Status of RPC R&D for the LHCb Upgrade II muon detector

M. De Serio on behalf of the Bari group

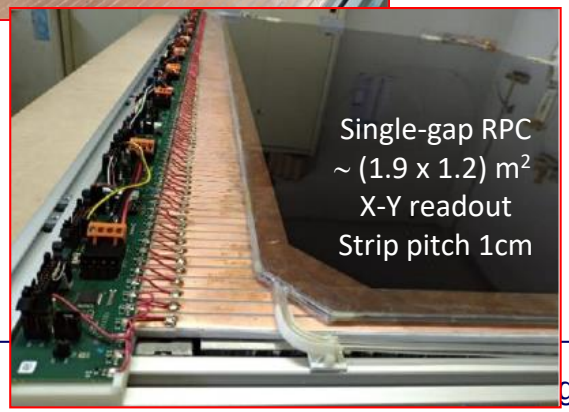
STANDARD RPCs

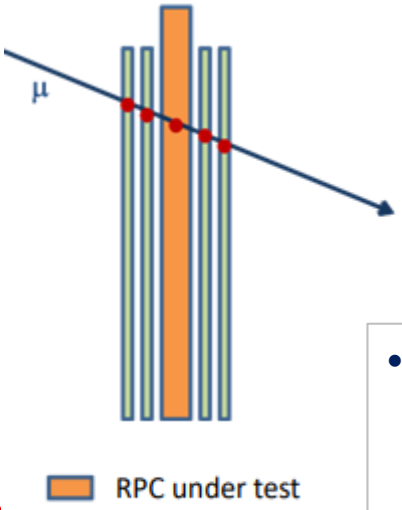
Gas gap and (Bakelite) electrode thickness: 2mm

Standard gas mixture for avalanche mode : 95.2% $C_2H_2F_4$ (R134a) / 4.5% iC_4H_{10} / 0.3% SF_6

Sustainable rates: < 1 kHz / cm^2

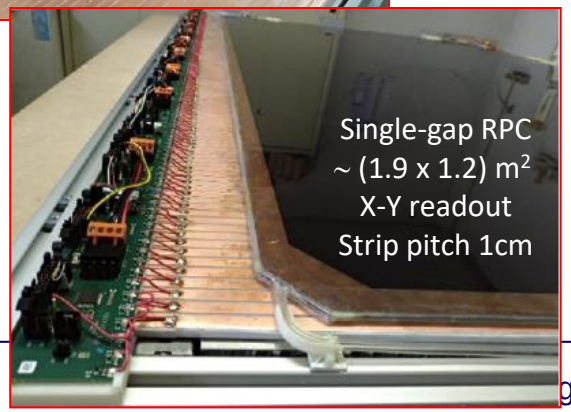
STANDARD RPCs @Bari

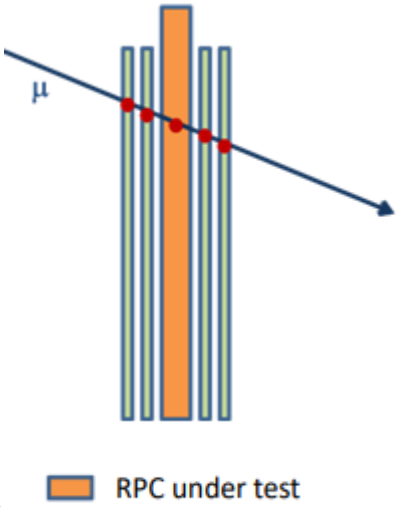


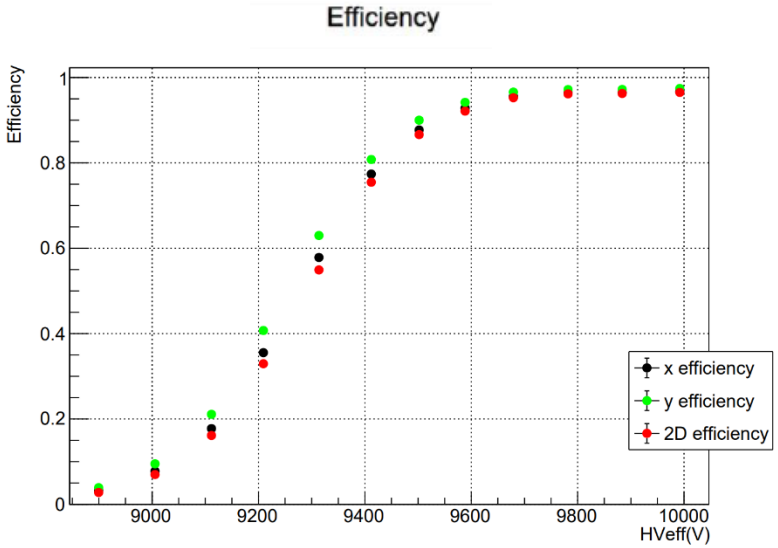


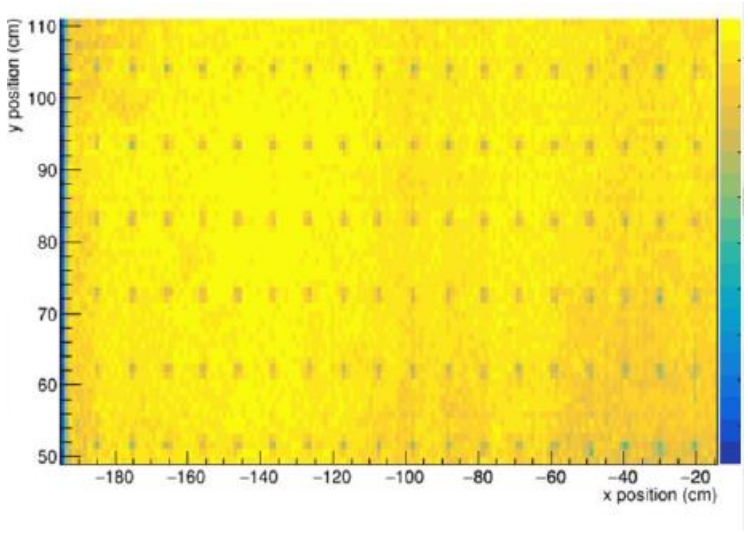
- FE boards equipped with 2 FEERIC chips (ALICE exp.)
- Custom FPGA-based readout boards and trigger supervisor
- Trigger provided by 4 chambers (streamer RPCs)
- Tracking

