Summary of RPC2020

Crispin Williams

a couple of points

- I have not done this before…. so I may screw up
- I would like to compliment the speakers (especially the younger speakers who have spoken with so much clarity and confidence
- Not all lectures of this morning included

An introduction to RPC 2020

Roma Tor Vergata University

10 Feb 2020

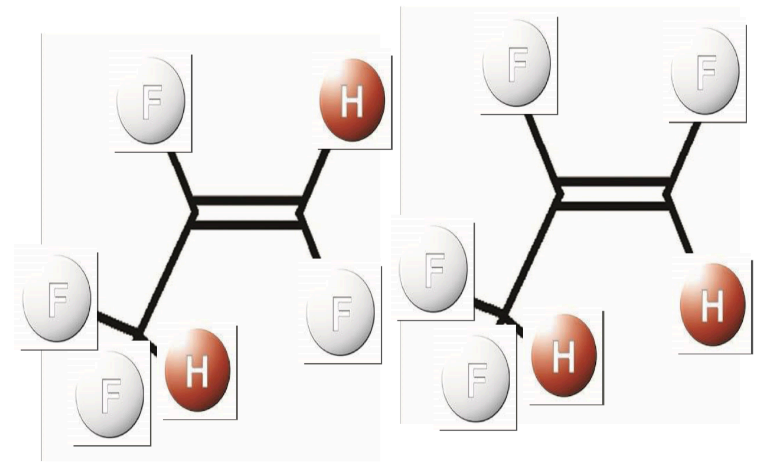
By R. Santonico

Search for new low GWP RPC gases

Present *magic mixture* $C_2H_2F_4$/i-C_4H_{10}/SF_6 = 94.7/5.0/0.3 shows a very large separation, in terms of applied electric field (> 0.5 kV/mm depending on the FE electronics), between avalanche and streamer mode operation

Our efforts to find a new low GWP RPC are mainly directed to reproduce this very confortable feature with the new series of industrial gases HFO (Hydro Fluoro Olefins)

SEARCH FOR NEW GASSES with low GWP

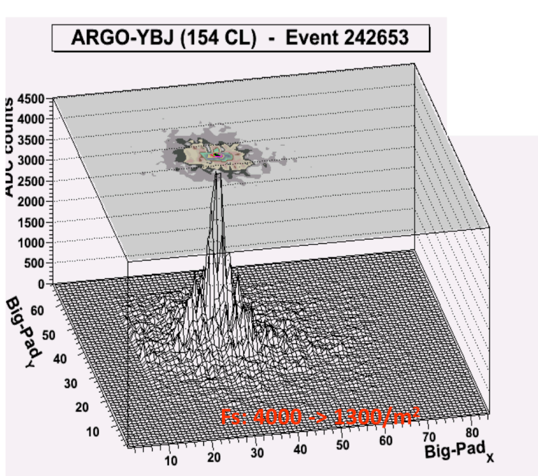


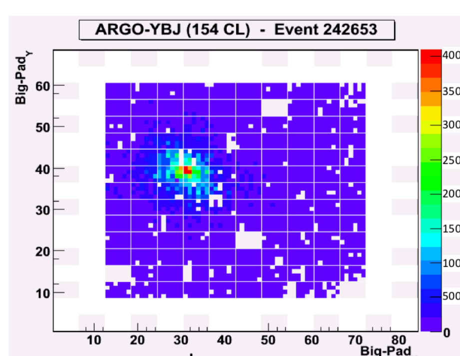
VERY LARGE ARRAYS OF RPCs/ CALORIMETERS

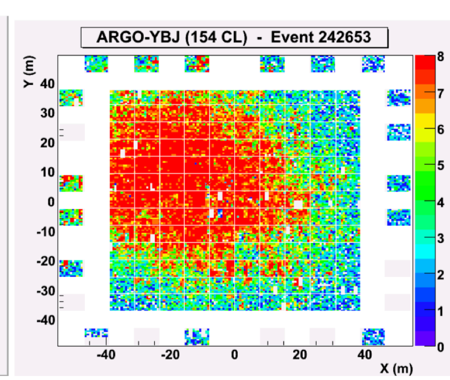
The RPC analog readout

Extending the dynamical range up to PeV

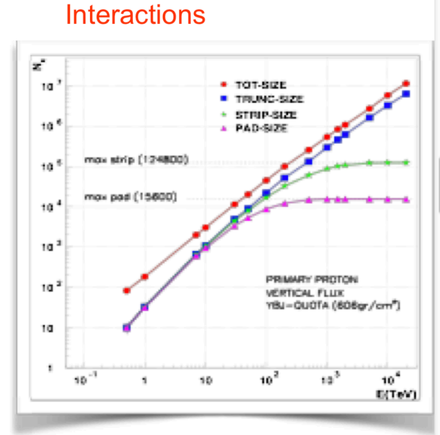
ARGO event







- Is crucial to extend the covered energy range above 100 TeV, where the strip read-out saturates
- Max digital density ~20/m^2 Max analog dens ~10^4/m^2
- Access the LDF in the shower core
- Sensitivity to primary mass
- Info/checks on Hadronic Interactions



Future RPC developments

R.Cardarelli

INFN sez. Tor Vergata

RPC meeting, Roma 10-14 /02/2020

- **Fake pulse (noise),** the experience shown the rate of fake pulse depend to the characteristic and flatness of the electrode surface, very low type of the surface work in order in the RPC, for instance:

  linseed oil
  glass
  mono-crystal semiconductor

  The fake pulse depends on the properties and flatness of the surface at the molecular level, the possible explanation why glass and linseed oil work very well, is they are high density liquids and therefore have surface oriented molecules .

- **Thickness of electrode,** it is another parameter that can be easily to decrease, the experience shows an increase in mechanical instability and a fragility for electric discharges. A large study is underway in the Roma2 laboratory and MRPC group. The thickness of electrode is tested in the range of 2-0.1 mm.

- **Average charge delivery in the gas** , historically, the first major step forward was made in the 1993s with the observation of the avalanche regime, instead of the streamer, that allowed an increase the rate capability by a factor 100, the introduction of a low noise front-end (1000 e^- RMS noise) ATLAS muon upgrade project RPC BIS78 allowed a further factor 10 in the rate capability of the order of 10 kHz/cm^2

- **Ionic to electron induction charge**, The study of the characteristics and correlations between the ionic and electronic signal increase the knowledge of the dynamics of avalanche evolution and can suggest method to increase the performances of the RPC.

Future RPC development

Counting rate parameter:

- **Resistivity of electrode**, apparently it is the simplest parameter to modify to obtain an increase in the rate capability . Experience shows that in the current RPC for resistivity values lower than 10^10 the detector becomes unstable. There are attempts with mono-crystal semiconductor electrodes (GaAs, Alessandro Rocchi RPC2020 presentation) that show stability for resistivity value of the order of 10^8. This is a possible development for the future in the range of the MHz/cm^2 rate capability.

- **Material of electrode**, different material are tested different group:

  phenolic paper (10^{11}-10^{10} ohm x cm resistivity)
  phenolic glass fiber (10^{11}-10^{10} ohm x cm)
  glass high low resistivity (10^{11}-10^{8} ohm x cm)
  ceramic (10^{11}-10^{9} ohm x cm)
  mono crystal semiconductor (GaAs, Si, ….) (10^{8}-10^{5} ohm x cm)

Had to wait to Wednesday to hear more on this

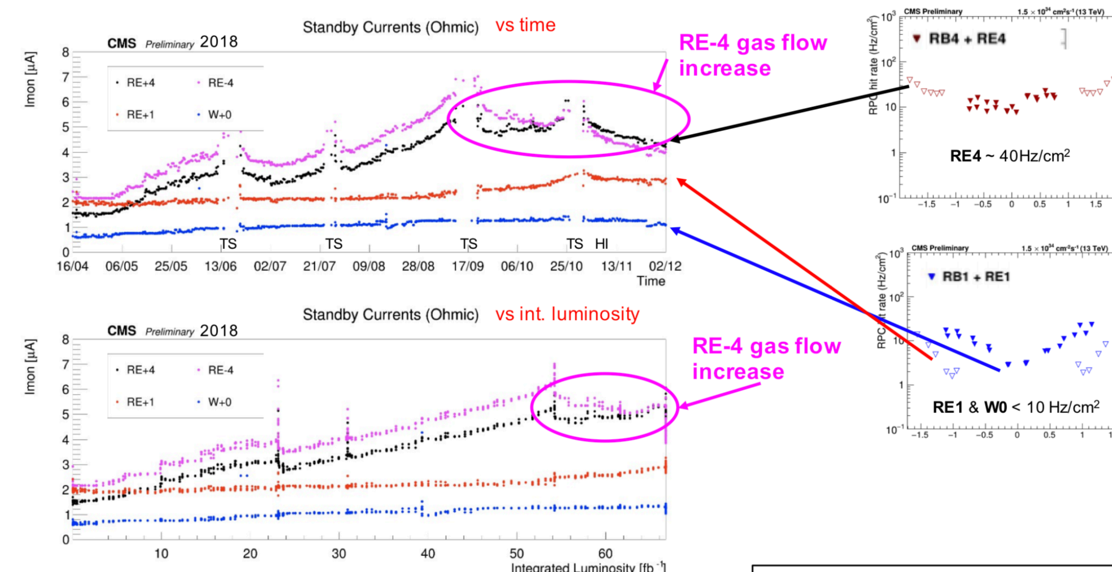
Experiences from the RPC data taking during the LHC RUN-2

Mehar Ali Shah
on behalf of the CMS collaboration
RPC2020, Roma

National Centre for Physics, Pakistan

Ohmic Current Monitoring

- **Ohmic current increase** was observed in regions of higher background: In endcap **RE4s** & in Barrel **RB1 & RB4** stations.
- **Ohmic current decrease** when there is no beam (TS) or the luminosity is very low (HI)



- **Ohmic current decay** is observed when there is no beam (TS) or the luminosity is very low (HI)
- Details of machine learning approach to spot abnormal currents can be found in Piecho's talk "A new approach for CMS RPC current monitoring using Machine Learning techniques"

- **Ohmic current** is influenced by the **background** and **gas flow**
- **Ohmic current** is **linear** as a function of th integrated luminosity

RPC2020, Roma

Conclusion

- After ~ 9 years of operation **(~ 185 fb-1**) and operating successfully in extreme conditions (8 TeV & 13 TeV & L ~ 2 x 10^{34} $cm^{-2}s^{-1}$) during RUN-1 & RUN-2, RPC performance is stable and fulfill the requirements for the trigger and reconstruction capabilities necessary for the CMS physics program.
  - **Average efficiency ~ 96%**
  - **Average cluster size ~ 2 strips**
- A reversible **ohmic current** increase was observed in the most exposed regions. Fine tuning of the gas is mandatory.
- No degradation has been observed to participate in the hadron collisions of **LHC Run-3.**

What is Ohmic correct?

Current drawn at half working voltage

The BIS78 Resistive Plate Chambers upgrade of the ATLAS Muon Spectrometer for the LHC Run-3

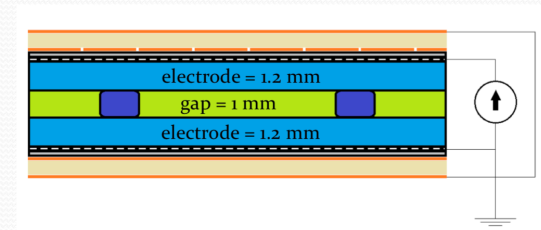
Lorenzo Massa
on behalf of the ATLAS Muon Collaboration

XV Workshop On Resistive Plate Chambers And Related Detectors
Roma Tor Vergata
12/02/2020

New generation of RPCs

New Gas Gap

- Thinner gas gap (2 mm → 1 mm)
- Thinner electrodes (1.8 mm → 1.2 mm)
  - Lower detector weight
  - Thinner supports allowed
  - More efficient signal collection
  - Almost halve the applied HV
  - Improved charge distribution
  - Double time resolution



New Front End Electronics

- New amplifier and discriminator
  - Higher rate capability
  - Radiation hardness
  - Better space-time resolution
  - Inexpensive high performance low power FE
  - More details in L. Pizzimento's talk

Amplifier in Silicon	
Gain	0.2-0.4 mV/fC
Power Consumption	3-5 V 1-2 mA
Band width	100 MHz

Discriminator in SiGe	
Threshold	0.5 mV
Power Consumption	2-3 V 4-5 mA
Band width	100 MHz

New Generation RPCs' Space-Time Resolution: 1 mm x 0.4 ns

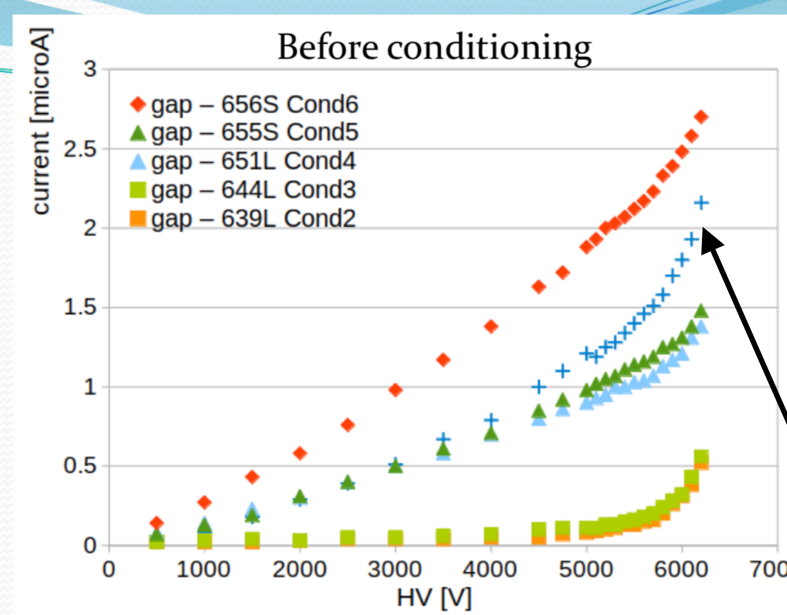
Gas gap QA/QC

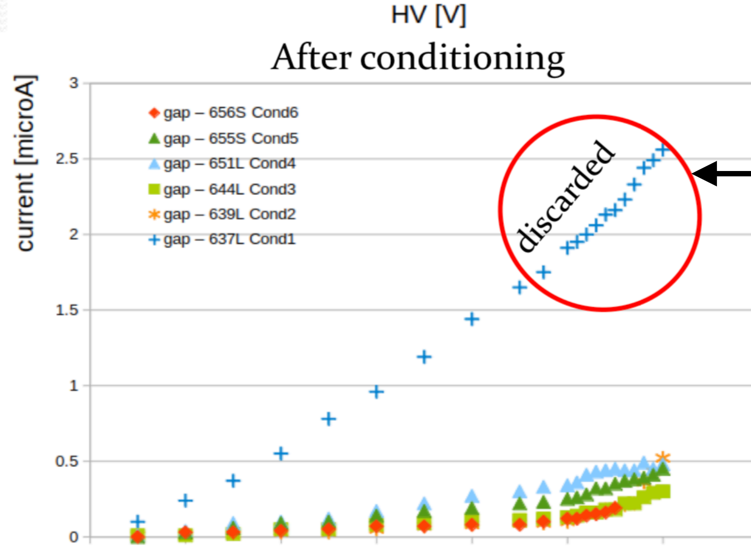
Acceptance test at the production site (General Tecnica)

- Electrode resistivity
- Spacer gluing strength test
- V/A characteristic
- Gas tightness
- HV insulation test

1 week of gamma irradiation at CERN

- Slow turn on at high rate (conditioning): all the gaps have to reach 40 μA in steps of 10 μA, which take around half day each.
- Stability test at HL-LHC like conditions: no change in the V/A characteristics after irradiation





In question/answer after presentation - it was not clear what had happened to this chamber

This gap became worse during reconditioning Has it been discarded?

Performance of the ATLAS RPC detector and Level-1 muon barrel trigger at $\sqrt{s} = 13$ TeV

RPC2020 Workshop - Rome

Heng Li
on behalf of the ATLAS Collaboration

University of Science and Technology of China

February 10, 2020

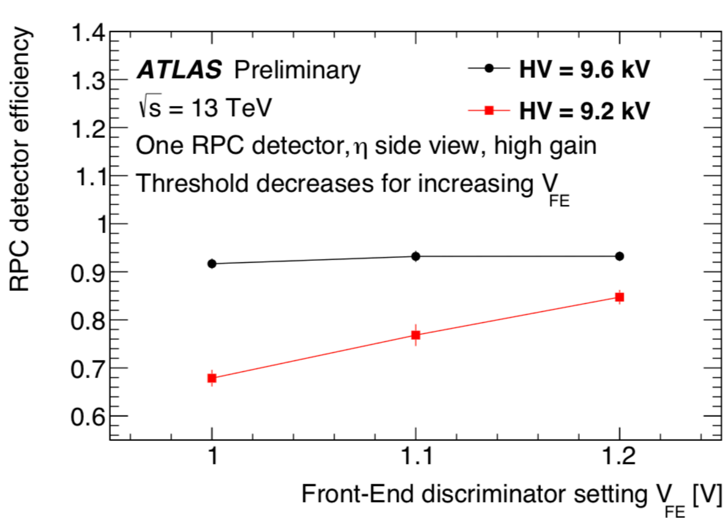
Summary and conclusions

- Muon barrel RPC triggers selecting muon candidates at 40 MHz collision rate are of crucial importance for the ATLAS experiment
- Many studies has been done to monitor the RPC performance continuously during the year
- ATLAS RPCs have been working with excellent performance (both detector and trigger) since the completion of the system in 2008 even working at a instantaneous luminosity of a factor of 2 larger than the designed
- Preliminary studies indicate that existing ATLAS RPCs will perform well at higher instantaneous luminosity
- Extra RPC chambers (BIS7/8) to install for Run 3 $\rightarrow$ See talk from Lorenzo Massa and extensive detector upgrades to prepare for High Luminosity LHC including new RPC inner triplet layer and new readout electronics $\rightarrow$ See talk from Yongjie Sun

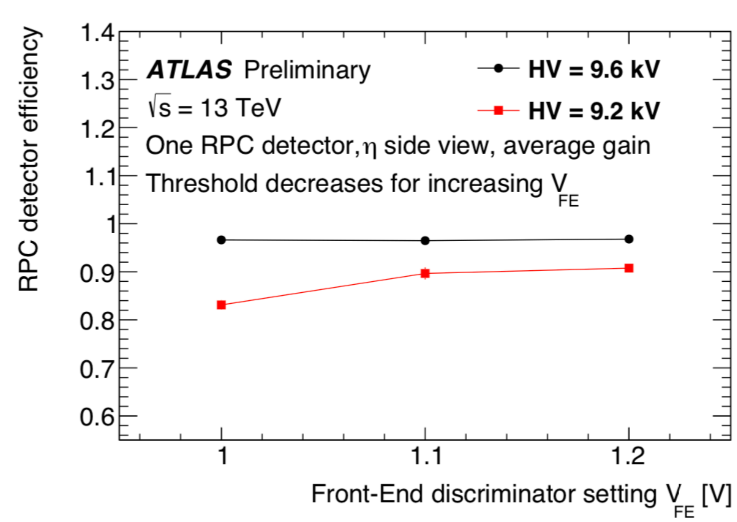
Front End discriminator thresholds scan

- ATLAS RPC detectors are planned to operate until $\sim$ 2040
- At HL-LHC ($\mathcal{L} \sim 7.5 \times 10^{34} cm^{-2} s^{-1}$) the integrated charge collected in the avalanche will be enough high to limit the detector lifetime
- It is proposed to lower the HV in the RPC gas-gaps (9.6 kV $\rightarrow$ 9.2 kV). At the same time, new RPCs will be installed in the innermost layer of the Muon Barrel Spectrometer to increase the redundancy of the trigger system and the trigger efficiency
- Study response of few RPC detectors at nominal and lower HV with different FE thresholds

high gain $\rightarrow$ efficiency increasing by $\sim$ 20%
at HV = 9.2 kV from V_{FE} = 1.0 V to 1.2 V



average gain $\rightarrow$ efficiency increasing by $\sim$ 10%
at HV = 9.2 kV from V_{FE} = 1.0 V to 1.2 V



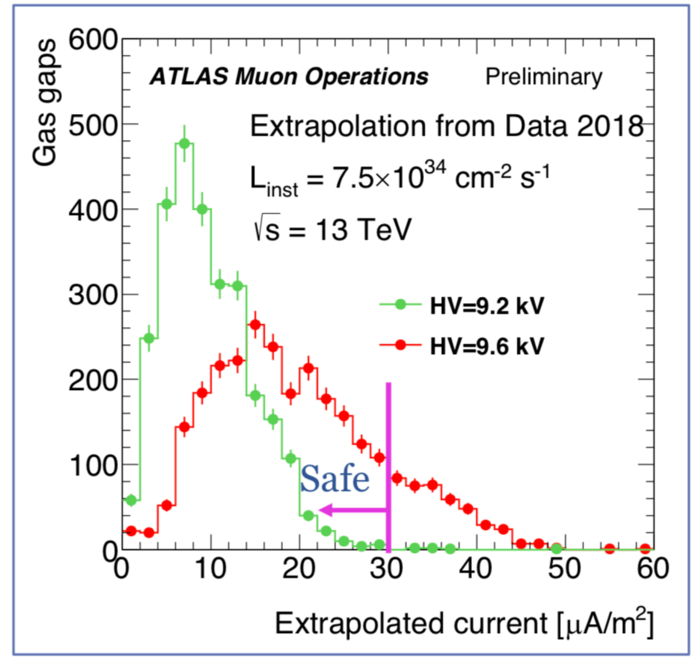
Mesage: Reduce voltage on RPC from 9.6 to 9.2 kV to increase RPC lifetime

Current vs HV and extrapolation at HL-LHC

Studies of gas gaps current density in th ATLAS RPC detector during 2018 data taking at Large Hadron Collider

Dimitrii Krasnopevtsev* on behalf of ATLAS Muon Collaboration

*University of Science and Technology of China



Luminosity scaling:
Gas volume current linearly dep instantaneous luminosity => scale facto

Safe threshold for current: 30 μA/
based on results reported in Muon upgrade report ATLAS-TDR-026, integrated charge is less than 30 m year (assuming LHC run 33% of time).

Mesage: Reduce voltage on RPC from 9.6 to 9.2 kV to increase RPC lifetime

Question: how much charge is produced in chamber for each MinI particle?

- ❑ RPC gas volumes currents were studied as a function of instantaneous luminosity, voltage and temperature for the condition with and without pp collisions.
- ❑ Studies at various luminosity and voltage showed:
  - expected linear increase of gas volume current was confirmed up to the highest instantaneous luminosity during the 2nd data taking period of LHC for various RPCs;
  - gas volumes current dependence from voltage at beam conditions can be linearly described at V=9-9.6 kV. Therefore gas volume currents can be scaled in a straightforward way between different voltages.
- ❑ Studies of gas volume current density extrapolations to HL LHC conditions showed:
  - lowering HV to 9.2 kV helps to address the overcurrent in affected gas volumes at HL LHC conditions, however with some drop of efficiency;
  - consistent increase of gas volume current density with temperature across the whole RPC was observed (~ 6 μA/m² per 10^{o}C).
- ❑ Curves of gas volumes current as function of HV (without collisions condition) are efficient instrument to monitor gaps state.

EP-DT
Detector Technologies

Gas mixture quality studies for the CMS RPC detectors during LHC Run 2

Roberto Guida, Beatrice Mandelli
CERN

Andrea Gelmi on behalf of the CMS collaboration
(Università e INFN Bari)

Conclusions

CMS RPC systems is operated under gas recirculation
- Gas recirculation fraction is ~90%

Creation of F-radicals due to the $C_2H_2F_4$ breaking
- Electric field and radiation play a key role
- Not all of impurities can be absorbed by the cleaning agents

Intensive gas analysis campaign for the CMS RPC system during Run 2
- Gas analysers used: GC (for impurities) and ISE (for F^-)
- Several gas points have been analysed in the gas system
- Gas analysis also performed for different RPC wheels for the F^- production

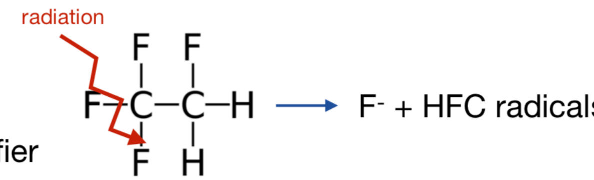
Clear correlation of F-radical creation with integrated luminosity and gas flow
- Impurities concentration and F^- production increase with integrated luminosity
- F^- production is lower with higher gas flow

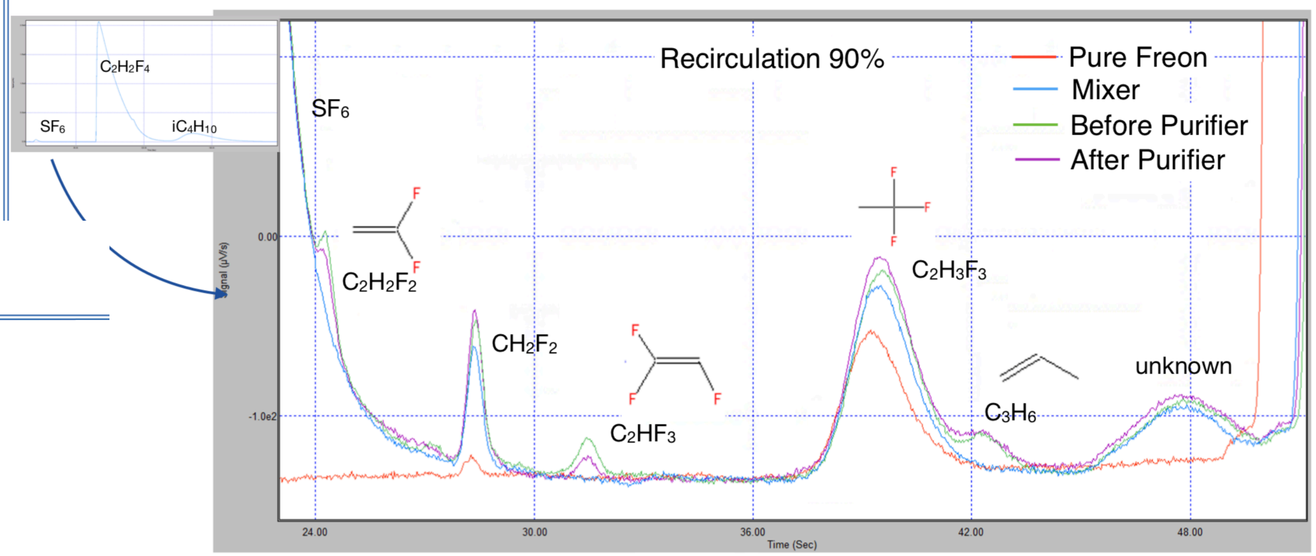
Studies on possible correlation between RPC $\boxed{\text{ohmic currents}}$ and F^- production
- The Ohmic current is influenced by the background and gas flow
- During LHC Run 3 the gas flow can be adjusted for each single RPC wheel to have less F^- production

Message from CMS: Ohmic current increase under high flux irradiation

GC analysis of the CMS RPC gas mixture

- Identification and quantification of impurities
  - Clearly created from $C_2H_2F_4$ breaking
  - Concentration is of the order of tens of ppm
  - Same impurities as seen in test at GIF
- Difference between "before" and "after" purifier
  - Purifiers help in eliminating impurities
- GC analyses every 2 weeks in RUN 2

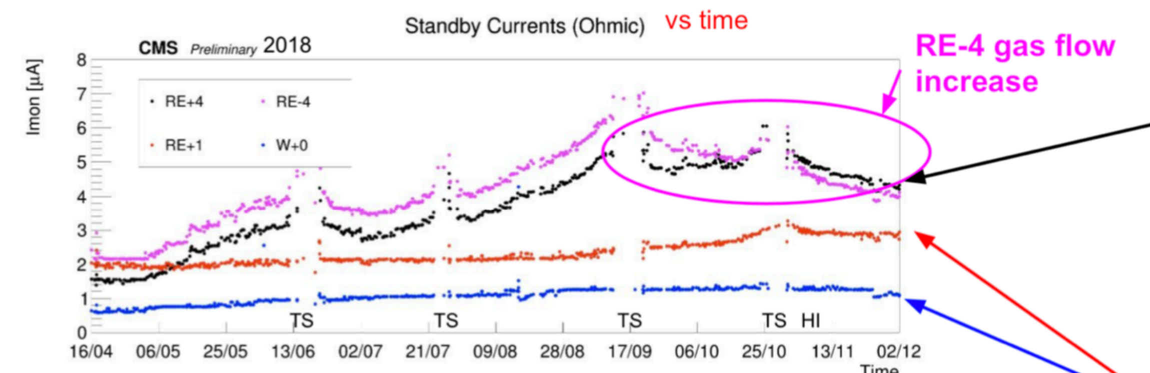


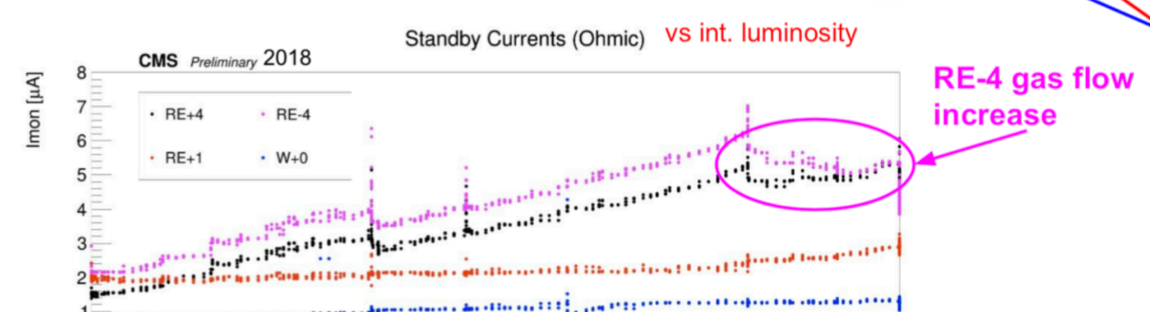


10 Feb 2020

RPC ohmic currents and gas flow

During LHC Run 2 the gas flow for RE-4 was
to verify any possible correlation between ohmic curr





A NEW GENERATION OF RPCS FOR NEXT GENERATION EXPERIMENTS

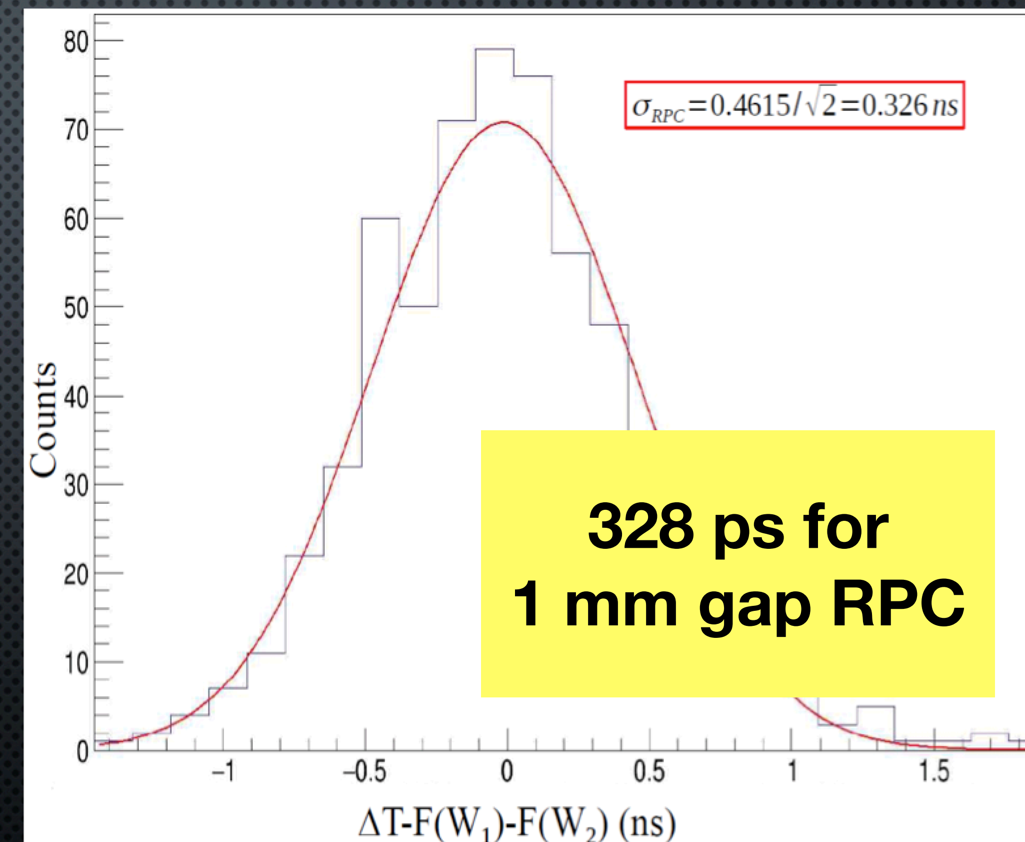
G. AIELLI

ROMA– FEBRUARY, 10 2020

XV WORKSHOP ON RESISTIVE PLATE CHAMBERS AND RELATED DETECTORS RPC2020

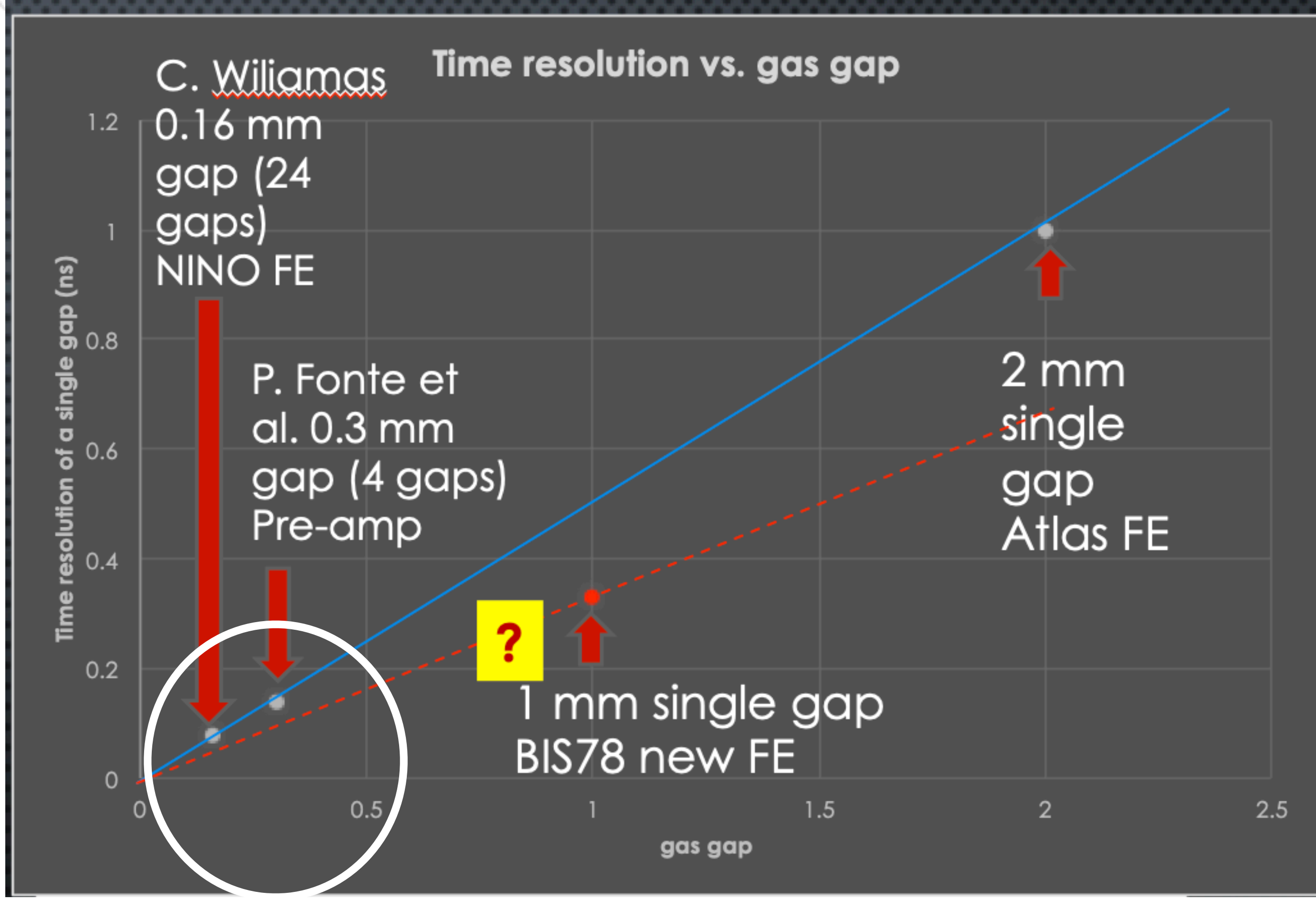
TIMING PERFORMANCE

Time resolution with time walk correction



328 ps for 1 mm gap RPC

Time resolution with time walk correction



$$\sigma_t = 1.28/(\alpha\text{-}\eta)v$$

W. Riegler, C. Lippmann and R. Veenhof NIMA 500(2003)144

This formula does not predict a linear relationship between gap size and resolution

