# TRACKING IN SUPER-FRS WITH GEM-TPC DETECTORS

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The Super-FRS is a superconducting fragment separator that will be built as part of the FAIR facility. For the slow-extraction part of the beam diagnostics system a total of 32 detectors are needed for beam monitoring and for tracking and characterization of the produced ions. Since GEM-TPC detectors can perform over wide dynamic range without disturbing the beam, they are suitable for this kind of in-beam detection.

## FAIR Facility

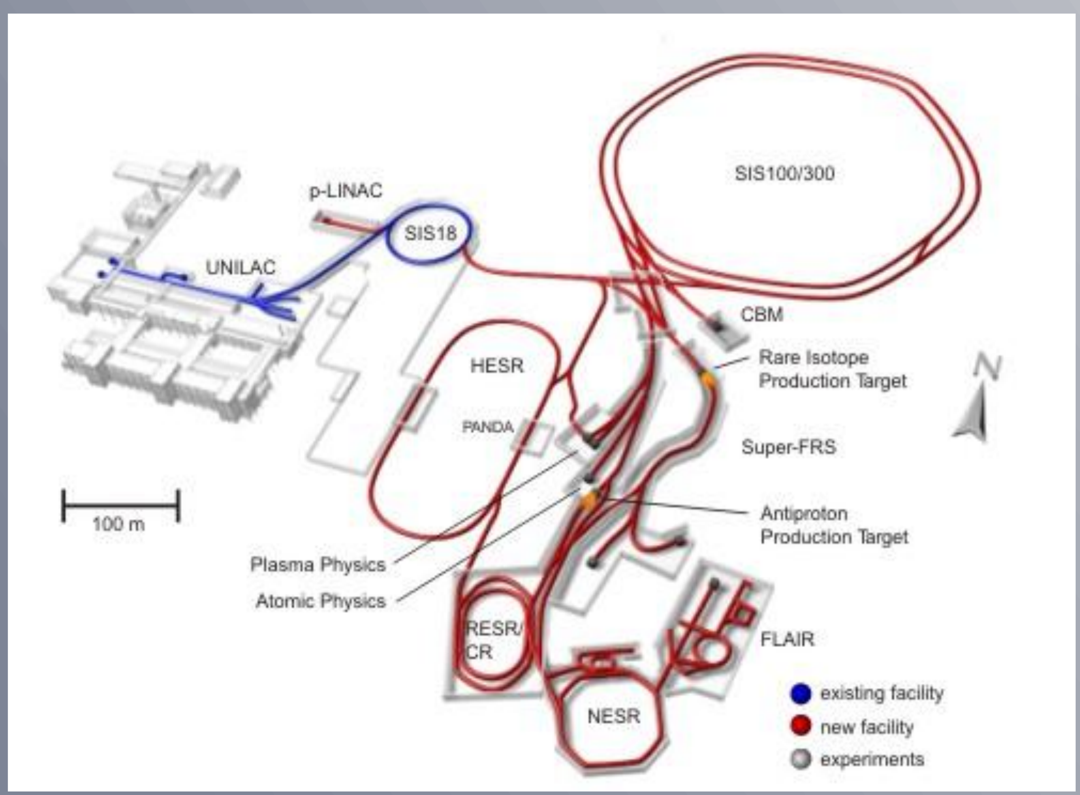



Diagram of the FAIR facility.

FAIR, Facility for Antiproton and Ion Research [1], is a new international accelerator facility for the research with antiprotons and ions. It will be build as an extension of the existing GSI facility [2]. The GSI facility will serve as pre-accelerator and injector for the new complex. Its core, a double-ring accelerator (SIS100 heavy ion synchrotron) with a circumference of 1100 meters, will be associated with a complex system of cooler and storage rings and experimental setups. The synchrotron will deliver ion beams of high intensities and energies. Thus also intensive secondary beams can be produced, providing antiprotons and exotic nuclei for groundbreaking experiments.

## NUSTAR Collaboration

NUSTAR (Nuclear Structure, astrophysics and Reactions) encompasses all experiments that will be benefiting from the Super-FRS [3]. The experiments will exploit beams of different energies and characteristics at three branches; the high-energy branch utilizes the radioactive ion beams at relativistic energies (300-1500 MeV/u) as created in the production process, the low-energy branch aims at using beams in the range of 0-150 MeV/u whereas the ring branch will exploit cooled and stored beams in the storage ring NESR.

