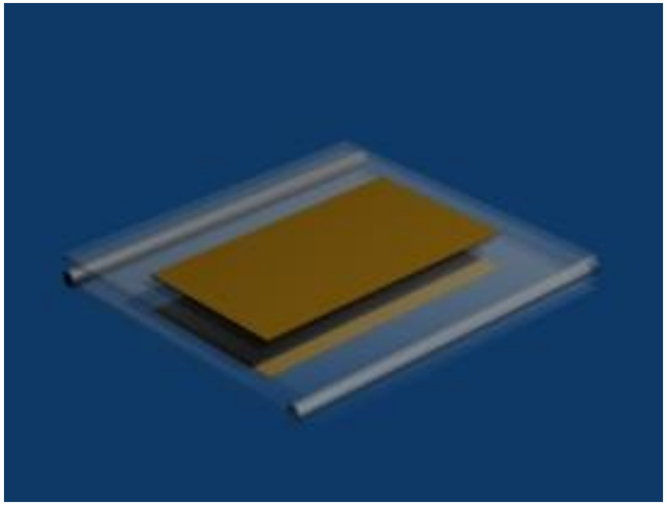
TIMING RESISTIVE PLATE CHAMBERS WITH CERAMIC ELECTRODES

ALEJANDRO LASO GARCIA

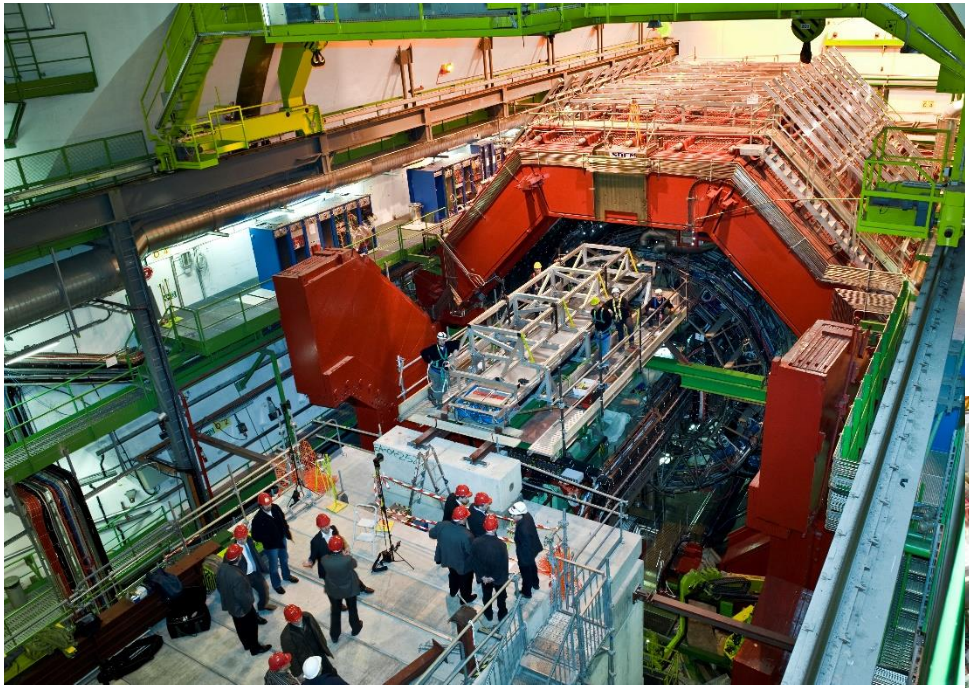
Matter and Technologies Kick-Off Meeting –
Hamburg, 18.02.2015

OVERVIEW

- Brief introduction to RPC operation
- Ceramic characterisation
- Prototypes description
- Beamtests
- Conclusion



APPLICATION OF RPC DETECTORS:
HIGH ENERGY PARTICLE AND NUCLEAR PHYSICS



ALICE Time-of-Flight Barrel

- $A \sim 150\ m^2$
- $\sigma < 100$ ps
- $\phi_{MAX} \sim 50\ cm^{-2}\ s^{-1}$

HADES Time-of-Flight Wall

- $A \sim 8\ m^2$
- $\sigma < 100$ ps
- $\phi_{MAX} \sim 10^3\ cm^{-2}\ s^{-1}$

DRESDEN concept HZDR
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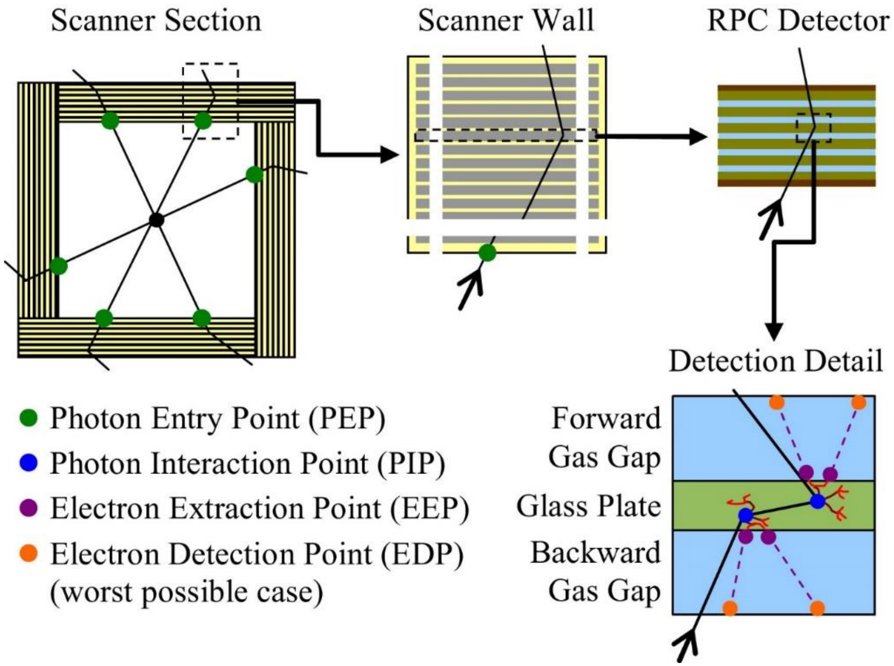
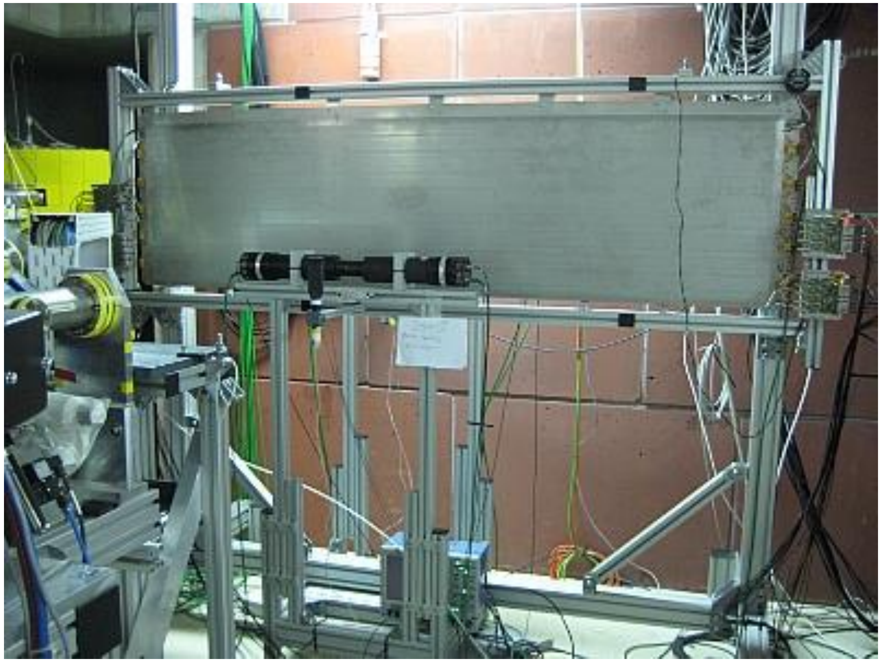
APPLICATION OF RPC DETECTORS: POSITRON EMISSION TOMOGRAPHY

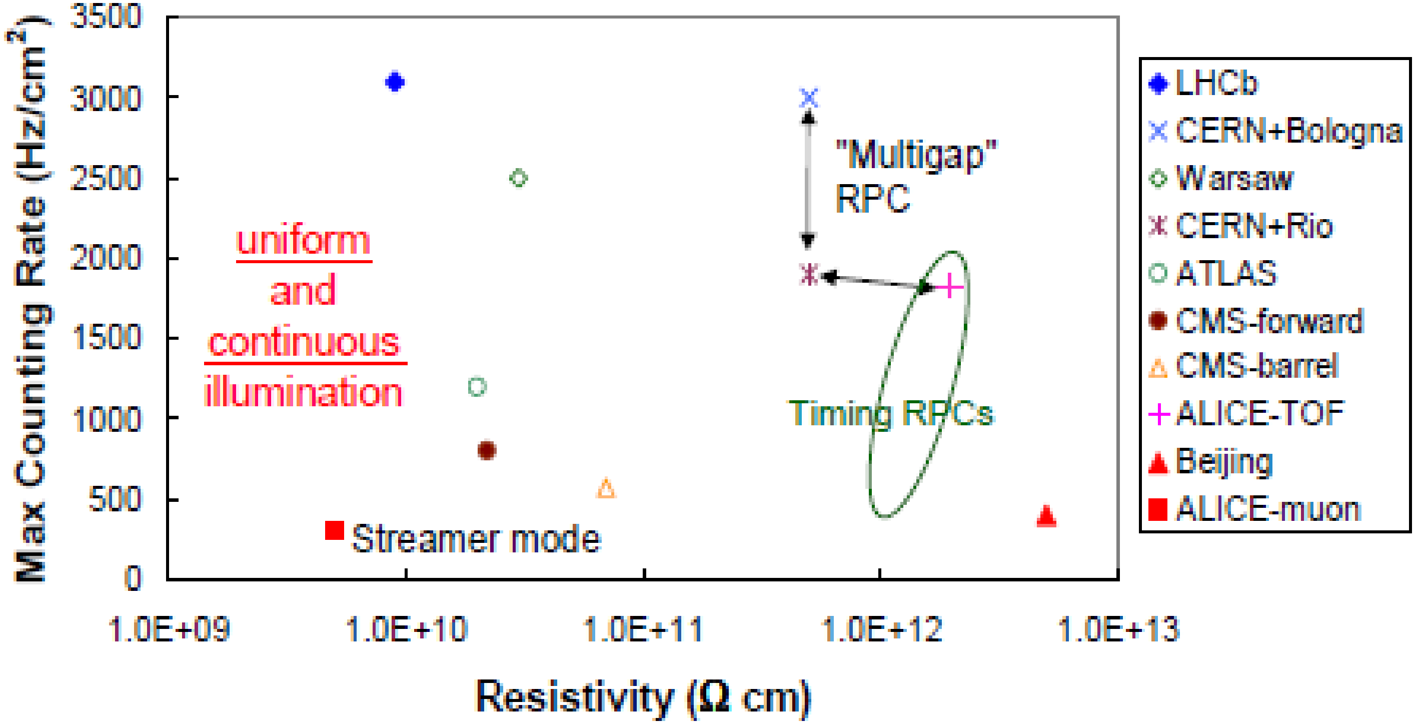




D. Domenici, International Symposium Detector Development, SLAC 2006

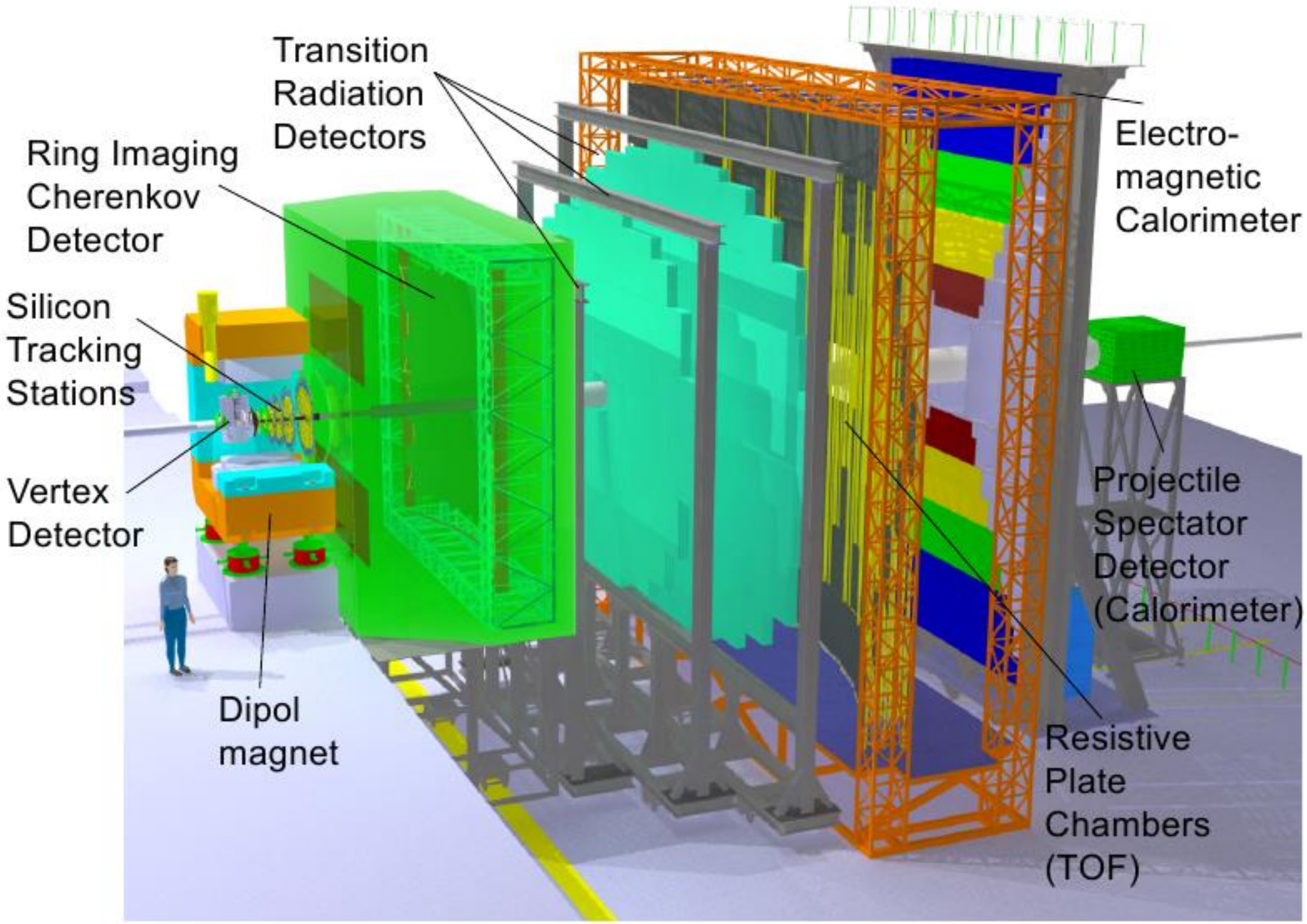
M. Röder et al., JINST 7 (2012) 11, P11030

