The ion ToF-Wall for the R^3B experiment at FAIR

R&D on Resistive Plate Chambers for the detection of relativistic heavy ions

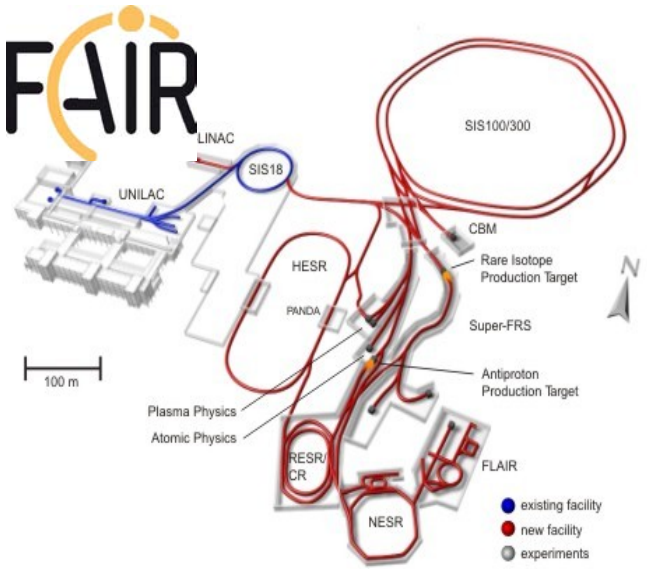
Y. Ayyad, J. Benlliure, E. Casarejos, I. Durán, H. Álvarez-Pol, C. Paradela, N. Montes, J.R. Pereira

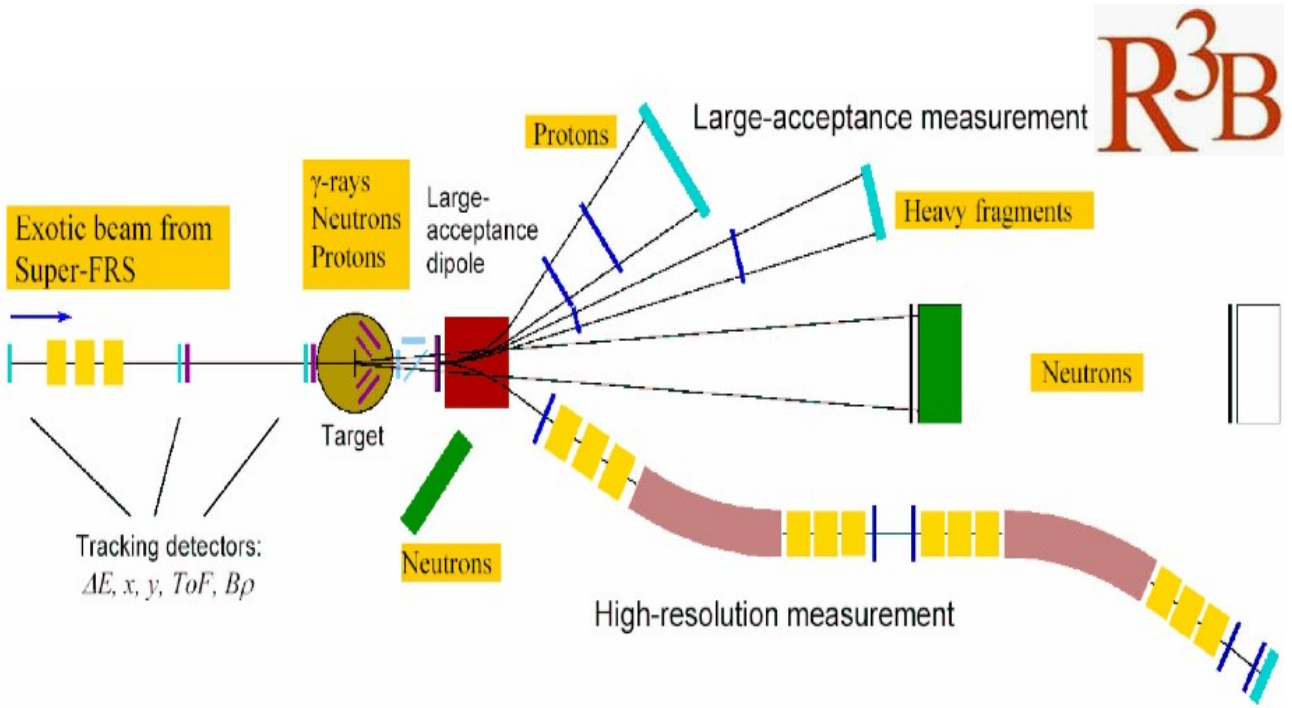
Universidade de Santiago de Compostela

Content

- Motivation: The R^3B experiment
- Resistive Plate Chambers
- Conceptual design of the iToF-Wall
- Experiments
  - Relativistic heavy ions (^{12}C, ^{64}Ni and ^{238}U)
  - Electrons
- Summary

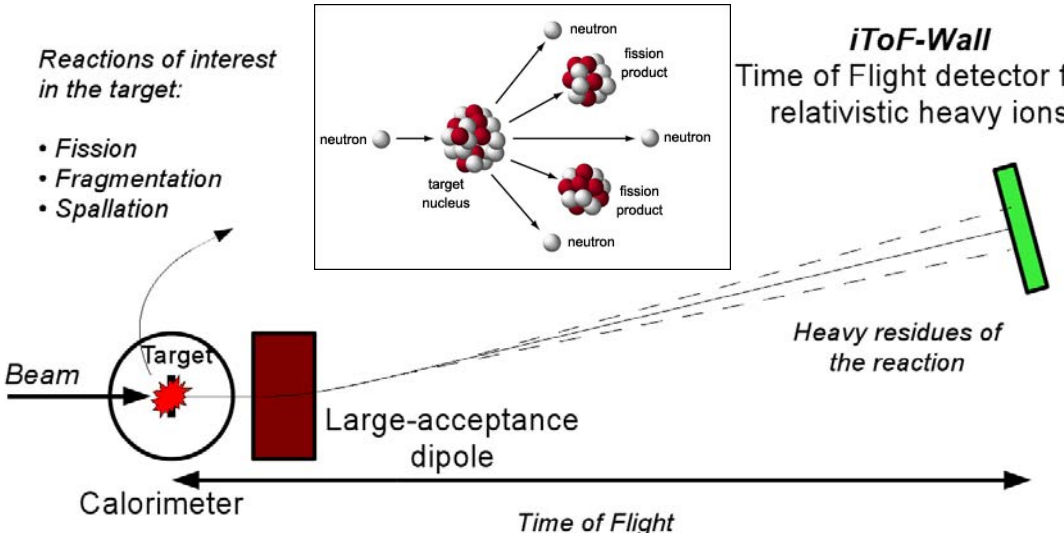
Ion ToF-Wall detector for R^3B experiment at FAIR



