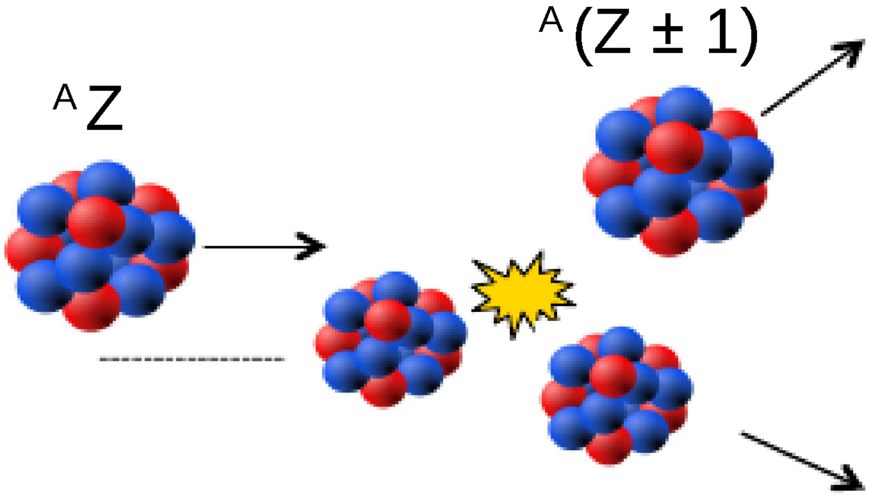


Excitation of baryonic resonances within isobaric charge-exchange reactions of medium-mass nuclei

JOSÉ LUIS RODRÍGUEZ SÁNCHEZ

for the FRS/Super-FRS collaboration

University of Santiago de Compostela, Spain
GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany

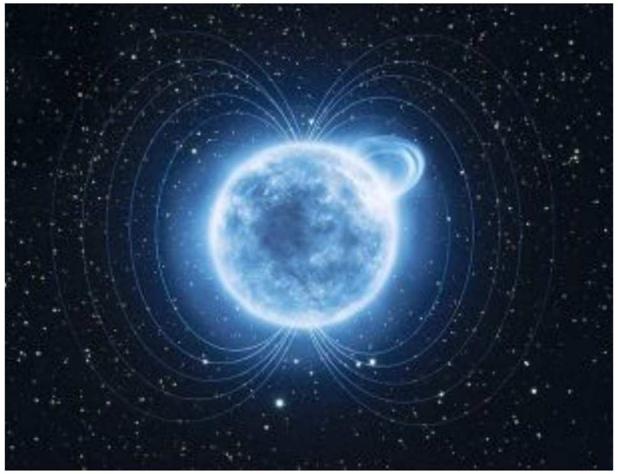
Outline

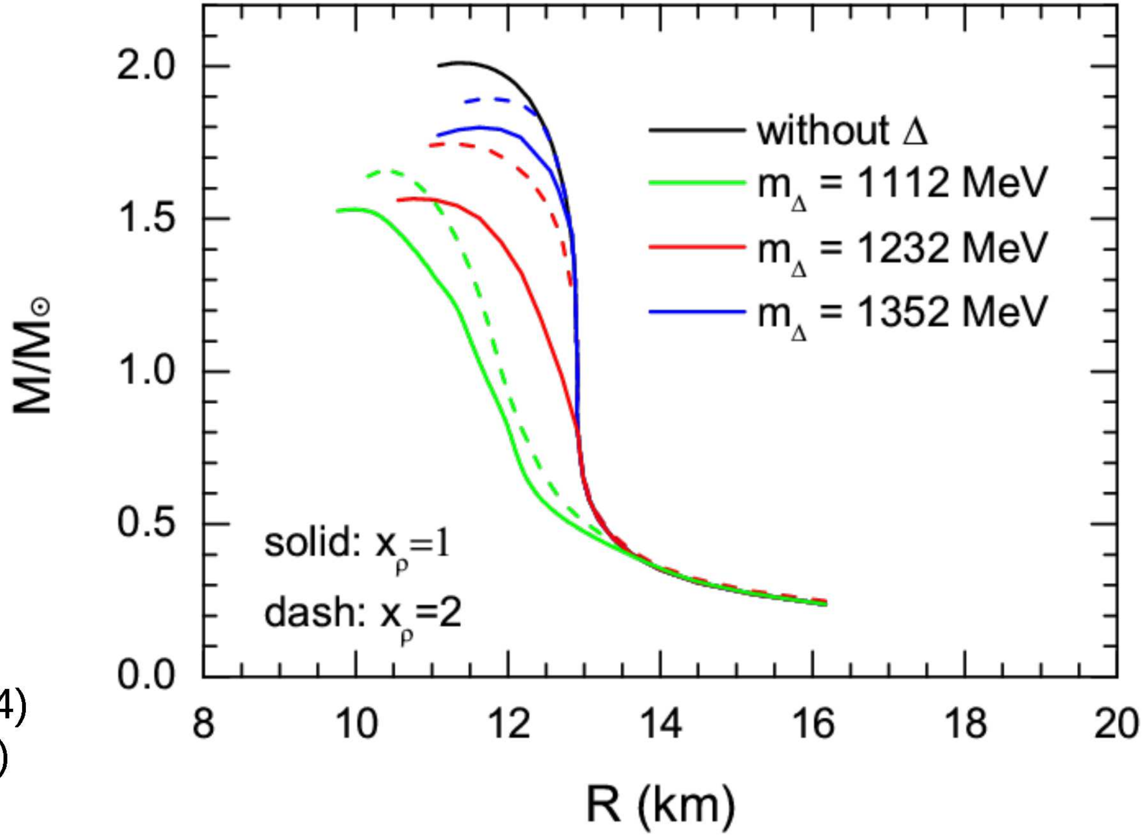
- ✗ Why the study of baryonic resonances in exotic nuclear matter
- ✗ Isobaric charge-exchange reactions as a tool to investigate the in-medium excitation of baryonic resonances
- ✗ Measurements carried out at the FRagment Separator FRS @ GSI
  - Experimental setup
  - Observables and measurements
- ✗ Results and comparison with elementary processes
  - Total isobaric charge-exchange cross sections
  - Missing energy spectra
- ✗ Future perspectives at GSI and FAIR
- ✗ Conclusions

Motivation for measuring baryonic resonances

After more than 60 years studying baryonic resonances, the accurate constraint of in-medium (density & isospin dependencies) properties of baryonic resonances is still needed for a better understanding of:

- not yet solved quenching problem of the Gamow-Teller strength
- Equation Of State of asymmetric nuclear matter (neutron stars)





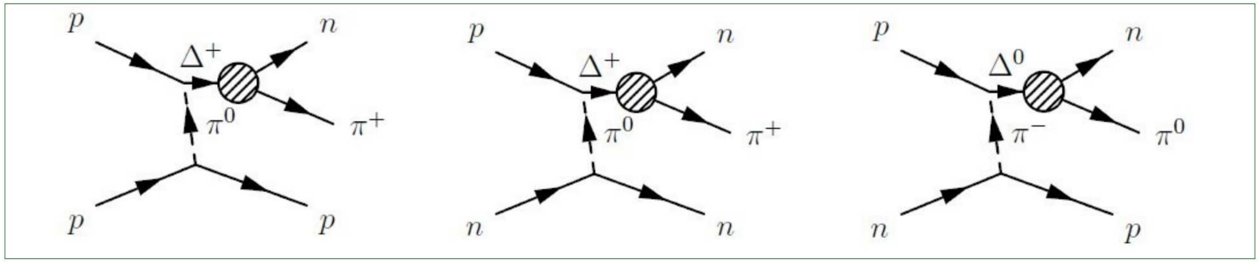
A. Drago et al., PRC 90, 065809 (2014)
B.J. Cai et al., PRC 92, 015802 (2015)

