Investigation of ceramic based Resistive Plate Chambers for high rate beam environments

HZDR

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Outline

1. The Beam Fragmentation T_0 Counter for CBM
2. Ceramics RPC for radiation harsh environment
3. High rate test of Ceramics RPC for the BFT_0C

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Beam Fragmentation T_0 Counter

- Important scopes of High Energy Heavy Ion experiments are the start-time and the reaction-plane determination.
- For CBM the use of RPC for the Beam Fragmentation T_0 Counter (BFT_0C) with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration.

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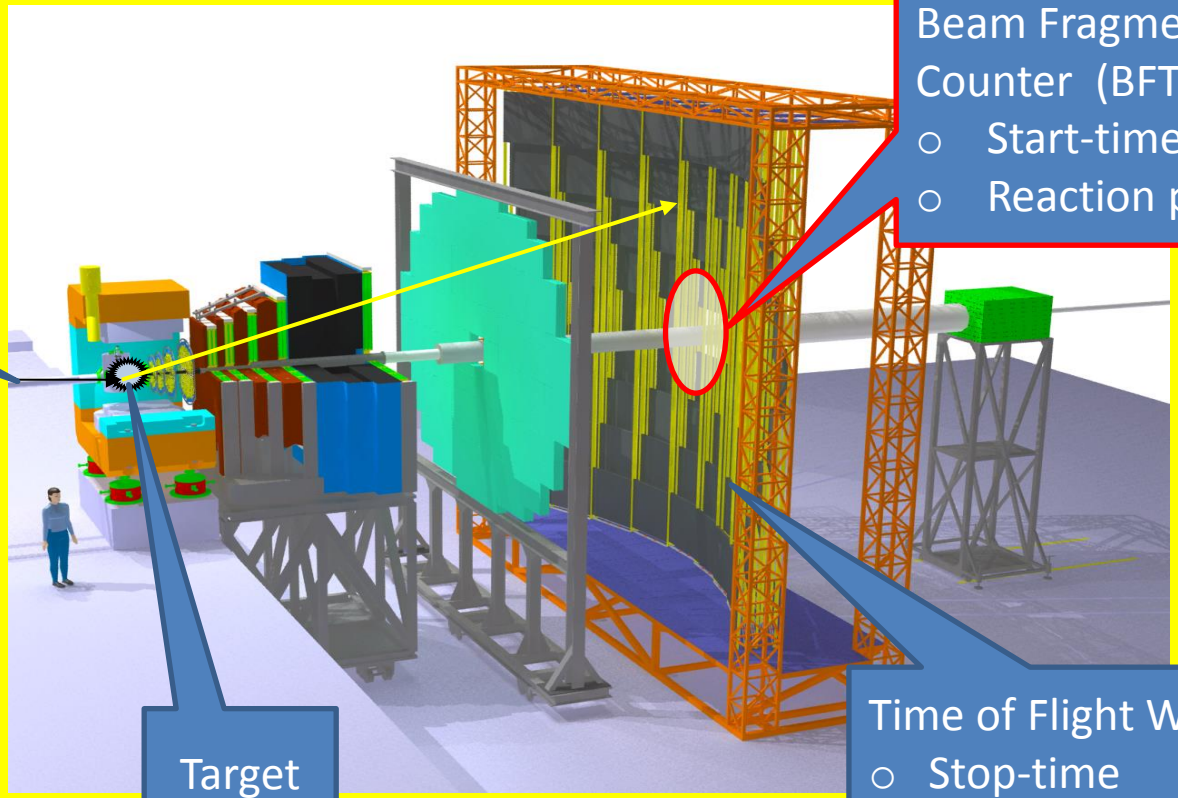
Beam Fragmentation T_0 Counter

Compressed Baryonic Matter Spectrometer



Ion Beam

Target

Beam Fragmentation T_0 Counter (BFT_0C):
- Start-time T_0
- Reaction plane

Time of Flight Wall
- Stop-time

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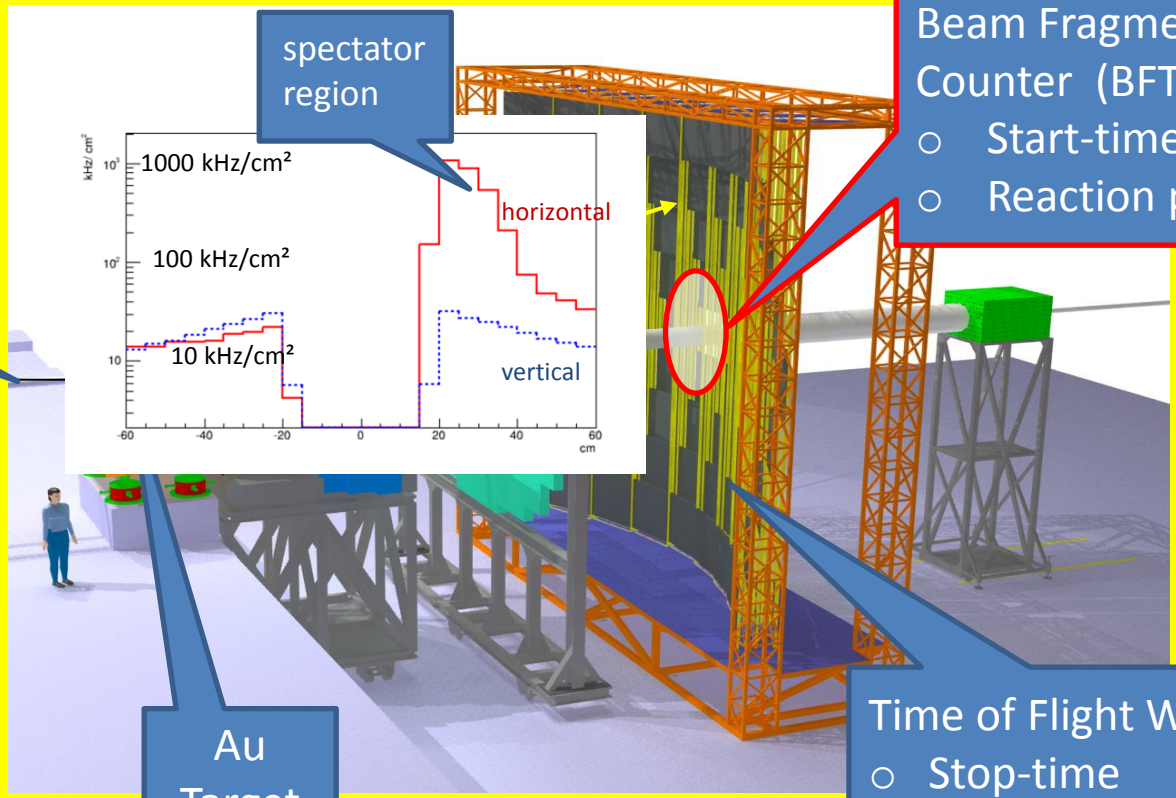
Beam Fragmentation T_0 Counter

