The Super-FRS and its Combination with High-Resolution Spectrometers

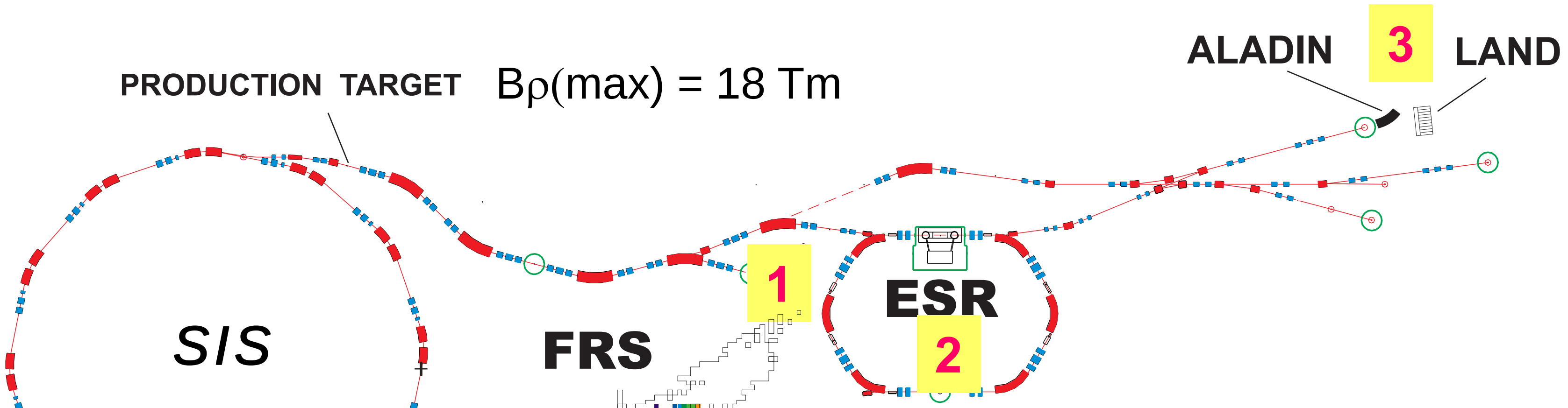
Hans Geissel

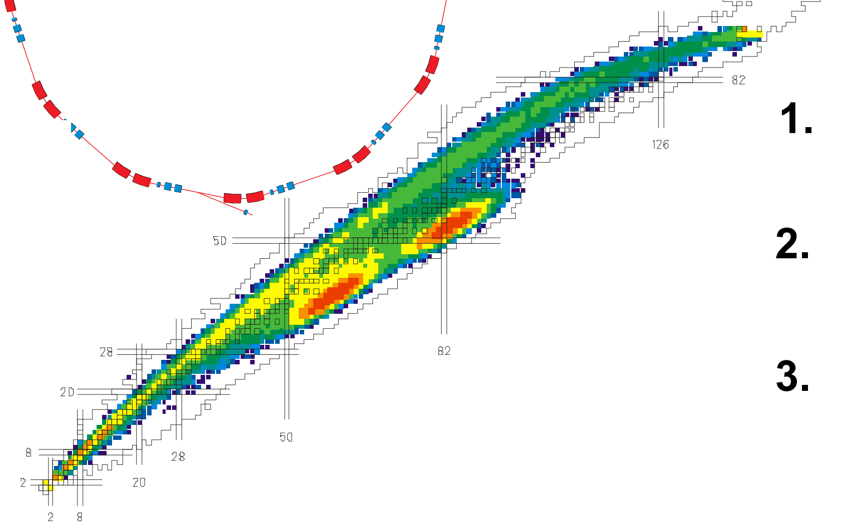
EMIS 2012

- **From FRS to Super-FRS**
- **Technical Status of Super-FRS**
- **Spectrometer Modes with the Super-FRS**
  (Focus on Low-Energy Branch)
- **Scientific Goals directly at the Super-FRS**

Secondary Nuclear Beam Facility

FRS: In-flight Separator & High-Resolution Spectrometer

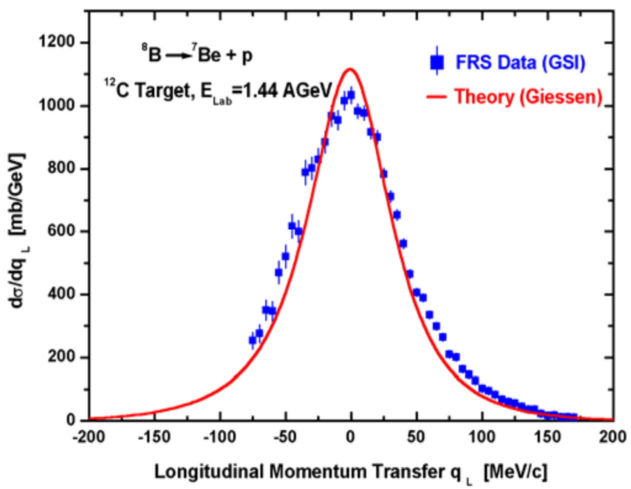




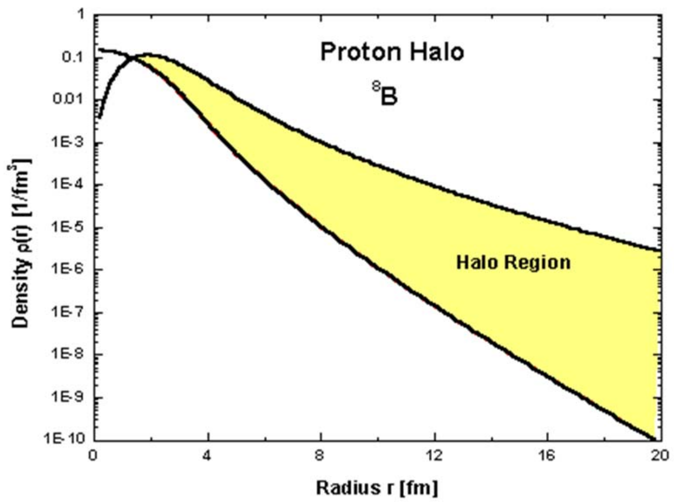
1. **Decay Spectroscopy,**
   High-resolution momentum measurements
2. **Masses, Lifetimes, Direct Reactions,**
   Isomeric Beams
3. **Reactions Studies (Complete Kinematics)**

