Performance of the SHiP RPCs with eco-gas

Ecogas@gif++ group meeting
25/11/2020

Bari SHiP-LHCb group

Bari RPC laboratory

Vertical telescope made of several RPCs:

- up to 8 OPERA chambers (~3x1 m^2) operated in streamer mode, used for triggering and tracking;
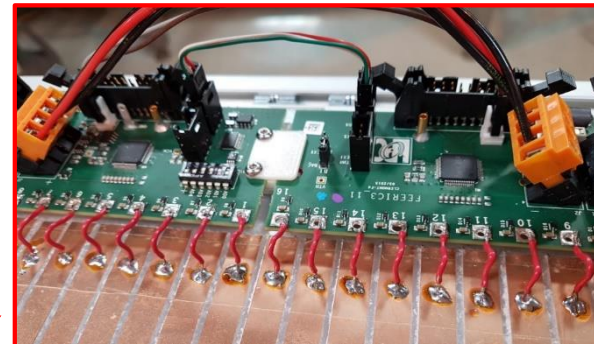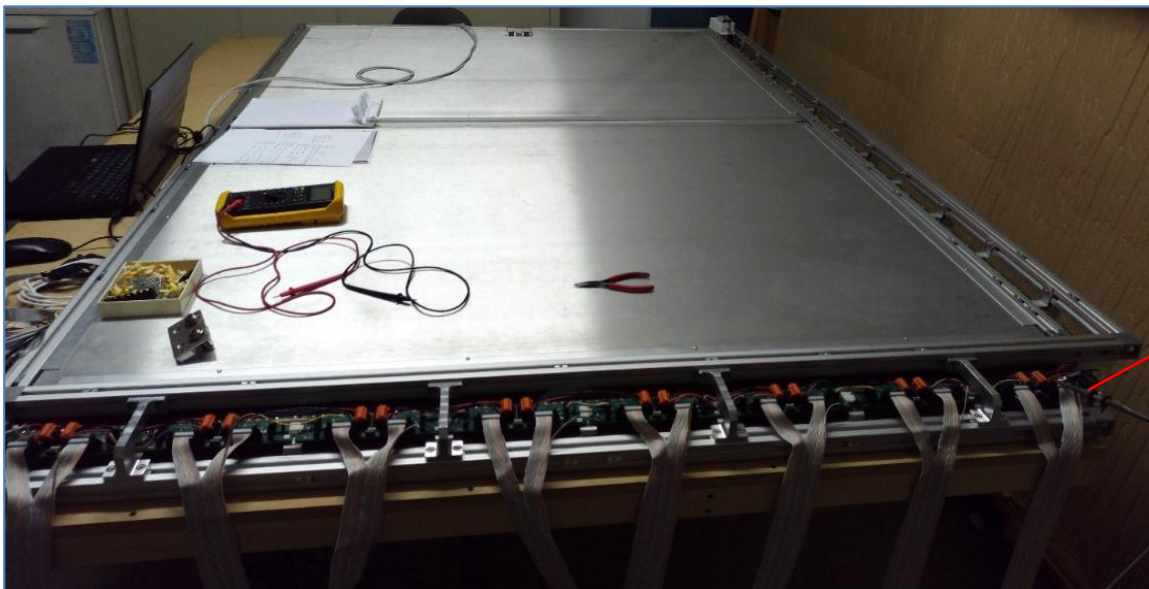- 1 avalanche RPC (~2x1 m^2, under test)

Two gas distribution systems: detectors can be operated/tested with different gas mixtures and/or pre-mixed gas

RPC under test in Bari

RPC for SHiP operated in avalanche mode:

- Gap width: 2mm
- readout by 2 panels of perpendicular strips: pitch ∼1cm
- Bakelite electrodes thickness: 2mm
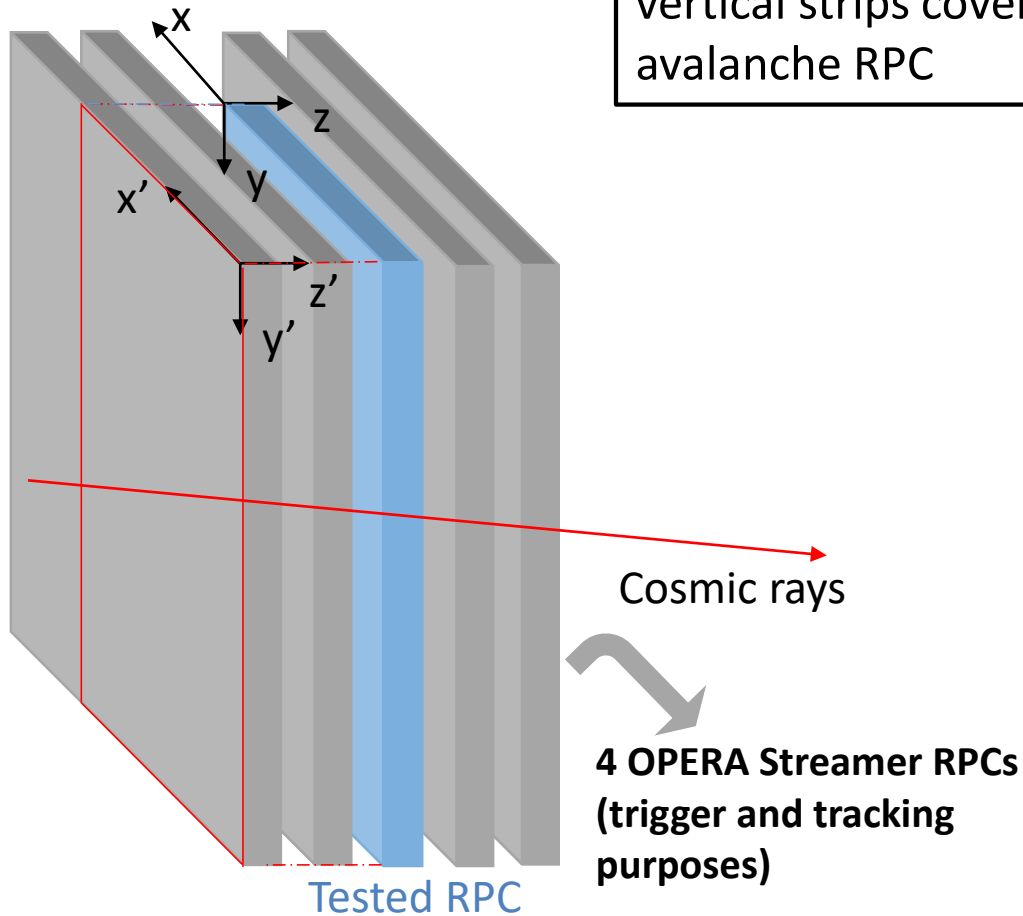- Active area: $(1.9×1.2)$ m^2

