

Micro Pattern Gaseous Detector Technologies and Applications: The Work of the RD51 Collaboration

Filippo Resnati (CERN and ESS)
on behalf of the RD51 Collaboration

Micro-Pattern Gaseous Detectors

From late '80, conceived to overcome the limitations of MWPCs with respect to position resolution, capability to cope with high particle fluxes, and long-term stability.

All MPGDs have in common:

- production techniques typical of PCB manufacturing
- dielectric materials as support for the electrodes
- proximity of anode and cathode electrodes

MPGD strengths

- High particle flux capable (MHz/mm²)
- Large dimensions (several m²)
- Not expensive (< 5 kCHF/m²)
- Good position resolution (<50 μ m)
- Excellent time resolution (<5 ns and even $O(100 \text{ ps})$)
- Radiation hard (10s year in forward muon chambers at LHC)
- Low material budget (<0.01 X_0)
- Compatible with magnetic field

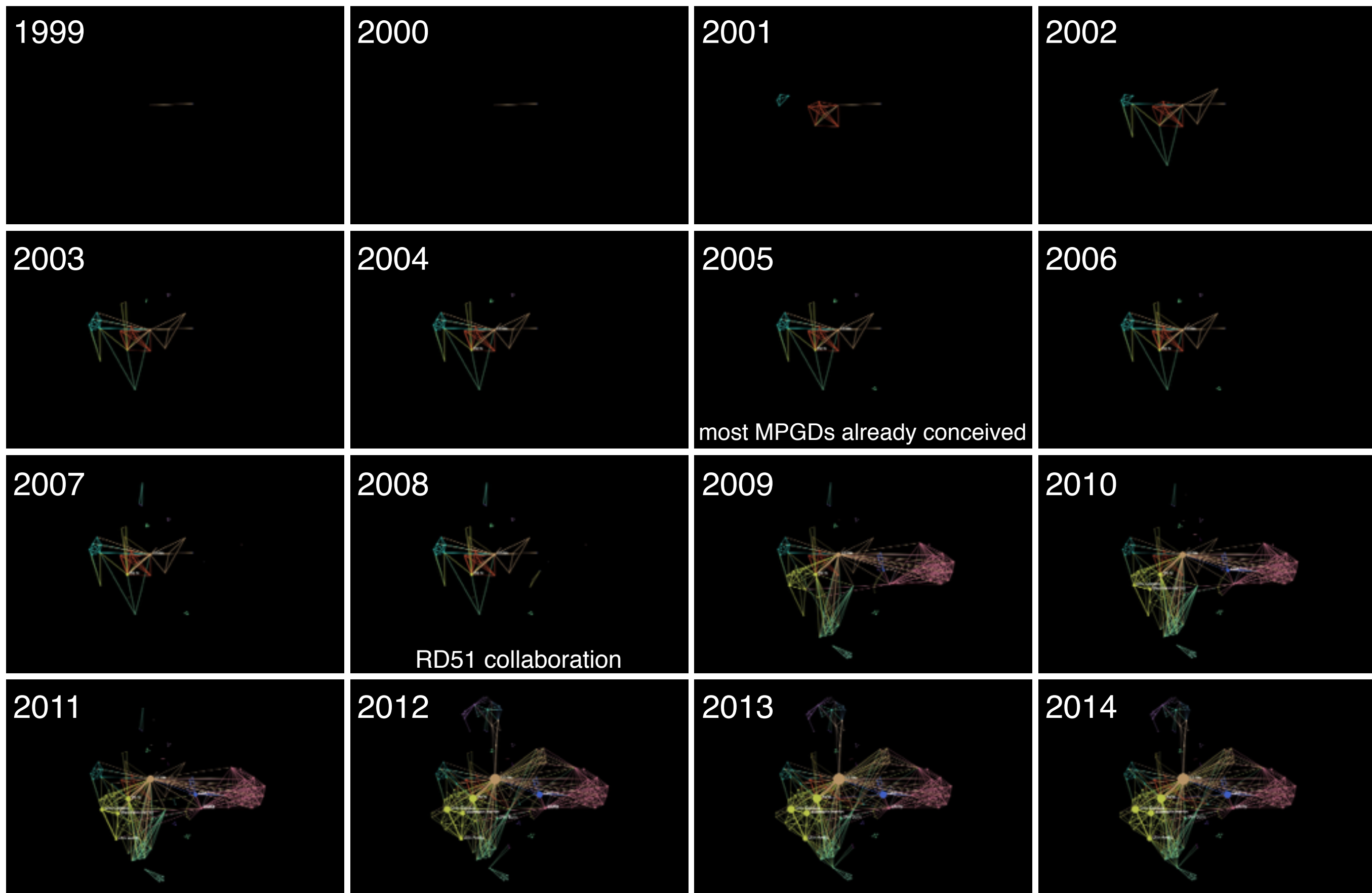
RD51 collaboration

Established in 2008 to foster the coherent and synergistic developments of MPGDs, to prove the scalability of the concepts, the industrialisation of the production, and to facilitate the circulation of information, ideas and solutions.

Goal:

Advance the techniques of MPGDs, related electronics, and software, enhancing the effectiveness of the developments, still maintaining the identity and the specificity of each project.

Institute collaborations on MPGD developments based on publications




A world-wide collaboration

86 institutes and more than 500 members



Unbiased benchmark of the effectiveness of the RD51 collaboration



FRONTIER DETECTORS FOR FRONTIER PHYSICS
Pisa Meeting on Advanced Detectors

Gas Detectors

Status Report of the Upgrade of the MEG-II detector

Speaker: Dr. Gilles De Lentdecker (Université Libre de Bruxelles)

Material: [Slides](#)

Micromegas Detectors for the MEG-II detector

Speaker: Michele Bianco (INFN)

Material: [Slides](#)

A continuous read-out TPC-like readout for thermal neutron detection using a GEM-detector

Speaker: Dr. Christian Lippmann (GSI Helmholtzzentrum für Schwerionenforschung)

Material: [Slides](#)

TPC-like readout for thermal neutron detection using a GEM-detector

Speaker: Mr. Bernhard Flierl (LMU Munich)

Material: [Slides](#)

Cylindrical Micromegas, an innovative detector for central trackers.

Speaker: Dr. Maxence Vandenbroucke (CEA Saclay)

Material: [Slides](#)

Resistive MPGDs based on the W80 technology

Speaker: Marco Poli Lener (LNF)

Material: [Slides](#)

Charge Transfer Properties Through Micromegas for Applications in Gaseous Detectors

Speaker: Filippo Resnati (CERN)

Material: [Slides](#)

Photo Detectors and PID

Status of the Development of Large Area Micromegas Detectors for Cherenkov Ringing Applications

Speaker: C. A. Santos (INFN, Sezione di Trieste, Trieste, Italy)

Material: [Slides](#)

Gas Detectors - Poster Session

A Dedicated Calibration Tool for the MEG and MEGII Positron Spectrometer
Speaker: Ms. Glada Rutar (Paul Scherrer Institut Villigen and ETHZ)
Material: [Poster](#) [Slides](#)

A compact Time Projection Chamber for the Crystal Ball
Speaker: Mr. Oliver Steffen (Institut für Kernphysik, Universität Mainz)
Material: [Poster](#)

A new construction technique of high granularity and high transparency Drift Chambers for modern High Energy Physics experiments
Speaker: Gianluigi Chiarello (LE)
Material: [Poster](#) [Slides](#)

A new cylindrical drift chamber for the MEG-II experiment
Speaker: Marco Grassi (PI)
Material: [Poster](#) [Slides](#)

A novel method to estimate the impact parameter on a drift chamber cell by using the information of single ionization clusters.
Speaker: Marco Venturini (PI)
Material: [Poster](#) [Slides](#)

A proposal to upgrade the ATLAS RPC system upgrade for the High Luminosity LHC
Speaker: Riccardo Vari (ROMA1)
Material: [Poster](#) [Slides](#)

Building and Commissioning of a Setup to Study A
Speaker: Mr. alim... (GSI), Dr. Saikat Biswas (Institute of Science Education and Research)
Material: [Slides](#)

Characterization of Large Area Resistive Strip Micromegas Detectors
Speaker: Mr. P... (Ludwig-Maximilians-Universität München)
Material: [Slides](#)

Characterization of a quadruplet prototype
Speaker: ... (University of Würzburg)
Material: [Slides](#)

Characterization of a detector prototype
Speaker: ... (National Institute of Science Education and Research, India)
Material: [Slides](#)

Cluster ions in micromegas detectors
Speakers: Mr. ... (Goethe University), Mr. Yalçın Kalkan (Uludağ University)
Material: [Slides](#)

