CSC aging studies and future plan/milestouns

G. Gavrilov

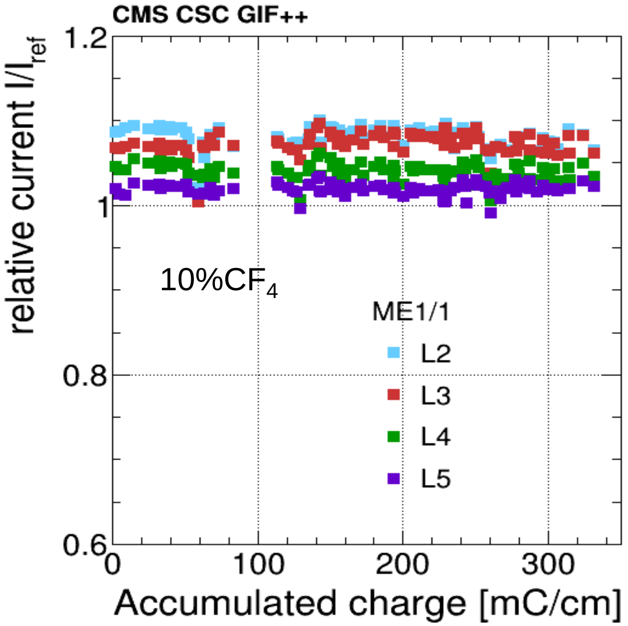
15 October 2019

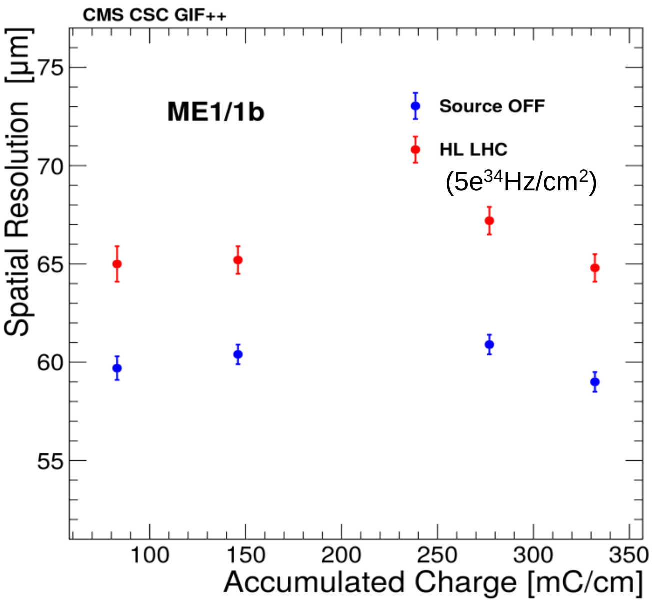
Longevity studies for CSC:

- Longevity for CSC is proved for the nominal CSC gas mixture (10%CF4) for the highest ME1/1 and ME2/1 occupancy regions, for HL-LHC conditions with a safety factor 3

  - GIF++ : close loop gas system, uniform irradiation, two types of chambers

No performance degradation was observed with 40%Ar + 50%CO_2 + 10% CF_4

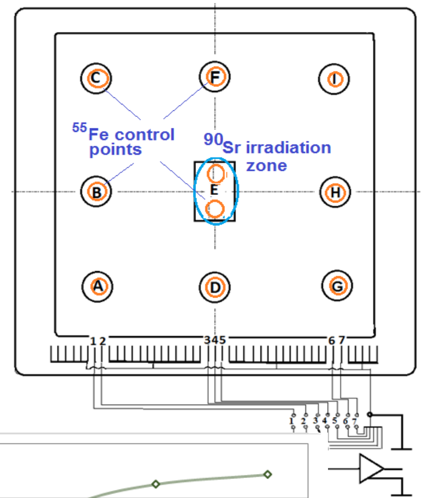




Longevity studies for CSC: $40\%Ar + 50\%CO_2 + 10\%\ CF_4$

Charge accumulation rate: ~ 0.1 C/cm/day

- Monitoring/measurements:
- Relative gain (^{55}Fe peak position);
- Dark current/count;
- Strip-to-strip resistance.

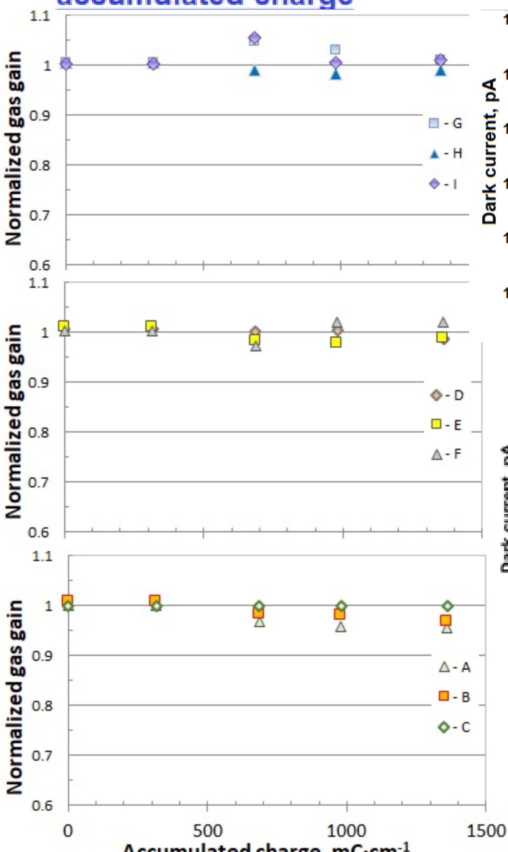


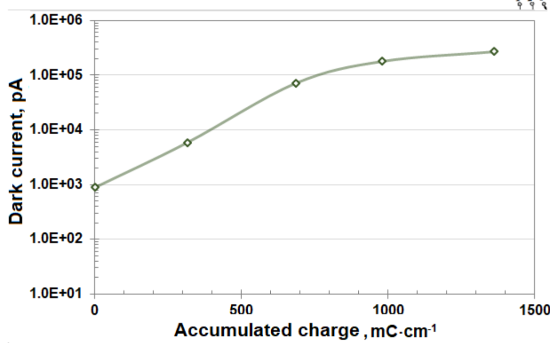
★ Motivation:

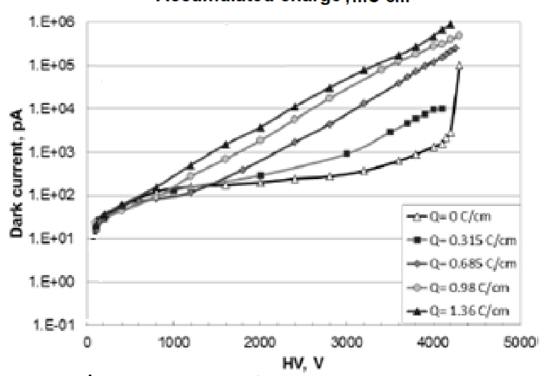
- Targeting test up to Q ~1.5 C/cm for longevity evaluation at HL-LHC luminosity
- Benchmark test for new gas mixtures studies
- Study of the cathode aging phenomena

^{90}Sr irradiation current 17 µA !

Relative gas gain as ^{55}Fe peak position vs accumulated charge

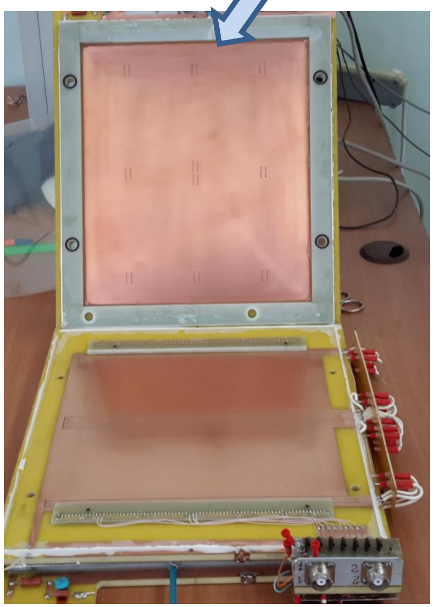




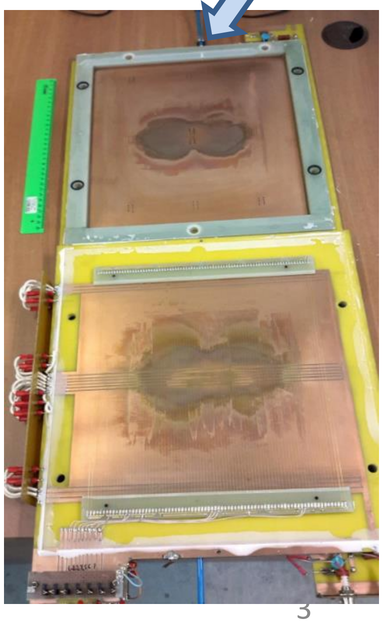


Dark current > 50 nA
at work point 3750 V after
accumulation of 685 nA/cm that is
equal to ~ 20 yrs HL-LHC

Reference layer after aging run



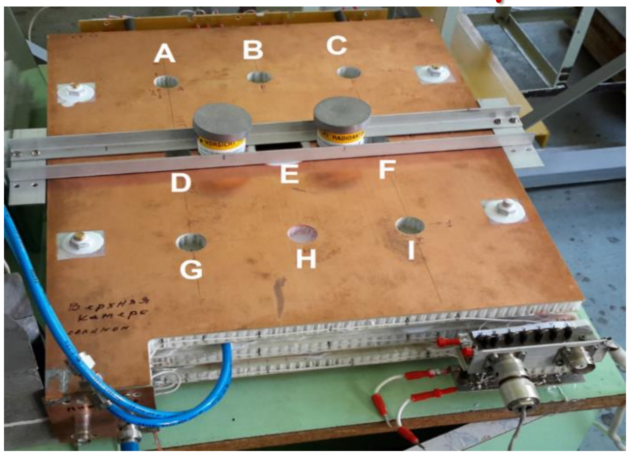
Irradiated layer after Q =1.36 C/cm



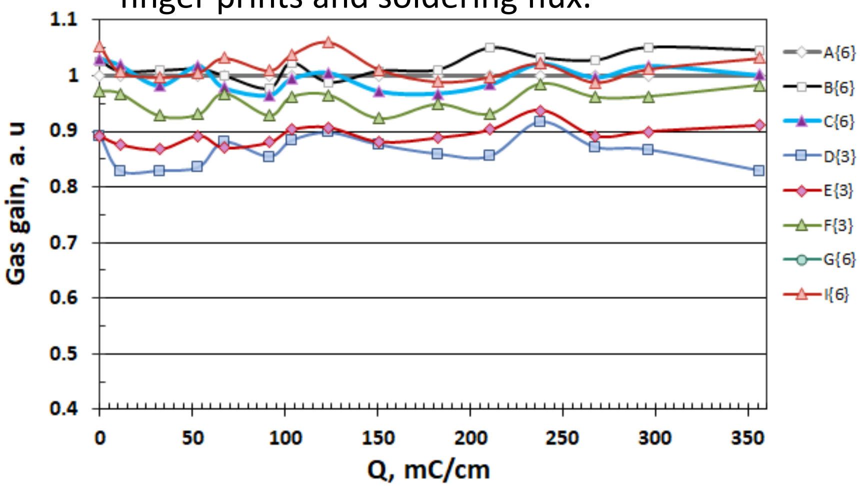
Longevity studies for CSC:

40%Ar + 50%CO_2 + 10% CF_4

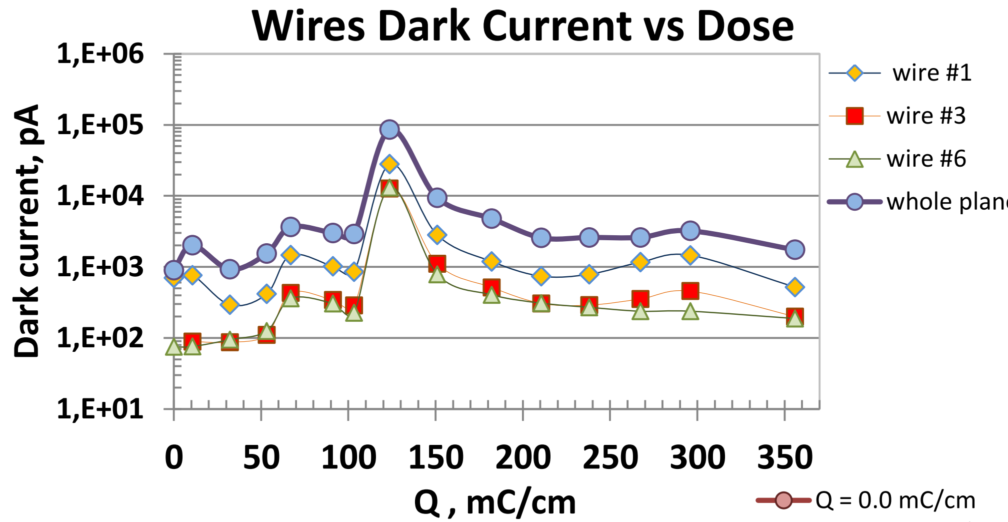
^{90}Sr irradiation current 1 μA !

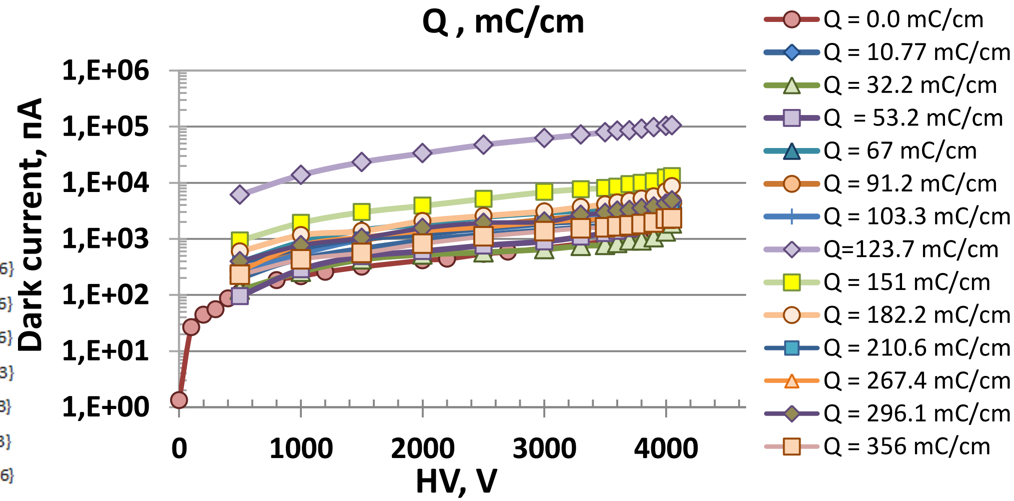


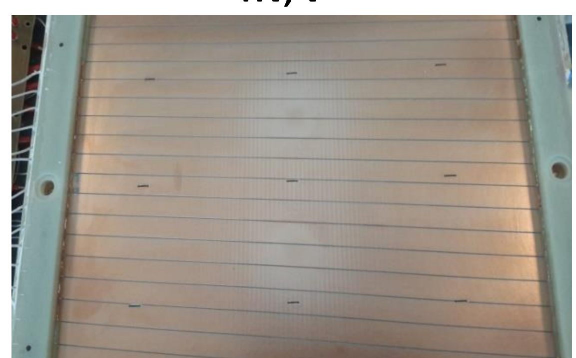
Cathode intently contaminated with RTV, finger prints and soldering flux.



No performance degradation was observed in longevity tests with CSC prototypes in PNPI







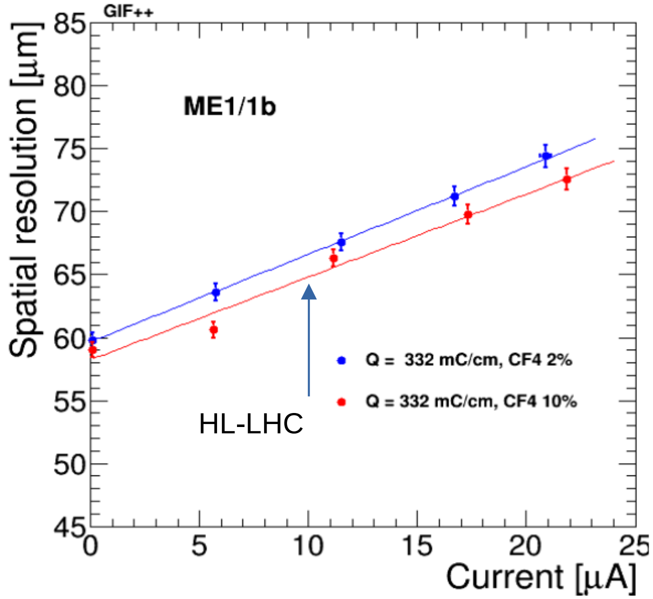
Cathode plane after Q = 356 mC/cm

Longevity studies for CSC with reduced amount of CF_4

Following the common approach of reducing usage of non-ecological gases, we performed studies with a reduced amount of CF_4

- Lab tests with small CSC prototypes and fast local irradiation with Cd for gas mixtures containing 10%, 5%, 2% and 0% CF_4
- Muon detection performance and longevity tests at GIF++ with 2% CF_4:
  - Muon detection performance (ME1/1, ME2/1) was found to be similar for 10% and 2% CF_4 gas mixtures
  - GIF++ longevity test with ME1/1 chamber was continued using 2% CF_4 gas mixture
  - Also a longevity test with a small prototype was done (relatively slow uniform irradiation, prototype material correspond to ME2/1 chamber type)

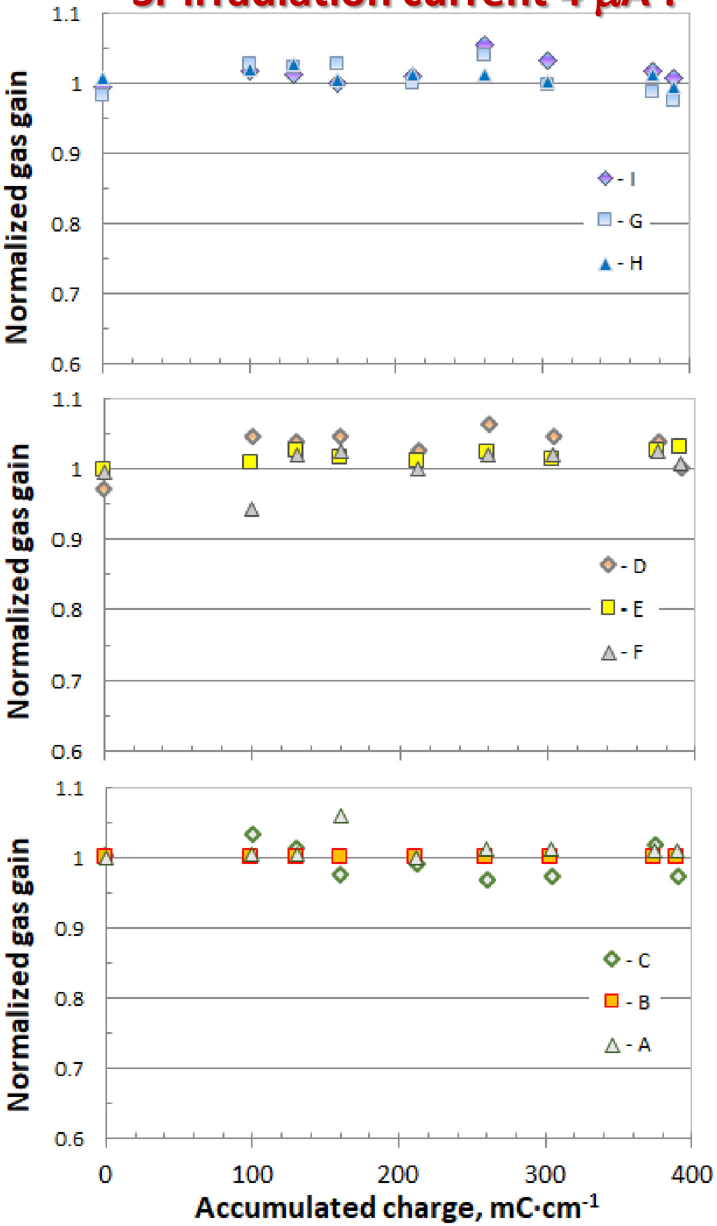
CSC spatial resolution as a function of background intensity for nominal (10%) and 2% CF4 gas mixtures