WORLDWIDE RPC MAP: STATUS OF 2004

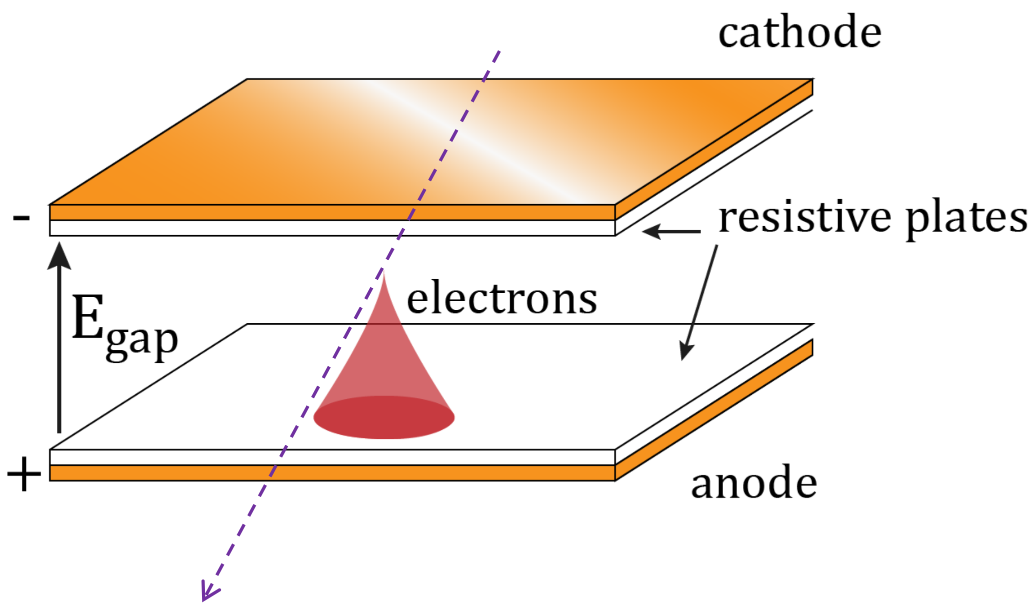


P. Fonte, CBM Collaboration Meeting 2004

NEXT GENERATION APPLICATIONS: COMPRESSED BARYONIC MATTER EXPERIMENT

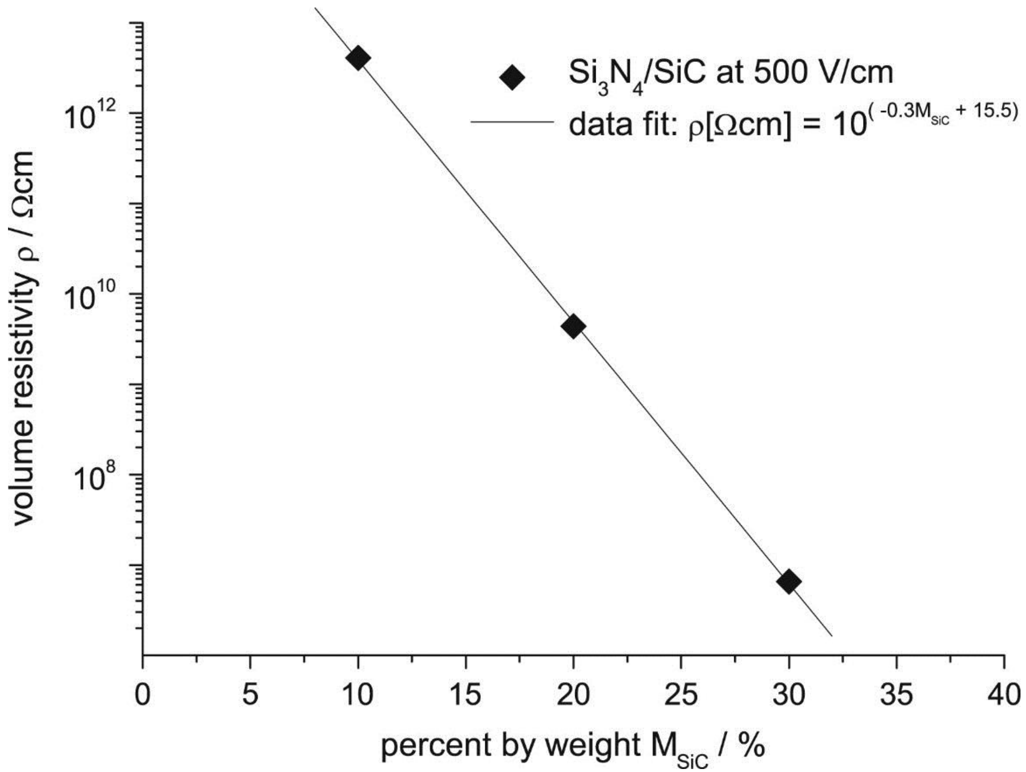


OPERATION OF RESISTIVE PLATE CHAMBERS (RPCs)



- Ionization of gas molecules.
- Avalanche formation due to high electric field strength.
- Signal collection in pick-up electrodes.
- Discharge confined due to high resistivity of materials.

MATERIAL RESEARCH: Si_3N_4/SiC COMPOSITES

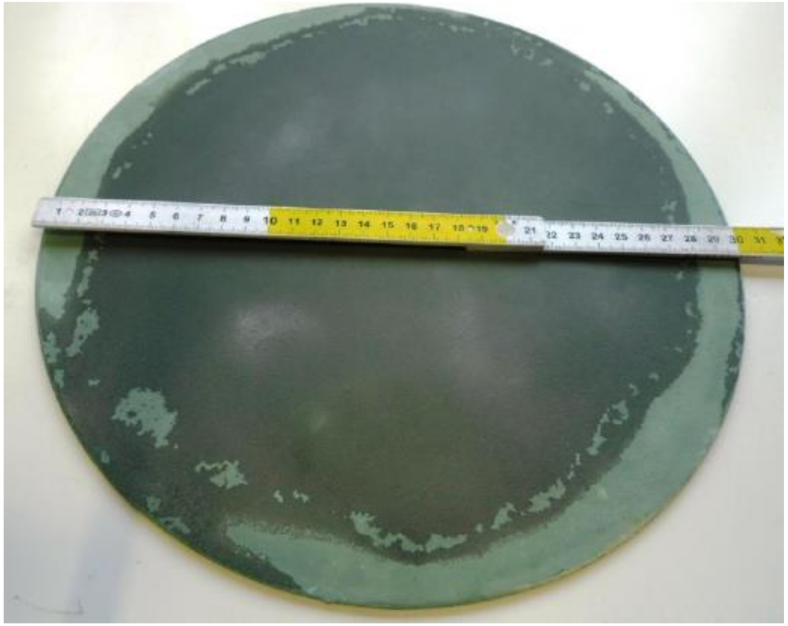


L. Naumann et al., NIM A 628 (2011) 138

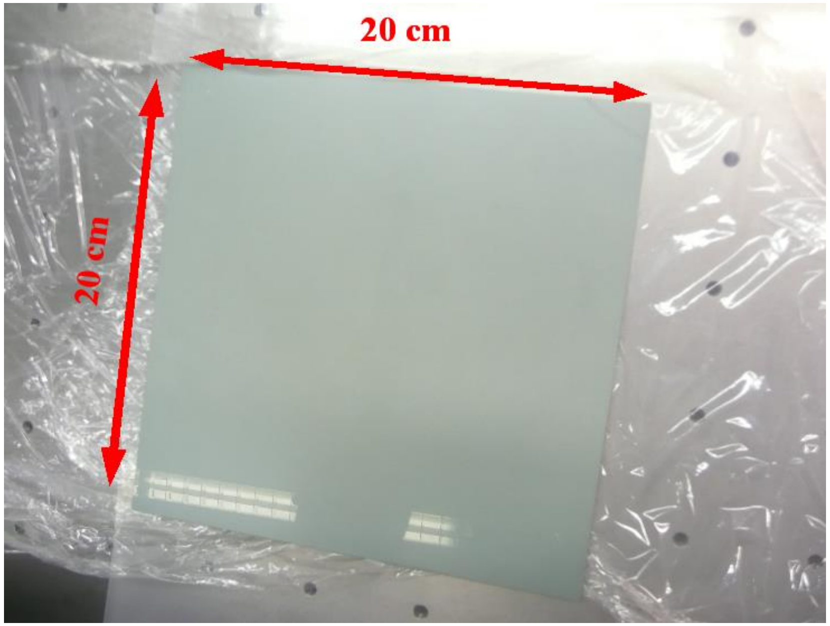
- Si_3N_4/SiC composites
- Bulk resistivity tunable:
  $\rho \sim 10^7 - 10^{13} \Omega$ cm
- Radiation hard material

Developed in collaboration with
Fraunhofer Institute for Ceramic Technologies, Dresden

