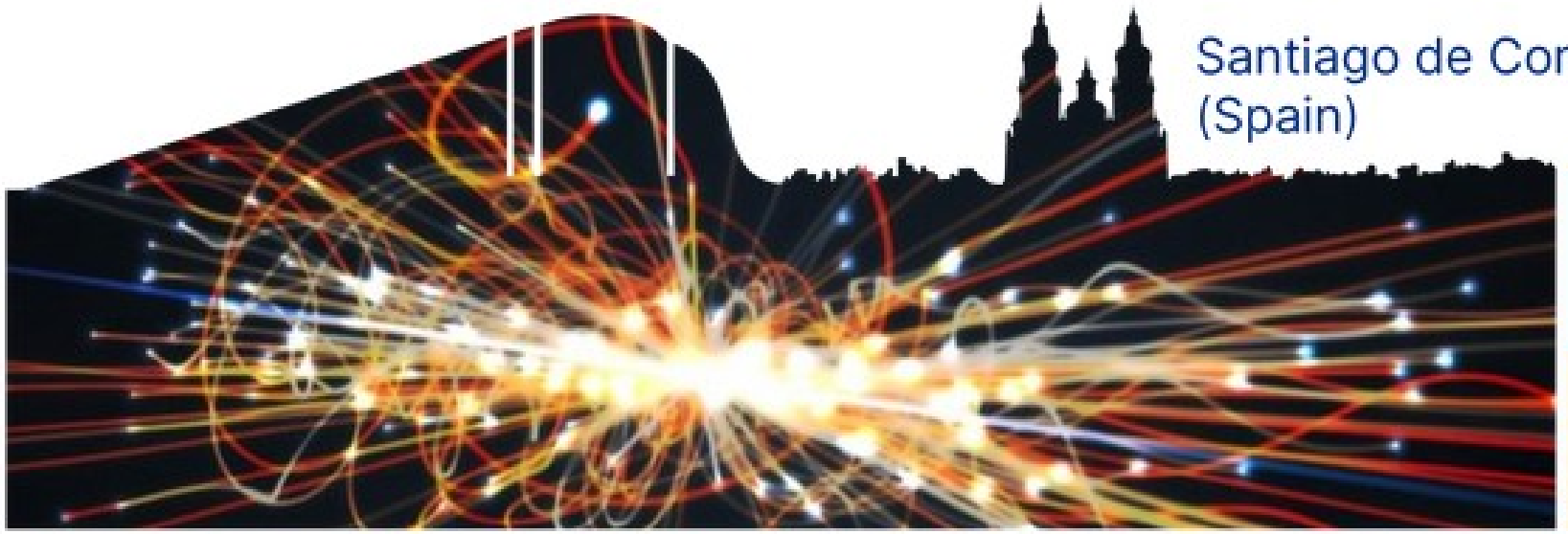



IGFAE
Instituto Galego de Fisica de Altas Enerxias

USC
UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

XUNTA DE GALICIA

# Summary talk

A. Blanco
LIP, Portugal

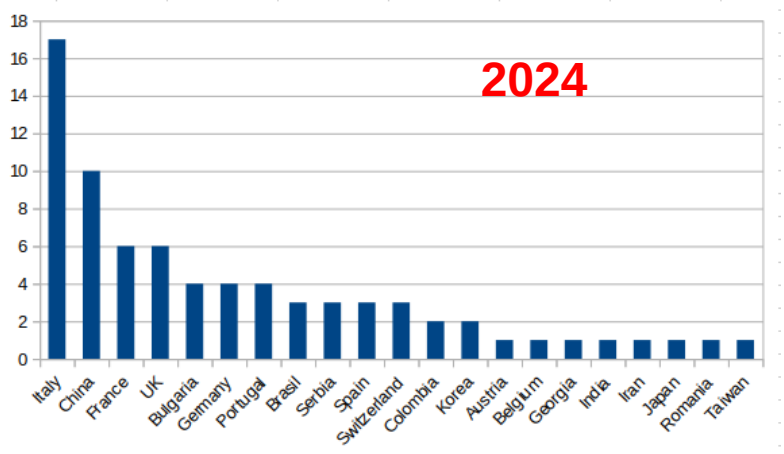
# RPC2024 in numbers

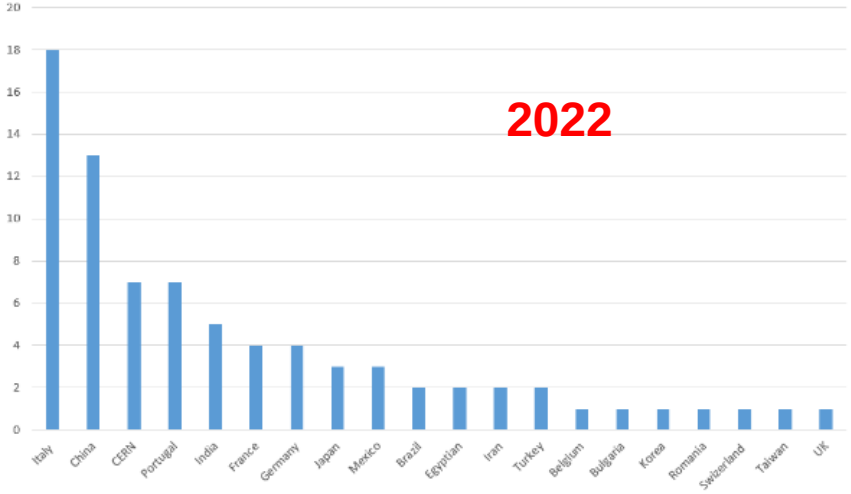
**A perfect local organization and nice and pleasant venue.**

- Participation

**RPC2024** 89 participants and 81 contributions (67 talks and 14 posters)
**RPC2022** 100 contributions
**RPC2020** 67 participants and 102 contributions
**RPC2018** 79 participants and 105 contributions
**RPC2016** 70 contributions

Mature community (with some statistical fluctuations), 20 countries similar distribution 2022




Summary of 81 contributions, lets try!!!

