(Future) R&D on Gaseous Detector Technologies

C. Rembser, E. Oliveri (CERN) on behalf of WG2
Guideline of the talk...

• This talk is at the moment more for us (Gaseous Detector Community) than for all EP, steering committee,...

• This talk is a starting point...
  • Something (well... a lot) is for sure overlooked ...
  • But it is not meant to be a complete summary ... neither a summary...
  • It is still biased by our experience ... 
  • ... but hopefully it could inspire all of us no matter what we do...

• This talk will shows mostly NOT YET AVAILABLE solutions

• If you don’t feel well represented is because:
  • You did already your job and you don’t need R&D!?!? (just be happy ...)
  • You are not beyond LHC phase II! R&D... too late!?! (joking ...) 
  • We forgot you !?! (sorry ...)
A few examples from our experience and from inputs received in WG2 about future R&D activities...

1: Primary ionization and Solid Converters
2: Material Science and nano/micro technologies
3: Pixels... Hybrids (gaseous/silicon)
4: Imaging (optical)
5: Sparks

Obviously not exhaustive... it doesn’t want to be...
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Primary ionization, the seed of our signal...

annoyed by the way we get the 2 MeV/g/cm² if it is in gas

We sort of like the density we have in terms of amplification in the gas...
but we DAMN pay in terms of primary ionization and efficiency

Solid converters...
Widening sensitivity, improving efficiency...
Peculiar signal properties (timing as an example in a while)...

They change unit for us!
From the firstwg2 meeting... Sauli and Peskov... both

**Ultimate Avalanche Chamber**

- Glass frame
- Resistive electrodes
- Cathode strips
- High resistivity layer
- Secondary emitter
- Readout strips
- Anode strips

**Secondary Emitter**

- Particle
- Resistor
- Solid converter
- Readout strips
- Number of sec. electrons increases with angle providing a reliable vertex

T. Francke et al., NIM A508, 2003, 83;
E. Cerron Zebalos et al., NIM A392, 1997, 150*

**Gas-filled resistive aerogel avalanche counter**

- Readout
- Cathode strips on glass
- Gas-filled resistive glass aerogel
- Anode strips on glass

**Photocathodes**

- Particle
- UV emitter
- Photocathode
- Avalanches
- Resistive anode

*From Fonte et al., NIM A443, 2000, 201 ("timing" RPCs)
Picosec... a clear example of improving 2-3 order of magnitudes “simply” getting primaries differently

New Bulk MM readout
3 mm MgF2 + 5.5nmCr + 18nm CsI
Drift = -475V, Anode=+275V

Almost 3 order of magnitude improvement in time resolution using radiator/photocathode instead of primary ionization in gas (I. Giomataris et al.)

24 ps with Single Stage Gaseous Detector!


This is “Proof of principle”...
A lot of R&D in front of us (photocathode)
Primary ionization and Solid Converters... Why so different from 30 years ago?

Solid Converters (secondary emitters, photocathodes, ...)

i.e. Material Science...
... and micro/nano technologies

New material and new techniques (build up functional structures... if what you need doesn’t not exist, maybe you can make it...)
Secondary emitters, porous structures...


(3) V.G. Gavalian, M.P. Lorikyan, K.J. Markarian, Nucl. Insr. and Meth. A350 (1994) 244
   M.P. Lorikyan, Nucl. Insr. and Meth. A510 (2007) 150

Innovative photocathodes by ND powder

Highly efficient and stable ultraviolet photocathode based on nanodiamond particles

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

L. Velardi, A. Valentini, G. Cicala,
UV photocathodes based on nanodiamond particles: Effect of carbon hybridization on the efficiency.
Diamond and Related Materials, Volume 76, 2017, Pages 1-8
(http://www.sciencedirect.com/science/article/pii/S0925963516306999)

S. Dalla Torre,

16/03/2018
R&D on Gaseous Detector Technologies
MEMS (Microelectromechanical systems) Technologies

Tynodes (ops vacuum) & ATOMIC LAYER DEPOSITION (ALD) as an example


MEMS fabrication of Tynodes: ALD MgO

Thermal ALD reactor with (Mg(Cp)₂) and H₂O as precursors
- Deposition temperature: 200 °C
- Measured stress: ~ -200 MPa
- Growth rate = 0.165 nm/cycle (3 + 15 + 1 + 15 sec)

Entering new fields... finding new problems... **Mandatory to build up knowledge and expertise** ... Different fields, different communities, different languages...

