Search for new RPC gases

B. Liberti
on behalf of Rome «Tor Vergata» group

Starting from HFO and CO2 binary mixtures

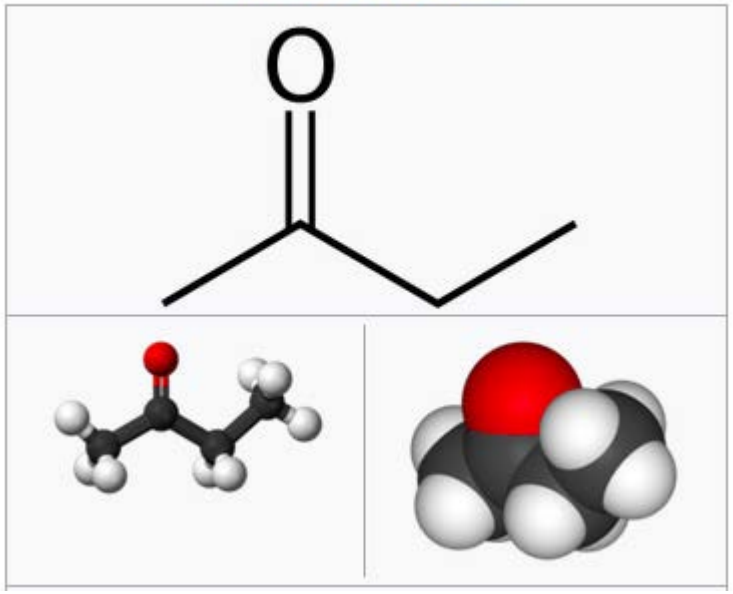
… we could not get Novec™ 5110 fluid, very promising eco-compatible substitute of SF6, so we decide to try some interesting molecules which are available at environmental temperature and pressure in liquid state :

1) Ethylmethylketone or MEK
2) Methyl tert-Butyl ether or MTBE
3) Dimethyl Sulfide

1) Ethylmethylketone or MEK

Names
Preferred IUPAC name
Butan-2-one[2]
Other names
Ethyl methyl ketone[2]
Methyl ethyl ketone (deprecated[2])
MEK
2-Butanone
Methylpropanone
Ethylmethylketone
Methylacetone

Butanone[1]

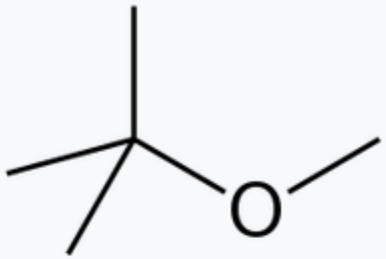


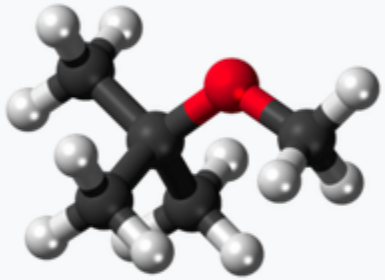
Properties	
Chemical formula	C_4H_8O
Molar mass	72.11 g·mol^{-1}
Appearance	Colorless liquid
Odor	mint or acetone-like[3]
Density	0.8050 g/mL
Melting point	−86 °C (−123 °F; 187 K)
Boiling point	79.64 °C (175.35 °F; 352.79 K)
Solubility in water	27.5 g/100 mL
Vapor pressure	78 mmHg (20°C)[3]
Acidity (pK_a)	14.7
Magnetic susceptibility (χ)	-45.58·10^{-6} cm^3/mol
Refractive index (n_D)	1.37880
Viscosity	0.43 cP

Pv(@0 C) = 225 mbar

2) Methyl tert-Butyl ether or MTBE

Methyl *tert*-butyl ether





Names	
IUPAC name	2-Methoxy-2-methylpropane
Other names	Methyl *tertiary*-butyl ether; Methyl *tert*-butyl ether; Methyl *t*-butyl ether; MTBE; *tert*-Butyl methyl ether; tBME; *tert*-BuOMe

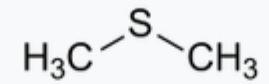
Properties	
Chemical formula	$C_5H_{12}O$
Molar mass	88.15 g·mol^{-1}
Density	0.7404 g/cm³
Melting point	−109 °C (−164 °F; 164 K)
Boiling point	55.2 °C (131.4 °F; 328.3 K)
Solubility in water	42 g/L (20 °C)[1]
Viscosity	0.36 cP at 25 °C

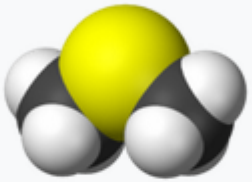
Pv(@0 C) = 830 mbar

Hazards	
NFPA 704	
Flash point	−33.0 °C (−27.4 °F; 240.2 K)

3) Dimethyl Sulfide

Dimethyl sulfide





Names
Preferred IUPAC name (Methylsulfanyl)methane[1]
Other names (Methylthio)methane[1] Dimethyl sulfide[1]

Properties	
Chemical formula	C_2H_6S
Molar mass	62.13 g·mol^{-1}
Appearance	Colourless liquid
Odor	Cabbage, sulfurous
Density	0.846 g cm^{-3}
Melting point	−98 °C; −145 °F; 175 K
Boiling point	35 to 41 °C; 95 to 106 °F; 308 to 314 K
log *P*	0.977
Vapor pressure	53.7 kPa (at 20 °C)
Magnetic susceptibility (χ)	-44.9·10^{-6} cm^3/mol
Refractive index (n_D)	1.435

