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

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on behalf of the RD51 Collaboration

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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

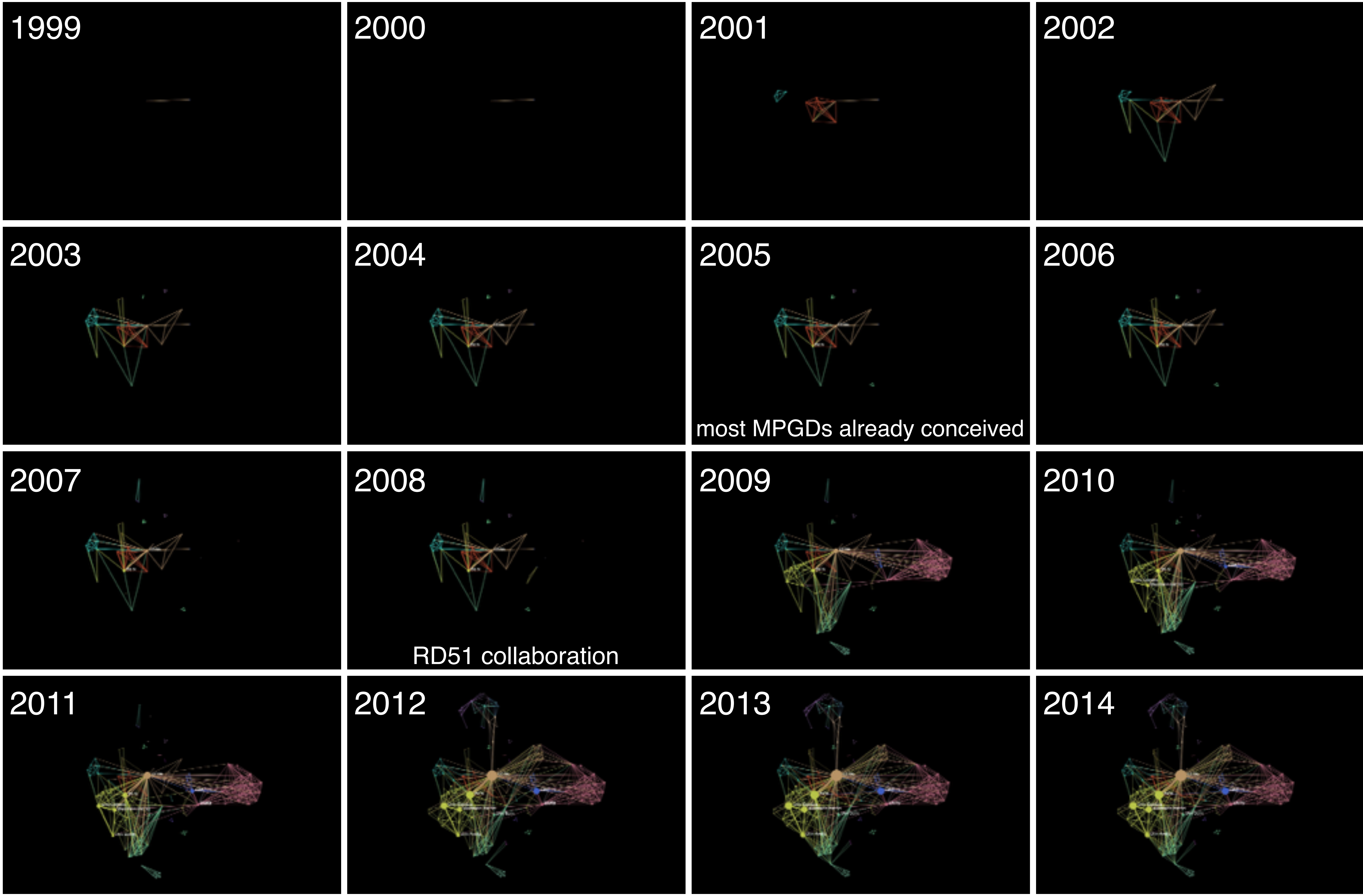
- High particle flux capable (MHz/mm^2)
- Large dimensions (several m^2)
- Not expensive (< 5 kCHF/m^2)
- Good position resolution (<50 um)
- Excellent time resolution (<5 ns and even *O*(100 ps))
- Radiation hard (10s year in forward muon chambers at LHC)
- Low material budget (<0.01 X_0)
- Compatible 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

