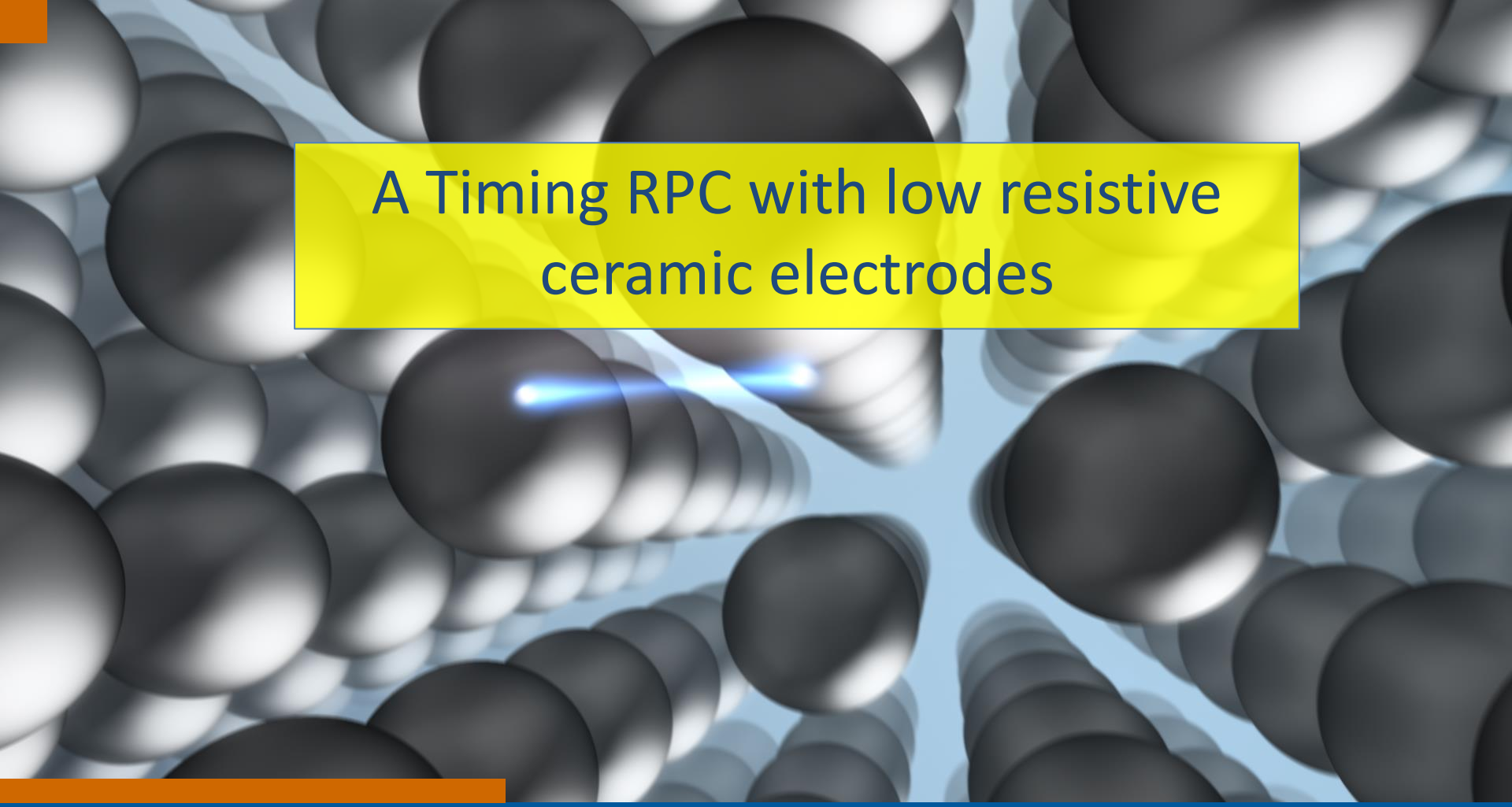
A Timing RPC with low resistive ceramic electrodes



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Introduction

- Important scopes of High Energy Heavy Ion experiments are the start-time and the reaction-plane determination.
- For CBM/FAIR the use of RPC for the Beam Fragmentation and Start Time Counter (BFT_0C) with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration.
- Latest tests with 8 prototypes have been provided with high flux electrons @ ELBE accelerator

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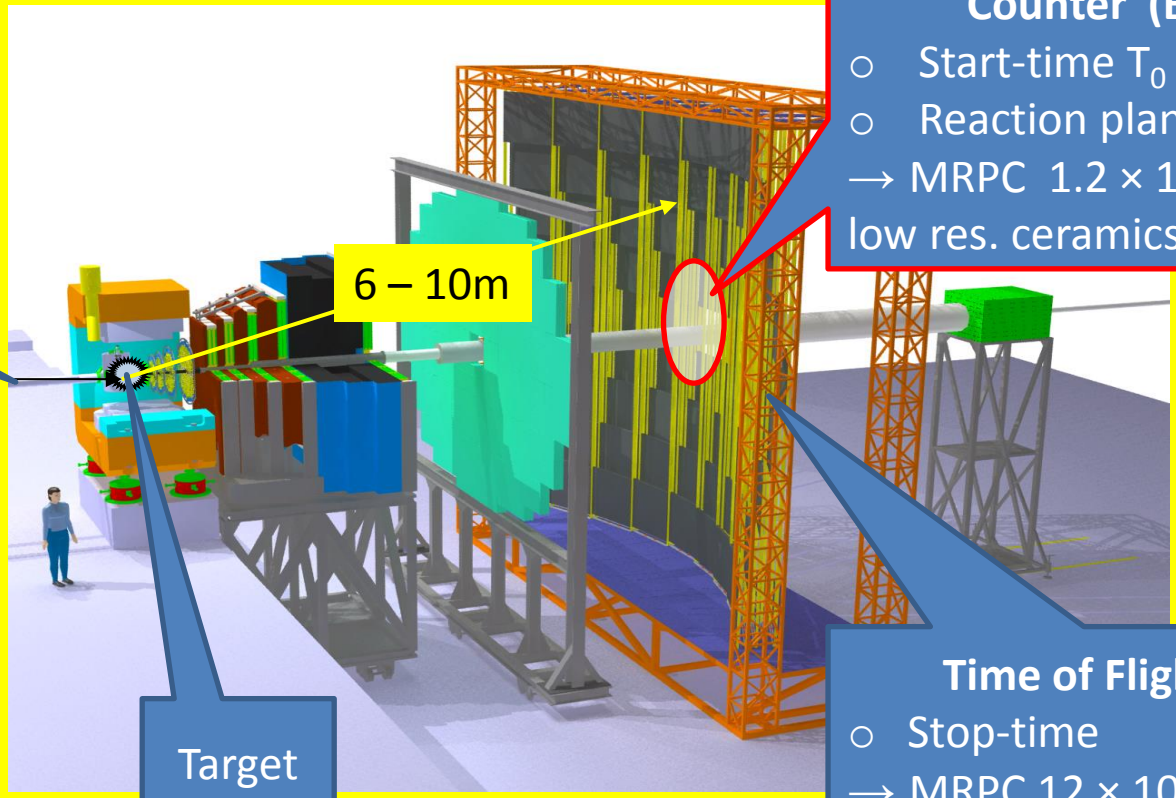
Compressed Baryonic Matter Spectrometer @ FAIR