STANDARD RPCs @Bari









TOWARDS NEW-GENERATION RPCs

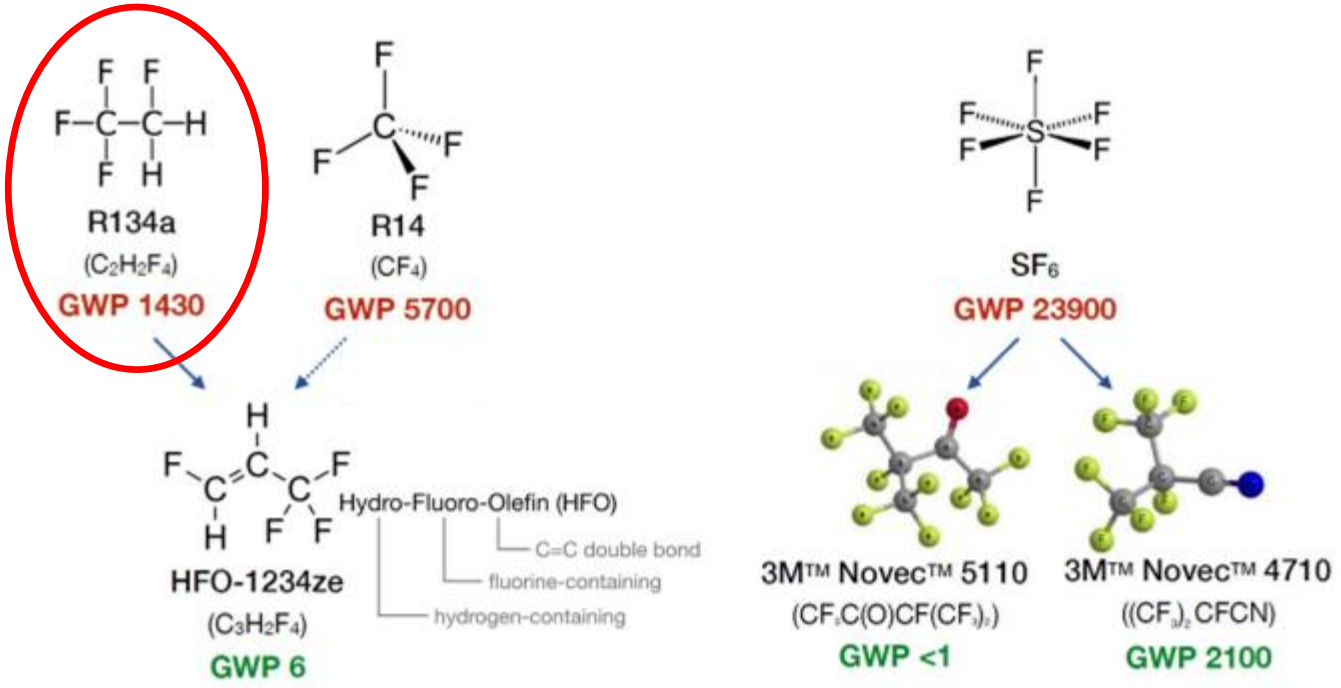
Future applications (e.g. HL-LHC) require significant progress in detector rate capability and longevity.

$$\langle V_{gas} \rangle = V - 2\rho d \langle Q \rangle \Phi_{eff}$$

Voltage drop to be minimized in order to reduce efficiency loss with increasing flux

- Reduce electrode resistivity
- Reduce electrode thickness
- Reduce average charge per event

TOWARDS NEW-GENERATION RPCs

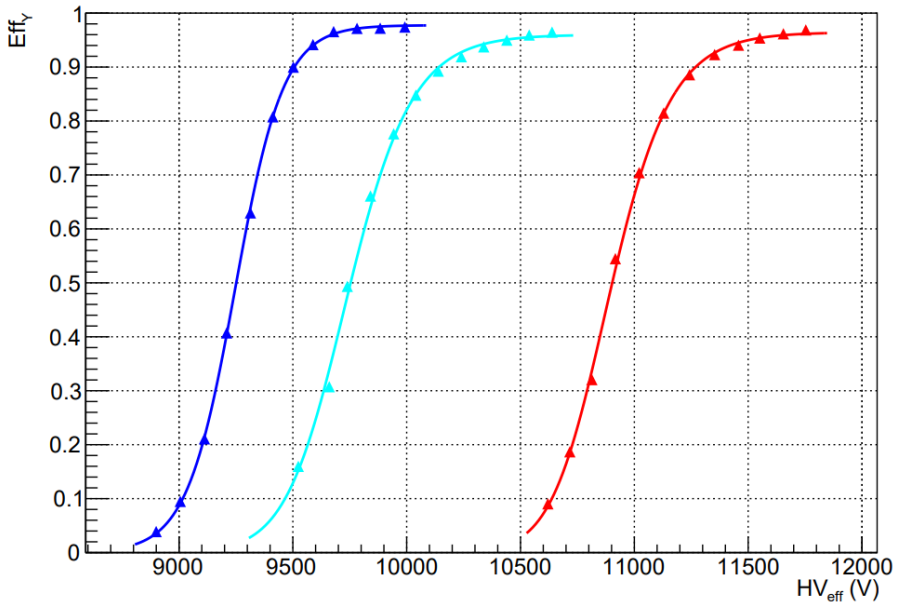


The use of fluorinated greenhouse gases with *high* Global Warming Potential has been limited by EU legislation. Alternative eco-friendly gas mixtures for RPCs to be identified.