Particle flux (UrQMD) 6 m behind the target on the BFT_0C



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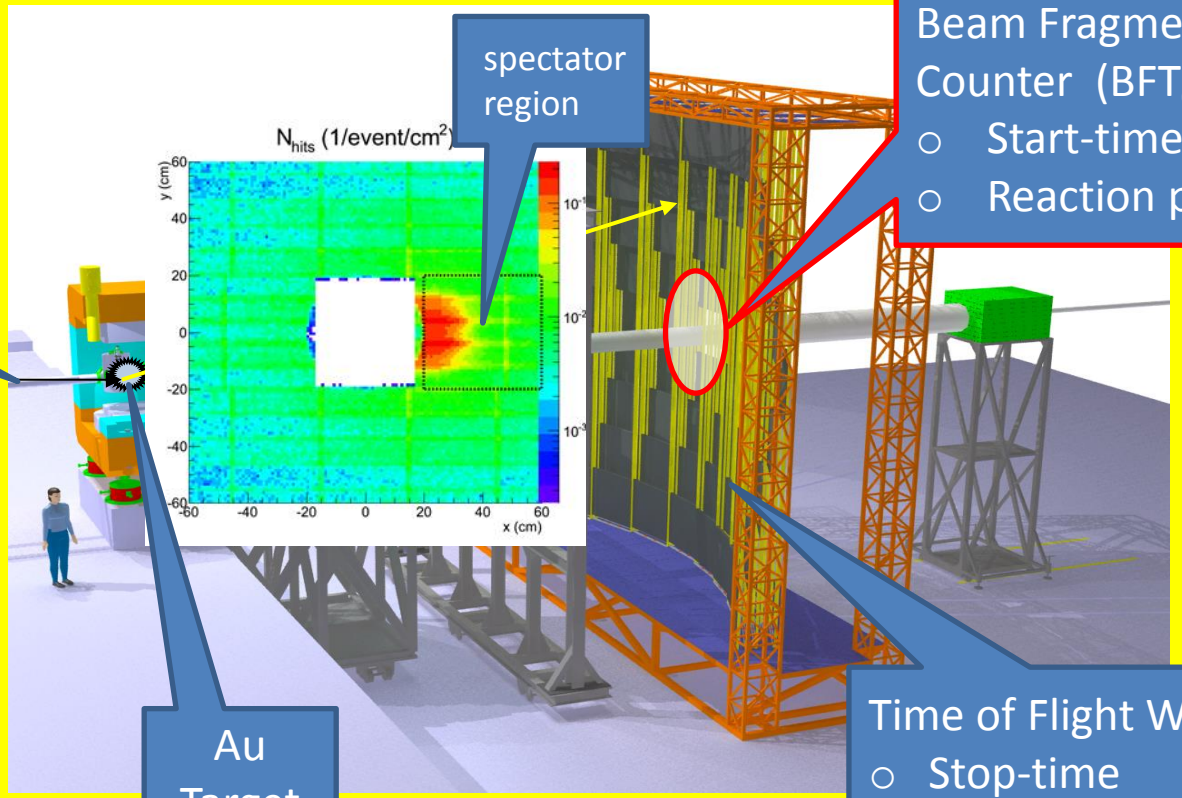
Beam Fragmentation T_0 Counter

Hit probability (UrQMD) 6 m behind the target



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Beam Fragmentation T_0 Counter

Challenges of the BFT_0C region:

- High-rate capability up to **$\geq 2x10^5 cm^{-2} \cdot s^{-1}$**

  → one floating electrode per cell
- Timing resolution: **$\sigma \leq 60$ ps**
- Efficiency: **≥ 98 %**
- Double-hit suppression: **≤ 2 %** → cell size 20x20 mm^2
- Cross-talk suppression: **$\leq 1 - 2$ %**

→ RPC with low resistive ceramics electrodes and chess-board like single cell design are under consideration