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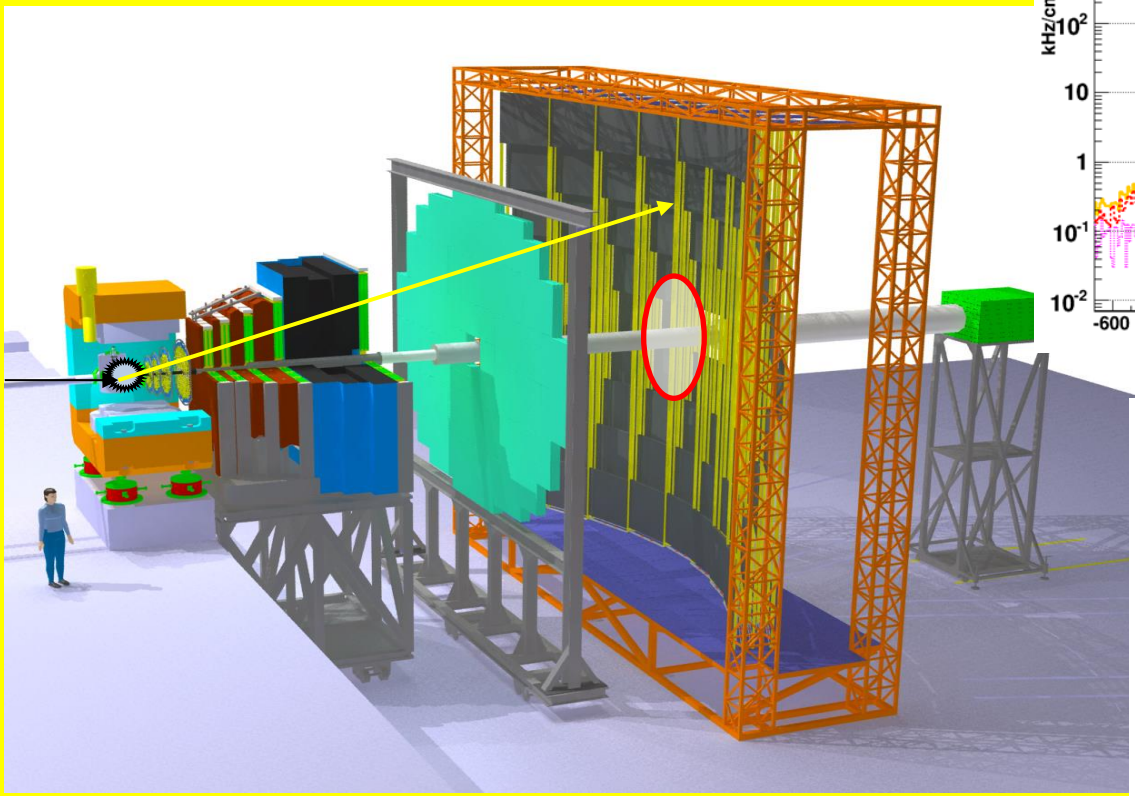
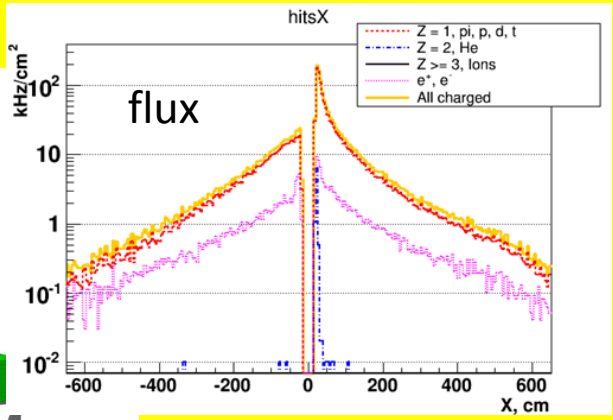
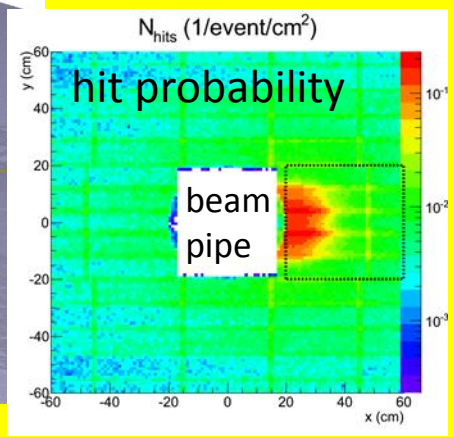
Beam Fragmentation T_0 Counter

SHIELD-Simulation : Au(10 AGeV) + Au ⟶ x







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Beam Fragmentation T_0 Counter

Challenges of the BFT_0C region:

- High-rate capability up to **$\geq 2\times10^5 cm^{-2}\cdot s^{-1}$**

  → one floating electrode per double gap cell

- Timing resolution: **$\sigma \leq 60$ ps**
- Efficiency: **≥ 98 %**
- Double-hit suppression: **≤ 2 %**

  → active cell size 20×20 mm^2

- Cross-talk suppression: **≤ 1 - 2 %**

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

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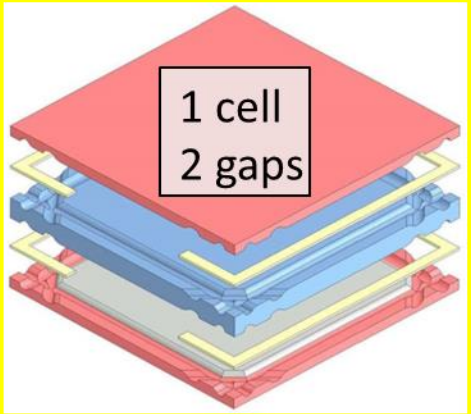
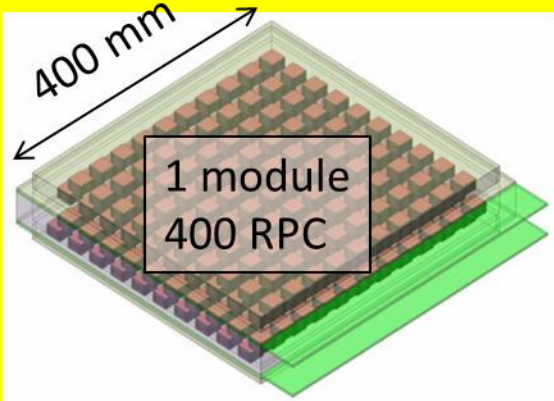
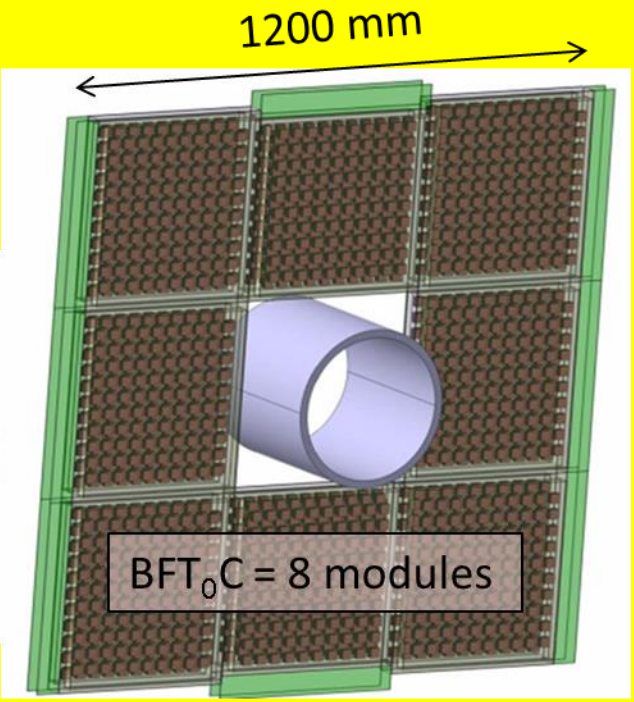
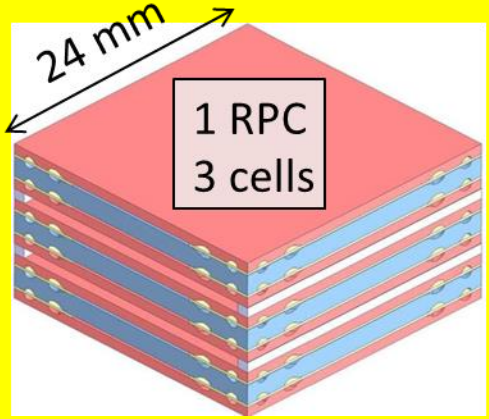
Beam Fragmentation T_0 Counter