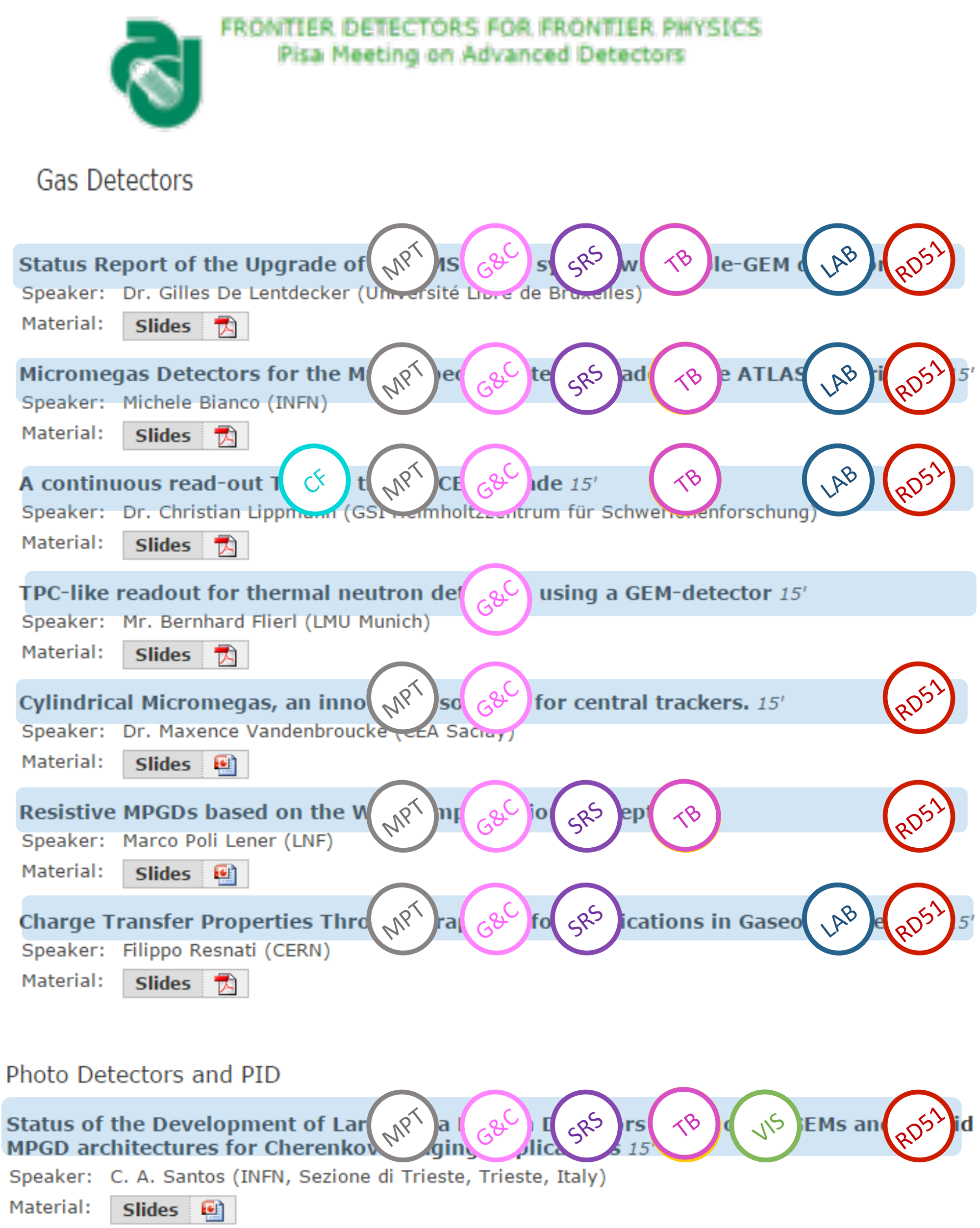


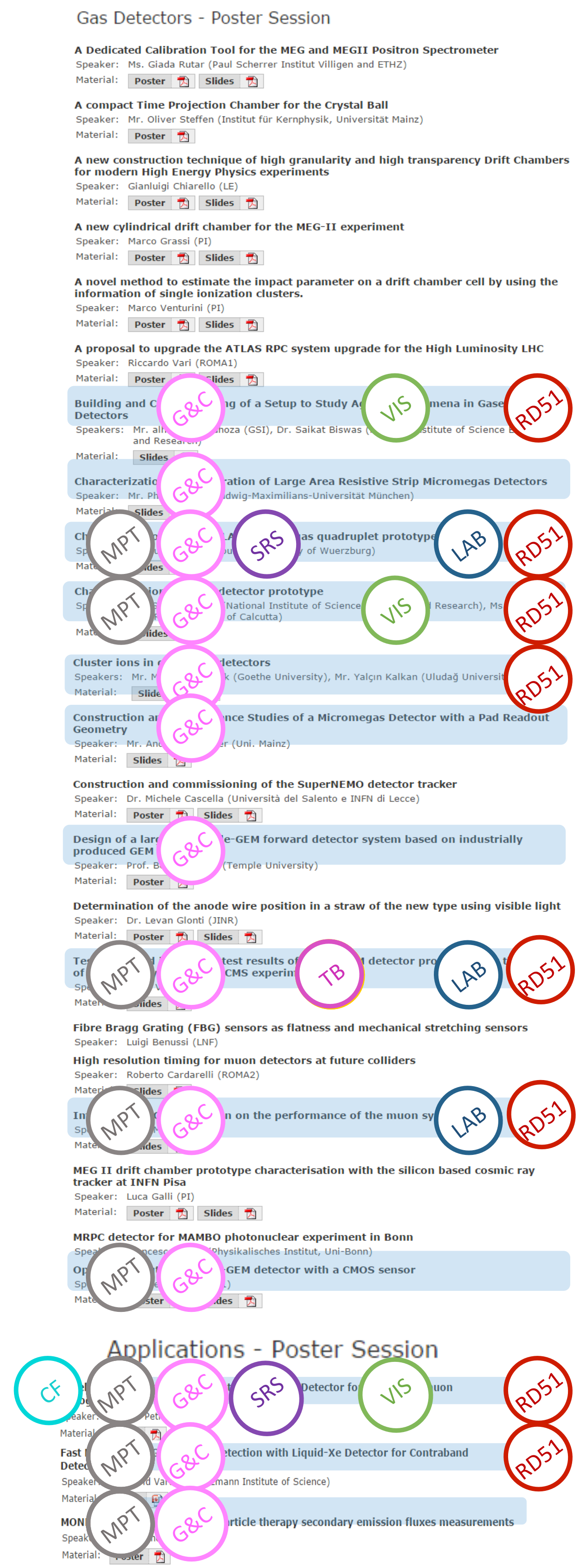
Collaboration Spotting http://collspotting.web.cern.ch

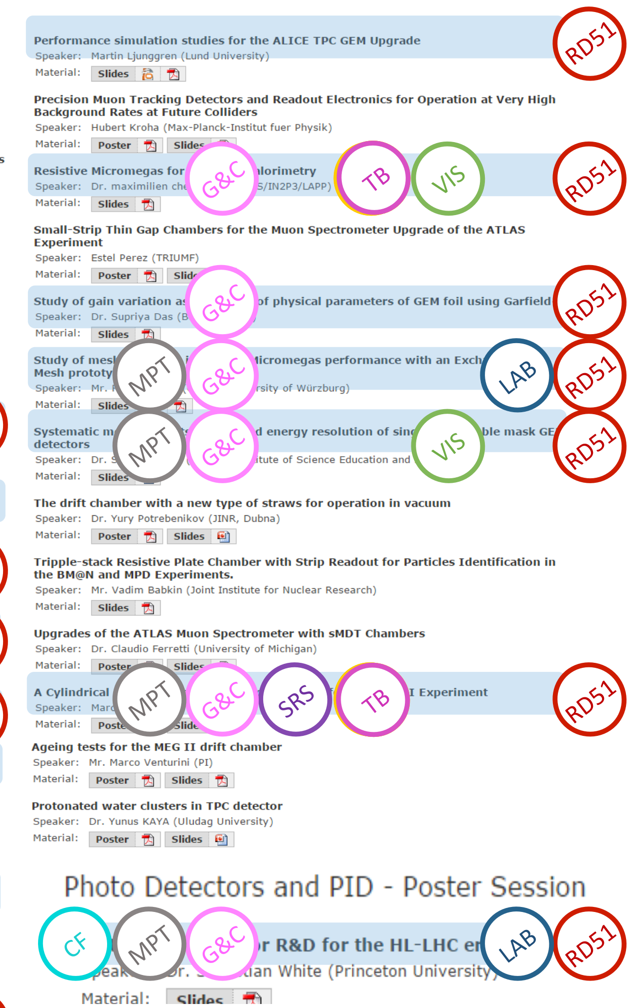
A world-wide collaboration

86 institutes and more than 500 members

Unbiassed benchmark of the effectiveness of the RD51 collaboration

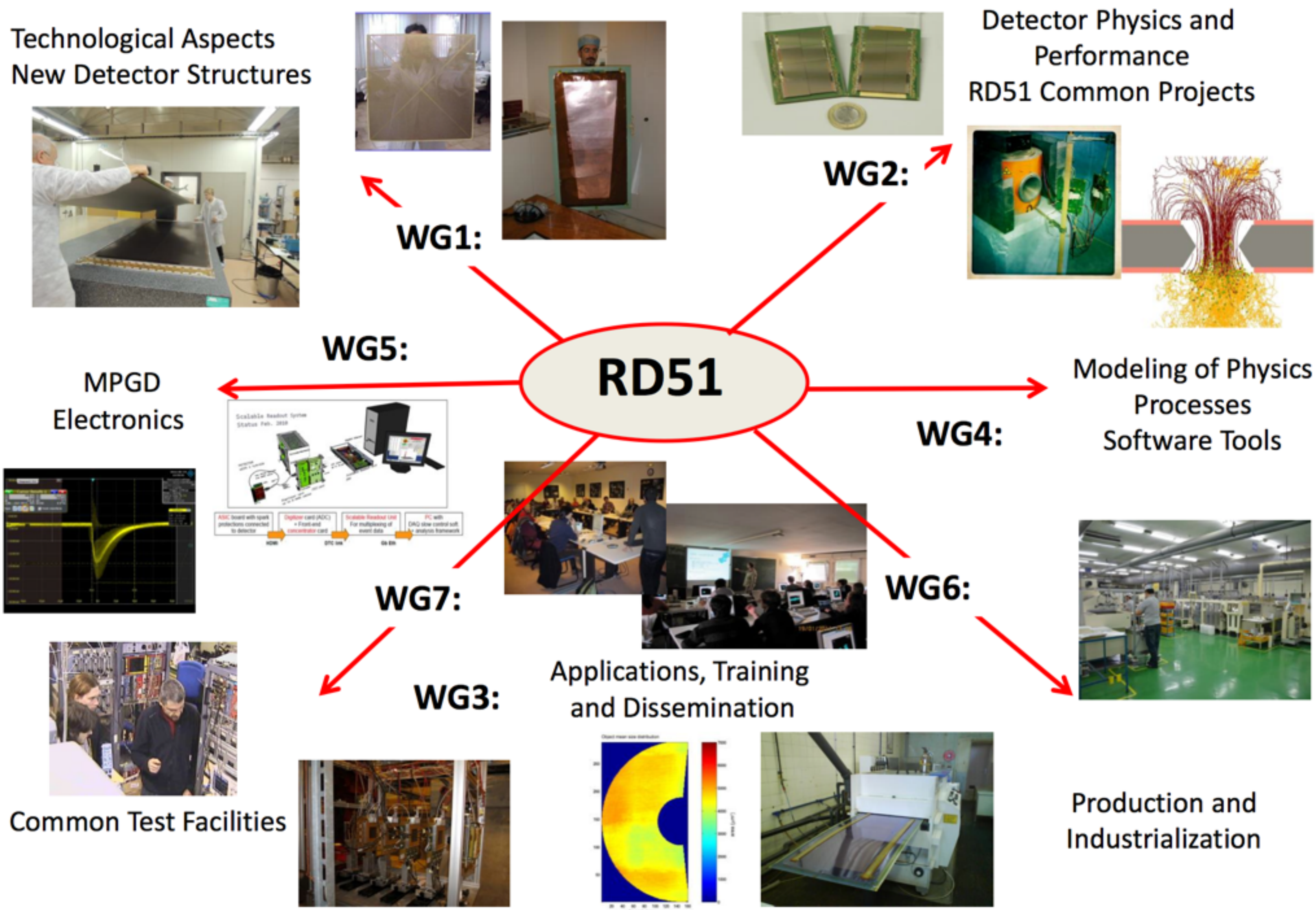






A total of 28 contributions from 2015 Frontier Detector for Frontier Physics involved (in one way or another) RD51 collaboration

- 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


Technological Aspects
New Detector Structures
WG1:
WG2:
Detector Physics and
Performance
RD51 Common Projects
RD51
WG5:
MPGD
Electronics
WG4:
Modeling of Physics
Processes
Software Tools
WG7:
WG6:
WG3:
Applications, Training
and Dissemination
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*(30x30cm^2)

