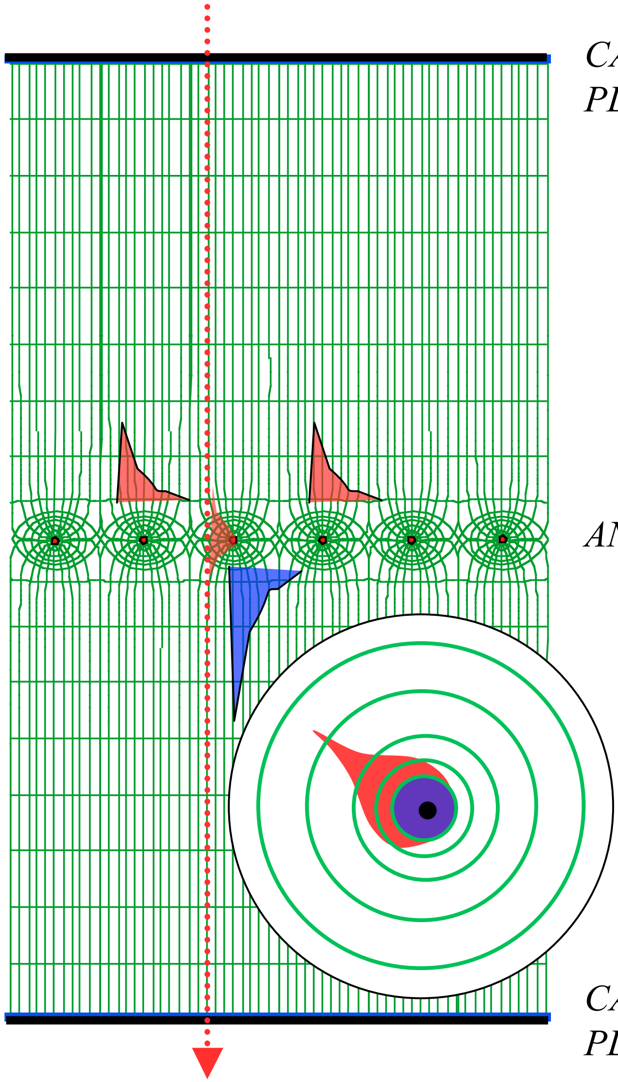
EDIT 2011

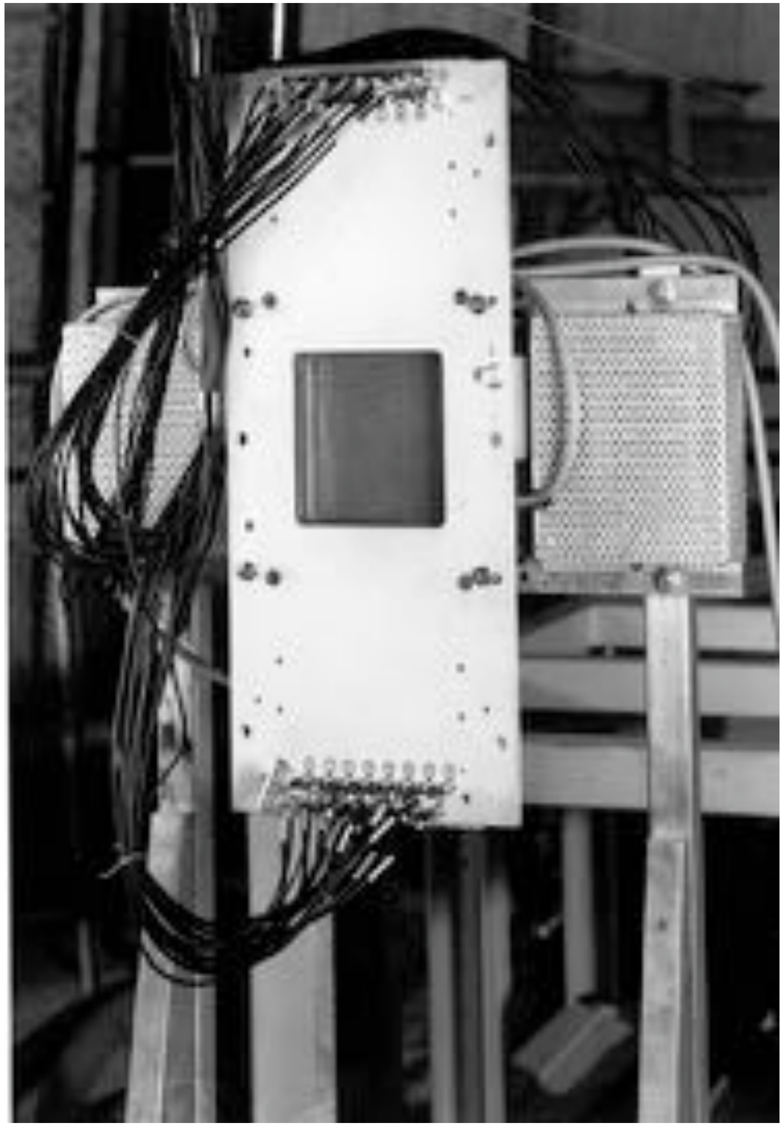
Excellence in Detectors and Instrumentation Technologies
CERN, Geneva, Switzerland - 31 January - 10 February 2011

40 YEARS OF ACHIEVEMENTS AND FAILURES WITH GASEOUS DETECTORS

Fabio Sauli
TERA Foundation and CERN

MULTIWIRE PROPORTIONAL CHAMBER (MWPC, 1968)





G. Charpak et al, Nucl. Instr. and Meth. 62(1968)235

Presented by Georges Charpak at the Versailles Symposium, in the session "Spark Chambers"

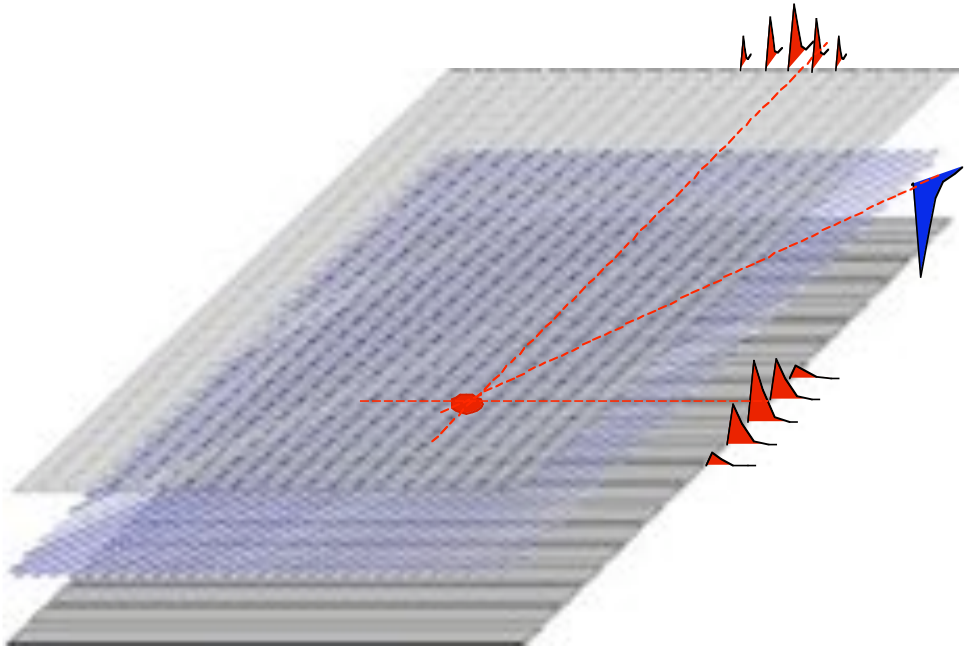
Chambres à Etincelles
Spark chambers

Rapporteur **M. CHARPAK**
Reporter CERN - GENEVE (Suisse)

G. Charpak, Proc. Int. Symp. Nuclear Electronics (Versailles 10-13 Sept 1968)

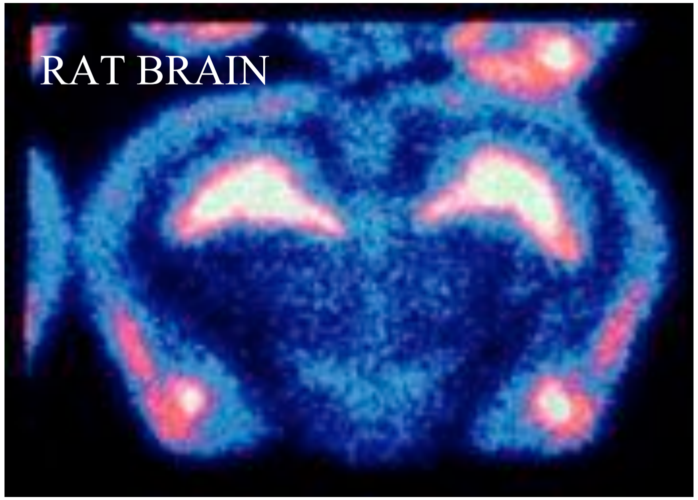
MWPC: CATHODE INDUCED CHARGES

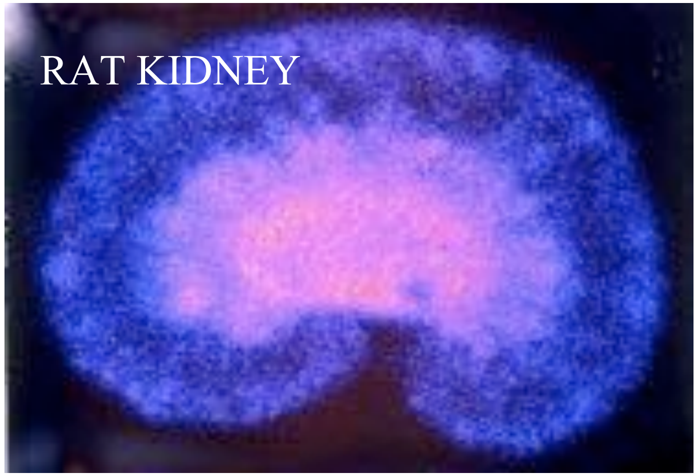
TWO-DIMENSIONAL COORDINATE READOUT



G. Charpak and F. Sauli,
Nucl. Instr. and Methods 113(1973)381

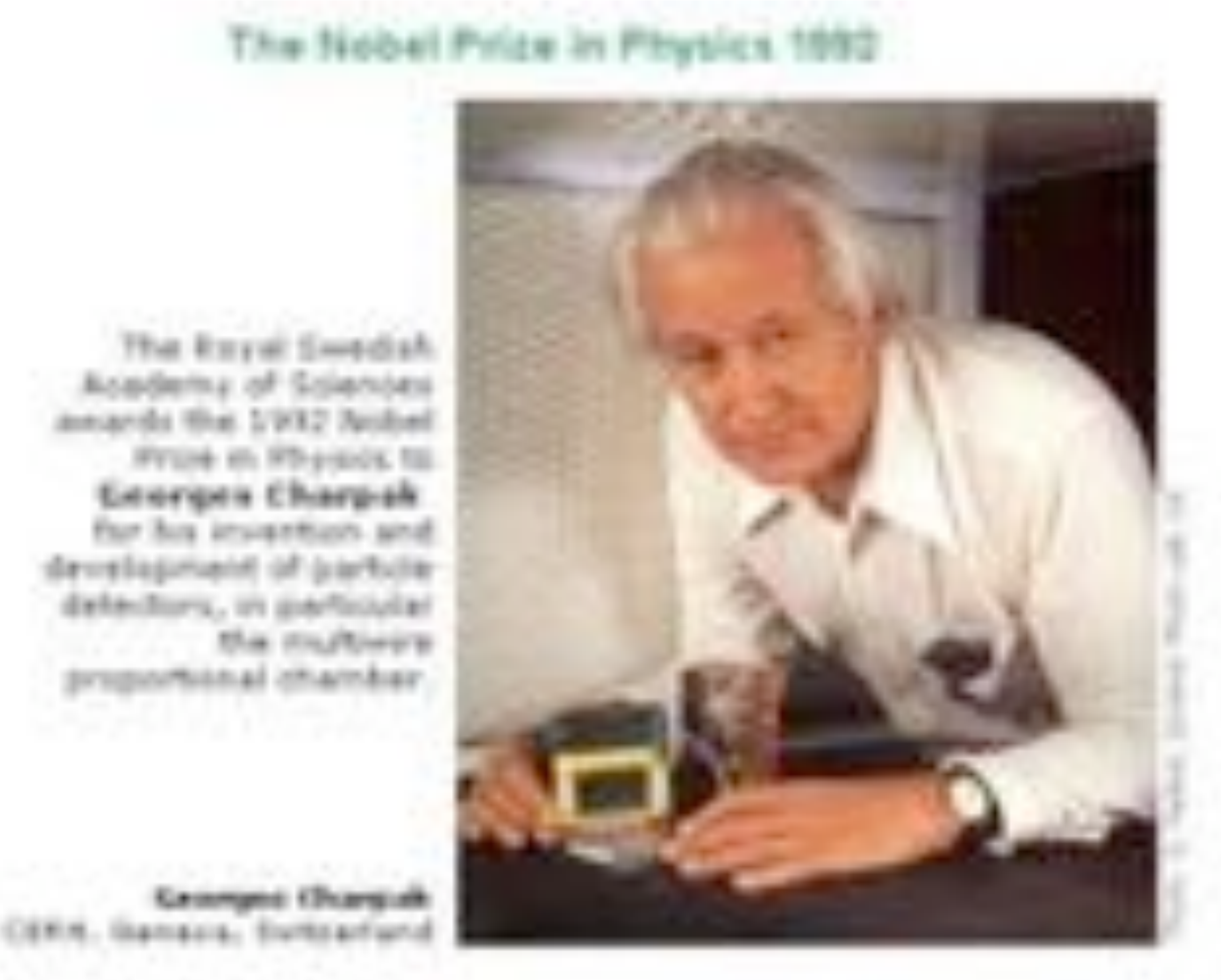
β - AUTORADIOGRAPHY





W. Dominik et al, Nucl. Instr. and Meth. A278(1989)779

GEORGES CHARPAK (1924 - 2010)



GAS DETECTORS DEVELOPMENTS

MULTIWIRE PROPORTIONAL CHAMBERS:
- LARGE SIZES
- TWO-DIMENSIONAL READOUT
- CATHODE STRIP CHAMBERS (CSC)

DRIFT CHAMBERS:
- VERY LARGE AREAS
- HIGH ACCURACY DRIFT CHAMBERS

IMAGING CHAMBERS:
- JET CHAMBER
- TIME PROJECTION CHAMBER (TPC)

WIRE ARRAYS:
- STRAW TUBES
- MONITORED DRIFT TUBES (MDT)
- TRANSITION RADIATION TRACKER (TRT)

WIRELESS GAS DETECTORS:
- RESISTIVE PLATE CHAMBERS (RPC)
- MULTIGAP RPC (MRPC)

MICRO-PATTERN GAS DETECTORS:
- MICRO-STRIP GAS CHAMBER (MSGC)
- MICROMEGAS
- GAS ELECTRON MULTIPLIER (GEM)

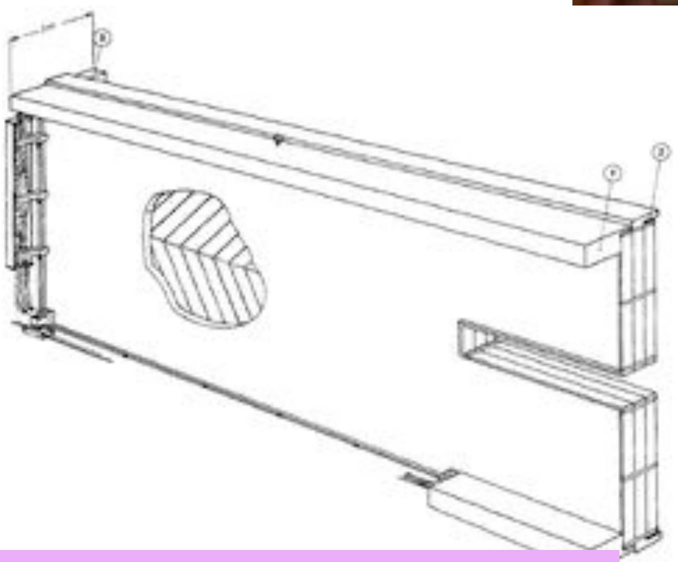
G. Charpak and F. Sauli, High resolution electronic particle detectors, Ann. Rev. Nucl. Part. Sci. 34 (1984) 285
W. Blum and G. Rolandi, Particle Detection With Drift Chambers (Springer-Verlag, Berlin 1993)
F. Sauli, From bubble chambers to electronics systems, Phys. Rep. 403-404 (2004) 471
F. Sauli and A. Sharma, Micropattern Gaseous Detectors, Ann. Rev. Nucl. Part. Sci. 49 (1999) 341
M. Titov, New developments and future perspectives of gaseous detectors, Nucl. Instr. And Meth. A581 (2007) 25

LARGE MWPC (1971)

G. Charpak et al, Nucl. Instr. and Meth. 97(1971)377

FIRST LARGE MWPC ARRAY: SPLIT FIELD MAGNET DETECTOR (1972)

LIGHT CONSTRUCTION
ON HONEYCOMB PLATES



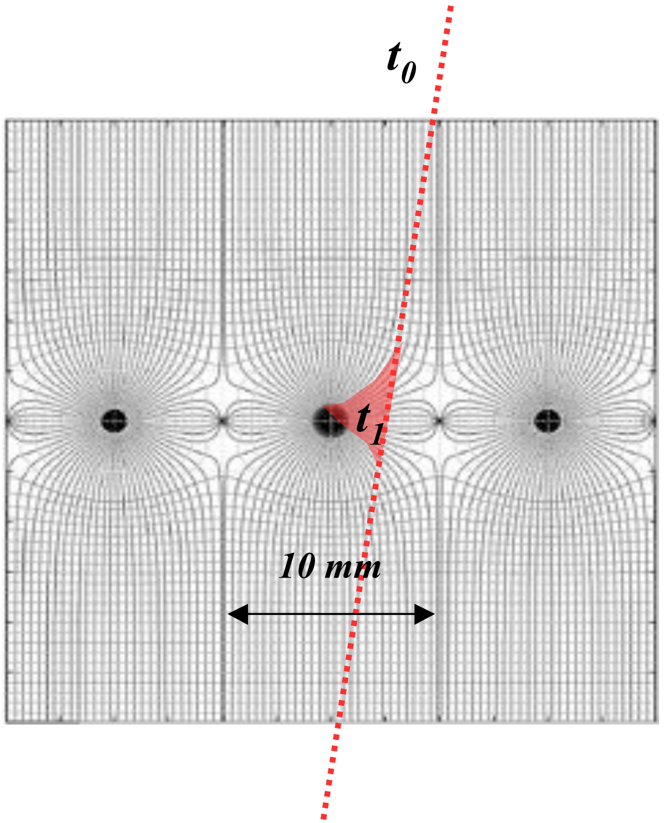
MWPC PERFORMANCES:

Localization	1-2 mm
Two-track resolution	2 mm
Rate capability	10^4 $mm^{-2}s^{-1}$
Size	1 m^2

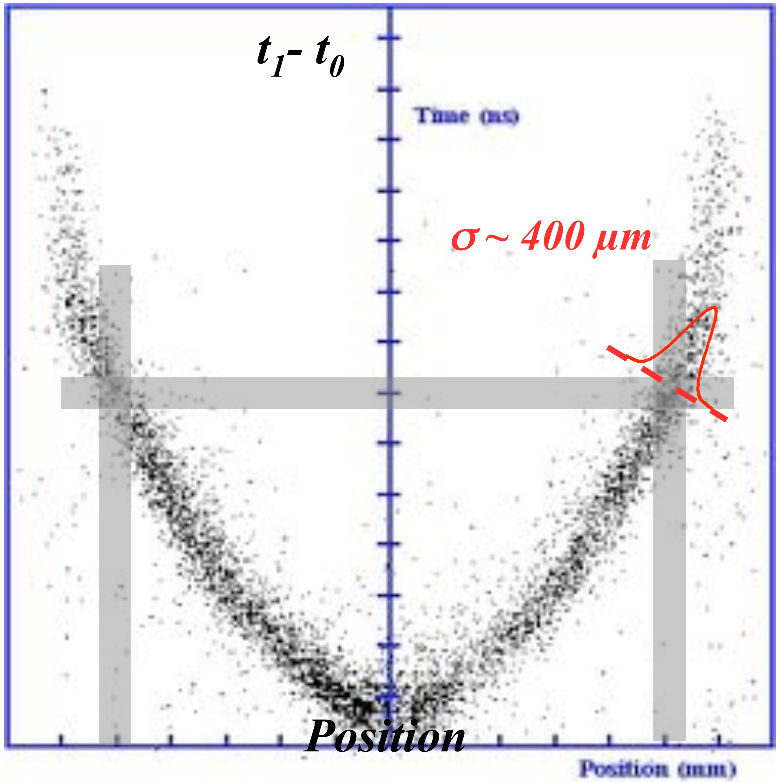
R. Bouclier et al, Nucl. Instr. and Meth. 115(1974)235