BFT_0C design









9600 cells

3200 read out channels

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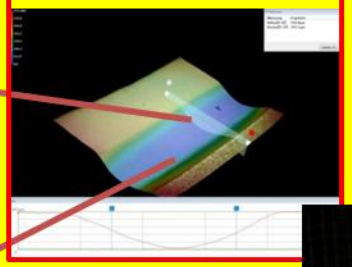
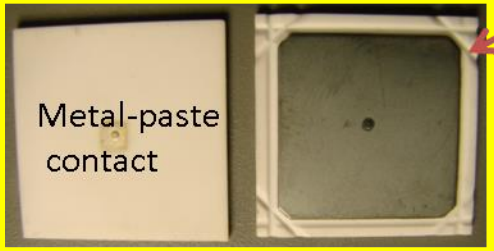
Prototyp of Ceramic RPC

Si_3N_4/SiC low resistive electrode

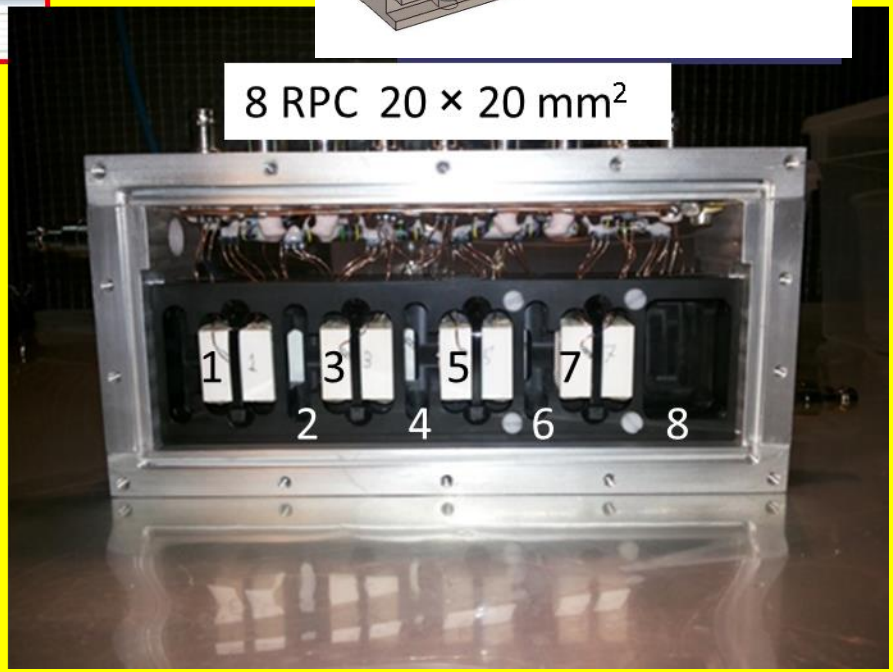
Rogowski shape



Al_2O_3 evaporated with Cu/Cr



Al_2O_3 250 µm spacers



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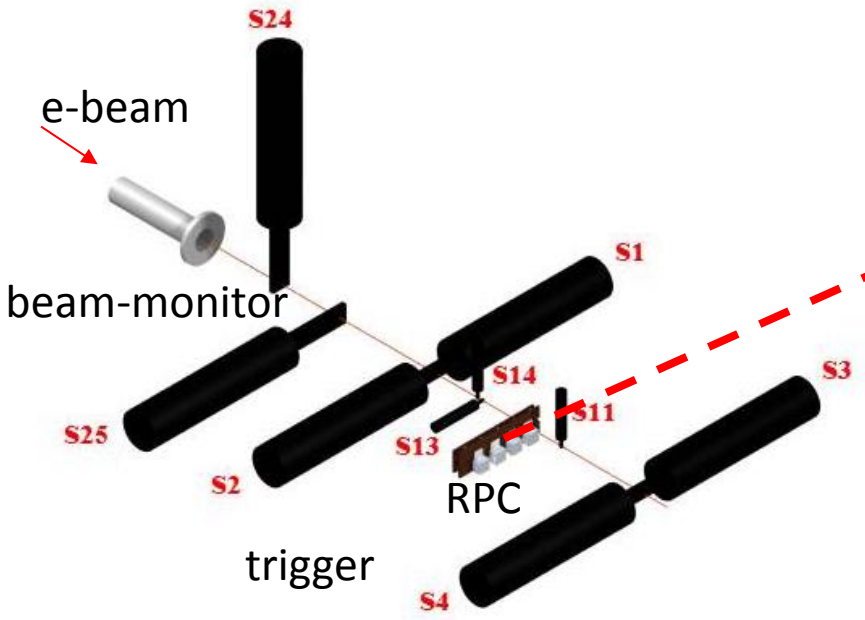
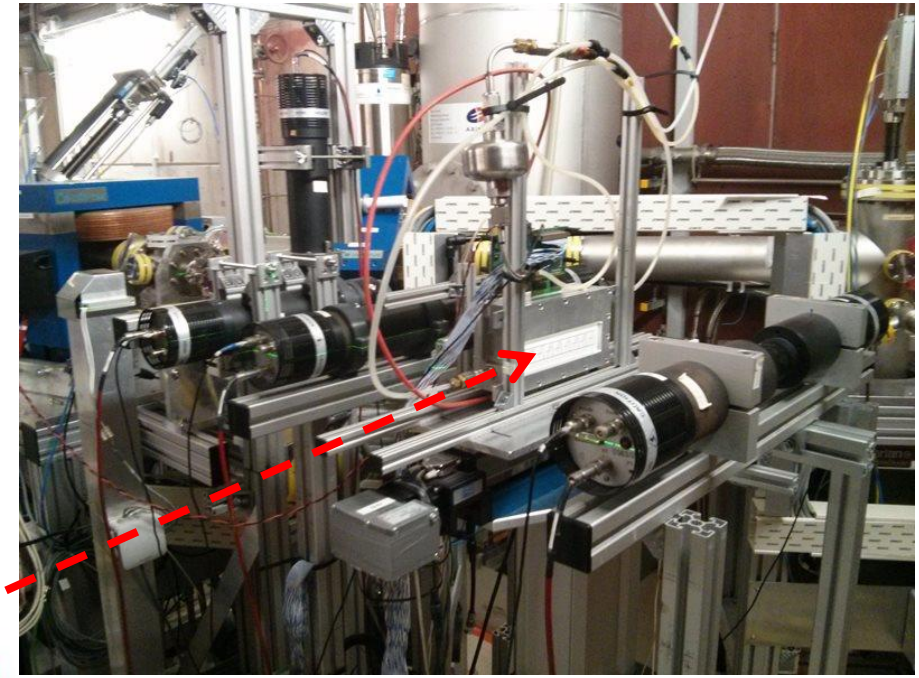
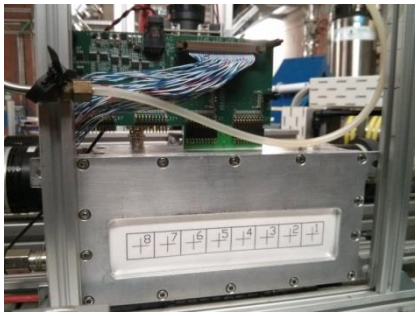
Prototype test @ ELBE (electrons)

monoenergetic , single electrons	
energy	30 MeV
pulse duration	5 ps
flux	≤ 500 kHz/cm^2





Gas:
90% Freon + 10%SF_6
RPC: 8 channels
Trigger scint. size:
5x5 to 20x20 mm^2



RPC

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Prototype upgrade

2015/16:

- ➢ Inside the RPC box
- HV supply: 8 single channels for 8 RPC
- Signal: direct passive HF-filter connection to Lemo feedthrough
- ➢ Outside the RPC box:
- Signal amplifier: MAXIM 3760 (analog and timing)
- DAQ: TDC and QDC → TIME and AMPLITUDE

2017:

- ➢ Inside the RPC box: HV-distribution and Readout board
- One HV supply for all 8 RPCs
- Signal shaper: no overshoot, 5 ns
- Signal amplifier: × 2 and 100 Ω diff. output
- ➢ Outside the RPC box:
- Signal amplifier: PADI X
- DAQ: VFTX → TIME and TOT

