High rate, fast time precision GRPC for LHC experiments upgrade

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in collaboration with Omega-Paris, Tsinghua university, NCEPU, Gent

Outline

Motivation

R&D on High Rate GRPC

R&D on Fast Timing GRPC

R&D on Large HR GRPC

Conclusion

Motivation

With the increase of CM energy and luminosity, LHC detectors, namely the muon detectors, in the high η region should be able to withstand **high rate**

Rates at Muon Trigger Upgrade

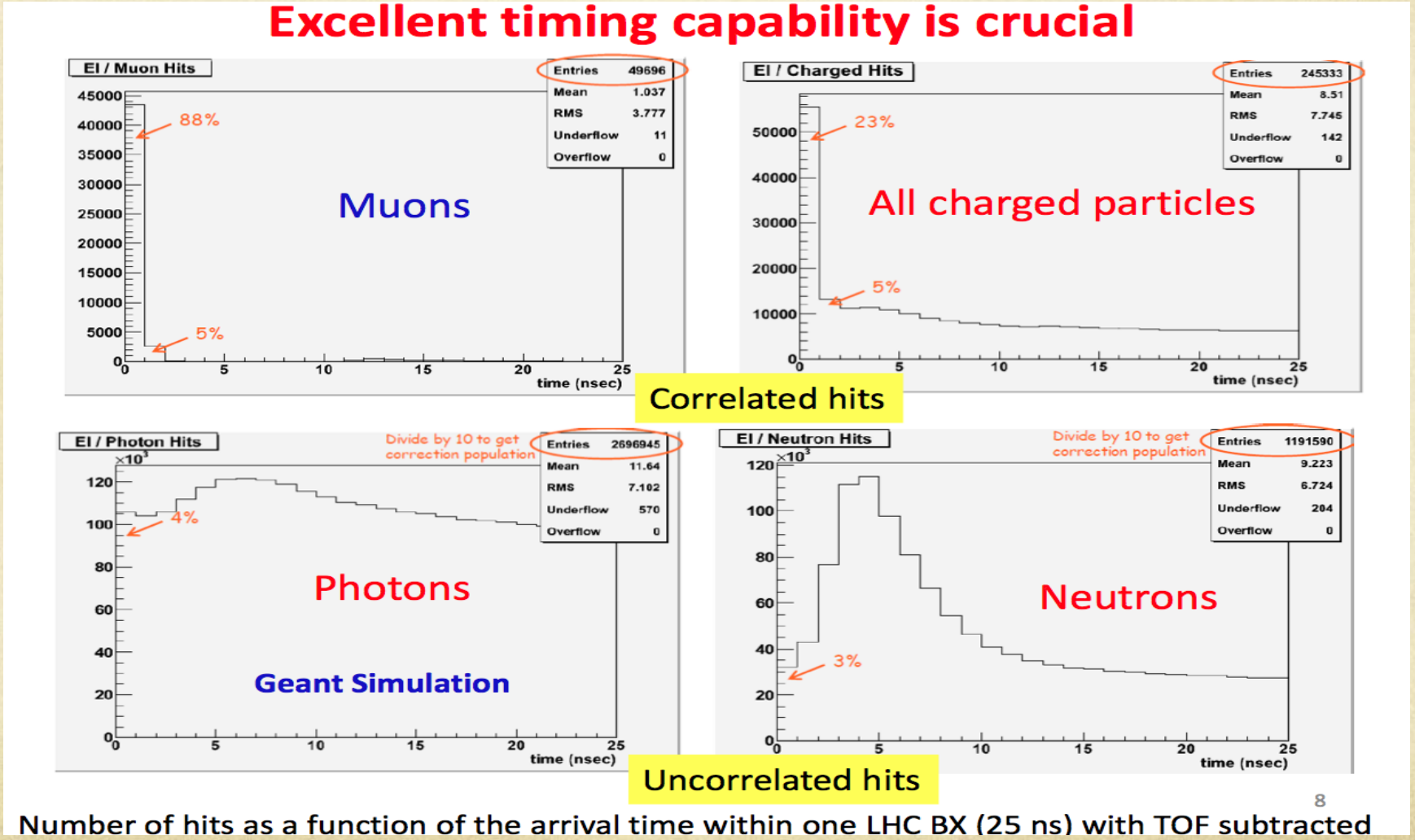
Parameter	LHC	HL-LHC
s	14TeV	14TeV
L	$10^{34}/cm^2s$	$10^{35}/cm^2s$
bunch spacing	25ns	12.5ns
interactions/crossing	≈ 12	≈ 62
$dN/d\eta$ crossing	75	375
CMS particle flux 1^{st} muon layer $\eta \approx 2.4$	$\approx 1kHz/cm^2$	$\approx 10kHz/cm^2$
CMS particle flux 1^{st} muon layer $\eta \approx 2.4$	$\approx 1kHz/cm^2$	$\approx 10kHz/cm^2$
ATLAS particle flux 1^{st} muon layer $\eta \approx 2.4$	$\approx 1 - 10kHz/cm^2$	$\approx 1 - 15kHz/cm^2$
ATLAS particle flux 1^{st} muon layer $\eta \approx 2.4$	$\approx 1 - 10kHz/cm^2$	$\approx 1 - 15kHz/cm^2$

A. Sharma, Frascati, RPC2012

Trigger rate should be maintained to keep the same physics selection capability.
One solution is to provide excellent **spatial precision** to reduce the ambiguity and hence the fake tracks.

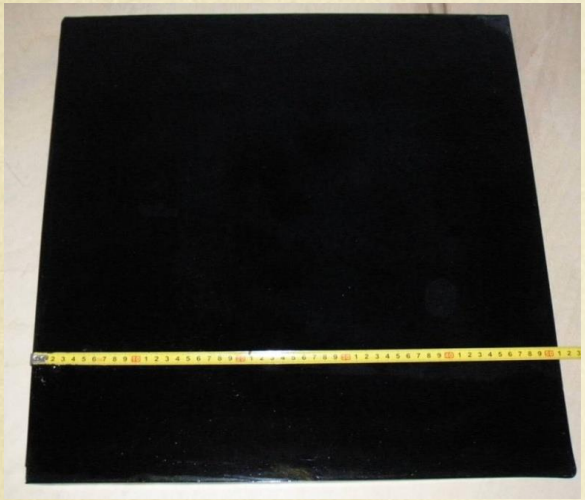
Motivation

Excellent **timing resolution** is another powerful and complementary option.



J.Zhu, ATLAS collaboration, RPC2012

- High-Rate GRPC : A new kind of glass developed by Tsinghua University



Glass Specifications:

Present max. dimension: 32cm×30cm

Bulk resistivity: ≈10^{10}Ω.cm

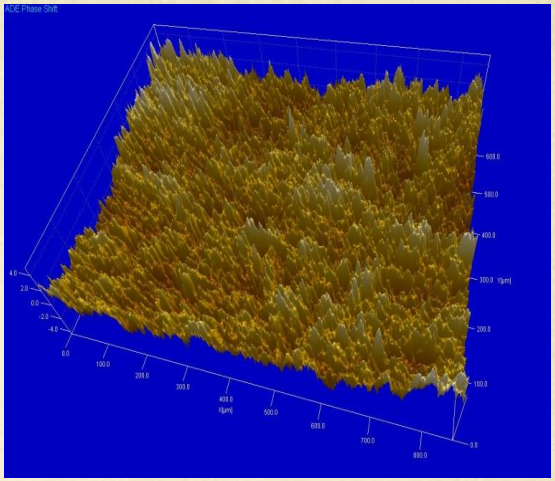
Standard thickness: 0.5mm--2mm

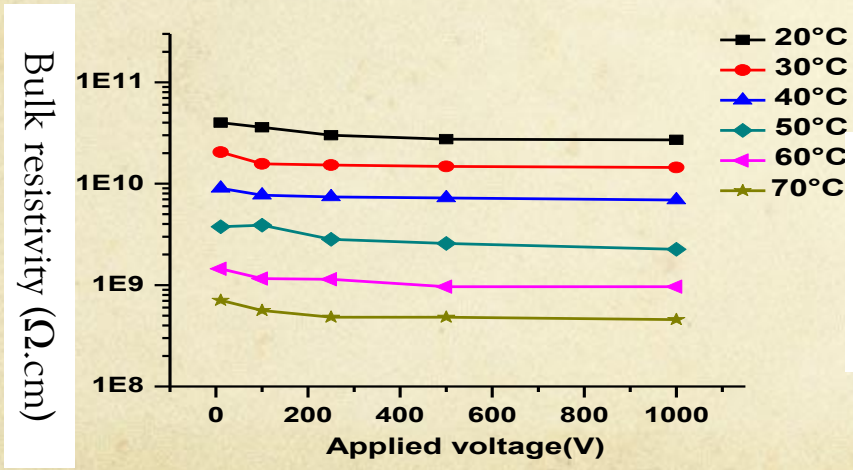
Thickness uniformity: ±0.02mm

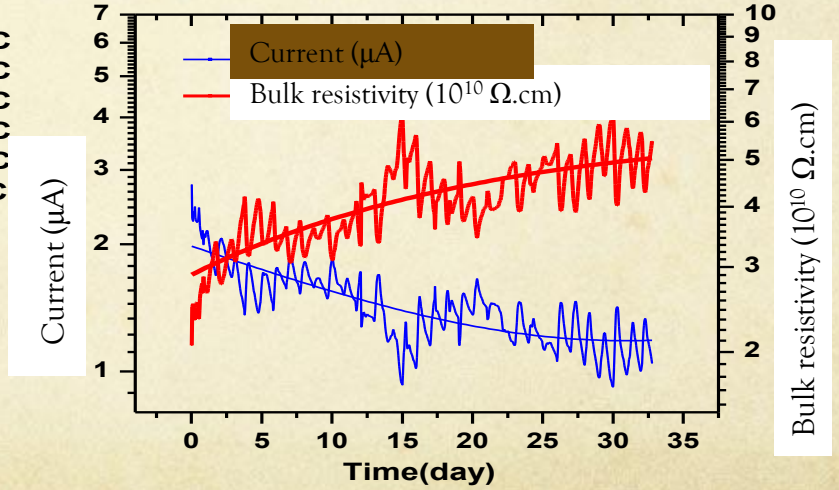
Dielectric constant: ≈7.5-9.5

Surface roughness: < 10 nm

DC measurement: Ohmic behavior, stable up to 1 C/cm^2





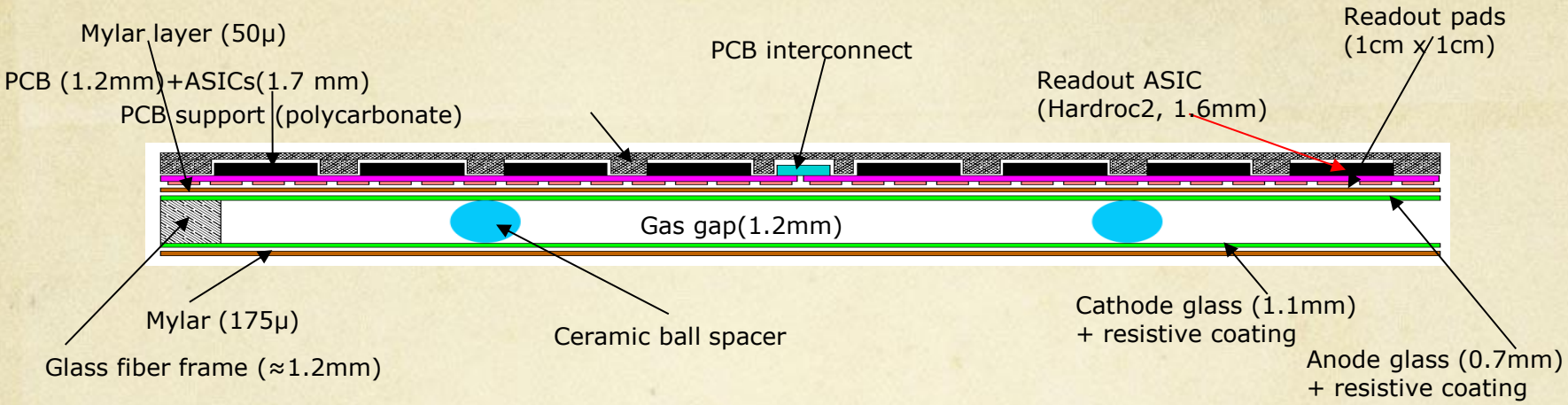


➢ Resistivity decreases with temperature

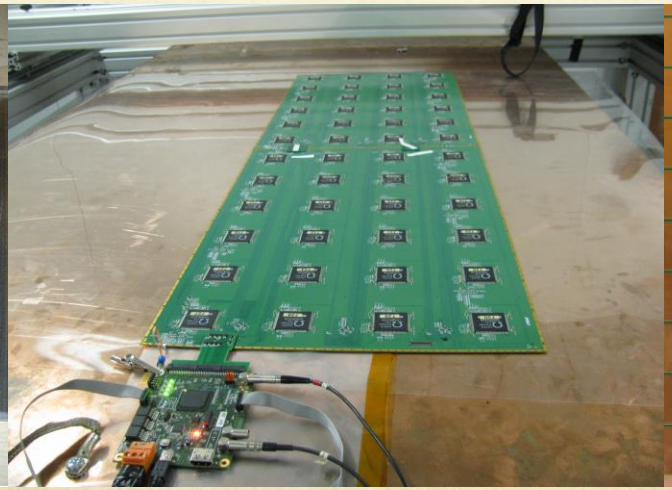
➢ Resistivity is very stable in DC measurement

