Investigations of the long-term stability of a GEM-TPC

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2016, Hamburg

HELMHOLTZ | ASSOCIATION

LC TPC

Universität Hamburg
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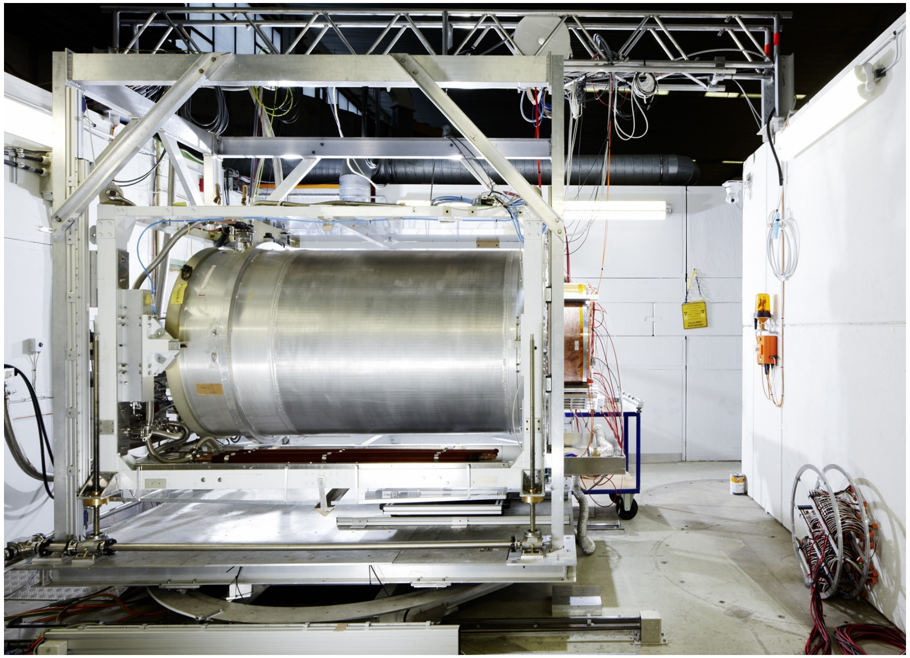
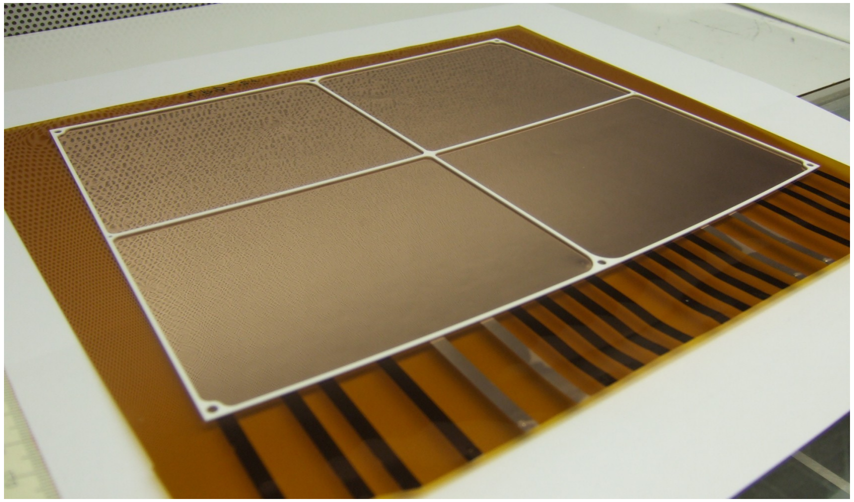
DESY

Goal of the Study

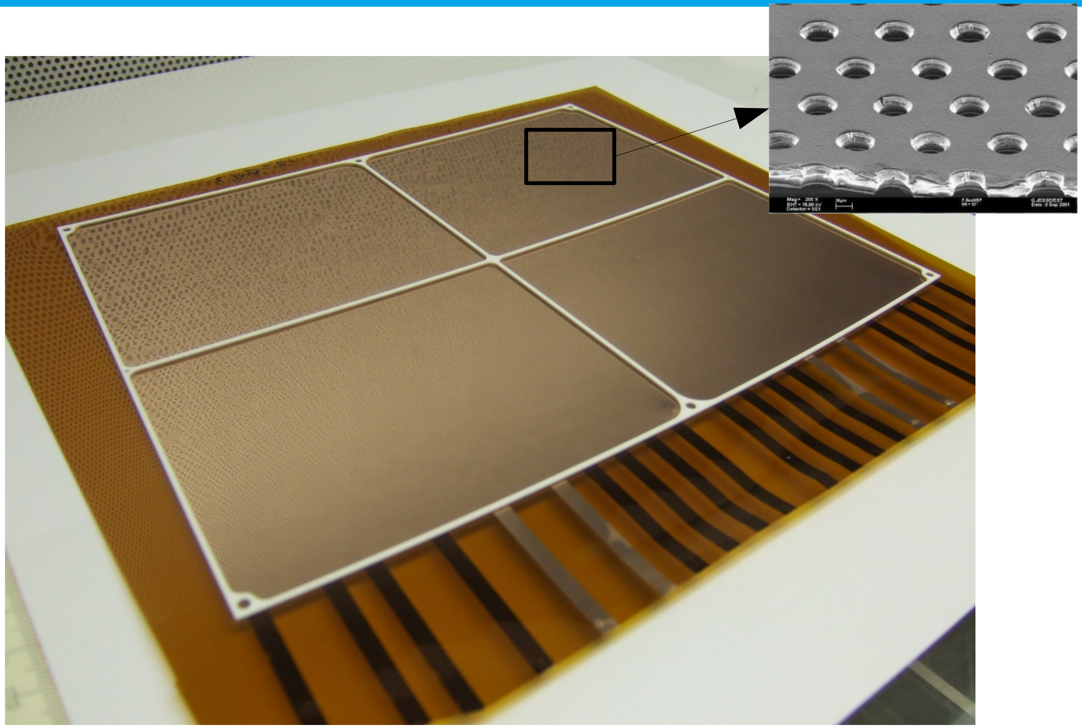




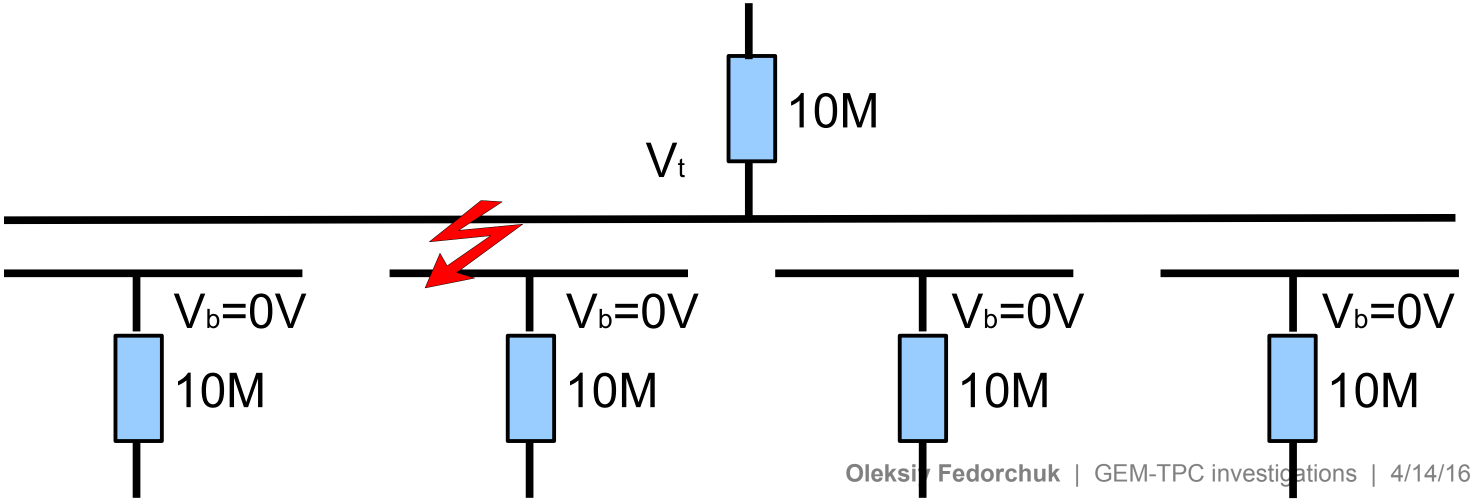
- Have built and operated TPC with triple GEM readout
- Test beam in March 2013 and later in Fall 2013 showed a problem with the high voltage long-term stability
- After several weeks of stable operation
  - Several observed discharges
  - 2 destructive discharges at the end of Test Beam
  - 1 destructive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

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

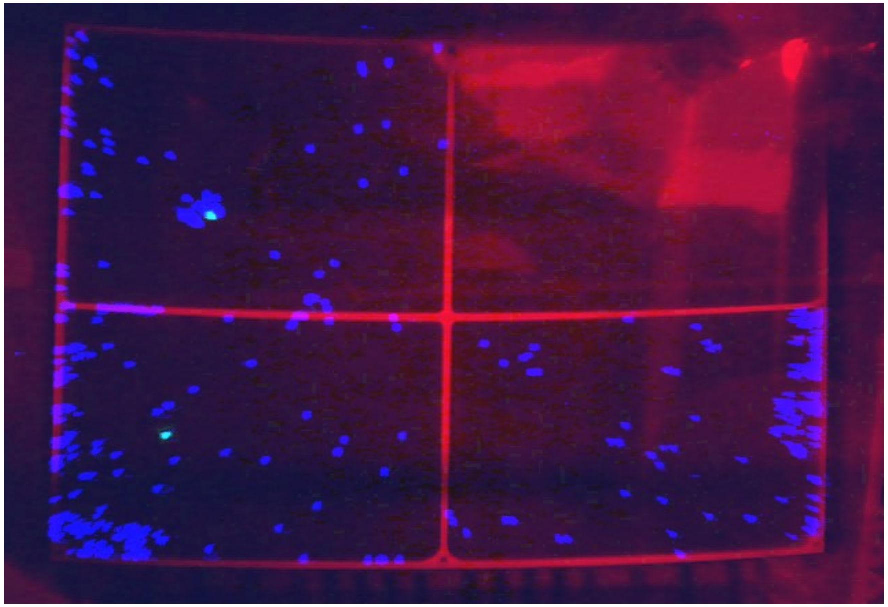
GEM structure and connection

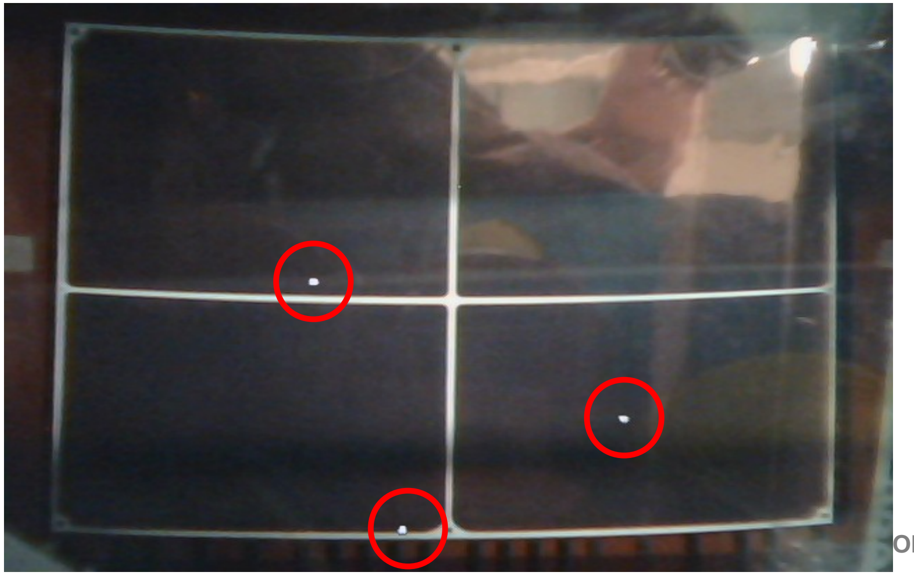


- previous experience with smaller (10x10) GEMs showed no problem
- study in detail the larger modules
- note: all measurements are based on small statistics of destroyed GEMs, drawing conclusions is difficult

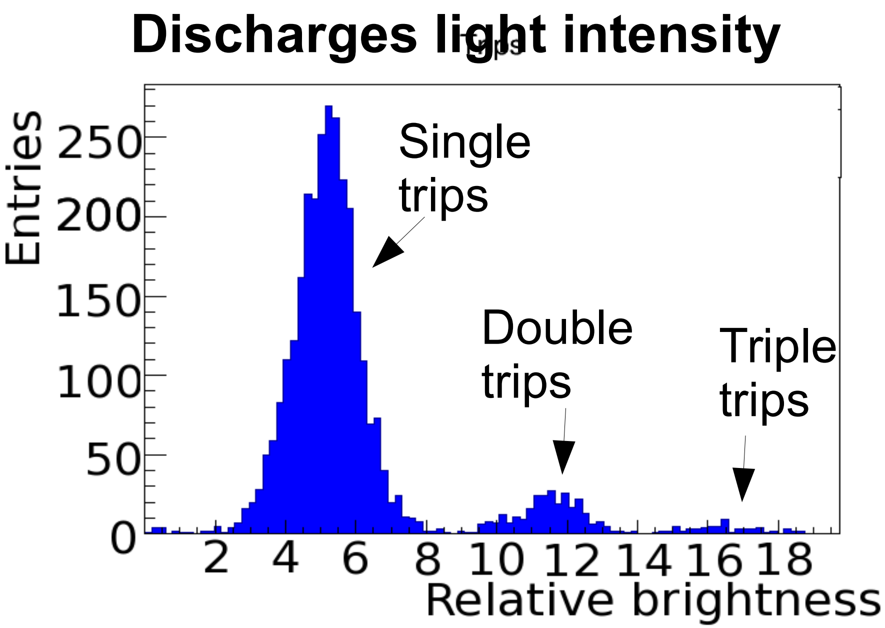


Experimental setup (EXTRAME CONDITIONS USED)



