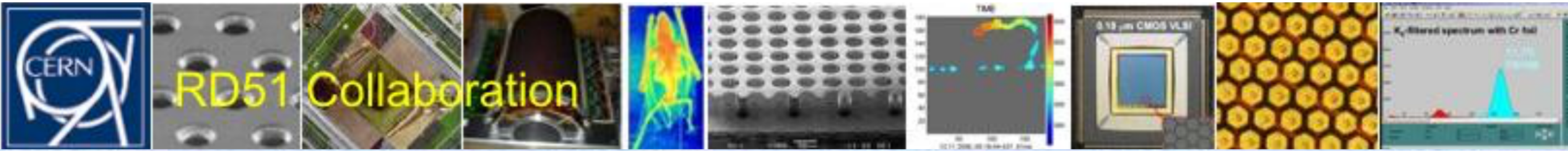


Recent development of Micro Pattern Gaseous detectors

Shikma Bressler - Weizmann Institute of Science
on behalf of the RD51 collaboration

TIPP'17 International Conference on Technology and Instrumentation in Particle Physics
MAY 22-26, 2017 | BEIJING, PEOPLE'S REPUBLIC OF CHINA

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

MPGDs at CERN

Some of them running,
Some of them approved for upgrades
Some of them under evaluation

TOTEM (GEM)

CMS(GEM, µRWELL)

COMPASS(2TGEM+mm, micromegas, GEM)

GLACIER(LEM)

NA48 (micromegas)

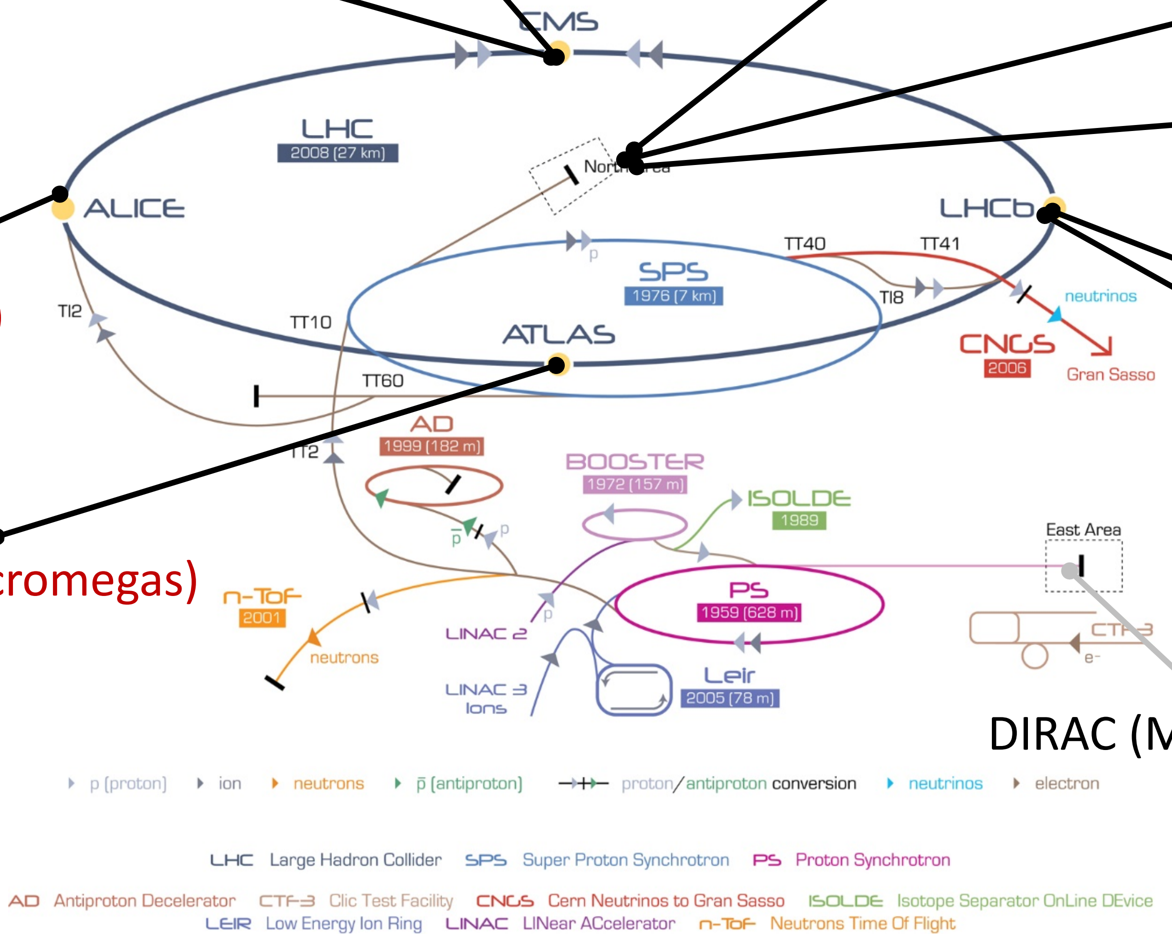
ALICE(GEM)

LHCb (GEM, µRWELL)

ATLAS(micromegas)

CAST(micromegas,InGrid)

DIRAC (MSGC-GEM)



RED = LHC

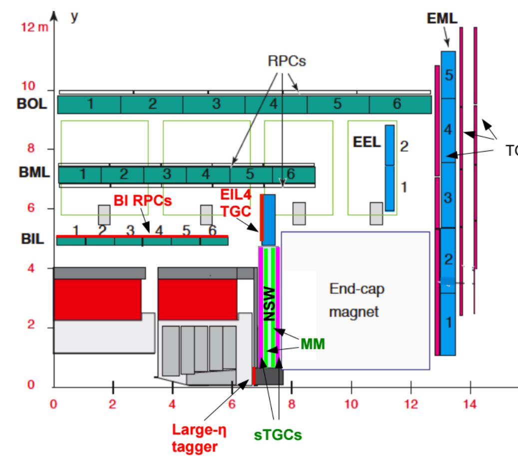
MPGDs and CERN

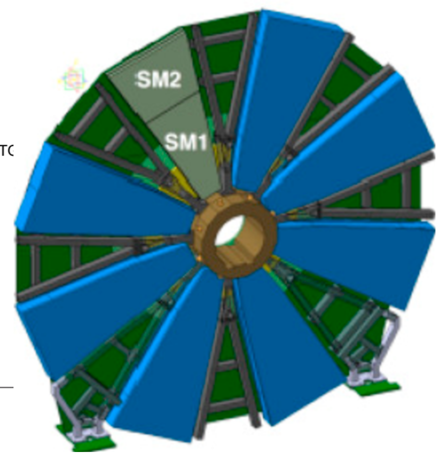
Example — Upgrade of CERN experiments

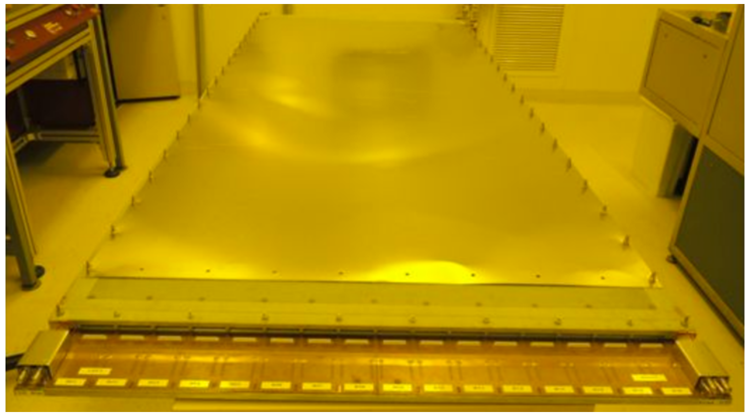
MICROMEGAS (MM) for ATLAS NSW

ATLAS-TDR-020

- Inner station of the ATLAS muon spectrometer
- Tracking and trigger device
- Unit size ~ 1.5×2 m^2
- Coverage area ~1200 m^2
- Construction on-going



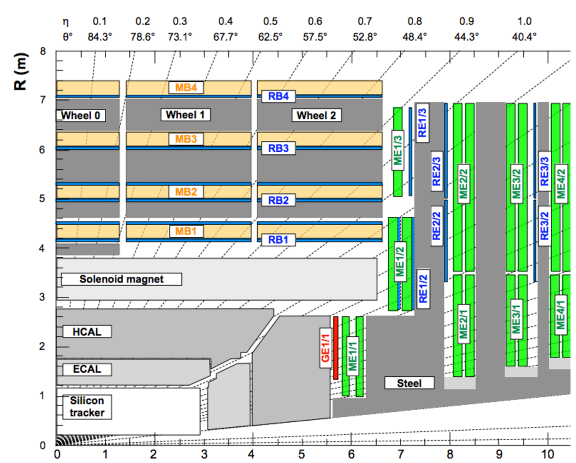


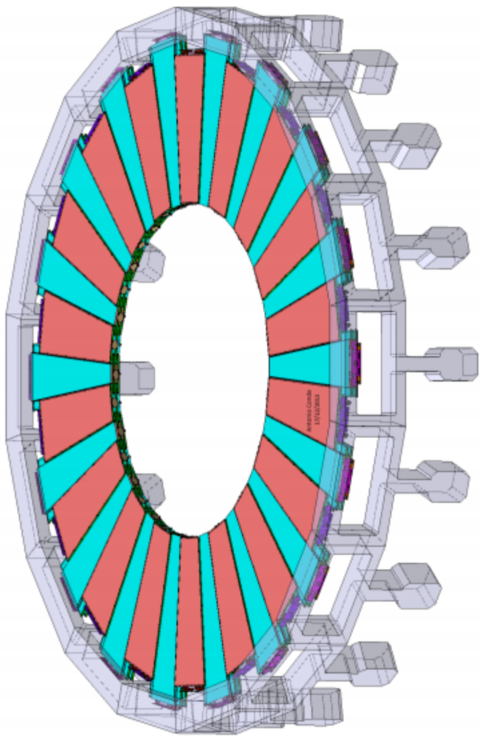


GEMs for CMS Muon Spectrometer

CMS-TDR-013

- Inner station of the ATLAS muon spectrometer
- Tracking and trigger device
- Unit size ~ 1.2×2 m^2
- Triple stage ⇒
  Coverage area ~1000 m^2
- Construction on-going



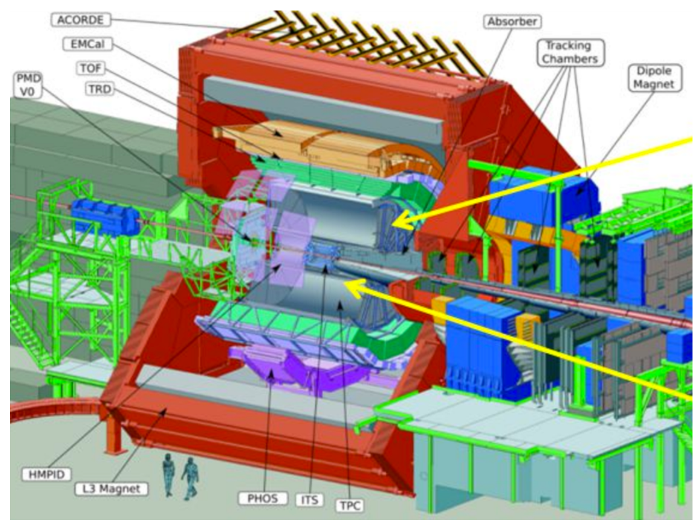


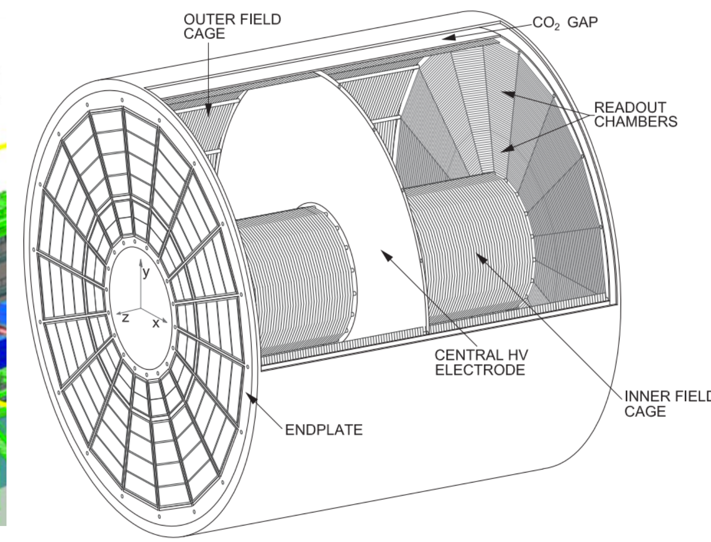
Example — Upgrade of CERN experiments

GEM for ALICE TPC

- TPC readout
- Unit size ~ 0.9×1.6 m^2
- Four-stage units
- Coverage area ~130 m^2
- Construction on-going

