State-of-the-art Micro-Pattern Gaseous Detectors (RD51)

24-29 May 2021 – TIPP 2021

Silvia Dalla Torre, INFN - Trieste
MAJOR CREDITS

ECFA Detector R&D Roadmap
(https://indico.cern.ch/event/957057/program)

Symposium of Task Force 1
"Gaseous Detectors", 29 April 2021
(https://indico.cern.ch/event/999799/)

– Organized by TF1 conveners:
  • Anna Colaleo (INFN, Bari)
  • Leszek Ropelewski (CERN)

I am in debt to Anna, Leszek, the whole TF1 team and all the speakers at the Symposium

MPGD2019

I am in debt to all the speakers at the Conference

RD51

I am in debt to all the RD51 collaborators
OUTLOOK

- MPGDs, historical hints
- MPGD, technologies
- MPGDs, applications
- MPGDs, present technological frontiers
- RD51, a collaboration for MPGD development and dissemination
  - Also a model for progressing in detector R&D

The field is so rich that it is impossible to be exhaustive! → Only examples
MPGDs history & RD51

First large-scale application of GEMs and Micromegas at the COMPASS experiment

 Adoption of MPGD technologies:
- LHCb forward tracking (GEM)
- ATLAS NSW (Micromegas)
- CMS forward tracking update (GEM)
- ALICE TPC upgrade (GEM)
- COMPASS RICH upgrade (hybrid MPGD)
- KLOE2 & BESIII (GEM)
- LBNO-DEMO (THGEM)
- n-detection at ESS (GEM)
- Muon radiography (Micromegas)
...
Resistive Anodes
Developed within the ATLAS-NSW project

J. Wotschack
CERN Det. seminar, 18/11/2011

THE CONCEPT
- Mesh (cathode)
- R-O strip (anode)
- Parallel Plate (gap ~ 100 µm)
- Ionization & drift (gap ~ 3-5 mm)

DISCHARGE RATE, THE ENEMY AND THE WAY-OUT

standard anode

beam: π, µ
120 GeV/c

Resistive anode

π no beam µ
MPGD TECHNOLOGIES: GEM

THE CONCEPT

Induction gap

Single mask production to misalignments, adopted for TOTEM, KLOE2, CMS

LARG-SIZE FOILS

MULTILAYER ARCHITECTURE TO LIMIT THE DISCHARGE RATE

Mass production to misalignments, adopted for TOTEM, KLOE2, CMS

Spacers between foils (COMPASS, TOTEM)

Stretching and gluing (LHCb, KLOE2)

Chemical Polyimide etching
Copper electro etching
Stripping

Mechanical stretching (CMS)

S. Bachmann et al., NIMA A479(2002)294

TIPP 2021, 24-29 May 2021
MPGD – TECHNOLOGIES, more

**MSGC - MicroStrip Gas Chamber**


The first MPGD concept!

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**A different technology**

- PCB industry
- Robust
- Self-supporting plates

introduced in // by different groups:

- R. Chechik et al., NIMA 535 (2004) 303

**µR-WELL**

NIMA 858 (2020) 162050

**µPIC**

NIMA 471 (2001) 264

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Novel architectures with emphasis on industrial production options
GEM pre-amplification: control the discharge rate in tracking

THGEM + MM for single photodetection: IBF control

THGEM + G-APD for electroluminescence

Coupling MPGD technologies to reduce discharge rate or IBF rate

Coupling with high granularity solid state sensors

GEM + medipix \rightarrow \text{GEMpix}

A. Bondaret al., B. NIMA 628 (2011) 364

On-line Event display ILC-TPC proto

Optical readout

J. Kaminski @ MPGD2015

Timepix chip + Miniaturized MM \rightarrow \text{Ingrid}
MPGD PERFORMANCE

MICROMEGAS
Space resolution
• COMPASS, ~90μm
  (NIMA 577 (2007) 455)

Time resolution
• COMPASS, ~ 9 ns
  (NIMA 577 (2007) 455)

Gain
• COMPASS: G ~ 6400
  (NIMA 469 (2001) 133)
• T2K TPC: G ~ 1500
  (NIMA 637 (2011) 25)

Material budget
• COMPASS, 0.3 % X0
  (NIMA 577 (2007) 455)

