

CMS RPC HL-LHC upgrade with fast timing detectors

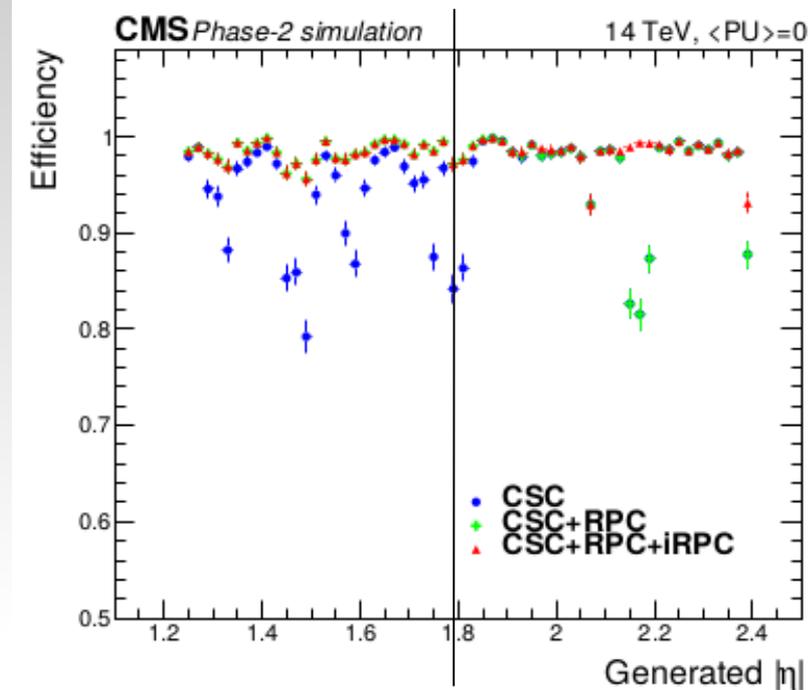
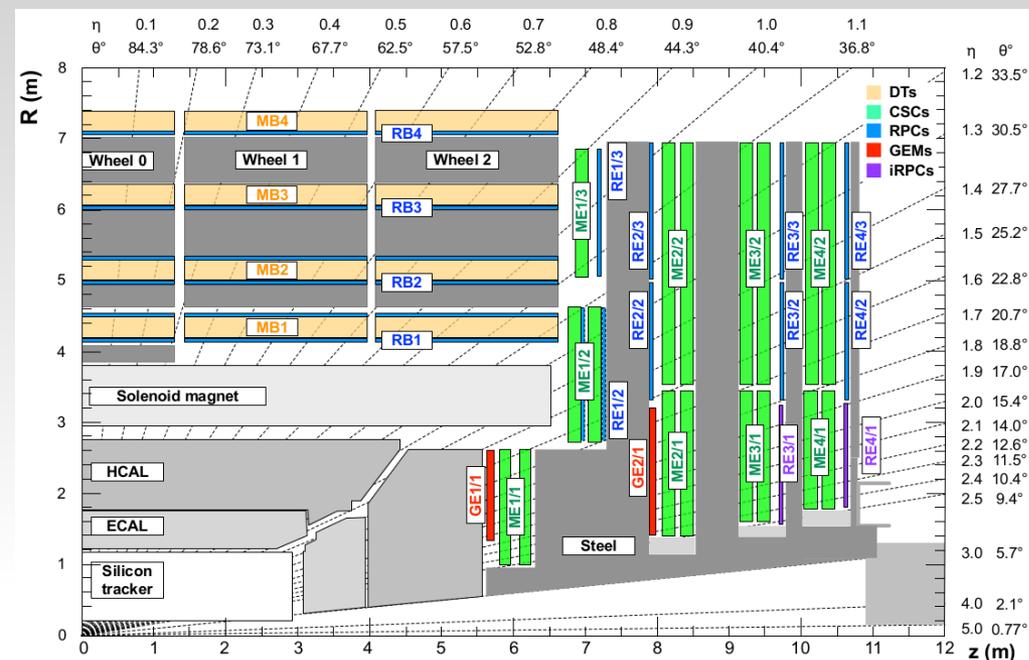
on behalf of the CMS MUON group

ICHEP, SEOUL, 2018

- 1) RPC upgrade project and motivation
- 2-3) Requirements and design
- 4-7) Validation of the prototype



1) CMS RPC upgrade project



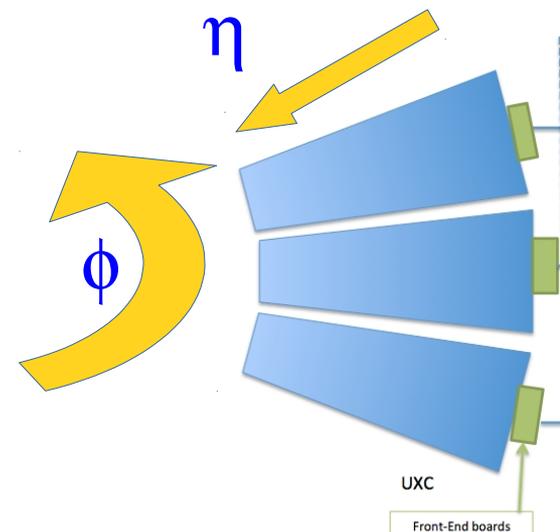
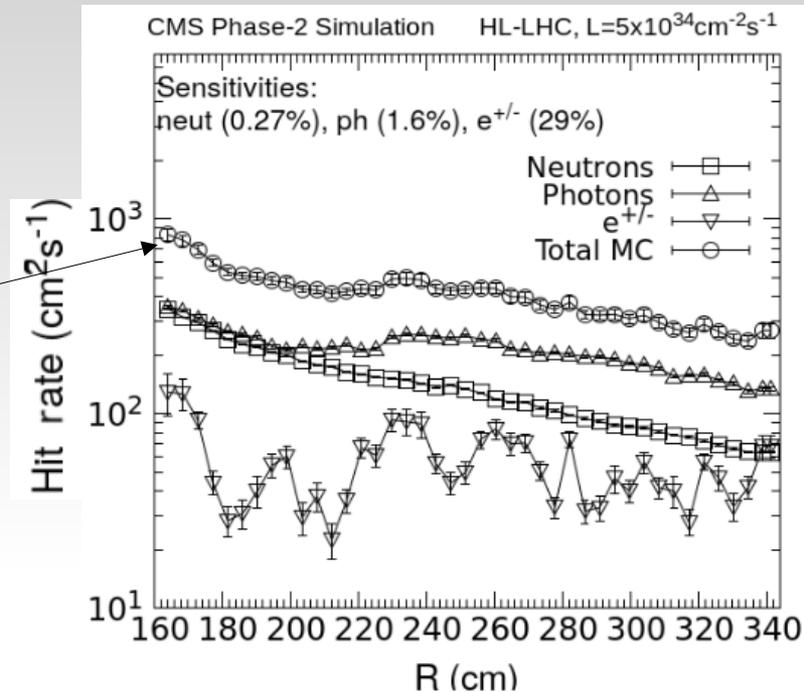
- Improved RPC (iRPC) added to the 2 outer stations of the endcap within $2.5 > |\eta| > 1.8$
- Off chamber electronics of the existing RPC chambers modified to take advantage of RPC internal time resolution (not presented).
- For more details of CMS Muon upgrade see A. Colaleo talk
- [CMS Muon Upgrade](#)

- IRPC motivation :
 - Redundancy
 - L1 muon trigger.
 - Dedicated HSCP trigger.