ALICE-TDR-016

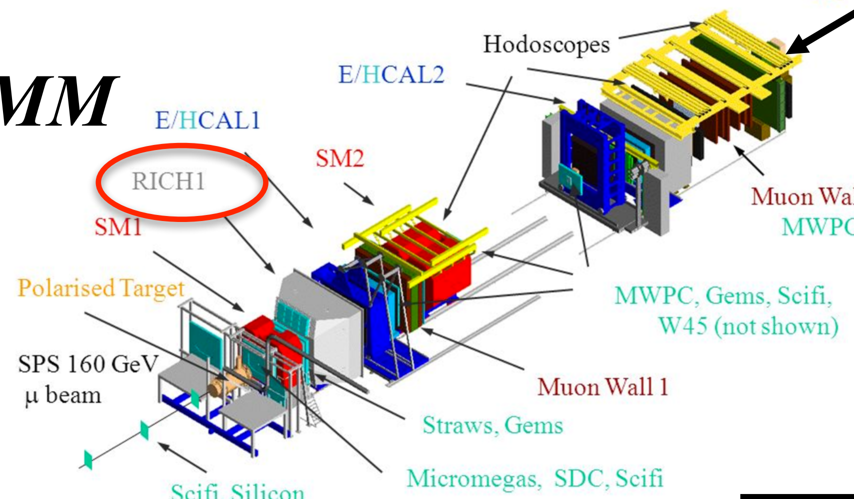


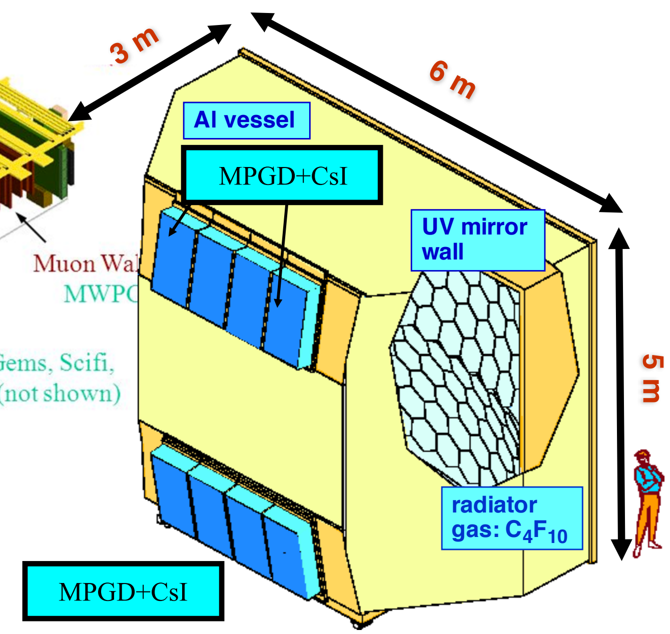


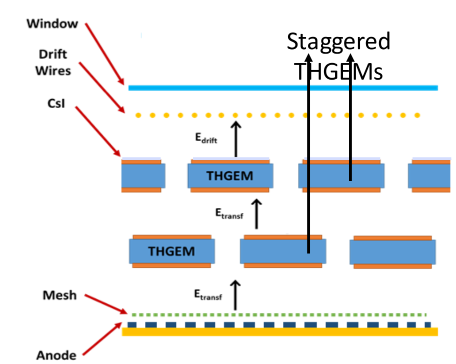
Hybrid MPGD for COMPASS RICH-I

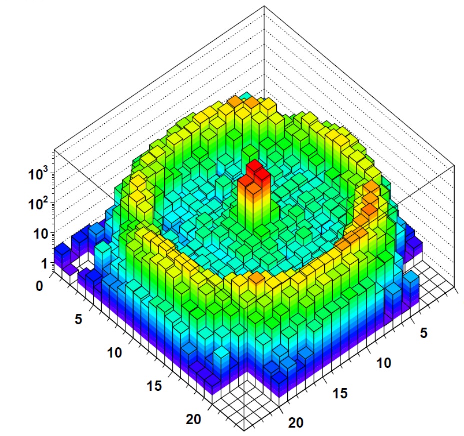
- Photon detection
- Two-stage ***THGEM + MM***
- Unit size ~ 0.6×0.6 m^2
- Coverage area ~4.5 m^2
- In operation

NIM A732 (2013) 264-268









*In COMPASS tracking is done with GEMS

Background — Gaseous detectors

- Experiments in Particle and Astro-particle Physics are large
- In the future some will be even larger
- Pose a growing demand for cost-effective large-area detectors, capable of operating stably over a broad range of conditions
  $\Rightarrow$ Need for advanced gaseous detectors
- Room for the development and implementation of MPGD technologies

Many applications

- Tracking
- Time Projection chambers
- Calorimetry
- Single photon (UV, visible) imaging (RICH)
- Neutron and X-Ray imaging
- Noble Liquids (UV and/or electron detectors)
- Homeland security
- Medical imaging
- More

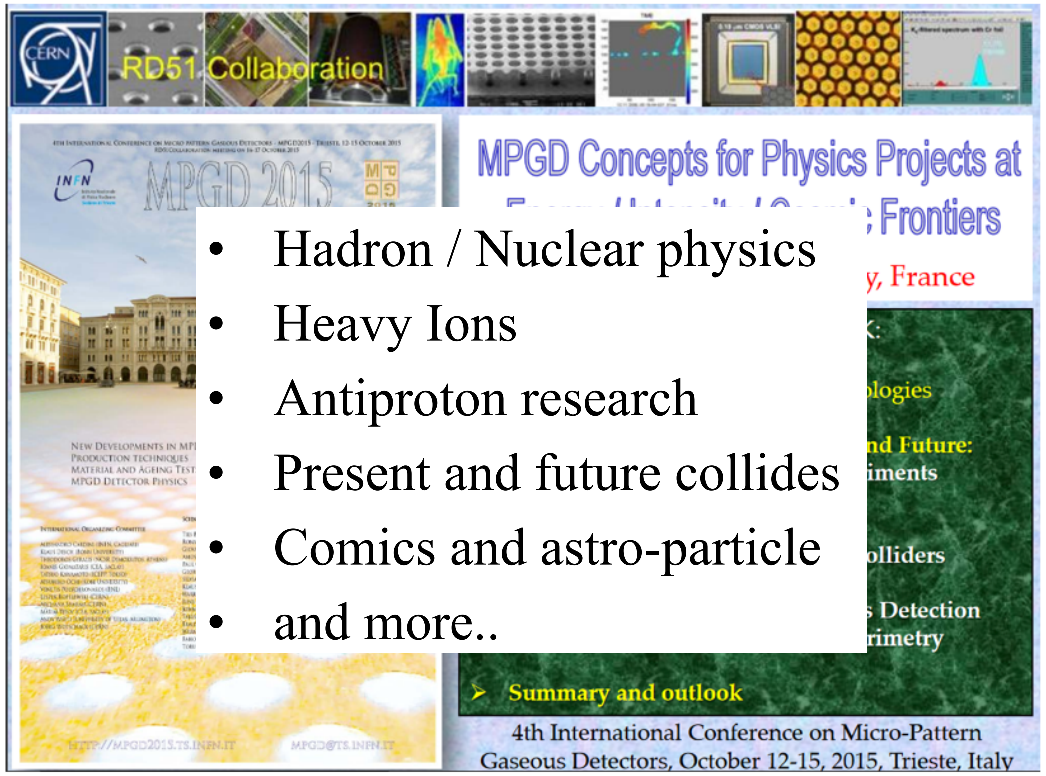
Background — Gaseous detectors

- Experiments in Particle and Astro-particle Physics are large
- In the future some will be even larger
- Pose a growing demand for cost-effective large-area detectors, capable of operating stably over a broad range of conditions
  $\Rightarrow$ Need for advanced gaseous detectors
- Room for the development and implementation of MPGD technologies

Many applications

- Tracking
- Time Projection chambers
- Calorimetry
- Single photon (UV, visible) imaging (RICH)
- Neutron and X-Ray imaging
- Noble Liquids (UV and/or electron detectors)
- Homeland security
- Medical imaging
- More

Detailed review

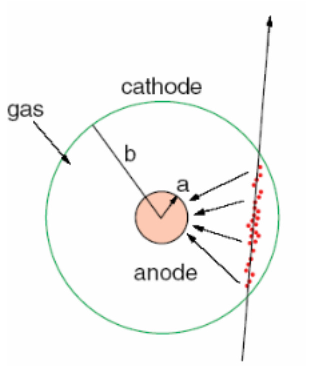


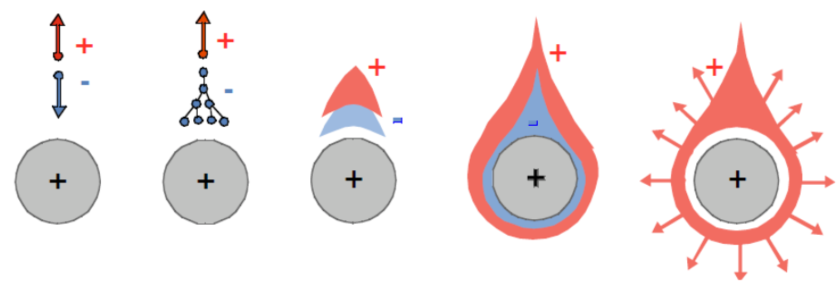
- Hadron / Nuclear physics
- Heavy Ions
- Antiproton research
- Present and future collides
- Comics and astro-particle
- and more..

https://agenda.infn.it/getFile.py/access?contribId=129&sessionId=7&resId=0&materialId=slides&confId=8839

Background Gaseous detectors

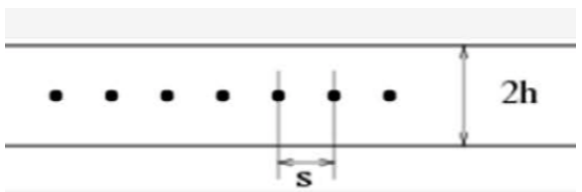
Gieger-Muller (1908)
Drift tube (1968)

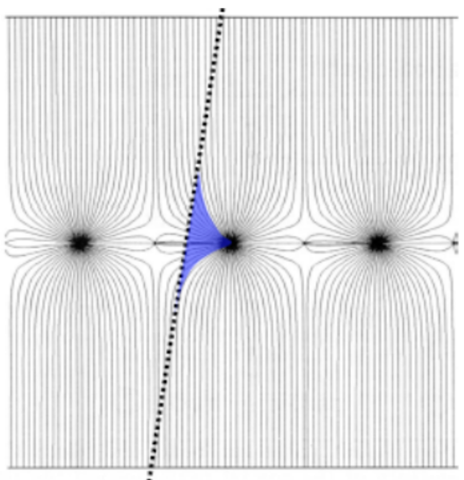




Multi-wire proportional chambers

G. Charpak (1968)

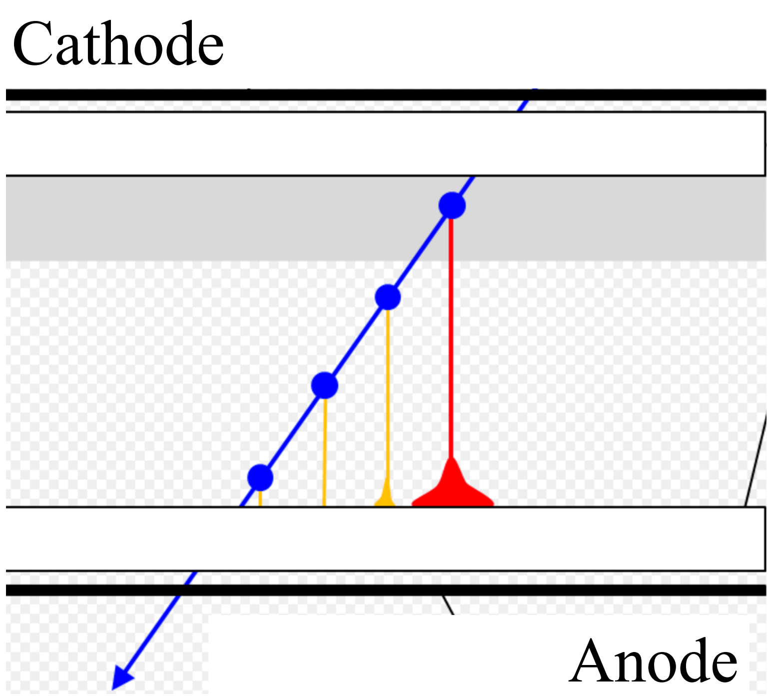




Position resolution
better than wire spacing
if charge induced on readout
anode is used

Resistive plate chambers

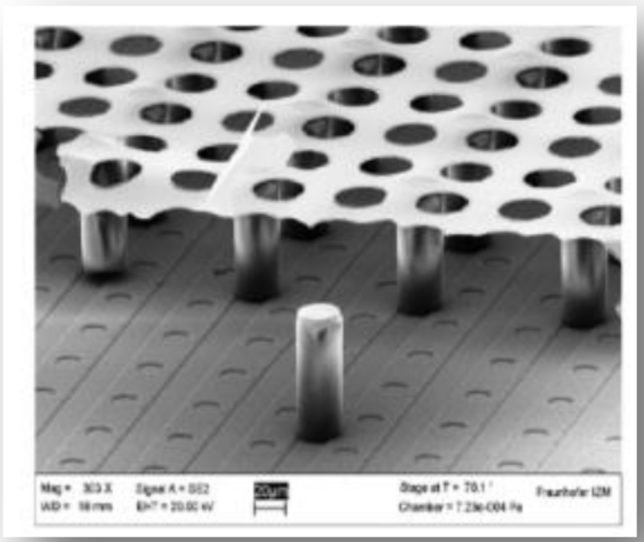
R. Santonico (1980)

