Detector developments for the Super-FRS

Chiara Nociforo

GSI Helmholtzzentrum für Schwerionenforschung
Darmstadt - Germany

12th International Conference on Nucleus-Nucleus Collisions, June 21-26, 2015, Catania, Italy

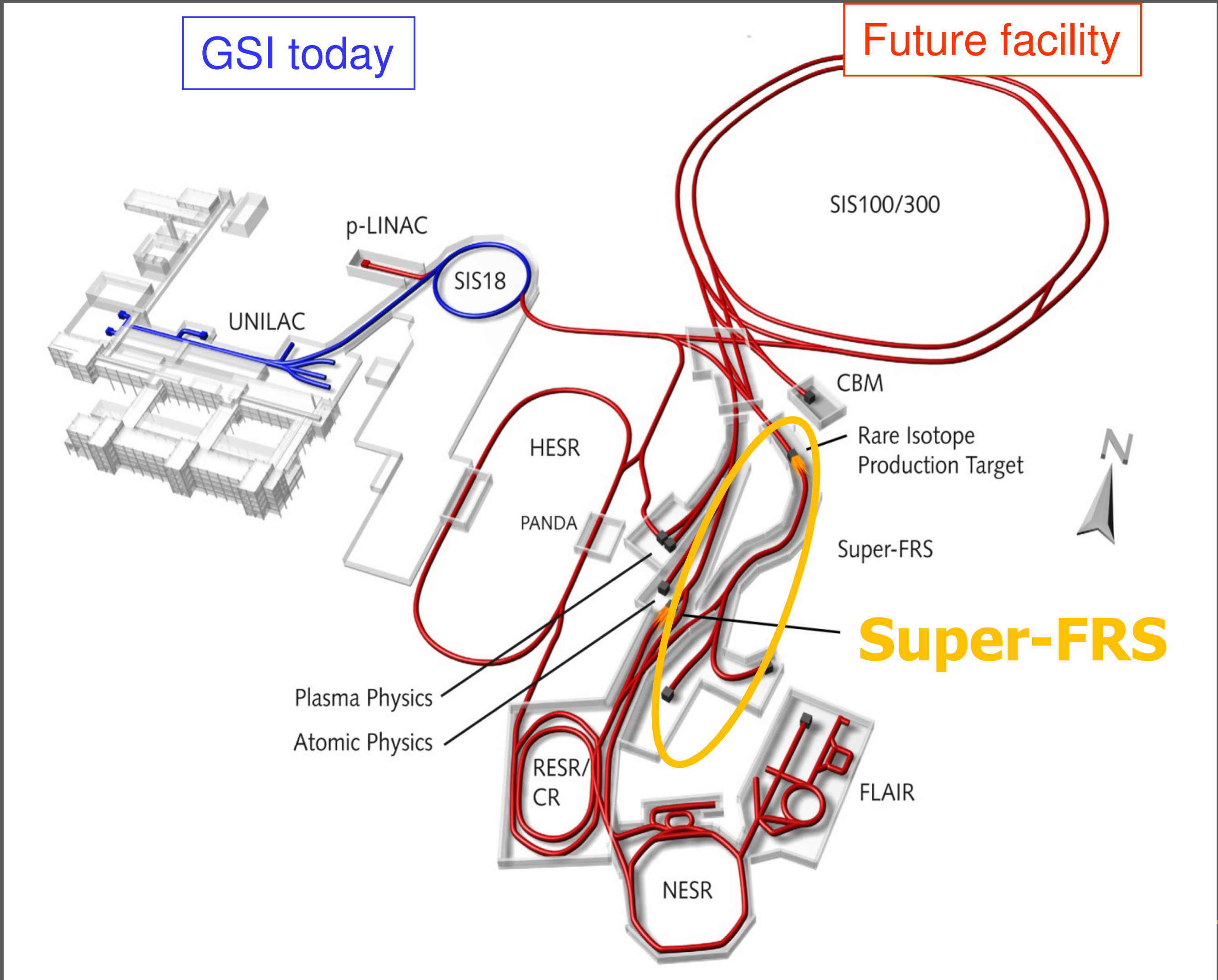
Contents

- Introduction to the **Super-FRS** at FAIR
  - new concept in-fligth RIB production and separation methods
  - comparison FRS – Super-FRS

- Technical challenges – **high intensity and high resolution** – in particle identification (PID)

- Recent developments & in-beam tests of Super-FRS focal plane detector prototypes.