MATERIAL RESEARCH: Si_3N_4/SiC COMPOSITES

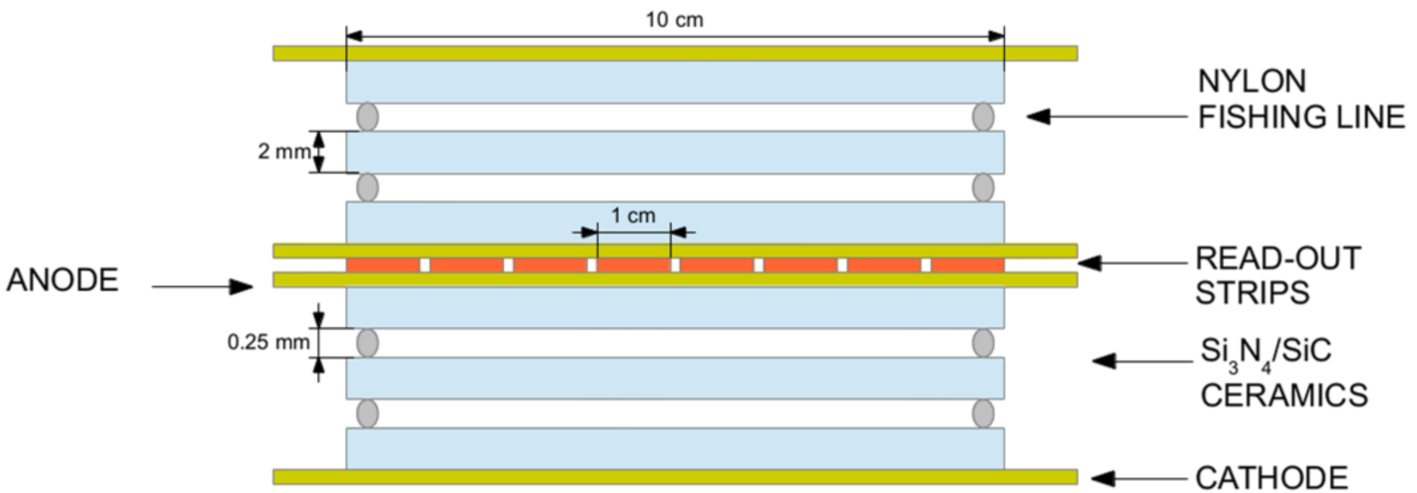


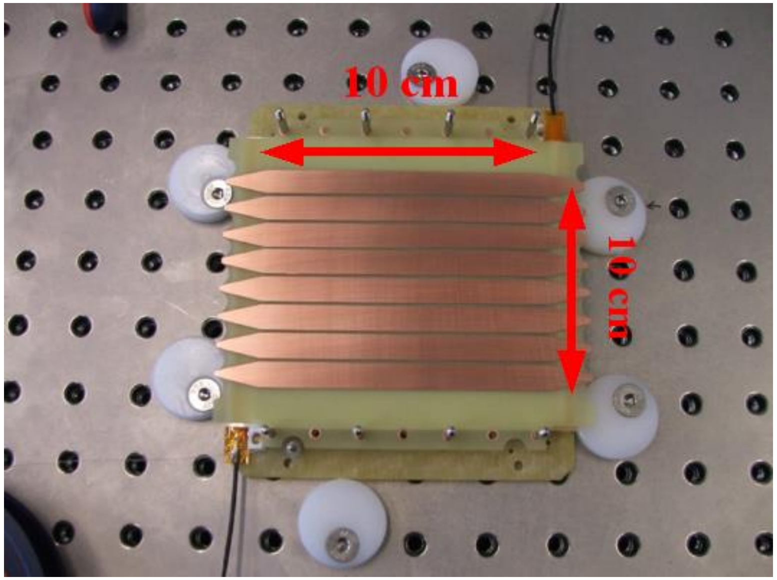
From wafer…



… to RPC electrode

CERAMIC RPC: 10x10 cm^2 PROTOTYPE

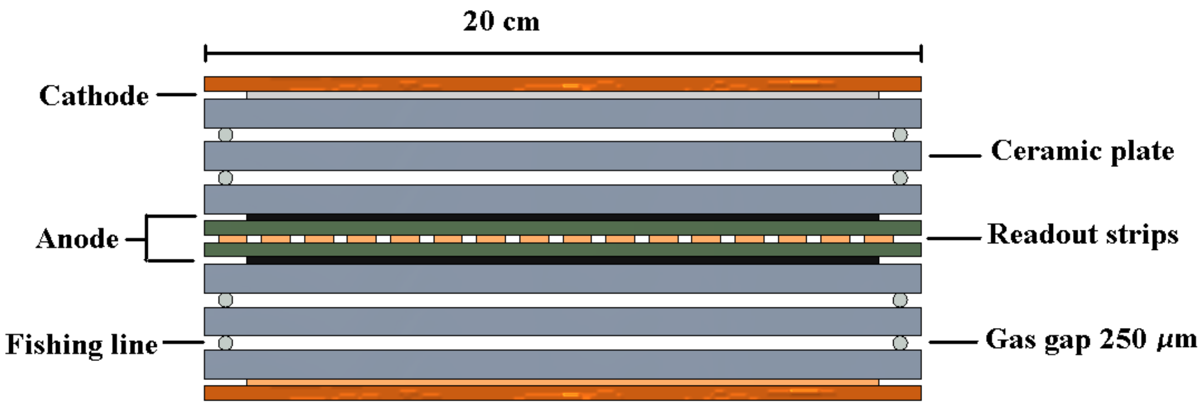


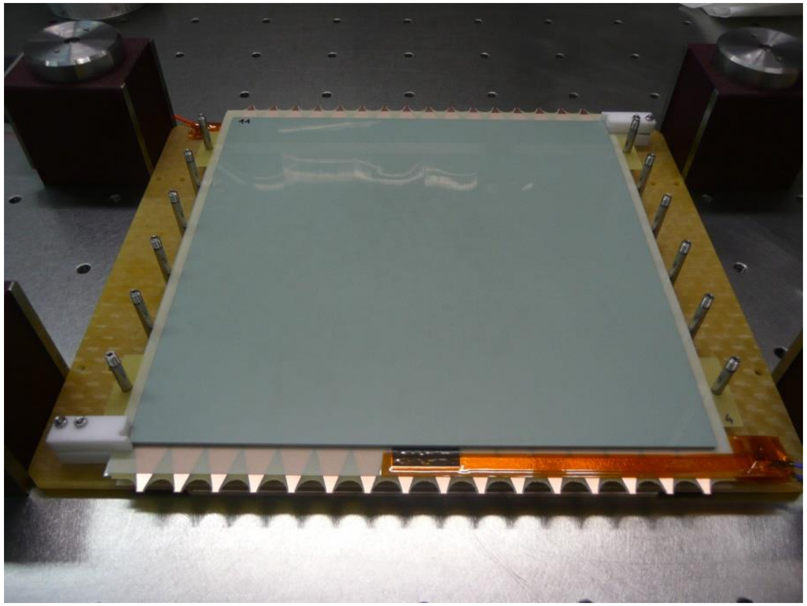


Active area: 100 x 100 mm^2
Bulk resistivity: $\rho \sim 10^9\ \Omega$ cm
Gas gaps: 2 x 2 gaps, 250 or 300 µm/gap
Gas mixture: 85%Freon / 10%i-Butane / 5% SF6

Read-out electronics GSI (FOPI)

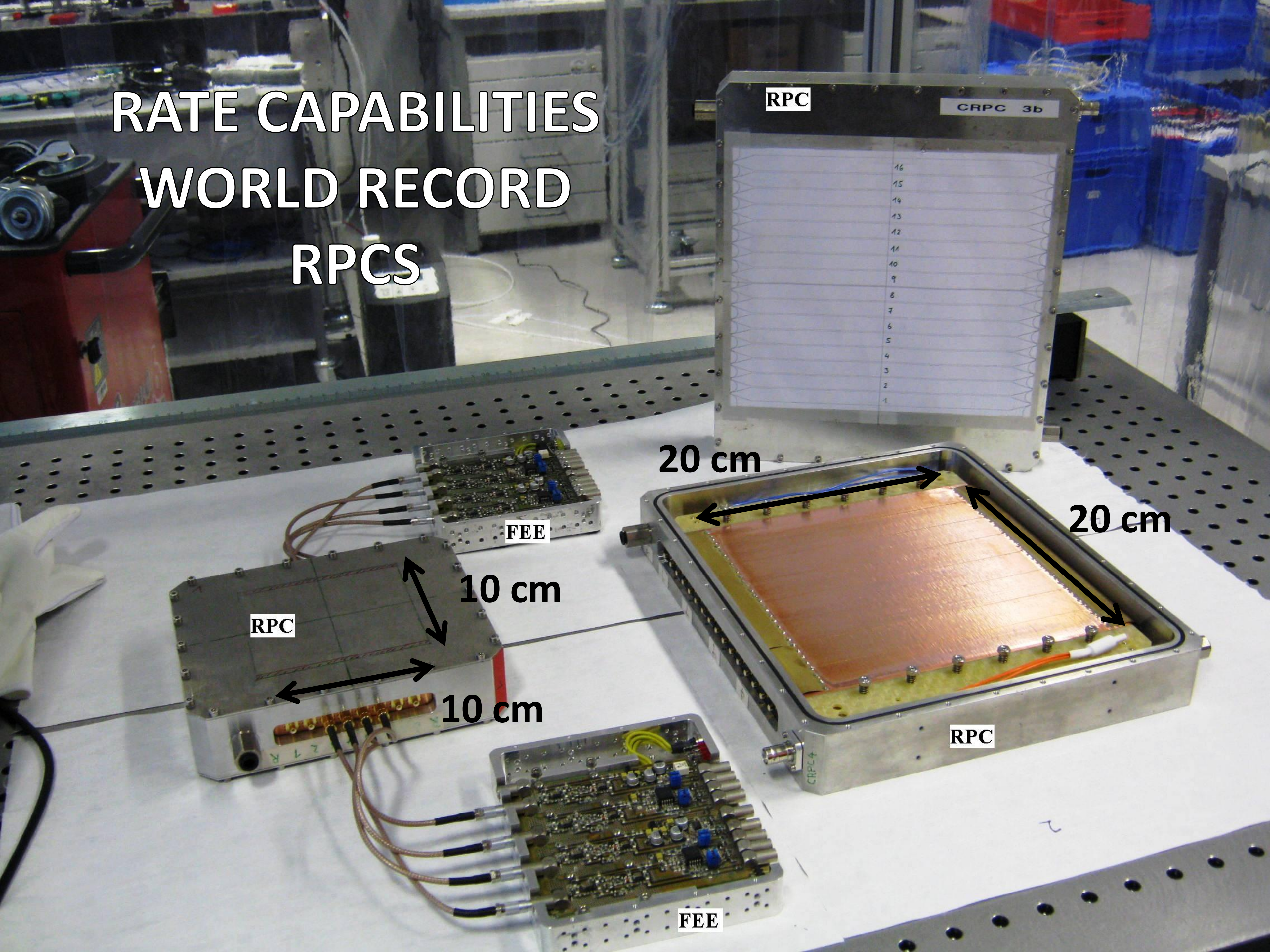
CERAMIC RPC: 20x20 cm^2 PROTOTYPE



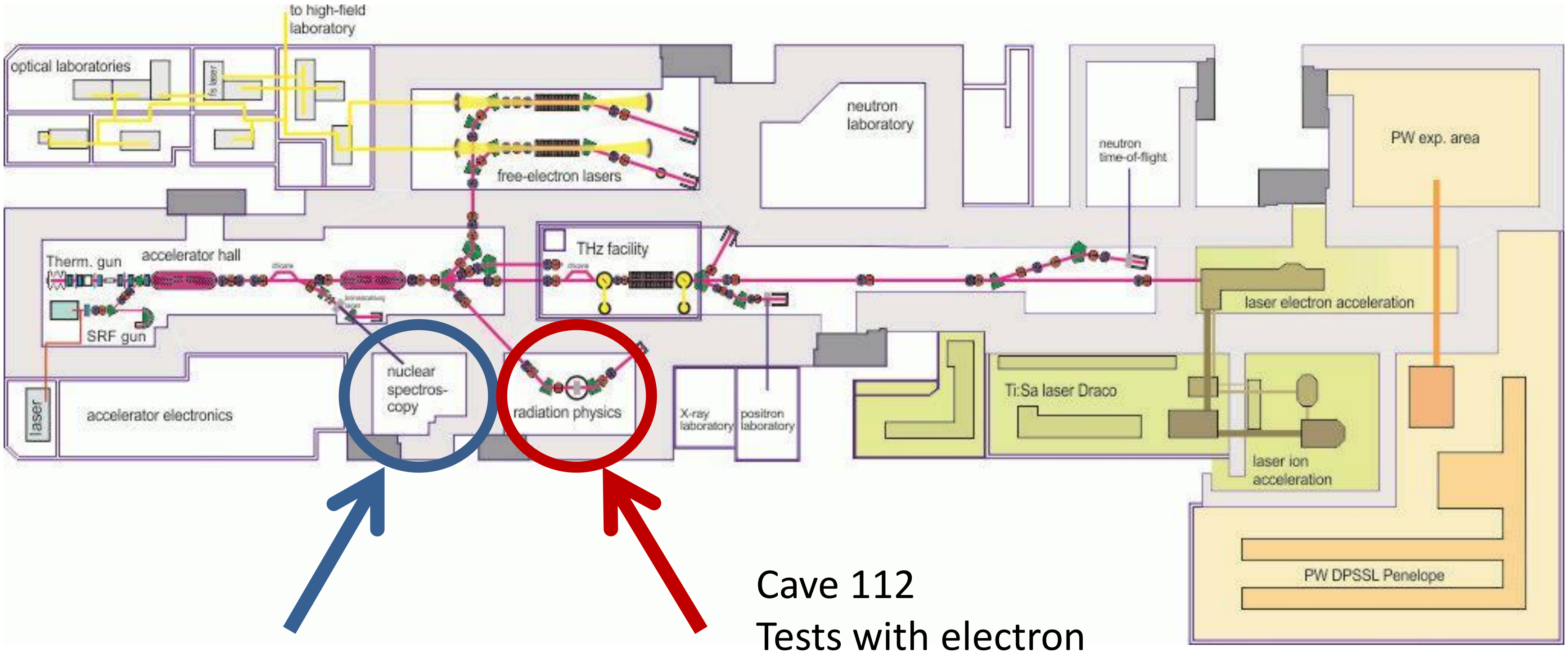


Active area: 200 x 200 mm^2
Bulk resistivity: $\rho \sim 10^{10}\ \Omega$ cm
Gas gaps: 2 x 2 gaps, 250 µm/gap
Gas mixture: 85%Freon / 10%i-Butane / 5% SF6

Read-out electronics GSI (FOPI)