Construction and Commissioning Studies of a Micromegas Detector with a Pad Readout Geometry
Speaker: Mr. ... (Univ. Mainz)
Material: [Slides](#)

Construction and commissioning of the SuperNEMO detector tracker
Speaker: Dr. Michele Cascella (Università del Salento e INFN di Lecce)
Material: [Poster](#) [Slides](#)

Design of a large area GEM forward detector system based on industrially produced GEM
Speaker: Prof. B... (Temple University)
Material: [Poster](#)

Determination of the anode wire position in a straw of the new type using visible light
Speaker: Dr. Levan Glonti (JINR)
Material: [Poster](#) [Slides](#)

Test of ...
Speaker: ...
Material: [Slides](#)

Fibre Bragg Grating (FBG) sensors as flatness and mechanical stretching sensors
Speaker: Luigi Benussi (LNF)

High resolution timing for muon detectors at future colliders
Speaker: Roberto Cardarelli (ROMA2)
Material: [Slides](#)

Investigation on the performance of the muon system
Speaker: ...
Material: [Slides](#)

MEG II drift chamber prototype characterisation with the silicon based cosmic ray tracker at INFN Pisa
Speaker: Luca Galli (PI)
Material: [Poster](#) [Slides](#)

MRPC detector for MAMBO photonuclear experiment in Bonn
Speaker: ... (Physikalisches Institut, Uni-Bonn)

Operation of a GEM detector with a CMOS sensor
Speaker: ...
Material: [Poster](#) [Slides](#)

Applications - Poster Session

Detector for ...
Speaker: ...
Material: [Slides](#)

Fast Detection with Liquid-Xe Detector for Contraband
Speaker: ... (Max-Planck-Institut für Physik)
Material: [Slides](#)

MON ...
Speaker: ...
Material: [Slides](#)

Photo Detectors and PID - Poster Session

... for R&D for the HL-LHC experiment
Speaker: Dr. ... (Princeton University)
Material: [Slides](#)

Performance simulation studies for the ALICE TPC GEM Upgrade
Speaker: Martin Junggren (Lund University)
Material: [Slides](#)

Precision Muon Tracking Detectors and Readout Electronics for Operation at Very High Background Rates at Future Colliders
Speaker: Hubert Kroha (Max-Planck-Institut für Physik)
Material: [Poster](#) [Slides](#)

Resistive Micromegas for ...
Speaker: Dr. maximilien ... (IN2P3/LAPP)
Material: [Slides](#)

Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment
Speaker: Estel Perez (TRIUMF)
Material: [Poster](#) [Slides](#)

Study of gain variation as a function of physical parameters of GEM foil using Garfield
Speaker: Dr. Supriya Das (B...)
Material: [Slides](#)

Study of mesh ... micromegas performance with an Exchange
Speaker: Mr. ... (University of Würzburg)
Material: [Slides](#)

Systematic measurement of the energy resolution of single mask GEM
Speaker: Dr. ... (Institute of Science Education and Research)
Material: [Slides](#)

The drift chamber with a new type of straws for operation in vacuum
Speaker: Dr. Yuri Potrebennikov (JINR, Dubna)
Material: [Poster](#) [Slides](#)

Triple-stack Resistive Plate Chamber with Strip Readout for Particles Identification in the BM@N and MPD Experiments.
Speaker: Mr. Vadim Babkin (Joint Institute for Nuclear Research)
Material: [Slides](#)

Upgrades of the ATLAS Muon Spectrometer with sMDT Chambers
Speaker: Dr. Claudio Ferretti (University of Michigan)
Material: [Poster](#) [Slides](#)

A Cylindrical ... Experiment
Speaker: ...
Material: [Poster](#) [Slides](#)

Ageing tests for the MEG II drift chamber
Speaker: Mr. Marco Venturini (PI)
Material: [Poster](#) [Slides](#)

Protonated water clusters in TPC detector
Speaker: Dr. Yunus KAYA (Uludağ University)
Material: [Poster](#) [Slides](#)

Legend:

- RD51 = project is in the list of RD51 member
- LAB = as a project they have/had permanent installation in the RD51 lab
- VIS = has used the RD51 lab for specific measurements
- TB = has used the RD51 test beam facility
- SRS = has used the RD51 Scalable Readout System (SRS)
- G&C = has used simulation tool for MPGD (Garfield etc.)
- MPT = MPGD from the MPT workshop
- CF = RD51 Common Fund Projects

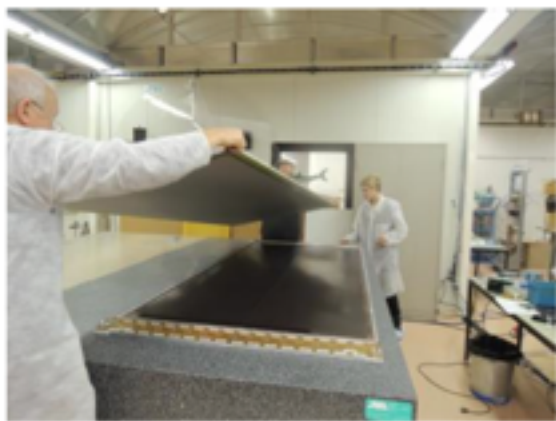
A total of 28 contributions from 2015 Frontier Detector for Frontier Physics involved (in one way or another) RD51 collaboration

Thanks to Eraldo Oliveri for the slide

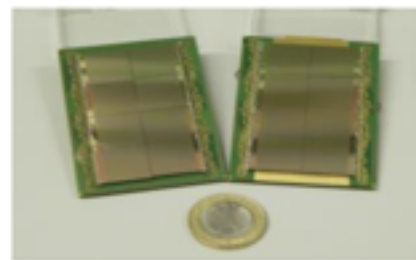
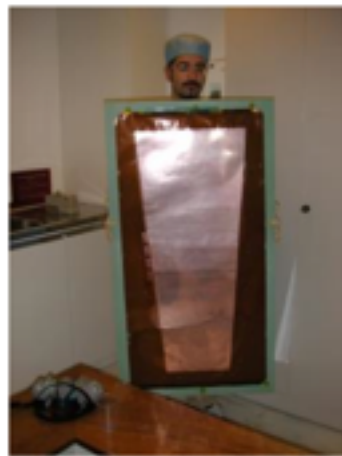
ICHEP - Chicago - 5th August 2016

7

Technological Aspects
New Detector Structures

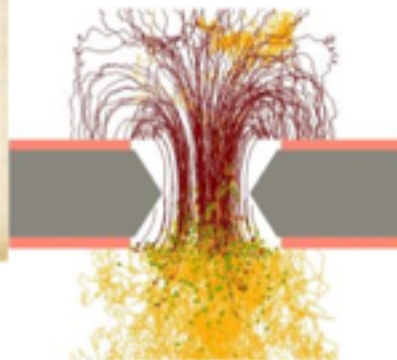


WG1:



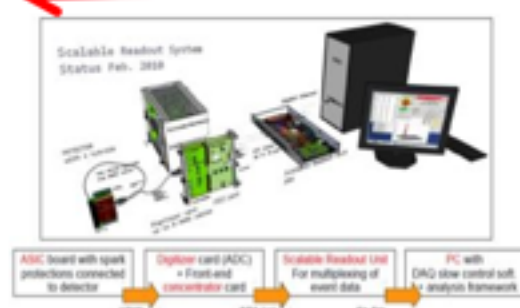
WG2:

Detector Physics and
Performance
RD51 Common Projects



WG5:

MPGD
Electronics



RD51

WG4:

Modeling of Physics
Processes
Software Tools



WG7:

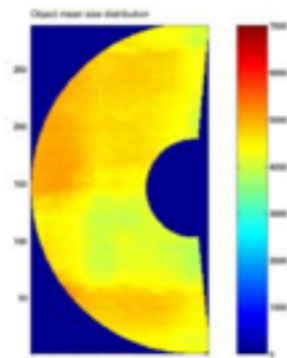
WG3:

Applications, Training
and Dissemination

WG6:



Common Test Facilities



Production and
Industrialization

Achievements

MPGD developments for LHC upgrades (ALICE TPC, ATLAS NSW, and CMS GE1/1) - and not only - originally emerged from RD51 activities to make large $O(m^2)$ and reliable (stable and spark protected) MPGDs.

Several other examples of successful developments profit from (or are part of) these activities:

- BESSIII tracker (cylindrical GEM)
- CLAS12 tracker (planar and cylindrical MM)
- COMPASS RICH (THGEM+MM)
- ...

