

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.

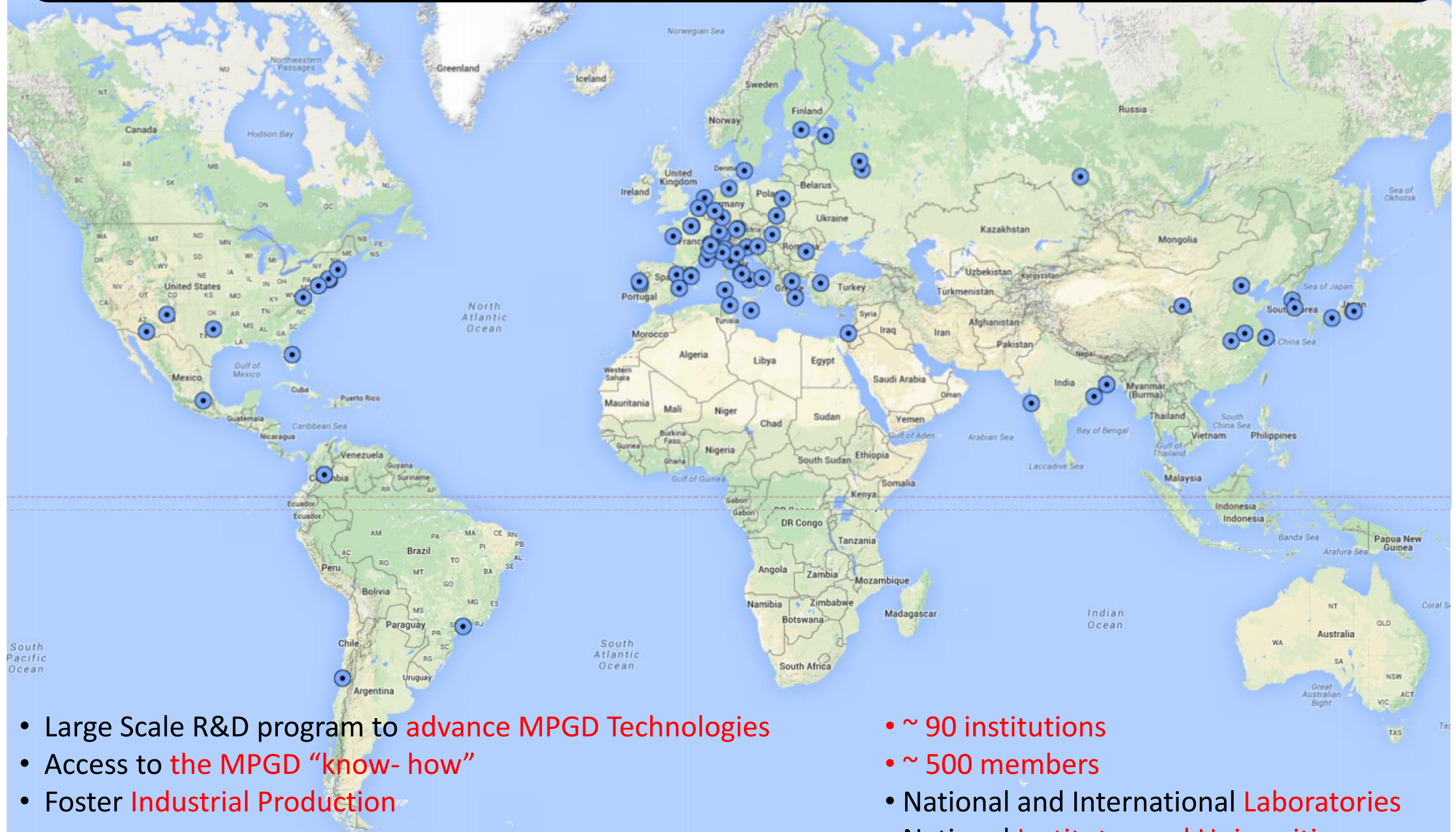
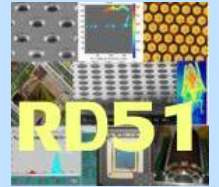
Micropattern Gaseous Detectors RD51

**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>



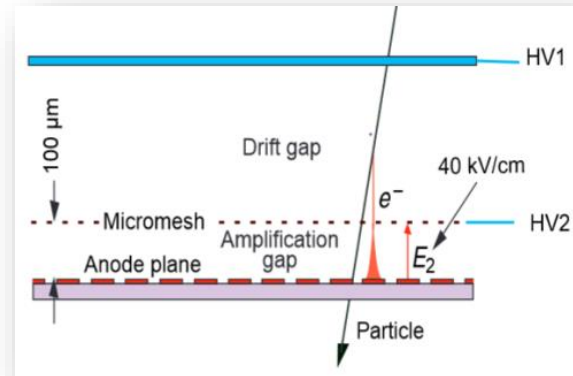
- Large Scale R&D program to **advance MPPD Technologies**
- Access to **the MPPD “know- how”**
- Foster **Industrial Production**

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

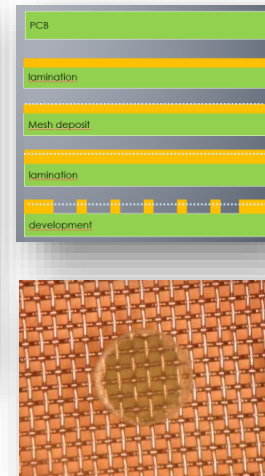
Micro Pattern Gaseous Detectors (MPGDs) and RD51 Collaboration

- 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

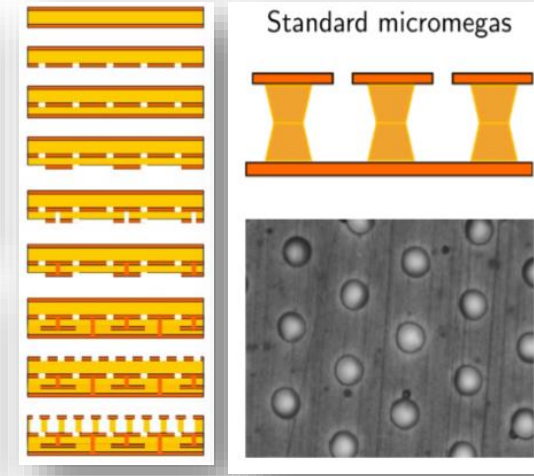
Micromegas



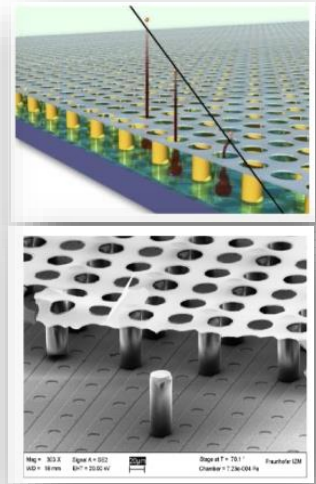
Bulk



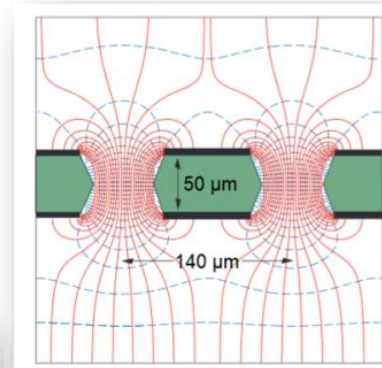
Micro bulk



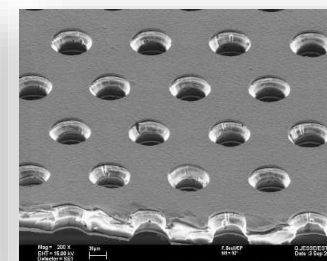
InGrid



GEM



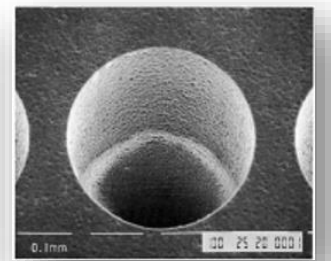
50μm GEM



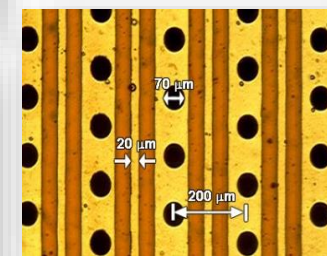
THGEM



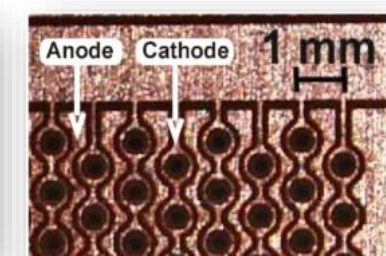
GLASS GEM



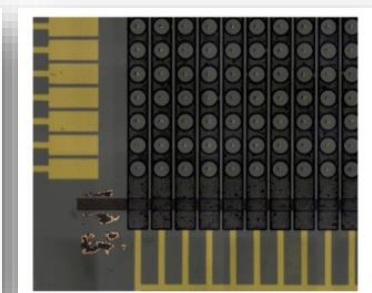
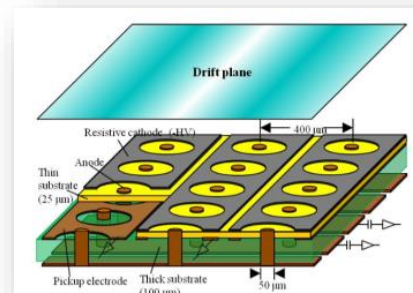
MHSP



THCOBRA



μPIC



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MICRO-PATTERN GASEOUS DETECTOR TECHNOLOGIES AND RD51 COLLABORATION

MAXIM TITOV

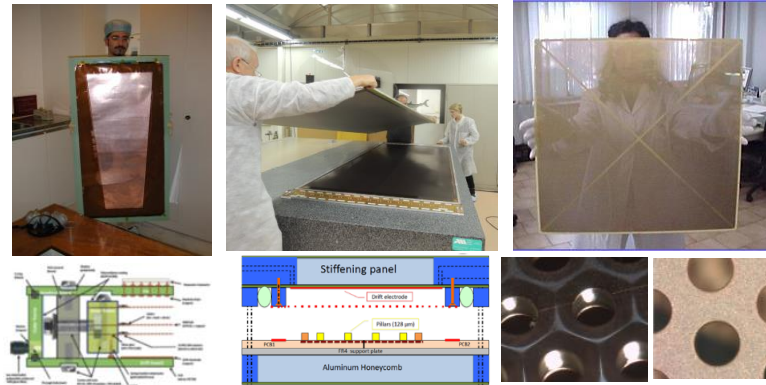
CEA Saclay, DSM/IRFU/SPP, 91191 Gif sur Yvette, France
maxim.titov@cea.fr

LESZEK ROPELEWSKI

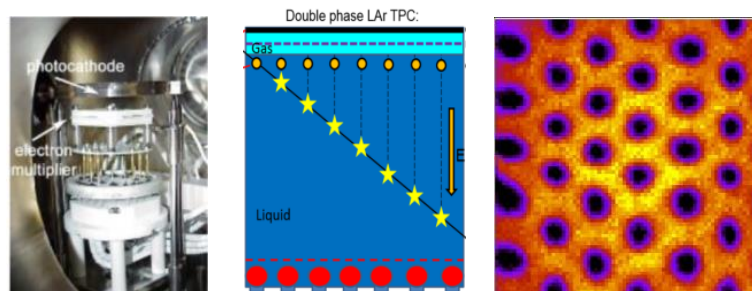
CERN PH, CH-1211, Geneva 23, Switzerland
leszek.ropelewski@cern.ch

