Charged particle timing in the sub-50 picosecond regime with MicroMegas based detector

E. Oliveri, EP-DT-DD, GDD

On behalf of the Picosec collaboration

September 29, 2017

the PICOSEC Collaboration

- CEA (Saclay): *T. Papaevangelou, I. Giomataris, M. Kebbiri, F.J. Iguaz, T. Gustavsson, D. Desforge, M. Pomorski, O. Maillard, C. Guyot, P. Schwemling*
- CERN: *J. Bortfeldt, F. Brunbauer, C. David, J. Franchi, M. Lupberger, H. Muller, E. Oliveri, F. Resnati, L. Ropelewski, M. van Stenis, T. Schneider, L. Sohl, P. Thuiner, R. Veenhof, S. White*[1].
- LIP: *M. Gallinaro*
- NCSR Demokritos: *G. Fanourakis*
- NTUA Athens: *Y. Tsipolitis*
- University of Santiago de Compostela: *D. Gonzalez-Diaz*
- University of Science and Technology of China: *Y. Zhou, Z. Zhang, J. Liu, B. Qi, X. Wang*
- University of Thessaloniki: *I. Manthos, K. Paraschou, S. Tzamarias, D. Sampsonidis*

[1] Also University of Virginia

outline

- *MIP’s detection with micromegas (Picosec) @ <50ps time resolution*
- *short overview of the RD51 Precise Timing Workshop @ CERN in Feb. 2017*

exactly 2 years ago….

Detector Seminar

Fast Timing Detector R&D for the HL-LHC era

by Sebastian White (Princeton University (US))

Friday 25 Sep 2015, 11:00 → 12:00 Europe/Zurich

40-S2-B01 - Salle Bohr (CERN)

Description There is a growing interest in applying timing measurement of physics objects (leptons, jets, photons) in the high pileup environment planned for the next decade at the LHC. Time of occurrence of events within the same bunch ("in-time pileup") can be used analogously to the more commonly used "event vertex position" tagging to resolve events of interest in this busy environment.
Extending to this 2-D tool (time and space discrimination) is likely key to enabling the challenging measurements of the next decade by suppressing pileup background.
In this seminar I will describe progress on fast sensors (Si and MPGD) we are developing in a collaboration of CERN, Princeton, Saclay- partly within an RD51 common project framework.

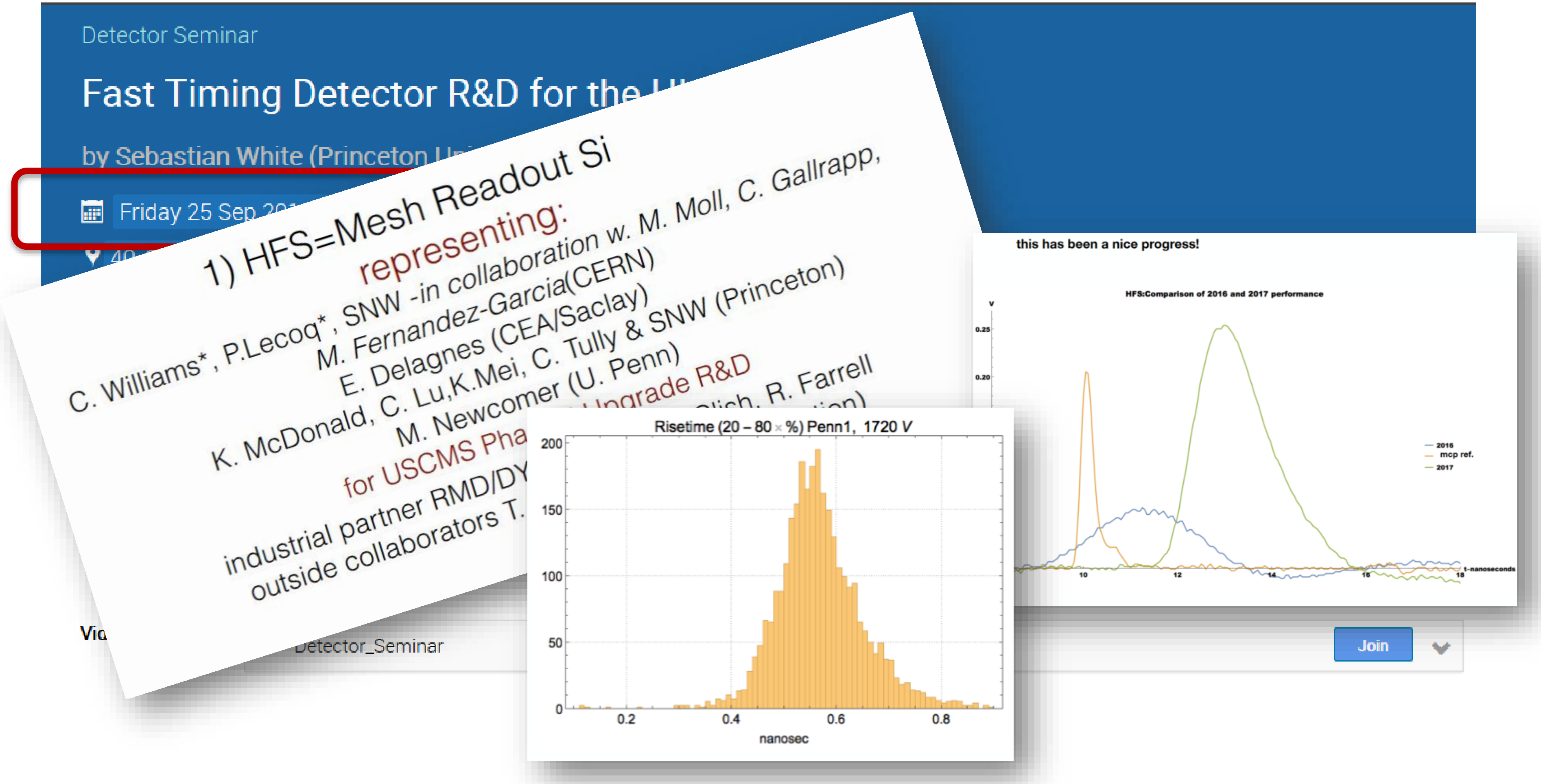
cern_seminar.pdf fnaltow.pdf ftwg-6-10-16.pdf

Organized by Ferdinand Hahn

Videoconference Rooms Detector_Seminar Join

https://indico.cern.ch/event/439571/

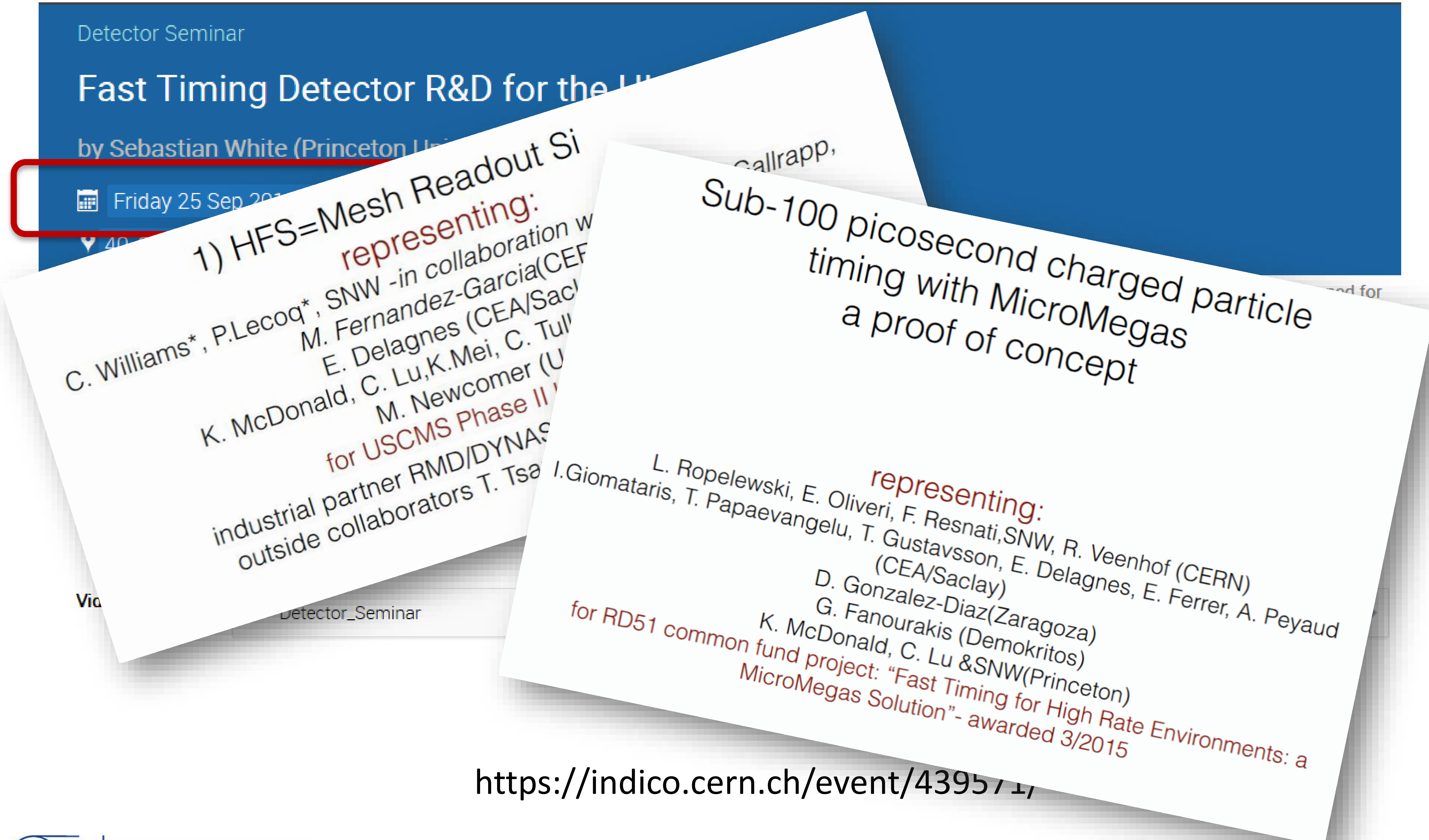
exactly 2 years ago….



Latest Results about HFS on …

https://indico.cern.ch/event/667256/contributions/2732294/attachments/1531105/2397080/rd51_9_2017.pdf (RD51 Collaboration Meeting)

exactly 2 years ago....



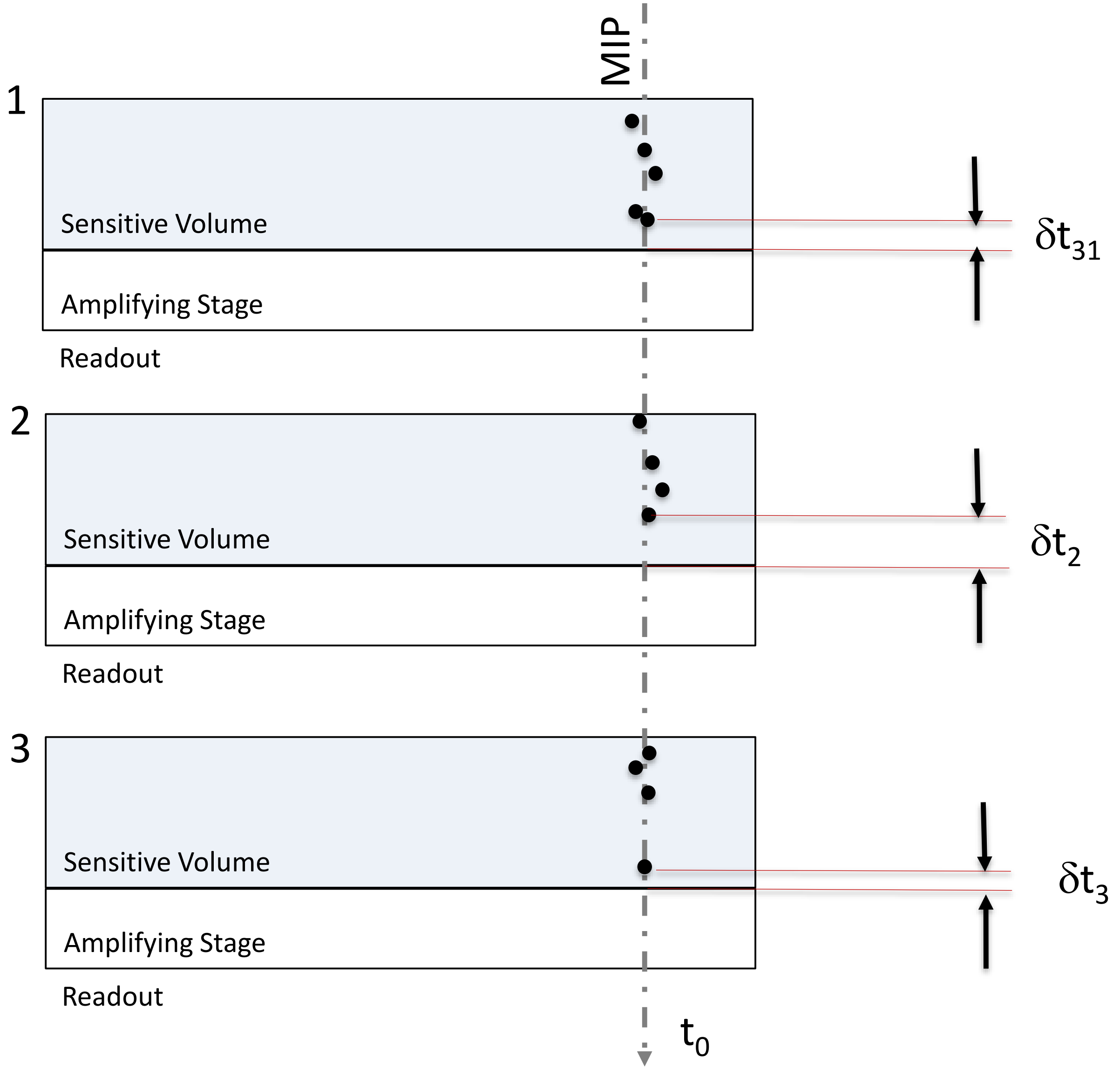
https://indico.cern.ch/event/439571/

Fast Timing with Micro Pattern Gaseous Detectors:

the approach followed by the Picosec collaboration

Direct Gas Ionization

Leading Edge of the signal… closest cluster to the amplification stage/readout



Direct Gas Ionization

PRINCIPLES OF OPERATION OF MULTIWIRE PROPORTIONAL AND DRIFT CHAMBERS

F. Sauli

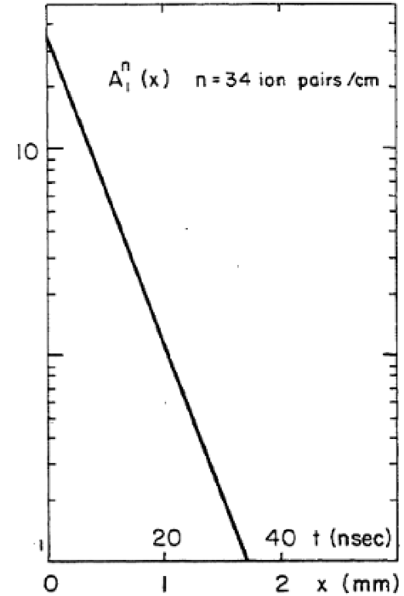
1977

Consider, in particular, the distribution of the pair closer to one end of the detection volume,

$$A_1^n(x) = n\, e^{-nx} , \qquad (5)$$

which is represented in Fig. 8, for n = 34, as a function of the coordinate across a 10 mm thick detector. If the time of detection is the time of arrival of the closest electron at one end of the gap, as is often the case, the statistics of ion-pair production set an obvious limit to the time resolution of the detector. A scale of time is also given in the figure, for a collection velocity of 5 cm/μsec typical of many gases; the FWHM of the distribution is about 5 nsec.

https://cds.cern.ch/record/117989/files/CERN-77-09.pdf



FWHM ~ 5nsec

Fig. 8

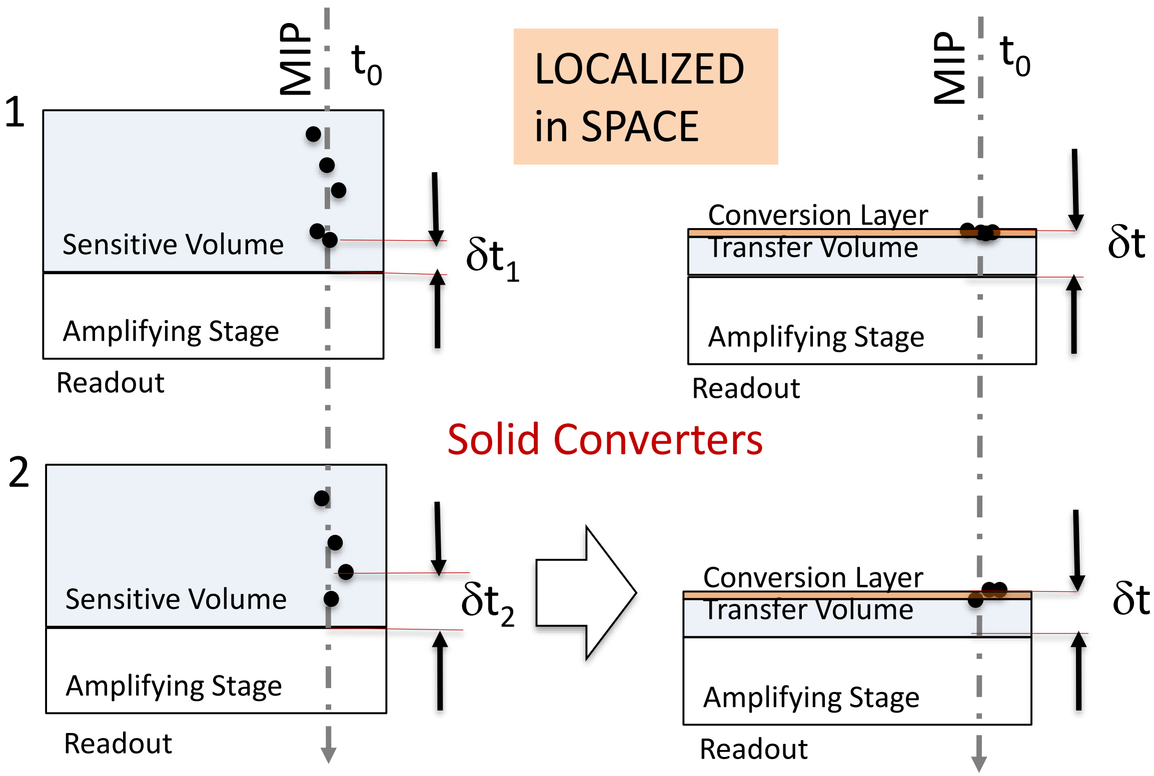
Statistics of primary ion pair production: probability of finding the closest pair at a distance x from one electrode in a counter, in argon-isobutane 70-30. The corresponding electron minimum collection time is shown, for a typical drift velocity of electrons of 5 cm/μsec.

Intrinsic Time Resolution

$\sigma(t_d)=1/nv_d$

There is no hope of improving this time resolution in a gas counter, unless some averaging over the time of arrival of all electrons is realized.

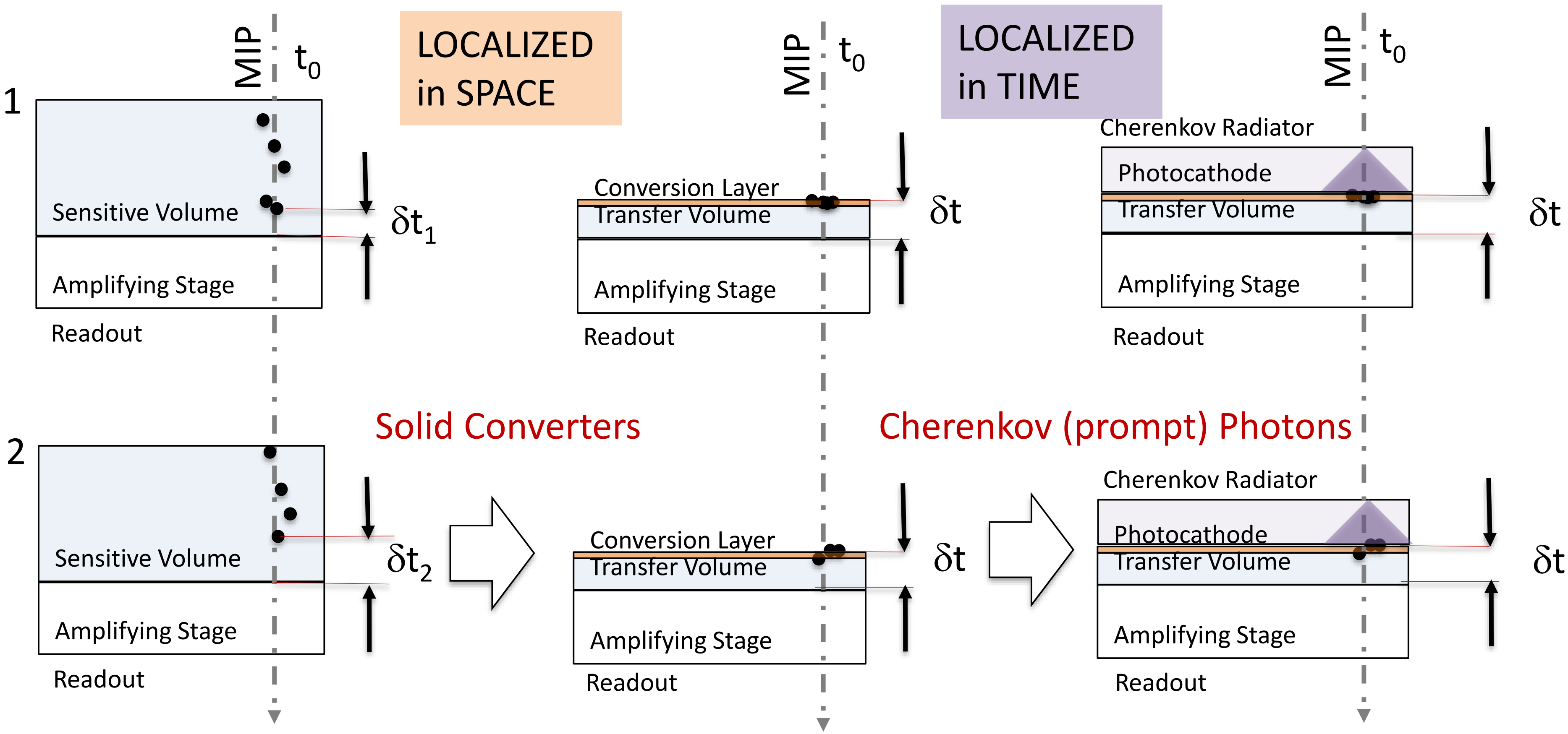
Solid Conversion Layer



Sensitive volume (if eventually needed) reduced in order to:

- Avoid direct gas ionization
- Reduce diffusion

Prompt Cherenkov Radiator



Primary electrons at the same time in the same place

Sub-nanosecond time response

1991

Nuclear Instruments and Methods in Physics Research A307 (1991) 63–68
North-Holland
63

Investigation of operation of a parallel-plate avalanche chamber with a CsI photocathode under high gain conditions

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[b] LIP-Coimbra, Univ. of Coimbra, Portugal
[c] WorldLab, Lausanne, Switzerland
[d] Univ. of California, Davis, CA, USA

Received 18 March 1991

We report results of a systematic study of the operational characteristics of a single-step parallel-plate avalanche chamber with CsI photocathode under high-gain conditions at room temperature and 1 atm pressure. Different mixtures of He and Ar with hydrocarbons were tested, as well as with ethylferrocene vapor which are known to form an adsorbed photosensitive layer on the CsI photocathode. The chamber can reach high gains, up to 10^6, has a very good time resolution (500 ps FWHM), and an energy resolution of 8.2% FWHM for 3×10^3 primary photoelectrons with a quantum efficiency of the CsI photocathode of about 20% at 193 nm. Photon feedback, caused by avalanche emission with wavelength longer than 200 nm, was observed for large total charge and found to be nearly independent of the concentration of quencher in the range 7 to 70 Torr. Breakdown appears at a total charge of 10^{10} electrons and is always of the slow type. There is good proportionality up to the breakdown limit.

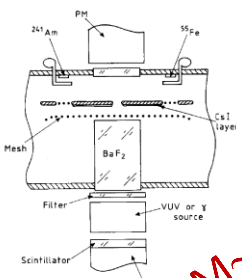

Fig. 1. Schematic view of the experimental setup.

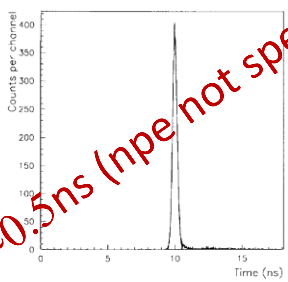

Fig. 7. Time resolution; the FWHM is 500 ps.

pp, FWHM~0.5ns (npe not specified)

1999

ELSEVIER
Nuclear Instruments and Methods in Physics Research A 449 (2000) 314–321
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.nl/locate/nima

Fast signals and single electron detection with a MICROMEGAS photodetector

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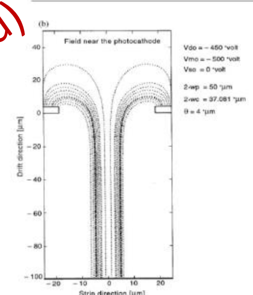
Received 3 December 1999; accepted 14 December 1999

Abstract

The performance of a new gaseous photodetector was investigated. It consists of a solid photocathode and a gas amplification structure of the MICROMEGAS type. Using a mixture of helium and isobutane at atmospheric pressure, a stable and high amplification gain close to 10^7 was achieved. Such a high gain and small fluctuations allowed the detection of single photoelectrons with a time resolution better than 700 ps. These performances are comparable with those obtained with the best photomultipliers.