Very difficult to measure time resolution below 50 ps

However this is an excellent result that needs to be independently verified

RPC 2020 – XV Workshop on Resistive Plate Chambers and Related Detectors

The FAIR Phase 0 program of the CBM Time-of-Flight project

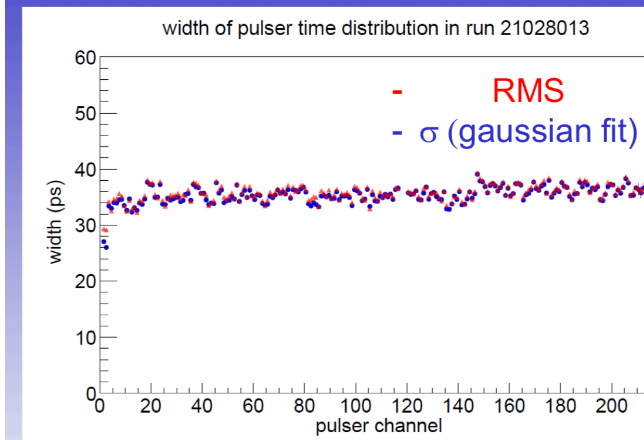
Ingo Deppner

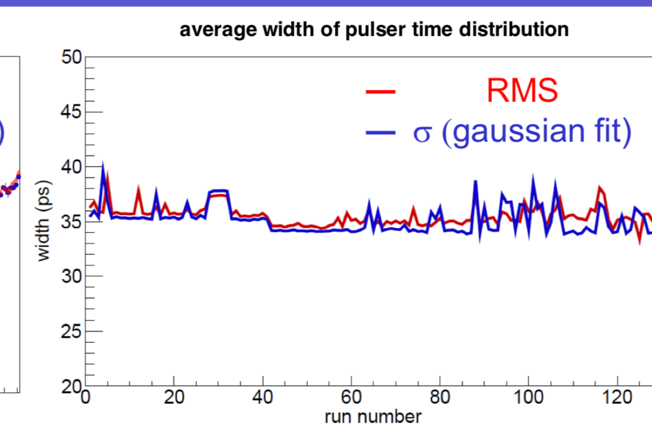
Physikalisches Institut der Uni. Heidelberg

Change from LHC to FAIR
Change from RPC to MRPC

System time resolution of the readout chain

CBM ToF





- In every first channel of all TDC cards (216) a pluser signal is injected when an trigger tocken from STAR is received
- The System time resolution of the readout chain is homogeneous for the full setup
- The System time resolution of the readout chain is in the order of 35 ps
- The stability of the system is demonstrated

Summary

- FAIR construction started
- CBM TOF ready for beam in 2024
- Preproduction for MRPC2 and MRPC3 finished
- CBM-TOF FAIR phase 0 projects in full swing
- Counter fulfill the specs
- eTOF system time resolution about 85 ps
- Matching efficiencies with TPC tracks in the order of 75%
- PID capability demonstrated

FAIR — Facility for Antiproton and Ion Research in Europe

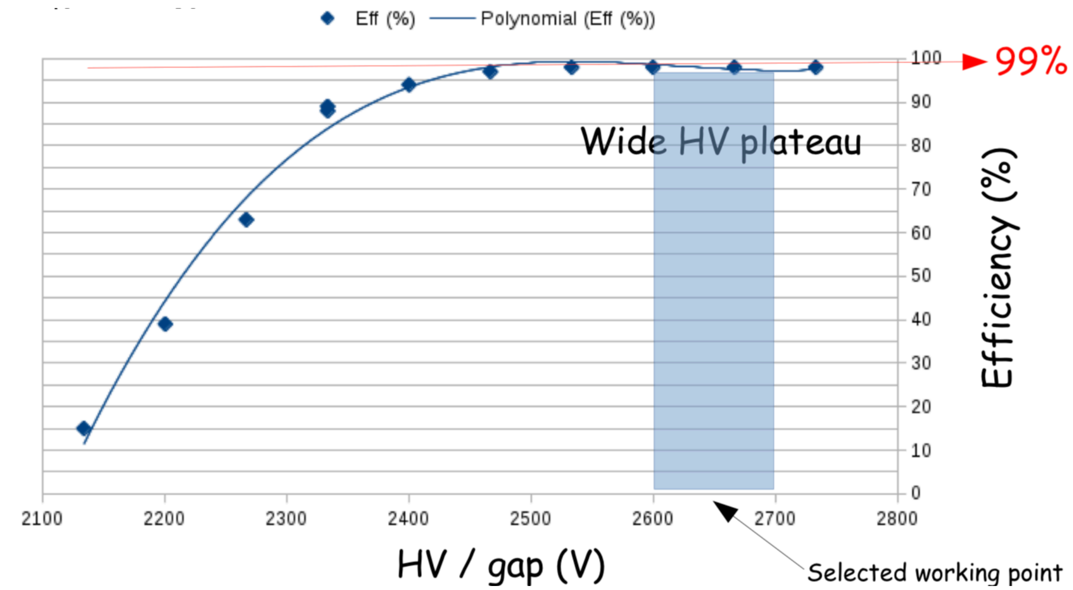
FAIR Phase 0 Research Program

Many critical aspects when precise timing needed for a large system such as fanout of clock to distributed TDC system

The SHiP timing detector based on MRPC

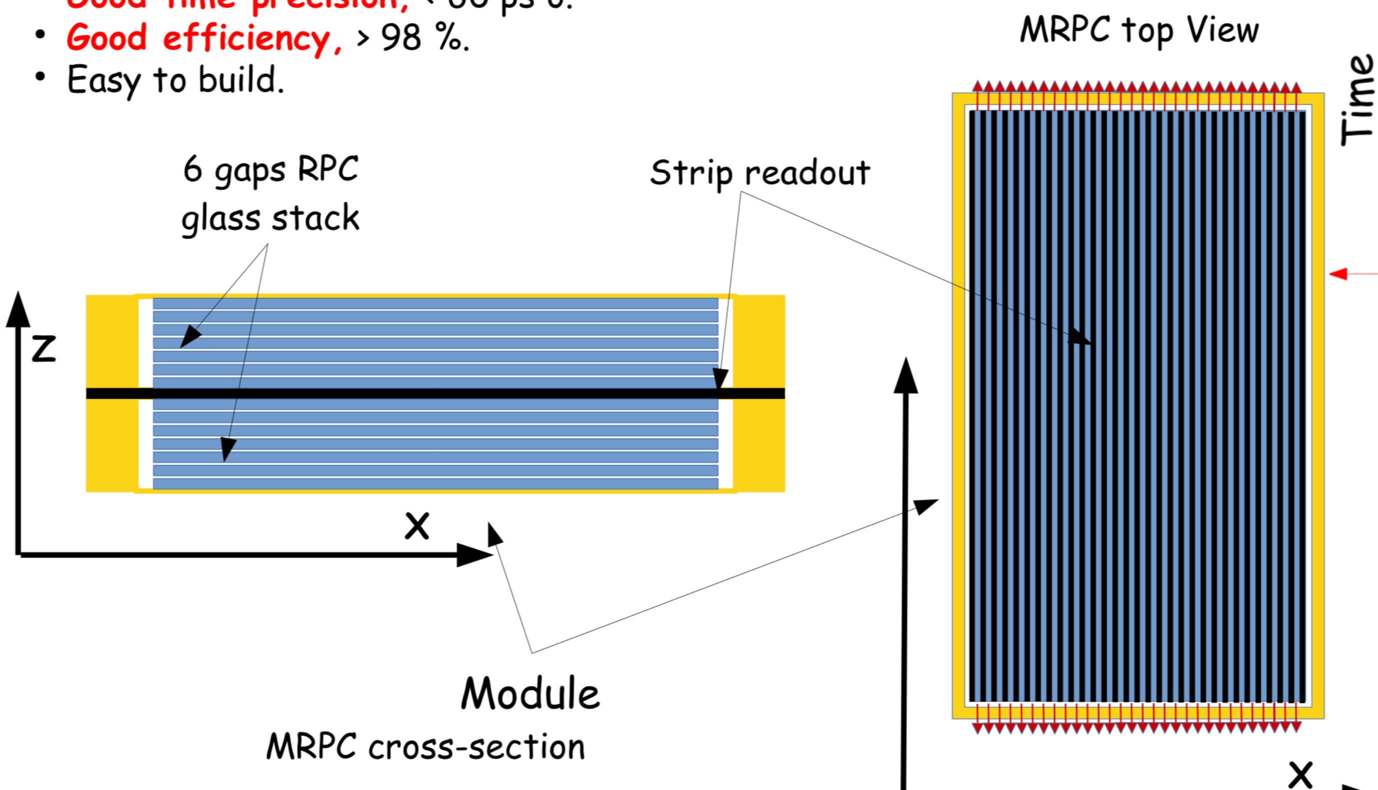
Alberto Blanco[1], Celso Franco[1], Custodio Loureiro[2], Filomena Clemencio[3], Guilherme Soares[1], João Saraiva[1], Luis Lopes[1], Nuno Leonardo[1], Paulo Fonte[1]

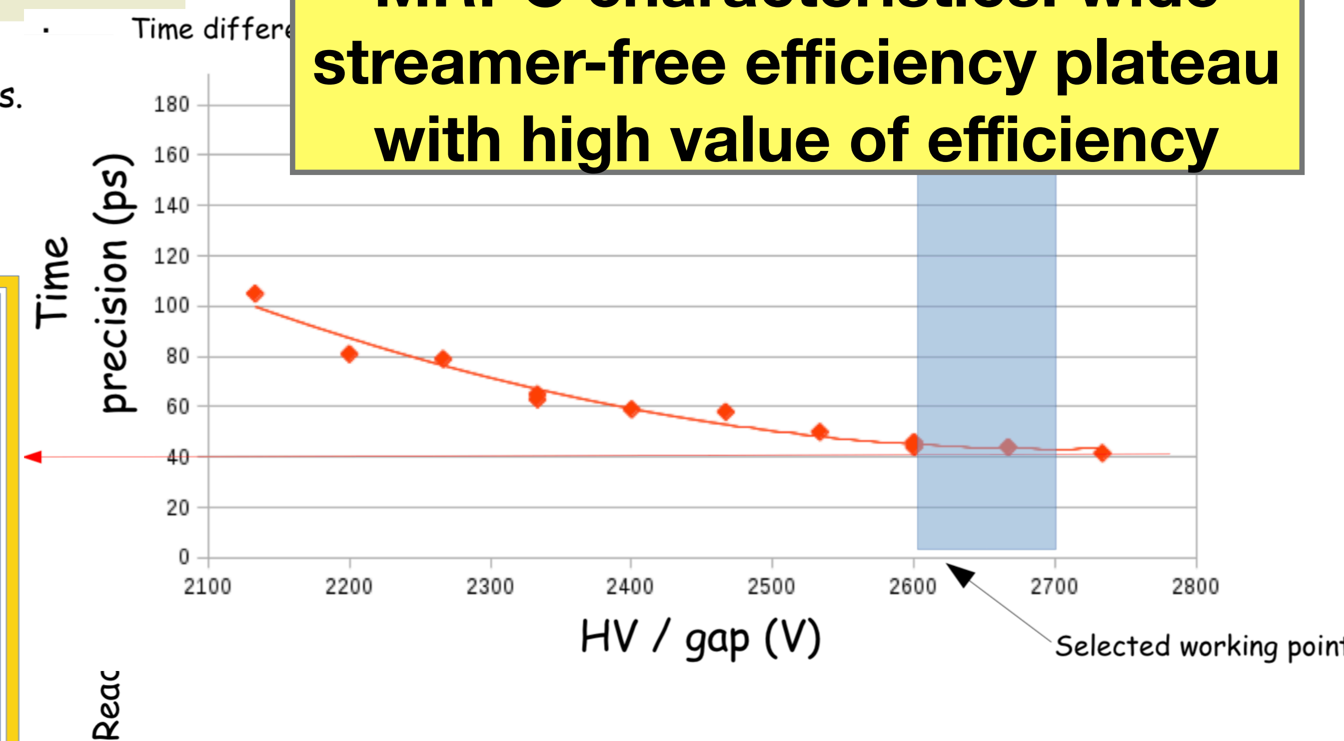
[1] LIP, Laboratório de Instrumentação e Física Experimental de Partículas
[2] LIBPhys, Departamento de Física, Universidade de Coimbra
[3] Escola Superior de Saúde do Politécnico do Porto



The TD implementation. Schematic drawing.

- Modules composed of two 6 (0.3 mm) gaps sealed glass stacks (SGS).
- Strips 37 mm width (placed in the middle of two SGS) readout in both sides.
- Active area of 1600x1200 mm² = 1,9 m².
- Good time precision, < 60 ps σ.
- Good efficiency, > 98 %.
- Easy to build.





It is good to be reminded of MRPC characteristics: wide streamer-free efficiency plateau with high value of efficiency

150 mm wide strips: and no degradation

Strips up to 150 mm width are possible without degradation.

Secondary Cosmic Ray detection with RPCs: a state-of-art review and possible applications in Space Weather studies

XV Workshop on Resistive Plate Chambers and Related Detectors RPC2020

Dennis Cazar Ramírez

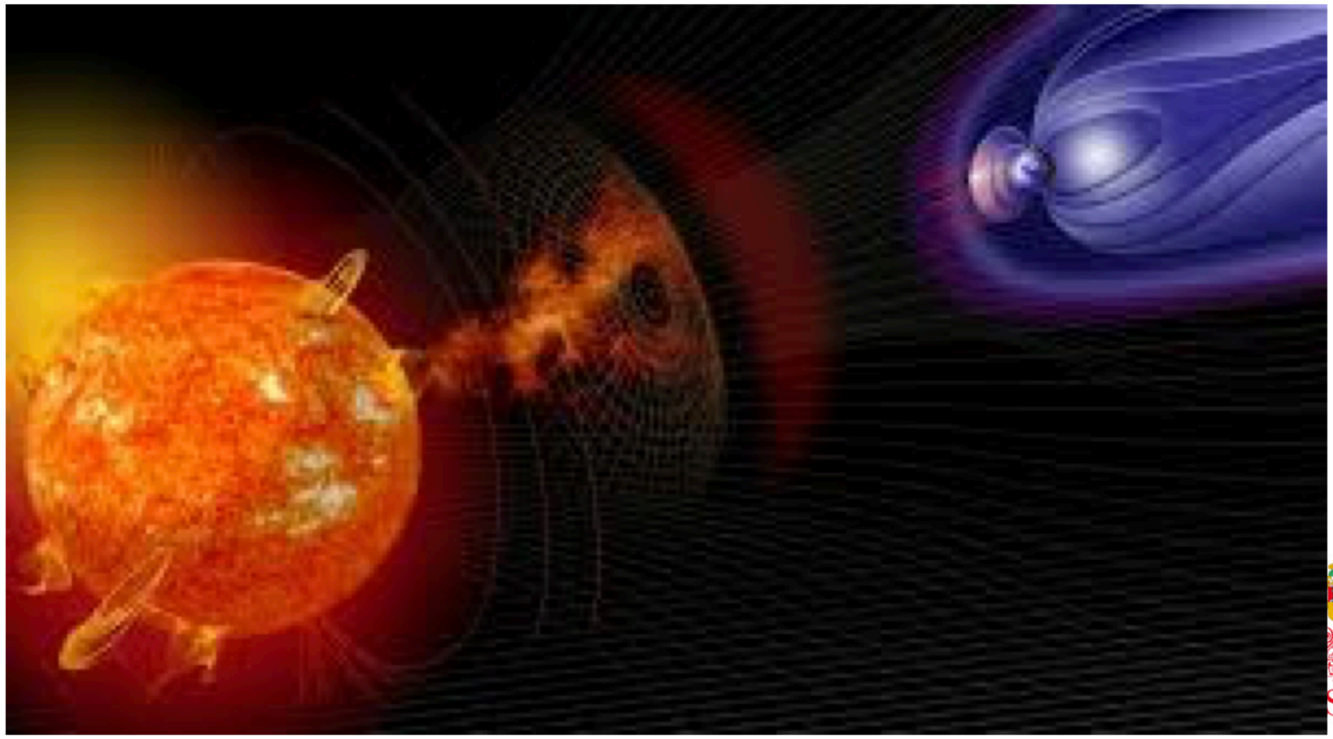
Colegio de Ciencias e Ingeniería
Universidad San Francisco de Quito
Quito - Ecuador
dcazar@usfq.edu.ec

February 10, 2020

Cosmic Ray Detection

Space Weather

- Through the detection of CR we can study the influence of the Sun, solar wind etc in our planet



Conclusions

- RPCs togheter with WCDwill create a hybrid CR detector
- Opportunities to develop low-cost RPCs detectors are open
- Latin America is gaining momentum in HEP
- Collaboration between Europe and Latin America can foster the growth of HEP comunity

Link with Italian EEE project

Exploring the Lifetime and Cosm Frontier with the MATHUSl Detector

Cristiano Alpigiani

on behalf of the MATHUSLA Collaboration

W

VERSITY of

➢ Dedicated detector sensitive to neutral long-lived particles that have lifetime up to the Big Bang Nucleosynthesis (BBN) limit (10^7 – 10^8 m) for the HL-LHC

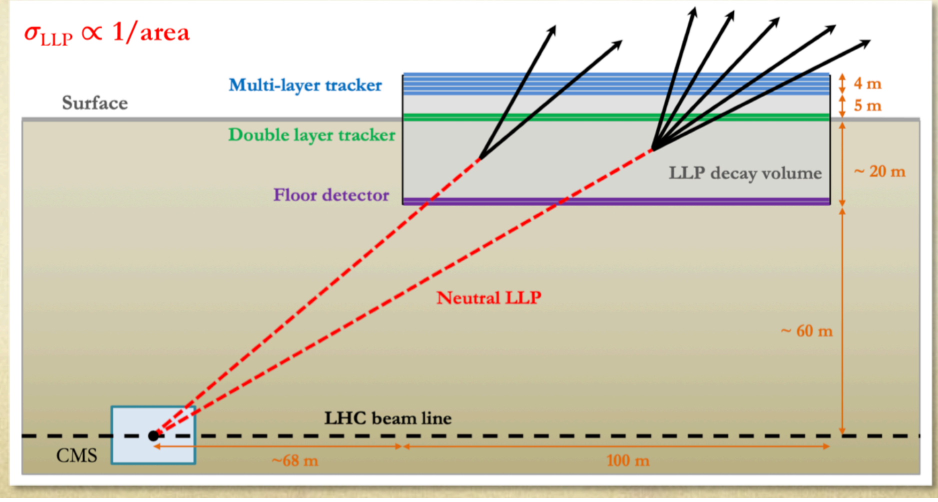
➢ Proposed a large area surface detector located above CMS

✓ Need robust tracking

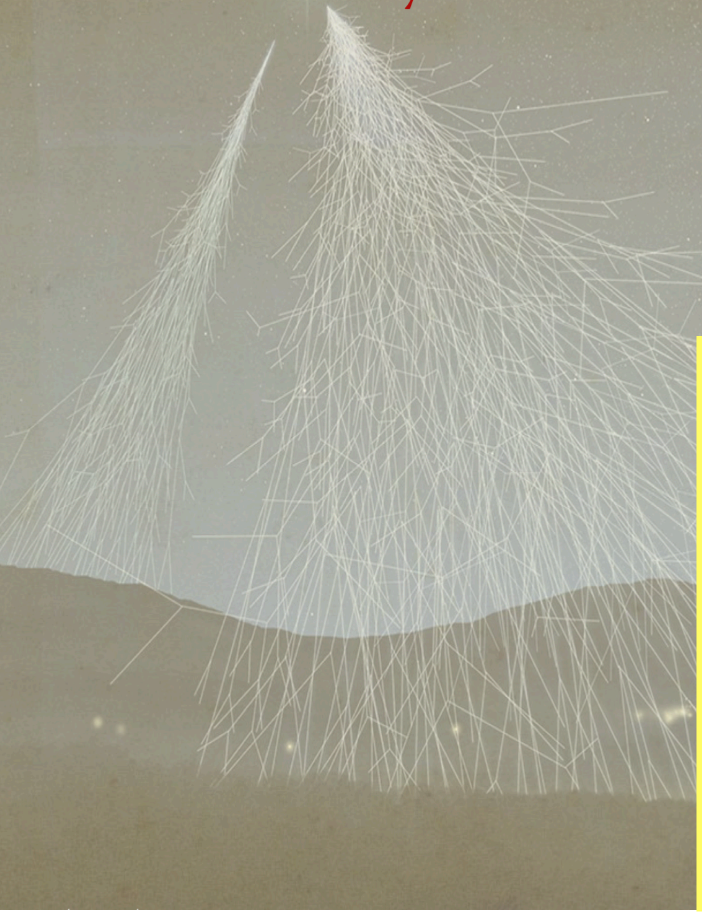
✓ Need excellent background rejection

✓ Need a floor detectors to reject interactions occurring near the surface

✓ Both RPCs and extruded scintillators + SiPMs are considered (good time/space resolut

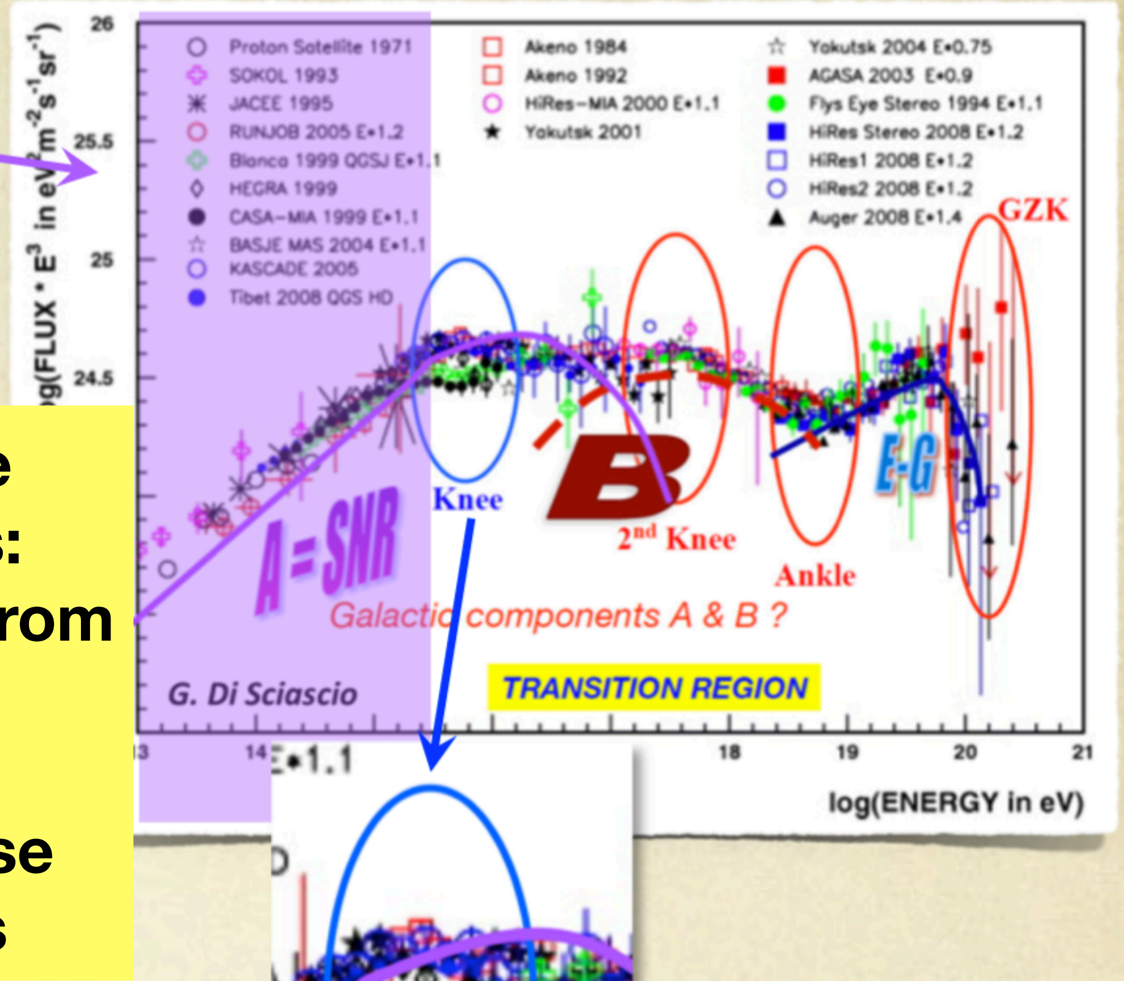


Cosmic Rays



Guaranteed return on the investment!

"Small" caveat...
I am not a CR expert! 😬



Clear interest with precise cosmic ray measurements: maybe also search for LLPs from LHC

But MATHUSLA wants to use scintillators and not RPCs

end of day 1

- CMS observe high ohmic current after high irradiation of RPCs
- ATLAS will reduce voltage (9.6 to 9.2 kV) on their RPCs to extend their life
- Very good time resolution of 1mm gap RPC (to be continued)
- CBM TOF - ultra high rate - need to take care of all details to get their expected time resolution
- SHIP MRPCs look impressive: **no degradation for very wide strips**

2D single-gap trigger RPCs for high-energy physics experiments

Kyong Sei Lee / Korea University

1. Motivation of R&D
2. Fundamental R&D on 2-mm single-gap RPCs for SHiP
3. 1-mm single-gap RPC: time resolution ~ 500 ps
4. 1.6-mm single-gap RPC: to lower the WP 9.6 kV -> 8.2 kV

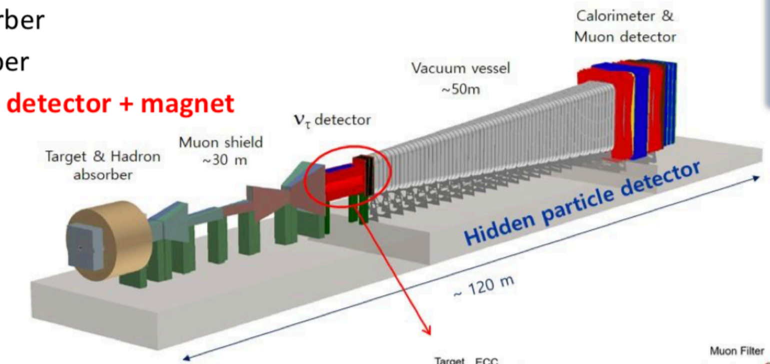
R&D target: SHiP tau neutrino RPCs

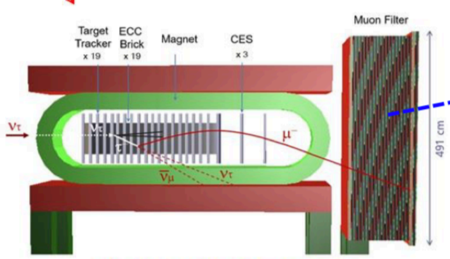
Better triggers for tau associated muons

Better VETO for neutrino associated muons impinging the decay vessel

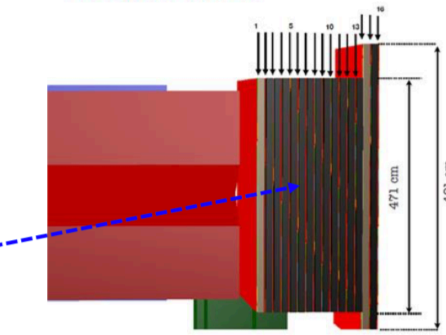
- SHiP detector system
- Target
- Hadron absorber
- Muon Absorber
- Tau neutrino detector + magnet

In RPC2020, "RPCs and readout system for the neutrino detector of the SHiP experiment" by Liliana Congedo
RPCs dedicated to Scattering Neutrino Detector (SND)





MUON FILTER



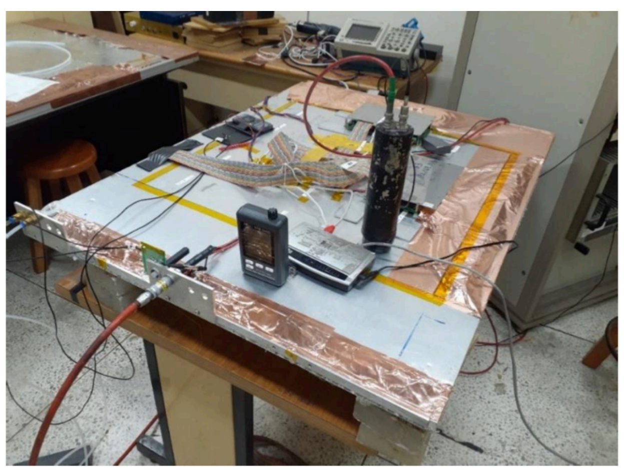
STRUCTURE
16 Rpc (3 cm) / 15 Fe layers (10 cm)
Frontal size:
(upstream: 13 RPC) 200 x 471 cm²
(downstream: 2 RPC) 210 x 491 cm²

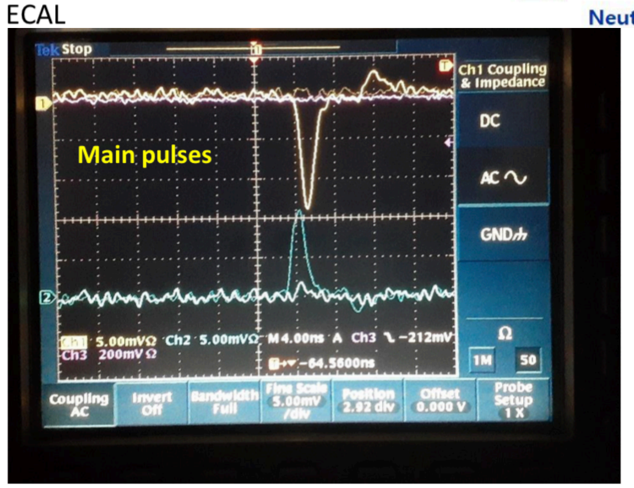
- Decay vacuum vessel
- Muon veto detectors
- Downstream detectors
  - ✓ ECAL

embers from 52 institutes, 17 countries
:1504.04956 (2015)

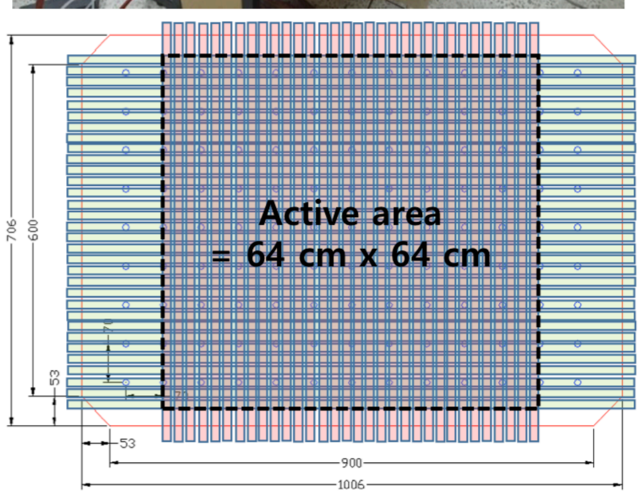
20, University of Rome "Tor Vergata" 3

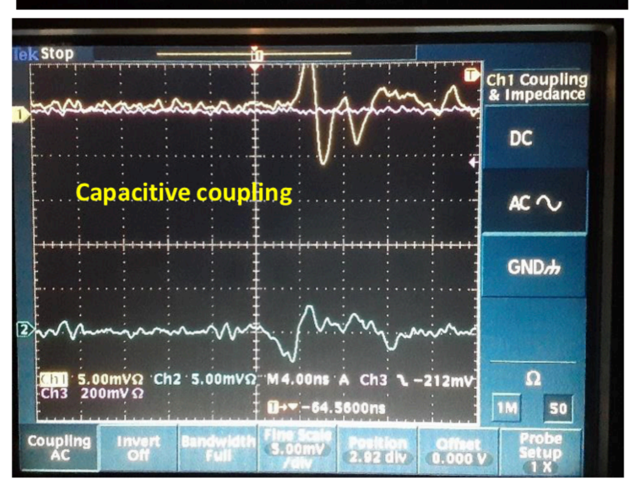
A small prototype using a 100 cm x 70 cm 1-mm single gap





64 cm x 64 cm active area using two orthogonal strips



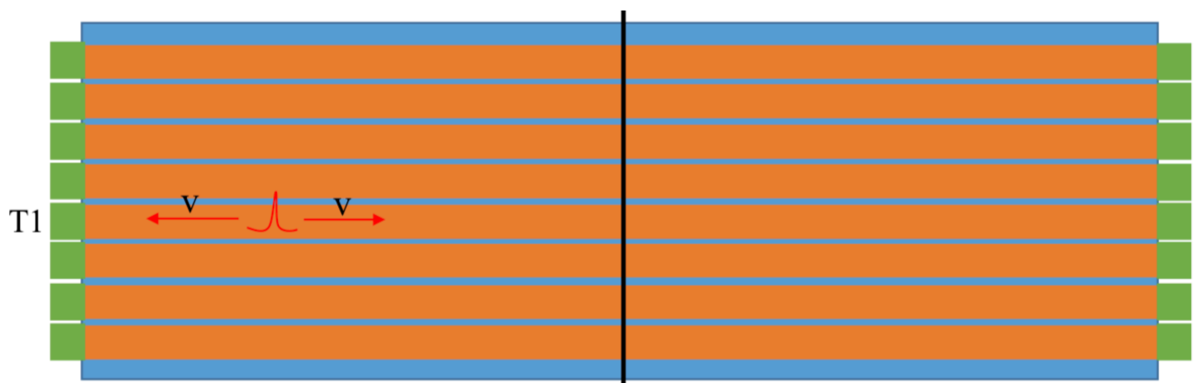


Noise introduced by crossed strop readout??

R&D on Double-end Readout RPC for ATLAS Phase-II Upgrade

Quanyin Li[1], Giulio Aielli[2], Yongjie Sun[1], Zhengguo Zhao[1]
[1] University of Science and Technology of China
[2] University of Rome “Tor Vergata”

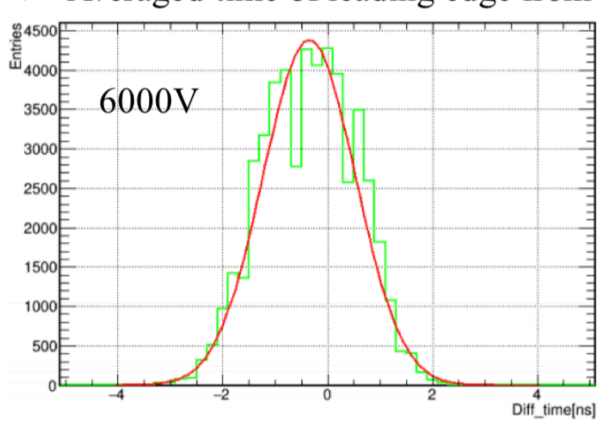
2020.02.11



Time Resolution(Double-ends improvement)

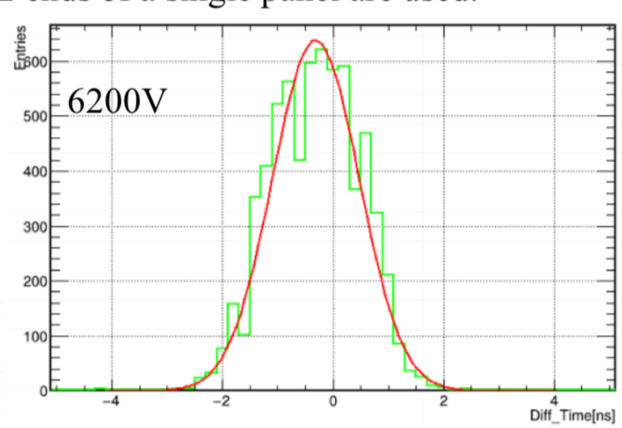
- According to the efficiency plateau, 6*rms is used..
- **Time of 0.5 of the peak value is used**.
- According to the transmission speed, the 2 panels are almost same.
- Averaged time of leading edge from 2 ends of a single panel are used.

Advantage: averaged time is not correlated with hit position.



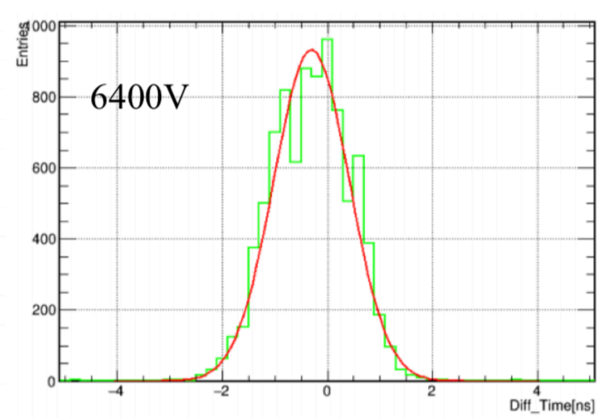
NO.	NAME	VALUE	ERROR
1	Constant	4.37827e+03	2.31562e+01
2	Mean	-3.53389e-01	4.04464e-03
3	Sigma	8.81388e-01	2.38050e-03

σ = 881/sqrt(2) cm = 623 ps



NO.	NAME	VALUE	ERROR
1	Constant	6.37540e+02	9.47195e+00
2	Mean	-3.13658e-01	1.00302e-02
3	Sigma	7.83283e-01	6.12206e-03

σ = 783/sqrt(2) cm = 554 ps

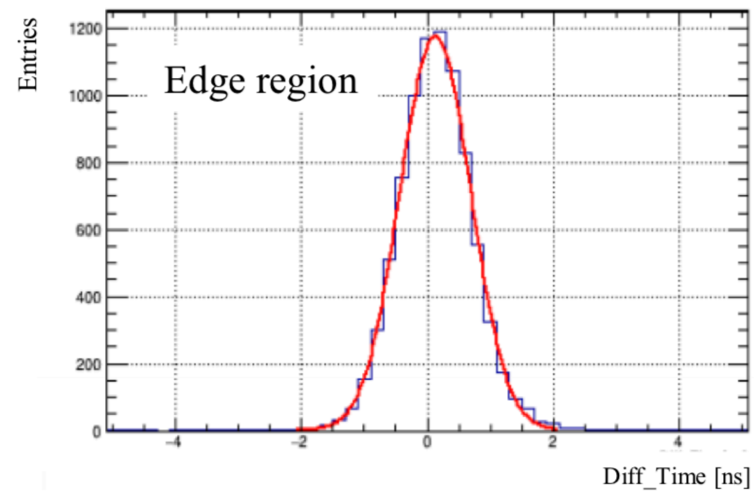


NO.	NAME	VALUE	ERROR
1	Constant	9.32715e+02	1.18528e+01
2	Mean	-3.04847e-01	7.84862e-03
3	Sigma	7.18182e-01	4.67391e-03

σ = 718/sqrt(2) cm = 507 ps

Time Resolution(Edge

- Test the performance at the edge region of detector.
- Time of leading edge(0.5 of peak) is used.