One example... Graphene...

P. Thuiner et al., Charge transfer properties through graphene layers in gas detectors, Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), 2014 IEEE
http://dx.doi.org/10.1109/NSSMIC.2014.7431248

T. Geralis,

**CsI Protection Layer**

Ion blocker

https://patentimages.storage.googleapis.com/49/85/44/01c1bd060e1e20/US8823259B2

**Radiator for TRD**

What is big (1µm, 1cm, 1m)?...
What is strong (you touch... you break)?

16/03/2018

R&D on Gaseous Detector Technologies
Once you build up knowledge...
You will maybe find a way to answer to captivating requirements...

Positive Ions detection via Auger Neutralization
(L. Arazi Ben Gurion University, Breskin/Bressler Weizmann)

10x better accuracy than with e- in position resolution
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What you can find if you look around in micro/nano techniques...

Obviously not exhaustive... it doesn’t want to be...
Micro/Nano technologies...  nano/microstructures...

Fig. 2 A double-gated MWCNT electron impact ionizer. The inner gate biases a voltage to field emit electrons from the MWCNT tip, while the outer gate protects the field emitter from ion back streaming.

Multiplexed electrospray has tremendous potential in a wide range of exciting applications, e.g., manufacturing, analytical instruments, and nanosatellite propulsion. Read more...

http://www.mtl.mit.edu/wpmu/lfv/

16/03/2018  R&D on Gaseous Detector Technologies
**LASER drilling...**

**Inputs from MPT workshop...**

FIGURE 10. Laser processing examples on glass with a 266 nm (UV) ns-laser (left-side) and with a 780 nm 100-fs laser (right-side).


**Futur possible detector processes**

- DRIE Plasma
- Smaller patterns to Microvials Micromegas
- Smaller holes in GEM
- Vacuum deposition of resistive material for protection or charge sharing
- DLC: Diamond like carbon
- ALD: Atomic layer deposition
- Laser:
  - Micrometric 3D structuring in dielectrics or metals
  - Ink jet printing
  - A new world to discover

**Steel Foil Micro-Drilling**

- High speed laser processing
- No melting
- Holes diameter in micrometer range

**Micro-Holes Drilling in Metals**

- Material: special steel (e.g. used for fuel nozzles), other
- Precise control of taper angle
- Variable geometry

**Glass Micro-Drilling**

- High quality
- Controlled geometry of hole
- Precise control of taper angle and diameter of holes in glass

https://www.wophotronics.com/markets/
DRIE Plasma

20 minutes de gravure avec Si ambiant (plaquette 4 pouces, 5 % de silicium exposé)

59 μm
5 μm
20 μm

30 minutes de gravure avec Si ambiant (plaquette 4 pouces, 5 % de silicium exposé)

100 μm
300 μm

Inputs from MPT workshop...

Futur possible detector processes

- DRIE Plasma
  - Smaller patterns → Microbulks Micromegas
  - Smaller holes in GEM
  - Vacuum deposition of resistive material for protection or charge sharing
    - SUC: Diamond like carbon
    - AUL: Atomic layer deposition
  - Laser
    - Micrometric 3D structuring in dielectrics or metals
  - Ink jet printing
    - A new world to discover

R. De Oliveira,
https://indico.cern.ch/event/702068/sessions/265605/attachments/1597953/2532624/Rui.pdf

https://cmi.epfl.ch/etch/-601E.html

16/03/2018
R&D on Gaseous Detector Technologies
Super Inkjet Printer

Example of Application

- Advanced technology: Printable electronics, Solar-cells, Touch panels, LED
- Alternative technology: Partial platings, Resists coating, Bumps forming, Dispenser devices
- Optics technology: Photomasks, Microlenses, Microfilters
- Biotechnology: Pipetting device of protein material, Cell scaffolds, Microarrays

“Future” Prototyping... you “print” your detector and you validate electrical field configuration, signal induction, charge evacuation ...

After you will take care of the proper production process, materials,...
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Gaseous Detector & Pixel Readout

Two electron tracks emitted from a $^{90}$Sr source recorded with a GridPix detector operating in a magnetic field.

Every single electron released by the incoming particles is recorded.