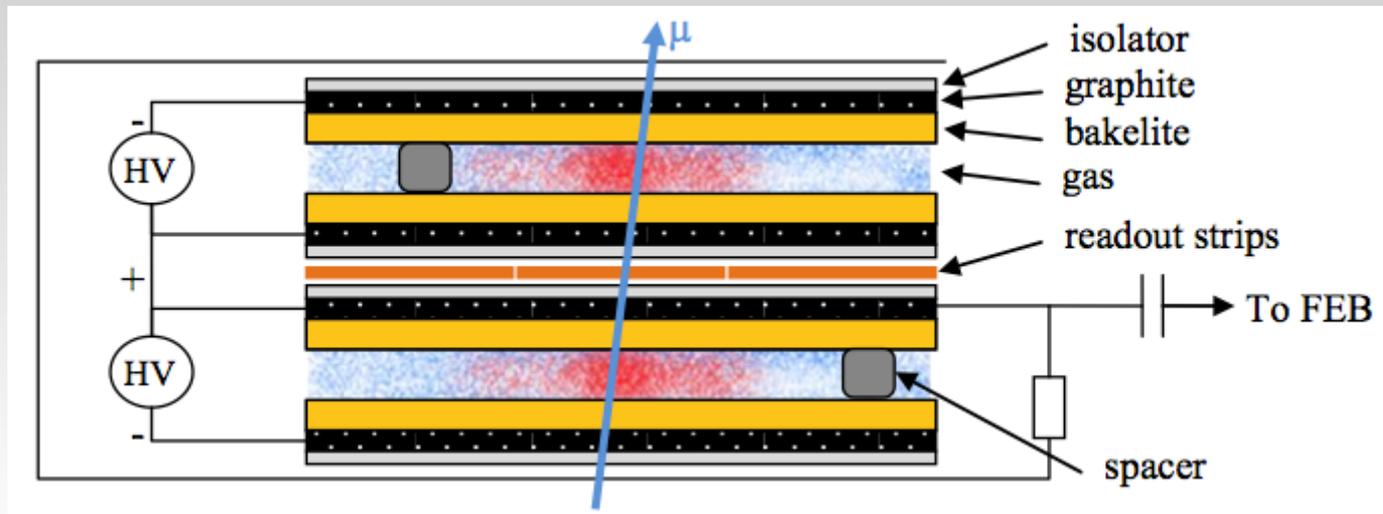
Documentation :
CERN-LHCC-2017-012

2) Requirements for the iRPC chambers

	Present system	iRPC
$ \eta $ coverage	0 – 1.9	1.8 – 2.4
Max expected rate (Safety factor SF = 3 included)	600 Hz/cm ²	2 kHz/cm ²
Max integrated charge at 3 ab ⁻¹ (SF = 3 included)	~ 0.8 C/cm ²	~ 1.0 C / cm ²
ϕ granularity	~ 0.3 °	~ 0.2°
η resolution	~ 20 cm	~ 2 cm
T resolution	1.5 ns	< 1 ns



3) iRPC chambers design



■ Resistivity of HPL: 1 - 6e10 (RPC) → < 2e10 Ω cm (iRPC)

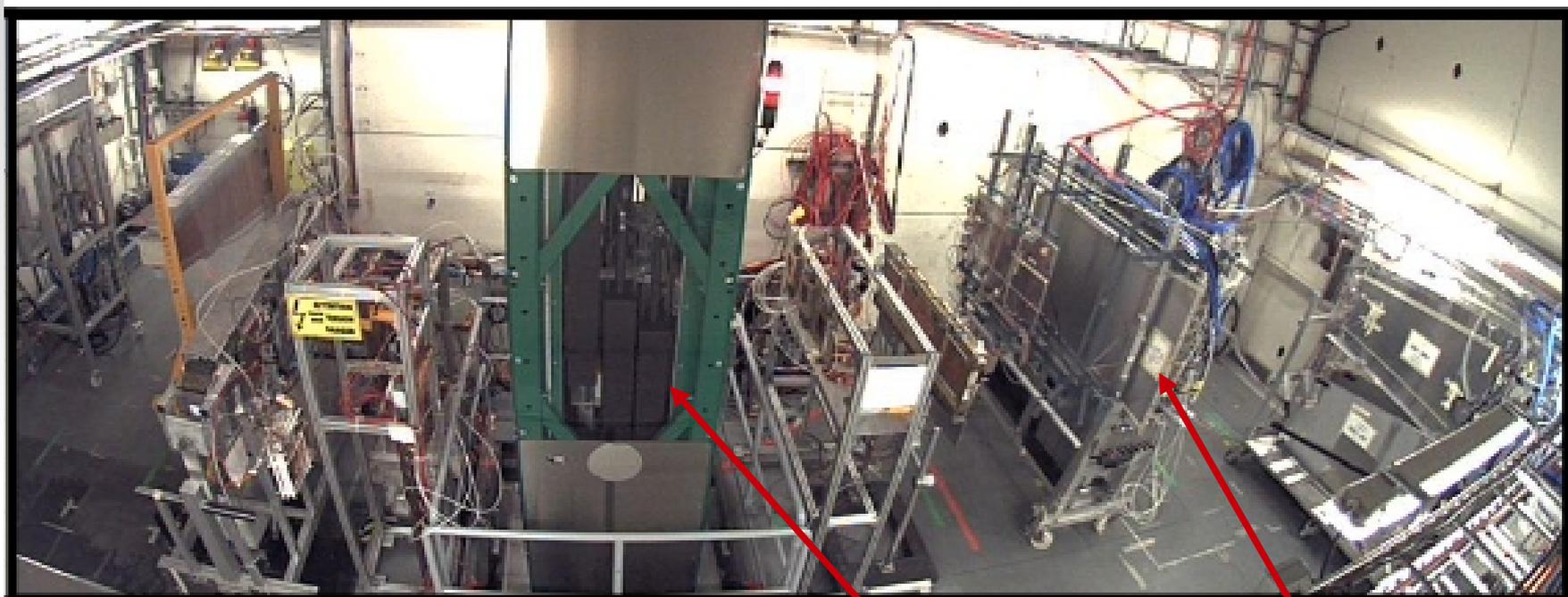
■ Gap/electrode thickness: 2.0 mm (RPC) → 1.4 mm (iRPC)

- Reduce the pick up charge and operational voltage. Less ageing.
- Reduce recovery time.
- Efficiency of extracting pickup charge.

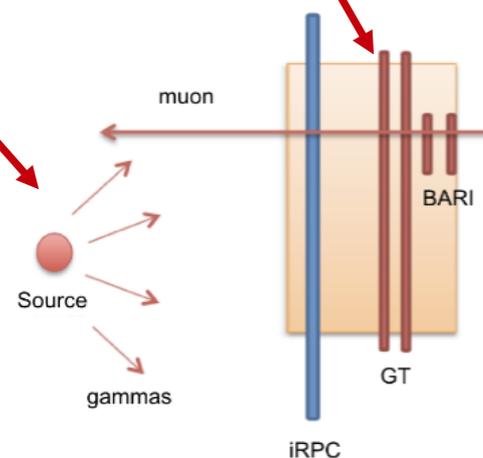
■ Electronic threshold : 150 fC (RPC) → 50 fC (iRPC)

- Better sensitivity to reduced charge.

4) Validation of iRPC detector



- Located at the end of CERN SPS H4 line that provide 150 GeV Muon beam.
- Irradiation with a 13 Tbq ^{137}Cs source.
- We use 4 tracking RPC chambers to study the iRPC prototypes.



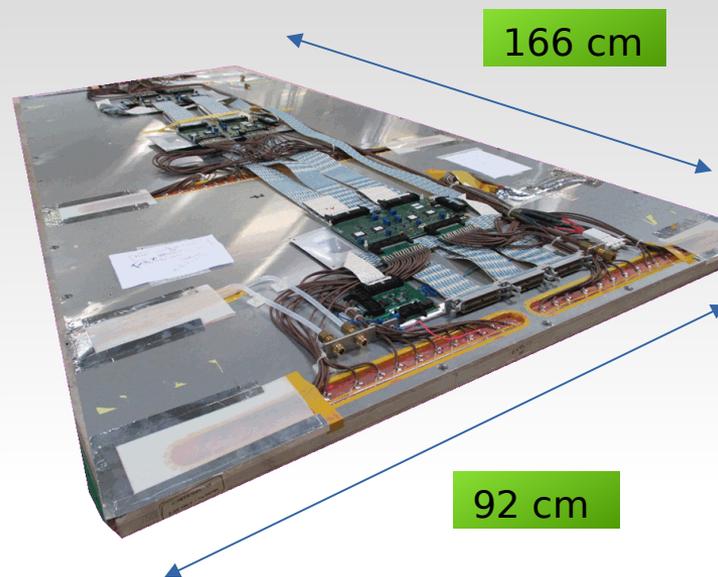
4) Validation of iRPC detector

A prototype close to full size was designed and built at KODEL laboratory of Korea University to validate the HPL gaps produced in Italy.