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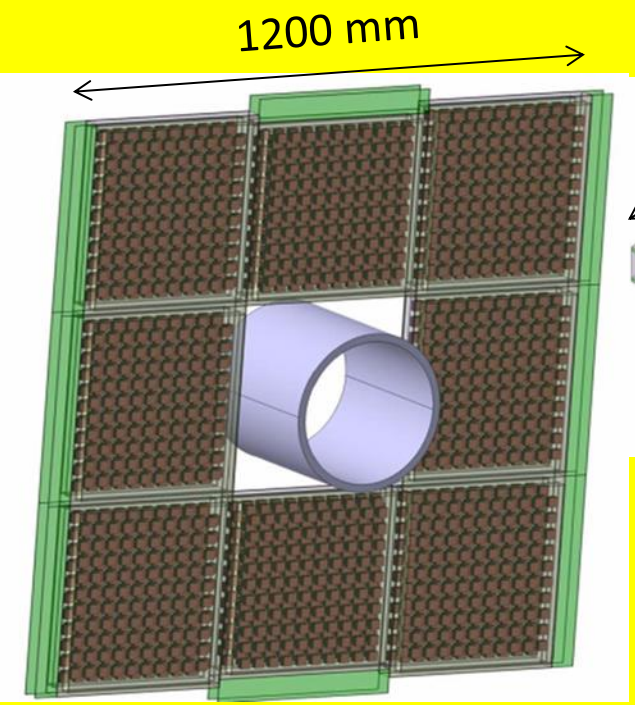
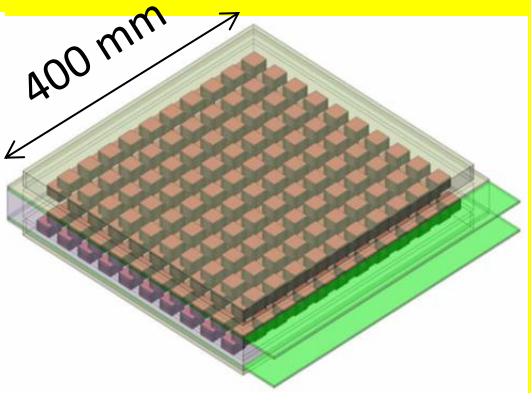
Beam Fragmentation T_0 Counter

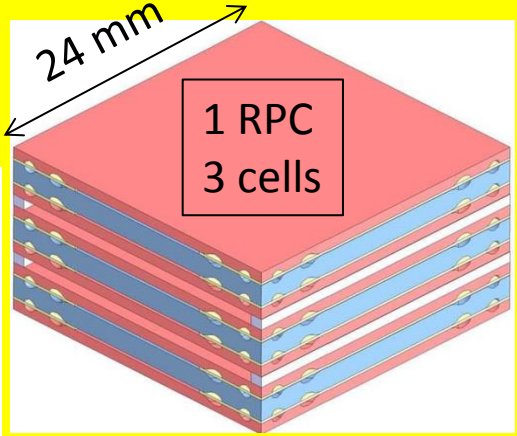
BFT_0C design

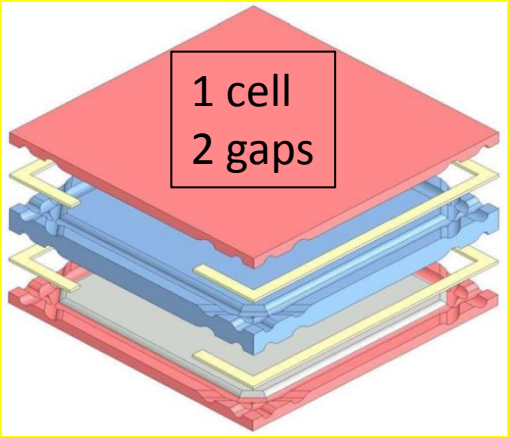


BFT_0C = 8 modules



1 module
400 RPC





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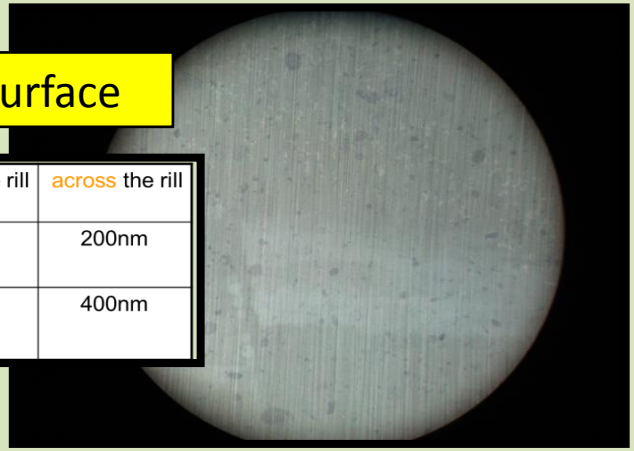
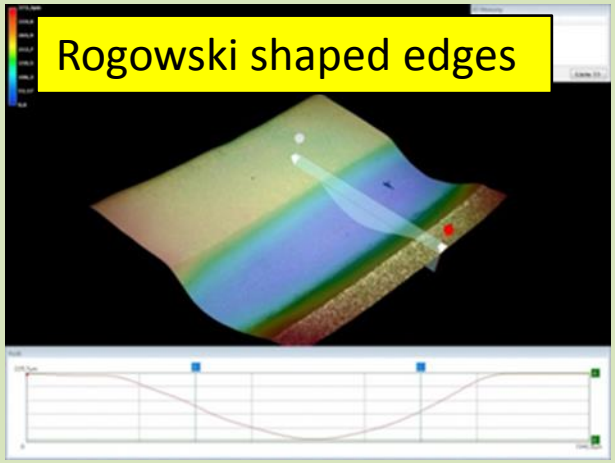
Ceramics for RPC

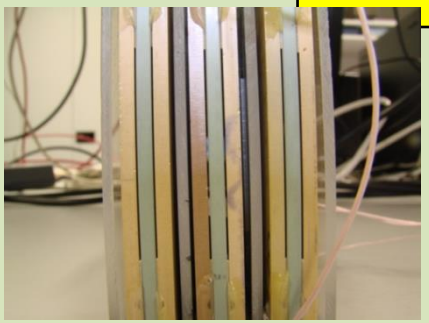
polished surface



Probe No.	along the rill	across the rill
13	90nm	200nm
2 -12	160nm	400nm

Rogowski shaped edges





Reduction of dark rate:

- Surface roughness:
  - Si_3N_4/SiC sub-µm
  - Cr-layer on $Al_2O_3 \leq 50$ nm
- Rogowski shaped edges
- Spacers: Al_2O_3 outside the active cell area