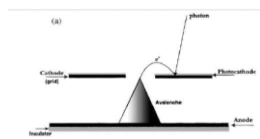


Fig. 1. (a) Principle of the photodetector in the reflective mode; (b) simulation of the electric field lines relevant for photoelectron collection.

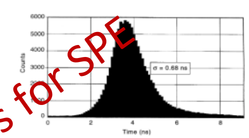


Fig. 11. Time distribution of the anode discriminated current signal of single photoelectrons for the CsI photoconverter.

mm, σ<0.7ns for SPE

2001

ELSEVIER
Nuclear Instruments and Methods in Physics Research A 483 (2002) 670–675
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

GEM photomultiplier operation in CF_4

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Received 17 July 2001; received in revised form 31 July 2001; accepted 1 August 2001

Abstract

The properties of a 3-GEM (Gas Electron Multiplier) element photomultiplier, with a semitransparent CsI photocathode and CF_4 gas filling, are presented. Compared to other gas mixtures, such as CH_4, Ar/CH_4, Ar/N_2 and $He/Ar/N_2$, CF_4 has superior performance: the highest gain, approaching 10^7, the fastest, 8 ns wide signal and the lowest photoelectron backscattering; the latter allows to reach photocathode quantum efficiency values approaching that in vacuum. The time resolution of the multi-GEM photomultiplier for single photoelectrons was measured to be 2 ns. These properties are of high relevance for applications in Cherenkov detectors and in tracking devices.

PACS: 29.40.C; 29.40; 85.60.G

Keywords: GEM; CF_4; Gaseous photomultipliers

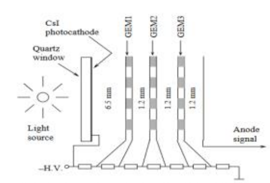

Fig. 1. A schematic view of the triple-GEM photomultiplier (GPM).

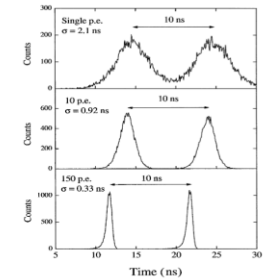

Fig. 6. Detector time resolution in CF_4. Time distributions of two groups of GPM anode pulses, delayed by 10 ns, with respect to the H_2 lamp trigger are shown. The distributions for 1, 10 and 150 photoelectrons released from the photocathode per light-pulse are shown. The data were measured at a gain of 1.2×10^6.

GEM, σ~2ns for SPE

.. But we want to go down to tens of ps…

RD51 Common Fund Proposal

Picosec collaboration

Request for Project Funding from the RD51 Common Fund
- Date: *20-05-2014*

Title of project: Fast Timing for High-Rate Environments: A Micromegas Solution

Contact persons: *Sebastian White (co-PI), Rockefeller/FNAL swhite@rockefeller.edu*
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3. *CERN, contact person, Leszek Ropelewsky*
Leszek.Ropelewski@cern.ch
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4. *Universidad deZaragoza, Diego González Díaz*
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Ext. Collaborators:

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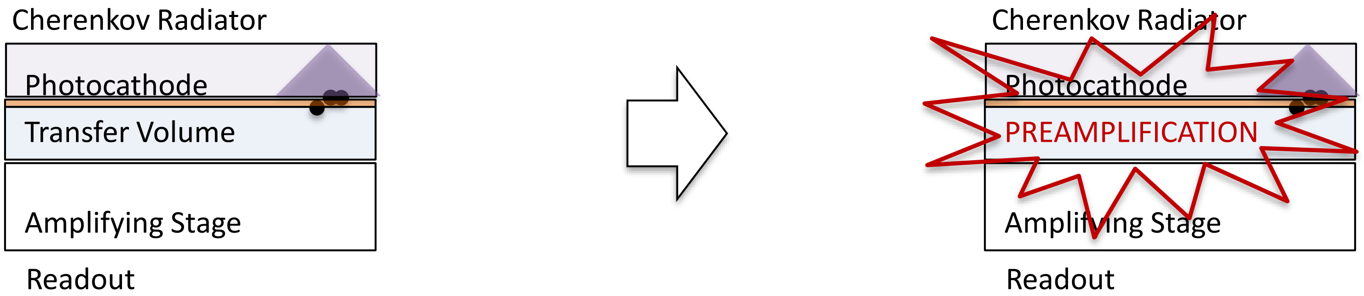
+ *Umesh Joshi (FNAL)*

2. *Princeton University, contact person K.T. McDonald,*
kirkmcd@princeton.edu
+ *Changguo Lu*

Approved by RD51 MB @ CERN on 30.01.2015

Timing with proportional counters
The Picosec concept



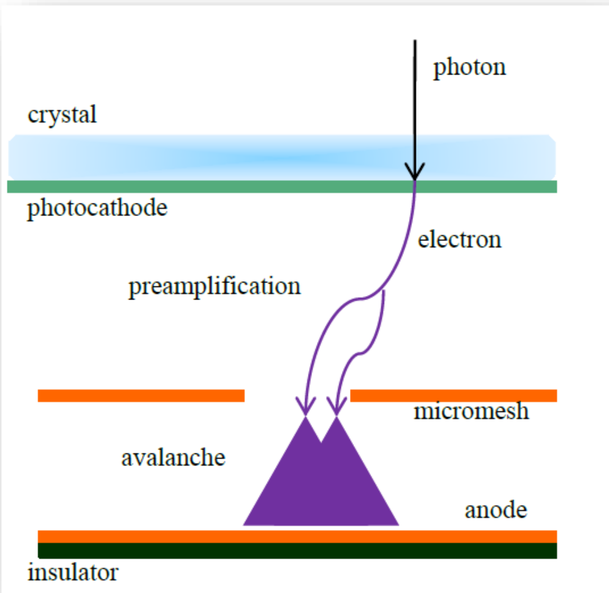
Sensitive volume reduced in order to:

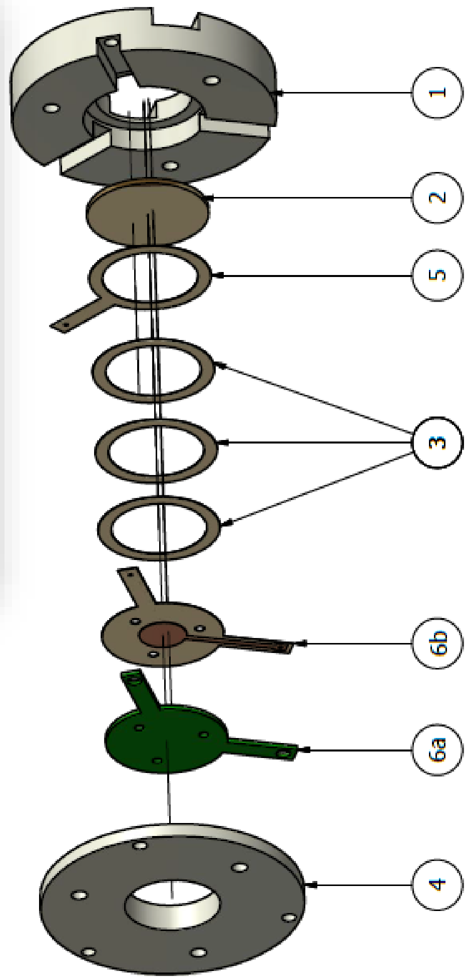
- Avoid direct gas ionization
- Reduce diffusion

Pre-amplification: direct gas ionization and diffusion effect even more reduced

First prototype

The first Picosec prototype (1cm diameter active area)





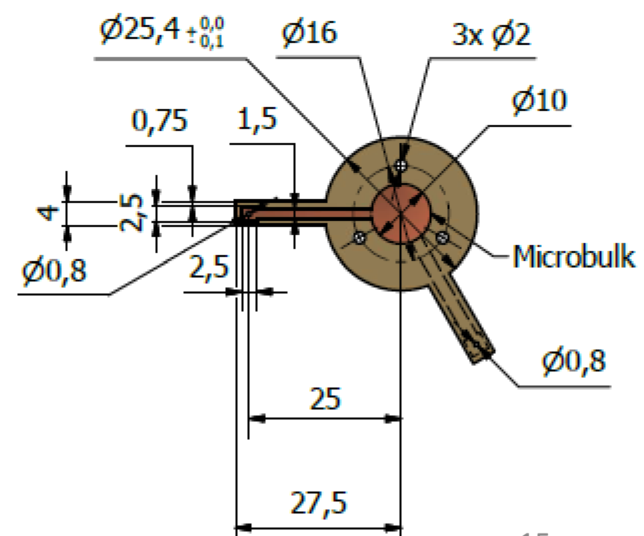
Montage Pico Seconde
Dossier de plans, Saclay

LISTE DE PIECES			
ARTICLE	QTE	NUMERO DE PIECE	DESCRIPTION
1	1	Support interne	
2	1	Cristal	
3	3	entretoise Kapton	
4	1	Support interne - couvercle	
5	1	Anneau alim cristal	
6 6a 6b	1	microbulk PCB Microbulk actif	

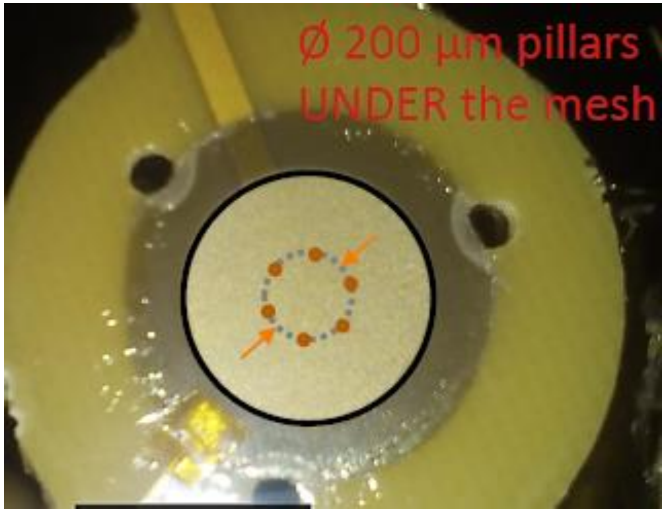
Tolérance générale: ±0.1 sauf indications spéciales

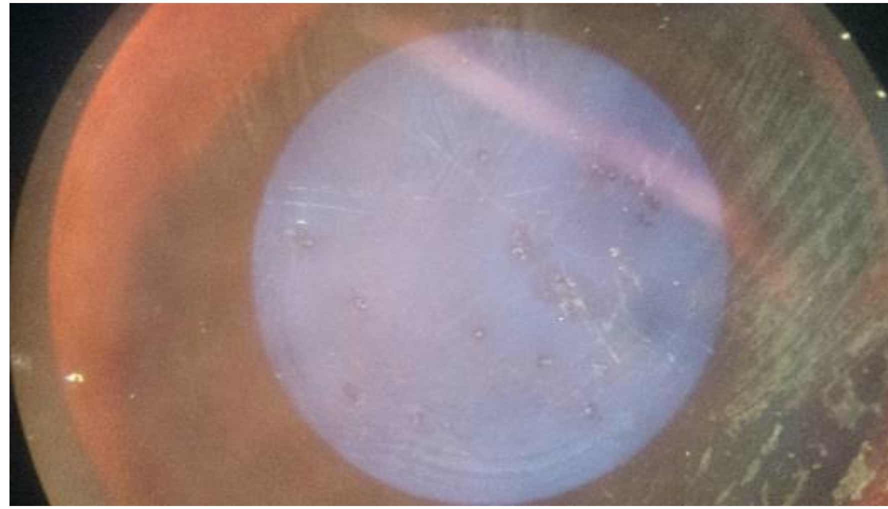
Conçu par	Vérifié par	Matière		Date	Quantité
Desforge	Beltramelli			21/05/2014	

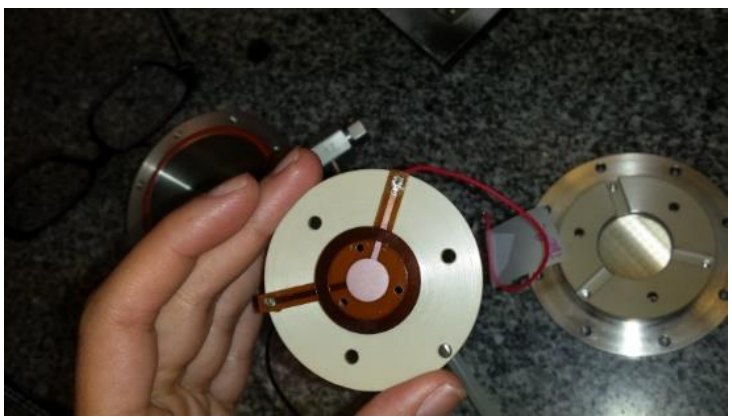
Pico Seconde	Capteur		
	Montage	Modification	Feuille 2 / 9

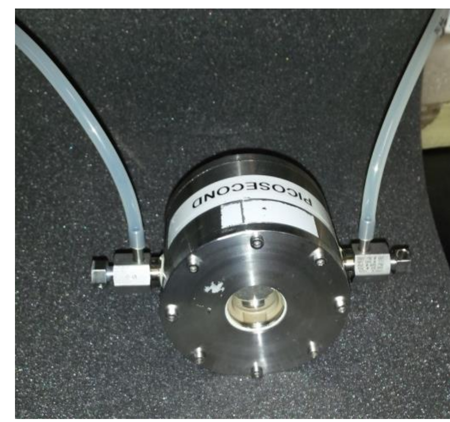


First prototype









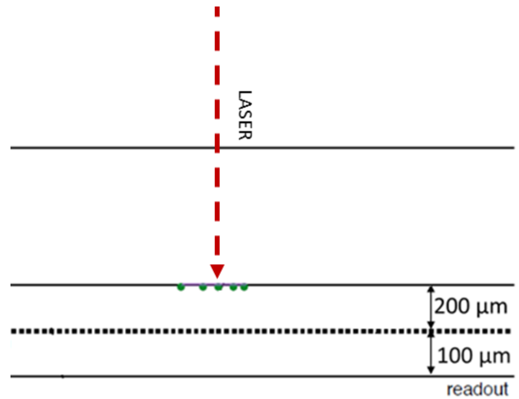
As a detector: pretty small
As a readout channel: <u>pretty large</u>

Measurements

- **Laser**

  IRAMIS facility @ CEA Saclay

  UV laser with σ_t << 100 fs

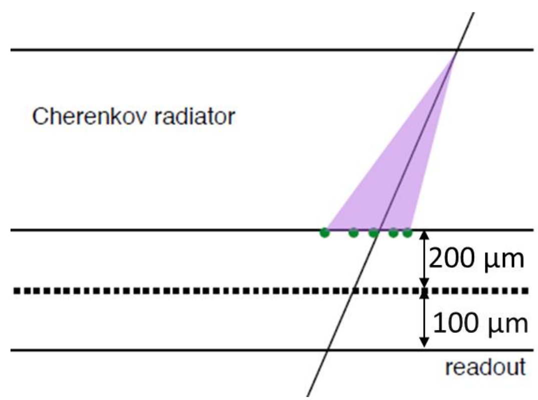


You forget about radiator and photo conversion. Just focused on n_{phe}, no matter how they are produced..
Main interest on n_{phe} =1

- **Muon Beam**

  H4 North Area SPS Extraction Line

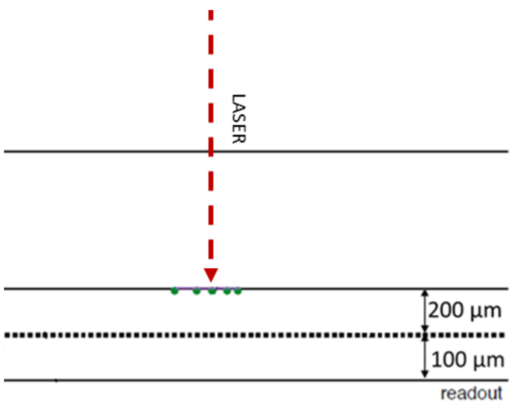
  150 GeV muons

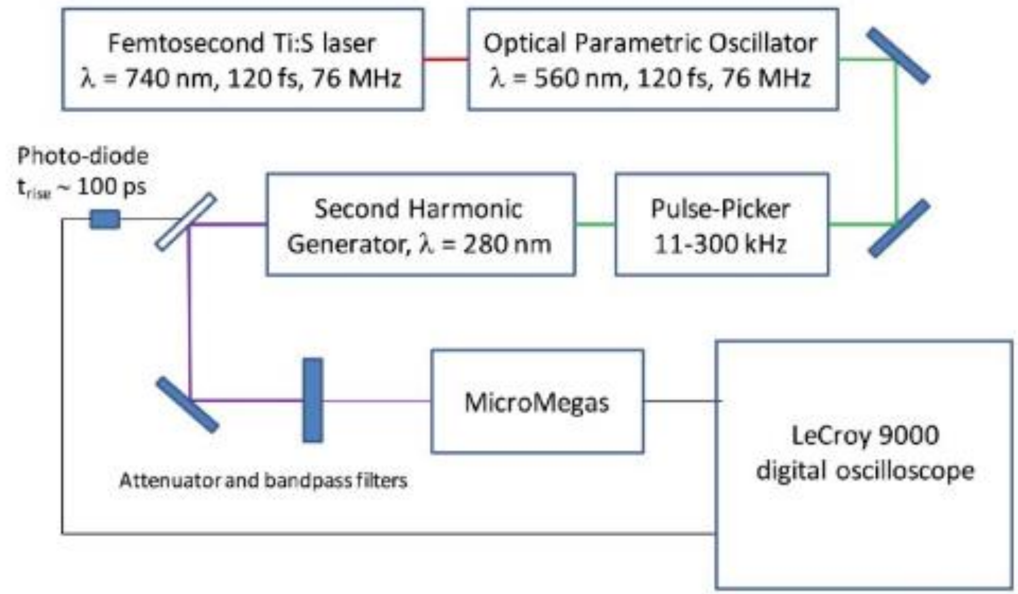


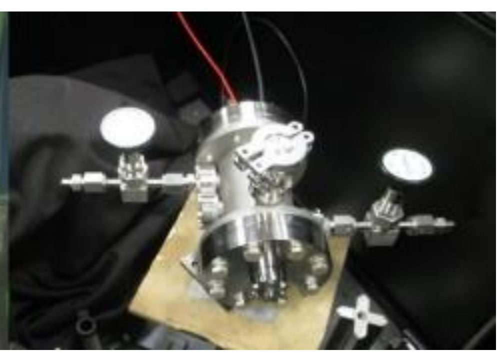
Cherenkov **production, transmission, conversion and pe extraction** in the business

Measurements - Single PE - Laser

IRAMIS facility @ CEA Saclay







First set of Laser Data (2015)

LIDyL laboratory (CEA/Saclay).
Ti:sapphire laser (Coherent MIRA 900) 120 fs pulses at 550 nm.
Ne-C2H6, 90-10

Al Cathode

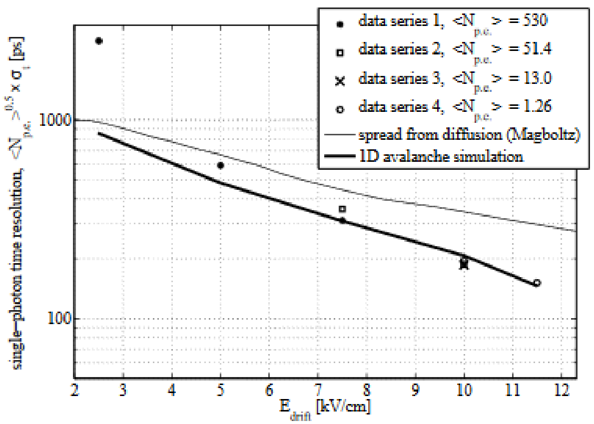


Figure 7. Dependence of the measured time resolution with the drift field, scaled to the single photoelectron case. The difference between the thin and thick lines indicates the improvement due to pre-amplification, according to a stochastic 1D avalanche model.

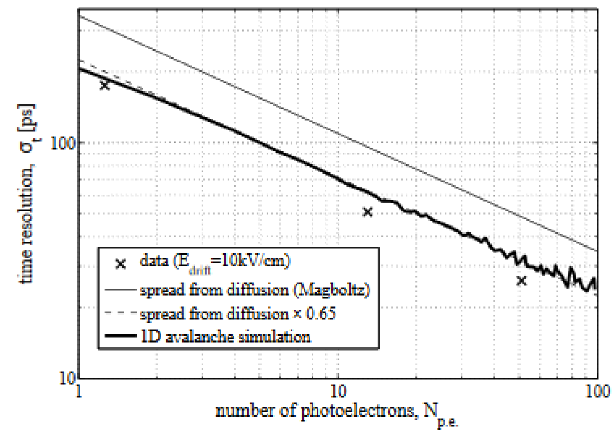
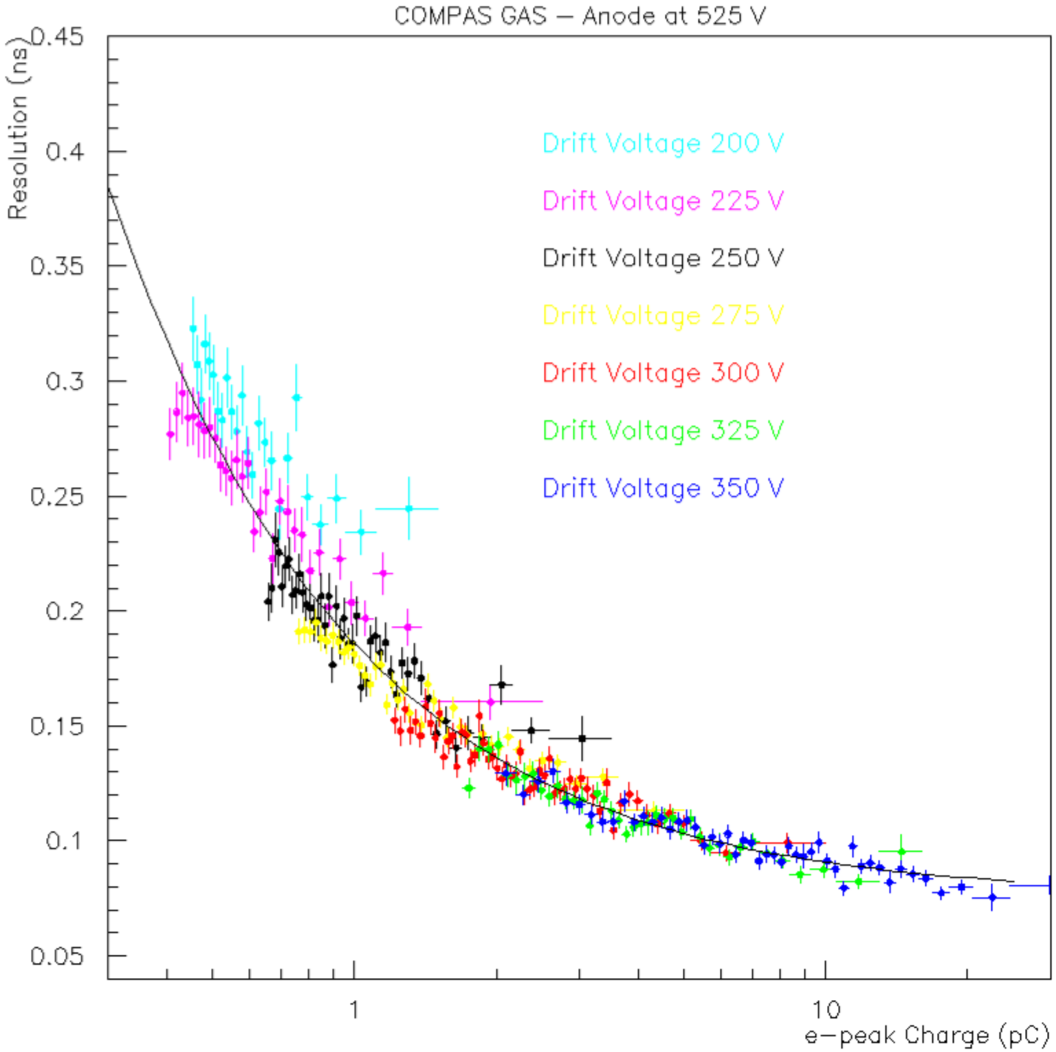


Figure 8. Dependence of the measured time resolution with the mean number of photoelectrons, for fixed amplification and drift fields. A resolution of 200 ps per single photoelectron and 27 ps for 50 photoelectrons has been achieved.

