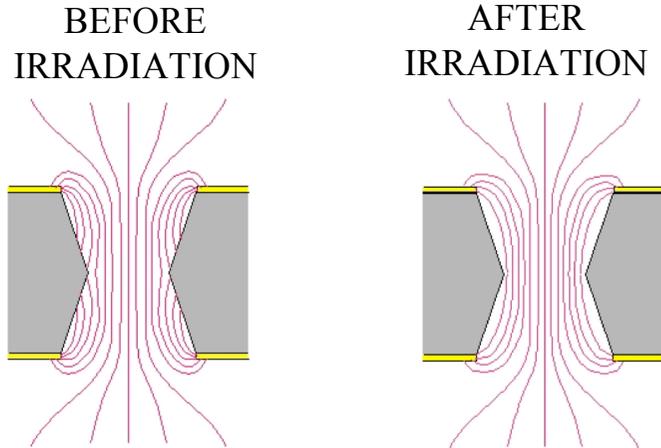
RADIATION HARDNESS:



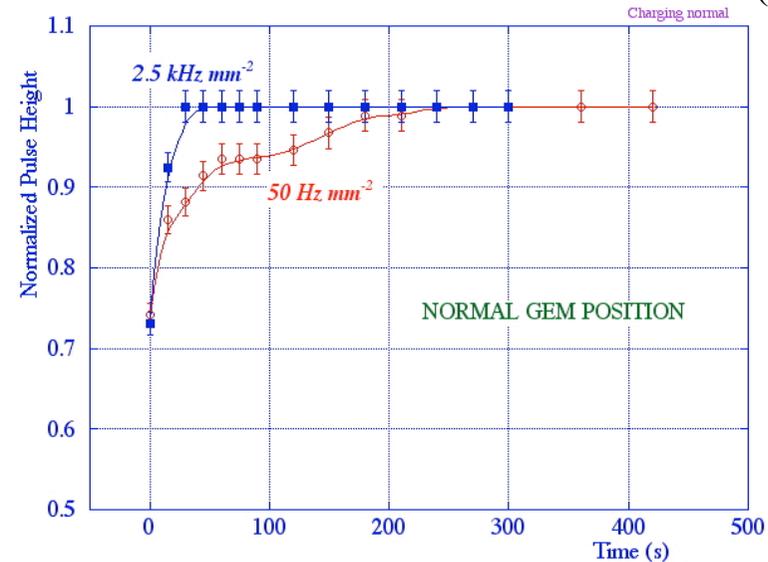
~ 4 10¹⁴ MIPS cm⁻²

M. Alfonsi et al, Nucl. Instr. and Meth. A518(2004)106

GAIN INCREASE:
CHARGE ACCUMULATION ON THE HOLE SURFACE MODIFY THE FIELD

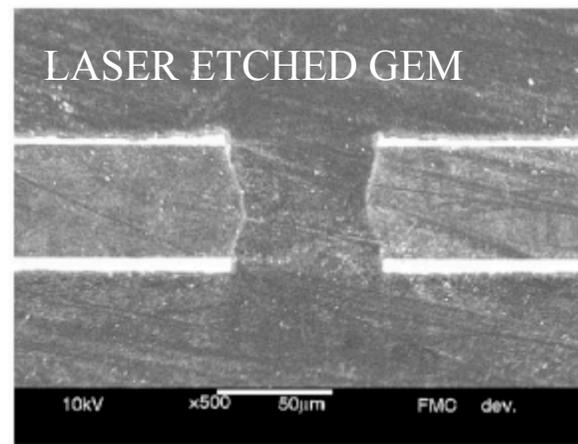


RATE DEPENDENCE OF CHARGING UP (CERN)

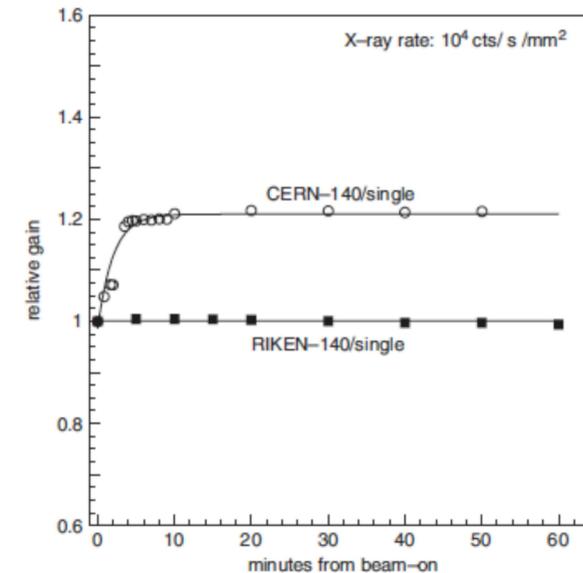


C. Altumbas et al, Nucl. Instr. and Meth. A490(2002)177

CYLINDRICAL HOLES:
NO CHARGING UP
(RIKEN)

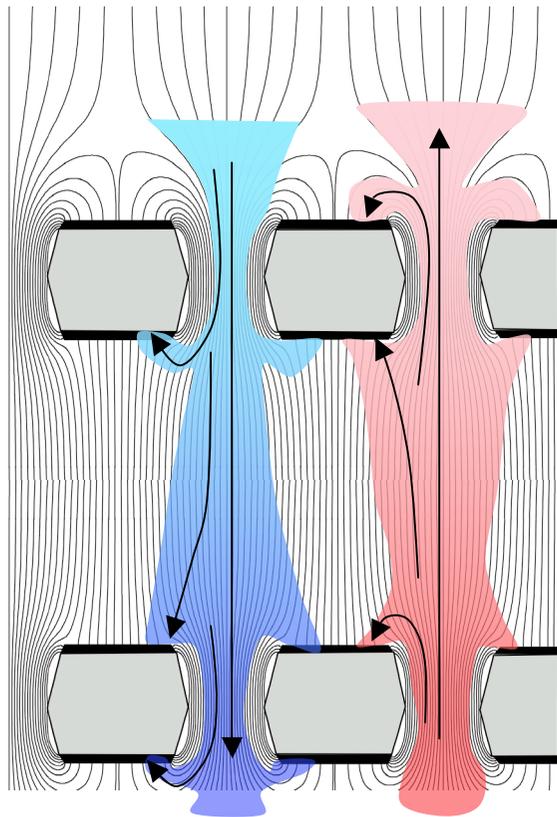


T. Tamagawa et al, Nucl. Instr. And Meth. A560(206)418

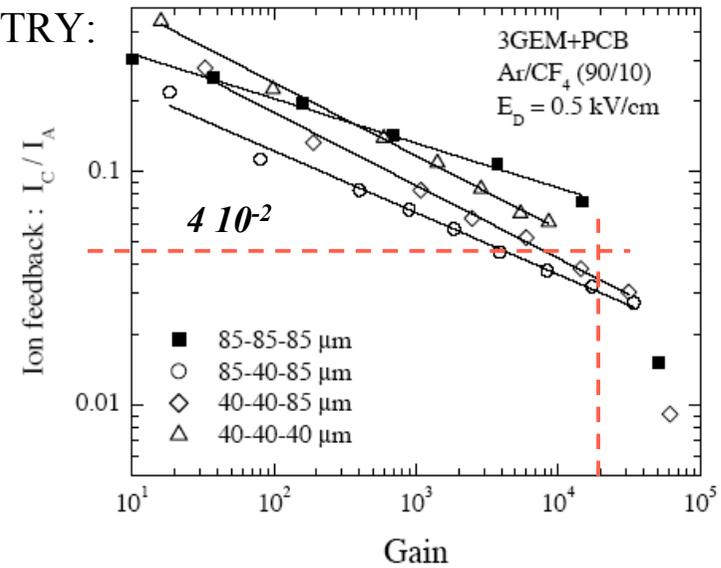


MULTIGEMS

The fractional ion feedback in multi-GEM detectors results from a complex interplay of geometry, fields, diffusion:

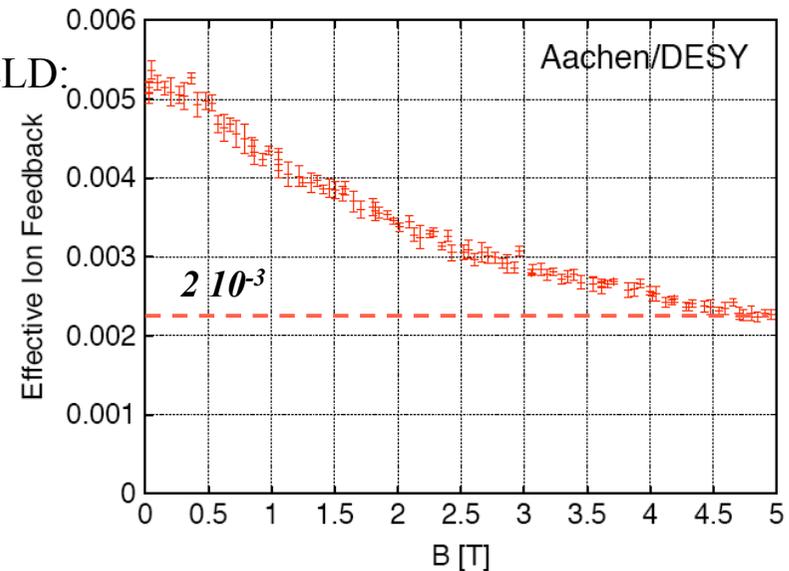


GEOMETRY:



A. Bondar et al, Nucl. Instr. and Meth. A496(2003)325

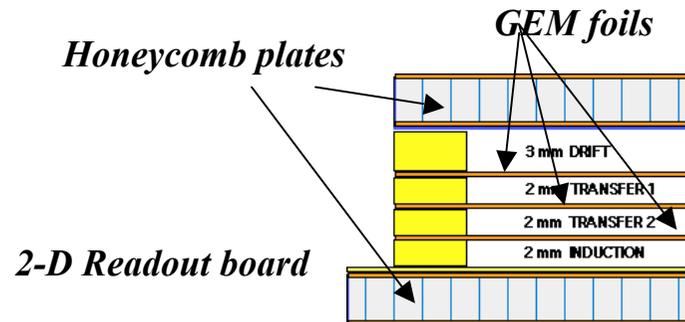
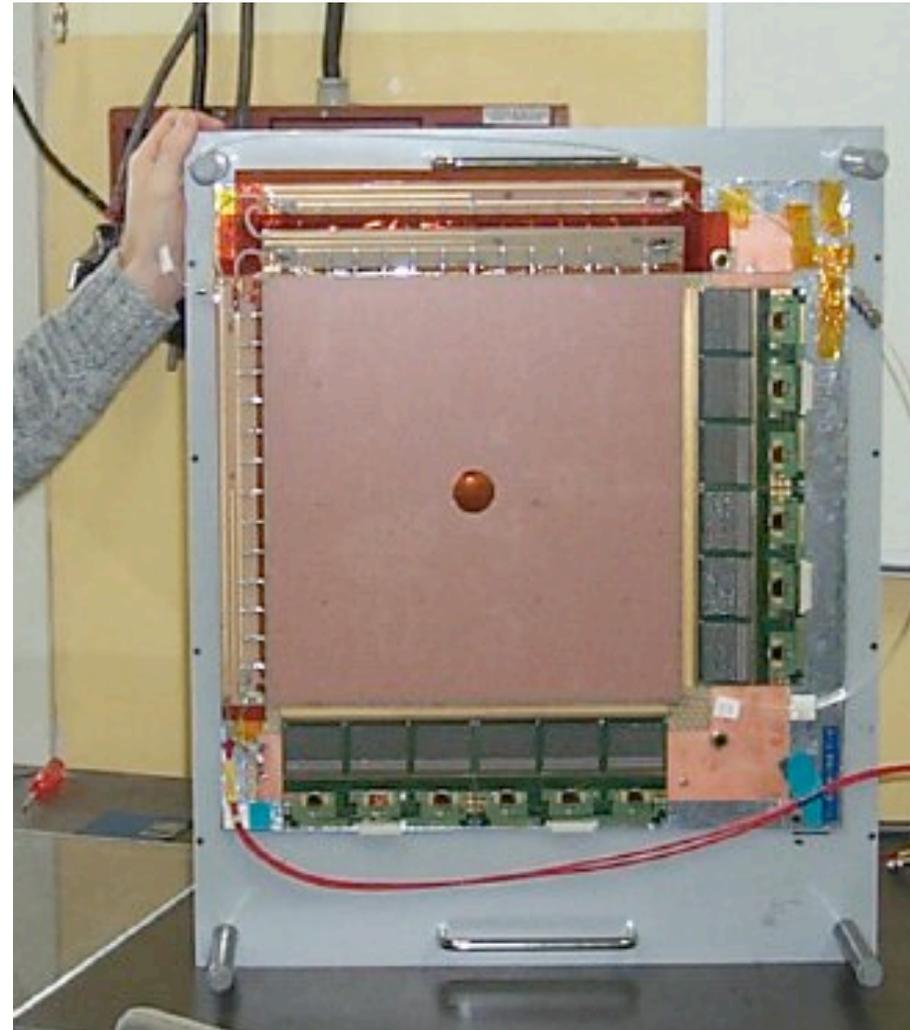
MAGNETIC FIELD:



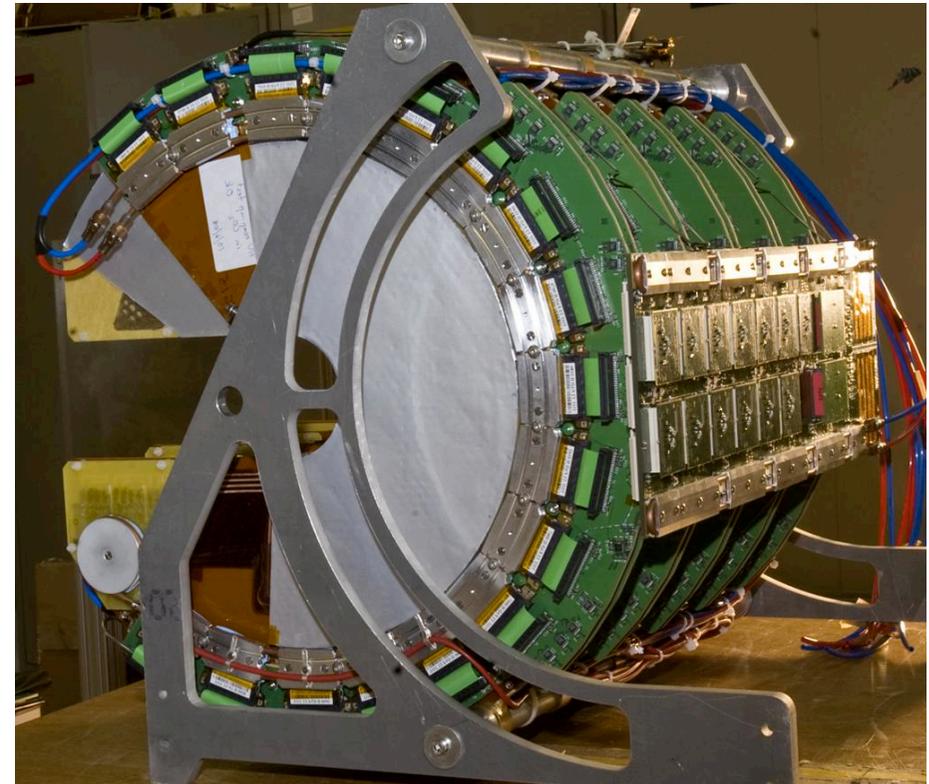
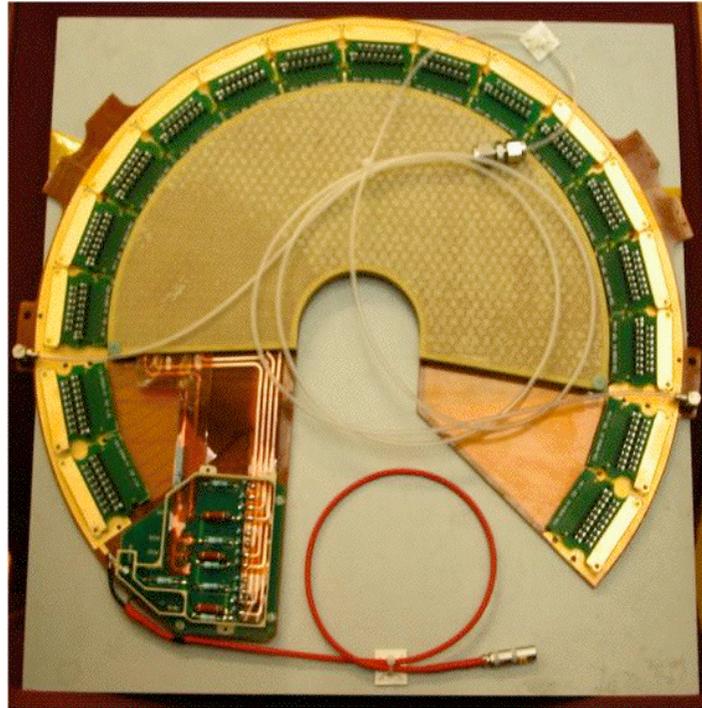
M. Killenberg et al, Nucl. Instr. and Meth. A530(2004)251

LIGHT MULTIGEM CONSTRUCTION31x31 cm² active

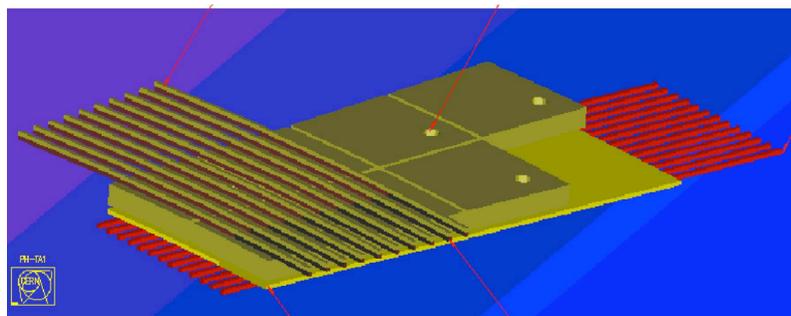
2-D strip readout

Total thickness in active area $\sim 0.7\% X_0$ Pitch: 400 μm Top strips: 80 μm Bottom strips: 350 μm *C. Altumbas et al, Nucl. Instrum. Methods A490(2002)177**B. Ketzer et al, Nucl. Instr. and Meth. A535(2004)314**Fabio Sauli - CHIPP Winter School 2010*

SEMI-CIRCULAR DETECTORS (LHC)



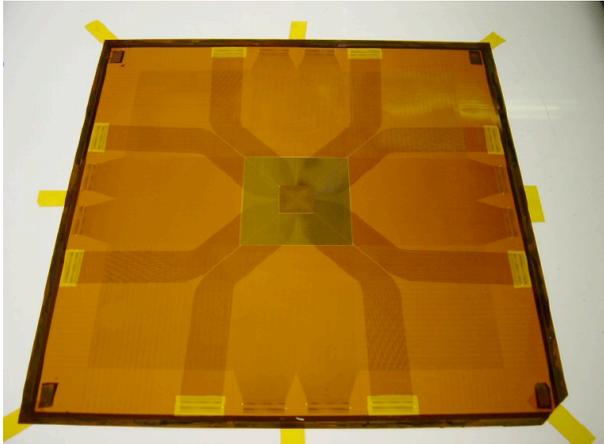
STRIPS AND PADS READOUT



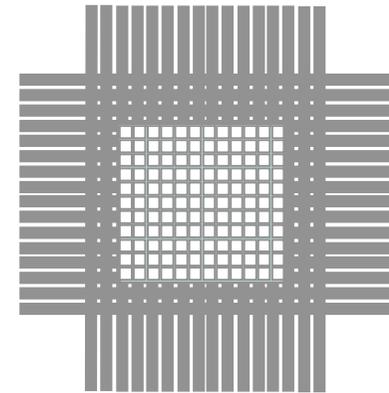
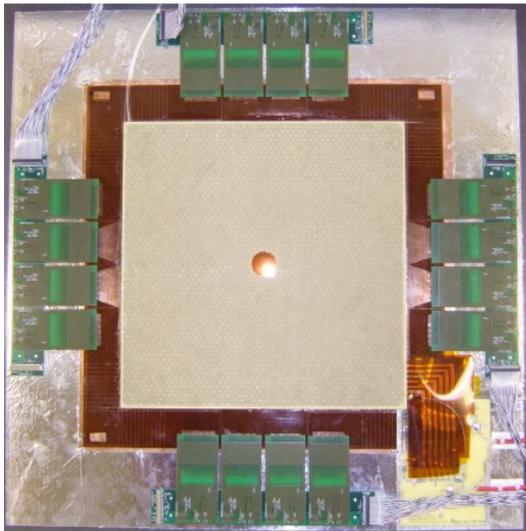
*M.G. Bagliesi et al,
Nucl. Instr. And Meth. In press (2009)*

COMPASS UPGRADE: TRIPLE GEM WITH PIXEL AND STRIPS READOUT

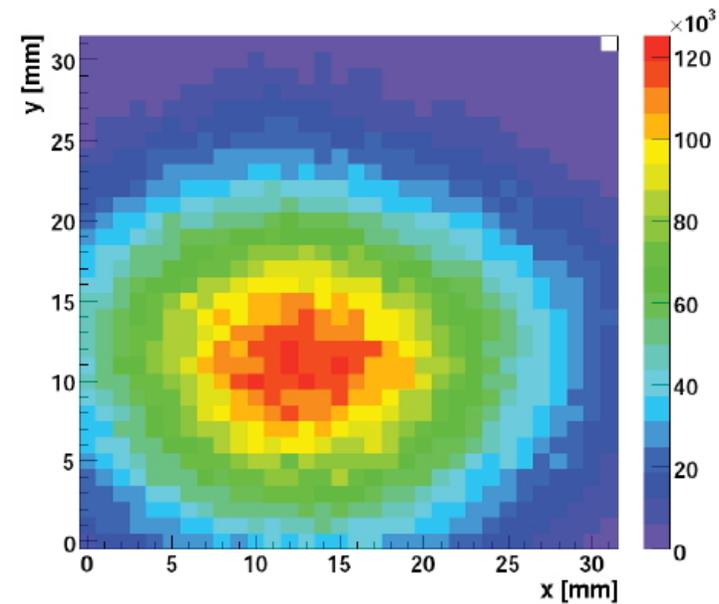
Center: 32x32 PIXELS, 1 mm² each
Sides: 512x512 STRIPS, 400 μm pitch



F. Haas et al, Vienna Instr. Conf (Feb. 2007)

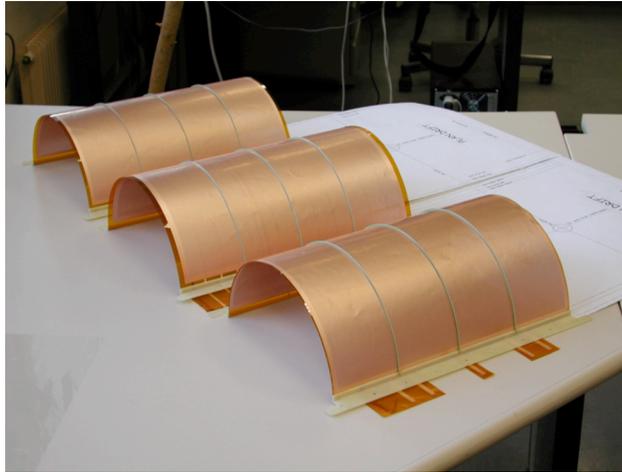


HIGH FLUX BEAM:

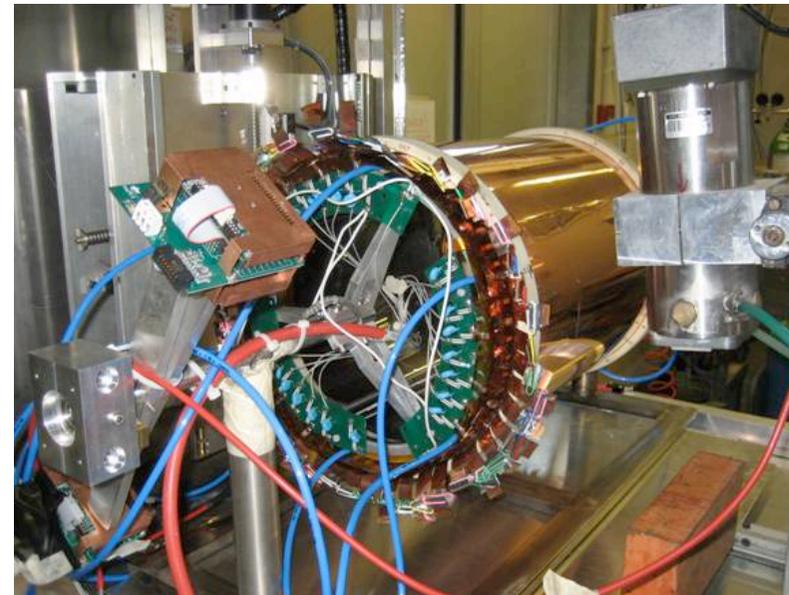
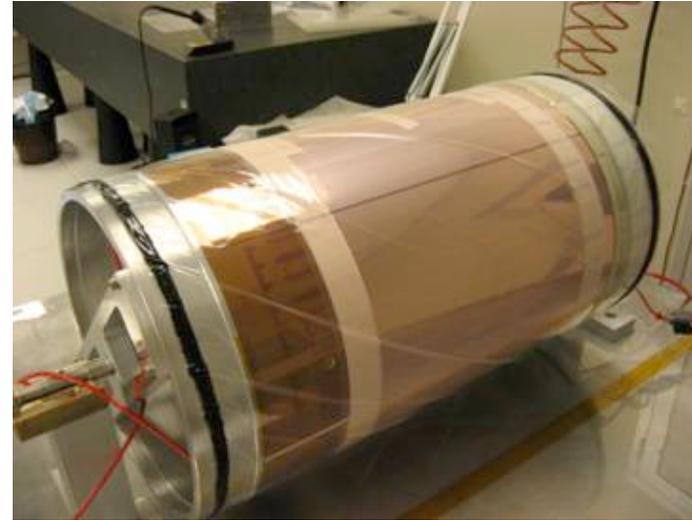


B. Ketzer et al, IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, 19-25 Oct. 2008)

CERN PROTOTYPE



CHLOE UPGRADE (LNF Frascati)

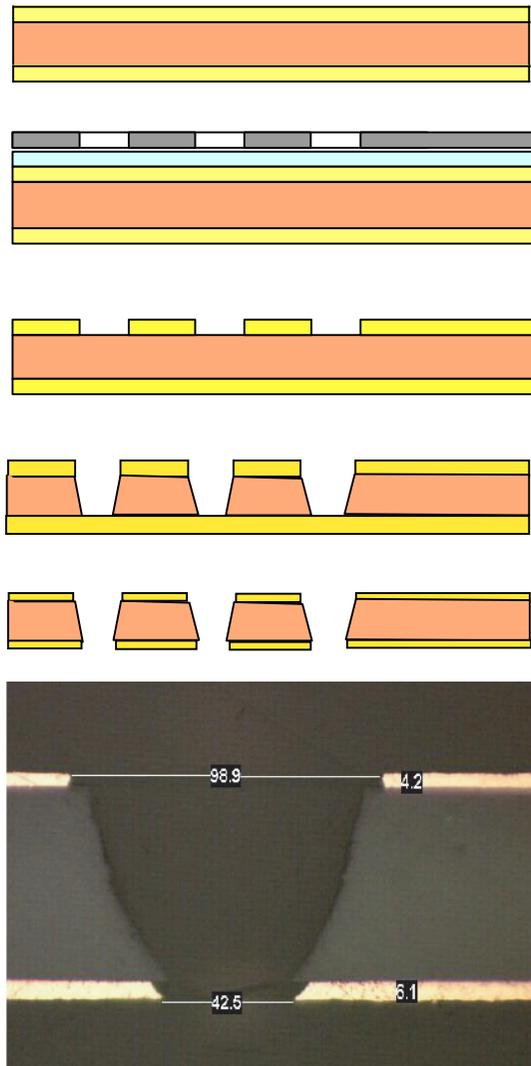


L. Ropelewski, Vienna Instr. Conf. 2007

G. Bencivenni, RD51 Workshop (Paris Oct. 2008)

Fabio Sauli - CHIPP Winter School 2010

SINGLE MASK PROCESS



*R. De Oliveira,
MPGD Int. Conf. (Crete, June 12-15, 2009)*



*S. Duarte Pinto et al,
IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, Oct. 2008)
M. Alfonsi et al, Nucl. Instr. And Meth. In press (2009)*

MECHANICAL DRILLING OF METAL-CLAD PC BOARD:

- SELF-SUPPORTING
- HIGH GAIN

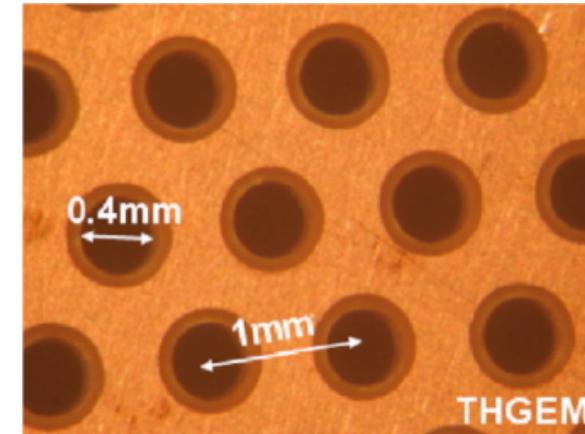
LARGE ELECTRON MULTIPLIER (LEM)

P. Janneret, Thesis at Neuchatel University (2001)

LARGE TGEM: INFN TRIESTE: 60x60 cm²



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



WEIZMANN INSTITUTE: 30x30 cm²



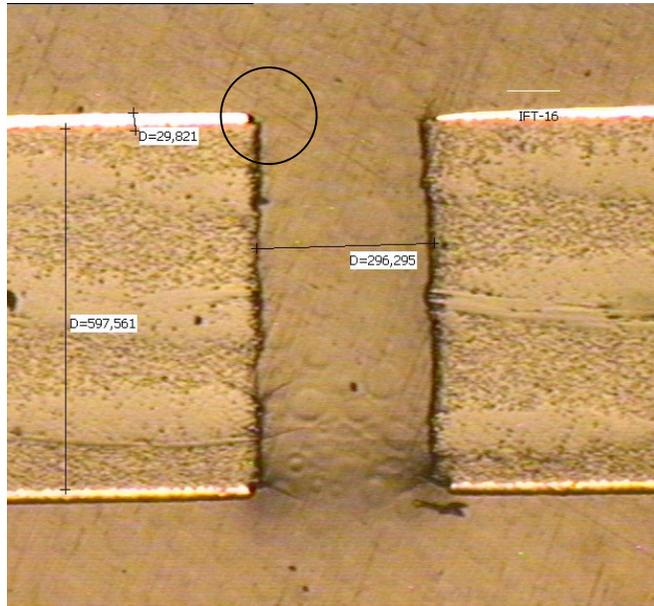
RIM vs RIMLESS

LARGE RIM:

- HIGH GAIN
- LARGE CHARGING UP

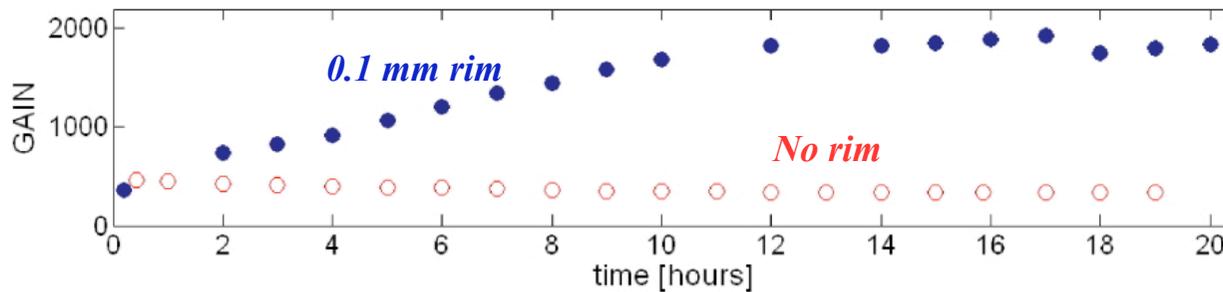
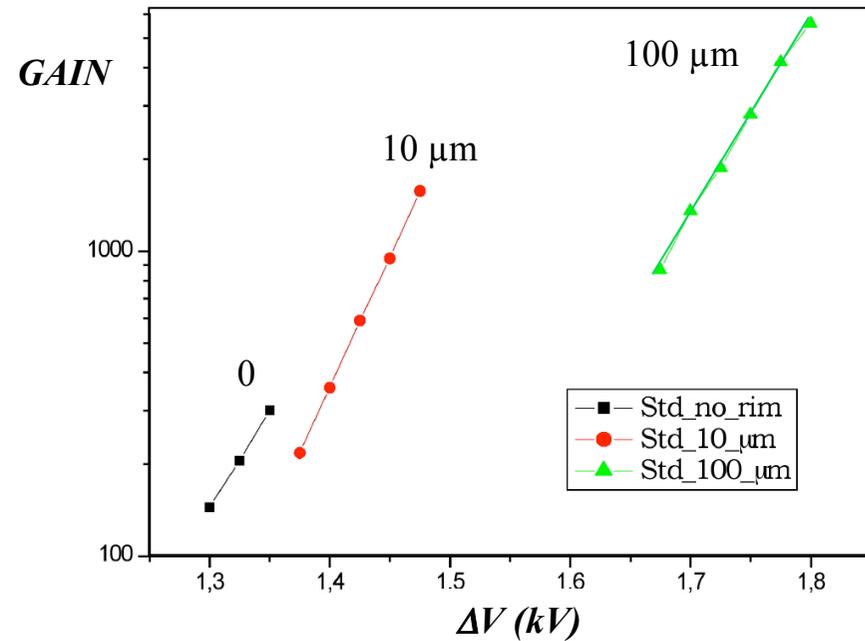
RIMLESS:

- LOW GAIN
- STABLE



Single TGEM

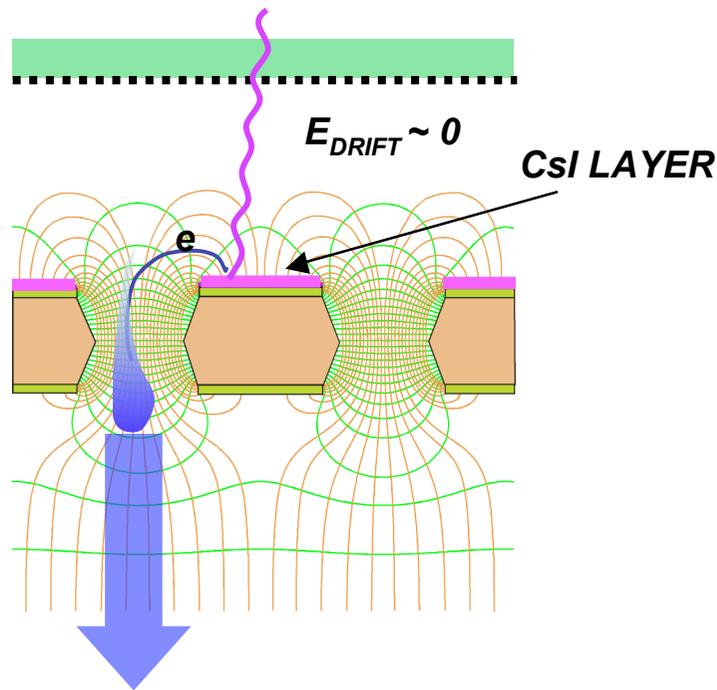
0.4 mm thick 0.4 mm \varnothing holes, 0.8 mm pitch:



S. Dalla Torre, Int. Conf. on Technology and Instrumentation in Particle Physics (TIPP 2009)

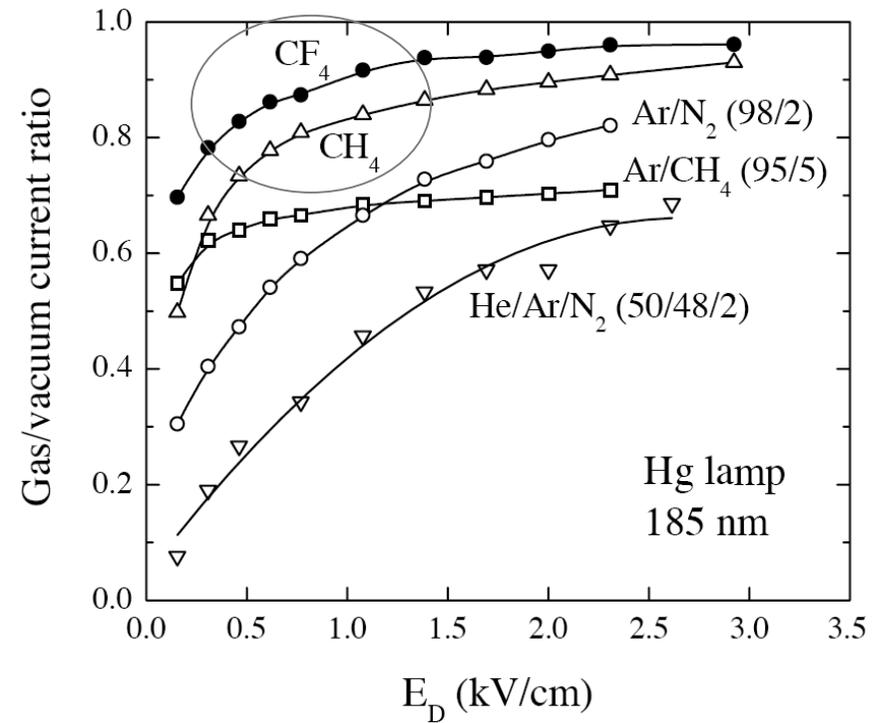
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PHOTOSENSITIVE GEM: REFLECTIVE CsI PHOTOCATHODE COATING



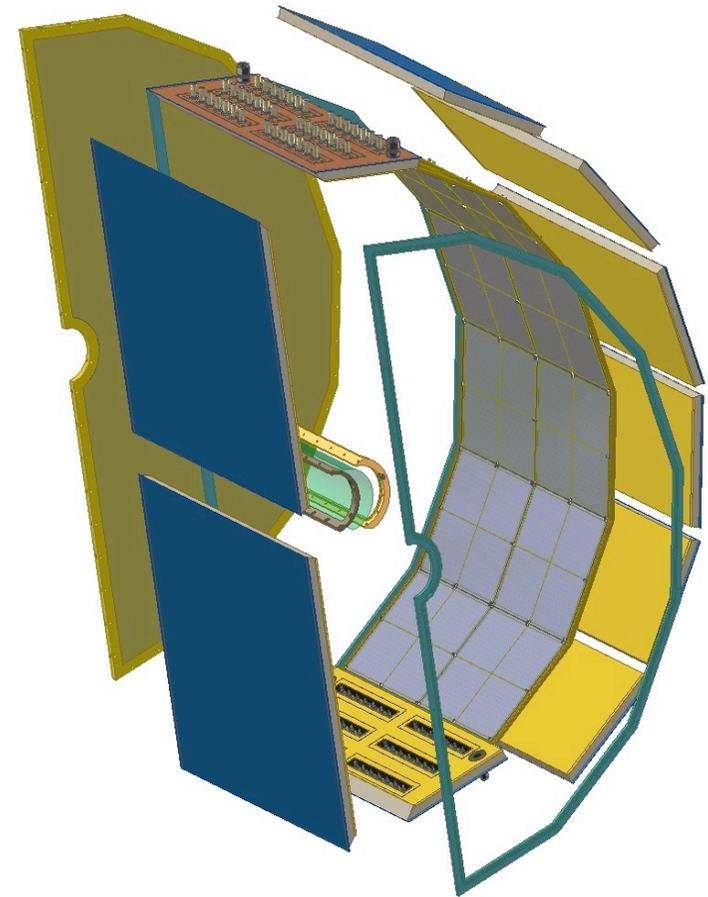
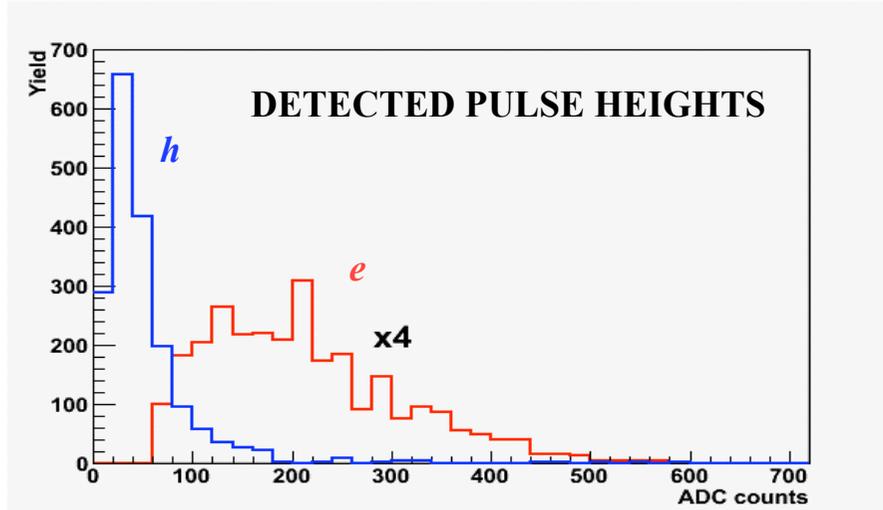
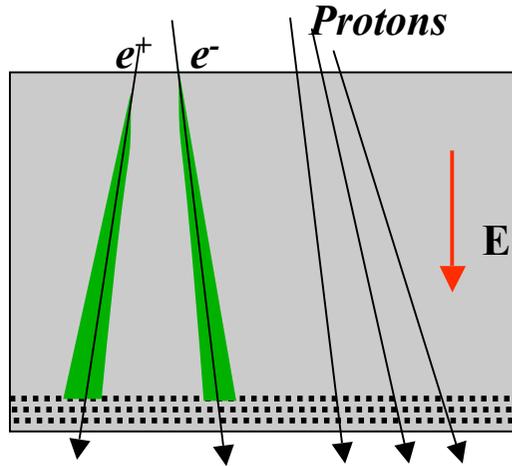
*D. Mormann et al,
Nucl. Instr. and Meth. A478(2002)230*

BACKSCATTERING:
RELATIVE QUANTUM EFFICIENCY AS A
FUNCTION OF EXTRACTION FIELD



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

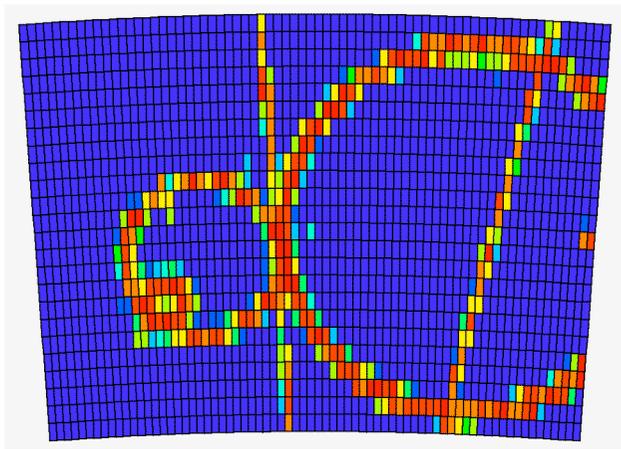
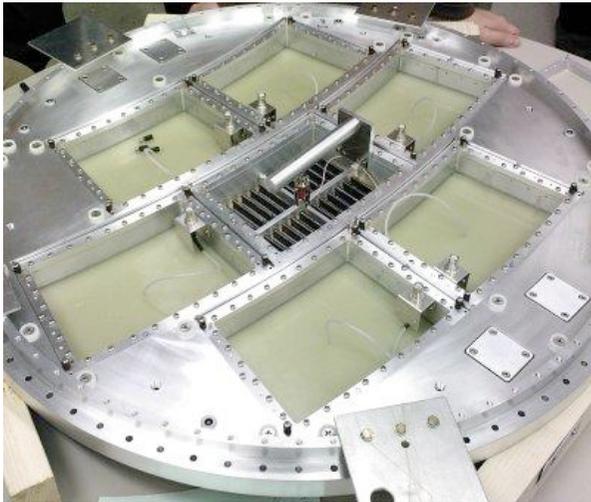
FIRST EXPERIMENT WITH CsI GEM: PHENIX HADRON BLIND
 CHERENKOV PHOTON EMISSION IN RADIATOR



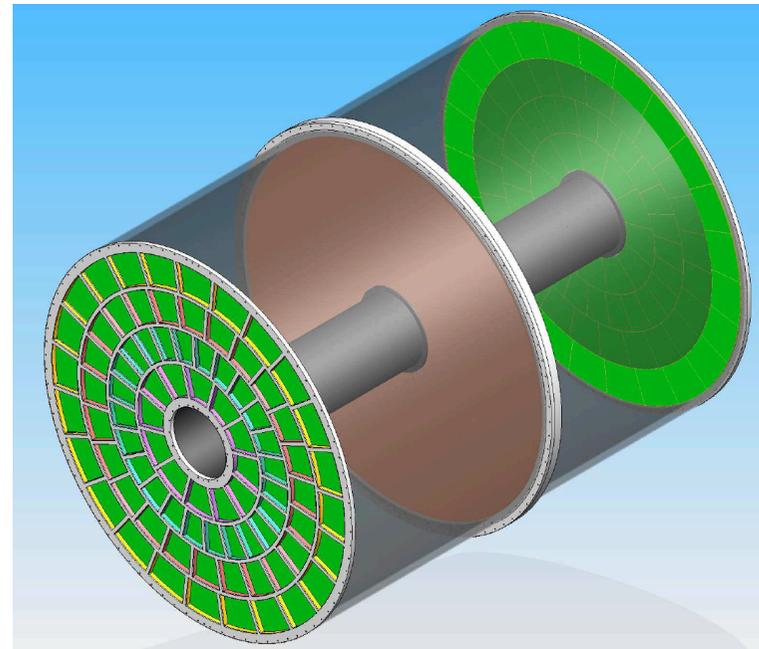
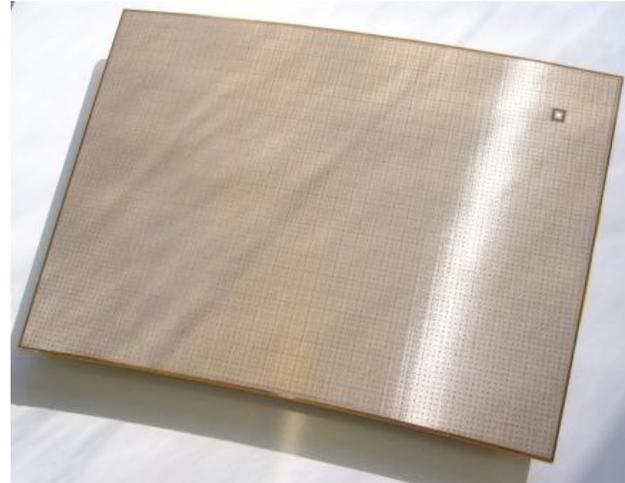
C. Aidala et al, Nucl. Instr. Methods A502(2003)200

