Upgrade del sistema Resistive Plate Chambers (RPC) di CMS per la fase II di LHC

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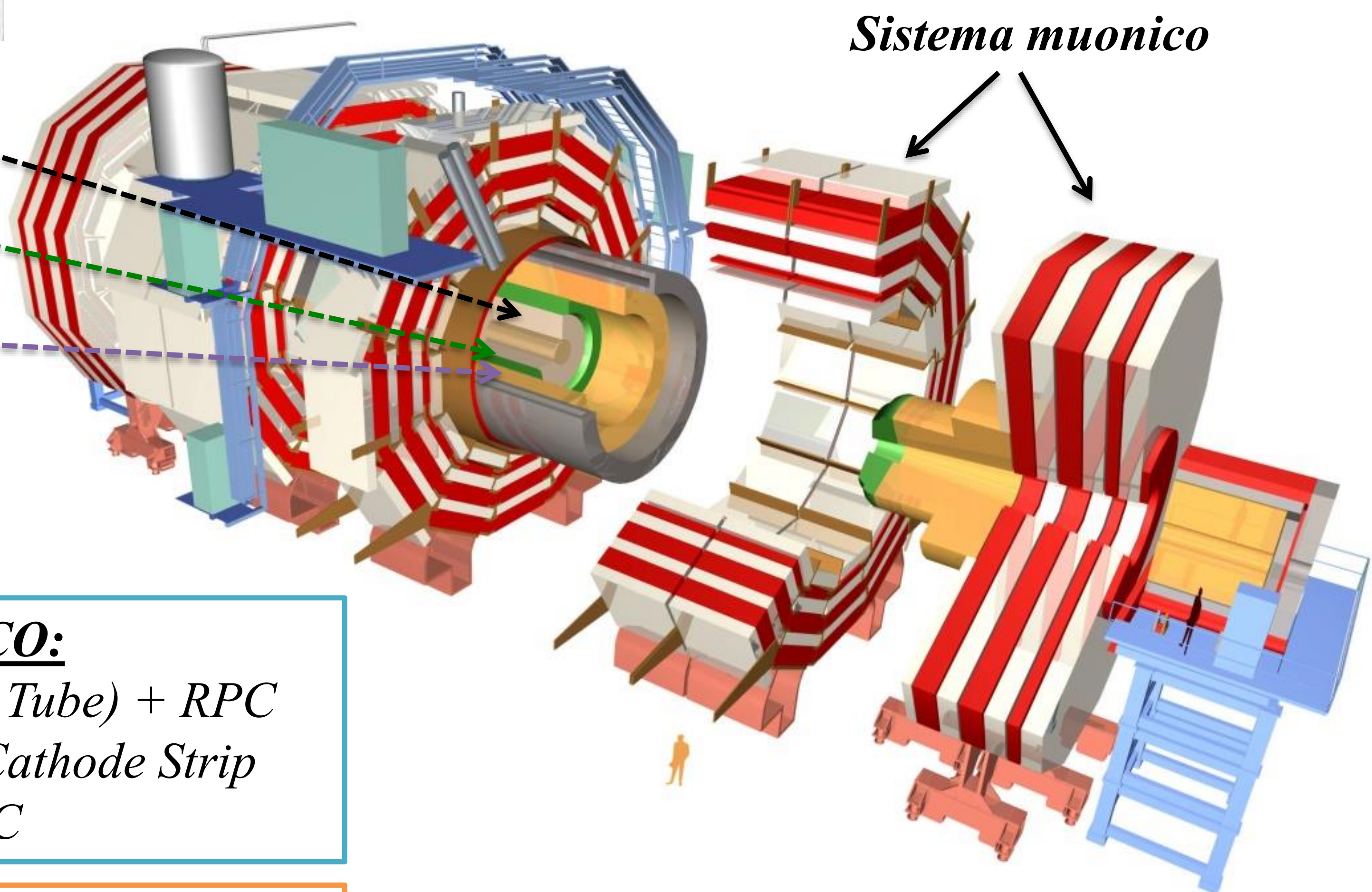
L'esperimento CMS @ LHC



SISTEMA MUONICO:
- *Barrel: DT (Drift Tube) + RPC*
- *Endacap: CSC (Cathode Strip Chambers) + RPC*

- *Ridondanza (4 stazioni con 3 tecnologie di rivelatori)*
- *Robustezza*
- *Efficienza*

Peso: 12000 t
Lunghezza: 21.6 m
Diametero: 15 m
Campo magnetico: 3.8 T

Il sistema Resistive Plate Chamber (RPC) di CMS

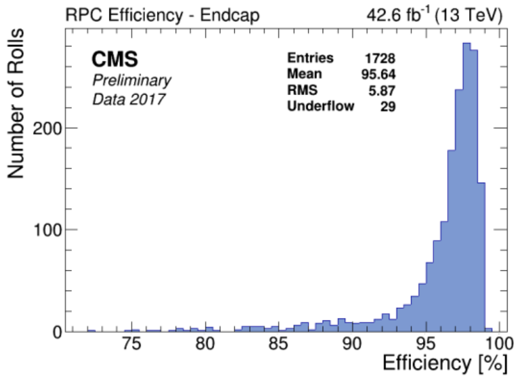
- *Informazioni (spaziali e temporali) RPC usate per il trigger, identificazione e tracciamento*
- ***Prestazioni ottime e stabili:***

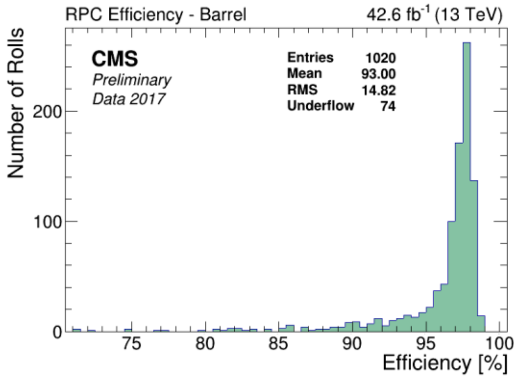
efficienza ≈ 95%, risoluzione spaziale 1cm

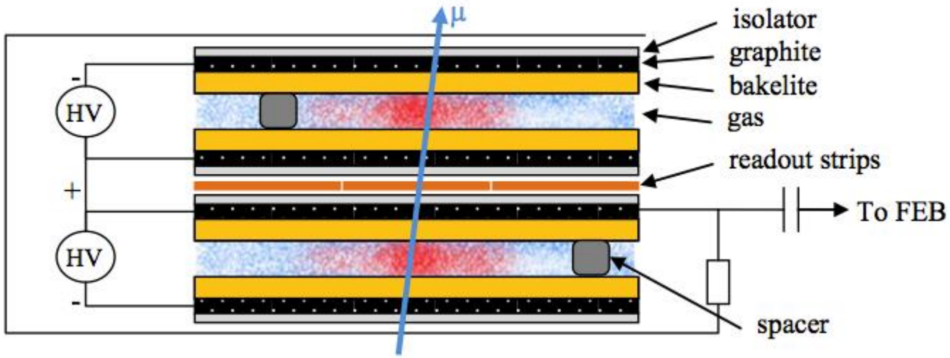
- *Sistema RPC* $0 < |\eta| < 1.9$
- *1056 camere:*

  480 Barrel & 576 Endcap

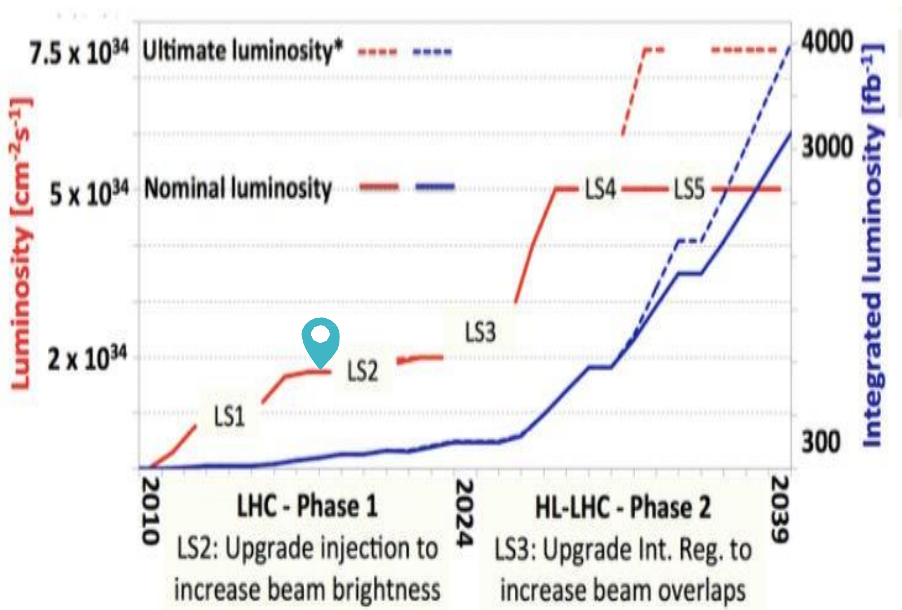
- *Regime a valanga*
- ***Doppia gap***
- *Resistività elettrodi HPL:* $\rho = 1\text{-}6 \cdot 10^{10}\ \Omega cm$
- *Spessore gas gap & elettrodi 2mm*
- *Miscela di gas* $C_2H_2F_4$ *(95.2%) +* $isoC_4H_{10}$ *(4.5%) +* SF_6 *(0.3%)*