NO.	NAME	VALUE	ERROR
1	Constant	1.17638e+03	1.64398e+01
2	2 Mean	1.26428e-01	6.22083e-03
3	3 Sigma	5.65436e-01	4.92479e-03

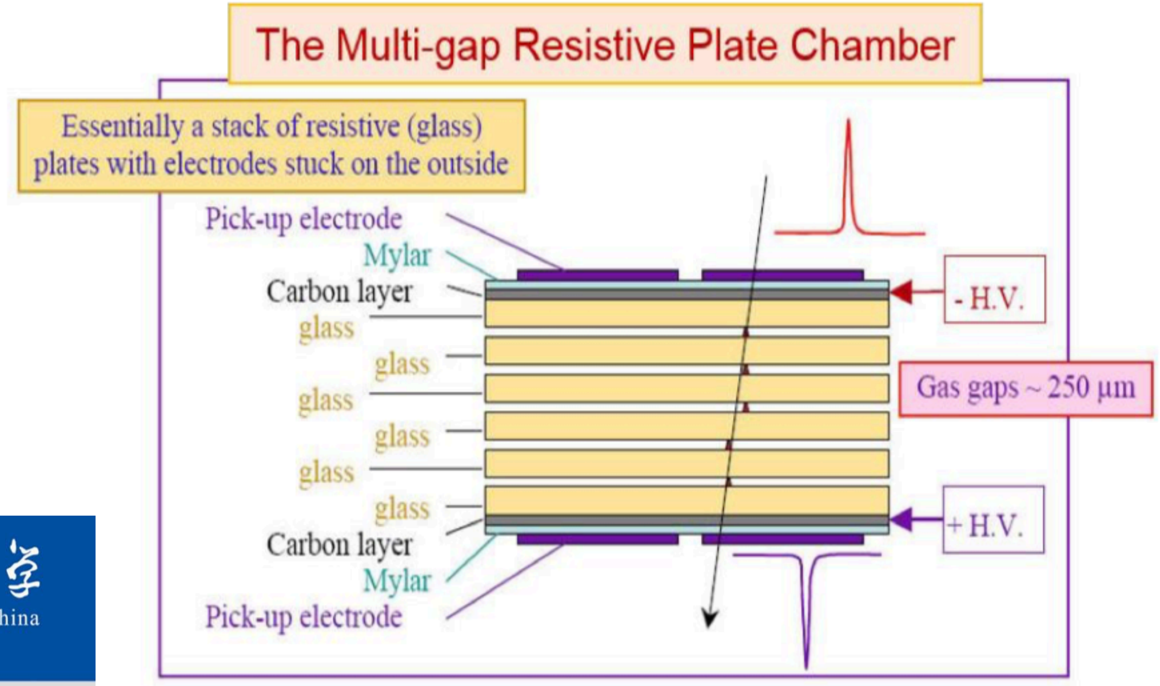
σ = 565/sqrt(2) cm = 399 ps

Impressive - why is edge zone better?

Approaching Giulio’s measurement

A new way to enhance rate capability of MRPC

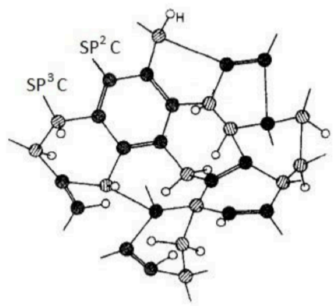
Xinjian Wang、 Yongjie Sun、Yi Zhou



DLC: Diamond Like Carbon

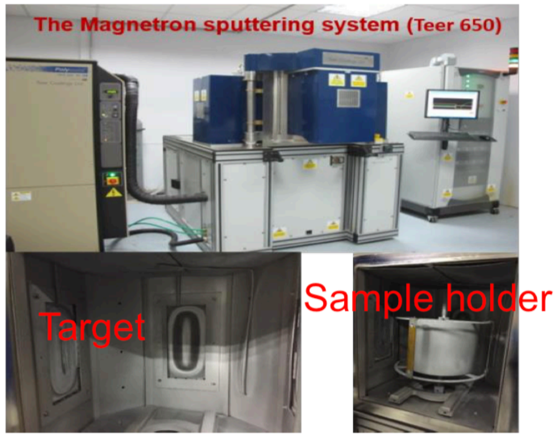
中国科学技术大学 University of Science and Technology of China

A kind of "Metastable amorphous carbon material which contains both diamond-structure and graphite-structure"

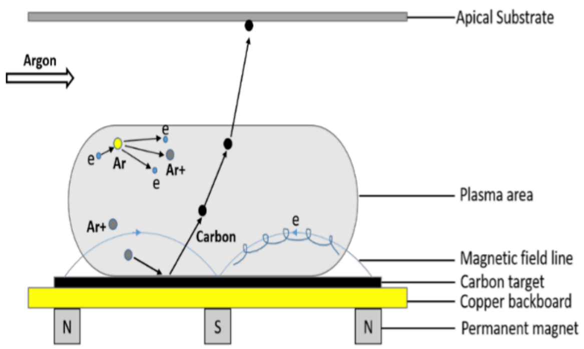


- Surface resistance stable and a
- Resistant to discharge and radia
- Chemical stability and thermal s

✓ Manufactured by Magnetron Sputte deposition



State Key Laboratory of Solid Lubrication, Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences



Schematic of Magnetron Sputtering dep

Summary

中国科学技术大学 University of Science and Technology of China

- ◆ Put forward a new way to enhance rate capability of MRPC by DLC coating in glass
- ◆ Made different kinds of MRPC prototype, test by cosmic ray
- ◆ Encountered two main problems : large leak current and low efficiency
- ◆ Found reasons and improving method
- ◆ Preliminary test by X-ray

Future work

- ☐ Strengthen adhesion between DLC coating and glass
- ☐ Test graphitic glass + DLC coating
- ☐ Rate capability research by beam test

Thank you!

Our group tried a similar idea - painted the glass surfaces: big difference between anode and cathode.

Also observed this 50% maximum of efficiency

RPC2020

The CEE-eTOF wall constructed with new sealed MRPC

Botan Wang, Dong Han, Yi Wang, Xiaolong Chen

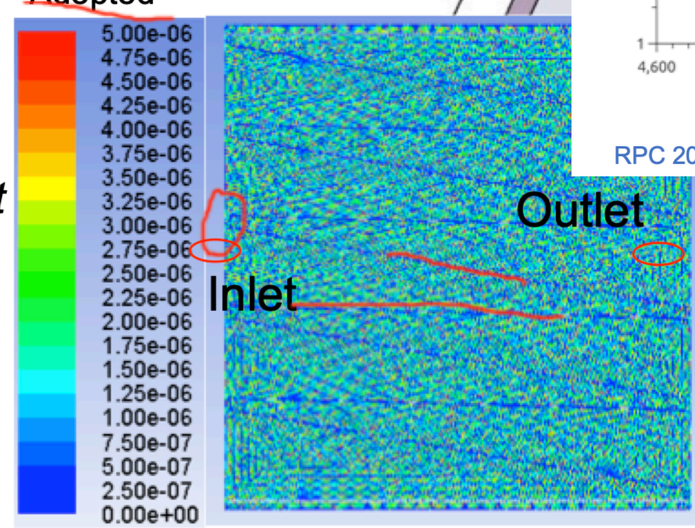
Key Laboratory of Particle and Radiation Imaging, Department of Engineering Physics, Tsinghua University, Beijing, China

Structural design of sealed MRPC

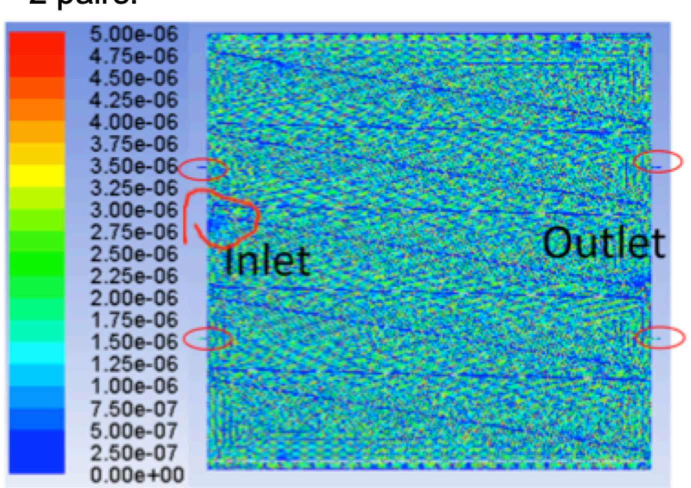
Gas flow uniformity

- Inlet/outlet placement
- 3D Flow field simulation by *ANSYS Fluent*
- Low velocity zone indicates pollutant concentration.

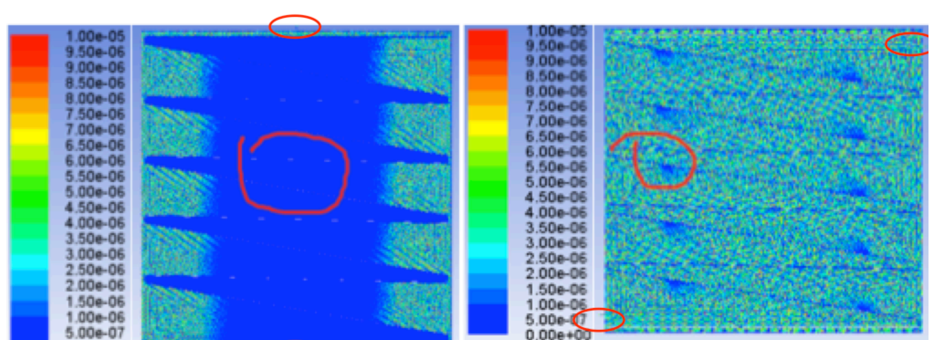
Adopted



2 pairs:



Gas flow: 3ml/min



Tubes at different position

Cosmic test results

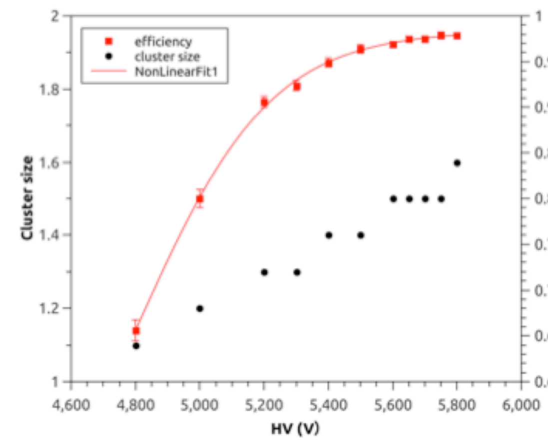
Standard gas flow 4 ml/min (minimum setting for mixer)

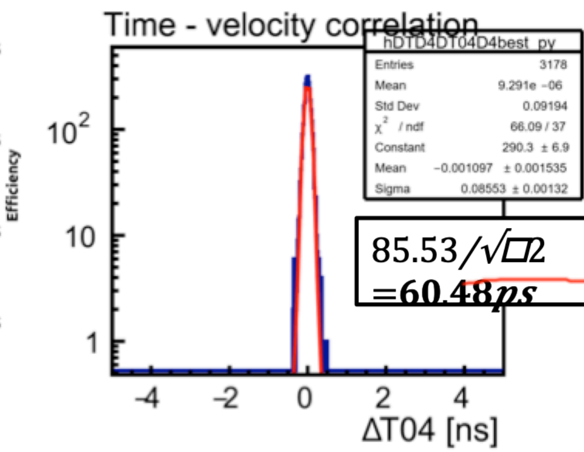
Freon/iC_4H_{10}/SF_6 90/5/5; Temp: 25˚C, dark current ~20nA

At working point 5600V(112kV/cm): Eff 97.5%, time resolution 85.5ps (time difference)

Reference MRPC3a, flow 50ml/min for gas box:

Working HV 5300V (106kV/cm), eff 97.9%, time resolution 83ps





Examine very low gas flow

In my opinion this is a very nice result

Performance and aging studies for the ALICE muon RPCs

ALICE MUON RPCs

Luca Quaglia[1] on behalf of the ALICE collaboration
And:
Roberto Guida[2], Beatrice Mandelli[2], Laura Alvigini[3]

[1]Università degli studi di Torino and INFN Torino

[2]CERN EP-DT-FS

[3]University of Pavia and IUSS

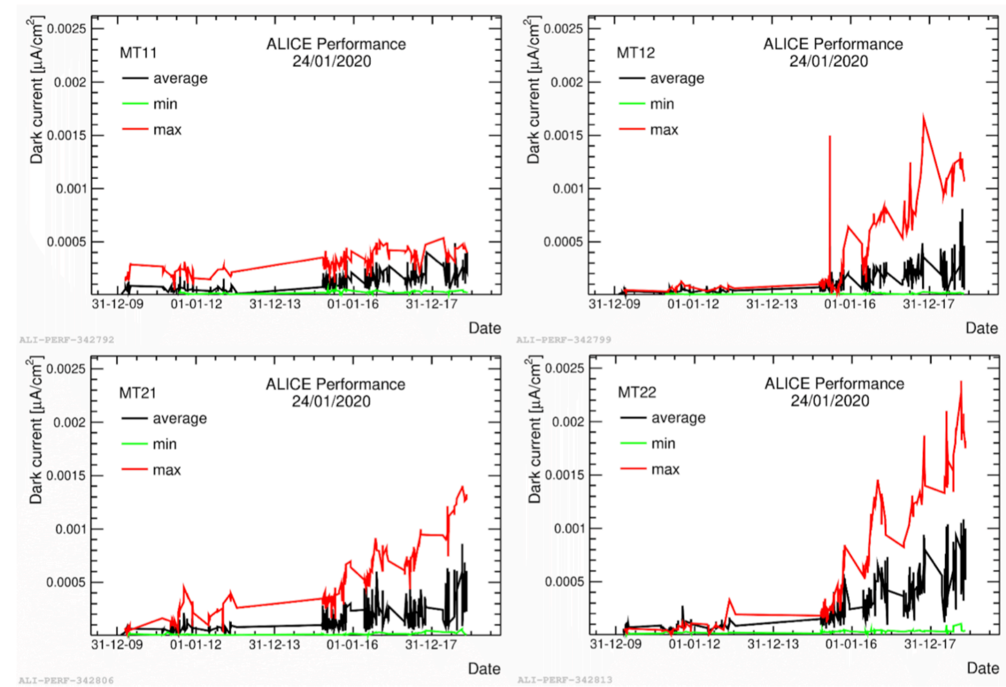
February 11, 2020

ALICE

INFN TORINO
Istituto Nazionale di Fisica Nucleare
Sezione di Torino

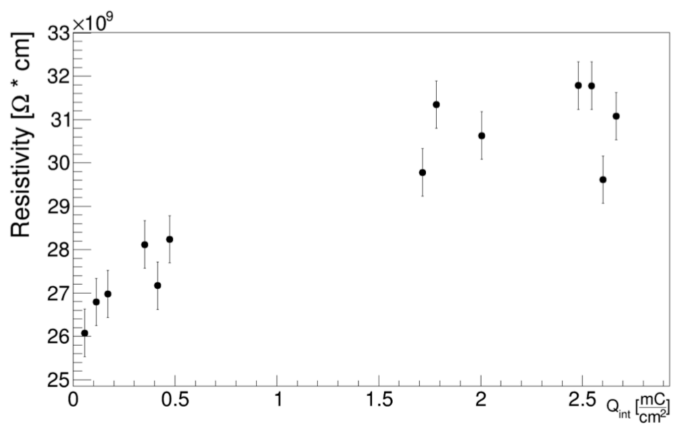
Dark current

- Dark current = the current absorbed by the detector when not irradiated
- Same color code as integrated charge
- Increase in the absorbed dark current over time
- Not accompanied by a loss of efficiency → causes are under investigation

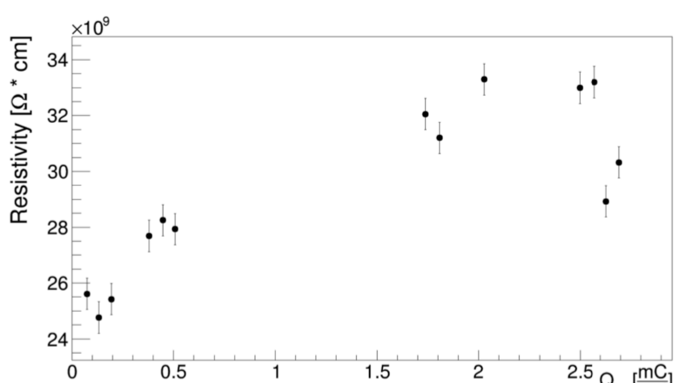


Increase of dark current with accumulated charge

Bulk resistivity trend



Resistivity trend for MT 22 IN 1



Resistivity trend for MT 22 IN 2

- Bulk resistivity increases as the integrated charge increases
- Probably due to a drying effect of the plasma on the bakelite

Factors that influence the timing properties and rate capability of Multigap Resistive Plate Chambers

Crispin Williams

Summary

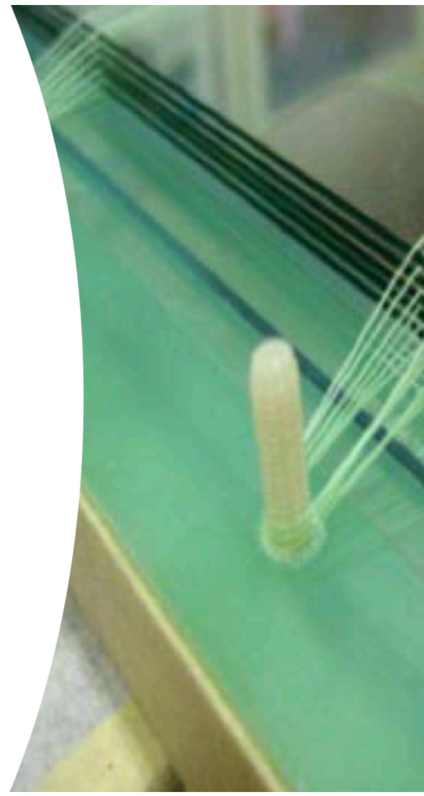
- Intrinsic jitter produced at the beginning of avalanche process:
  - reduced by working at high Townsend coefficient
  - Taking 'average' of many avalanches
- Other contributions to time jitter
  - Time slewing - finite rise time of electronics - however relatively easy to correct
  - Single-ended / Differential read-out front-end electronics important for time resolutions below 150 ps
  - Voltage drop on resistive plates - more R&D needed

Characteristics and performance of the Multigap Resistive Plate Chambers of the EEE experiment

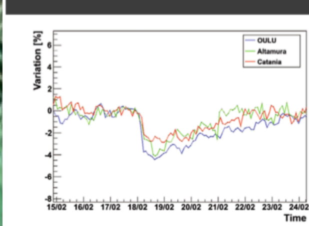
F. Coccetti for the EEE Collaboration

fabrizio.coccetti@centrofermi.it

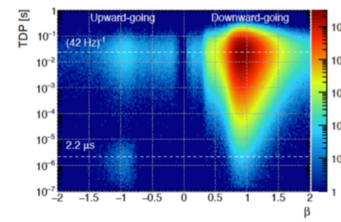
CENTRO FERMI — MUSEO STORICO DELLA FISICA E CENTRO STUDI E RICERCHE ENRICO FERMI



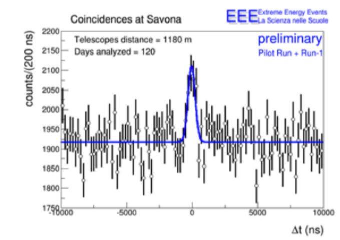
Scientific results



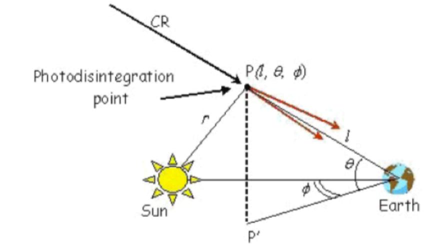
Forbush decrease



Upward going particles

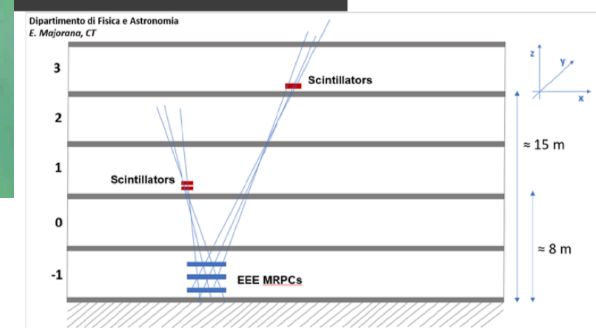


Detection of EAS

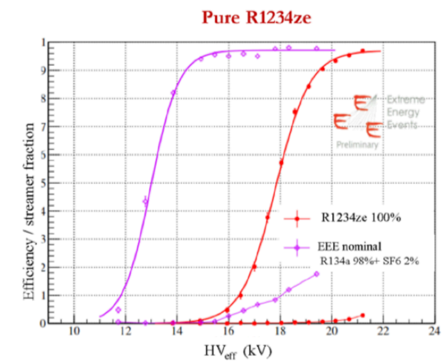


Long Distance Correlations (LDC)

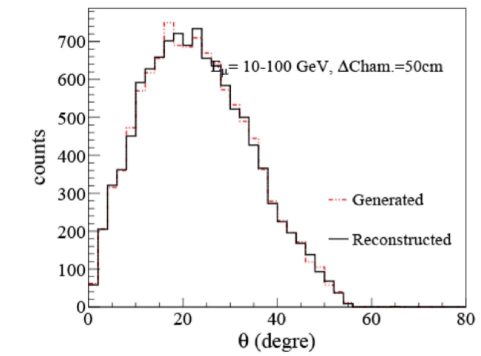
New studies



Chiara Pinto's talk on long time scale structure stability



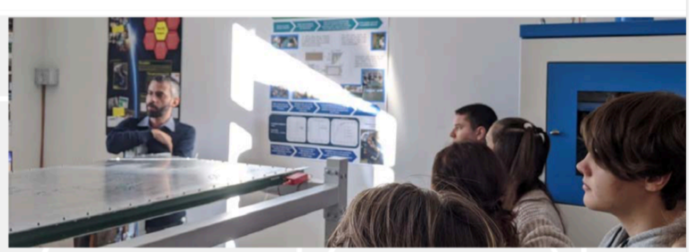
Maria Paola Panetta's talk on strategies to reduce the Global Warming Impact

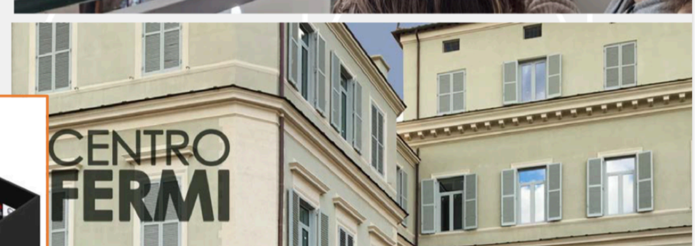


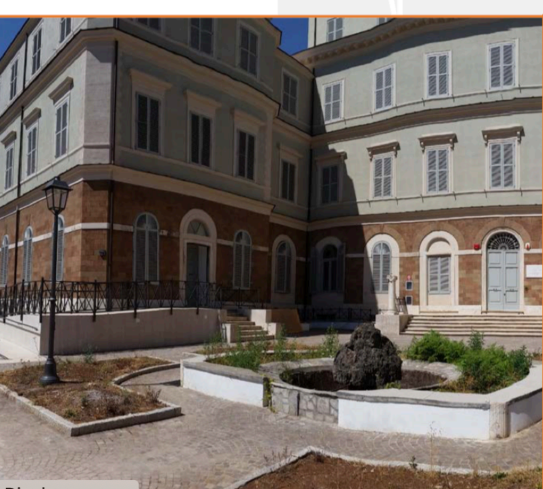
Giuseppe Mandaglio's talk on GEANT-GEMC simulation for EEE telescopes

Final summary

- ~ 180 MRPCs (1.6 m x 0.8 m) [59 sites] - **230 m²**
- ~ 15 years of data taking
- Performance in heterogeneous conditions







Display a menu

A school has a muon telescope - in coincidence with other schools: can do experiments locally - excellent to attract potential physics students.

Strategies to reduce the Global Warming Impact in the MRPC Array of the EEE Experiment

M. P. Panetta
for the EEE Collaboration

Extreme Energy Events
Science inside Schools

CENTRO FERMI
MUSEO STORICO DELLA FISICA E CENTRO STUDI E RICERCHE ENRICO FERMI

Our strategies to reduce this Global Warming Impact in the EEE MRPC array

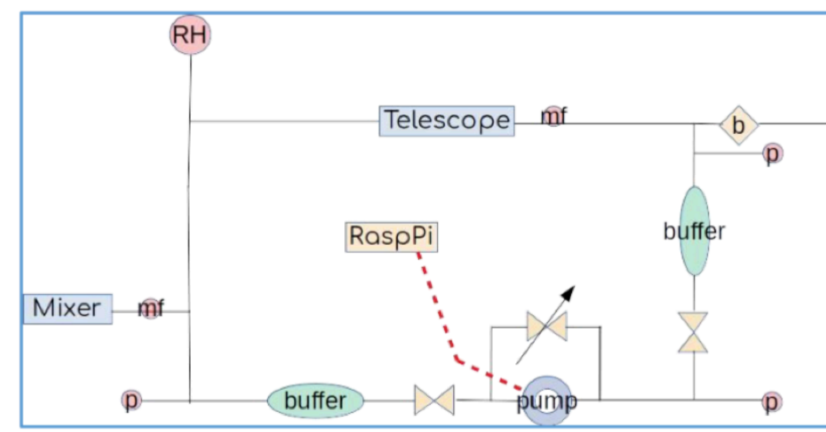
The EEE Collaboration has started 3 important actions

- Gas flow reduction — short-term
- Gas recirculation system — long-te
- New Eco-friendly gas mixtures

Gas Recirculation System

A recirculation system is installed and under study on a EEE Telescope at CERN

OUR GOAL:
A simple, small, easy-to-use system to be eventually installed in each EEE Station, to be monitored by school teams



Updates on Gas Studies:
New mixture test are ongoing using Ar/CO_2 : 93/7, 95/5, 90/10, 80/20.

- Promising : Largely used on MPGD
- very high charge

(cheap 30 euro/m^3)

Very good program to fix leaks in the chambers - chambers built without O rings

I believe that strongly electronegative gas is needed

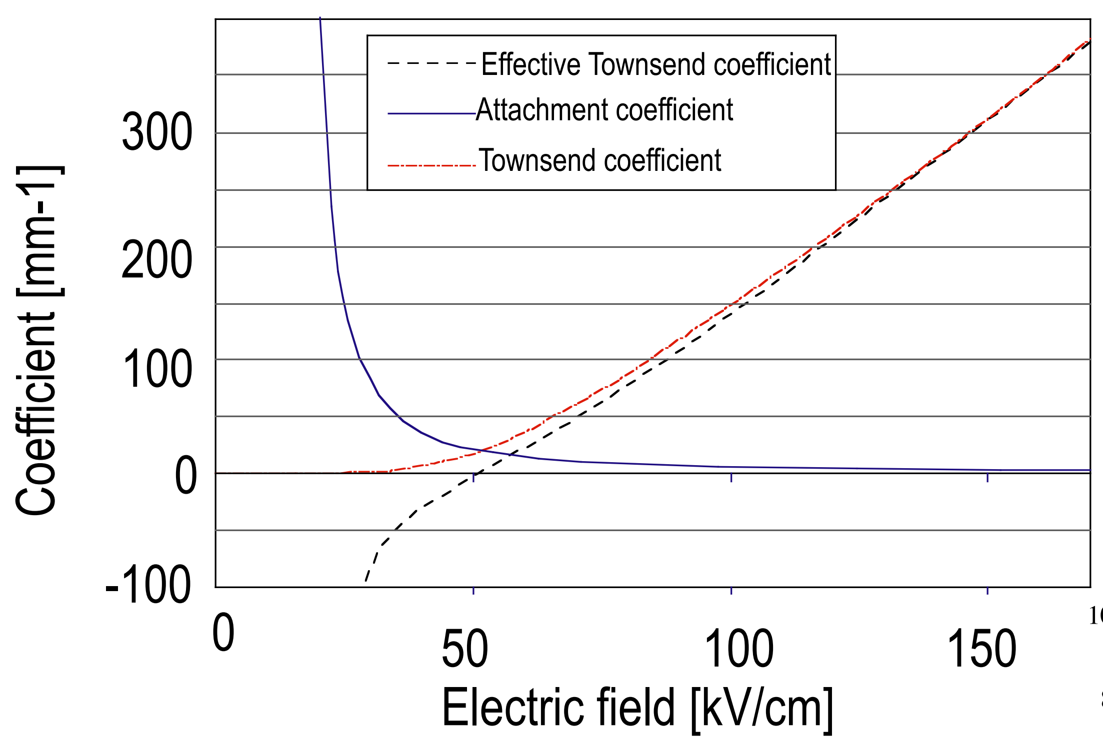
Avalanche in narrow gap where space charge effects are important

Primary ionisation: electrons accelerated towards anode ionising the gas $Ne^{\alpha x}$

if number of electrons exceeds some limit (10^6 - 10^7) space charge severely reduces field for electrons at ‘head’ of avalanche: reduces α and increases attachment coefficient η: electrons → negative ions : avalanche stops growing but there is a signal as electrons move to anode

Operation of MRPC not dependant on gap size

Magboltz output for 90% $C_2F_4H_2$ 5% SF_6 5% $i\text{-}C_4H_{10}$



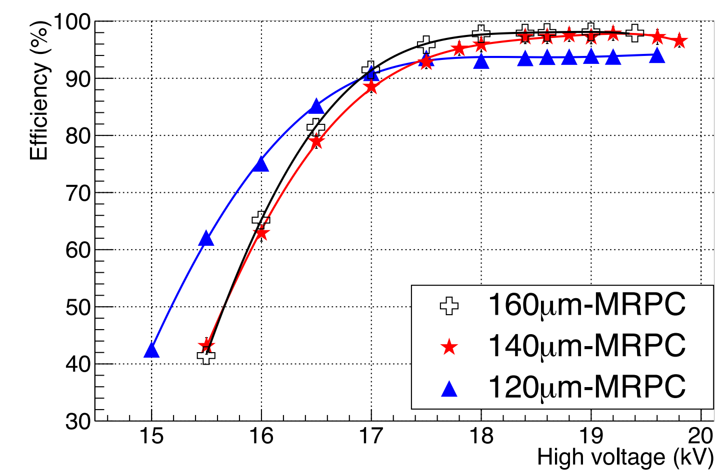
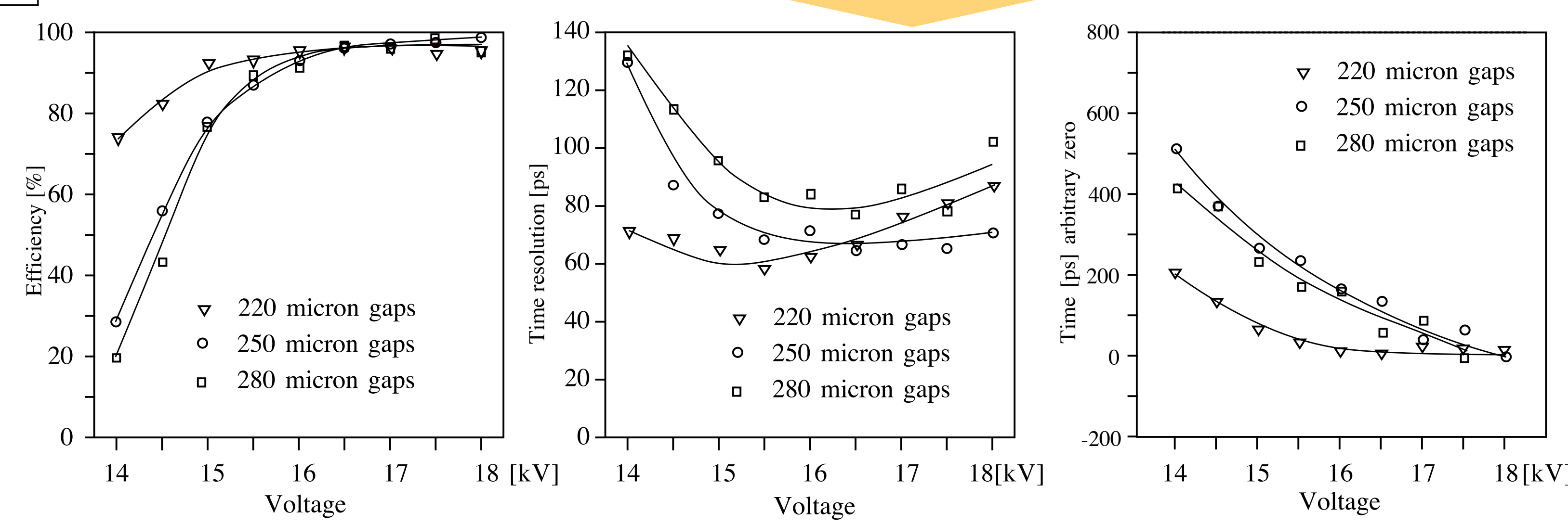


Fig. 6. The efficiency of the three MRPCs as
The lines are to guide the eye.

Recent R&D

ALICE TOF R&D



I am not sure Ar/CO^2 gas has the correct properties for MRPC

RPC 2020
ROME

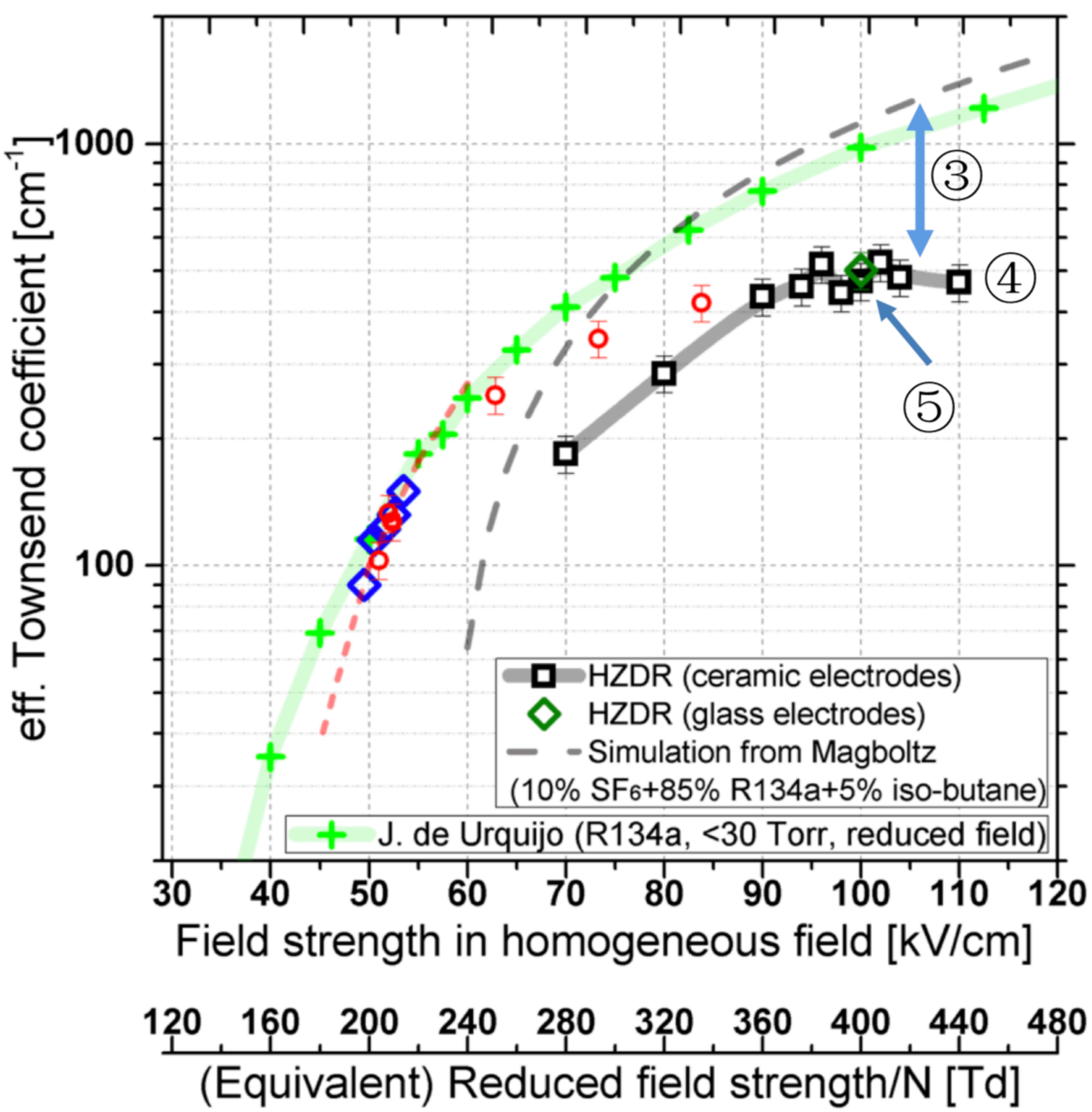
XV Workshop
Resistive Pla
and Related

HELMHOLTZ ZENTRUM
DRESDEN ROSSENDORF

Precise investigations of gas parameters in timing RPC with laser test facility

X. Fan
L. Naumann

Measurement of α_{eff}



Compared to measurement results from:

- [1] W. Riegler, et al., NIMA. A 500 (2003) 144.
- [2] G. Chiodini et al., NIMA. 602 (2009) 757.
- [3] J. de Urquijo et al., Eur. Phys. J. D 51 (2009) 241.

