Summary

Roberto Cardiarelli and Ingo Deppner

A little bit of statistics

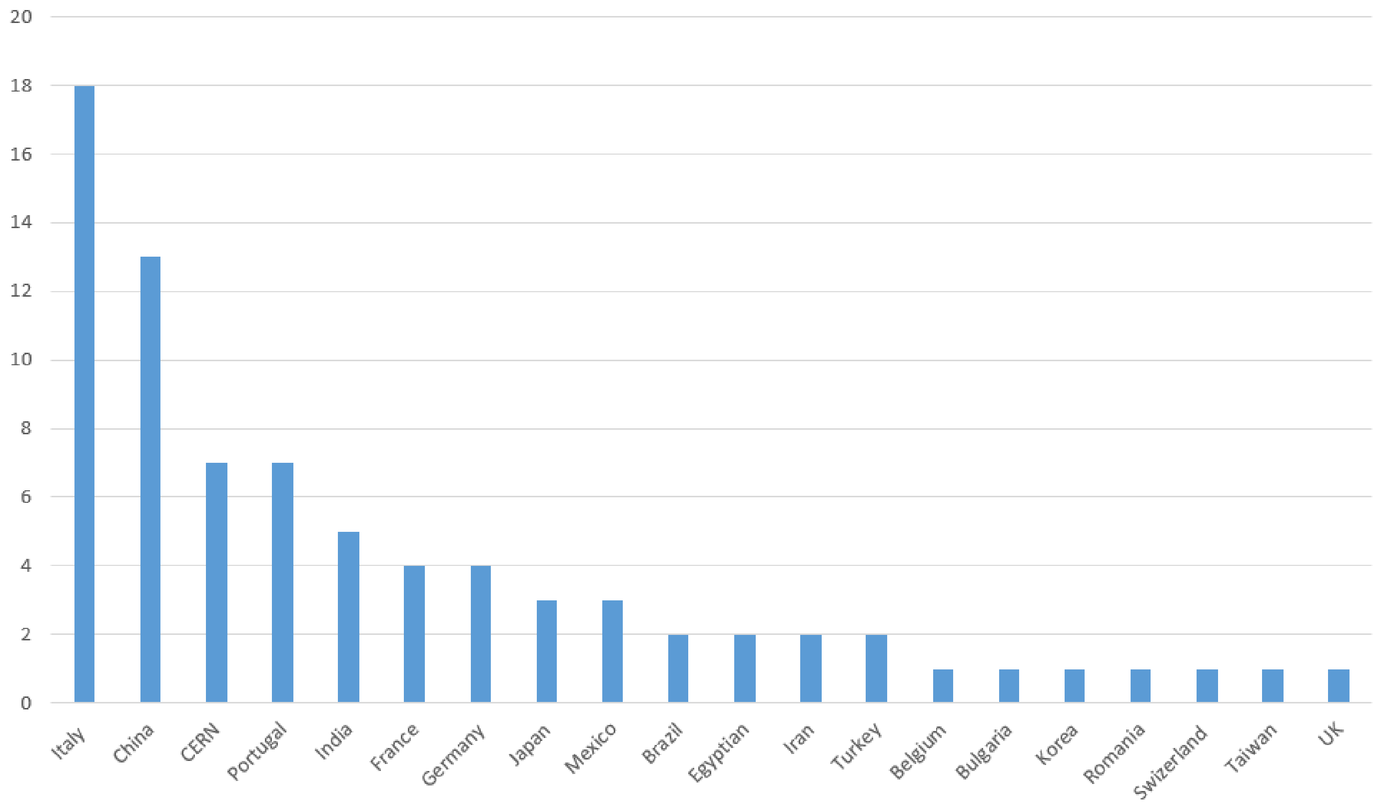
56 Talks (4 days)

26 Poster (3 h)

our time budget for this summary is 20 min => 14 s/contribution

from 20 different countries

Indeed a international conference



Outline

- Discussed topics
- 2 selected challenge which affects the RPC as well as the MRPC community in near future

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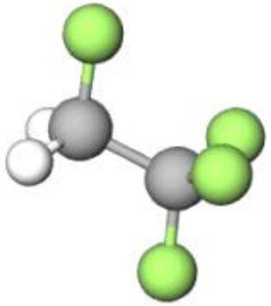
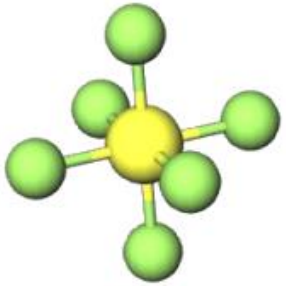
What were the most shown formulas on this conference?

