Recent in-beam Super-FRS detector tests

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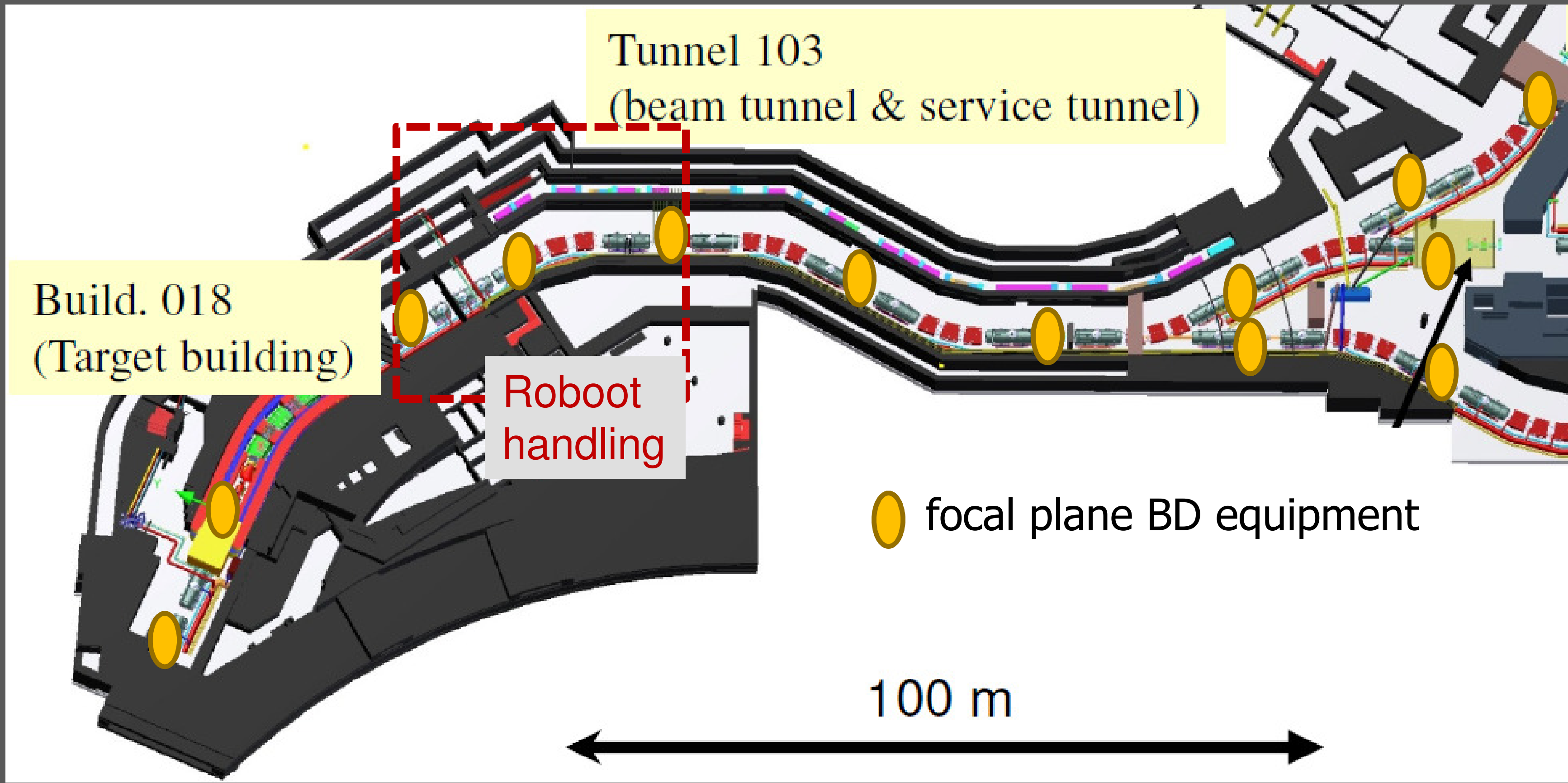
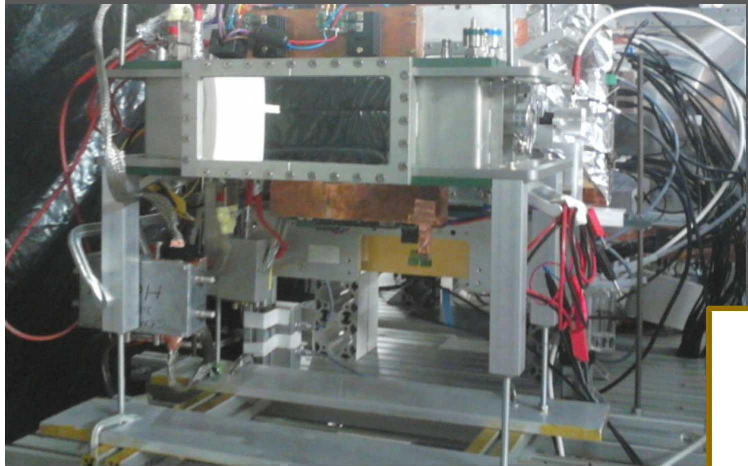
Overview

The Super-FRS itself takes well established detecting systems, like the FRS one, to their operation limits



PID detector prototypes



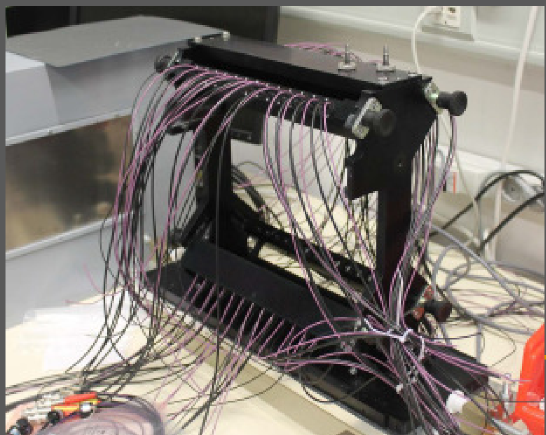
Twin GEM-TPC
(x, y)
Partner:
Helsinki IP

Silicon
(ToF, ΔE)
Partner:
IOFFE PTI St. Petersburg

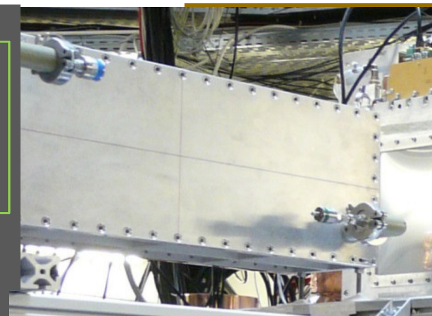
$$Z \leftarrow \; -dE/dx = \mathrm{f}(Z, \beta)$$ atomic number

$$A/Q = \frac{B\rho}{\gamma\beta m_u}$$ $Z \neq Q$ charge state

Segmented plastic scintillator (ToF)
Partner: IFJ Krakow



Bρ – ToF – ΔE method



Triple MUSIC
(ΔE)
Partners: CEA, Helsinki IP

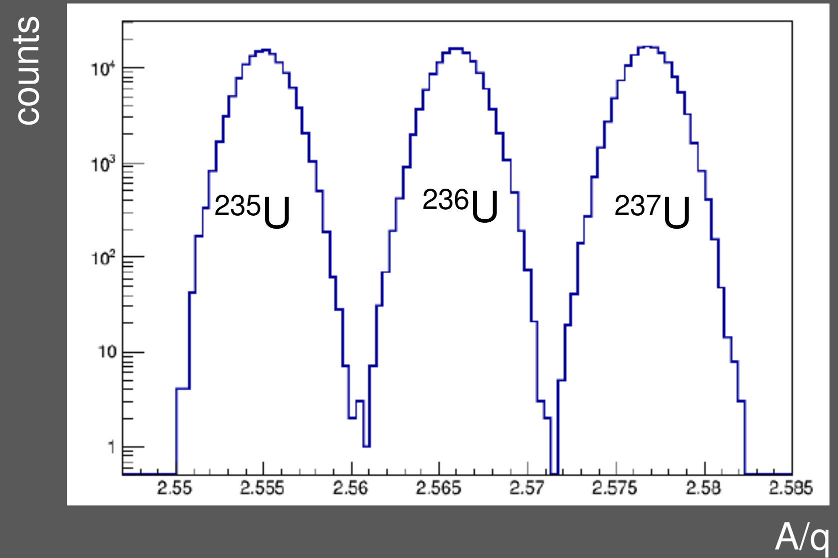
Other diagnostics (ToF, intensity, x, y)

Technical challenges

- **Clean full PID on event-by-event basis**

  → momentum tagging $\Delta x \sim 1mm$
  → ToF measurements $\Delta ToF \sim 100ps$ (FWHM)
  → charge resolution $\Delta Z \sim 0.2e$

