RICH 2016

Status and Perspectives of

Gaseous Photon Detectors

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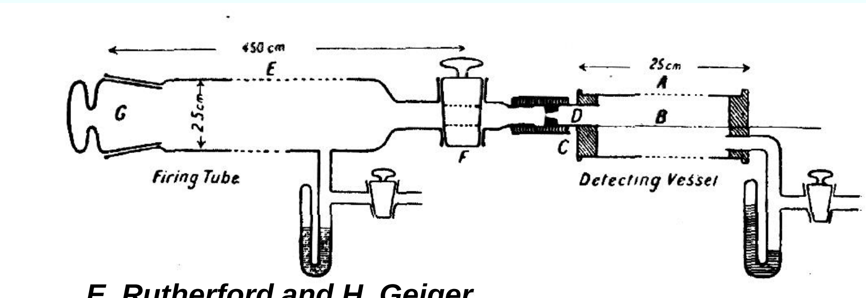
Gaseous Photon Detectors

- Historical overview
  - MWPCs with CsI Photocathodes
    - GEM-based PDs
      - THGEM-based PDs
      - Other architectures
    - Gaseous detectors for visible light
  - Cryogenic gaseous photon detectors
- Large area coverage

Glorious tradition: 100 years of gaseous detector developments

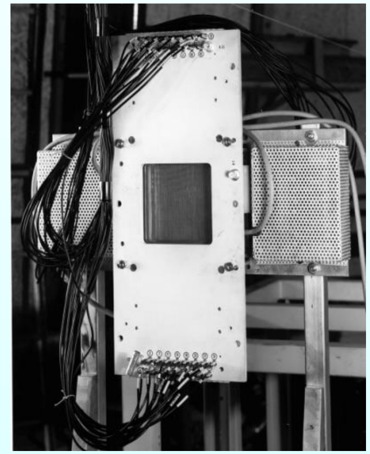
1908: FIRST WIRE COUNTER USED BY RUTHERFORD IN THE STUDY OF NATURAL RADIOACTIVITY

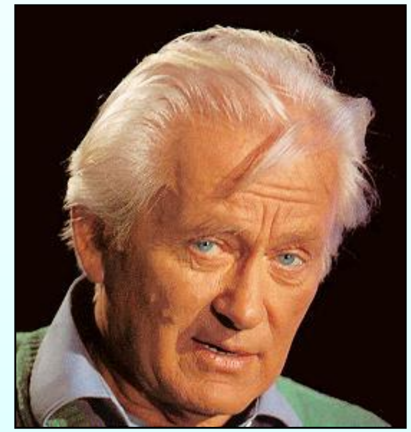


E. Rutherford and H. Geiger , Proc. Royal Soc. A81 (1908) 141

Nobel Prize in Chemistry in 1908

1968: MULTIWIRE PROPORTIONAL CHAMBER

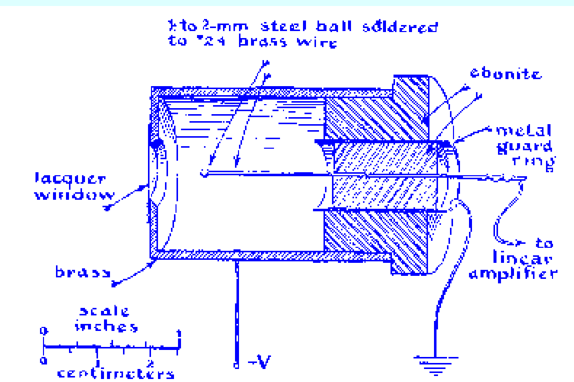




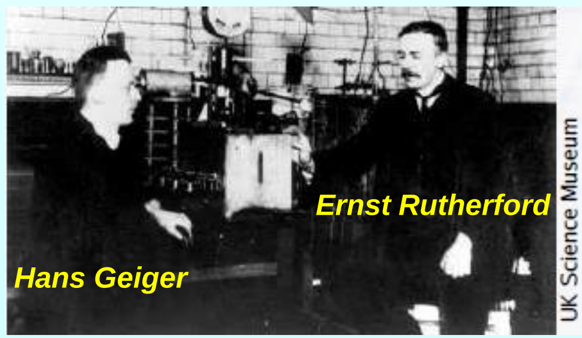
Nobel Prize in 1992

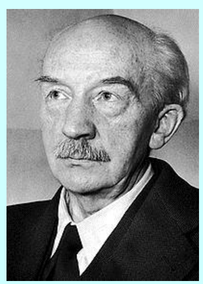
G. Charpak, Proc. Int. Symp. Nuclear Electronics (Versailles 10-13 Sept 1968)

1928: GEIGER COUNTER SINGLE ELECTRON SENSITIVITY

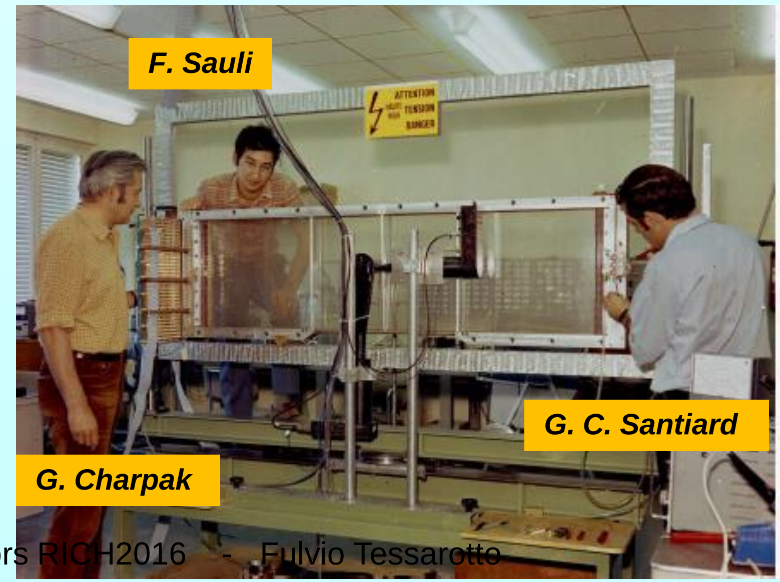


H. Geiger and W. Müller, Phys. Zeits. 29 (1928) 839





Walther Bothe Nobel Prize in 1954 for the "coincidence method"

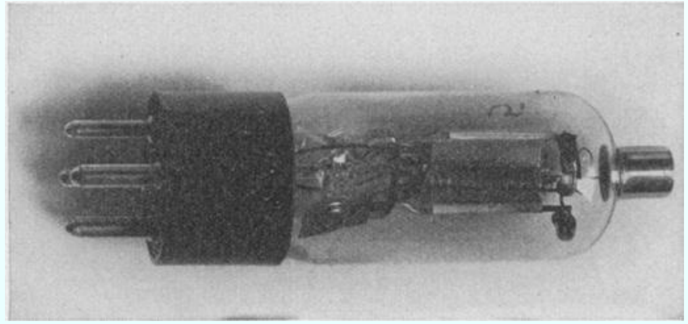


photon conversion and Cherenkov light

John Sealy Townsend

Heinrich Rudolf Hertz
photoelectric effect, 1887

A. Einstein, Nobel Prize in 1921



Iams, H. E. and B. Salzberg, "The secondary emission phototube," Proc. IRE **23**, 55 (1935).

Pavel Cherenkov 1904-1990

Ilya Frank and Igor Tamm

Nobel Prize in 1958

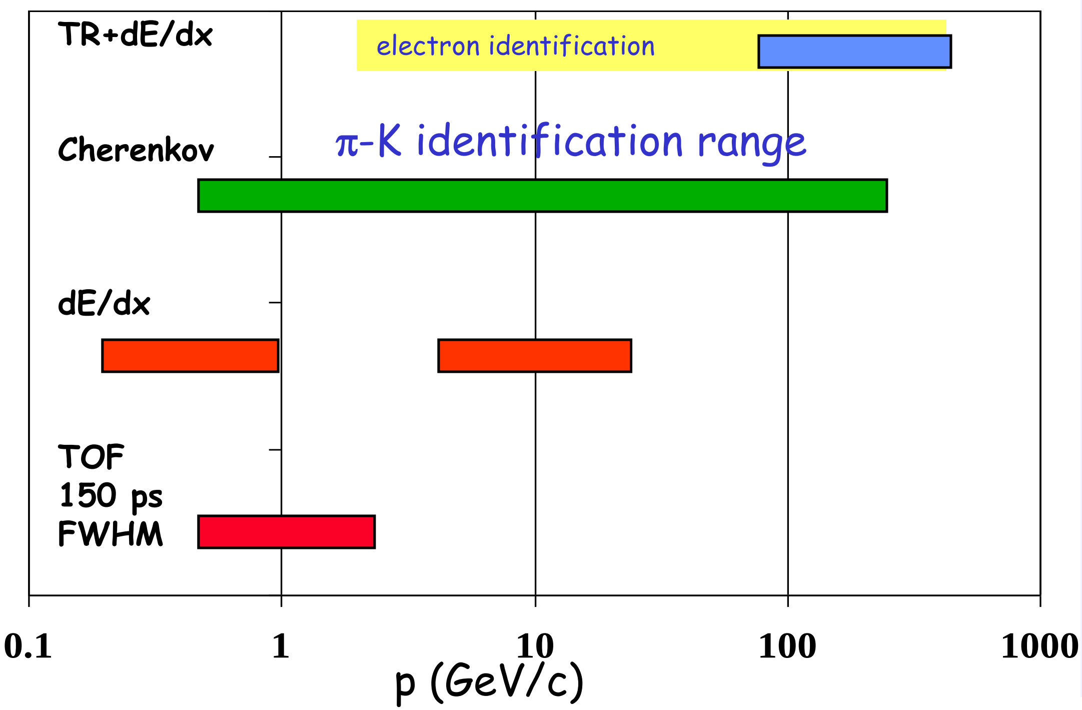
Arthur Roberts 1912-2004

Tom Ypsilantis 1928-2000

Motivation

- **need for π-K identification from HEP Experiments**
- Large momentum acceptance → Cherenkov angle measurement technique
- Large angular acceptance → large area of efficient single photon detection

Particle Identification Techniques:



- **1970s: large area position sensitive gaseous detectors available**
- **Suitable photo-ionizing agent:**

  benzene: Seguinot-Ypsilantis NIM 142 (1977) 377,
  TEA (7.6 eV) NIM 173 (1980) 283,
  TMAE (5.3 eV) NIM 178 (1980) 125.

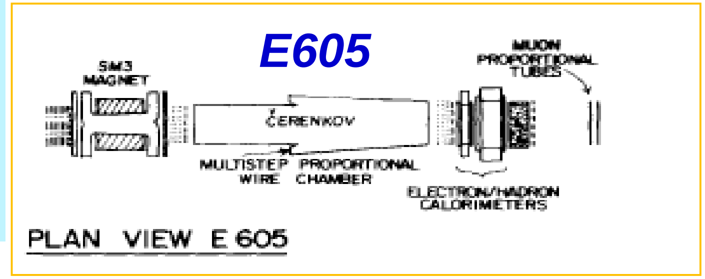
- **a gas gain high enough to detect single photoelectrons**

→ **conflicting requirements because of the copious UV emission by the multiplication avalanche.**

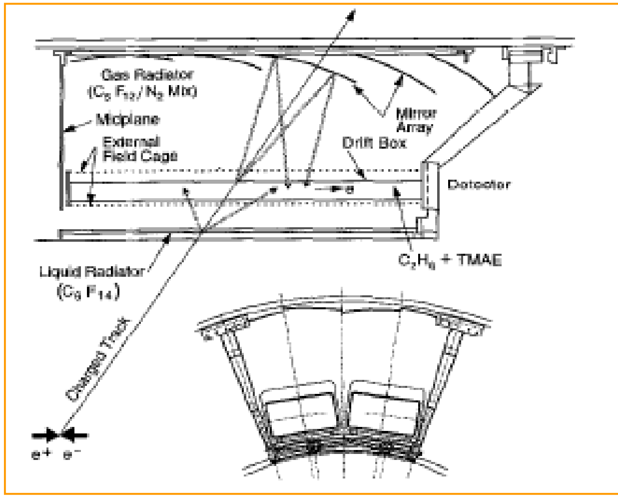
- **solution: multistep avalanche chamber**
  (Charpak-Sauli Phys. Lett. B 142 (1977) 377) **or TPC**

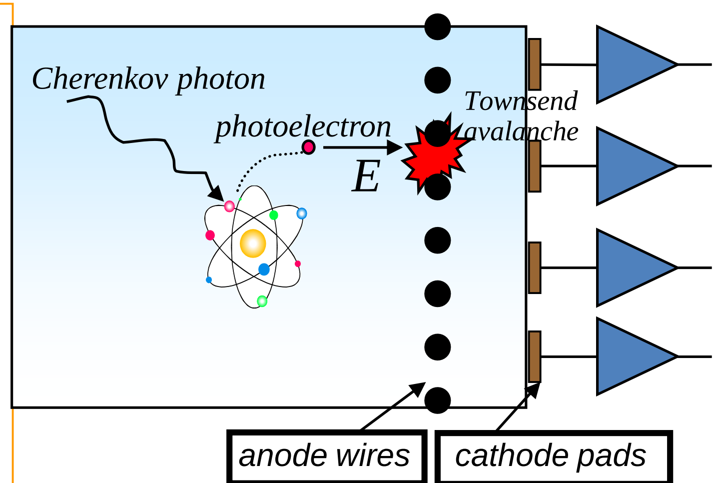
Gaseous detectors: 1) cheap, 2) magnetic insensitive, 3) low material budget

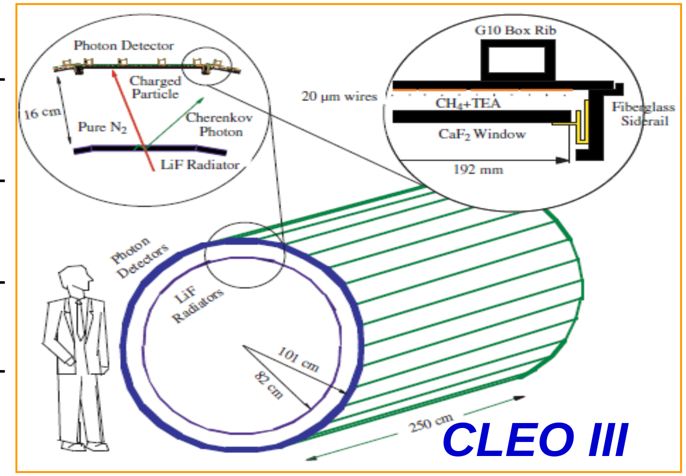
RICH with large area gaseous PD's
1st generation: photoconverting vapours



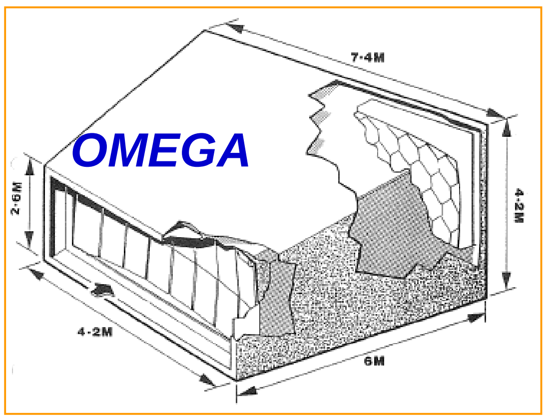
SLD - CRID

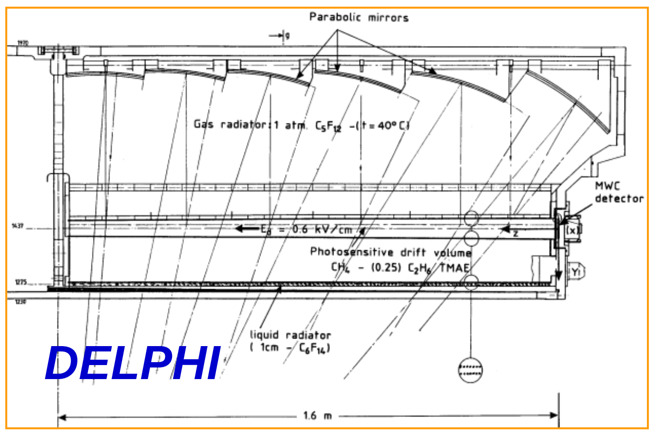


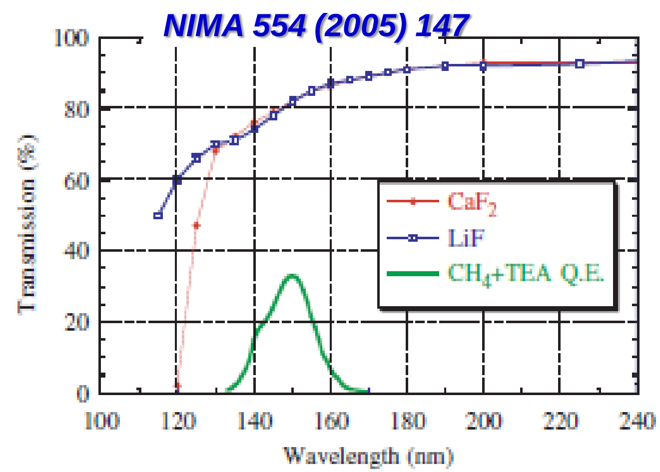




TEA (Tri-Ethyl-Amine)

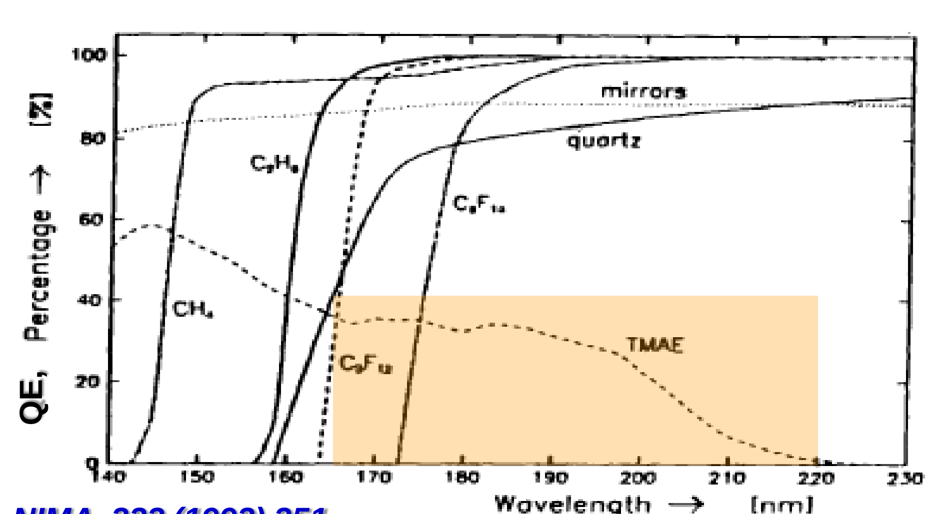




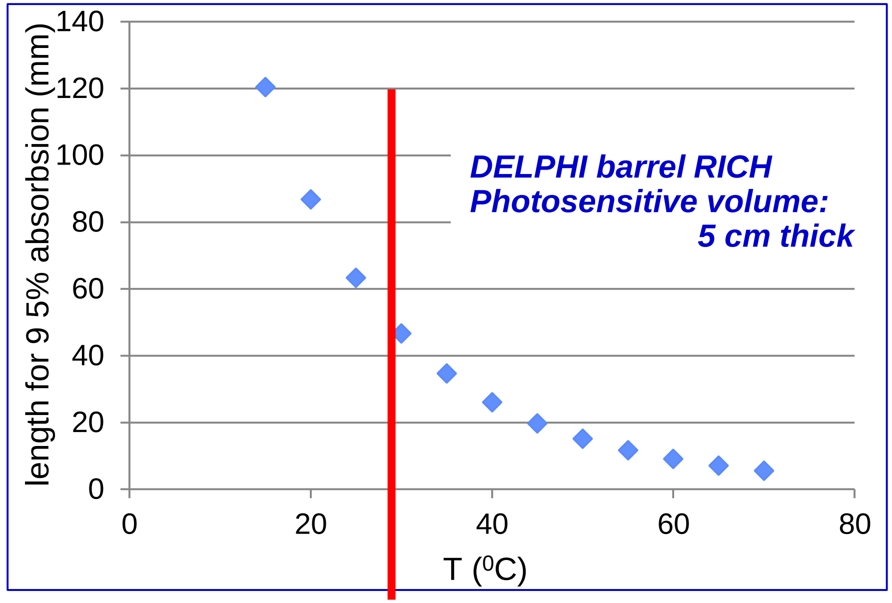


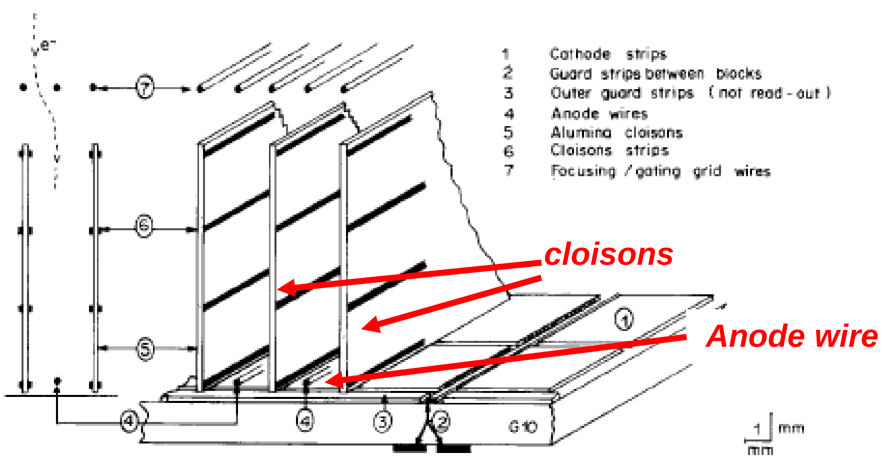
TMAE (Tetrakis-Dimethylamine-Ethylene)

TMAE



NIMA 323 (1992) 351





DELPHI barrel RICH, NIMA 273 (1988) 247

- **thick photosensitive volume (slow photon detectors, parallax error)**
- **heating and temperature control (T _bubbling <T_operation)**
- **photon feed-back from amplification region (protections)**
- **chemically extremely reactive**

Thin CsI film

1956:
CsI layer has large QE for photons with hν > 6 eV (Philipp and Taft)

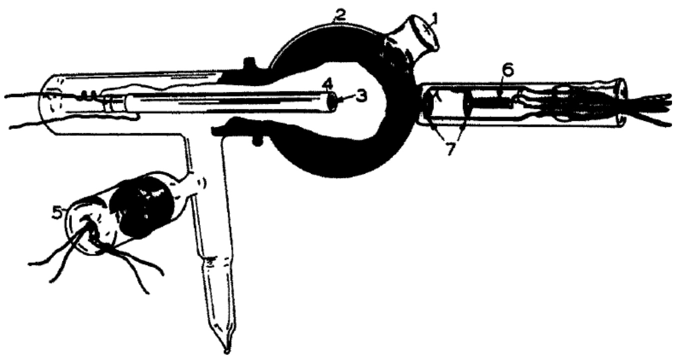


FIG. 1. Cutaway sketch of phototube; (1) 9741 glass bubble window, (2) graphite coated collector sphere 4 inches in diameter, (3) ⅜ inch glass tube, platinum painted, (4) nickel sleeve insulated from tube by glass beads, (5) ion gauge, (6) evaporating cylinder and helical platinum heater, (7) collimating shields.

