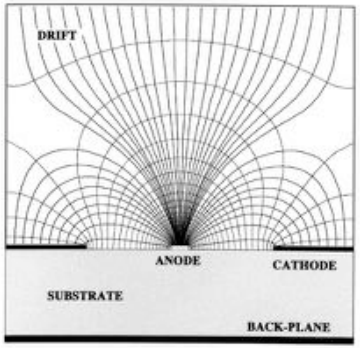
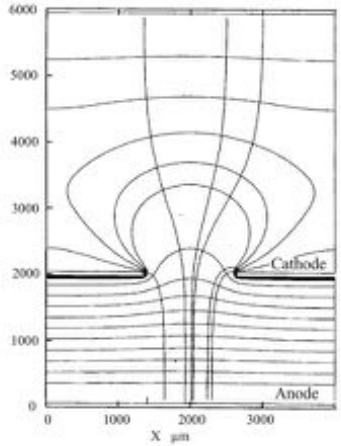
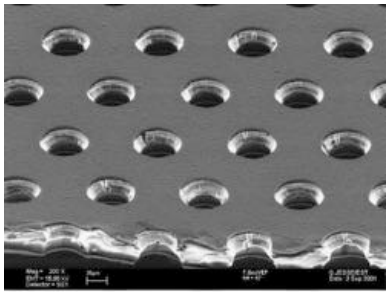
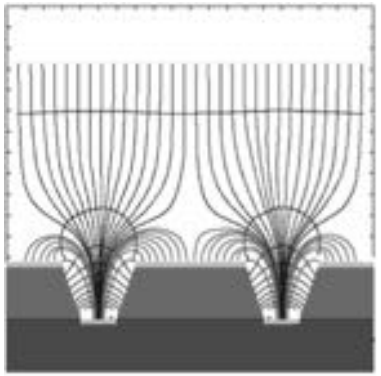
Micro-Pattern Gaseous Detectors

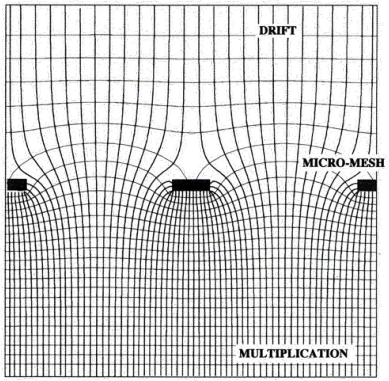
Fabio Sauli
TERA Foundation and CERN

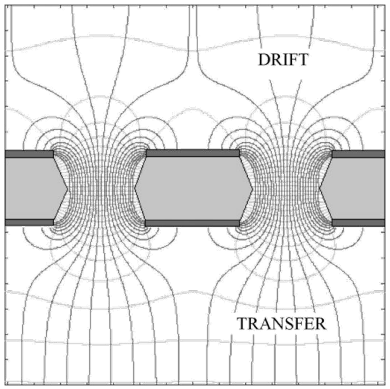


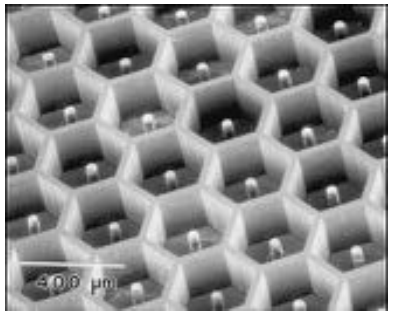








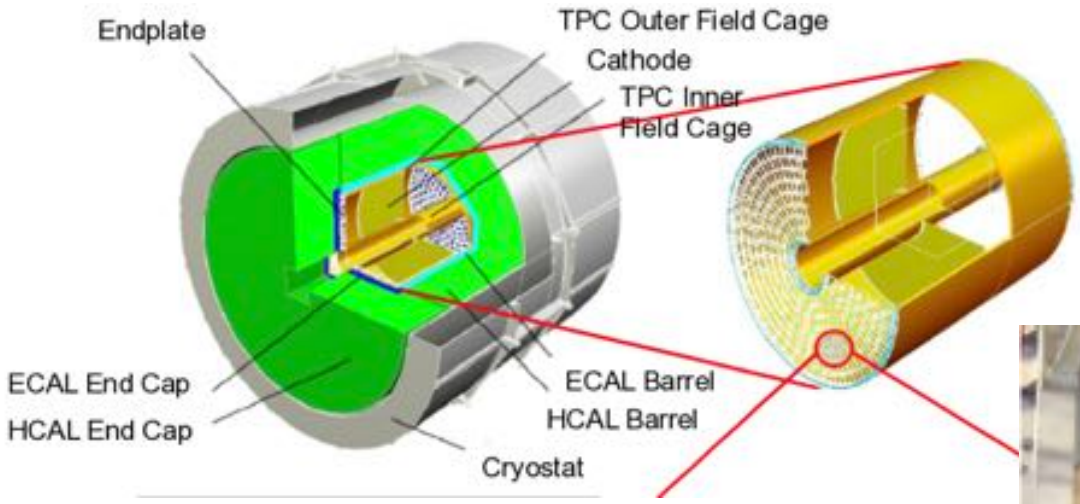




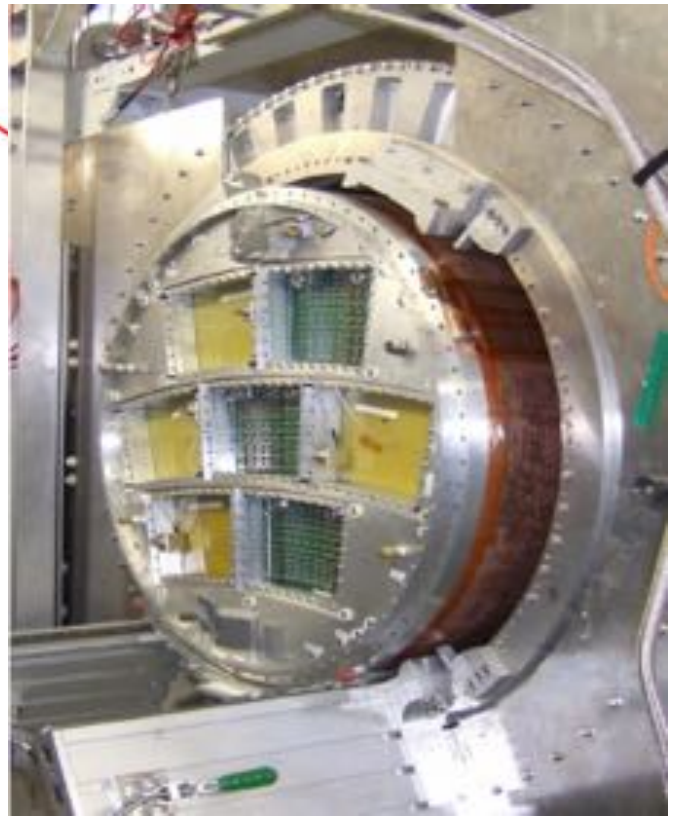
Bethe Forum on Particle Detectors
Bonn, March 31-April 11, 2014

PART 2

MPGD READOUT OF TIME PROJECTION CHAMBERS

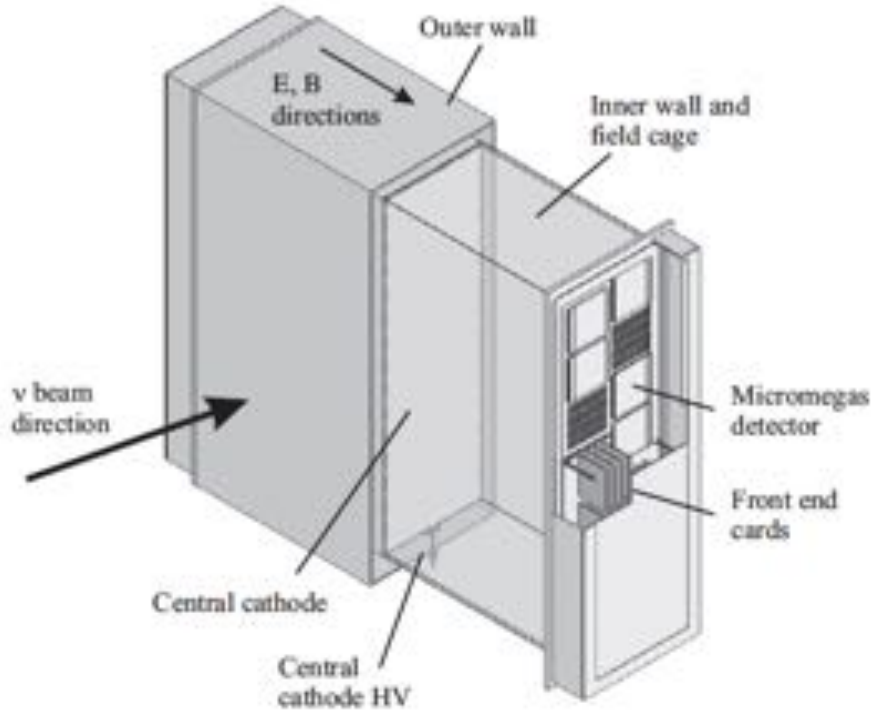


GENERAL PURPOSE END-CAP
FOR PROTOTYPE ASSEMBLY AND TEST

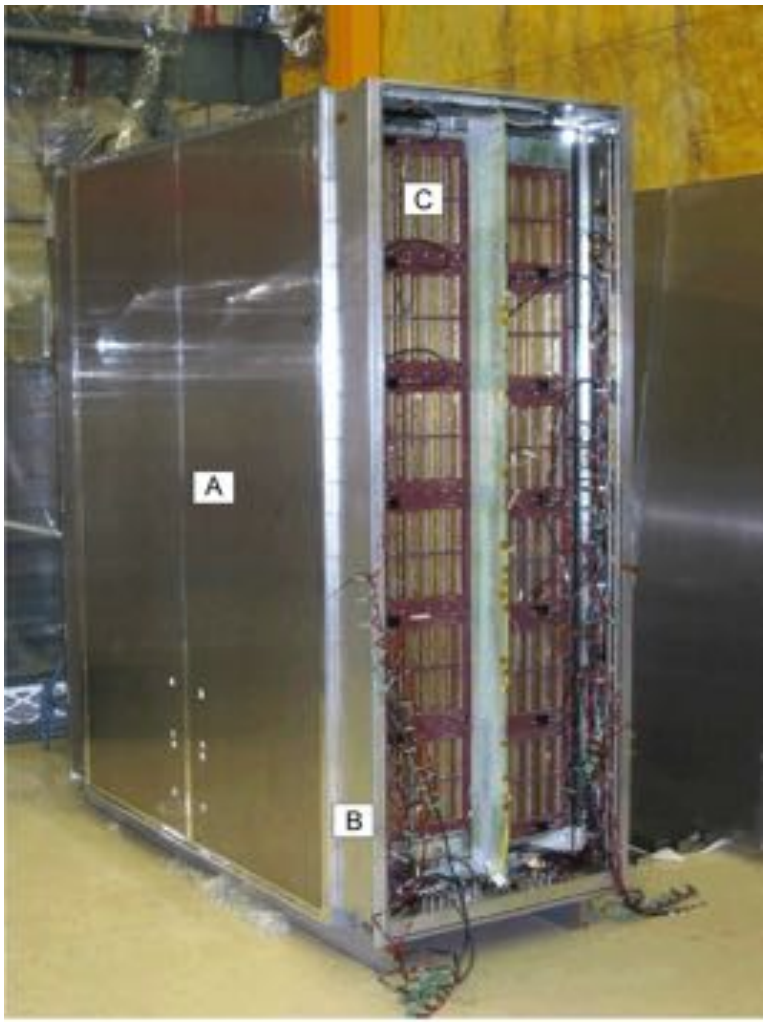


72 MICROMEGAS MODULES (35x36 cm^2)

READOUT: 36x48 PADS of 9.7x6.9 mm^2

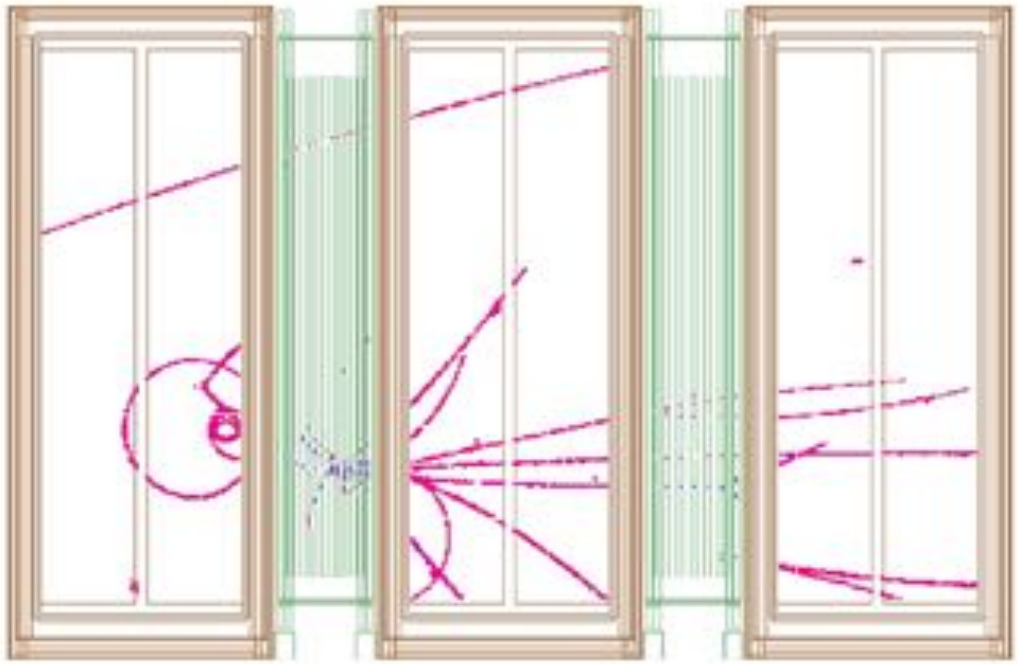


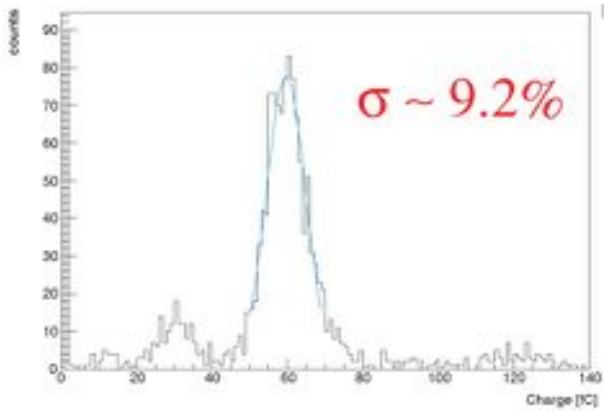
A. Delbart, Nucl. Instr. and Meth. A623(2010)105

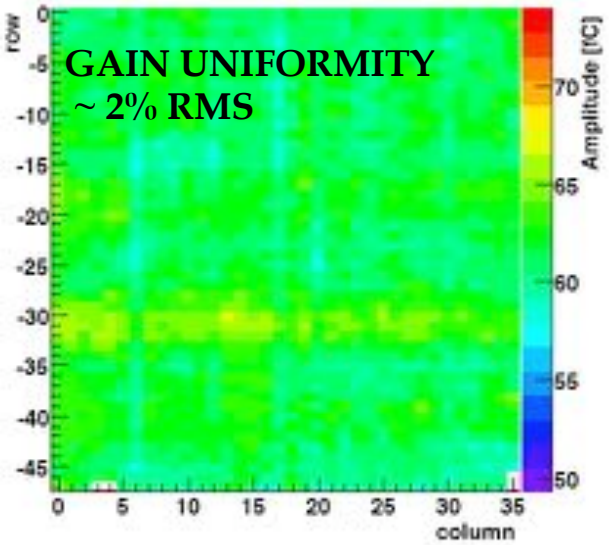


N. Abragall et al, Nucl. Instr. and Meth. A637(2011)25

ENERGY RESOLUTION ON ^{55}Fe:

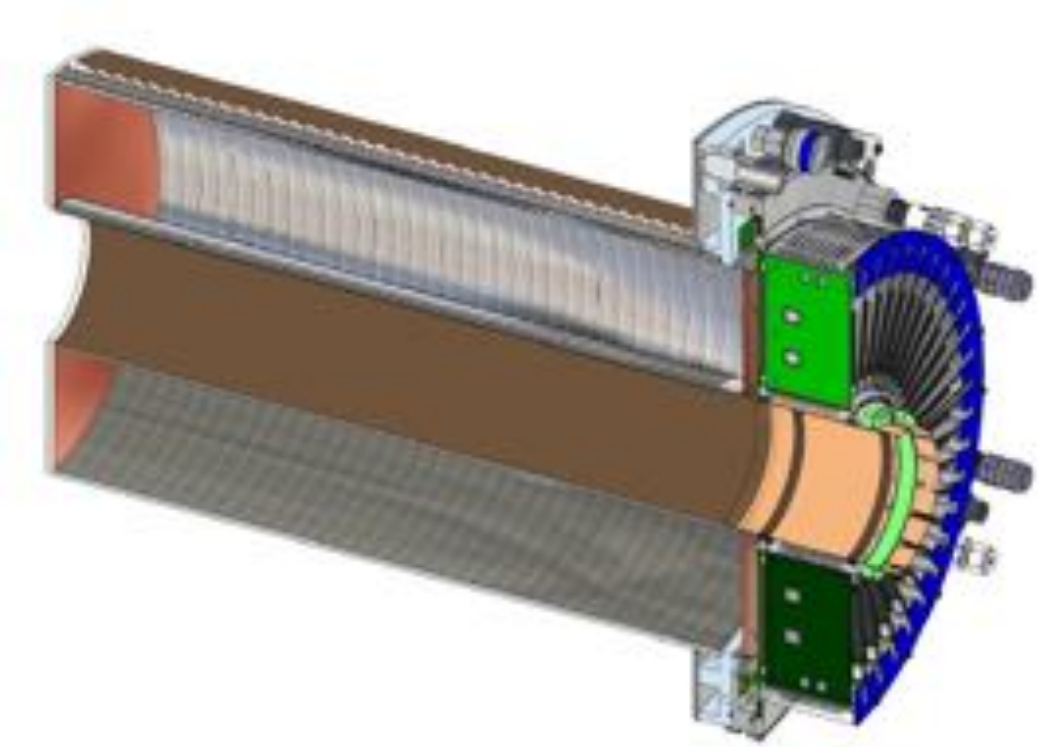






N. Abragall et al, Nucl. Instr. and Meth. A637(2011)25

FOPI GEM-TPC: PROTOTYPE STUDY
FOR THE ALICE TPC UPGRADE

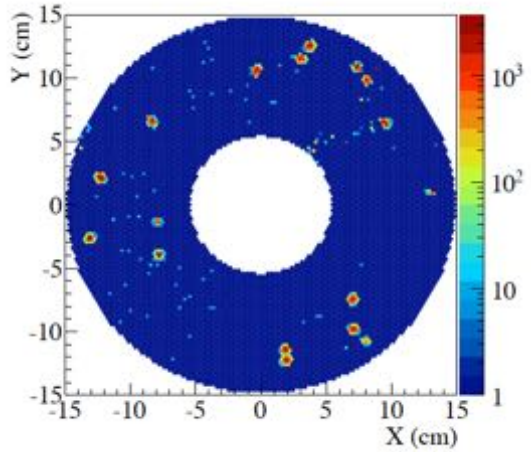


B. Ketzer, Nucl. Instr. and Meth, A732(2013)237

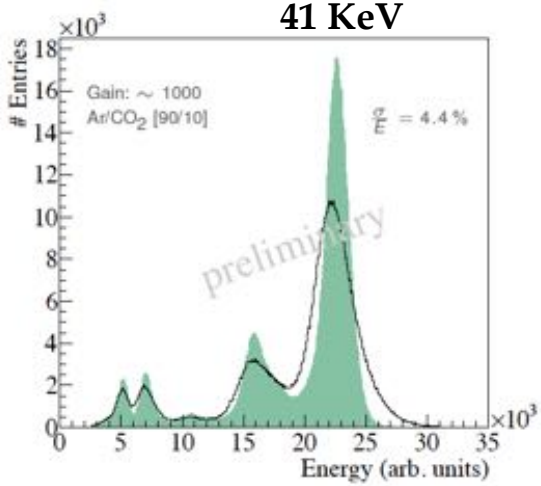
GEM TPC READOUT:
10,254 HEXAGONAL PADS, 3 mm Ø

FOPI GEM-TPC: ENERGY RESOLUTION

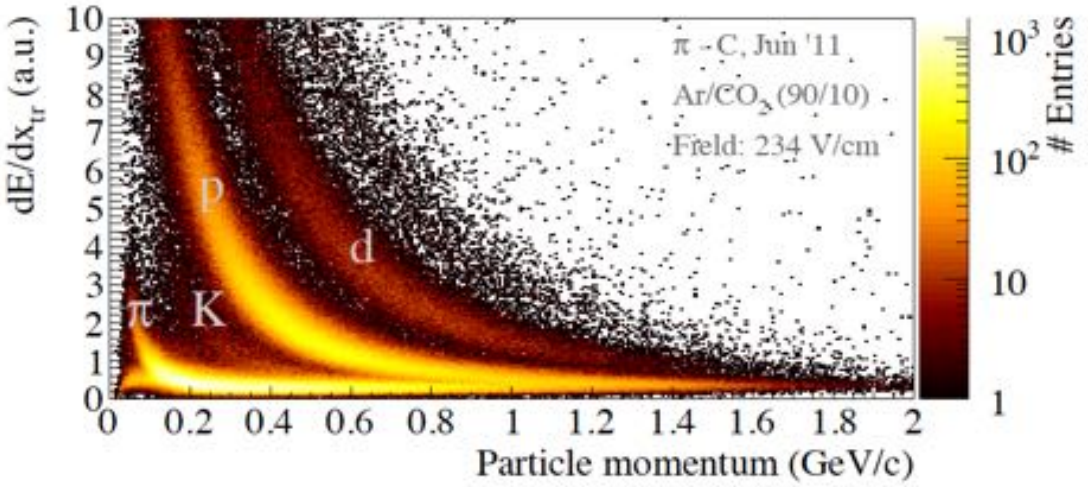
CALIBRATION: ^{83m}Kr SOURCE IN THE GAS VOLUME



41 KeV



dE/dx RESOLUTION IN 0.6 T:

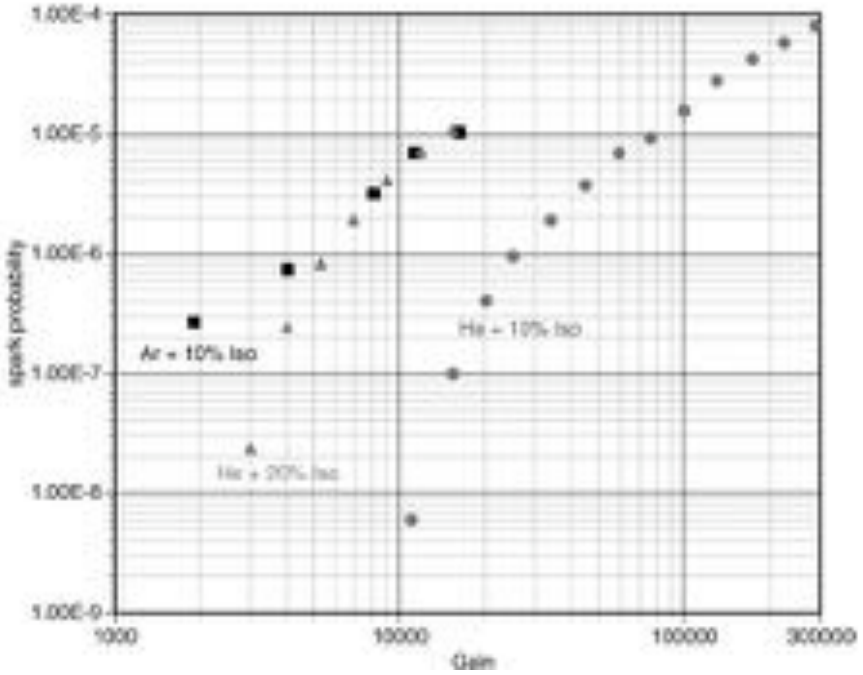


F. Böhmer et al, Nucl. Instr. and Meth. A737(2014)214

MPGDs: HAVE THEY SOLVED THE MWPC PROBLEMS?

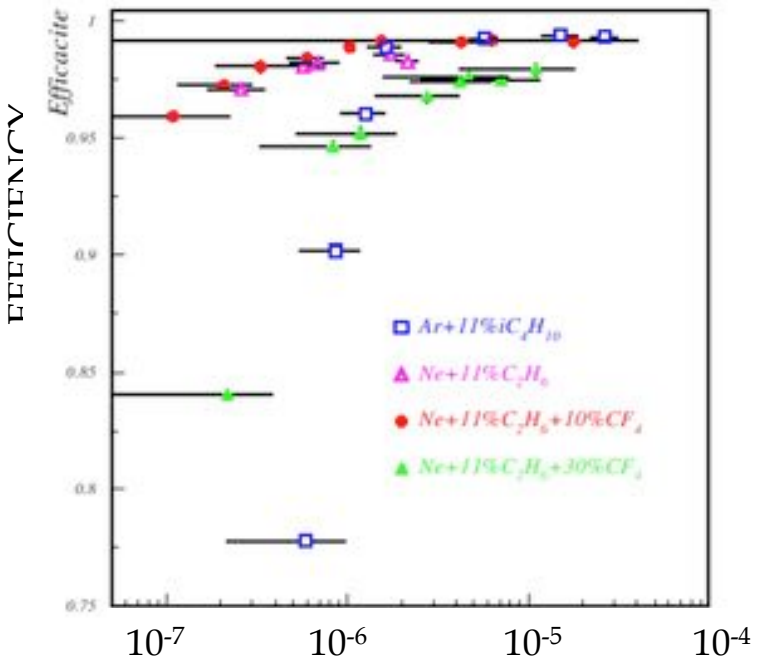
- DISCHARGES AND SPARKING
- GAIN REDUCTION AT HIGH RATES
- RADIATION DAMAGE (AGING)
- POSITIVE IONS' BACKFLOW IN TPCs

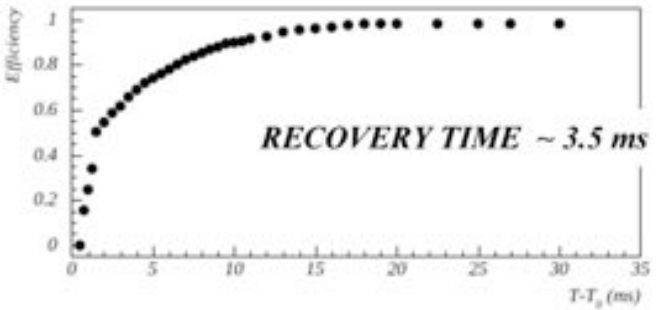
SPARK PROBABILITY IN HADRON BEAM



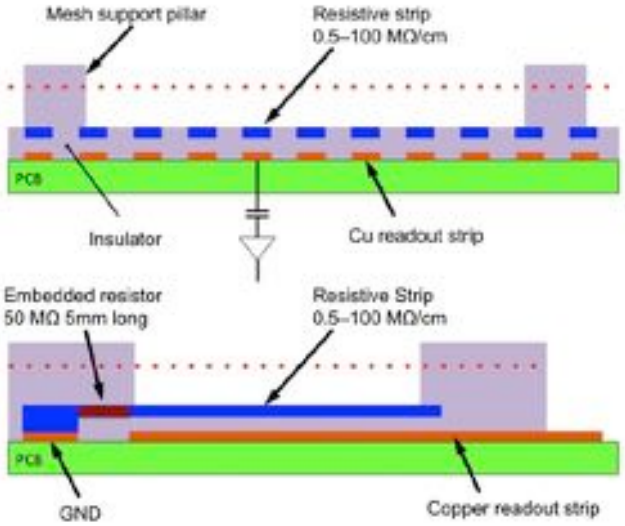
For a gain of 5.10^3 , 10^6 particles s^{-1}:
~ one discharge per second

A. Delbart et al, Nucl. Instr. and Meth. A478(2002)205
A. Bay et al, Nucl. Instr. and Meth. A488(2002)162

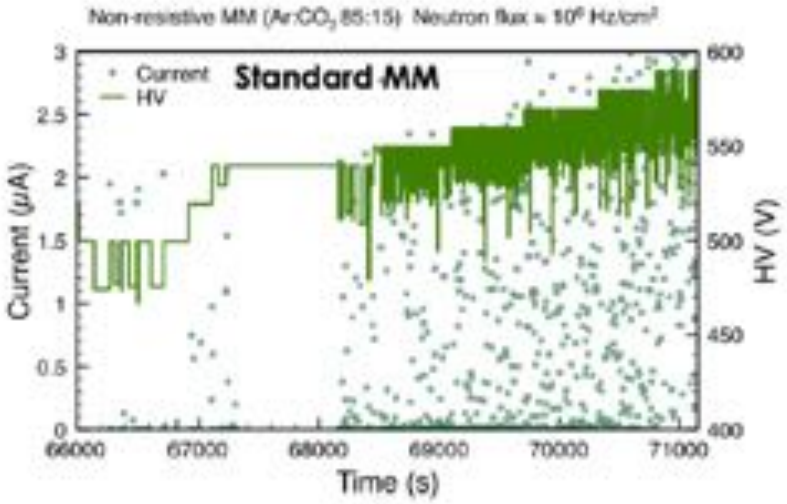




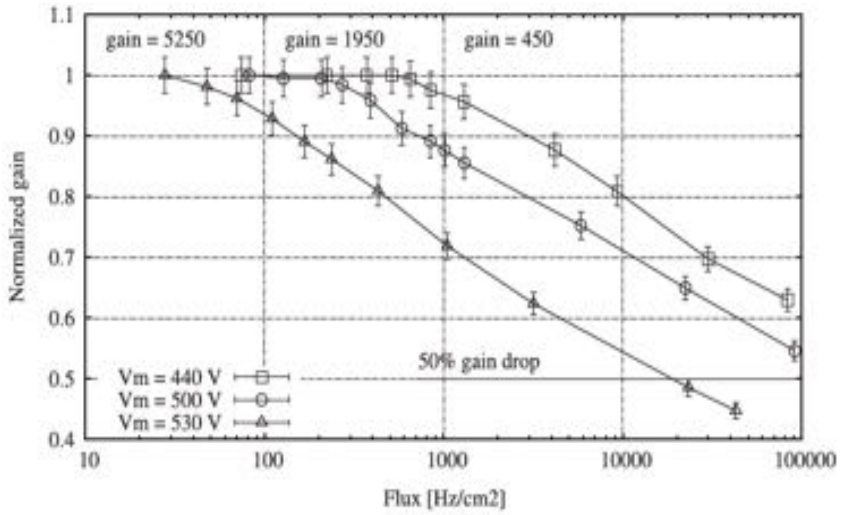
D. Neyret, MPGD2009 (Crete, June 12-17, 2009)

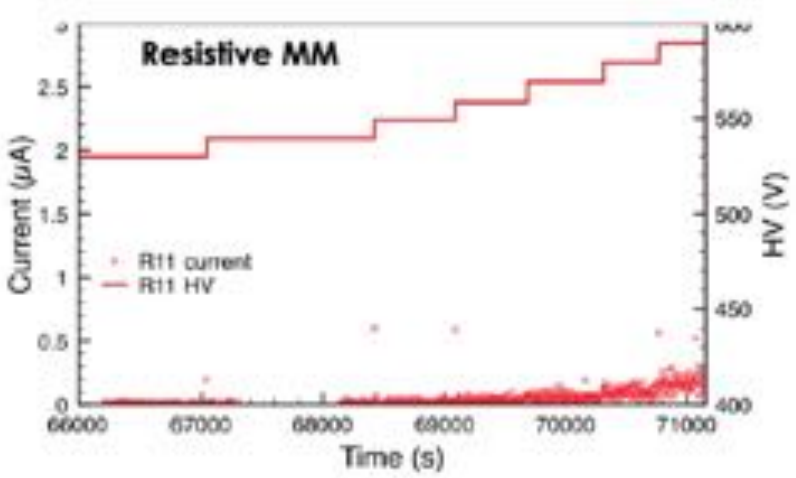


SPARK RATES IN NEUTRON BEAM EXPOSURE:



RATE CAPABILITY:



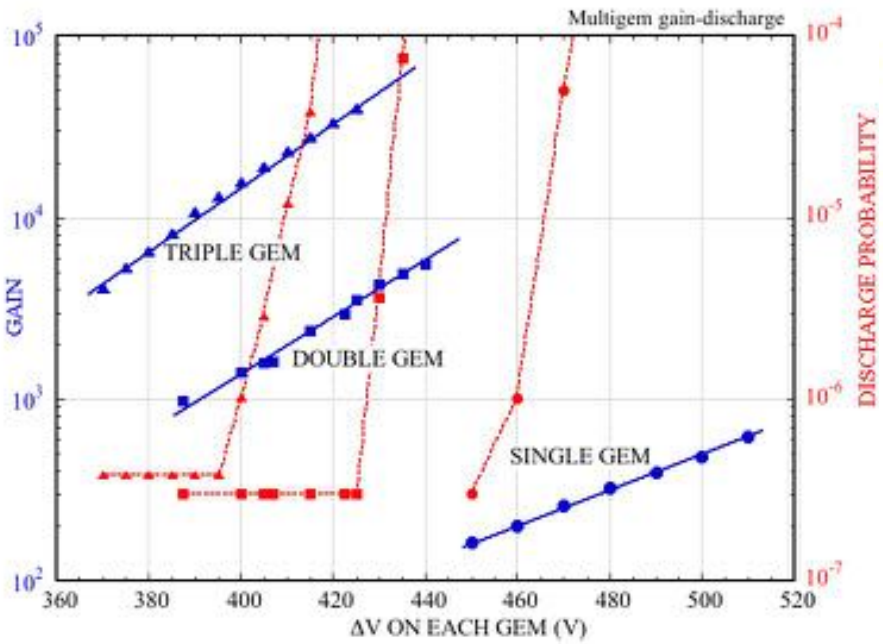


J. Galán et al, Nucl. Instr. and Meth. A732(2013)229

T. Alexopolous et al, Nucl. Instr. and Meth. A640(2011)110

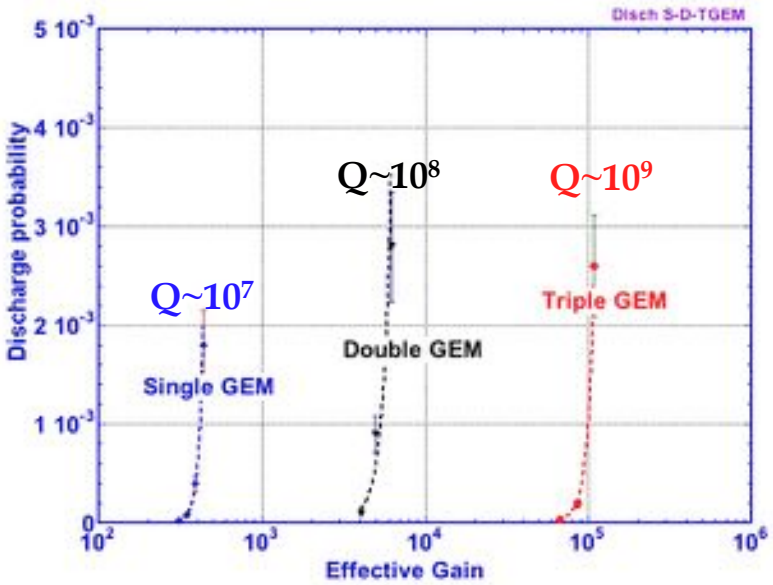
GAIN VS VOLTAGE – 5.9 keV

DISCHARGE RATE ON ~ 5 MeV α



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

DISCHARGE PROBABILITY VS GAIN:

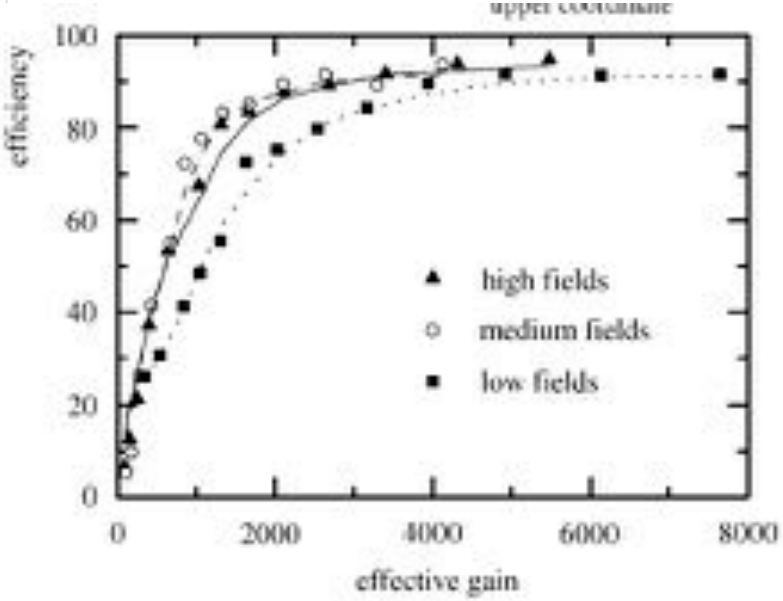


WHAT ABOUT THE RAETHER LIMIT?

IN MULTI-GEMS, THE CHARGE SPREADS OVER MANY INDEPENDENT HOLES!

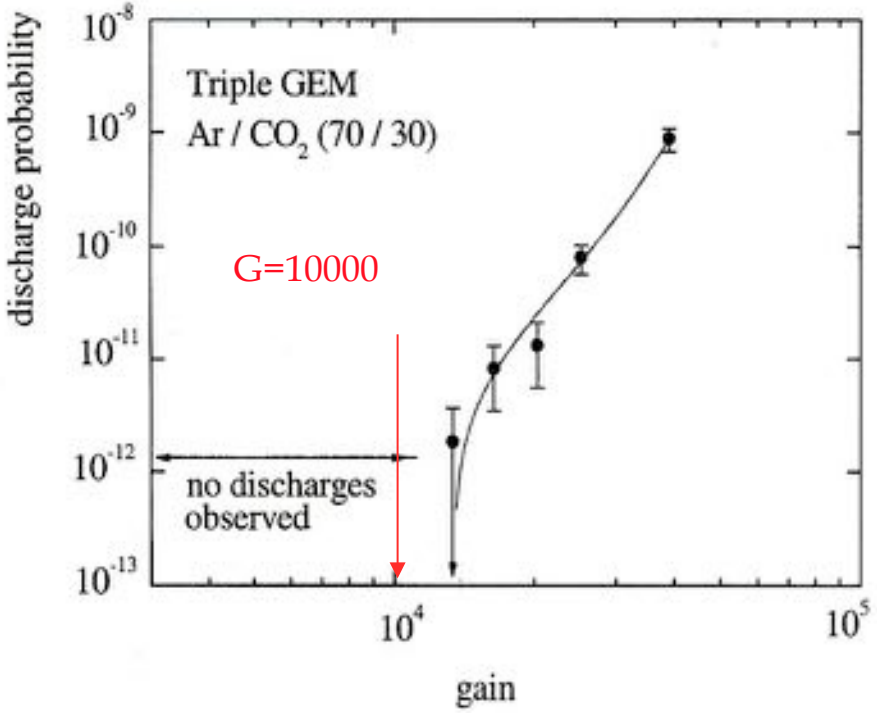
COMPASS TRIPLE GEM DETECTOR

EFFICIENCY VS VOLTAGE

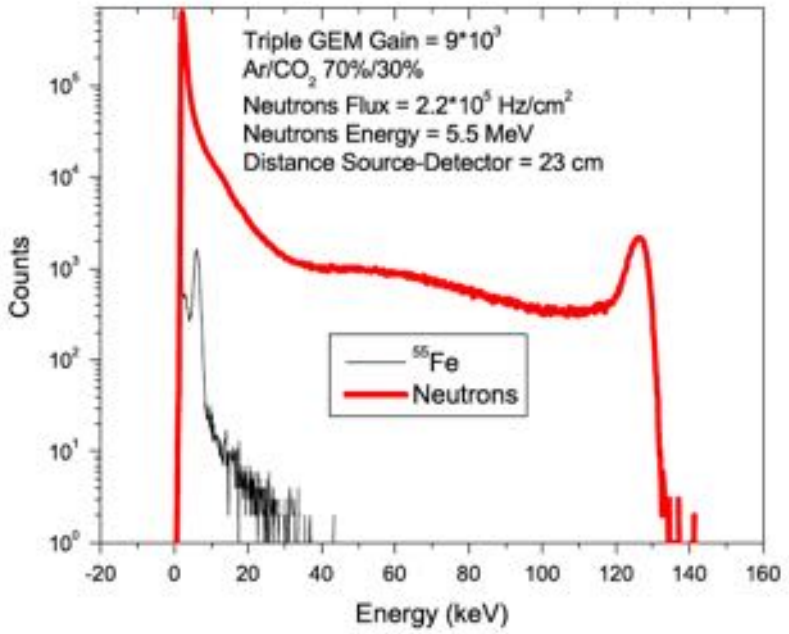


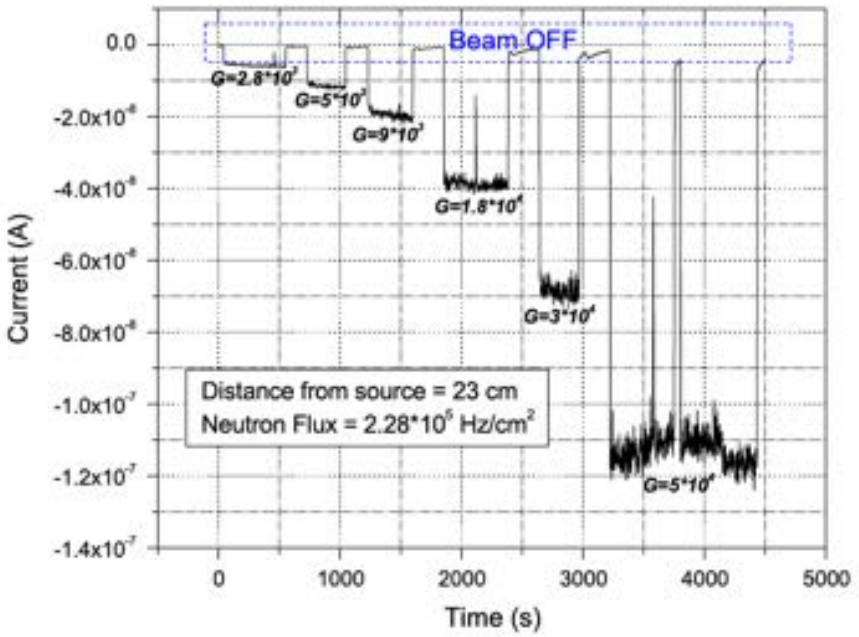
S. Bachmann et al,
Nucl. Instr. and Meth. A470(2001)548

DISCHARGE RATE VS GAIN
No discharges in 12 hrs of operation at gain 10^4



10x10 cm^2 TRIPLE-GEM tested in neutron beam



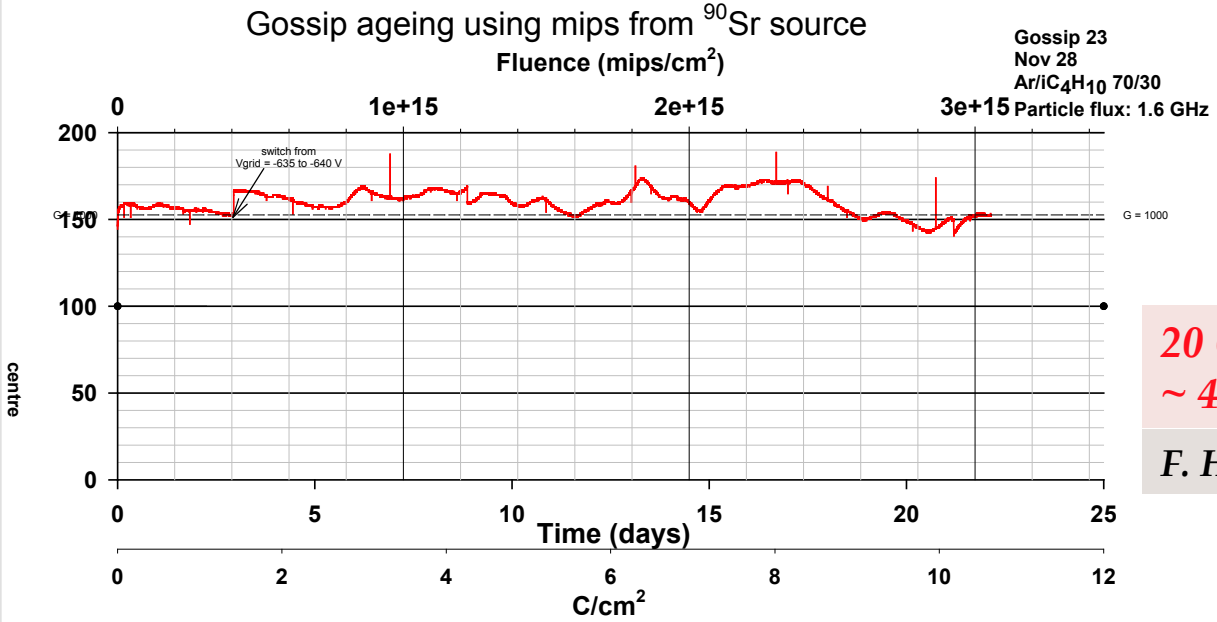


G. Croci et al, Nucl. Instr. and Meth, A71292013)108

Systematic irradiation of small (10x10 cm^2) prototypes:

Irradiation with	Charge Deposit (mC/cm^2)	HL-LHC Equivalent	Results
X-Ray	225	5 HL-LHC years equivalent	No evidence of ageing
Neutron	0.5	10 years HL-LHC years equivalent	No evidence of ageing
Gamma	14.84	10 years HL-LHC years equivalent	No evidence of ageing
Alpha	2.4	5 x 10^8 sparks equivalent	No evidence of ageing

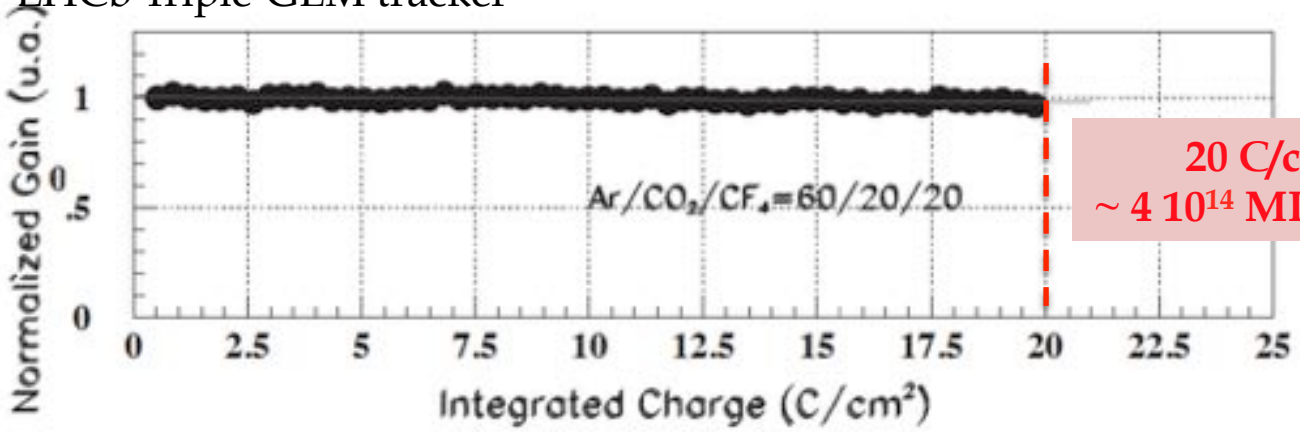
G. Iakovidis, MPGD 2013



20 C cm^{-2}
~ 4 10^{14} MIPS cm^{-2}

F. Hartjes, MPGD 2009

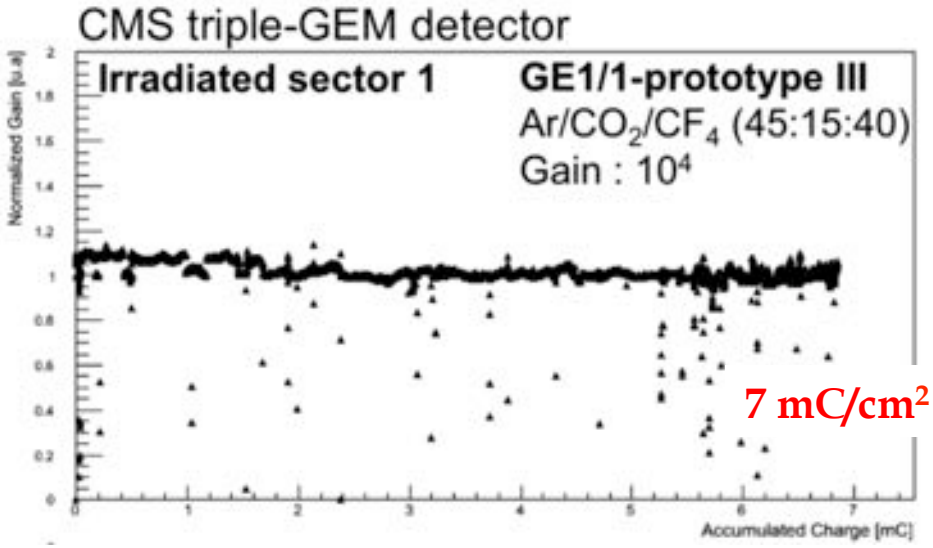
LHCb Triple-GEM tracker



20 C/cm²
~ 4 10¹⁴ MIPS cm⁻²

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

CMS Muon Upgrade Triple-GEM Exposed at the Gamma Irradiation Facility (GIF) at CERN