The glass was applied with 1000V for about 32days, integrated charge: 1 C/cm^2

- **Single gap**

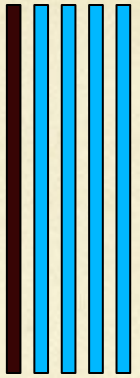


Total thickness (detector 3 mm+ readout electronics 3 mm): 6.0mm



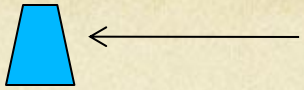
Tsinghua glass (10^{10} Ω.cm)

Same electronics readout used in the SDHCAL



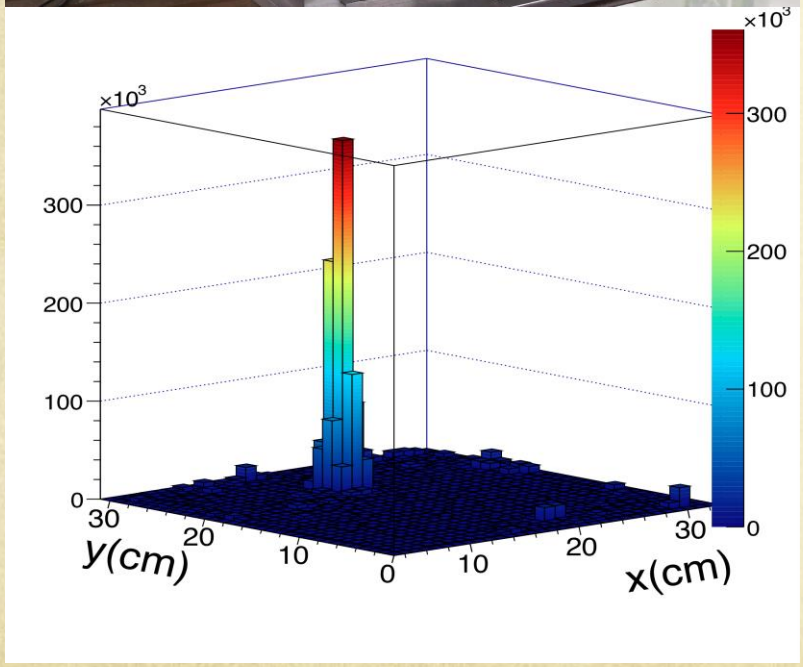
2 Scint-PM

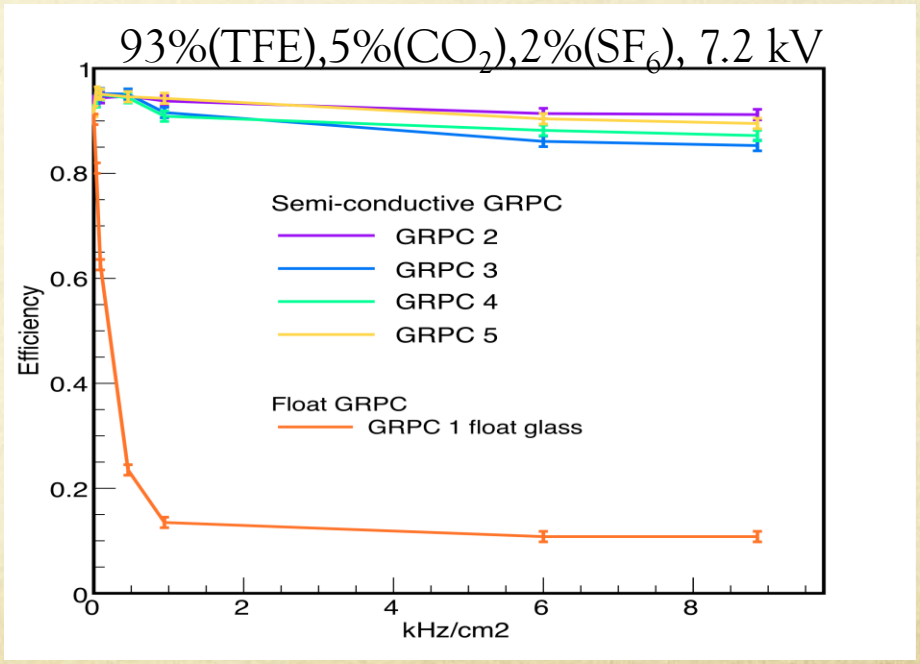
Beam counter Scint-PM



DESY electron beam

1 standard GRPC+ 4 low-resistivity GRPC

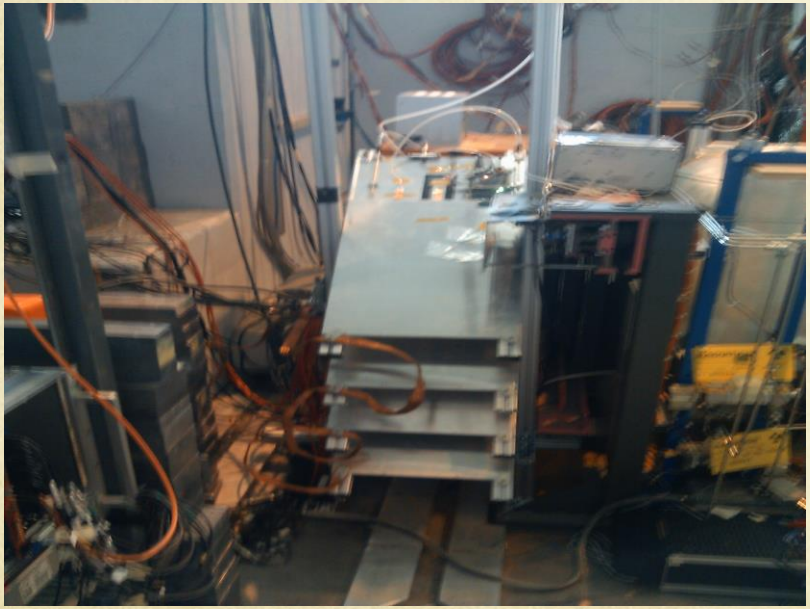




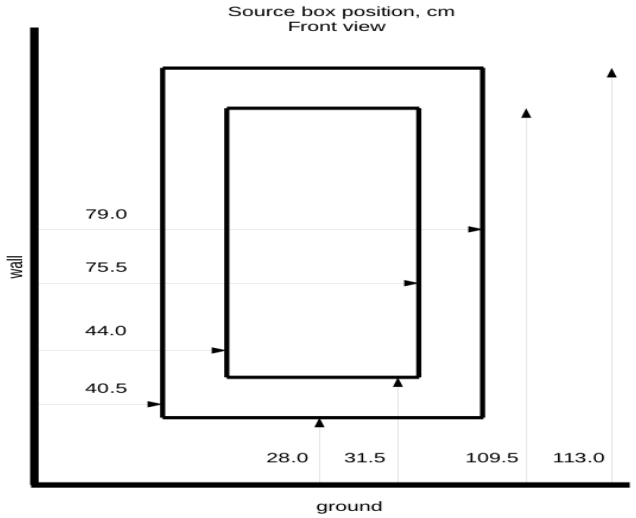
9 kHz/cm^2 is highest rate one can get at DESY

Threshold =100 fc

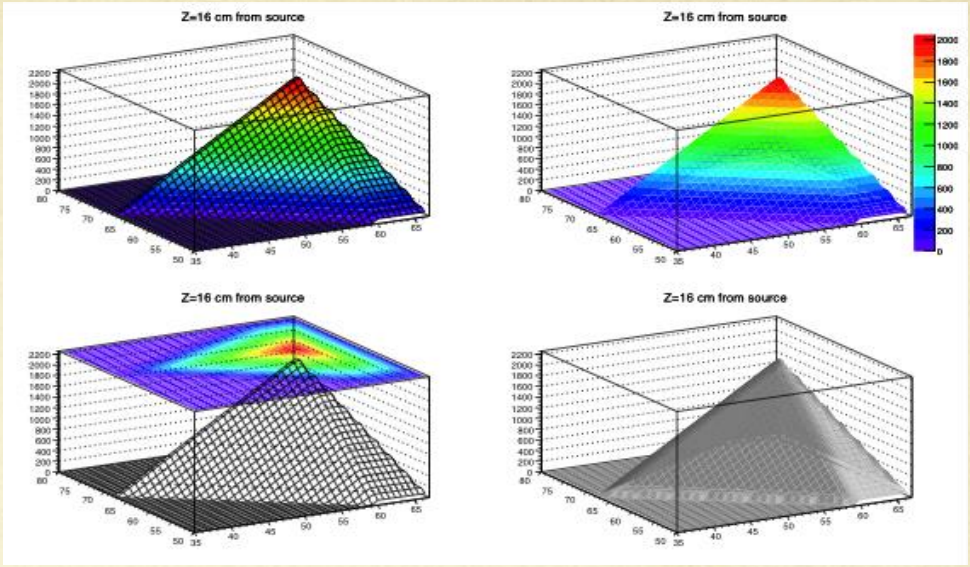
The same chambers 1 standard + 4 small (32x30 cm^2) low resistivity GRPC are brought to GIF in June 2013 and exposed to the GIF source at small distance with the aim to check the effect of long time exposure to high rate on the whole surface and to check their efficiency in these conditions using the cosmics.
With the lateral aperture of the source essentially two RPCs are exposed to the gamma irradiation.

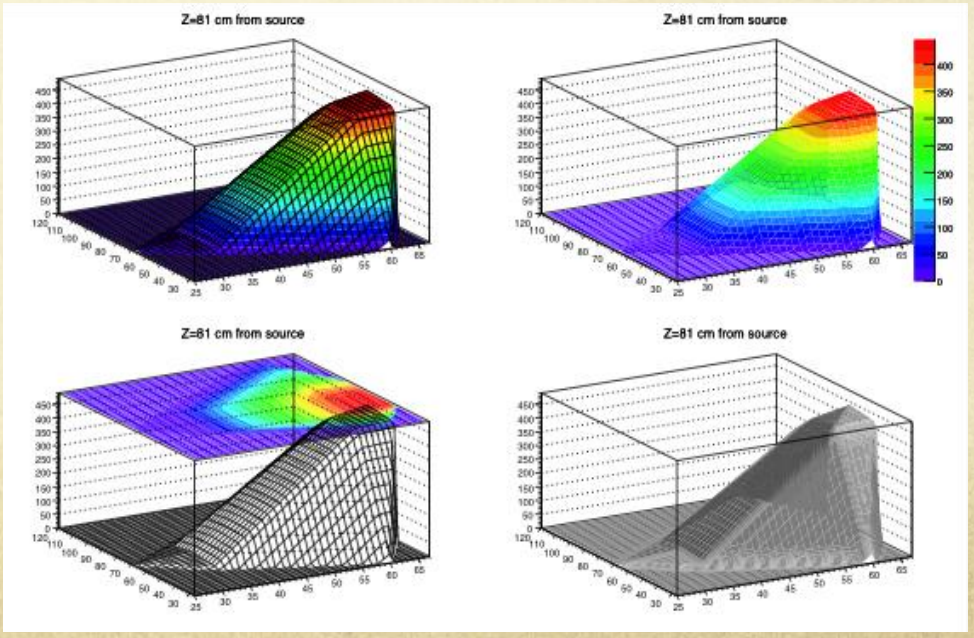


Gamma rate: 7.1 10^6 gamma/(cm2 s) as given by GIF staff.



