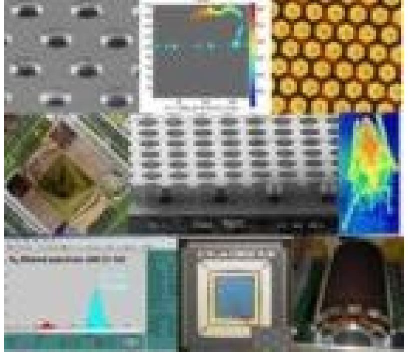


RD51

Development of MicroPattern Gaseous Detector Technologies

11/9/2019 – 139th LHCC Meeting - OPEN Session

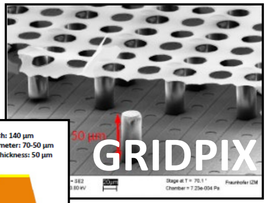
Silvia Dalla Torre, INFN - Trieste
on behalf of the RD51 Collaboration

The whole matter illustrate by examples
(a fully comprehensive review is impossible)

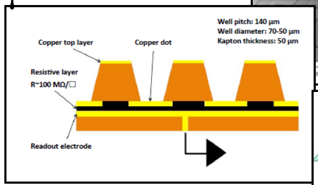
RD51- Mission and achievements

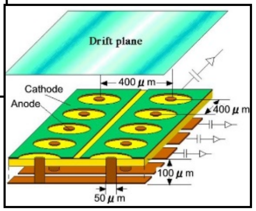
- **Support to the development of MPGDs and dissemination of these technologies (by examples)**

- **DEVELOPMENT**
  - **Consolidation of the better established technologies**
    - GEM: single mask for large size; mechanical stretching for mass production
    - MICROMEGAS: resistive anode for reliability of large size
  - **Novel architectures**
    - μPIC, μR-WELL, GRIDPIX, hybrids, …



μR-WELL

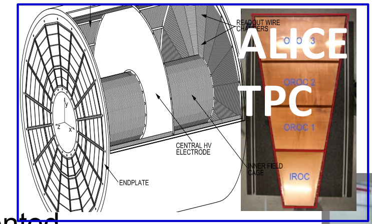




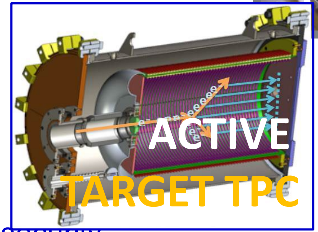
μPIC

- **DISSEMINATION by recent examples**
  - **In HEP**

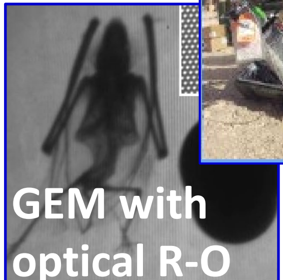
CERN
    - ALICE, TPC read-out, 130 m² to be instrumented
    - ATLAS, small wheels, 1200 m² to be instrumented
    - CMS, forward detectors, 1000 m² of GEM foils to be instrumented
    - COMPASS RICH, 4.5 m² hybrid MPGDs for single photon detection
    - KLOE2 & BES III, cylindrical GEMs



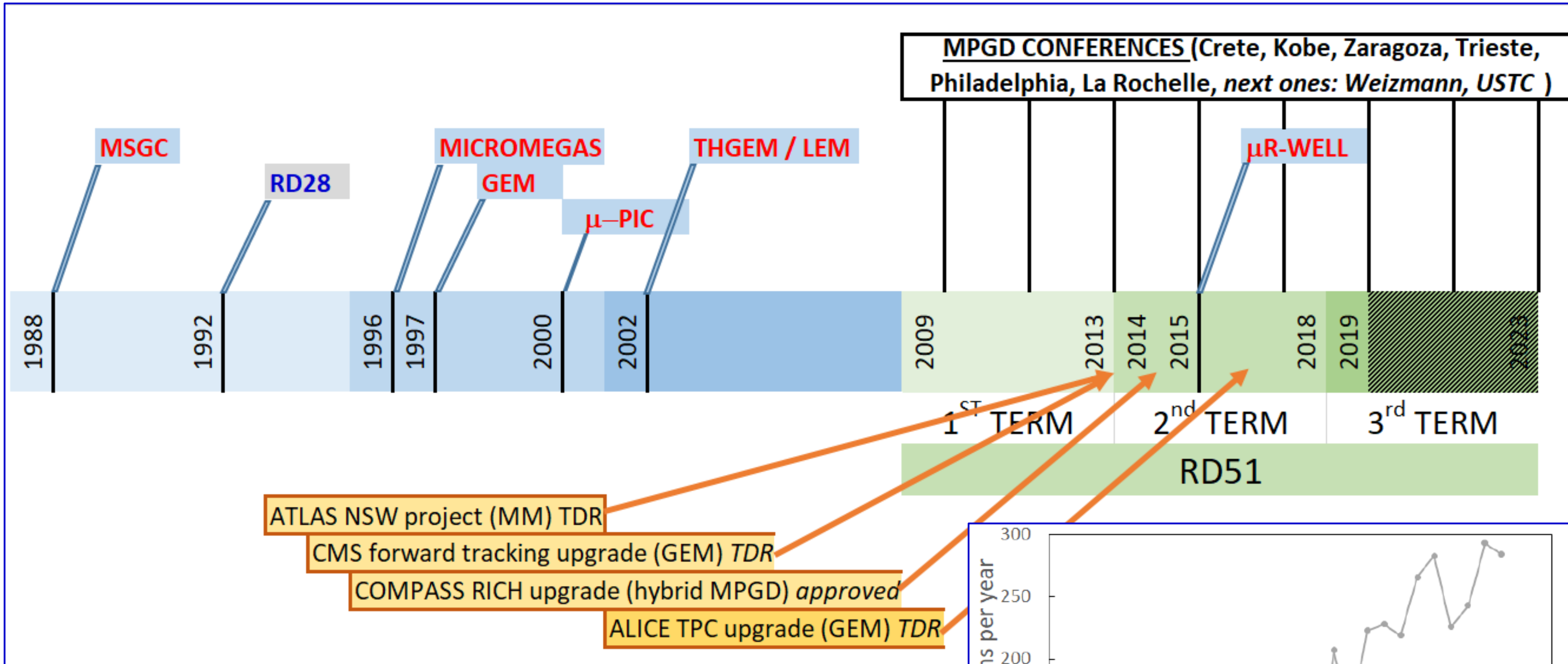
  - **In fundamental research, beyond HEP**
    - LBNO-DEMO (WA105), THGEM PCBs
    - read-out in low-energy nuclear physics ACTIVE TARGET TPCsS
  - **Beyond fundamental research**
    - n-detection: instrumenting ESS beam lines
    - Muon radiography for geological and archeological studies
    - Radiographies by GEMs with optical read-out: industry, homeland security

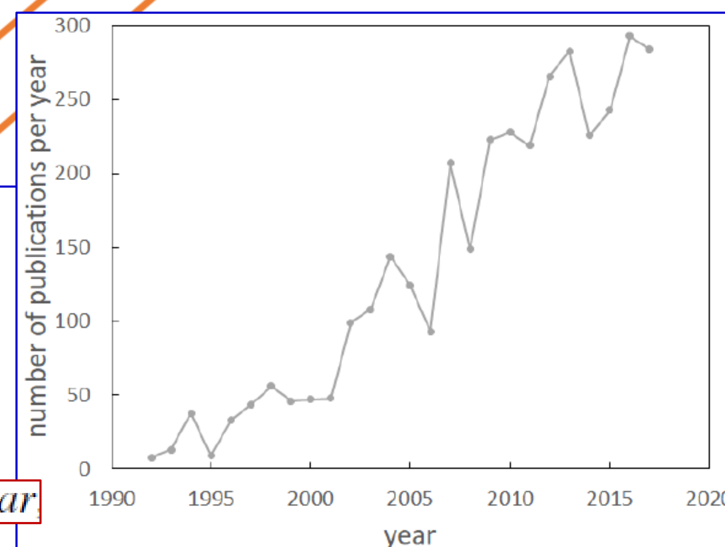


- **SUPPORT**
  - **Common infrastructures** (GDD lab, common test beam)
  - **Electronics** (read-out, dedicated instrumentation)
  - **Simulation** (Garfield maintenance, update and development)
  - **Scientific cultural reference, know-how entry point, MPGD net-working**



HISTORY OF MPGDs & RD51





Number of publications dedicated to MPGDs per year

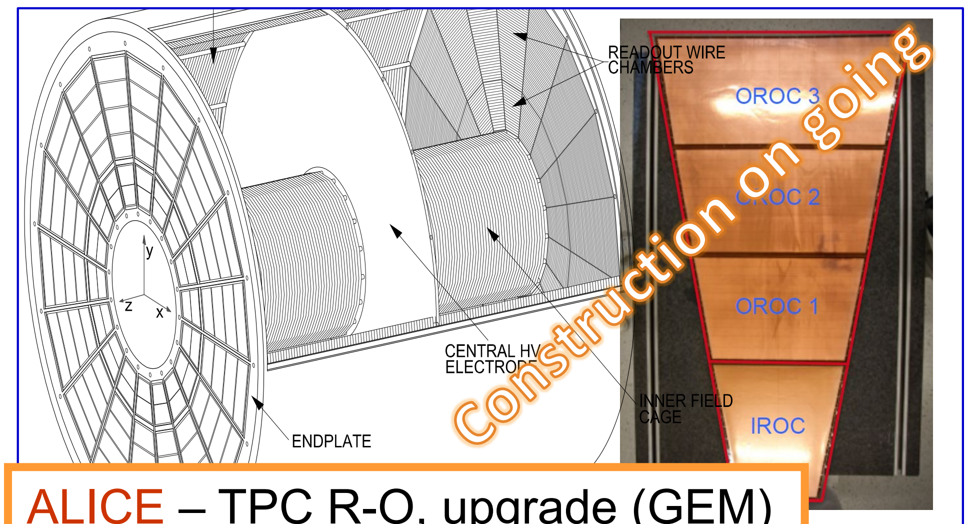
MPGDs & UPGRADE OF CERN EXPERIMENTS

ATLAS –
NSW project (MM)
Detector size: ~1 x 2.5m^2

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

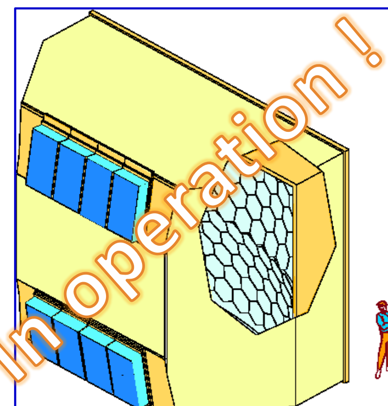
CMS – forward muon spectrometer (GEM)
Goal: ~1.2 x 2 m^2