$\sigma_x = 0.5mm$
$\sigma_t = 20ps$



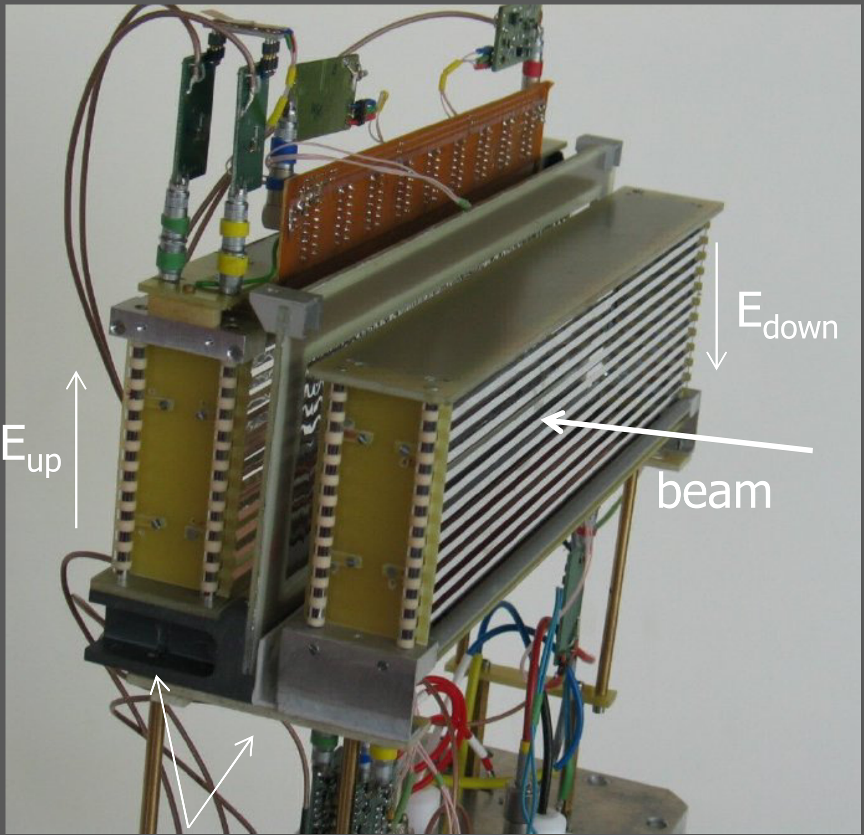
Monte Carlo simulations (MOCADI)

Yields not scaled

- **Increasing intensity of produced radioactive beams** requires detecting system with high-rate capability

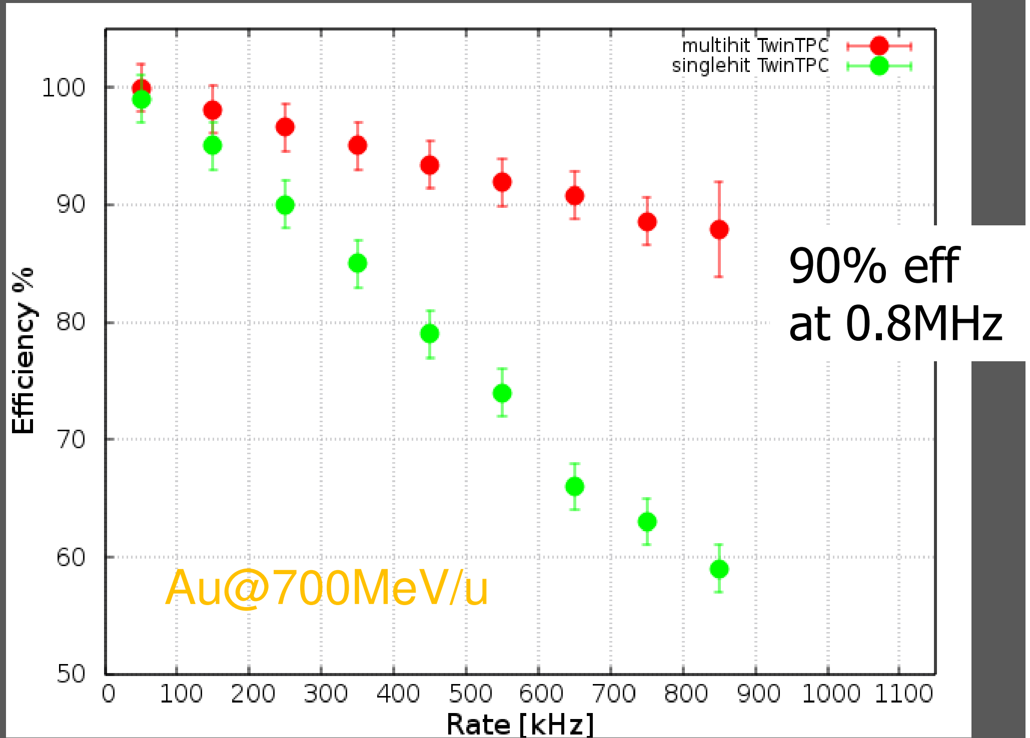
Test of FRS Twin TPC

CUBratislava



$200 \times 70 \times 30$ mm^3

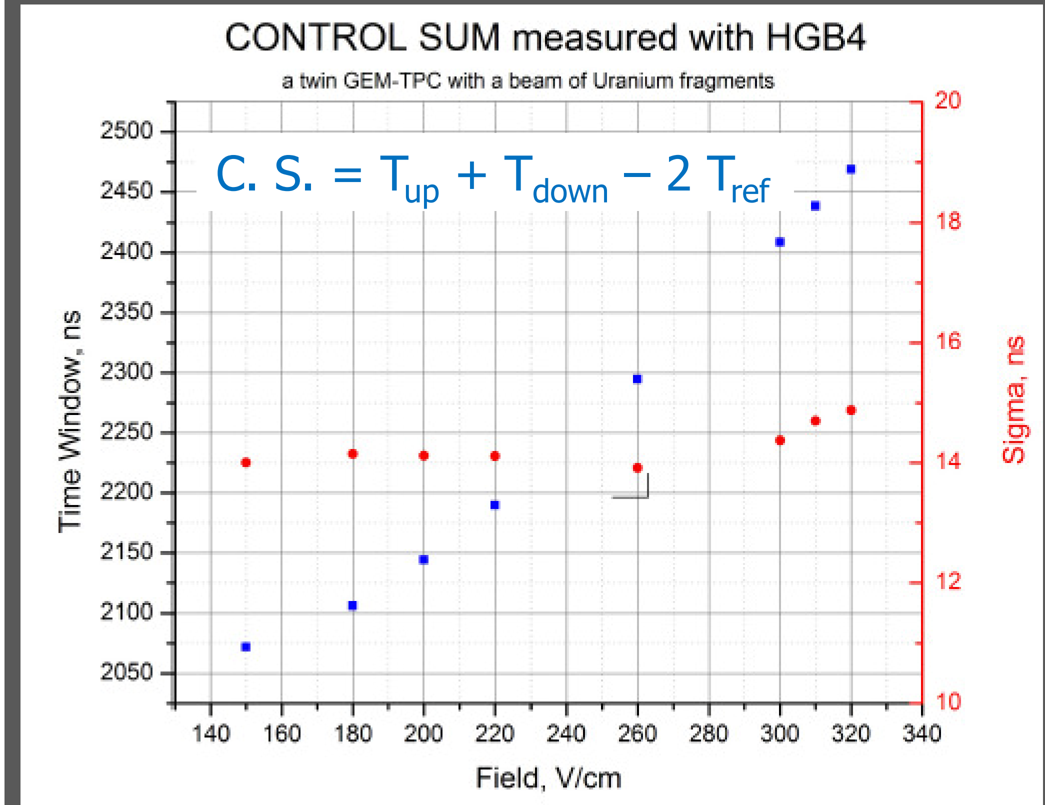
- Delay line, multi-hit TDC (V1290) readout



A. Prochazka et al., *GSI report* (2014)

Test of Twin GEM-TPC prototype

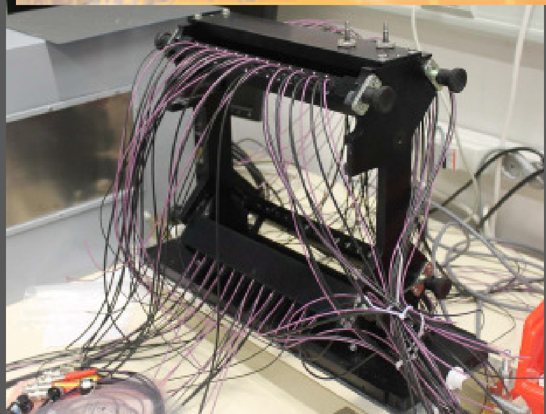
September 2014 Series of in-beam tests of Ca, Bi, U @300 MeV/u in Cave C



F. Garcia, B. Voss et al., *GSI report* (2014)

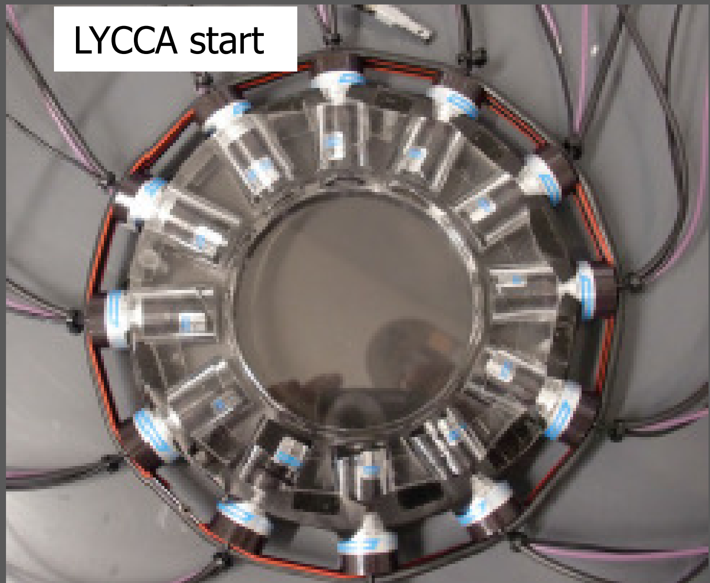
- Ar/CO_2 gas at 1 atm
- GEMEX1C readout for x-coordinate (working only for short time)
- drift time from third GEM signals

Plastic scintillator prototypes



see Finger coll. meeting

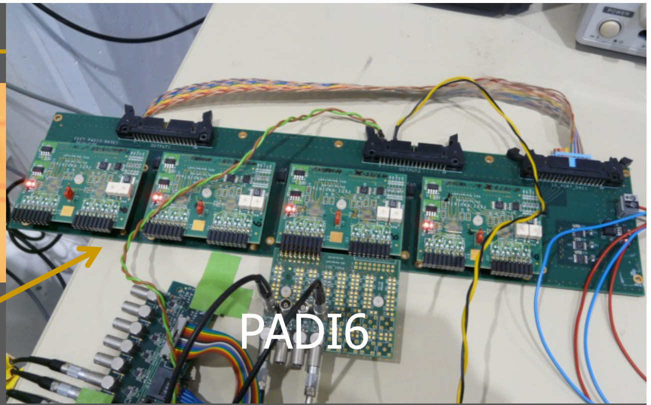
- Finger (HISPEC/DESPEC)
  - 51 strips, 4.4 mm wide of BC420, Hamamatsu R9880U-01 PMTs
  - resolution σ_t ~70ps
  - partner: IFJ Krakow