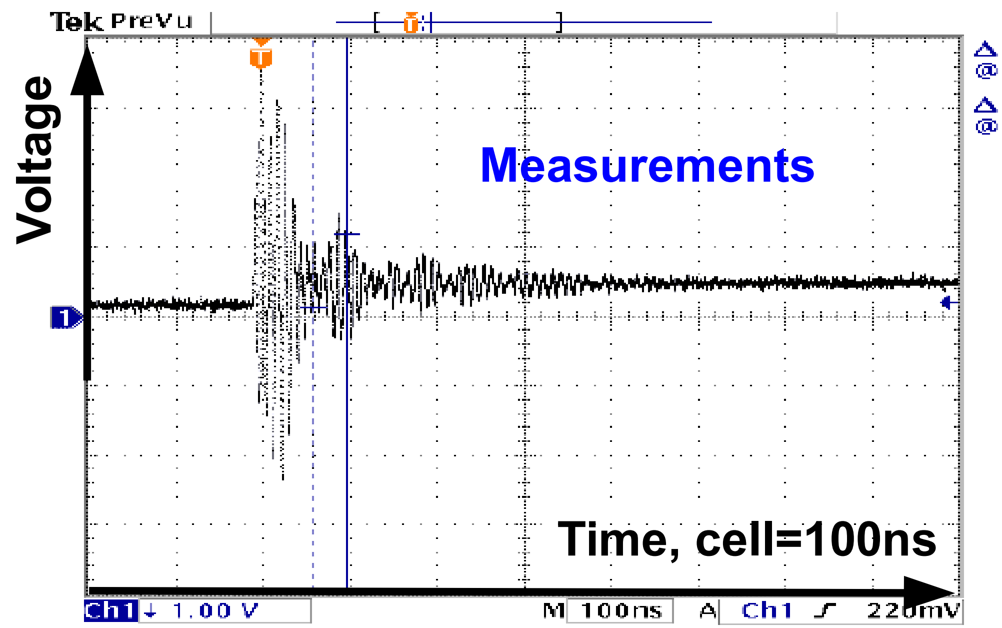


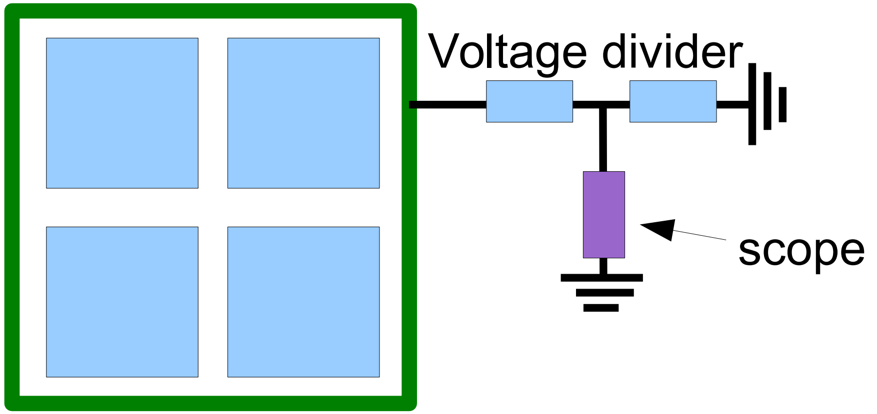
- We built a system to observe the light produced by discharges
- Light integrated over couple of thousands discharges
- U=650V instead of 250V or 360V

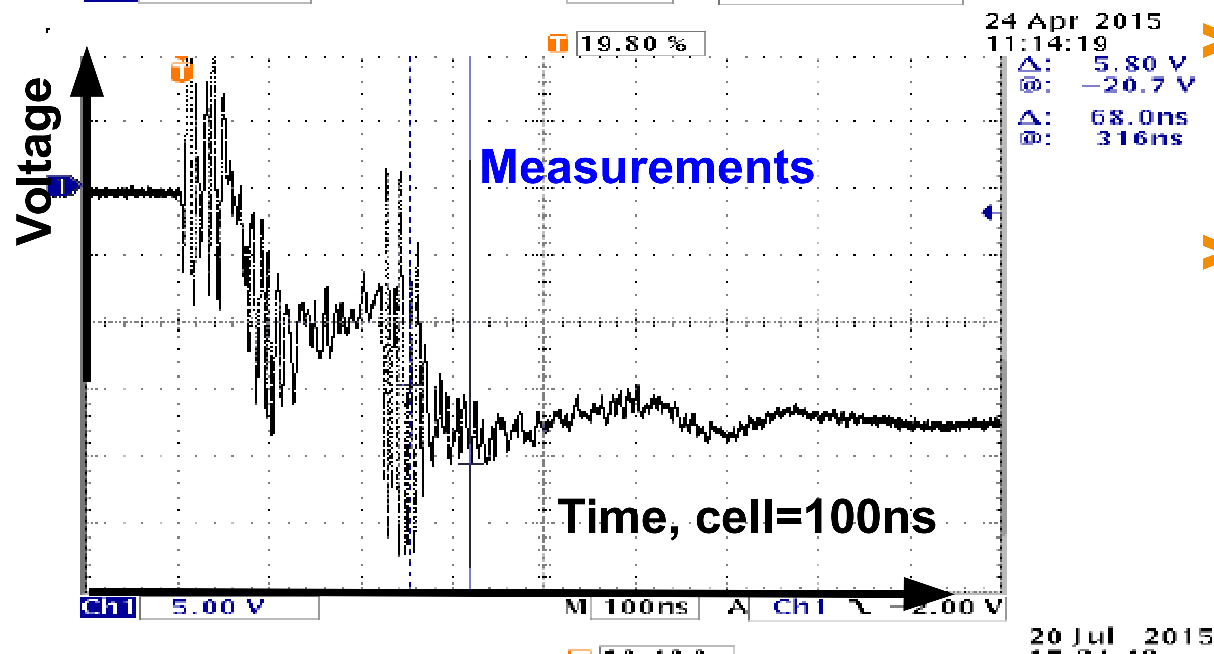


- **observe multiple discharges: They happen in different sectors (within one time frame of 33ms)**

Oscilloscope measurements





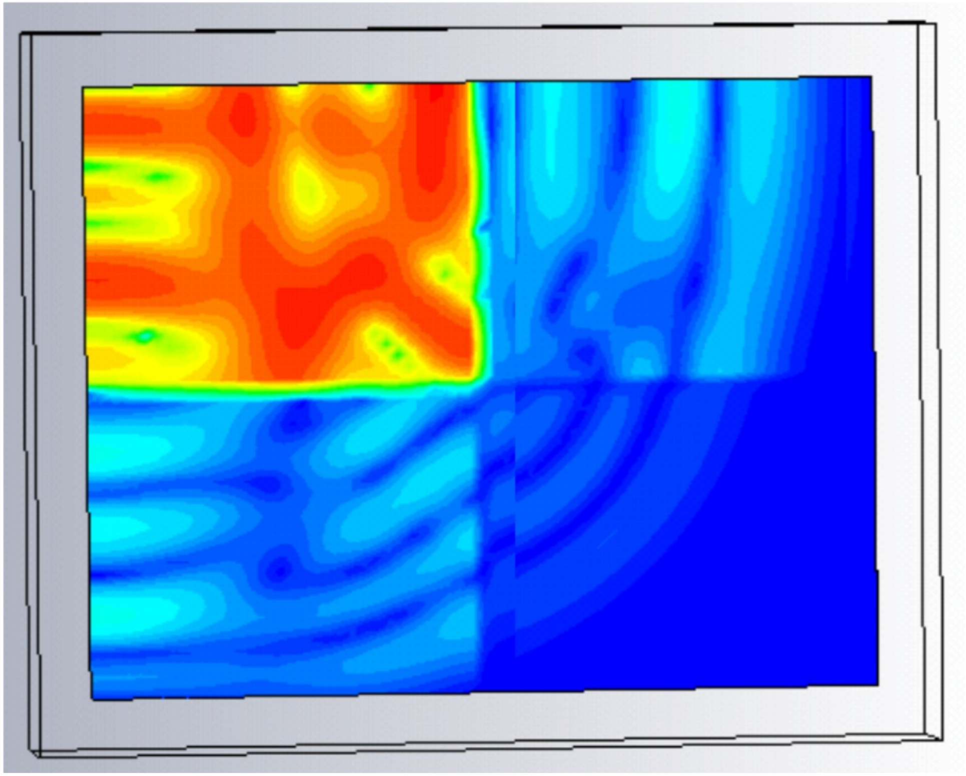


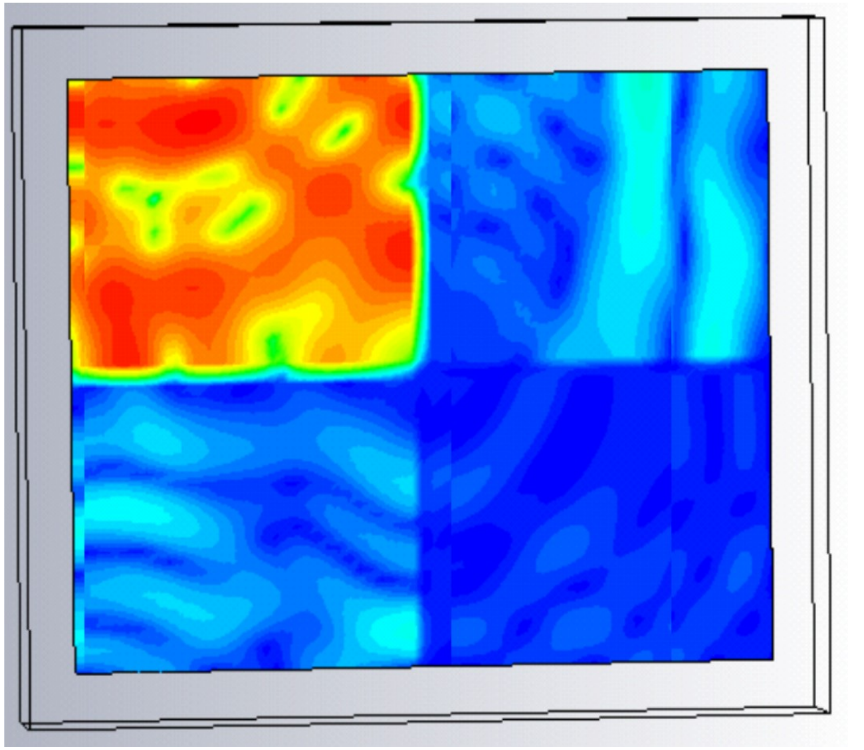
- we observe oscillations of the potential after a spark
- we observe a clear sequential behavior of multiple discharges
- we suspect that the oscillations enhance the probability for multiple discharges

DESY

Discharge simulations (http://desy.de/~fedorch/Oscil/)

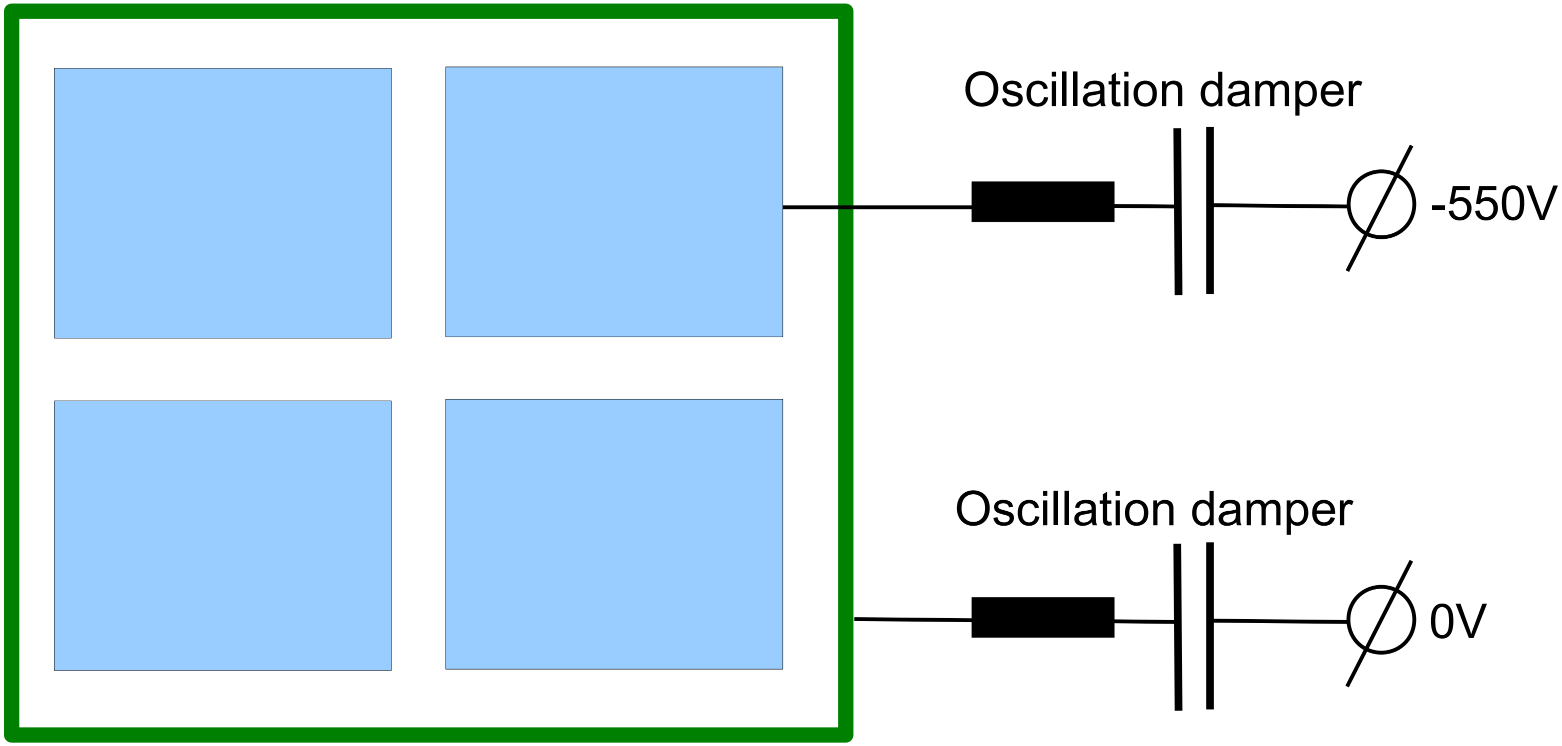
- Discharge causes current oscillations on GEM surface in different sectors (CST® simulations)





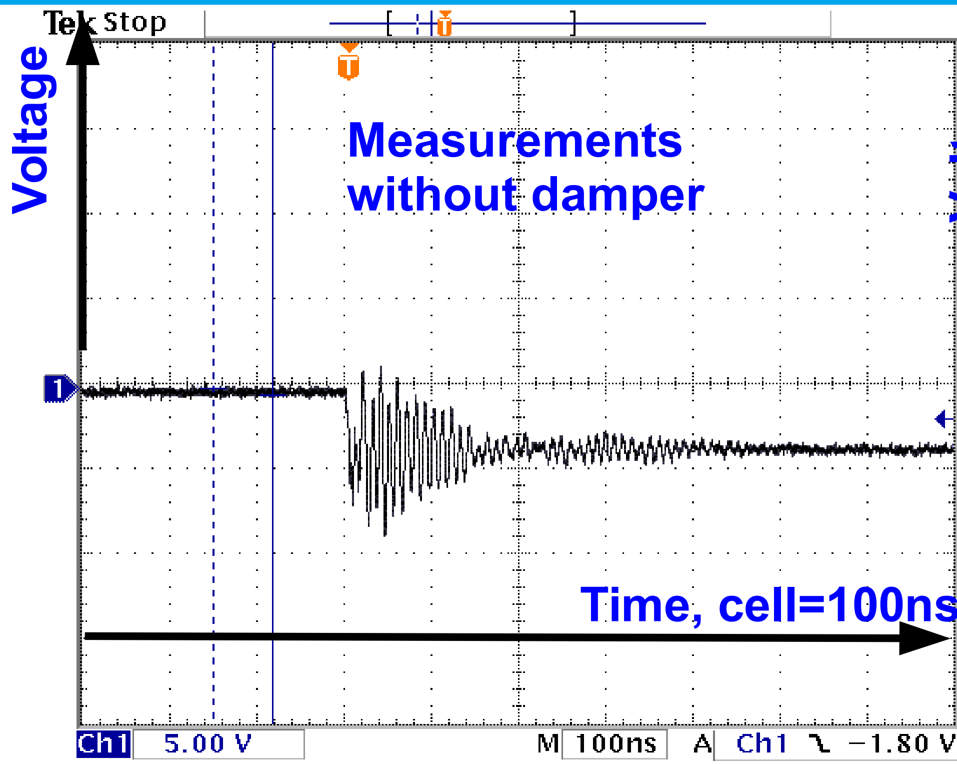
- **Voltage oscillations caused by electromagnetic wave reflected from borders.**

