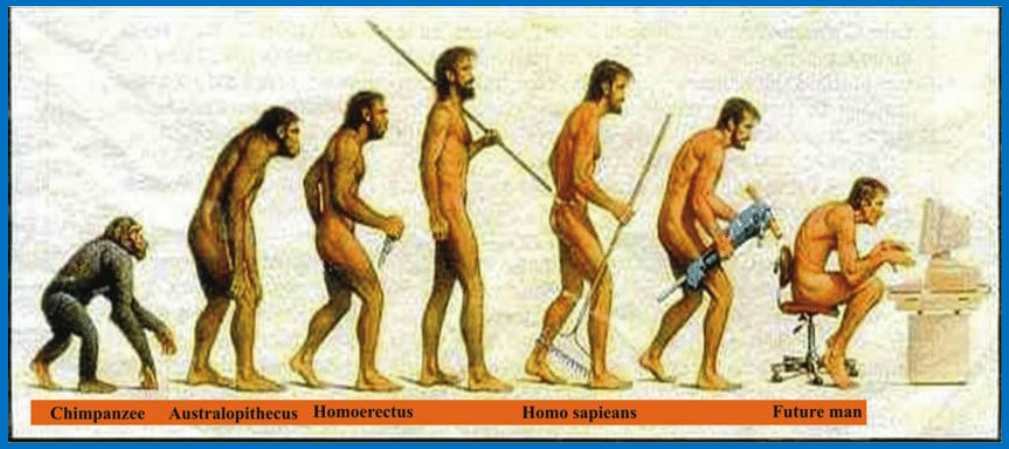
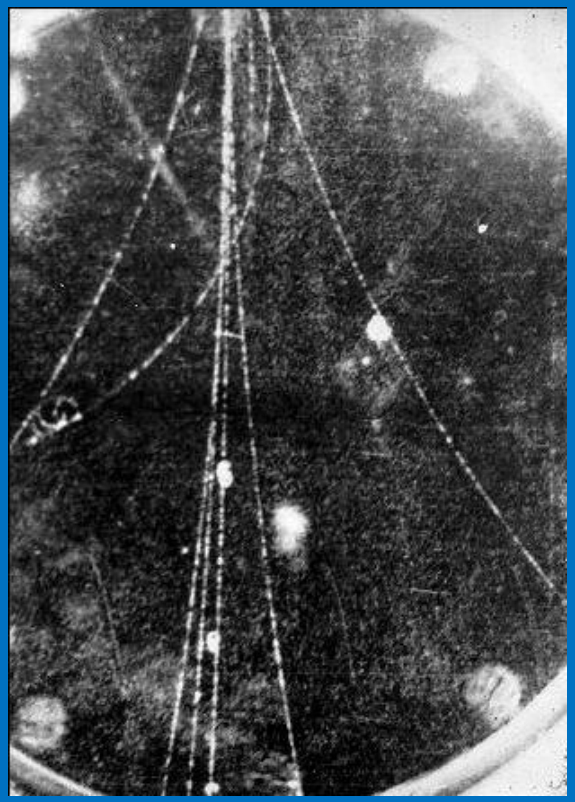
FROM MWPC TO MPGD

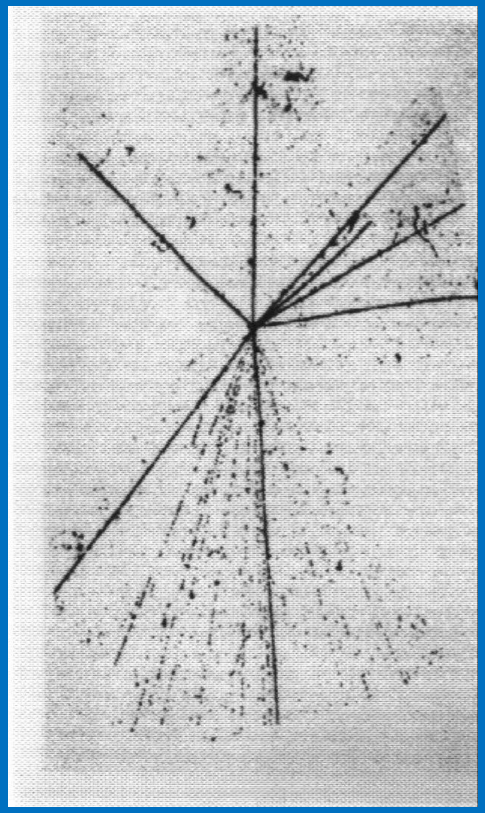
Fabio SAULI
CERN



DRD1 Gaseous Detectors School
CERN November 27 – December 6, 2024

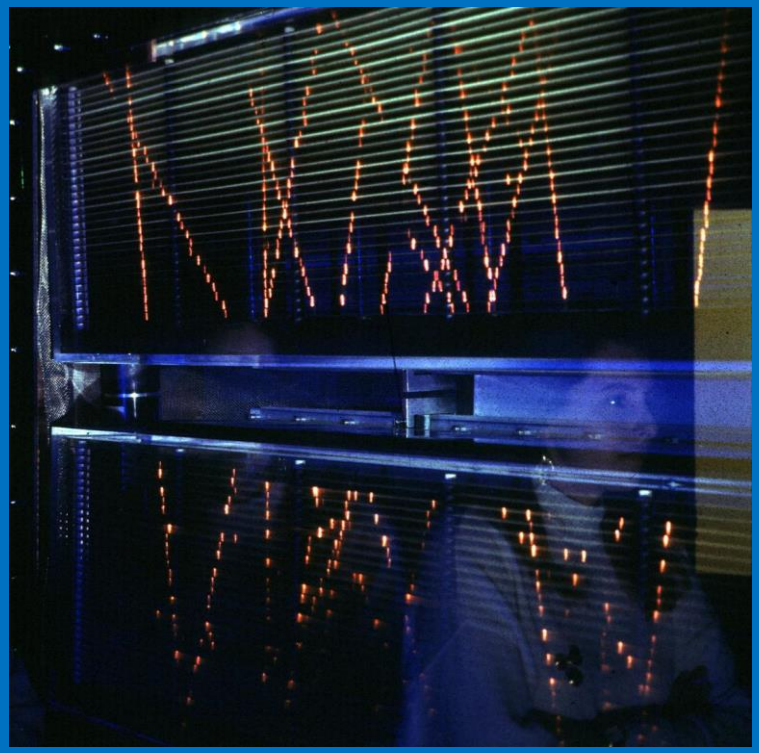


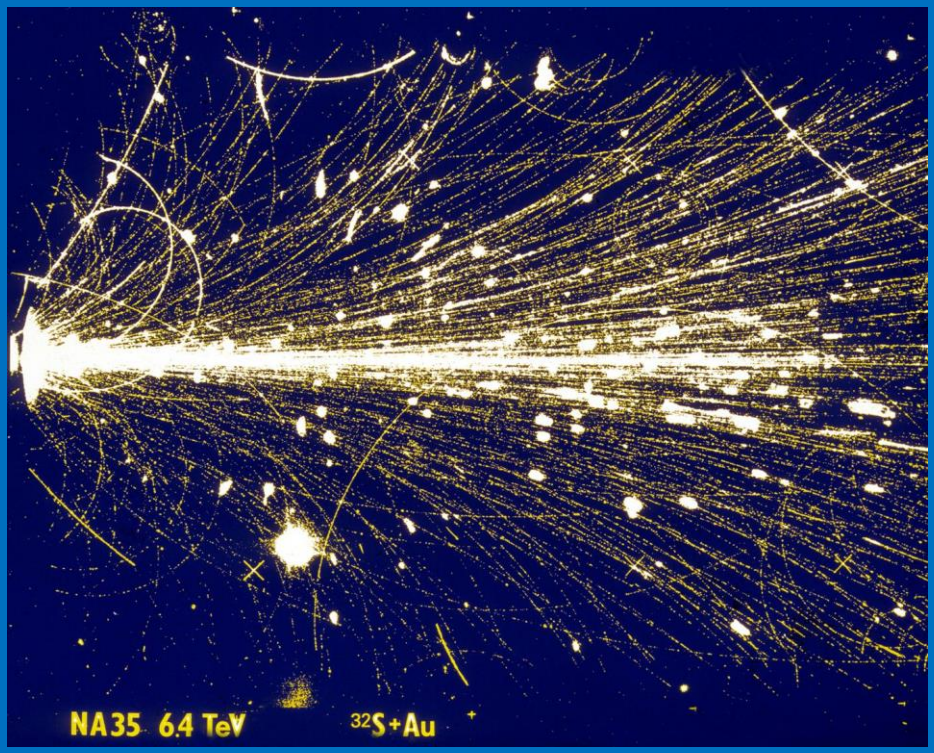
~ 1930
CLOUD CHAMBER



~1940
EMULSIONS

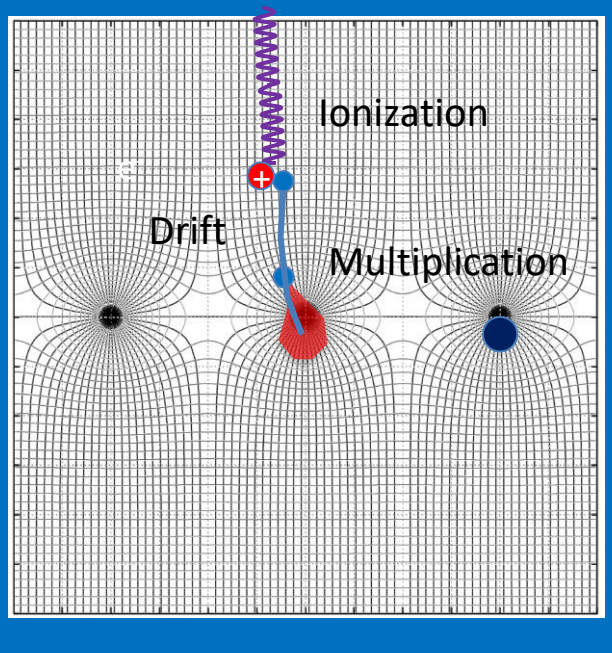
~ 1960
BUBBLE CHAMBER





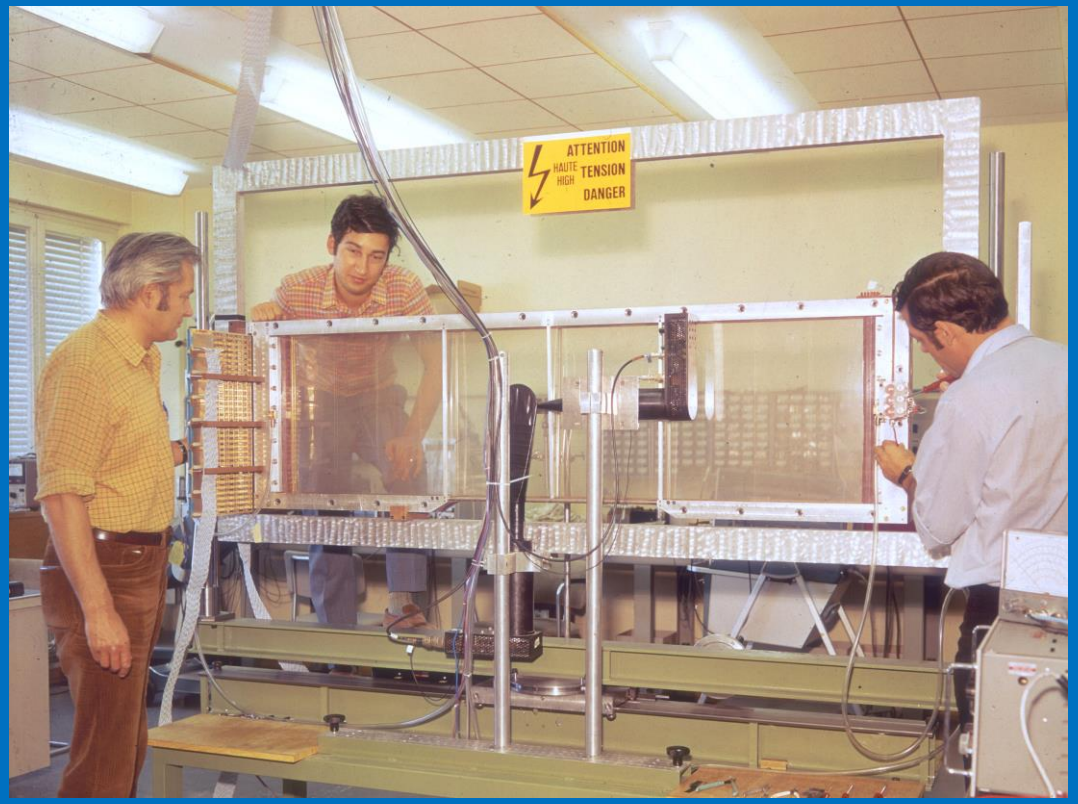
~1960

SPARK AND STREAMER CHAMBERS



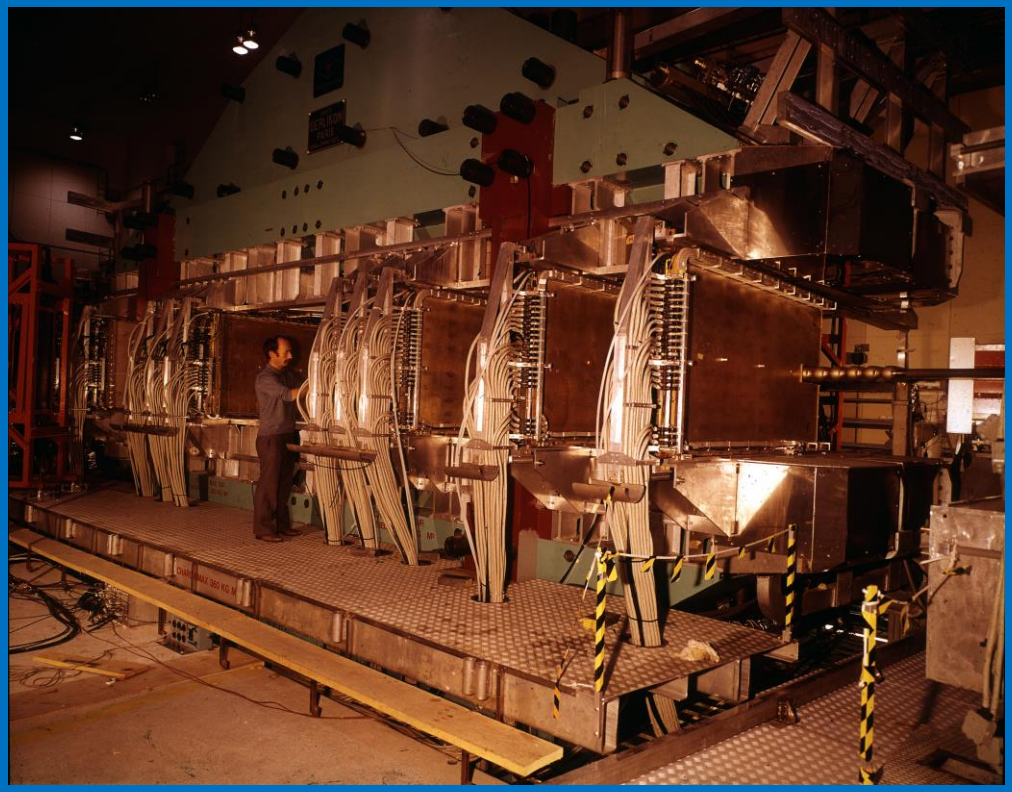
G. Charpak et al,
Nucl. Instr. Meth. 62(1968)282

