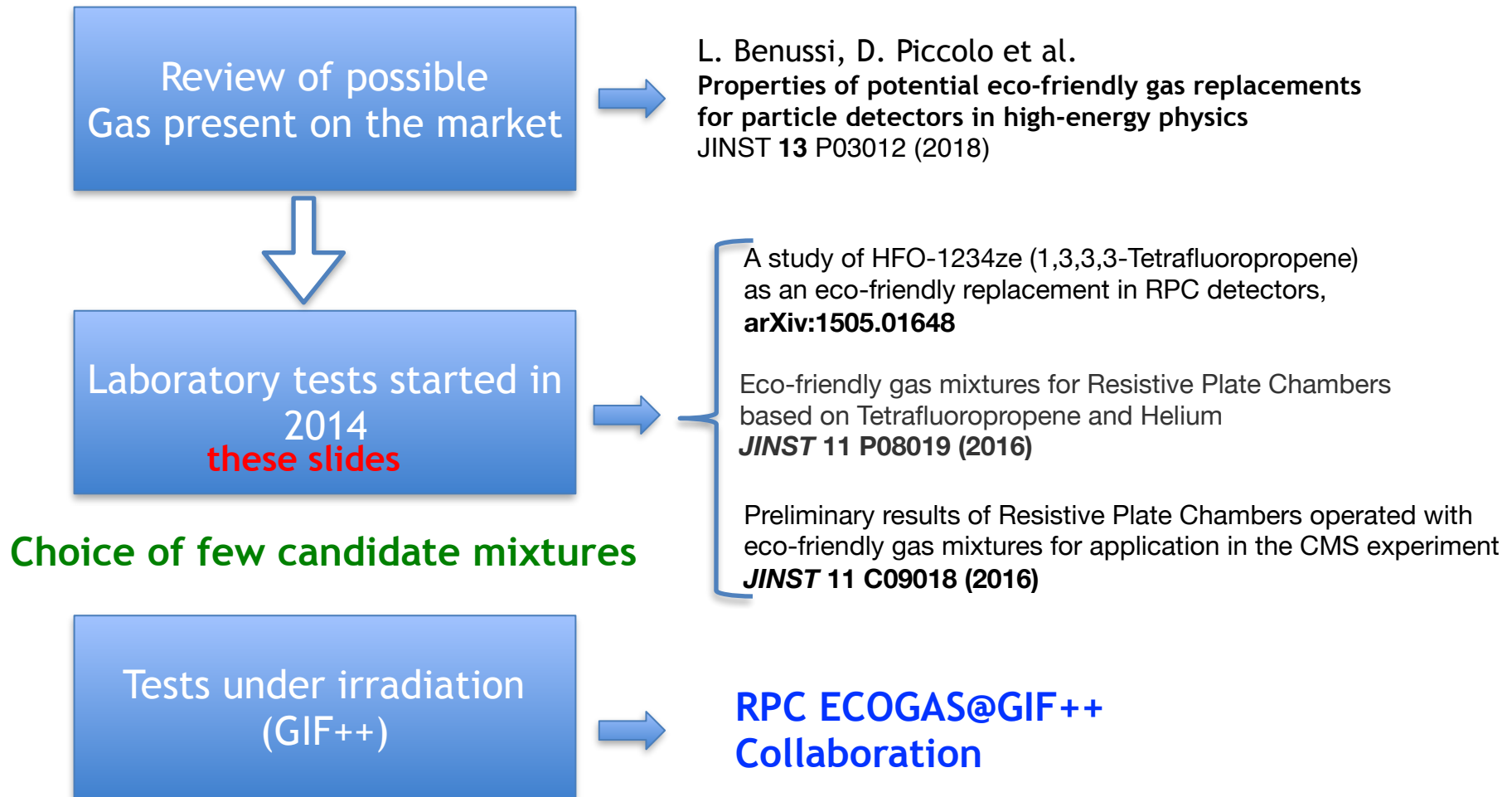


LNf Test results of Resistive Plate Chambers operated with eco-friendly gas mixtures for application in the CMS experiment

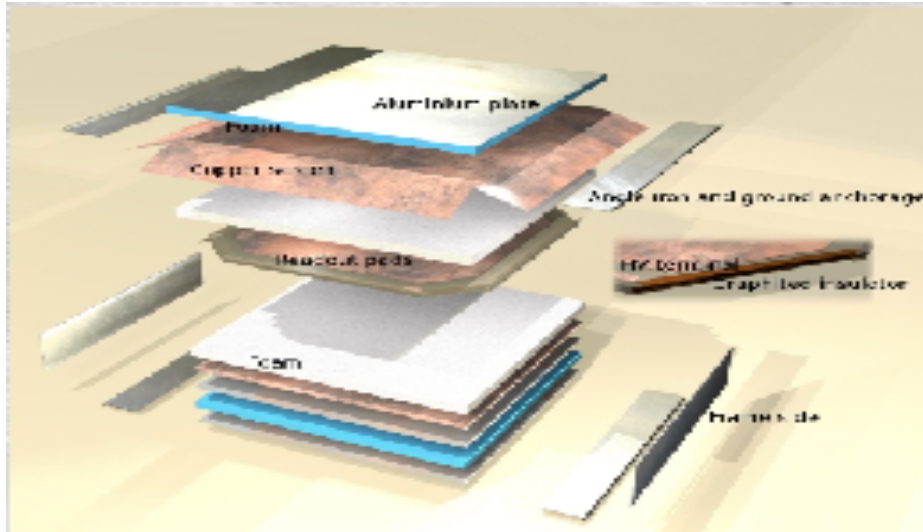
D. Piccolo for CMS LNf group

dpiccolo@lnf.infn.it

The search for an ecogas replacement at LNF



S. Bianco, L. Benussi, D. Piccolo, L. Passamonti, D. Pierluigi, A. Russo



- single gap RPCs, 2 mm wide gas gap
- 50 x 50 cm²
- Double Pad readout
 - partial cancellation on single mode noise
 - Expected about x2 induced signal charge
- Scintillator layers on top and bottom for trigger

Data taken with oscilloscope

- **Gas chromatograph: for gas mixture analysis**
- 4 channels Oscilloscope lecroy104xi (5 Gsamples, 1 GHz): for signal readout
 - Full digitization of signal