MWPC WITH FIELD WIRES BETWEEN ANODES

K_0 leptonic decays (CERN-Heidelberg, 1971)



TIME TO SPACE CORRELATION:

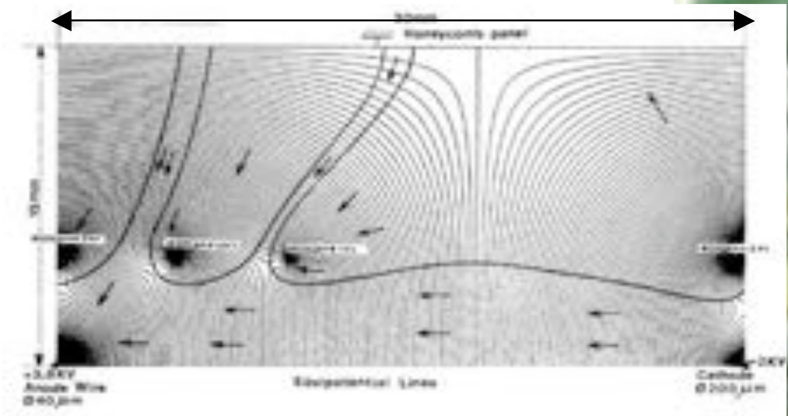


A. H. Walenta, J. Heintze and B. Scürlein, Nucl. Instr. and Meth. 92(1971)373

LARGE DRIFT CHAMBERS: WA1 NEUTRINO EXPERIMENT (1977)

6 cm WIDE DRIFT CELLS

3 cm (x2)

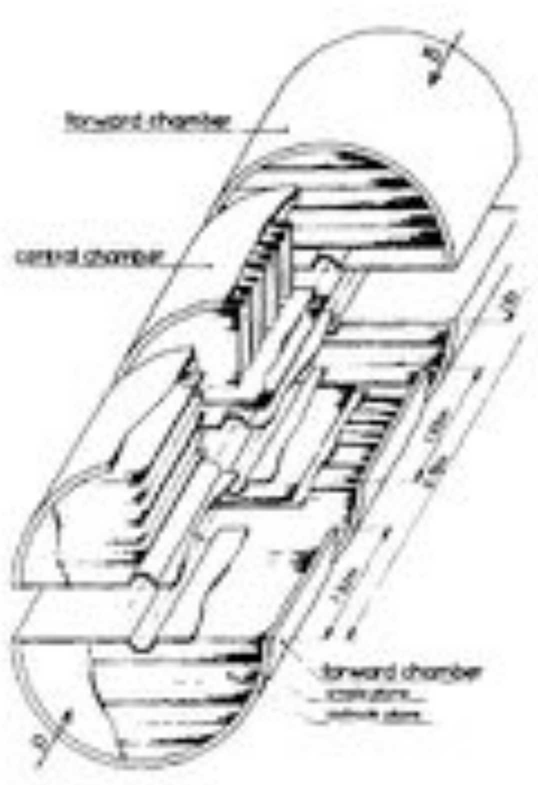


DRIFT CHAMBER PERFORMANCES:

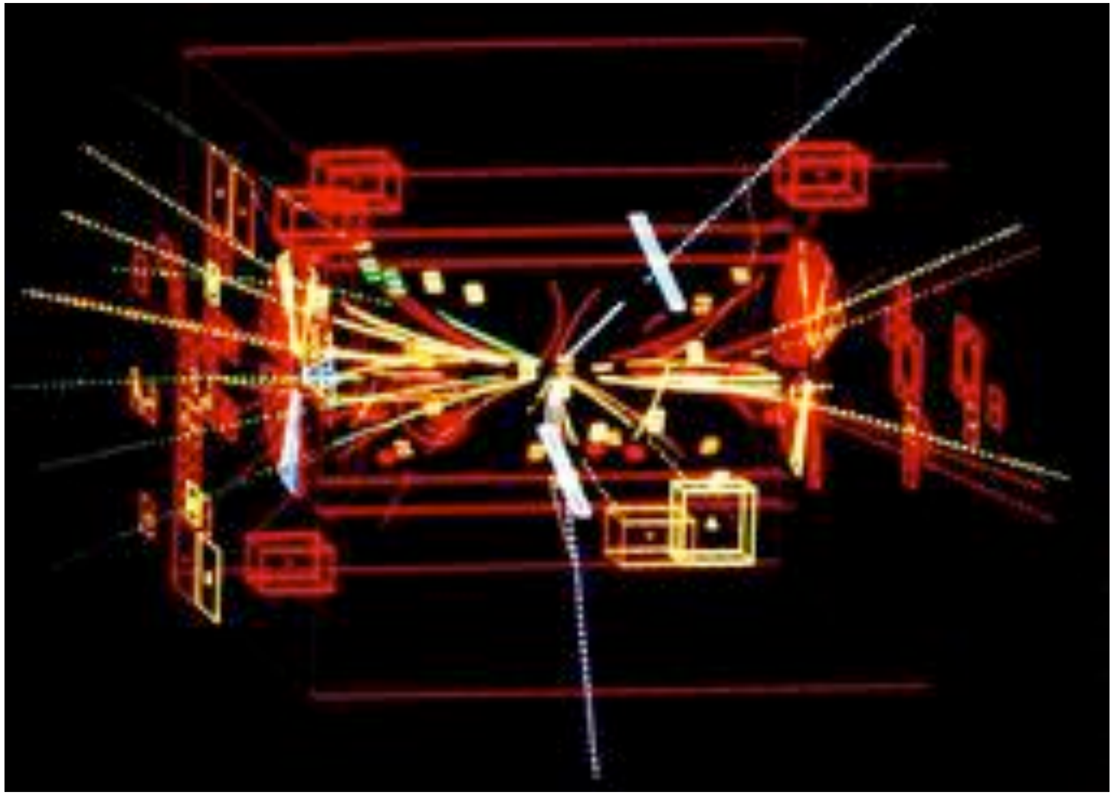
Localization	50-500 µm
Two-track resolution	5 mm
Rate capability	10^2-10^3 $mm^{-2}s^{-1}$
Size	10 m^2

G. Marel et al, Nucl. Instr. and Meth. 141(1977)43

UA1 DRIFT CHAMBER MODULES



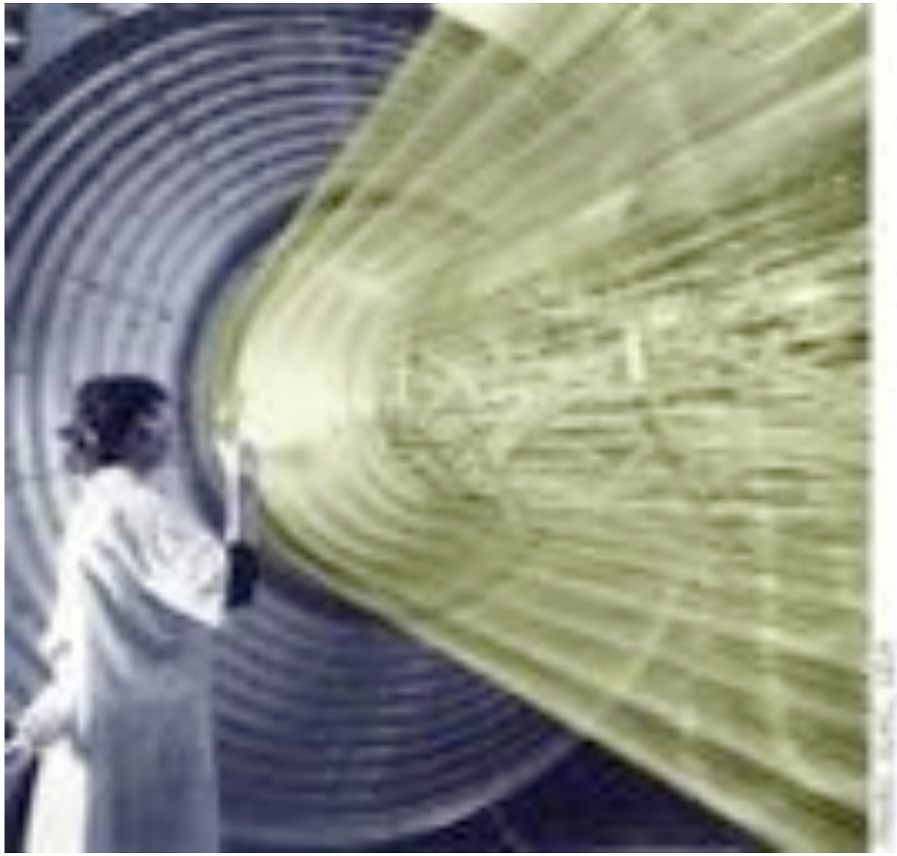
p - $\bar{p}$ INTERACTION



S. P. Beingessner et al, Nucl. Instr. and Meth. A272(1988)669

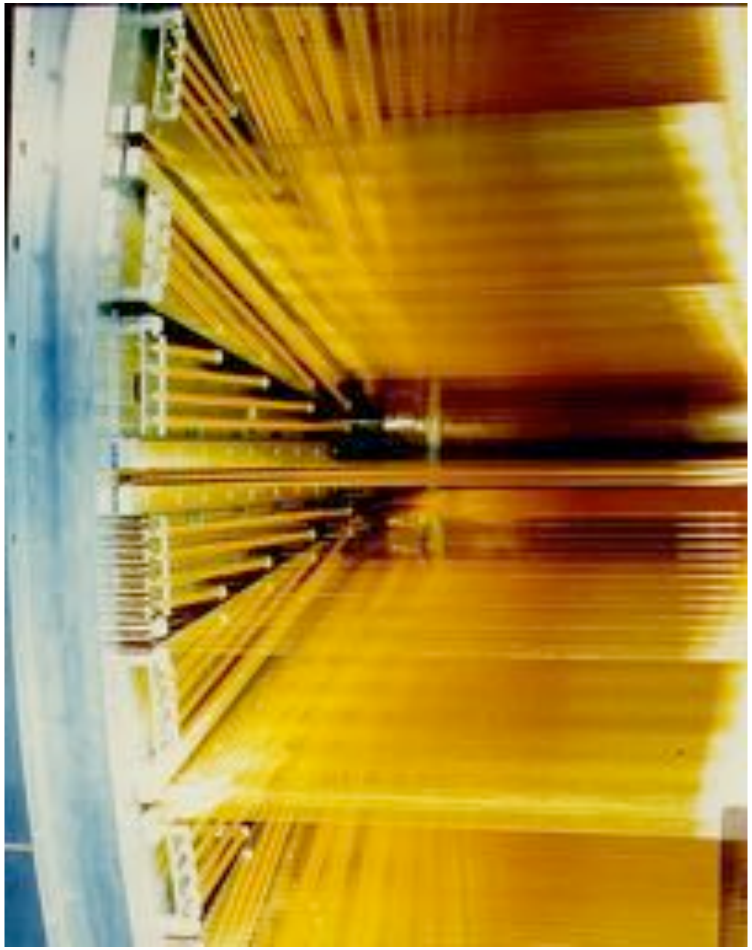
VOLUME DETECTORS: CYLINDRICAL MULTIWIRE DRIFT CHAMBERS

ASSEMBLY OF A CYLINDRICAL DC AT SLAC



A. Ferrari, Nucl. Instr. And Meth. A494(2002)193

L3 TIME EXPANSION CHAMBER



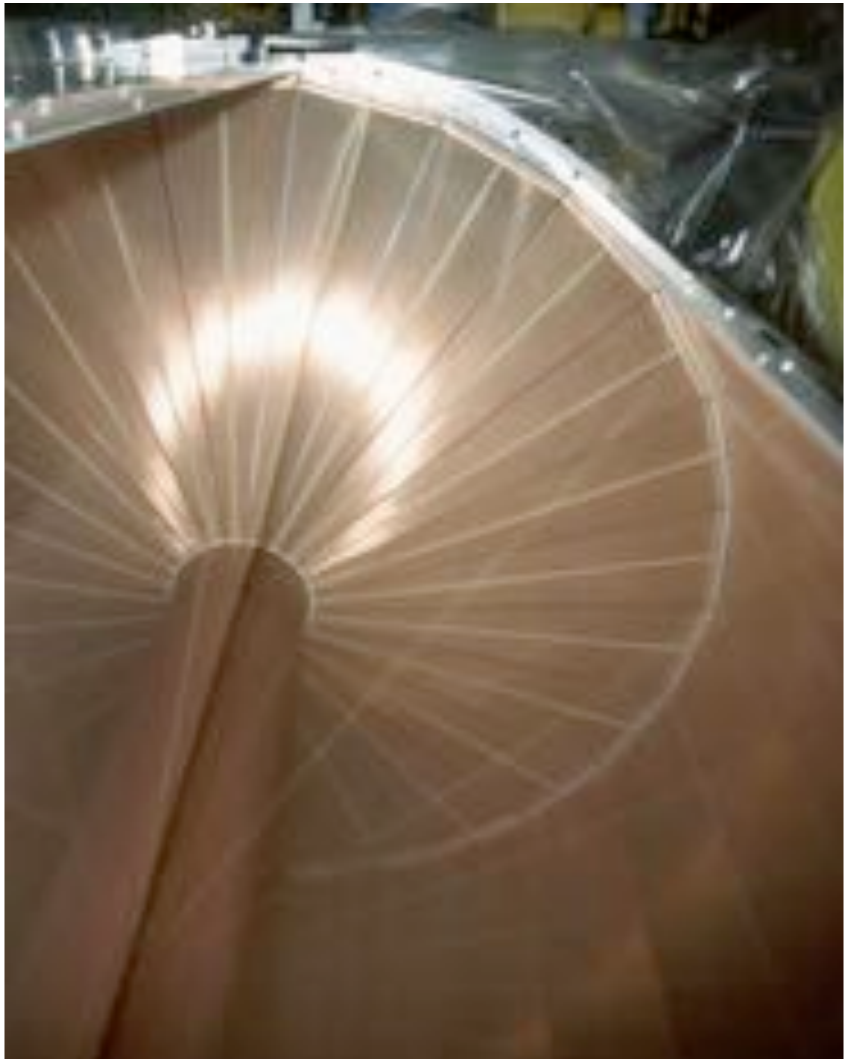
B. Adeva et al, Nucl. Instr. and Meth. A289(1990)35

VOLUME DETECTORS: JET CHAMBERS

JADE JET CHAMBER (DESY 1980)

H. Drumm et al, Nucl. Instr. and Meth. 176(1980)333

OPAL JET CHAMBER (CERN 1992)

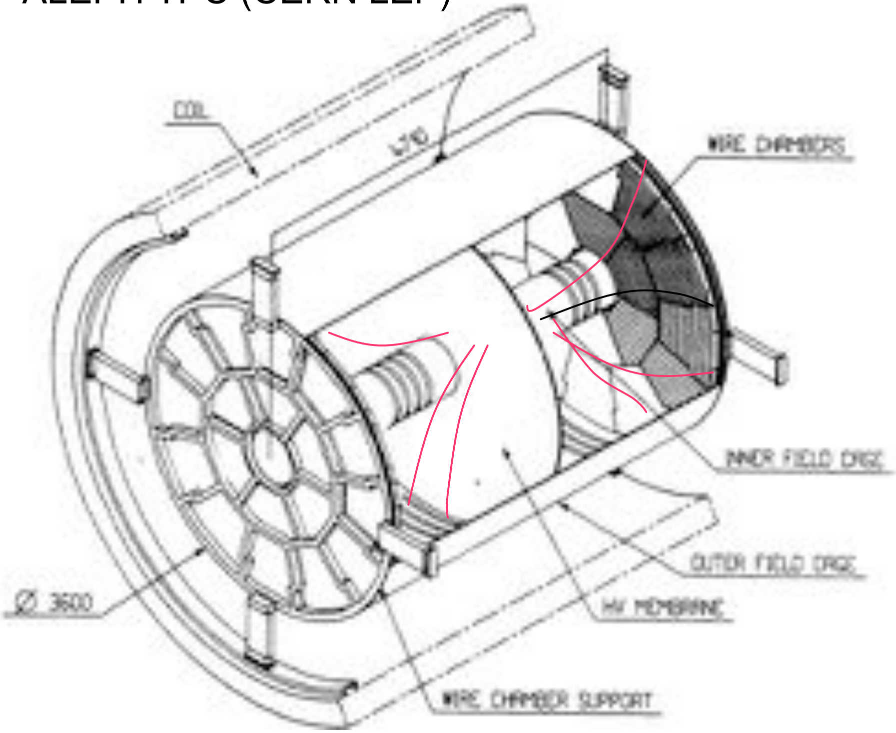


O. Biebel et al, Nucl. Instr. and Meth. A323(1992)169

TIME PROJECTION CHAMBERS

D.R. Nygren and J. N. Marx, Physics Today No.31 Vol. 10(1978)

ALEPH TPC (CERN LEP)

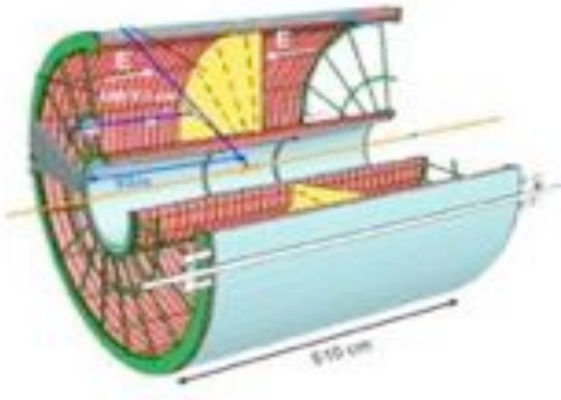


A. Decamp et al,
Nucl. Instr. and Meth. A294(1990)121

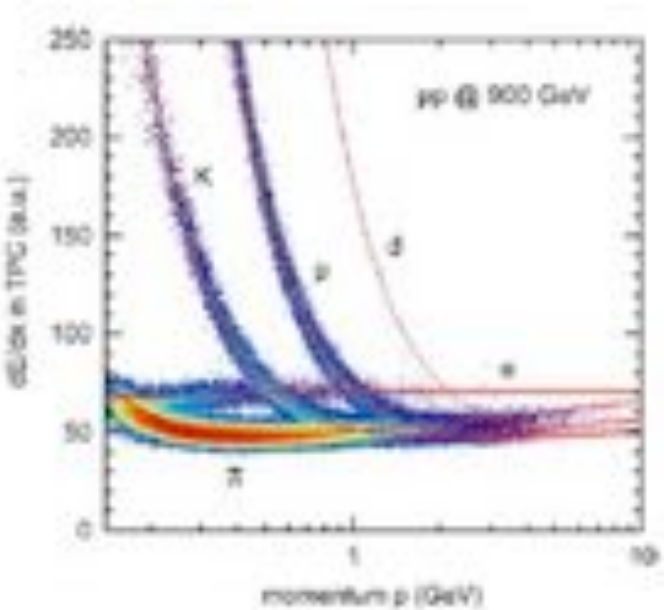
TWO-JET EVENT IN DELPHI (CERN LEP):

DELPHI Collaboration,
Nucl. Instr. and Meth. A303(1991)233

ALICE TIME PROJECTION CHAMBER



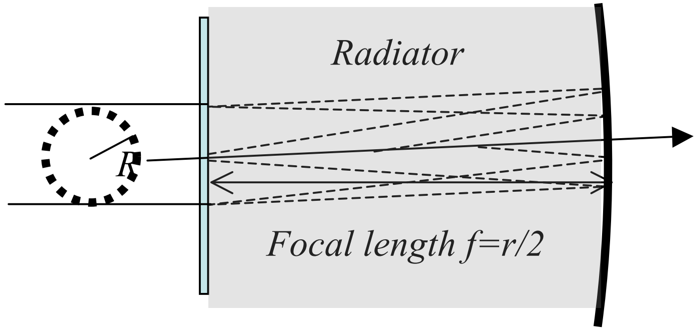
PARTICLE IDENTIFICATION:



J. Alme et al, Nucl. Instr. and Meth. A662(2010)316

TIME PROJECTION CHAMBERS:

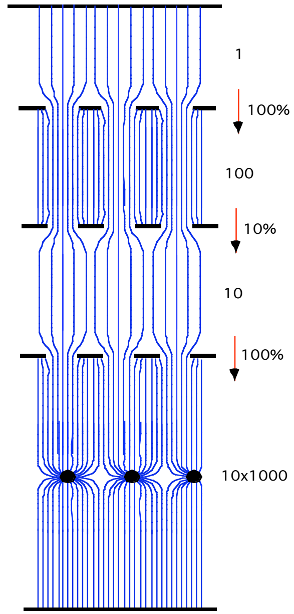
Localization	200 µm (X-Y), 1 mm (Z)
Two-track resolution	5-10 mm
(Rate capability) Memory time	10-20 µs
Size	100 m^2



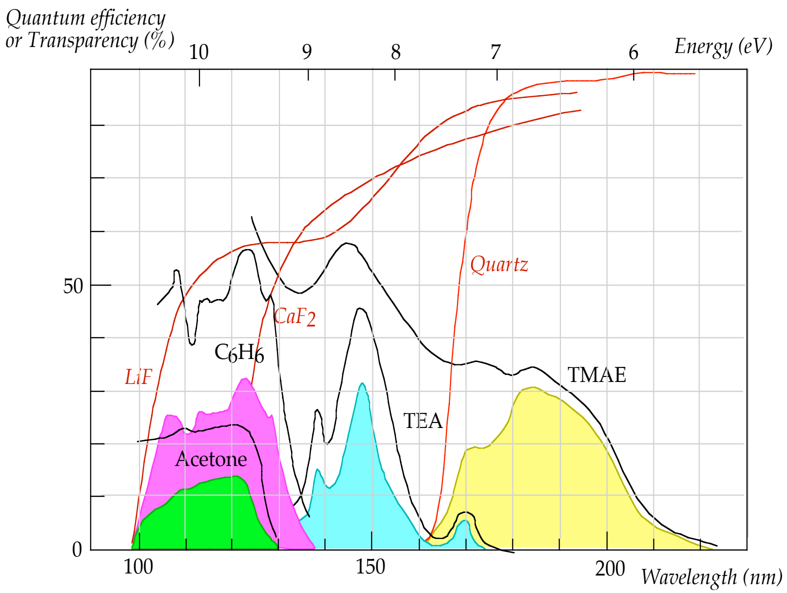
J. Seguinot and T. Ypsilantis, Nucl. Instr. and Meth. 142(1977)377

MULTISTEP CHAMBER: HIGH GAIN IN PHOTOSENSITIVE GAS MIXTURES

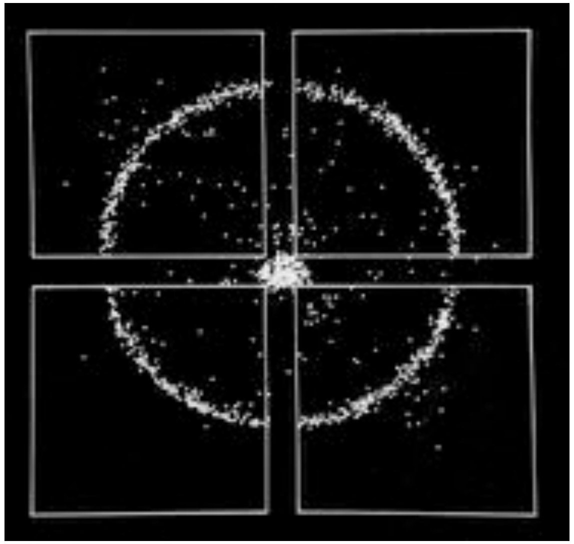
G. Charpak and F. Sauli, Phys. Lett. 78B (1978)523



PHOTOSENSITIVE VAPOURS AND WINDOWS:

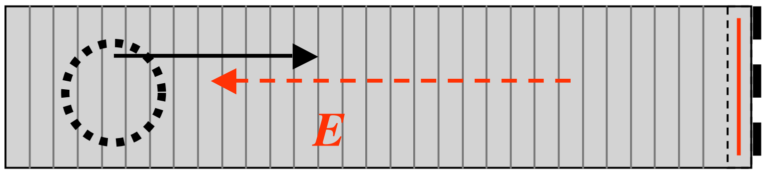


OVERLAPPING RINGS:

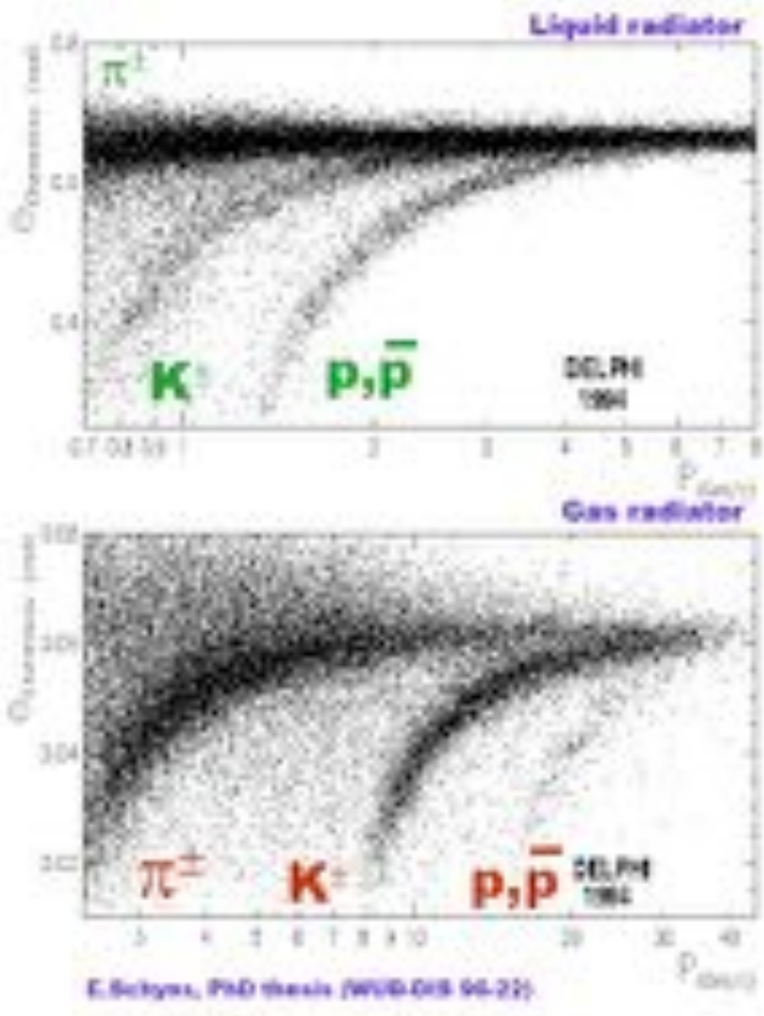


G. Charpak et al, Nucl. Instr. and Meth. 164(1979)419

DRIFT CHAMBERS WITH PHOTOSENSITIVE VAPOR (TMAE)



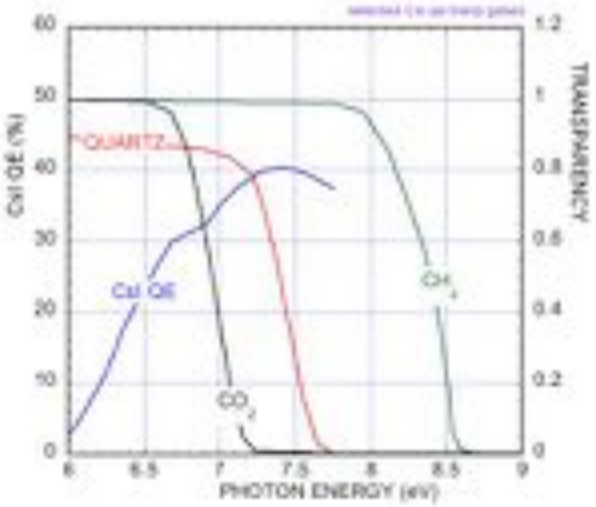
PARTICLE IDENTIFICATION:



DOUBLE RADIATOR: GAS AND LIQUID

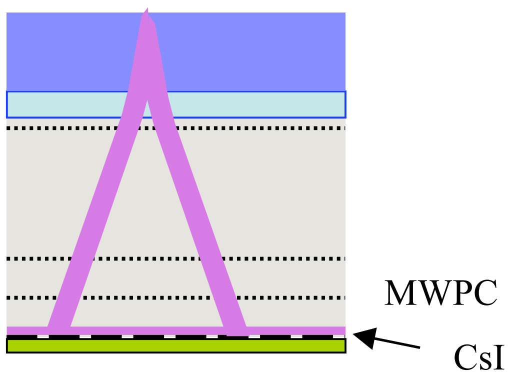
R. Arnold et al, Nucl. Instr. and Meth. A270(1988)255

DEVELOPMENT OF SOLID PHOTOCATHODES:

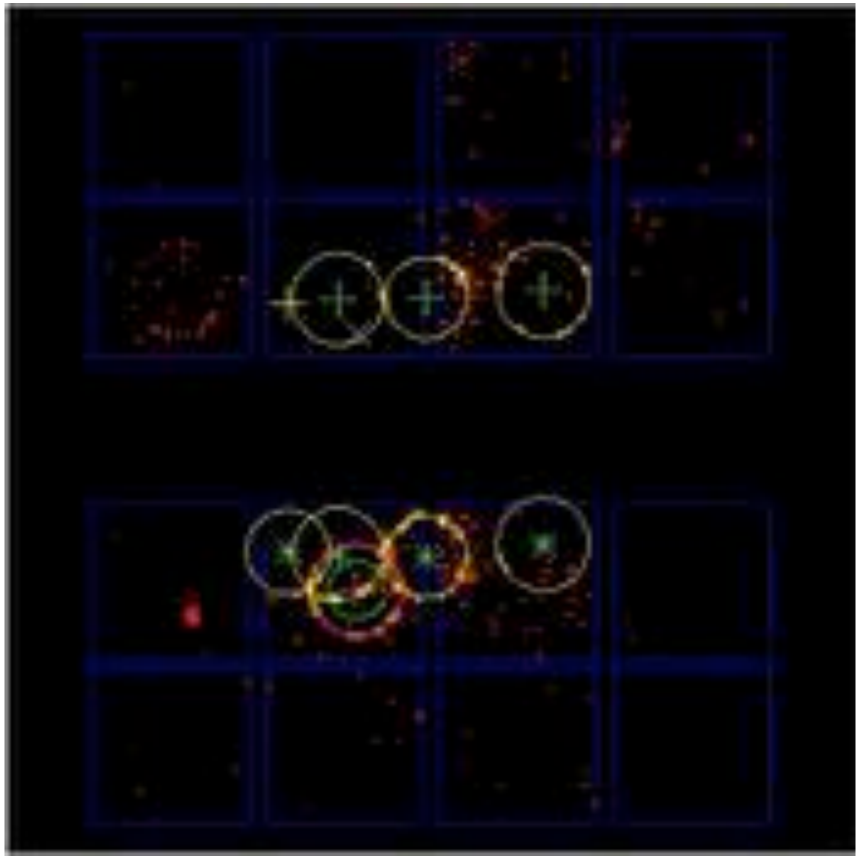


A. Breskin et al, Nucl. Instrum. Methods A483(2001)670

PROXIMITY FOCUSING MWPC
WITH CsI PHOTOCATHODES:



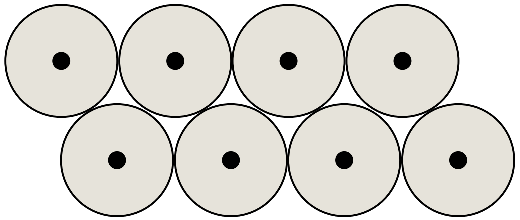
COMPASS RICH:



E. Albrecht et al,
Nucl. Instr. and Meth. A502(2003)112

STRAWS AND DRIFT TUBES

M. Bellomo et al,
Nucl. Instr. and Meth. A573(2007)340



E. Stanecka, Nucl. Instr. and Meth. A581(2007)295

PARALLEL PLATE CHAMBER WITH HIGH RESISTIVITY ELECTRODES:

R. Santonico and R. Cardarelli, Nucl. Instr. and Meth. A263(1988)20

RPC PERFORMANCES:	
Localization	2-10 mm
Two-track resolution	10-20 mm
Rate capability	10^3 $cm^{-2}s^{-1}$
Size	10 m^2

CMS BARREL RPCs

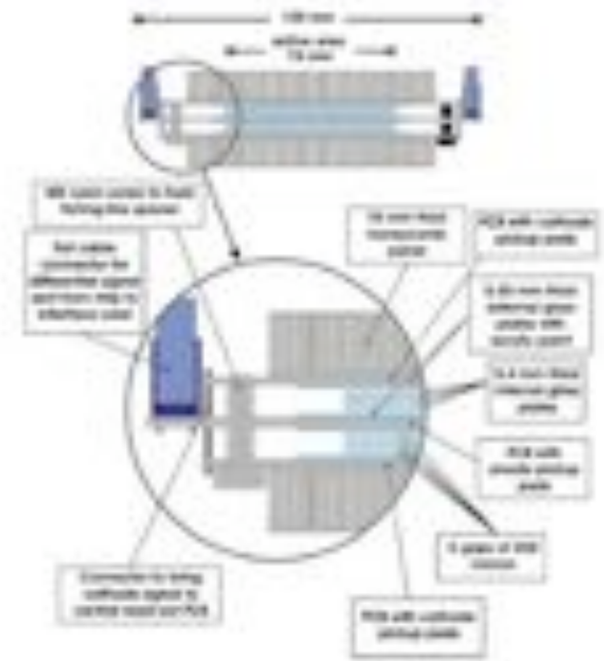
MULTIGAP RESISTIVE PLATE CHAMBER

NARROW GAP PARALLEL PLATE COUNTERS

HV

HIGH RESISTIVITY GLASS
~ 10^{13} Ω cm^{-1}

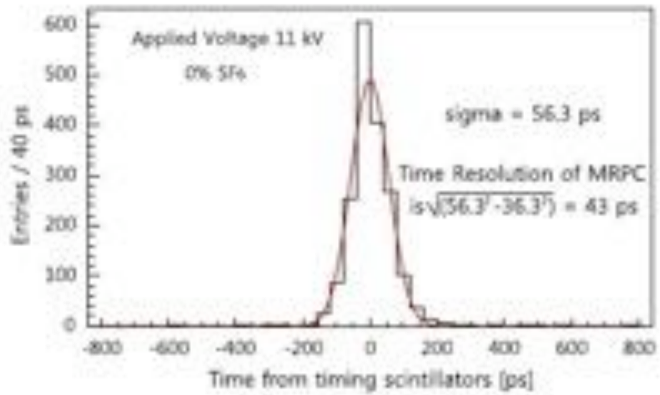
GND



E. Cerron Zeballos et al, Nucl. Instr. and Meth. A396(1997)93

ALICE TIME OF FLIGHT MODULE:

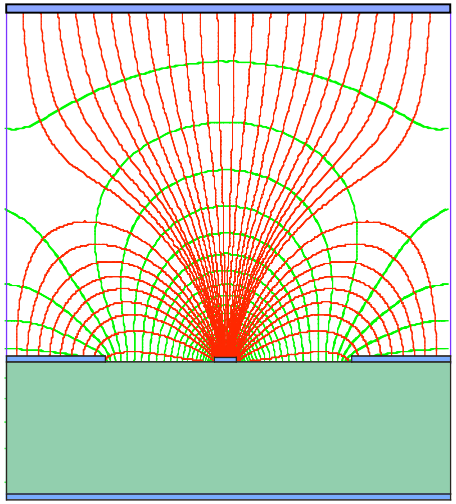
TOF RESOLUTION ~ 50 ps



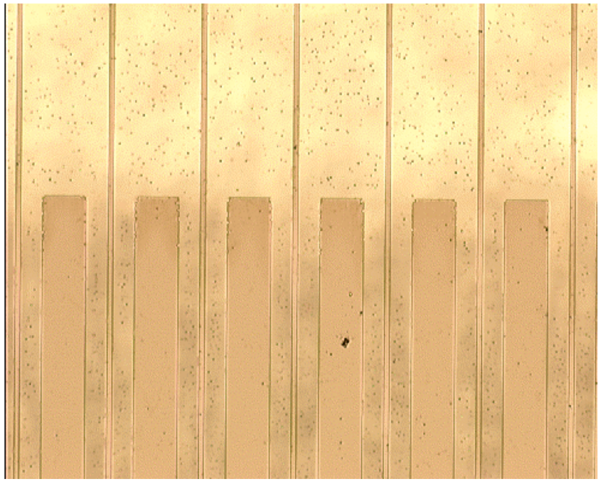
A. Akindinov et al, Nucl. Instr. and Meth. A 615 (2010) 37

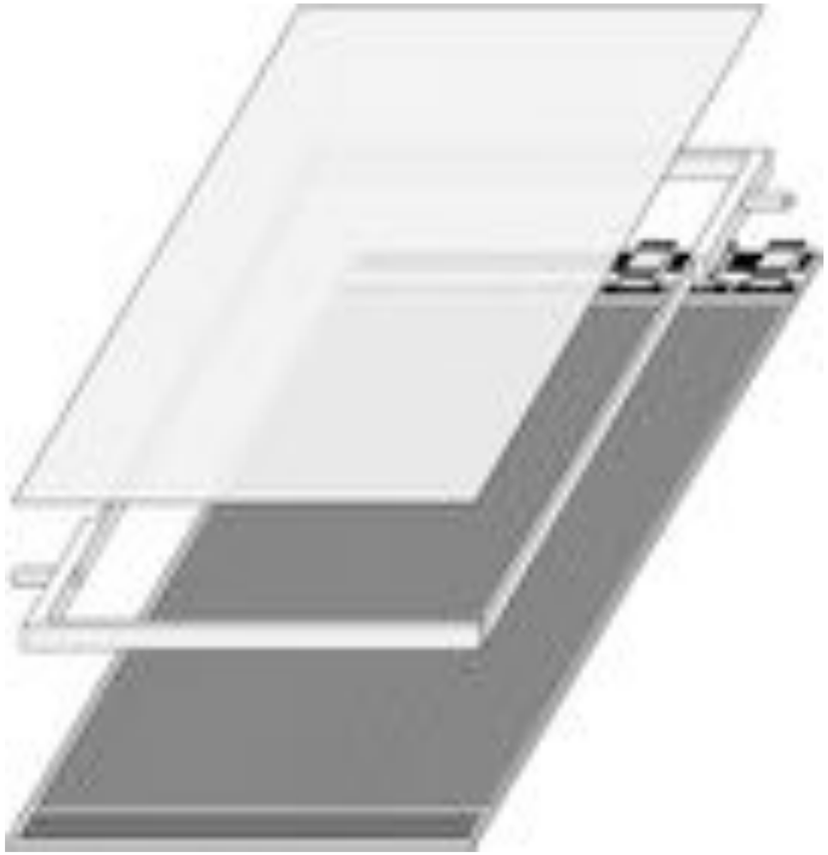
MICRO-STRIP GAS CHAMBER (MSGC)

MSGC: THIN METAL STRIPS ON GLASS



LIGHT AND COMPACT DETECTORS:

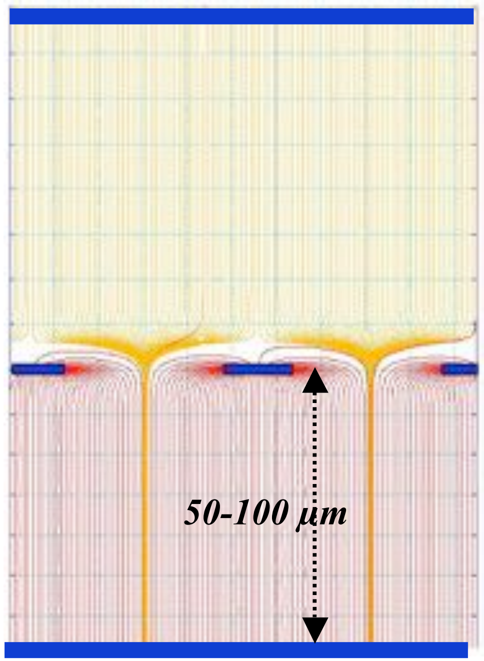


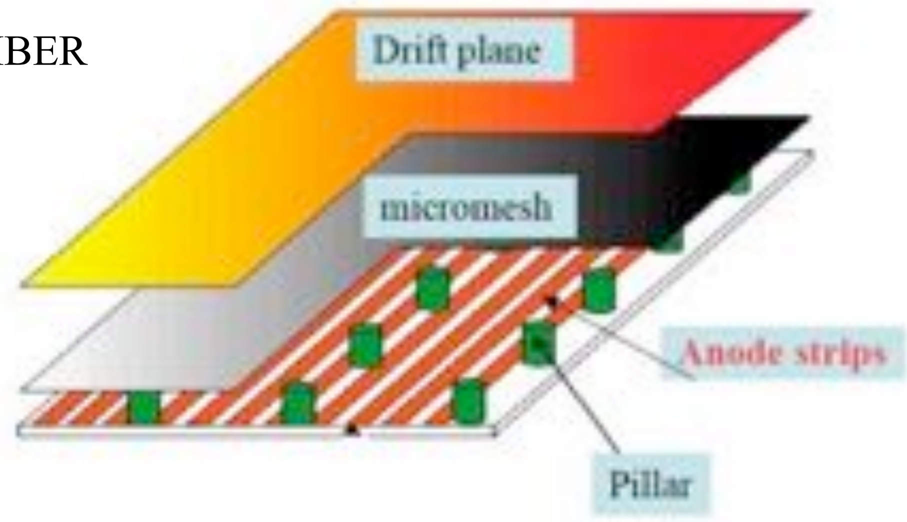


A.Oed, Nucl. Instr. and Meth. A263(1988)351

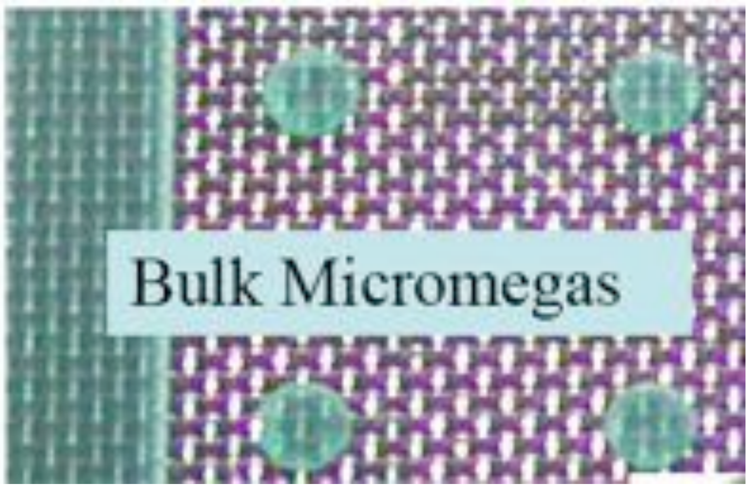
A. Barr et al, Nucl. Instr. and Meth. A392(1997)99

NARROW-GAP PARALLEL PLATE CHAMBER



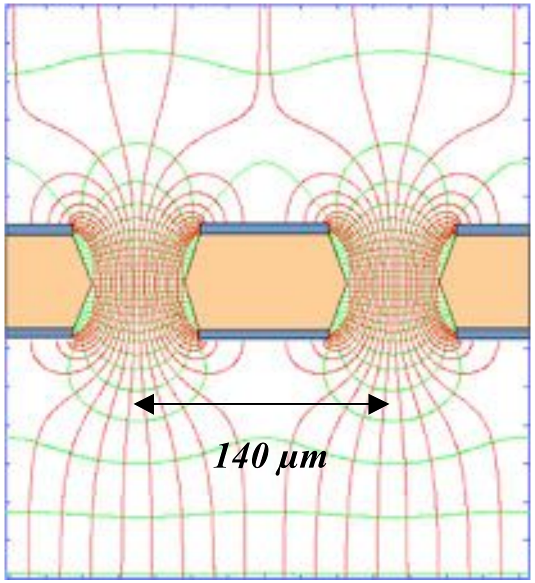


Y. Giomataris et al,
Nucl. Instr. and Meth. A376(1996)29

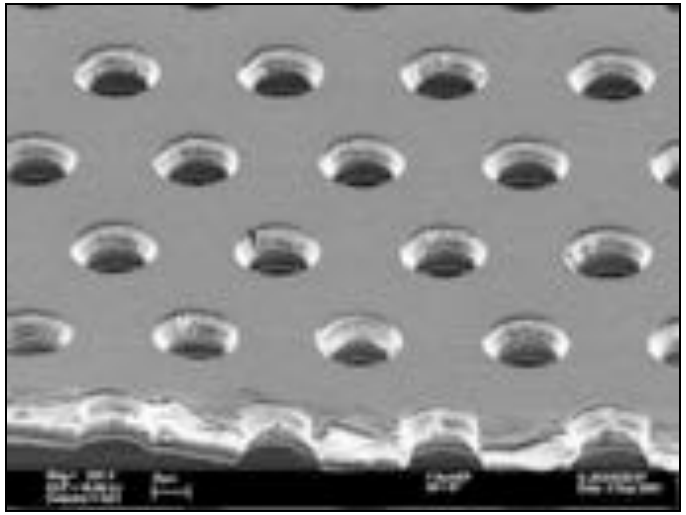


J. Bouchet et al, Nucl. Instr. and Meth. A574(2007)425

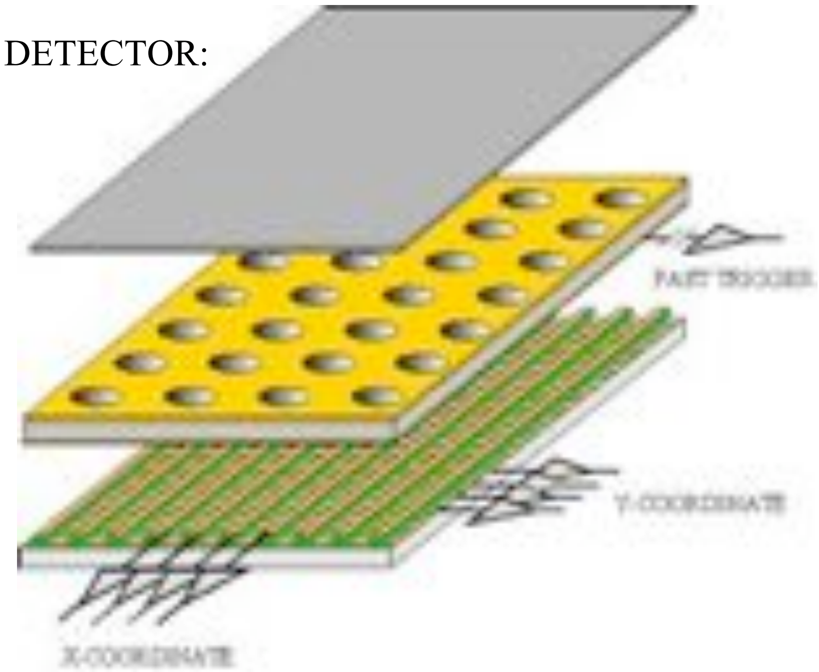
GEM:
GAS ELECTRON MULTIPLIER



50 µm Cu-clad kapton foils
with high density of holes

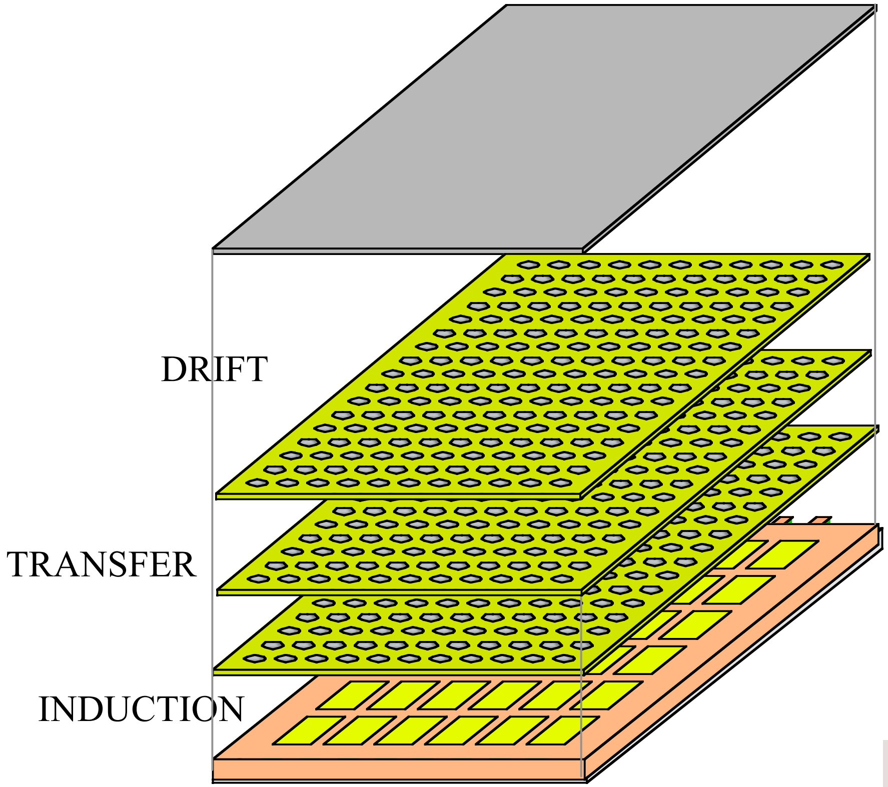


2-D GEM DETECTOR:

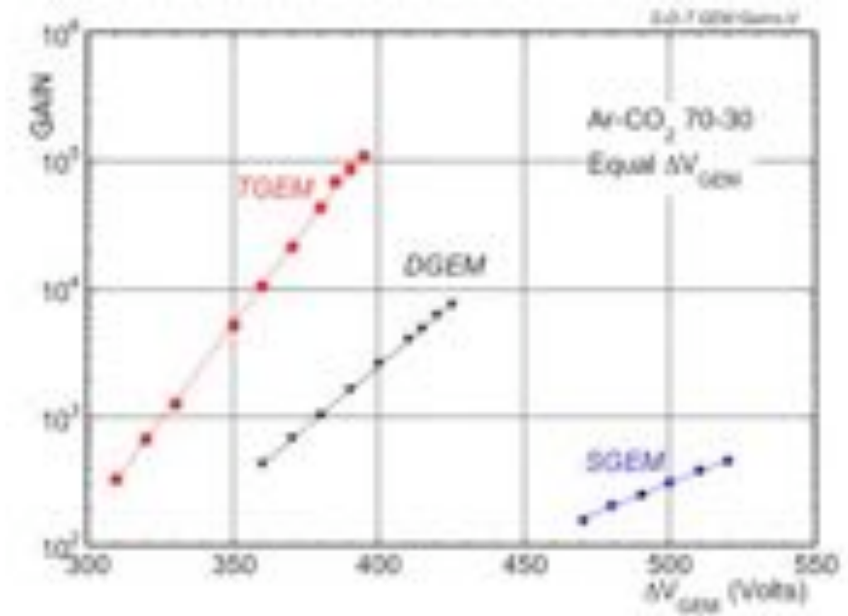


F. Sauli,
Nucl. Instr.and Meth. A386(1997)531

GEM FOILS MOUNTED IN CASCADE:
- HIGHER TOTAL GAIN
- LOWER VOLTAGE GRADIENT ON EACH FOIL

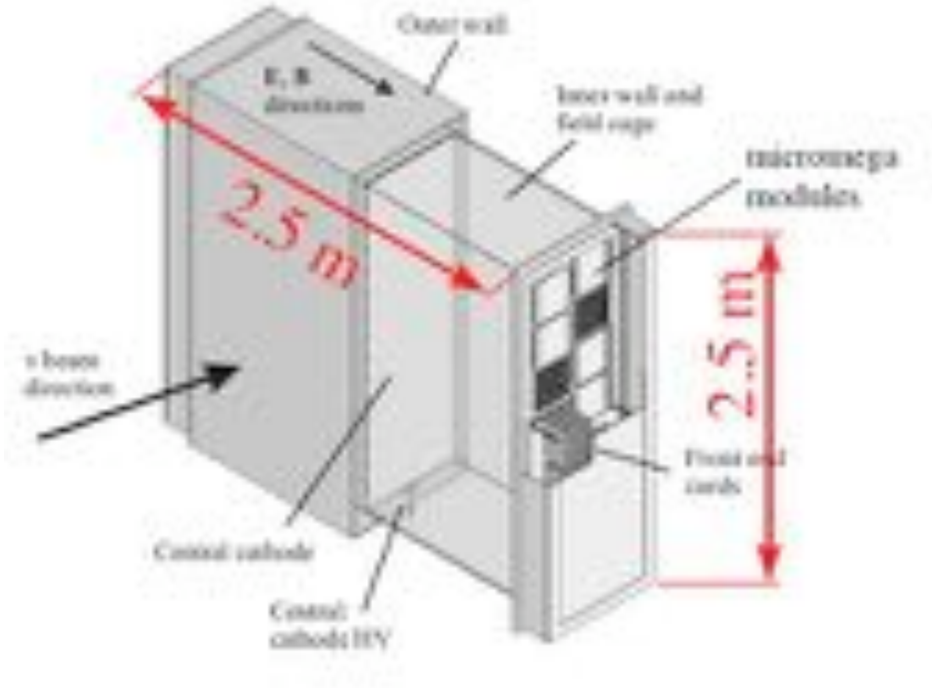


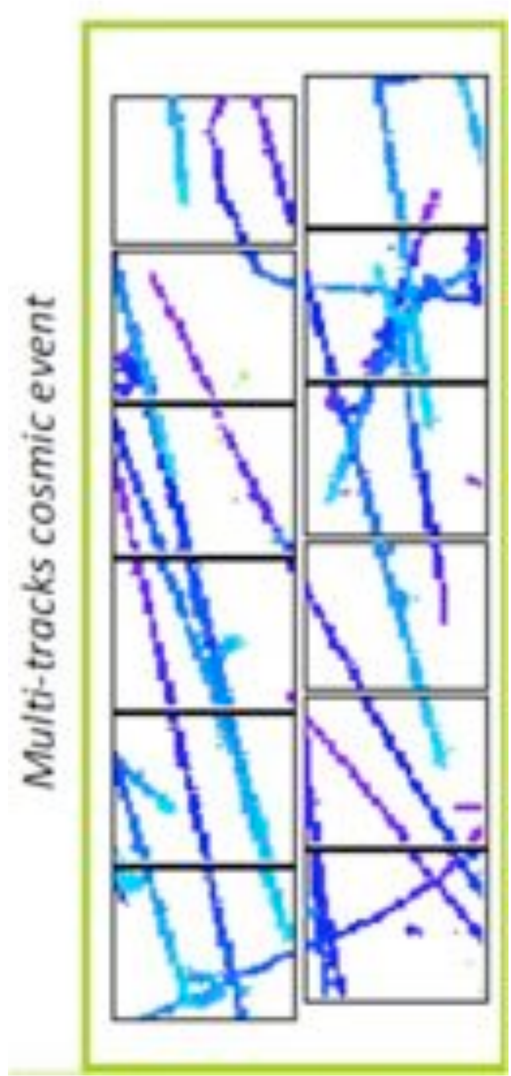
SINGLE, DOUBLE AND TRIPLE GEM GAIN



C. Büttner et al, Nucl. Instr. and Meth. A409(1998)79

MICROMEGAS TPC FOR T2K (KEK)