③ α_{eff} measured for timing RPC field (around 100 kV/cm) is ~2 times less than prediction from reduced pressure.

④ α_{eff} seem to reach a plateau for timing RPC field (around 100 kV/cm).

⑤ α_{eff} is not affected by electrode material.

Space charge effects ??

Discussions with Lothar indicate that space charge is unlikely

Personally I believe that we need more of these measurements

The ALICE Muon IDentifier (MID)

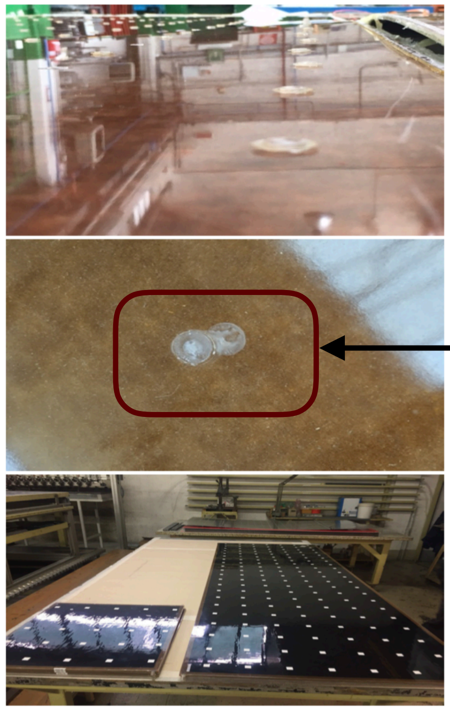
Livia Terlizzi on behalf of the ALICE collaboration

University and INFN Torino
XV Workshop on Resistive Plate Chambers and Related Detectors - RPC2020

February 11, 2020

Status of the RPC production (2)

- One of these chambers was opened, and it was observed that there were **glueing problems** with the spacers (the glueing procedure was automated before Run 1 while it is now done manually)
  $\rightarrow$ general carelessness in the previous production process
- **Several iterations with the firm (General Tecnica)** to try and solve the problem
  $\rightarrow$ gluing tests in October 2019: **successful**
- New pre-production batch of 3 detectors in mid-December 2019
  $\rightarrow$ **if the tests are successful full production will be relaunched**
  $\rightarrow$ these 3 RPCs are currently being tested



Problem with the bakelite production

THE TRISTAN DETECTOR
2018-2019 LATITUDE SURVEY OF COSMIC RAYS

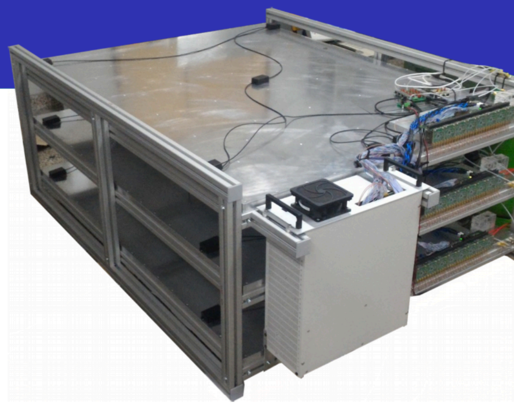
J.P. Saraiva[1], A. Blanco[1], J.A. Garzón[2],
D. García-Castro[2], L. Lopes[1], V. Villasante-Marcos[3]

LIP, Laboratory of Instrumentation
& Experimental Particle Physics

LIP – RPC Group

joao.saraiva@coimbra.lip.pt

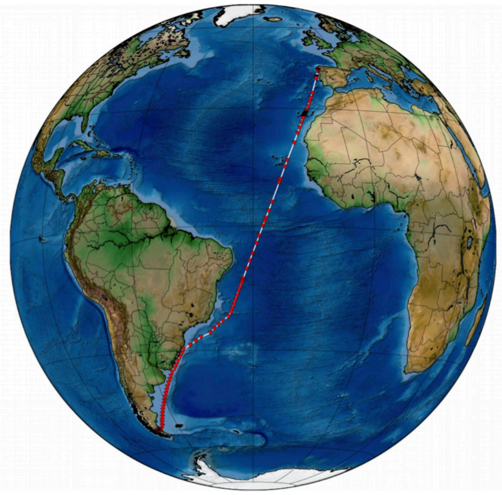
TRISTAN Detector



3 RPC planes to study Secondary Cosmic Rays

Designed to be part of the **ORCA Observatory**[1]
in the Livingston Island[2]

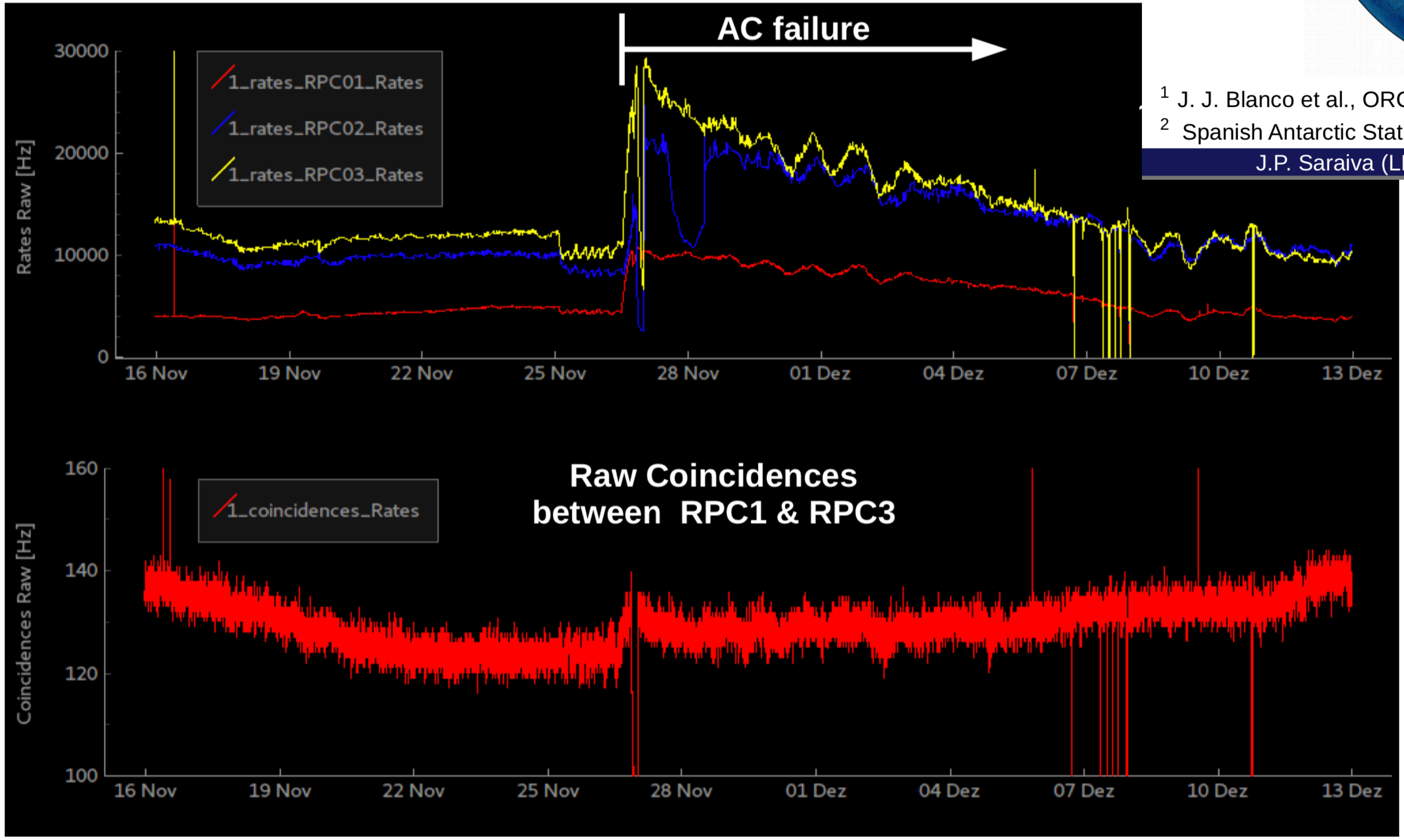
Before installation in the Antarctic base, the detector made a **Latitude Survey** from Vigo (Spain) to Punta Arenas (Chile)



[1] J. J. Blanco et al., ORCA (Antarctic Cosmic Ray Observatory): 2018 latitudinal survey, ICRC 2019

[2] Spanish Antarctic Station “Juan Carlos I” in the Livingston Island - Antarctica

Background Rates & Raw Coincidences



Rather extreme conditions - but it is good to see RPCs operating well

RPCs used for MuonTomography have more extreme concerns for power/gas etc

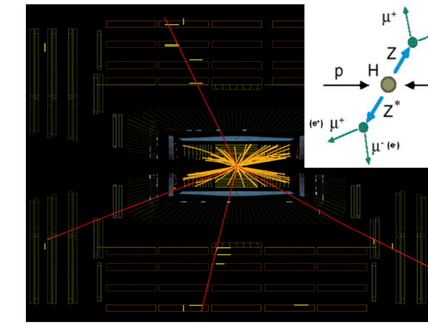
RPC System in the CMS Level-1 Muon Trigger

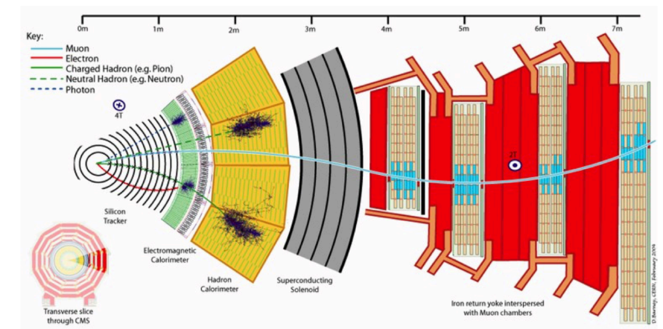
Brieuc François[1] on behalf of the CMS collaboration

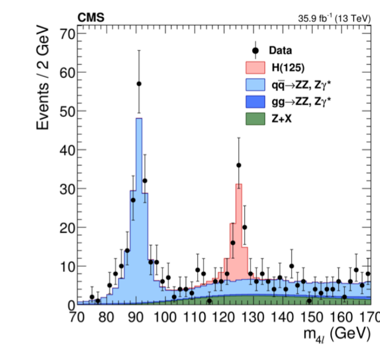
RPC2020, Roma

Muons in Trigger

- Many interesting processes involve muons
  - Higgs, SM Physics, BSM (e.g. 2HDM, HSCP), …
- Muons have a clean experimental signature
  - Suitable candidate for triggering purposes!
- About ¾ of data analyses in CMS rely on muon(s)!



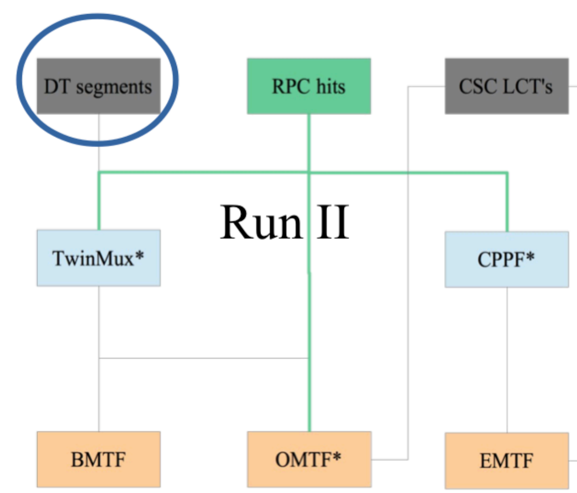




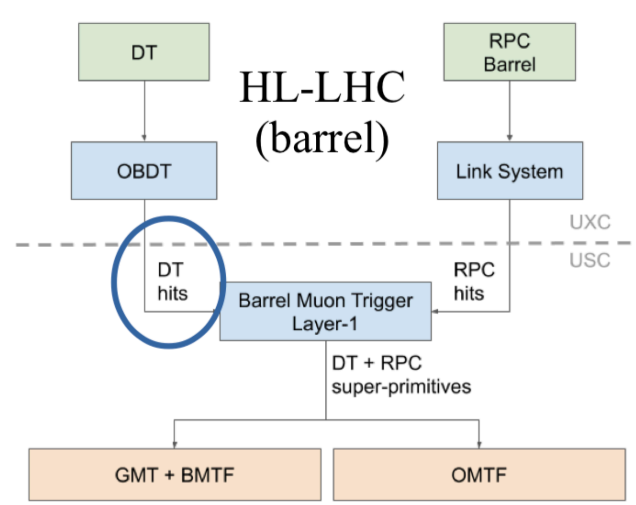
Phase II Level-1 Trigger

Key aspects of the L1Trigger Upgrade

- 100 → 750 kHz **rate** to HLT
- 3.6 → 12.5 µs **latency**
- Refactored architecture
  - Merging sub-detectors information even earlier (DT and RPC **hits** available in the same boards)
- Increased **bandwidth**
- Availability of tracking information



* Module with RPC hit clustering and cluster selection



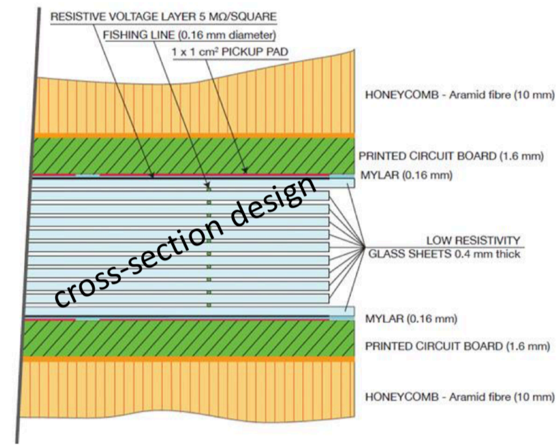
Impressive increase in trigger capability to take care of higher luminosity

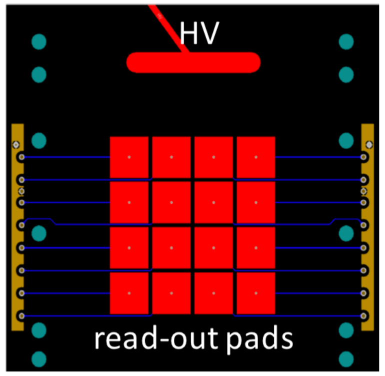
A bit outside my expertise but a well presented talk

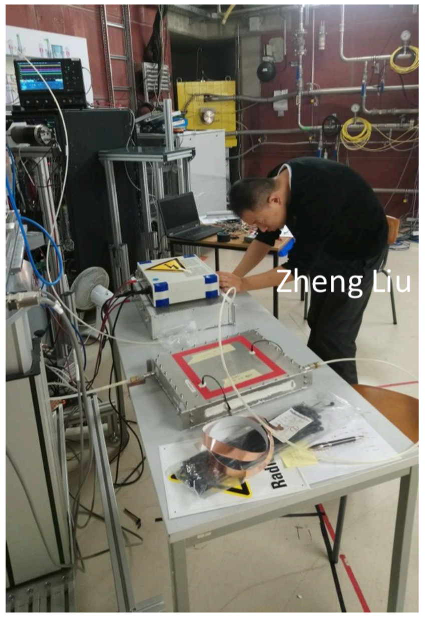
First high rate test of a MRPC detector with novel low resistivity float-glass electrodes

CERN · DTS · DRESDEN concept · HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Detector test: MRPC construction







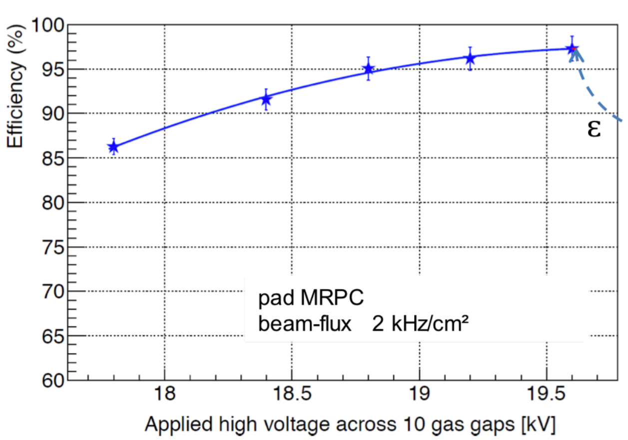
MRPC:

Gas-gaps:	10 per 160 μm
Floating electrodes:	9 per 400 μm
Read-out pads:	2x (4x4) per 1x1 cm²
HV-electrode area:	5x6 cm²
Gas-mixture:	C2H2F4(95%), SF6 (5%)
Gas-flow:	30 ml/min

Fantastic rate capability :
increase in resistivity is a new challenge!
Flip HV every so often

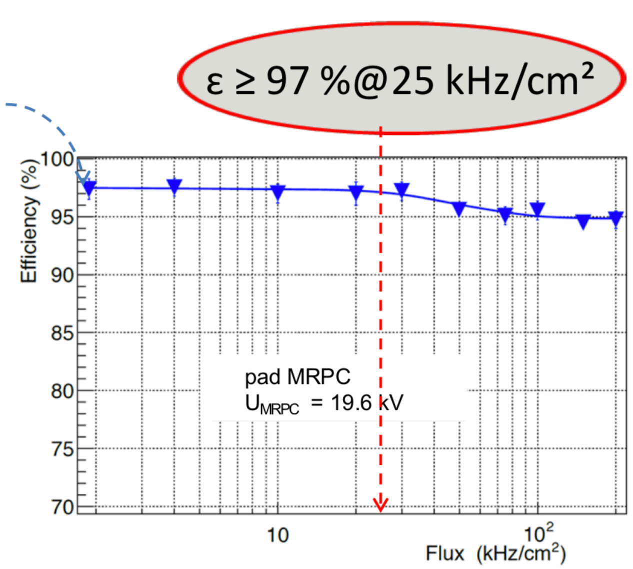
Detector test: MRPC working characteristc and rate capability

Efficiency vs. HV

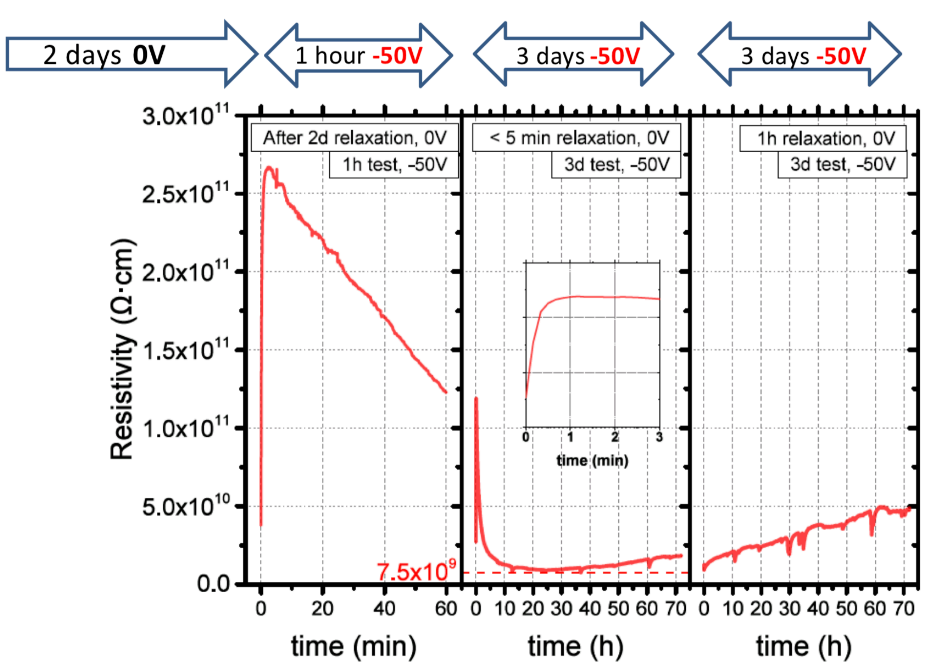


Efficiency vs. flux

ε ≥ 97 %@25 kHz/cm²



with opposite polarization



gain ≤ 10

Linearity and rate capability measurements of RPC with semi-insulating crystalline electrodes operating in avalanche mode

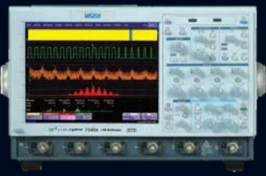
A. Rocchi, R. Cardarelli, B. Liberti, on behalf of the ATLAS RPC Tor Vergata group

XV WORKSHOP ON RESISTIVE PLATE CHAMBERS AI
DETECTORS RPC2020
(UNIVERSITY OF ROME "TOR VERGATA" , 10 - 14 FEBRUARY 202

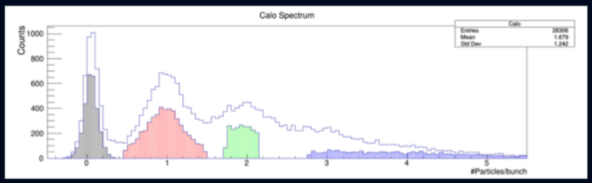
Linearity response
(Experimental setup at BTF LNF)

Beam energy	250 MeV
Bunch lenght	10 ns (microbunched 0,35 ns)
LINAC repetition rate	40 Hz
Beam spot size	σ_x~2 mm; σ_y~1 mm
Beam particles	e^-

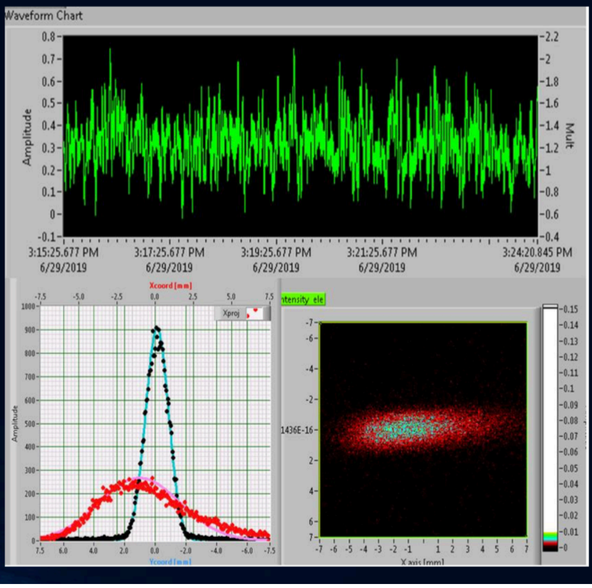
DAQ LeCroy 7300A: 3GHz; 10GS/s



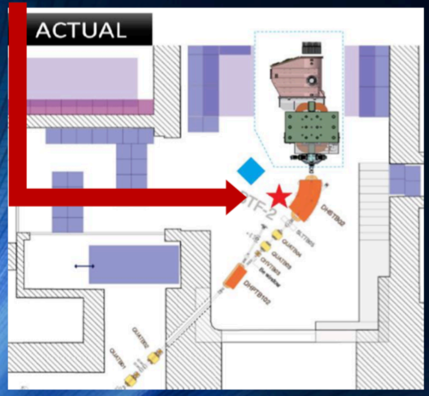
Offline multiplicity on CALO BTF



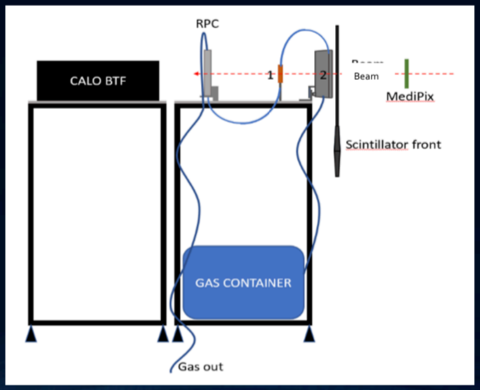
Online beam monitoring on MediPix



We were here !



$95\%C_2H_2F_4+4.5\%iC_4H_{10}+0.5\%SF_6$



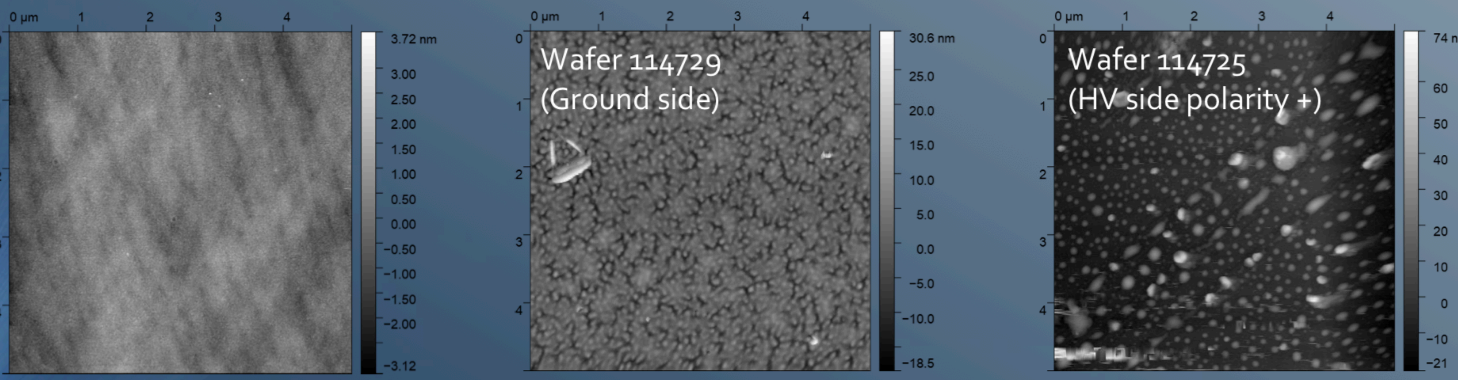
"Upgrade of the DAFNE Beam Test Facility (BTF)"

Ageing
(Preliminary)

The surfaces of two used wafers have been analyzed with the Atomic Force Microscopy

- Microstructures 58-96 n m tall with different shapes were found at the center of the wafer
- The edge of the wafer (out of the detector active region) shows a uniform flat surface

Edge	Center



Thanks to Prof. Ernesto Placidi

Linear response up to 36 kHz/cm²
Interesting evidence of ageing

Nuclear Inst. and Methods in Physics Research, A 908 (2018) 285–290

ELSEVIER

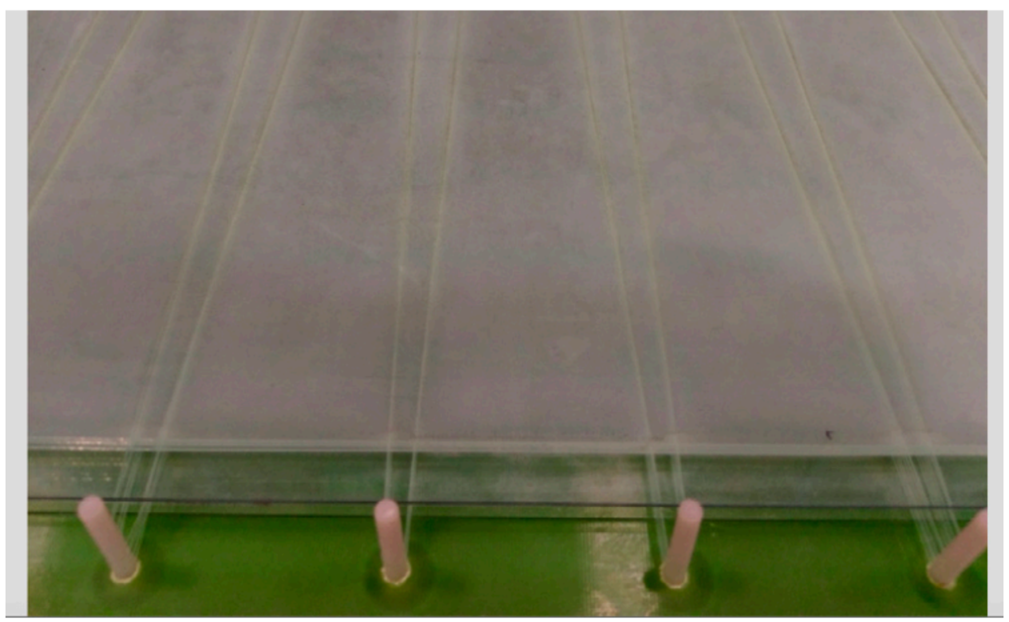
Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

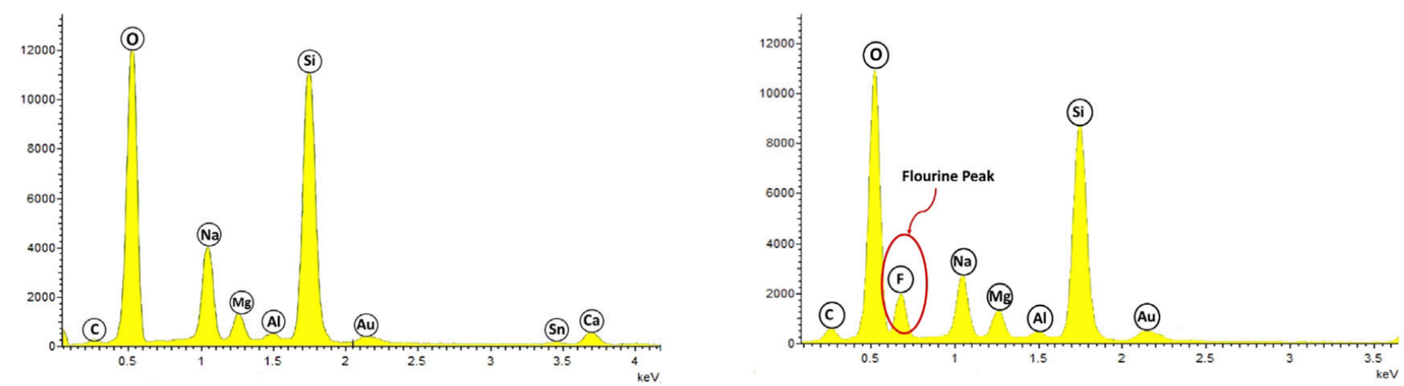
journal homepage: www.elsevier.com/locate/nima

Study of ageing in glass MRPCs

F. Carnesecchi [b,c,d], D.W. Kim [g,h], Z. Liu [a,e], O. Maragoto Rodriguez [e,f,*], W. Park [e,g], M.C.S. Williams [a,b], A. Zichichi [a,b,c,d], R. Zuyeuski [d,e]



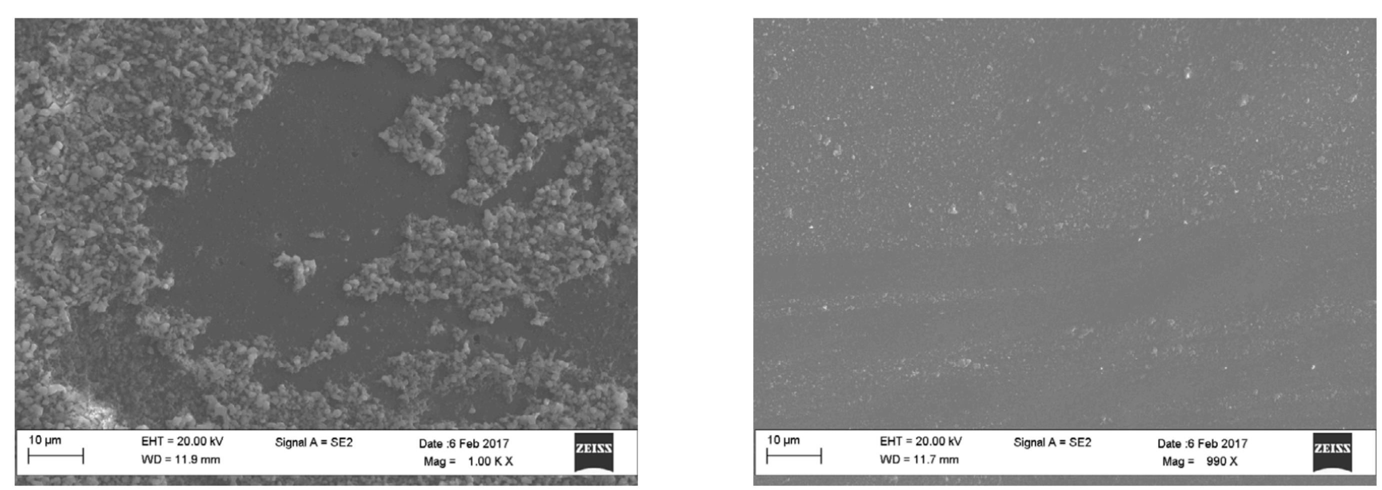
10 year old MRPC - glass plates had become opaque



(a) (b)

Fig. 6. EDX spectrum of a virgin glass sheet (a) and one that has been used for ten years (b).

