Radiation hard ceramic RPC development

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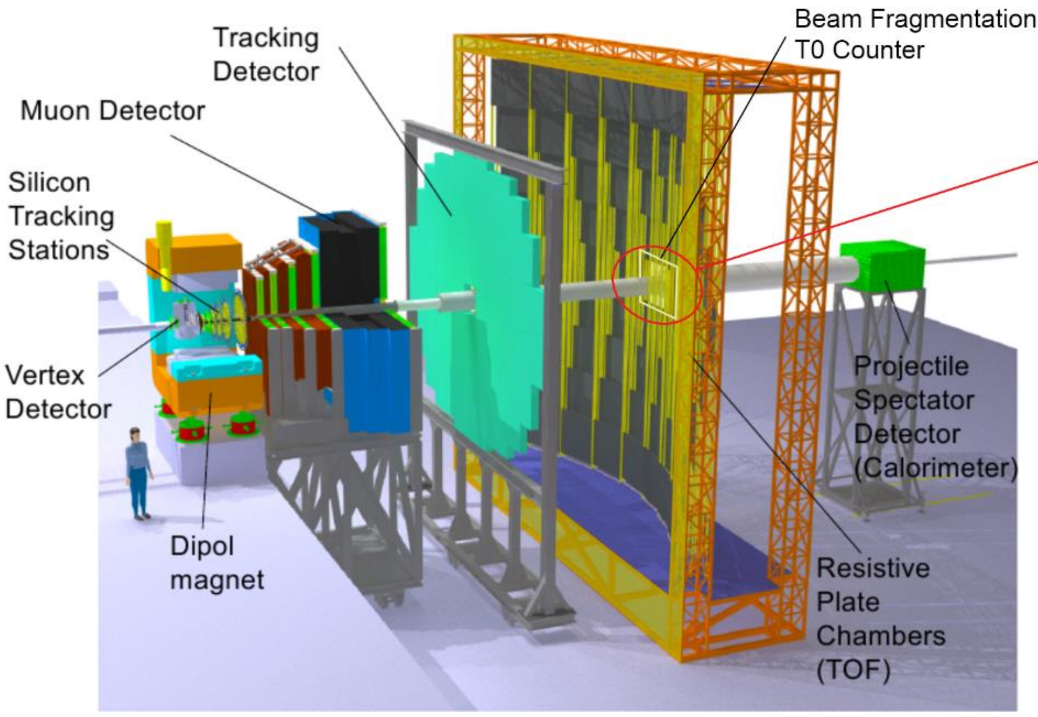
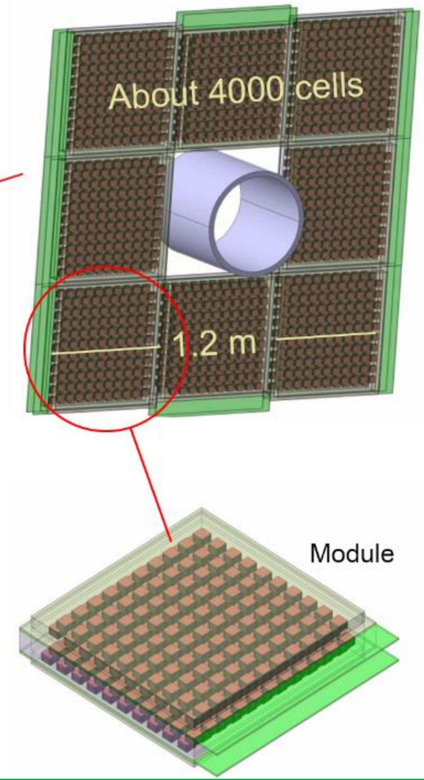
Beam Fragments T0 Counter at CBM Experiment

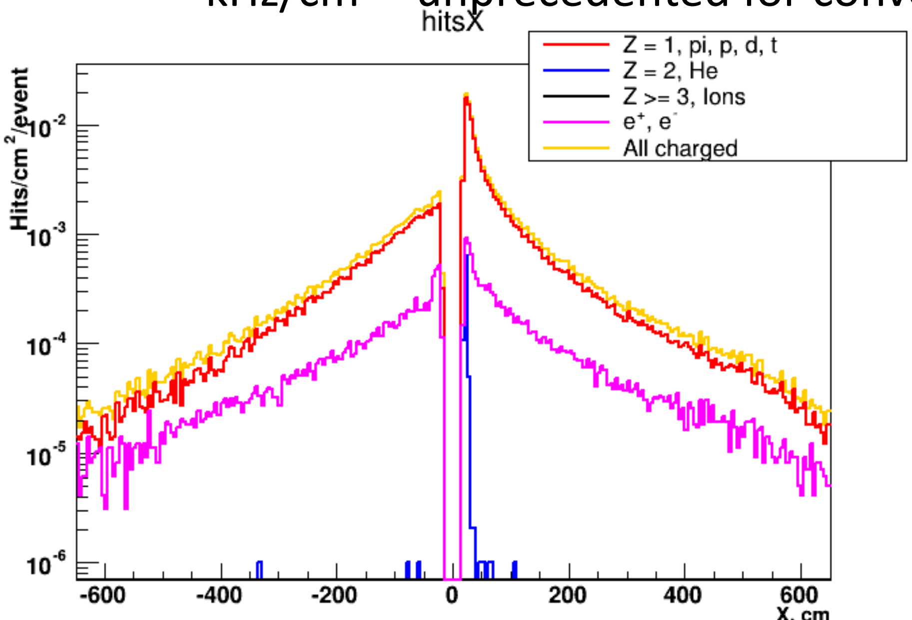


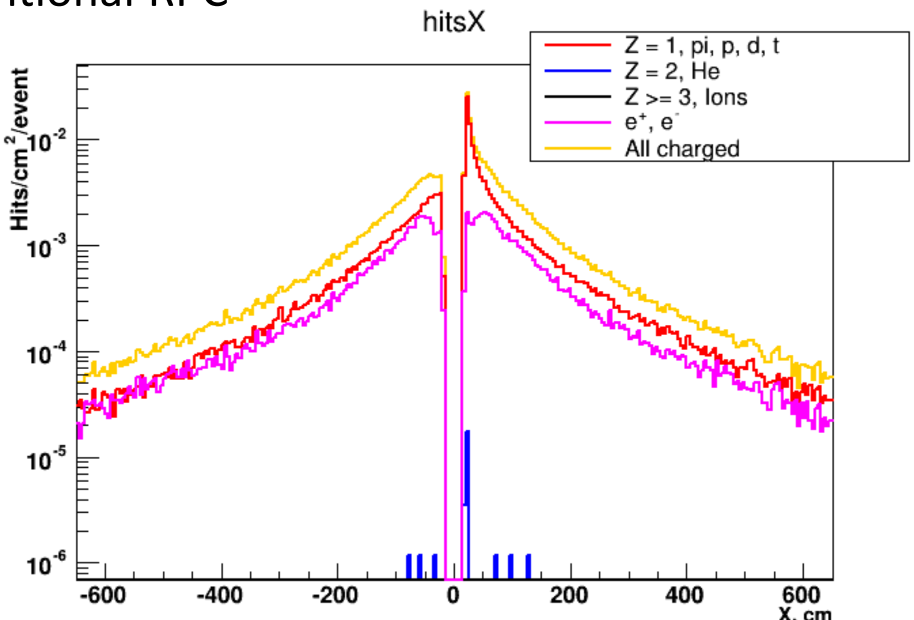


- Forward part of the TOF detector for the start time, reaction plane and PID determination in the CBM experiment.
- T0 reference, obtained "**online**", is going to be used by other detectors and in 4D event reconstruction.
- Event plane determination (together with PSD).
- Particles identification for tracks having signal in STS.

