

Timing RPC for prompt gamma radiation detection

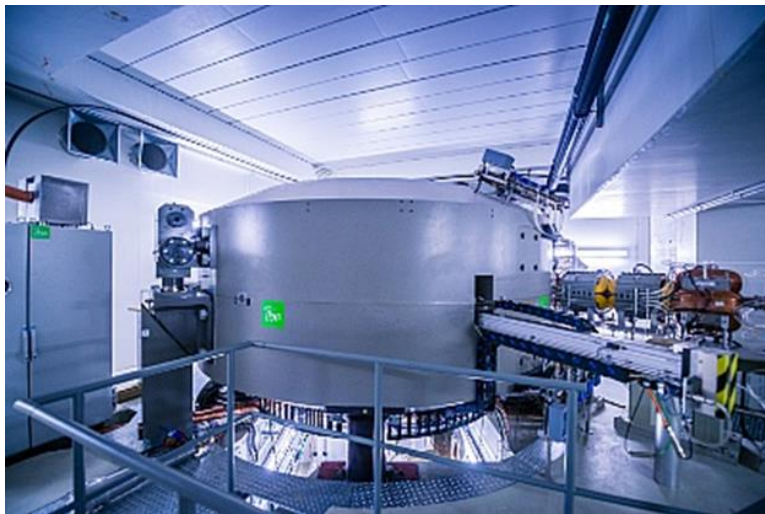
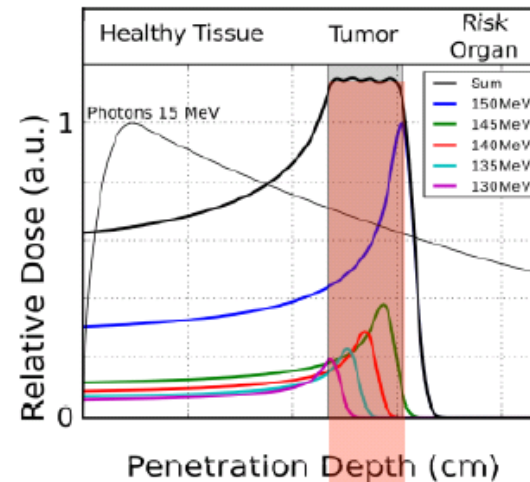
RPC 2016

Lothar Naumann

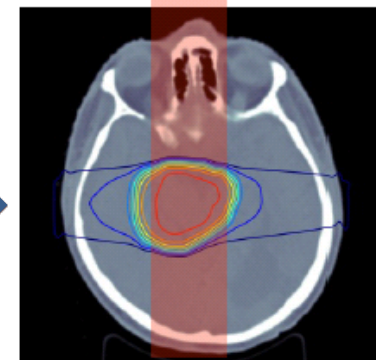


RPC for Proton Therapy

- Proton therapy is a modern treatment for deep seated tumors
- Tumor dislocation or modification during the treatment period occurs
- Improvement of the proton therapy with online beam parameter settings

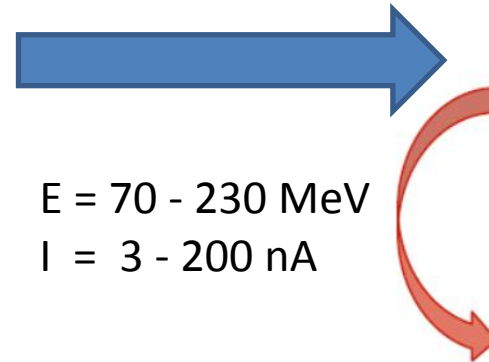


$E = 70 - 230 \text{ MeV}$
 $I = 3 - 200 \text{ nA}$

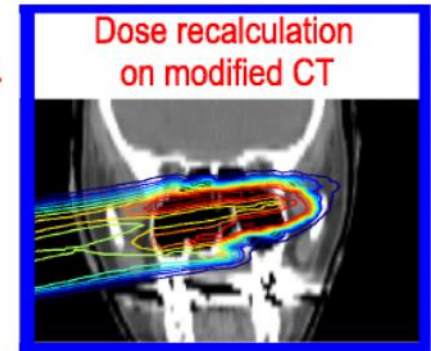


*Fiedler et al.,
2011 IEEE NSS/MIC*

PRC for Proton Therapy



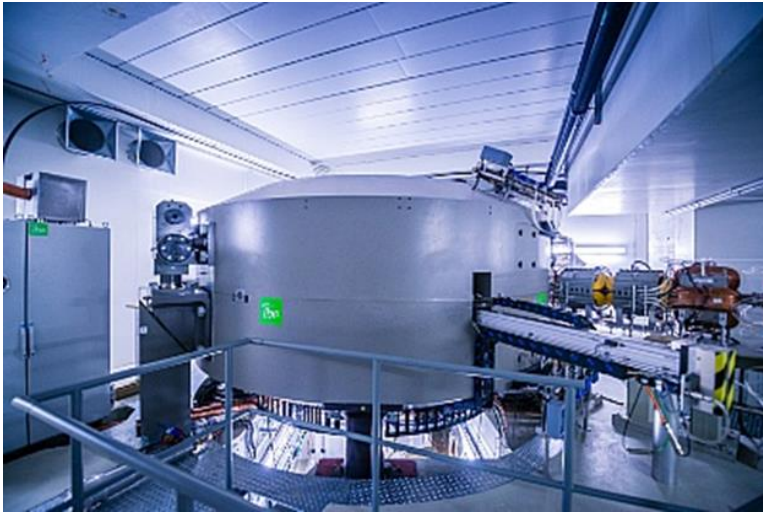
$E = 70 - 230 \text{ MeV}$
 $I = 3 - 200 \text{ nA}$



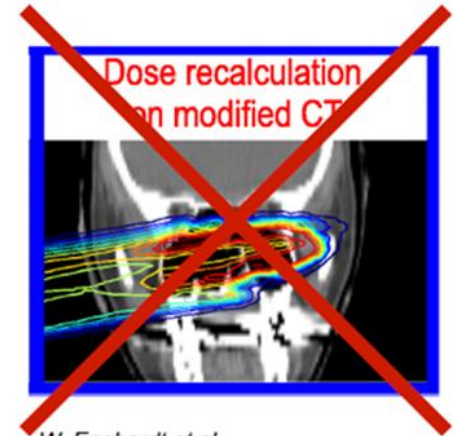
*W. Enghardt et al.,
Radiother. Oncol. 73 (2004) S96*

- Proton therapy is a modern treatment for deep seated tumors
- Tumor dislocation or modification during the treatment period occurs
- Improvement of the proton therapy with online beam parameter settings