The NUSTAR facility at FAIR



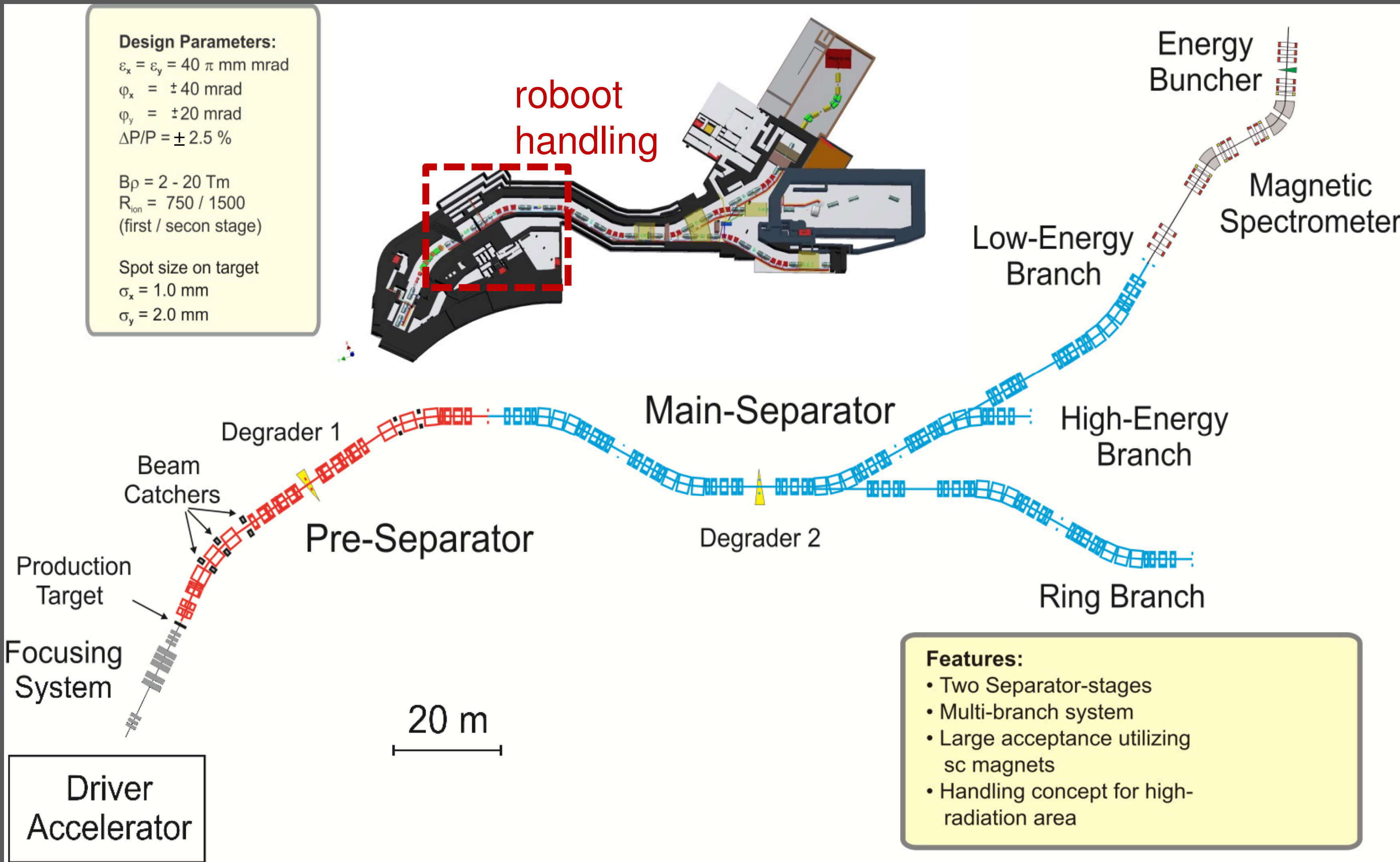
Primary Beams

- 5×10^{11} $^{238}U^{28+}$ (pulsed) 3.5×10^{11} $^{238}U^{28+}$ (DC) @1.5 GeV/u
- factor **100** in intensity over present

Secondary Beams

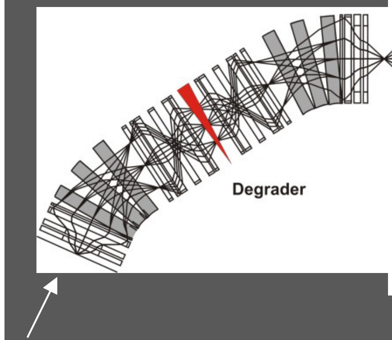
- broad range of RIBs up to 1-2 GeV/u
- up to factor **10000** in intensity over present