→ **0.5 Hz/cm²**

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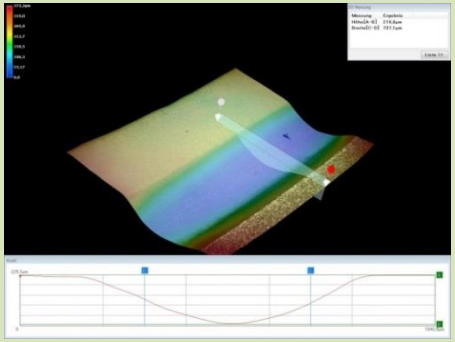
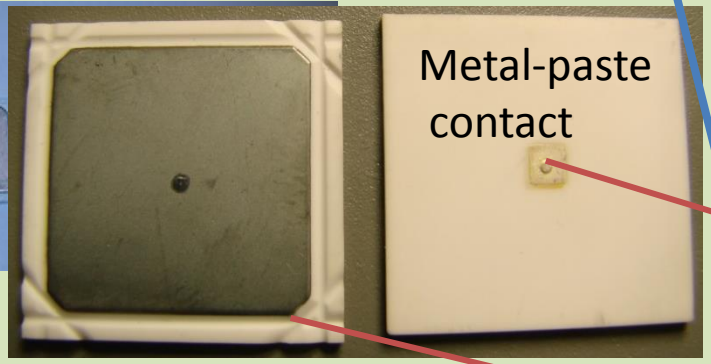
Ceramics for RPC

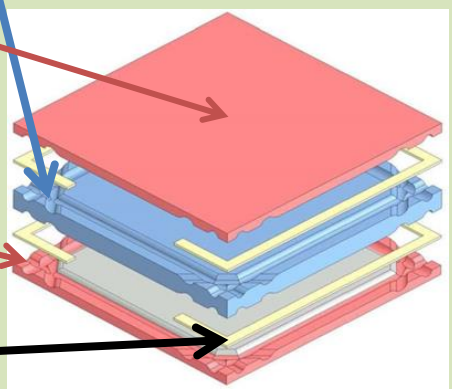
Si_3N_4/SiC resistive electrode shaped both sides



