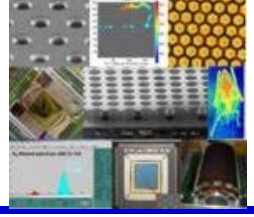
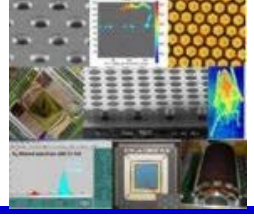


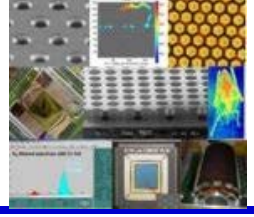
MPGDs:
a tool for progress in HEP

S. Dalla Torre

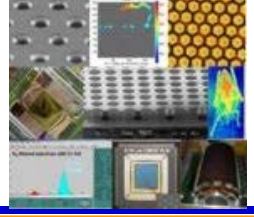


OUTLOOK

- **Introduction: facts about MPGDs**
- **APPLICATIONS**
  - **The overall application panorama (non an exhaustive list)**
  - **Selected examples**
    - **Large tracking systems**
    - **TPC sensors**
    - **Single photon sensors for RICHes**
- **Conclusion**



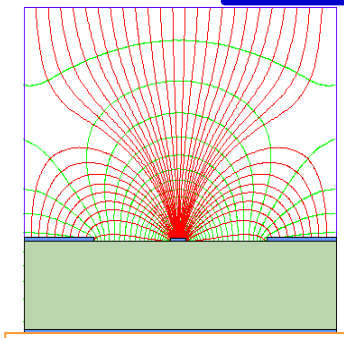
INTRODUCTION

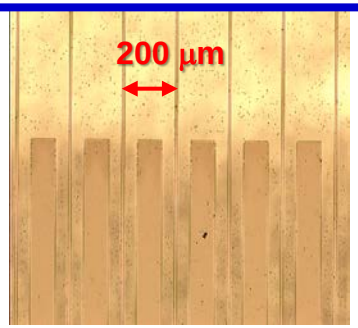


MPGD: THE ERALY DAYS

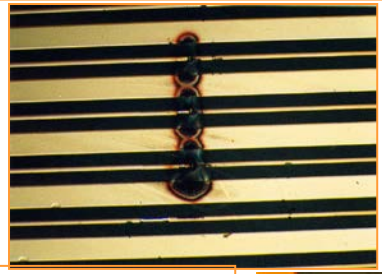
MSGC - MicroStrip Gas Chamber

A. Oed, NIMA 263(**1988**) 351

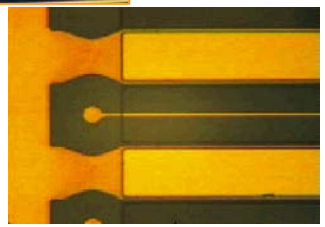




- **High E-values at the edge between insulator and strips → damages**
- **Charge accumulation at the insulator → gain evolution vs time**

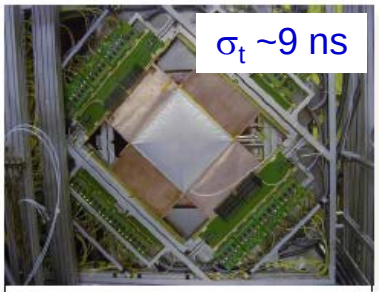


Later (~ 1999-2000): Passivation of the cathode edges → MSGC operational !



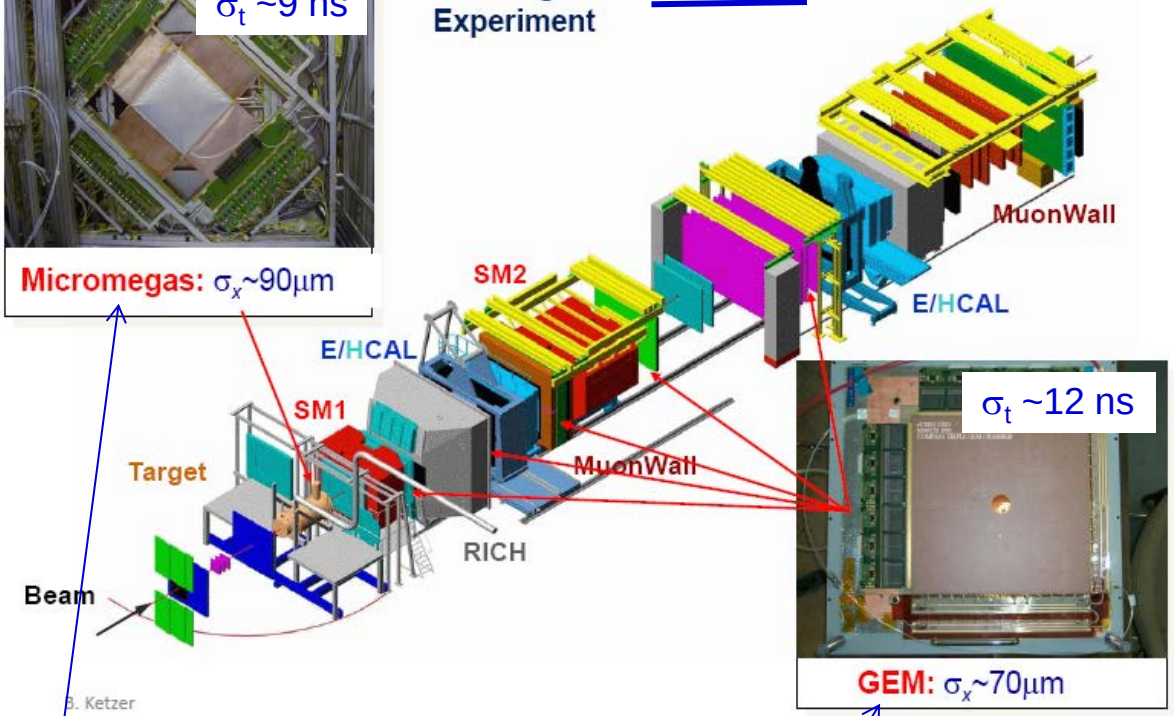
slide by **W. Riegler, CERN Academic Traning, April 2008**