Large GEMs

Historically, GEMs were produced with *double-mask* technique

Precision mask alignment implies constraints on detector size $O(30 \times 30 \text{ cm}^2)$

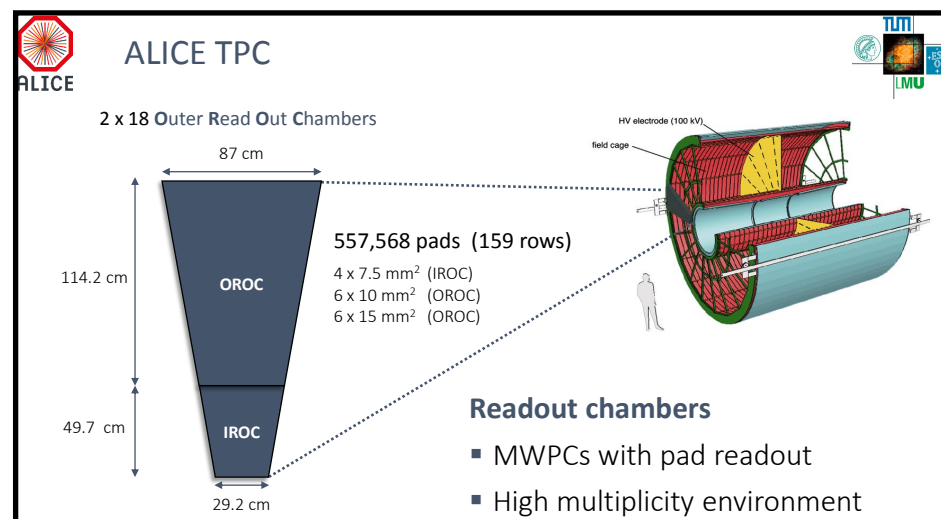
Development of the *single-mask* method

Size of the raw material is now the limit $O(>1 \text{ m} \times 60 \text{ cm})$

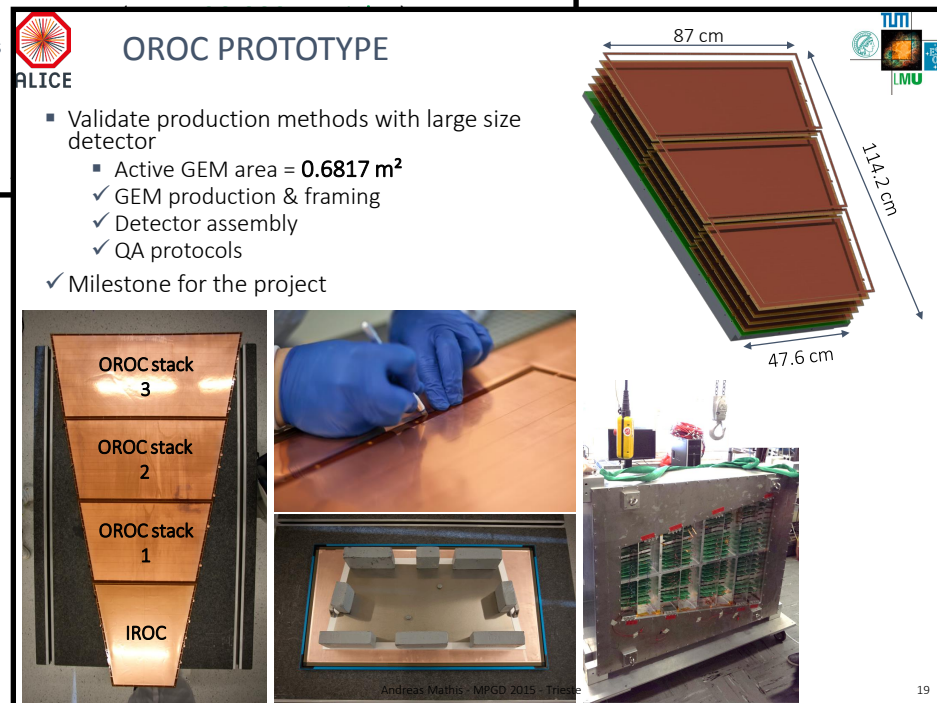
Significant reduction of GEM price per square metre

Large GEMs at LHC

ALICE TPC (4 GEMs)
130 m²



In production

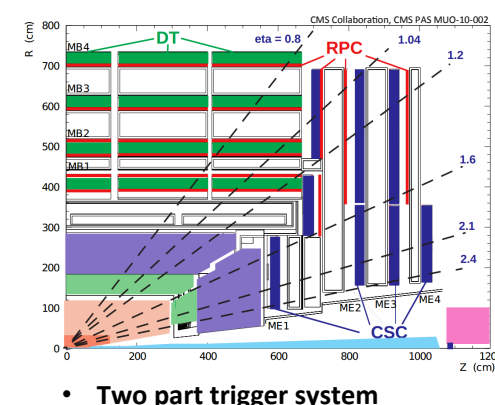


A. Mathis, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=9&sessionId=2&resId=0&materialId=slides&confId=8839>

CMS GE1/1 (GEM)
1000 m²

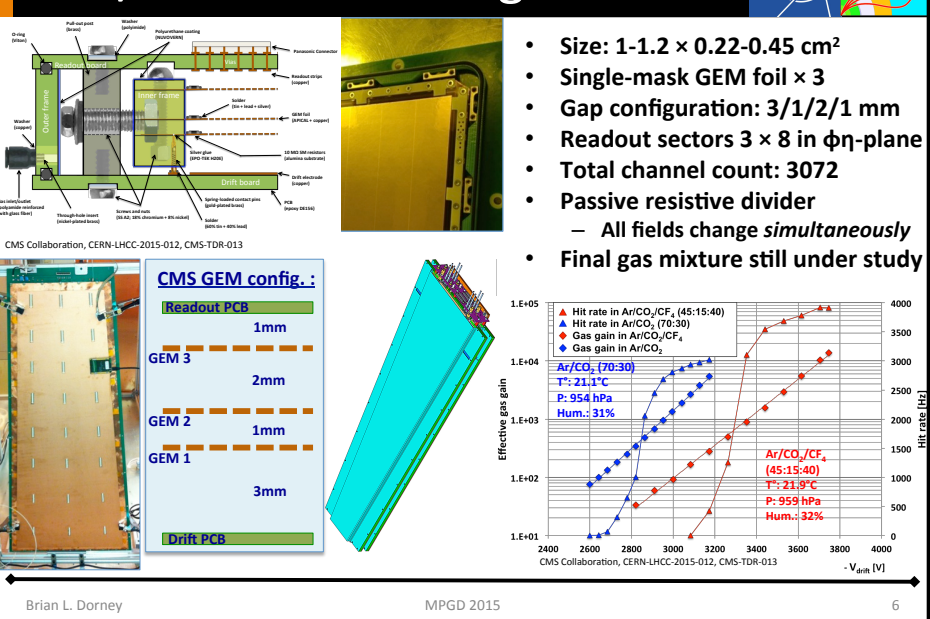
CMS Trigger and Original Muon System Design

- Redundant muon system
 - Drift tubes (DT); $|\eta| < 1.2$
 - Resistive plate chambers (RPC); $|\eta| < 1.6$
 - Cathode strip chambers (CSC); $1.0 < |\eta| < 2.4$
- Original RPC's coverage planned to extend to entire CSC range
 - Un-instrumented due to rate capability concerns
- Only CSC system provides muon information beyond $|\eta|$