Al_2O_3 evaporated with Cu/Cr



Al_2O_3 250 µm spacers



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Ceramics for RPC

RPC design: active area 20x20 mm^2; 6 gaps 250 µm

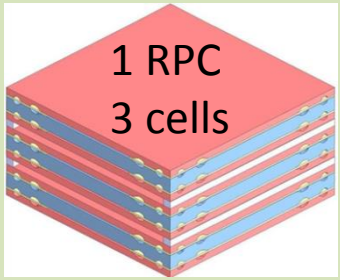
Si_3N_4/SiC resistive electrodes

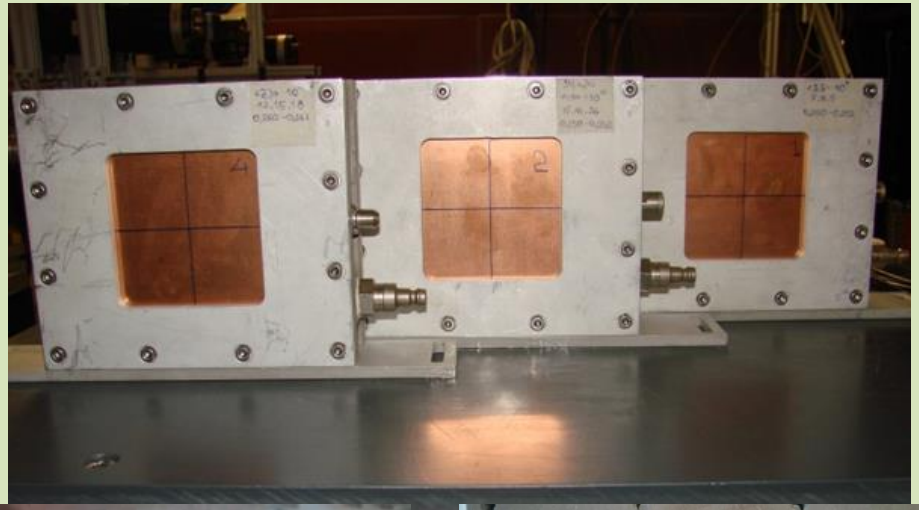
mCRPC0 – $2x10^{10}$ Ω cm

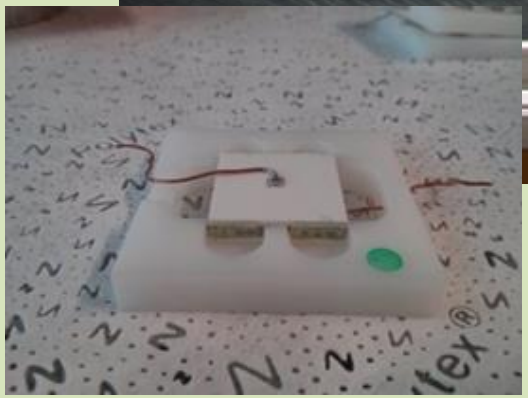
mCRPC1 – $3x10^{9}$ Ω cm

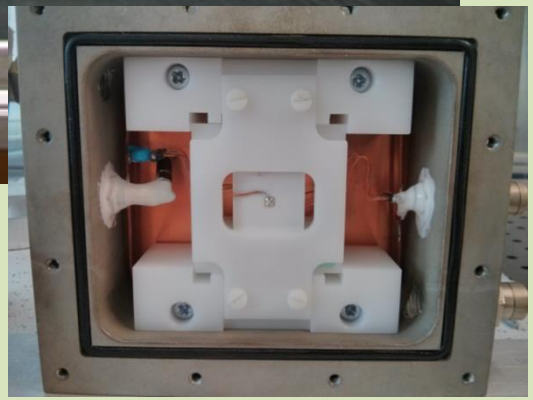
mCRPC2 – $5x10^{8}$ Ω cm

mCRPC3 – $7x10^{9}$ Ω cm









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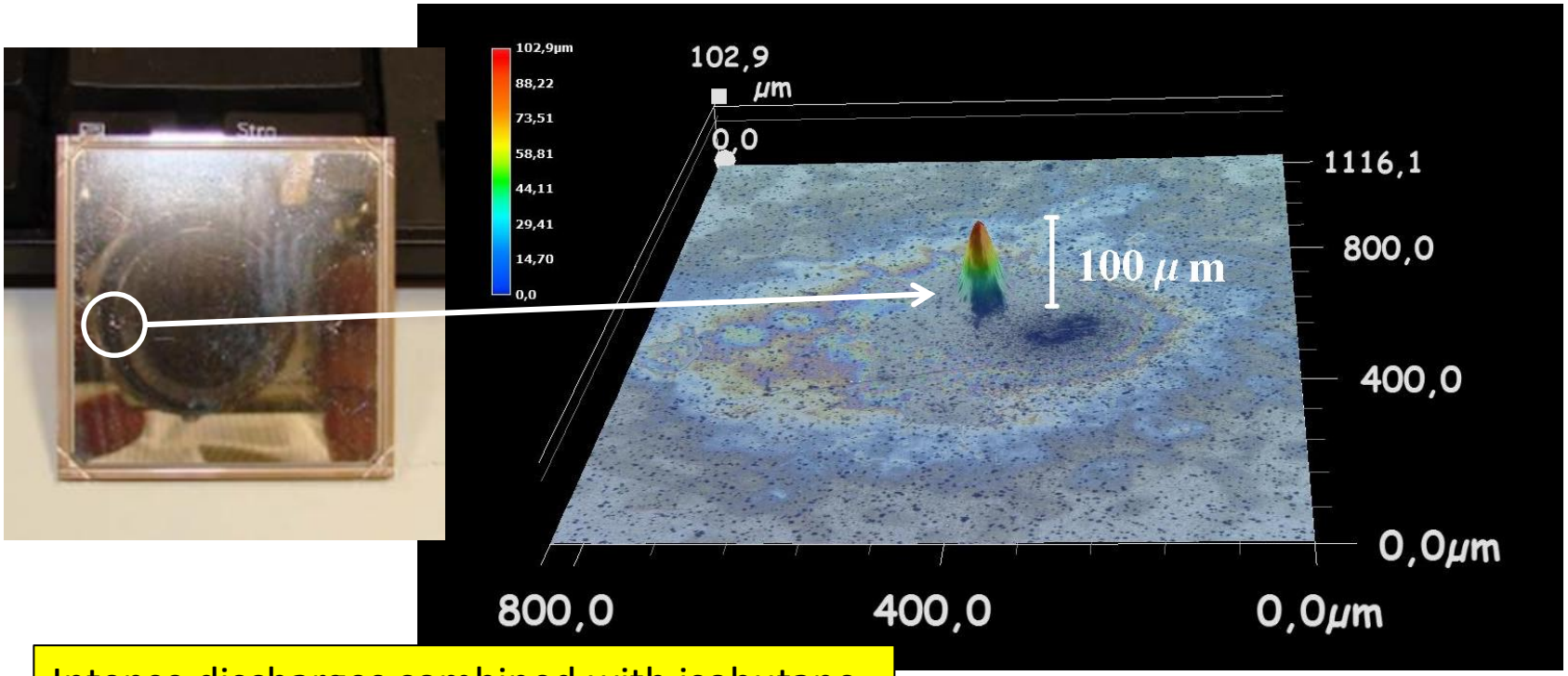
RPC gas mixture



Intense discharges combined with isobutane provokes whisker generation at Cr-surface

→ **No isobutan!**

Gas-mixture for RPC: 90% Freon + 10% SF_6

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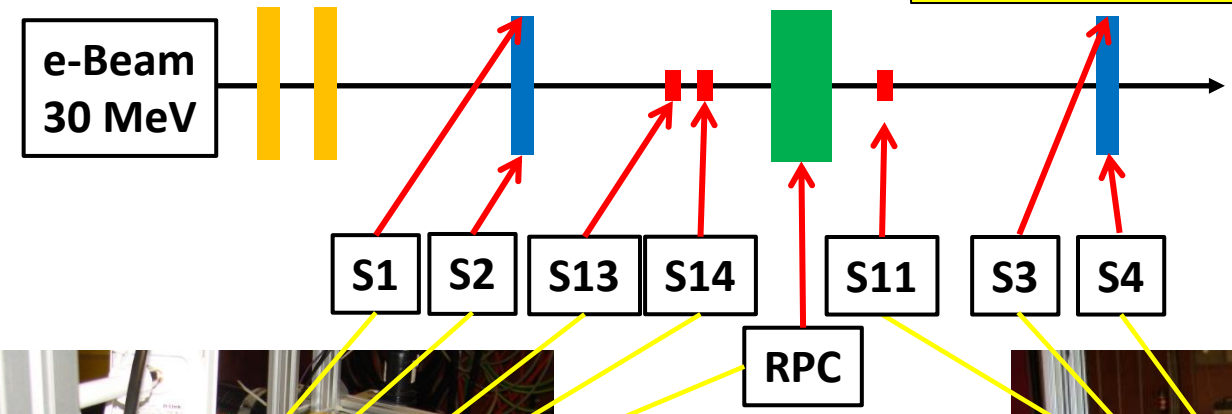
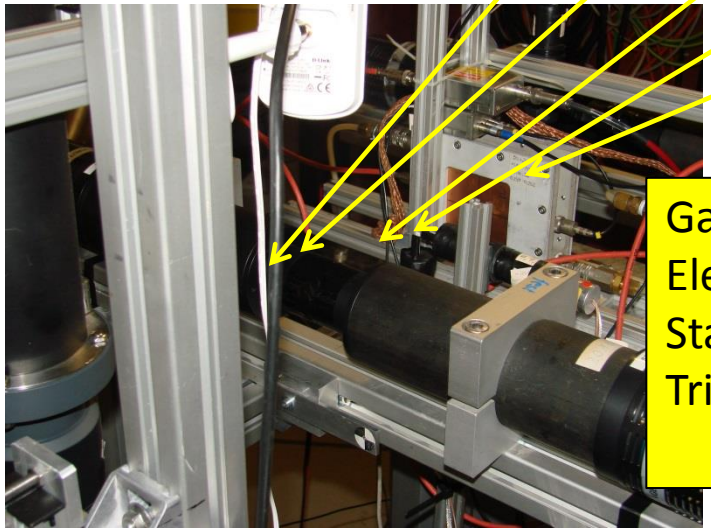
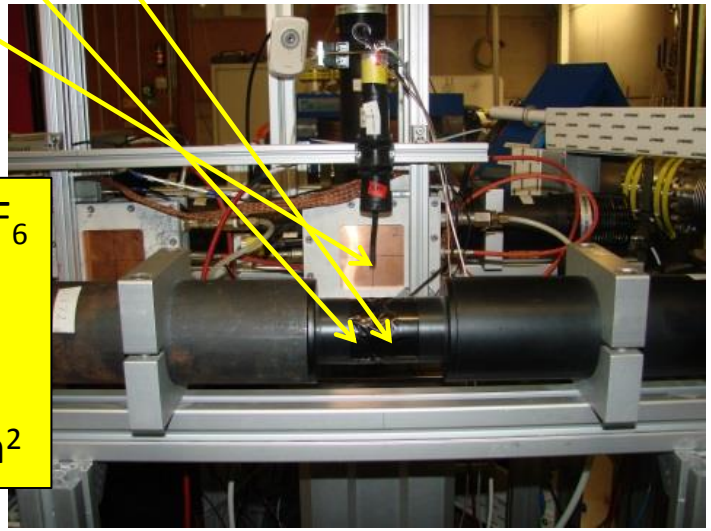
RPC test facility @ ELBE (electrons)