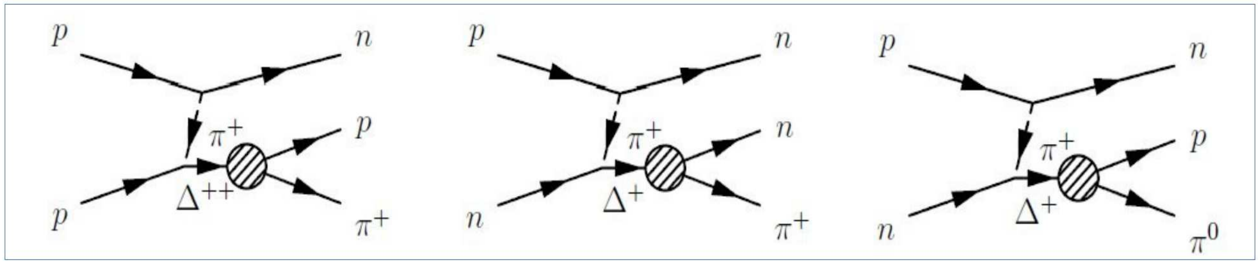
Motivation for measuring baryonic resonances

After more than 60 years studying baryonic resonances, the accurate constraint of in-medium (density & isospin dependencies) properties of baryonic resonances is still needed for a better understanding of:

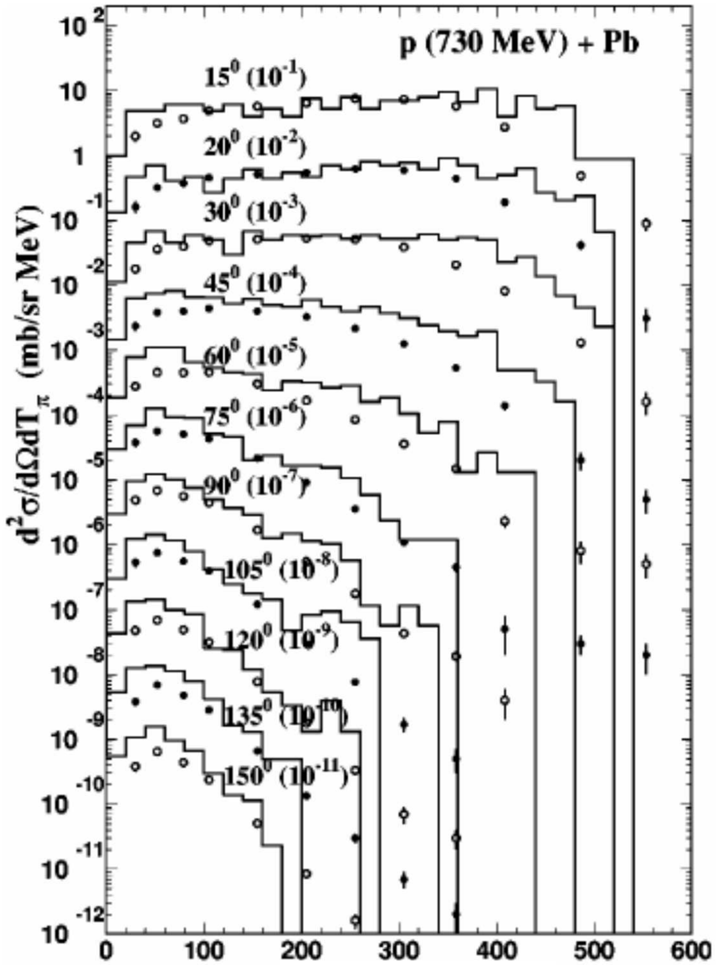
- pion production on relativistic heavy ion collisions (fragmentation and spallation reactions)

Projectile excitations



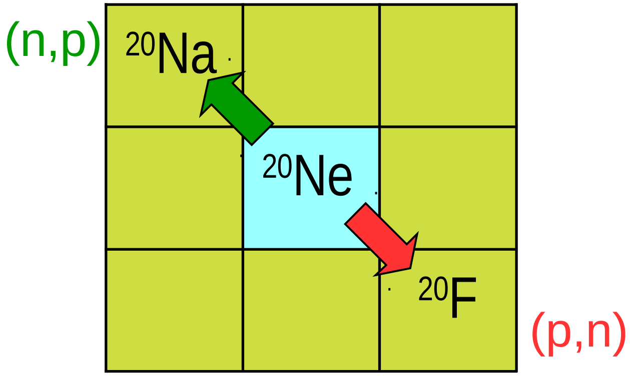


Target excitations



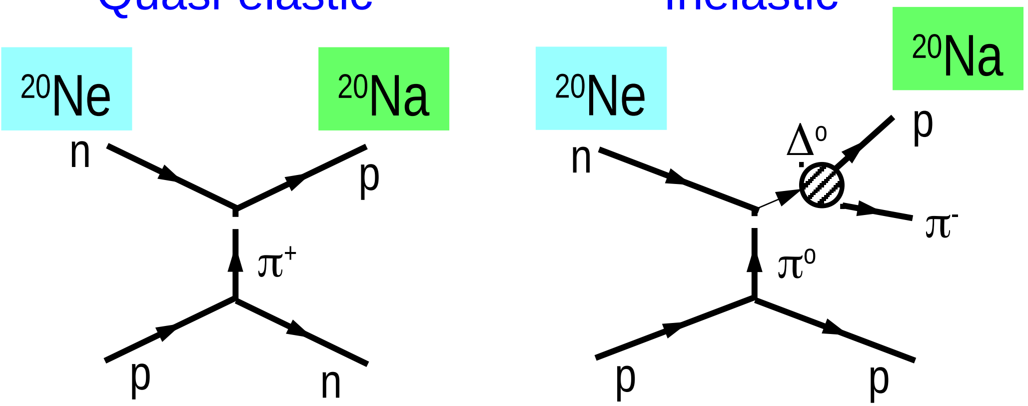
E. Oset et al., PLB 224, 249 (1989)
P. Fernandez et al., NPA 592, 472 (1995)
A. Boudard et al., PRC 66, 044615 (2002)

Isobaric charge-exchange reactions investigated in inverse kinematics allow for the direct observation of in-medium excitation of the Δ resonance for the (p,n) and (n,p) channels