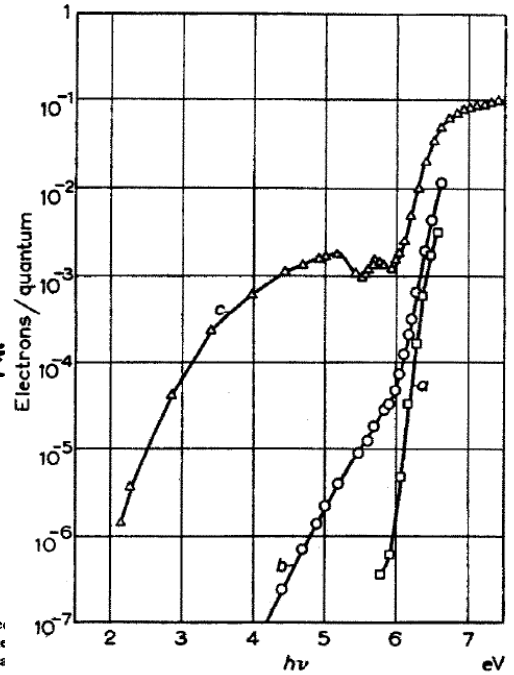
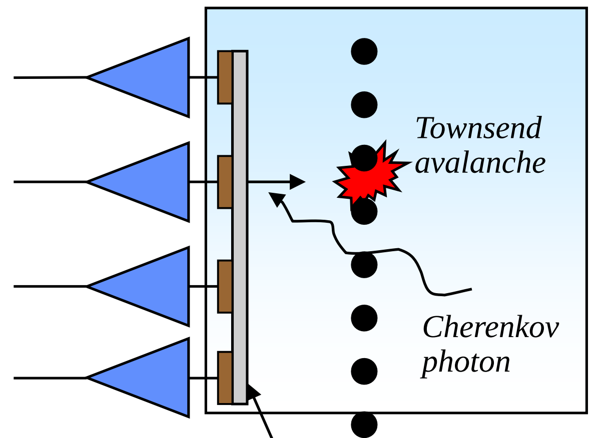


FIG. 2. Spectral distribution of the photoelectric yield for CsI surfaces: (a) thick film, (b) single crystal, (c) thin film evaporated in presence of excess Cs.

CsI is highly reactive with water: it took many years to develop appropriate substrate preparation, deposition method, handling technology for high QE gaseous PDs

Semitransparent photocathode:
thin metallic film and precise thickness.

Reflective photocathode:
no metallic film and non critical thickness (important for large area)



thin layer (300 - 500 nm) of CsI on a cathode pad plane

J. Phys. Chem. Solids. Pergamon Press 1956. Vol. 1. pp. 159–163.

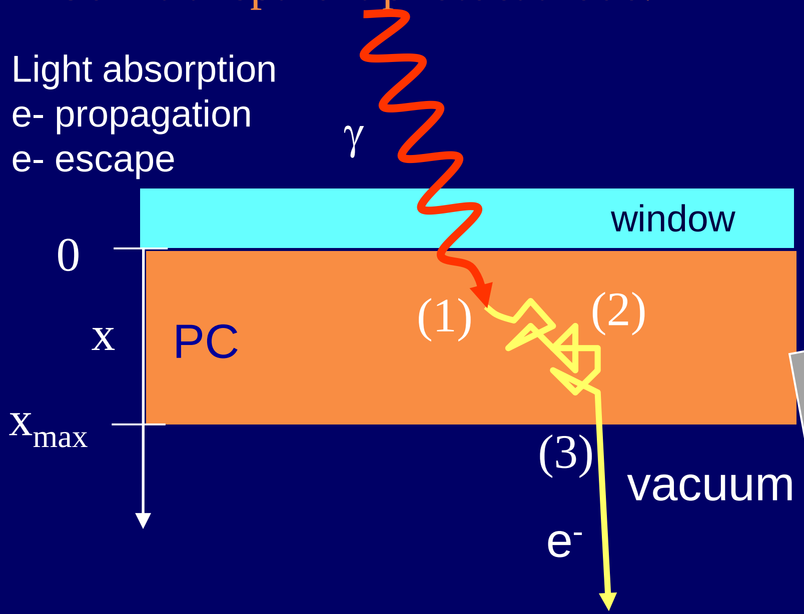
PHOTOELECTRIC EMISSION FROM THE VALENCE BAND OF CESIUM IODIDE

H. R. PHILIPP AND E. A. TAFT
General Electric Research Laboratory, Box 1088, Schenectady, New York

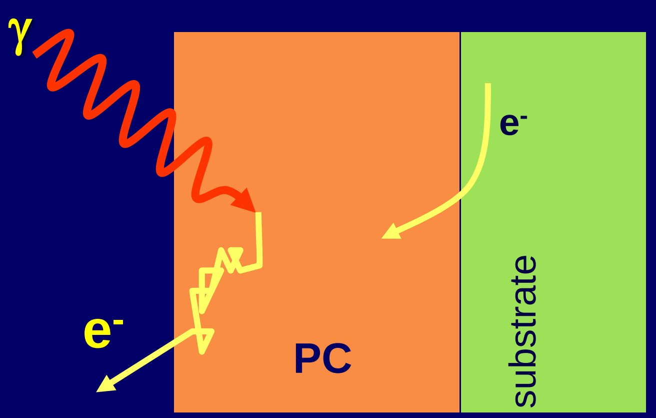
Thin film photo cathodes

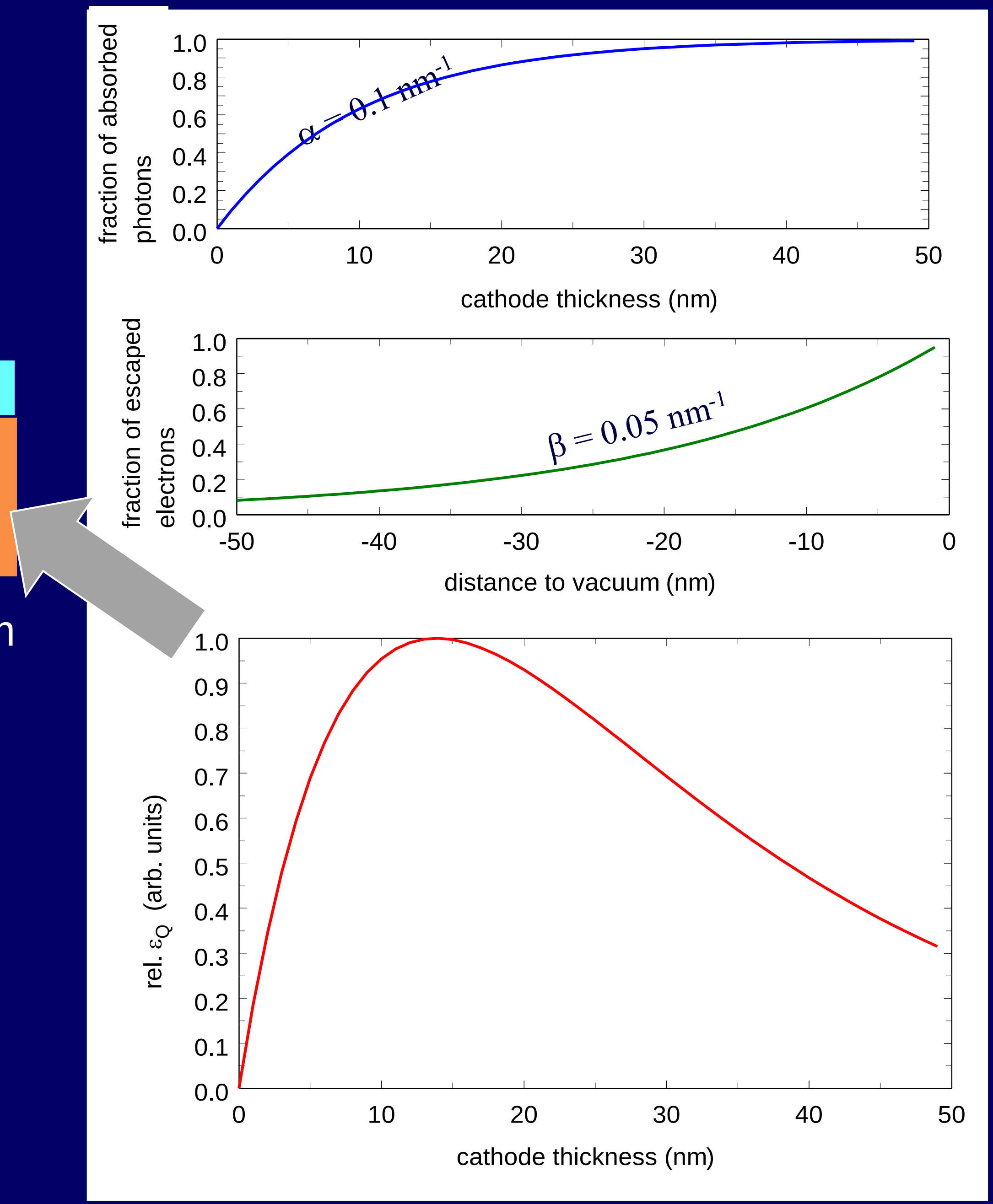
Semitransparent photocathode:

(1) Light absorption
(2) e- propagation
(3) e- escape



Reflective photocathode:





RD26: the technology of MWPCs + CsI

1992, F. Piuz et al. Development of large area advanced fast-RICH detector for particle identification at LHC operated with heavy ions

TO ACHIEVE HIGH CsI QE:

Substrate preparation:

Cu clad PCB coated by Ni (7 μm) and Au(0.5 μm), surface cleaning in ultrasonic bath, outgassing at 60 ºC for 1 day

Slow deposition of 300 nm CsI film:

1 nm/s (by thermal evaporation or e$^-$-gun) at a vacuum of ~ 10^{-7} mbar, monitoring of residual gas composition

Thermal treatment:

after deposition at 60 ºC for 8 h

Careful Handling:

measurement of PC response, encapsulation under dry Ar, mounting by glove-box.

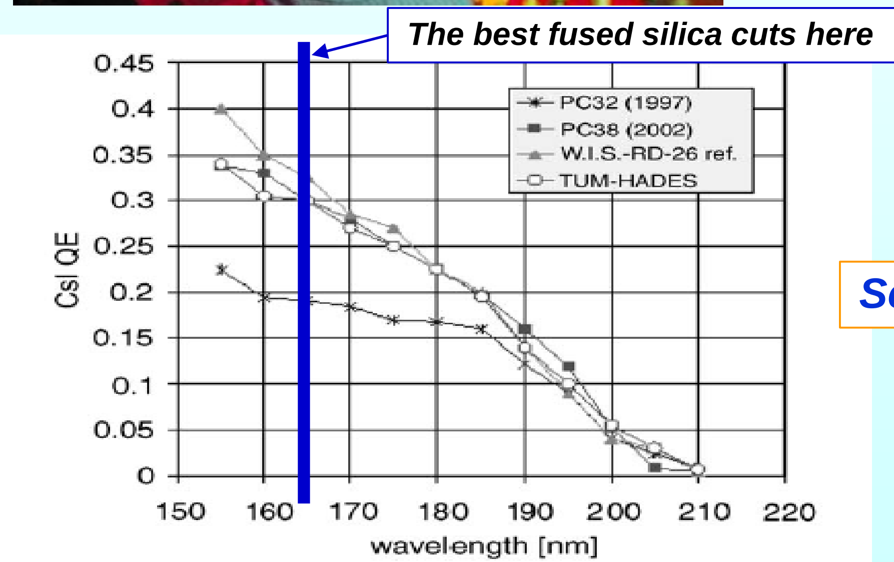
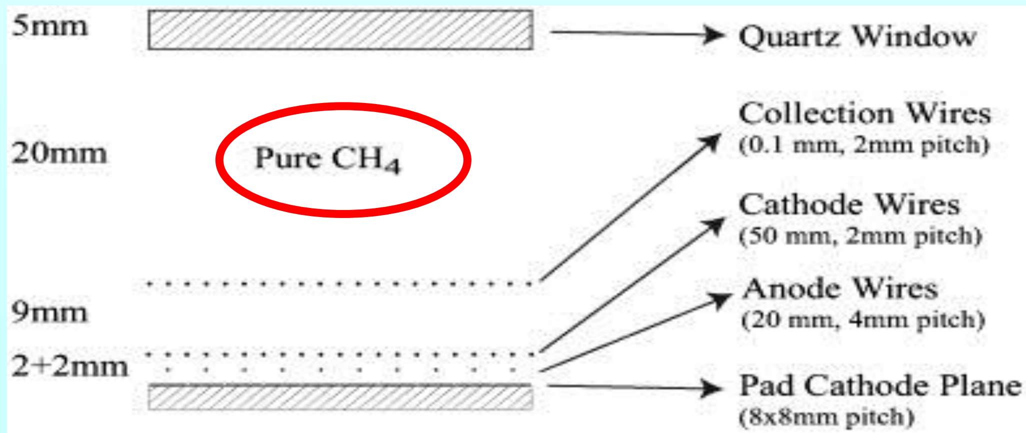


Fig. 1. The QE of CsI PCs produced at CERN for ALICE and at TUM for HADES, compared to that measured at the W.I.S. on small samples (reference for RD-26). PC32 is one of the four PCs equipping the ALICE-RICH prototype used in STAR at BNL.

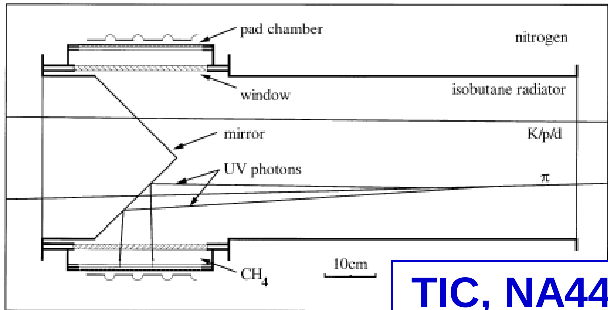
A. Di Mauro, NIM A 525 (2004) 173.

Schematic structure of the COMPASS Photon Detector:



RICH with large area gaseous PD's
2nd generation: MWPC's + CsI

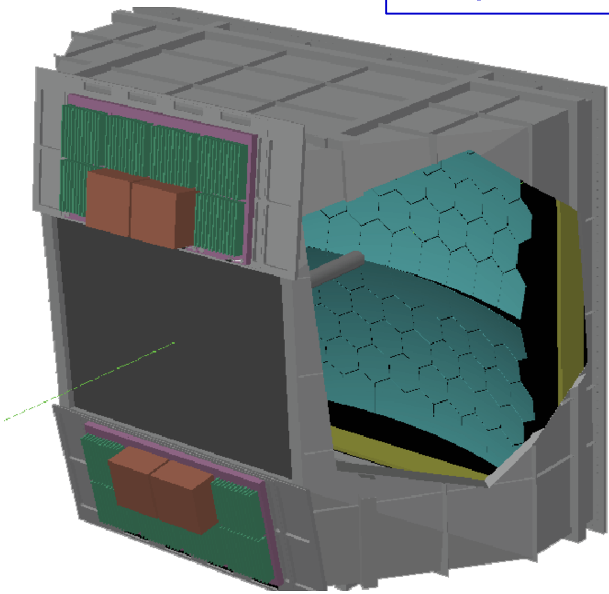
- **MWPCs with solid state photocathode (the RD26 effort)**



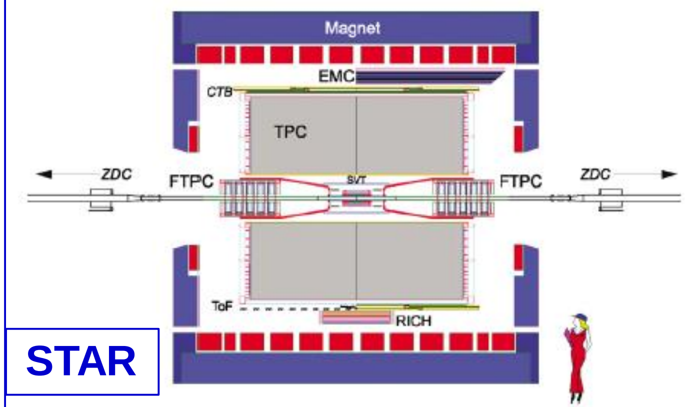
TIC, NA44

ALICE-HMPID
2009
CsI > 10 m²

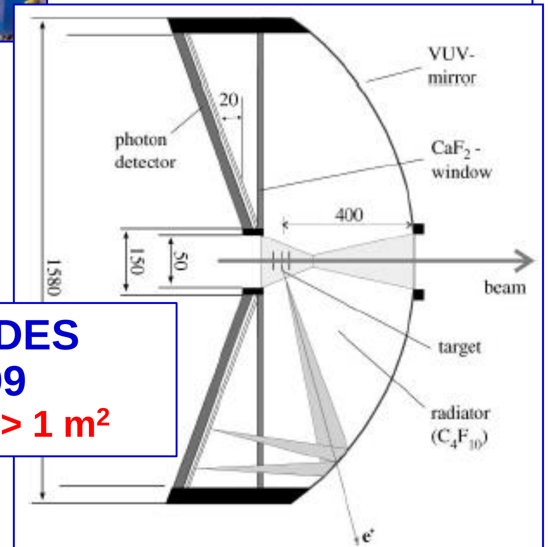
JLAB-HALL A



COMPASS RICH-1 2002
CsI > 5 m²

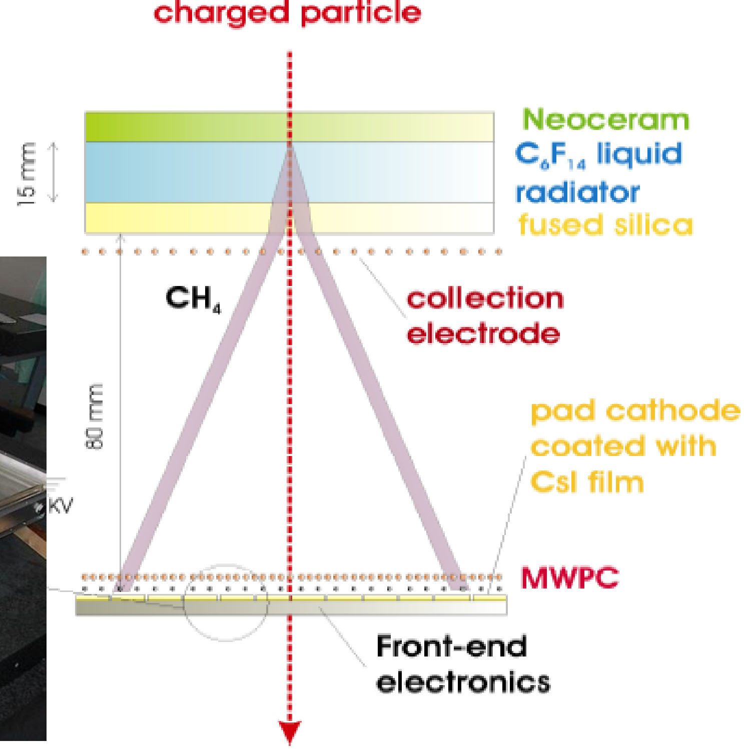


STAR



HADES
1999
CsI > 1 m²

ALICE HMPID

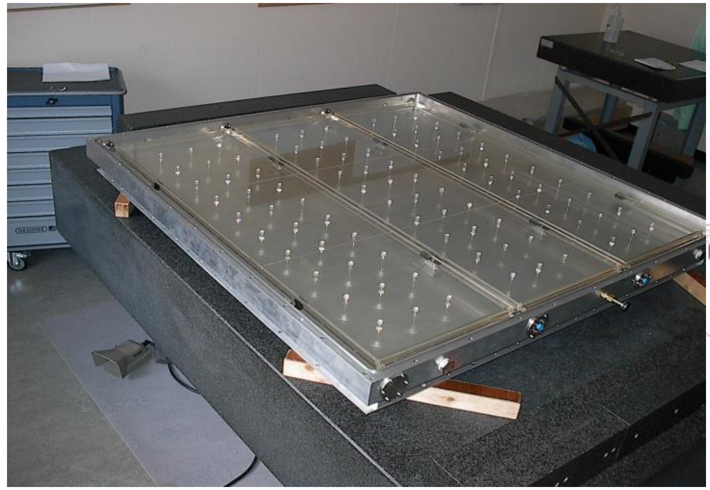


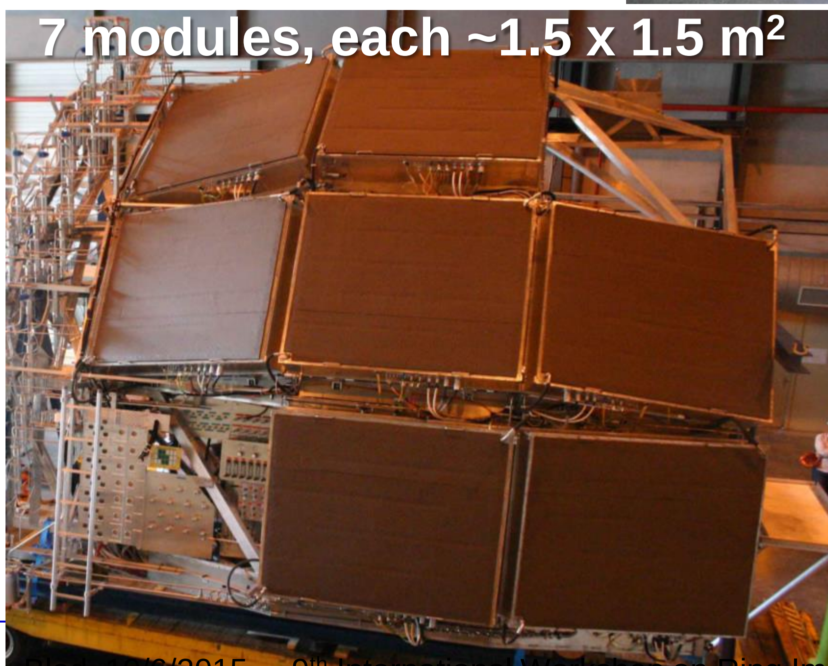
RADIATOR: 15 mm liquid C_6F_{14}, n ~ 1.2989 @ 175nm, $\beta_{th} = 0.77$

PHOTON CONVERTER: Reflective layer of CsI (QE ~ 25% @ 175 nm)

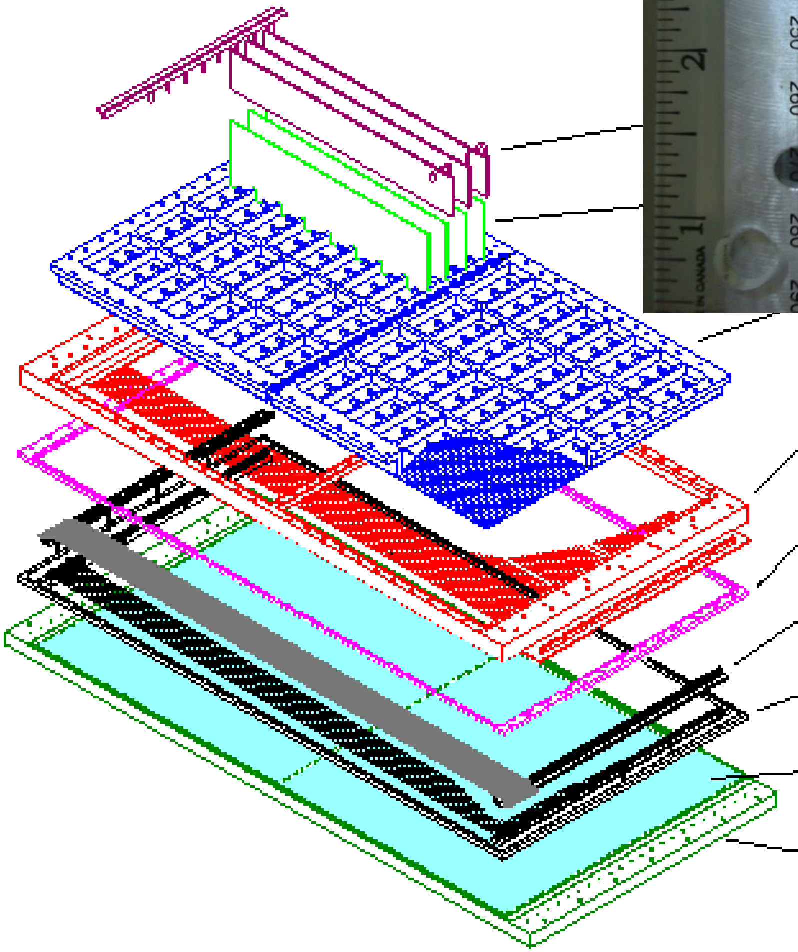
PHOTOELECTRON DETECTOR: MWPC with CH_4 at atmospheric pressure (4 mm gap) HV = 2050 V.