monoenergetic , single electrons
energy 30 MeV
pulse duration 5 ps
flux ≤ 500 kHz/cm²

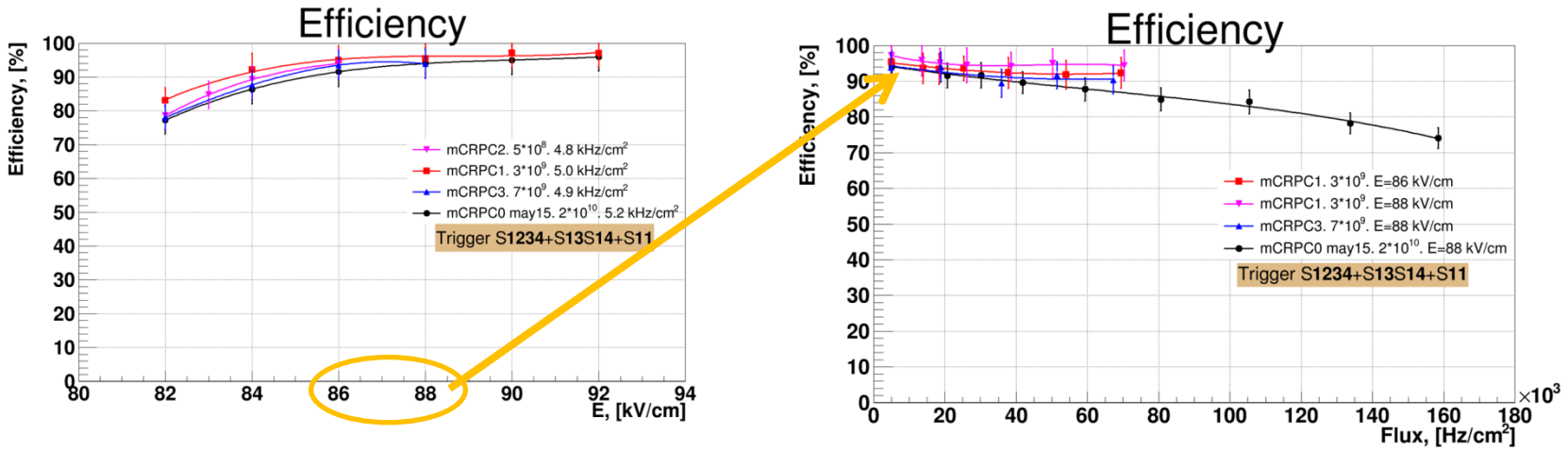


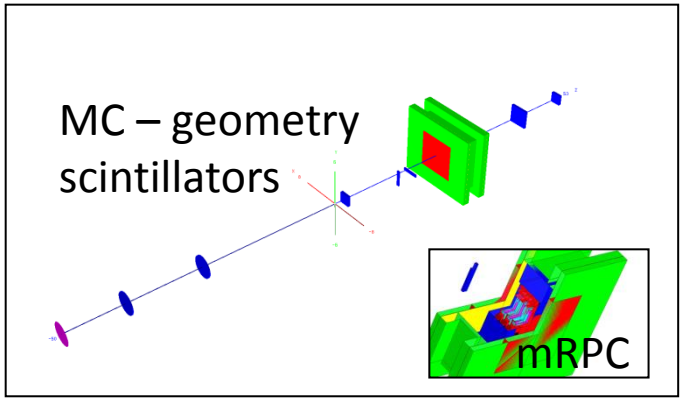




Gas: 90% Freon + 10% SF_6
Electronics: MAX3760
Start system: σ_{RF} = 35 ps
Trigger scint. size:
5x5 to 20x20 mm²

RPC test - electrons





- $2x10^{10}$ Ωcm: ε fast degrease with flux
- $5x10^{8}$ Ωcm: ε is not capable to get on the efficiency plateau: unstable work and lots of streamers starting from 87-88 kV/cm
- 10^{9} Ωcm: most suitable resistivity order for our aims