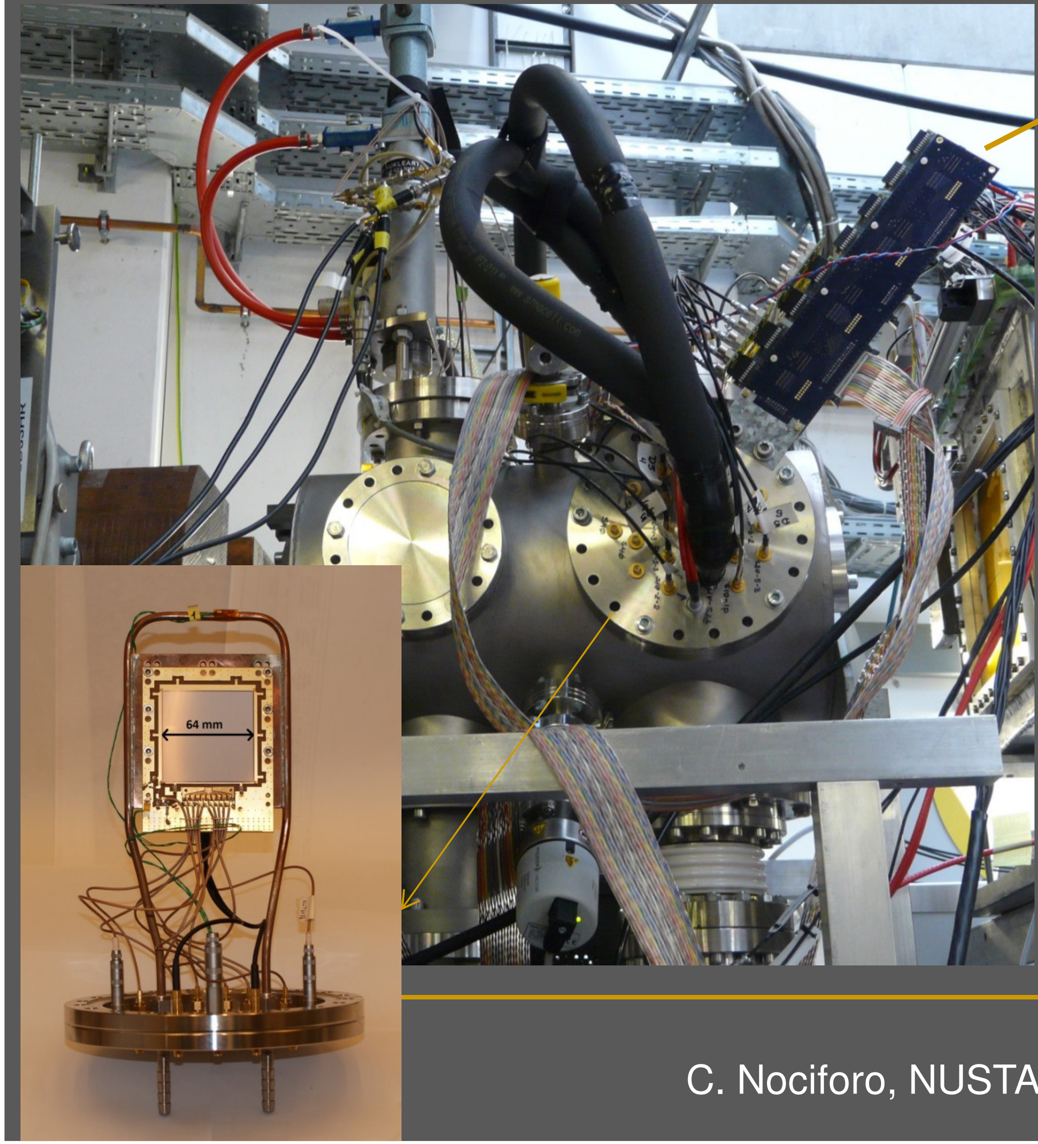


- Plastic scintilllator (Super-FRS)
  - vacuum design based on LYCCA-multi-PMT
  - resolution σ_t ~20ps
  - rise-fall-time-based energies available
  - partner: LUND

R. Hoischen et al., NIM A654, 354 (2011)

Test of Si prototype





<u>August 2014</u>

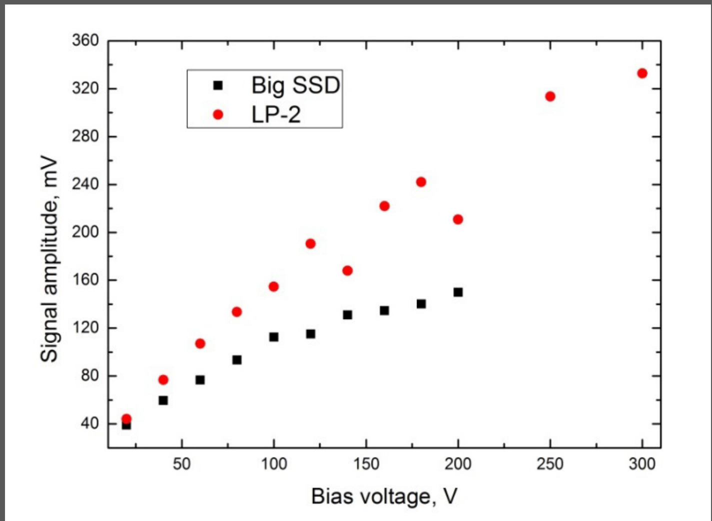
- large area 64x64x0.3 mm^3 ToF single-sided strip-detector (SSD) tested in vacuum and cooled down
- ToF measured with smaller detectors of different topologies
- different DAQs, e.g. CAEN FADCs TD5743/2 (12 bits 3.2-5 GS/s)
  → res. down to 15 ps, working only for few kHz rate

V. Eremin, O. Kiselev et al., *GSI report* (2014)

PADI6/VFTX results (Big SSD vs small SSD)