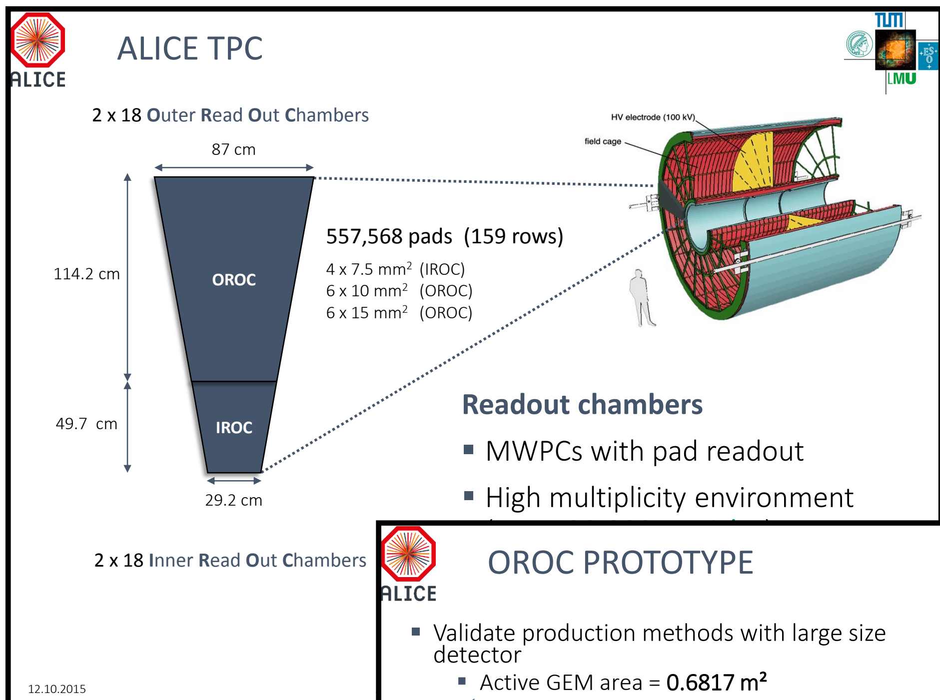
Development of the *single-mask* method

Size of the raw material is now the limit *O*(>1m x 60cm)

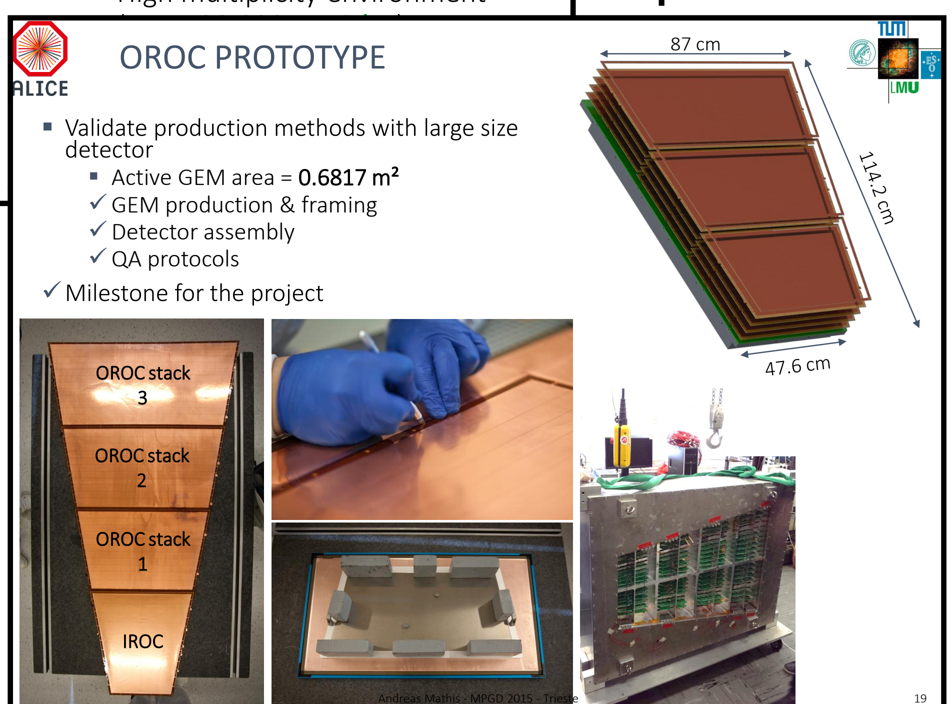
Significant reduction of GEM price per square metre