In production

GE1/1 Detector Design



B. Dorney, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=66&sessionId=2&resId=0&materialId=slides&confId=8839>

4 GEMs to
reduce the IBF

No glue required
for the stretching

Resistive MM

Discharges may occur in any MPGD

Reduction of the discharge probability and discharge effects is mandatory

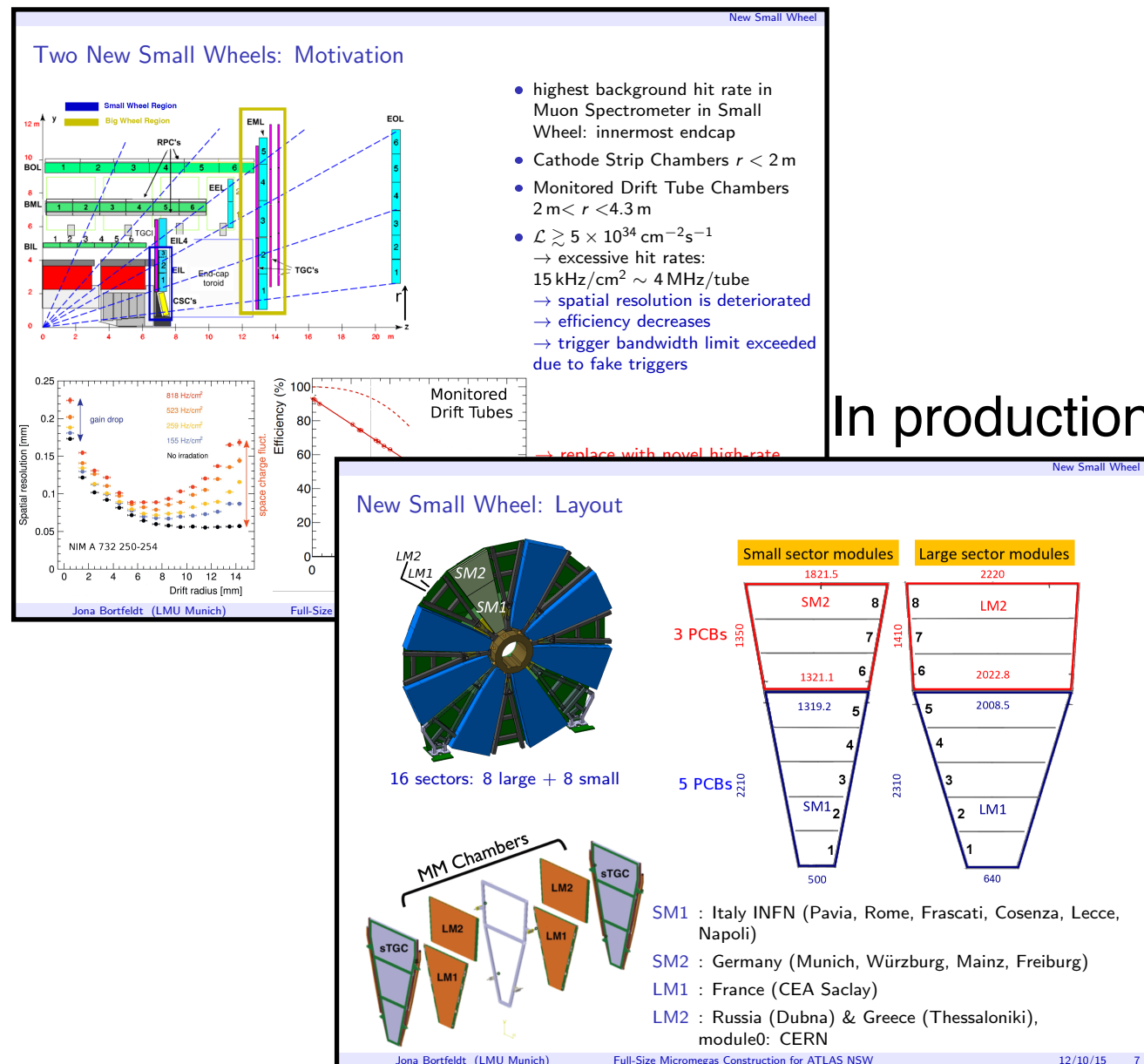
Development of resistive electrodes that locally quench the discharges

Apply these techniques to the MM anode

Enable a natural way for the two views readout

Resistive MM at LHC

ATLAS NSW (MM)
1200 m²



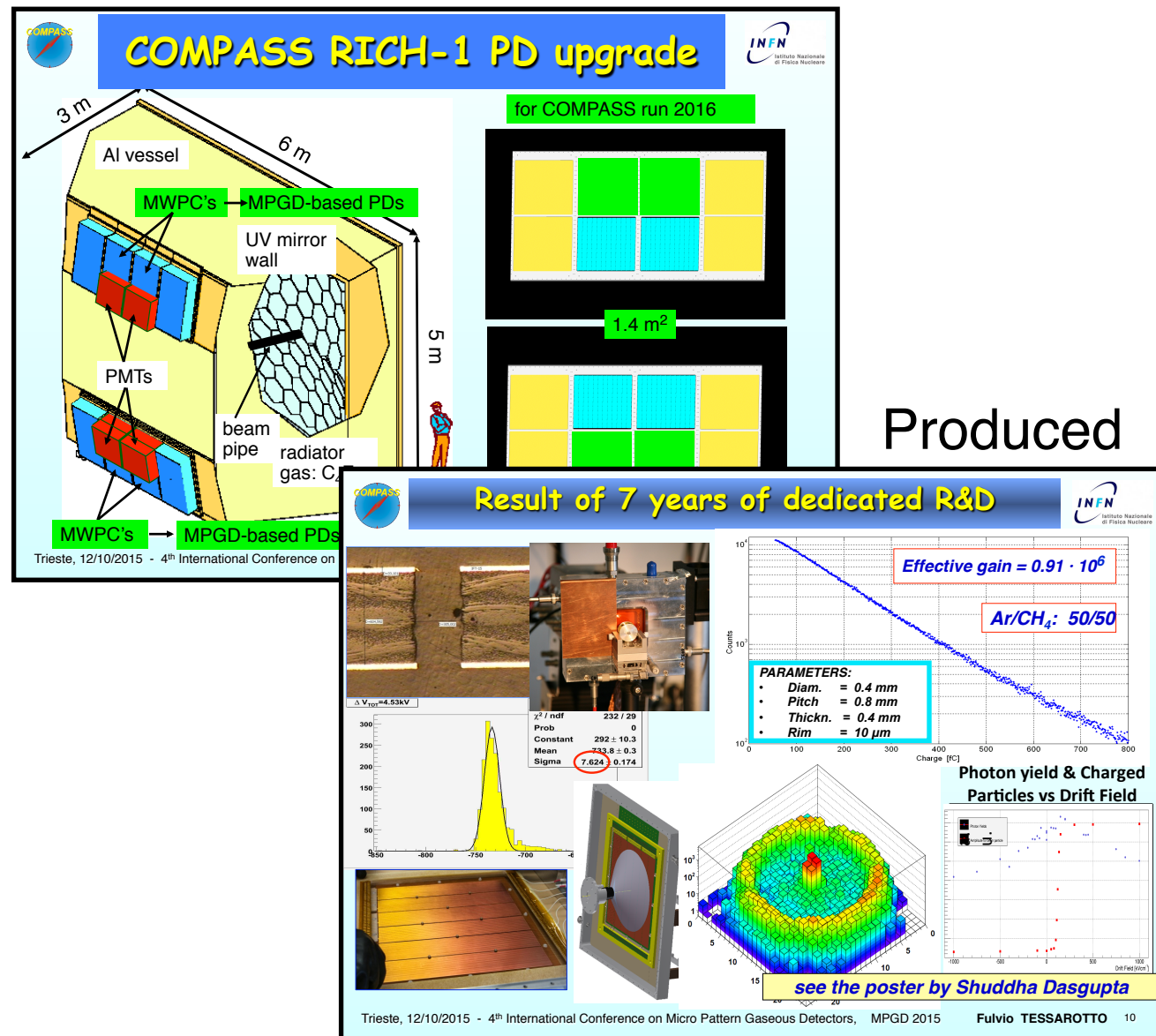
Micromegas mesh is laid on pillars and *fixed* by electrostatic force
 Floating mesh eases the production and the assembly phases

Industrialisation:
 Production of detector components will be done at PCB companies
 Tenders were asked to ELTOS and ELVIA

J. Bortfeldt, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=51&sessionId=2&resId=0&materialId=slides&confId=8839>

Hybrid detectors

COMPASS RICH
2 THGEMs and bulk MM
4.5 m²



Very large and stable gain is required for single Cherenkov photon detection

2x THGEMs and a non-resistive bulk MM and CsI photocathode

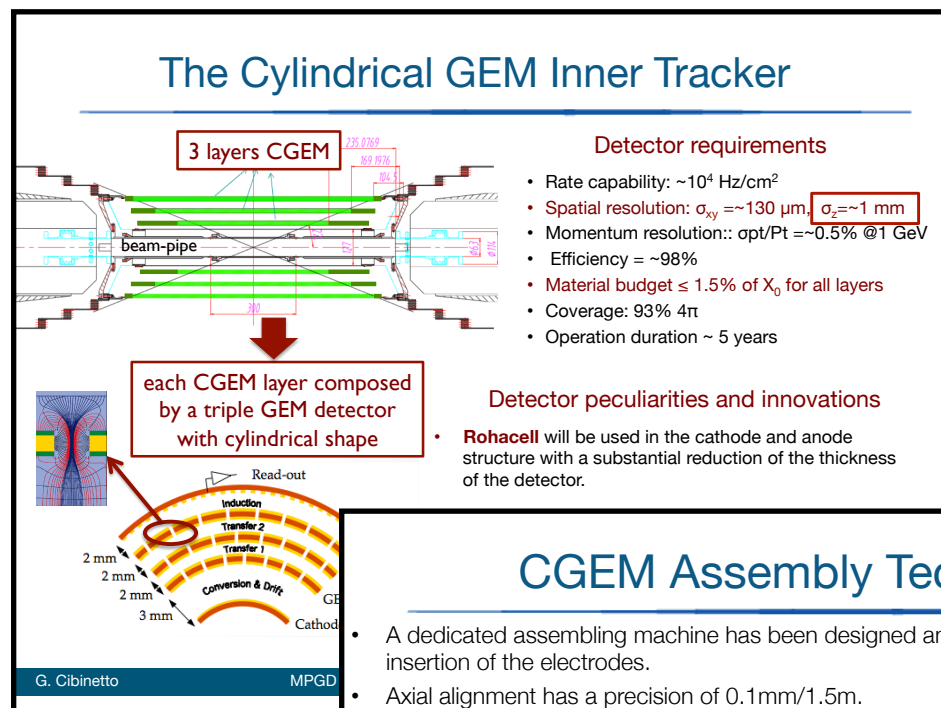
Big effort put on reducing the discharge probability and gain uniformity