## Super-FRS

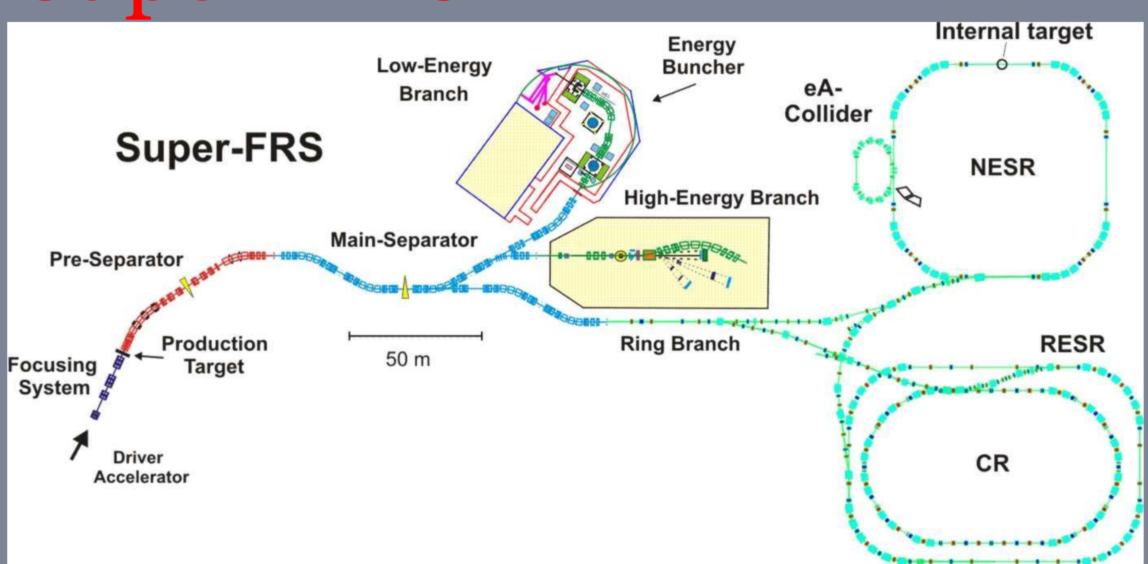



Diagram of the Superconducting Fragment Separator.

The Super-FRS (Superconducting Fragment Recoil Separator) will be the most powerful in-flight separator for exotic nuclei up to relativistic energies. Rare isotopes of all elements up to uranium can be produced and spatially separated within some hundred nanoseconds, thus very short-lived nuclei can be studied efficiently. The new rare-isotope facility is based on the experience and successful experimental program with the present FRS [4]. The layout of the Super-FRS consists of magnets with Bρmax of 20 Tm.

## Beam Diagnostics

The main task of the detection system of the Super-FRS is threefold:

1. It can be used to set up and adjust the separator.
2. It provides the necessary measures for machine safety and monitoring.
3. It allows for an event-by-event particle identification, tracking and characterization of the produced rare ion species.

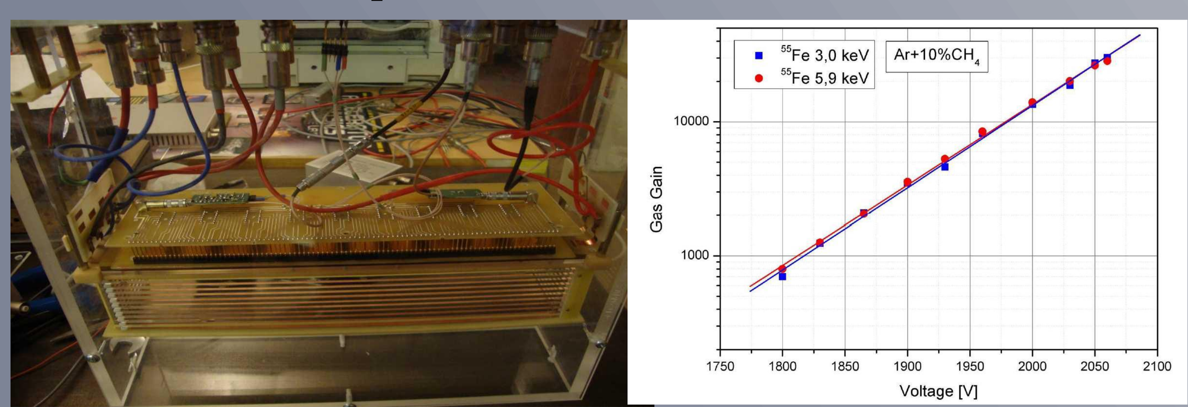
Furthermore, the beam intensities at different locations in the separator are to be monitored, e.g. to normalize measured rates in order to extract absolute cross sections. The main design goal is to get an easy to maintain, reliable system. An online monitoring has to be performed, especially in the target and beam catcher areas. The design of the detector systems should allow extended periods of operation without hands-on maintenance.