T. Papaevangelou et al. Fast Timing for High-Rate Environments with Micromegas, MPGD 2015 & RD51 Collaboration meeting, 12-17 October 2015 Trieste, Italy
https://agenda.infn.it/contributionDisplay.py?contribId=83&confId=8839
https://agenda.infn.it/getFile.py/access?contribId=83&sessionId=2&resId=0&materialId=paper&confId=8839

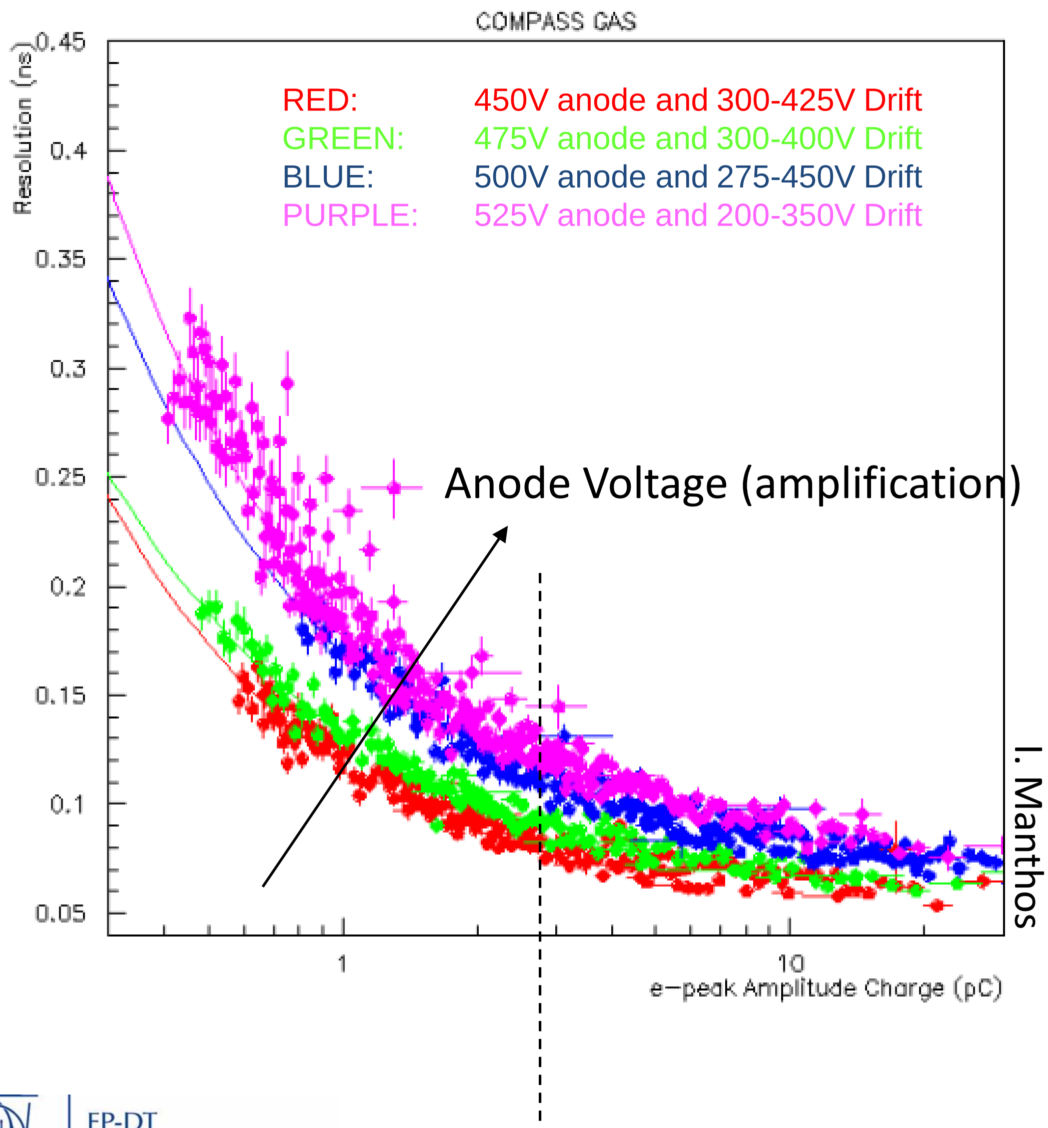
Laser Test (2017) - SPE



I. Manthos

Single-Photoelectron
Time Resolution

Laser Test (2017) - SPE

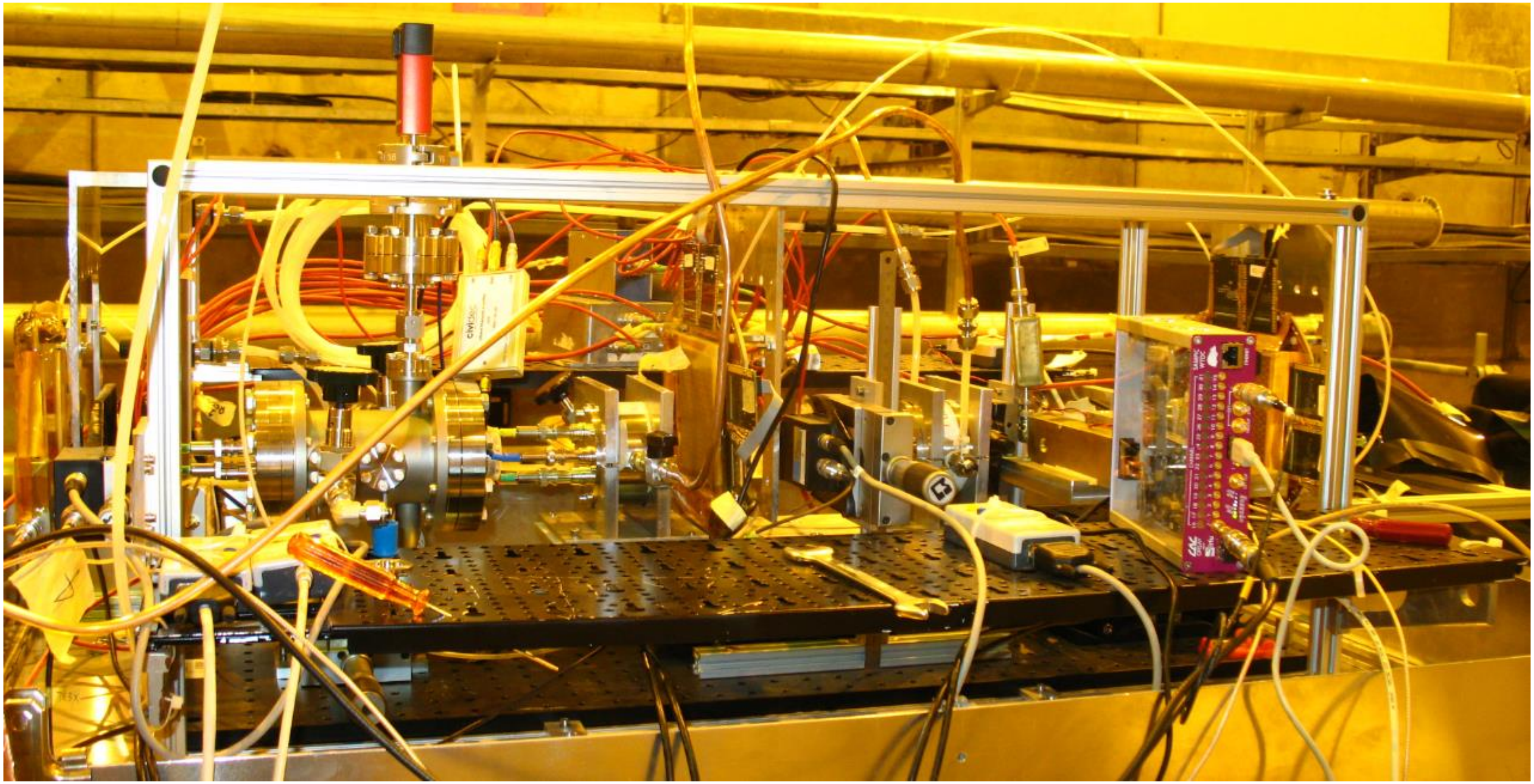


Single-Photoelectron Time Resolution

Given the same e-peak Amplitude Charge, Higher Anode Voltage (higher Amplification – lower Pre-amplification) has a worse energy resolution

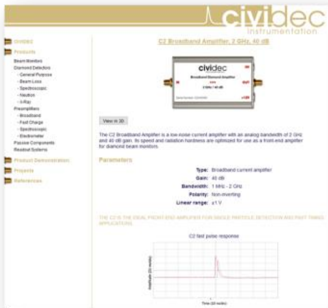
The pre-amplification drives the time resolution

Test beam measurement setup



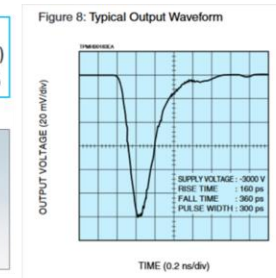
Test beam measurement setup

DATA ACQUISITION:
CIVIDEC C2 Broadband Amplifier, 2GHz, 40dB + 20Gs/s-2.5GHz Oscilloscope



WaveRunner 625Zi
2.5 GHz, 20 GS/s, 4ch, 16 Mpts/Ch DSO with 12.1" WXGA Color Display. 50 ohm and 1 Mohm Input. 40 GS/s and 32 Mpts/Ch in interleaved mode.

TIMING: MCP-PMT (<6ps time resolution measured on beam)

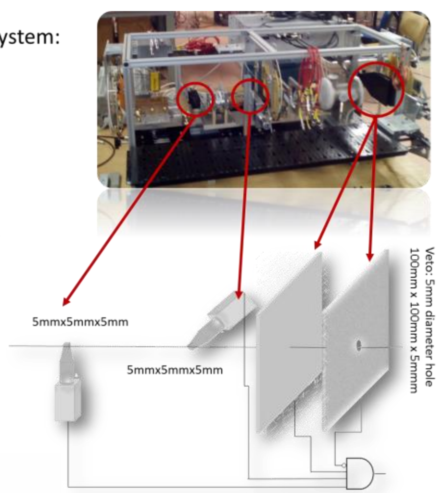


TRIGGERING: Scintillators

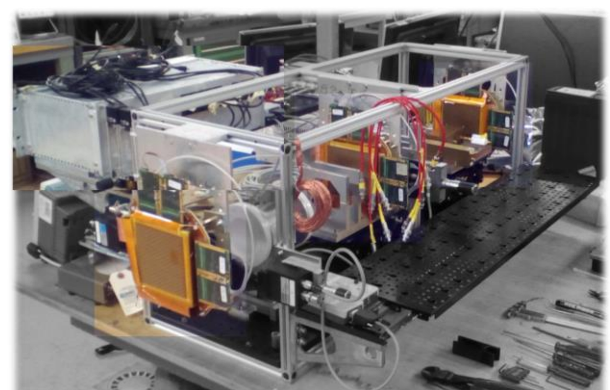
Triggering Scintillators System:

Efficiency measurement:
Triggering Area smaller than Detector Active Area

Single muon event selection:
Rejection of high multiplicity events (showers produced in our system) – VETO scintillator 5mm diameter hole

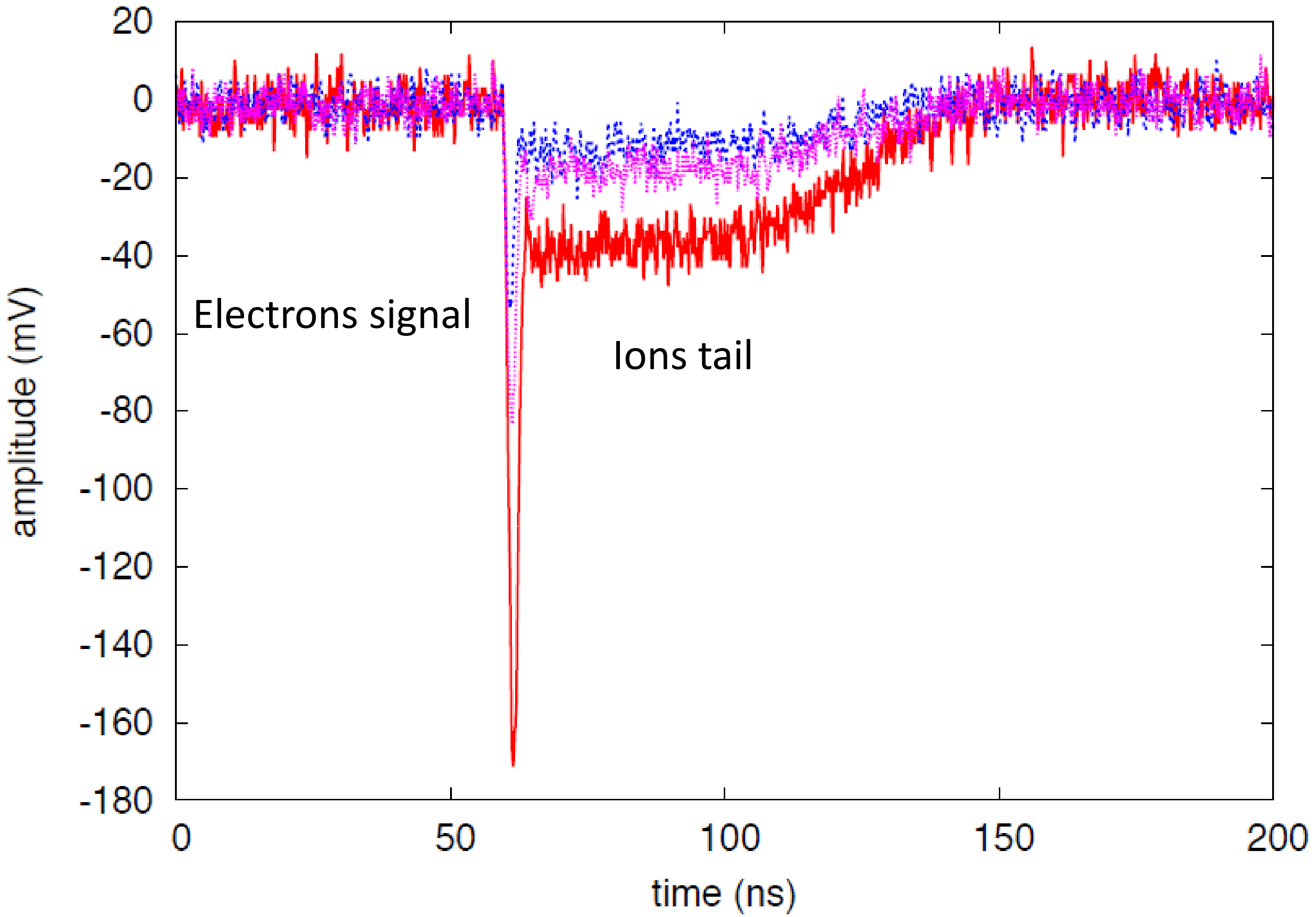


TRACKING: Triple GEM (50um resolution)

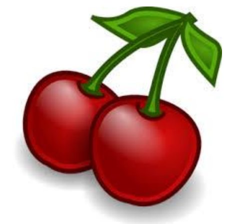


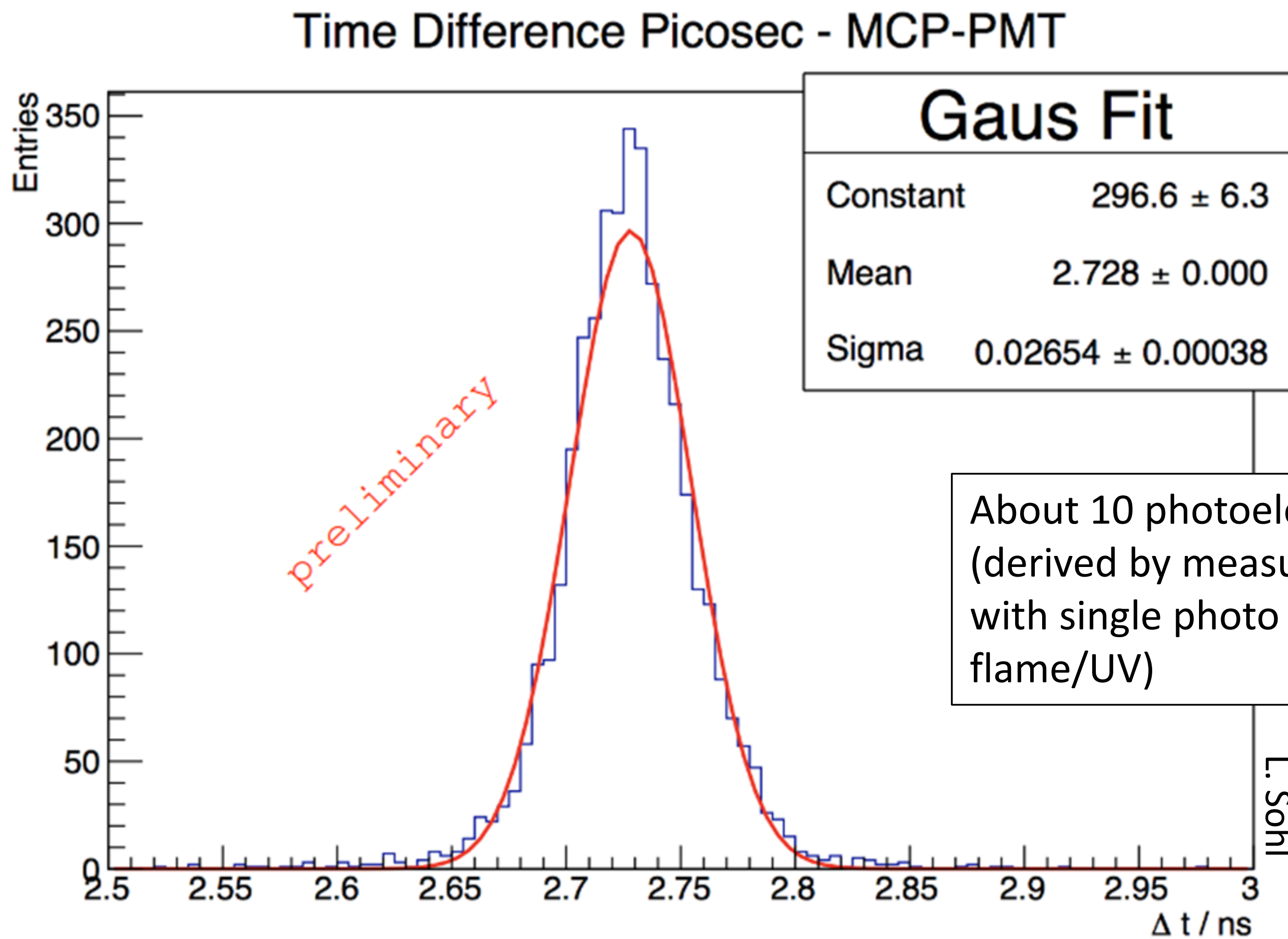
Three Triple GEM, XY readout, 400um pitch

Measurement – MIP(muons)



One of the best results achieved among the run analyzed…

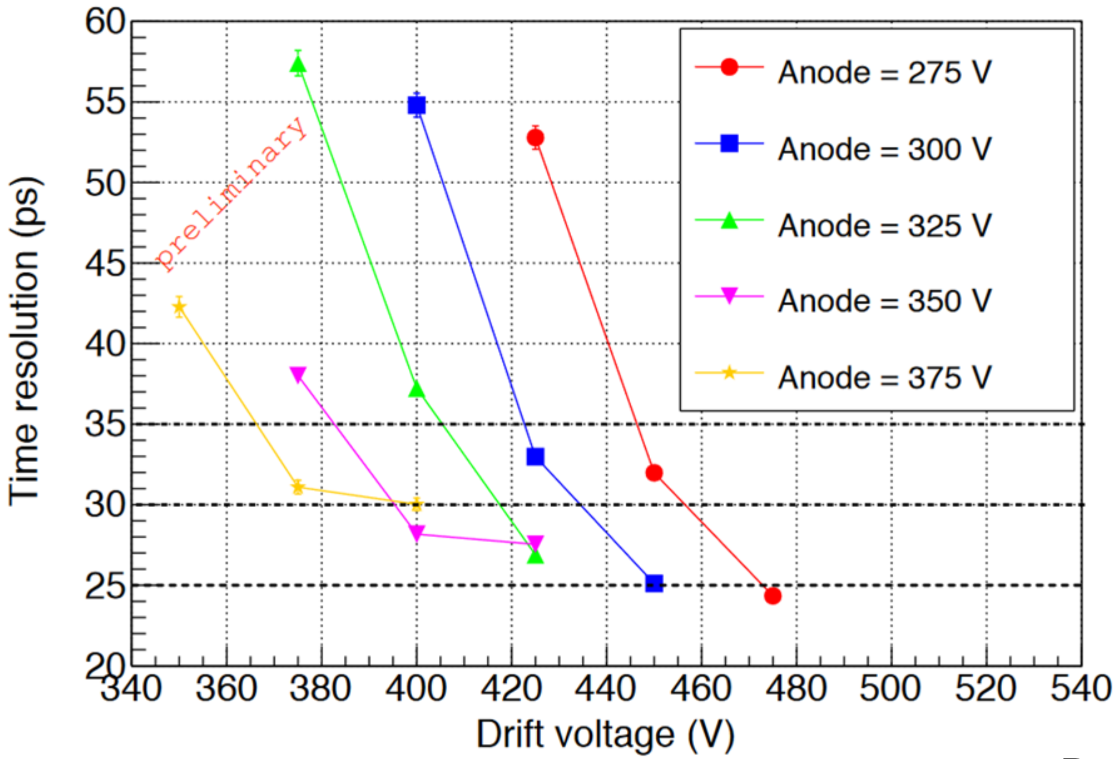




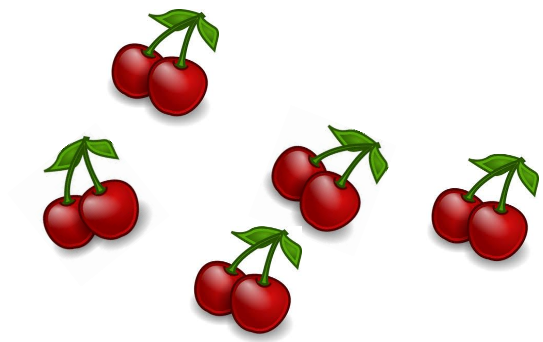
About 10 photoelectrons (derived by measurements with single photo electron flame/UV)

New Bulk MM readout
3 mm MgF2 + 5.5nmCr + 18nm CsI
Drift = -425V, Anode=+325V

Cherry picking… but we are not in front of a single cherry….



F.J.I. Gutiérrez



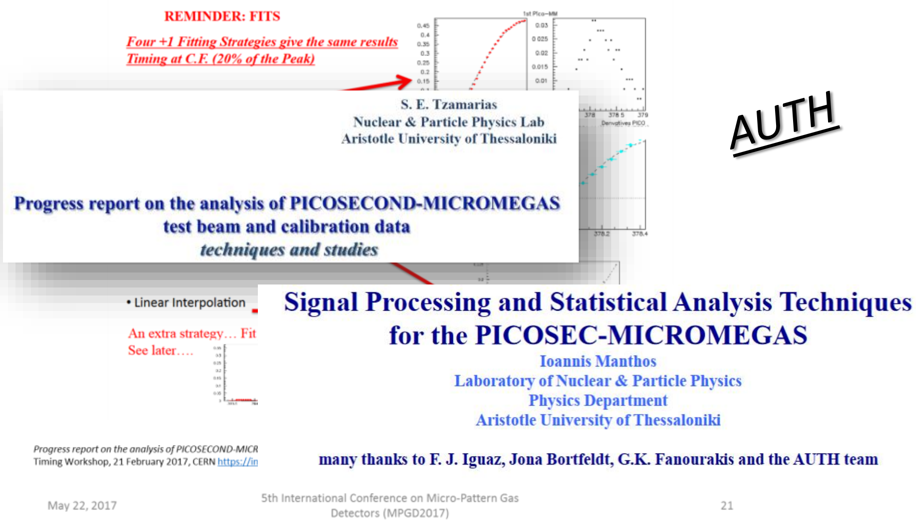
many Data still to be analysed …

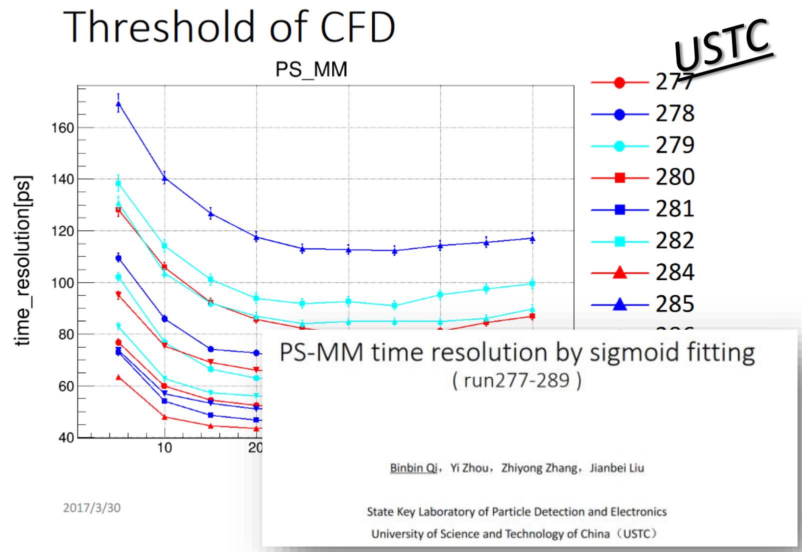
New Bulk MM readout

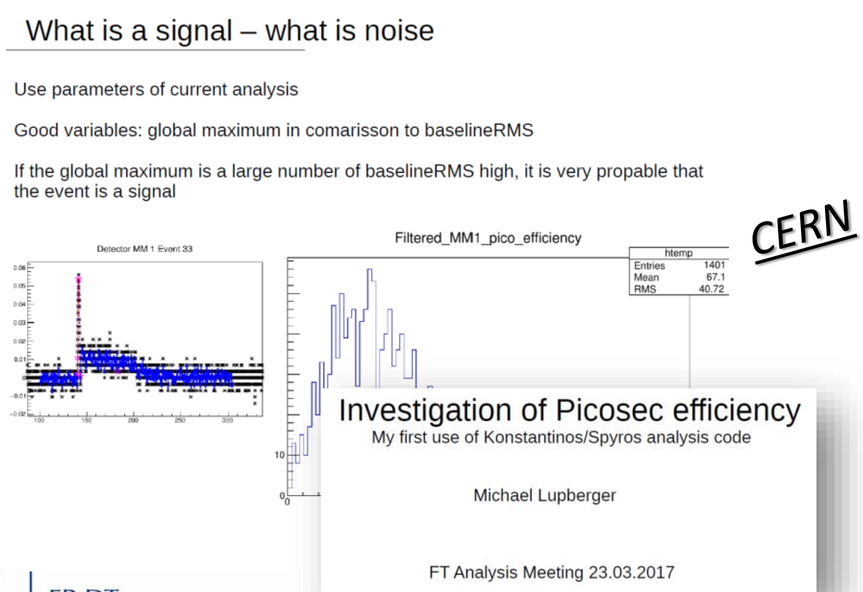
3 mm MgF_2 + 5.5nmCr + 18nm CsI

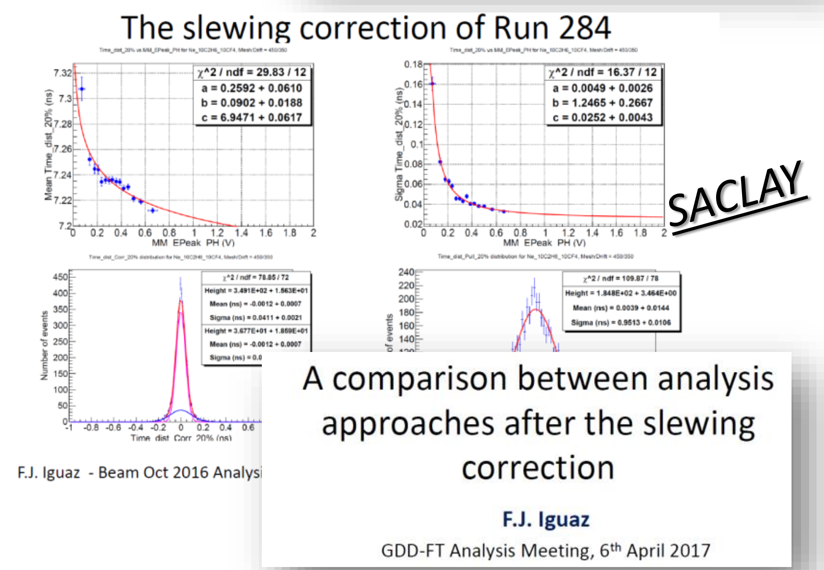
Signal Processing and Data Analysis

(“fairness towards the detector”.. S. Tzamarias..)