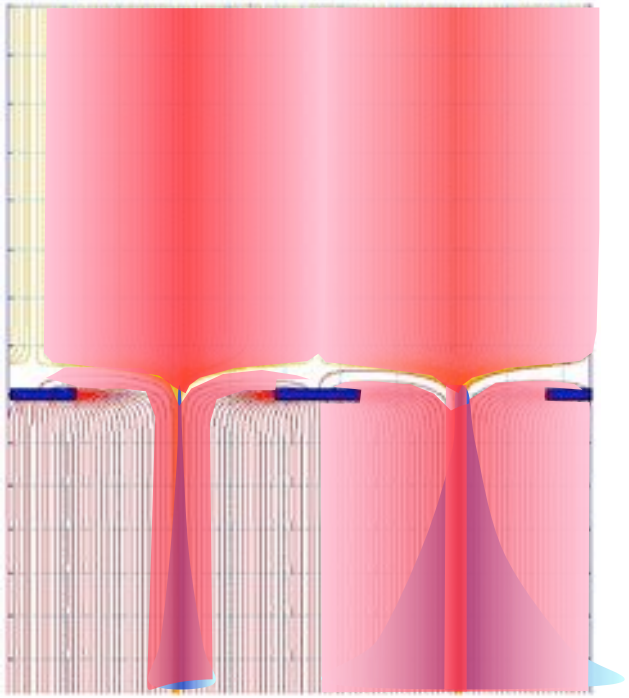
7 mC/cm²

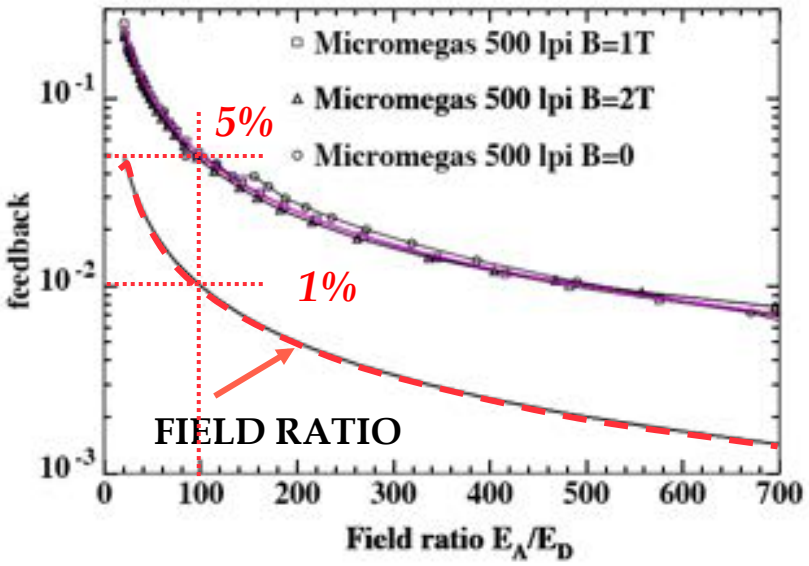
D. Abbaneo et al, JINST 9(2014)C01053

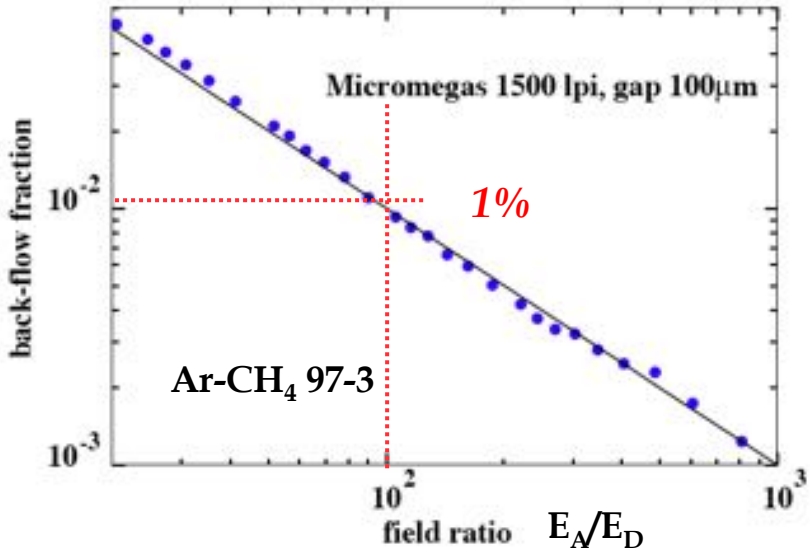
$$IBF = \frac{I_{DRIFT}}{I_{ANODE}}$$ (MWPC-TPC: IBF~30%)

MICROMEGAS:

The ions backflow depends on avalanche spread but cannot be smaller than the field ratio:



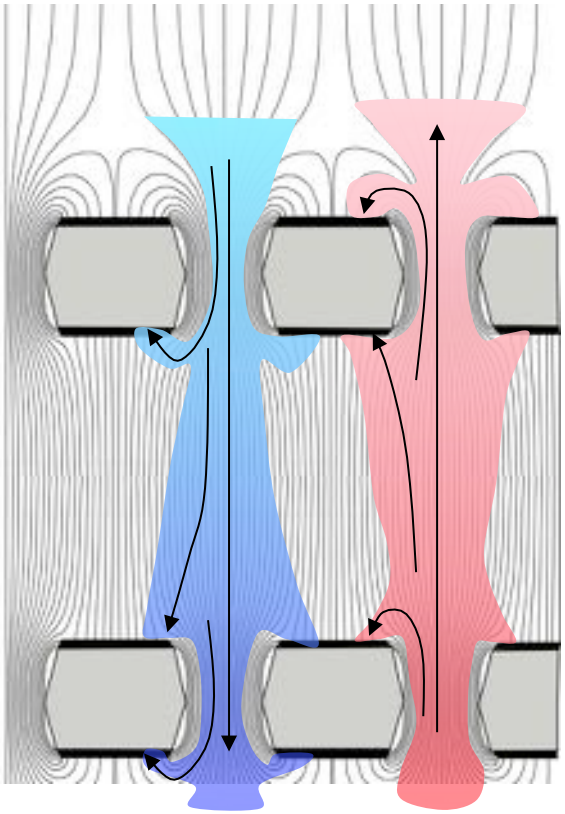




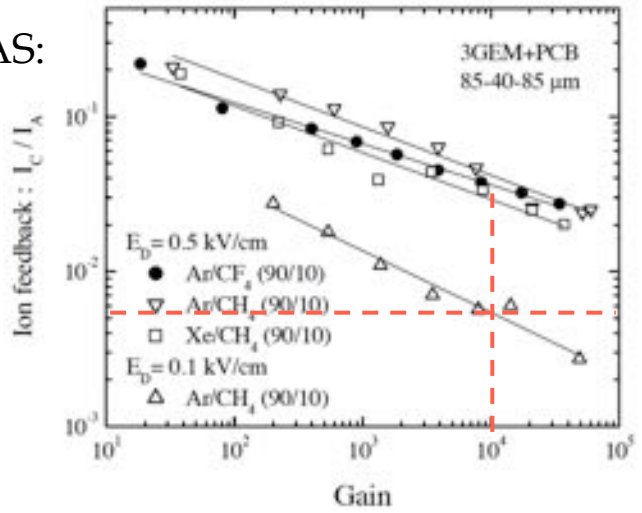
P. Colas et al, Nucl. Instr. and Meth. A535(2004)226

IBF IN MULTIGEM DETECTORS

The fractional ion backflow results from a complex interplay of geometry, fields, diffusion:



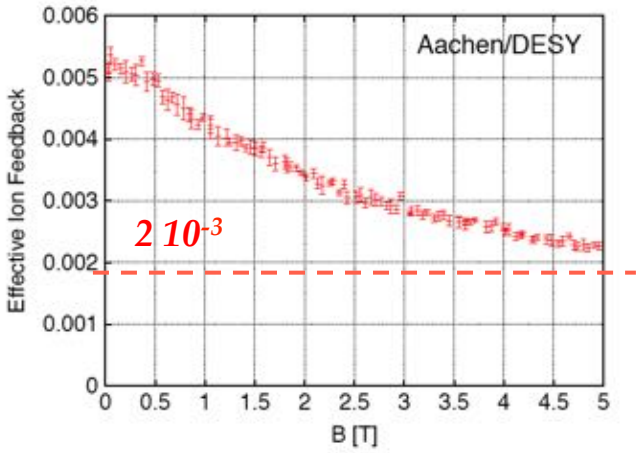
GAS:



5 10^{-3}

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

MAGNETIC FIELD:



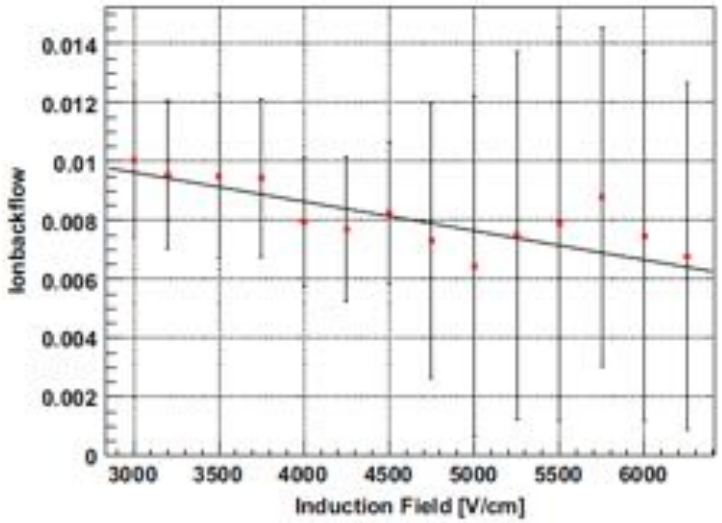
THE WISH:

$$IBF \leq \frac{1}{GAIN} \approx 10^{-4}$$

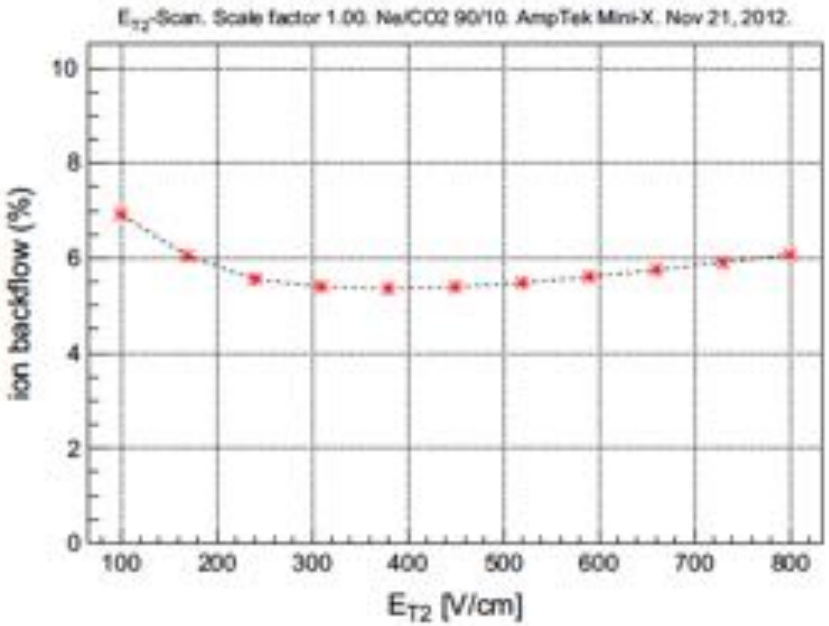
M. Killenberg et al, Nucl. Instr. and Meth. A530(2004)251

GAS DEPENDENCE OF THE IBF

Ar-CO_2 70-30: ~ 0.8%

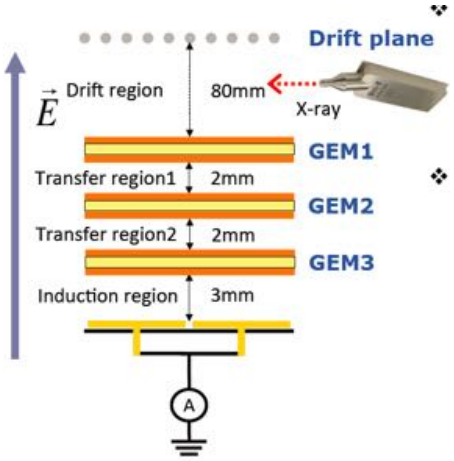


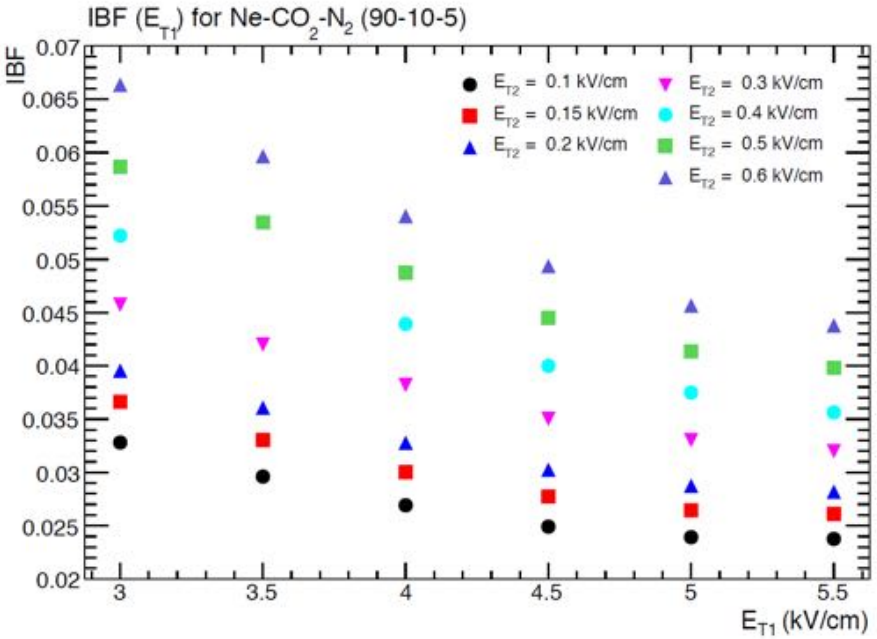
Ne-CO_2 (ALICE): ~ 5%



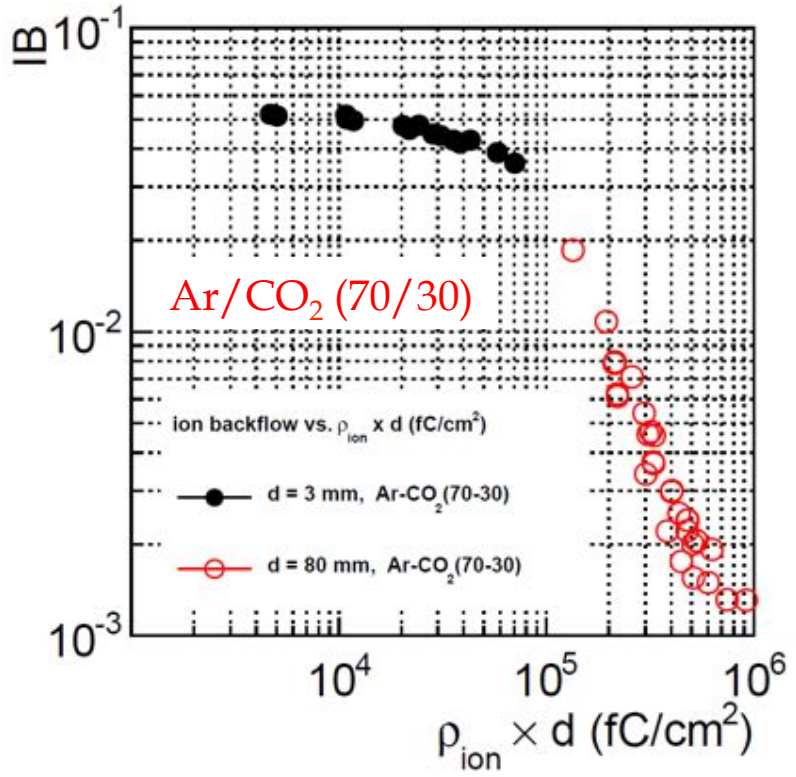
B. Ketzer et al, Nucl. Instr. and Meth. A732(2013)237