## GEM-TPC Trackers

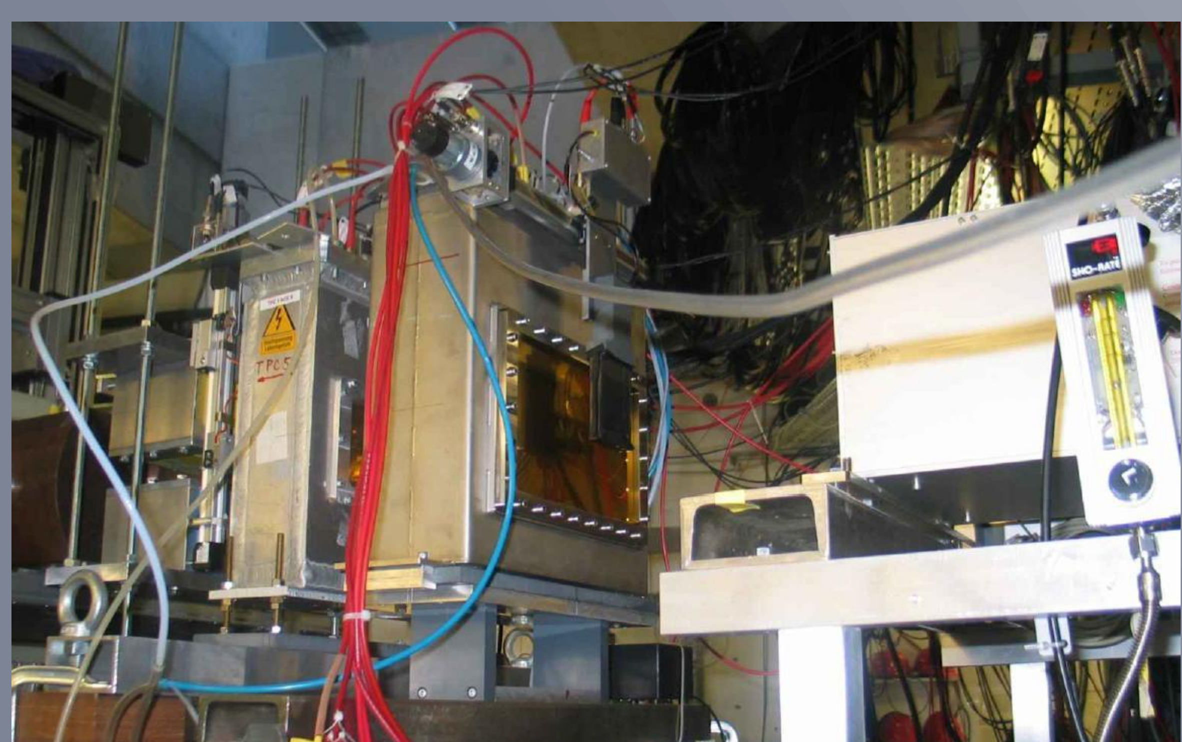
At the Super-FRS slow extraction is defined to have with extraction times above 100 ms. Beam diagnostics systems will be installed in all intermediate foci PF(0-4), MF(1-12) with an active area of (40 × 20) cm$^2$. From the experience obtained with Time Projection Chambers (TPC) presently operating with the FRS, it is seen that the detectors can be used as high efficiency in-beam detectors for experiments using slow-extraction beams. By using Gas Electron Multipliers (GEM) in anode plates the signal resolution can be improved. At the same time the ion backflow can be reduced without any gating requirements.

## Prototype Detector

The first prototype GEM-TPC was constructed jointly by groups in Helsinki and Bratislava. The first detector had triple-GEM amplification and field cage dimensions of (10 × 6 × 5) cm$^3$. It has been tested in laboratory measurements in Bratislava and in beam tests with FRS separator at GSI.