Frascati test station: Notes on the analysis

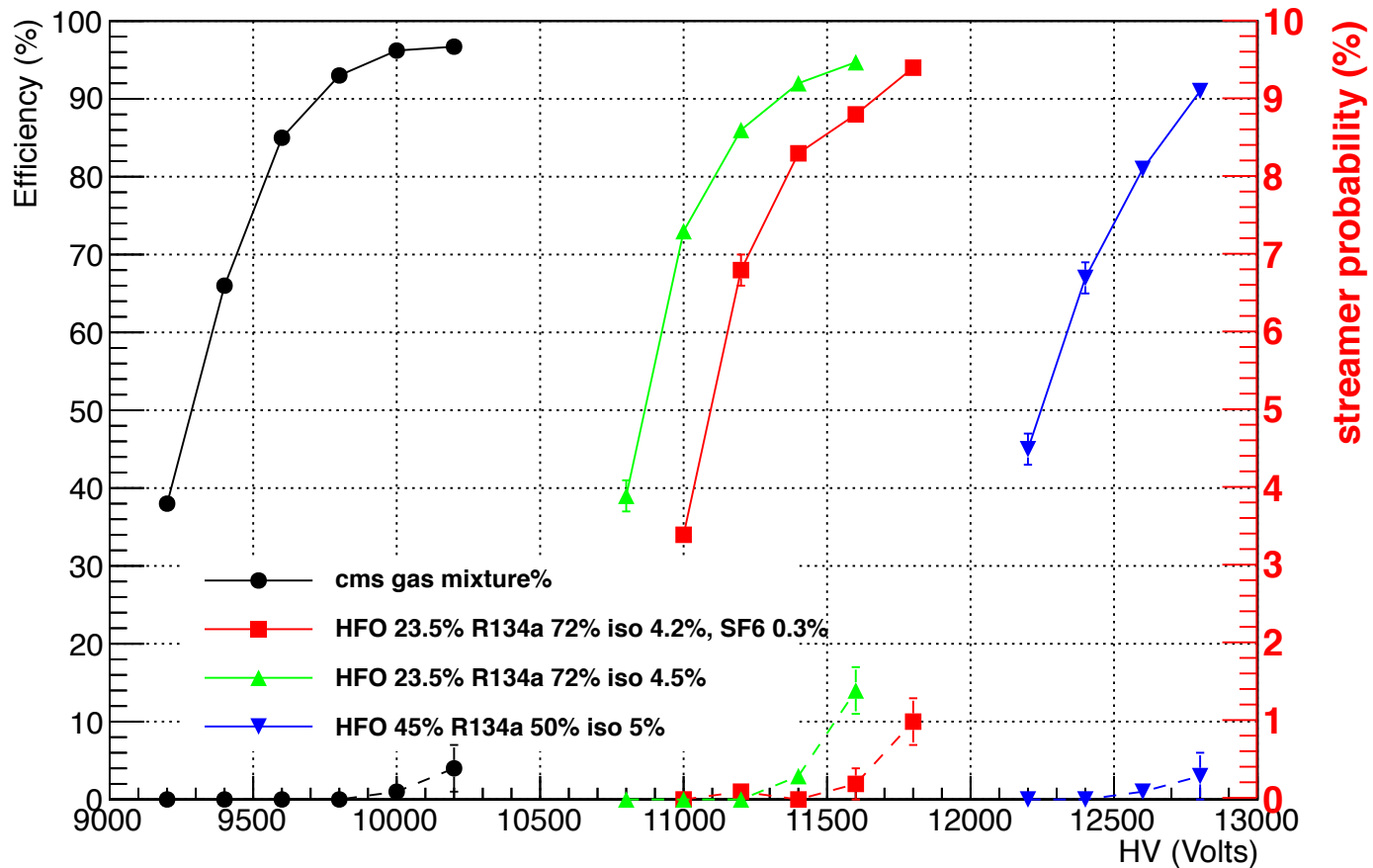


- Threshold used for analysis of RPC:
 - Efficiency: $Q_{\text{induced}} > 300 \text{ fC}$ (to be divided for ~ 2 because of double pad readout) and $|V_{\text{max}}| > 0.4 \text{ mV}$ (*similar to CMS Front electronic threshold*)
 - Streamer: $Q_{\text{induced}} > 40 \text{ pC}$ (to be divided for ~ 2 because of double pad readout)
- HV corrected at $P_0=990 \text{ mbar}$, $T_0 = 20 \text{ degrees}$
- Time resolution is extracted from the difference between time over threshold (0.8 mV) of trigger RPC and test RPC
- CMS standard gas mixture:
R134a (95.2 %) i-C₄H₁₀ (4.5 %) SF₆ (0.3%)

Replacing R134a with HFOze



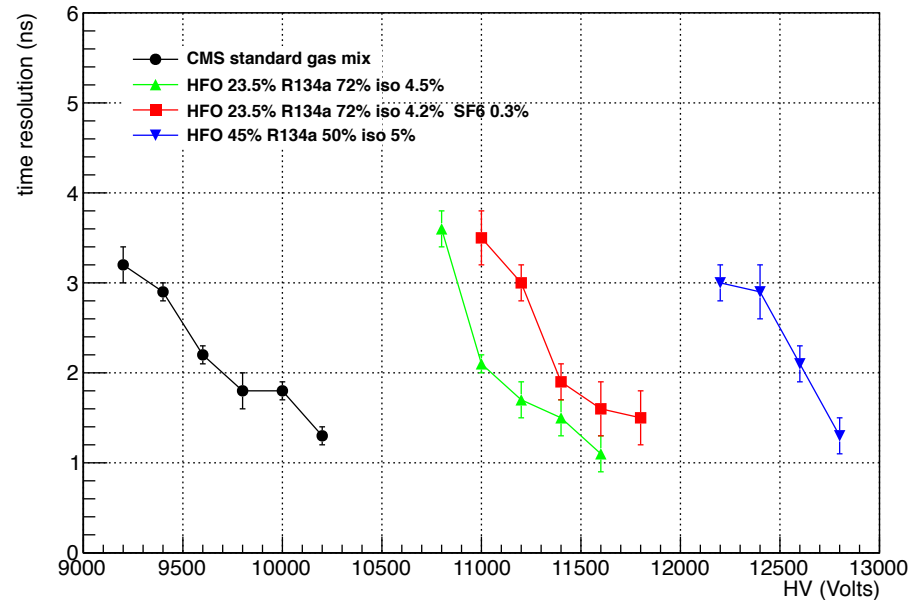
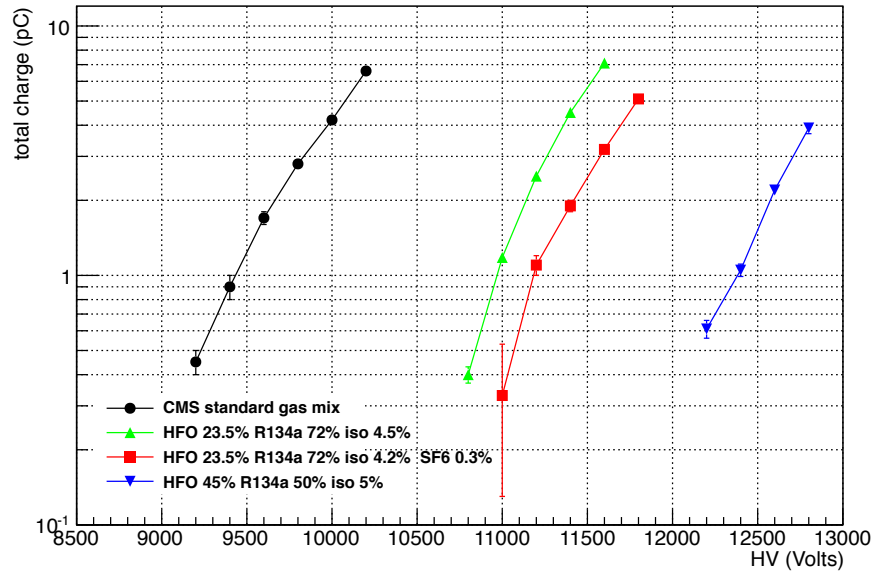
— efficiency
- - - Streamer probability



LNF
Test
station

HV normalized to P=990 mbar and T= 20 °c

Replacing R134a with HFOze



Pad Induced charge to be
divided by ~2 (double pad readout)

LNF Test station

Summary:

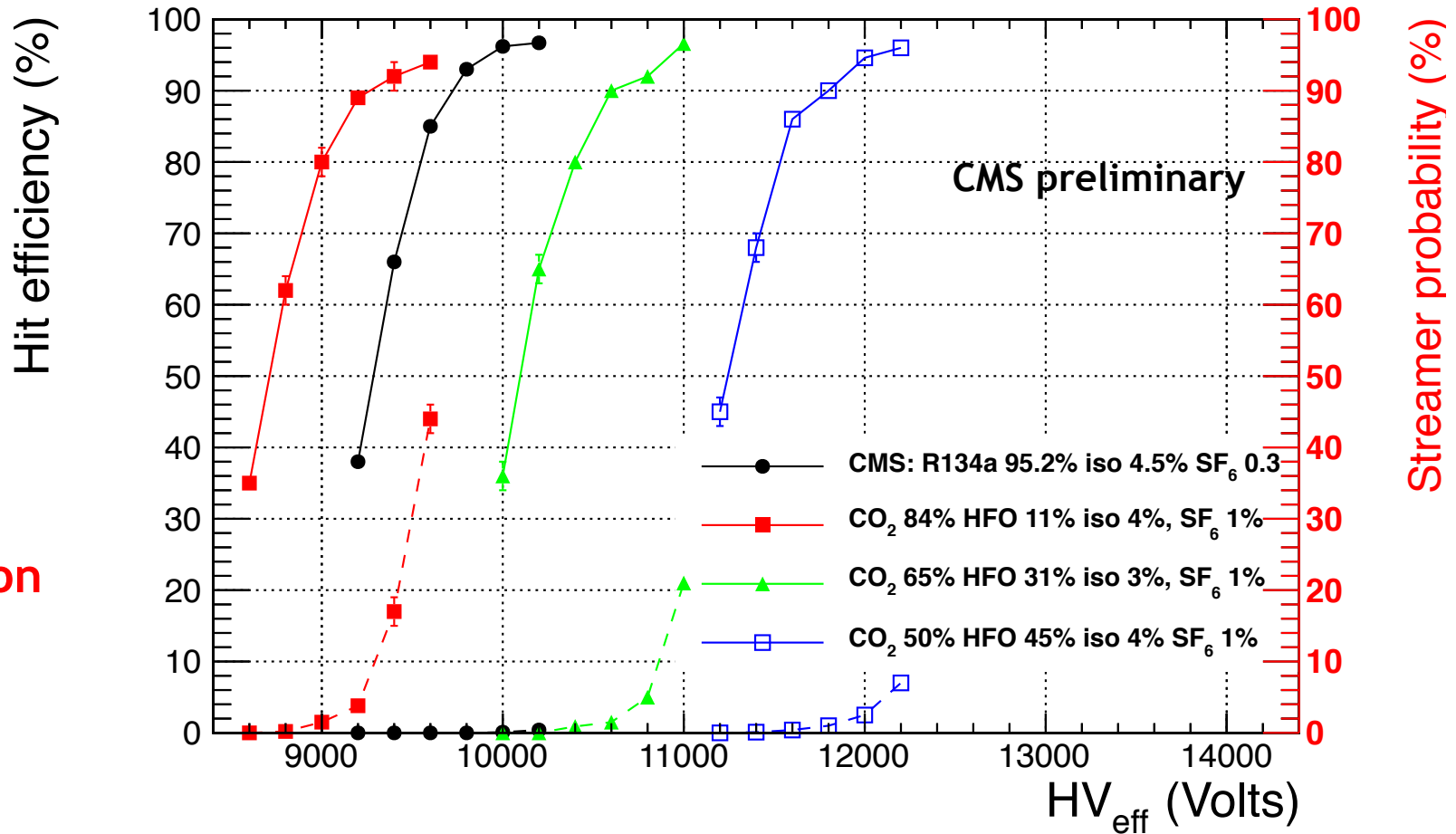
HFO shows interesting quenching properties BUT cannot be used alone to replace R134a (large shifts of working voltage)

CO₂/HFO based gas mixtures



efficiency
Streamer probability

LNF
Test
station

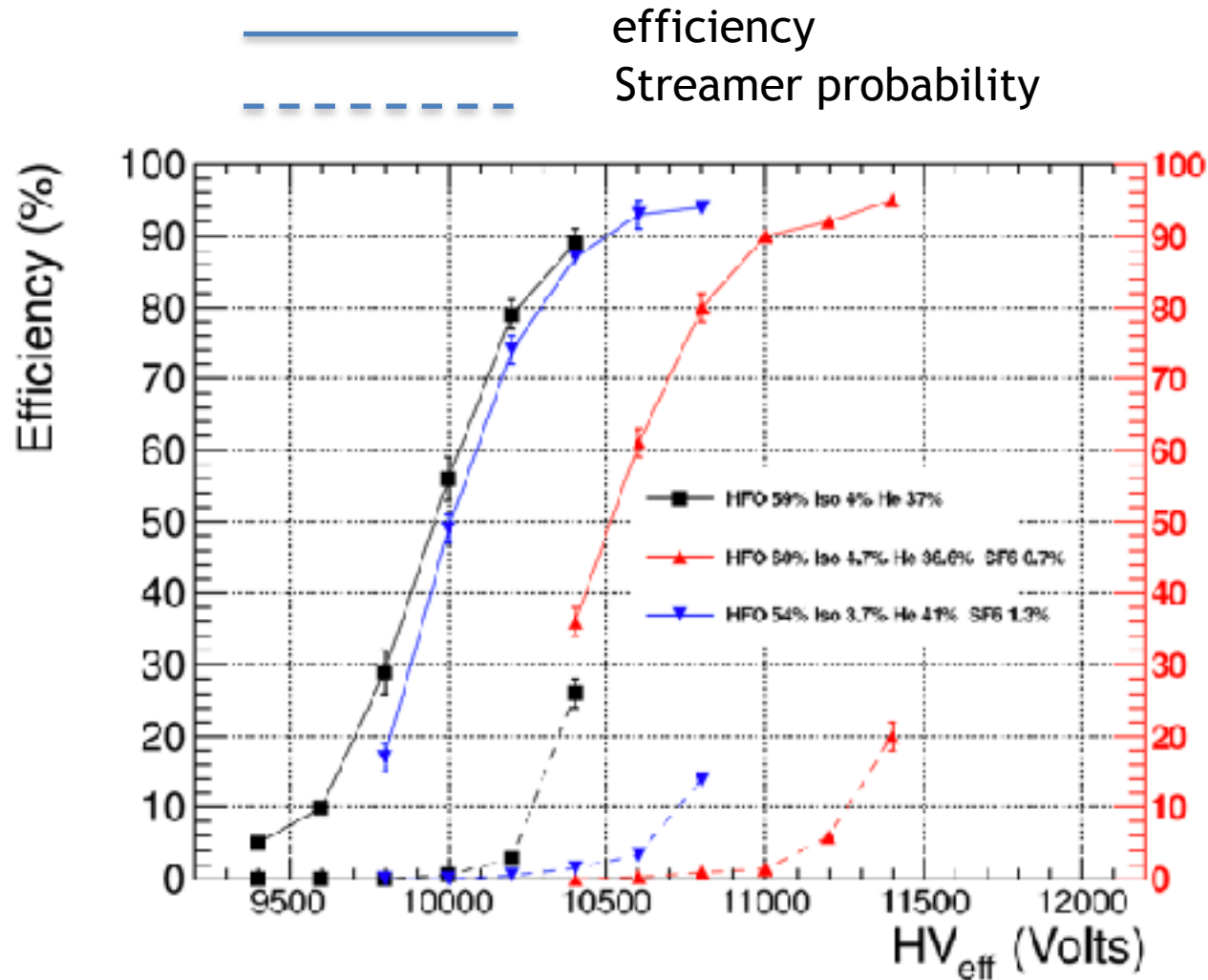


HV normalized to P=990 mbar and T= 20 °C

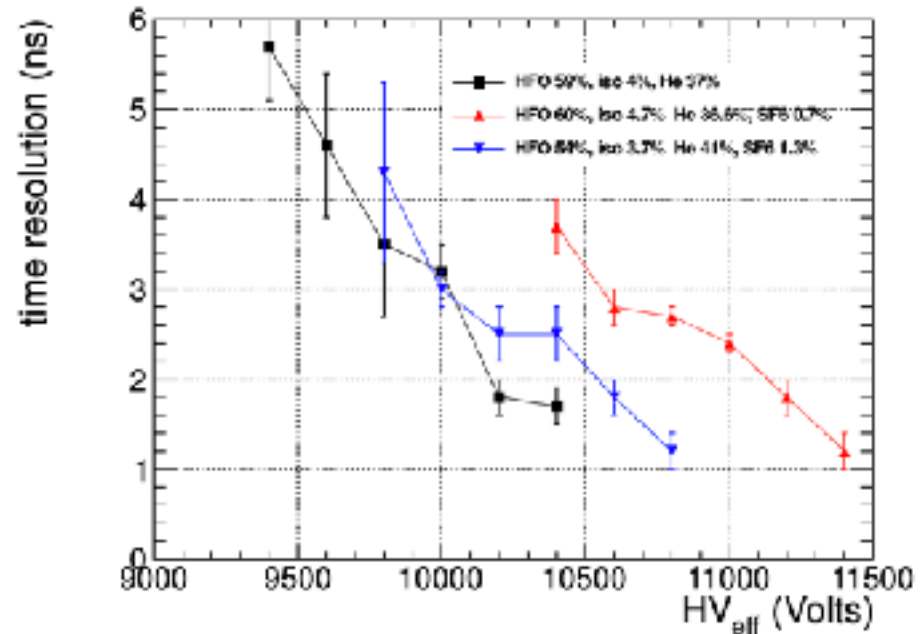
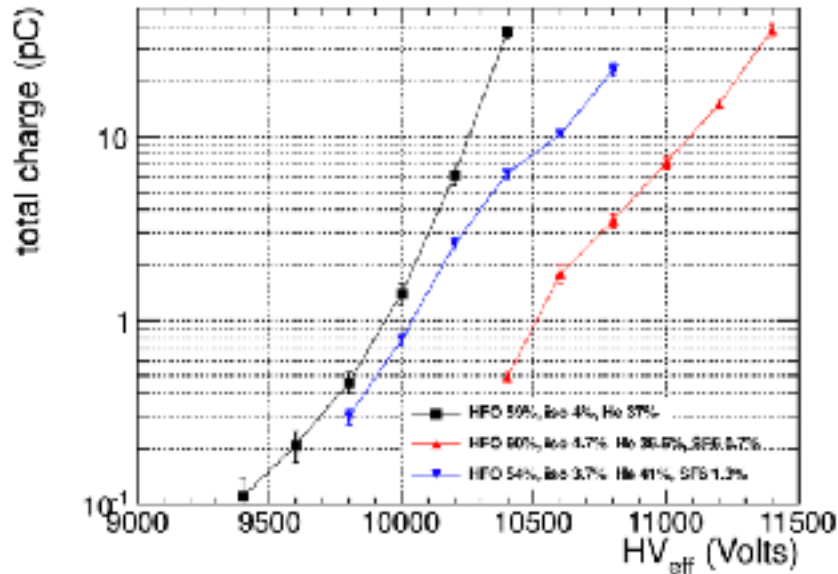
He/HFO based gas mixtures