# RPC2024 Topics

**LHC experiments**
**ATLAS, ALICE, CMS**
Operation
Upgrades HL-LHC

**New experiments**
Nuclear physics
BSM
Cosmic rays
HEP

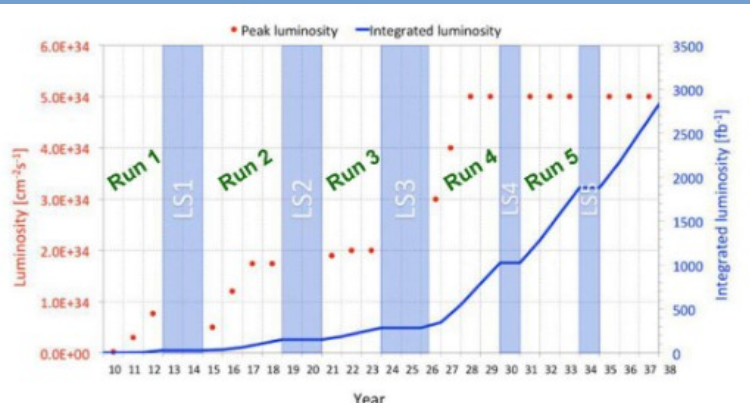
**R&D**

**ECO gases**

**Physics simulations**
Gas multiplication
Other topics

**Applications and new ideas**
Tomography
New ideas

# LHC experiments, ALICE, ATLAS, CMS




ALICE Muon system 2 ALICE TOF system 1
ATLAS Muon system 7+1
CMS Muon system 5+12

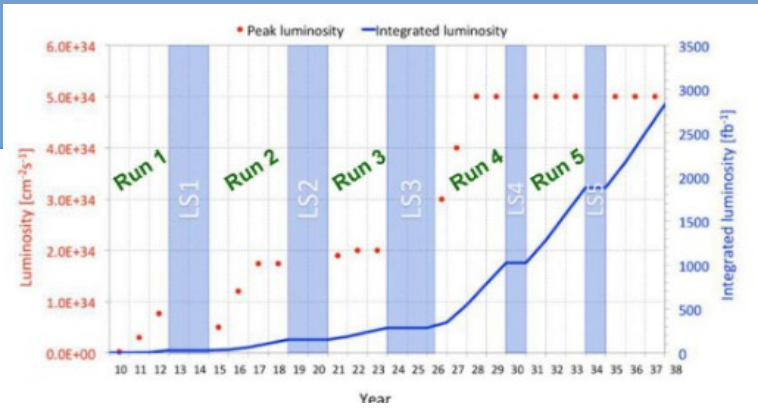
**Operation.** Very stable performance. Great concern to reduce environmental impact.

ALICE-Muon New FEE => lower HV => Higher rate capability (Maxi avalanche to avalanche).
ALICE-TOF New digital readout module.
ATLAS Introduces $CO_2$ to reduce GWP.
CMS Implementation of the gas recuperation on the exhaust and disconnection of leaky chambers.