1000 m^2 of GEM foils, tracking & trigger

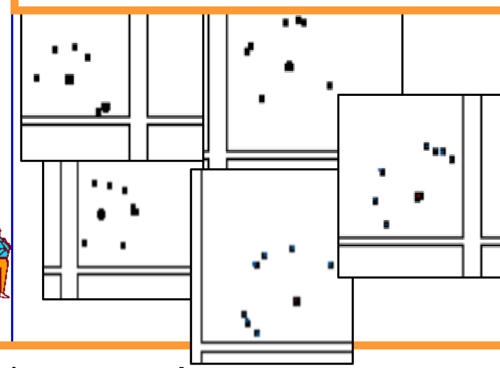


ALICE – TPC R-O, upgrade (GEM)
size: ~.9 x 1.6 m^2

130 m^2 of GEM foils



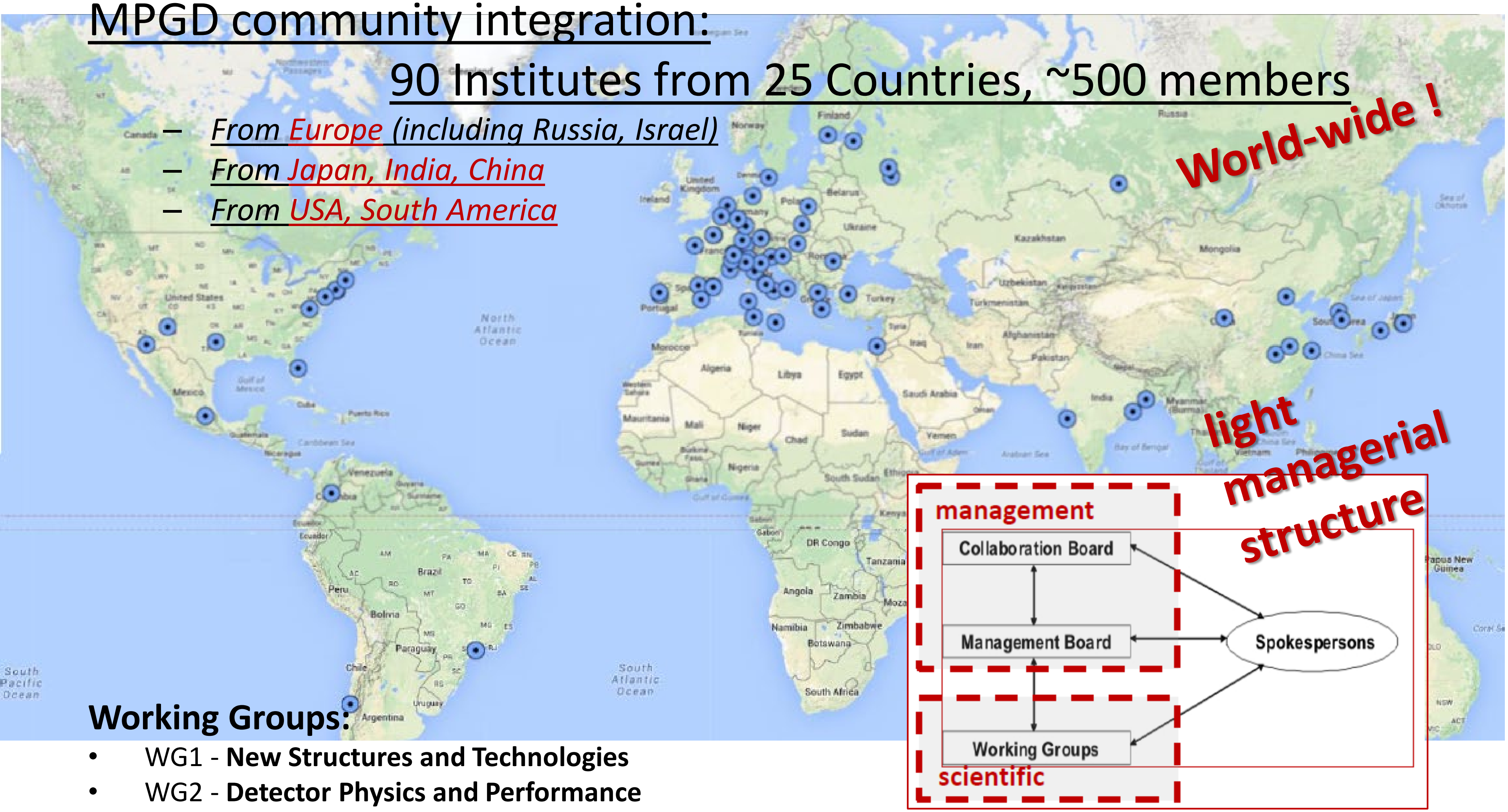
On-line ring images



COMPASS RICH-1 upgrade
Hybrid MPGD-based photon detectors

1.5 m^2 of MPGD multipliers (THGEM, MM)

RD51 – HOW ?



MPGD community integration:

90 Institutes from 25 Countries, ~500 members

- From Europe (including Russia, Israel)
- From Japan, India, China
- From USA, South America

World-wide !

light managerial structure

Working Groups:

- WG1 - **New Structures and Technologies**
- WG2 - **Detector Physics and Performance**
- WG3 - **Training and Dissemination**
- WG4 - **Modeling of Physics Processes and Software Tools**
- WG5 - **Electronics for MPGDs**
- WG6 - **Production and Industrialization**
- WG7 - **Common Test Facilities**

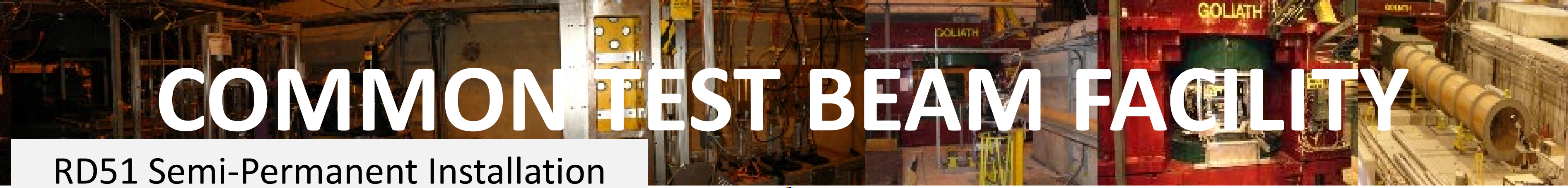
MEETINGS

2 Collaboration meetings / y (one outside CERN)

1-2 miniweeks / y

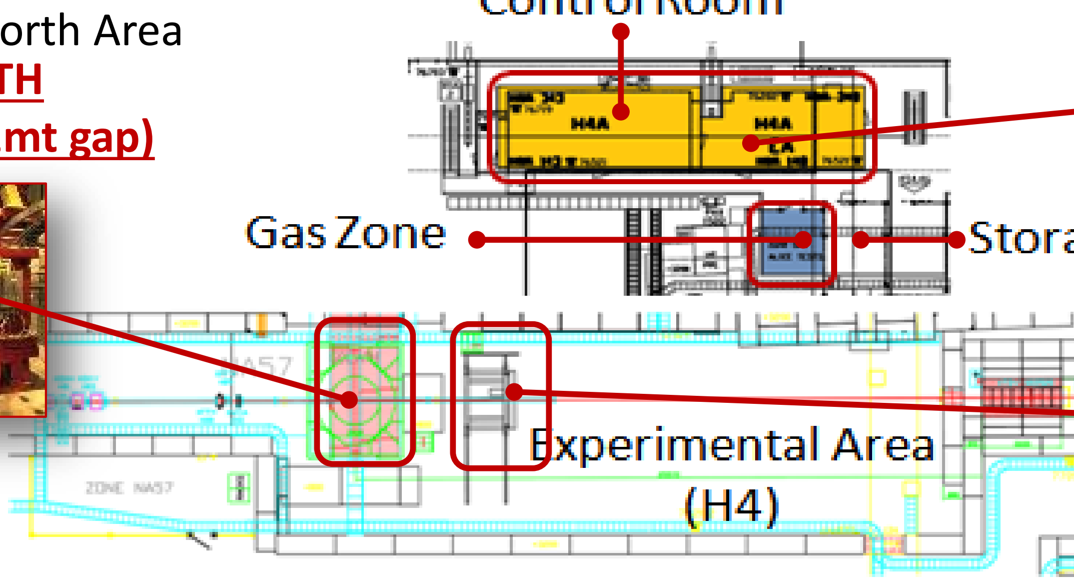
RD51 SUPPORT TO THE MPGD COMMUNITY for DEVELOPMENT & DISSEMINATION

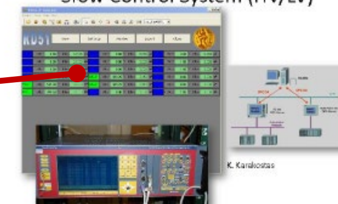
COMMON TEST BEAM FACILITY



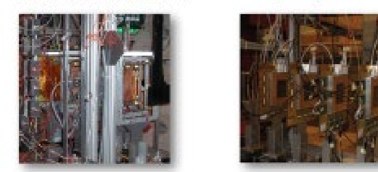
RD51 Semi-Permanent Installation

EHN1-H4 North Area
GOLIATH
(1.5T Max, 1mt gap)





RD51 trackers

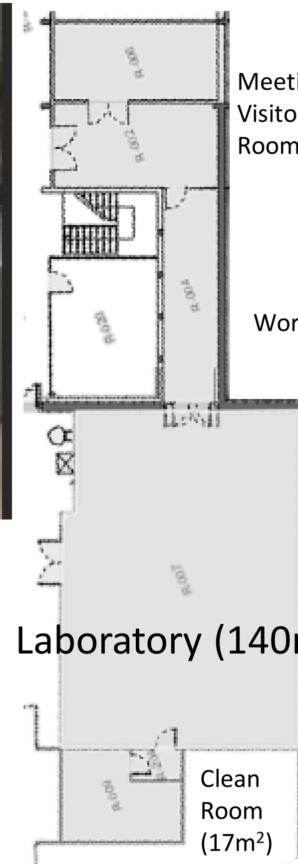


RD51 Test Beams , up to 2018, typically
3 periods of 2 weeks sharing the beam with GIF++
~ 30 different groups in total with several running in parallel