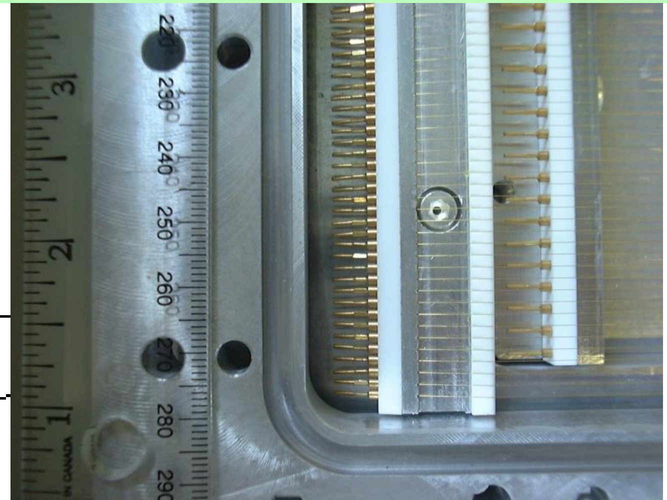
- Analogue pad readout



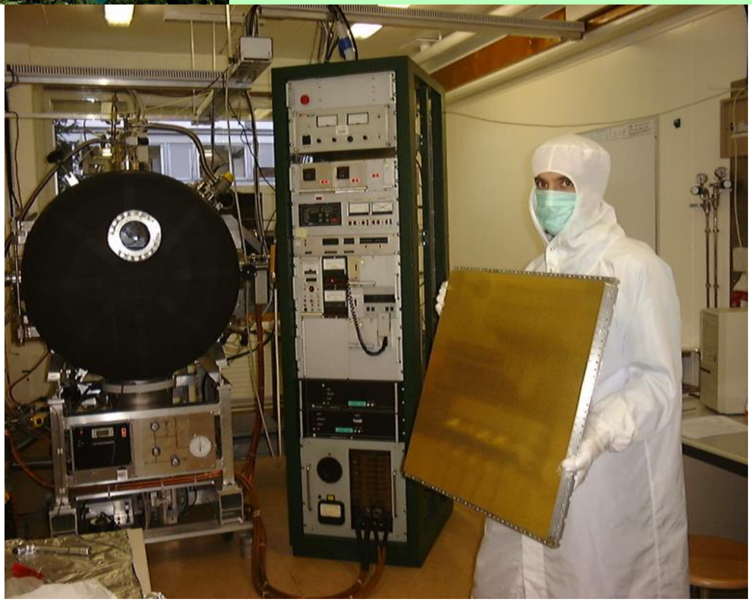
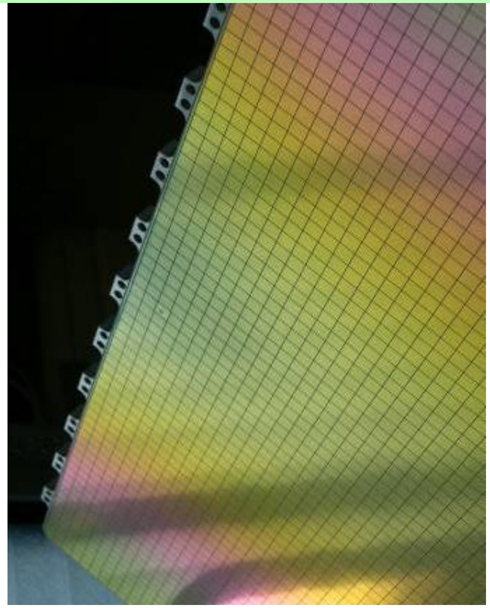


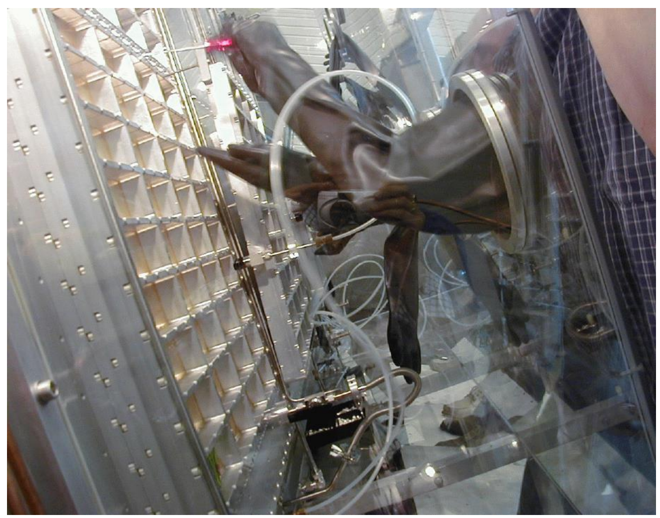
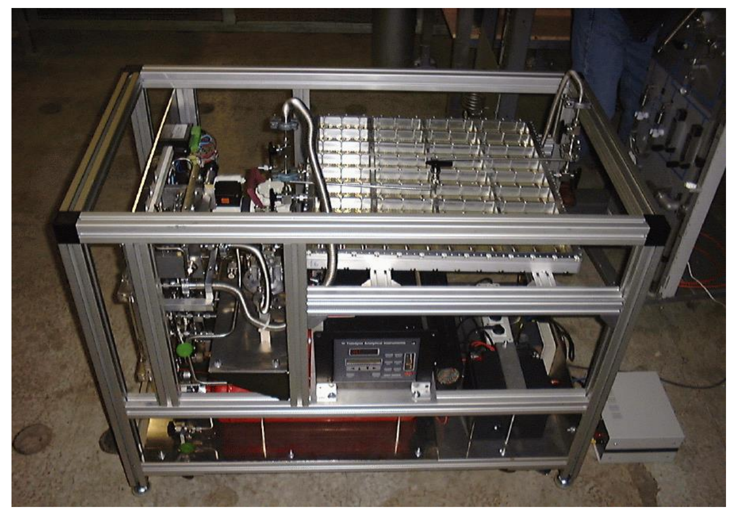
COMPASS MWPC's with CsI





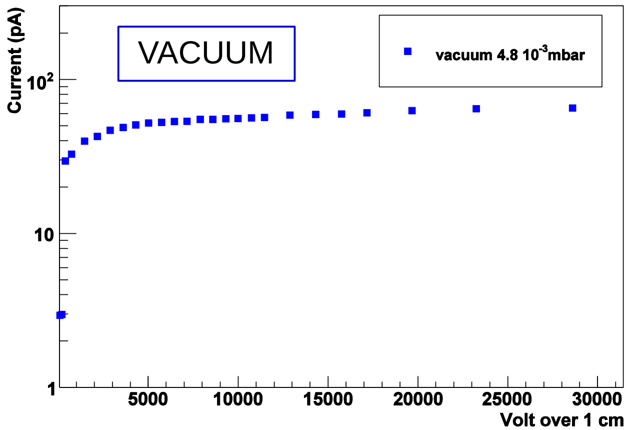
COMPASS photocathodes

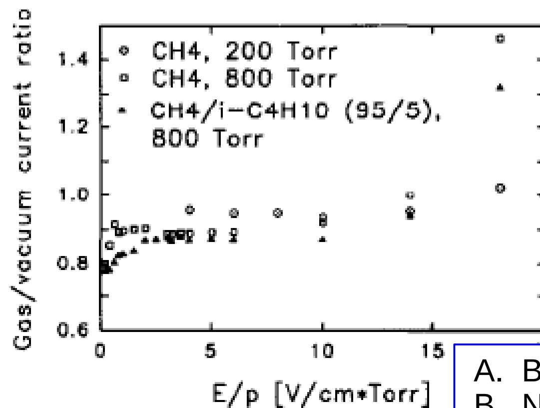



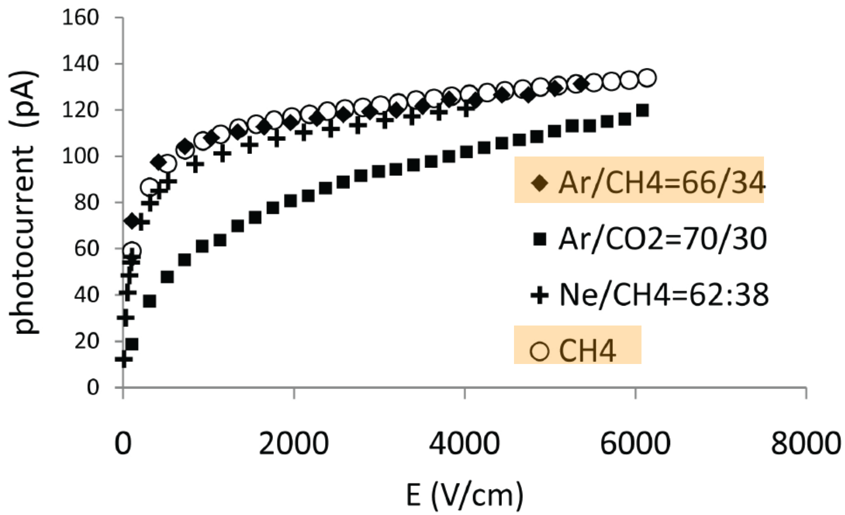
PHOTOELECTRON EXTRACTION

- Photoelectron extraction from a CsI film, the role of gas and E

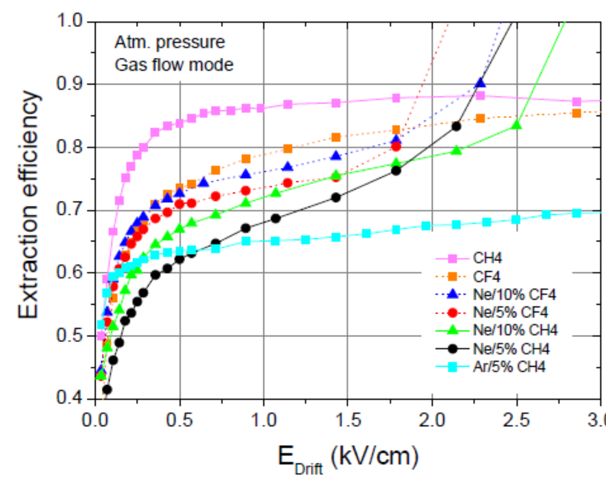




A. Breskin et al.,
B. NIM A 367 (1995) 342



M. Alexeev et al., NIM A (2010) in press

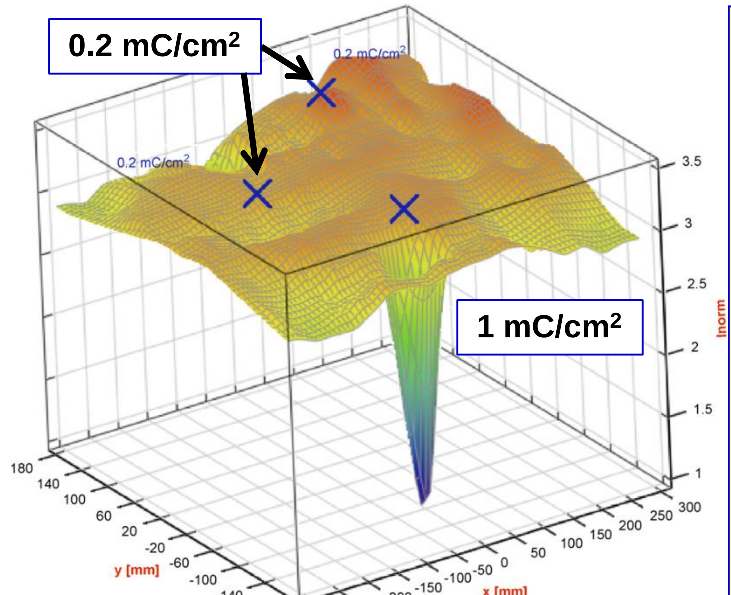


C. D. R. Azevedo et al., 2010 *JINST* 5 P01002

MWPCs with CsI: the limits

- **Severe recovery time (~ 1 d) after detector trips**
  - *Ion accumulation at the photocathode*
- **Feedback pulses**
  - *Ion and photons feedback from the multiplication process*
- **Aging after integrating a few mC / cm²**
  - *Ion bombardment of the photocathode*

moderate gain: <10^5
(effective gain: <1/2)
not fast



H. Hoedlmoser et al., NIM A 574 (2007) 28.

MWPCs → slow signal formation

+ low gain → "slow" electronics (signal integration, low noise level)

- *Gassiplex FE : integration time ~ 0.5 μs, time res> 1 μs*
- *APV (COMPASS RICH-1 upgrade) : resolution ~ 400 ns*

→ Detector memory, i.e. not adequate for high rates

MPGD-BASED PDs

- Reduced photon feed-back and Ion BackFlow (IBF)
  - Reduced ageing
  - High gain → high photoelectron detection efficiency
- Intrinsically fast gaseous detectors

  Short integration time

  High rate environments

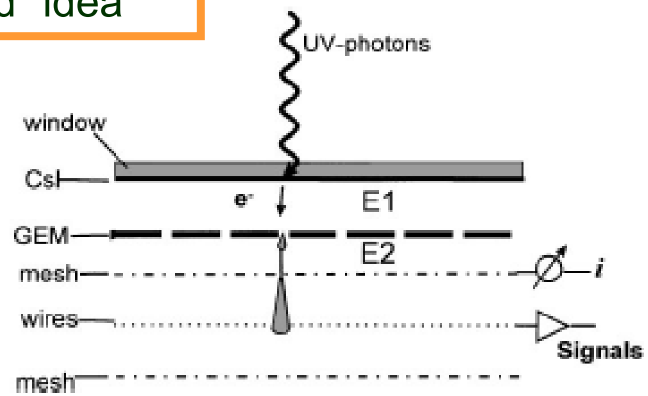
→ **MICROPATTERN GASEOUS DETECTORS**

ION & PHOTON BLOCKING GEOMETRIES

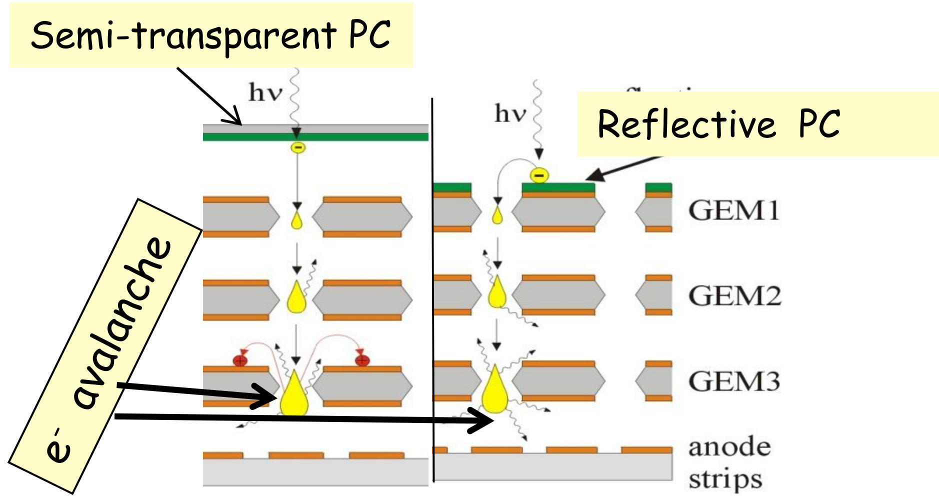
GEM-based PDs

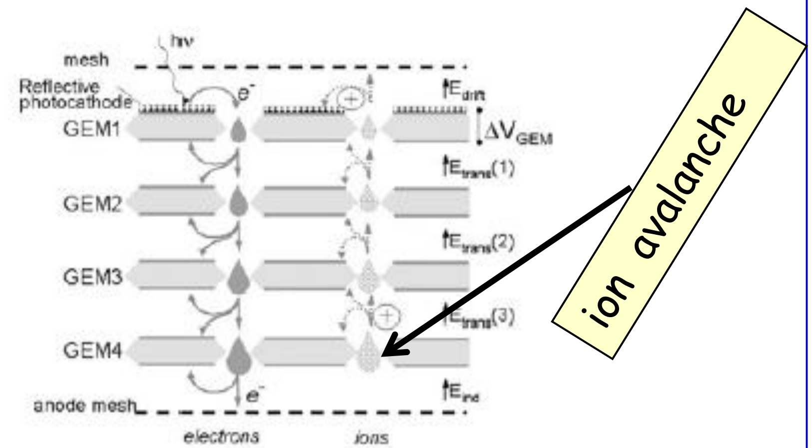
NO photon feedback
Reduced ion feedback

An "old" idea



R. Chechik et al., NIM A 419 (1998) 423

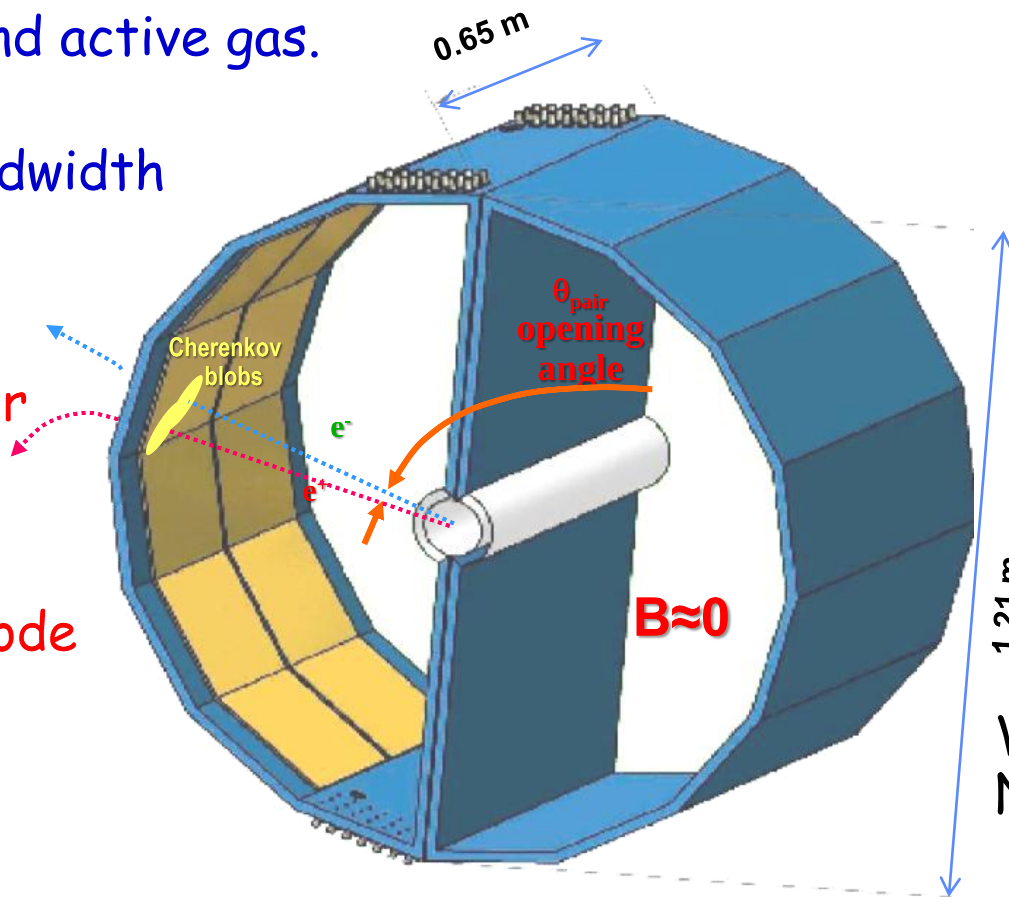


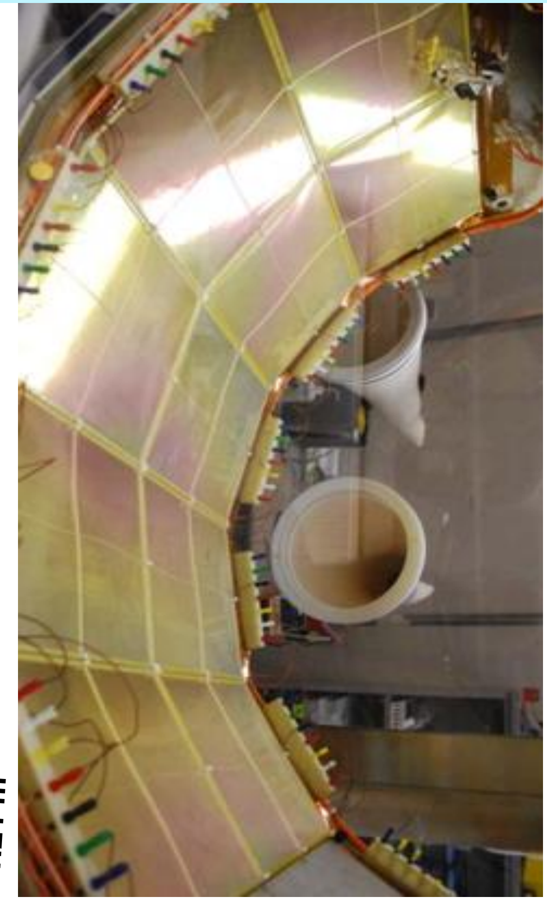


A. Breskin and R. Chechik, NIM A 595 (2008) 116

HBD- Cherenkov detector with GEMs +CsI

- ✓ Proximity focus configuration, no window, no mirror
- ✓ CF_4 radiator and active gas. L_{rad}=50 cm
- ✓ Very large bandwidth 108 - 200 nm (6.2 - 11.5 eV)
- ✓ triple GEMs for signal multiplication
- ✓ CsI photocathode