RATE CAPABILITIES
WORLD RECORD
RPCS
RPC
CRPC 3b
20 cm
20 cm
FEE
10 cm
RPC
10 cm
RPC
FEE

ELBE LAYOUT



Cave 112
Tests with electron beams

Cave 109
Tests with MeV photons

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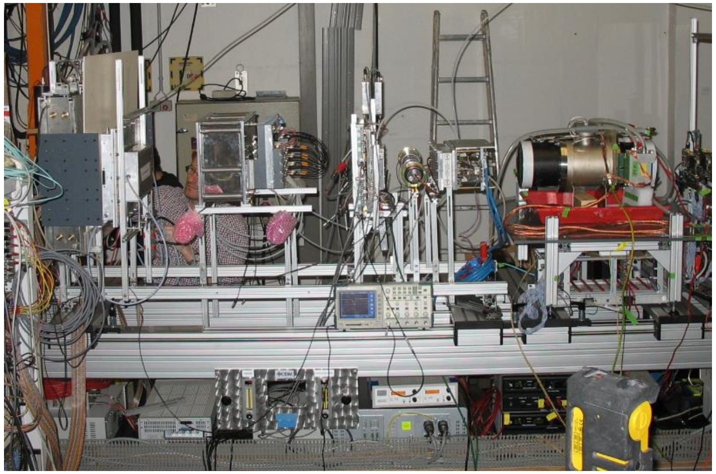
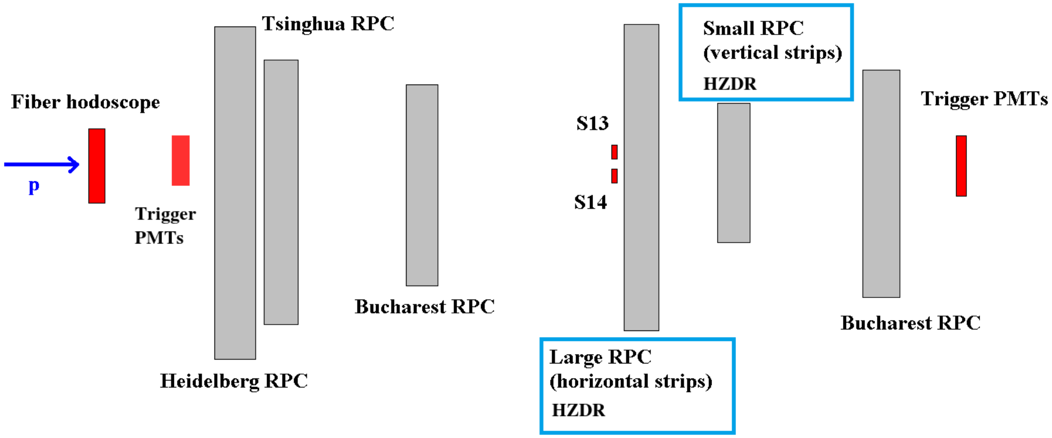
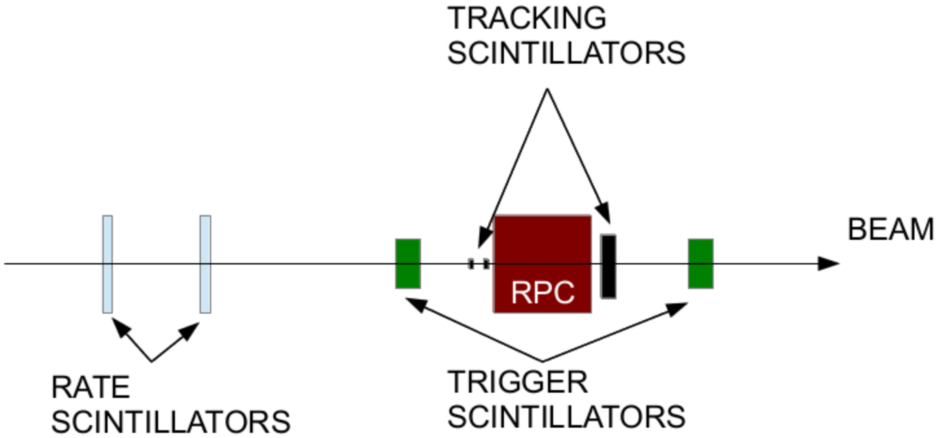
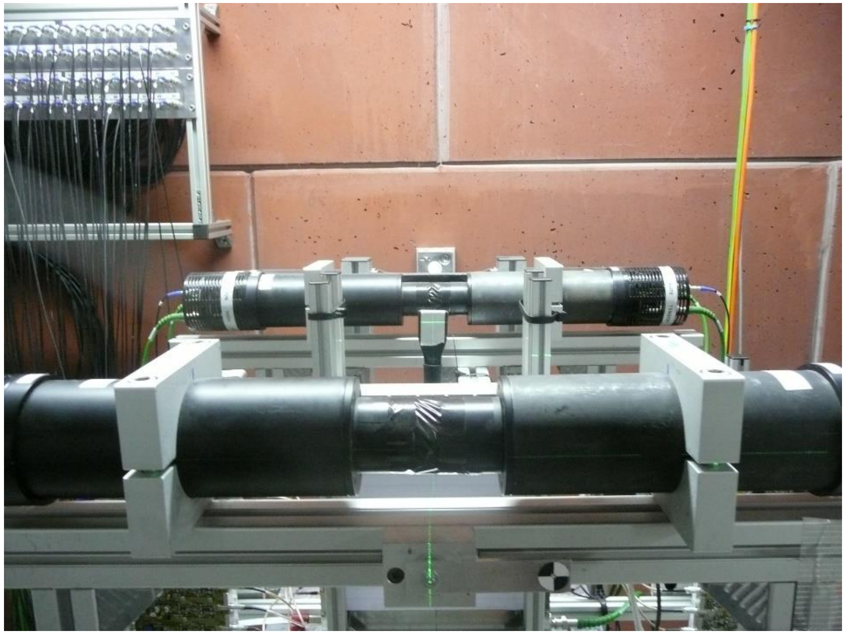
ELECTRON AND PROTON IRRADIATION SET-UP









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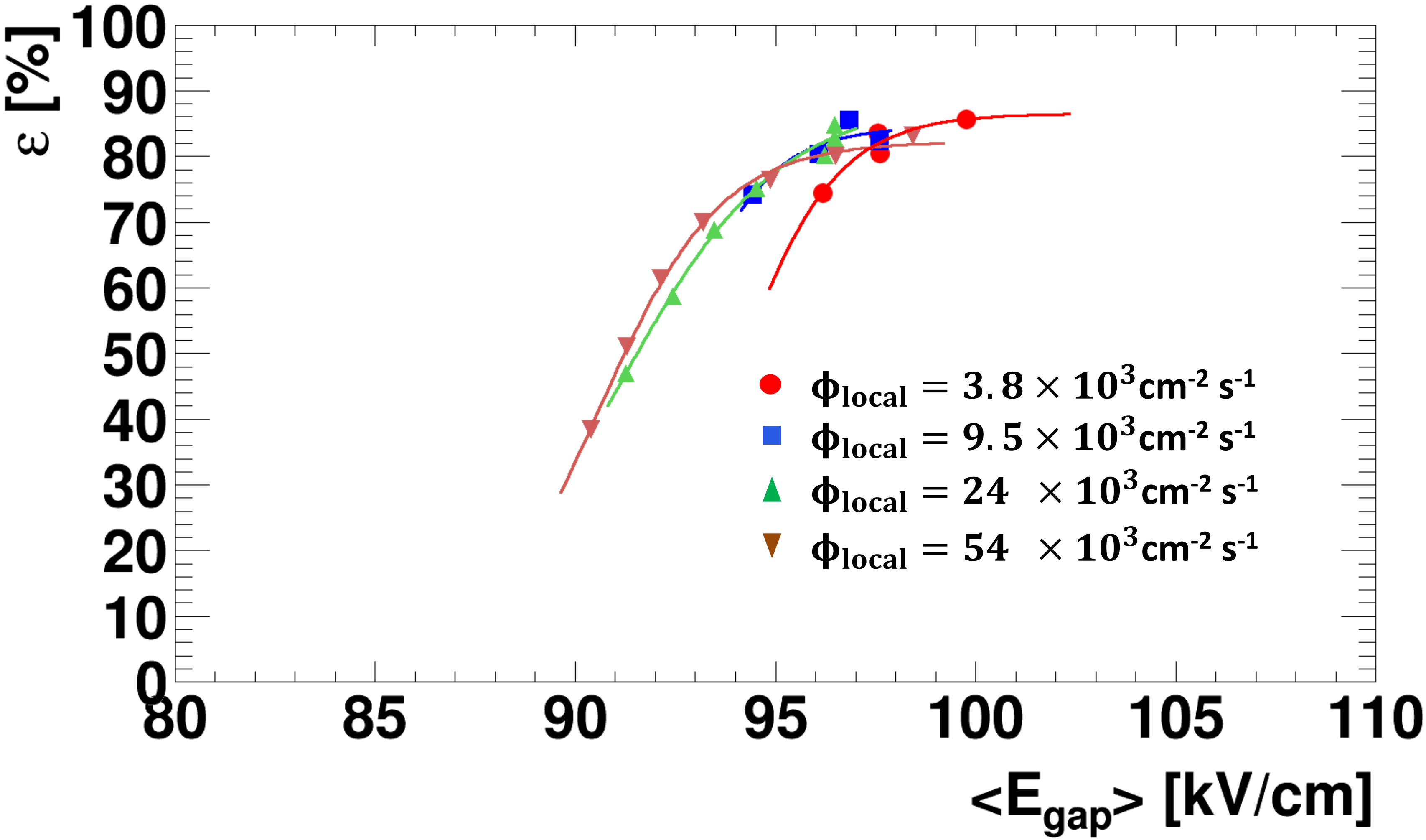
ELECTRON CRPC RESPONSE (20x20 cm^2)



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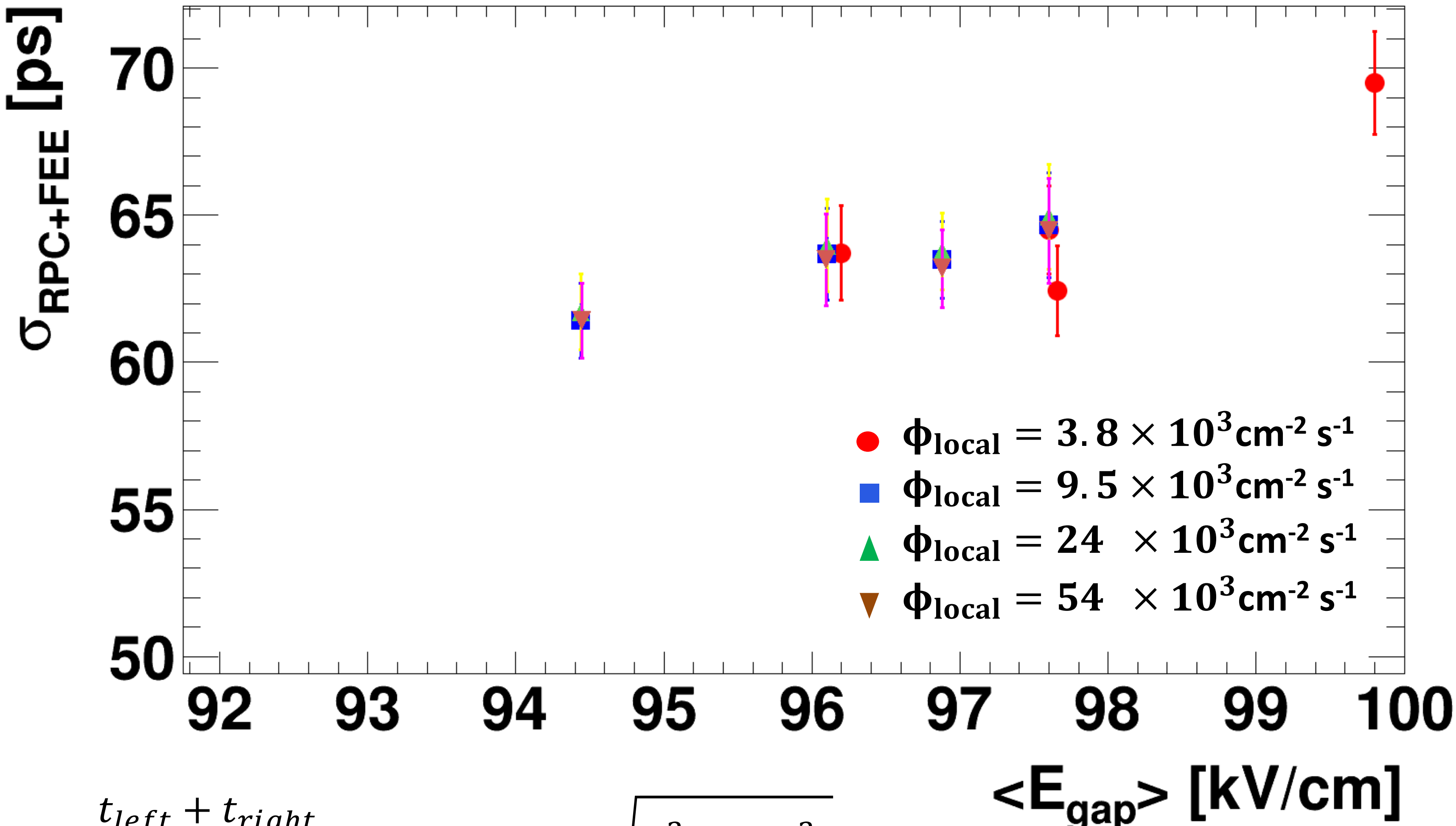
ELECTRON CRPC RESPONSE (20x20 cm^2)



$$t_{ToF} = \frac{t_{left} + t_{right}}{2} \qquad \sigma_{RPC+FEE} = \sqrt{\sigma_{TOF}^2 - \sigma_{RF}^2}$$

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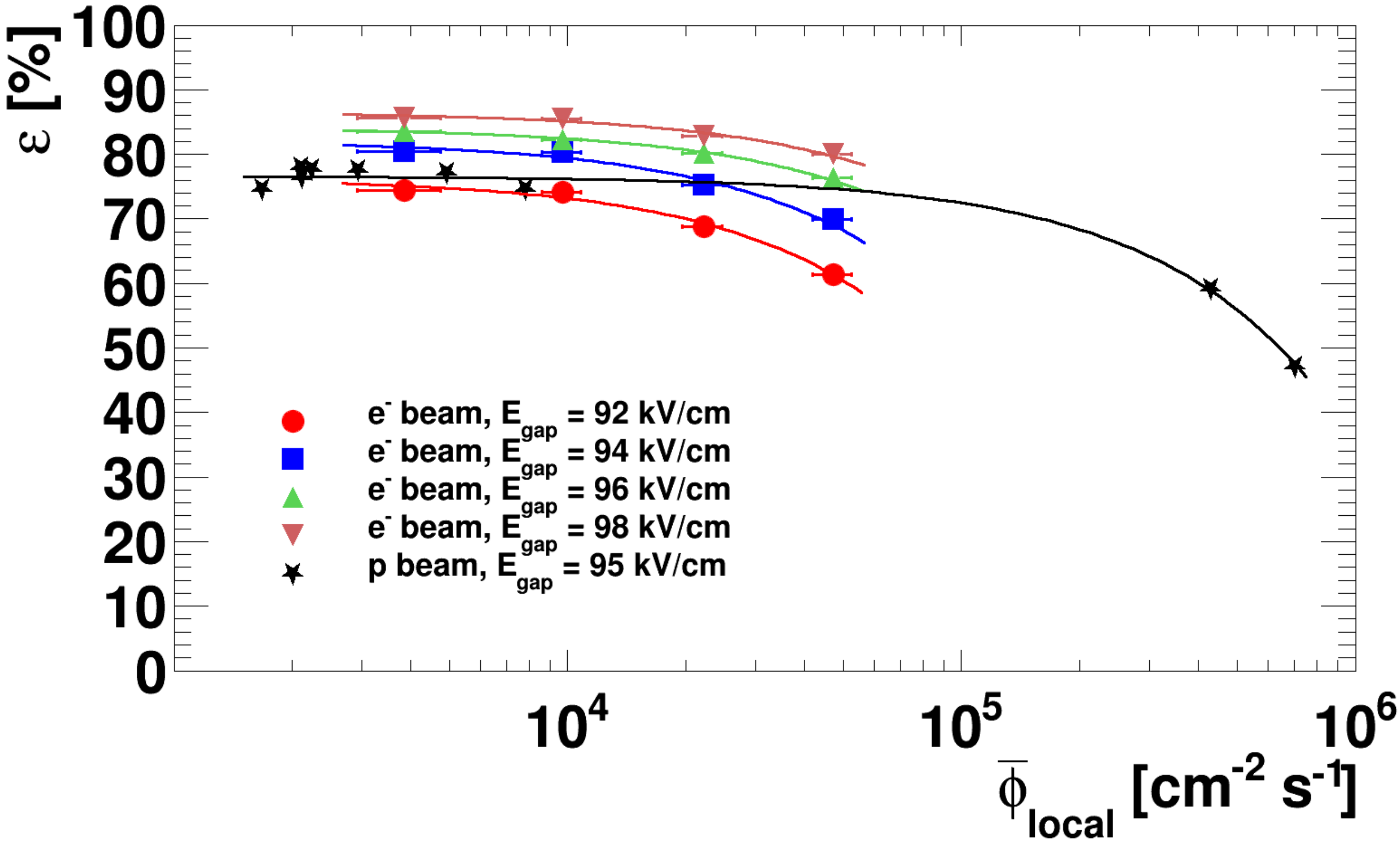
ELECTRON AND HADRON CRPC RESPONSE (20x20 cm²)