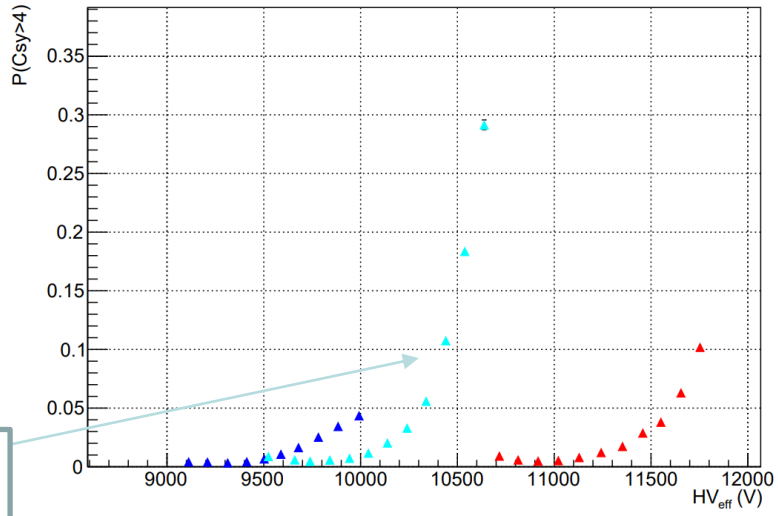
ECO-FRIENDLY GAS MIXTURES FOR AVALANCHE RPCs

The replacement of R134a with HFO results in a significant increase of the operating voltage $\Rightarrow$ addition of CO_2 to compensate for higher electron attachment coefficient of HFO w.r.t. R134a

Bari lab



- 95.2% R134a/ 4.5% iC_4H_{10} / 0.3% SF_6 (standard)
- 60% CO_2/ 35% HFO/ 4.5% iC_4H_{10} / 0.5% SF_6
- 69.5% CO_2/ 25% HFO/ 5% iC_4H_{10} / 0.5 % SF_6



- Fraction of events with *large charge content* > 10% at the WP increasing very rapidly with applied HV

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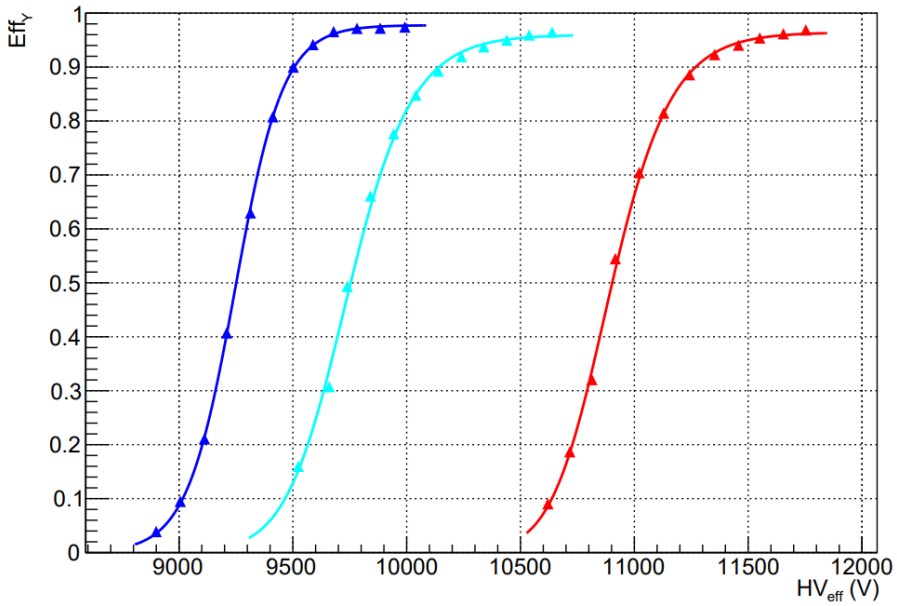

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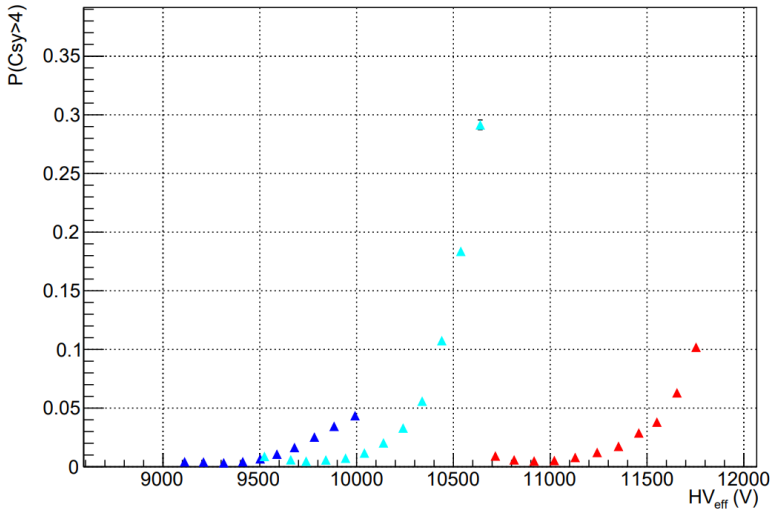
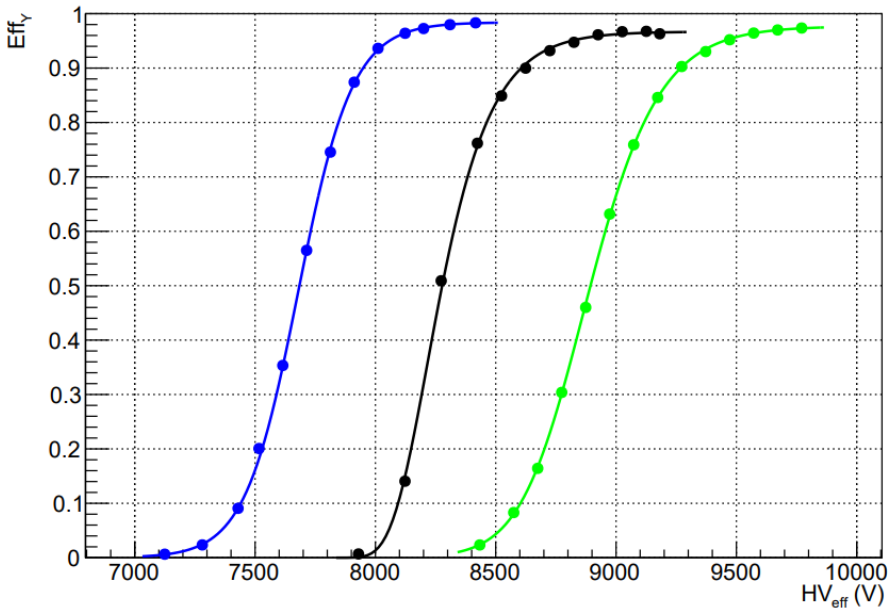