Layout of the Super-FRS

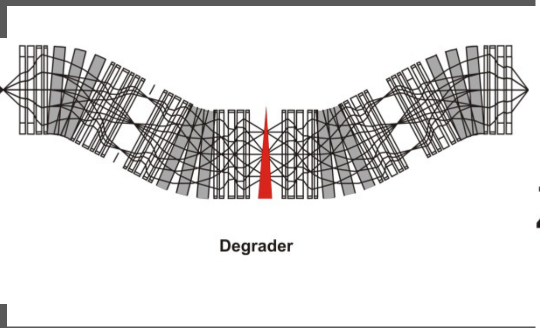


2-stage separation
e.g. ^{100}Sn

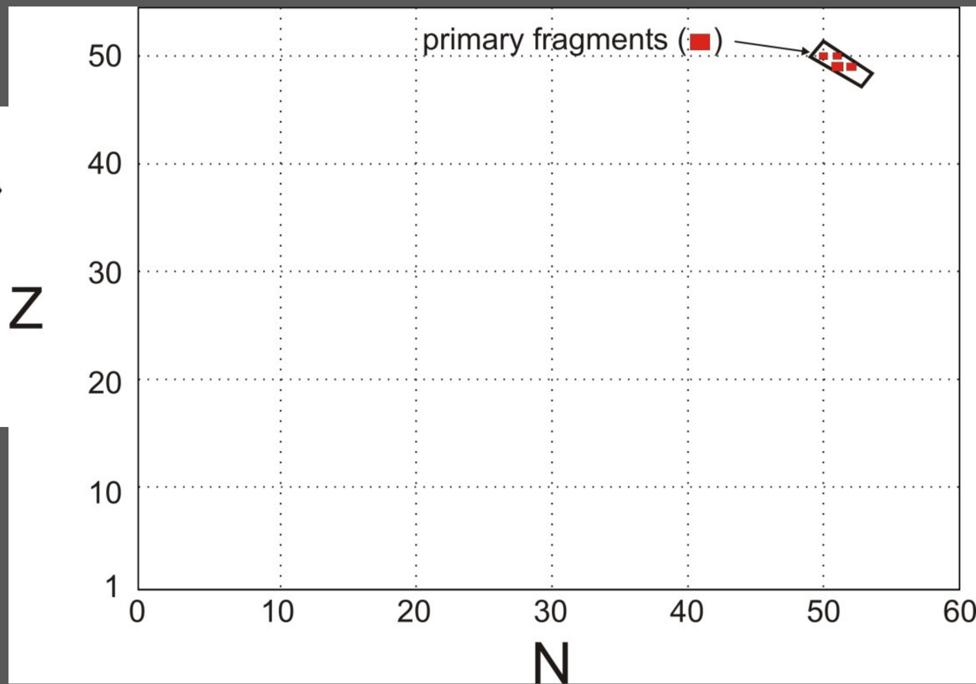
1-stage separator



2-stage separator

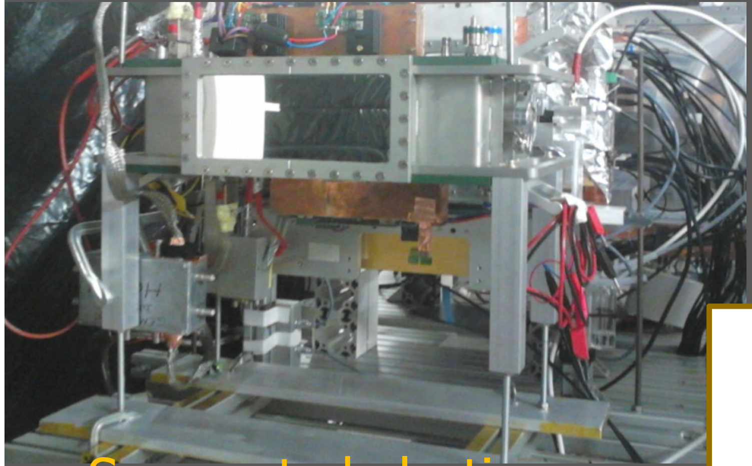


Fragmentation of ^{124}Xe @ 1 GeV/u



- Strong reduction of contaminants
- Optimization of fragment rate
- Main separator used for secondary reaction studies

PID detector prototypes



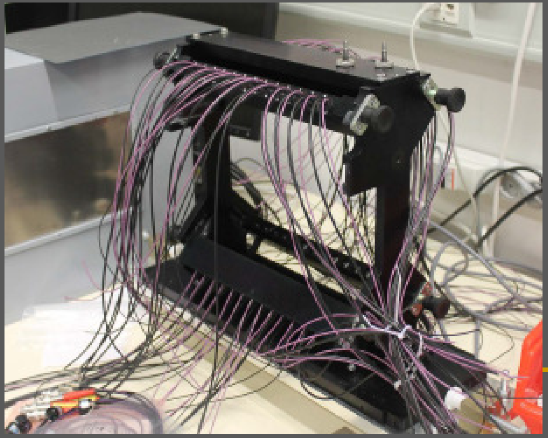
Twin GEM-TPC
(x, y)
Partner:
Helsinki IP

Silicon
(ΔE, x, y)
Partner:
St. Petersburg

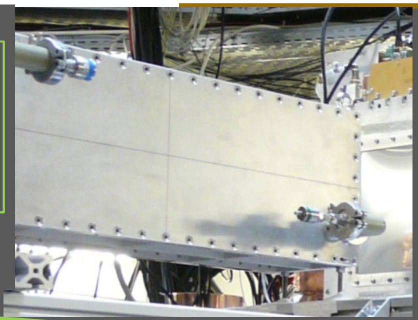
$$Z \leftarrow -dE/dx = f(Z, \beta)$$ atomic number

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

Segmented plastic scintillator (ToF)
Partner: IFJ Krakow



Bρ – ToF – ΔE method



Triple MUSIC
(ΔE)
Partner: CEA

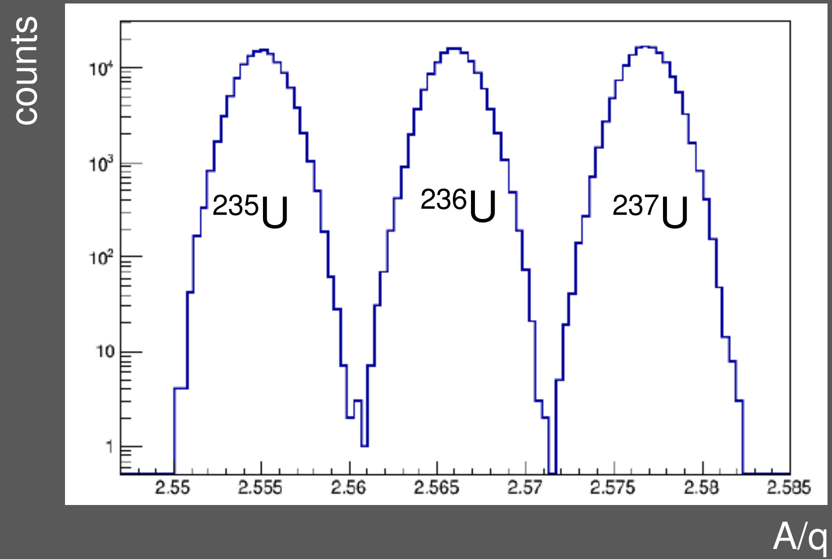
Other diagnostics (ToF)