Industrialisation:
ELTOS and ELVIA actually produced the THGEM PCBs

F. Tassarotto, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=104&sessionId=2&resId=0&materialId=slides&confId=8839>

Different shapes

BESSIII (Cylindrical GEM)



In production

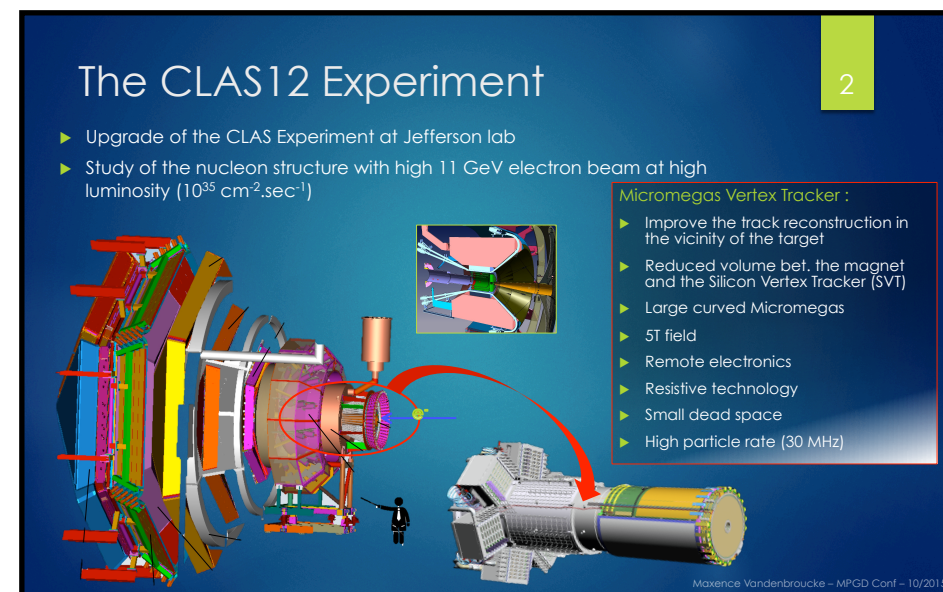
CGEM Assembly Technique

- A dedicated assembling machine has been designed and realized to perform the insertion of the electrodes.
- Axial alignment has a precision of 0.1mm/1.5m.
- The structure can rotate by 180° around its central horizontal axis.



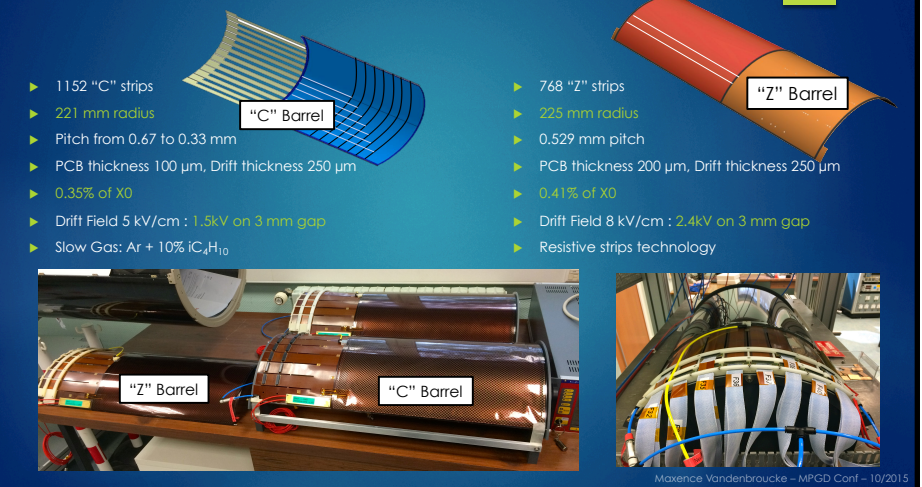
G. Cibirnetto, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=28&sessionId=2&resId=0&materialId=slides&confId=8839>

CLAS12 (Cylindrical MM)



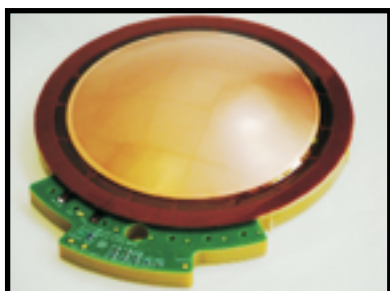
Produced

CLAS12 Barrel Detectors



M. Vandenbroucke, MPGD2015, <https://agenda.infn.it/getFile.py/access?contribId=81&sessionId=2&resId=0&materialId=slides&confId=8839>

Spherical GEMs are also possible
arXiv:1011.5528



Future perspectives

Extend the scope of MPGDs:

- other applications in HEP (e.g. calorimetry)
- other applications in non-HEP (e.g. rare event search)
- applications beyond fundamental physics

Extending the performance of MPGDs:

- increase detection efficiency for gammas and neutrons
- improve the time resolution

Academia Industry Matching

Understand the requirements, possible new applications, and new communities

On neutron detection (1st)

On neutron detection (2nd)