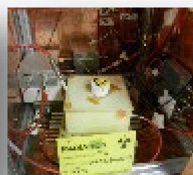
Examples of detectors from different projects at the test beam facility

CMS (GEM) | WIS/A/C(WELL, THGEM) | ATLAS NSW (mm) | BESS III & SHIP (GEM) | LAPP/DEM/IRFU(mm) | ALICE TPC (GEM and mm)

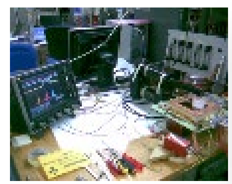
EP-DT-DD GDD Laboratory (Detector R&D) available to the RD51 Collaboration



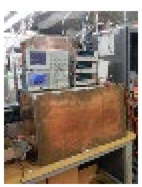
Permanent Users (ALICE, ATLAS, ESS) station

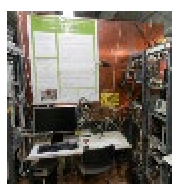
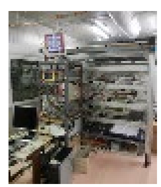

Temporary Users Working station



Active (X-Ray) and Radioactive Sources

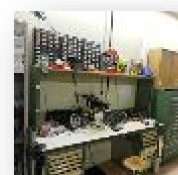




Cosmic Stands

Clean Room

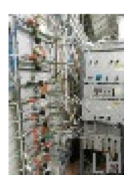
Workshops



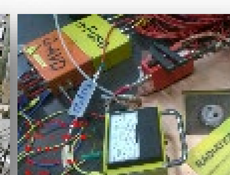
Optical Readout &
Measurements


Vacuum
Systems

Gas & Monitoring
(RGA,…) Systems




MPGD Electronics

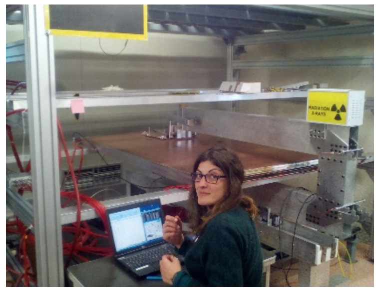



Technical support
MPGD Detectors
Gas system and services
MPGD Readout electronics
Radioactive Sources
Interface with CERN services (Thin Film and Glass Lab, MPT Workshop, RP, gas, metrology, irradiation facilities,…),

DIRECT SUPPORT TO EXPERIMENTS

- ***Facilities Lab and Beam*** (one example… ATLAS NSW micromegas)

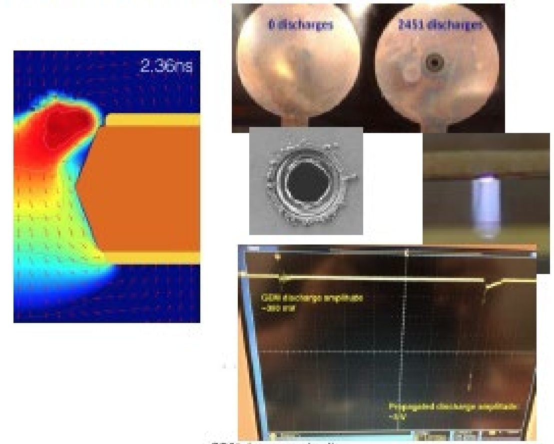
ATLAS NSW - RD51 mm trackers (GDD lab)



ATLAS NSW - Cosmic stands (GDD lab)

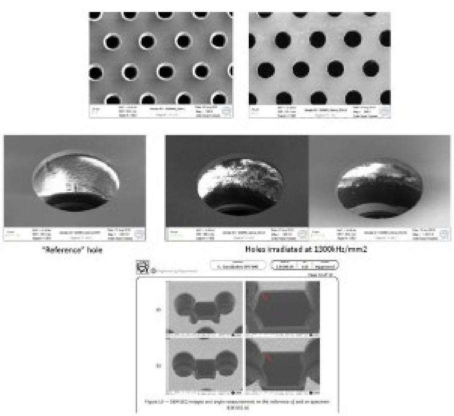
RD51/GDD Lab

Discharge studies ALICE/CMS

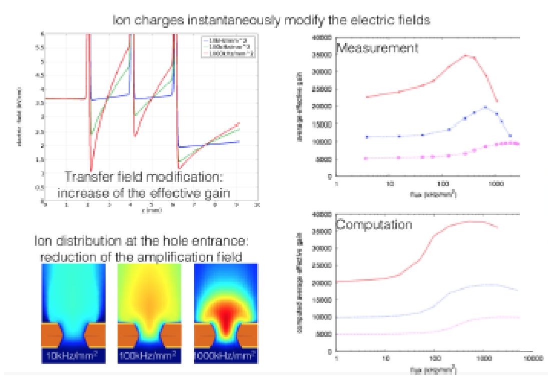


~99% (suspended)

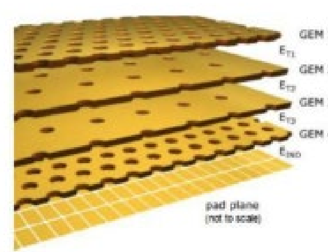
Effect of extreme operating conditions on the GEM detector components

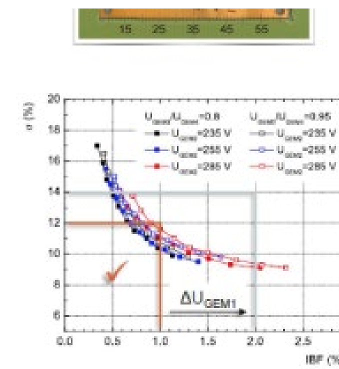


Ion density effects in multiGEM



ALICE TPC IBF

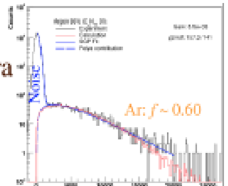


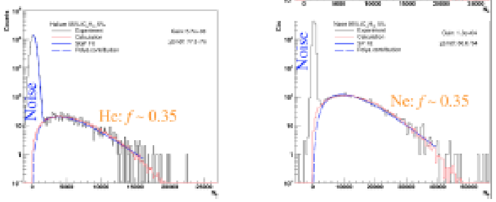


Modelling of physics processes and software tools

Single-electron spectra

blue: Pólya signal + Gaussian noise fit;
red: Monte Carlo (Magboltz), not fits !
Ar 95 % iC$_4$H$_{10}$ 5 %, E=28.12 kV/cm.
Ne 95 % iC$_4$H$_{10}$ 5 %, E=26.25 kV/cm.
He 95 % iC$_4$H$_{10}$ 5 %, E=26.25 kV/cm.





Mesh transparency

- Electron tracking requires improvement.

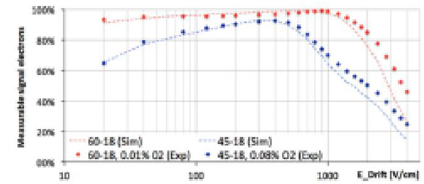


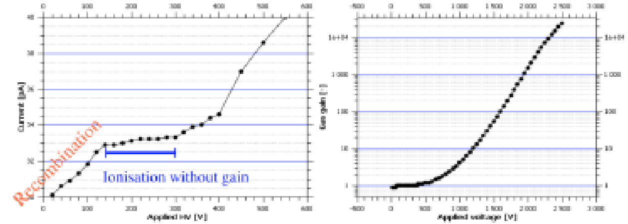
Fig. 5. Fraction of measurable signal electrons dependence on the drift field for two mesh geometries, experimental data (normalized signal strength) and simulation prediction (non-lost electrons after drift and mesh transition).

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

AGH University of Science and Technology

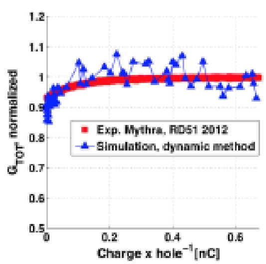
High-precision data from AGH

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

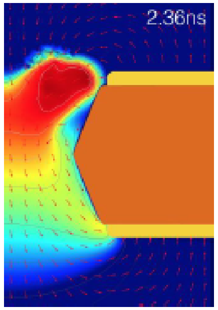


Charging-up of a GEM

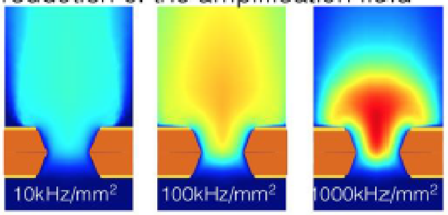
- Gain changes as a result of the charge deposits.
- Electron tracking to be refined.



- [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.