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 $\Delta Z \sim 0.2e$

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



Monte Carlo simulations (MOCADI)

Yields not scaled

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

ToF focal plane detectors

- units working in vacuum
- active area 10 – 10^4 mm^2
- total rate 1-10 MHz
- high precision time distribution and time stamping over 100 m

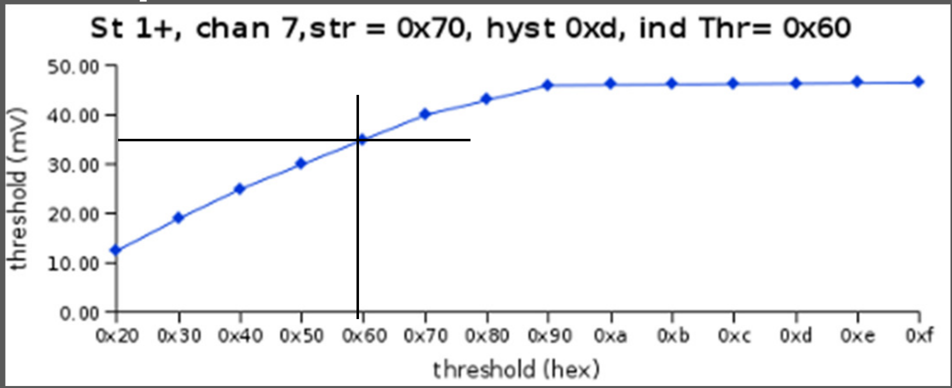
Radiation hard detector (diamond, silicon)

pcCVD-DD ⟶ (200 x 40) mm^2 , 20 units 20x20x0.3 mm^3

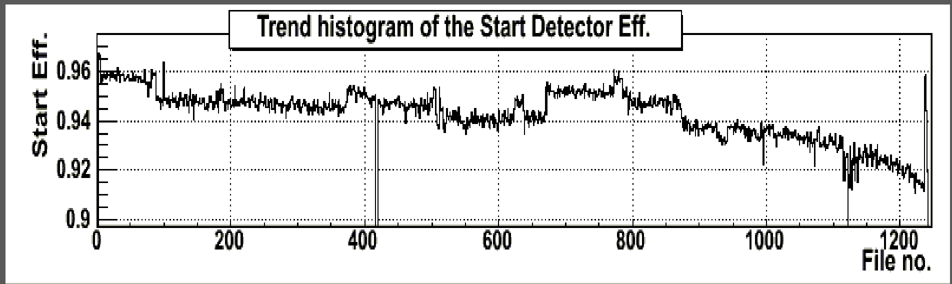
- 100 days operation @1MHz: 1.08x10^9 ions/mm^2

Absorbed dose = 4.4x10^5 Gy (^{238}U@350 MeV/u)

Radiation hardness study with Au beam - amplitude reduction

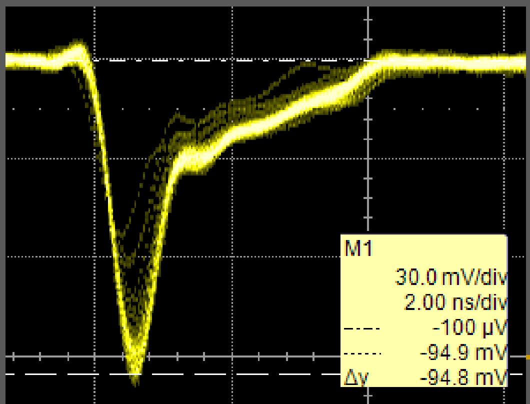


Threshold characteristics (Aug11): cut amplitudes lower than 35mV



+ 30 % DAQ off + 30 % beam times in 2010

→ 3.04 x 10^{11} Au ions / mm^2



Analog signals, Au beam, HV: 100V
Amplitude; 94 mV

- ➔ After 3.04 x 10^{11} Au ions /mm^2 about 5% of signals below 35 mV
- ➔ Total absorbed dose : 7.9 Grad (312 MeV / Au ion)
- ➔ Amplitude reduction by a factor of 2.7
- ➔ Precise CCE measurment needed