Expected particle fluxes

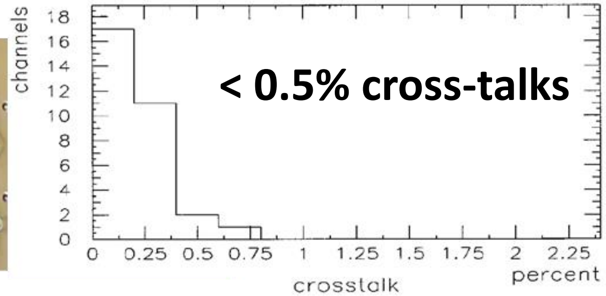
- Interaction rates on target up to 10 MHz
- Particle flux at BFTC region up to 150 – 200 kHz/cm^2
- MRPC are needed to fulfil the requirements
  - time resolution ~ 60 ps
  - efficiency ~ 98%
  - radiation-hard material
  - low resistivity floating electrodes for operation at rates up to 200 kHz/cm^2 - unprecedented for conventional RPC

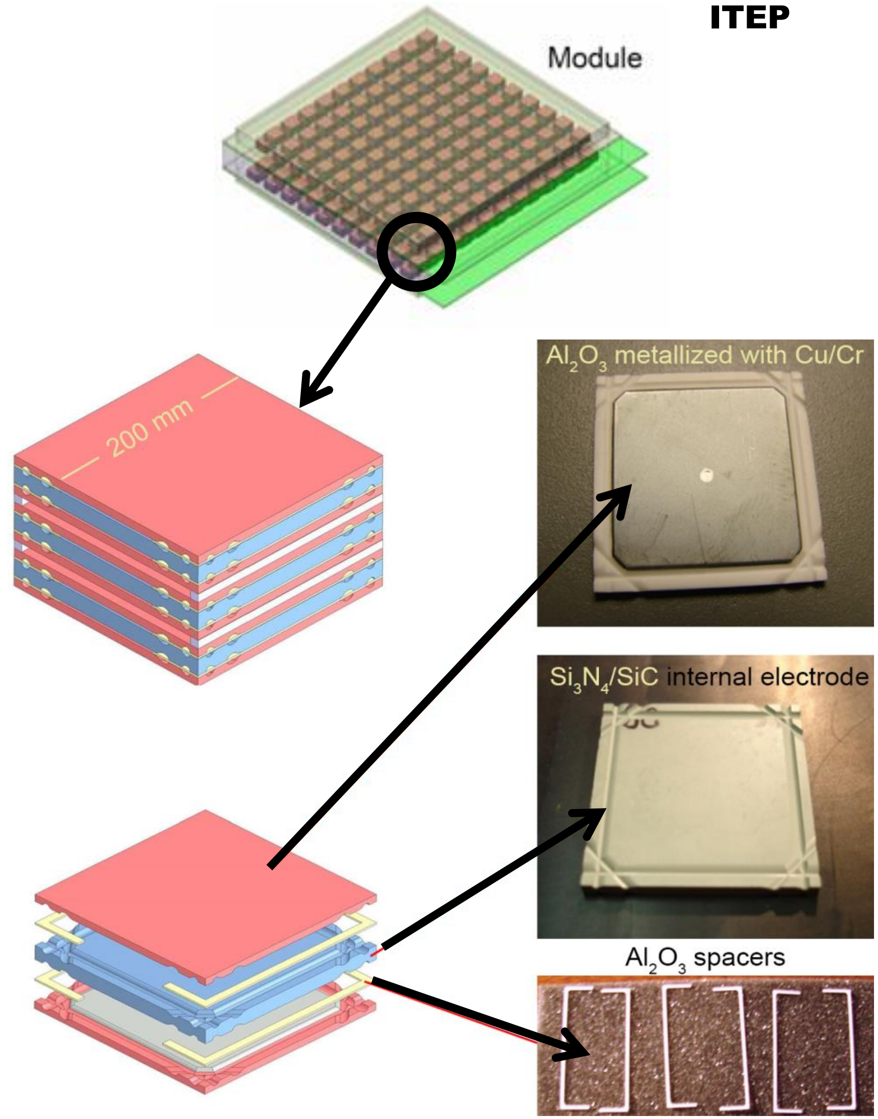




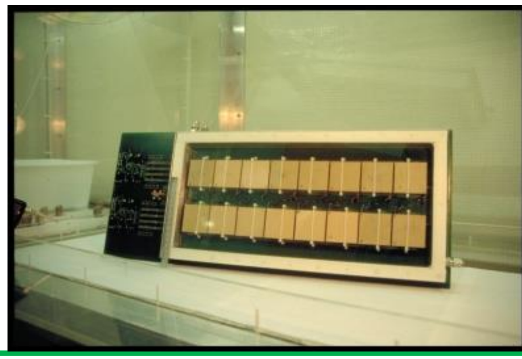
Au-Au events at 4 (left) and 10 (right)AGeV, generated by SHIELD.
TOF wall at 6 and 10 m from the target.

Ceramic RPC cell





ALICE TOF R&D experience

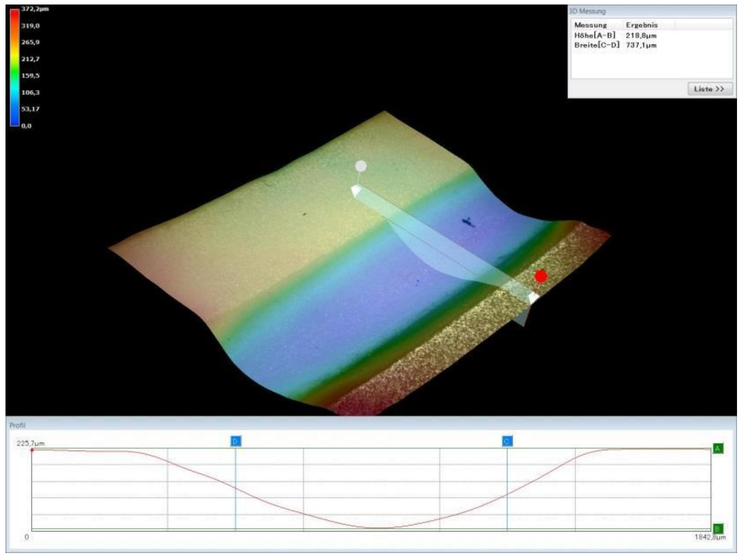


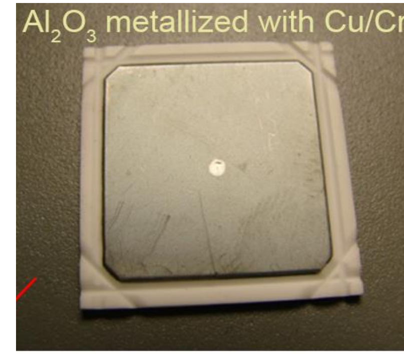
Six 250 µm gaps chamber composed of 3 double gap "sandwich" chambers of each two Al_2O_3 electrodes and one SiC/Si_3N_4 resistive electrode

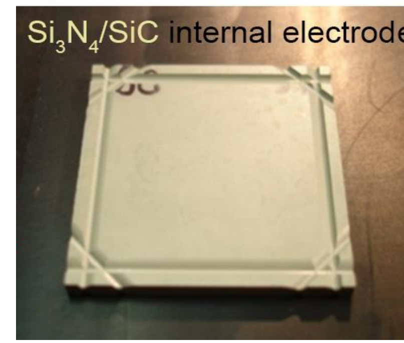
Low-resistivity Si_3N_4/SiC ceramics have proven to operate well in the high radiation environment. The bulk resistivity of Si_3N_4/SiC is variable within a wide range from 10^7 Ω·cm to 10^{12} Ω·cm and can thus be optimized for BFTC operating conditions.

Minimizing streamers probability

5x5 cm electrodes from ALICE R&D







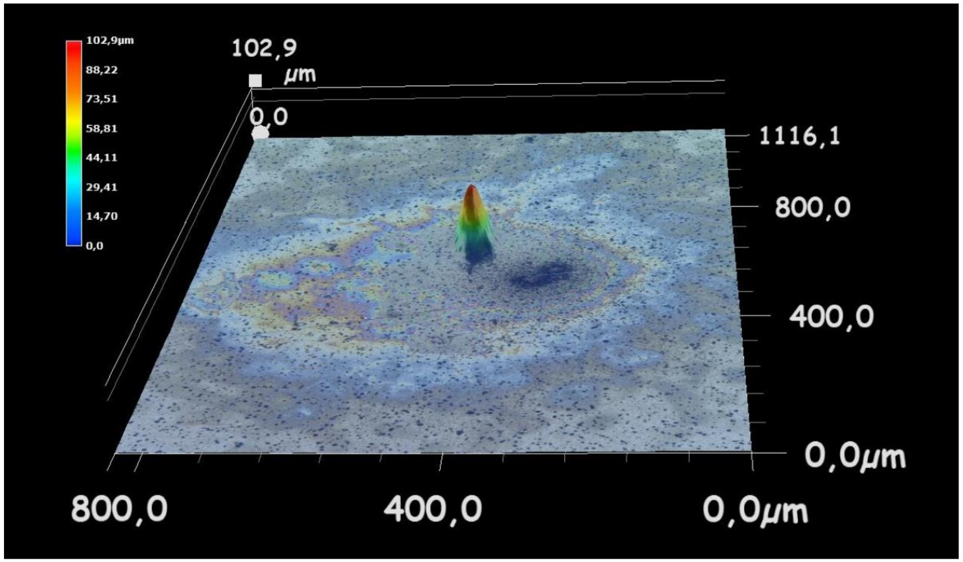
All electrodes have Rogowski-shaped edges (internal Si_3N_4/SiC electrodes — on both sides) to minimize the electric breakdown probability.