- Performance comparable with standard mixture
  WP still above 11 kV

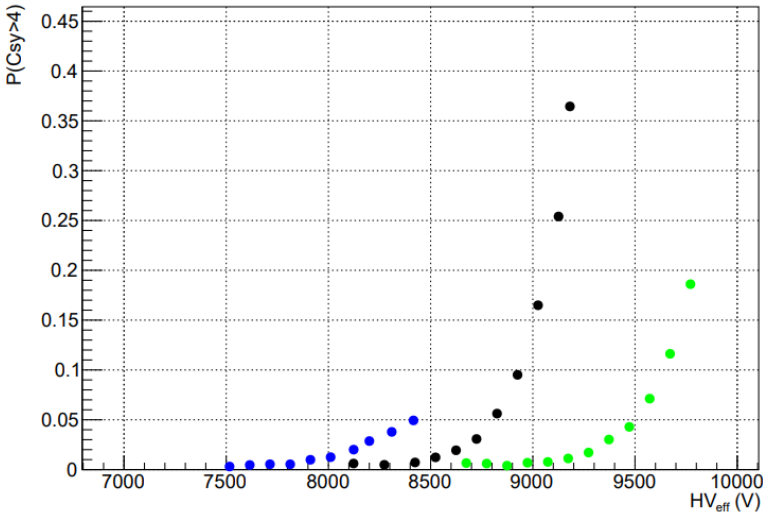
THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

Similar gas mixtures were tested using a 1.6 mm thick gap, comparable performance, WP shifted towards lower values

Bari lab



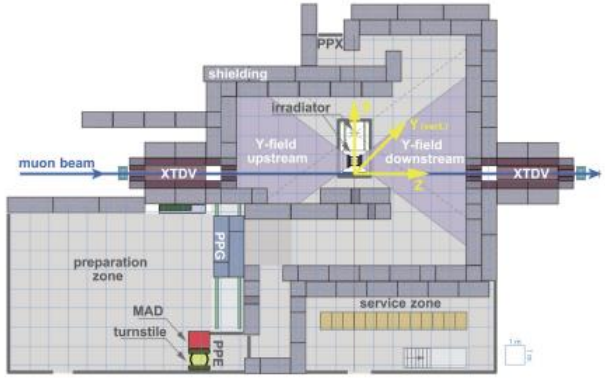
- 95.2% R134a/ 4.5% iC_4H_{10} / 0.3% SF_6 (standard)
- 60% CO_2/ 35% HFO/ 4% iC_4H_{10} / 1% SF_6
- 69% CO_2/ 25% HFO/ 5% iC_4H_{10} / 1 % SF_6



THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

Parallel studies ongoing at GIF++ with a *small* chamber (1.6 mm thick gap and electrodes)

GIF++



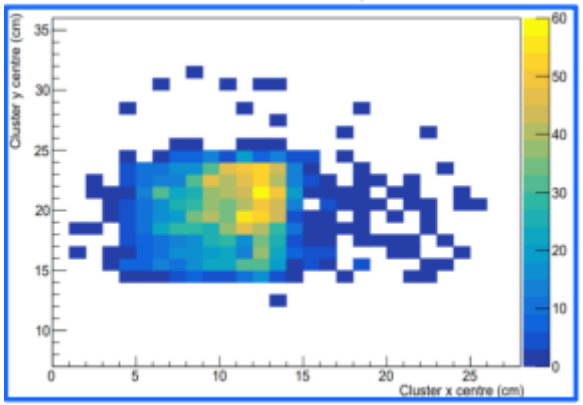
- ^{137}Cs source, activity 14 TBq
- Muon beam, energy 100 GeV
- System of filters providing different attenuation factors

THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

Parallel studies ongoing at GIF++ with a *small* chamber
(1.6 mm thick gap and electrodes)