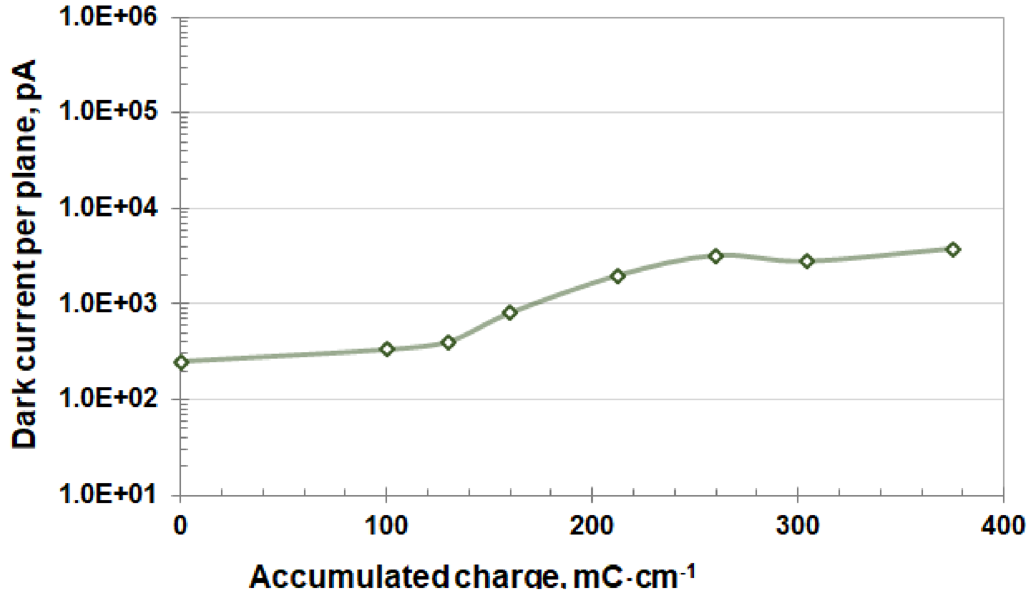


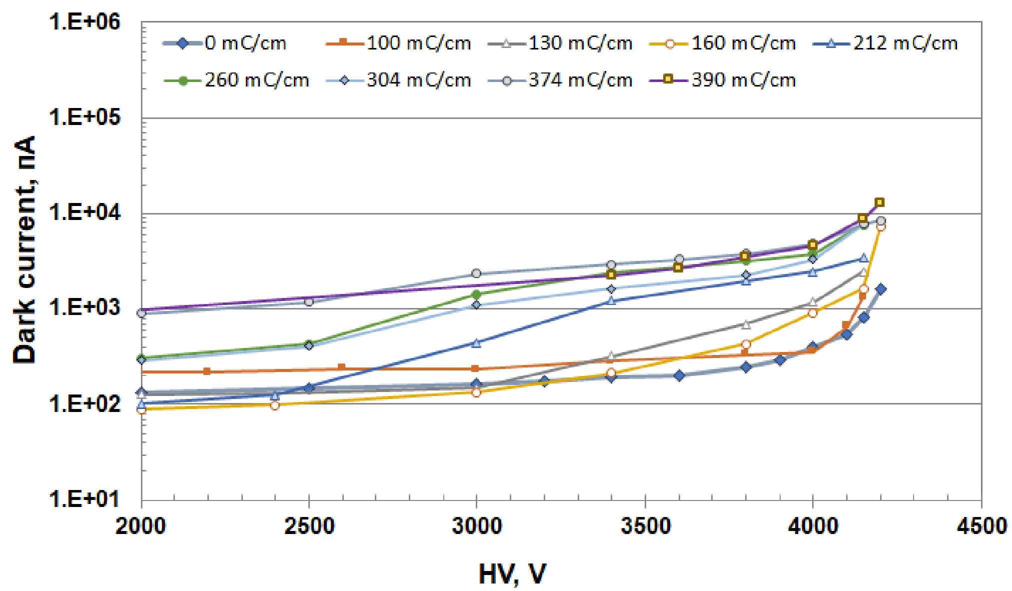
Longevity studies for CSC with reduced amount of CF_4

37%Ar + 61.3%CO_2 + 1.7% CF_4

^{90}Sr irradiation current 4 μA !



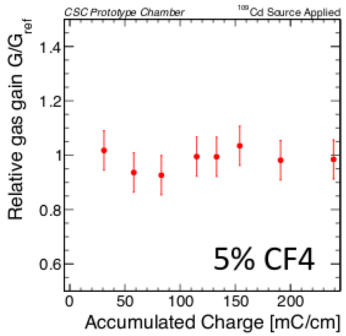


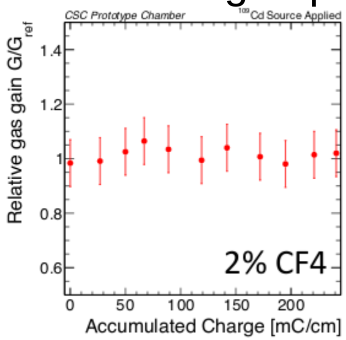


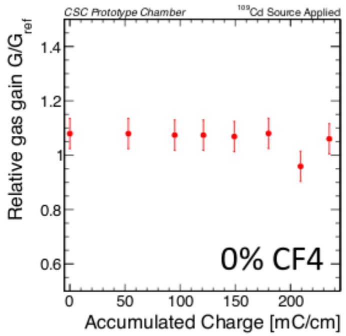
Longevity studies for CSC with reduced amount of CF_4

- **No significant degradation in chamber performance was observed** neither with prototypes up to 3xHL-LHC accumulated charge, nor with ME1/1 chamber which accumulated additional 2xHL-LHC charge up to now

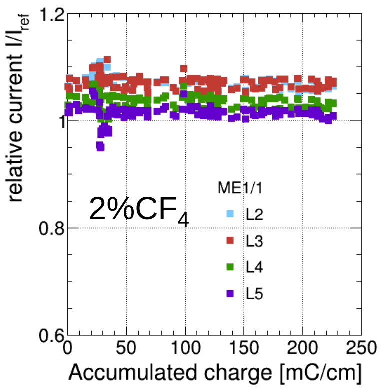
prototypes

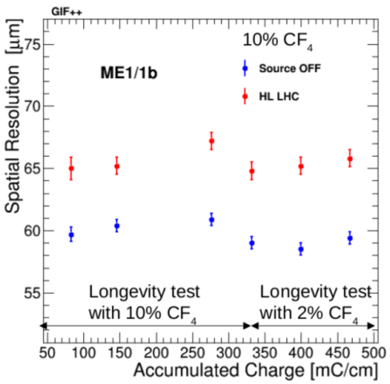






ME1/1 at GIF++



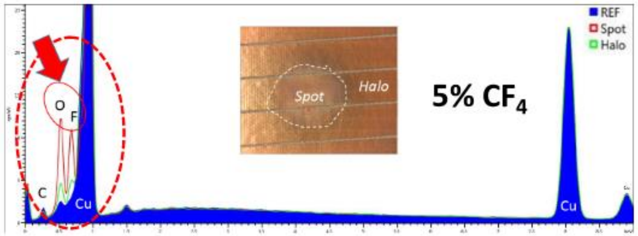


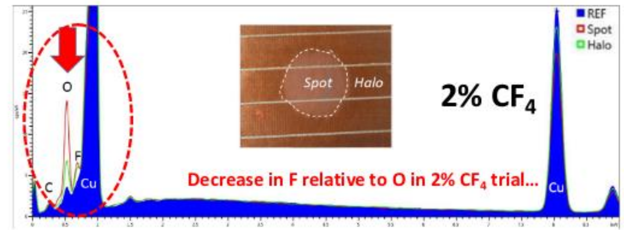
- Irradiated prototypes were disassembled and cathode surfaces and anode wires are being carefully studied with SEM/EDS and more dedicated analysis techniques

Longevity studies for CSC with reduced amount of CF_4

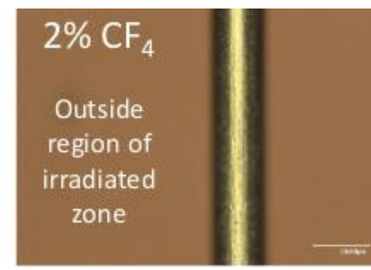
Comparison of SEM/EDS results for the electrode surfaces irradiated with gas mixtures containing 5% and 2% CF4:

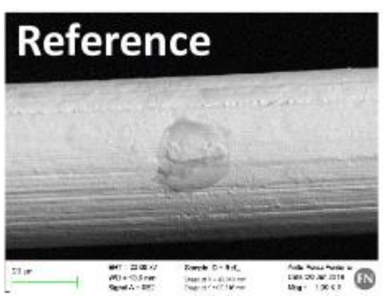
Cathode surface: different ratio between O and F presence on the cathode

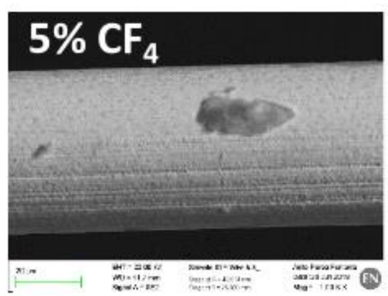


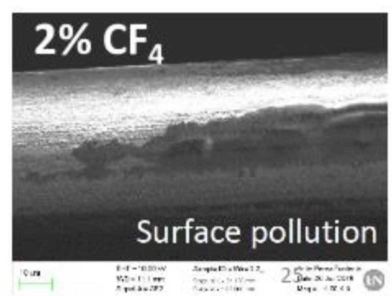


Anode surface: visually dark in the area irradiated with 2% CF4, confirmed with SEM. Wires irradiated with 5% CF4 look similar to the reference non-irradiated wires.









A definite presence of the dark flakes (Carbon?) on the irradiates wires at 2% CF4 !!

Метод энергодисперсионной рентгеновской спектроскопии (англ. *Energy-dispersive X-ray spectroscopy*, ***EDX*, *EDRS*** *или* ***EDS***) — аналитический метод элементного анализа твёрдого вещества, базирующийся на анализе энергии эмиссии его рентгеновского спектра, вариант рентгеноспектрального анализа.

Motivation of choice:

- The hydrofluoroolefine HFO_{1234ze} (CF3CH=CHF) is a refrigerant gas which was proposed as a replacement to CF4;
- HFO_{1234ze} has an extremely low global warming potential on a hundred years horizon – GWP < 1.
- Ozone Depletion Potential (ODP) of HFO_{1234ze} in CCl_3F units – ODP = 0

Electron swarm parameters of the hydrofluoroolefine HFO1234ze

A. Chachereau, M. Rabie, C. M. Franck, Power Systems and High Voltage Laboratories, ETH Zurich, Physikstr. 3, 8092 Zurich, Switzerland. E-mail: alisec@ethz.ch

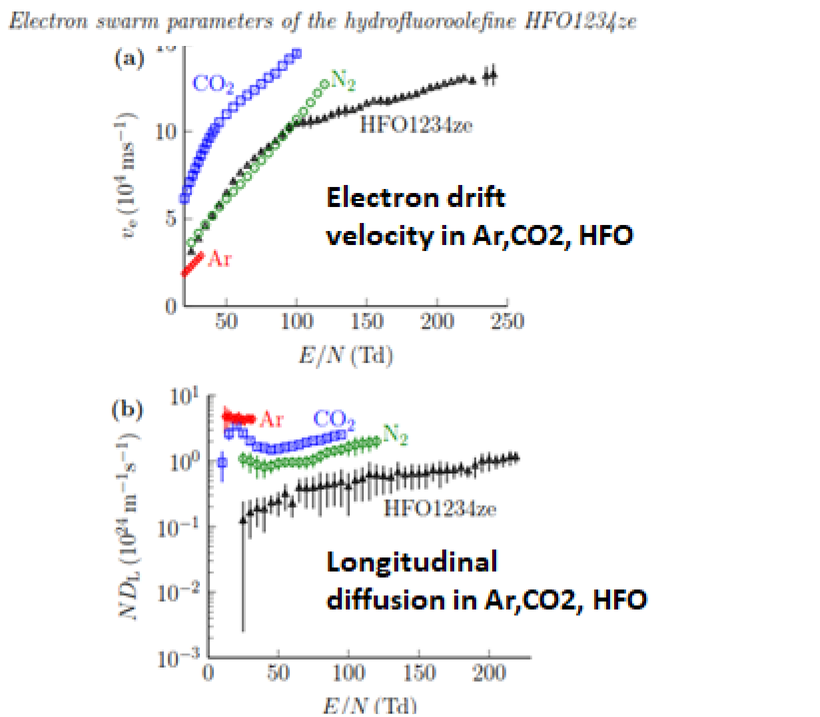
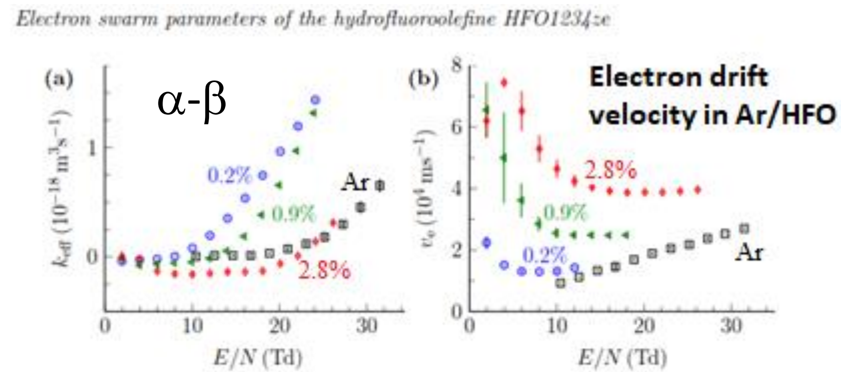
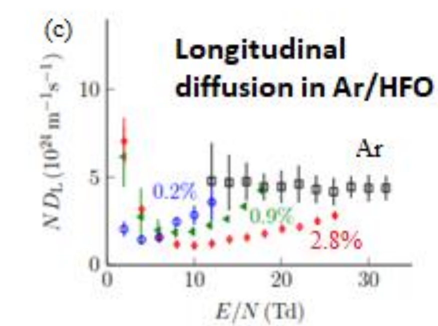


Figure 4: (a) Electron drift velocity v_e and (b) density normalized longitudinal electron diffusion coefficient ND_L in HFO1234ze, N_2, CO_2 and Ar as a function of E/N.