MULTIGEM DETECTORS





RATE (CHARGE DENSITY) DEPENDENCE:

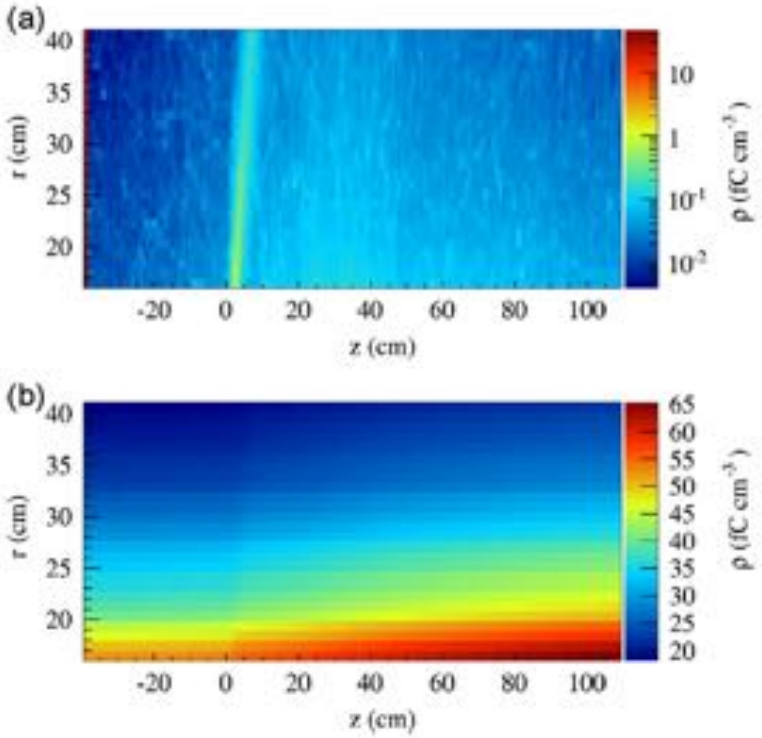


ALICE UPGRADE STUDIES

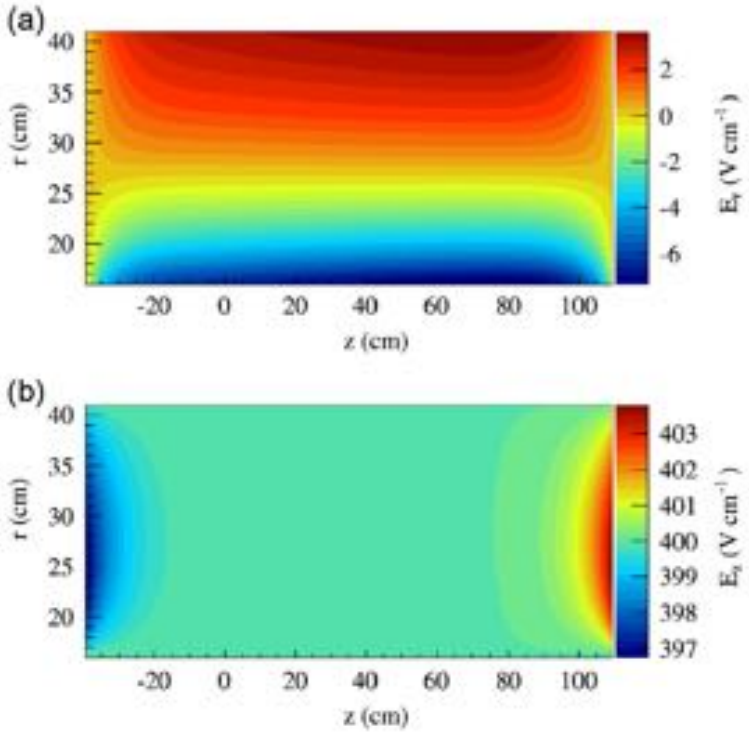
B. Ketzer
INSTR2014 Novosibirsk

SIMULATION STUDIES FOR PANDA
$2\ 10^7$ p-p ANNIHILATIONS
TRIPLE GEM OPERATED IN Ne-CO_2 90-10
GAIN M=2000 IBF $2.5\ 10^{-3}$ ($M^{-1}=0.5\ 10^{-3}$)

SPACE CHARGE DENSITY

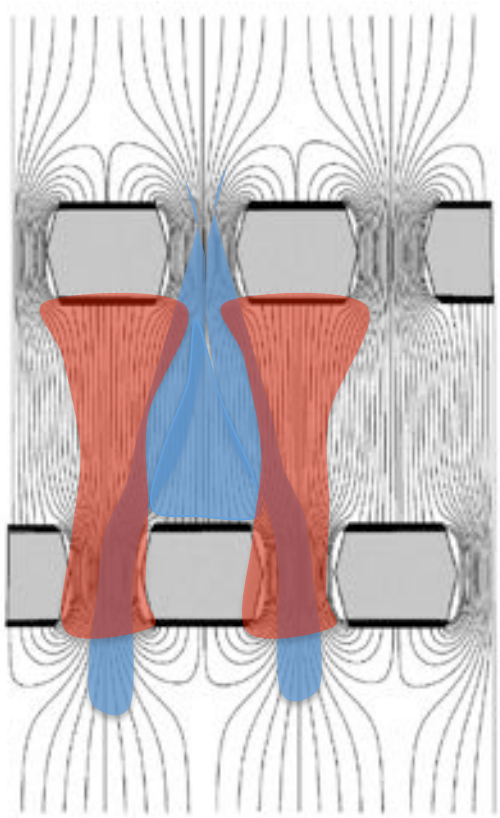


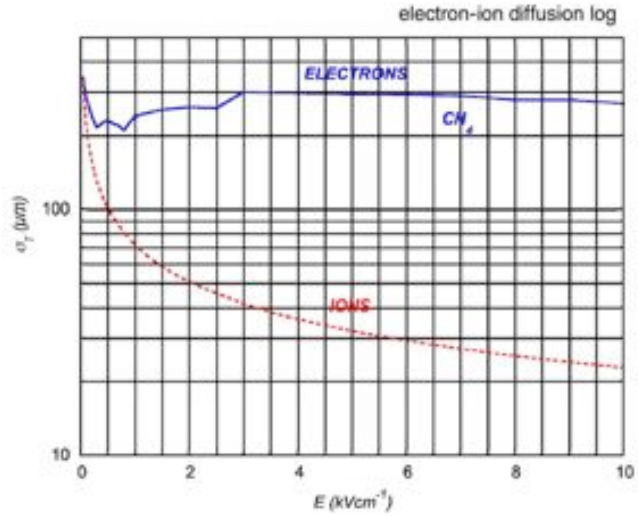
ELECTRIC FIELD DISTORTIONS

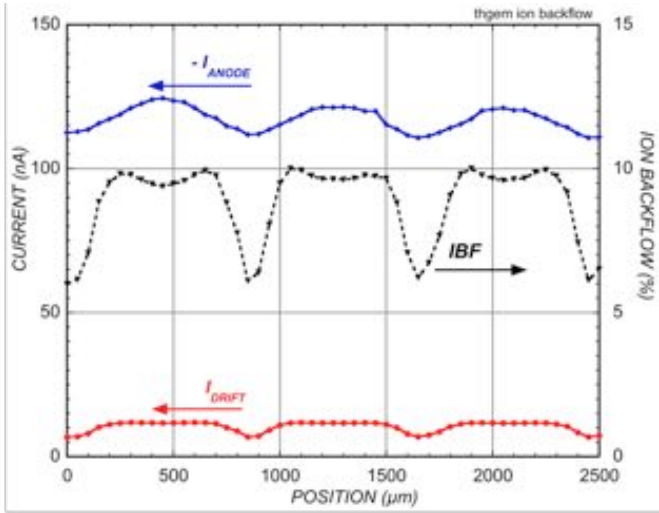


F.W. Bohmer et al,Nucl. Instr. and Meth. A719(2013)101

EXPLOIT THE DIFFERENCE BETWEEN IONS' AND ELECTRONS' DIFFUSION IN AN OFFSET DOUBLE THICK-GEM

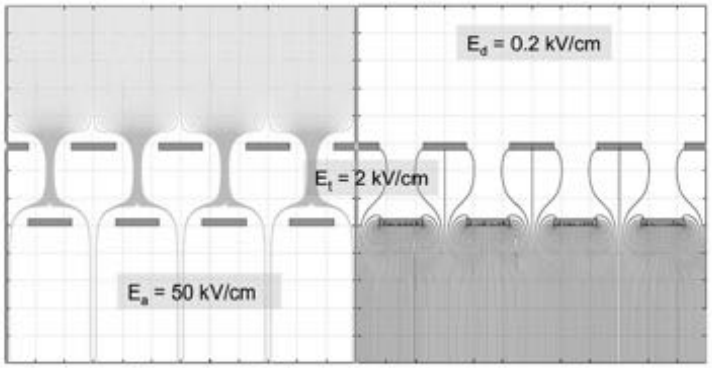


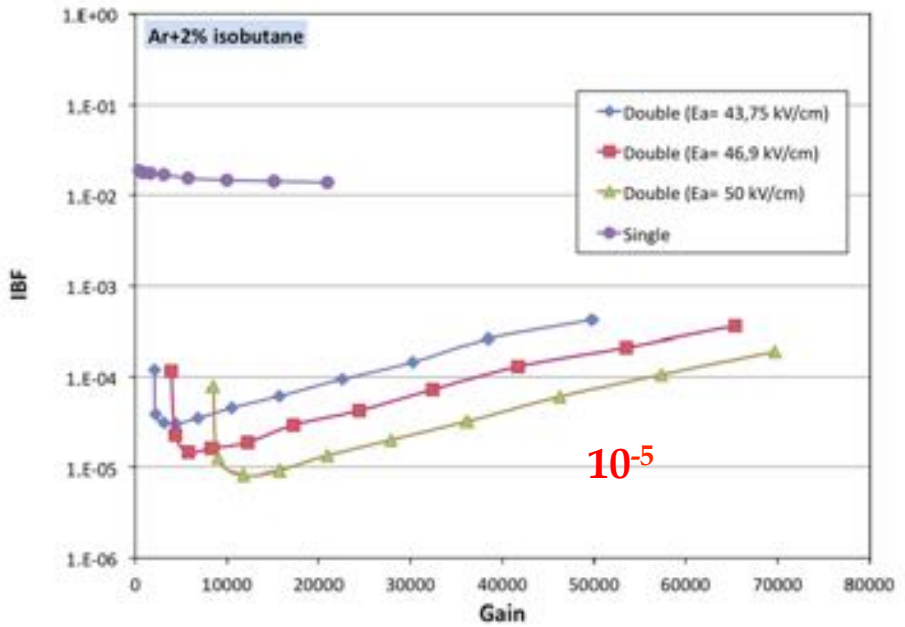




F. Sauli et al,
Nucl. Instr. and Meth. A560(2006)269

MICROMEGAS WITH OFFSET METAL MESHES:





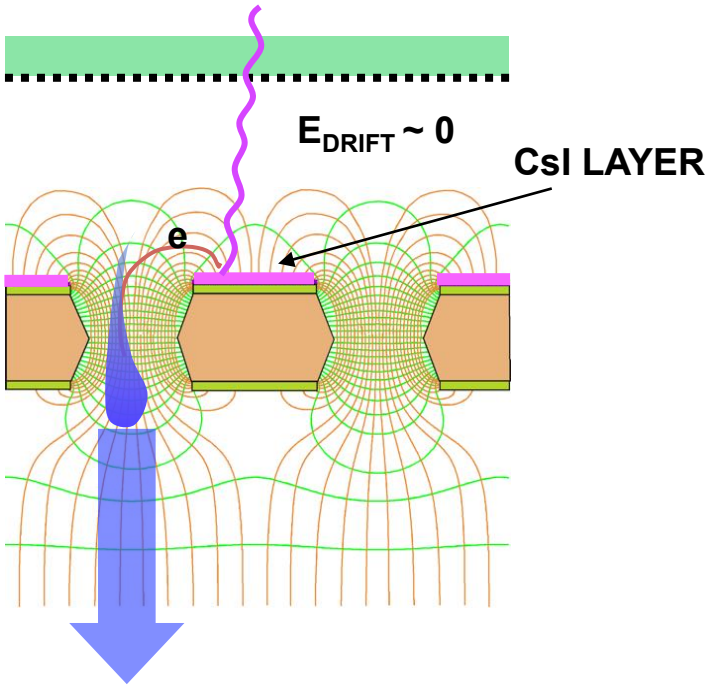
F. Jeanneau et al, Nucl. Instr. and Meth. A623(2010)94

OPEN PROBLEMS:
LARGE AREAS?
EFFECT OF MAGNETIC FIELD?
REALISTIC TPC GAS?

NEW IDEAS WELCOME!

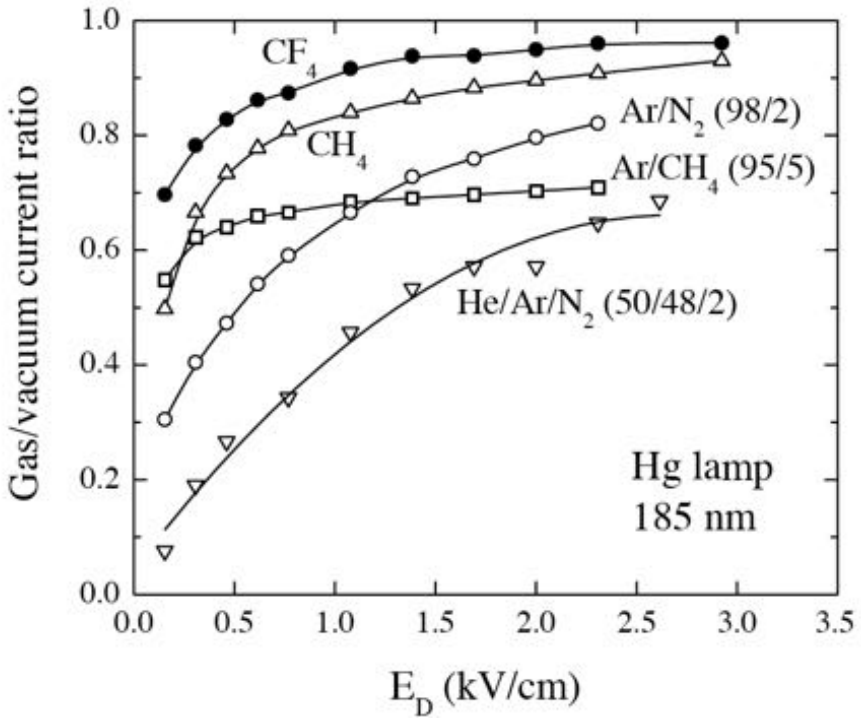
MPGD APPLICATIONS

REFLECTIVE CsI PHOTOCATHODE COATING

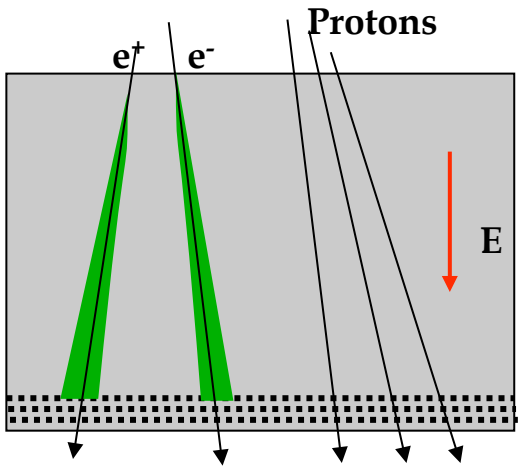


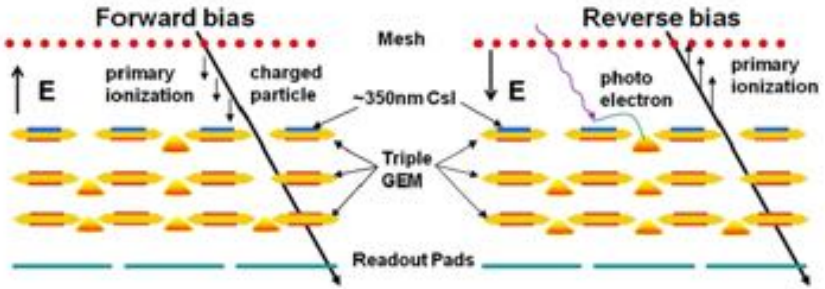
D. Mormann et al,
Nucl. Instr. and Meth. A478(2002)230