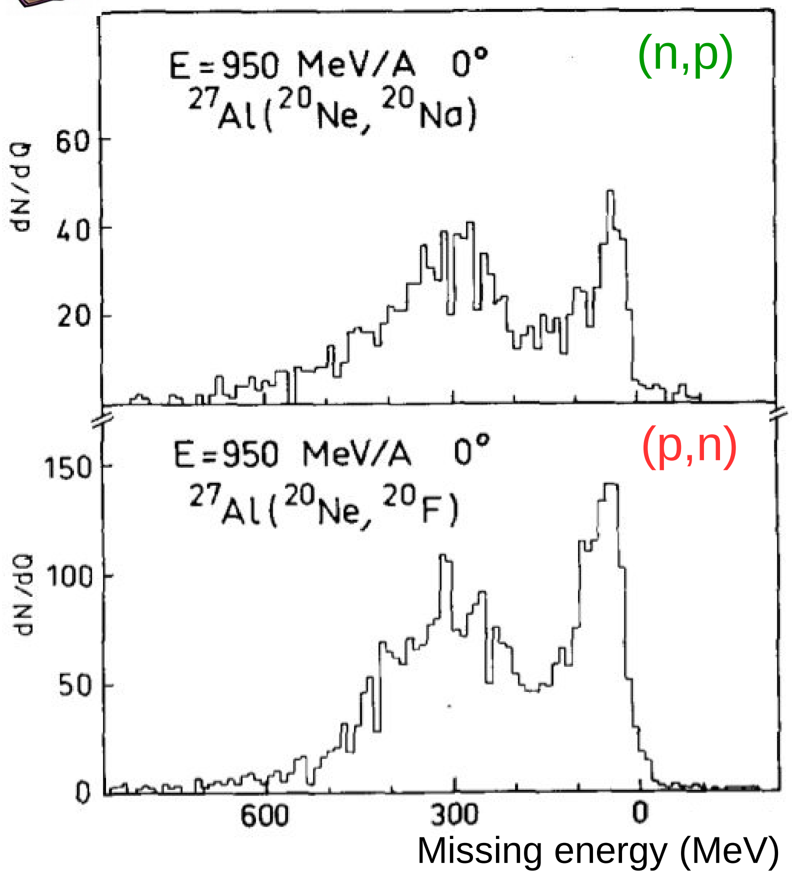
Quasi-elastic

Inelastic



p(^{20}Ne, ^{20}Na)X

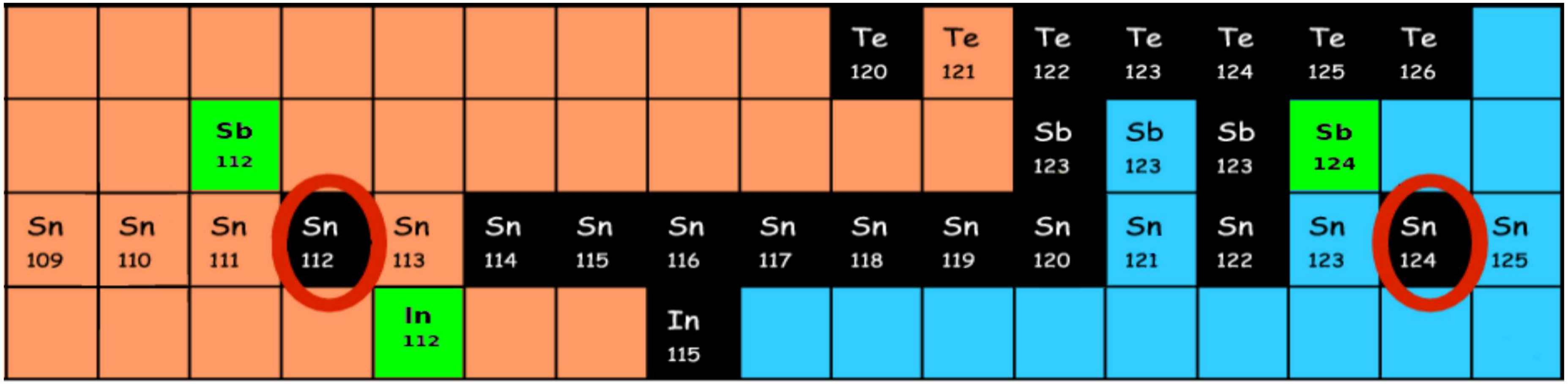
D. Bachelier et al., PLB 172, 23 (1986)



In the inelastic charge-exchange process the pion must scape in order to preserve the isobar character of the reaction

The momentum recoil induced by the pion emission proves the excitation of the resonance

To investigate the baryonic resonances excited in isobar charge-exchange reactions we use stable tin projectiles covering a large range in mass number



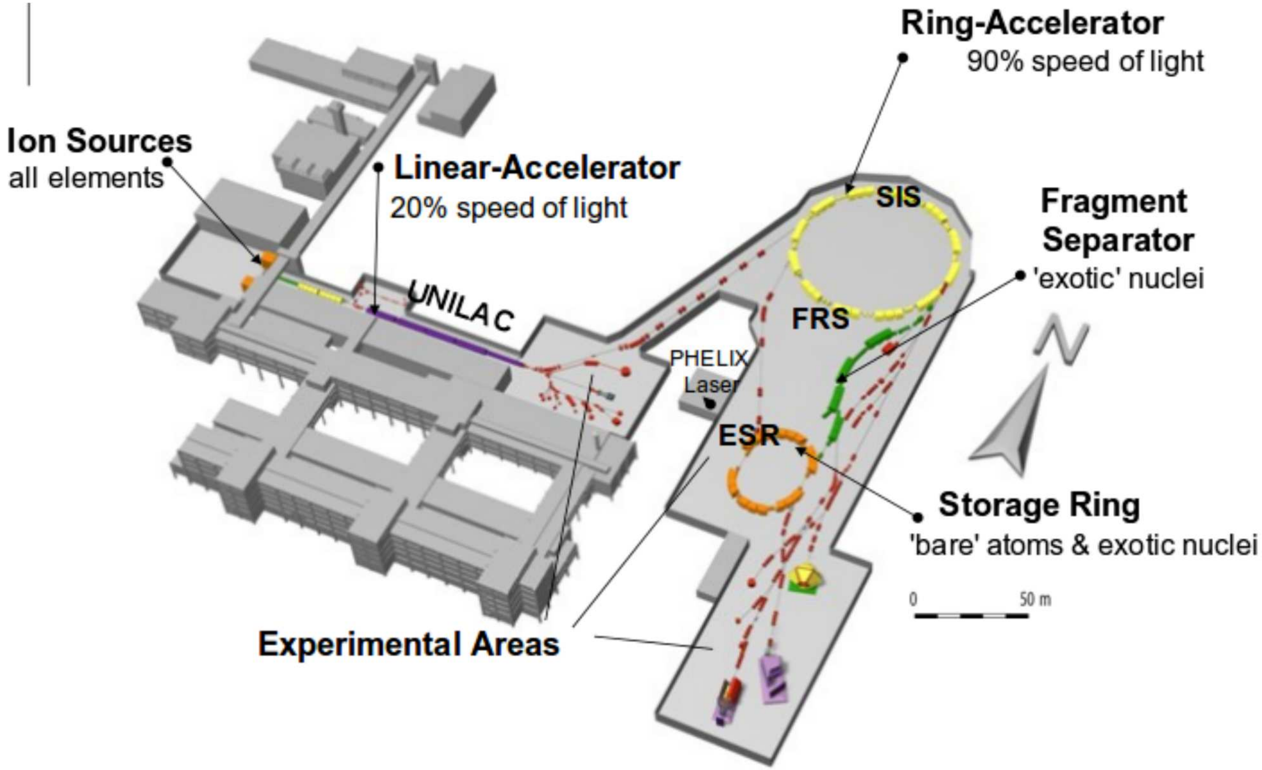
Reactions investigated at 1A GeV

- ✓ ^{124}Sn + targets of CH_2, C, Cu, Pb → ^{124}Sb
- ✓ ^{112}Sn + targets of CH_2, C, Cu, Pb → ^{112}Sb, ^{112}In

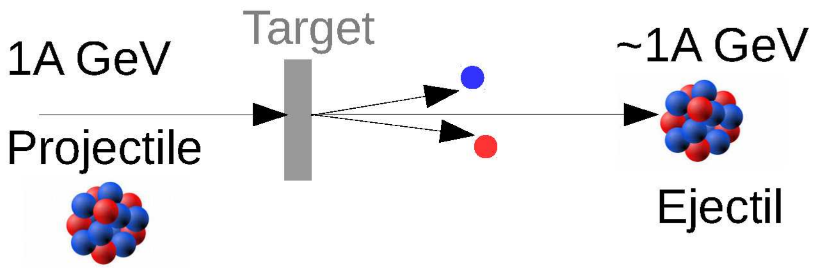
Proton target data obtained from CH_2 target by subtracting contributions of C target