Z. Fraenkel et al, Nucl. Instr. Methods A546(2005) 466

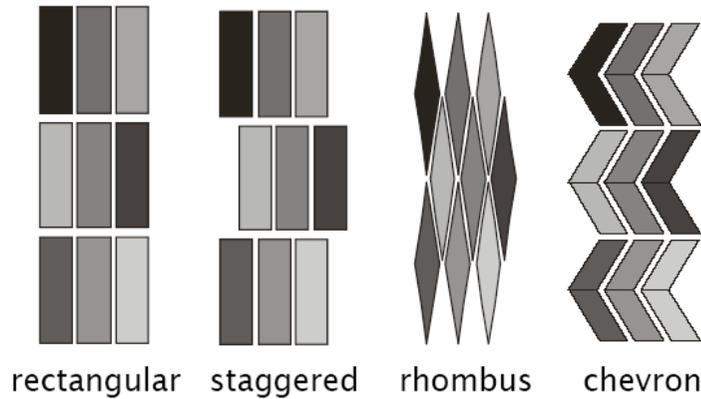
COMPOSITE END-PLATE ASSEMBLY



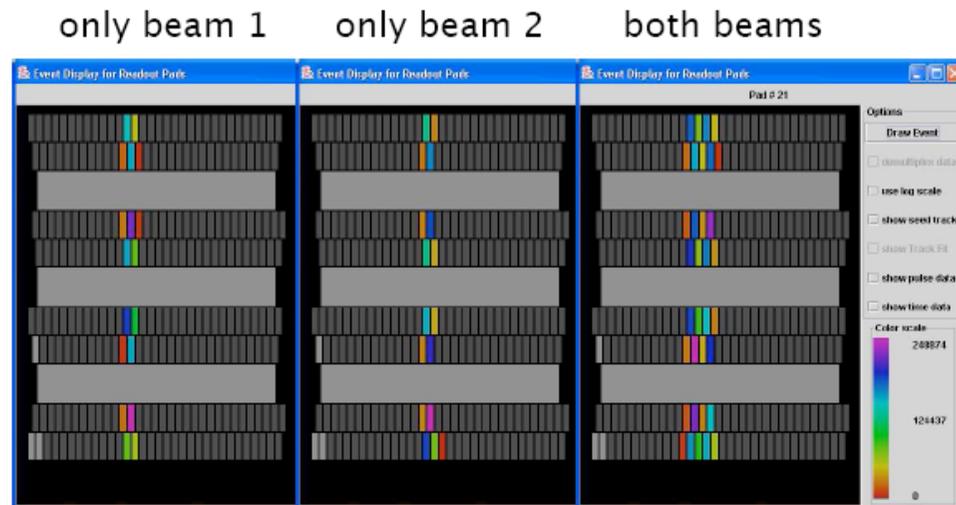
P. Colas and K. Dehmelt, Int. Conf. on Technology and Instrumentation in Particle Physics (TIPP 2009)

MICROMEAS MODULE 17X21 CM² ACTIVE

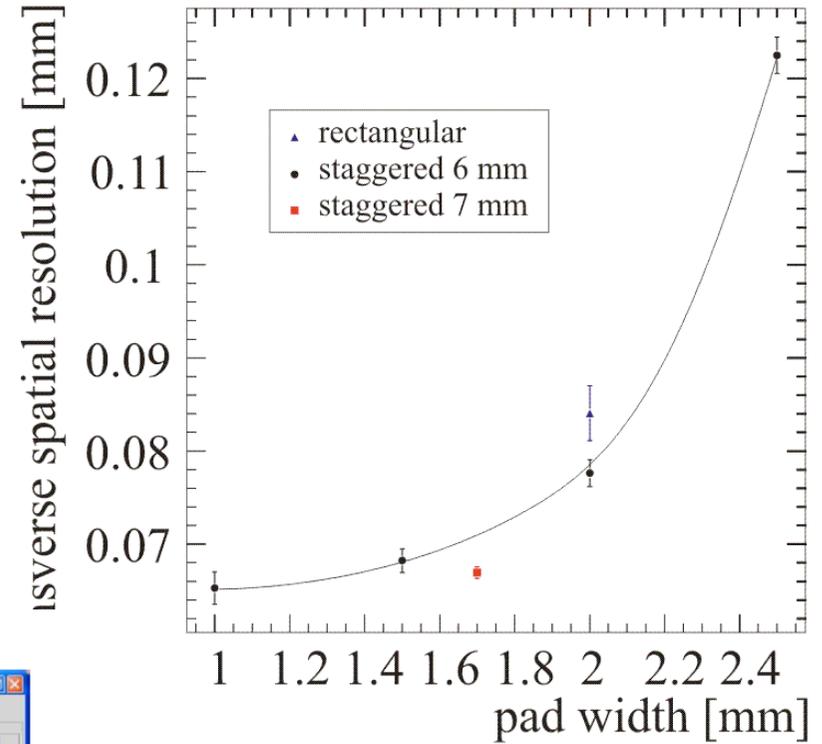
OPTIMIZATION OF PAD SIZE & SHAPE



*B. Ledermann et al,
Nucl. Instr. and Meth. A581(2007)232*

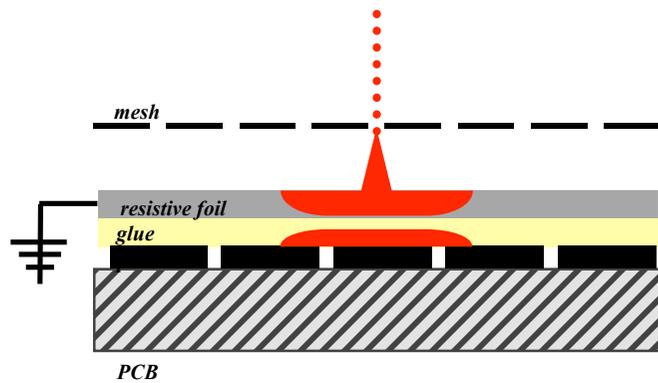


RESOLUTION VS PAD WIDTH:

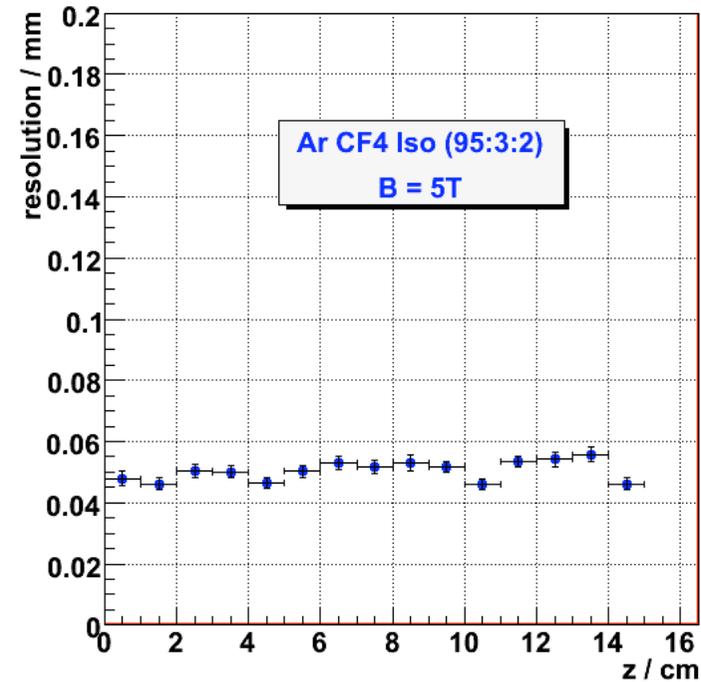
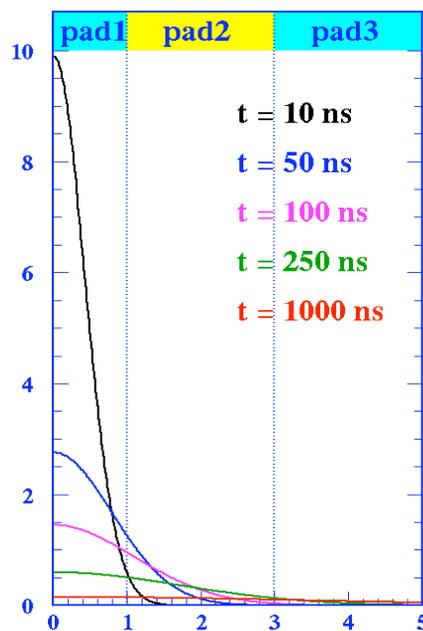


TWO-TRACK RESOLUTION STUDIES WITH LASER BEAMS (Victoria-DESY)

REDUCE PAD NUMBER: CHARGE SHARING WITH RESISTIVE FOIL ON ANODE



MEASURED RESOLUTION @ 5 TESLA
MICROME GAS WITH RESISTIVE ANODE:

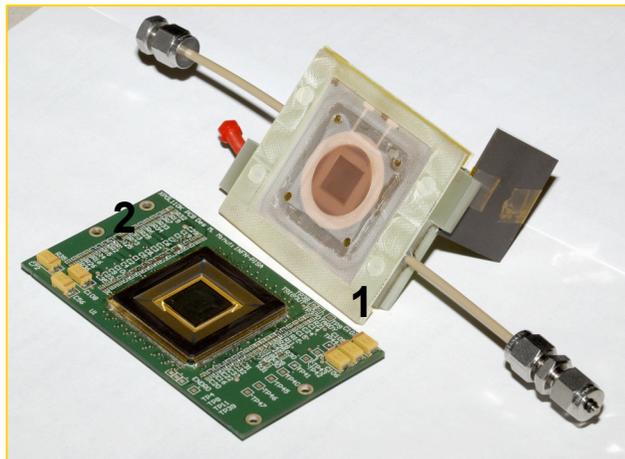
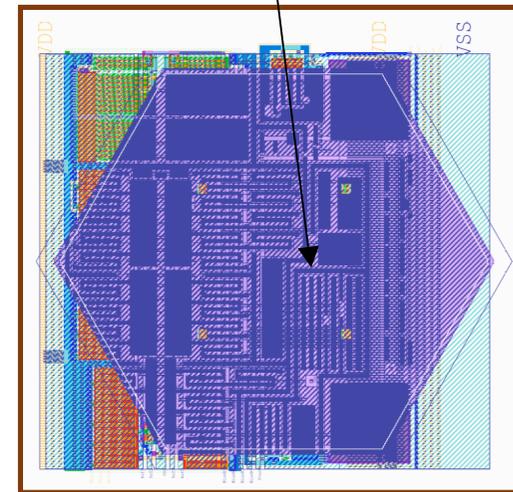
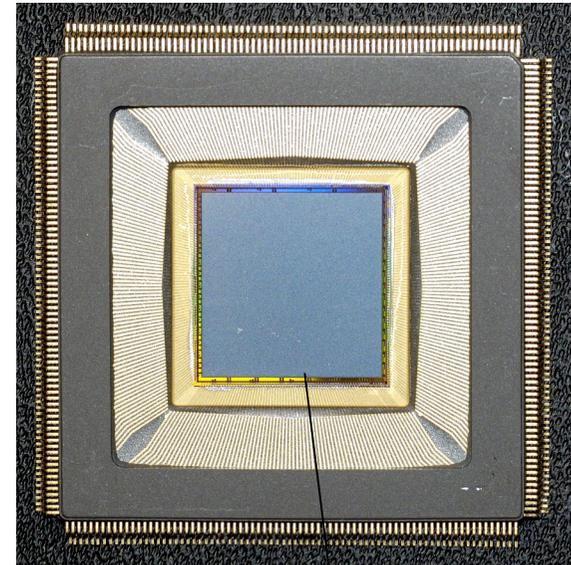
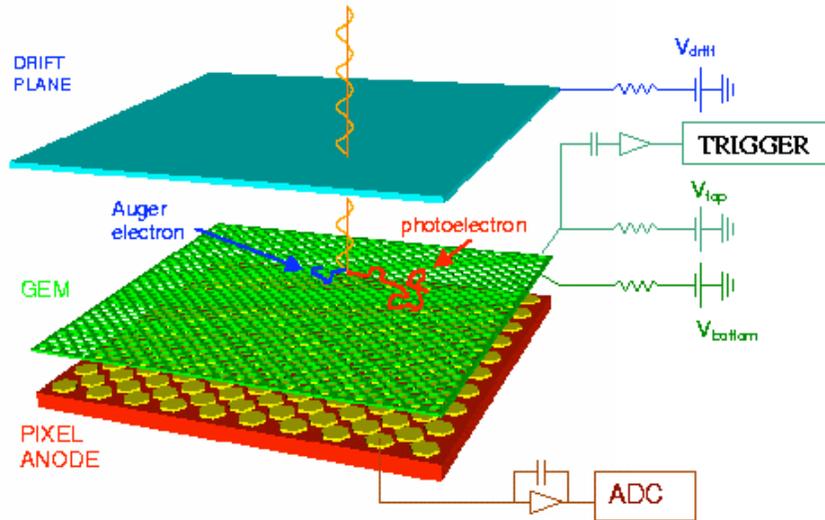


