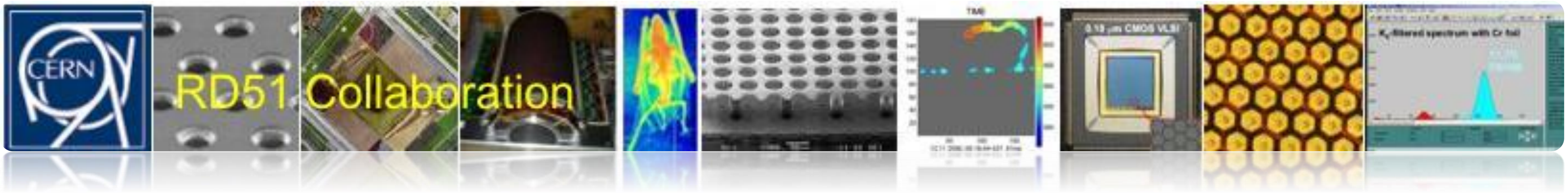


May 2018

R&D PROPOSAL
RD51 EXTENSION BEYOND 2018

EDITORS:
S. Dalla Torre (INFN Trieste), E. Oliveri (CERN),
L. Ropelewski (CERN), M. Titov (CEA Saclay)

Abstract

The RD51 Collaboration, in charge of the development and dissemination of MicroPattern Gaseous Detectors (MPGD) since 2008, proposes to extend its activity, after 2018, for a further five-year term. Since the RD51 initial years, the community of MPGD developers and users has grown considerably. It is reflected by the many MPGD-based applications in high energy and nuclear physics experiments as well as in other basic and applied-research fields. They rely on the parallel progress of detector concepts and associated technologies. The cultural, infrastructure and networking support offered by RD51 has been essential in this process. The rich portfolio of MPGD projects, under constant expansion, is accompanied by novel ideas on further developments and applications.

The proposed next term of RD51 activities aims at bringing a number of detector concepts to maturity, initiating new projects and continuing the support to the community. Among leading proposed projects are ultrafast, high-rate MPGDs; discharge-free, high-resolution imaging detectors with resistive elements and high-granularity integrated electronics; novel noble-liquid detector concepts, including electroluminescence in gas bubbles; studies of environment-friendly counting gases and long-term sealed-mode operation; optical-readout detectors with radiation-hard imagers for fundamental research experiments and radiography and more.

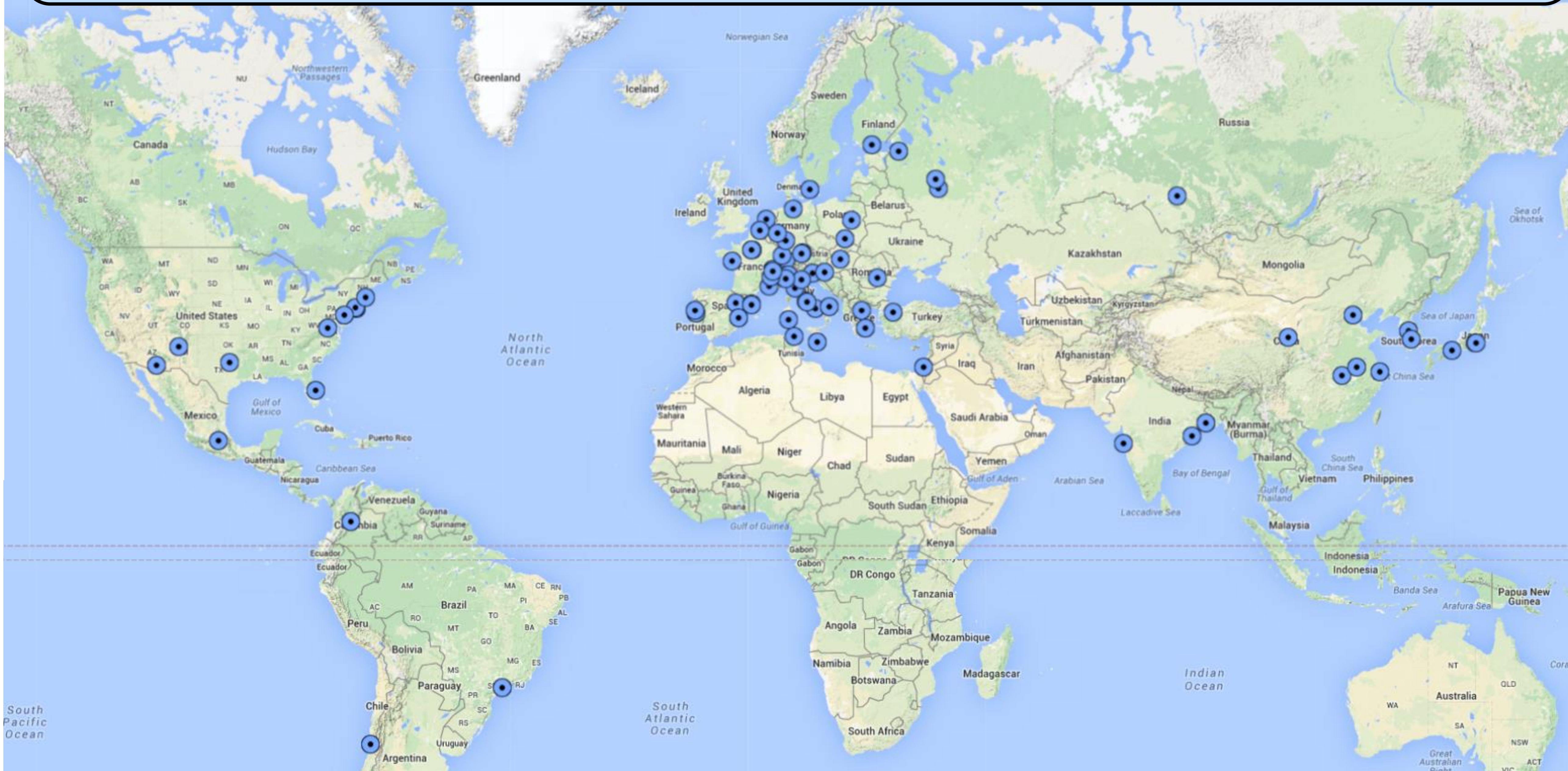
The proposed R&D program is also expected to enrich our basic knowledge in detector physics, to form a generation of young detector experts - paving the way to new detector concepts and applications. The vast R&D program requires acquiring additional, up-to-date knowhow in advanced technologies.

Micropattern Gaseous Detectors RD51

LHCC R&D Session
May 2018

Leszek Ropelewski CERN EP DT GDD & RD51

The main objective is to advance MPGD technological development and associated electronic-readout systems, for applications in basic and applied research”.
http://rd51-public.web.cern.ch/rd51-public



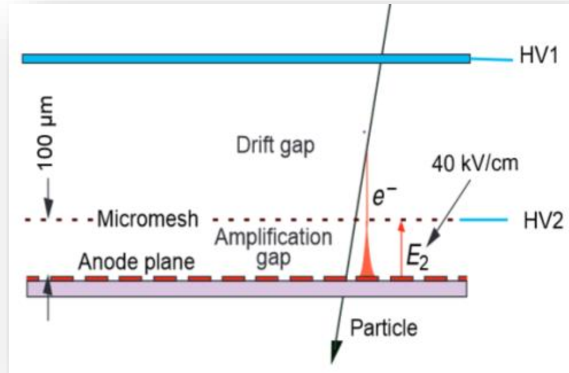
- Large Scale R&D program to advance MPGD Technologies
- Access to the MPGD “know- how”
- Foster Industrial Production

- ~ 90 institutions
- ~ 500 members
- National and International Laboratories
- National Institutes and Universities

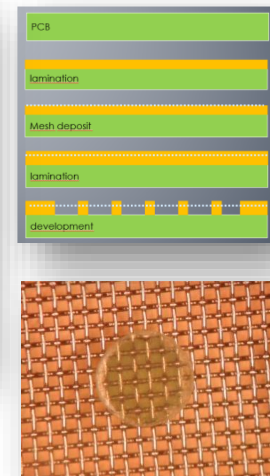
Micro Pattern Gaseous Detectors (MPGDs) and RD51 Collaboration

- High Rate Capability
- High Gain
- High Space Resolution
- Good Time Resolution
- Good Energy Resolution
- Excellent Radiation Hardness
- Good Ageing Properties
- Ion Backflow Reduction
- Photon Feedback Reduction
- Large Size
- Low Cost

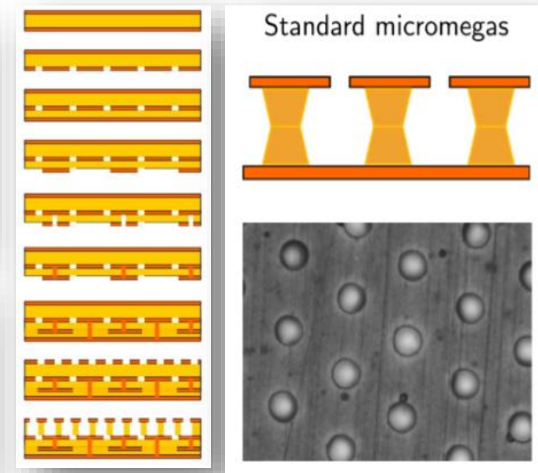
Micromegas



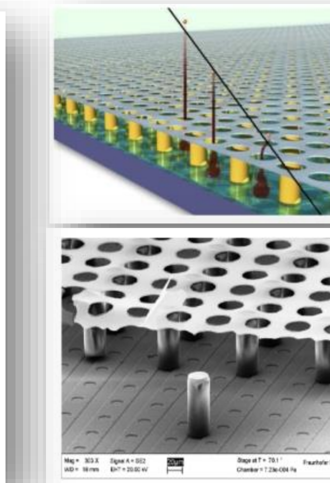
Bulk



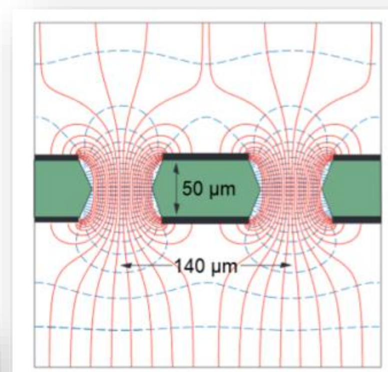
Micro bulk



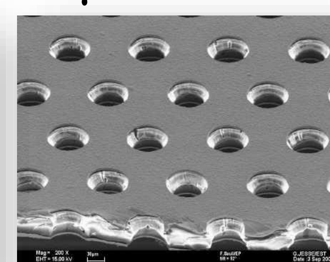
InGrid



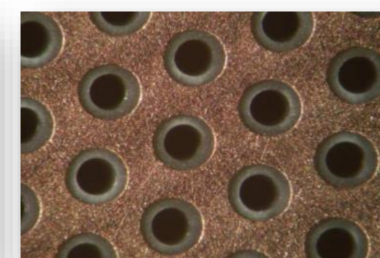
GEM



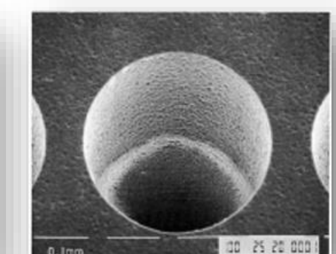
50µm GEM

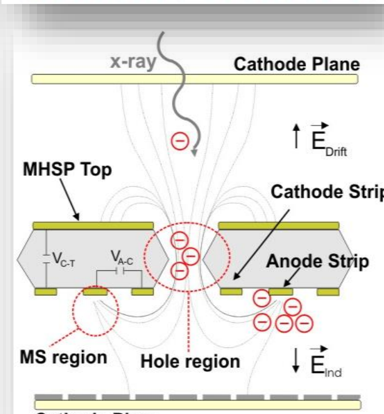


THGEM

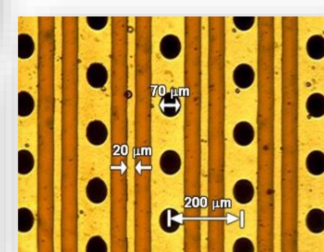


GLASS GEM

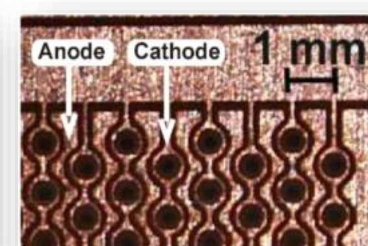


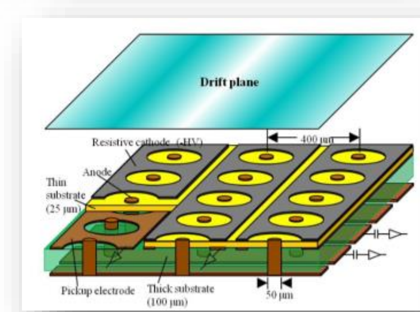


MHSP

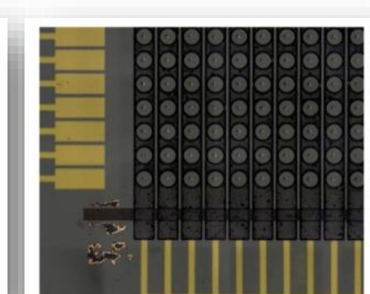


THCOBRA





µPIC



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DOI: 10.1142/S0217732313400221

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MICRO-PATTERN GASEOUS DETECTOR TECHNOLOGIES AND RD51 COLLABORATION

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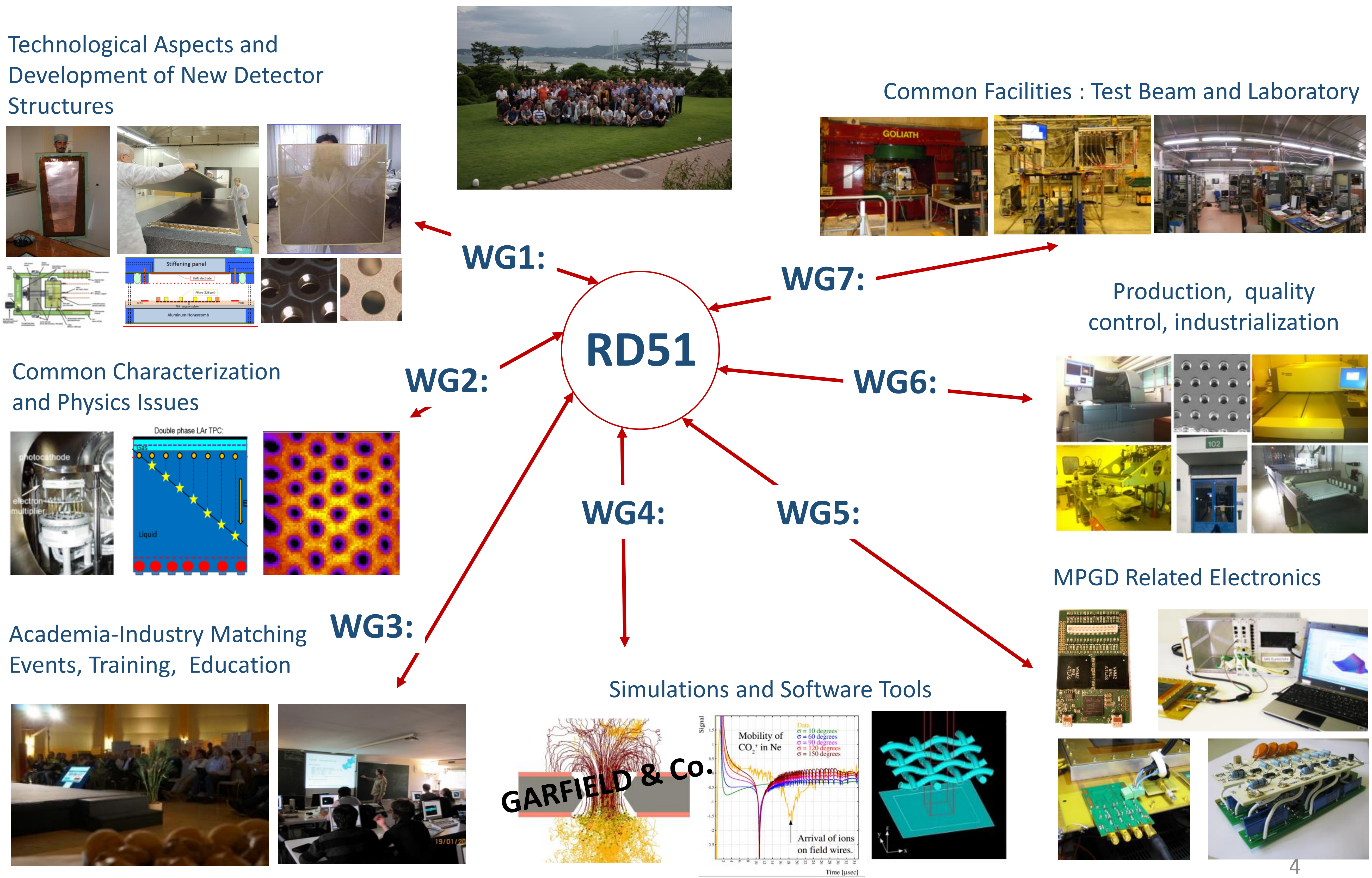
RD51 (well consolidated) Working Groups