1 Td – 250 V/cm

20 Td – 5000 V/cm -> CSC cathode plane;

100 Td – 25000 V/cm -> gas discharge zone

Figure 8: (a) Effective ionization rate coefficient, (b) electron drift velocity and (c) density normalized longitudinal electron diffusion coefficient in pure Ar and in the mixtures of 0.2%, 0.9% and 2.8% HFO1234ze in Ar as a function of E/N.

Table 1. Summary of various refrigerant candidates. Also shown is the Chemical Abstracts Service (CAS) Registry Number.

Molecular name	Chemical formula	CAS	Refrigerant identifier	GWP	ODP
Chloropentafluoroethane	C_2ClF_5	76-15-3	R115 [49]	7370	0.44
Hexafluoroethane	C_2F_6	76-16-4	R116 [47]	-	-
2,2-Dicloro-1,1,1-trifluoroethane	$C_2HCl_2F_3$	306-83-2	R123 [38]	120	0
1-Chloro-3,3,3-Trifluoropropene	$C_3H_2ClF_3$	2730-43-0	R1233zd [45]	4.7-7	0
2,3,3,3-Tetrafluoropropene	$C_3H_2F_4$	754-12-1	R1234yf [46]	4	0
1,3,3,3 Tetrafluoropropene	$C_3H_2F_4$	29118-24-9	R1234ze [43]	6	0
Trifluoroiodomethane	CF_3I	2314-97-8	R13I1 [44]	0.4	0.01-0.02
1,1,1,2-Tetrafluoroethane	CH_2FCF_3	811-97-2	R134a [35]	1430	0
Tetrafluoromethane	CF_4	75-73-0	R14 [31]	7390	0
1,1,1-trifluoroethane	CH_3CF_3	420-46-2	R143a [30]	4300	-
1,1-Difluoroethane	$C_2H_4F_2$	75-37-6	R152a [51]	124	0
Octafluoropropane	C_3F_8	76-19-7	R218 [40]	-	-
Propane	C_3H_8	74-98-6	R290 [39]	3	0
Difluoromethane	CH_2F_2	75-10-5	R32 [48]	650	0
Isobutane	C_4H_{10}	75-28-5	R600a [42]	3	0
Sulfur Hexafluoride	SF_6	2551-62-4	R7146 [32]	23000	0.04
Carbon Dioxide	CO_2	124-38-9	R744 [37]	1	0
Octafluorocyclobutane	C_4F_8	115-25-3	R318 [41]	-	-
Pentafluoroethane	HF_2CF_3	354-33-6	R125 [28]	3400	0
Trifluoromethane	CHF_3	75-46-7	R23 [29]	0	0
R409:	$CHClF_2$	75-45-6 2837-89-0 75-68-3	R22 (60%), R142b (25%), R124 (15%)	1700-620	0.5/0.065/0.02
R407c:	CH_2F_2, CF_3CHF_2, $CH2FCF_3$	75-10-5, 354-33-6, 811-97-2	R32 (21-25%), R125 (23-27%), R134a (50-54%)	650 3400 1430	0 0 0

Freon :	I [eV]	$\left(\frac{-dE}{dx}\right)_{min}$ [MeV g ·cm^{-2}]	X_0 [g·cm^{-2}]	N_p [cm^{-1}]
CF_4 – Tetrafluoromethane (R14)	107.1	1.70	33.99	63.6
$CF_3CH{=}CHF$ – Hydrofluoroolefine (R1234ze, HFO_{1234ze})	91.97	1.77	35.82	89.5
iC_4H_{10} – isobutane (R600a)	47.85	2.24	45.23	81.0

G. Saviano et al.,
Properties of potential eco-friendly gas replacement for particle detectors in high –energy physics
//Journal of Instrumentation, 2018, 13 P03012

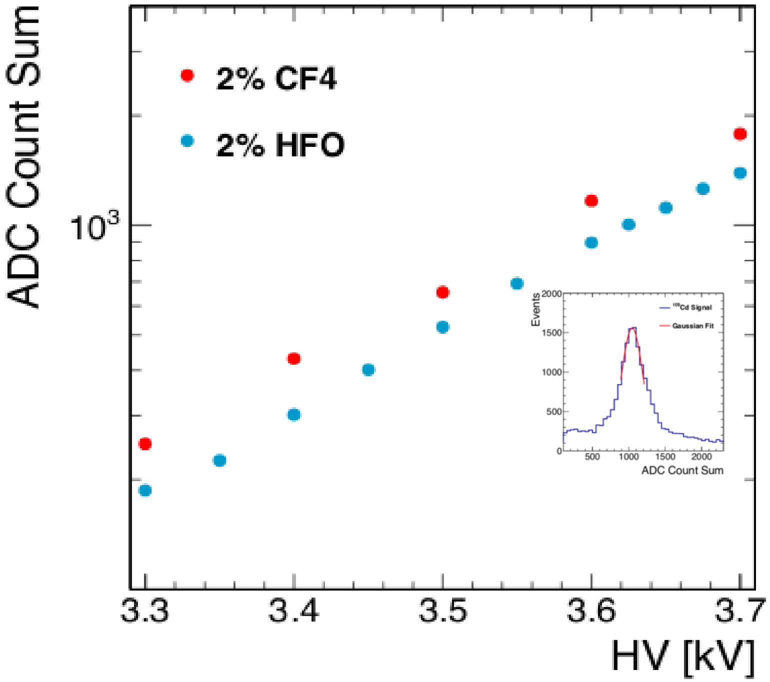
R1234ze [43]	114.0	4.82	-29	1/0/0	-

Incompatible with strongly oxidizing materials and finely divided Mg and Al.

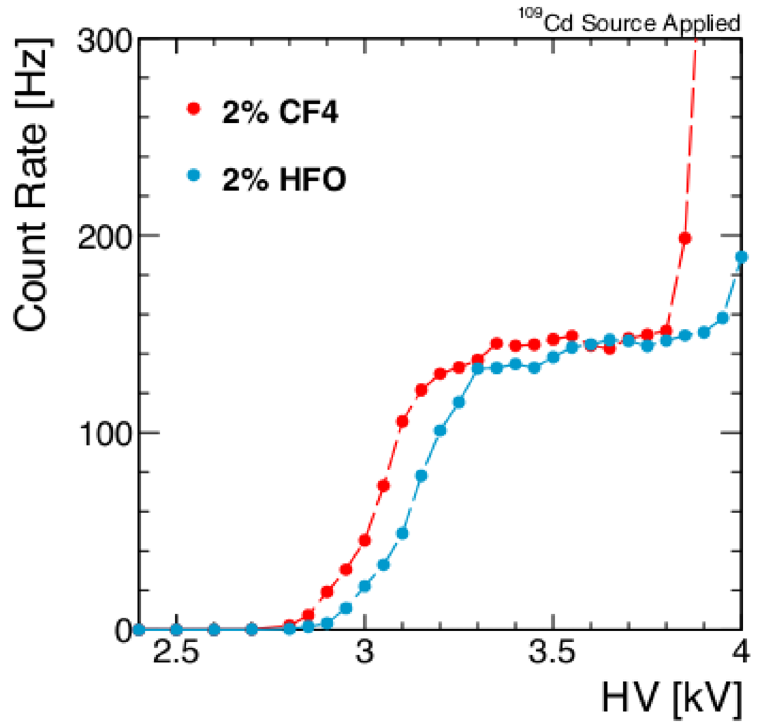
If involved in a fire, production under thermal decompose into pyrolysis products containing Fluorine, Carbon Monoxide, Carbonyl halides, and Hydrogen halides can occur. Polymerization may also occur.

Very first performance studies of a CSC prototype operated with HFO_{1234ze} were done at CSC 904 lab comparing $Ar/CO_2/CF_4$ and $Ar/CO_2/ HFO_{1234ze}$ 40% / 58% / 2% gas mixtures