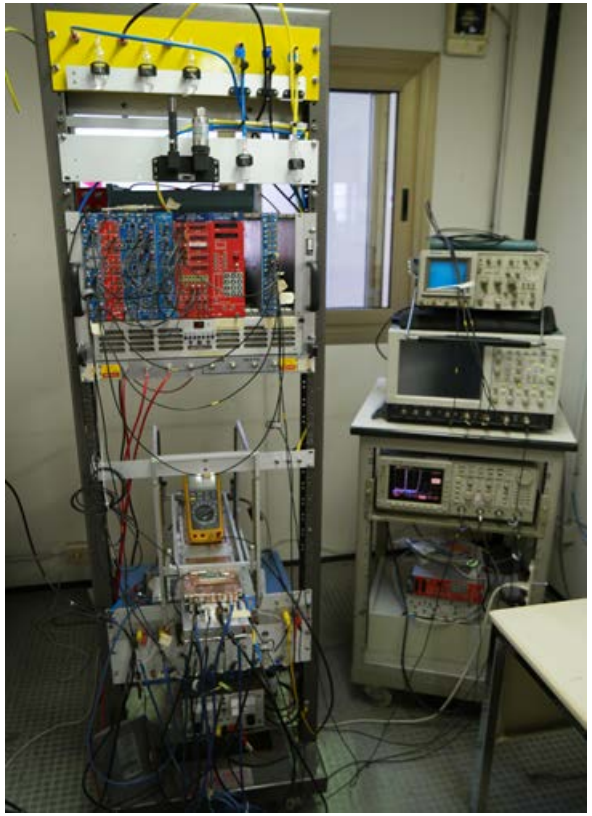
Thermochemistry	
Std enthalpy of formation ($\Delta_f H^{\ominus}_{298}$)	-66.9--63.9 kJ mol^{-1}
Std enthalpy of combustion ($\Delta_c H^{\ominus}_{298}$)	-2.1818--2.1812 MJ mol^{-1}
Hazards	
Safety data sheet	osha.gov
GHS pictograms	
GHS signal word	**DANGER**
GHS hazard statements	H225, H315, H318, H335
GHS precautionary statements	P210, P261, P280, P305+351+338
Flash point	−36 °C (−33 °F; 237 K)
Autoignition temperature	206 °C (403 °F; 479 K)
Explosive limits	19.7%

Pv(@0 C) = 270 mbar

Experimental Set-Up 1.

- To handle with liquid components we had to develop a new small gas setup
- The liquid is kept in a bottle with a plug inside a refrigerator.
- The temperature is monitored and controlled, around 4 C.
- The liquid in the bottle has fixed vapor pressure Pv(@ 0-5 C).
- One pipe through first hole on the plug fluxes the original gas mixture in the bottle. One pipe through second hole on the plug fluxes towards the detector the new gas mixture with defined volume fraction of the molecules from the liquid.
- The final fraction is fixed by the molecular vapor pressure Pv
- To reduce final fraction of new component we splitted the original gas flux, the fraction sent in the bottle is rejoined with the fraction of the original mixture.

Experimental Set-Up 2.



3 RPCs compose the hodoscope and generate the trigger signal.
The triggered area is a finger of 50 cm x 1.3 cm.

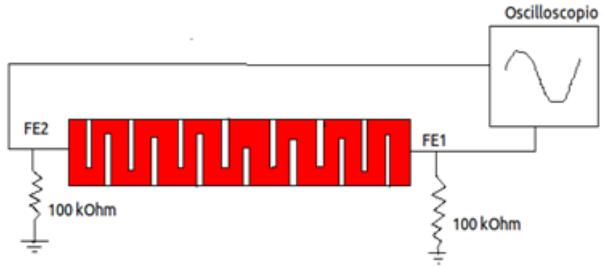
The RPC under test has 52.6 cm x 7.6 cm of active area.
The read-out strip area is 50 cm x 2.7 cm.

One RPC of Confirm is acquired with similar read-out strip and used for timing and efficiency precision measurment.

Pulses are acquired by means of a digital oscilloscope (5 GSample/s and 1GHz analog bandwidth) and registered by a dedicated LabView program.
The DAQ rate is less 1 Hz.
No Full Geometrical Acceptance

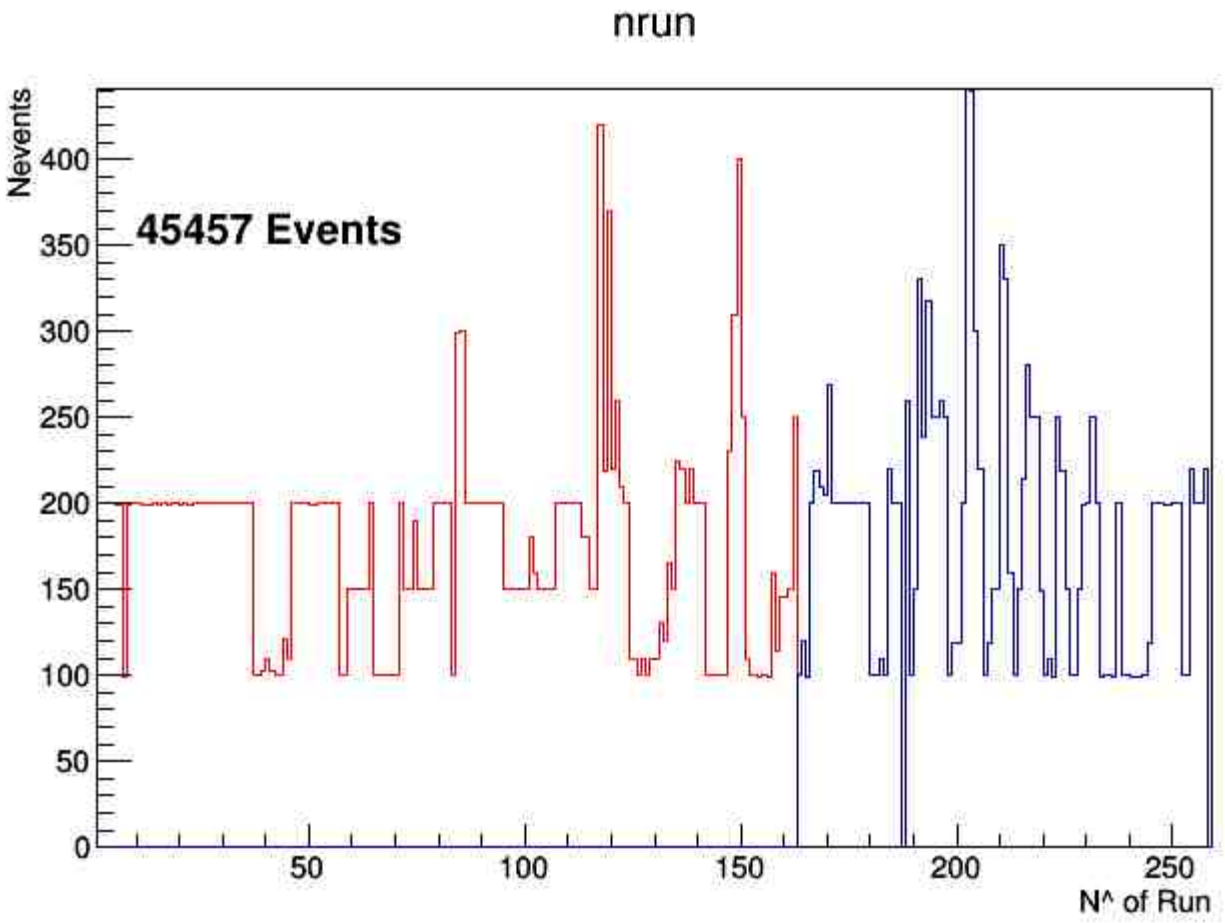
Experimental Set-Up 3.