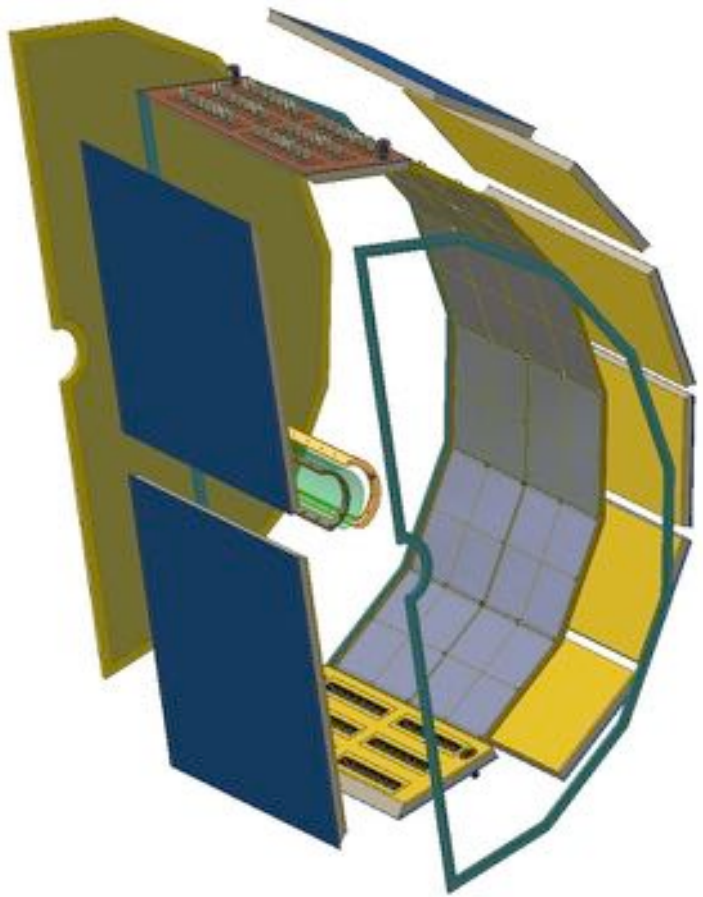
RELATIVE QUANTUM EFFICIENCY AS A FUNCTION OF EXTRACTION FIELD:



A. Breskin et al,
Nucl. Instr. and Meth. A483(2001)670



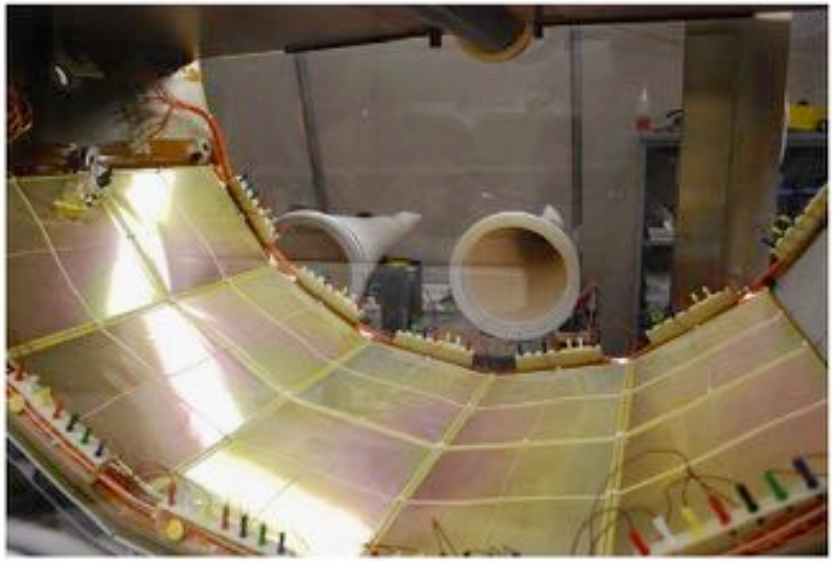




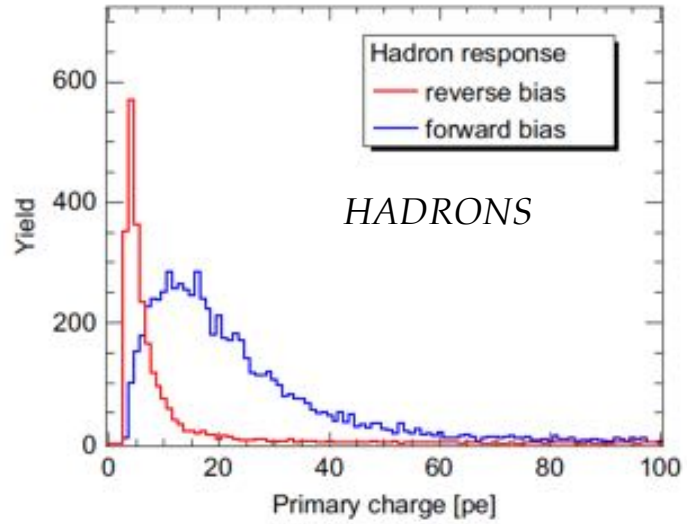
C. Aidala et al, Nucl. Instr. and Methods A502(2003)200

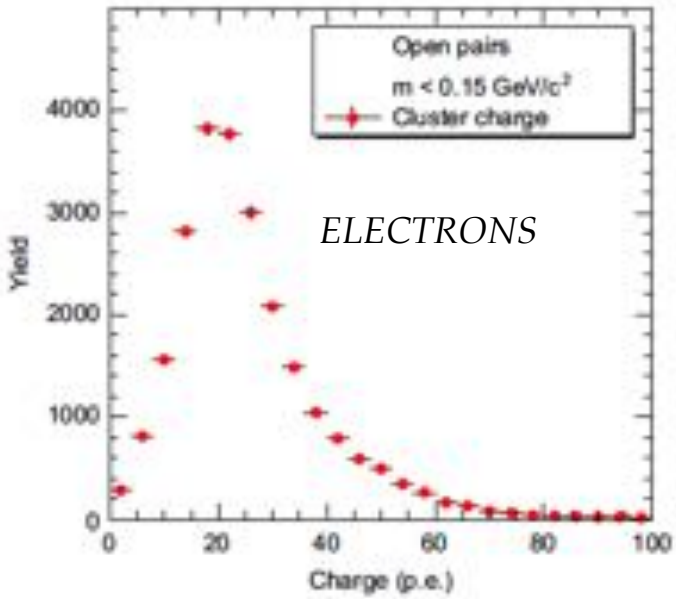
Z. Fraenkel et al, Nucl. Instr. and Methods A546(2005) 466

TRIPLE-GEM MODULES 268x221 mm^2
HEXAGONAL PADS READOUT
GAS FILLING: PURE CF_4

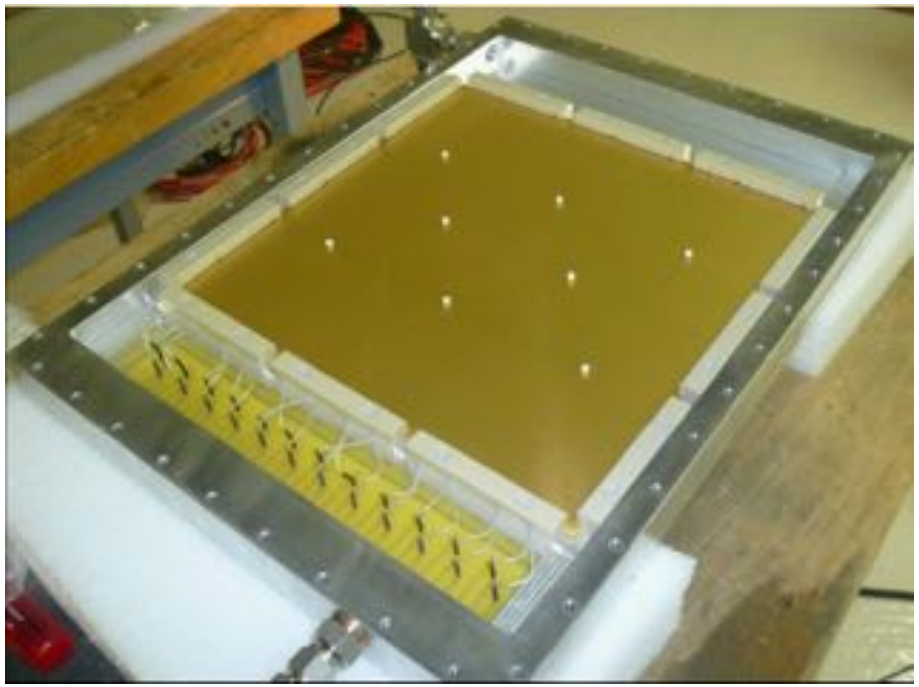


W. Anderson et al,
Nucl. Instr. and Meth. A645(2011)35

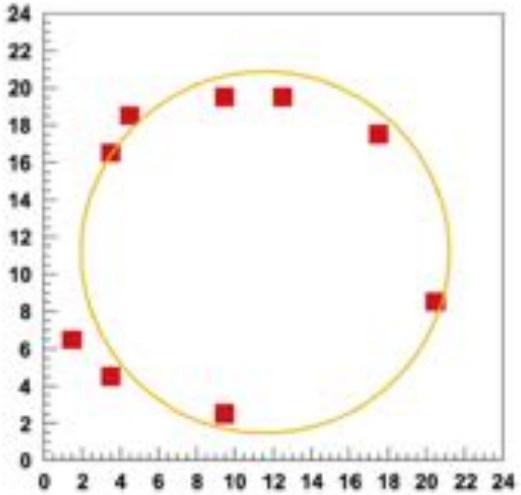




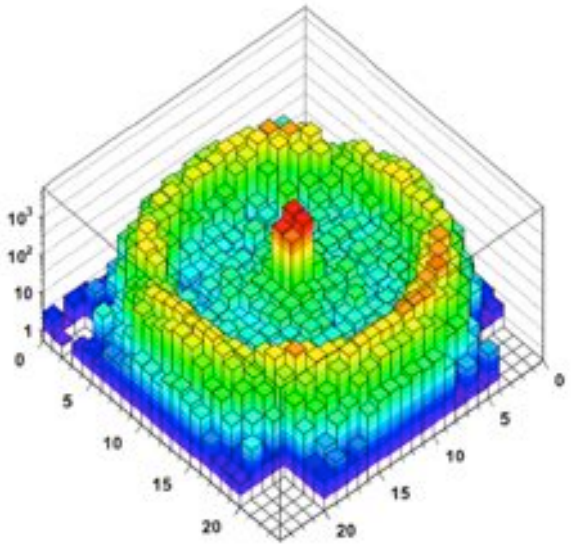
COMPASS RICH-1 UPGRADE
TRIPLE-THICK GEM CsI-COATED 30x30 cm^2



TEST BEAM: SINGLE EVENT

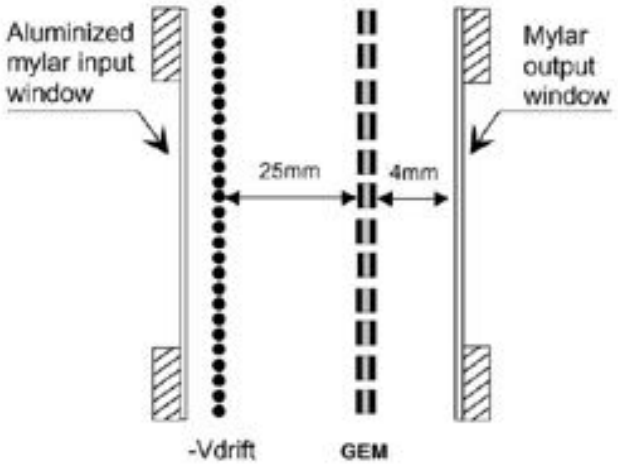


EVENTS OVERLAP:



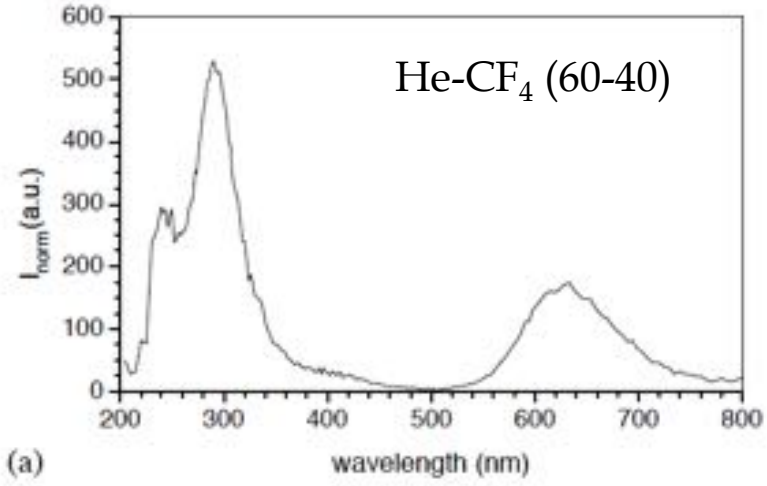
M. Alexeev et al, Nucl. Instr. and Meth. A732(2013)264

GEM SCINTILLATION

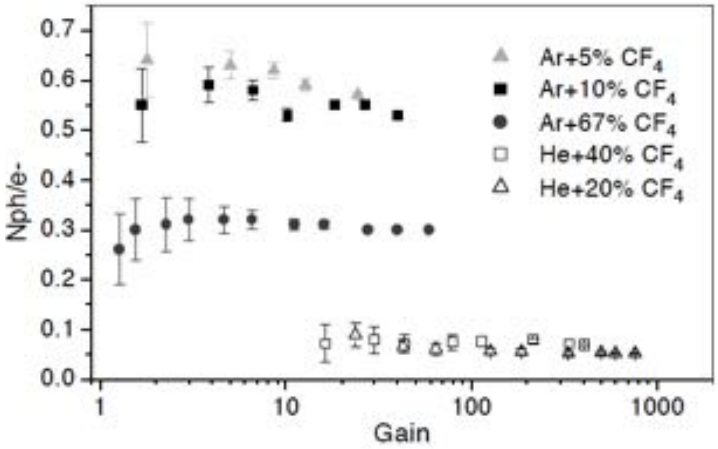


Monochromator

EMISSION SPECTRUM:

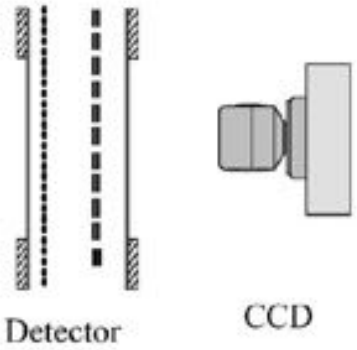


PHOTON YIELD/ELECTRON

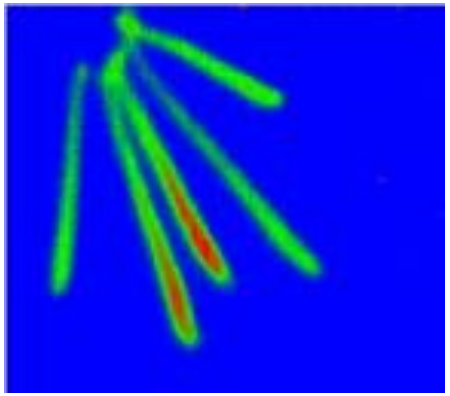


M.M.F. Fraga et al, Nucl. Instr. and Meth. A504(2003)88

GEM-BASED OPTICAL TPC

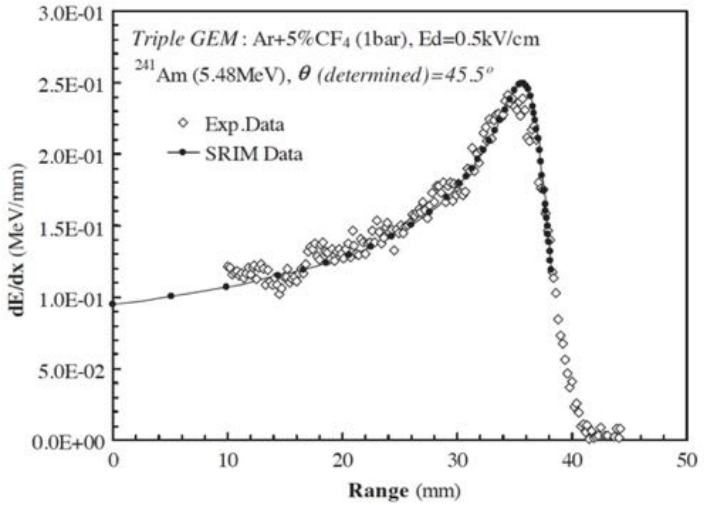


LIGHT YIELD OF END-OF RANGE 5.48 MeV α:



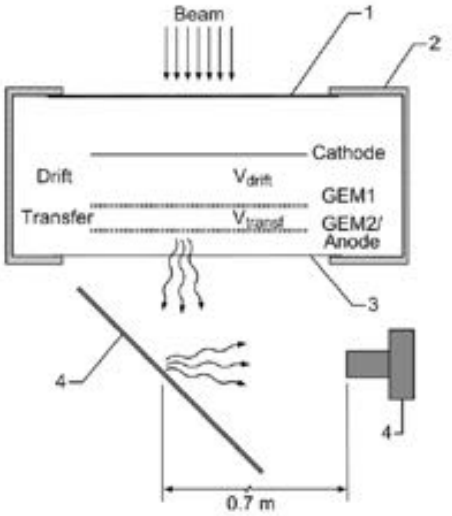
NEUTRON INTERACTIONS IN ^{3}He

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

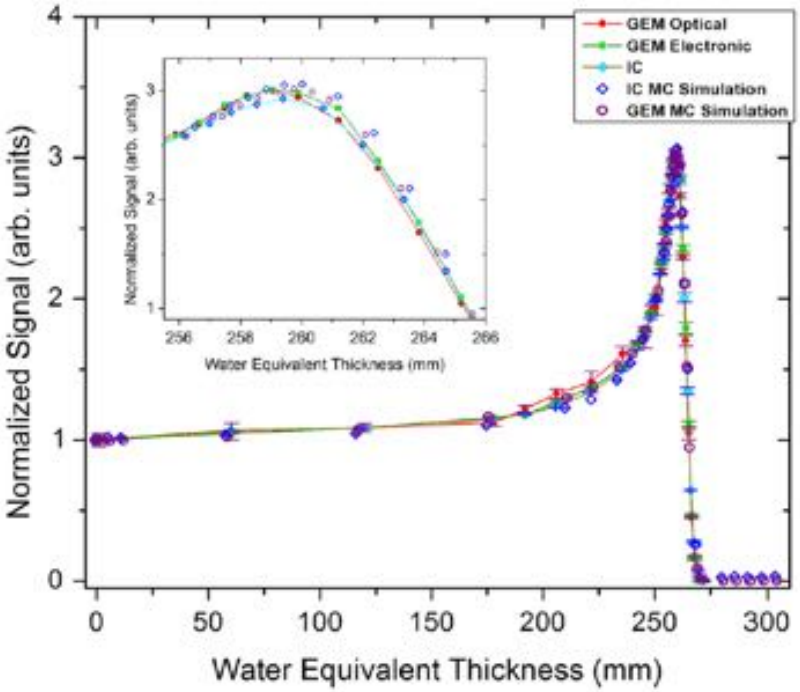


L.M.S. Margato et al,
Nucl. Instr. and Meth. A535(2002)231

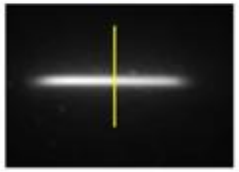
DOSE MEASUREMENT IN HADROTHERAPY

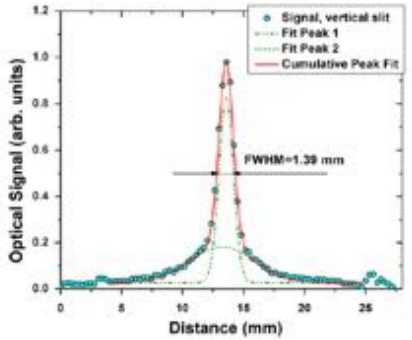


BRAGG PEAK:



COLLIMATED BEAM PROFILE

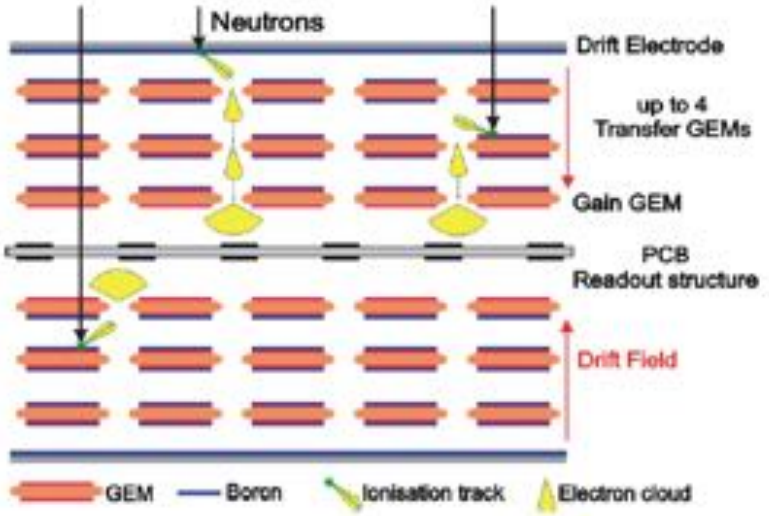




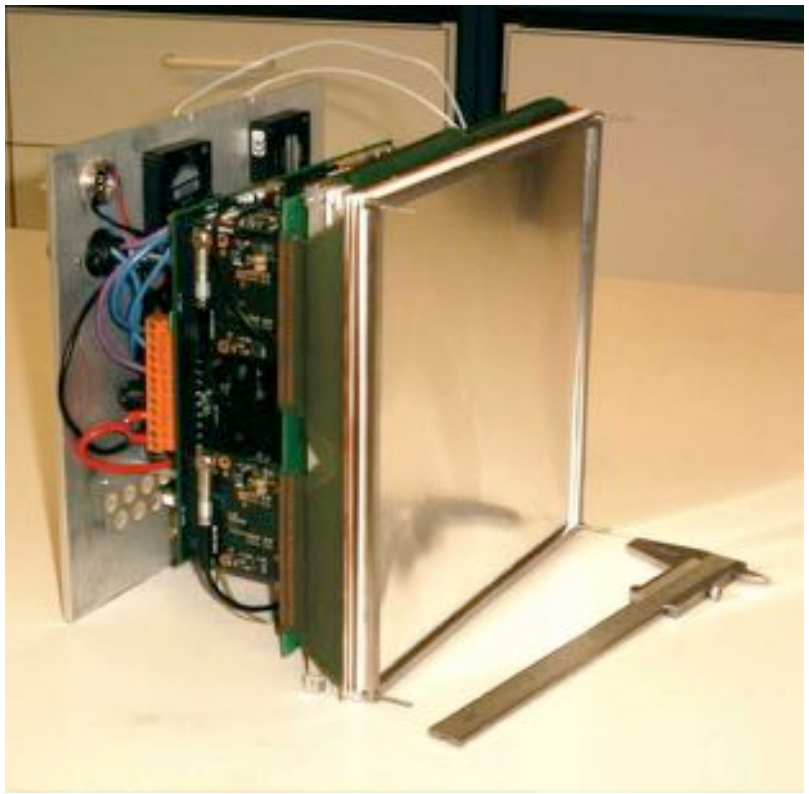
A.V. Klyaxhko et al,
Nucl. Instr. and Meth. A694(2012)271

CASCADE

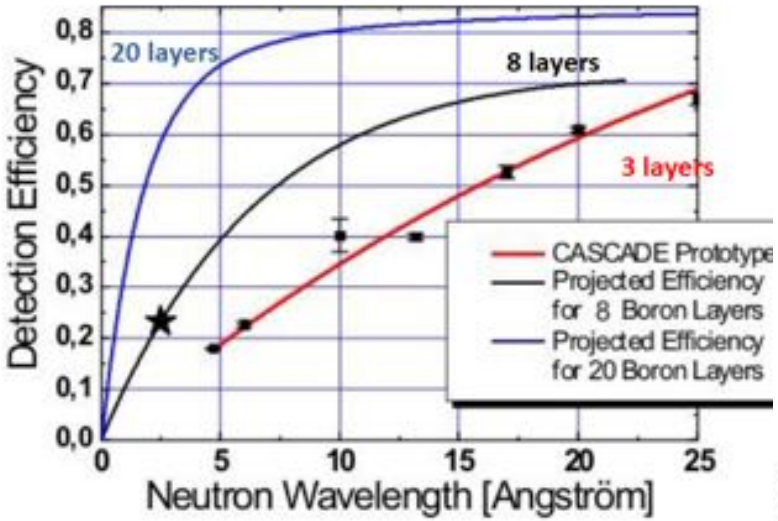
^{10}B-COATED GEM ELECTRODES



M. Klein and Ch. Schmidt,
Nucl. Instr. and Meth. A628(2011)9

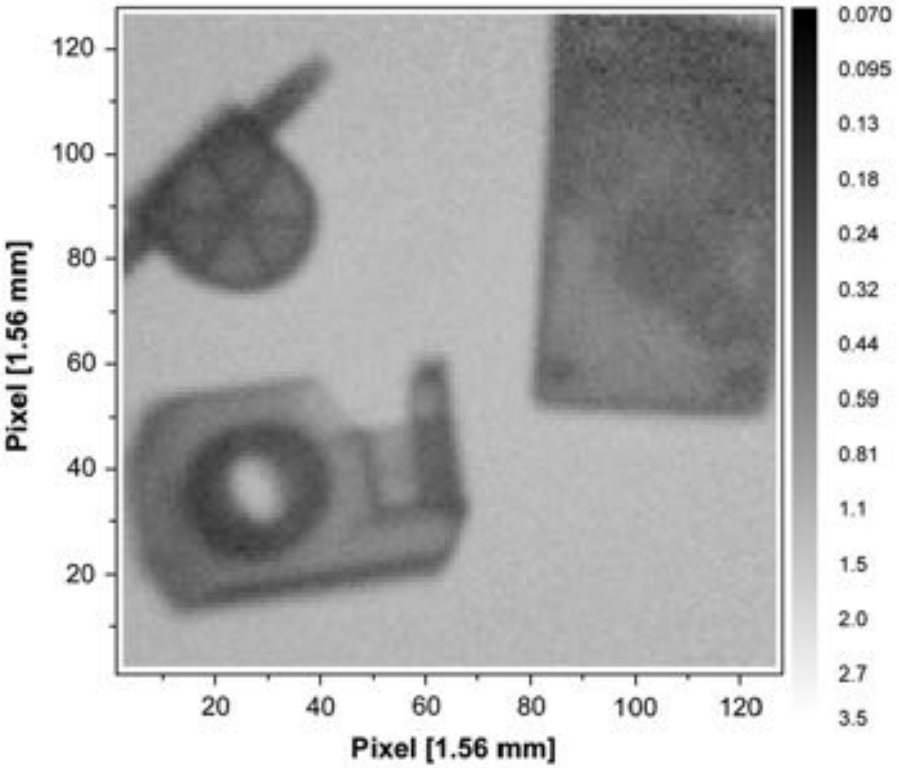


CASCADE

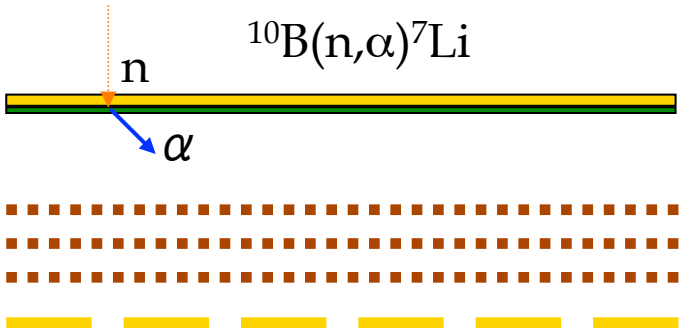


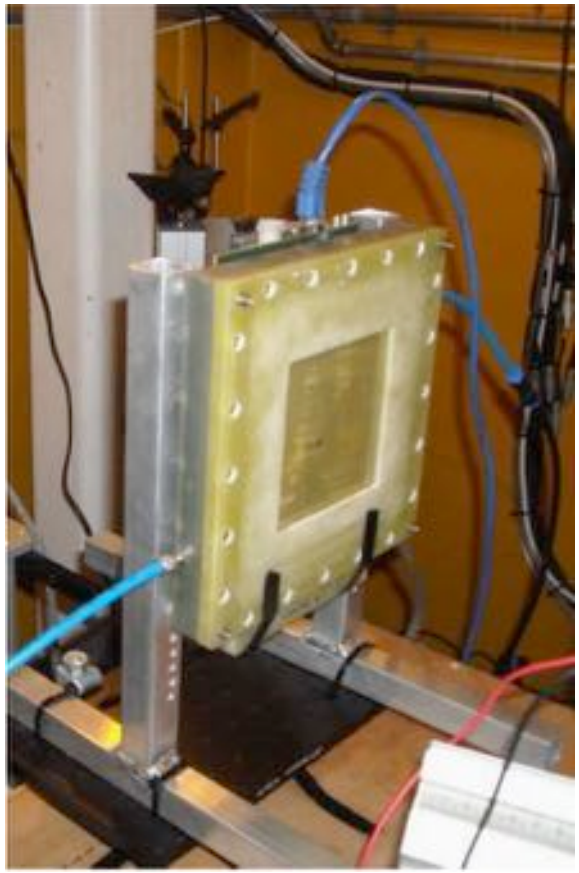
M. Klein and Ch. Schmidt,
Nucl. Instr. and Meth. A628(2011)9

EXAMPLE OF NEUTRON RADIOGRAPHY

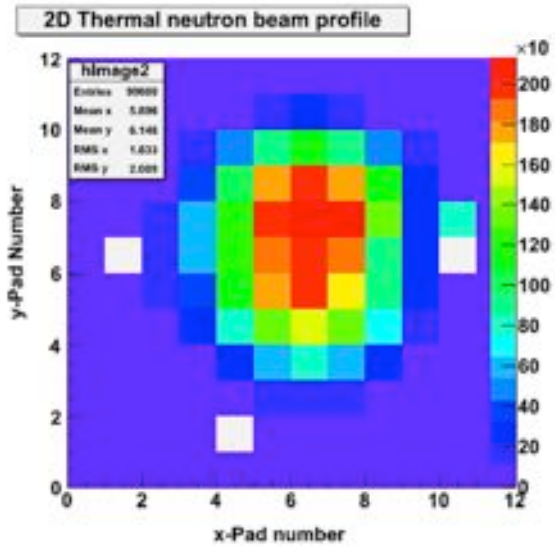


bGEM: Aluminum foil cathode coated with 1 μm of Boron Carbide



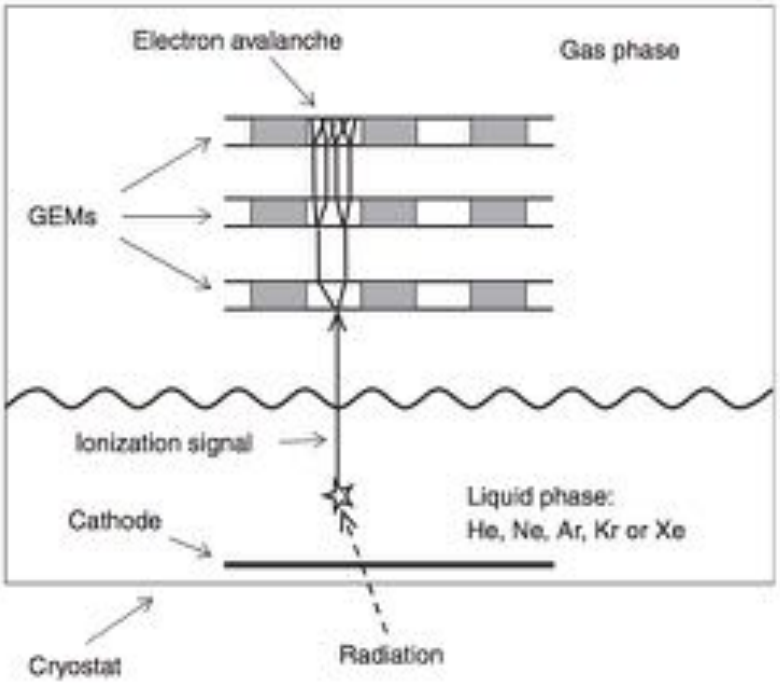


2-D THERMAL NEUTRON BEAM PROFILE



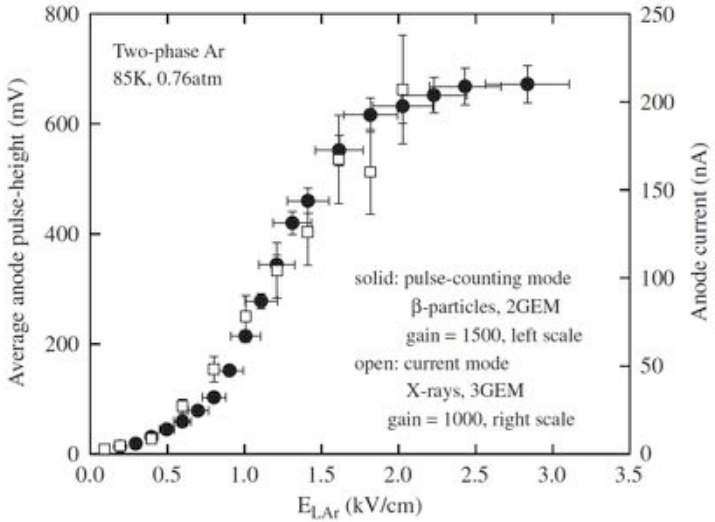
G. Croci et al, Nucl. Instr. and Meth. A732(2013)217

