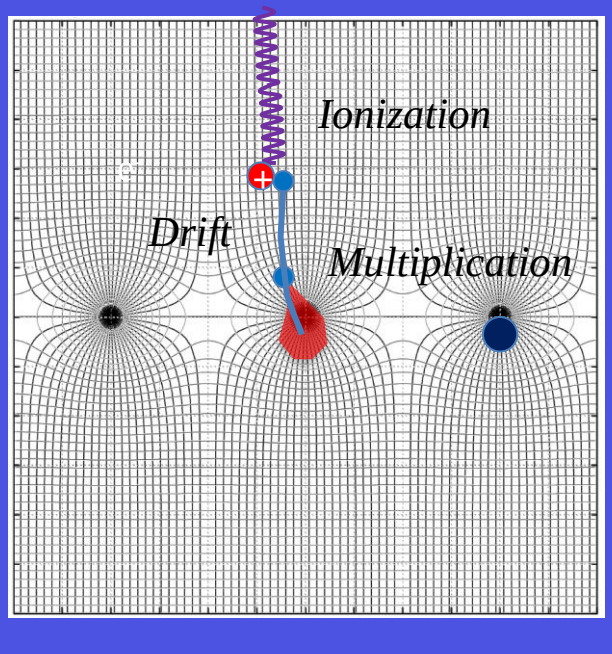
FROM MWPC TO MPGD

Fabio SAULI
CERN

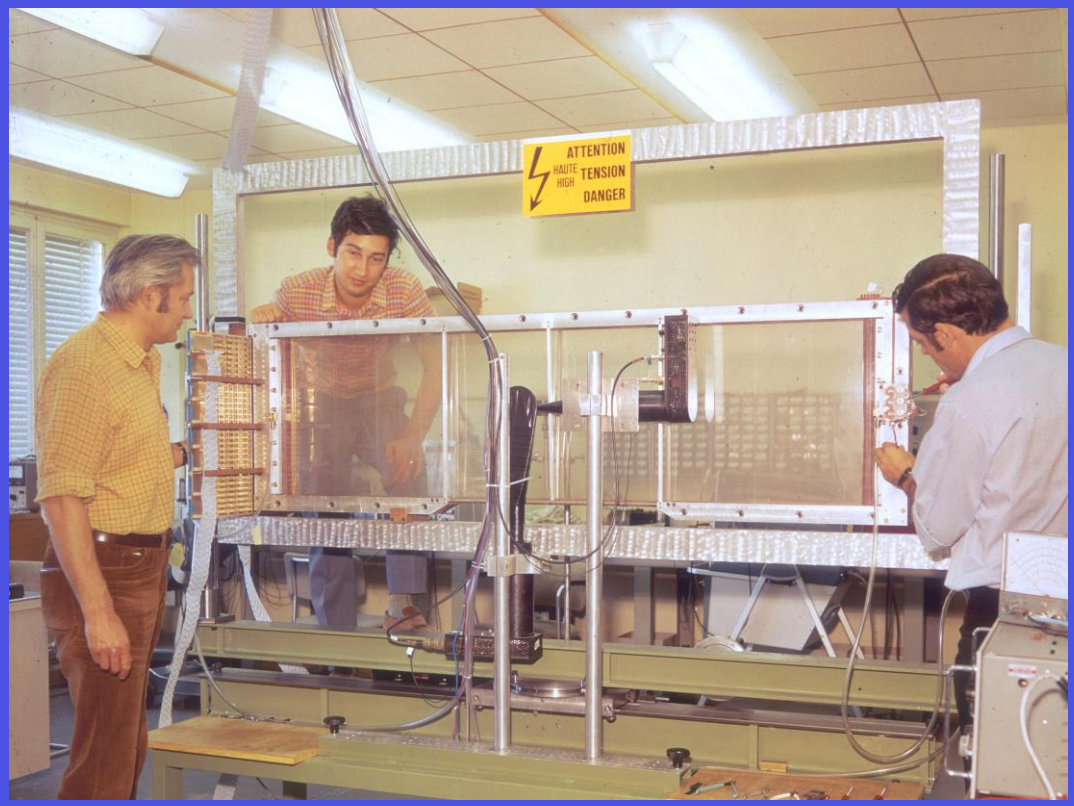
RD51 Micro Pattern Gaseous Detectors School
CERN November 27, 2023 to December 1, 2023

MULTIWIRE PROPORTIONAL CHAMBER (MWPC)



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

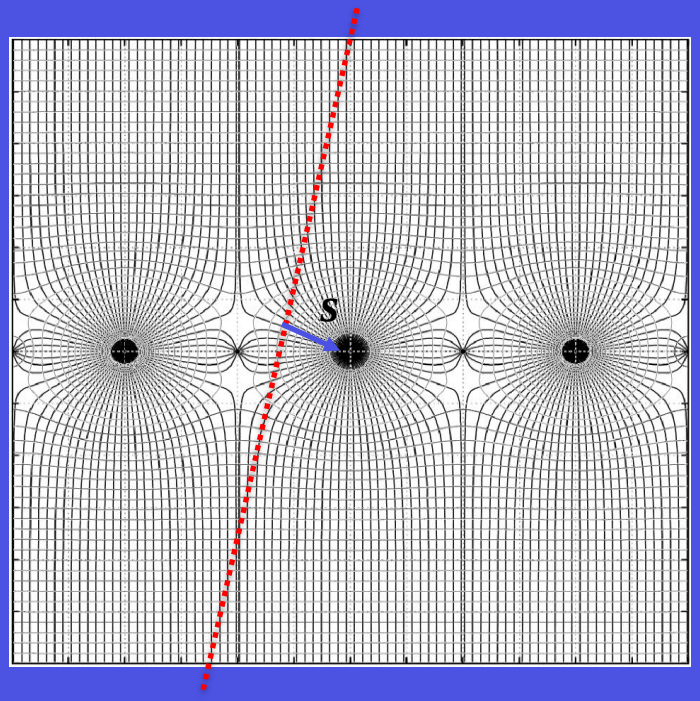
FIRST LARGE MWPC (CERN 1970)



Georges Charpak

Measurement of electron drift time t

$s = w\,t$



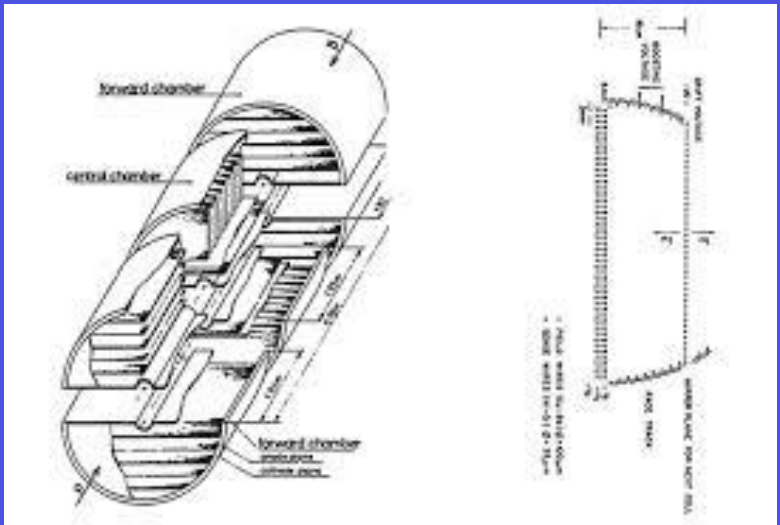
A. H. Walenta et al
Nucl. Instr. Meth. 92(1971)373

WA1 NEUTRINO DETECTOR AT CERN

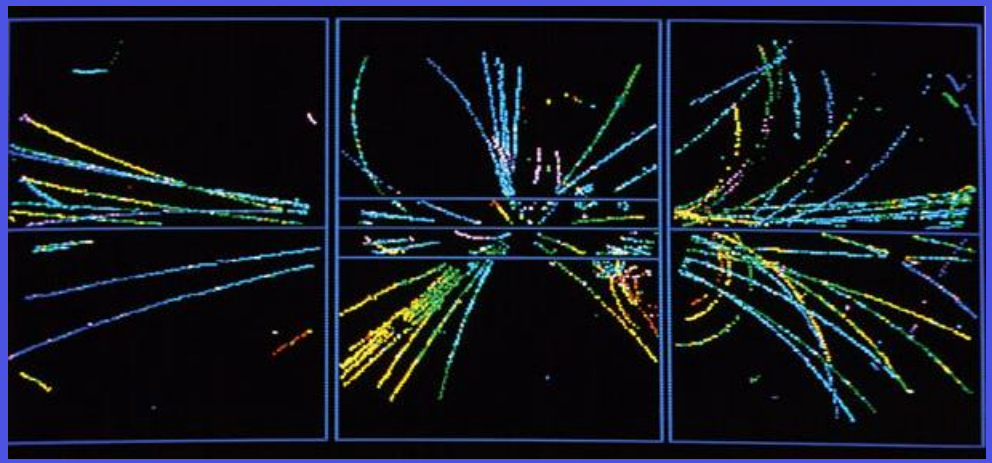
G. Marel et al, Nucl. Instr. Meth. 141(1977)43

UA1 EXPERIMENT - CERN PROTON-ANTIPROTON COLLIDER

XY FROM WIRE CHAMBER
Z FROM ELECTRONS DRIFT TIME

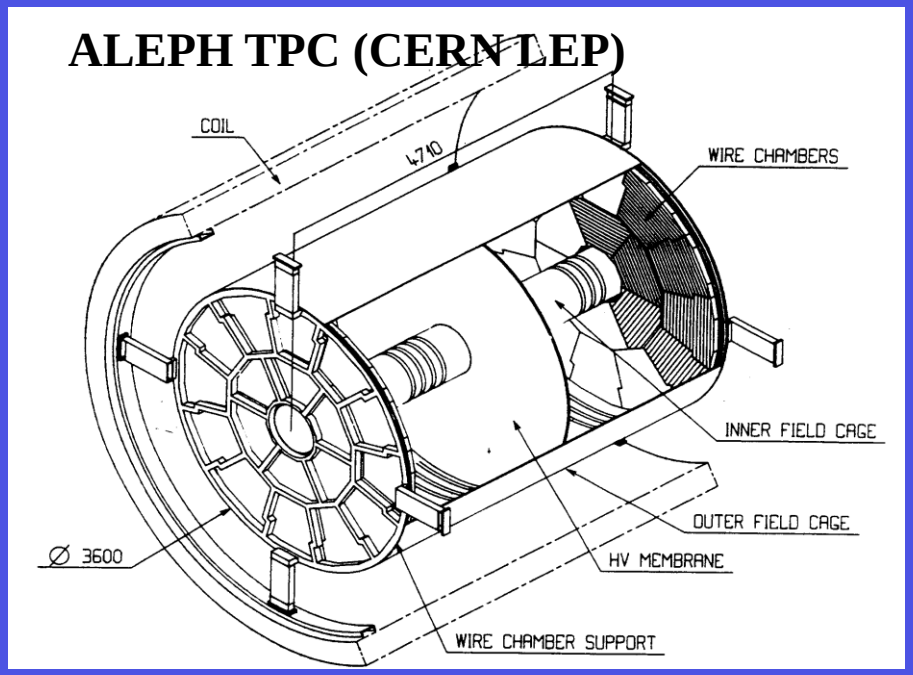


$\bar{p}p$ COLLISION (1982)



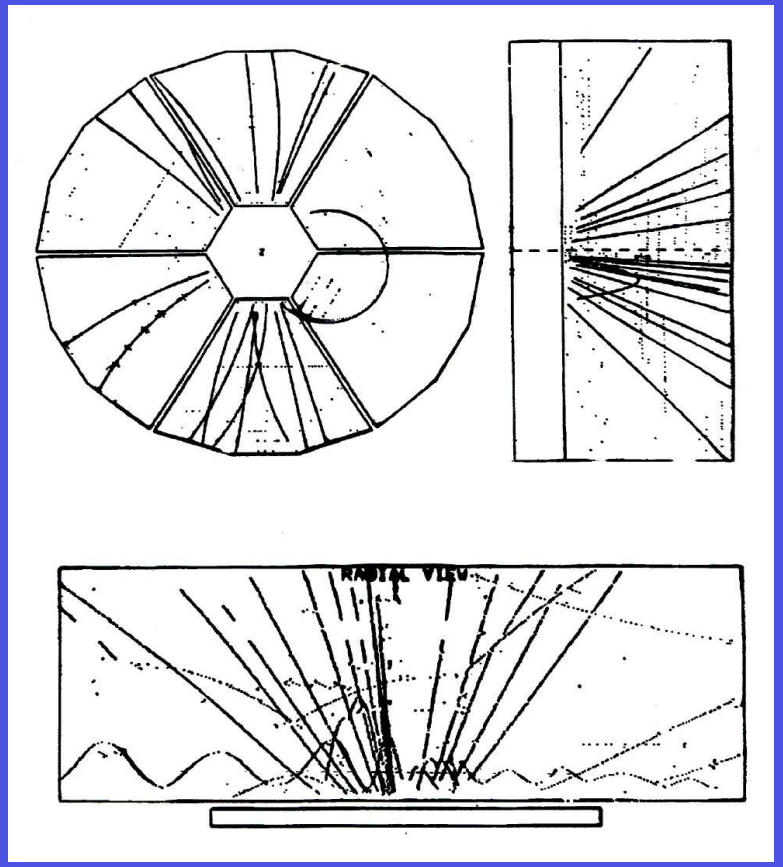
Discovery of the W and Z vector bosons
C. Rubbia, Simon van der Meer
Nobel Laureates 1984

DAVID NYGREN (1975)