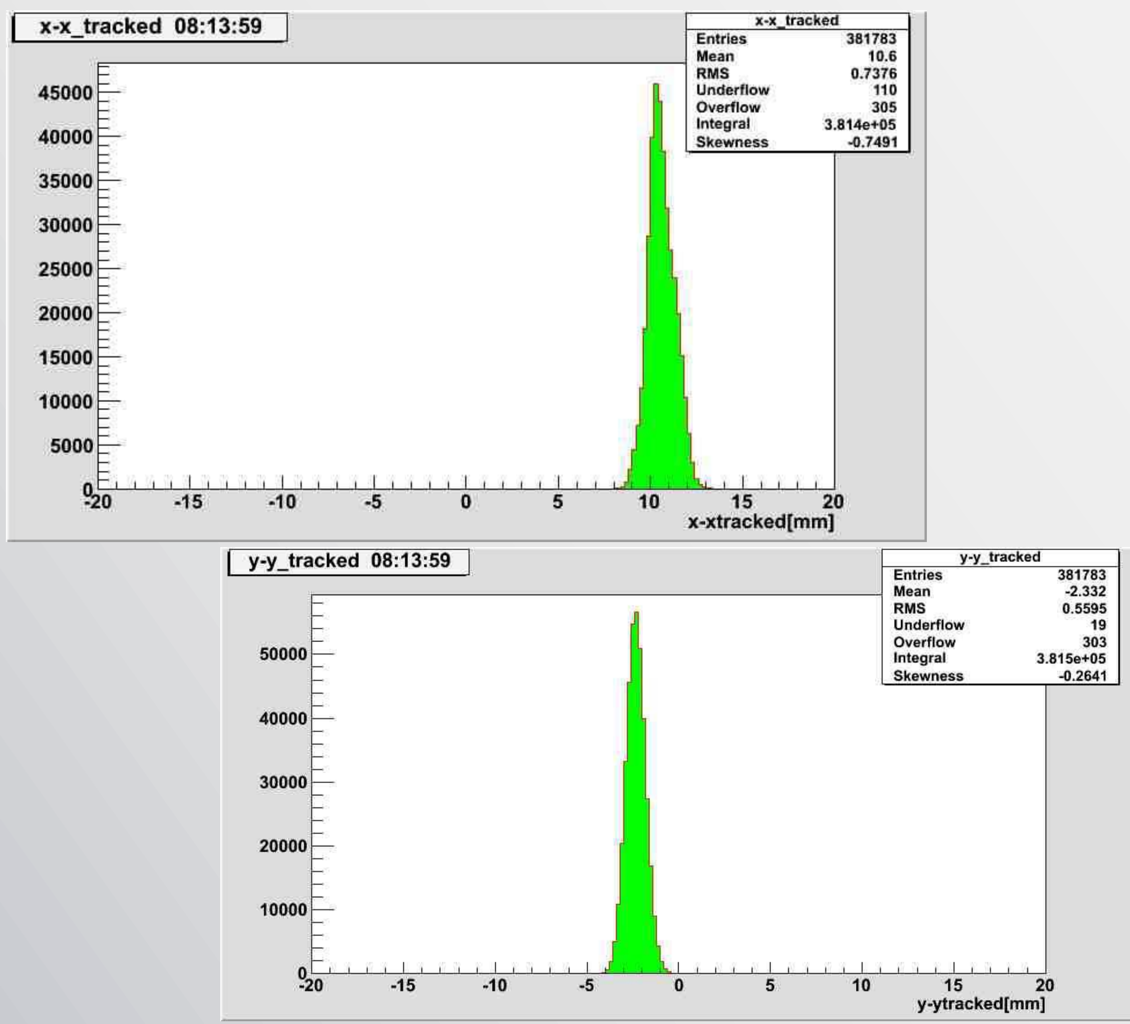

GEM-TPC prototype assembled in laboratory and the measurement results of the gas gain studies with the detector.



GEM-TPC prototype installed in the experimental area of FRS separator.