First Large Scale Use of GEMs and MICROMEGAs



Micromegas: σ_x~90μm

Tracking in the COMPASS Experiment



GEM: σ_x~70μm

MICROMEGAS (MM) :
Y. Giomataris et al,
NIMA A376 (**1996**) 29

GEM:
F.Sauli, NIMA A386 (**1997**) 531

MPGD in HEP, TODAY

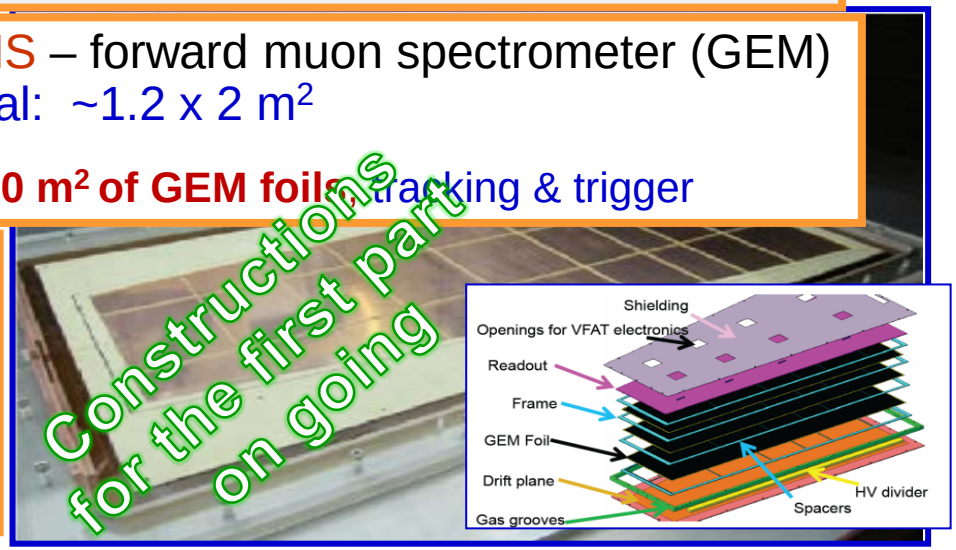
THESE PROJECTS TEST OF THE MATURITY OF THE MPGD TECHNOLOGY AND THE CONFIDENCE OF THE COMMUNITY

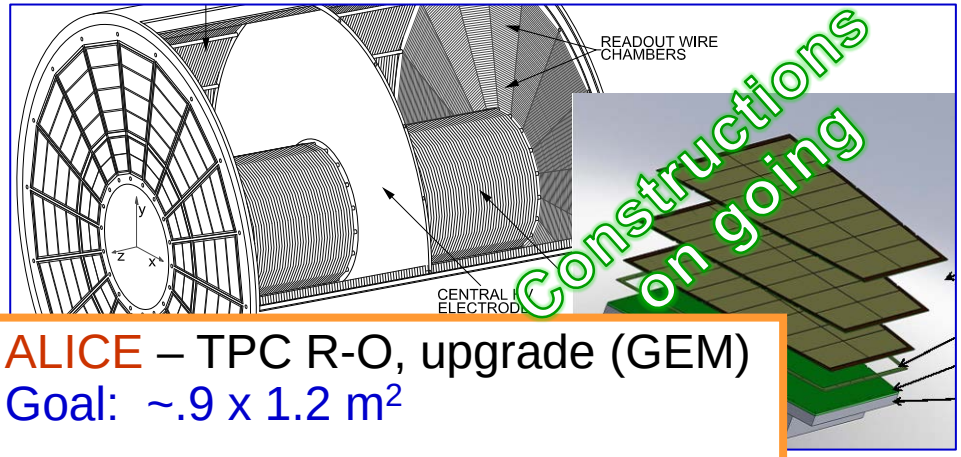
ATLAS – MM
Detector size: ~1 x 2.5m^2

New Small Wheel, ATLAS muon system, 1200 m^2, tracking & trigger

CMS – forward muon spectrometer (GEM)
Goal: ~1.2 x 2 m^2

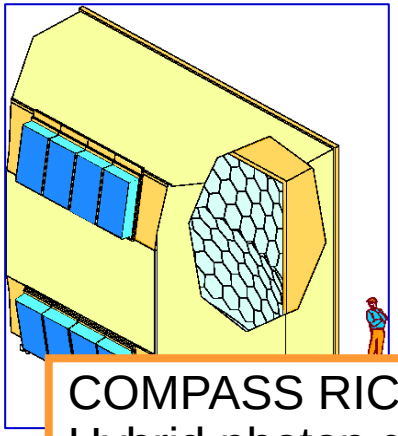
1000 m^2 of GEM foils, tracking & trigger

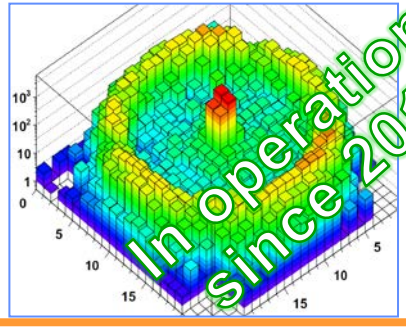




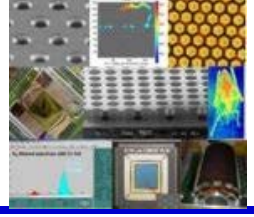
ALICE – TPC R-O, upgrade (GEM)
Goal: ~.9 x 1.2 m^2

130 m^2 of GEM foils





COMPASS RICH-1 upgrade
Hybrid photon detectors
4.5 m^2 of MPGD multipliers (THGEM, MM)



MPGD: THE RD51 COLLABORATION

"The proposed R&D collaboration, RD51, aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research." (RD51 proposal, 28/7/ 2008)