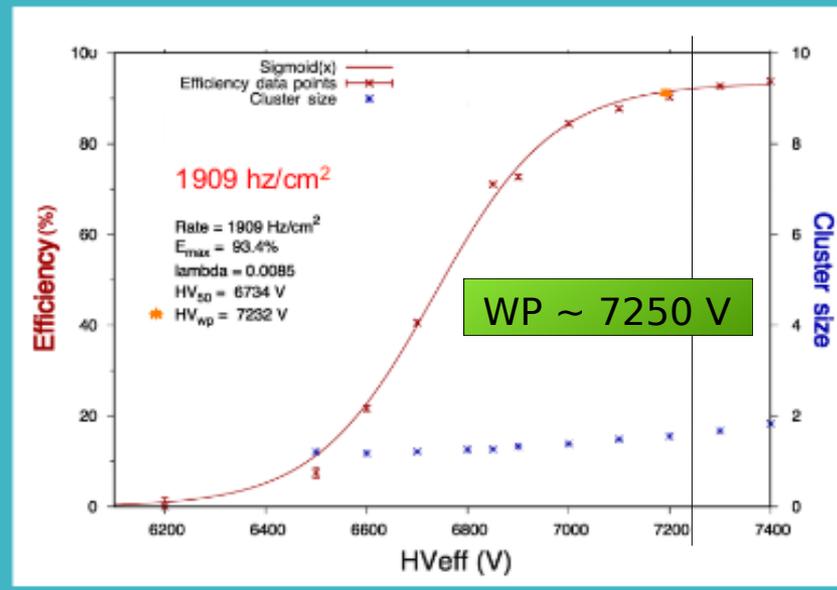
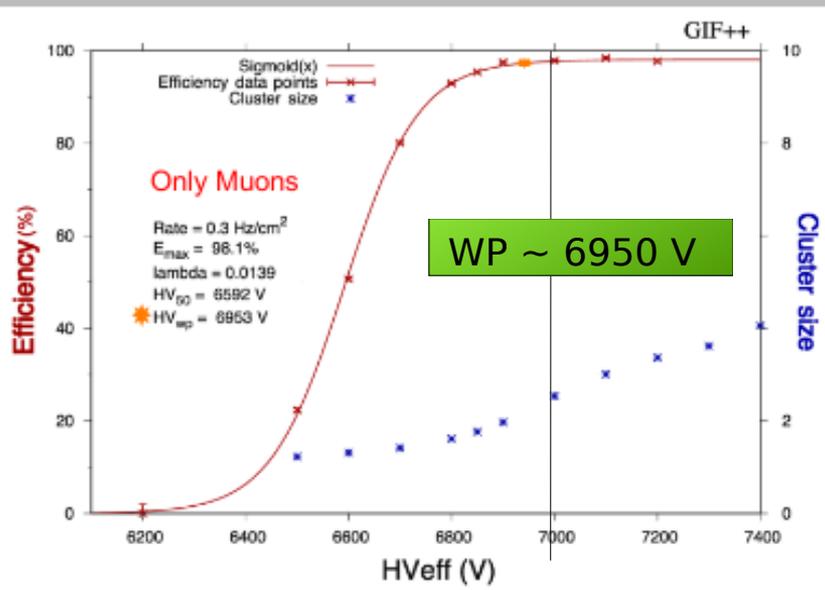
Custom electronics:

- voltage-sensitive KODEL electronics
- 96 strips: pitch 1.5 – 2.8 cm
- 3 partitions with strips readout from 1 side

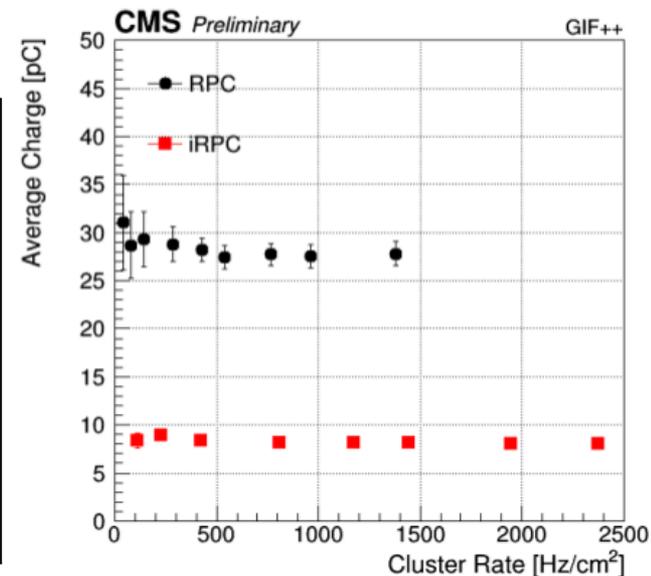
Gas : humidified 50% CMS mixture
95.2 % C₂H₂F₄ +
4.5% isoButan +
0.3% SF₆



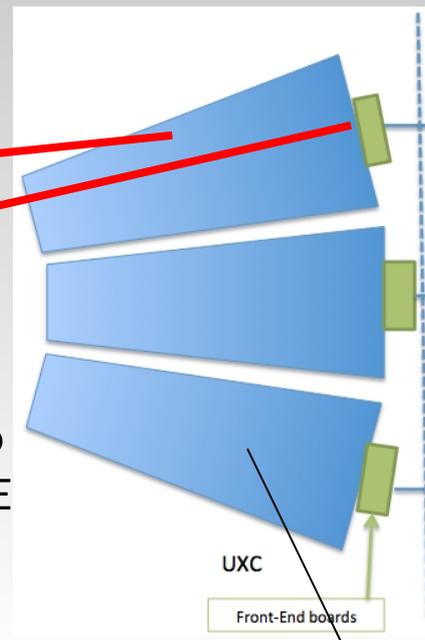
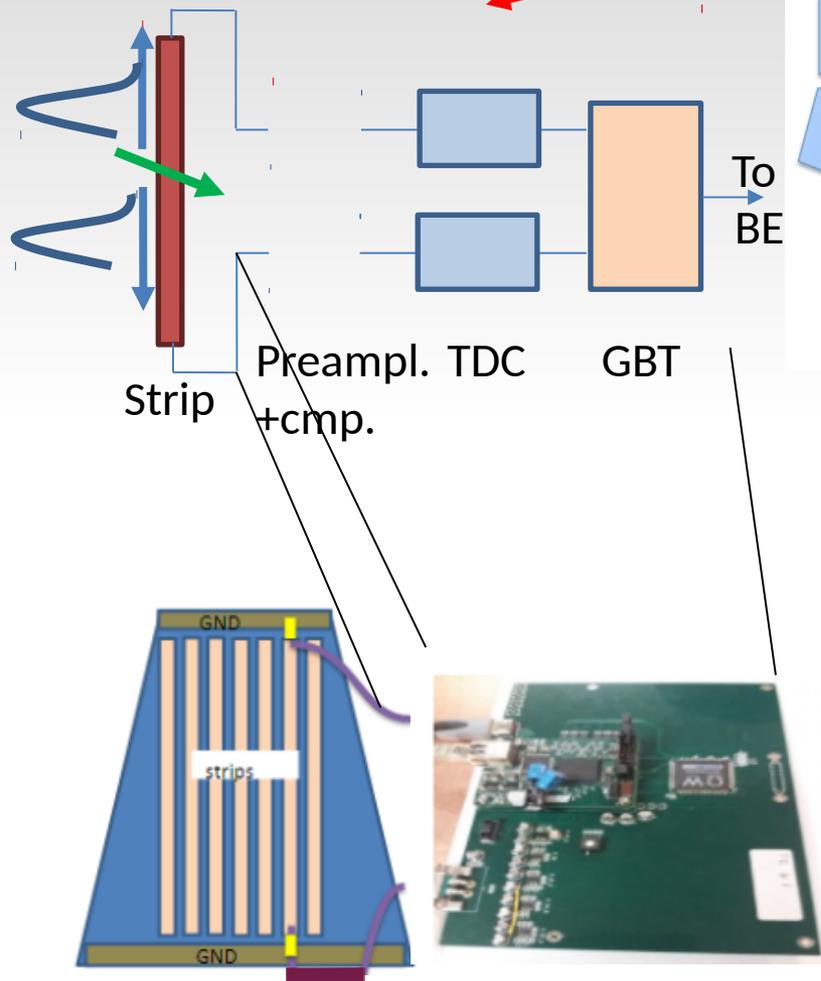
4) Validation of iRPC detector