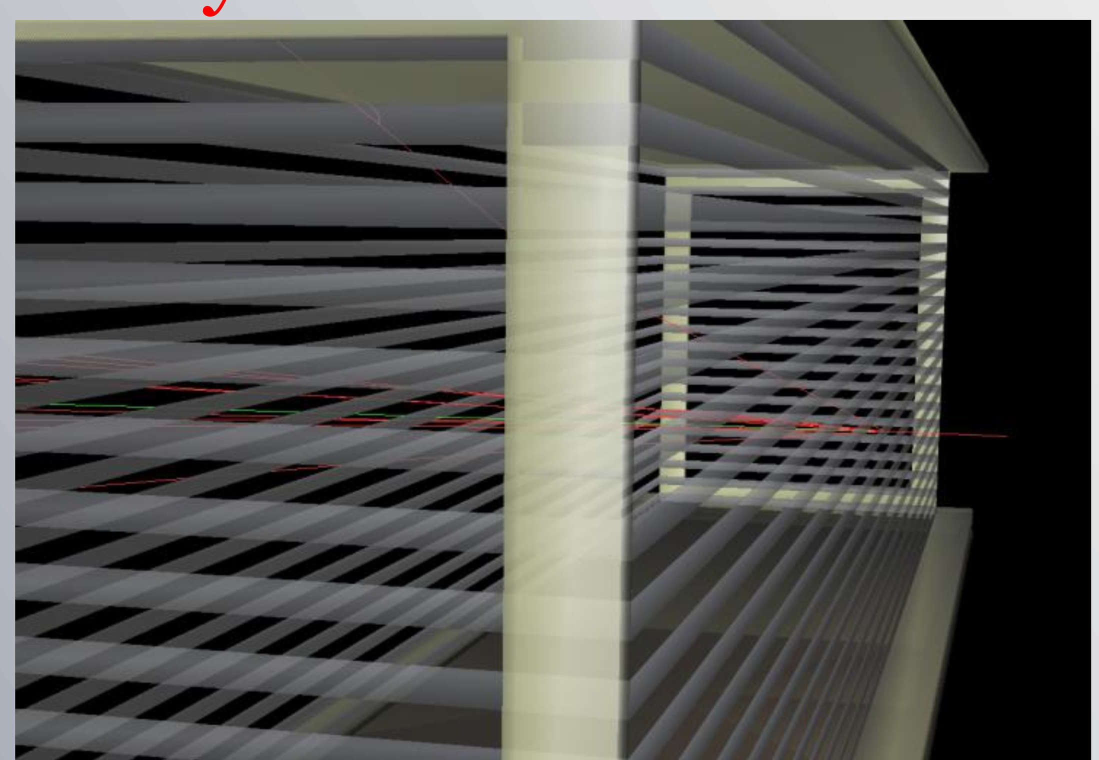
## Measurement Results

The first estimates for resolution of the prototype detector was determined by using two surrounding TPCs as reference trackers. By measuring the beam properties with two TPCs the resolution of the GEM-TPC was calculated. This gives slightly worse resolution for the GEM-TPC since the beam is not focused on both of the reference detectors.

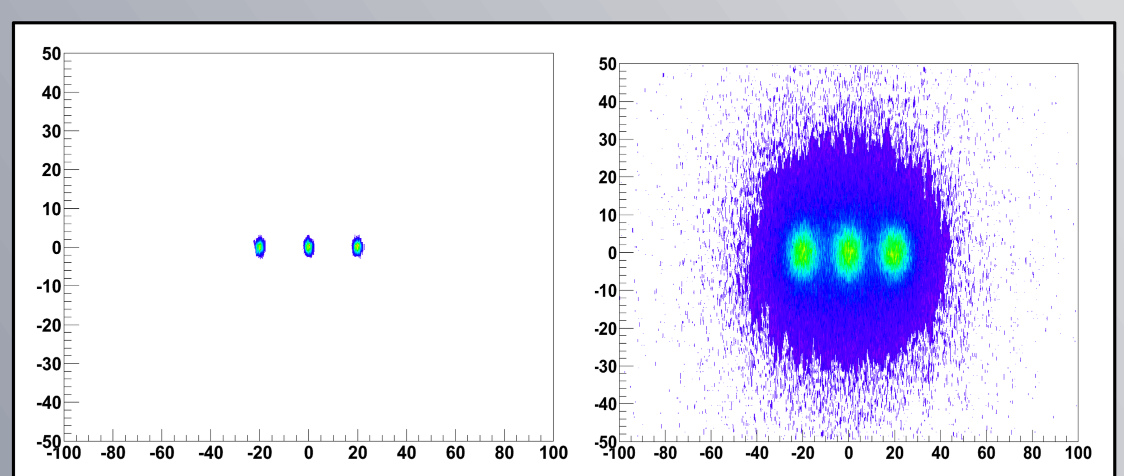



First measurement results obtained with the GEM-TPC detector. External resolutions $\sigma_x \approx 400$ µm and $\sigma_y \approx 300$ µm for $^{64}$Ni.

## Analysis With Simulations



Geant4 simulation of beam of heavy ions entering the gas volume of the TPC.



XY-distribution of secondary electrons from beams of $^{134}$Sb, $^{132}$Sn and $^{130}$In with beam energy of 100 MeV. Spot size of the left image is 1 mm and of the right 4 mm.

## References

1) G. Rosner, *Nucl. Phys. B – Proceedings Supplements*, **167**, p. 77-81 (2007).
2) http://www.gsi.de
3) H. Geissel et al., *Nucl. Instr. and Meth.* **B204**, p.71-85 (2004).
4) H. Geissel et al., *Nucl. Instr. and Meth.* **B70**, p. 286 (1992).