Polymerised coating on the surface



Towards high counting rate RPC-based neutron detectors: current state and perspectives

ís Margato
LIP - Coimbra, Dep. Física, Universidade de Coimbra (PT)
ISEC - Instituto Superior de Engenharia de Coimbra (PT)

LIP Coimbra is very busy group

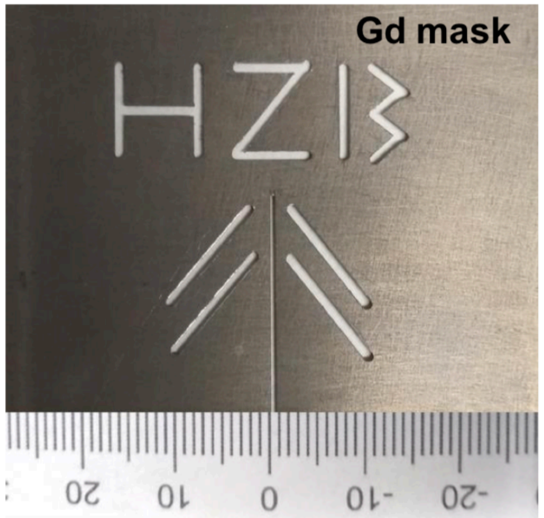
Conclusions

- It seems to be possible to reach 100 kHz/cm² with a ^{10}B-RPC based neutron detector by combining low resistive electrodes and a multilayer configuration
  - Counting rates of the order of 10 kHz/cm² are demonstrated for single gap RPCs
  - A further factor of 10 increase in the counting rate can be provided by using a Multilayer configuration
- Gamma sensitivity < 10^{-6} was demonstrated for 0,511 MeV

RPC detector at a beamline at HZB-Berlin

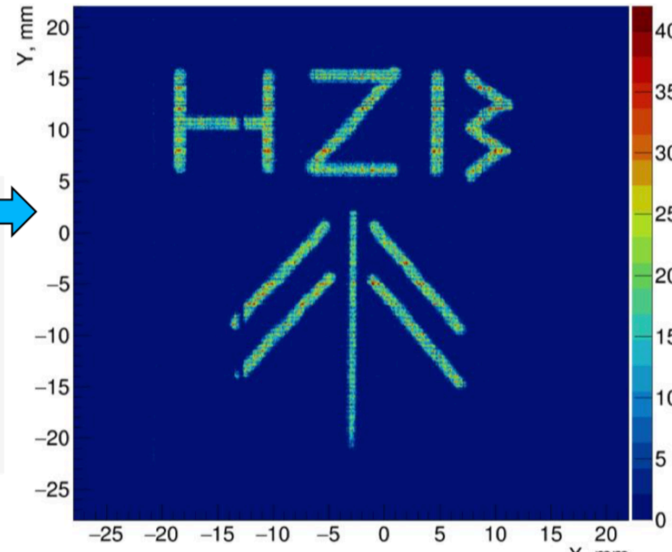
Gd mask: 0.25 mm thick
Letters and oblique slits: 1mm width

Vertical slit: 0,4 mm width

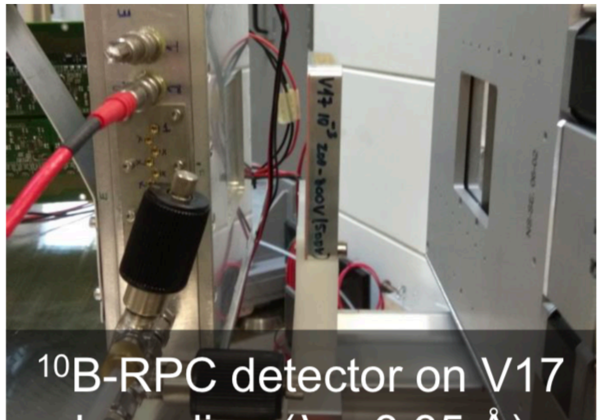


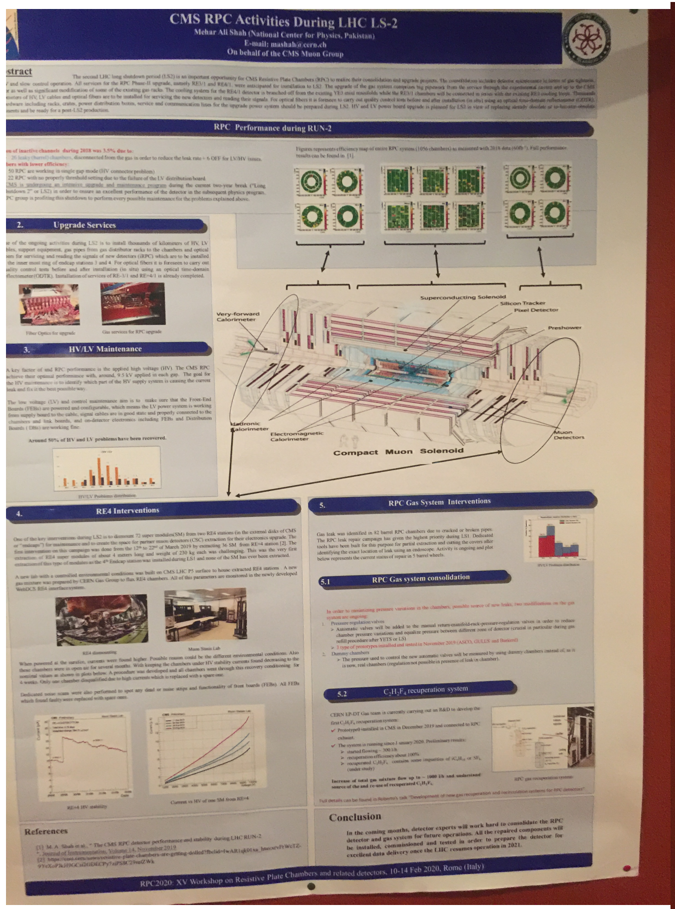
2D Image
Gd mask installed directly in front of the detector

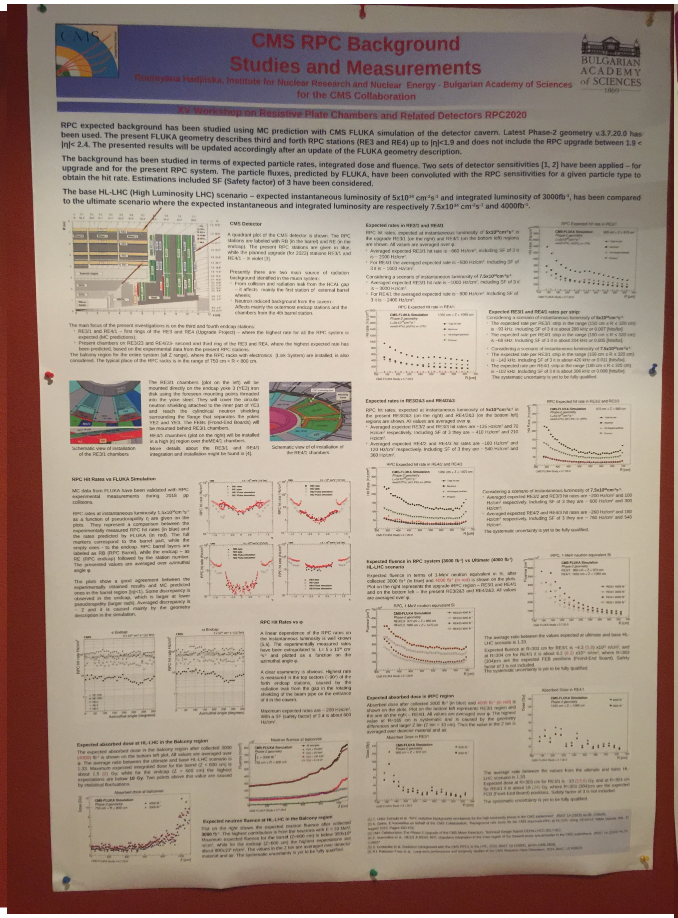
Position reconstruction: COG algorithm

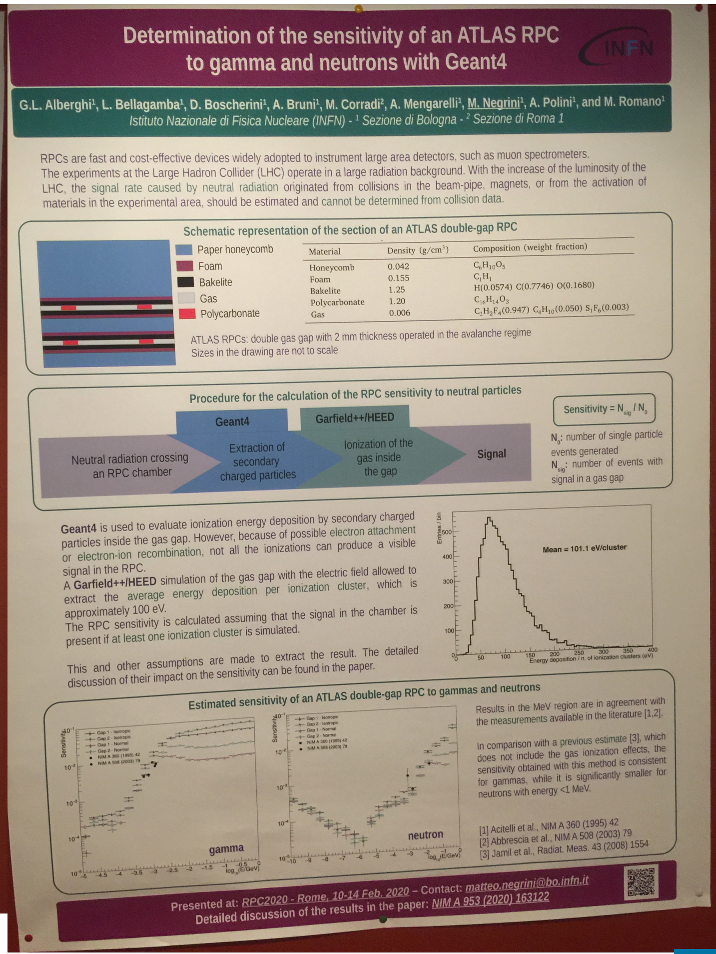


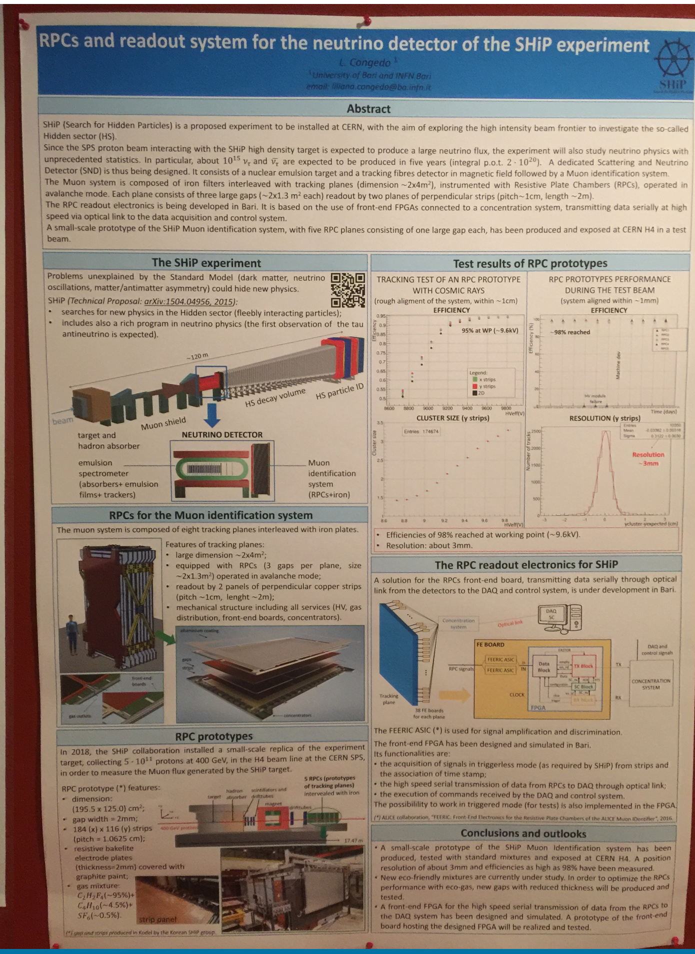
Very impressive results

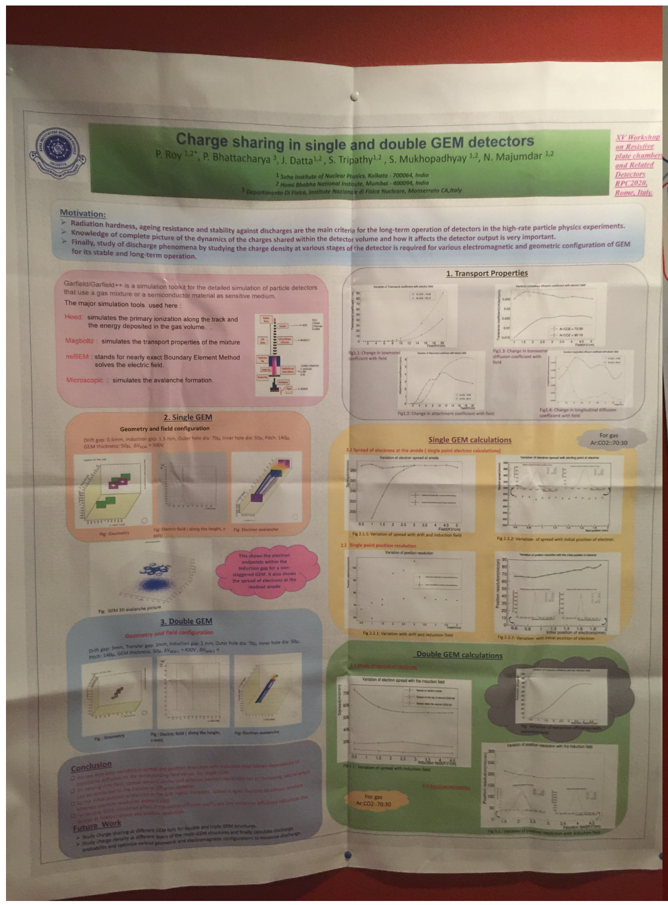


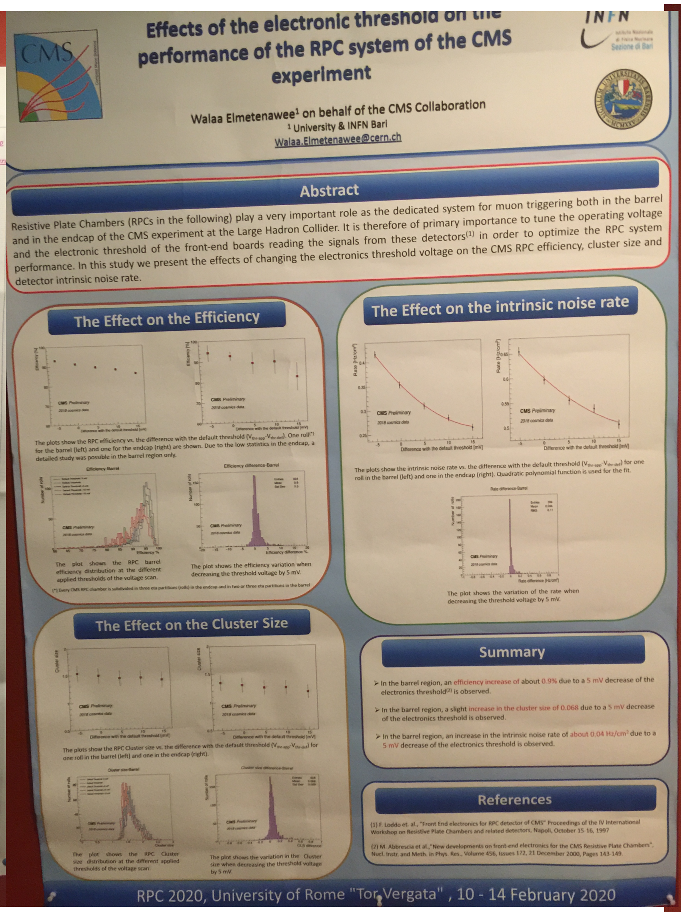


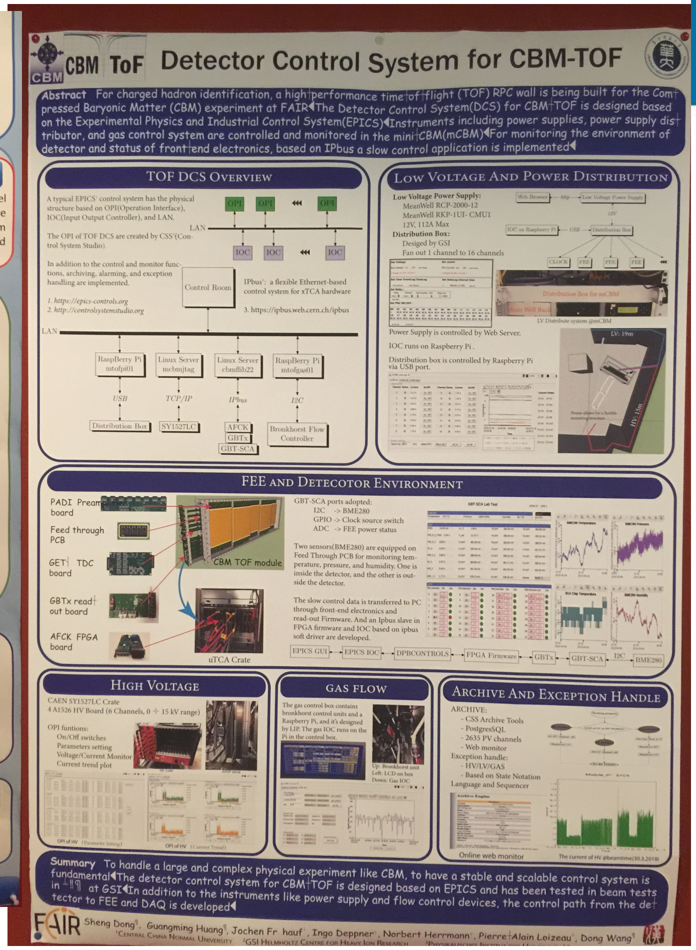


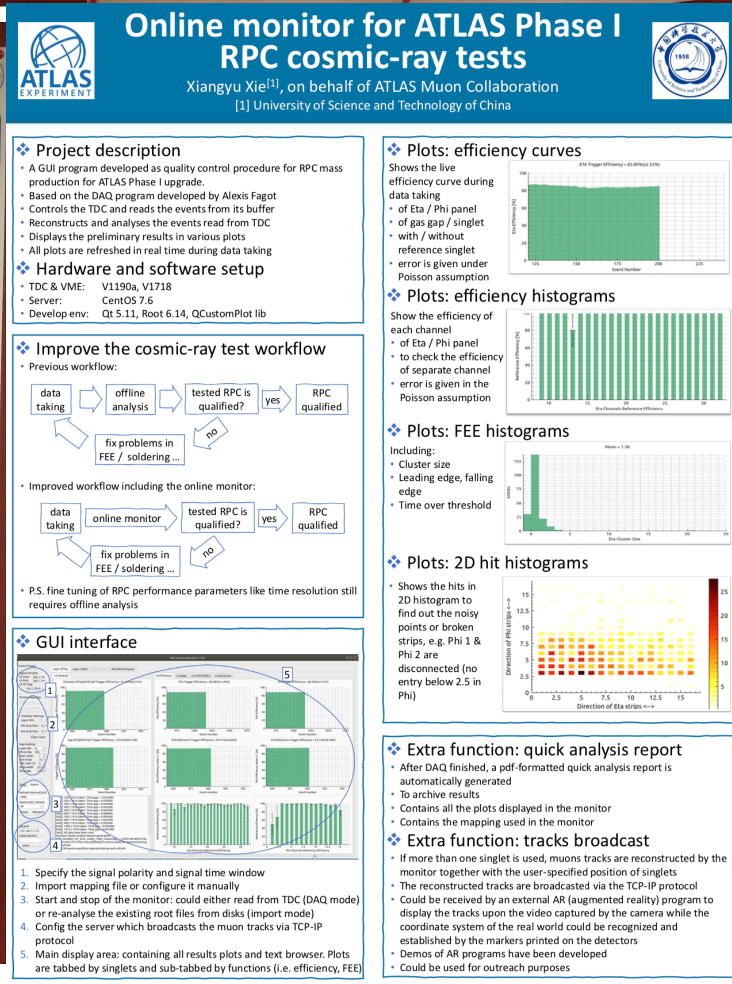












Only 1 poster has been uploaded to website (Wednesday afternoon)

End of day 2

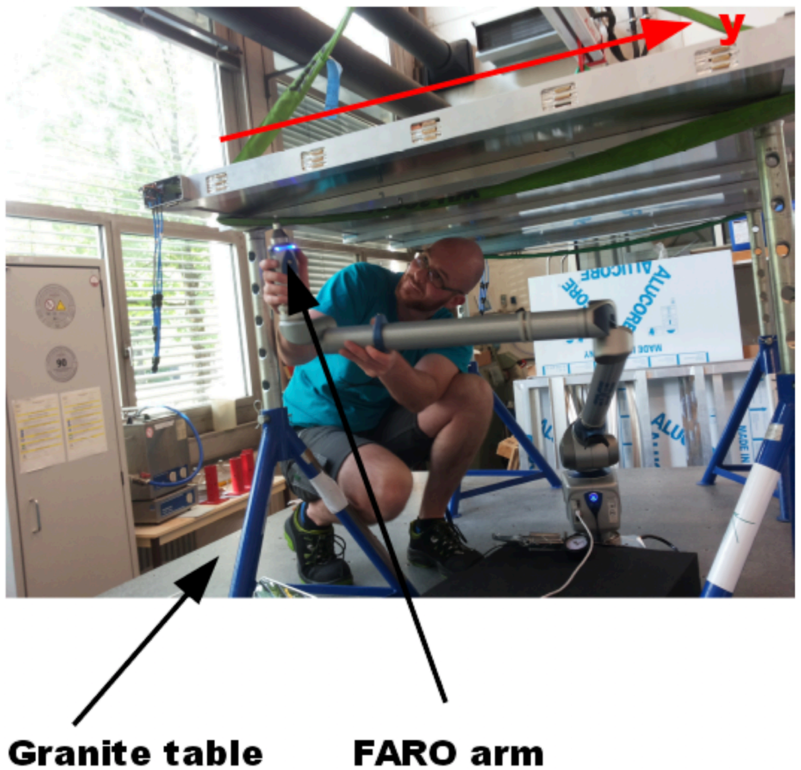
- ALICE Muon RPCs - bad planes being replaced - maybe more sensitive front-end electronics would help?
- 1 mm gap RPCs built in China have good performance
- Start considering very low gas flows - recirculating gas systems…
- Townsend coefficient - do we really know how good calculated value is??
- Very high rates with tests up to 200 kHz/cm^2 : new challenge - need and easy way to flip applied HV
- Ageing - is this going to be an issue?

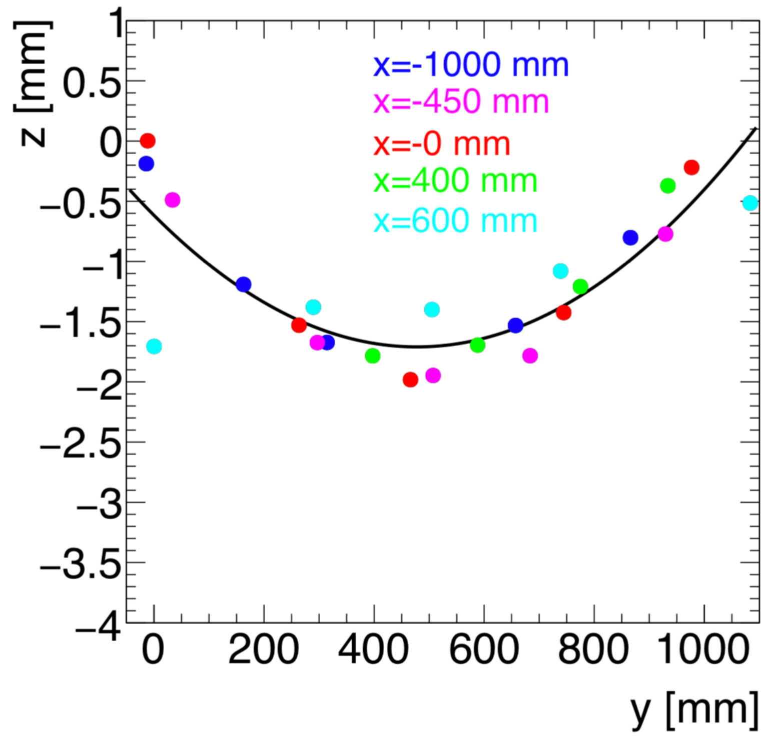
Design and construction of the mechanical structure for thin-gap RPC triplets for the upgrade of the ATLAS muon spectrometer

O. Kortner on behalf of the ATLAS Muon Collaboration

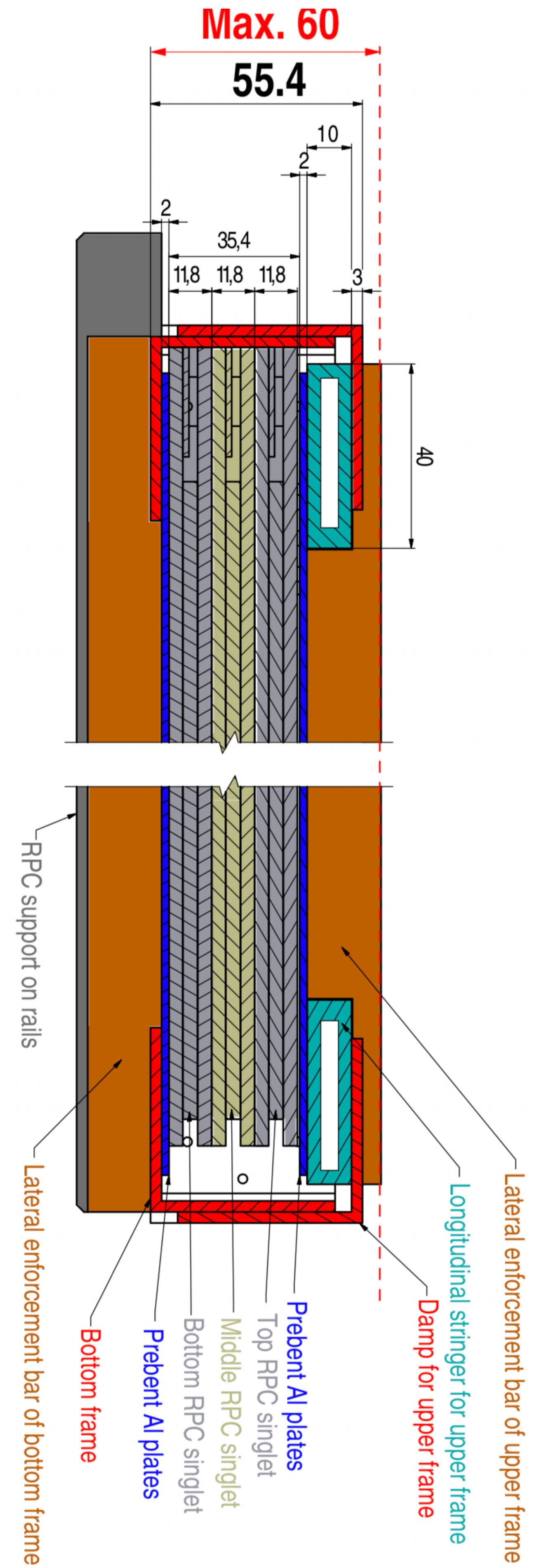
Measurement of the rigidity of the BIS-7 mechanics

Measurement of the height of the bottom of the mechanical structure under the load of an RPC triplet



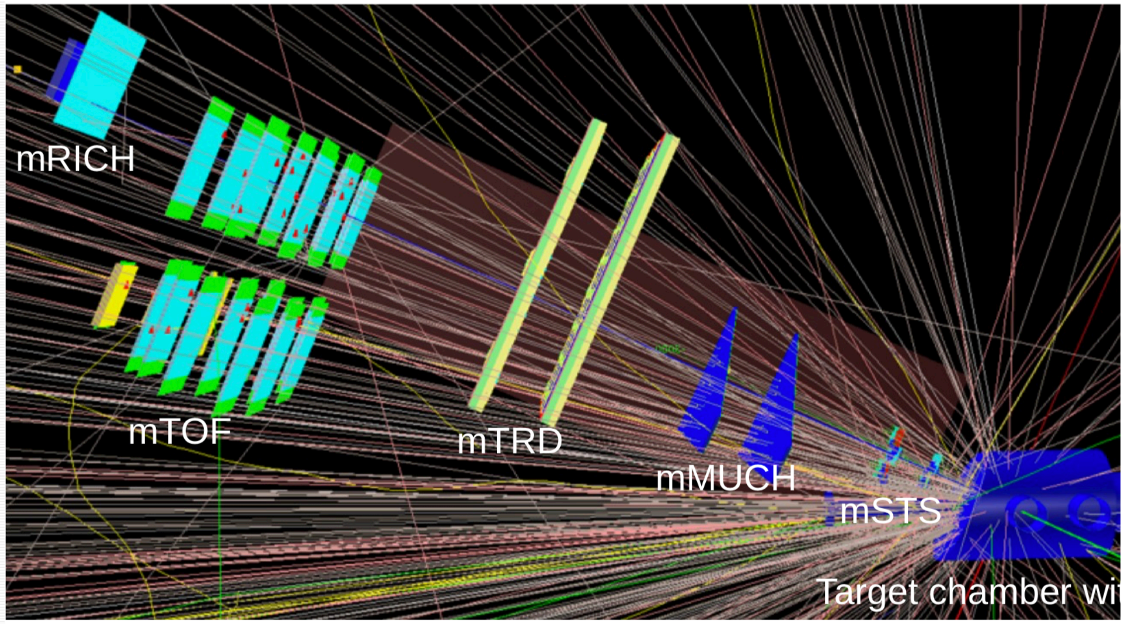


Sag of the stiffening rods <2 mm.



Problem:
fit a triplet of 1 mm gap RPCs in a 6 cm gap:
Mechanics of large planar devices needs attention

mTOF performance during mCBM beamtime at GSI

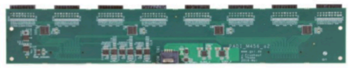


Qiunan Zhang
Tsinghua University & Heidelberg University

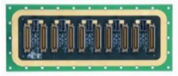
Data driven readout chain

- PreAmplifier DIscriminator (PADI): amplification (~250), threshold (10~20 fC)
- GSI Event-driven TDC with 4 channels (GET4): signal arriving time and TOT are measured
- Radiation hard ASIC GBTx: collects and combines GET4 data. Signal changed to optical signal
- Data Processing Board (DPB): collects data from GBTx and builds μ-time slices(data package)
- First Level event selector Interface Board (FLIB): combines μ-time slices for data selection and storag
- 1600 channels:32*2(sides)*5(MRPCs)*5(modules) + 128 channels: 32*2(sides)*2(MRPCs)

PADI: Preamplifier board 32 CH

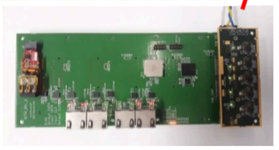


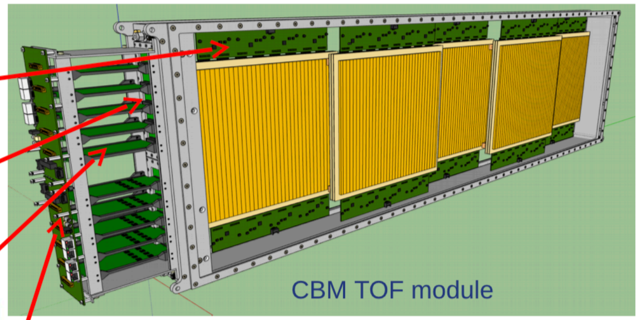
Feed through PCB



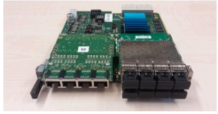
GET4: TDC board 32 CH

Backplane with GBTx chip

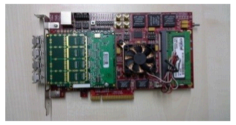




DPB: FPGA board



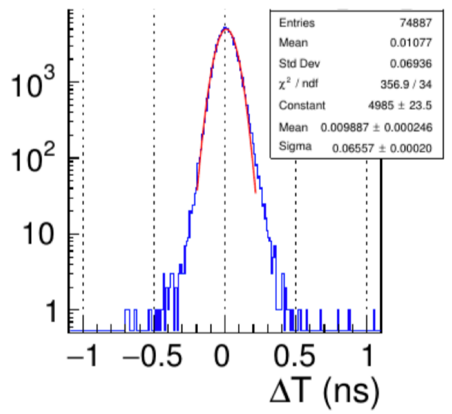
FLIB: FPGA card



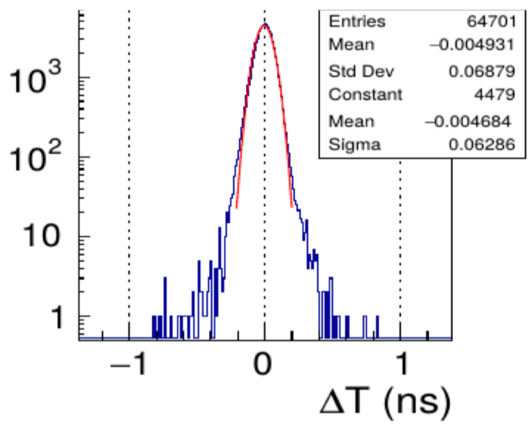
‘Streaming DAQ’
Every hit anywhere in detector is recorded
Ambitious by necessary!

Preliminary time resolution of mTOF

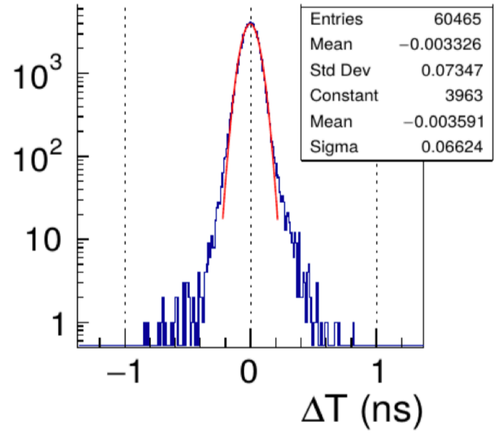
Layer 1 row 2 MRPC2



Front MRPC3



Back MRPC3

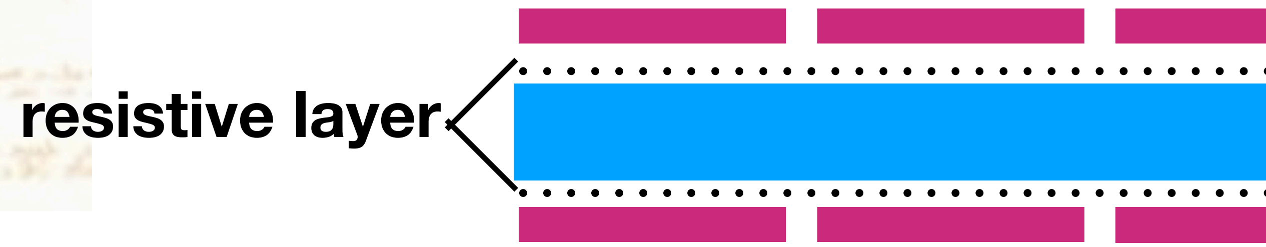


Time resolution of mTOF counters is ~ 65 $\pm$ 5 ps.

Very excellent time resolution at high rates

improved-RPC for CMS Muon system upgrade for HL-LHC

Priyanka Kumari[1] on behalf



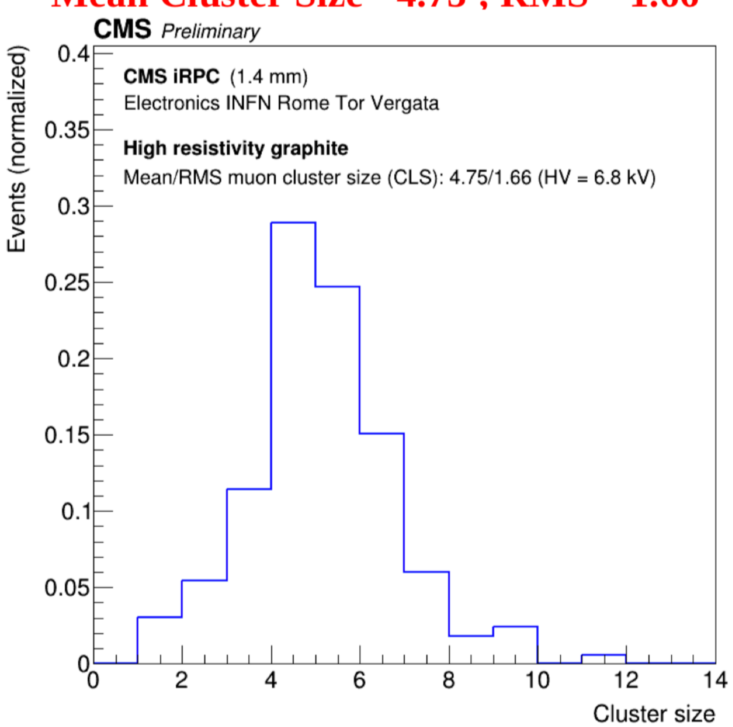
Resistive layer spreads charge image on pickup strips

Muon Cluster Size for high and low Resistivity Graphite

- For high resistivity graphite, muon cluster size is low with narrower cluster size distribution as comapred to low resistivity graphite.
- We expect this behaviour because of difference in graphite resistivity, directly influencing cluster size through cross talk by the capacitive coupling of the strips.

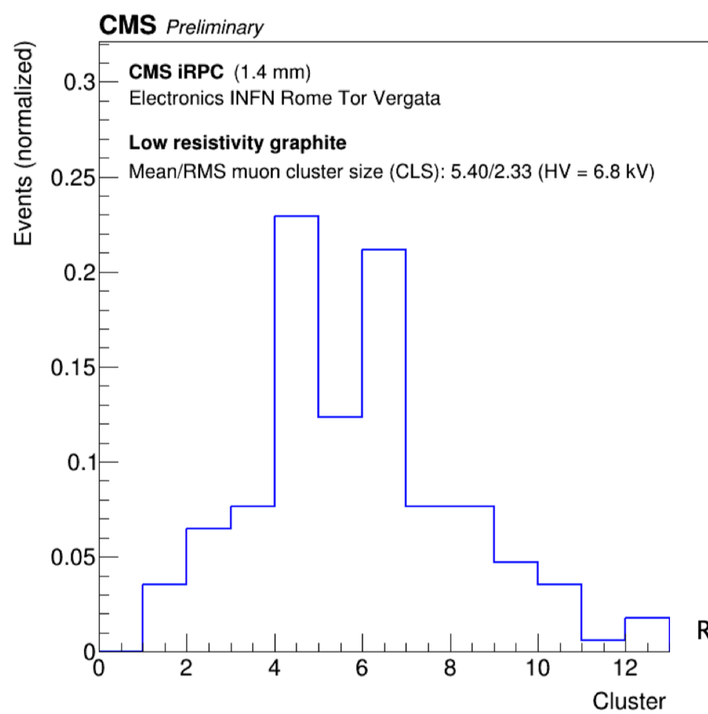
High Resisitivity Graphite : 600 kΩ

Mean Cluster Size - 4.75 ; RMS – 1.66



Low Resisitivity Graphite : 50 kΩ

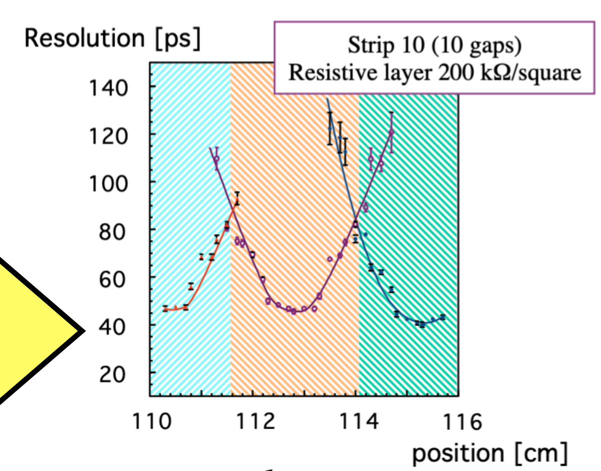
Mean Cluster Size – 5.40 ; RMS – 2.33



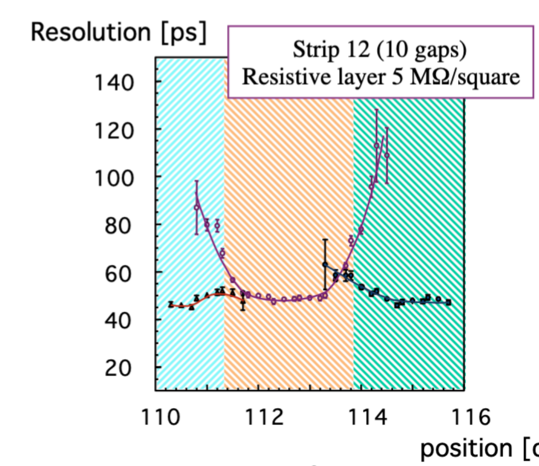
High resistivity graphite is chosen over low because of the small muon cluster siz

N.B. ALICE TOF MRPC found that resistivity should be larger than 1 MΩ/square to prevent charge spreading on pickup strips

ALICE TOF TDR



200 kΩ/square



5 MΩ/square

Paolo Fonte reminded us of Riegler's work

The ATLAS RPC system upgrade for the High Luminosity LHC

Yongjie Sun, on behalf of the ATLAS Muon Collaboration

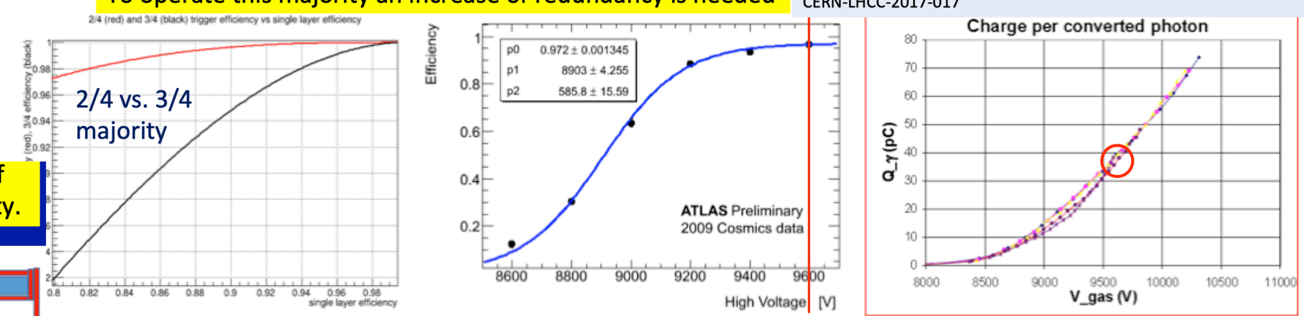
Is the current RPCs still usable?