D. Decamp et al,
Nucl. Instr. Meth. A294(1990)125

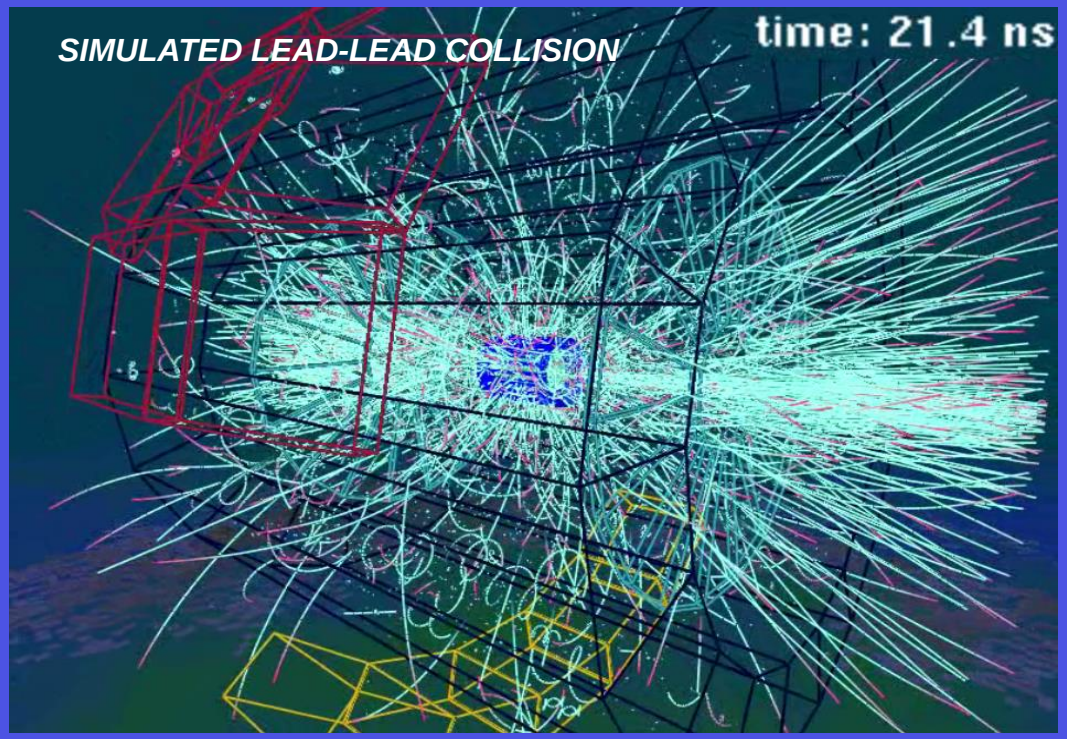
LBL PEP-4 TPC



3-D TRACKING
dE/dx: PARTICLE IDENTIFICATION

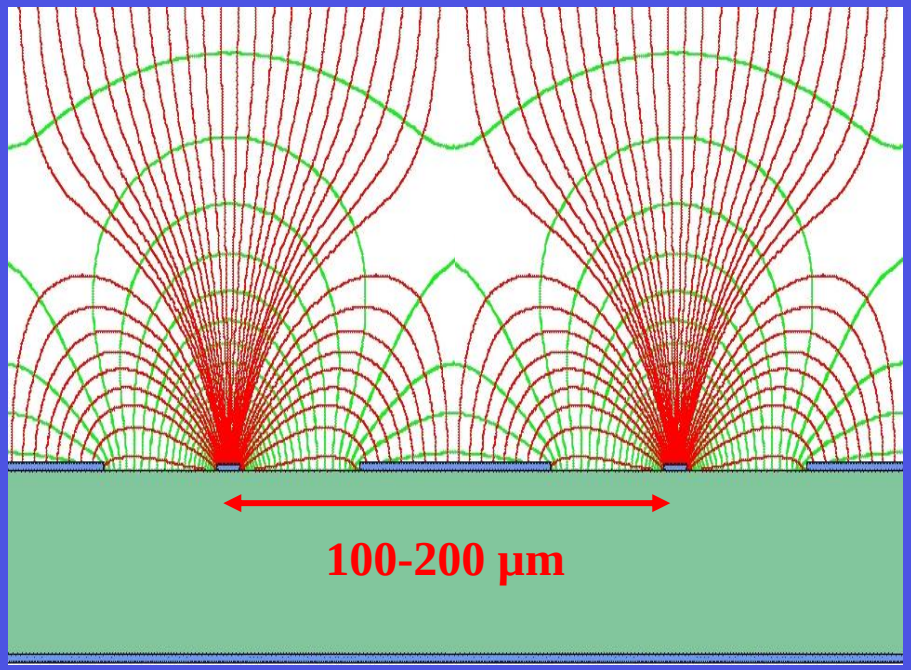
LHC: 10^9 pp COLLISIONS/sec

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

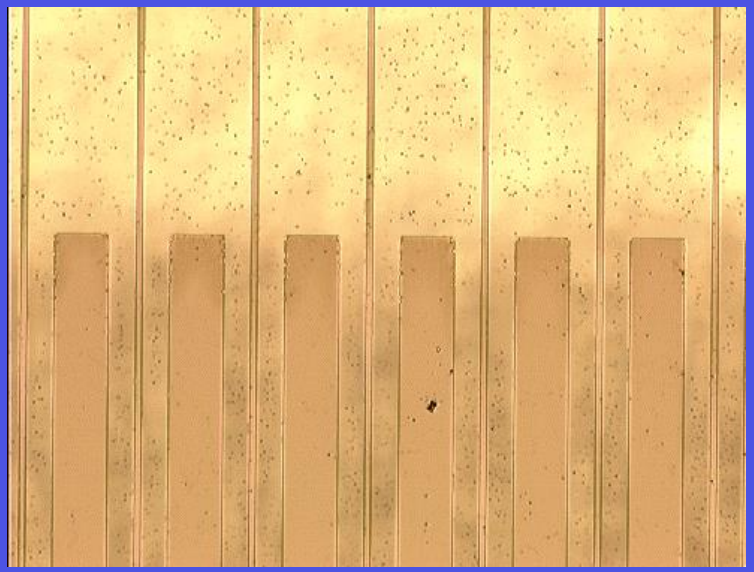


MWPC LIMITATIONS:
TWO-TRACKS RESOLUTION ~ mm
RATE CAPABILITY ~ 10^4 mm^{-2} s^{-1}
AGING
HARD TO BUILD, FRAGILE

Anton Oed, 1988



ALTERNATING ANODE AND CATHODE STRIPS ENGRAVED ON GLASS WITH PHOTOLITHOGRAPHY



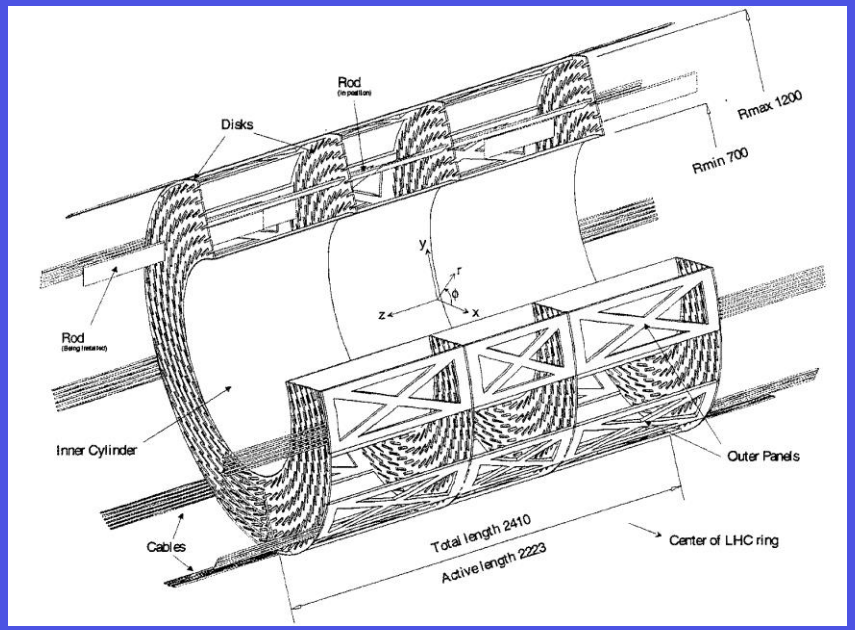
A. Oed, ucl. Instr. Meth. 263(1988)351

- **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

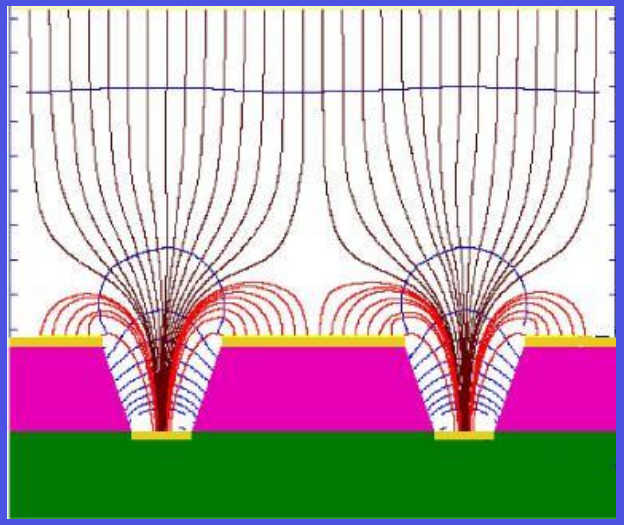
DISCHARGE PROBLEMSAND LONG TERM RELIABILIY



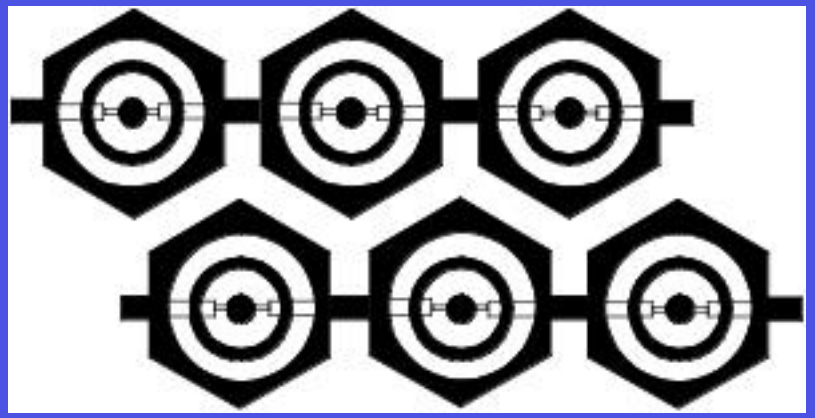
GAIN TO DETECT MIPs (100 e^-) : ~10^4 $\Delta Q \sim 10^6$

~ MeV NEUTRON CONVERSION (~ 10^4 e^-) $\Delta Q \sim 10^8$ >> RAETHER LIMIT!

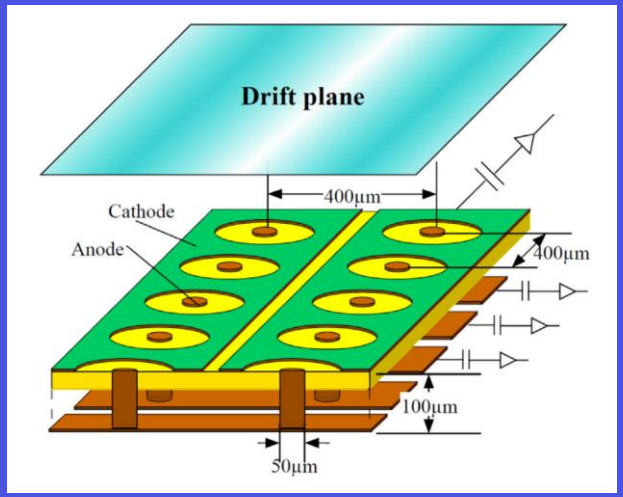
MICRO GROOVE (R. Bellazzini, 1999)



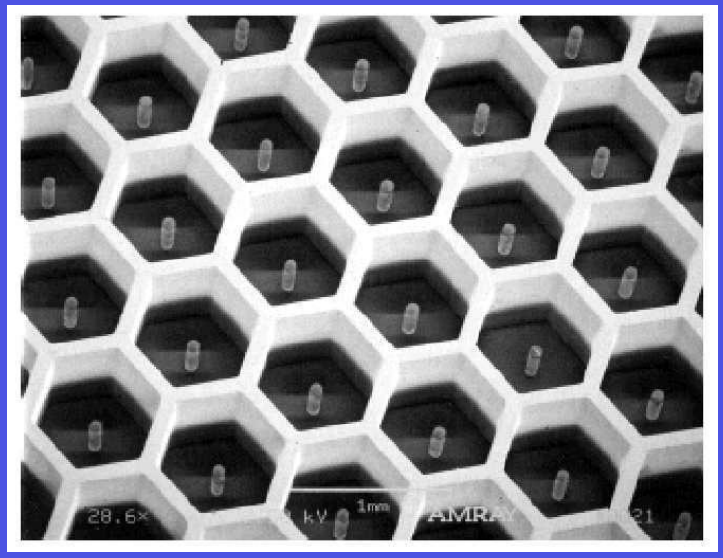
MICRODOT (S.Biagi, 1995)



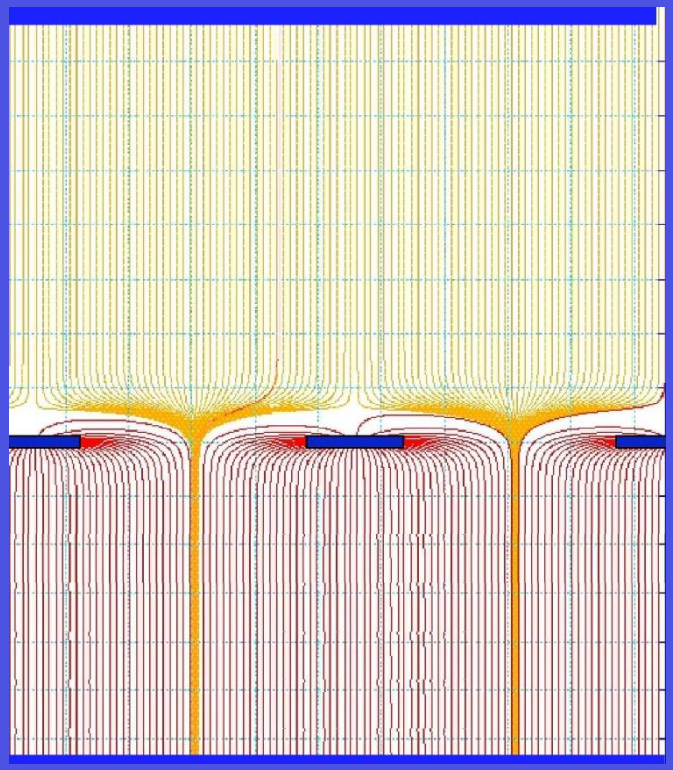
MICRO-PIXEL DETECTOR (A.Ochi, 2001)



MICRO-PIN ARRAY (P. Rehak, 2000)