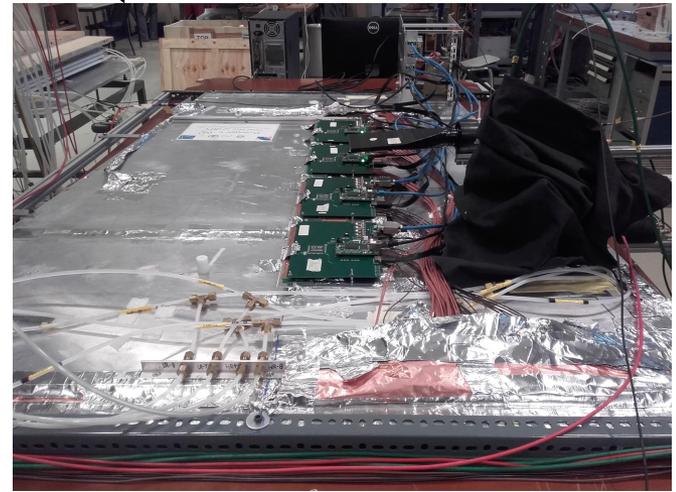
- Source off: 98 % efficiency at Working Point (WP) ~ 7 kV.
- Background of 2 kHz/cm²: 94% efficiency with WP + 300 V.
- The average charge (or the gain) within the gap is constant at WP optimized for each rate. The iRPC charge is 3 times lower than for RPC.



5) iRPC electronics

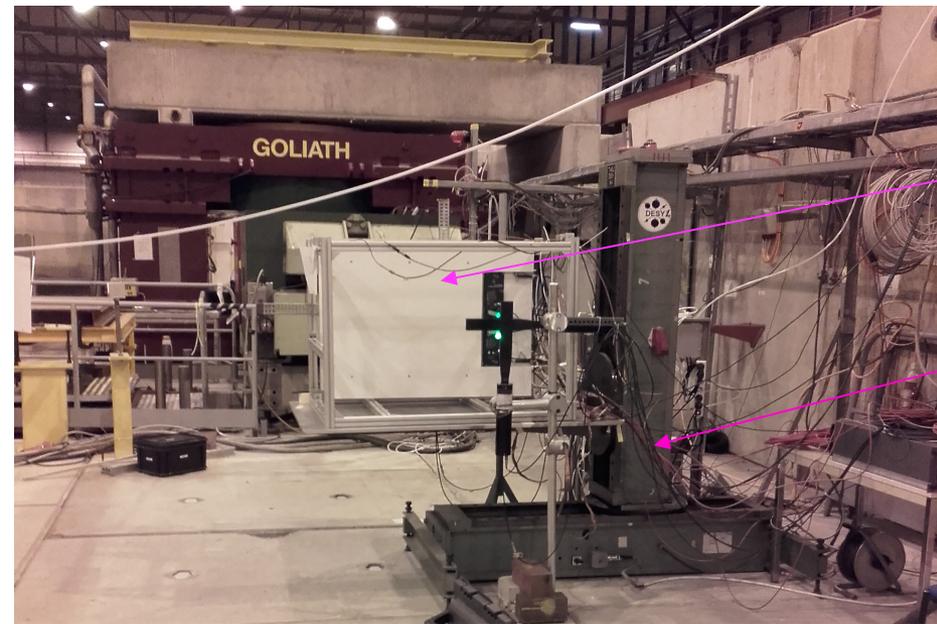


- Electronics scheme of the project with 2 sided readout: 2 cm resolution in $|\eta|$ with limited number of channels.
- Based on OMEGA ASIC (PETIROC) and Wave union TDC, designed at IPNL.
- Both sides are connected to the same PETIROC to reduce the jitter.

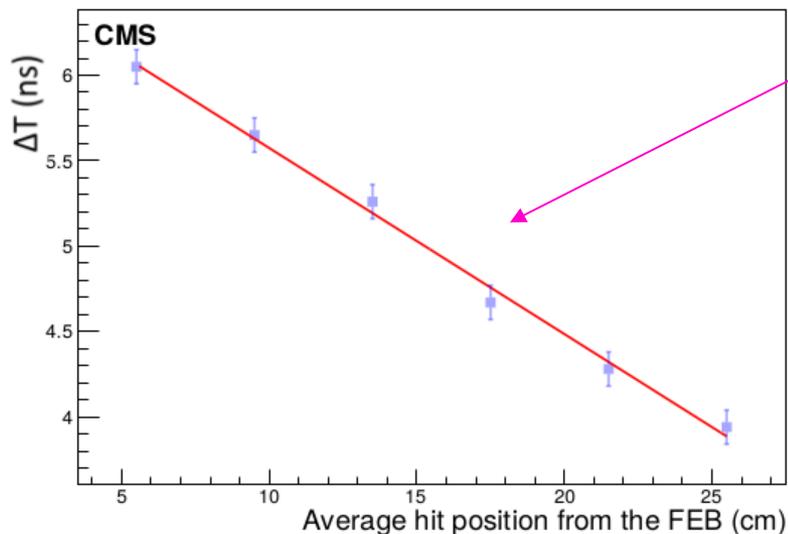


FULL SIZE PROTOTYPE

6) Proof of principle of the 2-sided readout

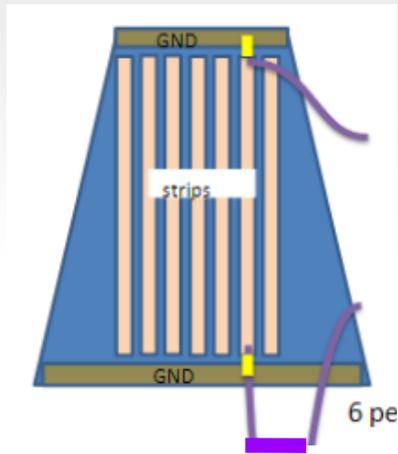


- A prototype with $\frac{1}{4}$ size of the 2-sided readout was tested in Muon beam in SPS at CERN.
- Installed on moving table with a position precision < 1 mm.
- Linear correlation between beam position and timing difference between 2 ends of the strip.



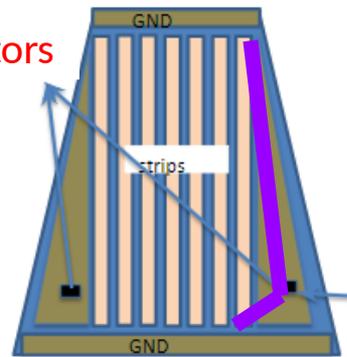
7) Electronics calibration for full size prototype

1) Connection of the strips to FEB :
Measured impedance of strips $\sim 45 \Omega$.