Large GEMs at LHC

ALICE TPC (4 GEMs)
130 m²



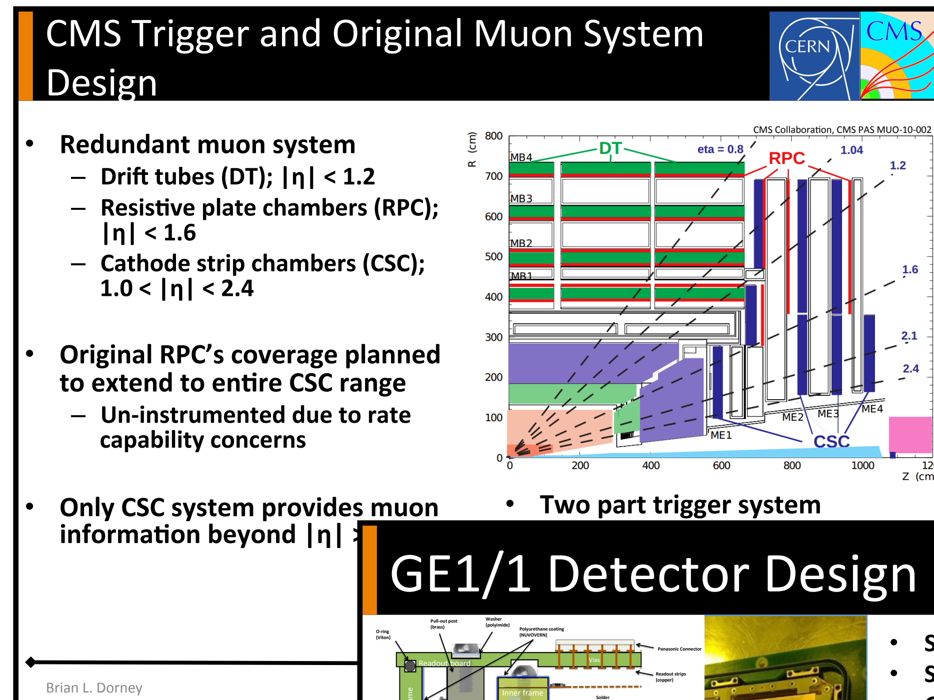
In production



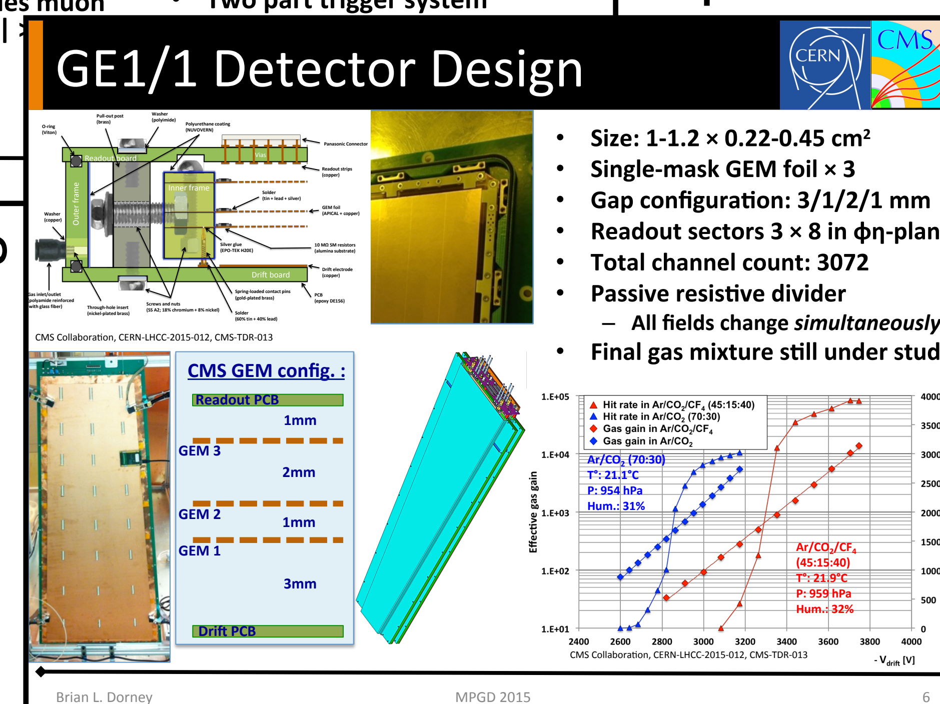
4 GEMs to reduce the IBF

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



In production



No glue required for the stretching

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

Resistive MM

Discharges may occur in any MPGD

Reduction of the discharge probability and discharge effects is mandatory

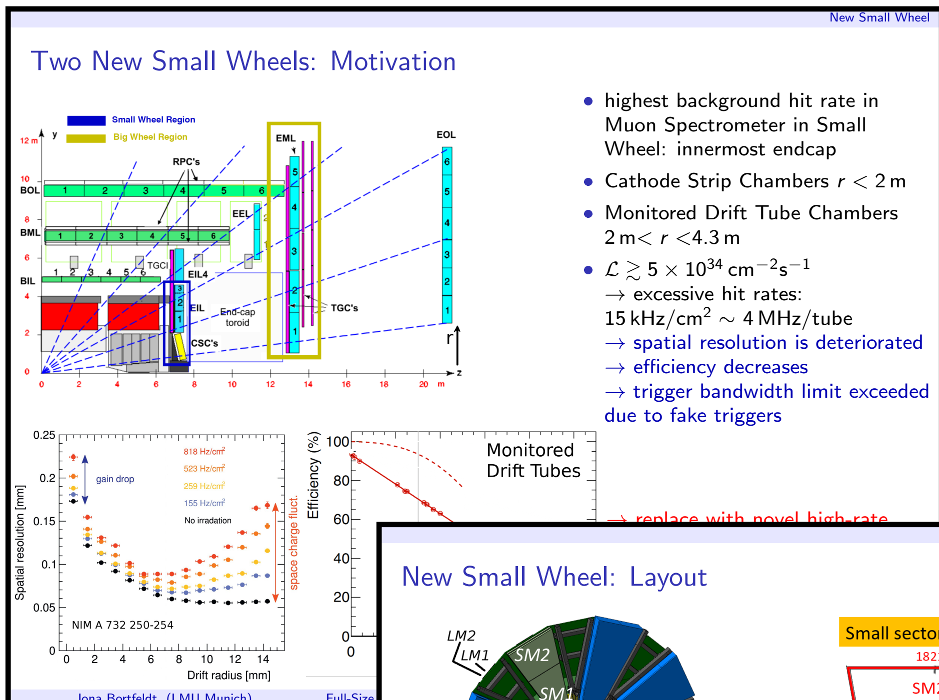
Development of resistive electrodes that locally quench the discharges

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



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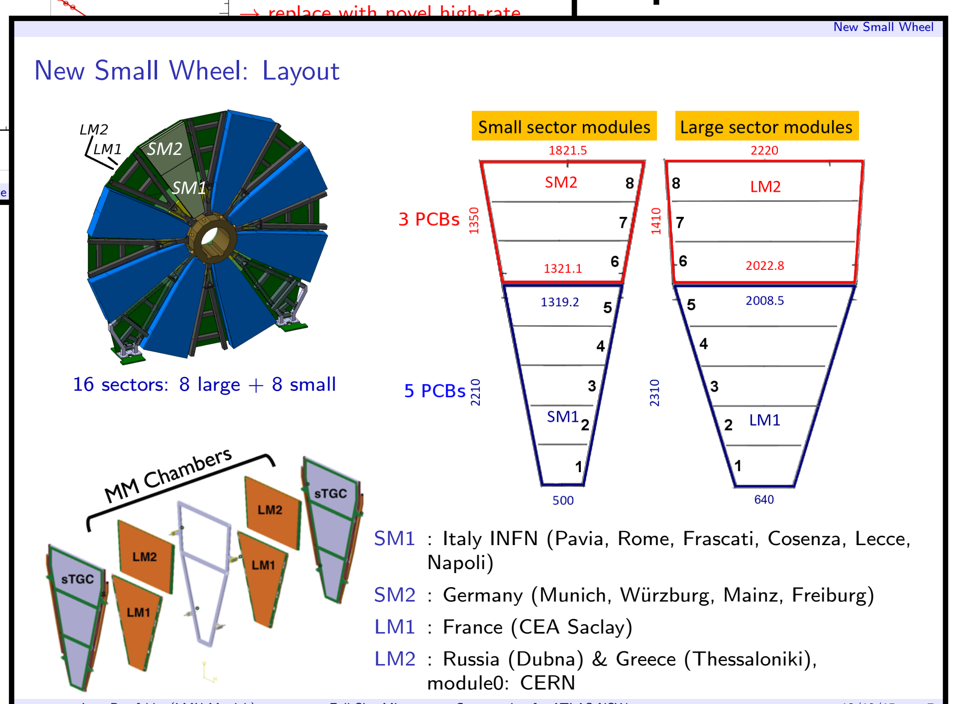


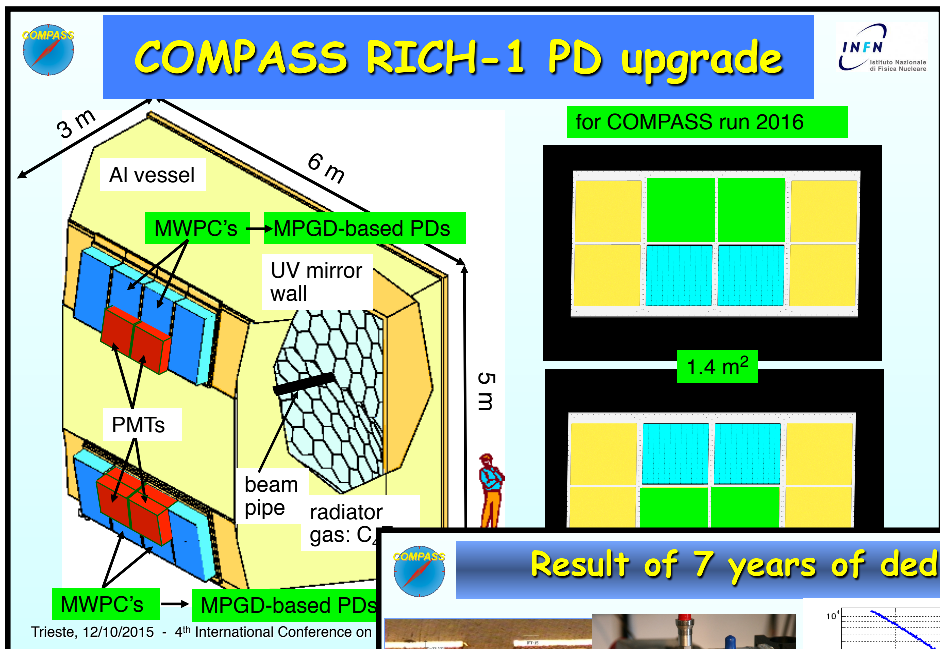
J. Bortfeldt, MPGD2015, https://agenda.infn.it/getFile.py/access?contribId=51&sessionId=2&resId=0&materialId=slides&confId=8839

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 by done at PCB companies
Tenders were asked to ELTOS and ELVIA

Hybrid detectors

COMPASS RICH
2 THGEMs and bulk MM
4.5 m^2



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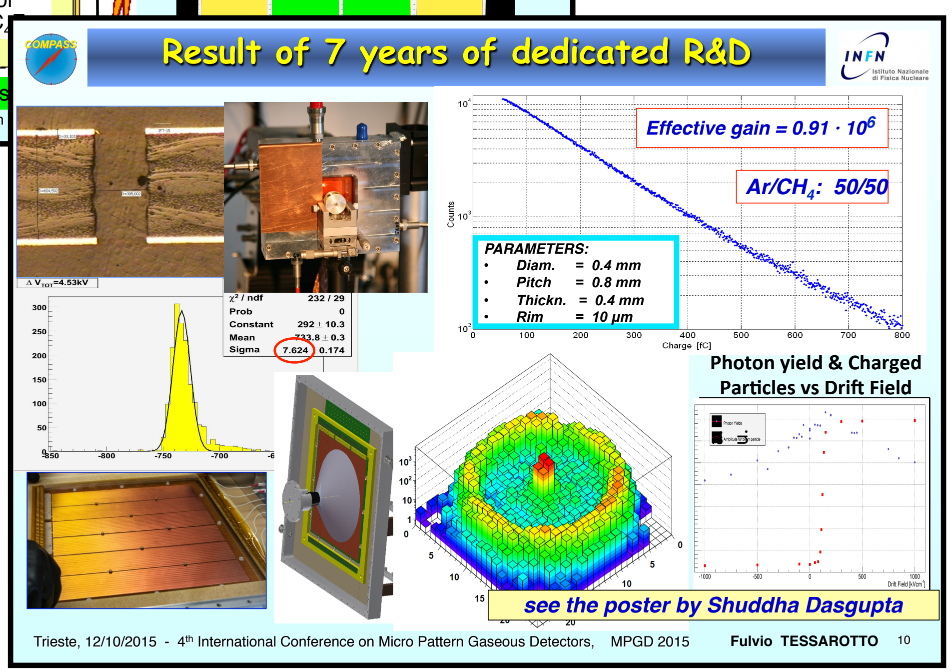