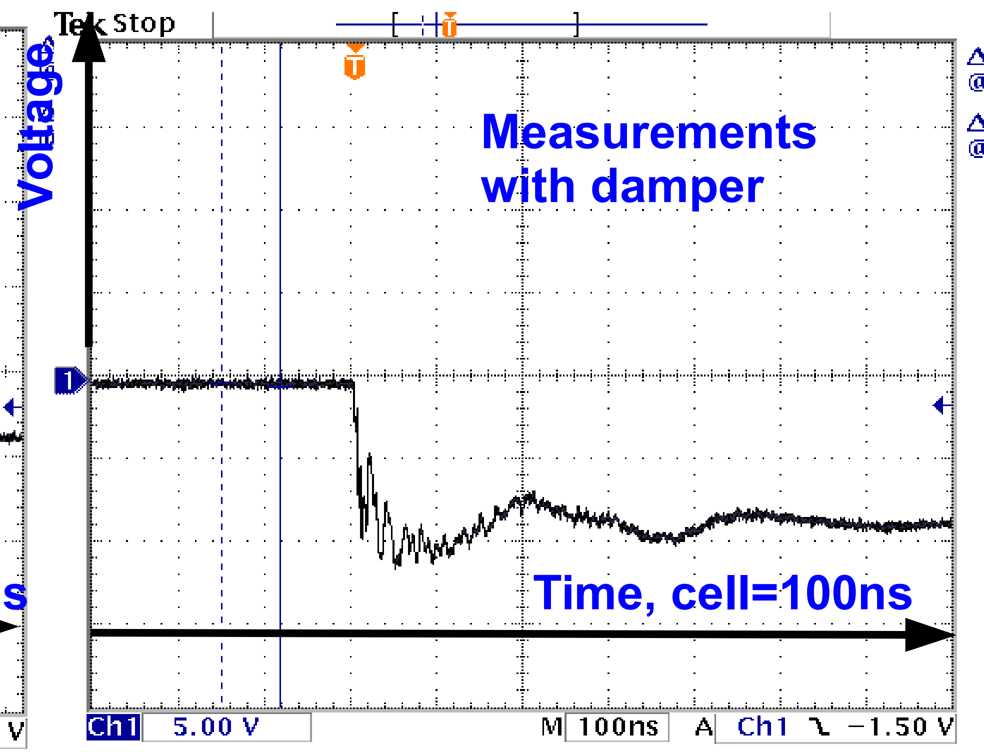
Oscillations damper



- Introduce a damping circuit to damp out the peaks of the oscillations
- Goal is to drain the oscillations from the module faster to avoid triggering discharges in other sectors

Filter implementation experimental effect (neighbor sector)





520V	Without RC (22hours)	With RC (47hours)	Without RC again (63hours)
Registered discharges	**166**	**75**	**75**
Multy discharges among	**13**	**0**	**5**

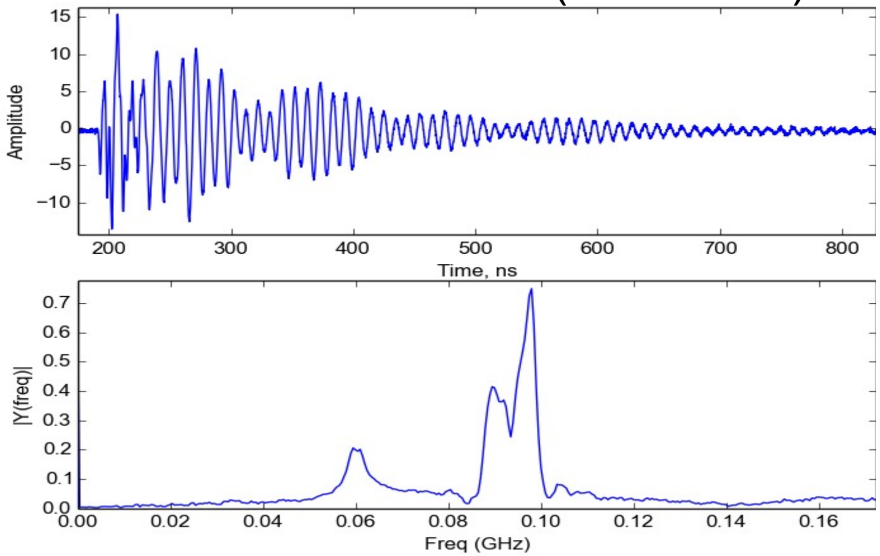
> **Filtering of oscillations helps to get rid of multiple discharges**

Intermediate conclusions

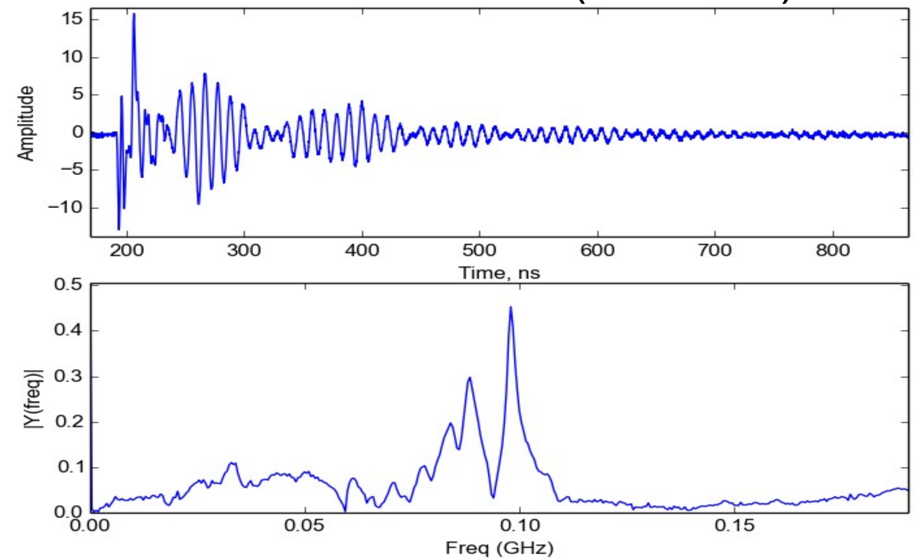
- We see multiple discharges (~100ns time difference).
- We see and simulate voltage oscillations directly after a discharge.
- The oscillations are triggered by a discharge in one GEM
- We see evidence that introducing a filter (damper) can significantly reduce the multiple discharge rate
- However:
  - we have never been able to connect destructive discharges with
  - multiple discharges. They are most likely not the cause of the destruction
  - However this does not prove that oscillations do not take a part in the destruction process.

Fourier transformation

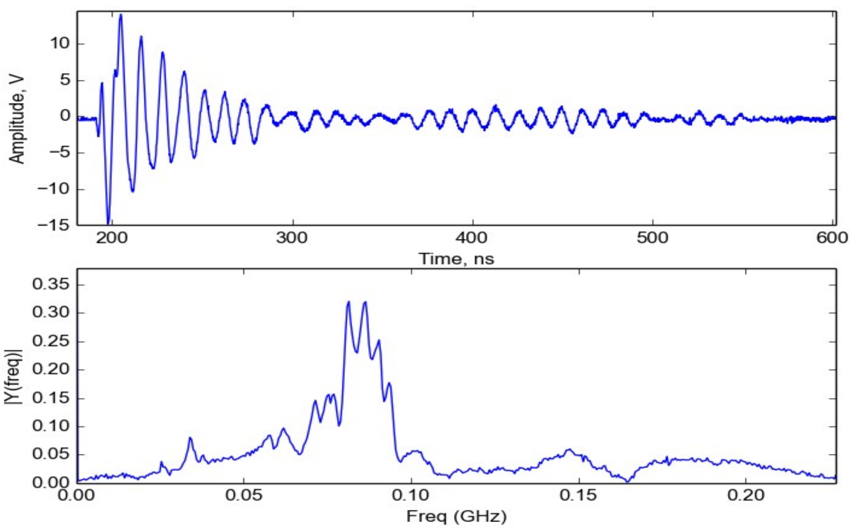
Common electrode (~22x18cm)



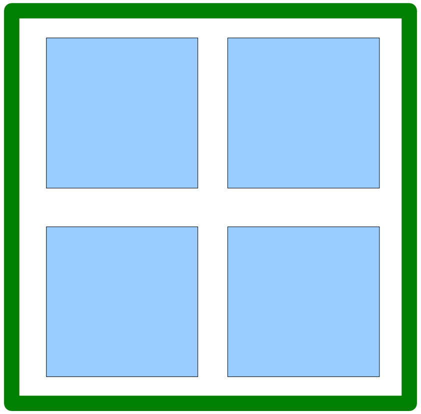
Sector electrode (~11x9cm)



10x10cm GEM

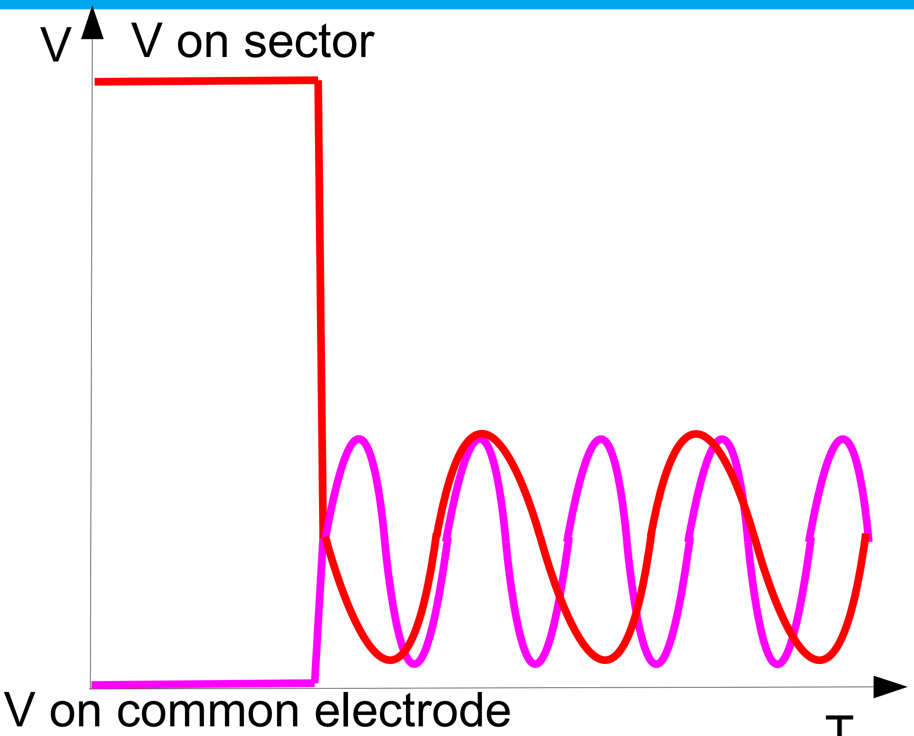


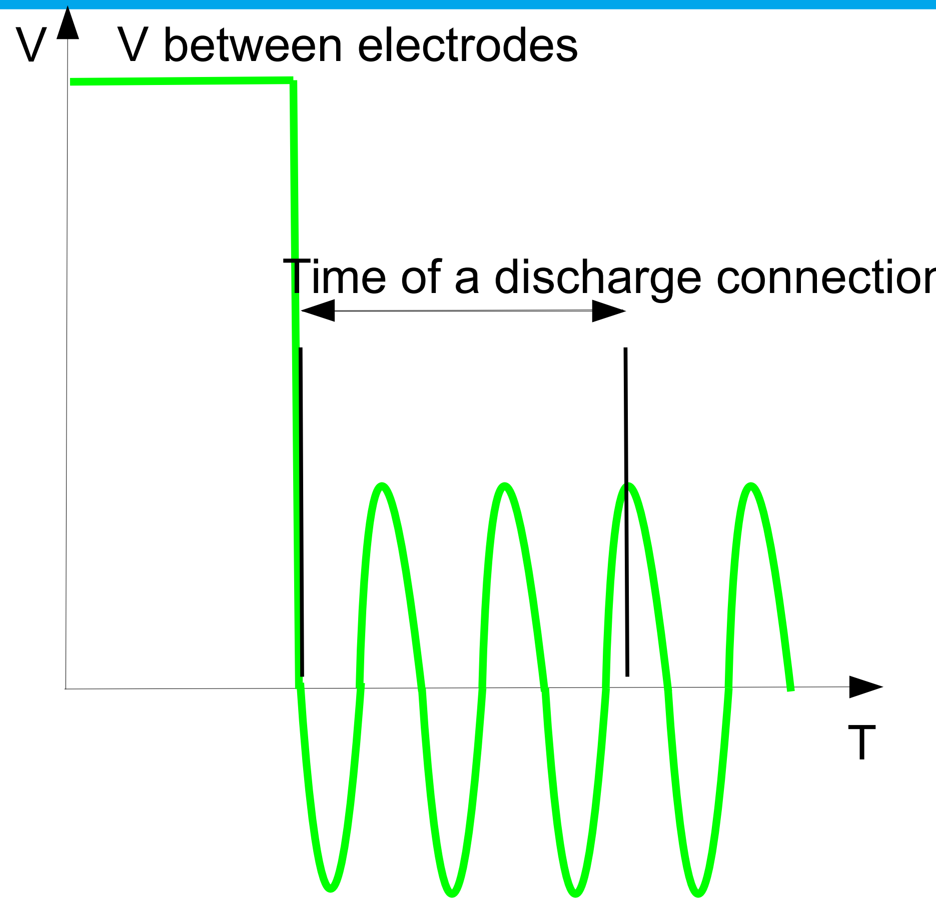
- TDS 3054b
- 500MHz bandwidth
- 5GS/s
- 50Ohm load
- 100x attenuatior
- Multiple modes for single sector
- Low frequency for common



- **Oscillation profile for common electrode and sector is not the same**

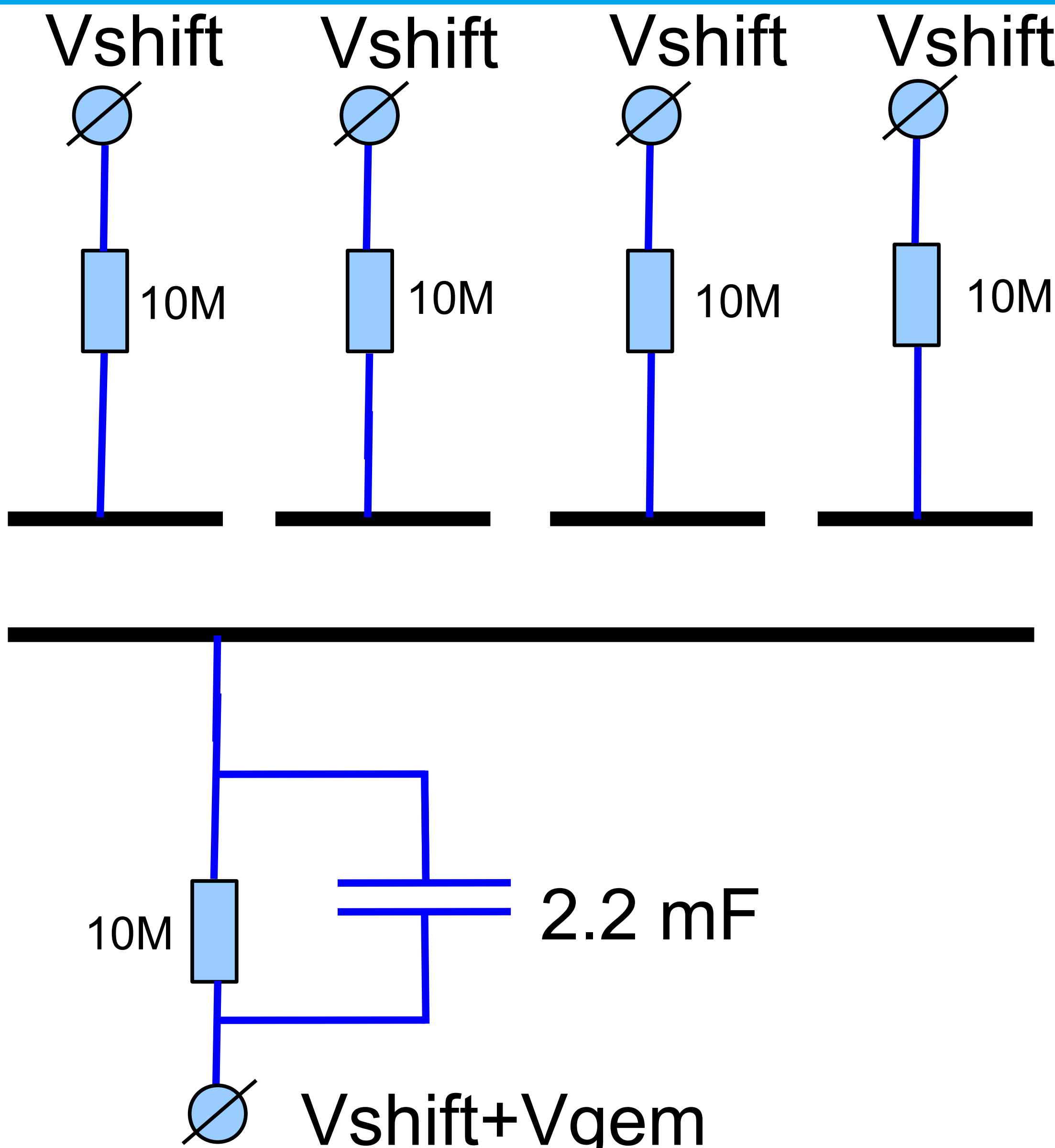
Idea of oscillation destruction influence