- ✓ The prompt fast signal induced on the read-out strip is read out at both strip ends for each event.
- ✓ The full waveforms of the signals called FE1 and FE3 are acquired at different voltage scale sensibility to read properly avalanche and if any streamer in the same
- ✓ The full waveforms of the ionic slow signal is acquired.
- ✓ Signals parameters are extracted and recorded.



All data presented here are obatained on 2 mm gas gap

Data Analysis 1.

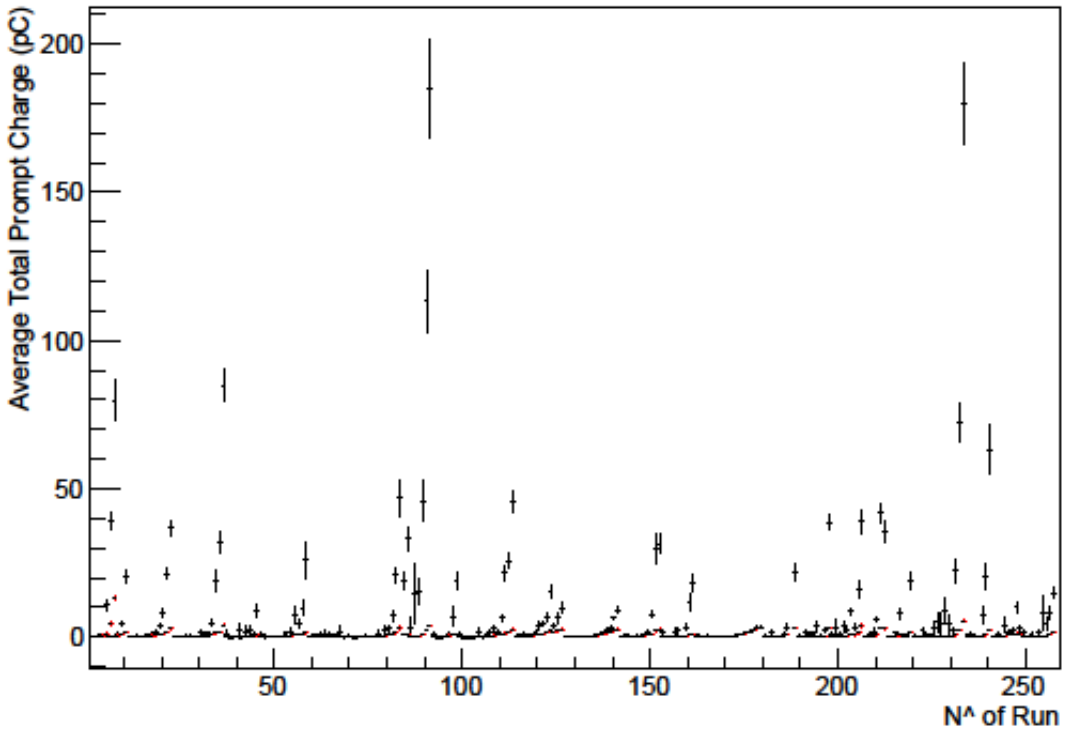


- ✓ Lots of different Mixtures!
- ✓ Lots of different behaviour!

- ✓ **The signal dedicated to avalanche is compared to 5*rms_bck, this is for most of the Runs equivalent to 1.8 mV.**
- ✓ **The prompt charge is integrated over a 10 ns window around the maximum.**
- ✓ **Definition of Streamer is very difficult,** a combination of maximum amplitude, time duration and charge should be necessary.

The kind of beasts at the zoo is impressive, we forget about saturated avalanche and we definitely give up and decide that…

Data Analysis 2.