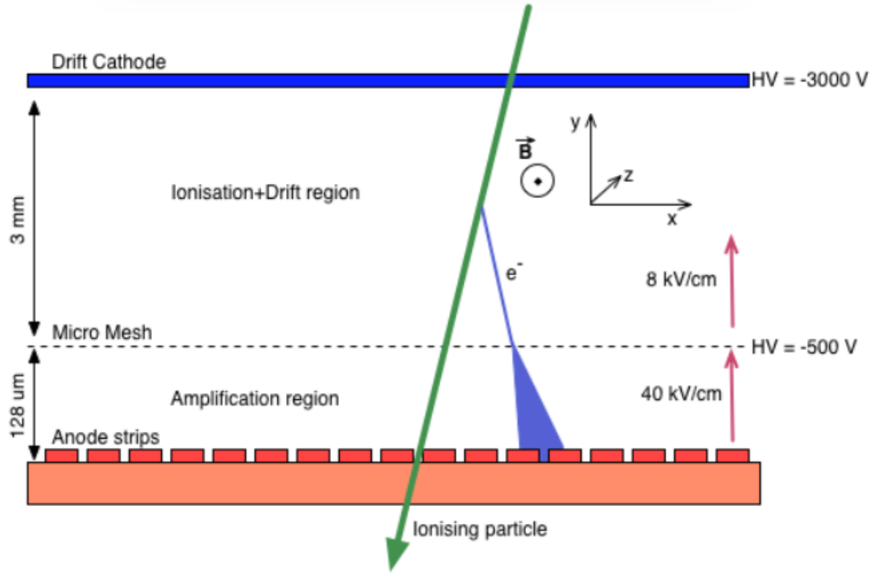


MPGD Concepts

Micromegas - Meshes

Giomataris (1998)

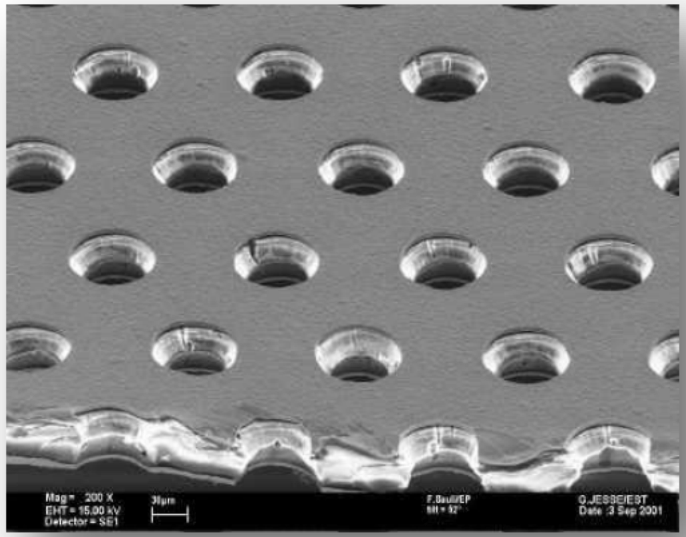




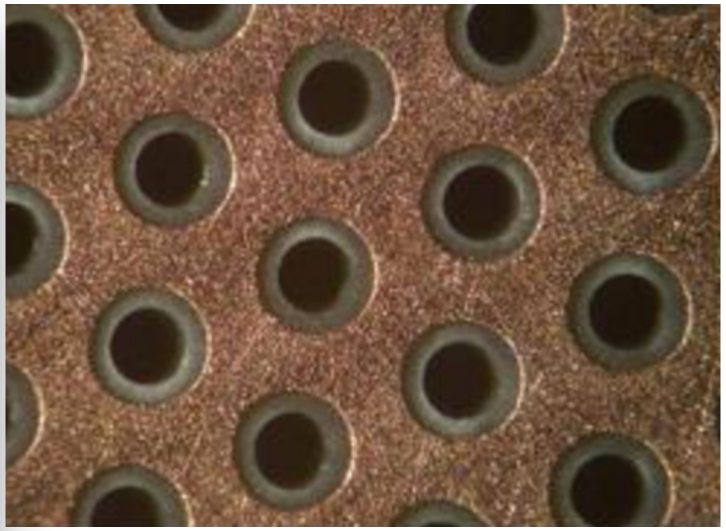
http://garfieldpp.web.cern.ch/garfieldpp/examples/mmlowenergypion/

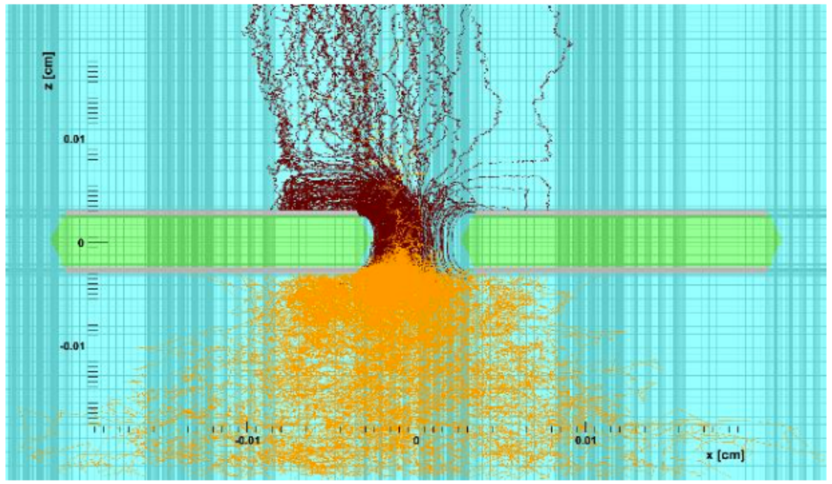
GEM/THGEM - holes

Sauli (1997)



Breskin (2004)
10 fold larger than GEM

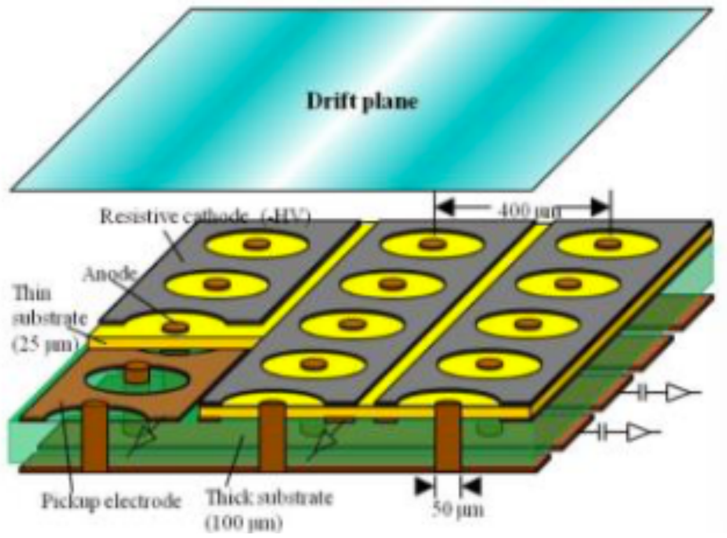




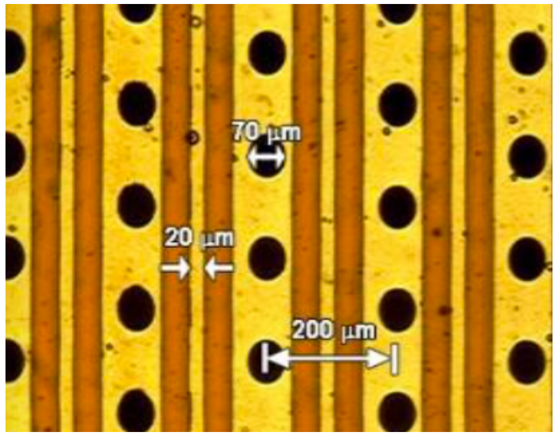
http://www-flc.desy.de/tpc/projects/GEM_simulation/

MPGD Concepts

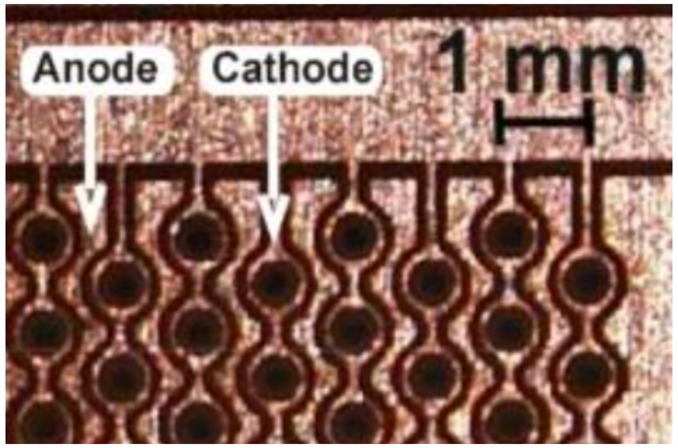
μ-pic

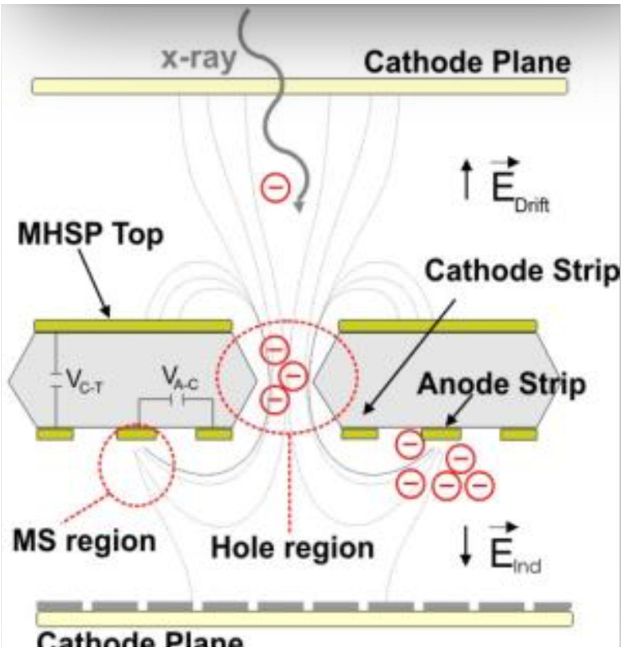


MHSP



THCOBRA





In today's talk

Demonstrate how concrete needs, smart ideas and persistent R&D effort - yield large variety of ideas and solutions

In today's talk

Demonstrate how concrete needs, smart ideas and persistent R&D effort - yield large variety of ideas and solutions

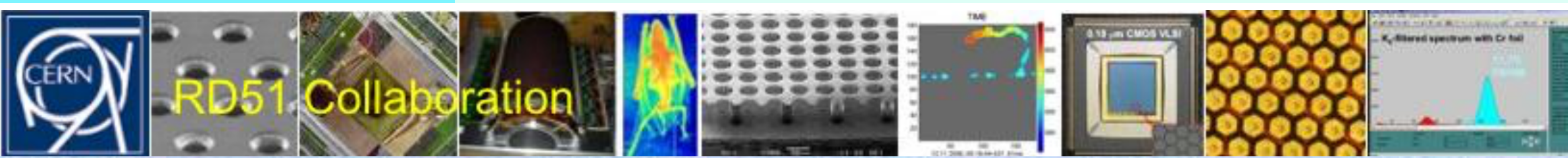
Focus on recent developments and ongoing R&D

In today's talk

Demonstrate how concrete needs, smart ideas and persistent R&D effort - yield large variety of ideas and solutions

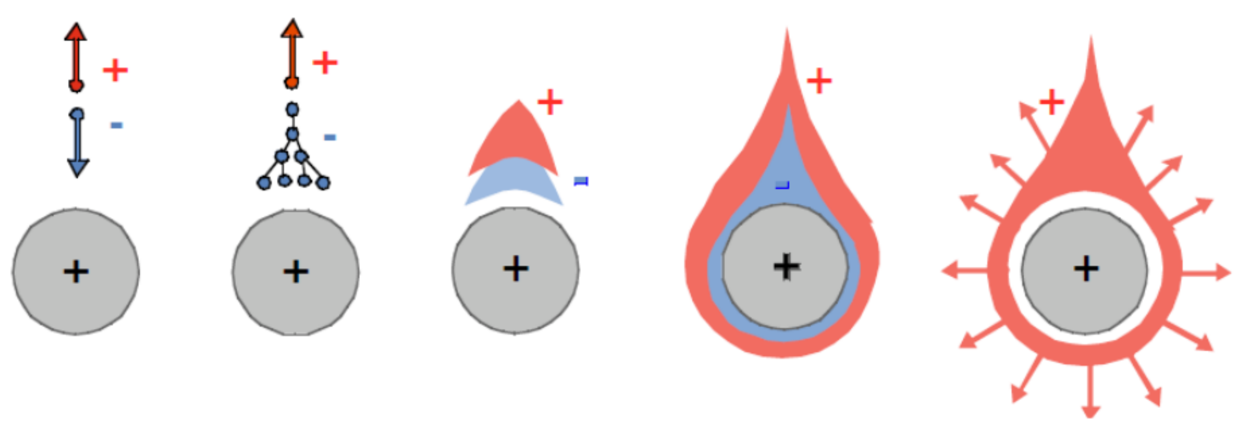
Focus on recent developments and ongoing R&D