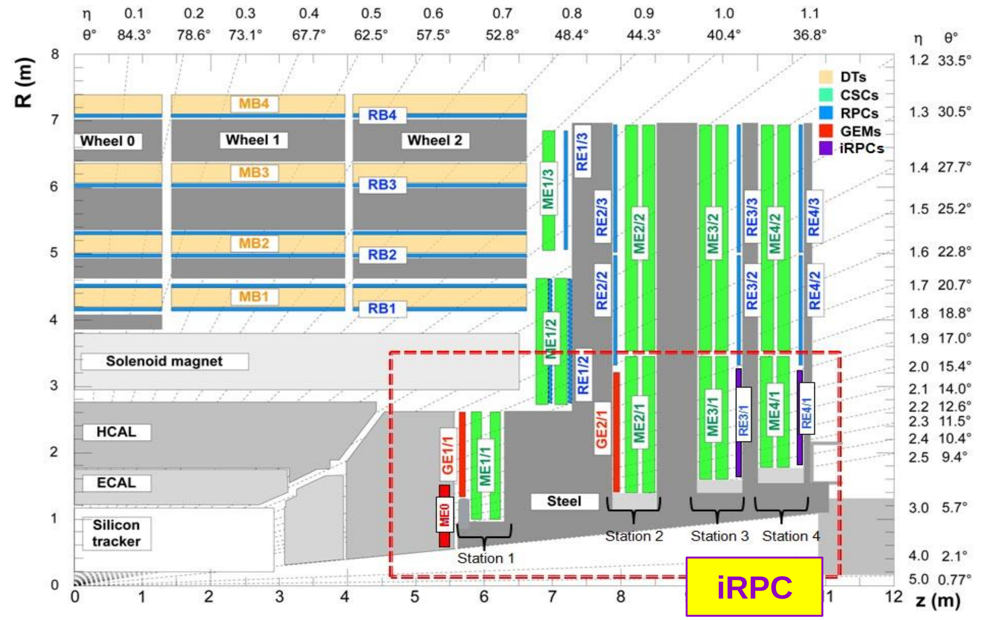


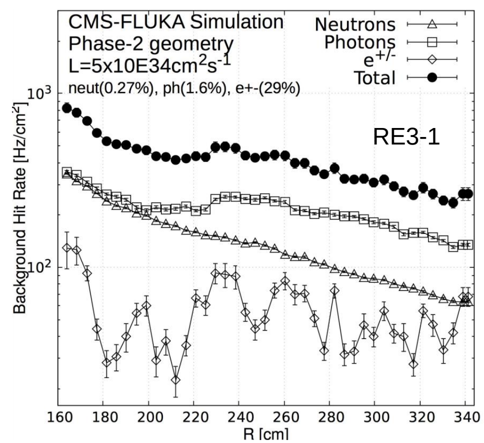




L'estensione del sistema RPC @ HL-LHC





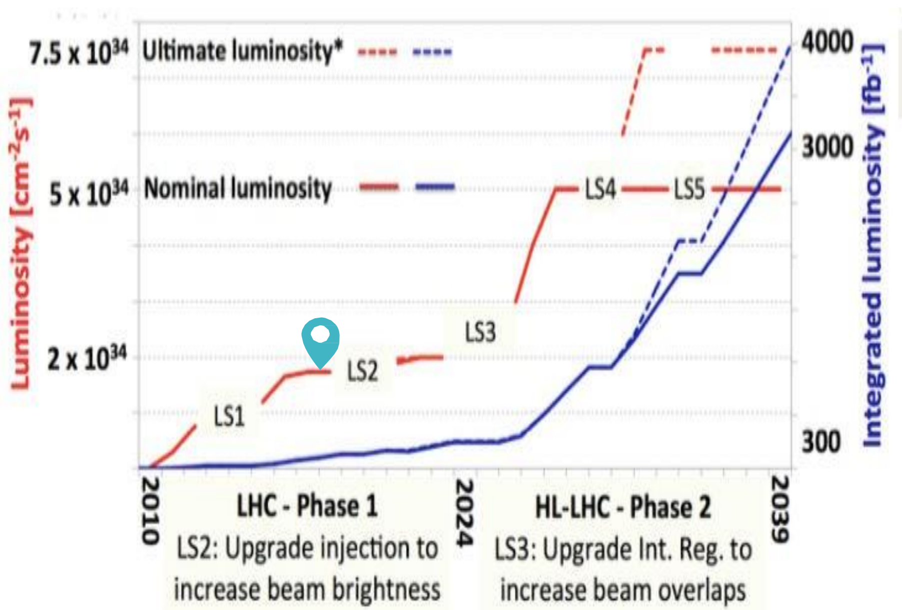


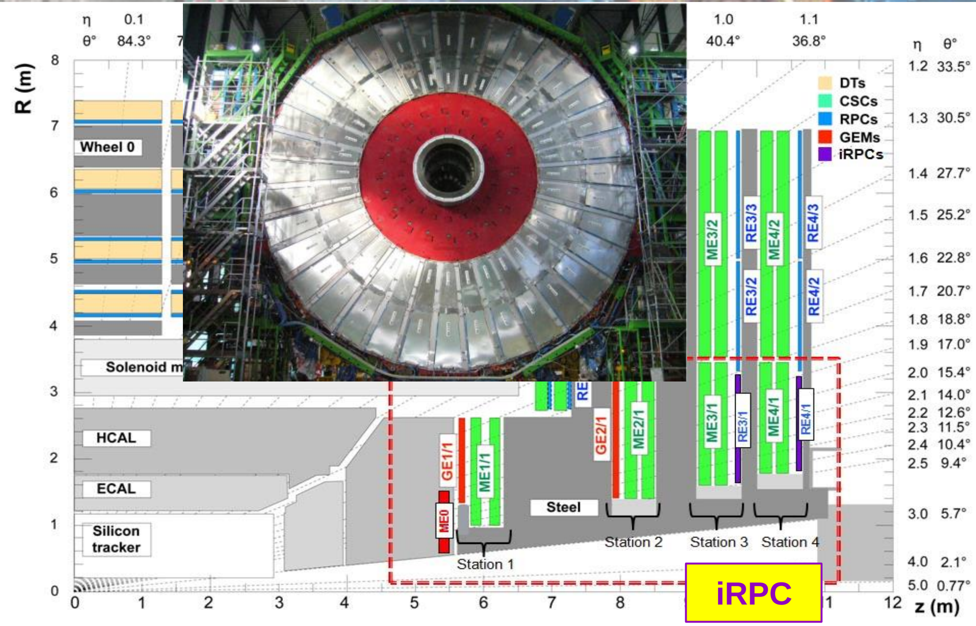
HL-LHC → *aumento del background rate & pile-up*

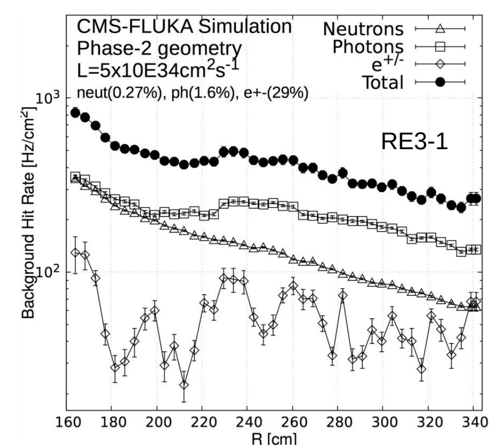
*Regione 1.8 < | η | < 2.4 : **background rate (2kHz/cm²)**, bassi valori del **campo magnetico**, mancanza di **ridondanza** (presenti solo CSC)*

→ ***upgrade del SISTEMA MUONICO per mantenere elevate prestazioni***

L'estensione del sistema RPC @ HL-LHC







HL-LHC ***→*** *aumento del background rate & pile-up*

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→ upgrade del SISTEMA MUONICO per mantenere elevate prestazioni