Gaseous Amplifying stage directly coupled to the pixelated readout chip

Getting the best from the two...

The Precursor: Bellazzini et al.


R. Bellazzini,
https://indico.cern.ch/event/16213/contributions/1411055/attachments/189478/266002/MPGD_CERN07.pdf
**InGrid & TimePix, the ultimate gaseous TPC**

(H. Van Der Graaf)

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**CAST**

![Image of InGrid structure and Timepix ASIC](https://agenda.linearcollider.org/event/7795/contributions/40334/attachments/32507/49403/QUAD_development.pdf)

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).

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

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

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**A large TPC prototype for a linear collider detector**

P. Schade, J. Kaminski, NIMA, 628, 1, 1 February 2011, Pages 128-132

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GEMPIX (F. Murtas et al.)

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

Clearly in WG1 and WG5
(Silicon detectors, IC technology...)

maybe also in the next slides...
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Imagin(in)g the future...

This photograph, taken in 1932 by American physicist [Carl D Anderson](https://en.wikipedia.org/wiki/Carl_D._Anderson) (link is external), shows a track left by the first positron ever identified. The line across the centre of the image is a 6 millimetre lead plate separating the upper and lower halves of the chamber. (Image: [Wikimedia Commons](https://commons.wikimedia.org/wiki/Carl_D._Anderson) (link is external))

This photograph of tracks in the Gargamelle bubble chamber provided the first confirmation of the weak neutral-current interaction. A neutrino, which leaves no track, enters from the top and knocks on an electron, giving it enough energy to create the small downward “shower” of curling tracks. The Gargamelle collaboration announced the discovery of the weak neutral current in July 1973 (Image: [Gargamelle/CERN](https://home.cern/about/updates/2015/06/seeing-invisible-event-displays-particle-physics))

https://home.cern/about/updates/2015/06/seeing-invisible-event-displays-particle-physics
Optical Readout (ongoing/done...)

D. Pinci, 

L. Ropelewski, 

D. Pinci et al. (INFN, Sapienza,...)

F. Resnati, F. Brunbauer (CERN GDD)

Depth dose curve
Which kind of future is waiting for us... or will be built by us...?

On-chip Optics Functions

1. **Light collecting**
   - Microlens
   - Lightpipe
   - BSI (Back Side Illumination)

2. **Color filtering**
   - Color filter
   - Vertical color separation

3. **New specific functions**
   - Polarization image sensor
   - Phase detection autofocus
   - Computational photography

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https://indico.cern.ch/event/706286/

Report on IEEE-ISSCC 2018: micro-nano-pico, we must go on

by Erik Hejne (Czech Technical University (CTU))

Tuesday 13 Mar 2018, 09:00 → 10:00 Europe/Zurich

13-2-305 (CERN)

Several new trends have been presented at the main integrated circuit design conference ISSCC in San Francisco. Data transmission makes big steps in speed and capacity; power conversion applies new materials that allow much larger steps. Downscaling of chips continues apparently still everywhere, but by using different approaches than in the ‘easy’ past. An 18FMM in the so-called 7 nanometer node was reported, where 3.5nm EUV lithography was used instead of the multi-exposure 193nm ultraviolet light. A 1Tb flash memory uses a thin stack of 96 layers. Imagers become smaller and more complex, and much cheaper as well. The particle physics community ought to study carefully what is going on, so that new possibilities can be exploited for future experiments, or to enhance the current ones far beyond the planned upgrades.

https://indico.cern.ch/event/709523/

Stacked imager

© 2018 M. Sakakibara et al; Sony; paper 5.1

13 March 2018
Micro-Particle Tracking

Experimental physicist Zhehui Wang and his team join Vision Research at the Los Alamos National Laboratory in New Mexico. In short, they were using a Phantom v2512 Ultrahigh-speed camera to capture micro-particle explosions. What they found was even more amazing! Something that had never been seen before, the micro-particles were exploding a second time. To learn more go to our blog at http://bit.ly/microparticles

Don’t get excited... wait for the next slides...
**Compressed ultrafast photography (CUP)**


**Carefully read the time between frames**

Figure 3 | CUP of laser pulse reflection, refraction, and racing in different media. a. Representative temporal frames showing a laser pulse being reflected from a mirror in air. The bright spot behind the mirror is attributed to imperfect resolution. b. As a but showing a laser pulse being refracted at an air–resin interface. c. As a but showing two racing laser pulses; one propagates in air and the other in resin. d. Recovered light speeds in air and in resin. The corresponding movies of these three events (a, b, c) are shown in Supplementary Videos 2, 3 and 4. Scale bar (in top right subpanel), 10 mm.

http://coilab.caltech.edu/research_6.html
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Sparks...