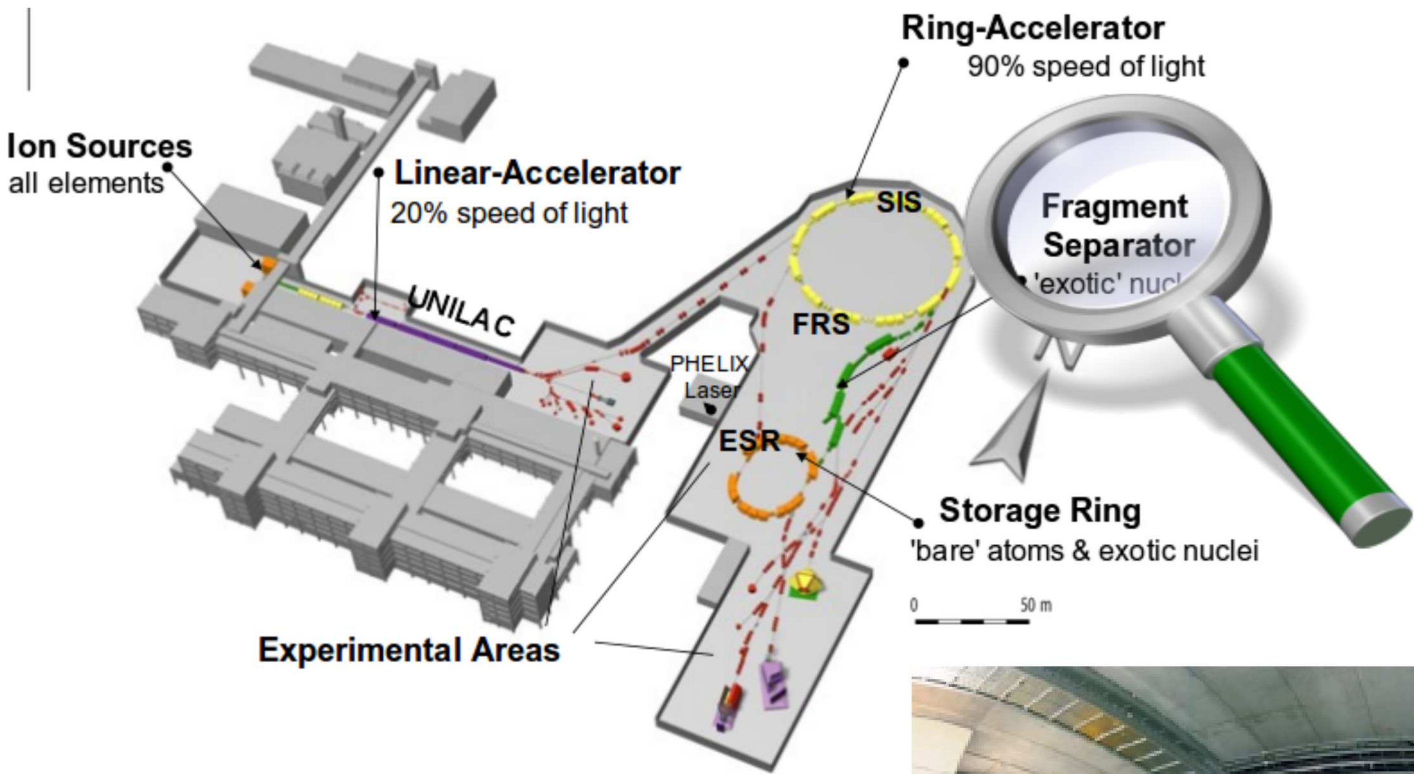
Observables

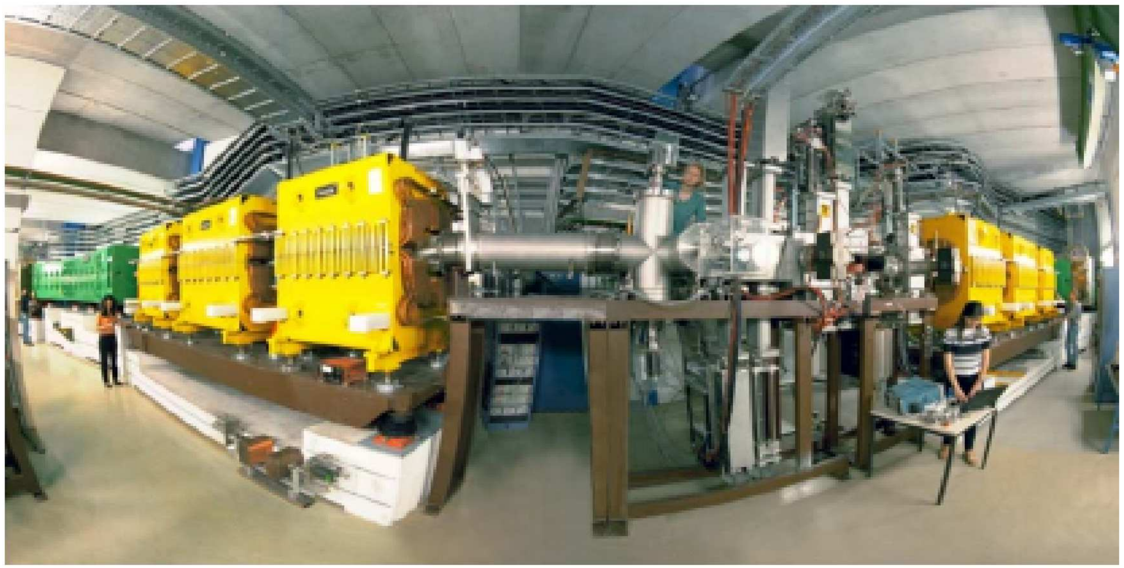
- ✓ Isobaric charge-exchange cross sections (isospin dependence)
- ✓ Missing-energy spectrum (properties of Δ resonance in nuclear medium)



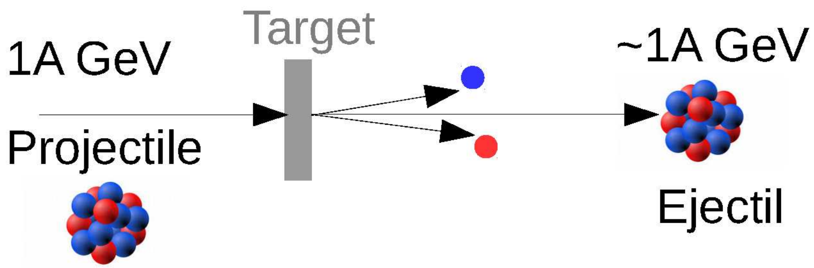
- Projectiles at high kinetic energies
- Inverse kinematics