ELECTRONICS: the Scalable Readout System (SRS)

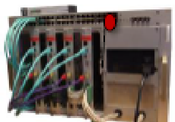
CERN

SRS & APV25 FE chip

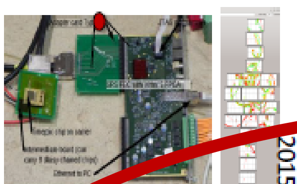
Worldwide use in the RD51 community (>2000 hybrids)

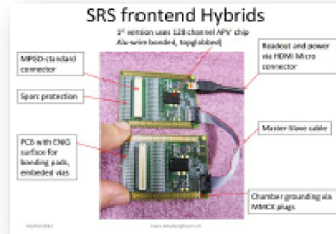
SRS+SiPM (NEXT TPC)

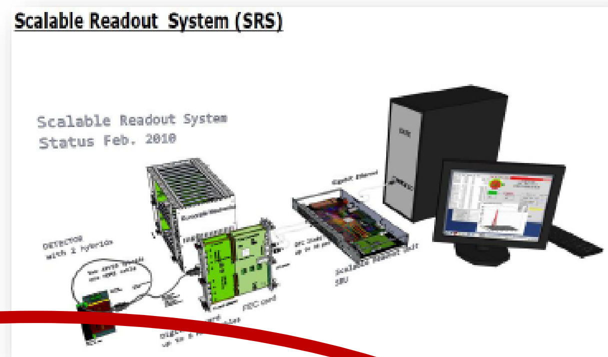
SRS-FEC+TOTEM DAQ



SRS+Timepix (LC-TPC) – Bonn/Desy

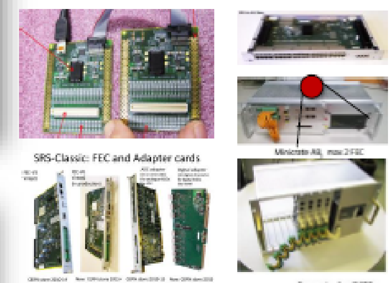




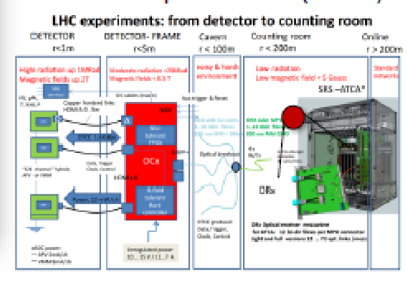


SRS: Different System

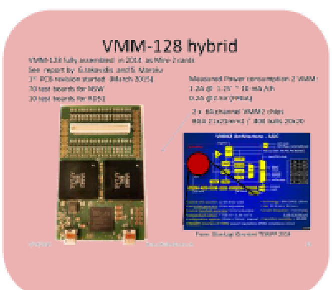
SRS for R&D on Detectors

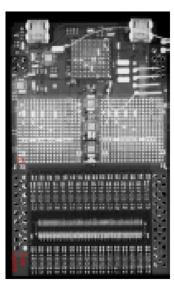


SRS for experiments (ATCA)



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

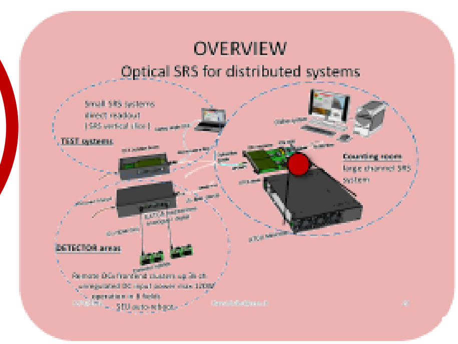




Baseline solution for RD51 SRS community.

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

SRS for spatially distributed system (optical SRS)

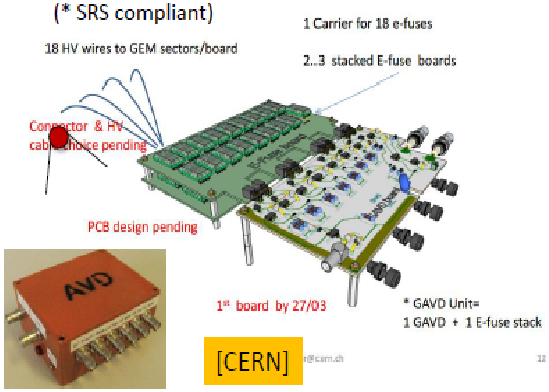


ELECTRONICS: lab equipment for developed by the RD51 community (examples)

GAVD board and E-fuse board

36 ..54 e-fused sectors per G-AVD Unit*

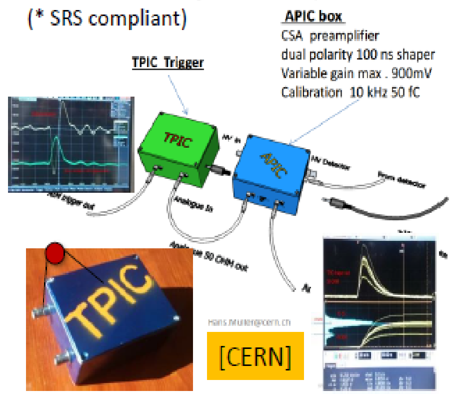
(* SRS compliant)



[CERN]

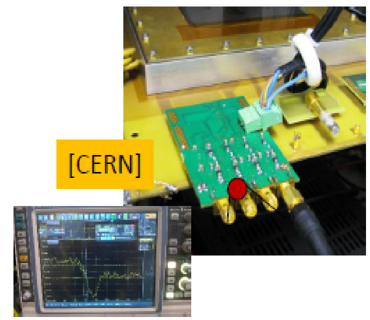
APIC Analogue Pickup box

(* SRS compliant)



[CERN]

QUAD MPGD signal amplifier 2 GHz, 25dB

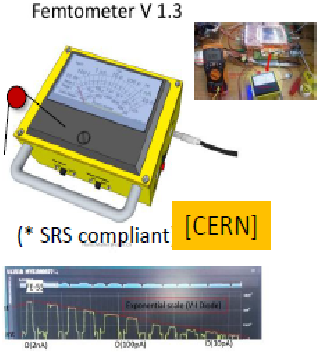


[CERN]

a scalable HV power supply system with SoC control and real-time, high resolution I, V monitoring

INFN-Trieste

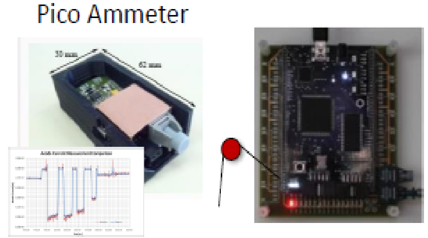
Femtometer V 1.3



(* SRS compliant)

[CERN]

Floating Multichannel Pico Ammeter

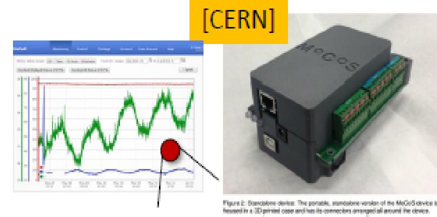


(Optical data transmission)

[Zagreb Univ.]

MoCoS: Monitoring and control system

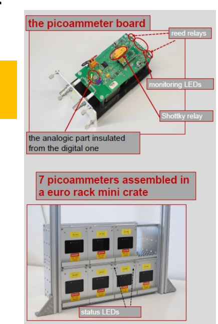
[CERN]



(* SRS compliant)

a Radio-Controlled High-Voltage Insulated Picoammeter

INFN-Trieste



TECHNOLOGY: MPGD PRODUCTION @ CERN

by the MPT workshop

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 500
•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

Production

on:

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 2012
End: end 2017

CERN Building 107

+ support to novel R&D

TECHNOLOGY: INDUSTRIALIZATION

Technology Industrialization → transfer "know-how" from CERN workshop to industrial partners

GEM Technology (contacts)
- Mecharonix (Korea, Seoul)
- Tech-ETCH (USA, Boston)
- Scienergy (Japan, Tokyo)
- TECHTRA (Poland, Wroclaw

THGEM Technology (contacts):
- ELTOS S.p.A. (Italy),
- PRINT ELECTRONICS

GEM Licenses signed by:
- Mecharonics, 21/05/2013
- TECH-Etch, 06/03/2013
- China IAE, 10/01/2012
- SciEnergy, 06/04/2009
- Techtra, 09/02/2009
- CDT, 25/08/2008
- PGE, 09/07/2007

MicroMegas Technology(contacts):
- ELTOS S.p.A. (Italy)
- TRIANGLE LABS(USA, Nevada)
- SOMACIS (Italy, Castelfidarco)
- ELVIA (France, CHOLET)

The long-lasting TT effort

GEM Industrialization Status (today):

TECH-ETCH
- Single Mask process fully understood. Many 10cm x 10cm produced and characterized.
- 40cm x 40cm GEM successfully produced
- CMS GE1/1 size of 1m x 0.5m started

TECHTRA
- Production Line Operational
- Stable process for 10cm x 10cm
- Single Mask process completely understood – 10cm x 10cm produced
- 30cm x30cm Single Mask Produced

Regularly producing for CERN store

MECARO
- 10cm x 10cm double mask produced and tested
- 30cm x 30cm double mask under evaluation @ CERN
- CMS GE1/1 size of 1m x 0.5m

Capability to produce CMS GE1/1 foils

MICROMEGAS industrialization status (today):

ELVIA
- Bulk MM detectors are routinely produced with size up to 50x50cm^2
- production for ATLAS NSW started

ELTOS
- Several small-zize Bulk MM detectors produced
- production for ATLAS NSW started

THGEM industrialization status (today):

ELTOS
- THGEM for COMPASS RICH upgrade (final polishing in house)
- LEMs for LBNO-DEMO

MPGD TT today

CULTURAL NET-WORK, DISSEMINATION & TRAINING

RD51 schools

MPGD assembly - 2009

MPGD Simulation - 2011

MPGD Electronics - 2014

RD51 MPGD Lectures:

MPGD students lectures (1 week) at the International Workshop on Advance Detectors & RD51 CM in Kolkata - 2014

SCHOOLS

XII ICFA School (Bogota, Colombia) - 2013

Danube School on Instrumentation -2014
in Elementary Particle & Nuclear Physics (Novi Sad Serbia)

Open Lectures Signal generation, modelling and processing- 2017

RD51 Open Lectures: Signal generation, modelling and processing

W. Riegler, R. Veenhof, F. Resnati, S. Tzamarias

Purpose of the lectures is to discuss new developments on the methods and tools used to describe the signal generating processes as well as techniques of analysing data of gaseous detectors. The lectures are geared towards people who are doing, or intend to do, research and developments on gas-based detectors but are also open to anyone interested on the subject.

Please, fill the registration to the Open Lectures (right panel) in particular if you are planning to follow them in person at CERN.

Lectures will be broadcasted via Vydio.

Access to the lectures is free. Certificate of Attendance will be provided under request.