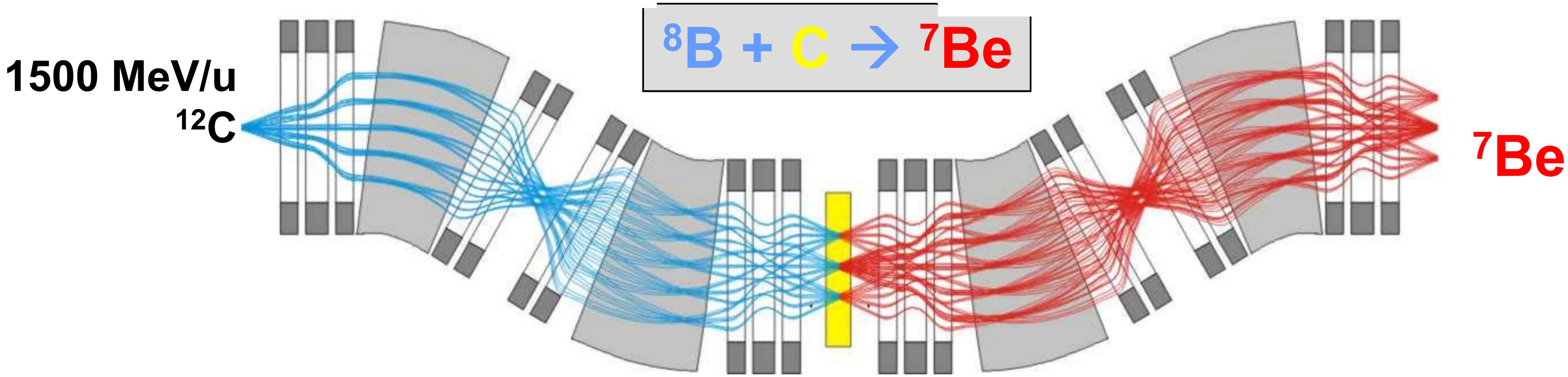
Nuclear Structure via Precise Momentum Measurements at Relativistic Energies

Discovery of the p-Halo in ^{8}B



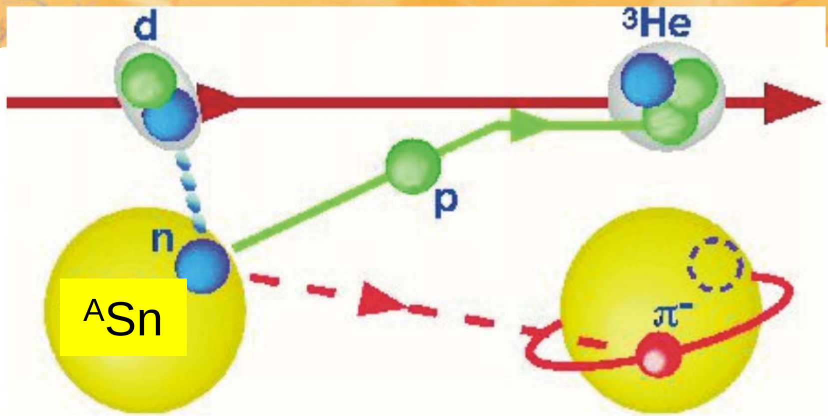
W. Schwab et al.
Z. Phys. A350, 283

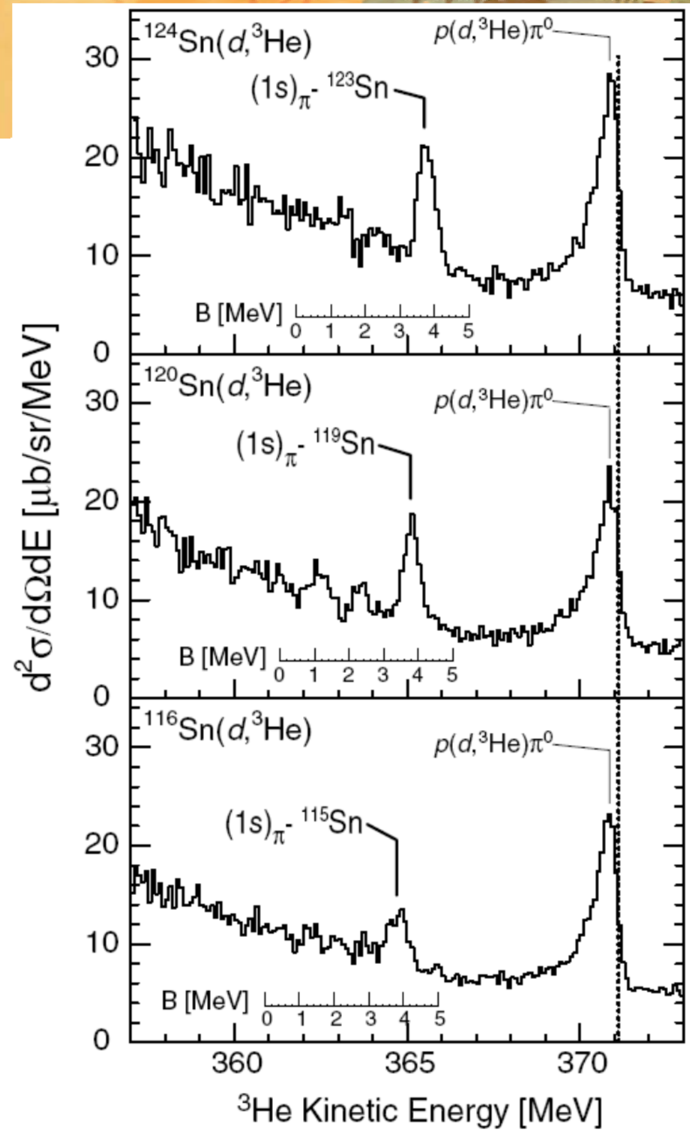




Hans Geissel, EMIS 2012

Discovery of deeply-bound pionic states





- Pion-nucleus interaction
  → binding energy, width, mass shift
- Partial chiral restoration in nuclear medium
  → well-defined quantum states
  → normal nuclear density