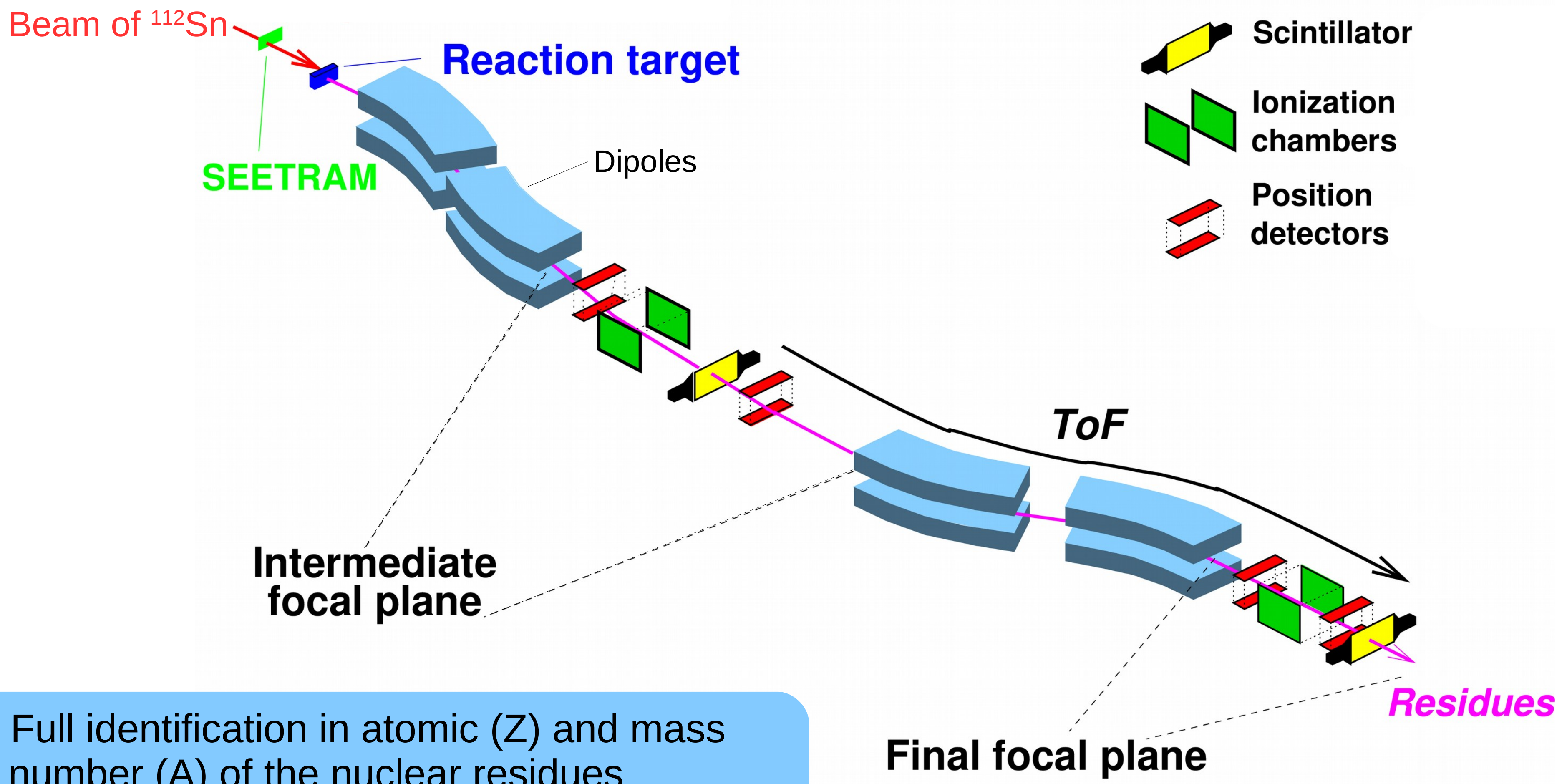




- Projectiles at high kinetic energies
- Inverse kinematics



High-resolution magnetic spectrometer



- Full identification in atomic (Z) and mass number (A) of the nuclear residues
- Momentum spectra

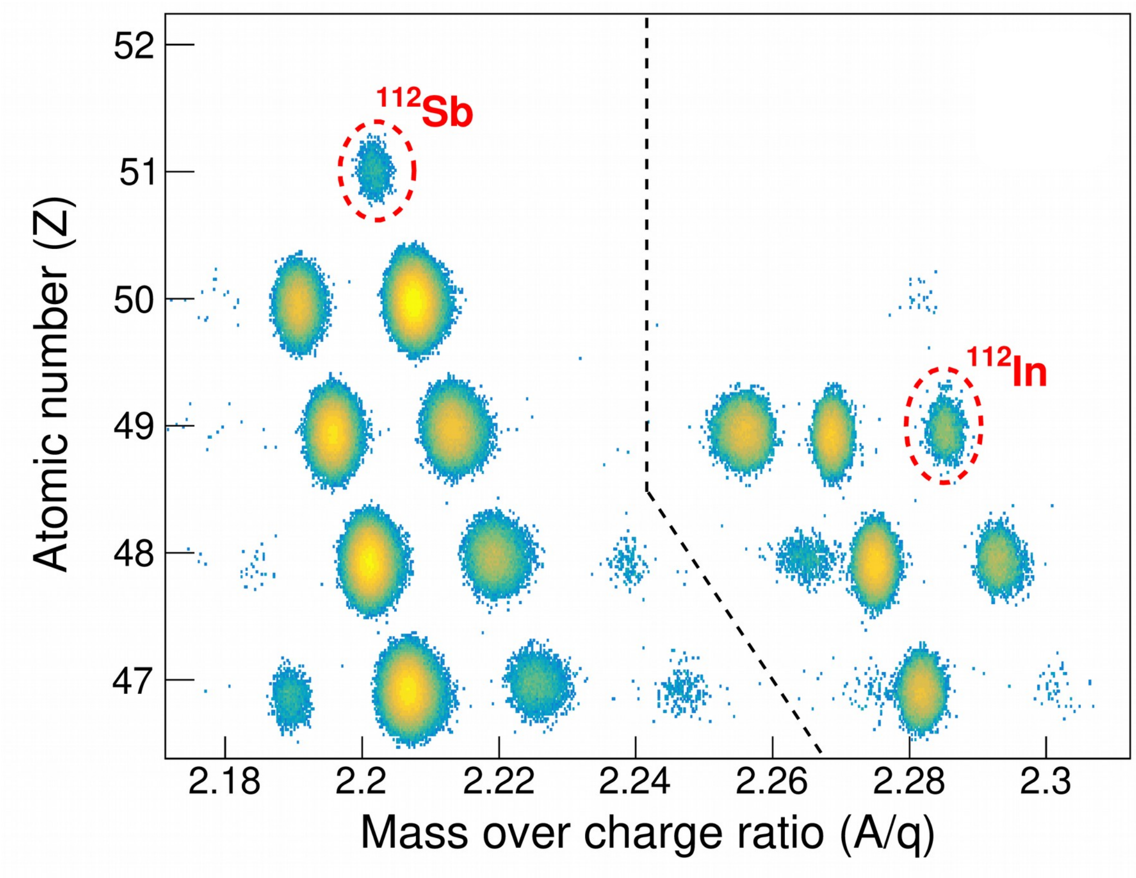
Energy loss measurements: $\Delta Z/Z \sim 0.5\%$