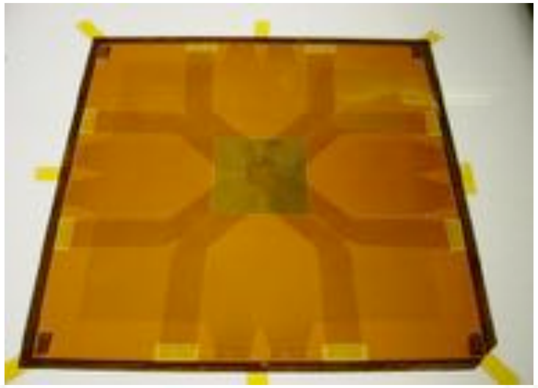


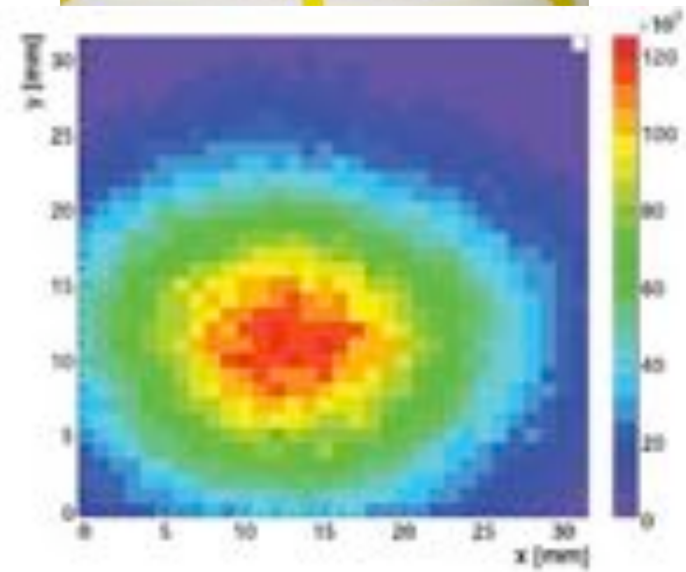


A. Delbart et al, Nucl. Instr. and Meth. A623(2010)105

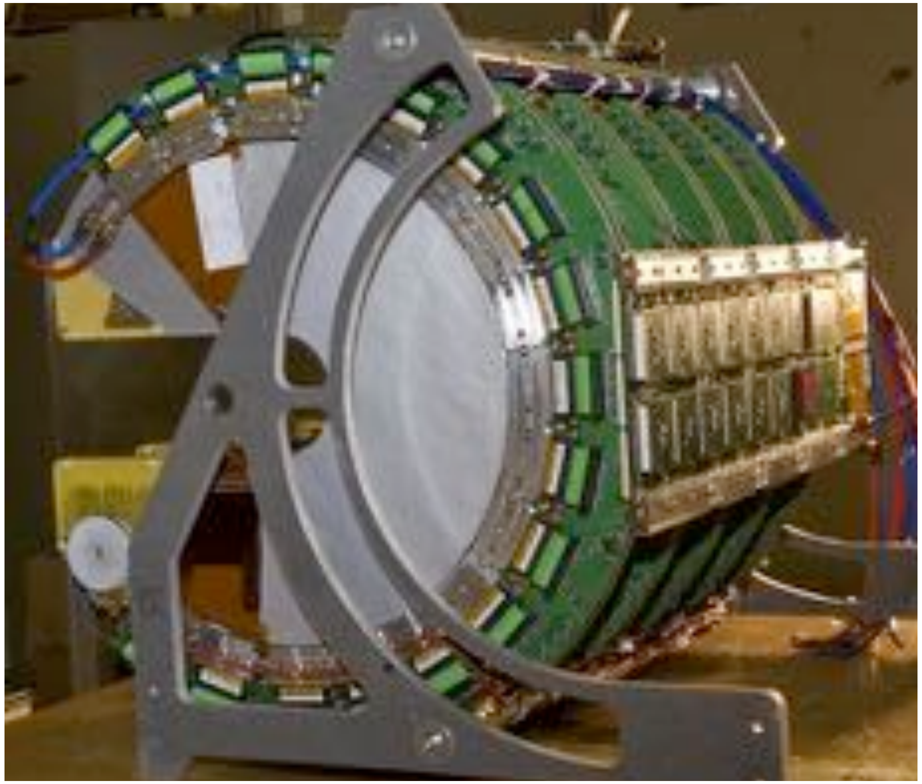
MPGD EXAMPLES: GEM

COMPASS UPGRADE:
GEM WITH PIXEL AND STRIPS READOUT





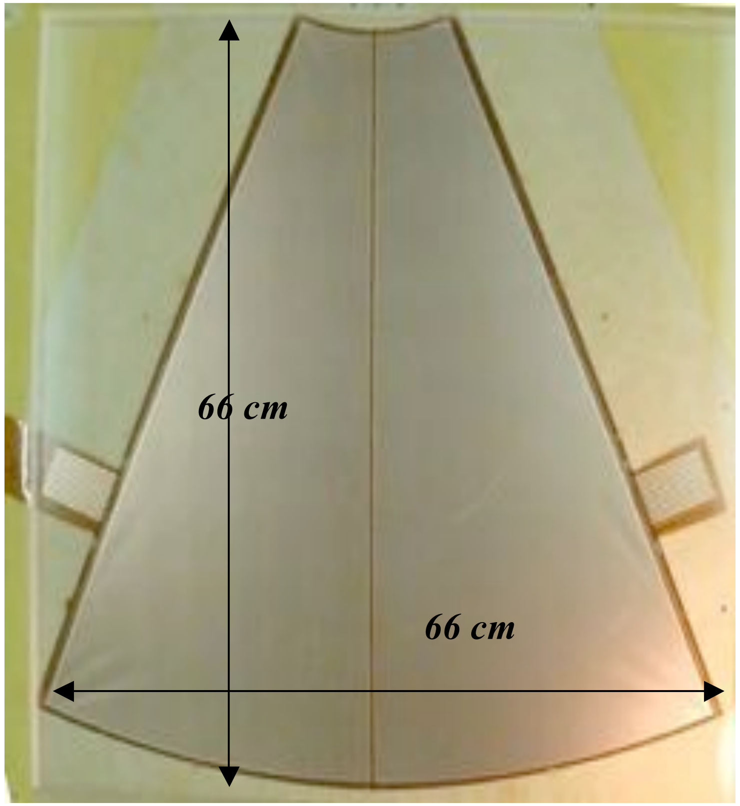
TOTEM GEM TRIGGER-TRACKER TELESCOPE



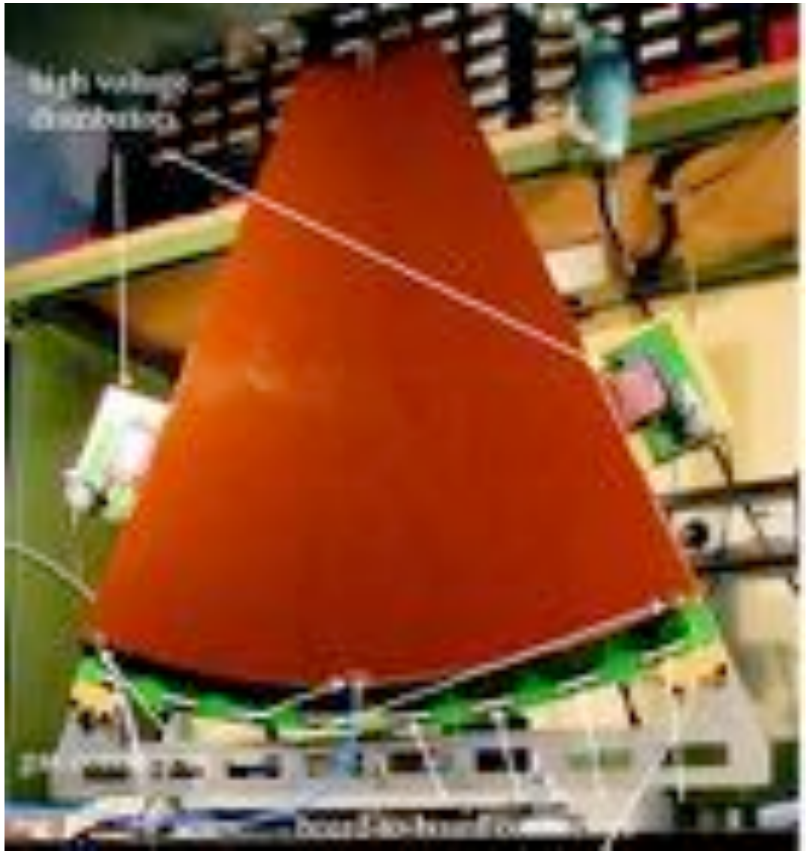
B. Ketzer et al, IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, 19-25 Oct. 2008)

M.G. Bagliesi et al, Nucl. Instr. and Meth. A617(2010)313

LARGE GEM FOILD SPLICED TOGETHER:



M. Alfonsi et al,
Nucl. Instr. and Meth. A617(2010)151

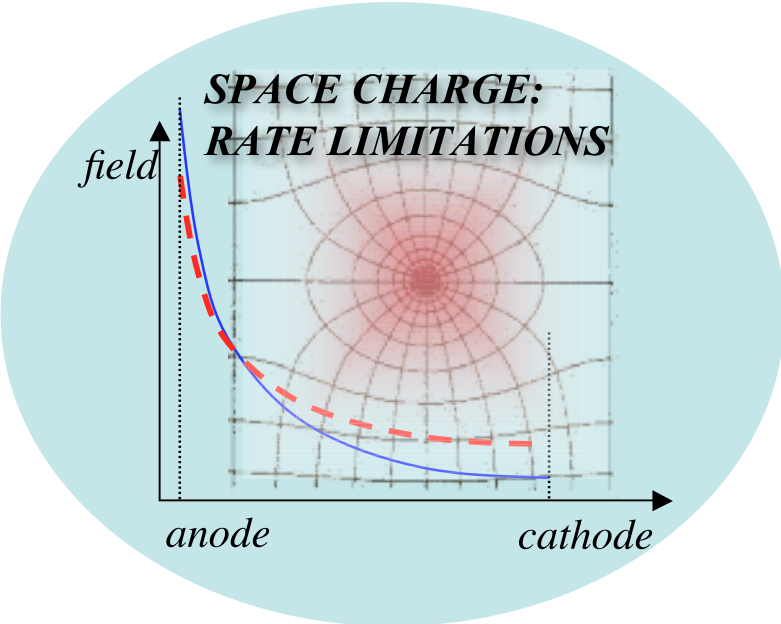


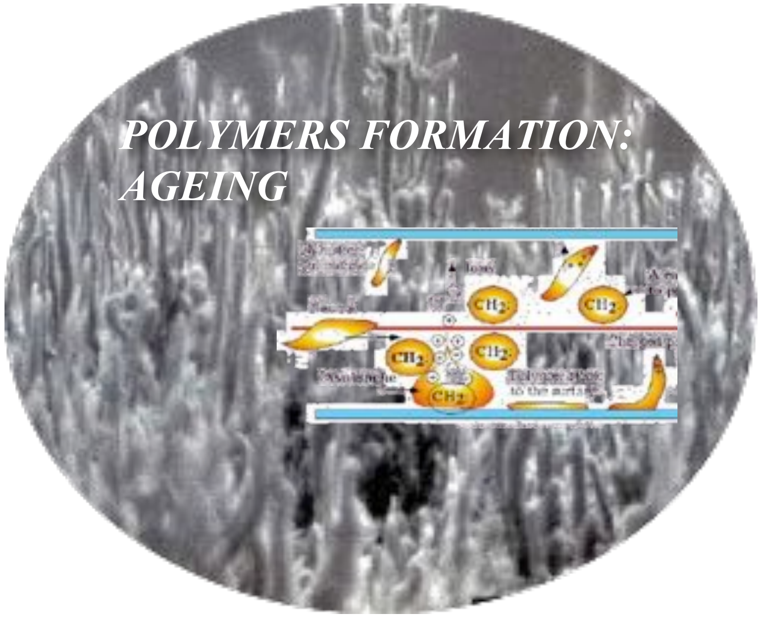
UNDER STUDY FOR CMS HIGH ETA UPGRADE

MPGD PERFORMANCES:

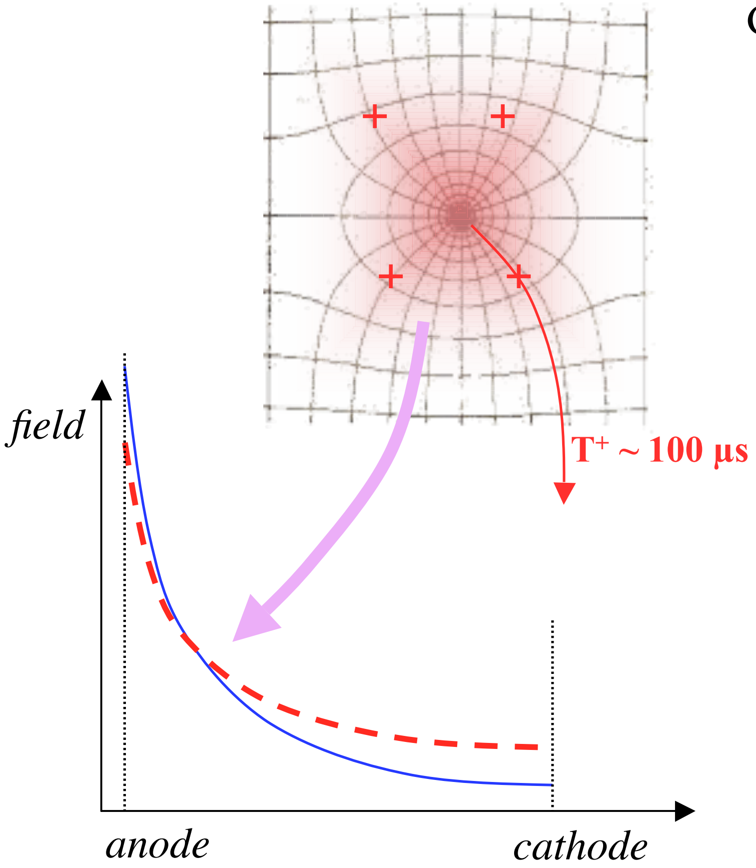
Localization	50-100 µm
Two-track resolution	1 mm
Rate capability	10^6 $cm^{-2}s^{-1}$
Size	1 m^2

THE THREE ENDEMIC DISEASES OF GASEOUS DETECTORS

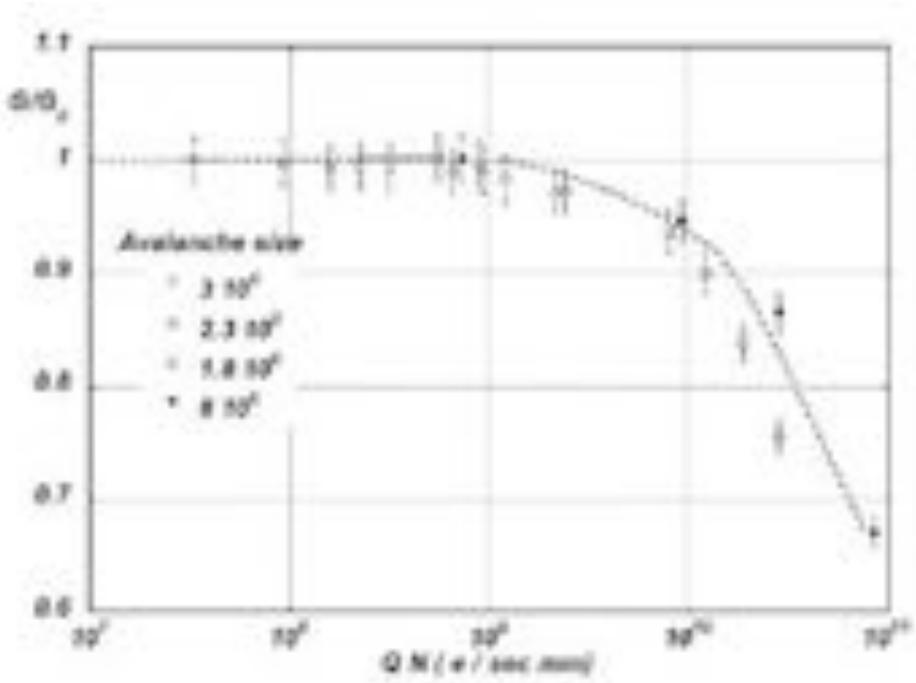




SLOW IONS ACCUMULATION IN THE DRIFT VOLUME
Typical ions collection time:
100 µs (MWPC) to 100 ms (TPC)



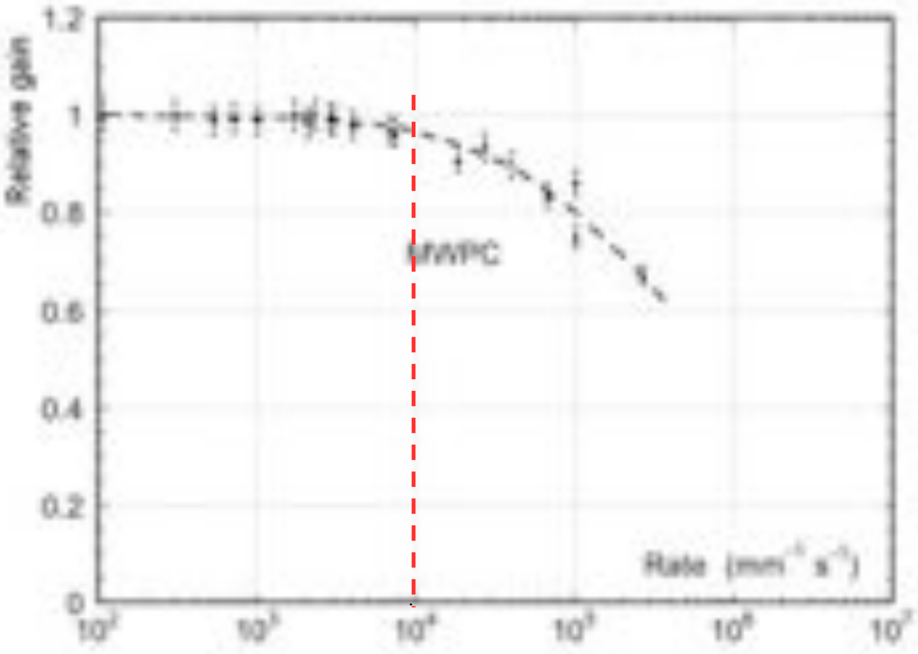
GAIN REDUCTION VS CHARGE PRODUCTION RATE:



H. A. Walenta, Phys. Scripta 23 (1981) 354

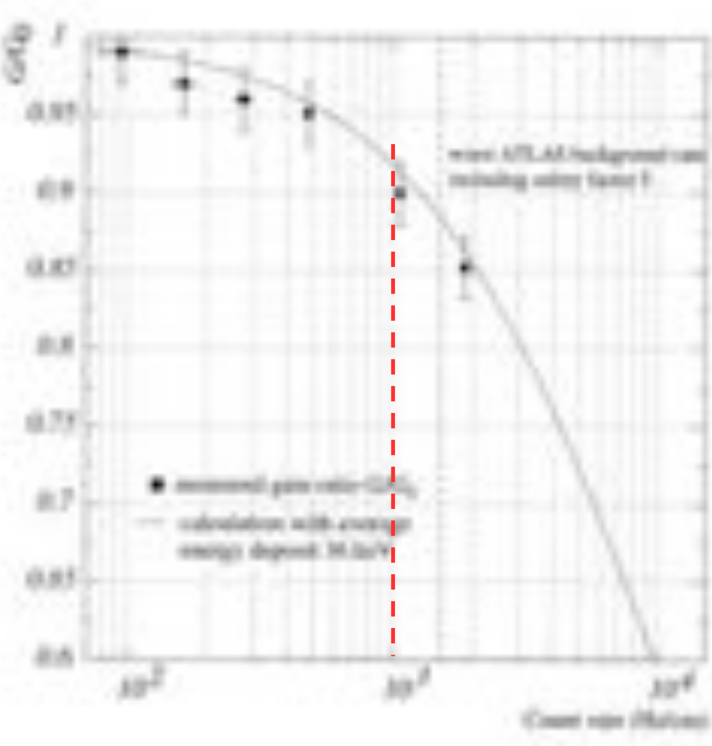
GAIN REDUCTION WITH PARTICLE RATE

MWPC (1975):



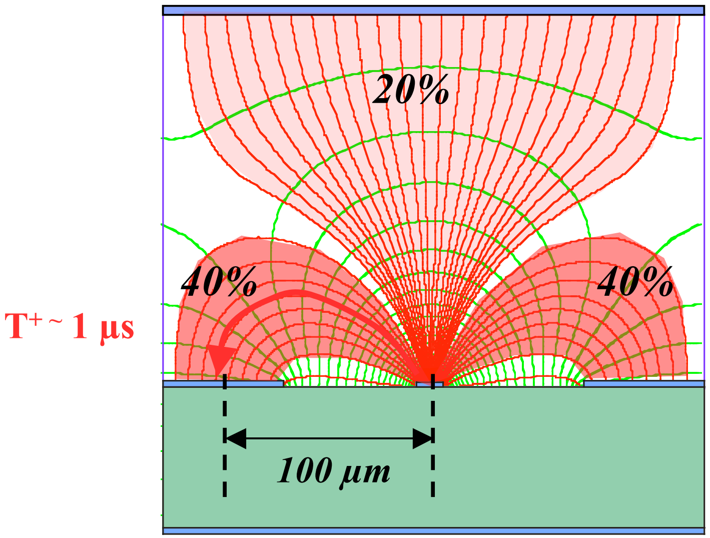
G. Charpak et al, Nucl. Instr. and Meth. 124(1975)183

ATLAS MONITORED DRIFT TUBES (2000):



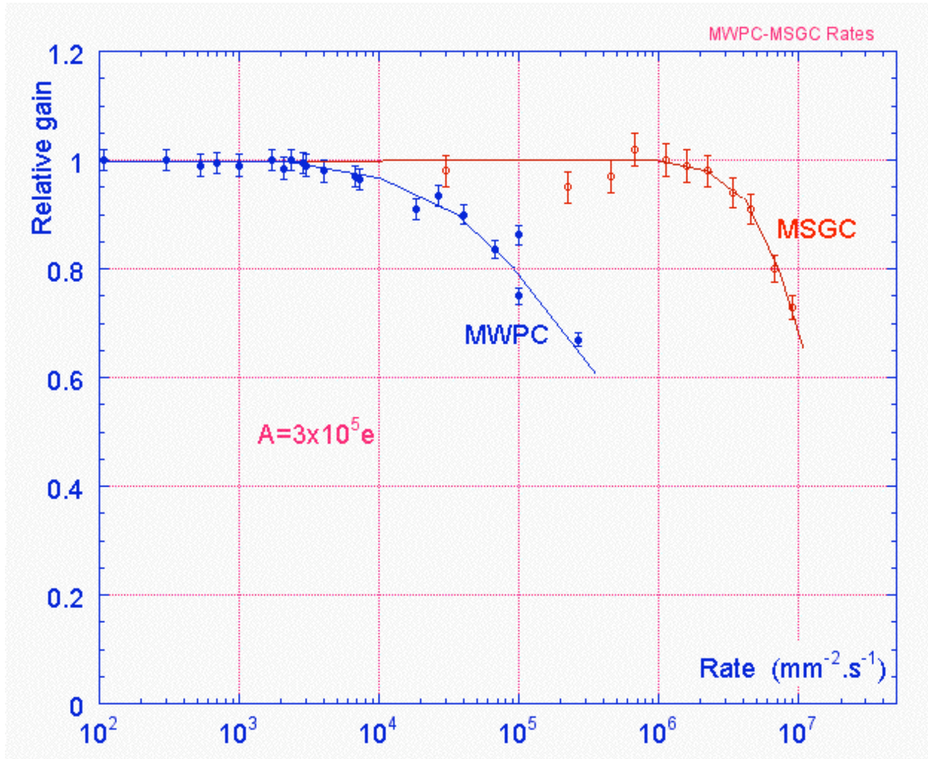
M. Aleksa et al,
Nucl. Instr. and Meth. A446 (2000)435