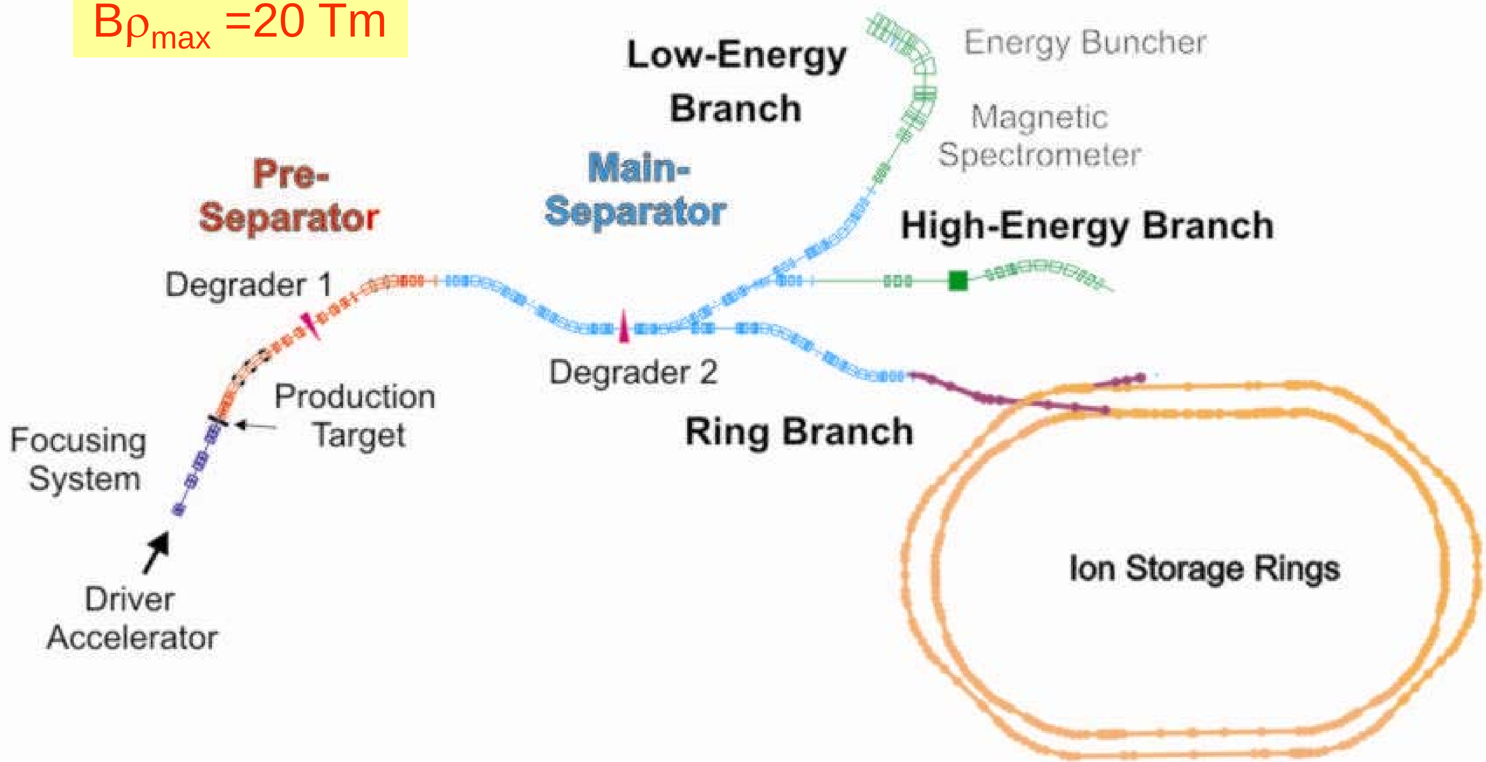
see Talk T. Nishi

H. Geissel et al., Phys. Rev. Lett. 88 (2002) 122301
K. Suzuki et al., Phys. Rev. Lett. 92 (2004) 072302

R. Hayano, K. Itahashi, T. Yamazaki

The NUSTAR Facility at FAIR
(The 3 Branches of the Super-FRS)