Rate capability
• ATLAS-NSW resistive, lin. up to 100kHz/cm²
  (2013 JINST 8 C12007)
• COMPASS pixelated with GEM pre-amplification, operated up to ~1·10⁵/s/mm²
  (D. Neyret, MPGD2015)

GEM
Space resolution
• COMPASS, ~70μm
  (NIMA 577 (2007) 455)

Time resolution
• COMPASS, ~ 12 ns
  (NIMA 577 (2007) 455)
• LHCb 4.5 ns (dedicated effort)
  (NIMA 535 (2004) 319)
• Phenix HBD: G ~ 4000
  (NIMA 646 (2011) 35)

Material budget
• COMPASS, 0.4 % X0
  (NIMA 577 (2007) 455)
• COMPASS pix.ed, 0.2 % X0
  (NP B PS 197 (2009) 113)

Rate capability
• COMPASS pixelated, stable up to 1.2·10⁵/s/mm²
  (NP B PS 197 (2009) 113)

μ–R WELL
Space resolution
• ~60-80 μm

Time resolution
• ~5-6 ns (JINST 12 (2017) C06027)

Gain
• > 10⁴

Material budget
• < 1% X0 (G. Bencivenni private comm.)

Rate capability
• ≥10 MHz/cm² (high-rate version)

MPGD gain record in experiment
(NIMA 936 (2019) 416)

Hybrid (2 THGEMs + MM) photon detectors of COMPASS RICH:
GAIN: ~15000
DISSEMINATION
@ CERN, major LHC exp.s

ATLAS
New Small Wheels (MICROMEGAS) 1200 m²

CMS
Muon system (GEMs) 220 m²

LHCb
Muon upgrade
By high-rate μ_RWELL 90 m²

ATLAS - HL-LHC
Options for the very forward muon tagger: μ-PIC, μ_RWELL, pixelized resistive MM

ALICE
TPC upgrade GEMs 32 m²
DISSEMINATION, @ CERN, beyond main LHC exp.s

COMPASS RICH photon detector upgrade

First Large Scale Use of GEMs and MICROMEGAs

\[ \sigma_t \sim 9 \text{ ns} \]

Tracking in the COMPASS Experiment

Micromegas: \( \sigma_x \sim 90 \mu \text{m} \)

GEM: \( \sigma_x \sim 70 \mu \text{m} \)

\[ \sigma_t \sim 12 \text{ ns} \]

Beam

Target

SM1

SM2

MuonWall

RICH

E/HCAL

MuonWall

B. Ketzer

NIMA 617 (2010) 151

NIMA 936 (2019) 416

60 cm

Csi coating
DISSEMINATION, around the world

**MPGDs in US labs**

- JLab, CLAS12 end-cap (MM)
- JLab, CLAS12 upgrade ($\mu$-RWELL)
- JLab, Super BigBite (GEM)
- JLab Hall A (GEM) 40 x 50 cm$^2$
- JLab, GLUEX $\mu$-RWELL/GEM
- JLab, Forward GEM Tracker
- BNL, STAR Forward GEM Tracker
- BNL, sPHENIX TPC (GEM)

**Other MPGDs around the world**

- Frascati, KLOE2 Cylindric triple GEM
- Beijing, BESIII (GEMs)
- JLab, CLAS12 barrel (MM)
- JLab, Prad (GEM)
DISSEMINATION, MPGDs options for the EIC