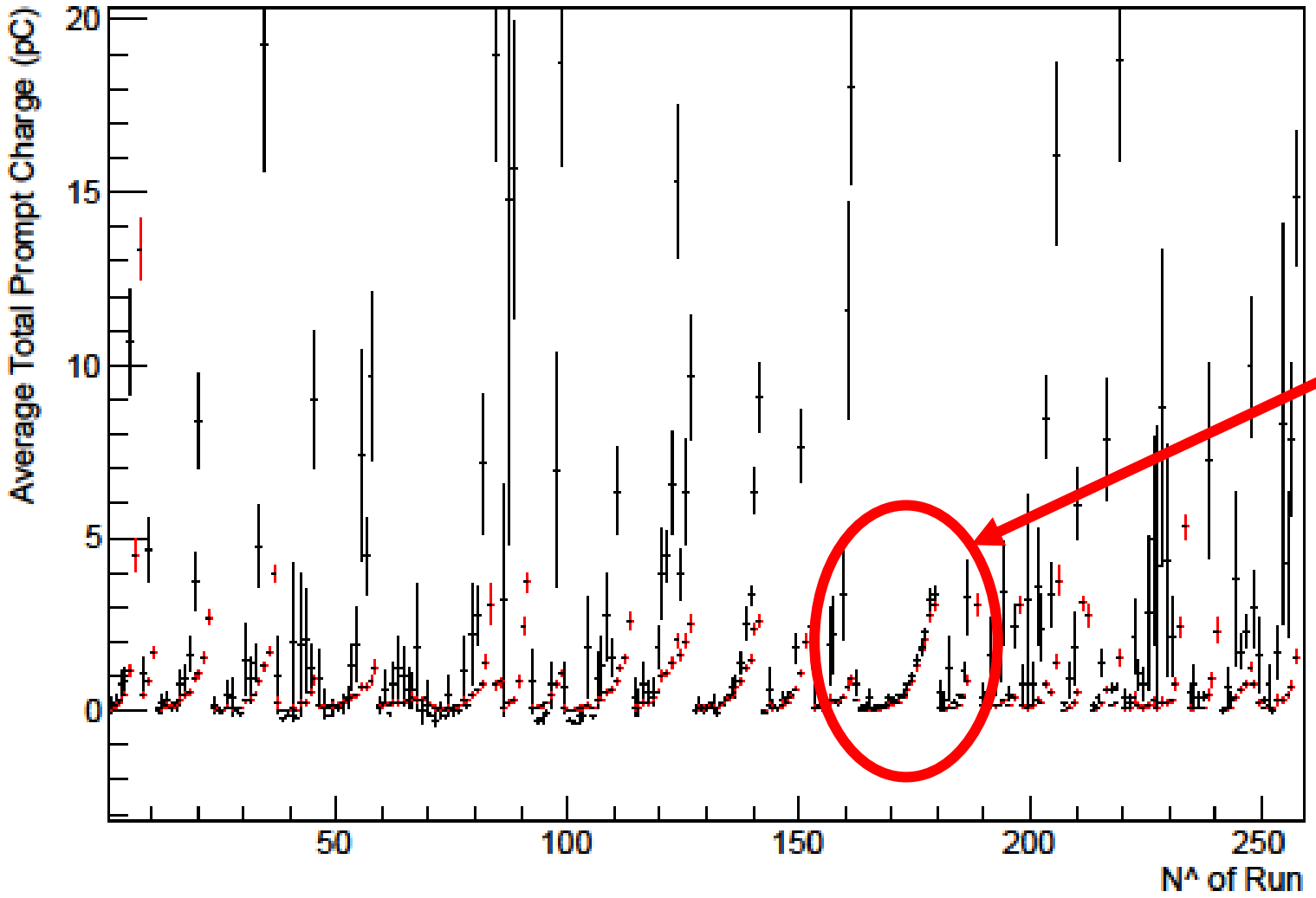


The total prompt charge, i.e. the integral over the full event time window, is the best parameter to evaluate the goodness and the acceptability of given working point.

The total prompt charge vs the run number shows great variability, up to hundreds of pC.
The greatest value for each scan is more or less corresponding to the greatest efficiency.
The prompt charge associated to the first avalanche is superimposed in red.

So we can spoil the conclusions …NO Magic Mixture!

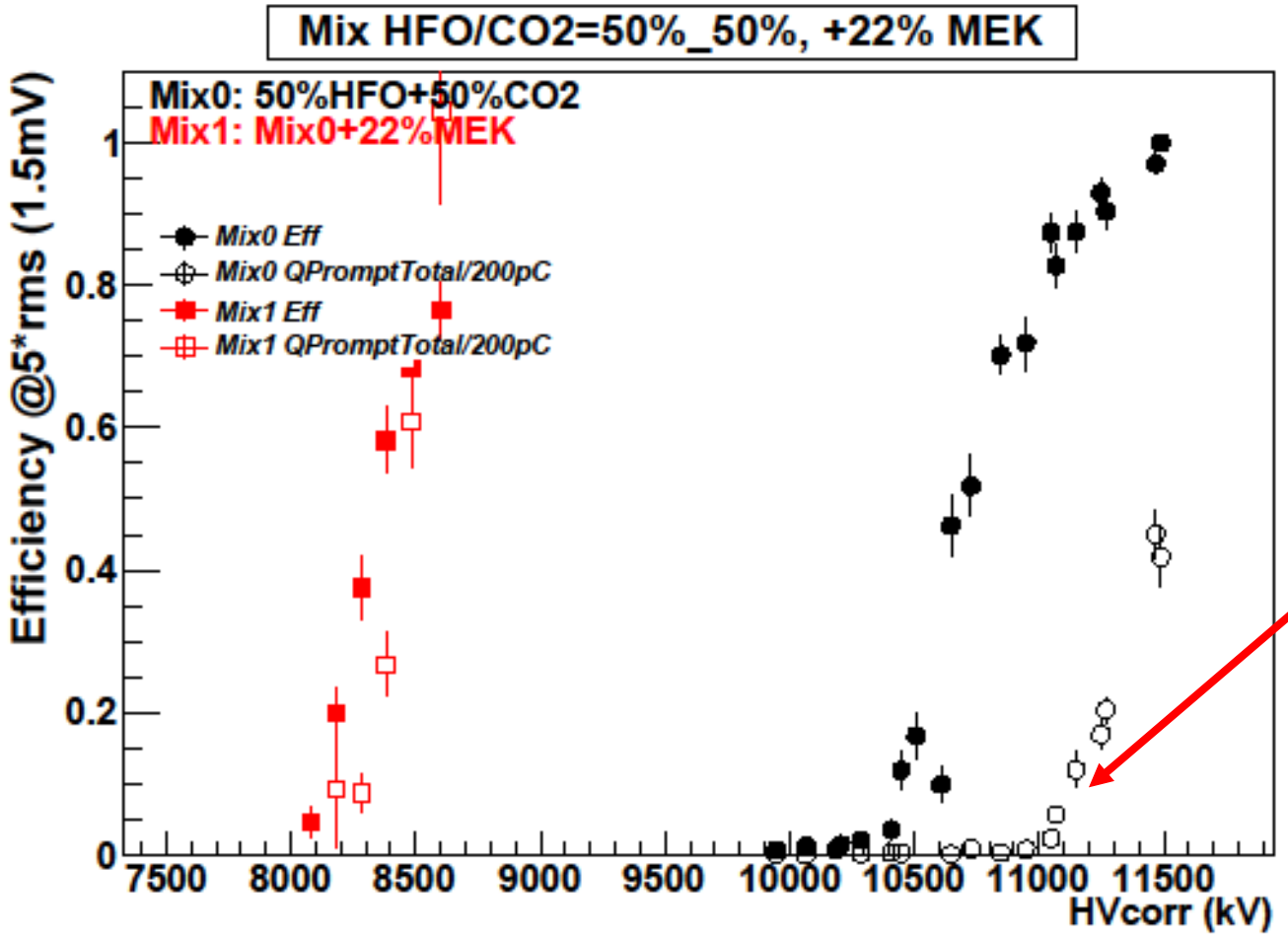
Data Analysis 3.



