GEM discharge protection with a resistive copper oxide layer

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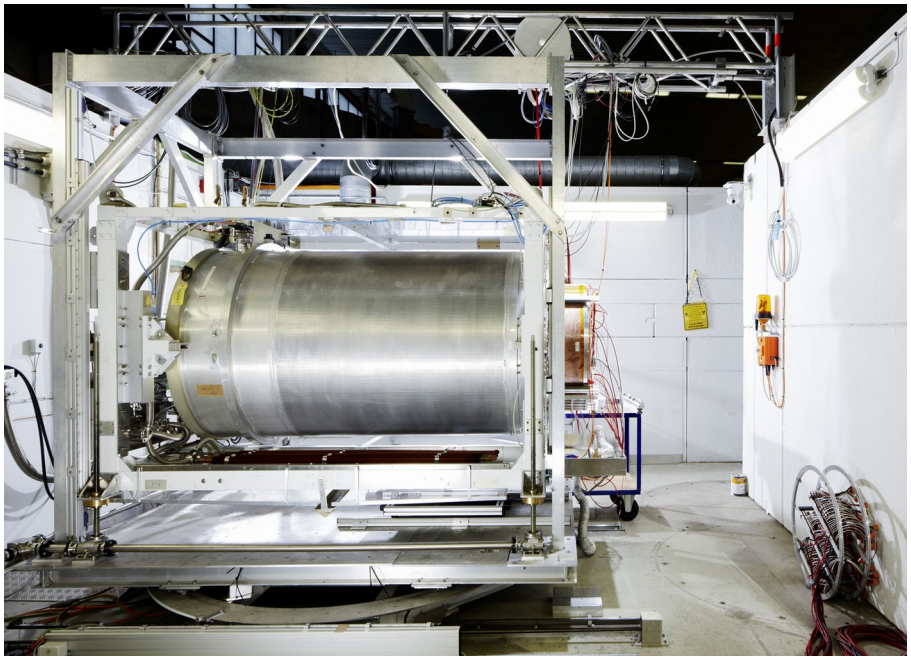
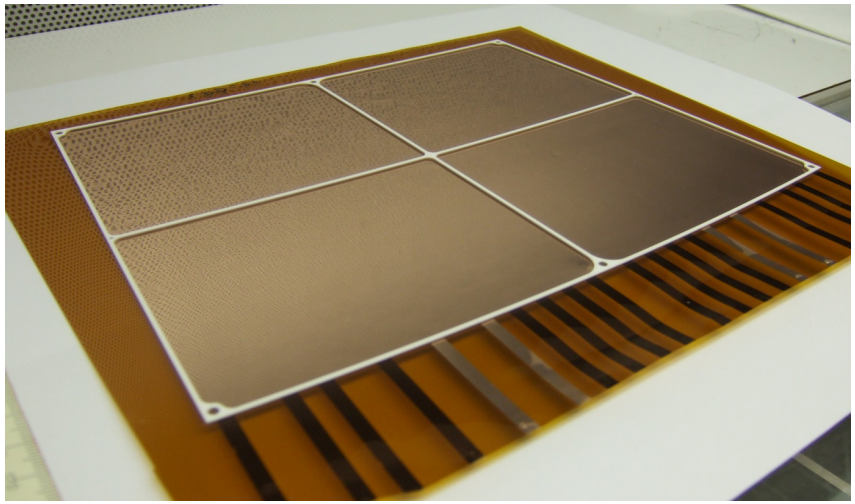
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DESY