RPC for Proton Therapy



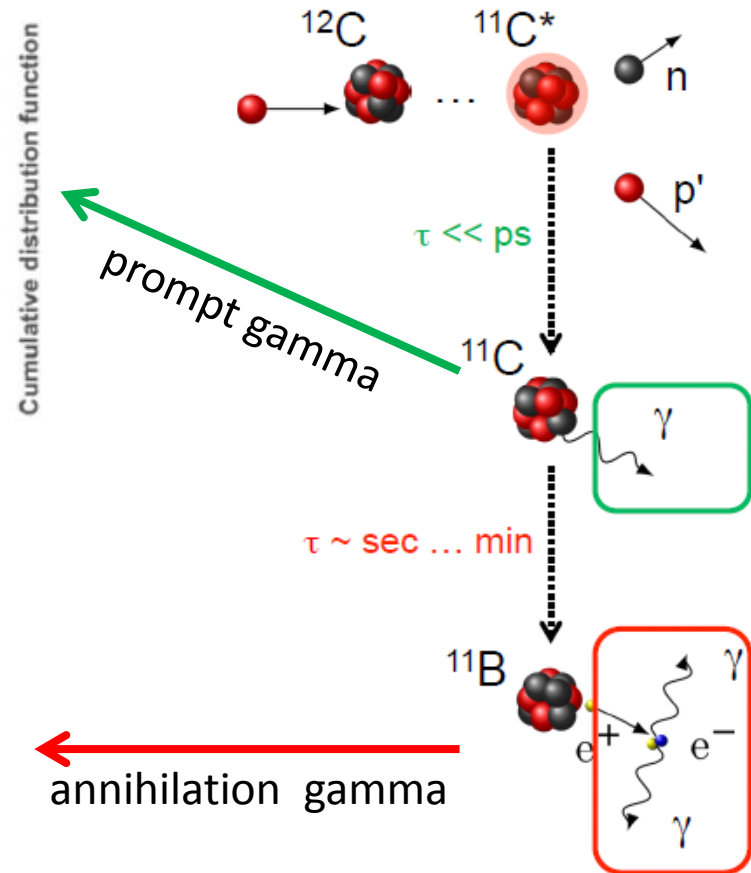
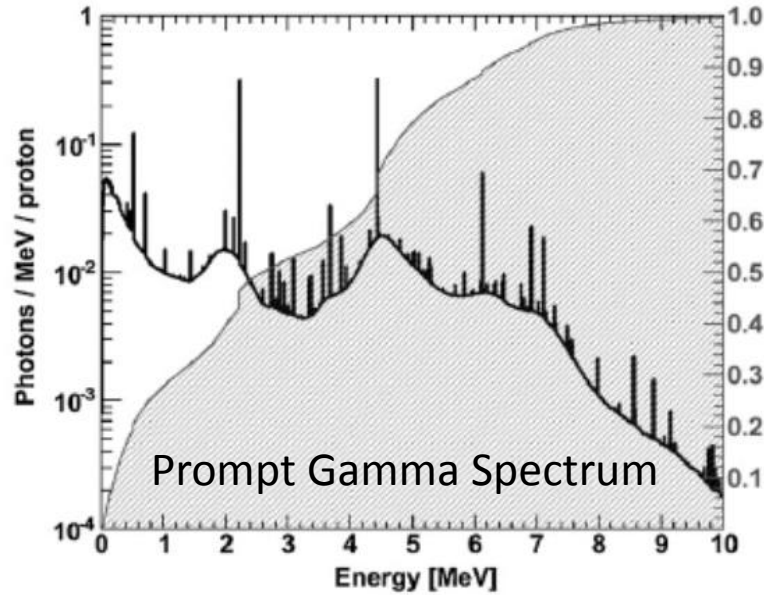
$E = 70 - 230 \text{ MeV}$
 $I = 3 - 200 \text{ nA}$



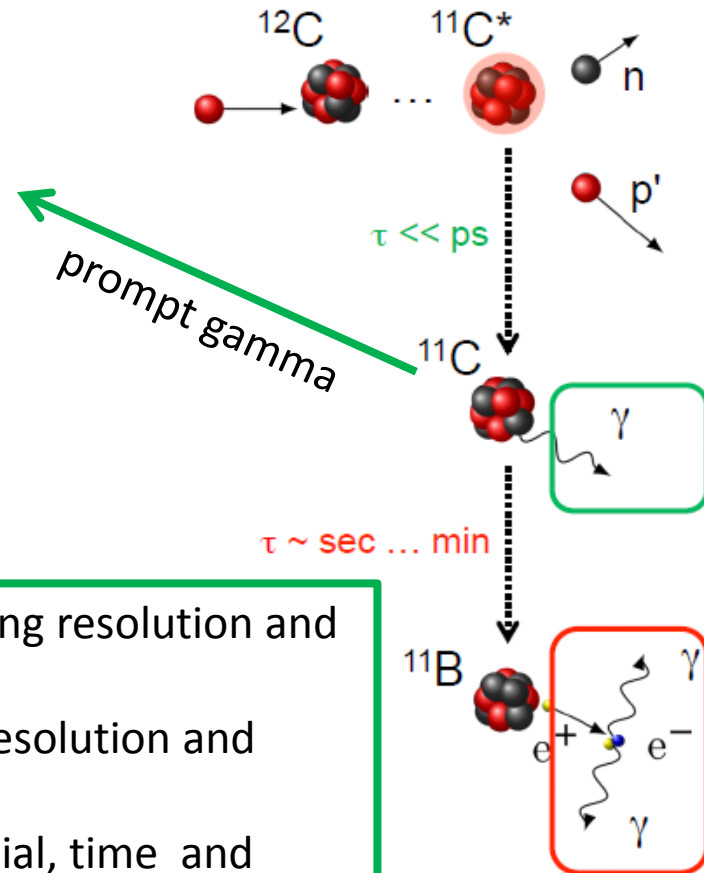
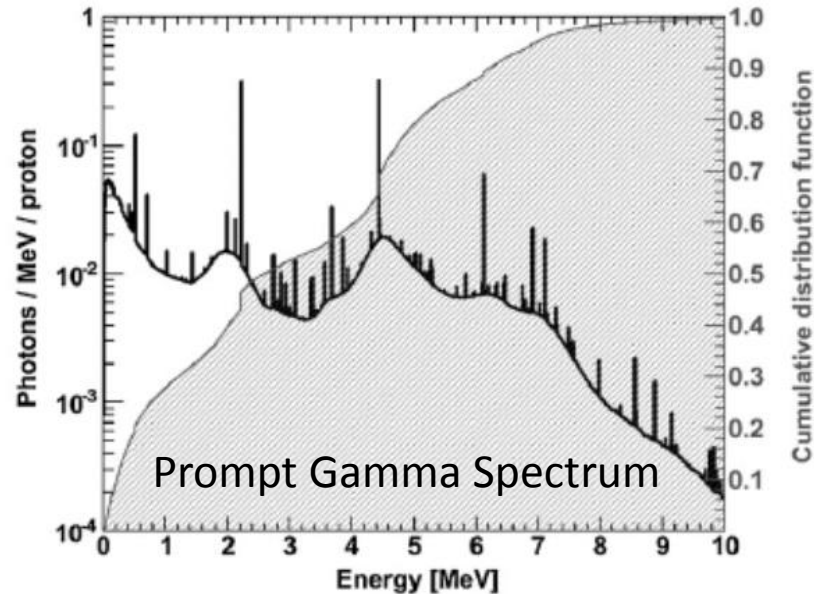
*W. Enghardt et al.,
Radiother. Oncol. 73 (2004) S96*