MSGC: FRACTIONAL ION COLLECTION ON ELECTRODES



J. J. Florent et al,
Nucl. Instr. and Meth. A329 (1993) 125

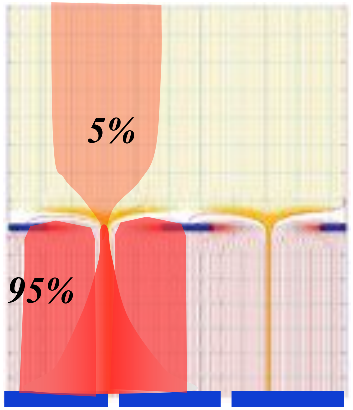
EFFICIENCY VS RATE: MSGC VS MWPC



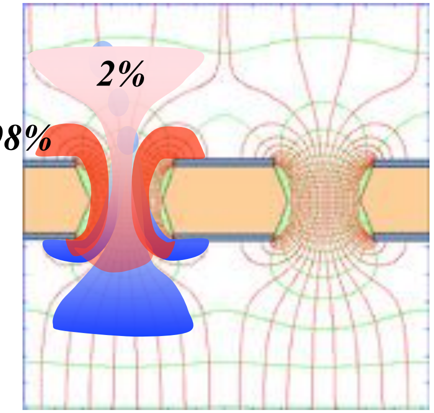
R. Bouclier et al,
Nucl. Instr. and Meth.A367(1995)168

FRACTIONAL ION COLLECTION ON ELECTRODES

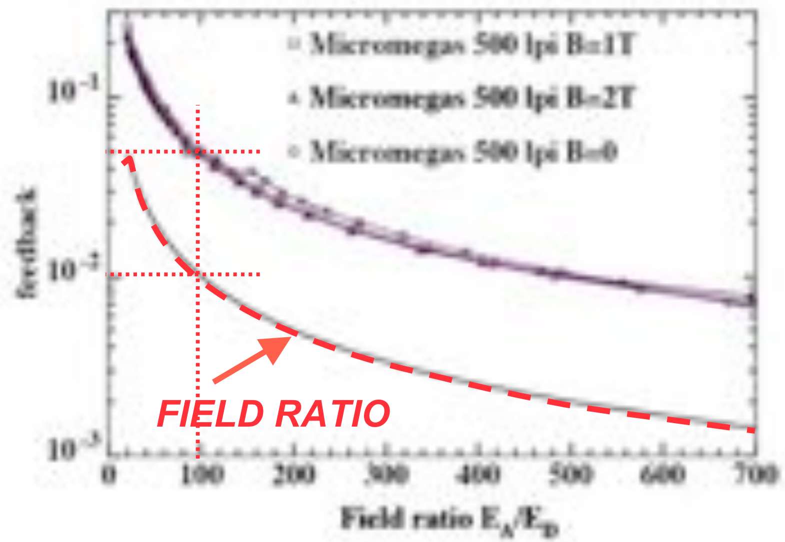
MICROMEGAS



GEM

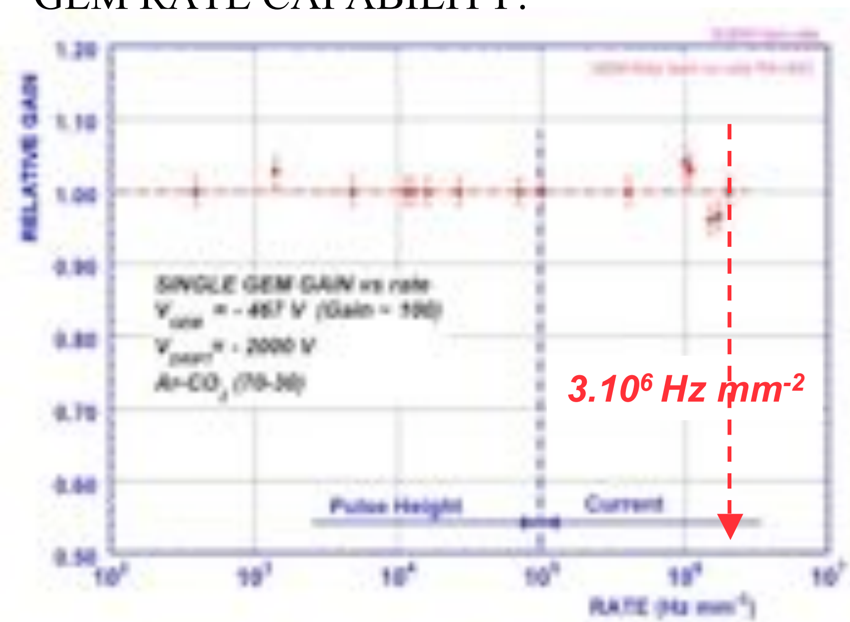


$T^{+} < 1\ \mu s$



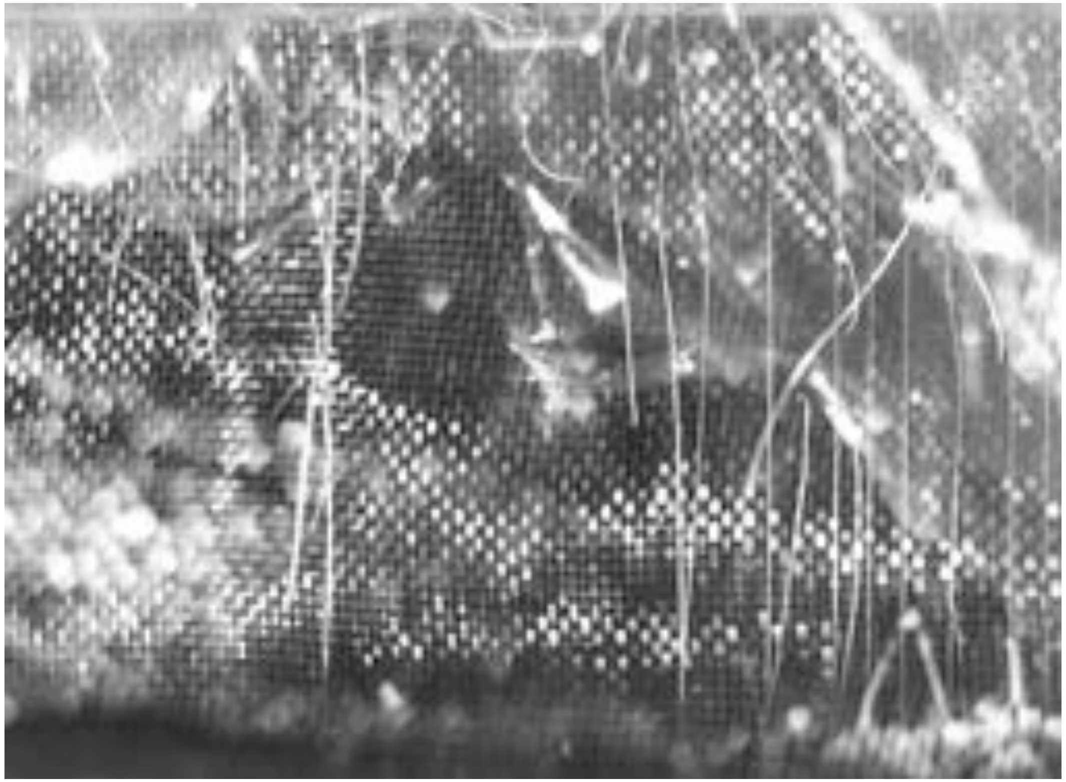
P. Colas et al, Nucl. Instr. and Meth. A535(2004)226

GEM RATE CAPABILITY:



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

MWPC DISCHARGE DAMAGES



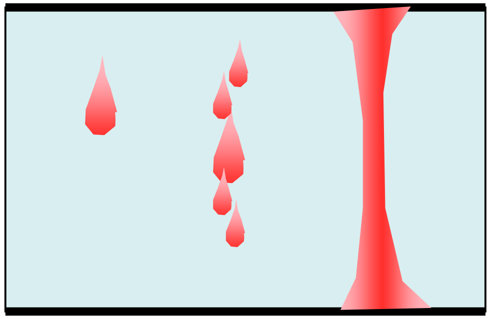
AMOS THERMODYNAMICS EXPERIMENT

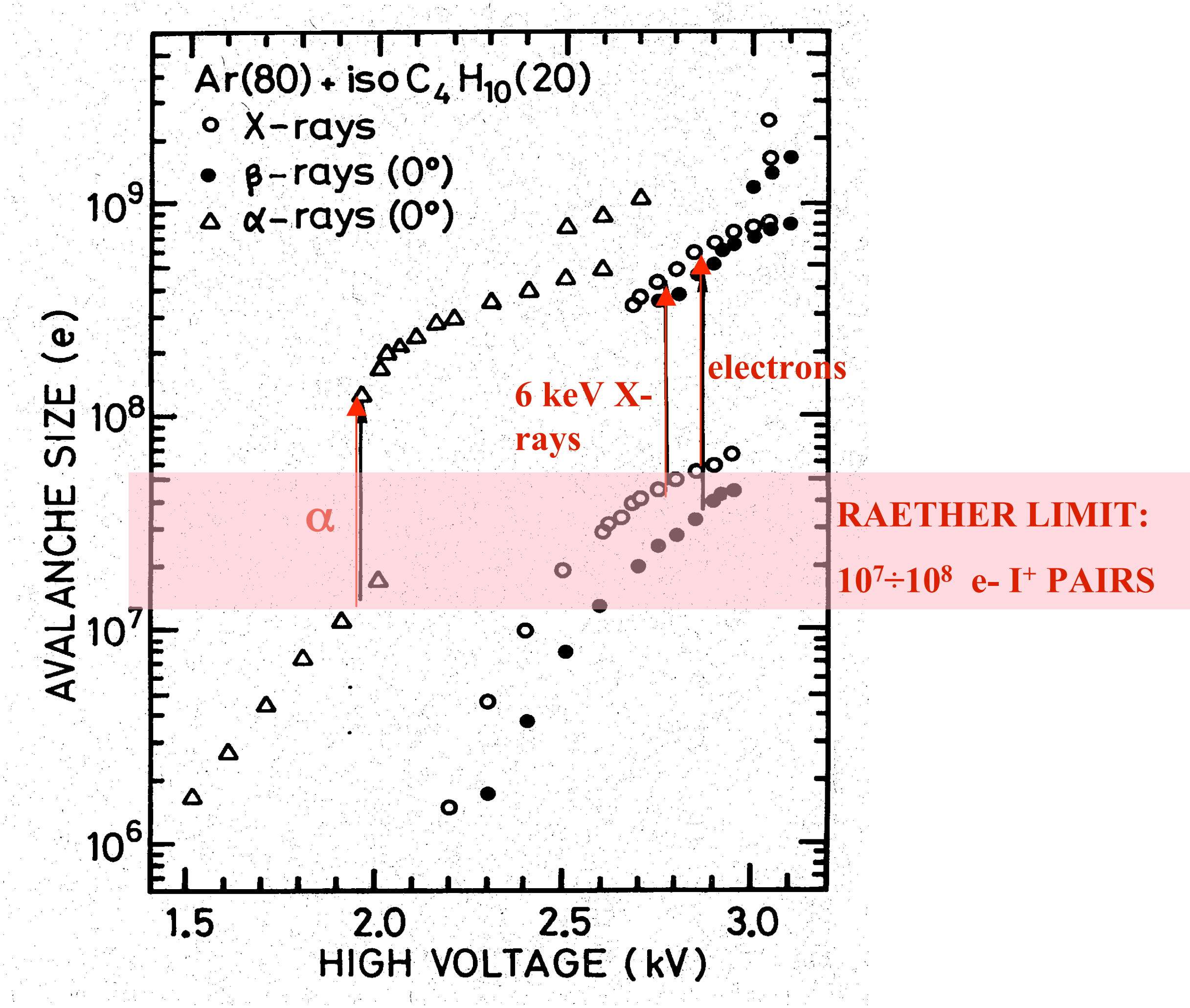
A. Breskin et al, 1973 (Unpublished)

AVALANCHE

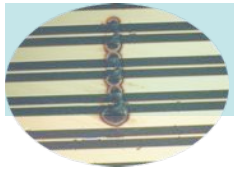
STREAMER

DISCHARGE)



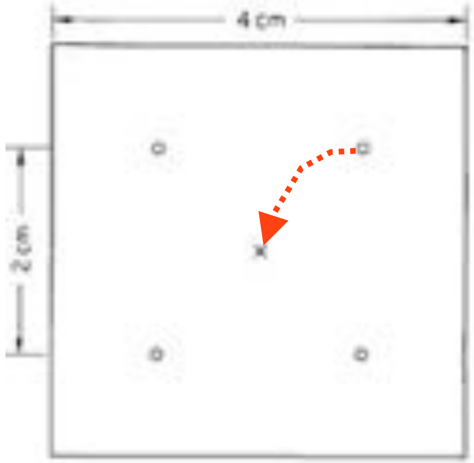


N. Koori et al Jap.J.Appl. Phys. 25 (1986) 986



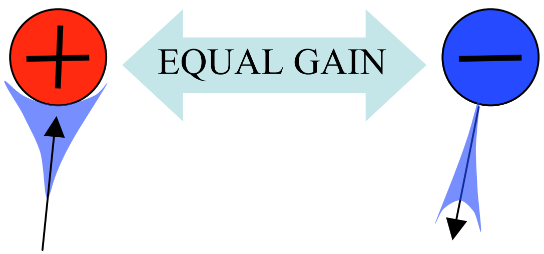
THE RAETHER LIMIT: MWPC DISCHARGES

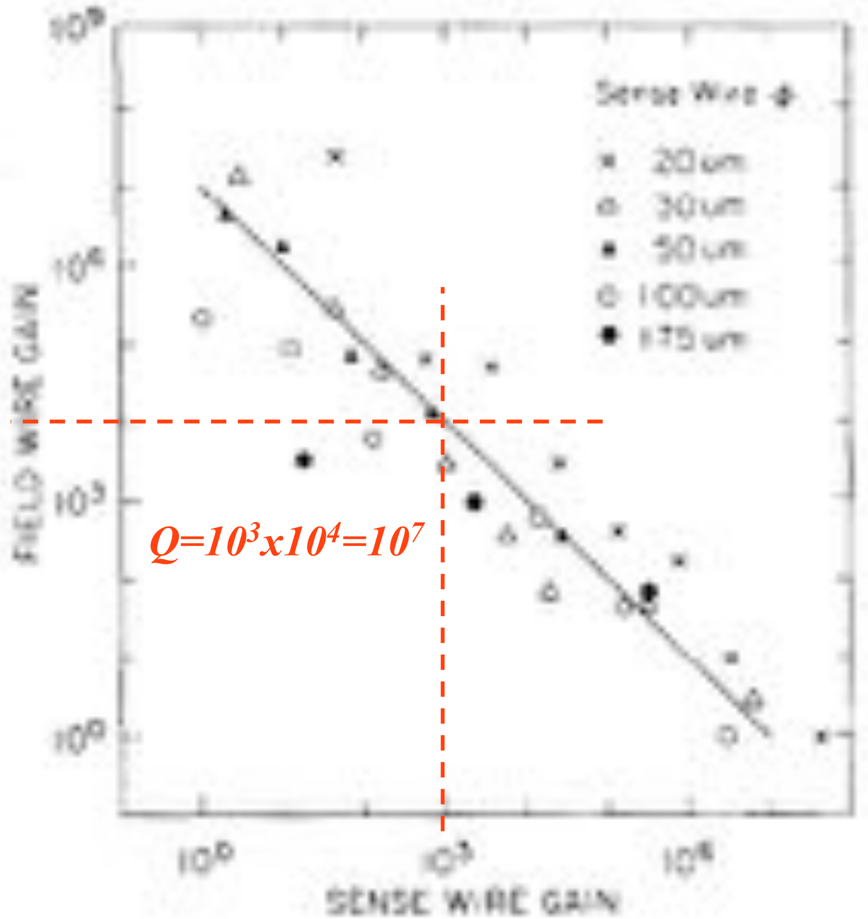
MAXIMUM GAIN IN MWPC:
PRODUCT OF CATHODE AND ANODE AVALANCHE MULTIPLICATION



ANODE
normal avalanche

CATHODE
reverse avalanche





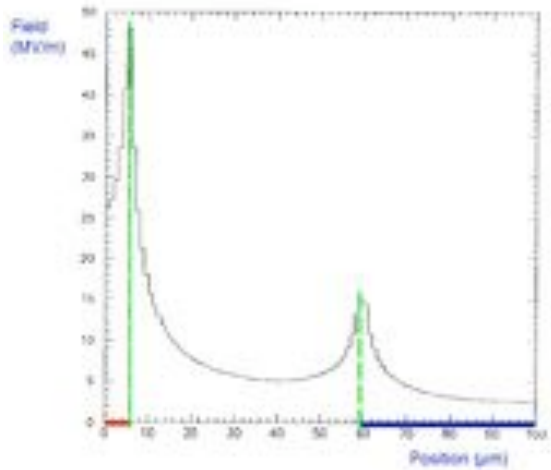
P. Giubellino et al, Nucl. Instr. and Meth. A245(1986)155

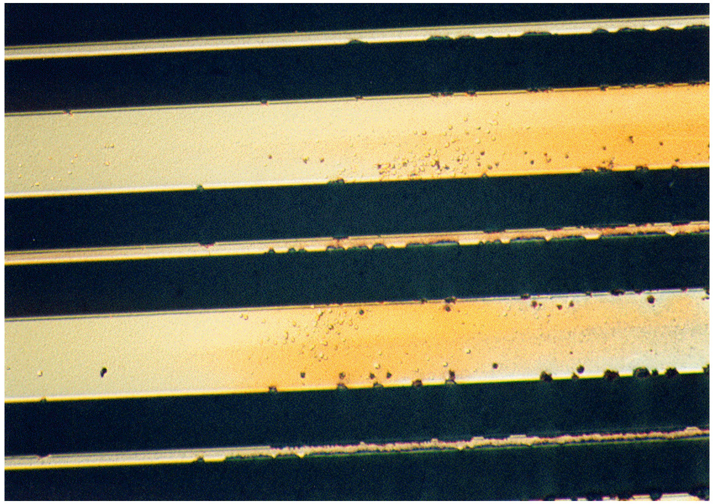
LIMIT TO CATHODE WIRE DIAMETER

DISCHARGES IN MICROSTRIP GAS COUNTERS

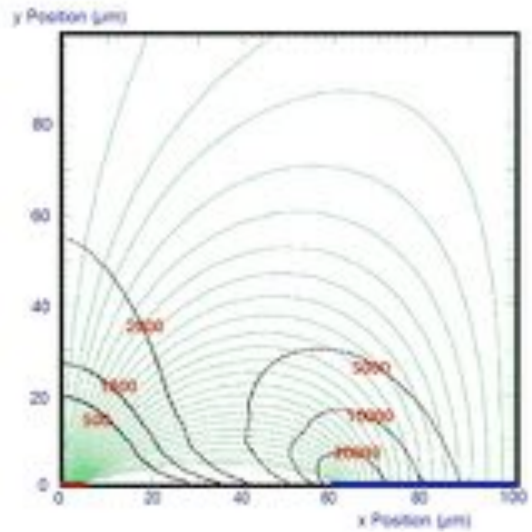
DISCHARGE DAMAGES IN MSGC:

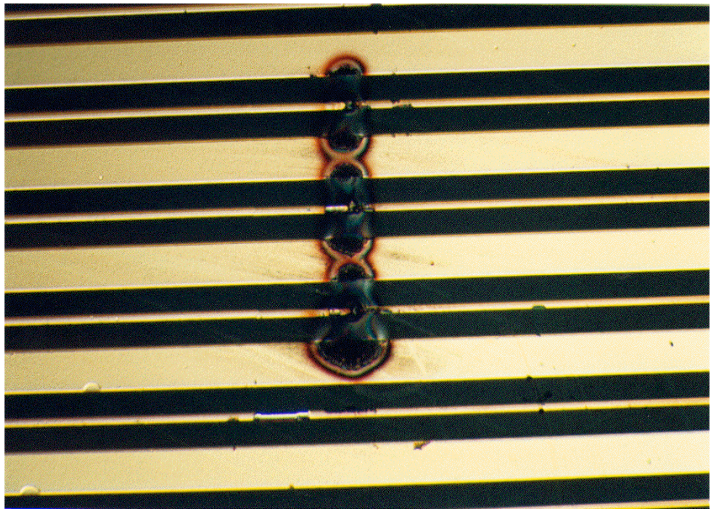
HIGH FIELD ON CATHODE STRIP EDGES: SECONDARY EMISSION



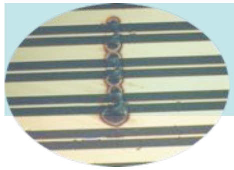


COMPUTED EQUAL GAIN LINES:



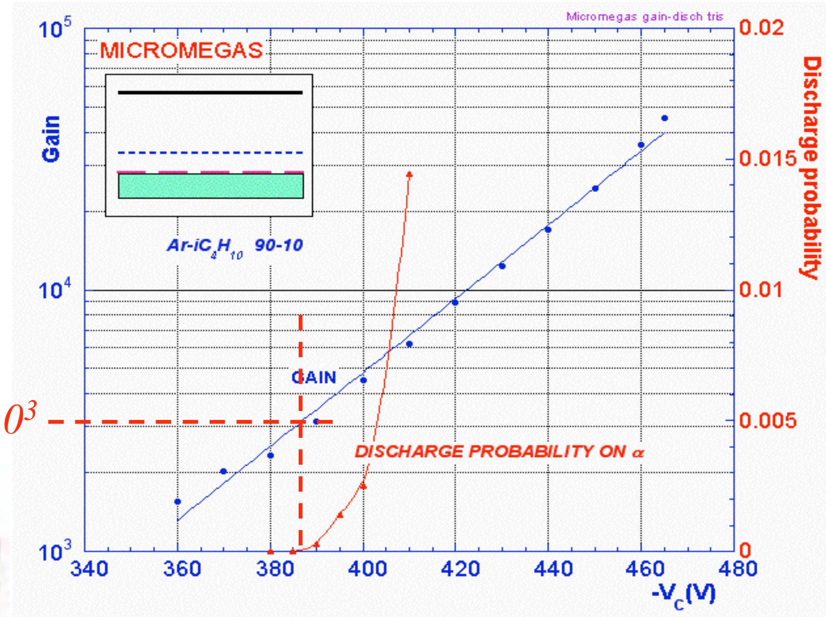


R. Bouclier et al, Nucl. Instr. and Meth. A365(1995)65



GAIN AND DISCHARGES IN MPGDs

MICROMEGAS:

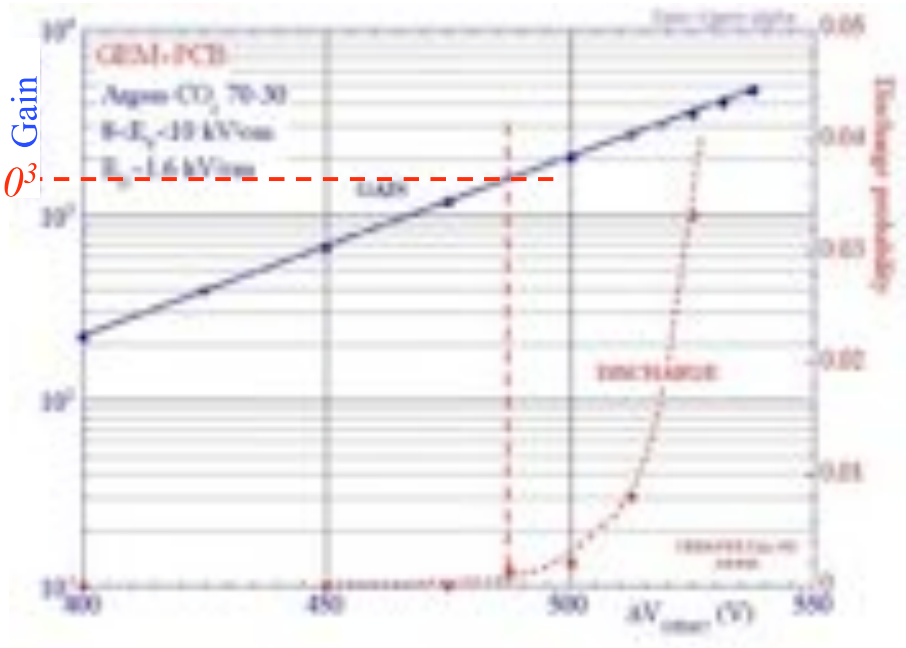


2 10^3

TEST PROCEDURE:
- GAIN VS VOLTAGE ON X-RAYS
- DISCHARGE VOLTAGE WITH INTERNAL HIGHLY IONIZING TRACKS

$^{220}Th \rightarrow {}^{220}Rn \rightarrow 6.4\ MeV\ \alpha$

GEM:



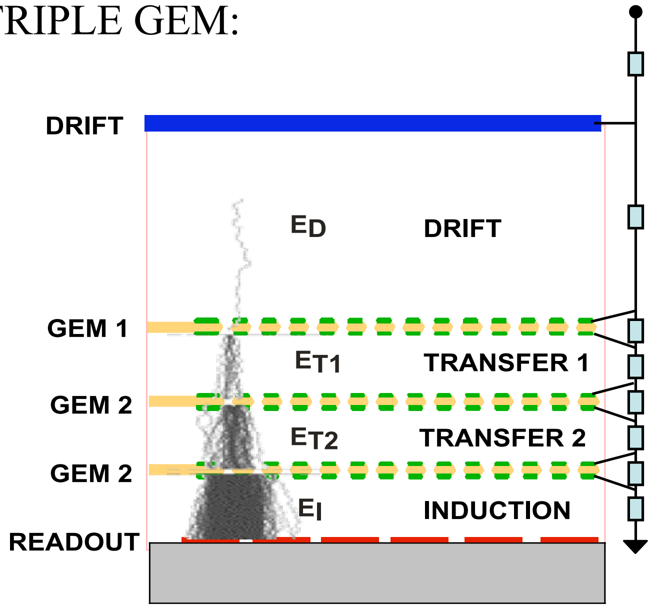
1.5 10^3

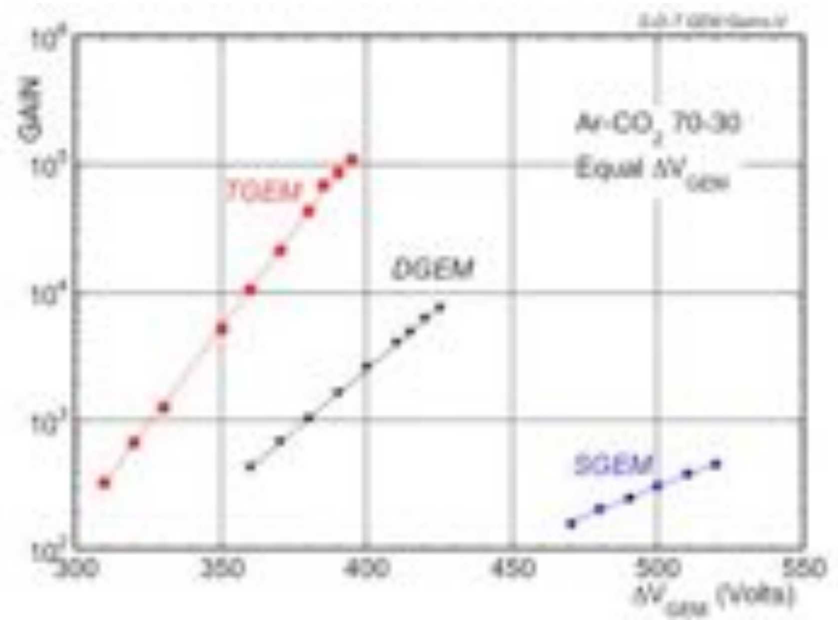
A. Bressan et al
Nucl. Instr. and Meth. A424(1999)321

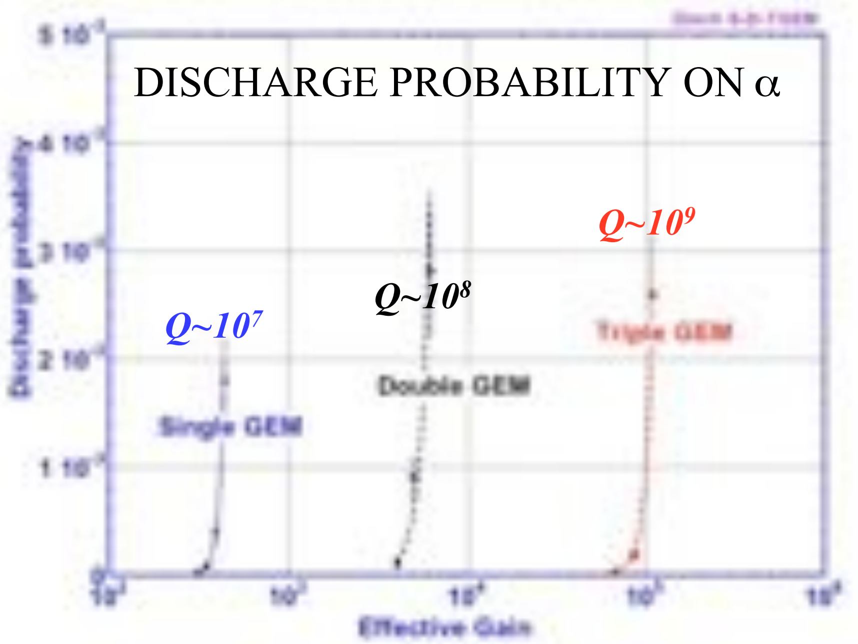
ΔE_α ~ 500 keV ~ 10^4 e

Q ~ 2×10^7 e

TRIPLE GEM:

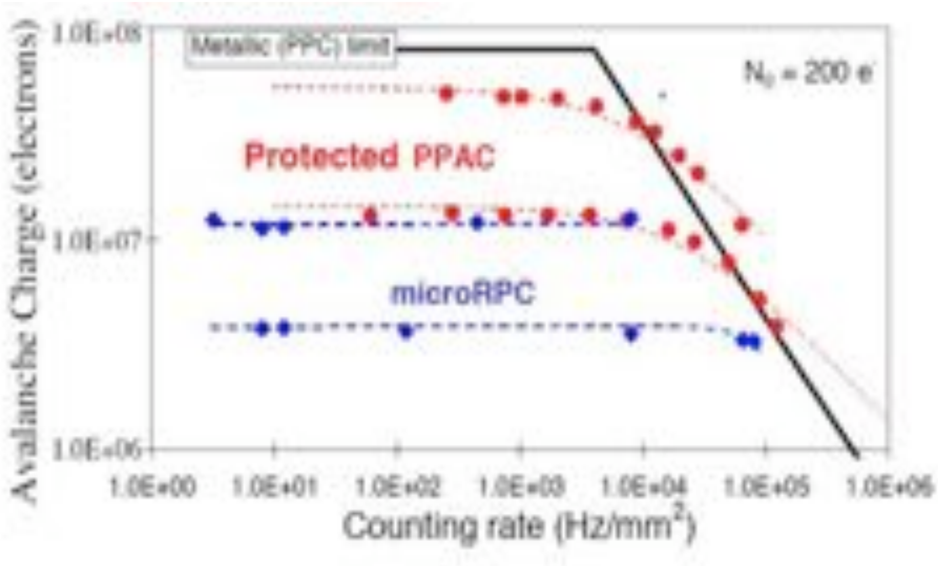






S. Bachmann et al, Nucl. Instr. and Meth. A479 (2002) 294

PARALLEL PLATE CHAMBERS (RPCs):
RATE DEPENDENCE OF DISCHARGE VOLTAGE

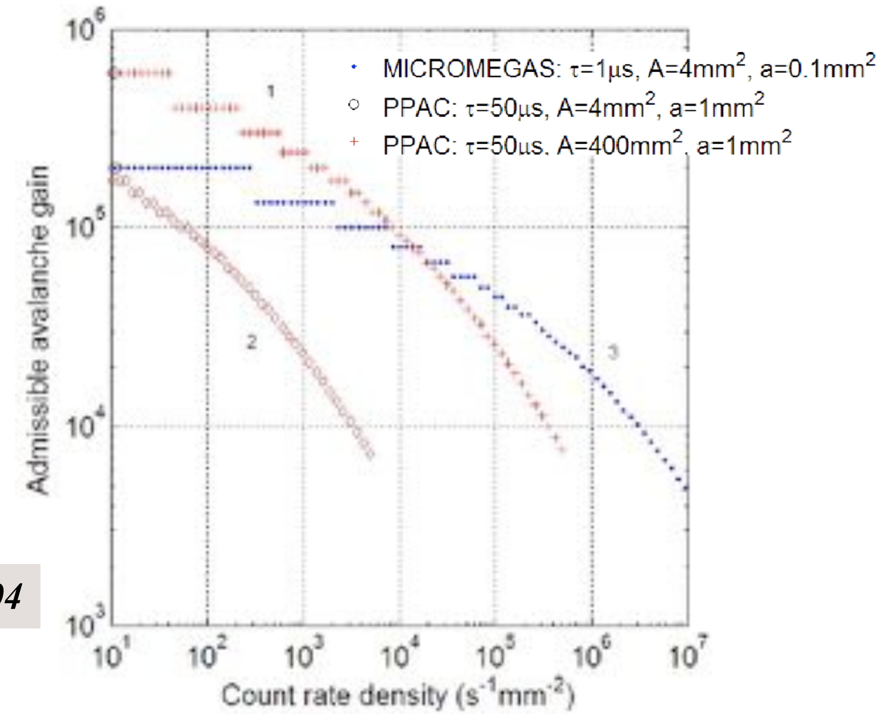


P. Fonte et al, Nucl. Instr. and Meth. A 431 (1999) 154

HOW CAN THE RAETHER LIMIT DEPEND ON RATE?

NAIVE CALCULATION:
Avalanche size ~1 mm^2
Ions clearing time ~1 µs
For R=10^5 Hz mm^{-2}:
Probability of two avalanches overlapping ~ 10%

(SERIOUS) STATISTICAL CALCULATION OF AVALANCHE OVERLAP PROBABILITY:



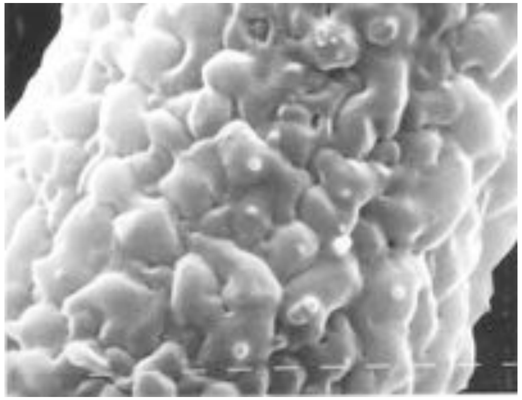
P. Fonte and V. Peskov, RD51 Note-2009-004

TIME DEGENERACY OF GASEOUS COUNTERS (AGING)

MWPC SINGLES COUNTING RATE (^{55}Fe source)

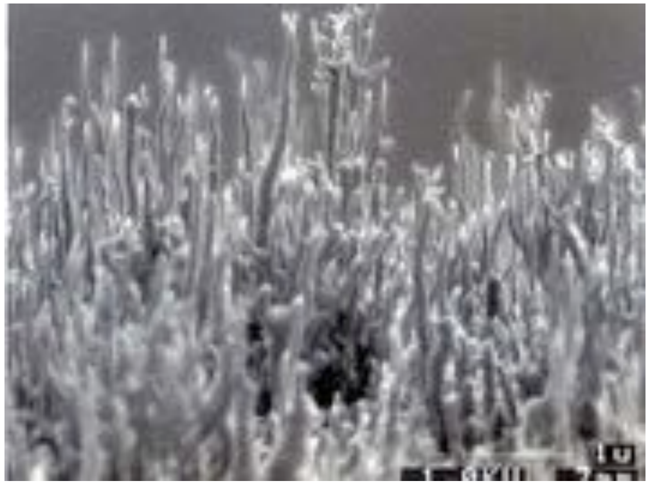
AFTER IRRADIATION WITH ~ 10^7 e/ cm^2 (^{90}Sr β source):

ORGANIC DEPOSITS

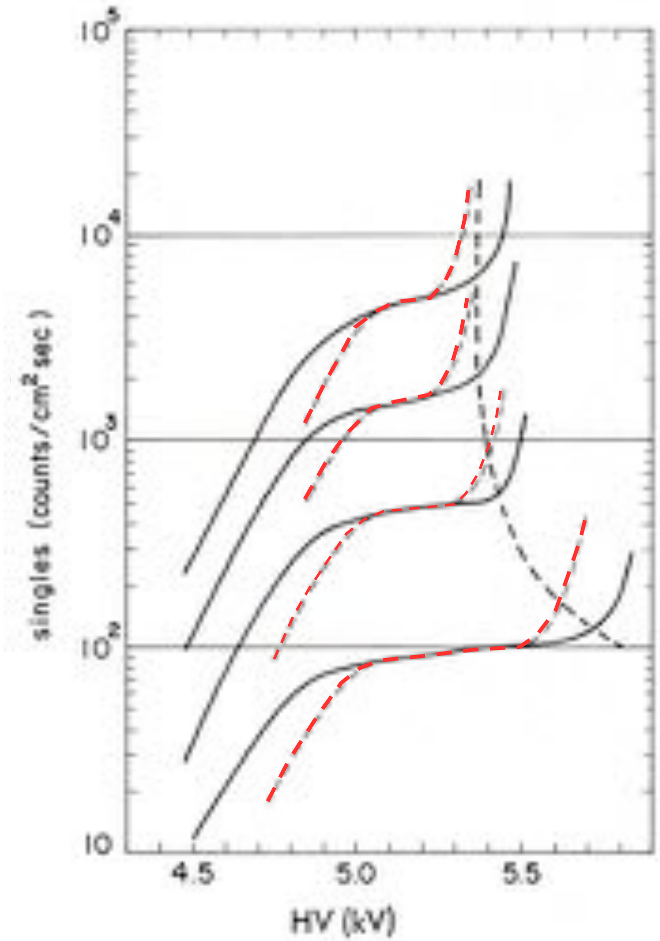


R. Kotthaus, Nucl. Instr. and Meth. A252(1986) 531

SILICON FILAMENTS GROWTH



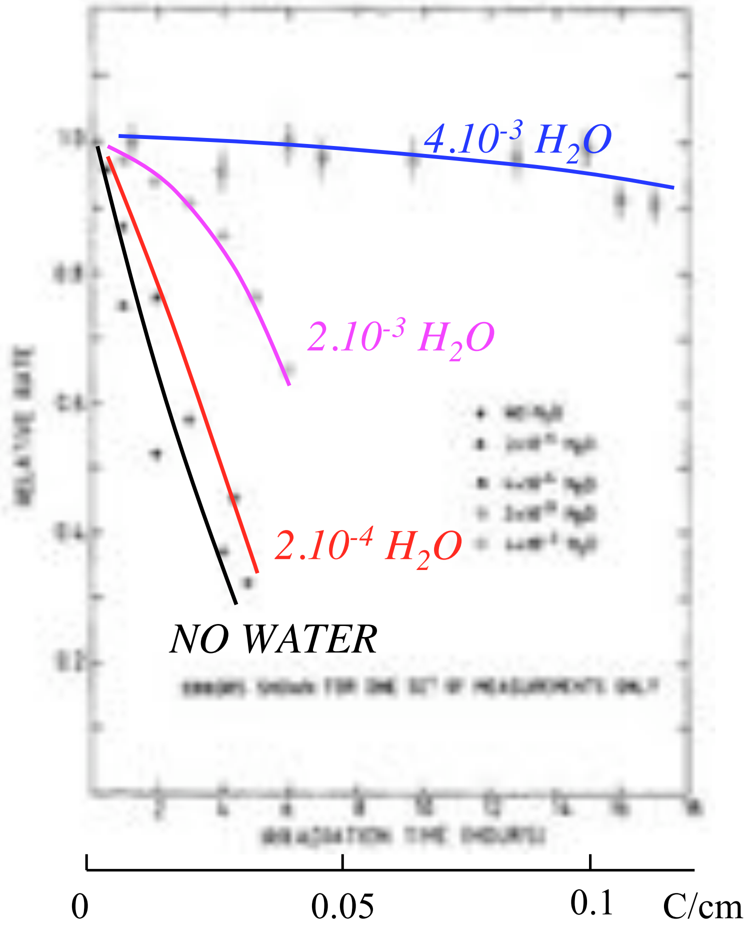
M. Binkley et al, Nucl. Instr. and Meth.A515(2003)53