$$\phi_{max} \leq \frac{\Delta V}{\rho d \bar{q}}$$

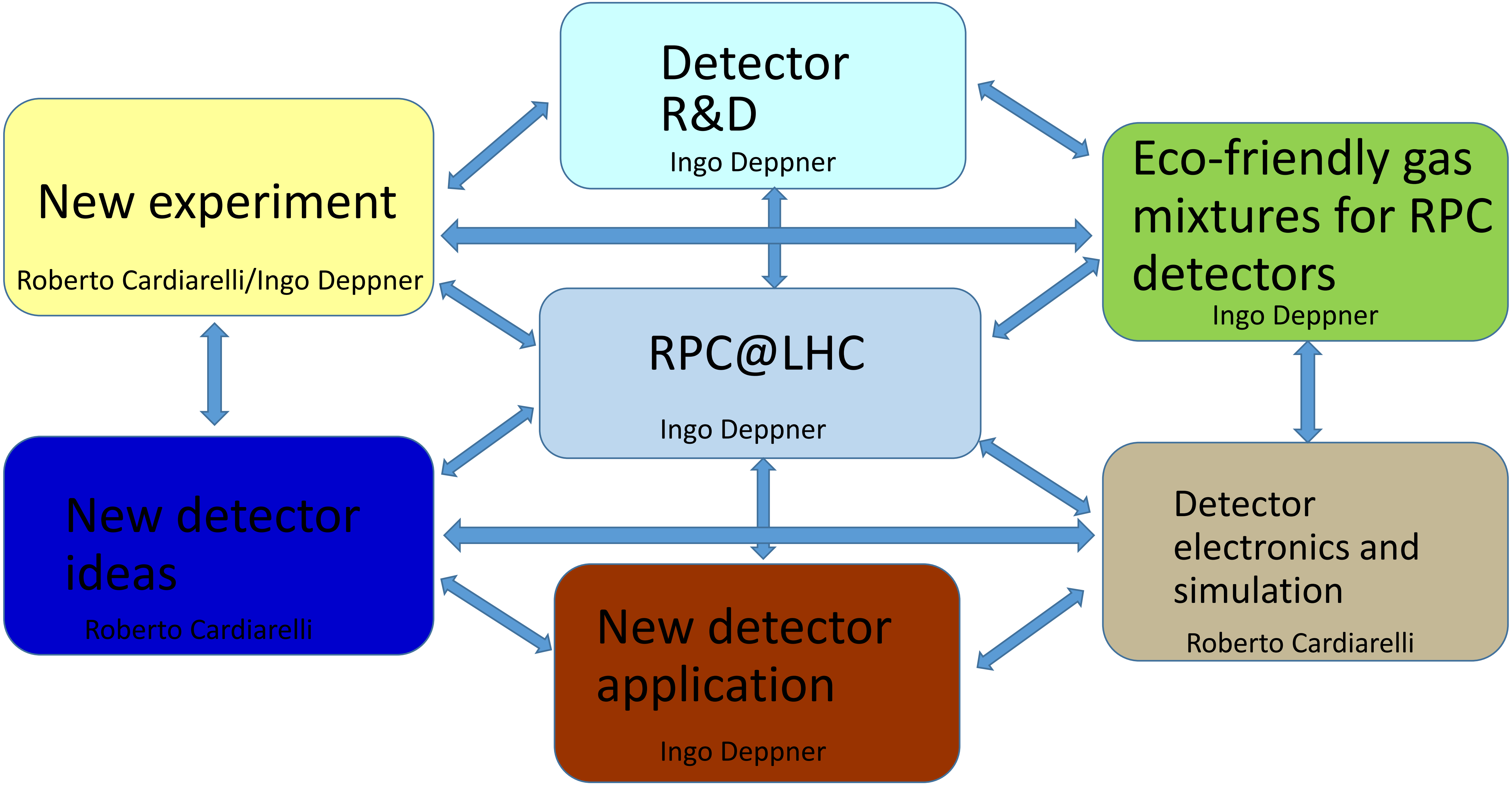


GWP ($C_2H_2F_4$) ~ 1430

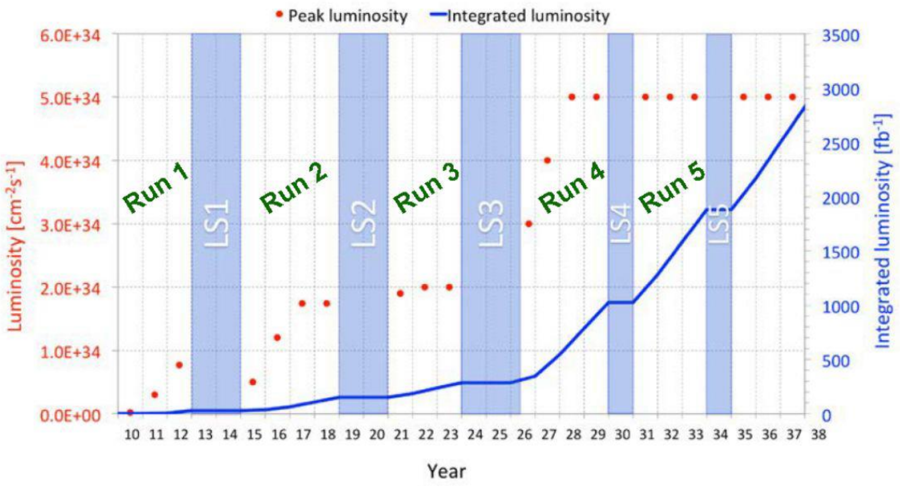


GWP (SF_6) ~ 22800

Discussed topics



RPC@LHC



- ALICE muon system + upgrades, 1 presentation
- ATLAS muon system + upgrades, 3 presentations
- CMS muon system + upgrades, 2 presentations

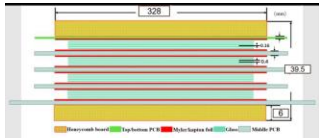
Observed issues during Run2:

- All 3 experiments experienced gas leaks and mitigation was only partially possible
  - some chambers could be repaired others were switched off
- HV, LV problems reported, PS connectors and cables replaced

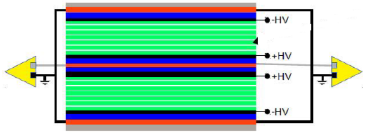
Upgrades:

- All 3 experiments have upgrade programs for Run4 und beyond to cope with the HL-LHC conditions
- Prototypes with increased rate capability installed during LS2 and being tested during Run 3
- A higher luminosity leads to higher detector aging -> long term stability tests at anticipated detector load required

New Experiments



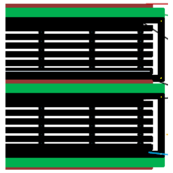
– **CEE (CSR-external Target Experiment), Lanzhou/China**
Gap size 160 μm, 24 gaps, time resolution 30 ps, discussed issues: reflections



(SHiP)

– **R3B (Reaction with Relativistic Radioactive Beams), GSI/Darmstadt/Germany**