- Proton therapy is a modern treatment for deep seated tumors
- Tumor dislocation or modification during the treatment period occurs
- Improvement of the proton therapy with real time range assessment

Treatment control

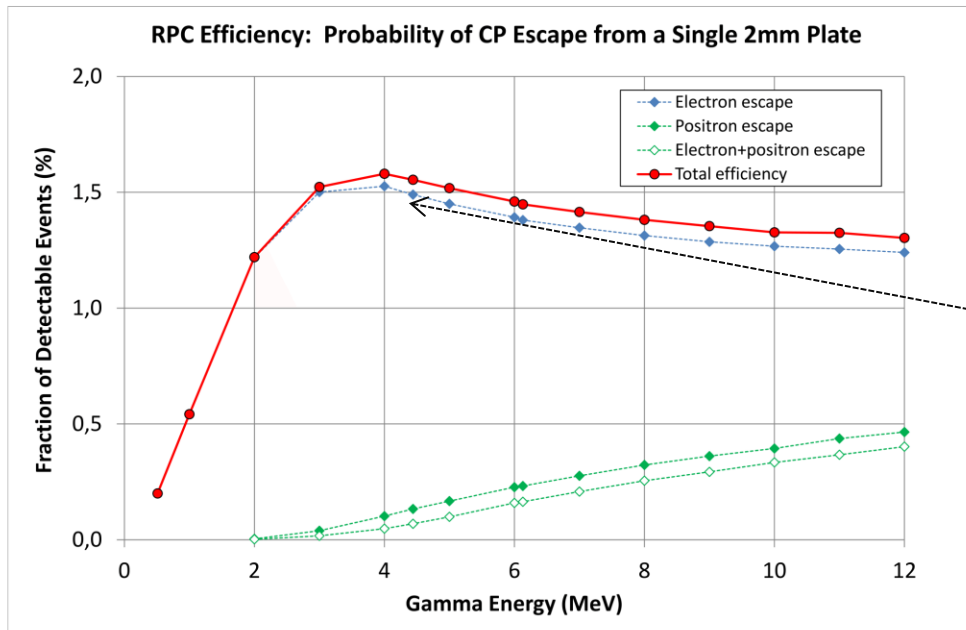


Treatment control



- Prompt Gamma **Timing**: Timing Detector timing resolution and count rate capabilities →RPC ?
- Prompt Gamma **Imaging**: Slit camera spatial resolution and count rate capabilities →RPC ?
- Prompt Gamma **Origin**: Compton camera spatial, time and energy resolutions and count rate capabilities → **no RPC !**

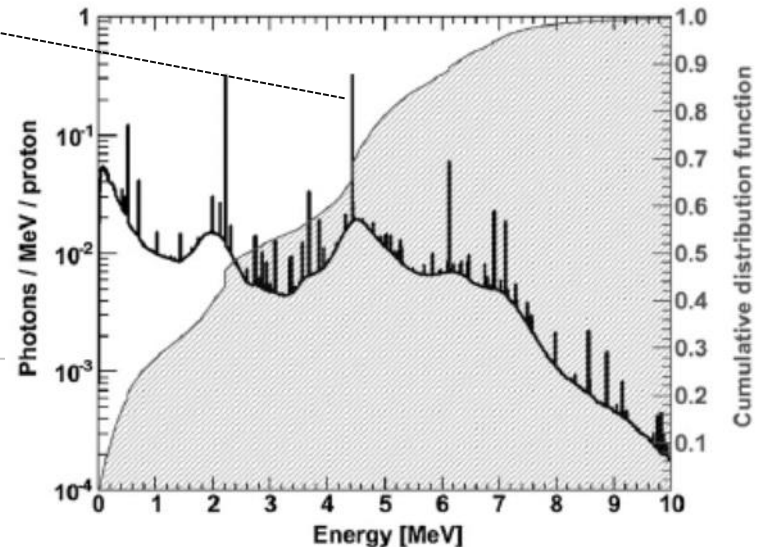
Ceramics RPC efficiency (sim.)