LNF
Test
station



HV normalized to P=990 mbar and T= 20 °C



Total Induced charge to be divided by ~ 2 (double pad readout)

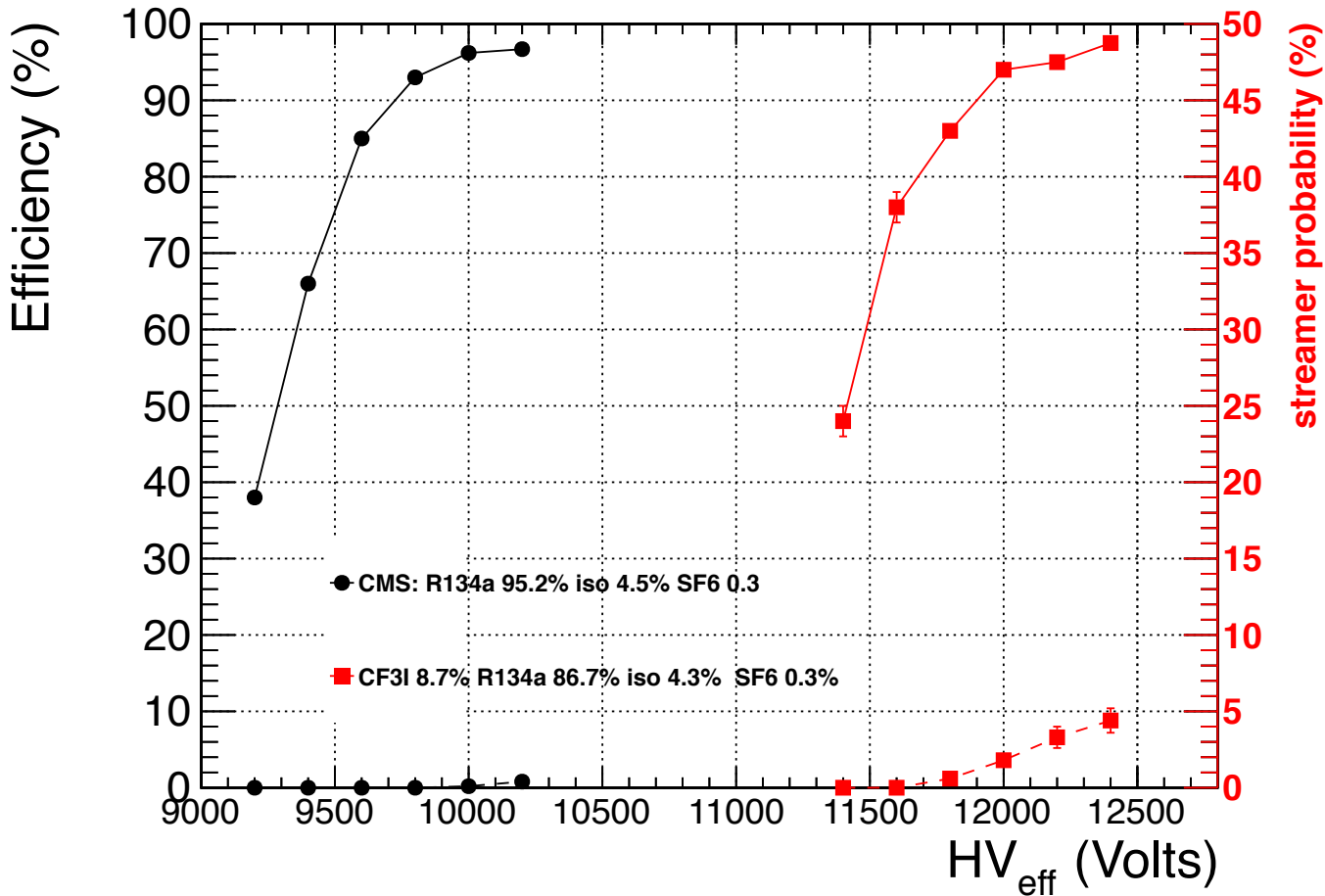
LNF Test station

Summary: Use of Helium to reduce working voltage shows reasonable results, but not clear if Helium could be used in CMS

CF₃I vs R134a



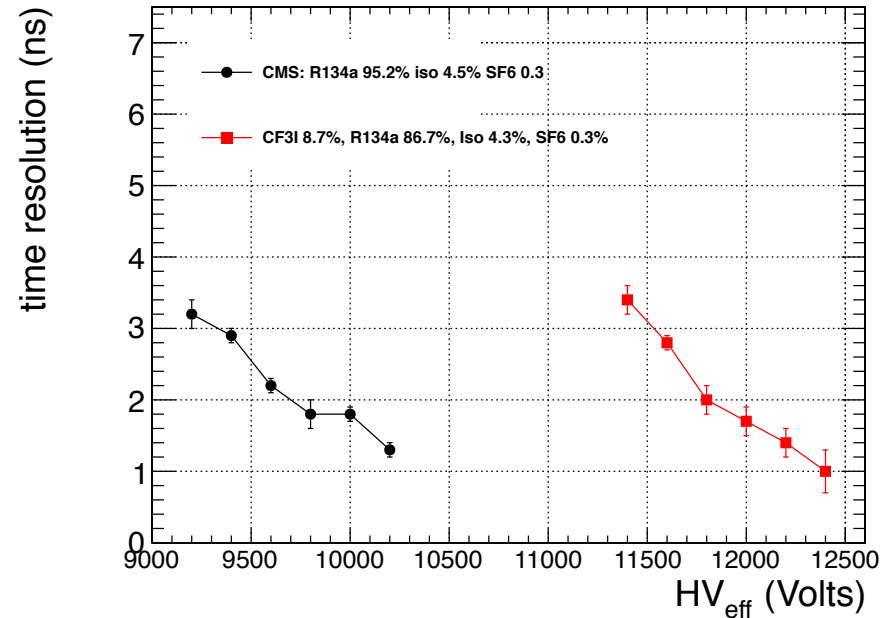
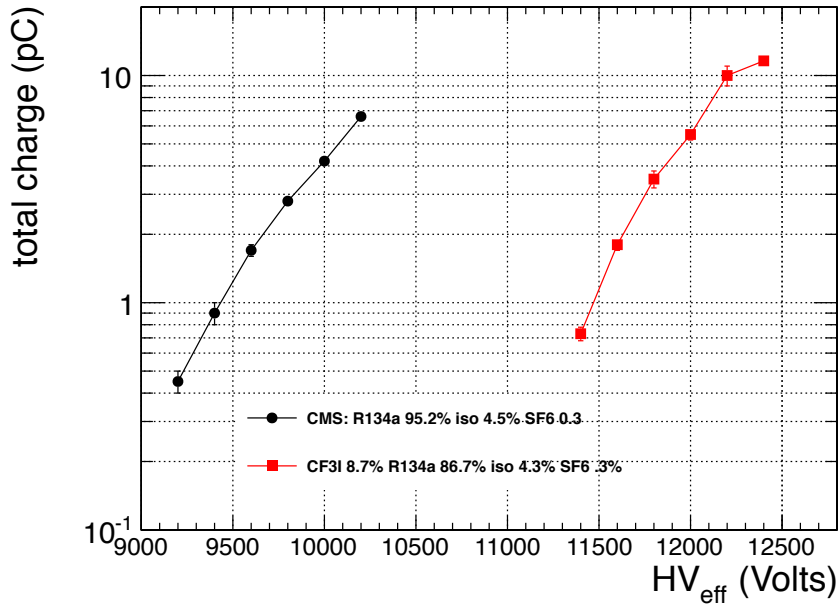
— efficiency
- - - Streamer probability