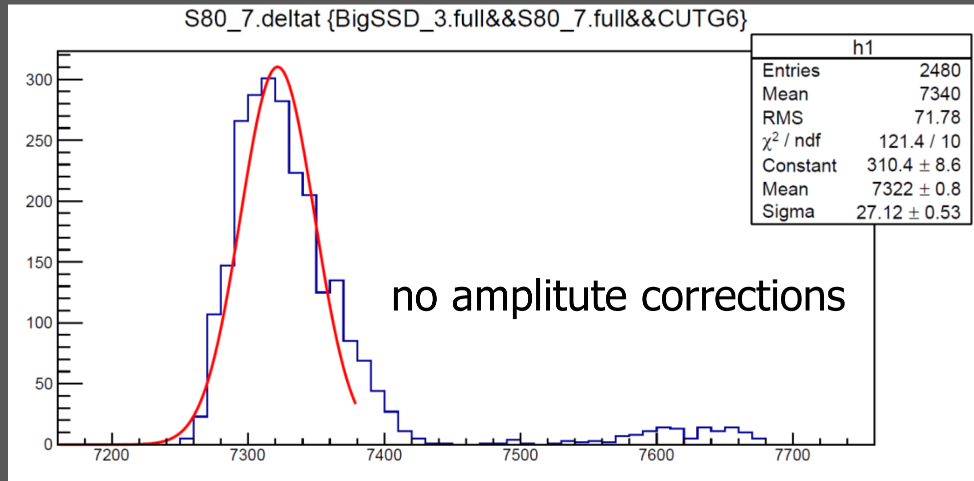
^{197}Au@900MeV/u

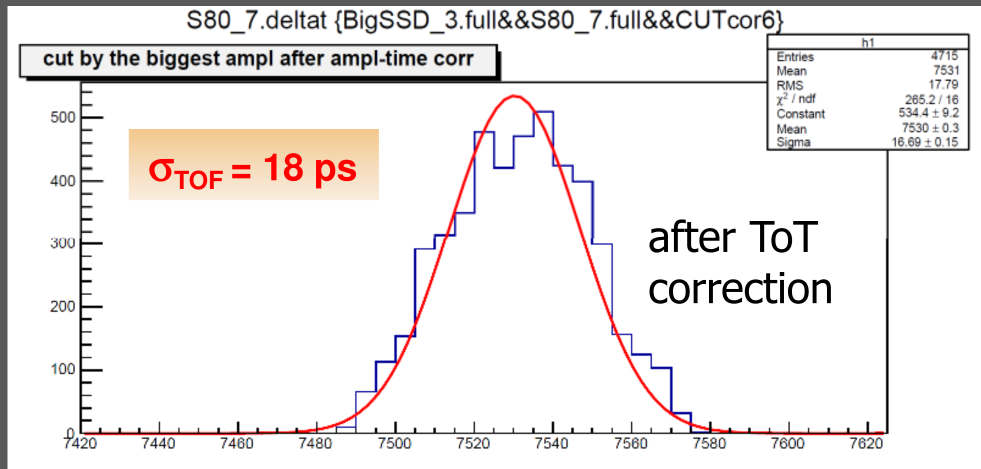
- detectors overbiased for good timing



- time resolution of two BigSSDs can be σ_{ToF} =25-30 ps

O. Kiselev et al.

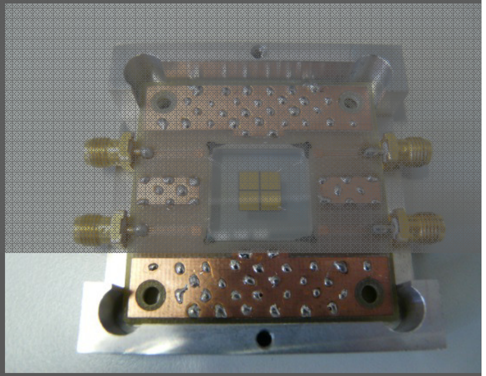




Diamond in-beam tests

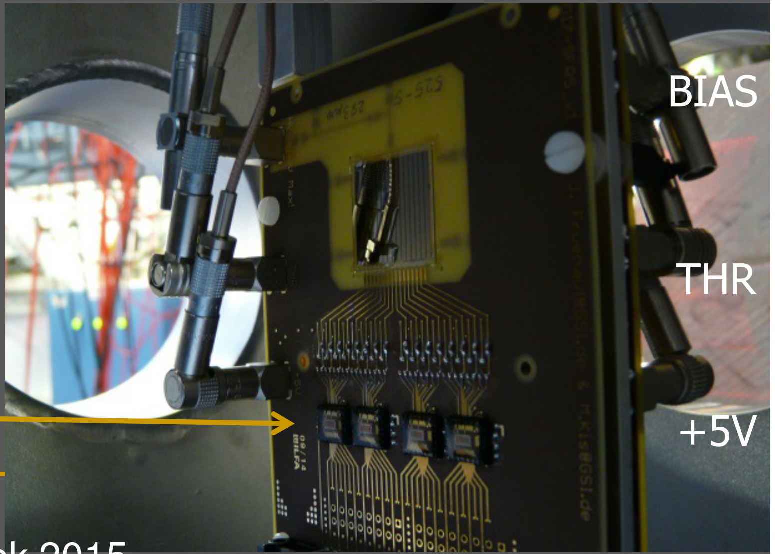
February 2014
First test of (E6) pcCVD-DD samples at ACCULINNA separator with 40.5 MeV/u ^{40}Ar beam

- 4 Al contacts, ΔE~20-600 MeV (DBA amp, V_{in} < 50 mV)
- total rate 10^{11} ions/cm^2 , test with α particles



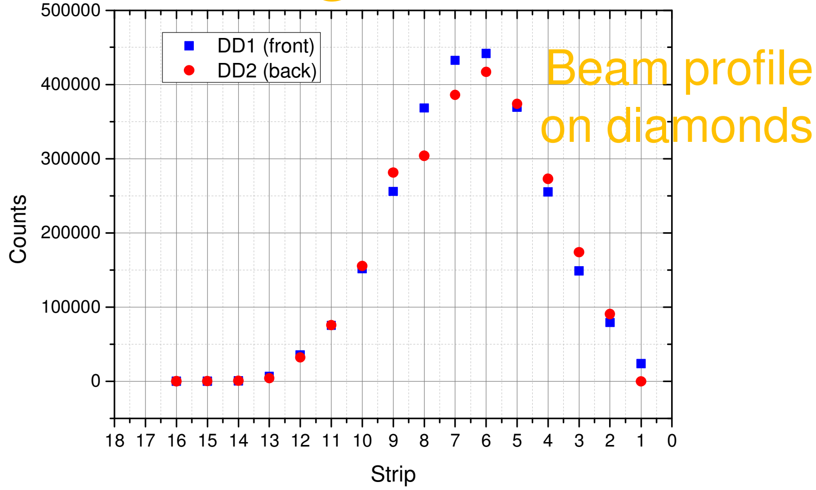
August 2014
First ToF measurements at FRS with 900 MeV/u ^{197}Au beam with (E6) pcCVD-DD 20x20x0.3 mm^3

- 16-strip design: (1x18) mm^2 each (0.15 mm gap), C = 4.3 pF/strip
- metallization: 50nm/100nm (Cr/Au) by photolithography (GSI-DL)
- PADI7, gain ~250, 4x4chs

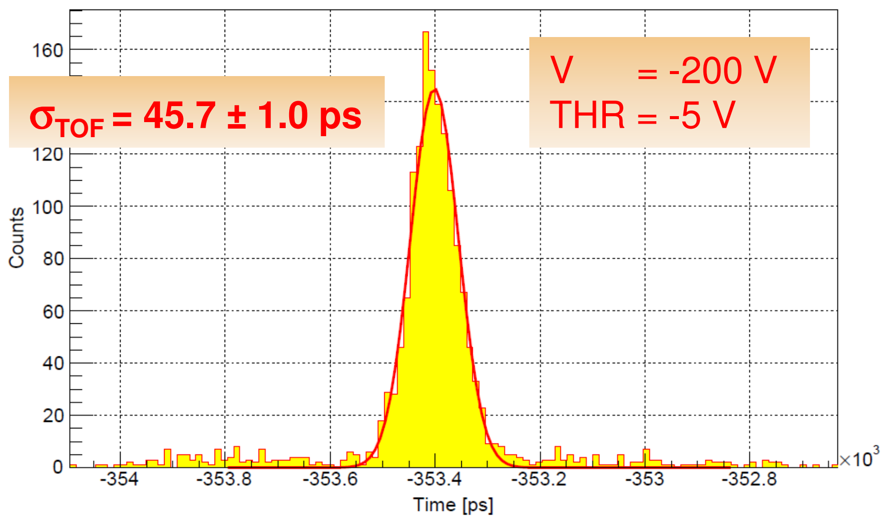


σ_{intr} contribution

^{197}Au@900MeV/u



DIA ToF [S2-S4]: Strip 6 S4 vs Strip 7 S2 - cut xy



S2-S4 Detector resolution

F. Schirru et al. , *GSI report (2014*)

$$\sigma_{DD} = \sqrt{\sigma_{ToF}{}^2 - \sigma_j{}^2} = \sqrt{(45.7)^2 - (15)^2} = 43.2 \text{ ps}$$

$\sigma_{intr,DD1}$=25 ps

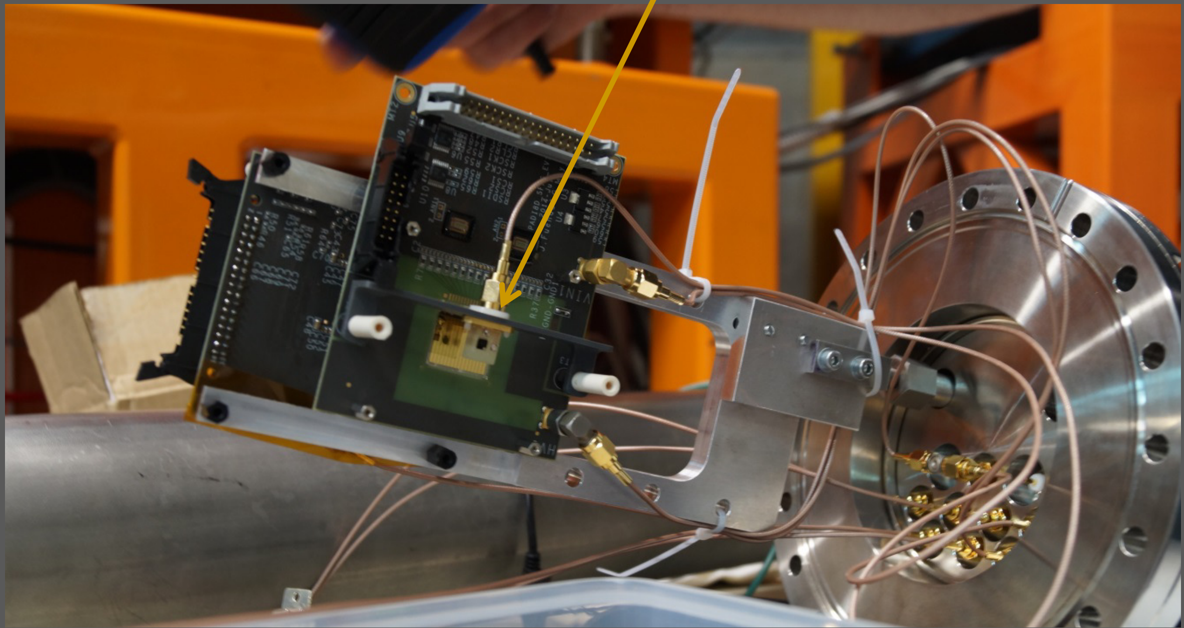
$\sigma_{intr,DD2}$=35 ps

Measured PADI/VFTX intrinsic time resolution: 15 ps (σ)

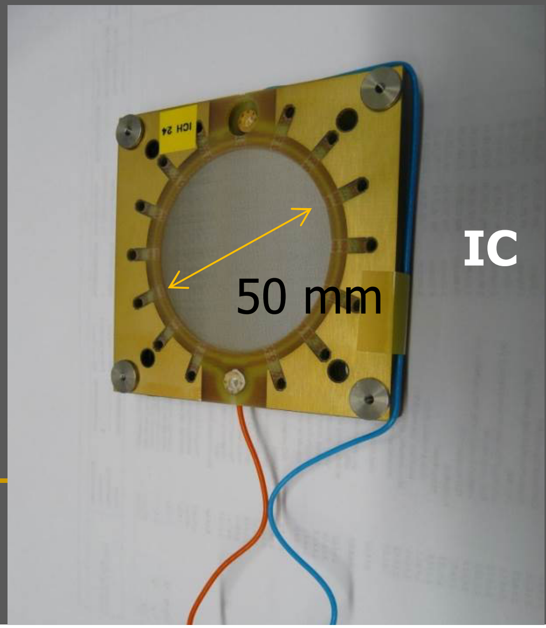
Irradiation test at LNS-INFN

May 2015

Series of irradiation of 10^7 $^{12}C/mm^2$ s @62 MeV/u followed by data taking via digital scope (10 GS/s) at low rate to monitor the time resolution and CCE of pcCVD-DD (0.3mm) and scCVD-DD (0.09mm)