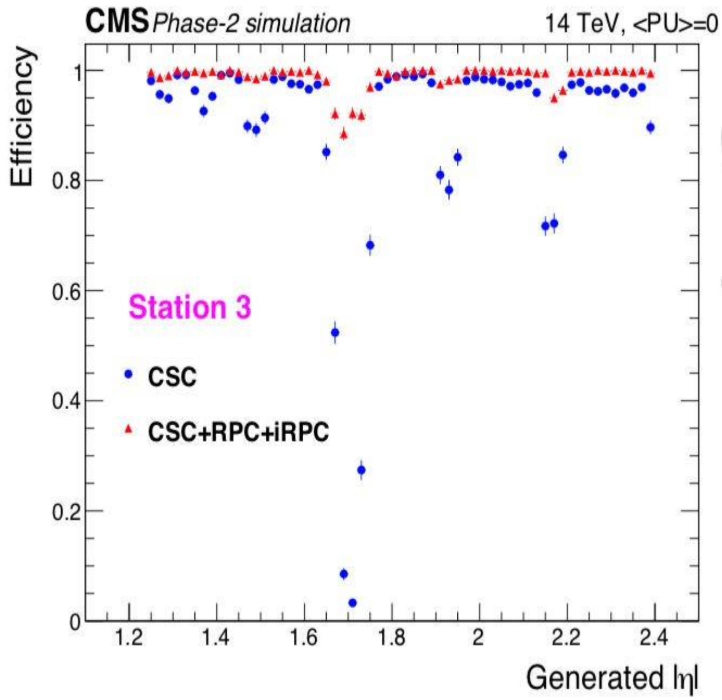
Motivazioni estensione sistema RPC

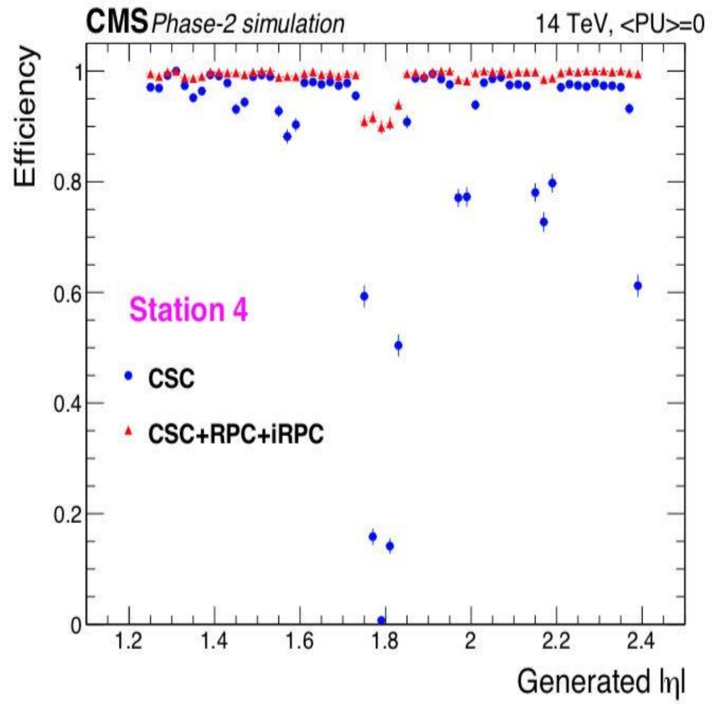
Estensione del sistema RPC *1.8 < | η | < 2.4*

18 camere per disco (20º) → 72 in totale

- *Completamento RE3-4/1 & aumento ridondanza*
- *Estensione contributo del sistema RPC al tracciamento e trigger*

✓ *Miglioramento dell'efficienza del trigger includendo RPC*





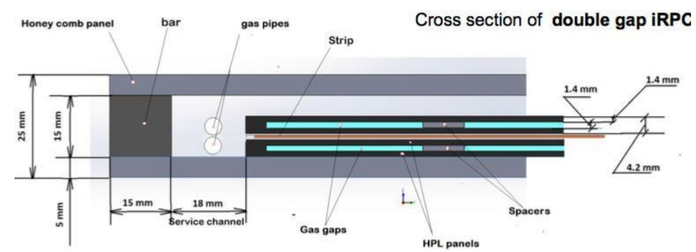
I nuovi improved RPC (iRPC)

Requisiti:

- *Rate capability ≈* ***2 kHz/cm²*** *[1]*
- *Efficienza >* ***95%***
- *Risoluzione spaziale ≈* ***1-2 cm***
- *Risoluzione temporale ≈* ***1.5 ns***

[1] incluso fattore di sicurezza 3

Nuova generazione di RPC
→ ***improved RPC*** *(iRPC)*



Sono stati studiati tutti i fattori rilevanti per il miglioramento del rilevatore:

- *Resistività elettrodi*
- *Spessore elettrodi*
- *Spessore gas gap*

	RPC	iRPC
Resistività (Ωcm)	$1 - 6 \times 10^{10}$	**$0.9 - 3 \times 10^{10}$**
Elettrodi	2 mm	**1.4 mm**
Gas Gap	2 mm	**1.4 mm**

Geometria degli iRPC

- ***Resistività eletrodi***

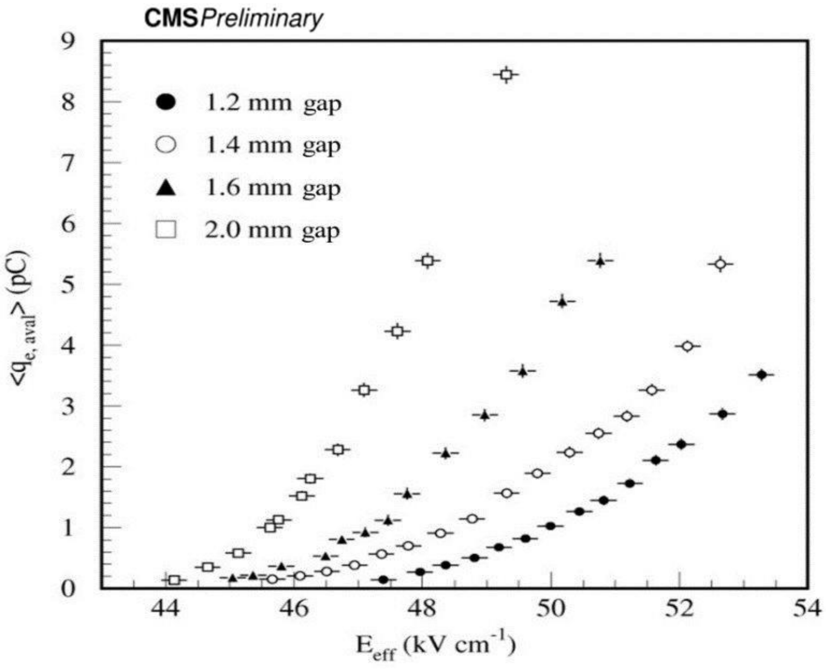
  da 1-6·10^10 Ωcm → 0.9-3·10^10 Ωcm
  - *Aumento rate capability*

- ***Spessore elettrodi***

  da 2.0 mm → 1.4 mm
  - *Riduzione tempo morto*
  - *Riduzione attenuazione segnale indotto su strip lettura*

- ***Spessore gas gap***

  da 2.0 mm → 1.4 mm
  - *Riduzione carica valanga*
  - *Riduzione tensione di lavoro*
  - *Riduzione effetti aging*
  - *Migliore risoluzione temporale*

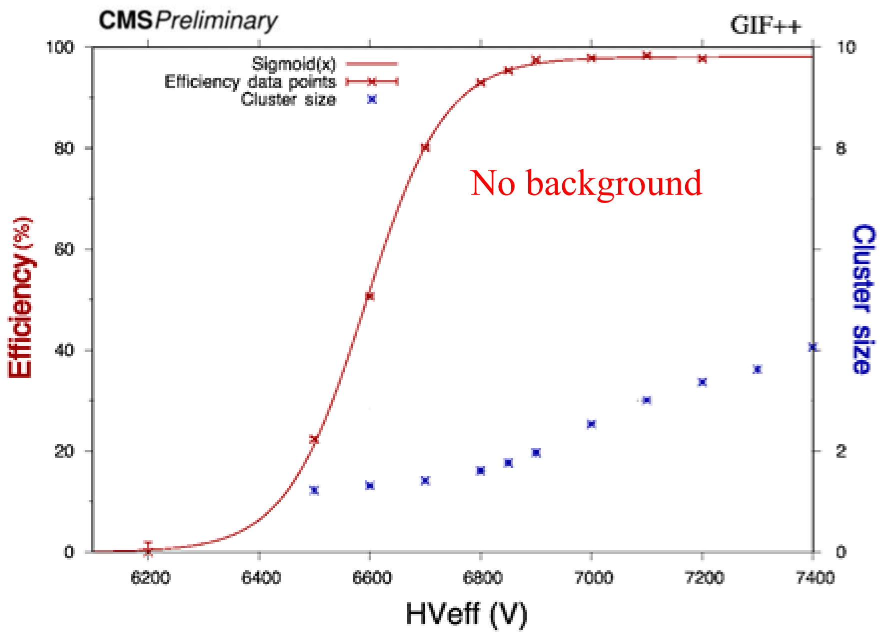


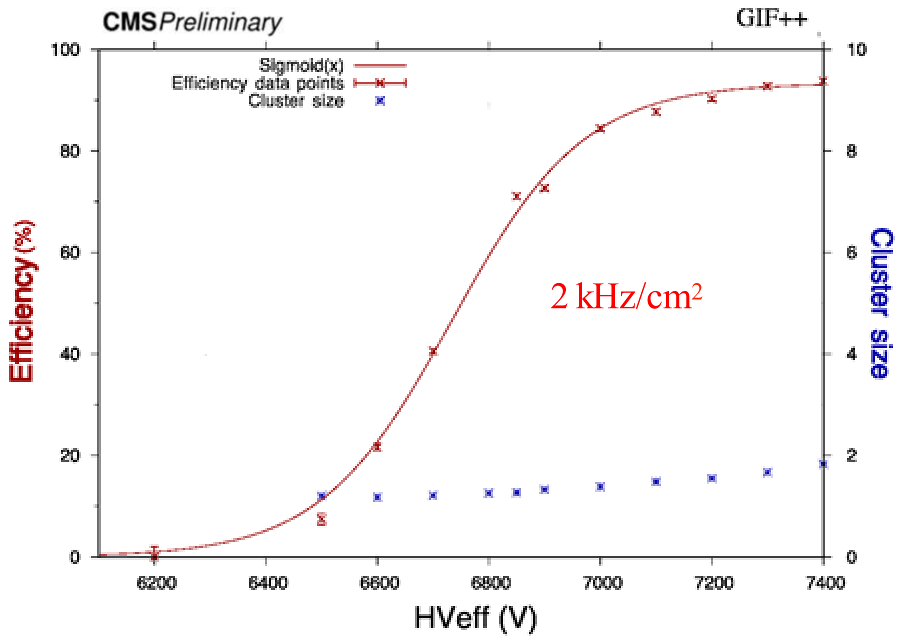
gas gaps con spessori inferiori sono più sensibili alle disuniformità