LNF
Test
station

HV normalized to P=990 mbar and T= 20 °c

CF₃I vs R134a



Total Induced charge to be
divided by ~2 (double pad readout)

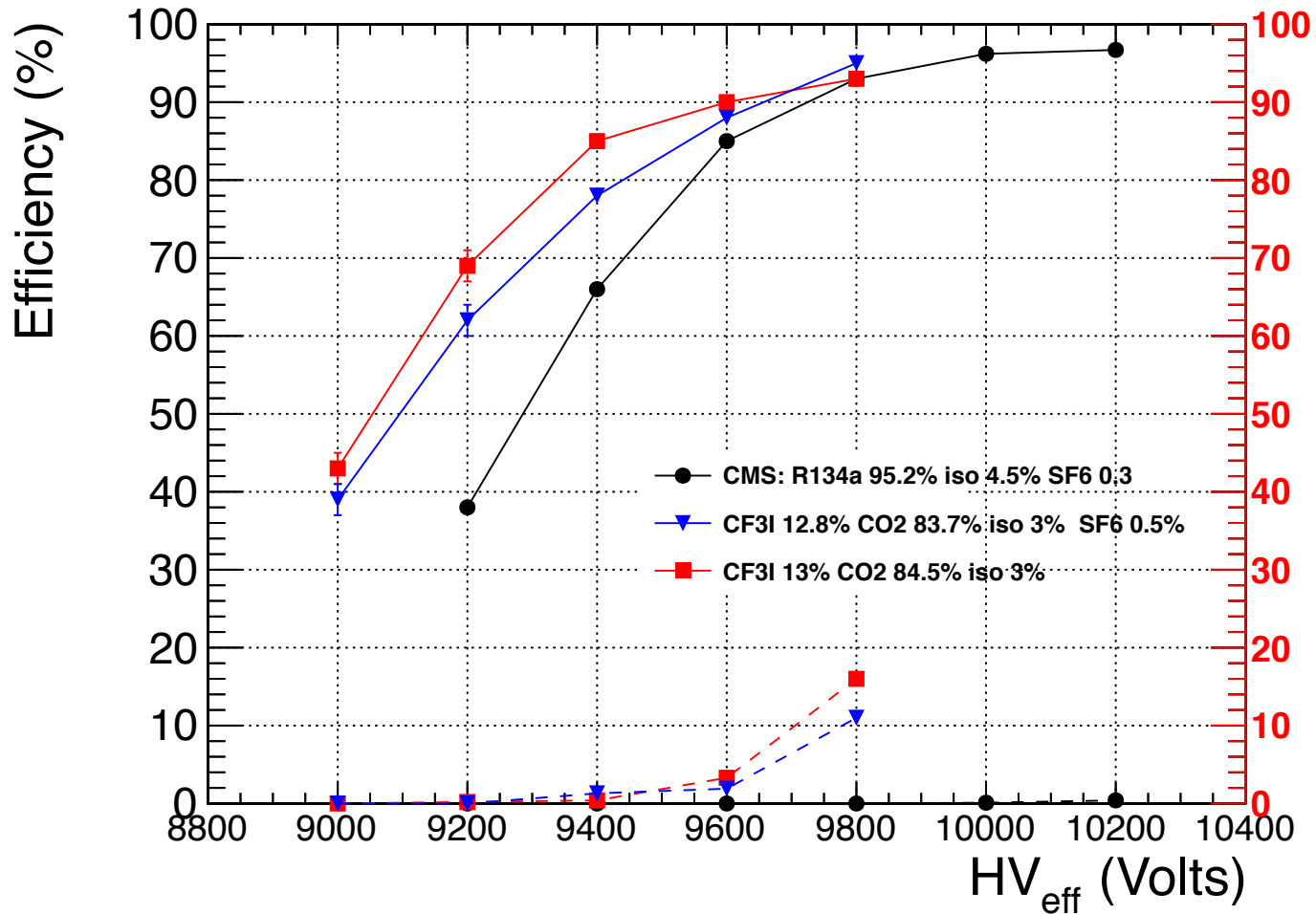
LNF Test station

Summary:

Large quenching power BUT for the same efficiency average charge and streamer probability seem to be slightly higher

CF₃I-CO₂ based gas mixtures

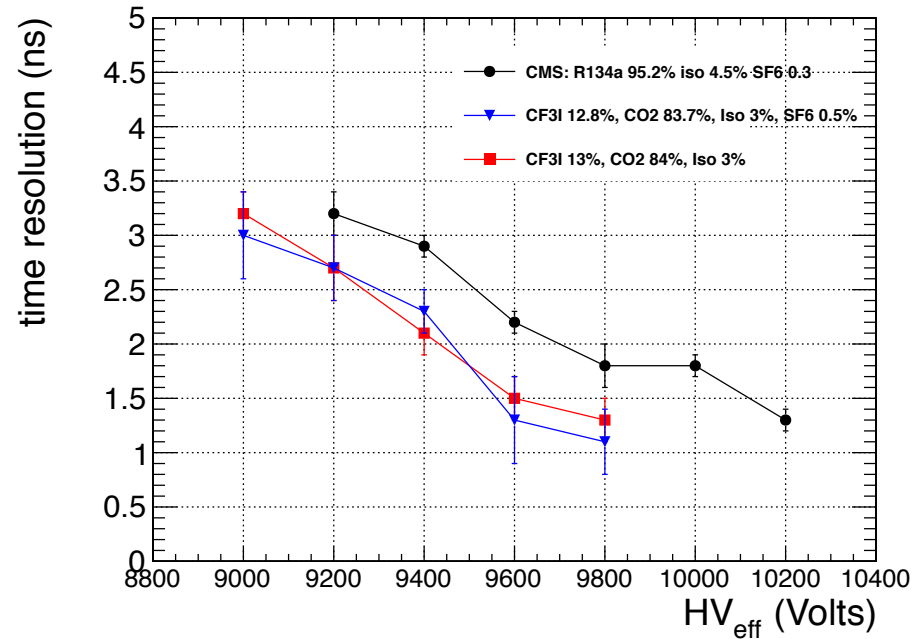
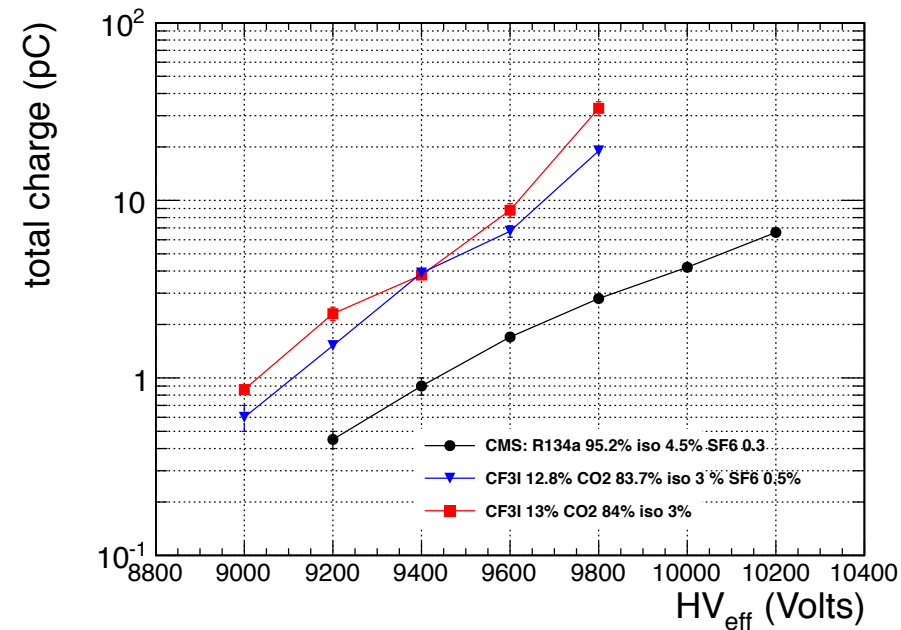
— efficiency
- - - Streamer probability