MicroPattern Gaseous Detectors Conference 2019

MPGD 2019 LA ROCHELLE

Previous conferences:

MPGD2009, Crete, Greece
MPGD2011, Kobe, Japan
MPGD2013, Zaragoza, Spain
MPGD2015, Trieste, Italy
MPGD2017, Philadelphia, USA

Next conferences:

MPGD2021, Weizmann, Israel
MPGD2023, USTC, China

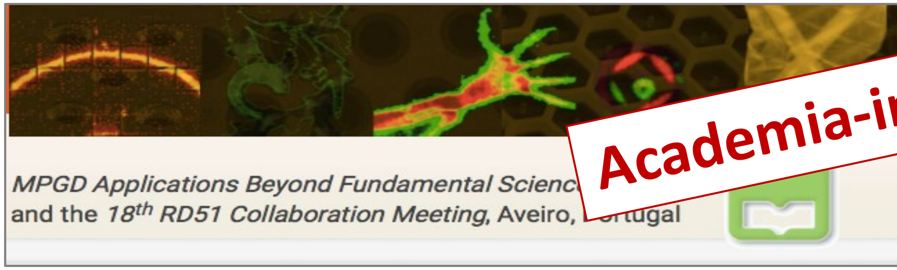
CULTURAL NET-WORK: special events

Academia-Industry Matching Events (understanding requirements, applications, approaching new communities and technologies)

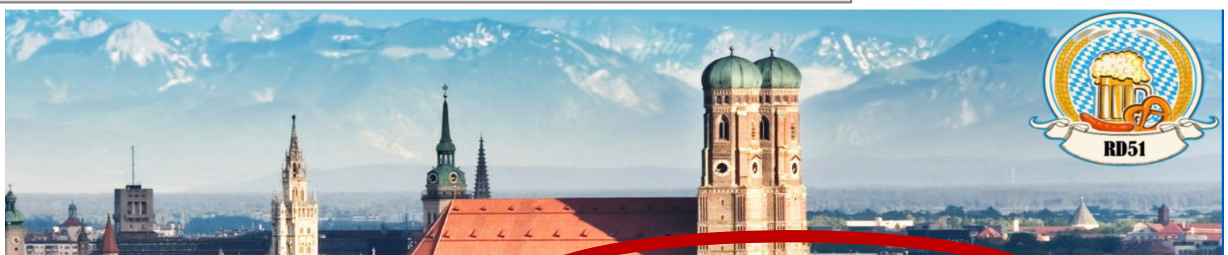
Academia-Industry Matching Event
Special Workshop on Neutron Detection with MPGDs
Neutron Detection 1st - 2013

Academia-Industry Matching Event
Second Special Workshop on Neutron Detection with MPGDs
Neutron Detection 2nd - 2015

RD51 Academia-Industry Matching Event
Special Workshop on Photon Detection with MPGDs
Photon Detection- 2015



Academia-industry matching events



RD51 Collaboration Meeting and the "MPGD Stability" workshop Munich 18-22 June 2018

Workshop on Resistive Coatings for Gaseous Detectors

13 May 2019, 09:00 → 14 May 2019, 18:00 Europe/Rome
Aula Multimediale (INFN Bari)
Piet Omer J Verwilligen (BA)

Bari (Italy), 13-14 may 2019

WORKSHOP on specific aspects

TUESDAY, 21 FEBRUARY

13:00 **Precise timing workshop**

09:00 **Welcome**

This workshop is intended to address the needs of a rapidly developing interest group in RD51 for fa
results from the RD51 PICOSEC project demonstrate feasibility of MPGD-based timing devices in the

Precise Timing Workshop
CERN, 21-22 February 2017

CULTURAL NET-WORK: collaborative effort

Transversal collaborations among groups from different countries, experiments, physics areas of interest encouraged and supported by RD51

(2019)
Discharge Consortium in quest for Spark-Less-Avalanche-Microstructures
Pixelated resistive bulk Micromegas with integrated electronics
Resistive materials and resistive-MPGD concepts & technologies

(2018)
Modular & General purpose Ultra Low Mass GEM Based Beam Monitors
DLC based electrodes for future resistive MPGDs
Study of negative ion mobility and ion diffusion for Negative Ion TPCs

(2017)
Development of modular multilayer GEM units

(2016)
Sampling Calorimetry with Resistive Anode MPGDs (SCREAM)
New Scintillating gases and structures for next-generation scintillation-based gaseous detector

(2014)
Measurement and calculation of ion mobility of some gas mixtures of interest
Fast Timing for High-Rate Environments: A Micromegas Solution
Development of a novel Micro Pattern Gaseous Detector for Cosmic Ray Muon Tomography

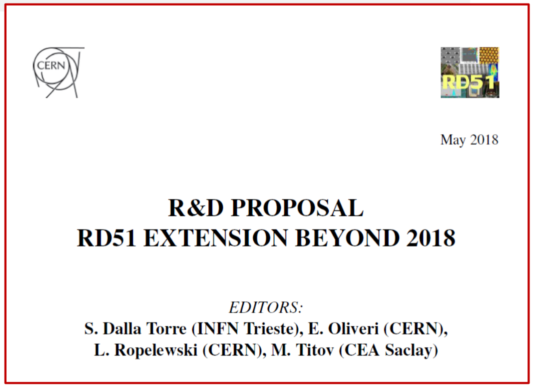
RD51 & THE CERN and THE HEP CONTEXTs

RECENT DOCUMENTS BY RD51

May 2018

- “R&D PROPOSAL: RD51 Extension beyond 2018”
  - Resulted in the approval of RD51 till 2023

https://arxiv.org/abs/1806.09955



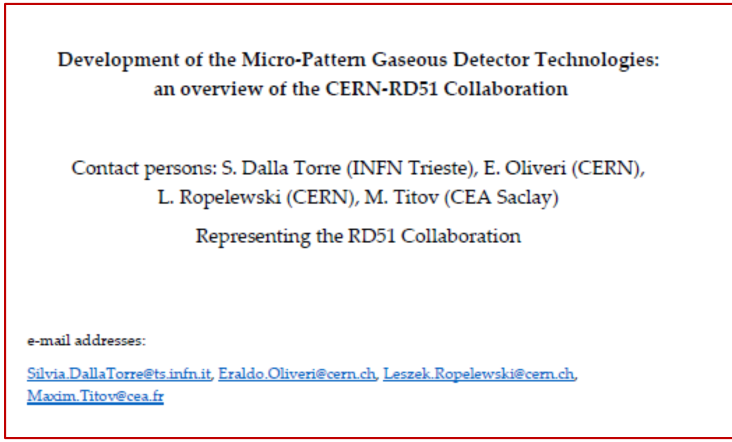
December 2018

- Input for the EPPSU process:

“Development of the MPGD Technologies: an overview of the CERN-RD51 Collaboration”

  - The RD51 model for detector R&D is presented

https://indico.cern.ch/event/765096/contributions/3295721/



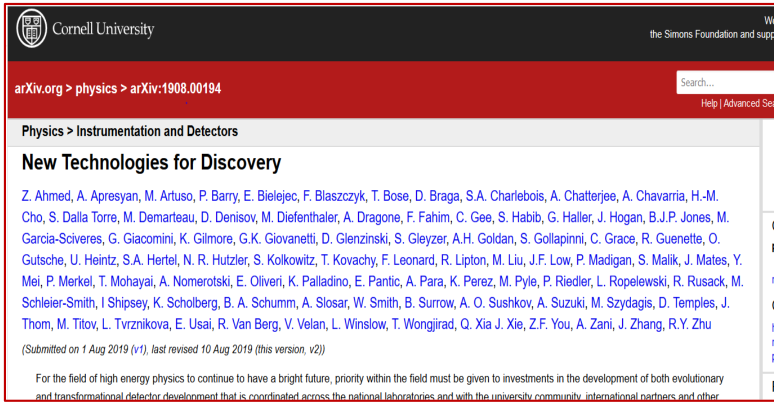
Summer 2019

- Document for the US BRN (Basic Research Needs) in preparation based on CPAD report

“New Technologies For Discovery”

  - Progress of MPGDs and RD51 model

https://arxiv.org/abs/1908.00194



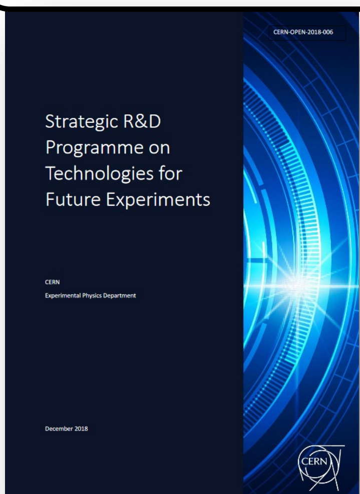
RD51 RESULTS & MODEL RECOGNIZED WITHIN THE CERN STRATEGIC R&D PROGRAM

https://cds.cern.ch/record/2320737/files/LHCC-SR-006.pdf

Contents

1. Thanks to the enormous progresses achieved during the RD51 years, MPGD are considered as key technology in the strategic EP strategic R&D programme on technologies for future experiments…

2. … as well as the R&D frameworks, fully shared in both documents



https://ep-dep.web.cern.ch/sites/ep-dep.web.cern.ch/files/CERN-OPEN-2018-006.pdf

3. R&D Programs share research lines/people on Advanced MPGD Concepts

Resistive materials and architectures (Screen printing, DLC, embedded resistors… SCREAM, mRWELL, RPWELL,..); Fast and precise timing; New materials and technologies (solid converters, manufacturing techniques,… ; Hybrid detectors (MPGD hybrids, optical readout, integrated pixel ASICs); …

RD51 & NEXT PROJECT (in preparation) for the European call "H2020 Innovation Pilot on Detector Technologies" (AIDA++)

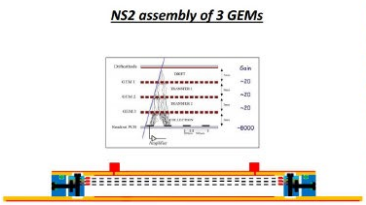
- Expressions of Interest (EoI) submitted last July
- 18 EoIs (/162) related to MPGDs
- Signed by 23 Institutions (/ 26) collaborating in RD51

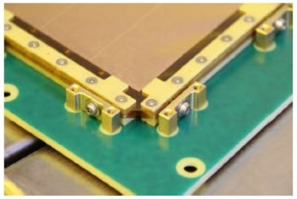
CONSOLIDATION OF MPGD TECHNOLOGIES & NEW TECHNOLOGIES

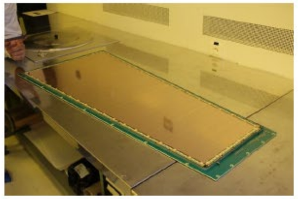
(a few examples)

GEM & MM CONSOLIDATION

GEM single mask and NoStretch-NoSpacer (NS2)