Goal of the Study

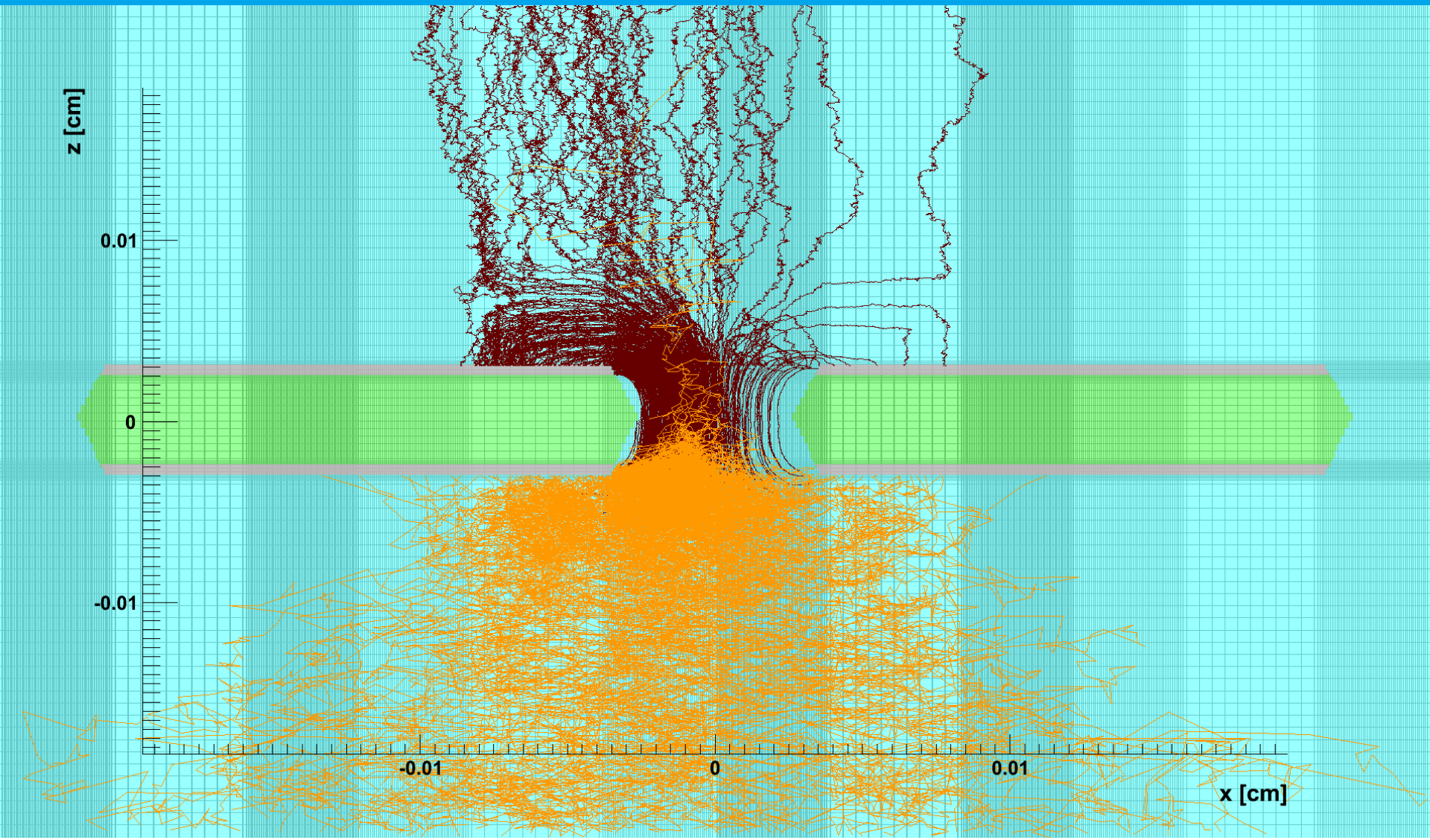


- Have built and operated TPC with triple GEM readout
- Test beam in March 2013 and later in Fall 2013 showed a problem with the high voltage long-term stability
- After several weeks of stable operation
  - Several observed discharges
  - 1 destructive discharges with extreme conditions
  - 2 destructive discharges at the end of Test Beam