RD51 @ CERN Development of MPGD technologies



Stability — The challenge of discharges

- Known problem in gaseous detectors
- Several reasons
  - Local defects in production
    ⇒ Strong local fields
    ⇒ Spontaneous emissions
  - Raether limit
    ⇒ Spontaneous breakdown of the gas when the charge density reaches certain limit which depends on the field
    ⇒ In MPGD ~10^7-10^8 electrons
- Self-quenching mechanism
  - ~Exists in wire-chambers
  - Does not exist in MPGD

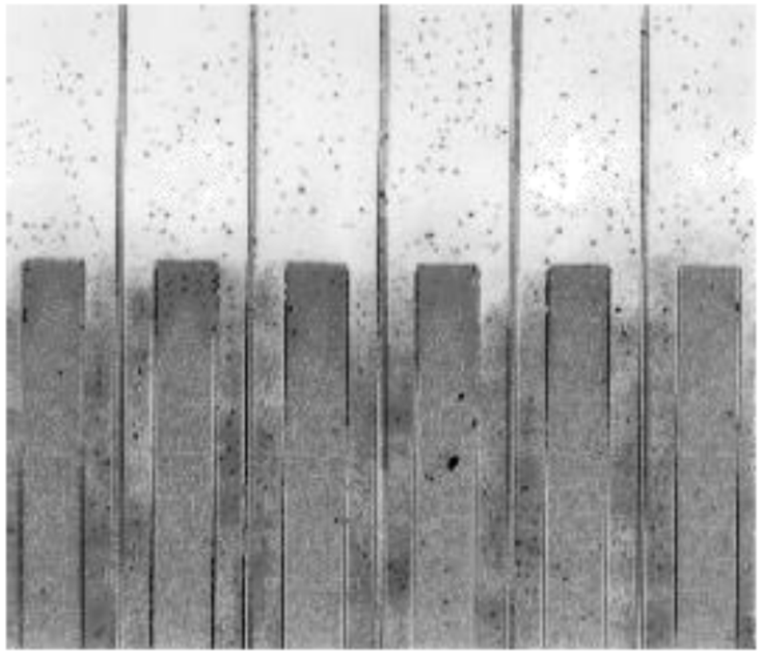


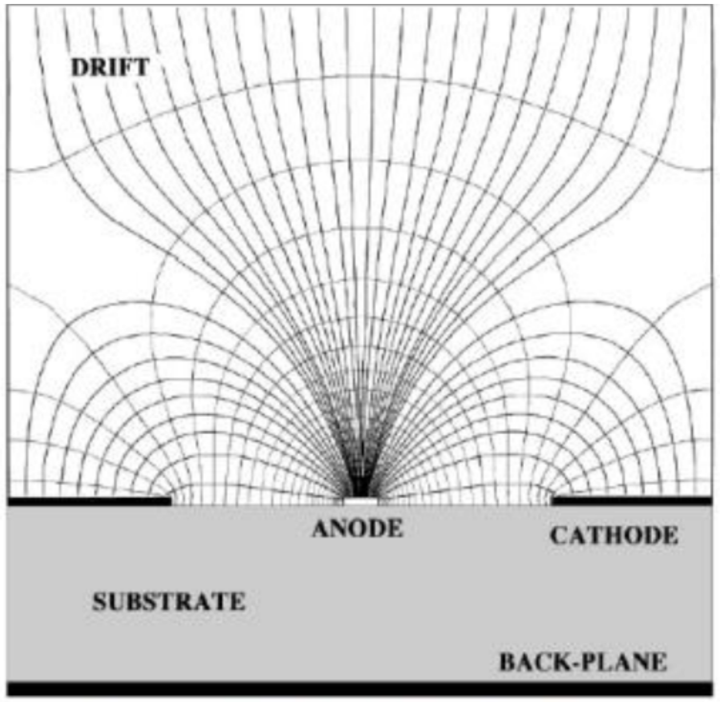
ionization | Electron multiplication | Last stage of the avalanche | Ions drift toward the cathode

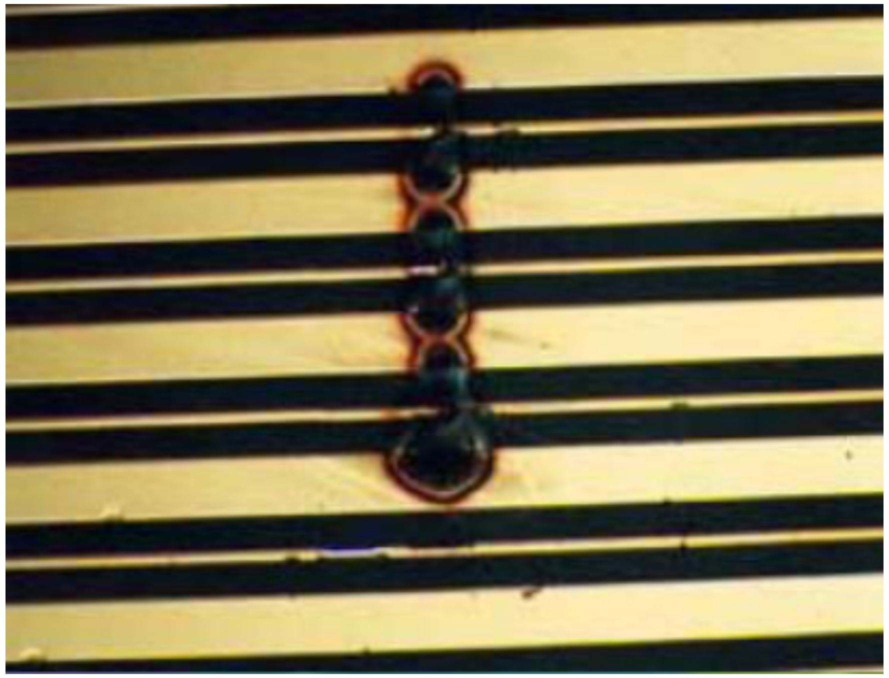
Stability — The challenge of discharges

- Results in long dead times
- Can destroy the detector
- Can destroy the readout electronics

Micro-Strip-Gaseous-Counter (MSGC)
Oed (1988)





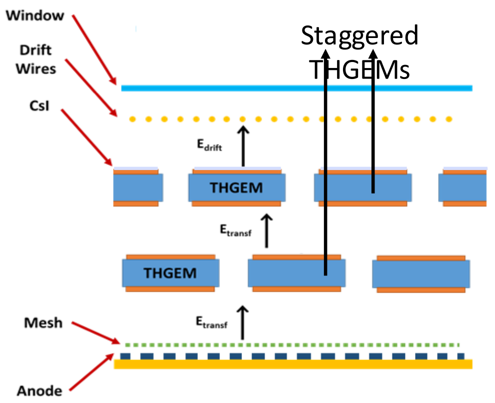


Stability — The challenge of discharges

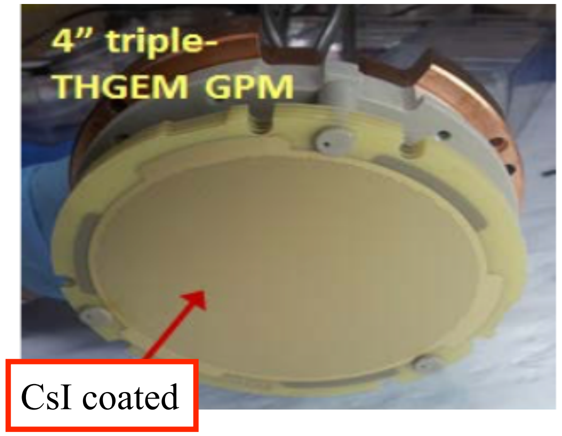
Solution I - cascade detectors

- Smaller field in each stage
- Charge spread between several holes ⇒ smaller charge density
- Stay away from the discharge regime
- Advantage in blocking Ion Back Flow

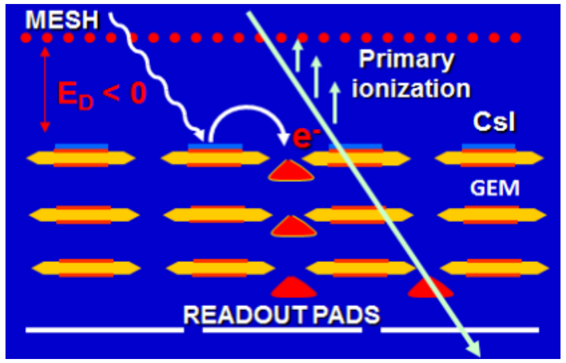
Hybrid configuration for COMPASS RICH-I



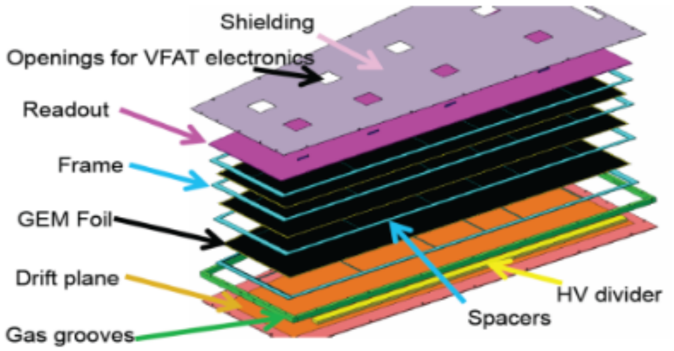
Triple-THGEM for Gaseous Photon Multipliers



Triple-GEM for Phoenix HBD



Triple-GEM for CMS MS



Solution II - resistive configurations

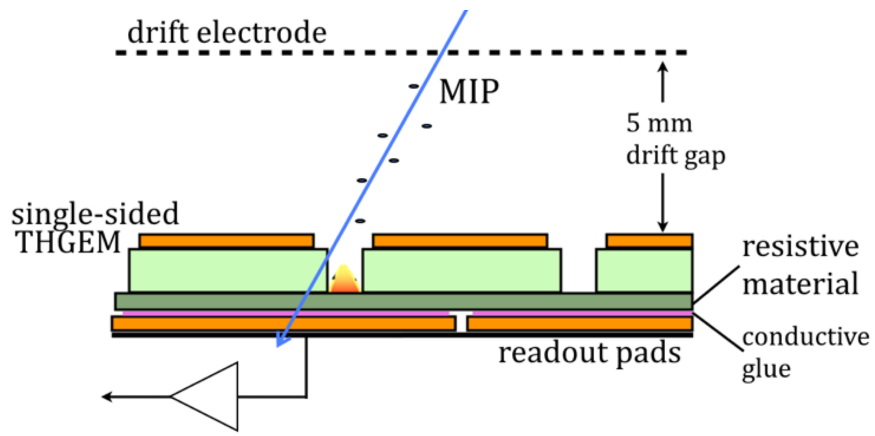
- Create self-quenching mechanism
- Delay the charge evacuation and force local field reduction
- Several attempts

Resistive configuration

Recent example - the RPWELL detector

A. Rubin
JINST 8 (2013) P11004

- Single sided THick Gaseous Electron Multiplier (THGEM)
- Coupled to the readout anode through material of high bulk resistivity



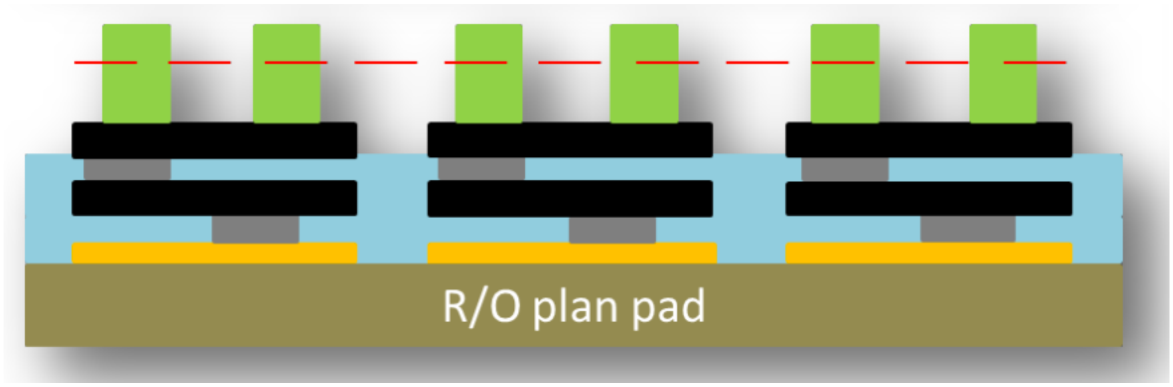
Voltage supplied to the RPWELL electrode creates a strong field inside the holes - amplification region

The signal is induced on the readout anode

Discharge quenching is achieved by delaying the charge on the RP - local reduction of the field

Recent example - readout with embedded resistors

- Good solution for complex readout geometries like pads
- Exploits advances in multi-layer PCB production techniques



Signal induced on the readout plan

Charges evacuate through a network of resistors

De Oliveira, Peskov, Chefdeville et. al.

Stability

Gain variation

The challenge

- The presence of insulators and resistive materials cause gain variations
  - Charge-up and charge-down
  - Rate dependance
  - Reported by many groups

    Breskin et. a.l.