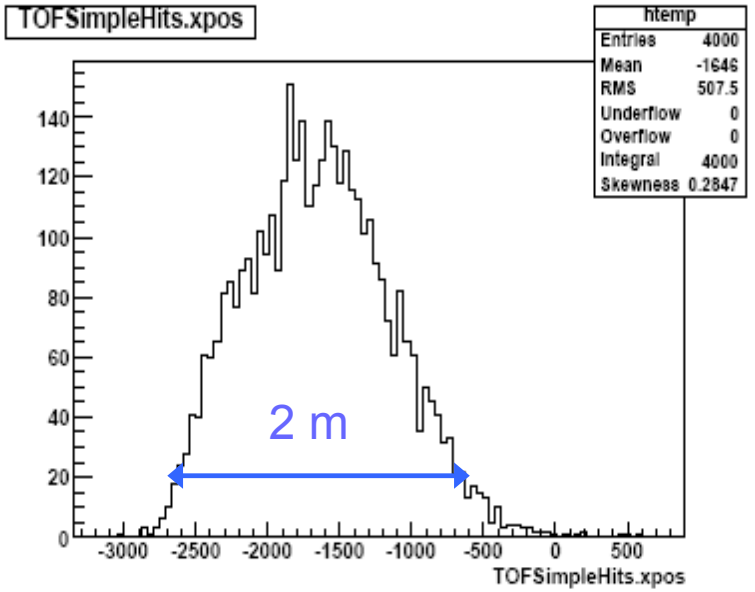


- **FAIR**: **F**acility for **A**ntiproton **I**on **R**esearch
- **R^3B:** **R**eactions with **R**elativistic **R**adioactive **B**eams
- Universal detection setup for ***kinematical complete measurements***
- Reaction studies: *knockout, quasi-free scattering, elastic p scattering, fission, spallation, fragmentation, charge exchange*
- *Identification of the heavy fragments produced in **fission, spallation and fragmentation** reactions using Time-of-Flight technique*
- *Ion ToF-Wall detector required for isotopically **separate masses around A=200***

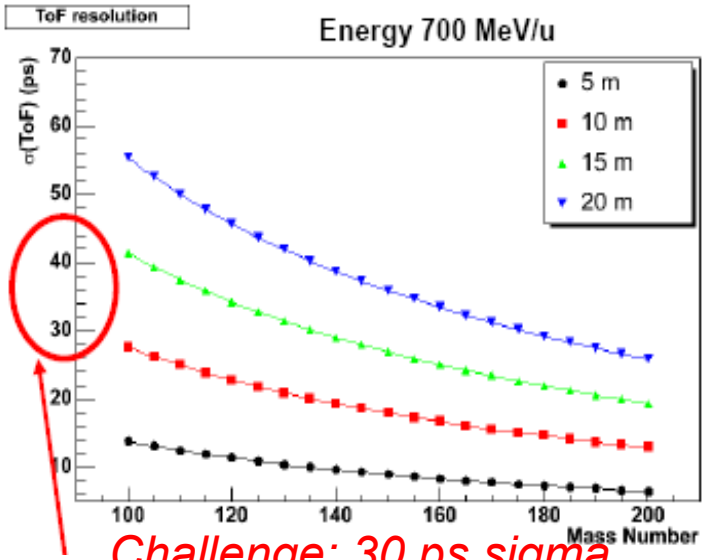
Ion ToF-Wall detector for R^3B experiment at FAIR



- Adapted to ***relativistic heavy ions***
- High ***ToF*** resolution
- Large angular ***acceptance***
- ***Multi-hit*** capabilities at low rates (<100 Hz)
- At 15 m, ***2x1 m²*** of area and ***40 ps*** of time resolution are needed to cover the challenging objectives
- ***Simulations*** performed with GEANT4 reveal the geometry and conceptual design of the detector