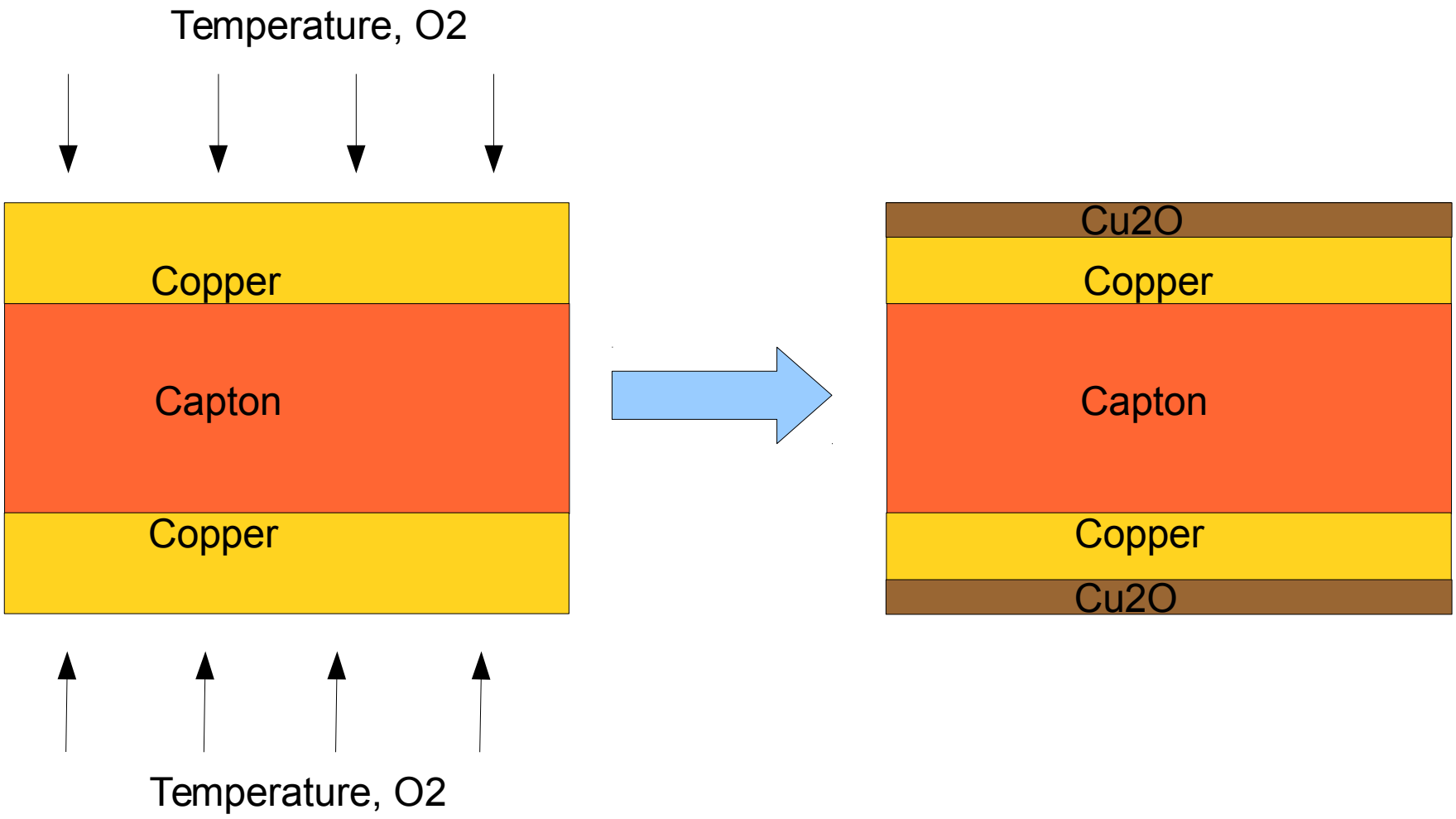


- **Goals of this study:**
  - Study the discharge process
  - Find the way to increase GEM resistance to destructive consequences of a discharge

Gas Electron Multipliers (GEM) simulations



Idea of growing oxide resistive layer



Copper oxides as resistive coating material

Effect of post-annealing on the properties of copper oxide thin films obtained from the oxidation of evaporated metallic copper

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T (°C)	t (μm)	AVT (%)	Band gap (eV)	Carrier type	Resistivity		Mobility ($cm^2 V^{-1} s^{-1}$)	Carrier concentration (cm^{-3})
					R_{sh} (Ω/□)	ρ (Ω–cm)		
RT	0.15	0.1	–	n	0.29	3.51×10^{-6}	18.30	9.72×10^{22}
100	0.15	5.1	2.70	n	1.82	2.73×10^{-5}	6.11	3.75×10^{22}
200	0.17	65.6	3.02	p	6.37×10^{6}	108	1.56	3.69×10^{16}
250	0.17	49.4	2.57	p	1.48×10^{7}	251	1.27	1.95×10^{16}
300	0.17	38.0	2.85	p	3.24×10^{7}	551	0.21	5.45×10^{16}
350	0.18	44.4	2.03	n	1.07×10^{7}	192	0.26	1.25×10^{17}
400	0.18	43.0	2.79	n	3.22×10^{6}	58	0.22	4.98×10^{17}
450	0.18	36.4	2.80	n	1.73×10^{6}	31	0.28	7.19×10^{17}

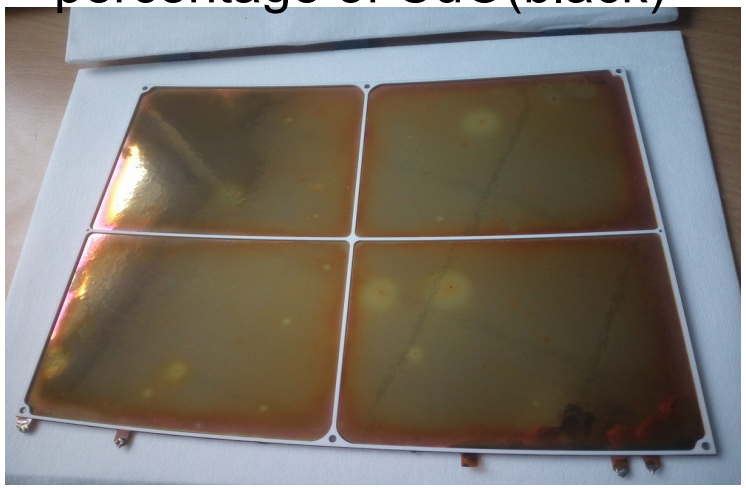
T—annealing temperature; t—film thickness; AVT—average visible transmittance; R_{sh}—sheet resistivity; ρ—electrical resistivity.

