https://thedeansprimary.files.wordpress.com/2015/05/future.jpg

(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…

A few examples from our experience and from inputs received in WG2 about future R&D activities…

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Obviously not exhaustive… it doesn't want to be…

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

6. Atomic and nuclear properties of materials 1

6. ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS

Table 6.1. Revised May 2002 by D.E. Groom (LBNL). Gases are evaluated at 20°C and 1 atm (in parentheses) or at STP [square brackets]. Densities and refractive indices without parentheses or brackets are for solids or liquids, or are for cryogenic liquids at the indicated boiling point (BP) at 1 atm. Refractive indices are evaluated at the sodium D line. Data for compounds and mixtures are from Refs. 1 and 2. Futher materials and properties are given in Ref. 3 and at `http://pdg.lbl.gov/AtomicNuclearProperties`.

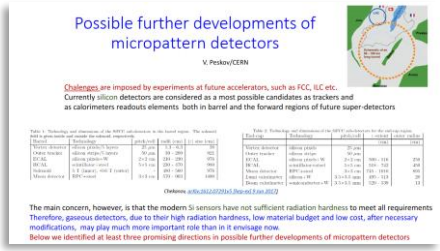
Material	Z	A	$\langle Z/A \rangle$	Nuclear [a] collision length λ_T {g/cm^2}	Nuclear [a] interaction length λ_I {g/cm^2}	$dE/dx\|_{\rm min}$ [b] $\left\{\frac{\rm MeV}{\rm g/cm^2}\right\}$	Radiation length [c] X_0 {g/cm^2}	{cm}	Density {g/cm^3} ({g/ℓ} for gas)	Liquid boiling point at 1 atm(K)	Refractive index n ($(n-1)\times10^6$ for gas)

They change unit for us!

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

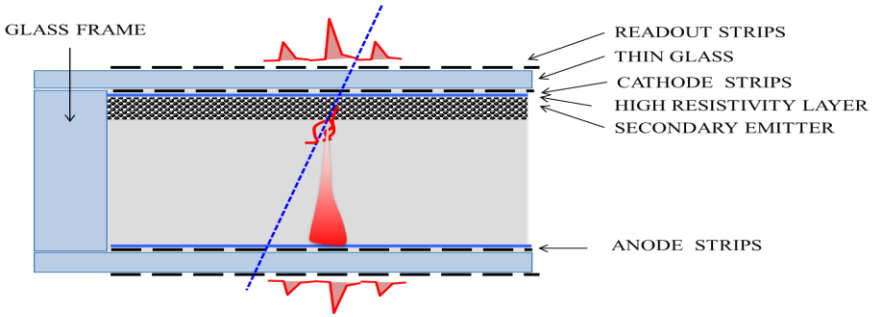
From the first wg2 meeting… Sauli and Peskov… both

F. Sauli, https://indico.cern.ch/event/702148/contributions/2879852/attachments/1606377/2548943/01_SAULI-SEEDS.pptx

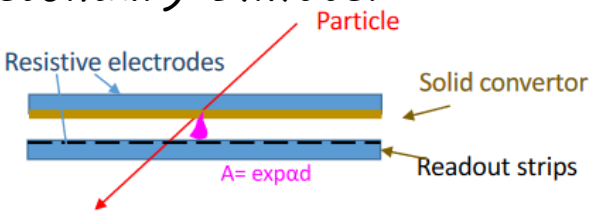


V. Peskov, https://indico.cern.ch/event/702148/contributions/2906906/attachments/1606378/2548963/Possible_further_development_of_micropattern_detectors.pdf

Ultimate Avalanche Chamber



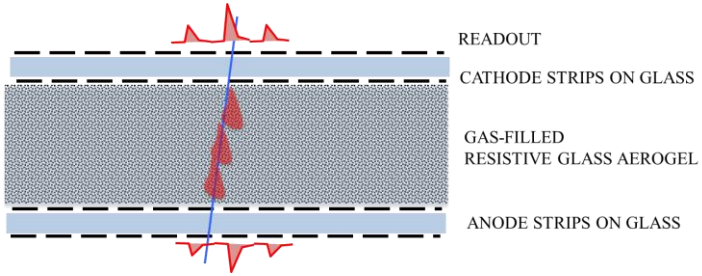
Secondary Emitter



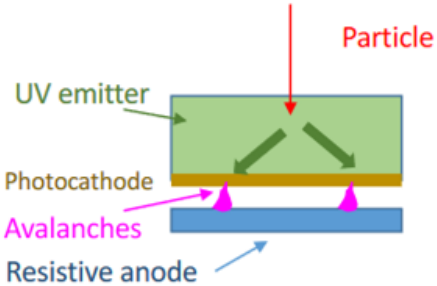
Number of sec. electrons
increases with angle providing a reliable vertex

I. *Crotty et al IEEE Nucl. Sci. Sympos. Conf. Rec., 1, 1996, 362*
T. Francke et al., NIM A508, 2003, 83;
E. Cerron Zebalos et al., NIM A392, 1997, 150

Gas-filled resistive aerogel avalanche counter



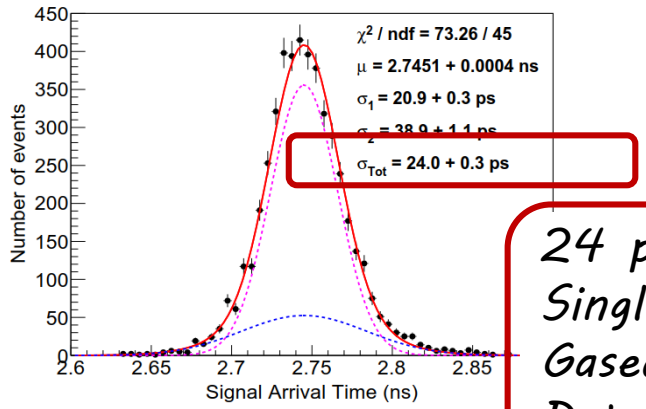
Photocathodes



P. 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

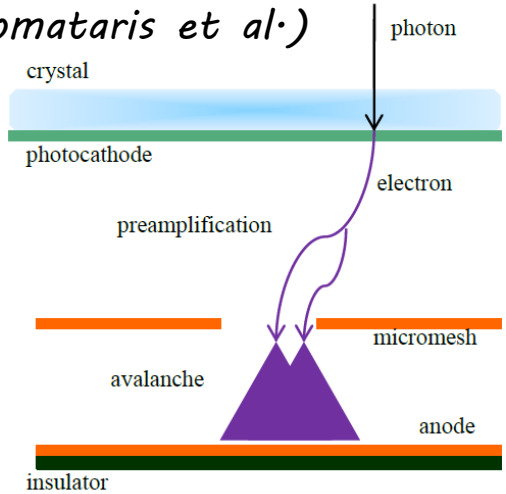


24 ps with Single Stage Gaseous Detector!

Figure 13: Beam test: An example of the signal arrival time distribution [illegible] and the superimposed fit with a two Gaussian function (red line for the combination and dashed blue and magenta lines for each Gaussian function), for an anode and drift voltage of 275 V and 475 V, respectively. Statistical uncertainties are shown.

J· Bortfeldt et al·, https://arxiv·org/abs/1712·05256

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



R&D on photocathodes mandatory…

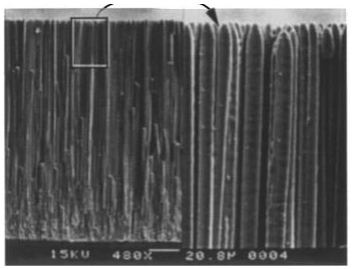
This is "Proof of principle"…
A lot of R&D in front of us (photocathode)

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

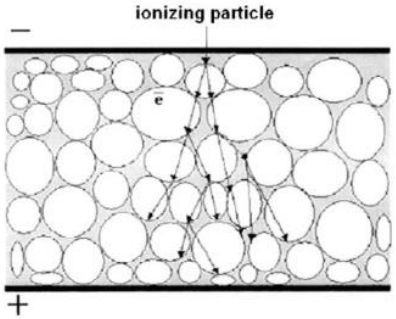
i.e. Material Science...
... and micro/nano technologies

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

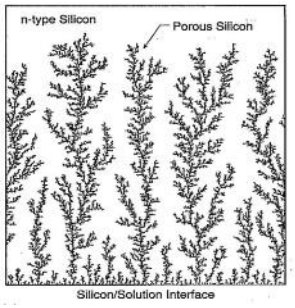
Secondary emitters, porous structures…



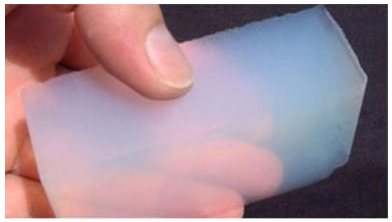
Columnar CsI (1)



Porous Dielectric (3)



Porous Silicon (2)



Silica Aerogel (4)

F. Sauli, https://indico.cern.ch/event/702148/contributions/2879852/attachments/1606377/2548943/01_SAULI-SEEDS.pptx

(1) H.S. Cho, I.J. Park, W.S. Hong, V. Perez-Mendez, J. Kadyk, Nucl. Insr. and Meth. A 422 (1999) 269

(2) R.L. Smith and S.D. Collins, J. Appl. Phys. 71 (1992) R1

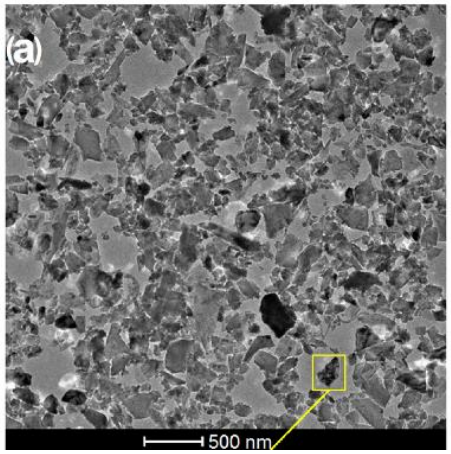
Barash, E. F. et al. Nucl. Instrum. and Meth A 315 (1992) 170.

(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

(4) M. Caresana and G. Zorloni, Nucl. Insr. and Meth. A874 (2017) 35

Innovative photocathodes by ND powder



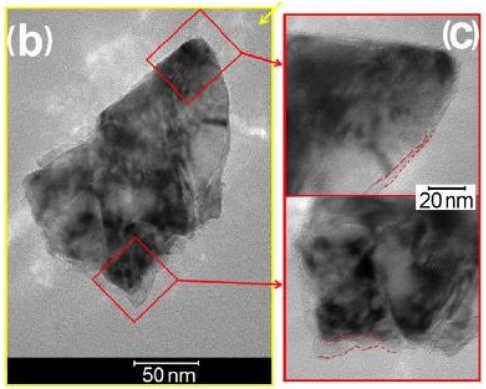
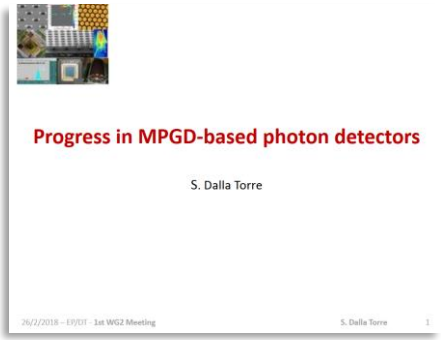


FIG. 2. TEM images of the (a) as-received nanodiamond (ND) particles, a single ND particle and (c) details of the single ND particle.



S. Dalla Torre, https://indico.cern.ch/event/702148/contributions/2901005/attachments/1606391/2548975/EP-DT_WG2_16022018_Dallatorre_gaseousPD.pdf

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

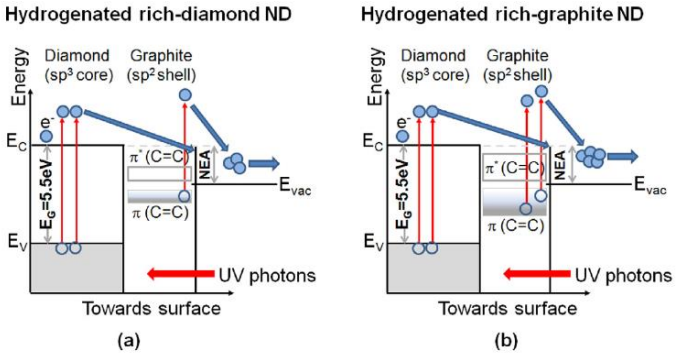


Fig. 6. Schematic energy-band representing the electron emission process from hydrogenated (a) rich-diamond and (b) rich-graphite ND particle surfaces under UV photon irradiation. Bands for diamond (sp^3 core) and bonding (π) and anti-bonding (π^*) states for graphite (sp^2 shell), whose state density depends on the ND particle type.