Indeed .....
this is Standard Mixture!!!

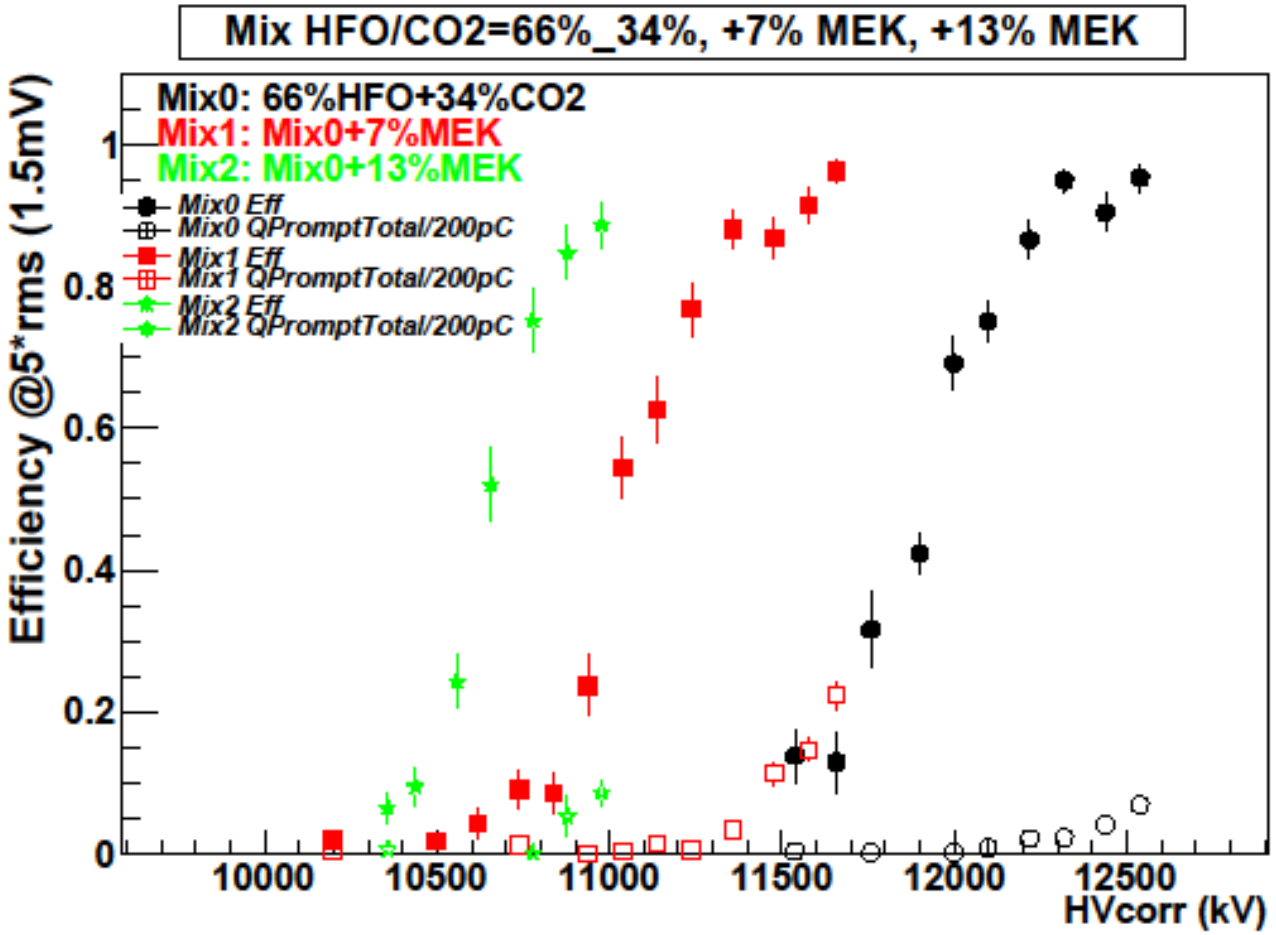
But let's go to the details

MEK in HFO/CO2=50/50 1.