On photon detection



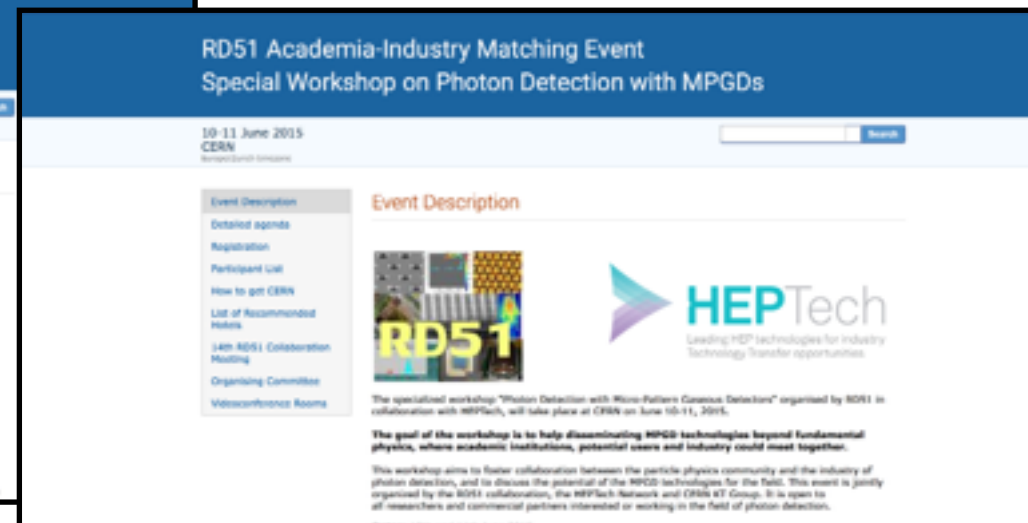
<https://indico.cern.ch/event/265187/>

14-15 October 2013
arXiv:1410.0107



<https://indico.cern.ch/event/365840/>

16-17 October 2015
arXiv:1601.01534



<https://indico.cern.ch/event/392833/>

10-11 June 2015

At the *Globe de l'Innovation* in front of CERN



Precise timing

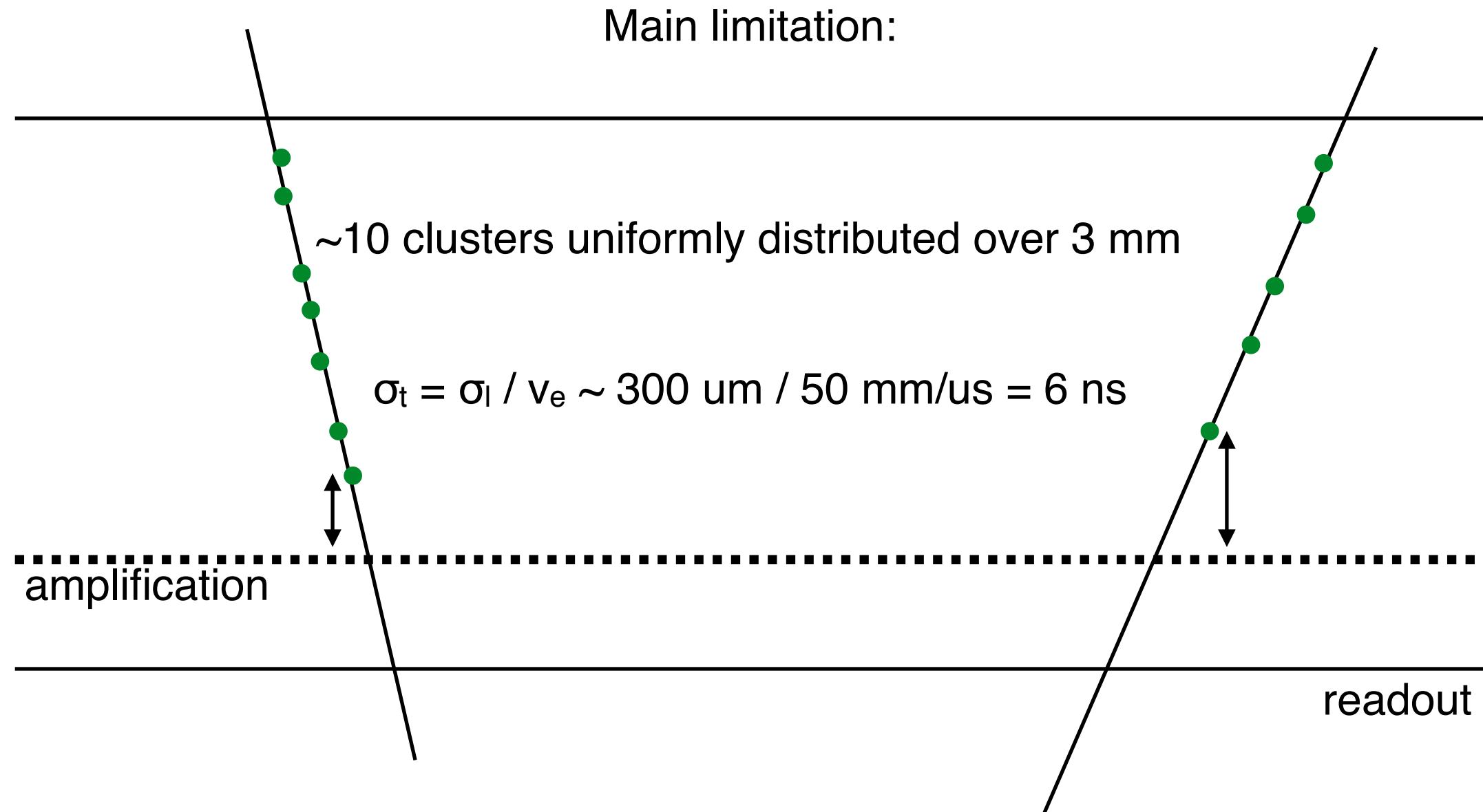
Driving reason:

development of large area and high-flux-capable detectors for pile-up mitigation in HL-LHC experiments

Presently, intrinsic time resolution to MIPs of MPGDs is of few nanoseconds

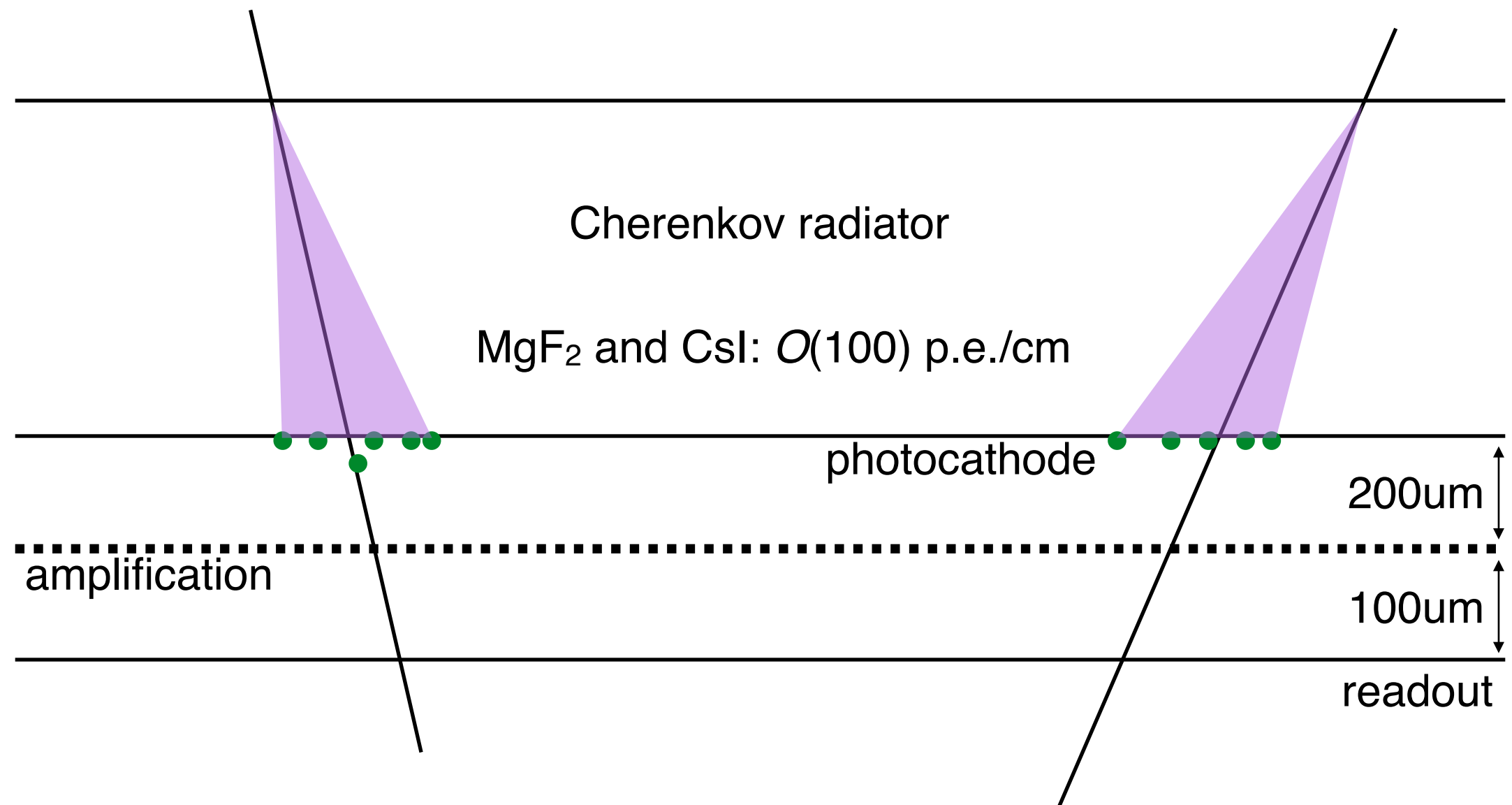
Improvement of almost two orders of magnitude needed