Low Radius (LR)

Connectors

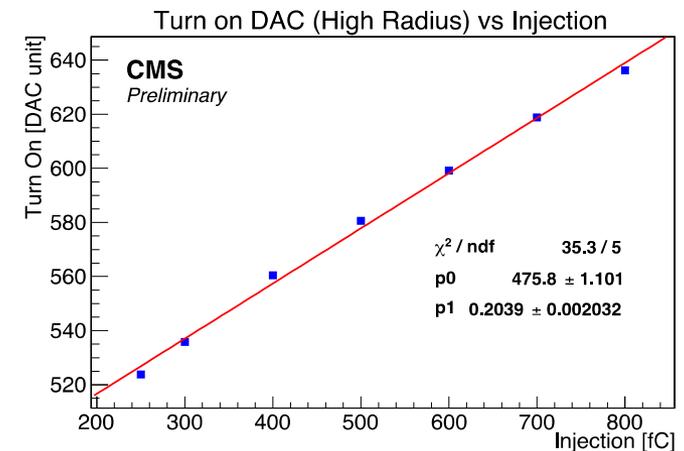
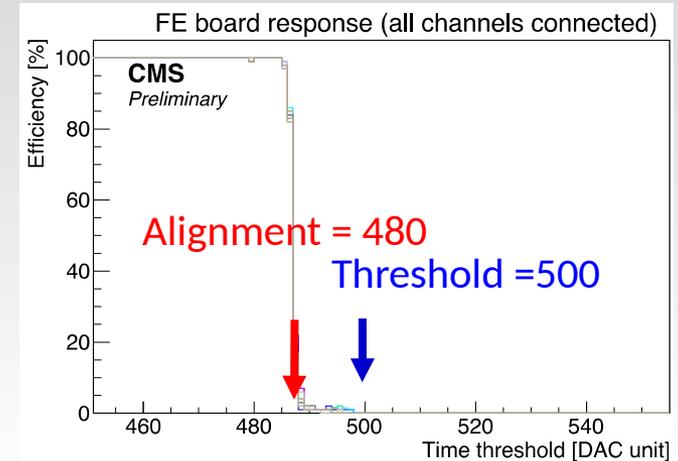


High Radius(HR)

Solution 1 **COAX** :
connect with
coaxial cables.
Impedance 50Ω .

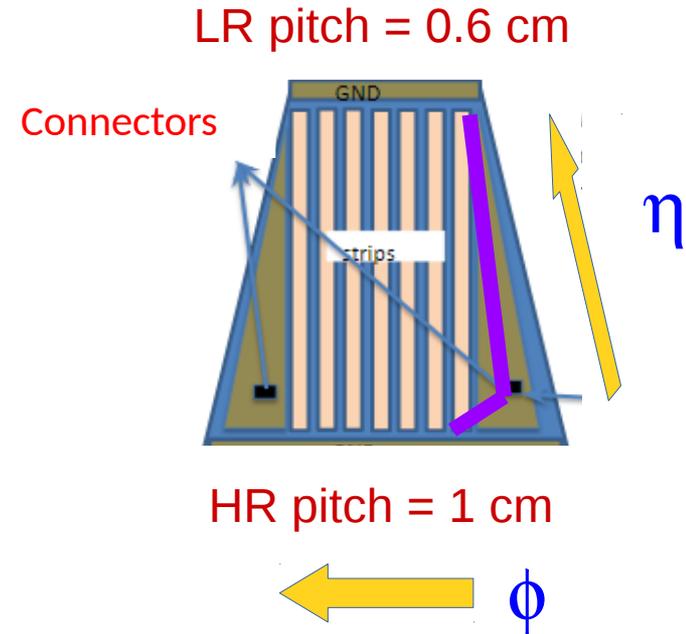
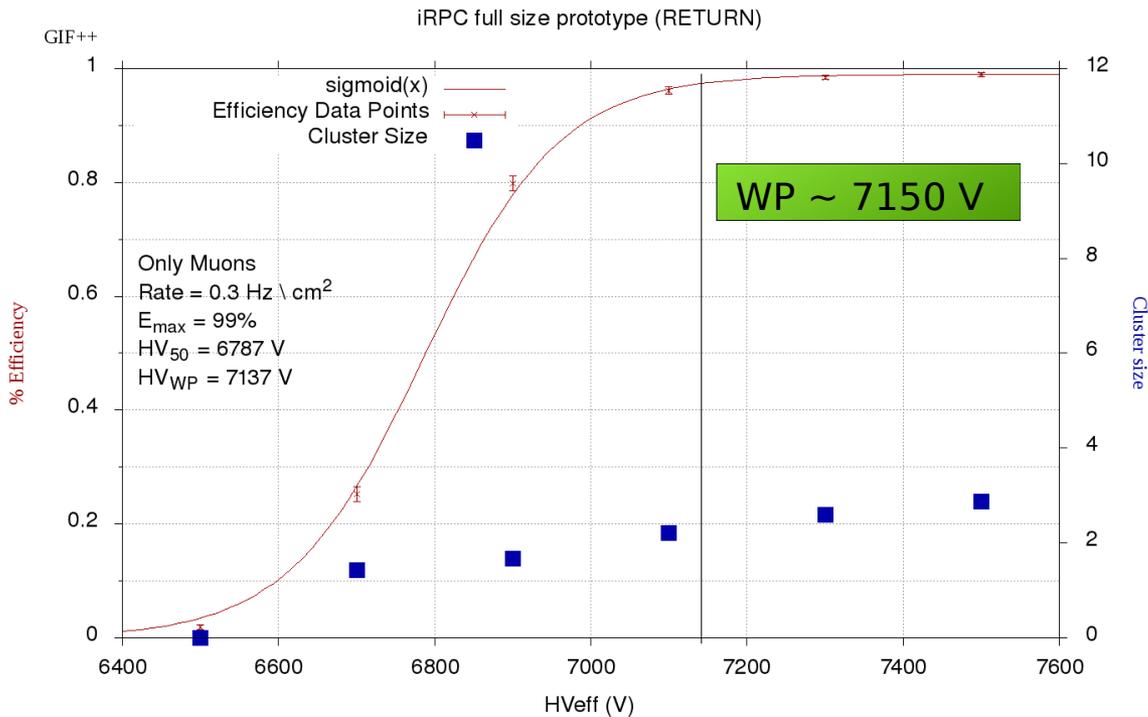
Solution 2 **RETURN** :
connect with a return
line within PCB.
Impedance 45Ω .