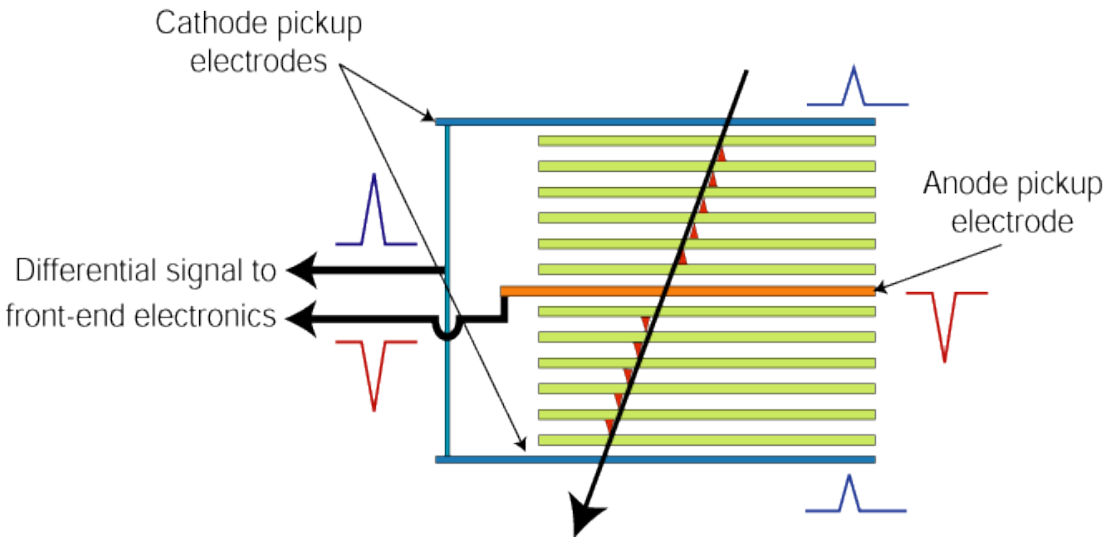


Horizontal distribution at 15 m of fission fragments from 238U+p @ 450 MeV/u

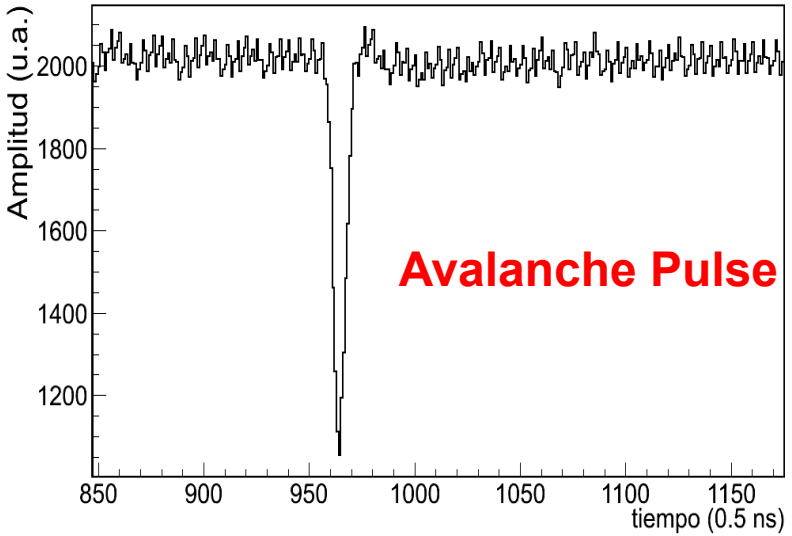


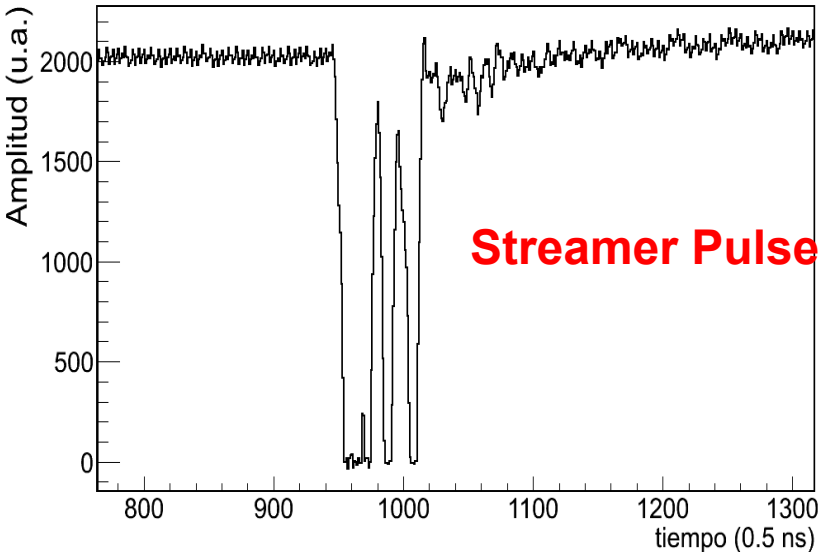
Challenge: 30 ps sigma for A=150

Resistive Plate Chambers. Operation principle

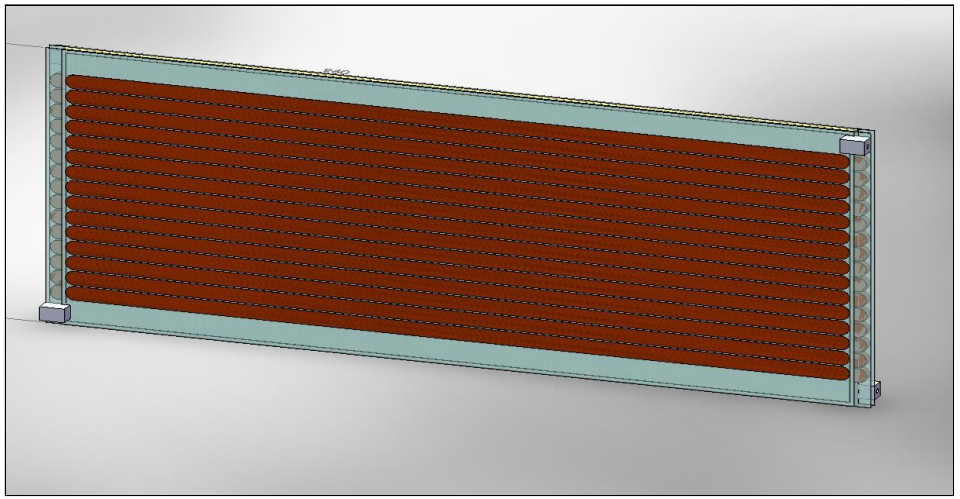


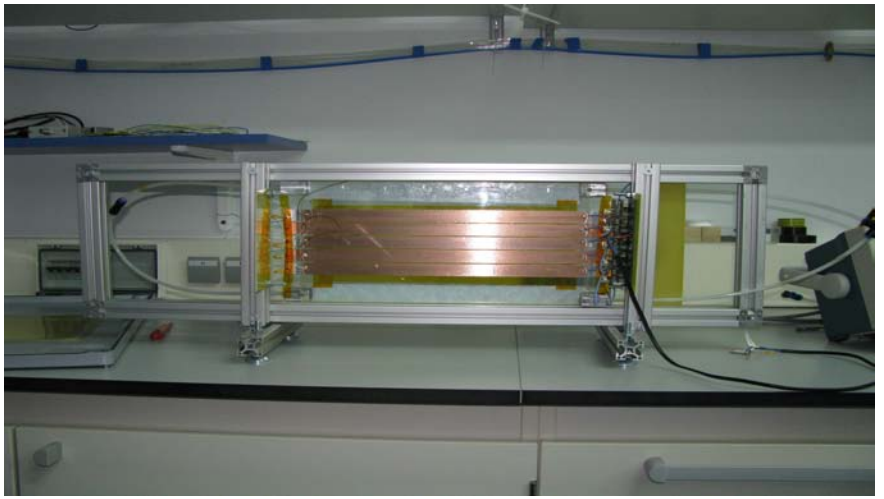
- RPCs are parallel plate chambers with a small gap (typically 300 μm) which contain a proper gas mixture.
- Chamber operates in avalanche (Townsend) or streamer mode depending on the high voltage field applied between the resistive plates.
- Multistrip RPCs have demonstrated to provide high efficiency and time resolution for MIPs (Minimum Ionizing Particles)