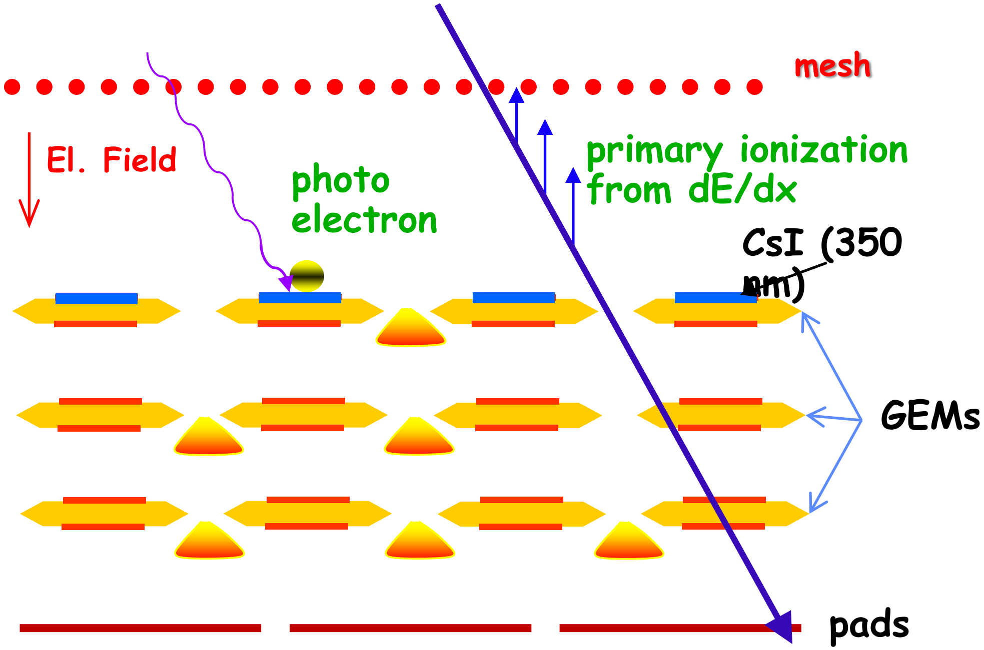


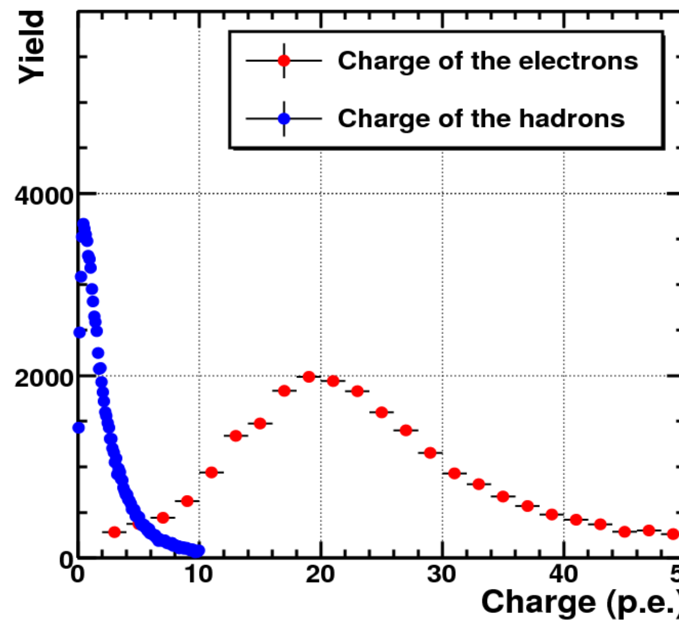


W. Anderson et al., NIM A 646 (2011) 35

HBD - hadron blindness

❖ Electron signals are relatively rare (compared to hadrons)

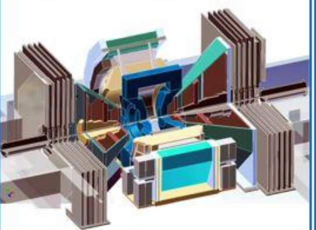


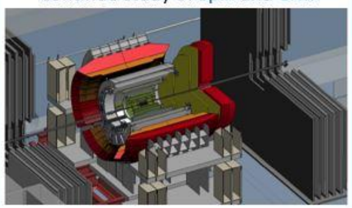


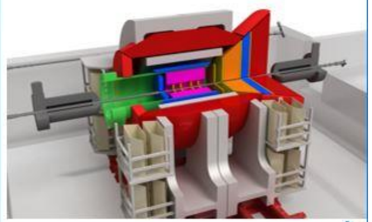
a. Detector operated in reverse bias mode to repel the ionization charge from dE/dx
b. Cherenkov light is formed only by e^+ or e^-
c. Successfull operation at PHENIX since seversl years
d. <u>It is not a detector of single photons</u>

a PID for EIC proposal

Current PHENIX	sPHENIX (+fsPHENIX)	An EIC detector
15 years of operation Produced broad spectrum of studies of QGP and Hadron Physics 140+ published papers to date Last run in 2016	Comprehensive upgrade based on the BaBar magnet Goal is to do a systematic study the QGP near T_c by measuring jets and heavy quarkonia Possible addition of a forward spectrometer (fsPHENIX) to continue study of Spin and CNM	Further upgrades of sPHENIX leads to a capable Day 1 detector for eRHIC Study polarized ep and eA physics Large coverage of tracking, calorimetry and PID







~2000 2017→2020 ~2025 Time

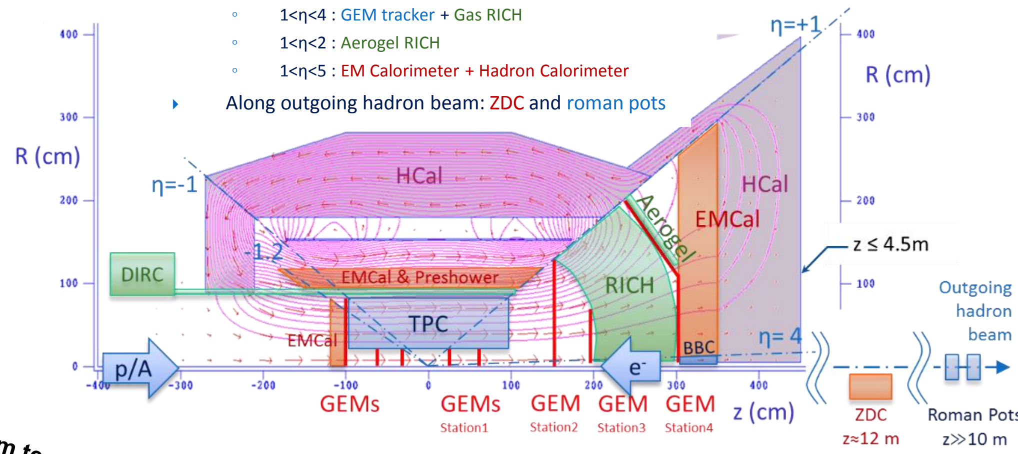
RHIC: A+A, spin-polarized p+p, spin-polarized p+A

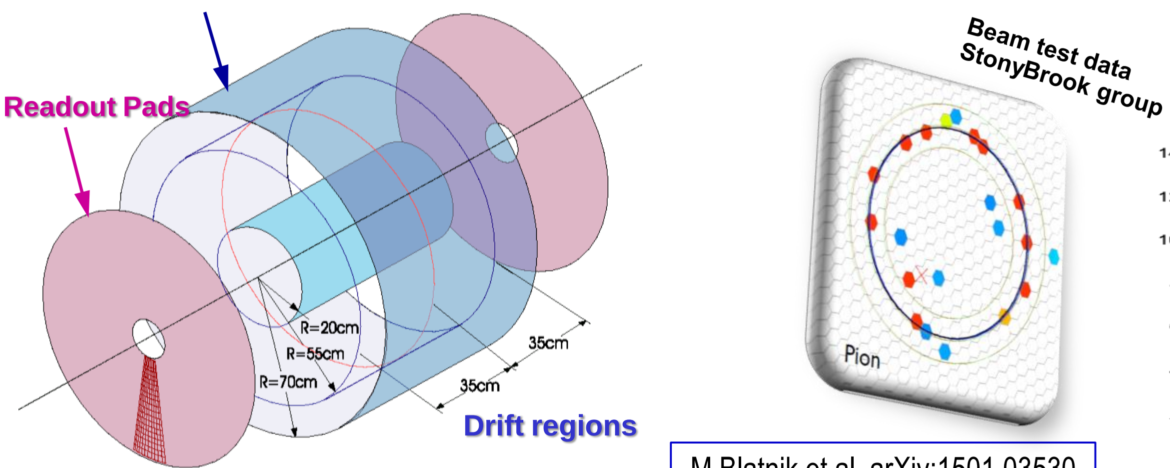
EIC: e+p, e+A

sPHENIX → eRHIC Detector

LOI: arXiv:1402.1209

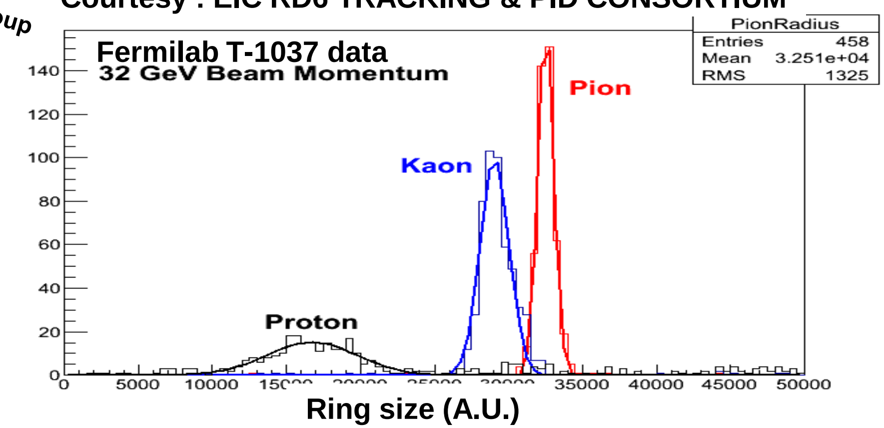
- -1<η<+1 (barrel) : sPHENIX + Compact-TPC + DIRC
- -4<η<-1 (e-going) : High resolution EM calorimeter + GEM trackers
- +1<η<+4 (h-going) :
  - 1<η<4 : GEM tracker + Gas RICH
  - 1<η<2 : Aerogel RICH
  - 1<η<5 : EM Calorimeter + Hadron Calorimeter
- Along outgoing hadron beam: ZDC and roman pots





M.Blatnik et al. arXiv:1501.03530

Courtesy : EIC RD6 TRACKING & PID CONSORTIUM



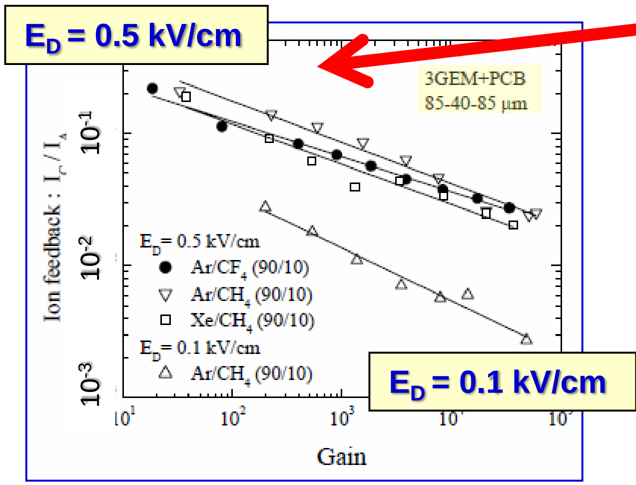
GEM-based PDs and IBF

rich literature about IFB in GEM-based detectors

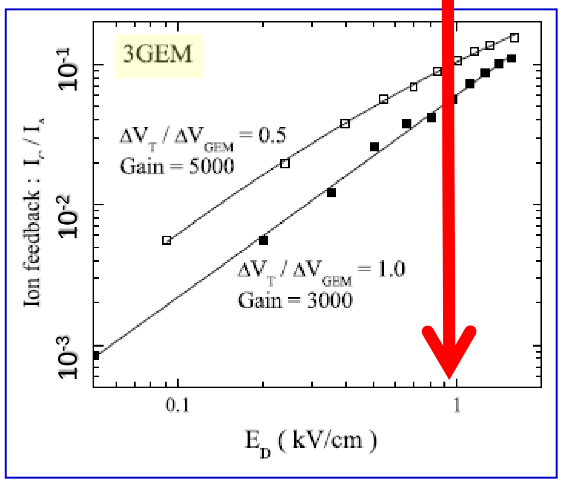
here examples with semi-transparent PC

- strong dependence from gain and E_{DRIFT}
- poor dependence from pressure and gas type

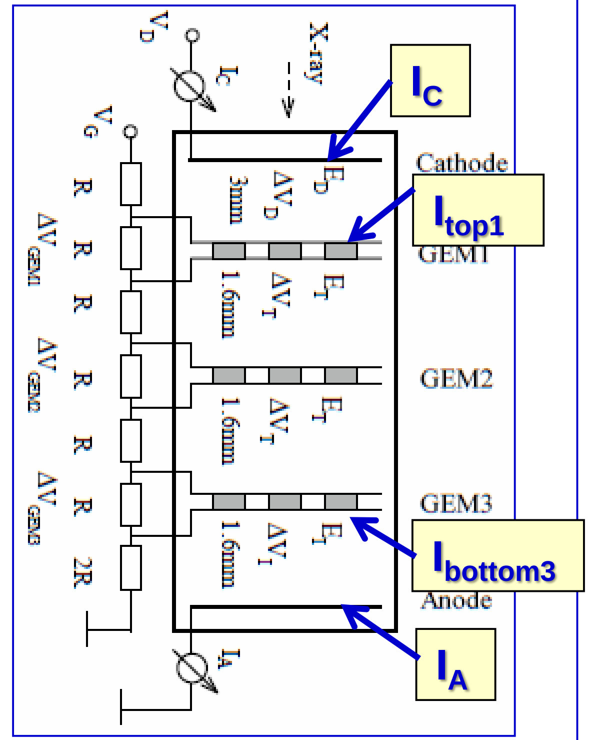
E ~ 1 kV/cm needed for good photoelectron extraction



A. Bondar et al., NIMA 496 (2003) 325



A. Breskin et al., NIMA 478 (2002) 225d



The same for reflective PCs : small and reversed E_D is needed

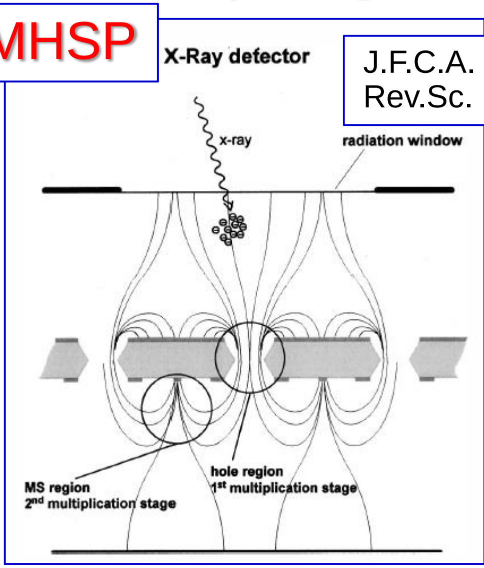
IBF: a few % level in effective GEM-based photon detectors

OVERCOMING IBF

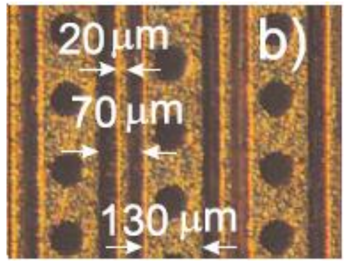
More complex geometries needed with extra electrodes to trap the ions:

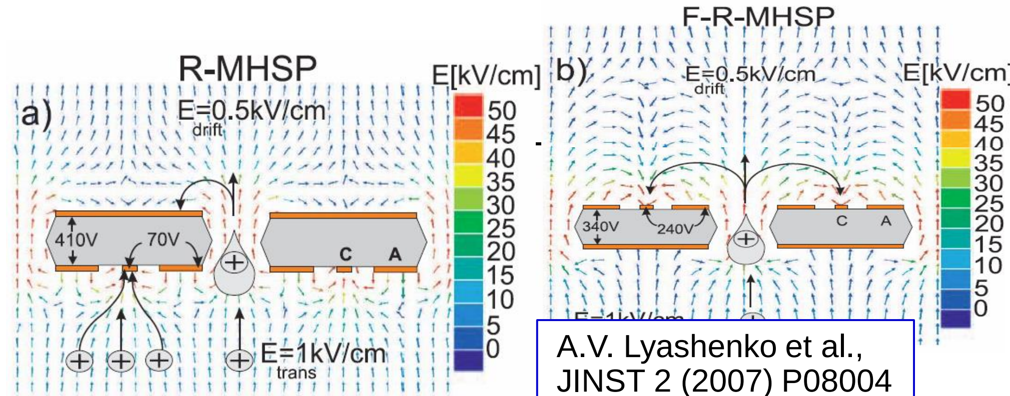
Micro-Hole & Strip Plate (MHSP), COBRA

MHSP



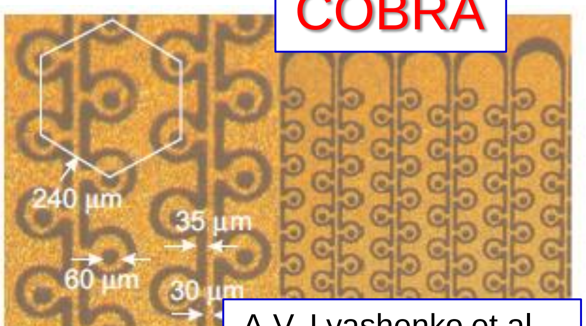
J.F.C.A. Veloso et al.,
Rev.Sc. Instr. 71 (2000) 2371



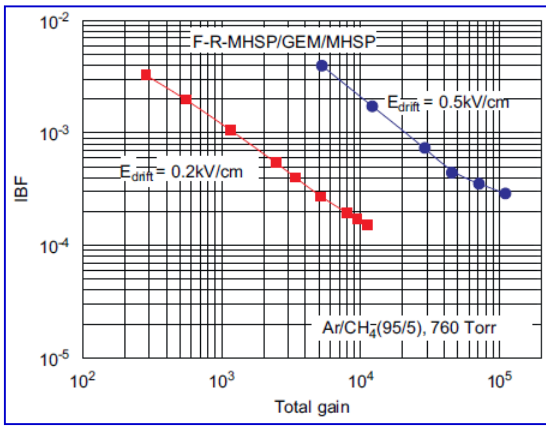


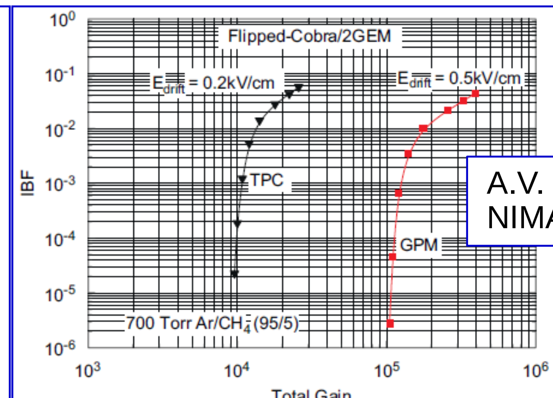
A.V. Lyashenko et al.,
JINST 2 (2007) P08004

COBRA



A.V. Lyashenko et al.,
NIMA 598 (2009) 116





A.V. Lyashenko et al.,
NIMA 598 (2009) 116

GEM-based PDs and GAIN

INFN Istituto Nazionale di Fisica Nucleare

LARGE GAIN RELEVANT FOR SINGLE PHOTON DETECTION

- GEM-based PDs in laboratory studies
  - for single photoelectron detection, they have been operated at gains > 10^5 (see, for instance, the plots of the previous slides)

- GEM-based detectors in experiments
  - Always a MIP flux and small rates of heavily ionizing fragments crossing the detectors (even when the detectors are used as photon detectors)
    - At COMPASS: G ~ 8000 (B. Ketzer, private comm.)
    - At LHCb: G ~ 4000 (M.Alfonsi NIMA 581 (2007) 283)
    - At TOTEM: G ~ 8000 (G. Catanesi, private comm.)
    - Phenix HBD: G ~ 4000 (W. Anderson et al., NIMA 646 (2011) 35)

→ In experiments, small chances to operate GEM-based PDs at gains > 10^4

THGEM-based PDs, why ?

PCB technology, thus:

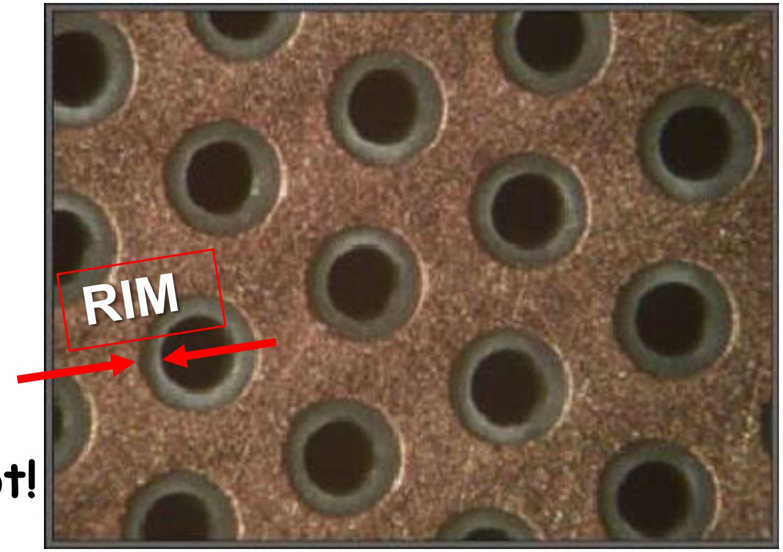
- robust
- mechanically self supporting
- industrial production of large size boards
- large gains have been immediately reported (rim !)