- ATLAS RPC have shown a very stable and effective running throughout Run - 1 and Run – 2
- The HL-LHC rate is a litter higher than the design limit at high-η region (100 vs 340 Hz/cm²)
- The longevity is dominated by integrated charge limitation of 0.3 C/cm².
- If we apply on the BM station a 2/4 majority instead of the 3/4, it allows a consistent reduction of gap efficiency without affecting the trigger efficiency

- The charge estimation for 10 years of LHC operation:
  30 pC/count×20 Hz/cm²×10⁷ s/yr ×10 yr = 60 mC/cm²
- At HL-LHC luminosity, a factor of 8 applies

To operate this majority an increase of redundancy is needed

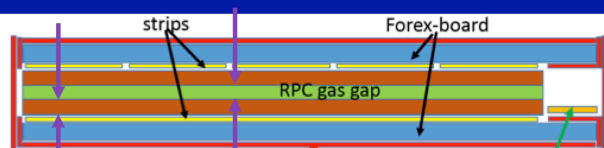
From "TDR for the Phase-II Upgrade of the ATLAS Muon Spectrometer", CERN-LHCC-2017-017



New generation of RPC for BI

The challenge is to build a new generation of RPCs with higher rate capability and longevity.

- Higher rate capability: → kHz/cm²
- Longer longevity: >10 years @ HL-LHC
- Higher spatial resolution: <1 cm
- Higher time resolution: ~ 0.5 ns



- Reduced bakelite thickness:
  - Less voltage loss in bakelite → improve the rate capability, larger induced signals
- Reduced gap size:
  - Less charge produced per event → improve longevity, rate capability
  - Less high voltage applied but higher field → better time resolution
- New generation FE electronic:
  - Higher amplification factor and high S/N ratio to compensate the lost gas amplification.
- Improved readout panel and method
  - Better mechanics structure, better signal transmission and better spatial resoluti

Good Question

The answer

Summary and outlook

- ✓ The tasks and methods for the ATLAS RPC upgrade towards the HL-LHC have been well defined.
- ✓ As a pilot project, the BIS78 production in Phase-I progresses smoothly. Side A production will be completed by march 2019
- ✓ Beyond BIS78, new methods in developing show even more positive results.
- ✓ Benefit from the upgrade, the new generation of RPC indicates a wider use field in the future.

Environment-friendly gas mixtures for Resistive Plate Chambers: an experimental and simulation study

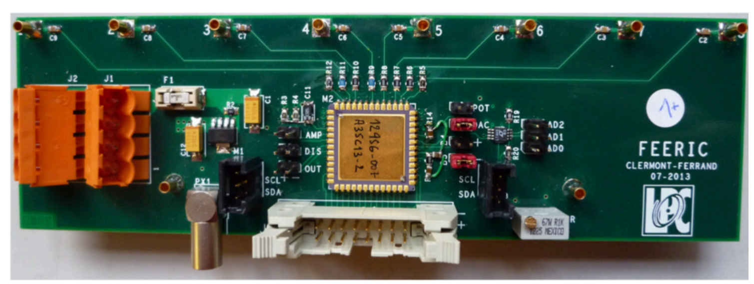
A. Bianchi*, S. Delsanto, P. Dupieux, A. Ferretti, M. Gagliardi, B. Joly, S. P. Manen, M. Marchisone, L. Micheletti, L. Quaglia, A. Rosano, L. Terlizzi and E. Vercellin

*INFN and University of Torino | antonio.bianchi@unito.it

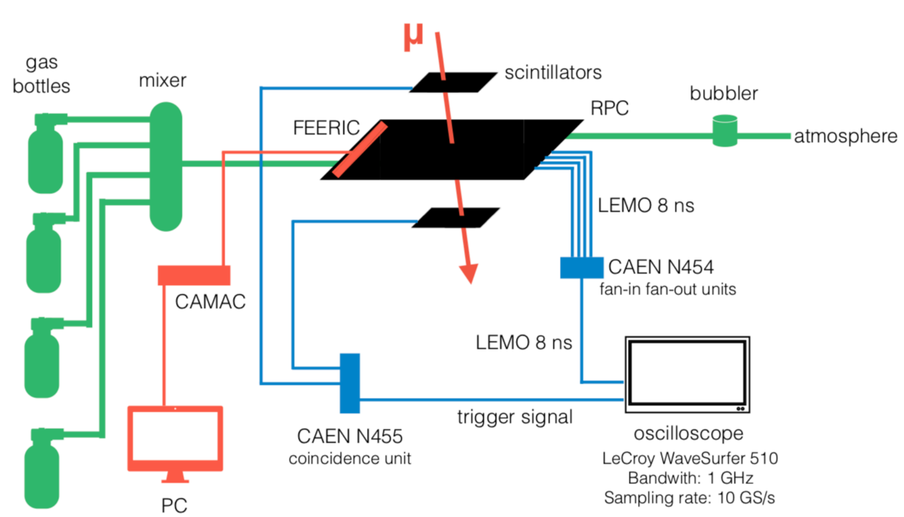
Experimental set-up

R&D studies on eco-friendly gas mixtures:

- small-size (50 x 50 x 0.2 cm^3) RPC inside a Faraday cage
- trigger: three scintillators coupled with photomultipliers
- HV is applied with temperature and pressure correction (p_0 = 1000 mbar and T_0 = 20 °C)
- possibility to mix at maximum 4 different gases with H_2O vapor
- signals in read-out strips (2 x 50 cm^2) discriminated by FEERIC front-end electronics and acquired by oscilloscope
- FEERIC amplifies signals (input charge range = 0.1÷1 pC)

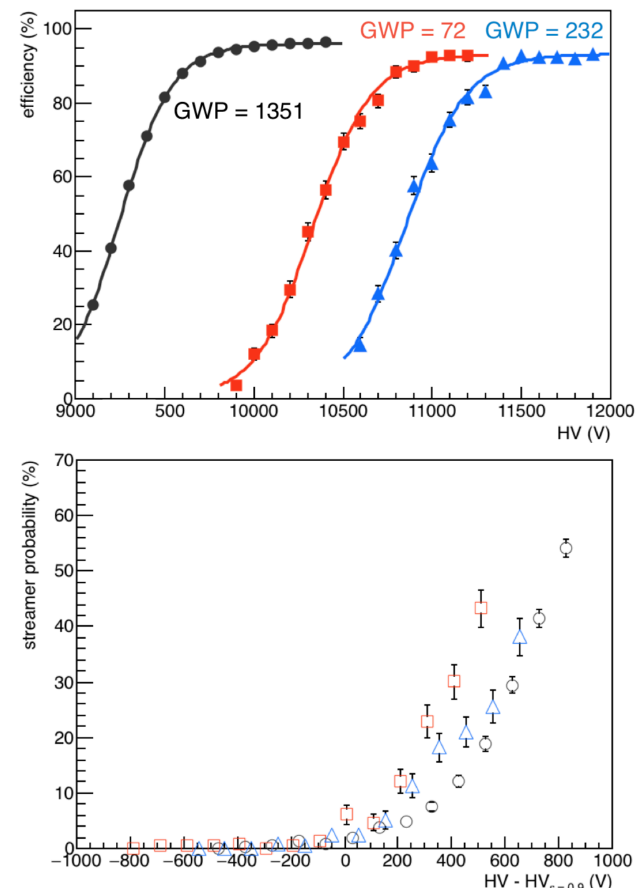


Dupieux P. et al., *Upgrade of the ALICE muon trigger electronics*, JINST 9.09 (2014)



total trigger area: ~6 x 6 cm^2

Promising gas mixtures with low GWP



A. Bianchi *et al.* 2019 *JINST* **14** P11014

Mixture $C_2H_2F_4/iC_4H_{10}/SF_6$ (89.7/10.0/0.3):
- ● efficiency
- ○ streamer probability

Mixture $CO_2/C_3H_2F_4/iC_4H_{10}/SF_6$ (50.0/39.7/10.0/0.3):
- ■ efficiency
- □ streamer probability

Mixture $CO_2/C_3H_2F_4/iC_4H_{10}/SF_6$ (50.0/39.0/10.0/1.0):
- ▲ efficiency
- △ streamer probability

50% CO_2, 39.7% $C_3H_2F_4$, 10% i-C_4H_{10}, 0.3% SF_6:

- GWP: 72 (~20 times lower than the GWP of ALICE mixture)
- the working point is quite close to the working point of the ALICE RPCs during LHC Run 1 and Run 2 (~1.0 kV)
- the streamer probability is not as low as in the current ALICE mixture

50% CO_2, 39% $C_3H_2F_4$, 10% i-C_4H_{10}, 1% SF_6:

- GWP: 232 (~5 times lower than the GWP of ALICE mixture)
- the working point is higher (~1.5 kV)
- the streamer probability is similar to the ALICE mixture, although slightly higher

→ in both cases, values of cluster size are similar to those obtained with the ALICE mixture

→ more details in A. Bianchi *et al.* 2019 *JINST* **14** P11014

Important and relevant study of possible gas mixtures:
N.B. May be necessary to study single gap RPC separately from MRPCs

Outgassing and Leak Test studies in INO RPC Detectors

Department of Physics and Astrophysics, University of Delhi, India

A. Phogat, A. Kumar, H. Kumar, R. Ahmad, Moh Rafik Md. Naimuddin

Leak Test Schematics & Experimental Setup

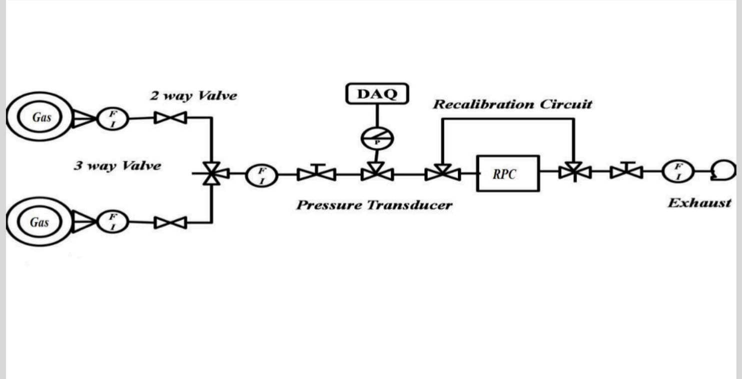
➢ Gas leakage setup uses different electronic and pneumatic components: flow meters, gauge pressure sensor, atmospheric pressure sensor, temperature sensor, digital display, Arduino board, etc.

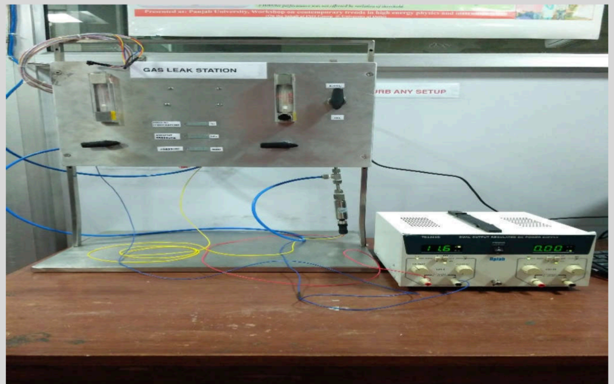
➢ Flow meters: measures flow rate of gases

➢ Gauge pressure sensor (piezoelectric): provides current output for given gauge pressure and measures the corresponding pressure drop

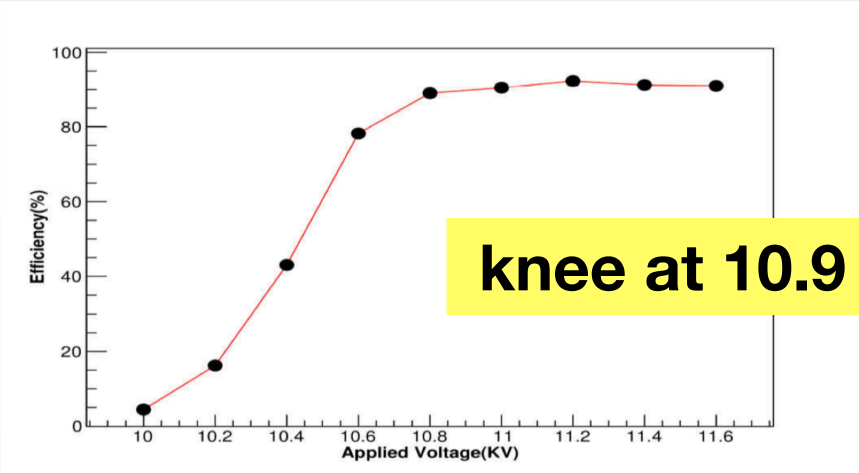
➢ Atmospheric pressure and temperature: piezoresistive, monolithic, signal conditioned silicon sensor

➢ Arduino Mega 2560 board: open source computing platform interfaced to PC. The pressure and temperatre data readout by ARDUINO MEGA 2560





Efficiency



knee at 10.9 kV

➢ Working Point: the lower the better (Electric field play a key role: The impurities in the gas, which are transported with the gas flow may directly deposit on the surface of electrodes due to electrostatic forces)

➢ Temperature: the lower the better 20°C to 22°C (At high operating temperature, the chamber draw more current)

➢ Relative humidity: best value 35-40% for stable resistivity and low leakage current.

Glass RPCs - in my opinion should be run without water

Conclusions

➢ **A quantitative estimation of the leak test of an RPC is obtained without using conventional manometer.**

➢ **We demonstrated that materials such as polycarbonate buttons, spacers and the 3M scotch-epoxy adhesive DP-125 produces no significant pollutant outgassing at room temperatures, and thus do not affect the lifetime of gas detectors.**

➢ **These materials are suitable for the assembly of RPC detectors in the cosmic experiments.**

➢ **The result of last 75 days shows no permanent extra component in the return mixture from the RPC detector in the open loop gas system and comic background.**

➢ **But some extra component has been observed, but their occurrence is random in time and also they vary in area percentage of the mixture (Need more study).**

Aging study on Resistive Plate Chamber of the CMS muon detector for HL-LHC

Reham Aly (INFN & University of Bari)
On behalf of the CMS Muon Group

- RPC longevity studies: ongoing @ GIF++ since July 2016
  - 78% of the expected integrated charge at HL-LHC has been collected, additional ~ 1.5 year to complete the test.
  - Stable noise rate and dark current.
  - An increase of electrodes resistivity has been observed, due to the low humidity and gas flow rate with respect to the high background conditions. We recover and mitigate the effect with 60% of gas Humidity and $\boxed{\text{3 gas volume exchange per hour.}}$
  - Stable performance from different test beams, Efficiency remains stable as a function of Integrated charge and background Rate ➡ New trigger system to measure detector performance with cosmic muons.

No Evidence of any aging effect has been observed

To keep resistivity constant : need to increase gas flow to 3 volume changes / hour

end of day 3

- CMS can control ageing by increasing gas flow to 3 volumes exchanged every hour
- CBM making progress towards high rate operation
- Confirmation from our Chinese colleagues that the ATLAS 1 mm gap chambers are the way forward

A neural network based algorithm for MRPC position reconstruction

Yancheng Yu

MRPC simulation

RPC 2020

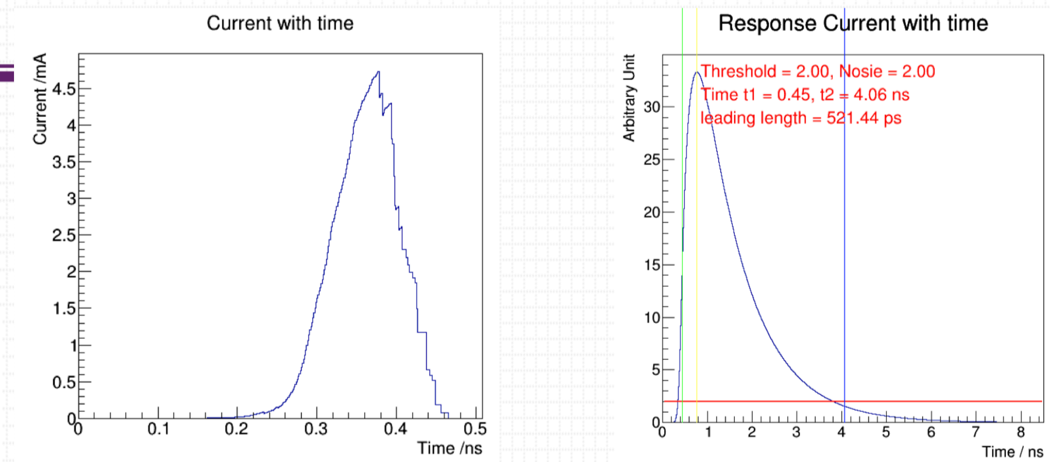
- Space charge effect: $\sim 10^7$ electrons

Werner Riegler, Christian Lippmann. Nucl. Instrum. Meth. A 500 (2003) 144.

- Include the Front-end electronics response by convolving the original current with a simplified FEE response function:

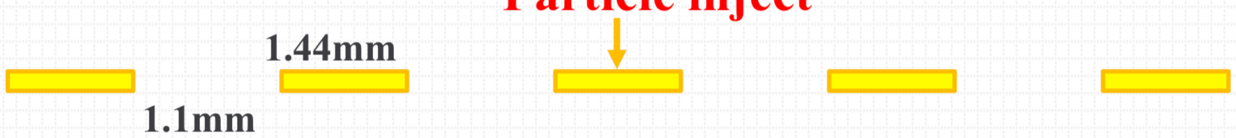
$$f(t) = A\left(e^{-t/\tau_1} - e^{-t/\tau_2}\right)$$

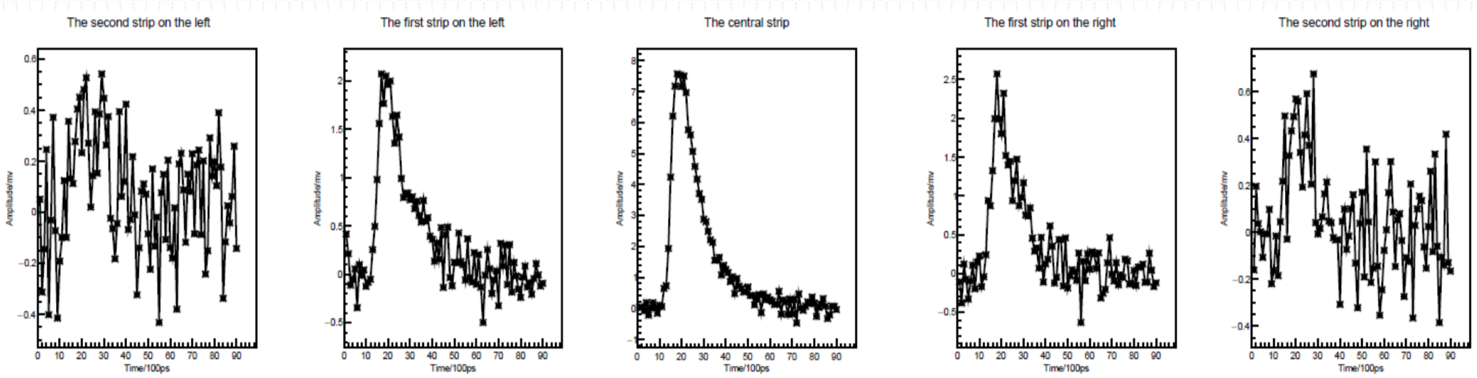
ise: by adding a random number sampled from Gauss(0, σ) to every time bin



MRPC simulation

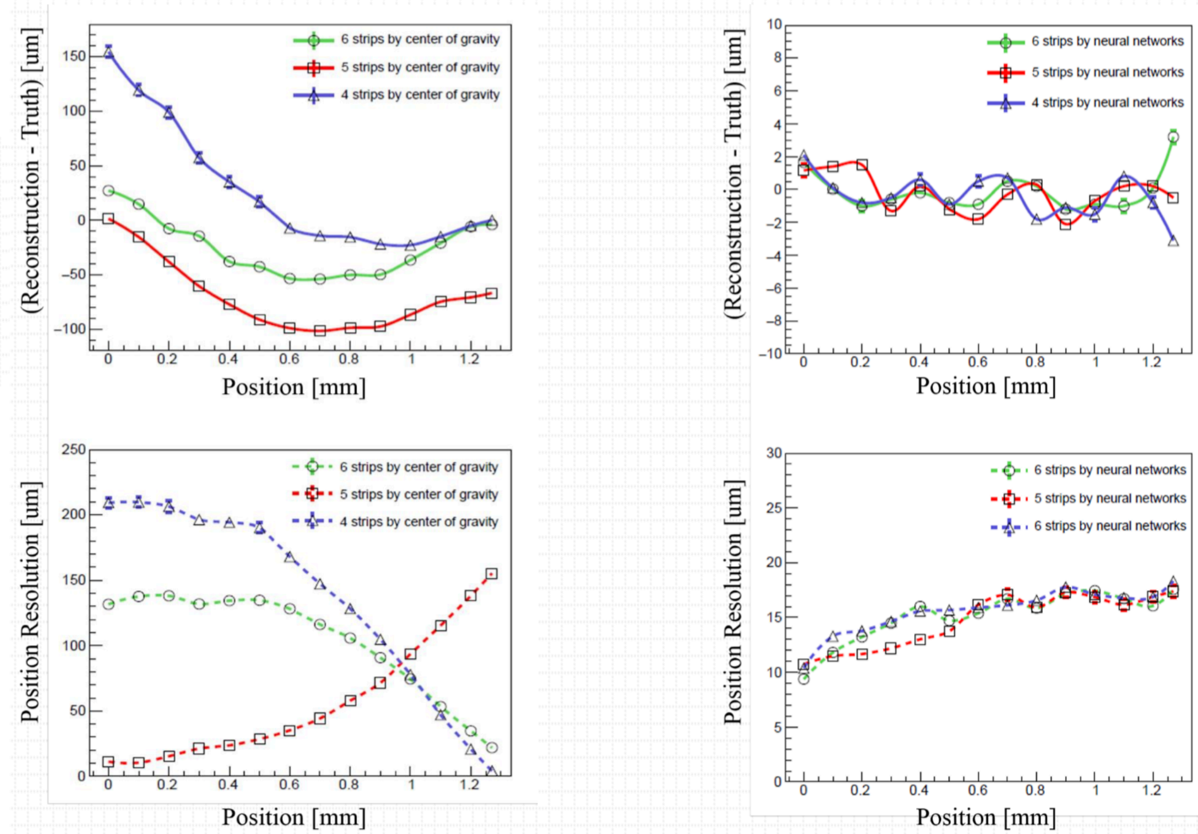
RPC 2020





- **Induced signals** generated by the energy deposition of **all sensitive areas**
- **Induced signals** on each readout electrode
- **Information** about time, charge, cluster size……
- **Position resolution**

Center of gravity (COG) VS Neural network



Very big improvement with Neural Network
Needs confirmation with real data

However need charge to be spread onto many strips - high channel count

Time reconstruction in MRPC detector using deep-learning algorithms

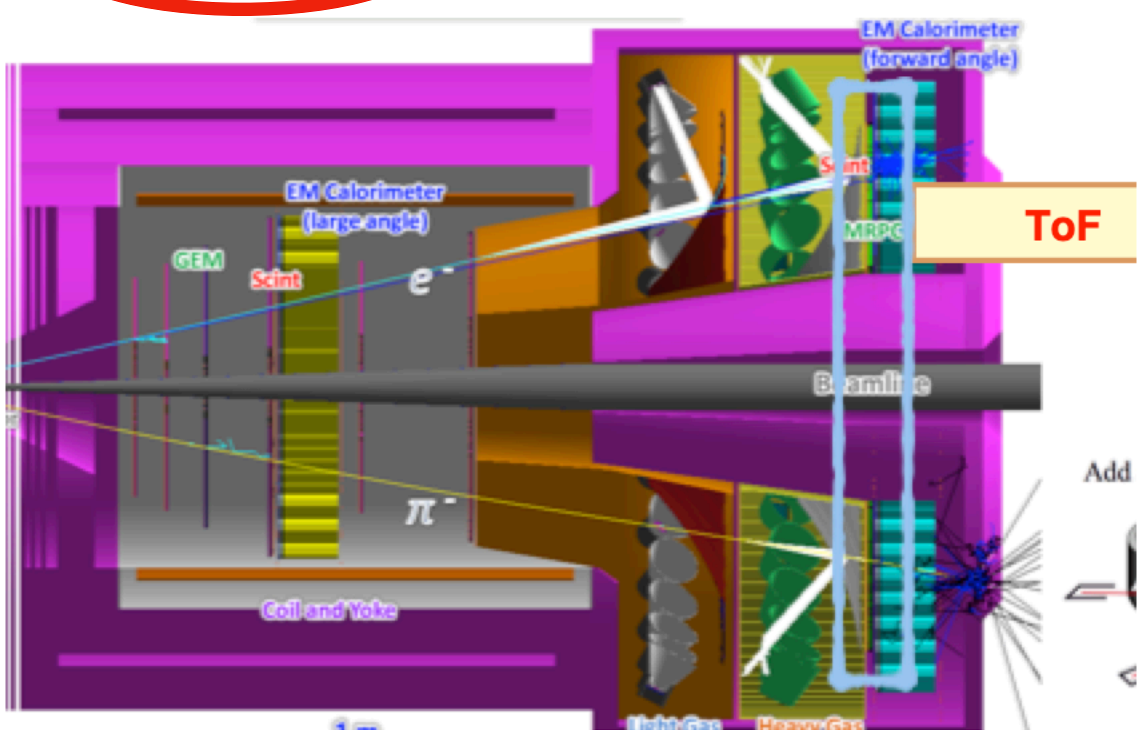
60ps nowadays

Fuyue Wang

- SoLID(Solenoidal Large Intensity Device) @ JLab
- Separation between π/K up to momentum of 7GeV/c

A challenge for MRPC: 20 ps time resolution

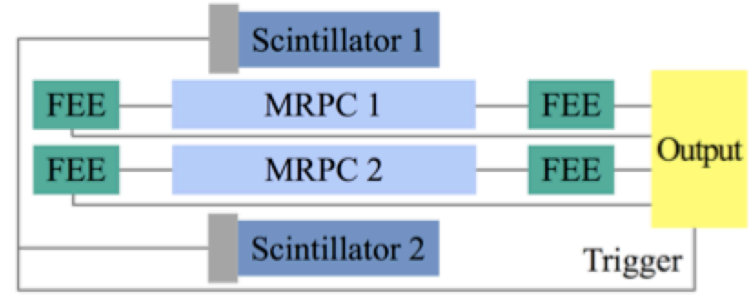
- Time resolution of present MRPCs：
  80ps@ALICE，?0ps@STAR，60ps@CBM

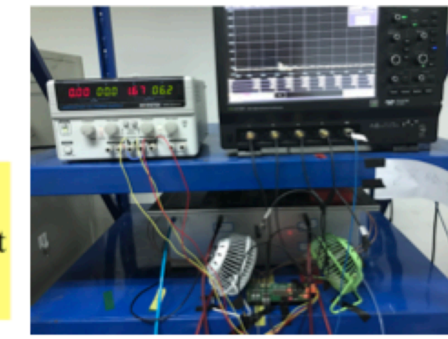


Experiment

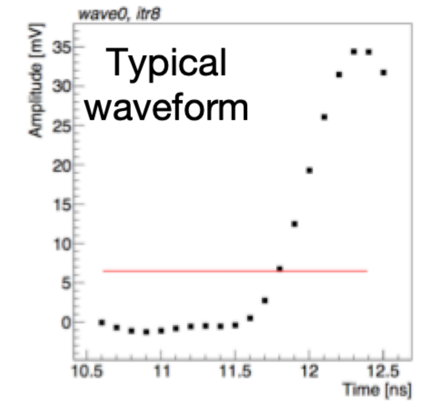
Tsinghua University

- 2 identical MRPC: 4x8 gaps, 0.104 mm
- Cosmic ray experiment





- High performance FEE from USTC: NIMA 925 (2019) 53–59
- Waveform digitizer: Lecroy HDO6104A Oscilloscope, 1GHz bandwidth, 10Gs/s sampling rate
- MRPC waveform rising time around 1 ns, 10 points



Rather slow amplifier to allow sampling of leading edge

Results summary

Tsinghua University

	Train Input	Test input	output	Reso
1	Exper. waveform + reference time		Time difference give by distance/c	19.71 ps
2	Exper. waveform + reference time		Time difference given by ToT	23.62 ps
3	Simu. waveform	Exper. waveform	Rising time	16.84 ps

- Learn from the simulation: true information of waveform and time, therefore resolution is the best when simulation matches the experiment data.
- Learn from the ToT time: performance highly depends on the accuracy of ToT method. Time resolution is not so good as the other 2.
- Learn from the time given by distance/c: closely related when selection of perpendicular events are made. Time resolution is relatively good!

The 1st and 2nd methods prove that the learning based algorithms can be designed only with experiment data.

Incorrect comparison between sampled waveform versus fixed threshold since preamplifier was slow

A new approach for CMS RPC current monitoring using Machine Learning techniques

M. Bonchev[1], A. Dimitrov[1], L. Litov[1], B. Pavlov[1], P. Petkov[1]
on behalf of the CMS collaboration
RPC2020, R

Aim: Development of an Automatic Monitoring Tool able to spot abnormal RPC current behavior and warn for possible hardware problems.

Training & Validation Datasets

- Datasets are prepared by specially developed RPC Current Automat:
  - Synchronizes I_{mon}, V_{mon} and environmental parameters
  - Sets additional flag according to LHC status for each data point
- Training and Validation datasets:
  - at least 1 year long
  - include at least 2 HV working points
- 446 Generalized Linear Models trained on 2 data for 446 RPCs in the Barrel.

Non-trivial problem : may be very necessary at high luminosity

Summary

- ML model for predicting RPC currents is developed and tested on 446 Barrel RPCs
  - Found RPCs with known problems and RPCs to be closely followed
- The tool will be used for predicting RPC currents behaviour in the conditions of new data taking period
- Validation shows overall accuracy ~ 1 μA
- Byproduct application - Historical Analysis of the RPC Currents

Next steps:

- Extend the model including RPC rates
- Development an online monitoring tool based on the presented approach and Implement automatic warning notifications upon chamber current abnormal behavior

Study on RPC signal attenuation

Xiangyu Xie

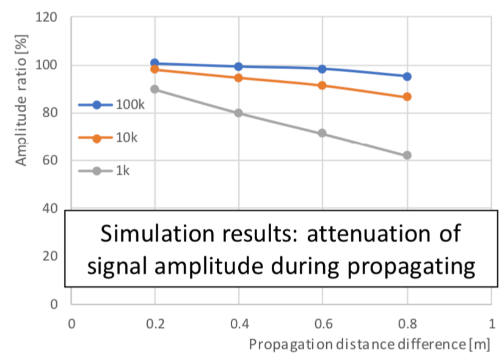
Motivation

❖Thin-gap RPC for ATLAS Phase II upgrade has smaller avalanches

❖Simulation indicates the existence of ‘attenuation’ [backup 0]

- ‘Attenuation’ means the reduction or loss of charge, amplitude and frequency of the signal readout from one strip

❖Positive correlation between attenuation and signal propagation



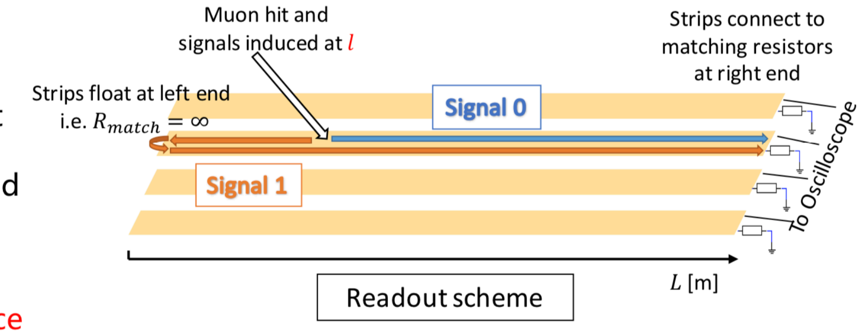
Simulation results: attenuation of signal amplitude during propagating

Experiment setup: readout scheme

❖Readout scheme

1. Consider signal 0 & signal 1 induced identically by muon hit at distance l
2. Signal 0 gets absorbed at right end by the matching resistor
3. Signal 1 gets reflected at left end, absorbed at right end after signal with longer propagation distance

right end waveforms recorded oscilloscope without amplifiers



Readout scheme

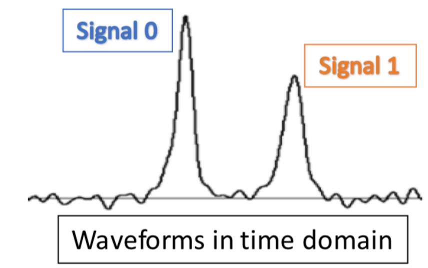
ing edge difference

es the hit

ding edge difference $= \frac{2}{velocity} \times l$

pagation distance difference $= 2 \times l$

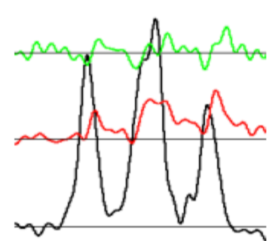
itioning accuracy $< 10\ mm$ [backup 1]



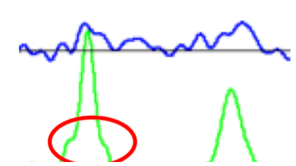
Waveforms in time domain

❖Selection of events

1. RMS (noise) $< 400\ \mu V$
2. Number of peaks = 2, to cut muon bundles events
3. Overlapped signal 0 and signal 1
4. Signal amplitude $> 5\ mV$ && $< 29\ mV$ (full scale of oscilloscope $= 30\ mV$)
5. Abnormal signal width due to noise [backup 2]
6. Outliers: charge of signal 1 $> 1.05 \times$ charge of signal 0



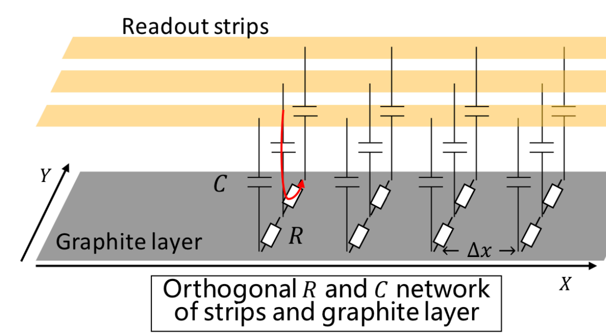
Selection 2 example: 2 muons hit on one strip ‘simultaneously’



Potential countermeasure

❖Highly simplified model of readout strips and graphite

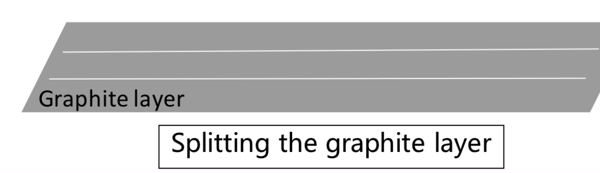
- C: equivalent capacitance between one strip and graphite per unit length
- R: equivalent orthogonal resistance between two equivalent capacitance per unit length, $\propto \rho_s$
- Orthogonal diffusion on graphite [ref 1]



Orthogonal R and C network of strips and graphite layer

❖Potential countermeasure

- Split the graphite layer like readout strips with narrower spacings
- $R \to \infty$, not depends on ρ_s
- Effective in simulation [backup 4]



Splitting the graphite layer

❖$A_{amplitude}$ strongly depends on graphite ρ_s

❖When $\rho_s > 1\ M\Omega/\square$, $A_{amplitude}$ approaches a constant value

❖$A_{amplitude}$ has an upwards shift comparing to A_{charge}

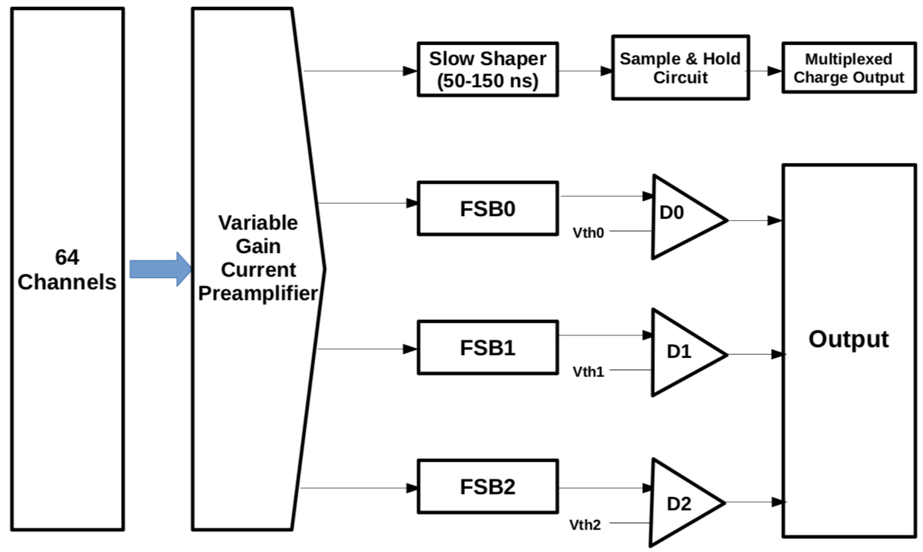
Why not use 1 MOhm/square for resistive coating

How much charge produced in chamber per MinI particle

Uniformity study of large size glass RPC detector using an alternative front-end electronics for INO-ICAL Experiment

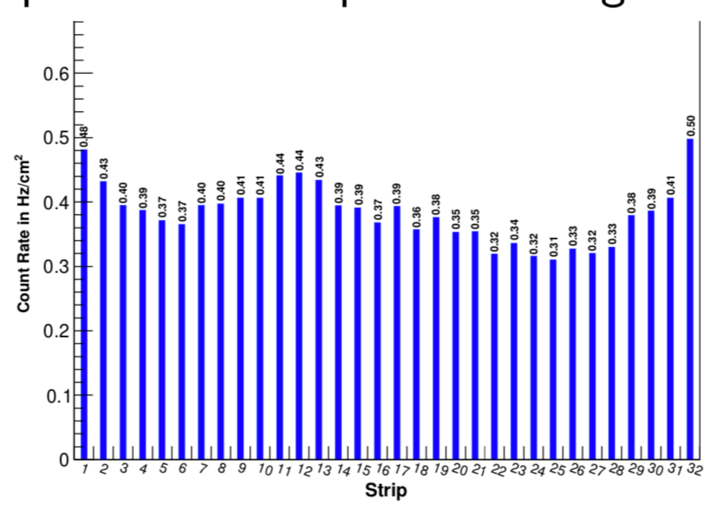
Synoptic layout of HARDROC2 chip

Md. Naimuddin



FSB: Bipolar Fast Shaper
D0,D1,D2: Discriminators

- A variable slow shaper (50-150ns) followed by a Track and Hold buffer to provide a multiplexed analog charge output up to 10pC



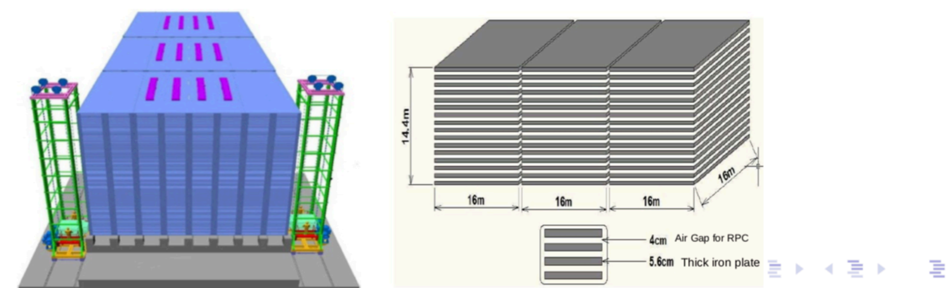
Maybe these chambers are working in streamer mode??