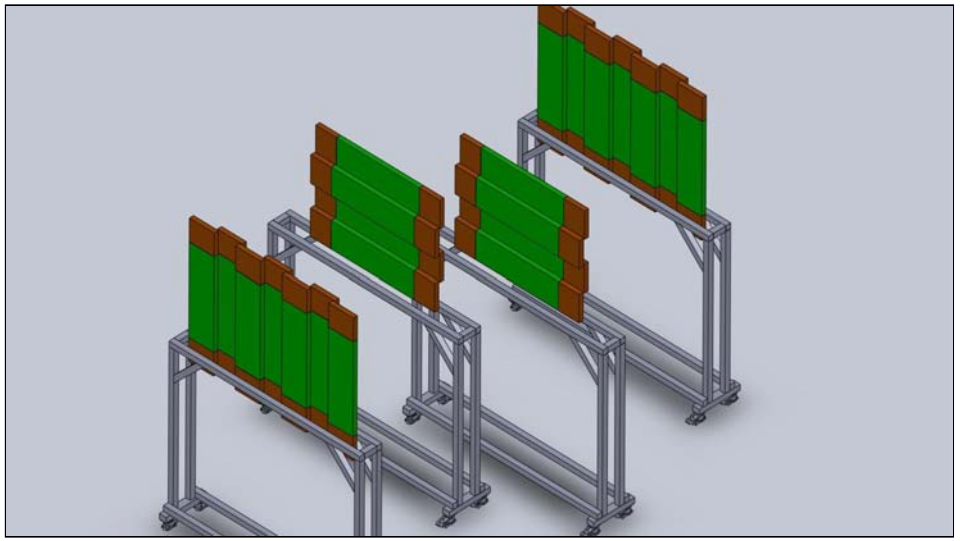




Conceptual Design

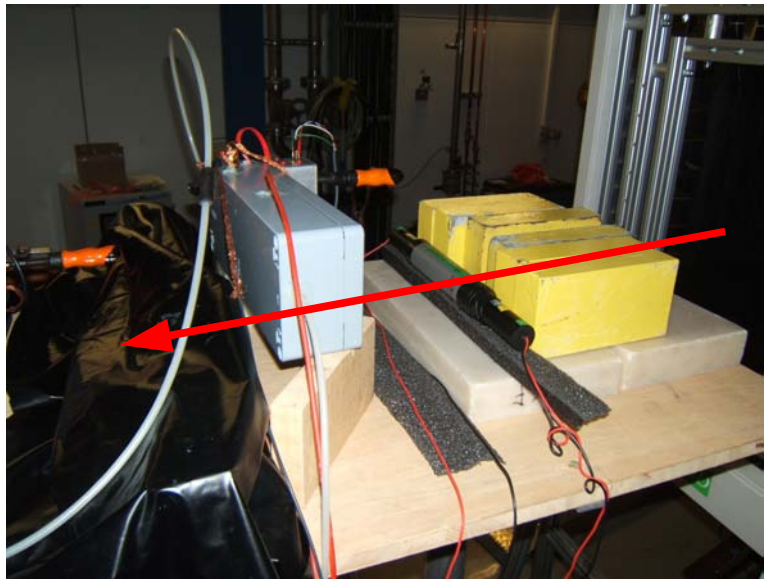


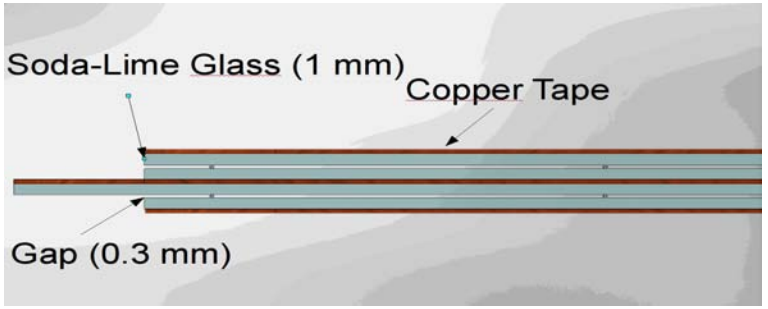


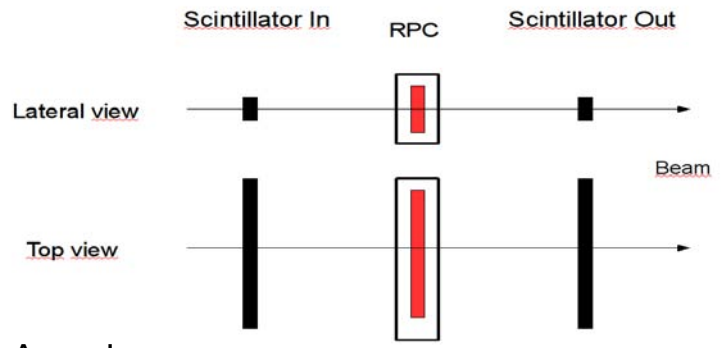


- Active detection core made of narrow-gap timing RPCs, adapted for heavy ions
- Modular design with adaptable geometry
- RPC modules of 100 x 31 cm^2 segmented in 15 strips of 1m x 25 mm
- ToF-Wall made of several detection planes, each with modules covering the acceptance surface
- Planes with strips in two different orientations result in a segmentation with enough position resolution, and multi-hit capabilities
- Overlapping detection planes also improve the time resolution