RD51 Achievements and Highlights

- Consolidation of the Collaboration and MPGD community integration (90 Institutes, ~500 members); Conferences, Meetings , Workshops, AIMEs, Schools, Lectures, Trainings

- Major progress in the MPGD technologies development in particular large area GEM (single mask), MicroMegas (resistive), THGEM; some picked up by experiments (including LHC upgrades);

  ALICE, TPC read-out, ~ 500 m^2 of GEM foils
  ATLAS, small wheels, 1200 m^2 to be instrumented
  CMS, GE1/1 forward detectors, 250 m^2 of GEM foils
  COMPASS RICH, 4.5 m^2 to be instrumented, single photon detection

- Secured future of the MPGD technologies development through the EP DT MPT workshop upgrade and FP7 AIDA & AIDA2020 contribution;

- Contacts with industry for large volume production, MPGD industrialization and first industrial runs;

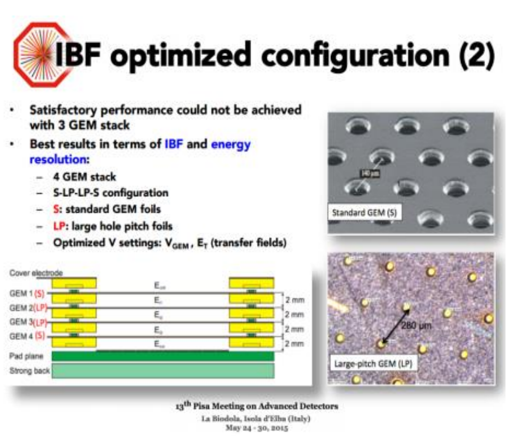
- Major improvement of the MPGD simulation software framework for small structures allowing first applications;

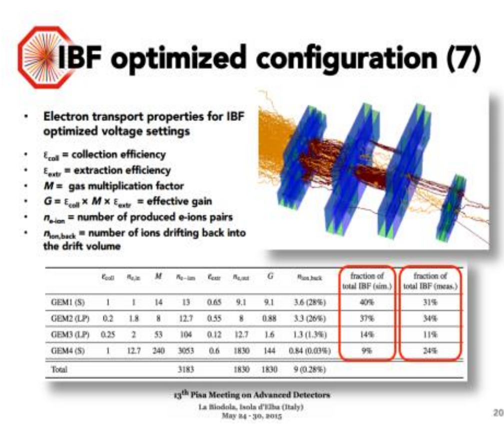
- Development of common, scalable readout electronics (SRS) (many developers and > 50 user groups); Production (PRISMA company and availability through CERN store); Industrialization (re-design of SRS in ATCA in EISYS); SRS Technology CERN spin-off, APV and VMM interfacing.

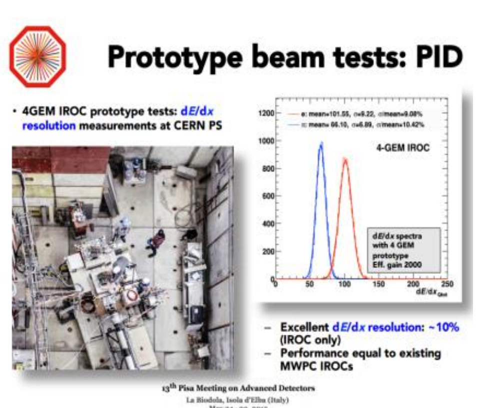
- Infrastructure for common RD51 test beam and lab facilities (>20 user groups)

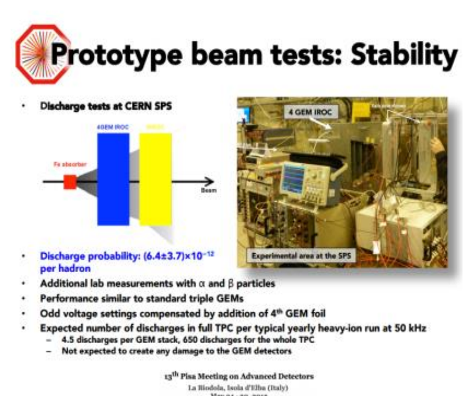
Examples of CERN/LHC Upgrades

ALICE (GEM)



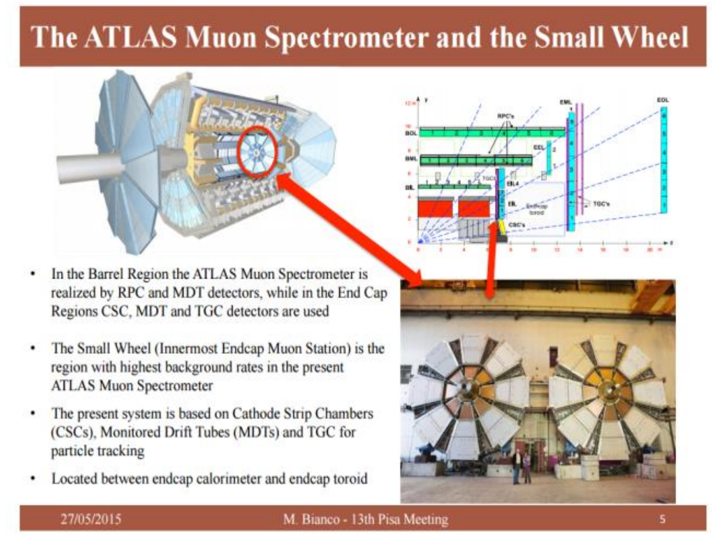


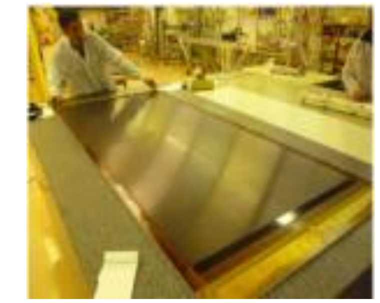


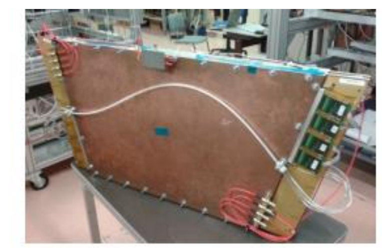


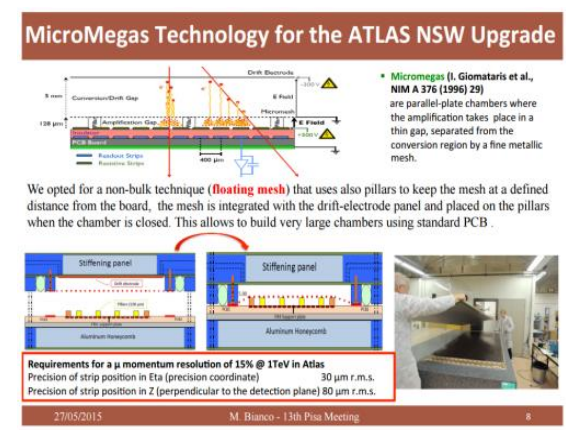
A continuous read-out TPC for the ALICE upgrade, C. Lippmann, Elba 2015

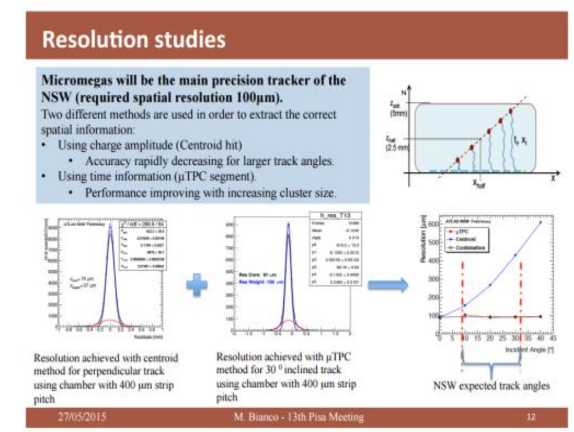
ATLAS NSW (mm)

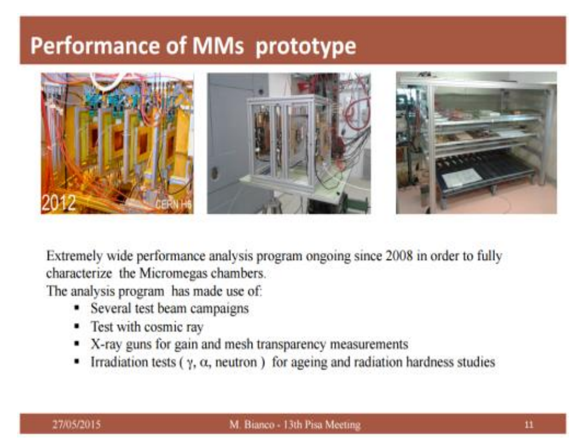


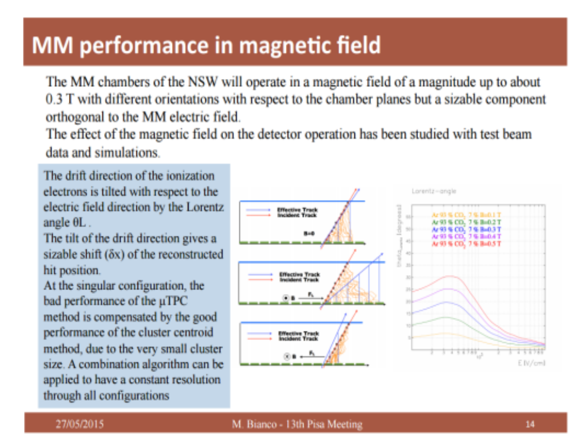












Micromegas Detectors for the Muon Spectrometer Upgrade of the ATLAS Experiment; M. Bianco, Elba 2015

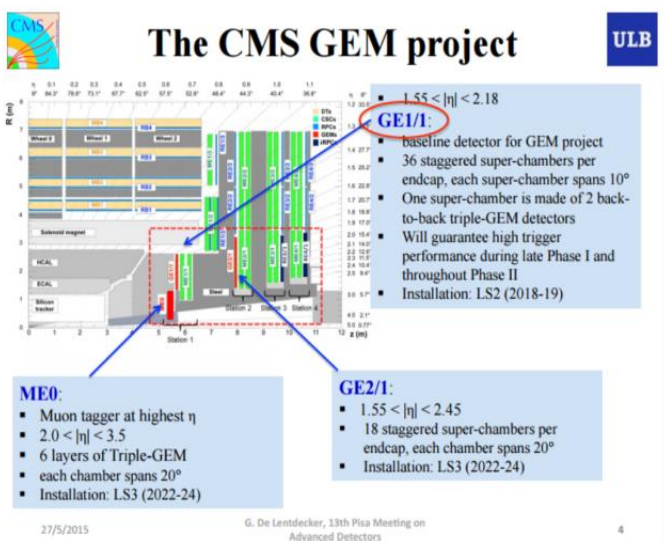
LHC Upgrades: Original R&D efforts emerged from RD51 activities.

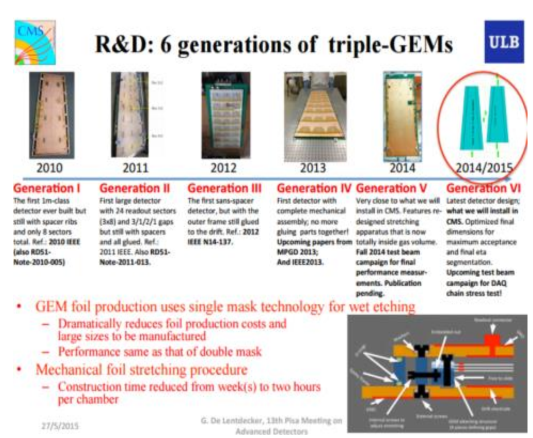
Today: production phase under the project effort , access to RD51 facilities (laboratory, test beam, workshops) and tools (simulation, electronics,…) to facilitate this particular phase

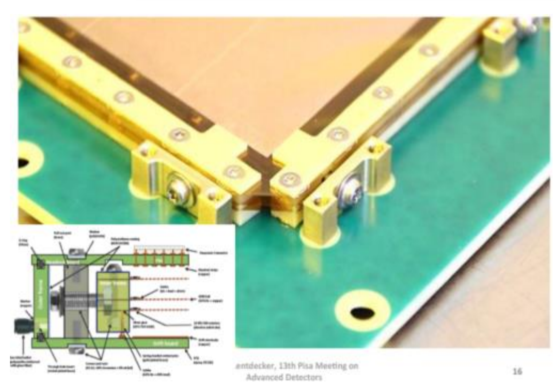
Examples of CERN/LHC Upgrades

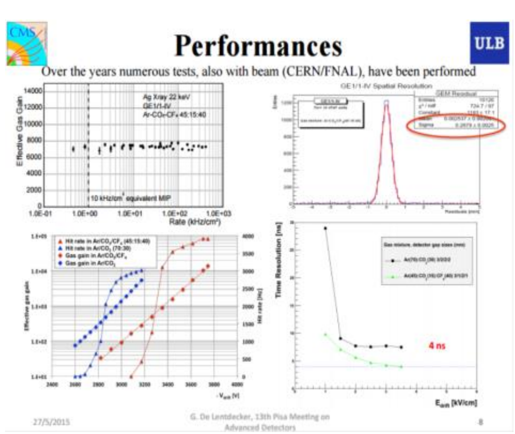
CMS (GEM)

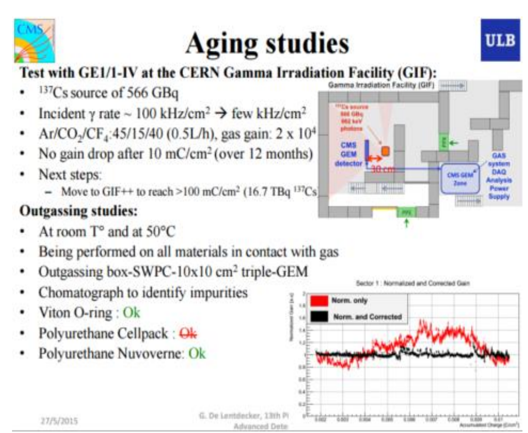
Status Report of the Upgrade of the CMS muon system with triple-GEM detectors, G. De Lentdecker, Elba 2015