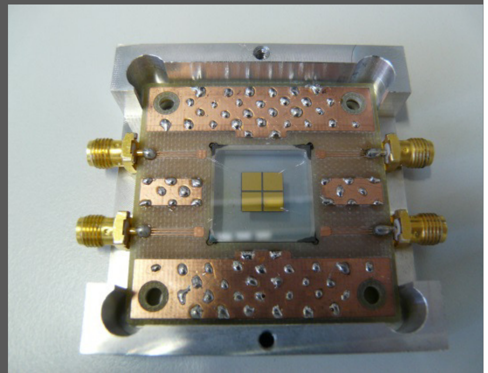
1Grad = 10^7 Gy

Diamond in-beam tests

Feb 2014

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

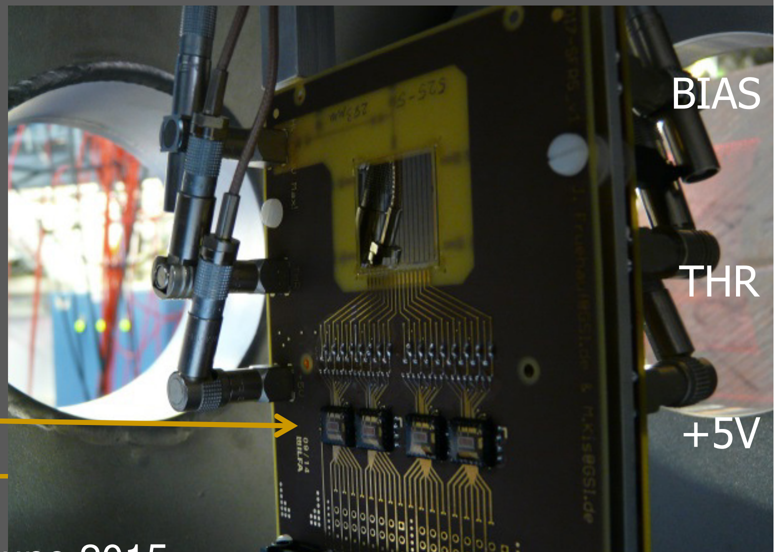
- 4 Al contacts, ΔE~20-600 MeV (DBA amp, V_{in} < 50 mV)
- total rate 10^{11} ions/cm^2 , test with α particles



Aug 2014

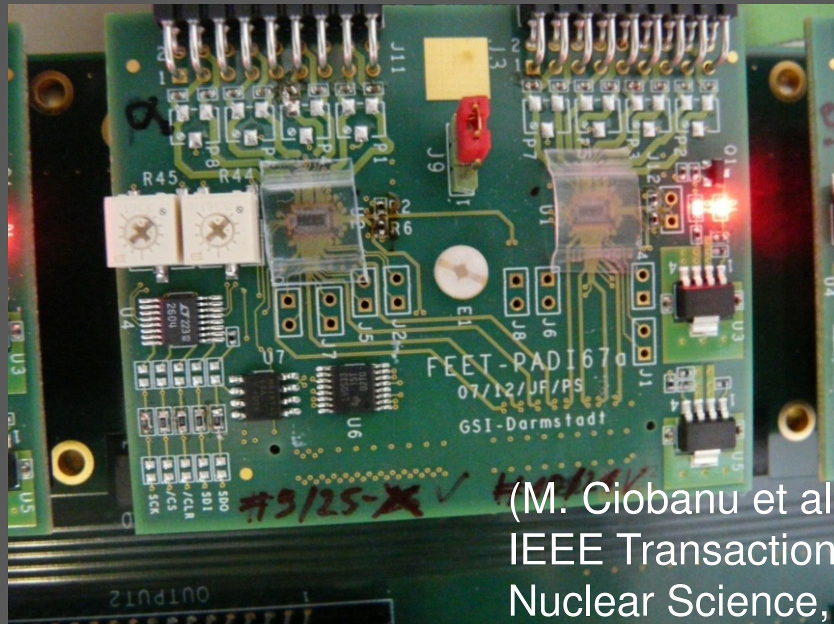
First ToF measurements at FRS with 900 MeV/u ^{197}Au beam with (E6) pcCVD-DD 20x20x0.3 mm^3

- 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

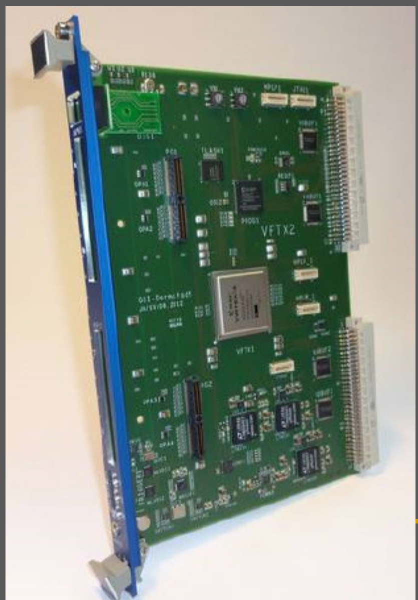


Electronics with ToT capability

- **PADI** ASIC 0.18 μm CMOS
  - rise time < 500 ps
  - 30 fC <Q< 2000 fC
  - σ_{tE} < 15 ps
  - LVDS digital outputs
  - 350 MHz bandwidth