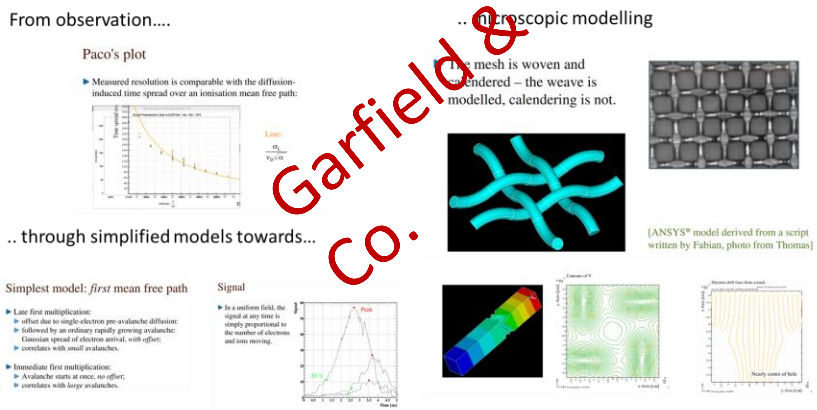




Detector Modelling

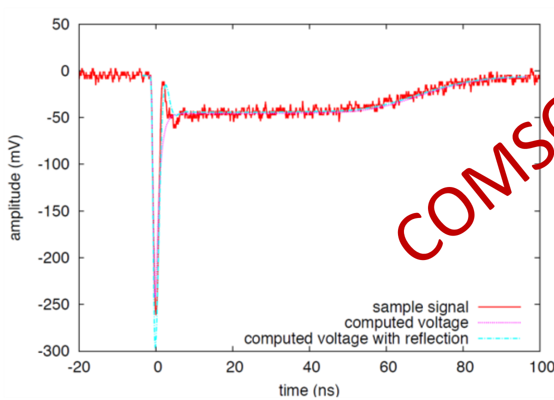
(i.e. detector understanding)

Detector Modelling: microscopic modelling (R. Veenhof)



Garfield & Co.

Development of simulations of the induced signals

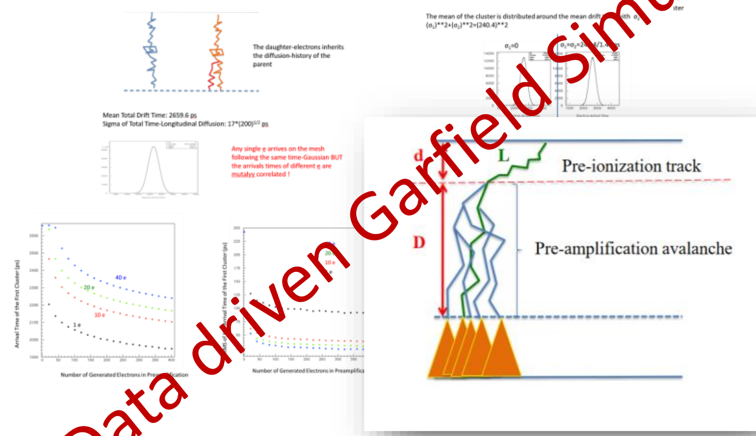


COMSOL

F. Resnati, Internal GDD-FT Joint Meeting

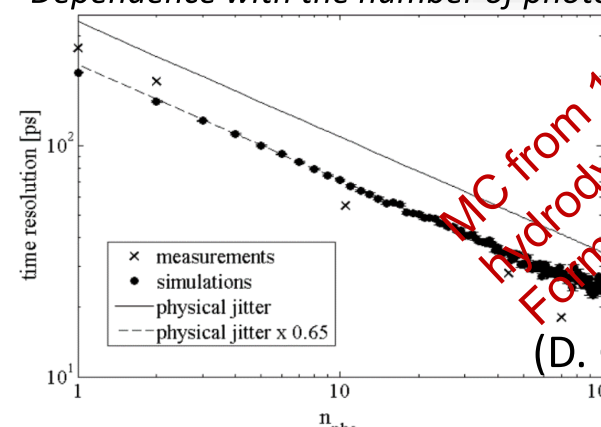
(F. Resnati)

Detector Modelling: Data driven MC (S. Tzamarias, K. Paraschou)



Data driven Garfield Simulation

Dependence with the number of photoelectrons



MC from 1D hydrodynamic Formalism

https://indico.cern.ch/event/607147/contributions/2476949/attachments/1416536/2169035/TimingWorkshop2.pdf

(D. Gonzalez-Diaz)

Magboltz (hydro input) + COMSOL (hydro average solution) + MATLAB (hydro stochastic solution)

Ongoing/Future activities on…

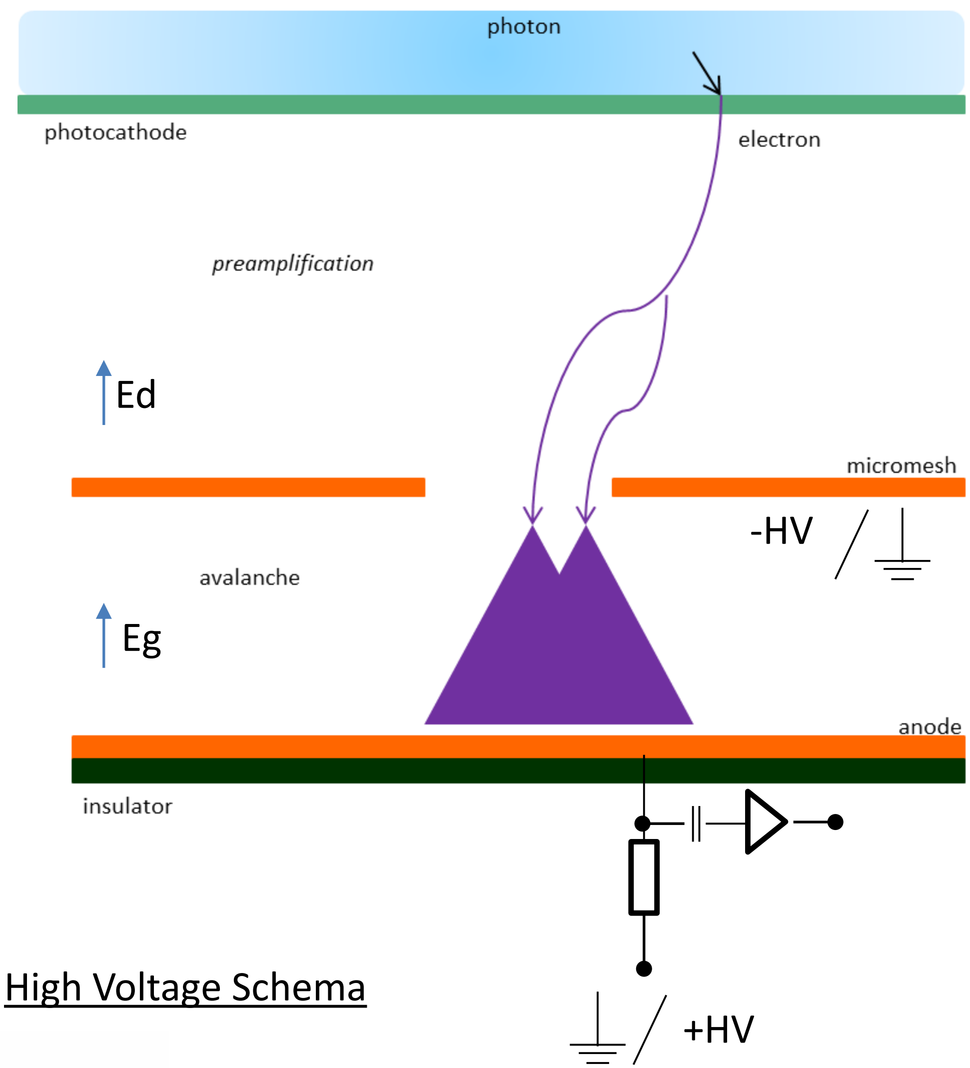
- Optimization (get as much as we can…)
- Use of techniques and technologies proven to be effective for more reliable/robust detector…
- Scale up and prove that we can preserve what we have…
- Electronics…
- Longevity… *photocathode*

Optimization

A large number of degree where we can easily play…
(typical of these technologies)

Crystal:

-Different Thicknesses of MgF_2 (2,3,5mm)
-Different Material



Photocathode:

CsI and different:
-producer (CERN, Saclay, Hamamatsu)
-thicknesses (11, 18, 25, 36nm)
-metallic interface (Al, Cr)
-metallic interface thicknesses (Cr 3,5.5nm)
-Metallic

Al(8nm), Cr (10,15,20nm)

Diamond, B-doped Diamond on Cr

Gas Mixture

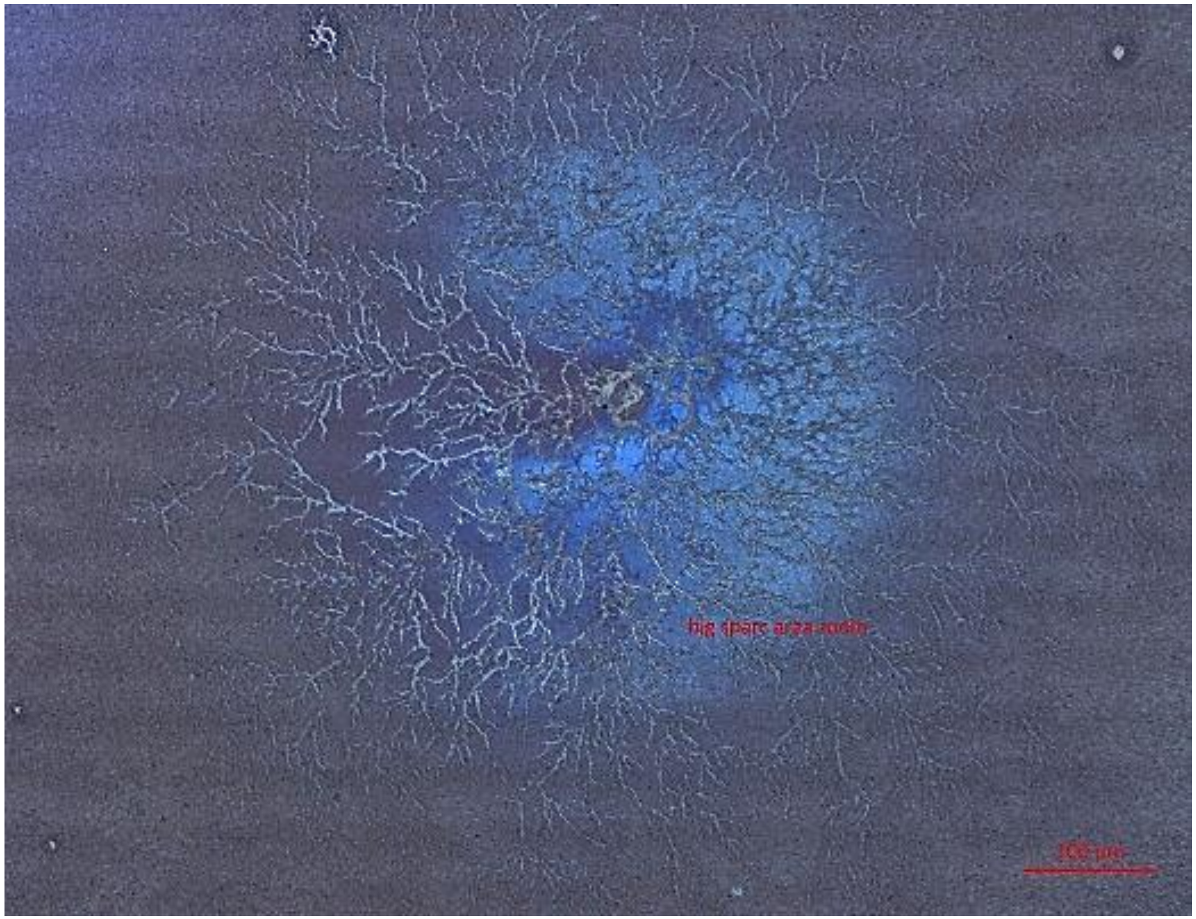
Electric Fields

Mesh:

-standard bulk
-bulk with reduced number of pillars
-thin mesh
-micro-bulk (laboratory tests)

High Voltage Schema

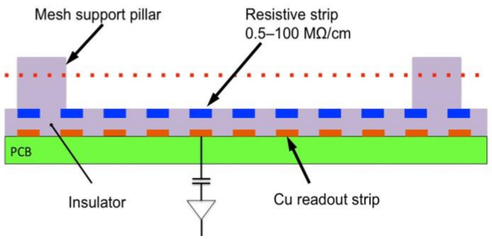
Photocathode: Picture of a sparks



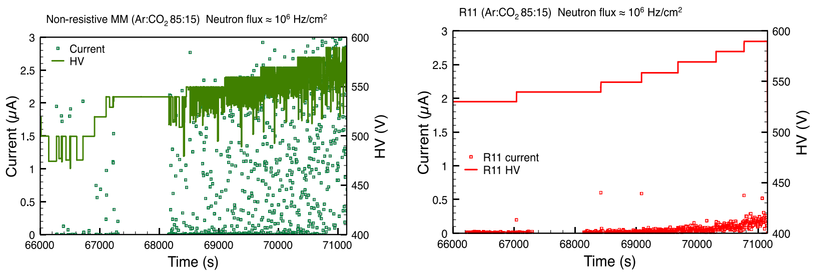
Picosec (T. Schneider)

Robustness/Reliability

ATLAS New Small Wheel - MicroMegas (J. Wotschack et al.)



G. Iakovidis, arXiv:1310.0734v1 [physics.ins-det] 2 Oct 2013



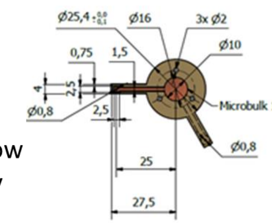
Nuclear Instruments and Methods in Physics Research A 640 (2011) 110–118

A spark-resistant bulk-micromegas chamber for high-rate applications

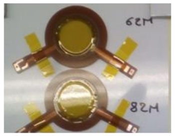
T. Alexopoulos [a], J. Burnens [b], R. de Oliveira [b], G. Glonti [b], O. Pizzirusso [b], V. Polychronakos [c], G. Sekhniaidze [d], G. Tsipolitis [a], J. Wotschack [b,*]

Resistive mesh / photocathode protection…. ?

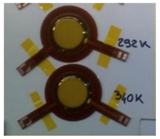
- A: Resistive plane a la "mamma"
  - Better protection
- B: Discrete Resistors a la "compass RICH" (Trieste)
  - Larger flexibility on resistor value
- C: Embedded Resistors a la "Chefdeville-Geralis-Peskov"
  - Tested using low resistivity plane a la "mamma" with discrete resistor a la "compass RICH"



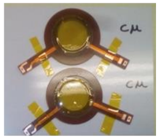
Type A, High Resistivity



Type A, Low Resistivity



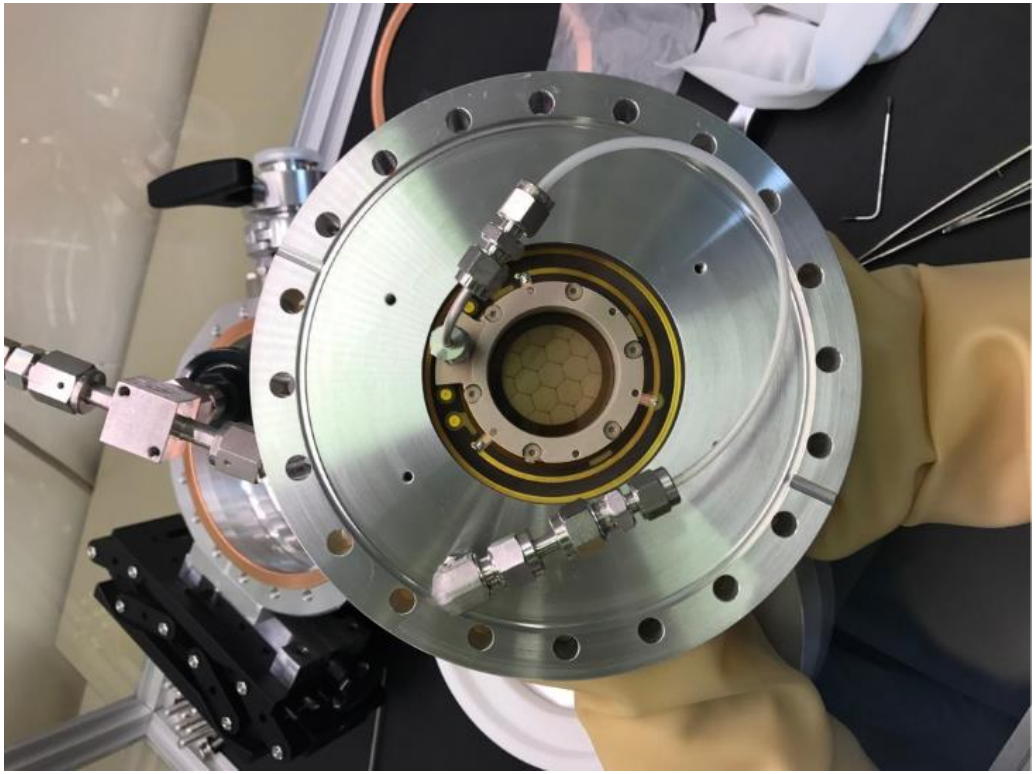
Type B, Discrete resistors



CERN MPT Workshop (A. Texteira et al.)

- Spark damage and spark rate minimized
- Capability f running in high rate pion beam in SPS
- Time resolution slightly worse

MultiPad Picosec



preserving the signal integrity and stability with ***larger meshes***

preserving the ***gaps uniformity*** on larger surfaces

…

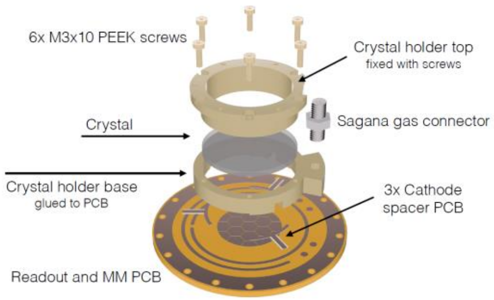
preserving signal integrity with routing/vias/…
coupling between channels and S/N

….

Scaling up

MultiPad Picosec

Detector assembly

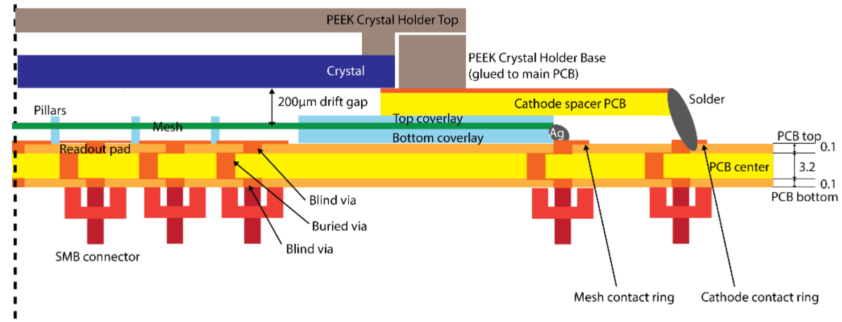


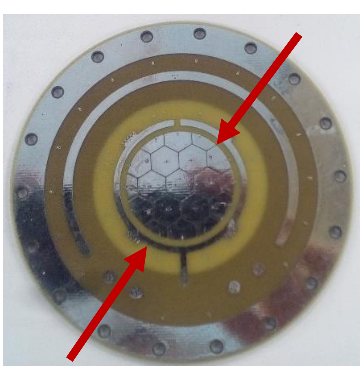
multiPad picoSec

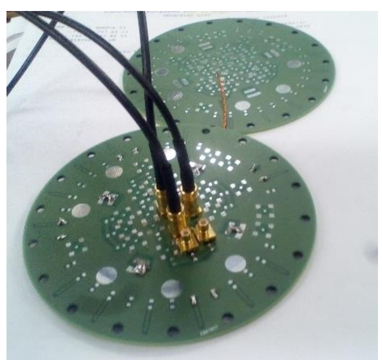
Design details and production reference

Florian M. Brunbauer

on behalf of the GDD group
May 9, 2017

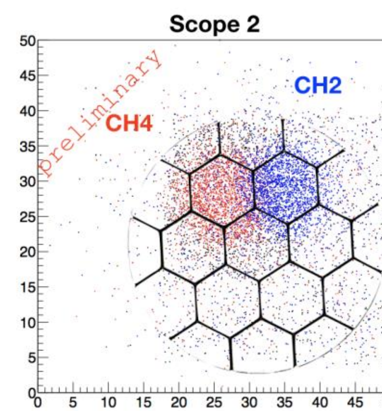






~35mm Active area, 19 pads (7 full size)

- First Measurement in August with a larger drift gap
  - Good quality of Signal Shape
  - No crosstalk
  - Time Resolution twice worse (due most likely by the larger drift – to be tested)
- Next week measurements n beam with same gaps as in prototype to verify the resolution



L. Sohl

Electronics
…going towards integrated/multichannel…

2018 (and beyond..) Picosec Electronics

- Amplifier

For single channel readout more than happy with CIVIDEC and with their important support.. Not feasible for multichannel readout

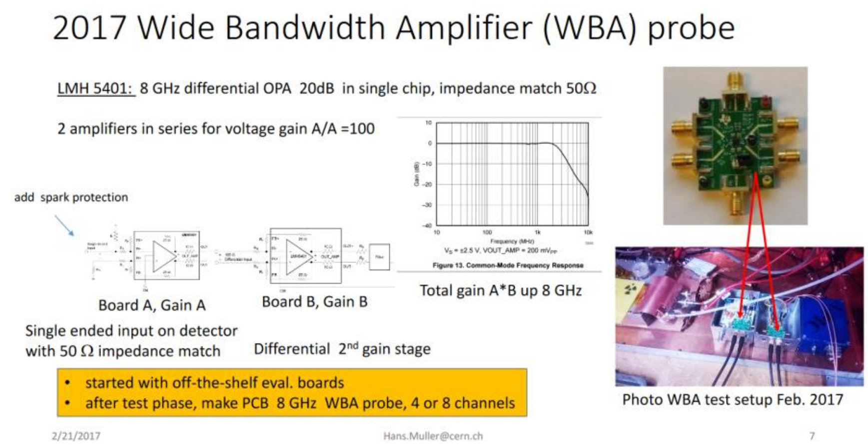
  – Custom (CERN/RD51)
  – Custum/Embedded Electronics (Saclay)
  – Multichannel.. Far future…

- Digitizer

Oscilloscope… same comment as for CIVIDEC

  – SAMPIC
  – …

- …



H. Muller, Precise Timing Workshop, Feb 2017
https://indico.cern.ch/event/607147/contributions/2476905/attachments/1415650/2398258/Plans_fast_electronics_for_MPGD.pdf