2) Definition of the threshold



3) Injected charge for calib.:
 $2.45 * (500 - 480) = 50 \text{ fC/side}$

7) Test of the full size prototype in GIF++



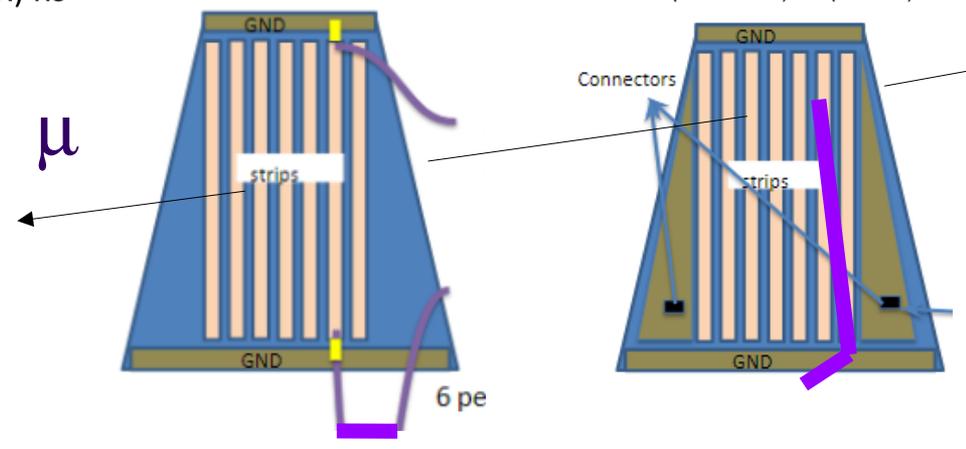
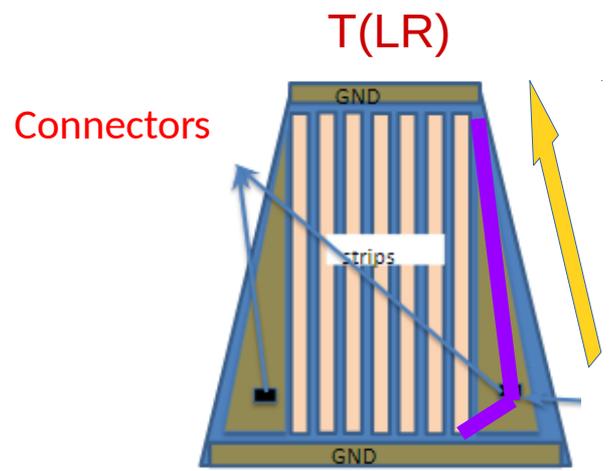
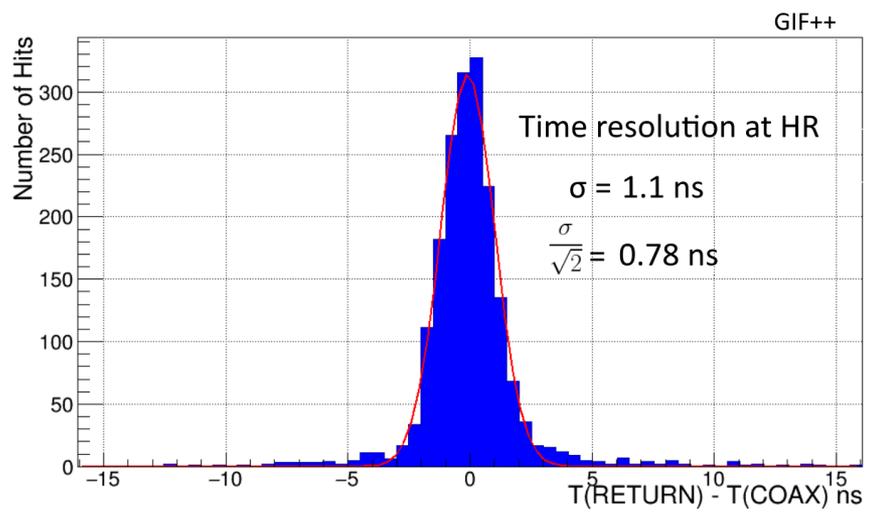
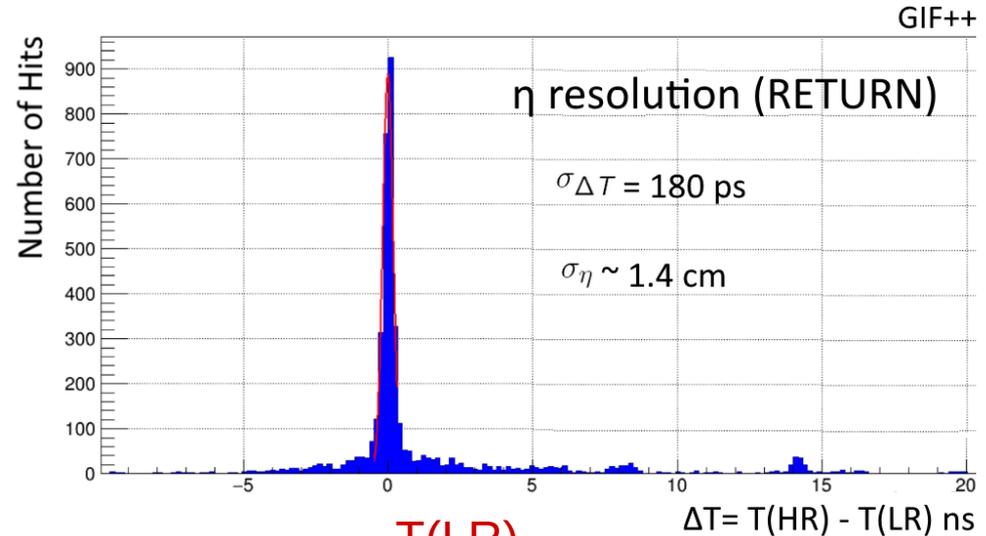
Both prototypes were tested in GIF++ in May 2018 and validated with muons and source off: all specifications fulfilled.

RETURN chamber is technically easier to handle and to manufacture.

7) Test of the full size prototype in GIF++

η resolution $\sigma_{\eta} = V * \sigma_{\Delta T} / 2$

Intrinsic time resolution



T(HR)

T(COAX) at HR

T(RETURN) at HR

CONCLUSIONS

■ Several prototype of iRPC was validated :

- 1.4 mm HPL gaps read by 1-side readout electronics was validated with muon beam for background rates up to 2 kHz/cm² in GIF++.
- A prototype with 2-side readout by PETIROC ASIC and 1.4 mm HPL gaps is validated with muon beam, but without background.

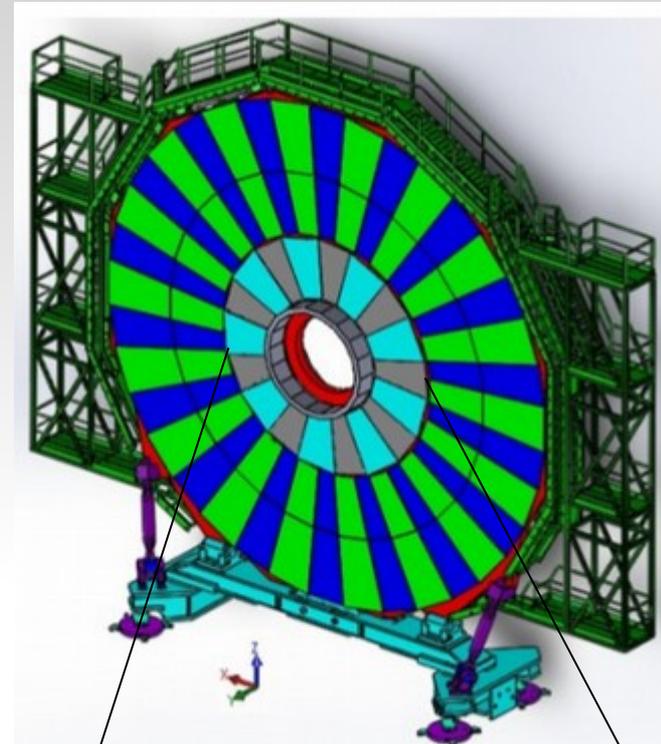
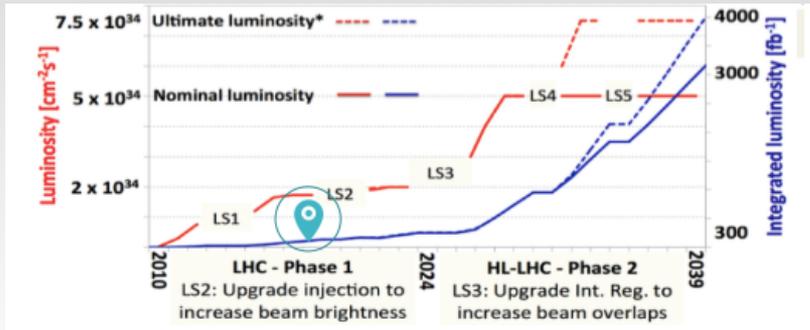
■ Next steps in 2018:

- To test the prototype with background up to 2 kHz/cm² at GIF++.
- Build the final prototype.

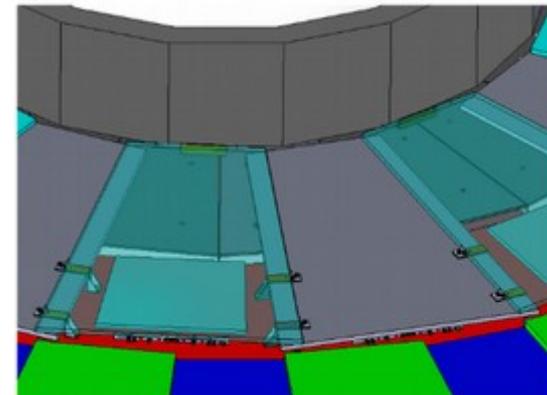
BACKUP



HL-LHC project



- New Resistive Plate Chambers (iRPC) would occupy the 2 outside rings of the endcap.
- They are associated to respective Cathode Strip Chambers (CSC) stations.