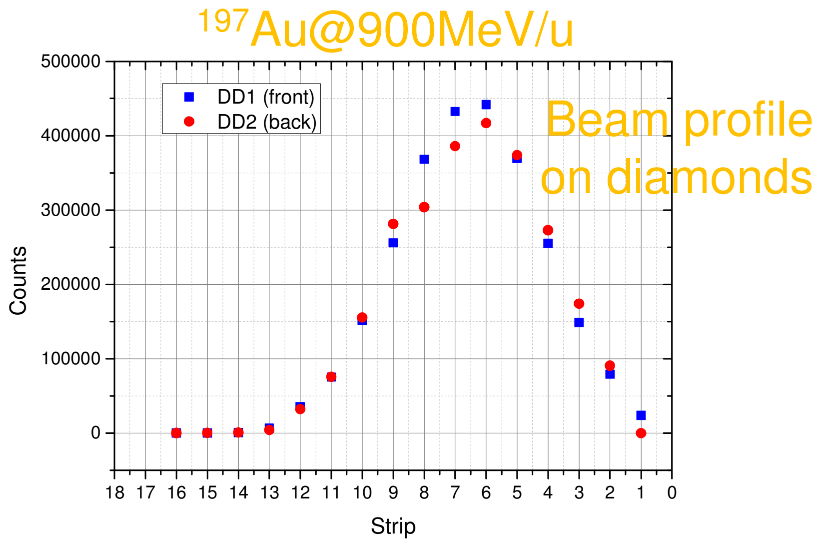


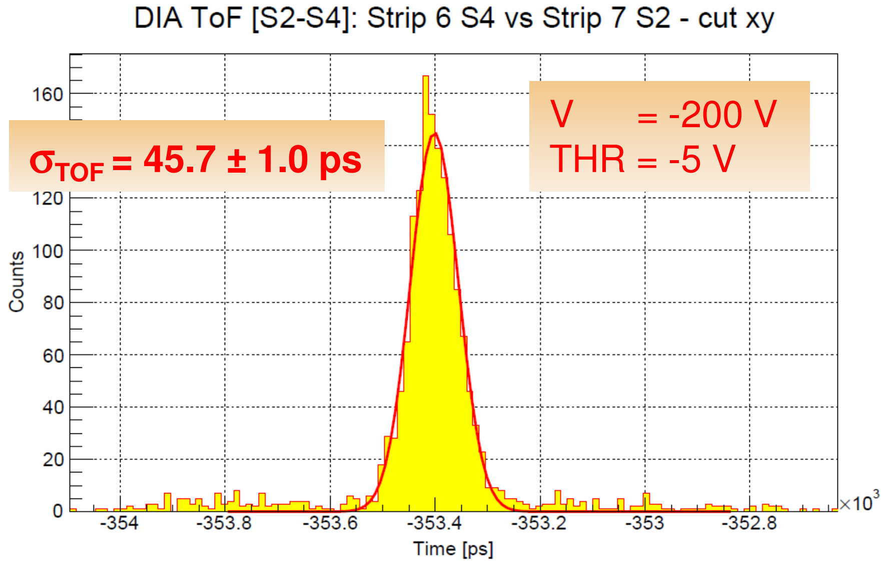
(M. Ciobanu et al., IEEE Transactions on Nuclear Science, vol.58, no. 4, p. 2073, Aug. 2011)



- **VFTX** (28 chs) VME FPGA TDC
  - LVDS inputs
  - 200 MHz clock (external & internal)
  - σ_t < 10 ps

σ_{intr} contribution





S2-S4 Detector resolution

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

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

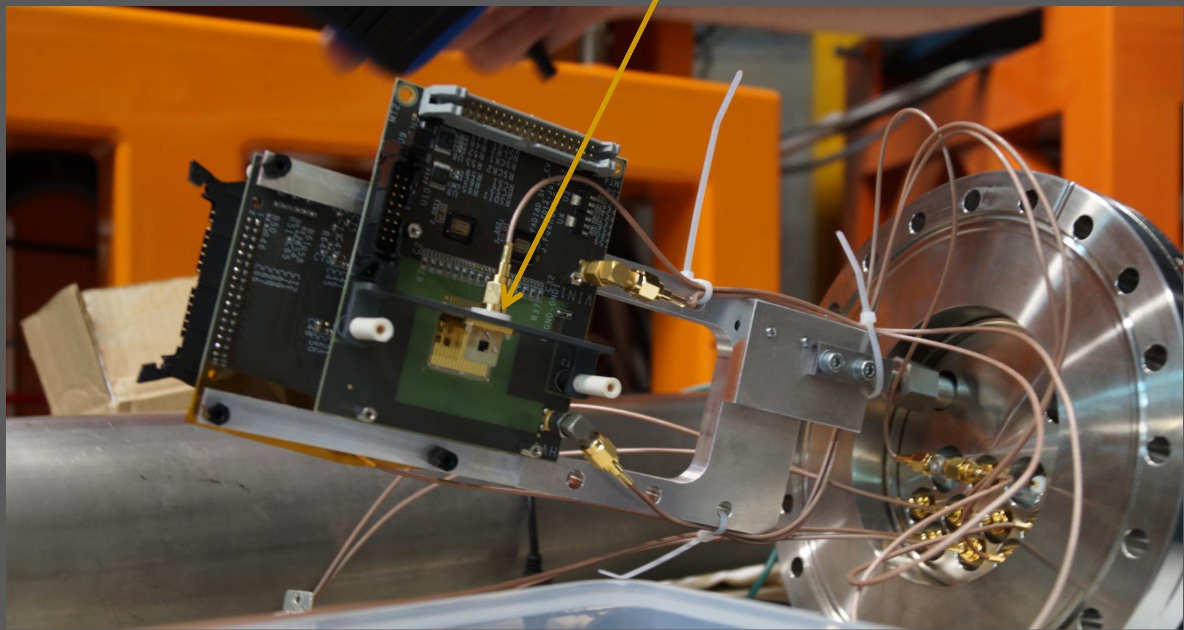
$\sigma_{intr,DD2}$=35 ps

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

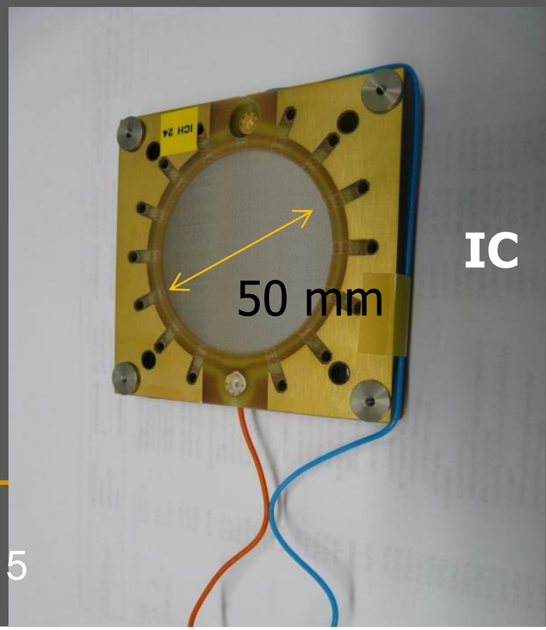
Irradiation test at LNS-INFN

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)