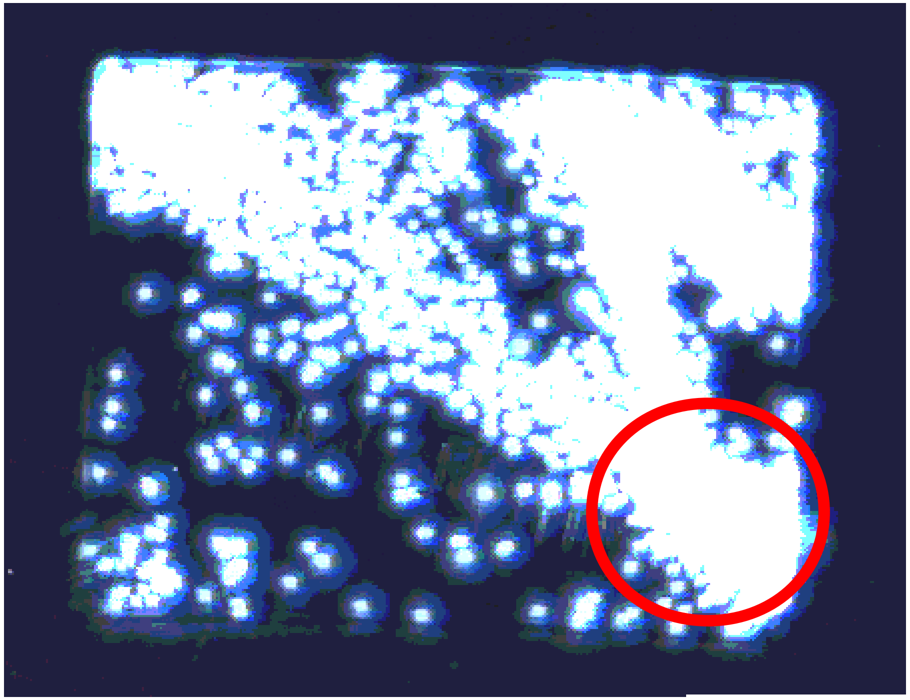
- If time of a discharge connection is higher than oscillation period (~10ns) then we have a current oscillations in discharge channel during a discharge.

Scheme of the setup

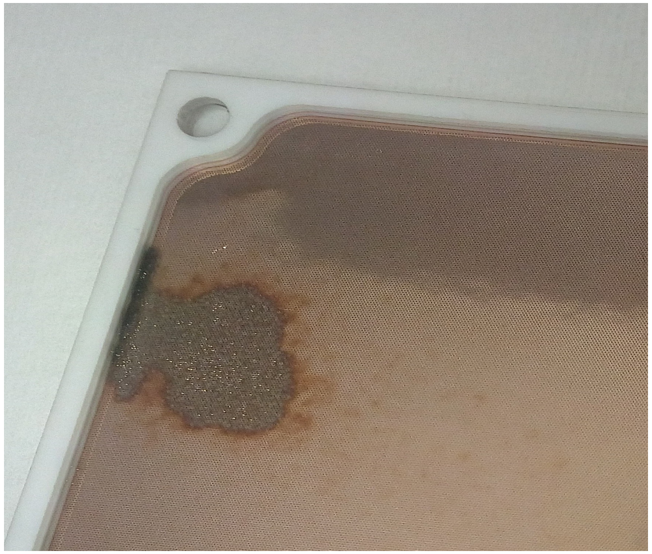


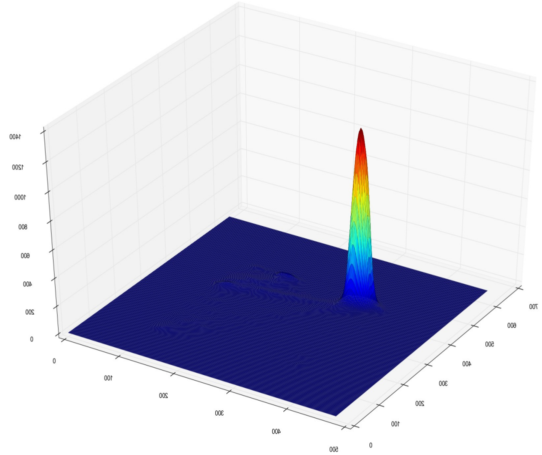
- This setup has been build after reconsidering results of lot and lot of previous measurements.
- We still try to connect oscillations and destructiveness.

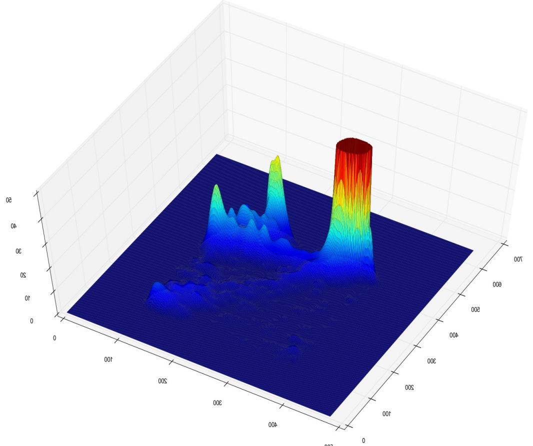
The tough guy!



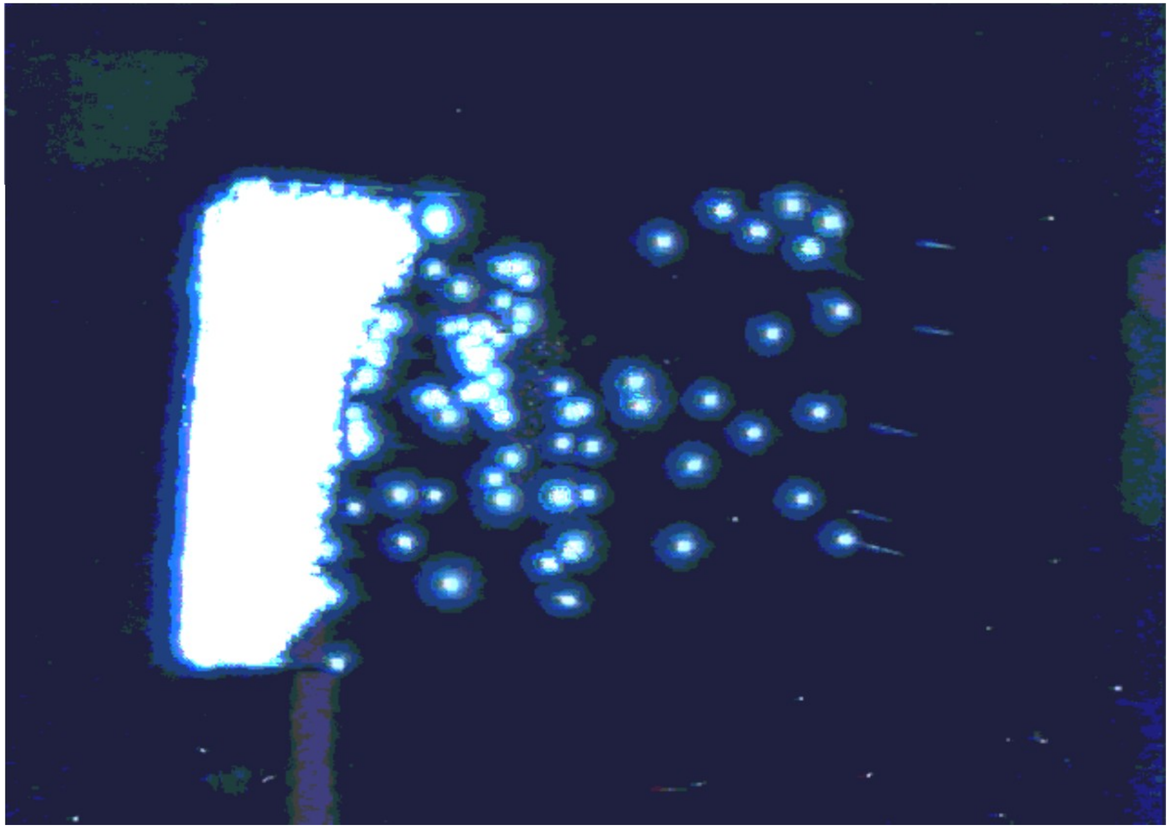
- operated double framed GEM under extreme conditions with protective circuit
- recorded about 30000 discharges
- towards the end deterioration of performance, constant current
- physical damage to the GEM observed, details are under study





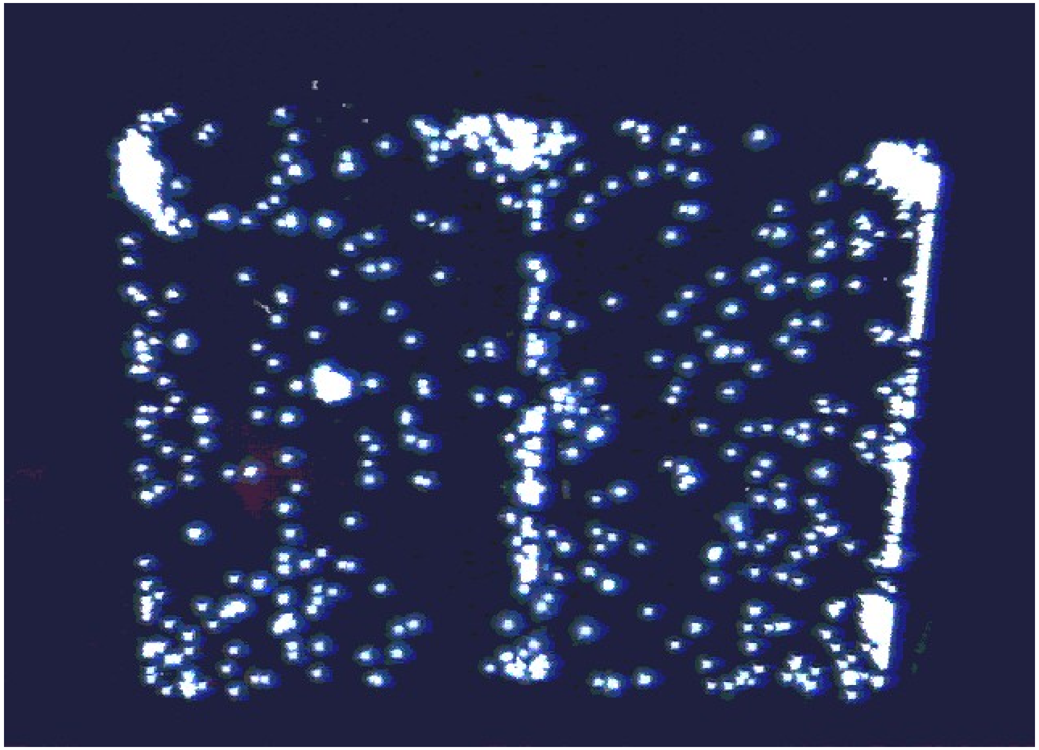


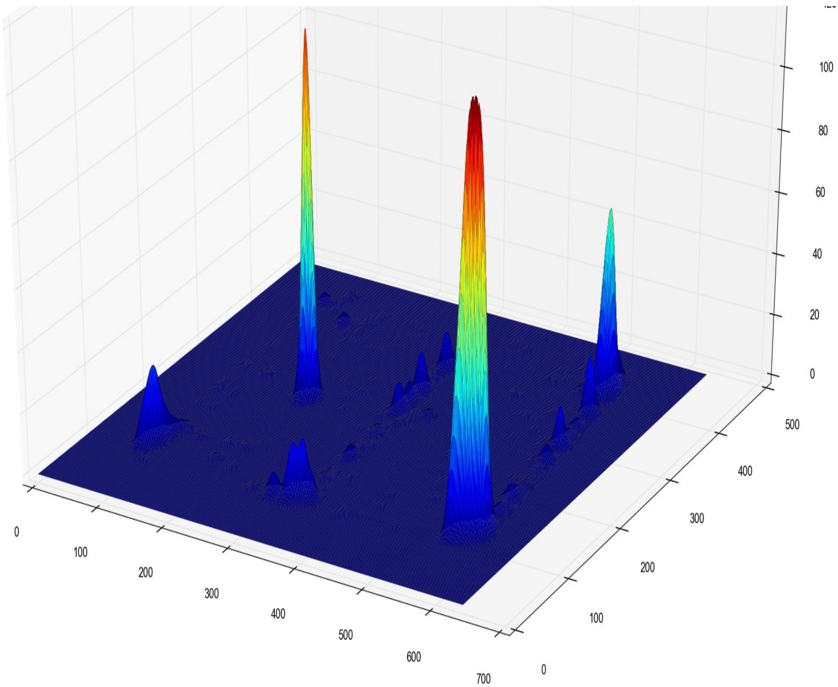
Repetition of the test (about 150,000 discharges)



- About 150,000 discharges.
- Stage of testing the protective circuit
- Sector died at the end