Strips readout by ALICE FEERIC ASICs [1], providing LVDS digital signals

[1] P. Dupieux, B. Joly, F. Jouve, S. Manen and R. Vandaële, *Upgrade of the ALICE muon trigger electronics*, 2014 *JINST* **9** C09013.
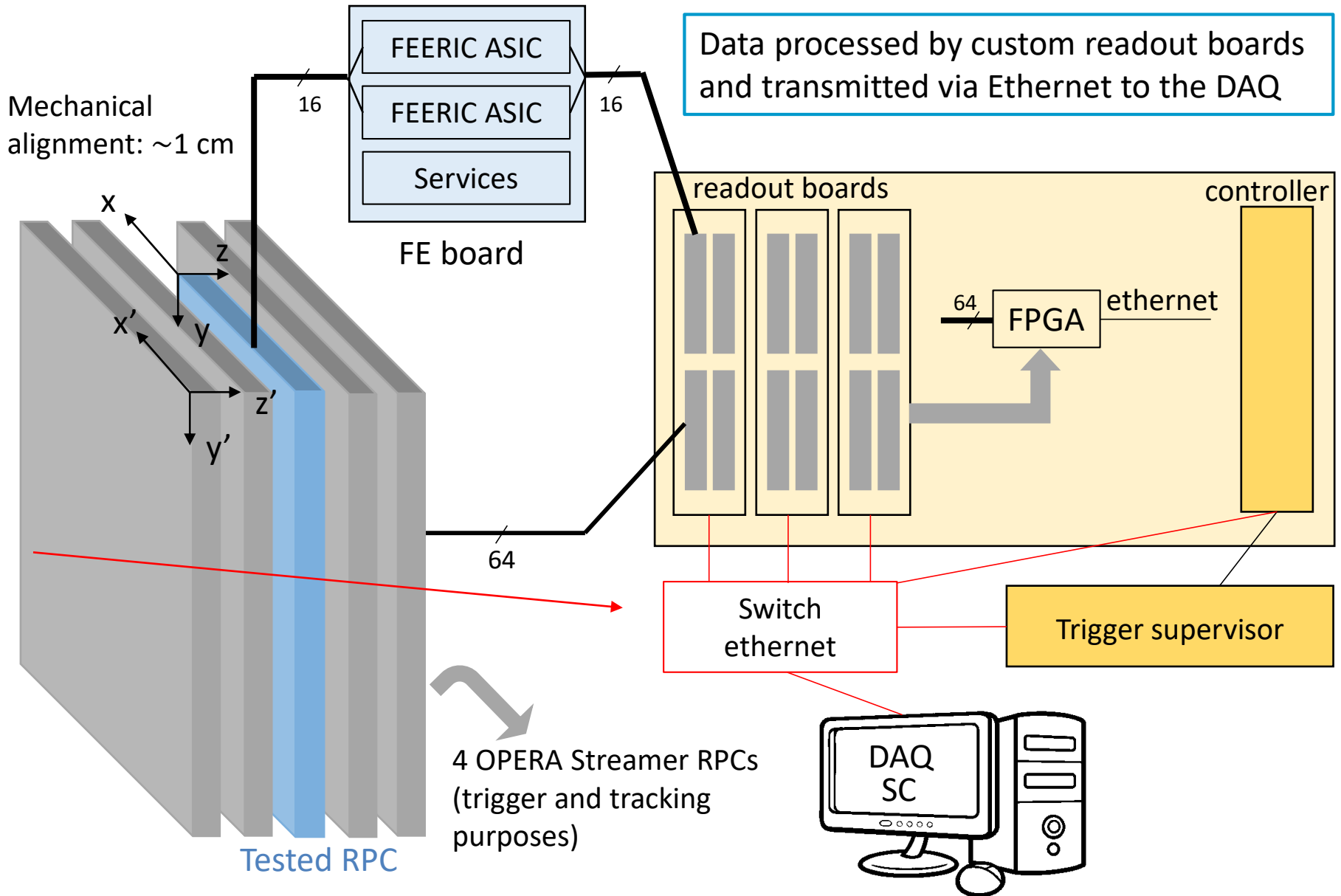
Experimental setup

Mechanical
alignment: ~1 cm

Trigger:
coincidence of the streamer RPC
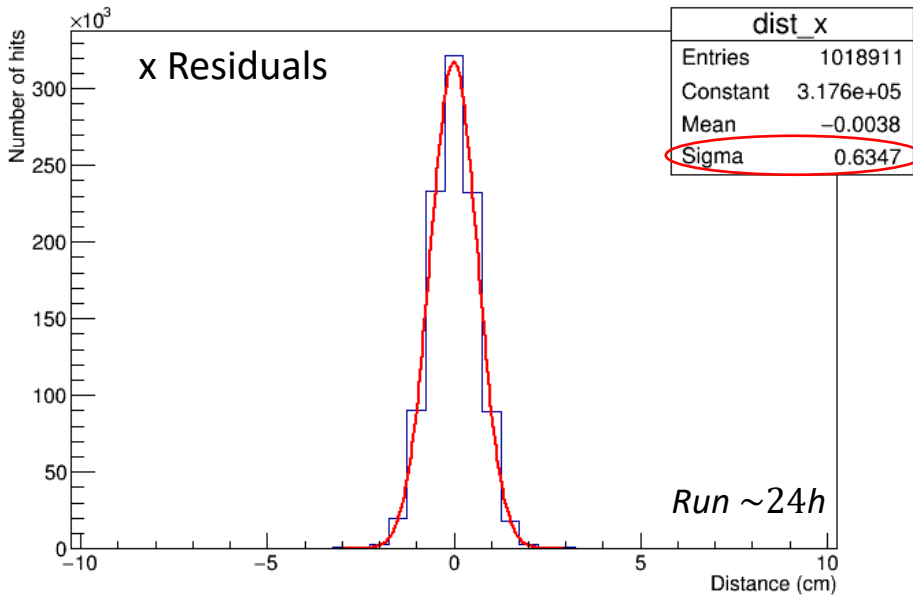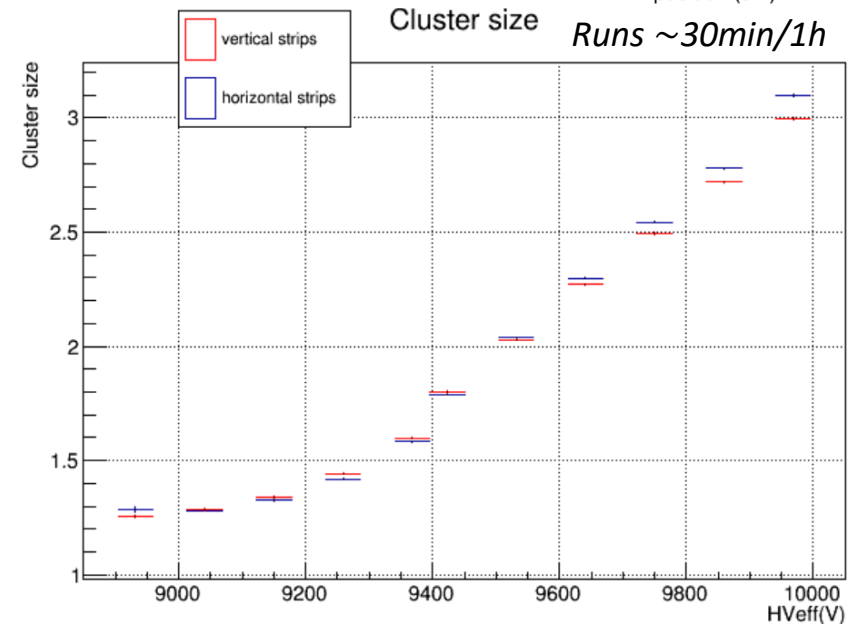vertical strips covering the area of the
avalanche RPC