Timing with MPGDs



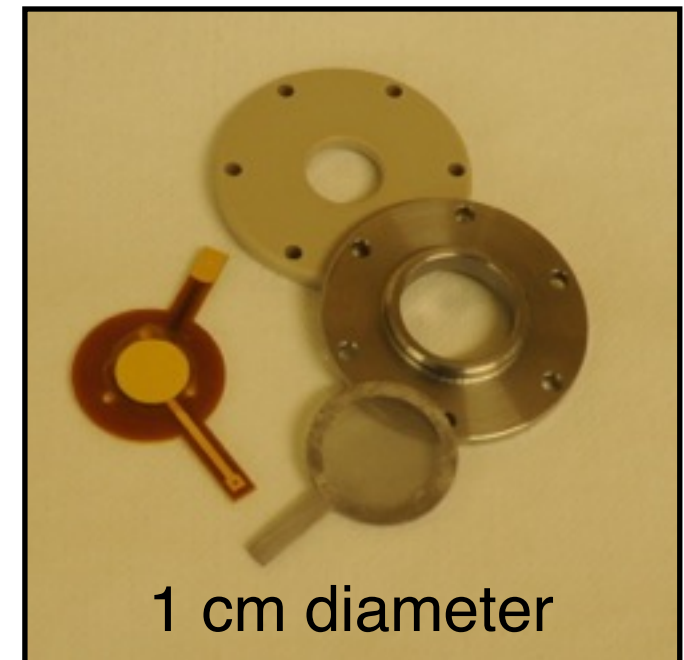
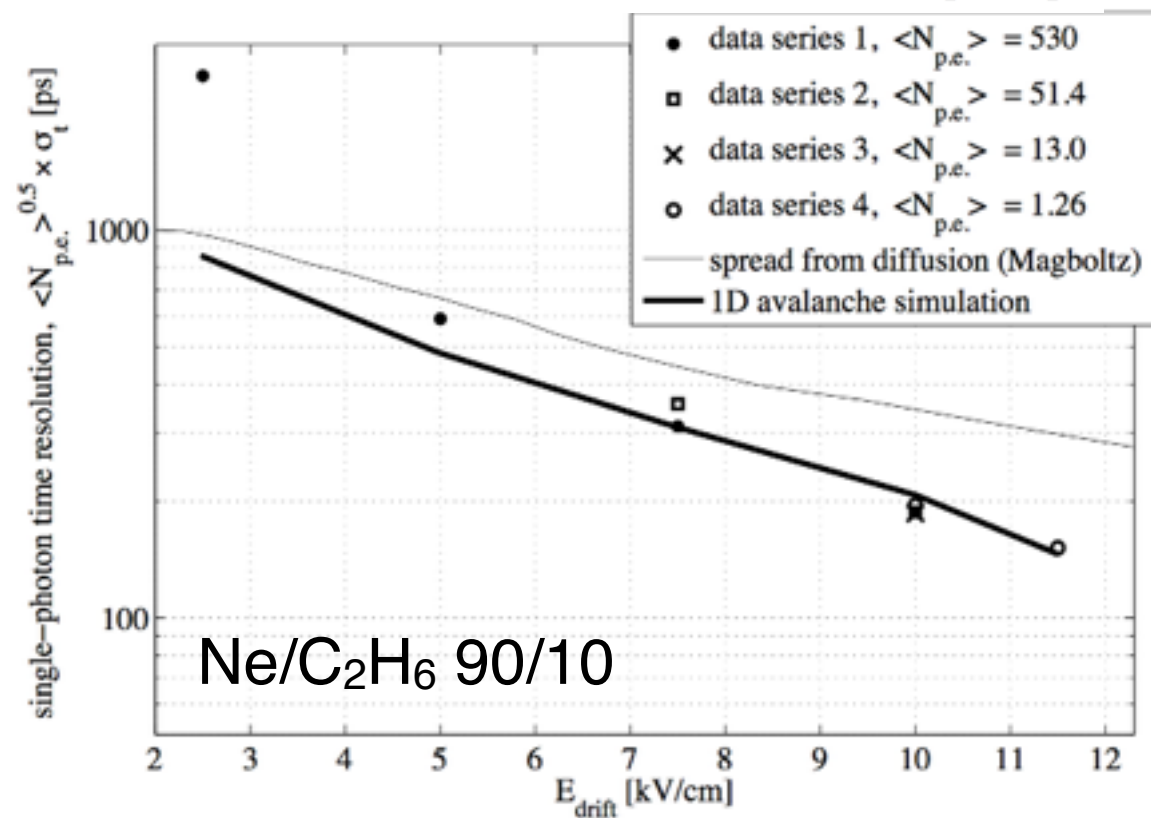
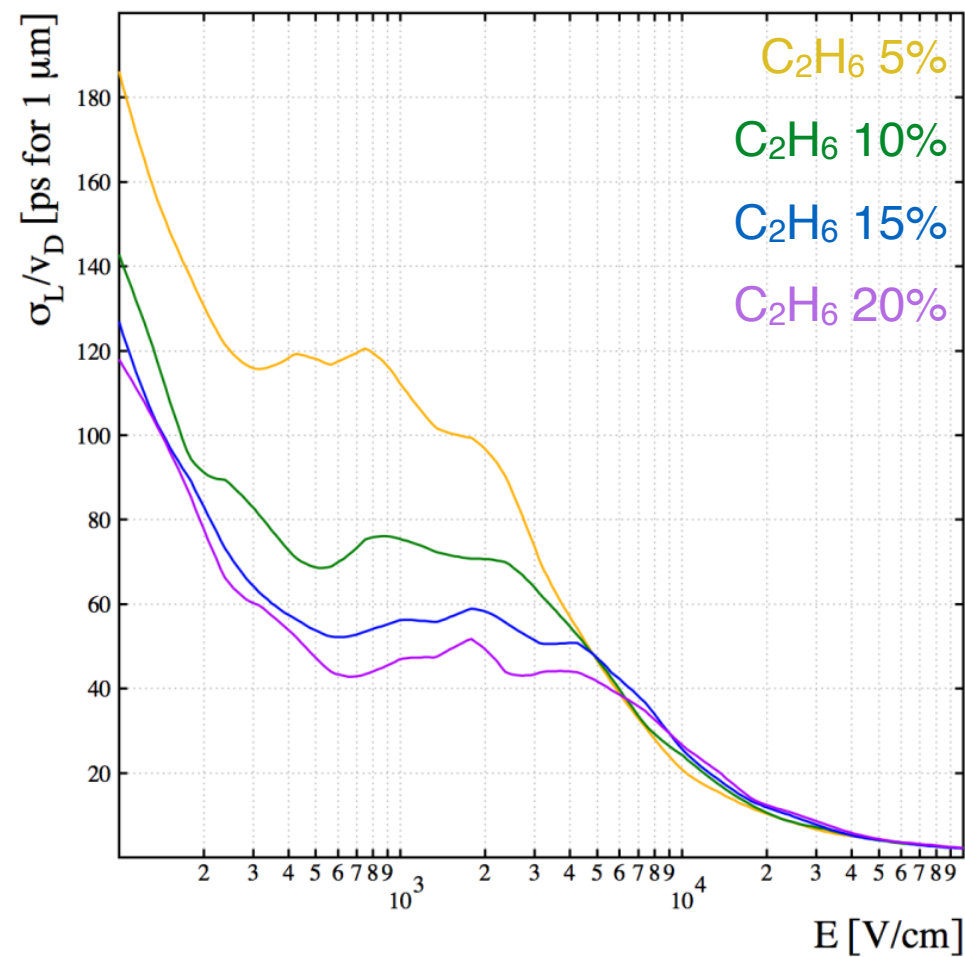
Statistics of the number of clusters helps, but contributions also from diffusion, electron velocity, signal to noise...

Timing with next MPGDs



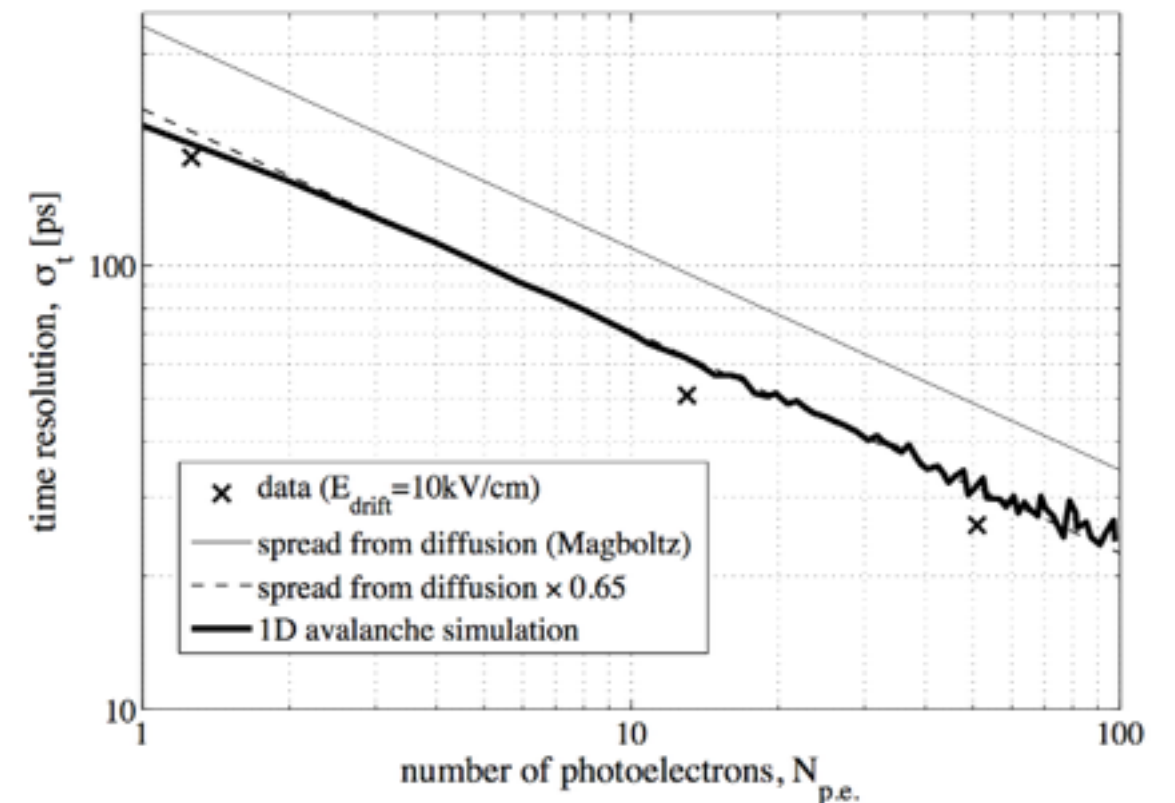
Limiting factor becomes the gas diffusion