RD51 (well consolidated) Working Groups

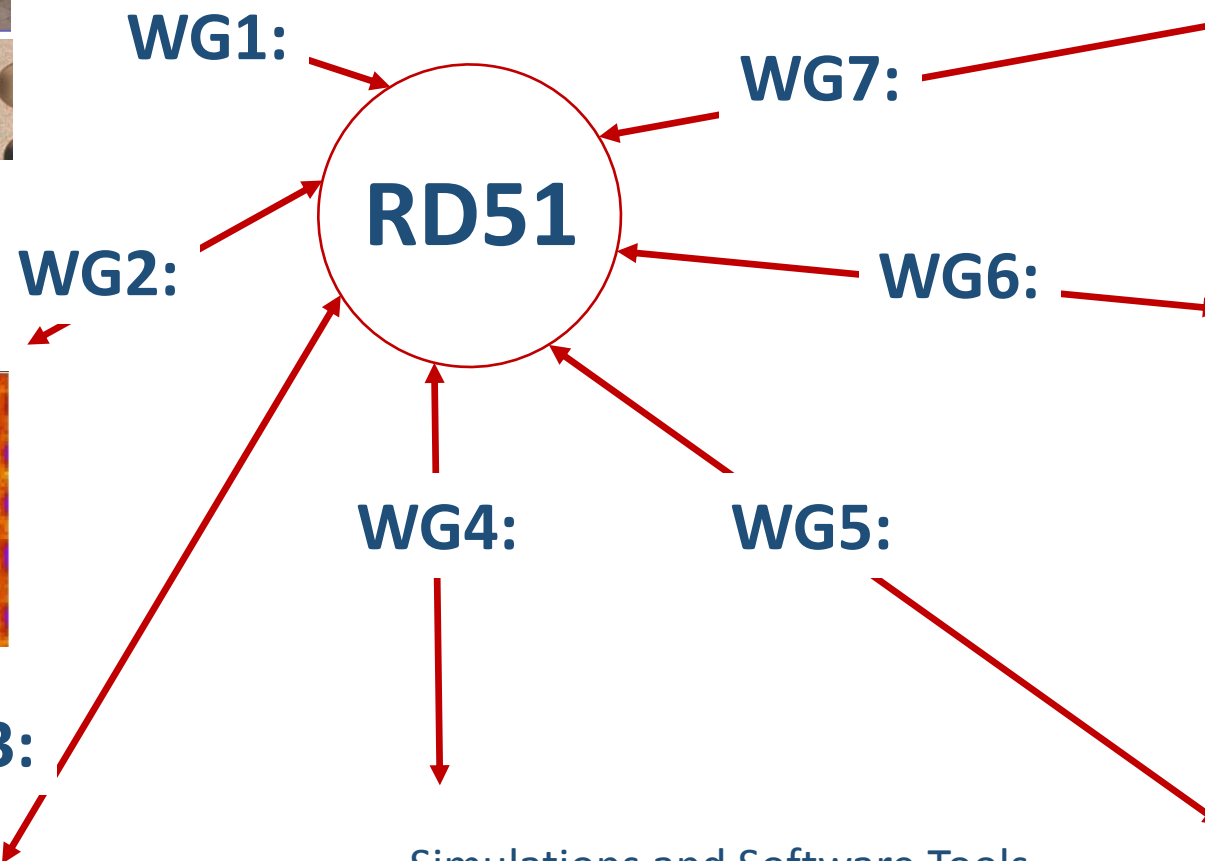
Technological Aspects and Development of New Detector Structures



Common Characterization and Physics Issues



Academia-Industry Matching Events, Training, Education



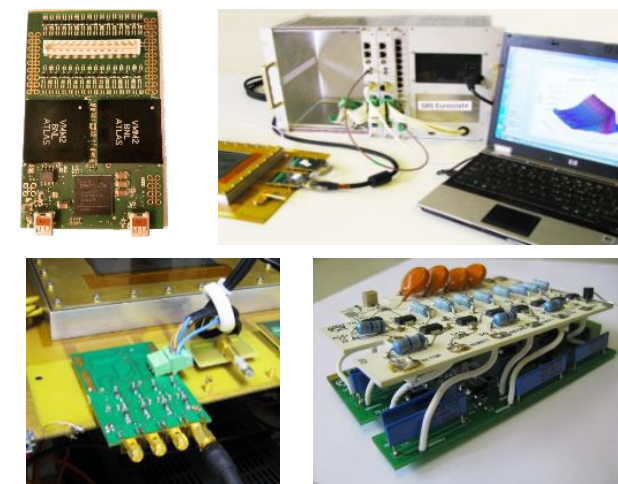
Common Facilities : Test Beam and Laboratory



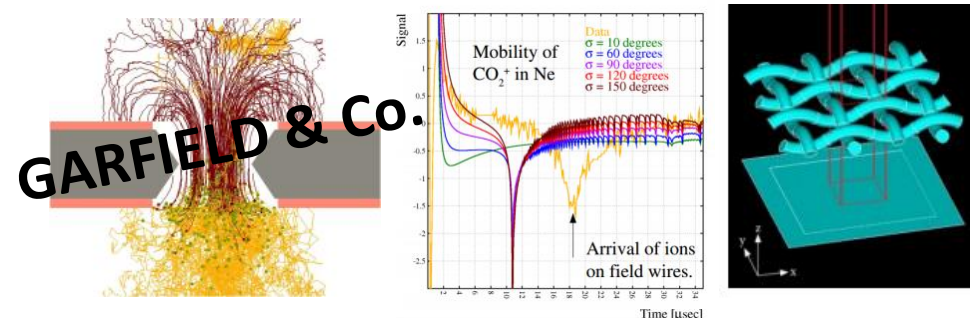
Production, quality control, industrialization



MPGD Related Electronics



Simulations and Software Tools



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 MPPGD 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 m² of GEM foils
ATLAS, small wheels, 1200 m² to be instrumented
CMS, GE1/1 forward detectors, 250 m² of GEM foils
COMPASS RICH, 4.5 m² to be instrumented, single photon detection
- **Secured future** of the MPPGD 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 MPPGD **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)



ALICE

- The ALICE upgrade strategy
- ALICE TPC overview
- Operation from RUN1 to RUN3
- GEM readout for the TPC
- Ion backflow optimization
- Prototype tests
- Expected performance in RUN3
- Read-out electronics
- Summary and Outlook


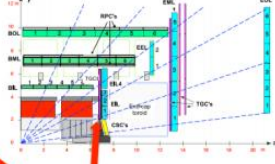
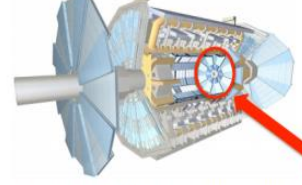
Content





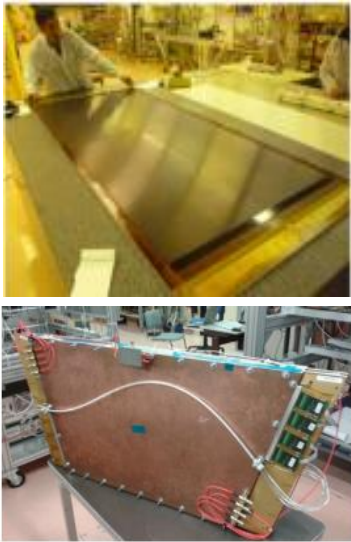
ATLAS NSW (mm)

The ATLAS Muon Spectrometer and the Small Wheel



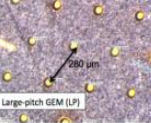
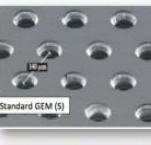
- In the Barrel Region the ATLAS Muon Spectrometer is realized by RPC and MDT detectors, while in the End Cap Regions CSC, MDT and TGC detectors are used
- The Small Wheel (Innermost Endcap Muon Station) is the region with highest background rates in the present ATLAS Muon Spectrometer
- The present system is based on Cathode Strip Chambers (CSCs), Monitored Drift Tubes (MDTs) and TGC for particle tracking
- Located between endcap calorimeter and endcap toroid

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IBF optimized configuration (2)

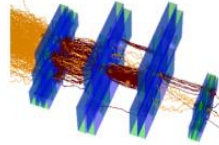
- Satisfactory performance could not be achieved with 3 GEM stack
- Best results in terms of IBF and energy resolution:
- 4 GEM stack
- S-LP-LP-S configuration
- 5: standard GEM foils
- LP: large hole pitch foils
- Optimized V settings: V_{GEM} , E_z (transfer fields)



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La Biodola, Isola d'Elba (Italy)
May 04 - 09, 2015

IBF optimized configuration (7)

- Electron transport properties for IBF optimized voltage settings
- ϵ_{coll} = collection efficiency
- ϵ_{ext} = extraction efficiency
- M = gas multiplication factor
- $G = \epsilon_{coll} \times M \times \epsilon_{ext}$ = effective gain
- n_{back} = number of produced e-ions pairs
- n_{back} = number of ions drifting back into the drift volume

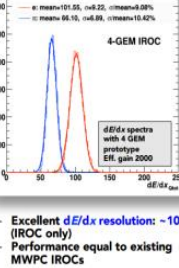



	ϵ_{coll}	ϵ_{ext}	M	n_{back}	G	n_{back}	Fraction of total IBF (sim.)	Fraction of total IBF (meas.)		
GEM1 (S)	1	1	14	0.65	9.1	3.6 (28%)	40%	31%		
GEM2 (LP)	0.2	1.8	8	0.55	8	0.88 (3.3 (26%))	37%	34%		
GEM3 (LP)	0.25	2	53	0.12	12.7	1.6 (1.3 (1.3%))	14%	11%		
GEM4 (S)	1	12.7	240	3053	0.6	1830	144	0.84 (0.03%)	9%	24%
Total	3183	1830	1830	9 (0.28%)						

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Prototype beam tests: PID


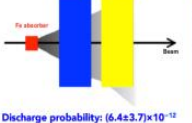
- 4GEM IROC prototype tests: dE/dx resolution measurements at CERN PS



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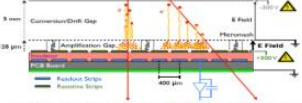
Prototype beam tests: Stability

- Discharge tests at CERN SPS
- Discharge probability: $(6.4 \pm 3.7) \times 10^{-12}$ per hadron
- Additional lab measurements with α and β particles
- Performance similar to standard triple GEMs
- Odd voltage settings compensated by addition of 4th GEM foil
- Expected number of discharges in full TPC per typical yearly heavy-ion run at 50 kHz
- 4.5 discharges per GEM stack, 650 discharges for the whole TPC
- Not expected to create any damage to the GEM detectors



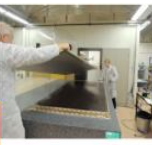
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MicroMegas Technology for the ATLAS NSW Upgrade



Micromegas (J. Giomataris et al., NIM A 376 (1996) 29) are parallel-plate chambers where the amplification takes place in a thin gap, separated from the conversion region by a fine metallic mesh.

We opted for a non-bulk technique (**floating mesh**) that uses also pillars to keep the mesh at a defined distance from the board, the mesh is integrated with the drift-electrode panel and placed on the pillars when the chamber is closed. This allows to build very large chambers using standard PCB.



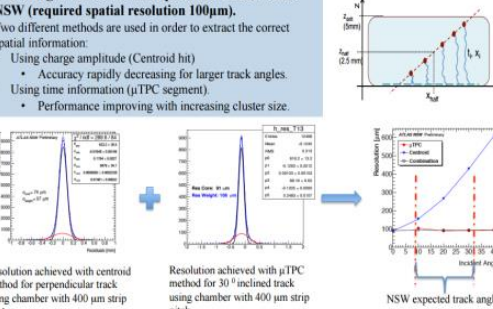
Requirements for a μ momentum resolution of 15% @ 1TeV in ATLAS
Precision of strip position in Eta (precision coordinate) 30 μ m r.m.s.
Precision of strip position in Z (perpendicular to the detection plane) 80 μ m r.m.s.

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Resolution studies

Micromegas will be the main precision tracker of the NSW (required spatial resolution 100 μ m). Two different methods are used in order to extract the correct spatial information:

- Using charge amplitude (Centroid hit)
- Accuracy rapidly decreasing for larger track angles.
- Using time information (μ TPC segment)
- Performance improving with increasing cluster size.




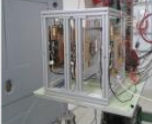

Resolution achieved with centroid method for perpendicular track using chamber with 400 μ m strip pitch

Resolution achieved with μ TPC method for 30° inclined track using chamber with 400 μ m strip pitch

NSW expected track angles

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Performance of MMs prototype



Extremely wide performance analysis program ongoing since 2008 in order to fully characterize the Micromegas chambers. The analysis program has made use of:

- Several test beam campaigns
- Test with cosmic ray
- X-ray guns for gain and mesh transparency measurements
- Irradiation tests (γ , α , neutron) for ageing and radiation hardness studies

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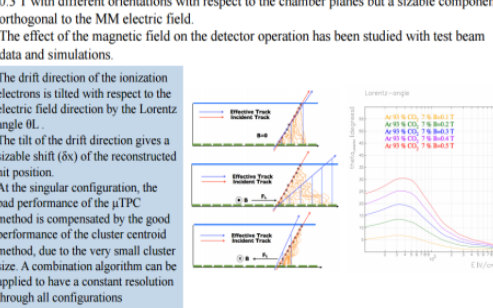
MM performance in magnetic field

The MM chambers of the NSW will operate in a magnetic field of a magnitude up to about 0.3 T with different orientations with respect to the chamber planes but a sizable component orthogonal to the MM electric field. The effect of the magnetic field on the detector operation has been studied with test beam data and simulations.

The drift direction of the ionization electrons is tilted with respect to the electric field direction by the Lorentz angle θ_L .

The tilt of the drift direction gives a sizable shift (δx) of the reconstructed hit position.