First term: 2009-2013, now 5-year prolongation till the end of 2018

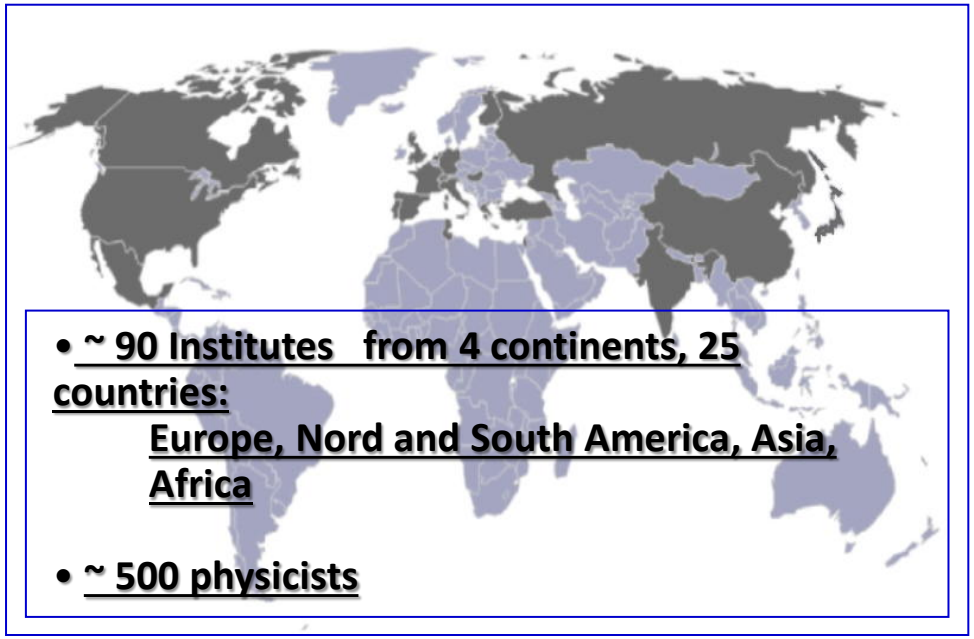
RD51 – fundamental boost for MPGDs: networking, know-how, technologies, common infrastructures, common tools

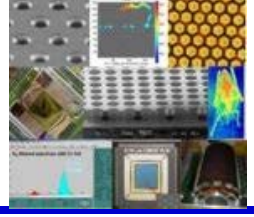
Among common infrastructures:

- RD51-GDD lab
- Common test beam at CERN SPS

Among common tools:

- GARFIELD → GARFIELD ++
- SRS - Scalable Readout System



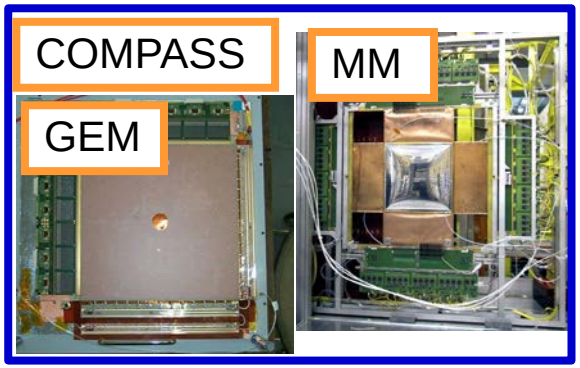


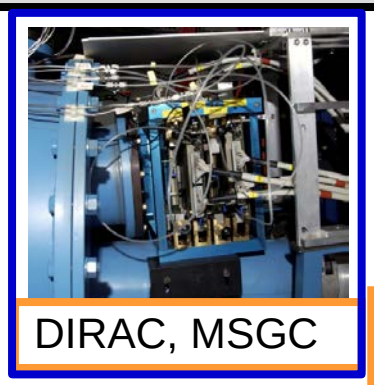
APPLICATIONS:

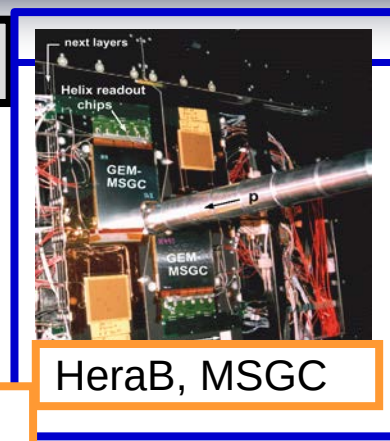
PANORAMA

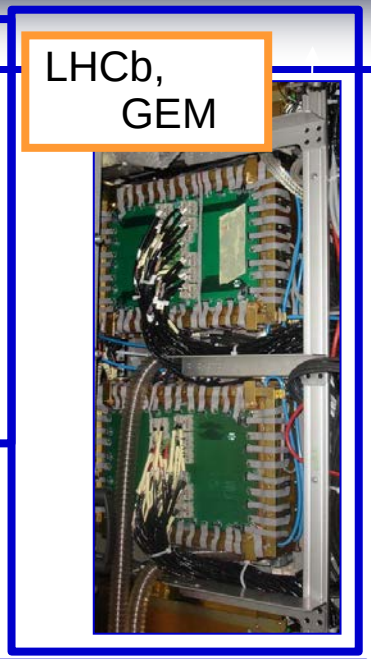
HEP & PARTICLES

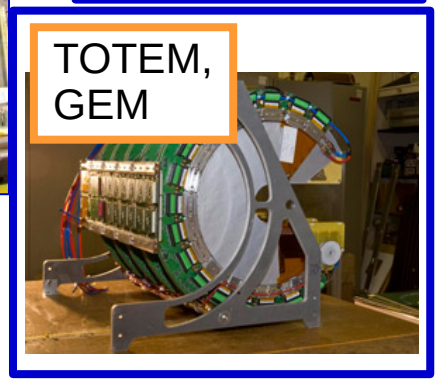
Completed / Running / future Experiments









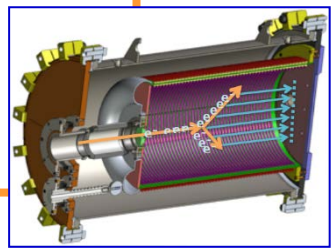


+ ATLAS, CMS, ALICE (already mentioned)
+ ....