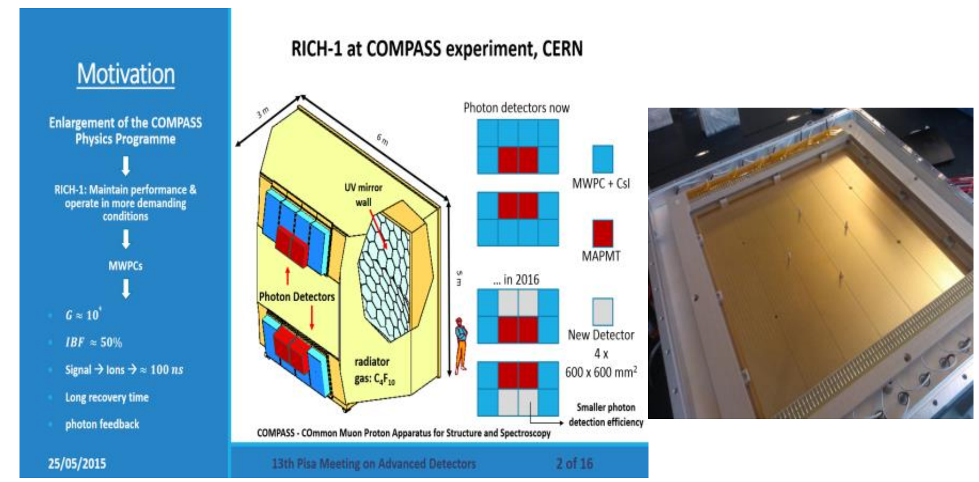


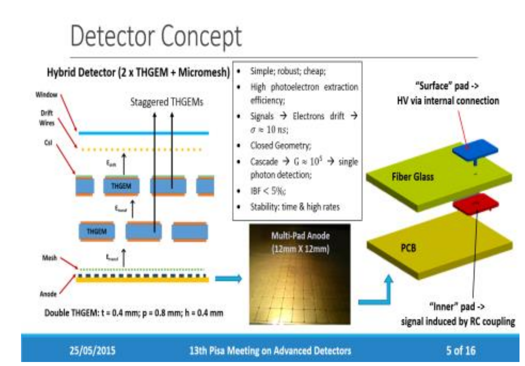


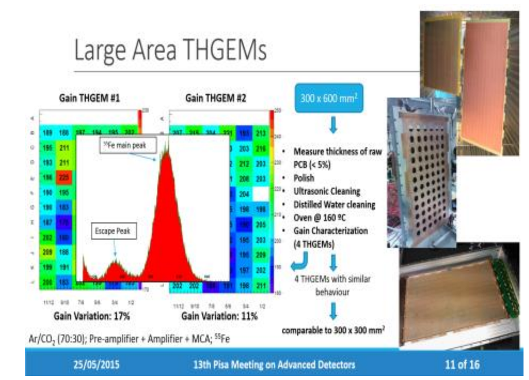


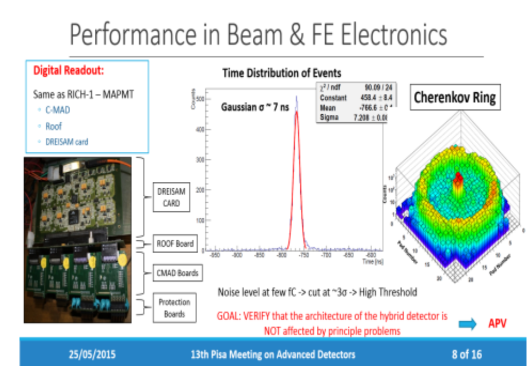
COMPASS RICH-1 (THGEM+MM)

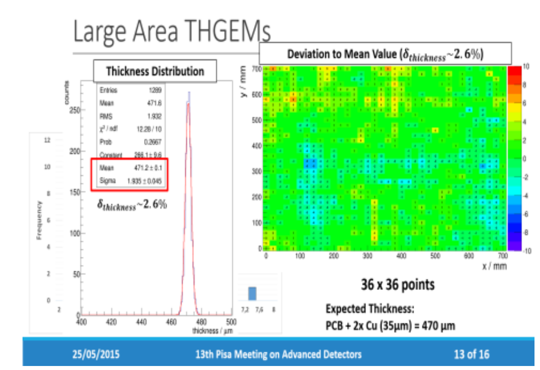
Status of the Development of Large Area Photon Detectors based on THGEMs and Hybrid MPGD architectures for Cherenkov Imaging Applications , C.A.Santos, Elba 2015







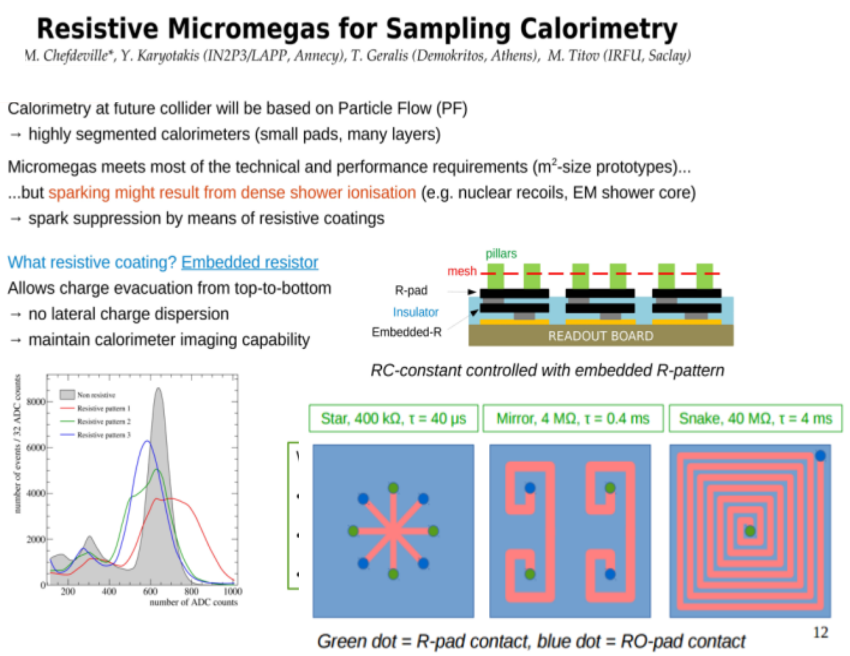




LHC Upgrades: Original R&D efforts emerged from RD51 activities.
Today: production phase under the project effort , access to RD51 facilities (laboratory, test beam, workshops) and tools (simulation, electronics,…) to facilitate this particular phase

Novel Technologies, New Ideas and Applications.

Calorimetry with MPGD

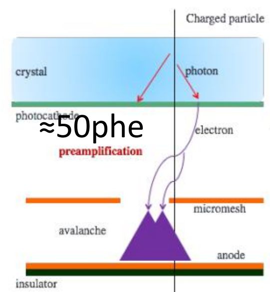


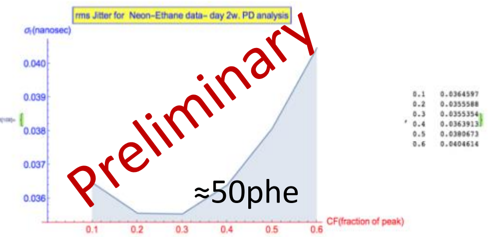
Fast Timing

MicroMegas based:

(initial tests March/April 2015)

Ne-Ethane(10%)-200 micron drift+50micron Micro Bulk

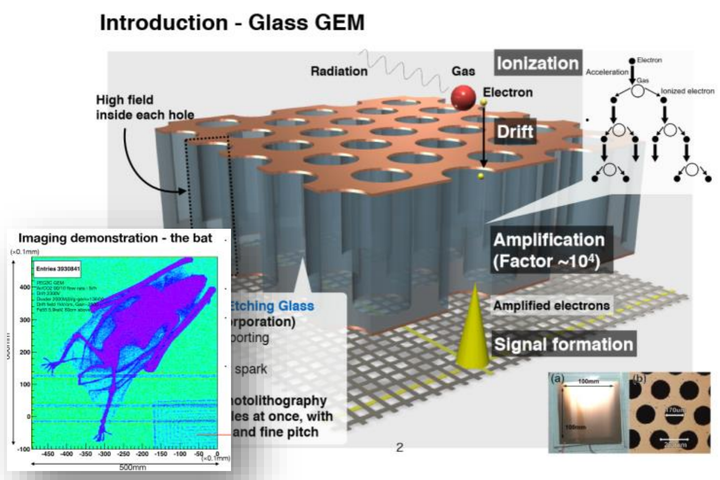




36 picosecond rms on first try!!

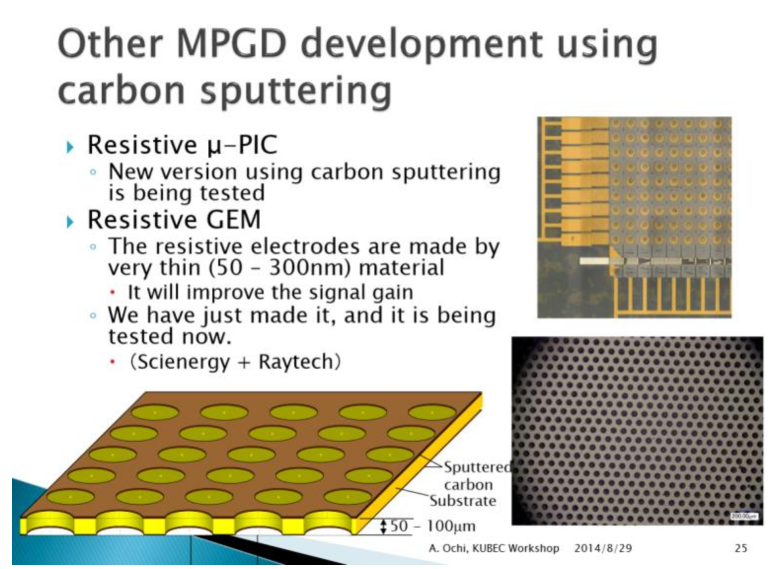
Saclay Chamber <-

New Materials (Glass GEM)



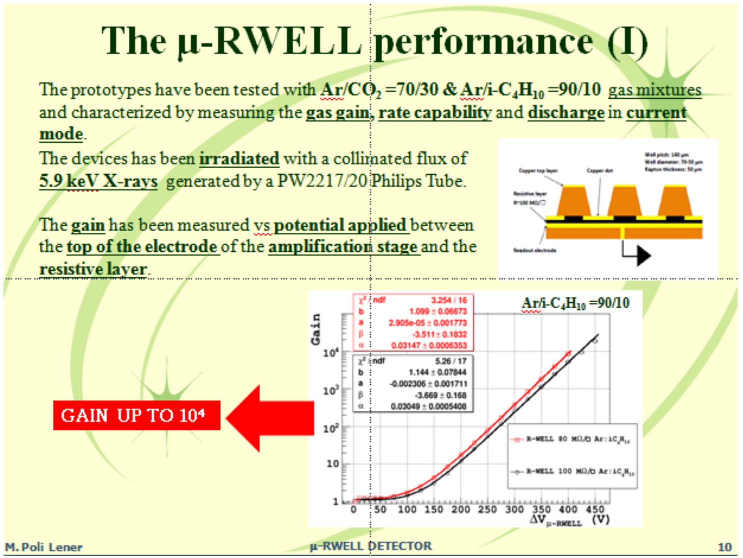
The Latest Results of Crystalized Glass GEM, Y. Mitsuia, RD51 miniweek (GDD/RD51 lab)

Resistive Material

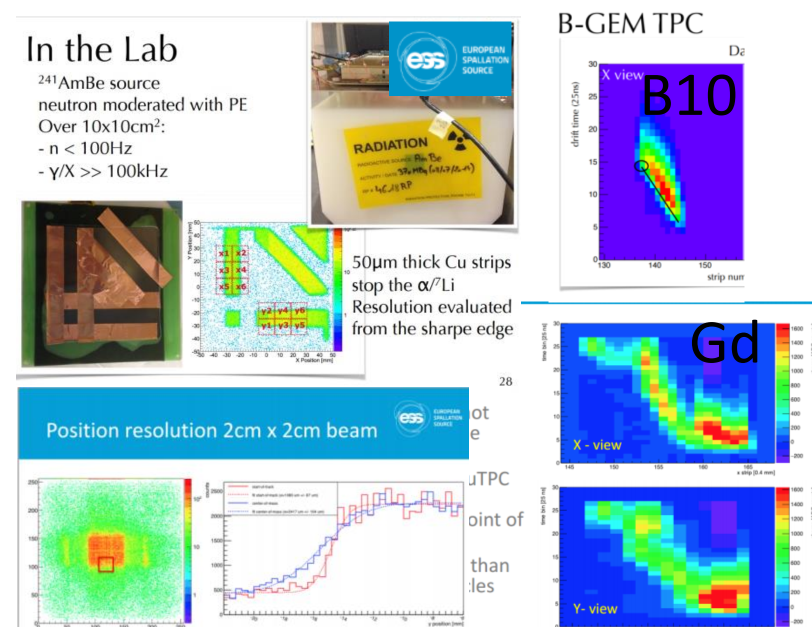


A. Ochi

New Large Area Thin Detectors



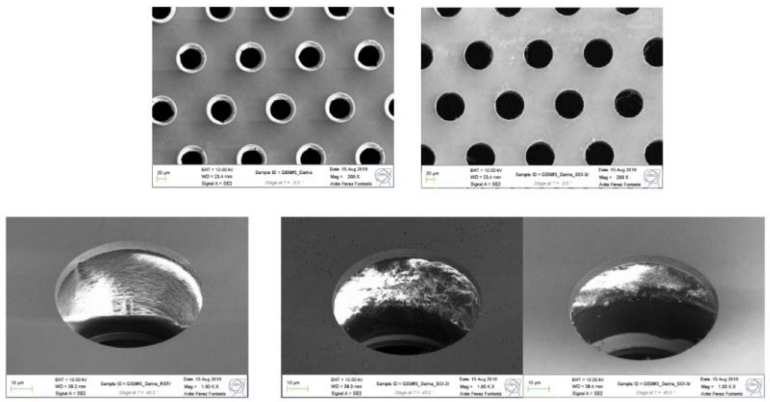
Neutrons Detection

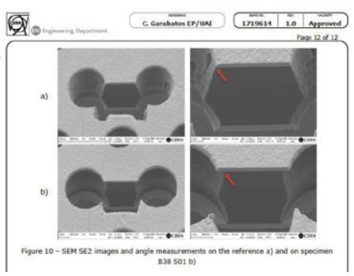


European Spallation Source (ESS)

R&D Support to the Projects and Experiments

Effect of extreme operating conditions on the GEM detector components





Gating GEM

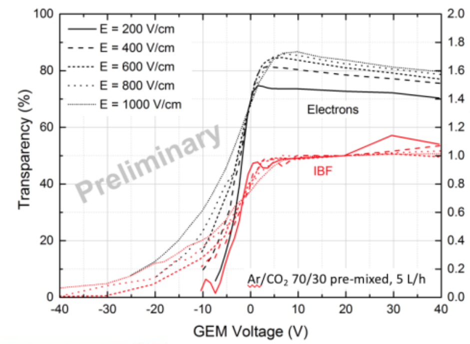
Ion back-flow at equal fields

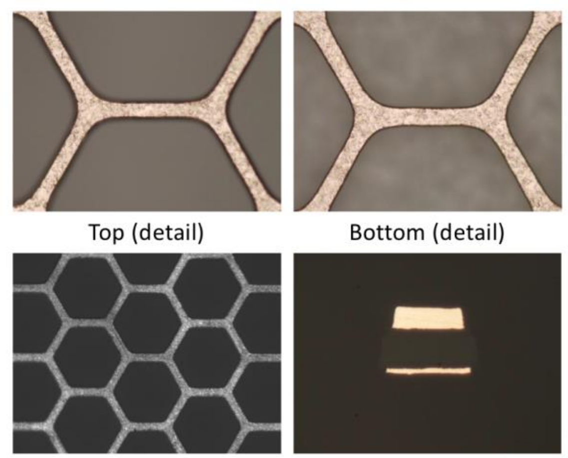
Ion back-flow reaches **maximum** at approx. **same voltage** as for electron transparency

Higher voltages than for electrons to fully **close gate**

Very preliminary data with large error bars (not shown)!