Spostamento parte dell'amplificazione del segnale dalla gas gap all'elettronica

Prestazioni degli iRPC

iRPC test @ Gamma Irradiation Facility (GIF++) @ CERN
in diverse condizioni di irraggiamento





- ✓ ***Efficienza** > 95%*
- ✓ *Aumento della tensione di lavoro ≈ 300 V*

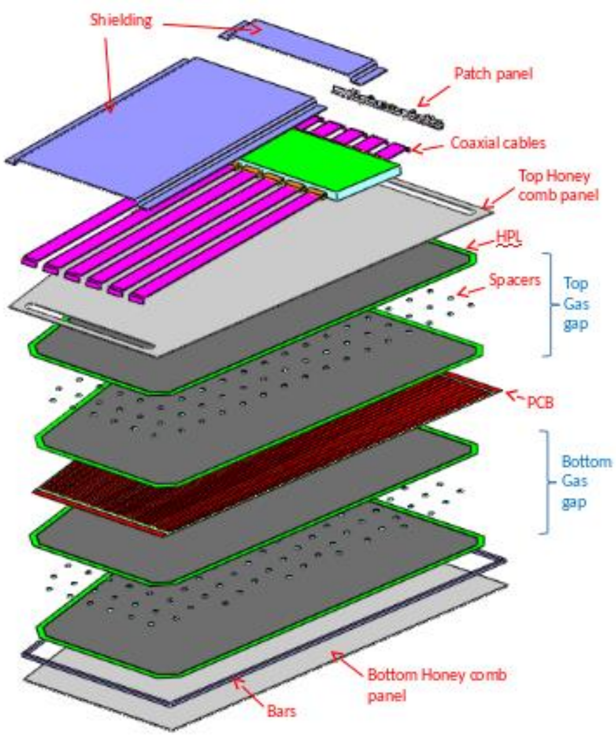
La nuova elettronica (FEB)

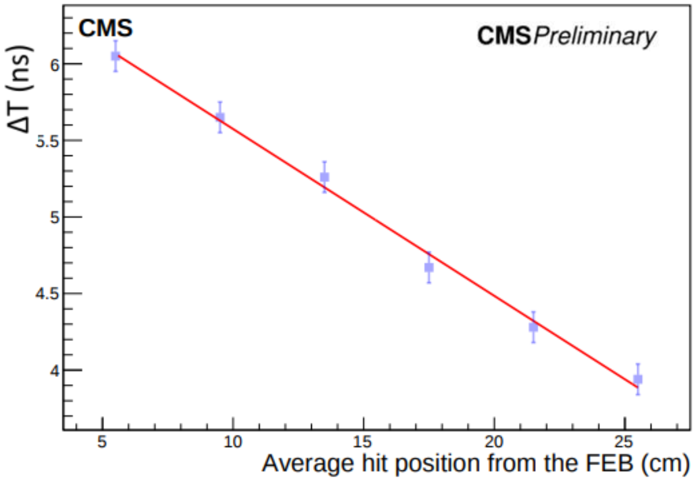
Nuova elettronica più sensibile al fine di rivelare segnali generati da bassi valori di carica (10 fC) senza influenzare le prestazioni del rivelatore

BASELINE: ***PETIROC ASIC + TDC***

- *32 canali*
- *Basso noise rate*
- *Veloce pre-amplificatore e discriminatore in tecnologia SiGe*
- *Lettura doppia coordinata:* ***XY (2D)***

2 FEB + 2 TDC



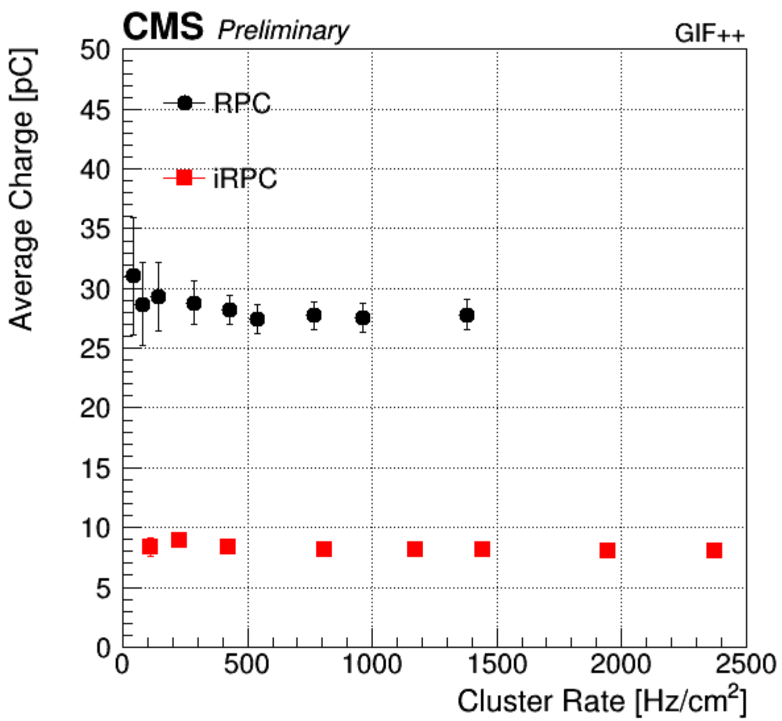


Y= L/2-V(T1-T2)/2*
*σ(Y) = V*σ(T1-T2)/2*
Y risoluzione ~1.8 cm

iRPC studi di longevity

iRPC devono soddisfare le specifiche di CMS per l'intero periodo di HL-LHC

→ *test di irraggiamento iRPC iniziati @ GIF++*



Tempo effettivo @ luminosità nominale		T = $6 \cdot 10^{10}$ s
iRPC Rate atteso		R ≅ *2 kHz/cm²*
iRPC carica media		q ≅ 8 pC

⇩

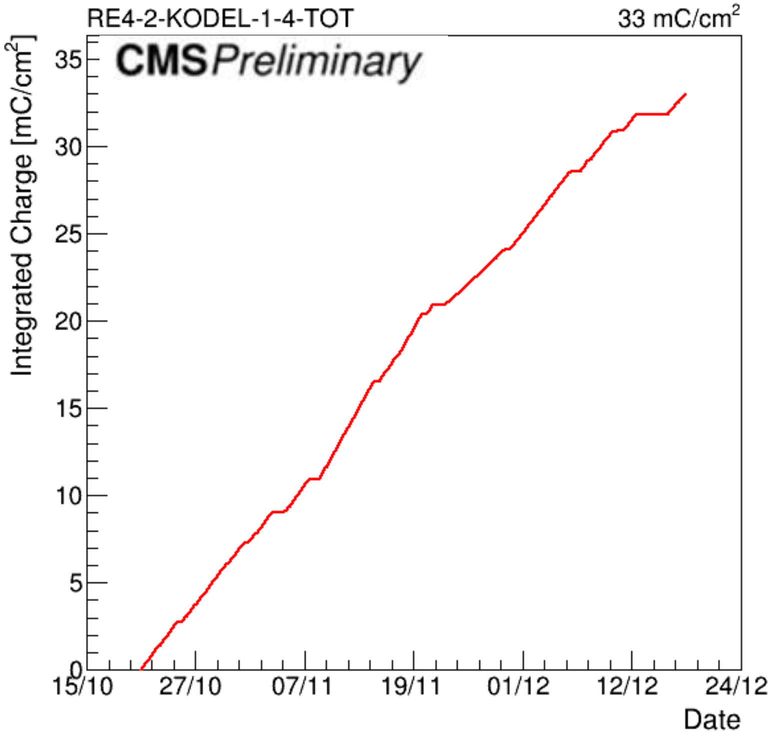
Carica integrata: $Q = T \cdot R \cdot q$

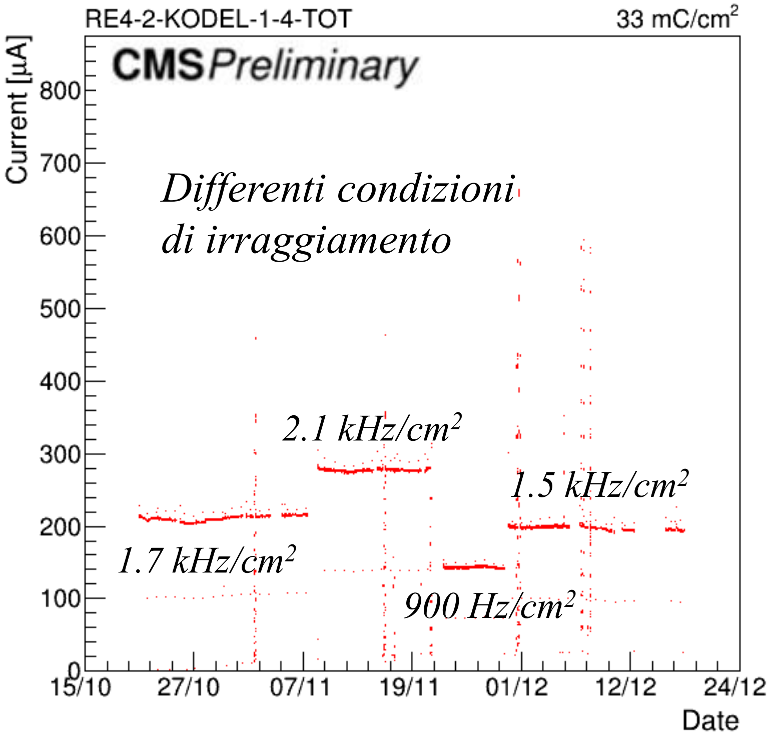
Carica integrata stimata:

≅ 1 C/cm² (incluso fattore sicurezza 3)

$$q = \frac{current}{gamma\ cluster\ rate}$$

iRPC studi di longevity





iRPC

- *Ottobre 2017*
- *Flusso gas ~ 5 l/h*
  (1 vol gas/h)

3 %

Principali parametri del rivelatore ***stabili***

Conclusioni

- ***Estensione del sistema CMS-RPC alla regione ad alto eta per Upgrade di fase II:*** *iRPC rivelatori basati sull'attuale tecnologia RPC ma con diversa geometria per migliorarne le prestazioni*

- *Test iRPC in diverse condizioni di irraggiamento:* ***prestazioni pienamente soddisfacenti***

- *Nuova* ***elettronica*** *(FEB), a bassa soglia e lettura 2D, testata con successo*

- *Studi di* ***longevity*** *per validare tecnologia iRPC per l'intero periodo di HL-LHC*

- ***Installazione*** *iRPC prevista durante YETS 2021-2022 e YESTS 2022-2023*

Grazie

per l'attenzione

Contatto:

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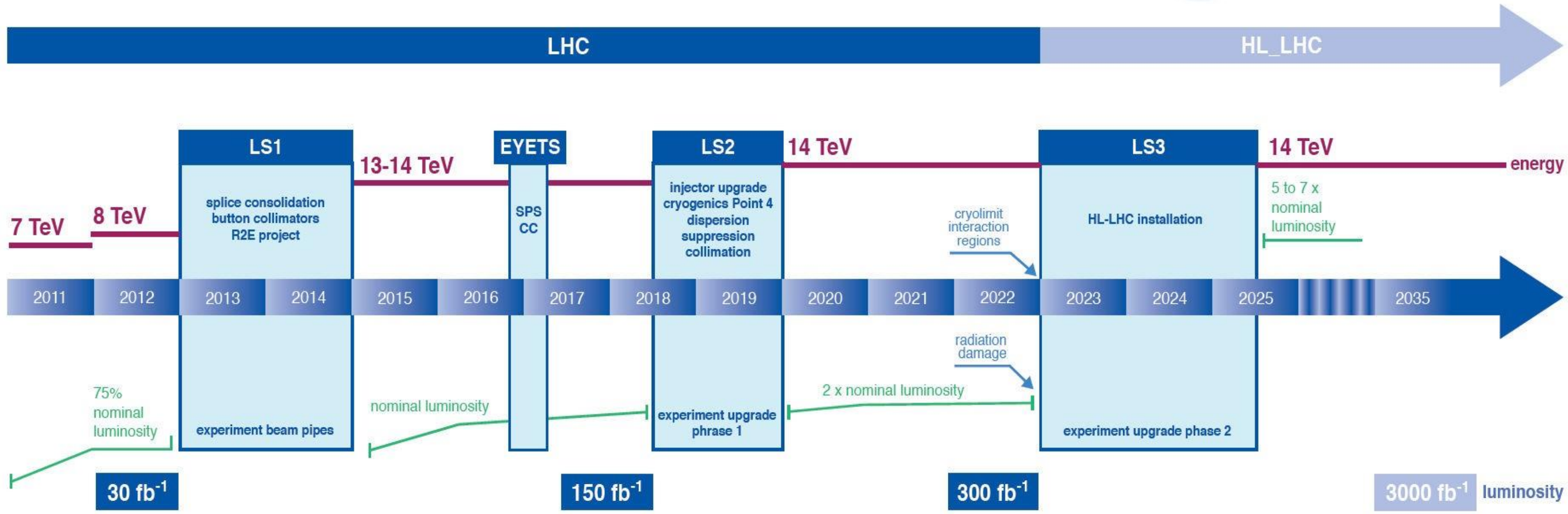
Back up slide

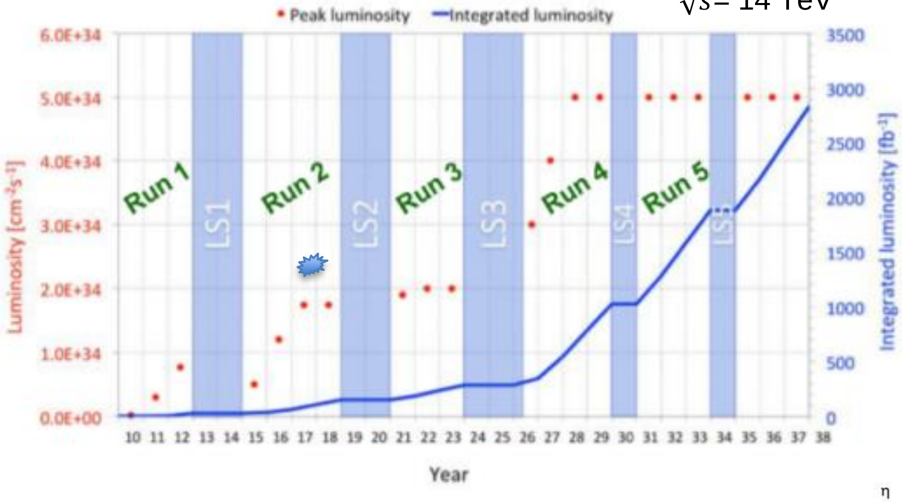
LHC / HL-LHC Plan



		LHC	Earlier HL-LHC	Ultimate HL-LHC
Collider	instantaneous luminosity ($cm^{-2}s^{-1}$)	10^{34}	5×10^{34}	7.5×10^{34}
	pileup collisions	30	150	200
	integrated luminosity (fb^{-1})	500	3000	4000
CMS	L1 trigger (kHz)	100	500	750
	L1 trigger latency (μs)	3.6	12.5	