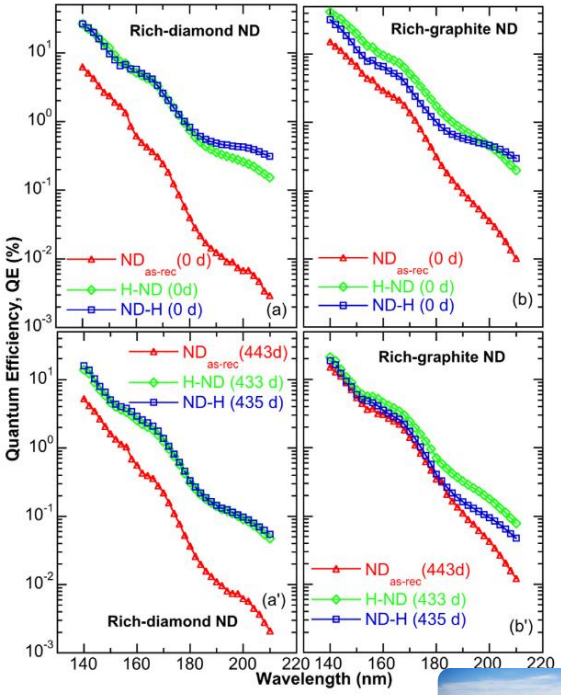


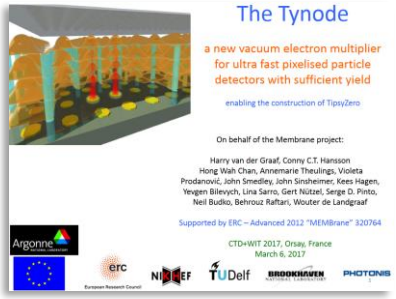
Fig. 4. Quantum efficiency of photocathodes based on (a–a') rich-diamond and (b–b') rich-graphite ND layers vs wav

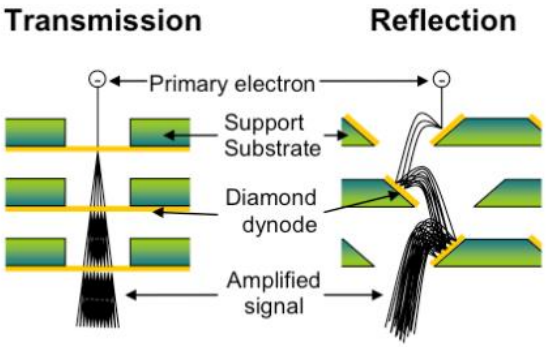
L. Velardi, A. Valentini, G. Cicala,
UV photocathodes based on nanodiamond particles: Effect of carbon hybridization on the effic
Diamond and Related Materials, Volume 76, 2017,Pages 1-8
(http://www.sciencedirect.com/science/article/pii/S0925963516306999)

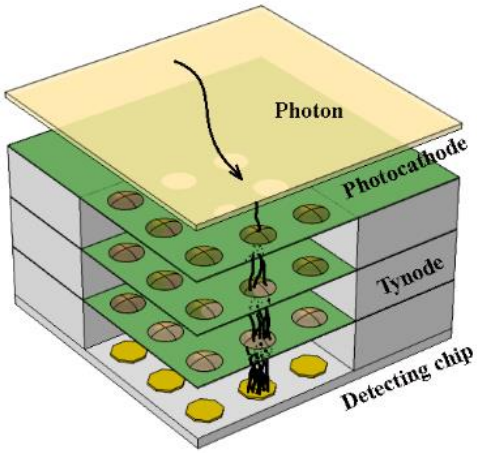
MEMS (Microelectromechanical systems) Technologies

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

H. Van Der Graaf, https://indico.cern.ch/event/577003/contributions/2445009/attachments/1422530/2180614/WIT2017.pdf







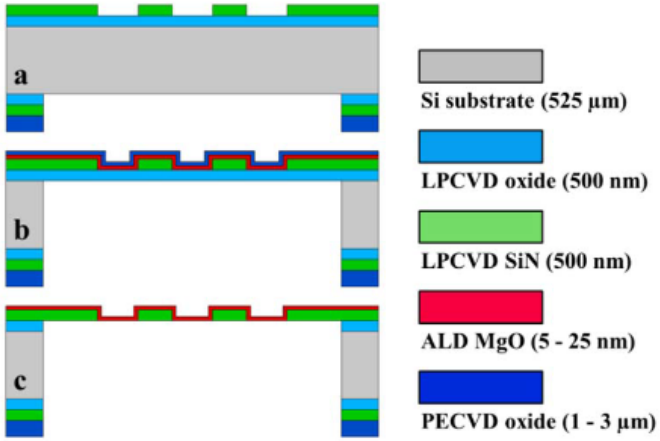
https://indico.cern.ch/event/577003/contributions/2445009/attachments/1422530/2180614/WIT2017.pdf

MEMS fabrication of Tynodes: ALD MgO

Thermal ALD reactor with $(Mg(Cp)_2)$ and H_2O as precursors

- Deposition temperature: 200 °C
- Measured stress: ~ -200 MPa
- Growth rate = 0.165 nm/cycle (3 + 15 + 1 + 15 sec)

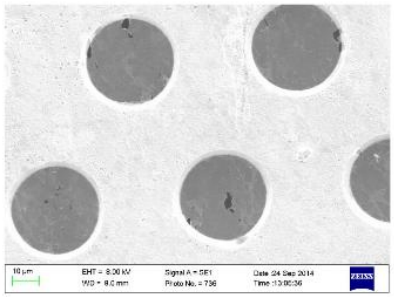
Argonne NATIONAL LABORATORY



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

One example… Graphene…

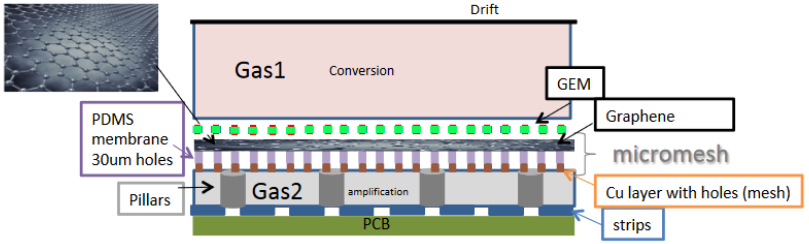
Ion blocker



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

https://indico.cern.ch/event/525268/contributions/2287826/attachments/1334368/2006514/160912ThuinerGraphene.pdf

Double phase (membrane)



T. Geralis, https://indico.cern.ch/event/702148/contributions/2907959/attachments/1606409/2549020/Geralis_mM_Graphene.pdf

CsI Protection Layer

(12) **United States Patent**
Moody

(10) **Patent No.: US 8,823,259 B2**
(45) **Date of Patent: Sep. 2, 2014**

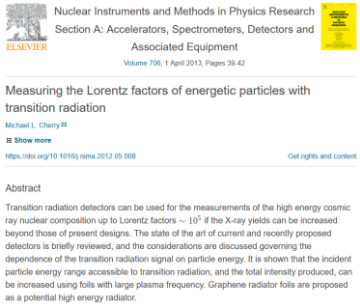
(54) **GRAPHENE SHIELD ENHANCED PHOTOCATHODES AND METHODS FOR MAKING THE SAME**

(71) Applicant: **Los Alamos National Security, LLC**, Los Alamos, NM (US)

USPC **313/542**
(58) **Field of Classification Search**
CPC H01J 23/04; H01J 1/34; H01J 40/06; C01B 2204/22; C01B 2204/20; C01B 2204/32; G02F 2202/36; H01G 11/32; H05B 33/26; Y10S 977/742

https://patentimages.storage.googleapis.com/49/85/44/01c1bd060e1e20/US8823259.pdf

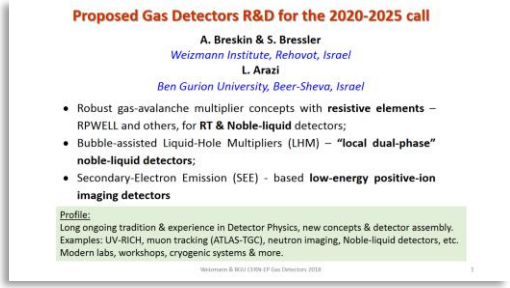
Radiator for TRD



https://www-sciencedirect-com.ezproxy.cern.ch/science/article/pii/S0168900212004792?via%3Dihub

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

Once you build up knowledge…
You will maybe find a way to answer to captivating requirements…


Proposed Gas Detectors R&D for the 2020-2025 call

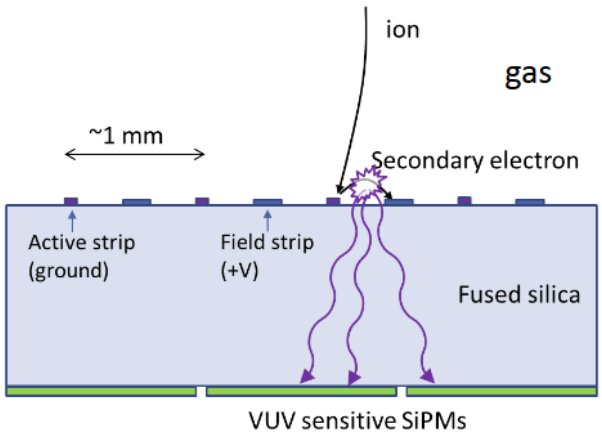
A. Breskin & S. Bressler
Weizmann Institute, Rehovot, Israel
L. Arazi
Ben Gurion University, Beer-Sheva, Israel

- Robust gas-avalanche multiplier concepts with **resistive elements** – RPWELL and others, for **RT & Noble-liquid** detectors;
- Bubble-assisted Liquid-Hole Multipliers (LHM) – **"local dual-phase" noble-liquid detectors**;
- Secondary-Electron Emission (SEE) - based **low-energy positive-ion imaging detectors**

Profile:
Long ongoing tradition & experience in Detector Physics, new concepts & detector assembly. Examples: UV-RICH, muon tracking (ATLAS-TGC), neutron imaging, Noble-liquid detectors, etc. Modern labs, workshops, cryogenic systems & more.

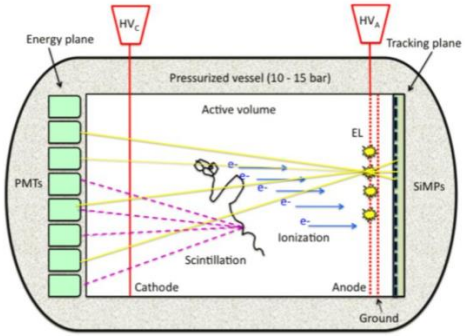
A. Breskin, https://indico.cern.ch/event/702148/contributions/2879860/attachments/1604667/2548949/06_BRESKIN-WIS_BGU_for_WG2_26_02_18.pdf

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

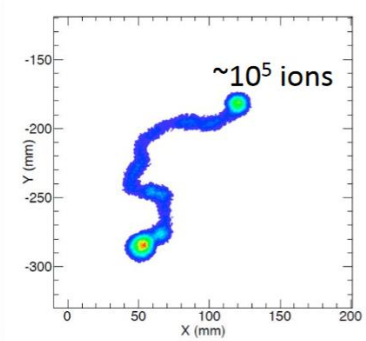


- Potential application: $\beta\beta0\nu$ in high-pressure Xe TPC

New idea: ions ➔ topology & electrons ➔ energy



MC of ββ0ν event – 2 blobs at the ends



10x better accuracy than with e- in position resolution

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

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…

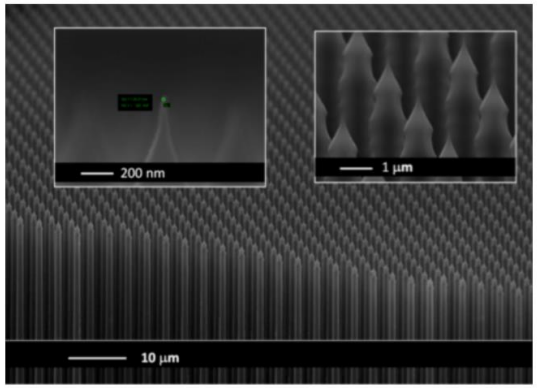


Fig. 5 A massive array of silicon field emitters individually ballasted by high aspect-ratio FETS.

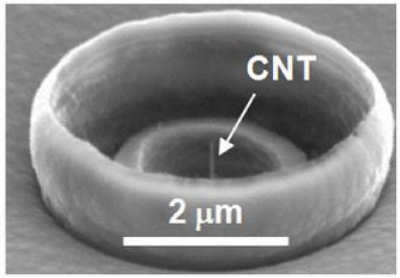


Fig. 2 A double-gated MWCNT electron impact ionizer. The inner gate biases a voltage to field emit electrons from the MWCNT tip, while the outer gate protects the field emitter from ion back streaming.

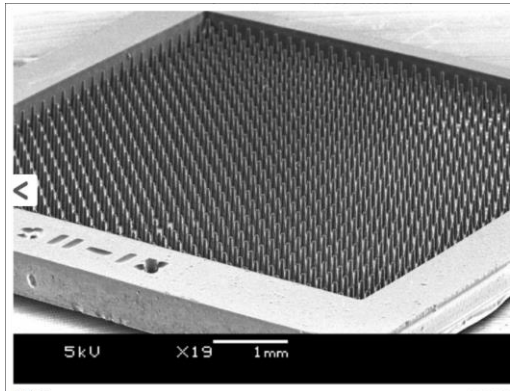
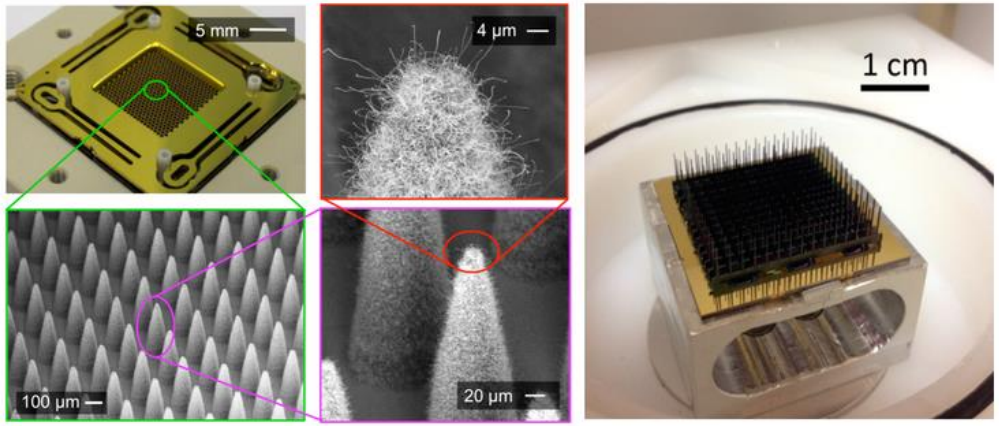
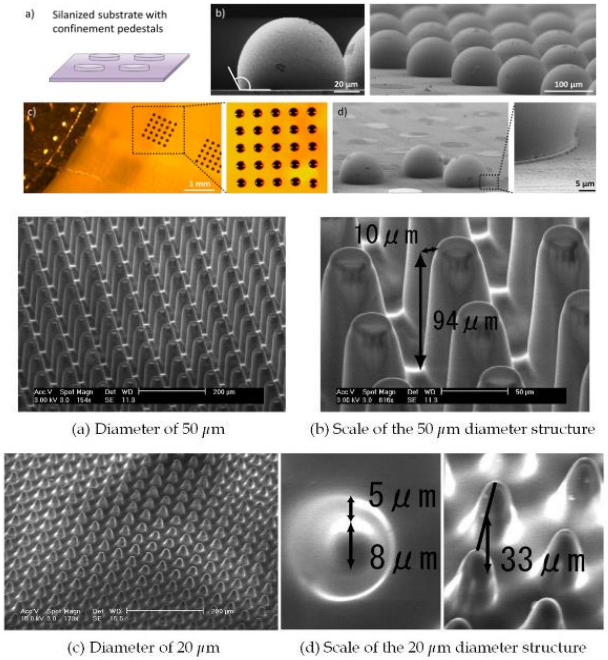


Figure 2
Fig. 2. An array of 1000 externally-fed ESI emitters (from Velasquez-Garcia et al, JMEMS 2006).
Image 3 of 7 (play slideshow)
CLOSE



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



(a) Diameter of 50 µm
(b) Scale of the 50 µm diameter structure
(c) Diameter of 20 µm
(d) Scale of the 20 µm diameter structure

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

LASER drilling…

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
  - DLC : Diamon like carbon
  - ALD : 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

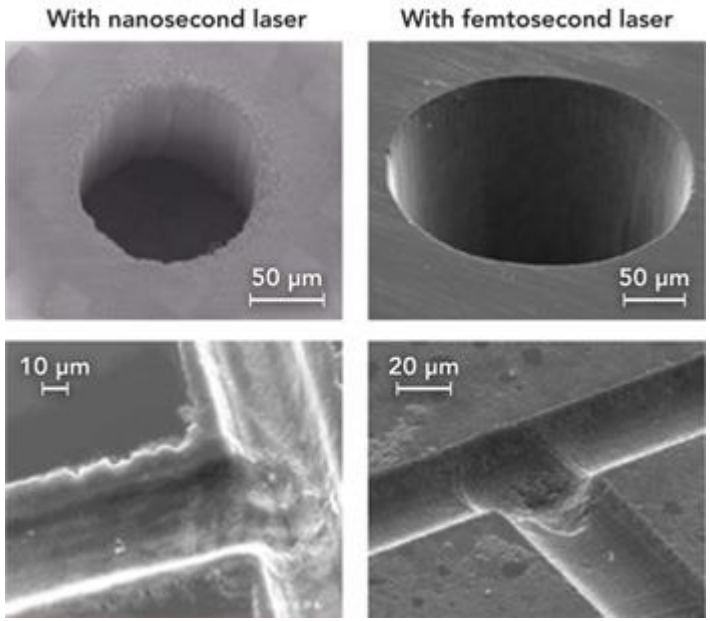
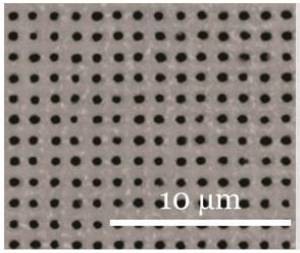


FIGURE 10. Laser processing examples on glass with a 266 nm (UV) ns-laser (left-side) and with a 780 nm 100-fs laser (right-side).