Introduction

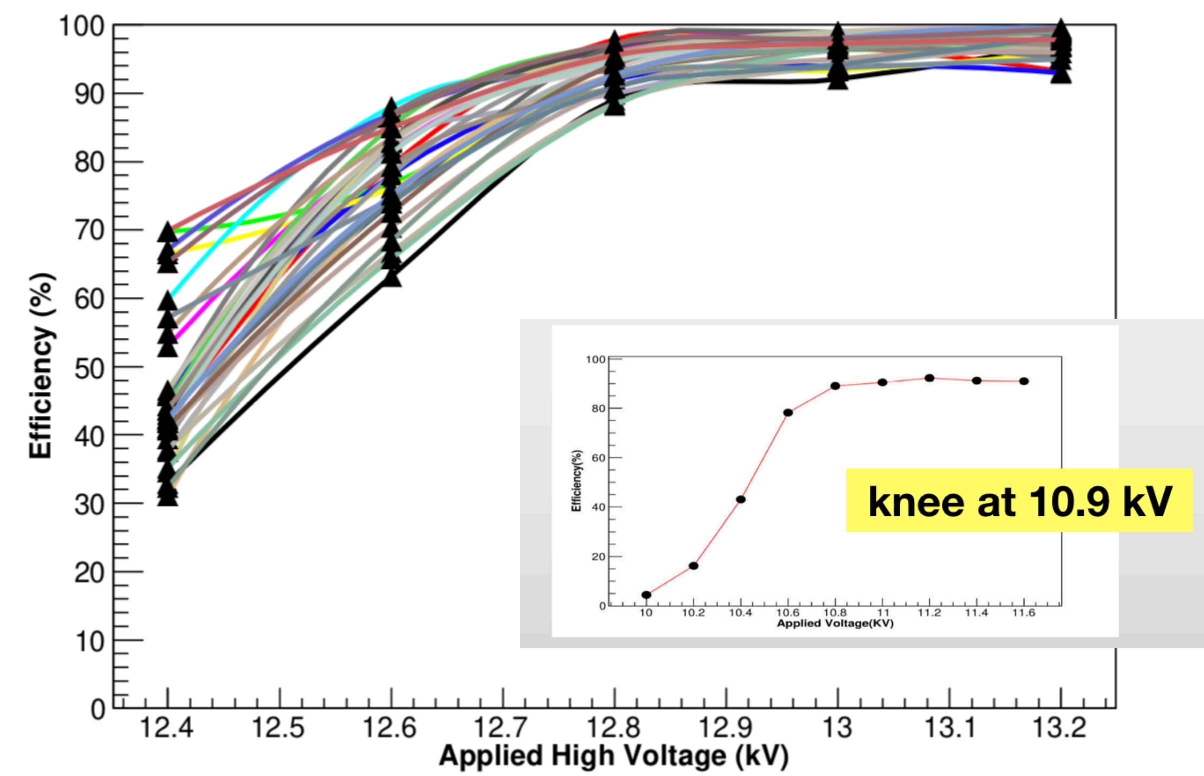
The proposed 51 kton magnetized Iron-CALorimeter (ICAL) detector at India-based Neutrino Observatory (INO) aims to study the atmospheric neutrinos and antineutrinos in an underground lab.

The complete detector require approx 29,000 Resistive Plate Chambers (RPCs) for detecting charged particles, which in turn requires 3.7 millior electronic channels to be read out.

Such a large number of channels require an efficient, compact, low powe consumption and cost-effective readout system.



nan Phogat*, Moh Rafik, Ashok Kumar, M HARDROC



CMS RPC Upgrade Phase-II of new Link System

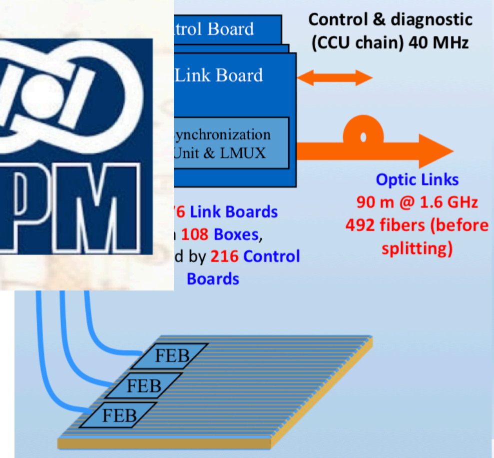
Behzad Boghrati[1,2], Roghayeh Ghasemi[1], Vahid Amoozegar[1], Mohammad Ebrahimi[1], Elham Zareiyan[1], Mojtaba Mohammadi Najaf Abadi[1]

on behalf of the CMS Muon Group

RPC2020, Roma

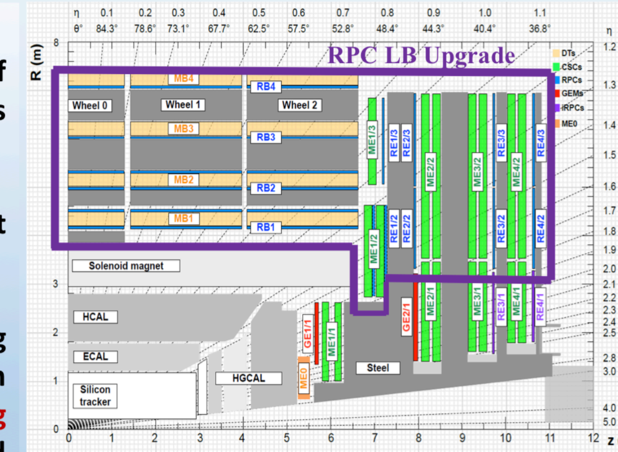
Link System Upgrade Motivation

Link Board System



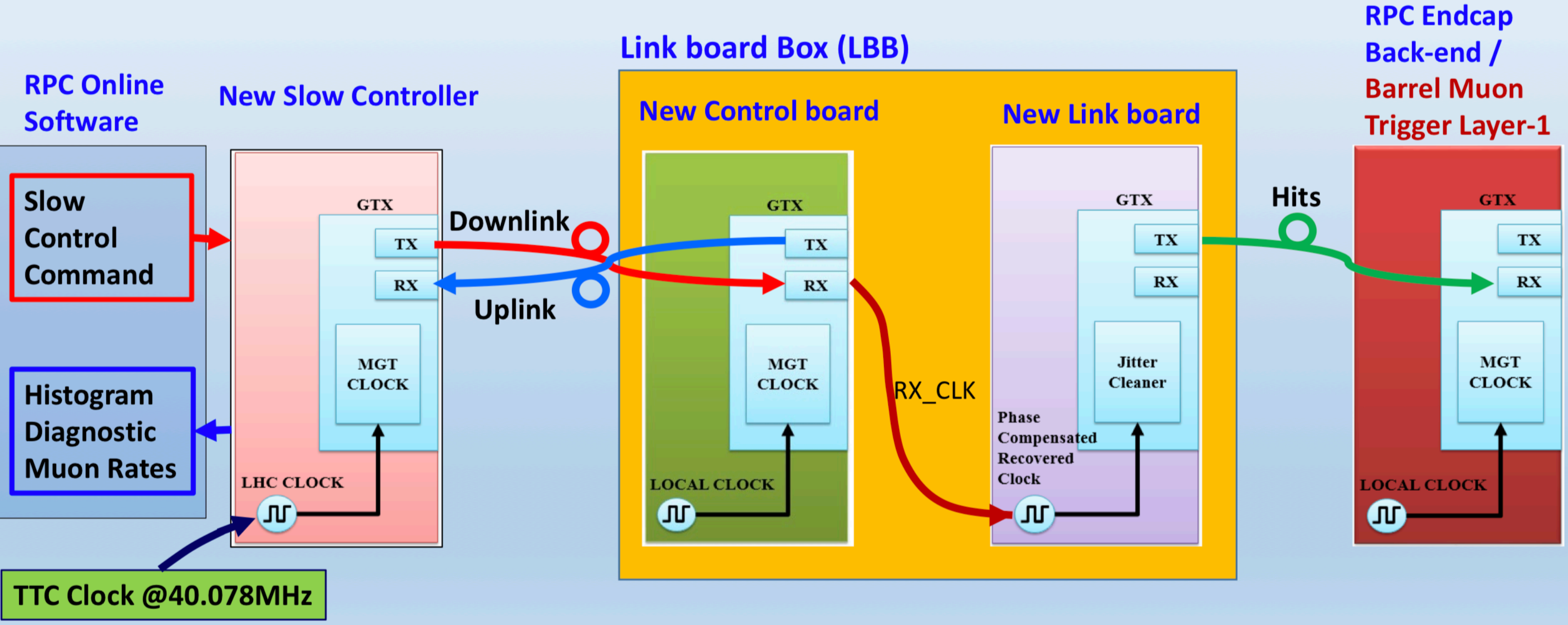
Upgrade Motivation

- Despite the intrinsic resolution of the RPCs, the CMS trigger system is based in the 25 ns sampling.
- Data transmission speed is about 1.6 Gbps
- Control, diagnostic and monitoring of the Link system has been designed based on CCU ring (combination of copper cable and fiber optic), very susceptible to electromagnetic interference



- CCU ring is not very fast, the bandwidth (40 MHz) share between 12 control boards
- Most radiation hard electronic components are obsoleted
- Electronic aging, presently the Link system at the end of LS2 is already 13 years old

Control, Diagnostic and Synchronization of New Link System using New Slow Controller



I am a bit out of my depth here but I appreciated the clear presentation

- New Link system improves the muon hit time to 1.56 ns and using the high bandwidth of data transmission (10.24 Gbps) will increase the speed of data taking of RPC chambers

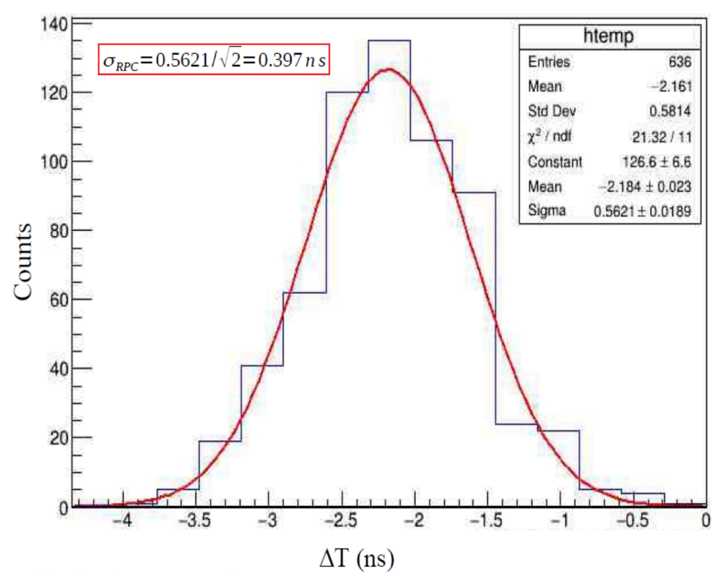
XV workshop on Resistive Plate Chambers and Related Detectors (RPC2020)
Roma, 10 - 14 February 2020.

Performance of the BIS78 RPC detectors: a new concept of electronics and detector integration for high-rate and fast timing large size RPCs

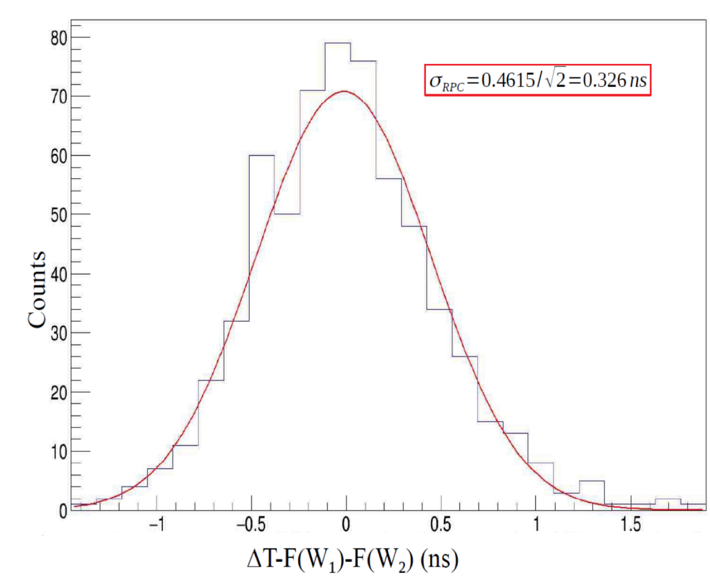
Very impressive time resolution for 1 mm gap RPC

BIS78 RPCs performance – Time resolution

Raw time resolution without correction



Time resolution with time walk correction

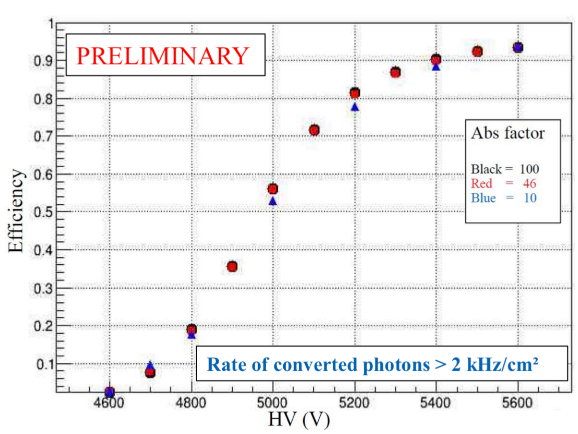


Obtained at HV=5.6 kV

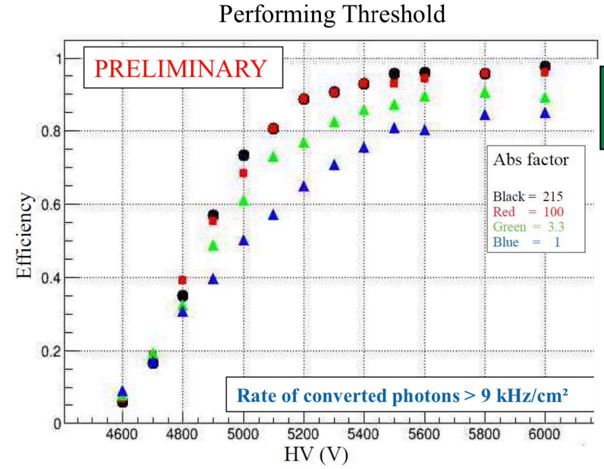
Test at GIF ++

BIS78 RPCs performance – Rate capability

Conservative Threshold



Performing Threshold



Looks very impressive : this breakthrough needs confirmation

Conclusion

The new generation of RPC detector equipped with the newly developed Front-End electronics achieved the following:

1. **High performance along with huge uniformity**
2. **Raw time resolution of 400 ps and 330 ps considering the time walk correction**
3. ***Rate capability*** **> 9 kHz/cm²**

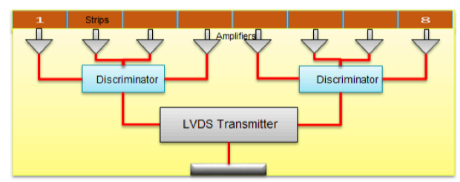
Towards a two-dimensional readout of the improved CMS Resistive Plate Chamber with a new Front-End electronics

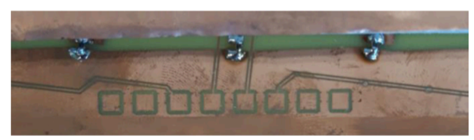
Sabino Meola*

Front-End Electronics

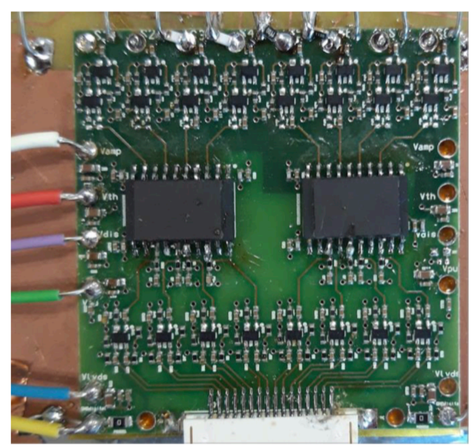
More info: https://arxiv.org/pdf/1806.04113.pdf

- **Front-End Electronics developed at Rome Tor Vergata**
  - Front-End: 8 pre-amps + 2 custom ASIC discriminators
  - Directly mounted on the PCB
  - PullUp and LVDS transmitters integrated
  - Typical achievable thresholds: ~ 1-20 fC
  - 5 LV adjustables: *TH/DISC/AMP/PU/LVDS*





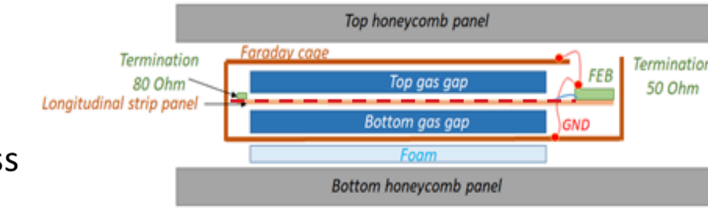
Amplifier	Discriminator
Si Bipolar Junction Transistor (BJT) technology	Si-Ge Hetero Junction bipolar Transistor (HJT) technology
Sensitivity: 0.2-0.4 mV/fC	Minimum threshold 0.5 mV
Low intr. noise: 1000 e- RMS	Regulation within order of mV
Possibility to match input impedance to strip	Time Over Threshold



Radiation Hardness: 1 Mrad, 10^{13} n/cm^2

- A real size iRPC 1.4 mm with new Tor Vergata front-end electronics has been tested with cosmics.
  - Muon performance (efficiency and cluster size) measured for longitudinal and orthogonal strips separately
  - Combined Longitudinal+Orthogonal measurements driven by the orthogonal strips

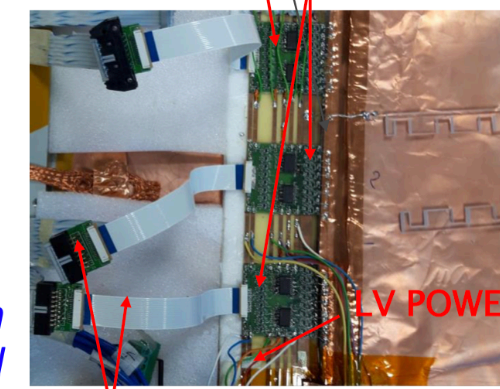
Improved RPC: Chamber Design



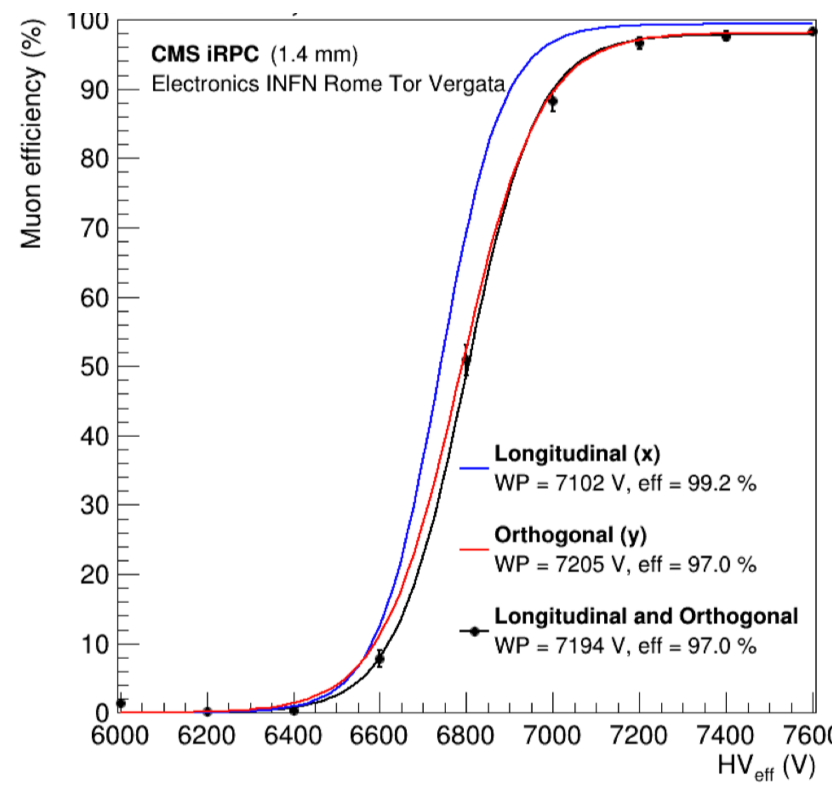
- **iRPC**
  - Double gap, top and bottom gaps
  - 1.4 mm electrode and gap thickness
  - Resistivity 0.9 - 3x10^{10} Ωcm
  - PCB strip plane (terminated), pitch ~ 4-8 mm, length ~ 1.6 m
  - Position resolution of the order of cm in both dimensions
  - RPC real size dimensions
    - Bases 58x100 cm
    - Lenght 167 cm

→ Integration of electronics with chamber needed with low threshold and noise reduction

FEs mounted on PCB



SIGNAL (LVDS) to TDC



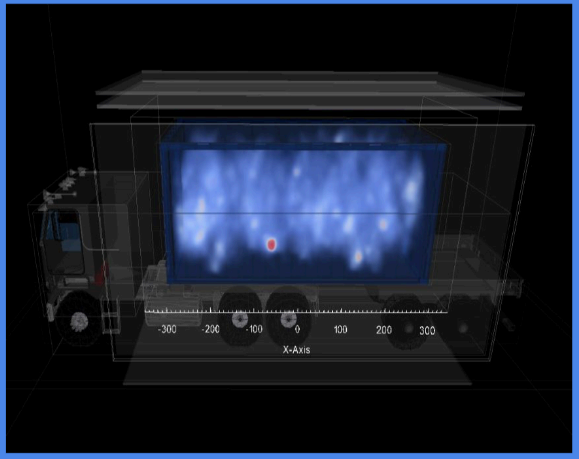
X-Y strip readout works well
No time resolution presented

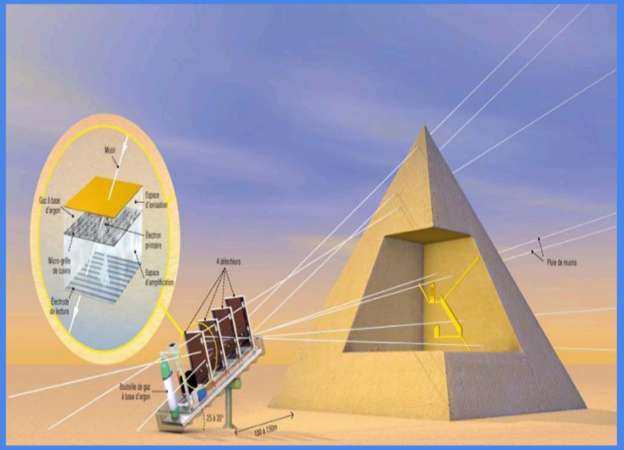
Precise Tracking of Cosmic Muons Using Time-over-Threshold Property of NINO ASICs

S. Tripathy[1,2], J. Datta[1,2], N. Majumdar[1], S. Mukhopadhyay[1], S. Sarkar[1]

Motivations

- Natural Cosmic Ray source.
- Other applications like imaging large structures, monitoring volcanoes anc
- Based on Coulomb Scattering. (High-Z/ Low-Z discrimination)
- Accurate measurement of scattering angle requires precise tracking.





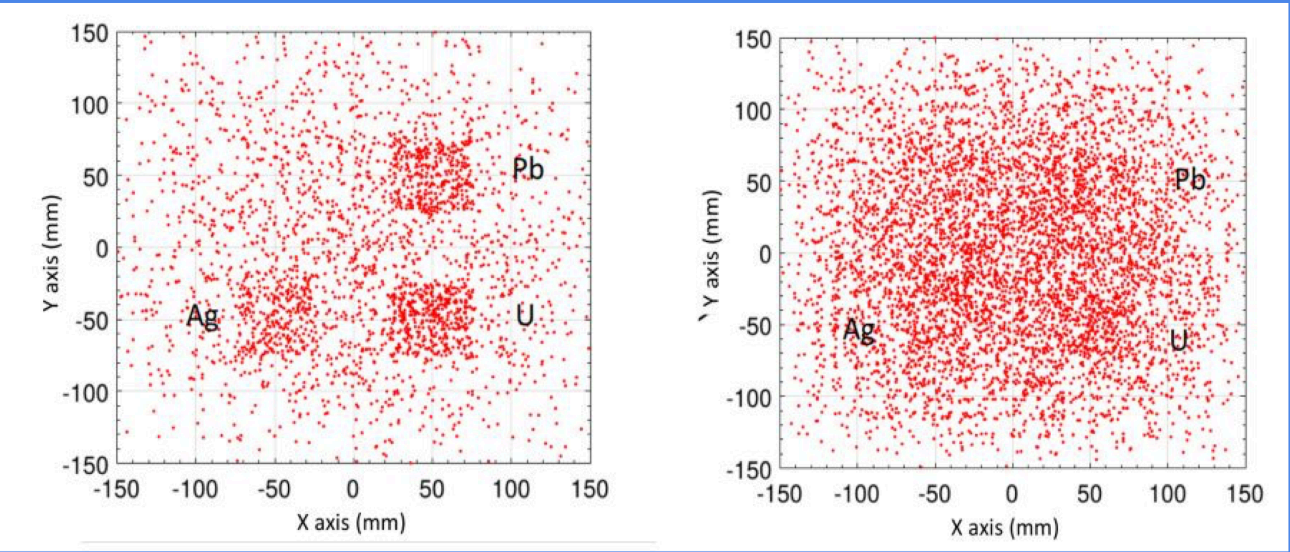
Summary

- TOT measurement property of NINO has been exploited to find the center of the hits.
- A simple FPGA based DAQ for the cosmic muon imaging system.
- Use of PLL to use 2 different clks, one for event selection(50 MHz) and other for pulse width measurement (500 MHz).
- Pulse widths of the detector at avalanche and nearly streamer mode voltages have been studied.

Future Targets

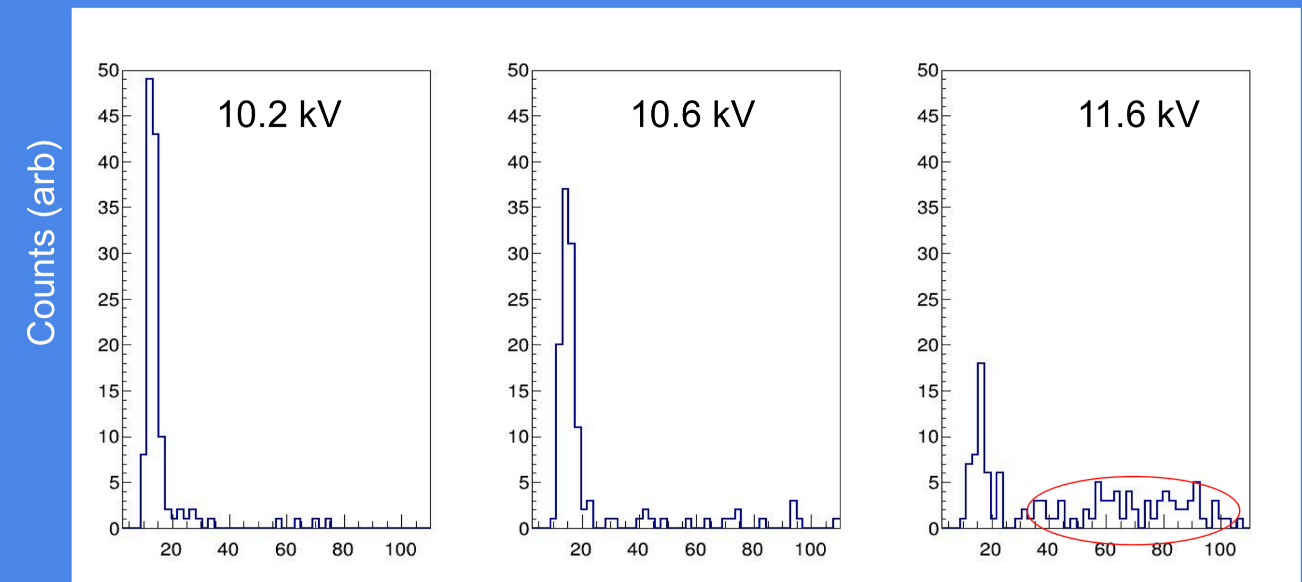
- Calibration of o/p pulse and i/p charge has to be done.
- Use of thinner strips for better resolution
- Better FPGA clk for precise measurement,
- Utilize in the muon imaging system.

Effect of Resolution on Image reconstruction



Ideal Resolution 1 cm Resolution

Pulse Width at different Working Voltage



Width (ns)

Time-over-Threshold used to select the largest pulse height

NINO is a fine front-end ASIC!

Front-End electronics for CMS iRPC detectors

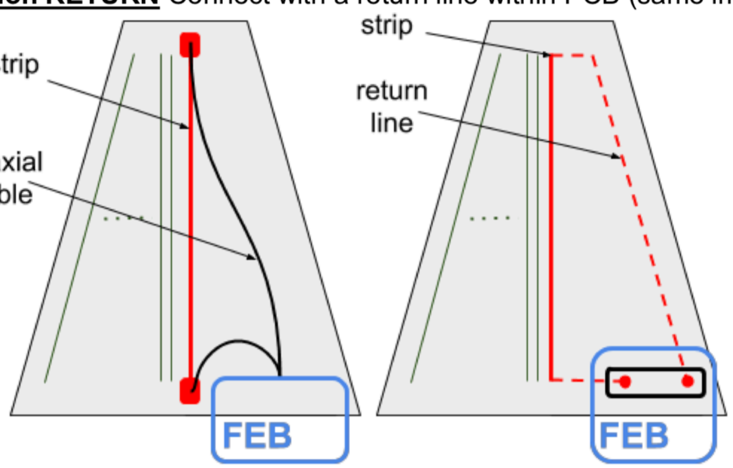
Shchablo Konstantin[1] on behalf of the CMS Muon group

RPC2020, Roma

RETURN & COAX redout of PCB-strip panels

Solution COAX Connect with coaxial cables. Cable impedance = 50 Ω..

Solution RETURN Connect with a return line within PCB (same impedance 45 Ω).



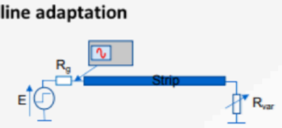
To minimize signal reflections, the stripline impedance must be controlled up to the asic.
3 methods were used to measure strip impedance :

- **Direct measurement of line parameters with a RLC meter (at 2MHz)**

Side	C_p (pF)	G_p (µS)	L_s (nH)	R_s (mΩ)	Z_c (Ω)
Wide	244	934	482	467	**43,5**
Narrow	244	934	487	461	**44**

- **Direct measurement with potentiometric line adaptation**

Z_c= 46 Ω



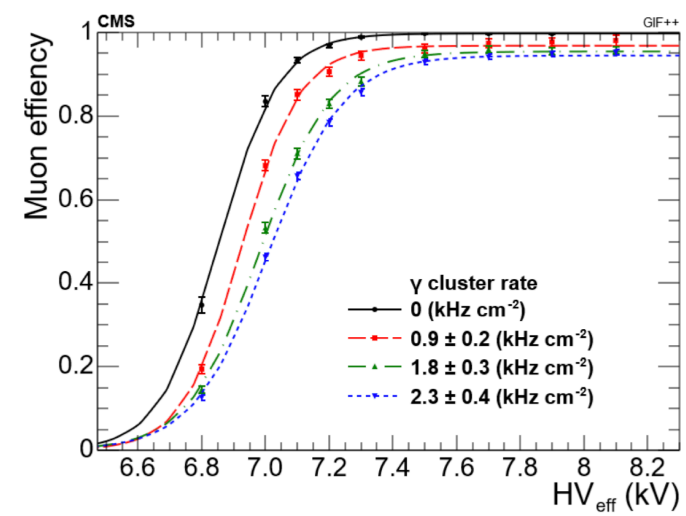
- **Reflection Method**

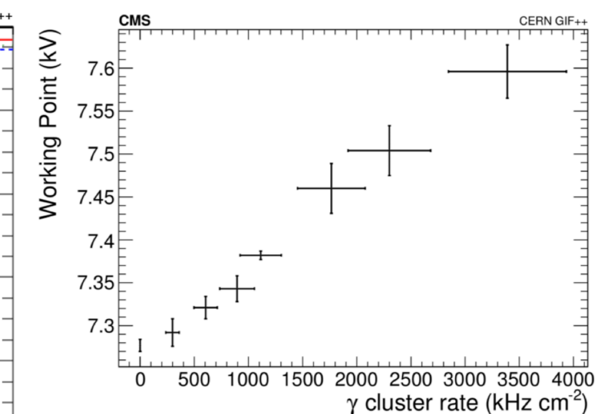
$$Z_c = \frac{R_g . V_s}{E - V_s}$$

Z_c=41Ω

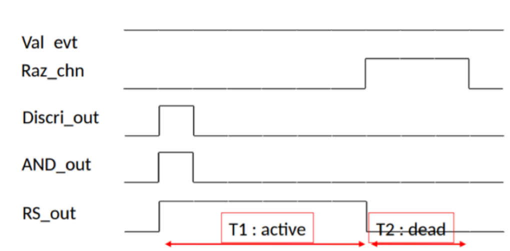
14 TBq 137Cesium is used in GIF++ with different attenuation coefficients is used to obtain different gamma irradiation levels.