Comparing to GEMs

- Geometrical dimensions X ~10
  - But e⁻ motion/multiplic. properties do not!
  - Larger holes:
    - dipole fields and external fields are strongly coupled
    - e⁻ dispersion plays a minor role

About PCB geometrical dimensions:

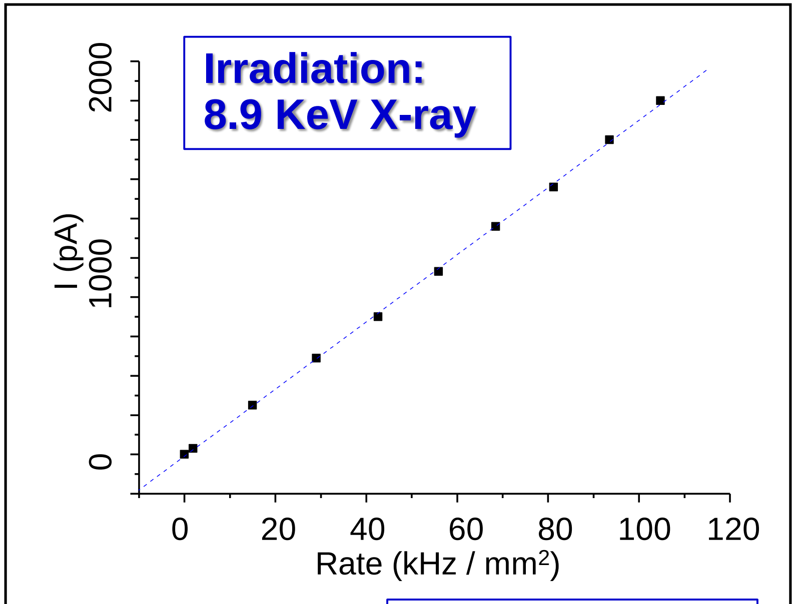
Hole diameter :	0.2 – 1 mm
Pitch :	0.5 – 5 mm
Thickness :	0.2 – 3 mm



introduced in // by different groups:
L. Periale et al., NIM A478 (2002) 377.
P. Jeanneret, PhD thesis, Neuchatel U., 2001.
P.S. Barbeau et al, IEEE NS50 (2003) 1285
R. Chechik et al, .NIMA 535 (2004) 303

THGEM rate capability and IBF

High rate device



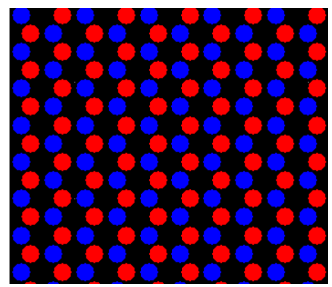
single THGEM, no RIM

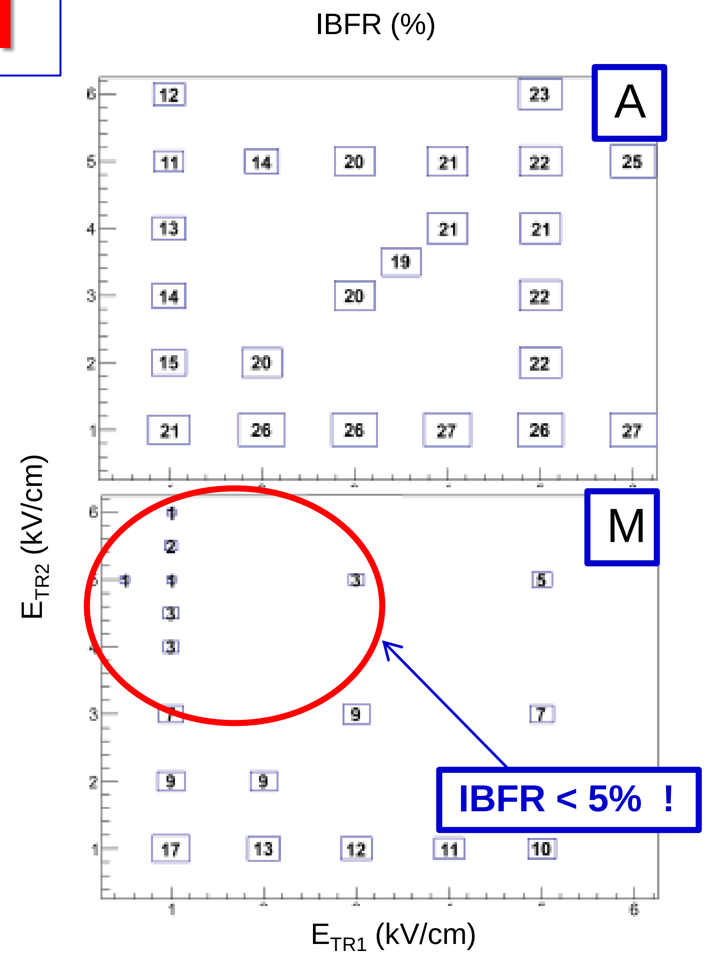
M. Alexeev *et al.* *JINST* 10 (2015) P03026

The gain in Thick GEM multipliers and its time-evolution

IBF control

Triple THGEM:
Ion Back Flow
reduction by
staggering plates



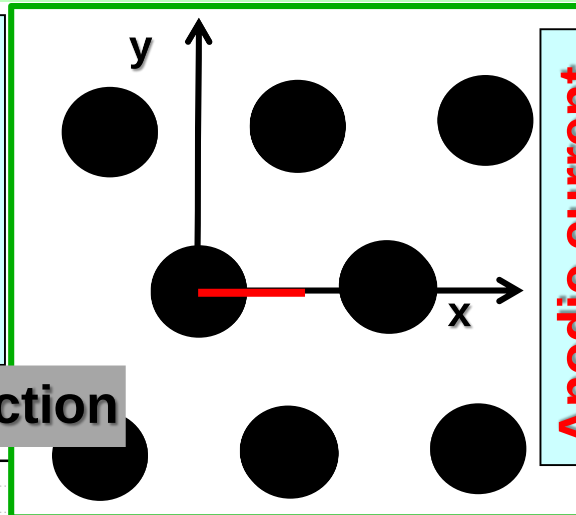


M. Alexeev et al., JINST 7 (2012) C002014

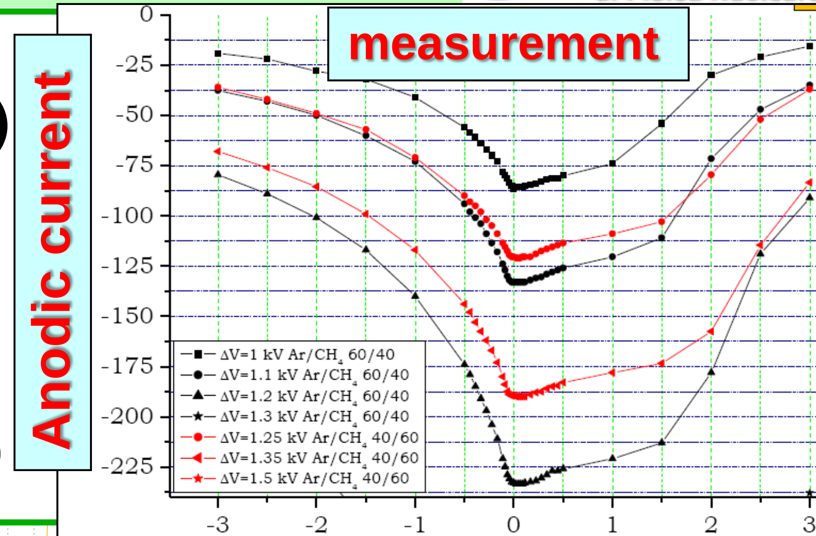
PHOTOELECTRON EXTRACTION

photoelectron trajectories from a THGEM photocathode, simulation, multiplication switched off

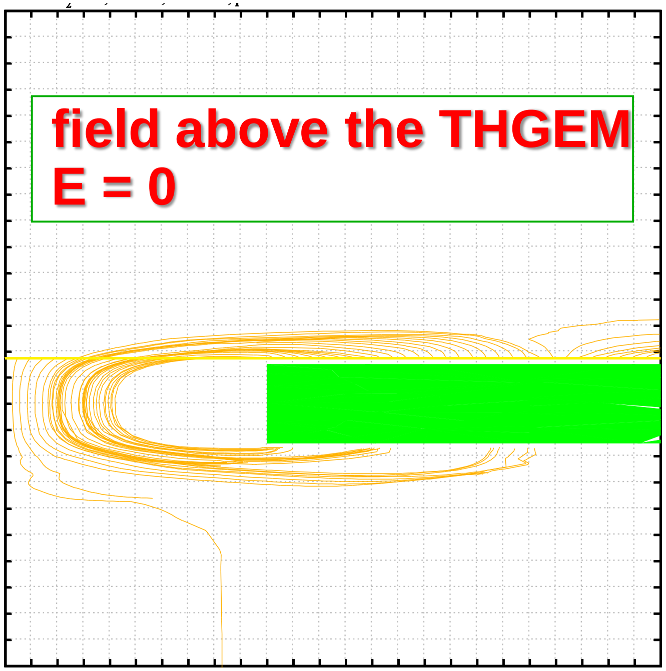
thickness 0.6 mm, diam. 0.4 mm, pitch: 0.8 mm, ΔV = 1500 V



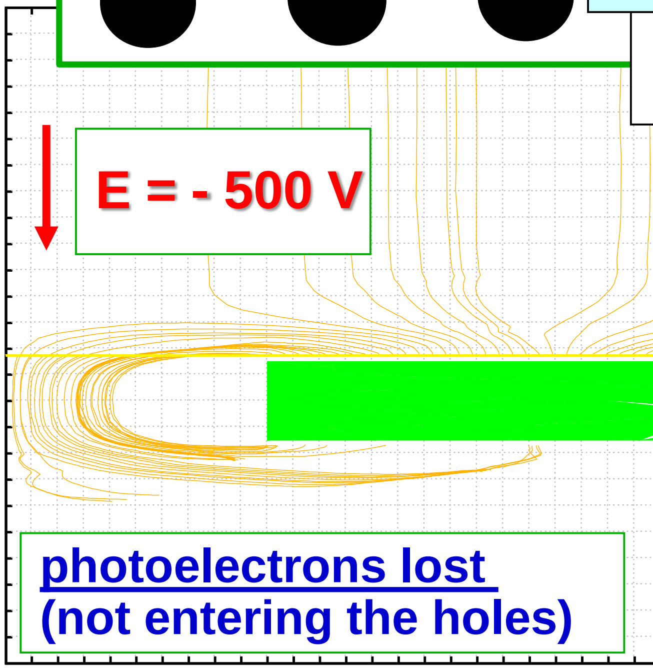
x cross-section



external electric field applied

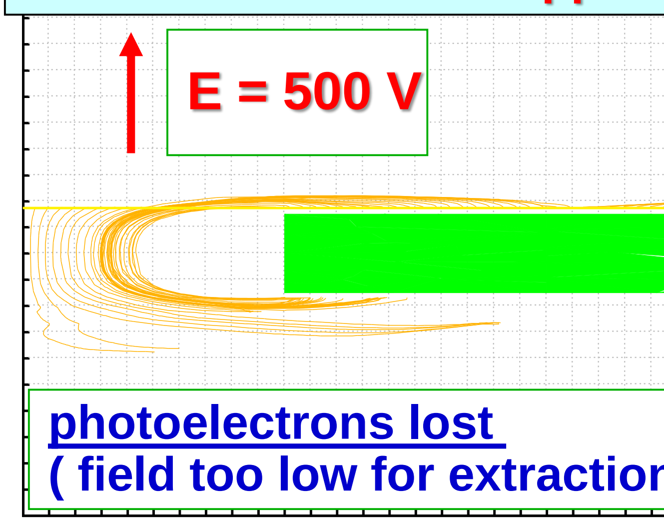


field above the THGEM
E = 0



E = - 500 V

photoelectrons lost
(not entering the holes)



E = 500 V

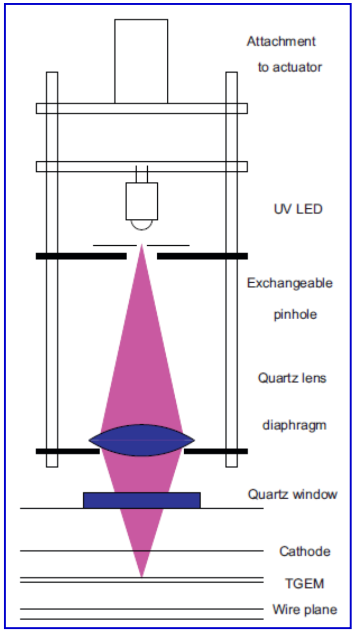
photoelectrons lost
(field too low for extraction)

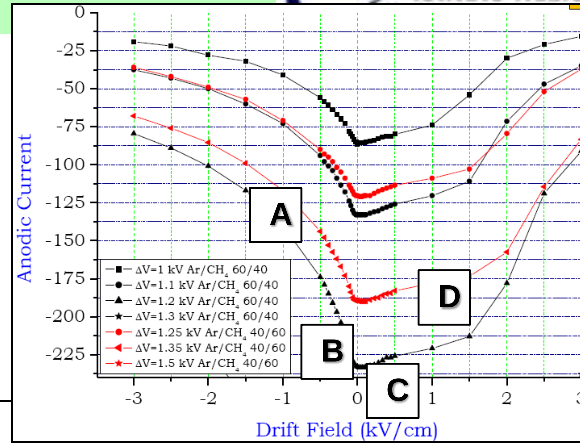
LEOPARD

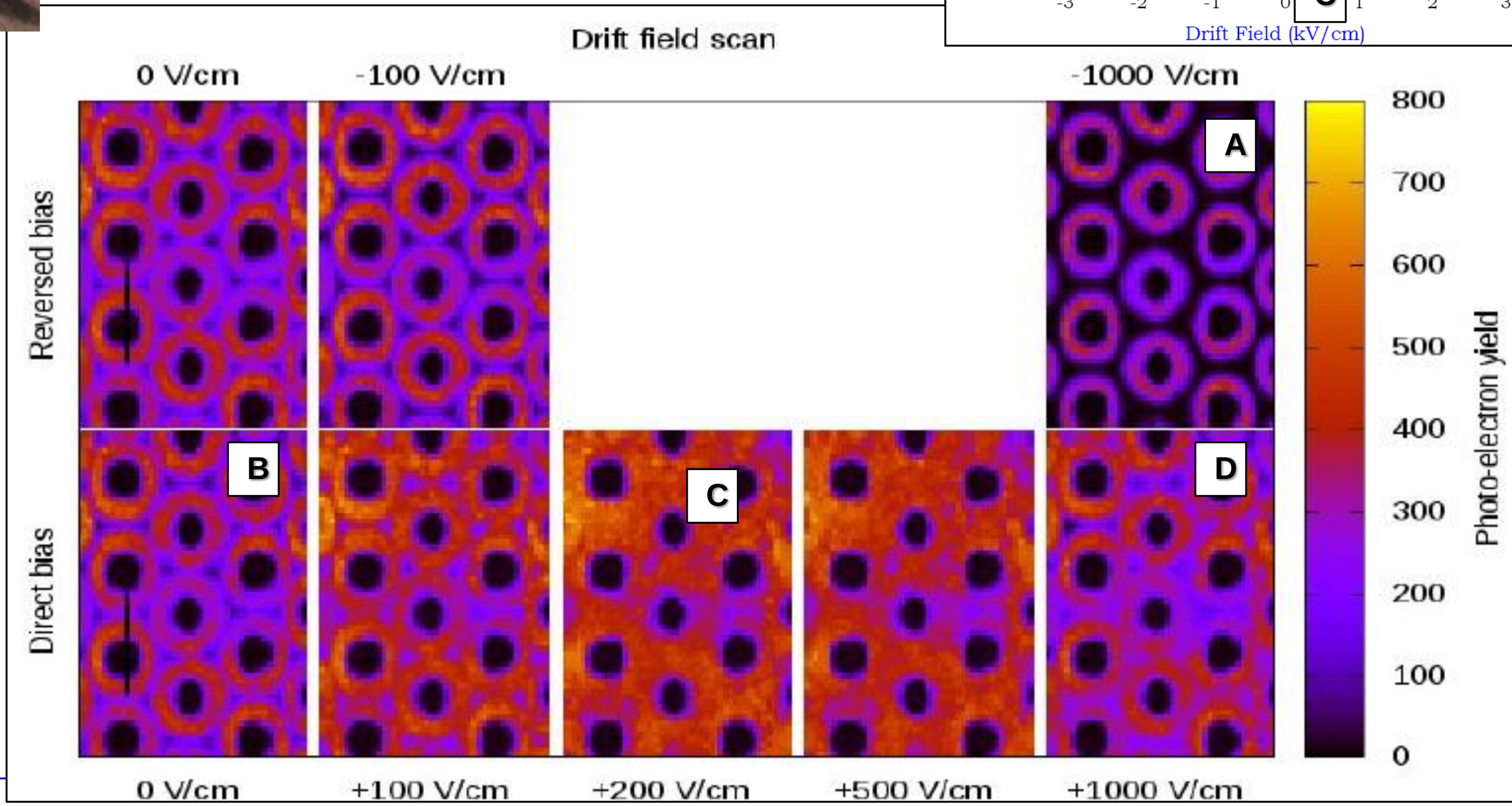
Photoelectron extraction from THGEM PC fully confirmed by direct observation with "Leopard"

G.Hamar talk on Thursday

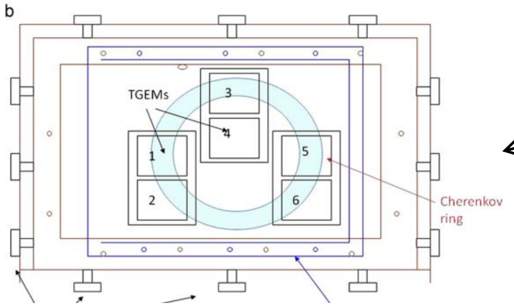
G.Hamar and D.Varga, NIMA 694(2012) 16





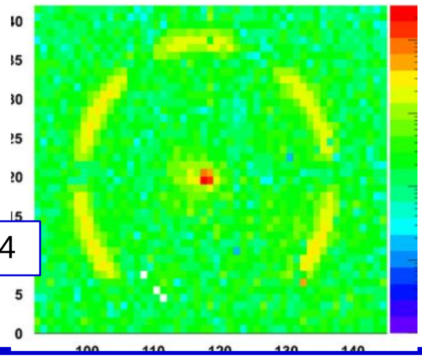


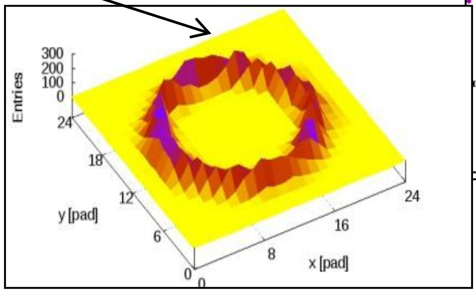
THGEM R&D for RICHes

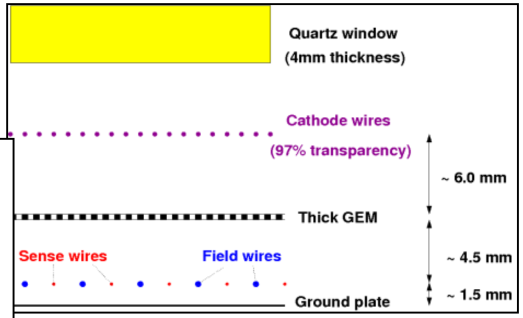


ALICE VHMPID
THGEM & HYBRID

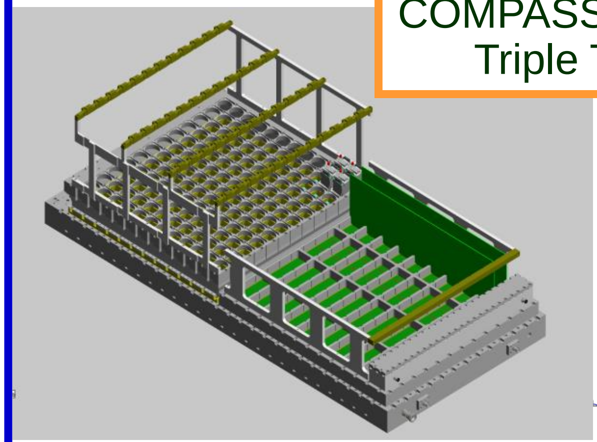
V.Peskov et al., NIMA 695 (2012) 154

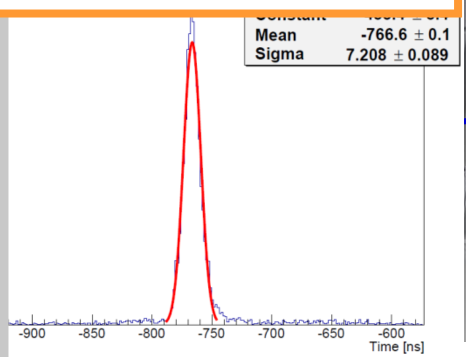


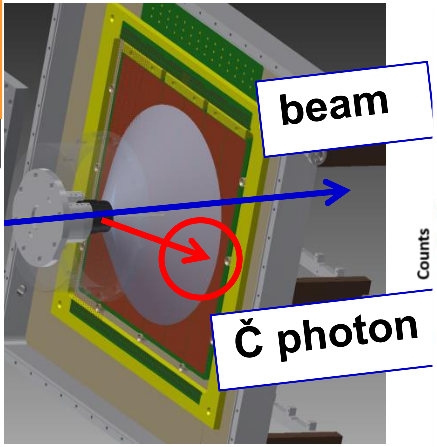


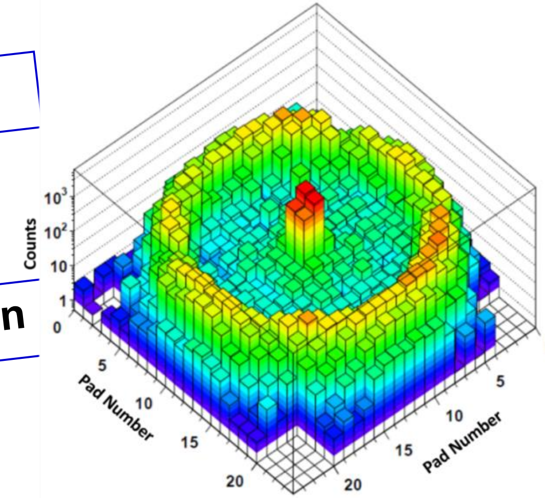


COMPASS, RICH-1 upgrade by
Triple THGEM detectors









NUMBER OF DETECTED PHOTONS

V.Peskov et al., NIMA 695 (2012) 154

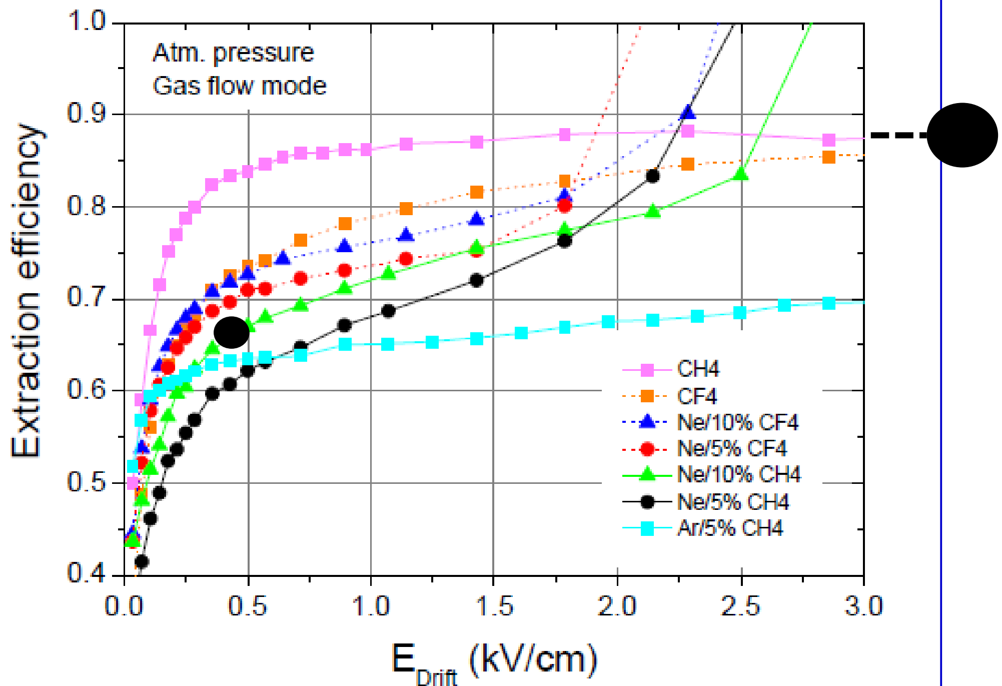
N of detected photons is ~60-70% of MWPCs with CsI

- $Ne+10\%CH_4$, used with ΔV at 650-750 V

5. Conclusions and Outlook

We report the first successful implementation of a set of CsI-TGEMs with a liquid radiator where a Cherenkov ring has been observed. The results obtained are encouraging and suggest that the present performance could be improved in the future by optimizing elements of the design. We are launching now systematic studies on TGEM geometry optimization allowing increasing the value of η_{rel}, ε_{col} and A_{eff}. We also are planning to investigate

→ Relative extraction efficiency Respect to pure methane at E ~ 7kV/cm ~ 75%

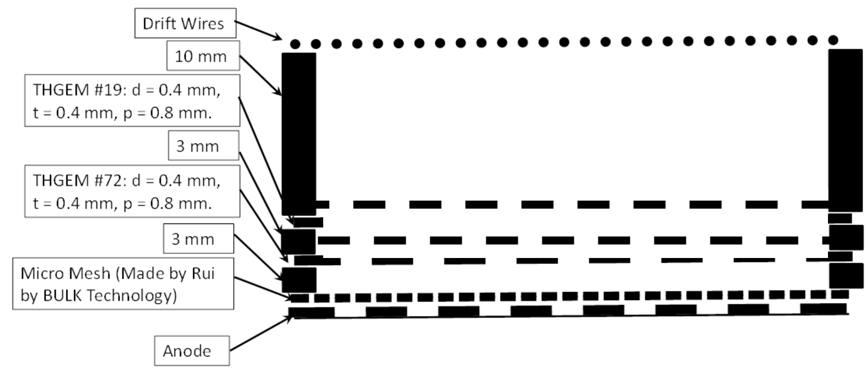


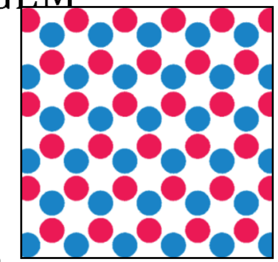
C. D. R. Azevedo et al., 2010 *JINST* 5 P01002