Quintuple GEM photon detector for a windowless gaseous RICH

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

Low material-budget with ultra-low mass Cr GEM foils

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

GEM-TRD

Extended e-PID with a GEM-based Cherenkov TPC

Set of coaxial cylindrical MM / µ-RWELL

For tracking in the barrel region
<table>
<thead>
<tr>
<th>Experiment / Timescale</th>
<th>Application Domain</th>
<th>Gas Detector Technology</th>
<th>Total detector size / Single module size</th>
<th>Operation Characteristics / Performance</th>
<th>Special Requirements/ Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILC TPC DETECTOR:</td>
<td>e+e- Collider Tracking + dE/dx</td>
<td>MM, GEM (pads InGrid (pixels))</td>
<td>Total area: ~ 20 m²</td>
<td>Max. rate: &lt; 1 kHz, Spatial res.: &lt;150 µm, Time res.: ~ 15 ns, dE/dx: 5 %</td>
<td>Si + TPC Momentum resolution: dp/p &lt; 9 × 10⁻⁶ /GeV Power-pulsing</td>
</tr>
<tr>
<td>CEPC TPC DETECTOR</td>
<td>e+e- Collider Tracking + dE/dx</td>
<td>MM, GEM (pads InGrid (pixels))</td>
<td>Total area: ~ 2 x 10 m²</td>
<td>Max. rate: &gt;100 kHz/cm², Spatial res.: ~100 µm, Time res.: ~ 100 ns, dE/dx: &lt;5 %</td>
<td>- Higgs run, - Z pole run, - Continues readout, - Low IBD and dE/dx</td>
</tr>
<tr>
<td>SUPER-CHARM TAU FACTORY</td>
<td>e+e- Collider Inner Tracker</td>
<td>Inner Tracker / (cylindrical µRWELL, or TPC / MPGD read.)</td>
<td>Total area: ~ 2 - 4 m², Single unit detect: 0.5 m²</td>
<td>Max. rate: 50-100 kHz/cm², Spatial res.: ~100 µm, Time res.: ~ 5 - 10 ns, Rad. Hard.: ~ 0.1-1 C/cm²</td>
<td>Challenging mechanics &amp; mat. budget &lt; 1% X0</td>
</tr>
<tr>
<td>ELECTRON-ION COLLIDER (EIC)</td>
<td>Electron-Ion Collider Tracking</td>
<td>Barrel: cylindrical MM, µRWELL</td>
<td>Total area: ~ 25 m²</td>
<td>Luminosity (e-p): 10³³, Spatial res.: ~50 - 100 um, Max. rate: ~ kHz/cm²</td>
<td>Barrel technical challenges: low mass, large area Endcap: moderate technical challenges</td>
</tr>
<tr>
<td>ILC TPC DETECTOR:</td>
<td>Muon Collider Tracking</td>
<td>µ-RWELL</td>
<td>Total area: 225 m², Single unit detect: (0.5 x 0.5 m²) ~0.25 m²</td>
<td>Max. rate: 10 kHz/cm², Spatial res.: ~60-80 µm, Time res.: 5-7 ns, Rad. Hard.: &lt;100 mC/cm²</td>
<td></td>
</tr>
<tr>
<td>FCC-ee and/or CEPC IDEA PRESHOWER DETECTOR START: &gt;2030</td>
<td>Lepton Collider Tracking</td>
<td>µ-RWELL</td>
<td>Total area: 3000 m², Single unit detect: ~0.25 m²</td>
<td>Max. rate: &lt;1 kHz/cm², Spatial res.: ~150 µm, Time res.: 5-7 ns, Rad. Hard.: &lt;10 mC/cm²</td>
<td></td>
</tr>
<tr>
<td>FCC-ee and/or CEPC IDEA MUON SYSTEM START: &gt;2030</td>
<td>Lepton Collider Tracking/Triggering</td>
<td>µ-RWELL</td>
<td>Total area: 3000 m², Single unit detect: ~0.25 m²</td>
<td>Max. rate: &lt;500 kHz/cm², Spatial res.: &lt;100 µm, Time res.: ~ 3 ns, Rad. Hard.: ~ C/cm²</td>
<td>Redundant tracking and triggering;</td>
</tr>
<tr>
<td>FCC-hh COLLIDER MUON SYSTEM START: &gt; 2050</td>
<td>Hadron Collider Tracking/Triggering</td>
<td>All HL-LHC technologies (MDT, RPC, MPGD, CSC)</td>
<td>Total area: ~ 3500 m², Single unit detect: 0.3-0.4 m²</td>
<td>Max. rate: &lt;100 kHz/cm², Spatial res.: ~100 µm, Time res.: &lt;10 ns, Rad. Hard.: &lt; C/cm²</td>
<td>Redundant tracking and triggering;</td>
</tr>
<tr>
<td>MUON COLLIDER MUON SYSTEM START: &gt; 2050</td>
<td>Muon Collider</td>
<td>RPC or new generation fast Timing MPGD</td>
<td>Total area: ~ 3500 m², Single unit detect: 0.3-0.4 m²</td>
<td>Max. rate: &lt;100 kHz/cm², Spatial res.: ~100 µm, Time res.: &lt;10 ns, Rad. Hard.: &lt; C/cm²</td>
<td>Redundant tracking and triggering;</td>
</tr>
</tbody>
</table>
DISSEMINATION, low energy nuclear physics