F. Tessarotto, MPGD2015, https://agenda.infn.it/getFile.py/access?contribId=104&sessionId=2&resId=0&materialId=slides&confId=8839

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

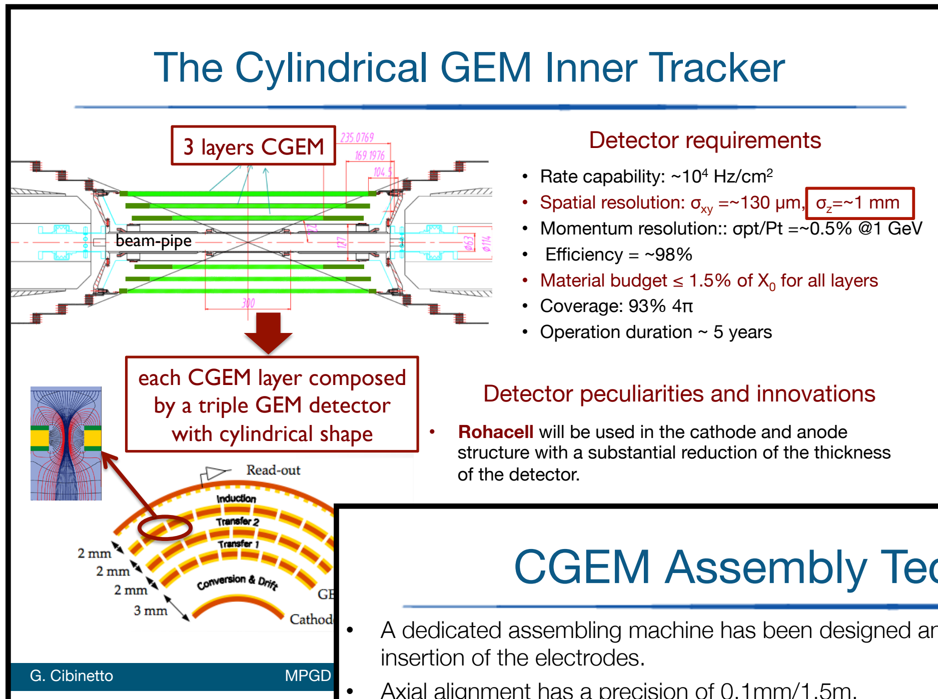
2x THGEMs and a non-resistive bulk MM and CsI photocathode

Big effort put on reducing the discharge probability and gain uniformity

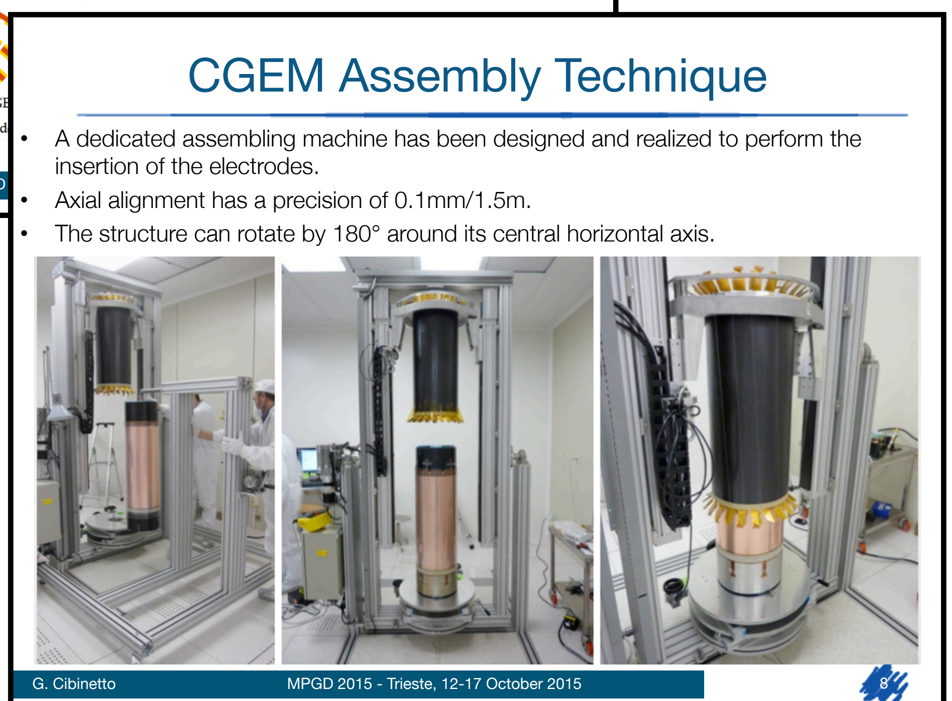
Industrialisation:
ELTOS and ELVIA actually produced the THGEM PCBs

Different shapes

BESSIII (Cylindrical GEM)

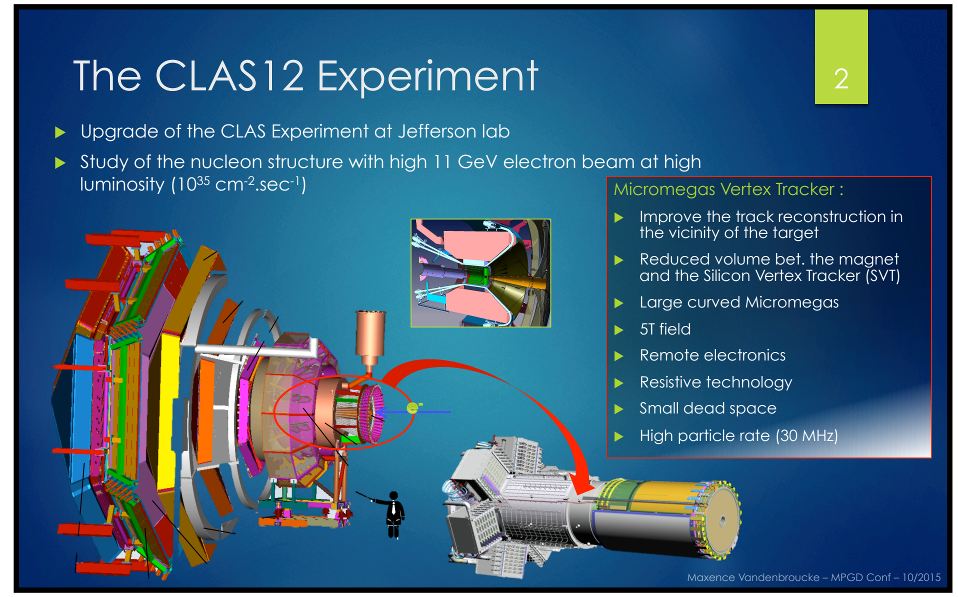


In production



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

CLAS12 (Cylindrical MM)



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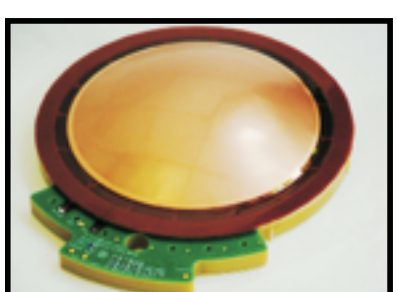
M. Vandenbroucke, MPGD2015, https://agenda.infn.it/getFile.py/access?contribId=81&sessionId=2&resId=0&materialId=slides&confId=8839



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)

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

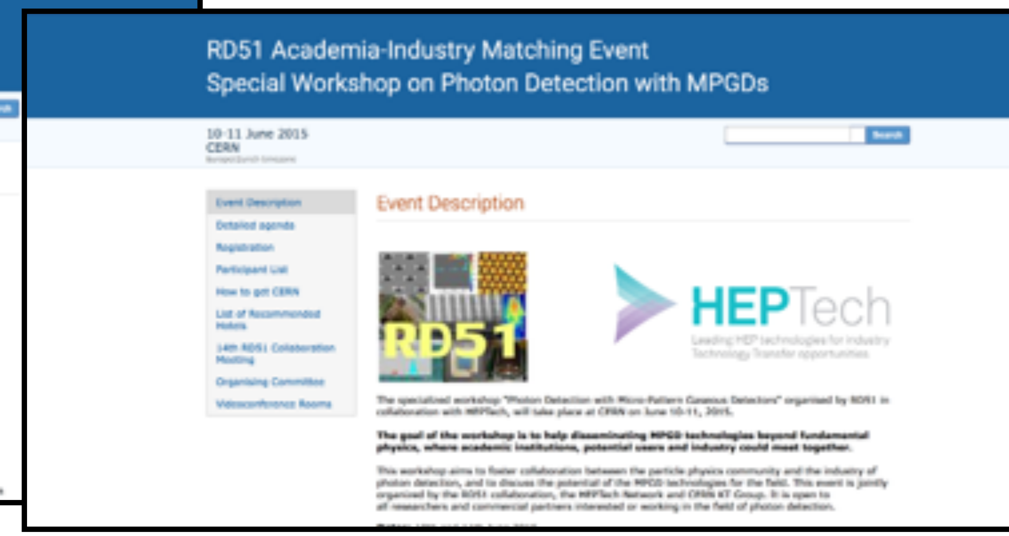
14-15 October 2013
arXiv:1410.0107

On neutron detection (2nd)