#	x	y	z	T	P	mGy	Bq/cm²/s
1	60	68	81	19.2	951.3	420.5	2.33686e+06
2	60	27	81	19.2	951.5	7.695	42763.6
3	60	120	81	20.3	951.3	2.034	11303.6
4	60	50	81	20.3	951.3	425.3	2.36353e+06
5	60	80	81	20.5	951.5	351	1.95062e+06
6	67	50	81	20.2	951.5	432.3	2.40243e+06
7	67	68	81	20.2	951.5	447.4	2.48635e+06
8	67	80	81	20.5	952.7	331.5	1.84225e+06
9	35	80	81	20.5	952.7	6.96	38679
10	35	68	81	20.5	952.7	17.96	99809.6
11	35	50	81	20.5	952.7	9.144	50816.2
12	25	68	81	20.2	951.9	4.554	25308.1
13	**60**	**80**	**40**	**19.7**	**952.7**	**19.71**	**109535**
14	**60**	**68**	**40**	**19.7**	**952.7**	**1119**	**6.21865e+06**
15	**60**	**50**	**40**	**19.7**	**952.7**	**949.6**	**5.27724e+06**
16	**67**	**50**	**40**	**20**	**952.4**	**971.2**	**5.39727e+06**
17	**67**	**68**	**40**	**20**	**952.4**	**1122**	**6.23532e+06**
18	**67**	**80**	**40**	**20**	**952.4**	**38.07**	**21156**
19	35	68	16	20	952.4	3.285	18255.8
20	60	80	16	20	952.4	8.676	48215.4
21	60	68	16	20	952.4	2107	1.17093e+07
22	60	50	16	20	952.4	30.29	168331
23	67	80	16	19.7	952.7	10.54	58574.2
24	67	68	16	19.7	952.7	10.74	59685.7
25	67	50	16	19.7	952.7	25.83	143546

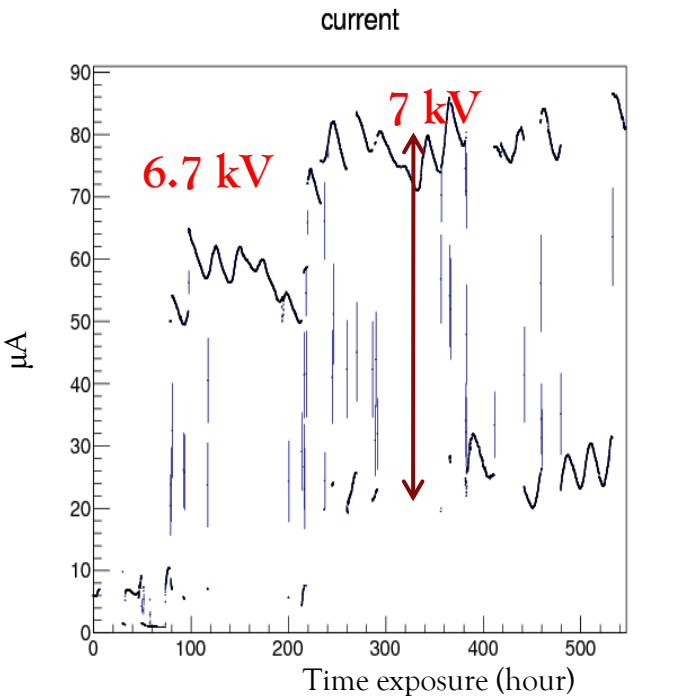


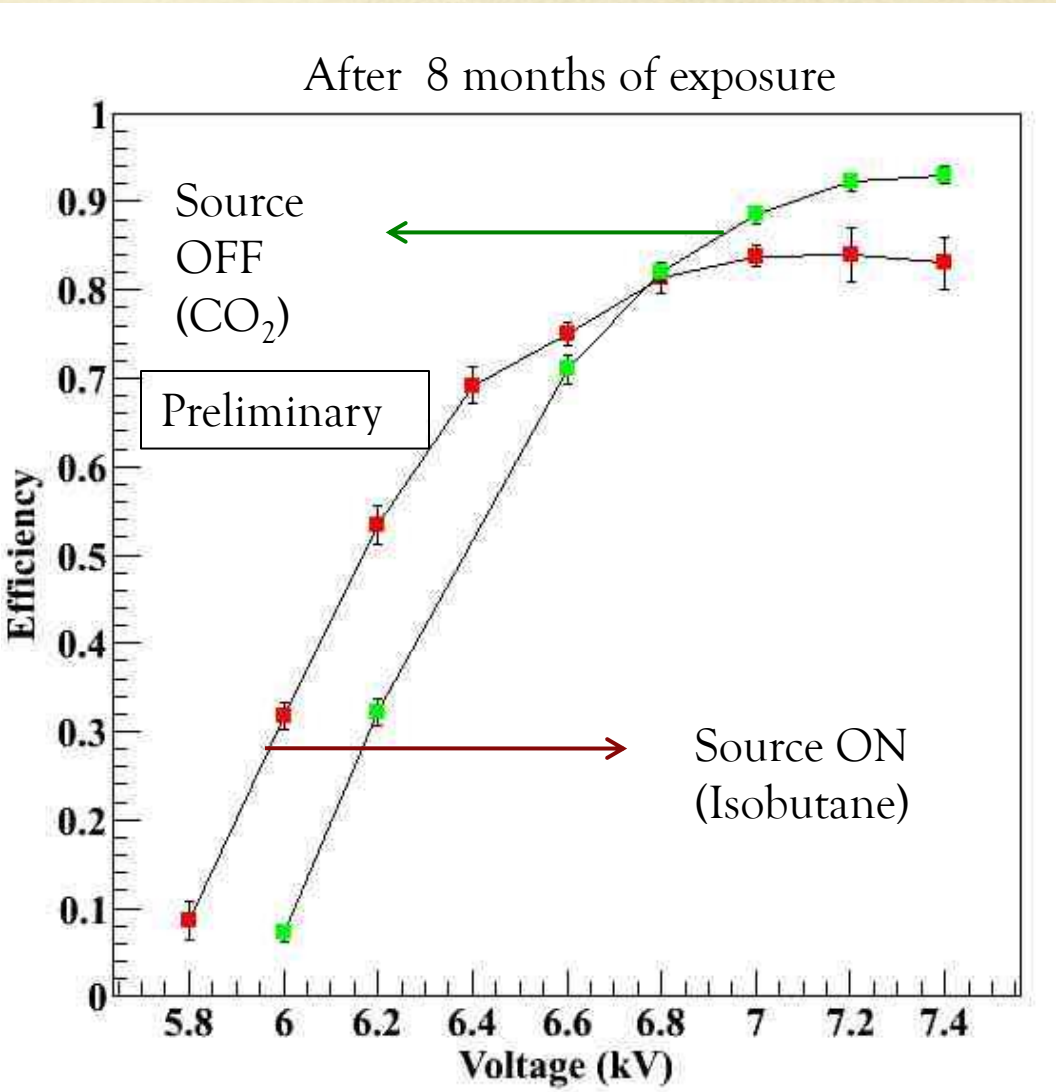


R&D on high rate RPC

Measuring the current with and without source one can deduce that the effective average gamma rate penetrating in the RPC is higher than 10 kHz/cm^2

93.7%(TFE),4.5%(CO_2),0.3%(SF_6)





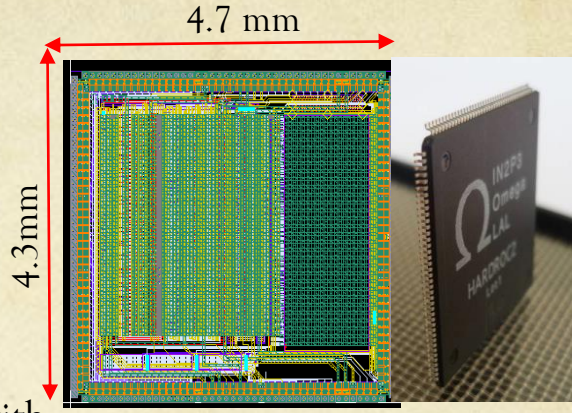
N.B : F-product including HF were measured and found to be negligible

R&D on fast timing RPC

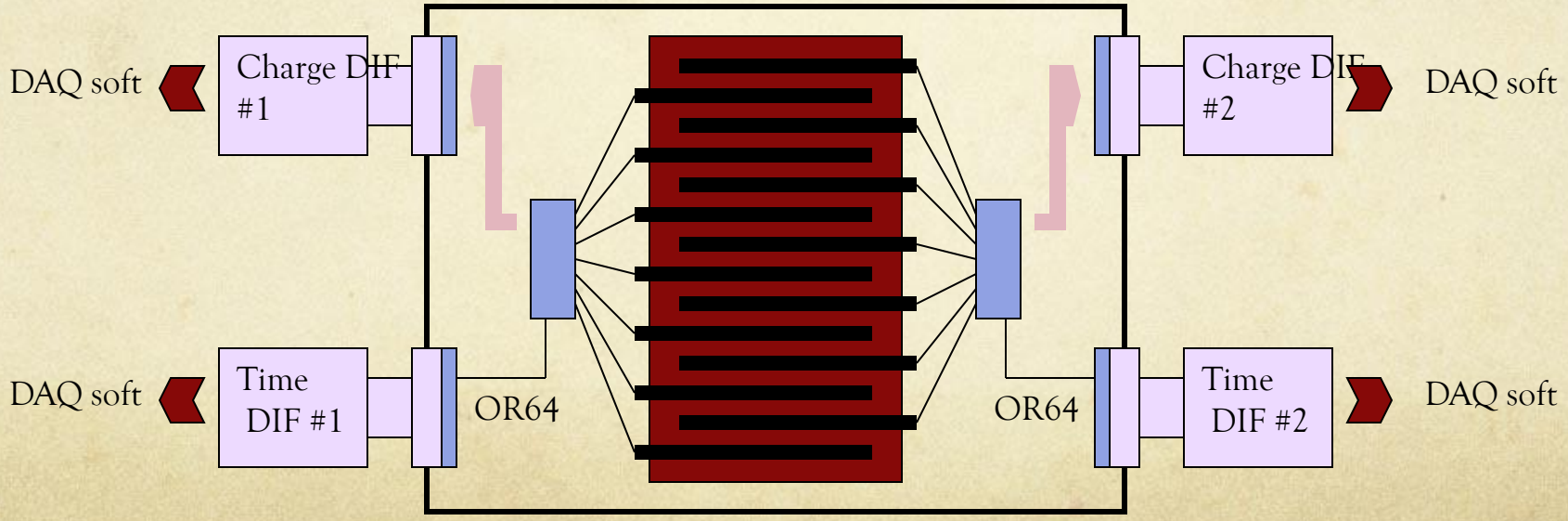
To achieve 1 nanosecond

-Double gap GRPC is a good option.
-HARDROC ASIC : 64-channel, 2-bin readout, three comparators
-SDHCAL DAQ
-TDC using the vernier principle with 100 ps time resolution

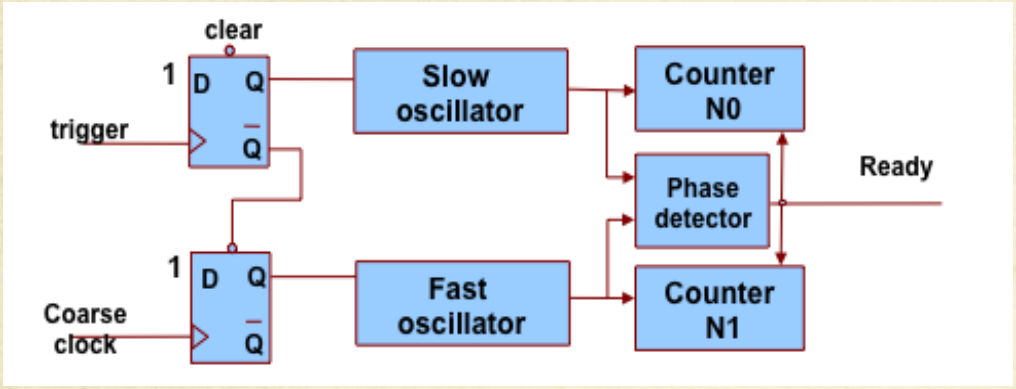
(*use the **U64** available signal for each of the three comparators as input*)

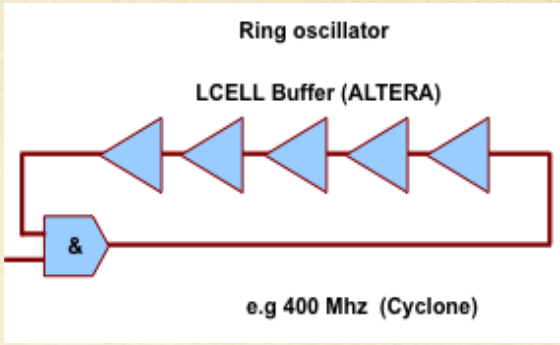


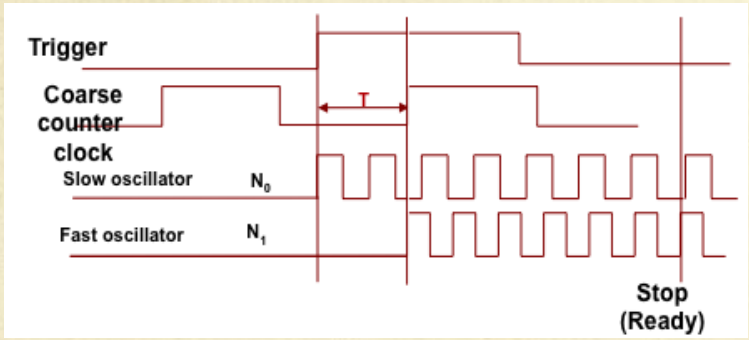
A adouble-face PCB with pick-up strips (pitch of 2.5 mm) on the two faces with 1 mm staggering between the two faces was conceived and produced
ASICs are embedded on the PCB.