FIRST LARGE MWPC (CERN 1970)

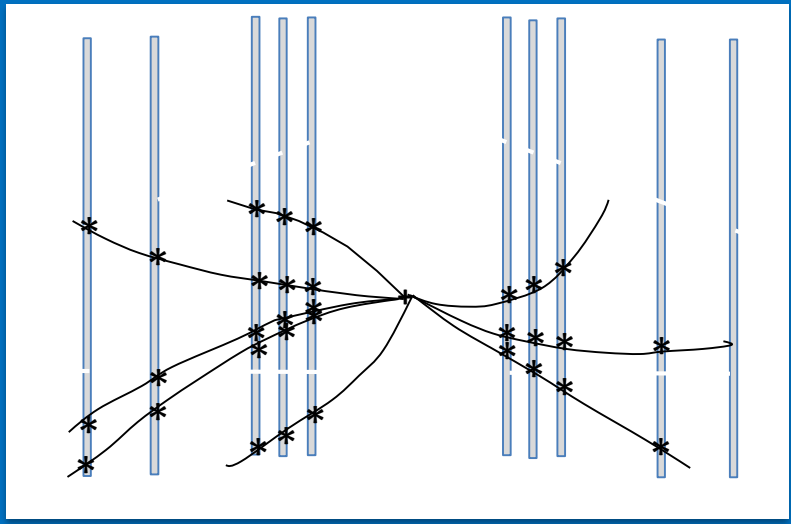


Georges Charpak

1973: SPLIT FIELD MAGNET DETECTOR AT CERN'S p-p STRORAGE RING

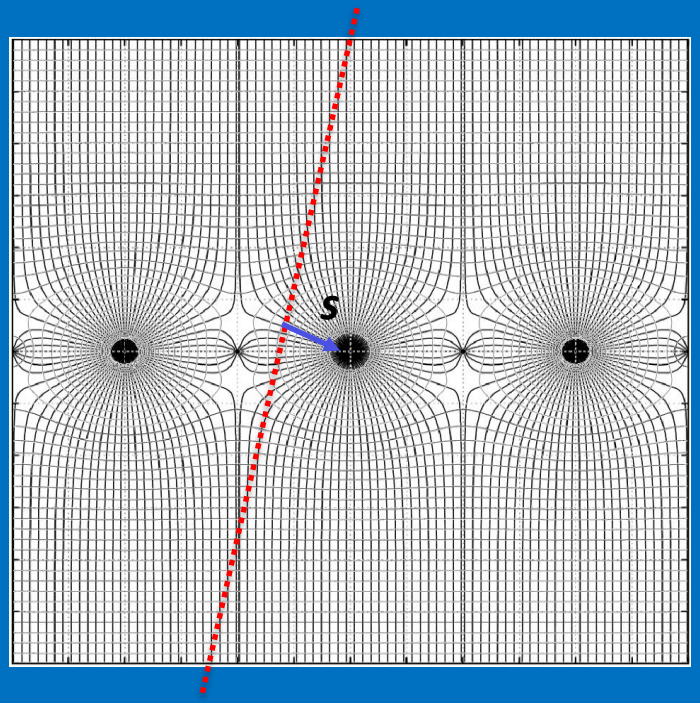


p-p collisions 62+62 GeV



Measurement of electron drift time *t*

$s = w\,t$



A. H. Walenta et al
Nucl. Instr. Meth. 92(1971)373

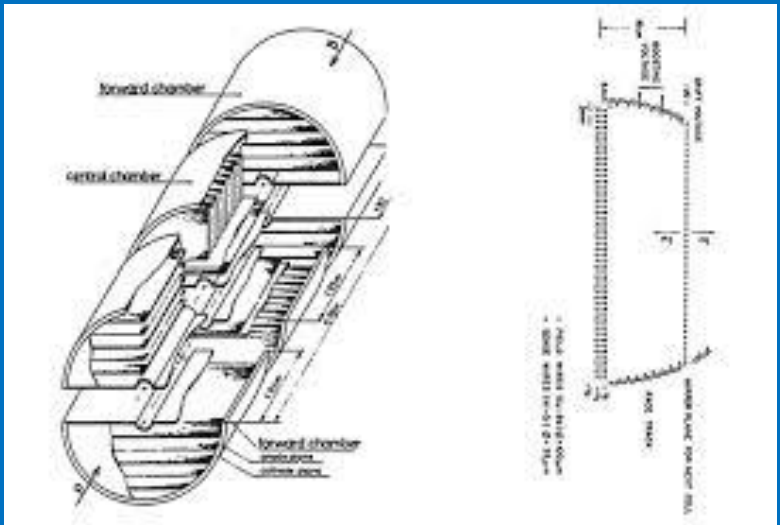
WA1 NEUTRINO DETECTOR AT CERN

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

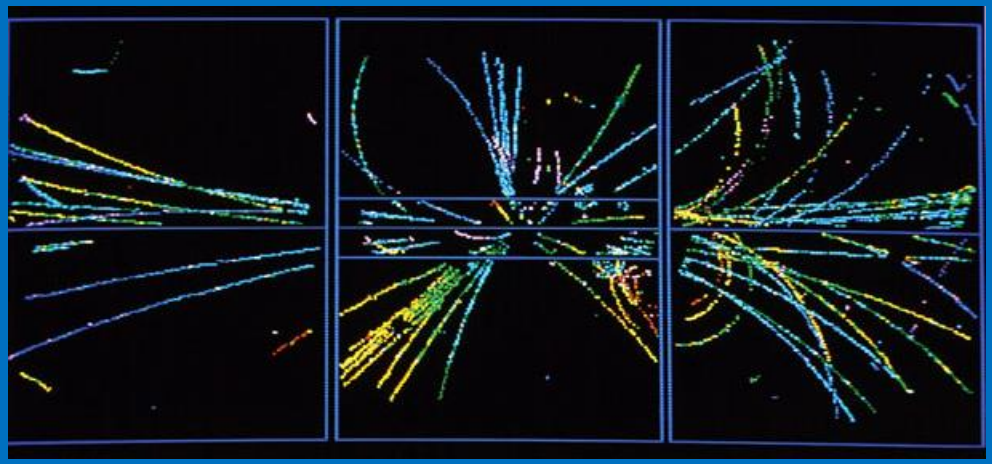
1983: UA1 DRIFT CHAMBERS SYSTEM

UA1 EXPERIMENT - CERN PROTON-ANTIPROTON COLLIDER

XY FROM WIRE CHAMBER
Z FROM ELECTRONS DRIFT TIME

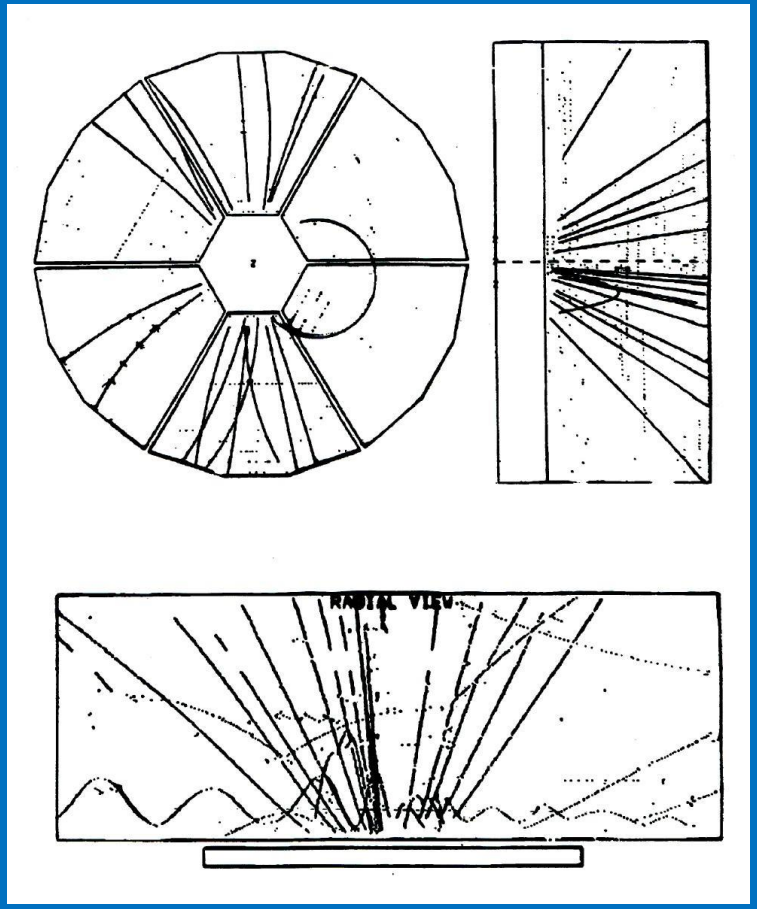


$p\bar{p}$ COLLISION (1982)

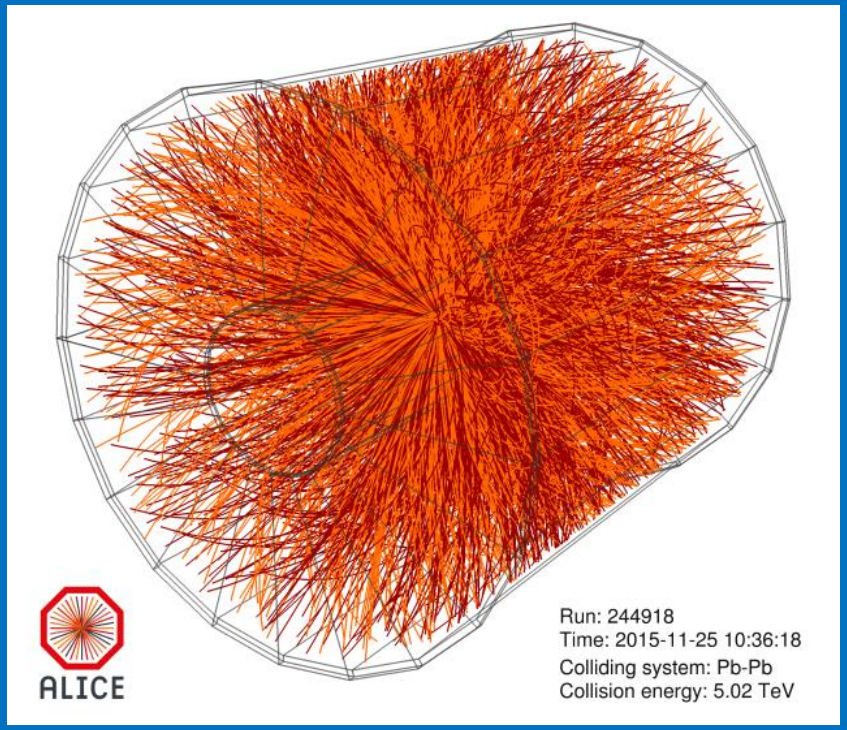


Discovery of the W and Z vector bosons
C. Rubbia, Simon van der Meer
Nobel Laureates 1984