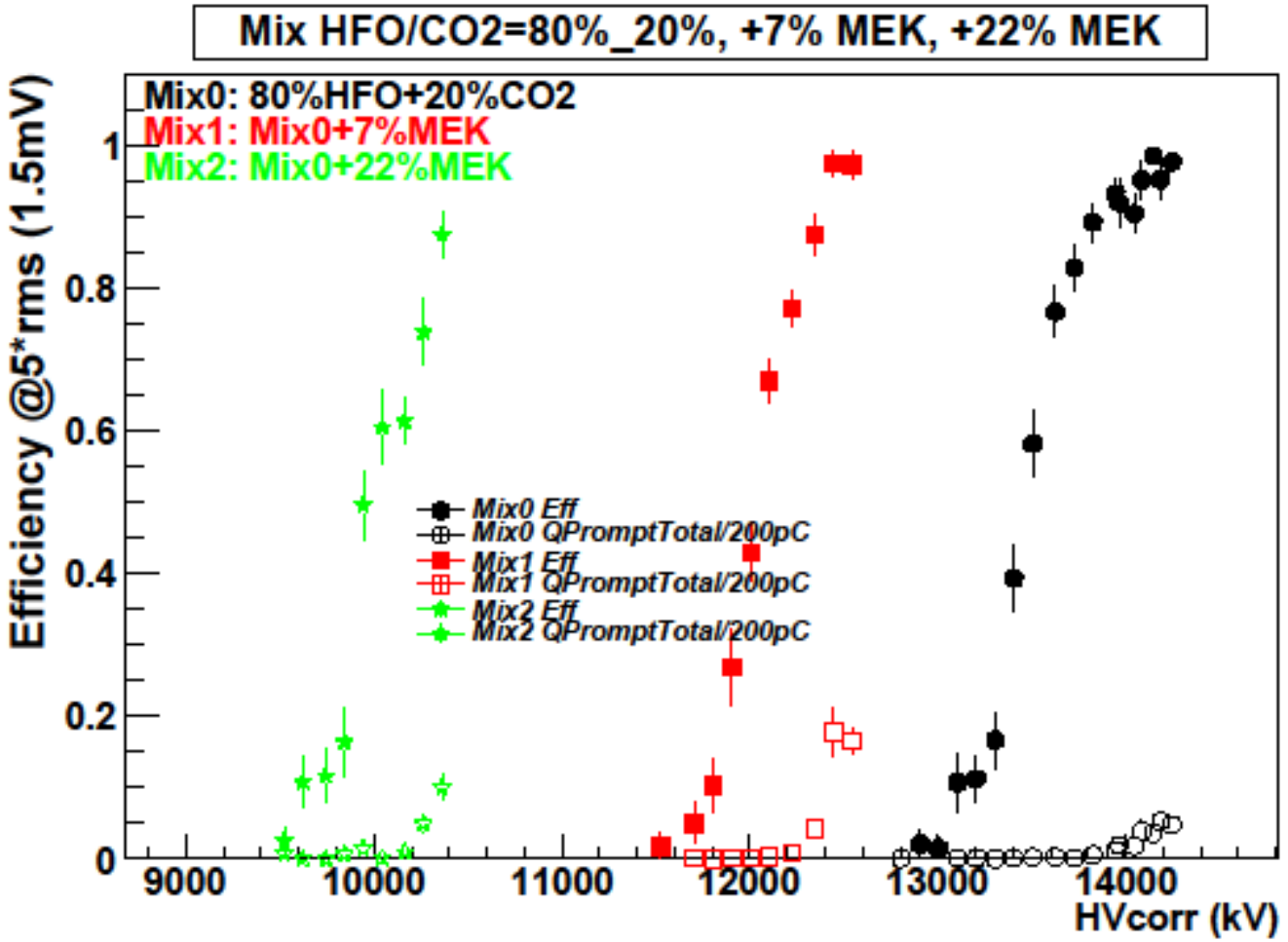


Please note that in the following the total prompt charge is always divided by 200 pc!! So one point at 0.1 means 20 pc of prompt charge

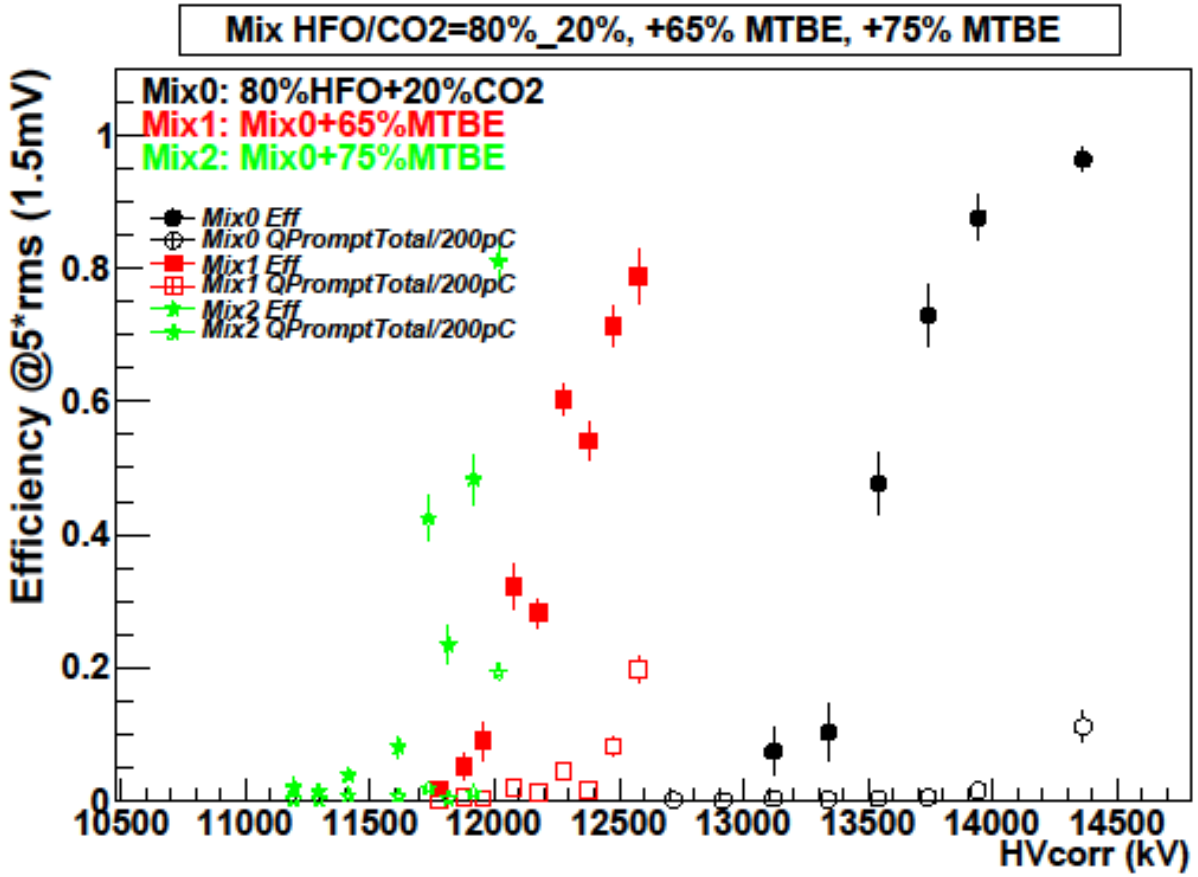
MEK in HFO/CO2=66/33 2.