x

z

x'

y

z'

y'

Cosmic rays

**4 OPERA Streamer RPCs
(trigger and tracking
purposes)**

Tested RPC

3

Mechanical alignment: ~1 cm

FEERIC ASIC

FEERIC ASIC

Services

FE board

16

16

Data processed by custom readout boards and transmitted via Ethernet to the DAQ

readout boards

controller

64

FPGA

ethernet

64

Switch ethernet

Trigger supervisor

DAQ SC

4 OPERA Streamer RPCs (trigger and tracking purposes)

Tested RPC

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RPC performance with standard gas mixture

Standard gas mixture: 95% $R134a$ - 4.5% iso - 0.5% SF_6

x Residuals

Run ~24h

dist_x	
Entries	1018911
Constant	3.176e+05
Mean	−0.0038
Sigma	0.6347

efficiency scatter plot *@9750 V*

Run ~24h

Efficiency   *Runs ~30min/1h*

- x efficiency
- y efficiency
- 2D efficiency

Cluster size   *Runs ~30min/1h*

- vertical strips
- horizontal strips

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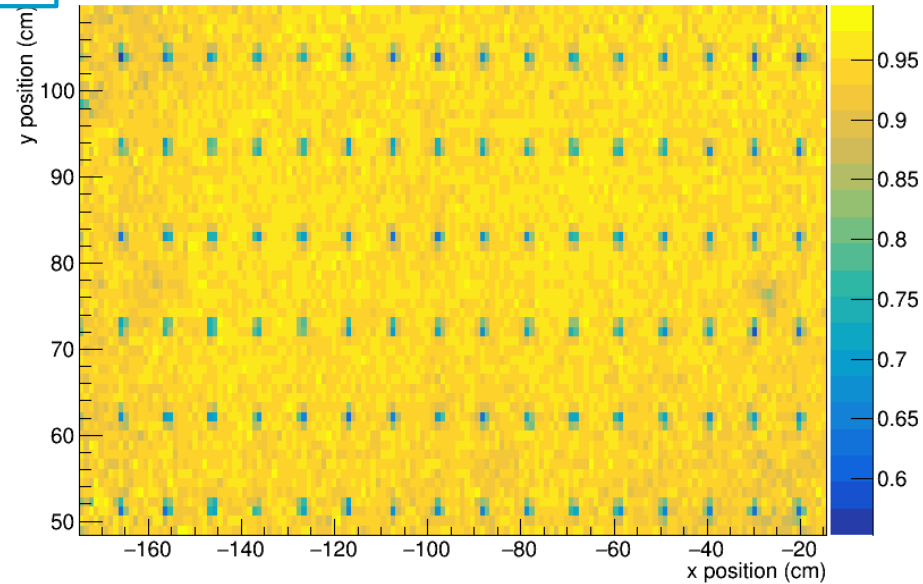
Eco-friendly gas mixtures tested

- First step: different concentrations of R134a replaced with HFO-1234ze

HFO-based mixtures:

1) 84.5% R134a - 10% HFO (GWP=1329)

2) 74.5% R134a - 20% HFO (GWP=1186)

3) 69.5% R134a - 25% HFO (GWP=1115)

4) 0% R134a – 94.5% HFO (GWP=125)
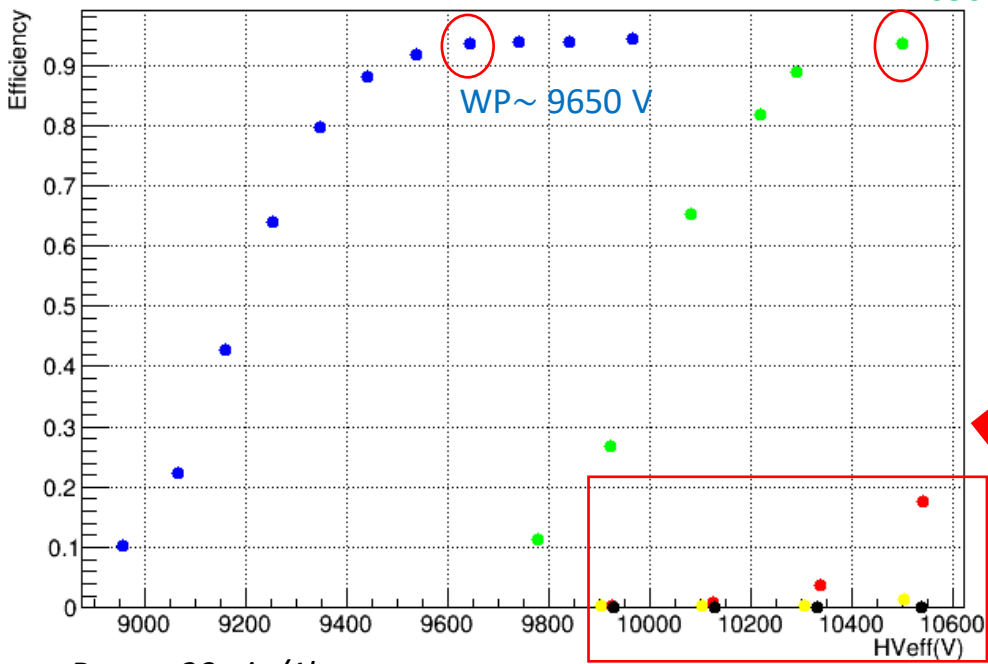
WP significately increases