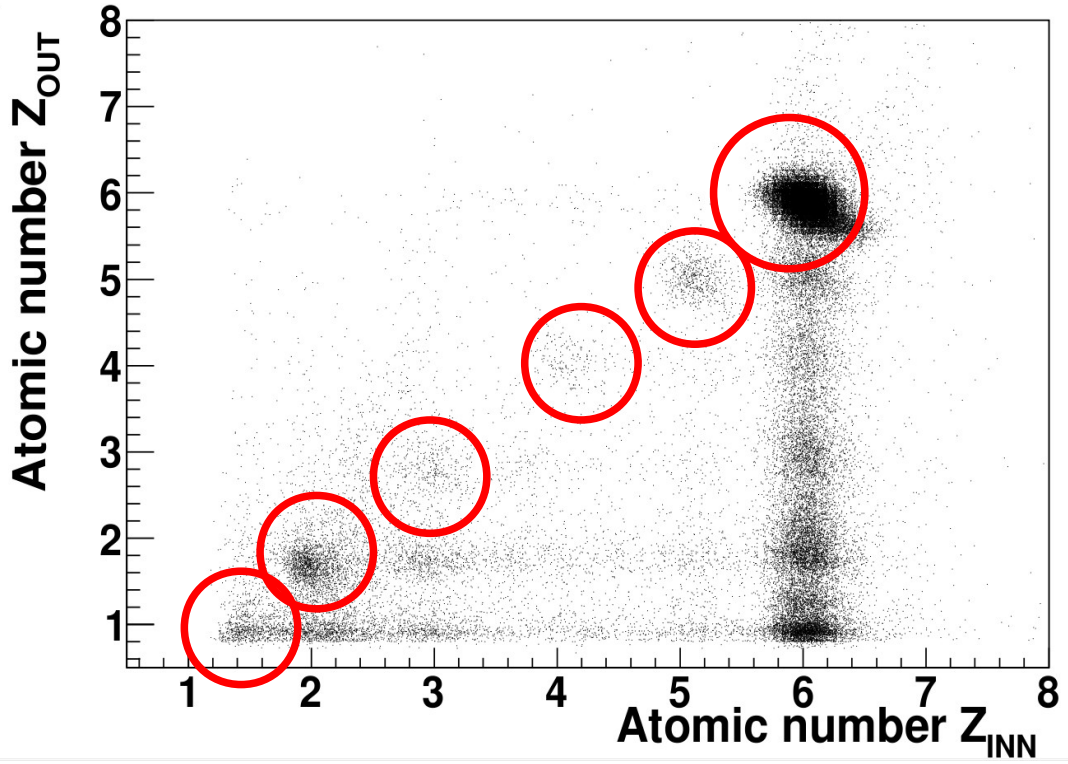
Tests with fast heavy ions at GSI



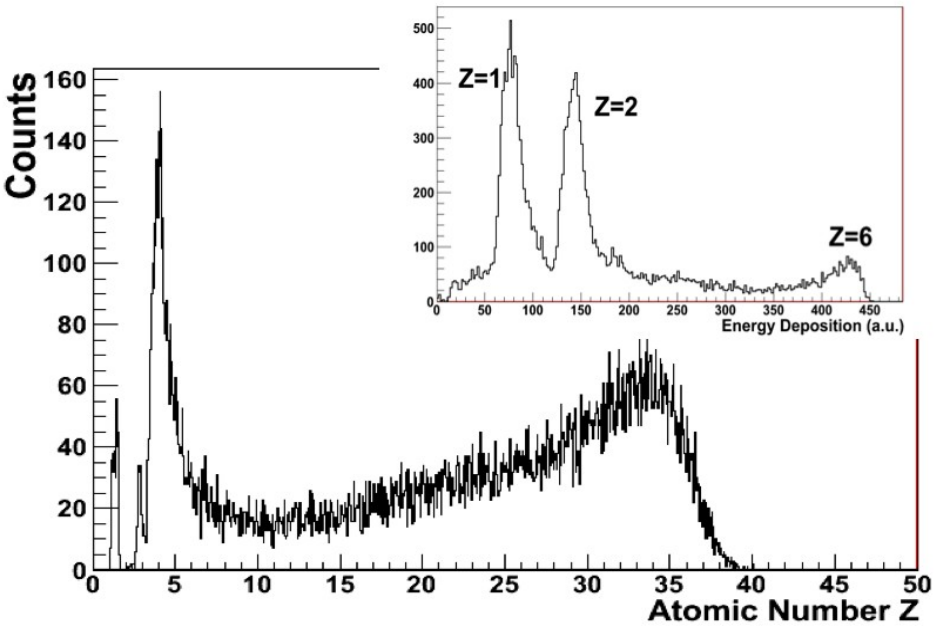


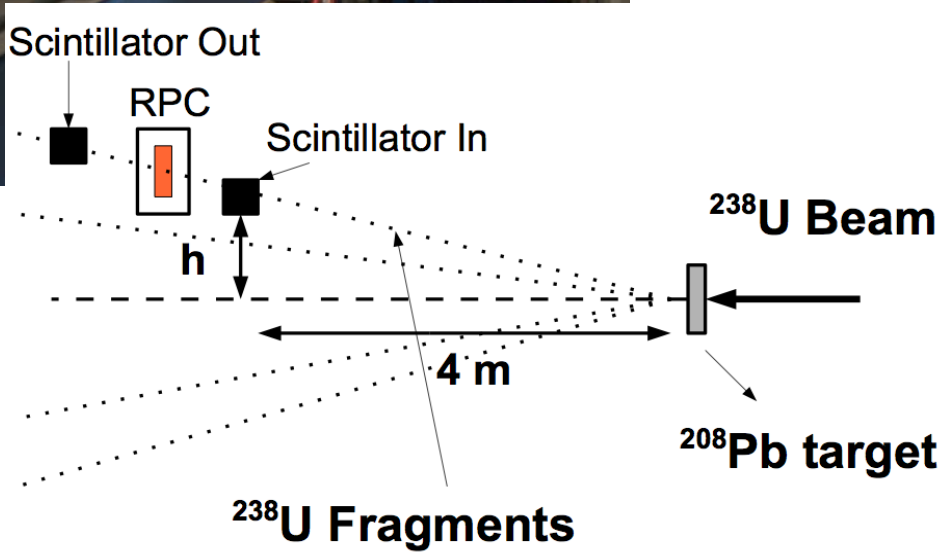


- RPCs have been tested with ^{12}C at 750 AMeV and ^{64}Ni at 600 AMeV
- Short dimensions prototypes (15 cm x 2,5 cm): 1 mm glass thickness, 2 x 300 um gap. Gas mixture: 90% $C_2H_2F_4$ & 10% SF6. Tightness assured by the box
- Several ionic species are identified by the trigger scintillators (BICRON)