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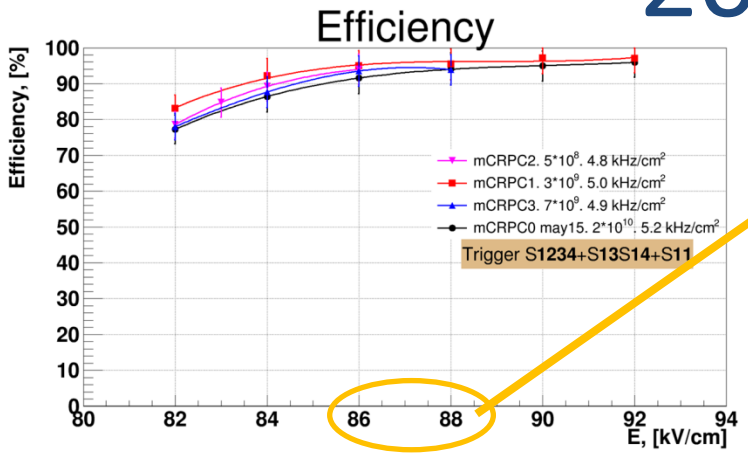
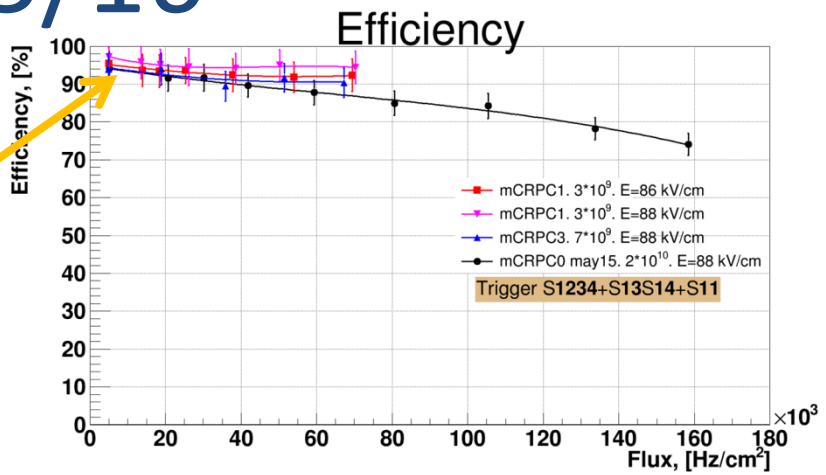
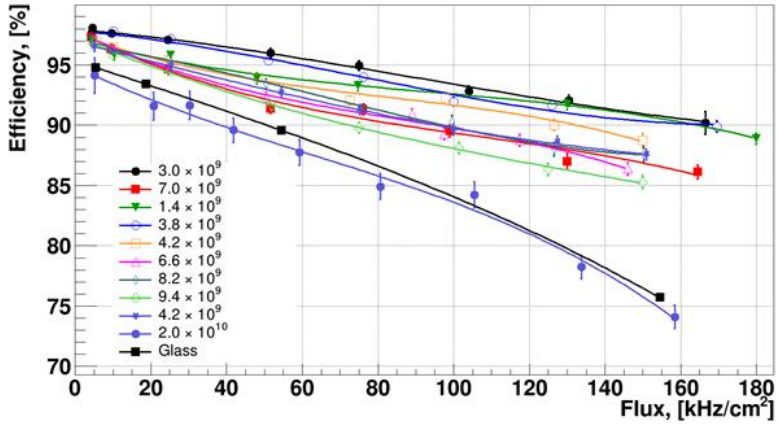
Working curve: Resistivity selection 2015/16





- $2x10^{10}$ 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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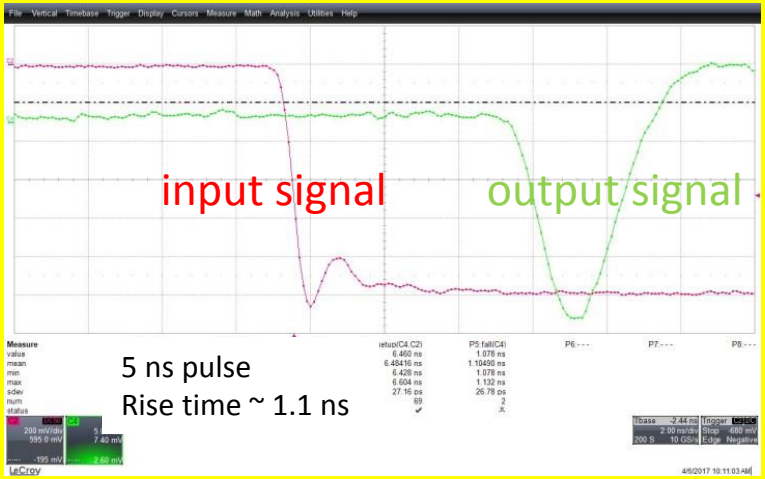
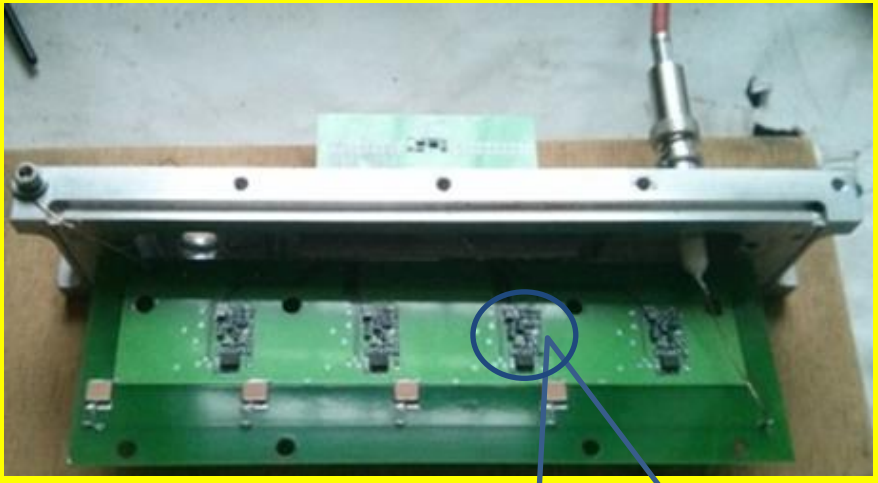
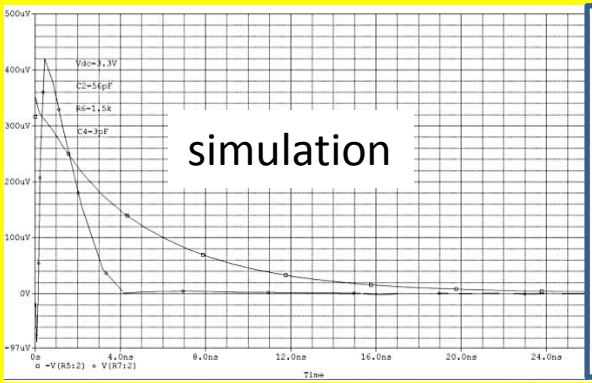
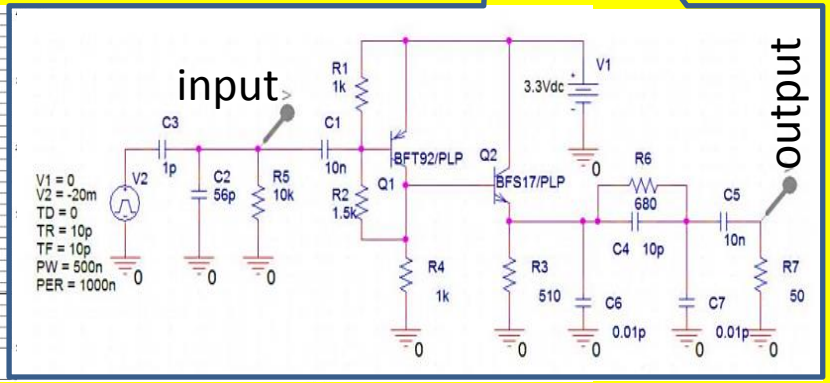
Readout board