- Second step: CO2 addition in order to reduce the WP

HFO/CO2 mixtures:

5) 25% HFO - 20% R134a - 49.5% CO_2 (GWP=408)

6) 25% HFO - 0% R134a - 69.5% CO_2 (GWP=122)
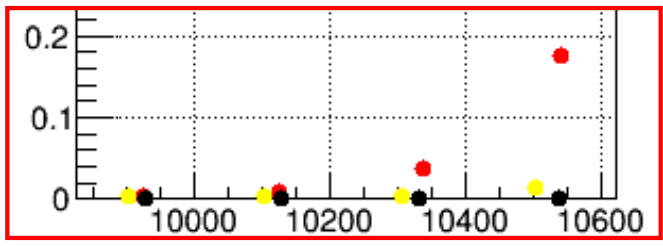
RPC performance with HFO-based mixtures

2D efficiency

WP~ 10500 V

WP~ 9650 V

Efficiency

HVeff(V)

Runs ~30min/1h

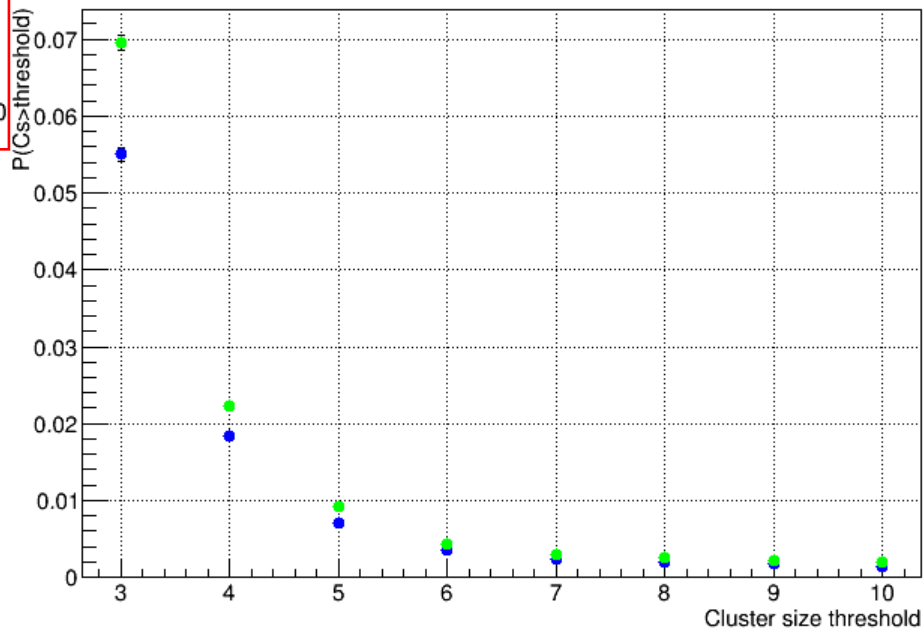Probability cluster size > Threshold (horizontal strips)

P(Cs>threshold)

Cluster size threshold

Standard gas mixture:
94.5% R134a - 0% HFO- 5% iso - 0.5% SF_6
84.5% R134a - 10% HFO - 5% iso - 0.5% SF_6
74.5% R134a - 20% HFO - 5% iso - 0.5% SF_6
69.5% R134a - 25% HFO - 5% iso - 0.5% SF_6
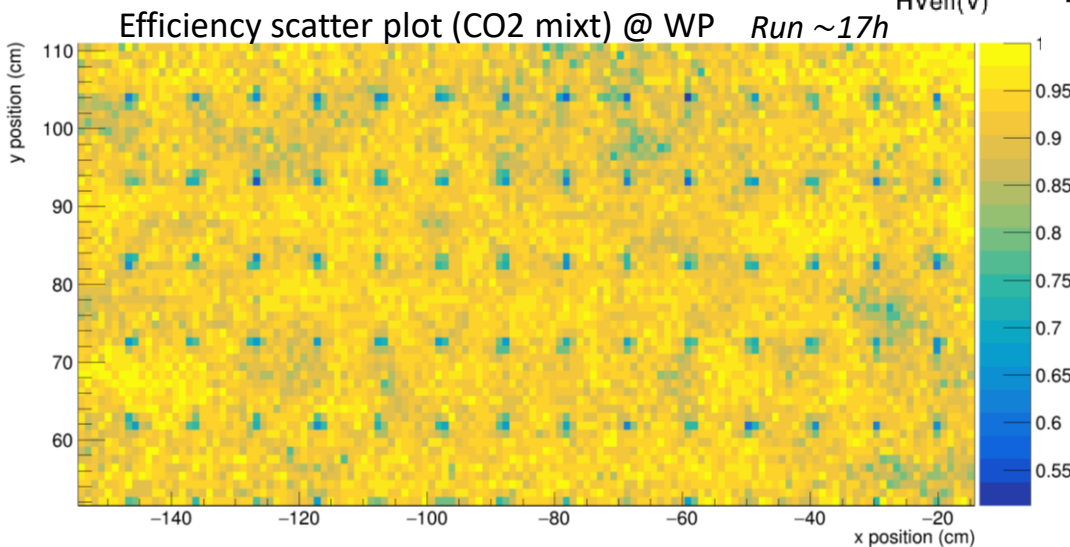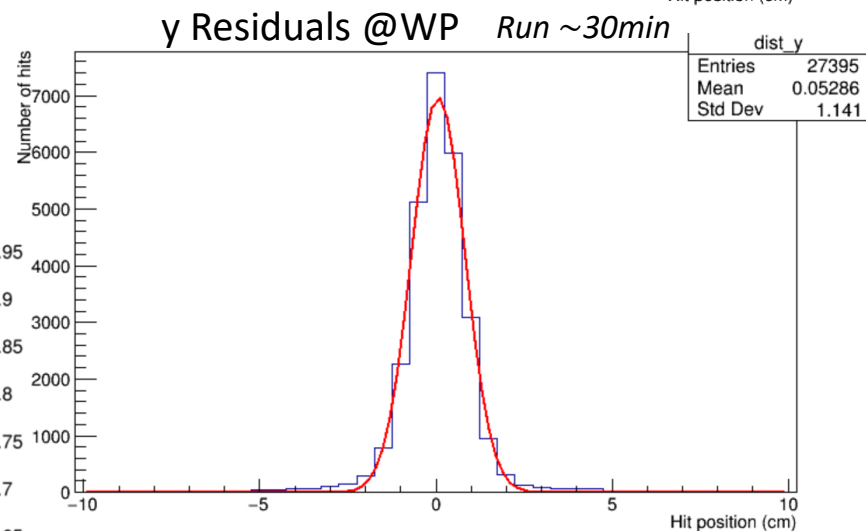0% R134a - 94.5% HFO - 5% iso - 0.5% SF_6