LNF
Test
station

HV normalized to P=990 mbar and T= 20 °c

CF₃I vs R134a



Total Induced charge to be
divided by ~2 (double pad readout)

LNF Test station

Summary: preliminary results.
More work needed to explore if CO₂/CF₃I gas mixtures could be
used. **BUT the CF₃I is very toxic**

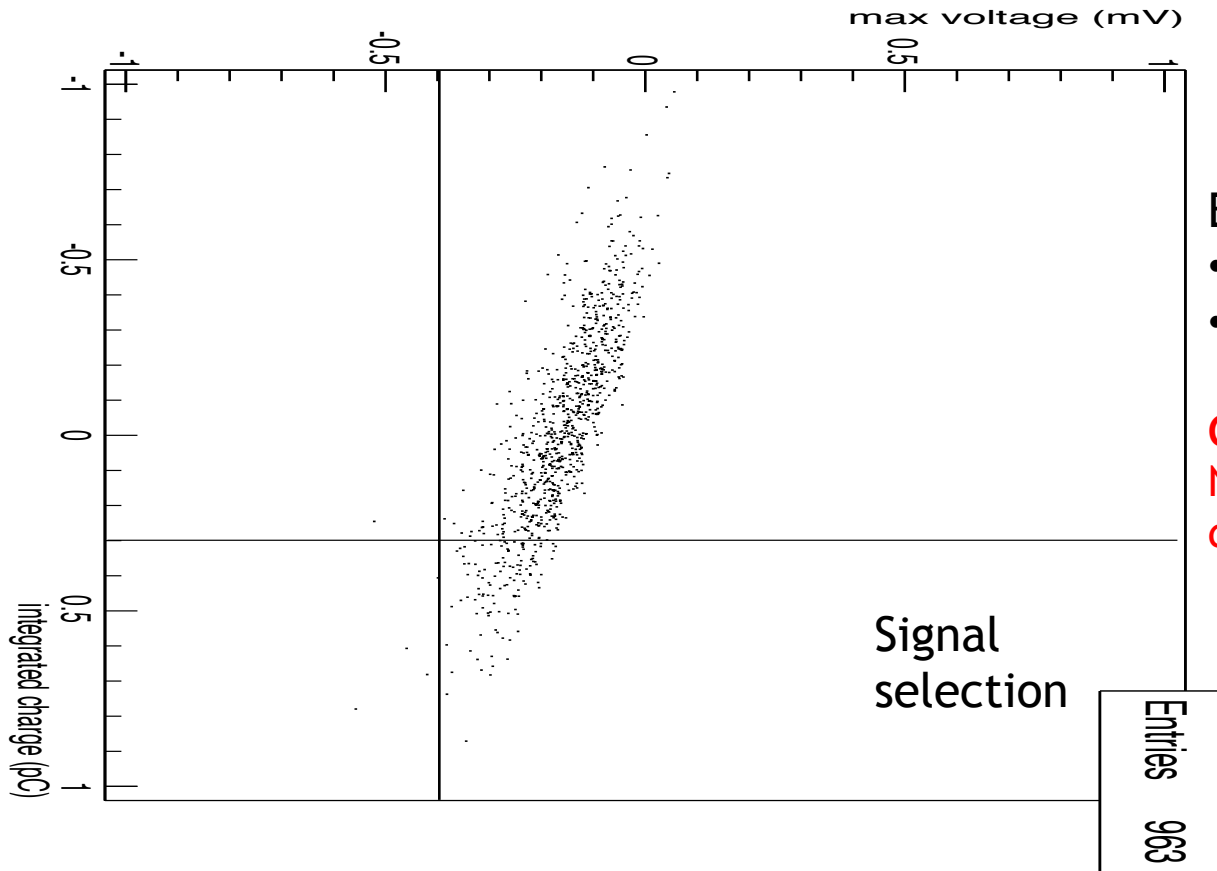
Conclusions



- Several ecological (or semi-ecological) gas mixtures have been tested
- HFO-1234ze has interesting quenching properties but cannot be used alone to replace the R134a (high working voltage shift)
- CO₂/HFO-1234ze gas mixtures seem to give interesting results
- Use of Helium help in reducing working voltage and is a interesting line to be followed
 - Not clear if possible to use in CMS
- CF₃I is a very interesting candidate from theoretical point of view
 - Very expensive
 - Very quenching
 - Toxic
 - Still the streamer probability and average charge seems to be slightly higher with respect to standard gas mixture for the same Efficiency
 - CO₂/CF₃I based gas mixture studies are only preliminary

Backup

Control region distributions

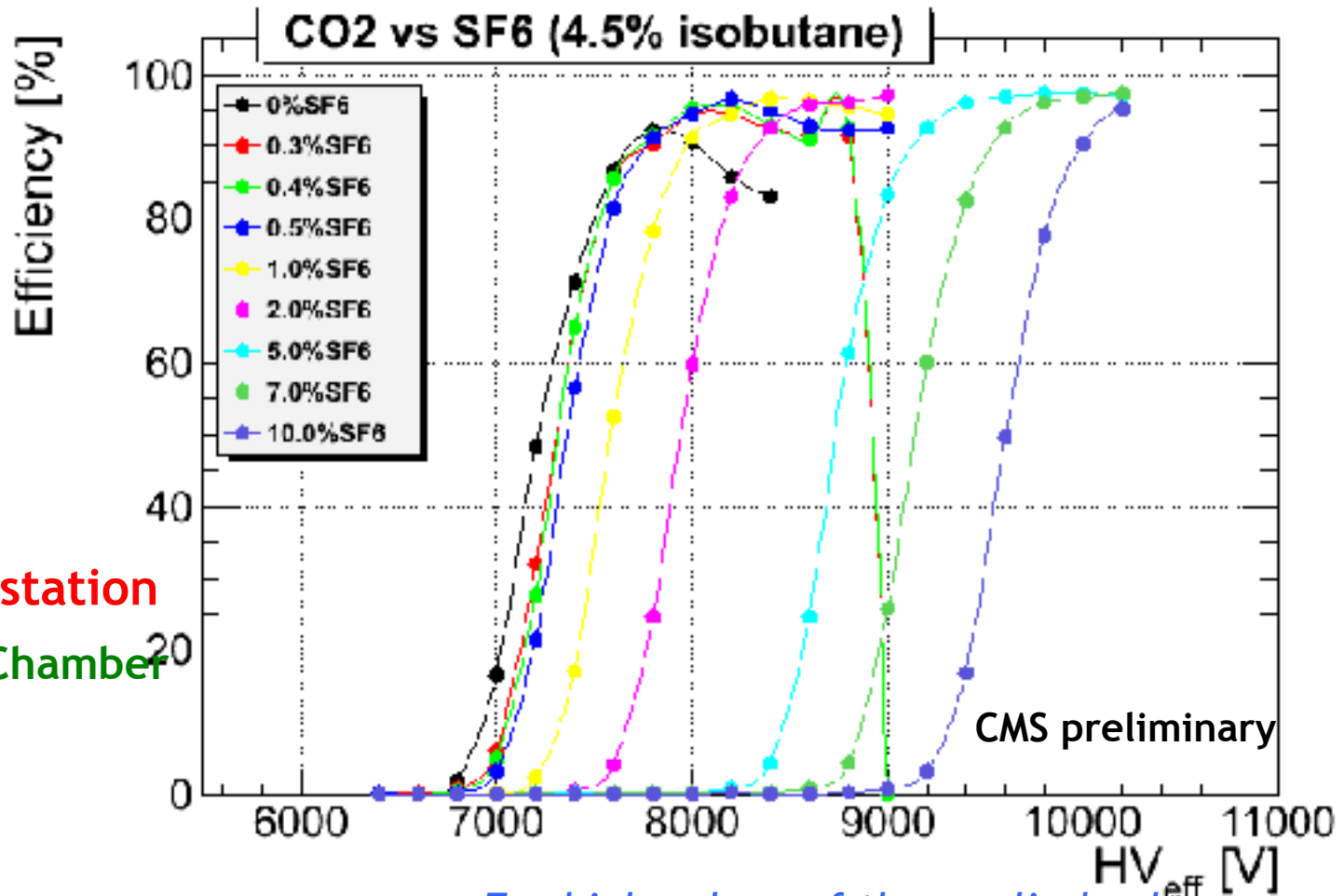


Efficient signal selection:

- Integrated charge > 0.3 pC
- $|V_{\text{max}}| > 0.4$ mV

Cuts verified un the control region
Noise contamination in efficiency
definition lower than 0.5 %

CO₂/SF₆ based gas mixtures



Ghent Test station

Double gap Chamber

For high values of the applied voltage one of the Gaps trips and the chamber works in single mode.

HV normalized to P=990 mbar and T= 20 °C

Possible eco-gas replacements

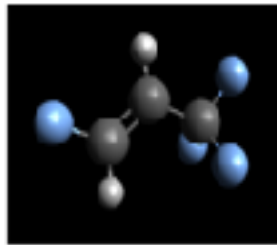
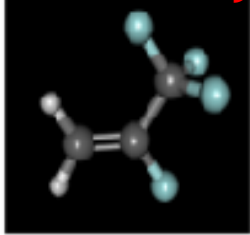


Tetrafluoroethane

It comes in two allotropic forms

HFO-1234ze

HFO-1234yf

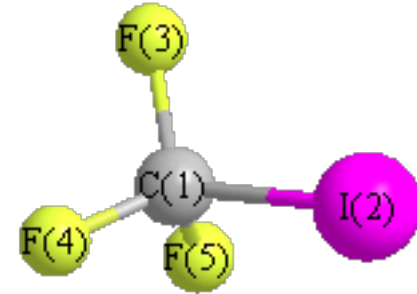


| Molecule | CC ₂ F ₂ | CF ₄ | R134a |
|------------------------|--------------------------------|-----------------|-----------|
| ionization energy (eV) | 10.24 | 12.81 | 12.40 |
| Molecule | R152a | HFO1234ze | HFO1234yf |
| ionization energy (eV) | 10.78 | 9.34 | 9.37 |

Molecule similar to R134a (C₂H₂F₄) BUT
HFO-1234ze GWP=6, HFO-1234yf GWP=4
R134a GWP = 1430

HFO-1234yf HMIS code =2
 (moderate flammability)

In this talk we concentrate on HFO-1234ze
(HFO in the labels will mean HFO-1234ze)



GWP and ODP close to 0

High quenching power

Very expensive ! We were able to buy just a small bottle of 0.5 kg for very few preliminary tests

The “ecological” gas issue



➤ The European Community has prohibited the production and use of gas mixtures with Global Warming Power > 150 ($\text{GWP}(\text{CO}_2) = 1$)

✓ This is valid mainly for industrial (refrigerator plants) applications

✓ Scientific laboratories would be excluded

✓ CERN could require to stick to these rules anyhow

➤ $\text{C}_2\text{H}_2\text{F}_4$ is the main component of the present RPC gas mixture:

✓ $\text{GWP}(\text{C}_2\text{H}_2\text{F}_4) = 1430$, $\text{GWP}(\text{SF}_6) = 23900$, $\text{GWP}(\text{iC}_2\text{H}_{10}) = 3.3$

➤ $\text{C}_2\text{H}_2\text{F}_4$ and SF_6 Crucial to ensure a stable working point in avalanche

➤ To test molecules similar to $\text{C}_2\text{H}_2\text{F}_4$ but with lower GWP

$\text{C}_3\text{H}_2\text{F}_4$ - tetrafluoropropene ($\text{GWP}=4-6$)

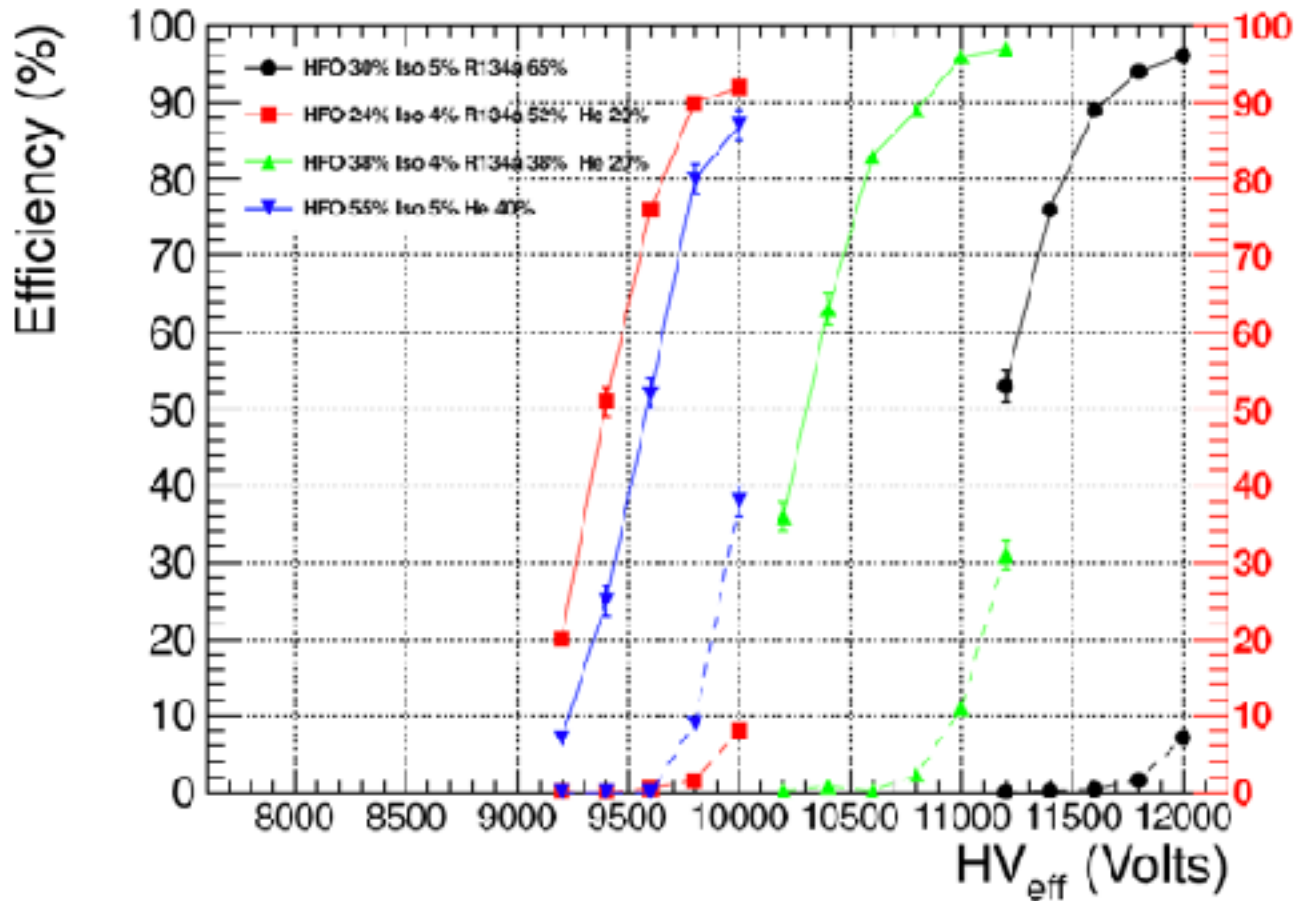
✓ Should replace $\text{C}_2\text{H}_2\text{F}_4$ as automotive air-conditioning refrigerant