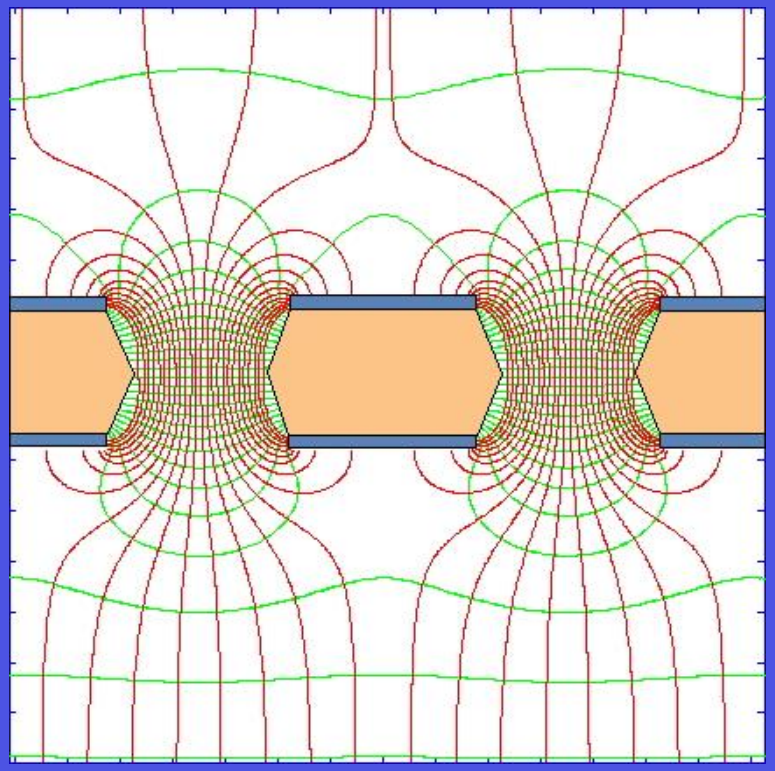


MICROMEGAS



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

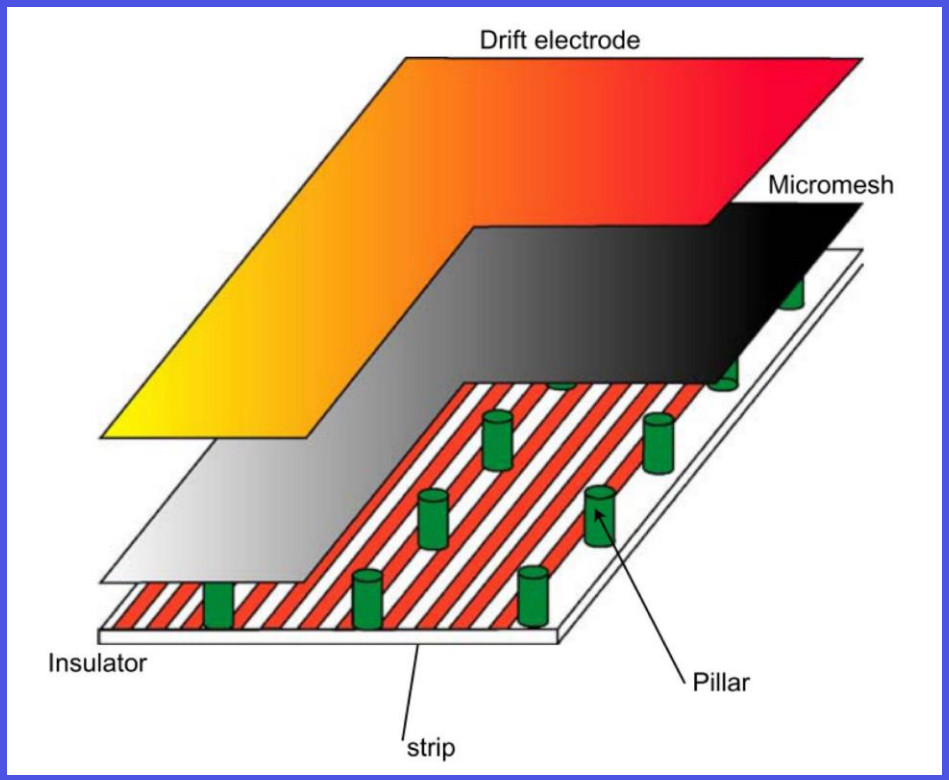
GAS ELECTRON MULTIPLIER (GEM)

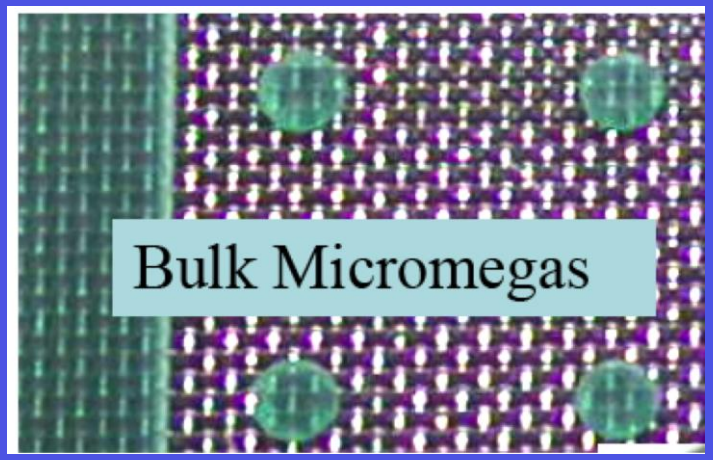


F. Sauli, Nucl. Instr. Meth. A386(1997)531

Esther Ferrer Ribas: MPGD TECHNOLOGIES 1

Eraldo Oliveri: MPGD TECHNOLOGIES 2

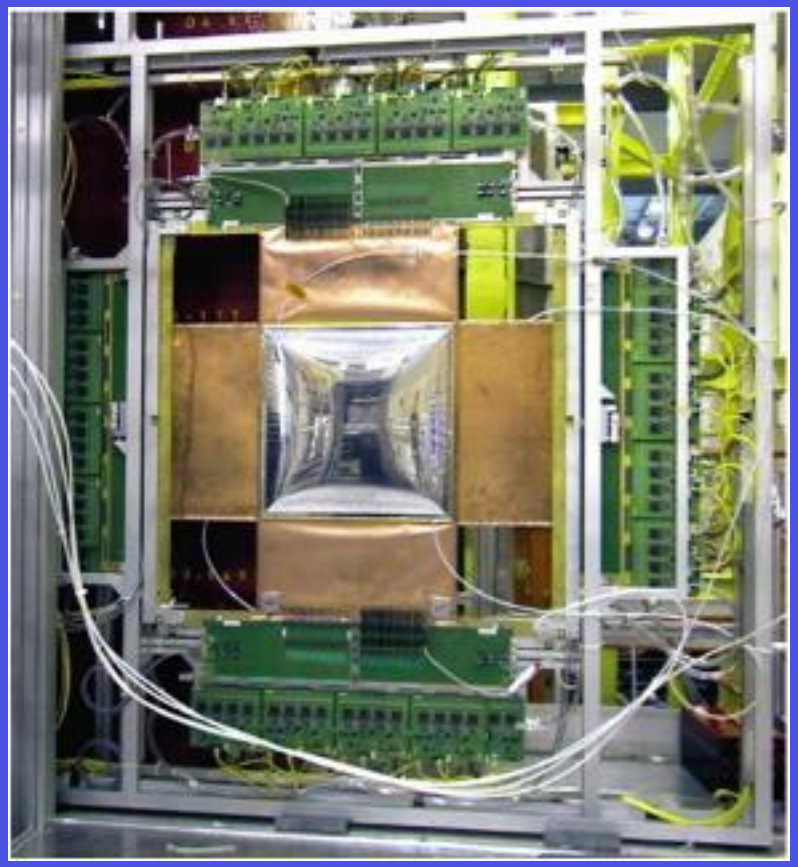




I. Giomataris et al,
Nucl. Instr. Meth. A560(2006)405

Rui de Oliveira: MPGD MANUFACTURING

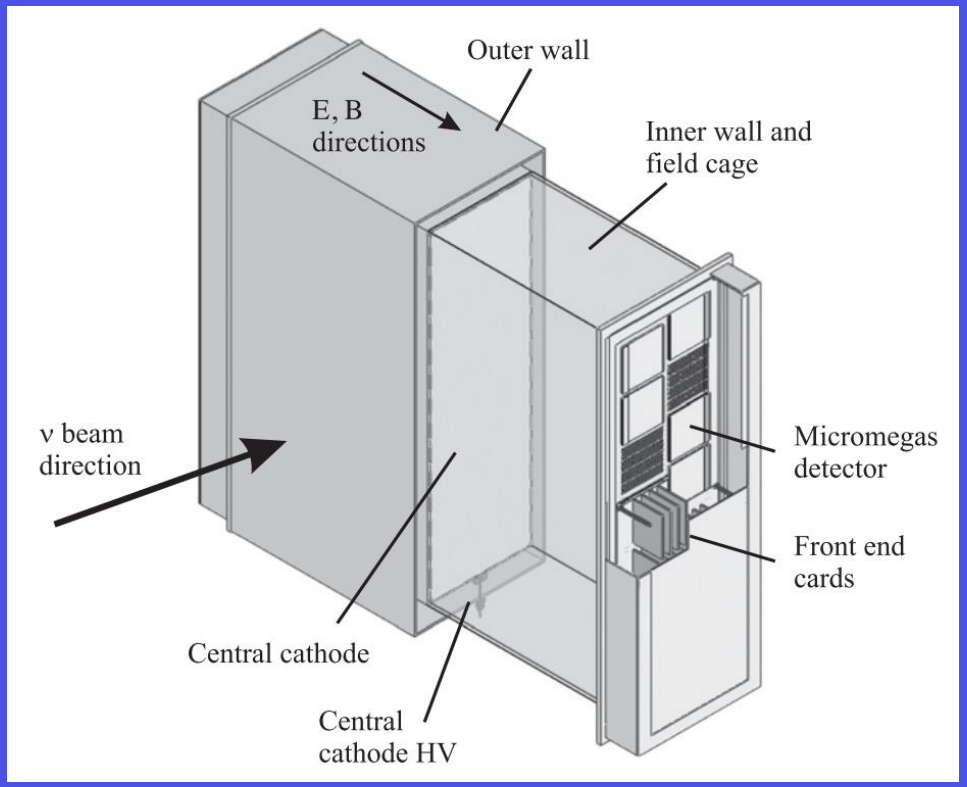
COMPASS SPECTROMETER TRACKER AT CERN

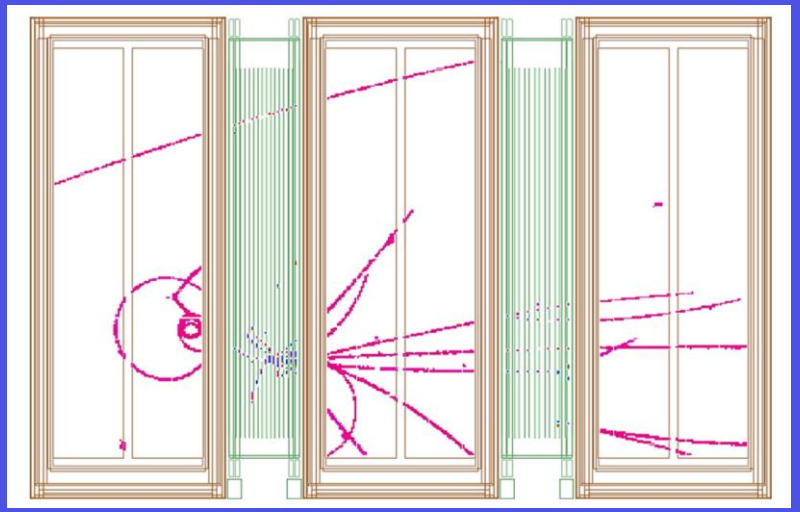


12 PLANES 40x40 cm^2 aCTIVE
3 XYUV STATIONS
POSITION ACCURACY ~ 70 µm

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

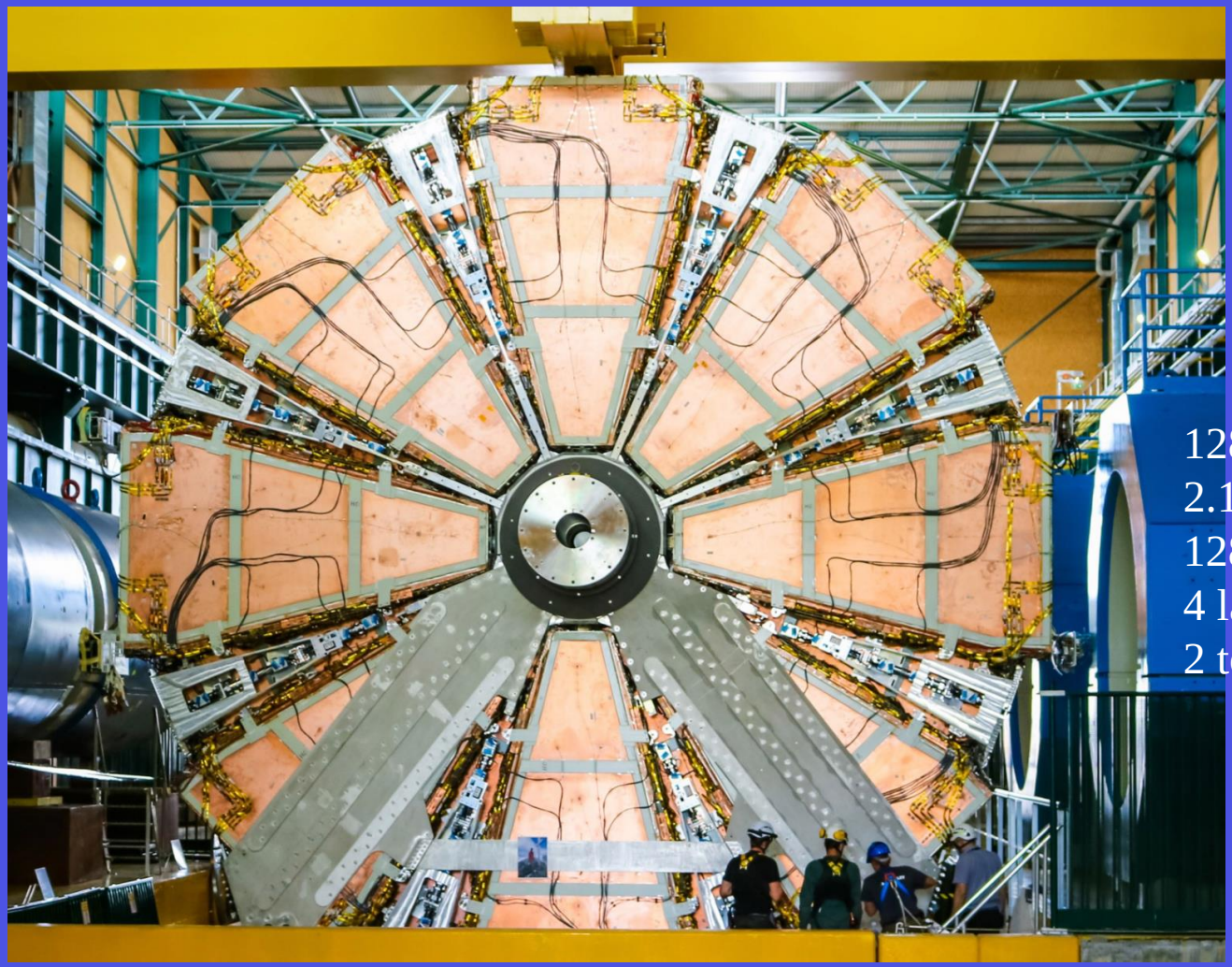
TIME PROJECTION CHAMBER FOR THE T2K NEAR DETECTOR