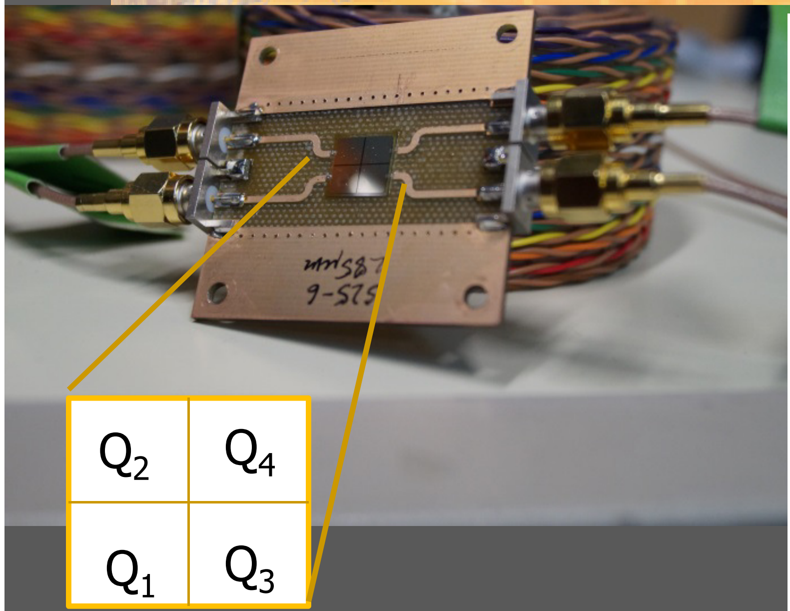
- new chip PADI7D, 8x2 chs (distance reduced), new threshold control and range



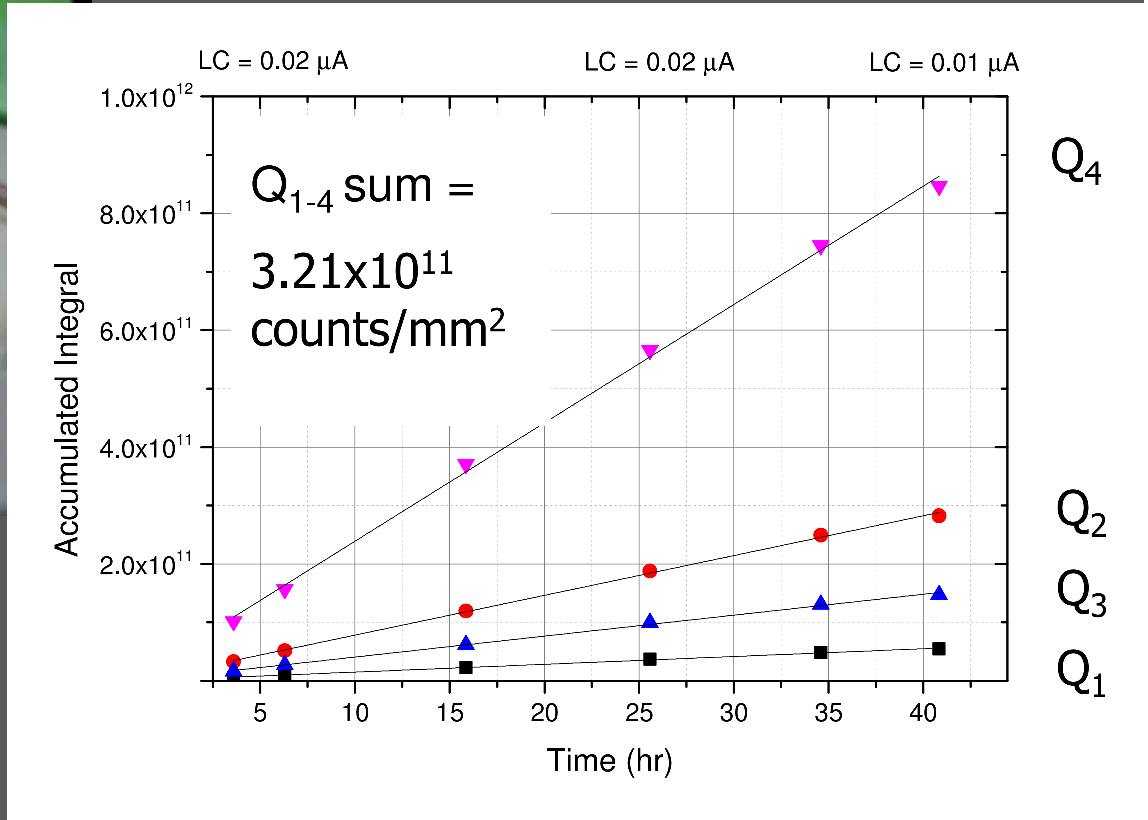
IC

- beam current measured by ionization chamber IC

Results (run with collim.)



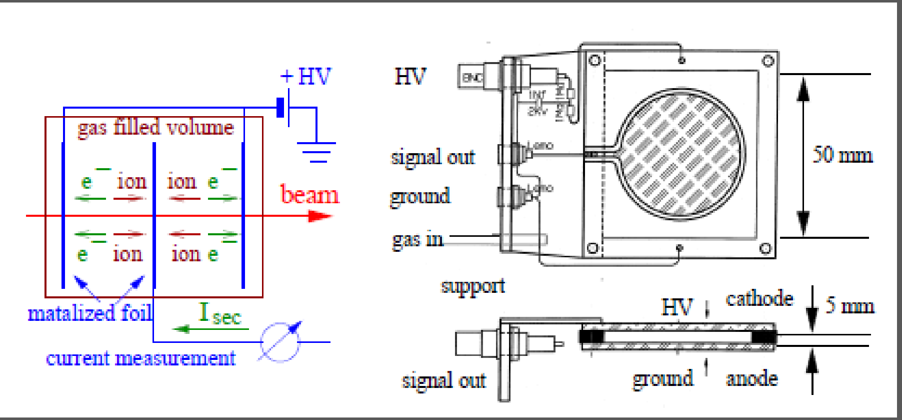
(E6) pcCVD-DD 10x10x0.3 mm^3

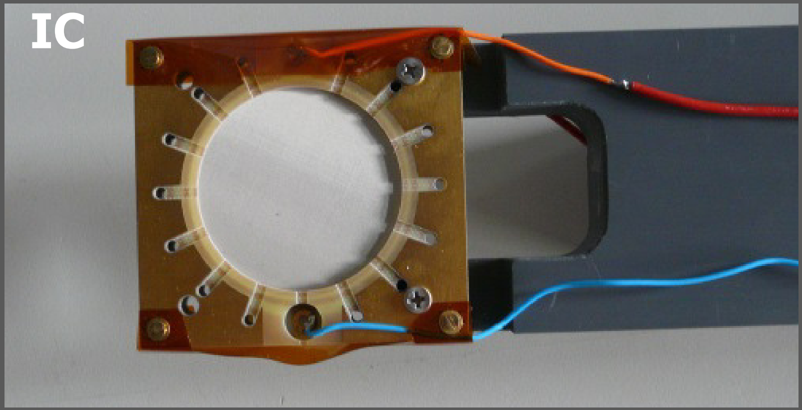


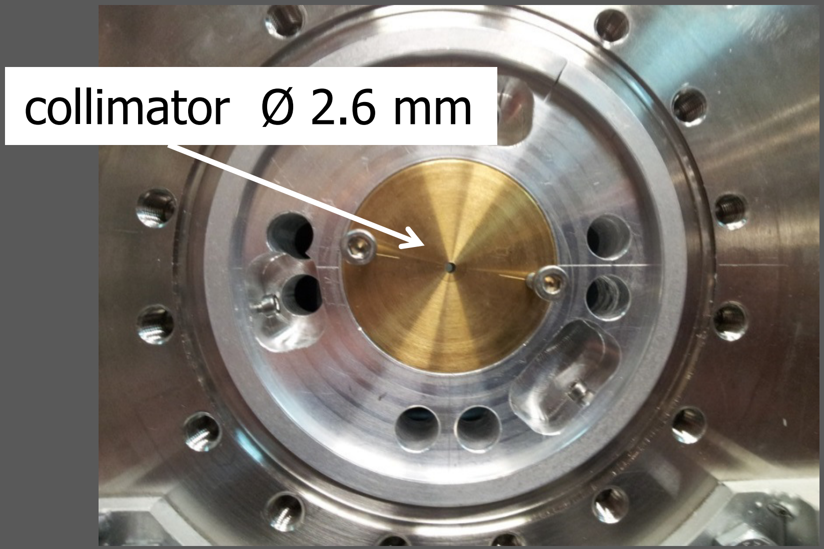
Minimum absorbed dose = 1.8×10^6 Gy (^{12}C@62 MeV/u)