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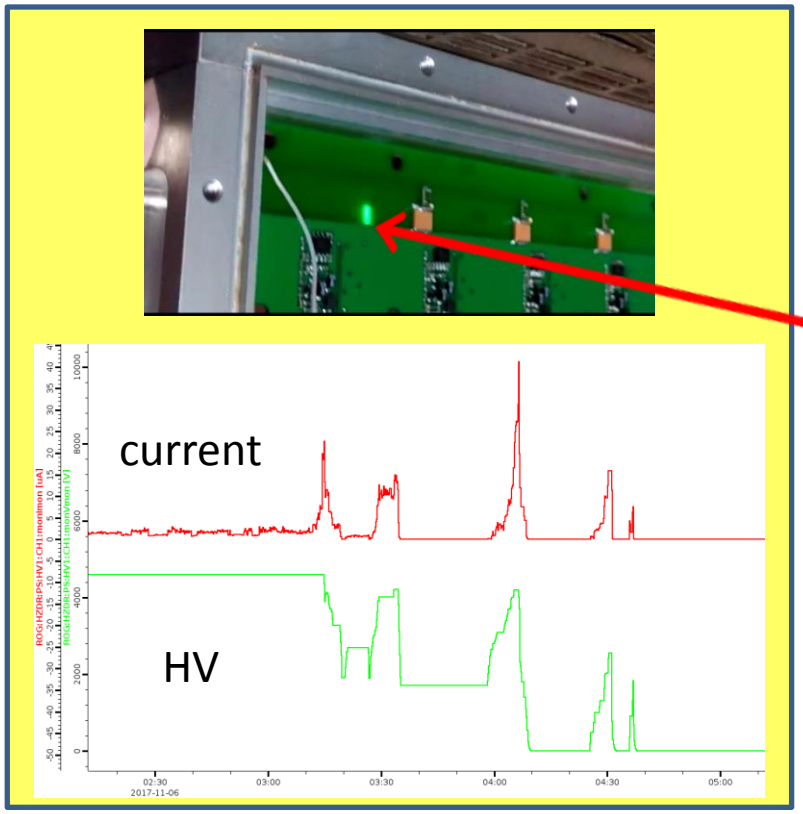
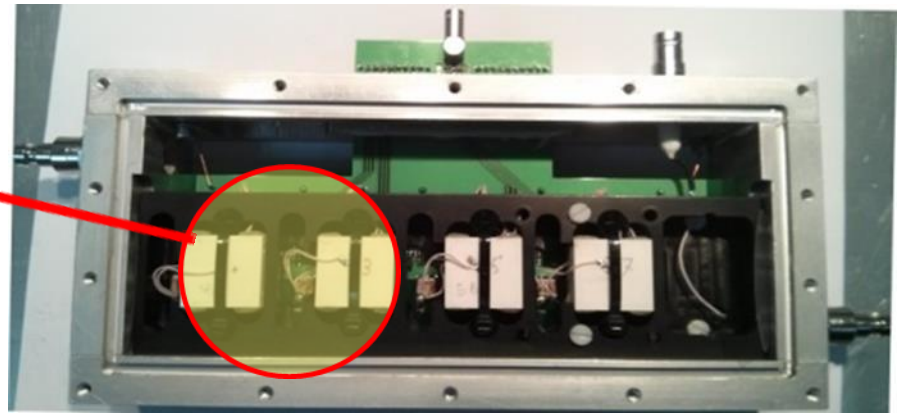
Readout board: HV problem

HV break through in channel 2

after 5 days of operation under high load (electrons, gammas)





→ PCB failure !

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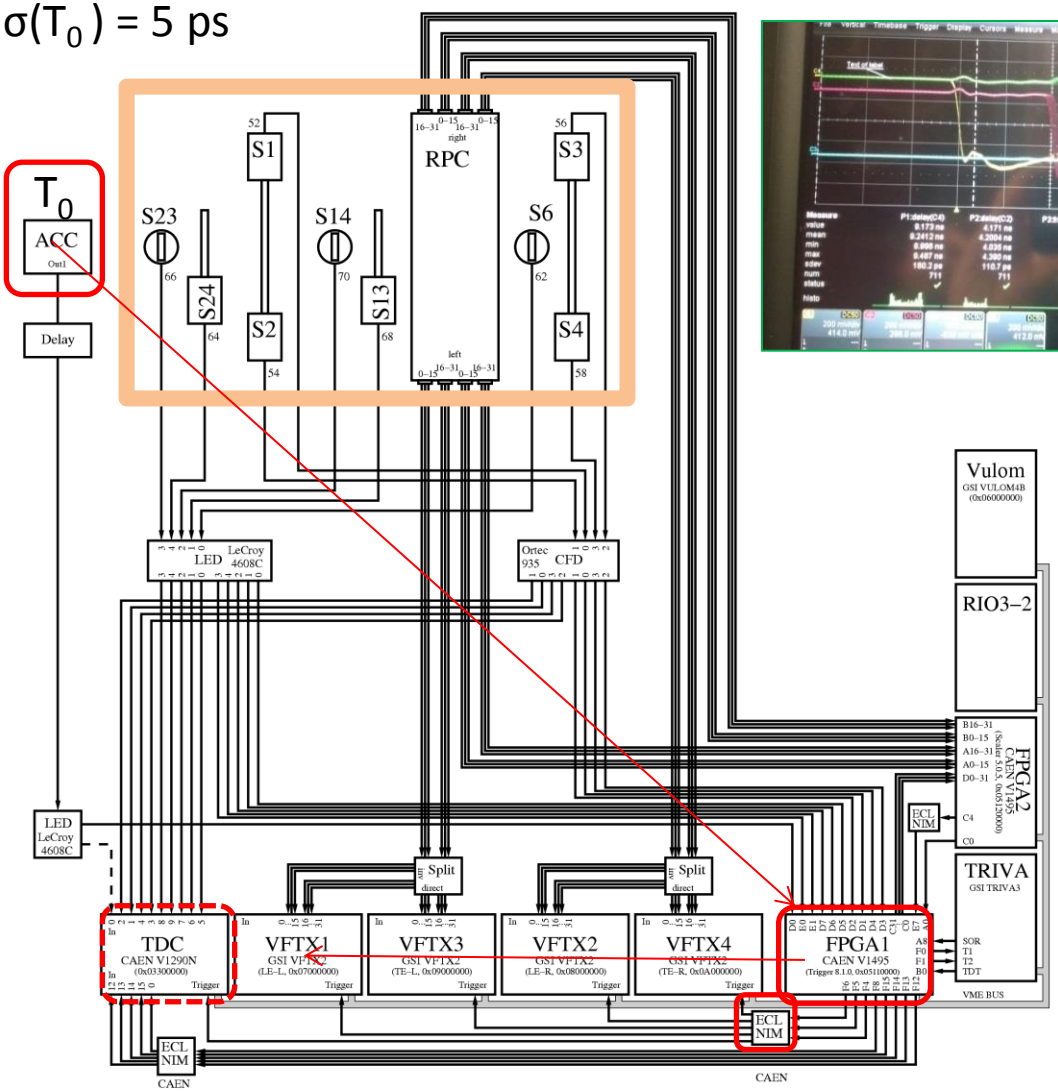
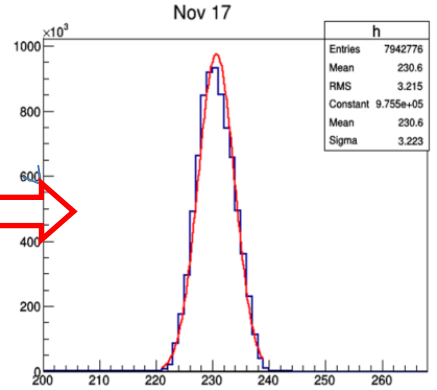
DAQ: time jitter problem

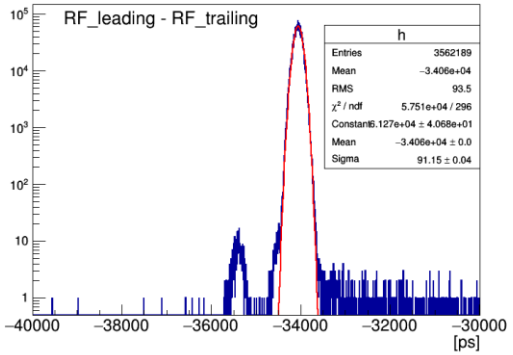
Accelerator

$\sigma(T_0) = 5$ ps





FPGA 1 ($\sigma_{To} \approx$ 80ps)