Gap size 300 μm, 12 gaps, time resolution 100 ps, discussed issues: calibration

– **HADES TOF Forward Detector, GSI/Darmstadt/Germany**
Gap size 260 μm, 4 gaps, glass 2 mm -> 1 mm, time resolution 90 ps – 160 ps depending on rate, discussed issues: rate capability (material thickness, temperature), conclusion: 0.6 kHz/cm^2 @ 31ºC



– **π20 spectrometer (Japan Proton Accelerator Research Complex J-PARC) Tokai/Japan**
TOF-RPC: Gap size 260 μm, 10 gaps, time resolution 60 ps - 70 ps, discussed issues: HV electrode
TOF-tracker: Gap size 260 μm, 5 gaps, strip pitch 5 mm, spatial resolution 3.8 mm

– **CBM-TOF (Compressed Baryonic Matter) FAIR/Darmstadt/Germany**
Gap size 200 – 250 μm, 10 -12 gaps, time resolution 40 - 60 ps, discussed issues: high rate capability and gas aging

– **CALICE SDHCAL Calorimeter**, discussed issues: including timing information => RPC -> MRPC

– **CBM-MuCH (Compressed Baryonic Matter) FAIR/Darmstadt/Germany**
Gap size 2 mm, 1 gap, **requirement ~30 kHz/cm^2**, discussed issues: Test results obtained at GIF++ -> 90% efficiency at ~ 2.72MHz/cm2

– **ANUBIS, CODEX-β /CERN** Physics beyond SM
discussed issues: construction and usage of BIS7 chambers, first counter test results are promising