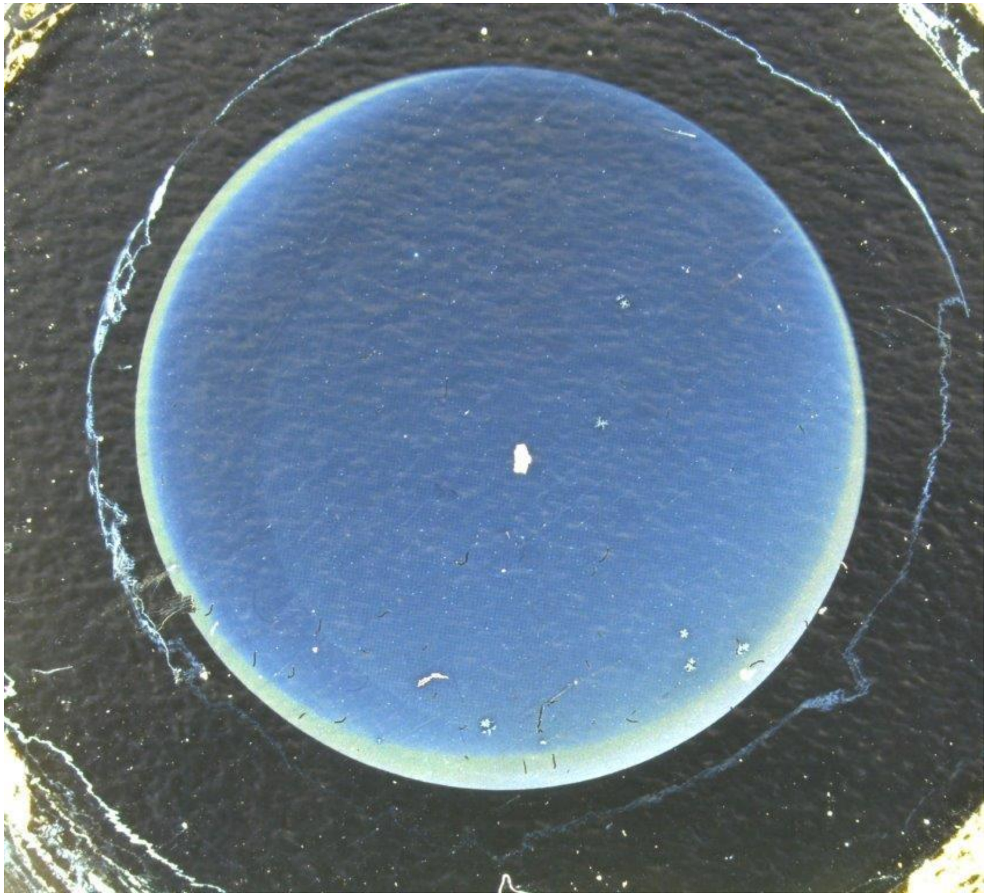
SAMPIC: PERFORMANCE SUMMARY

		Unit
Technology	AMS CMOS 0.18µm	
Number of channels	16	
Power consumption (max)	180 (1.8V supply)	mW
Discriminator noise	2	mV rms
SCA depth	64	Cells
Sampling speed	1 to 8.4 (10.2 for 8 channels only)	GSPS
Bandwidth	1.6	GHz
Range (unipolar)	~ 1	V
ADC resolution	7 to 11 (trade-off time/resolution)	bits
SCA noise	< 1	mV rms
Dynamic range	> 10	bits rms
Conversion time	0.1 (7 bits) to 1.6 (11 bits)	µs
Readout time / ch @ 2 Gbit/s (full waveform)	450	ns
Single Pulse Time precision before correction	< 15	ps rms
Single Pulse Time precision after time INL correction	< 3.5	ps rms

Status of development on the SAMPIC Waveform TDC, D. Breton, RD51 precise Timing Workshop, 21-22 February 2017, CERN,
https://indico.cern.ch/event/607147/contributions/2476911/attachments/1415361/2168327/SAMPIC_RD51_Breton.pdf

Longevity (photocathode)

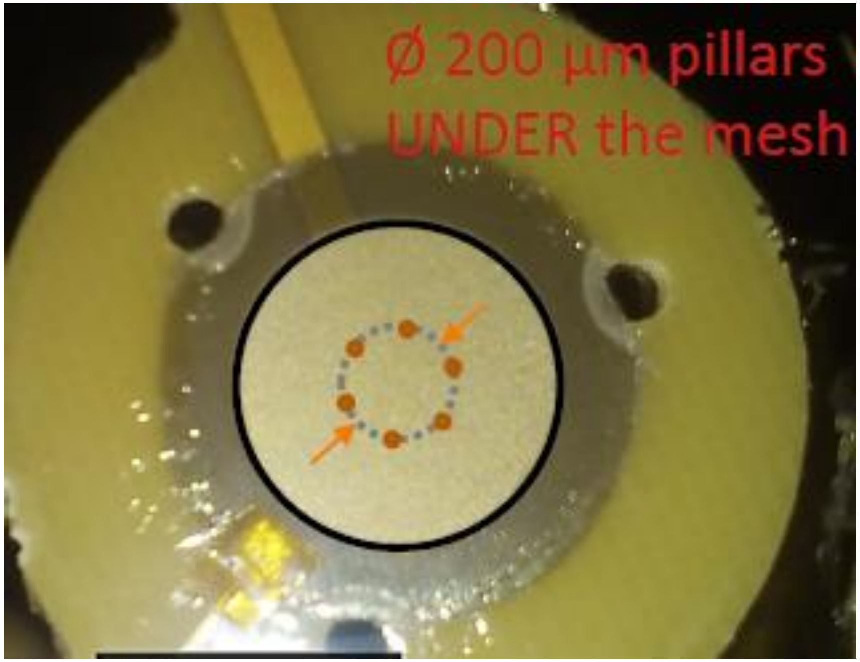
(not necessary a serious problem in all the possible application requiring fast timing but to be addressed clearly in the high rate ones)



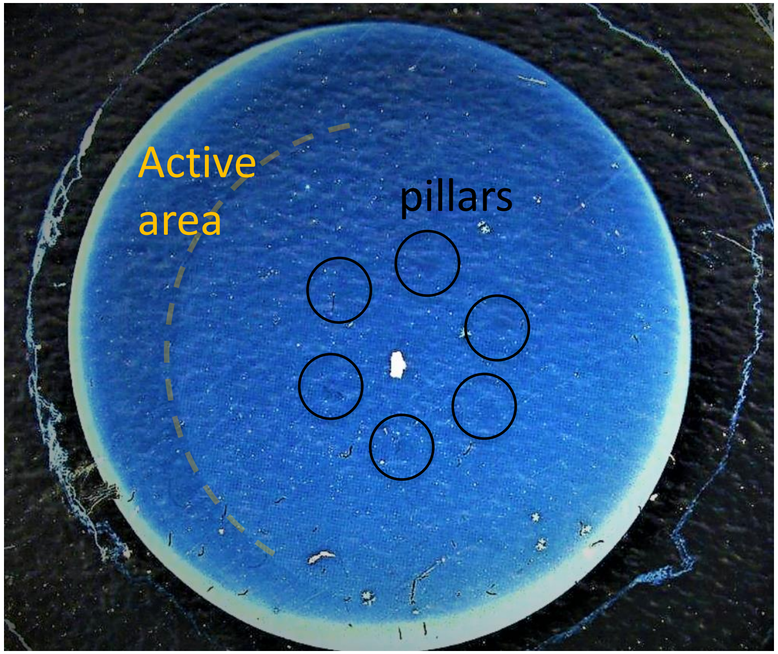
Self Portrait of Picosec micromegas, Prevessin-Moen, 2017

Photocathode:

Self Portrait of Picosec micromegas, Prevessin-Moen, 2017



Resistive Picosec
Long run in high intensity pion beam
About 0.1-0.2mC/cm2
air exposed to take the picture



Misalignment
Mesh structure
Pillar

Photocathode CsI protection

CsI Protection Layers

Protection Layers (looking for new materials and protective structures… starting from literature – Va'vra[WIS] https://cds.cern.ch/record/287770/files/SCAN-9509070.pdf just as an example)

Under Investigation

Dielectric Coating

WIS-96/2/Jan.-PH

Photoemission through thin dielectric coating films

A.Buzulutskov *, A.Breskin and R.Chechik,
Department of Particle Physics
The Weizmann Institute of Science, 76100 Rehovot, Israel

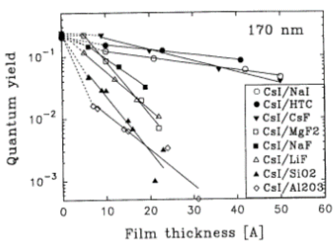
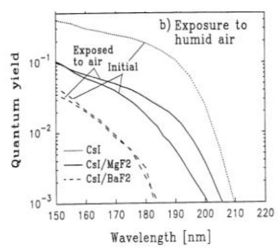
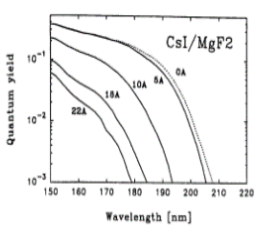


Fig.9





http://cds.cern.ch/record/315752/files/SCAN-9611227.pdf

Graphene Layers (P.Thuiner, CERN)

Graphene Shield Enhanced Photocathodes and Methods for Making the Same
US 20130293100 A1

ABSTRACT

Disclosed are graphene shield enhanced photocathodes, such as high QE photocathodes. In certain embodiments, a monolayer graphene shield membrane ruggedizes a high quantum efficiency photoemission electron source by protecting a photosensitive film of the photocathode, extending operational lifetime and simplifying its integration in practical electron sources. In certain embodiments of the disclosed graphene shield enhanced photocathodes, the graphene serves as a transparent shield that does not inhibit photon or electron transmission but isolates the photosensitive film of the photocathode from reactive gas species, preventing contamination and yielding longer lifetime.

Publication number	US20130293100 A1
Publication type	Application
Application number	US 13/886,517
Publication date	7 Nov 2013
Filing date	3 May 2013
Priority date	7 May 2012
Also published as	US8823259
Inventors	Nathan Andrew Moody
Original Assignee	Los Alamos National Security, Llc
Export Citation	BiBTeX, EndNote, RefMan

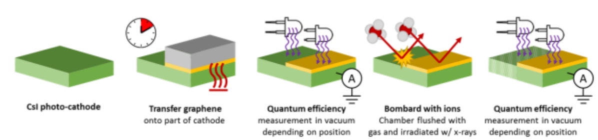
Patent Citations (4), Referenced by (3), Classifications (4), Legal Events (2)

External Links: USPTO, USPTO Assignment, Espacenet

Photo-cathode protection
Ongoing study

Degradation of photo-cathodes' **quantum efficiency** during operation with time due to **ion bombardment**

Graphene as **protective layer** transferred onto photo-cathodes



Thin Film & Glass Lab (CERN), T. Schneider …

Photocathode – searching for alternatives

- Photocathode: Saclay (Pomorski et al) … preliminary test doe already on beam

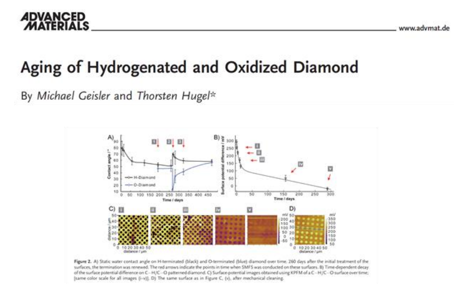
- Photocathode: Russian Academy of Sciences, Moscow (Mikhail Negodaev) PC production ready to go after specs defined more precisely by us.

Diamond Coatings – Material Science

Mikhail Negodaev, Russian Academy of Sciences (RU)

Surface Treatment (lowering work function): hydrogenation (hydrogen absorption).

The sample with hydrogenation of surface can be stored on air, but not a long time (for some weeks). The kinetics of the loss of hydrogen at room temperature during the year, see Fig. 2 of article (in attachment).



Diamond Doping:

Nitrogen doping is possible in the CVD process, however, they note that the donor level of nitrogen is 1.7 eV (can not be activated at room temperature).

Boron Doping not possible

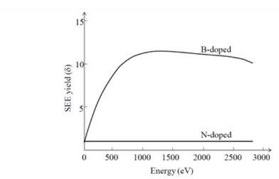


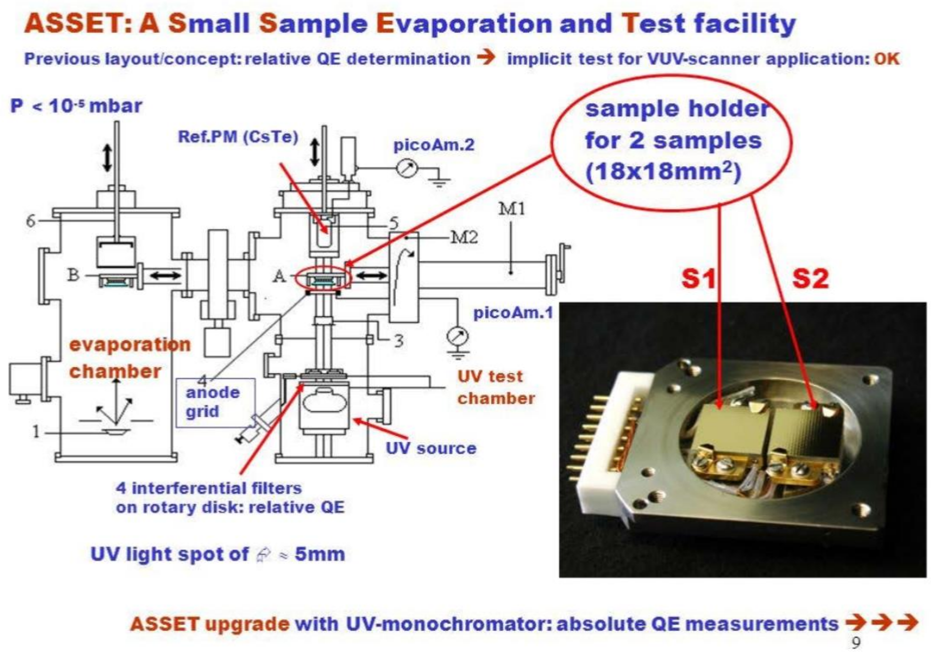
Figure 1.14- SEE yield δ obtained from an N-doped diamond film in comparison with a B-doped film with resistivity in the range of 50-170 kΩ cm, both H-terminated.[122]

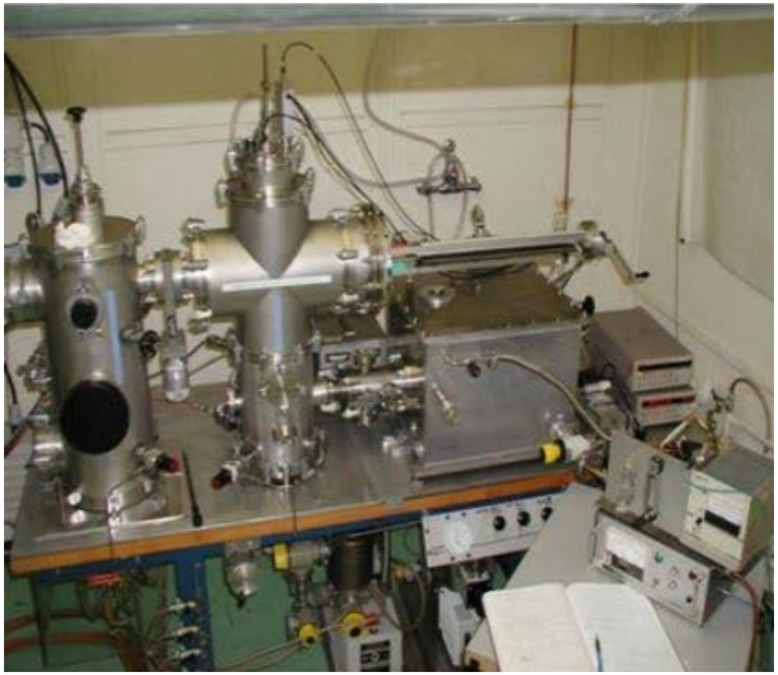
http://www.chm.bris.ac.uk/pt/diamond/raquelthesis/Raquel-Vaz-PhD-thesis.pdf

- DLC (Yi)

- Metals,… MgO,….

Setup to characterize photocathodes performances





ALICE set up for photocathode evaporation/testing

timetable

2014	2015	2016	2017
Proposal Submission	First Prototype and laser test	New Prototypes, laser tests and measurements with charged particles (test beam campaign)	Resistive micromegas prototypes, Multi-channel anode and larger area, photocathodes (CsI protection, Diamond,..), New electronics

- *Successful measurement campaigns in 2016*
  - *Less than 50ps - "100%" efficient (MIPs) - achieved with CsI and about 10pe*
- *Modelling and data analysis successfully going on*
- *R&D (not exclusively Picosec related) on*
  - *Intrinsic limit*
  - *Detector Optimization (**new photocathodes, protection layer, secondary emitter**,.., resistive mm)*
  - *Detector Scaling.. Larger area and multi channel..*
  - *Electronics*

References

- *Fast Timing for High-Rate Environments with Micromegas*, T. Papaevangelou, MPGD 2015 & RD51 Collaboration meeting 12-17 October 2015 Trieste – Italy https://agenda.infn.it/contributionDisplay.py?contribId=83&sessionId=2&confId=8839 , https://arxiv.org/abs/1601.00123

- *RD51–H4 –May/June 2016 Test beam,* M Lupberger, RD51 Mini-Week 6-9 Jun 2016, CERN https://indico.cern.ch/event/532518/contributions/2195706/attachments/1287366/1915899/PicosecondeTestBeam.pdf

- *Report on PICOSEC Beam tests* , S. White, MPGD Applications Beyond Fundamental Science Workshop and the 18th RD51 Collaboration Meeting, Aveiro, Portugal, 12-16 September 2016 https://indico.cern.ch/event/525268/contributions/2298965/attachments/1335651/2008896/aveiroSeb.pdf

- *Picosec: test beam summary and outlook*, F. Resnati, MPGD Applications Beyond Fundamental Science Workshop and the 18th RD51 Collaboration Meeting, Aveiro, Portugal, 12-16 September 2016 https://indico.cern.ch/event/525268/contributions/2297868/attachments/1336635/2010819/testBeam.pdf

- *(Ultra-) Fast tracking of Minimum Ionizing Particles with a Micromegas detector*, T. Papaevangelou, 14th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD16) 3 - 6 October 2016 Siena, Italy http://www.bo.infn.it/sminiato/sm16/04_Giovedi/Mattina/10_Papaevangelou.pdf

- *A picosecond Micromegas EUV photodetector*, T. Papaevangelou, 8th symposium on large TPCs for low-energy rare event detection, 5-7 December 2016, Paris https://indico.cern.ch/event/473362/contributions/2317653/attachments/1384392/2105987/TPapaevangelou_MM_PicosecondPhotodetector.pdf

- A progress report on the analysis of pico-MM test beam data, S. Tzamarias, RD51 Mini-Week 12-15 Dec. 2016, CERN https://indico.cern.ch/event/588409/contributions/2403609/attachments/1388584/2114309/PICO-MM.pdf

- *Precise time tagging of MIPs with Micromegas,* E. Oliveri , RD51 Mini-Week 12-15 Dec. 2016, CERN https://indico.cern.ch/event/588409/contributions/2379813/attachments/1387552/2112624/RD51MiniWeek_Dec2016_picosec.pdf

- *PICOSEC, a timing study*, S. White , RD51 Mini-Week 12-15 Dec. 2016, CERN https://indico.cern.ch/event/588409/contributions/2406479/attachments/1388700/2115204/rd51miniweek_12_16.pdf

- *Progress report on the analysis of PICOSECOND-MICROMEGAS test beam and calibration data: techniques and studies*, S. Tzamarias, RD51 mini week – Precise Timing Workshop, 21 February 2017, CERN https://indico.cern.ch/event/607147/contributions/2476948/attachments/1413066/2167106/PreciseTiming.pdf

- *Fast timing with Micromegas: Status and Plans,* T. Papaevangelou, RD51 mini week – Precise Timing Workshop, 21 February 2017, CERN https://indico.cern.ch/event/607147/contributions/2476873/attachments/1412920/2167034/TPapaevangelou_MM_PicosecondProject.pdf

- *Novel Detector Developments: The Picosecond-Micromegas*, S. E. Tzamarias at HEP-2017 Ioannina Greece, http://hep2017.physics.uoi.gr/7-4/5-TzamHEP2017.pdf

- *Charged particle timing based on Micromegas in the sub-50 picosecond regime* E. Oliveri, MPGD 2017 & RD51 Collaboration Meeting, 22-26 May 2017, Temple University - Philadelphia https://indico.cern.ch/event/581417/contributions/2556727/attachments/1463192/2261230/MPGD2017_picosec.pdf

… coming soon…

- *Picosec: charged particle timing to 24 ps with Micromegas*, F.J. Iguaz, Instrumentation Days on gaseous detectors 2017, 7th November 2017, LPC Caen
- *Picosecond Timing Sensor Development Employing Micro Pattern (Gaseous or Si) Detector Technology*, S. White, abstract submitted to the "New Technologies for Discovery" meeting

Last RD51 Collaboration Meeting (this week)

Picosec : status and perspectives,

Francisco Jose Iguaz Gutierrez (Université Paris-Saclay (FR)),
https://indico.cern.ch/event/667256/contributions/2730933/attachments/1529763/2394157/20170926_FJIguaz_WG1_Picosec.pdf

Signal processing and statistical analysis techniques for the PICOSEC-MICROMEGAS,

Ioannis Manthos (Aristotle University of Thessaloniki),
https://indico.cern.ch/event/667256/contributions/2735115/attachments/1530756/2395755/YiannisPresentation2.pdf

Progress report on the modelling of slewing and resolution effects in the PICOSEC-MicroMegas detector,

Konstantinos Paraschou (Aristotle University of Thessalon¡ki (GR)),
https://indico.cern.ch/event/667256/contributions/2732572/attachments/1529392/2393101/KostasPresentation.pdf

Beam Testing of Fast Timing Picosec Detectors in 2017,

Lukas Sohl (Ruhr-Universitaet Bochum)
https://indico.cern.ch/event/667256/contributions/2732292/attachments/1530884/2396008/Collaboration_Meeting_sohl.pdf

Last (this week) RD51 Collaboration Meeting

Picosec : status and perspectives,

Francisco Jose Iguaz Gutierrez (Université Paris-S

https://indico.cern.ch/event/667256/contributions/27309 ... /G1_Picosec.pdf

Signal processing and stati...
MICROMEGAS,

Ioannis Manthos (Ar

https://indico.cern.c ... nisPresentation2.pdf

Progr ... esolution effects in the
PICOSE

Konstantin ... essaloniki (GR)),

https://indico.ce ... attachments/1529392/2393101/KostasPresentation.pdf

Beam Testing ... Picosec Detectors in 2017,

Lukas Sohl (Ruhr-Un ... t Bochum)

https://indico.cern.ch/event/ ... 256/contributions/2732292/attachments/1530884/2396008/Collaboration_Meeting_sohl.pdf

LARGE INTEREST IN THE PROJECT/RESULTS FROM OUT COMMUNITY…

FAST TIMING & PICOSEC DEVELOPMENTS

IMPORTANT ROLE IN THE FUTURE OF THE COLLABORATION

in the context of

STRETCHING of the LIMITS of MPGD based Detector

LARGE INTEREST IN THE PROJECT/RESULTS FROM OUT COMMUNITY…

Gaseous..

- Large area .. preserving performances..
- Large area … @ affordable costs

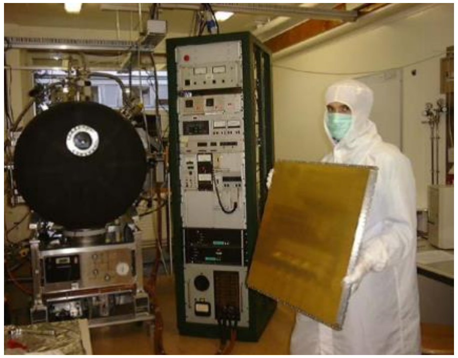
MPGD versatility

- Possibility to adapt the detector to a large variety of requirements

… in situ Detector Design/ Production (expertise and technology)/Testing

Photocathodes: CERN/Thin Film & Glass Lab

~ 100mt from where we are now



MPGD Sensors:
CERN/MPT Workshop

~ 50mt from where we are now

Similar Slide can be shown in Saclay….