Magnetic rigidity and time of flight

$\Delta B\rho/B\rho < 0.1\%$ $\Delta A/A \sim 0.1\%$

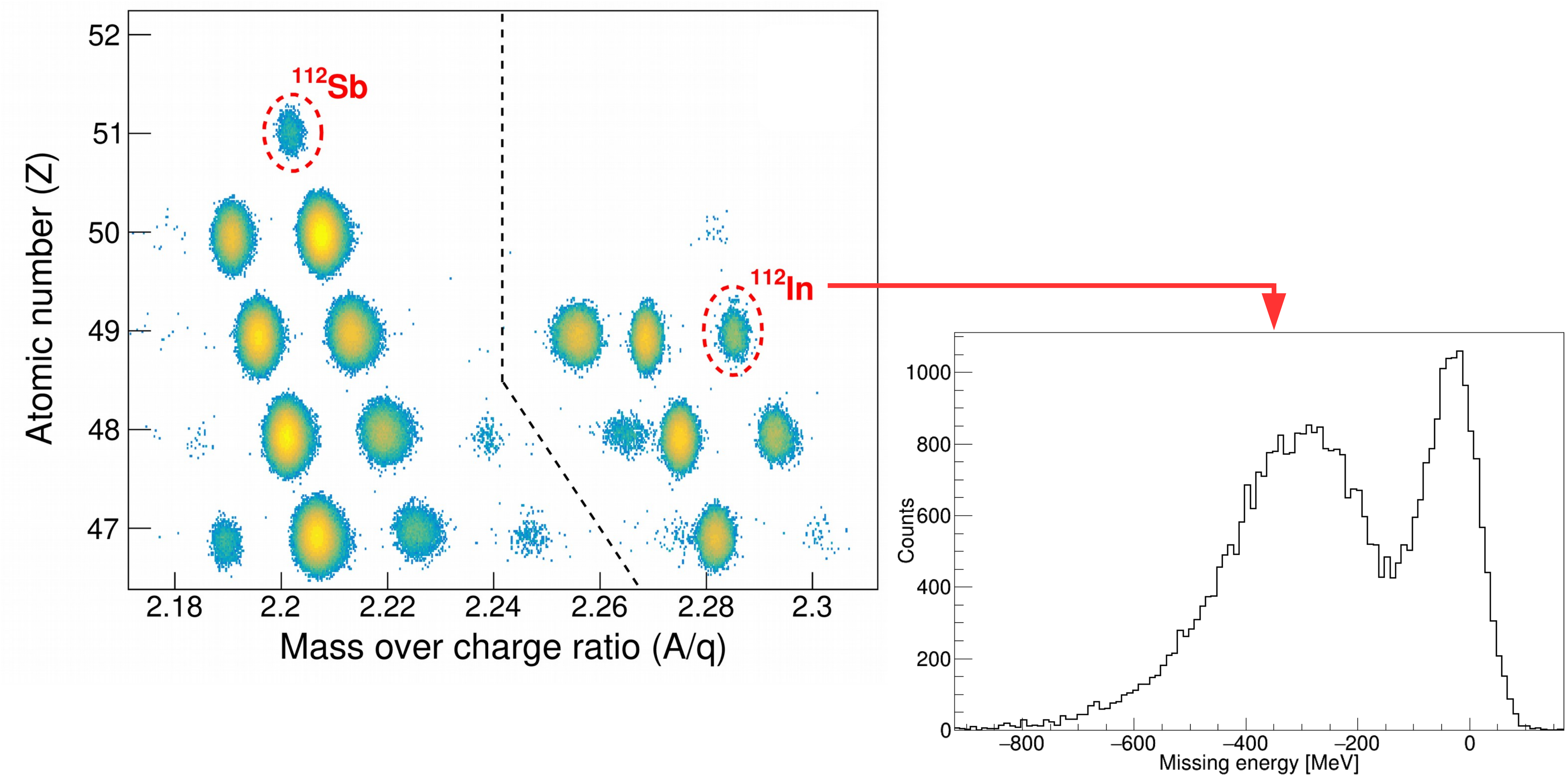
H. Geissel et al., NIMB 70, 286 (1992)

^{112}Sn (1A GeV) + ^{12}C (~100 mg/cm^2)



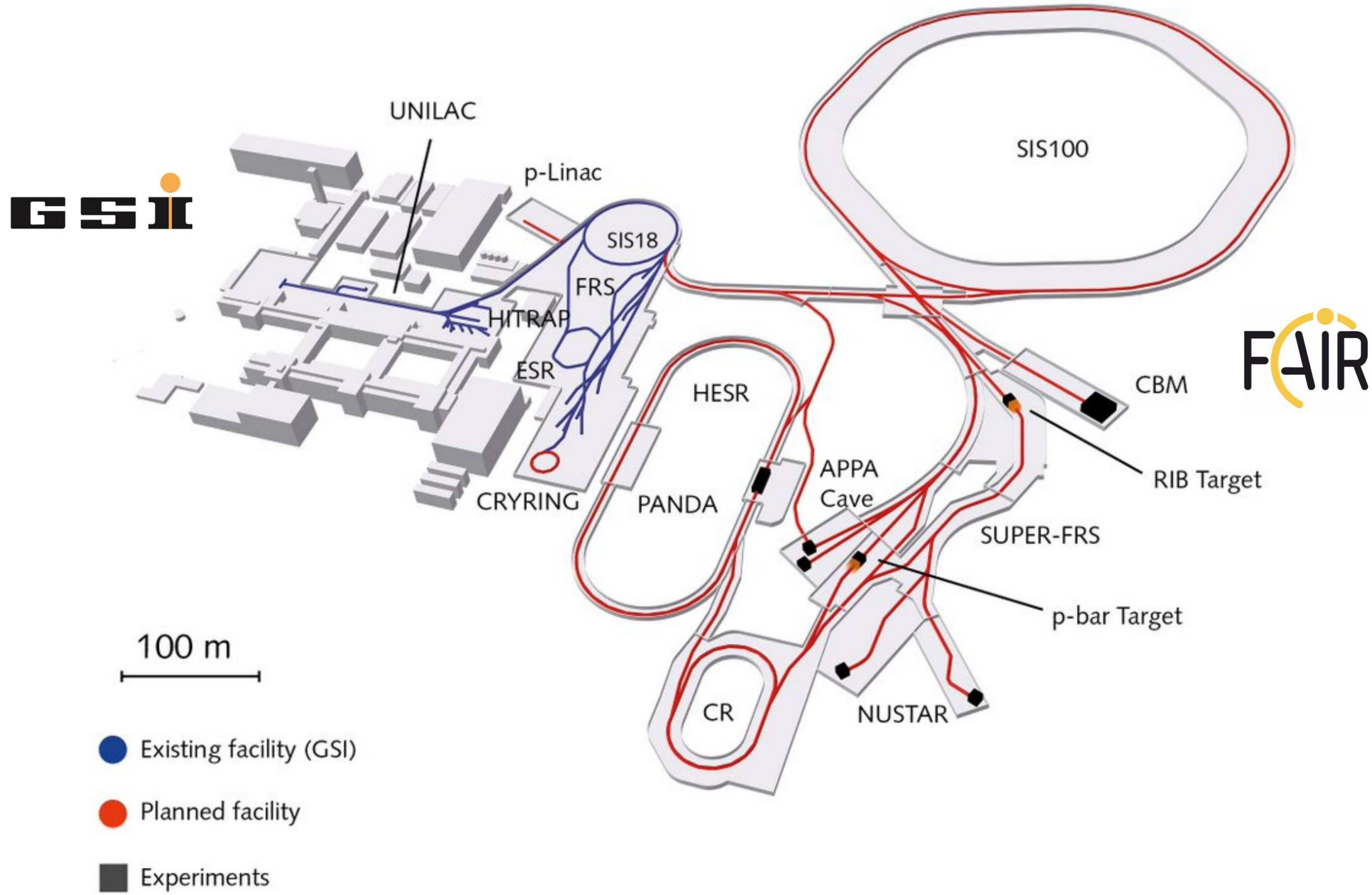
✗ Full identification in atomic and mass number of ^{112}Sb and ^{112}In nuclear residues

^{112}Sn (1A GeV) + ^{12}C (~100 mg/cm²)