Results for 4 sector GEM

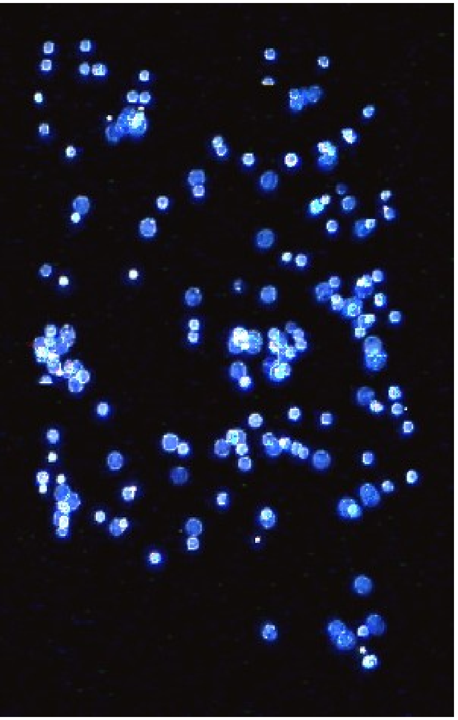




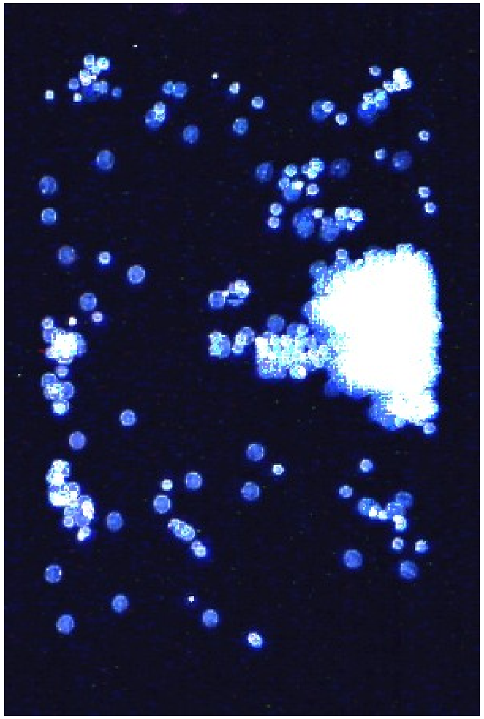
- have done a long term study with a full sector and with additional protective circuit
- have observed >10,000 discharges
- still no damage
- test continues to run

Results (http://desy.de/~fedorch/Trip_animation/)

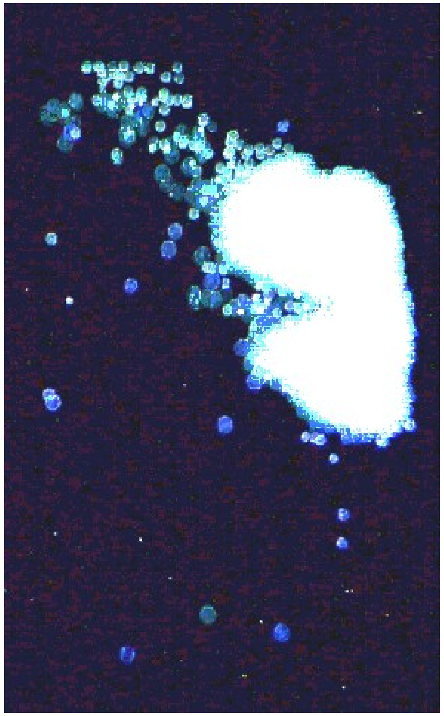
Vsh=0,2.2mF, 200E



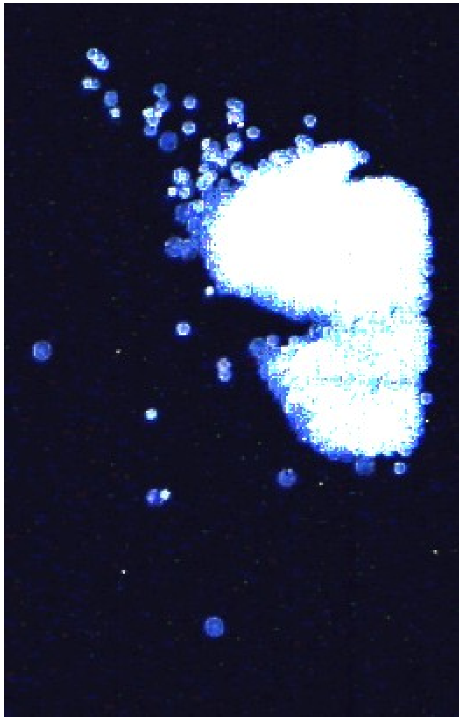
Vsh=1kV,2.2mF,40kE



Vsh=2kV,2.2mF,163kE



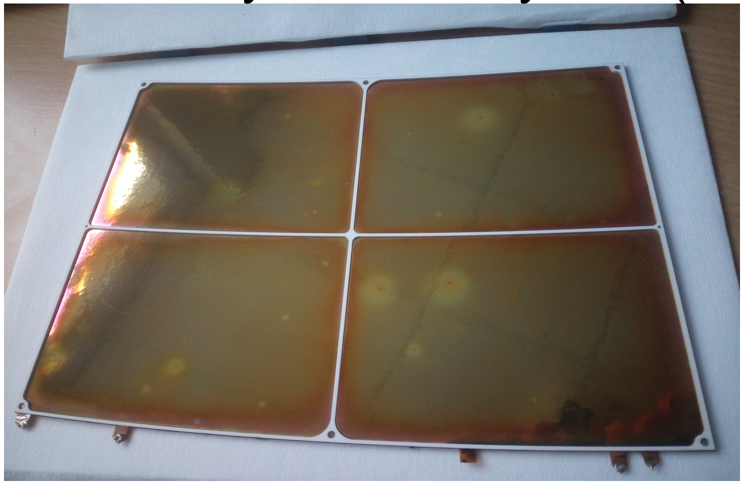
Vsh=2kV,0mF,40kE



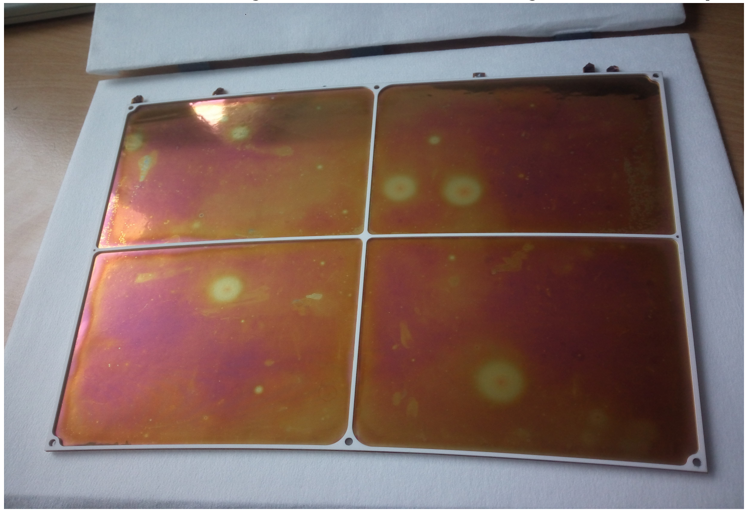
- **Why did the sector not burn without protection?**
  - Is just a luck? Very robust sector
  - Influence of the burned area?

We try to grow oxide layer (3 hours at 200C)

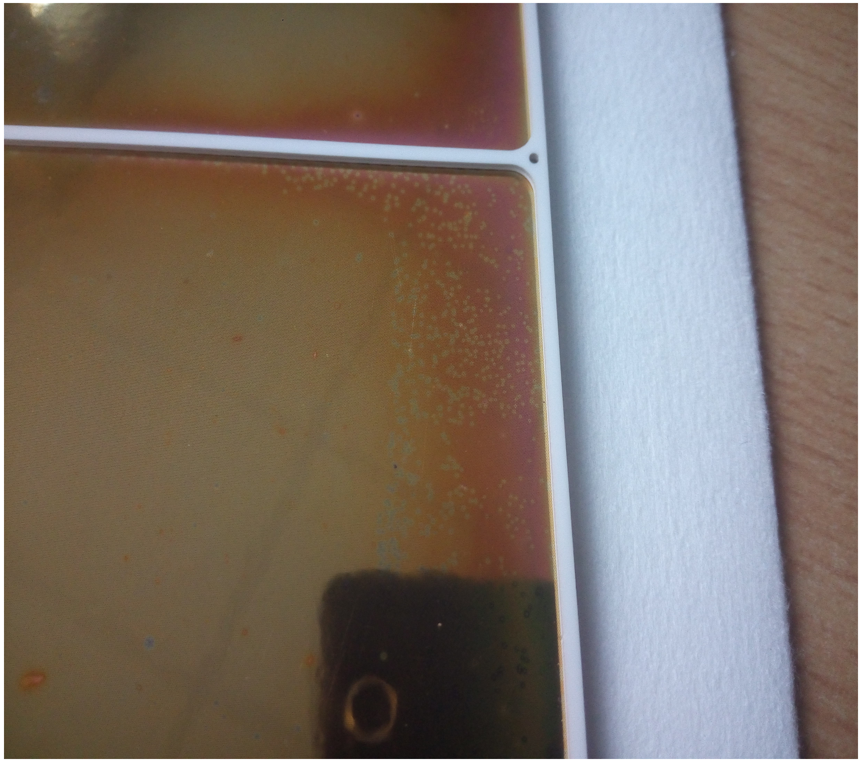
- Presumably covered by CuO(black)



- Presumably covered by Cu_2O(red)

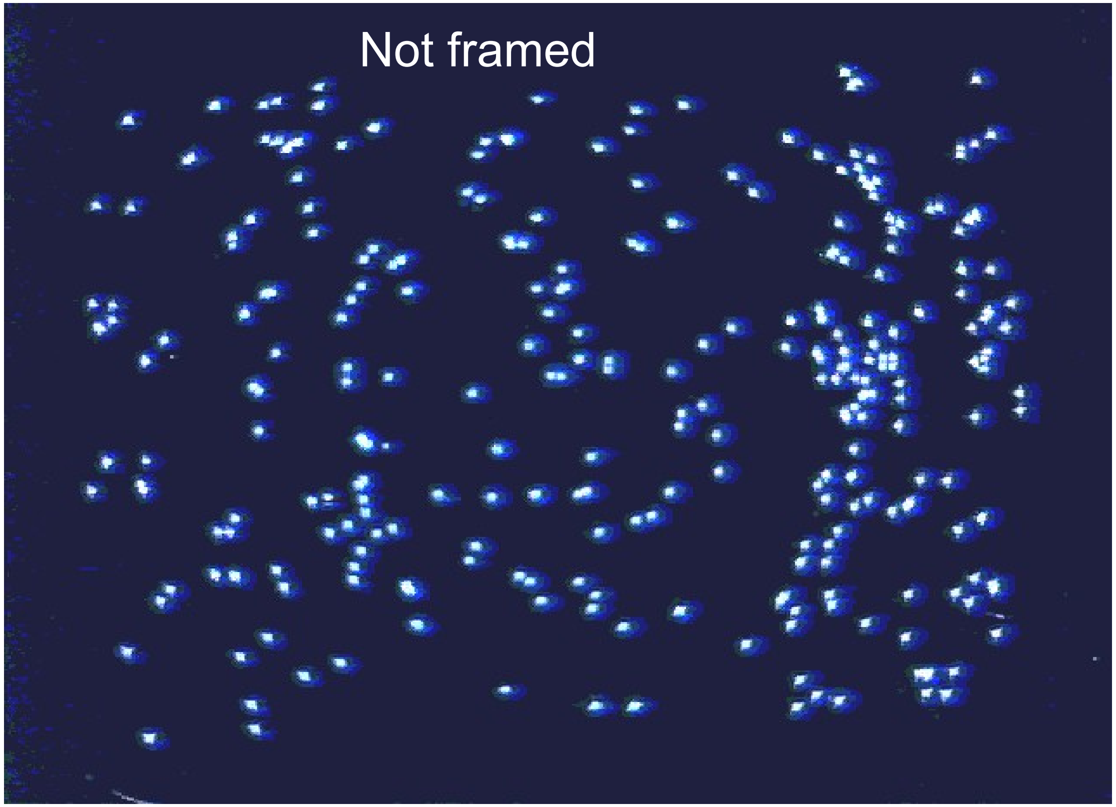


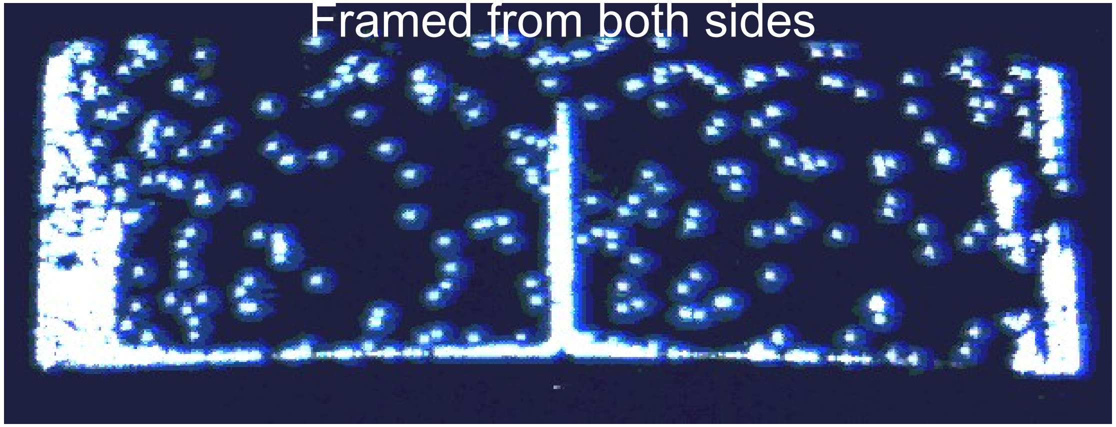
- Presumably trace of previous sparks

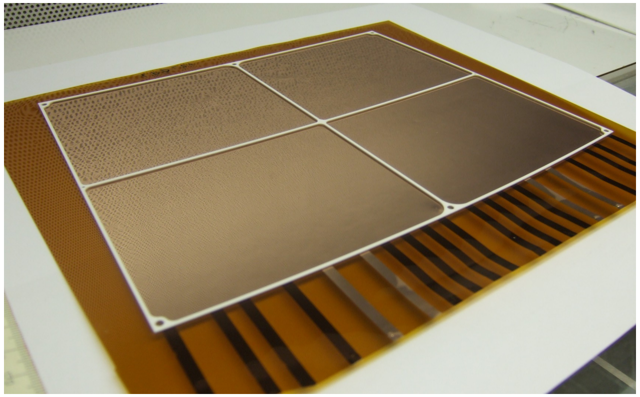


- First example is stable after >10ksp
- Next example is waiting for testing

Impact of the Module Mechanics







- Unframed GEM.
- 247 events at 620 V for 20 hours. **4 Sectors**

- Framed from both sides
- 2503 events at 600 V for 24 hours. 2 Sectors

DESY

Summary

- Voltage oscillations in GEM:
  - We see multiple discharges (~100ns time difference).
  - We see and simulate voltage oscillations directly after a discharge.
  - These oscillations have been created by a electromagnetic wave in GEM by a discharge.
  - We see an evidence that filtering of the oscillations changes the rate of multiple discharges.
- We see evidence that additional protective circuit significantly reduces destructive impact of discharges
  - further validation is needed
- Impact of ceramic frames on discharges has been observed
  - Further studies are needed to quantify this.
  - This might imply changes to the building procedure of the module

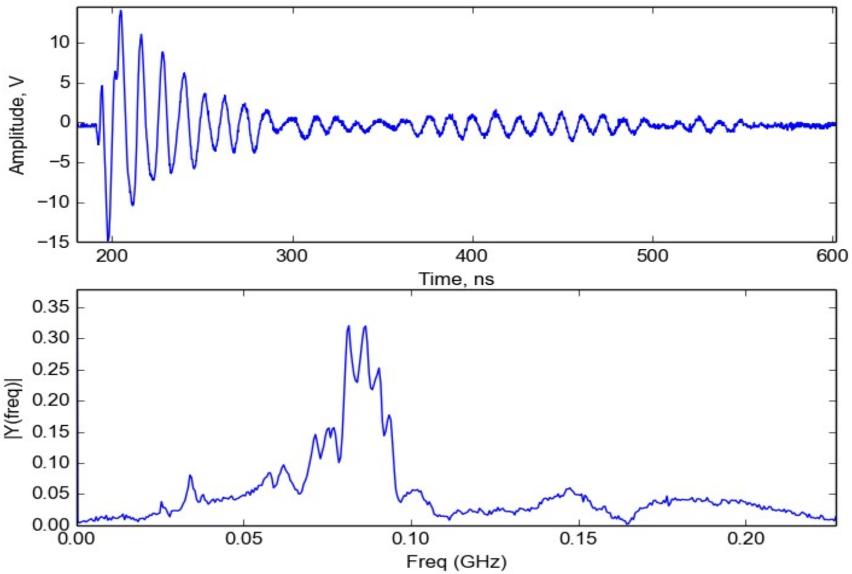
Summary(II). Protective mechanisms

- Protective capacitor
  - Dump oscillations. If length of a discharge is bigger then ~10ns then oscillations force current oscillations that presumably cause destruction. Measurements of discharge is needed.