The fringe fields created at the edges of a parallel plate configuration can be much higher than the electric field in the centre. This problem was studied by Rogowski in the 1920th. rounded shape of the edge of the electrode following Rogowski equations is optimal to reduce the electric fields at the edges of an RPC.

Aging studies

Gas aging

The working gas is mixed of $C_2H_2F_4$ and SF_6 in 90%/10% or 95%/5% proportions. The use of iso-butane has been abandoned due to its observed harmful effect on the surface of metallized electrodes resulting in formation of localized polymer whiskers.

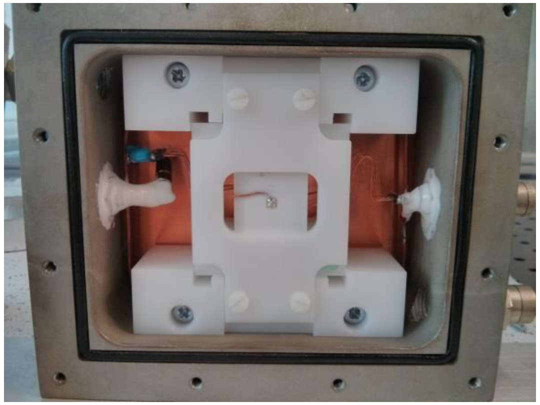


Detector material aging

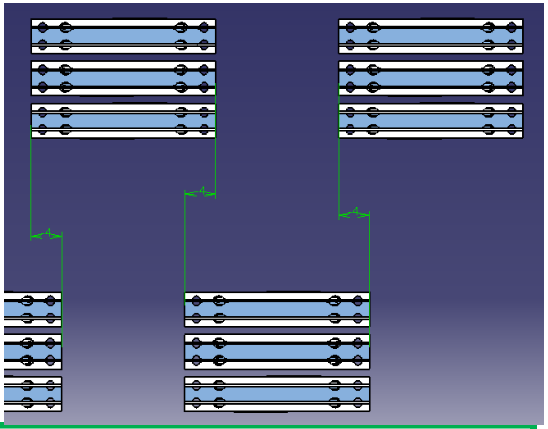
Two probes of low bulk resistive plates have been exposed to non-ionizing radiation doses in the order of 10^{13} n_{eq}/cm^2 at the neutron beam of MEDAPP at FRM II in Munich. The bulk resistivity of both probes was measured before and after the irradiation. A factor of 2 decrease of the bulk resistivity has been observed. This decrease has no impact on efficiency and time resolution. For the Al_2O_3 electrodes an irradiation with fluxes up to $10^{15}n_{eq}/cm^2$ is possible without any degradation of the detector performance.

Testing modules

Assembling of RPCs in module cassets



Mini-module mechanically assembled



Wide range of bulk resistivity (10^7- 10^{12} Ω·cm) of a floating electrodes was tested in order to find optimal resistivity value for BFTC conditions and requirements.

Beam facilities

ELBE – an electron Linac facility at Helmholtz-Zentrum Dresden-Rossendorf (Germany), which provides with 30 MeV electron beam with a single electron in a bunch.

+ Allows to vary particle flux in a wide range from few Hz/cm^2 up to 1 MHz/cm^2.

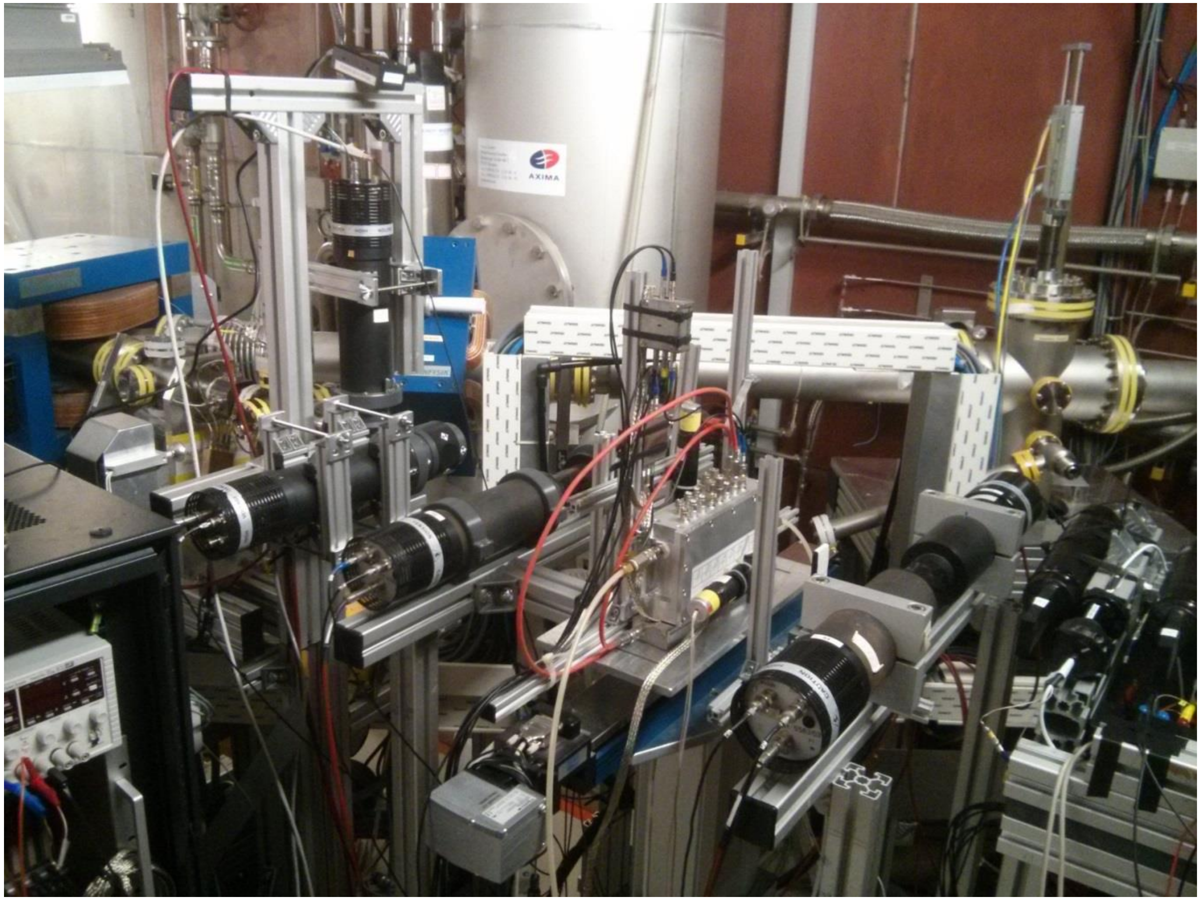
+ Independent time reference from accelerator RF

- High electrons rescattering in detectors material.