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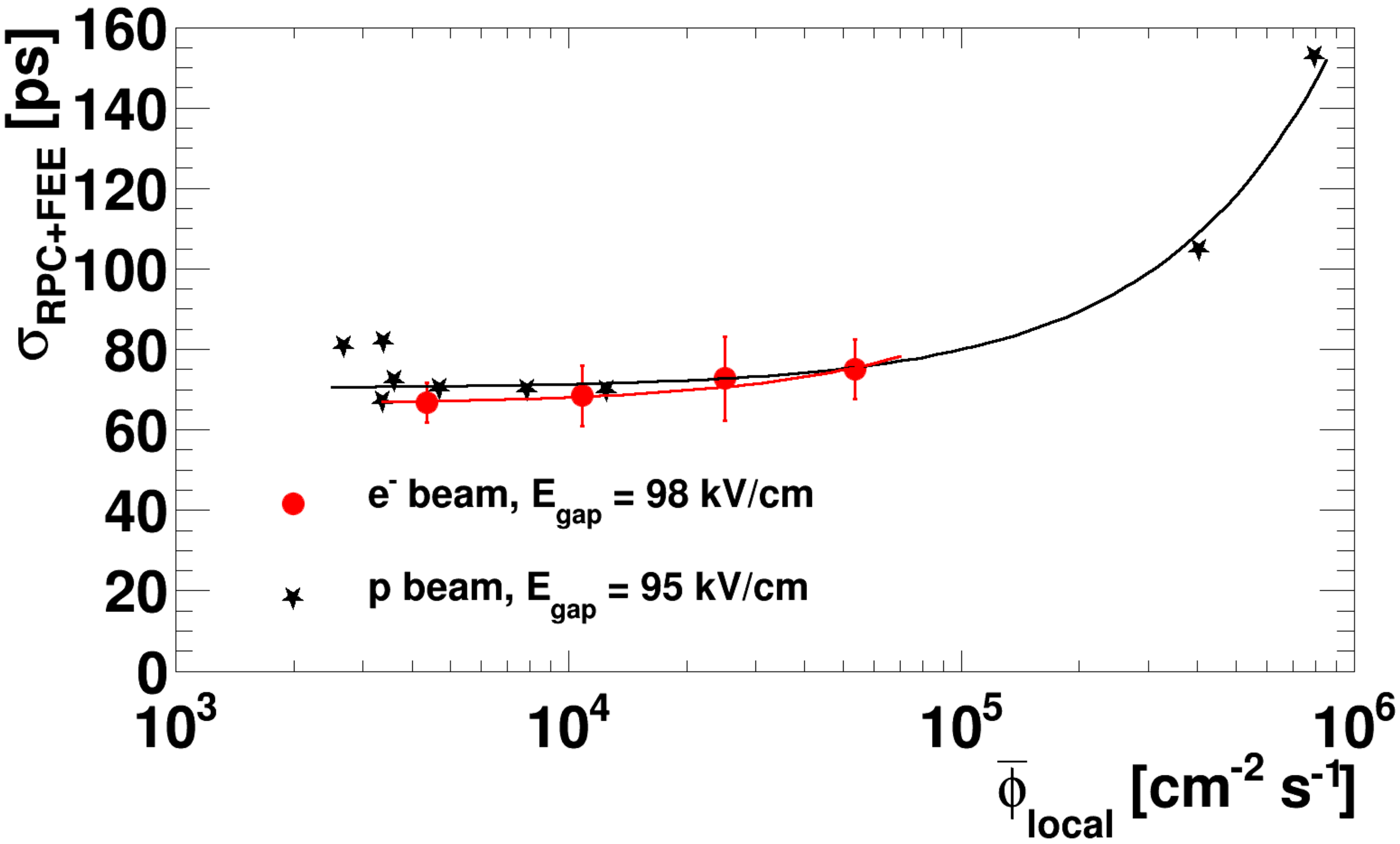
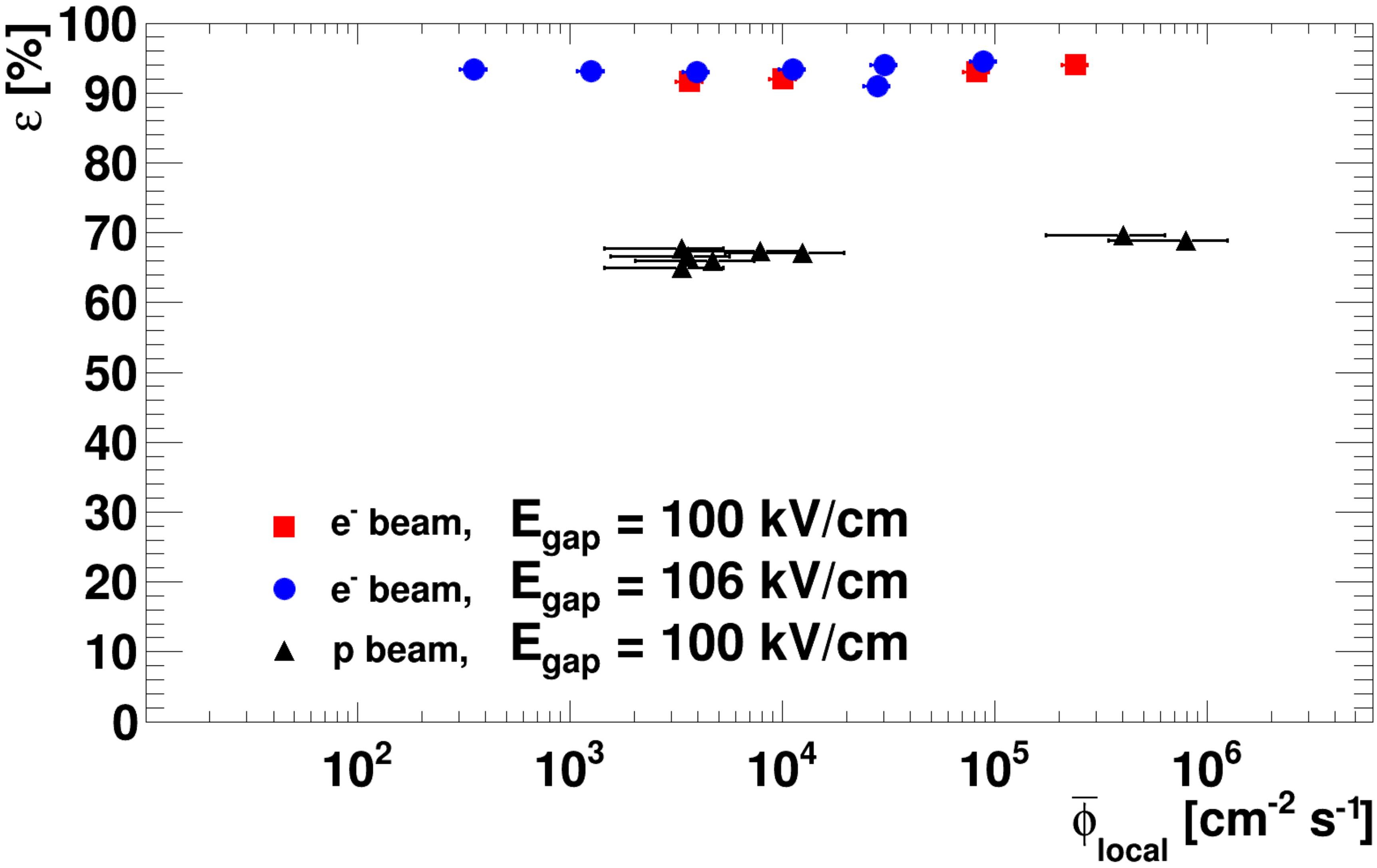
ELECTRON AND HADRON CRPC RESPONSE (20x20 cm^2)



ELECTRON AND HADRON CRPC RESPONSE (10x10 cm²)



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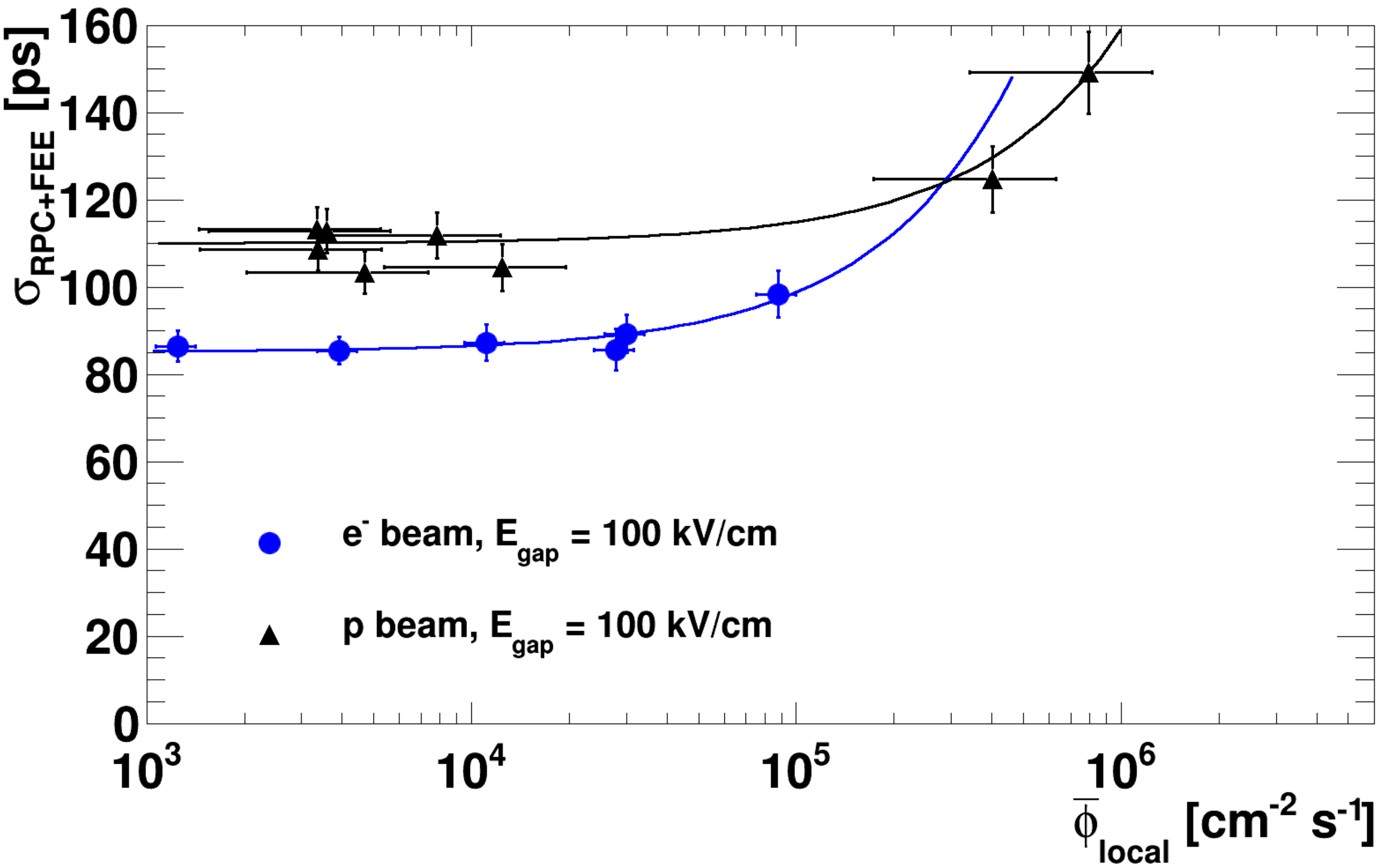
ELECTRON AND HADRON CRPC RESPONSE (10x10 cm²)