**Upgrades for HL-LHC.** Production of new RPC and upgrades well advanced.

ALICE-Muon New RPCs will replace the most exposed ones.
ALICE-TOF New TDC board (based on picoTDC) for replacement of the HPTDC chip
ATLAS Thinner gas gaps (1 mm) and electrodes and new more sensitive and timing capable FEE.
CMS Upgrade link electronics and installation of new iRPC with thinner gas gaps and electrodes. New FEE.

# LHC experiments, ALICE, ATLAS, CMS

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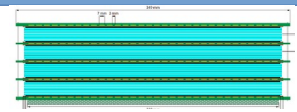
$$\phi_{max} \leq \frac{\Delta V}{\rho d \bar{q}}$$

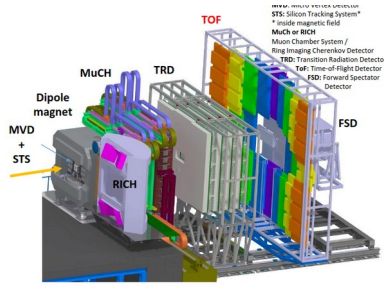
# New experiments

## Nuclear physics, Beyond the Standard Model (BSM), HEP

**- CEE iTOF-MRPC @ Heavy-Ion Research Facility at Lanzhou (China)**
24 gaps 150 um, 3.4 m² ~1500 ch, < 40 ps. Description of the performance and mass production.



**- CBM @ Facility for Antiproton and Ion Research FAIR (Germany)** x4 Talks
**Outer and inner wall** 8-10 gaps 200-250 um, 120 m² ~100k ch, < 80 ps, < 50 kHz. eTOF and mCBM discussed. Gas pollution. Fishing line replaced by pad spacers. preMass production started.

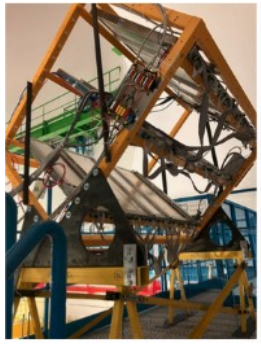


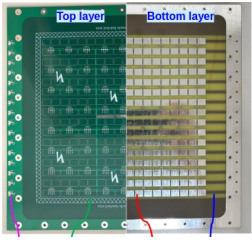

**- T-SDHCAL for future Higgs Factory**
Incorporate now timing capability to SDHCAL including MRPCs and timing FEE. First prototypes shown.

***- SHiP @ CERN and Comet @ J-Parc (Japan)***
Possibility of using improved RPCs from CMS HL-LHC upgrade.

***- CODEX-b @ LHCb (CERN)***
Re-use of BIS7 RPC design from ATLAS Phase-2 upgrade.
Experiment described and basic test discussed.
***- ANUBIS @ ATLAS (CERN)***
Re-use of BIS7 RPC design from ATLAS Phase-2 upgrade
Experiment described and first test discussed from demonstrator.

Transverse experiment Physics BSM

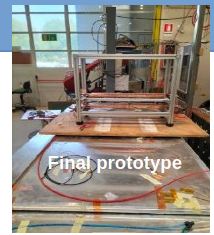





***- MARQ (Multi-purpose Analyzer for Resonance and Quark dynamics Spectrometer) @ J-Parc (Japan).***
RPC will be used as TOF wall and Muon wall. Discussion of carbon less RPC and first prototype 70 ps and ~1 mm (2 Talks)

# New experiments

## Cosmic rays

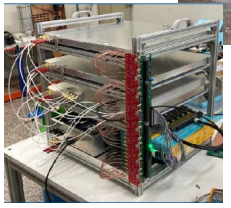



### - SWGO Southern Wide-field Gamma-ray Observatory @ (Chile?)

Proposing use of RPC (modification version from ATLAS) in combination with Water Cherenkov Tanks**.**
Project described and preliminary test discussed (including simulation of operation at high altitude).

### - MARTA @ Pierre Auger observatory (Argentina)

RPC in combination with Water Cherenkov Tanks for e/u separation. Results of the first station of an engineering array shown. Stable operation for long period under outdoor conditions.



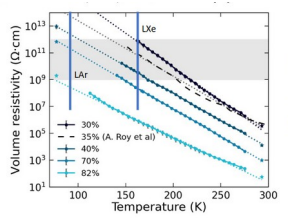
### - Mini-trasgo initiative (worldwide)

Creation of a global network of small cosmic muon monitors based on portable, low cost RPCs telescope. First results from first station shown.