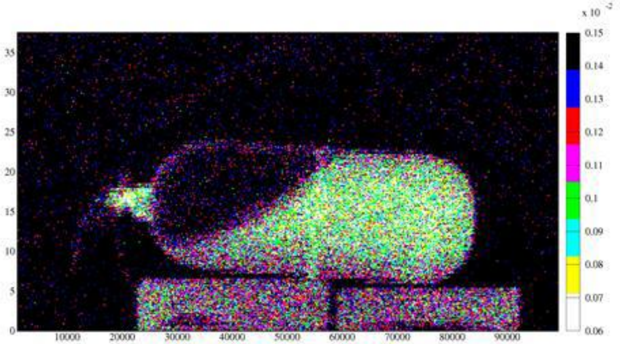
– Cosmic ray experiments – Rinaldo
– MATUSLA

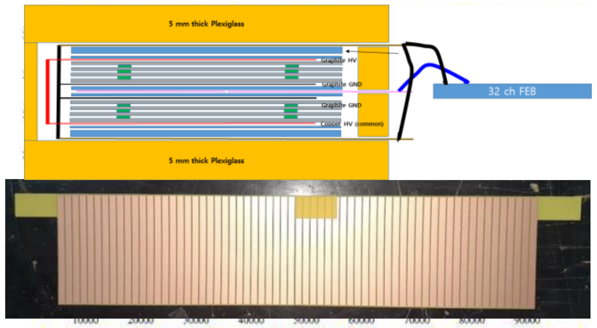
} **see summary by Roberto Cardiarelli**

New detector application

Tomography

Gammas (^{137}Cs source) 5%efficiency@HV=12.1kV
in a 7-cm deep vertical mode Detector
Position resolutions in the vertical ~2 mm and in the
Scanning direction ~ 2 mm or better

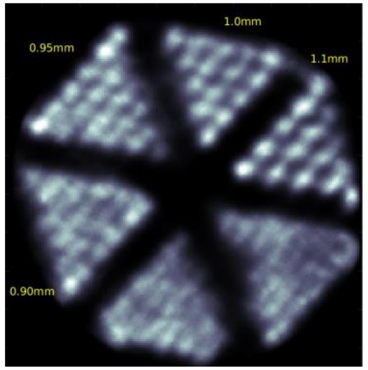


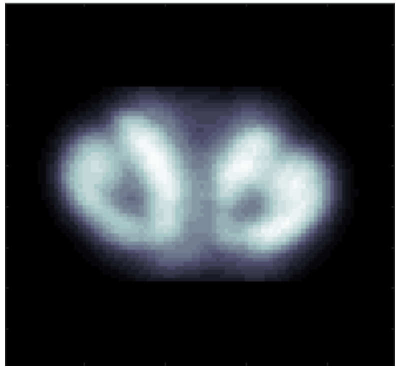


PET

2 presentations

- Radial resolution better than 1 mm
- Sensitivity of 0.09 %
- Thickness of MRPC limited





Muography

Transmission tomography

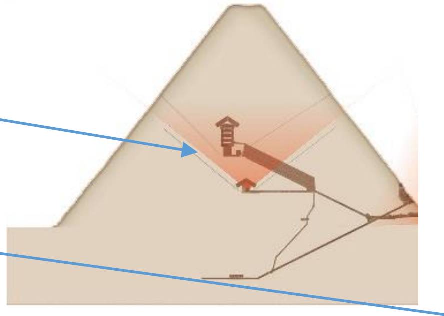
1 presentation

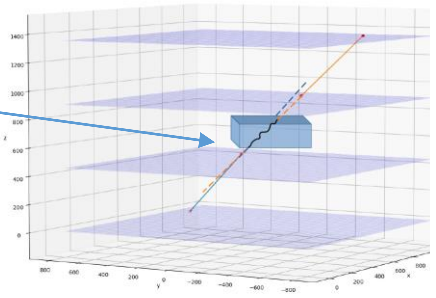
Scattering tomography

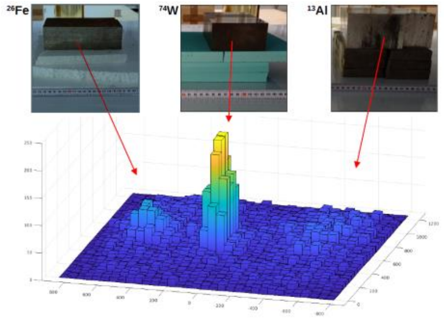
2 presentations

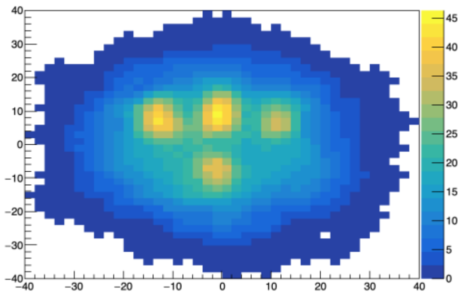
High granularity needed

Innovative method to reduce elec. Channels while keeping the granularity presented