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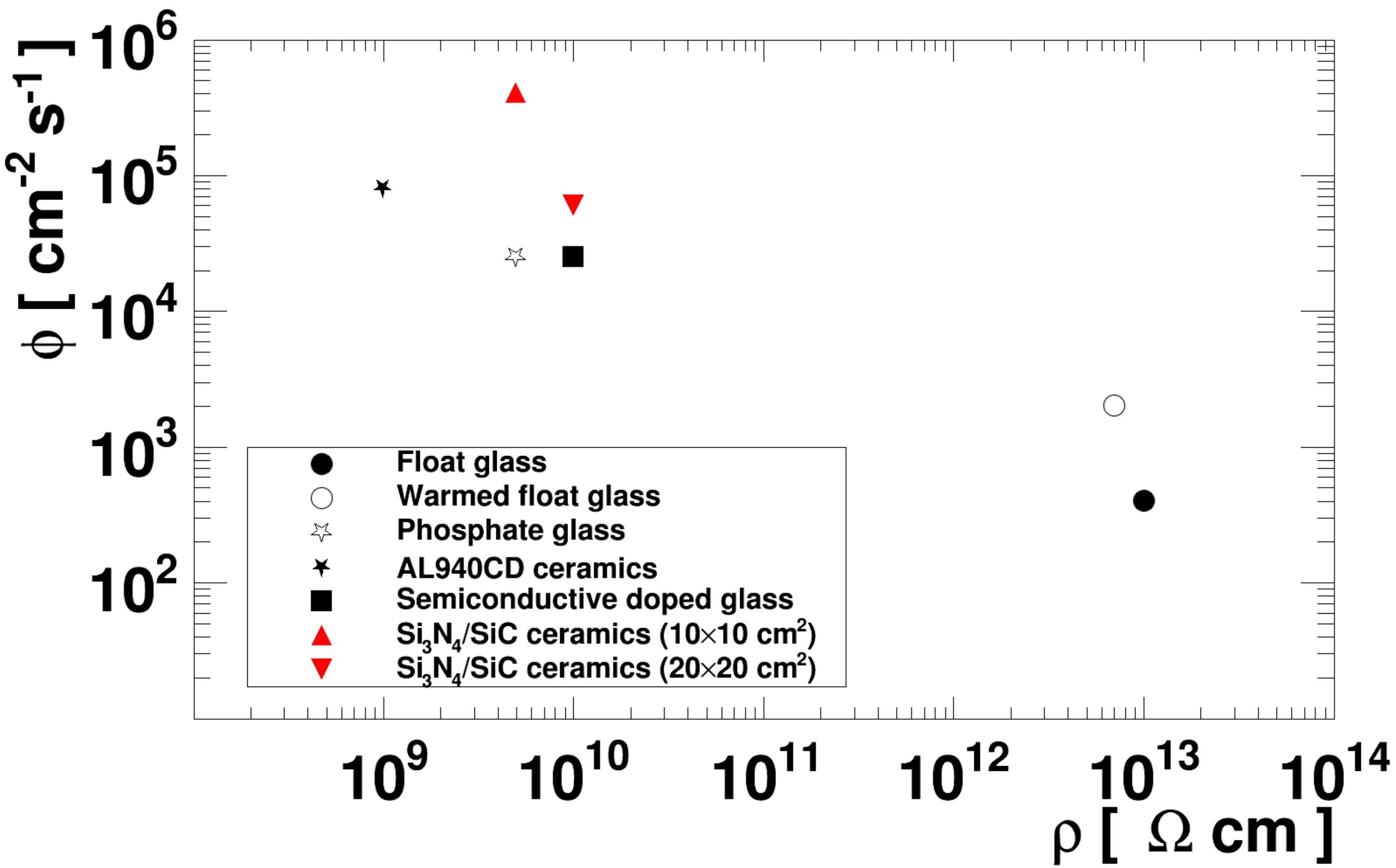
WORLDWIDE RPC MAP: STATUS OF 2014



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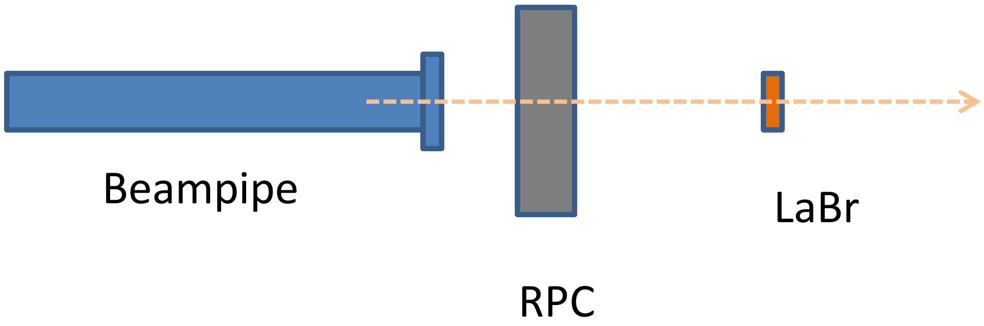
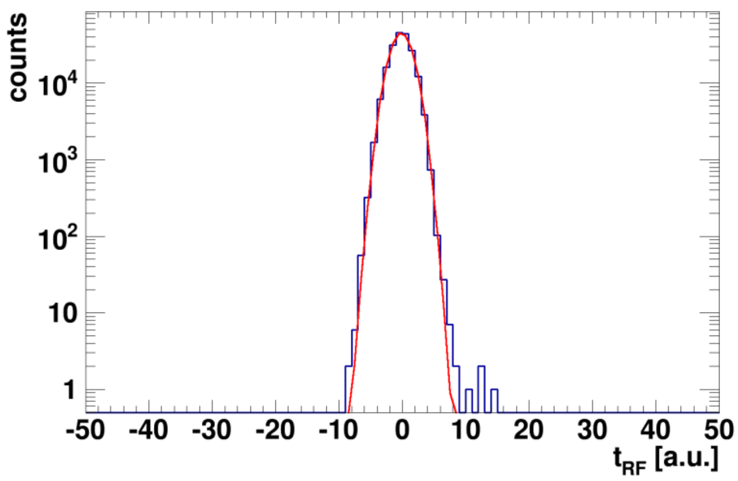
PHOTON IRRADIATION SET-UP

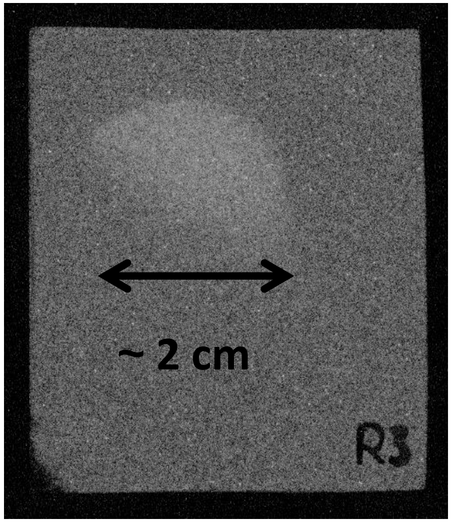
$E_\gamma < 12.5$ MeV

Trigger: RPC_{OR} & RF
Reference timing: RF





$FWHM_{RF}$ = 94 ps



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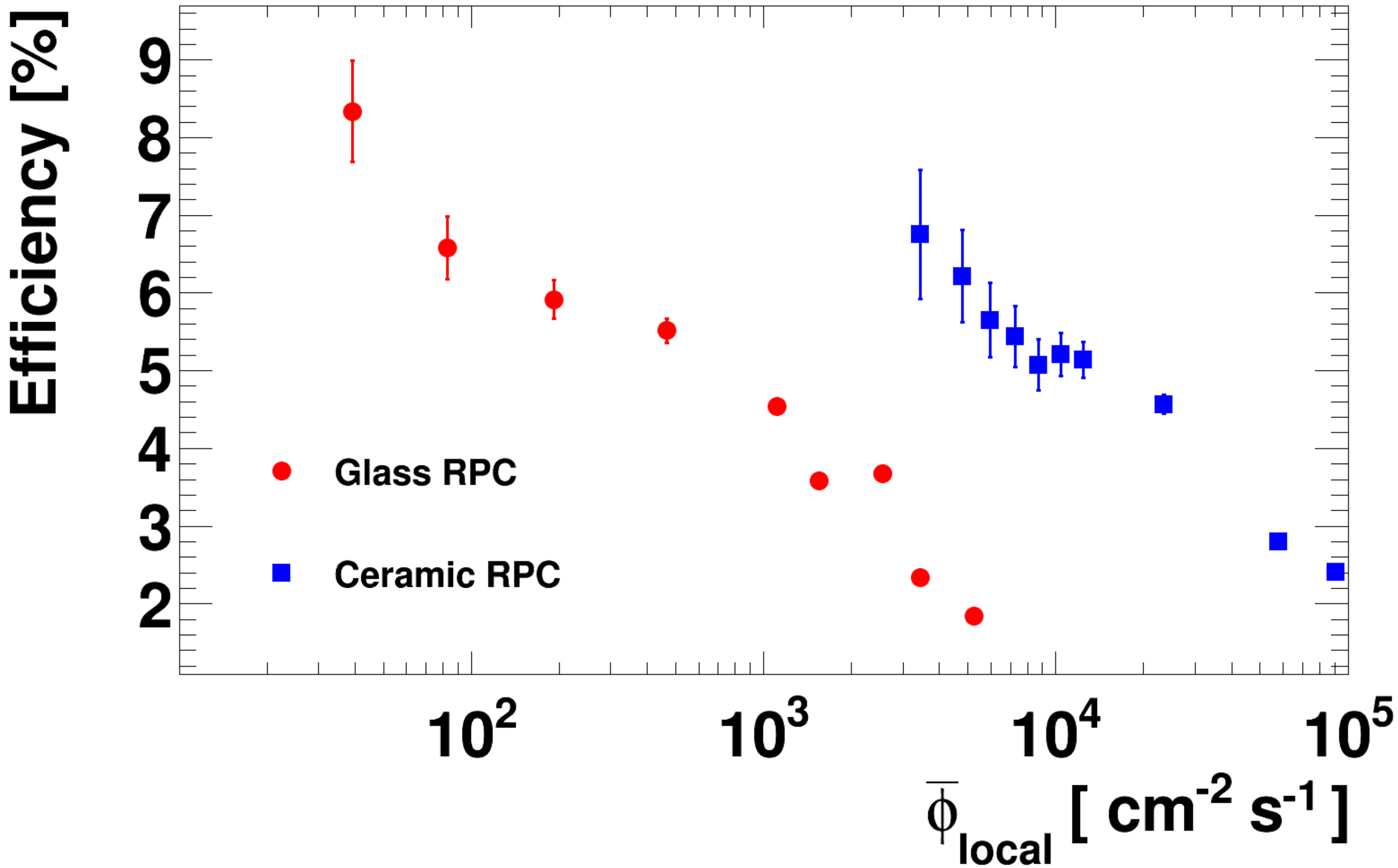
PHOTON DETECTION PERFORMANCE



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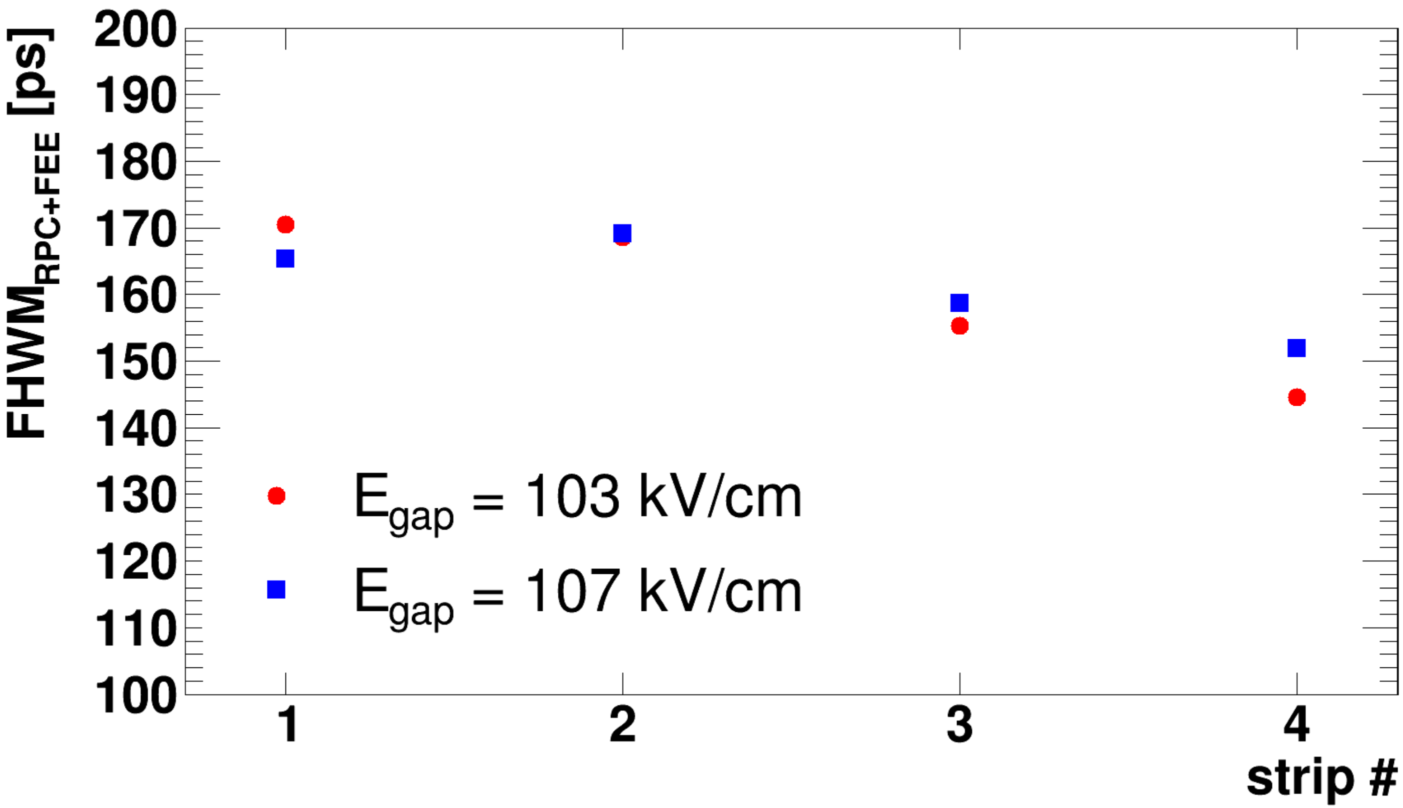
GLASS RPC TIMING