IBF normalized to ΔV_{GEM} = 20 V

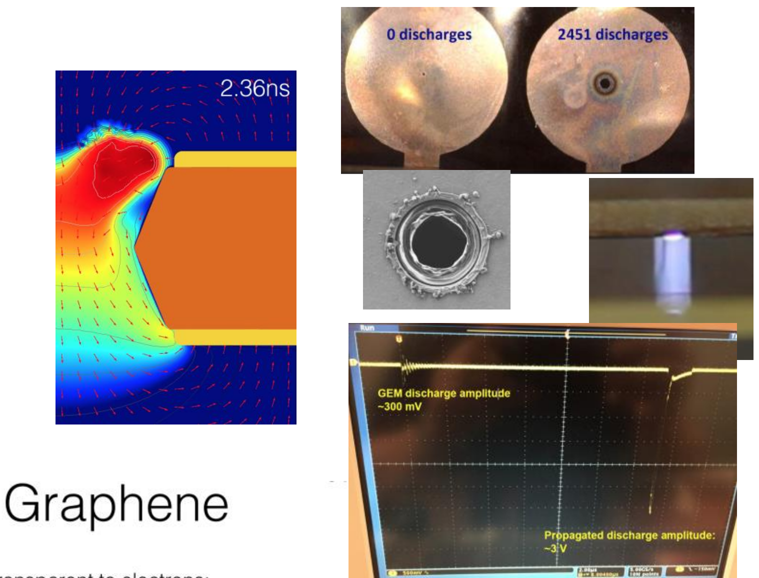




Top (detail) | Bottom (detail)

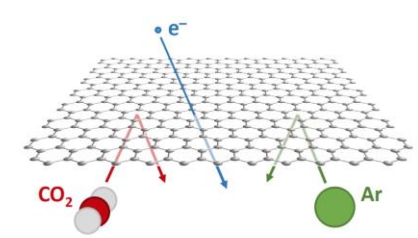
Top | Cross-section (detail)

Discharge studies ALICE/CMS

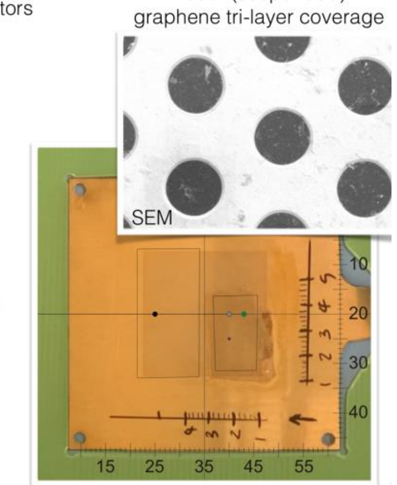


Graphene

Membrane opaque to ions and transparent to electrons:
- solution of the ion back-flow in gaseous detectors
- protective layer on photocathodes
- enhancement of electron emission

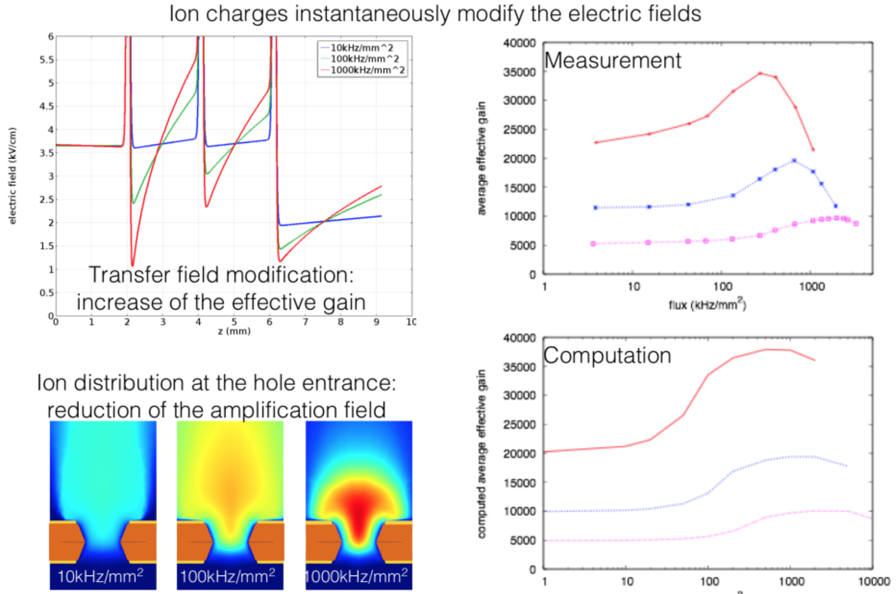


~99% (suspended) graphene tri-layer coverage



Ion density effects in multiGEM

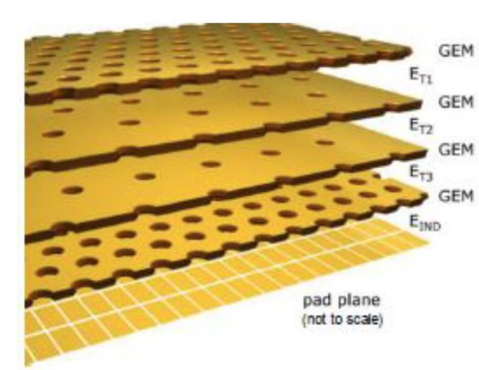
Ion charges instantaneously modify the electric fields

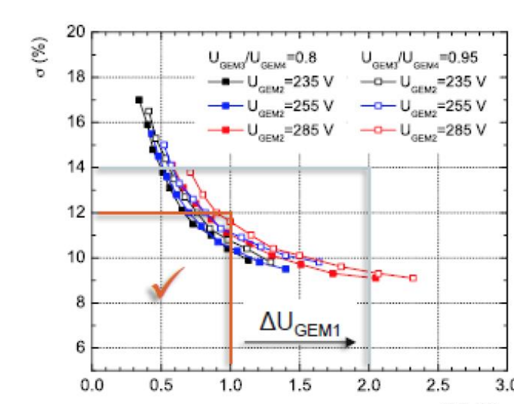


Transfer field modification: increase of the effective gain

Ion distribution at the hole entrance: reduction of the amplification field

ALICE TPC IBF



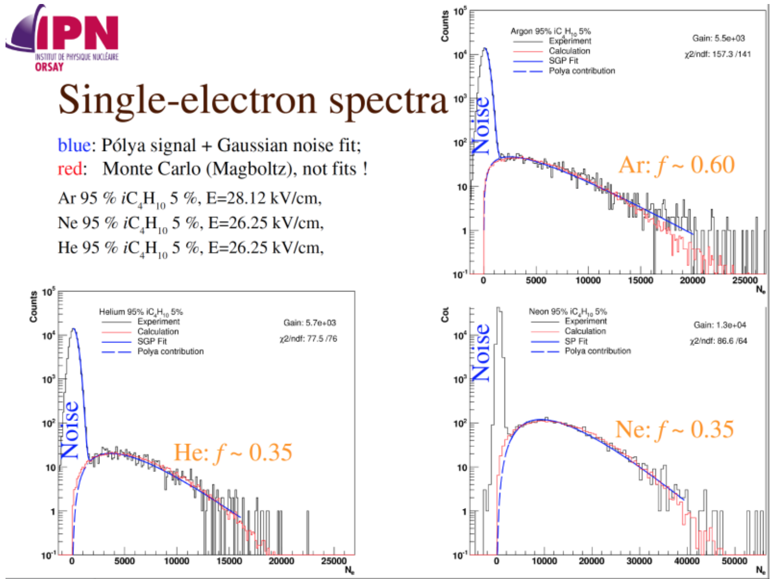


Modelling of Physics Processes and Software Tools

Single-electron spectra

blue: Pólya signal + Gaussian noise fit;
red: Monte Carlo (Magboltz), not fits !

Ar 95 % iC_4H_{10} 5 %, E=28.12 kV/cm,
Ne 95 % iC_4H_{10} 5 %, E=26.25 kV/cm,
He 95 % iC_4H_{10} 5 %, E=26.25 kV/cm,



Mesh transparency

- Electron tracking requires improvement.

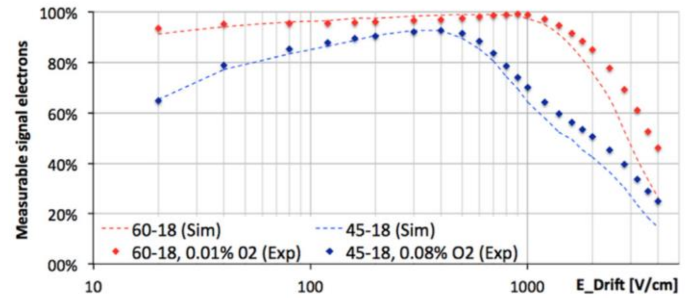


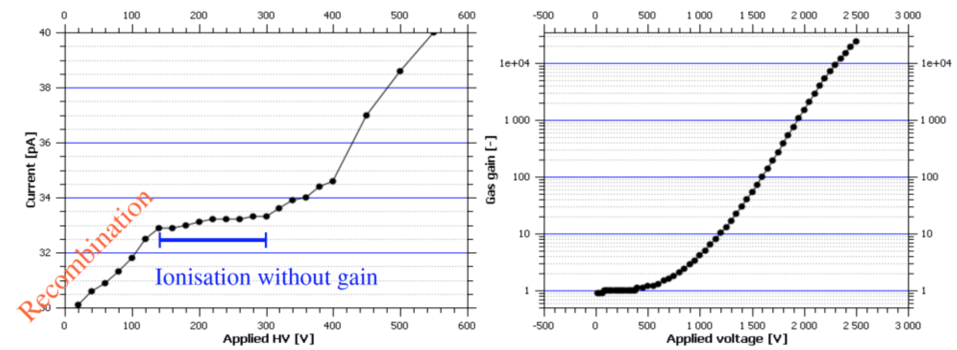
Fig. 5. Fraction of measurable signal electrons dependence on the drift field for two mesh geometries, experimental data (normalized signal strength) and simulation prediction (non-lost electrons after drift and mesh transition).

- [Fabian Kuger et al. 10.1016/j.nima.2015.11.011]

AGH University of Science and Technology

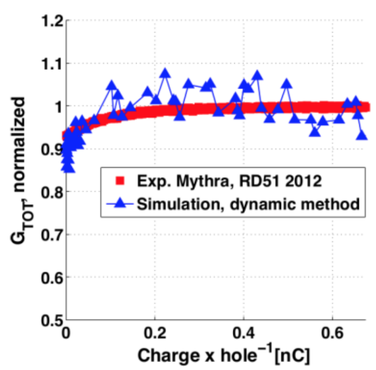
High-precision data from AGH

- Current reference is taken at the ionisation level.
- Main source of error: ~5 %.

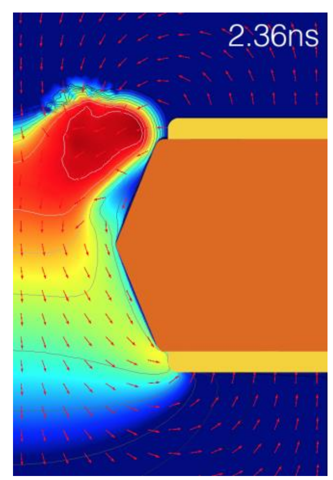


Charging-up of a GEM

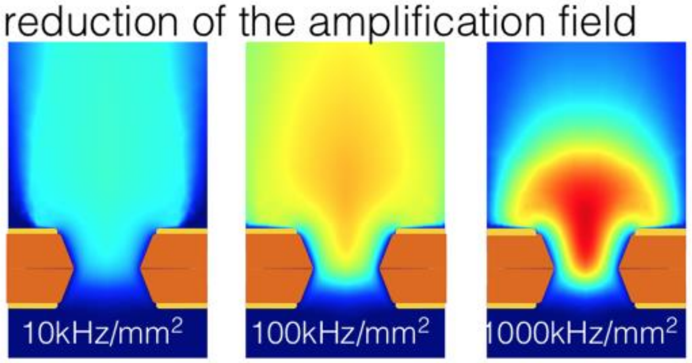
- Gain changes as a result of the charge deposits.
- Electron tracking to be refined.



- [Pedro Correia et al. 10.1088/1748-0221/9/07/P07025]



Ion distribution at the hole entrance: reduction of the amplification field



Gas detector simulation: new areas

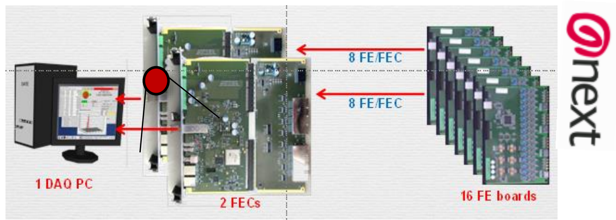
- Discharges and Resistive layers.
- Ion diffusion.
- Refinement of ionisation esp. at low energy.
- Integration of boundary element methods.

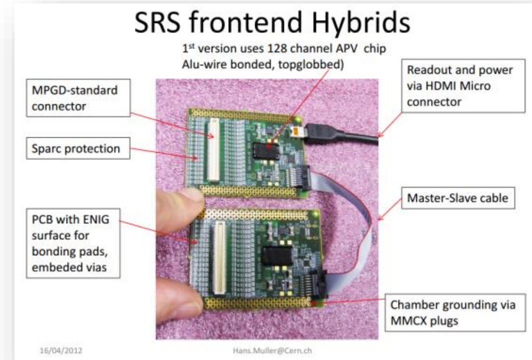
The RD51 Scalable Readout System (SRS) Electronics and Instruments for Detectors

SRS & APV25 FE chip

Worldwide use in the RD51 community (>2000 hybrids)

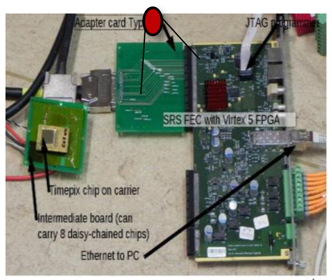
SRS+SiPM (NEXT TPC)

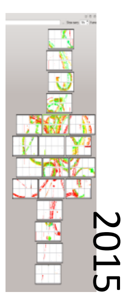


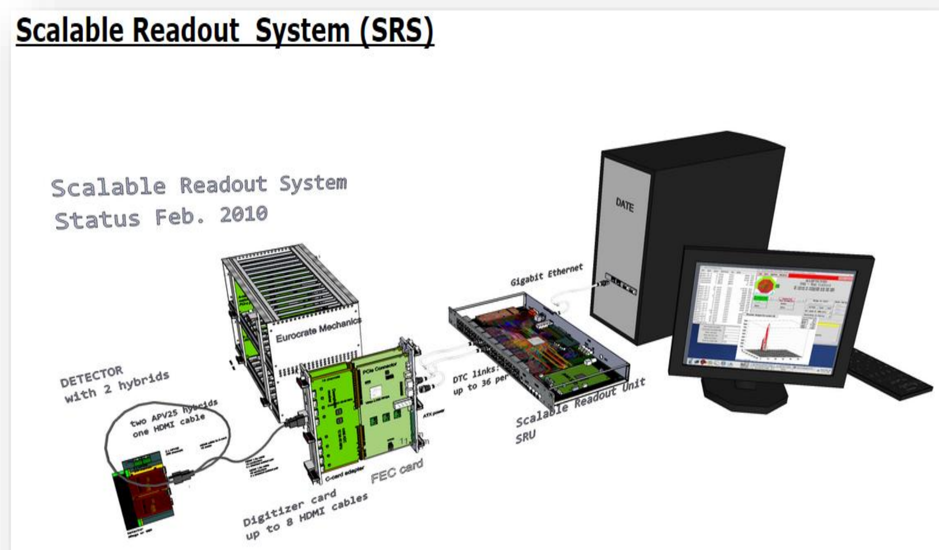


SRS-FEC+TOTEM DAQ

SRS+Timepix (LC-TPC) – Bonn/Desy

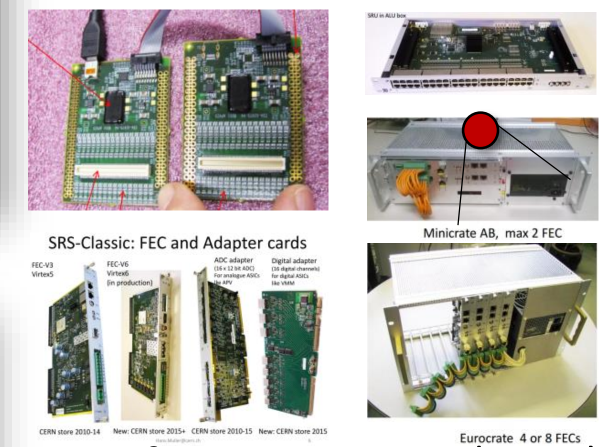




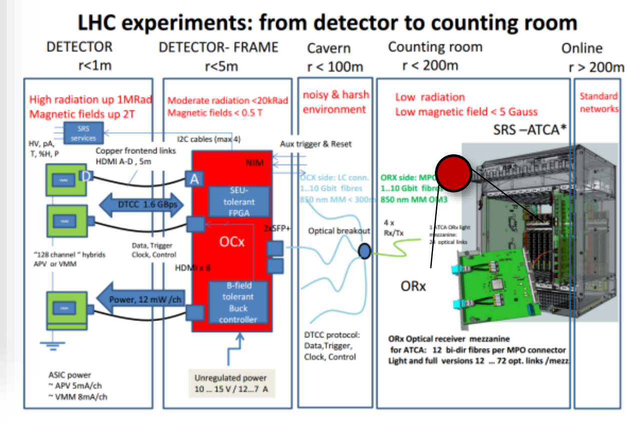


SRS: Different System

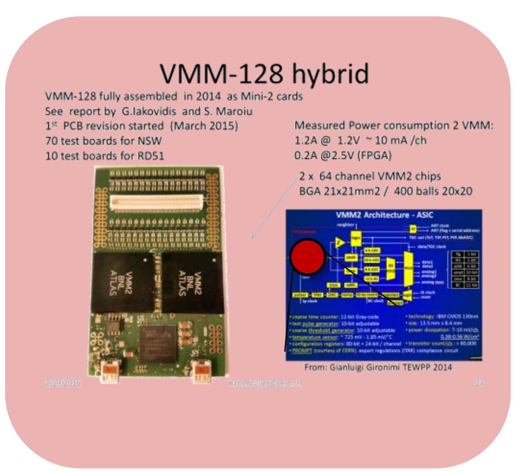
SRS for R&D on Detectors

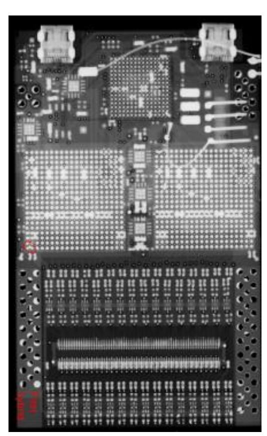


SRS for experiments (ATCA)