Precise Timing Workshop

(@ RD51 mini Week, CERN, February 2017)

RD51 Mini-Week

20 Feb 2017, 14:00 → 23 Feb 2017, 13:00 Europe/Zurich

6-2-024 - BE Auditorium Meyrin (CERN)

Leszek Ropelewski (CERN) , Silvia Dalla Torre (Universita e INFN, Trieste (IT))

Precise Timing Workshop

Tuesday 21 February 2017

Precise timing workshop - 6-2-024 - BE Auditorium Meyrin (09:00-13:00)

time	[id] title	presenter
09:00	[100] Welcome	ROPELEWSKI, Leszek DALLA TORRE, Silvia
09:05	[101] Intro	WHITE, Sebastian
09:20	[102] Fast timing with Micromegas: Status and Plans	PAPAEVANGELOU, Thomas
09:45	[123] Progress report on the analysis of PICOSECOND-MICROMEGAS test beam and calibration data: techniques and studies	TZAMARIAS, Spyros
10:15	[104] FAST project - Precision timing with crystal + SiPM	LUCCHINI, Marco Toliman
10:40	Coffee Break	
11:00	[105] Results and Plans for HyperFast Silicon based on 2016 PICOSEC data	WHITE, Sebastian
11:25	[106] The LAPPD Project	MINOT, Michael J.
11:50	[108] LGAD	FORSTER, Fabian Alexander
12:15	[107] TOTEM timing Detector	BERRETTI, Mirko
14:00	[110] CsI and gaseous detectors	TESSAROTTO, Fulvio DALLA TORRE, Silvia
14:25	[111] New Directions on Robust Photocathodes	SMEDLEY, John
14:50	[112] MPGD Fast Electronics	MULLER, Hans
15:15	[113] Fast timing techniques	RIVETTI, Angelo
15:40	[103] Using Fast Timing to Separate Scintillation and Cherenkov Light for THEIA at Homestake	KLEIN, Josh
16:05	Coffee Break	
16:25	[114] New Transimpedance Fast preamplier used in PICOSEC for silicon	NEWCOMER, Mitchell Franck
16:50	[115] News on "SuperNino"	WILLIAMS, Crispin
17:15	[116] Status of development on the SAMPIC Waveform TDC	BRETON, Dominique Robert
17:40	[117] new TDC chip to accompany the PETIROC developed by OMEGA group	MATHEZ, Herve LAKTINEH, Imad

Wednesday 22 February 2017

Precise timing workshop - 6-2-024 - BE Auditorium Meyrin (09:00-13:10)

time	[id] title	presenter
09:00	[118] Advantages of fast sampling for timing measurements	MINAFRA, Nicola
09:25	[120] Time resolution of a MCP-PMT and test infrastructure in the solid state detector lab	CENTIS VIGNALI, Matteo
09:50	[121] A Picosecond X-ray Source	RESNATI, Filippo
10:15	Coffee Break	
10:35	[122] "Tynodes"	VAN DER GRAAF, Harry
11:05	[126] A new prototype for the fast timing mpgd (FTM) and the development of fast readout electronics (FATIC)	RANIERI, Antonio VERWILLIGEN, Piet
11:30	[124] Gas detector modelling for fast timing detectors	GONZALEZ DIAZ, Diego
11:55	[141] RD51 Precise Timing Workshop Closeout	ROPELEWSKI, Leszek

https://indico.cern.ch/event/607147/

picosec

- T. Papaevangelou, ***Status and Plan***

https://indico.cern.ch/event/607147/contributions/2476873/attachments/1412920/2167034/TPapaevangelou_MM_PicosecondProject.pptx

- S. Tzamarias, ***Analysis*** – techniques and studies

https://indico.cern.ch/event/607147/contributions/2476948/attachments/1413066/2167105/PreciseTiming.pptx

- D. Gonzalez Diaz, Detector ***Modelling***

https://indico.cern.ch/event/607147/contributions/2476949/attachments/1416536/2169034/TimingWorkshop2.pptx

Detectors

- M. Lucchini, SiPM+Crystal
- S. White, Hyperfast Silicon
- Minot, LAPPD
- F. Forster, LGAD
- M.Berretti, Diamond, LGAD
- H. Van Der Graaf, Tynodes
- P. Verwilligen, FTM
- M. Centis Vignalis, MCP-PMT

Electronics

- H. Muller, MPGD Fast Electronics
- A. Rivetti, Fast Timing Tecniques
- N. Minafra, sampling

- M. Newcomer, New Transimpedence Fast Amplifier
- C. Williams, SuperNino
- D. Breton, Waveform TDC - SAMPIC
- H. Mathez,TDC+PETIROC
- A. Ranieri, FATIC Fast readout FE
- M. Minot, DRS4

photocathodes

- J. Smedley, New direction on Robust pc
- F. Tessarotto, CsI & Gaseous Detector
- M.Minot, LAPPD
- H. Van Der Graaf, Tynode

Infrastructure/instrumentation

- M. Centis Vignali, Infrastructure @ SSD lab
- F. Resnati, Picosec taggable X-Ray source

Application

- J. Klein, Theia

A short/fast overview of the contributions …

spotting…

issues/problems/aspects common to picosec

Nuclear Instruments and Methods in Physics Research A 830 (2016) 30–35

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Detection of high energy muons with sub-20 ps timing resolution using L(Y)SO crystals and SiPM readout

A. Benaglia [a,*], S. Gundacker [a], P. Lecoq [a], M.T. Lucchini [a], A. Para [b], K. Pauwels [a], E. Auffray [a]

[a] CERN, CH-1211, Genève 23, Switzerland
[b] Fermilab National Accelerator Laboratories, Batavia, IL, USA

10ps

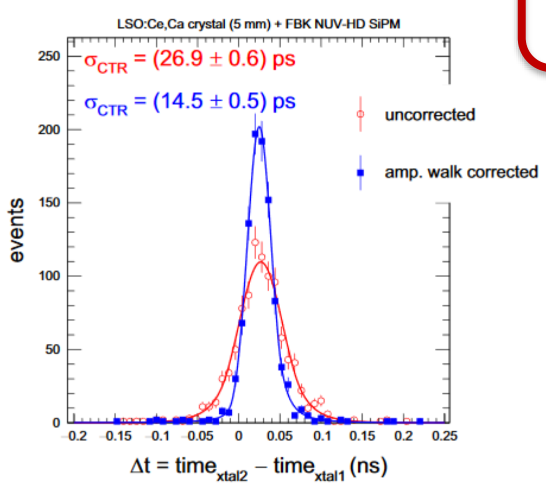


Fig. 8. Distribution of Δt observed for 5 mm long LSO:Ce,Ca crystals coupled to *FBK* SiPMs. Red empty points and blue solid squares correspond to the uncorrected and time walk-corrected distributions, respectively. The CTR values as extracted from a Gaussian fit to the data are superimposed. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

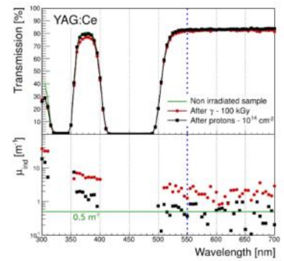
M. Lucchini

Addressing radiation tolerance and high rate challenges

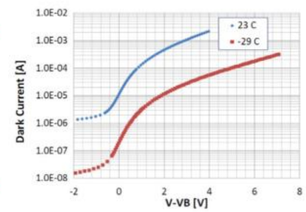
Several crystals proven to be radiation tolerant under both high levels of ionizing doses and hadron fluences (YAG, LuAG, GAGG, LYSO)

SiPMs with small cell size (12/15 um) operating at low temperature can withstand high neutron fluences

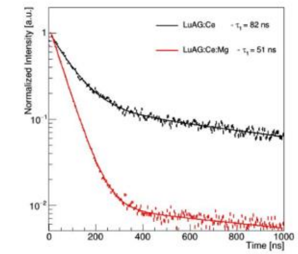
Dedicated project (*INTELUM*) to engineer the crystal composition and reduce scintillation decay constants (Mg, Ca codoping)



M.Lucchini et al, IEEE Trans. Nucl. Science, vol.63, issue 2 (2016) 586-590



A.Heering et al, NIM A 824 (2016) 111-114



M.Nikl et al, Cryst. Growth Des., 2014, 14 (9), pp 4827–4833

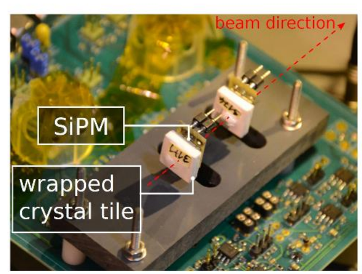
From single sensors to full detector

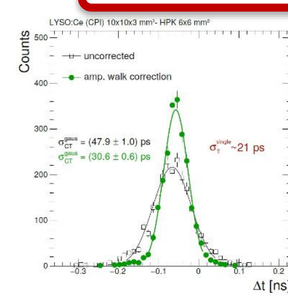
Challenges:

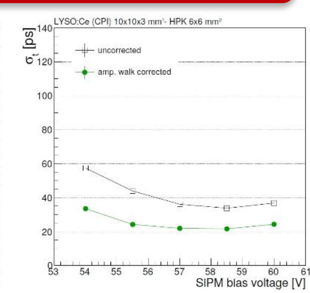
- Large number of channels
- Power consumption
- Cost
- Large area to be covered

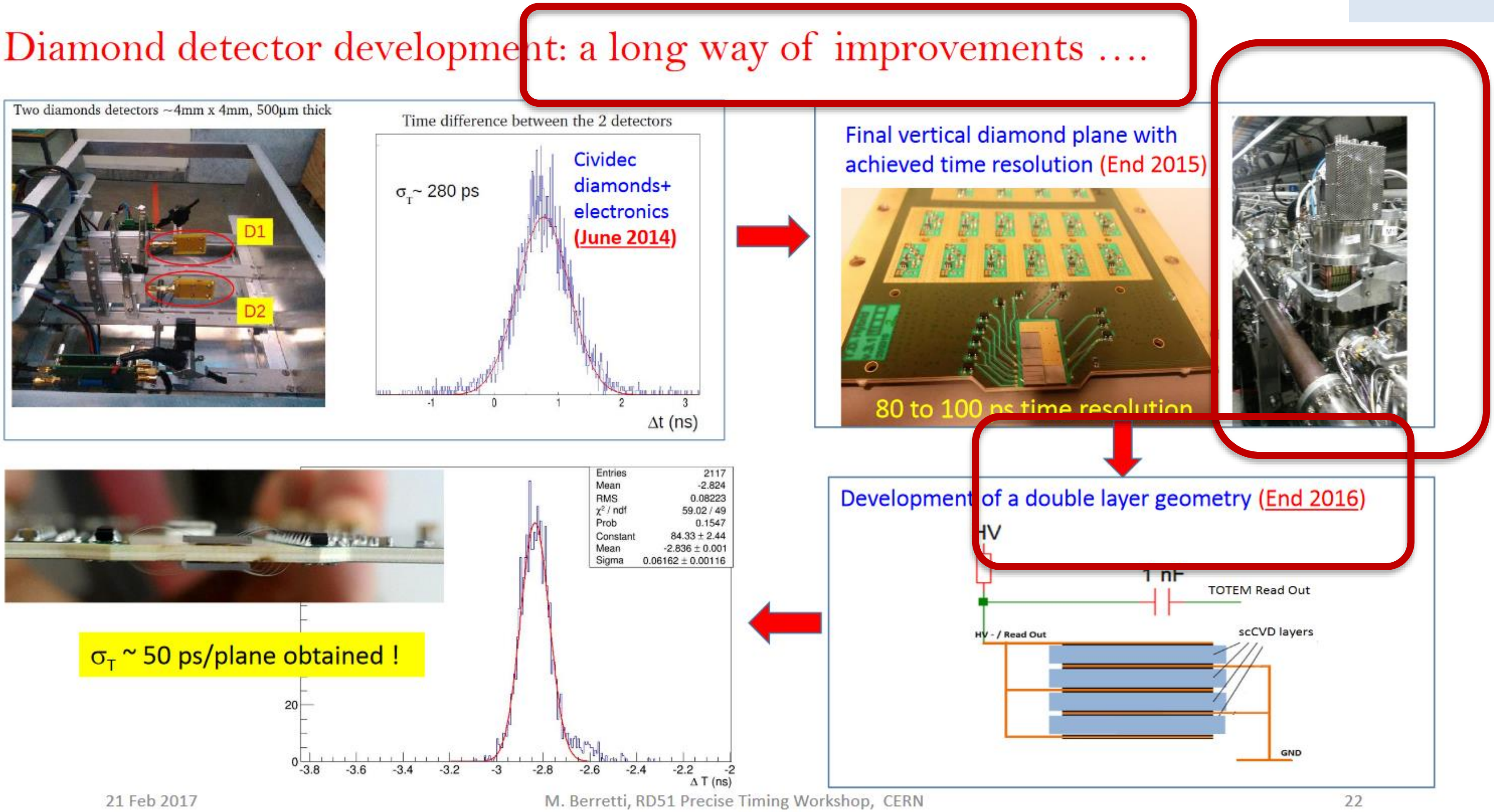
Strategies:

- Thin crystals with large section read-out with small SiPMs
- Operation at low bias voltage
- Exploring new (cheaper) materials







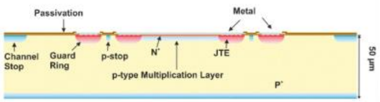


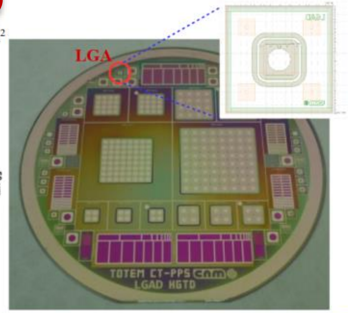
https://indico.cern.ch/event/607147/contributions/2476891/attachments/1415670/2167553/RD51WorkshopFeb2017-Mirko3.pdf

M. Berretti

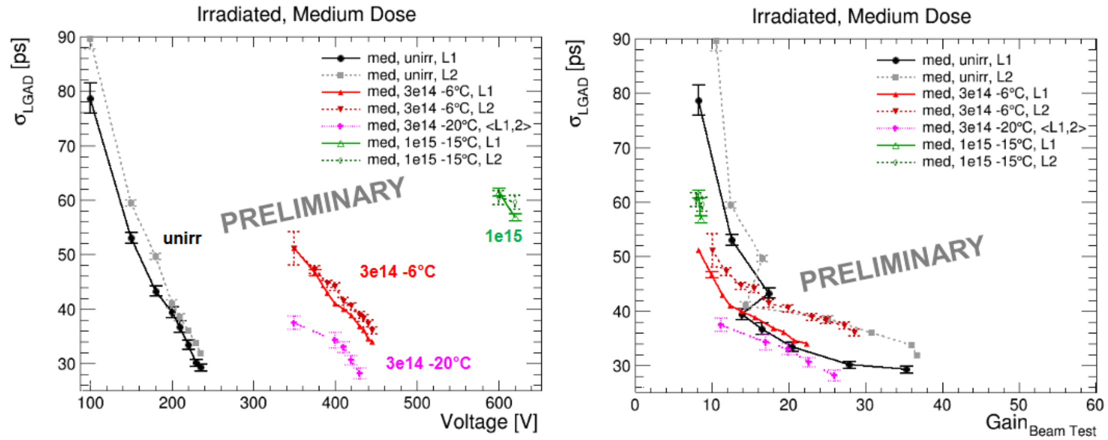
Samples from 50 µm LGAD Run

- Studied small LGAD pad diodes LGA from 50 µm SOI CNM run 9088 as RD50 project
  - Active area: 1.3x1.3 mm², multiplication layer 1x1 mm²
  - 3 different charge multiplication layer doses:
    1.8 (low), 1.9 (med) and 2.0 (high) x 10^{13}/cm²
  - Tested before and after irradiation at JSI Ljubljana to 3e14 and 1e15 n_{eq}/cm²
  - Time Resolution studied at CERN SPS (120 GeV pion) during AFP test beams:
    - June/July: med dose, unirradiated
    - September: low + med dose, unirradiated
      med dose, 3e14 + 1e15 n_{eq}/cm²





Time Resolution (irrad)



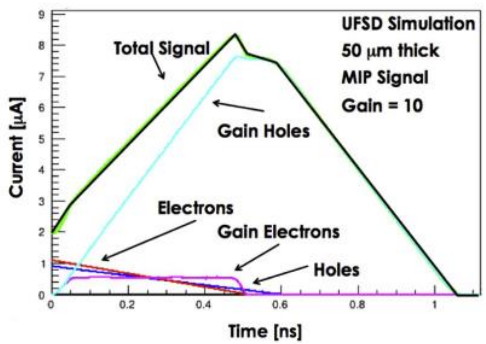
- At 3e14 similar time resolution achieved as before irradiation (at higher V)
  - -6°C: 34 ps at 445 V
  - -20°C: 28 ps at 430 V
- At 1e15 gain is highly reduced and voltage stability not high enough to compensate for it
  - 60 ps at 620 V
- Time resolution only dependent on gain in all cases before and after irradiation
  → “universal”

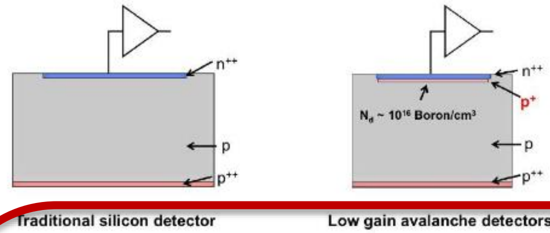
F. Foerster

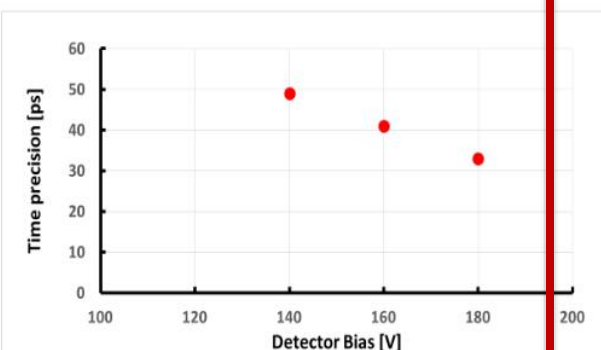
https://indico.cern.ch/event/607147/contributions/2476892/attachments/1415493/2166988/FFoerster_RD51_Miniweek_210217.pdf

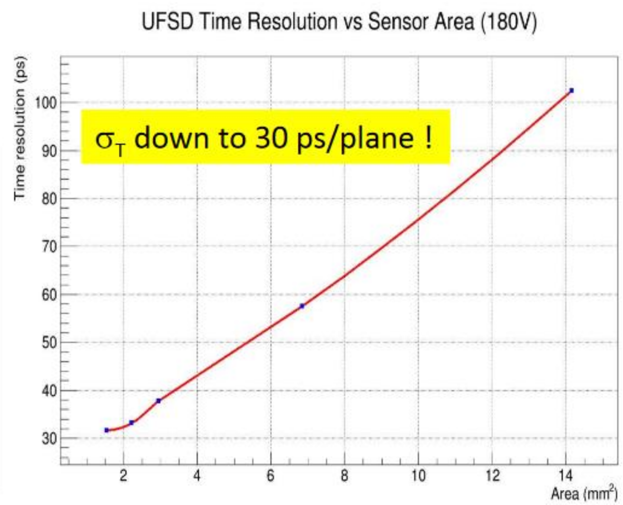
Ultra Fast Silicon Detector on the modified TOTEM board.

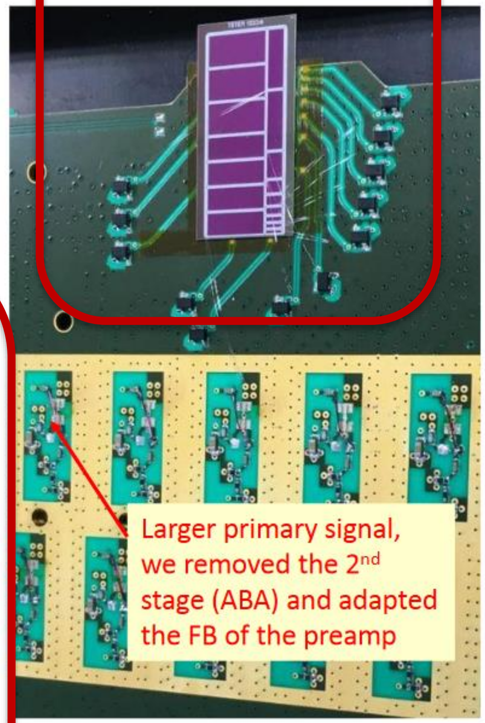
Joint work TOTEM - UFSD Torino group (N. Cartiglia et al)











21 Feb 2017

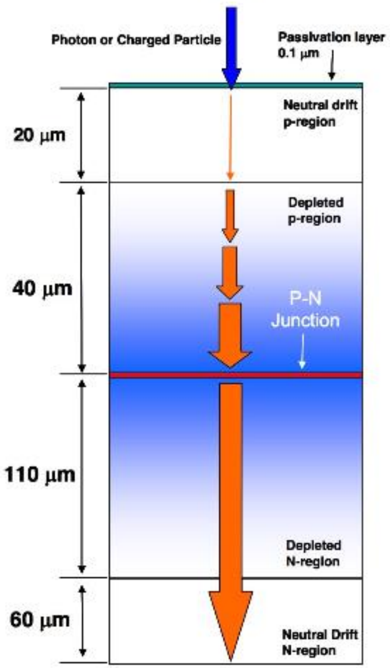
M. Berretti, RD51 Precise Timing Workshop, CERN

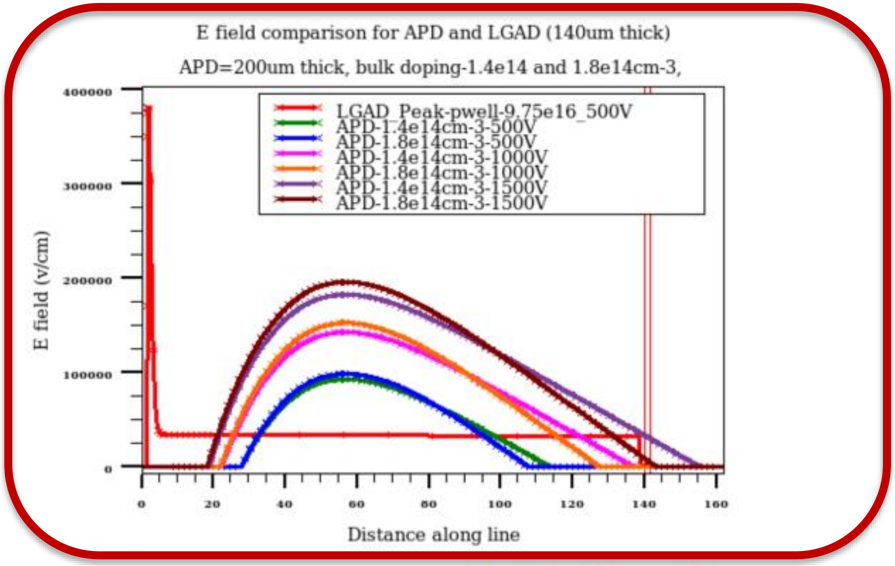
25

https://indico.cern.ch/event/607147/contributions/2476891/attachments/1415670/2167553/RD51WorkshopFeb2017-Mirko3.pdf

M. Berretti

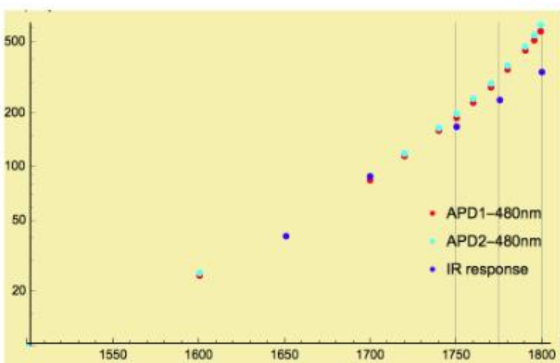
HyperFastSilicon(HFS) structure

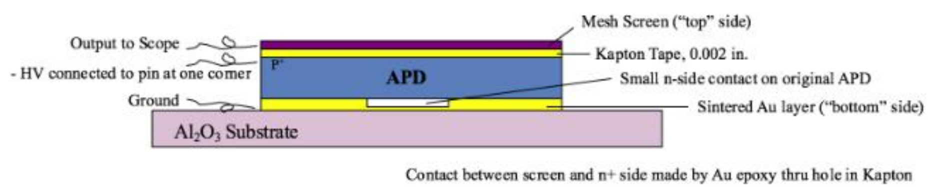




S. White

Sketch by Thomas Tsang





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The Timed Photon Counter PC "Tipsy"concept: advancing PMT's

Photomultiplier tubes

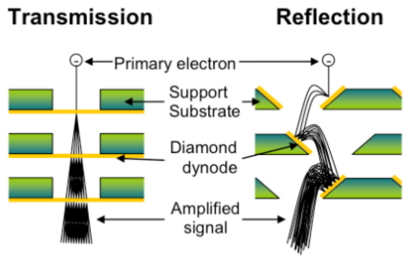
- High gain
- Low noise
- Secondary Electron Yield (SEY)

j

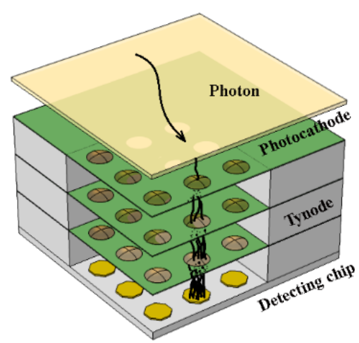
Gain = δ^N

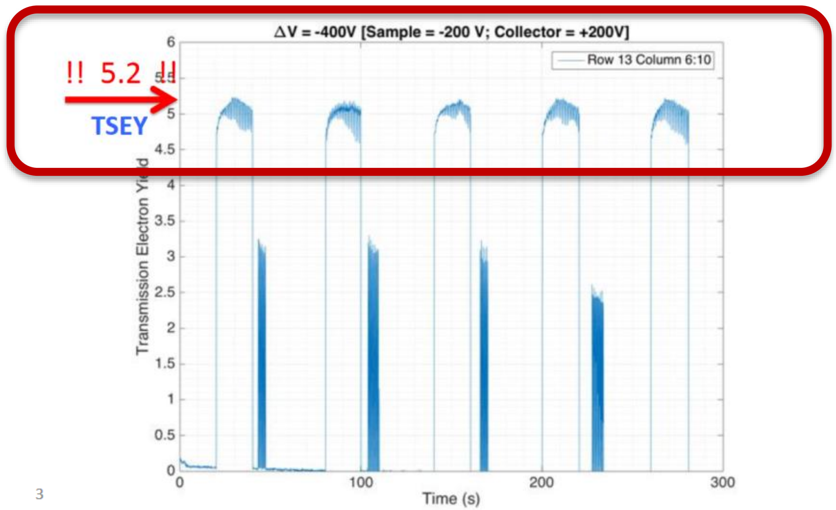
...Can we make it smaller?

$$SEY = \delta = \frac{\#\,of\,secondary\,electrons}{\#\,of\,primary\,electrons} = \frac{I_{SE}}{I_{PE}}$$



- Transmission dynodes – **Tynodes**
- **Dark noise free** electron multiplication mechanism
- Stacking the photocathode, Tynodes and pixel chip → **compact device**
- Pixelated detector → **spatial resolution** (imaging)
- Operation of the detector in **high B-field.**
- Time resolution: few ps due to form factor and straight electron path's
- 2D spatial resolution = 10 µm





3

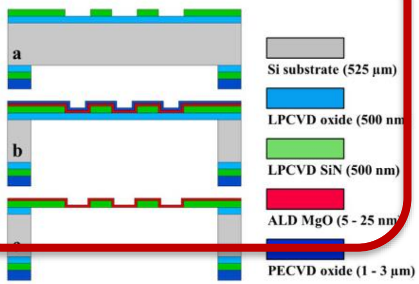
H. Van Der Graaf

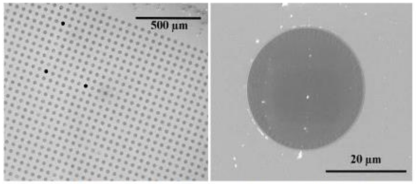
Detector/photocathodes

https://indico.cern.ch/event/607147/contributions/2476947/attachments/1416443/2168890/RD51Tynode.pdf

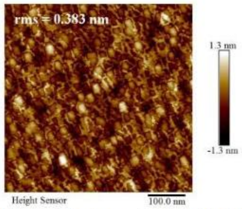
MEMS fabriaction of Tynodes: ALD MgO

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)





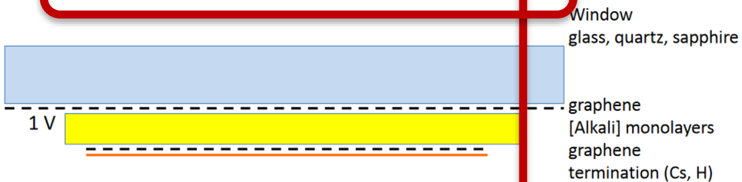
SEM captures of 5 nm thin MgO membranes in 64 x 64 array