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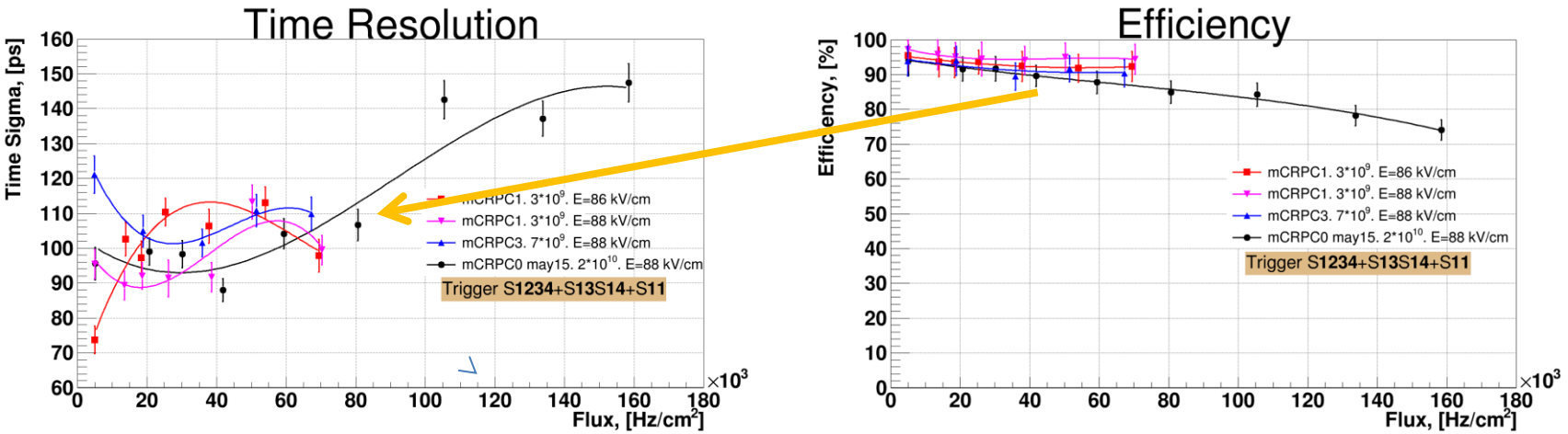
RPC test - electrons



- For all probes (0,1,3) the time resolution remains between 90 ps and 110 ps below the flux of $7x10^4$ $cm^{-2}s^{-1}$
- For probes (1,3) no data exists above $7x10^4$ $cm^{-2}s^{-1}$ due to DAQ problems at higher rates
- For probe (0) with $2x10^{10}$ Ωcm in correlation with the steep efficiency drop below 90 % beginning from $4x10^4$ $cm^{-2}s^{-1}$ the time resolution is rising and amounts to 150 ps at $1.6x10^5$ $cm^{-2}s^{-1}$

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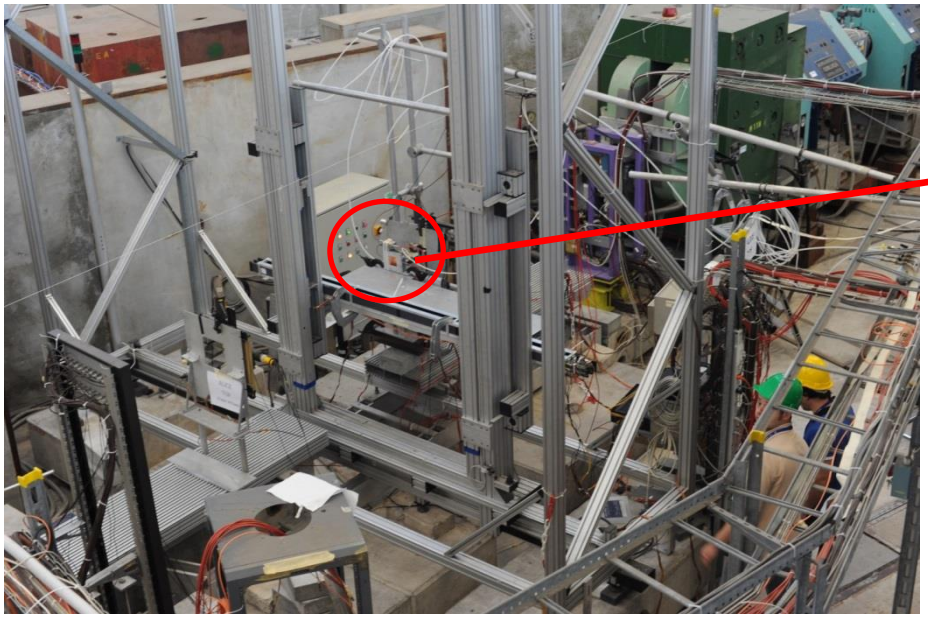
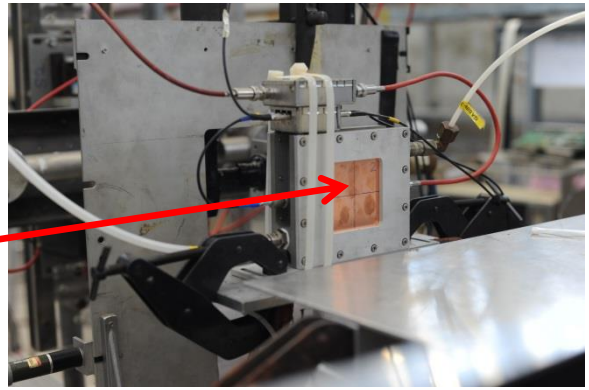
RPC test facility @ CERN (pions)





Beamline: T10
Pion rate: few kHz/cm^2
Gas: 90% Freon + 10% SF_6
Electronics: MAX376012
Trigger scint. size: 20x20 mm^2
Start system: σ_{RF} = 50 ps