1.5 % electrons/ γ

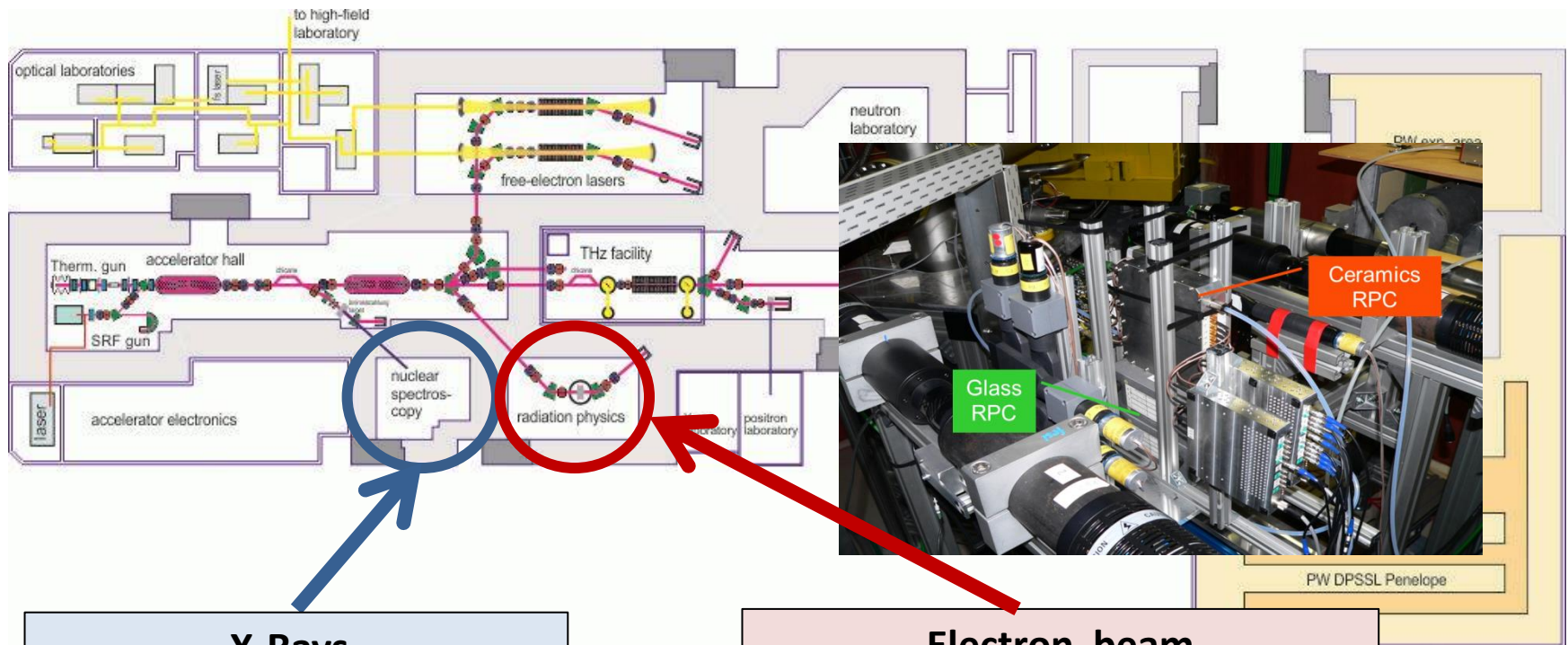
Compton scattering in a single ceramic sheet of 2 mm effects an escape of electrons and positrons

GEANT4 physics list QGSP_BIC_HP



energy spectrum of prompt γ -rays
 $E_p = 150$ MeV; PMMA target

X-Rays@Electron accelerator (ELBE)

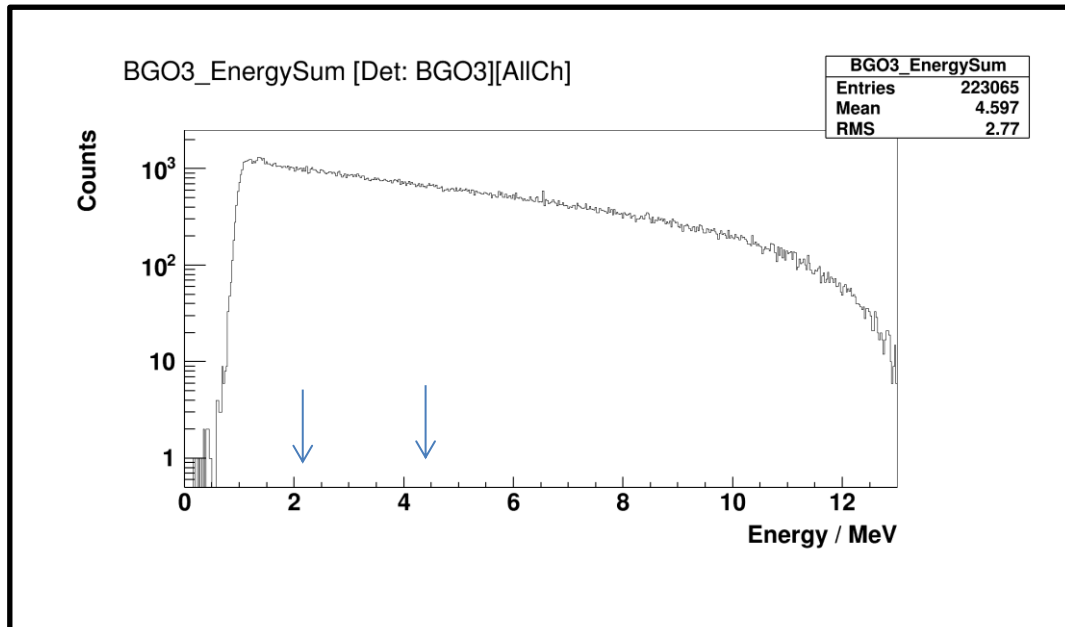


X-Rays
 energy spectra ≤ 20 MeV
 pulse duration 5 ps
 flux ≤ 500 kHz/cm²

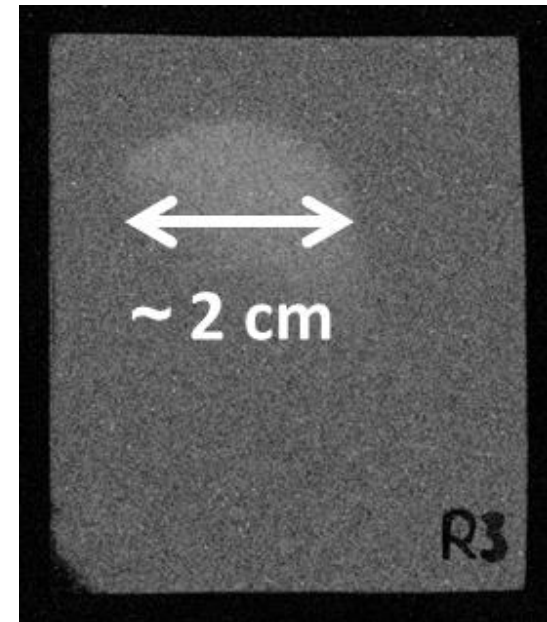
Electron beam
 monoenergetic , single electrons
 energy 12 - 40 MeV
 pulse duration 5 ps
 flux ≤ 500 kHz/cm²