AFM image of released 25 nm thin MgO membrane

Tipsy's only limitation: its efficiency equals the QE of photocathodes: 0.4 at best

Therefore: the High Quantum-Efficiency (QE) Photocathode



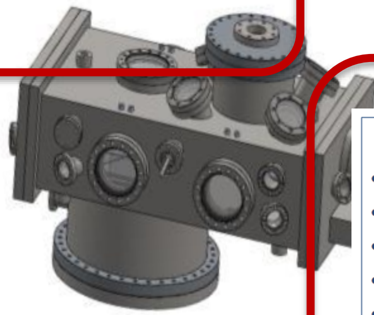
- *Active* photocathode: drift field pushing electrons to emission vacuum surface
- electric field created in between by potential defining graphene planes
- all layers build up individually by *atomic layer deposition* ALD
- electron emission stimulated by negative electron affinity by *termination*
- First designed after *ab initio* simulations of 3D atomic building blocks

Proposal *for theoretical concept* study: let us first understand the present state-of-the-art

H. Van Der Graaf

Incom LAPPD Integration & Sealing

Process & Hardware



Motivation

- Large Area: 200 x 200 mm^2
- Flat Geometry
- PMT Sensitivity: QE >20% w/bi-alkali photocathode
- Picosecond Timing: resolution <60 pS, <100pS for SPE
- Sub-mm spatial resolution
- Lower Cost per Unit Area

Process:

- UHV – with Conflat seals, scroll, turbo and ion pump.
- Tile kit components pre-assembled & locked in place .
- Baked to low 10^{-10} torr range
- In-tank operation of tile / scrubbing
- Window Transfer Process
- Multi-alkali Photocathode deposited on underside of window.
- Hot Indium Hermetic Seal – between sidewalls & top window

Hardware:

- Single "Fully Bakeable" Chamber: 30"L X 16"W X 8"H
- Simple window transfer between photocathode deposition & sealing.
- Electrical interconnects for in-process monitoring
- Readily expandable for volume production

February 21, 2017 RD51 CERN - Minot, LAPPD™ Commissioning Update Page 6

M. Minot

https://indico.cern.ch/event/607147/contributions/2476890/attachments/1413628/2166936/RD51_CERN_-MINOT_LAPPDTM_Commissioning_02-21-2017_FINAL.pdf

Stony Brook University

BROOKHAVEN NATIONAL LABORATORY

New Directions in Robust Photocathodes

Using the tools of materials science to engineer alkali antimonide cathodes for performance and speed

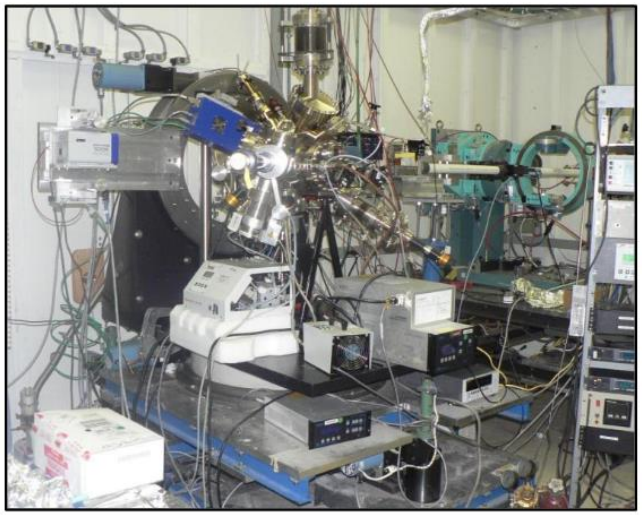
John Smedley

Brookhaven Nation

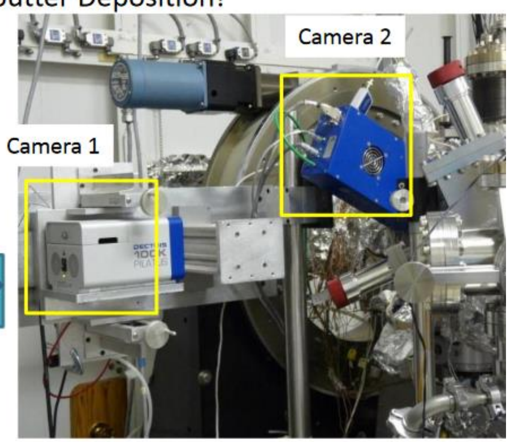
Electron Photon Instrumentation Cente

https://indico.cern.ch/event/607147/contributions/2476904/attachments/1415494/2166992/2017_CERN_talk.pdf

In operando analysis during growth
(setup at NSLS/X21 & CHESS G3 – ISR soon)



- UHV system (0.2 nTorr base pressure)
- Residual Gas Analyzer (RGA)
- Heating/cooling substrate/cathode
- Load lock
  - fast exchange of substrates
  - gun transfer
- Horizontal deposition of Sb, K and Cs.
- Sputter Deposition!

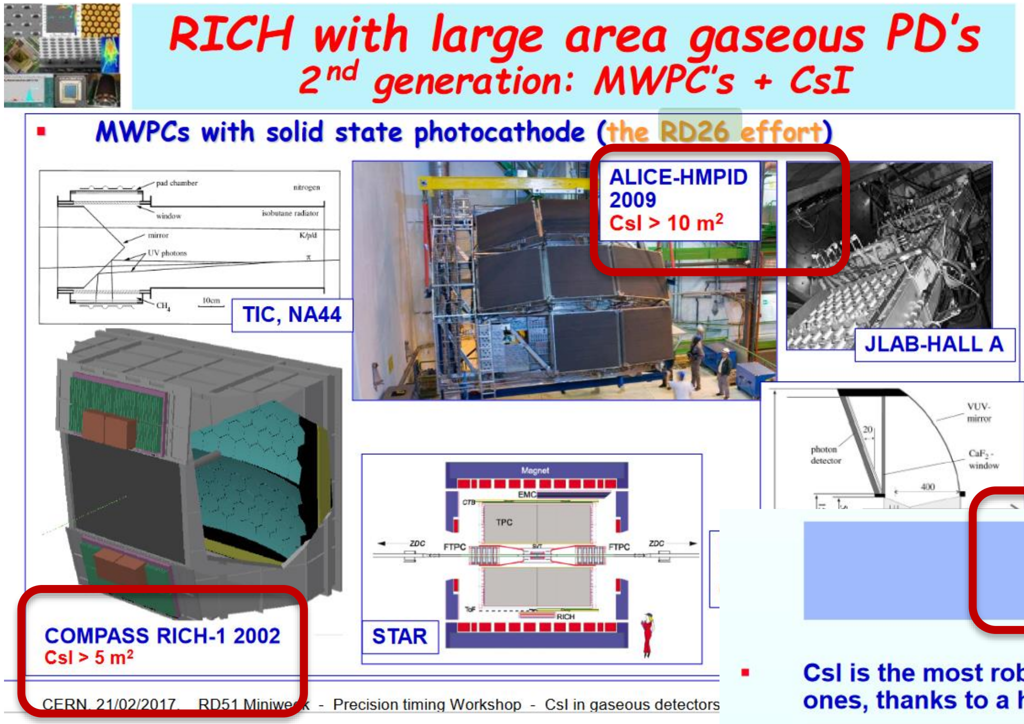


J. Smedley

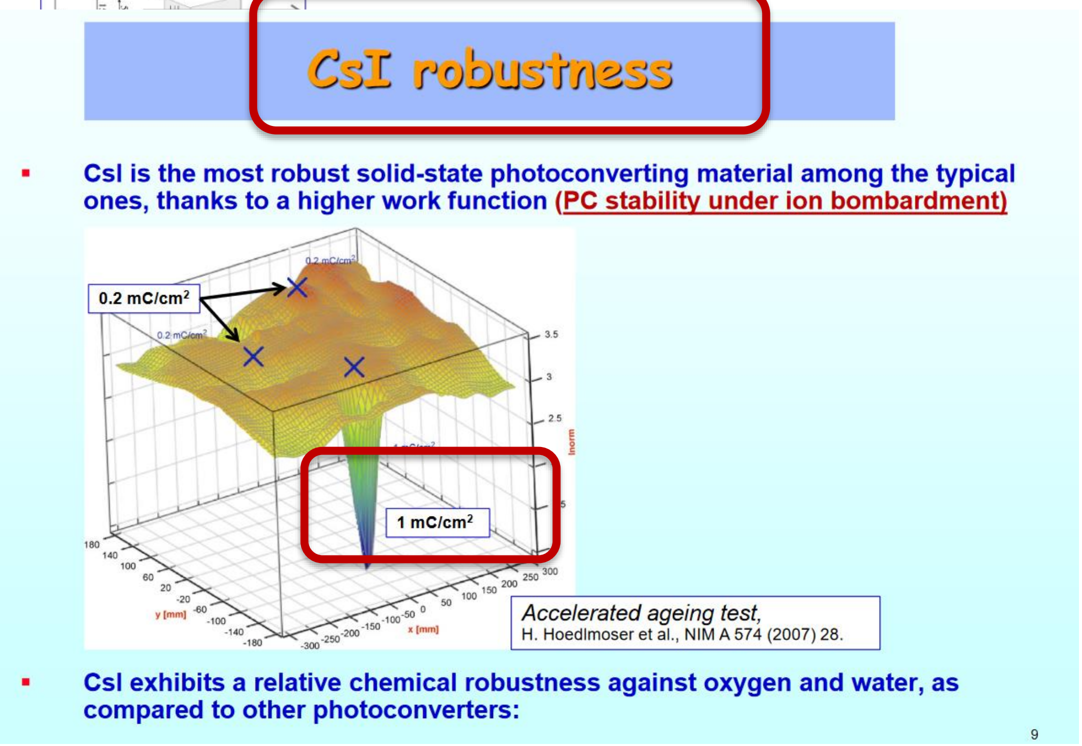
Two 2D detectors (Pilatus 100K)

XRF, XRD, XRR, GISAXS, QE

photocathodes



https://indico.cern.ch/event/607147/contributions/2476899/attachments/1412528/2167750/fulvio_tessarotto_21_02_2017.pdf



F. Tessarotto

photocathodes

F. Tessarotto

The CERN CsI evaporation system

H. Hoedlmoser et al. / Nuclear Instruments and Methods in Physics Research A 566 (2006) 338–350 339

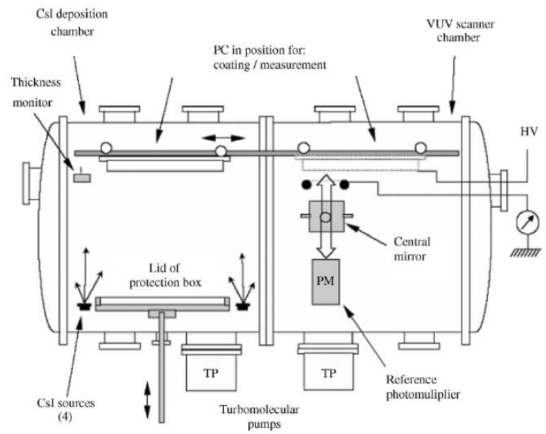


Fig. 1. Layout of the CsI production chamber. Left: CsI evaporation side, right: photo-current measurement side. The reader is referred to Refs. [2,3,8,9] for detailed descriptions of the plant.

CERN, 21/02/2017, RD51 Miniweek - Precision timing Workshop - CsI in gaseous detectors - Fulvio Tessarotto 34

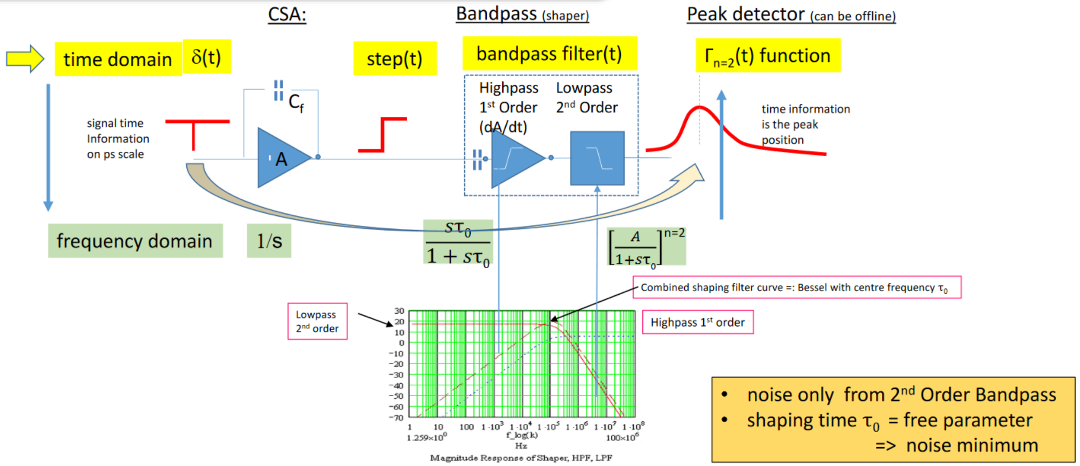
glovebox for CsI THGEM mounting

CERN, 21/02/2017, RD51 Miniweek - Precision timing Workshop - CsI in gaseous detectors - Fulvio Tessarotto 37

https://indico.cern.ch/event/607147/contributions/2476899/attachments/1412528/2167750/fulvio_tessarotto_21_02_2017.pdf

So we do the following:

Time-to-Frequency (TFC) convolution



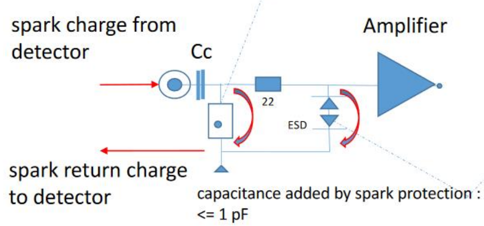
https://indico.cern.ch/event/607147/contributions/2476905/attachments/1415650/2398258/Plans_fast_electronics_for_MPGD.pdf

H. Muller

Spark protection on WBA

1.) Spark gap (0.5pF) at input triggers at ~ 65V
with impulse discharge current < 2kA
2.) ESD diode (0.5pF) at chip input triggers at ~ 5V
3.) input Voltage on amplifier < 5V

-> max current through ESD diode
65V/22Ω ~ 3A
(diode can handle up 12A @20 us)



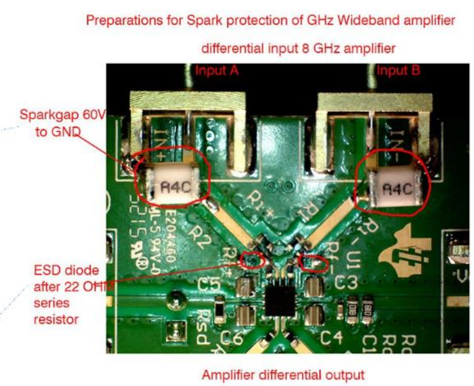
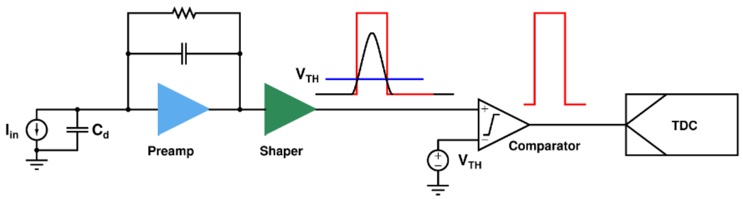


photo new WBA amplifier

electronics

Timing systems: single shot



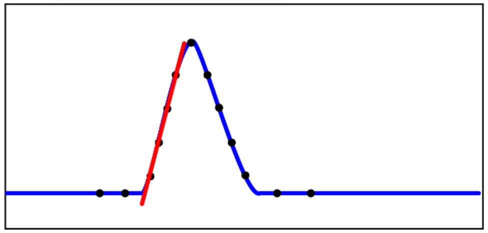
- The sensor signal is usually amplified and shaped
- A comparator generates a digital pulse
- The threshold crossing time is captured and digitized by a TDC
- TDC can be embedded on the front-end chip or external

▸ Timing is derived from a single sample

A. Rivetti (INFN-Torino) Fast timing techniques February 21, 2017 6 / 28

Timing systems: multiple shot

A. Rivetti



- The sensor signal is usually amplified and shaped
- The full waveform is sampled and digitized at high speed
- In many systems, sampling and digitization are decoupled
- Timing is extracted with DSP algorithms from the digitized waveform samples

▸ Timing is derived from multiple samples

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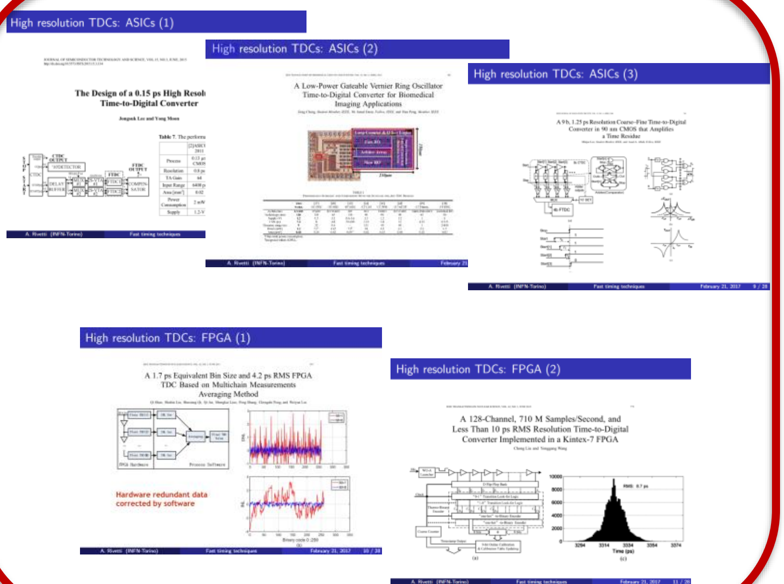

Waveform samplers: some example

ASIC	Year	Node	Time res.	Max sample/ch	Channels
LABRADOR3	2005	250 nm	16 ps	260	
BLAB	2009	250 nm	< 5 ps	65536	
DRS4	2014	250 nm	≈ 1 ps	1024	
PSEC4	2014	130 nm	≈ 1 ps	256	
SamPic	2014	180 nm	≈ 3ps	64	

- Typical small channel count per ASIC
- Resolution: same pulse split and sent to diff[...]nt channels difference measured

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Digital timing extraction

- Different algorithms are used to compute the timing from the digitized samples
- There is nothing such an optimal method
- Some techiques can be more suited that others for real time execution on FPGA
- Some examples of digital algorithm:
  - Digital leading edge
  - Digital constant fraction
  - Interpolation
  - Initial slope approximation
  - Reference pulse
  - ...

To learn more: E. Delagnes, Precise Pulse Timing based on Ultra-Fast Waveform Digitizers, Lecture given at the IEEE NSS Symposium, Valencia, 2011

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https://indico.cern.ch/event/607147/contributions/2476907/attachments/1412613/2167568/RD51_Feb2017_TimingTechniques.pdf

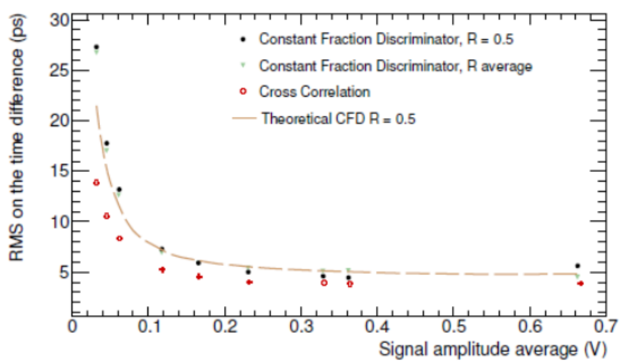
Application to real signals

RMS on the time difference between two signals with respect to the signal amplitude.

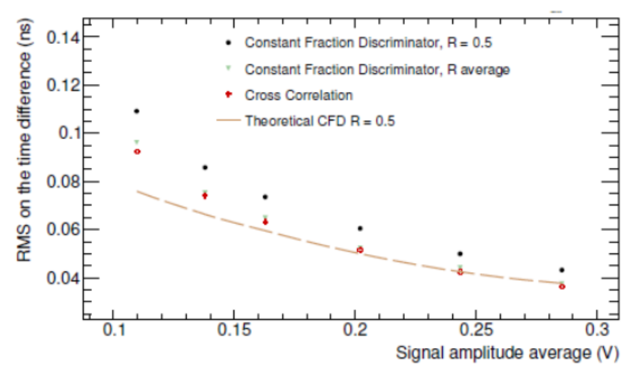
	Offline method	ΔT_{12} fitted-value, (ΔT_{12} RMS), [resolution]
1	Simple Threshold	1450 (1490) [1025] ps
2	Position of the Maximum	719 (754) [508] ps
3	Normalized Threshold (70%)	467 (491) [330] ps
4	Normalized Threshold (50%)	353 (359) [250] ps
5	Normalized Threshold (30%)	336 (341) [238] ps
6	Fitted Normalized Threshold (35%)	308 (315) [217] ps
7	Offline CFD	306 (298) [210] ps
8	Extrapolation of normalized Threshold	277 (281) [196] ps

Many other algorithms are possible, but usually with *similar* performance.
Example with two diamond detector read using Cividec C6 Amplifiers.

Timing performance of diamond detectors with Charge Sensitive Amplifier readout



Signal generator, acquired using the SAMPIC chip at 6.4 GS/s.



Laser tests with 300 μm USFDs read-out with Cividec C2 BDA, acquired using the SAMPIC chip at 6.4 GS/s.

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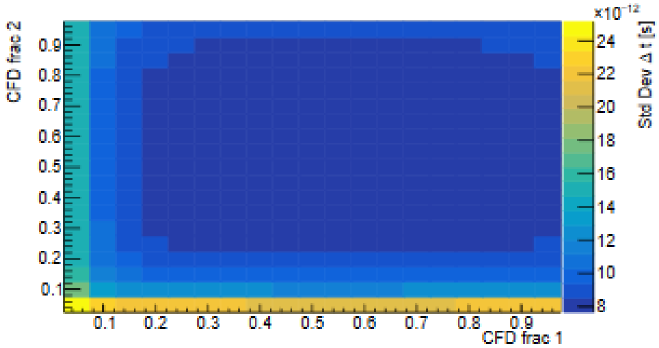
https://indico.cern.ch/event/607147/contributions/2476937/attachments/1412845/2168625/RD51_Feb2017.pdf

N. Minafra

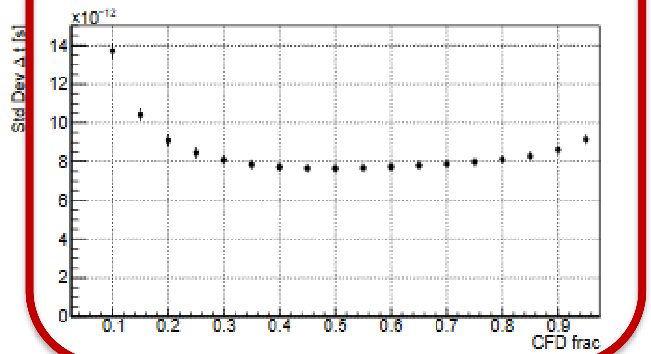
Timing using Constant Fraction Discriminator

Resolution $\rightarrow$ std dev of $\Delta t = t_2 - t_1$

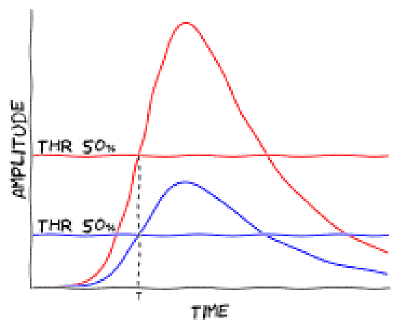
Resolution map



Diagonal of the 2d plot

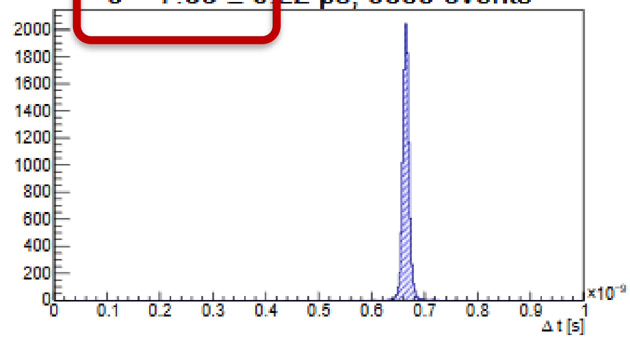


- Reduction of time walk



Δt distribution, CF = 0.45

σ = 7.66 ± 0.22 ps, 9855 events



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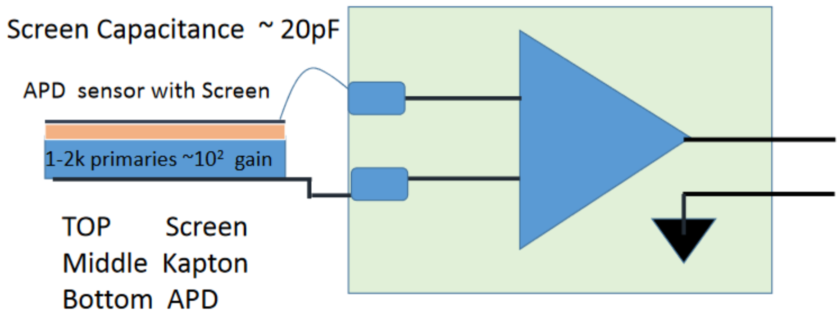
M. Centis Vignali

https://indico.cern.ch/event/607147/contributions/2476941/attachments/1412544/2167490/presentation.pdf

APD with Screen Readout



https://indico.cern.ch/event/607147/contributions/2476908/attachments/1415543/2168192/Fast_Timing_Amplifier_V3.pdf

Two basic Approaches to detector readout

M. Newcomer

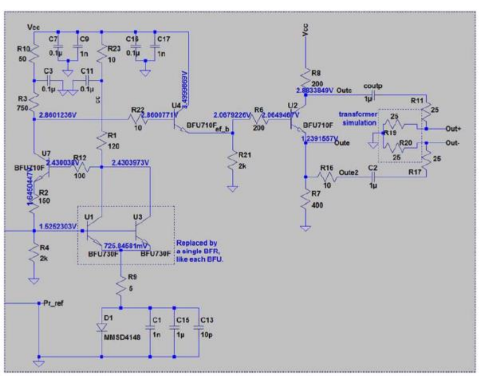
High Z amplify the voltage on the Detector

Low Z Transfer the charge to the Preamplifier

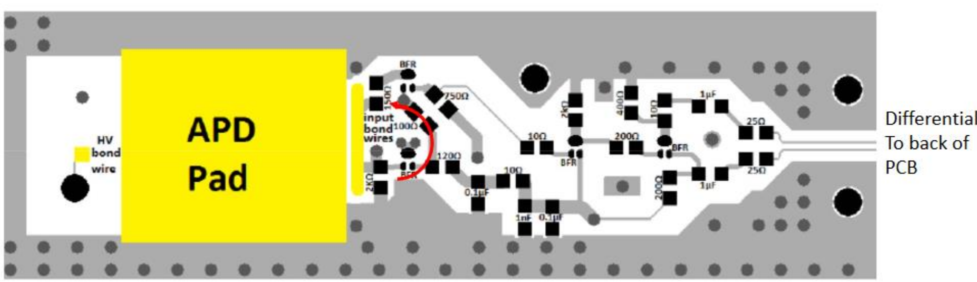
Fast Timing APD Amplifier RD51 Report February 2017

The feedback path still contributes significant delay into the charge restoration on the detector.