Low Pressure Active Target – TPC, Hybrid MPGD (THGEM + MM)
@ NSCL, MICHIGAN
M. Cortesi, MPGD2015

NIFFTE @ Los Alamos LANSCE TPC with MM
J. RUZ, MPGD2013

Schematic layout of the low-pressure TPC

Accelerator mass spectrometry (THGEM)
@ Budker Institute, Novosibirsk

HypTPC - Structure

Gas Vessel

Field Cage
Gating Grid
Triple GEM
Pad Plane

E=130 V/cm

620

616

50 µm GEM

Gating wires

130 V/cm (E_{Drift})

4.2 mm

50 µm GEM

2 kV/cm

2 mm

100 µm GEM

1.5 V_{GEM}

3.1 kV/cm

2 mm

Pads

E42 experiment @ J-PARC, Tokai for H-dibaryon search with HypTPC
Sensors: GEMs with non-standard geometry
DISSEMINATION, neutron detection

GEM & GEM-derived detectors playing a major role for n detection ($^3$He shortage)

- Fast Neutrons: Polyethylene converter + Aluminium
  - Neutrons are converted in protons through elastic scattering on hydrogen
- Thermal Neutrons: $^{10}$B converter
  - Neutrons are detected using the products ($\alpha$,Li) from nuclear reaction $^{10}$B(n,\alpha)7Li

New architectures to increase the efficiency for ESS

Band-GEM

Efficiency: 40-50%
T2K: TPC read-out by MM, resistive MM in the upgrade to increase space resolution

NEWAGE0 Detector @ Kamioka mine
Negative-Ion TPC With $\mu$-PIC for Directional Dark Matter Search

Cygno for Directional Light Dark Matter search by detecting electroluminescence in GEMs

DUNE double-phase read-out by LEM (= THGEM)

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MPGDs Silvia DALLA TORRE

DISSEMINATION, $\nu$-physics, rare events, astrophysics

D. Attie, MPGD2019

D. Autiero, 2020

D. Pinci, MPGD2019

DUNE demonstrator WA105

NASA IXPE: X-ray polarimetry to study acceleration processes in astrophysical sources, using 50$\mu$m pitch GEMs

C. Sgro', 2017

T2K: TPC read-out by MM, resistive MM in the upgrade to increase space resolution

IAXO International Axion Observatory sources, using Ingrid technology

2014 JINST 9 T05002
Gas detectors for sure are not portable devices like Timepix. Timepix Family is one of the best example of detector with wide applications beyond fundamental research.

But when you need:
- big detection areas,
- high radiation tolerances
- measure high intensity particle fluxes,
- medical imaging (big areas)
- detect thermal neutrons with high efficiency
- study on micro dosimetry
- low energy Xrays

then you need gas detectors, in spite of the need of HV and gas supply systems.

examples: medical, cultural-heritage, muography, radioactive wastes (plasma fusing and nuclear plants already mention with other n-detectors)
**Muography**

**Applications:** vulcanology, archeology, civil engineering, nuclear reactor monitoring

**Discovery of a big void in Khufu’s Pyramid by observation of cosmic-ray muons**

*MM telescope*  
(Nature 552 (2017) 386)

**Measurement of radioactive waste**

**X-ray Energy real-time measurement**

**Hadron therapy monitoring detecting electroluminescence from GEMs**

Glass GEM, T. Fujiwara  
MPGD 2019

**Proton radiography with GEMs and MM-TPC**

NIMA 718 (2013) 160

30x30cm² active area  
J. Bortfeldt, MPGD2019

**Mitigate parallax error by radial drift field in GEMs,**  
NIMA 875 (2017) 16

**X-ray fluorescence for cultural heritage**

THCOBRA, J. Anal. At. Spectrom., 2015,30, 343
TECHNOLOGICAL FRONTIERS,

MOTIVATIONS:
- operation at high gain for single e and precise timing
- long-term detector stability: tens of C/cm²
- operation at high rate: 10 MHz/cm² (and beyond)

THE ENEMY: DISCHARGES
- Mechanical imperfections
- Micrometric structures in MPGD
- Transition from avalanche to streamer mode for too many ionization electrons

A WAY-OUT
Diverging processes can be quenched by means of resistive electrodes

GO RESISTIVE!