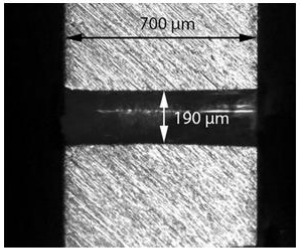
https://www.industrial-lasers.com/articles/print/volume-27/issue-04/features/fermtosecond-laser-micromachining-a-back-to-basics-primer.html



Steel Foil Micro-Drilling

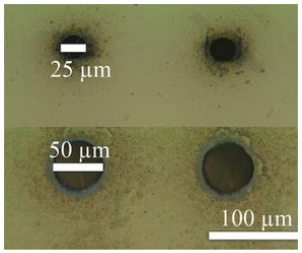
- High speed laser processing
- No melting
- Holes diameter in micrometer range

https://www.wophotonics.com/markets/



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

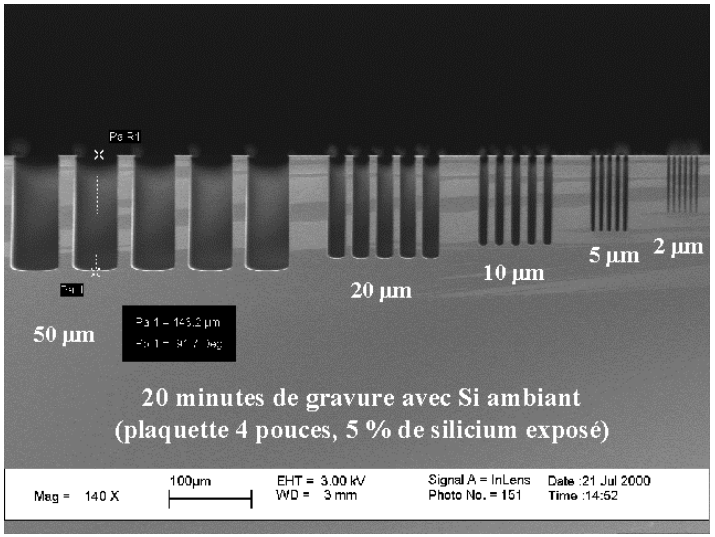
- High quality
- Controlled geometry of hole
- Precise control of taper angle and diameter of holes in glass

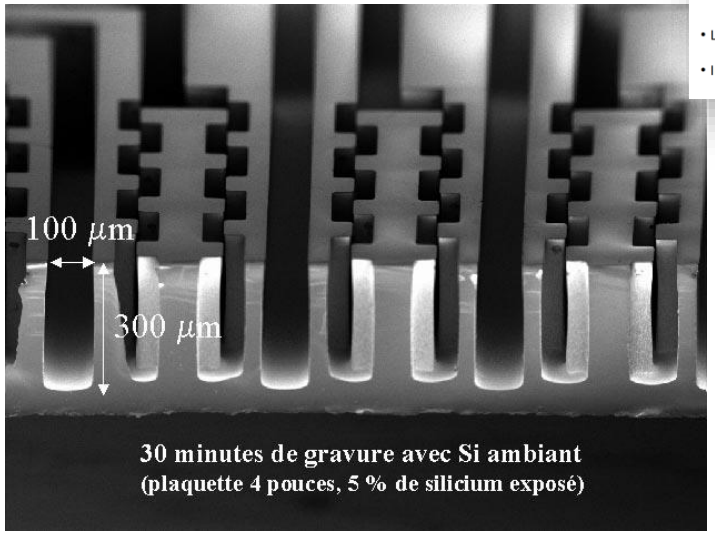
DRIE Plasma

Inputs from MPT workshop…

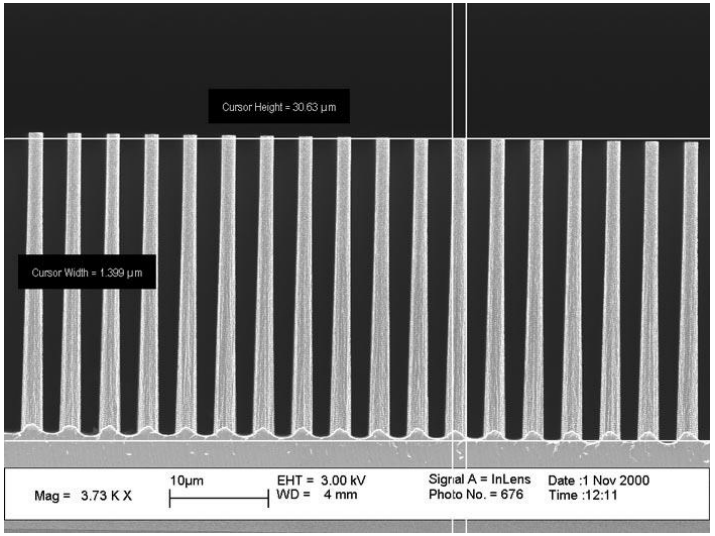
Futur possible detector processes

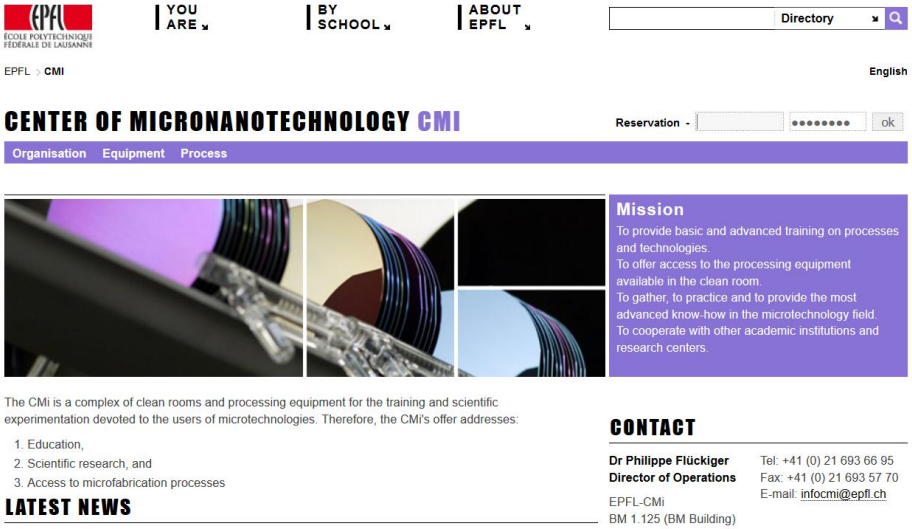
- DRIE Plasma
  - Smaller patterns → Microbulks Micromegas
  - Smaller holes in GEM
- Vacuum deposition of resistive material for protection or charge sharing
  - DLC : Diamon like carbon
  - ALD : Atomic layer deposition
- Laser
  - Micrometric 3D structuring in dielectrics or metals
- Ink jet printing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





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





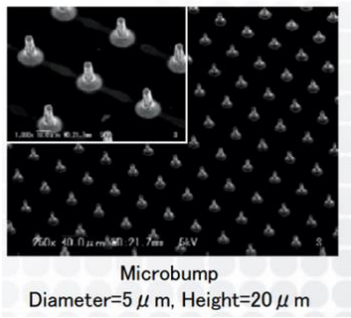
https://cmi.epfl.ch/etch/-601E.html

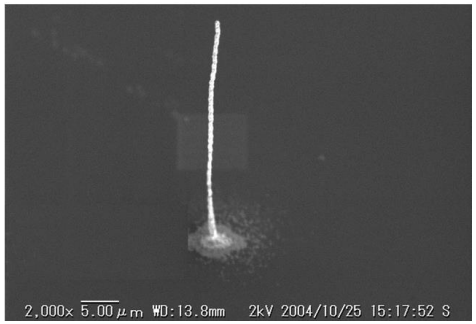
Super Inkjet Printer

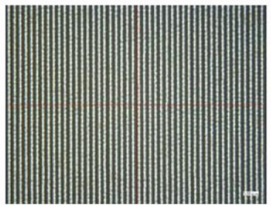
Inputs from MPT workshop…

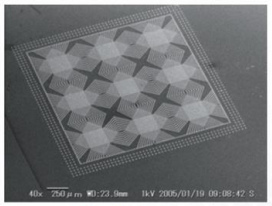
Example of Application

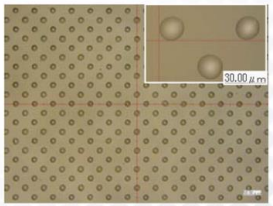
- Advanced technology: Printable electronics, Solar-cells, Touch panels, LED
- Alternative technology: Partial platings, Resists coating, Bumps forming, Dispenser devices
- Optics technology: Photomasks, Microlenses, Microfilters
- Biotechnology: Pipetting device of protein material, Cell scaffolds,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






Silver ink, L/S=1 μ m


Circuit pattern



Microlens (resin ink)

Futur possible detector processes

- DRIE Plasma
  - Smaller patterns→ Microbulks Micromegas
  - Smaller holes in GEM
- Vacuum deposition of resistive material for protection or charge sharing
  - DLC : Diamon like carbon
  - ALD : Atomic layer deposition
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  - 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://www.printedelectronics.com/printed/systems/super-ink-jet/

http://www.sijtechnology.com/en/

"Future" Prototyping… you "print" your detector and you validate electrical field configuration, signal induction, charge evacuation …

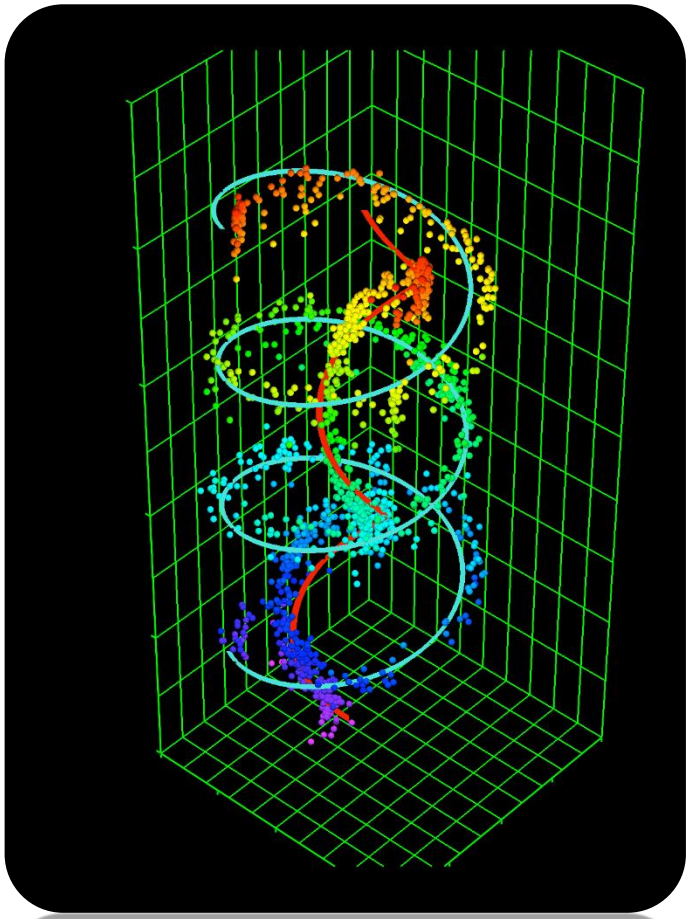
After you will take care of the proper production process, materials,…

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…

Gaseous Detector & Pixel Readout



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

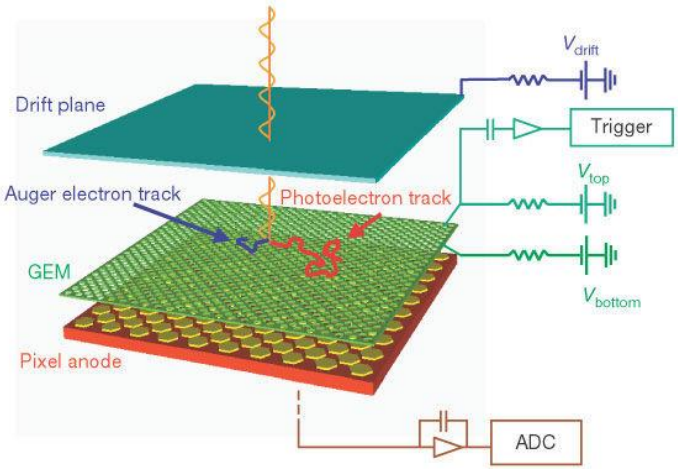
Every single electron released by the incoming particles is recorded.

https://www.nikhef.nl/~i56/Designs%20under%20review/Temp/index/Thesis_03-08-2017%20corr%20Fred.pdf

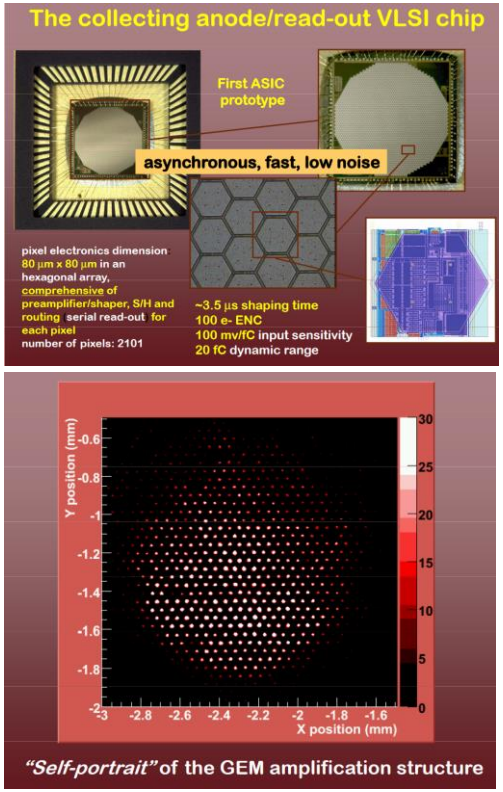
Gaseous Amplifying stage directly coupled to the pixelated readout chip

Getting the best from the two…

The Precursor: Bellazzini et al.