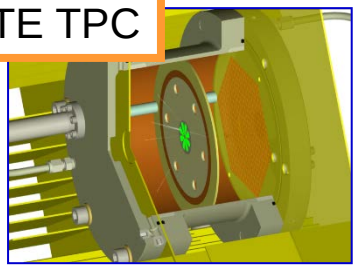
BEYOND HEP & PARTICLES

Low energy nuclear physics

THGEM + MM active target TPC @ NSLC



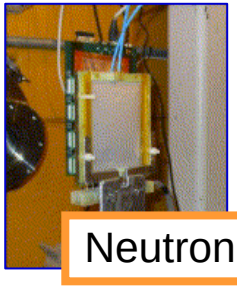
MM for NIFFTE TPC



NSC active Target (THGEM)

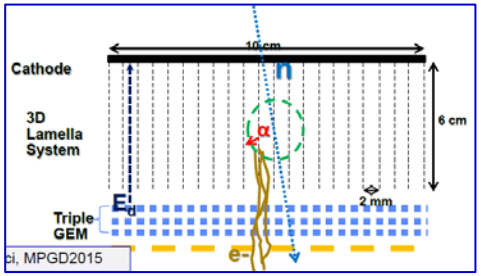
n detection

D20 difractometer @ILL, MSGD



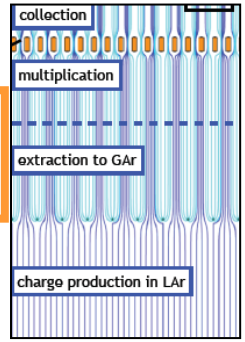
Neutron GEM @ SIS

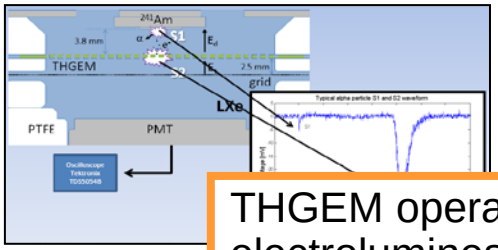
The band-gem detector (lamellae with 10B4C coating) for ESS



Rare event cryogenic detectors

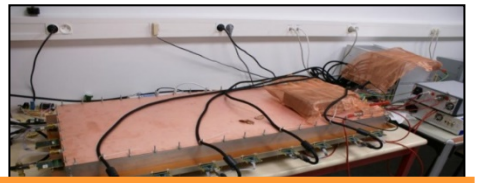
LEMs (THGEMs) for Ar double-phase TPC





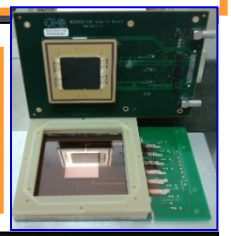
THGEM operated in LXe, electroluminescence detected

society

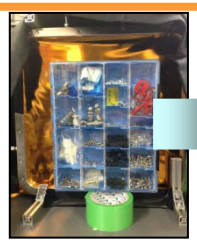


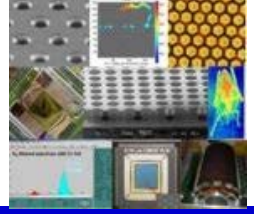
2 layer MM TPC for geological studies

GEM-PIX for medical applications and radioactivity monitoring (waste, tokamak)



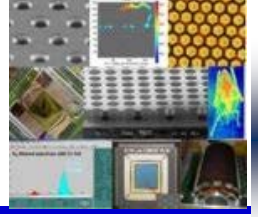
Scintillating glass-GEMs for non destructive inspections





APPLICATIONS:

SPECIFIC EXAMPLES



LARGE TRACKING SYSTEMS

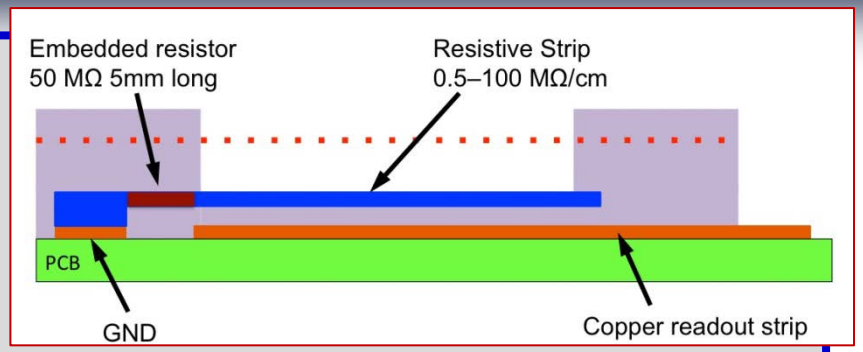
Challenges

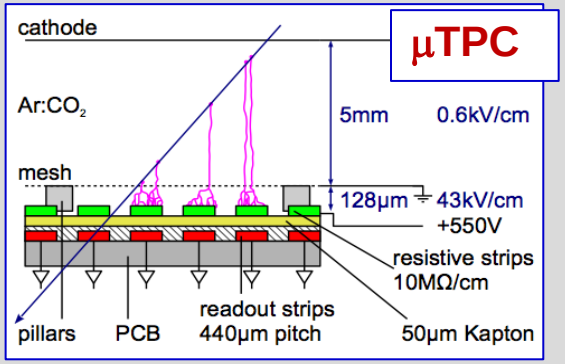
- **unprecedented large detector size**
  - extrapolation of production techniques and performance scaling the size
  - ATLAS New Small Wheel: ~ 1 x 2.5 m^2
  - CMS forward muon spectrometer: ~1.2 x 2 m^2
- **unprecedented mass production**
  - ATLAS New Small Wheel: 1200 m^2 of detector surface
  - CMS forward muon spectrometer: 1000 m^2 of GEM foils
- **mechanical precision**
  - ATLAS NSW, absolute strip position accuracy: 30 μm RMS in η, 80 μm RMS in z