BNL-SLAC TIME PROJECTION CHAMBER
David Nygren

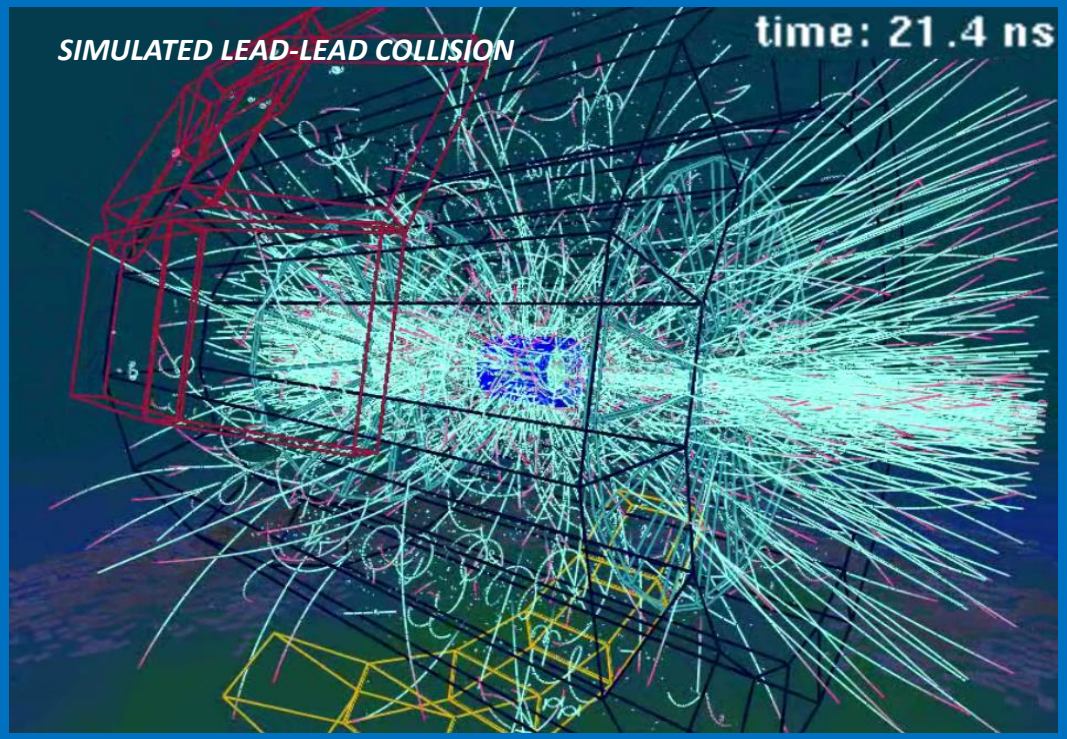


~2000: ALICE TPC AT LHC

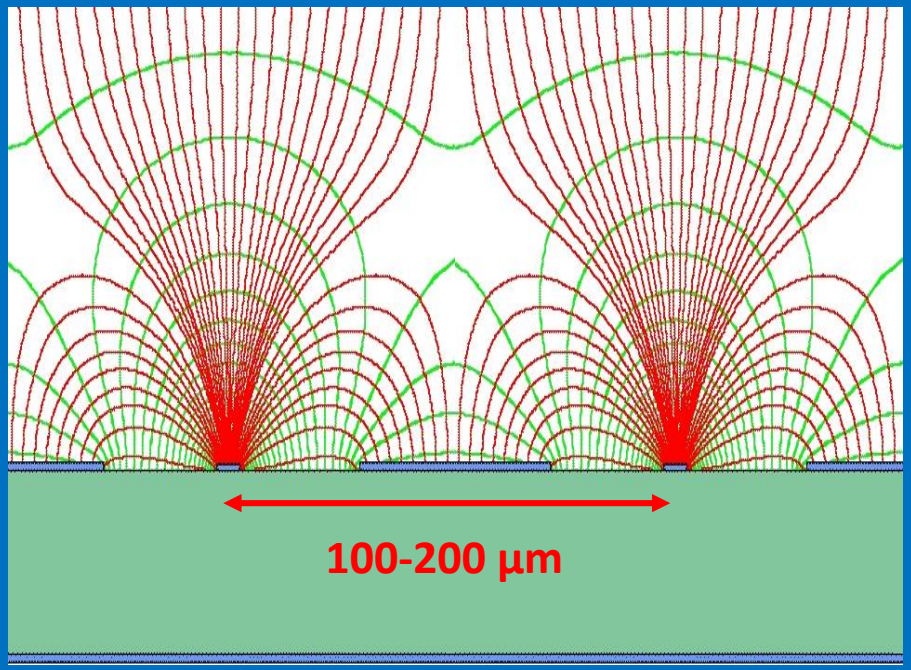


10^9 pp COLLISIONS/sec

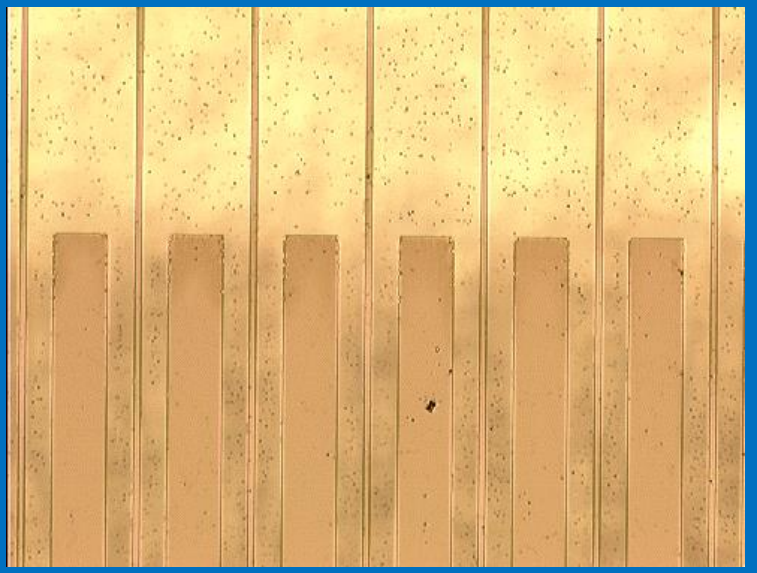
HIGH LUMINOSITY LHC: UP TO 50 kHz Pb-Pb MINIMUM BIAS EVENTS



MWPC LIMITATIONS:
TWO-TRACKS RESOLUTION ~ mm
RATE CAPABILITY ~ 10^4 mm^{-2} s^{-1}
AGING
HARD TO BUILD, FRAGILE



ALTERNATING ANODE AND CATHODE STRIPS ENGRAVED ON GLASS WITH PHOTOLITHOGRAPHY



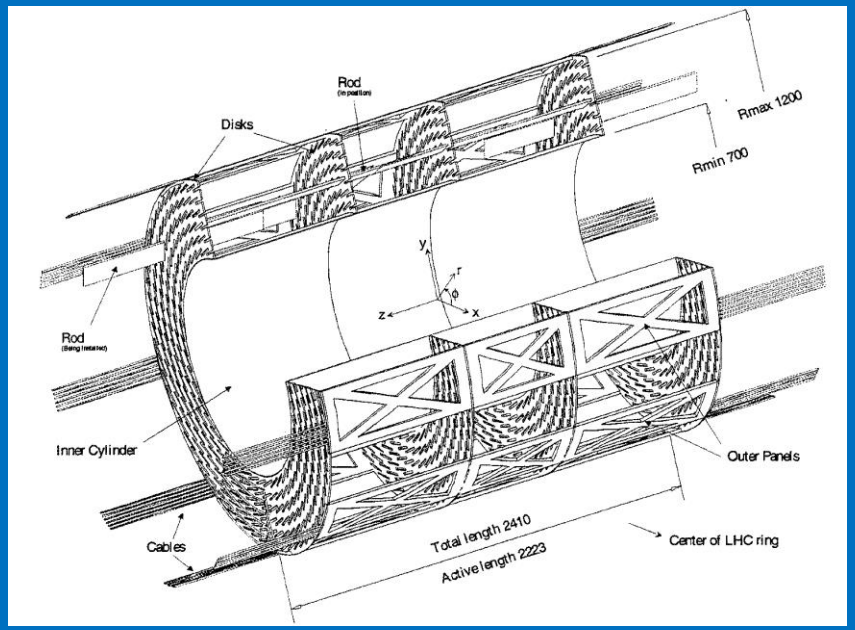
A. Oed, ucl. Instr. Meth. 263(1988)351

- **Space Accuracy ~ 50 µm**
- **Two-track Resolution ~ 500 µm**
- **Rate capability ~ 10^6 mm^{-2} s^{-1}**

CMS MSGC BARREL TRACKER (1999)

~ 15,000 MSGCs

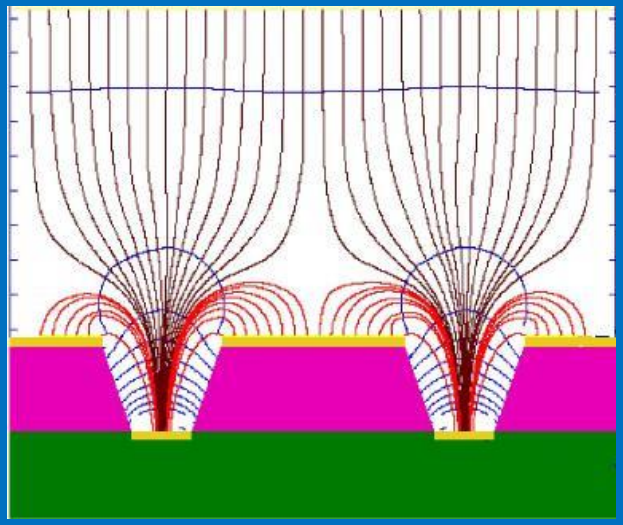
DISCHARGE PROBLEMSAND
LONG TERM RELIABILIY



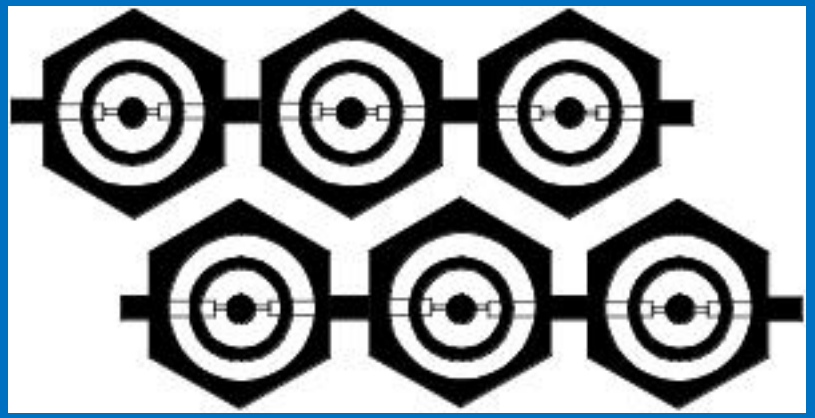
GAIN TO DETECT MIPs (100 e^-) : ~10^4 D Q ~ 10^6

~ MeV NEUTRON CONVERSION (~ 10^4 e^-) DQ ~ 10^8 >> RAETHER LIMIT!

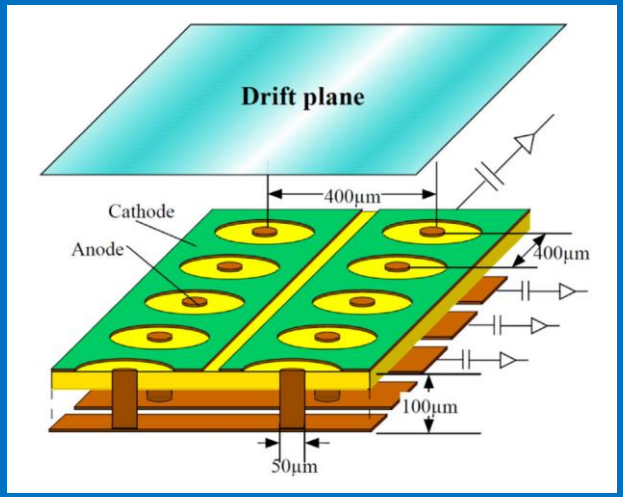
MICRO GROOVE (R. Bellazzini, 1999)



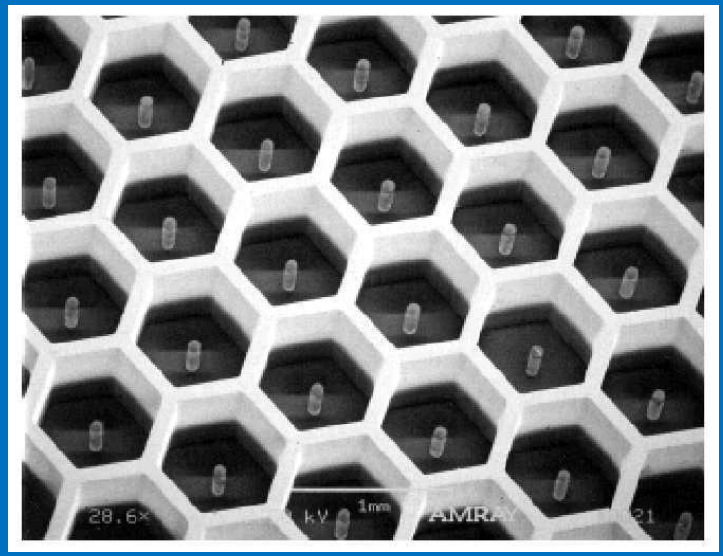
MICRODOT (S.Biagi, 1995)



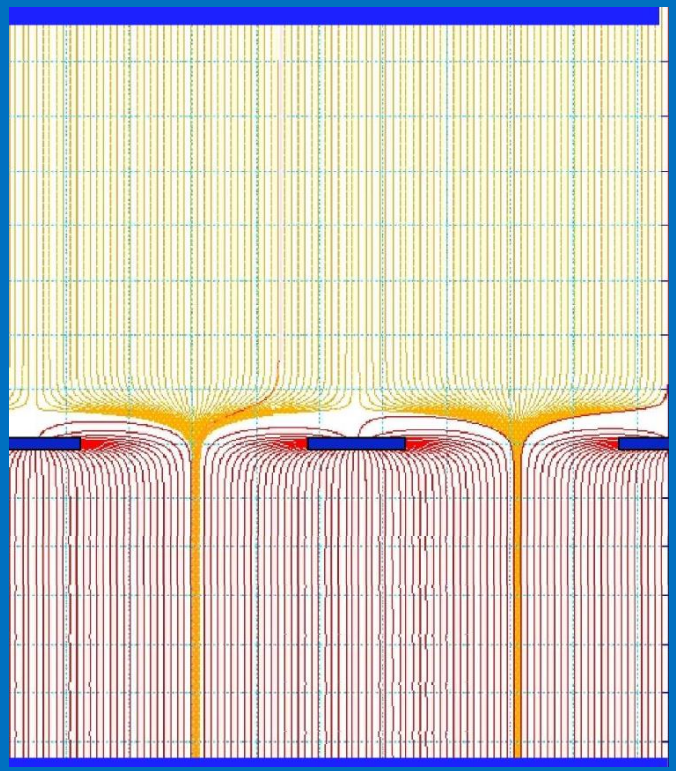
MICRO-PIXEL DETECTOR (A.Ochi, 2001)



MICRO-PIN ARRAY (P. Rehak, 2000)