An efficient photoelectric X-ray polarimeter for the study of black holes and neutron stars E. Costa, P. Soffitta, R. Bellazzini , A. Brez, N. Lumb, G. Spandre Nature, Vol. 411 (2001) 662



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)

CAST

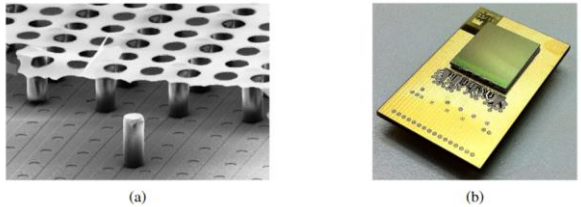
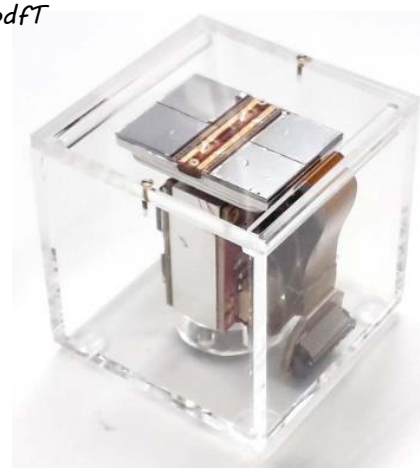


Figure 1: SEM image of an InGrid structure on top of a Timepix ASIC (a), taken from [13]. In the SEM image parts of the mesh have been removed to show the good alignment between pixels and mesh holes. And a bare Timepix ASIC on a carrier board (b).

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

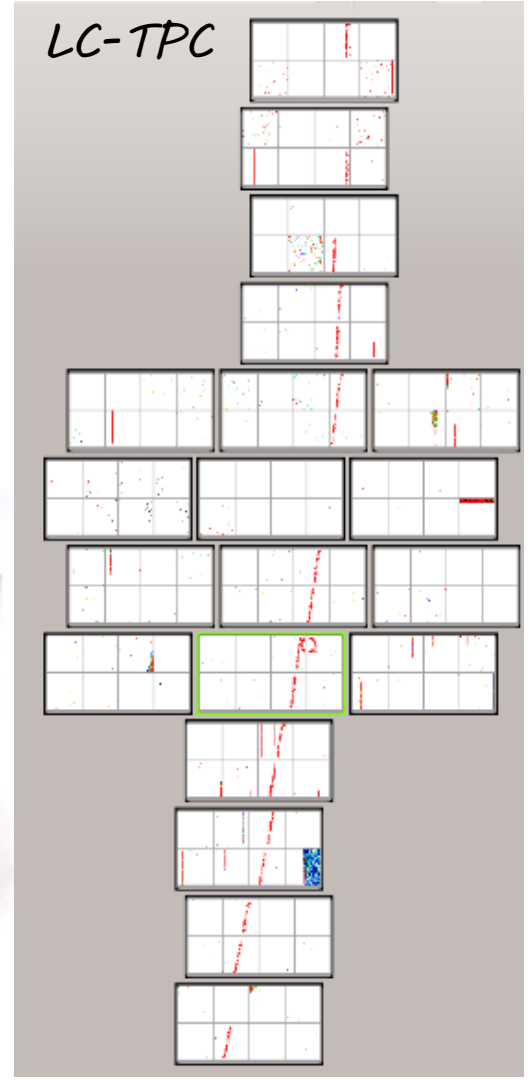
256 x 256 pixels, 55 x 55 μm pitch, about 1.4x1.4 cm2 sensitive area

The "QUAD"

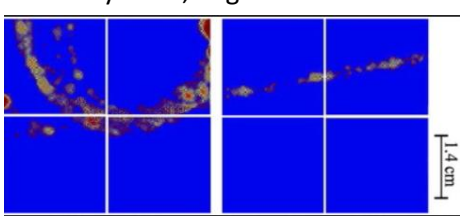


F. Hartjes, https://agenda.linearcollider.org/event/7795/contributions/40334/attachments/32507/49403/QUAD_development.pdf

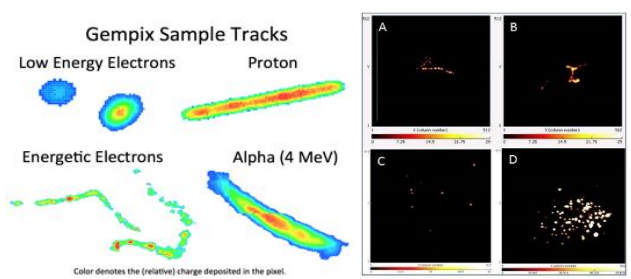
LC-TPC



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



GEMPIX (F. Murtas et al.)



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

The future...

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

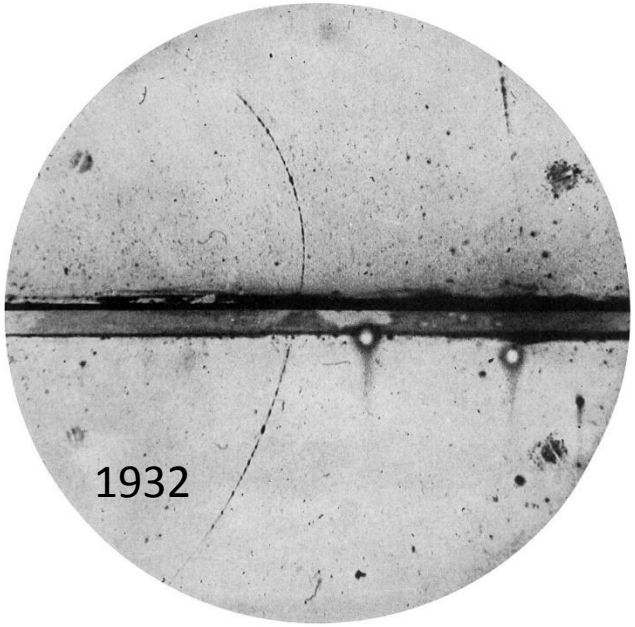
maybe also in the next slides...

A few examples from our experience and from inputs received in WG2 about future R&D activities…

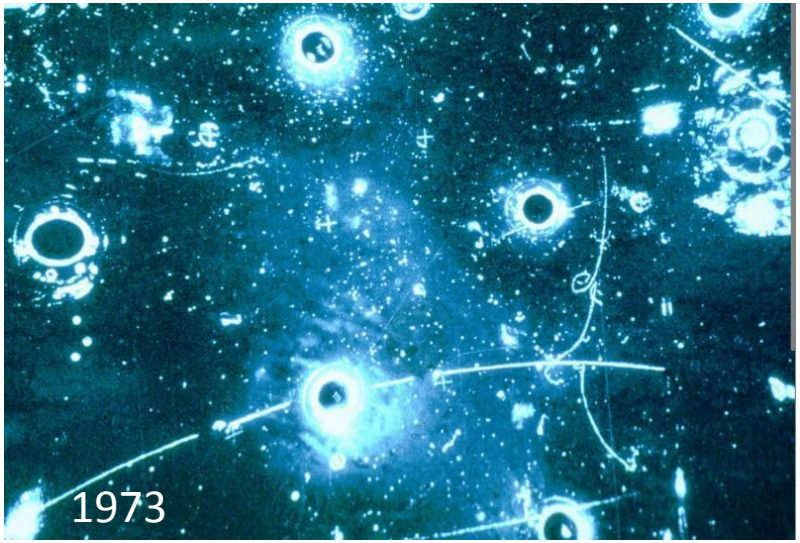
1: Primary ionization and Solid Converters
2: Material Science and nano/micro technologies
3: Pixels… Hybrids (gaseous/silicon)
4: Imaging (optical)
5: Sparks

Obviously not exhaustive… it doesn't want to be…

Imagin(in)g the future…



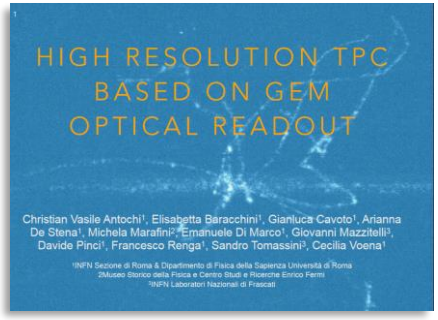
This photograph, taken in 1932 by American physicist Carl D Anderson (link is external), shows a track left by the first positron ever identified. The line across the centre of the image is a 6 millimetre lead plate separating the upper and lower halves of the chamber. (Image: Wikimedia Commons (link is external))

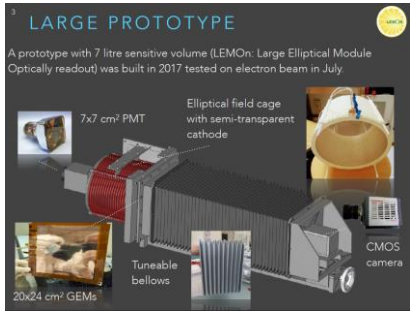


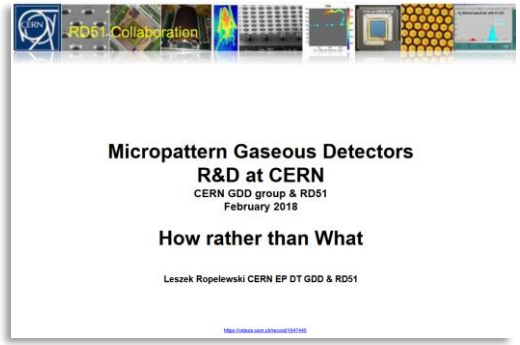
This photograph of tracks in the Gargamelle bubble chamber provided the first confirmation of the weak neutral-current interaction. A neutrino, which leaves no track, enters from the top and knocks on an electron, giving it enough energy to create the small downward "shower" of curling tracks. The Gargamelle 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

Optical Readout (ongoing/done…)

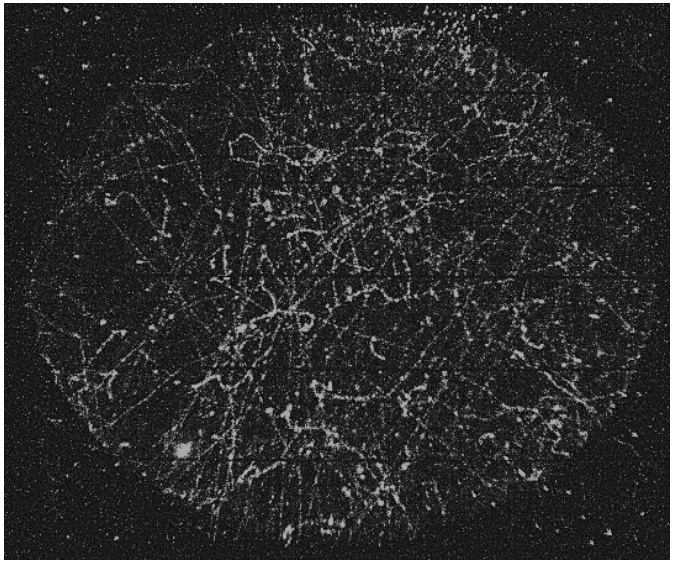




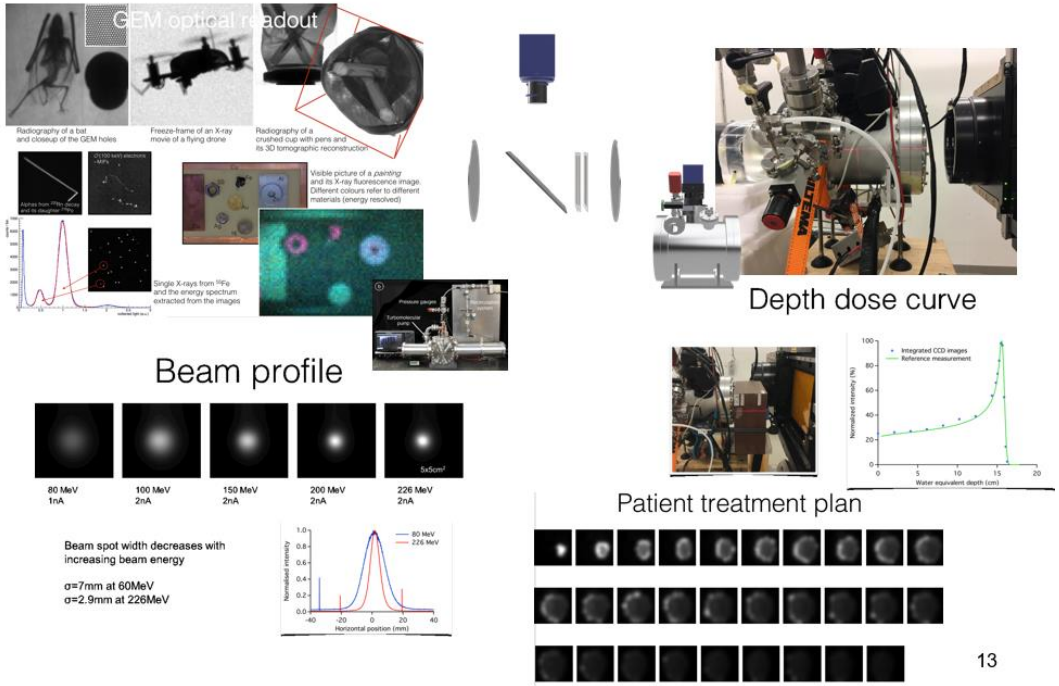


L. Ropelewski, https://indico.cern.ch/event/702148/contributions/2907960/attachments/1606418/2549044/EP_RD_short.pdf

D. Pinci, https://indico.cern.ch/event/702148/contributions/2908379/attachments/1606458/2549126/gas_WG_2018_pinci.pdf



D. Pinci et al. (INFN, Sapienza,…)



F. Resnati, F. Brunbauer (CERN GDD)

Which kind of future is waiting for us… or will be built by us…?