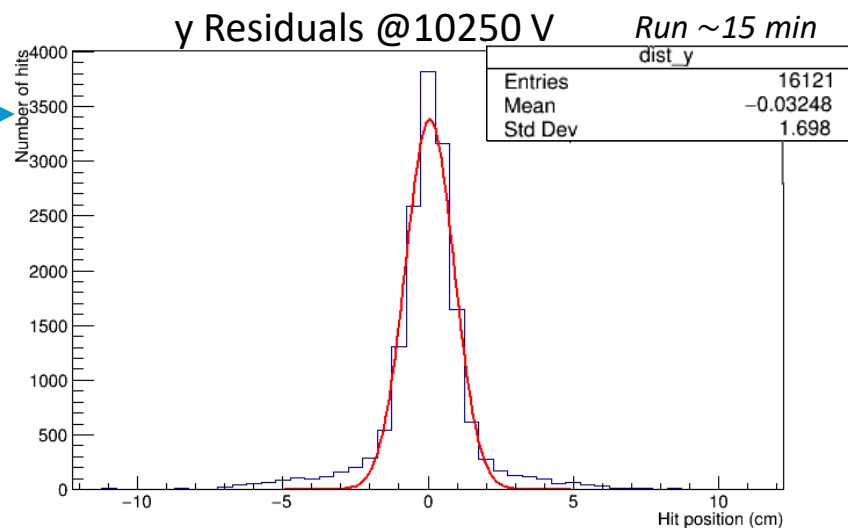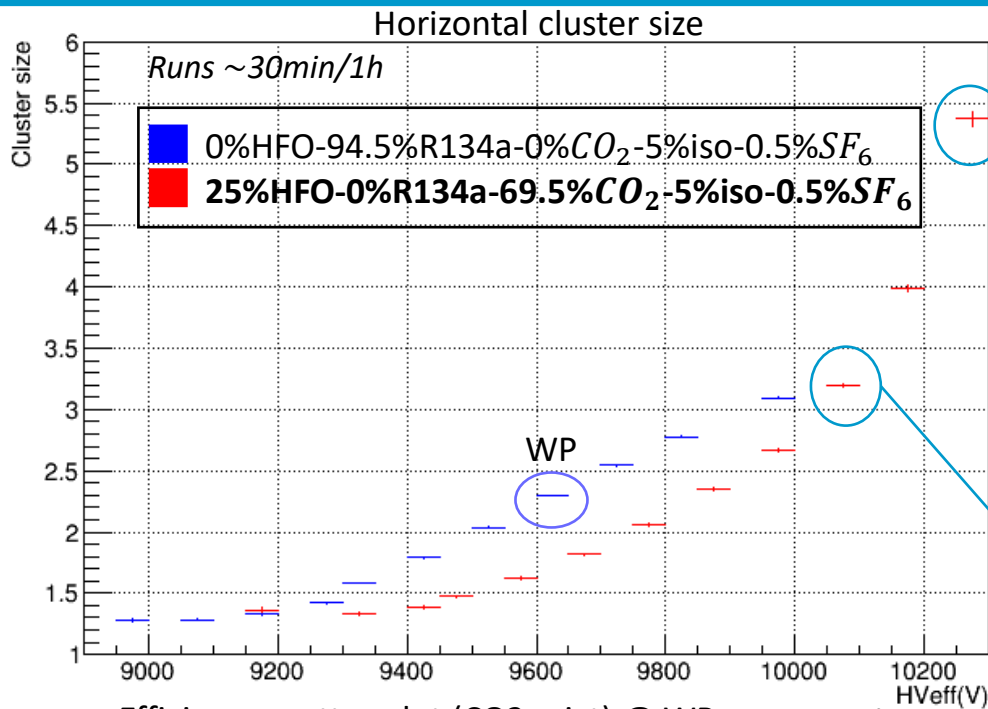# RPC performance with HFO/CO2 mixtures

Horizontal cluster size

Runs ~30min/1h

$0\%HFO\text{-}94.5\%R134a\text{-}0\%CO_2\text{-}5\%iso\text{-}0.5\%SF_6$

$25\%HFO\text{-}0\%R134a\text{-}69.5\%CO_2\text{-}5\%iso\text{-}0.5\%SF_6$

WP

y Residuals @10250 V   *Run ~15 min*

dist_y	
Entries	16121
Mean	−0.03248
Std Dev	1.698

Efficiency scatter plot (CO2 mixt) @ WP   *Run ~17h*

y Residuals @WP   *Run ~30min*

dist_y	
Entries	27395
Mean	0.05286
Std Dev	1.141

A cluster is considered as correlated to the reconstructed track if it is within 10 cm from the expected position

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RPC performance with HFO/CO2 mixtures