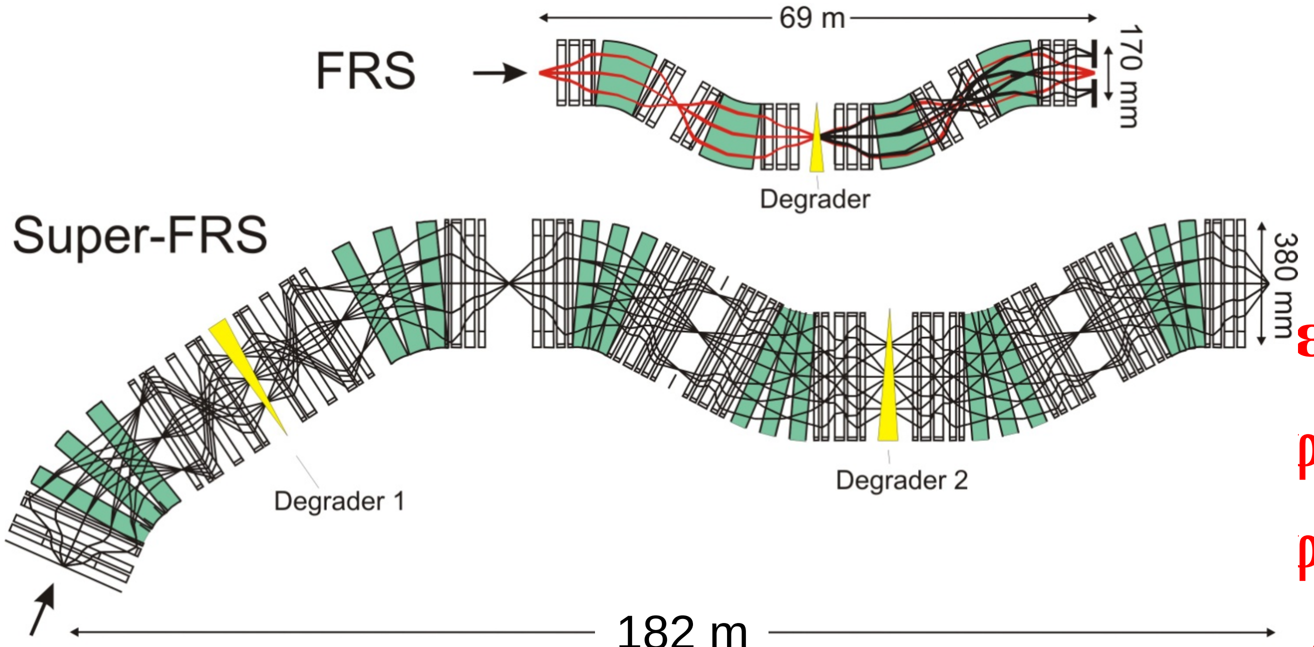
$B\rho_{max}$ =20 Tm



Powerful Separator with multiple degrader stages

High-resolution magnetic spectrometer

Comparison of FRS with Super-FRS



$\varepsilon_x = 20\,\pi\,\mathrm{mm\ mr}$

$\frac{\Delta p}{p} = \pm 1\,\%$

$B\rho_{max} = 18\ \mathrm{Tm}$

$R_{ion} = 1500$

$\varepsilon_x = \varepsilon_y = 40\,\pi\,\mathrm{mm\ mr}$

$\rho_x = \pm 40\ \mathrm{mr},$

$\rho_y = \pm 20\ \mathrm{mr}$

$\frac{\Delta p}{p} = \pm 2.5\,\%$

$B\rho_{max} = 20\ \mathrm{Tm}$

$R_{ion} = 1500$

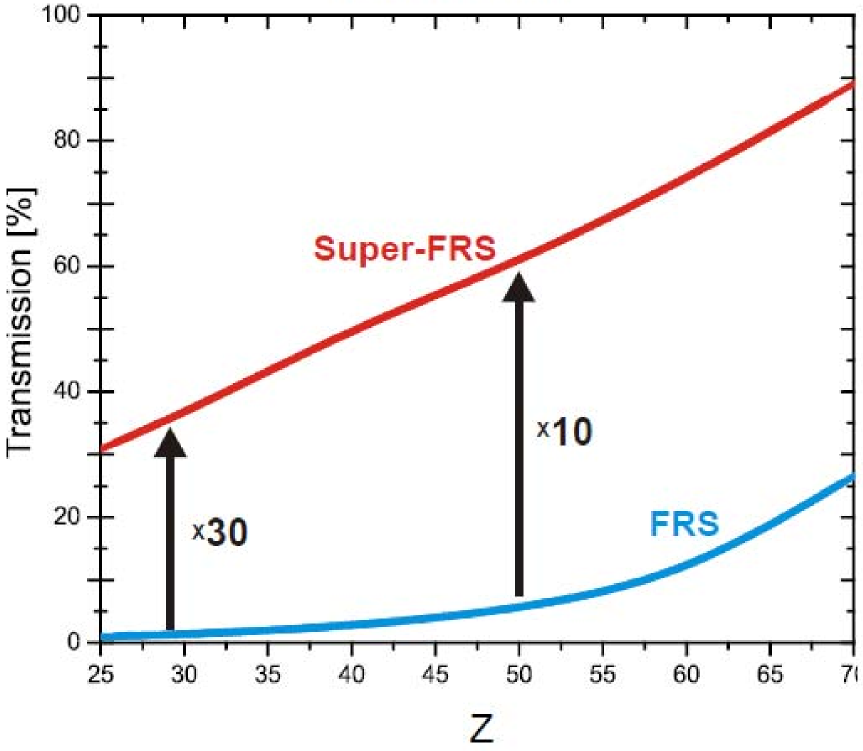
Separation with two degrader stages

s. Poster M. Winkler

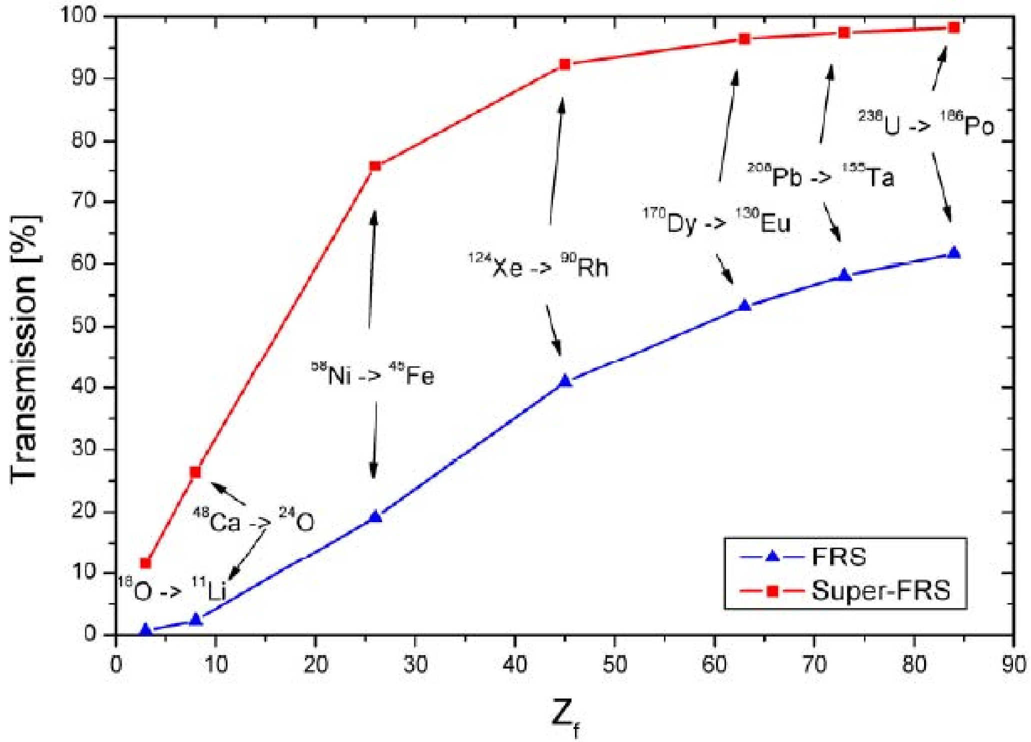
Gain in Transmission for Fission Products and Projectile Fragments