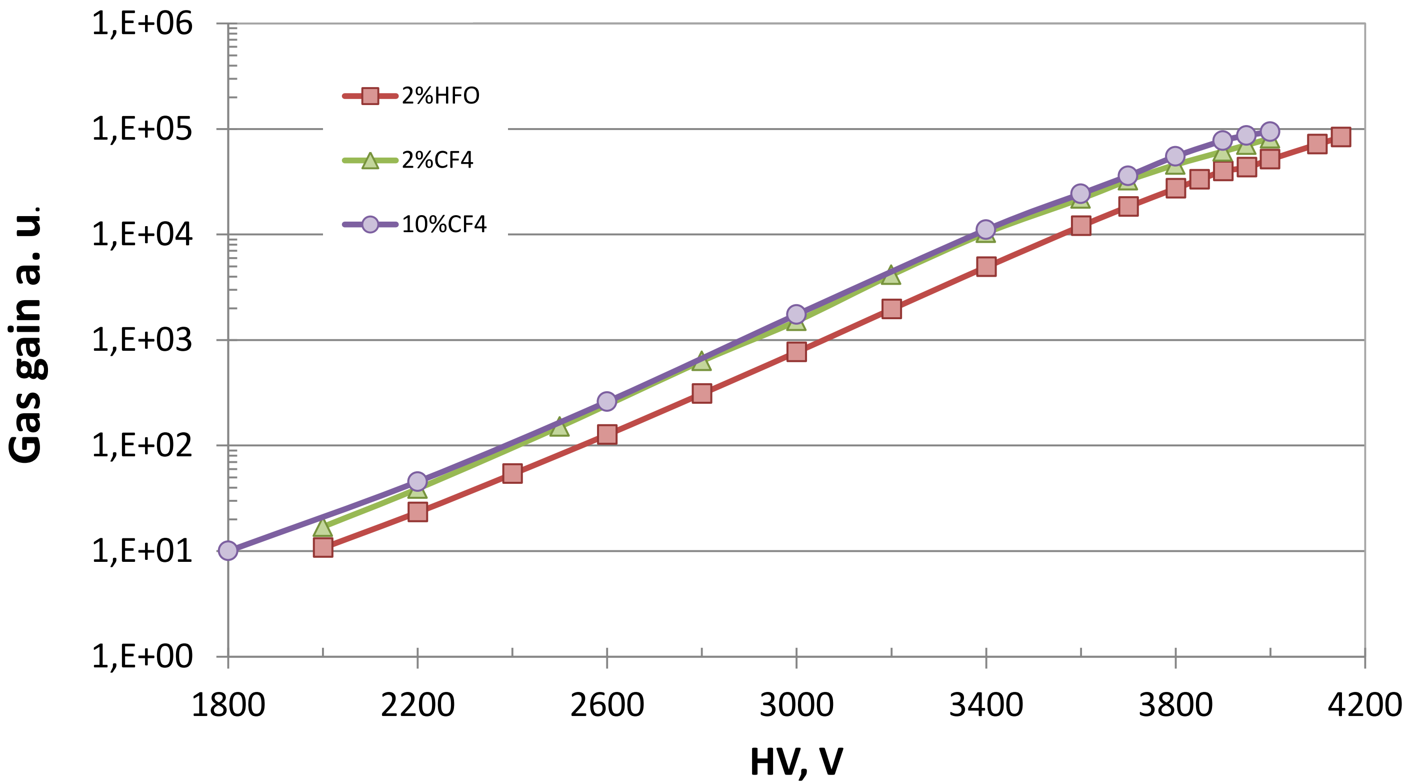
Relative gas gain vs HV measured as a peak position of measured ^{109}Cd spectrum



Efficiency plateau measured with ^{109}Cd source using standard CSC electronics



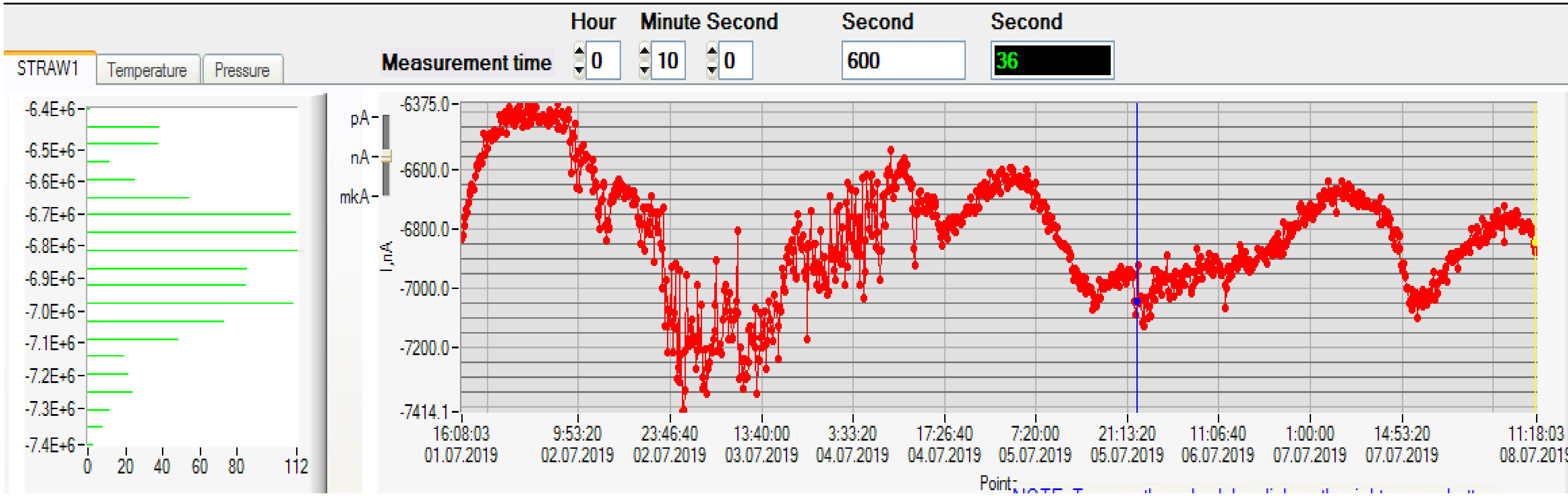
Gas gain measured by ionization current method

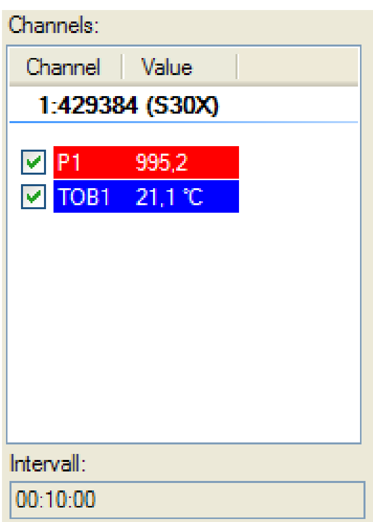


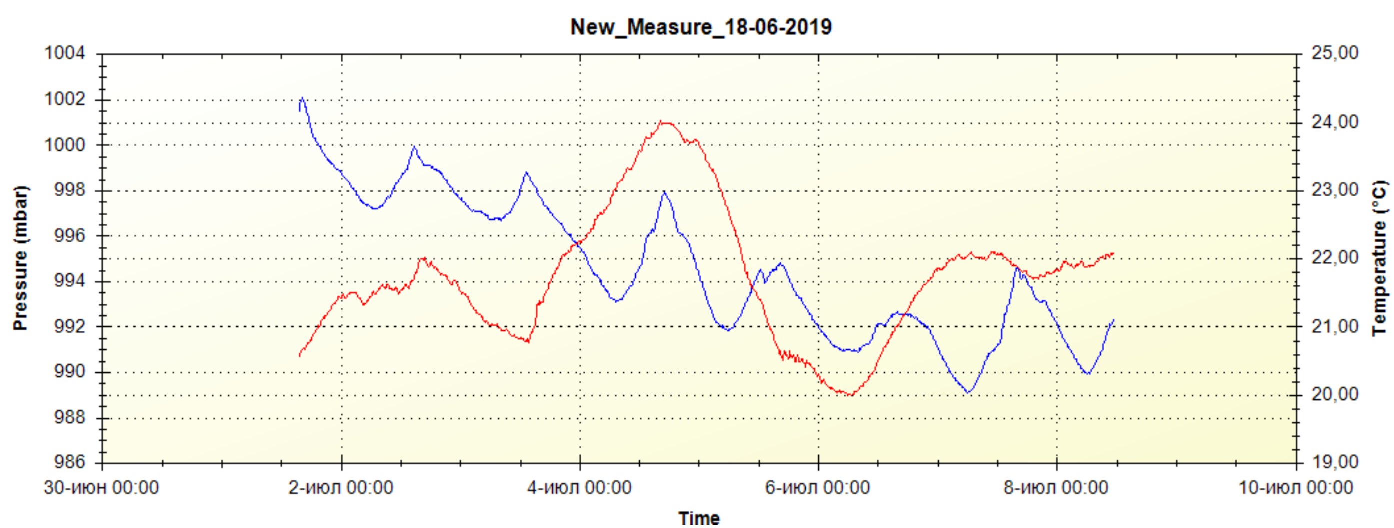
CSC HV working point → Gas gain = 5×10^4
is available at

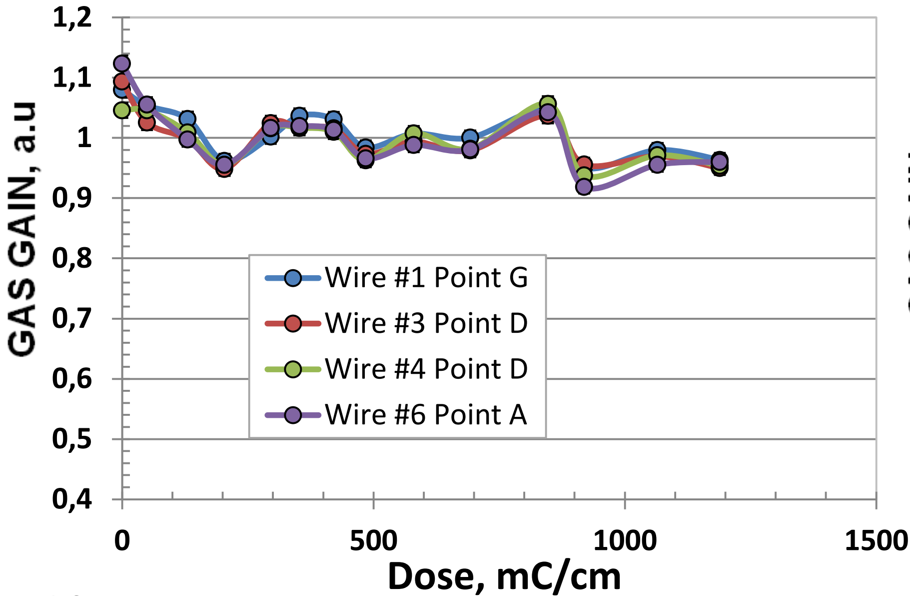
HFO: 2%   CF4: 10%   2%
HV, V: 3850   3750 3800