Very appealing for the future: VMM (NSW ATLAS FE chip)

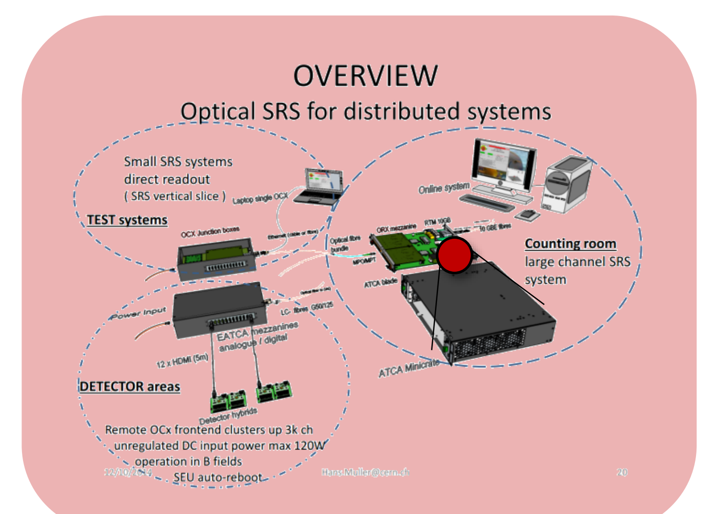




Baseline solution for RD51 SRS community.

Interest and support from ESS (European Spallation Source) and ALICE FOCAL

SRS for spatially distributed system (optical SRS)



EP-DT-DD GDD Laboratory available for the RD51 Collaboration Members

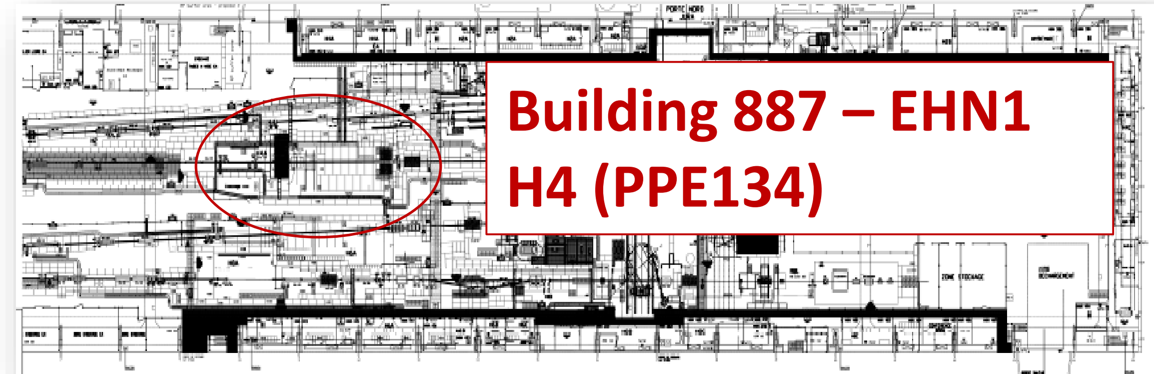
Permanent installations (Today): ALICE, ATLAS, ESS
CMS moved roughly two years ago to TIFF, access to the lab for specific measurements
More than 15/20 groups per year coming to perform measurements

Clean Rooms

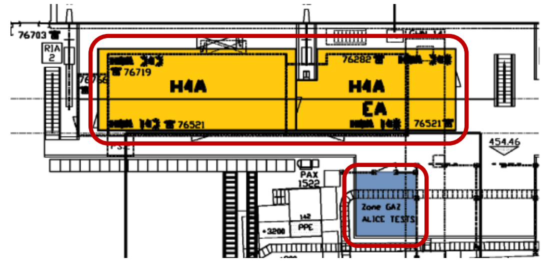
Mechanical and Electronic Workshop

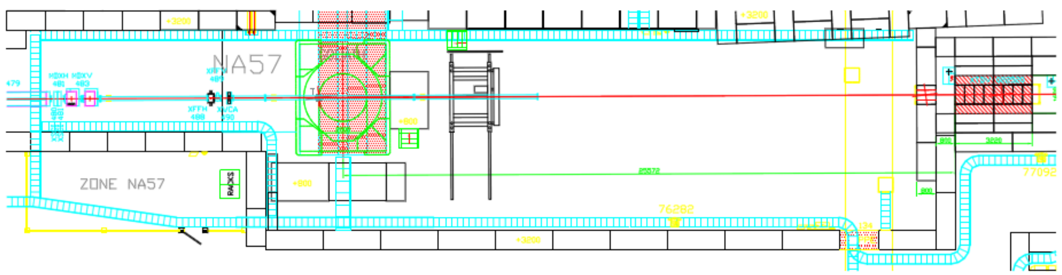
Technical support
MPGD Detectors
Gas system and services
Readout electronics (std and custom RD51 SRS&APV)
Radioactive Sources
Interface with CERN services (RP, gas, metrology, irradiation facilities,…)

Semi Permanent Test Beam Facility in the SPS Extraction Line

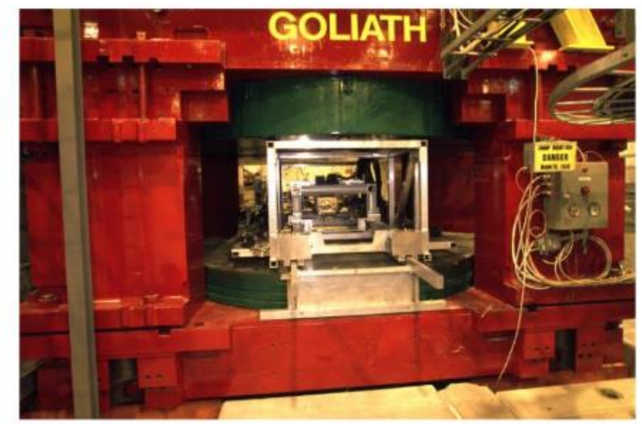


Three periods of two weeks each per year
About fifteen-twenty users per year

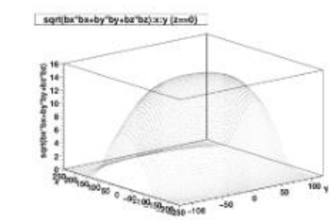




Goliath Magnet → Ship?



M. Alfonsi (CERN) RD51-WG7 2009-VI 28/04/2009



Field map realized during NA57 experiment, file decoded by Frascati group

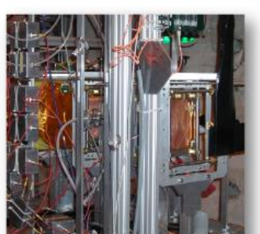
Power: about 2MW
Maximum field: 1.4T
Gap volume: around 8 m^3

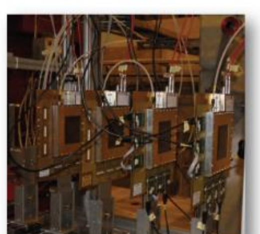
A warm and special thanks to the SPS, the North Area Facility and to all the people that supports our installations

Rd51 trackers

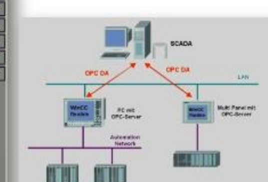
- Triple GEM Tracker
  - XY strips readout, 400um pitch
  - 10x10 cm^2
  - APV (VFAT2)
  - DAQ&FE: SRS/APV (TURBO/VFAT)

- Resistive µmegas tracker
  - XY strips readout, 250um pitch
  - 9x9 cm^2
  - APV
  - DAQ&FE: SRS/APV





Slow Control System (HV/LV)



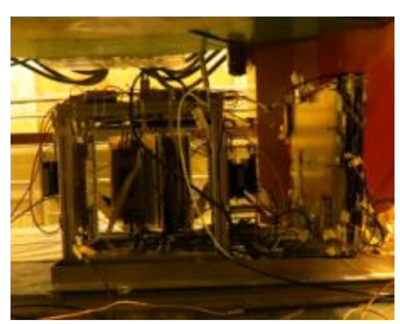
K. Karakostas

9/23/2014 1st User meeting 5

Examples of the test beam user teams

CMS (GEM)

WIS/A/C(WELL, THGEM)



ATLAS NSW (mm)

BESS III & SHIP (GEM)

LAPP/DEM/IRFU(mm)

ALICE TPC (GEM and mm)

Technology: MPGD Production and Development @ CERN

MPGD Projects….

•SBS tracker	GEM 600mm x 500mm
•ALICE TPC upgrade	GEM 600mm x 400mm
•CMS muon	GEM 1.2m x 450mm
•ATLAS NSW muon	Micromegas 2m x 1m
•COMPASS pixel Micromegas	GEM & Micromegas 500mm x 500mm
•BESIII	GEM 600mm x 400mm
•KLOE	GEM 700mm x 400mm
•SOLID	GEM 1.1m x 400mm
•CLAS 12	Micromegas 500mm x 500mm
•LSBB (geoscience)	Micromegas 1m x 500mm
•Prad	GEM 1.5m x 55cm
•CBM	GEM 1m x 450mm
•ASACUSA	Micromegas

•Most of them are still at the R&D phase but some are already in production:

•ATLAS NSW	1300 m2
•SBS Tracker	100 GEMs
•ALICE TPC upgrade	350 GEMs
•COMPASS pixel Micromegas	20 GEM + Micromegas
•BESIII	15 GEM
•CLAS 12	30 Micromegas
•CMS	450 GEM



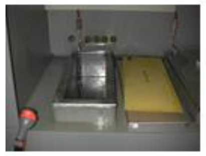
New Capabilities….


UV exposure unit limited to 2m x 0.6m → 2.2m x 1.4m



Resist developer limited to 0.6m width → 1.2m
Resist stripper "
Copper etcher "
Dryer "


GEM electro etch limited to 1m → 2m



GEM polyimide etch limited to 1m → 2m



Ovens limited to 1.5m x 0.6m → 2.2m x 1.4m



Laminator limited to 0.6m width → 1.2m


Installation of the new infrastructure (to fabricate 2x1m^2 Bulk MM & 2x0.5m^2 GEM) COMPLETED

Construction of the new workshop's building:

Start : beginning of 2012
End: end of 2017


CERN Building 107
Basis of Design

RD51 Future

R&D Environment

R&D Environment

Expertise, infrastructure and tools

People – **core service; generic and support R&D group**

Minimum infrastructure – **R&D lab** and test beam facilities

Community:
- open information and experience exchange;
- organization of the conferences, meetings, workshops, schools, lectures, trainings, AIMEs
- contribution to the development, maintenance and user support of the infrastructure, electronics and software tools
- education of the **new generation of instrumental physicists**

Interdisciplinary CERN wide Instrumentation R&D Infrastructure
Alternatively **access** to CERN and external facilities :
- MPT
- Thin Film Deposition
- Mechanics, designer office, 3D printing
- Metrology
- …
- Nano Lab (EPFL)
- Industry (strategic partnership) and TT

Generic R&D support grants to explore innovative ideas

Detector R&D dedicated **electronics** support

Detector physics and simulation **software tools** support

Diversified Resources

CERN
Collaborating institutions and projects contributions
Industry
EU projects
Project synergies

Project Oriented R&D

R&D support to the projects and experiments

Access to the R&D environment

MPGD Generic R&D

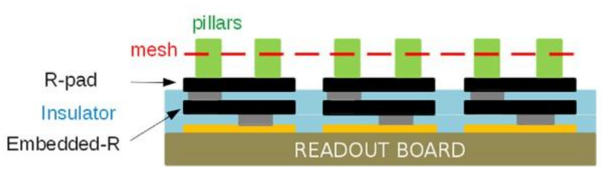
Moving performance to the limits and developing new concepts and applications

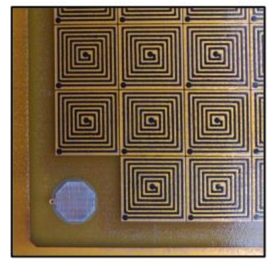
RD51 Future

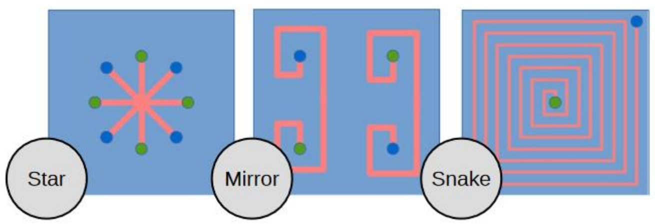
Flagship technologies – **Resistive materials and architectures**

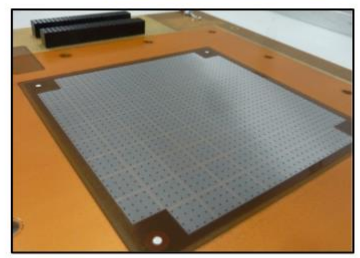
Pad boards
10X10 matrix of 1x1 cm2 pads
Routing on the outside to a 'Gassiplex' connector (96 channels)