✓ other possibility could be CF_3I - Trifluoroiodomethane with $\text{GWP} \sim 0$ & $\text{ODP} \sim 0$

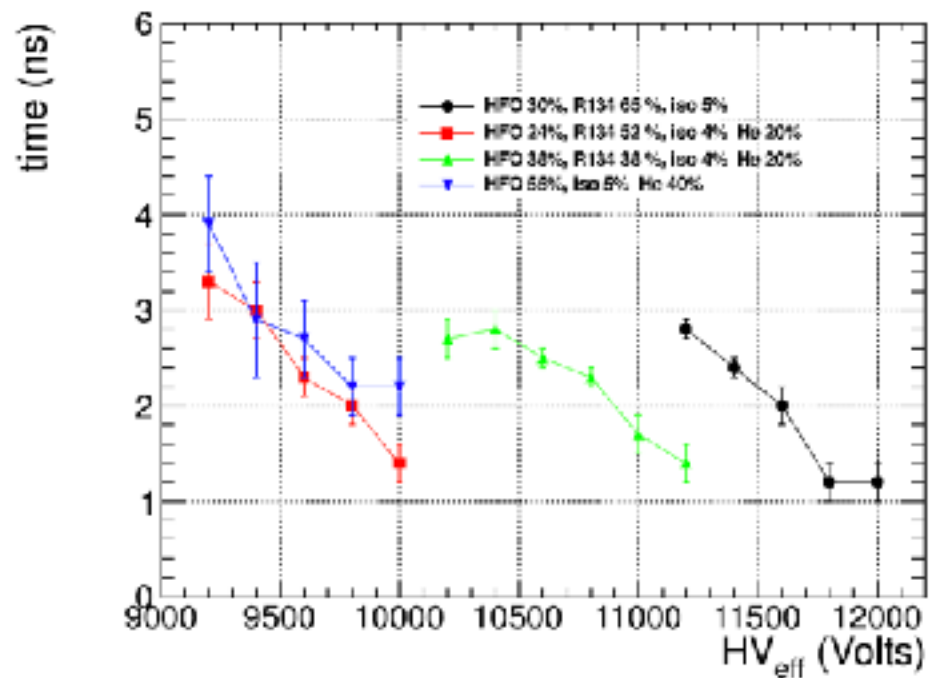
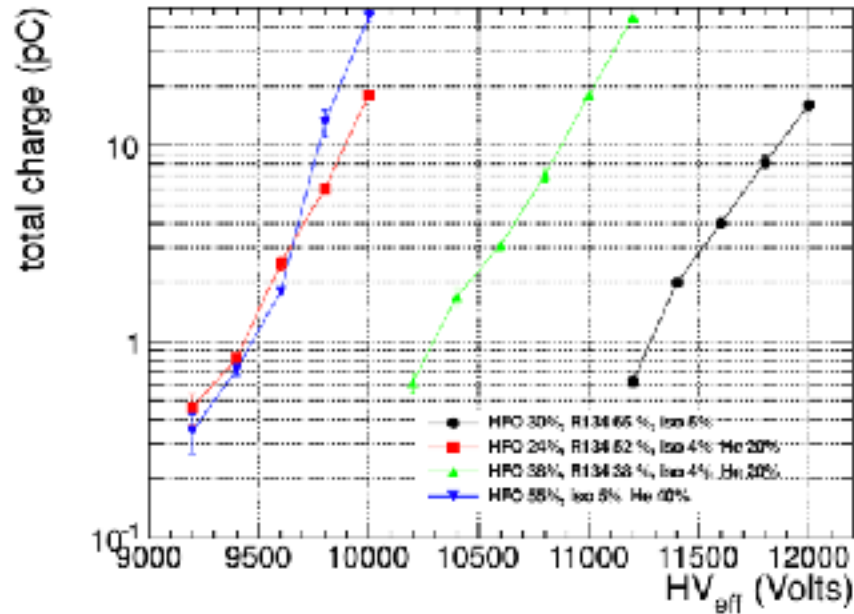
He/HFO based gas mixtures

— efficiency
- - - Streamer probability

LNF
Test
station

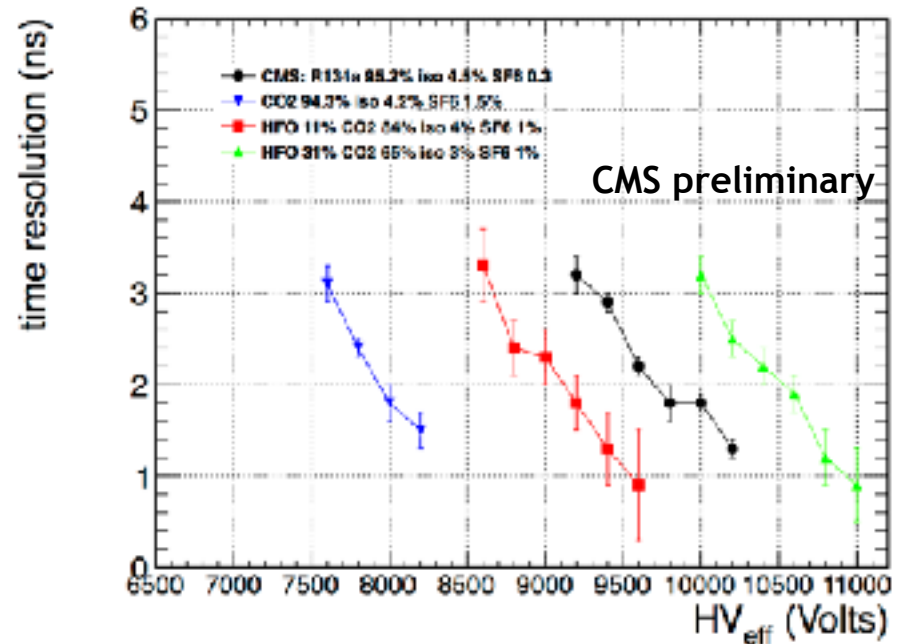
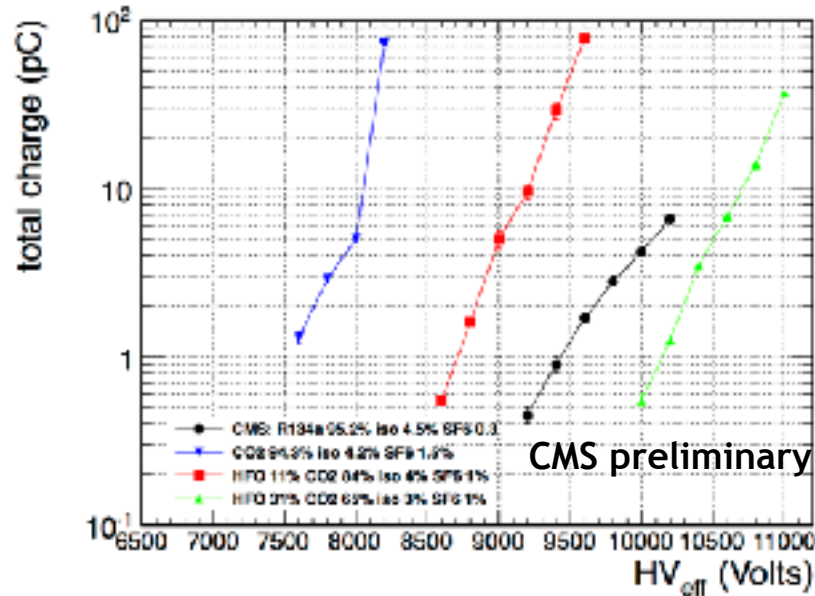


HV normalized to P=990 mbar and T= 20 °C



Total Induced charge to be
divided by ~2 (double pad readout)

LNF Test station



Total Induced charge to be divided by ~2 (double pad readout)

LNF Test station

Charge and time resolution for HFO at 45% not available (to be recovered)