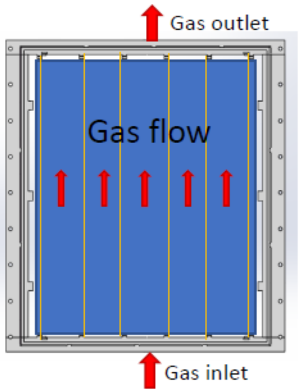


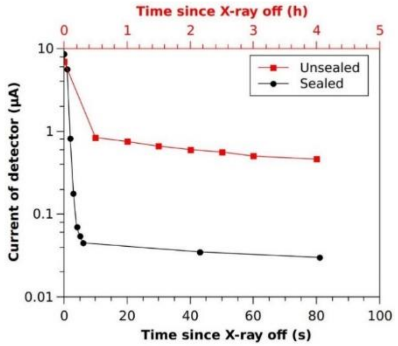


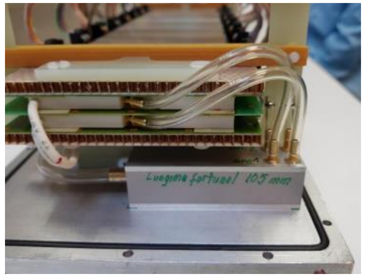
Detector R&D

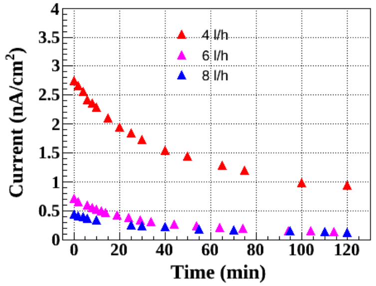
Sealed (M)RPCs (3 presentations)

- Reduced gas flow for sealed counter (helps only for low flux)
- Mitigation of chamber aging and gas pollution
- X-Ray test indicate that sealing the counter, introducing squared spacers and increasing the gas flow is minimize the gas pollution and mitigates chamber aging



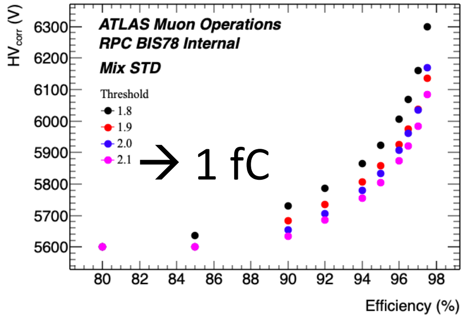






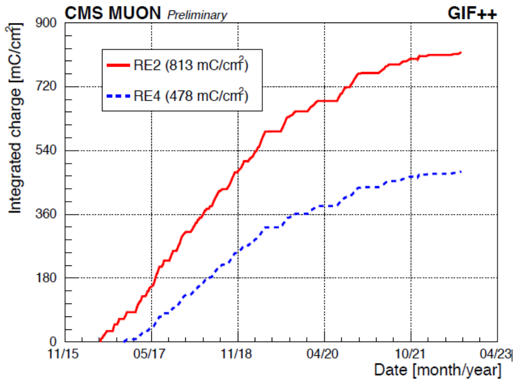
Extensive R&D on BIS78 RPCs designed for the ATLAS upgrade:

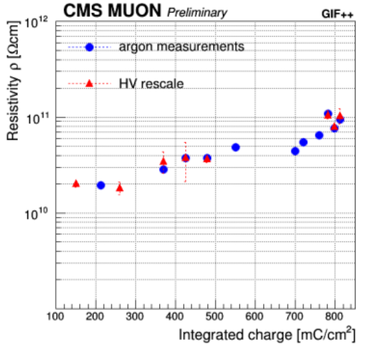
- Gas gap 1mm, FE threshold 1-4 fC, 3 independent singlets providing 3D+t particle localization
- stable running at low threshold, reached time resolution $\frac{280\ ps}{\sqrt{3}} = 160ps$
- test with eco friendly gases