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

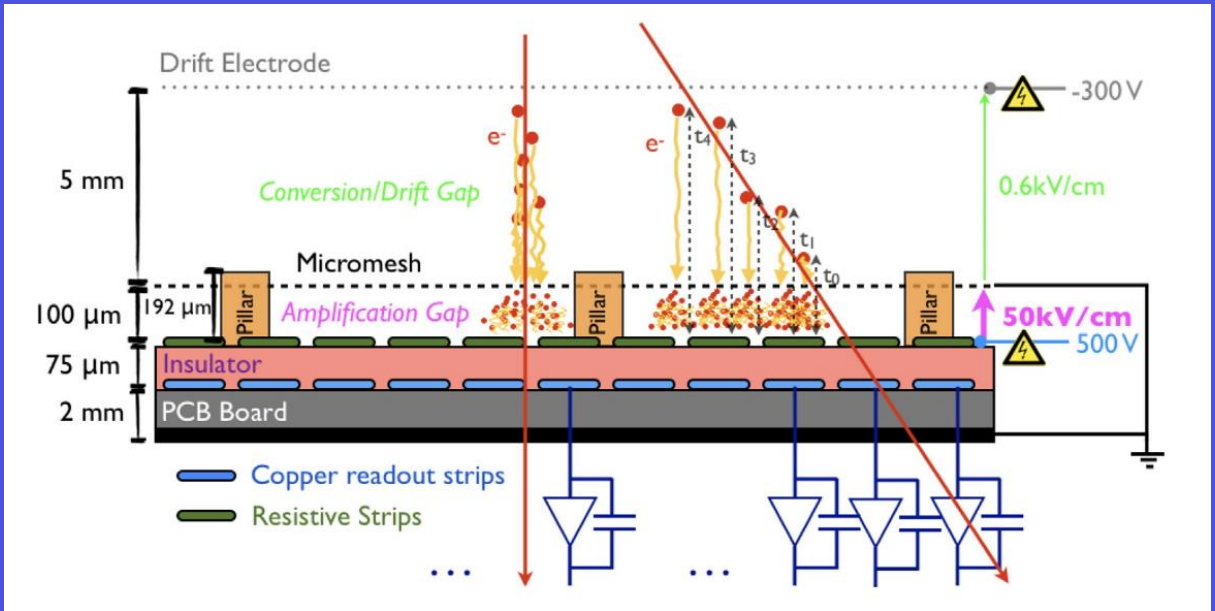
ATLAS MICROMEGAS UPGRADE



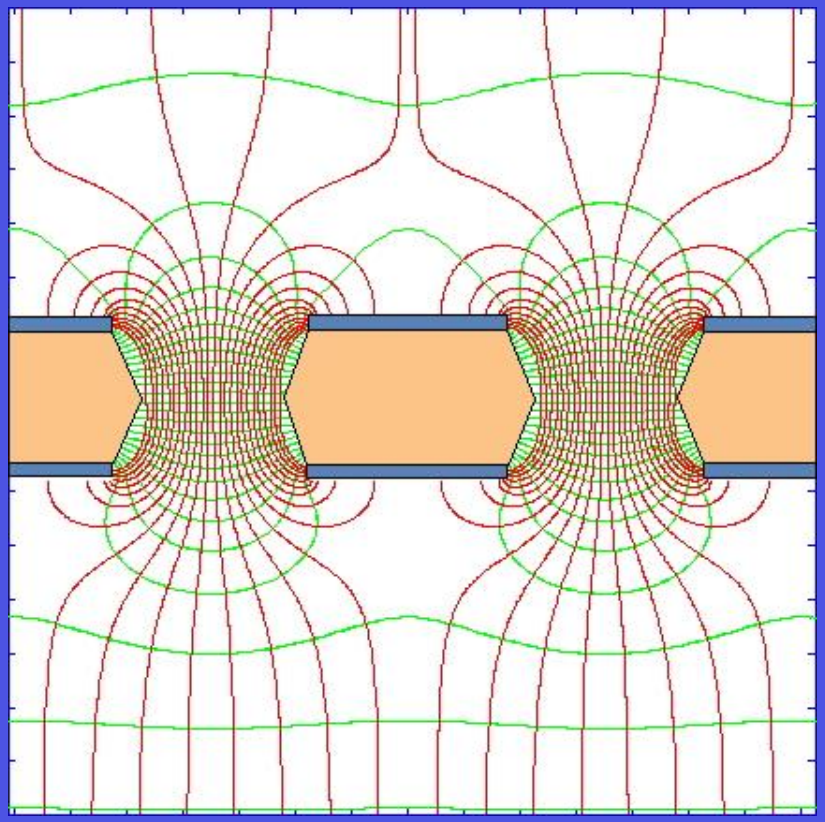
1280 m2 active surface
2.1 M readout channels
128 detectors / 4 types
4 layers
2 to 3 m2 area