HYBRID MPGD PDs (THGEM + MM)

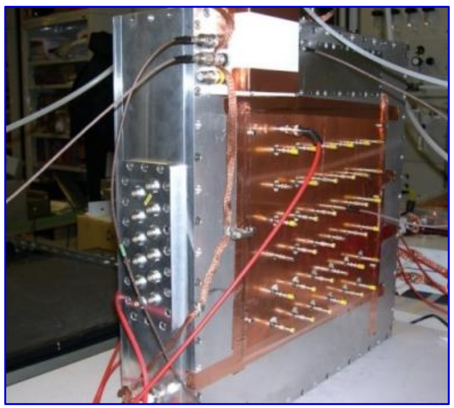
- The 1st THGEM forms the PC
- The 2nd THGEM (staggered) forces the electron diffusion
- The MM provides large gain, made larger by the diffusing the impinging electron cloud

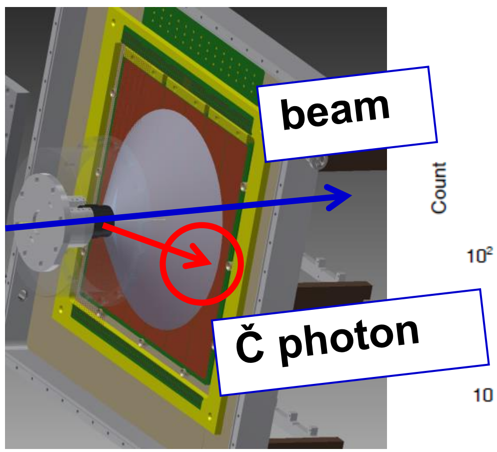
Setup Hybrid (300 X 300 mm^2) with double THGEM





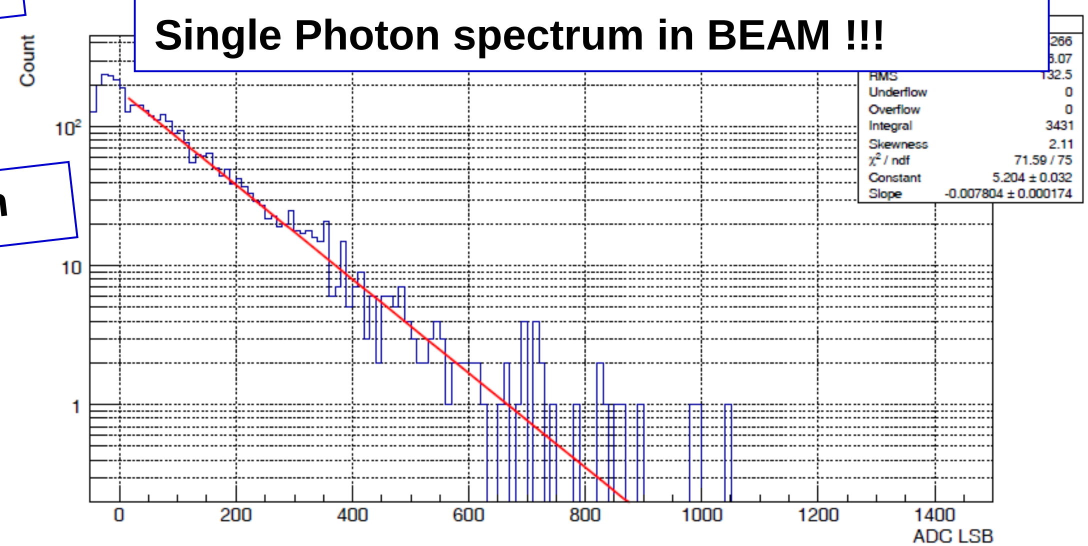
THGEM staggered !





Gain ~ 130K

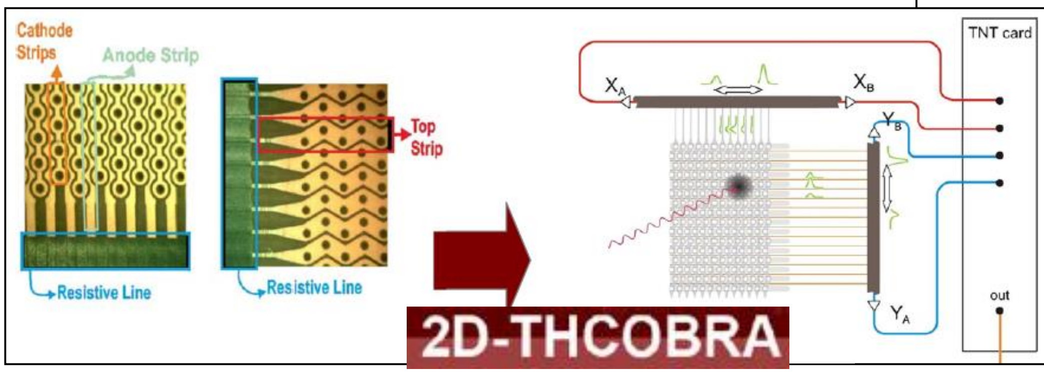
Single Photon spectrum in BEAM !!!



The same architecture independently studied in parallel as GPM for DM searches (see later)

HYBRID MPGD PDs (THGEM + THCOBRA)

- 2 THGEMs
- a THCOBRA with 2 d R-O structure

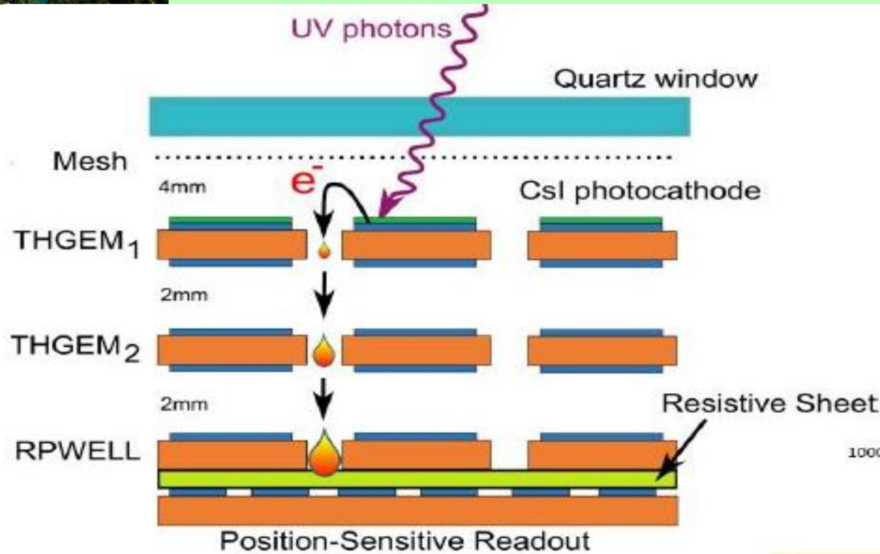


Parameters			
Structure	Hole Diameter (µm)	Pitch (µm)	RIM (µm)
THGEM 1	400	800	5
THGEM 2	700	1300	100
2D THCOBRA	400	1000	80

- Gas Photomultiplier (GPM) : 2D-THCOBRA
  - Good Performance
    - Gain of 10^6
    - IBF values of about: 20%
  - 2D THCOBRA adequate to obtain image
  - Position Resolution: FWHM= 300 µm, σ= 128µm
  - Count rate of 100kHz

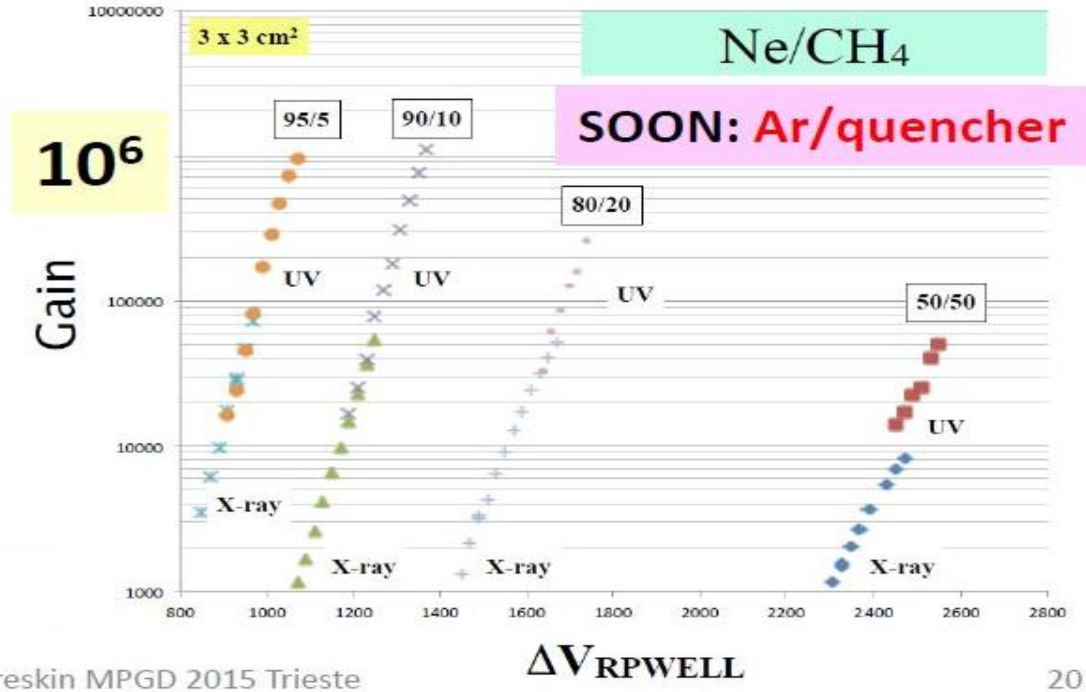
T. Lopes 2013 JINST 8 P09002

RPWELL



R&D @ Weizmann

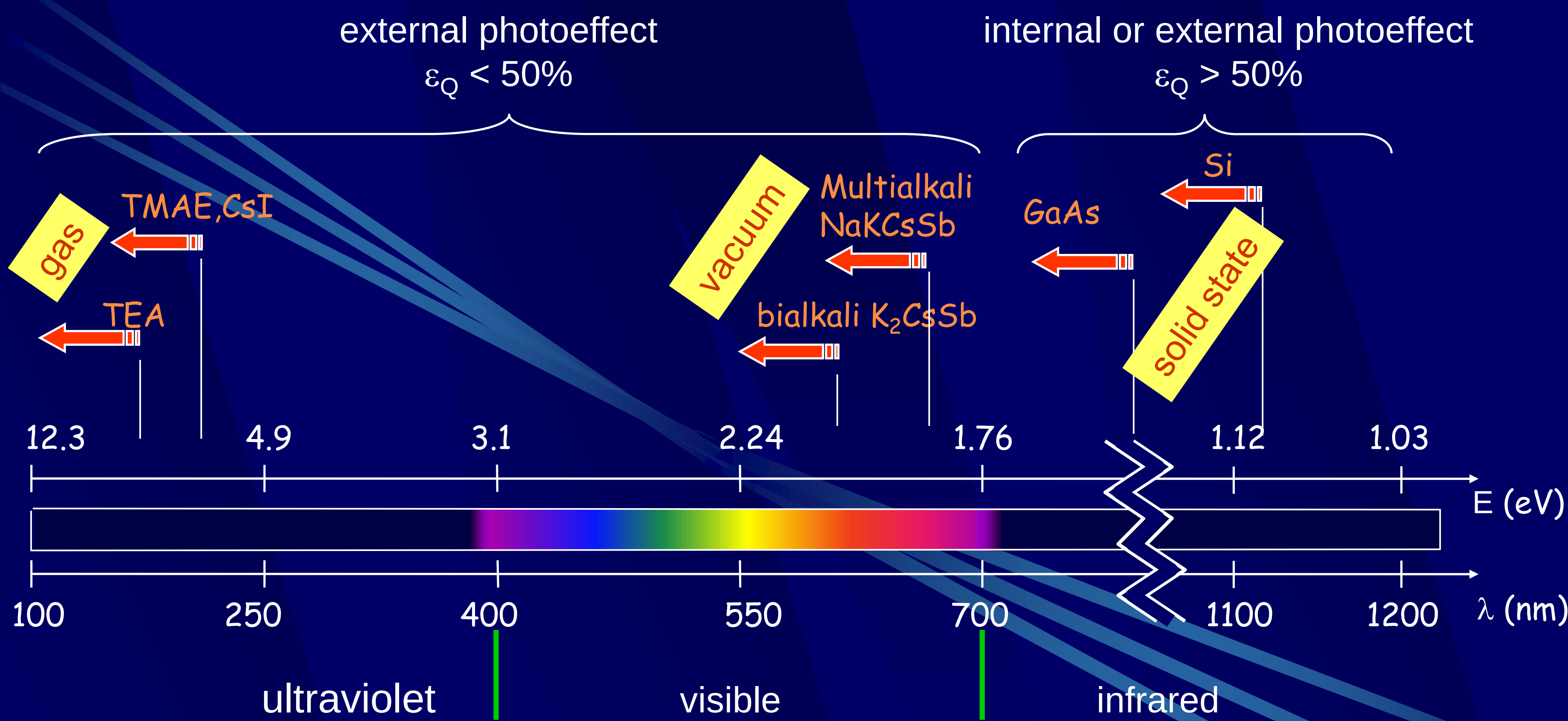
- RT & noble-liquid T
- RPWELL vs nTHGEMs+RPWELL
- Gases
- stability



A Breskin MPGD 2015 Trieste 20

Different photocathodes and their thresholds

$$\varepsilon_Q = Q.E. = N_e / N_\gamma$$



- Photon detection involves often materials like K, Na, Rb, Cs (alkali metals). They have the smallest electronegativity → highest tendency to release electrons.
- Most photocathodes are VERY reactive; Exceptions: Si and CsI.

PHOTOCATHODES FOR VISIBLE LIGHT

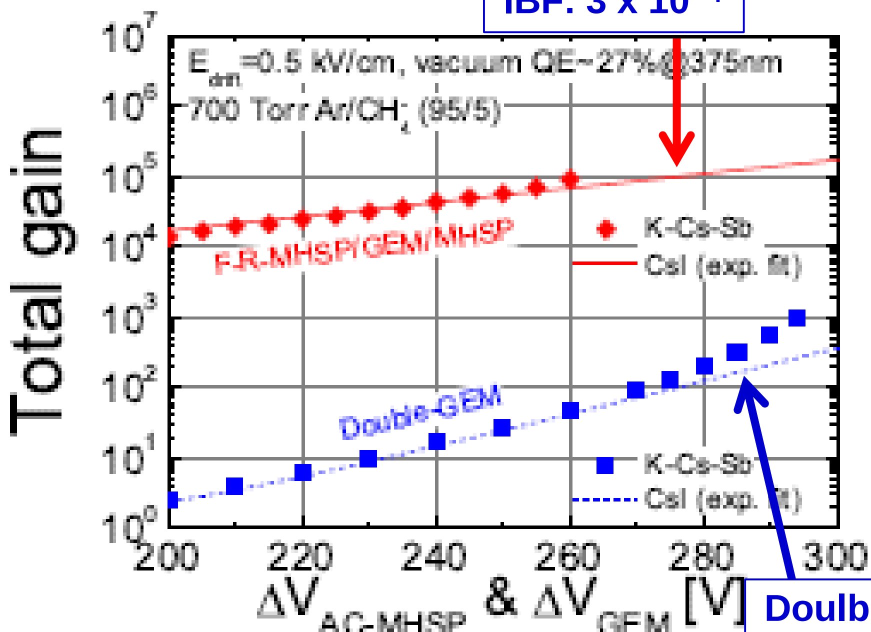
- <u>Chemical reactivity</u> (gas purity better than ppm level needed → UHV materials and sealed detectors)
- <u>PC stability under ion bombardment</u> - work function lower than CsI one
- AGEING CsI: -16% QE at 25μC/mm²
  Bilkaly: -20% QE at 0.4μC/mm²

F.Tokanai et al., NIMA 628 (2011) 190

T.Moriya et al., NIMA 732 (2013) 263

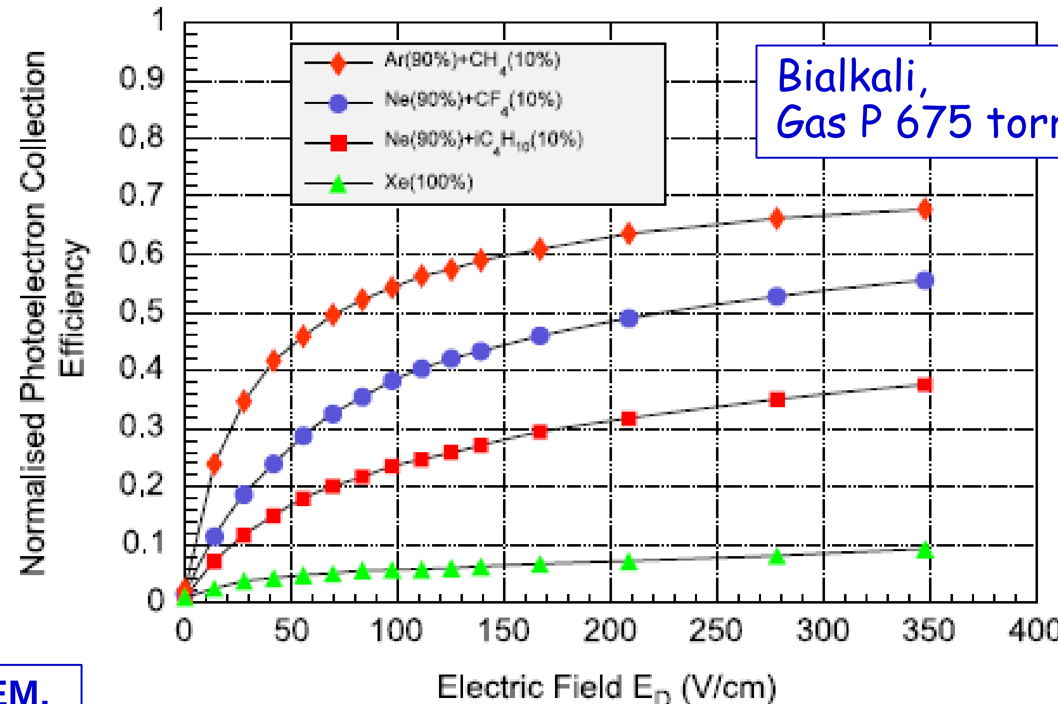
K-Cs-Sb vs CsI

F-R-MHSP, IBF: 3 x 10 $^{-4}$



Doulble GEM, IBF: ~ 10 $^{-2}$

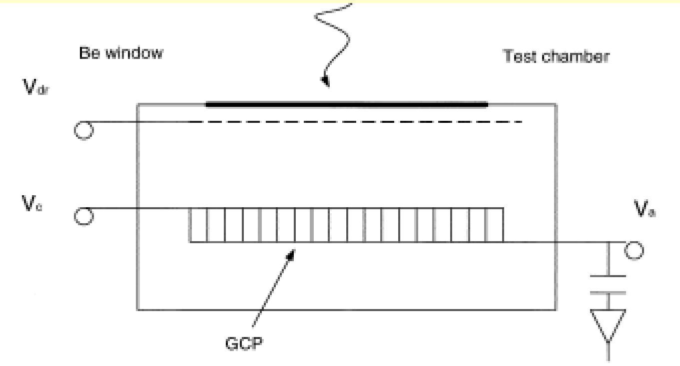
A.V.Lyashenko et al., 2009 JINST 4 P07005



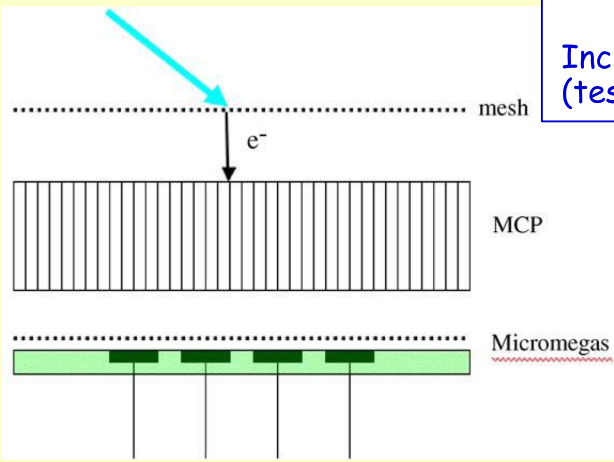
Bialkali, Gas P 675 torr

F. Tokanai et al., NIMA 610 (2009) 164

The Capillary Plate (CP) approach

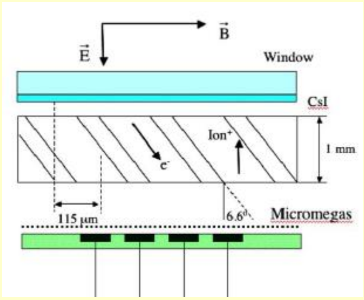


V. Peskov et al., NIMA 433 (1999) 492



MCP coupled to Micromegas

Inclined to reduce more the IBF (tested with CsI)

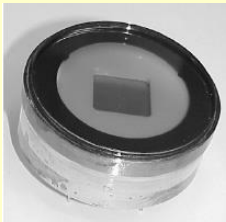


J.Va'vra and T. Sumiyoshi, NIMA, 435 (2004) 334

GASEOUS DETECTORS FOR VISIBLE LIGHT

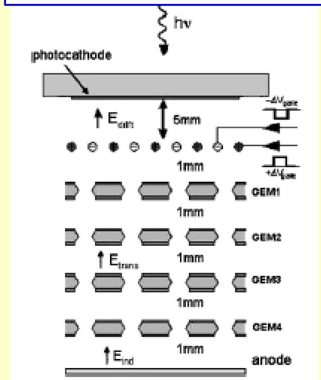
the GEM approach

Multiple GEM sealed



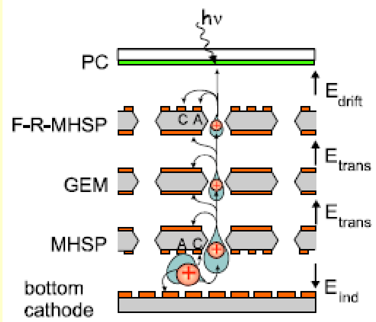
R.Chechik et al., NIMA 502 (2003) 195

Pulsed ion gating



A. Breskin et al.,
B. NIMA 553 (2005) 46

K-Cs-Sb - Continuous mode, not a sealed PD



A.V.Lyashenko et al., 2009 JINST 4 P07005

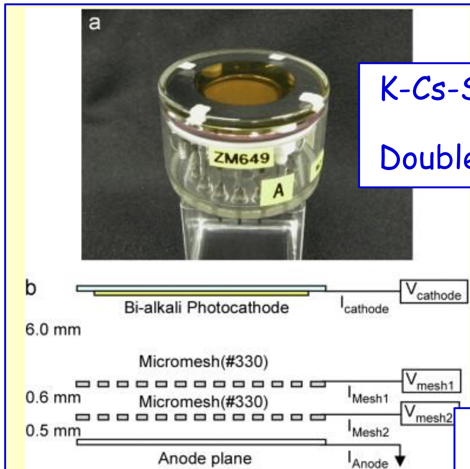
Poor compatibility of bialkali and GEM material ?