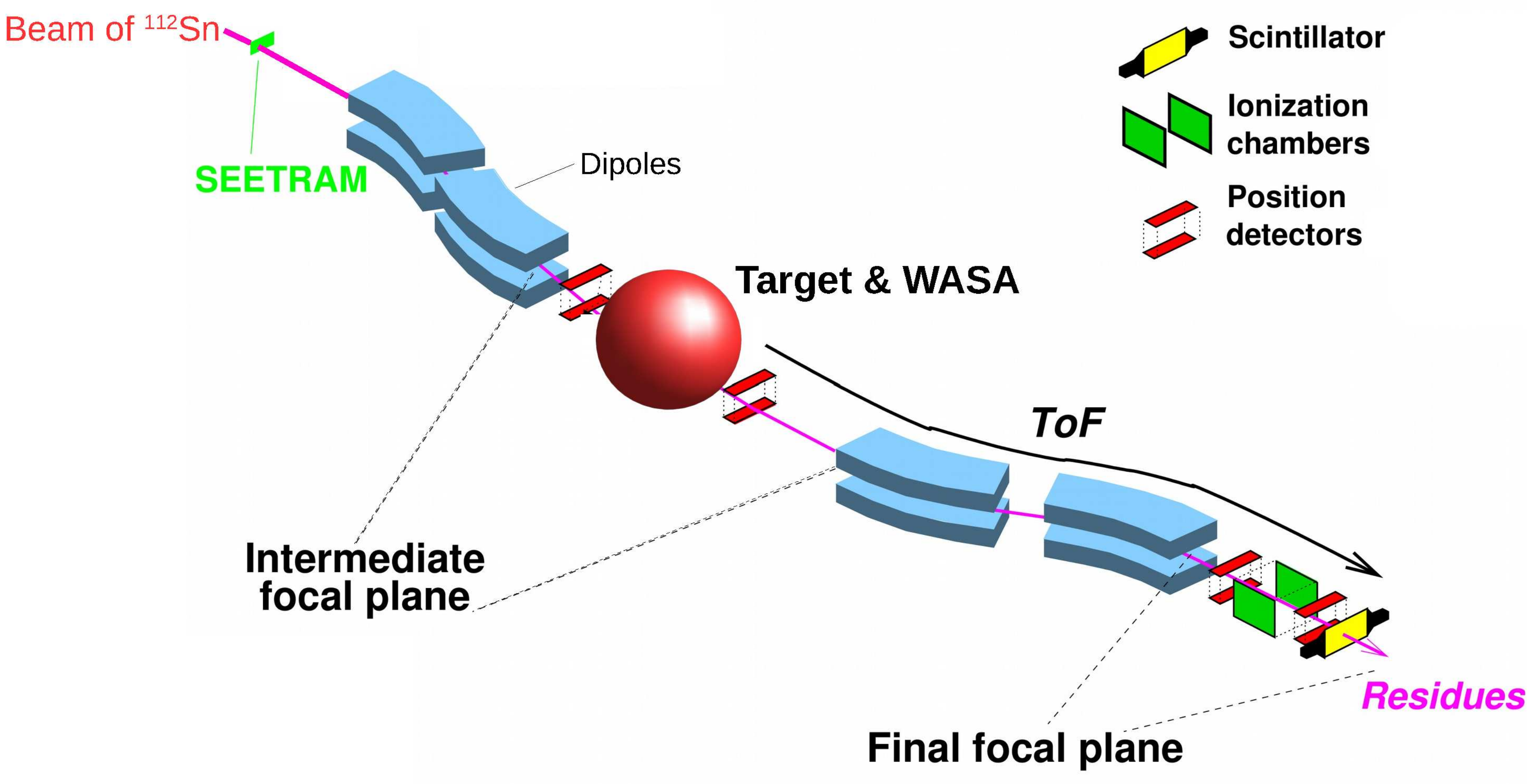


- ✗ Full identification in atomic and mass number of ^{112}Sb and ^{112}In nuclear residues
- ✗ Missing-energy spectra with a resolution of 10 MeV

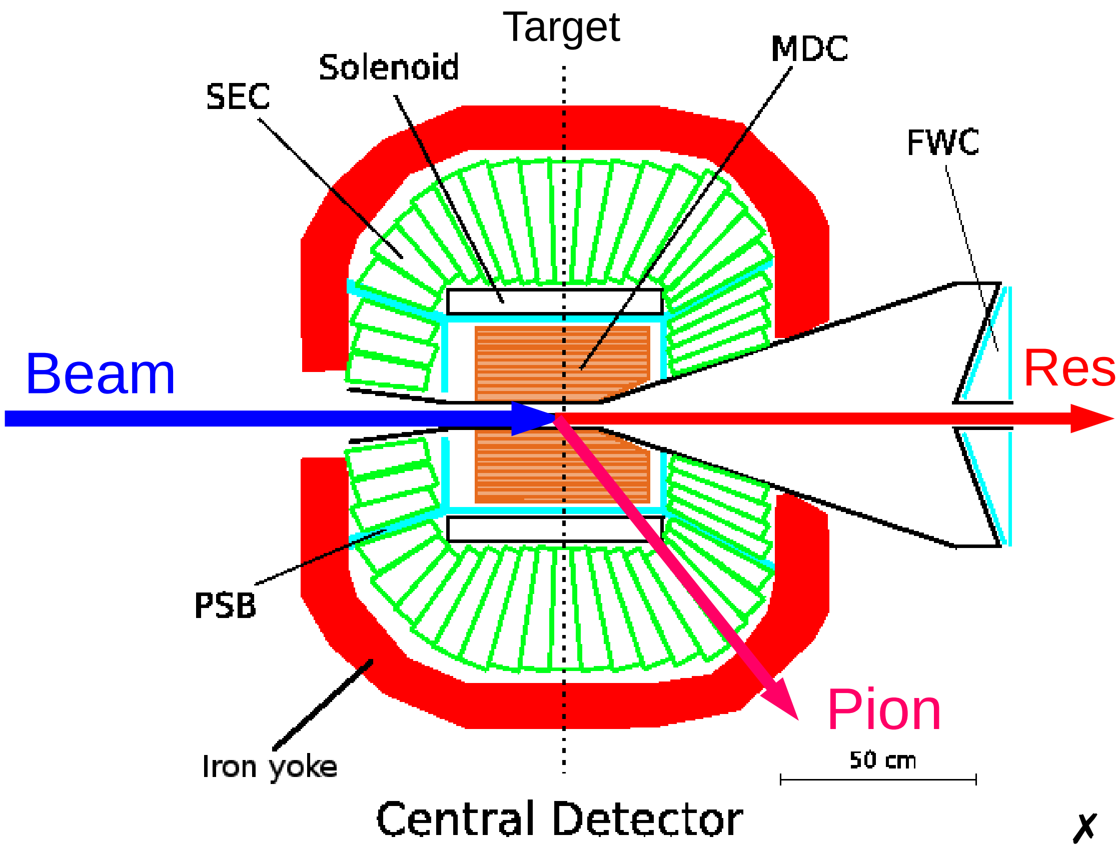
Facility for Antiproton and Ion Research (Germany)



- **Exclusive measurements** of the resonances measuring the pions in coincidence with the isobaric charge-exchange fragments
- The target and the detectors to measure the pions will be installed in the intermediate focal plane of the FRS

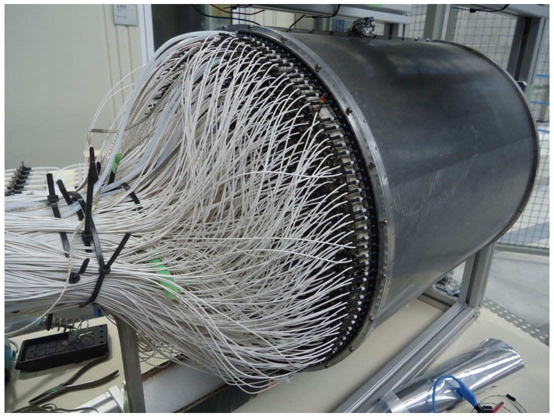


WASA (Wide Angle Shower Apparatus) detector will be used to measure the pions in coincidence with the isobaric charge-exchange fragments in 2021-2022