Runs ~30min/1h   2D efficiency

WP~ 9650 V   WP~ 10100 V   WP~ 10300 V

Standard gas mixture:
0% HFO- 94.5% R134a - 0% CO_2 - 5% iso - 0.5% SF_6
25% HFO - 20% R134a - 49.5% CO_2 - 5% iso - 0.5% SF_6
25% HFO - 0% R134a - 69.5% CO_2 - 5% iso - 0.5% SF_6
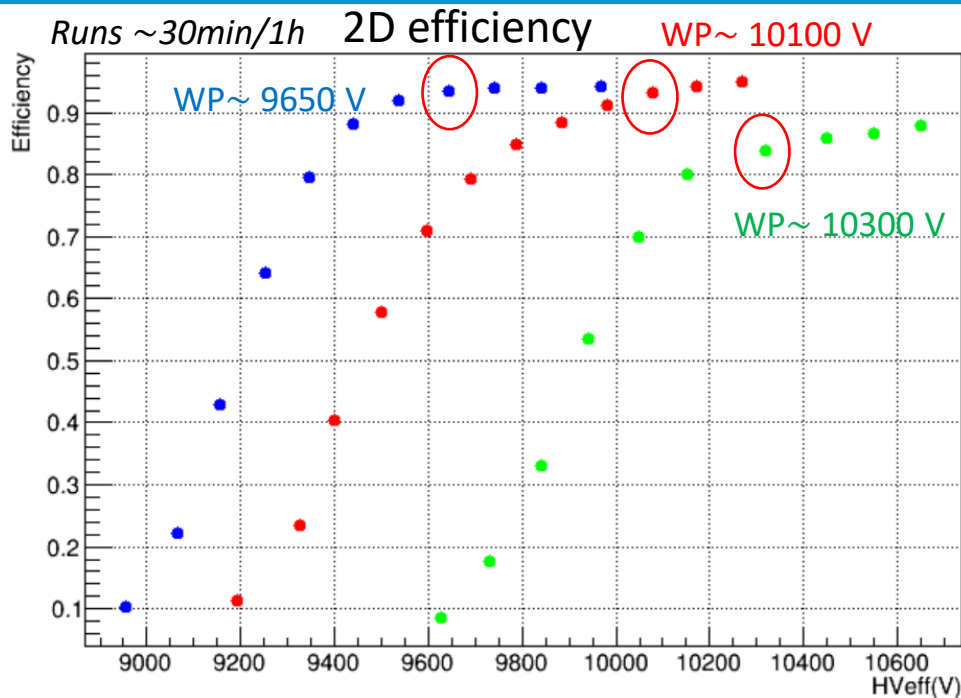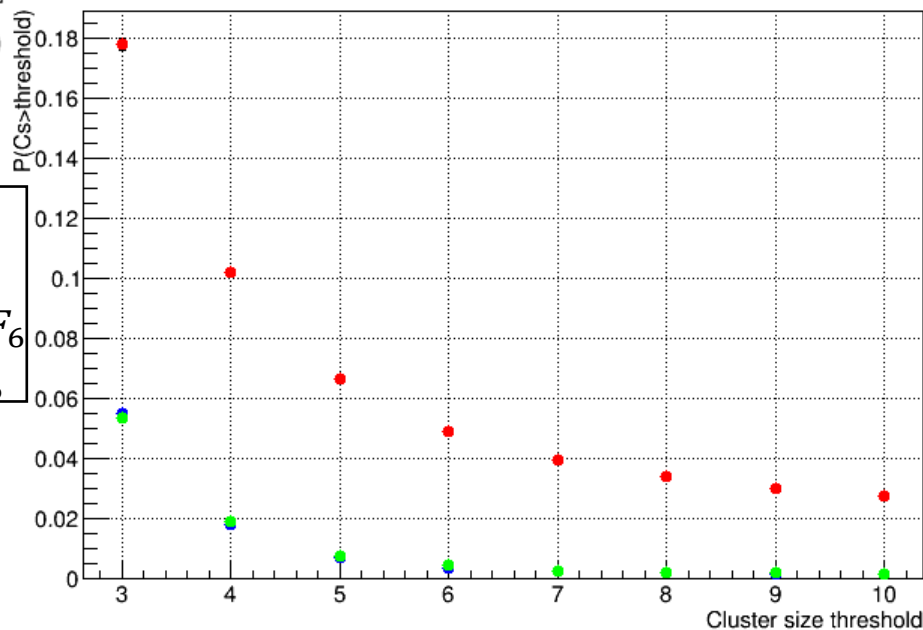
Probability cluster size > Threshold (horizontal strips)

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Summary

Gas mixture	GWP	WP (V)	2D Eff	Av. cluster size (H)	Prob Cs > 3 (H)
0% HFO- 94.5% R134a – 0% CO2- 5% iso - 0.5% SF6 (standard)	1471	9650	94%	2.3	5.5%
10% HFO- 84.5% R134a – 0% CO2- 5% iso - 0.5% SF6	1329	10500	94%	2.4	7%
25% HFO - 20% R134a - 49.5% CO2- 5% iso - 0.5% SF6	408	10300	84%	2.2	5.4%
25% HFO - 0% R134a - 69.5% CO2- 5% iso - 0.5% SF6	122	10100	93.5%	3.2	18%

Thank you for your attention!

Tracking, alignment and corrections

- Analyze the best model described by 1,2, 3 predictors;

- Model performance evaluation (residuals, outliers, cross validation…);

- Compare the 3 models obtained and choose the best;

- Correction applied (process repeated also for y).

Main criteria

Num. of predictors

Statistics	Objective	Equation
Mallows's C_p	Minimize	$C_p = \frac{1}{n}(RSS + 2d\hat{\sigma})$
Akaike Information Criterion	Minimize	$AIC = \frac{1}{n\hat{\sigma}^2}(RSS + 2d\hat{\sigma}^2)$
Bayesian Information Criterion	Minimize	$BIC = \frac{1}{n}(RSS + log(n)d\hat{\sigma}^2)$
adjusted R^2	Maximize	$R_{adj}^2 = 1 - \frac{RSS/n-d-1}{TSS/(n-1)}$

Example: k-fold cross validation for:
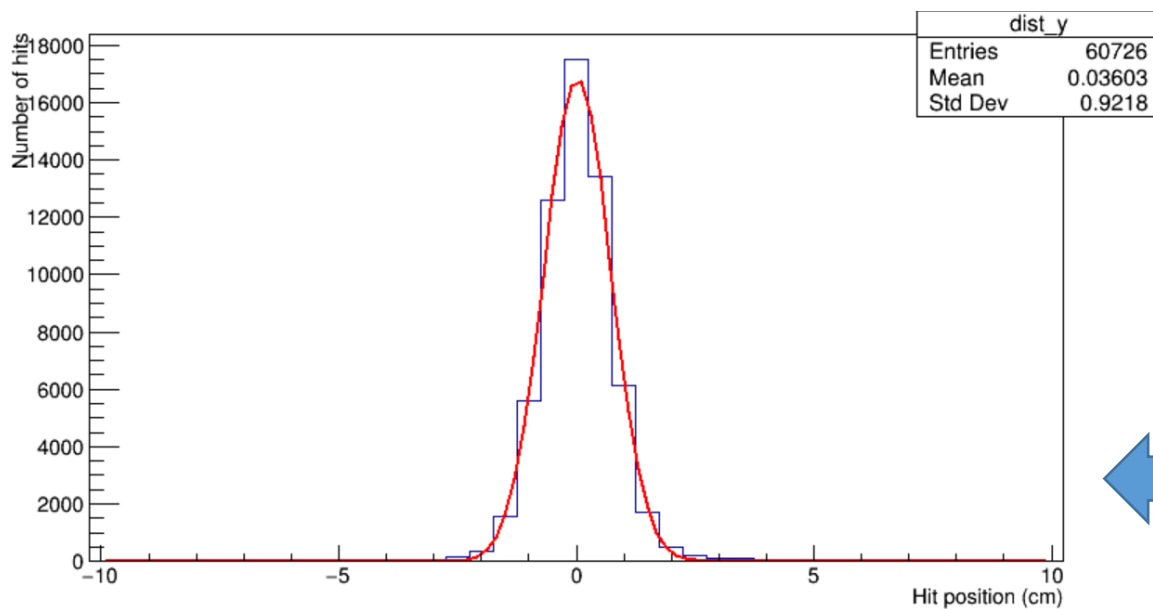$$x_{meas} = B_0 + B_1 \cdot x_{exp} + B_2 \cdot x_{exp} \cdot slopex$$

results:

RMSE	Rsquared	MAE
1.830243	0.9979425	0.6071656

$RMSE = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \hat{y}_j)^2}$
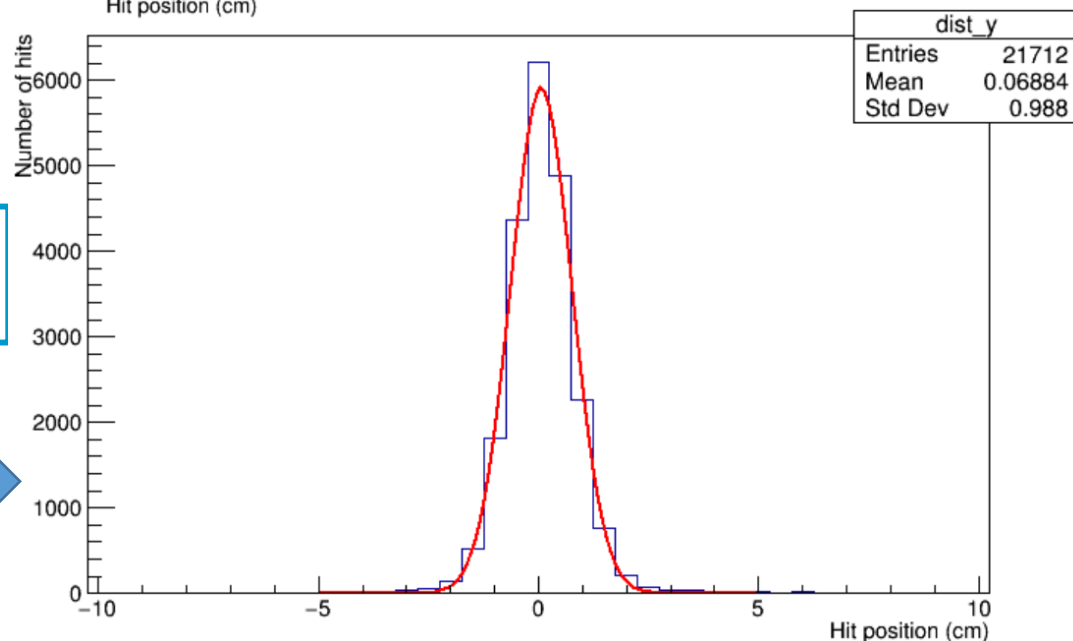
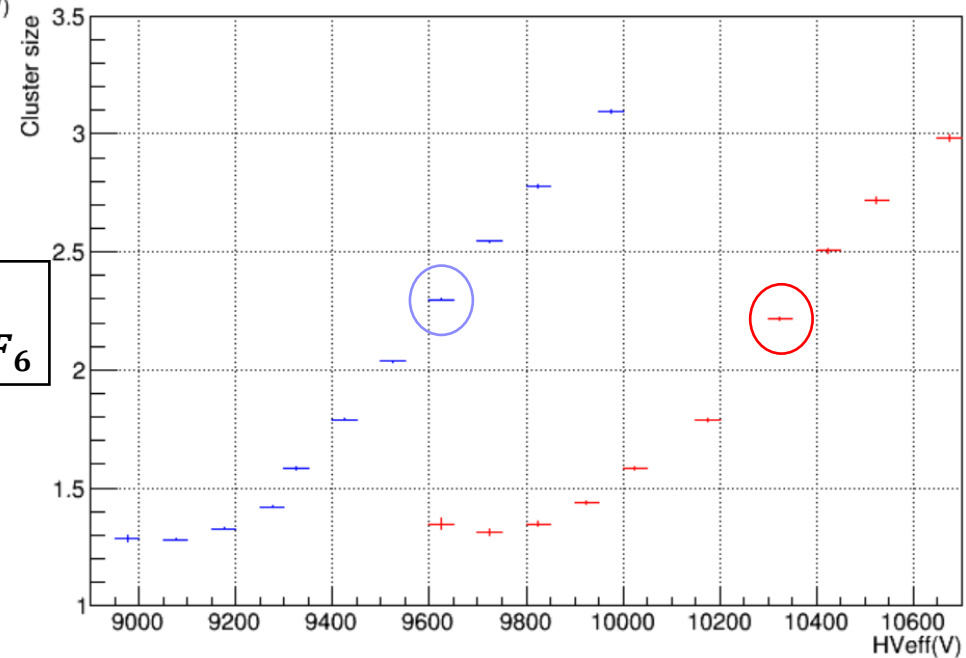$MAE = \frac{1}{n}\sum_{j=1}^{n}|y_j - \hat{y}_j|$
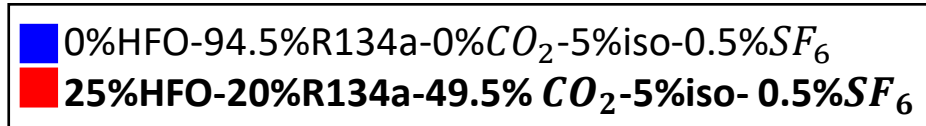
10% HFO - 84.5% R134a
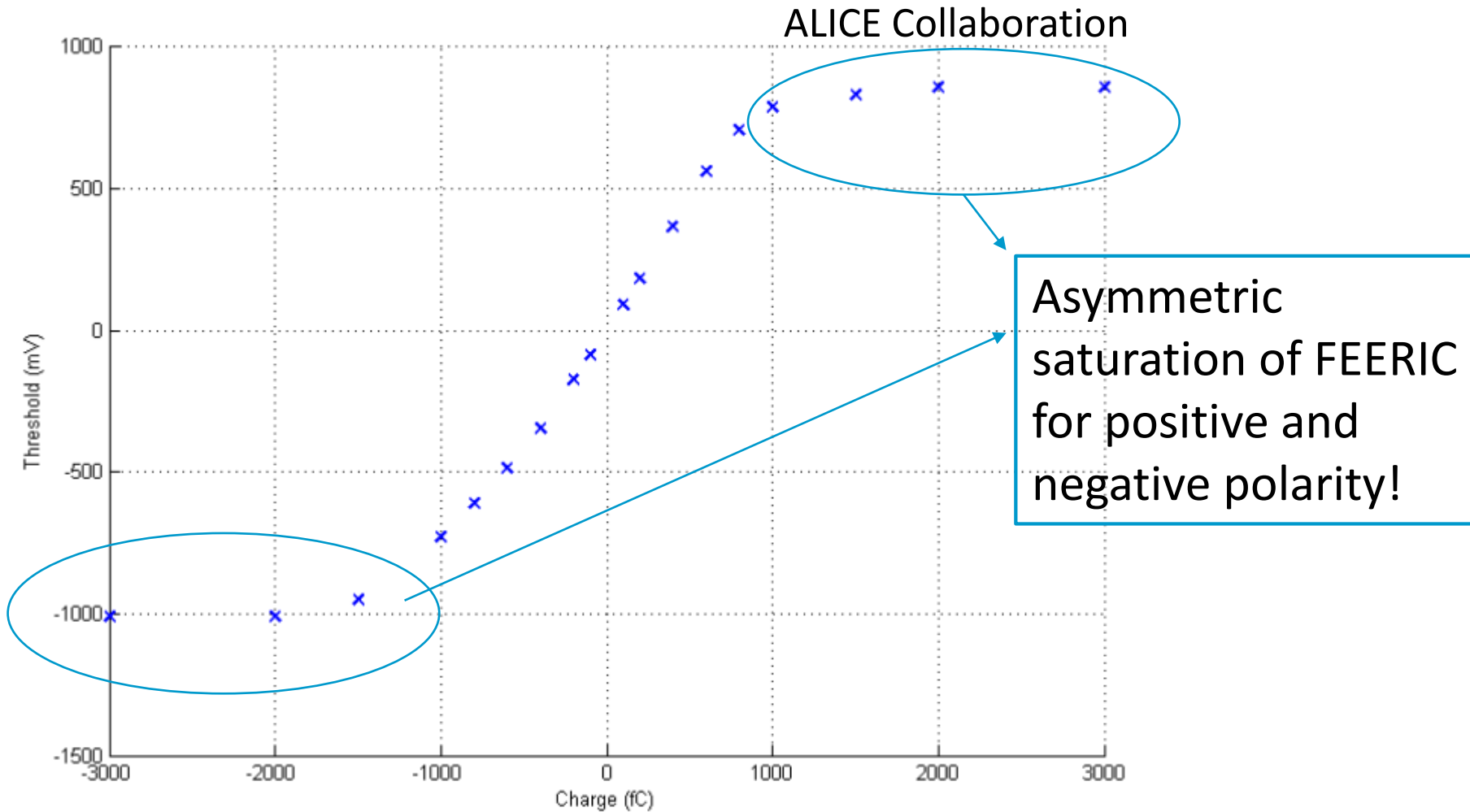5% iso - 0.5% SF_6
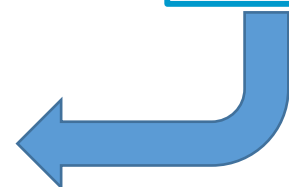
25% HFO - 20% R134a - 49.5% CO_2
5% iso - 0.5% SF_6