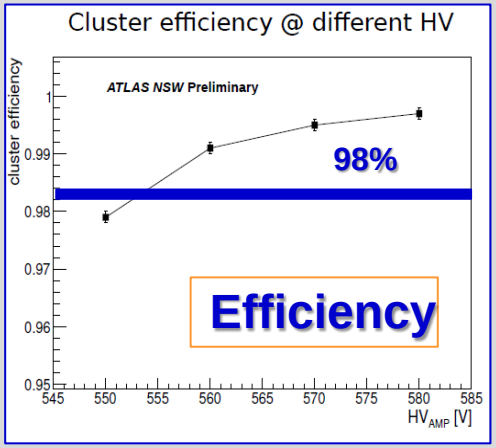
LARGE TRACKING SYSTEMS

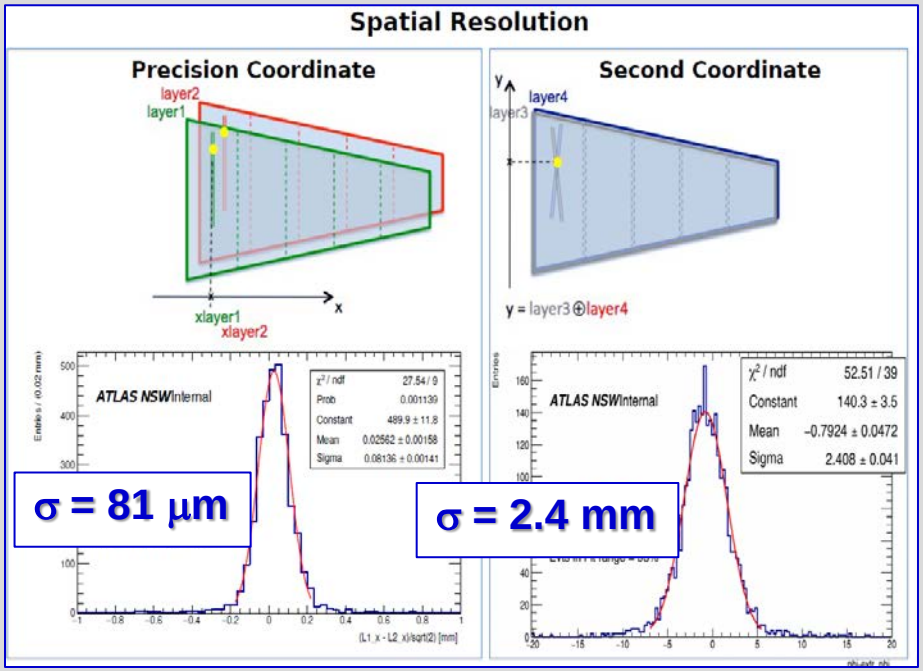
ATLAS New Small Wheel - MM

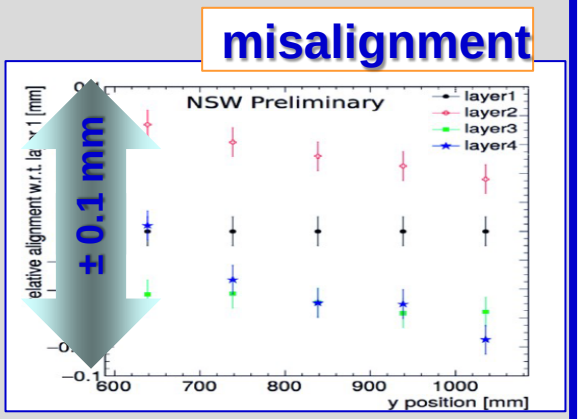
- **A technological break-through: <u>the resistive anode</u>**
- **The μTPC approach to preserve the space resolution for inclined tracks**
- **Construction distribute to various**
  - **production sites working in //**
  - Germany – BMBF, France – Saclay, CERN/Dubna/Thessaloniki, INFN (Pavia, Roma1, Roma3, Frascati)
- ***Performance flavor from the first modules***