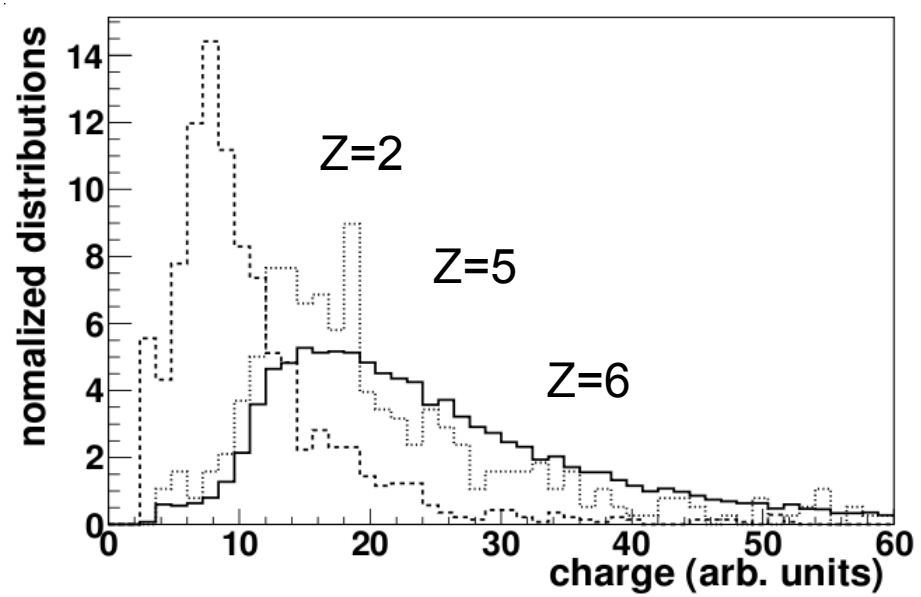
Tests with fast heavy ions at GSI

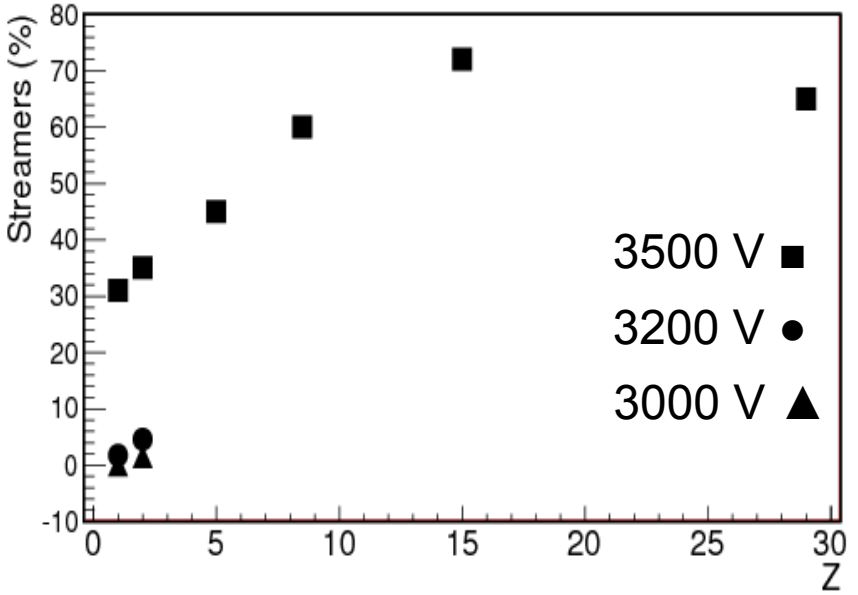


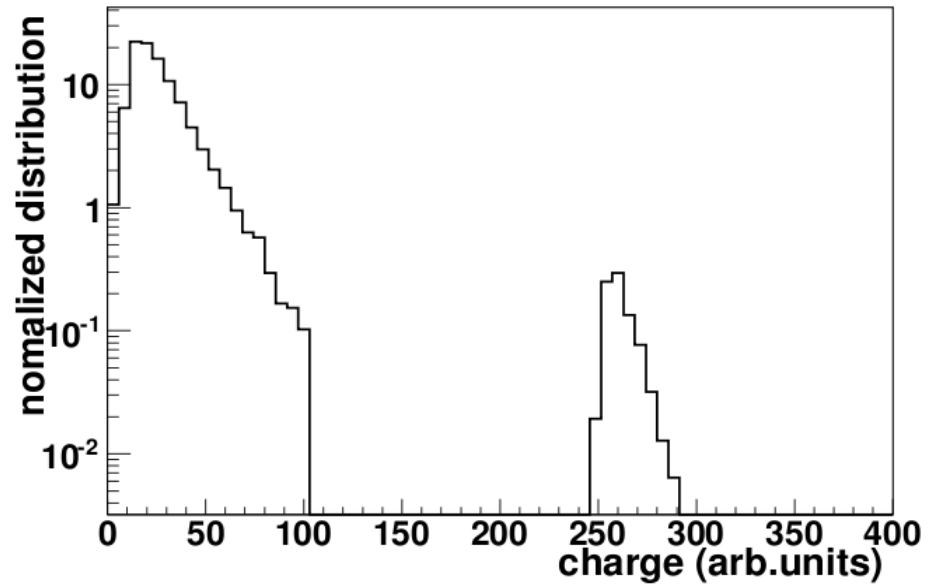


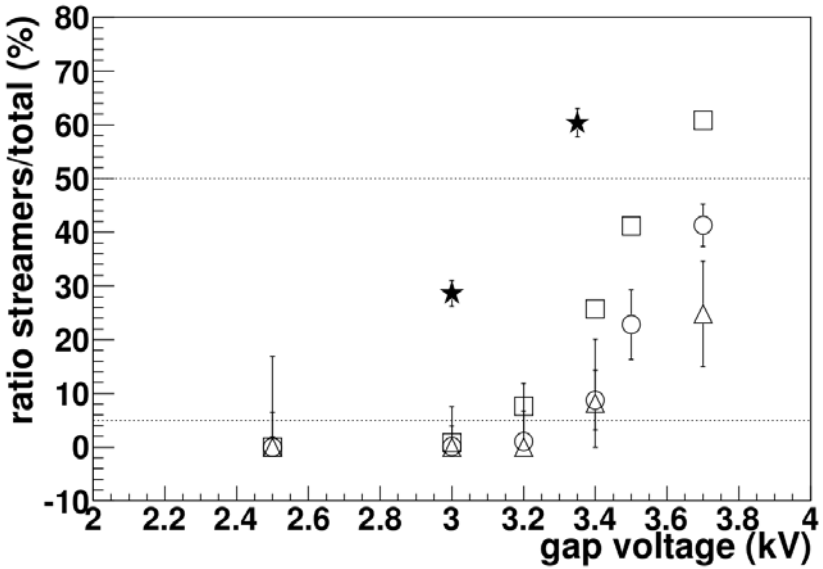
- Test performed with ^{238}U fragments at 500 AMeV using the same setup and prototypes as C test
- Efficiency and streamer ratio is measured
- Heavy fragments with Z up to 35 are identified