“The beautiful flash of light attending the discharge of common electricity“ M. Faraday (Wikipedia)

A cosmic-muon track in the spark chambers of a neutrino experiment at the Proton Synchrotron at CERN in 1963 (Image: CERN)

A detector in the past...
A problem to fix now...
Maybe again a “BRILLIANT” detector in future

• Understanding them (fundamental studies in R&D)

• Minimizing the risk, making them less harmful and quenching them (electric field, resistive electrodes) ...

• Maybe using them...

https://home.cern/about/updates/2015/06/seeing-invisible-event-displays-particle-physics
Sparks(1)…Fundamental studies (R&D Priority)

The physics and the modelling (Paulo Fonte)


The Measurements

LHCb (Alessandro Cardini)

A Systematic Study on Discharge-Induced GEM-Failure Phenomena

Alessandro Cardini

ALICE (Piotr Gasik)

Propagating discharges


CMS/GDD (Jeremie Merlin)


http://garfieldpp.web.cern.ch/garfieldpp/examples/avalanches_streamers/animation.html


http://garfieldpp.web.cern.ch/garfieldpp/exam
Spark(2)... $E$ fields


We should keep in mind the previous slides on micro/nano technologies

Filed Shaping (multilayer pcb) New 3D structures...
Sparks (3)... R&D on resistive materials and new architectures

to defeat the intrinsic limitation of resistive electrodes...

rate capability
Improving (M)RPC rate capabilities

$$\Delta V = I \cdot R = q \Phi \rho \cdot d$$

Smaller $\rho$ ... Low resistivity
Smaller $d$ ... thinelectrodes
Smaller $q$ ... FE electronics

Doped Glass $10^3$-$10^4 \Omega \cdot \text{cm}$ developed by Tsinghua University

Beam

Standard GRPC LR-GRPC

Ceramics: ok but small size plate an
Doped PEEK or doped PVDF:
Resistivity values $10^6$-$10^{14} \Omega \cdot \text{cm}$ were obtained by changing the dose of the doping material in PEEK. For PVDF $10^{10}$-$10^{13} \Omega \cdot \text{cm}$ were obtained.

Efficiency

(1 - 100) %

Material Resistivity (material science)
Embedded Resistors...
Finding the right impedance and defining the proper charge evacuation channels (SCREAM/CALICE)

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

If you don’t have the proper resistance... you can make it!
(Embedded Resistors, de Oliveira et al. in 2010)
DLC Layers... μRWELL...

Low Rate... R&D almost finished

High Rate... still R&D

The High Rate scheme (LHCb)

1. Copper layer 5 μm
   Kapton layer 50 μm
   DLC layer: 0.1 – 0.2 μm
   (10-200 MΩ/□)

2. 2nd resistive kapton layer with ~ 1/cm² “through vias” density

3. DLC-coated kapton base material
   2nd resistive kapton layer
   Insulating layer
   pad/strips readout on standard PCB
   “through vias” for grounding

4. DLC-coated base material after copper and kapton chemical etching (WELL amplification stage)

https://indico.inp.nsk.su/event/8/session/7/contribution/64/material/slides/0.pptx

G. Bencivenni,
https://indico.cern.ch/event/702148/contributions/2907416/attachments/1606380/2549792/07_BENCIVENNI-The--RWELL.pdf

Large area
Single amplification stage
Single detector element
(simplified assembly)

... a dream for large area/large volume detectors

Proper Resistivity and proper charge evacuation schema
DLC Layers on Pads micromegas for Precision tracking in high rate/occupancy environment

14th TOPIAL SEMINAR ON INNOVATIVE PARTICLE AND RADIATION DETECTORS
3-6 OCTOBER 2016
SIENA, ITALY

Small-pads resistive micromegas

M. Alivaggi,a,b M. Biglietti,a V. Canale,a,b M. Della Pietra,a,b C. Di Donato,a,c S. Franchino,c
P. Iengo,a M. Iodice,d,e F. Petrucci,a,d,e G. Sekhniaidze and O. Sidropoulos,a,b

Figure 2. Left-top: sketch of the small pad micromegas detector with embedded resistors structure; left-bottom: layout for the first prototype; right: the readout PCB of the constructed prototype.