Ne-C₂H₆



Detector operated in sealed mode

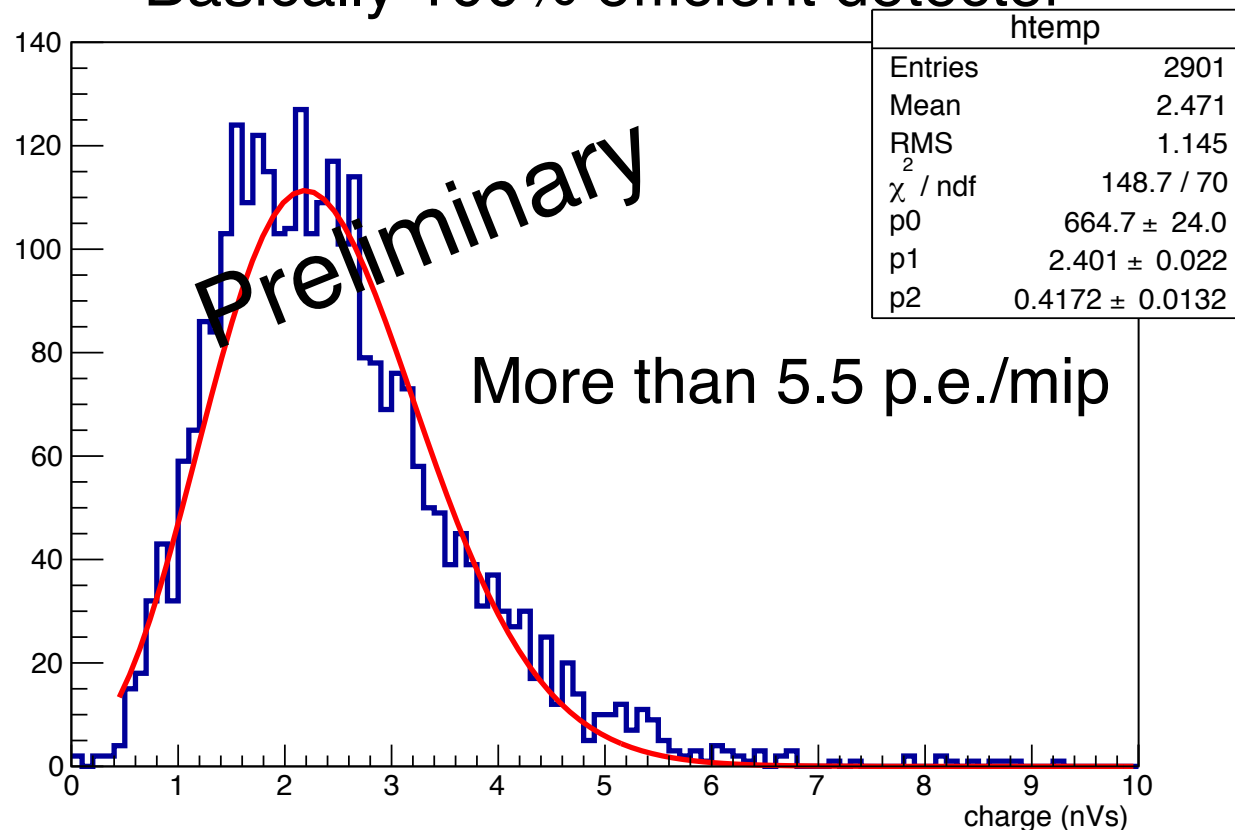
Tests with a femtosecond laser at LIDyL laboratory in CEA/Saclay



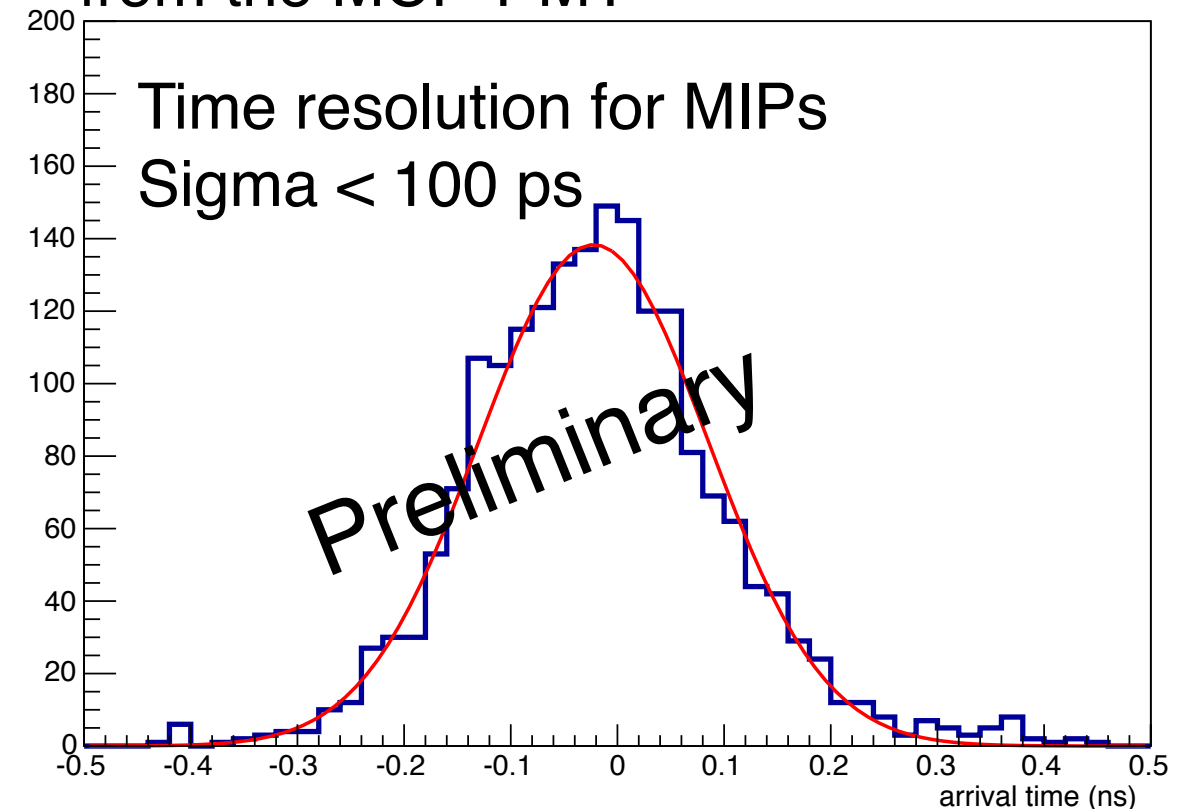
First test beam

Same detector operated in Ne/C₂H₆/CF₄

Basically 100% efficient detector



Without unfolding the t_0 measurement from the MCP-PMT



Time resolution will naturally improve because:
Photocathode improvement will lead to > 2x p.e.
Improvement of the gas quality will lead to larger gain

Tests of different gases and photocathodes planned
in the next test beam (starting from next Wednesday)

Summary

RD51: consolidated international collaboration of 86 institutes

Major progresses in the MPGD technologies, some of which picked up by large experiments

Always developing new structures and new ideas to meet the new requirements

Development of new production techniques, industrialisation of the established ones and quality control

Dissemination via schools, workshops, and specialised events to reach new potential users and understand new requirements