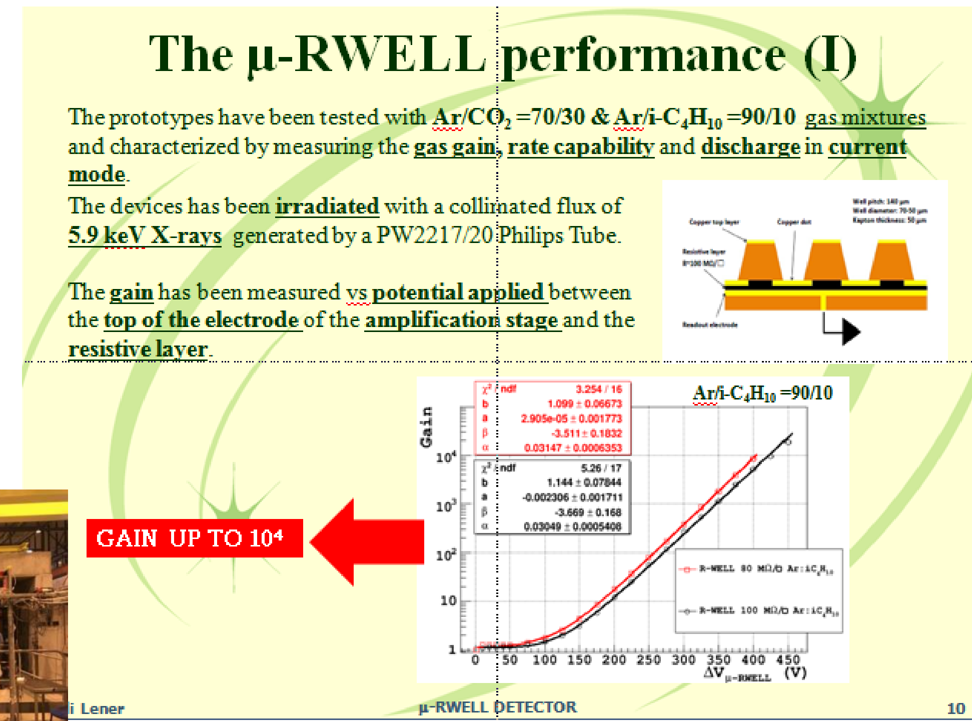
R-structures and Bulk-Micromegas
Serigraphy and photolithography at CERN MPGD workshop

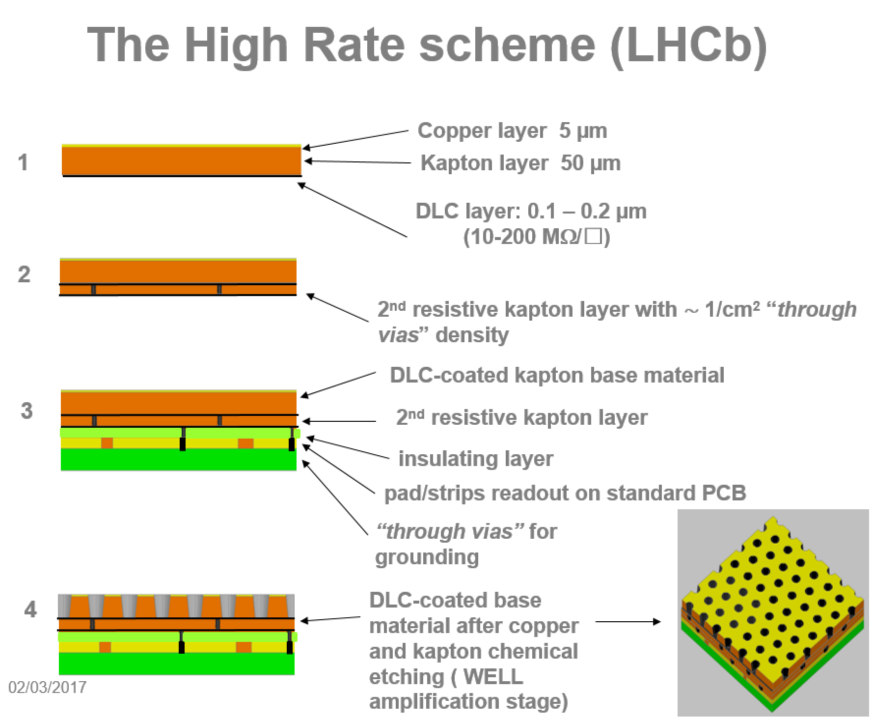


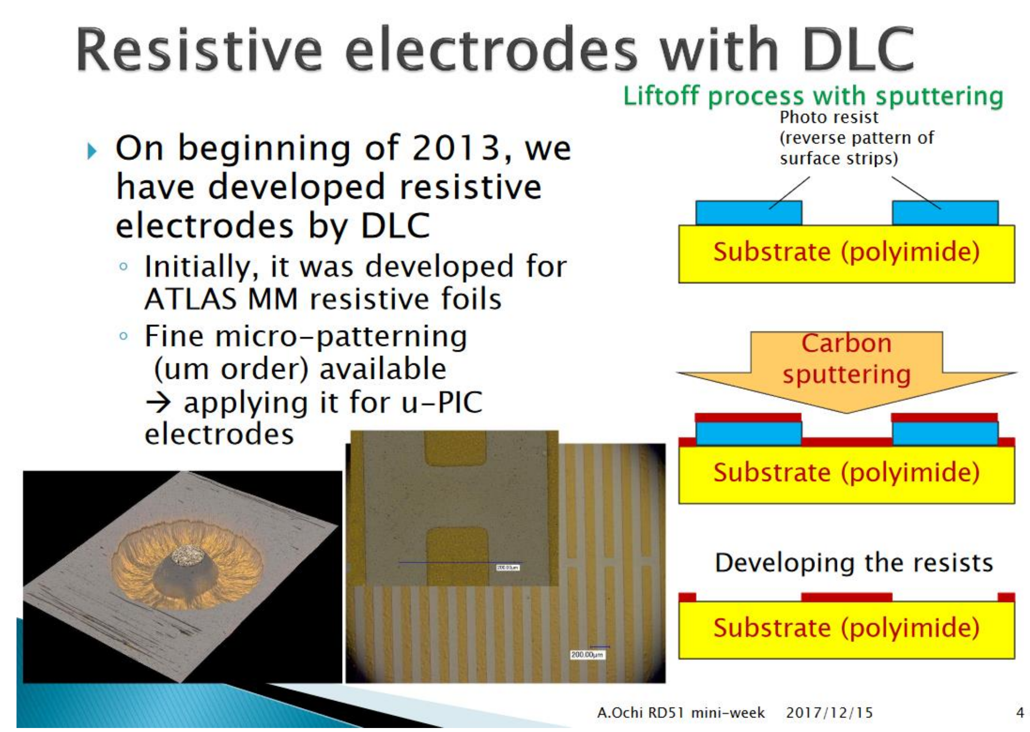






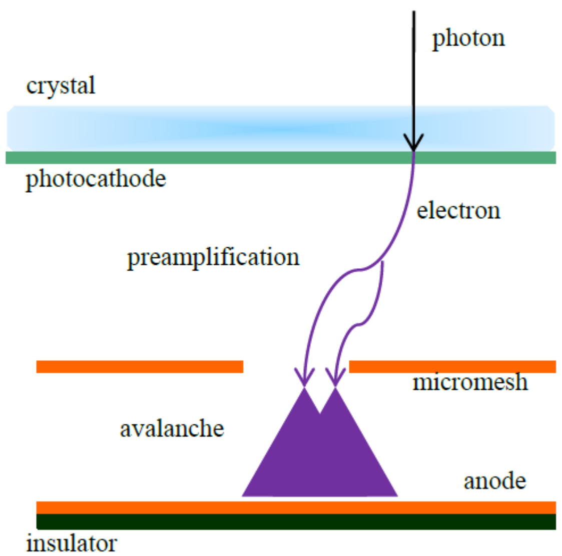


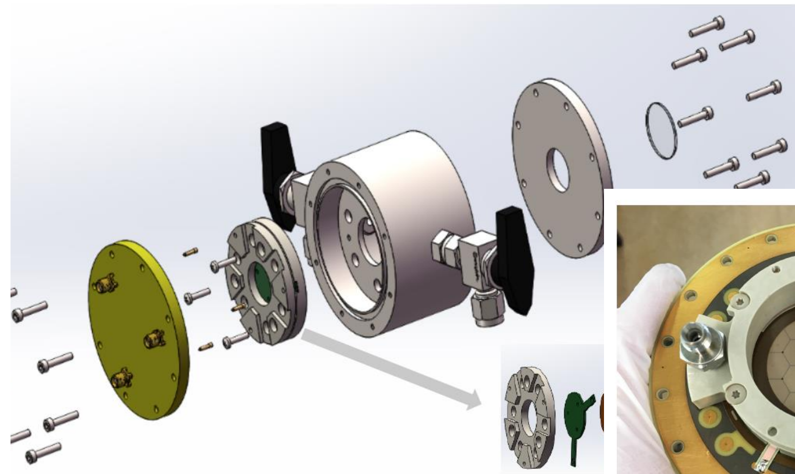


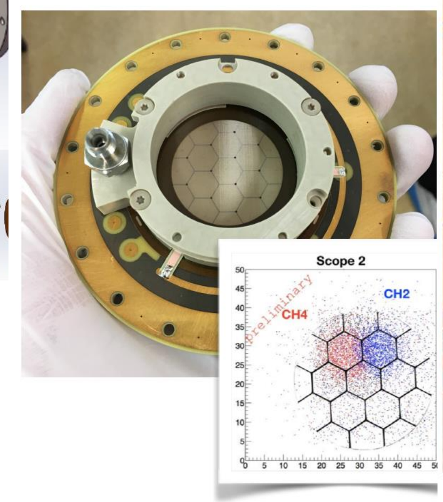


RD51 Future

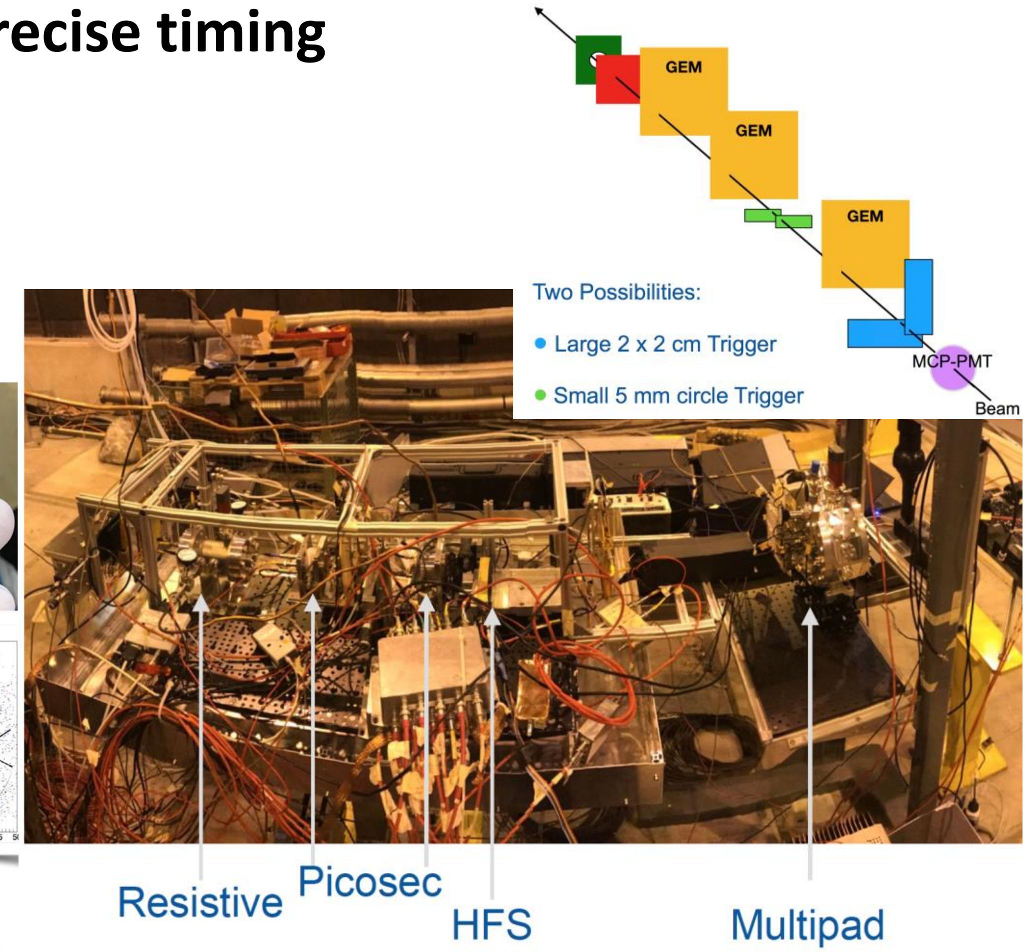
Flagship technologies – **Fast and precise timing**

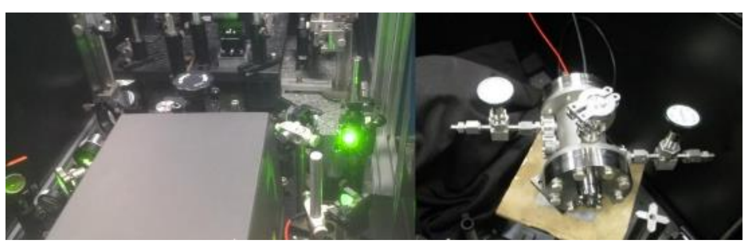


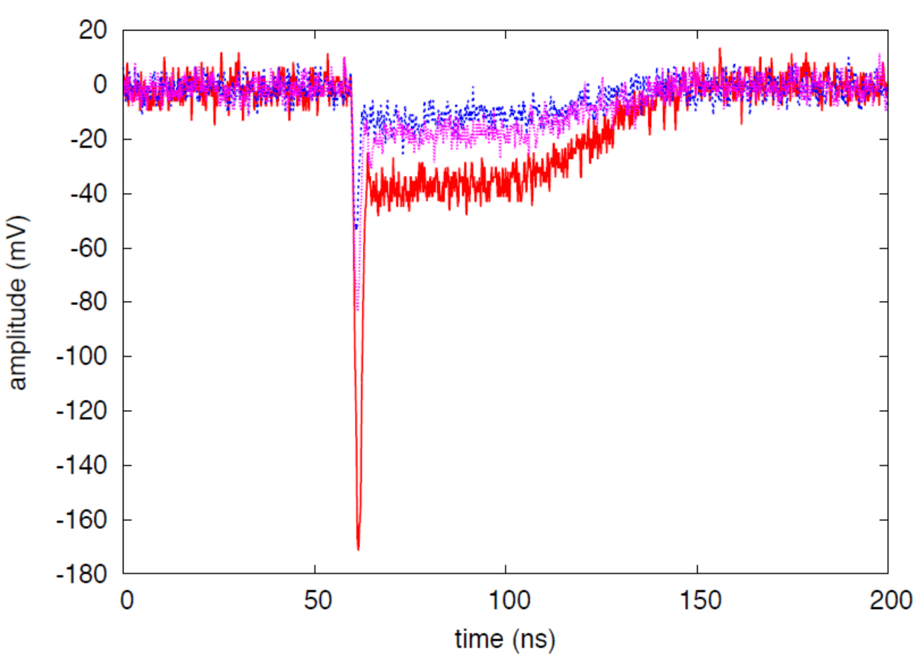


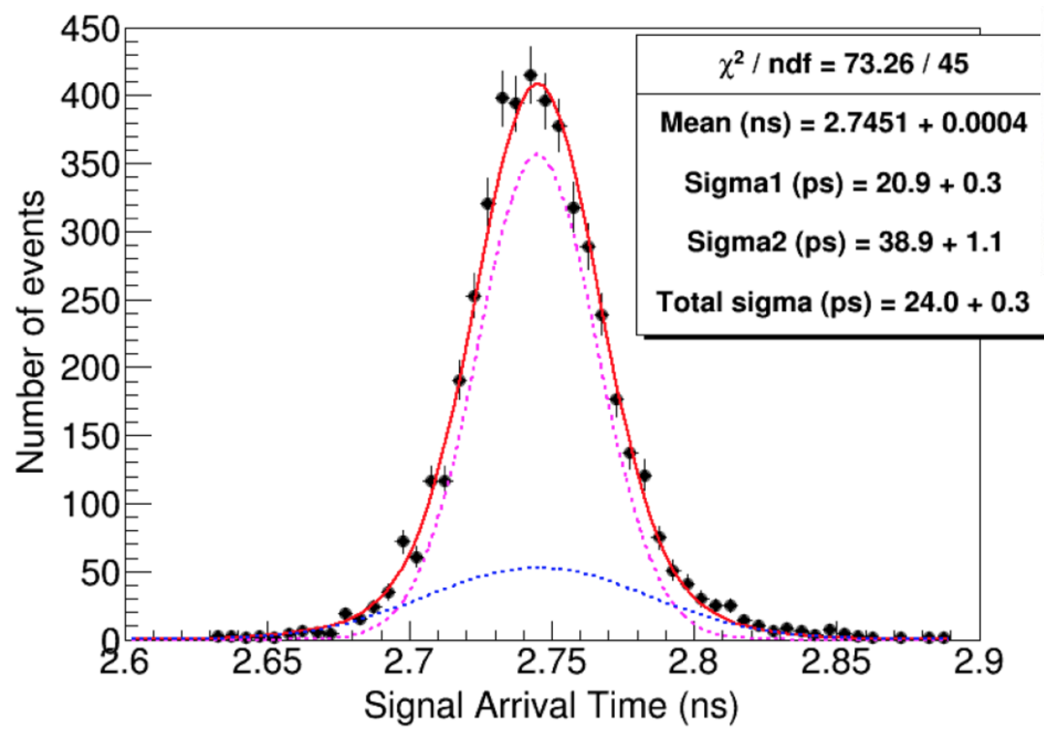


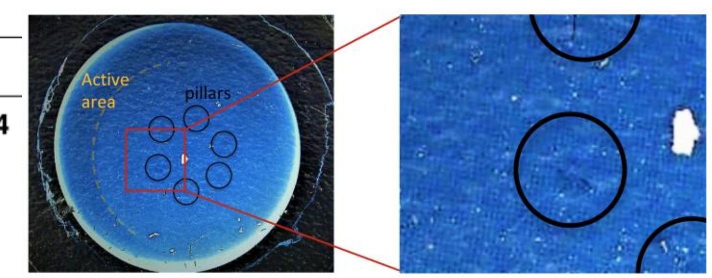
36ps time resolution for signal shared on 3 pads