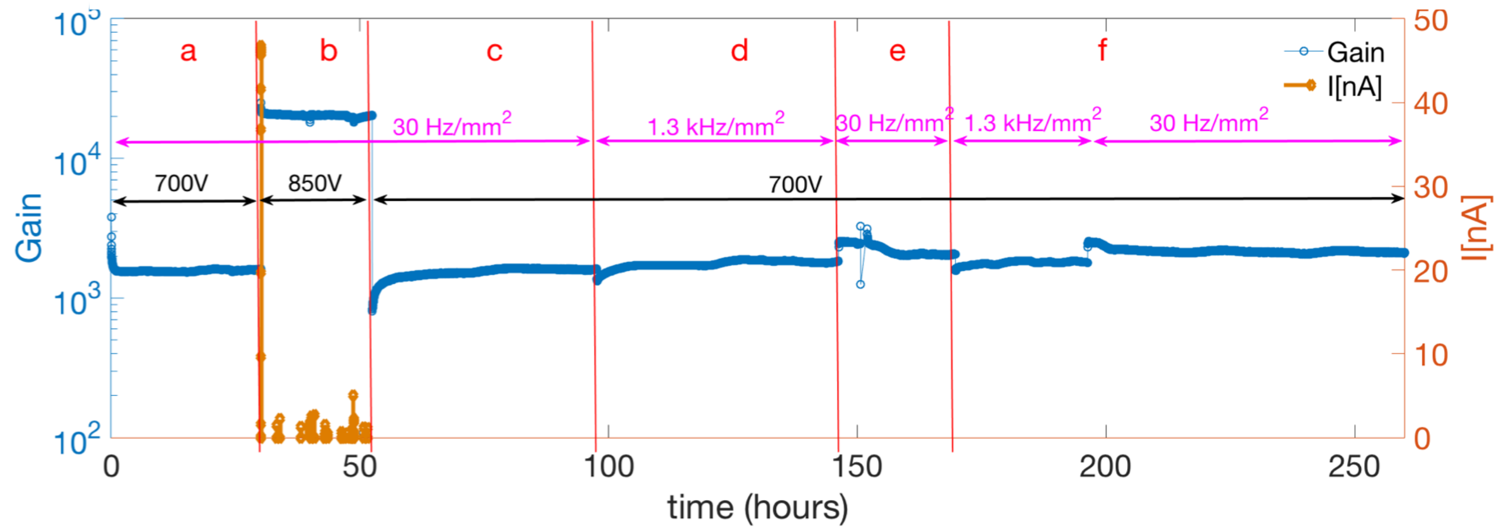
    Alexeev et. al.

    Cortesi et. al.

    Many more

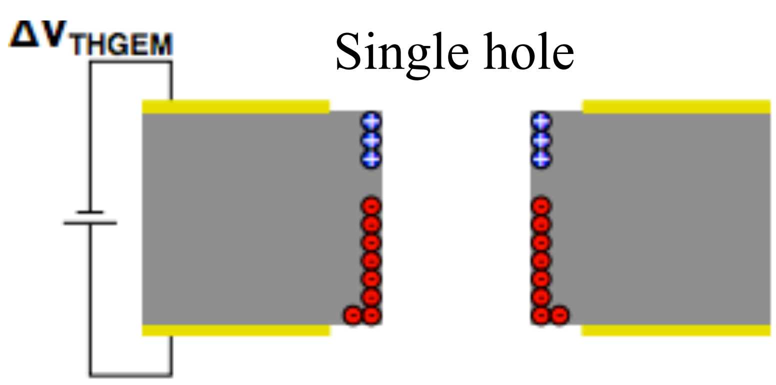
Measurements with RPWELL

voltages/gain transition **rate transition**



Major R&D effort

- Understand and model the effect
- Find conditions for steady-state
- Minimize it
- Optimize the detector performance



Correia et. al.

Electrons and Ions accumulated on the insulators cause local field variation

Cylindrical symmetry

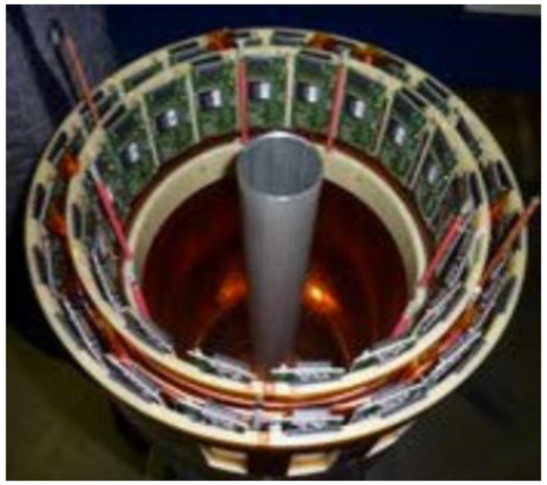
The challenge

- Colliders (but not only) geometry is cylindrical
- Can gaseous detector resume this symmetry ?

Many realizations

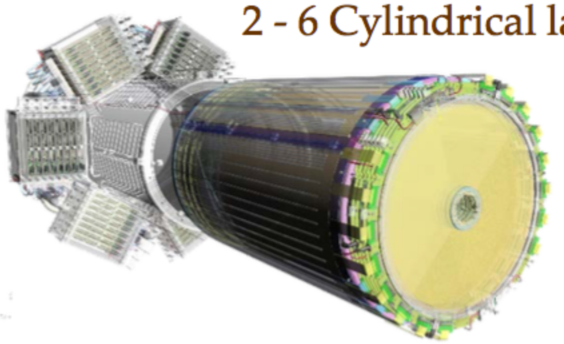
- KLOE-2 @ DAFNE
- BESIII Upgrade @ Beijing
- CLAS12 @ JLAB
- ASACUSA @ CERN
- MINOS @ FERMILAB
- CMD-3 Upgrade @ BINP

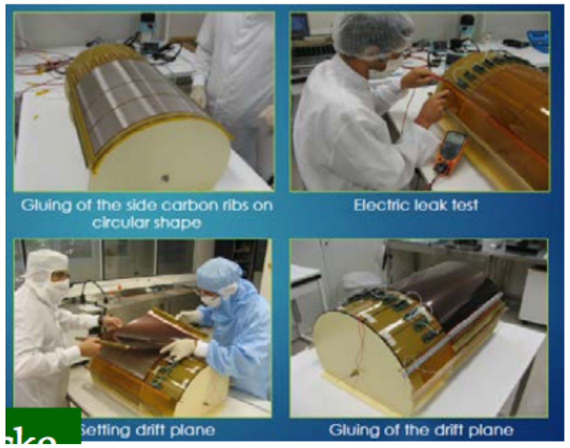
KLOE-2



ASACUSA

High rate ~ 10 MHz
2 - 6 Cylindrical layers



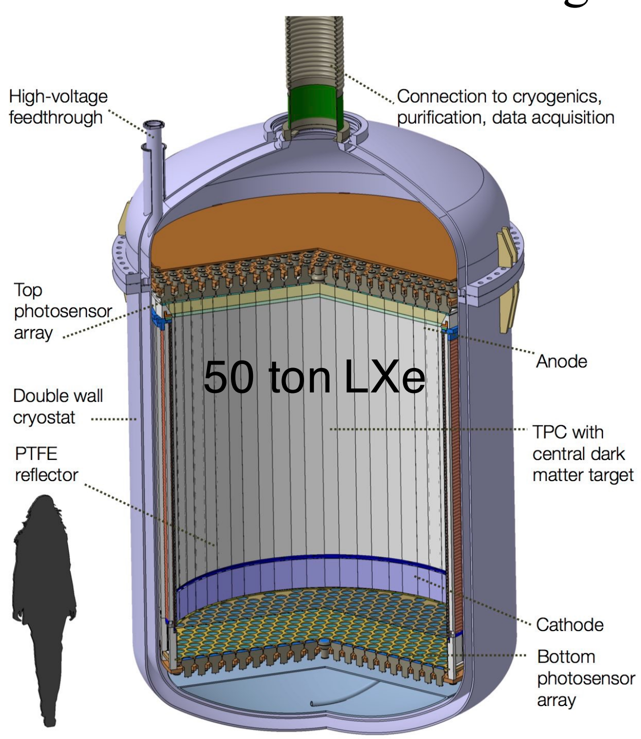


Cryogenics

The physics challenge

- Multi-ton Noble-Liquid TPC-based experiments
  - Dark matter: Xenon N-Ton, Darwin, …
  - Neutrino: Dune, ..
- Demand for large area coverage of light and/or charge readout
- Several alternatives
  - Single-phase: readout based on wire planes
  - Dual-phase: readout based on Large-Electron-Multiplier (LEM/THGEM), …