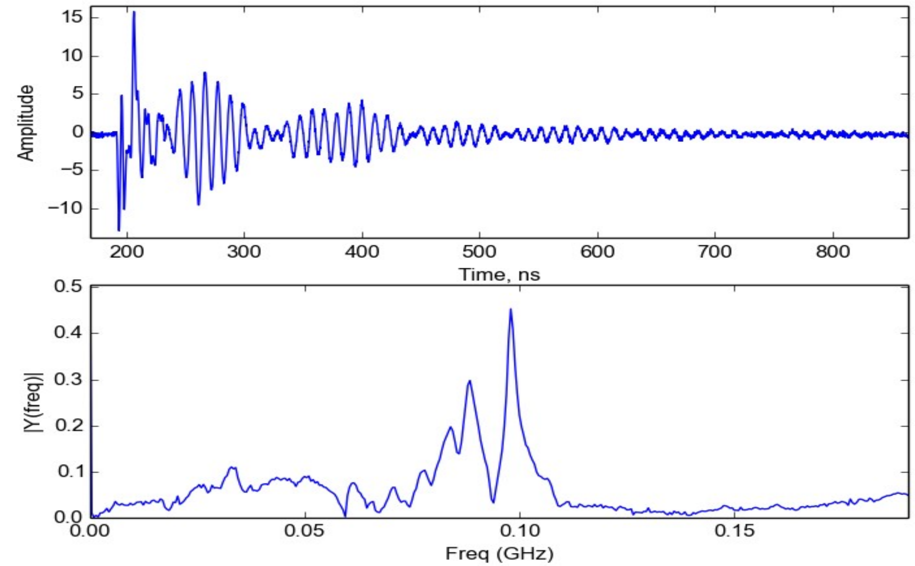
- Coating of less conductive material:
  - GEM oxidation. Couple of hours in T>=200.
  - High cleanliness is needed to avoid “pictures” on GEM surface.
  - More GEMs need to be tested for validation.

Fourier transformation

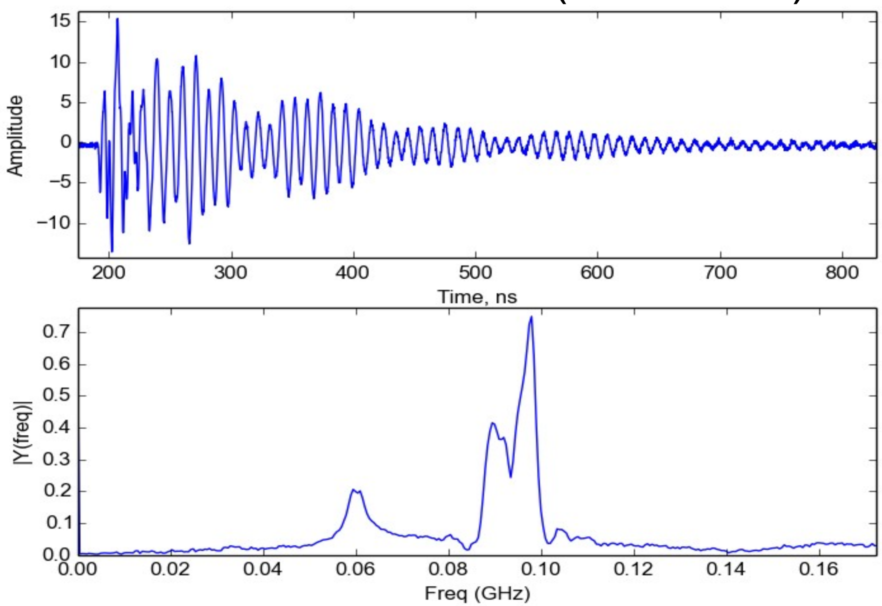
10x10cm GEM



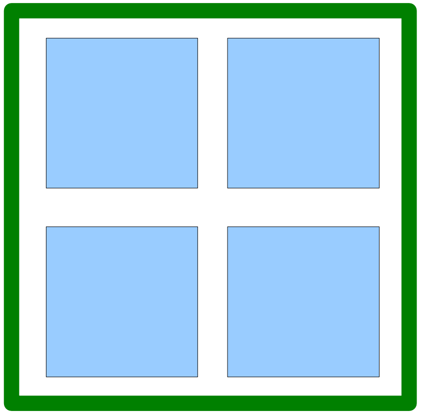
Sector electrode (~11x9cm)



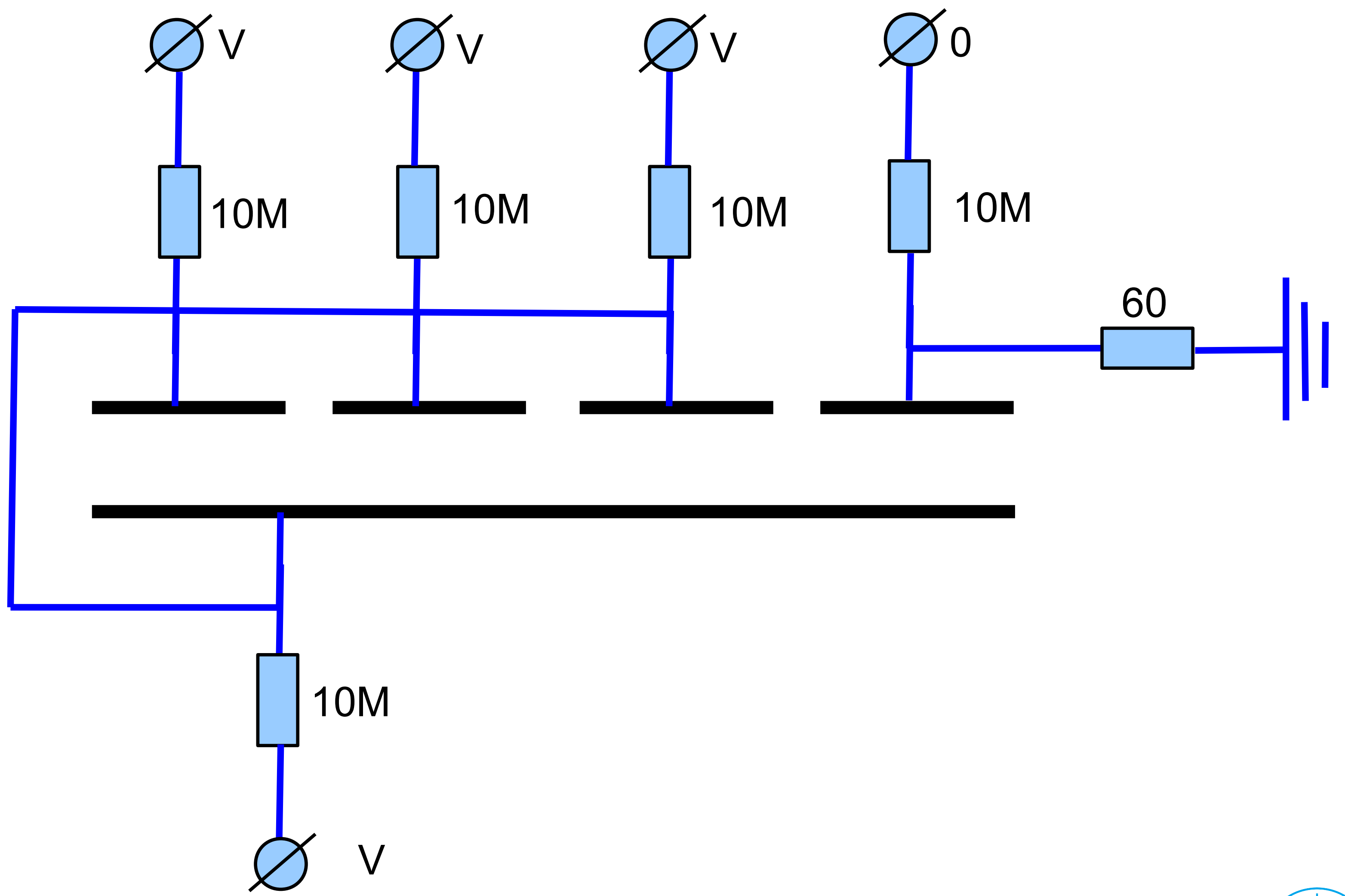
Common electrode (~22x18cm)



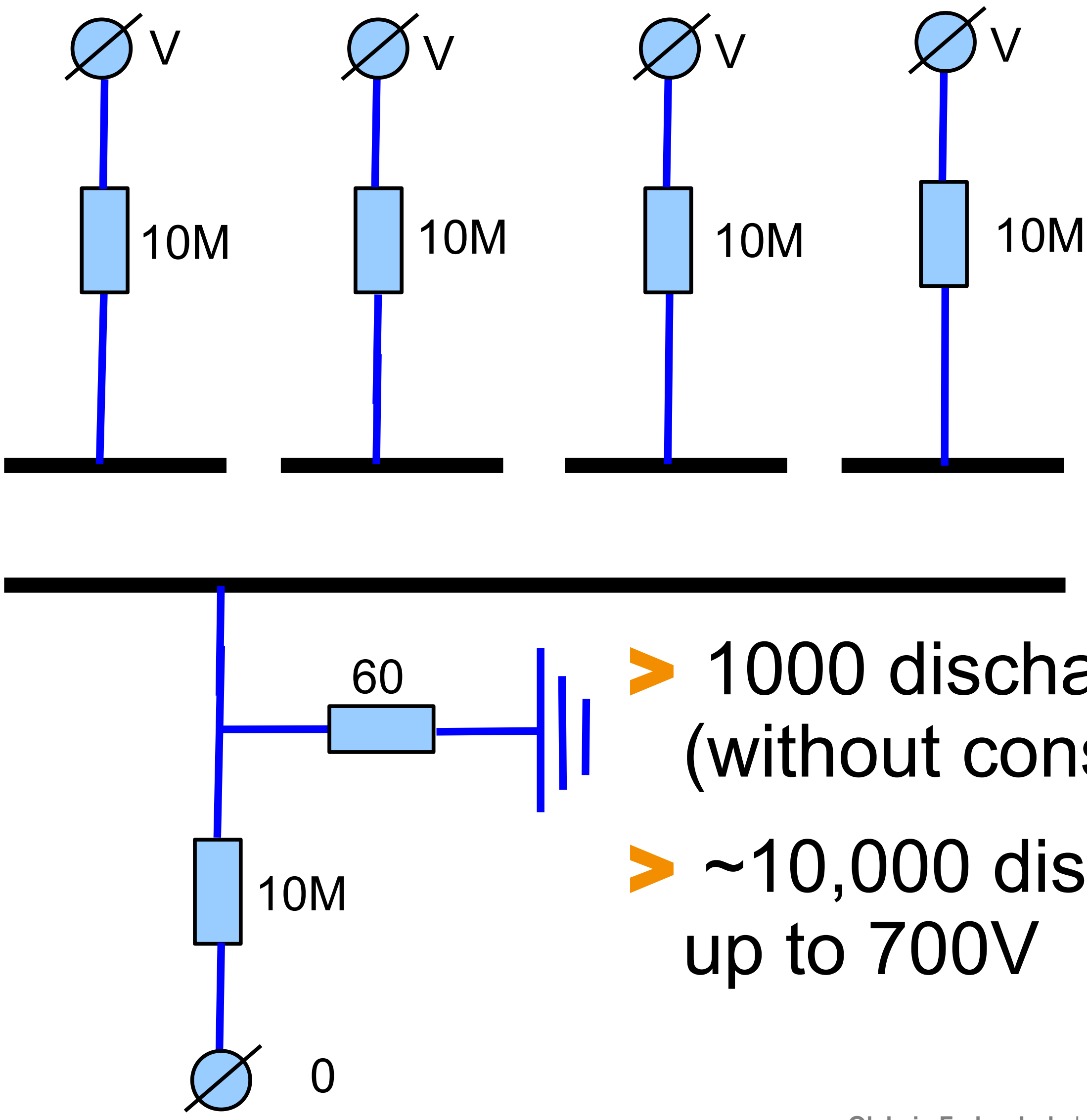
- TDS 3054b
- 500MHz bandwidth
- 5GS/s
- 50Ohm load
- 100x attenuatior
- Multiple modes for single sector
- Low frequency for common