CERN – 5 GeV pion beam

+ almost no rescatterings of the hadrons

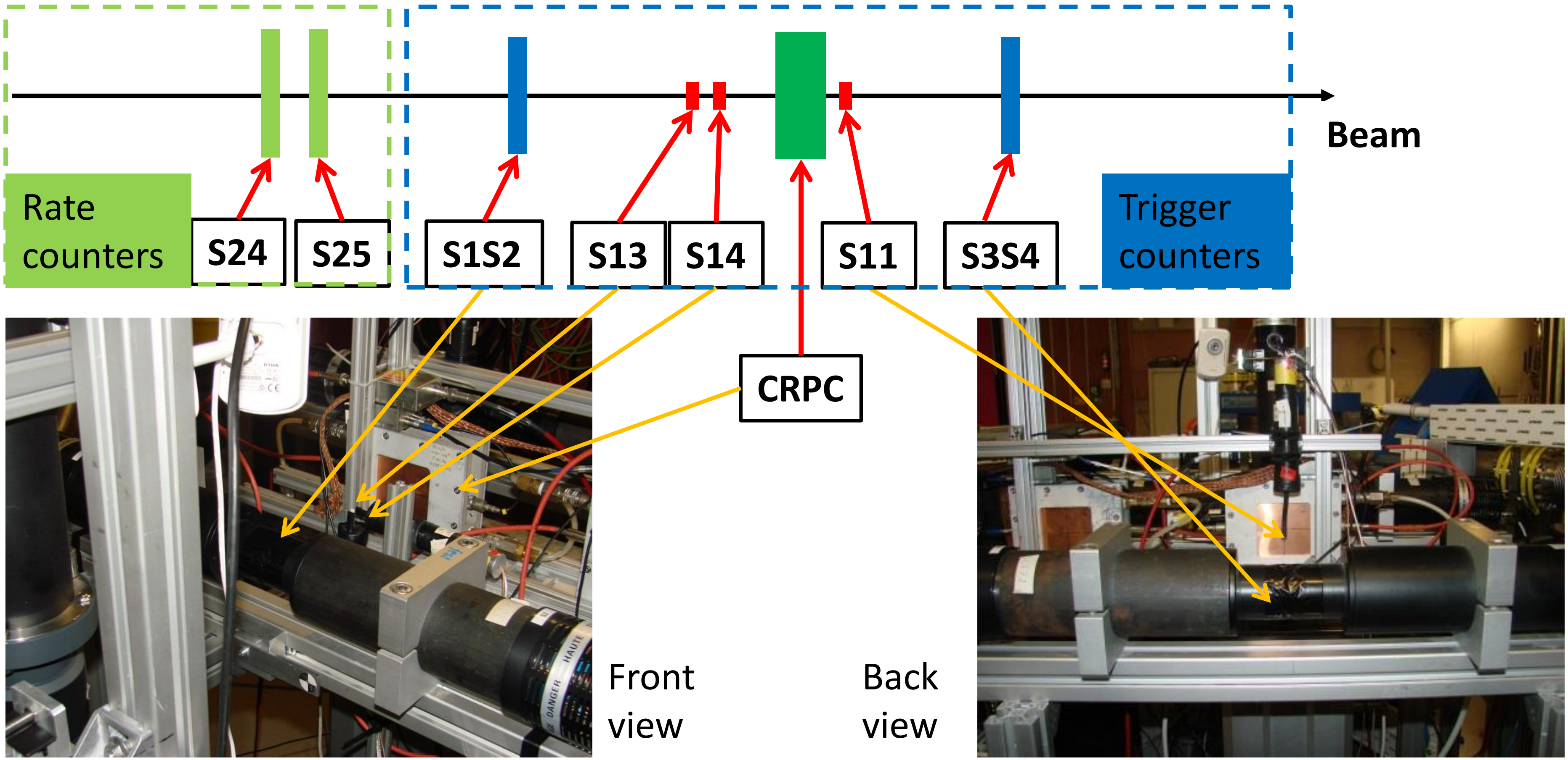
- low particle flux up to few kHz/cm^2



Whole view of the setup at HZDR with mini-module installed.

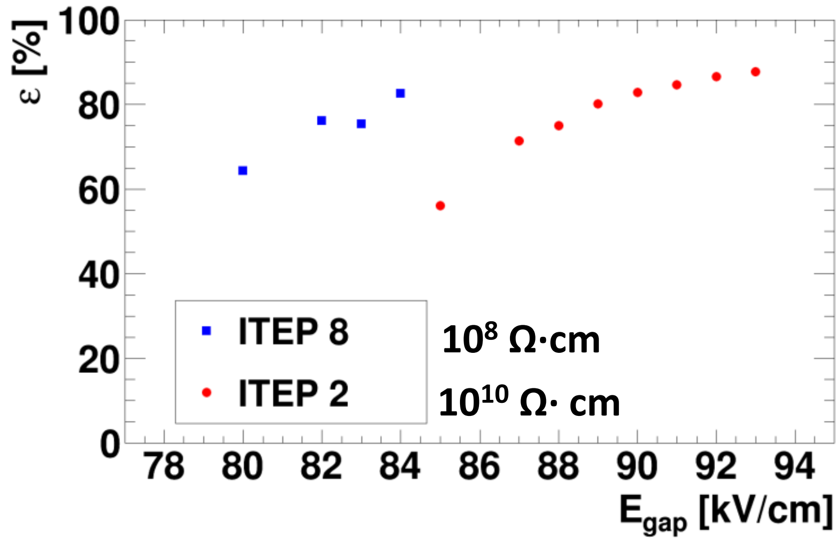
Test setup at Rossendorf

Gas: 90% freon + 10% SF_6.
Electronics: MAX3760 preamplifier + CAEN TDC.
Start system resolution about 35 ps.

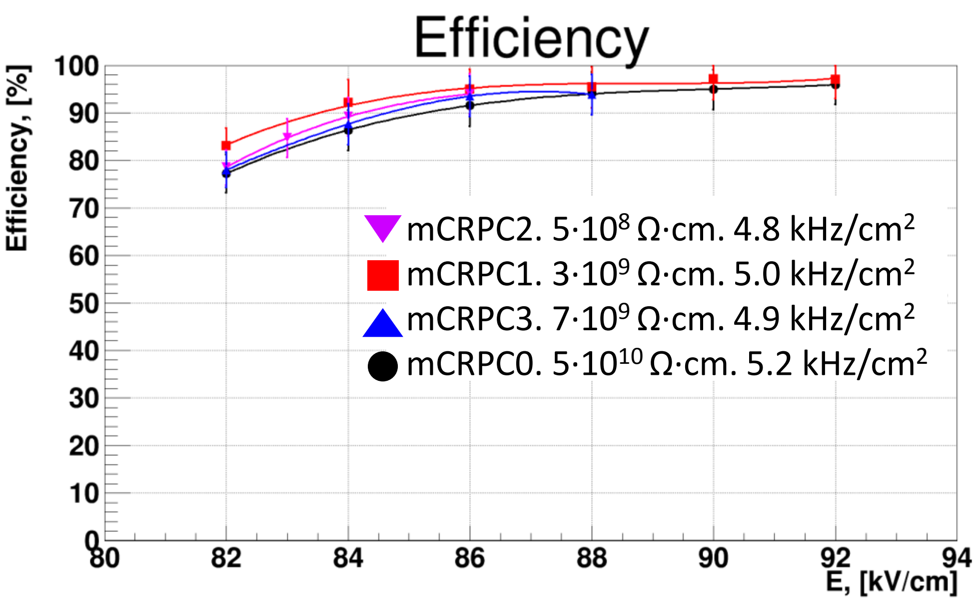


Results: Working curve

Tests with flat low resistive floating electrodes and grooved metallized signal electrodes: chambers are not able to get on efficiency plateau due to discharges at the edge of the detector.
Electrodes left from ALICE TOF R&D.
5x5 cm²

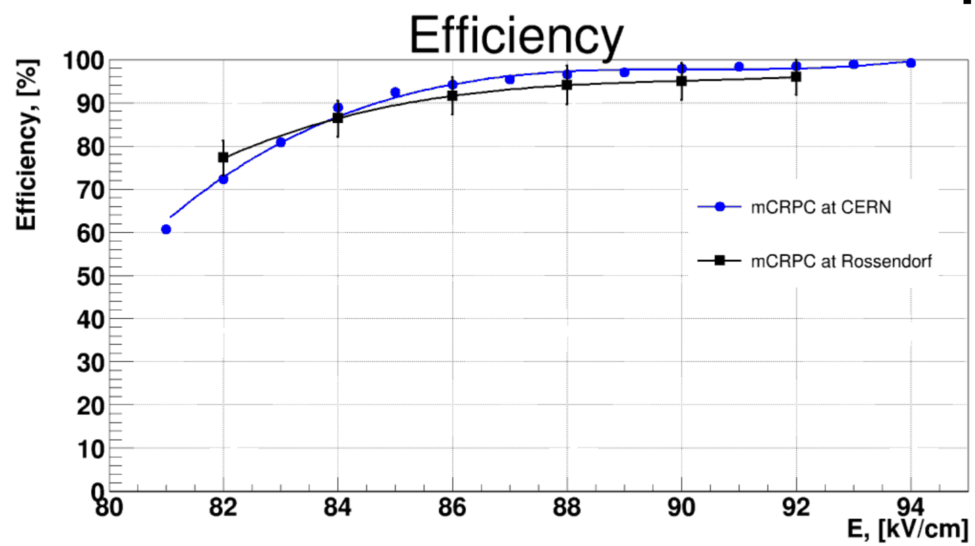


Efficiency (~96-98%) is consistent with expectation. MAXIM 3760 preamplifier was used, for comparison with ALICE R&D data.
New electrodes 2x2 cm²



Results: Working curve

Difference in order of 1-2% is due to different position of chambers (angle to beam, distance from the edge, materials in front) was found. Efficiency at CERN beam is higher due to rescatterings of soft electrons at HZDR setup.