Average over the whole detector:

E = 103 kV/cm $\overline{FWHM}_{\text{RPC+FEE}}$ = 160 ps
E = 107 kV/cm $\overline{FWHM}_{\text{RPC+FEE}}$ = 161 ps

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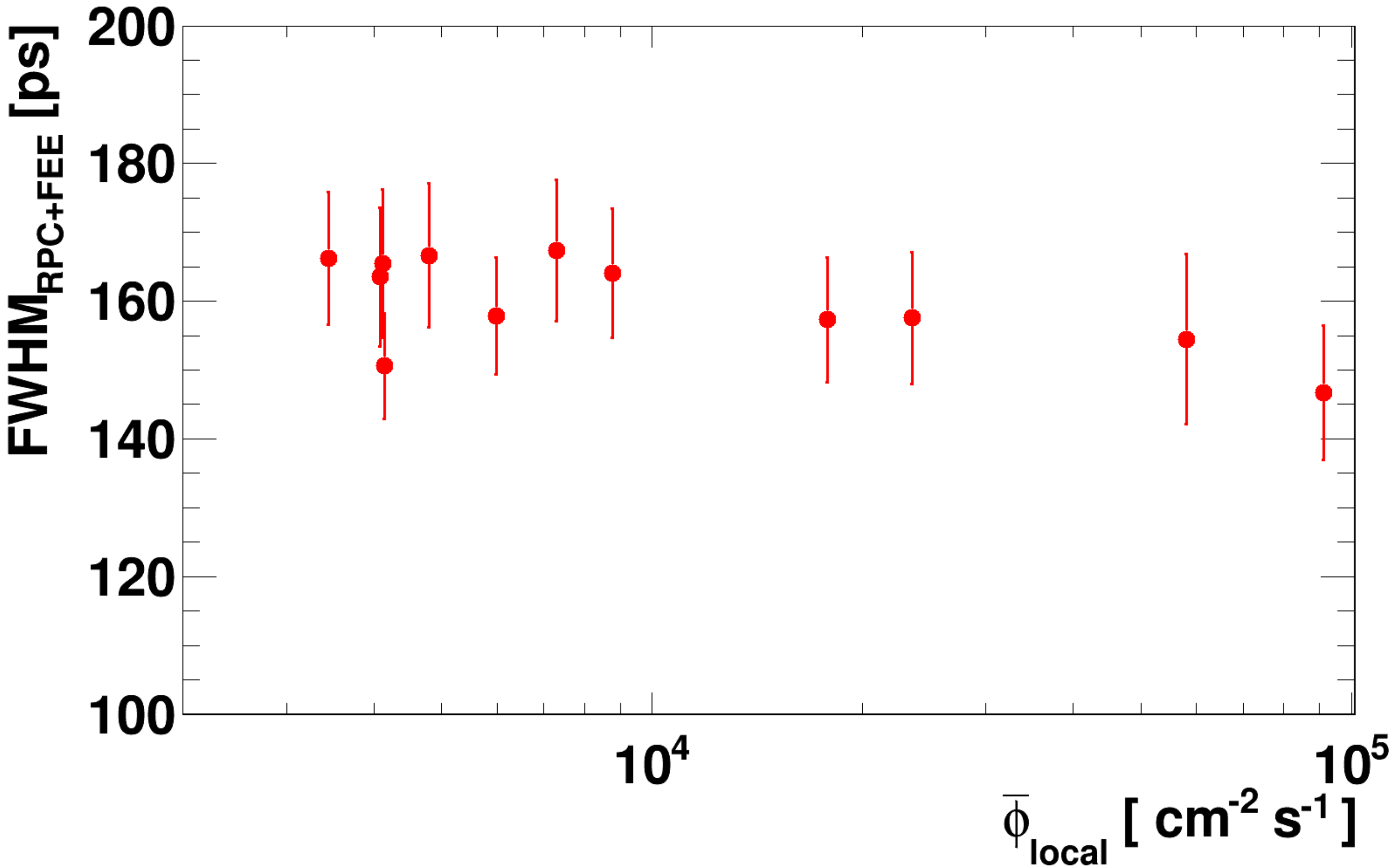
CERAMIC RPC TIMING



DRESDEN concept HZDR

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CONCLUSIONS AND OUTLOOK

- Si_3N_4/SiC suitable material for high-rate RPCs.
- Material characterisation and QA establishment.
- Planning and execution of tests: in lab, at ELBE (HZDR), at COSY (FZJ), at SIS-18 (GSI).
- Efficiencies of CRPCs up to 95% and time resolution σ < 100ps for MIPs
- CRPCs developed represent as of today the highest rate-capable RPCs in the world with $\Phi \sim 2.5 \times 10^5$ cm^{-2} s^{-1}.
- Studies for medical applications (promt gamma imaging ongoing).

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THANK YOU FOR YOUR ATTENTION

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EXTRA MATERIAL

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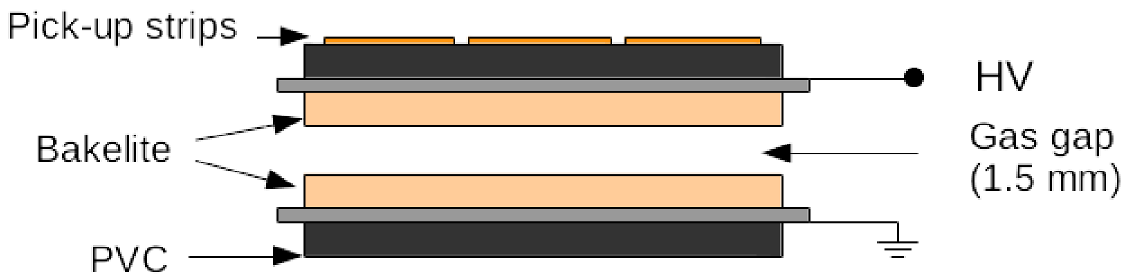
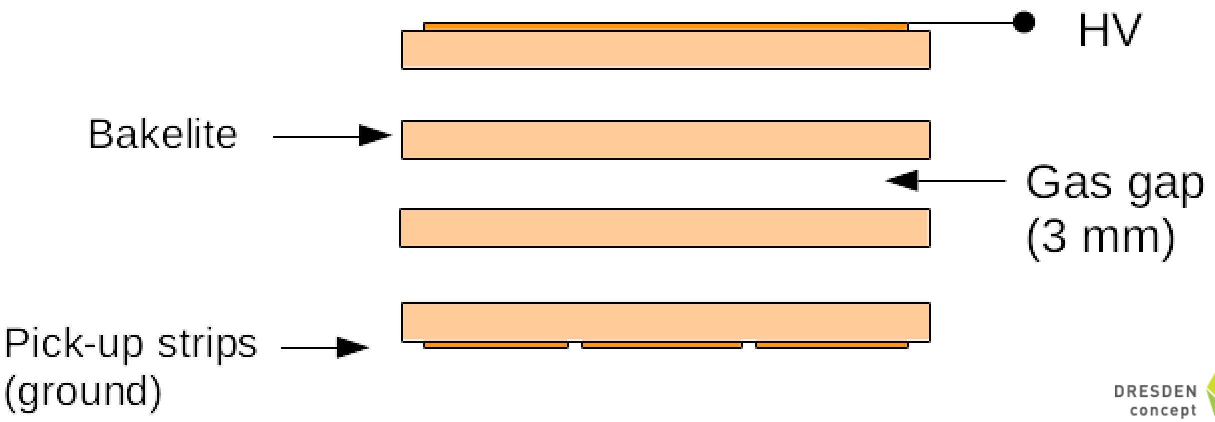
EVOLUTION OF RPCS

- First developed by Santonico and Cardarelli and introduced in 1981 in Nucl. Instr. Meth. 187 (1981) 377.

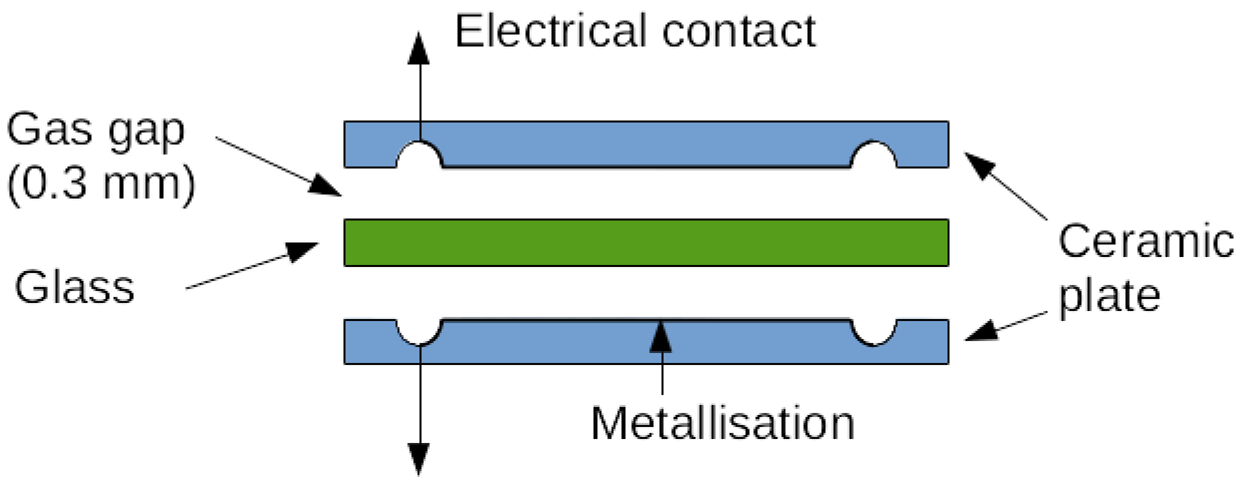


- Multi-gap structure introduced in 1996 by Cerron Zeballos et al. In Nucl. Instr. Meth. A 374 (1996) 132.



EVOLUTION OF RPCS

- Timing RPCs introduced by Fonte et al. in 2000
  Nucl. Instr. Meth. A 443 (2000) 451.



- Time resolution $\sigma \sim 100$ ps.

- New way towards Time-of-Flight applications.

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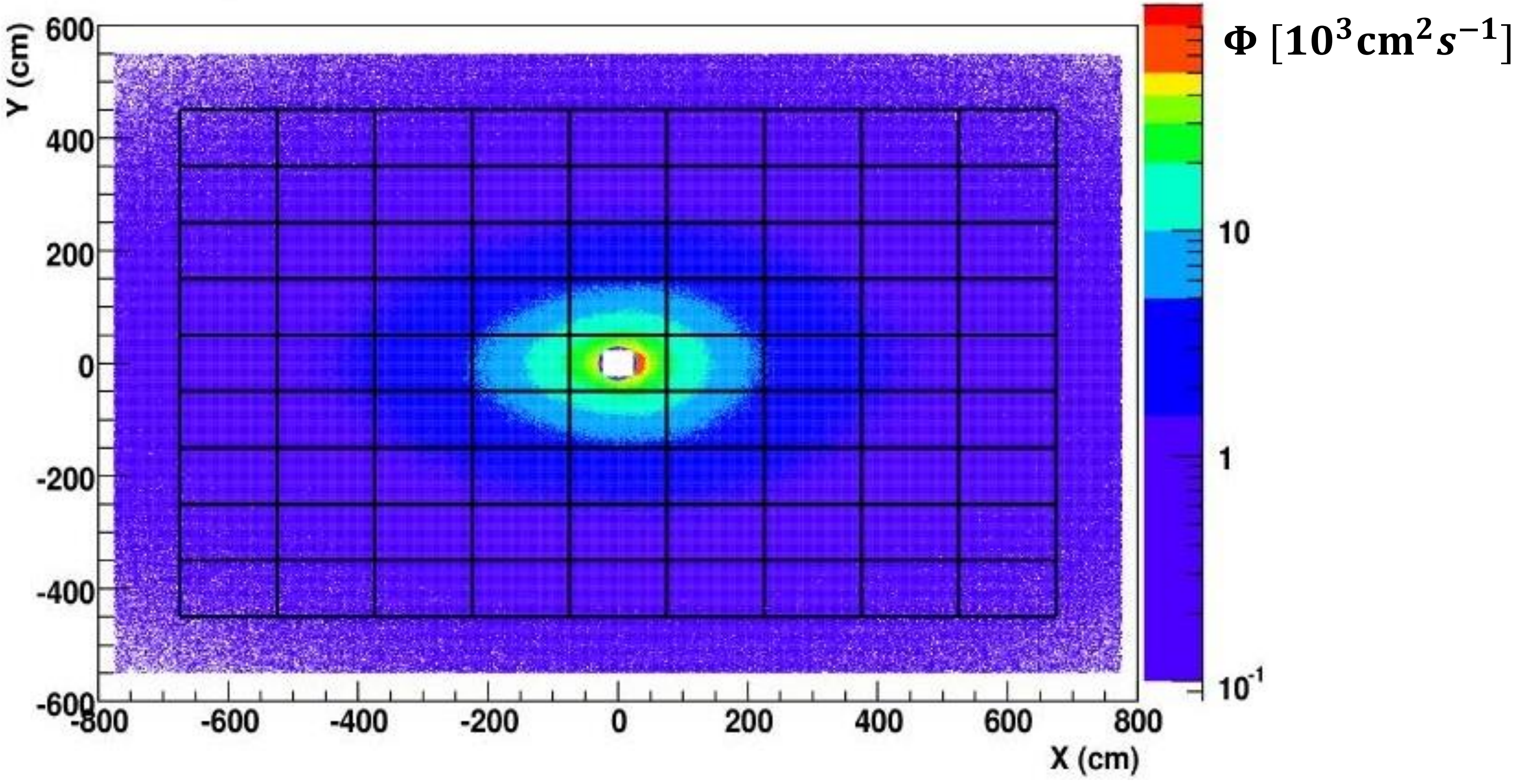
NEXT GENERATION APPLICATIONS: COMPRESSED BARYONIC MATTER EXPERIMENT