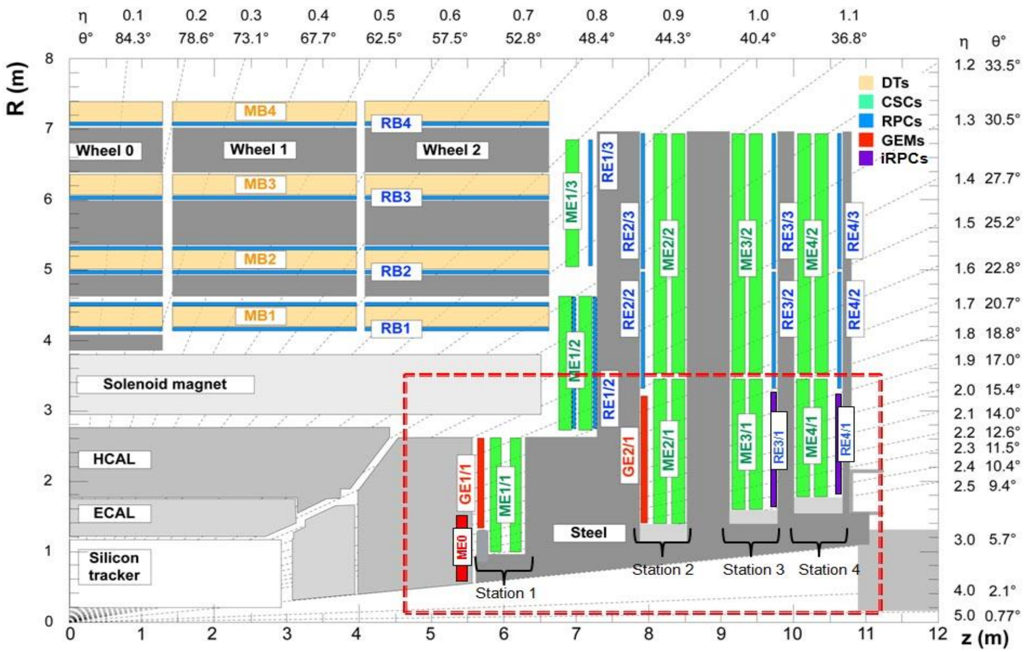
HL-LHC & CMS

$\sqrt{s}$= 14 TeV



$$L = \frac{R_{inel}}{\sigma_{inel}}$$

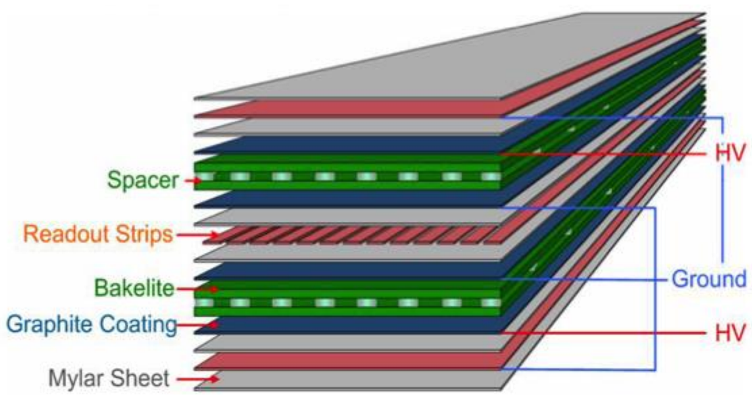
$$L = \int_0^t L(t')\, dt'$$

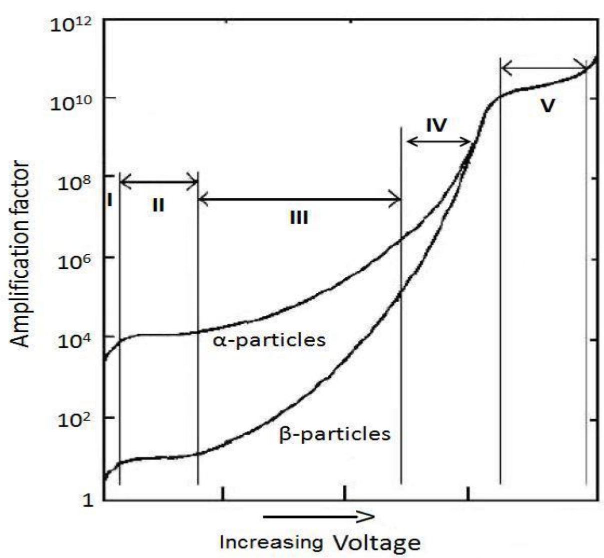


$$\eta = -\ln\left(\tan\frac{\theta}{2}\right)$$

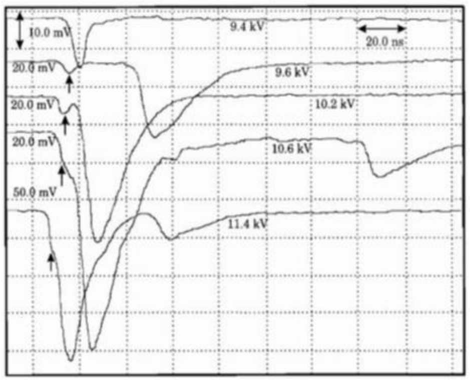
CMS RPC design

- **Covers $0 < |\eta| < 1.8$**
- **1056 chambers** (480 in Barrel and 576 in Endcap)
- 120000 **electronic channels** and 400 m^2 **of active area**
- **Double gaps gas chamber:** 2 mm gas width
- **Electrodes:** High Pressure Laminate
- **HPL** bulk resistivity: $\rho = 1 - 6 \times 10^{10}\ \Omega\text{cm}$
- **Humidified Gas mixture:** $C_2H_2F_4$ + isoC_4H_{10} + SF_6 (40% of H2O)
  95.2% 4.5% 0.3%
- Close loop with 10% -15% of fresh gas
- Operated in **avalanche mode**





$$S = \left(-\frac{dE}{dx}\right) = \frac{4\pi N_A}{m_e c^2}\,\rho\,\frac{Z}{A}\frac{z^2}{\beta^2}\ln\left[\left(\frac{2m_e c^2\beta^2\gamma^2}{I}\right) - \beta^2 - \frac{\delta}{2} - \frac{C}{Z}\right]$$



Gamma Irradiation Facility (GIF++)

To certify the RPC system at HL-LHC conditions a new LONGEVITY STUDY started @ ***Gamma Irradiation Facility (GIF++) CERN*** *in 2016****:***

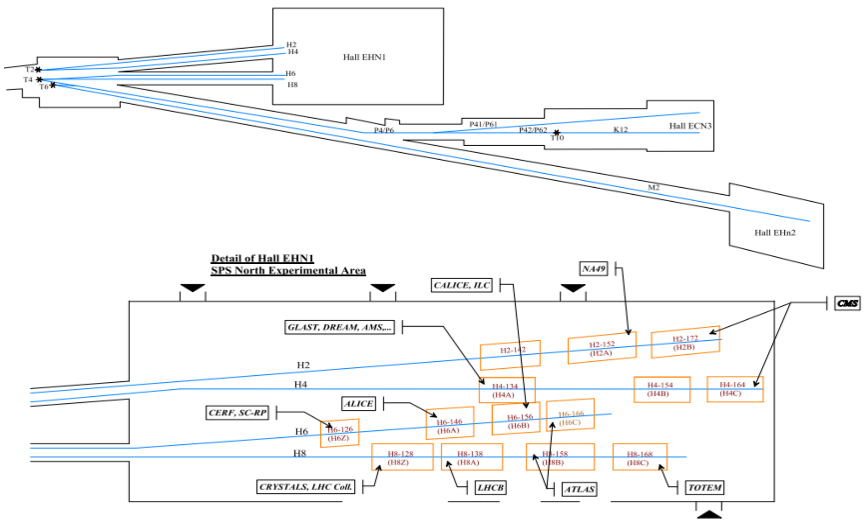
- ***^{137}Cs source***
  - → *~13 TBq*
  - → *Filter system (ABS source attenuation)*
  - → *Photons Energy spectrum 0-662 keV*

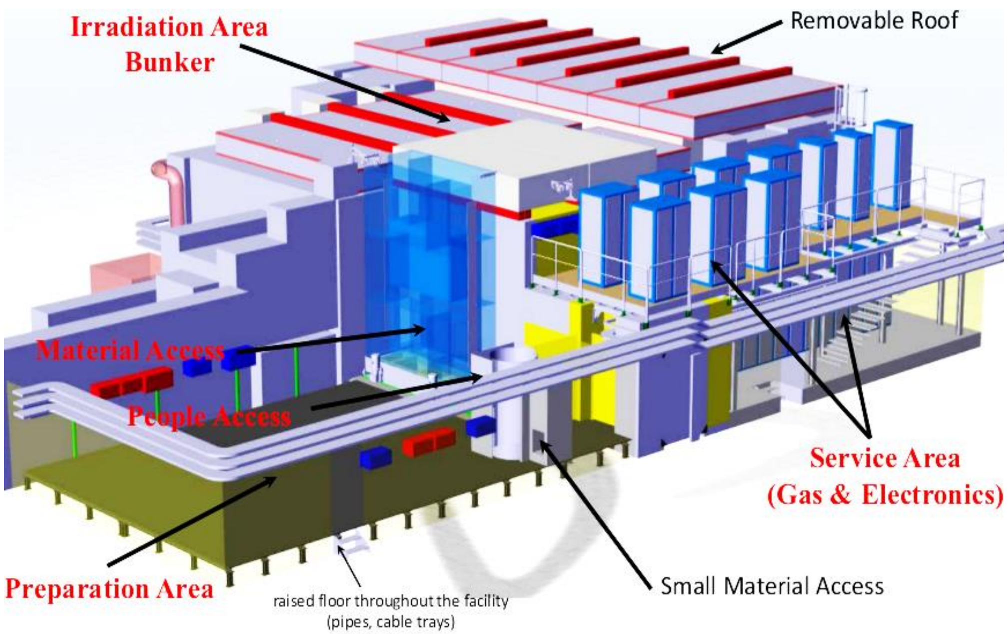
- ***Muon beam***
  - → *Energy up to 100 GeV, 10^4 muons/spill*
  - → *3-4 times per year*

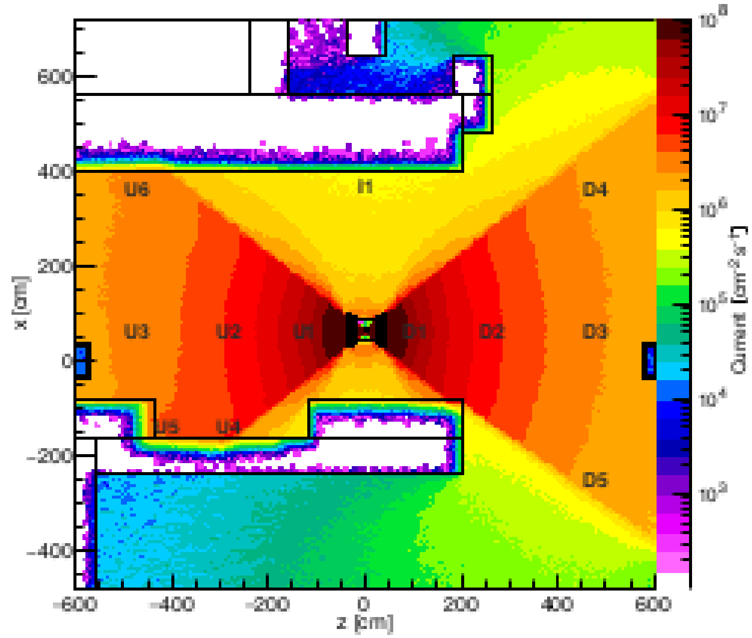
- ***Main parameters under control***
  - ***Environmental parameters***
  - → *Temperature, Humidity, Pressure*
  - ***Gas parameters***
  - → *gas composition,*
  - → *gas flow,*
  - → *gas Temperature, Humidity, Pressure*

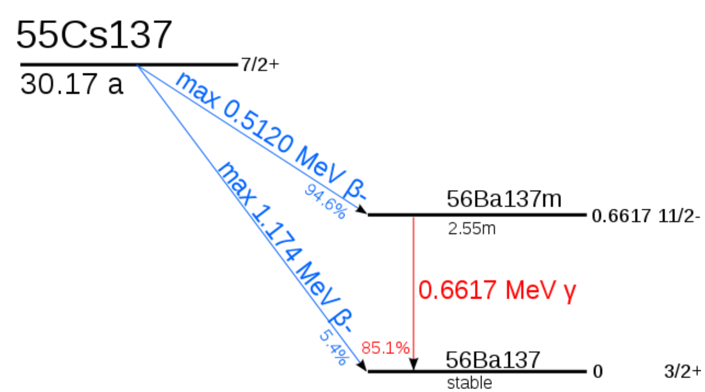
GIF++ allows to test real size detectors in a similar background condition as in CMS