X-Rays@ ELBE

energy spectrum

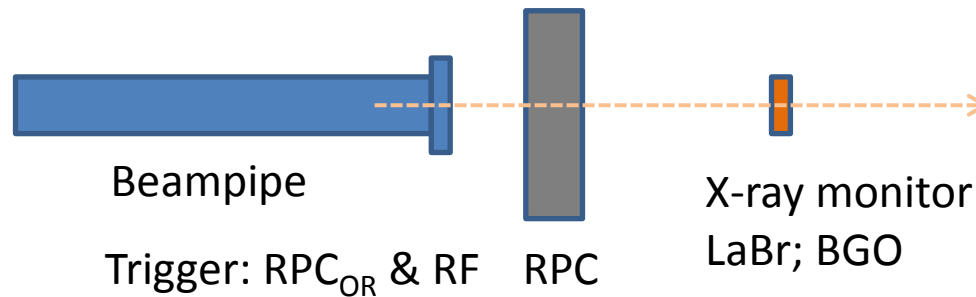


beam size

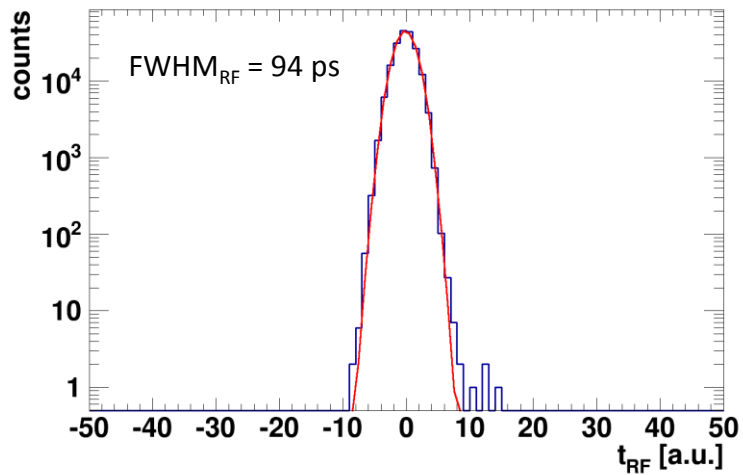


X-Rays@ELBE

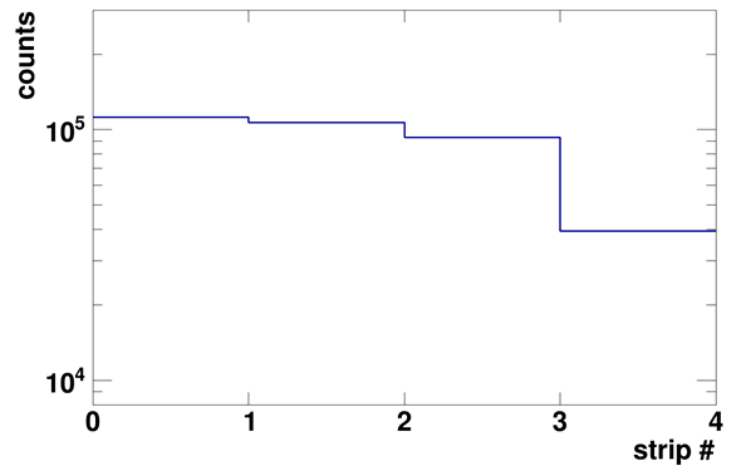
$E_\gamma < 12.5 \text{ MeV}$



Reference timing: ELBE RF

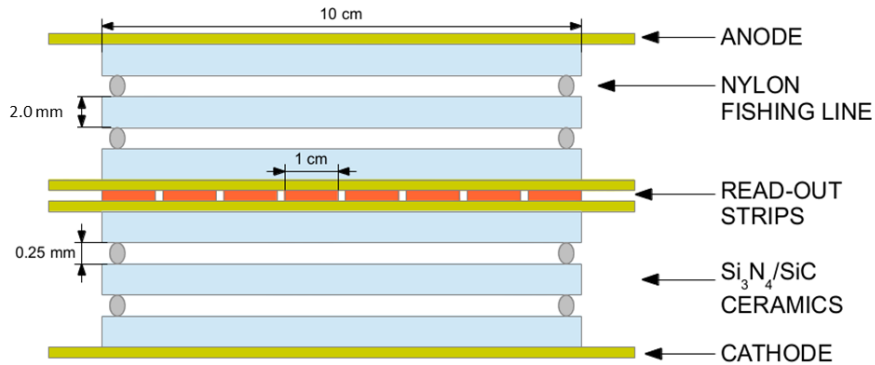


Event distribution



RPC - design

Ceramics RPC

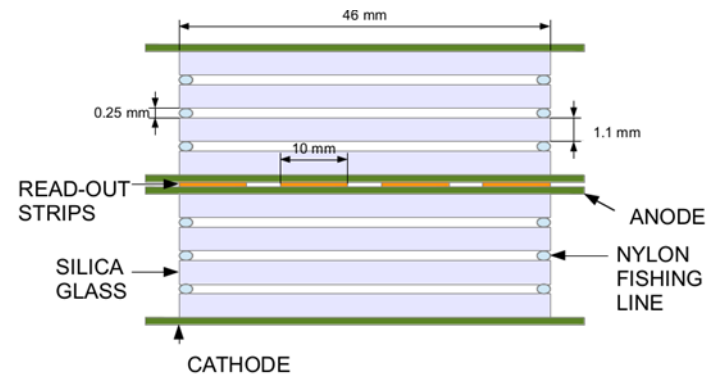


Active area: 100 x 100 mm²
 Bulk resistivity: $\rho \sim 10^9 \Omega \text{ cm}$
 Gas gaps: 2 x 2 gaps, 250 $\mu\text{m/gap}$

Gas mixture: 85%Freon/10%i-Butane/5% SF₆
 Read-out electronics: GSI (FOPI)