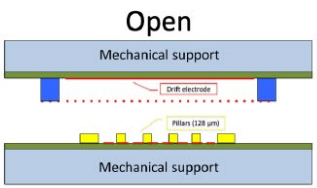


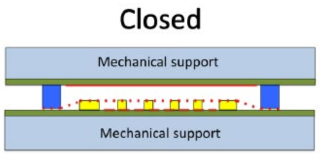


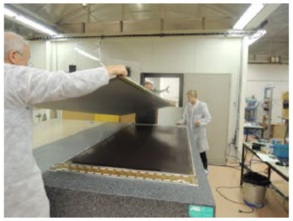


THGEM finishing

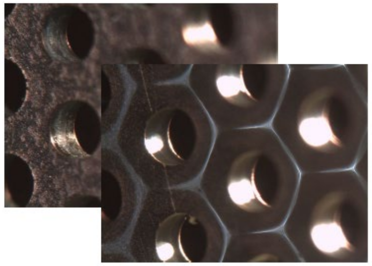
Assembly of resistive anode MMs



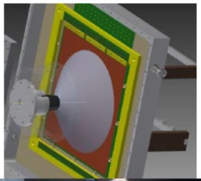




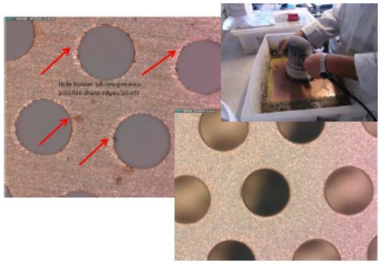
Polyurethane Treatment

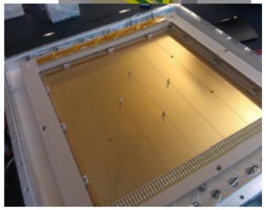


Non-treated THGEM suffers from: limite
max. gain, response non-uniformity and
time instabilities



Polishing and Cleaning

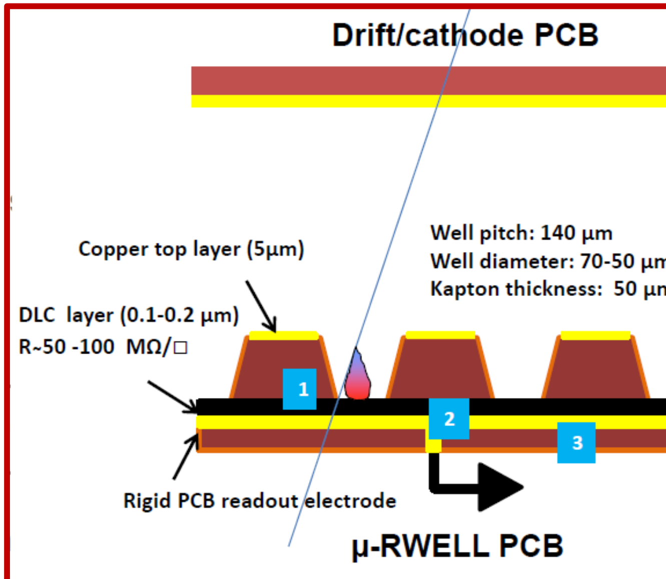




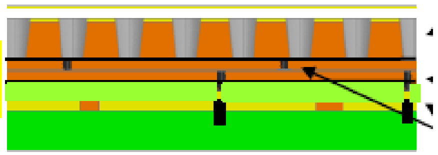
µR-WELL

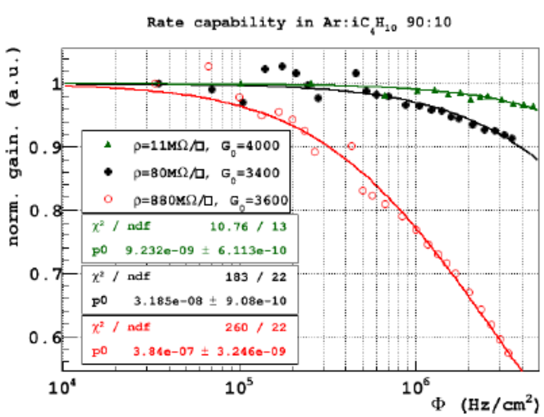
Compact, single amplification stage

- **Thanks to the resistive plane:**
  - **very realiable**
  - **almost completely *discharge-free***
  - **adequate for high particle rates O(1MHz/cm^2) thanks to the *segmented-resistive-layer***
- **performance:**
  - **gain ≥10^4**
  - **rate capability > 1 MHz/cm^2**
  - **space resolution < 60 µm**
  - **time resolution < 6 ns**



G. Bencivenni et al., 2015_JINST_10_P02008





High rate version:
Double resistive layer and multiple connections

Rate capability up to 10^7 Hz/cm^2

Perspectives

single-resistive layer (moderate-rate):
- Interest for CMS – upgrade phase_2, Tracking at EIC
- progressing towards large-size with industrial Partners

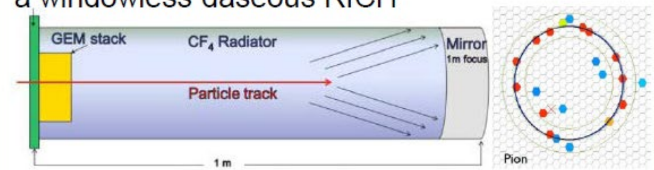
double-resistive layer (high rate):
- suitable for LHCb-Muon upgrade
- Tracking at e+e- colliders

RD51 DISSEMINATION worldwide / beyond HEP

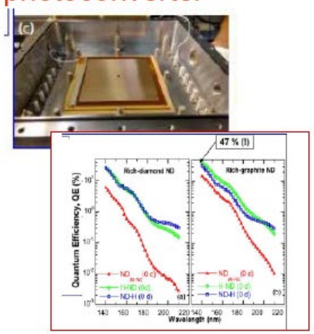
(a few examples)

MPGD R&Ds for EIC

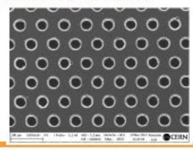
Quintuple GEM photon detector for a windowless gaseous RICH



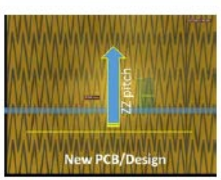
RICH r-o with hybrid MPGDs with **miniaturized pads** and **novel nanodiamond photoconverter**

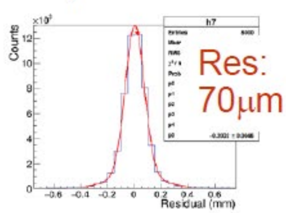


Low material-budget with **ultra-low mass Chromium GEM foils**



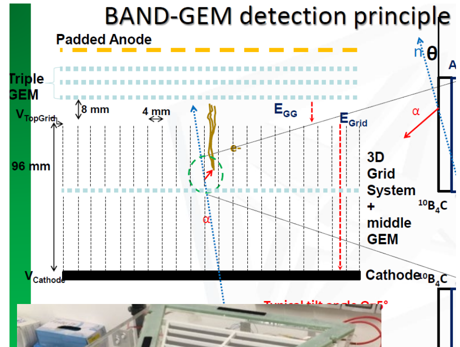
Zigzag GEM read-out for low channel count preserving fine space resolution in TPC r-o

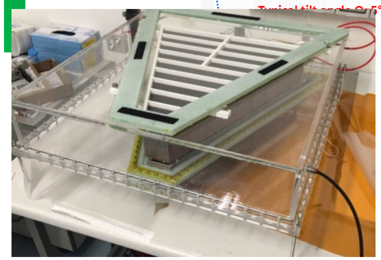




n-DETECTION by MPGDs

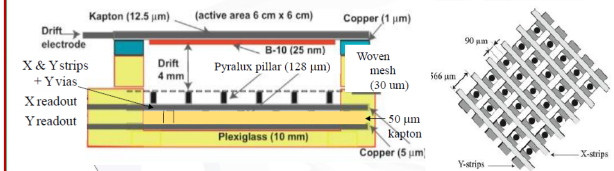
BAND-GEM detection principle

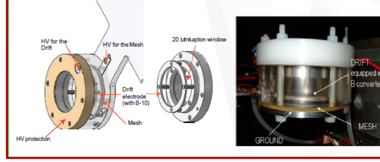




CERN/n-TOF 2D X-Y neutron beam profiler

128 µm Bulk-micromegas technology with 2D X-Y readout (CAST-like) Use of $^{10}B(n,\alpha)^7Li$ for up to 1 MeV neutron conversion

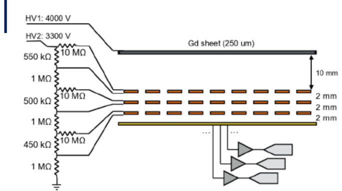


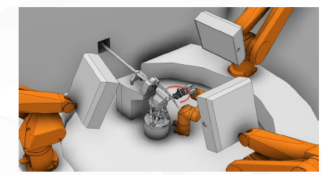


Specifications

- ✓Ar+2%iC$_4$H$_{10}$+10%CF$_4$
- ✓6x6 cm² active area
- ✓Φ 60 mm, 24 nm $^{10}B_4C$ layer on a 1 µm copper coated 12,5 µm Kapton foil
- ✓212 channels : readout with 2 x 96 ch. Gassiplex cards

Gd-GEM for NMX @ ESS

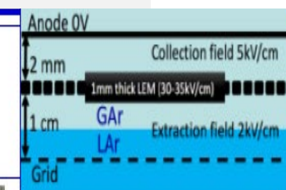


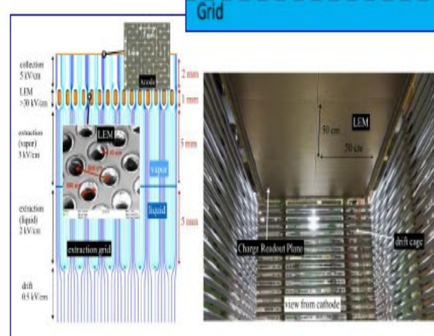


MPGD & DETECTION OF RARE EVENTS

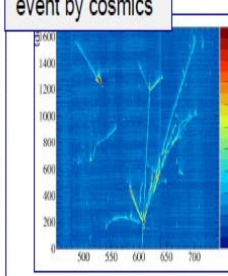
WA105 (3x1x1 m³ LAr prototype) (LBNO-DEMO)

- double phase for read-out by LEMs (THGEM)
- Top: 50 x 50 cm² LEMs, 2-D anode
- PMT plane, bottom