DARWIN baseline design



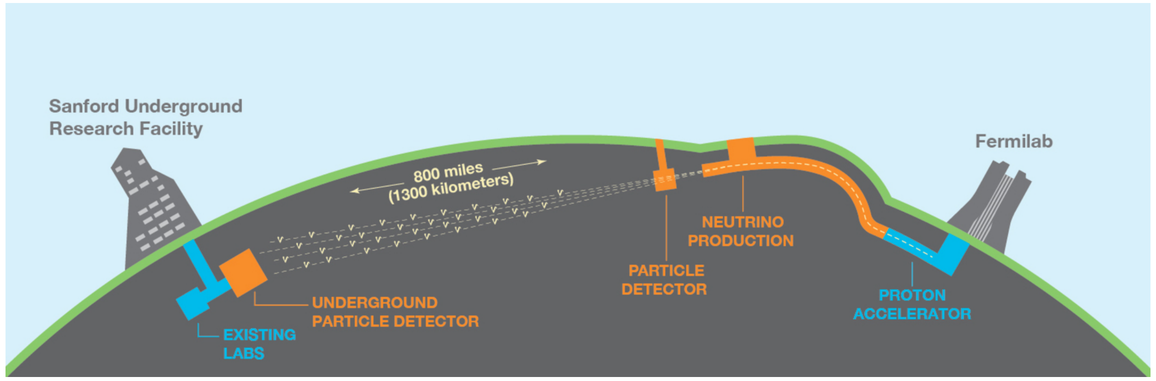
50 ton LXe

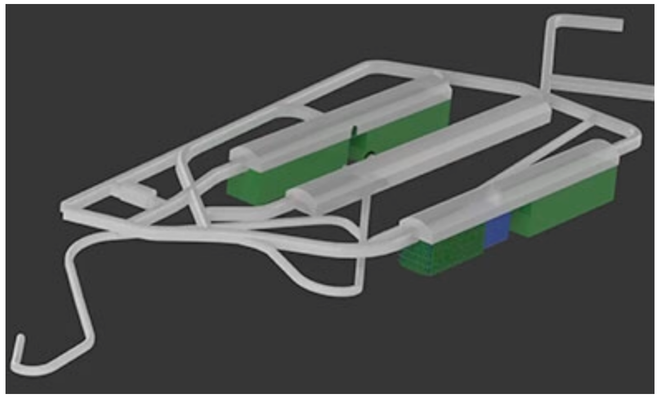
Baseline - PMT

R&D - SiPM, MPGD-LHM,GPM

DARWIN collaboration
arxiv:1606.07001

DUNE baseline design





tens ton LAr

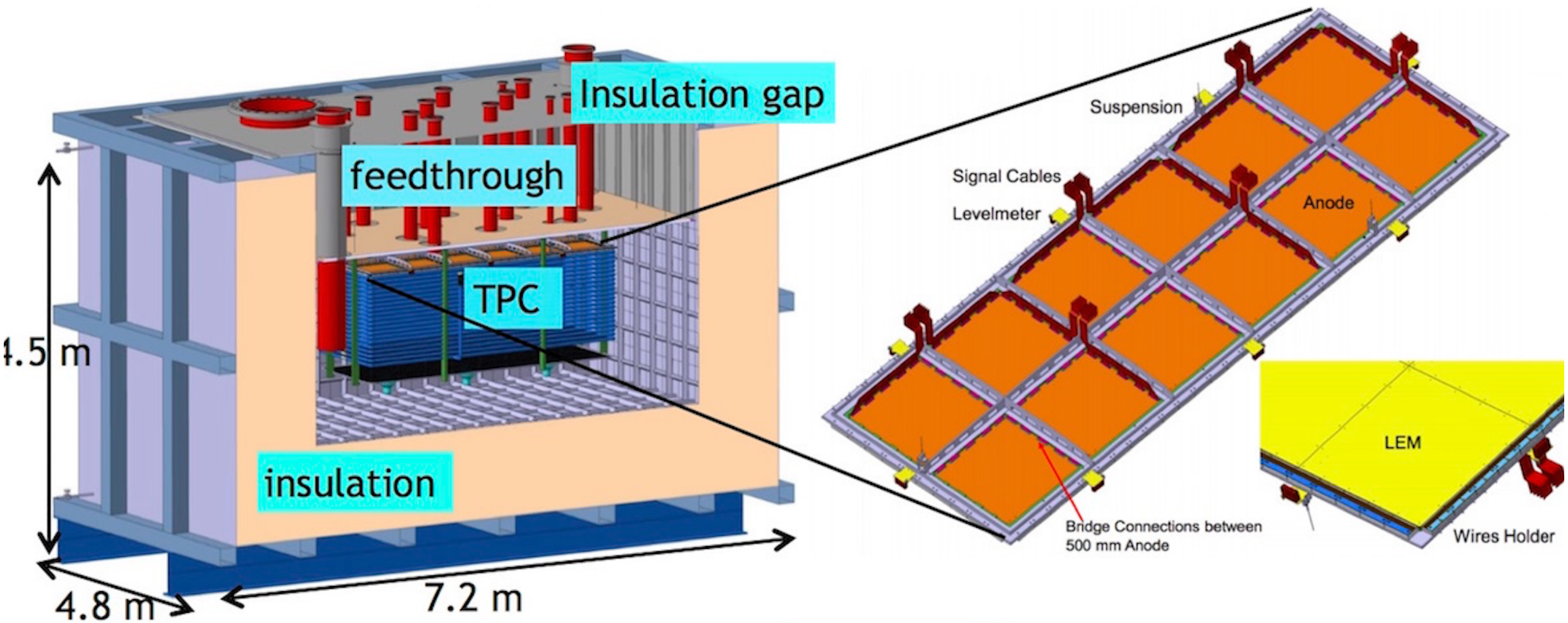
Baseline - wire planes

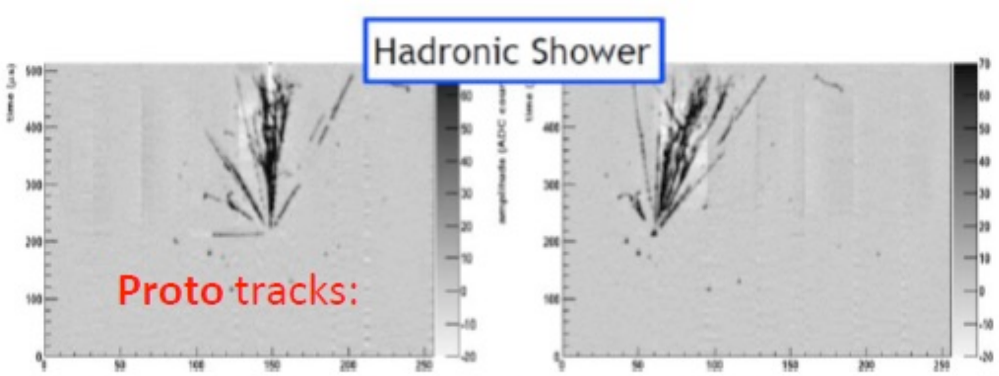
R&D - LEM

Cryogenics — Ongoing effort - dual-phase

A. Rubbia
JINST 8 (2013) P04012

- Prototype at CERN (WA105)





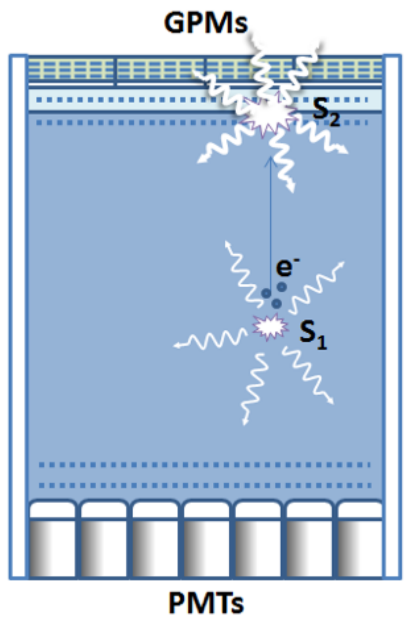
high ionization density in LAr→ need low gain

Cryogenics

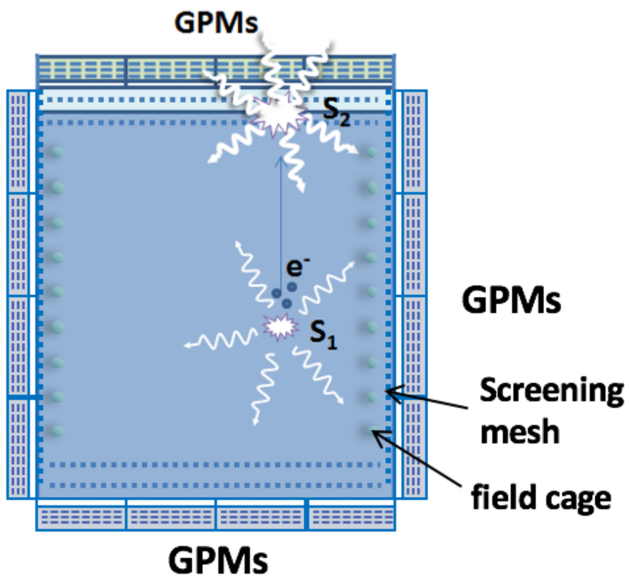
Ongoing effort - GPMs

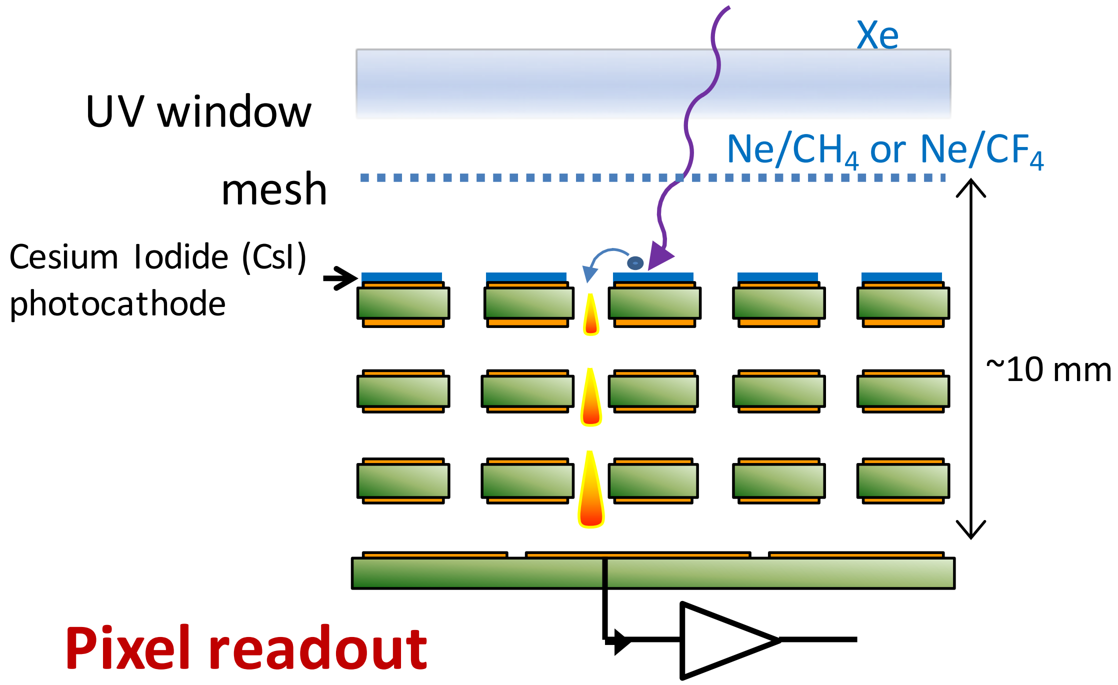
- Gaseous Photon Multiplier (GPM)