Gamma Irradiation Facility (GIF++)



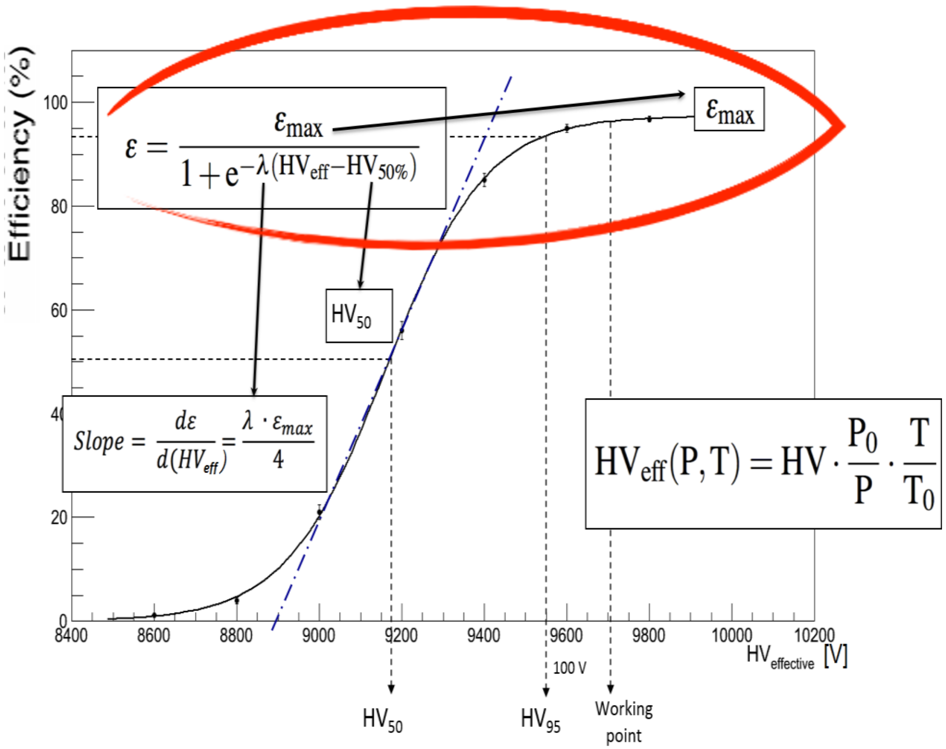


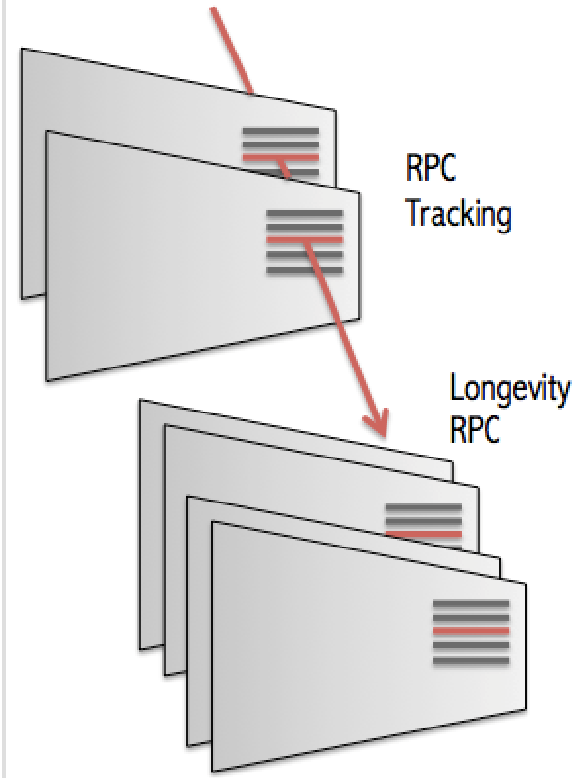




RPC Efficiency

Detector performance measured with muon beam using additional RPCs for muon tracking





$$\lambda = \frac{1}{HV_{90\%} - HV_{10\%}}$$

$WP = HV_{95} + 150V$ (HV_{95} : HV_{eff} where the ε is 95% of ε_{max})

HV correction

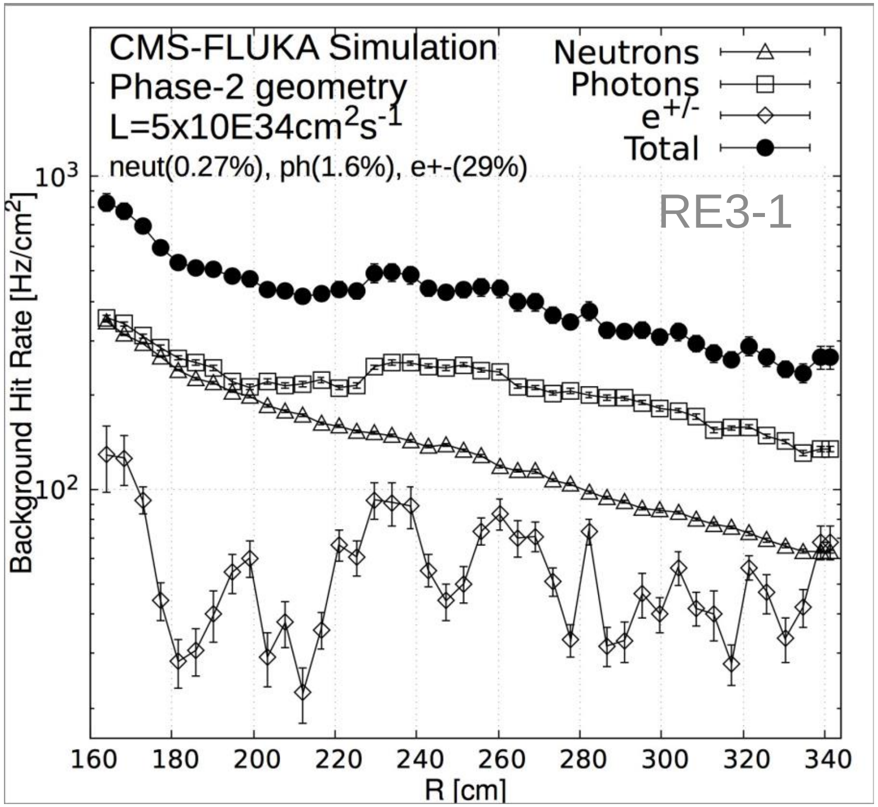
$$HV_{app} = HV_{eff}\left(1 - \alpha + \alpha\frac{P}{P_0}\frac{T_0}{T}\right)$$

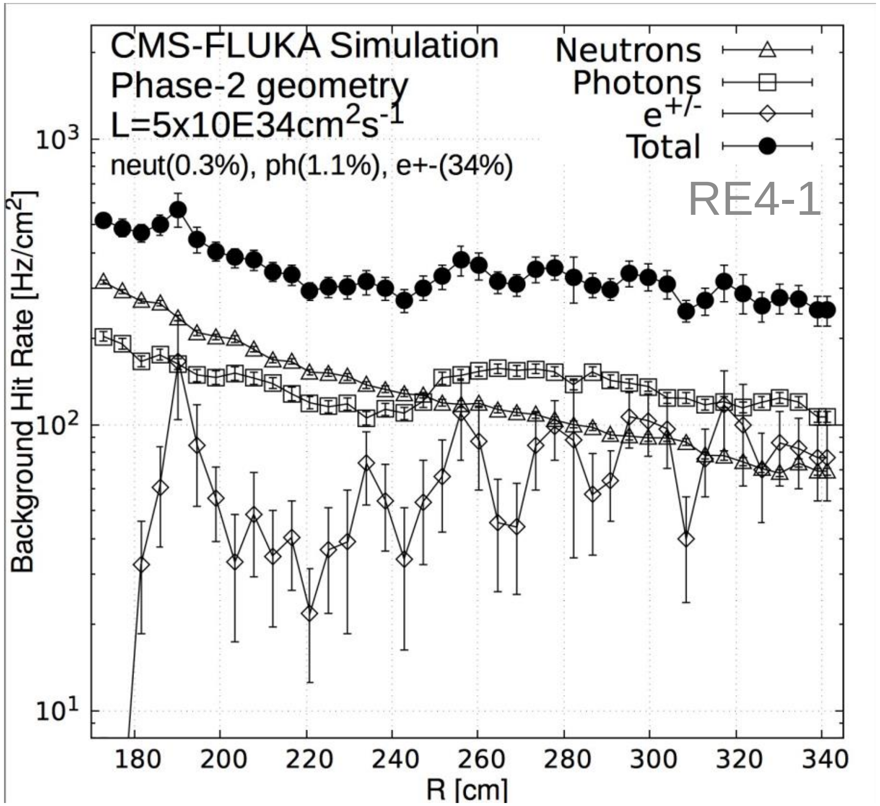
P_0 = 990 mbar
T_0 = 293.15 K
α = 0.8

Expected conditions at HL LHC in the forward region

Expected background flux in the RPC forward region at HL-LHC has been simulated

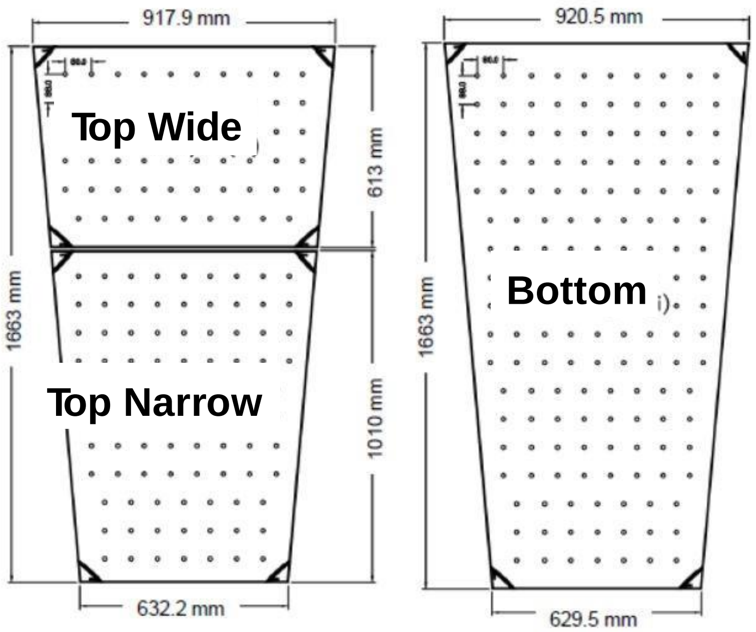
The average expected values:
*RE3/1 – **550 Hz/cm2**;*
*RE4/1 – **430 Hz/cm2***