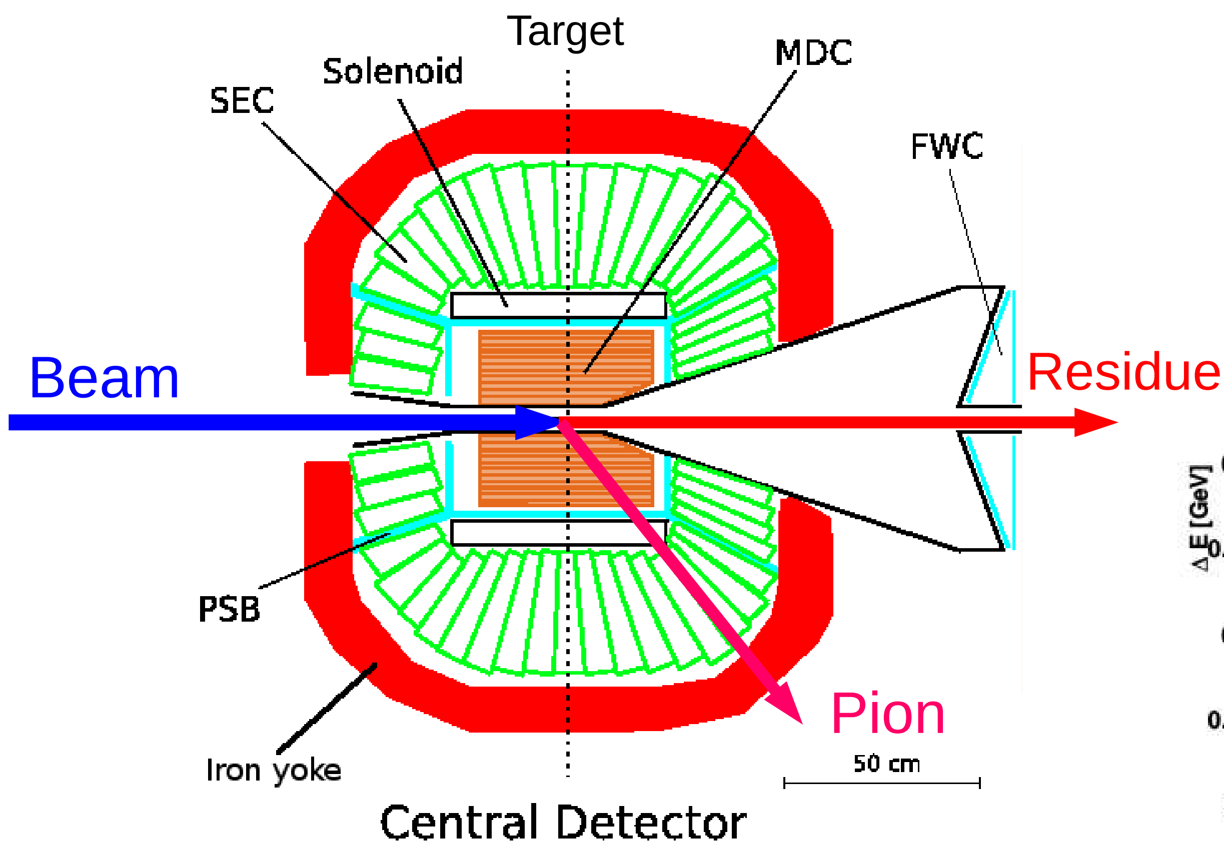
✗ Plastic scintillator barrel (PSB) and Mini drift chamber (MDC) covering polar angles from 18º to 170º
- Both detectors tested at GSI (2018)
- Time of flight resolutions of 100ps

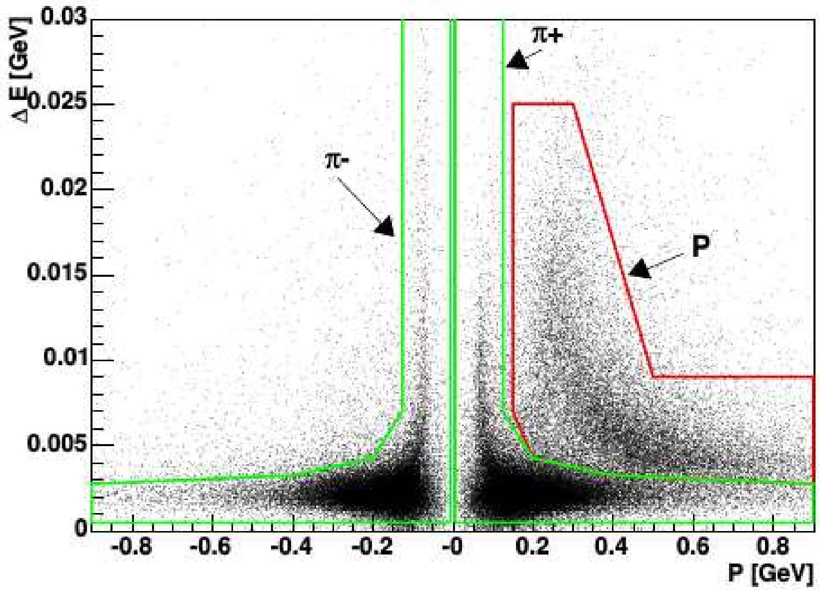
Mini drift chamber at GSI



✗ Solenoid with a magnetic field of 1.3 T
- Also installed at GSI to be tested between September and December 2019

WASA (Wide Angle Shower Apparatus) detector will be used to measure the pions in coincidence with the isobaric charge-exchange reactions in 2021-2022





- ✗ Expected energy resolution between 3 and 6 %
- ✗ Geometrical efficiency ~ 80%

Summary and outlook

Excitation of the Δ-resonance was investigated within isobaric charge-exchange reactions identified with the Fragment Separator FRS at GSI

- Full identification of the isobaric charge-exchange residues
- Missing-energy spectra obtained with a resolution of around 10 MeV

Total isobaric charge-exchange cross sections are sensitive to the abundance of neutrons and protons in the nuclear surface, we could extract information about the neutron skin thickness

Missing-energy spectra show

- Energy shift in the inelastic peak between proton target and the other ones
- Comparison with elementary process proves that the mass of the Δ-resonance changes with the nuclear density, but all the RMF models overestimate the observed variation

Exclusive measurements will be performed in 2021-2022 using the WASA detector

- Improving missing-energy resolution by optimizing the FRS dispersive mode
- Tagging of pions will allow to separate the quasi-elastic and inelastic components
- Invariant mass could be used to distinguish between projectile and target excitations
- Identification of other resonances, like Roper(1440), Δ(1600) ...

Collaborators

H. Alvarez-Pol, Y. Ayyad, S. Beceiro, J. Benlliure, M. Caamaño, D. Cortina-Gil, P. Díaz-Fernández, C. Paradela, D. Perez-Loureiro, J. Vargas

T. Aumann, J. Atkinson, K.H. Behr, K. Boretzky, A. Estrade, H. Geissel, E. Haettner, A. Kelic-Heil, Y. Litvinov, S. Pietri, A. Prochazka, T.R. Saito, C. Scheidenberger, M. Takechi, Y. Tanaka, H. Weick, J. Winfield

I. Vidaña

E. Casarejos

H. Lenske

S. Schadmand, V. Serdyuk

Thank you for your attention!