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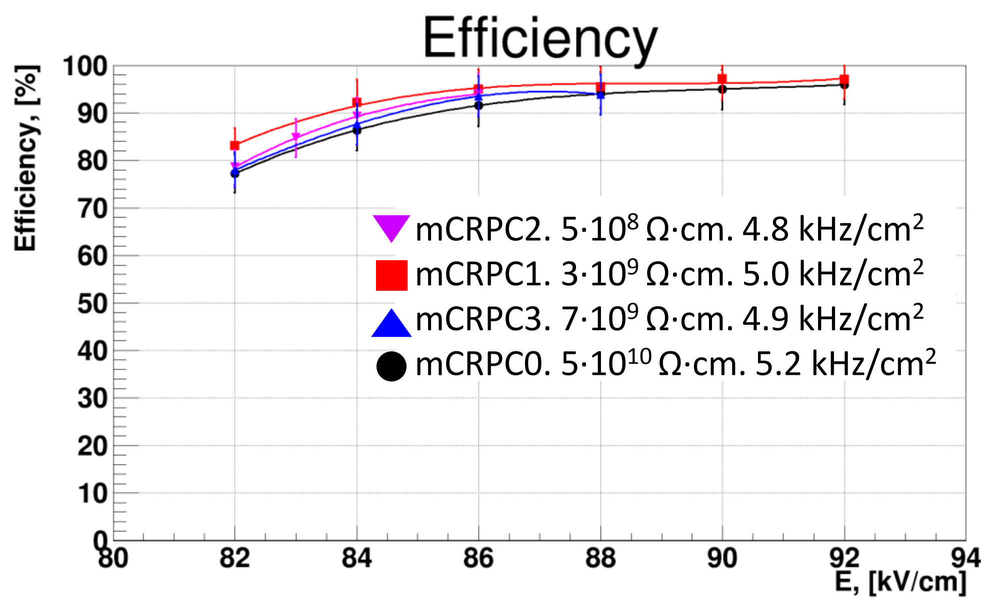
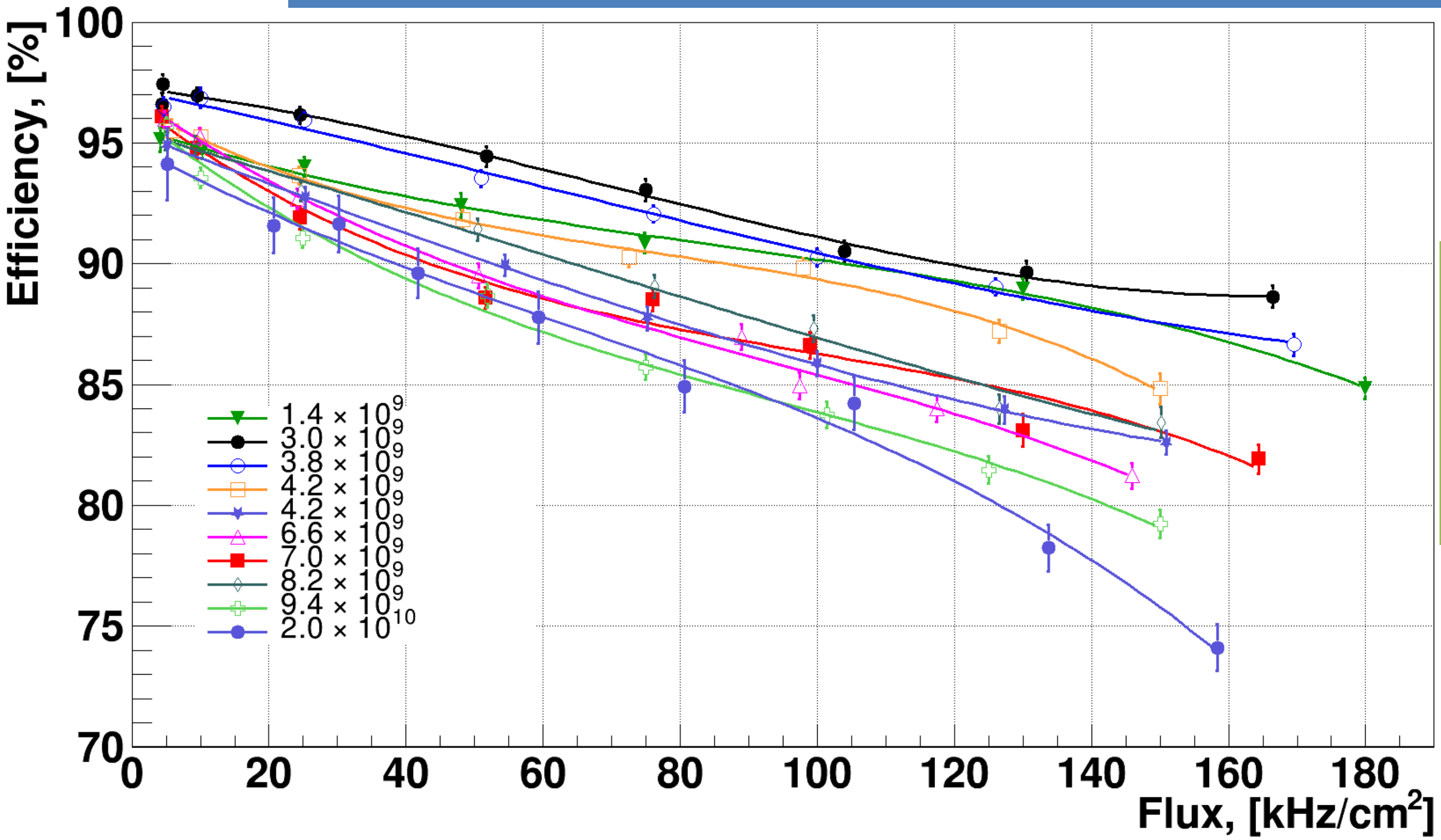