Longevity studies, Long term stability test at GIF++

- No Evidence of any aging effect has been observed





Study of ionic signal properties with different read-out methods

RPC Background Studies at CMS Experiment

Eco-friendly mixtures for RPC detectors

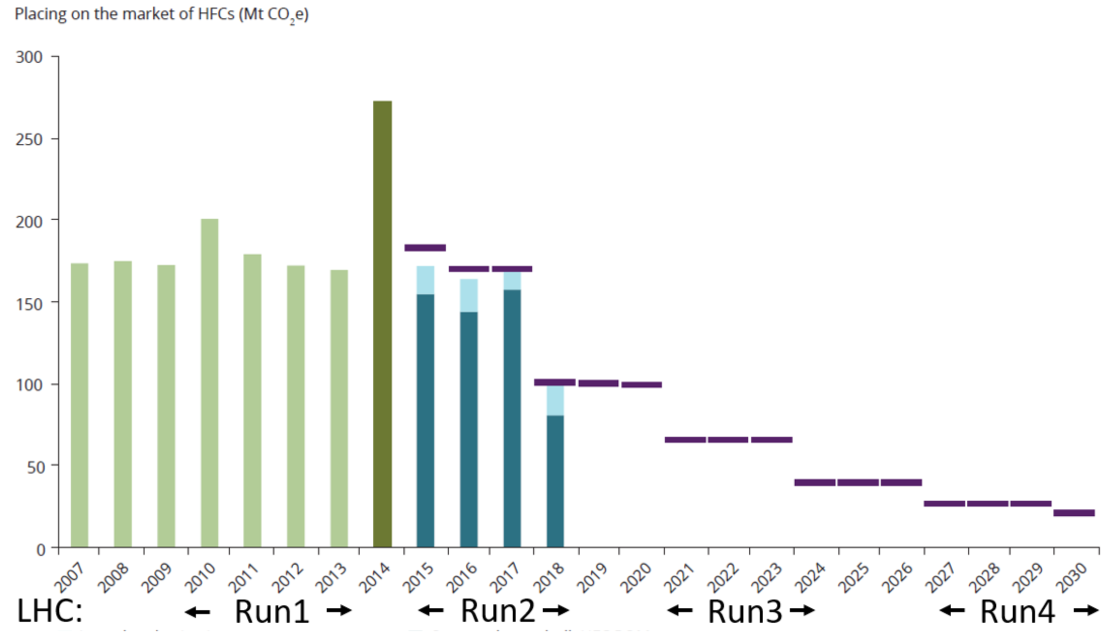
7 presentations on eco friendly gases for wide gaps RPCs
1 contribution eco friendly gases for thin gap MRPC

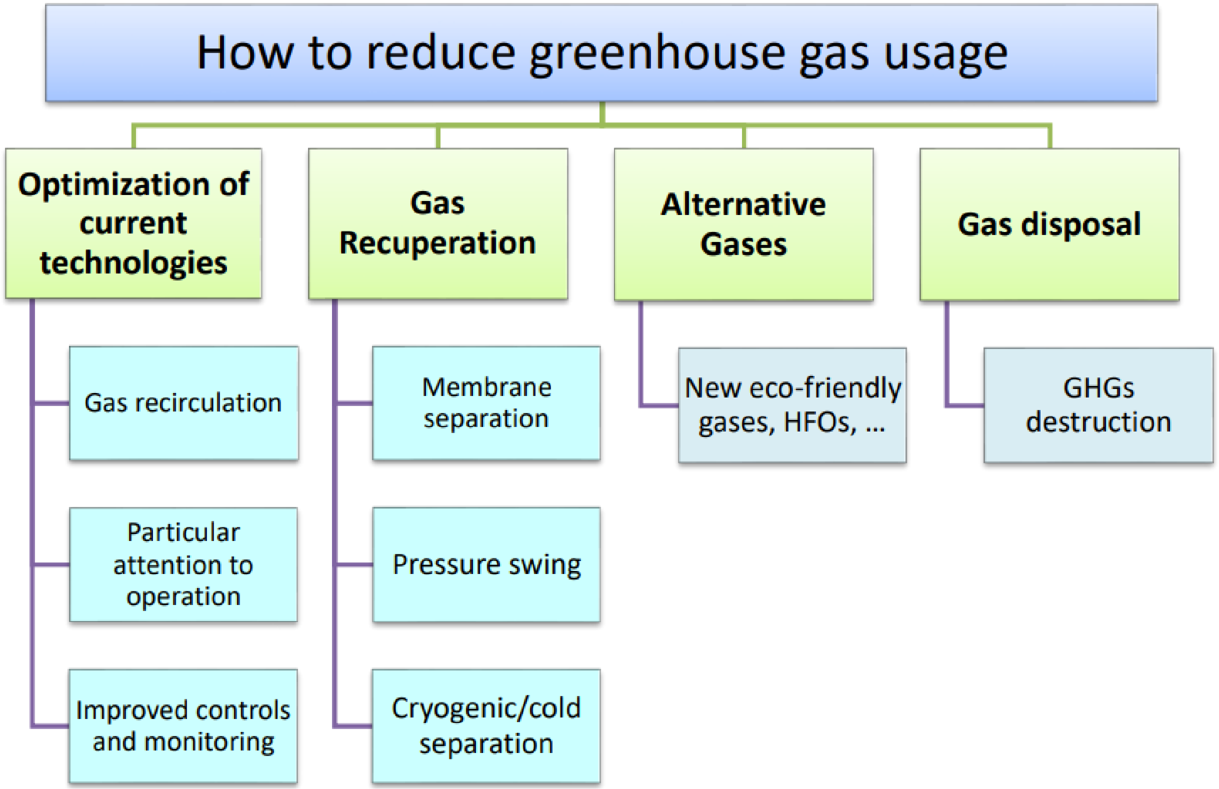
	Trigger RPCs	Timing MRPCs	GWP
R134a	94.7%	85% - 98%	1430
Iso-Butane	5%	0% - 5%	20
SF6	0.3%	2% - 10%	22800