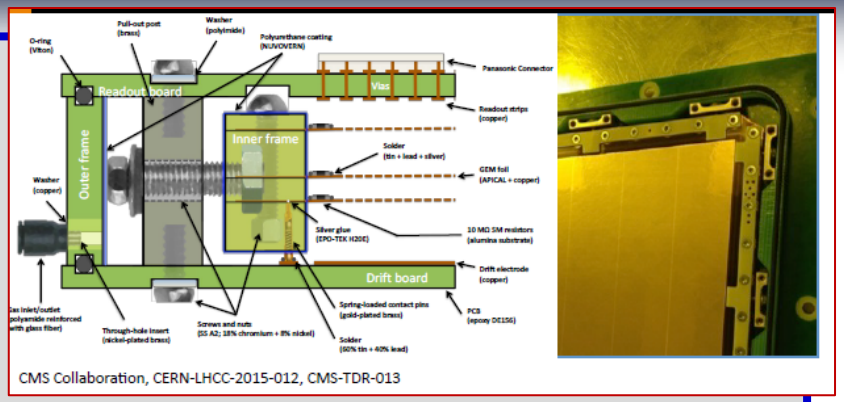






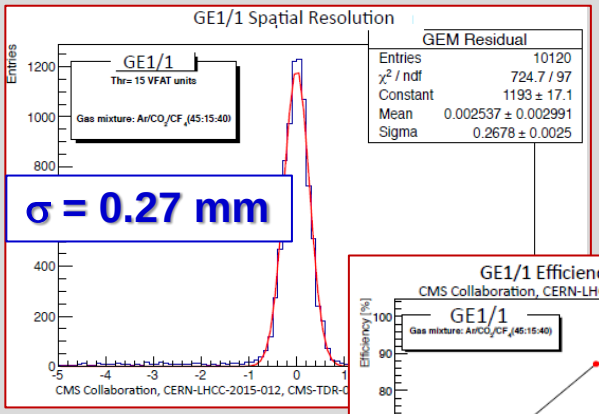
LARGE TRACKING SYSTEMS

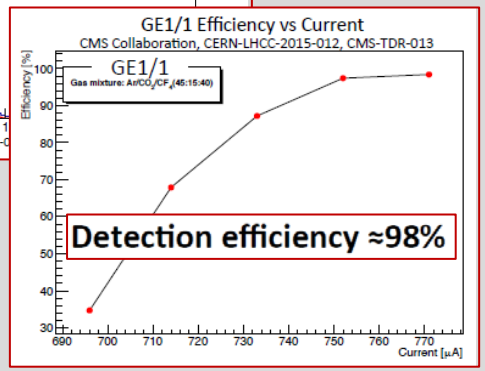
CMS forward muon spectrometer - GEM

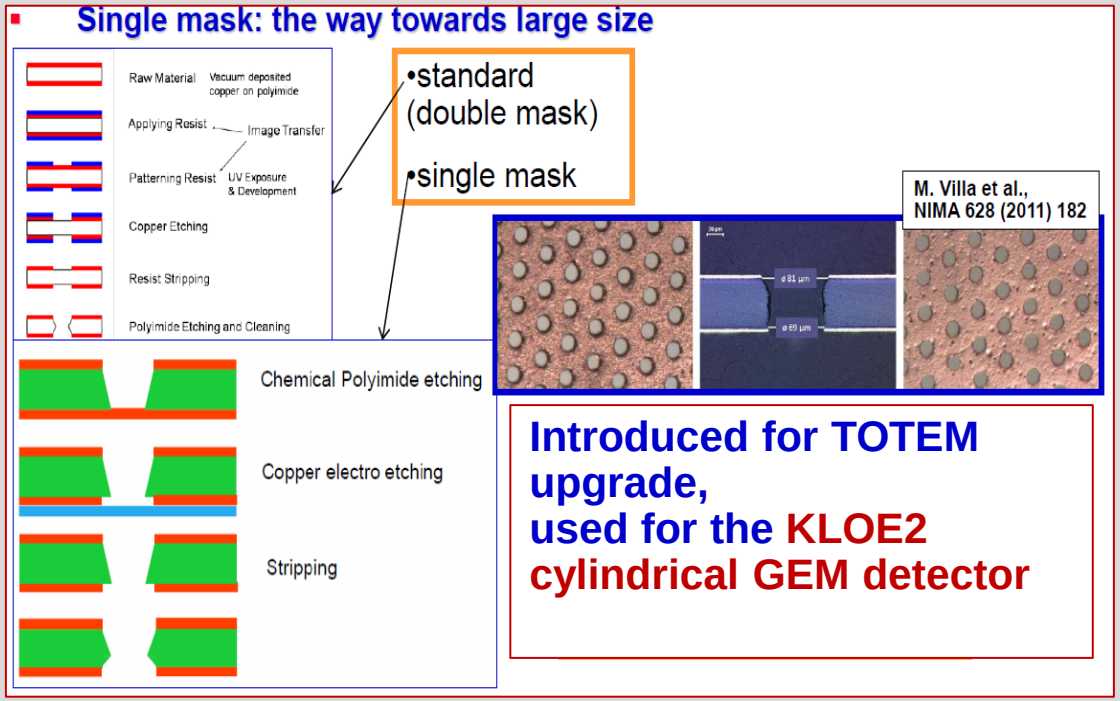


CMS Collaboration, CERN-LHCC-2015-012, CMS-TDR-013

- **2 novel technological ingredients**
  - Foils mechanically stretched
  - Single-mask GEM foils
- **Construction centralized at CERN**
  - GEM foil production at CERN for the first portion (2018-20), then industry (approach to be tested for large-size, mass production)
- ***Prototype performance***



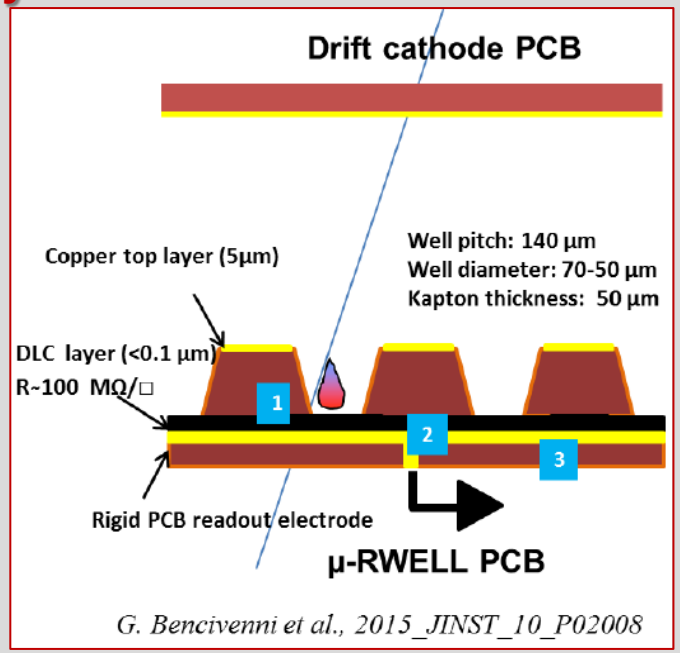




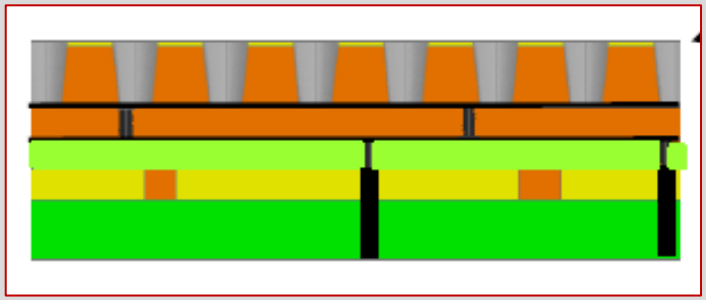
LARGE TRACKING SYSTEMS

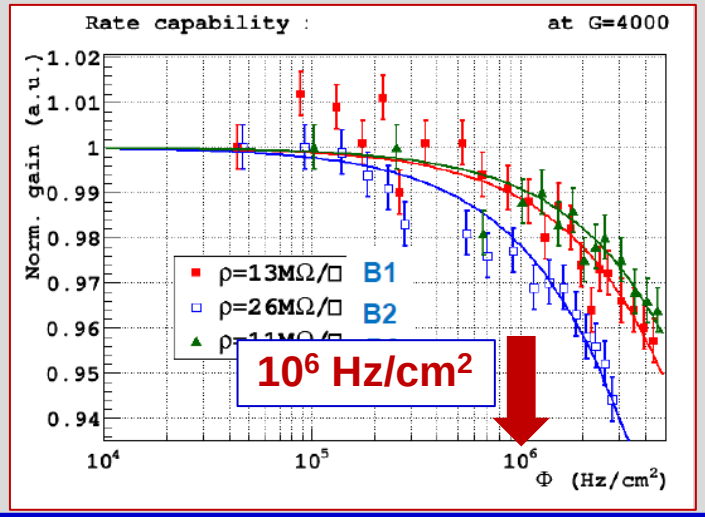
μRWELL : a novel MPGD technology for large tracking systems ?