TDC principle

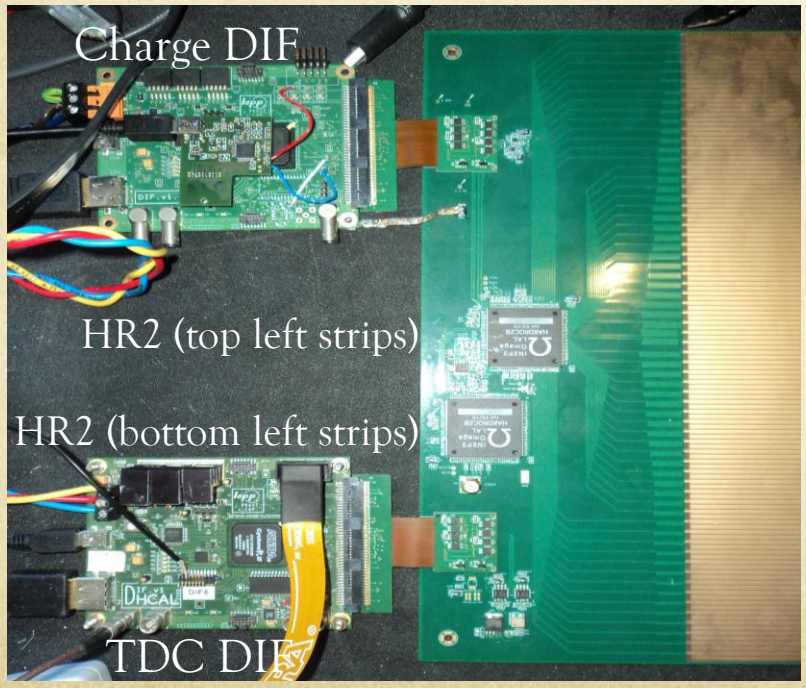






$$T = N_0 T_{slow} - N_1 T_{fast}$$

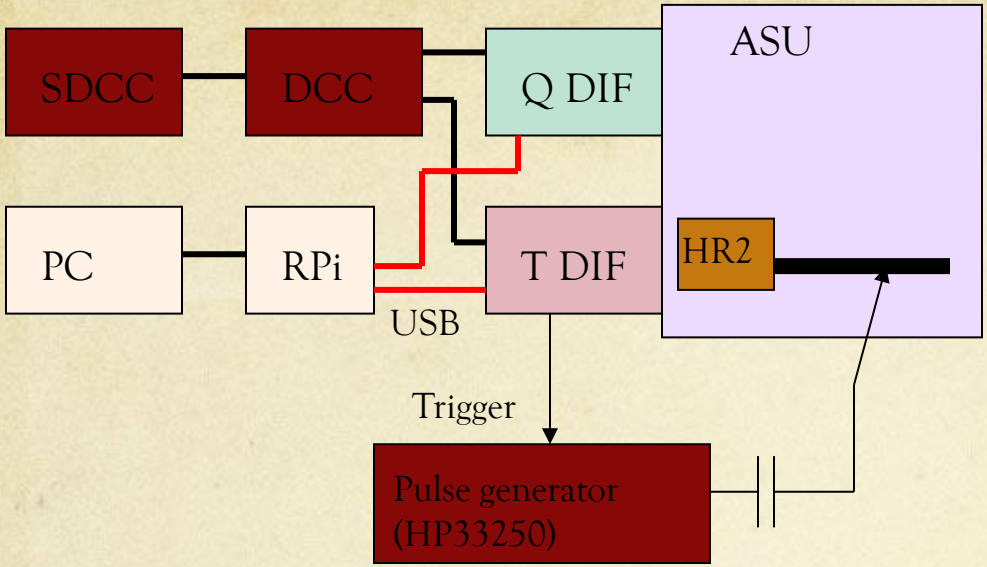
Double face PCB with strips for spatial and timing measurements

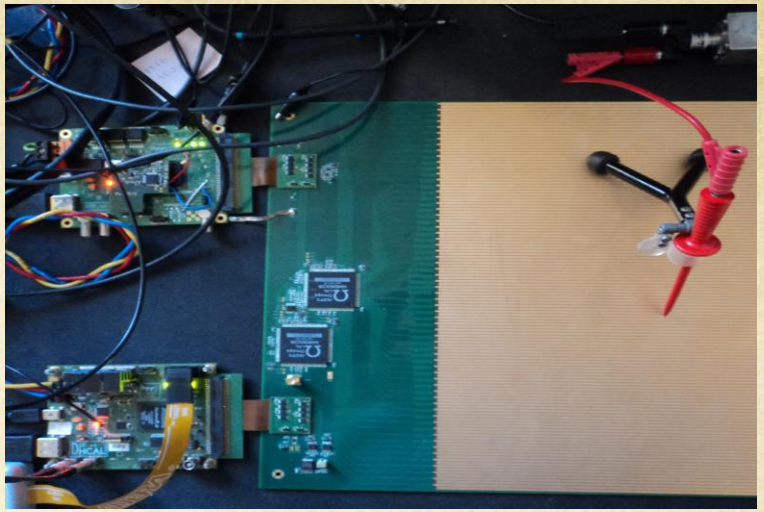


2.5 mm pitch

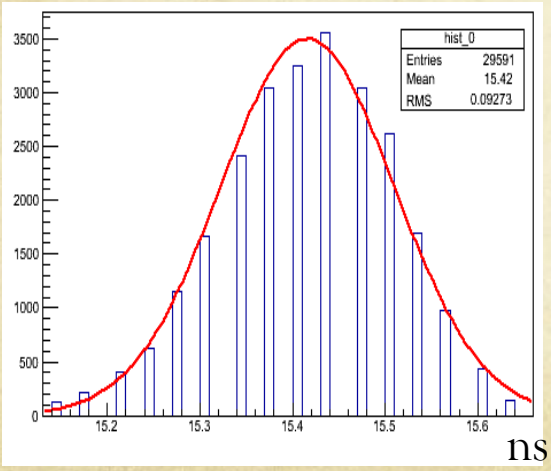
HR2 (top right strips)

HR2 (bottom right strips)

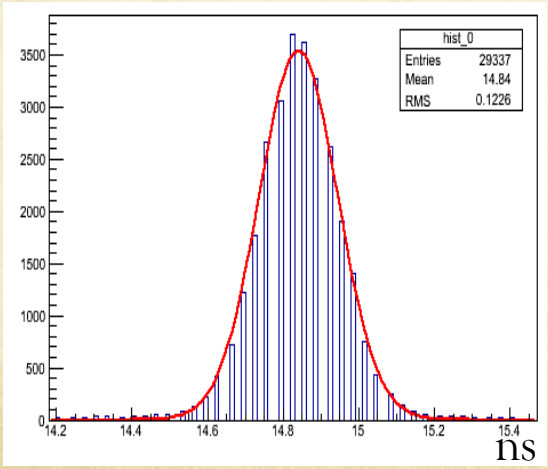




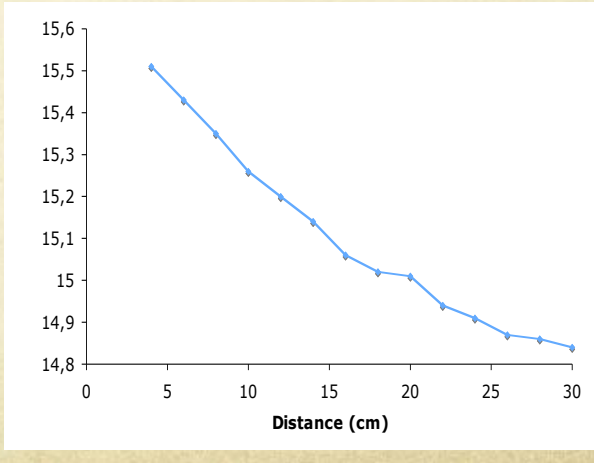
- Injection is made with a pulse generator on one strip (other channels are disabled)
- Pulse generator is triggered by the DIF (synchronous with the DIF clock)
- Delay between pulse and trigger is adjusted inside the generator