FIRST LARGE SCALE APPLICATION

NEW FRONTIER IN RATE CAPABILITY

ATLAS New Small Wheels

MM: born non-resistive, Consolidated with resistivity

Here is an image of a pixelated resistive bulk Micromegas with integrated electronics.

A new technology, born resistive

Improving of GEM stability with resistivity, under study
Current developments on Resistive MPGD - DLC

- Diamond Like Carbon (DLC) coatings: properties of DLC have offered new possibilities opening the way to develop new detector structures.
- Stable and mechanically robust material

**Mastering DLC technology**

**Cu-coated DLC manufacture**

**Cr & Cu co-deposition** (a few nm)

**PEDP technique** for large-area μ-RWELL

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**Carbon dry sputtering → DLC**

- Sputtered carbon
  - Diamond like, and amorphous structure
  - It means, carbon particles of molecular size!
- Fine structure with proper resistivity is available
  - with liftoff method

**Image from Tribology International Vol 37, 11-12, p907**

Random mixture of sp3 (diamond like) and sp2 (graphite like) carbon makes conductive paths of molecular size.

**A. Ochi, RD51 mini-week CERN 05/12/2018**
**TECHNOLOGICAL FRONTIERS, FINE TIME RESOLUTION**

**MOTIVATIONS:**
- Mitigation of pile-up in present and future colliders
- Extended TOF systems
- ... and medical applications (PET)

**THE major OBSTACLE:**
- Fluctuations in primary ionization
**TECHNOLOGICAL FRONTIERS,**  **CONTROL ION BACK-FLOW (IBF)**

**MOTIVATIONS**
- **in Photon Detectors (PD)**
  - photocathode ion bombardment
- **in TPC**
  - space charge $\rightarrow$ field distortion

**MPGD technologies and optimized IBF reduction**

- **Triple GEMs with staggered holes**, IBF <1%
  
  A. Bondar et al., NIM A 496 (2003) 325

- **Quadruple GEMs with non-standard geometry (ALICE TPC)**

- **Triple THGEMs with staggered holes**, IBF~1%

2013 JINST 8 P01021

- **MICROMEGAS, intrinsic ion blocking properties**

- **Hybrid architectures**

- **WORLD RECORDS**
  
  MHSP
  
  IBF $\sim 10^{-4}$
  
  NIMA 548 (2005) 375

  DMM
  
  IBF: $2.5 \times 10^{-4}$
  
  NIM A 976 (2020) 164282

2 THGEMs & 1 MM
COMPASS RICH
NIMA 936 (2019) 416

R. Majka, IEEE-NSS 2015

2 THGEMs & 1 MM
Proposal for ALICE TPC


Main credit: F. Tessarotto, TF1 symposium, 29 April 2021
TECHNOLOGICAL FRONTIERS,  OPTICAL R-O

MOTIVATIONS:
- Pixellated readout approaches (optical, hybrid, ASICs) offer unprecedented levels of detail in recorded events

High-rate of images with bubble chamber resolution

- $\mu$ track with $\delta$-ray
- X-rays
- $\alpha$-particle
Optical TPCs

Atmospheric pressure Optical TPC

Rare event searches: directional dark matter

Triple GEM with CMOS + PMT/SiPM readout requiring low radioactivity background

High Pressure TPC

Towards neutrino-nucleus cross section experiments

Stitched optical readout (4 CCD cameras) + electronic signals from meshes used for amplification

1 m³ high pressure TPC (up to 5 bar)

Low-pressure TPC with optical+electronic readout

Migdal effect search in low-pressure CF₄ for DM searches

CMOS + electronic readout of transparent strip anode

High Pressure Xe gas TPC with electroluminescent amplification

Neutrinoless double beta decay searches in ¹²⁶Xe

PMTs for energy measurement & to from S1, SiPM-based tracking plane recording electroluminescence
RD51, aims at facilitating the development of advanced gas-avalanche detector technologies and associated electronic-readout systems, for applications in basic and applied research. The main objective of the R&D programme is to advance technological development and application of Micropattern Gas Detectors.