Stable chemical compounds

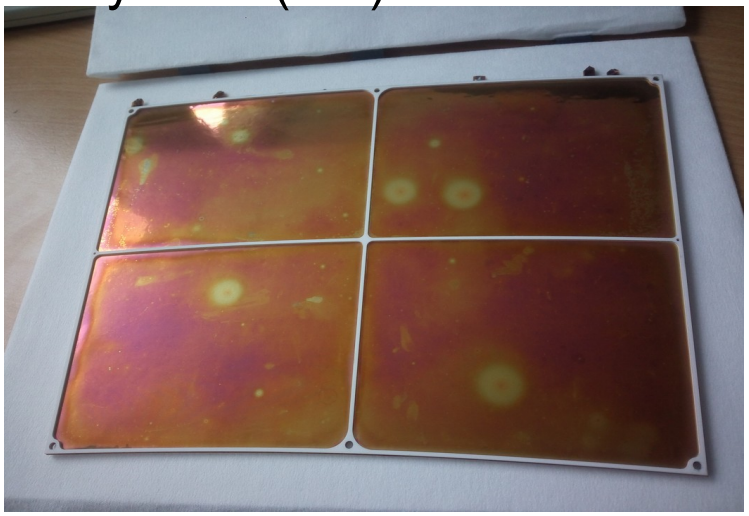
- Cu: ~10^{-1} Ohm/cm^2
- Cu2O: ~10^{7} Ohm/cm^2
- CuO: ~10^{6} Ohm/cm^2

First tries oxide layer (3 hours at 200C)

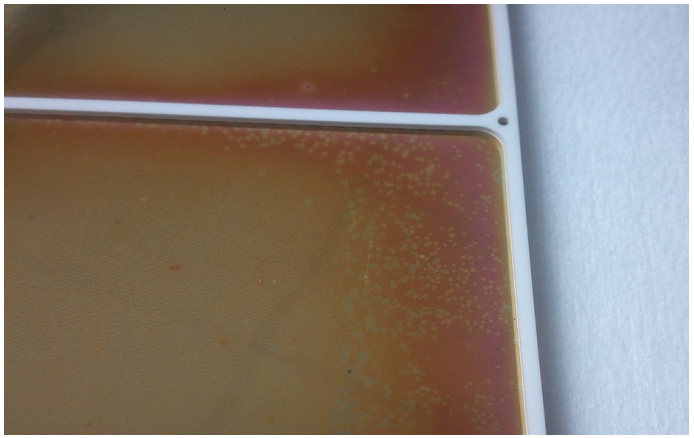
- Presumably covered with bigger percentage of CuO(black)

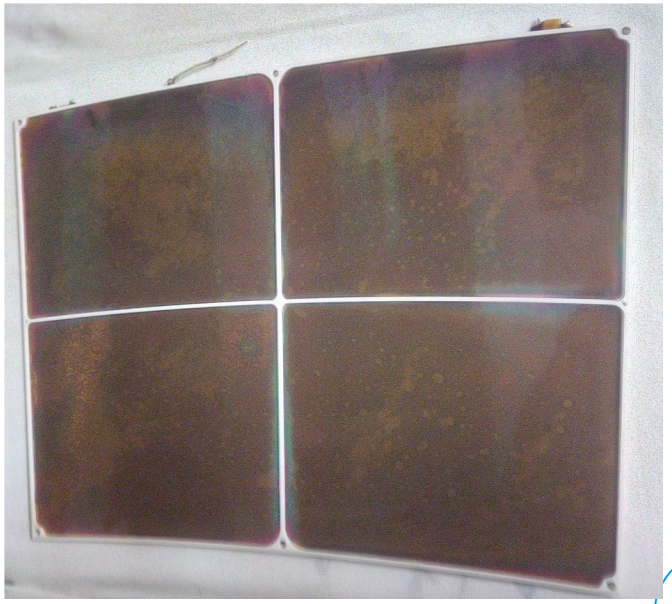


- Presumably covered mostly by Cu_2O(red)