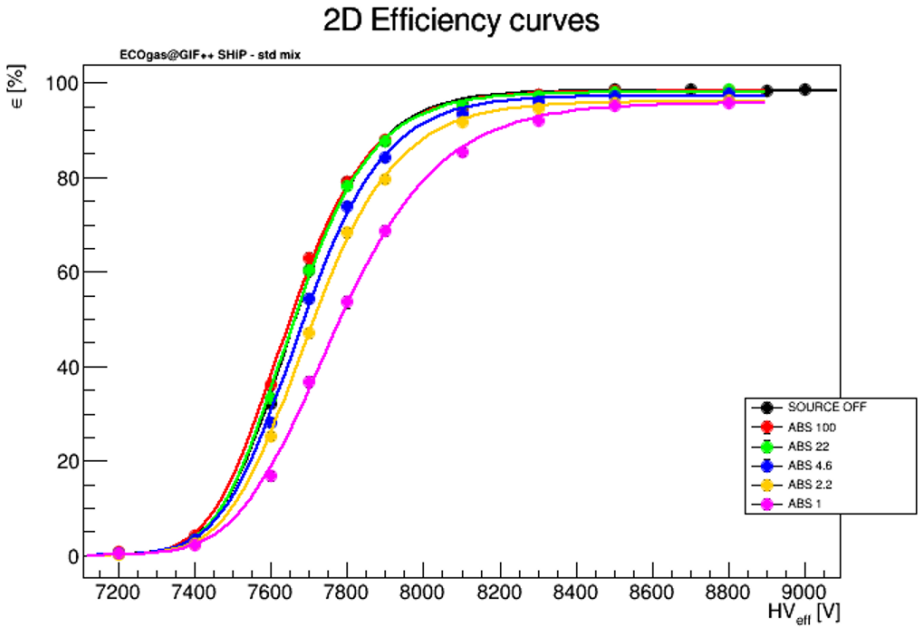
GIF++

- TDC readout
- Trigger: two beam scintillators + two additional scintillators, effective area (10 × 10) cm²
- No tracking



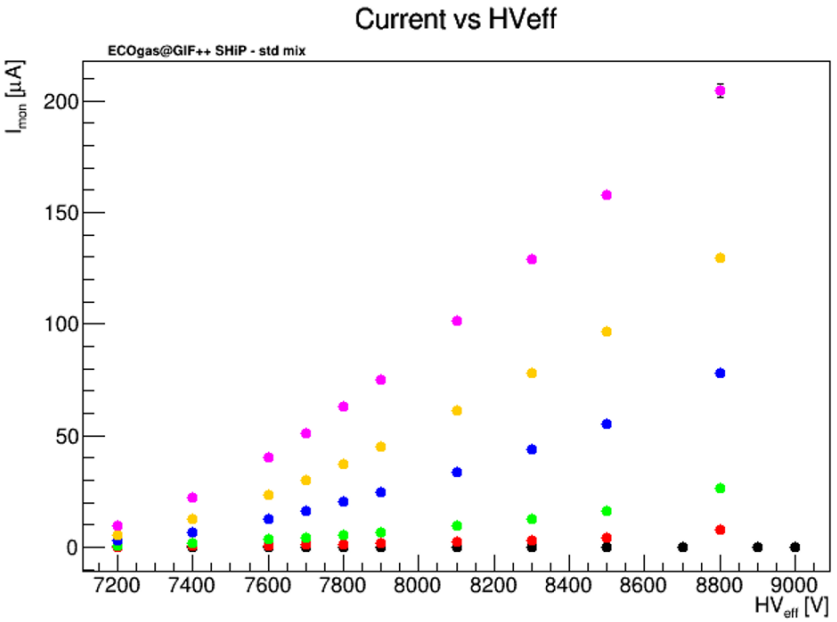
THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

GIF++



95.2% R134a/ 4.5% iC_4H_{10} / 0.3% SF_6 (standard)

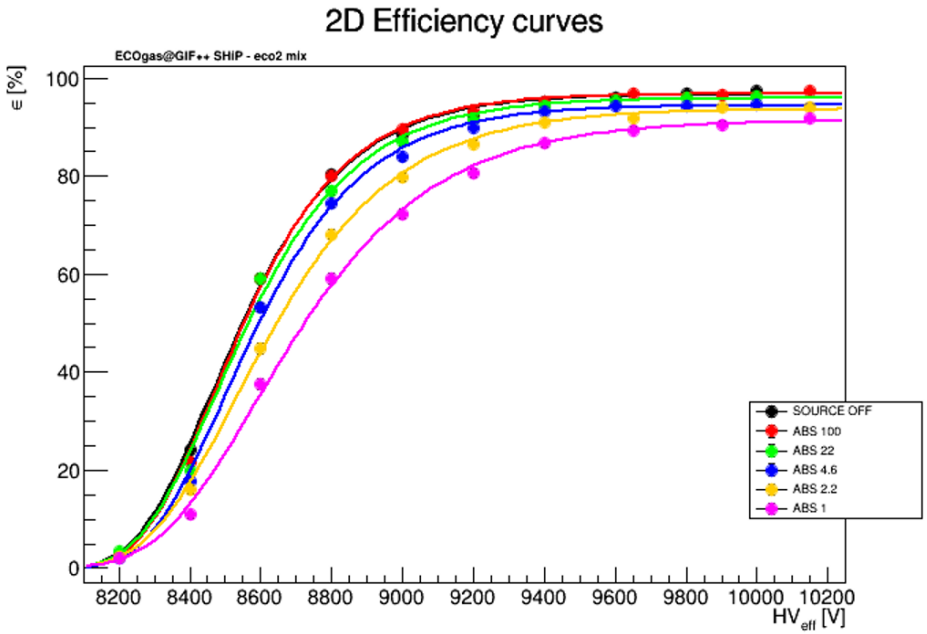
Efficiency degradation between source OFF and ABS 1: ~ 2%