6mm from start of strip



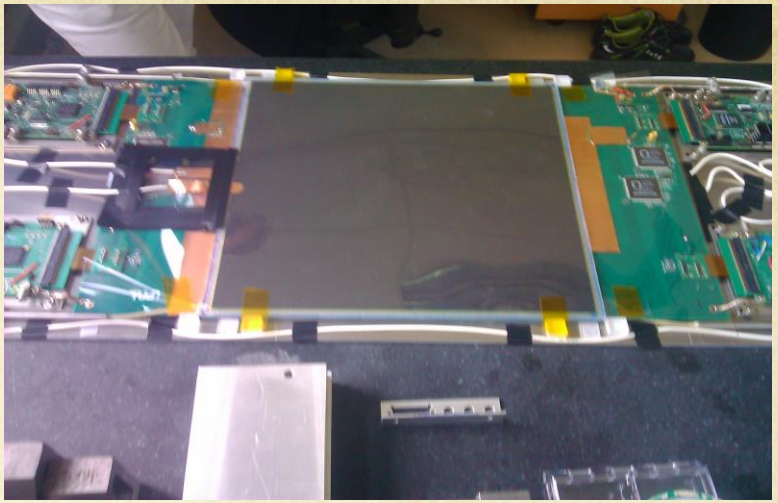
30 mm from start of strip

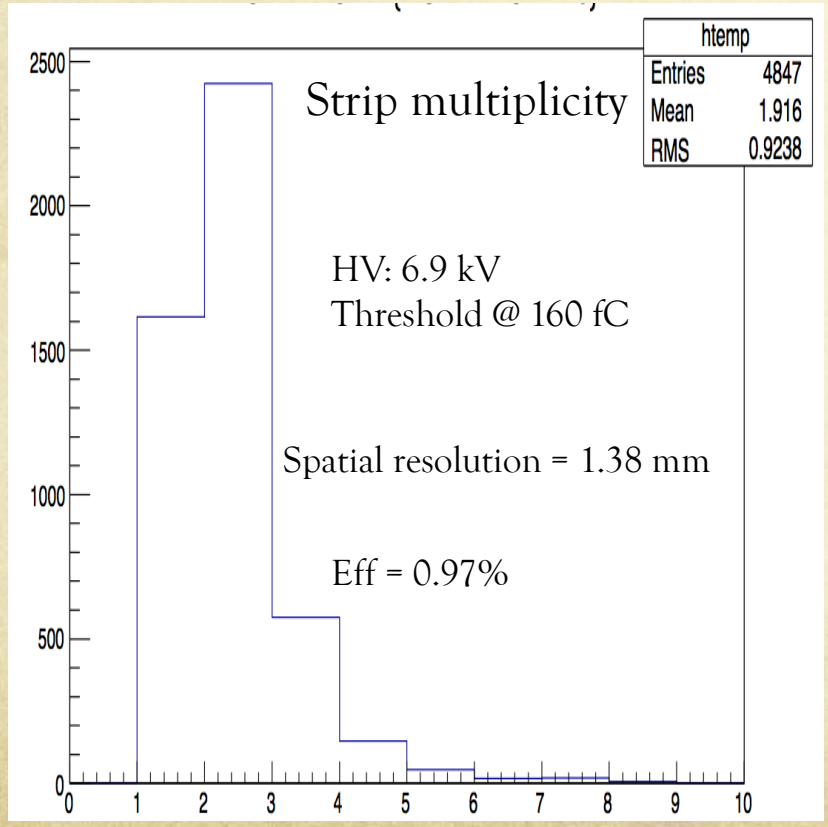


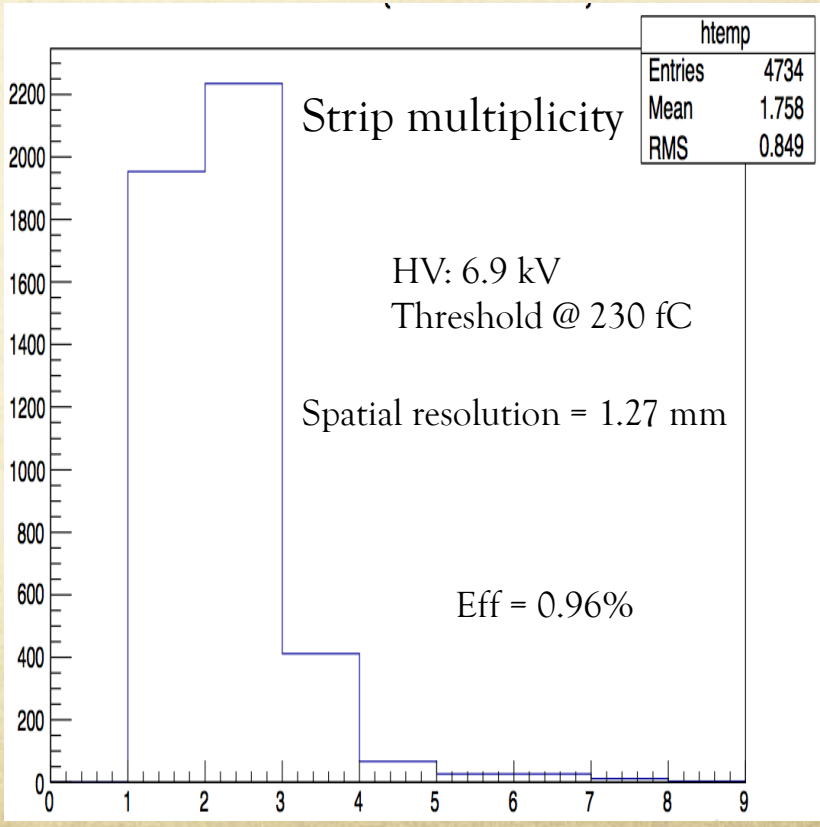
Ongoing tests

Using the coincidence of three Scint-PM signals as a trigger and time reference. We are currently studying

1- Spatial resolution : being studied
2- Time resolution : to follow soon







-To achieve sub-nanosecond

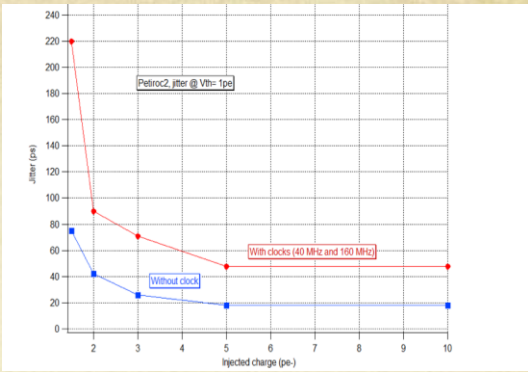
-Multi-gap GRPC is needed. The more gaps the more precise the time measurement.

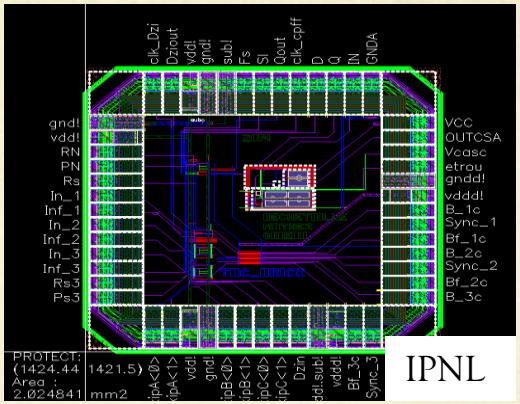
-OPTIROC ASIC : 16/32-channel, high bandwidth preamp (GBWP> 10 GHz), <3 mW/ch, dual time and charge measuremen (160 fC-400 pC), **jitter < 20 ps rms**

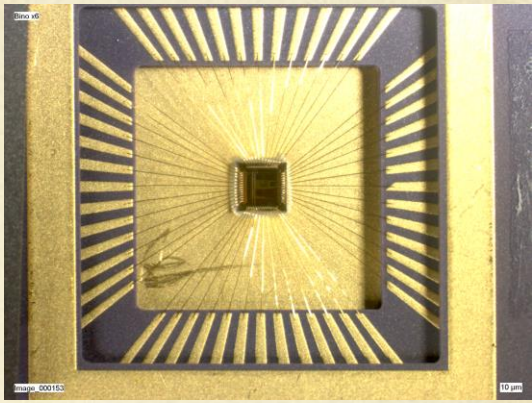
-TDC chip using the vernier principle with 10 ps time resolution is produced and being tested. Another TDC using the white rabbit technology could also be used

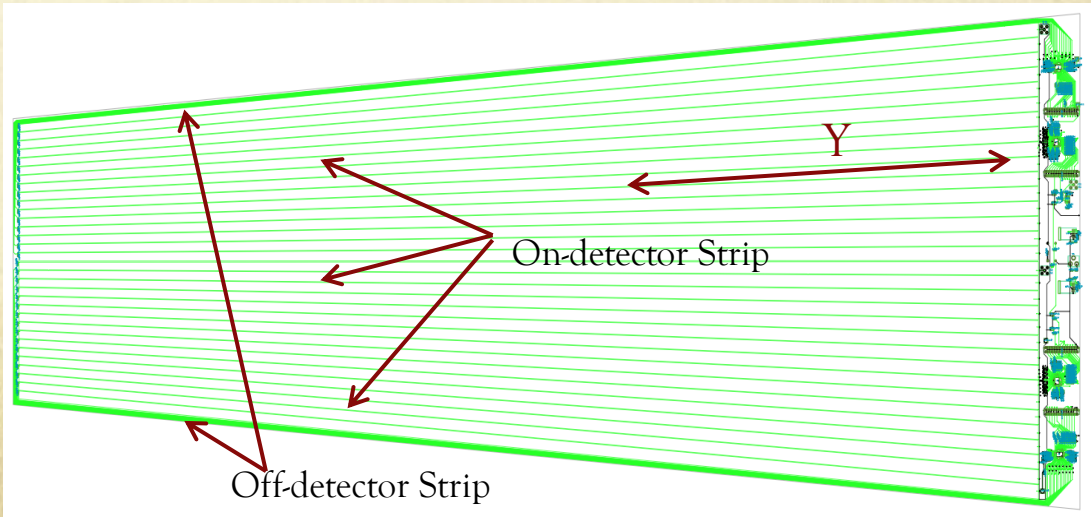
-.New PCB with pick-up strips read from both sides is being designed information with the aim to achieve Y-position determination $Y= L/2-v*(t_2-t_1)/2$. Time resolution can be measured: $(t_1+t_2)- L/v$


OMEGA group




IPNL



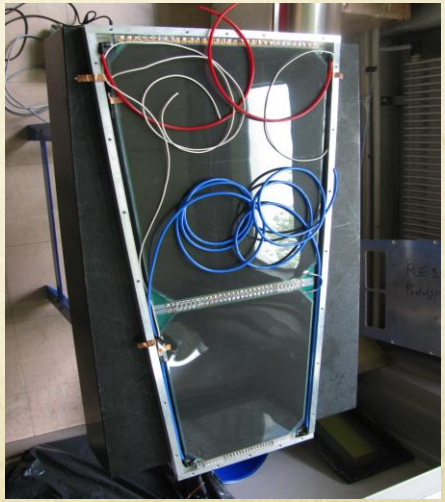


R&D on large high-rate RPC

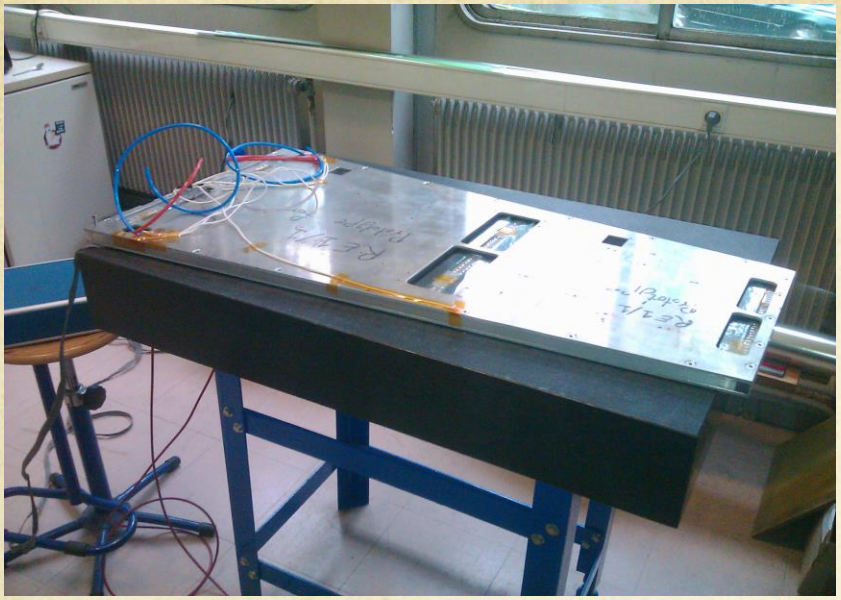
The small size of the semi-conductive glass is a limitation to build large RPC a la CMS for instance. However solutions do exist: Gluing is one of them (HARP)