Detector Seminar

Recent Progress of Visible Image Sensors

by Prof. Nobukazu Teranishi (University of Hyogo and Shizuoka University - Japan)

Friday 23 Feb 2018, 11:00 → 12:00 Europe/Zurich

40-S2-B01 - Salle Bohr (CERN)

Description Image sensor technologies have been advanced drastically these 4 decades, and they have brought fruitful success in the market. The sales amount was more than 4 billion pieces in 2015. In this presentation, pixel shrinkage trend and recent technical trends at visible image sensors are reviewed:

1. pixel shrinkage,
2. photon counting,
3. stack and 3D structure,
4. sensitivity expansion to invisible, especially near IR,
5. ToF (time of flight) and gesture.

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

EP-ESE Electronics Seminars

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

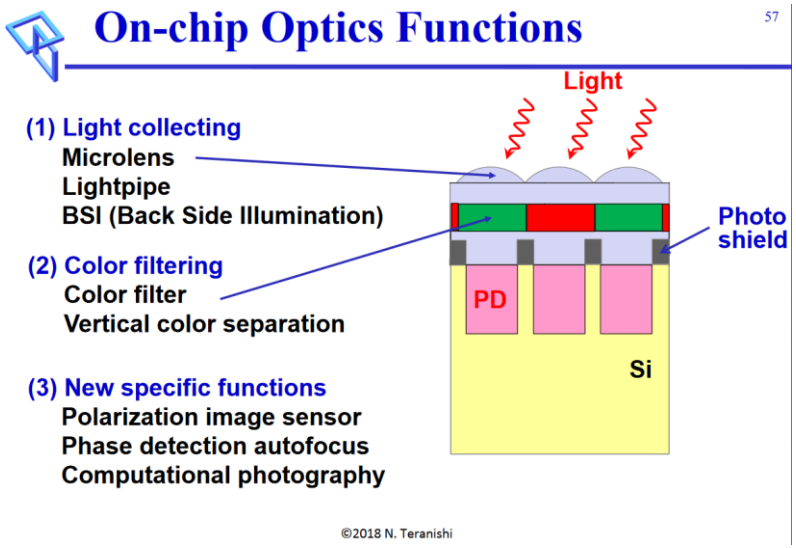
by Erik Heijne (Czech Technical University (CZ))

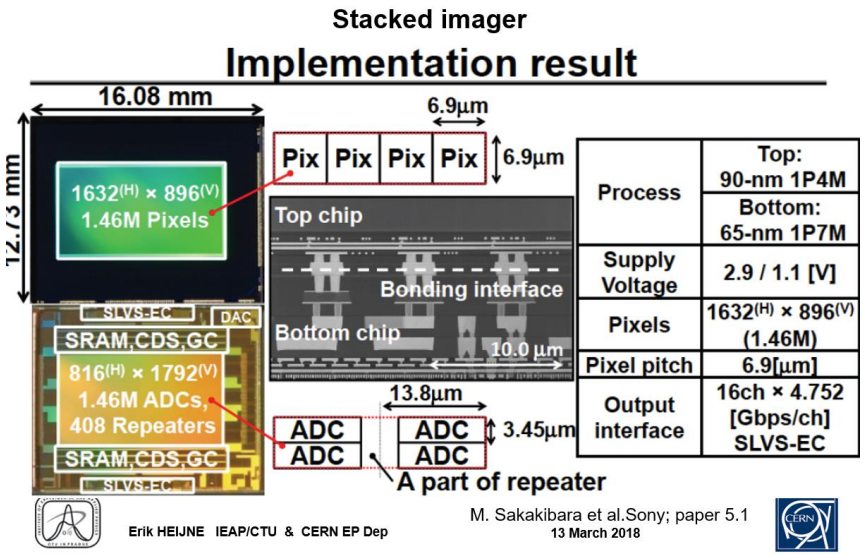
Tuesday 13 Mar 2018, 09:00 → 10:00 Europe/Zurich

13-2-005 (CERN)

Description 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 SRAM in the so-called 7 nanometer node was reported, where 13.5nm EUV lithography was used instead of the multi-exposure 193nm ultraviolet light. A 1 Tb 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/





Optical Readout… talking about frame rate…

Phantom v2512

The Phantom® v2512 provides a widescreen CMOS sensor and delivers a speed of over 25,000 frames-per-second at full resolution.

- **ISO Color 6,400D* 10,000T***
- **ISO Mono 32,000D* 100,000T**
- **1280 x 800 resolution**
- **28 micron pixel size, 12-bit depth**
- **265ns minimum exposure with the FAST option available at all frame rates and resolutions**
- **1 µs minimum exposure standard**
- **Up to 663,250 fps standard or 1,000,000 fps with the FAST option at reduced resolutions**
- **Available with 72GB, 144 GB, or 288GB of memory**
- **Records directly to a 1TB or 2TB CineMag IV**
- **Ultra-fast 10GB Ethernet for fast downloads**
- **Convenient "Quiet Fans" mode turns off fans for vibration-sensitive applications**

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

25kHz

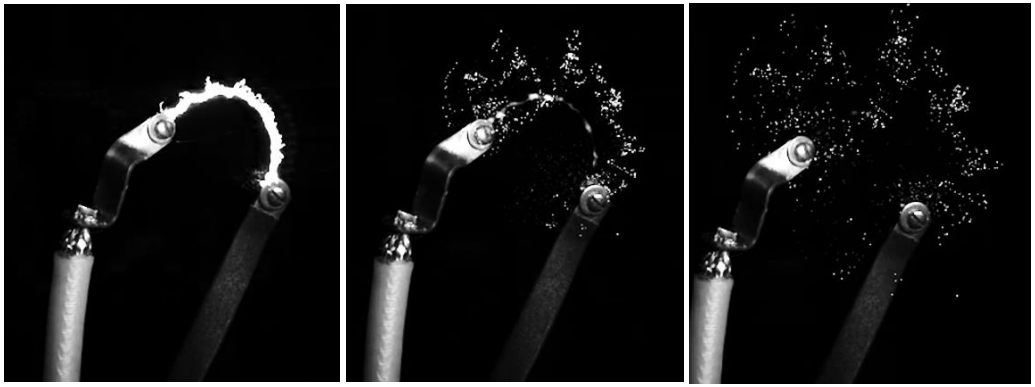
100KHz

1MHz

Common resolutions and frame-rates, other resolutions available

- CMOS sensor
- 1280 x 800 pixels
- 28 µm pixel size
- 35.8 mm x 22.4 mm
- 12-bit depth
- TE and heat pipe cooled
- CAR in 128 x 16 increments
- ISO Monochrome 32,000D; 100,000T
- ISO Color 6,400D; 10,000T
- E.I. range 32,000-160,000D (mono);6,400-32,000D (Color)

About 100kEUR (!?) today…·



https://youtu.be/DBVvAjd2n2Q

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)

http://coilab.caltech.edu/epub/2014/GaoL_2014_Nature_v516_p74.pdf

Carefully read the time between frames

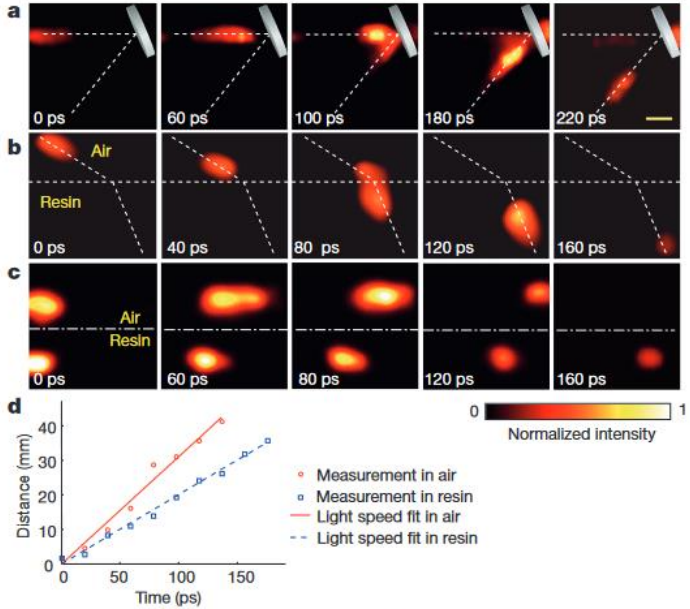
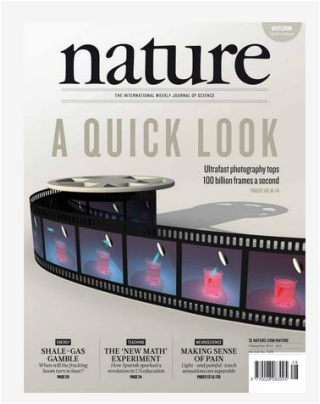
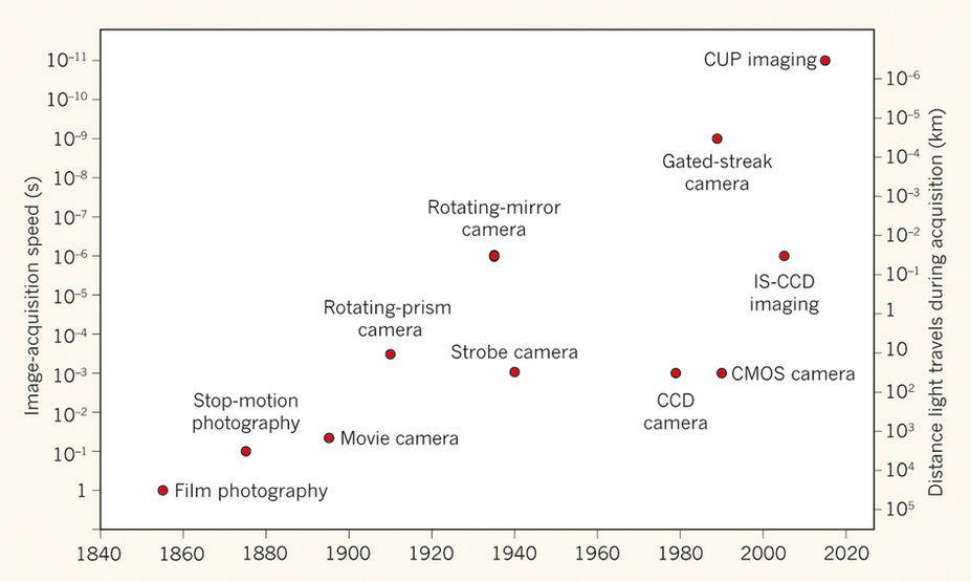


Figure 3 | CUP of laser pulse reflection, refraction, and racing in different media. a, Representative temporal frames showing a laser pulse being reflected from a mirror in air. The bright spot behind the mirror is attributed to imperfect resolution. **b**, As **a** but showing a laser pulse being refracted 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.



Single-shot compressed ultrafast photography at one hundred billion frames per second



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

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2: Material Science and nano/micro technologies
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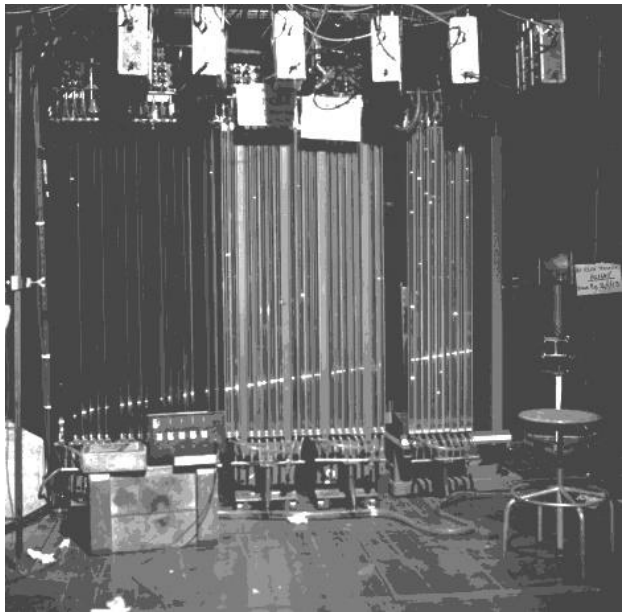
5: Sparks

Obviously not exhaustive… it doesn't want to be…

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)

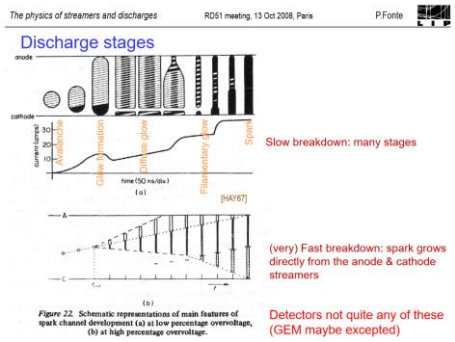
https://home.cern/about/updates/2015/06/seeing-invisible-event-displays-particle-physics

A detector in the past..
A problem to fix now…
Maybe again a "BRILLIANT" detector in future

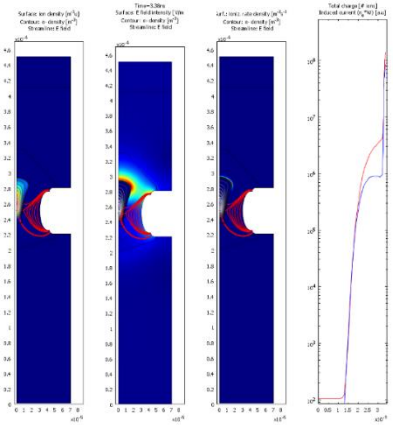
- *Understanding them (fundamental studies in R&D)*
- *Minimizing the risk, making them less harmful and quenching them (electric field, resistive electrodes) …*
- *Maybe using them…*

Sparks(1)…Fundamental studies (R&D Priority)

The physics and the modelling (Paulo Fonte)



P. Fonte, https://indico.cern.ch/event/35172/contributions/1754306/attachments/695948/955600/The_physics_of_streamers_and_discharges.pdf



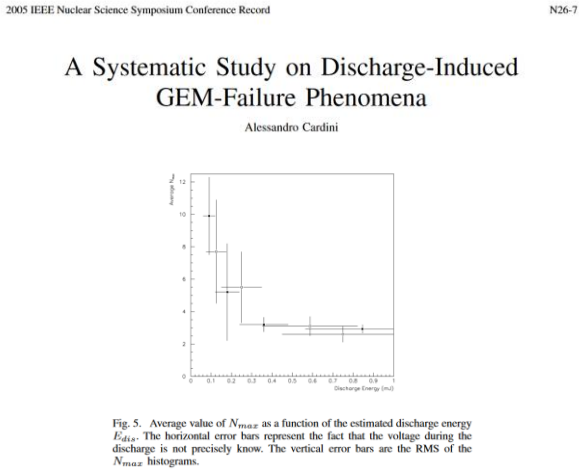
http://garfieldpp.web.cern.ch/garfieldpp/examples/avalanches_streamers/animation.html

P. Fonte, https://indico.cern.ch/event/89325/contributions/2108964/attachments/1089488/1554083/Calculation_of_streamer_development.pdf

http://garfieldpp.web.cern.ch/garfieldpp/examples/avalanches_streamers/step_by_step.pdf

The Measurements

LHCb (Alessandro Cardini)


2005 IEEE Nuclear Science Symposium Conference Record N26-7

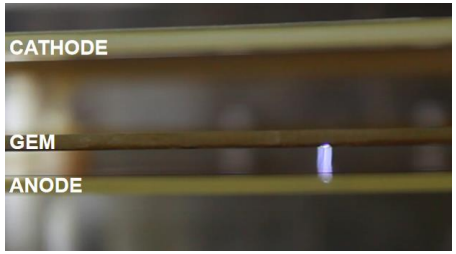
A Systematic Study on Discharge-Induced GEM-Failure Phenomena

Alessandro Cardini

Fig. 5. Average value of N_{max} as a function of the estimated discharge energy E_{dis}. The horizontal error bars represent the fact that the voltage during the discharge is not precisely know. The vertical error bars are the RMS of the N_{max} histograms.