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

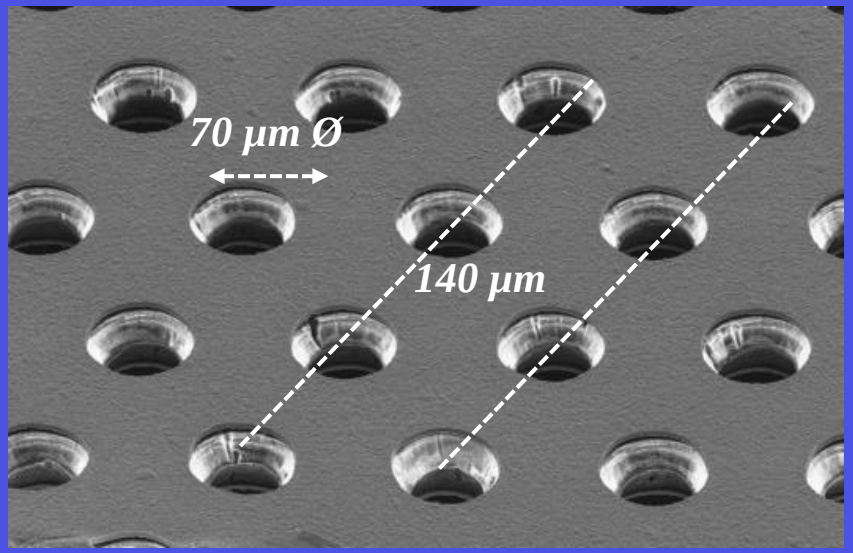
RESISTIVE MICROMEGAS: DISCHARGES SUPPRESSION



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

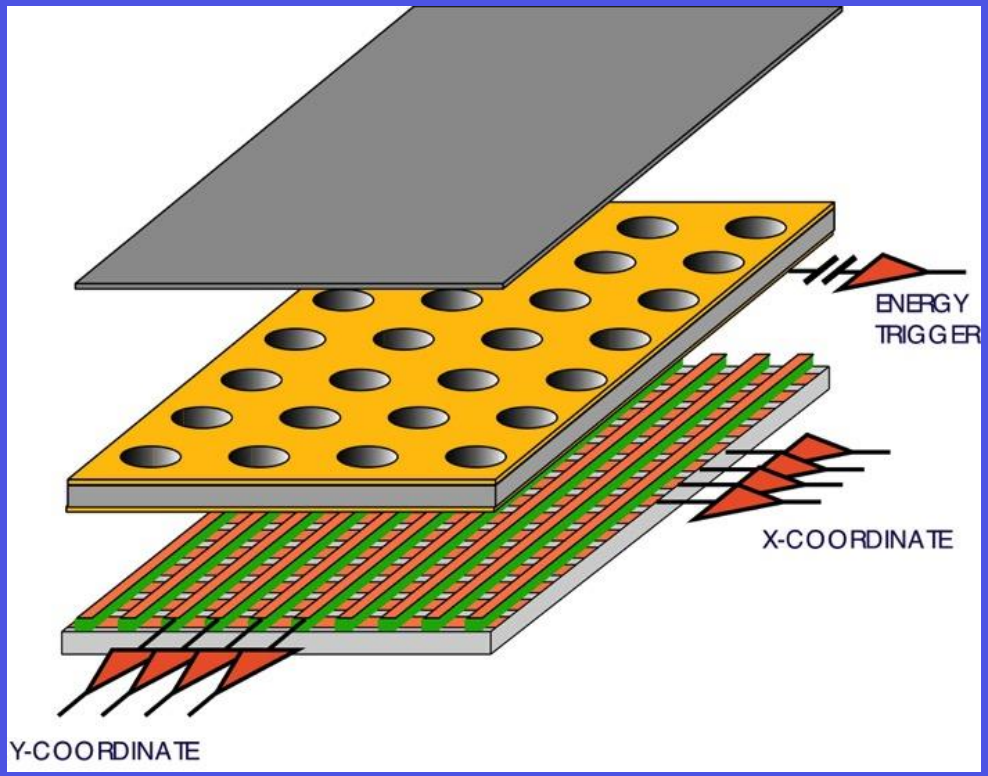


50 µm thick Kapton, 5 µm Cu-coated

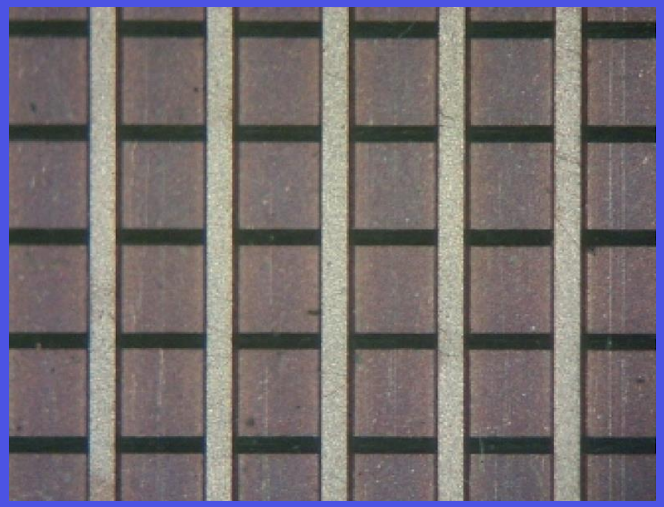


F. Sauli, Nucl. Instr. Meth. A386(1997)531

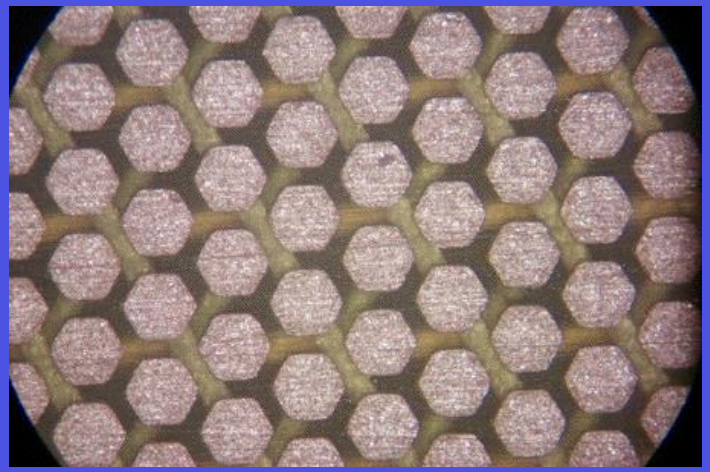
GEM CHAMBER WITH 2-DIMENSIONAL READOUT



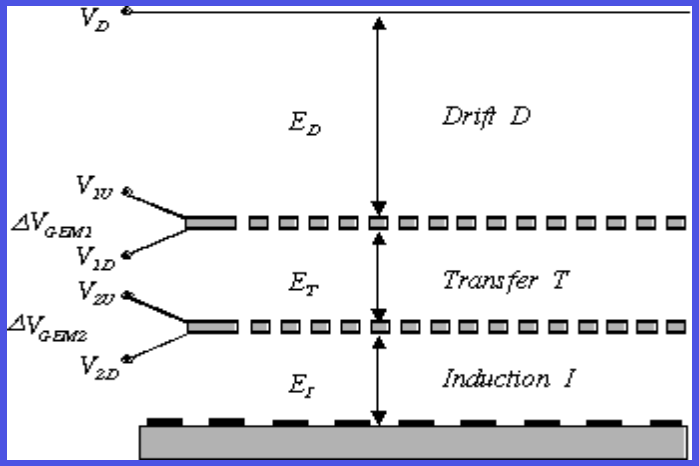
STANDARD XY 400 µm PITCH

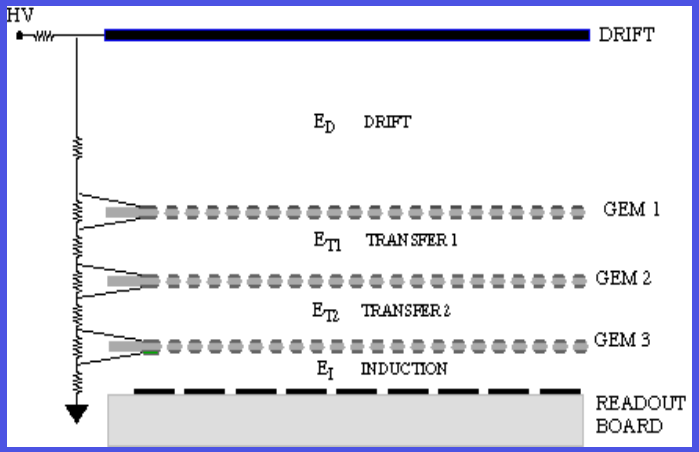


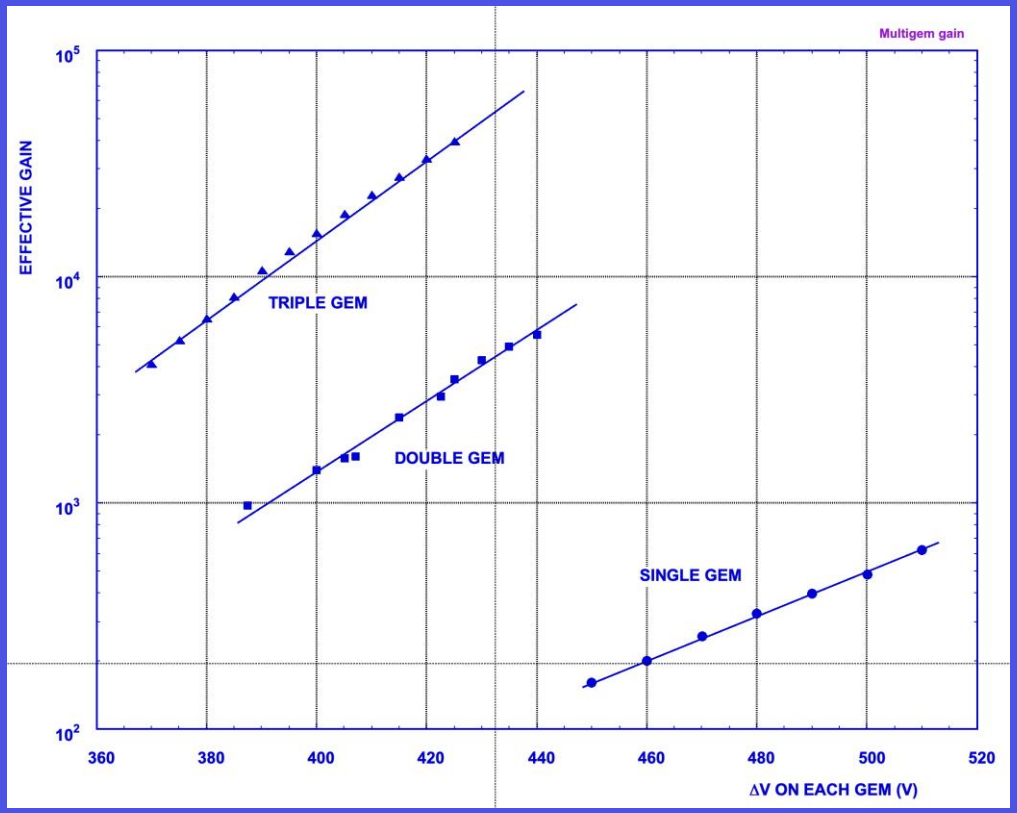
PAD MATRIX 500 µm PICH



LOWER VOLTAGE ON EACH GEM
HIGHER SAFE TOTAL GAIN





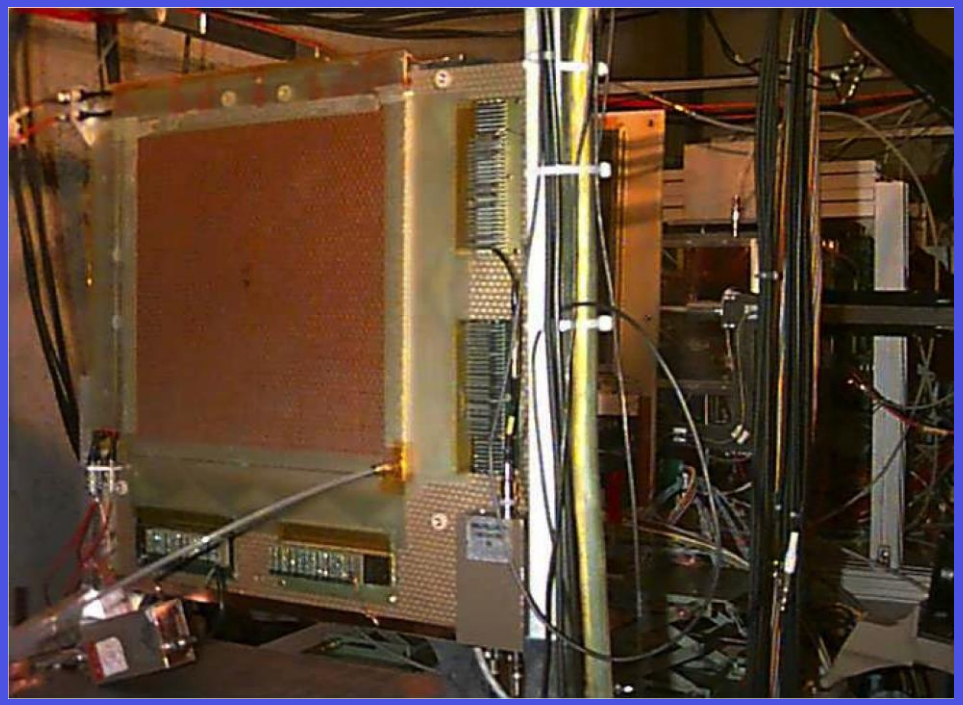


S. Bachmann et al, Nucl. Instr. Meth. A479(2012)294

COMPASS TRACKER AT CERN (2001-2020)

A 30x30 cm^2 GEM ELECTRODE

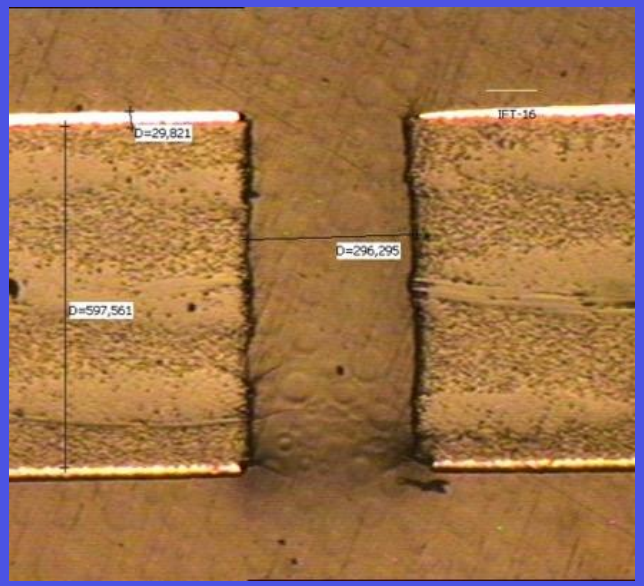
~ 30 TRIPLE-GEM DETECTORS
30x30 cm^2 – 2-D Readout



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

THIK GEM (also LEM: Large Electron Multiplier):
MECHANICAL DRILLING OF METAL-CLAD PCB