Bakelite resistivity ~ 10^{11} Ω cm

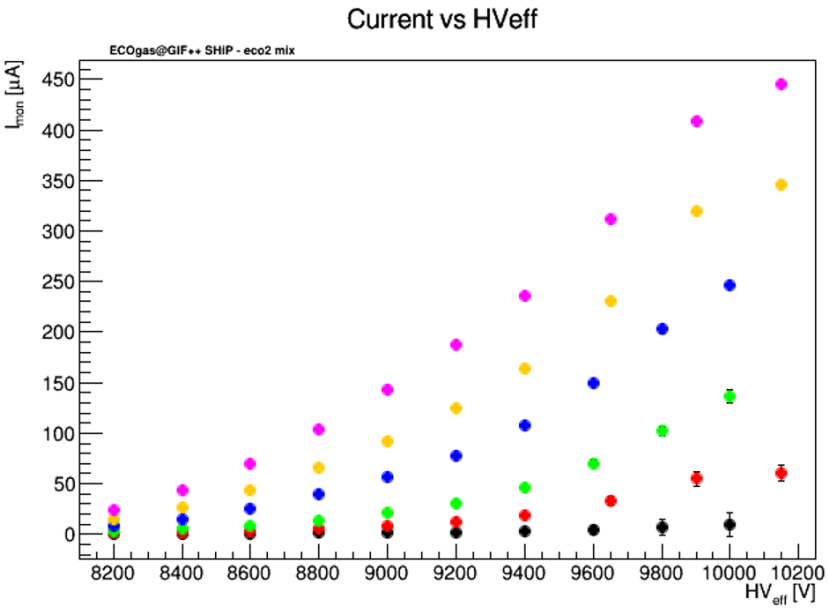
THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

GIF++



60% CO_2/ 35% HFO/ 4% iC_4H_{10} / 1% SF_6

Efficiency degradation between source OFF and ABS 1: < 5%



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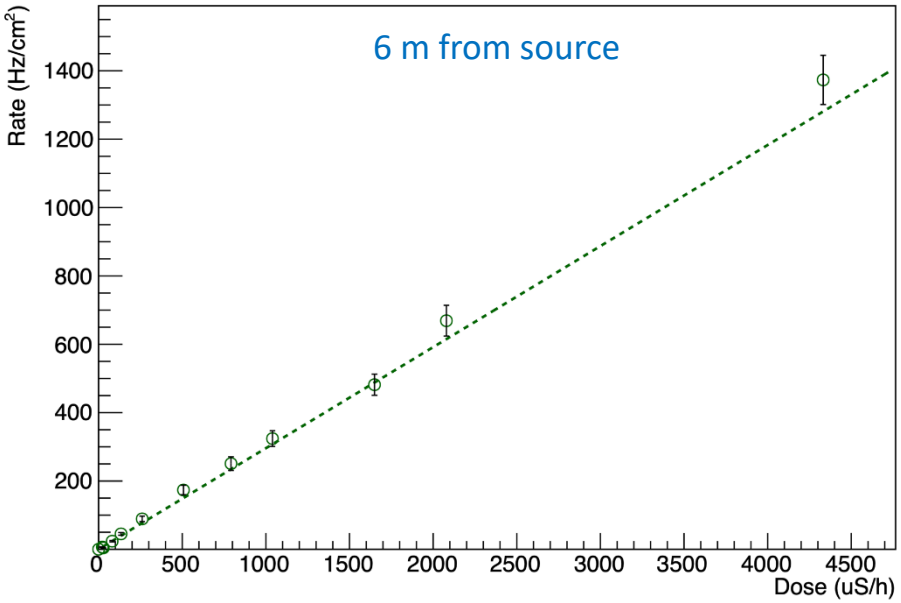
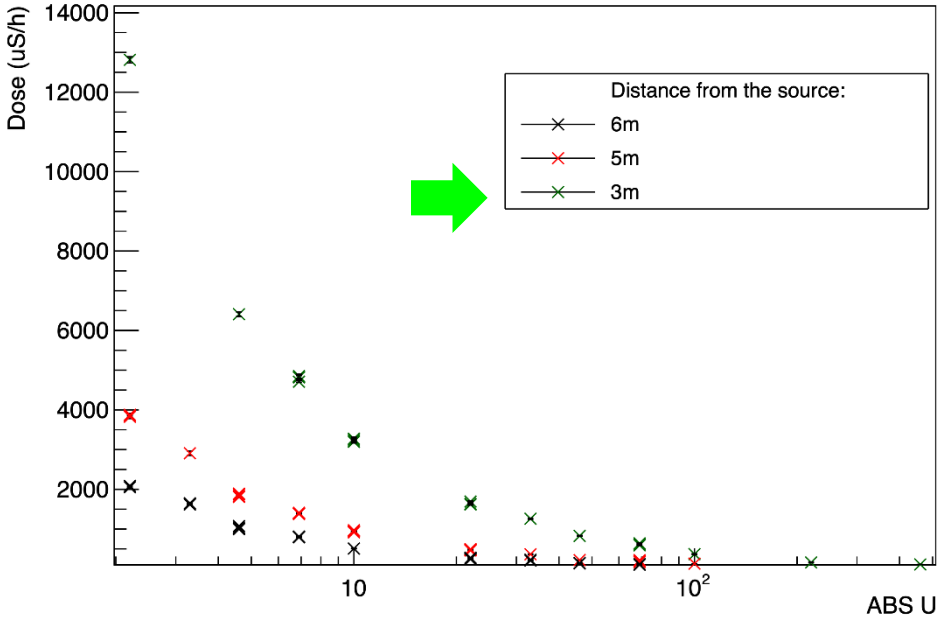
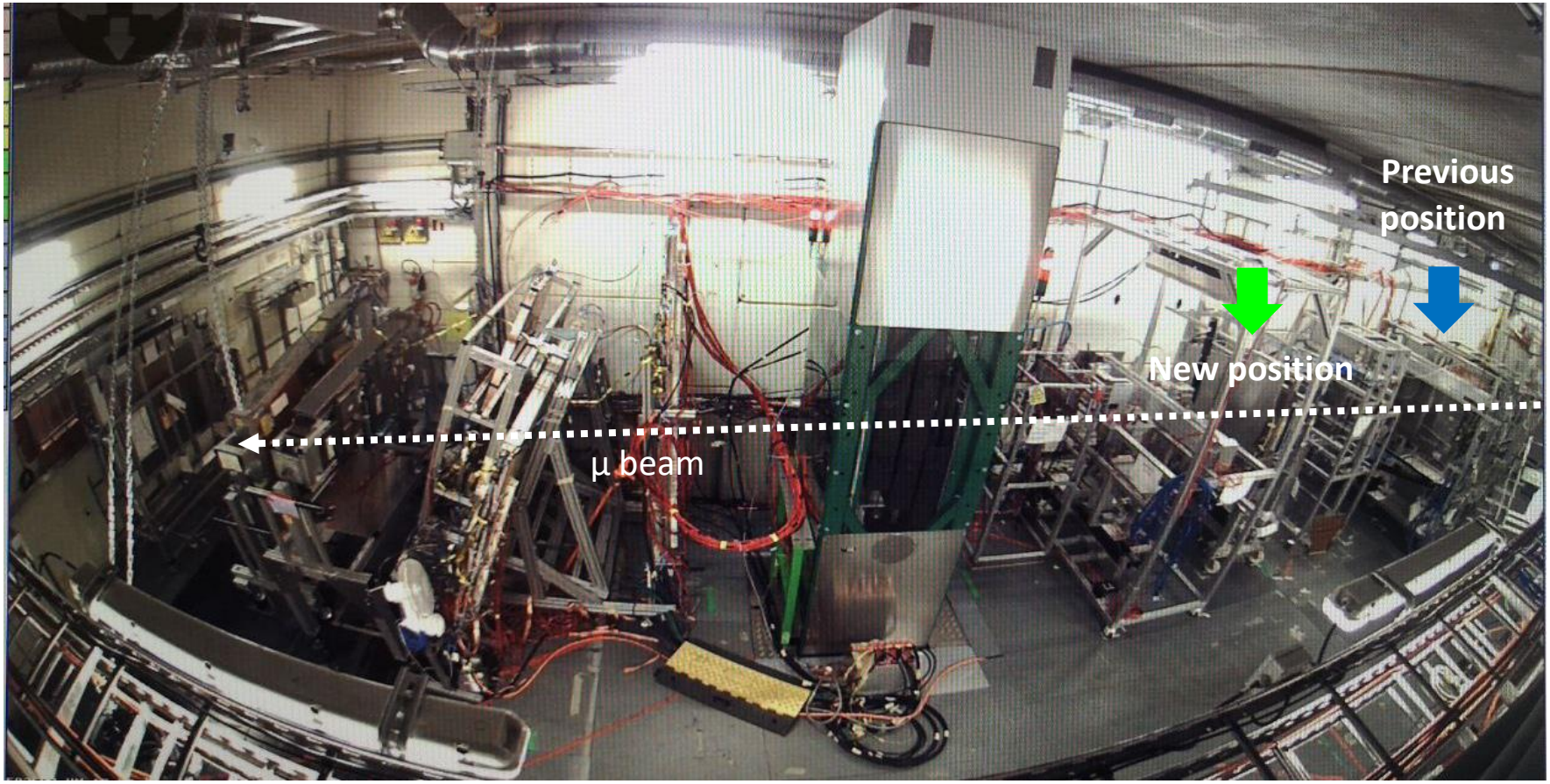