Results: Rate scan

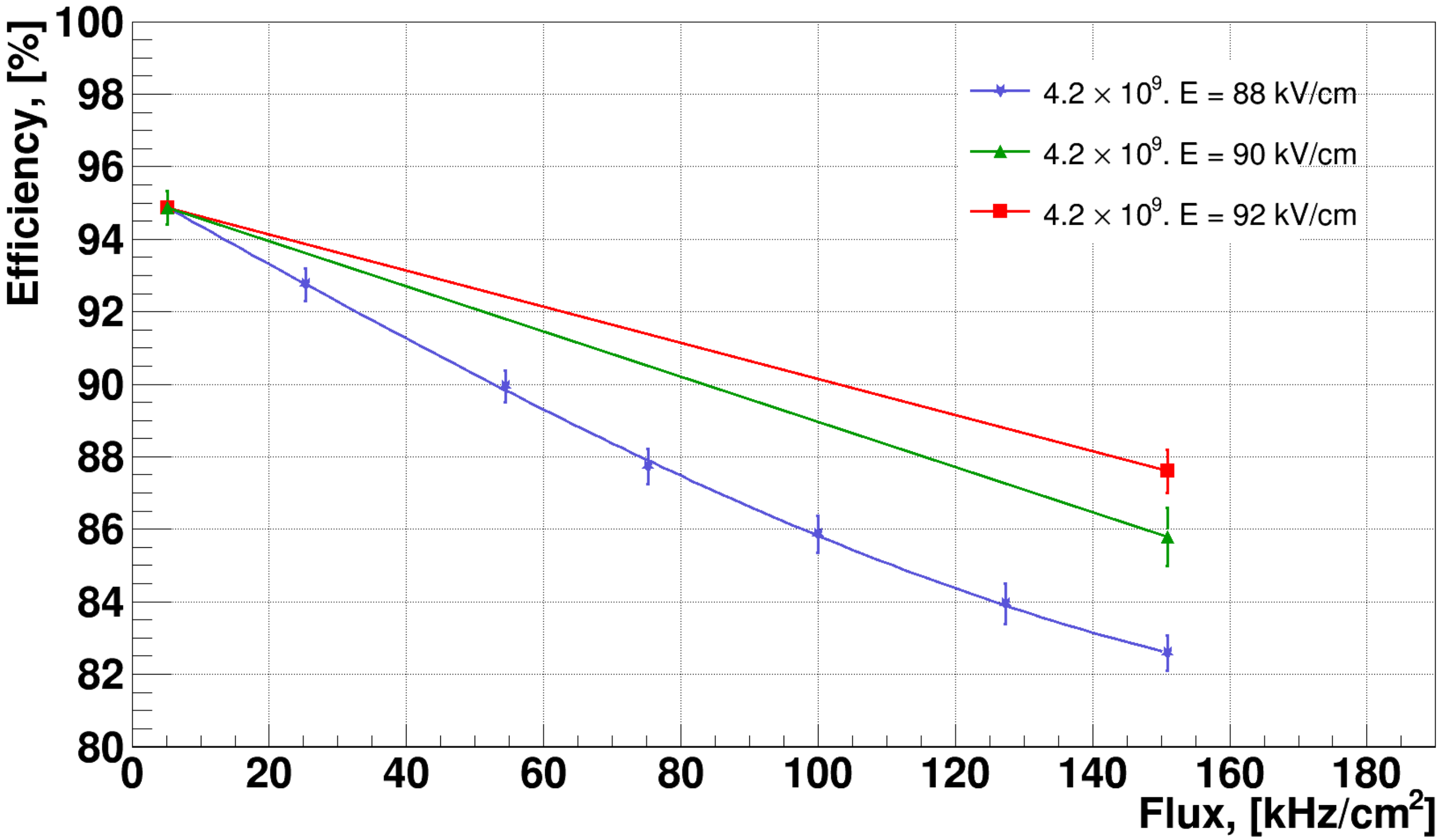


E= 88 kV/cm

Beginning of the plateau in order to work with chambers of different resistivity

Chambers with bulk resistivity of **1.4** and **3 · 10^9 Ω · cm** were having non zero current at high rates (> 150 kHz/cm^2): 0.5 – 1 μA also streamers were found even at low rates. **So, quenching is not enough at this resistivity**. In all other chambers current is zero even at high rates.

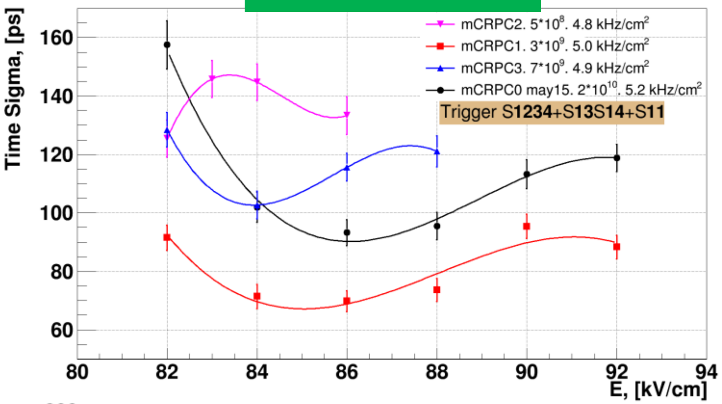
Results: Efficiency at Higher Voltage

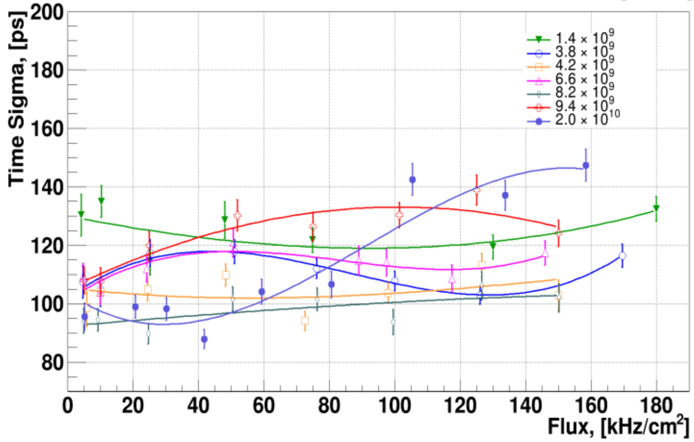


Two points were taken with higher voltage at highest rate: there is still space to work with high efficiency. Around 90% at about 150 kHz/cm^2.
Also, extra gaps could be added for even higher efficiency.