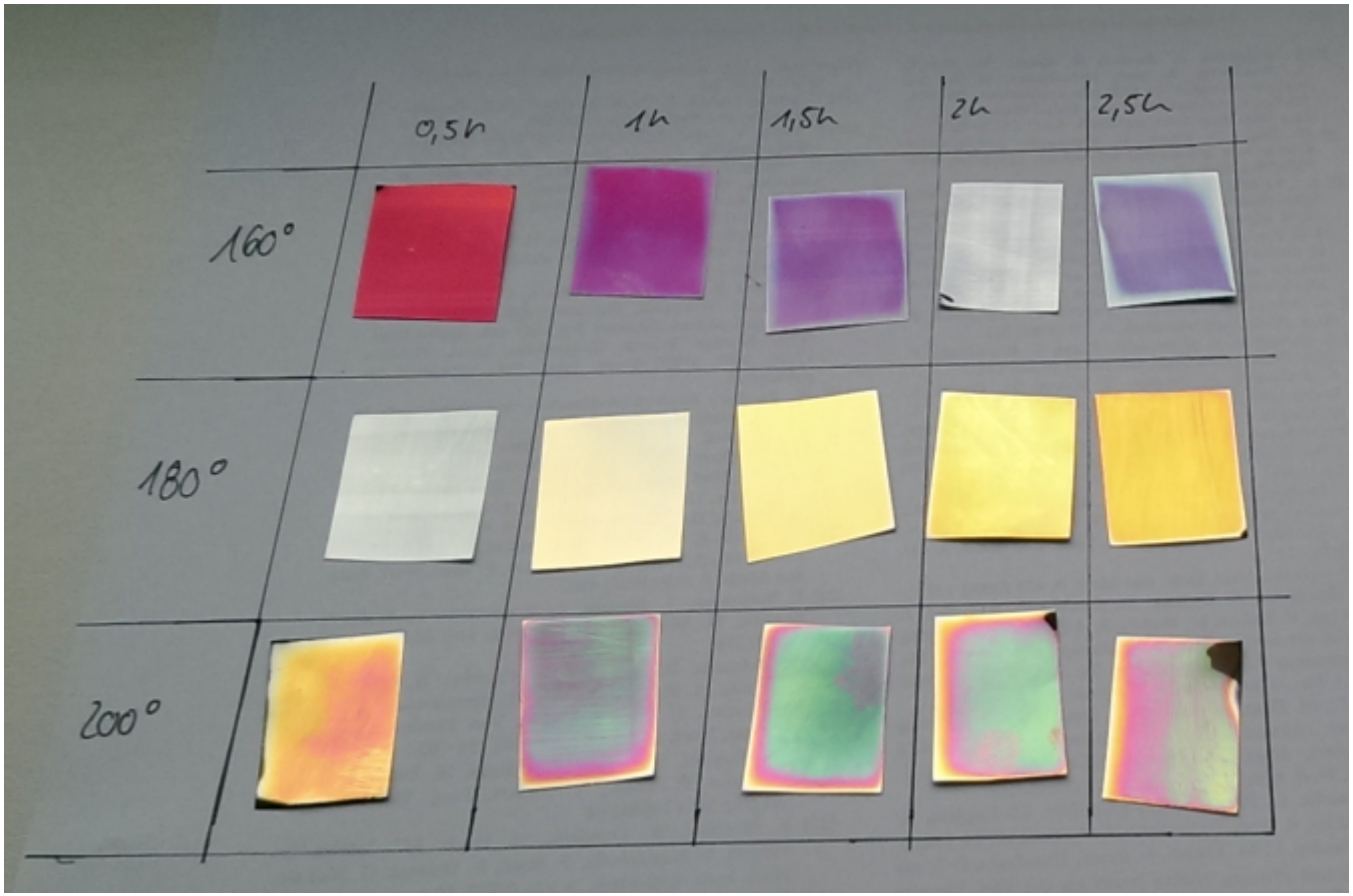


- Presumably trace of previous sparks





Various oxidization tests



Survival statistic for GEMs

Usual GEMs

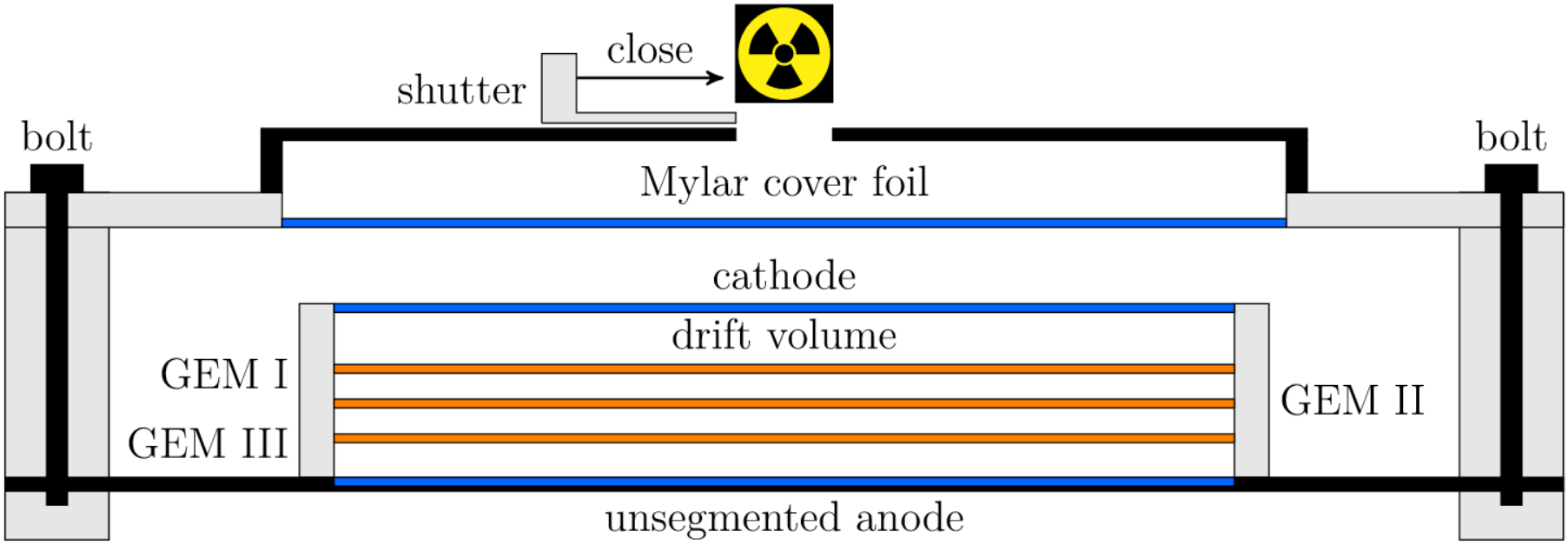
Sectors	Discharges before sector death
4	430
4	340
4	150
3	1100
3	5570
3	400
3	80
3	930
3	270
3	1430
2	2440
2	5390
2	130