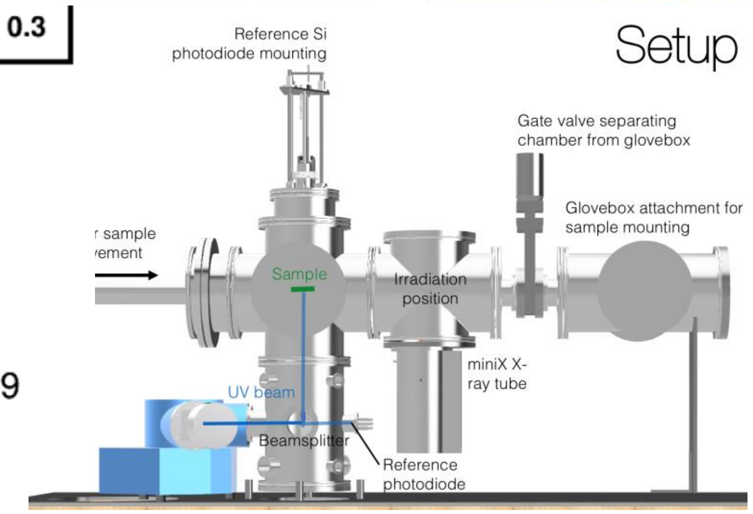








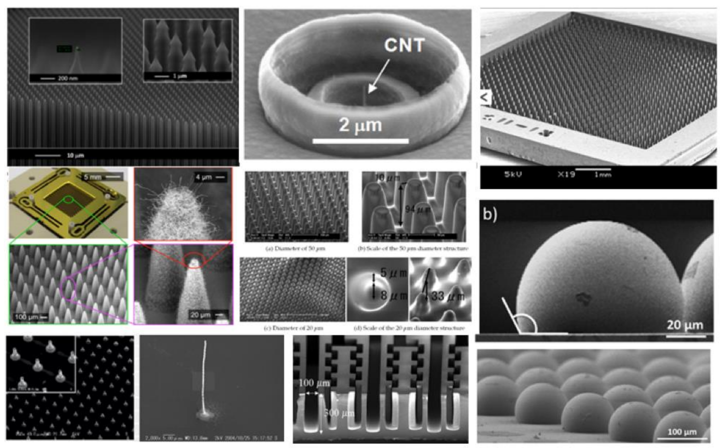


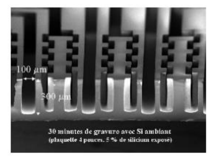


RD51 Future

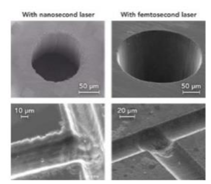
Flagship technologies – **New materials and technologies**

Prototyping: **new techniques as 3D/Ink-Jet printing, etching and laser** to create novel structures will spee ' up and enlarge the detector prototyping capabilities.

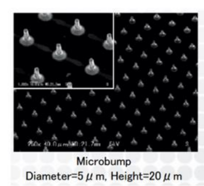




DRIE Plasma

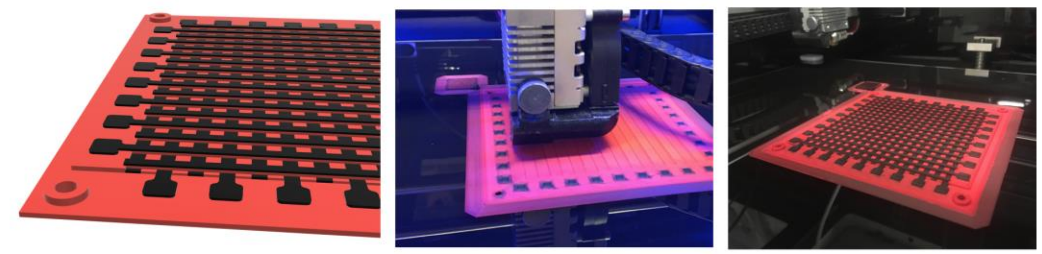


Laser Drilling



Super InkJet Printer

2D strip anode



2 layers of strips separated by insulating material

Bottom strips: 3mm wide at 6mm pitch
Top strips: 2mm wide at 6mm pitch

Signal feedthrough to the back for contacting

18kΩ resistance along track
2-7kΩ resistance through contact feedthrough

Innovative photocathodes by ND powder

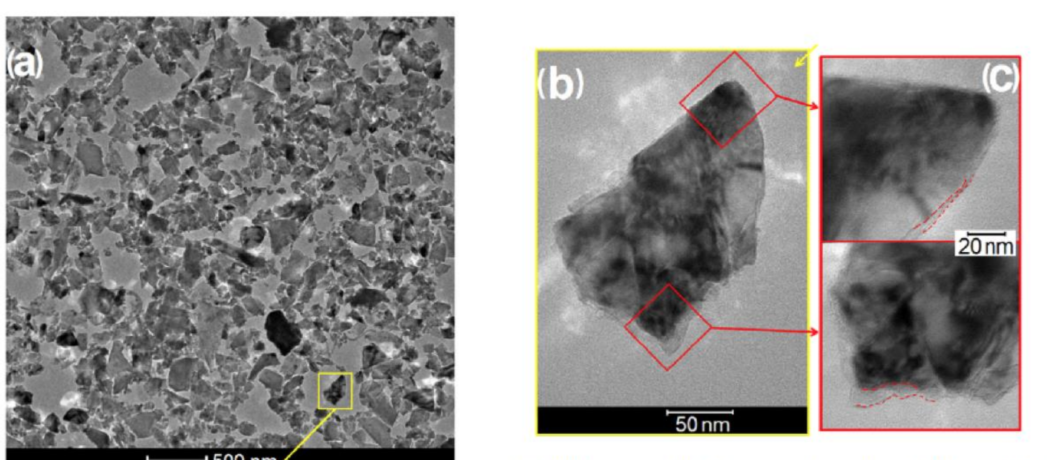
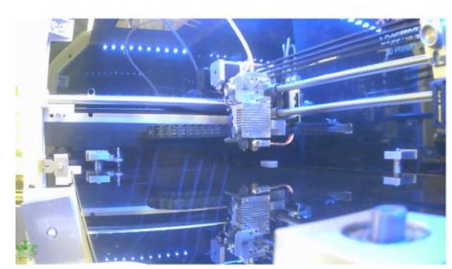


FIG. 2. TEM images of the (a) as-received nanodiamond (ND) particles, a single ND particle and (c) details of the single ND particle.

Highly efficient and stable ultraviolet photocathode based on nanodiamond particles
L. Velardi, A. Valentini, and G. Cicala, Appl. Phys. Lett.108, 083503 (2016)

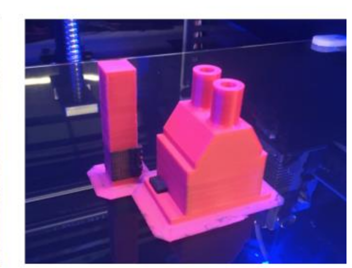
Ionisation chamber

Printed overnight with 0.1mm layer height and slow speed for high surface quality



Timelapse of printing

IR-image during printing



Finished print

RD51 Future

Flagship technologies – **Hybrid detectors**

InGrid & TimePix, the ultimate gaseous TPC
(H. Van Der Graaf)

CAST

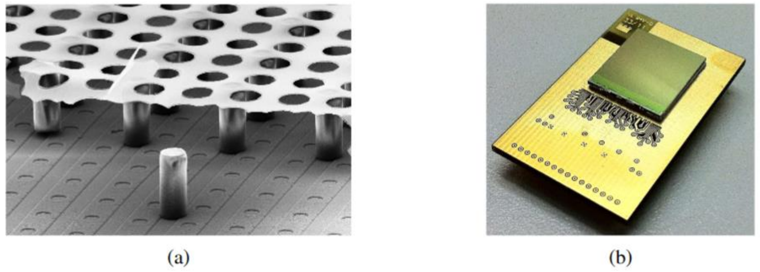


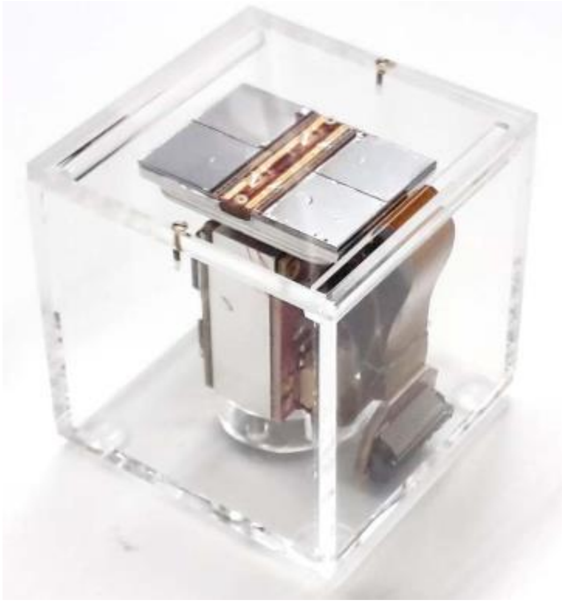
Figure 1: SEM image of an InGrid structure on top of a Timepix ASIC (a), taken from [13]. In the SEM image parts of the mesh have been removed to show the good alignment between pixels and mesh holes. And a bare Timepix ASIC on a carrier board (b).

https://cds.cern.ch/record/2025932/files/PoS(TIPP2014)060.pdfT

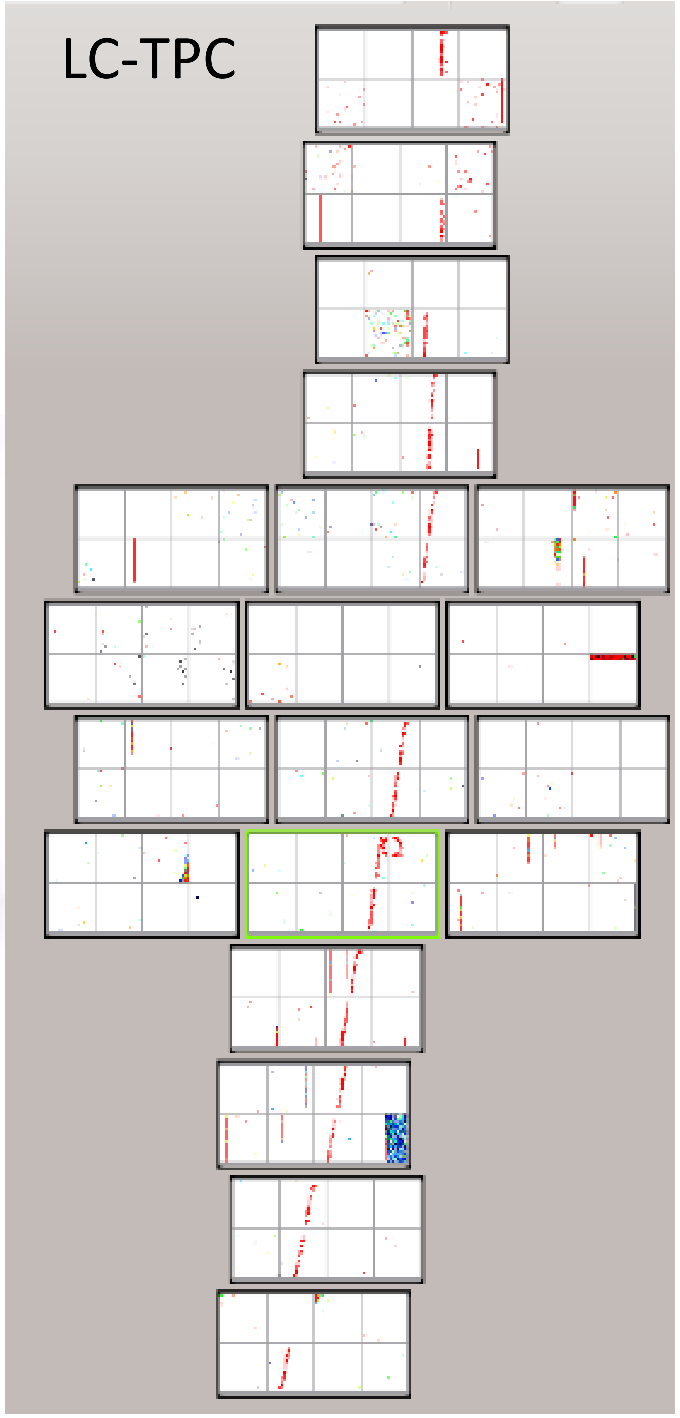
256 x 256 pixels, 55 x 55 µm pitch, about 1.4x1.4 cm2 sensitive area

F. Hartjes,
https://agenda.linearcollider.org/event/7795/contributions/40334/attachments/32507/49403/QUAD_development.pdf

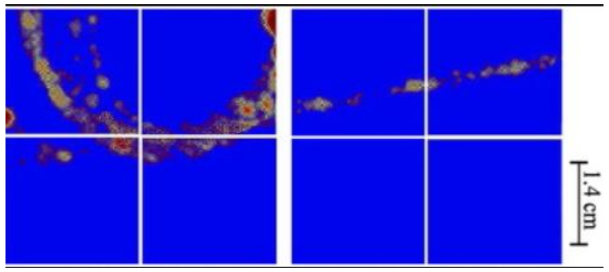
The "QUAD"



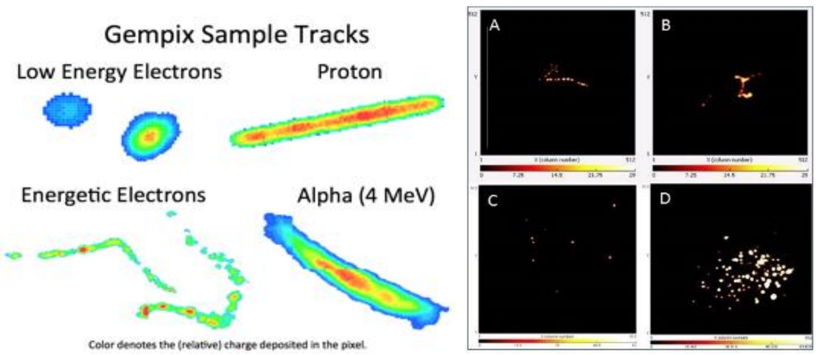
LC-TPC



A large TPC prototype for a linear collider detector P. Schade, J. Kaminski, NIMA, 628, 1, 1 February 2011, Pages 128-132



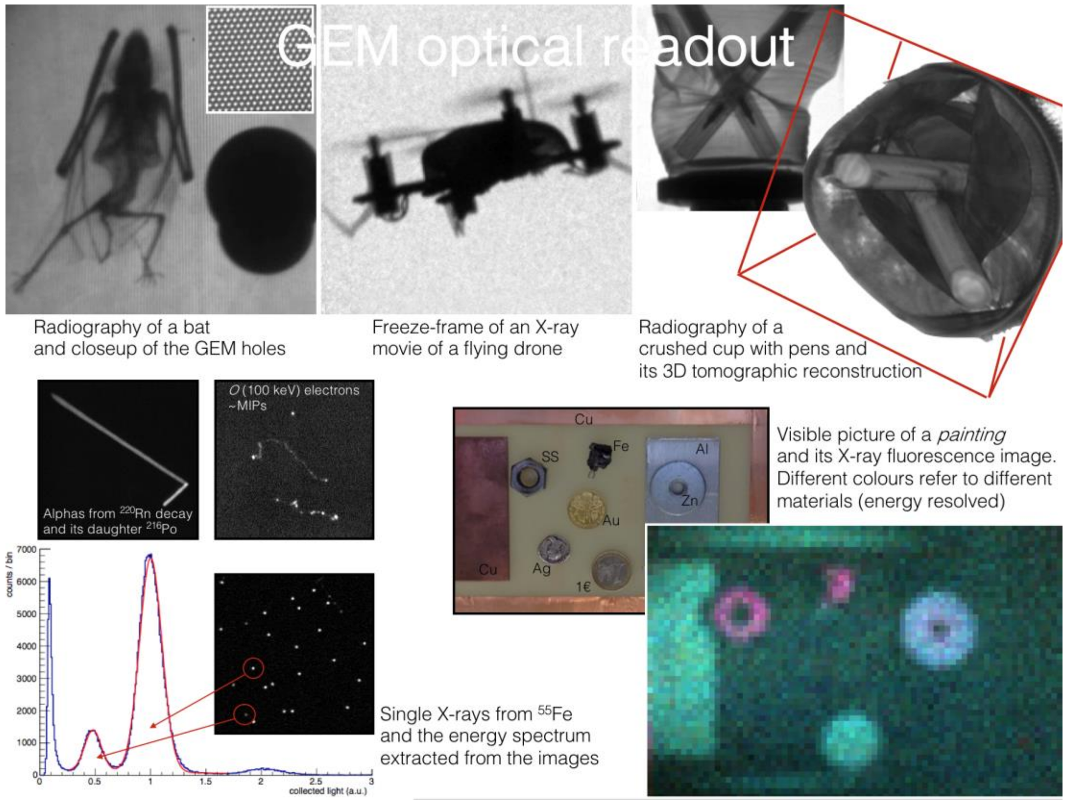
GEMPIX (F. Murtas et al.)