iRPC large prototype

iRPC Baseline design	
High Pressure Laminate Thickness	1.4 mm
The Number of Gas Gaps	2
Gas Gap & Electrode width	1.4 mm
Resistivity (Ω·cm)	$0.9\sim3 \times 10^{10}$
Strip pitch	0.7~1.2 cm
Electronics Threshold	< 50 fC



Large Size double-gap iRPC

- **two cut gaps (top) and a full gap (bottom)**
- **96 strips (strip pitch : 1.5~2.8 cm)**

Three Front-end electronics KODEL

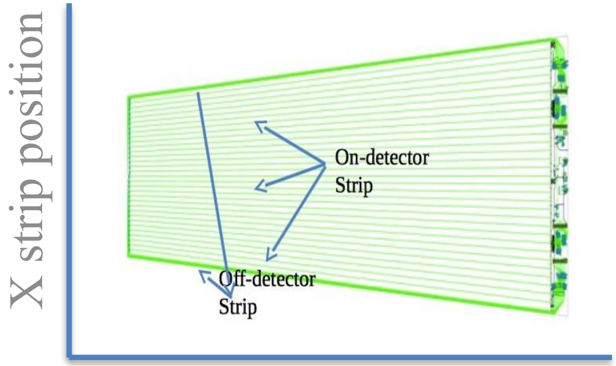
- **32 channel**
- **voltage-sensitive mode (KODEL customized)**

New front-end electronics

New electronic more sensitive in order to detect the lower charges (<10 fC) without affecting the detector performance.

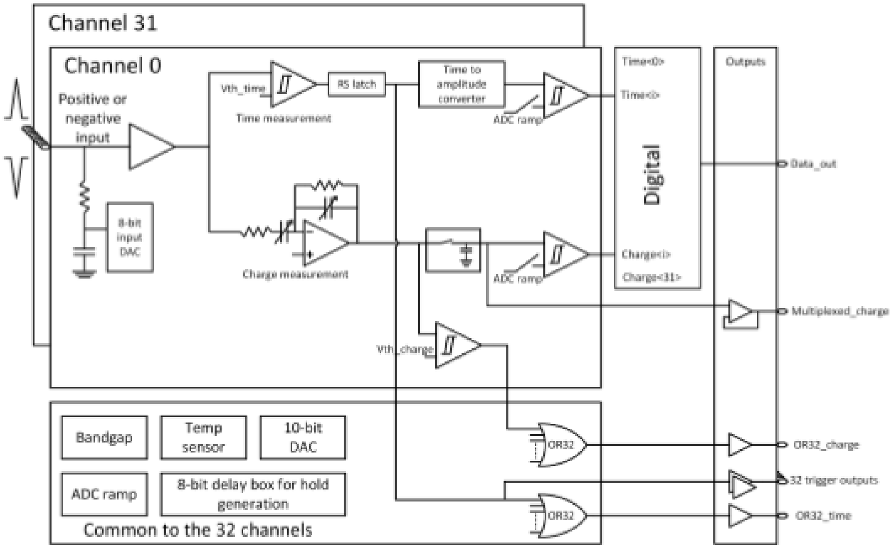
BASELINE: PETIROC ASIC + TDC

- *32 channels*
- *low noise*
- *gain 25*
- *fast pre-amplifier and fast discriminator in SiGe technology*
- *Readout double coordinate: **XY position (2D)***



Y (using timing of the "off-detector")

96 strips (0.2083°)
Strip pitch 11.8mm – 6.6mm
X resolution ~ 3 mm



New front-end electronics

Strip board :

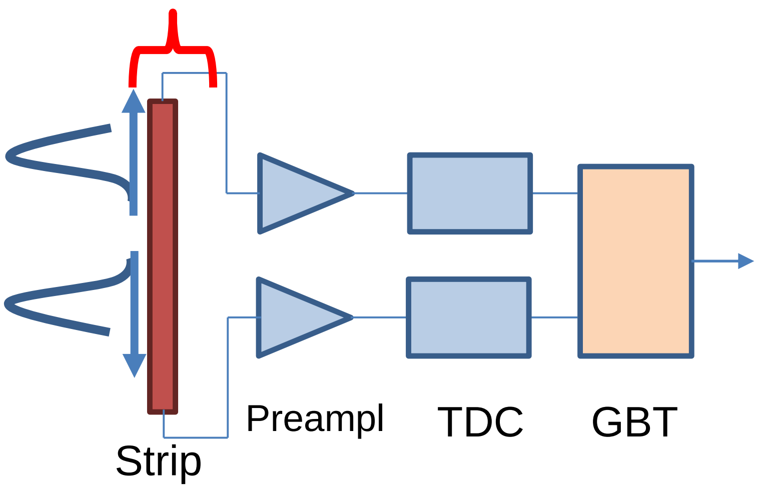
96 strips per chamber (1cm strip width at $\eta = 2.8$) between double gap RPC detectors

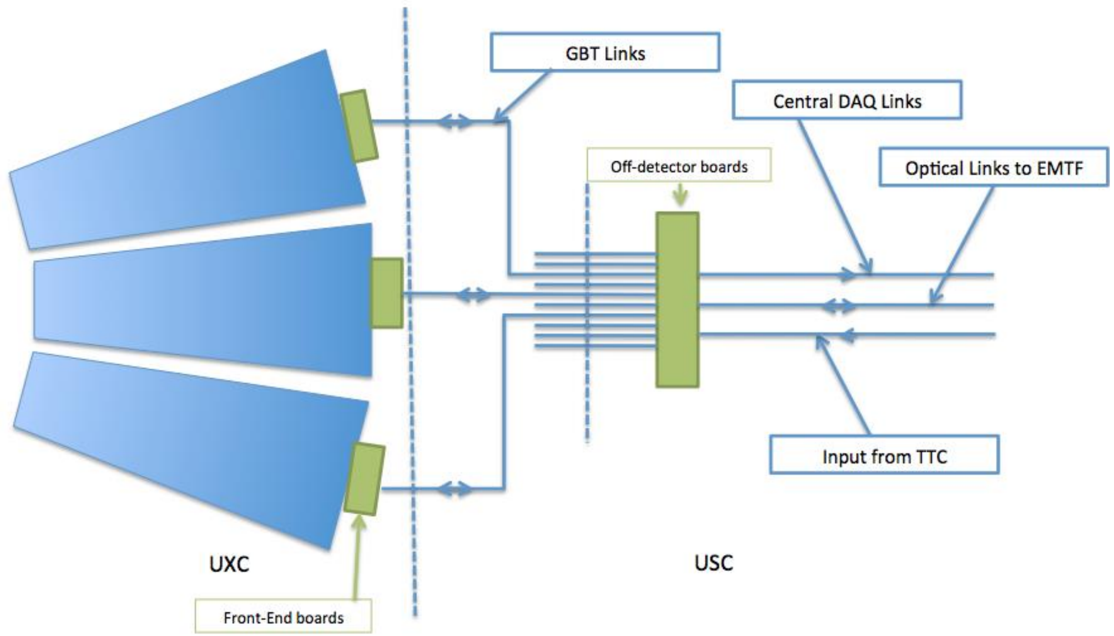
Front-end :

Readout on both sides of the strip

→ *Position along the strip ($\sigma = 1.8$ cm)* $Y = \frac{L}{2} - V.\frac{T2-T1}{2}$

Absolute timing ($\sigma << 1$ns)





New front-end electronics

A board of a medium size was designed and produced and tested on RPC detectors during TB. Channels: 32 on-detector strips with 3.5 mm pitch and 32 off-detector return strips 1 mm pitch. → 64 channels = 2 PETIROC + 2 TDC

T_2–T_1 *as a function of the hit distance to the FEB. The linear behavior allows a fit of V. Signal* ***Propagation Speed ~18 cm/ns***

The difference of arrival time of the signal on the two TDC channels associated to the two ends of the same strip after an injection of a 10 pC charge signal shown that a timing as good as ***30–35 ps****.*

Time resolution*: time difference between the strip ends signal and the the trigger signal (T0)* ***≈ 2 ns***