IONIZATION ELECTRONS ARE EXTRACTED FROM THE LIQUID, AMPLIFIED AND DETECTED

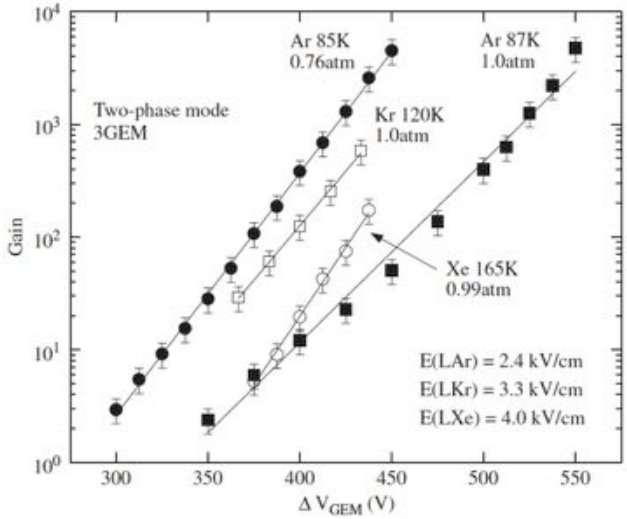


A. Bondar et al, Nucl. Instr. and Meth. A556(2006)273

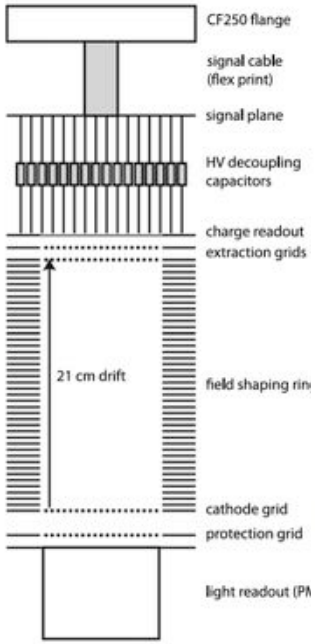
EXTRACTION PROBABILITY



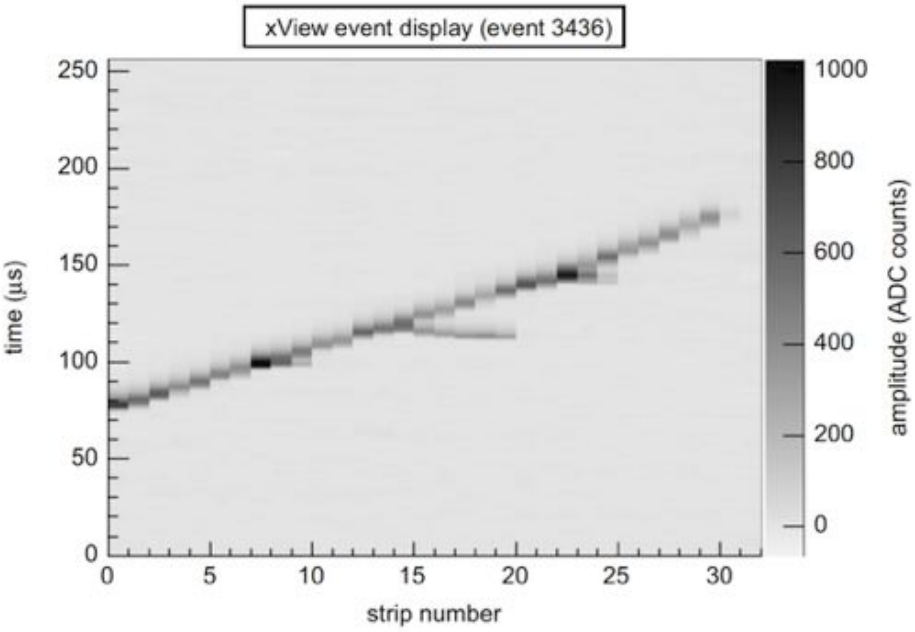
CRYOGENIC Triple-GEM GAIN



LIQUID ARGON TPC
LARGE ELECTRON MULTIPLIER (LEM)

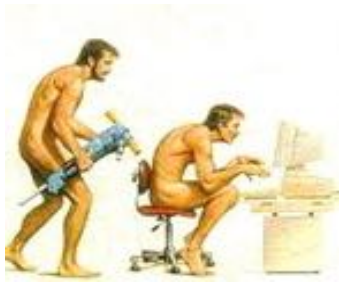


MUON TRACK IN THE LEM-TPC

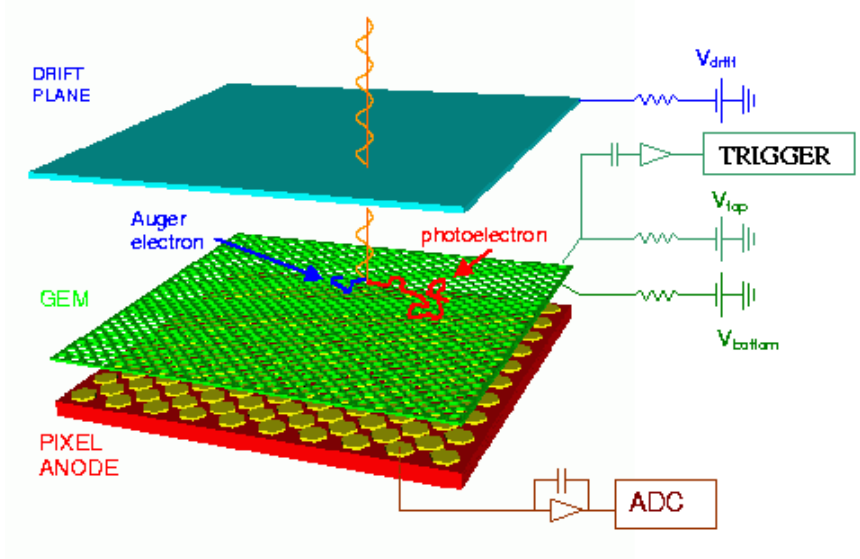


A. Badertscher et al, Nucl. Instr. and Meth. 641(2011)48

GAS MEETS SILICON

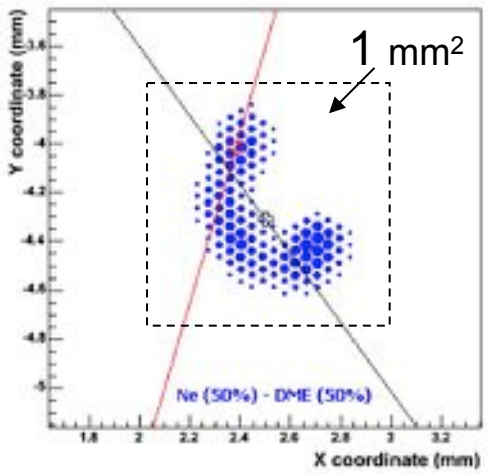


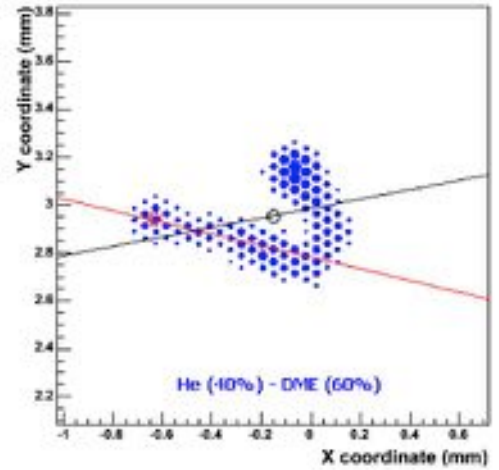
DEDICATED ASIC WITH PIXEL READOUT
~ 10^5 HEXAGONAL PIXELS AT 50 μm PITCH
HIGH GRANULARITY GEM, 50 μm PITCH



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

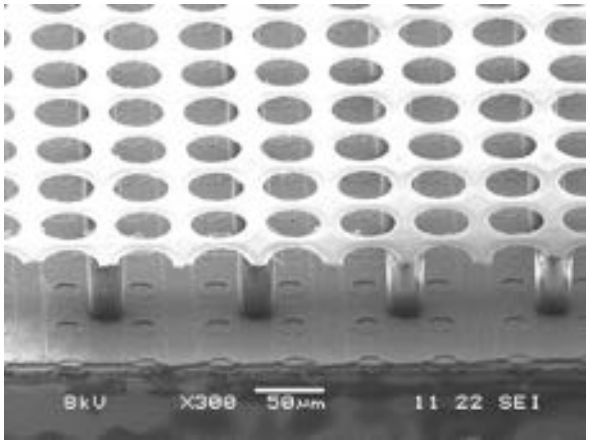
6 KeV PHOTOELECTRON:

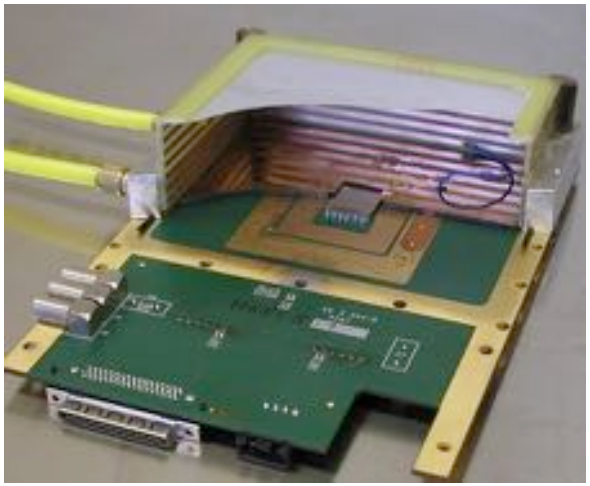




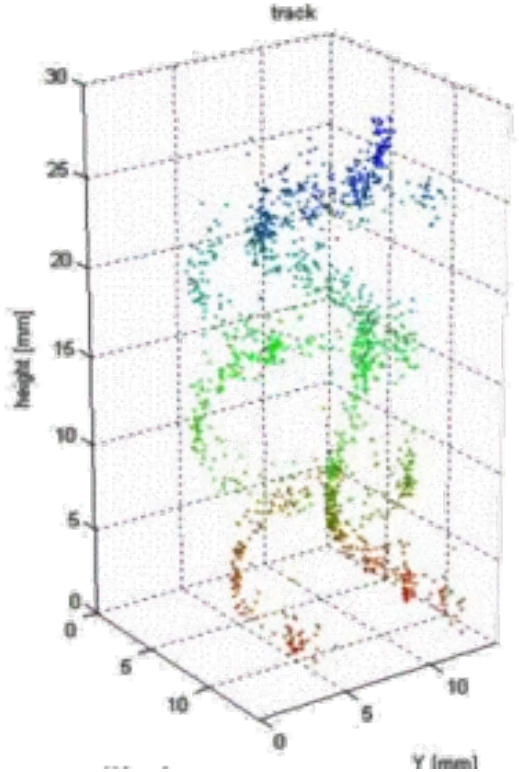
R. Bellazzini et al, Nucl. Instr. and Meth. A572(2007)160

MICROMEGAS OR GEM BUILT OVER A SILICON PIXEL READOUT:
INGRID, GRIDPIX, …..





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



H. Van der Graaf, Nucl. Instr. and Meth. A628(2011)27

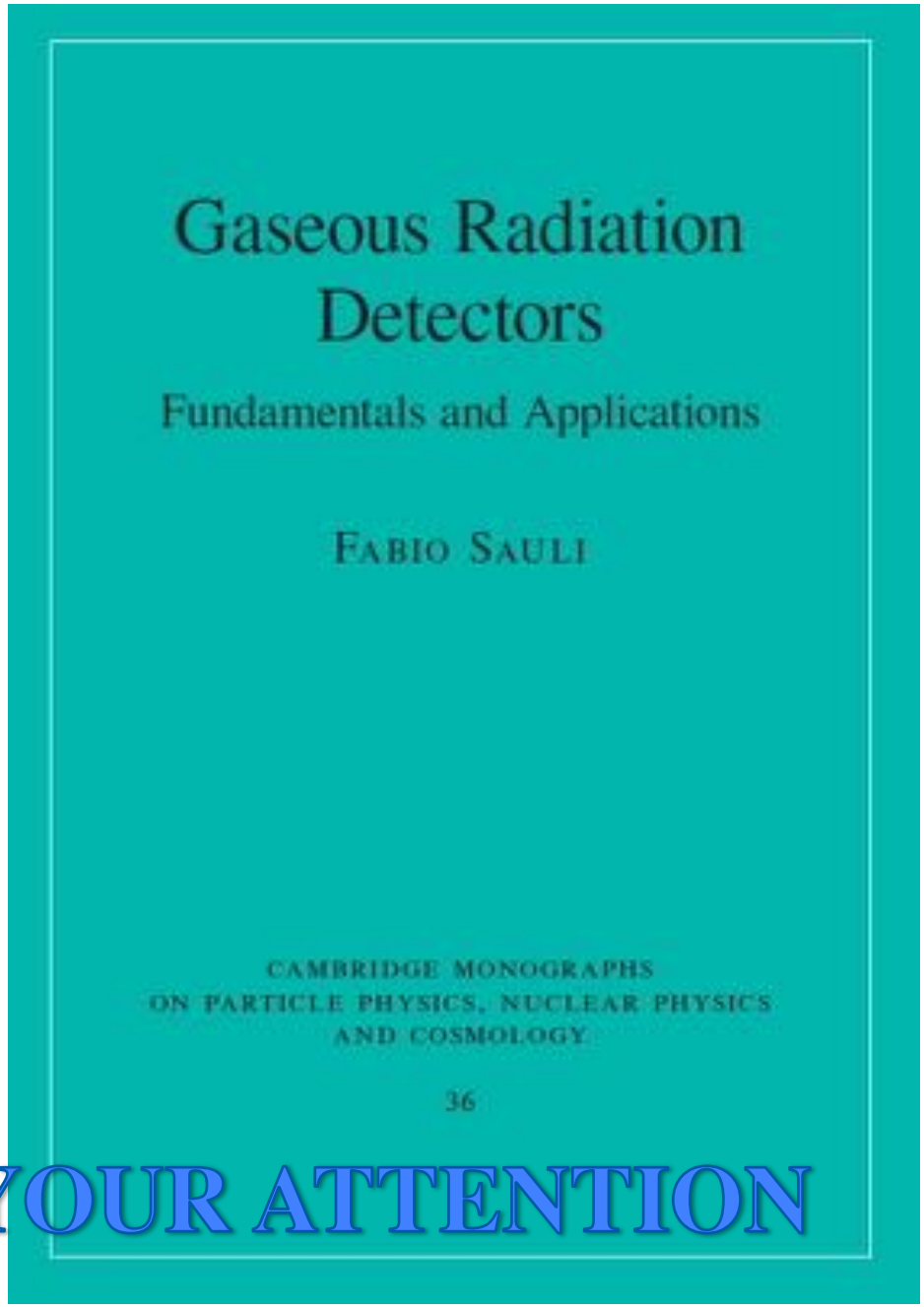
Harry van der Graaf Lectures

WAT'S NEXT?

THIS IS UP TO YOU!

AND IF YOU WANT TO KNOW MORE…

… COMING SOON



THANKS FOR YOUR ATTENTION