Oxidized GEMs

Sectors	Discharges before test was stopped
4	26700
3	~10000

DESY

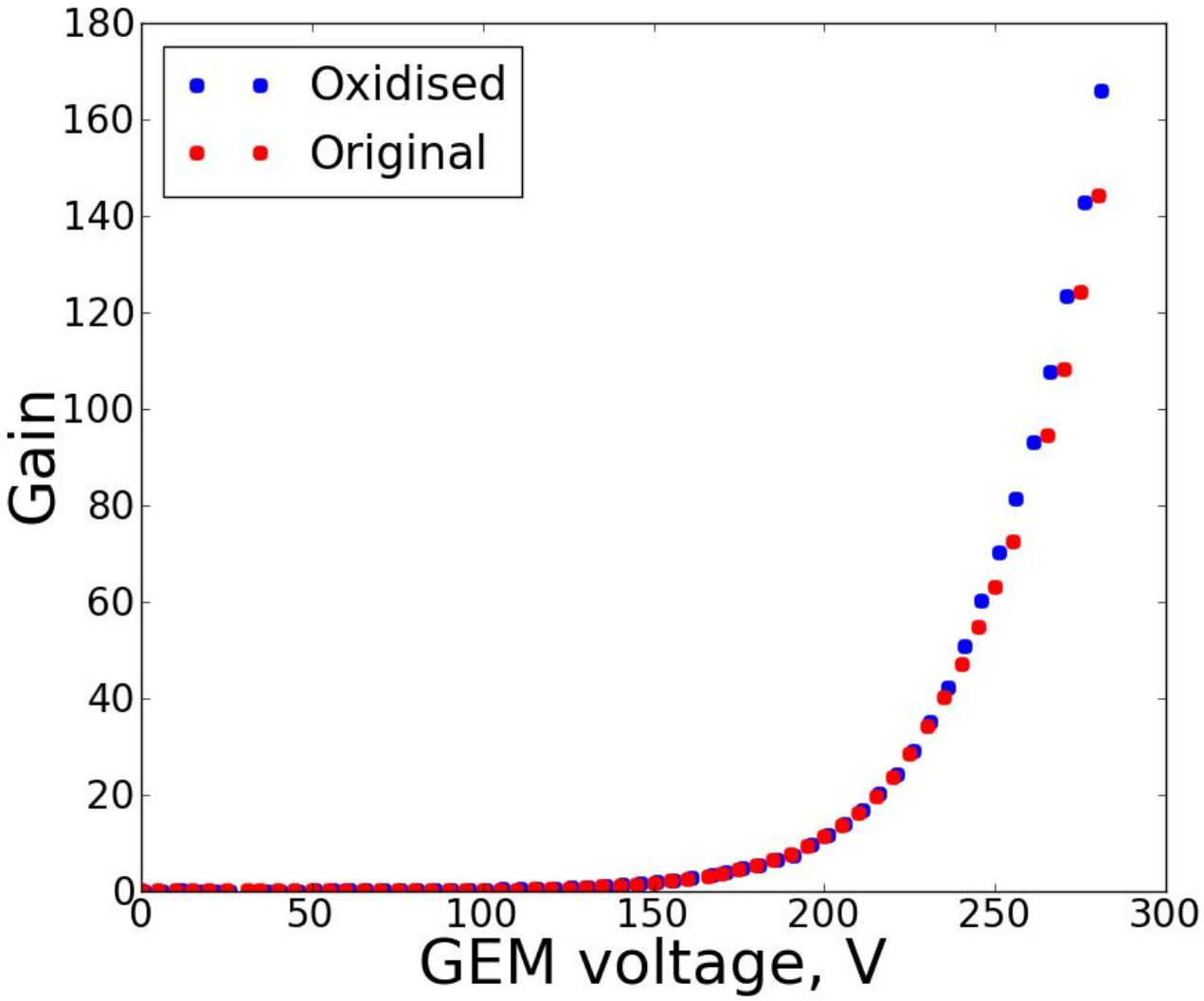
Gain test setup



We measured Gain using this formula, averaging 100 measurements every 50 ms, rising the voltage on third GEM from 0 to 280.