M. Dixit et al, Nucl. Instr. and Meth. A566((2006)281

K. Boudjemline et al, Nucl. Instr. and Meth.A574(2007)22

GEM DETECTOR WITH ASIC PIXEL ELECTRONICS

X-RAY POLARIMETER



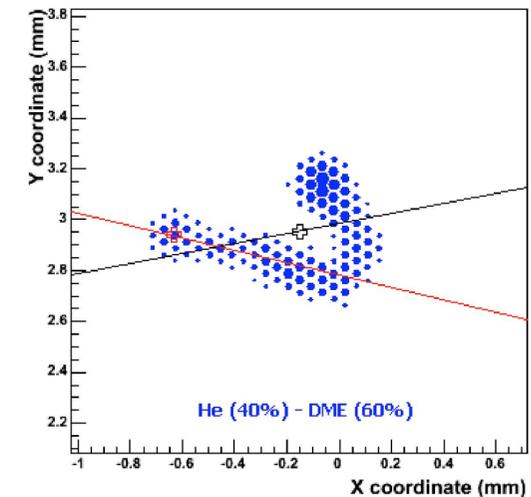
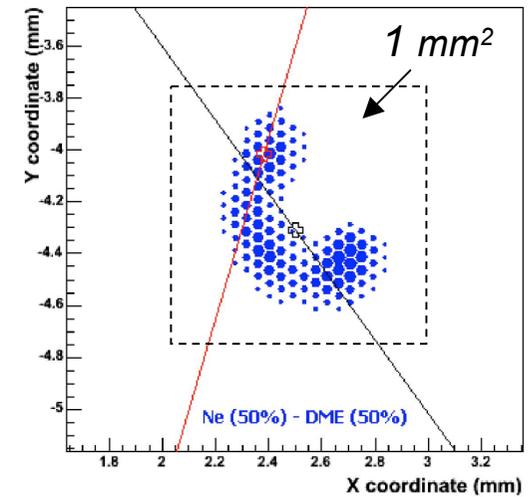
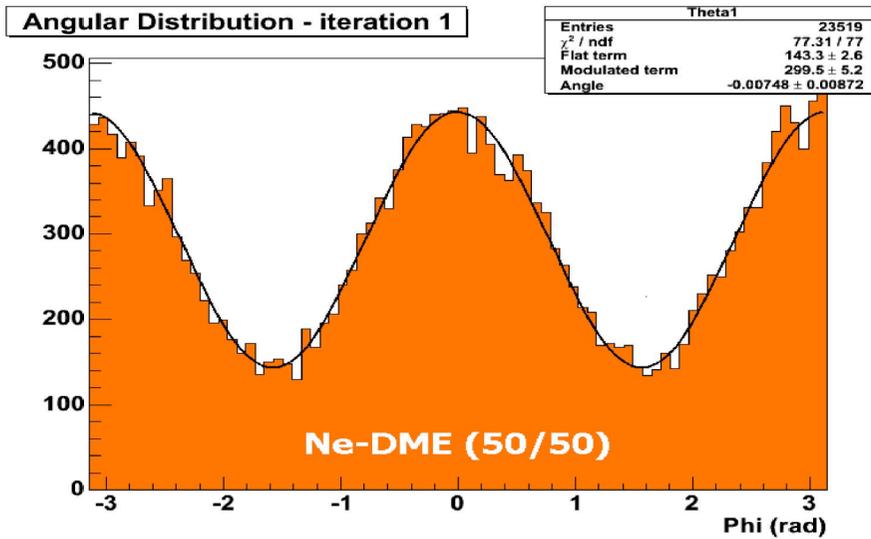
E. Costa et al, Nature 411(2001)662

R. Bellazzini et al, Nucl. Instr. and Meth. A478(2002)13

R. Bellazzini et al, Nucl. Instr. and Methods A435(2004)477

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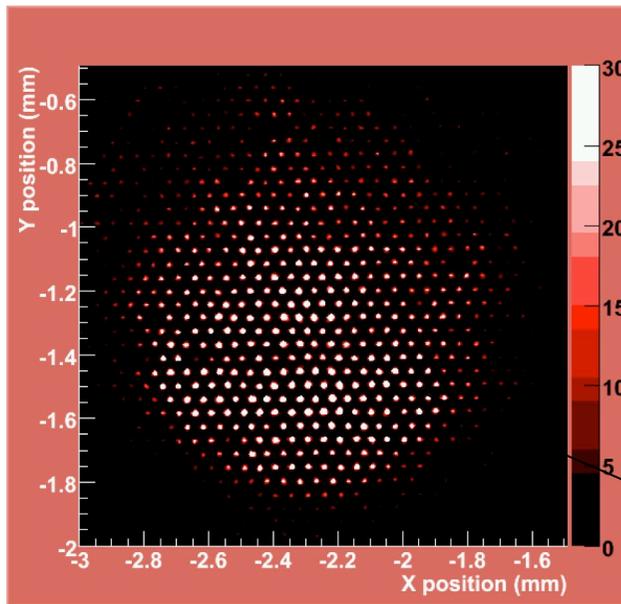
PHOTOELECTRON ANGULAR DISTRIBUTION FOR POLARIZED SOFT X-RAYS:



R.Bellazzini et al, Nucl. Instr. And Meth. A572(2007)160

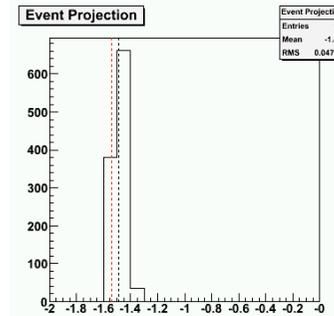
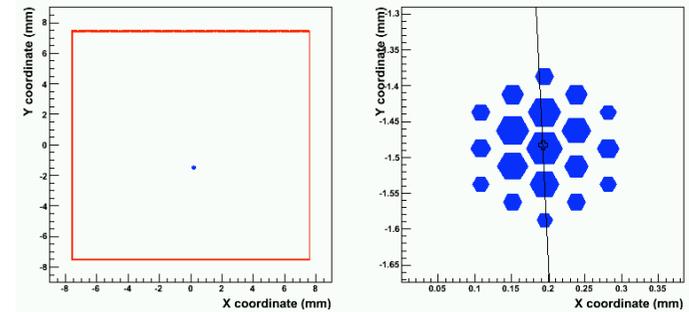
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IMAGE OF THE GEM FOIL
(30 μm HOLES AT 50 μm PITCH):



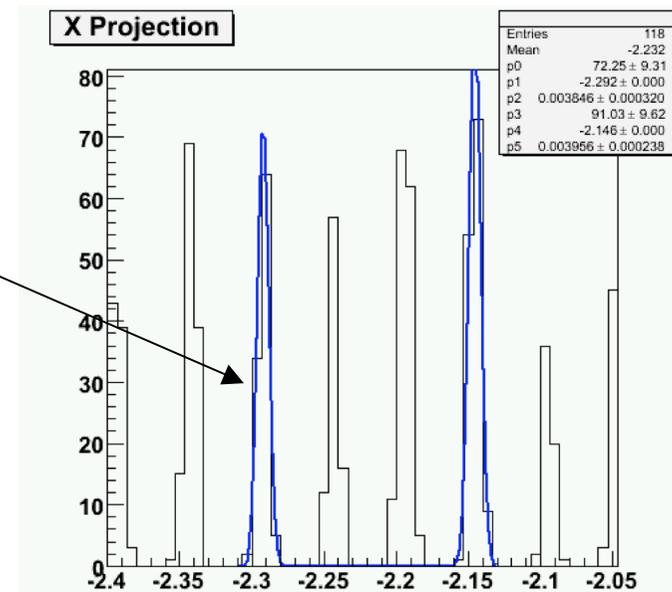
4 μm rms

R. Bellazzini et al, Nucl. Instr. And Meth. A581 (2007) 246



Event Number: 20
 Number of Clusters: 1
 Cluster Size (largest): 19
 Pulse Height: 1079.6
 Signal to Noise: 75.0
 Baricenter: 0.19 -1.48
 Conversion Point: 0.20 -1.53
 Second Mom Max: 0.0023
 Second Mom Min: 0.0022
 Shape (ratio of moments): 1.03
 Third Mom Max: 1.1e-05
 Phi (iteration 1): 1.6195
 Phi (iteration 2): 1.6515

⊕ Reconstructed Baricenter
 ⊗ Reconstructed Impact Pt.

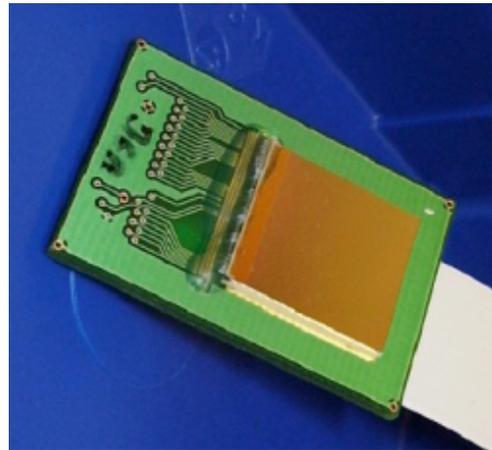


TRIPLE GEM TPC WITH SOLID STATE PIXEL READOUT

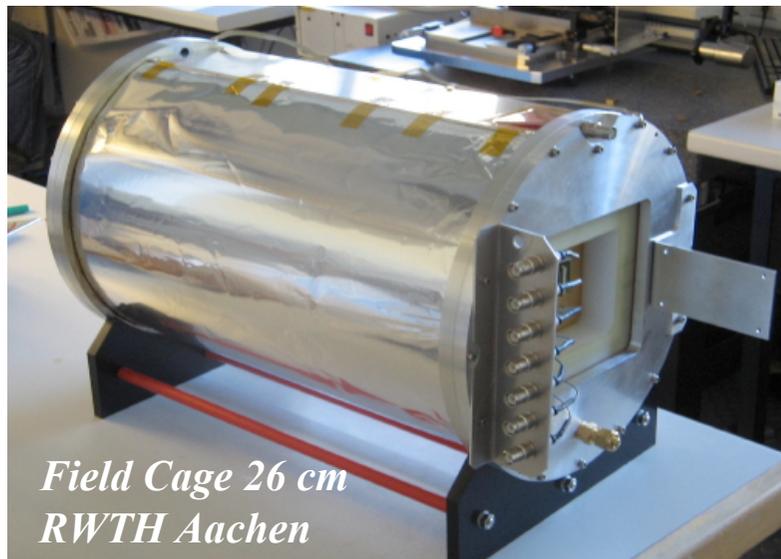
TIMEPIX

256x256 pixels, $55 \times 55 \mu\text{m}^2$

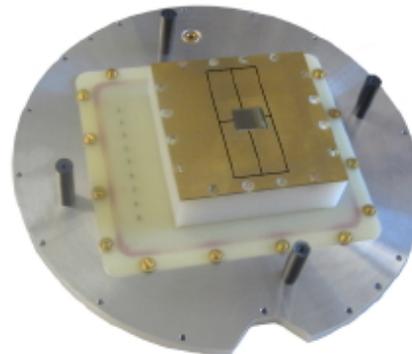
14x14 mm² active area



BONN UNIVERSITY ILC-TPC



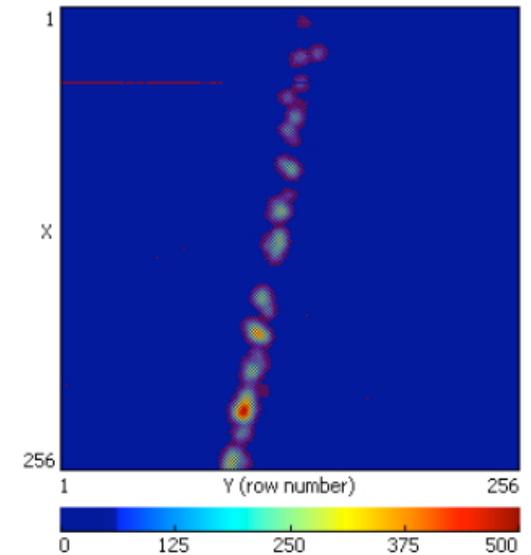
*Field Cage 26 cm
RWTH Aachen*



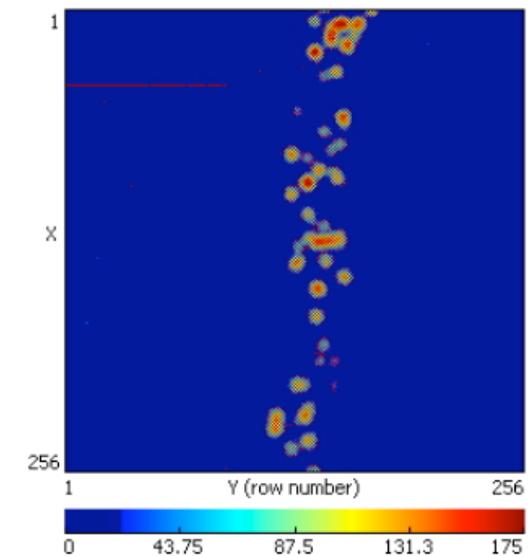
J. Kaminski, RD51 Coll. Meeting (Paris Oct. 13-15, 2008)