NIM to LVDS converter adds additional jitter to RF signal

VFTX 1- 4 ($\sigma_{VFTX} \approx$ 90ps)

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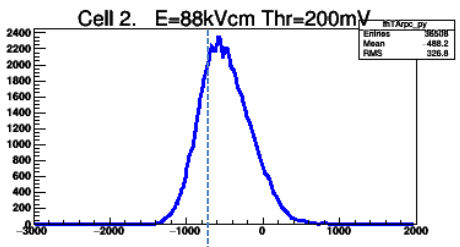
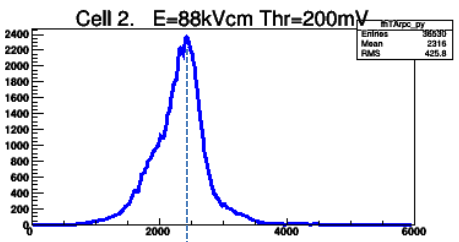
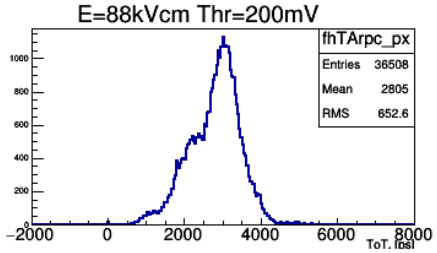
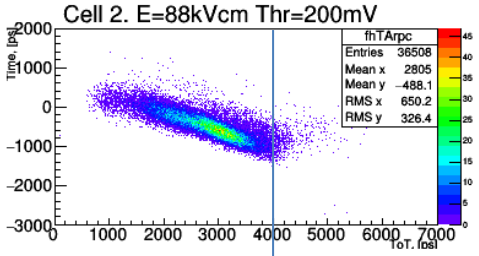
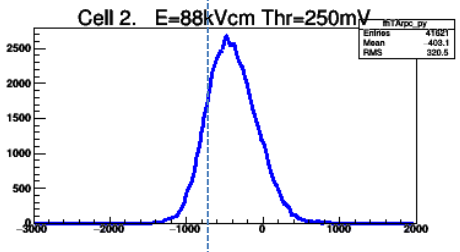
ToT and T vs. $U_{threshold}$ (RPC2)