At the singular configuration, the bad performance of the μ TPC method is compensated by the good performance of the cluster centroid method, due to the very small cluster size. A combination algorithm can be applied to have a constant resolution through all configurations



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

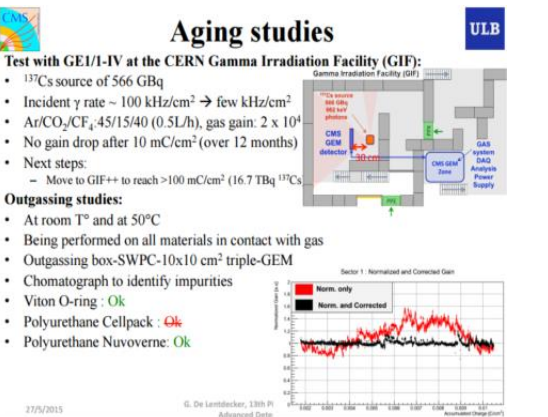
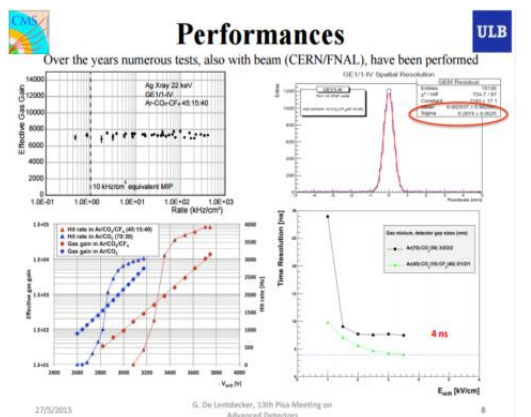
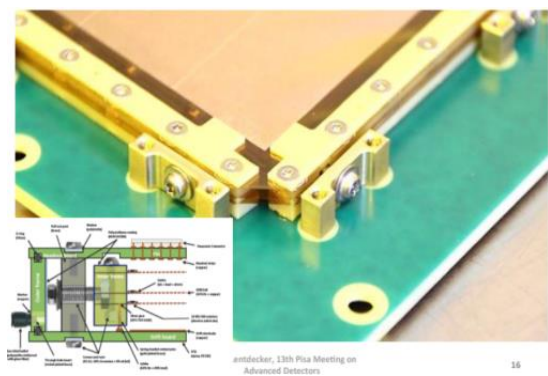
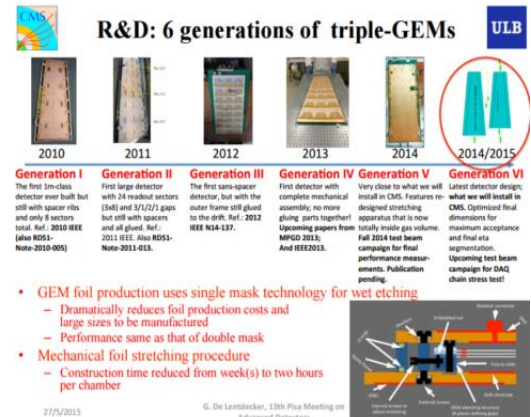
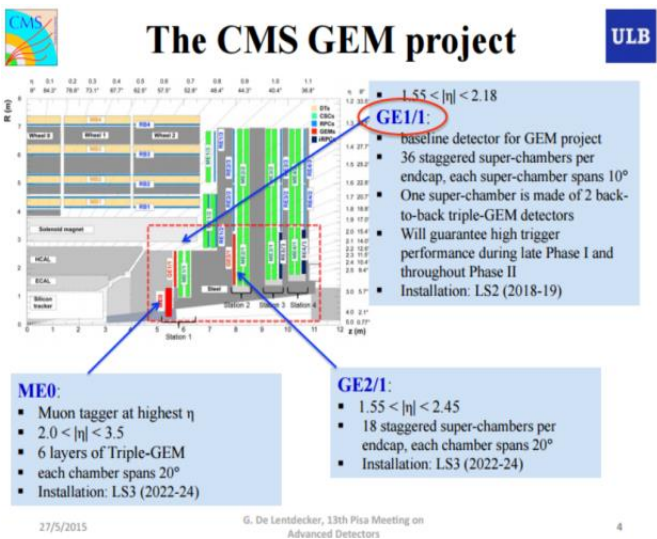
A continuous read-out TPC for the ALICE upgrade, C. Lippmann, Elba 2015

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

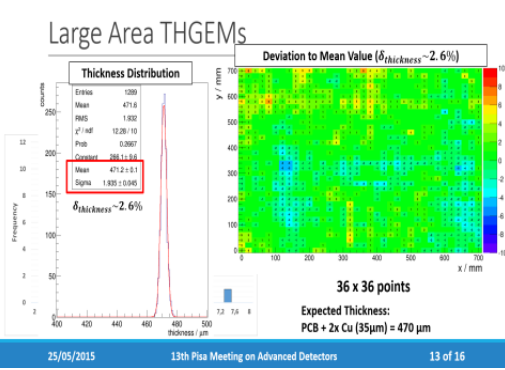
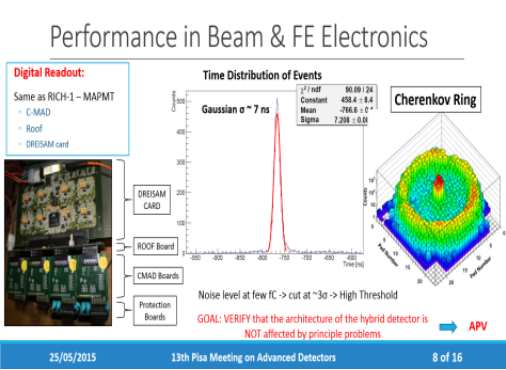
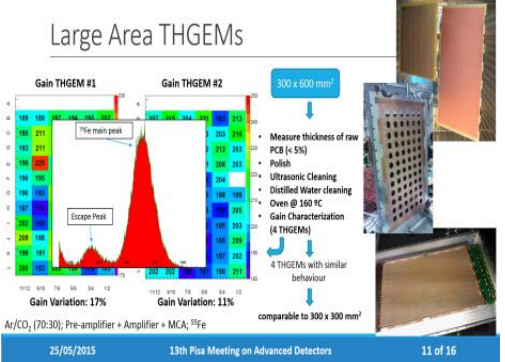
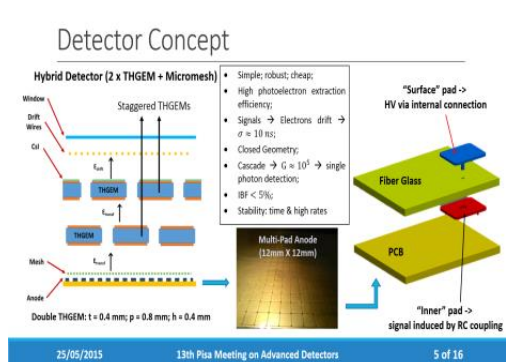
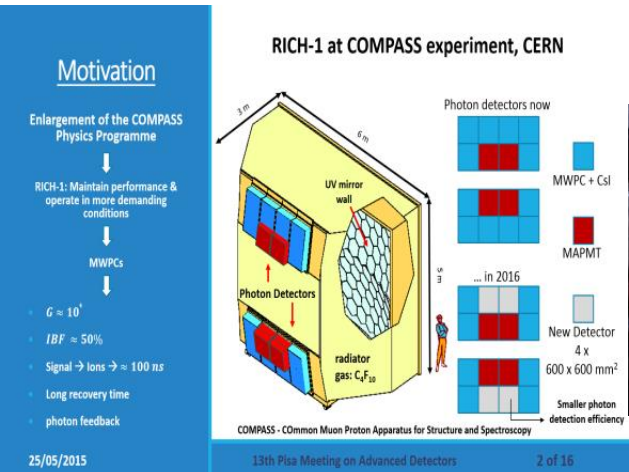
Today: production phase under the project effort, access to RD51 facilities (laboratory, test beam, workshops) and tools (simulation, electronics,...) to facilitate this particular phase

Examples of CERN/LHC Upgrades

CMS (GEM)



COMPASS RICH-1 (THGEM+MM)



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

Resistive Micromegas for Sampling Calorimetry

M. Chetdeville*, Y. Karyotakis (IN2P3/LAPP, Annecy), T. Gerasis (Demokritos, Athens), M. Titov (IRFU, Saclay)

Calorimetry at future collider will be based on Particle Flow (PF)

→ highly segmented calorimeters (small pads, many layers)

Micromegas meets most of the technical and performance requirements (m²-size prototypes)...

...but **sparking might result from dense shower ionisation** (e.g. nuclear recoils, EM shower core)

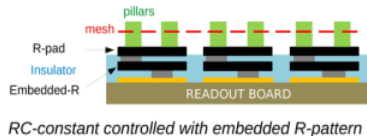
→ spark suppression by means of resistive coatings

What resistive coating? **Embedded resistor**

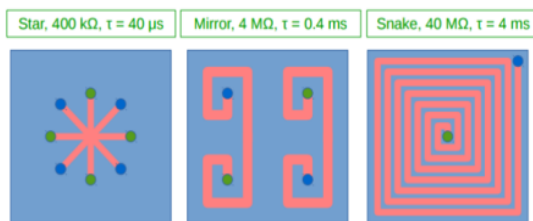
Allows charge evacuation from top-to-bottom

→ no lateral charge dispersion

→ maintain calorimeter imaging capability



RC-constant controlled with embedded R-pattern



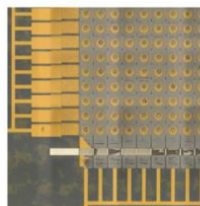
Green dot = R-pad contact, blue dot = RO-pad contact

12

Resistive Material

Other MPGD development using carbon sputtering

- Resistive μ -PIC
 - New version using carbon sputtering is being tested
- Resistive GEM
 - The resistive electrodes are made by very thin (50 – 300nm) material
 - It will improve the signal gain
 - We have just made it, and it is being tested now.
 - (Scienergy + Raytech)



A. Ochi, KUBEC Workshop 2014/8/29

25

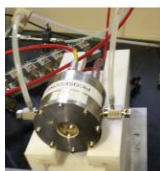
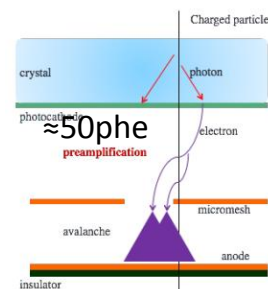
A. Ochi

Fast Timing

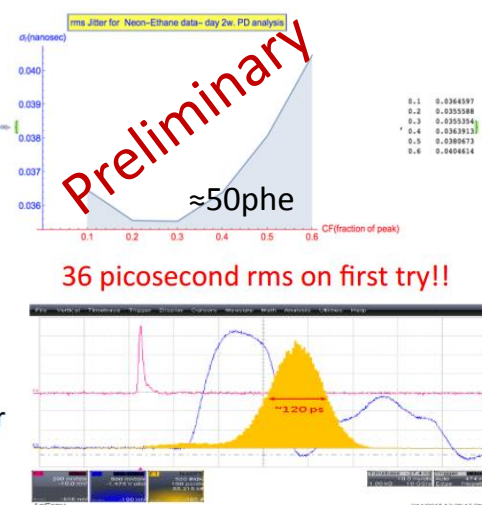
MicroMegas based:

(initial tests March/April 2015)

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

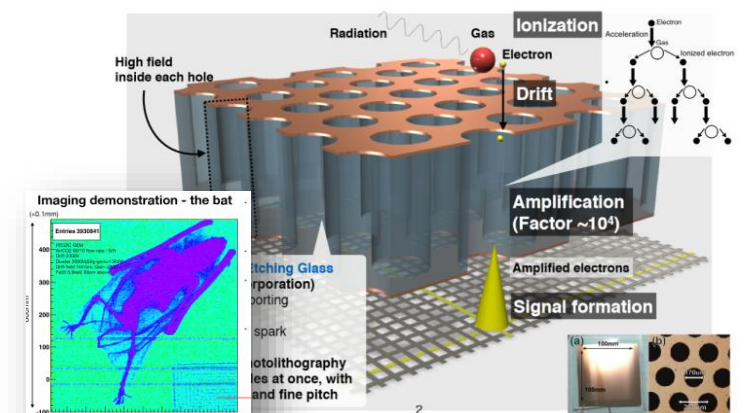


Saclay Chamber <-



New Materials (Glass GEM)

Introduction - Glass GEM



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

New Large Area Thin Detectors

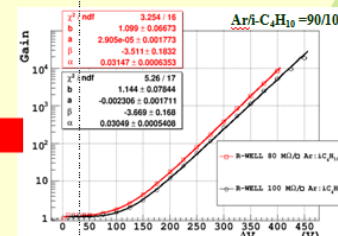
The μ -RWELL performance (I)

The prototypes have been tested with $\text{Ar}/\text{CO}_2 = 70/30$ & $\text{Ar}/\text{i-C}_4\text{H}_{10} = 90/10$ gas mixtures and characterized by measuring the **gas gain**, **rate capability** and **discharge in current mode**.