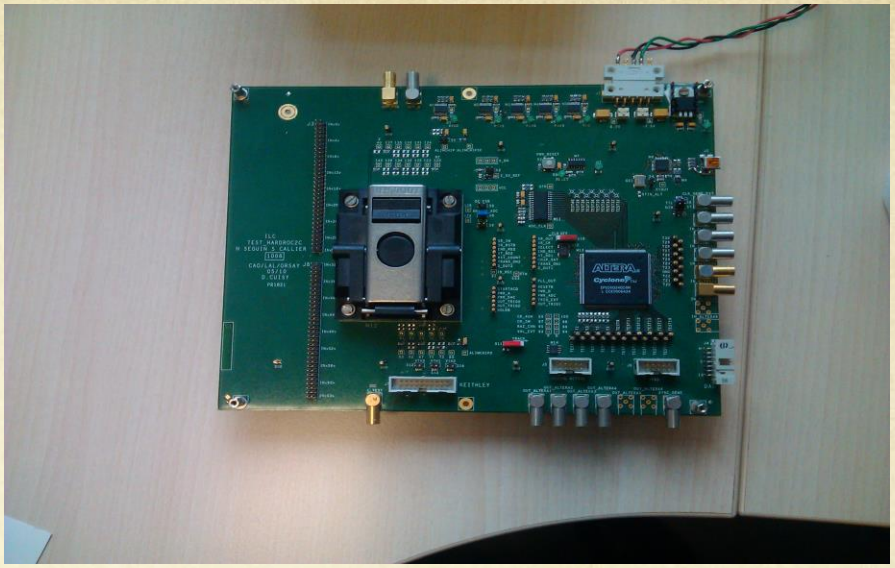




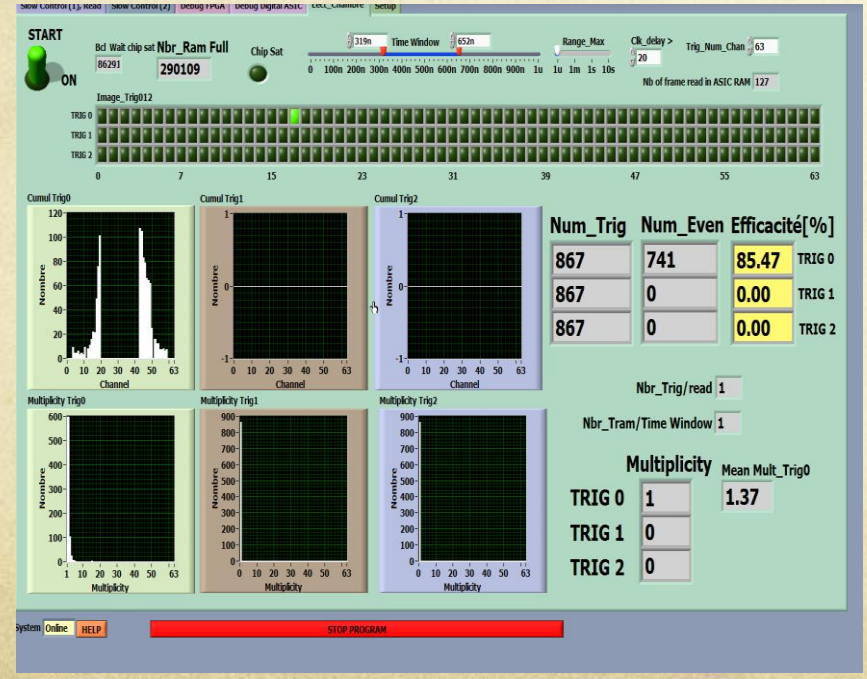



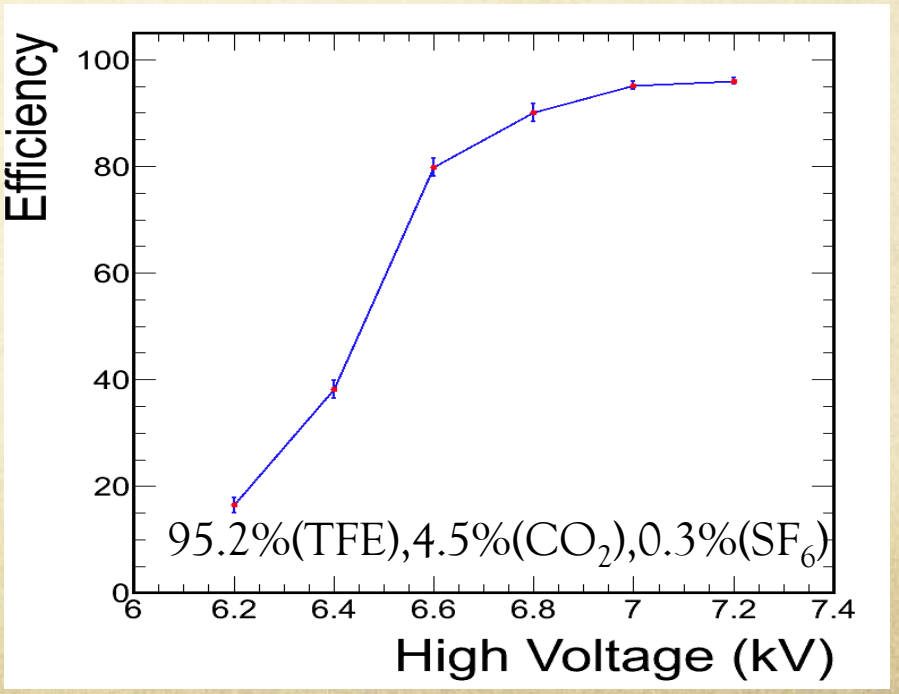
2-gap large chamber is built by gluing





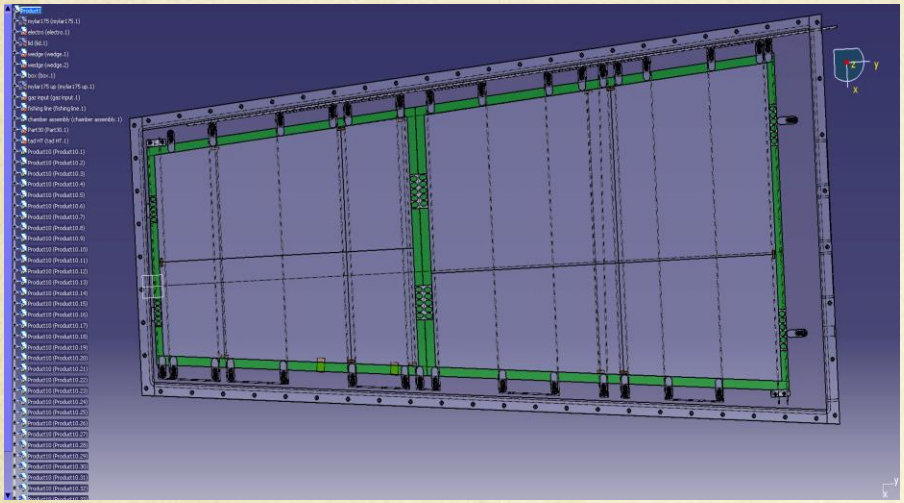
Strip (32 of #1 cm pitch) read out by HARDROC ASIC

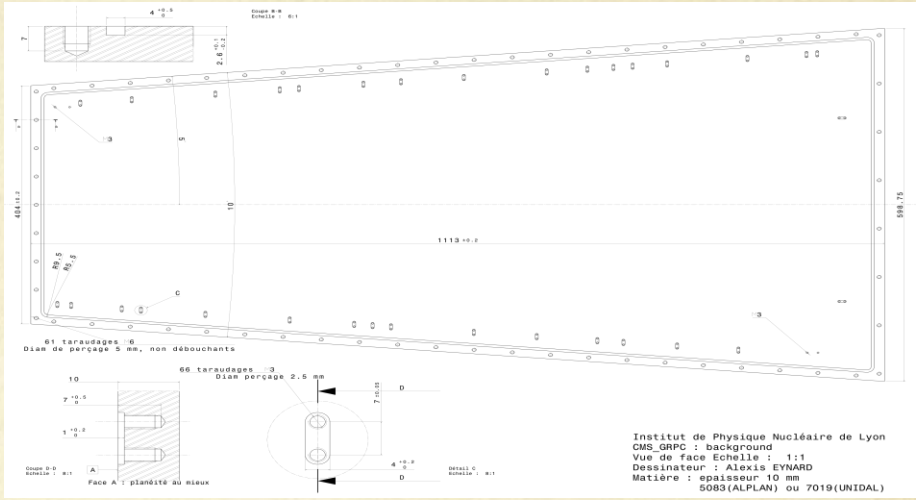


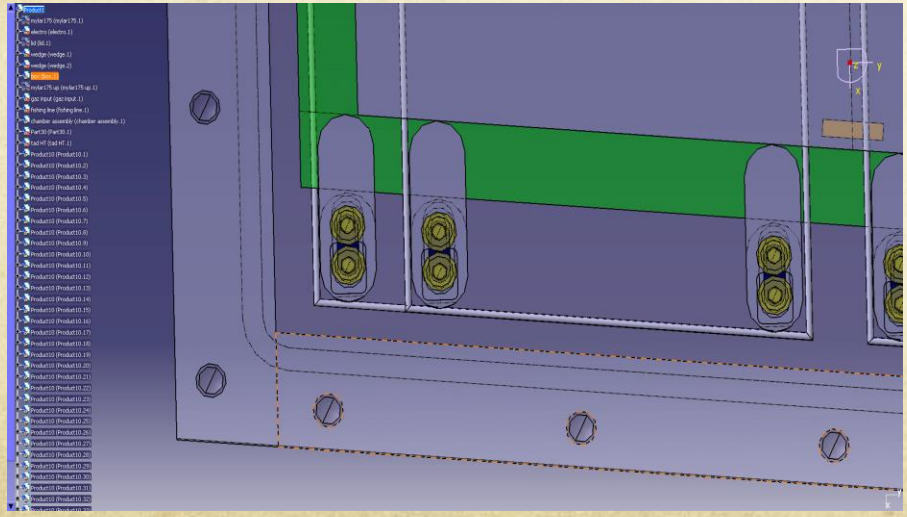


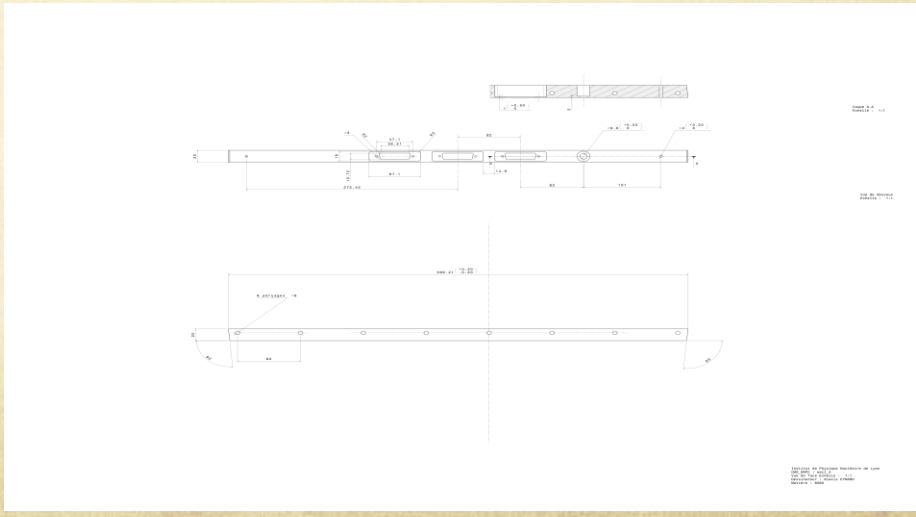
New scheme

build big chambers from putting together small chambers, fixed mechanically, and ensure the gas tightness by the cassette. This solution is being followed and we hope soon to have a detector built in this way using standard glass.









Conclusion and perspectives

-R&D on high rate and fast timing of large GRPC is very active.

-High rate capability is demonstrated. Single–gap detectors using Tsinghua low-resistivity glass are still efficient with few kHz/cm2 rate.

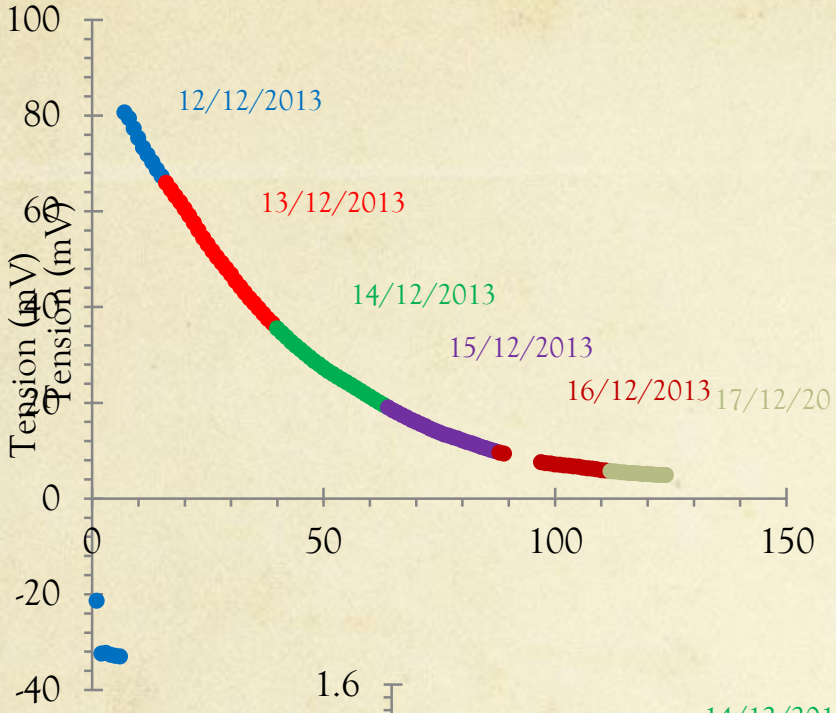
-The exploitation of the excellent time precision of the RPC is pursued by developing/exploiting high performance TDC and ASIC. < 50 ps timing precision seems to be reachable.