L. Naumann et al., Nucl. Instr. Meth. A 628 (2011) 138

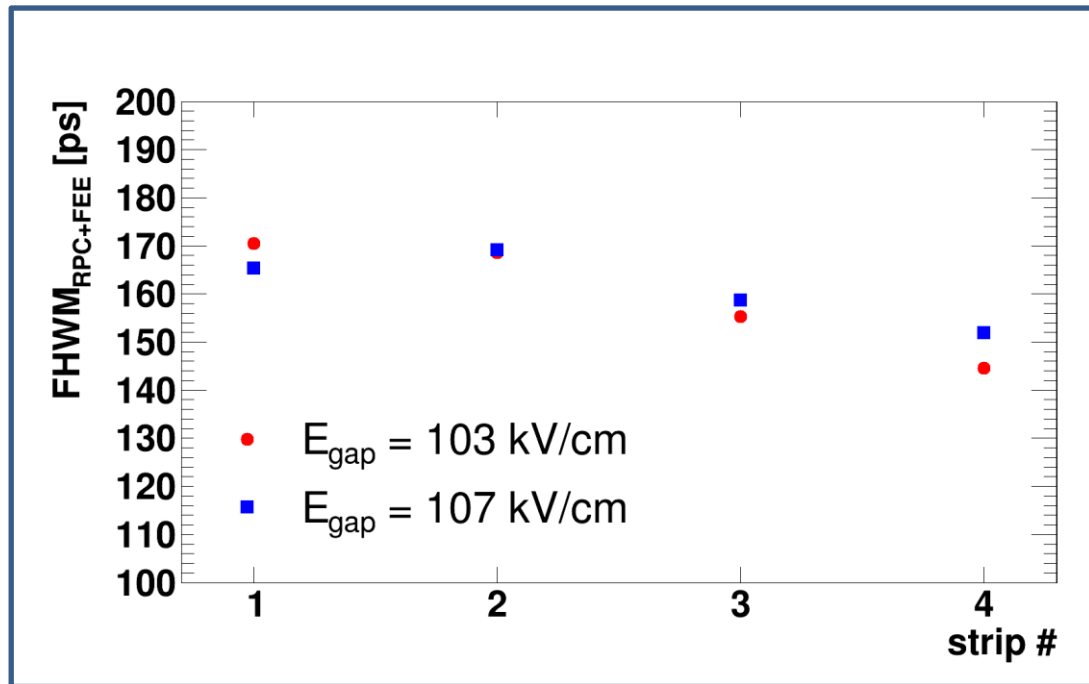
Glass RPC



Active area: 46 x 76 mm²
 Bulk resistivity: $\rho \sim 10^{12} \Omega \text{ cm}$
 Gas gaps: 2 x 3 gaps, 250 $\mu\text{m/gap}$

Kotte et al., Nucl. Instr. Meth. A 564 (2006) 155

Glass RPC- timing



$$t_{\text{ToF}} = \frac{t_{\text{left}} + t_{\text{right}}}{2}$$

Average over the whole detector:

$$\sigma_{\text{RPC+FEE}} = \sqrt{\sigma_{\text{ToF}}^2 - \sigma_{\text{RF}}^2}$$