The devices have been **irradiated** with a collimated flux of **5.9 keV X-rays** generated by a PW2217/20 Philips Tube.

The **gain** has been measured vs **potential applied** between the **top of the electrode** of the **amplification stage** and the **resistive layer**.

GAIN UP TO 10⁴



M. Poli Lener

μ -RWELL DETECTOR

10

Neutrons Detection

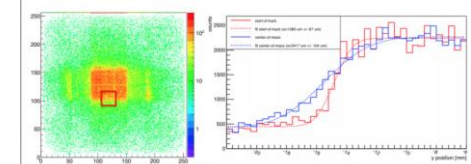
In the Lab

²⁴¹AmBe source
neutron moderated with PE
Over 10x10cm²:
- n < 100Hz
- $\gamma/X \gg 100$ kHz



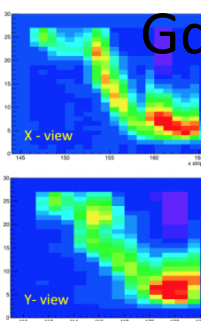
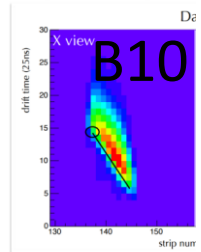
50 μ m thick Cu strips
stop the α/Li
Resolution evaluated from the sharp edge

Position resolution 2cm x 2cm beam



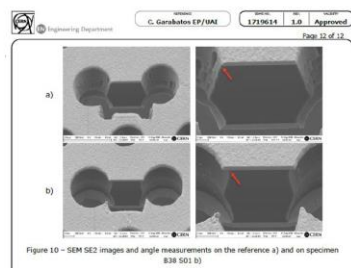
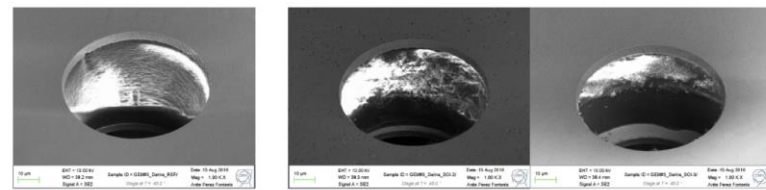
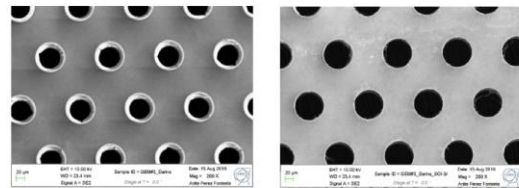
European Spallation Source (ESS)

B-GEM TPC



R&D Support to the Projects and Experiments

Effect of extreme operating conditions on the GEM detector components



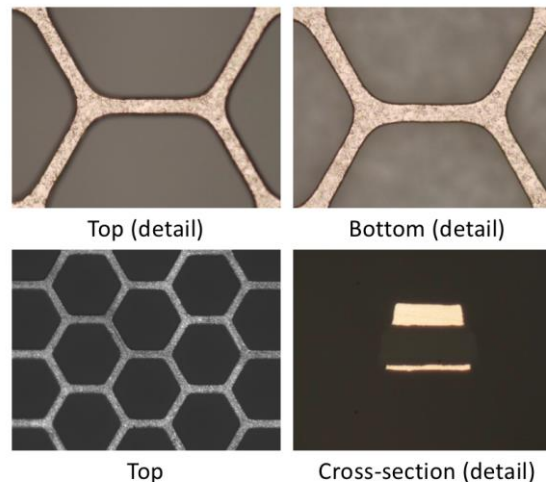
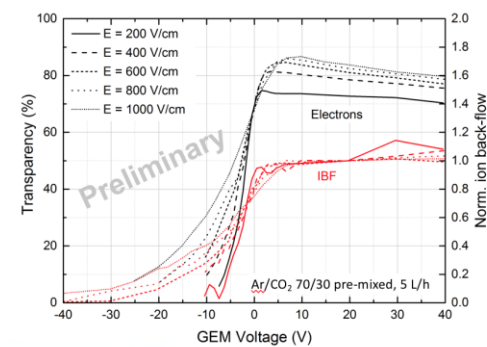
Gating GEM Ion back-flow at equal fields

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

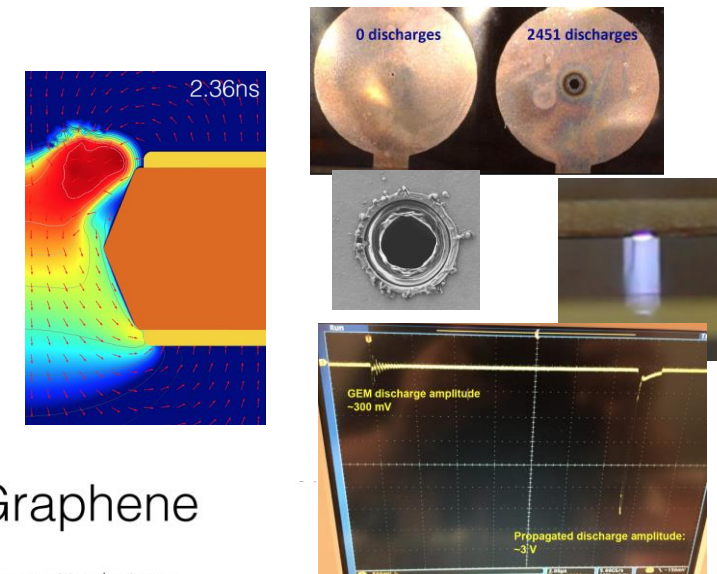
Higher voltages than for electrons to fully **close gate**

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

IBF normalized to $\Delta V_{\text{GEM}} = 20 \text{ V}$



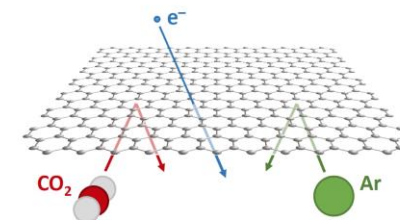
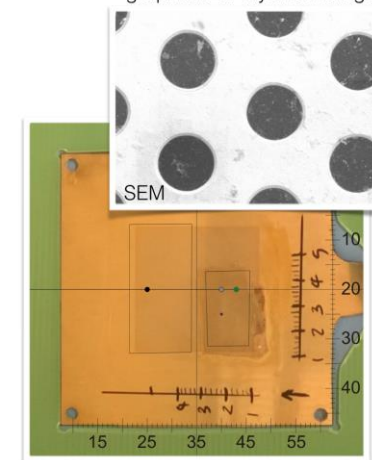
Discharge studies ALICE/CMS



Graphene

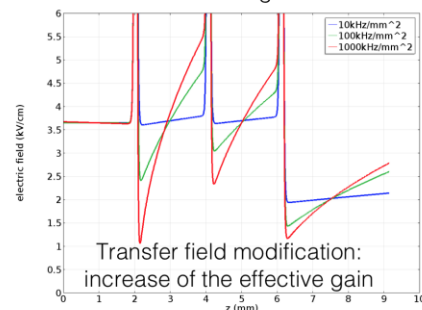
Membrane opaque to ions and transparent to electrons:
- solution of the ion back-flow in gaseous detectors
- protective layer on photocathodes
- enhancement of electron emission

~99% (suspended) graphene tri-layer coverage

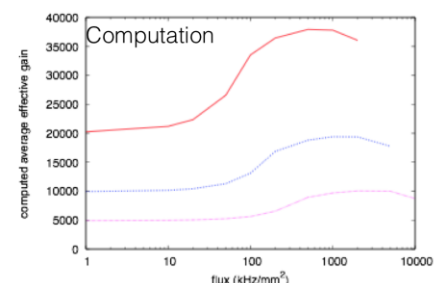
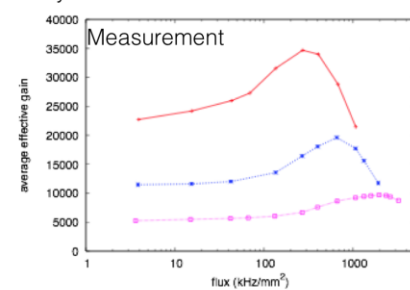
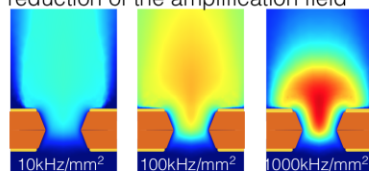


Ion density effects in multiGEM

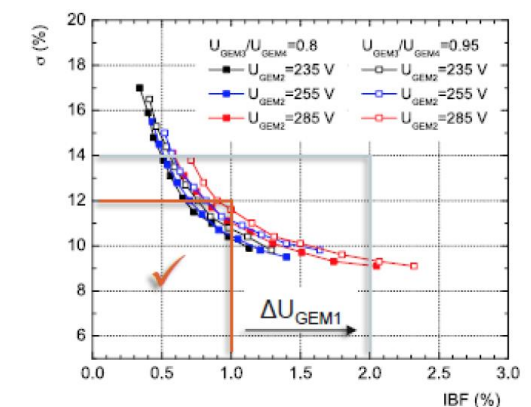
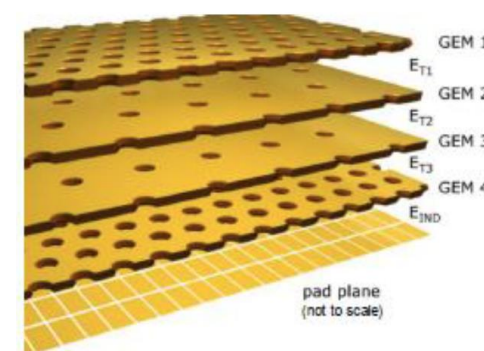
Ion charges instantaneously modify the electric fields



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



ALICE TPC IBF

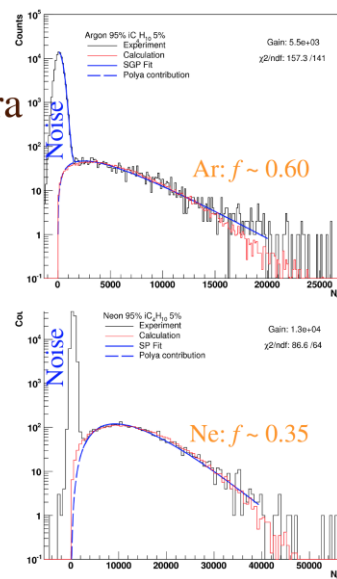
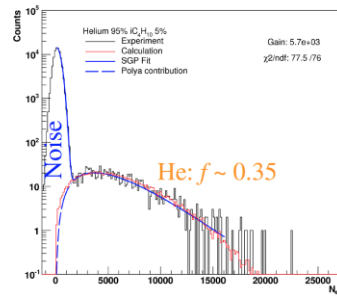


Modelling of Physics Processes and Software Tools



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.

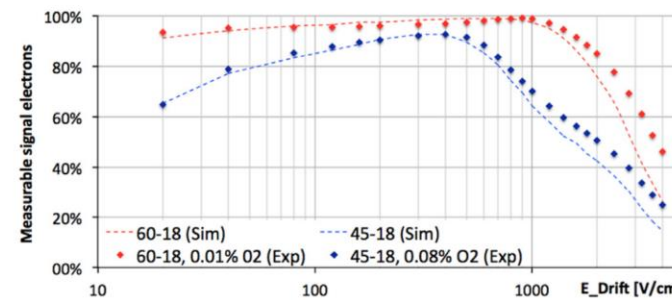


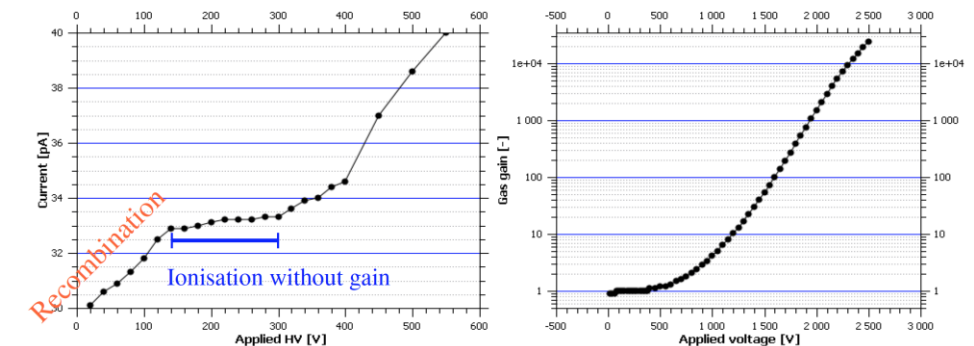
Fig. 5. Fraction of measurable signal electrons dependence on the drift field for two mesh geometries, experimental data (normalized signal strength) and simulation prediction (non-lost electrons after drift and mesh transition).