Cluster size distribution for other mixtures

Legend (top plot):
- 0%HFO-94.5%R134a-5%iso-0.5%SF_6
- **10%HFO-84.5%R134a-5%iso- 0.5%SF_6**

Legend (bottom plot):
- 0%HFO-94.5%R134a-0%CO_2-5%iso-0.5%SF_6
- **25%HFO-20%R134a-49.5% CO_2-5%iso- 0.5%SF_6**

FEERIC features

ALICE Collaboration

Asymmetric saturation of FEERIC for positive and negative polarity!
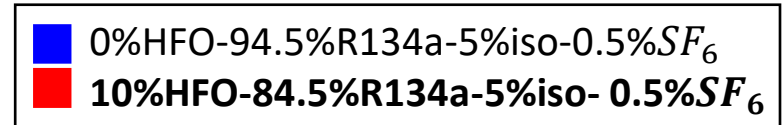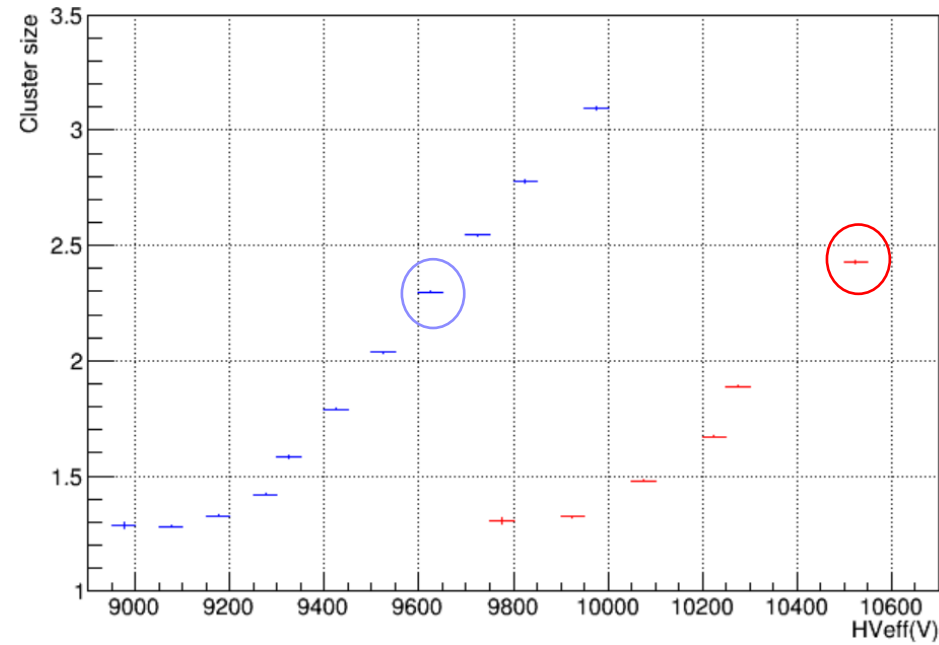
Threshold for 50% efficiency vs threshold (simulation)