Discrete Amplifier Design with Differential Output

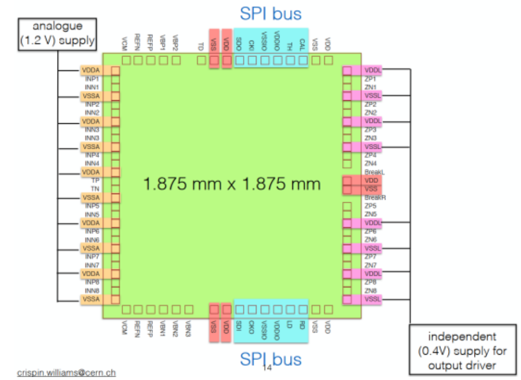


Fast Timing APD Amplifier RD51 Report February 2017 14

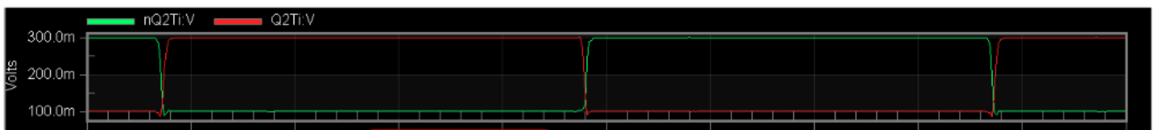


Fast Timing APD Amplifier RD51 Report February 2017 18

Design parameters of SuperNINO



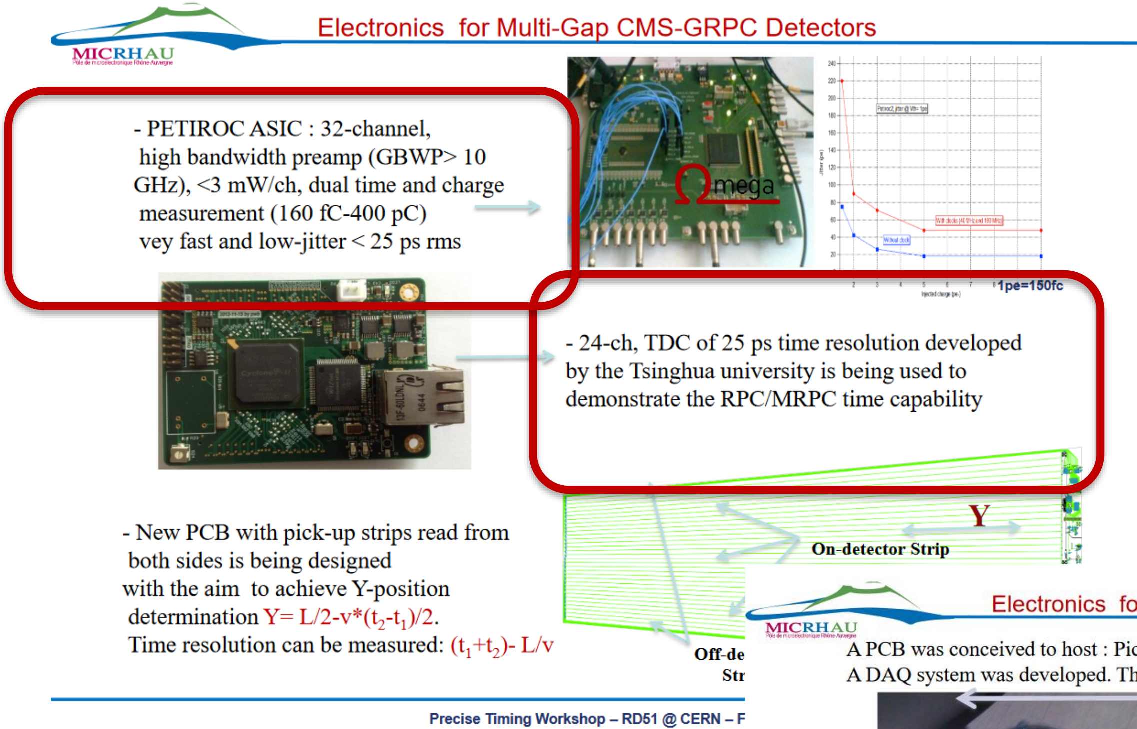
- No low frequency feedback
- Very low input impedance : we are working with a value of 5 Ω
- Output width related to charge integrated over first 20-100 ns.
- Power consumption less than 1/2 of original NINO
- LVS-200 output signals



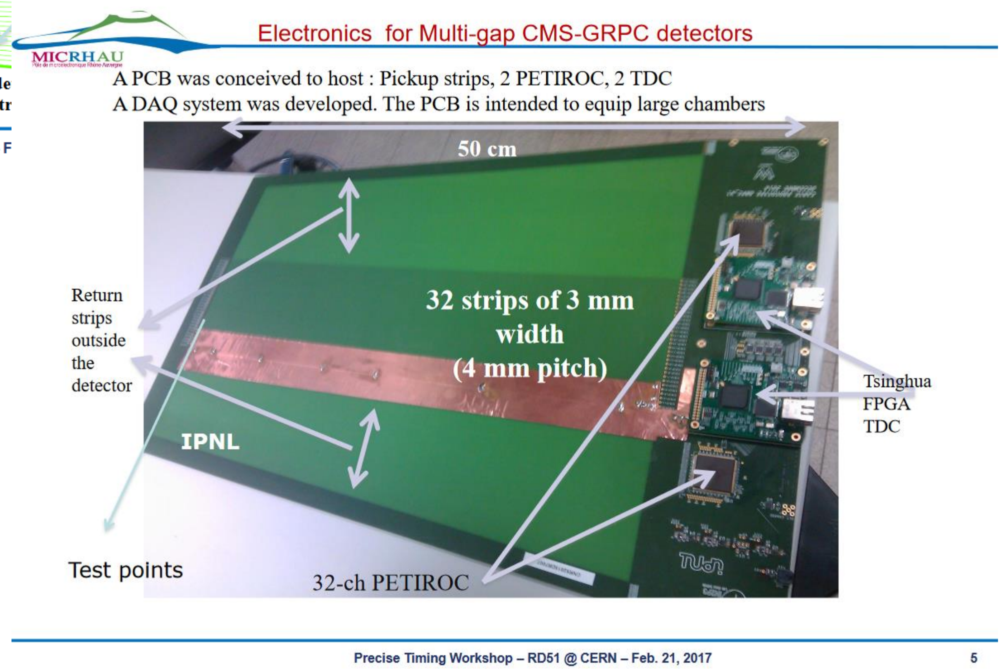
- 2 mm x 2 mm die - 8 channels - 65 nm UMC process

C. Williams

https://indico.cern.ch/event/607147/contributions/2476909/attachments/1415557/2167127/supernino-status.pdf



H. Mathez



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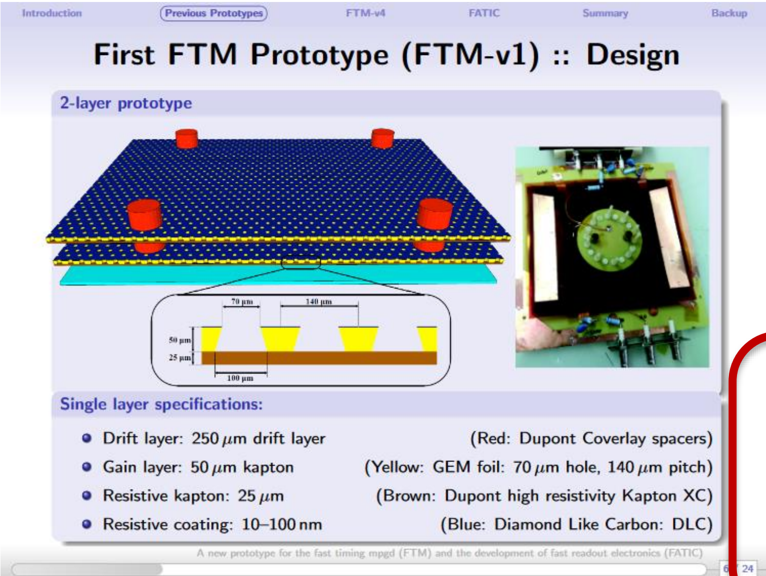

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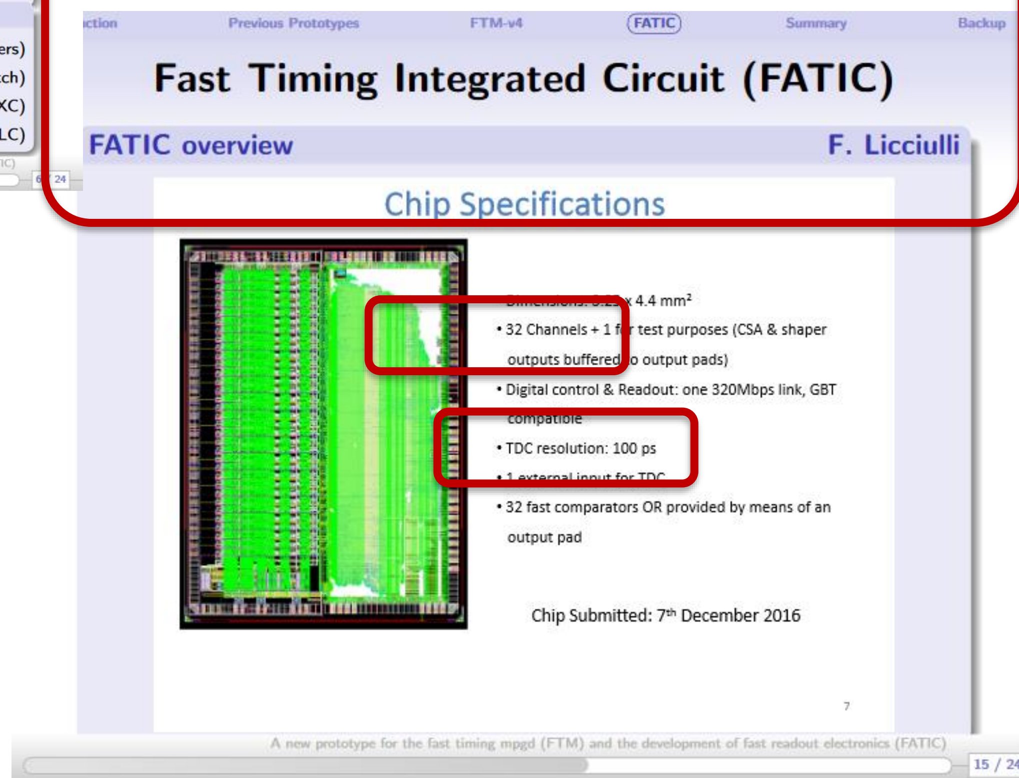
P. Verwilligen



https://indico.cern.ch/event/607147/contributions/2476911/attachments/1415361/2168327/SAMPIC_RD51_Breton.pdf

SAMPIC: PERFORMANCE SUMMARY

		Unit
Technology	AMS CMOS 0.18µm	
Number of channels	16	
Power consumption (max)	180 (1.8V supply)	mW
Discriminator noise	2	mV rms
SCA depth	64	Cells
Sampling speed	1 to 8.4 (10.2 for 8 channels only)	GSPS
Bandwidth	1.6	GHz
Range (unipolar)	1	V
ADC resolution	7 to 11 (trade-off time/resolution)	bits
SCA noise	< 1	mV rms
Dynamic range	> 10	bits rms
Conversion time	0.1 (7 bits) to 1.6 (11 bits)	µs
Readout time / ch @ 2 Gbit/s (full waveform)	450	ns
Single Pulse Time precision before correction	< 15	ps rms
Single Pulse Time precision after time INL correction	< 3.5	ps rms

NEW FEATURES IN NEXT VERSION

- **A new version of SAMPIC has been submitted in November 2016.**
- **Pin to pin compatible with the already existing mezzanines =>** "only" firmware and software modifications (no hardware).
- **Redesign of central trigger** to reduce its time response, multiplicity up to 3, smart filtering after coincidence for dead-time optimization …
- **Redesign of translator input block** to improve the shape of the signal and introduce the digital option => **SAMPET** version
- **Channel chaining option**: user-defined sets of channels can be chained in time. This permits either **increasing the sampling depth** of a single channel or **studying correlated events** on different channels.
- **Saturation** was not clean in the intermediate version. It will now happen in a clean way, whatever the conversion mode.
- **Auto-calibration** (ADC and Time INL): dedicated (DAC + buffer) and high frequency signal source => perform both calibrations in standalone.
- **Wide range DLL**: 3 different sizes of starving transistors can be selected in the main DLL in order to optimize its INL and jitter depending on the chosen sampling frequency => important for frequencies ≤ 3.2GS/s

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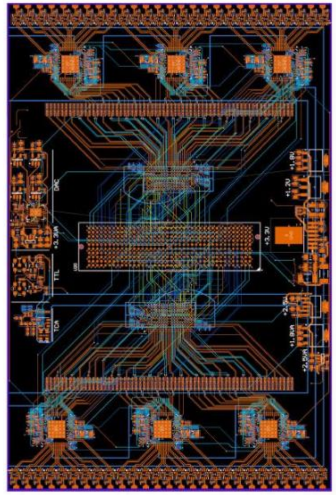
D. Breton

A PSI DRS4-based readout solution for Incom LAPPD is being developed

- Electrons amplified by a chevron pair of MCPs are deposited on one or more of the 28 LAPPD anode strips.
- High bandwidth amplifiers, coupled to the DRS4, sample these electrical pulses at each end of the anode strips.
- A companion FPGA board, provides reconfigurable triggering capability and control over digitization of the DRS4 samples.
- The readout card can record 1024 samples on all anode strip ends at up to 5 GSPS.



February 21, 2017 RD51 CERN - Minot, LAPPD™ Commissioning Update Page 18

M. Minot

Motivation

- Large Area: 200 x 200 mm^2
- Flat Geometry
- PMT Sensitivity: QE >20% w/bi-alkali photocathode
- Picosecond Timing: resolution <60 pS, <100pS for SPE
- Sub-mm spatial resolution
- Lower Cost per Unit Area

https://indico.cern.ch/event/607147/contributions/2476890/attachments/1413628/2166936/RD51_CERN_-MINOT_LAPPDTM_Commissioning_02-21-2017_FINAL.pdf

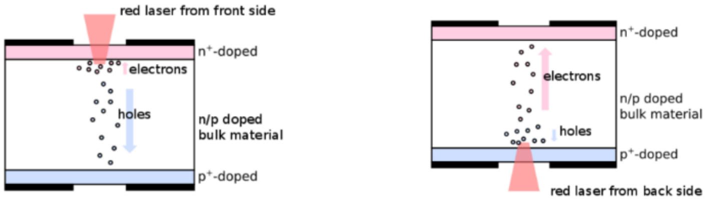
infrastructures

Transient Current Technique (TCT)

Measure $i(t)$ to investigate sensor's electric field and charge collection

$$i_{ind} = n \cdot q_0 \cdot v \cdot E_W = \frac{n q_0 \mu E}{d} \qquad E_W = 1/d \qquad v = \mu \cdot E$$

- Produce eh pairs using a pulsed laser
- Red laser → short absorption depth (few μm)
  → one type of charge carriers drifts
- Infrared laser → long absorption depth (≈mm)
  → similar to charged particle signal
- Read out the signal using an oscilloscope



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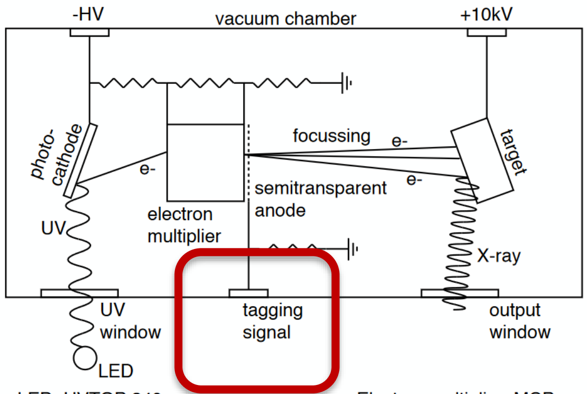
Two Photon Absorption TCT

- Point-like charge carrier generation
- 3D sensor scan
- Use wavelength for which Si is transparent
- e/h pair generation through virtual states
- Photons densly packed in space and time
- High intensity femtosecond laser
- Measurement performed at the SGIKER laser facility in Bilbao
- Application ongoing to acquire components for one setup

M. Centis Vignali

https://indico.cern.ch/event/607147/contributions/2476941/attachments/1412544/2167490/presentation.pdf

WLS: from UV to X-ray



LED: UVTOP 240
UV window: CaF_2
Photocathode: Au

Electron multiplier: MCP
Target: Cr (5.4 keV)
Output window: SS 25 um

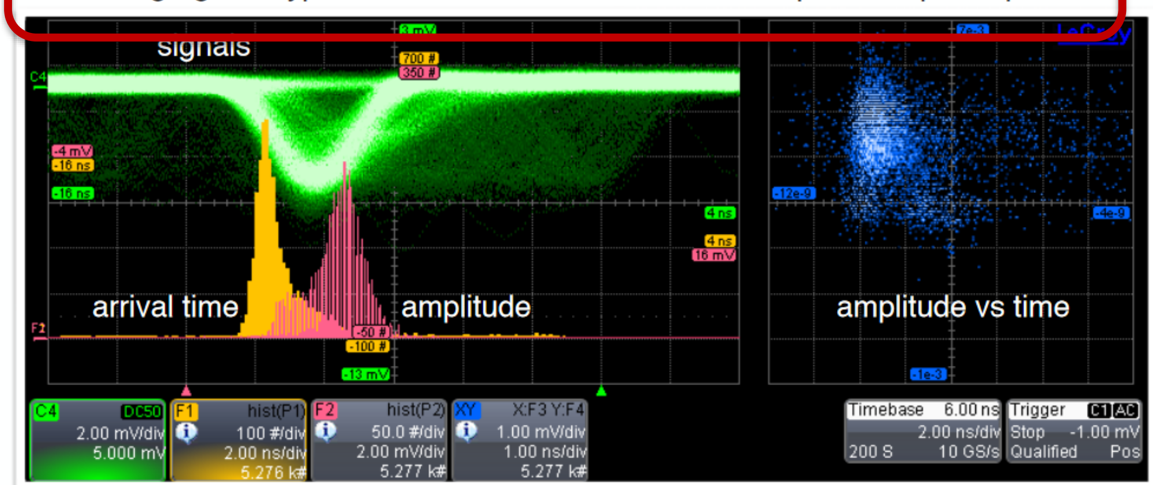
https://indico.cern.ch/event/607147/contributions/2476944/attachments/1413691/2168509/X-rayGenerator.pdf

Preliminary

3

Like silicon (detector)

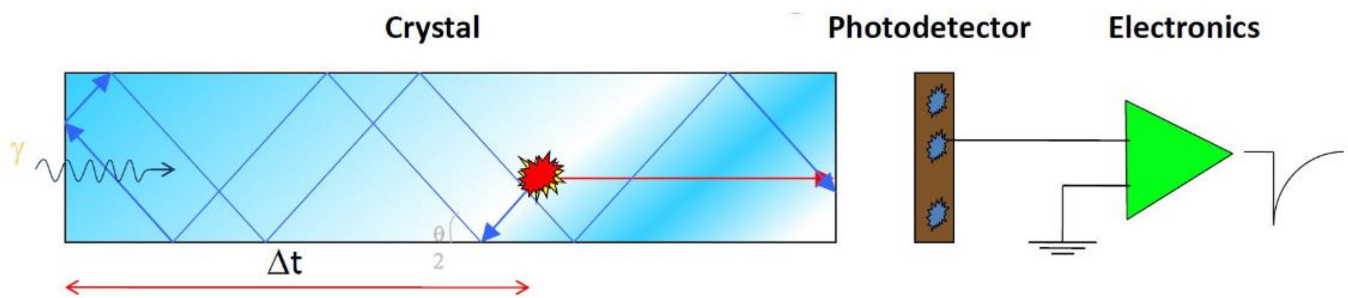
Again t_0 is set by the X-ray tagging signal.
Preliminary depth of interaction study (timing, charge, and signal shape)
in high-gain 'Hyper-fast' silicon detector with trans-impedance preamplifier



Mean free path of 5.4 keV X-rays in silicon (~1500 e^-/h^+): ~20 um

F. Resnati

FAST Challenges of the photodetection chain



$t_{kth\ pe} = \Delta t + t_{k'\ ph} + t_{transit} + t_{SPTR} + t_{TDC}$

Conversion depth — Scintillation process — Transit time jitter — Single photon time spread — TDC conversion time

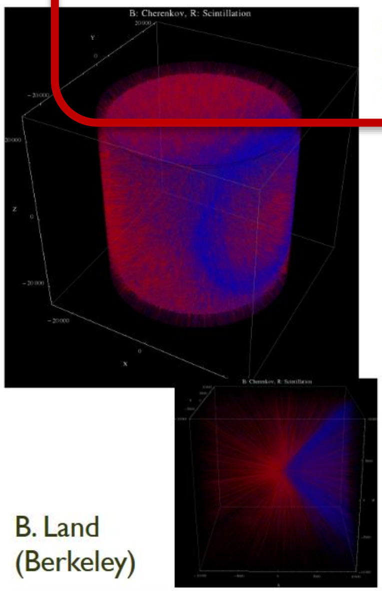
WG 2
Scintillator R & D
- Particule Interaction
- Light generation
- Light transport
- Light transfer
- Light collection

WG 3
Photodetector R & D
- Reduce SPTR and DCR
- Increase fill factor (PDE)
- Digital SiPM
- MCP for PET & HEP

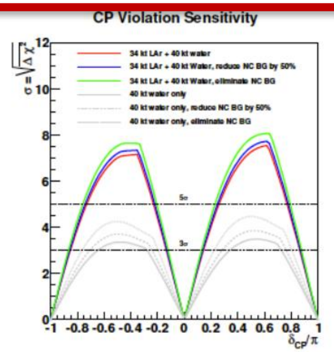
WG 4
Electronics R & D
- TDC < 10ps bins
- Monolithic architecture
- High bandwidth
- Low noise
- Massive parallel data
- High number of channels

M. Lucchini

Cherenkov/Scintillation Separation



Ability to discriminate "Chertons" from "Scintons" is most critical part to make broad program work:



B. Land (Berkeley)

100 ktonne THEIA=40 ktonne LAr
IF scintillation light "doesn't hurt"

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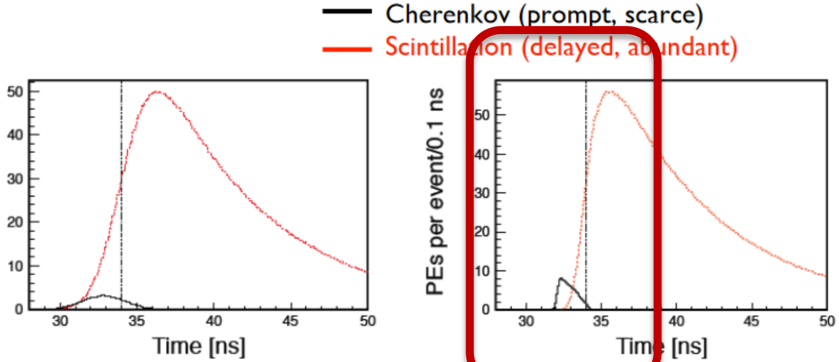
Cherenkov/Scintillation Separation

Separation via Timing

Simulation of 5MeV electrons in KamLAND-like detector



1.3 ns timing of standard PMT

0.1 ns time resolution e.g. LAPPD

C. Aberle et al, JINST 9 P06012 (2014)

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https://indico.cern.ch/event/607147/contributions/2476874/attachments/1415520/2167051/theia_timing_workshop.pdf

J. Klein

Large number of issues/problems/aspects common to Picosec…

Obviously biased by the organization on the workshop in the RD51/Picosec context

Conclusion

- Proof of Concept…
  - Charged particle timing in the sub-50 (well below…) picosecond regime achieve with MicroMegas based detector.
  - Important development on data analysis and detector modelling

- Toward detector/application…
  - Activities to optimize, improve robustness, scale up, …
  - Multichannel electronics…
  - R&D on photocathode for detector longevity (not necessarily crucial for all the possible application).. material science..
  - Technology/expertise (thin film lab, mpgd workshops, electronics…)

- Large interest in the MPGD/RD51 community.. toward the future…

- Many aspect in common with other fast timing project – large community – precise timing workshop - proper condition/environment for interdisciplinary exchanges