# R&D

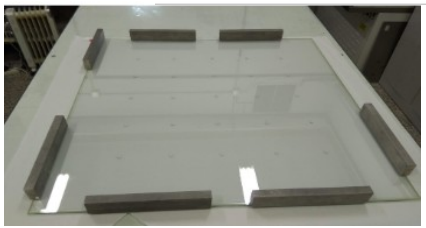
## - Use of phenolic glass electrodes.

New material with interesting properties. Similar to glass but with excellent mechanical properties. First prototypes described including performance.




## - Diamond Like Carbon and $Fe_2O_3$/YSZ ceramics.

Resistive protection for cryogenic temperature with potential to be used in RPCs. Characterization of samples and first results with detectors in LA (90 K).

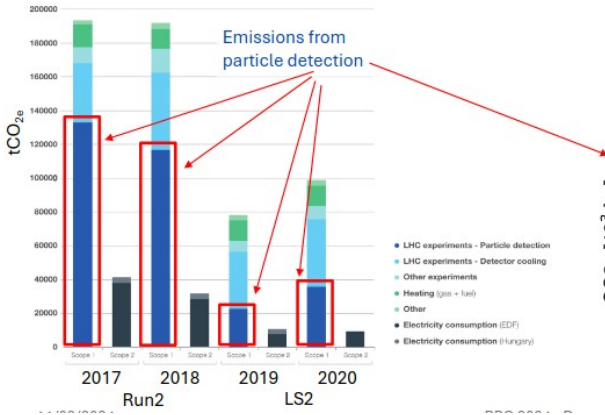


## - Zero flow MRPCs.

First device used @ SND experiment demonstrating the feasibility of the technology,

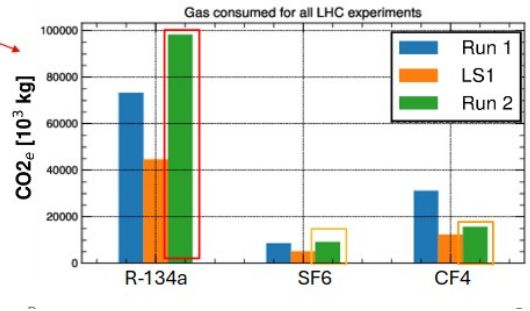
# Eco-friendly mixtures for RPC detectors

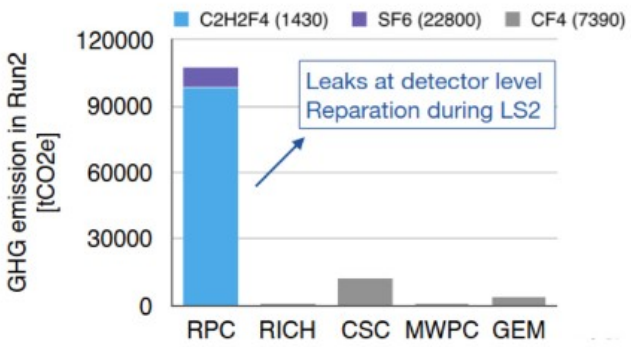
**The problem,** currently at CERN but not only (new CERN exp, FAIR, J-Parc, ...)




detector, used for ALICE, ATLAS and CMS systems

- $CF_4$ → due to operation of CSC and RICH systems
- $SF_6$ → Related to RPCs as R-134a



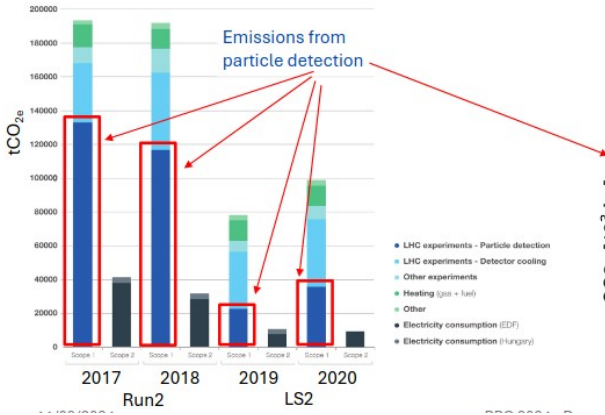

## New F-gas regulation: from phase down to phase out

**The new Regulation establishes the total elimination of HFCs by 2050**

- It is a major step towards climate neutrality
- First goal: reduction of 55% GHG emissions by the end of this decade compared to 1990 levels
- New restrictions also in the use of $SF_6$ and especially for high GWP gases
- It will result in a reduction in production and reduced quotas for F-Gas refrigerants, leading to an inevitable increase in prices for higher GWP refrigerants
  - It will probably affect not-EU market