[RD51 web-page, first lines]

HOW?

Networking by collaborations, technology dissemination and training

Main credit for this section: L. Ropelewsky, TF1 symposium, 29 April 2021
RD51, THE COLLABORATION

The main objective is to advance MPGD technological development and associated electronic-readout systems, for applications in basic and applied research.

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

- More than 80 groups
- More than 400 people
- National and International Laboratories
- National Institutes and Universities
RD51, THE STRUCTURE

- R&D support for the experiments and LHC upgrades WG1
- Generic R&D (new structures, ideas, detector physics) – RD51
- Common Projects WG2 Development of new structures and consolidation of the existing structures
- Applications and dissemination; Academia-Industry matching events, training, education WG3
- Development and Maintenance of Software & Simulation Tools; basic studies & software support for the RD51 community WG4
- Development and Maintenance of the SRS Electronics; An extended support for the SRS including new developments and implementations of additional features WG5
- MPGD Production and QA Control; Industrialization - GEM, Micromegas, Thick GEM; WG6
- Maintenance of the RD51 Lab and Test-Beam Infrastructure WG7
RD51, CERN based infrastructure

GDD web site

EP-DT-DD GDD Laboratory available for the RD51 collaboration

Permanent installations: CMS, ALICE, ATLAS, ESS
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
Radioactive Sources
Interface with CERN services (RP, gas, metrology, irradiation facilities, ...)

Semi permanent test beam facility
in the SPS extraction Line

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

Goliath Magnet

Examples of the test beam user teams

CMS (DESY)
WIGA/QM/IT (DESY)
ATLAS NOW (DESY)
BESS IN & SHIP (DESY)
LAPP/DAMIFIC (DESY) ALICE TPC (DESY and LLC)

Building 887 - EHN1 H4 (PPE334)
RD51, CERN based infrastructure

MPT workshop @ 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

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

Most of them are still at the R&D phase but some are already in production:
- ATLAS NSW: 1300 m²
- SBS Tracker: 100 GEMs
- ALICE TPC upgrade: 350 GEMs
- COMPASS pixel Micromegas: 20 GEM + Micromegas
- BESIII: 15 GEM
- CLAS 12: 30 Micromegas
- CMS: 450 GEM

Installation of the new infrastructure (to produce 2x1m² Bulk MM & 2x0.5m² GEM)

Construction of the new workshop's building

CERN Building 107 Basis of Design
TIPP 2021, 24-29 May 2021

RD51, TOOLS

Modelling of Physics Processes and Software Tools

- Single-electron spectra
- Mesh transparency
- High-precision data from AGH

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

Gas detector simulation: new areas
- Discharges and Resistive layers.
- Ion diffusion.
- Refinement of ionization esp. at low energy.
- Integration of boundary element methods.

Support for the detector simulation software

Electronics for gaseous detectors

RD51 SRS Electronics School (February 3 – 5, 2014)

Tremendous amount of work →
Fantastic school organization by Hans, Eraldi and team of 12 speakers and supervisors
→ VERY WELL RECEIVED BY PARTICIPANTS
THANK YOU VERY MUCH!!!
RD51, THE VISION: two-folded actions

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)

**SUPPORT TO GENERIC R&D AND BLE-SKY**, the dark-side of the moon: needed and, nevertheless, marginally supported or ignored

**Current and previous RD51 Common Projects**

- **Discharge Consortium in quest for Spark-Less-Avalanche-Microstructures**
  - Pixelated resistive bulk Micromegas with integrated electronics
  - Resistive materials and resistive-MPGD concepts & technologies
  - 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
  - Development of modular multilayer GEM units
  - Sampling Calorimetry with Resistive Anode MPGDs (SCREAM)
  - New Scintillating gases and structures for next-generation scintillation-based gaseous detector
CONCLUSIONS

I have presented FACTS about MPGDs (by examples)

• Even if the gallery could not be exhaustive, the DISSEMINATION and FERTILITY of the field is self-evident

• The RD51 approach to network in detector R&D has make possible the MPGD blossom and it is a possible model also for other detector R&D domains
THANK YOU