- Aiming at simplified construction reducing the number of components to 2 only
- Implement resistivity for high gain O(10^4) with a single multiplication layer, ~60 μm space res.
- High rate version by multiple grounding of the resistive plane



G. Bencivenni et al., 2015_JINST_10_P02008





HEP experiments:

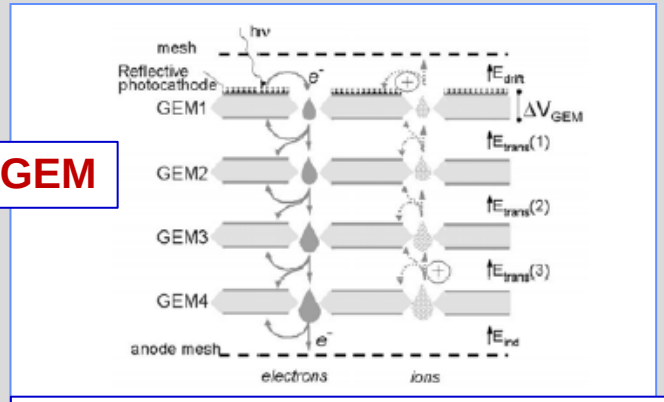
- Large area proposed for CMS, SHIP
- HR scheme with double resistive layer proposed for LHCb

NON-GATED TPC SENSORS

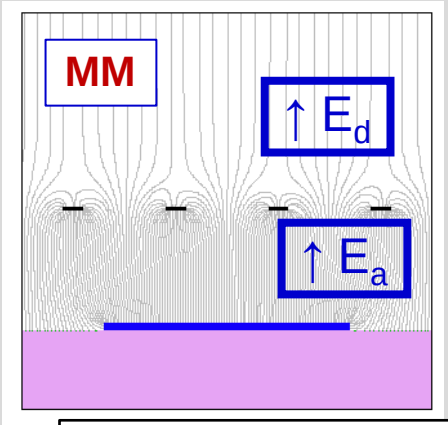
Needed to sustain high rates

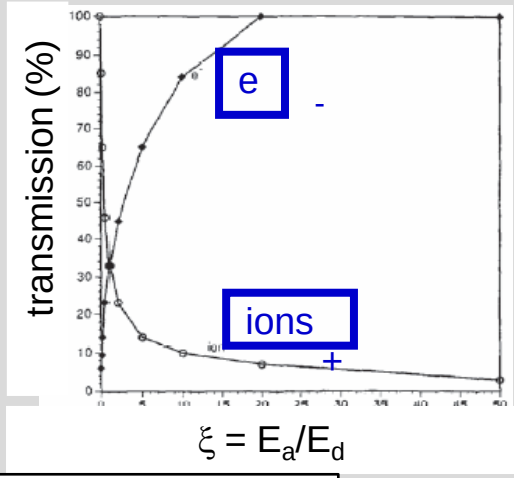
Challenge:

- **Trap the ions from the multiplication in the sensor: they do not enter the drift region where they would distort the electric field = limit IBF (Ion BackFlow)**
- **Use MPGDs, where ion trapping is intrinsic**



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





Y. Giomataris et al, NIMA A376 (1996) 29

RECALL: WHAT REALLY METERS IS GAIN x IBF !

- **NEXT STEP: the upgrade of ALICE TPC**

NON-GATED TPC SENSORS

ALICE TPC upgrade (MPGDs for operation at increased recording rate 0.5 →50 kHz)

- goal: No Gate, G = 2000 IBF = 1% → G x IBF = 20

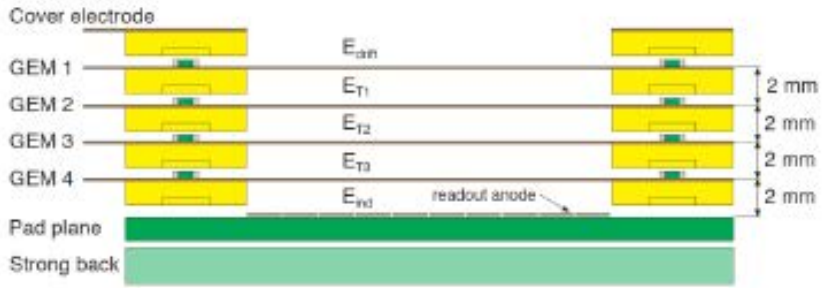
A. Mathis, MPGD2015

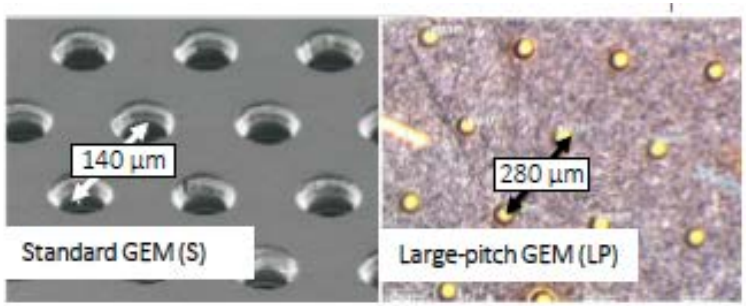
- S-LP-LP-S configuration

Staggered !

✓ IBF = 0.6 %

$\sigma_E/E \approx 9.5\%$





HYBRID = 2 GEM layers + 1 MM

alternative approach

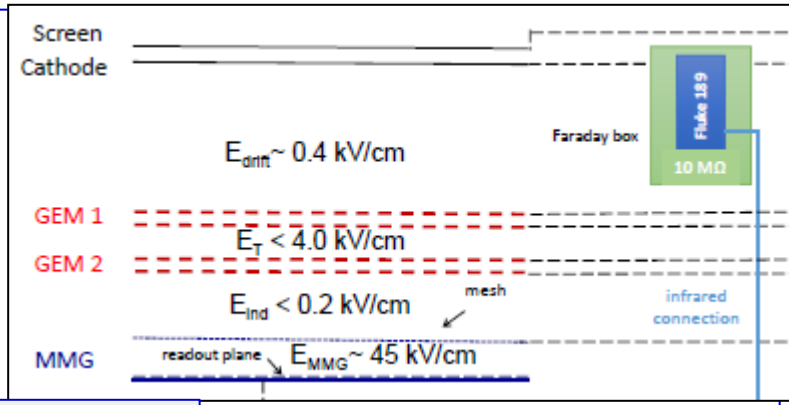
Studied for ALICE, proposed for PHENIX upgrade with TPC