Extremely poor QE of the bialkali PC:
the material of the GEM chemically reacts with the bialkali metals

F. Tokanai et al., NIMA 610 (2009) 164

GASEOUS DETECTORS FOR VISIBLE LIGHT

the MicroMegas approach



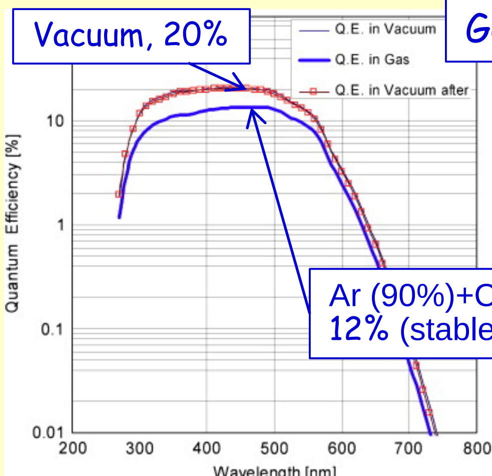
K-Cs-Sb

Double MM, Ni mesh

IBF : <2.5×10^{-3}

Gain < 10^4

Vacuum, 20%

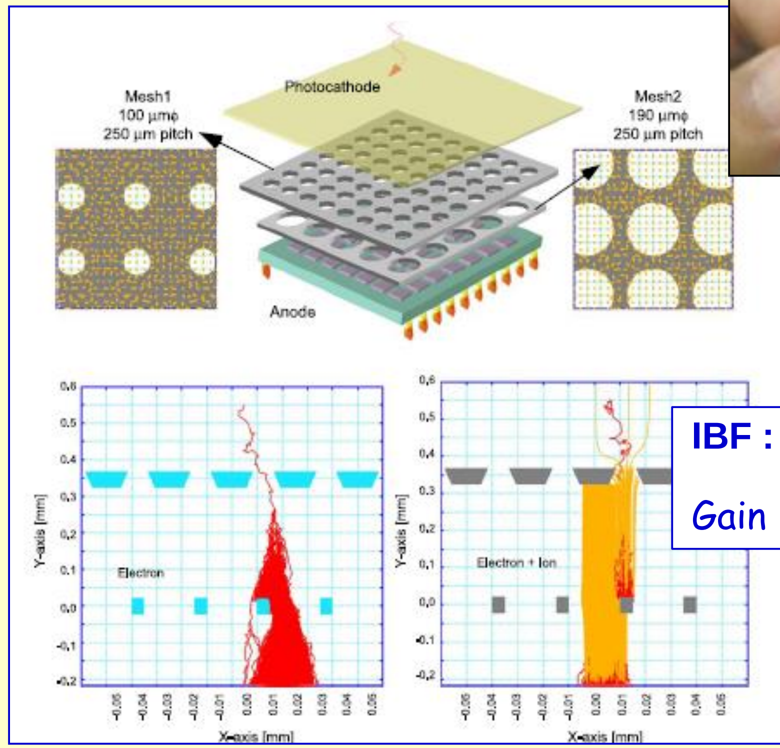


Ar (90%)+CH_4 (10%)
12% (stable) after 1.5 y

F. Tokanai et al., NIMA 610 (2009) 164

2 staggered MM layers to enhance ion trapping

In collaboration with HAMAMATSU



IBF : 6 ×10^{-4}

Gain : 10^4

F. Tokanai et al., NIMA 766 (2014) 176

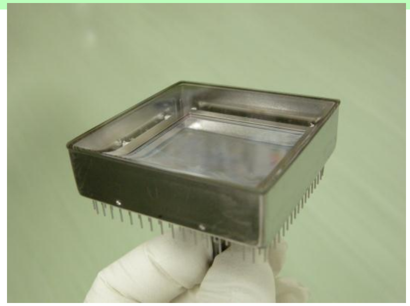
GASEOUS DETECTORS FOR VISIBLE LIGHT

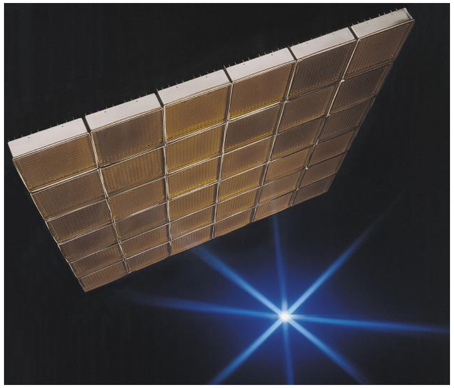
Gaseous PMT

Yamagata U. TMU, HAMAMATSU

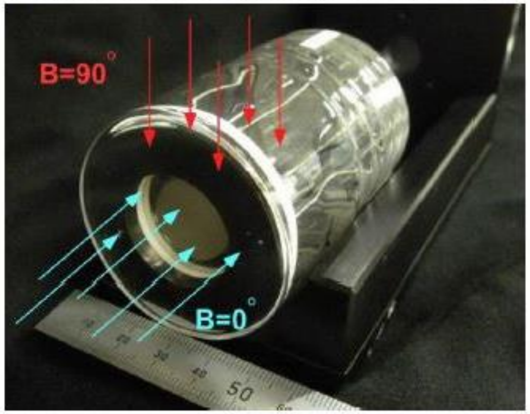
Sensor type	Sensitivity	Position Resolution	Timing Resolution	Uniformity	Price	Magnetic Field	Effective Area
Vacuum PMT	◎	△	◎	△	○	△	○
CCD / CMOS	△	◎	×	◎	△	◎	×
Gaseous PMT	○	○	○	○	◎	◎	◎

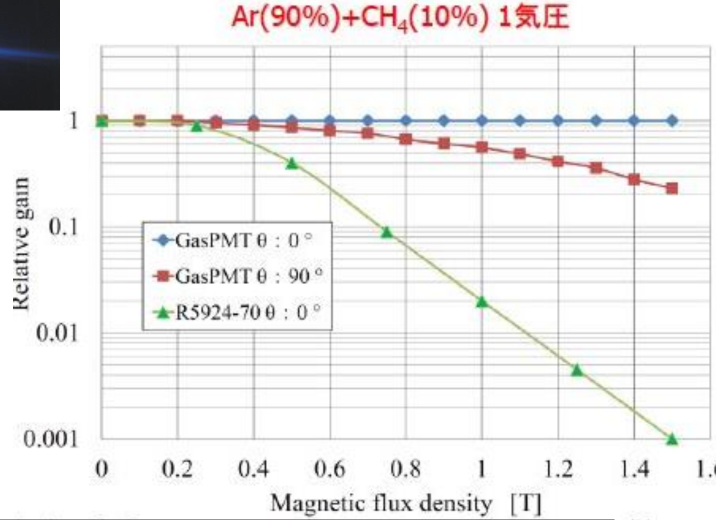
- The advantage of the **gaseous PMT**:
  - ✓It can achieve a **very large effective area** with moderate **position** and **timing** resolutions.
  - ✓It can be easily operated under a **very high magnetic field**.



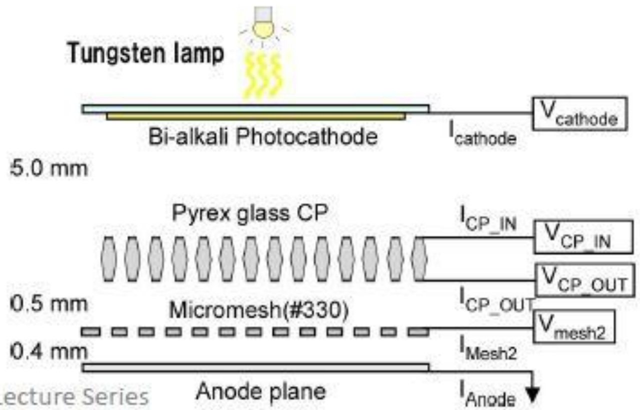


Operation in magnetic field environmen





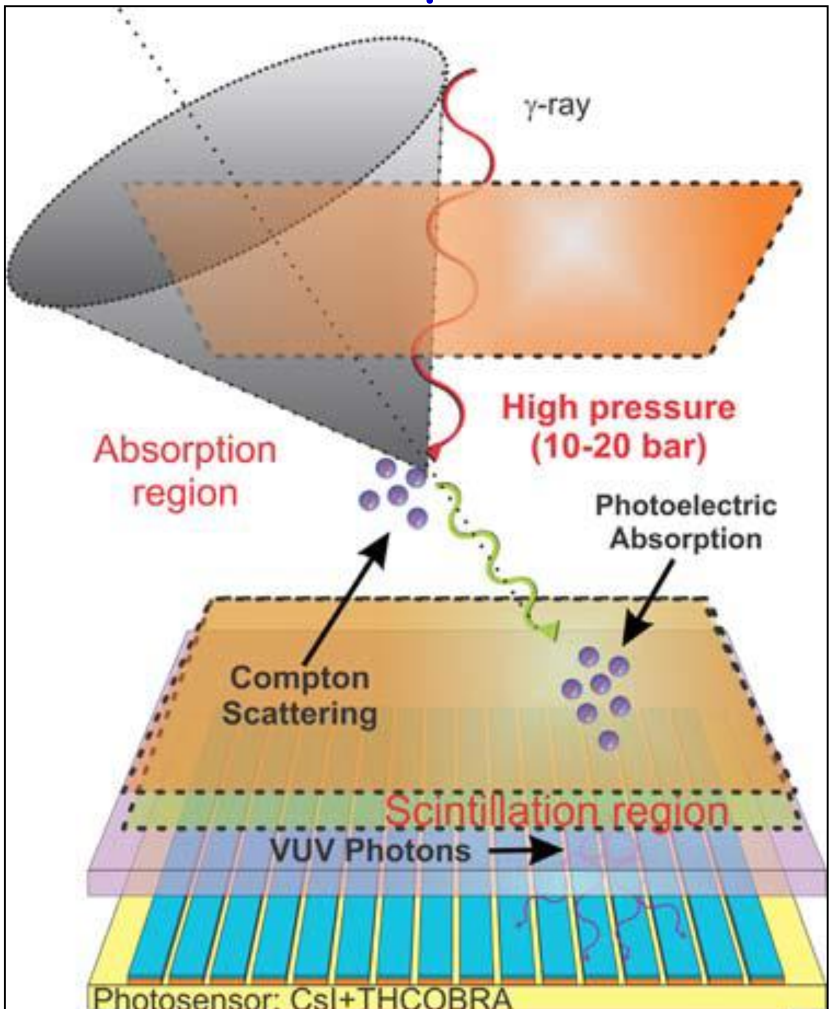
H. Sugiyama et al., NIMA (2016) in press

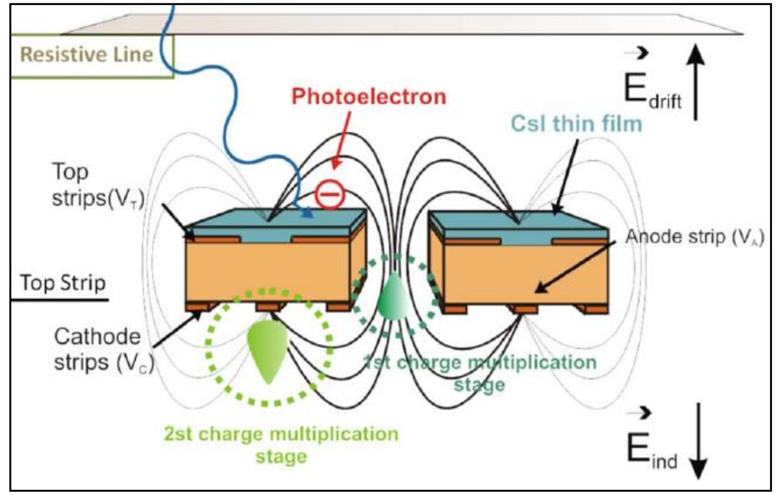


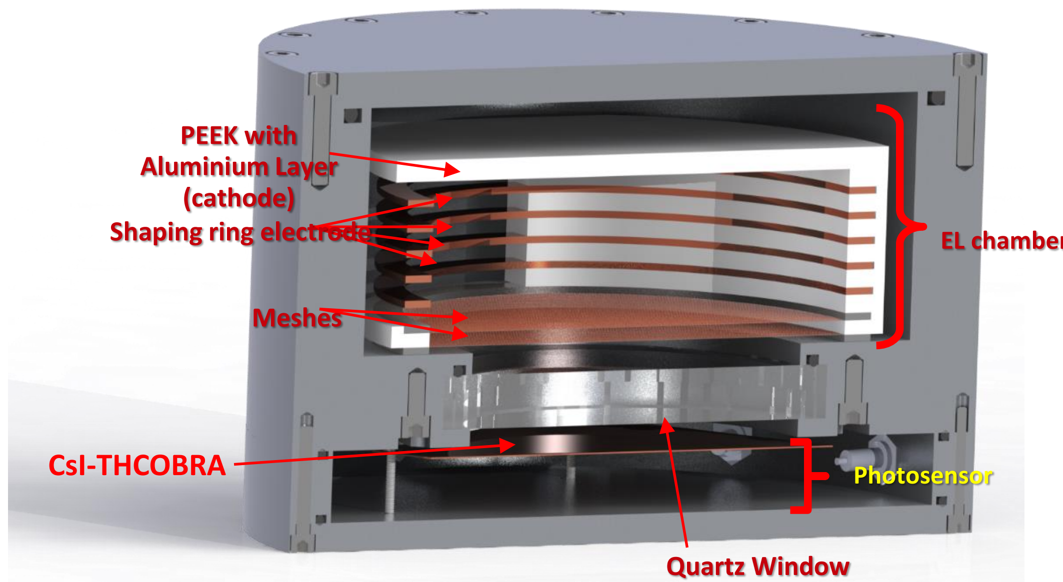
Gaseous Compton camera for medical imaging

Electroluminescence light is detected by THCOBRA with 2D R-O

Drift time provides the third coordinate







Scintillating Glass-GEM imager

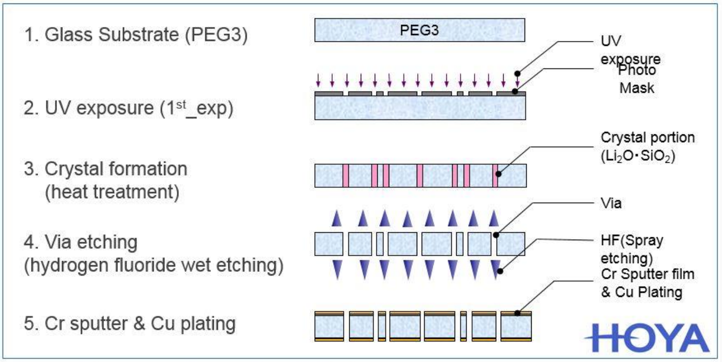
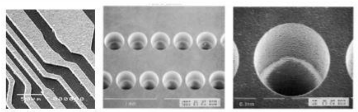
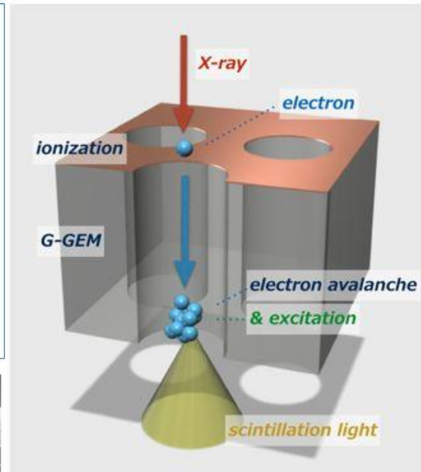
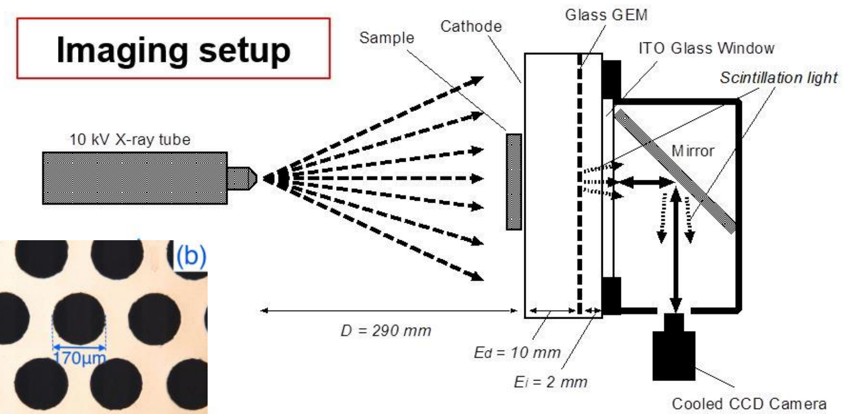


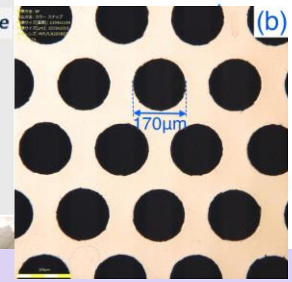
PHOTO ETCHABLE GLASS 3 : PEG3

- Promising technique for precise patterning
- Able to drill high aspect hole
- 680μm deep hole (ex. CERN GEM: 50μm)

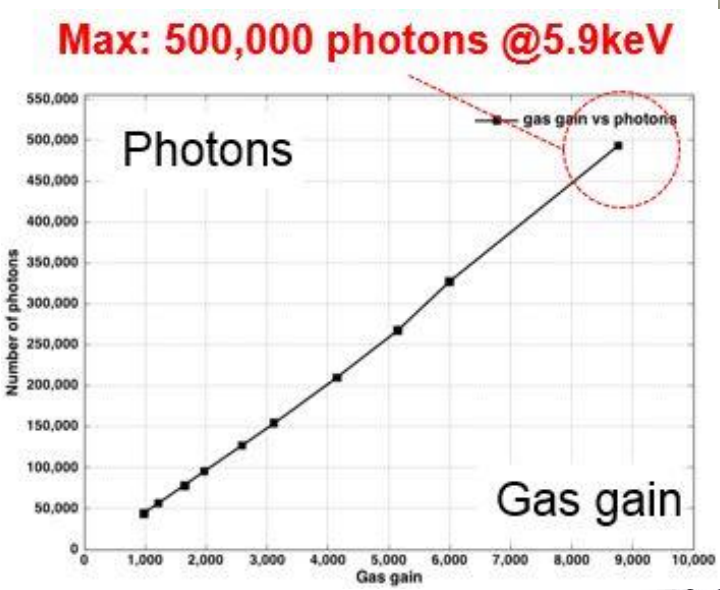


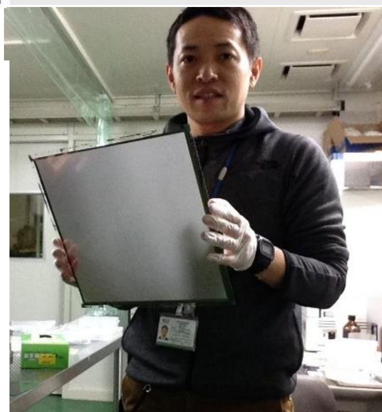


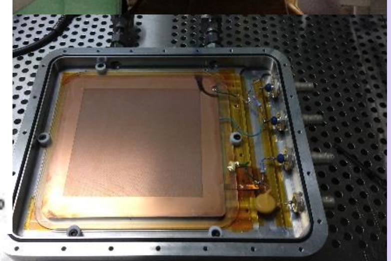


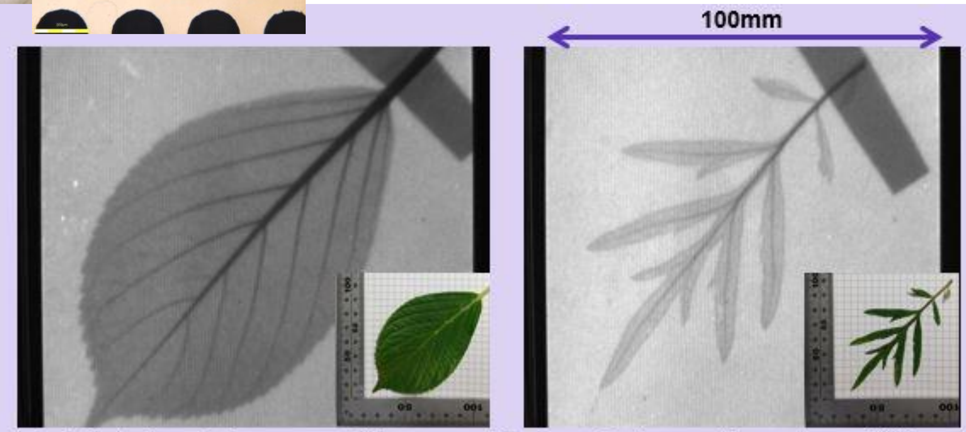


T. Fujiwara, et al., JINST 8 C12020, 2013









Obtained image of leaves (2 sec integration time)[10]

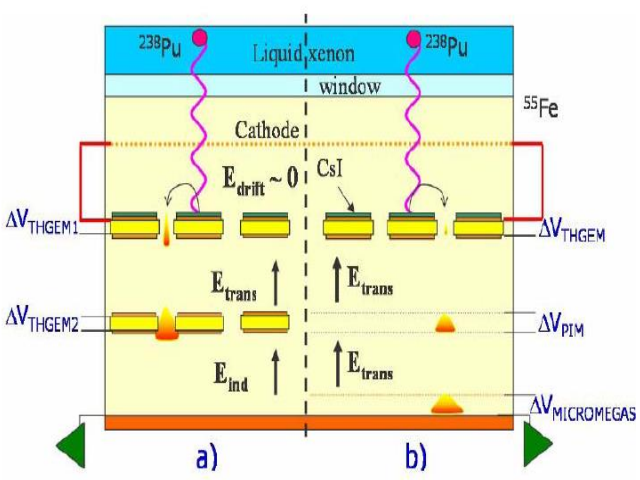
Excellent spatial resolution ≈500μm
Quick imaging of low Z material with low energy X-rays (≈7 keV)

CRYOGENIC MPGD-PDs

Read-out elements of cryogenic noble liquid detectors

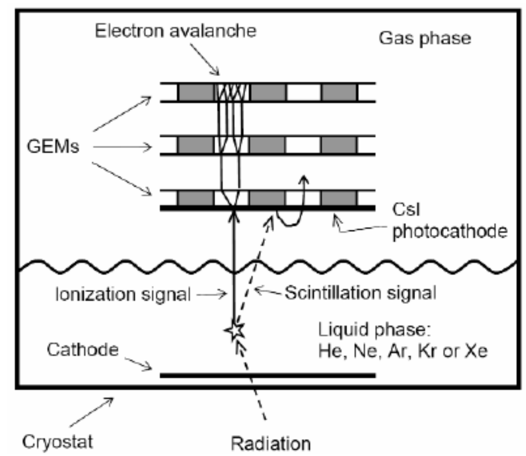
- Rear event detectors (ν, DM)
- Detecting the scintillation light produced in the noble liquids
- Options of scintillator light and ionization charge detection by a same detector !

with WINDOW



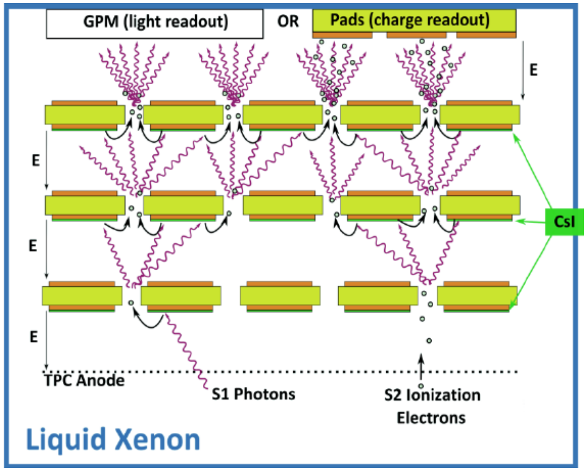
S.Duval et al., JINST 6 (2011) P04007

WINDOWLESS (2-PHASES)