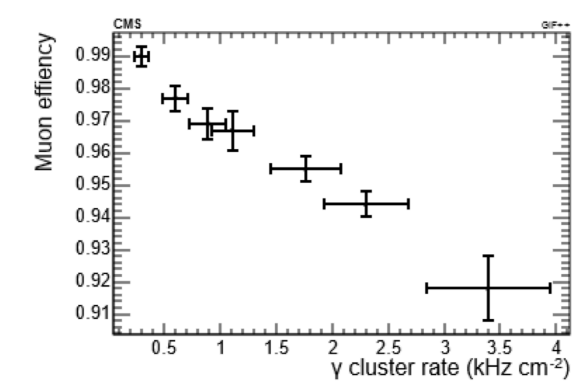
To test our chambers a rate of up to **2 kHz·cm⁻²** needs to be **seen** in our chamber.





Dead Time of FEBs





Want to mount electronics at one end - but readout both ends

Excellent results even at 2 kHz/cm2

Performance studies of RPC detectors with new environmentally friendly gas mixtures in presence of LHC-like radiation background

R. Guida, B. Mandelli, *G. Rigoletti*

Selected HFO based gas mixtures

Over 50 different gas mixtures tested

Tested 3, 4 and **5 components** gas mixtures

HFO based gas mixture

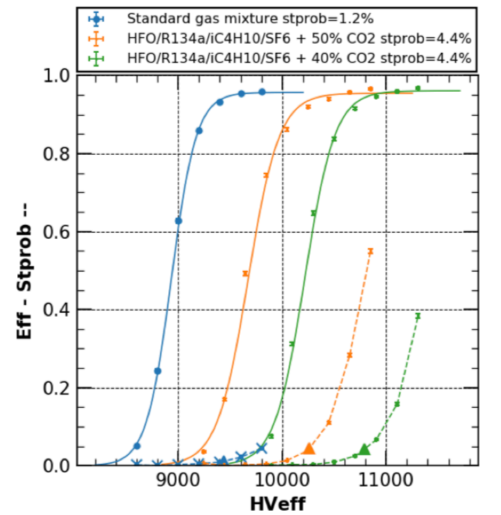
Performed best together with ***CO_2*** and ***R134a***

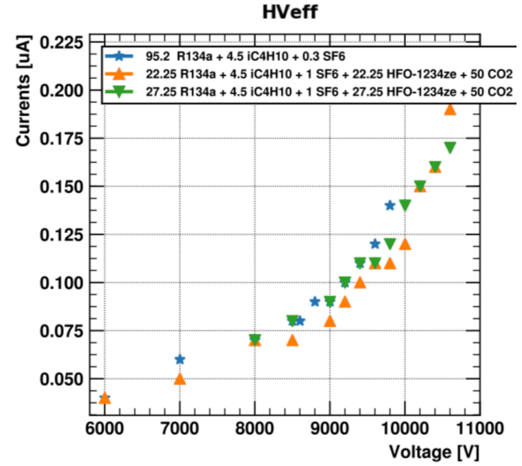
HFO + CO_2 + R134a + 4.5% iC_4H_{10} + 1% SF_6

Fine tuning of HFO gas mixtures

Two candidates that can compete with the standard gas mixture

Gas mixture	Working point [V]	St. Prob. [%]	Pulse charge av [pC]	Pulse charge st [pC]	Cluster size [#/2cm]	Time resolution [ns]
Standard	9440	1.2	0.8	10.1	2	1.9
HFO/R134a/iC4H10/SF6 + 50% CO2	10260	4.4	1.1	14.7	2.3	2
HFO/R134a/iC4H10/SF6 + 40% CO2	10790	4.4	1.1	11.8	2.2	1.8





Gianluca Rigoletti

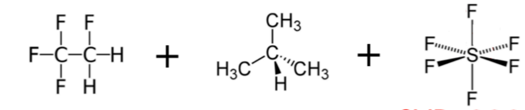
Greenhouse Gases in RPC operation

RPC gas mixture at LHC

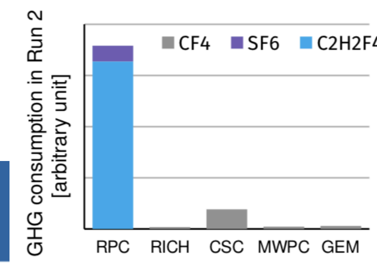
→ Made out of **three** components

→ **High Global Warming Potential** due to presence of *SF6* and *R134a*

~95% 4-5% 0.3%



GWP 1430 GWP 3.3 GWP 22800



GHG emissions

→ The **main** contribution is from ***R134a***

→ *R134a* and *SF6* due to ***leaks*** at ***detector level*** at ATLAS and CMS RPCs

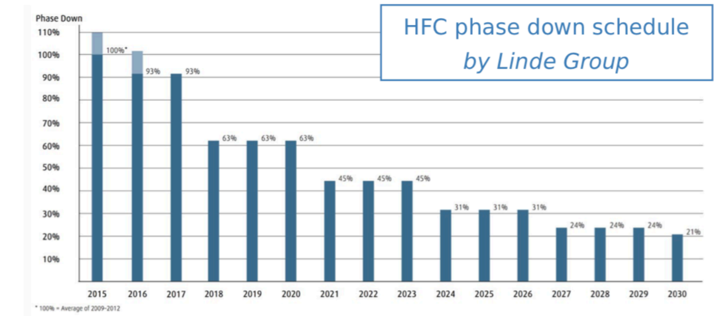
→ A campaign of ***leaks reparation*** is currently ongoing

European Union F- regulation

→ **Limit the total amount** of F- gases that can be sold → Phase down process

→ **Banning the use of F- gases** where eco friendly alternatives are present

→ **Preventing emissions** by requiring proper checks and servicing of the gases and recovery of the gases



Conclusions

R&D goal: find an eco-friendly gas mixture compatible with the current ATLAS and CMS RPC systems

Eco friendly gas mixture for RPCs

- HFO not suitable for direct substitution to R134a in currents 2mm gap RPCs
- HFO requires an inert gas to work at lower working points (<12 kV)

Characterization of RPCs with eco-friendly gas mixtures

- More than 50 different gas mixture tested
- HFO + CO_2 shows similar properties to the standard gas mixture

SF6 alternatives studies are on going

- Difficult to find eco-friendly gas with matching performance or safety
- Some promising gas mixtures show similar performance

RPCs operation with eco-friendly gas mixtures under background irradiation

- RPC tested up to HL-LHC expected rate (~300 Hz/cm^2 counting rate)
- Streamer probability and currents are slightly higher for HFO based gas mixtures
- Long term performance studies of eco-friendly mixture are currenly going on
- HFO seems to break more easily to R134a: studies ongoing on the causes and possible solutions

Personally I applaud these studies of gas mixtures - please continue!

RPC2020

XV Workshop on Resistive Plate Chambers and related detectors

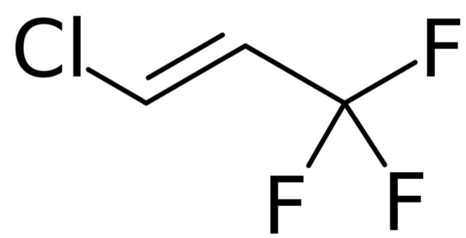
Characterization of new eco friendly gas mixtures for RPCs mainly based on HFO

By : PROTO GIORGIA
on behalf of Roma Tor Vergata group
Rome 14 Febbraio 2020

Measurements Of Total Charge :)
Total charge important for rate capability

New HFO-1233zd – Molecular description and measurement strategy

- More electronegative than HFO-1234zd
- Heavier than HFO-1234zd



- $HFO-1233zd/CO_2/i-C_4H_{10}/SF_6$=28%/66%/5%/1%

the first signal was at **14 kV**!!!

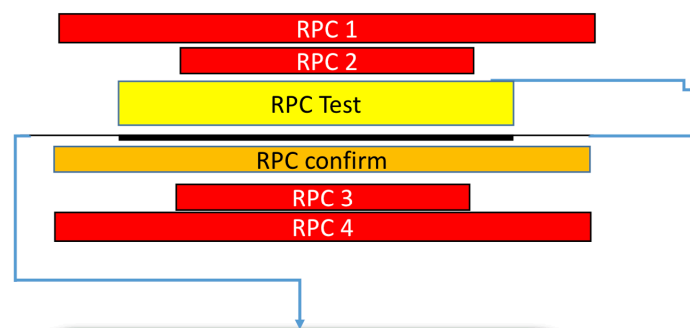
- Starting point

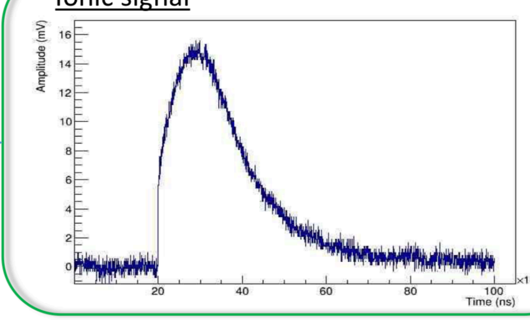
$HFO-1233zd/CO_2/i-C_4H_{10}/SF_6$ = 16%/78%/5%/1

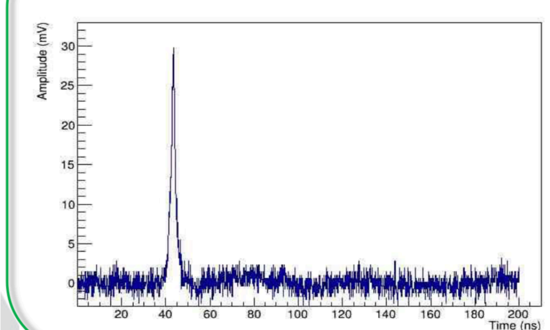
Removing SF_6

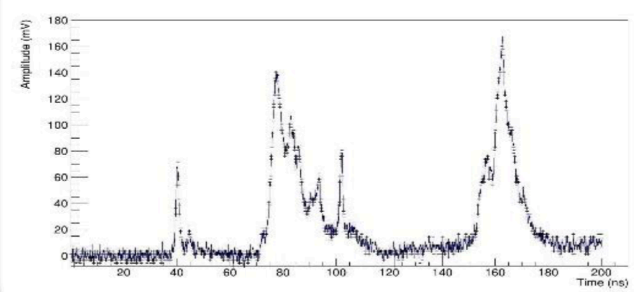
Adding i-Butane

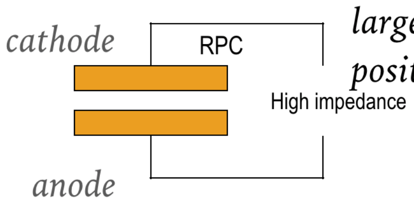
Experimental Setup



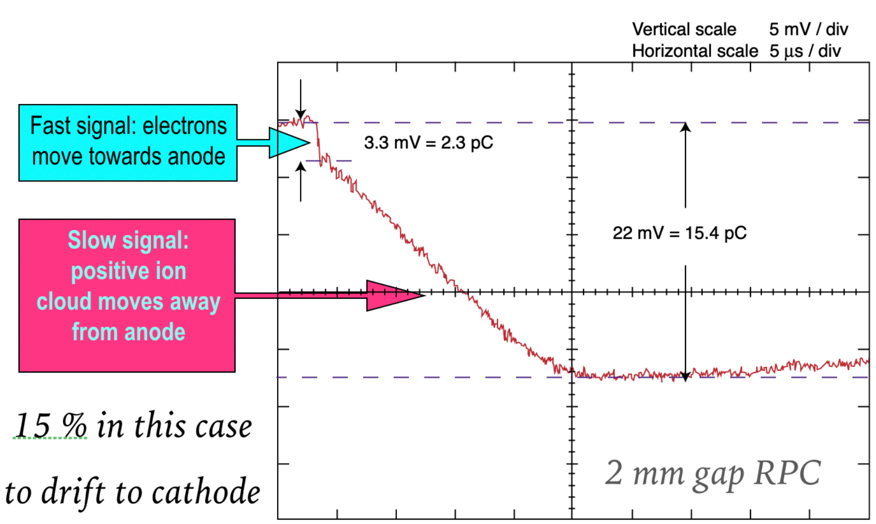








largest part of signal is generated by positive ions drifting back to cathode



fast/total = 3.3/22 = 15 % in this case

25 µs for positive ions to drift to cathode

Personally I applaud this study of gas mixtures - especially this fast/total charge measurement - please continue!

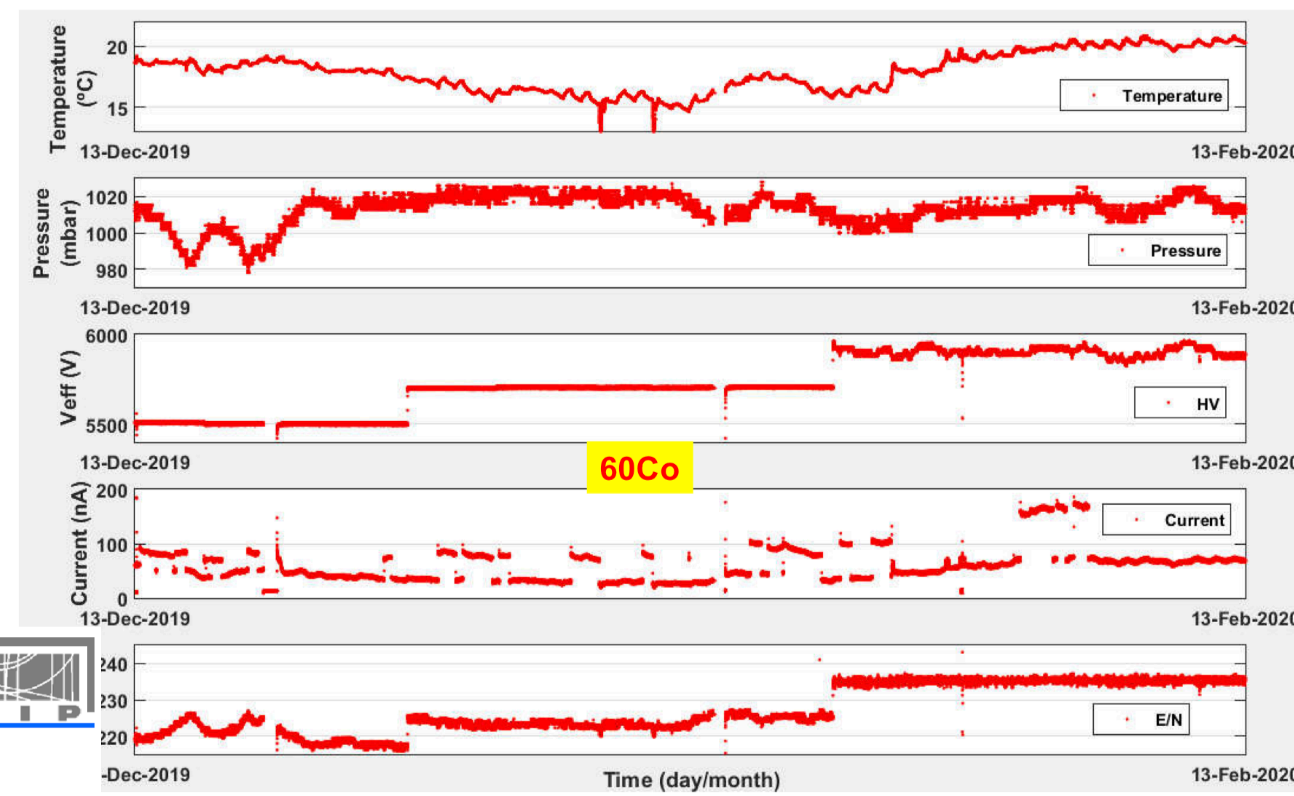
New advances in very low gas consumption

Another LIP-Coimbra contribution

P. Assis, A. Blanco, P. Fonte, L. Lopes, M. Pimenta

- **The "open" questions related with R-134a and SF_6**
  - **GWP**
  - **Price increase**
  - **No "real" substitutes that assure acceptable performances**
- **The challenge, for sure the most important**
  - **Build a zero gas flow RPC**

The history – Zero gas flow from 13-12-2019



CONCLUSIONS and Future Work

- **After 2 months the chamber stays stable and no degradation is observed.**
- **Chamber is frequently irradiated with 60Co, increasing the current by a factor 3 and no effect is observed in the "background" current.**
- **We are far from claiming the miracle!!, but it seems to be a productive way to go.**

A second chamber (twin) was build and has shown the same performance.

A truly zero gas flow:
very interesting study
Good for Cosmic ray operation

R&D on gas recirculation and recuperation systems for RPC detectors

M. Corbetta, R. Guida, B. Mandelli, G. Rigoletti
CERN, EP-DT Gas Team

Conclusions

R&D program aims in developing systems allowing to optimize GHG usage:

- For many gases used today there is no "easy" replacement available
- Availability and price of used GHGs can be affected (one more good reason for optimizing consumption)

Four strategies identified:

- **Optimization of current technologies**
  - Particular attention to gas system and detector operation
  - Gas systems development beyond original design
  - The specific case of ATLAS and CMS RPC detector systems
  - Improved/higher gas recirculation
  - Controls, Purifier and other module upgrades (here only example of distribution was presented)
  - Development of small gas recirculation system for laboratory application
- **Gas recuperation plant**
  - Recuperation system for R134a, SF_6 will be effective if leaks at detector will be reduced
  - R&D costs for R134a recuperation system is well justified by running costs
  - R134a recuperation prototype0 showed good performance (both quality and efficiency)

In my opinion - this is an essential and serious study - however I worry about the high flow rates needed - are there strange compounds being produced - are they really being removed or can they slowly build upon in recirculating systems

Greenhouse gases used for particle detection

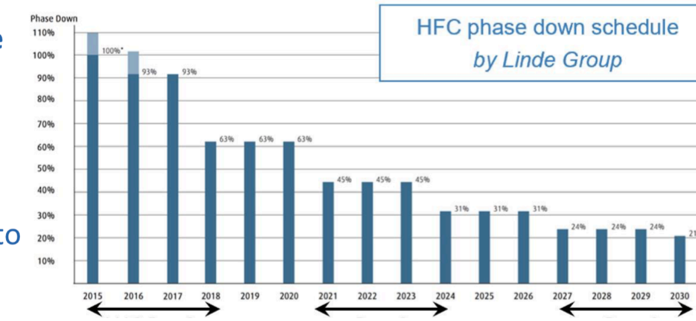
GHGs like R134a ($C_2H_2F_4$), CF_4, SF6, C_4F_{10}, … are used by several particle detector systems at the LHC experiments

Gas	GWP - 100 years
$C_2H_2F_4$	1430
CF_4	7390
SF_6	22800

Due to the environmental risk, "**F-gas regulations**" started to appear.
For example, the EU517/2014 is:

- **Limiting** the total amount to one-fifth of 2014 sales by 2030
- **Banning** the use of F-gases where less harmful alternatives are available.
- **Preventing** emissions of F-gases by requiring checks, proper servicing and recovery of gases.

F-gas regulations already affected **gas price** (especially for R134a in EU)
Future **availability** can also be affected (especially where replacements are available)
For the moment CERN/Switzerland seems to be not affected



Conclusions

- **New eco-gases**
  - HFO1234ze promising but difficult for already installed detectors (many constrains)
  - Many tests ongoing everywhere
  - New common effort: joint EcoGas collaboration for RPC at GIF++
  - However, it does not look for tomorrow
- **GHGs abatement/disposal**
  - Commercial systems exist. Adopted when gases cannot be reused.
  - Quite heavy infrastructures required
  - Gas availability can become a real problem in the future it is always better to minimize consumptio

Optimized gas systems, new recirculation plants, … are

- Nevertheless increasing complexity for operation
- Development and application of strict maintenance and operation procedures

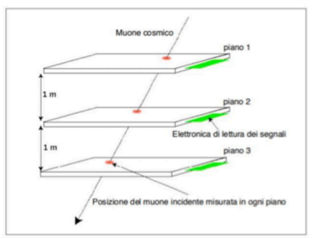
A simulation tool for MRPC telescopes of the EEE project

Giuseppe Mandaglio for EEE Collaboration

Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi

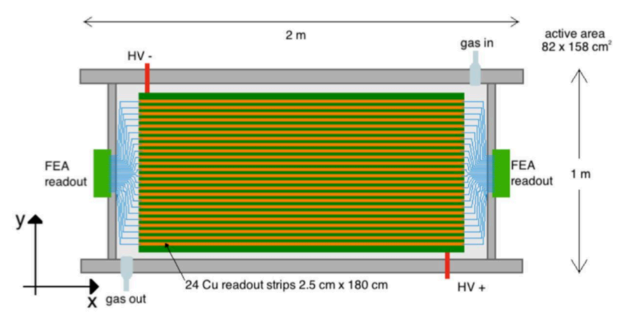
Dipartimento MIFT - University of Messina and INFN-Sezione di Catania

MRPC (Multigap Resistive Plate Chamber) telescope

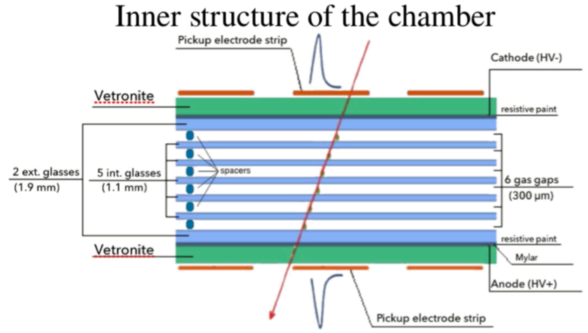


Picture of CATA-01 telescope hosted in UNICT

Top view of a chamber

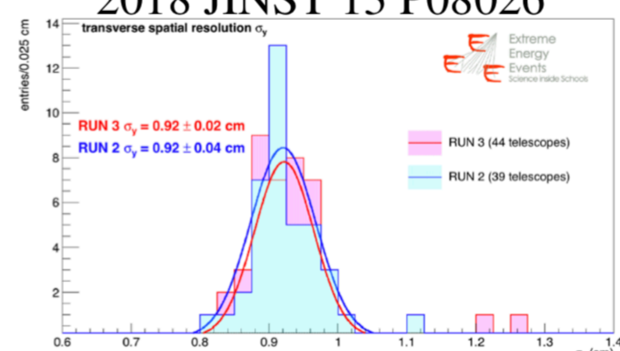


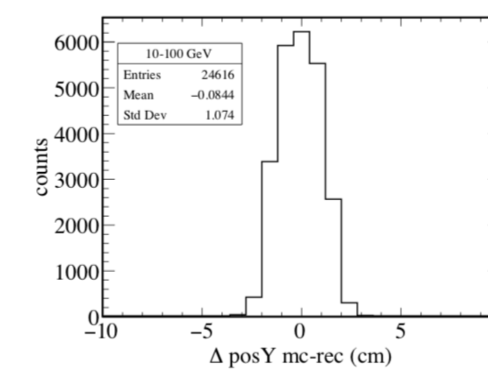
Inner structure of the chamber

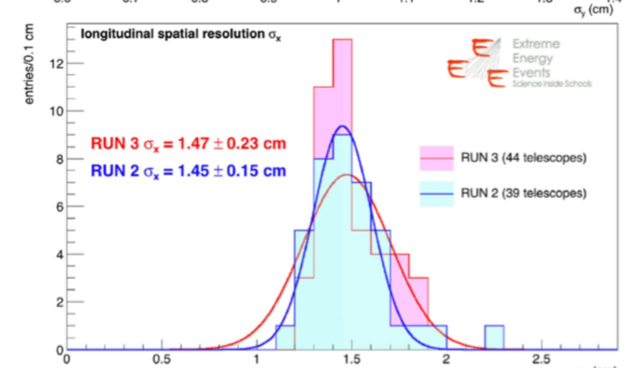


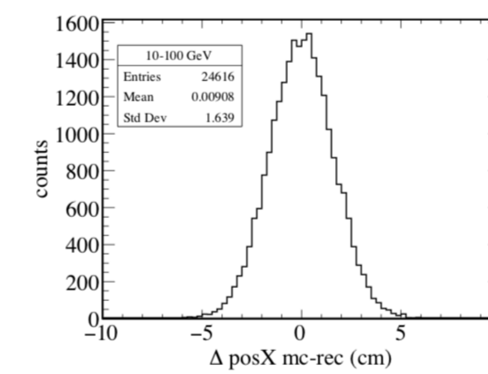
Experimental and simulated spatial resolution estimation E_{μ}=10-100 GeV

2018 JINST 13 P08026









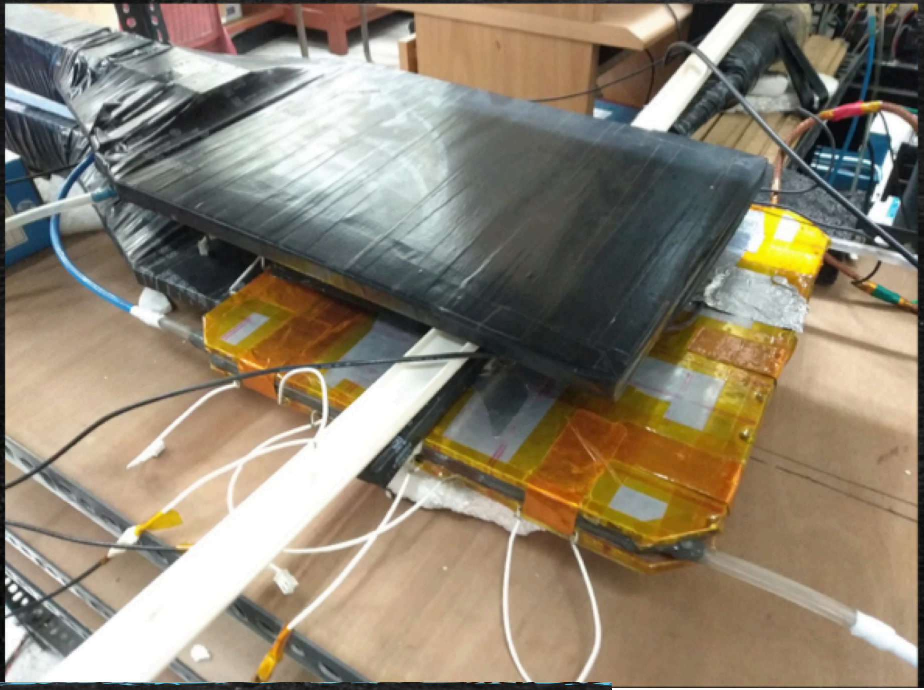
Experimental and simulated resolution estimations are in good agreement.

$\sigma_y = 0.92 \pm 0.02$ cm vs $\sigma_y = 1.074$ cm and $\sigma_x = 1.47 \pm 0.23$ cm vs $\sigma_x = 1.639$ cm

Study of Streamer Development in Resistive Plate Chamber

Presented By
Jaydeep Datta
Homi Bhabha National Institute, Mumb

Experimental Procedure



- We have used a 30 cm x 30 cm glass RPC.
- Coincidence of three scintillator signals are used as muon trigger.
- We have made spatial coincidence of the scintillators with one of the RPC strip.
- Data acquisition has been done for the coincident strip and one strip from either side of it, using oscilloscope and python based code on a computer.
- Data analysis has been done offline using ROOT and C++ based code.

The following table compares the streamer probability from simulation and experiment.

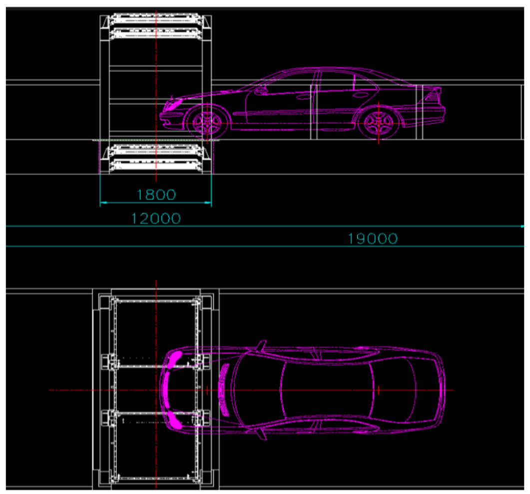
Voltage (in V)	Streamer Probability from Experiment	Streamer Probability From simulation
9400	0.00087 +/- 0.00011	0.008
9600	0.00091 +/- 0.00015	0.008
9800	0.00411 +/- 0.00181	0.0135
10000	0.02681 +/- 0.00052	0.0224

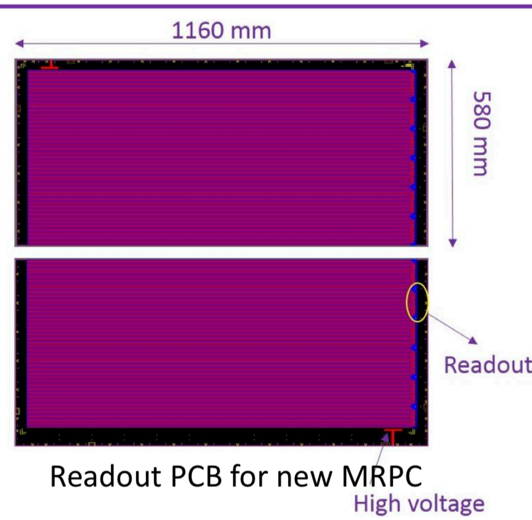
Need to suppress streamers in glass RPCs
Recall the Frascati experience (recover chambers by flowing ammonia)

MRPC technology used in muon tomography

X.L Chen

Second generation MRPC for car detection





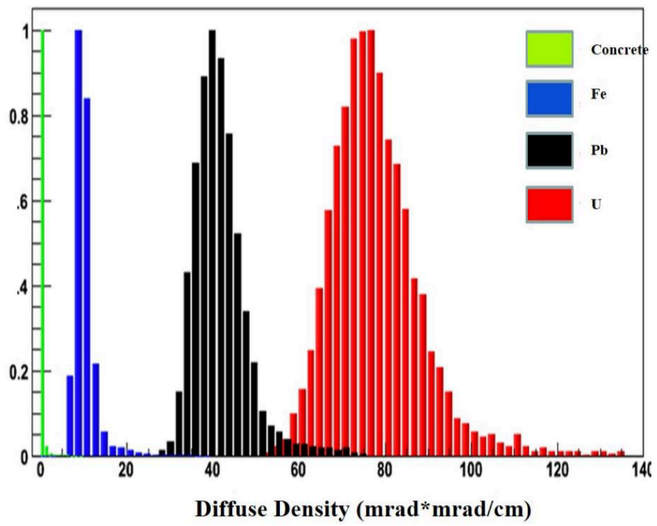
Readout PCB for new MRPC

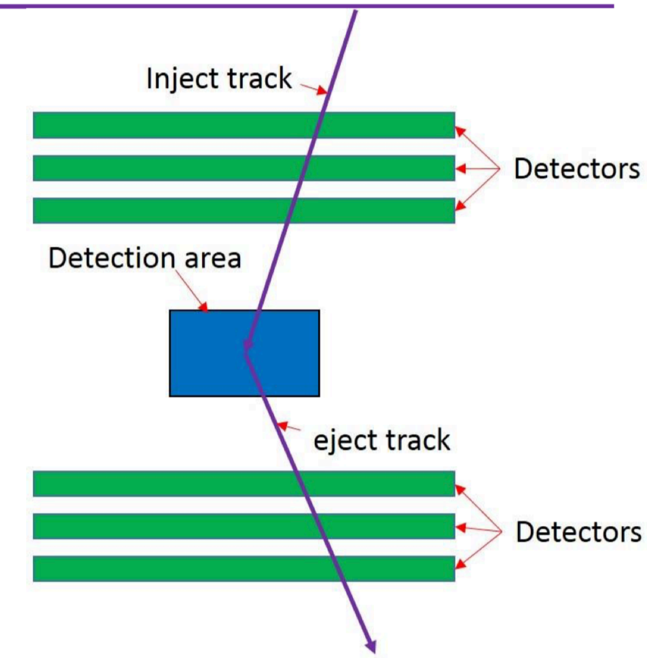
Car detection for industrial application

- Project has four layers, each layer sensitive area reach 1m*3m
- Need: larger sensitive area and smart structure to MRPC
- Work stably at difference temperature
- Also two board in one readout electrode

I find the operation of MRPC with no flow of gas very interesting

What's muon tomography

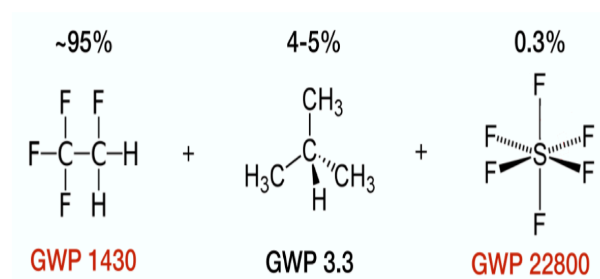


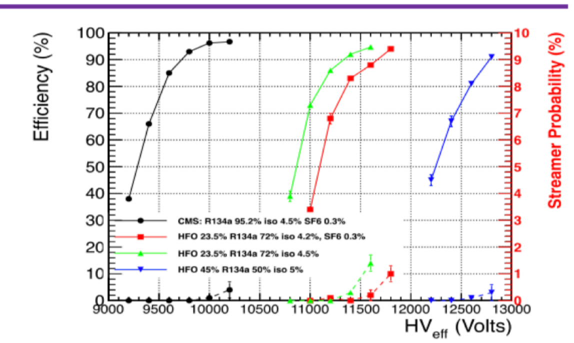


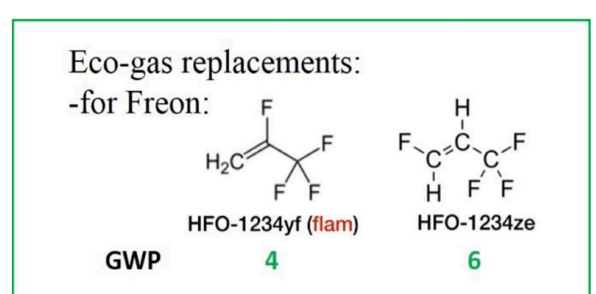
- When muon past through H-Z object, big diffuse angle
- Through track detector get inject and eject tract
- Get the diffuse angle and scatter point, reconstruction detection area information
- The key point is track detector

SMRPC(sealed MRPC) development

Motivation:







- European Union "F-gas regulation": Limiting the total amount of F-gases that can be sold in the EU; Banning the use of F-gases in many new types of equipment; Preventing emissions of F-gases from existing equipment
- High working point
- High cost, 5-7 times cost than Freon
- Eco-gas still on study

XV Workshop on Resistive Plate Chambers and Related Detectors RPC2020

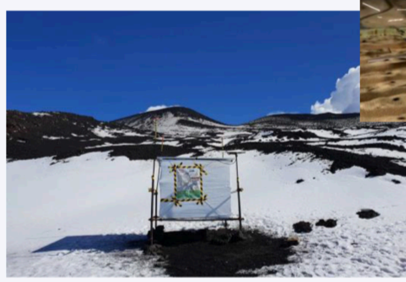
Use of the EEE MRPC telescopes to investigate possible instabilities of civil structures on a long time-scale

Chiara Pinto* for the EEE Collaboration

Applications of secondary cosmic rays

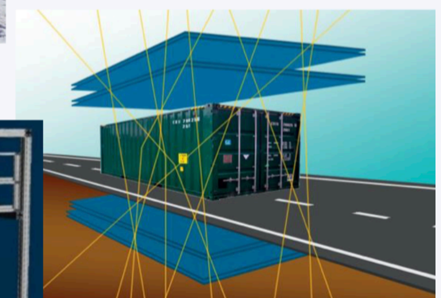
MUON ABSORPTION

- *Vulcanology*
- *Underground measurements*
- *Archaelogy*



MUON SCATTERING

- *Homeland security*
- *Safety – Nuclear reactor and waste*

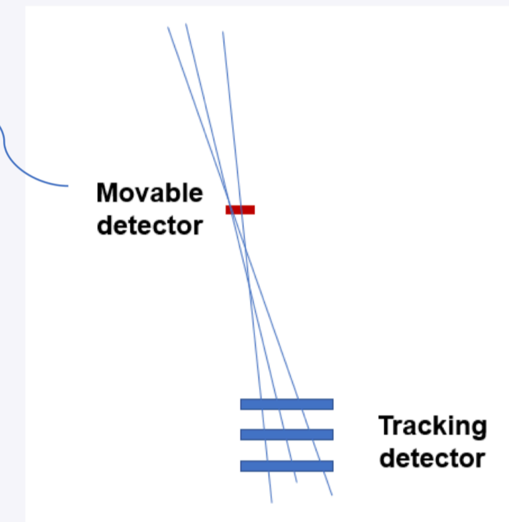


→ **Long term building stability monitoring**

Cosmic muons as a tool to monitor the stability of civil structures on a long-time scale

THE IDEA ➡ **Muons passing through a tracking detector and additional detectors are used as a tool to monitor small (mm) shifts of parts of the structure over long time periods.**

Moved to mimic possible deformations of the building



Extensive simulations and prototype detectors by Brescia Pavia groups (G.Bonomi et al.)

Technique applied to “Palazzo della Loggia” in Brescia as a case study.

Depend on: capability of the main tracking detector, geometry and position of the additional detectors, constant response of detectors, acquisition time,.. ⬅ ***PERFORMANCE***

Personally I like all these non-particle physics experiment

R&D must continue

Pile of discarded MRPCs

Bac half full of broken glass sheets

So what is next?

- Gas studies must continue… are the new low GWP gasses really stable enough to use at high rates

- Ageing - is this an issue?

- Better electronics - always useful - however latest may also offer a breakthrough

- Goal : 20 ps at 100 kHz/cm^2