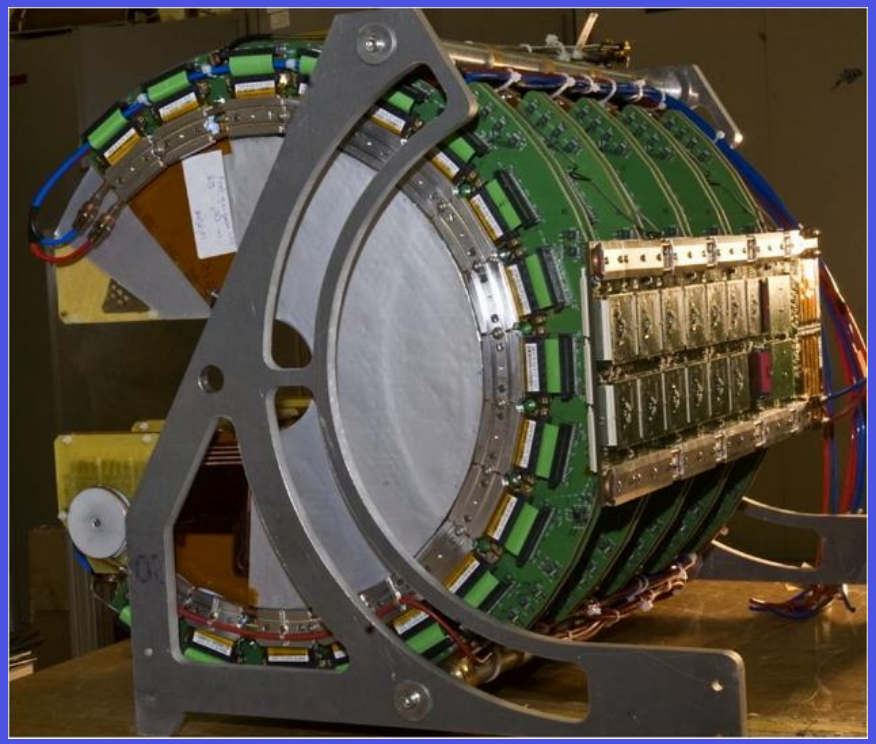
1 mm THICK, 400 μm HOLES



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

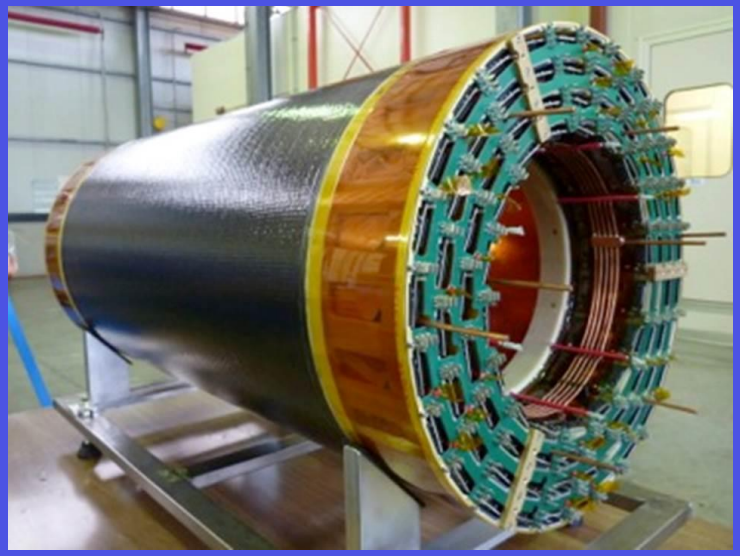
Rui de Oliveira: MPGD MANUFACTURING

HALF-MOON TRIPLE-GEM GEM DETECTORS FOR TOTEM AT CERN

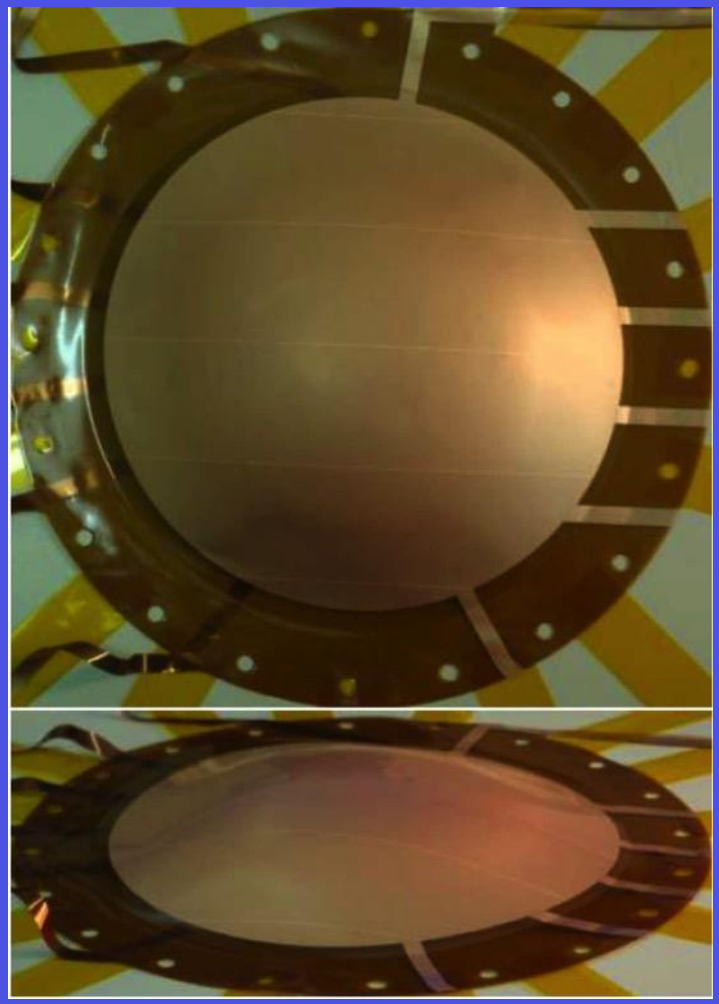


M.G. Bagliesi et al, Nucl. Instr. Meth. A617(2010)134

KLOE-2 INNER TRACKER



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

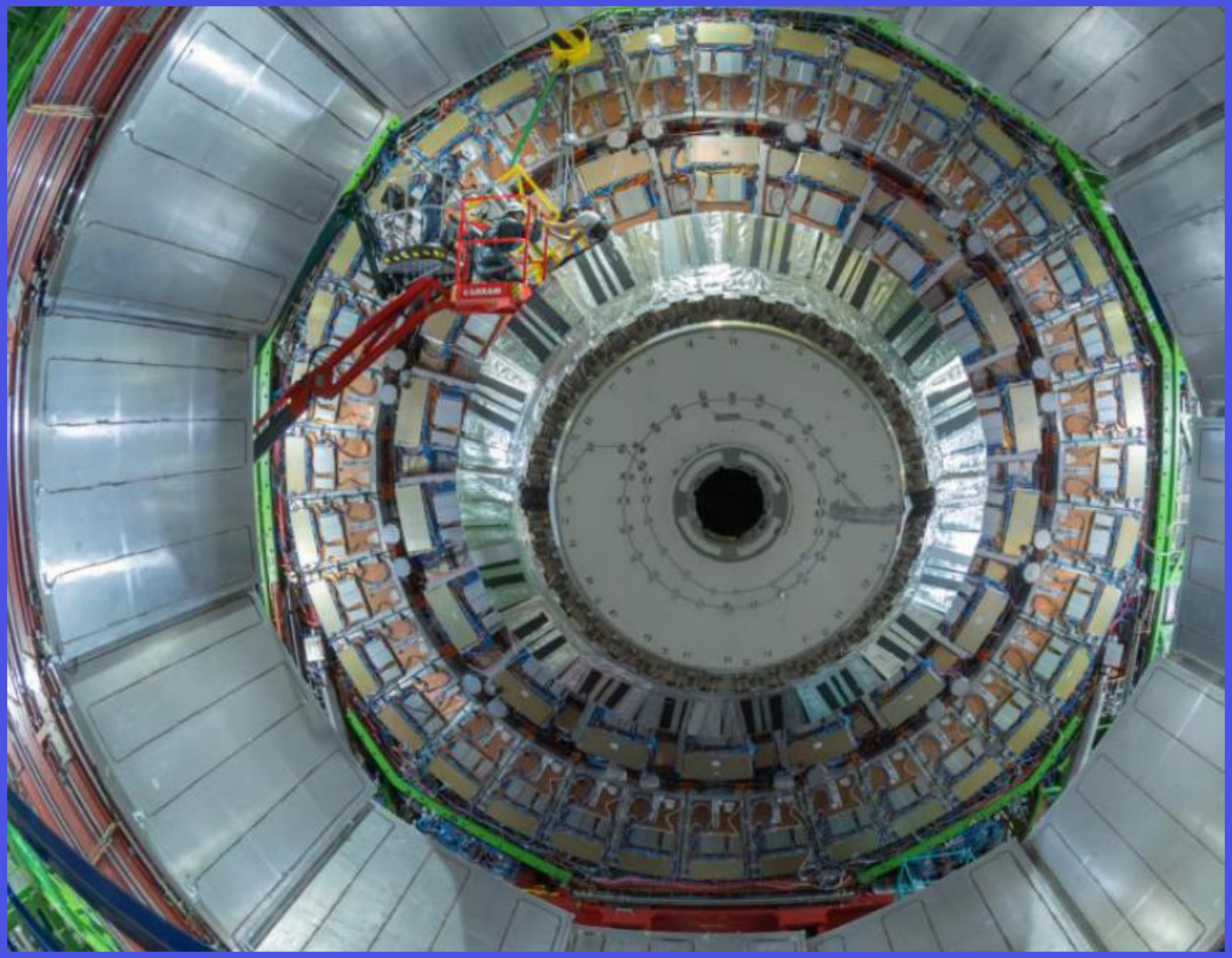


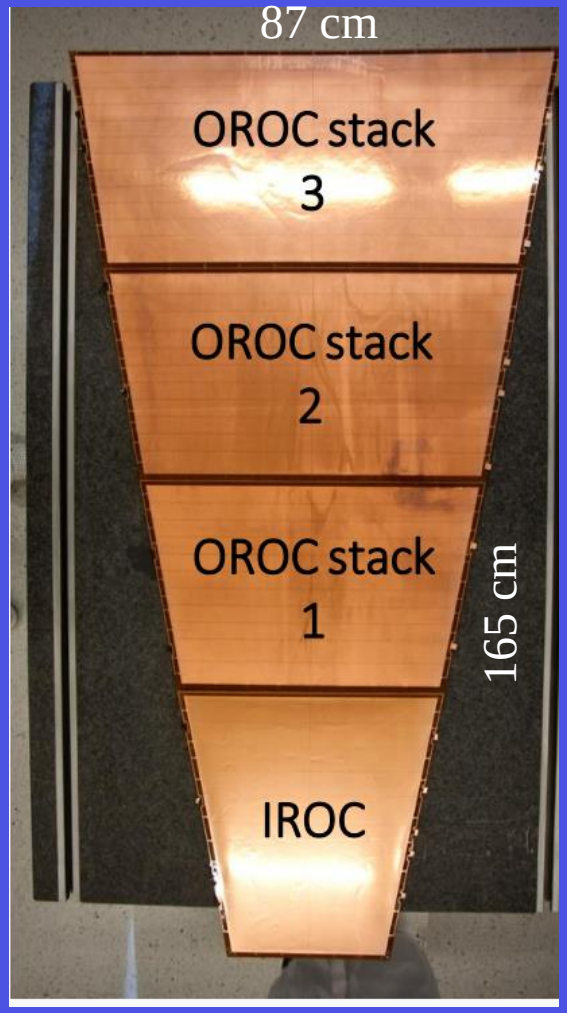
S. Duarte Pinto arXiv:1011.5528v1
IEEE 2011 Nucl. Sci. Symp. Conf. Rec.

GEM UPGRADE: 3 NEW STATIONS WITH TRIPLE-GEMs

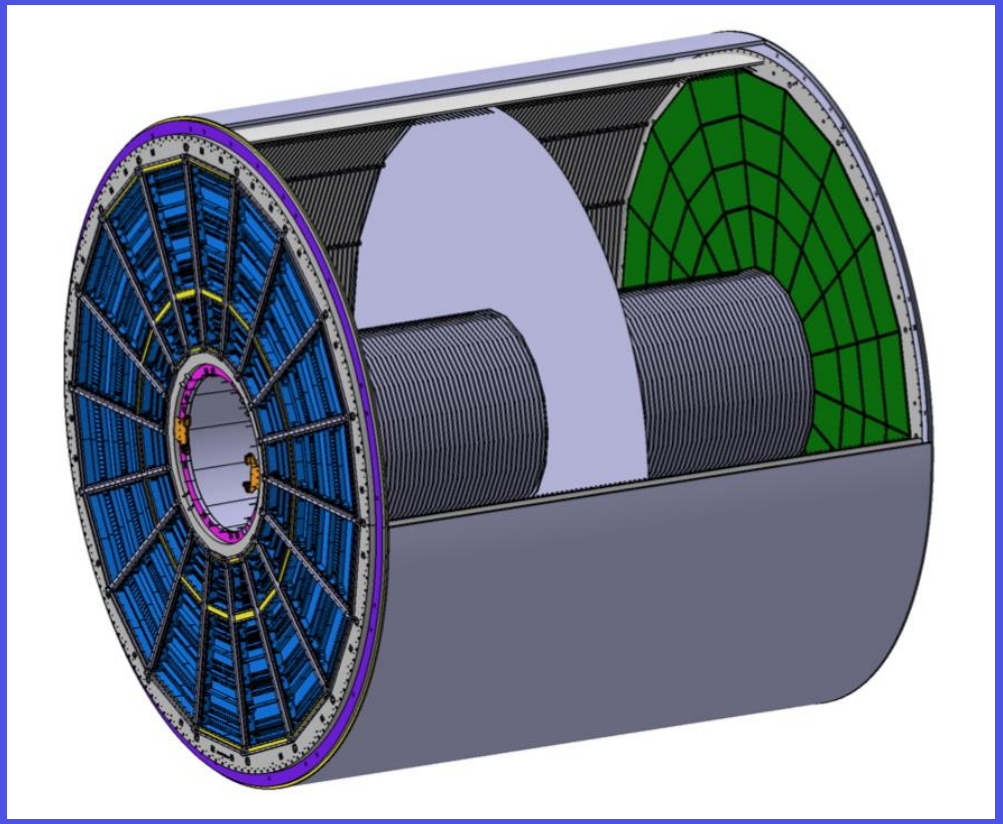
CERN DETECTORS TECHNOLOGIES

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





72 GEM MODULES

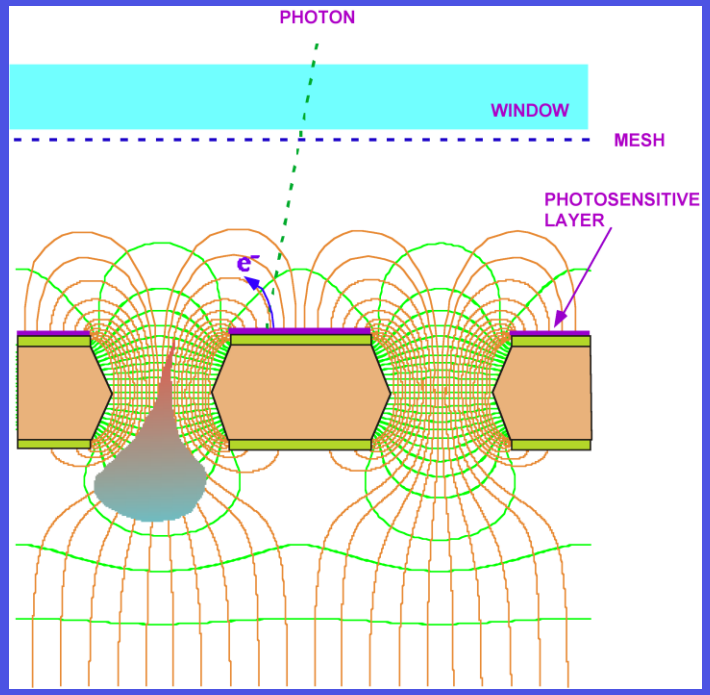


Piotr Gasik: GAS DETECTORS PHYSICS 2

J. Adolfsson et al, JINST16 (20210)P03021

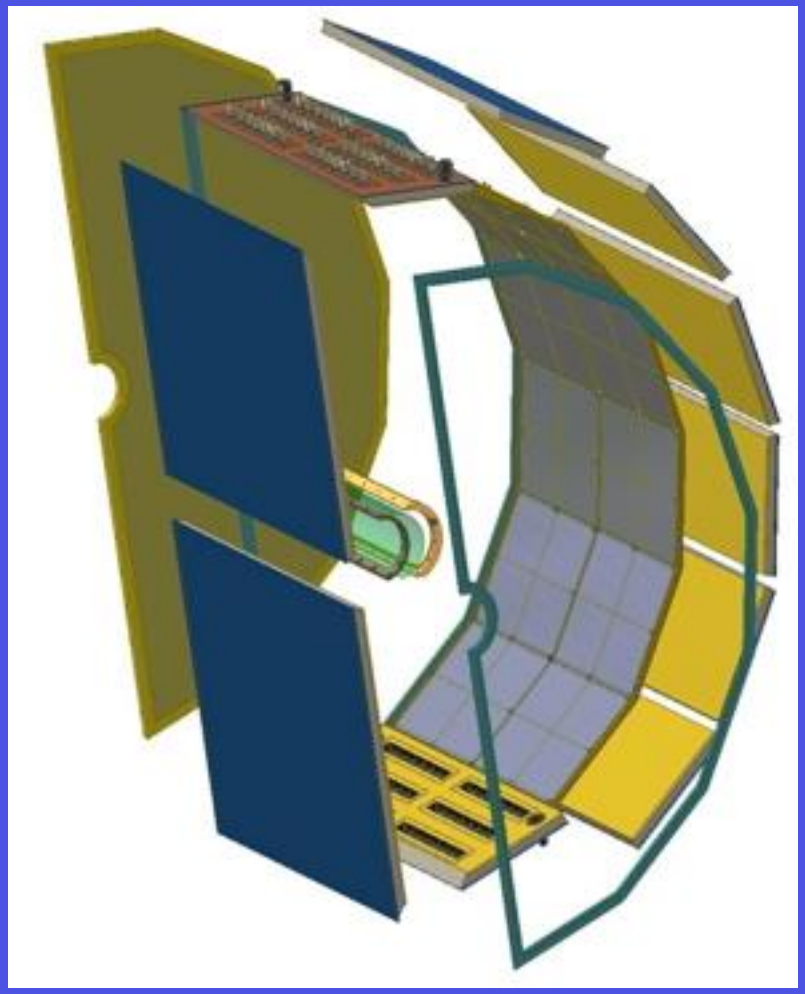
Paolo Iengo: MPGDs in LHC EXPERIMENTS

GEM WITH REVERSE CsI PHOTOCATHODE



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

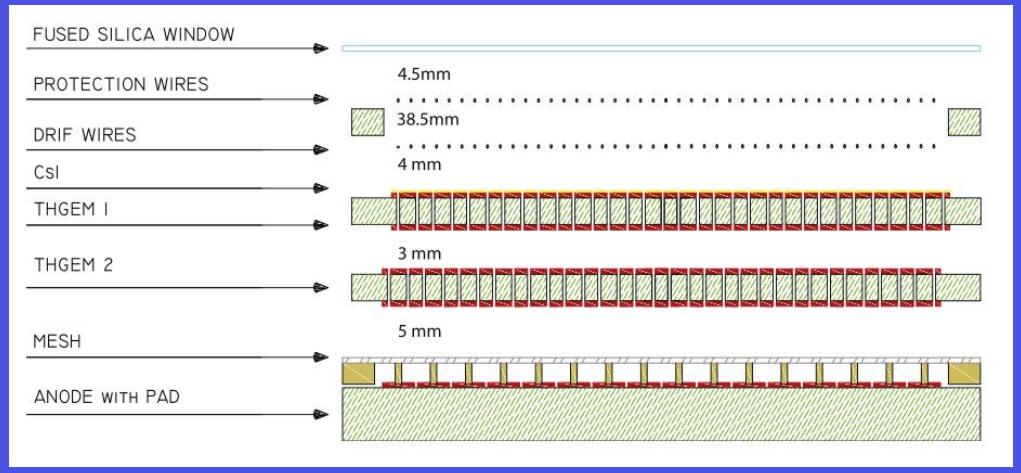
HADRON BLIND DETECTOR FOR PHENIX



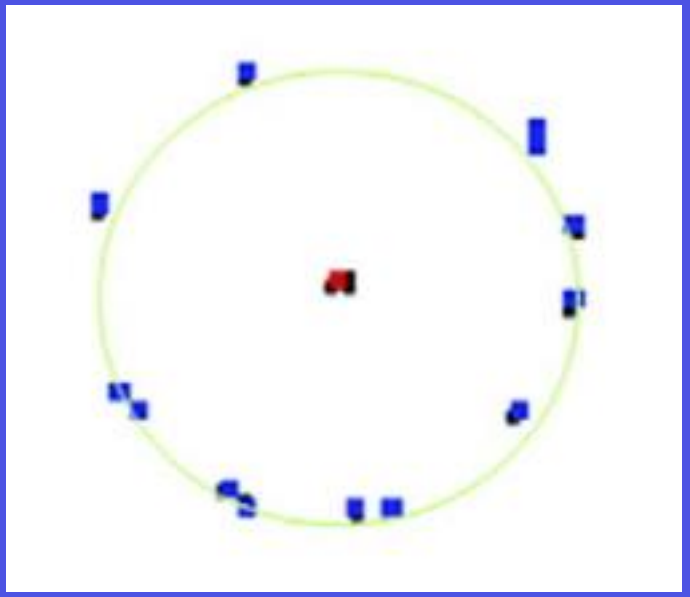
W. Anderson et al, Nucl. Instr. Meth. A646(2011)35