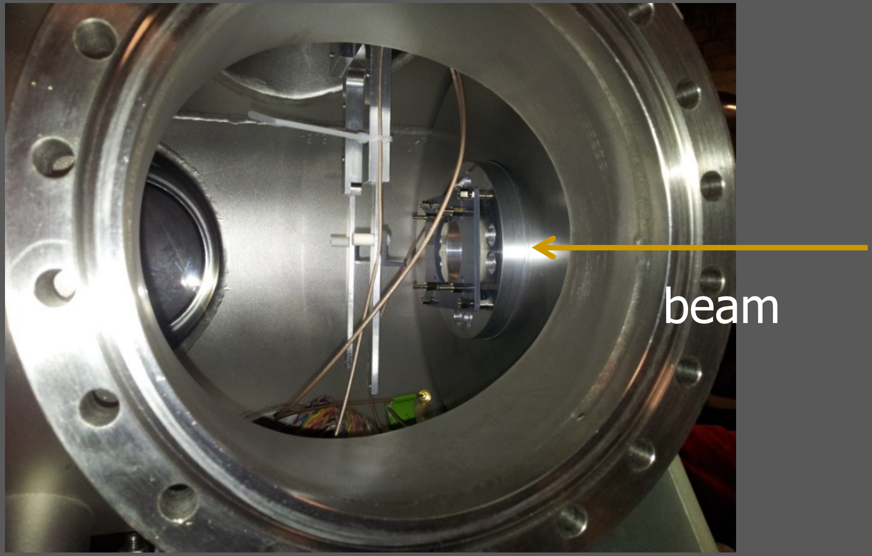
≈400 days operation

Experimental set up







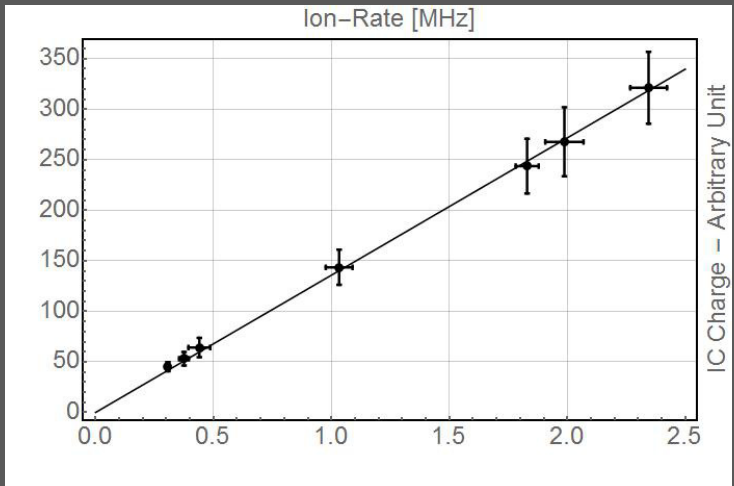


Total beam current

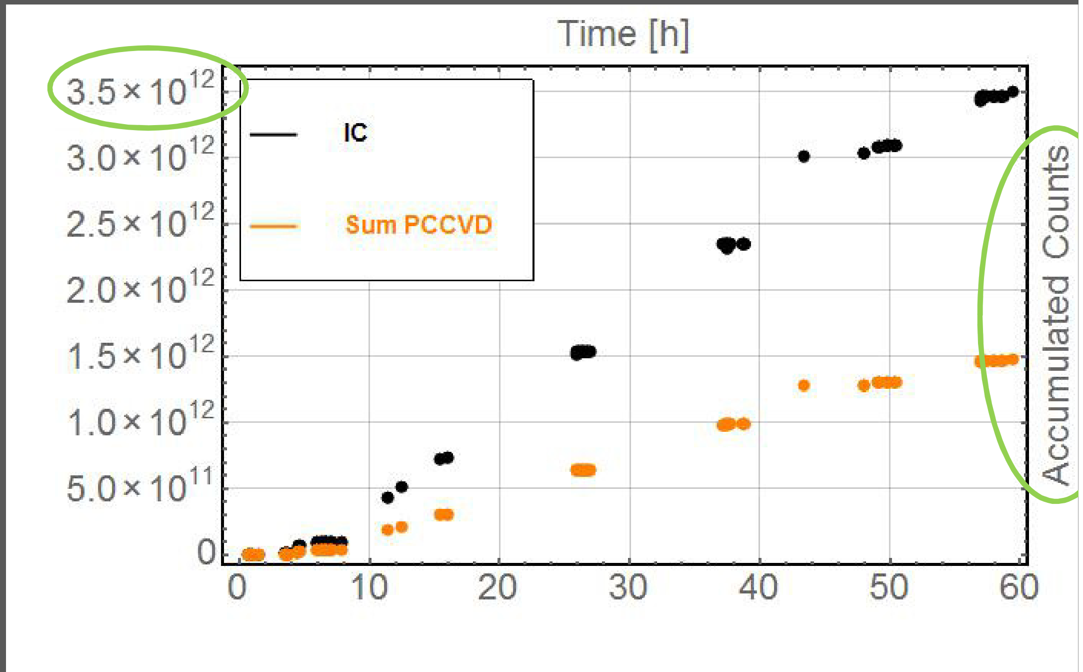
^{12}C@62MeV/u

- IC analogue signal fed into current-to-frequency converter

Calibration: IC vs scCVD-DD up to 2.5 MHz (with VULOM4b)



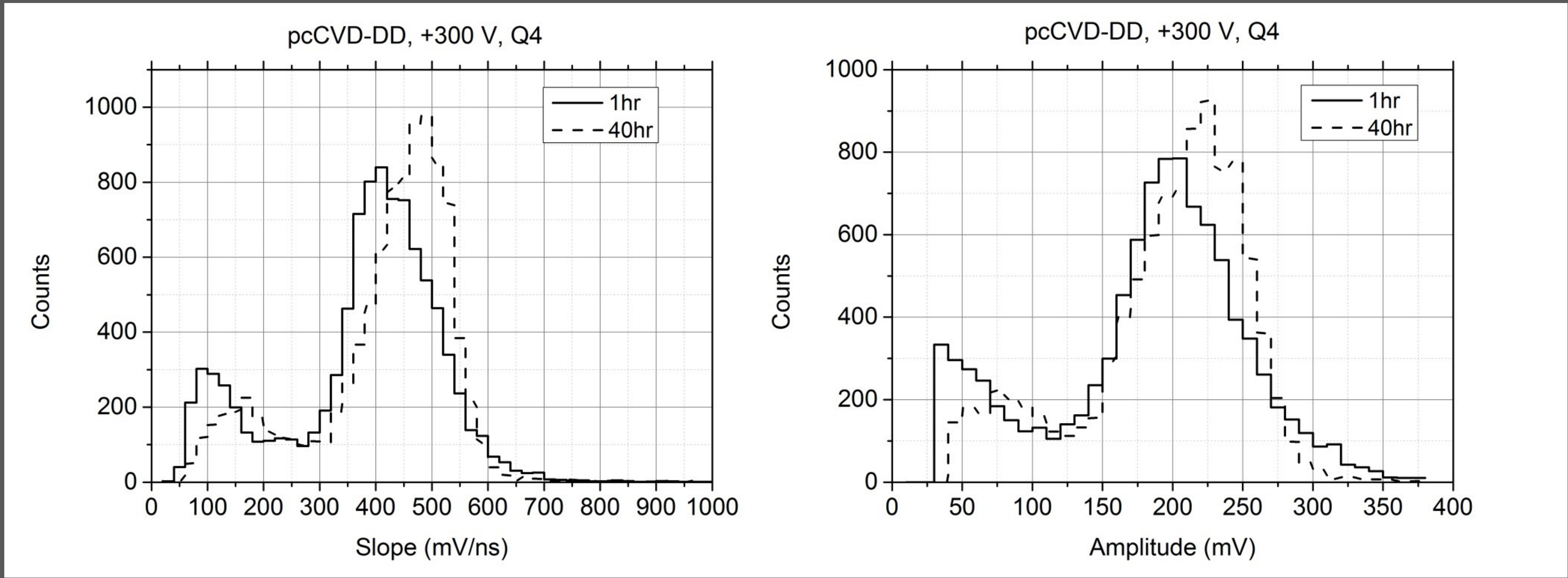
S. Schlemme et al.



- discrepancy mainly due to pile-up (8% at 7.7 MHz) but also detector inefficiency (dead layer, interstrip events)

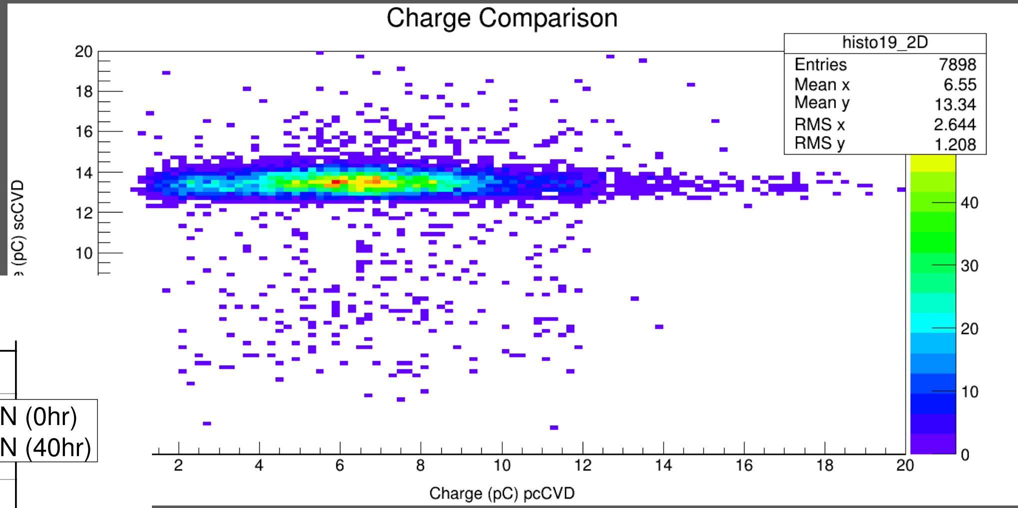
Digital waveform analysis (pcCVD-DD)

^{12}C@62MeV/u



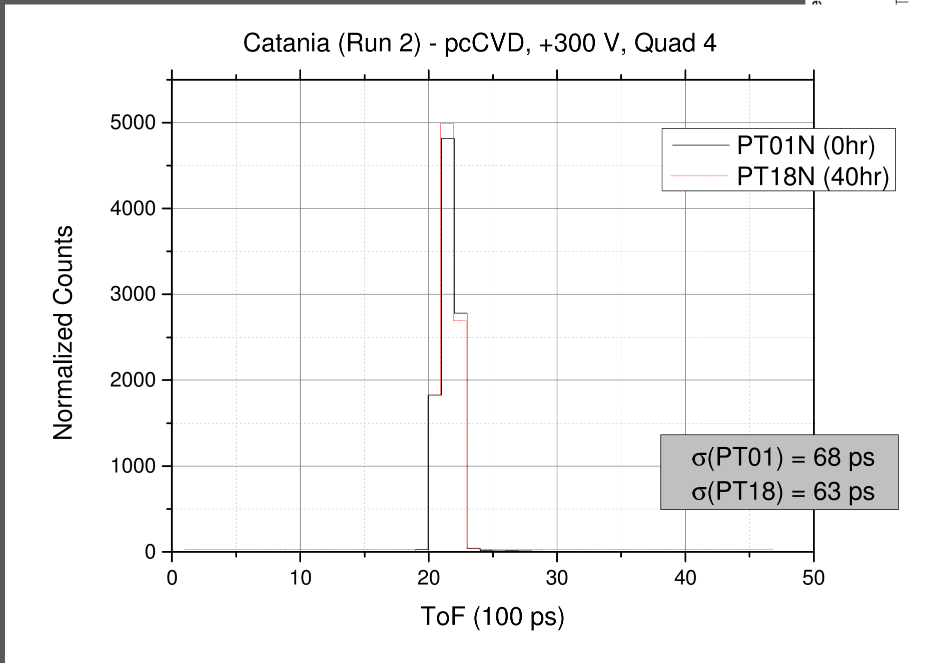
- no degradation of the signal observed at the end of the irradiation measurement