# Eco-friendly mixtures for RPC detectors

**The problem,** currently at CERN but not only (new CERN exp, FAIR, J-Parc, ...)

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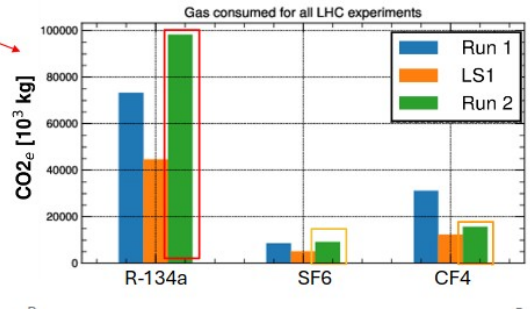
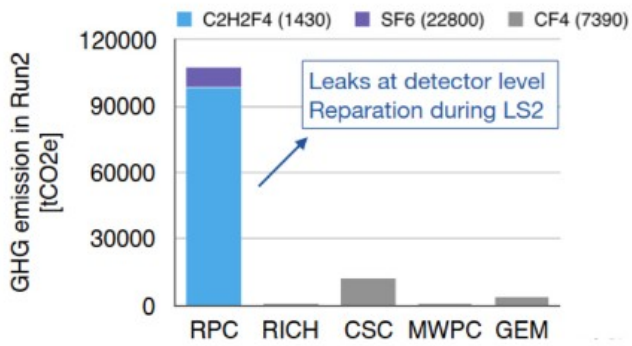


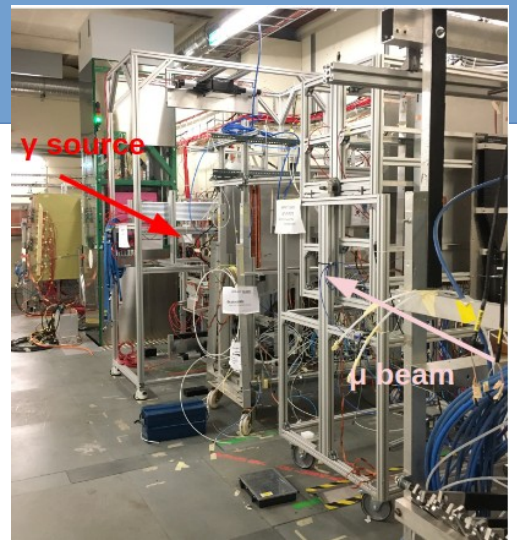

**The possible solutions** (so far) and $CO_2$ mixtures for immediate mitigation.

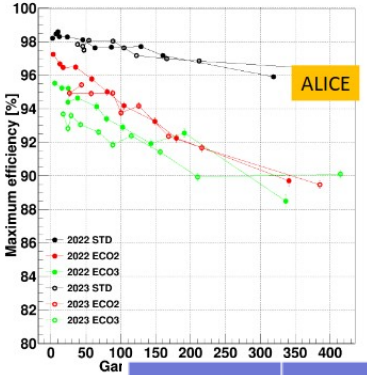
| | TFE (%) | HFO-1234ze (%) | $CO_2$ (%) | $iC_4H_{10}$ (%) | SF6 (%) | GWP | $CO_2e$ (g/l) |
|---|---|---|---|---|---|---|---|
| STD | 95.2 | - | - | 4.5 | 0.3 | 1485 | 6824 |
| ECO2 | - | 35 | 60 | 4 | 1 | 476 | 1522 |
| ECO3 | - | 25 | 69 | 5 | 1 | 527 | 1519 |
| Density (g/l) | 4.68 | 5.26 | 1.98 | 2.69 | 6.61 | - | - |
| GWP | 1430 | 7 | 1 | 3 | 22800 | - | - |

# Eco-friendly mixtures for RPC detectors

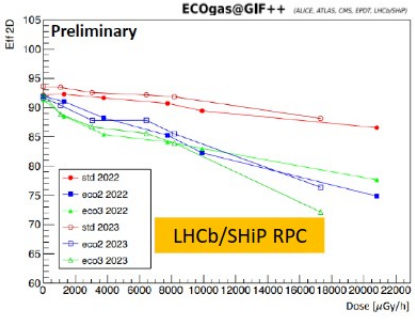
## The EcoGas@GIF++ collaborative effort after initial lab R&D

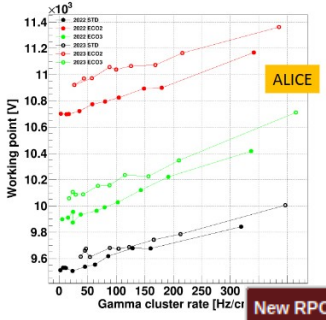
- In general the idea of replacing **TFE with HFO ( + $CO_2$ to reduce the HV)** seems to work.
- **ECO2 and ECO3** might be good candidate gas mixtures
- Interpretation of the effects observed not trivial
- **Same efficiency, shift in working point** after irradiation.