Moving towards the source (6 m → 3 m), test in preparation (July 2022)

THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES



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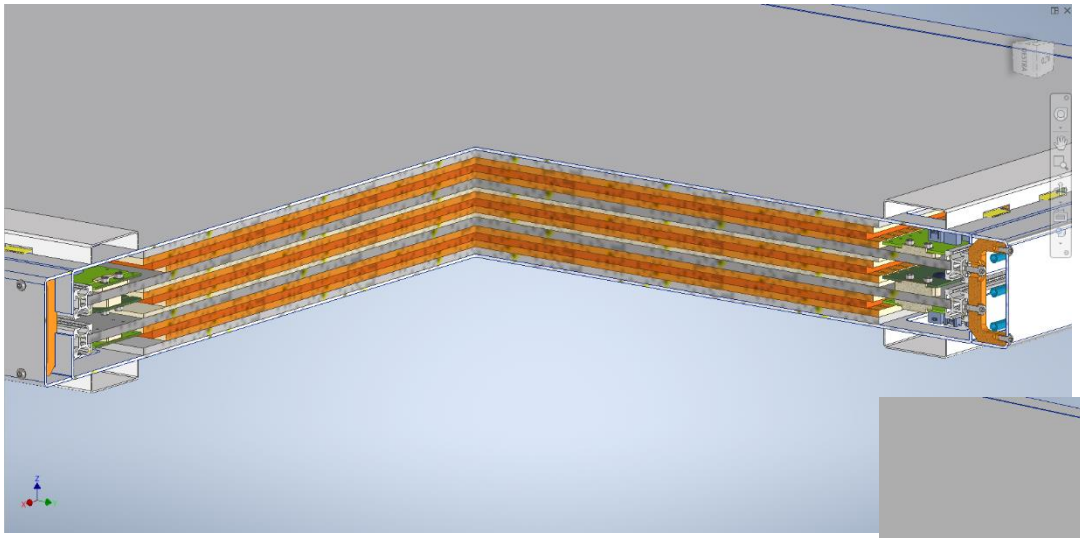
THIN RPCs IN COMBINATION WITH ECO-FRIENDLY GAS MIXTURES

Items to be further investigated and assessed:

- Production of fluorine radicals and HF
- Maximum rate capability
- Longevity

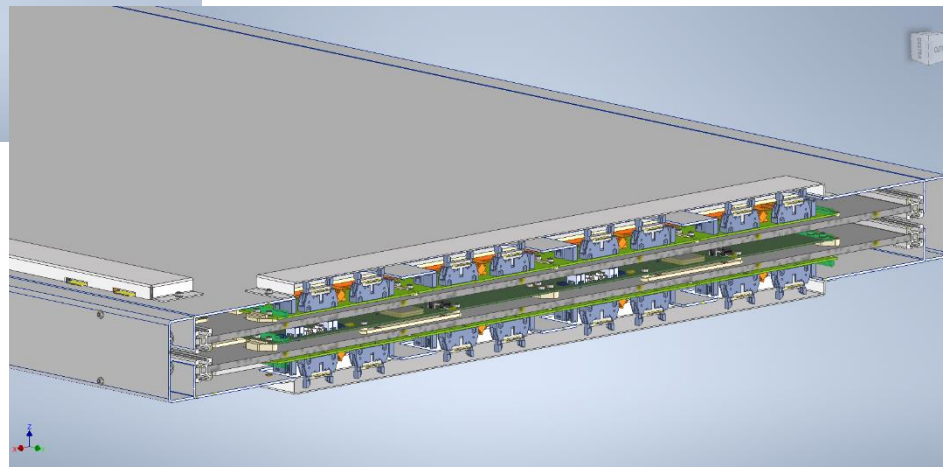
LHCb upgrade phase II @Bari

- **Design of an RPC triplet prototype with *thin* gap / electrodes operated with eco-friendly gas mixtures**



INFN Bari

External gaps: 1.6 mm, current electronics (FEERIC)
Internal gap: 1mm (synergy with CMS), FATIC2 chip



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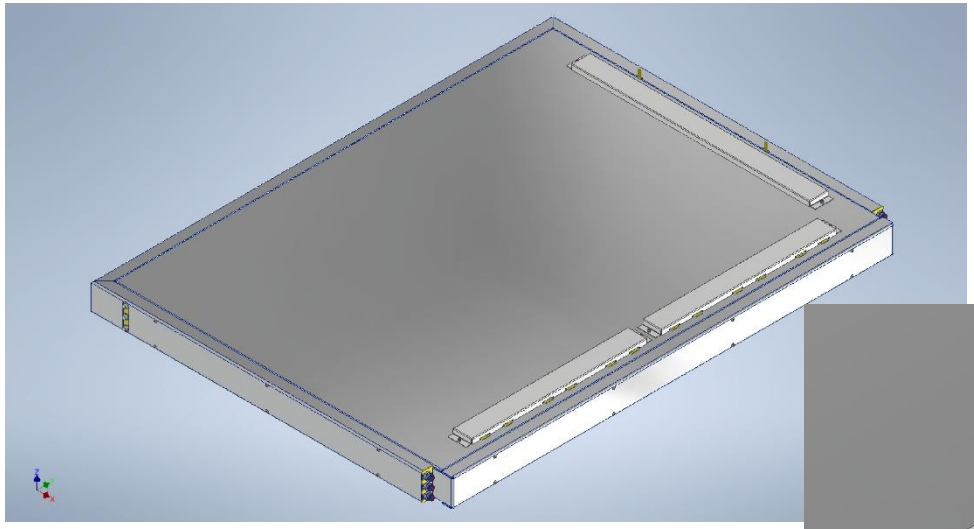
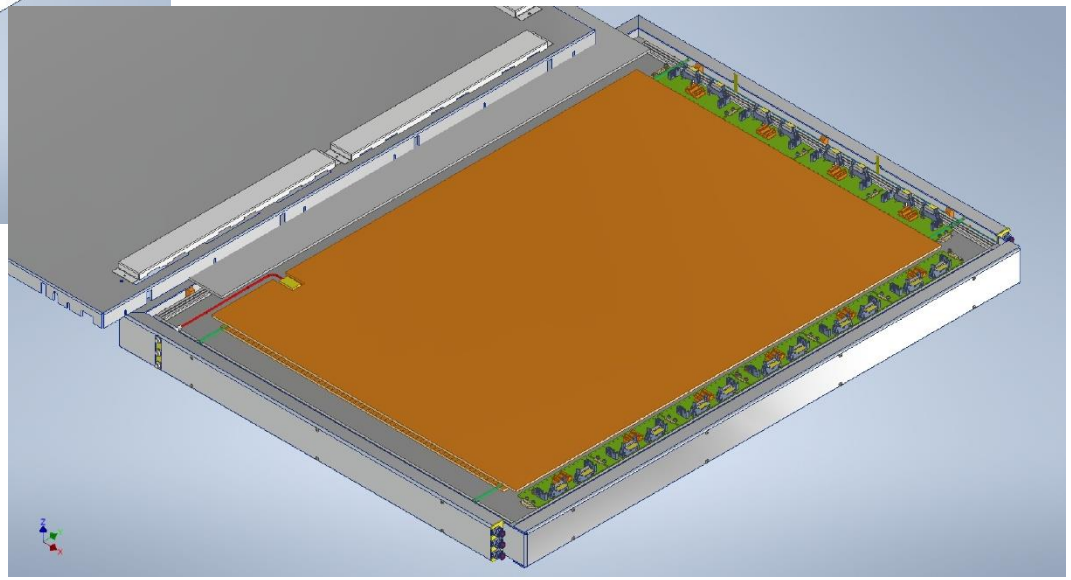


INFN Bari



Conclusions and Outlooks

R&D in progress on new-generation *thin* RPCs operated in avalanche mode with eco-friendly gas mixtures for high rate applications

Preliminary results on HFO/CO_2 gas mixture are promising, further tests in preparation to assess sustainable rate and longevity

Tests of thin RPCs with FATIC2 foreseen

Design of an RPC triplet prototype completed, construction by end of 2022