High Granularity Pads readout (few mm²) with Embedded Electronics [SCREAM in hi-density]

16/03/2018
R&D on Gaseous Detector Technologies

M. Iodice,

Left: principle of a fully scalable pad detector with readout chips wire bonded on the back of top-right: the RD51 front-end hybrid, mounting the APV25 chip. The core part of the front-end will be implemented on-detector; bottom-right: layout of the front-end circuit as designed to be 6x6 mm² on the back of each 128-pads sector.
Latest examples based on …DLC
Started in Japan/(A. Ochi)... now moving to China/(Y.Zhou)

Resistive electrodes with DLC

- 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 μ-PIC electrodes

\[ \text{Substrate (polyimide)} \]
\[ \text{Carbon sputtering} \]
\[ \text{Developing the resists} \]
\[ \text{Substrate (polyimide)} \]

\bullet ATLAS NWS mm (*)
\bullet μPIC
\bullet μR WELL
\bullet Small-Pads Micromegas
\bullet RPC
\bullet …

(*) screen printing as final choice because of cost

Proven to be the right direction to go

Other Facilities and infrastructure we can access

Facilities at State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics:
- DLC devices:
  - Teer 650 (~30cm × 30cm)
  - Hauzer 850 (>1m × 0.5m)
- Many other PVD & CVD devices for foil coating
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Now moving to WG2 and something in view of the R&D proposal

Obviously not exhaustive... it doesn’t want to be...
WG2

Micropattern Gaseous Detectors
R&D at CERN
CERN GDD group & RD51
February 2018

Leszek Ropelewski CERN EP DT GDD & RD51

https://videos.cern.ch/record/1847445
Topics covered by the WG2:

- Motivation, Detector Requirements & Physics Challenges;
- Gaseous Detector Technologies
  - MPGD, RPC, Others (wires, ...), ...·
- Detector Simulation and Modelling
- Gas System R&D
- Gaseous Detector Electronics
- Workshops, Infrastructures and Engineering
- New technologies and New materials

Topics inspired by (literally copied because successful) RD51 working groups structure.

Most of the next slides directly connected to RD51.
Detector Modelling

Modelling of Physics Processes and Software Tools

Charging-up of a GEM

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

Mesh transparency

- Electron tracking requires improvement.

High-precision data from AGH

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

Gas detector simulation: new areas

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

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

Key people...

Several tools...

(Garfield, heed, magboltz, degrad, geant4, COMSOL, spice,...)

Precision Measurements...

To face challenging processes

My personal bet...

no groups in the room involved in gaseous detector R&D that never used Garfield...
R&D Detector Electronics

Three cases: Electronics for detectors

Multichannel Electronics

Instrumentation

New readout electronics development (single channel)
**Gas (system)**

**Gas analysis...**

With recirculation system
GHG reduction up to 90%

R. Guida,
https://indico.cern.ch/event/702068/sessions/265605/
attachments/1597953/2532131/GasSystemRD.pdf

**Crucial for...**
**Recirculation & sealed operation...**
**Impurities, Outgassing Studies**

Eco-friendly...(recirculating and/or eco-gas)

GEM, CF4(LHCb)

RPC, R134a[C2H2F4]
(ATLAS, CMS)

**Mixing Systems**

Mini TPCs require gas, in small volumes

Nikhef gas mixing station, made by Fred Hartjes!

- JSP bottles 25 l, 25 bar as standard
- fully computer controlled
- allowed to use the bottles at CERN(!)
- more flexible and economical with respect to Industry (Linde, AirProducts)

H. Van Der Graaf,
https://indico.cern.ch/event/702148/contributions/2880983/attachments/1606379/2548947/03_VANDER
GRAAF-GasRD.pdf

B. Mandelli,
https://indico.cern.ch/event/667256/contributions/2733193/attachments/15530723/2395693/RD51_BMandelli.pdf

16/03/2018
R&D on Gaseous Detector Technologies
45
Workshops (1)

Outline

- Activities
- Photolithography Manufacturing steps
- PCB Multilayer
- Flex and Micro Vias (MCM-L, SBU, Low Mass)
- MCM-C (Multi-chip Modules Ceramic)
- MPGD (Micro Pattern Gas Detector)
- Exotic Metals Patterning
- Conclusions

Machines important...

but is the expertise of the WS people that makes the difference
Workshops (2)

Thin Film and Glass Lab

- Optical Quality Control Lab
- Glass & Ceramics Workshop
- Thin Film Lab

The activity in the Thin Film Lab covers the large field of Physical Vapour Deposition (PVD) based coatings. Metals, dielectrics and also organic materials can be evaporated. Most layers are for optical use but also other functional layers can be produced.