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

16-17 October 2015
arXiv:1601.01534

On photon detection



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

10-11 June 2015

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

Precise timing

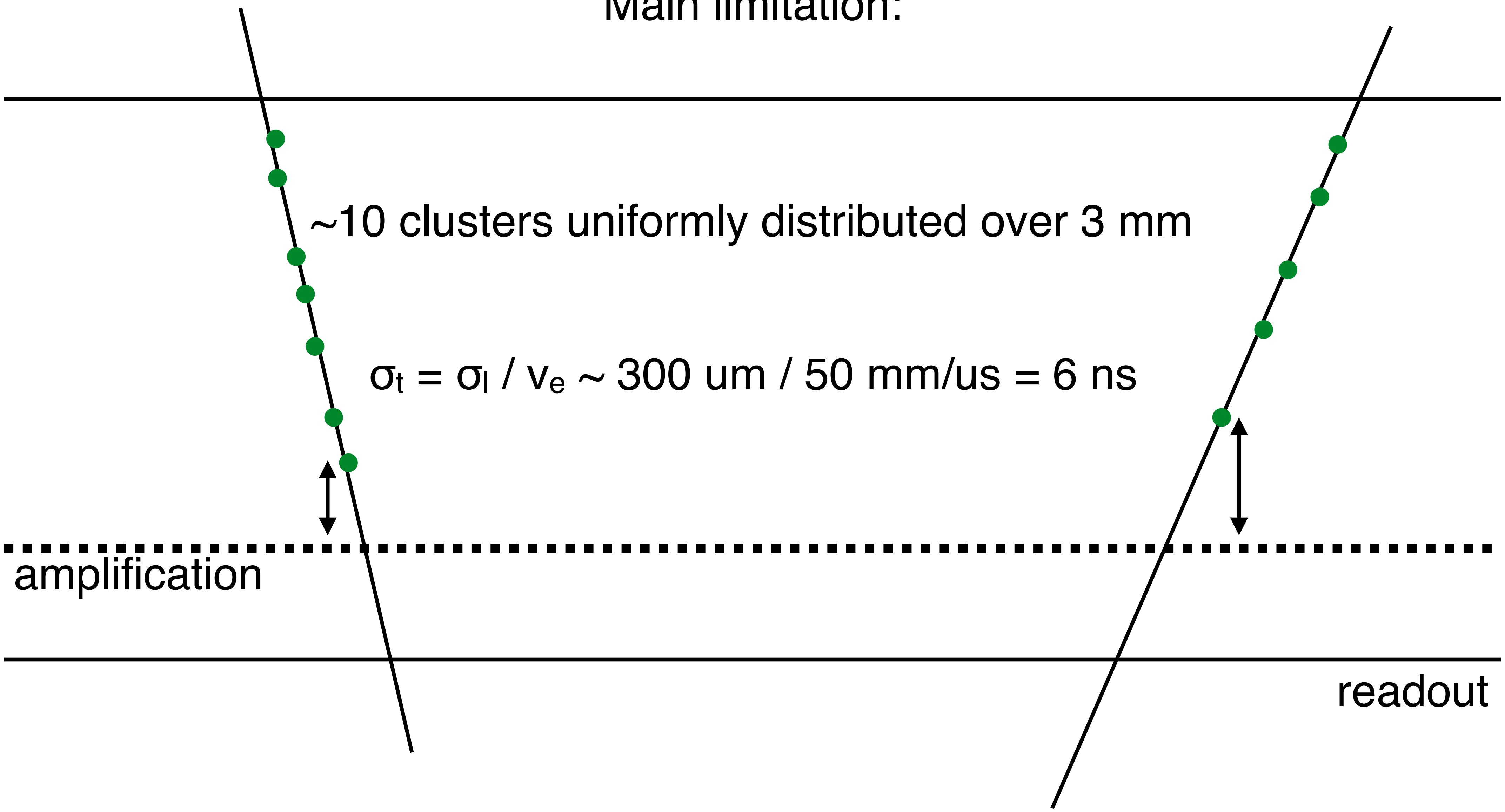
Driving reason:
development of large area and high-flux-capable detectors for pile-up mitigation in HL-LHC experiments

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

Improvement of almost two orders of magnitude needed

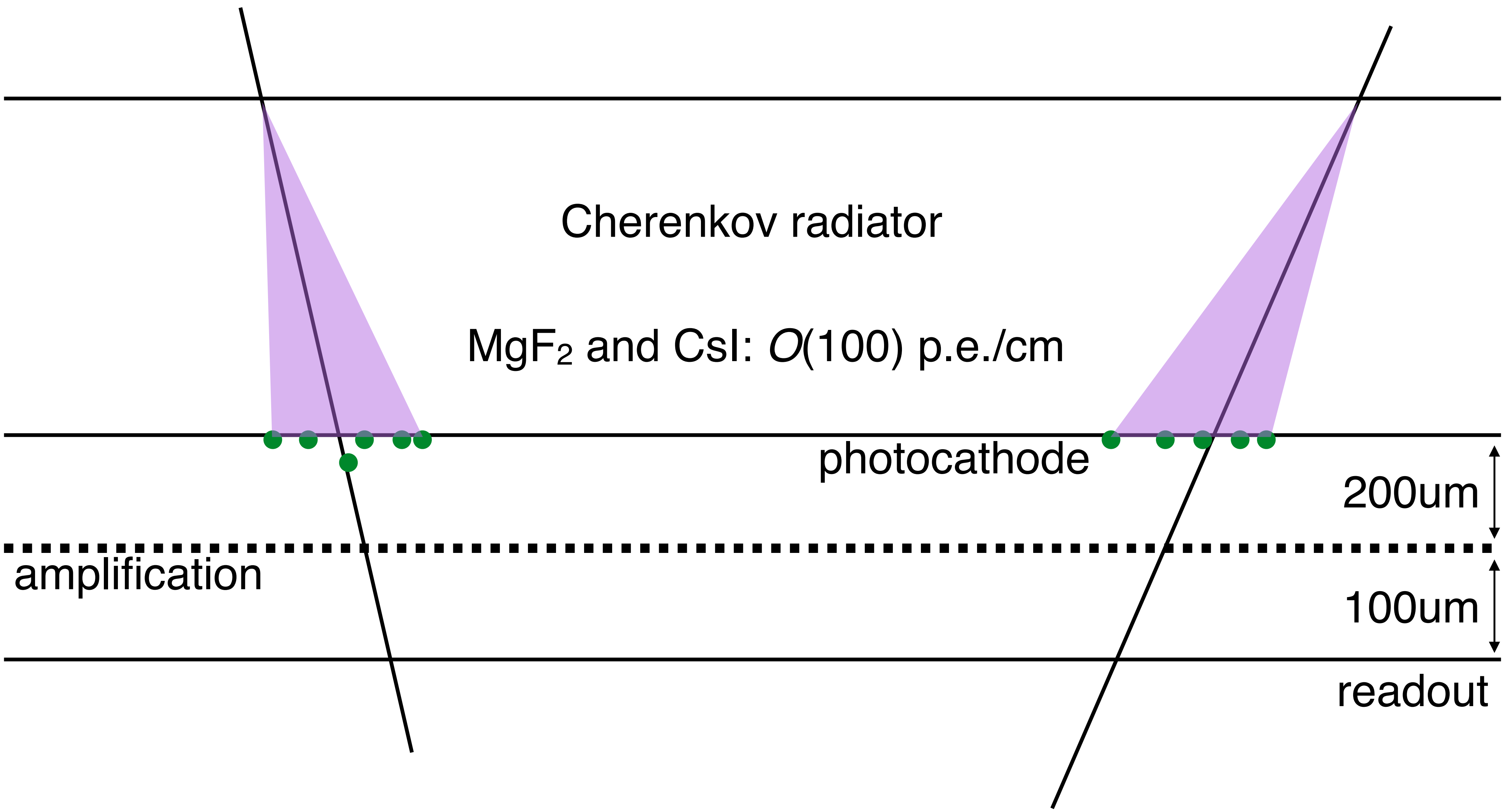
Timing with MPGDs

Main limitation:

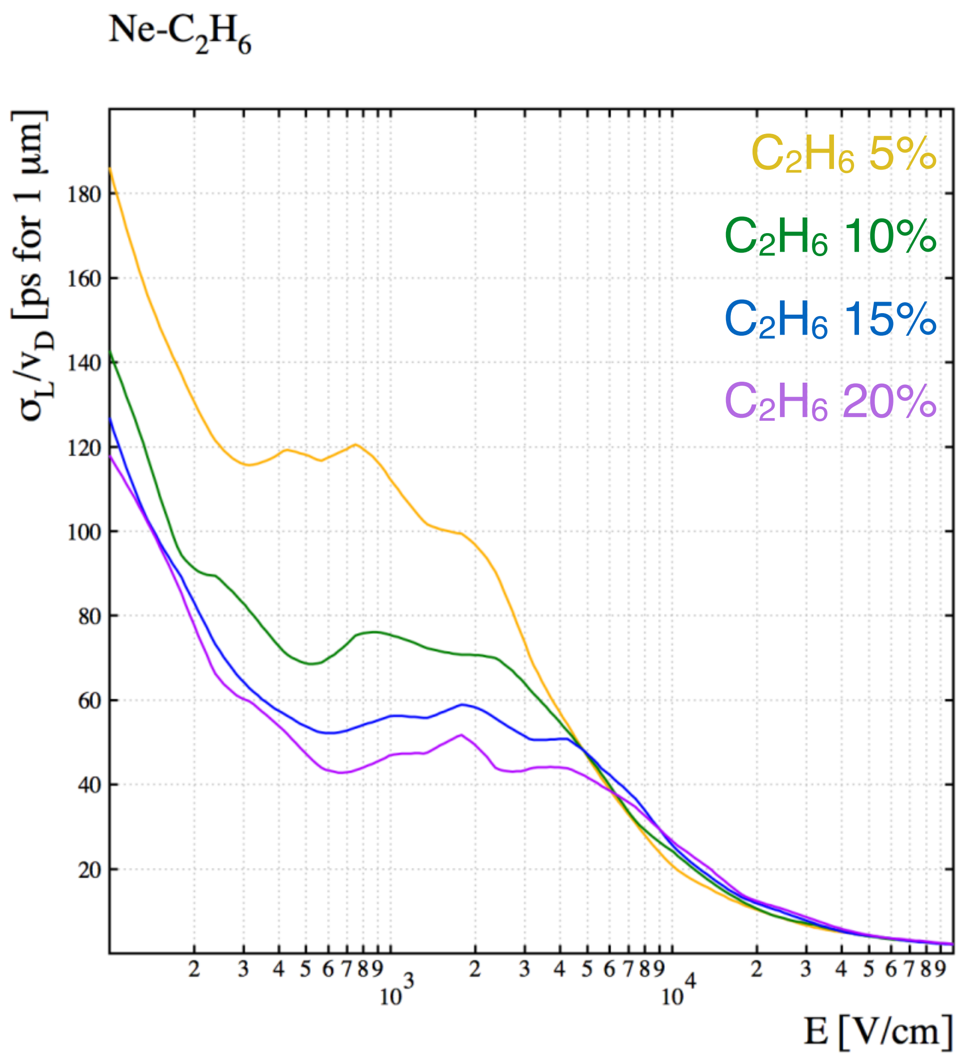


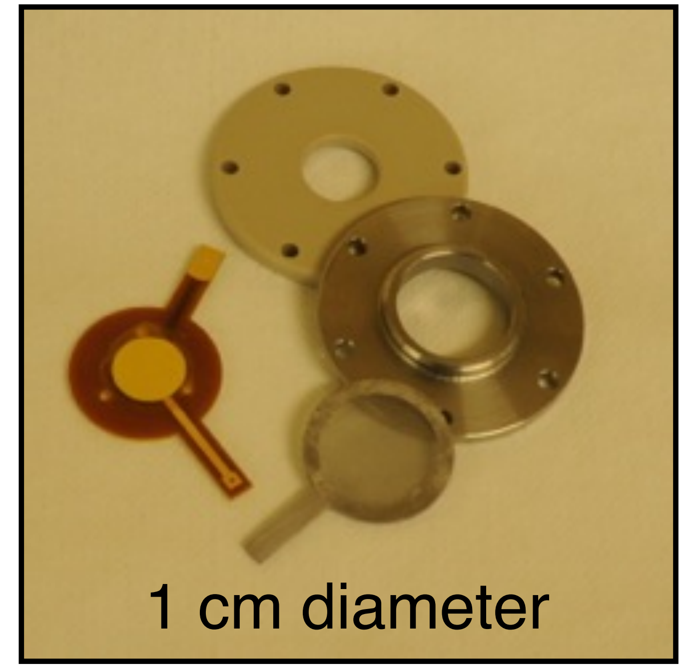
Statistics of the number of clusters helps, but
contributions also from diffusion, electron velocity, signal to noise…