$$G_{\mathrm{GEM\,III}}(U_{\mathrm{GEM}}) = \frac{I_{\mathrm{anode}} + I_{\mathrm{GEM\,III,\,anode}}}{I^{0}_{\mathrm{GEM\,III,\,cathode}}}.$$

Gain measurement results for 10x10cm GEM



- Gain for oxidized GEMs and original one is conserved.

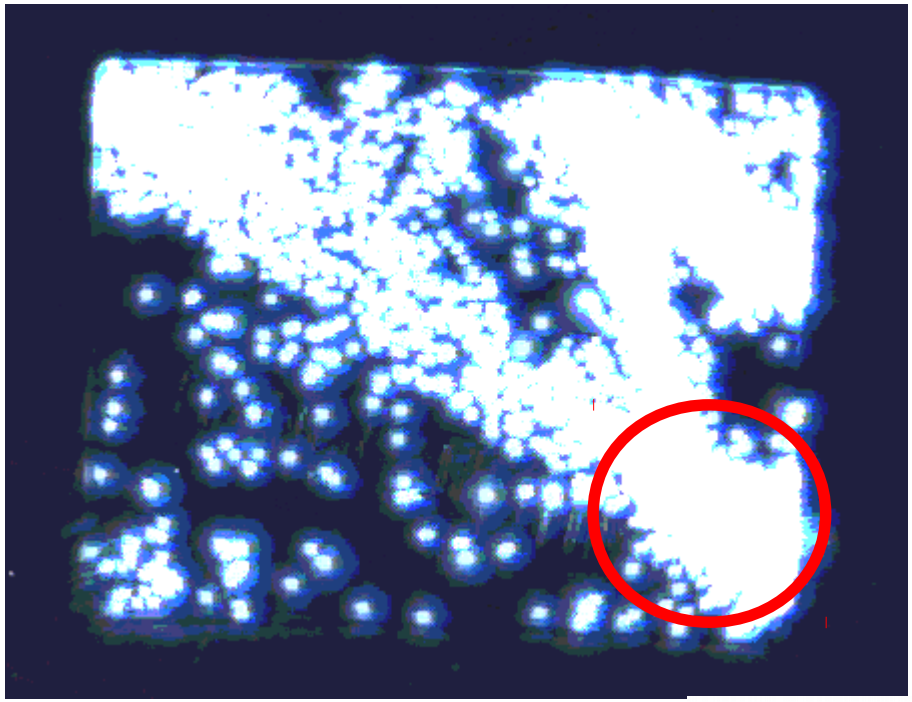
Summary

- Oxide layer can serve as protective coating for GEMs.
- It's easy to grow
- Gain after oxidation is conserved

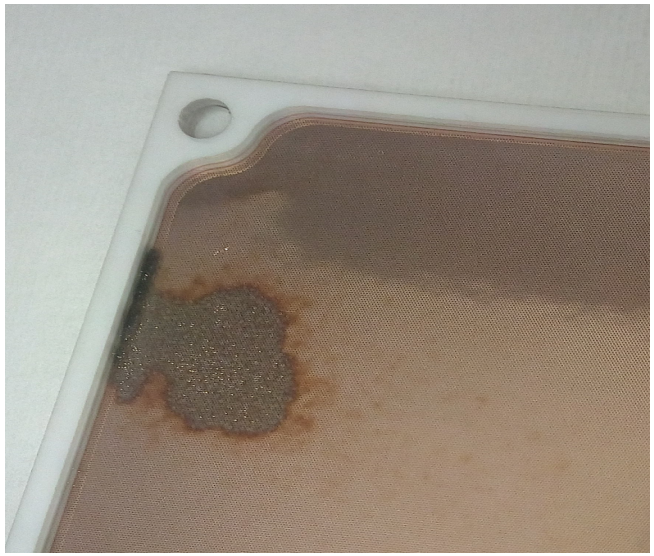
To be done:

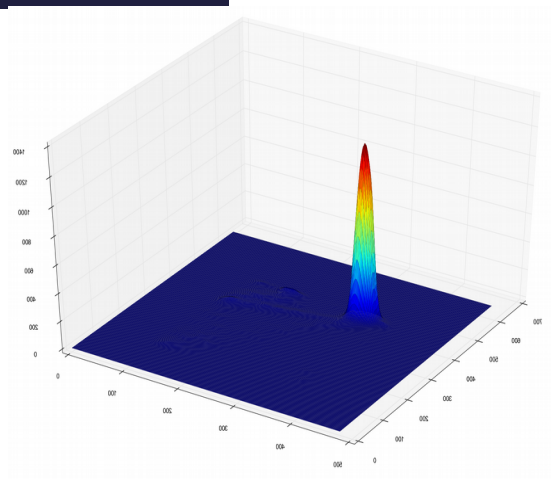
- Establishing the procedure: quantitative evaluation. Resistance.
- Build and test full 3 GEM stack