Tests with fast heavy ions at GSI

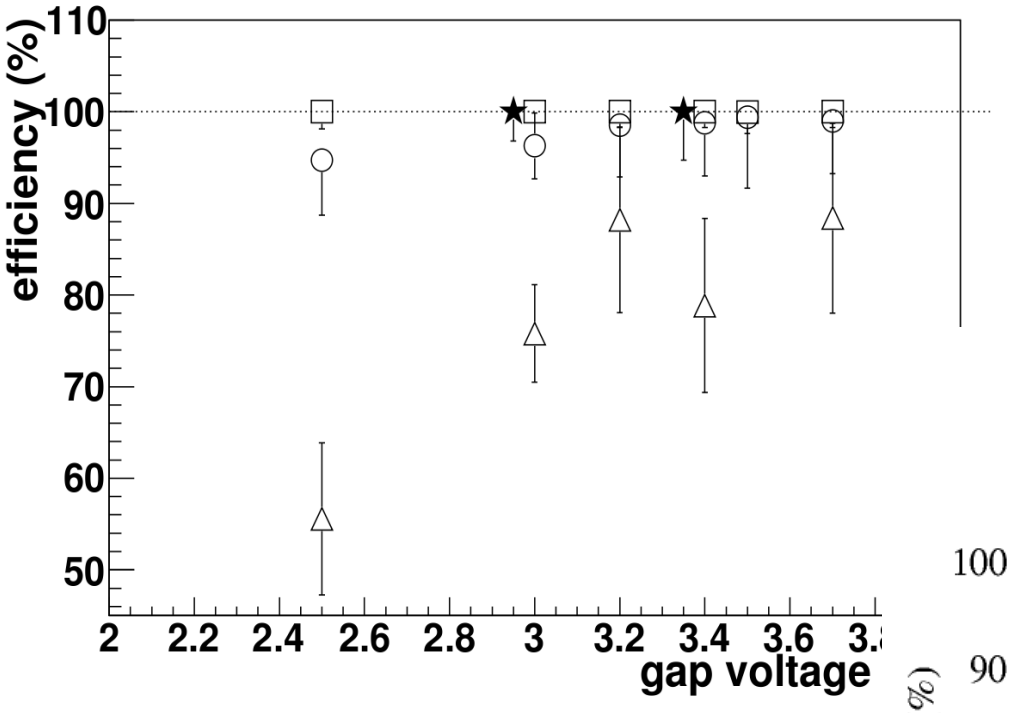






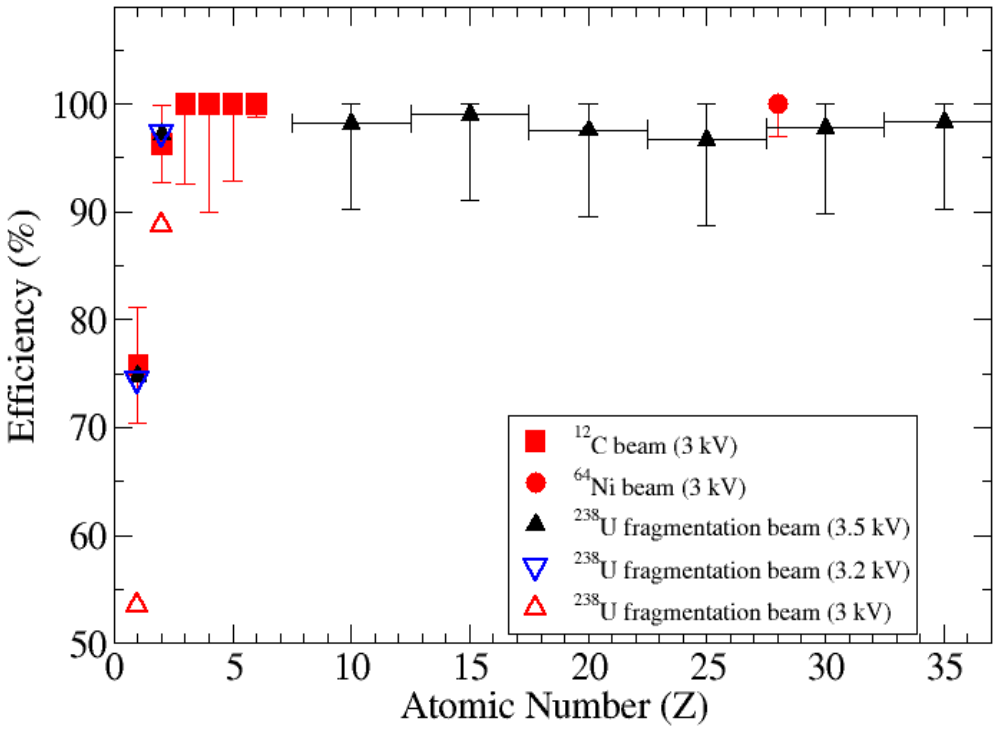


Tests with fast heavy ions at GSI



← Efficiency HV plateau allows us to define a proper working point for the detector

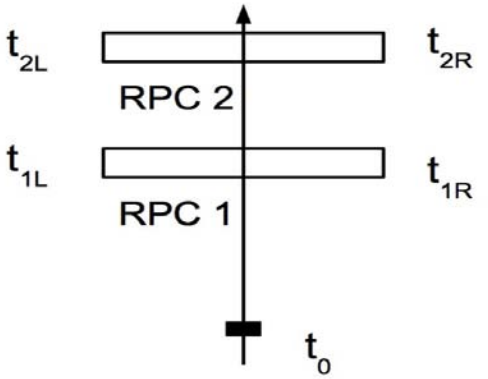
For Z=2 up to Z=35 full efficiency is reached at different working voltages →



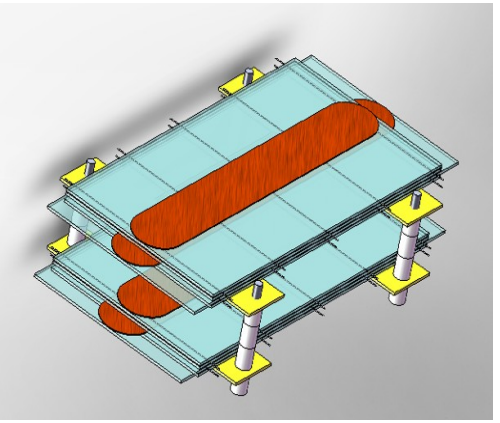
Test with electrons at ELSA. Time Resolution measurements

- ELSA: Infrared free electron laser in CEA/DAM (France)
- 15 MeV beam energy. Intensity modulated by a polarizer
- Double RPC prototype (USC) + Fast plastic Scintillator (CEA)
- Front-end electronics based on Transistor + Maxim amplifiers
- VME DAQ: TACQUILA board 16 channels TAC and QDC and flash-ADC boards