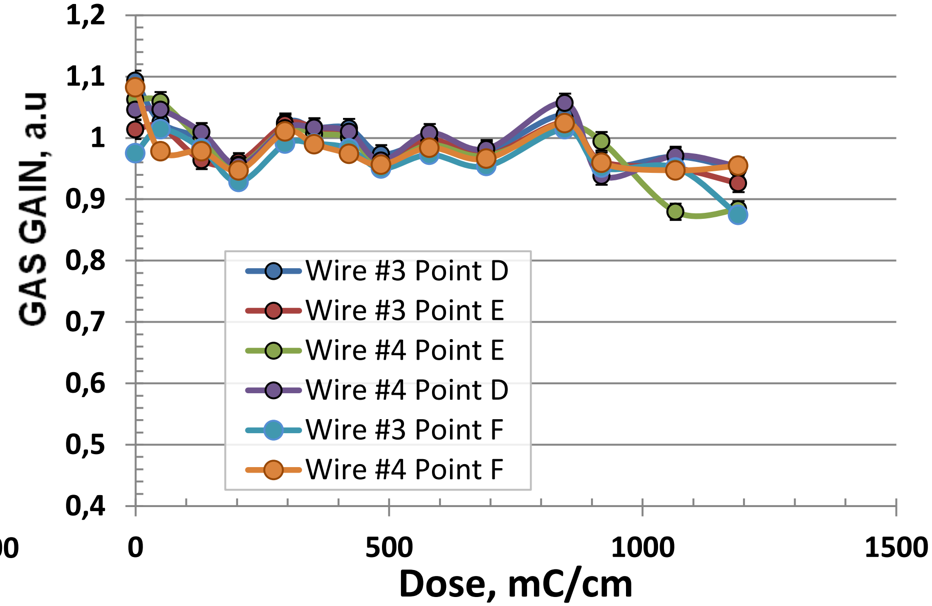
^{90}Sr current during irradiation

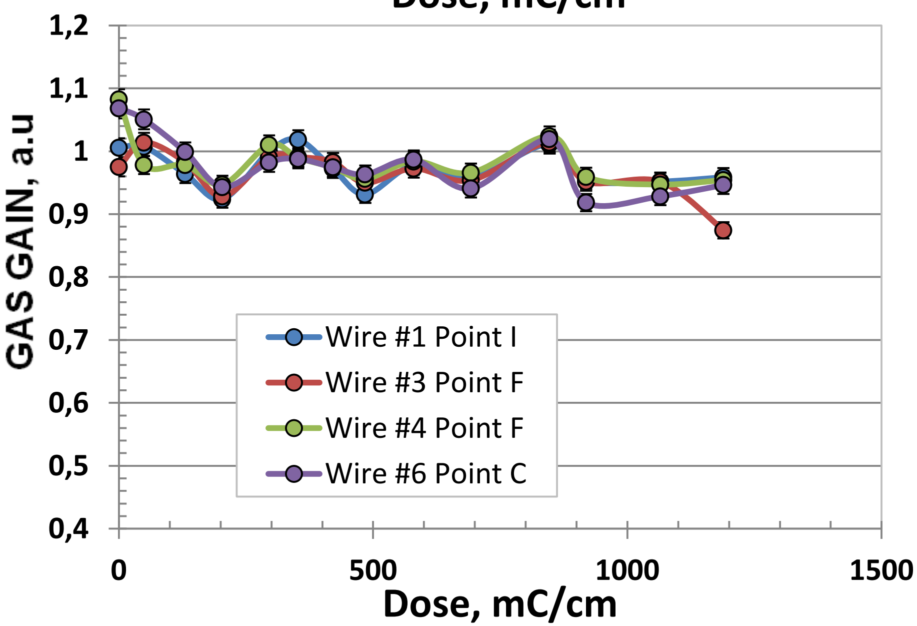


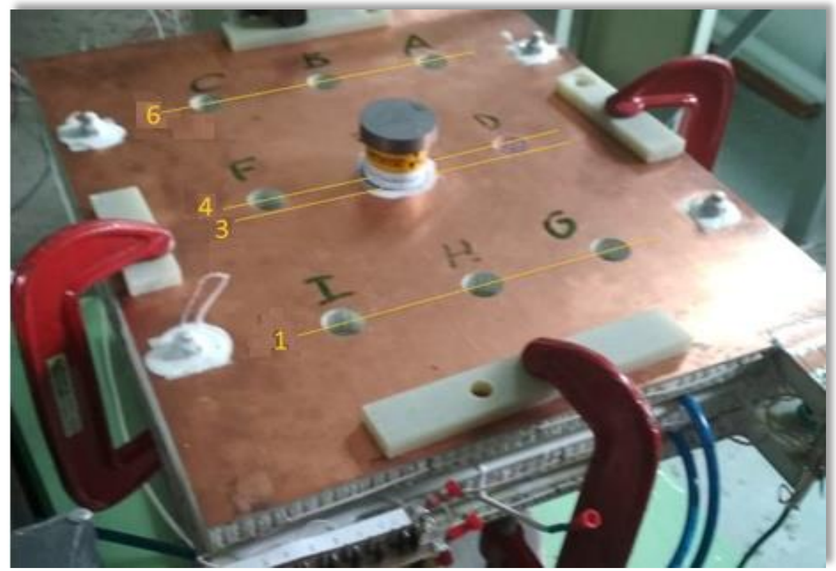




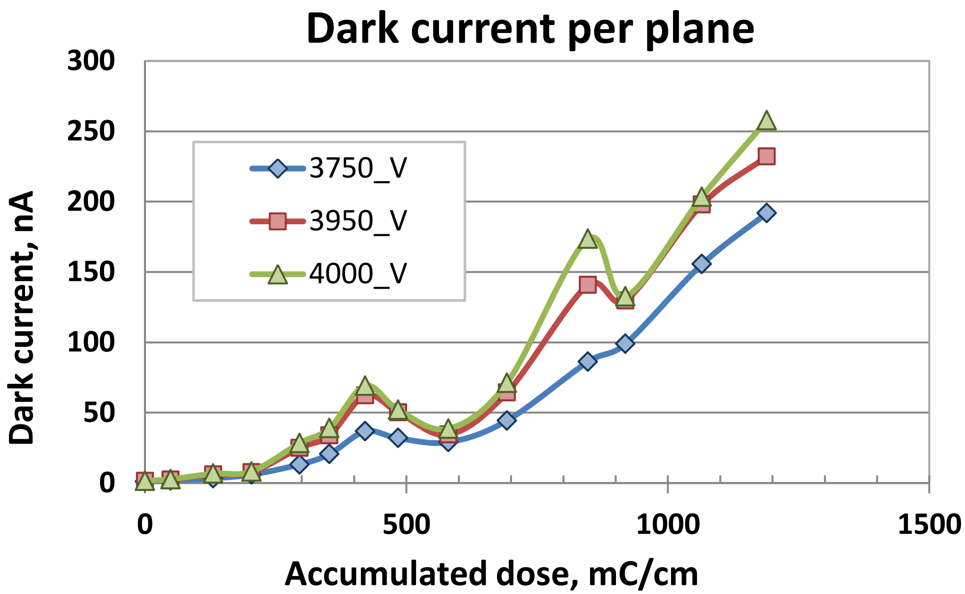


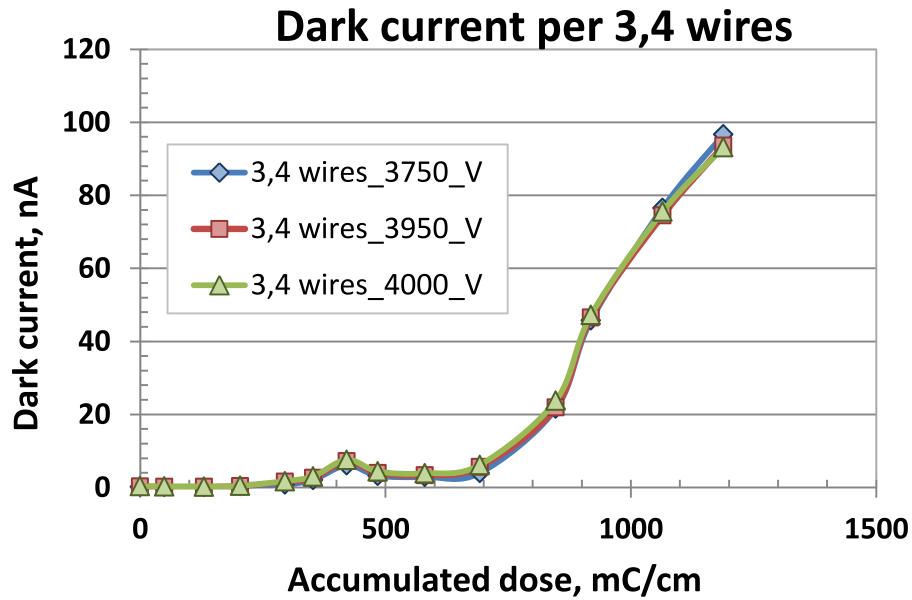


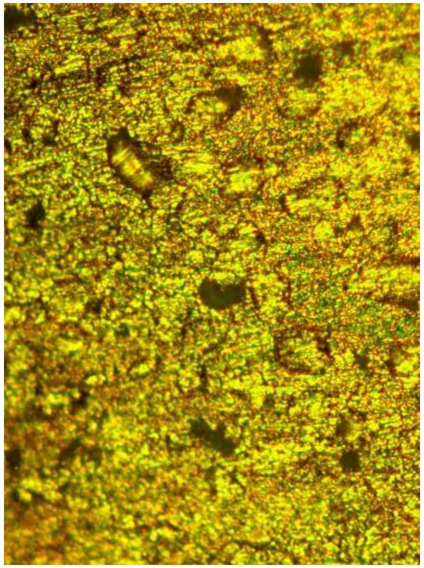




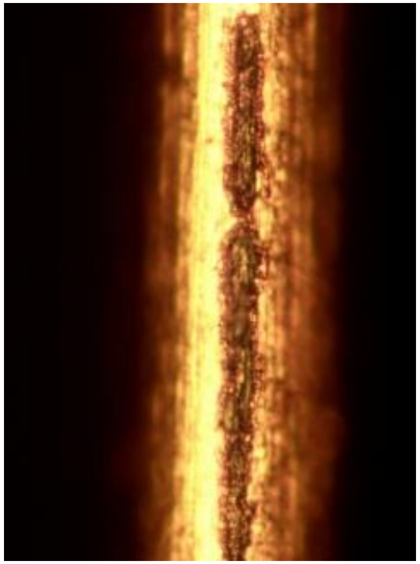
- Gas Gain degradation starts from ~1000 mC cm^{-1}
- Gas Gain reduces only on the irradiated wires, that is an indication of the anode wire aging