G. Charpak et al,
Nucl. Instr. and Meth. 99 (1972) 279

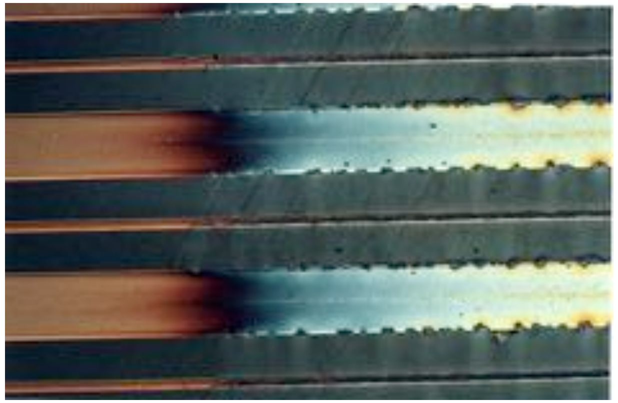
MWPC AGING: GAIN (EFFICIENCY) REDUCTION

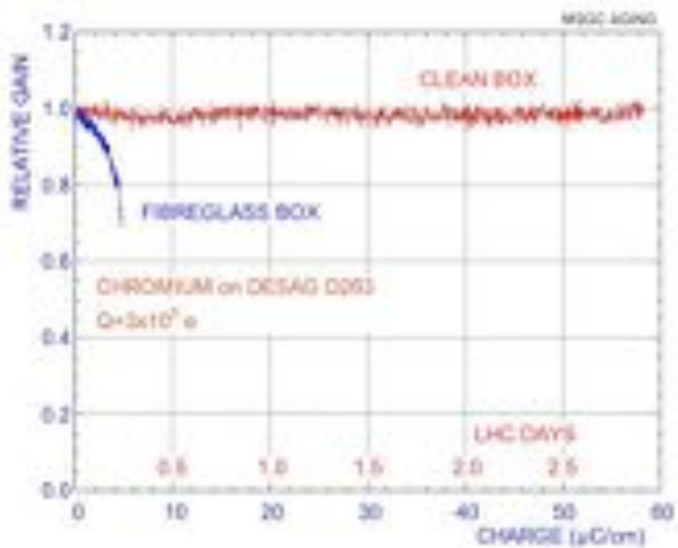
MWPC AGING ($Ar\text{-}iC_4H_{10} + H_2O$)



J.P. De Wulf et al,
Nucl. Instr. and Meth. A 252 (1986) 443

MSGC AGING



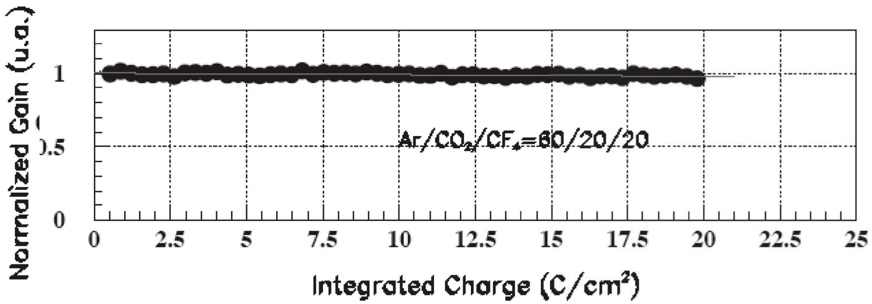


R. Bouclier et al, Nucl. Instr. and Meth. A348(1994)109

FOR $M=10^4$: 1 C/cm = 10^{12} MIPS

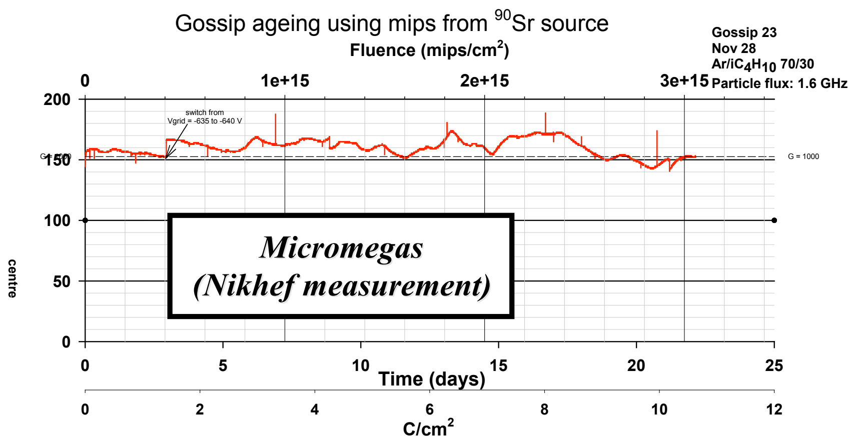
MPGD RADIATION HARDNESS

GEM :



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

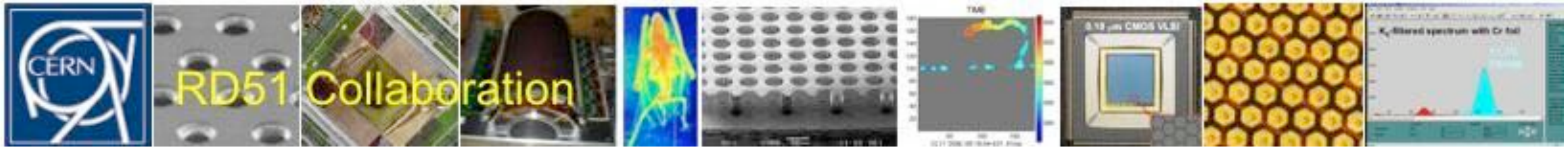
MICROMEGAS :



20 C cm^{-2}

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

F. Hartjes, MPGD09 (Crete, 12-15 June 2009)



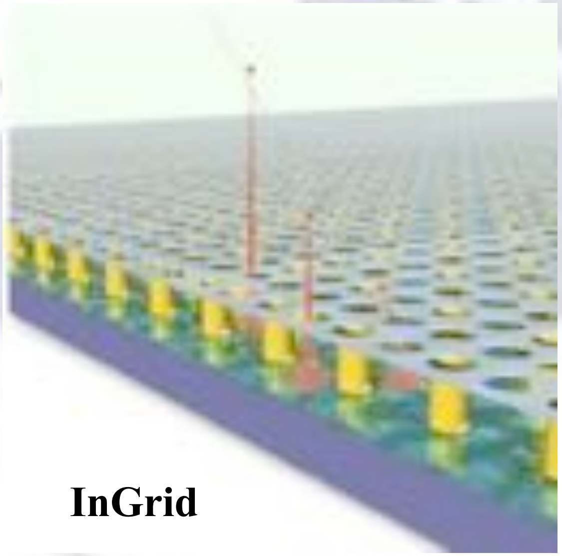
RD 51

Micro Pattern Gas Detectors Development

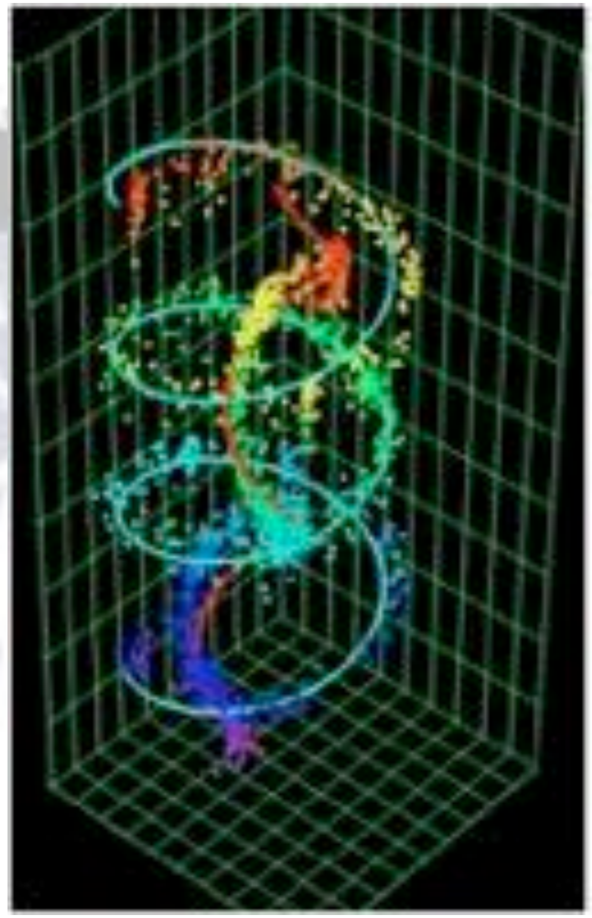
Spokespesons:

Leszek Ropelewski and Maxim Titov

~ 73 INSTITUTES WORLDWIDE, ~ 430 PARTICIPANTS



InGrid

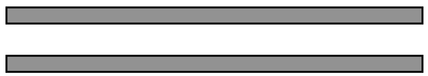


H. van der Graaf, Geseous detectors, Nucl. Instr. and Meth. A In Press (2010)

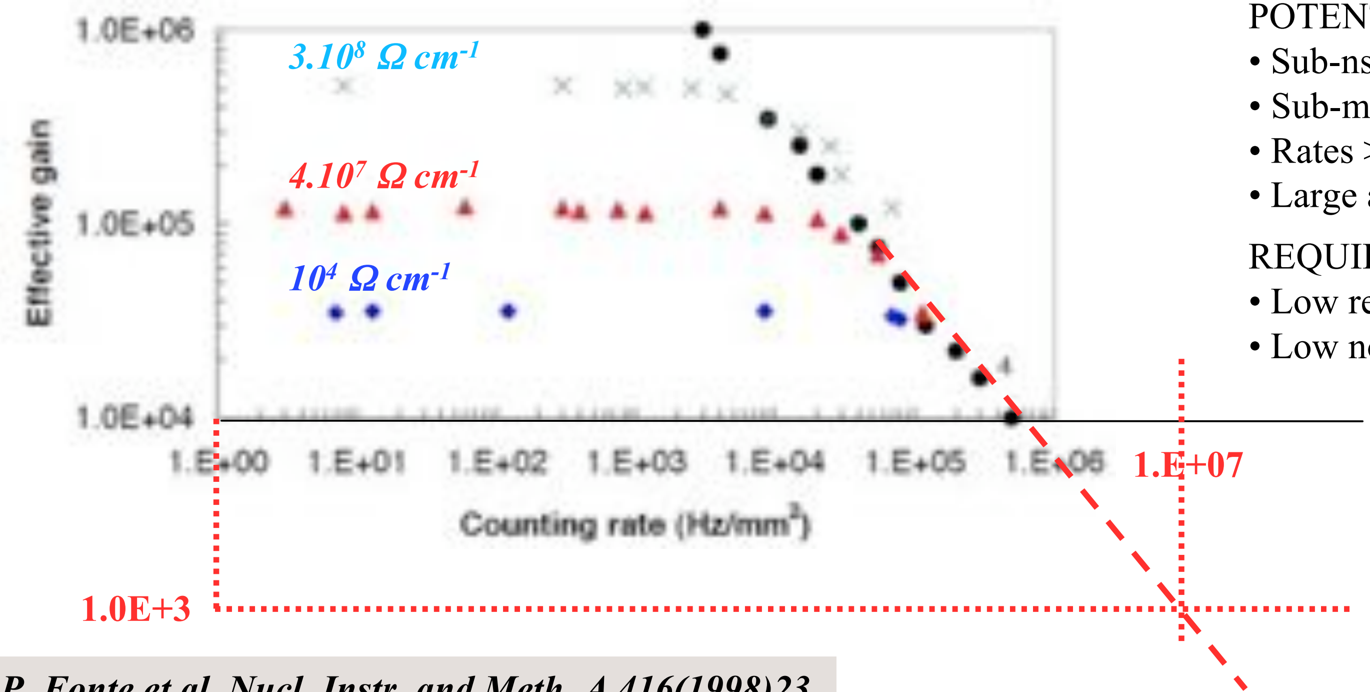
NEW DIRECTIONS

NARROW GAP, LOW-RESISTIVITY PARALLEL PLATE COUNTERS

SINGLE GAP:



MULTIGAP:



POTENTIALITIES:

- Sub-ns time resolution
- Sub-mm localization
- Rates >10^7 Hz mm^{-2}
- Large areas

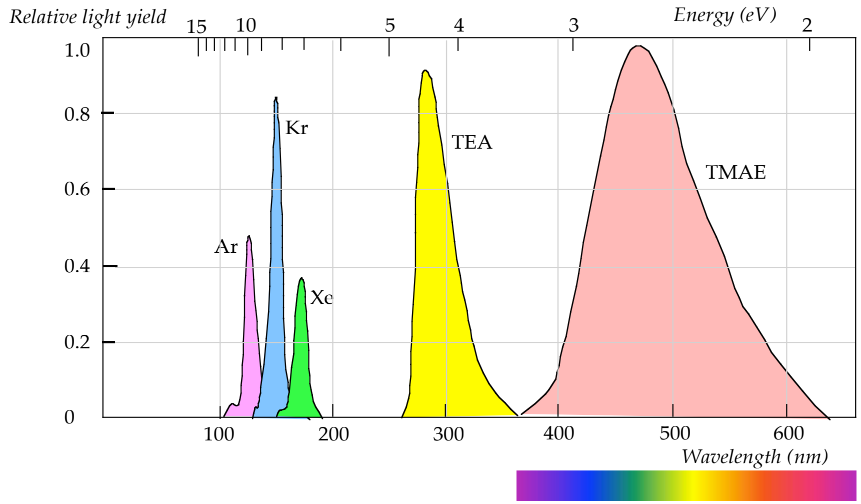
REQUIREMENTS:

- Low resistivity electrodes
- Low noise fast electronics

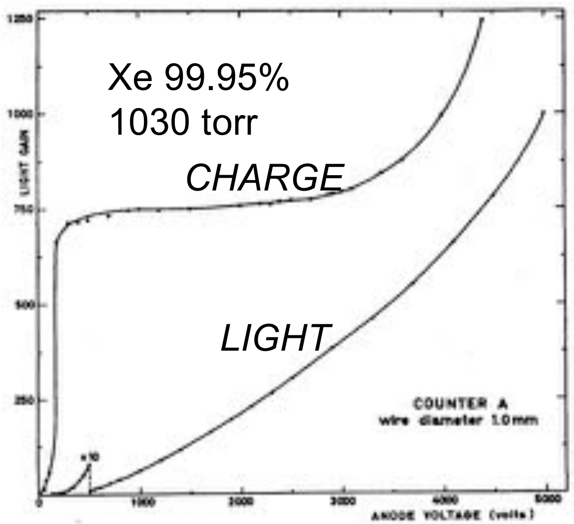
P. Fonte et al, Nucl. Instr. and Meth. A 416(1998)23

NEW DIRECTIONS

GAS SCINTILLATION SPECTRA
(PRIMARY AND FIELD-INDUCED):



HIGH FIELD PHOTON EMISSION
<u>BEFORE</u> CHARGE MULTIPLICATION:



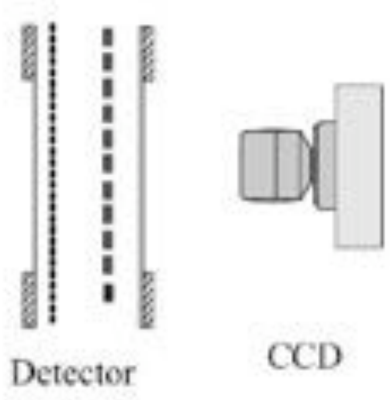
MAIN APPLICATIONS:
- SCINTILLATING PROPORTIONAL COUNTERS
- IMAGING CHAMBERS

- VERY FAST SCINTILLATION (ns)
- LIGHT EMISSION WITHOUT CAHRGE MULTIPLICATION

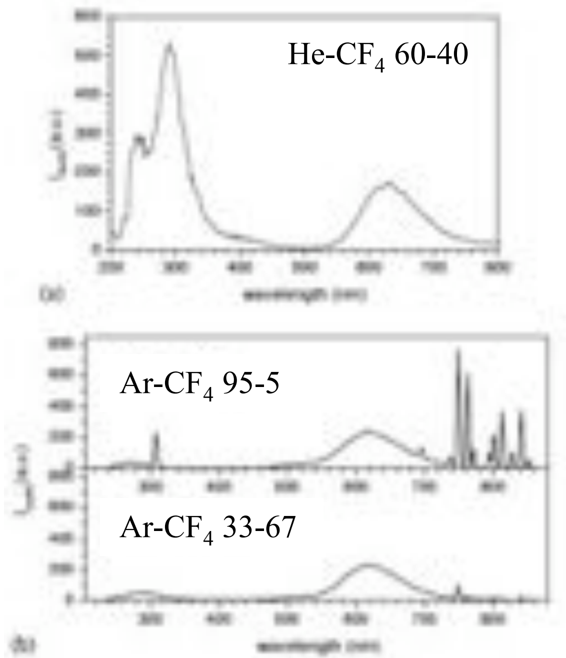
A.J.P.L. Policarpo et al, Nucl. Instr. and Meth. 102(1972)337

NEW DIRECTIONS

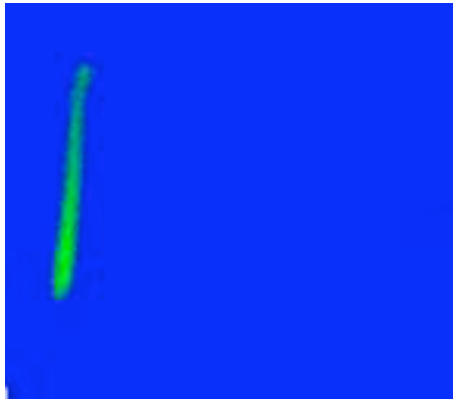
OPTICAL GEM:



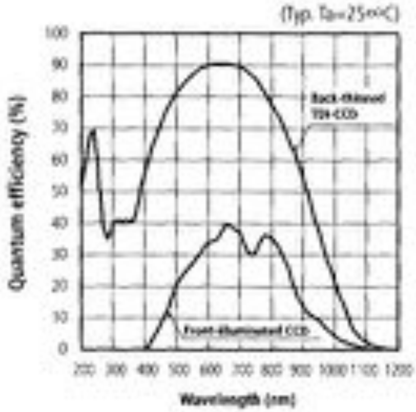
EMISSION SPECTRA:



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

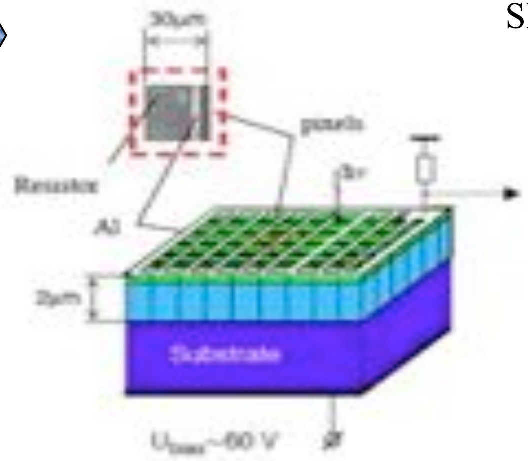


TYPICAL CCD SENSITIVITY:

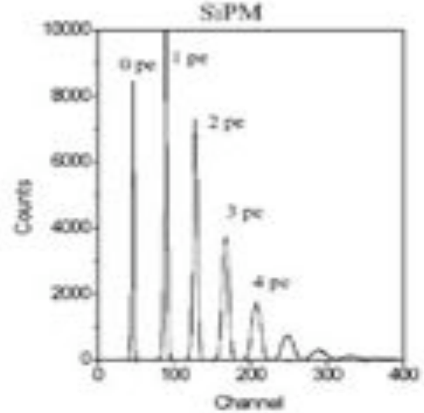


S.T.G. Fetal et al,
Nucl. Instr. and Meth. A581 (2007) 202

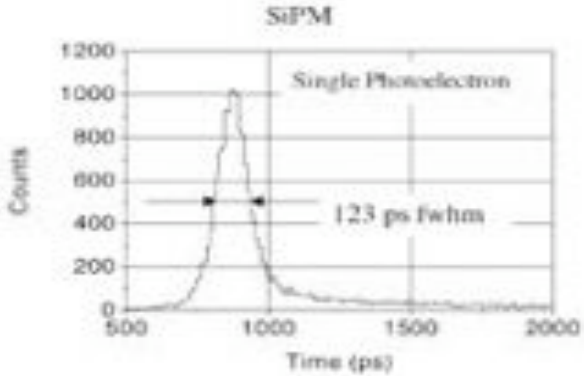
SILICON PHOTOMULTIPLIERS:



SINGLE PHOTON SENSITIVITY:

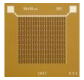


TIME RESOLUTION:



P. Buzhan et al, Nucl. Instr. and Meth. 504(2003)48

SIZE MATTERS: 1 mm^2



13x13 mm^2:

A. Del Guerra et al, Nucl. Instr. and Meth, A617 (2010)223


That's all Folks!