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



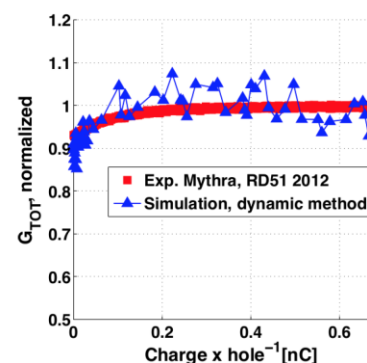
High-precision data from AGH

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



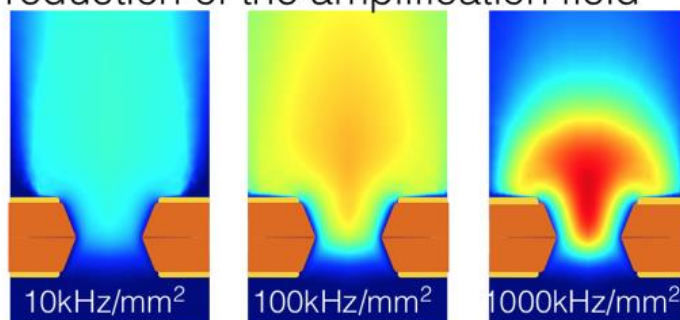
Charging-up of a GEM

- ▶ 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

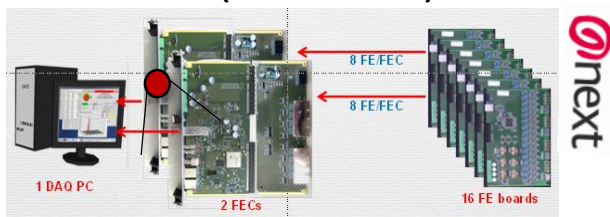
- ▶ Discharges and Resistive layers.
- ▶ Ion diffusion.
- ▶ Refinement of ionisation esp. at low energy.
- ▶ Integration of boundary element methods.

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

SRS & APV25 FE chip

Worldwide use in the RD51 community (>2000 hybrids)

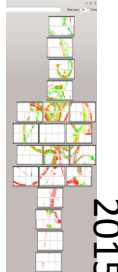
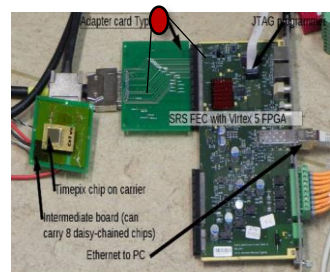
SRS+SiPM (NEXT TPC)



SRS-FEC+TOTEM DAQ

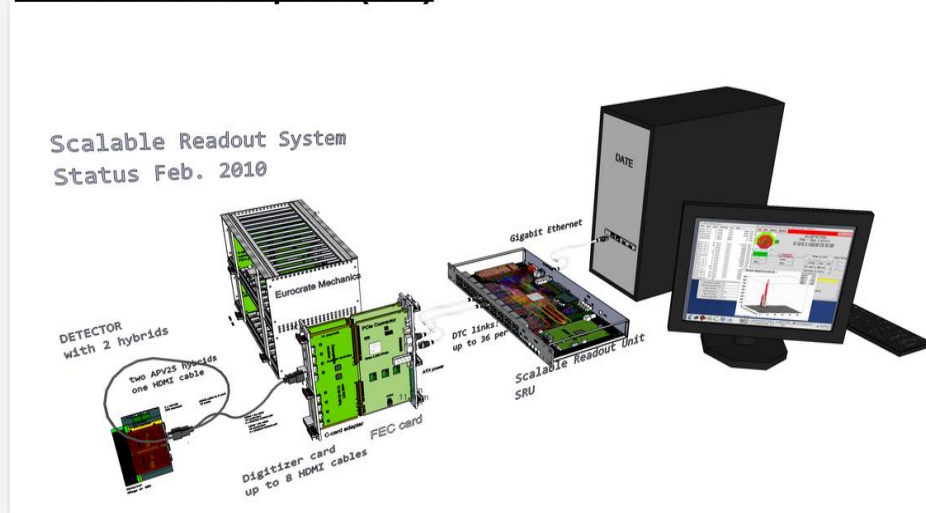


SRS+Timepix (LC-TPC) – Bonn/Desy



2015

Scalable Readout System (SRS)



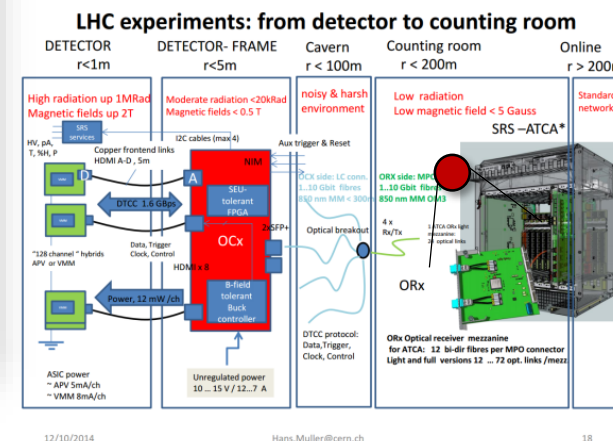
Very appealing for the future: VMM (NSW ATLAS FE chip)

SRS: Different System

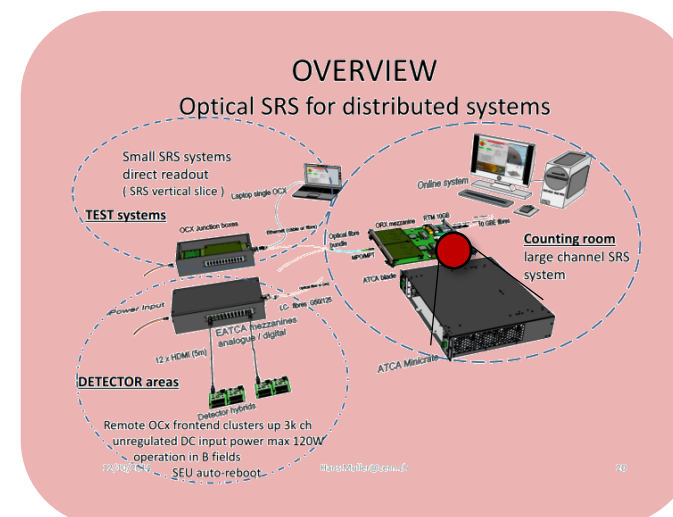
SRS for R&D on Detectors



SRS for experiments (ATCA)



SRS for spatially distributed system (optical SRS)



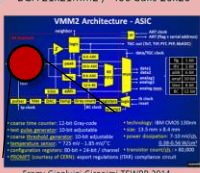
Baseline solution for RD51 SRS community.

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

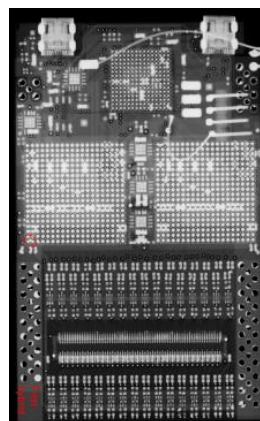
VMM-128 hybrid

VMM-128 fully assembled in 2014 as Mini-2 cards
See report by G.Iakovidis and S. Marou
1st PCB revision started (March 2015)
70 test boards for NSW
10 test boards for RD51

Measured Power consumption 2 VMM:
1.2A @ 1.2V ~ 10 mA /ch
0.2A @ 2.5V (FPGA)
2 x 64 channel VMM2 chips
BGA 21x21mm2 / 400 balls 20x20



From: Gianluigi Geronzi TEWPP 2014



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



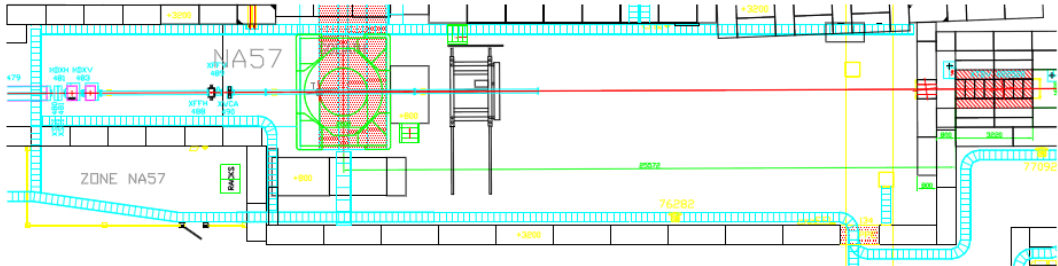
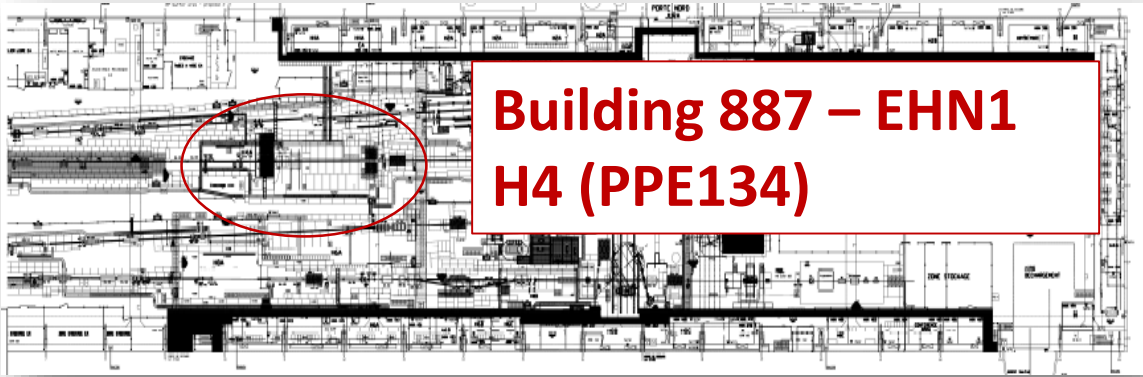
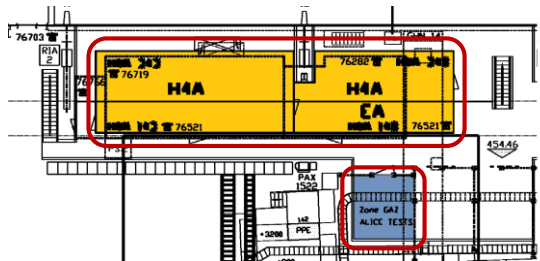
Mechanical and Electronic Workshop



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

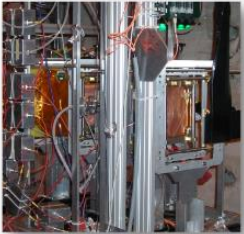
Three periods of two weeks each per year
About fifteen-twenty users per year



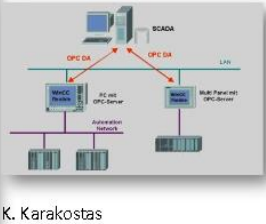
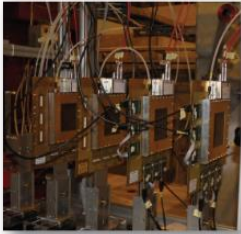
Rd51 trackers

Slow Control System (HV/LV)

- Triple GEM Tracker
 - XY strips readout, 400um pitch
 - 10x10 cm²
 - APV (VFAT2)
 - DAQ&FE: SRS/APV (TURBO/VFAT)

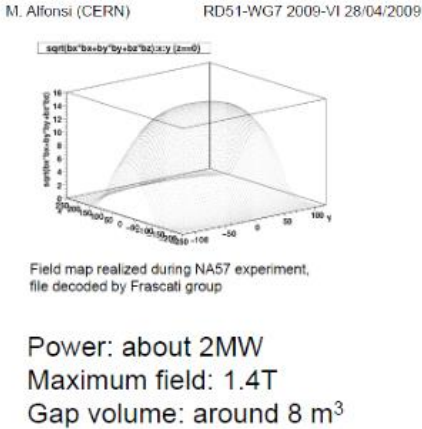
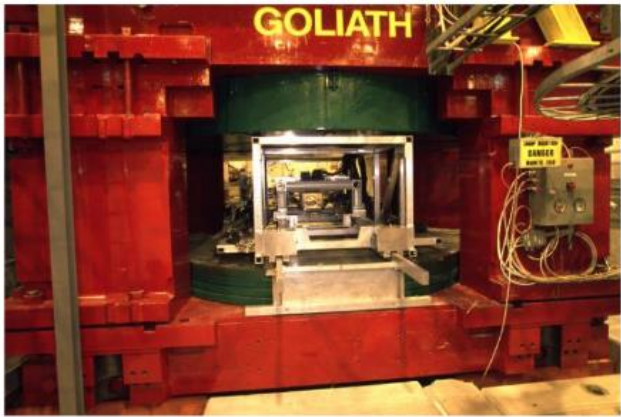


- Resistive μ egas tracker
 - XY strips readout, 250um pitch
 - 9x9 cm²
 - APV
 - DAQ&FE: SRS/APV



K. Karakostas

Goliath Magnet → Ship?