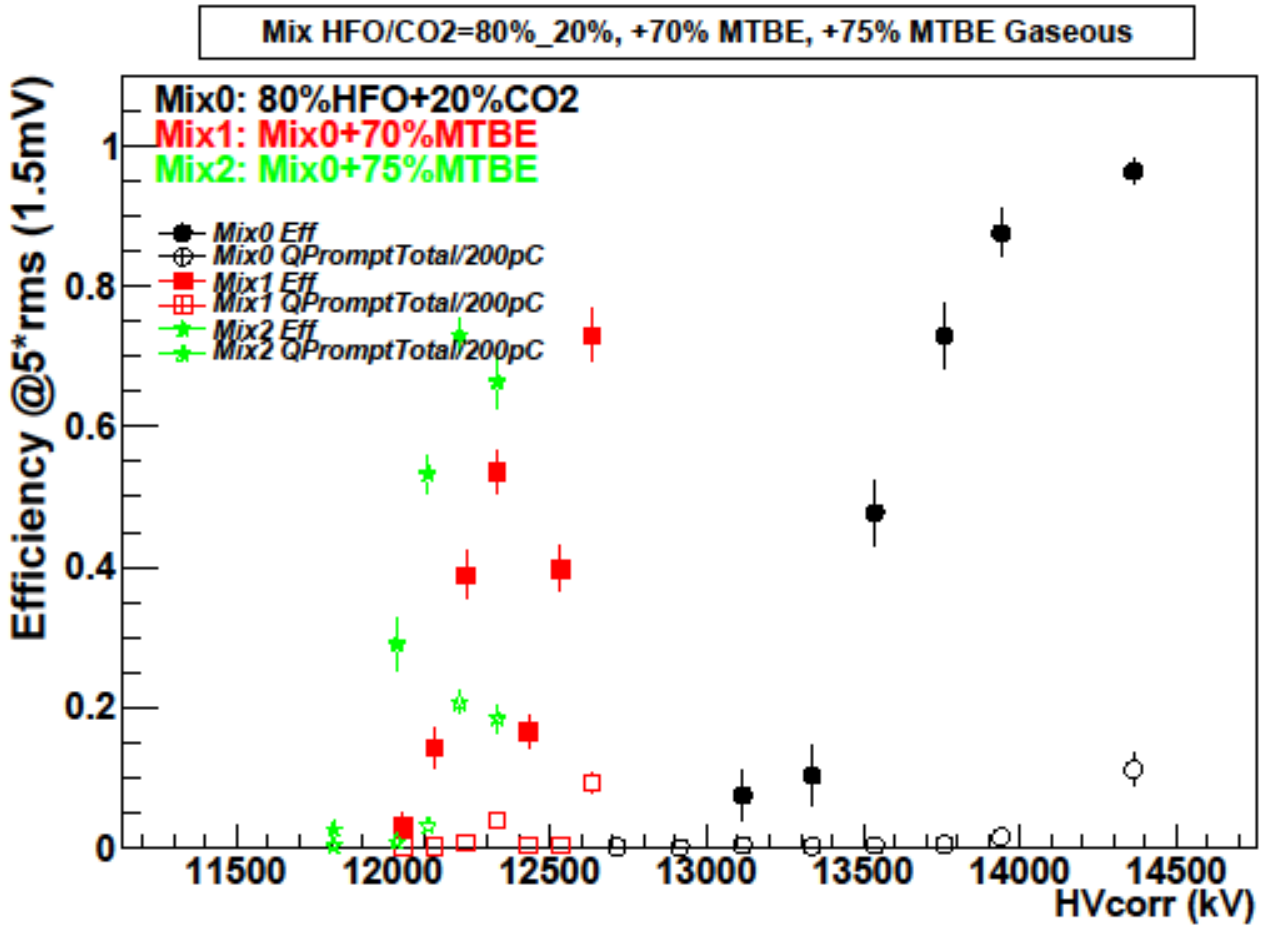
MEK in HFO/CO2=80/20 3.



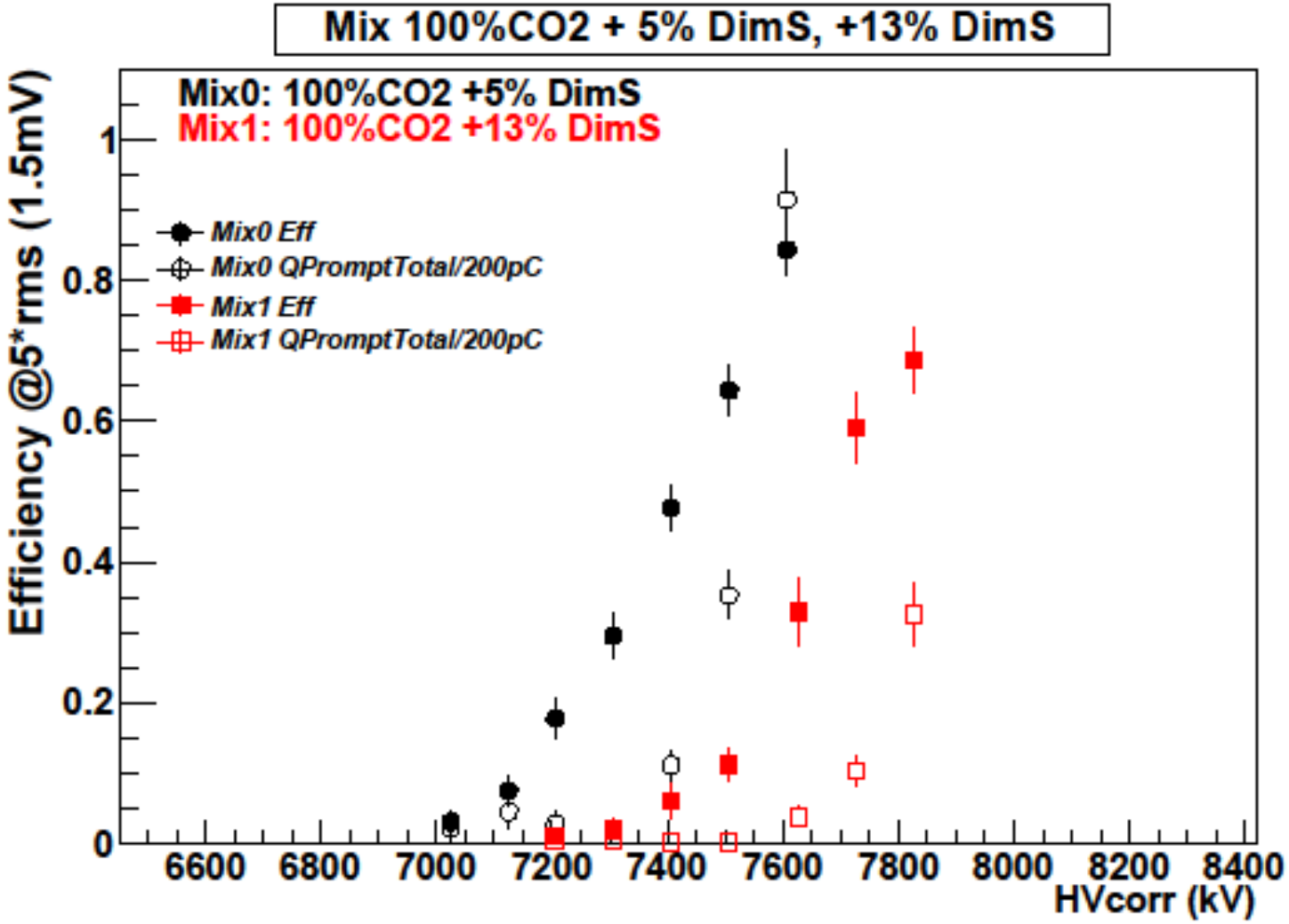
MTBE in HFO/CO2=80/20 1.