Our specialised Glass and Ceramic Workshop is equipped with dedicated diamond tools for hard material machining. This allows us to deal with specific material such as Glass, Pyrex, Quartz, Sapphire, Alumina, Ferrites and other ceramics.

For the quality control of these 2 branches (Coating +glass/ceramics machining) we have in our Optical Quality Control Lab several microscopes and spectrometers for the testing of our products.

T. Schneider,
https://indico.cern.ch/event/702068/sessions/265605/attachments/1597953/2537160/Overview_of_possible_coating_infrastructures.pptx
Main challenges in mechanics x gas detectors

- High precision mechanics on large size objects (~ 2 m)
- Stiffness and Stability (gravitational sags, thermal deformations, pressure)
- Gas uniformity and distribution (gas dynamics)
- Low material budget (new materials and processes)
- Material gas compatibility (absorption, desorption, purity, corrosion, radiations) and HV insulation
- Cooling solutions (design & materials)
- Cost and technological choices for large production
- Integration: High granularity detectors and precise timing detectors → FE electronics, services and readout (flexes, connectors, etc)

The above driving key Technologies development for new gas detector.

Areas of expertise requiring development and resources for R&D

- Design, Integration
- Simulations (Fluid-dynamics, structural, thermal, multi-physics)
- Material selection and characterization (low budget, gas, thermal and radiation requirements)
- Technology & processing (WS’s, Microfab, TFG, MTP, Composites, Additive Manufacturing, ….): precision, tooling, costs
- On-detector thermal management
- Monitoring techniques (ie composites: useful to correct on line ?)
- AOB

Synergies exist with plans for R&D in detector “mechanics”
R&D Laboratories (where you put everything together...)

I still regret the day I’ve decided to take the picture when the laboratory was clean... and empty!
Medium/Long term effects of R&D infrastructures in the CERN context

LS2 MPGD-based upgrades... as an example of “long-term” supports to experiments (R&D activities).

ATLAS NSW TDR

ATLAS TPC Upgrade TDR

ALICE TPC Upgrade TDR

CMS Muon Endcap Upgrade TDR

<2010

~2012

<2010

All of them with R&D Activities in the GDD lab at the beginning
Attracting expertise and resources...

ESS/CERN BrightnESS EU project
WG2 ... next step

• Preparation of a 3-5 days workshop (spring/summer)...
• WG2 Topics based...
• Work on each topic by sub-working groups before the WS

Topics covered by the WG2:
• Motivation, Detector Requirements & Physics Challenges;
• Gaseous Detector Technologies
• Detector Simulation and Modelling
• Gas System R&D
• Gaseous Detector Electronics
• Workshops, Infrastructures and Engineering
• New technologies and New materials
R&D on Gaseous Detector @ CERN

1. People (core/expertise)
2. Infrastructures (consolidate and covering new fields)
   (Infrastructure for “1”· and to attract expertise... all our colleagues)

Synergies in EP, at CERN and with external colleagues/institutes
If you will have some free time, it is maybe interesting for you to listen to the following speech...

Strongly linked to R&D and to R&D at CERN

Célébration du Prix Nobel de Physique 1992 Georges Charpak

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Célébration avec la division PPE. Interventions de Pierre Darriulat et Georges Charpak.

« en suite, j'ai trouvé que au cern Il y a au moins la possibilité d'une très grande liberté et Je pense que cette liberté vous la préservez... » 8:42

«Chaque grand groupe devrait avoir quelques marginaux, quelques bouffons qui font des choses qui ne sont pas exactement dans la ligne générale» 9:20

https://videos.cern.ch/record/1047445

(don’t rely on the correctness of the text, but concept should be ok...)
Thanks