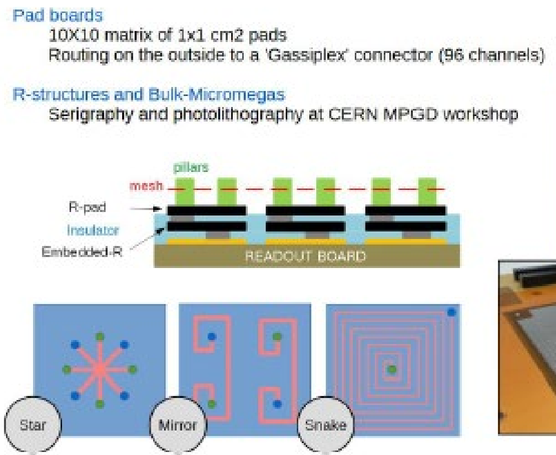
event by cosmics

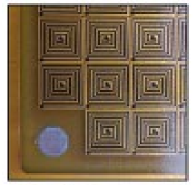


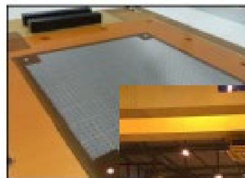
RD51 RUNNING TOWARDS THE FUTURE

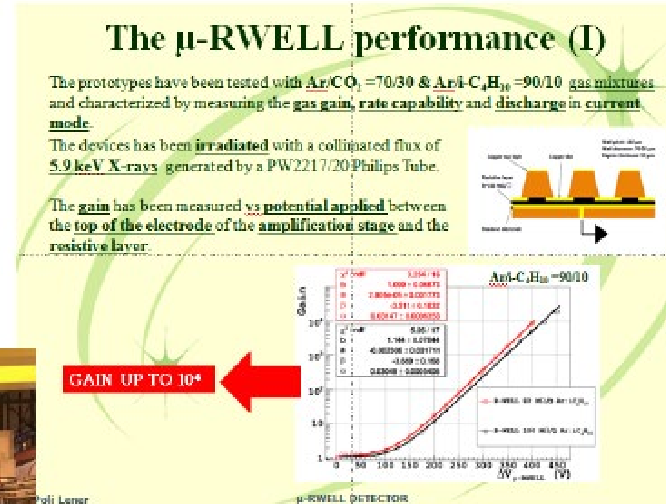
(a few examples)

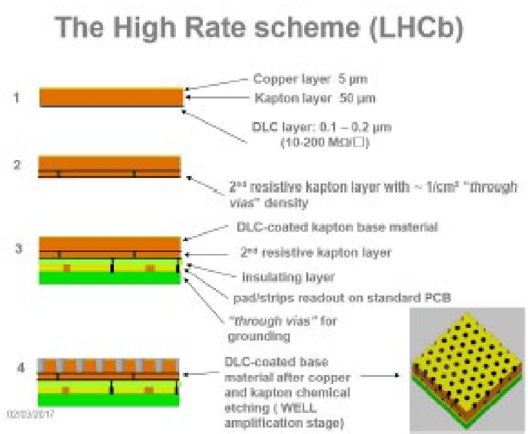
FLAGSHIP TECHNOLOGIES:
resistive materials and related architectures

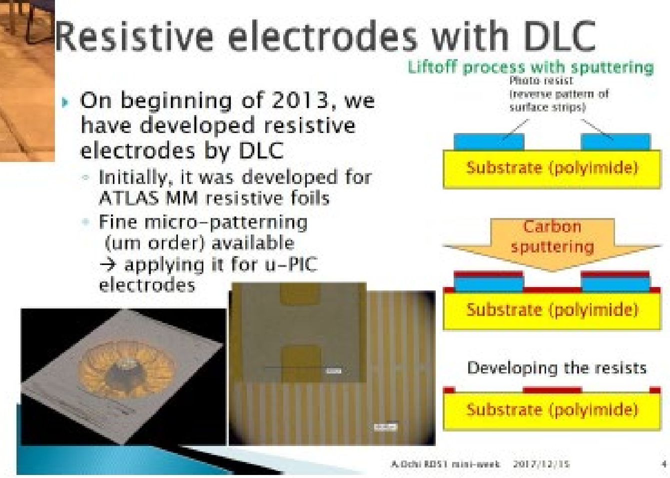






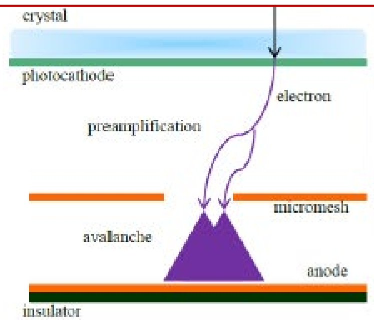


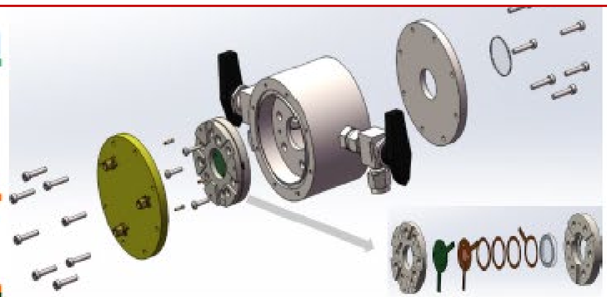


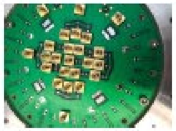


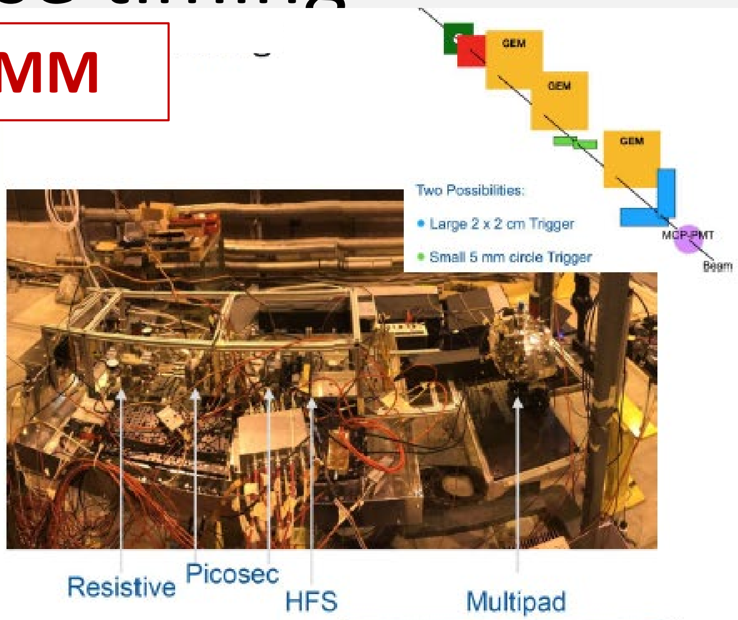
FLAGSHIP TECHNOLOGIES: fast and precise timing

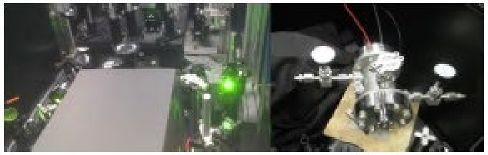
Cherenkov light + photoconverter (CsI) + MM

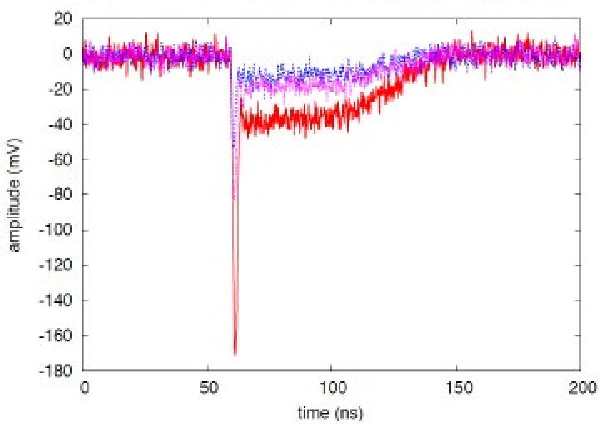


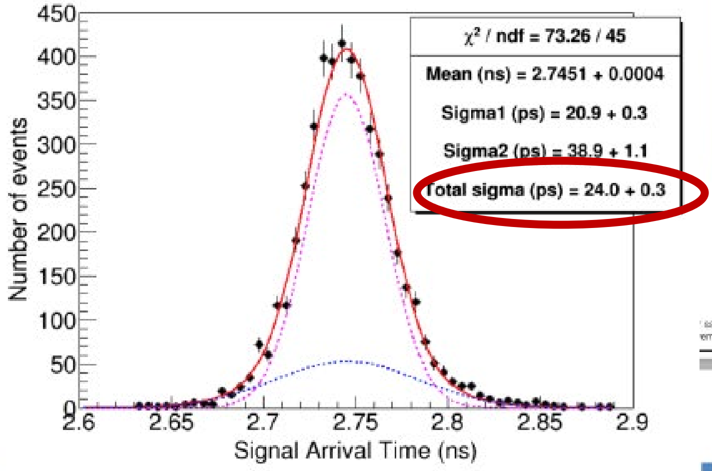


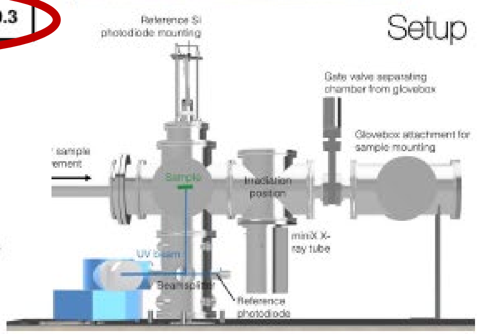








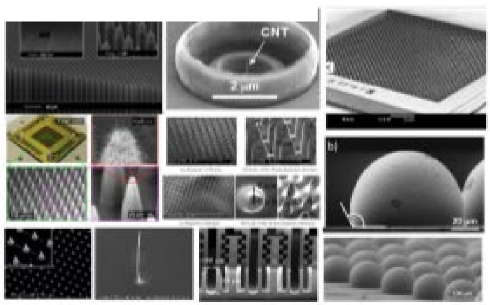


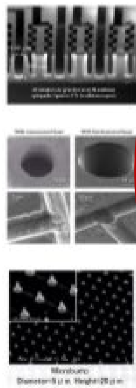


FLAGSHIP TECHNOLOGIES:
new materials and technologies

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

3-D PRINTING



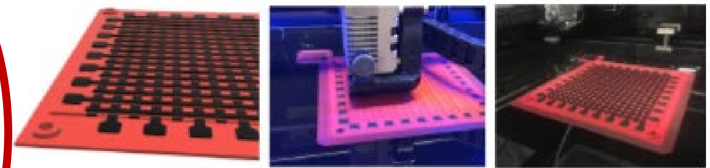


DRIE Plasma
Deep reactive-ion etching

Laser Drilling

Super InkJet Printer

2D strip anode

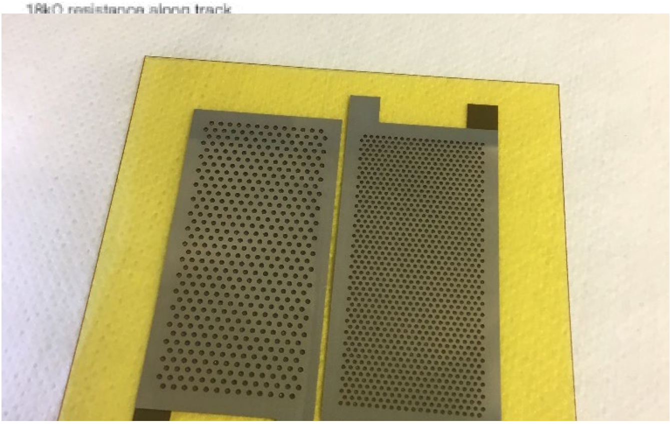


2 layers of strips separated by insulating material

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



THGEMs by 3-D PRINTING, working !