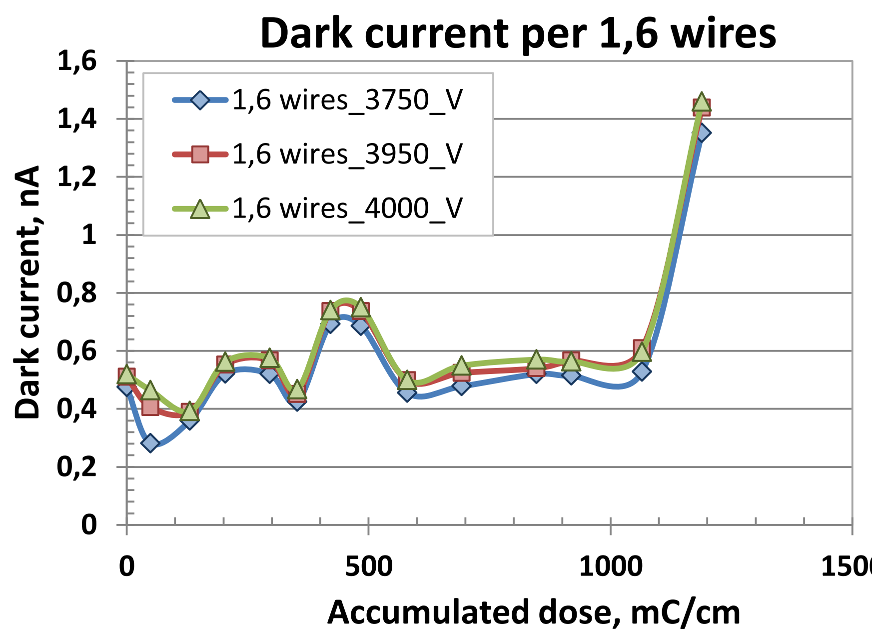




x 400 cathode



x 800 anode
point E, wire #4

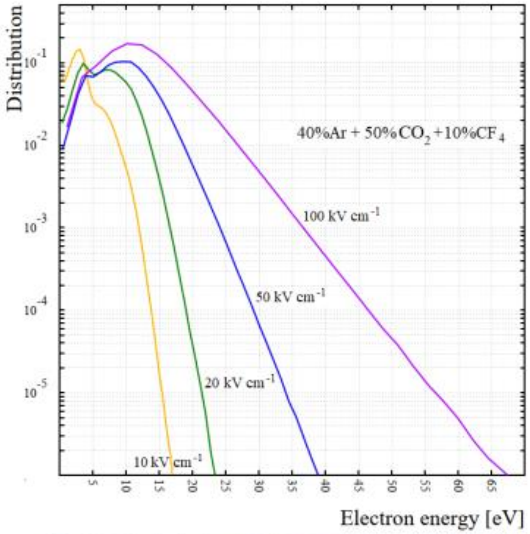


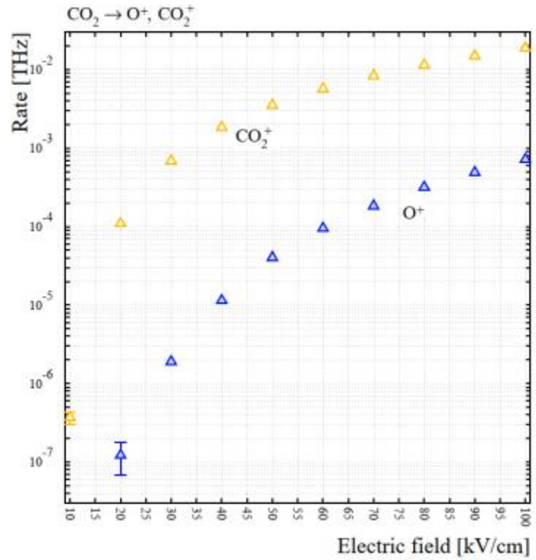
CONCLUSION

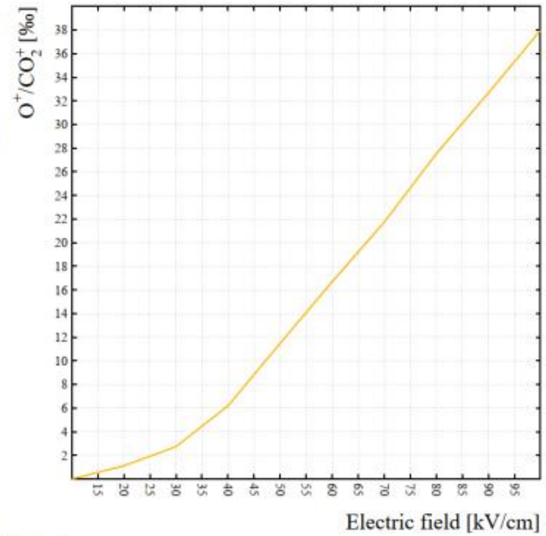
- Longevity for CSC is proved for the nominal CSC gas mixture (10%CF4). No performance degradation was observed for HL-LHC conditions with a safety factor 3.
- No degradation in chamber performance was observed neither with prototypes up to 3xHL-LHC accumulated charge, nor with ME1/1 chamber which accumulated additional 2xHL-LHC charge for the gas mixtures with reduced CF_4 contain
- 2%HFO_{1234ze} provides similar operation conditions as 10%CF4 containing CSCs gas mixture and up to Q ~ 800 mC/cm no any degradation of the amplitude and dark current is observed.
- A swelling effect on the anode wires in the prototype with 2%HFO_{1234ze} gas mixture appears at Q ~ 1000 mC/cm .
- To conclude about cathode plane and anode wires degradation, SEM/XEM study of the samples have to be done. A cross-check test with CSCs at GIF++ have to be performed.

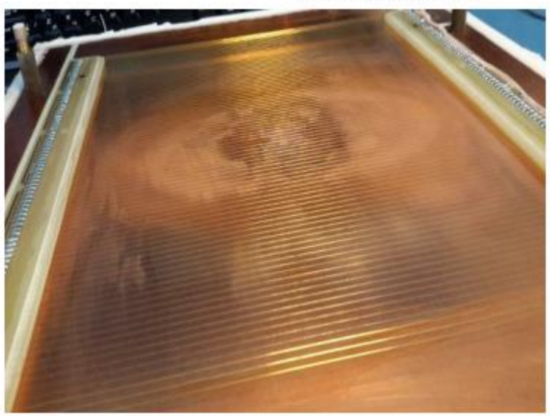
Backup

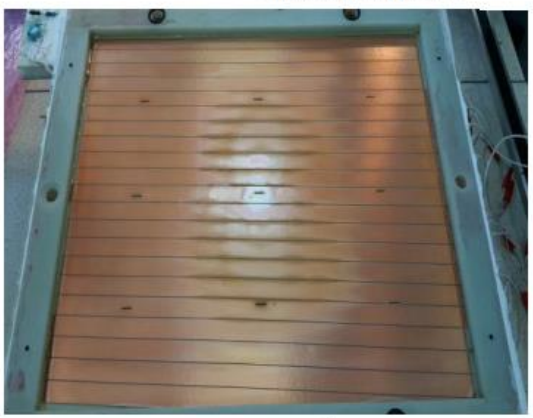
Oxygen generation in gas avalanche in the range of electric field of 10-100 kV/cm
Calculations with Magboltz&Garfield for 40%Ar+50%CO2+10%CF4











INVESTIGATION OF THE CATHODE PLANE RADIATION DAMAGE

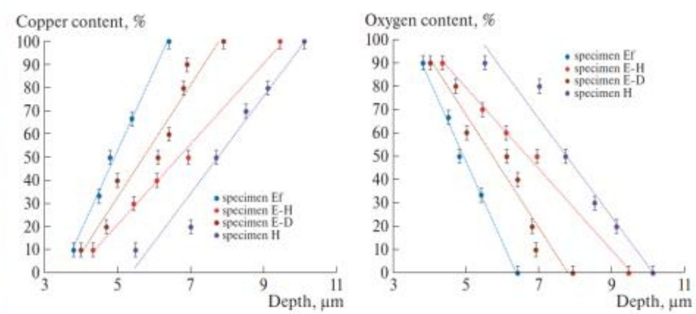
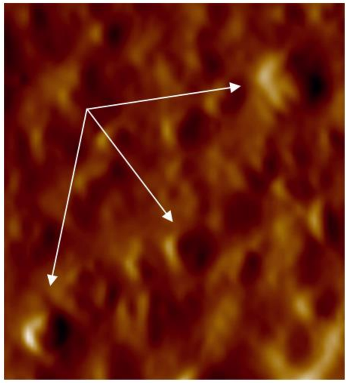


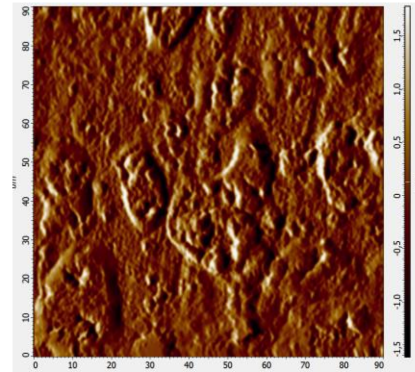
Fig. 9. (Left) copper and (right) oxygen distribution versus depth in copper foil.

Cathode damages

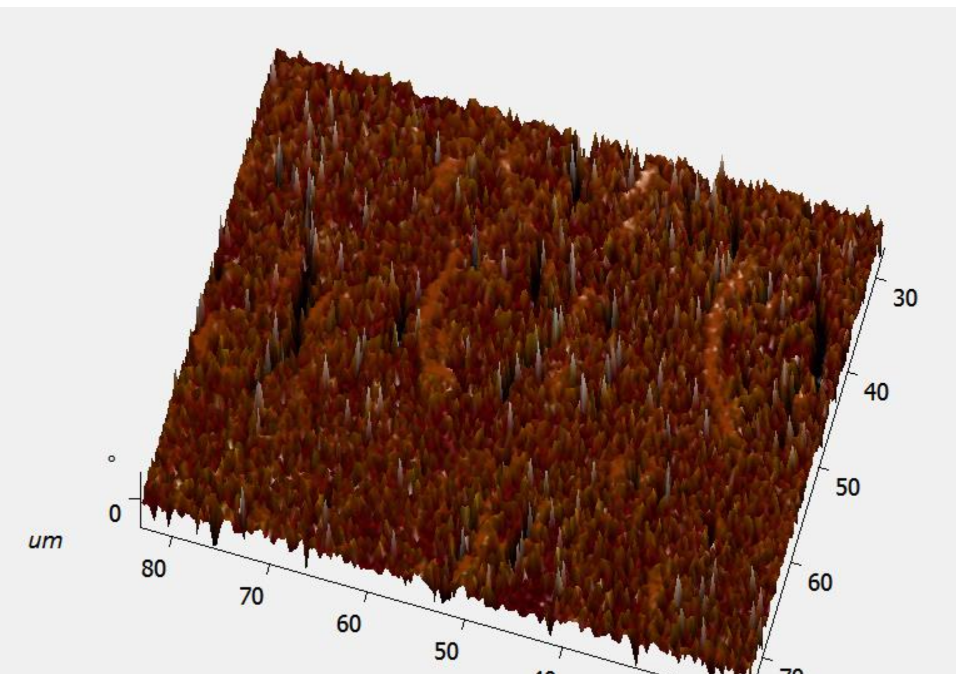


Blisters

Craters



Flaking



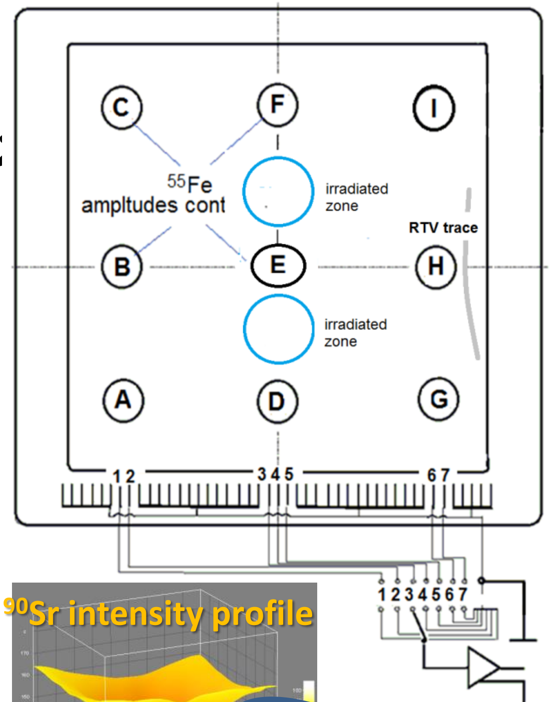
Needles
(Threads)

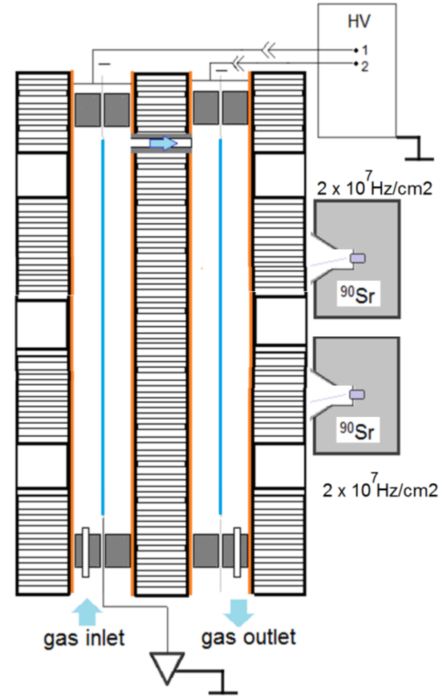
Sample	Number of point like objects
C	153
E-D	261
H	277
E-H	284
Ef	216