(2024 data still under analysis)

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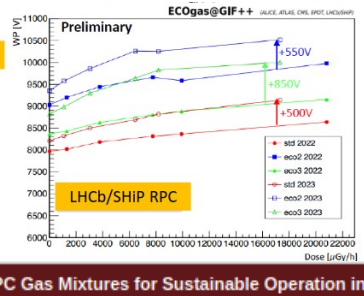



| RPC | Gap thickness | Electronics |
|---|---|---|
| ALICE | 2mm | FEERIC + TDC |
| ATLAS | 2mm | Digitizer |
| CMS | 2mm – double gap | CMS FEB + TDC |
| CMS upgrade | 1.4mm – double gap | CMS FEB + TDC |
| EP-DT | 2mm | Digitizer |
| LHCb/SHiP | 1.6mm | FEERIC + TDC |

**New RPC Gas Mixtures for Sustainable Operation in the CMS Experiment** — *Dayron Ramos Lopez* — 08:30 - 08:50

**Signal shape studies and rate dependence of HFO-based gas mixtures in RPC detectors** — *Luca Quaglia* — 08:50 - 09:10

**Evaluating the Performance and Long-Term Stability with LHC-like Background Irradiation of RPC Detectors with a CO2** — *Stefania-Alexandra Juks*

**Performance and longevity of CO2 based mixtures in CMS Improved Resistive Plate Chambers in the HL-LHC environm** — *Joao Pinheiro*

**Performance and long-term ageing studies on Eco-Friendly Resistive Plate Chamber detectors** — *Marcello Abbrescia* — 10:50 - 11:10

# Eco-friendly mixtures for RPC detectors

- **Searching for a replacement for $SF_6$ (x2 Talks).** Novotec 4710, $C_3H_2ClF_3$ candidates.

- **Recuperation of the gas @ exhaust** for immediate mitigation.

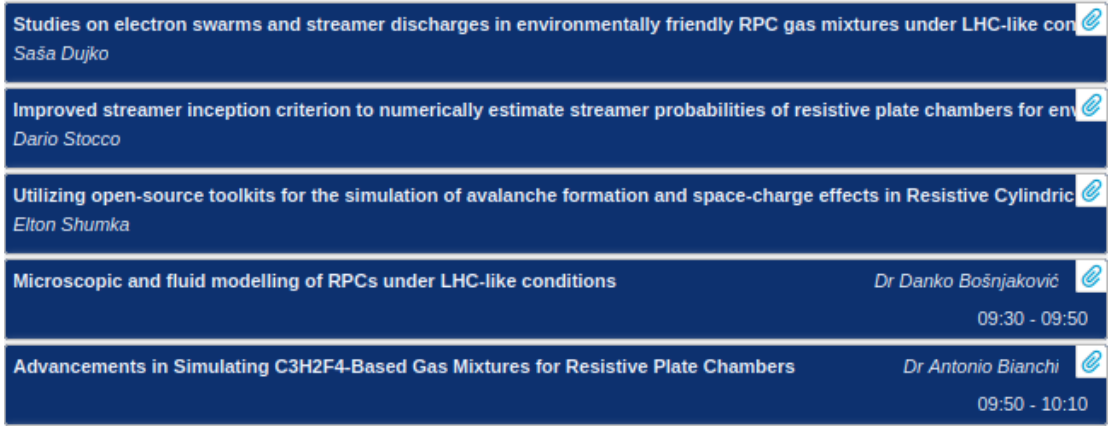
- **Anubis** (new experiment) also have joined to the effort.