The Problem:

- (M)RPC uses very eco-unfriendly gas - contribution to global warming -> governmental restriction
- EU HFC phase down => availability ↓ => price↑

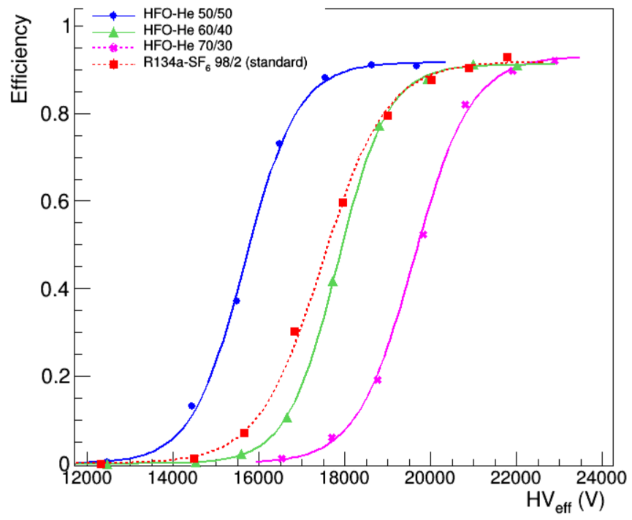
Figure ES.1 **Progress of the EU HFC phase-down**