A. Bondar et al.,NIMA 556 (2006) 273

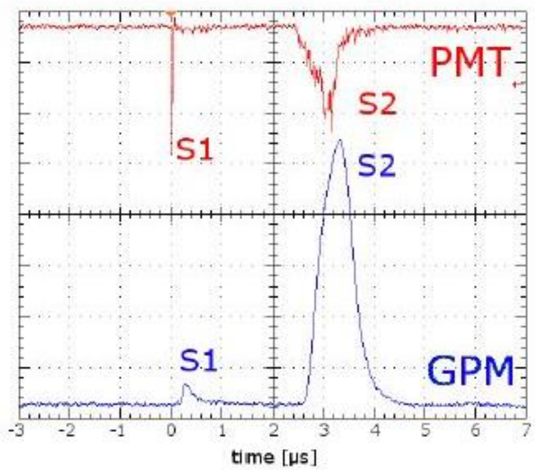
OPERATED IN THE CRYOGENIC LIQUID



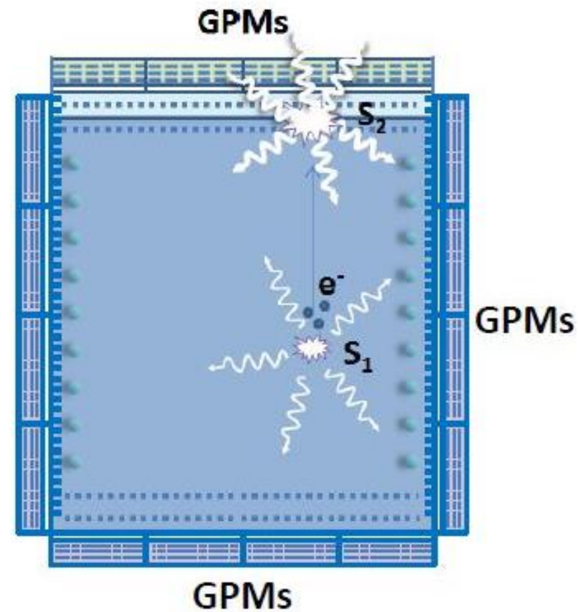
L.Arazi et al., JINST 8 (2013) C12004

Triple THGEM Gaseous Photo-Multiplier for DM

- WIS R&D on **GPMs** for future multi-ton LXe TPCs for dark matter searches (within DARWIN)
- Aim for **4π coverage** – not practical with PMTs (cost, bulkiness) or SiPMs (dark count rate)
- Successful demonstration of 4” cryogenic **triple-THGEM GPM** with reflective CsI coupled to dual phase LXe TPC: (arXiv:1509.02354)
  - Stable gain ~ 10^5
  - Large dynamic range: 1 – $O(10^3)$ photoelectrons
  - 1 ns timing (~ 200 PEs)
  - Expected PDE ~15% after optimization



- Also: on-going R&D on **n/γ imaging** with pixilated readout (arXiv:1501.00150)

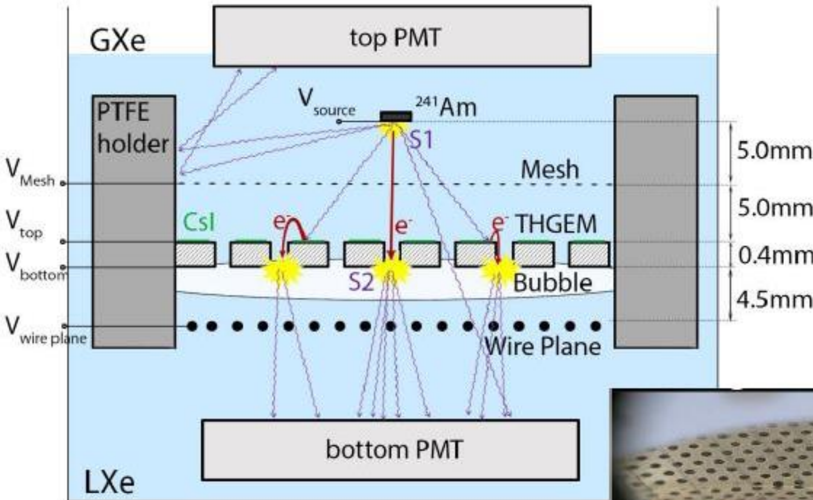


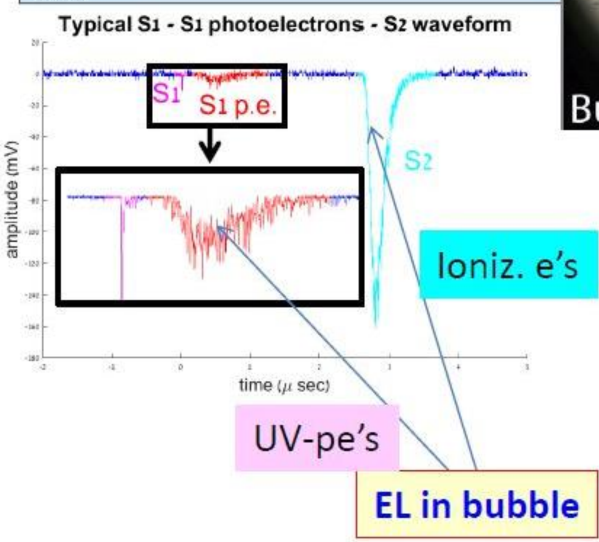
Bubble-assisted electroluminescence in LXe

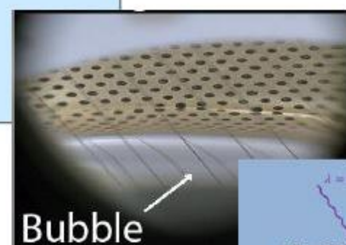
A "local dual-phase" noble-liquid detector

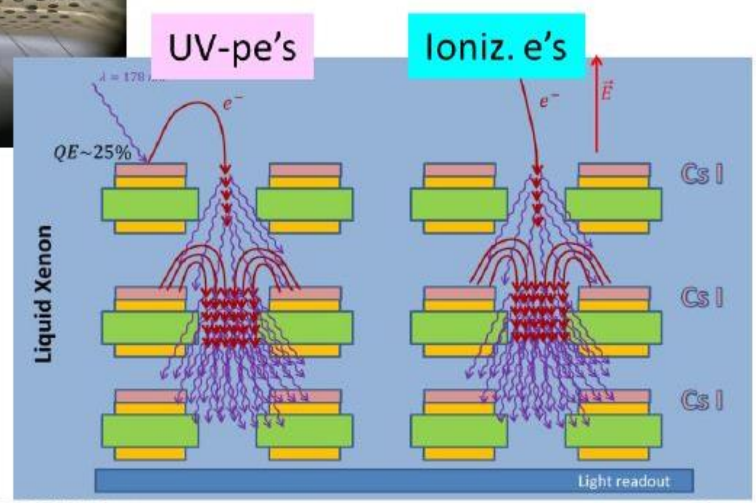
TOWARDS LARGE-SCALE NOBLE-LIQ DETs

Energy resolution 5MeV alphas: σ/E=7.5%
Time resolution: σ=10ns
Bubble (under THGEM, GEM) stable for days
CsI on THGEM: high pe extraction







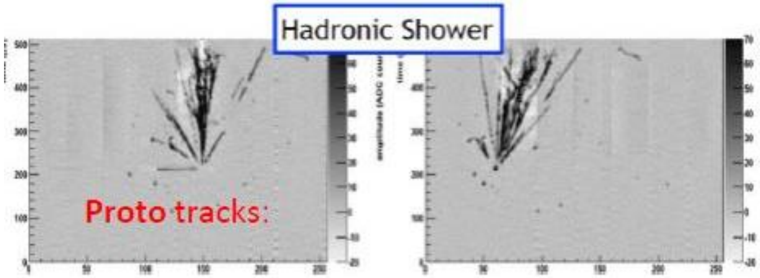


A Breskin MPGD 2015 Trieste 33

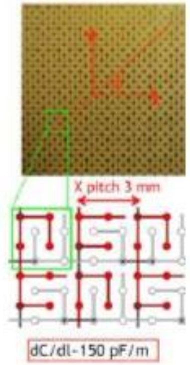
Breskin, *J. Phys. Conf. Ser.* 460(2013) 012020

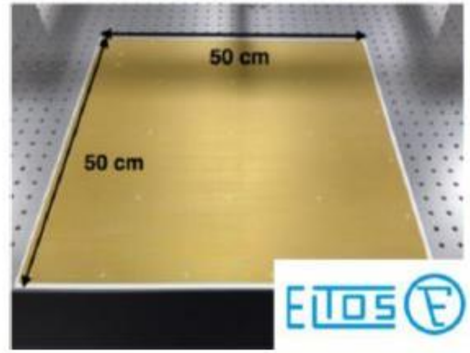
Dual-phase LAr LEM TPC

Goal: Neutrino oscillation experiments: WA105 (on ground) and future (underground) DUNE.



high ionization density in LAr→ need low gain



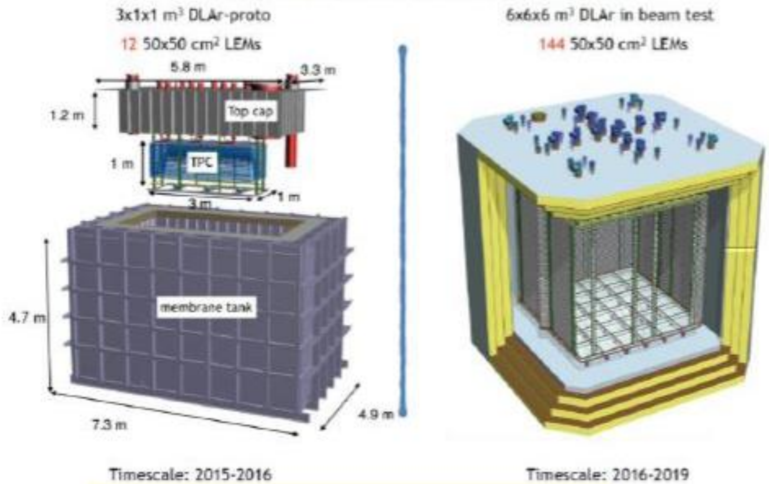


ptimised values

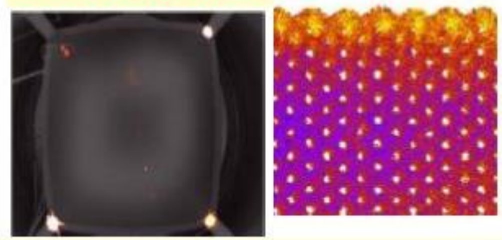
- 40 µm rim
- 1 mm FR4 thickness
- 500 µm diameter hole
- 800 µm hole pitch and hexagonal layout

C.Cantini et al., JINST 10 P03017 (2015)

"demonstrators"



DC: 5nA/LEM(50x50)
Stable gain ~20 (fine)



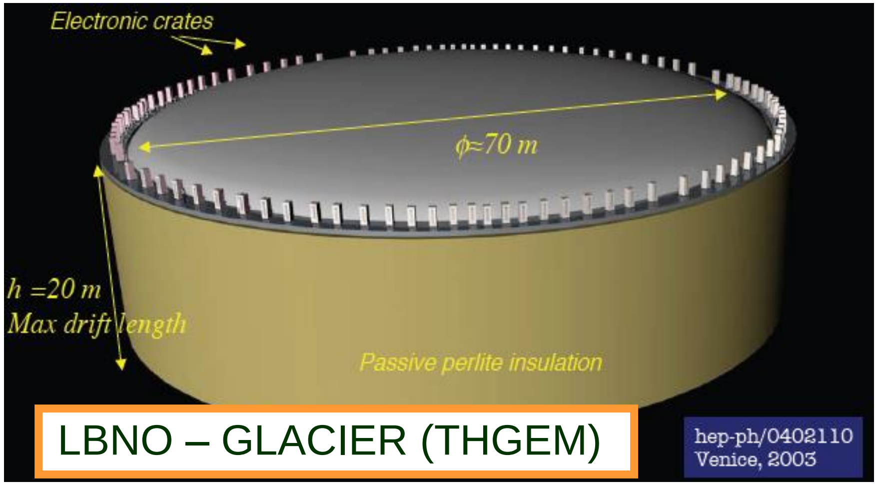
12 & 144 50x50cm² LEMs

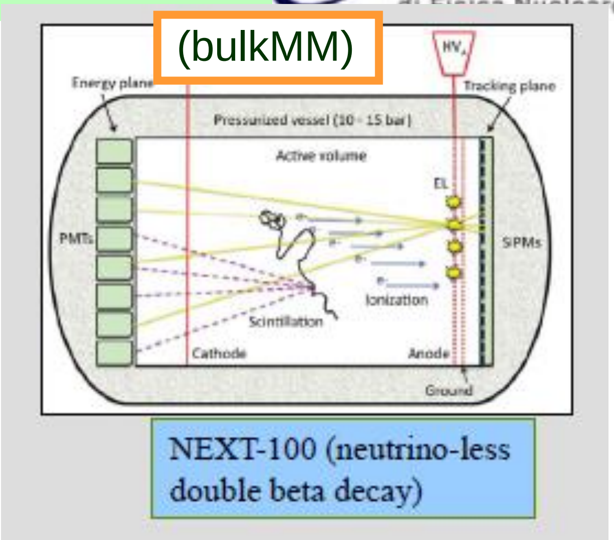
~3500V; spark on edges
(use COMPASS RICH solution?)
Charging up of rims: gain stabilizes. OK

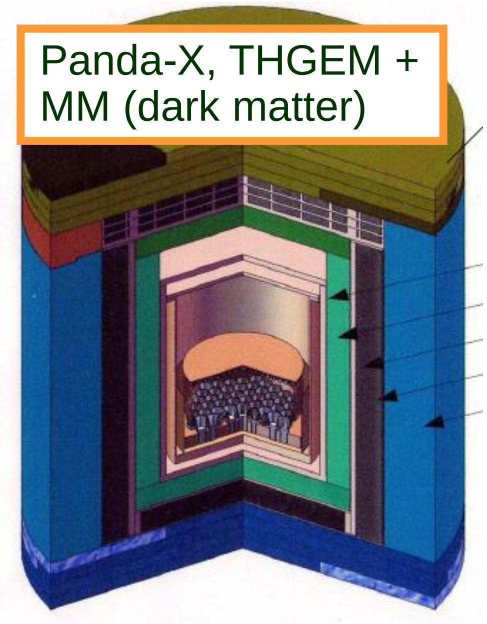
DUNE: ~3000 LEMs (50x50)

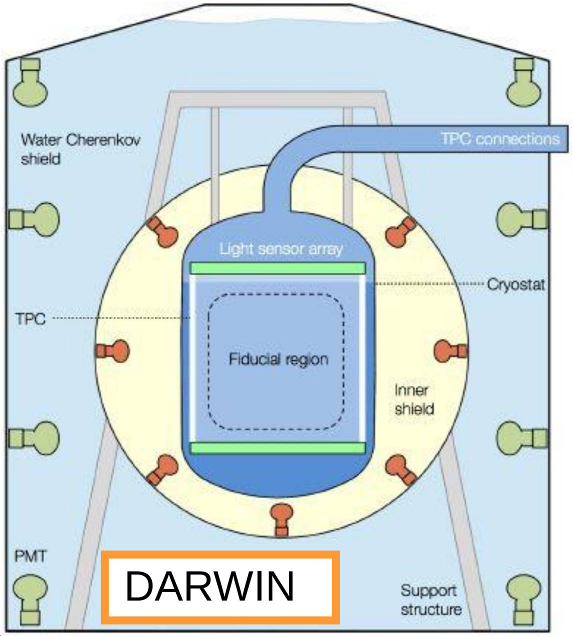
Ongoing R&D on RESISTIVE WELL concepts

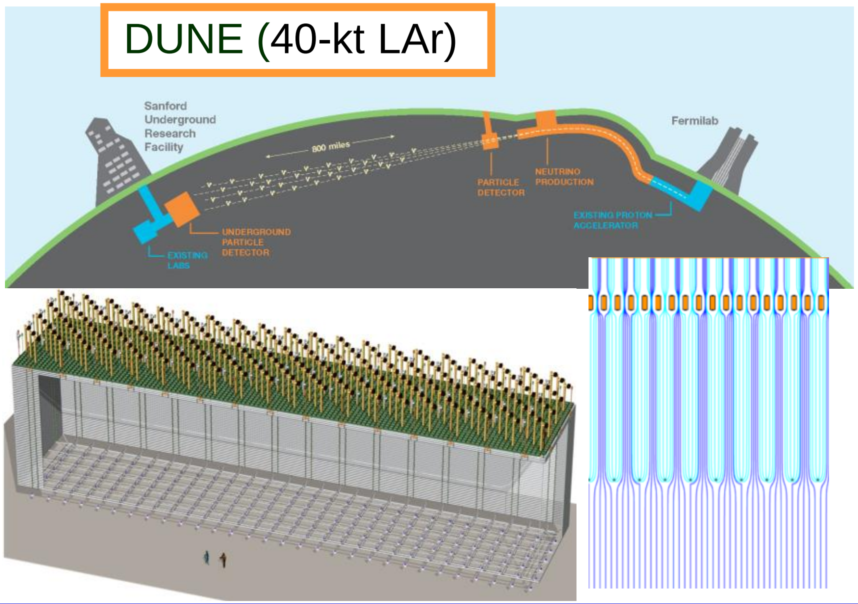
LARGE SIZE PROJECTS





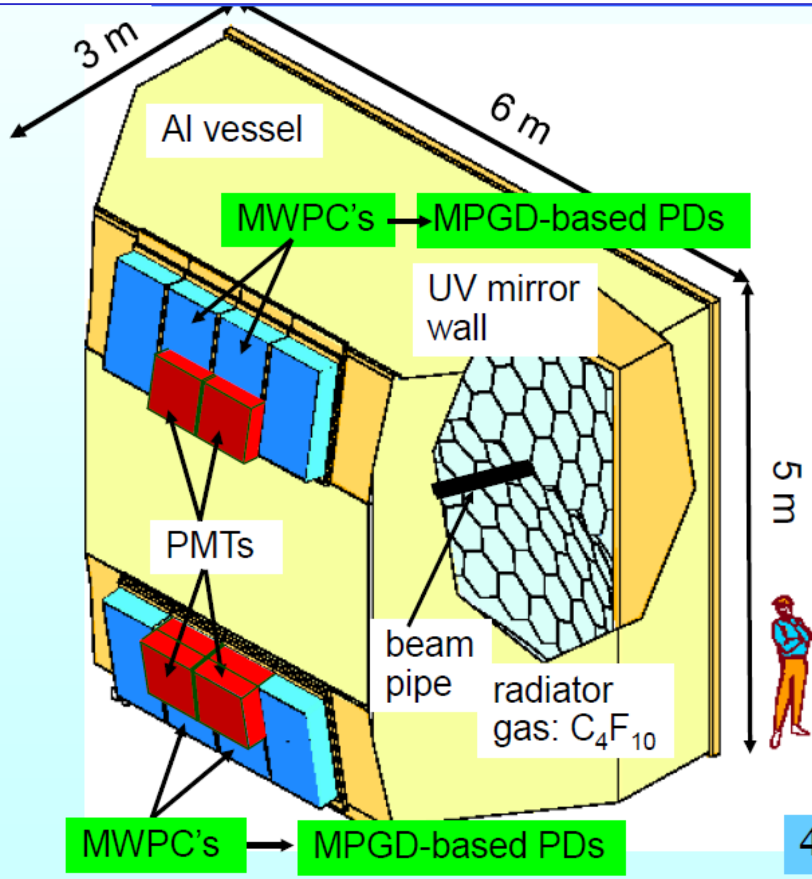


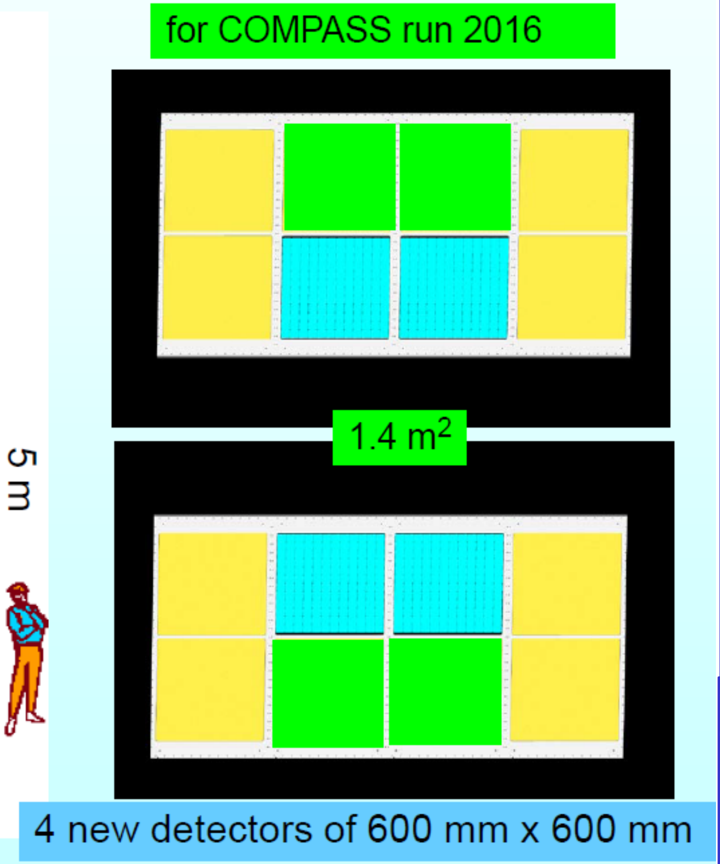


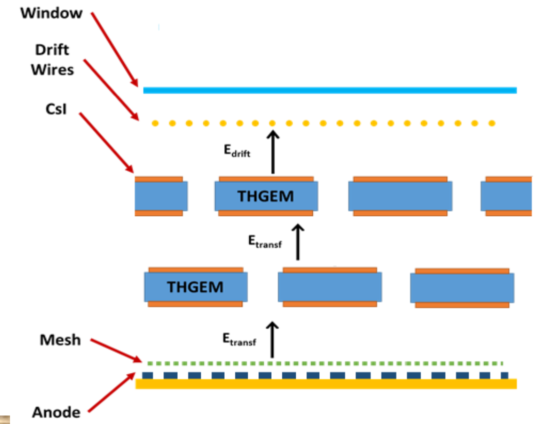


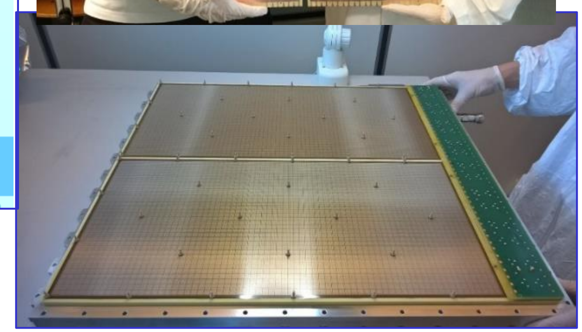
FIRST STEP TO LARGE SIZE

COMPASS RICH UPGRADE









presentation by Stefano Levorato

SUMMARY / CONCLUSIONS

Istituto Nazionale di Fisica Nucleare

- **GASEOUS PHOTON DETECTORS**
  - Most effective approach to instrument large surfaces at affordable costs
- **MPGD-BASED PHOTON DETECTORS**
  - Allow to overcome the limitations of open geometry gaseous PDs
  - A wide effort to refine and consolidate the technology
- **MANY APPLICATIONS OF MPGD-BASED PHOTON DETECTORS**
  - From PID to ν, DM, medical applications …
  - First step toward large area: Hybrid THGEM+MM for COMPASS
- **BRIGHT FUTURE FOR:**
  - Inventions: new ideas, new techniques
  - Technology consolidation, new applications
  - Large scale projects