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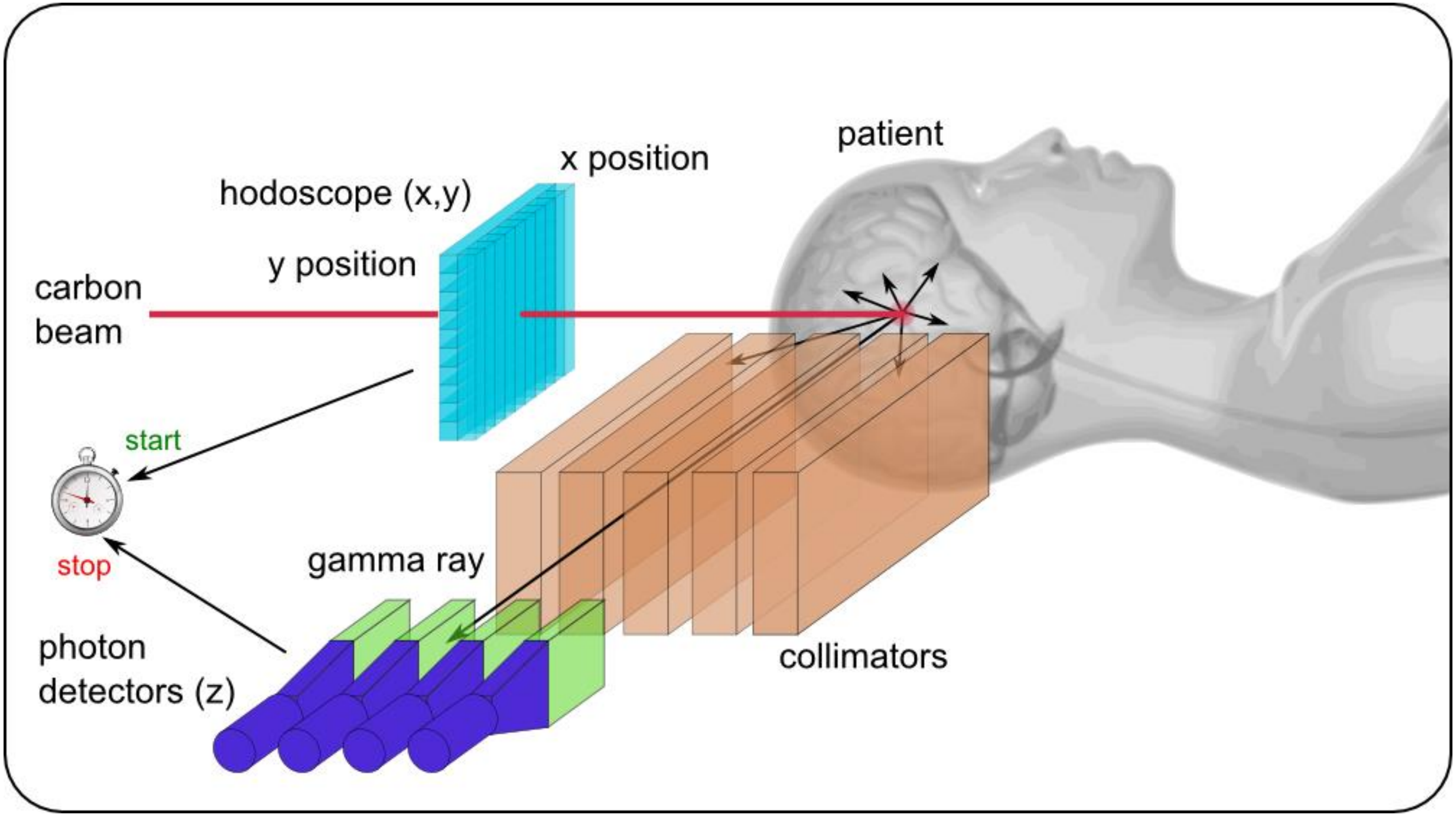
NEXT GENERATION APPLICATIONS: PROMPT GAMMA DETECTION IN HADRON THERAPY



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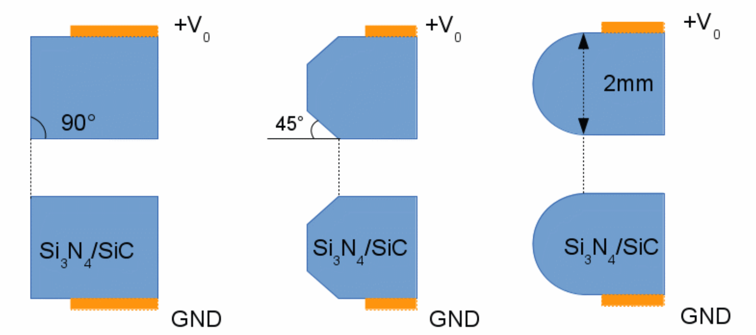
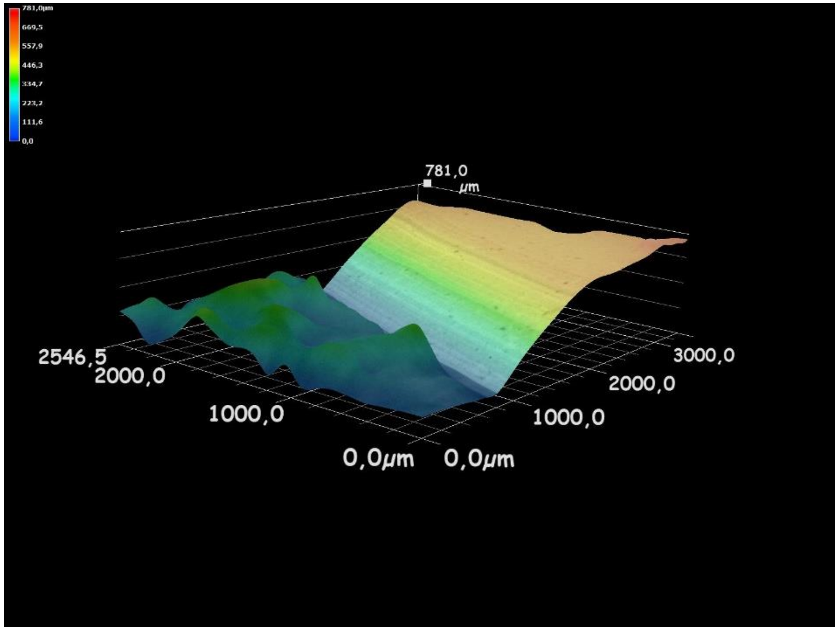
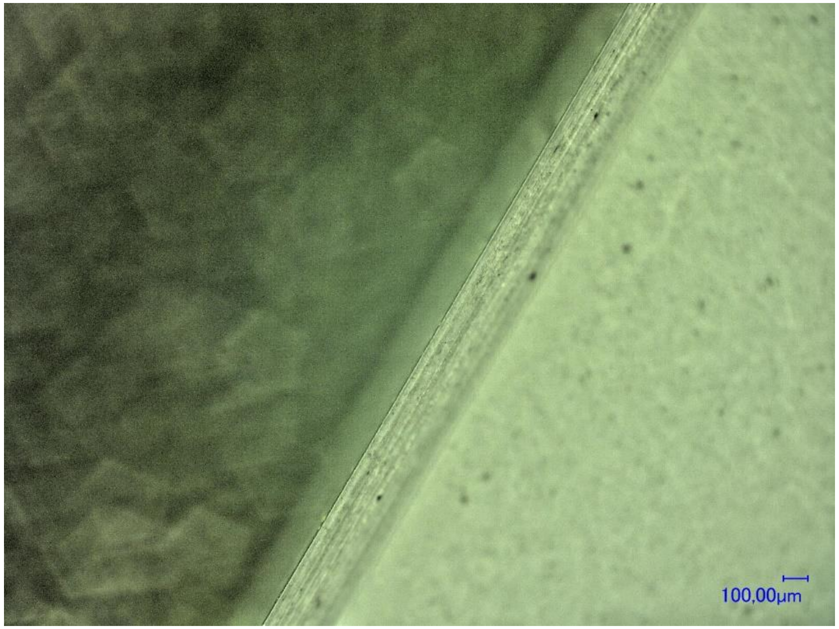
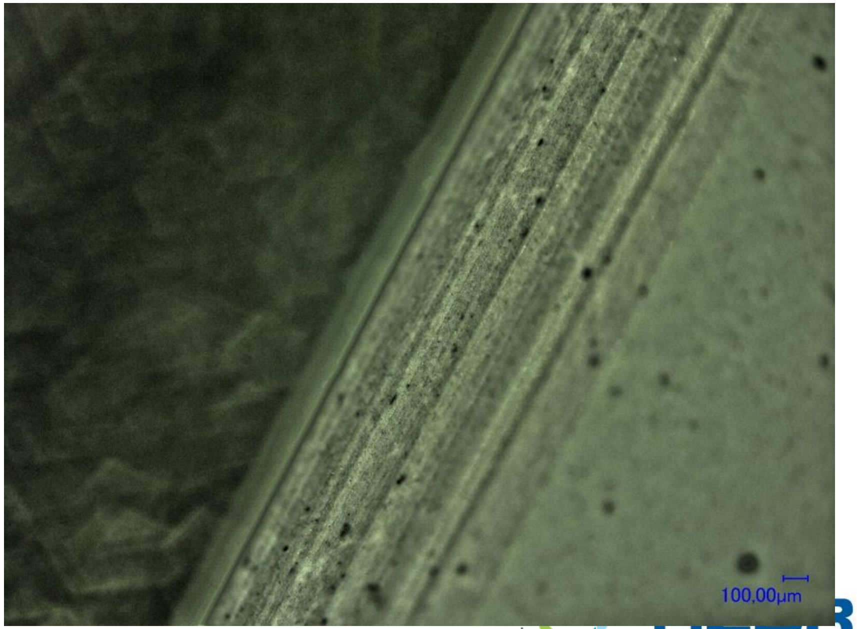
DETECTOR OPTIMIZATION









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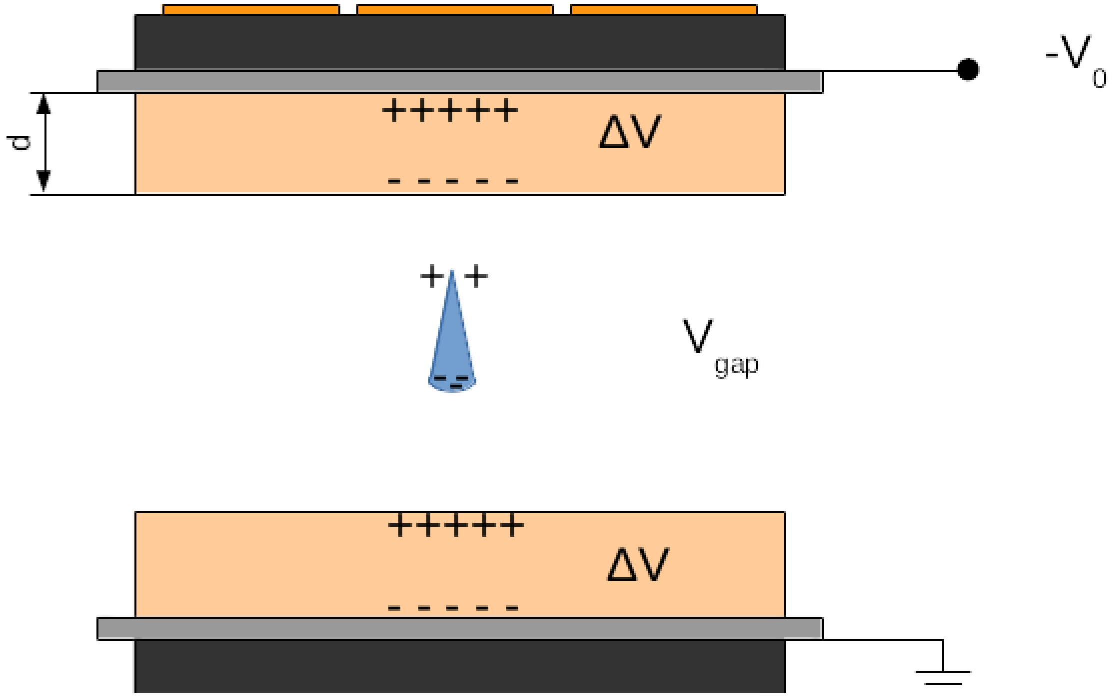
THE PATH TO HIGH-RATE RPCS

- Voltage drop due to resistive material:

$$V_{gap} = V_0 - 2 \times \Delta V = V_0 - 2 \times IR$$

- Charge in the avalanche:

$$IR = \Phi \times q_{aval}(V_{gap}) \times \rho(V_{gap}) \times d$$



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