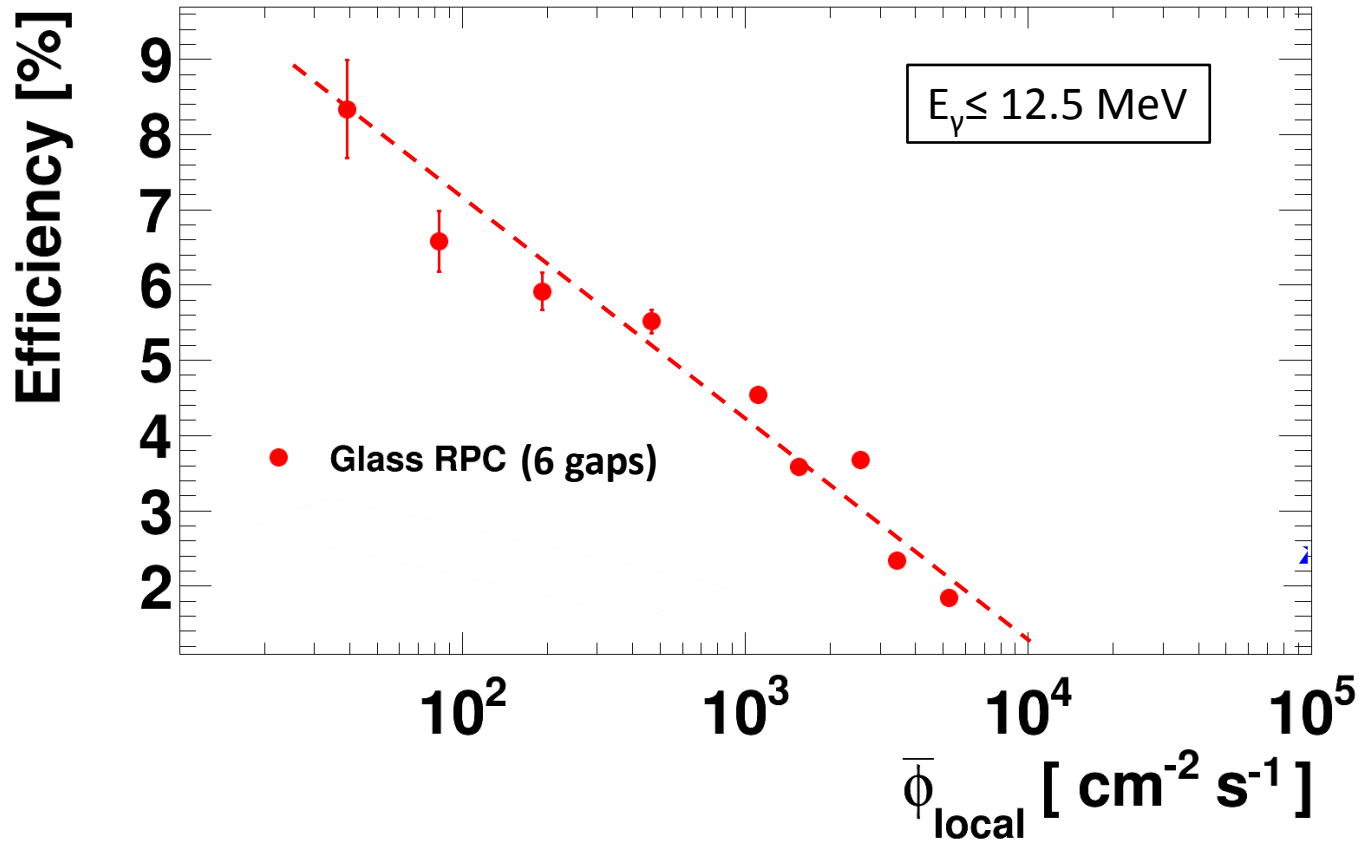
$$E = 103 \text{ kV/cm}$$

$$\overline{FWHM}_{\text{RPC+FEE}} = 160 \text{ ps}$$

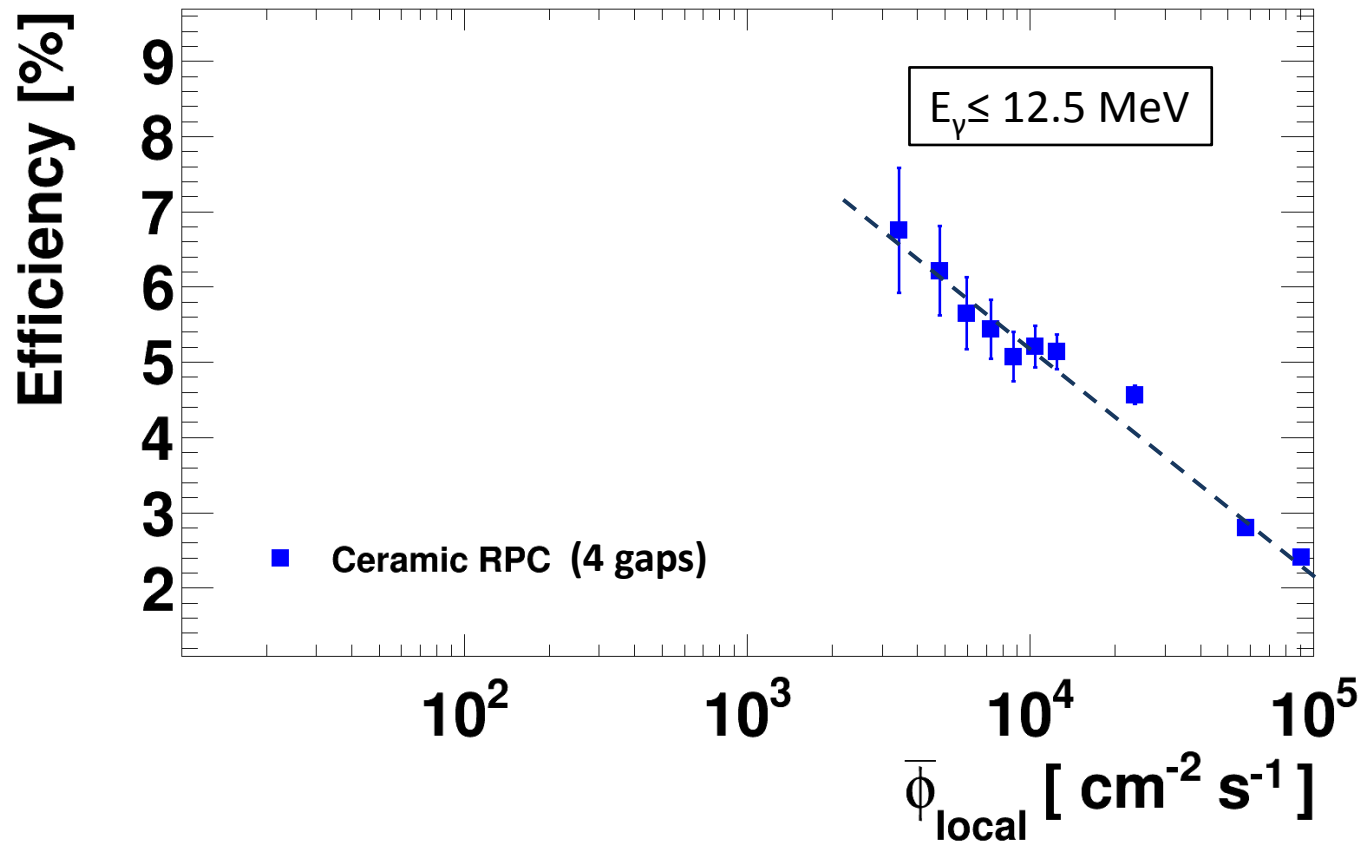
$$E = 107 \text{ kV/cm}$$

$$\overline{FWHM}_{\text{RPC+FEE}} = 161 \text{ ps}$$

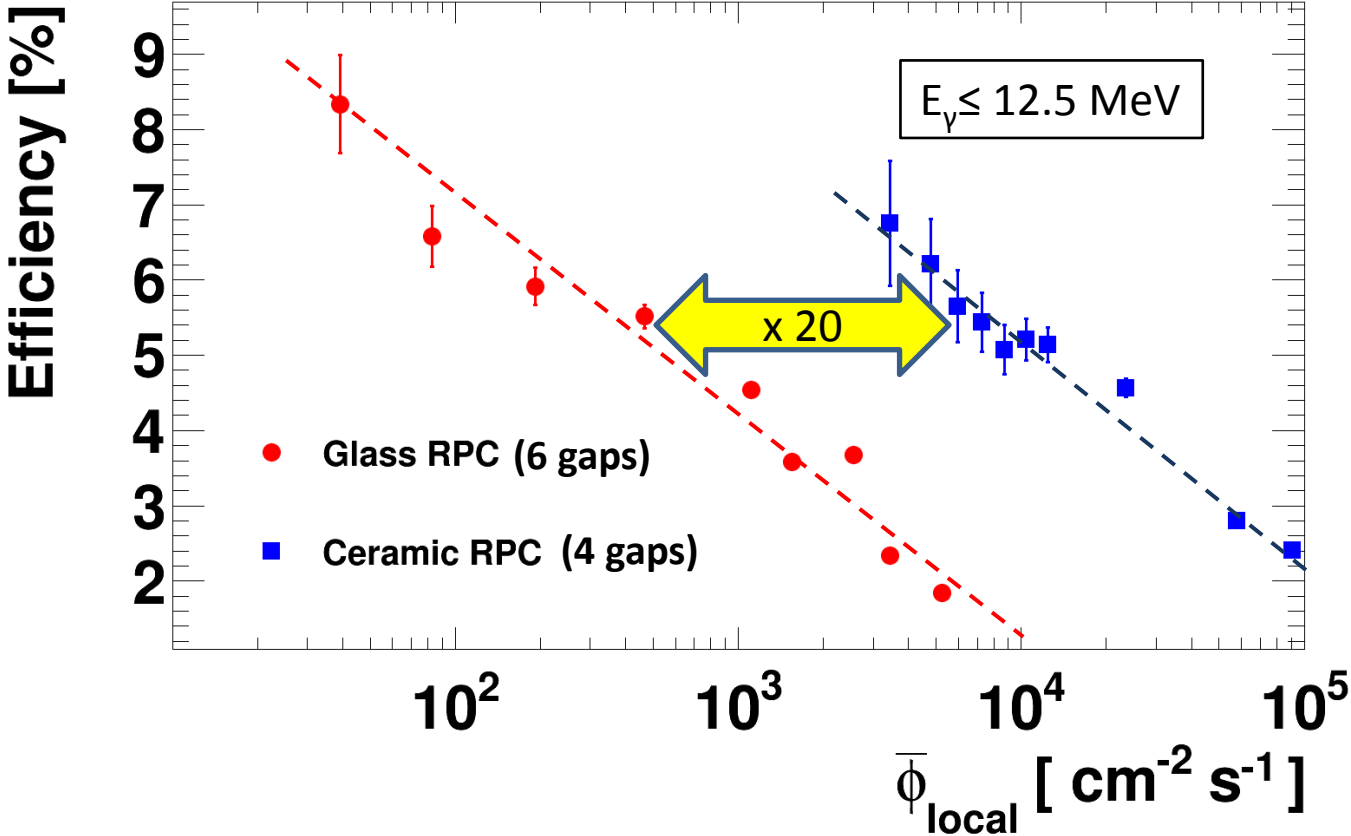
Glass RPC – efficiency vs. flux



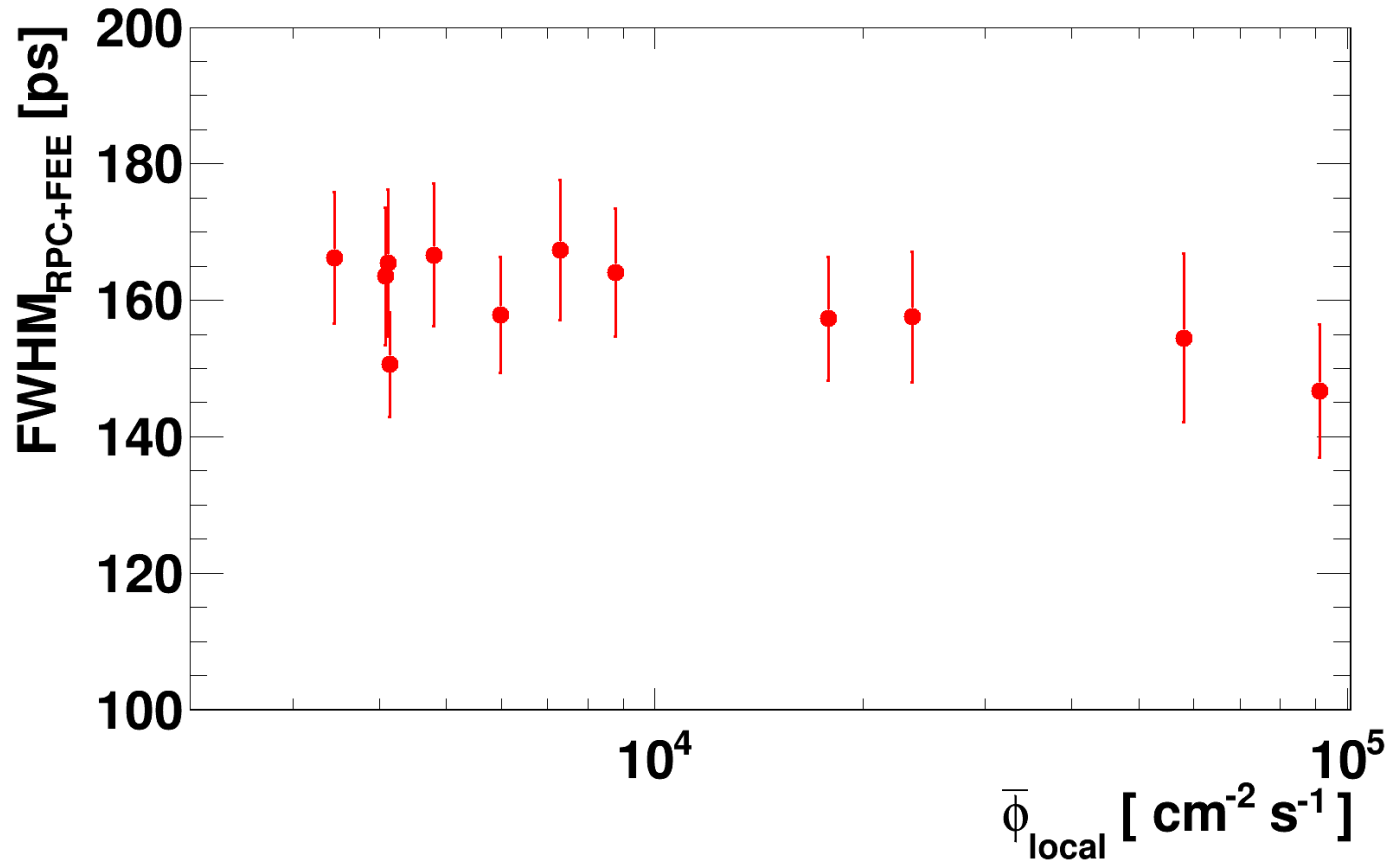
Ceramics RPC – efficiency vs. flux



RPC – efficiency



Ceramics RPC – timing vs.flux



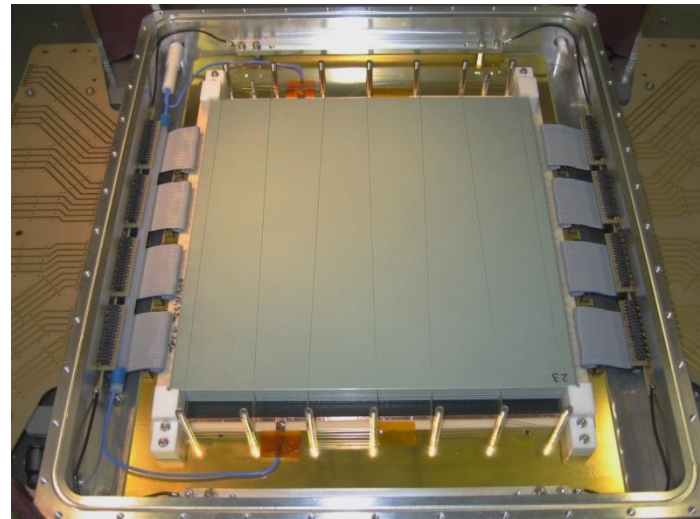
Conclusions

- X-rays at ELBE are comparable to prompt gammas, generated by proton beams in human tissue
- GEANT4 simulations and experimental results of the detector efficiency have been compared. The results are in agreement for fluxes of $10^4 \text{ cm}^{-2}\text{s}^{-1}$ and amounts to 1.5 % per gap
- RPC with float glass electrodes shows in comparison to ceramics system an degradation of the rate capability by a factor of 20
- The time resolution is constant and amounts to $\text{FWKH} = 150 \text{ ps}$ up to the flux of $10^5 \text{ cm}^{-2}\text{s}^{-1}$

Outlook

- Ceramics RPC for Prompt Gamma Timing
- Ceramics RPC for Prompt Gamma Imaging (slit camera system)
- Ceramics RPC test run with proton induced prompt gammas at OncoRay

20x20 cm²
6 gas gaps, 250 μm/gap
32 readout strips
PADI + VFTX



Acknowledgment:

HZDR - Dresden/Germany:

A. Laso Garcia, J. Dreyer, B. Kämpfer, R. Kotte,
H. Rohling, K. Römer, D. Stach, C. Wendisch

OncoRay - Dresden/Germany:

G. Pausch

RPC 2016

Lothar Naumann