More than one order of magnitude gain

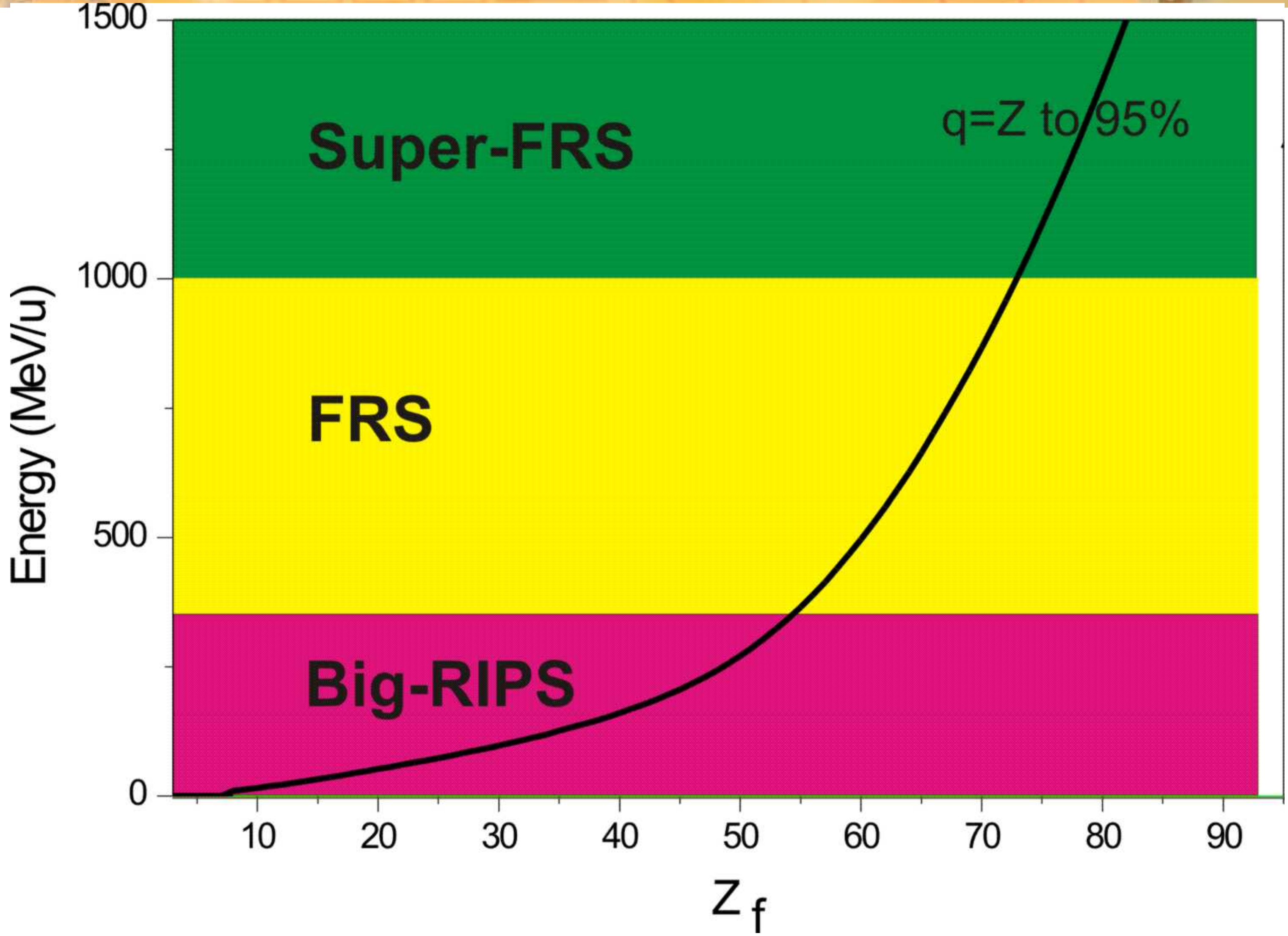
Fission



Fragmentation



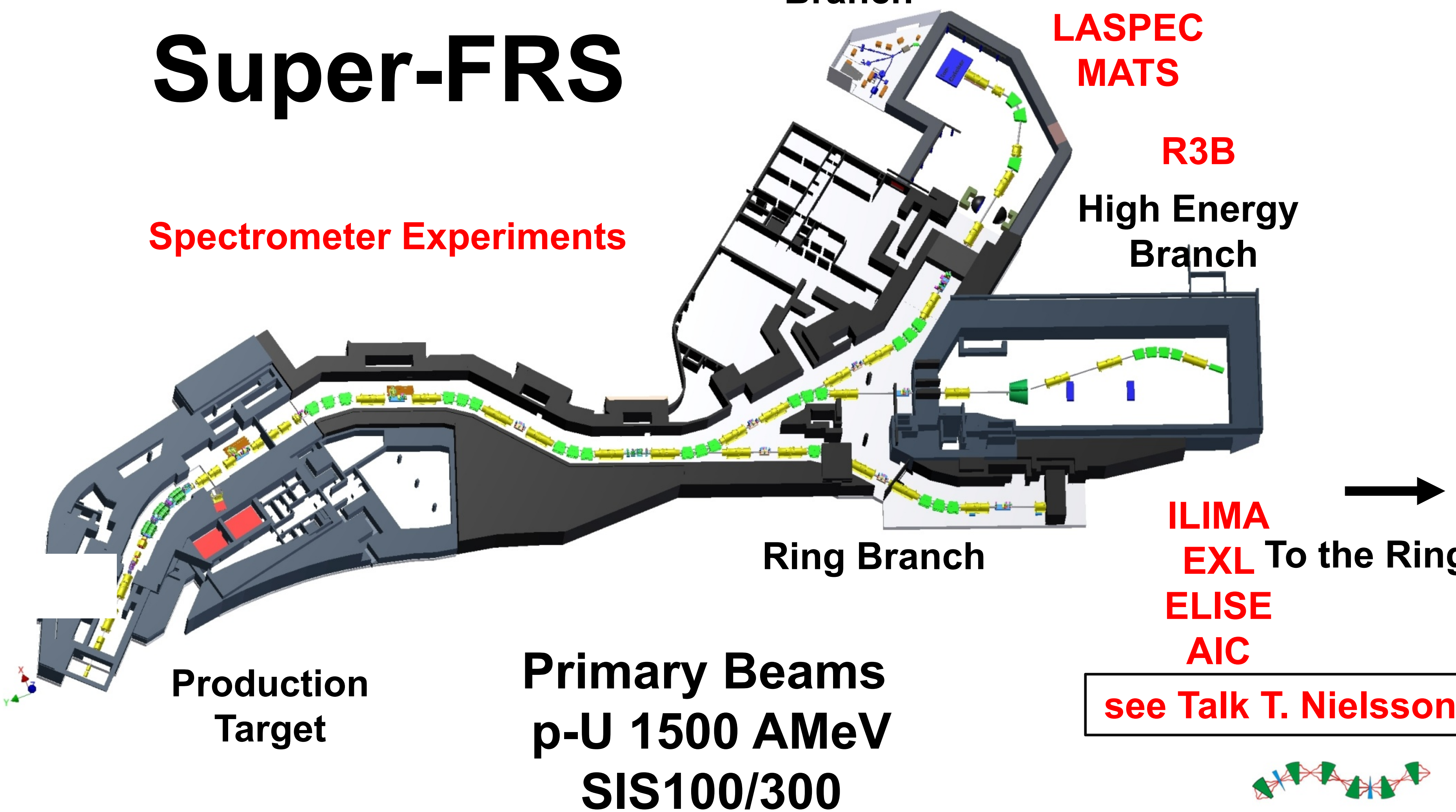
Maximum Energies for 95% complete Ionization



Hans Geissel, EMIS 2012

GSI and FAIR

The NUSTAR Facility and its Experiments