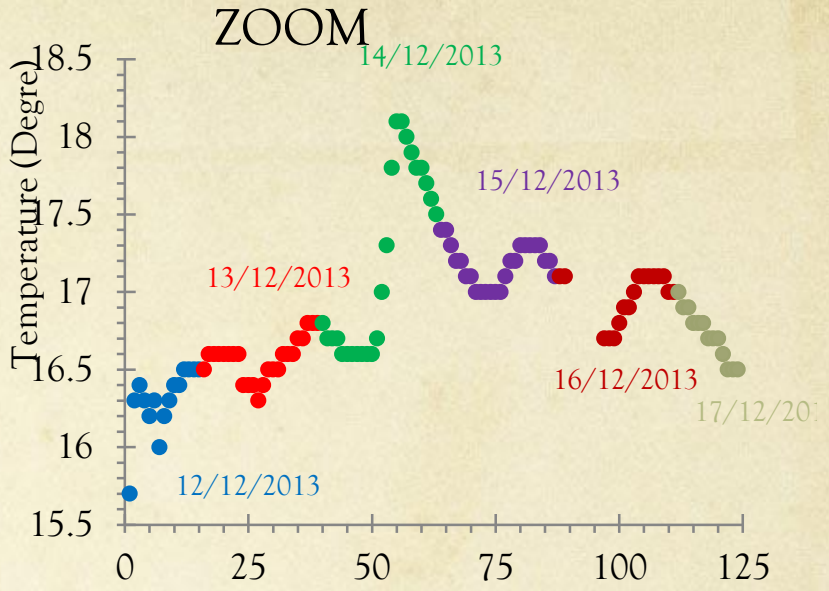
-A proposal to equip the high η of CMS with cost-effective muon detectors capable of supporting high rate and providing timing information is made.

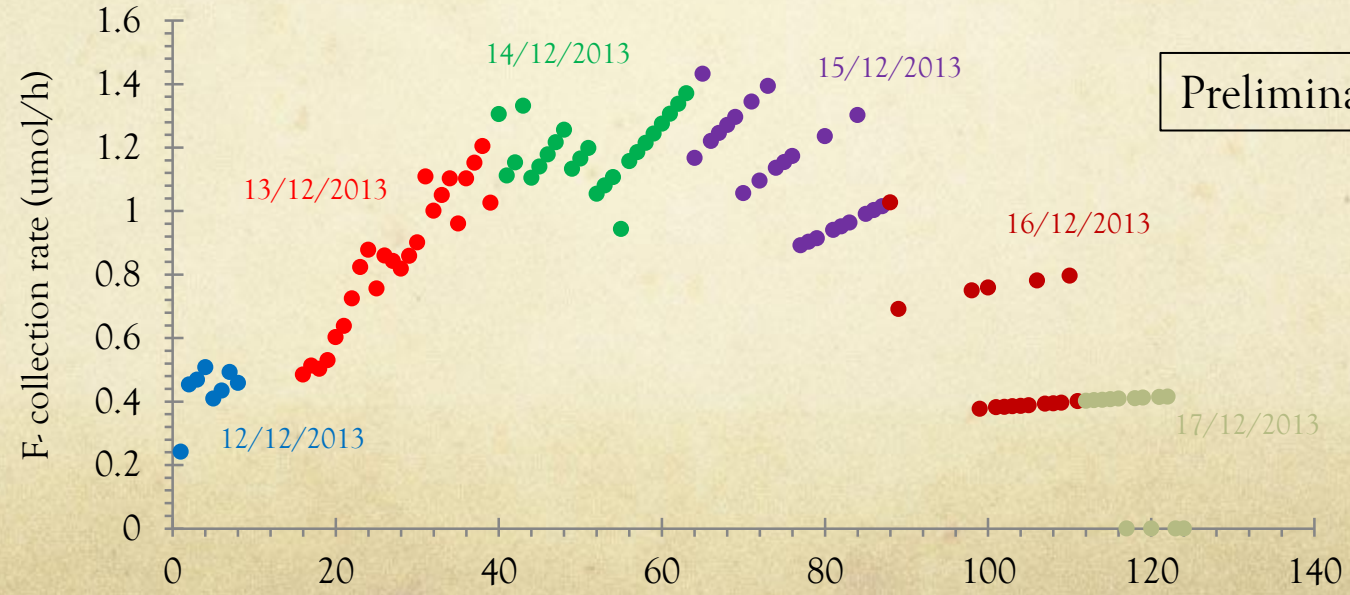
The time precision will allow to exploit the fourth dimension. New area of applications could benefit form this developments: medical application, astroparticles….

HF measurement based on method used for the CMS Bakelite RPC

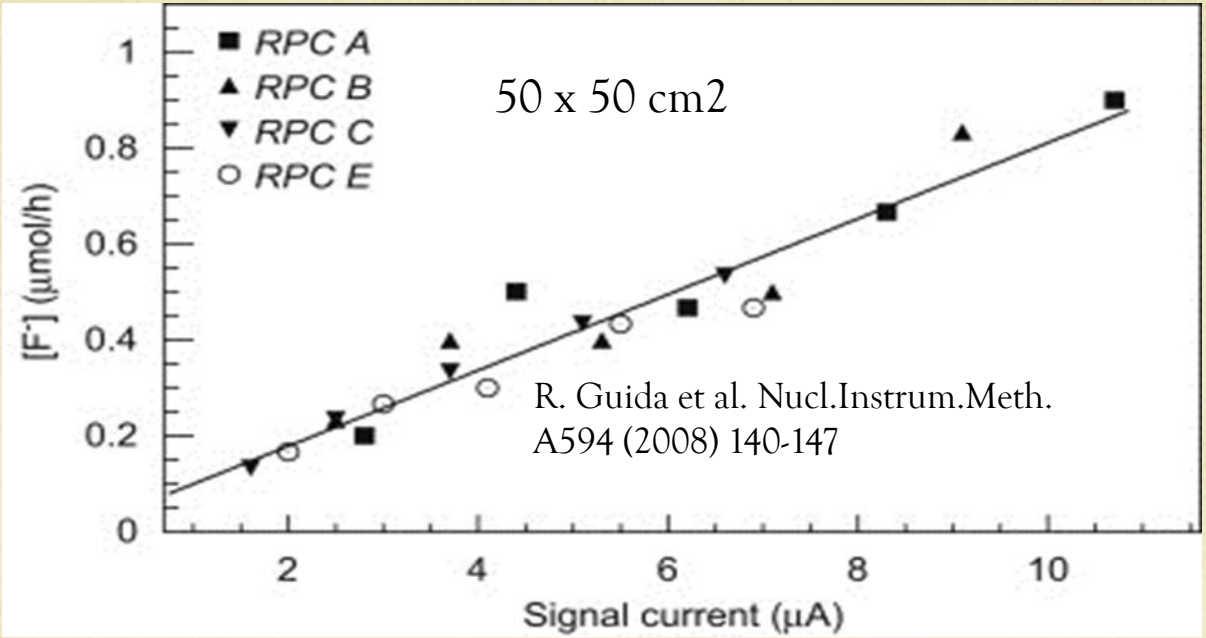
R. Guida et al. Nucl.Phys.Proc.Suppl. 158 (2006) 30-34

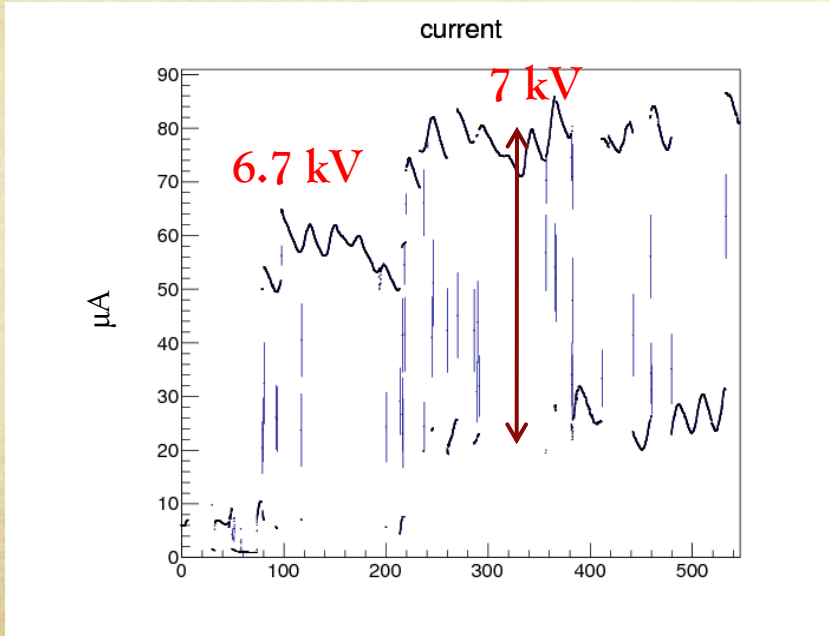


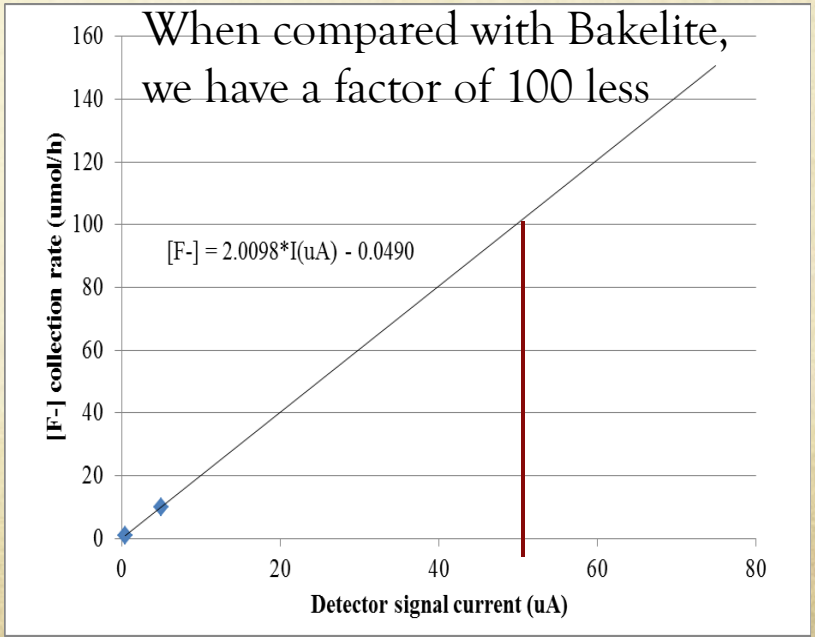


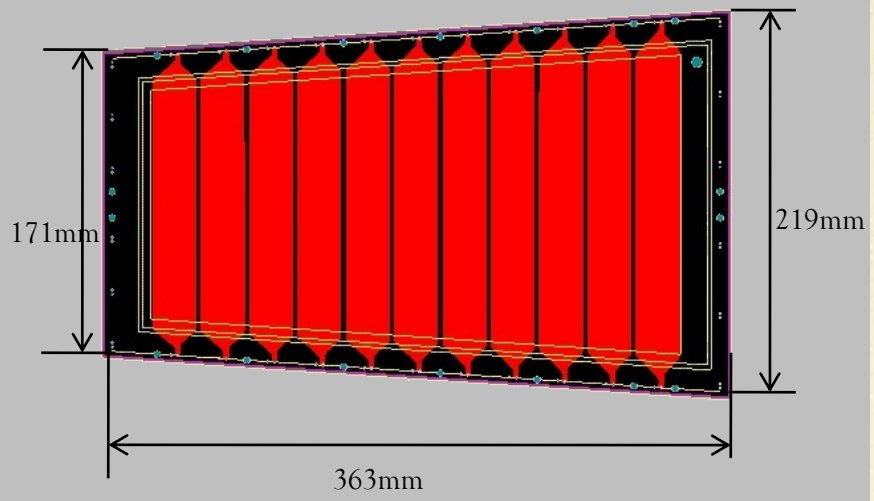


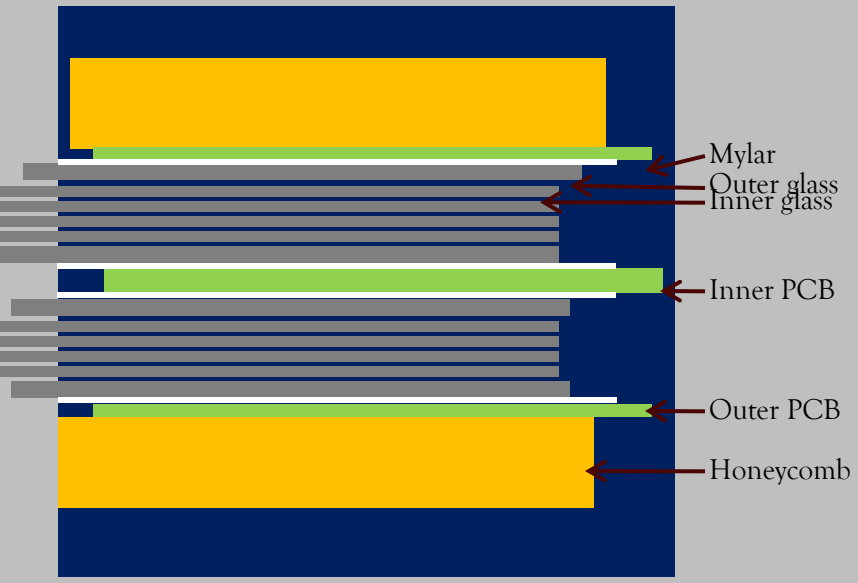
CMS Bakelite RPC measurement (2.5 m from the source): Strong dependence on the current