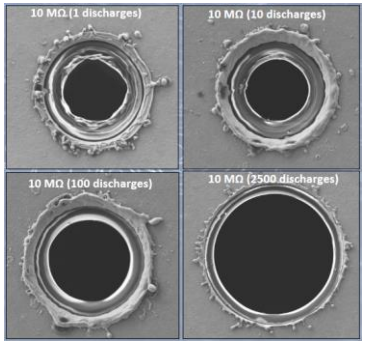
ALICE (Piotr Gasik)

Propagating discharges



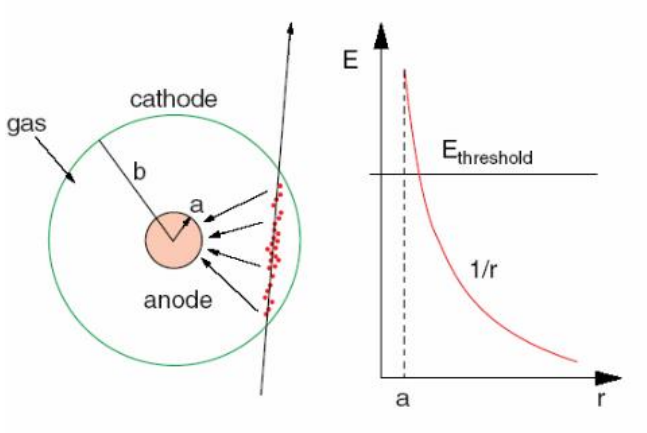
P. Gasik, https://indico.cern.ch/event/702782/contributions/2892482/attachments/1603148/2542305/gasik_20022018_RD51_propagation-protection.pdf

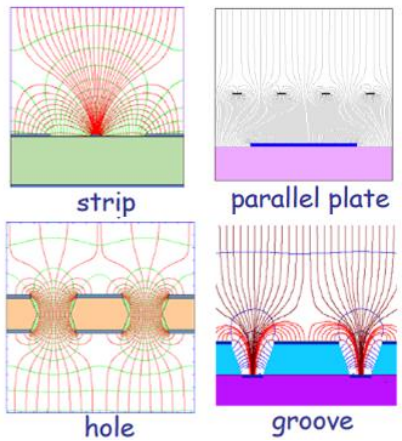
CMS/GDD (Jeremie Merlin)



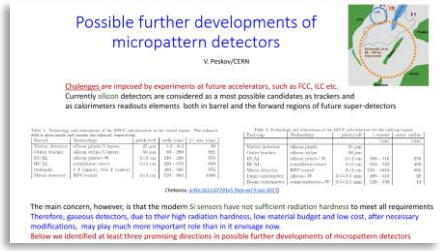
J. Merlin, P. Thuiner, https://indico.cern.ch/event/702782/contributions/2896222/attachments/1603539/2543274/JMerlin_Discharge_Effects_20022018.pdf

Spark(2)… E fields





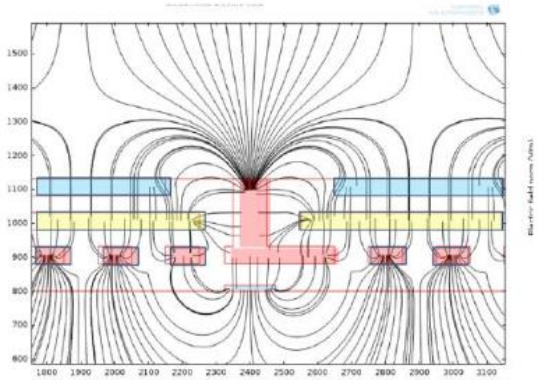
L. Ropelewski, http://leszek.home.cern.ch/leszek/GEM_at_CERN_seminar.pdf



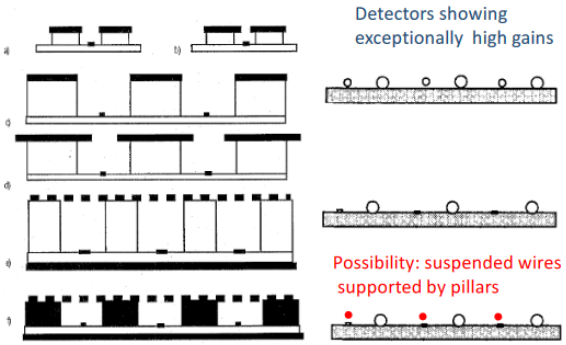
V. Peskov, https://indico.cern.ch/event/702148/contributions/2906906/attachments/1606378/2548963/Possible_further_development_of_micropattern_detectors.pdf

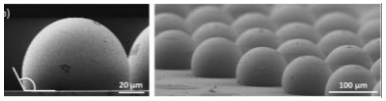
We should keep in mind the previous slides on micro/nano technologies

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

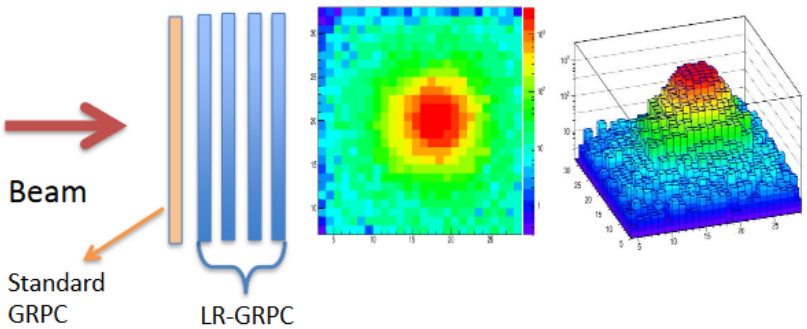
$\Delta V = I\,R = q\Phi\rho d$

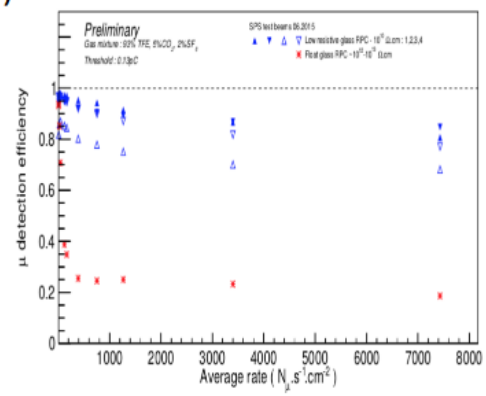
Smaller ρ ⋯ Low resistivity
Smaller d ⋯ thinelectrodes
Smaller q ⋯ FE electronics

R&D for a new generation of (M)RPC

I.Laktineh
Institut de Physique Nucléaire de Lyon

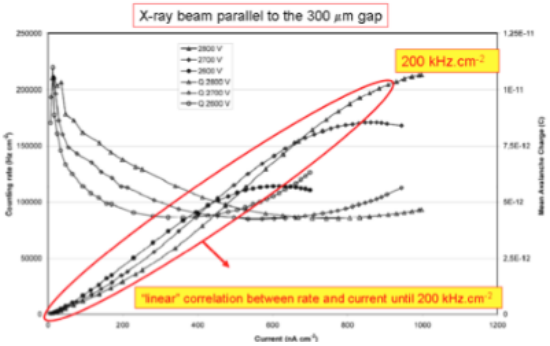
Doped Glass $10^{9\text{-}10}$ Ω.cm developped by Tsinghua University

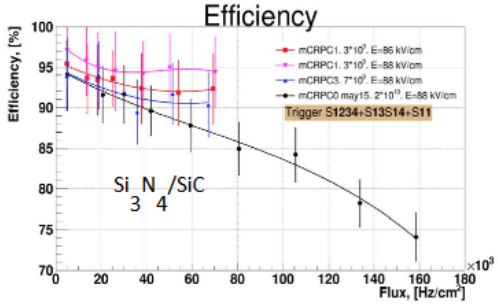




I. Laktineh, https://indico.cern.ch/event/702148/contributions/2879855/attachments/1606398/2549397/RPCRD-CERN.pdf

Ceramics: ok but small size plate an
Doped PEEK or **doped PVDF**:
Resistivity values 10^{6} -10^{14} Ω.cm were obtained by changing the dose of the doping material in PEEK. For PVdF 10^{10}-10^{13} Ω.cm were obtained
PEEK/PVDF obtained with injection seem to work quite well (Lyon PVdF, Krefine PEEK)





Material Resistivity

(material science)

Embedded Resistors…
Finding the right impedance and defining the proper charge evacuation channels (SCREAM/CALICE)

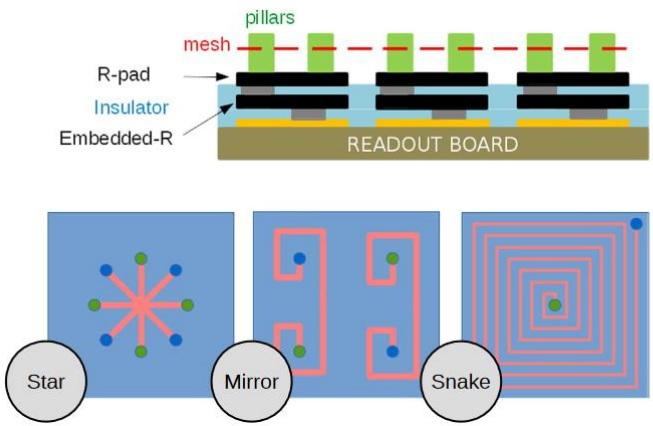
Resistive Micromegas for sampling calorimetry

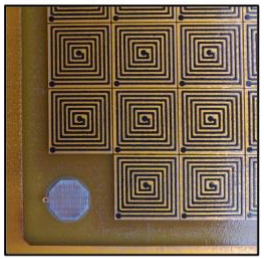
M. Chefdeville (LAPP, Annecy), T. Geralis (NCSR, Demokritos), M. Titov (IRFU, Saclay)
(another) WG2 meeting, CERN, Feb. 26th 2018

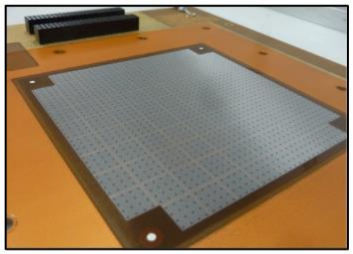
M. Chefdeville
https://indico.cern.ch/event/702148/contributions/2910267/attachments/1606383/2548954/11_CHEFDEVILLE-chefdeville.pdf

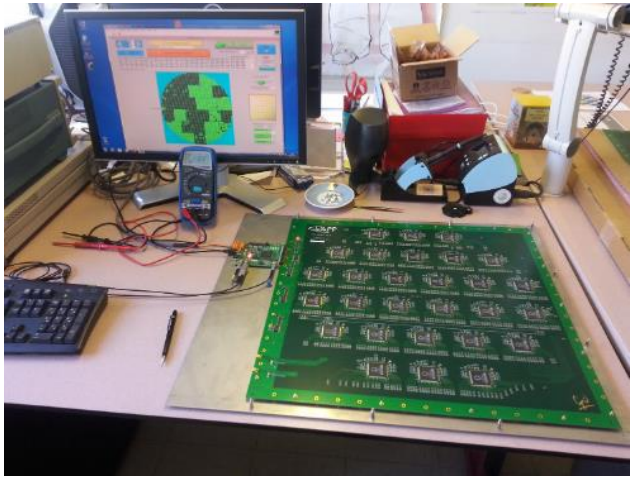
Pad boards
- 10X10 matrix of 1x1 cm2 pads
- Routing on the outside to a 'Gassiplex' connector (96 channels)

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









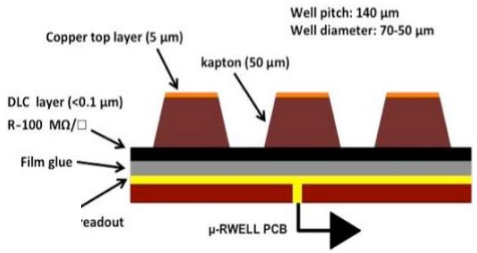
M. Chefdeville, https://indico.cern.ch/event/391665/contributions/1827414/attachments/1230092/1803859/chefdeville.pdf

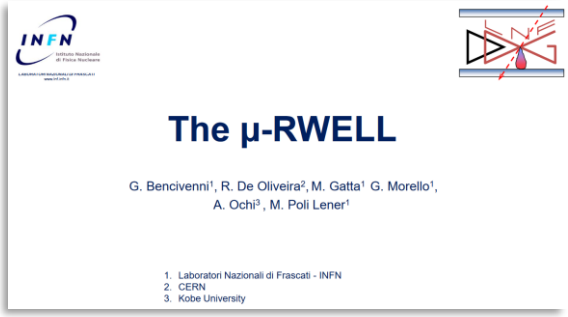
If you don't have the proper resistance… you can make it!
(Embedded Resistors, de Oliveira et al. in 2010)