Comparison with scCVD-DD



^{12}C@62MeV/u

- $Q_{sc} \sim 2\ Q_{pc}$, $d_{sc} = 1/3\ d_{pc}$ $\rightarrow CCE_{pc} \sim 20\ \%\ CCE_{sc}$



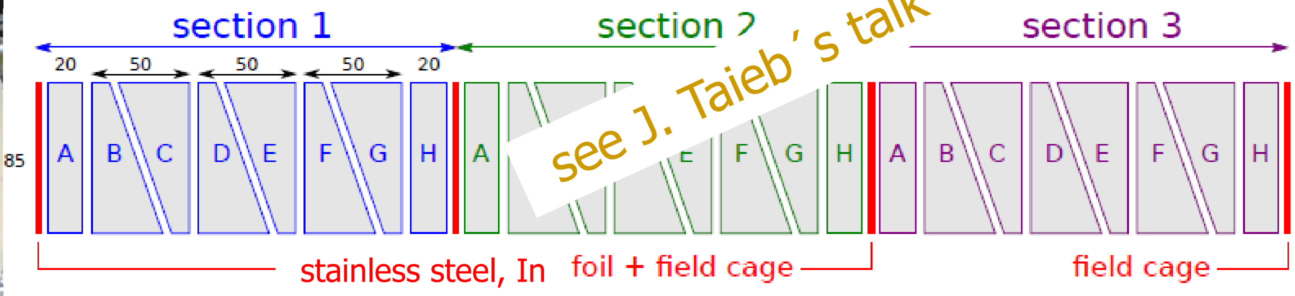
ToF: Q_4 pcCVD-DD vs scCVD-DD obtained from waveforms analysis

- no change in the measured ToF at the beginning and at the end of the irradiation

F. Schirru et al.

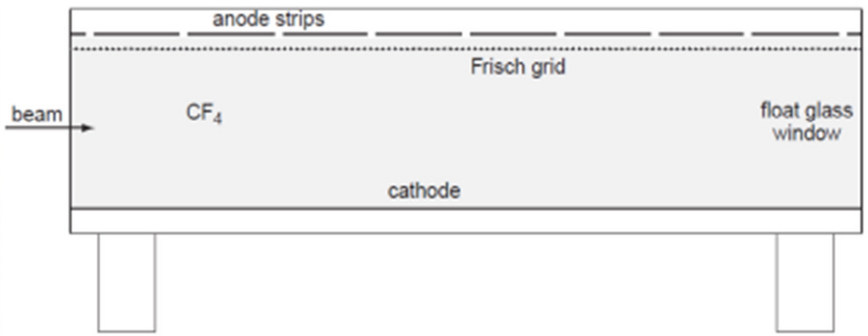
MUSIC design

a) Triple MUSIC/SOFIA



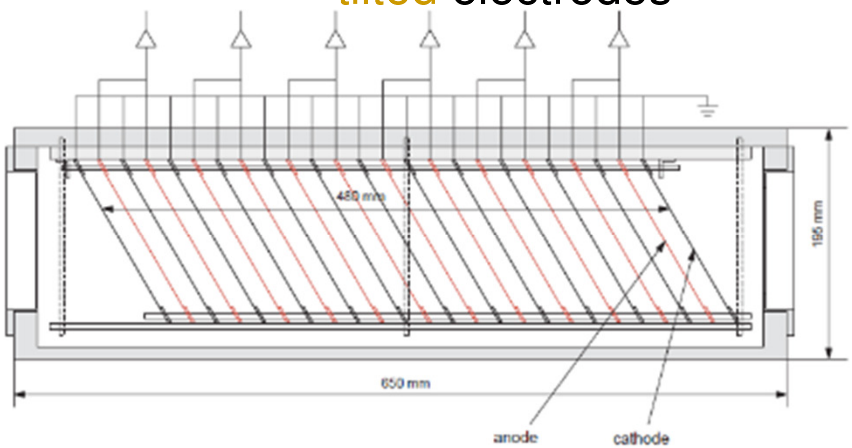
b) FRS MUSIC

´segmented anodes´



c) TEGIC

´tilted electrodes´

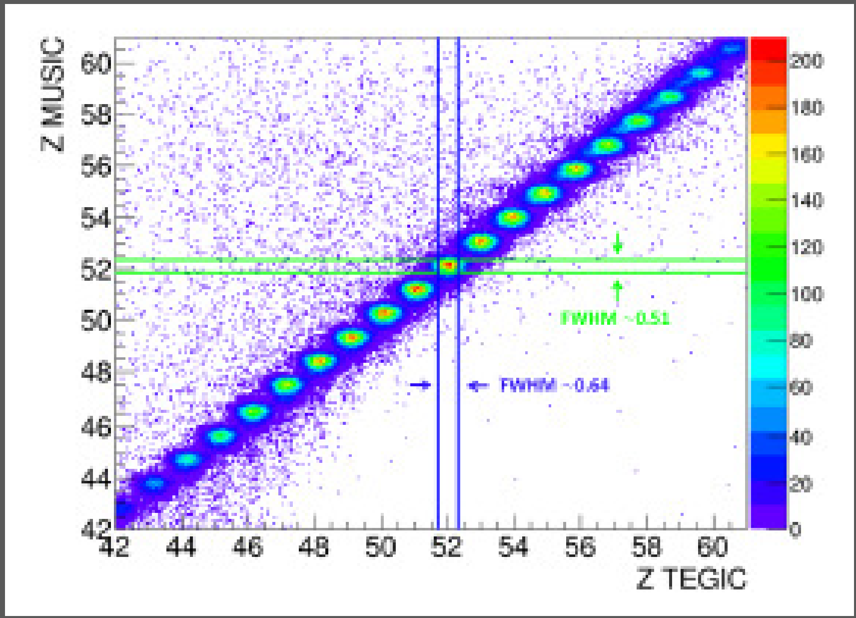


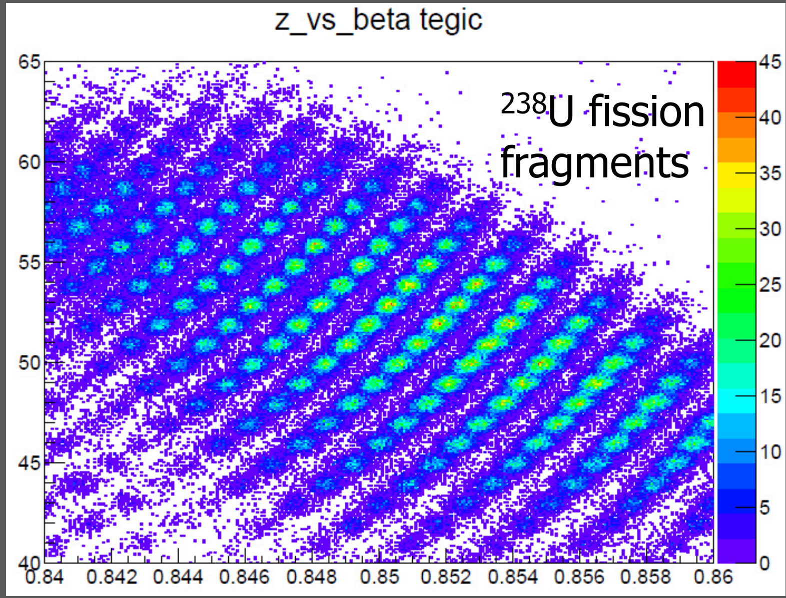
K. Kimura et al., *NIM A* 538 (2005) 608

Comparison TUM vs TEGIC prototype

March 2014

- anodes: 30° tilted and ´segmented´
- P10 gas at 1 atm
- readout FEBEX3a (ADC pipeline)





- Z resolution comparison in the Sn region at 700 MeV/u

$\Delta Z_{TUM} \sim 0.8\ \Delta Z_{TEGIC}$

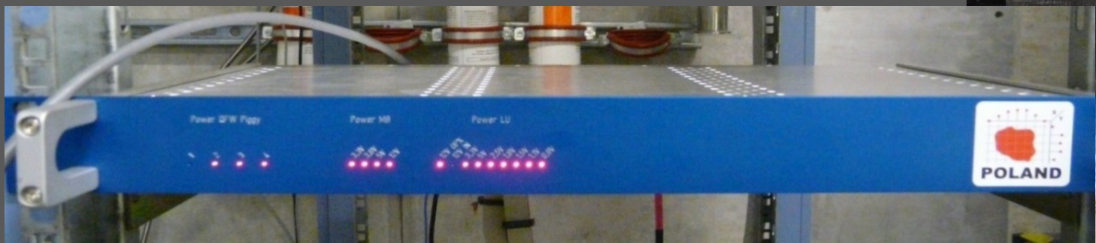
S. Maurus, R. Gernhäuser et al., *GSI report* (2014)