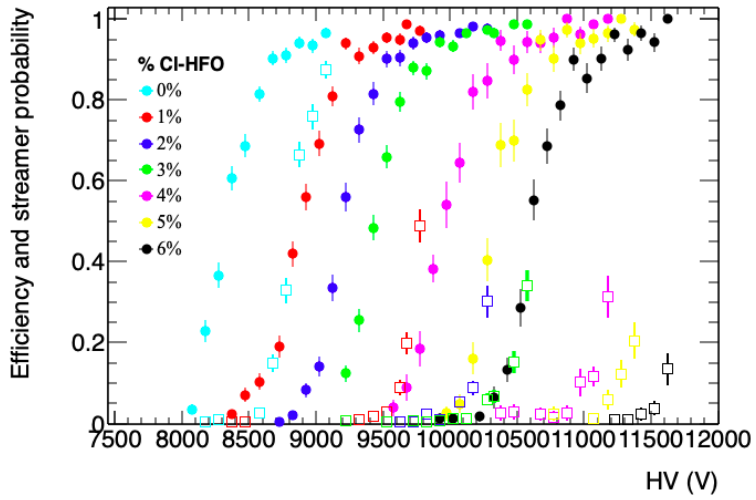




Eco-friendly mixtures for RPC detectors

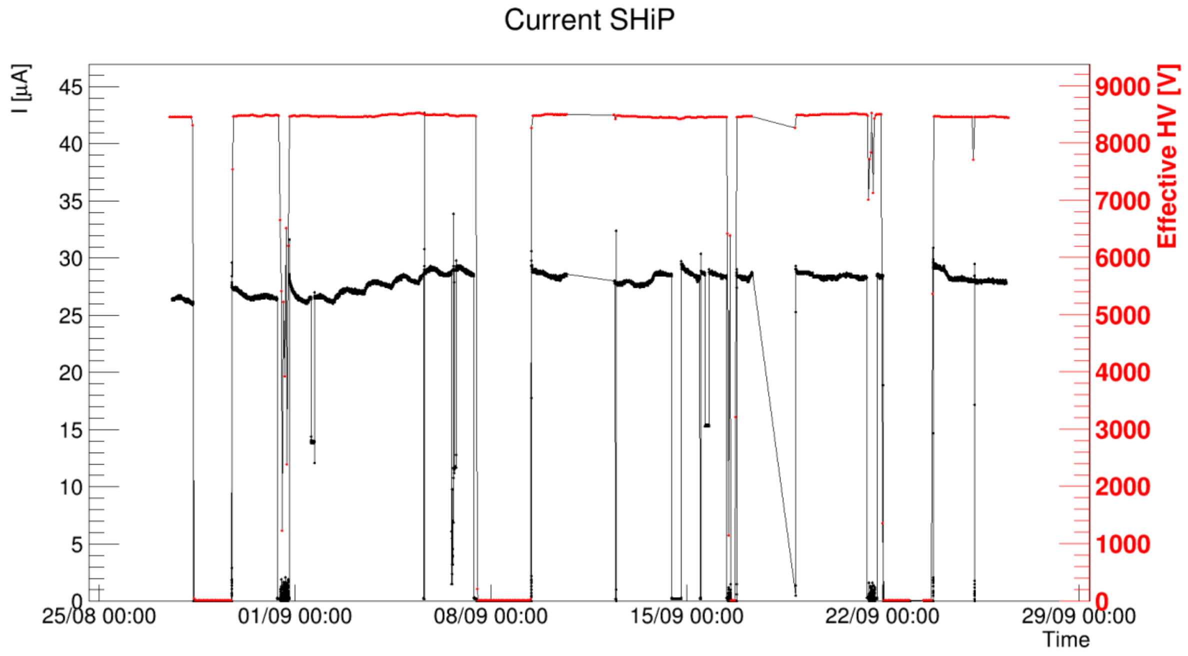
Replace R134a and SF6 with eco-friendly gases
R134a (C2H2F4) -> C3H2F4ze + CO_2 or He
SF6 -> Novec 5110 or (Cl-HFO) or Novec 4710 or
or C3H2ClF3





Many parameters as function of an enormous amount of different mixtures investigated.

- Change in working point
- Increase of streamer probability
- Increase in dark current
- Sensitive to UV light



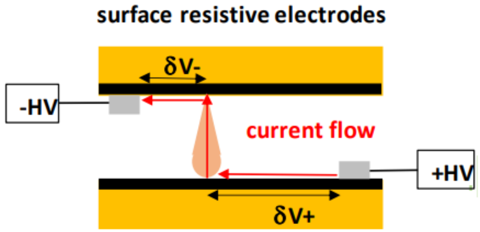
Long term stability test at high irradiation essential in order to guaranty the longevity of the counter

How to increase the rate capability of (M)RPCs

$$\phi_{max} \leq \frac{\Delta V}{\rho\, d\, \bar{q}}$$

Φ_{max} = maximum particulate flux
ΔV = allowable voltage drop at the resistive electrode, which do not compromise performance.
ρ = electrode resistivity
d = electrode thickness
q = average charge per avalanche

a) Minimization of the average charge per avalanche $\bar{q}$
   - decreasing the gap size
   - decreasing the working high voltage
   - increasing the quencher concentration in the gas
b) Decreasing the bulk resistivity ρ
   - select resistive material with lower bulk resistivity
      1) float glass: $\rho = 3\times10^{12}\ \Omega$cm
      2) low resistivity glass/Bakelite/SI-GaAs: $\rho \approx 10^{10}\ \Omega$cm
      3) ceramics: $\rho \approx 10^{9}\ \Omega$cm
   - increase temperature (25 K -> one order if magnitude)
c) Decreasing the glass thickness d
d) Go for sRPC (not a RPC any more)



- We thank all speakers for excellent presentations
- We thanks all poster presenter for explaining very well their work
- We thanks the auditorium for the questions, lively discussion and valuable input
- **Especially we thanks the organizers for the perfect organization of this RPC2022 workshop**