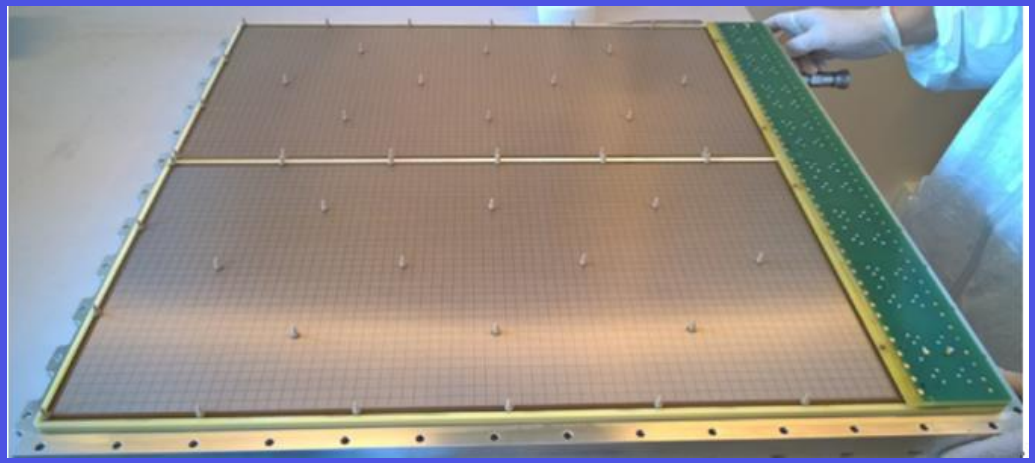
CHERENKOV RING IMAGING (COMPASS)

LARGE GAINS, REDUCED POSITIVE IONS BACKFLOW

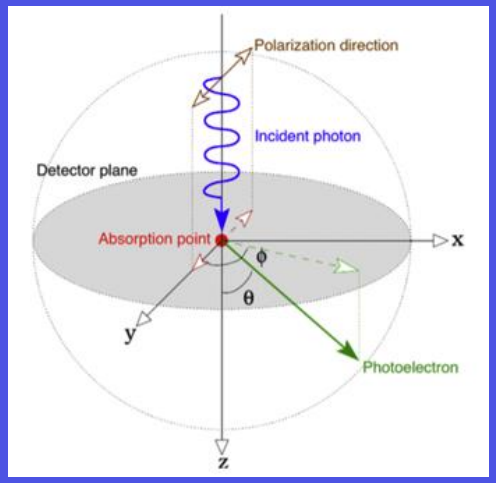


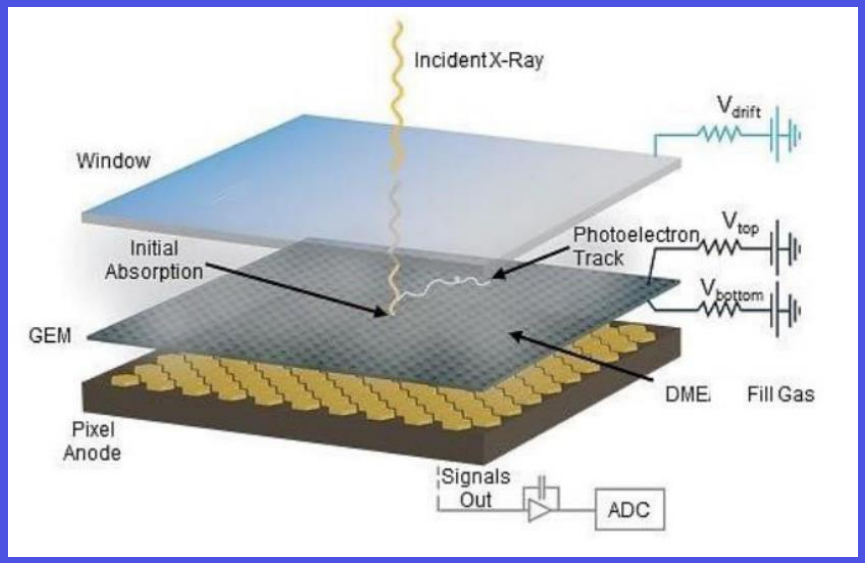
CHERENKOV RING



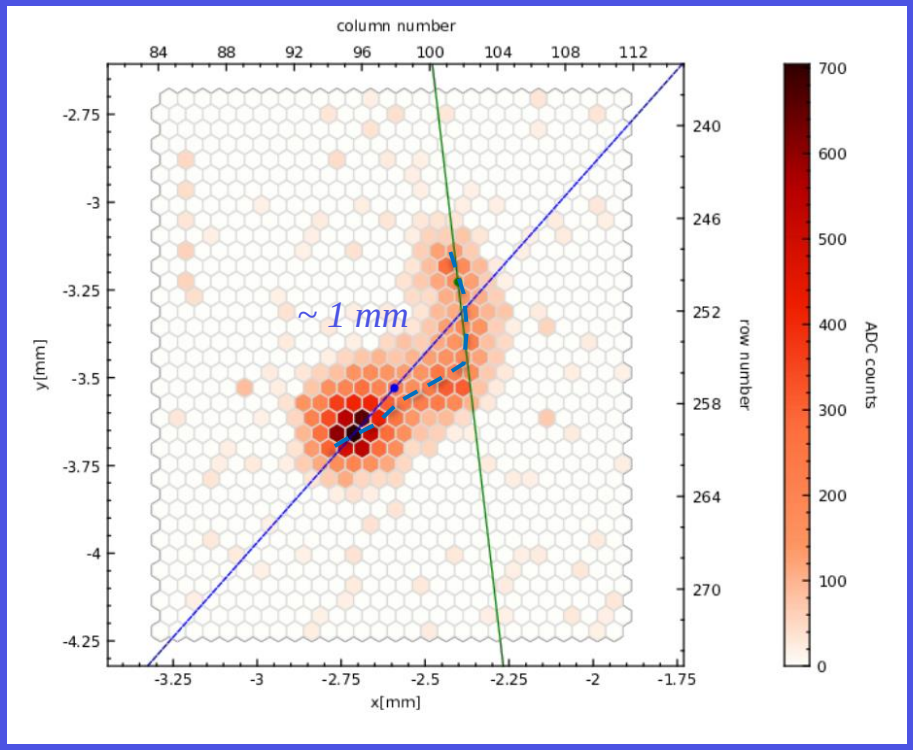


J. Agarwala et al, Nucl. Instr. Meth. A952(2020) 161832





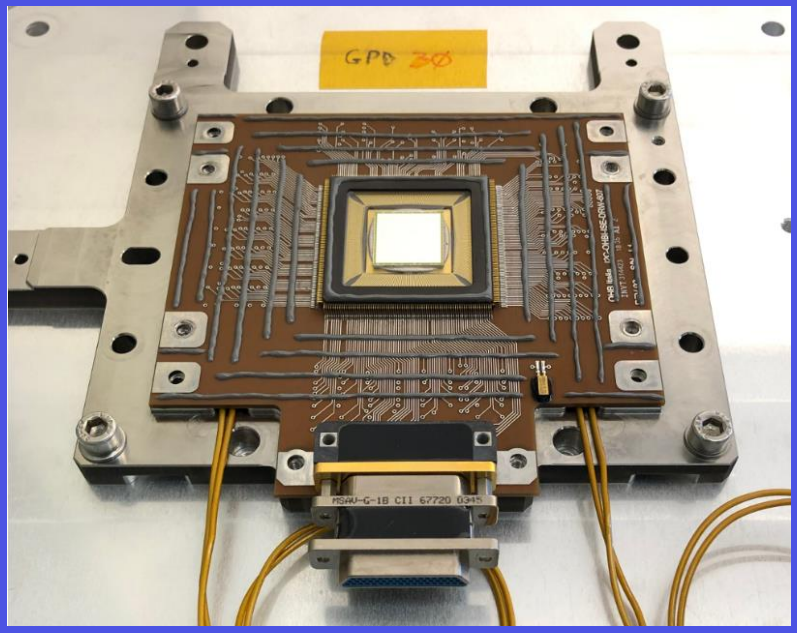
5.9 keV PHOTOELECTRON (80 μm pixels pitch):



L. Baldini et al, Astroparticle Physics (2021

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

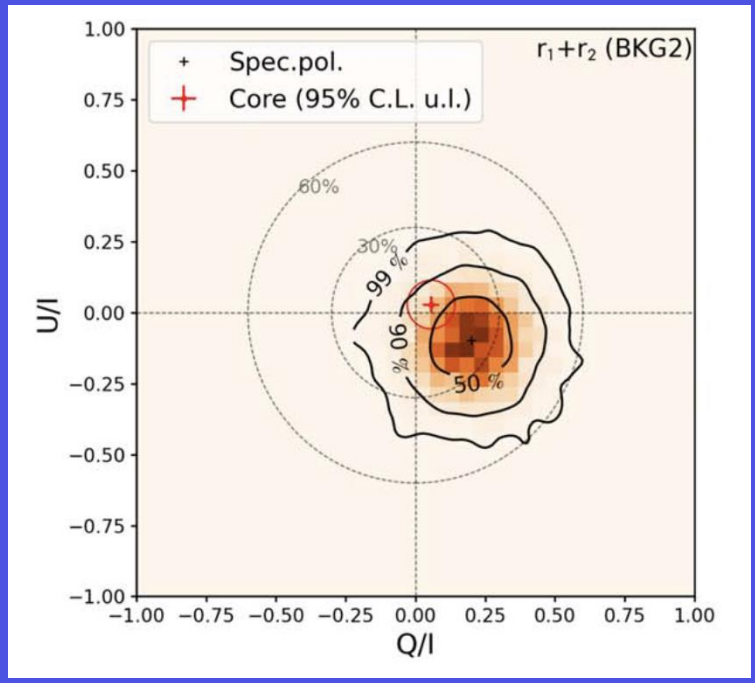
GAS PIXEL DETECTOR



L. Baldini et al, Astroparticle Physics (2021)

LAUNCHED DECEMBER 15, 2021

POLARIZATION MAP OF 221009A GAMMA RAY BURST

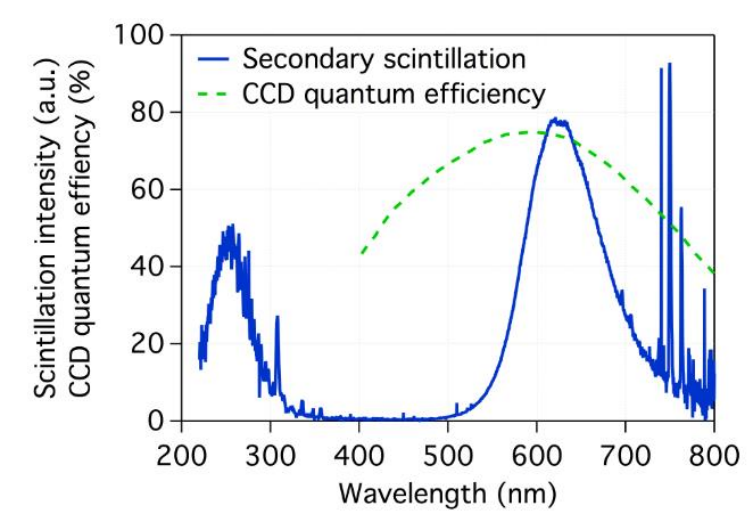


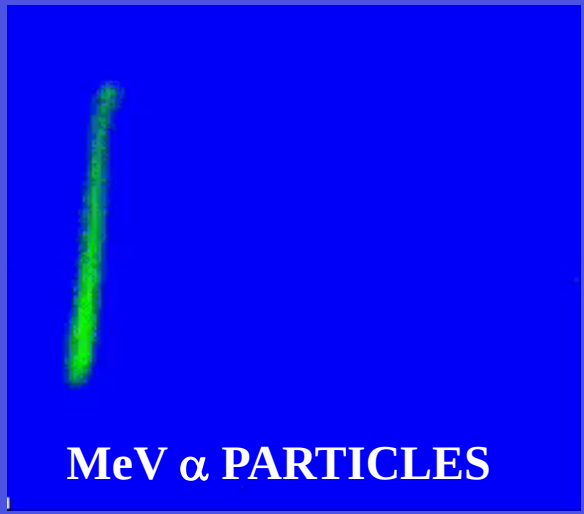
M. Negro et al,
Astro. J. Letters 946(1923)L21

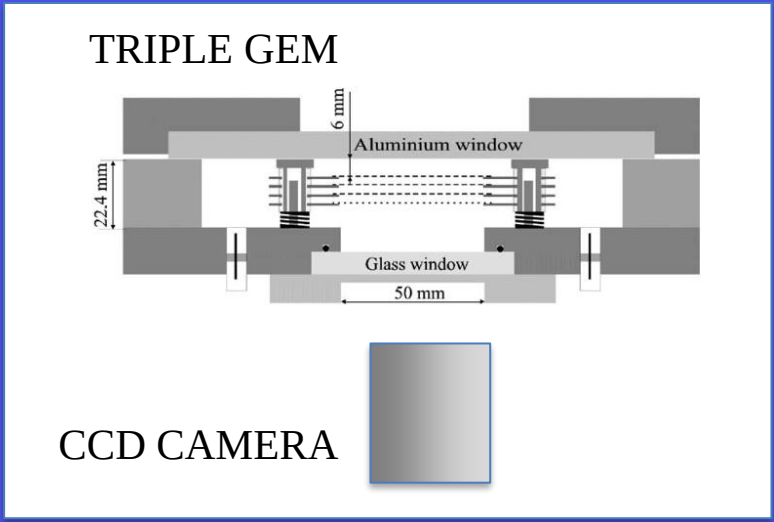
Marco Cortesi: Applications beyond HEP

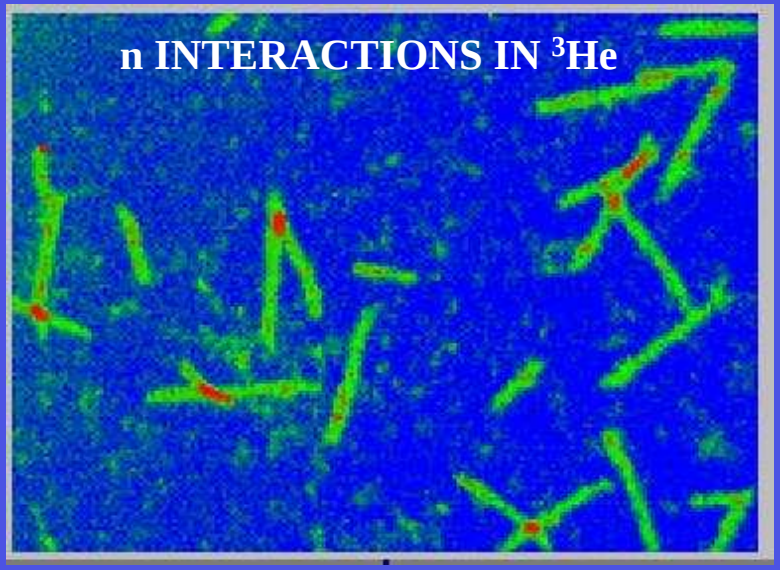
Jona Bortfield: Applications beyond fundamental research