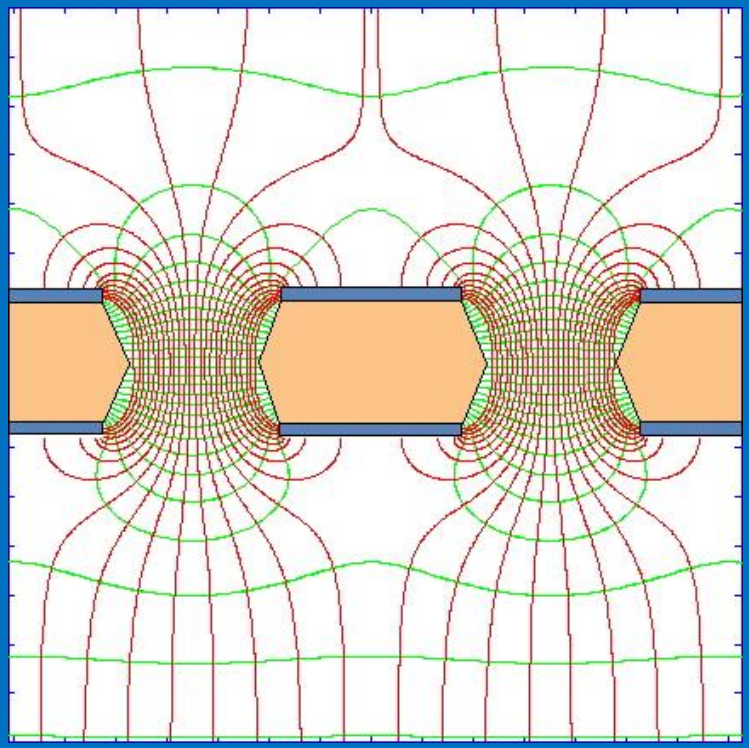


MICROMEGAS



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

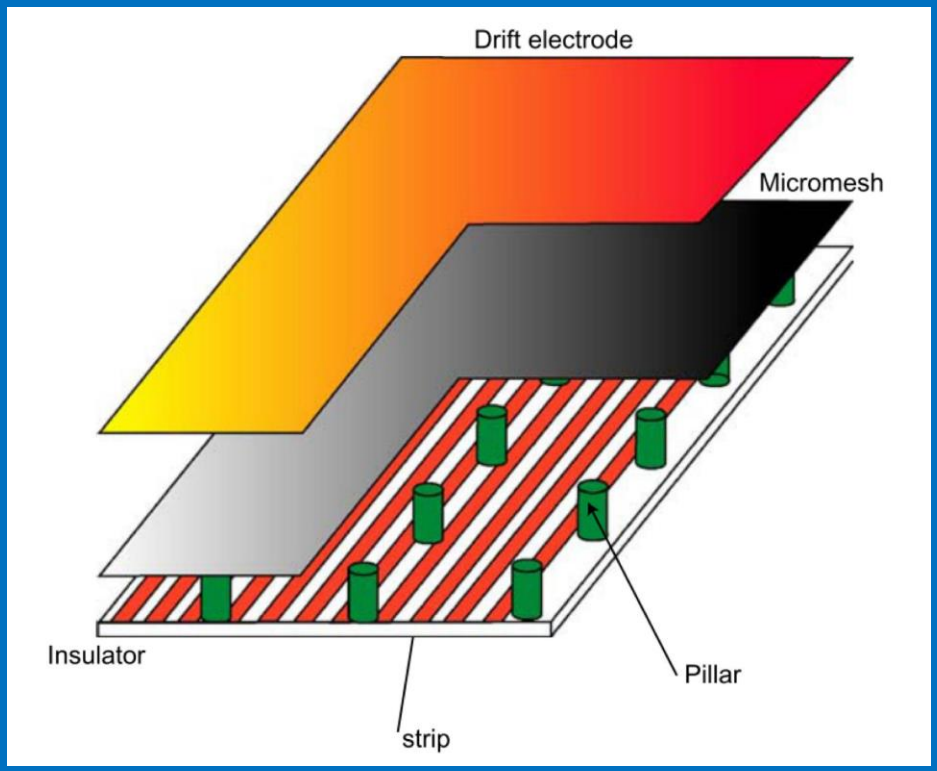
GAS ELECTRON MULTIPLIER (GEM)

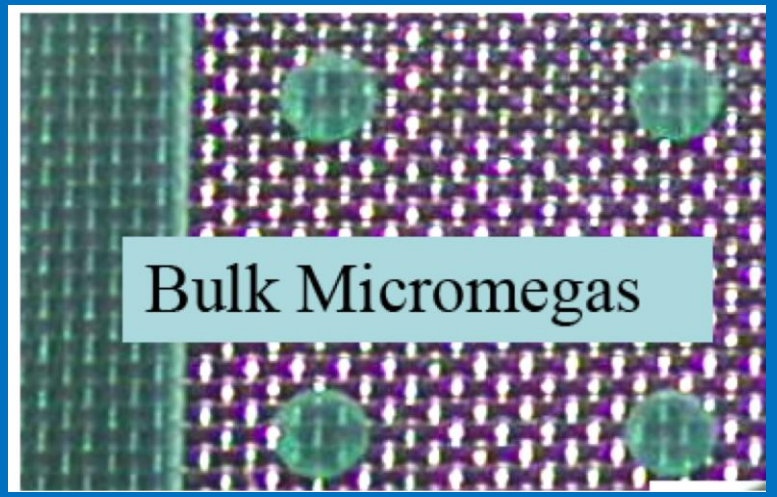


F. Sauli, Nucl. Instr. Meth. A386(1997)531

Esther Ferrer Ribas: MPGD TECHNOLOGIES

Rui de Oliveira: MPGD MANUFACTURING





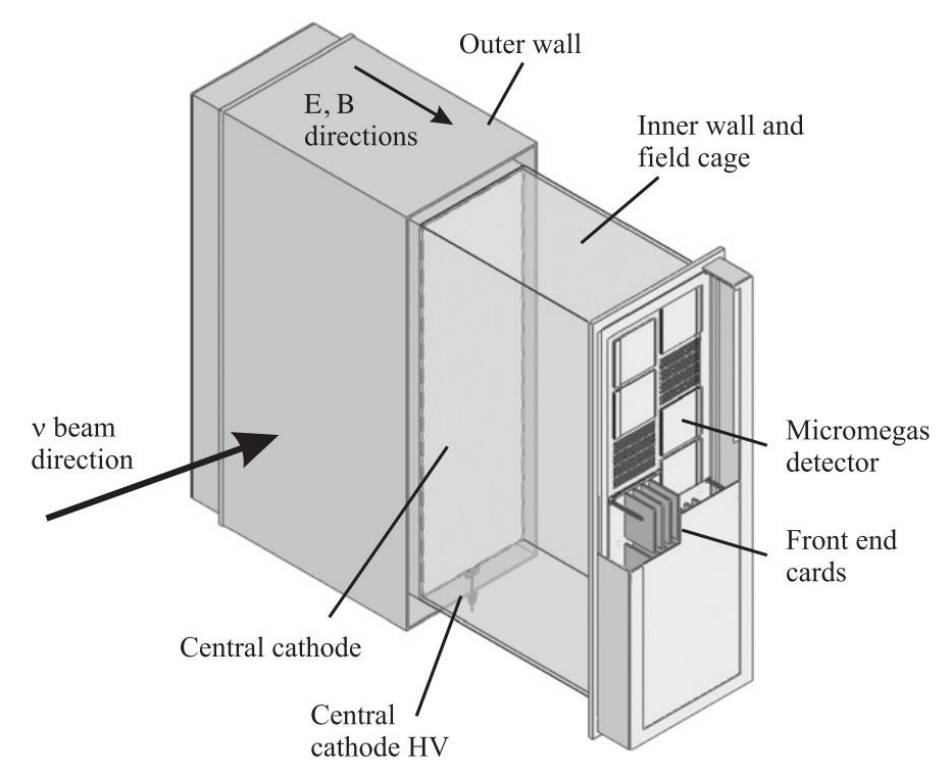
I. Giomataris et al, Nucl. Instr. Meth. A560(2006)405