Primary Beams
p-U 1500 AMeV
SIS100/300

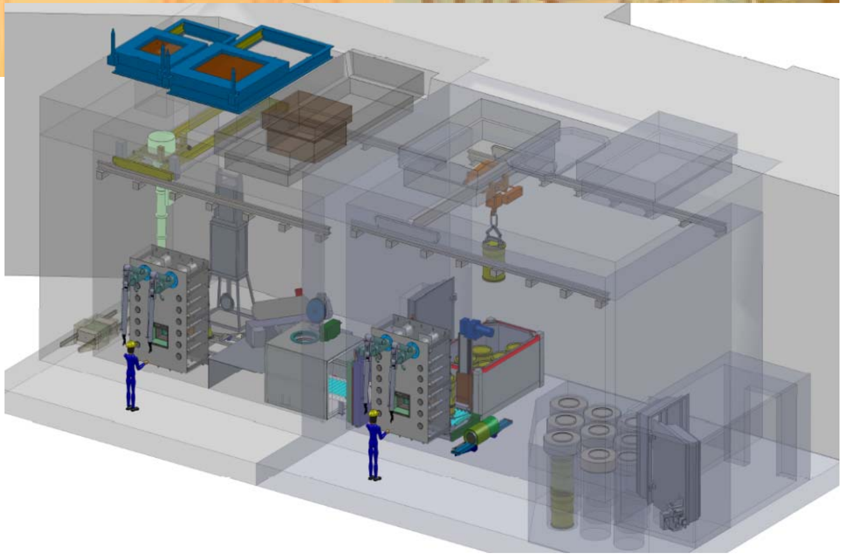
see Talk T. Nielsson

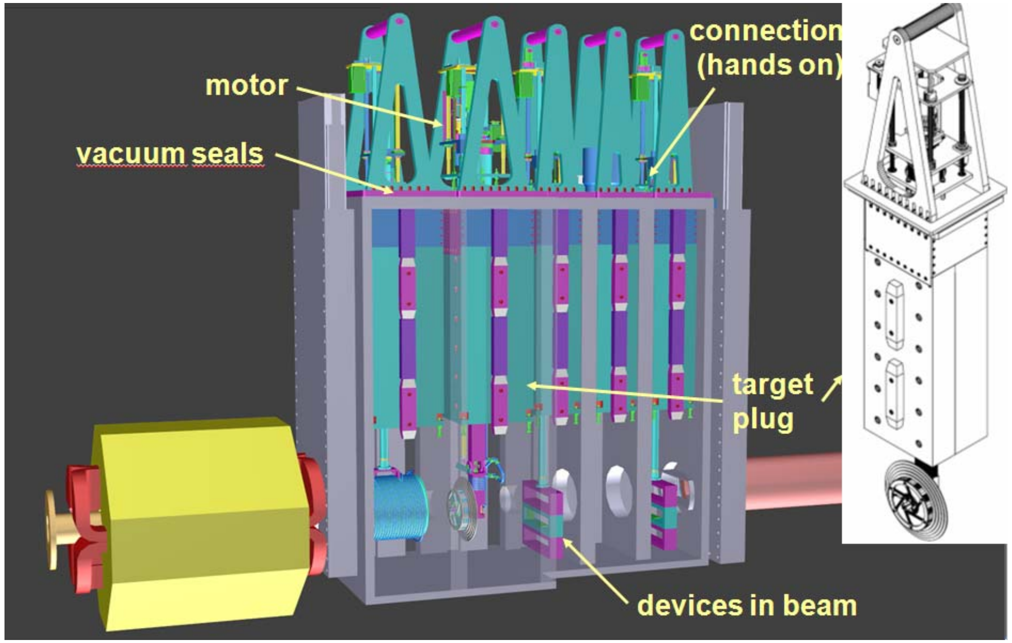
see Poster M. Winkler

Special Installation

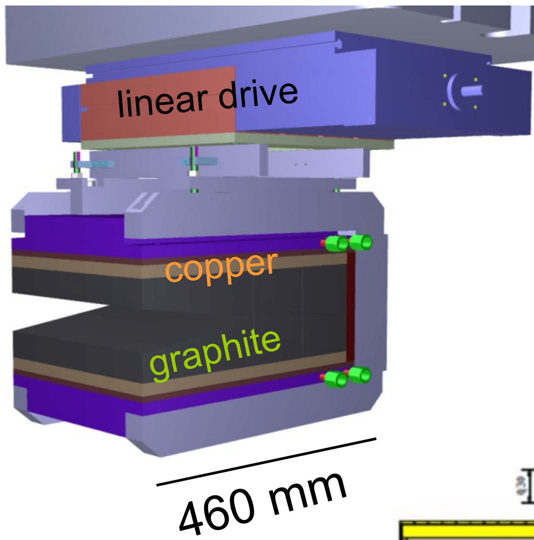
H. Weick
Ch. Karagiannis et al.