DLC Layers… μRWELL…

~~Low Rate… R&D almost finished~~

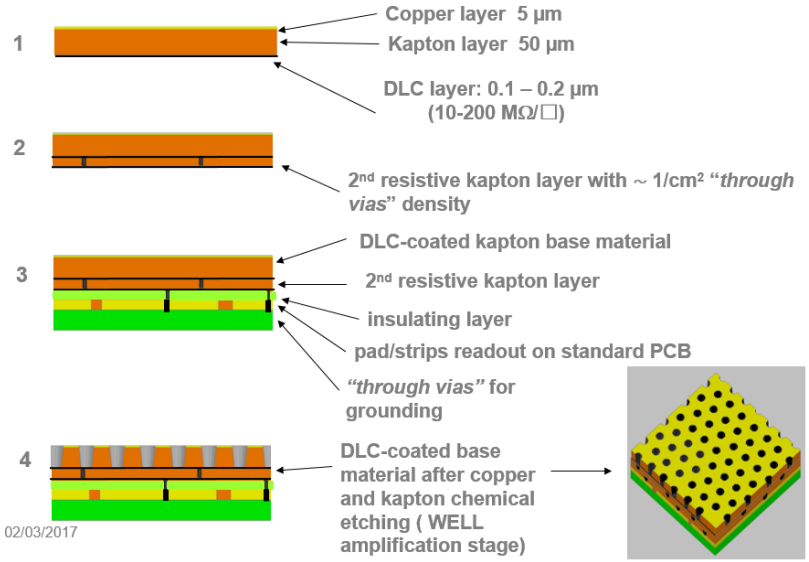
High Rate… still R&D





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

The High Rate scheme (LHCb)



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

- **Low Rate version** (single-resistive layer) **completed** & ready for **TT to Industry**
- **High Rate version still under study** in order to find the best solution for engineering/industrialization
- **DLC sputtering is ok** even though the **recent HR version of the detector could require still some R&D**

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

Jinst

Published by IOP Publishing for Sissa Medialab

Received: December 12, 2016
Accepted: February 24, 2017
Published: March 22, 2017

14th Topical Seminar on Innovative Particle and Radiation Detectors
3–6 October 2016
Siena, Italy

Small-pads resistive micromegas

M. Alviggi,[a,b] M. Biglietti,[d] V. Canale,[a,b] M. Della Pietra,[a,b] C. Di Donato,[a,c] S. Franchino,[f] P. Iengo,[g] M. Iodice,[d,1] F. Petrucci,[d,e] G. Sekhniaidze[a] and O. Sidiropoulou[g,h]

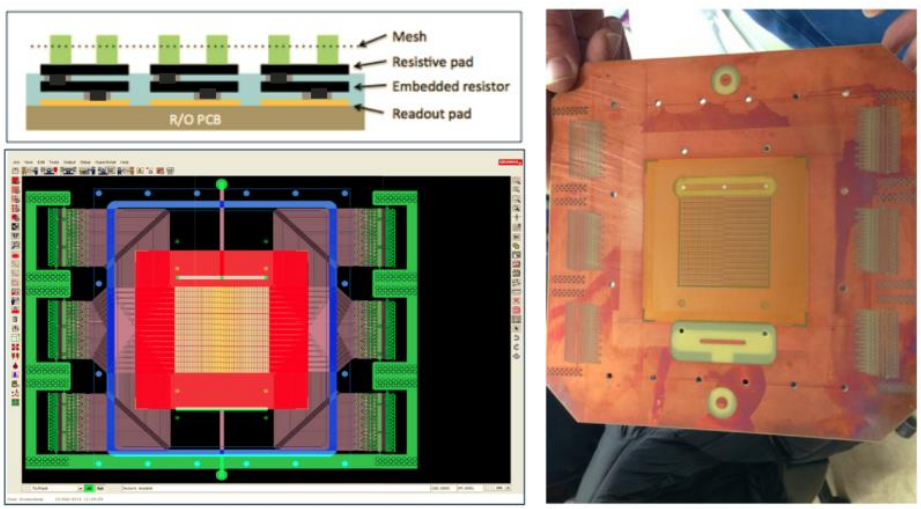
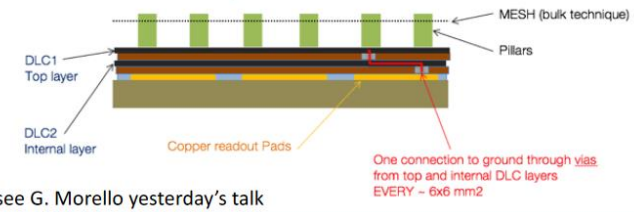


Figure 2. Left-top: sketch of the small pad micromegas detector with embedded resistors structure; left-Bottom: layout for the first prototype; right: the readout PCB of the constructed prototype.

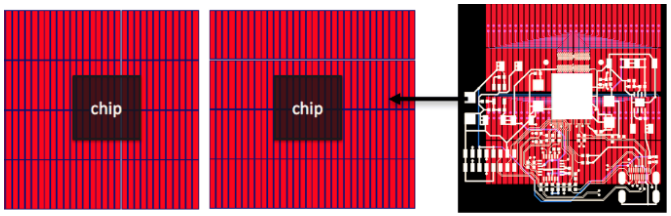
SERIES 2

- Double DLC resistive layer with a resistivity of ~50-70 MΩ/□
- Connection to ground through resistive vias
- Design driven by recent developments of μ-RWell detector
- Uniform resistive layer



see G. Morello yesterday's talk

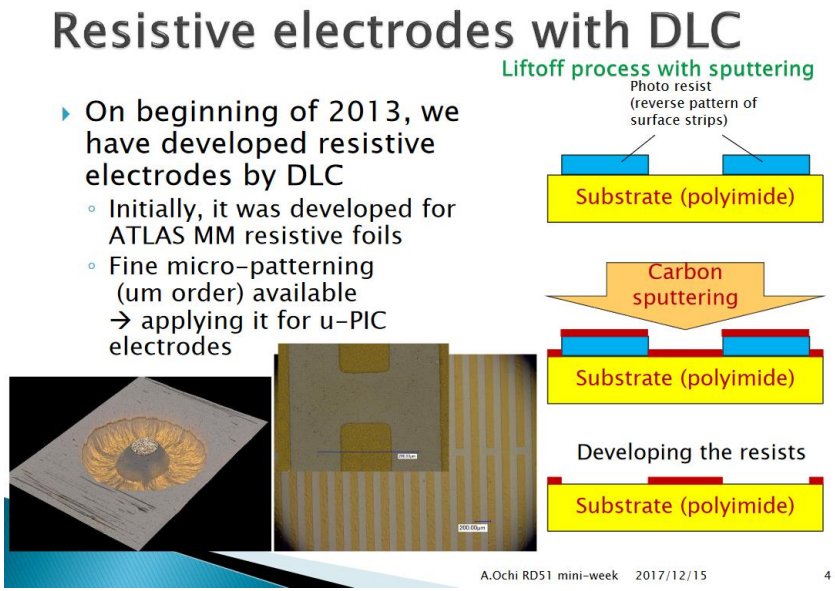
M. Iodice, https://indico.cern.ch/event/676702/contributions/2820589/attachments/1576110/2488917/Paddy_Update_15Dec2017_v4.pdf



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 ill be implemented on-detector; bottom-right: layout of the front-end circuit as designed to be ed on the back of each 128-pads sector.

High Granularity Pads readout (few mm^2) with Embedded Electronics [SCREAM in hi-density]

Latest examples based on …DLC
Started in Japan/(A· Ochi)… now moving to China/(Y·Zhou)



- *ATLAS NWS mm (*)*
- *μPIC*
- *μRWELL*
- *Small-Pads Micromegas*
- *RPC*
- *…*

A. Ochi, https://indico.cern.ch/event/676702/contributions/2819146/attachments/1576207/2489252/ochi_upic_171215_v2.pdf

(*) screen printing as final choice because of cost

Proven to be the right direction to go

Y.Zhou, https://indico.cern.ch/event/702148/contributions/2879856/attachments/1606401/2549007/12_Zhou-Introduction_of_USTC_group_2018-02-26.pdf

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

Done…

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 TM

How rather than What

Leszek Ropelewski CERN EP DT GDD & RD51

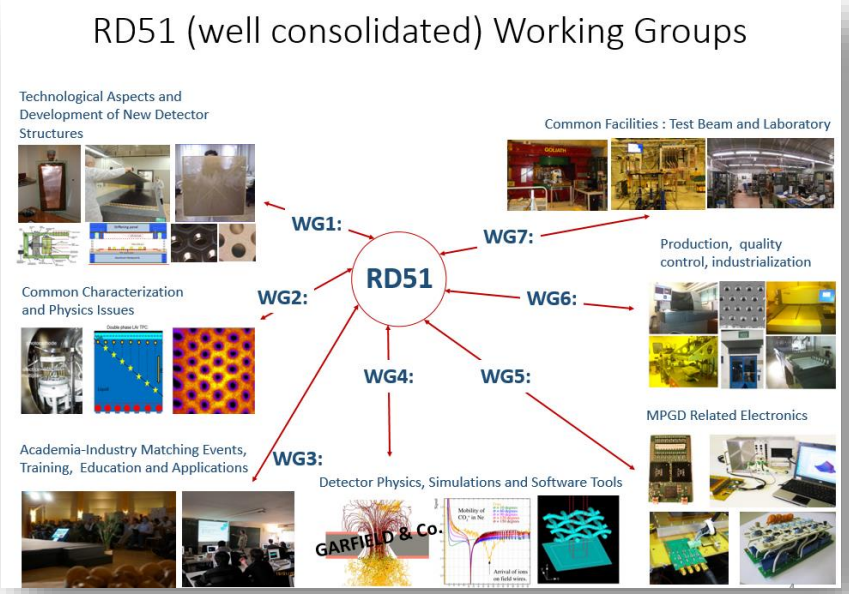
https://videos.cern.ch/record/1047445

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·

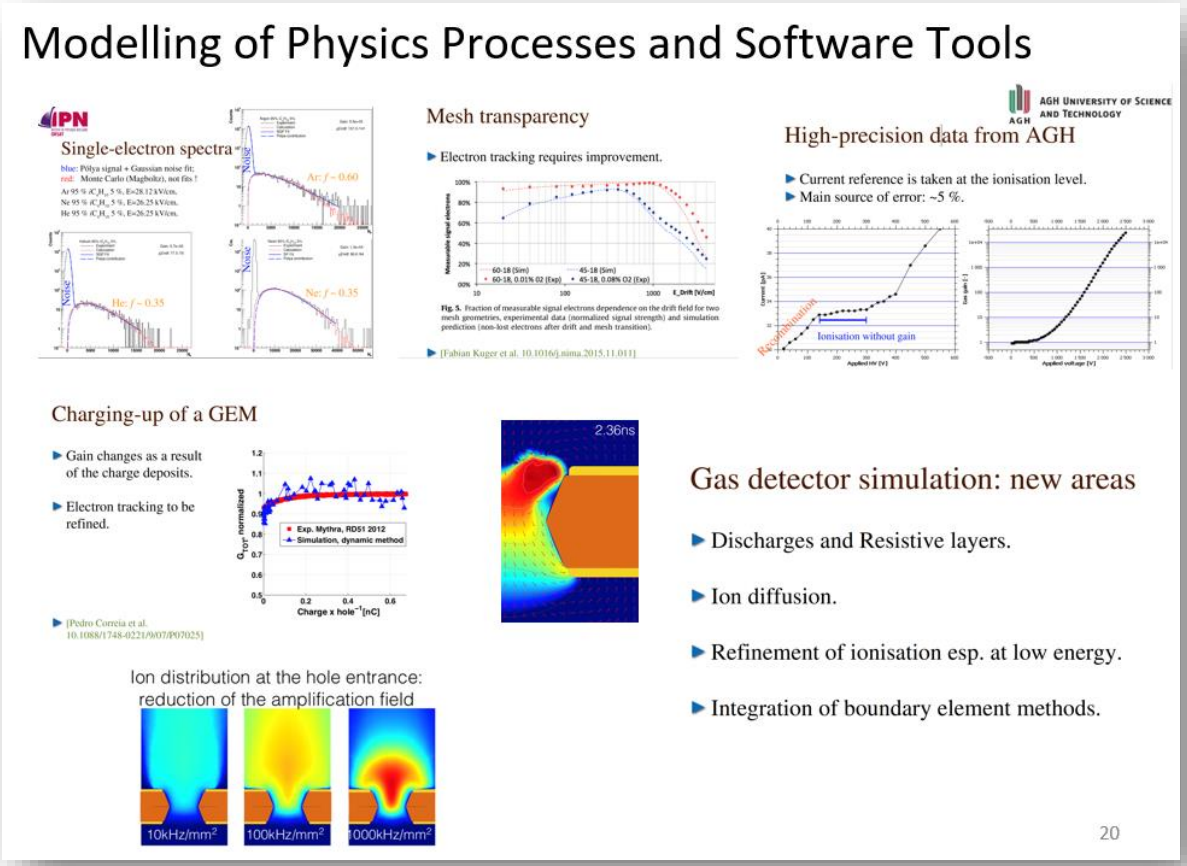
Most of the next slides directly connected to RD51



Detector Modelling

WG2 – gas detector simulation

R. Veenhof, H. Schindler, https://indico.cern.ch/event/702068/sessions/265605/attachments/1597953/2532204/simulations_9feb2018.pdf



Key people…

Several tools…

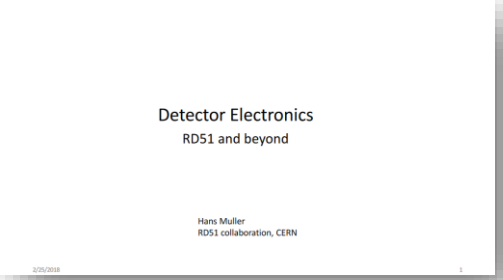
(Garfield, heed, magboltz, degrad, geant4, COMSOL, spice,…)

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



H. Muller, https://indico.cern.ch/event/702148/contributions/2880985/attachments/1606384/2548955/19_MULLER-Detector_electronics.pdf

Three cases: Electronics for detectors

multichannel readout systems

SRS (RD51) scalable readout system
from table-top to full experiment
> 100 SRS systems world wide

APV

SRS frontends

2009-2018

VMM

Single channel test & trigger

Single-channel & HV mesh trigger
CSA, Shaper, Pulsers, Trigger, HV bias

Sub-ns LED pulsers

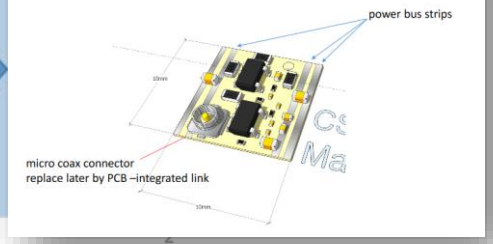
2014-2018

Scalable picosec frontends

Pre-amplifiers WBA, CSA, TIA, OTA
time & amplitude in sub-ns range

2018+ R&D

Single channel Macro for pSEC tests

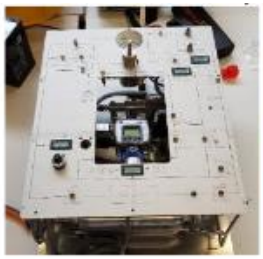


2/25/2018 Hans.Muller@cern.ch

Multichannel Electronics *Instrumentation* *New readout electronics development (single channel)*

Gas (system)

Gas analysis...