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

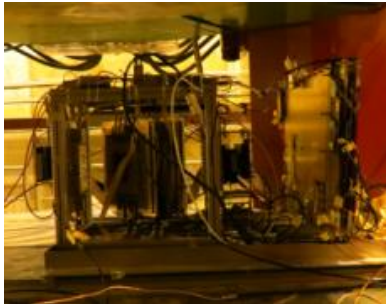
Examples of the test beam user teams



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

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

- ATLAS NSW
 - SBS Tracker
 - ALICE TPC upgrade
 - COMPASS pixel Micromegas
 - BESIII
 - CLAS 12
 - CMS
- 1300 m²
 - 100 GEMs
 - 350 GEMs
 - 20 GEM + Micromegas
 - 15 GEM
 - 30 Micromegas
 - 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 2x1m² Bulk MM & 2x0.5m² 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

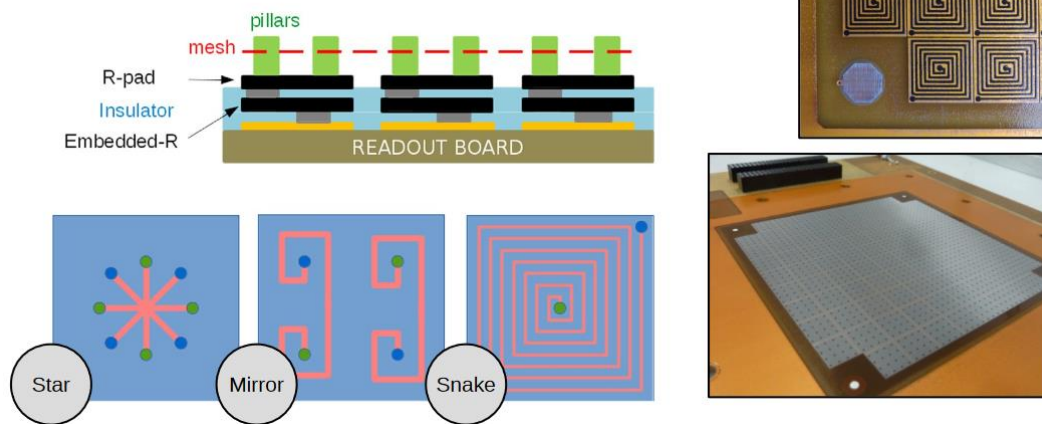
Flagship technologies – Resistive materials and architectures

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

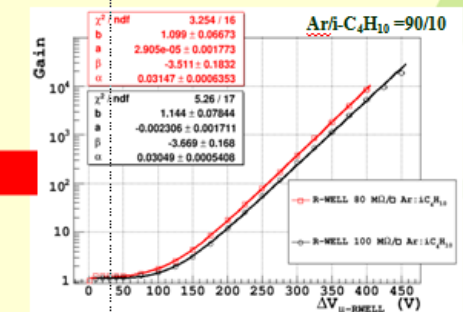
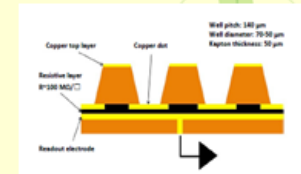


The μ -RWELL performance (I)

The prototypes have been tested with $\text{Ar}/\text{CO}_2=70/30$ & $\text{Ar}/i\text{-C}_4\text{H}_{10}=90/10$ gas mixtures and characterized by measuring the gas gain, rate capability and discharge in current mode.

The devices has been irradiated with a collimated flux of 5.9 keV X-rays generated by a PW2217/20 Philips Tube.

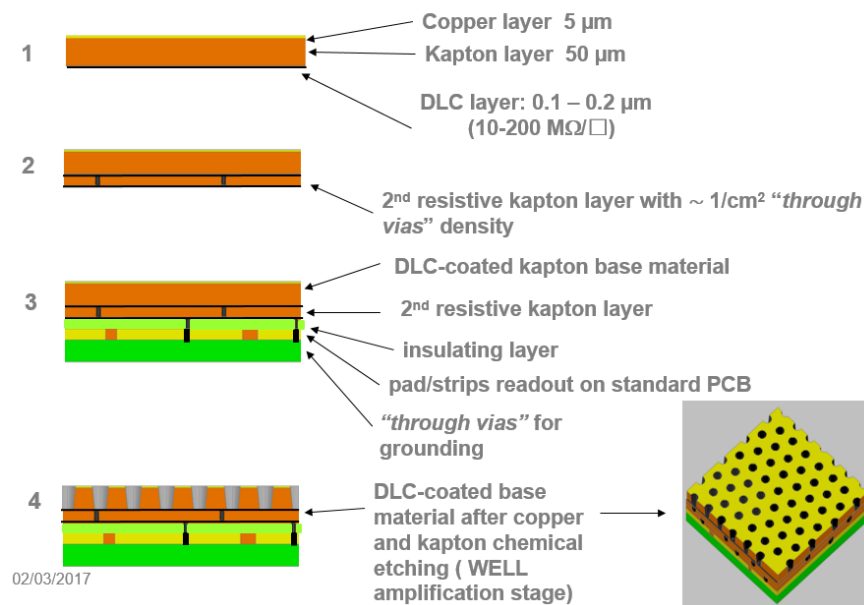
The gain has been measured vs potential applied between the top of the electrode of the amplification stage and the resistive layer.



GAIN UP TO 10⁴



The High Rate scheme (LHCb)

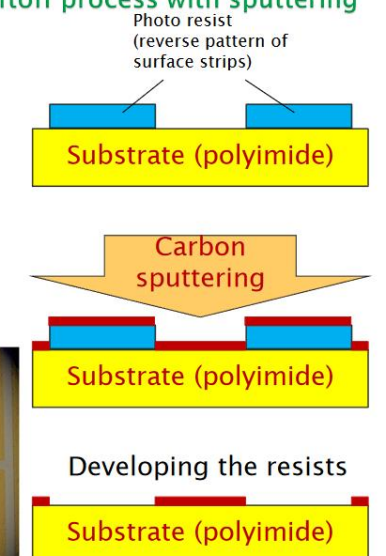
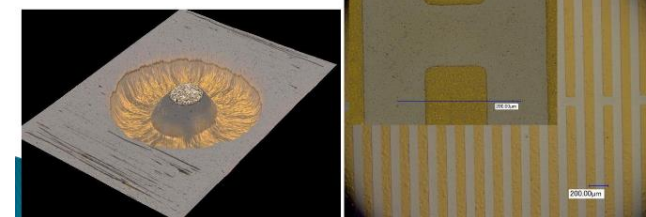


Resistive electrodes with DLC

Liftoff process with sputtering

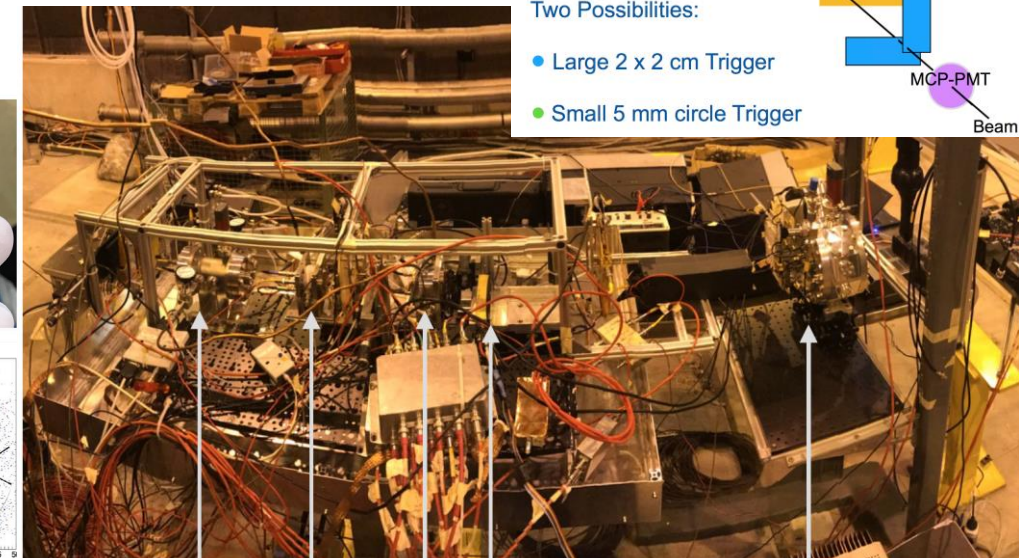
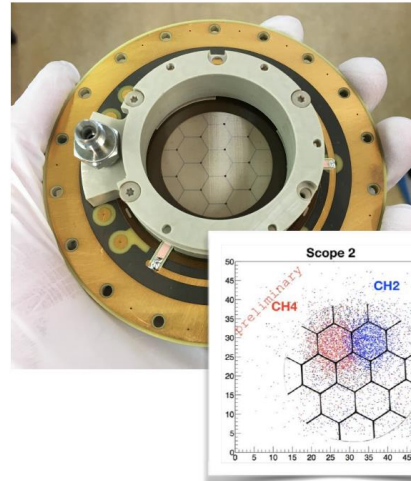
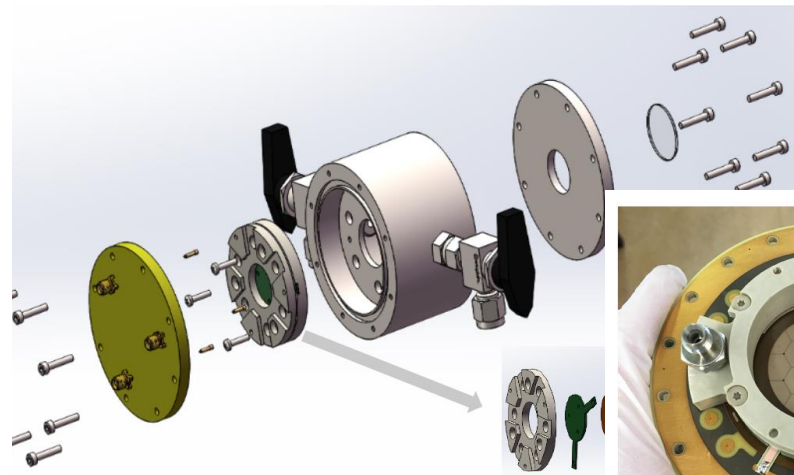
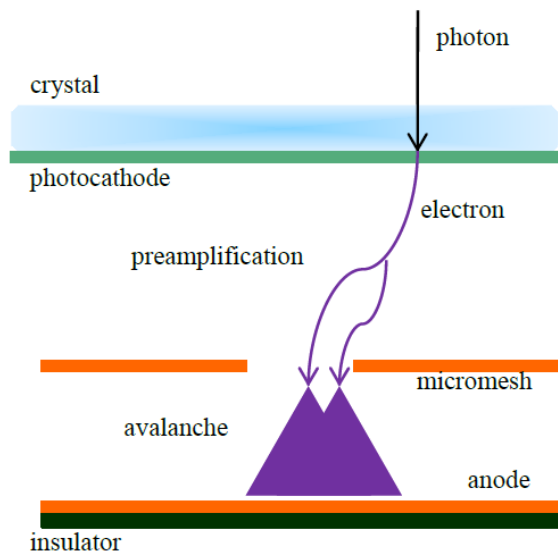
- On beginning of 2013, we have developed resistive electrodes by DLC

- Initially, it was developed for ATLAS MM resistive foils
- Fine micro-patterning (um order) available → applying it for u-PIC electrodes