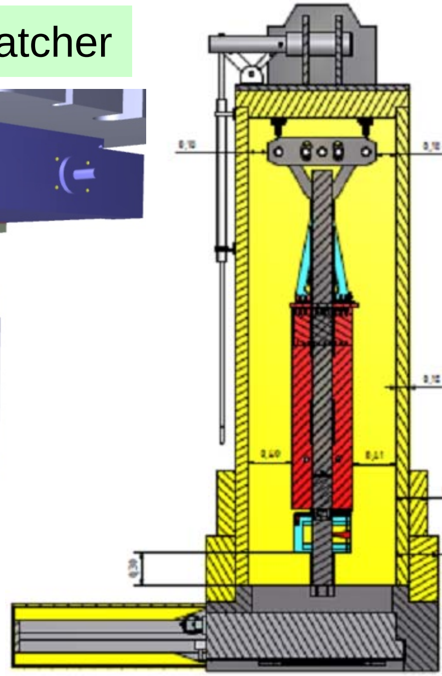
- **Target wheel** including target chamber, collimator,
- **Hot cell**, transport flask, and remote handling
- **Beam catcher**
- **Energy degrader**





movable beam catcher



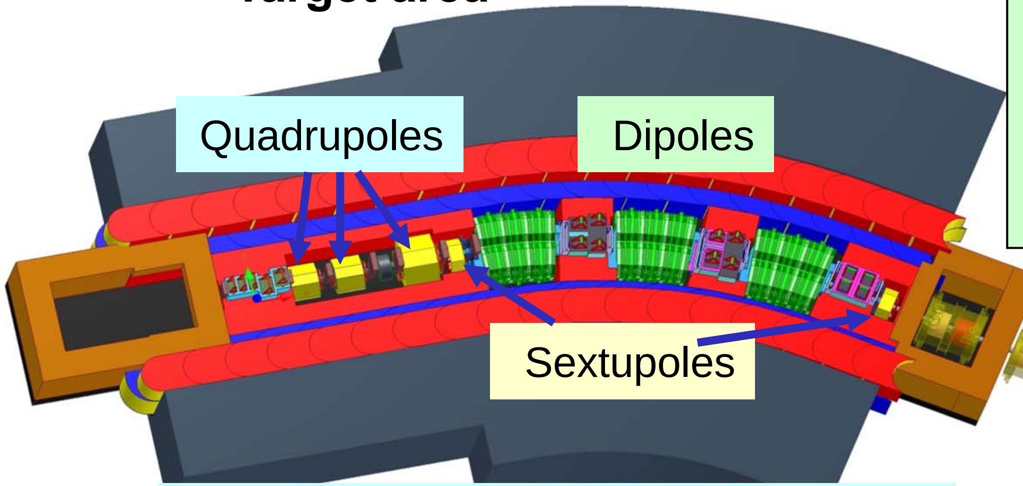


Radiation Resistant Magnets

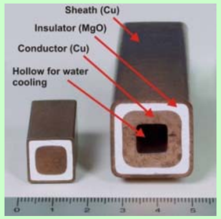
C. Mühle
C. Will
P. Vobly et al.

- 3 dipole, 3 quadrupole, and 2 sextupole magnets are required
  Normal conducting magnets using mineral insulated cable (MIC)
- Prototype dipole magnet built and tested by BINP (Russia)