Scheme of the setup



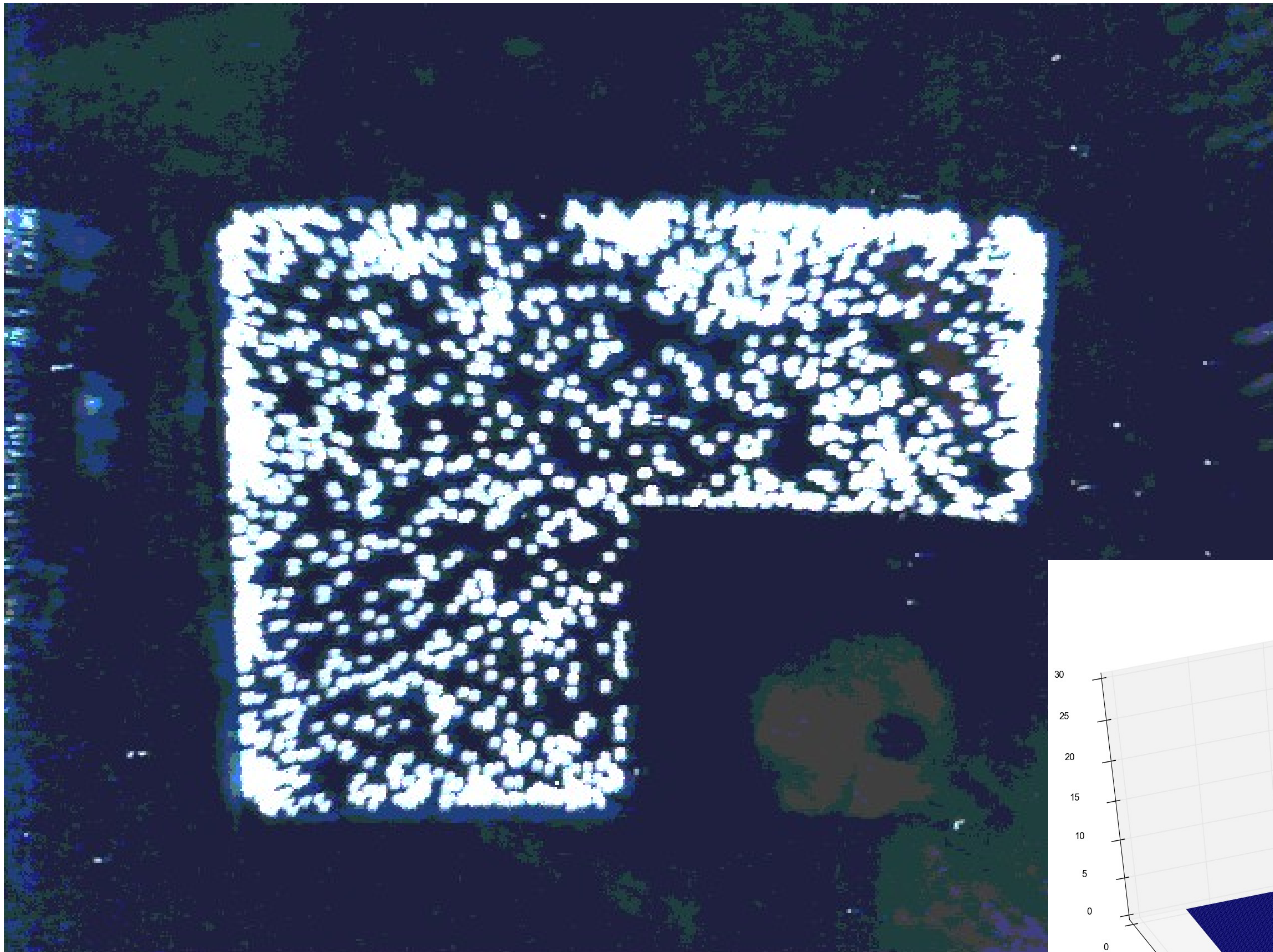
Scheme of the setup



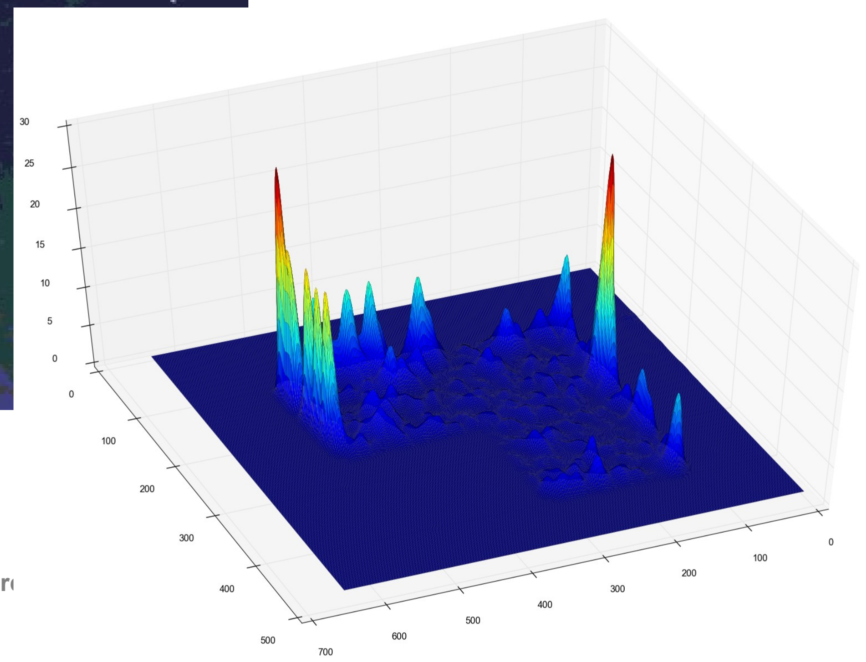
- 1000 discharges with 2 sectors (without consequences) up to 740V
- ~10,000 discharges with 4 sectors up to 700V

Discharges statistic (RC-filter company)

5573 trips has been detected. The fatal trip is a usual single trip.