Innovative photocathodes by ND powder

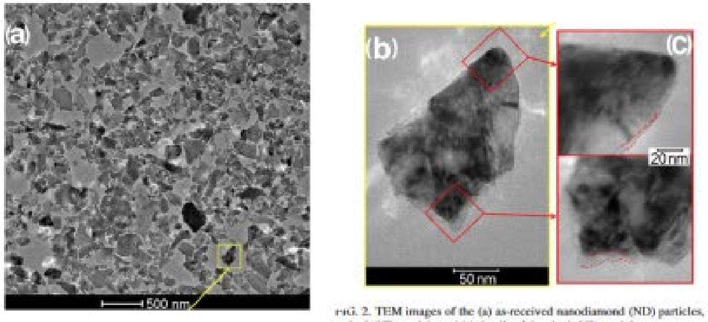


FIG. 2. TEM images of the (a) as-received nanodiamond (ND) particles, “ a single ND particle and (c) details of the single ND particle.

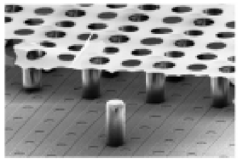
Highly efficient and stable ultraviolet photocathode based on nanodiamond particles
L. Velardi, A. Valentini, and G. Cicala, Appl. Phys. Lett.108, 083503 (2016)

FLAGSHIP TECHNOLOGIES:
hybrid detectors

MM on a TIMEPIX detector

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

CAST


(a)

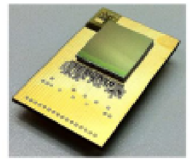

(b)

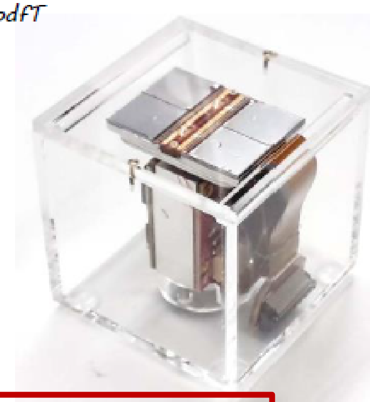
Figure 1: SEM image of an InGrid structure on top of a Timepix ASIC (a), taken from [13]. In the SEM image parts of the mesh have been removed to show the good alignment between pixels and mesh holes. And a bare Timepix ASIC on a carrier board (b).

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

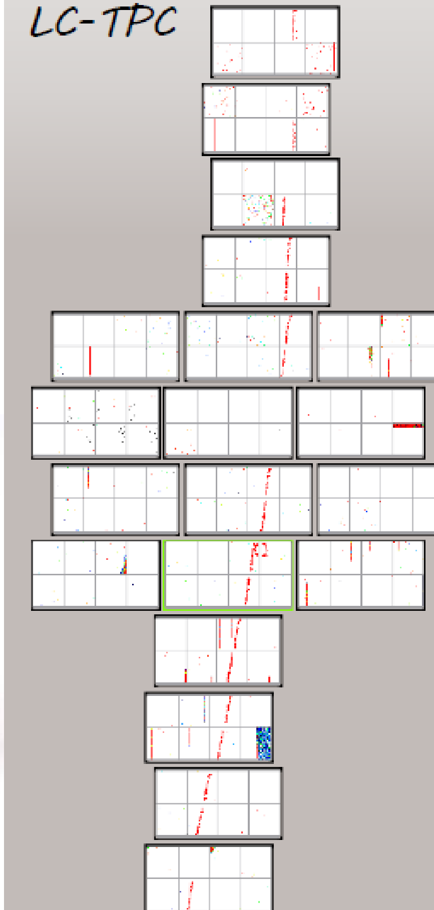
256 x 256 pixels, 55 x 55 μm pitch, about 1.4x1.4 cm2 sensitive area

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

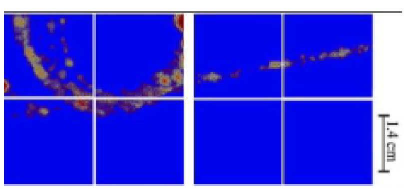
The "QUAD"



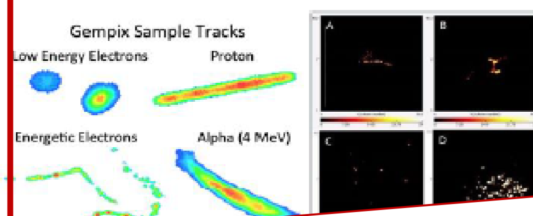
LC-TPC



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.)



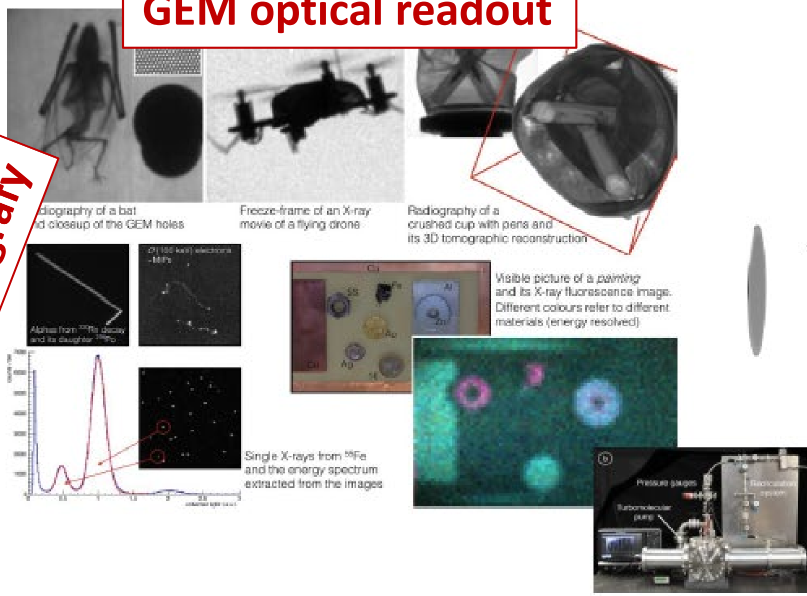
J. Kaminski, ...s://indico.cern.ch/event/391665/contributions/182...2/attachments/1230061/1802690/GridPix.pdf

GEM on a TIMEPIX detector

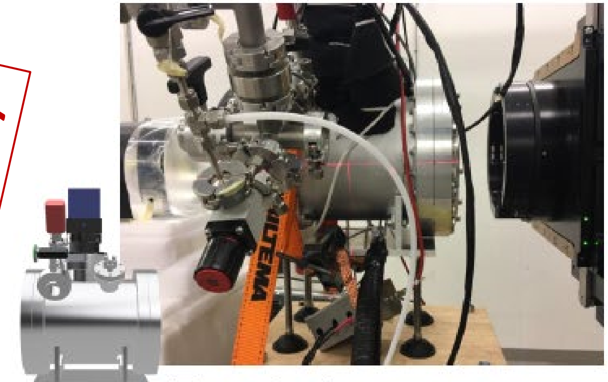
FLAGSHIP TECHNOLOGIES:
hybrid detectors

GEM optical readout

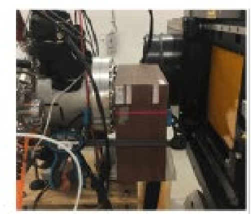
Radiografy

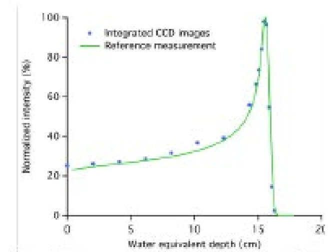


Medical application: dosimetry

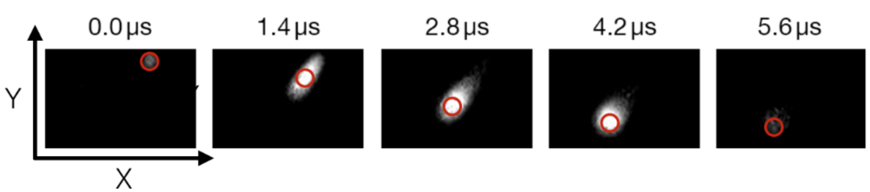


Depth dose curve

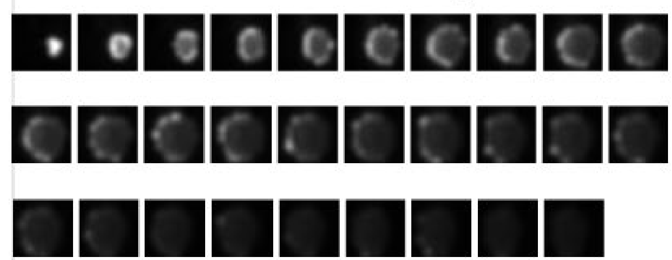




Coupled to fast camera readout:
HEP applications (TPC)



Patient treatment plan



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RD51 REQUESTS

RD51 REQUESTS

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 in view of 2021 (beams back !)

- 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:
  - Bond 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