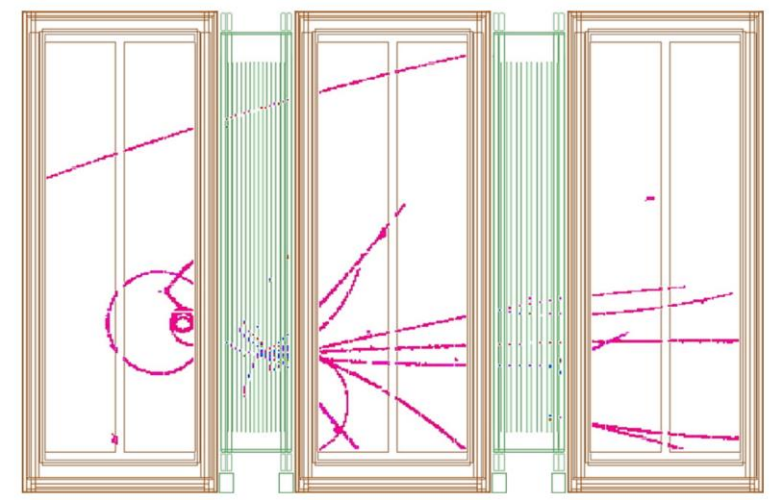
COMPASS SPECTROMETER TRACKER AT CERN

12 PLANES 40x40 cm^2 aCTIVE
3 XYUV STATIONS
POSITION ACCURACY ~ 70 µm

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

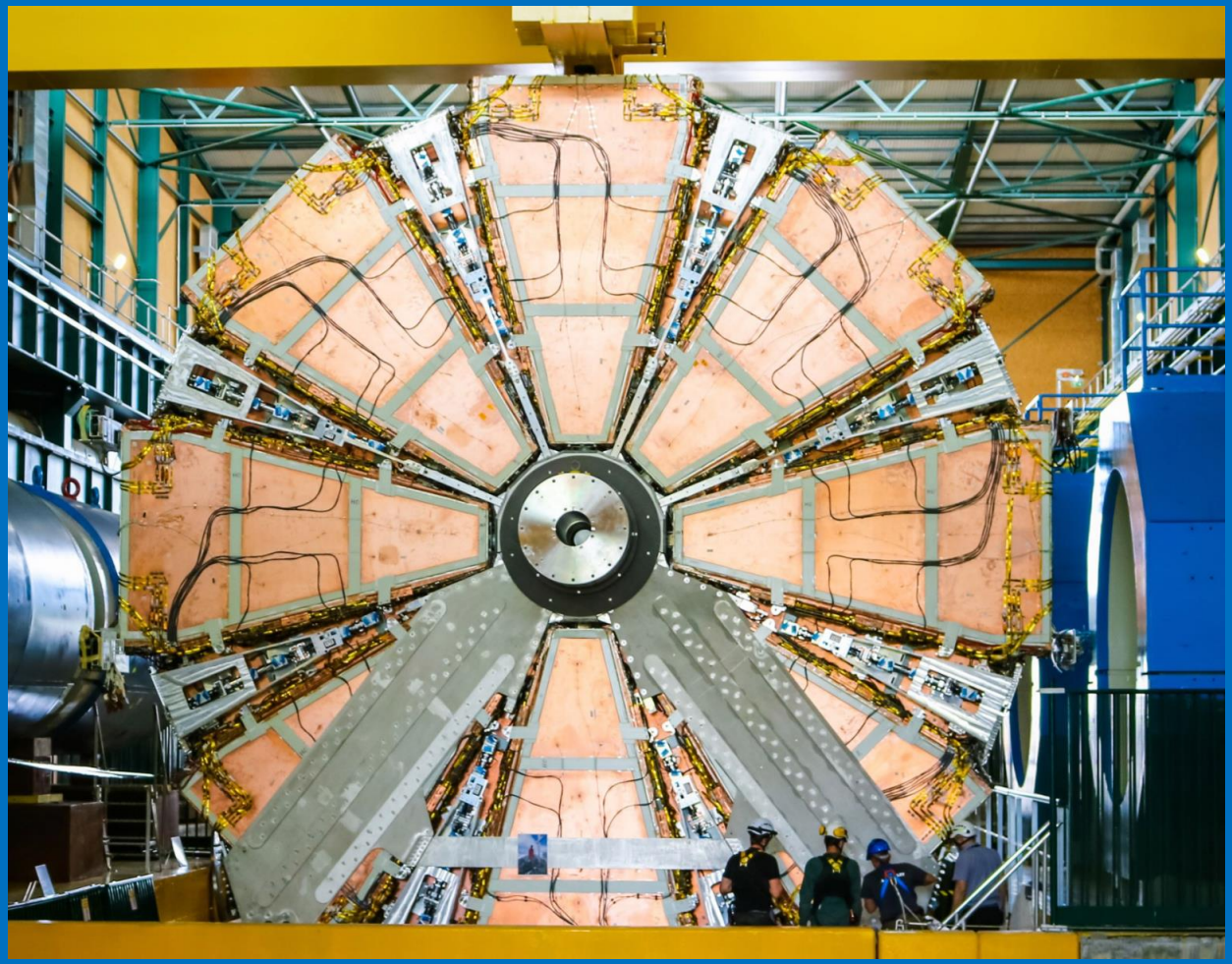
TIME PROJECTION CHAMBER FOR THE T2K NEAR DETECTOR





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

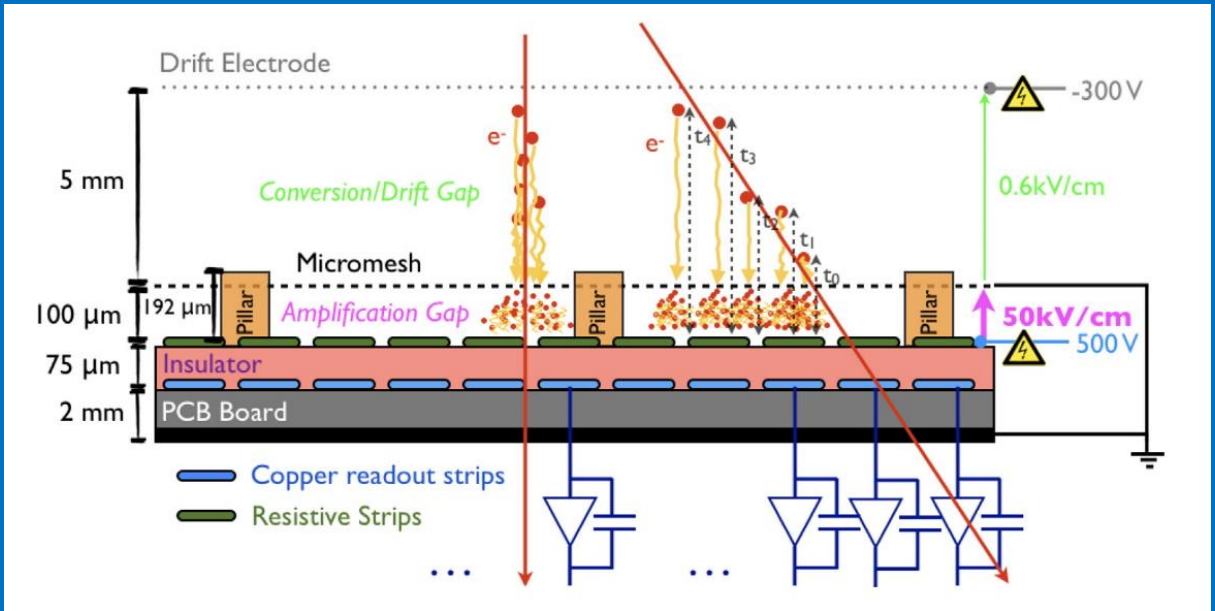
ATLAS MICROMEGAS UPGRADE



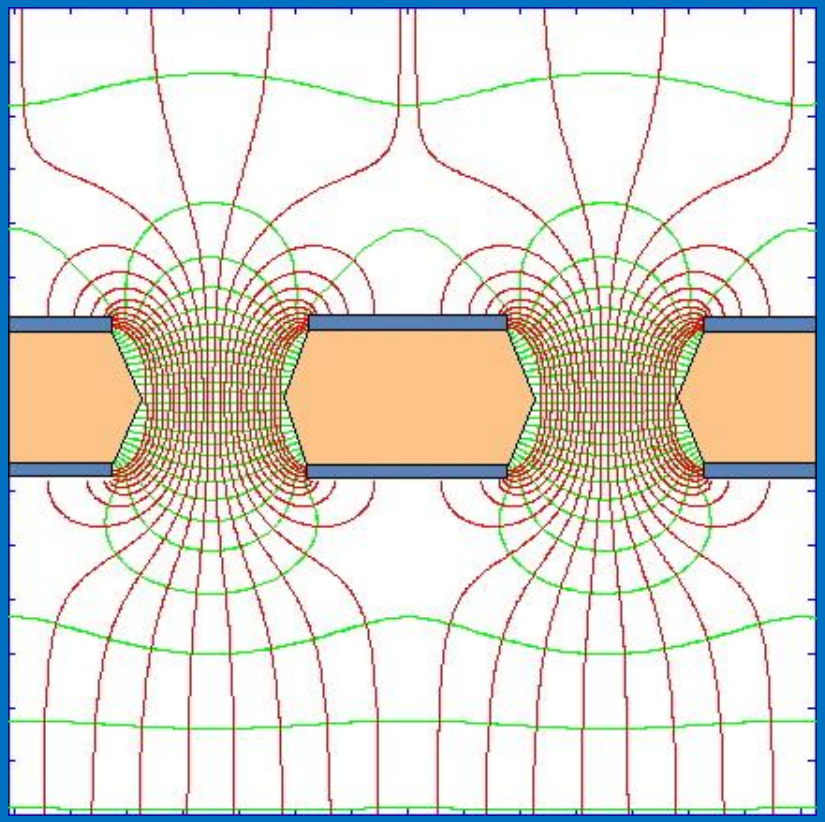
1280 m^2 active surface
2.1 M readout channels
128 detectors / 4 types
4 layers
2 to 3 m^2 area