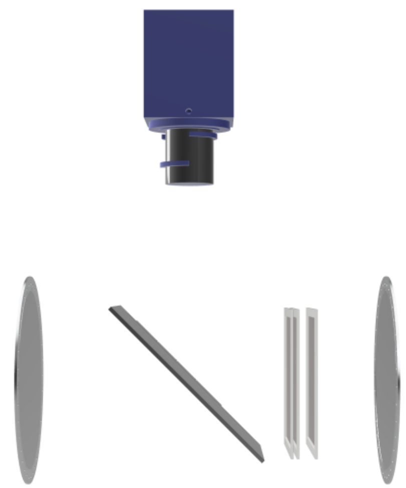


J. Kaminski,
https://indico.cern.ch/event/391665/contributions/1827282/attachments/1230061/1802690/GridPix.pdf

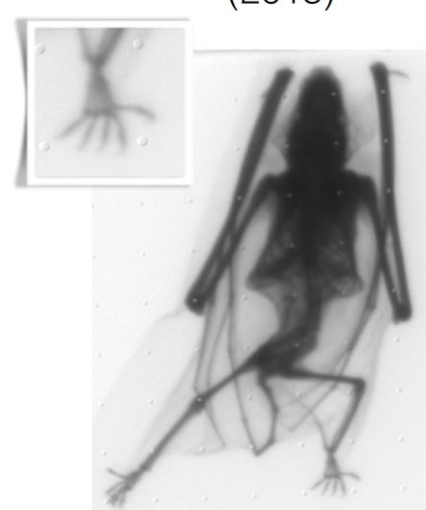
RD51 Future

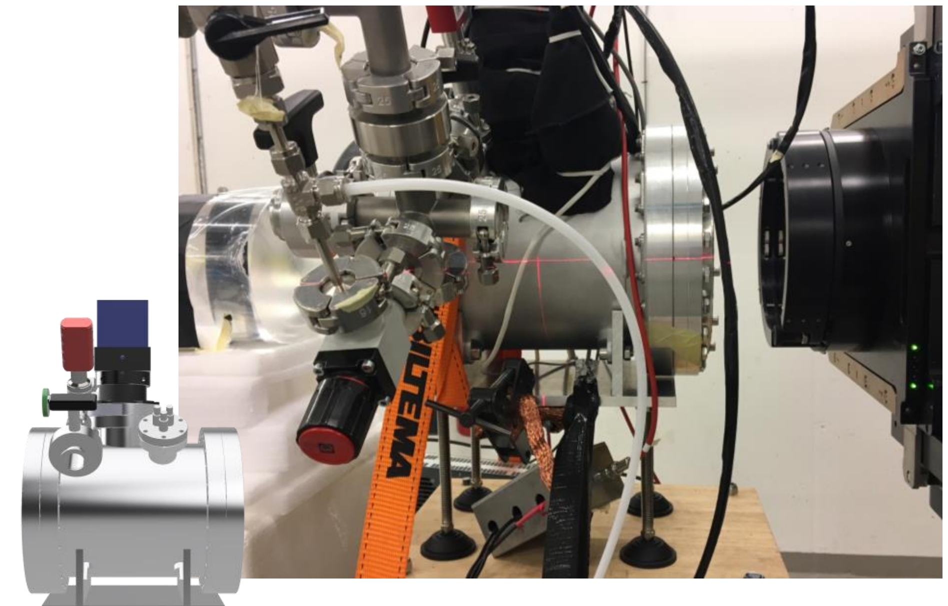
Flagship technologies – **Hybrid detectors**



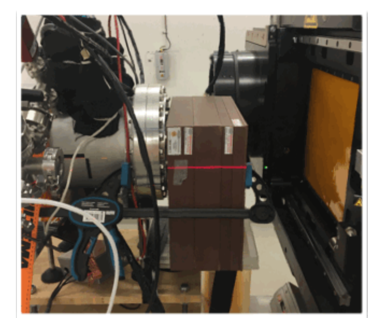


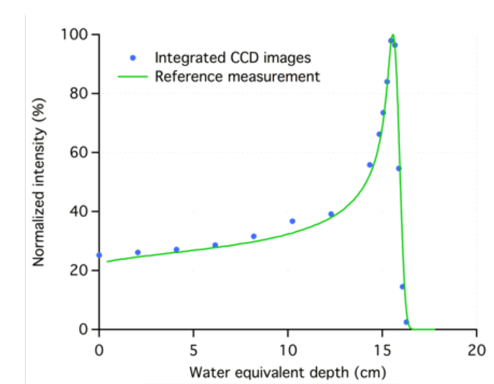
Optically read out MMs (2018)

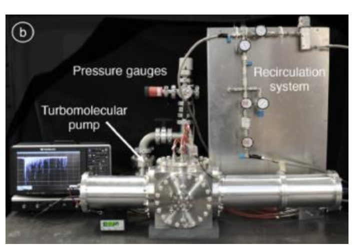




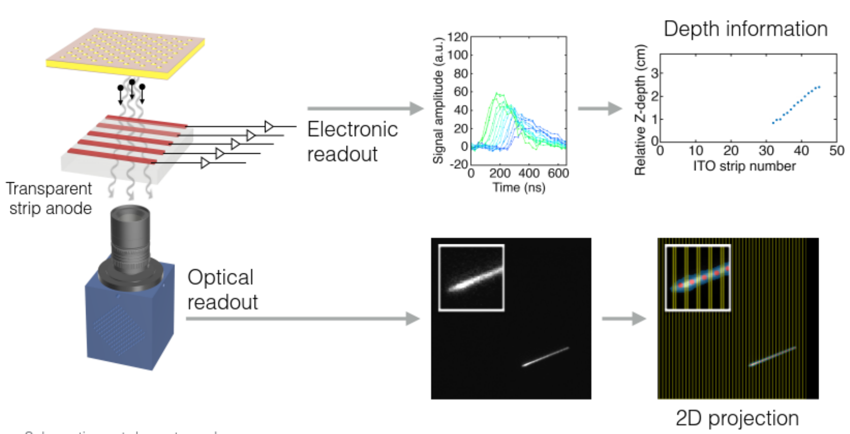
Depth dose curve



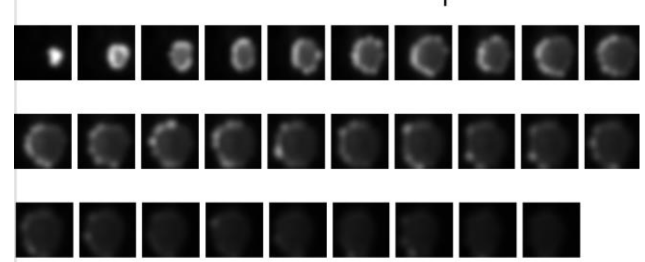


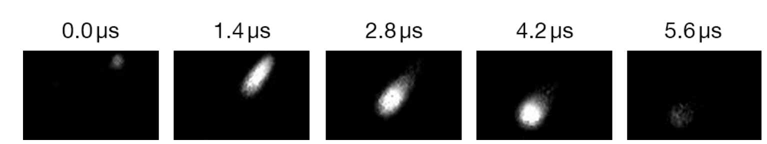


Combined electronic and optical readout

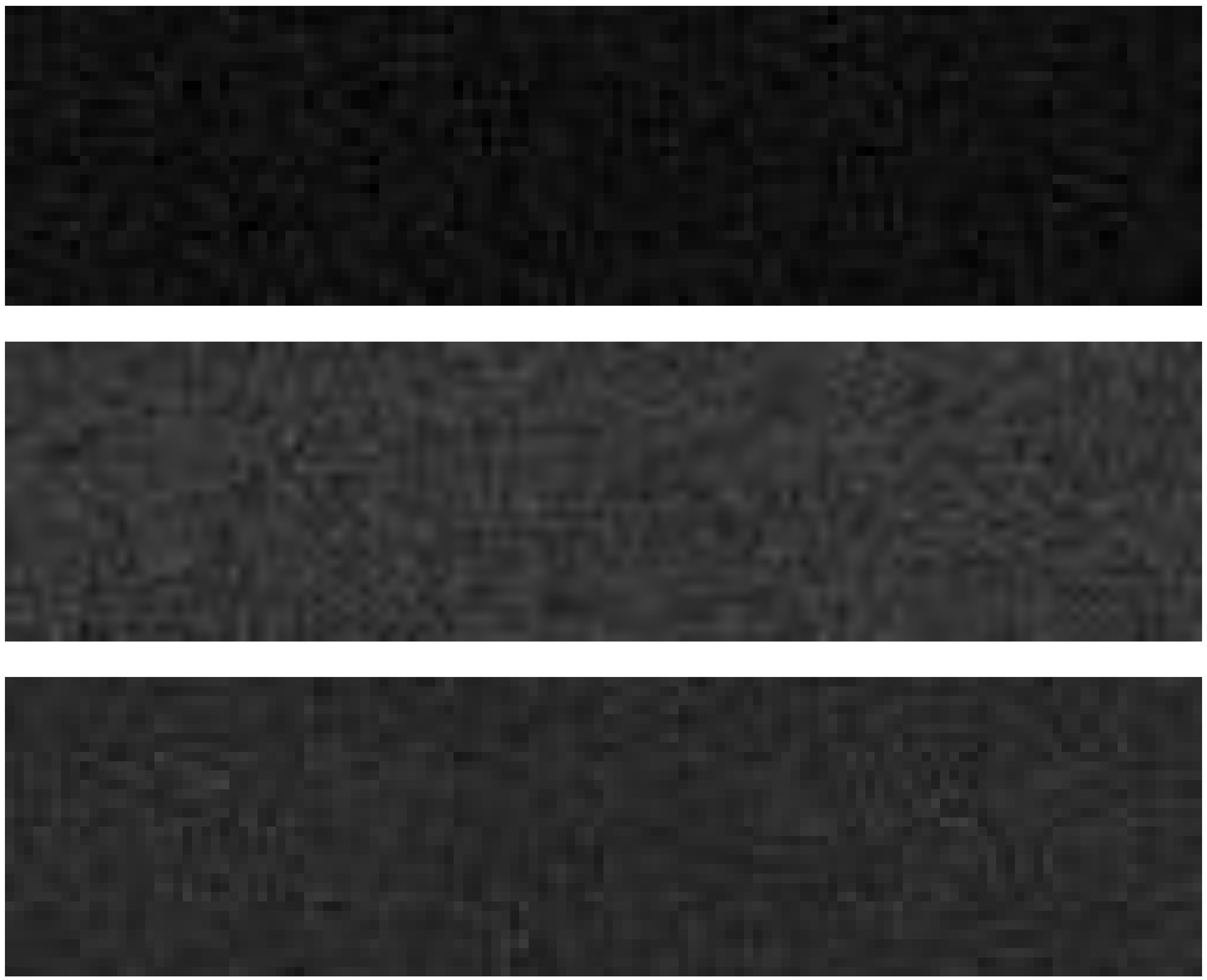


Patient treatment plan





Phantom High Speed Camera - oTPC α tracks almost SF



Phantom v2512

Resolution	FPS
1280 x 800	25,700
1280 x 720	28,500
1024 x 512	47,400
640 x 480	70,100
512 x 384	99,800
256 x 256	206,300
256 x 128	380,100
128 x 64	783,100
128 x 32	1,000,000
128 x 16	1,000,000

- 1 megapixel CMOS sensor
- 12 bit depth
- **25 kfps** at full resolution
- **1 Mfps** at 128x32
- ISO 100,000 sensitivity

RD51 Request

RD51 proposes to extend its activities for further five-year term.

RD51 requests limited support from CERN facilities at existing level:

• access to the Gaseous Detectors Development (GDD) lab space, infrastructure and maintenance support;

• office space and administrative support;

• maintenance of the semi-permanent setup at the SPS H4 test beam line and, correspondingly, access to the beams over several time periods for a total of six weeks per year;

• continuation of the collaborative access to the:
– the Micro Pattern Technology Workshop (EP-DT-EF MPT)
– the Thin Film and Glass Laboratory (EP-DT-EF TFG);

• access to other CERN technical facilities, in particular:
– Bonding Laboratory (EP-DT-DD)
– Electronics Assembly Workshop (TS-DEM-WS)
– Materials, Metrology & Non Destructive Testing (EN-MME-MM)
– Surface treatment, coating and chemical analysis (TE-VSC)
– the central computing resources for MPGD simulations.

LARGE HADRON COLLIDER COMMITTEE

Minutes of the one-hundredth-and-thirty-fourth meeting held on
Wednesday and Thursday, 30-31 May 2018

RD51: Development of Micro-Pattern Gas Detectors Technologies

• RD51 is an established collaboration with the aim to develop Micro-Pattern Gas Detector (MPGD) technologies, to support experiments using this technology, and to disseminate the technology within particle physics and in other fields. The collaboration is well organized into seven working groups covering activities from new detector structures and electronics, to modelling, test facility management and industrialization.
• The collaboration has achieved major progress in MPGD technologies, some of which have already been picked up by experiments: ALICE TPC readout, ATLAS NSW, CMS GE1/1 forward detectors, Compass RHICH detector. The committee congratulated the collaboration for its progress since the last review session.
• A prolongation request for 5 years has been submitted to the present session of the LHCC. Apart from the **support of the ongoing projects**, the proposal included plans to **explore new materials and technologies** to achieve ever better resolution in space and time and **open the door to new use cases both in HEP and elsewhere**.

• The **LHCC recommends** granting RD51 the 5-year extension requested, including CERN support at the level currently provided. Progress will be reviewed every year by the LHCC. The **LHCC considers** the working mode of RD51, with a small but focused core team and corresponding infrastructure at CERN, attracting contributions and bright ideas to be explored from collaborators around the world, to be an excellent setup. The **LHCC notes** that the CERN contribution to RD51 as listed in the proposal is crucial for the collaboration, and **strongly encourages** CERN to maintain its support of RD51.