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

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

Mixing Systems

Mini TPCs require gas, in small volumes

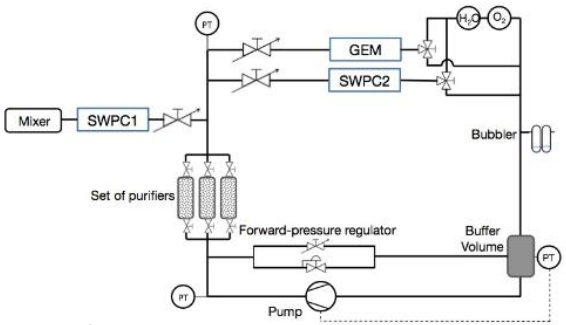
Nikhef gas mixing station, made by Fred Hartjes!

- 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_VANDERGRAAF-GasRD.pdf

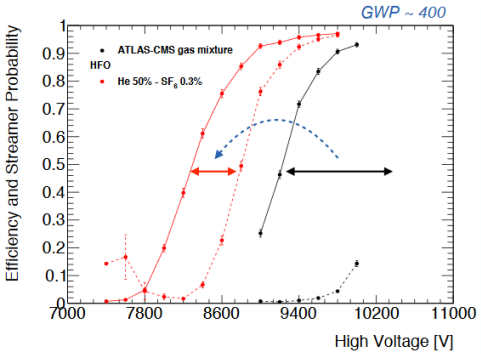
Eco-friendly...(recirculating and/or eco-gas)

GEM, CF4(LHCb)



With recirculation system
GHG reduction up to 90%

RPC, R134a[C2H2F4]
(ATLAS, CMS)



B. Mandelli,
https://indico.cern.ch/event/667256/contributions/2733193/attachments/1530723/2395693/RD51_BMandelli.pdf

Workshops (1)

PH-DT Micro-Pattern Technologies workshop

15/03/2018 Antonio TEIXEIRA 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

15/03/2018 Antonio TEIXEIRA 2

A. Teixeira, https://indico.cern.ch/event/352483/

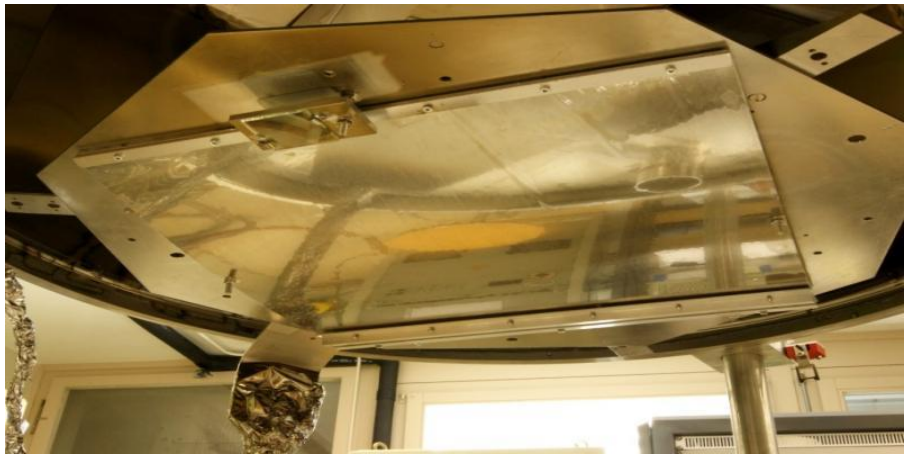
Micro-Pattern Technologies

Machines important…
but is the expertise of the WS people that makes the difference

Workshops (2)

Thin Film and Glass Lab

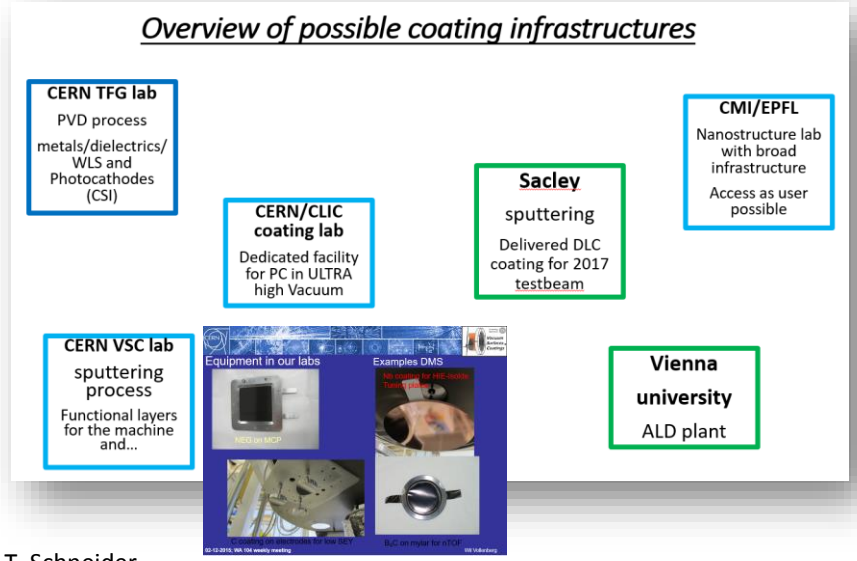
- Optical Quality Control Lab
- Glass & Ceramics Workshop
- Thin Film Lab



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

Engineering

Main challenges in mechanics x gas detectors

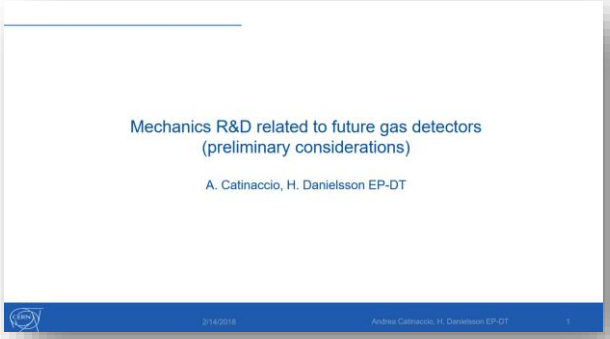
- High precision mechanics on large size objects (~ 2 m)
- Stiffness and Stability (gravitational sags, thermal deformations, pressure)
- Gas uniformity and distribution (gas dynamics)
- Low material budget (new materials and processes)
- Material gas compatibility (absorption, desorption, purity, corrosion, 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

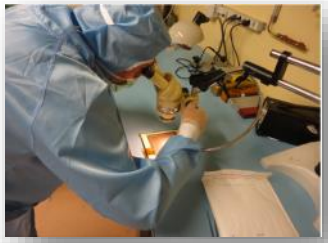
- Synergies exist with plans for R&D in detector "mechanics"

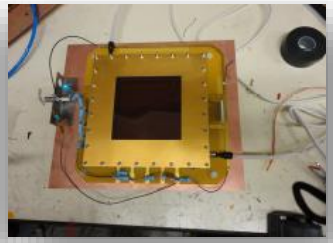


A. Catinaccio, H. Danielsson, https://indico.cern.ch/event/702068/sessions/265605/attachments/1597953/2537164/engineering_RD_gas_detector.pdf

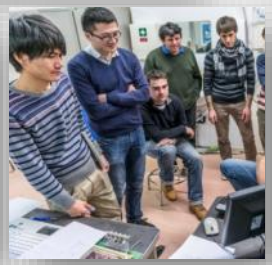
R&D Laboratories (where you put everything together…)

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

2013

https://cds.cern.ch/record/1552862/files/ATLAS-TDR-020.pdf

ALICE TPC Upgrade TDR

2014

https://cds.cern.ch/record/1622286/files/ALICE-TDR-016.pdf
https://cds.cern.ch/record/1984329/files/ALICE-TDR-016-ADD-1.pdf

CMS Muon Endcap Upgrade TDR

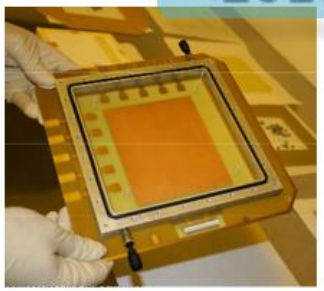
2015

https://cds.cern.ch/record/2021453/files/CMS-TDR-013.pdf

<2010

~2012

<2010



All of them with R&D Activities in the GDD lab at the beginning

EP-DT
Detector Technologies

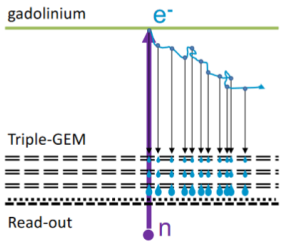
7

Attracting expertise and resources…

D. Pfeiffer, https://indico.cern.ch/event/702148/contributions/2879857/attachments/1606439/2549105/20180226_Pfeiffer_RD.pdf

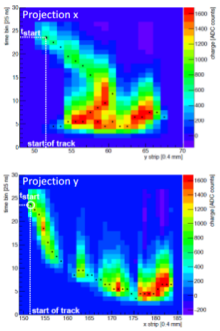
The NMX instrument
Read-out technique: Micro Time Projection Chamber (µTPC)

Already **working read-out technique** demonstrated for 10B† and Gd‡ neutron converters



position resolution of ***O*(200µm)** (strongly depending on read-out but generally improved by µTPC)

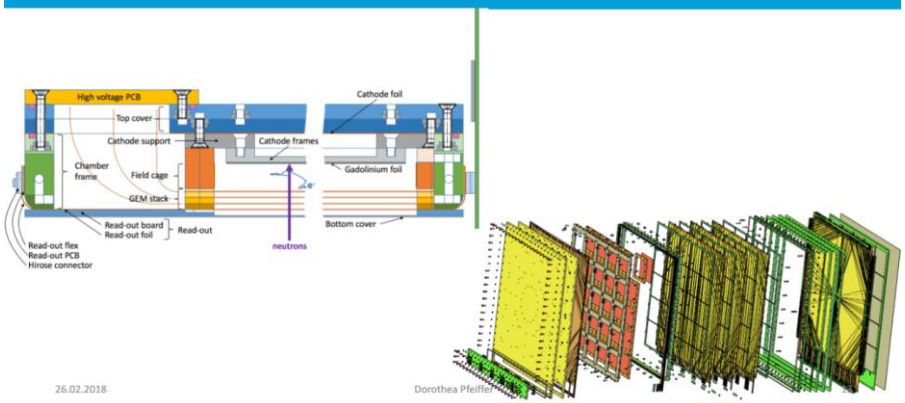
time resolution *O*(ns)



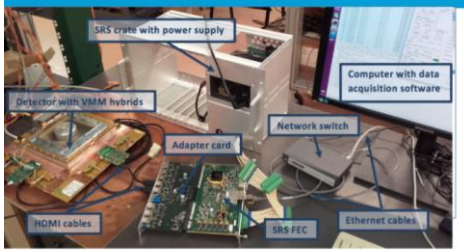
† D. Pfeiffer et al., JINST 10 (2015) 04, P04004 ‡ D. Pfeiffer et al, 2016 JINST 11 P05011 BrightnESS D4.3

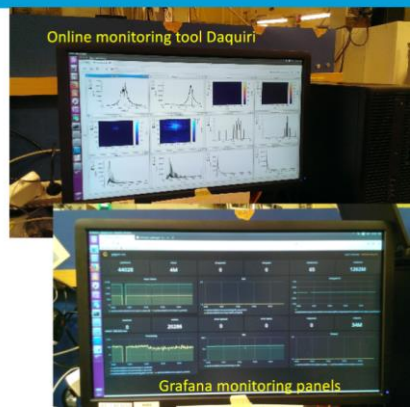
ESS/CERN
BrightnESS EU project

BrightnESS NMX Detector Prototype ZITA



Complete Readout Chain for VMM3 available





Submitted to NIM A:
M. Lupberger et al: "Implementation of the VMM ASIC in the Scalable Readout System"

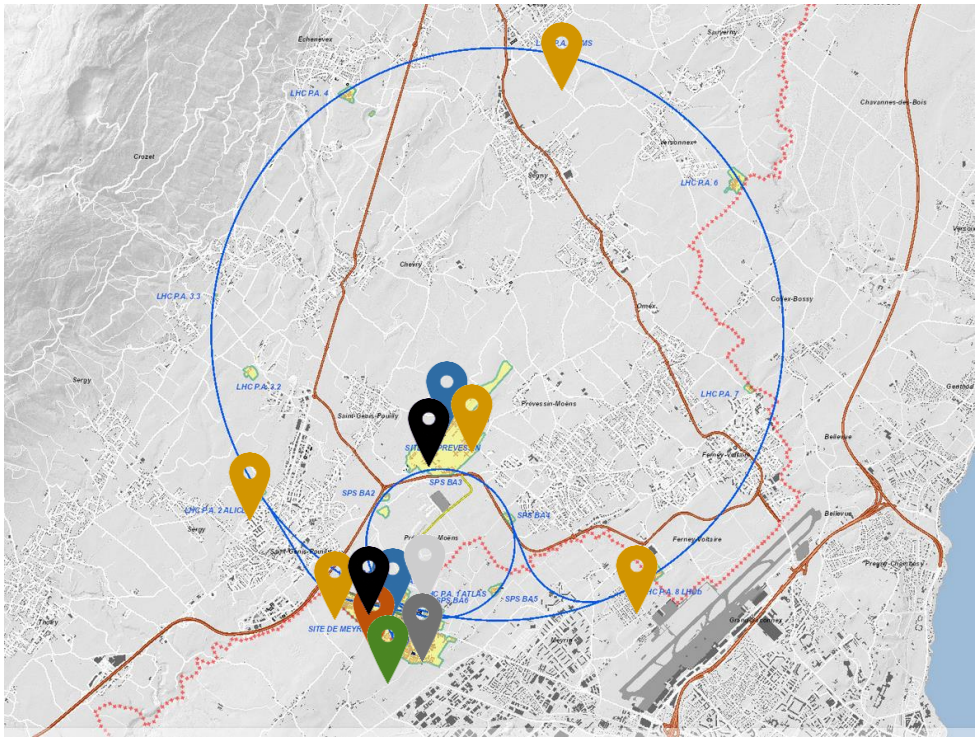
WG2 … next step

- 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



R&D Laboratory

Detector Simulation and Modelling

Gas System R&D

Gaseous Detector Electronics

Workshops (R&D and production), Infrastructures and Engineering

Testing Facilities

Experiments

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

© 1992 CERN Conditions of Use 15 December 1992 00:11:51 7525 Views

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…)

http://www.carsinc.org.au/general-news/cars-updated-vision-and-mission/

Thanks