T. Alexopoulos et al, Nucl. Instr. Meth. A955(2020)162086

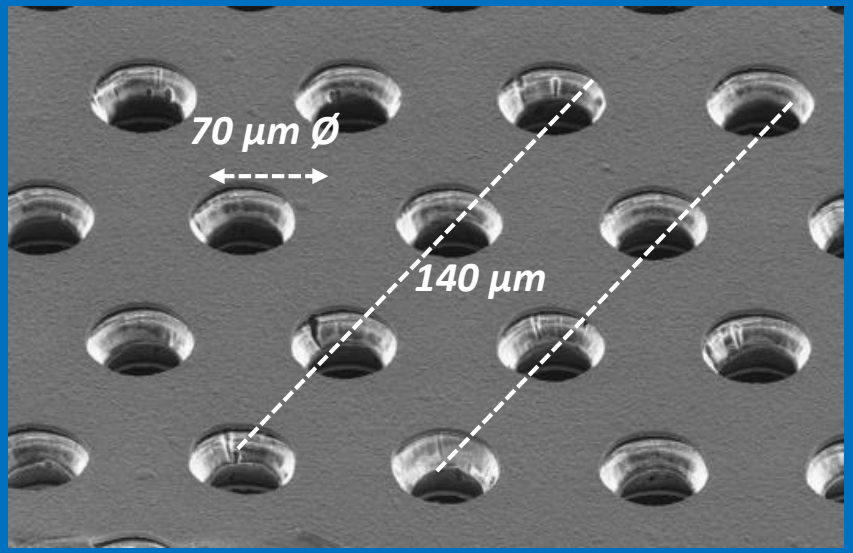
HIGH RESISTIVITY ANODE:
EFFECTIVE DISCHARGES SUPPRESSION



F. Kruger, Nucl. Instr. Meth. A845(2017)248

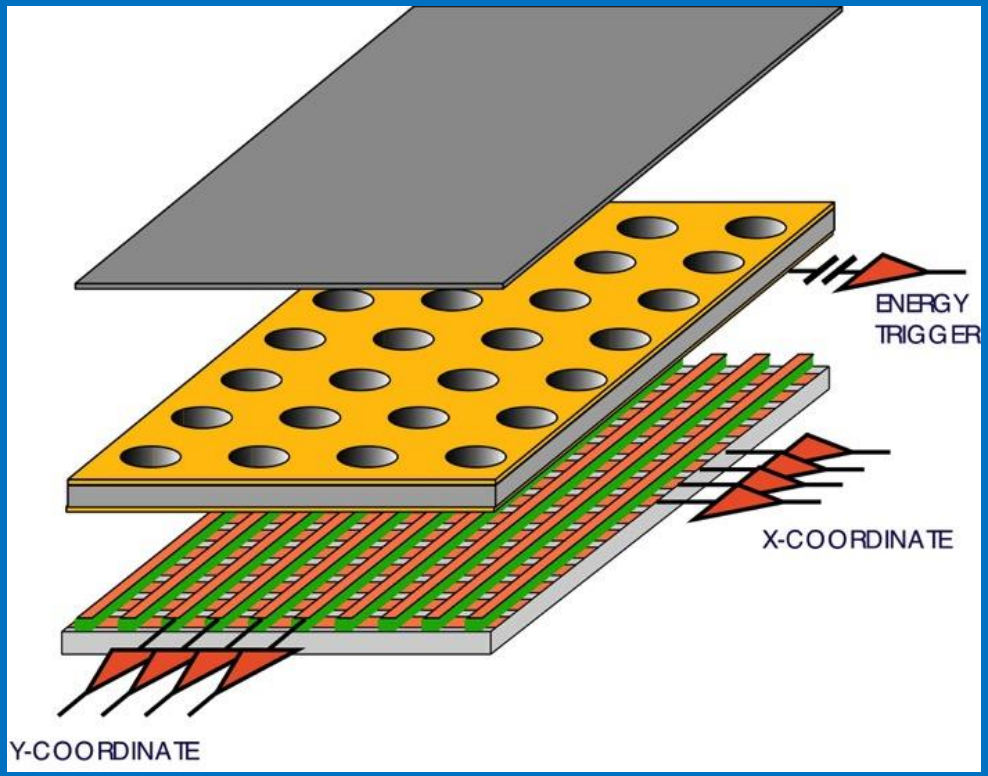


50 µm thick Kapton, 5 µm Cu-coated

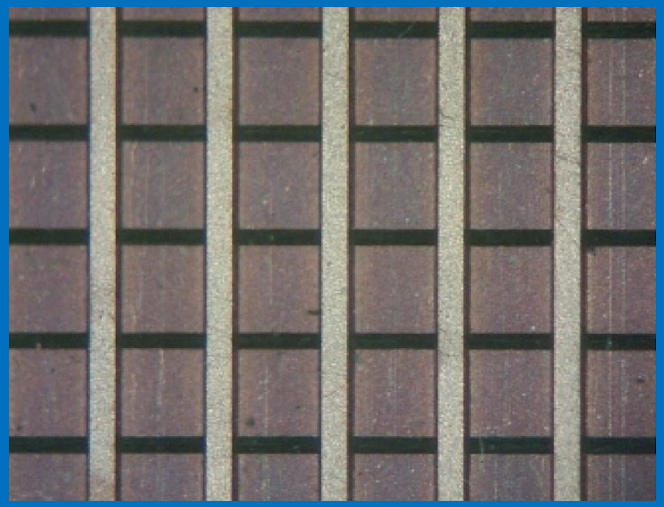


F. Sauli, Nucl. Instr. Meth. A386(1997)531

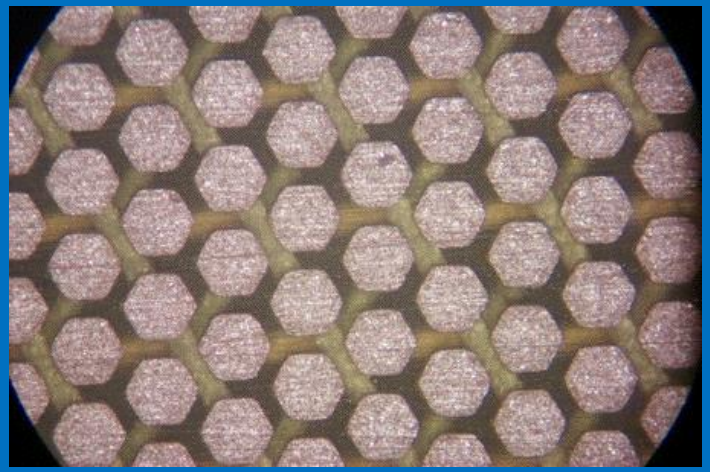
GEM CHAMBER WITH 2-DIMENSIONAL READOUT



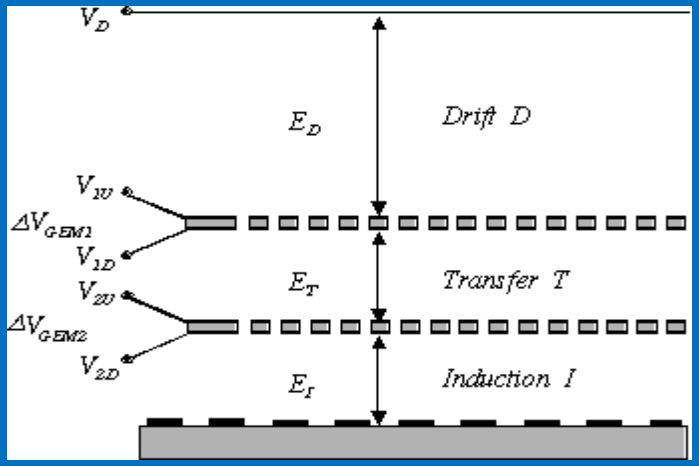
STANDARD XY READOUT400 µm PITCH

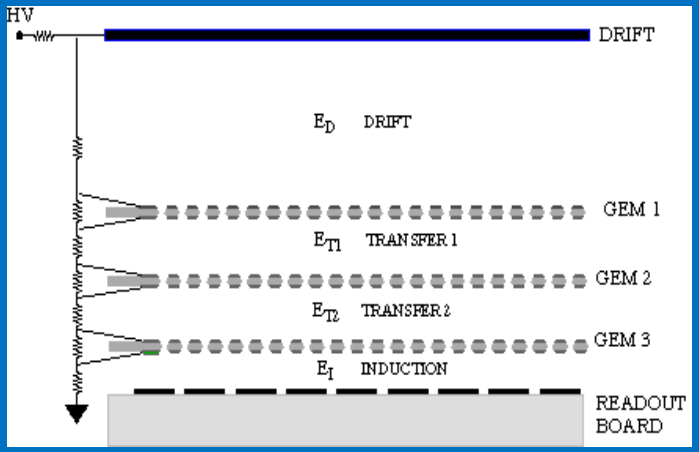


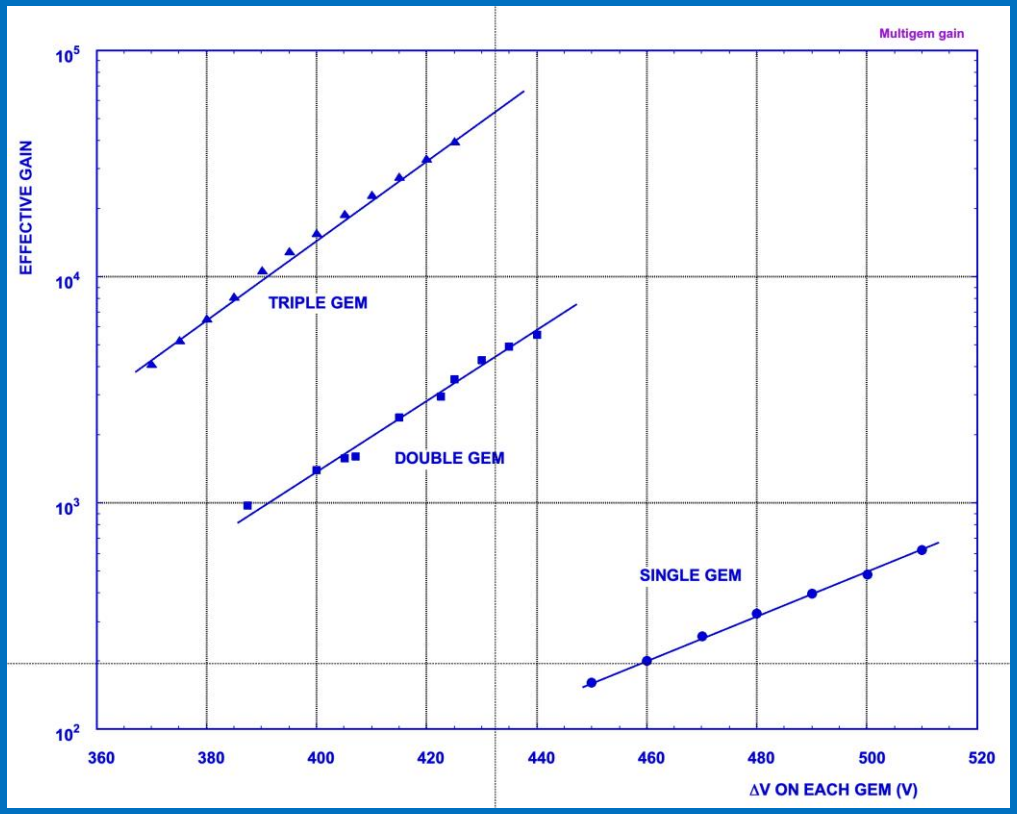
PAD MATRIX 500 µm PICH



LOWER VOLTAGE ON EACH GEM
HIGHER SAFE TOTAL GAIN





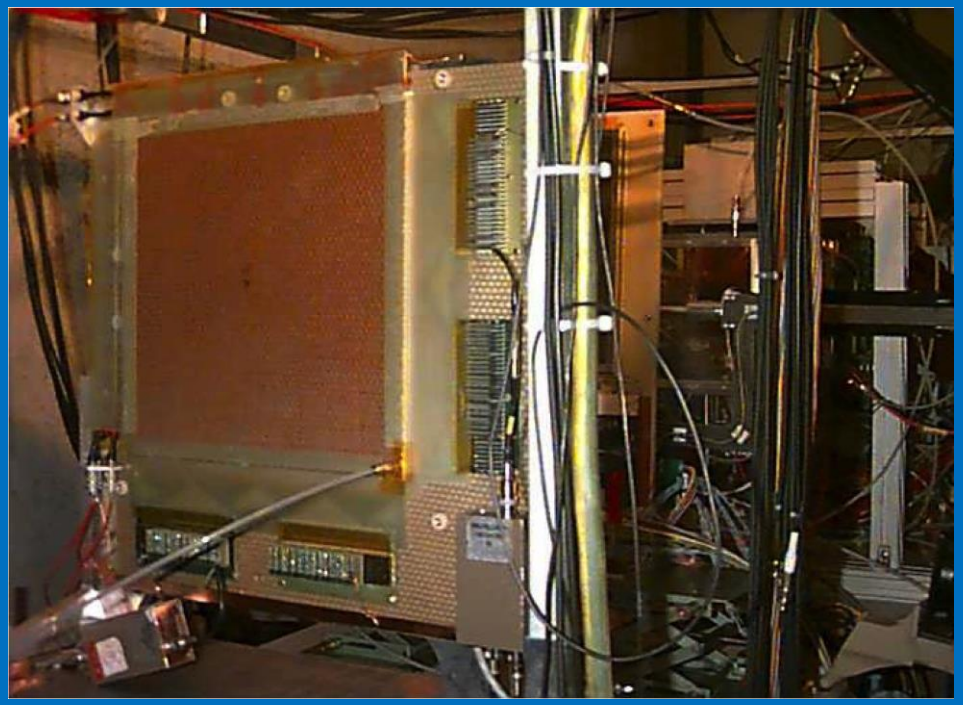


S. Bachmann et al, Nucl. Instr. Meth. A479(2012)294

COMPASS TRACKER AT CERN (2001-2020)

A 30x30 cm^2 GEM ELECTRODE

~ 30 TRIPLE-GEM DETECTORS
30x30 cm^2 – 2-D Readout

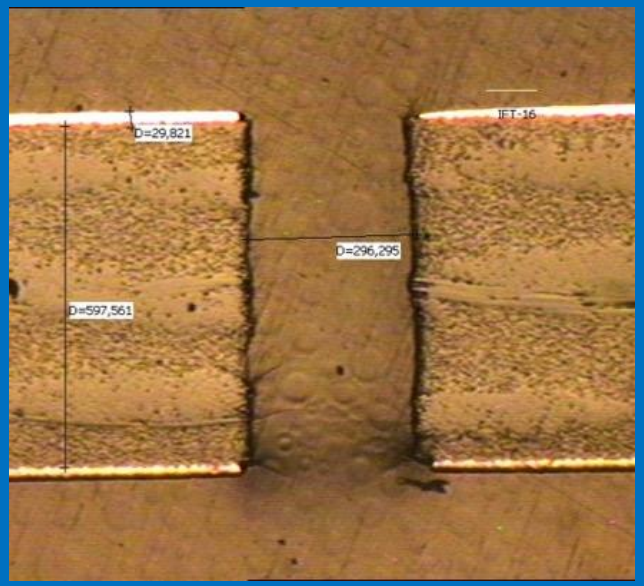


C. Altunbas et al, Nucl. Instr. Meth. A490(2002)480

2004: THIK GEM (also LEM: Large Electron Multiplier)