intrinsic property of ion collection at mesh in MM

IBF < 1% easily obtained, energy resolution ~ 10%

Anticorrelation between IBF reduction and energy resolution

MM discharges → next step: resistive MM

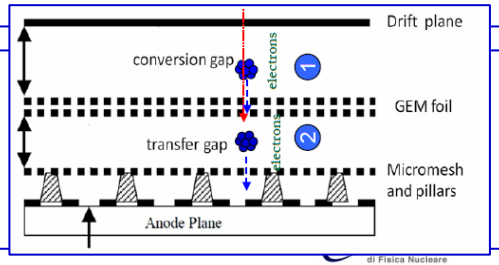


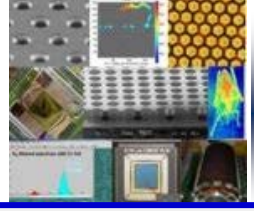
R. Majka, IEEE-NSS 2015

HYBRID = 1 GEM layer + 1 MM

IHEP studies

H.Qi, 2016





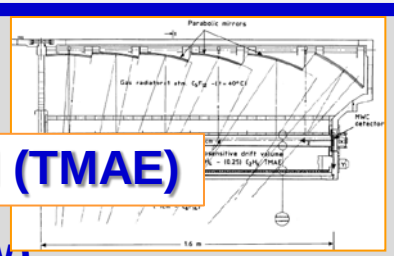
SINGLE PHOTON DETECTION BY GAS

Why gaseous photon detectors ?

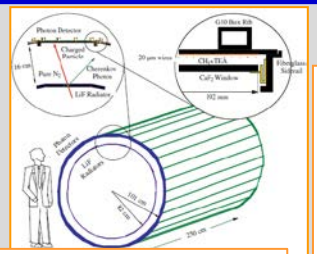
- the cheapest option for large detector area application
- operation in magnetic field thanks to low sensitivity to B
- minimum material budget, relevant when the photon detectors have to seat in the experiment acceptance

Development triggered by the needs of RICH detectors

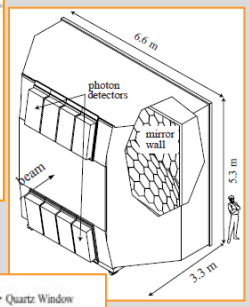
THE PAST OF GASEOUS PHOTON DETECTORS



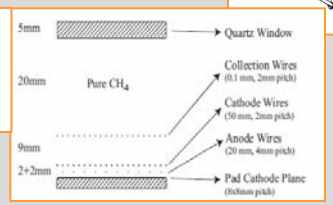
DELPHI (TMAE)



CLEO III (TEA)



COMPASS, MWPCs + CsI



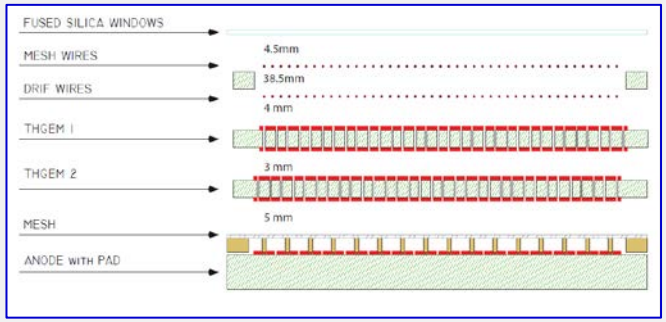
- Converting vapours
  - TMAE: Thick converter (parallax, slow) or heated detectors
  - TEA: restricted to the far VUV domain
- MWPC with CsI photocathode
  - Some limitations
    - Severe recovery time (~ 1 d) after detector trips (Ion accumulation at the photocathode)
    - Feedback pulses (Ion and photons feedback)
    - Aging after integrating a few mC / cm^2→ (Ion bombardment of the photocathode)

} moderate gain : < a few x 10^4 (effective gain: <1/2)

SINGLE PHOTON DETECTION BY MPGDs

The state of the art : the novel photon detectors of COMPASS RICH-1

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

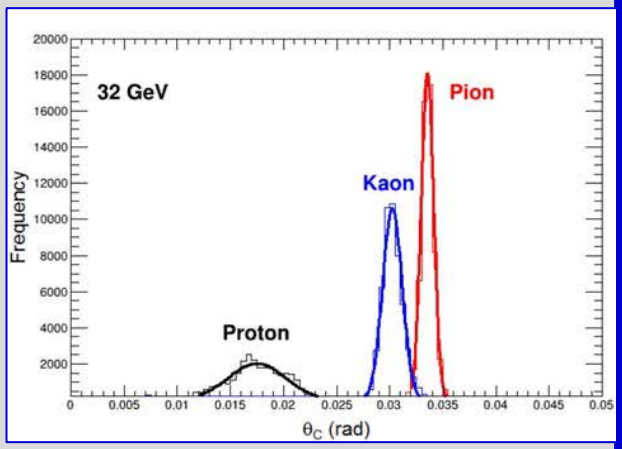


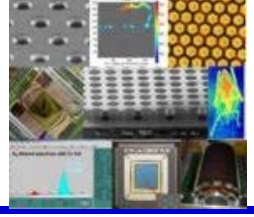
- **Installed in 2016, commissioning ongoing**
- **4 x (60 x 60 cm^2) detectors**
- **IBF < 5%, effective gain ~20 k in experiment environment**

Novel promising perspectives for RICH applications at Colliders using MPGDs

- **RICHes for high p (> 6 GeV/c) require gaseous radiator with long radiators to collect enough photons**
  - **CsI: photon conversion limited to 165< λ <205 nm**
  - More photons going windowless (PHENIX HBD, a Threshold Cherenkov c.) : exporting the windowless concept to a RICH ?
  - **Test beam at Fermilab with 1m of CF_4, reflecting mirror with reflection peak at 120 nm, and quintuple GEM detector with CsI**
  - **Promising results … stay tuned**

M. Blatnik et al., IEEE NS 62 (2015) 3256





CONCLUDING

As shown, MPGD are a world in fast and dynamic evolution, namely:

MPGD FUTURE
HAS ALREADY STARTED !