CF_4 SECONDARY SCINTILLATION



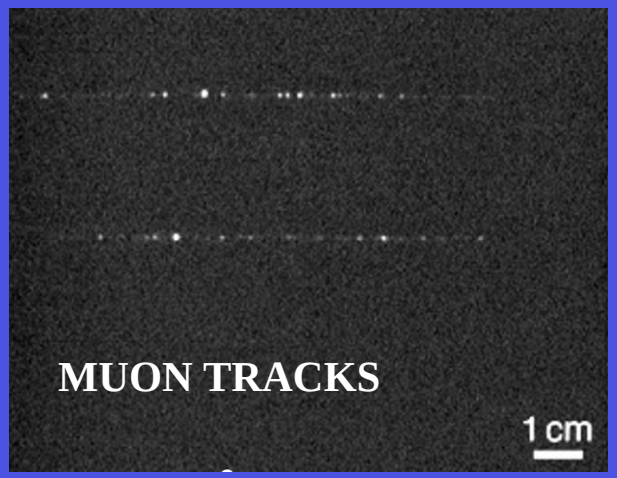


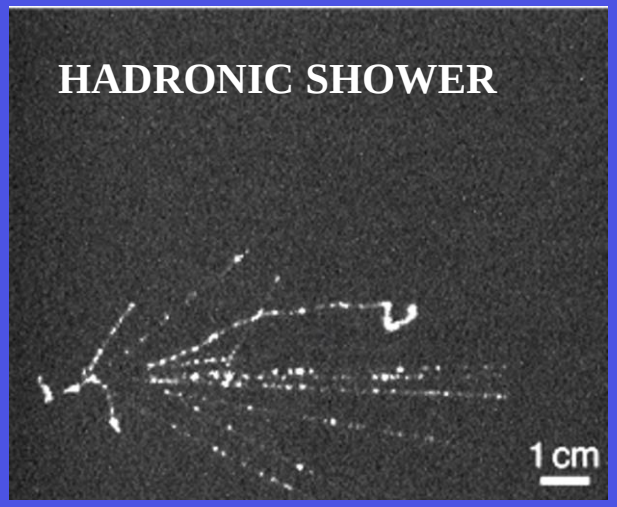




F.A.F. Fraga, et al, Nucl. Instr. and Meth. A478(2002) 357

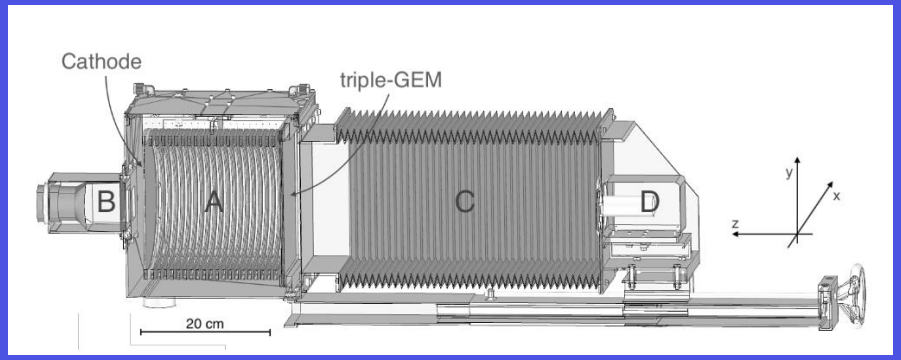
GEM: BEAM IMAGER



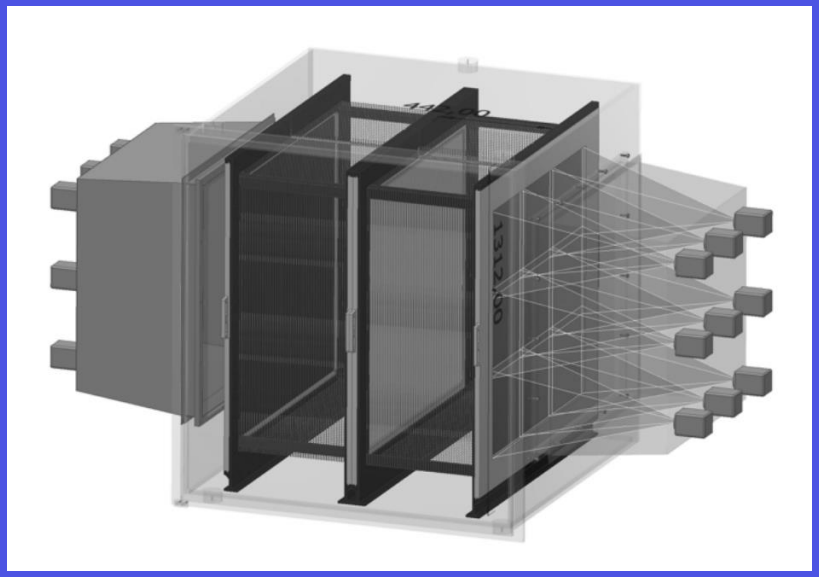


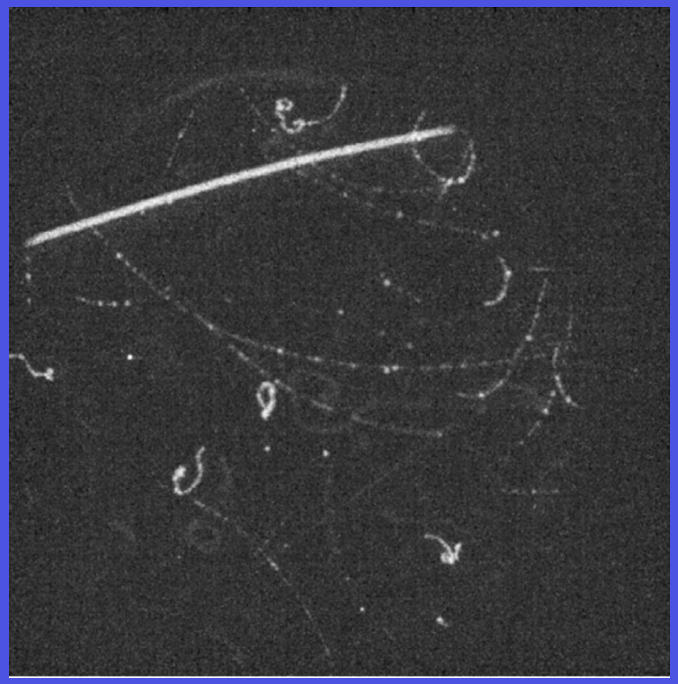
SOFT X-RAY RADIOGRAPHY

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



CYGNO:
DIRECTIONAL DARK MATTER SEARCH

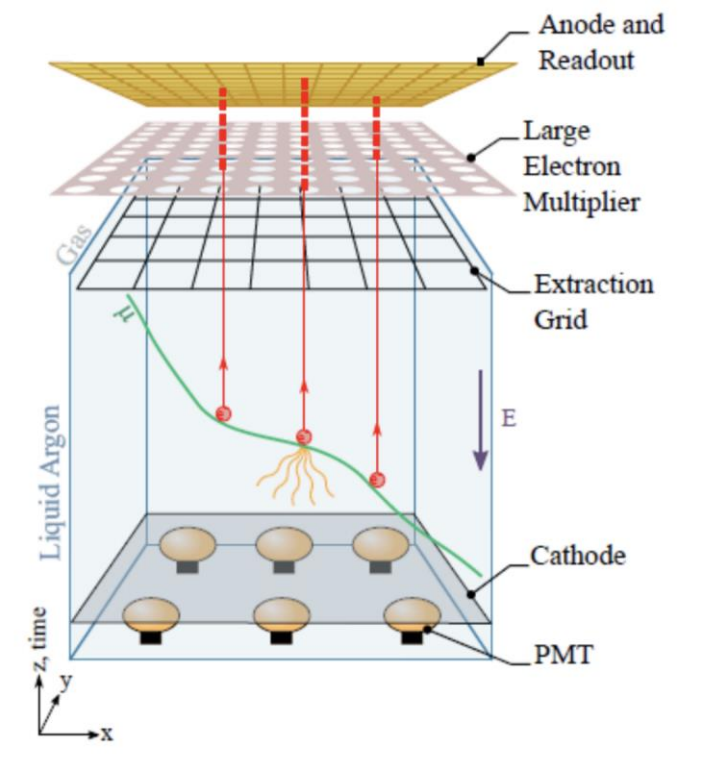


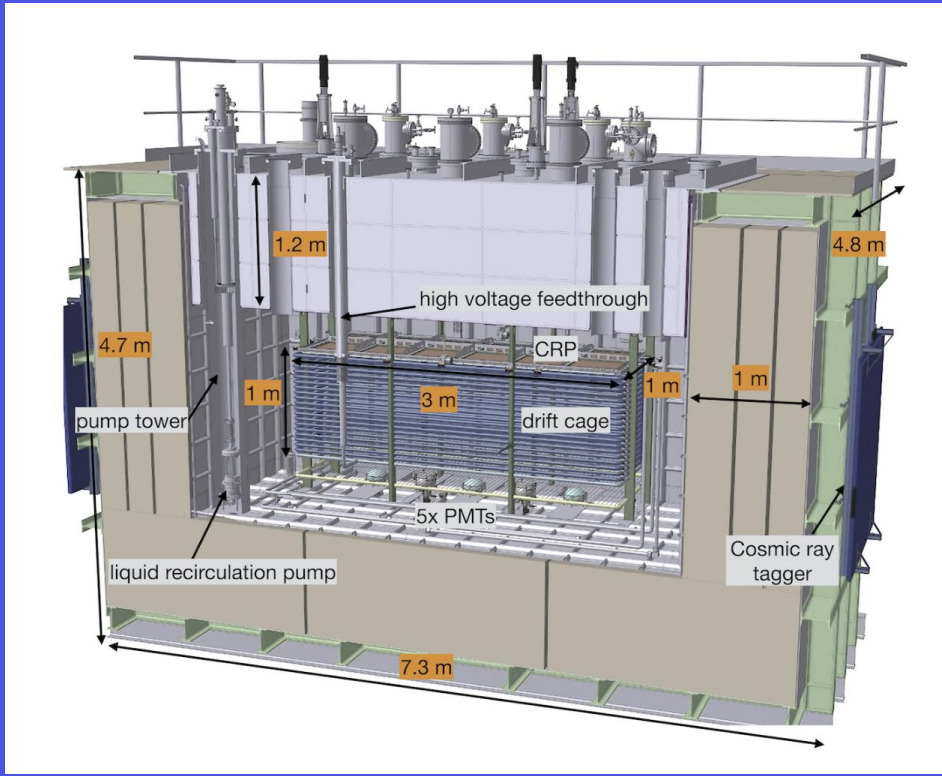


D. Pinci et al,
Nucl. Instr. Meth. A936(2019)453

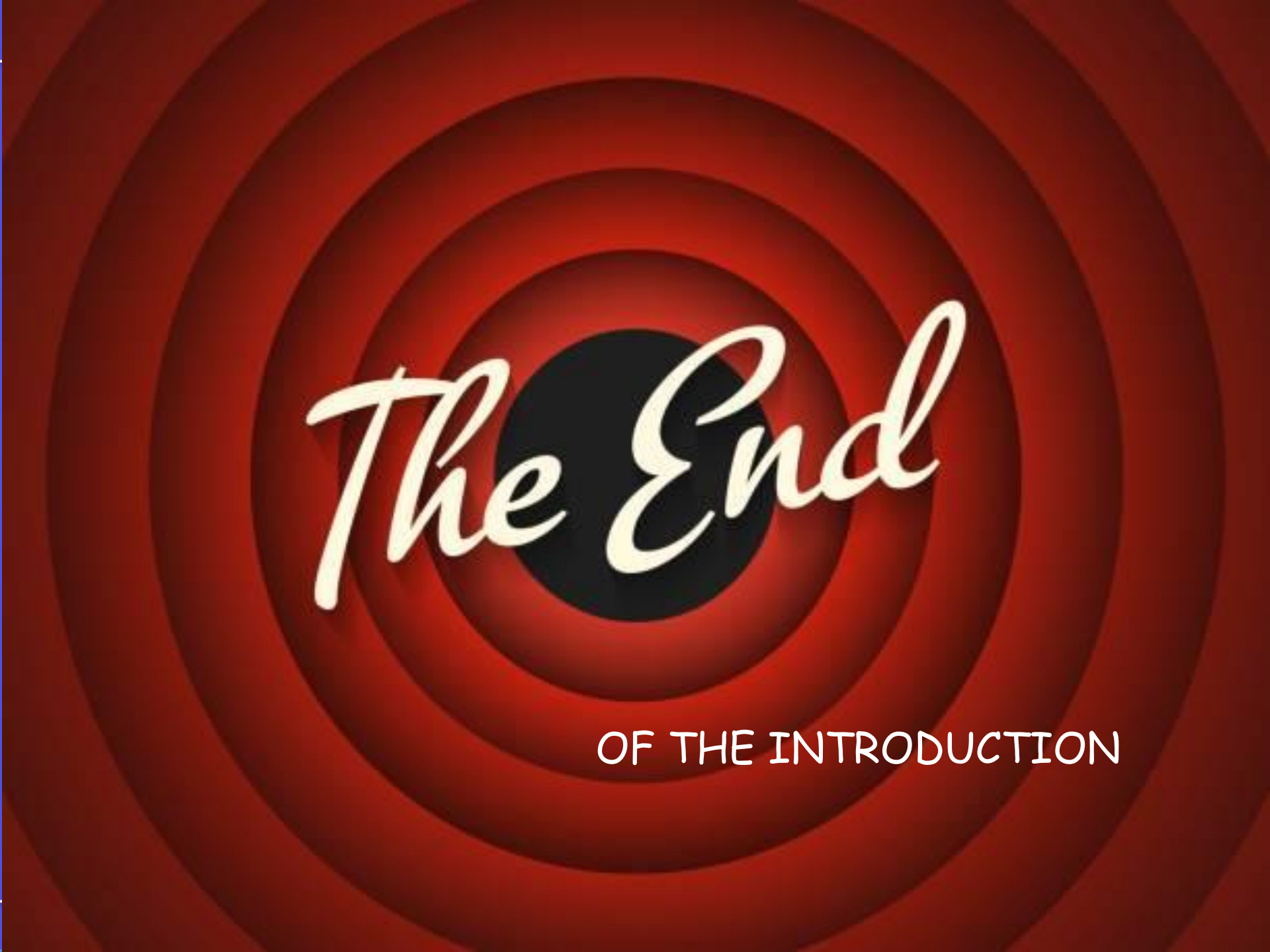
Davide Pinci: OPTICAL AND HYBRID READOUT TECHNIQUES

Proto-DUNE





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



OF THE INTRODUCTION