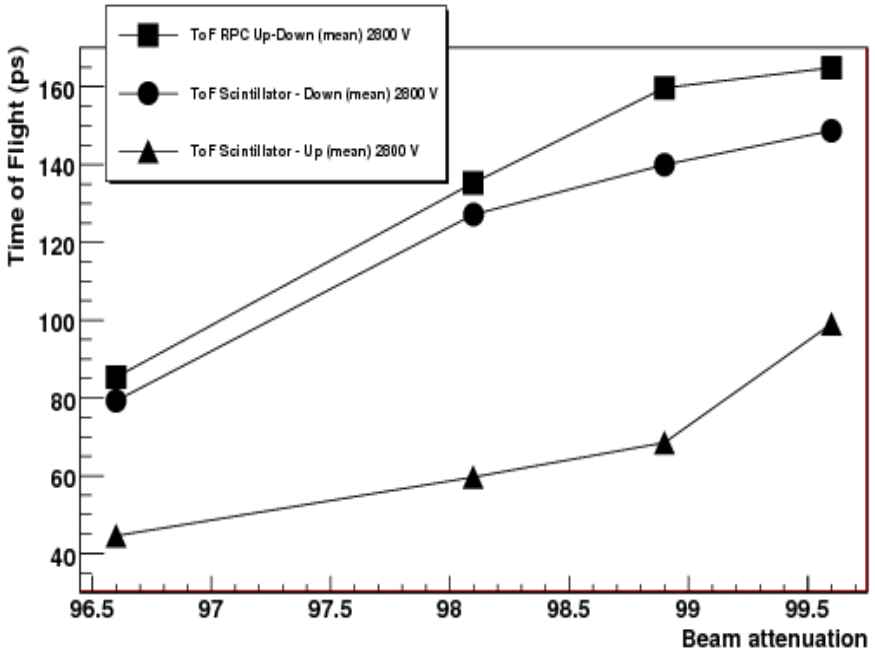
$$\frac{L}{v_c} = ToF = \frac{t_{1L} - t_{2L} + t_{1R} - t_{2R}}{2}$$

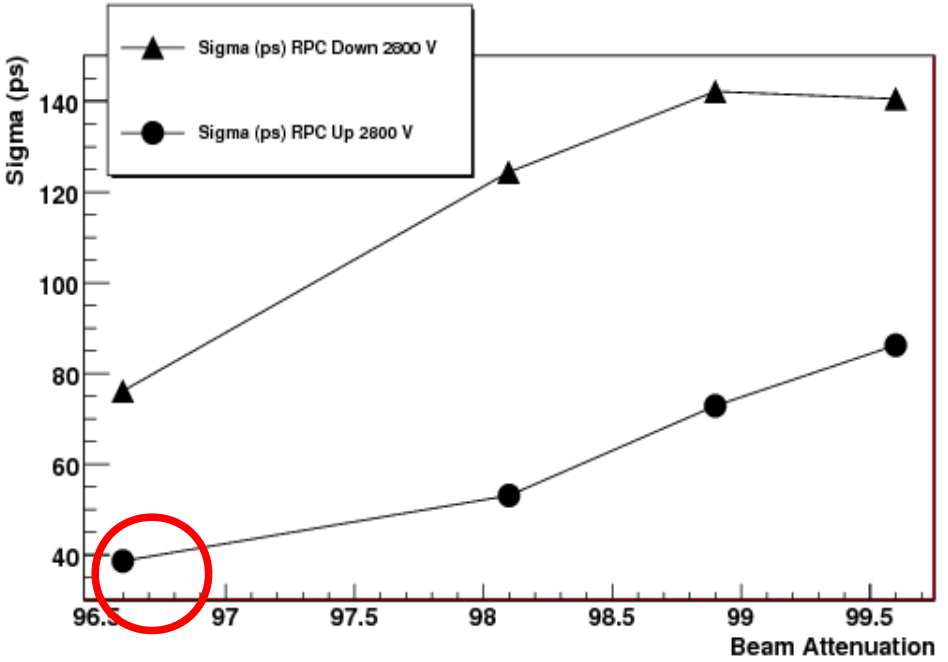


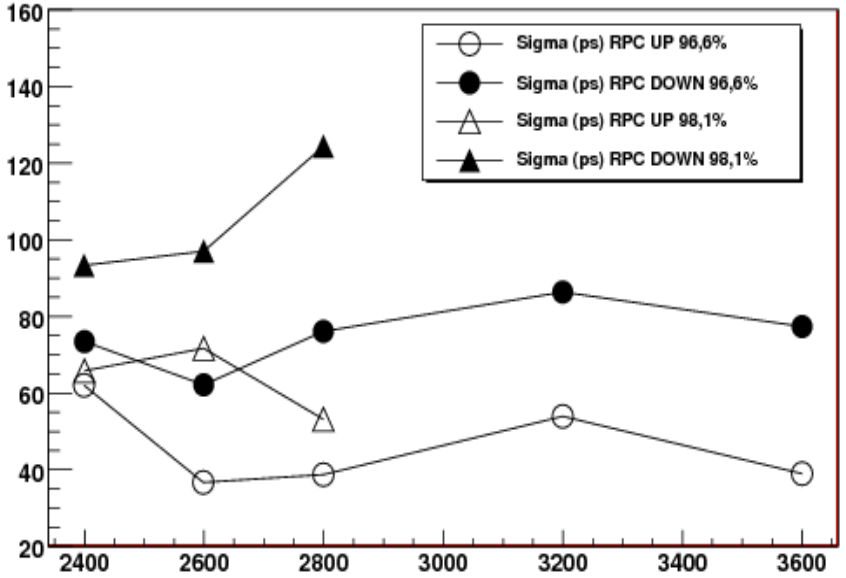
$$\sigma_{ToF} = \frac{1}{2}\sqrt{\sigma^2_{t_{1L}} + \sigma^2_{t_{1R}} + \sigma^2_{t_{2L}} + \sigma^2_{t_{2R}}}$$



Test with electrons at ELSA. Time Resolution measurements







- ToF measurements between RPCs and a reference fast plastic scintillator allows us to calculate the time resolution of the detector
- Electron beam attenuation simulates the charge deposition of heavy ions
- Values of < 40 ps (sigma) for low attenuation are obtained with a prototype
- Large HV plateau free of streamers

Summary

- Resistive Plate Chambers have been tested with relativistic heavy ions at GSI and with electron bunches at CEA – DAM (Bruyères-le-Châtel)
- Full detection efficiency is obtained in a large range of ionic species from Z=2 up to Z=35
- Streamer generation can be controlled with the working parameters of the RPC
- Time resolution of < 40 ps (sigma) has been obtained with short prototypes with electrons
- These results show the feasibility of the RPC technology for the construction of the ion Time-of-Flight detector
- More test with heavy ions are needed to compare our lastest results and to continue our R&D program