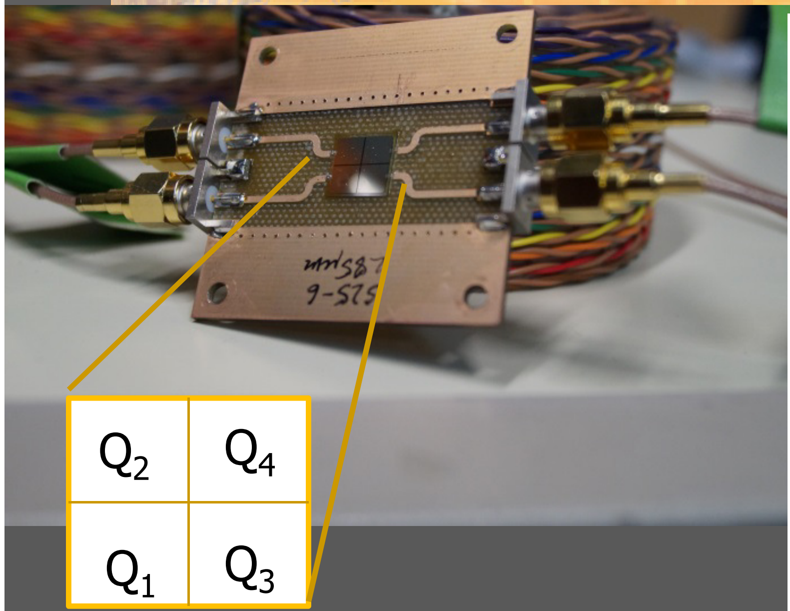
- new chip PADI7D, 8x2 chs (distance reduced), new threshold control



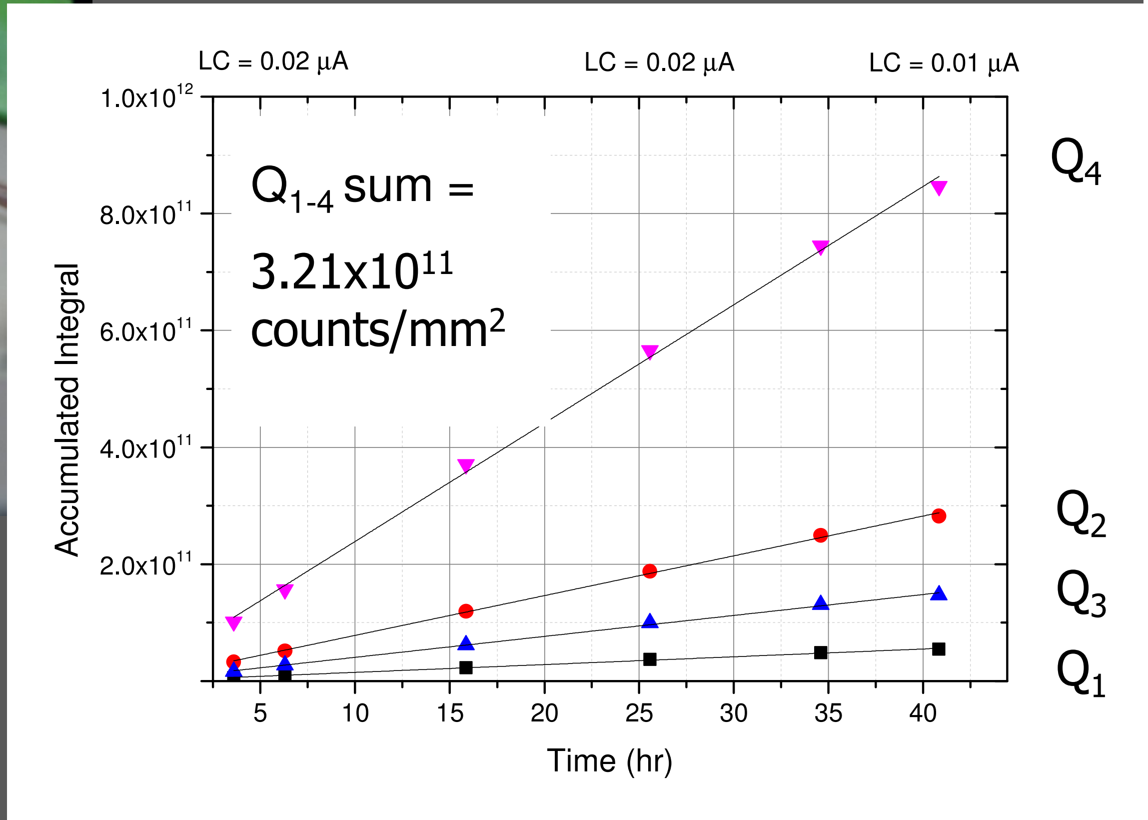
IC

- beam current measured by ionization chamber IC

Preliminary results (run with collim.)