Top array based on GPM

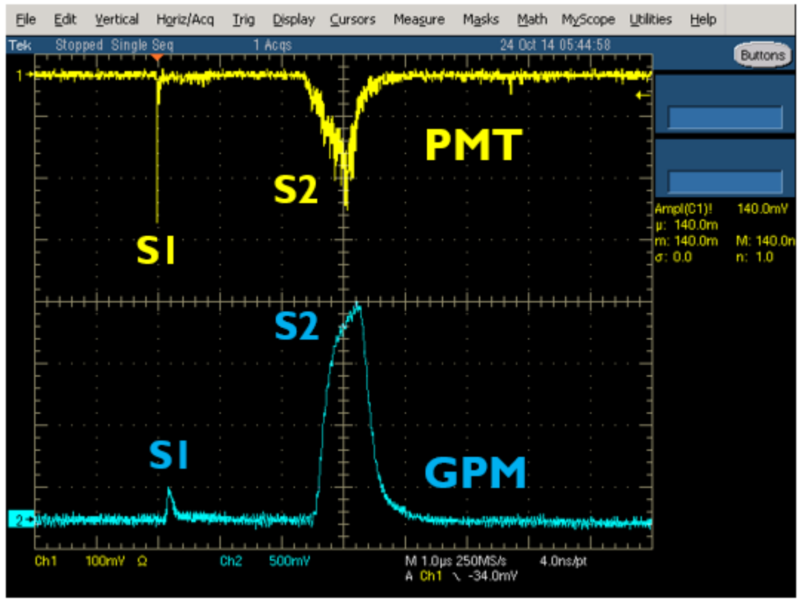


4π coverage of GPM

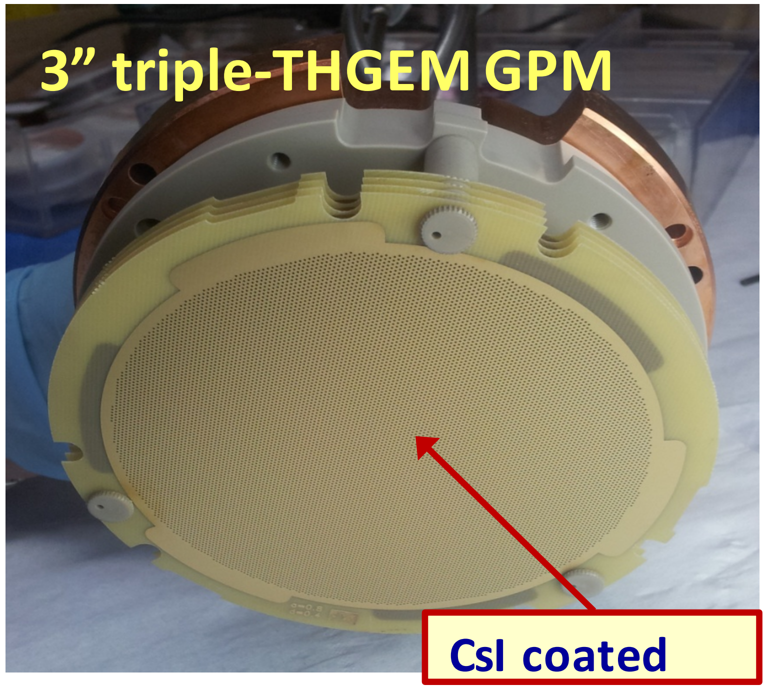




Pixel readout



L. Arazi
JINST 8 (2013) C12004

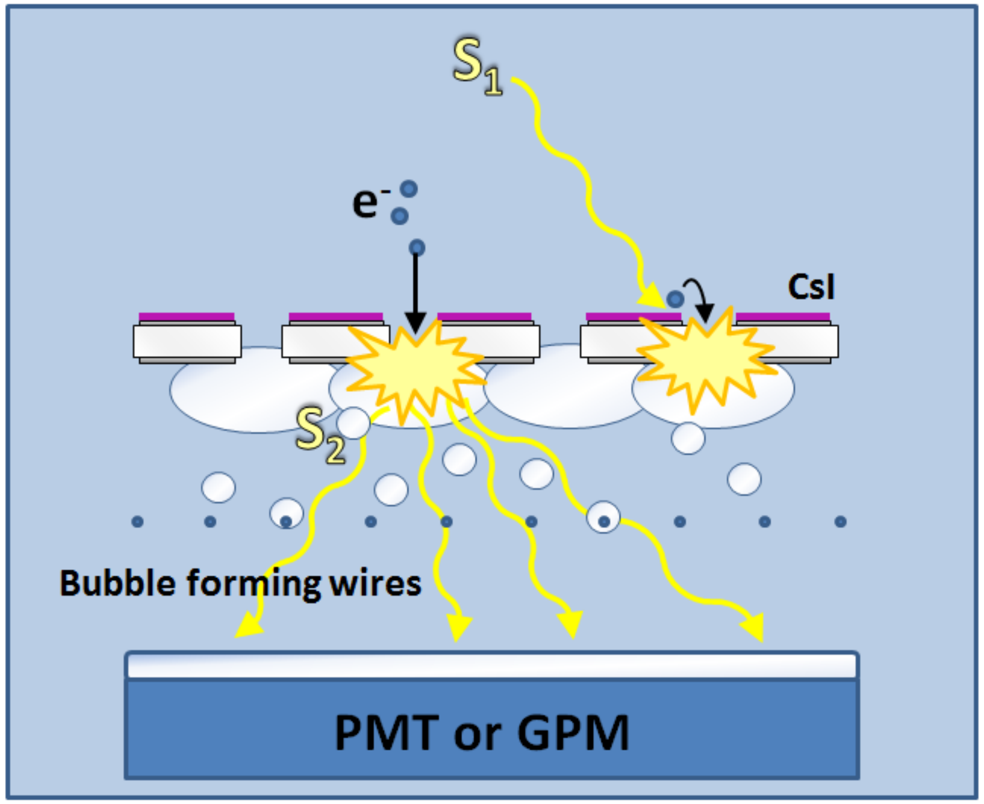


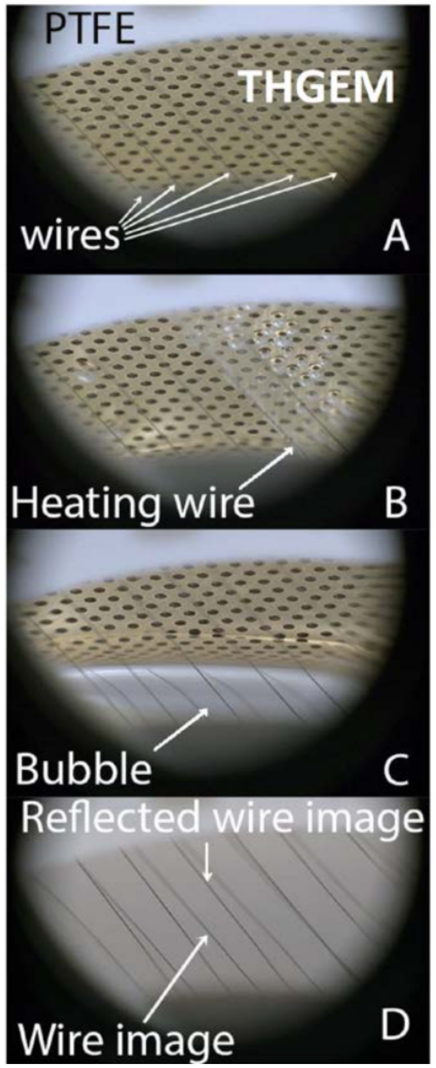
Cryogenics Novel concept - bubbles

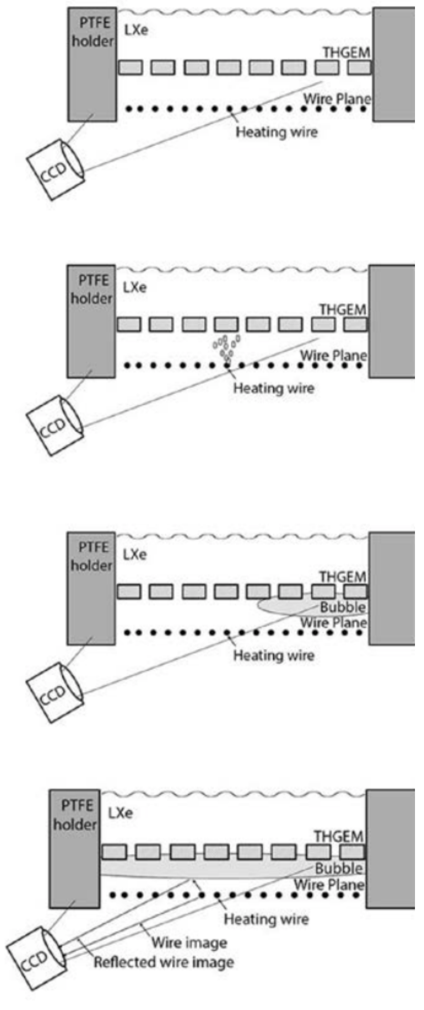
Bubble-Assisted Liquid Hole Multiplier (LHM)
A possible solution for single-phase noble-liquid TPC

E. Erdal
NIM A845 (2017) 218

- THGEM coated with CsI photocathode immersed in Noble-Liquid
- Hot resistive wires underneath form bubbles
- ***UV induced*** photo-electrons & ***ionization electrons*** trapped by the holes
- Both induce electroluminescence in the gas-bubble under electric field

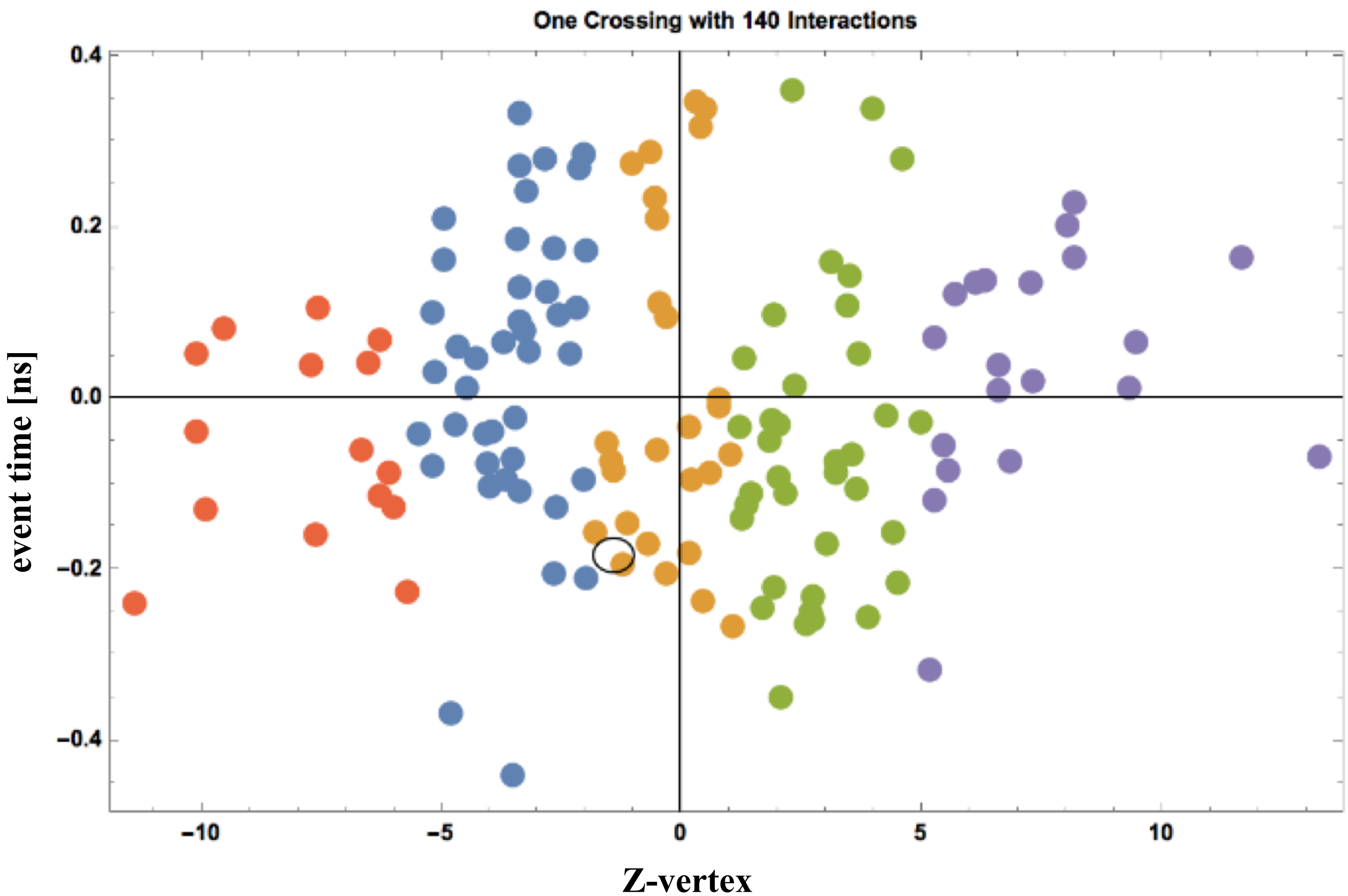






Motivation HEP

- Tracking at high pile-up environment
- Vertex discrimination based on time measurement

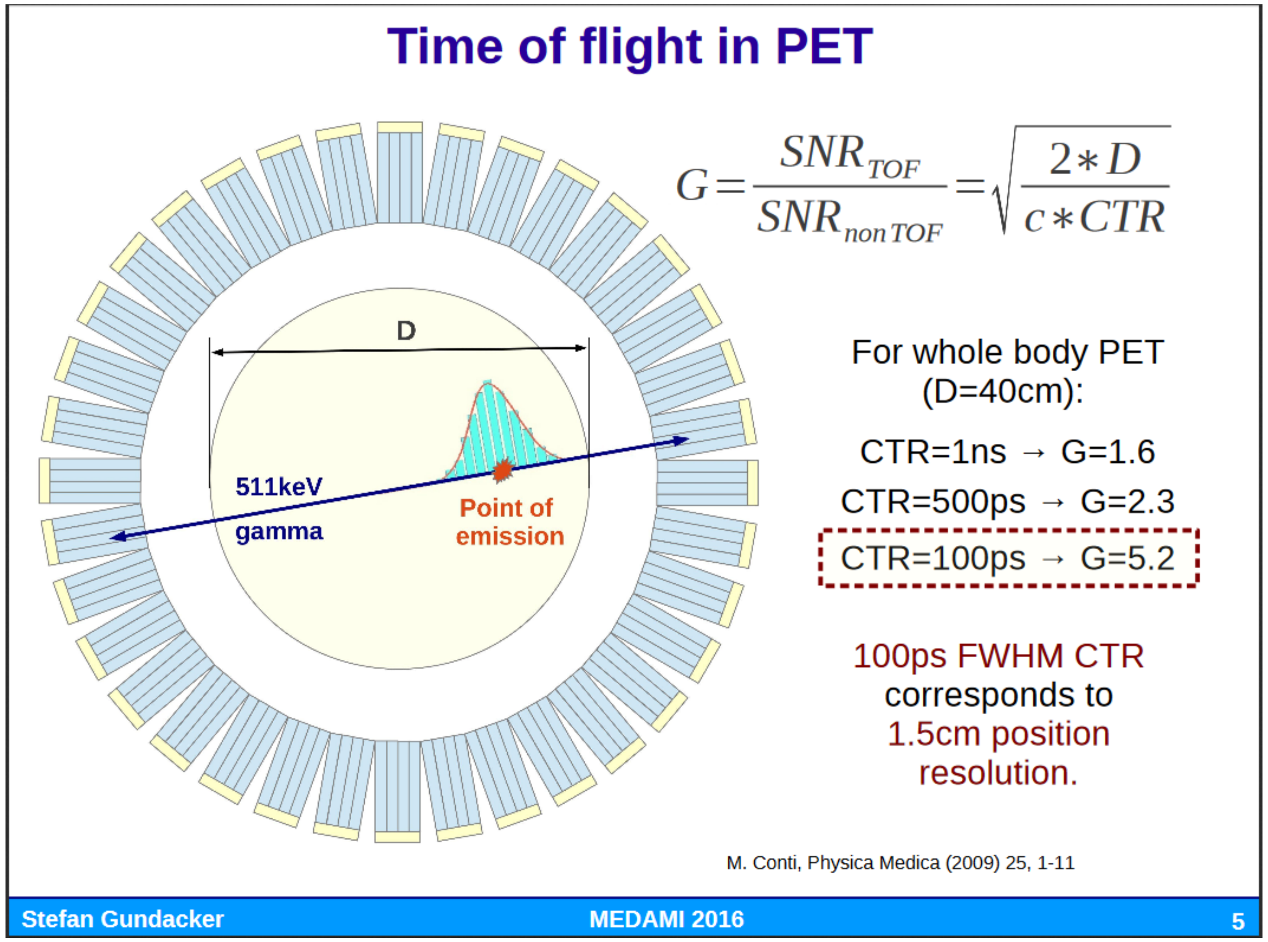


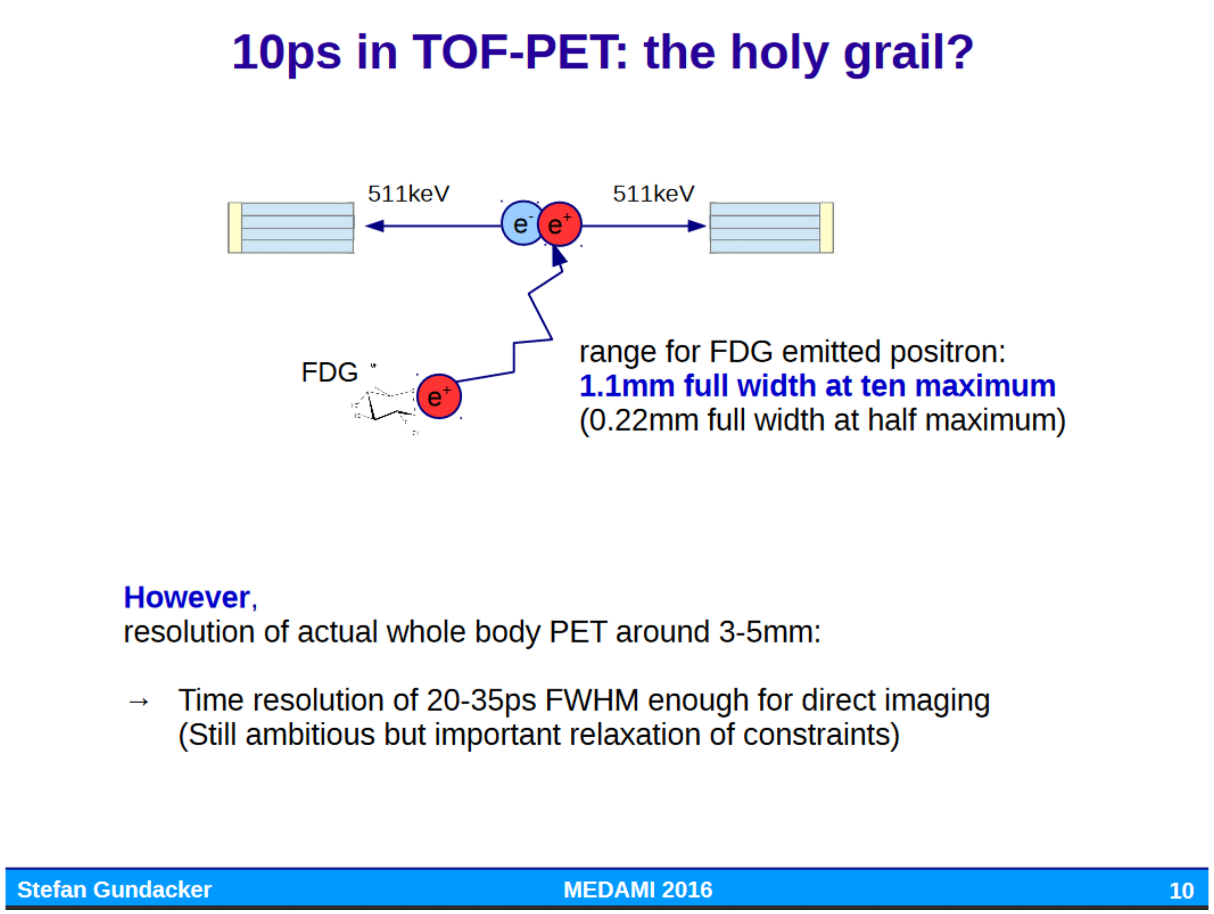
Simulated events with 140 vertices in CMS