- 1-488: **<640V**
- 489-849: **640V**
- 850-1688: **660V**
- 1689-3707: **680V**
- 3708-5573: **700V**

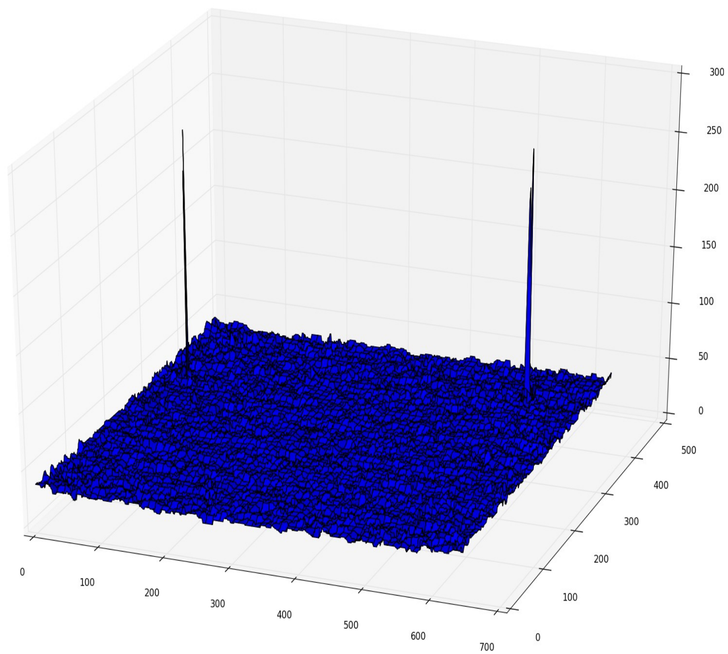


Further testings show that problem has not been solved

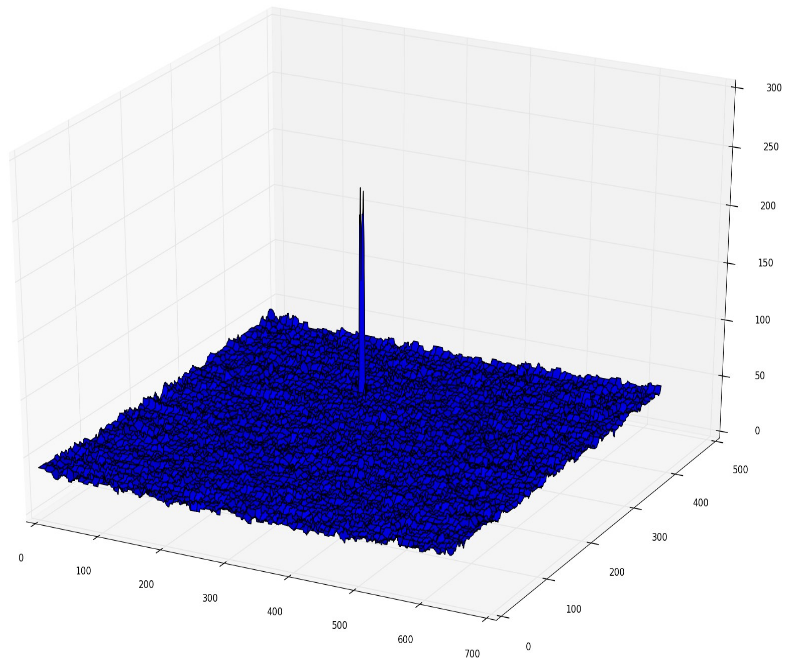
Using brightness distribution

Trip brightness spikes response for trip light

Double trip

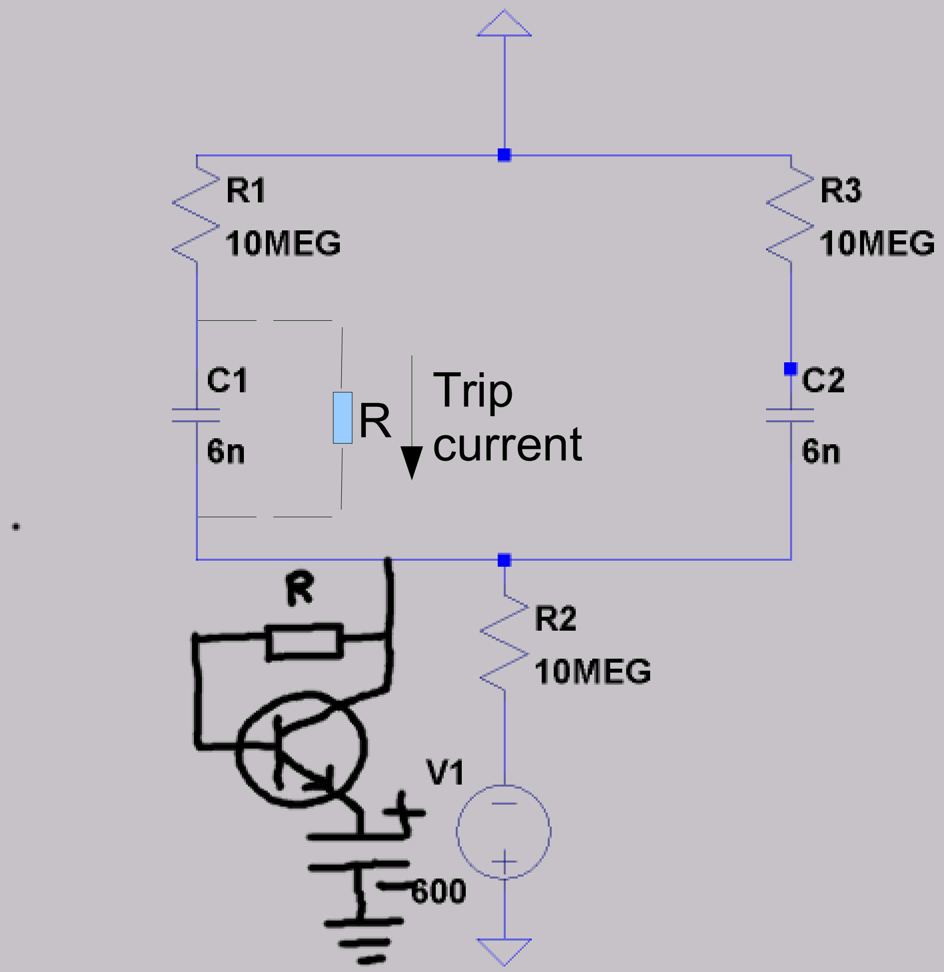


Single trip

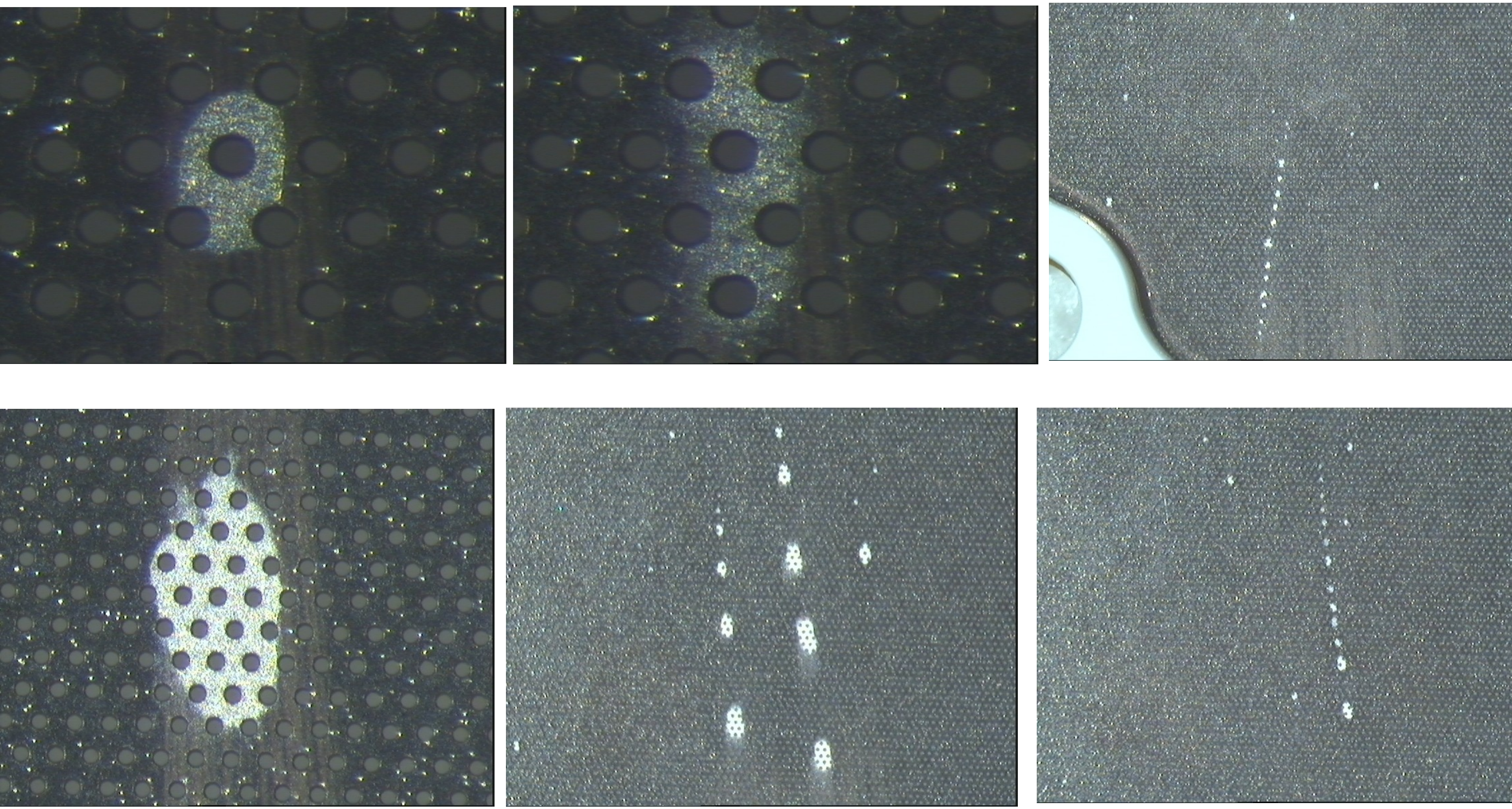


No comments

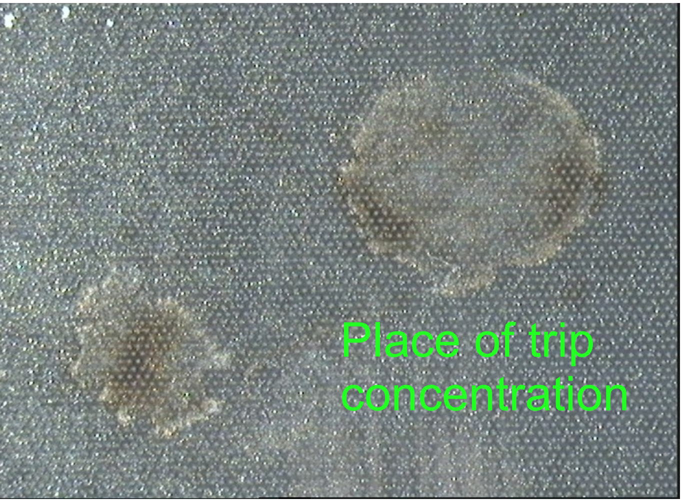
Possible rescue system

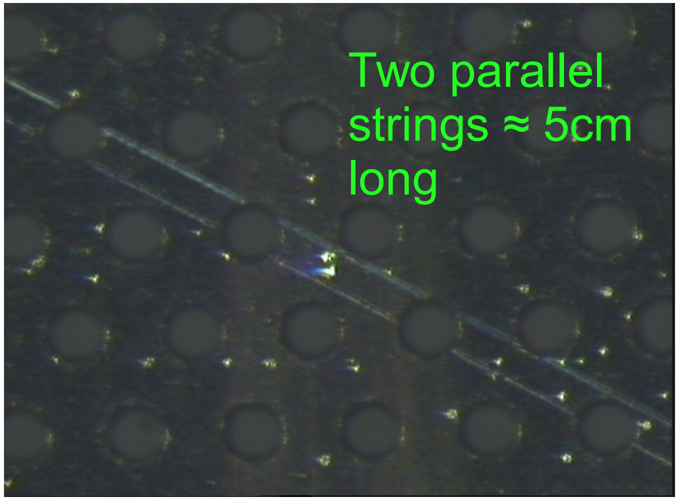


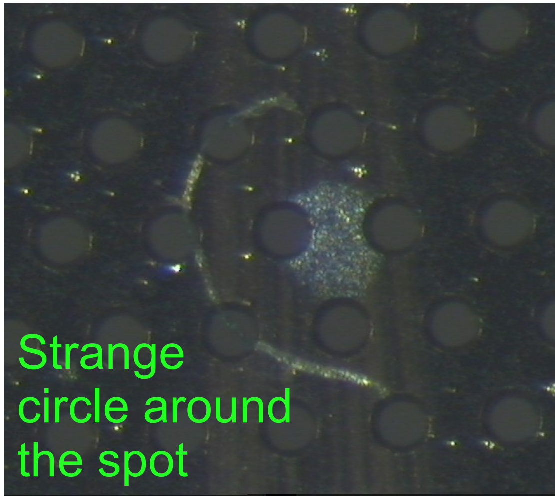
Bright spots

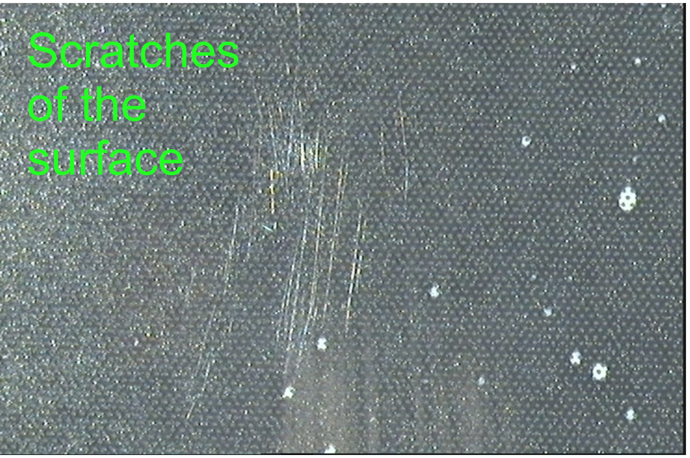


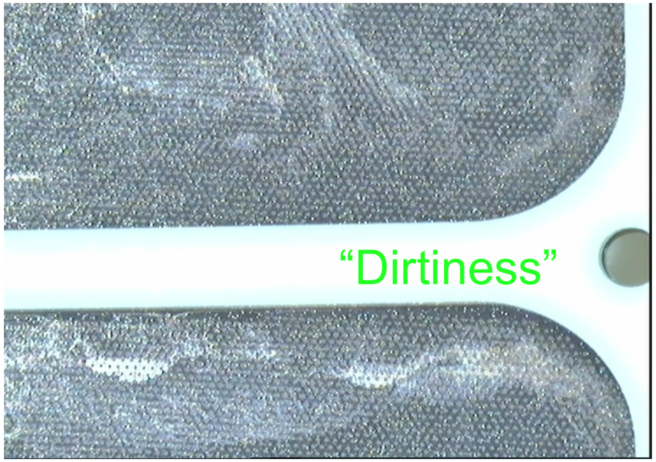
Other imperfections

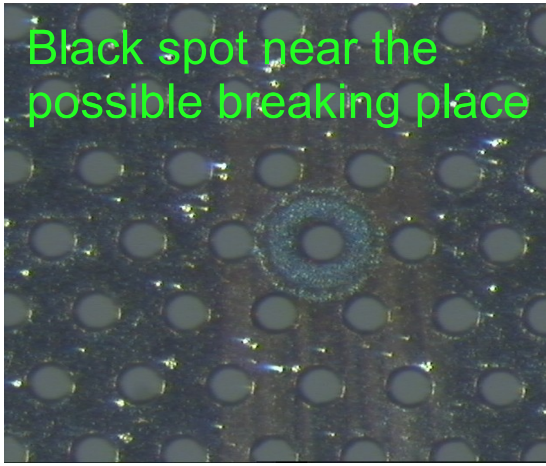




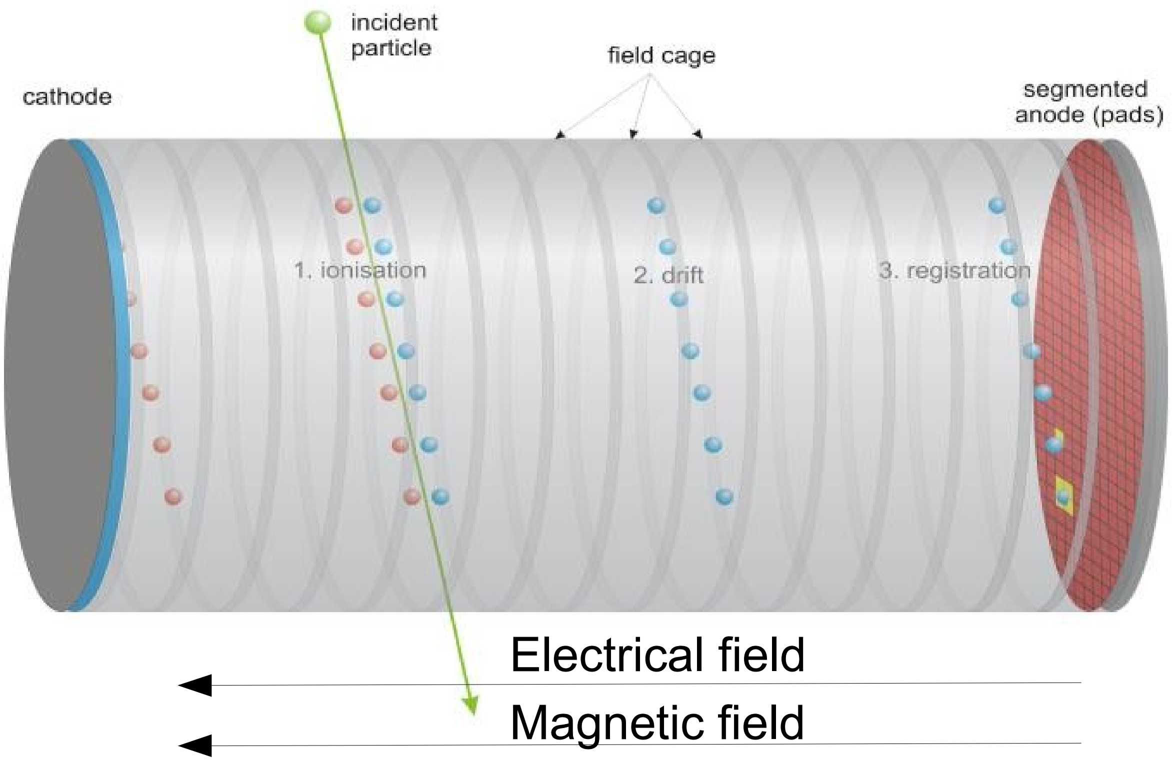








Time Projection Chamber (TPC) concept



- Planned sizes for the ILC: r = 1.8m, z = 4.7m
- Readout pad size: 5.85mm x 1.05mm
- Required precision: r φ = 60-100 um, z = 0.4-1.4 mm

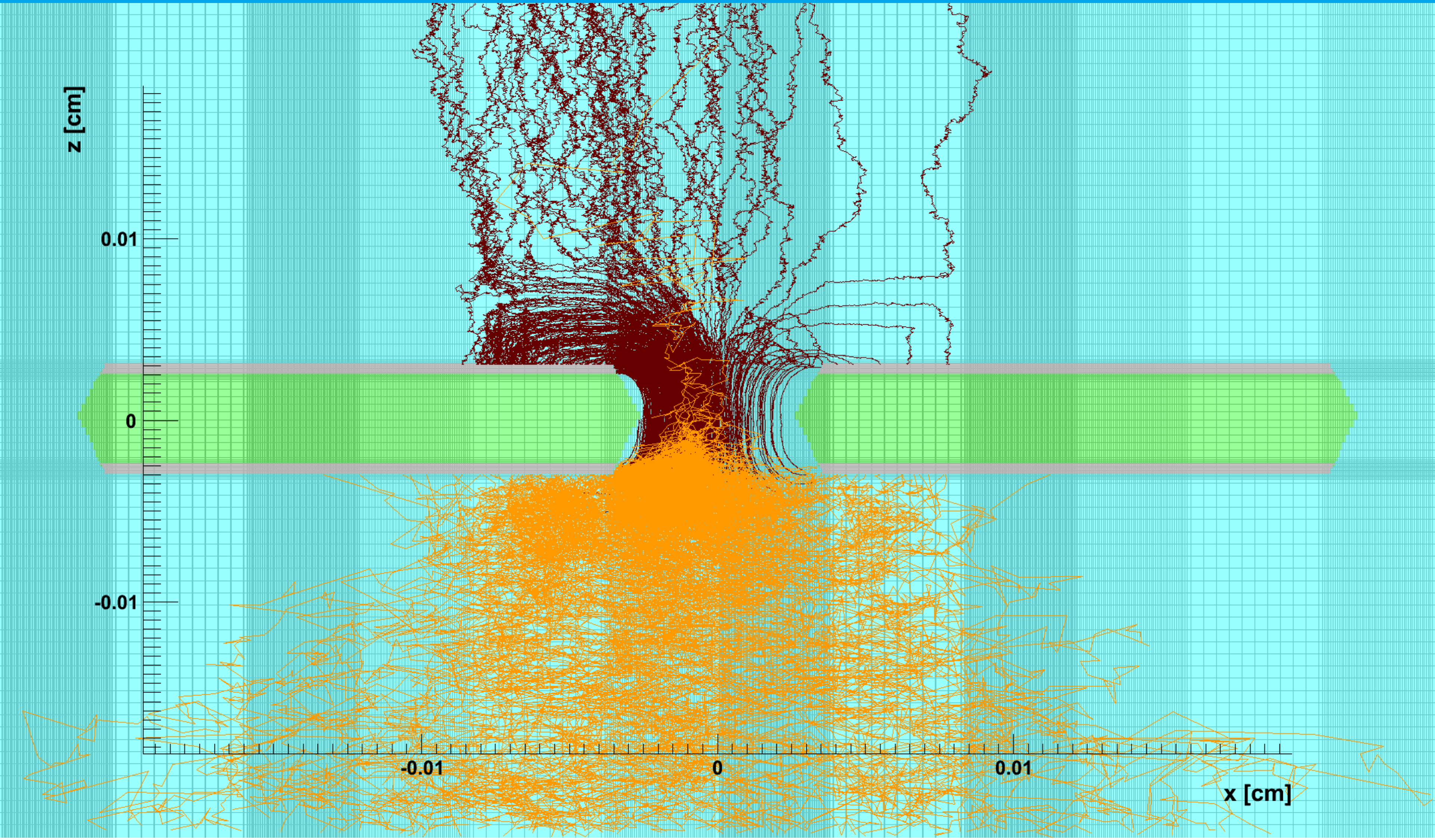
> Charged particles leave an electron - ion track.

> Electrons drifting in an electrical field to the anode.

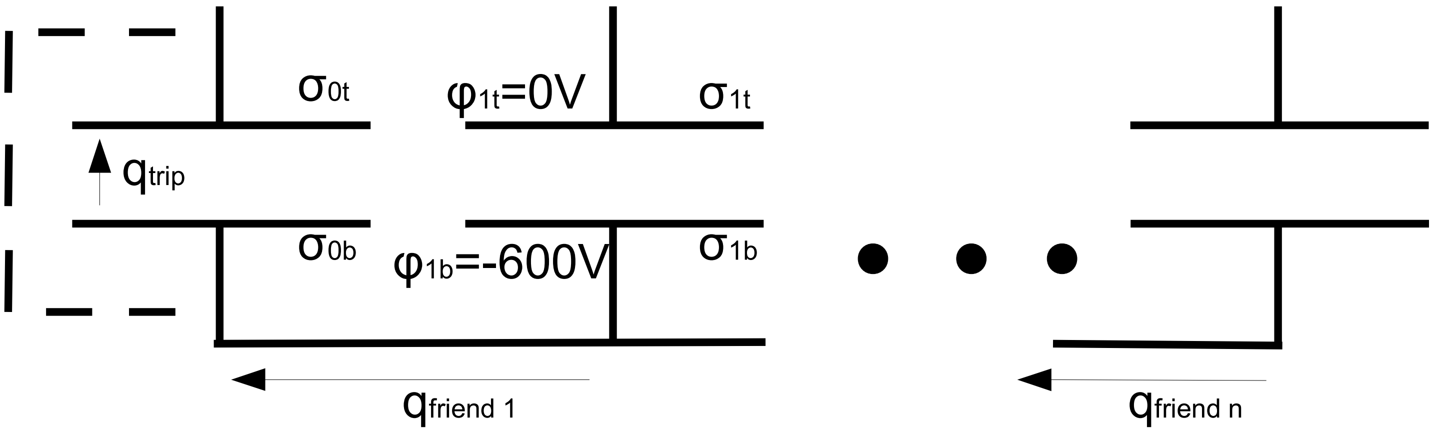
> The 2D trace is recorded by the sensitive part of anode.

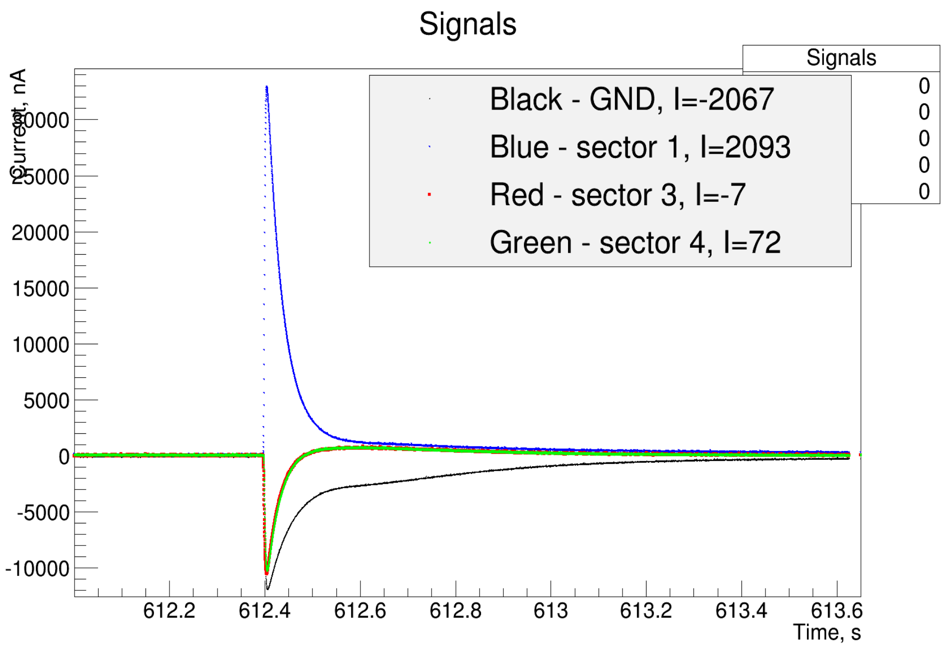
> The 3rd dimension is reconstructed with time-of-arrival information

Gas Electron Multipliers (GEM) simulations



Usual trips





- Electrode spectators shows total zero current
- Splash and tripped electrode has opposite sign and equal value of charge exchanging