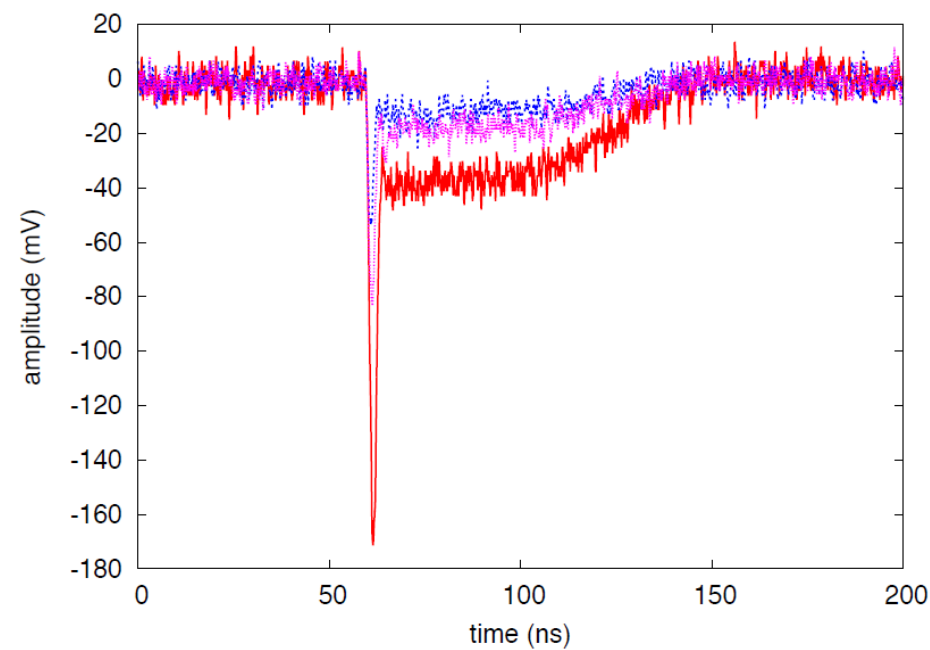
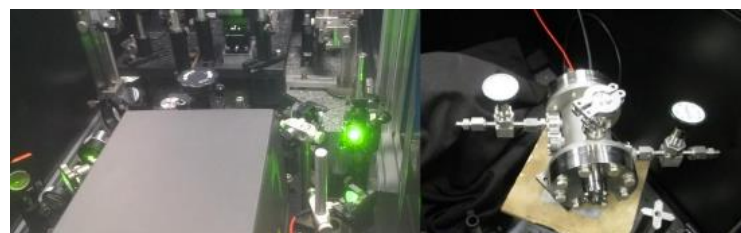
RD51 Future

Flagship technologies – Fast and precise timing

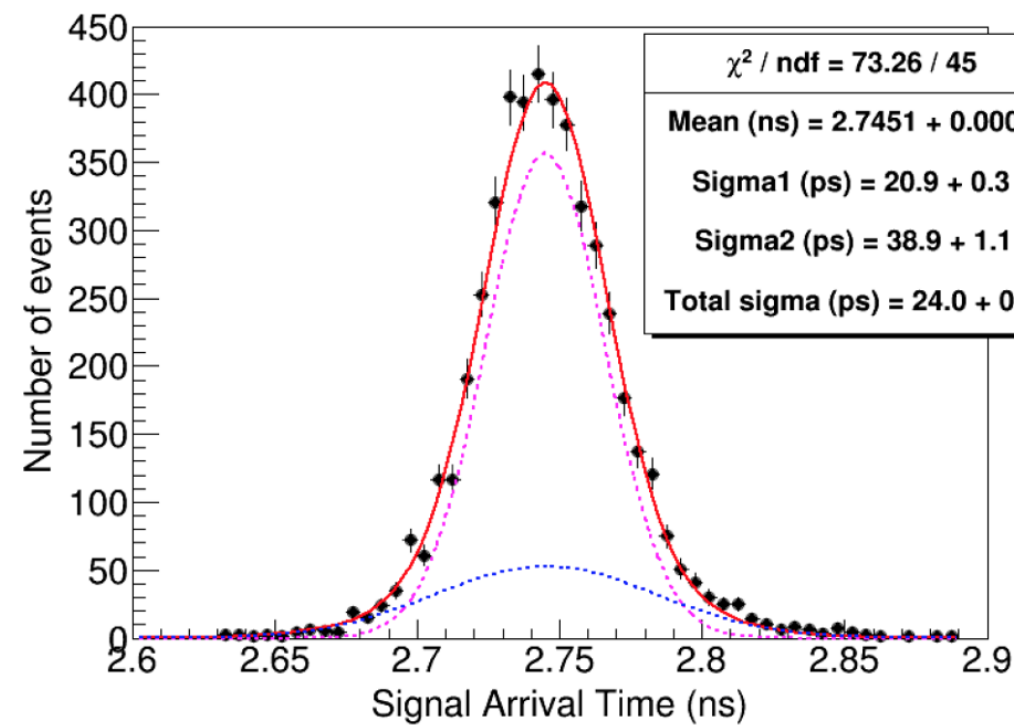


Two Possibilities:

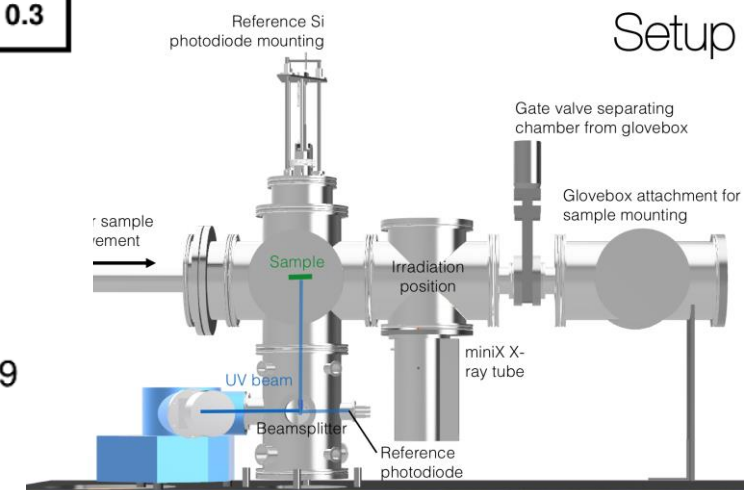
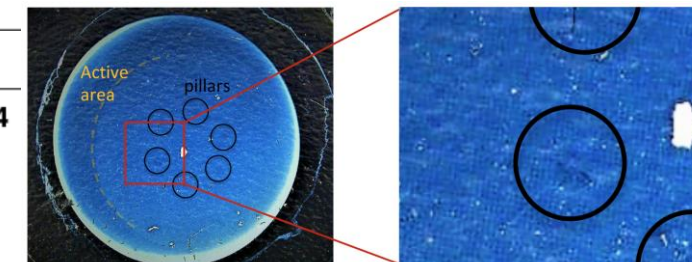
- Large 2 x 2 cm Trigger
- Small 5 mm circle Trigger



36ps time resolution for signal shared on 3 pads



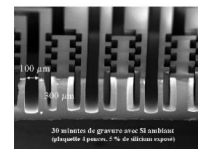
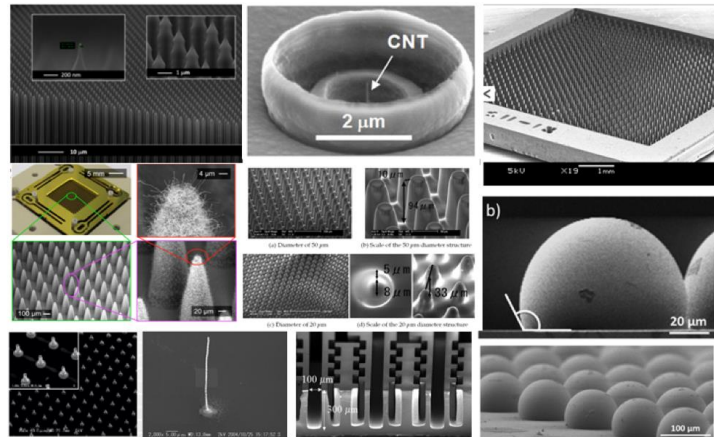
Resistive Picosec HFS Multipad



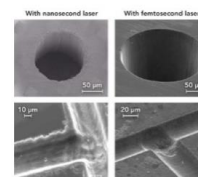
RD51 Future

Flagship technologies – New materials and technologies

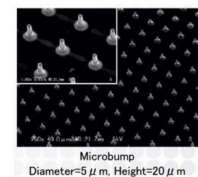
Prototyping: new techniques as 3D/Ink-Jet printing, etching and laser to create novel structures will speed up and enlarge the detector prototyping capabilities.



DRIE Plasma

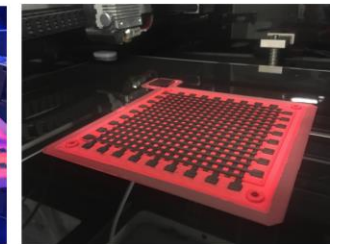
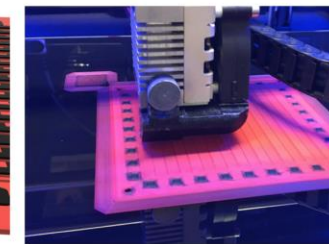


Laser Drilling



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

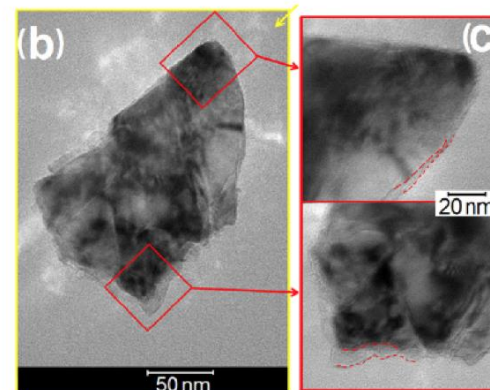
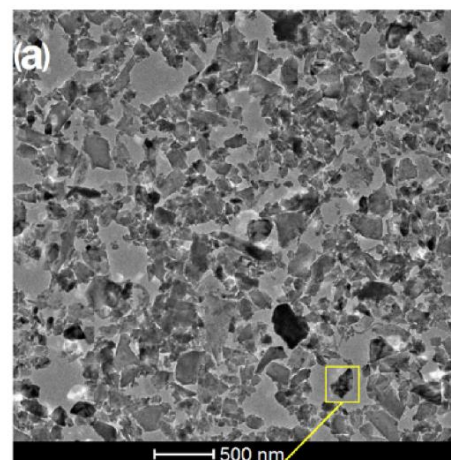
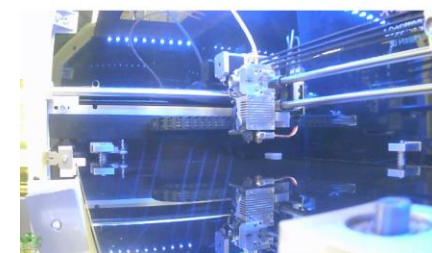


FIG. 2. TEM images of the (a) as-received nanodiamond (ND) particles, (b) a single ND particle and (c) details of the single ND particle.

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

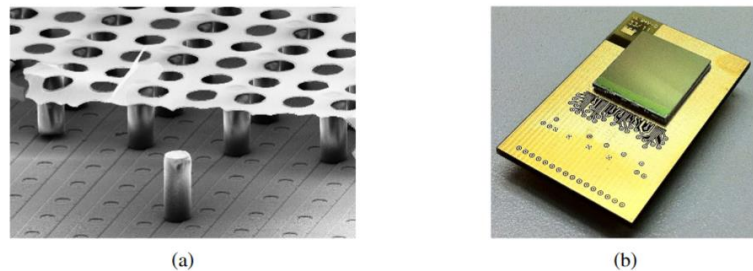


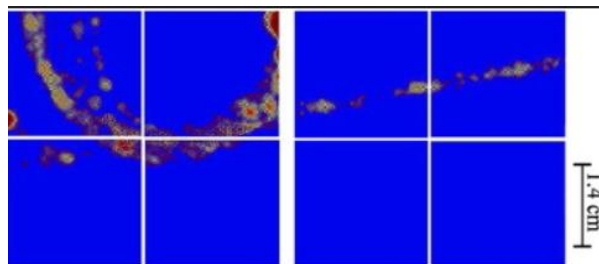
Figure 1: SEM image of an InGrid structure on top of a Timepix ASIC (a), taken from [13]. In the SEM image parts of the mesh have been removed to show the good alignment between pixels and mesh holes. And a bare Timepix ASIC on a carrier board (b).