SEM-grid test

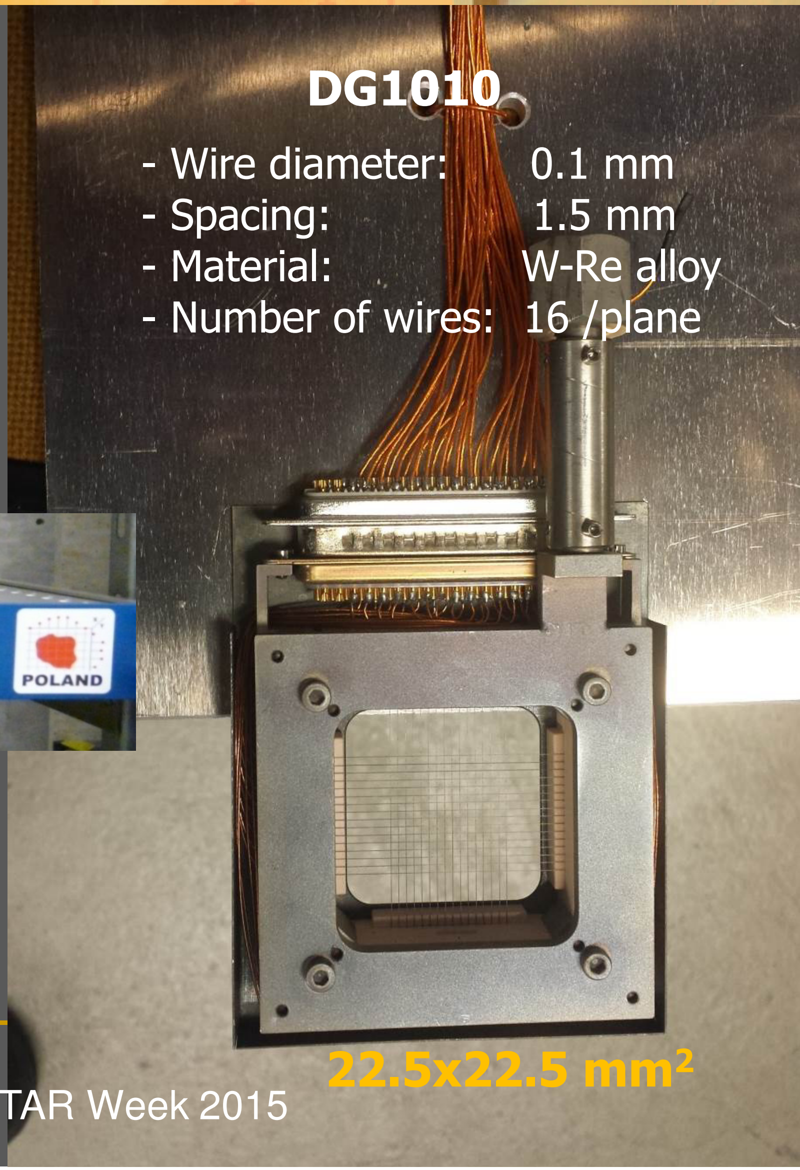
October 2014

- grid mounted in vacuum at FRS-F1 connected to current-to-frequency converter QFW ASIC with 50 m cable

POLAND (PrOfiLe AcquisitioN Digitiser)
S. Löchner et al.



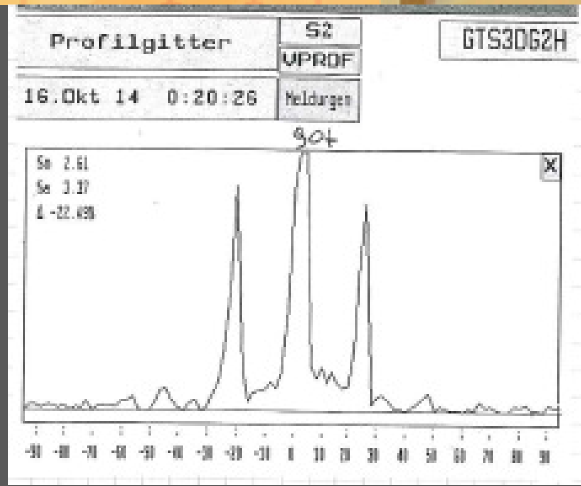
→ 2 input ranges (250 fC , 2.5 pC)
→ large dynamic range (100 fA - 130 mA)



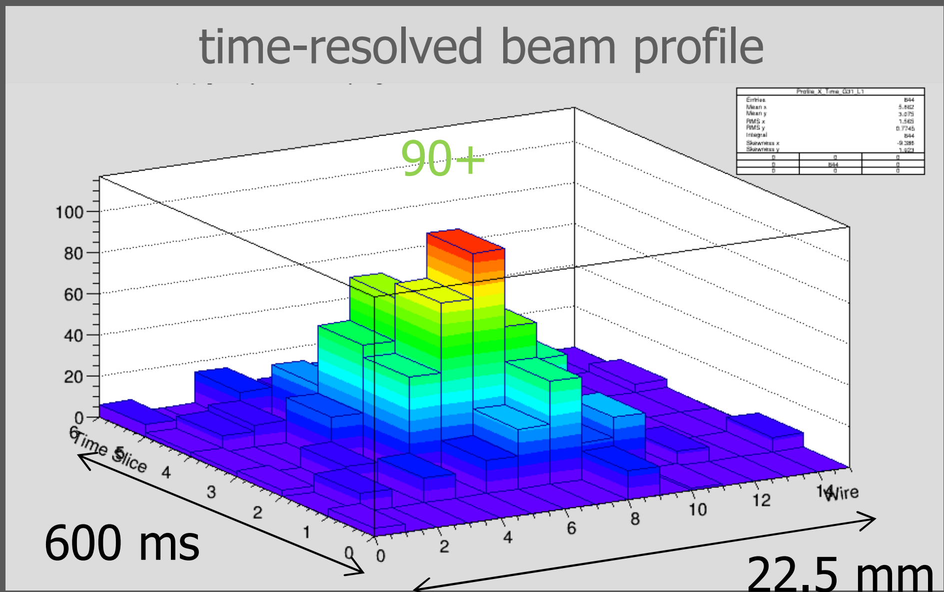
Beam profile (low intensity, slow extr.)

$^{238}U^{79+}$
from SIS
@300MeV/u

vacuum window   SEETRAM   x, y grids



measured by FRS standard grid



- $Q = 0.19$ nC $= 1.46\ Q_{sim}$
  $\rightarrow 1.33 \times 10^{7}\ {}^{238}U^{90+}$/spill

CN et al., *GSI report* (2014)

Beam profile (high intensity, fast extr.)

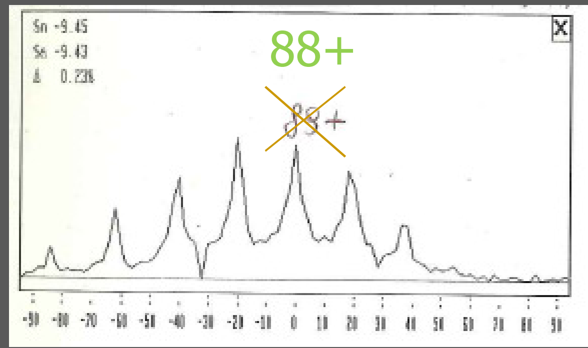
$^{238}U^{29+}$ from SIS

@125MeV/u

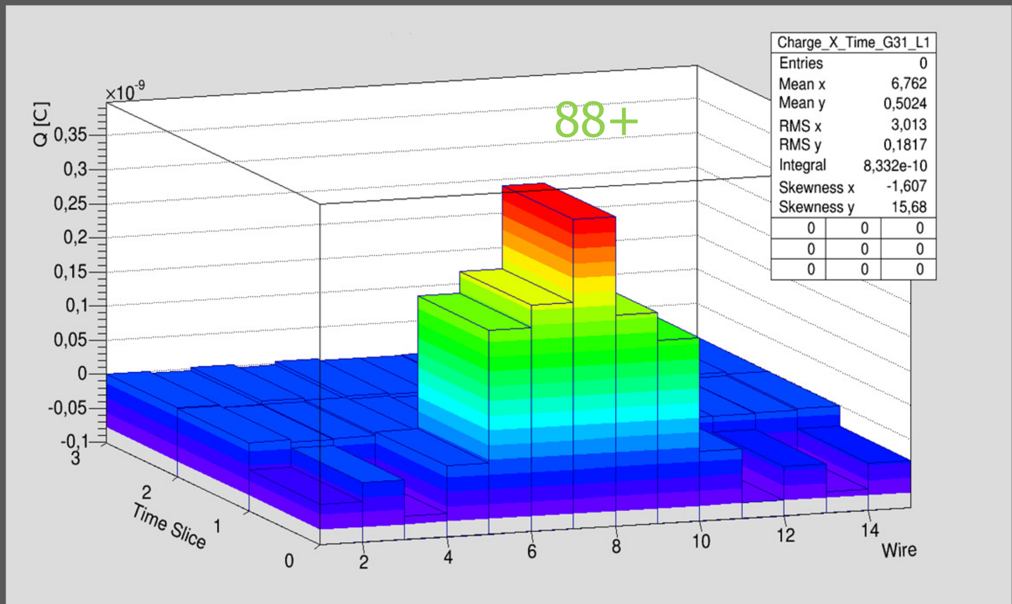
vacuum window

dipole

x, y grids



several charge states !



- $Q = 3\ nC = 0.36\ Q_{sim}$
  $\rightarrow\ 1.4 \times 10^8\ {}^{238}U^{88+}$/spill

area wires ≈7% area beam

CN et al., *GSI report* (2014)

Summary

- **Collections of recent developments & in-beam tests of the Super-FRS focal plane detector prototypes**

- **The excellent data, obtained non always in very comfortable experimental conditions, are the results of the *´choral´* activity and effort of several groups, technical staff, students, and providing a good basis for writing the technical specifications of the Super-FRS BD.**

New BD website:

https://www.gsi.de/de/work/fairgsi/rare_isotope_beams/super_frs/workpackages/beam_diagnostics.htm

Outlook

- **GEM-TPC**: extensively tests on the operational stability (efficiency stability, spatial uniformity, dead time due to discharges, probability of short circuits, aging etc...) -> in-beam test at Jyväskylä (October 2014)

  + new **GEMEX** board -> in-beam test at GSI (2016), approved exp. at RIKEN (2016)

- **MUSIC**: test of chambers (triple/double type) with a new preamp/readout electronics -> in-beam test at GSI (2016)

- **PDC**: new design of SEM detectors for intensity and profile measurements - > proposal submitted to LNS PAC for 2016

- **ToF** (not only material choice is important !): improvements of the FFE are needed - > next test of new modified chip in November 2015 at CERN (CBM detector test) and in Dubna (December 2015)

- **SEM:** different materials to test because of the high power absorption.