Timing with next MPGDs

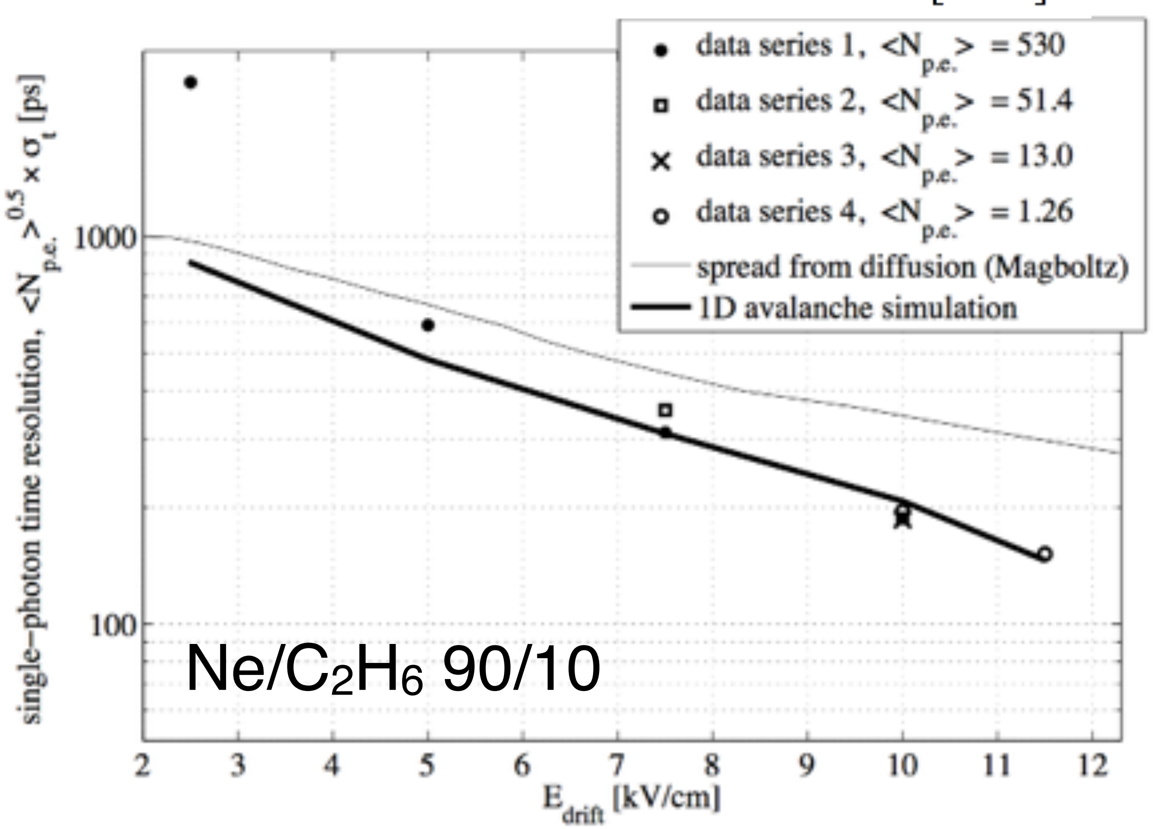


Limiting factor becomes the gas diffusion



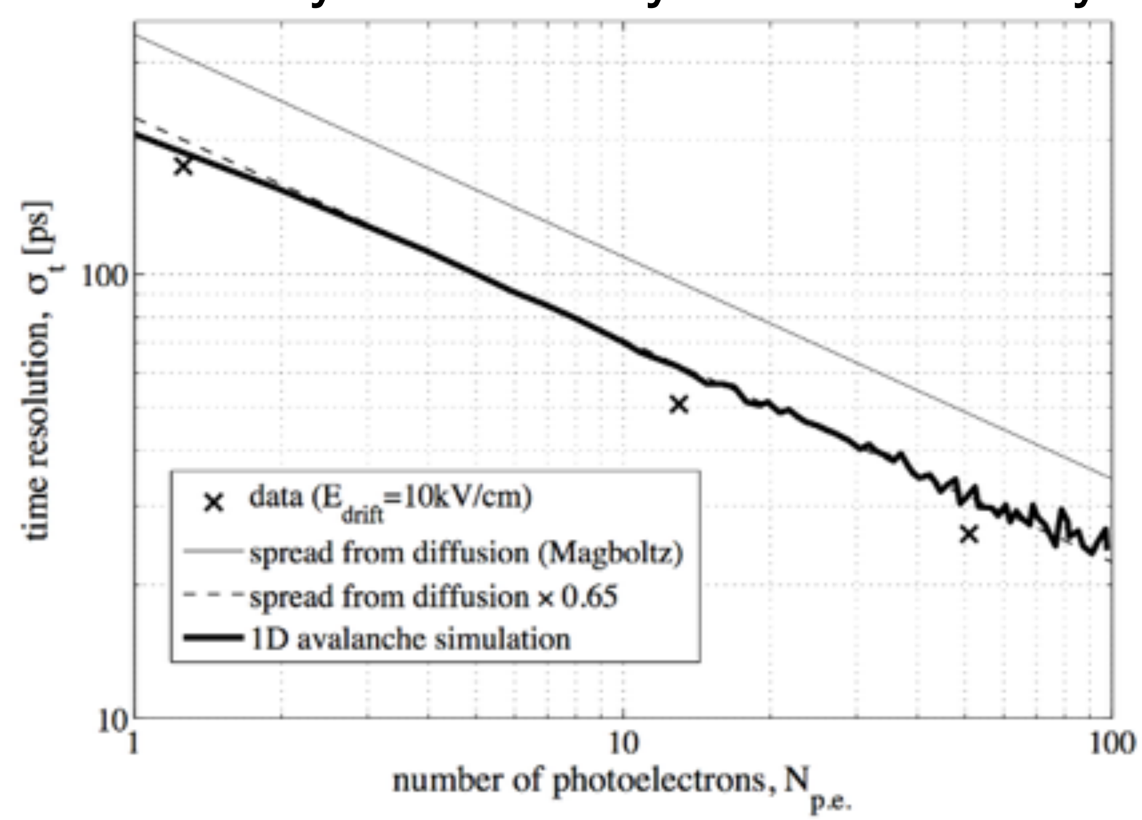


Detector operated in sealed mode



Ne/C_2H_6 90/10

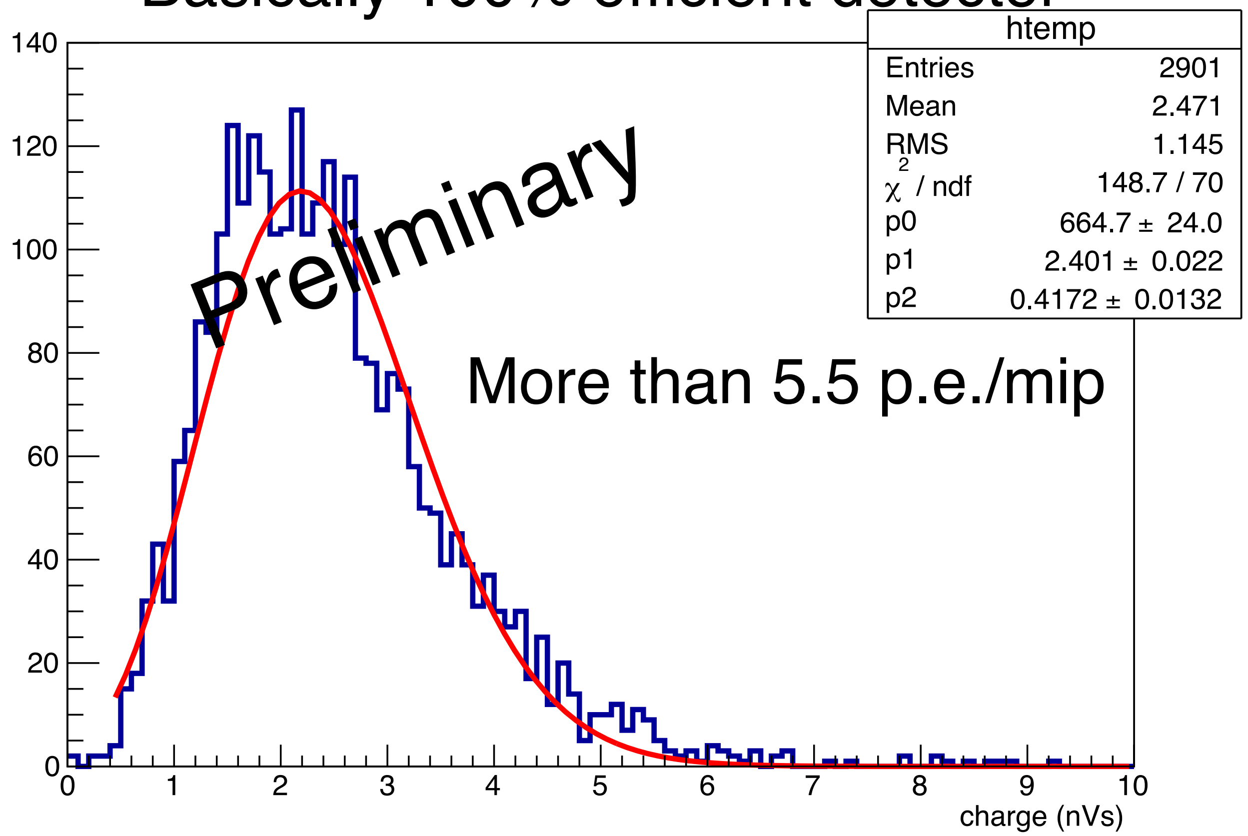
Tests with a femtosecond laser at LIDyL laboratory in CEA/Saclay



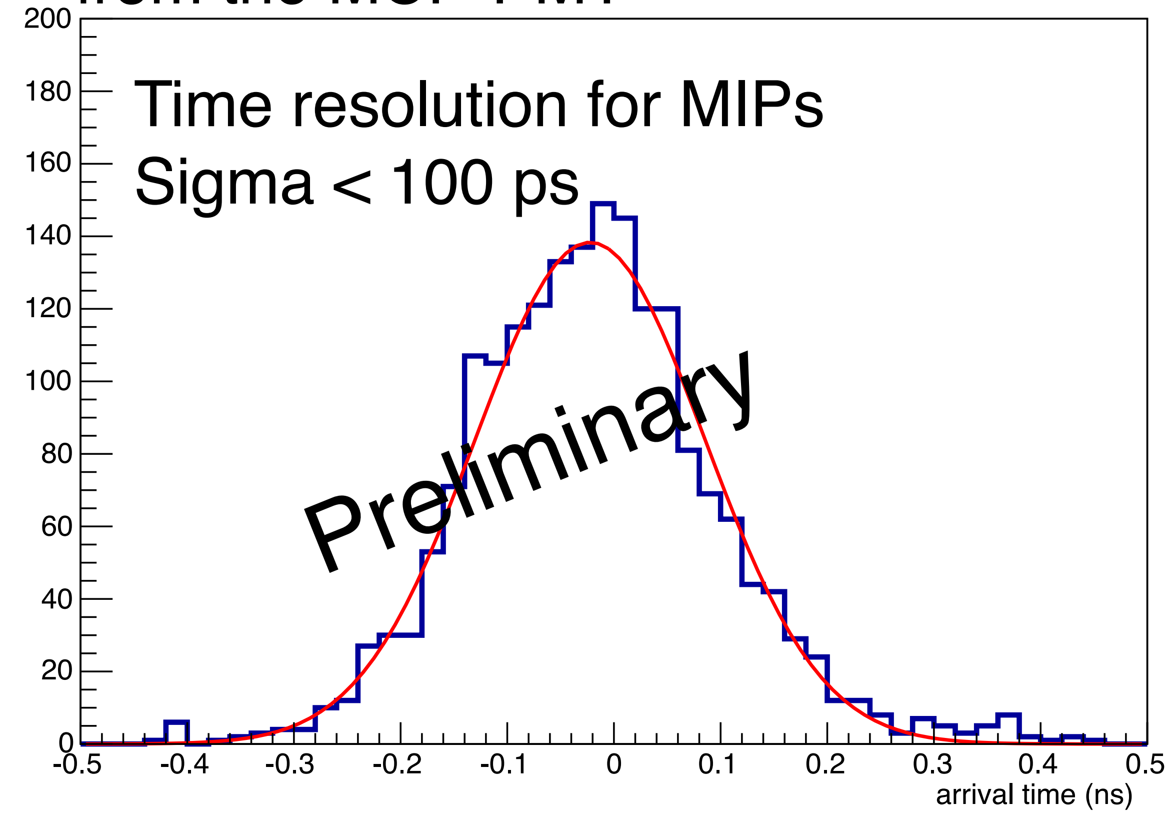
First test beam

Same detector operated in $Ne/C_2H_6/CF_4$

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