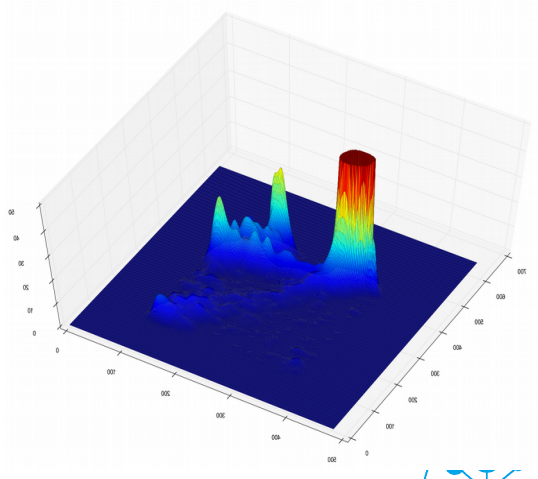
Observations of ultimate high number of discharges



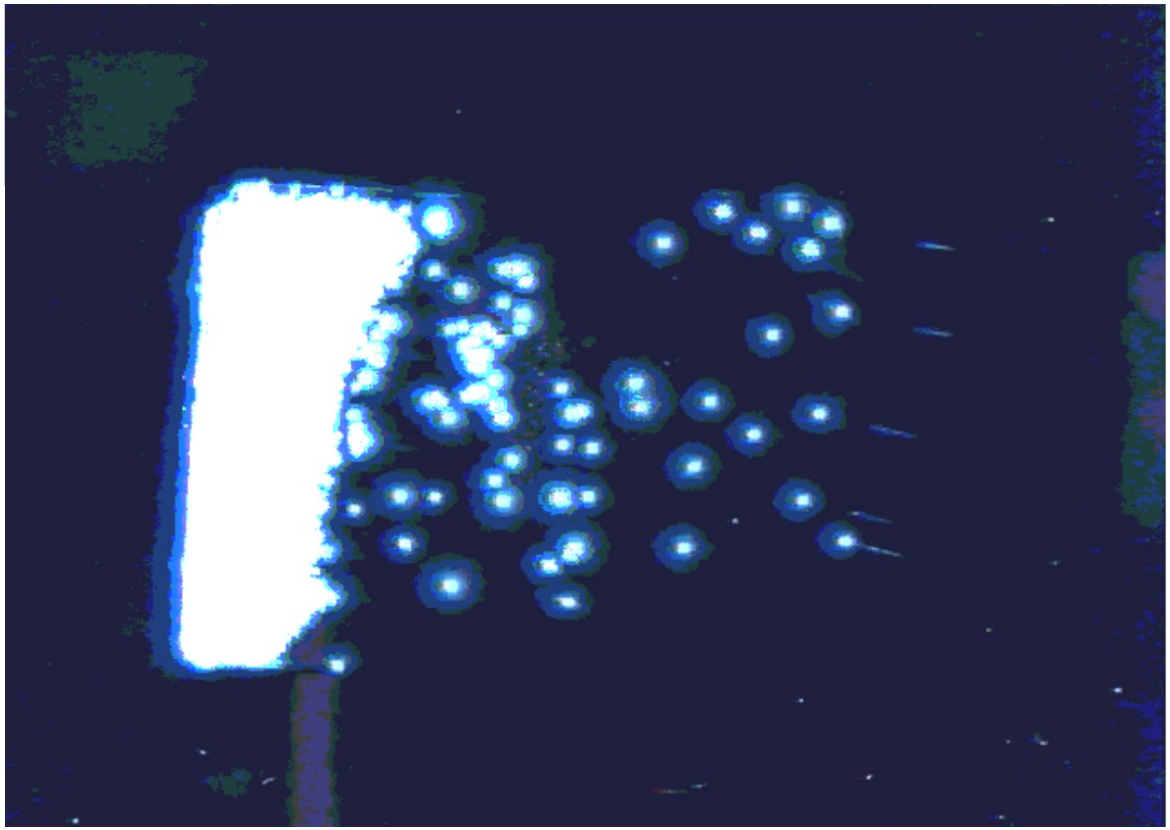
- operated double framed GEM under extreme conditions with protective circuit
- recorded about 30,000 discharges
- towards the end deterioration of performance, constant current
- physical damage to the GEM observed, details are under study







Repetition of the test (about 150,000 discharges)



- About 150,000 discharges.