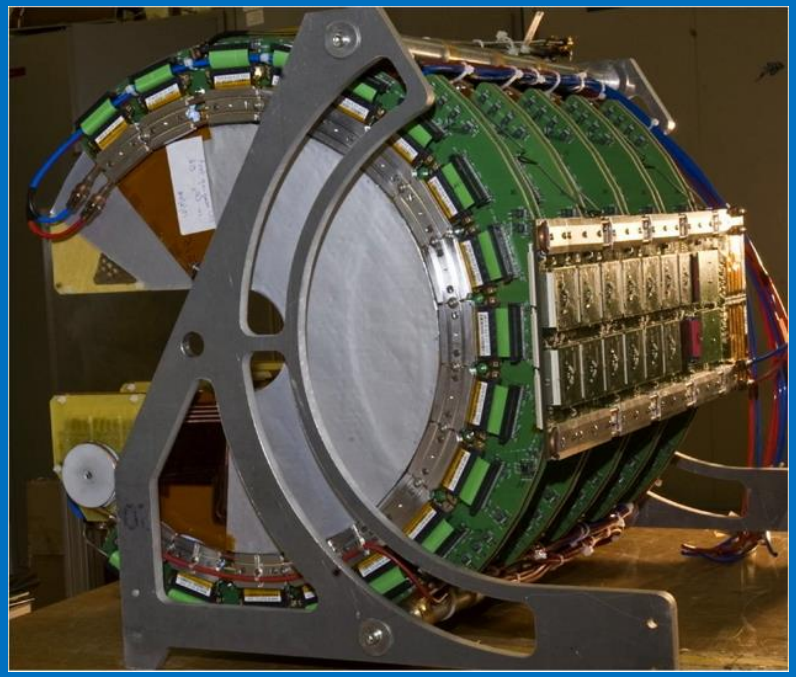
MECHANICAL DRILLING OF METAL-CLAD PCB

1 mm THICK, 400 µm HOLES



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

TRIPLE-GEM GEM DETECTORS
FOR TOTEM AT CERN



M.G. Bagliesi et al,
Nucl. Instr. Meth. A617(2010)134

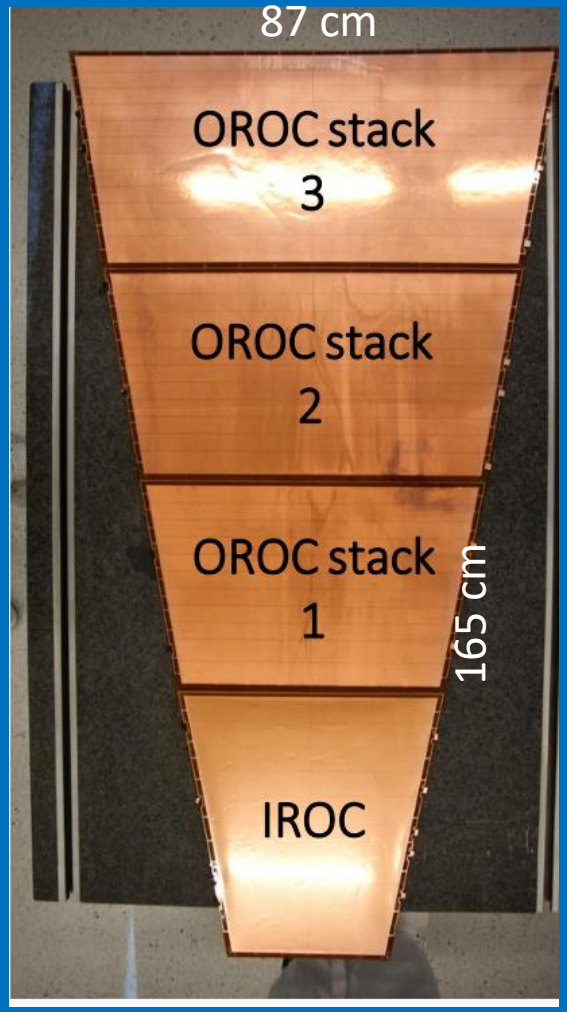
KLOE-2 INNER TRACKER

A. Balla et al,
Nucl. Instr. Meth. A732(2013)221

3 NEW STATIONS WITH TRIPLE-GEMs

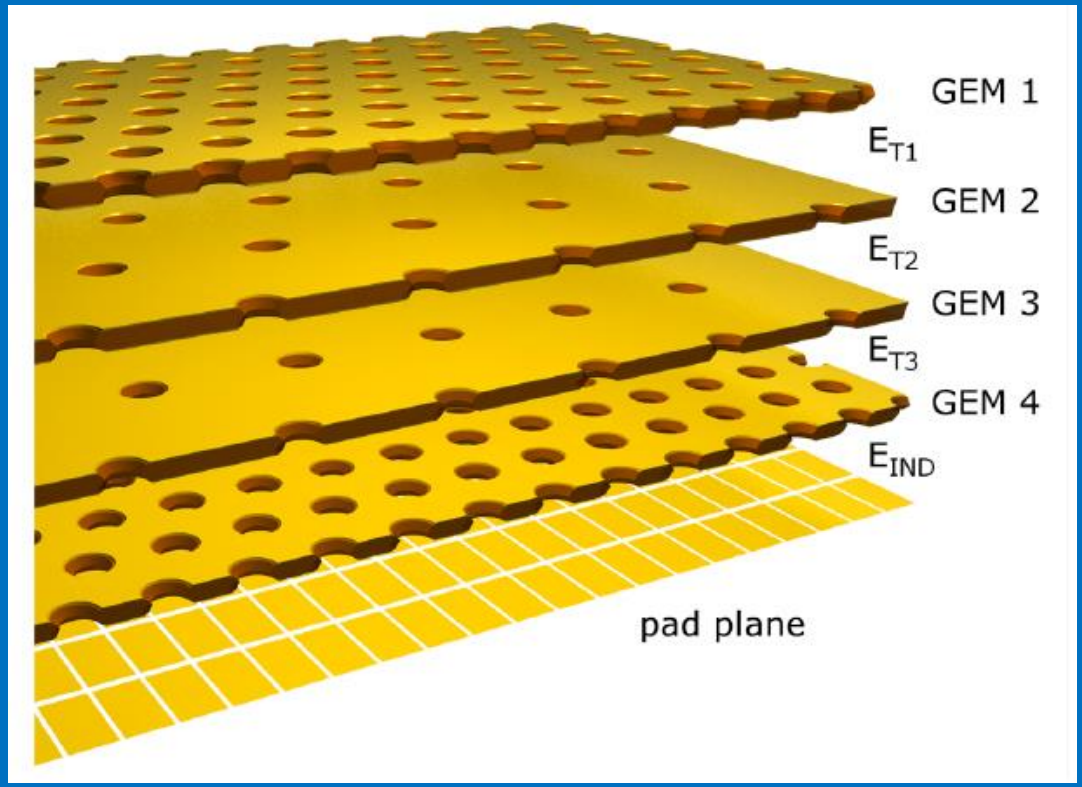
CERN DETECTORS TECHNOLOGIES

INSTALLATION OF 36 SUPER-CHAMBERS FOR FIRST AND SECOND END-CAP



72 GEM MODULES

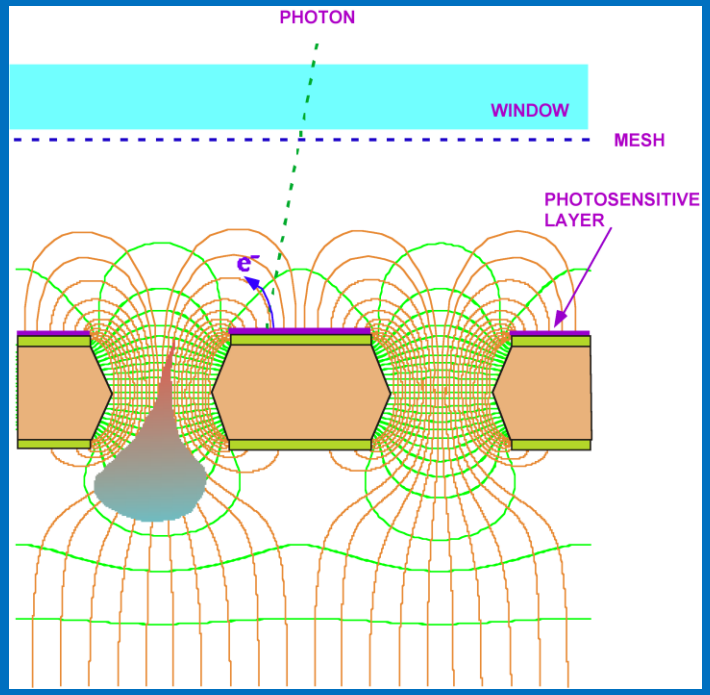
QUAD GEM FOR POSITIVE IONS SUPPRESSION



J. Adolfsson et al, JINST16 (20210)P03021

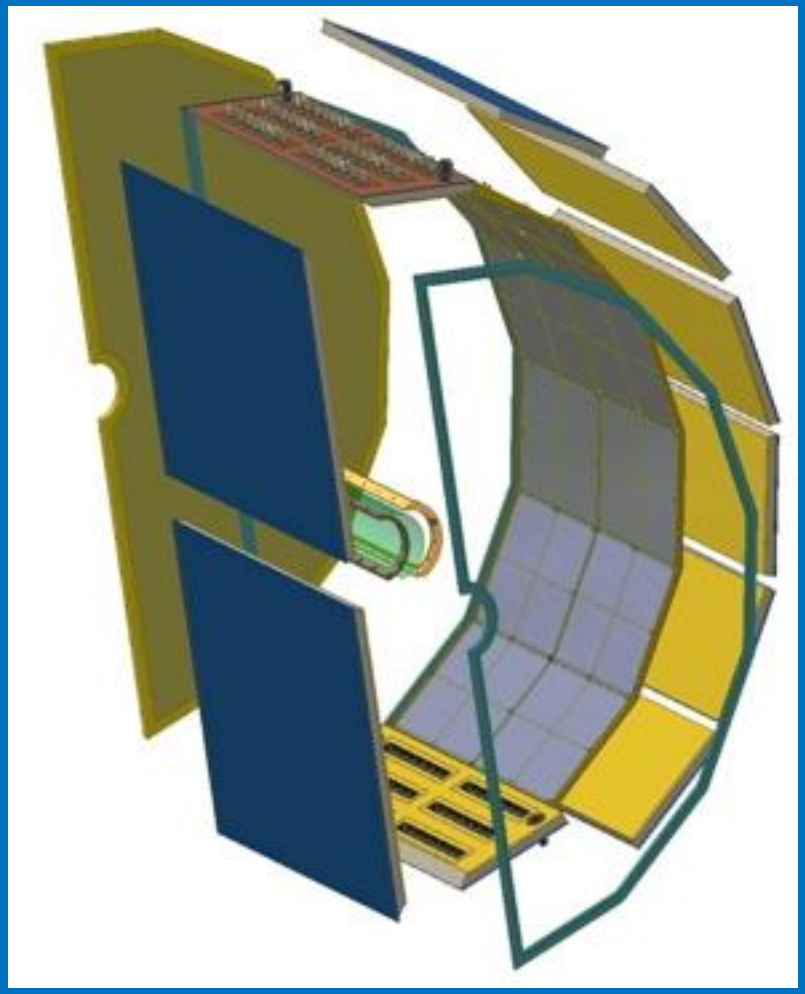
Paolo Iengo: GASEOUS DETECTORS IN HEP APPLICATIONS

GEM WITH REVERSE CsI PHOTOCATHODE



T. Meinschad, L. Ropelewski and F. Sauli, Nucl. Instr. Meth. A 535(2004)324

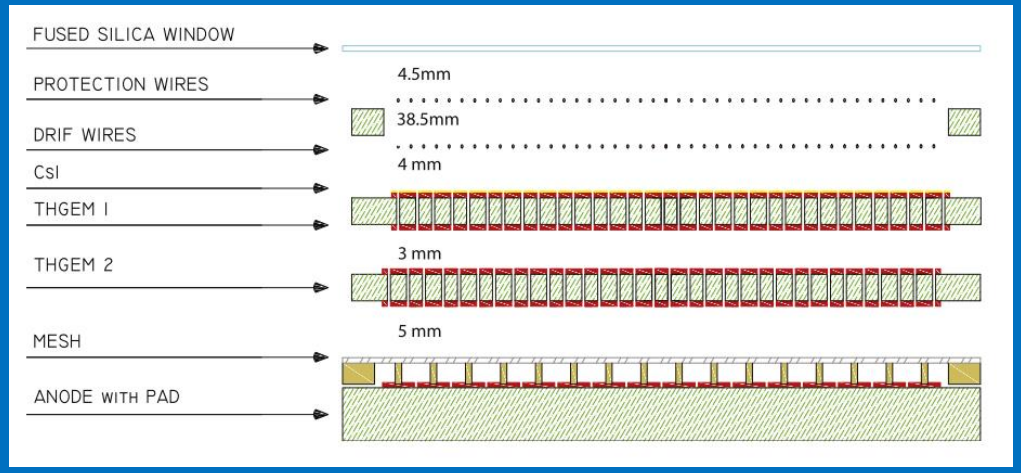
HADRON BLIND DETECTOR FOR PHENIX



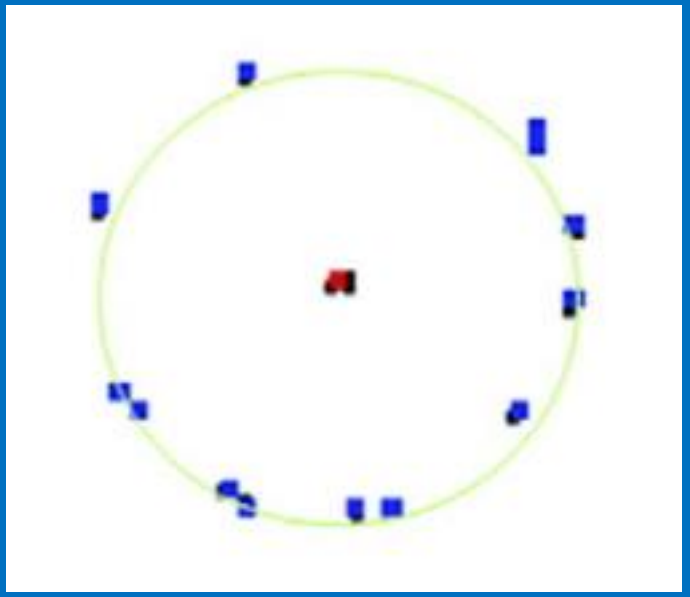
W. Anderson et al, Nucl. Instr. Meth. A646(2011)35

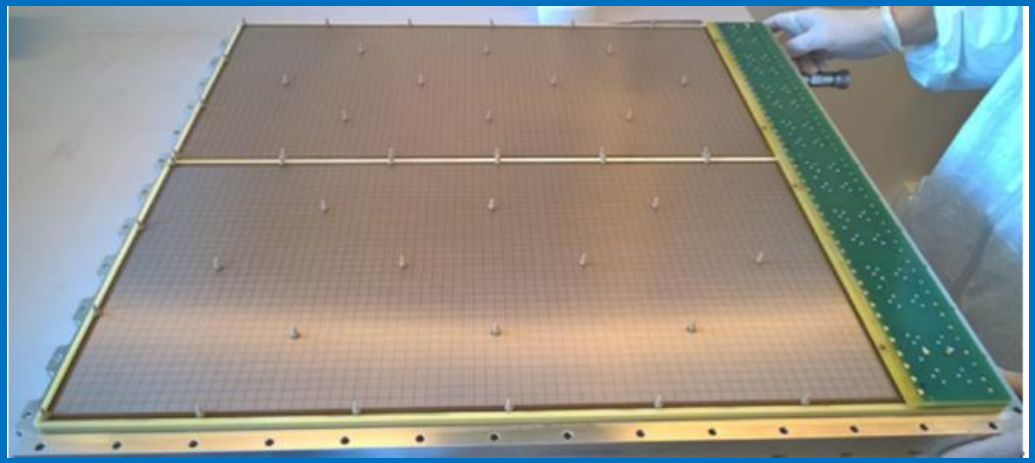
CHERENKOV RING IMAGING (COMPASS)

LARGE GAINS, REDUCED POSITIVE IONS BACKFLOW

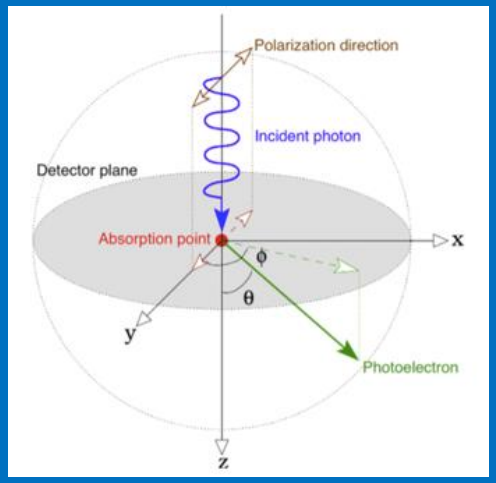


CHERENKOV RING

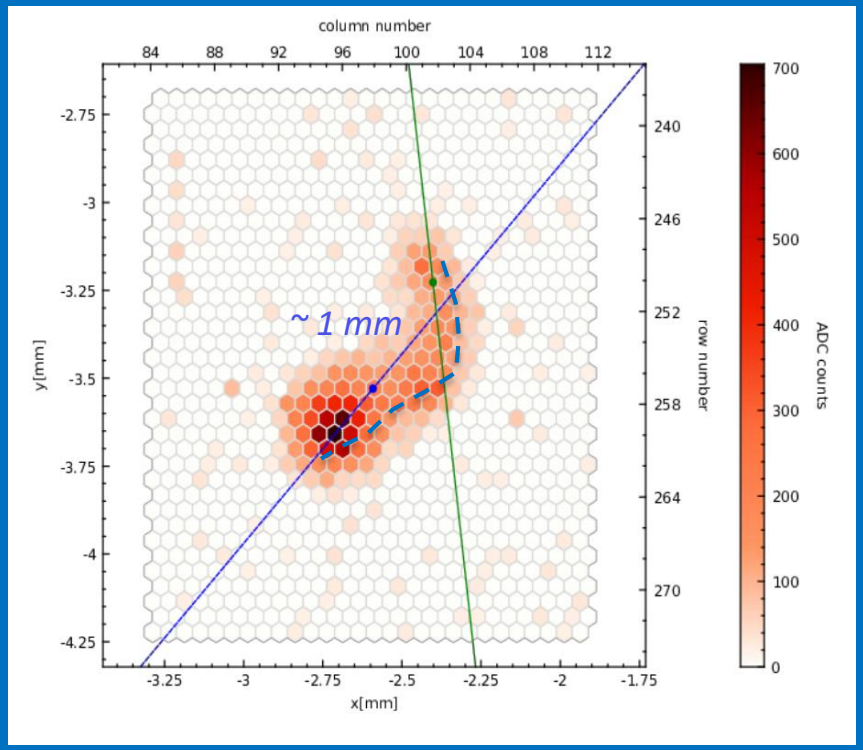


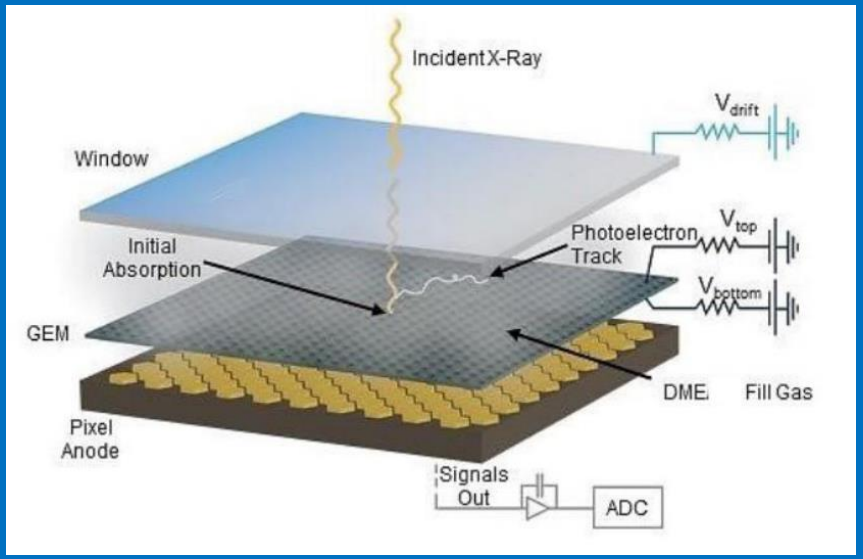


J. Agarwala et al, Nucl. Instr. Meth. A952(2020) 161832



5.9 keV PHOTOELECTRON (80 µm pixels pitch):

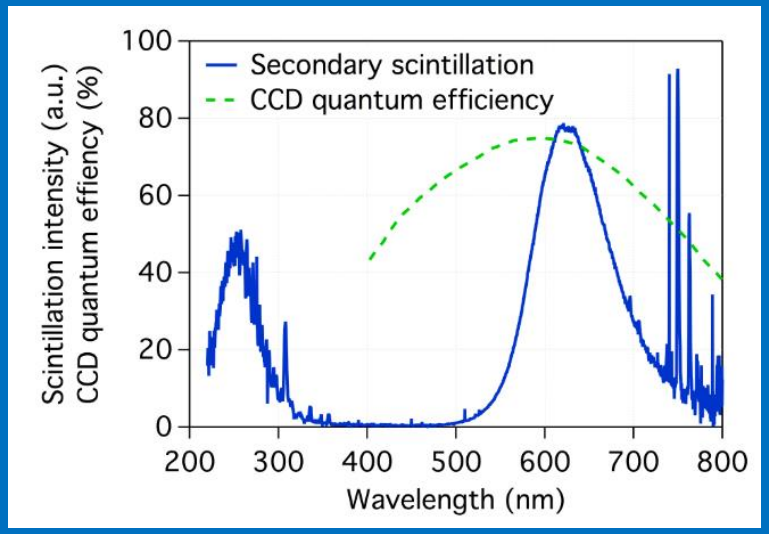


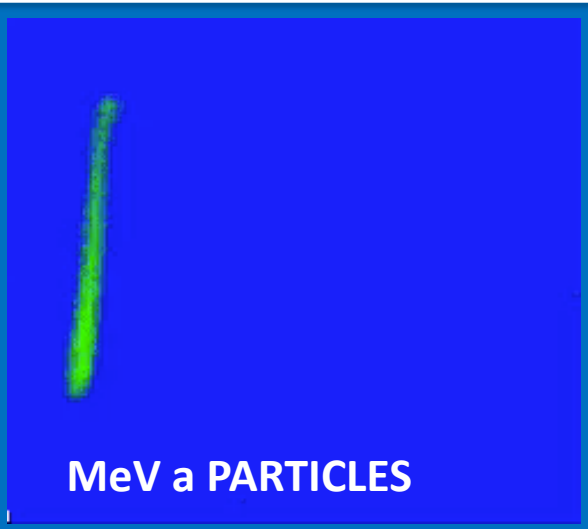


L. Baldini et al,
Astroparticle Physics (2021)

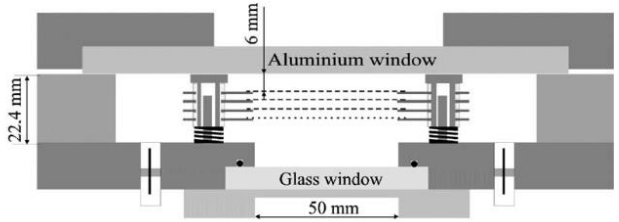
R. Bellazzini et al,
Nucl. Instr. and Meth. A720(2013)173