- **Effect of F- impurities in ALICE**

| | | |
|---|---|---|
| **Characterization of Glass Multigap RPC Detector with alternative gas to R134a and SF6** | *Mattia Verzeroli* | 09:10 - 09:30 |
| **Study of environment-friendly SF6 substitute for the Resistive Plate Chambers** | *Giorgia Proto* | 09:30 - 09:50 |
| **R134a recuperation and SF6 recuperation plants: status and plan** | *Roberto Guida* | 09:50 - 10:10 |
| **Operation of 1 mm HPL RPCs with low-GWP gas mixtures** | *Aashaq Shah et al.* | 10:30 - 10:50 |
| **Studies of F- Impurities Formation in ALICE MID RPC detectors: A Comparison between RUN2 and RUN3** *Mattia Verzeroli* | | |

# Physics simulations. Gas multiplication.

- **HOT TOPIC.** Study of Eco-friendly gas mixtures (ECO2, ECO3) or mixtures with reduced GWP.
- Improved / new codes, cross-sections and transport coefficients.
- **Different approaches:** Fluid models, microscopic. (some of them including readout modelling).
- In general, **good agreement** with available experimental data (**mature knowledge**).
- **Understanding discharge transition** (slow down ageing, improve dead time)
- **Many codes.** Do we need a working group, DRD1 ???
- Little attention to timing RPCs mostly focused on E/N ~200 Td.
- Cross-sections of HFO1234ze soon available on MagBoltz



# Physics simulations. Other topics.

$$\sigma_t = \sqrt{\sigma_{n_{cl}}^2 + \sigma_{n_0}^2 + \sigma_M^2} = \frac{1}{v_d}\frac{1}{\eta - \frac{1}{g}}\sqrt{\left(\frac{\sigma_{n_{cl}}}{n_{cl}}\right)^2 + \left(\frac{\sigma_{n_0}}{n_0}\right)^2 + \left(\frac{\sigma_M}{M}\right)^2}$$

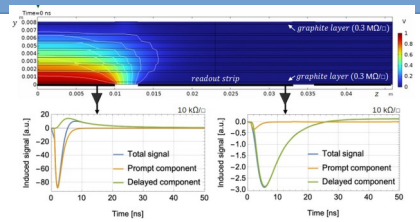
- Analytical simplified **timing resolution** expression. Resolution depends mostly on η and $v_d$.

- **Simulation time dependent weighting potentials in Garfield++.** Very relevant for RPC HV layer simulation.

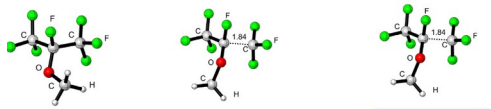
- **Quantum chemical calculations.** Looking for a replacement for HFC. HFE-347mmy1 proposed as possible candidate beyond HFO-1234.

- **GIF++ facility**, an actualized simulation of GIF++ (comparison with data, new geometry).

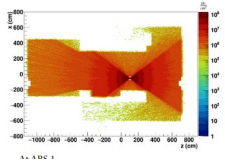
- **Muon Tomography.** Importance of TOF on the detection accuracy => MRPC can provide the necessary momentum resolution.

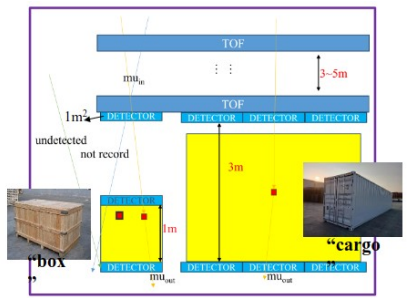



We examine how two basic processes in plasma affect the stability of $(CF_3)_2CF\text{-}O\text{-}CH_3$ (HFE-347mmy1) molecule



Ground state | Ionized state | electron attached -abstracted state






5 talks

**Time Resolution in Resistive Plate Chambers from Statistical Considerations** — *Marcello Abbrescia*
10:30 - 10:50

**Simulating MRPCs with Garfield++ and time-dependent weighting potentials** — *Djunes Janssens*
11:10 - 11:30

**Quantum chemical calculation of reactions in the plasma molecules important for the operation of the RPC system**
*Nebojsa Begovic*

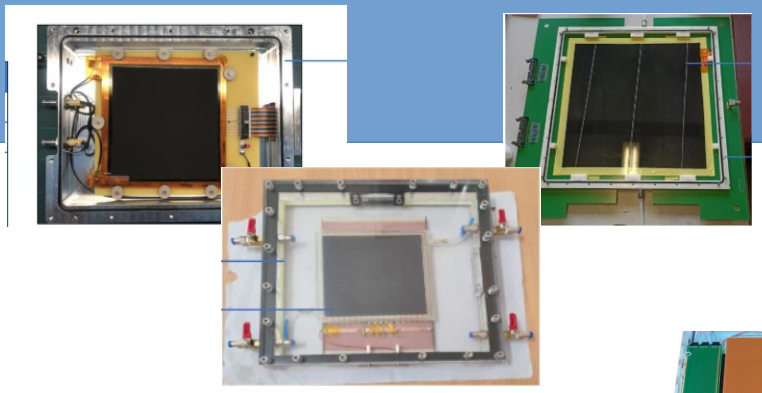
**Quantum chemical calculation of reactions in the plasma molecules important for the operation of the RPC system**
*Nebojsa Begovic*