(E6) pcCVD-DD 10x10x0.3 mm³

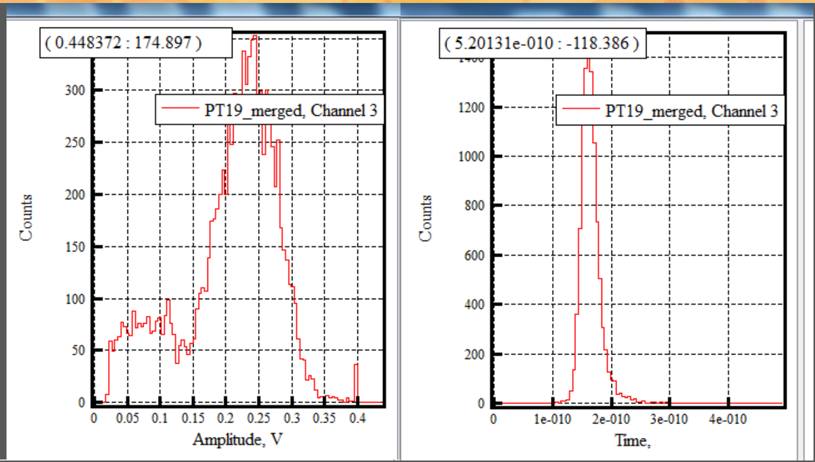


Minimum absorbed dose = 1.8×10^6 Gy (^{12}C@62 MeV/u)

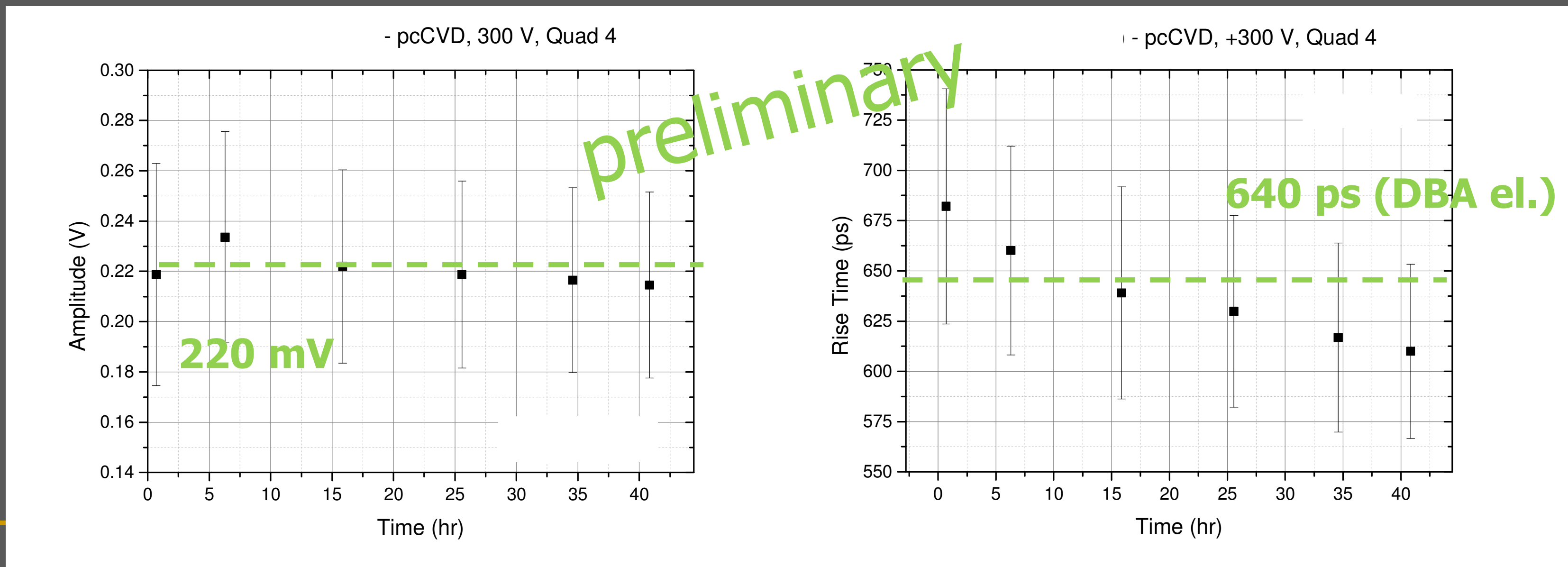
≈400 days operation

Digital waveform analysis

^{12}C@62MeV/u



after 40 hours



Summary

- The in-flight magnetic separator Super-FRS under construction at FAIR is ideal for the next-generation experiments with RIBs

- ToF detectors are crucial to obtain a clean PID; results of in-beam tests of strip diamond detectors (processed in house) performed in conditions similar to that of the Super-FRS show that σ_t ~25 ps is achievable

- Preliminary results of irradiation tests on pcCVD-DD sample does not show any damage after an absorbed dose of 1.8×10^6 Gy.

Acknowledgment

J. Fruehauf, M. Kiš, N. Kurz, F. Schirru, M. Träger, R. Visinka

GSI, Darmstadt, Germany

M. Ciobanu

Horia Hulubei National Institute for Physics and Nuclear Engineering, Magurele-Bucharest, Romania

S. Schlemme

TU Darmstadt, Germany