CF_4 SECONDARY SCINTILLATION

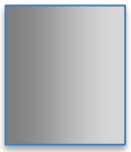


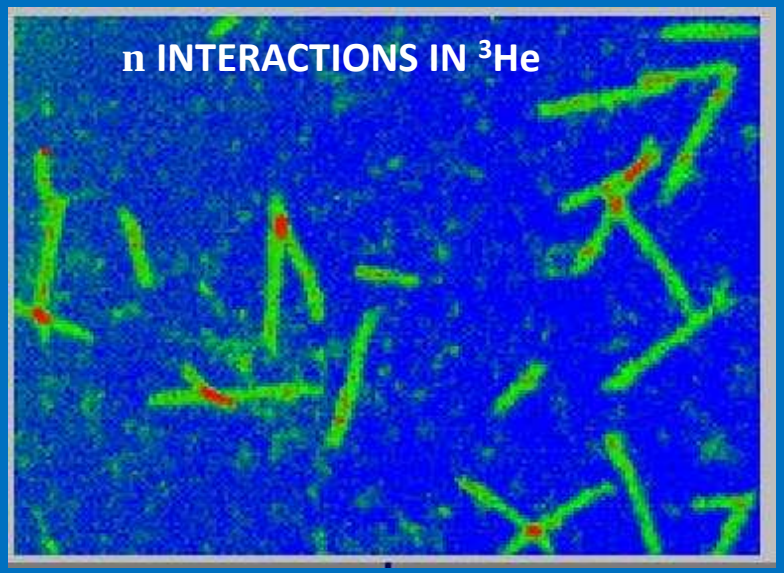


TRIPLE GEM



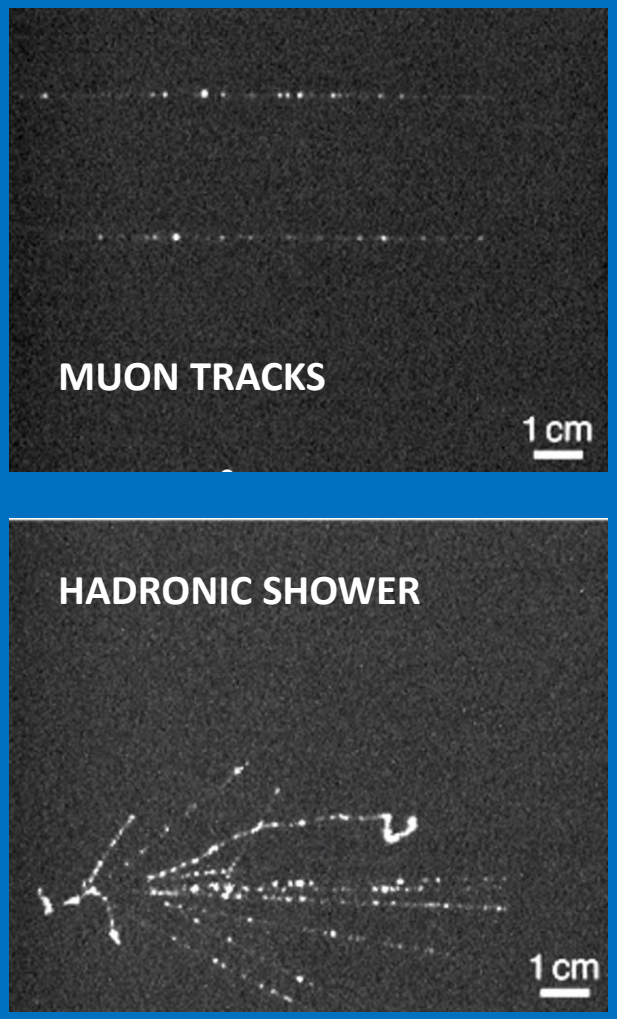
CCD CAMERA





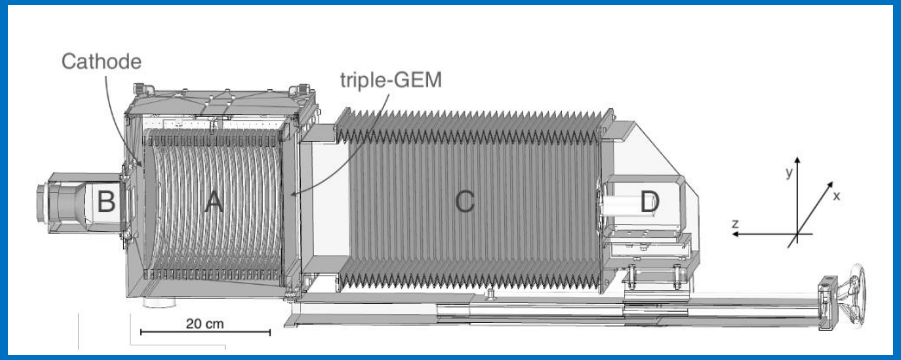
F.A.F. Fraga, et al, Nucl. Instr. and Meth. A478(2002) 357

GEM: BEAM IMAGER

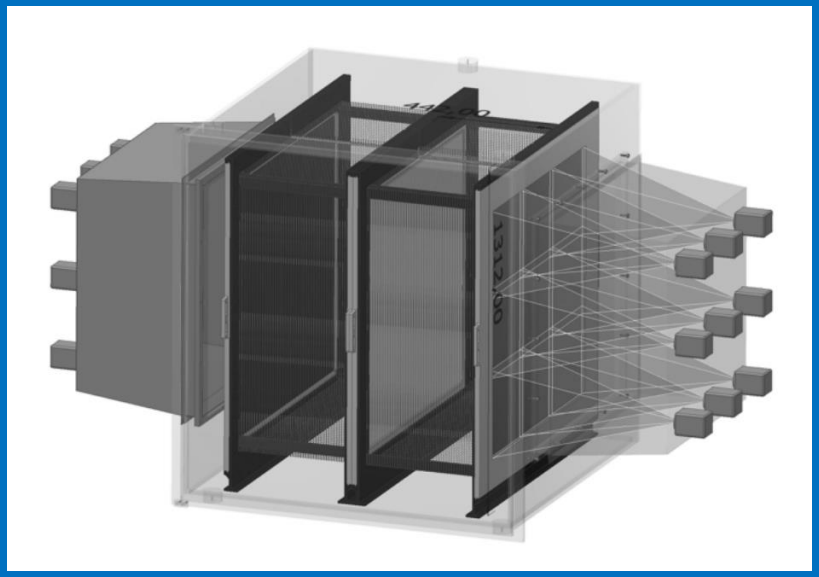


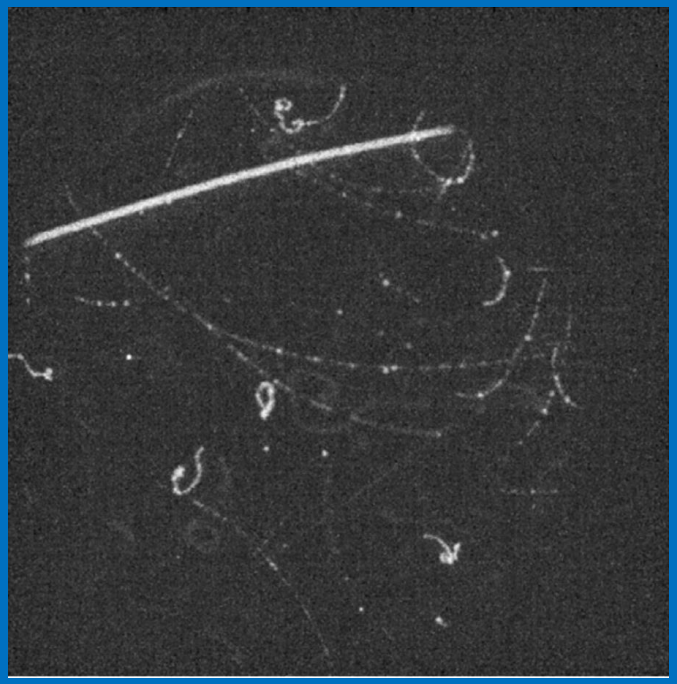
SOFT X-RAY RADIOGRAPHY

F. Brunbauer et al, JINST 13(2018)T02006



CYGNO:
DIRECTIONAL DARK MATTER SEARCH

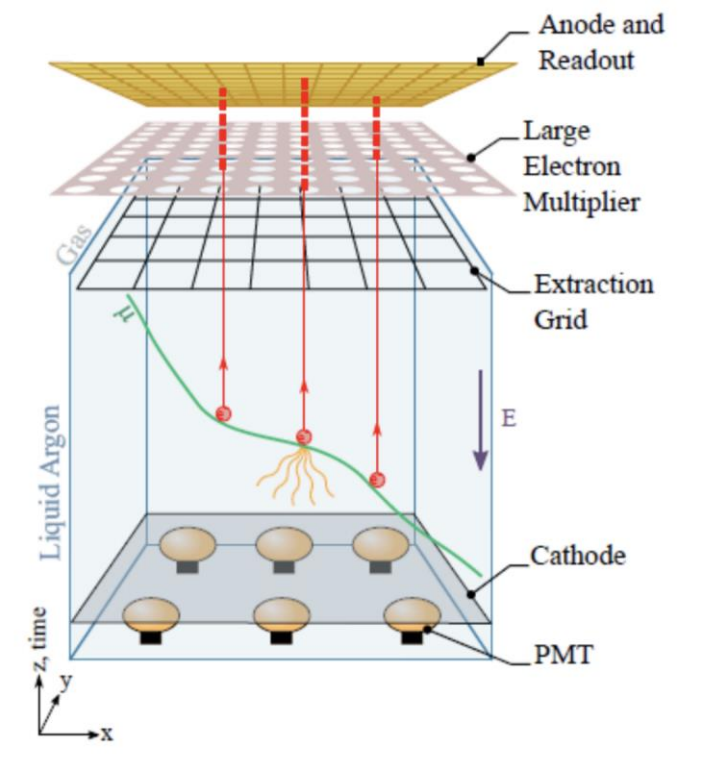


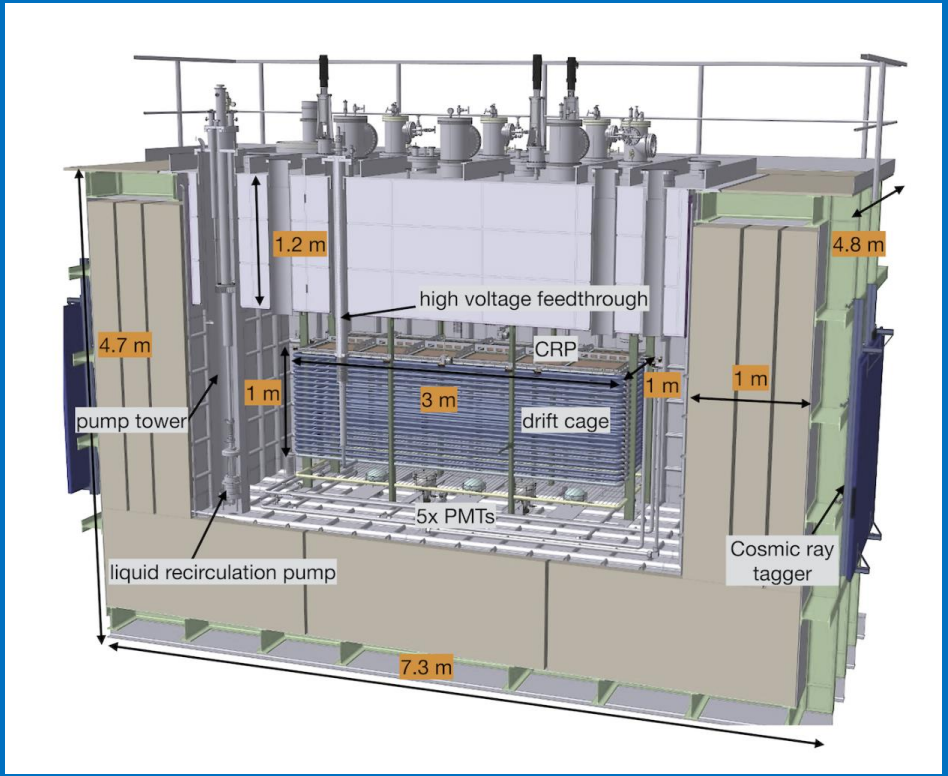


D. Pinci et al,
Nucl. Instr. Meth. A936(2019)453

Davide Pinci: OPTICAL AND HYBRID READOUT TECHNIQUES

Proto-DUNE





C. Cuesta et al, arXiv:1910.10115v1(2019)


The End