[https://cds.cern.ch/record/2025932/files/PoS\(TIPP2014\)060.pdf](https://cds.cern.ch/record/2025932/files/PoS(TIPP2014)060.pdf)

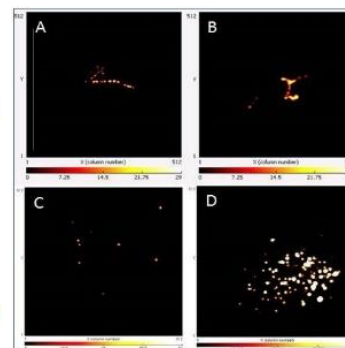
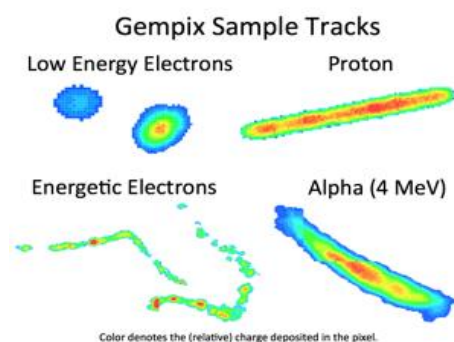
256 x 256 pixels, 55 x 55 μm pitch, about
1.4x1.4 cm² sensitive area

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

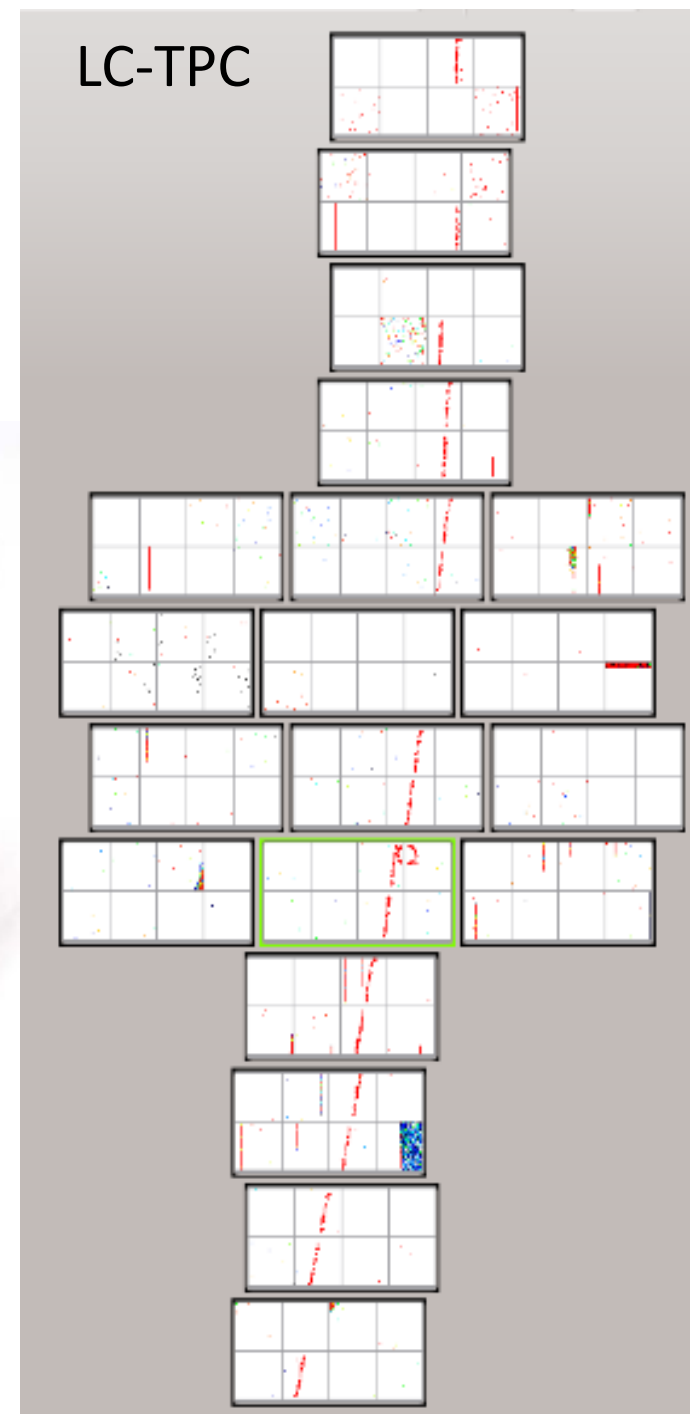
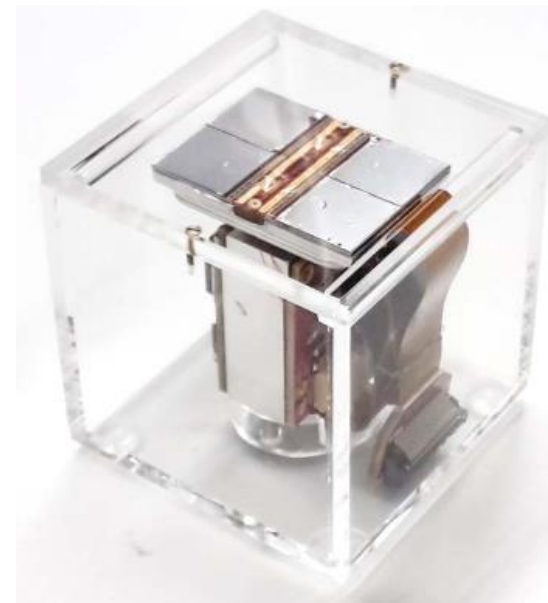
A large TPC prototype for a linear collider
detector P. Schade, J. Kaminski, NIMA, 628, 1, 1
February 2011, Pages 128-132



GEMPIX (F. Murtas et al.)



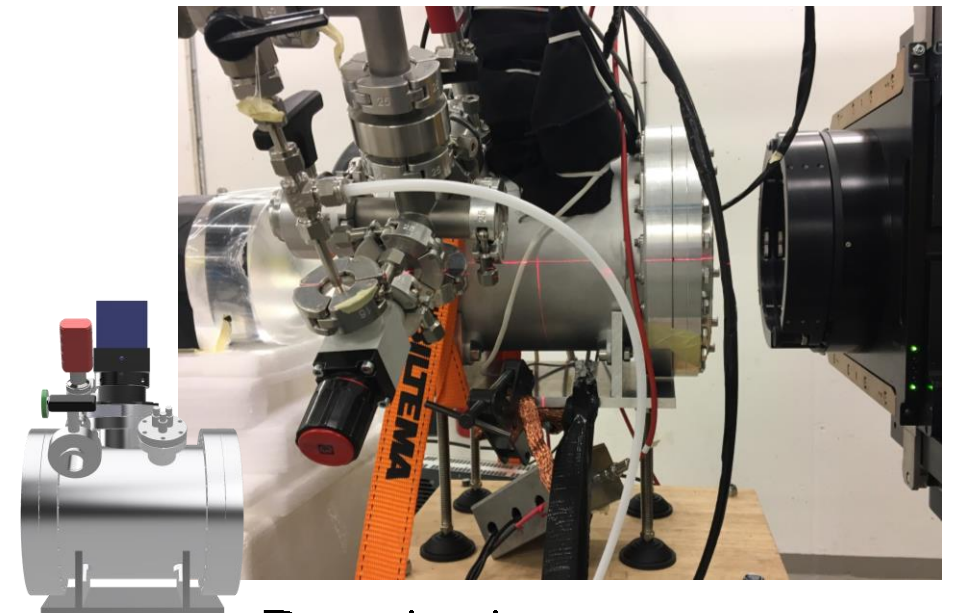
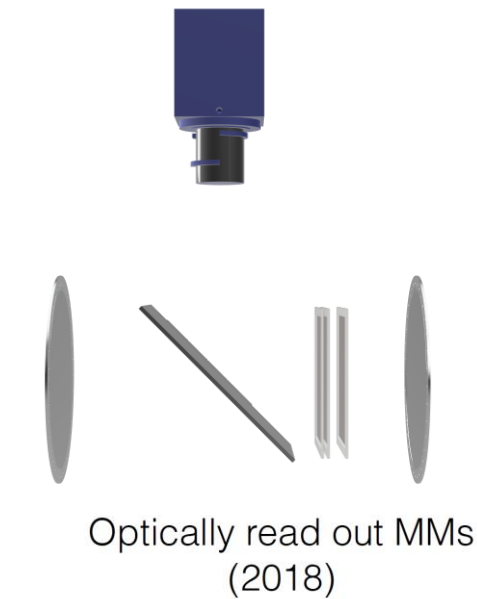
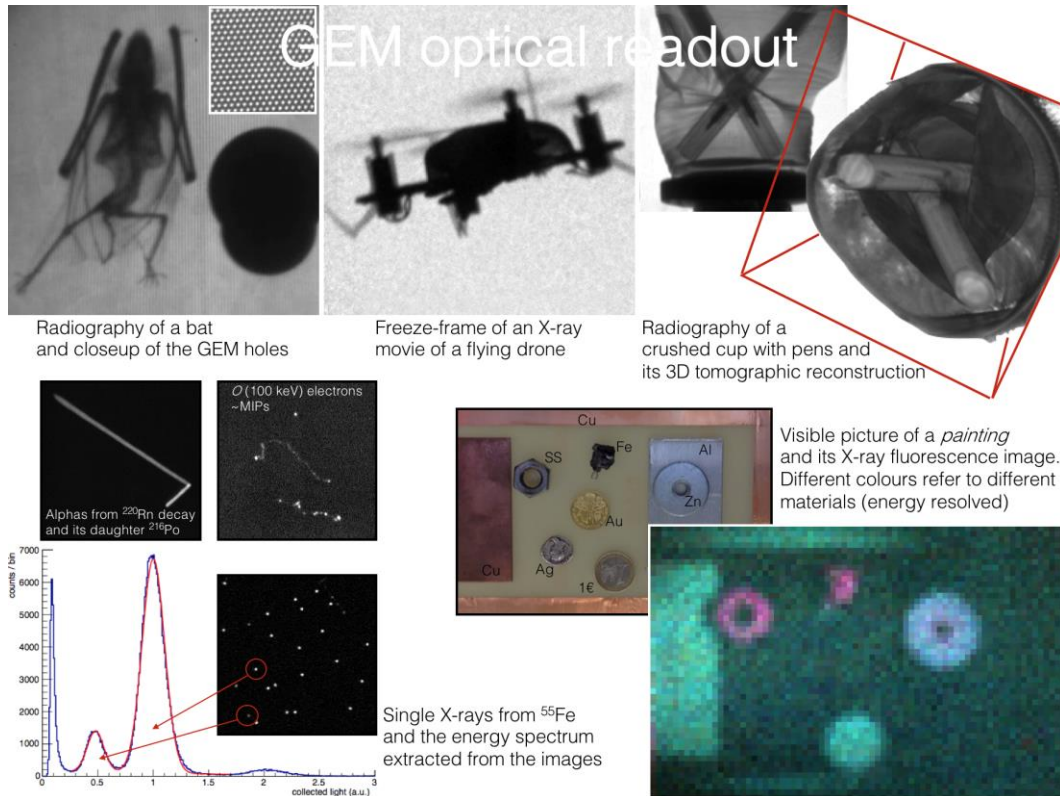
The “QUAD”



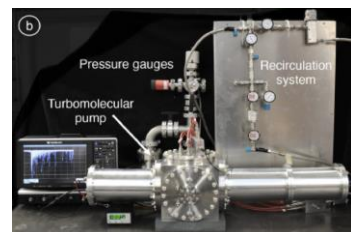
J. Kaminski,
<https://indico.cern.ch/event/391665/contributions/1827282/attachments/1230061/1802690/GridPix.pdf>

RD51 Future

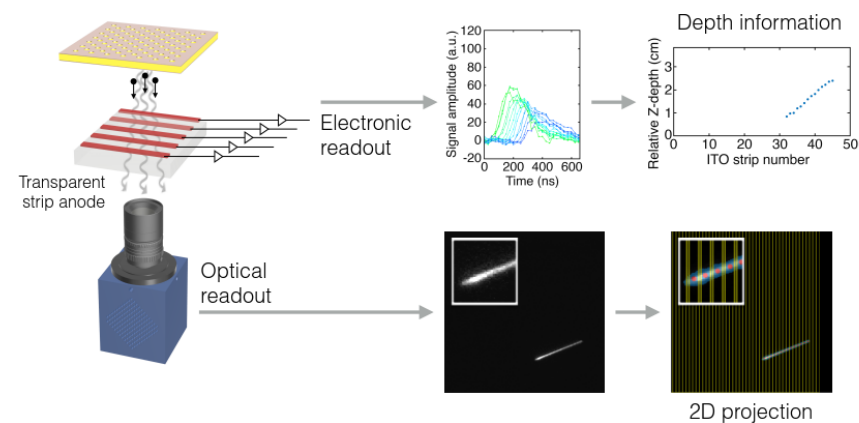
Flagship technologies – Hybrid detectors



Depth dose curve



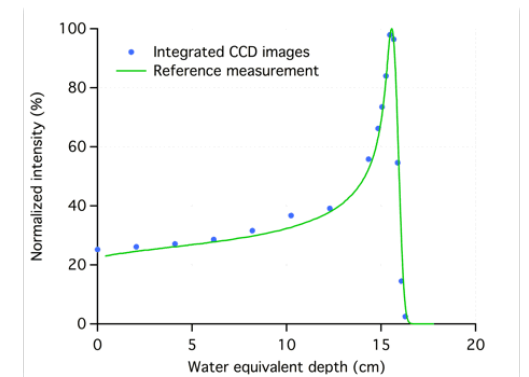
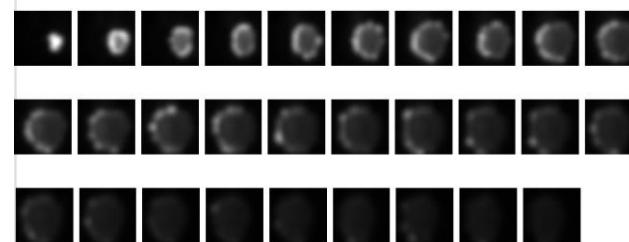
Combined electronic and optical readout



Schematics not drawn to scale

35

Patient treatment plan



Phantom High Speed Camera - oTPC α tracks almost SF



Phantom v2512



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

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

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.