Gas Mixture(Pre-mixed)	Freon 90% iso-butane 5% SF6 5%
Working Voltage	±6800V
Electrical field	~108.8kV/cm

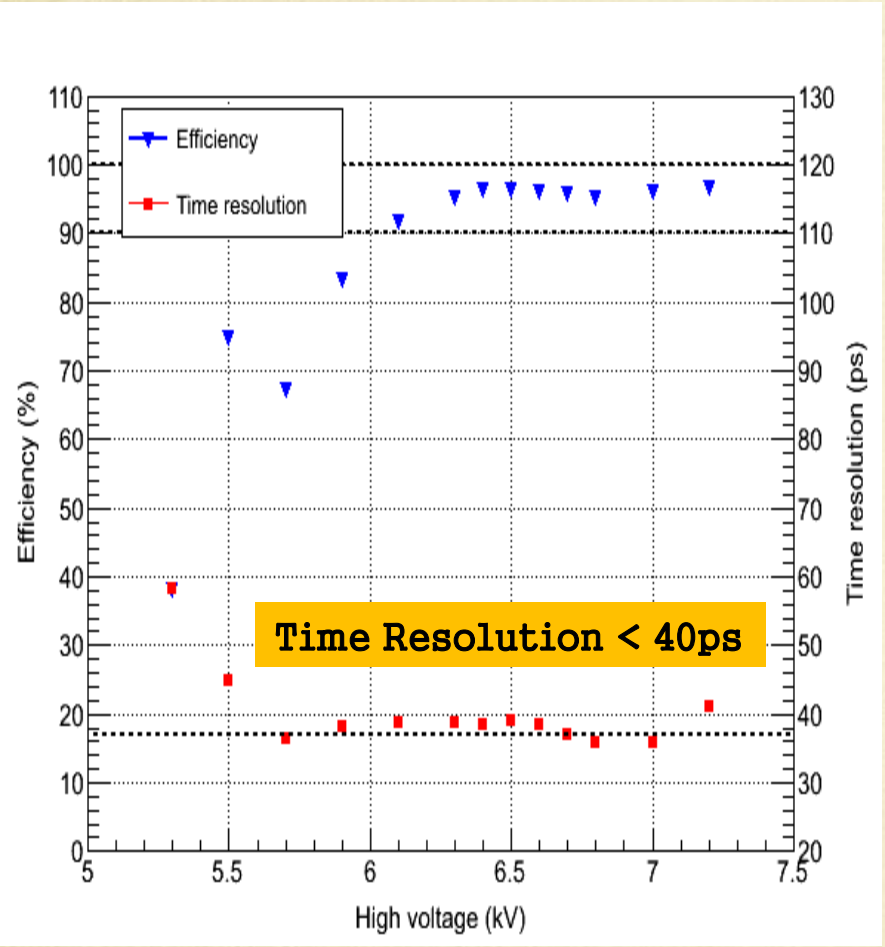
The design of MRPC readout

Interval	3mm
Strip width	25mm
Readout mode	Differential

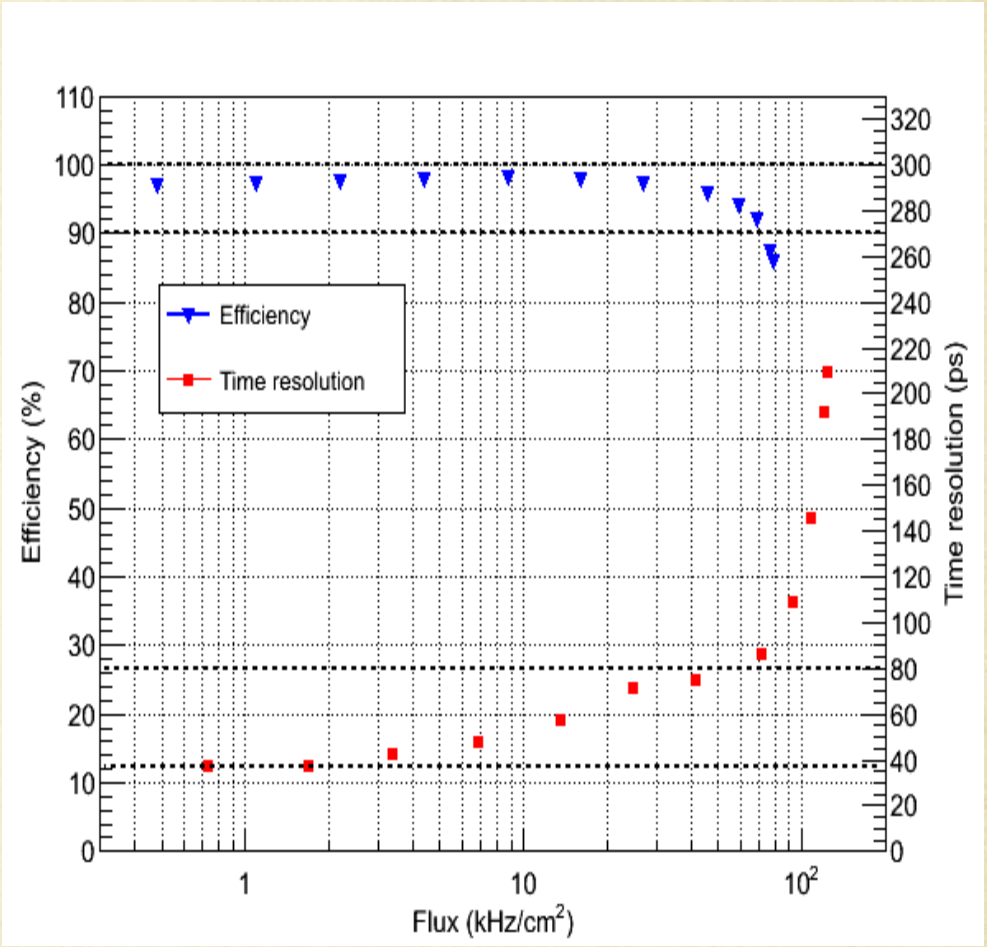
Dimensions

	Length/mm	Width/mm	Thickness/mm
Gas gap	-	-	0.25×10
Inner glass	320	130-171	0.7
Outer glass	330	138-182	1.1
Mylar	335	153-198	0.18
Inner PCB	350	182-228	1.6
Outer PCB	350	172-218	0.8
Honeycomb	330	153-198	6

Beam Test@HZDR June, 2012



HV scan



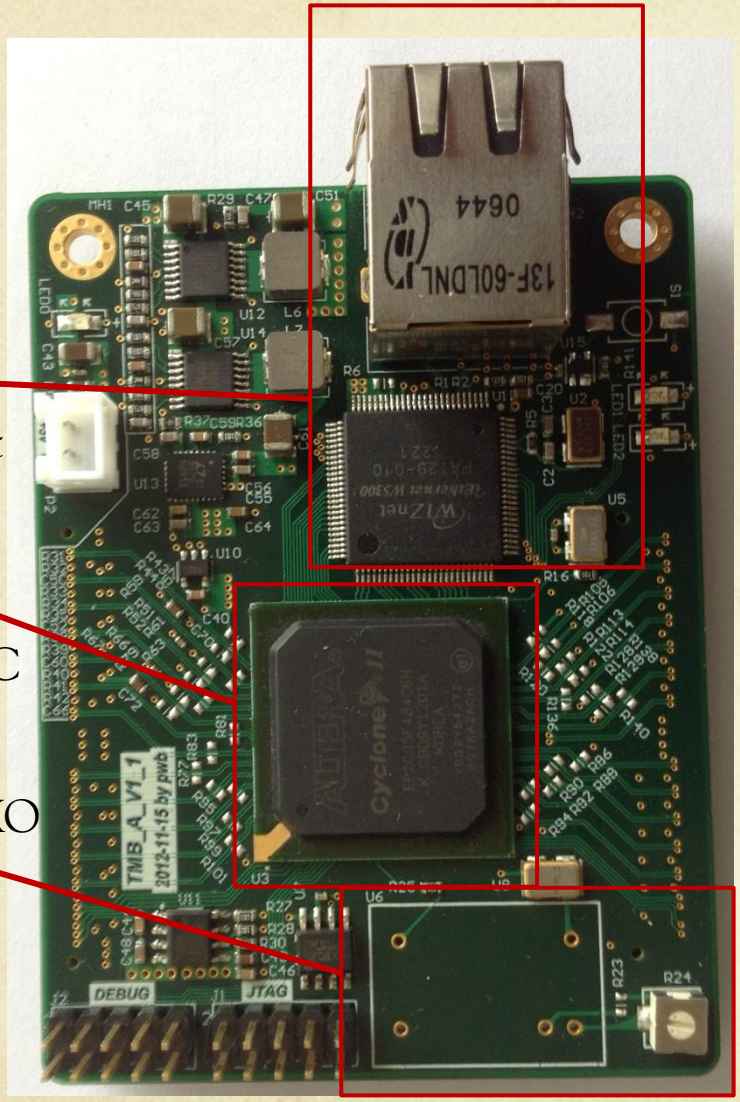
Rate scan

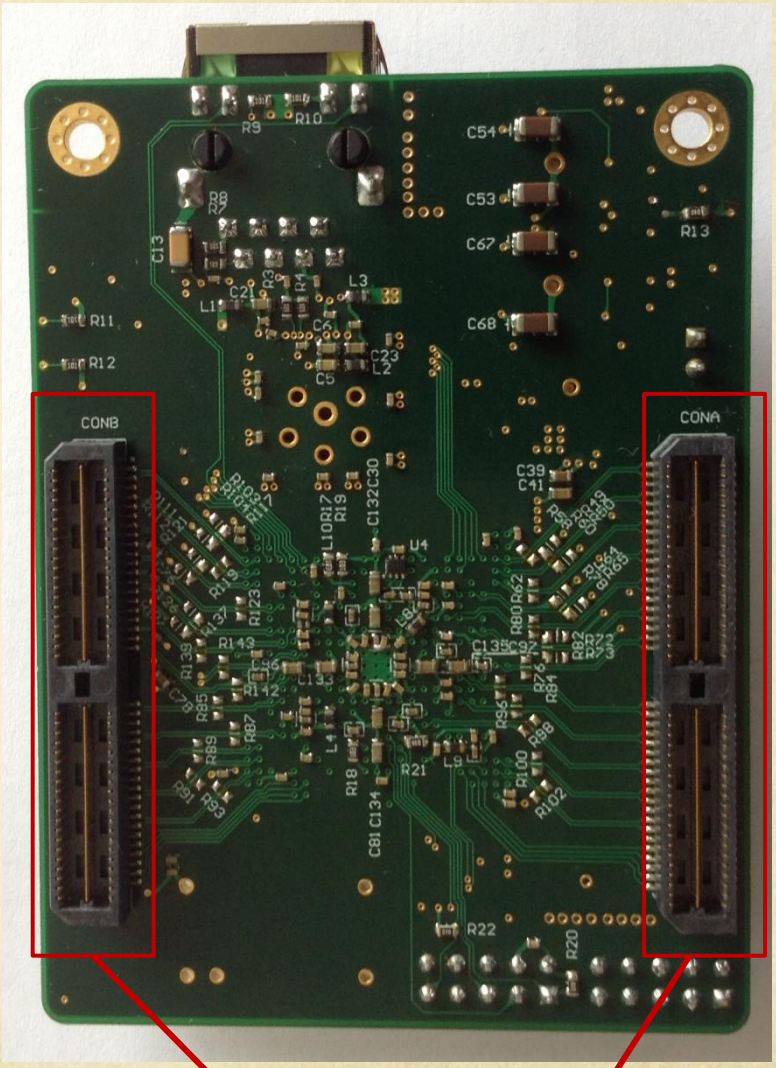
24Ch 25ps TDC module

100M Ethernet Readout with TCP/IP support

Cyclone-II FPGA EP2C35F484C6

Socket for TCXO (opt.)





Tsinghua university

Differential input connector