CSC ambiguities

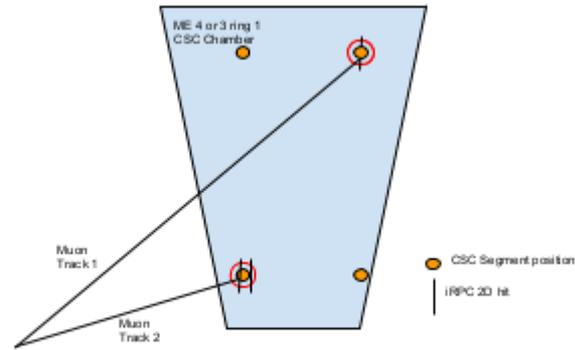
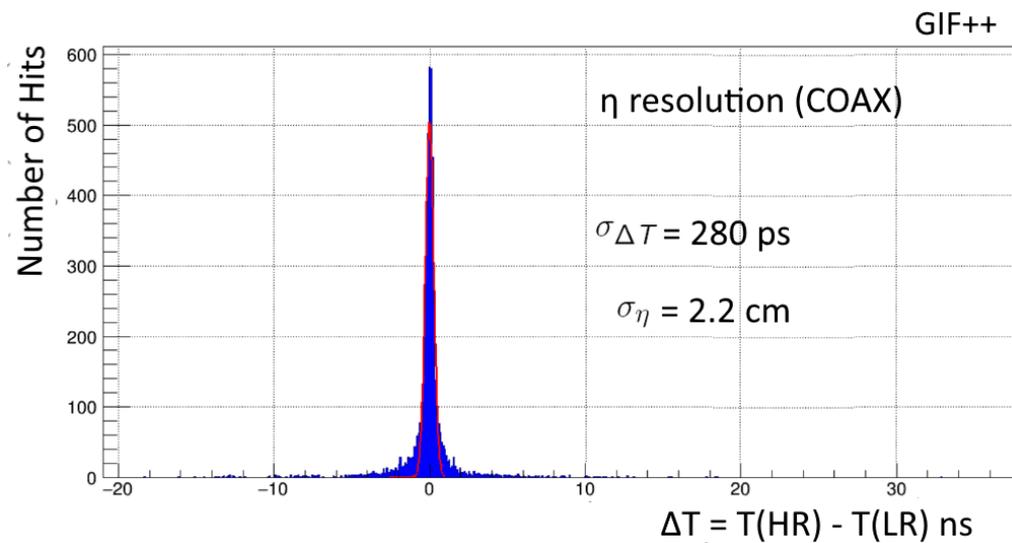
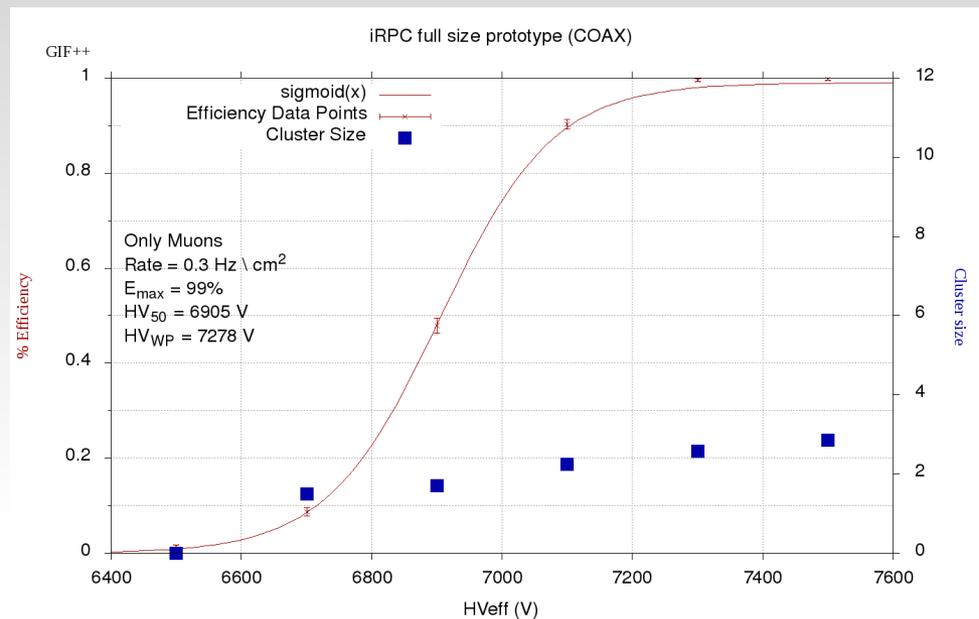


Figure 7.7: CSC and iRPC readout sketch when two muon/LCT cross the same chamber in the same readout window. Two pairs of hits are possible with only one of them being "real".

COAX CHAMBER



iRPC chambers design

Resistivity of HPL: $1\text{-}6\text{e}10 \rightarrow 0.9\text{-}2\text{e}10 \text{ } \Omega \text{ cm}$

→ Rate capability * 2.

Gap thickness: $2.0 \text{ mm} \rightarrow 1.4 \text{ mm}$

→ Reduce the pick up charge. Less ageing.

→ Reduce operational voltage. Less stress on the system.

→ A thinner electrode is sensitive to nonuniformities.

Electrode thickness: $2.0 \text{ mm} \rightarrow 1.4 \text{ mm}$

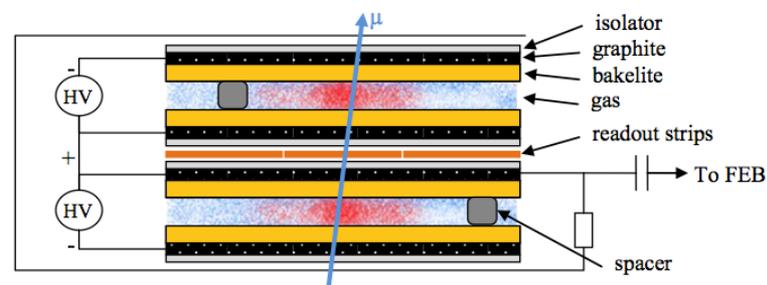
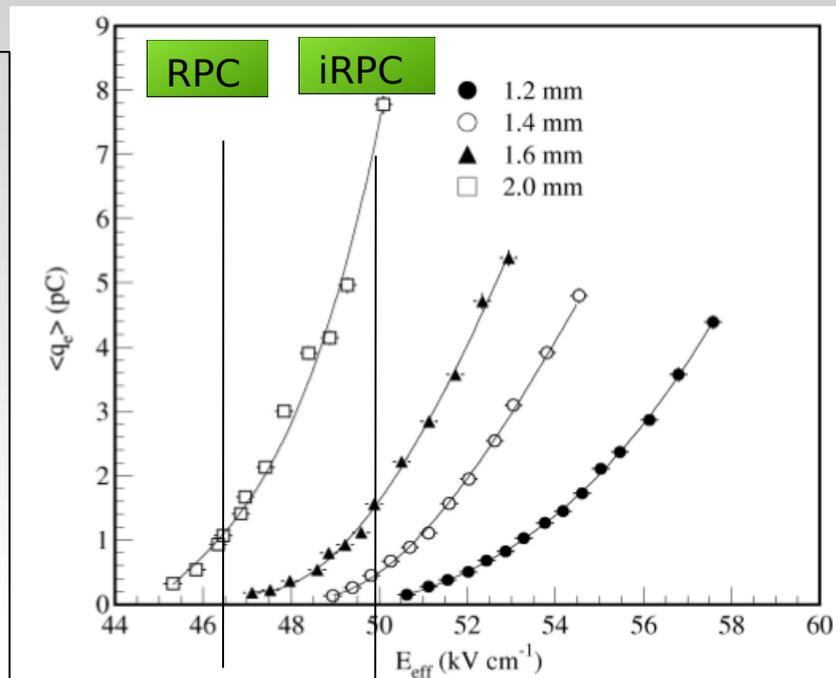
→ Reduce recovery time by 30%

→ Efficiency of extracting pickup charge increase by 70%.