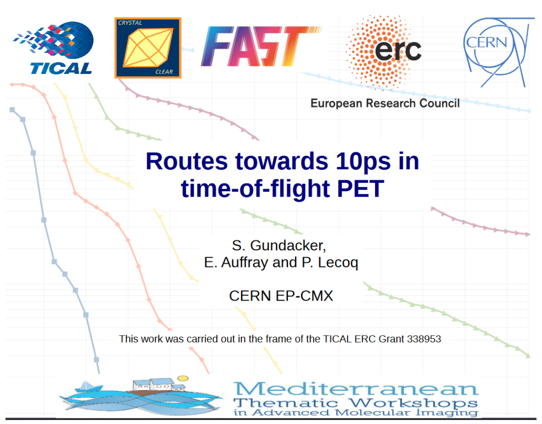
Motivation PET

NIM A804 (2015) 127-131

- Tracking at high pile-up environment





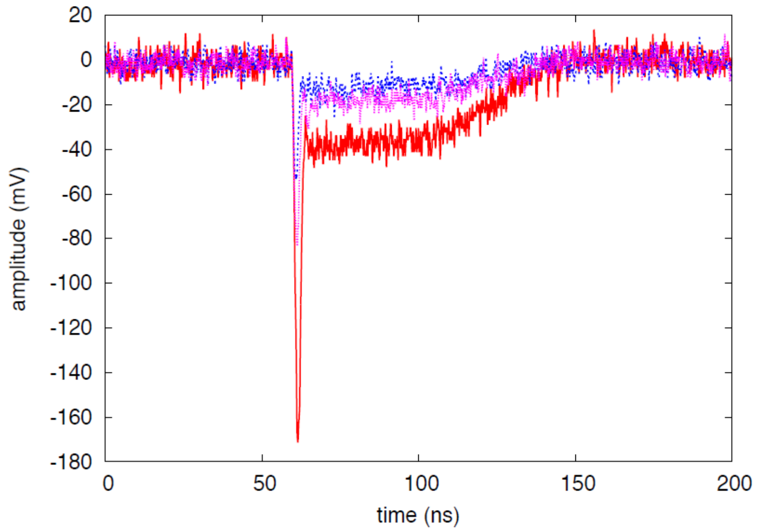


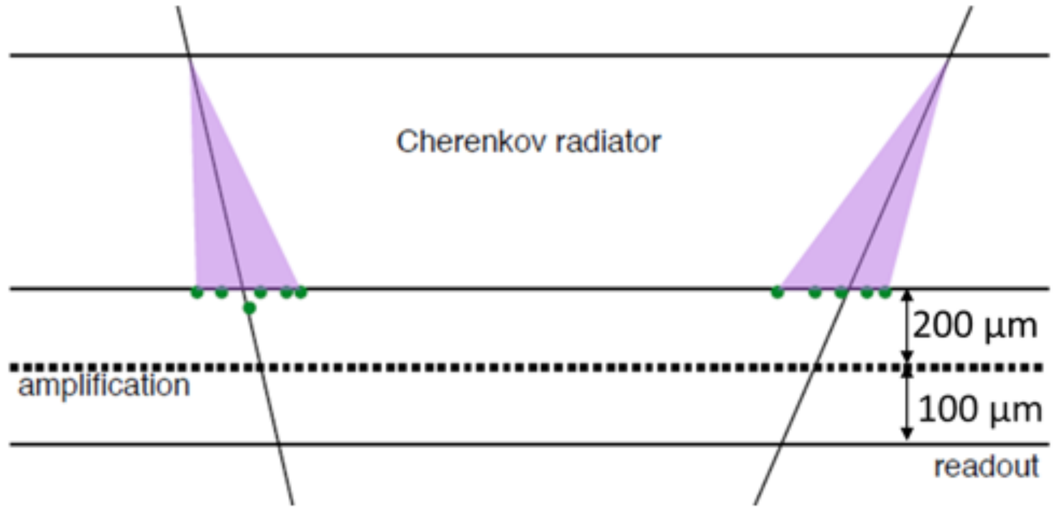
Novel concept

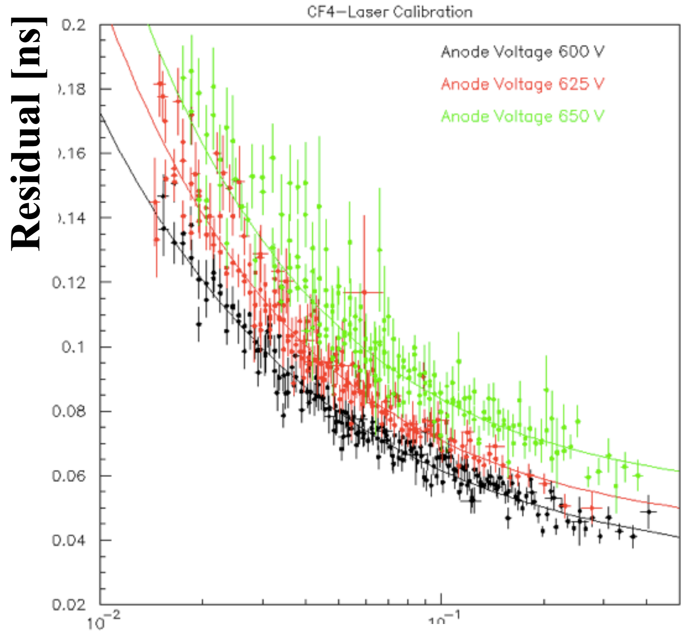
Readout based on MICROMEGAS

- Cherenkov radiation - prompt photon source
  ⇒ primary ionization localized in time and space
- Small drift & pre-amplification
  - low diffusion
  - low primary ionization in gas

muon pulse shape





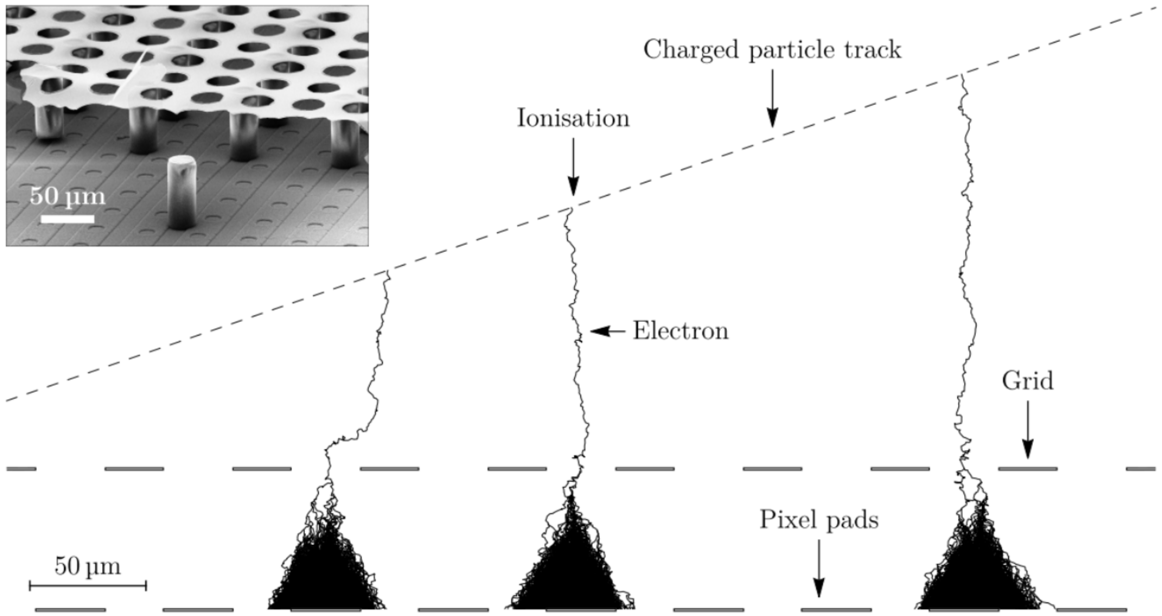


e-peak amplitude

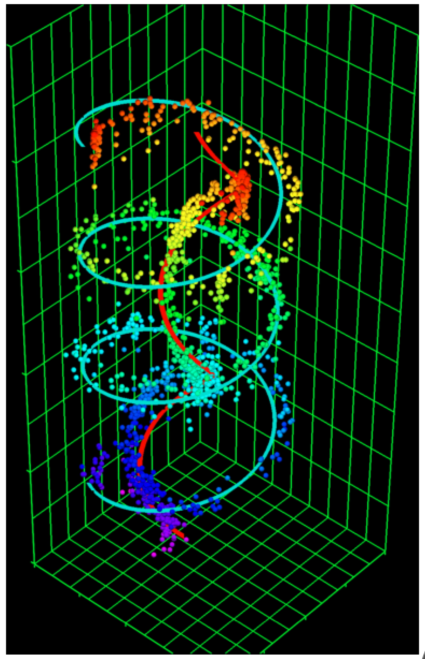
T. Papaevangelu
8th symposium on large TPCs for low-energy rare event detection,
5-7 December 2016, Paris

E. Olivery
MPGD2017, May 22, Philadelphia

- MM/GEM coupled to pixelated Timepix3 readout electronics
  x-y coordinate - by the pixel (~50μm)
  z coordinate - by timing (1.56 res.)
- Low threshold
- Sensitivity to single electron
  ⇒ Full track reconstruction
- Resolution dictated by longitudinal and transverse diffusion



z [mm]	σ_x [µm]	σ_y [µm]	σ_z [µm]
0.0	17.3	17.3	36.2
1.0	34.3	34.3	46.7
2.0	45.2	45.2	55.3
5.0	68.3	68.3	75.4
10.0	95.0	95.0	100.2



Technology Transfer

S. DallaTorre, 10 May, 2017

MPGD-related Technology Transfer

Production of detector components

- **GEMs**
  - TECHTRA (PL)
    - 10 x 10 cm² GEM foils, yield 90%
    - Complete 10 x 10 cm² detectors (30 x 30 coming)
    - Large GEMs foils (CMS-size) in progress, promising status, present yield 30% & long production time
  - MICROPACK (IND)
    - 10 x 10 cm² GEM foils, yield ~ 80%
    - 30 x 30 cm² GEM foils, in preparation; CERN evaluation in Spring 2017
  - KCMS-MECARO (ROK)
    - Well-equipped workshop
    - Gem foils up to 30 x 30 cm² successfully produced
    - Large GEMs foils (CMS-size) under production; CERN evaluation by Aug. 2017 → production
  - TECH-ETCH (USA)
    - Successful in the past up to 40 x 40 cm²
    - Apparently production abandoned because of lacking users' interest
- **BULK MICROMEGAS**
  - ELVIA (F)
    - 16 working detectors of 50 x 50 cm² built
  - ELTOS (I)
    - TT ongoing, 10 x 10 cm² produced
- **THGEMs**
  - ELTOS (I)
    - 60 x 30 cm² produced for COMPASS RICH, in house post processing
    - 60 x 30 cm² produced for WA105

TT effective IF and ONLY IF the community choose the industrial producers !

Electronics

- **SRS components now produced by industry**
  - Recall - one of the major RD51 **success:** 54 groups around the world are using SRS !

SRS procurement from 2017+

INHOUSE production RD51: stopped !

CERN Store: continued for team account owners only

NEW SRS production and purchase licencies* 2017

No team account ? ask CERN/KT for SRS purchase licence

Direct SRS sales starting in 2017:

SAMWAY Electronics: http://www.samwayelectronic.com

FEC and ADC cards, Eurocrates, SRS-ATCA mezzanines etc

SRS Technology: http://www.srstechnology.ch

APIC, hybrids, Powerbox, DVMcards, SRU, AVD etc

Summary

Recent development of MPGD

- Growing demand for large-area affordable detectors
- Continuous need for gaseous-detectors

- MPGDs are a great success
  - Wide dissemination in HEP, Nuclear Astro-particle physics and beyond
  - Flexibility and ability to adapt for different concepts
- Looking forward for the HL-LHC era and beyond
- Rich R&D program:
  - New concepts
  - New structures
  - New materials

In today's talk

Demonstrate how concrete needs, smart ideas and persistent R&D effort yield large variety of ideas and solutions

Takeaway

The field of gas detectors (MPGDs) is in constant movement forwards
The community is active and ready to stand up for any future challenge