**Upgraded simulation of the CERN Gamma Irradiation Facility (GIF++)** — *Nicola Ferrara*
16:40 - 17:00

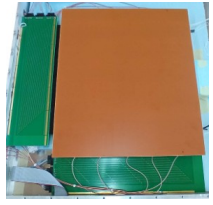
# Applications and new ideas

## Tomography

- Different **RPC prototypes** for muon tomography (x2)



- **A new readout** with sub-millimetre 2D position and TOF capabilities minimizing FEE for muon tomography. Demonstrate again the importance of TOF.

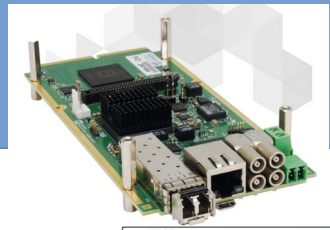


**Developmental Studies on the Performance Enhancement of Gas-Tight Resistive Plate Chambers (RPCs) for Muograph…**
*Samip Basnet*

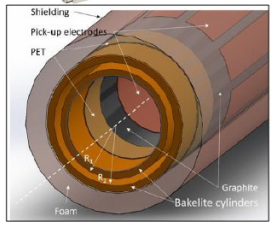
**A modular muon telescope for tomography and radiography applications** *Dr Raveendrababu Karnam*
09:20 - 09:40

**New Readout Codification in Large-Area Multi-Gap Timing RPCs for Muon Scattering Tomography**
*Joao Pedro De Carvalho Saraiva*

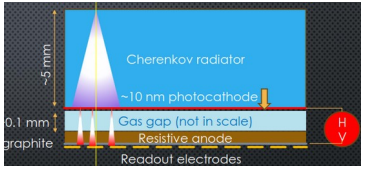
# Applications and new ideas



- **FERS-5200 readout system (CAEN).**
64/128 ch Time and ToT with 5 ps RMS (needs preAmp), with ASIC soon




- **Thin gap Resistive Cylindrical Chamber.** > 98% ans 200 ps



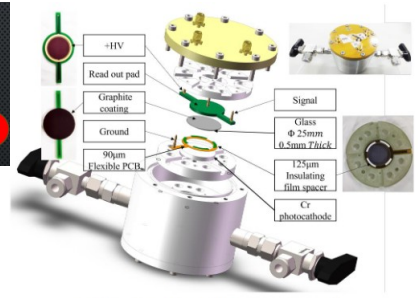




Figure 2: Exploded view and photographs of the detector.

- **Hybrid photodetector based on RPCs** x2 Talks

- **Cold/thermal neutron sensitive RPCs, based on $^{10}$B layers.**
High efficiency, count rate, position (XYZ) and timing resolution.

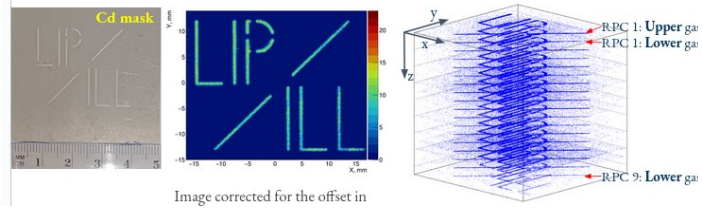



Image corrected for the offset in

| | | |
|---|---|---|
| **Picosecond timing performances of the FERS-5200 readout system** | *Mr Massimo Venaruzzo* | 11:00 - 11:20 |
| **Efficiency and time resolution of a thin gap Resistive Cylindrical Chamber** | *Alessandro Rocchi* | 11:20 - 11:40 |
| **A method to design a fast hybrid photodetector based on the RPC structure** | *Giulio Aielli* | 11:40 - 12:00 |
| **A high rate and high timing gaseous photodetector prototype with RPC structure** | *Mr Yiding Zhao* | 12:00 - 12:20 |
| **Progress with the nRPC-4D detector concept for neutron scattering applications: assessment of XYZ-position and nTO…** *Luís Margato* | | |

# Thanks to!!!!

- We thank all **speakers** for excellent presentations.

- We thanks all **poster presenter** for explaining very well their work.

- We thanks **to you** for the questions, lively discussion and valuable input.

- Especially we thanks the **organizers** for the perfect organization of this **RPC2024 conference.**