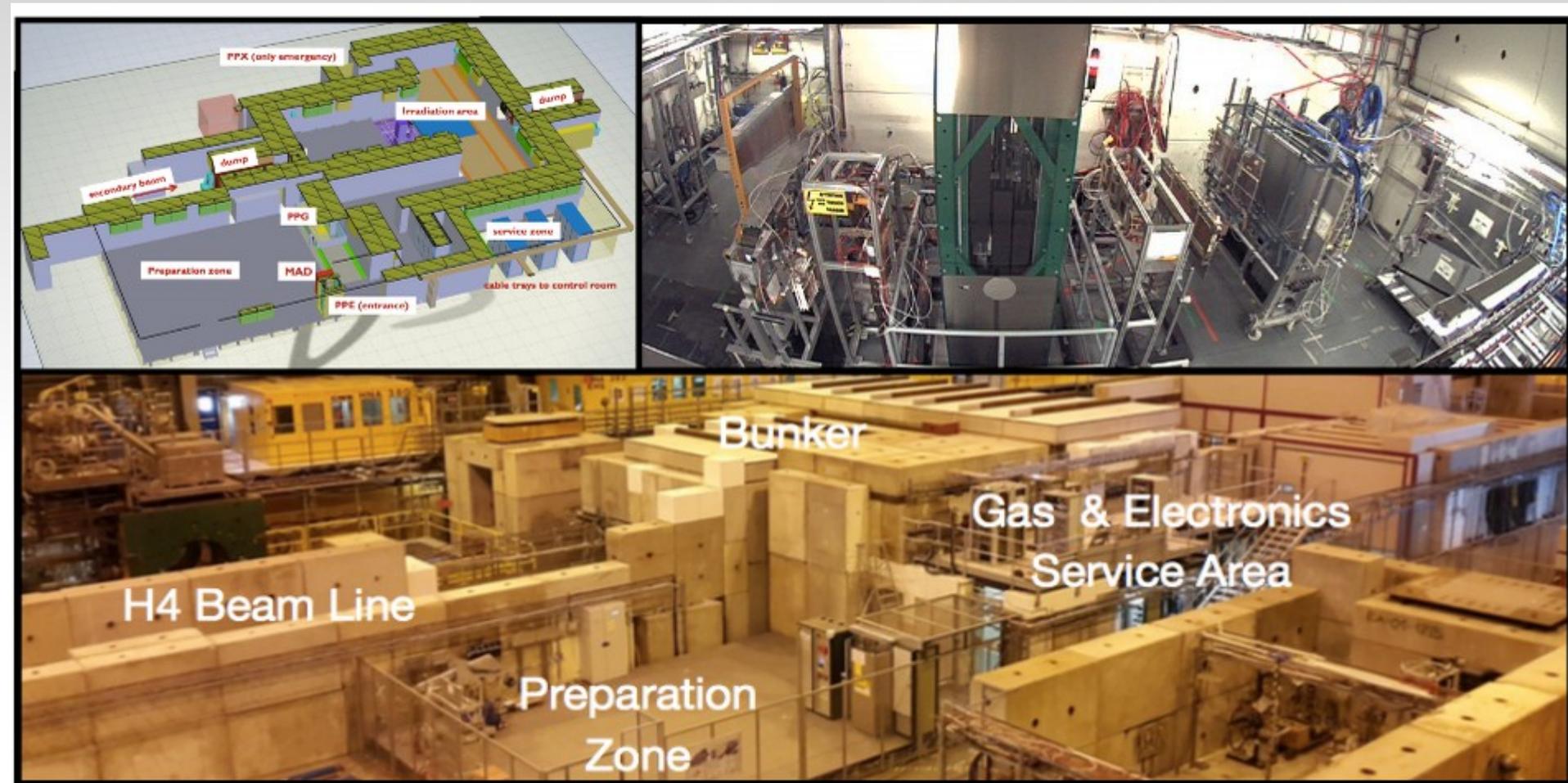
→ Rate capability * 2.

Electronic threshold : $150 \text{ fC} \rightarrow 50 \text{ fC}$

→ Better sensitivity to reduced charge.



Scheme of a CMS RPC chambers with High Resistivity Laminate (HPL).



H4 Beam Line

Bunker

Gas & Electronics
Service Area

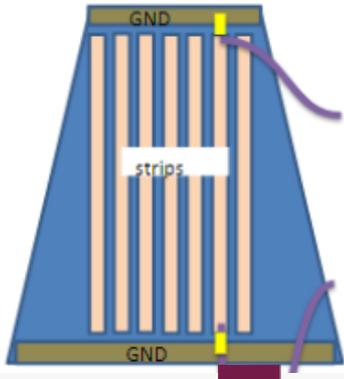
Preparation
Zone

- Locates in CERN Preveessin Site
- 100 GeV Muon beam from Super Proton Synchrotron (SPS)
& ~13 TBq ^{137}Cs gamma radiation source

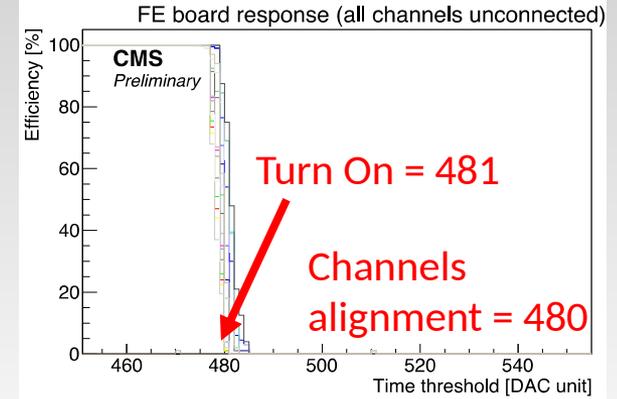
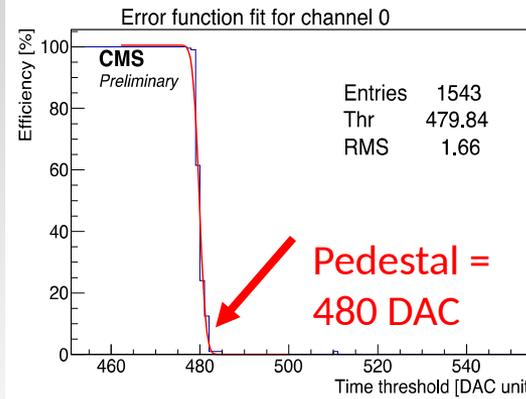
arxiv.org/abs/1611.00299

Electronics calibration for full size prototype

Low Radius (LR)



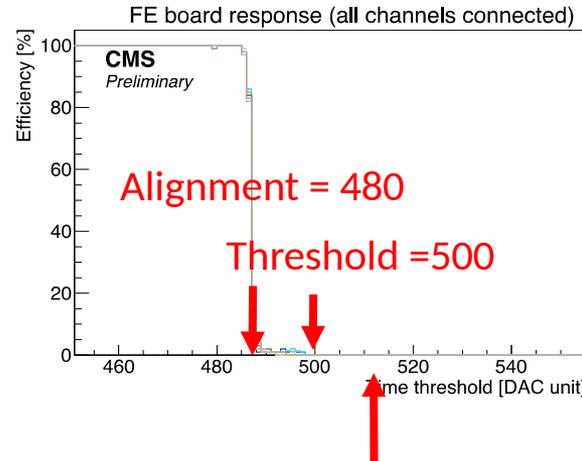
High Radius(HR)



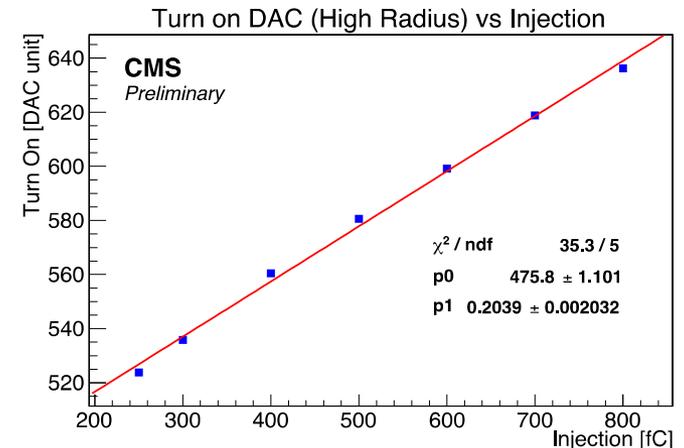
2) Charge injected to align each channel pedestal.

2) All channels together need extra alignment.

1) Impedance of strips $\sim 45 \Omega$. Use 50Ω lemo cables.*



3) Threshold is setup for operations 500. Increased to 510 for full chamber.



4) Calibration with injected charge. Electronics threshold: $2.45 * (510 - 480) = 73.5 \text{ fC/side}$

*A second prototype uses return line within the PCB matched to 45Ω .