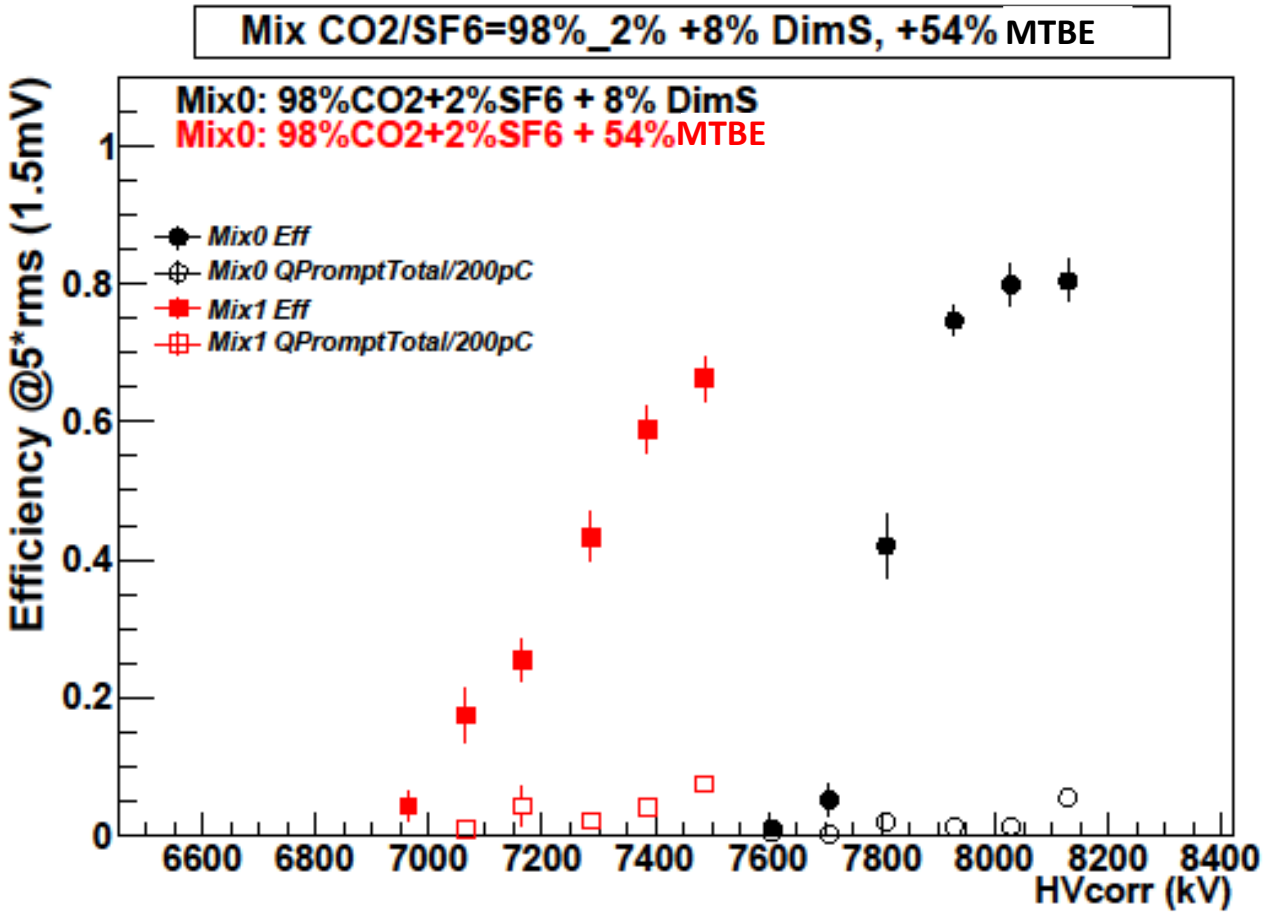
MTBE in HFO/CO2=80/20 2.



DimS in 100%CO2 2.



DimS in CO2/SF6=98/2 3.



Conclusions 1.

- MEK is able to lower the high voltage working point, the lower the higher is its concentration, and the lower the higher is HFO percentage in the binary mixture. But the average total prompt charge increases for equivalent efficiency.

- MTBE is very difficult to handle with, because of its very high vapor pressure. Because of very high currents in the gas gap, probably due to the vapor condensation, the high voltage could not be increased to achieve higher efficiency. No significant improvement for total charge with respect to lowering the working point.

- Dimethyl Sulfide is impressive with CO2. In increasing concentration should be better studied. But in excessive concentration it diverges the gap current.

Conclusions 2.

- Temperature in the liquid and outside must be better controlled and the setup should be refined to be able to better determinate the new molecular concentration in the mixture.

- All molecular relative concetration in the gas mixture are calculated very approximately

- Limits of flammability for all tested mixutures were beyond our interest, as well as the orrible smells and other possible complications.

- Time resolution and intrinsic efficiency of tested mixture are avaible but actually these parameters are without interest.

- **We made some mistakes and a lot of experience, we could not achieve concrete results and solutions for our ecologic problem... But we learned a lot and have a lot of fun!**