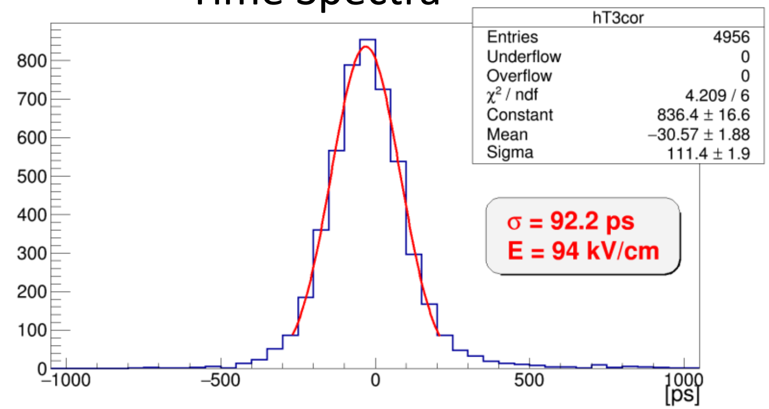
Results: Time Resolution

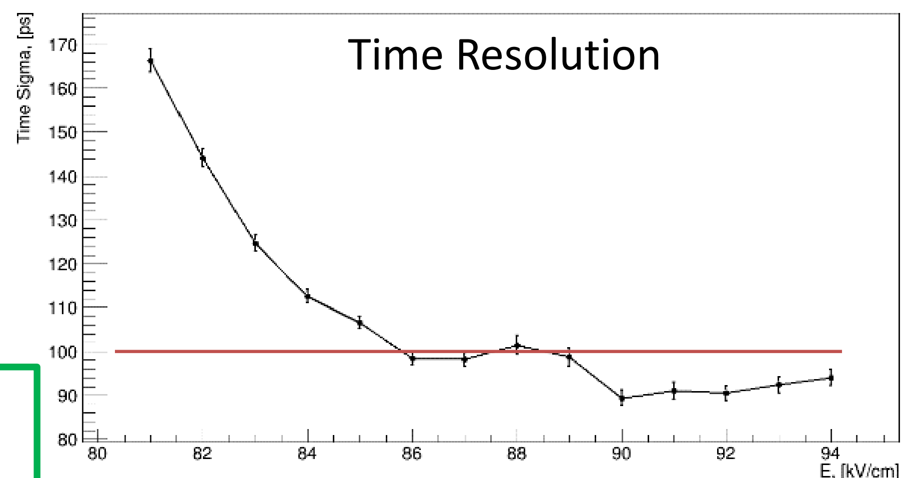
HZDR data





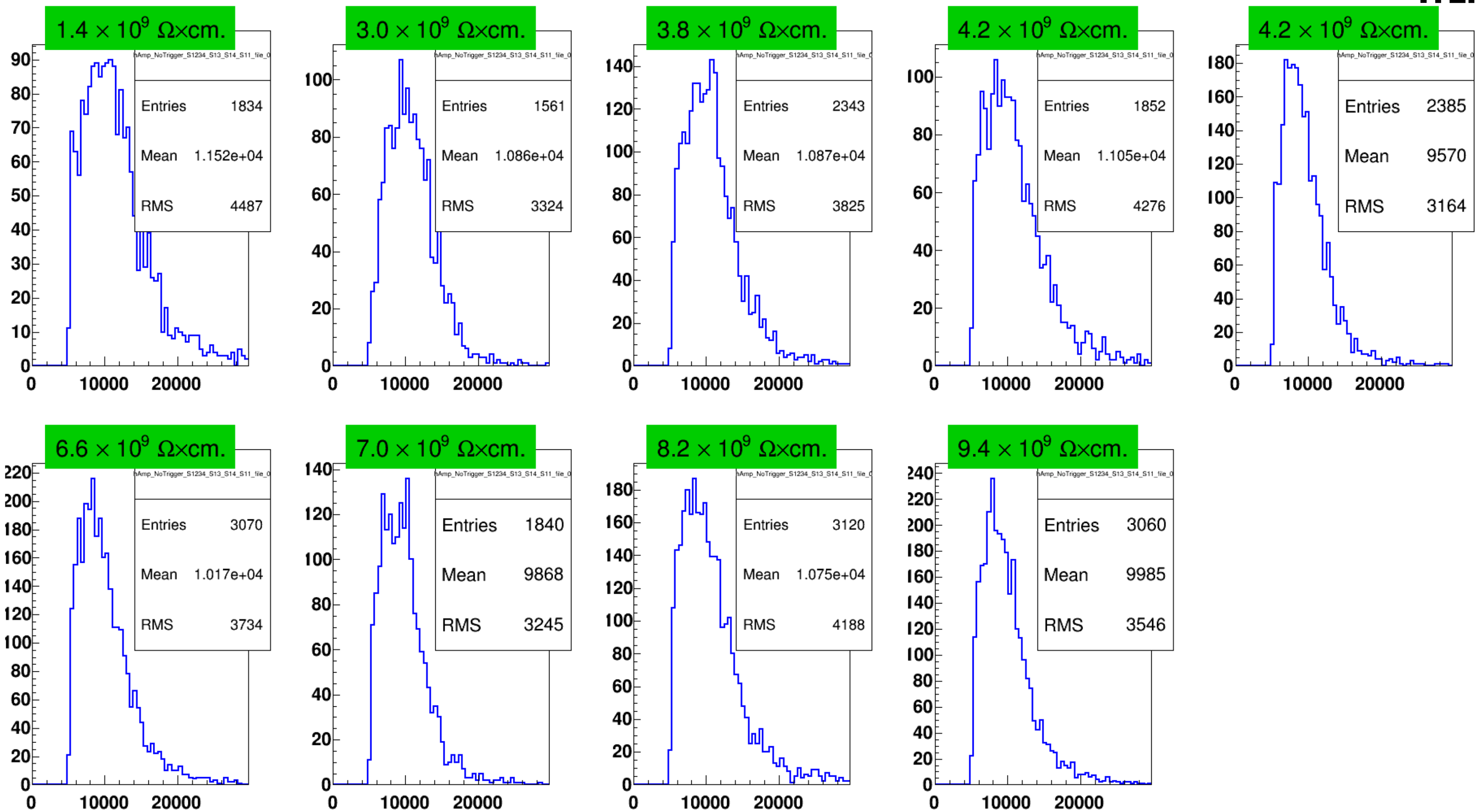
CERN data





Time resolution is at level of **80-120 ps**, depending on measurement conditions (test DAQ on FPGA, beam intensity fluctuations, high electronics jitter with MAX preamplifier).
Has to be measured with final electronics!

Results: Amplitude at Low Rate



Quite uniform chamber construction.
So, all chambers in mini-module can be put under the same voltage.

Conclusions

Developing of ceramic RPC able to operate in region of high particle fluxes (up to 160 kHz/cm^2) with efficiency higher than 90% is in final stage.

- The radiation hardness was proved.
- The mixture 90% $C_2H_2F_4$ / 10% SF_6 after long (a few months) operation showed no aging effects.
- Optimal value for bulk resistivity is found to be $R \approx 5 \cdot 10^9\ \Omega \cdot cm$
  If we need efficiency more than 95% at 200 kHz/cm^2 we should add two extra gaps → 8 gaps chamber.
- Chambers are constructed uniformly. It's confirmed that chambers can operate at the same voltage in future module.
- Time resolution at level of (80-120) ps. Strongly affected by measurement conditions. To be checked during CERN run with final ASIC PADI electronics (designed for CBM TOF).

Last check with final electronics before mass-production.

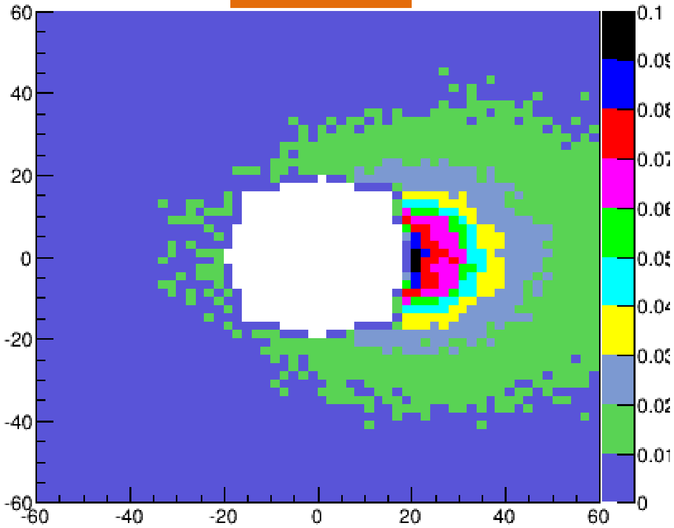
Thank you!