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COSMIC TRACK:
SHORT DRIFT

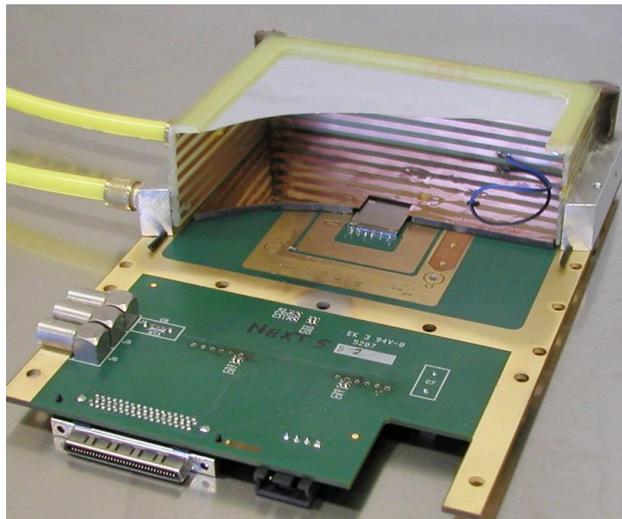
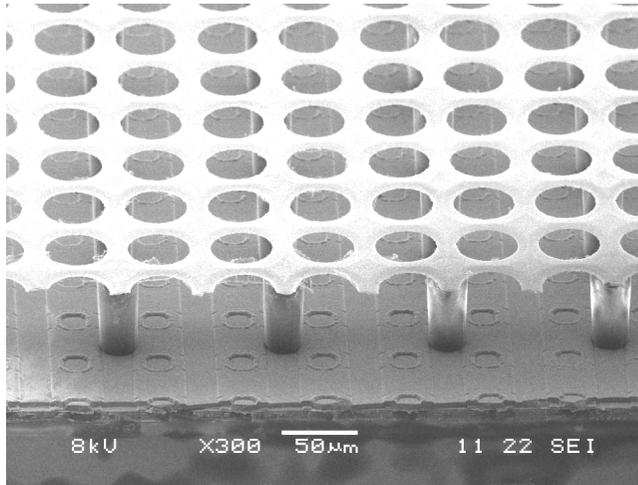


LONG DRIFT:

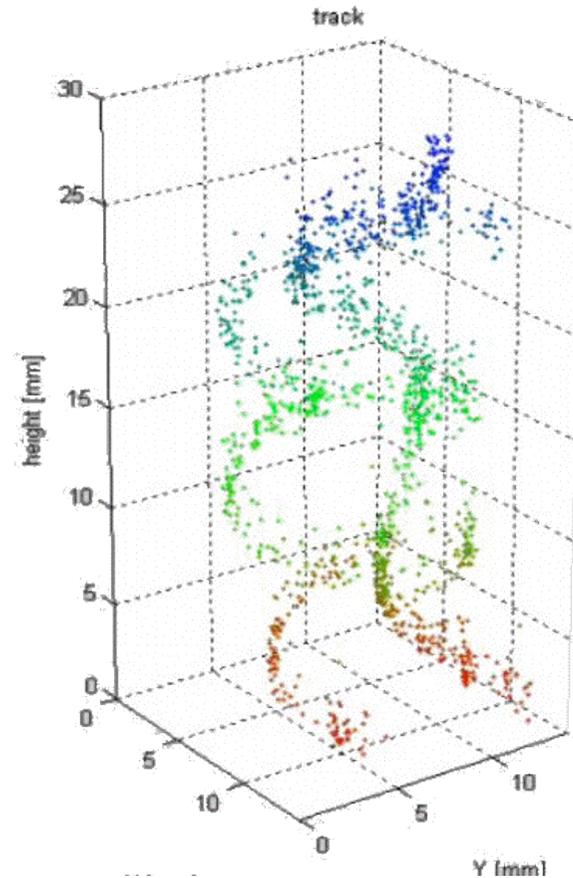


INGRID

Postprocessing of the TIMEPIX chip to build a metal mesh on insulating pillars:



ELECTRON TRACKS FROM ⁹⁰Sr IN MAGNETIC FIELD (0.2 T):



*H. Van der Graaf,
IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, October 2008)*

*I. Timmermans, Int. Conf. on Technology and
Instrumentation in Particle Physics (TIPP 2009)*

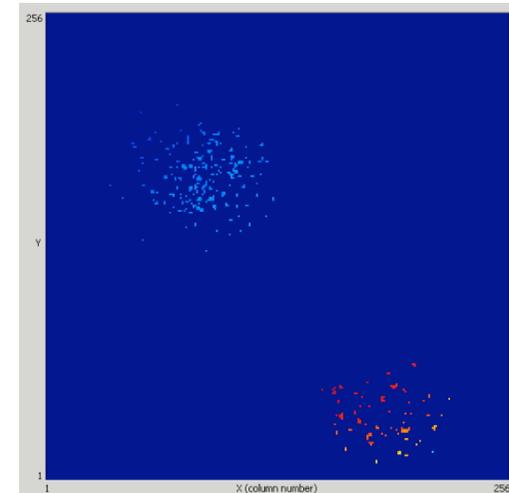
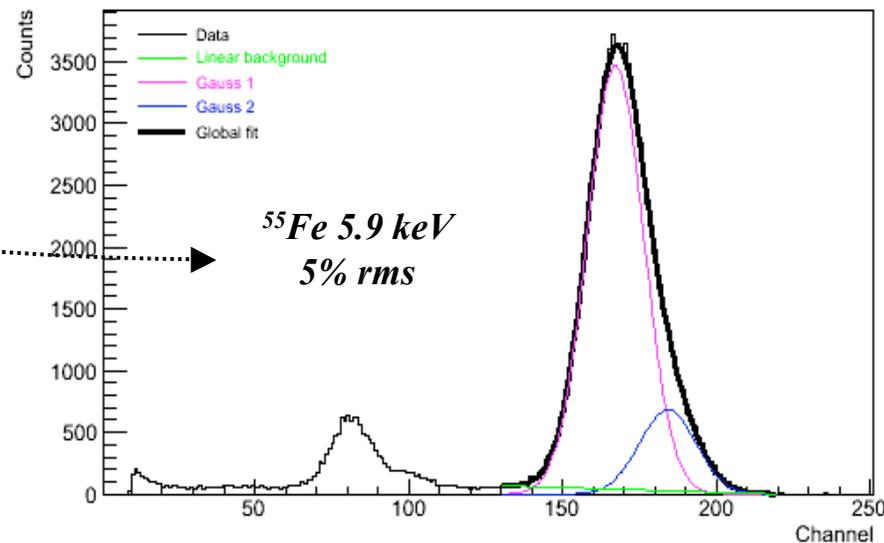
VERY GOOD ENERGY RESOLUTION

Due to low pixel capacitance and noise, the device can detect individual electrons released in the gas by an X-ray source. The pixel count provides the best energy resolution (close to the statistical limit):

$$\left(\frac{\sigma_E}{E}\right)^2 = \frac{F}{N} \quad \text{F: Fano factor}$$

For 5.9 keV in Argon- $i\text{C}_4\text{H}_{10}$
 $N \approx 220$, $F \sim 0.21$

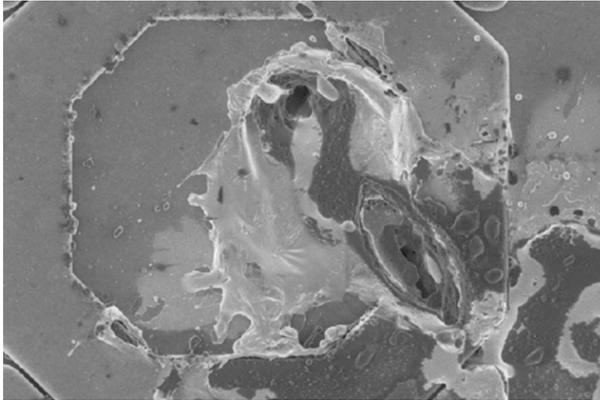
$$\frac{\sigma_E}{E} \approx 3.1\%$$

 ^{55}Fe X-RAYS CONVERSIONS IN ARGON

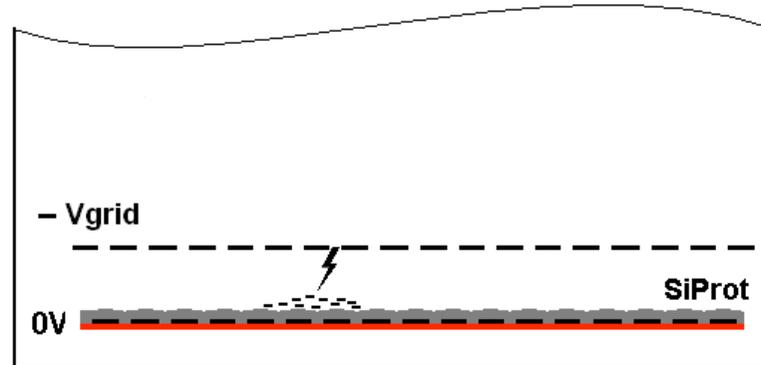
P. Colas, IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, Oct. 2008)

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SPARK DAMAGES
GRIDPIX PIXEL AFTER A DISCHARGE:

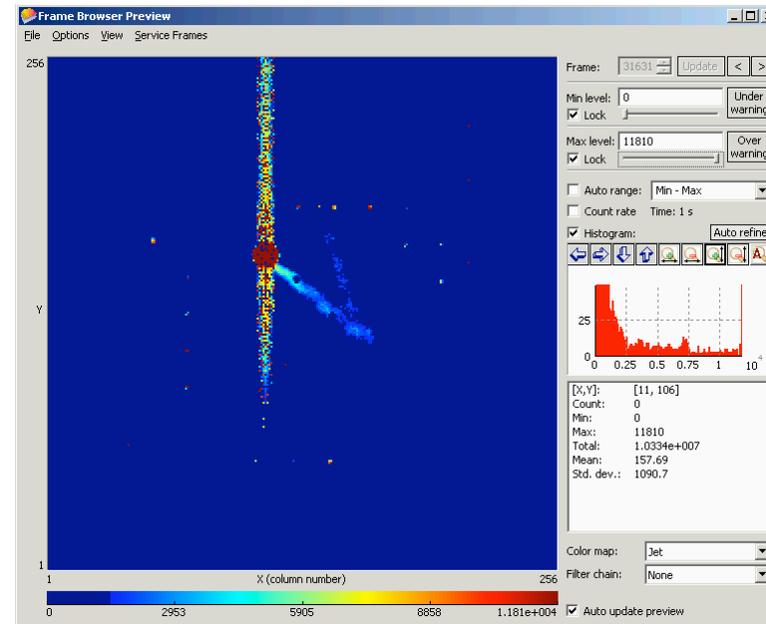


SPARK PROTECTION WITH
AMORPHOUS SILICON DEPOSIT (SiProt)

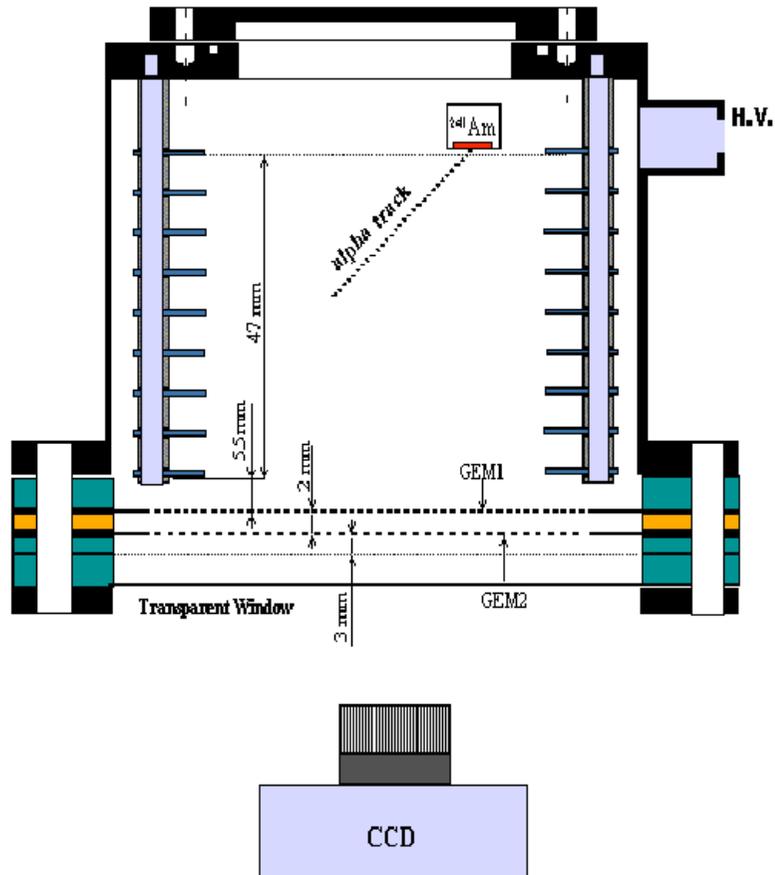


ALPHA PARTICLES WITH DISCHARGE QUENCHING:

*M. Franzen,
RD51 Coll. Meeting (Paris Oct. 13-15, 2008)*

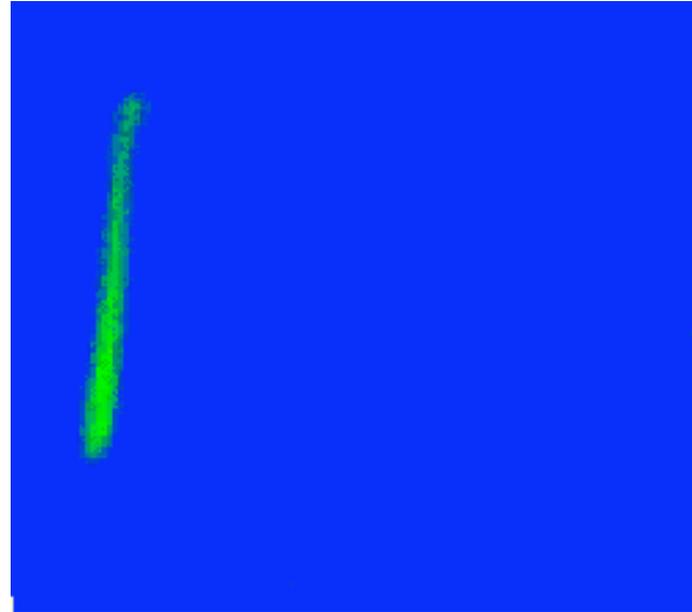


RECORDING OF LIGHT EMISSION IN GEM AVALANCHES

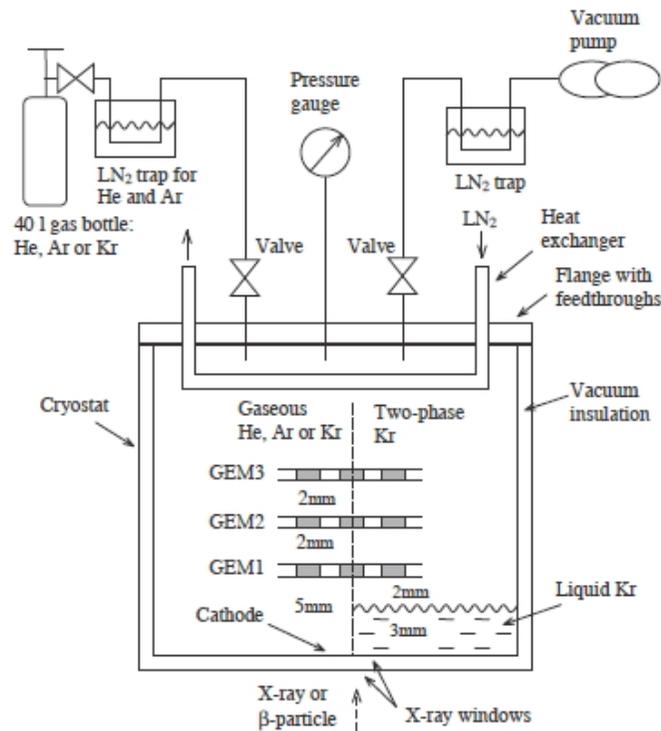


*F.A.F. Fraga et al,
Nucl. Instr. and Meth. A478 (2002) 357*

5 MeV α PARTICLES:

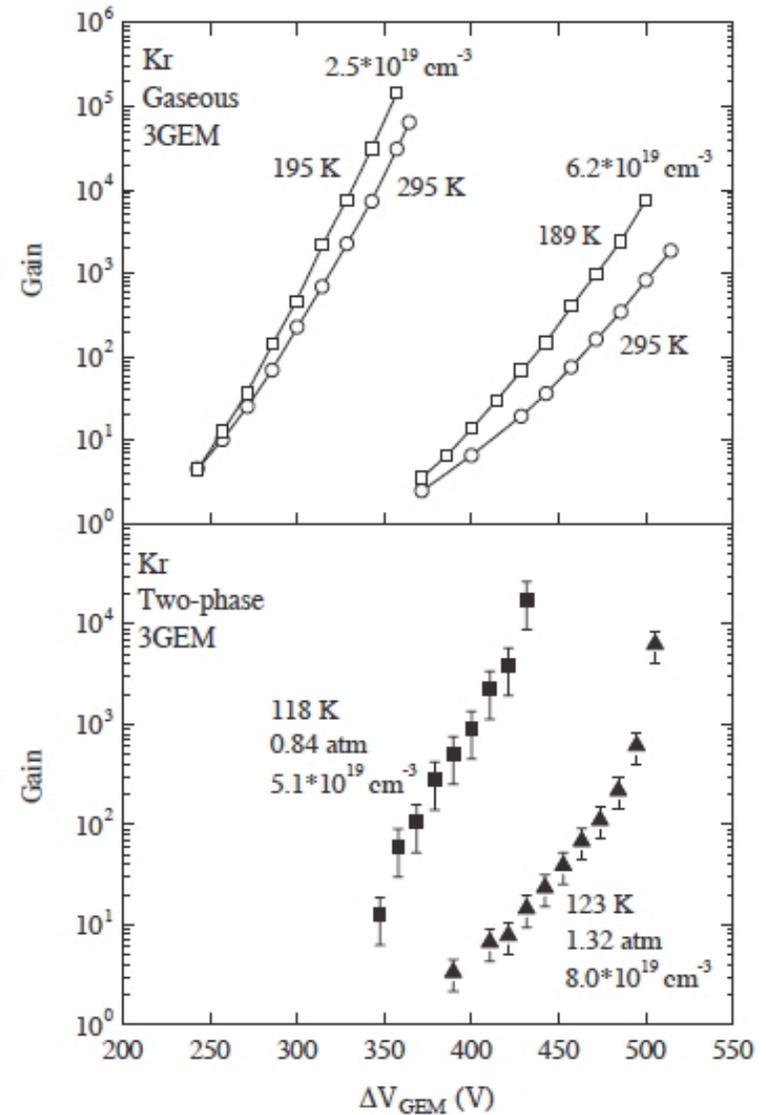


IONIZATION ELECTRONS EXTRACTED FROM LIQUID NOBLE GAS INTO A GEM AMPLIFIER

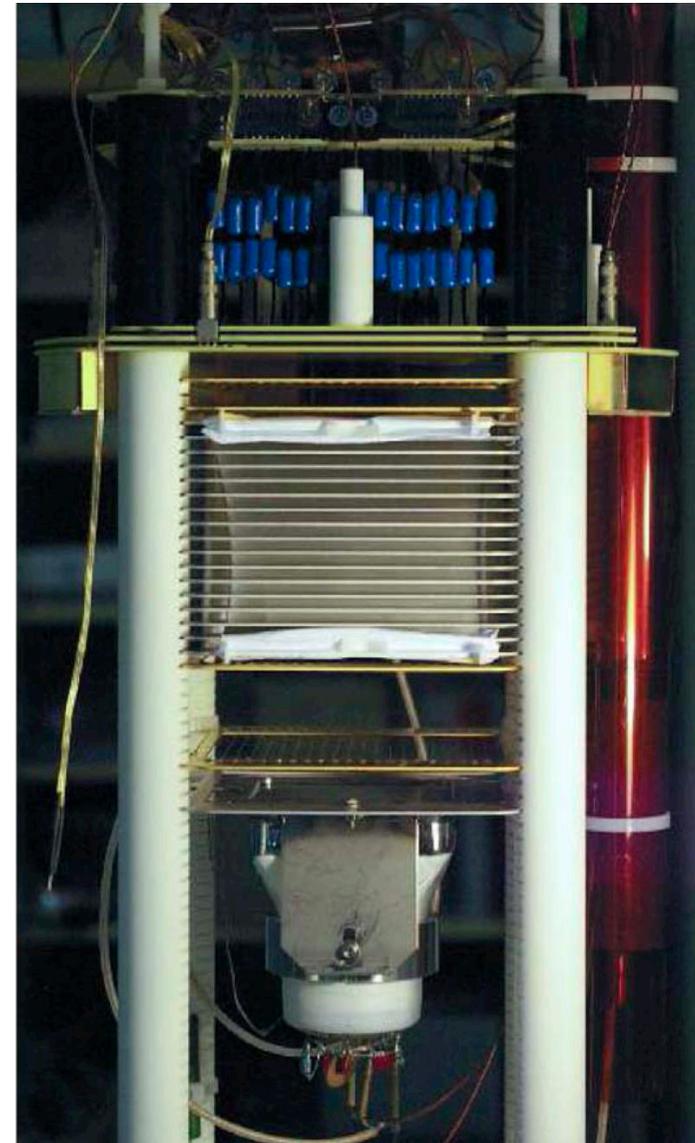
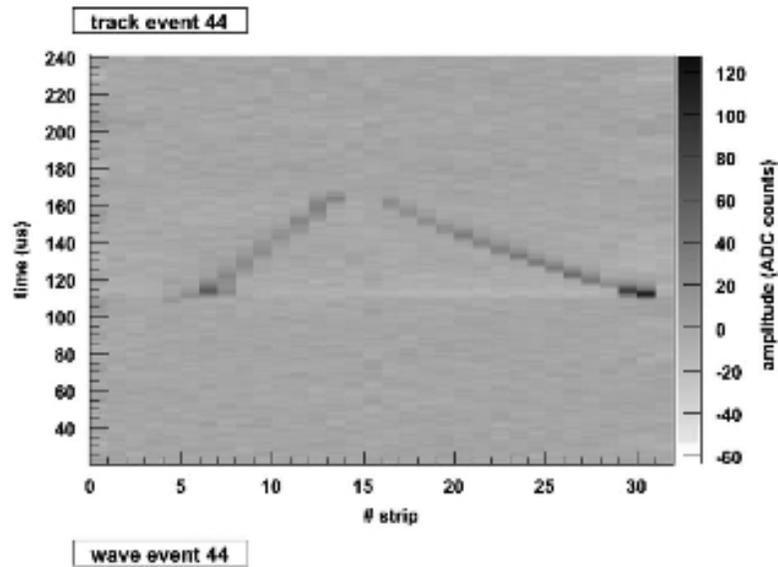
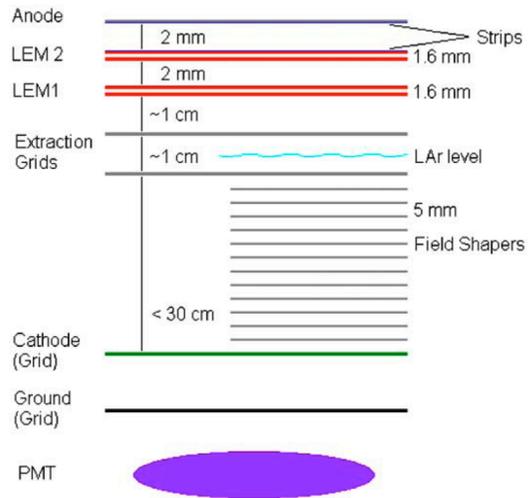


A. Bondar et al, Nucl. Instr. And Meth. A524(2004)130

GAIN: GAS AND TWO-PHASE



DOUBLE LEM OVER LIQUID ARGON TPC



A. Badertscher et al, Nucl. Instr. and Meth. In press (2009)