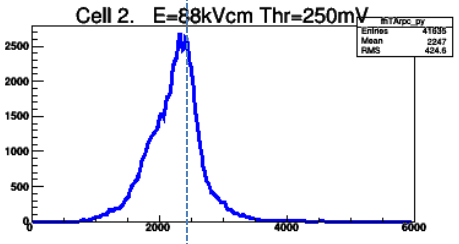


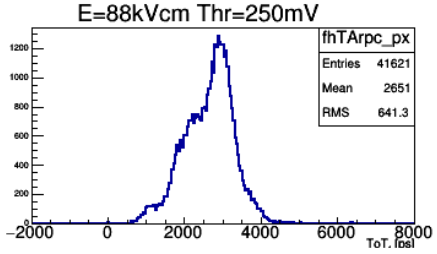


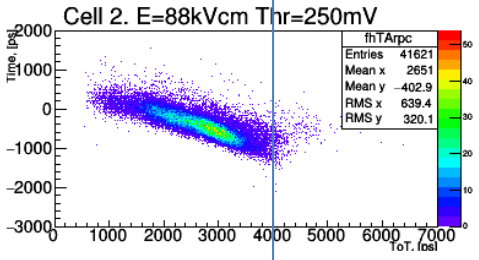


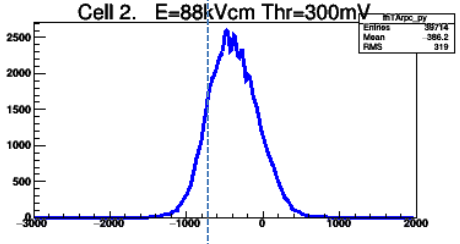


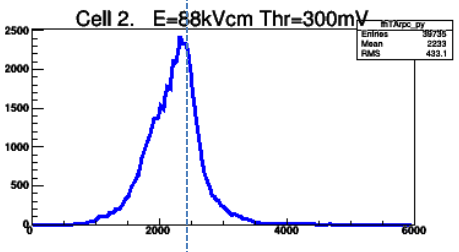


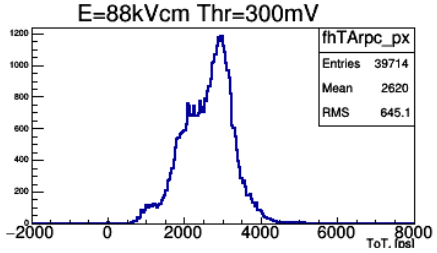


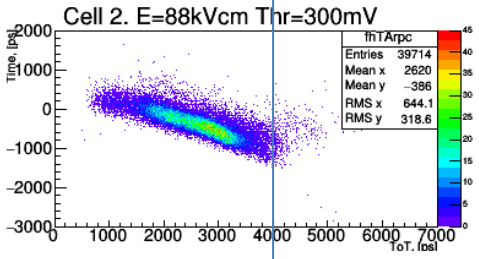


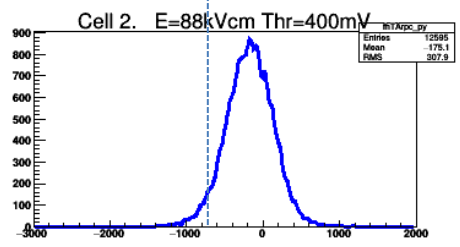


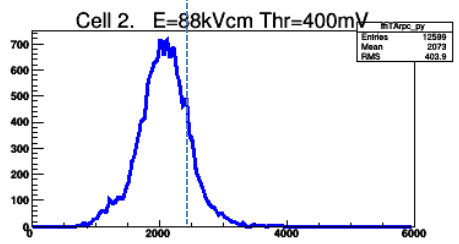


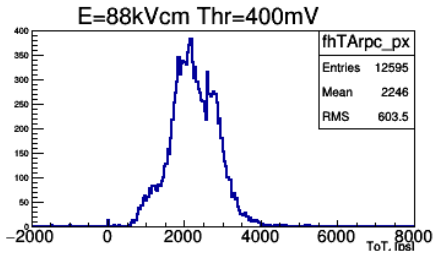


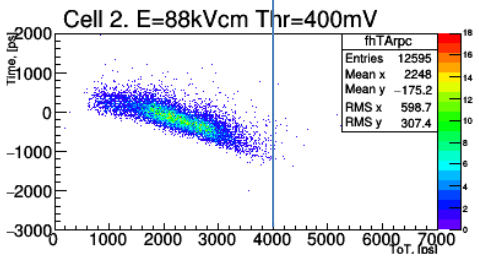












leading edge | trailing edge | ToT | ToT vs. leading edge

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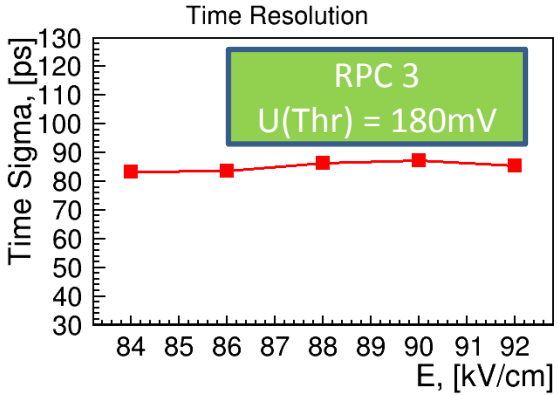
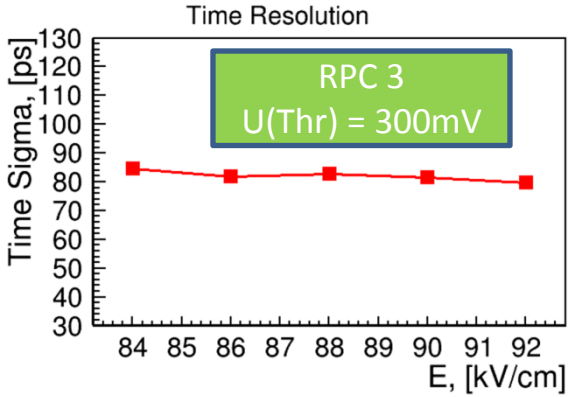
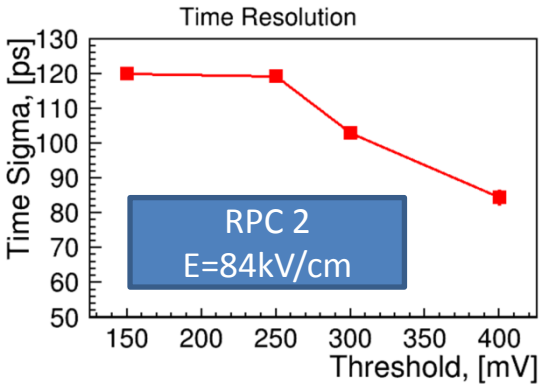
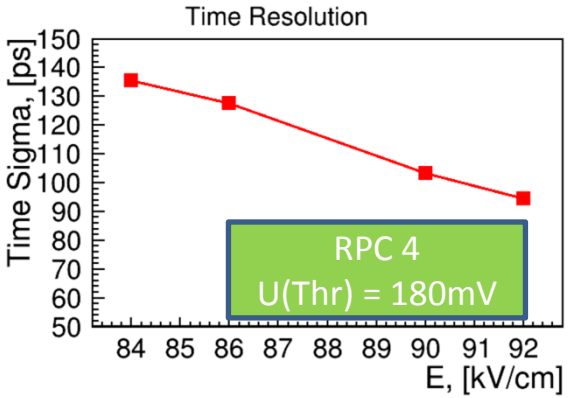
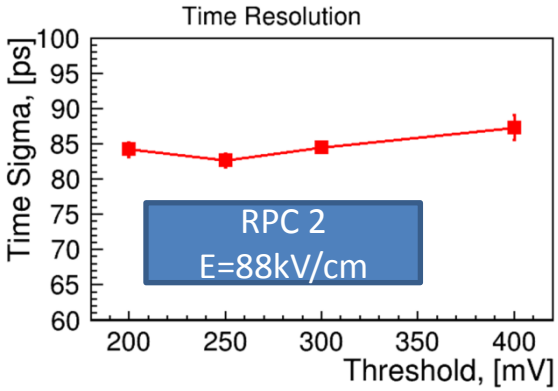
Time resolution











Time resolution σ ≥ 80 ps

after subtraction of the start time resolution ($\sigma_{To} \approx$ 80ps) and the jitter of the RF signal at VFTX ($\sigma_{VFTX} \approx$ 90ps)

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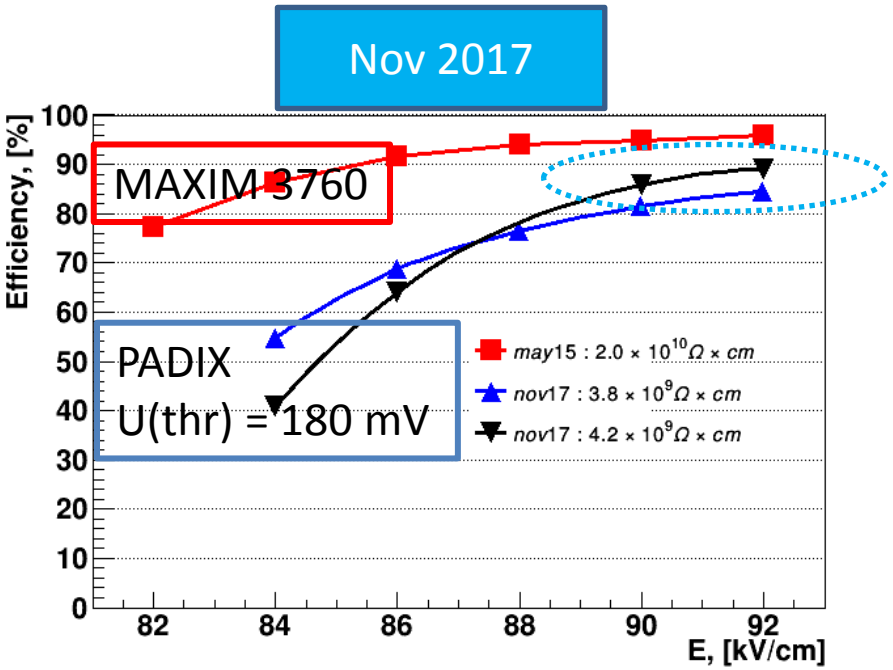
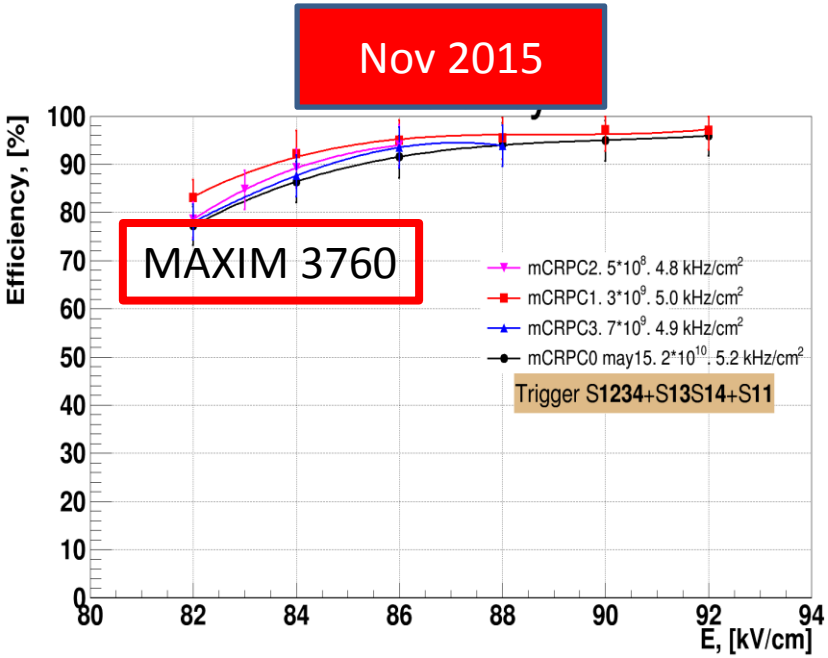
Working curve