Backup

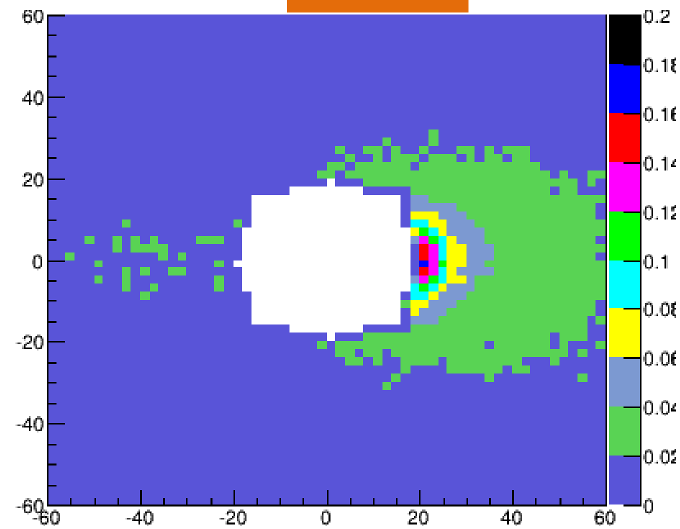
Conclusions

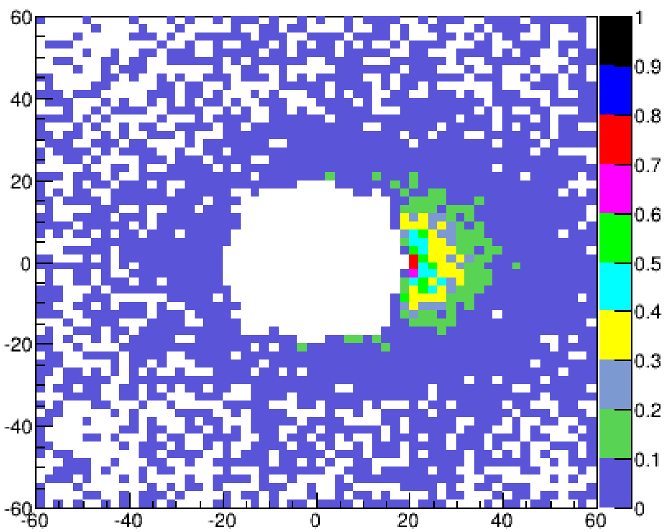
SIS100

SIS300

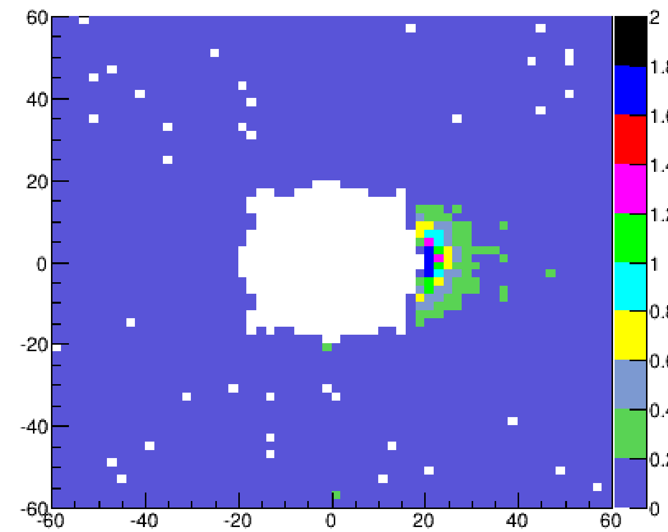


Hit density, Hits/cell/event



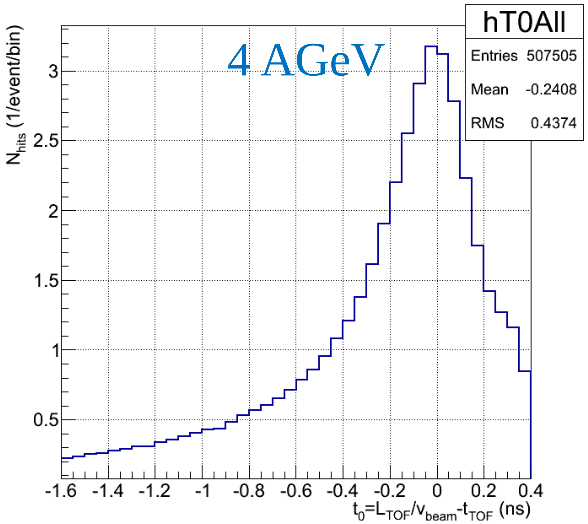


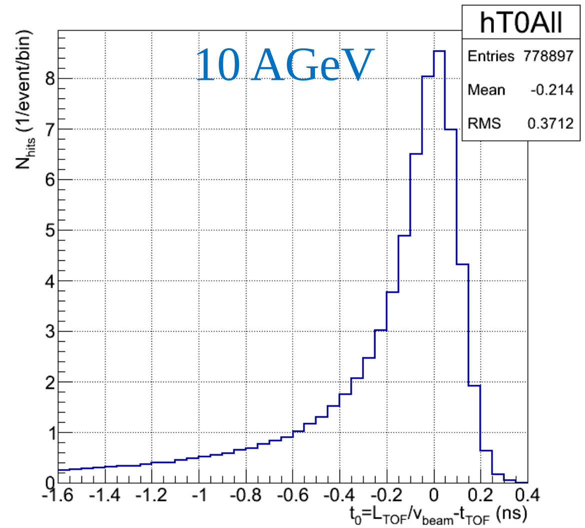
Double hit probability, %



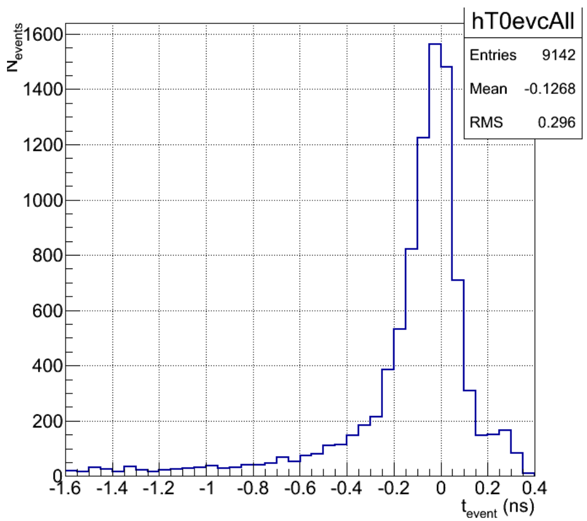
T0 estimation

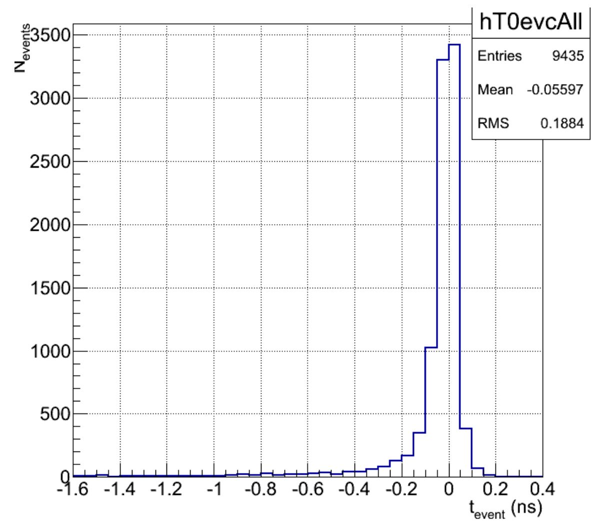
$$t_0 = L_{TOF} / v_{beam} - t_{TOF}$$





$$t_{event} = < t_0 > \text{ in the range } t_0 = t_0^{max} \pm 2\sigma_{TOF},\ \sigma_{TOF}=80 \text{ ps}$$





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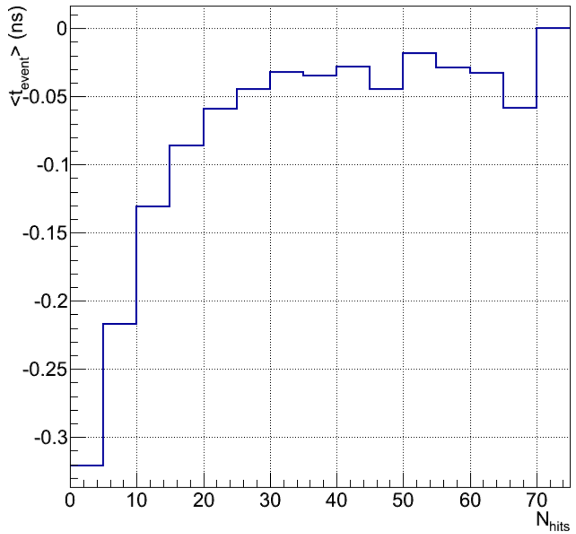
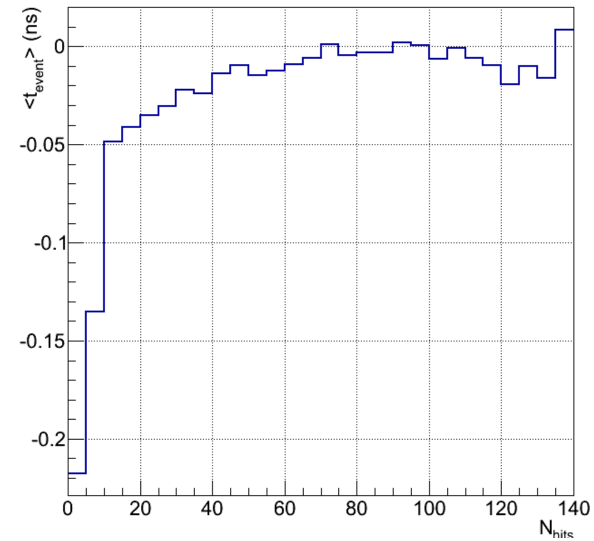
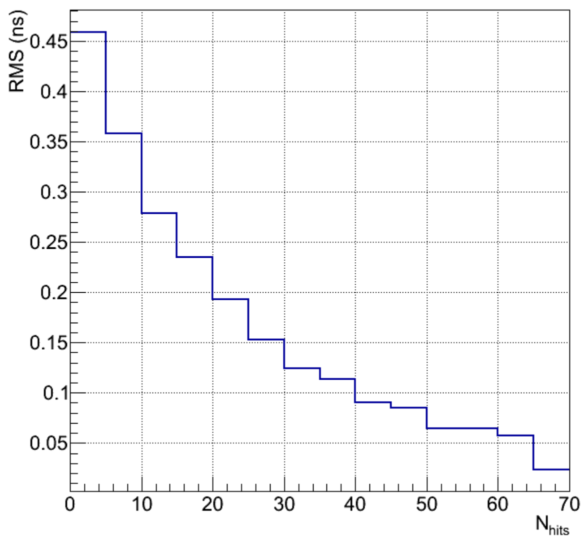
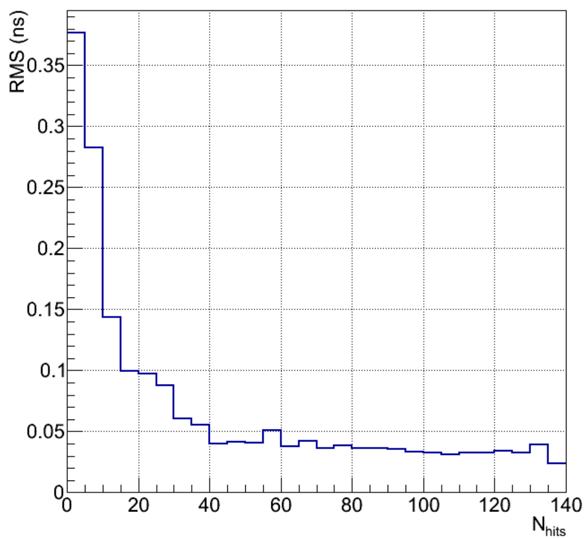




4 AGeV

10 AGeV





<t_{event}> and RMS dependences on N_{hits}