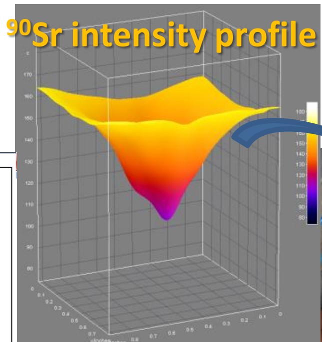
CSC prototype for longevity tests in PNPI

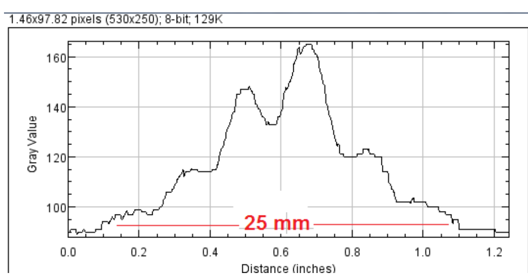
- 2 planes, each with 7 controlled anode wires;
- 50 μm gold-coated anode wire;
- 285 x 270 mm² sensitive area, 693 cm³ gas volume;
- S = 3 mm ;
- L = 4.5 mm ;
- Identical geometry and construction materials to CSC
- Gas flow during aging test was 2 sccm

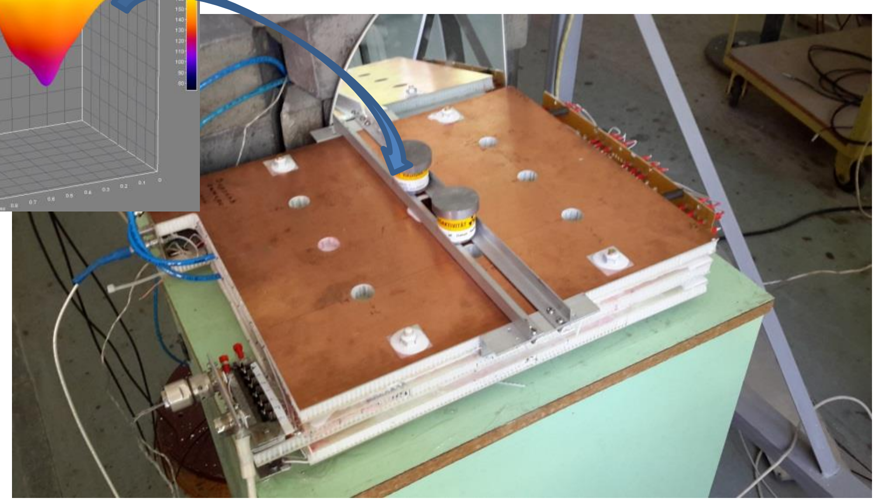
that is ~ 4 Volume per day ;





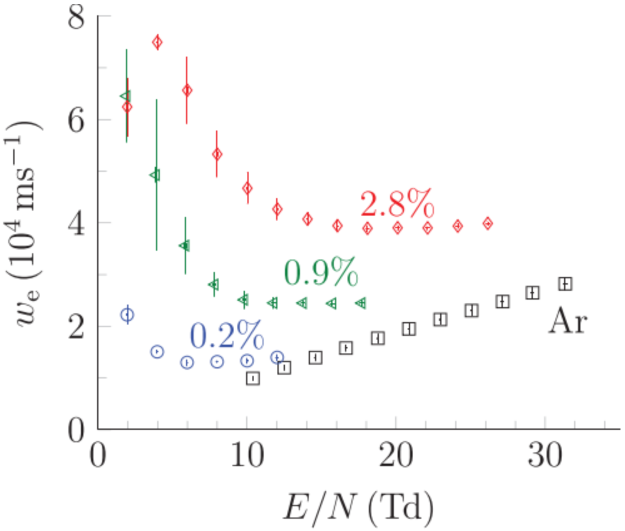


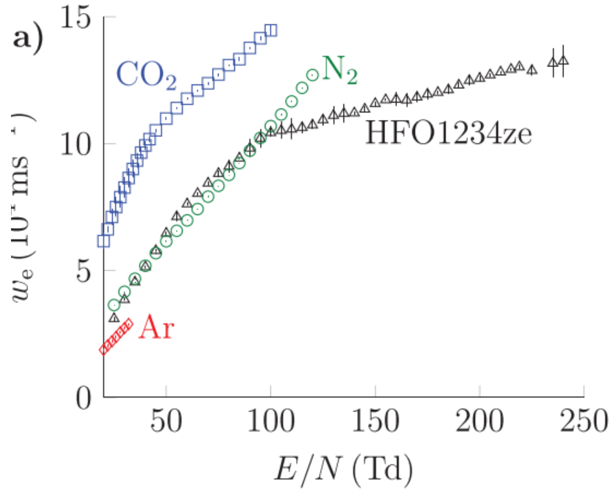


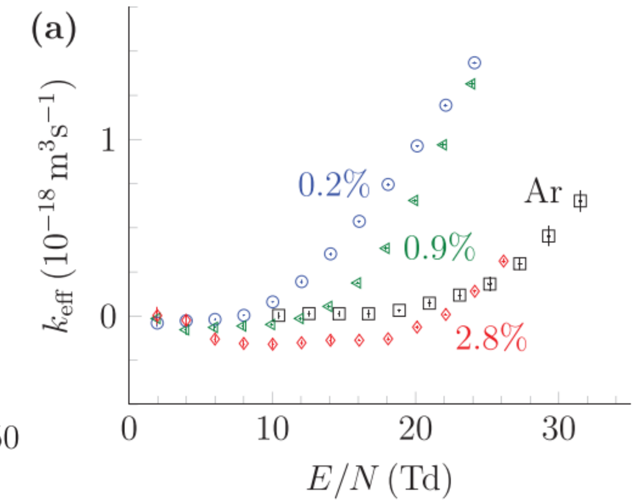


BUT

- Readout from anode wires only ;
- No gas recirculation is applied ;
- HV applied to the cathode.







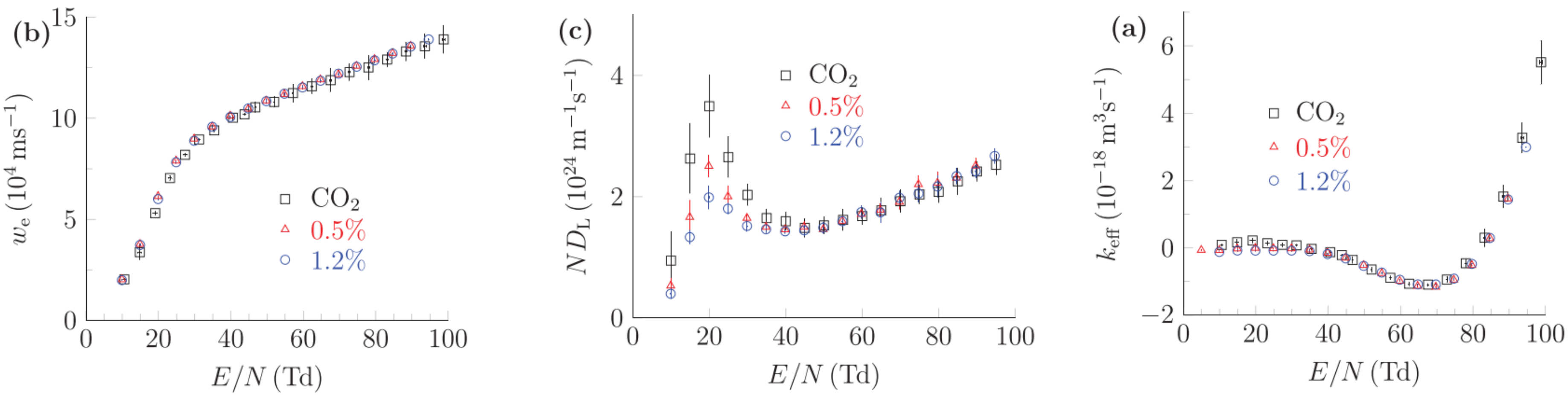


Figure 7. (a) Effective ionization rate coefficient, (b) electron drift velocity and (c) density normalized longitudinal electron diffusion coefficient in pure CO_2 and in mixtures of 0.5% and 1.2% HFO1234ze in CO_2 as a function of *E*/*N*.

IOP Publishing Plasma Sources Science and Technology
Plasma Sources Sci. Technol. **25** (2016) 045005 (12pp) doi:10.1088/0963-0252/25/4/045005

Electron swarm parameters of the hydrofluoroolefine HFO1234ze

A Chachereau, M Rabie and C M Franck

Power Systems and High Voltage Laboratories, ETH Zurich, Physikstr. 3, 8092 Zurich, Switzerland

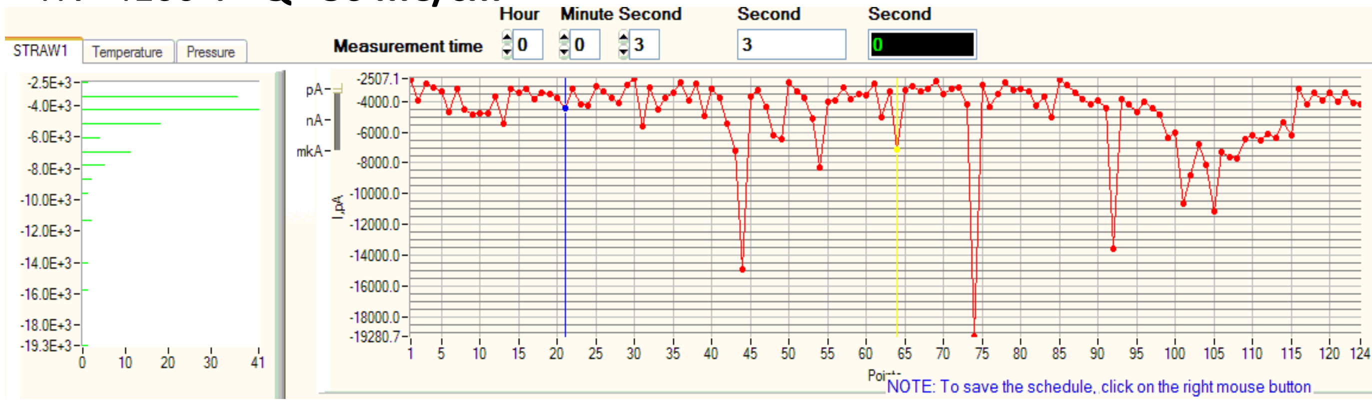
E-mail: alisec@ethz.ch

Malter effect checking tests,

that have been done after each irradiation run

Dark current

HV=4100 V **Q =56 mC/cm**



Test with ^{90}Sr