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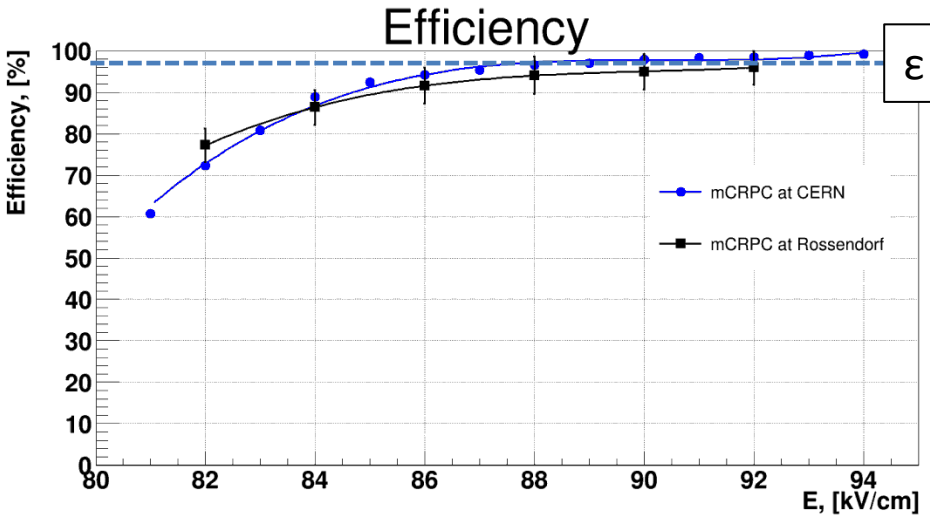
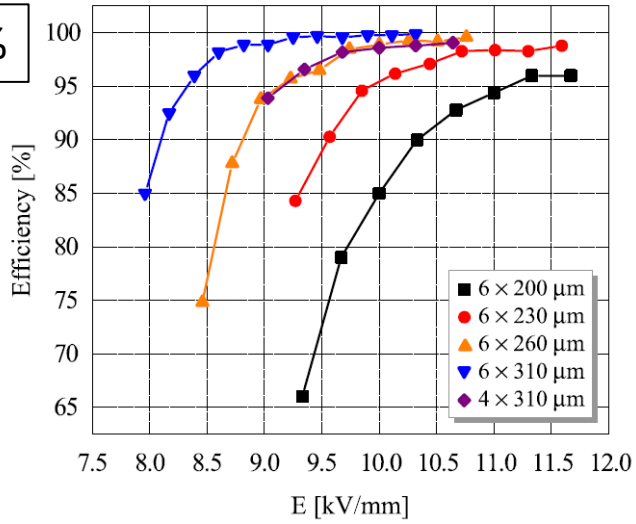
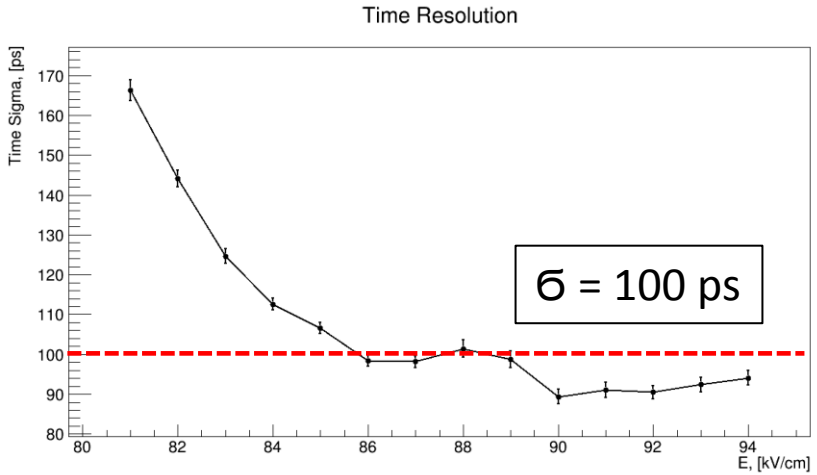
RPC test @ CERN (pions)







- Pion efficiency ε ≈ 98 %

about 3% higher than for 30 MeV electrons

- Time resolution σ ≈ 90 ps

comparable with electron results

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Summary

- A Beam Fragmentation T_0 Counter of 120x120 cm^2 in the innermost region of the CBM TOF wall with 2x2 cm^2 chess-board like single RPC cells is under consideration.
- Radiation hard low resistive Si_3N_4/SiC composite is a candidate for the floating electrodes of the RPC cells.
- A manufacturing process has been developed to produce ceramic electrodes with a bulk resistivity varying between 10^8 and 10^{10} Ω cm.
- The outer electrodes are Cr-plated Al_2O_3 sheets with a central contact pin.
- The dark count rate has been reduced to 0.5 Hz/cm^2 by special material treatments .
- To define the bulk resistivity, four RPC cells of different bulk resistivity have been investigated. 10^9 Ω cm is the most suitable resistivity order for our aims.
- RPC tests with relativistic electron and pion beam fluxes of up to 2x10^5 $cm^{-2}s^{-1}$ have been provided.
- The detection efficiency amounts to 98 % and is sufficient for CBM, while the time resolution amounts to 90 ps and needs still further improvement.

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Outlook

- Precise scan of the bulk resistivity in order to determine the optimal value with an acceptable values margin
- Assembling of eight RPC with following bulk resistivity's in a mini-module:
  1 ch. 1.4×10^9 ; 2 ch. 3.8×10^9 ; 2 ch. 4.2×10^9; 1 ch. 6.6×10^9; 1 ch. 8.2×10^9 and 1 ch. $9.4 \times 10^9\ \Omega$ cm
- Estimation of the streamer excitation
- Implementation of PADI-FEE
- Radiation hardness test of powered RPC cells with fast neutrons
- Start of the Si_3N_4/SiC ceramics composite production of 10 m^2 for all BFT0C-modules

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