No efficiency plateau due to pulse duration and shape

Efficiency plateau has been reached

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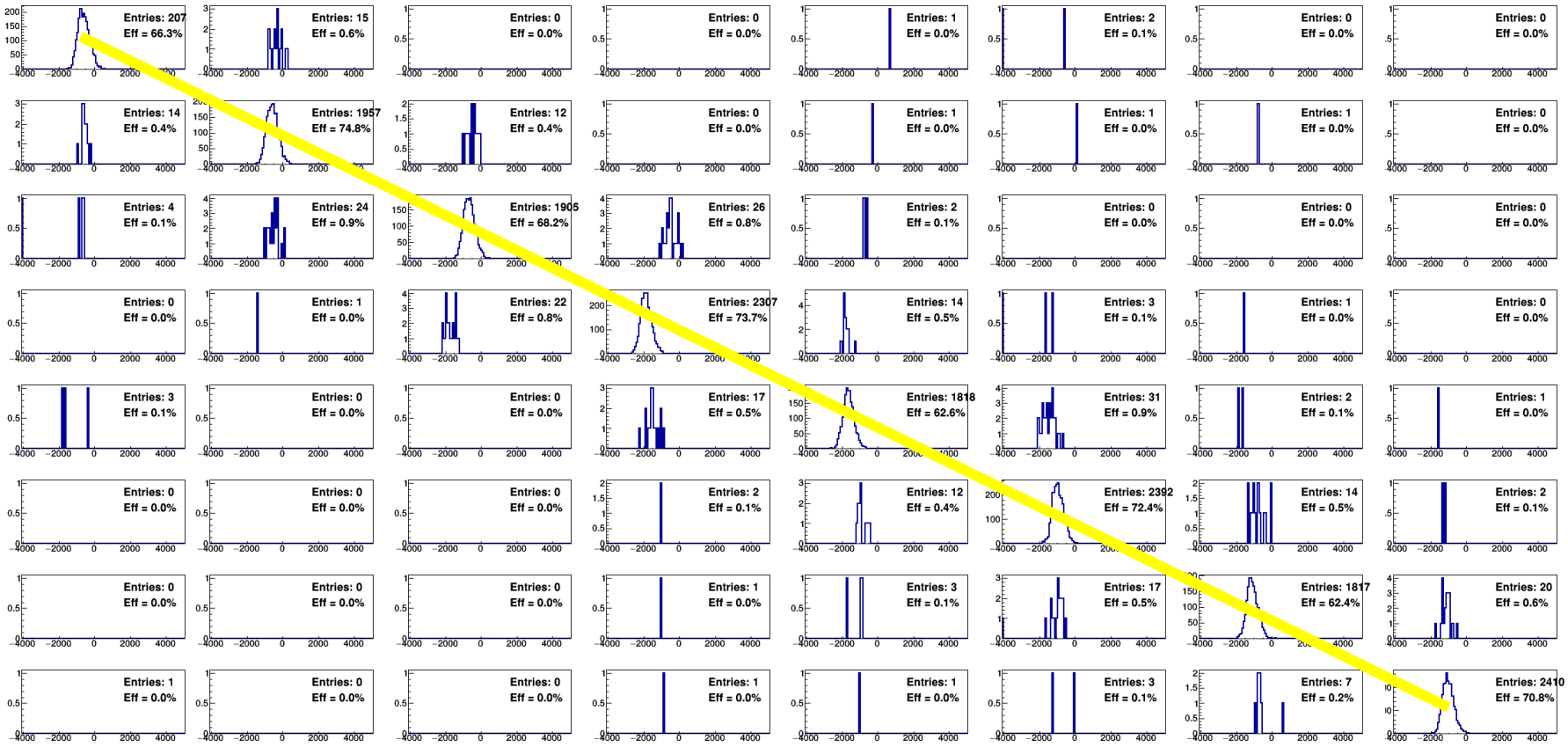
Crosstalk

E=88kV/cm; U_{thr} =180mV



ToT cross-talk probability in all 8 RPCs ≤ 1.2%

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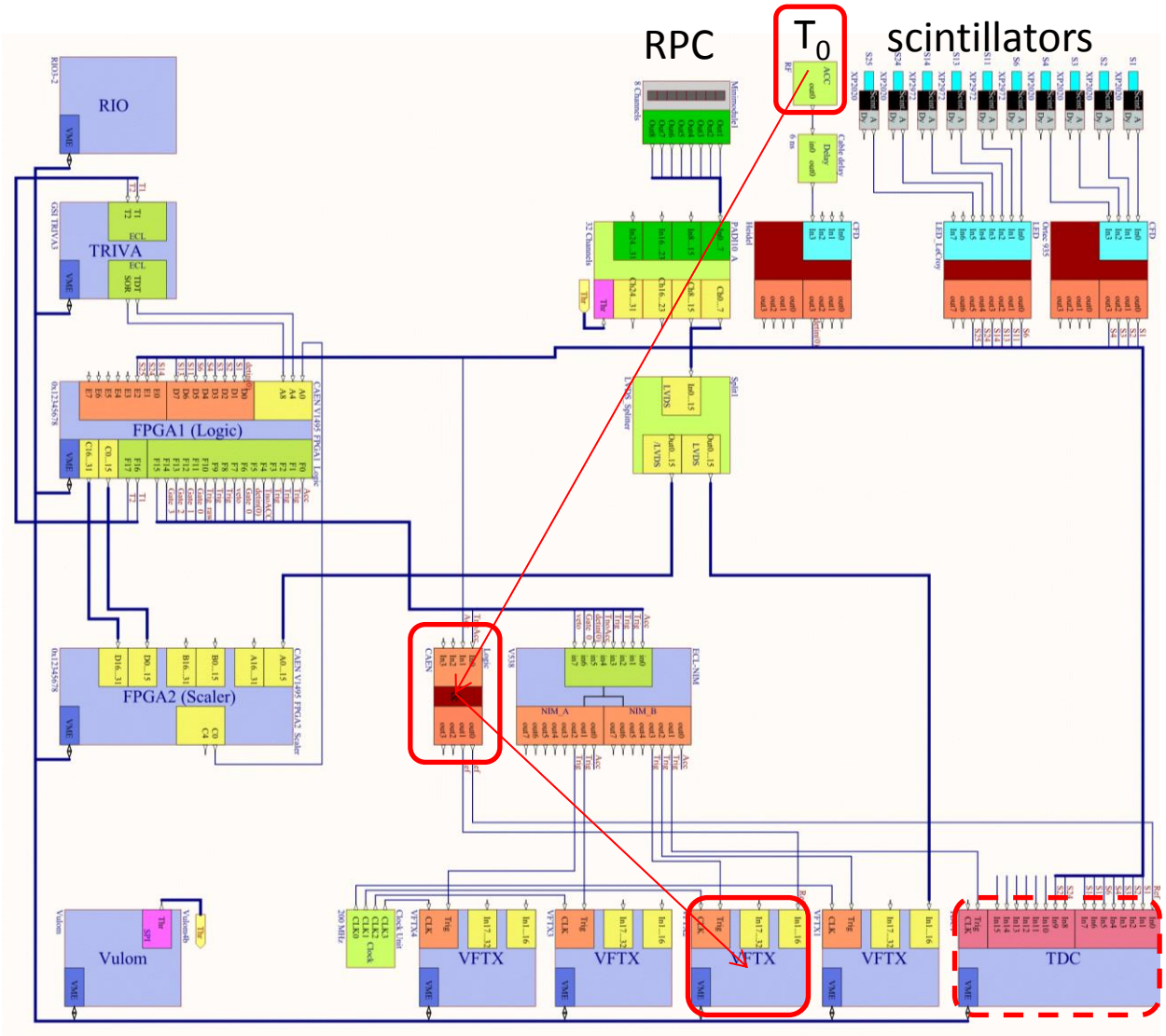
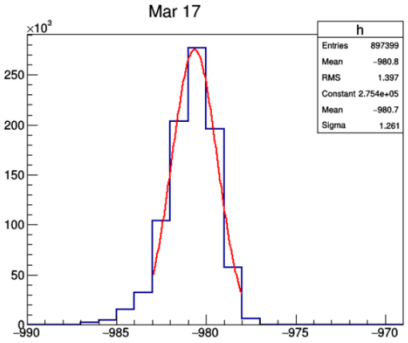
DAQ: time jitter problem solved



Accelerator
$\sigma(T_0) = 5$ ps

Constant Fraction Discriminator (NIM)

Logic Module (NIM)



VFTX = **V**ME **F**PGA **T**DC **X**

$\sigma(T_0) \geq$ 30 ps

Summary

- Small quadratic Ceramic RPC detectors are under consideration for the Beam Fragmentation and Start Time Counter for CBM/FAIR.
- Floating electrodes of low resistive Si_3N_4/SiC ceramics composite with a bulk resistivity of $(3.8 – 9.4) \times 10^9$ Ω cm have been successfully tested.
- The outer electrodes are Cr-plated pads on the Al_2O_3 sheets.
- Rogowski graves guaranty a low dark rate of 0.5 Hz/cm^2.
- The RPCs have been probed with relativistic electron and pion beam fluxes of up to 2×10^5 cm^{-2}s^{-1}
- PADIX FEE has been used and compared to the MAXIM-type amplifier
- Cross talks probability in the current design is better than 1.2%
- Efficiency improvement for RPC with PADIX FEE needs an extension of the signal length
- We understand the reason for insufficient time resolution. The high jitter of the FPGA has been corrected.

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Outlook

- Improvement of the Readout electronics to obtain the efficiency and timing behavior
- Radiation hardness test of powered RPC cells with fast neutrons
- Start of efficient Si_3N_4/SiC ceramics composite production of 10 m^2 for all BFT_0C-modules
- Assembling of a 20 × 20 cm^2 BFT_0C prototype with 100 RPCs for mCBM experiment.

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