Target area



MIC cable

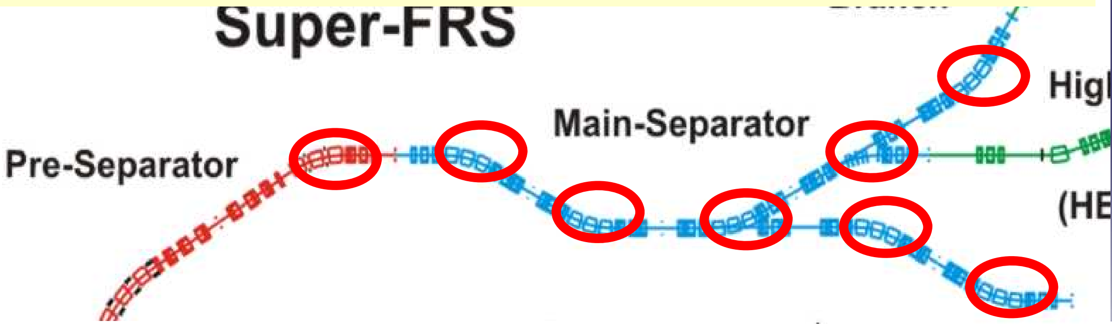


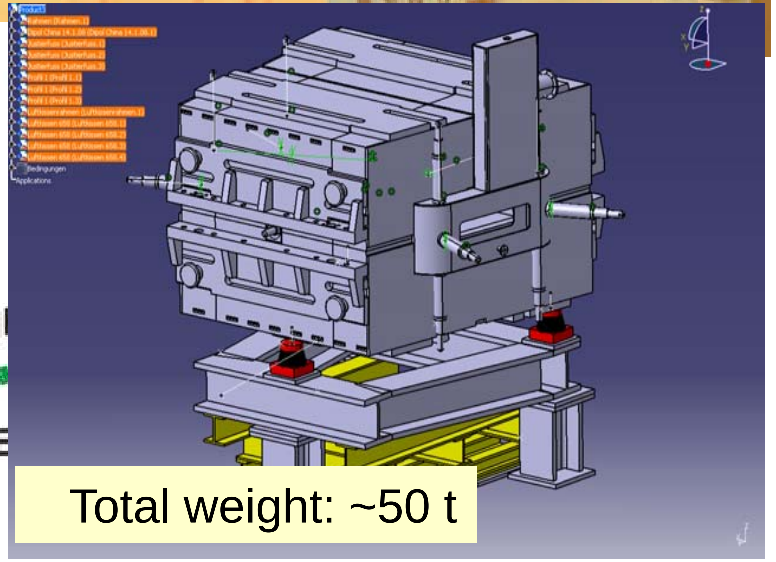
GOAL: No replacement due to radiation

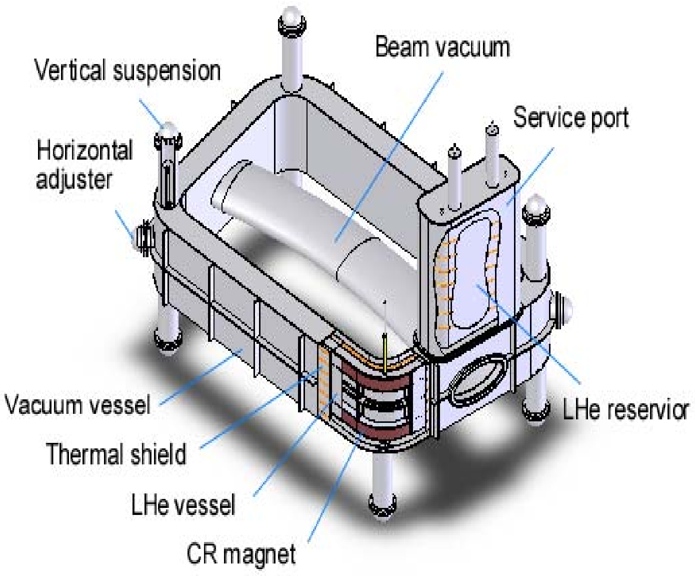
Superferric Dipole Magnets

H. Leibrock et al.
FAIR China Group

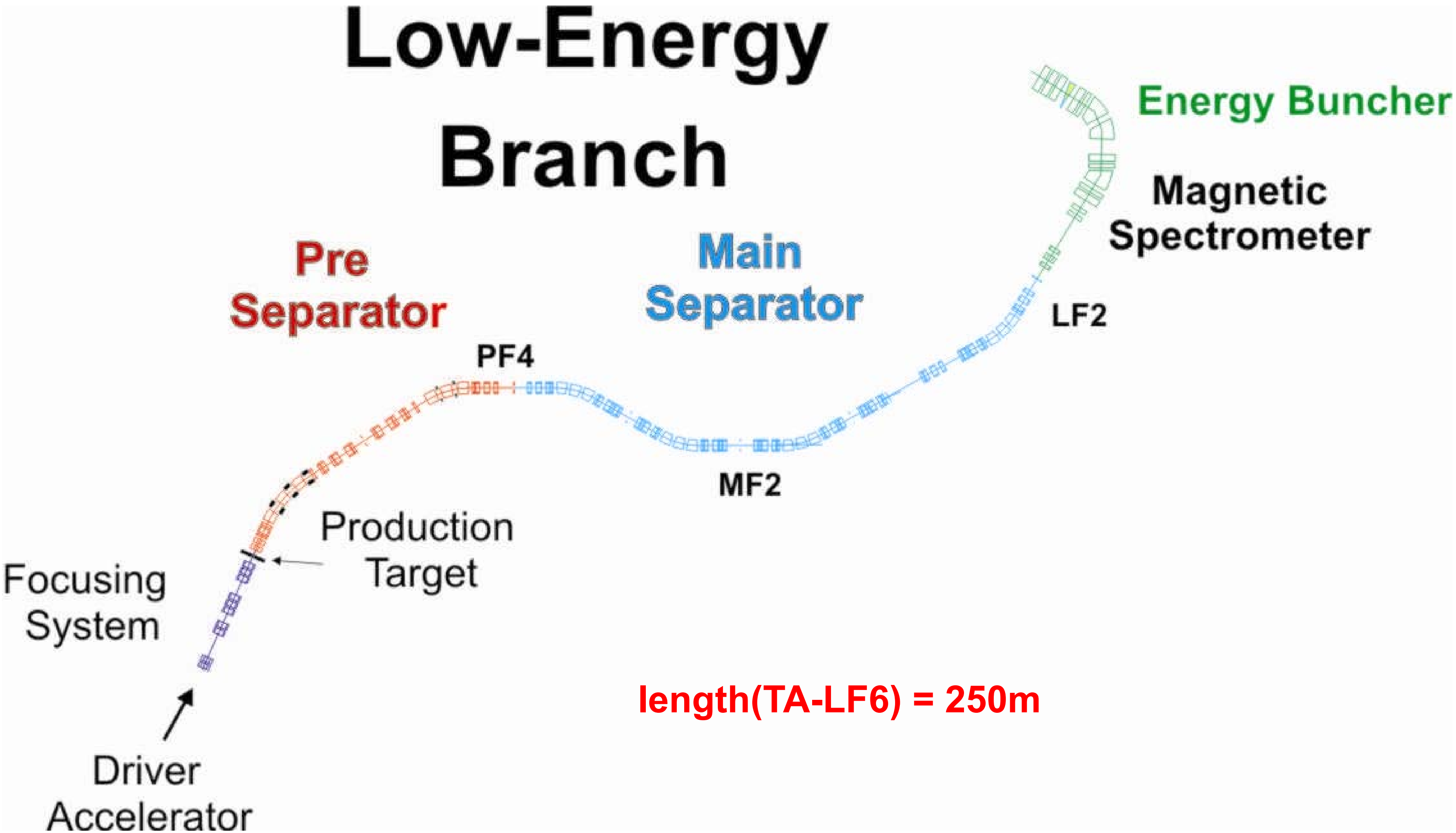
- 24 dipole magnets are required
  Iron dominated, warm iron, SC coil
- Large aperture ±190mm x ±70mm; 50 ton
- Prototype built and tested by FAIR China Group







LEB of Super-FRS

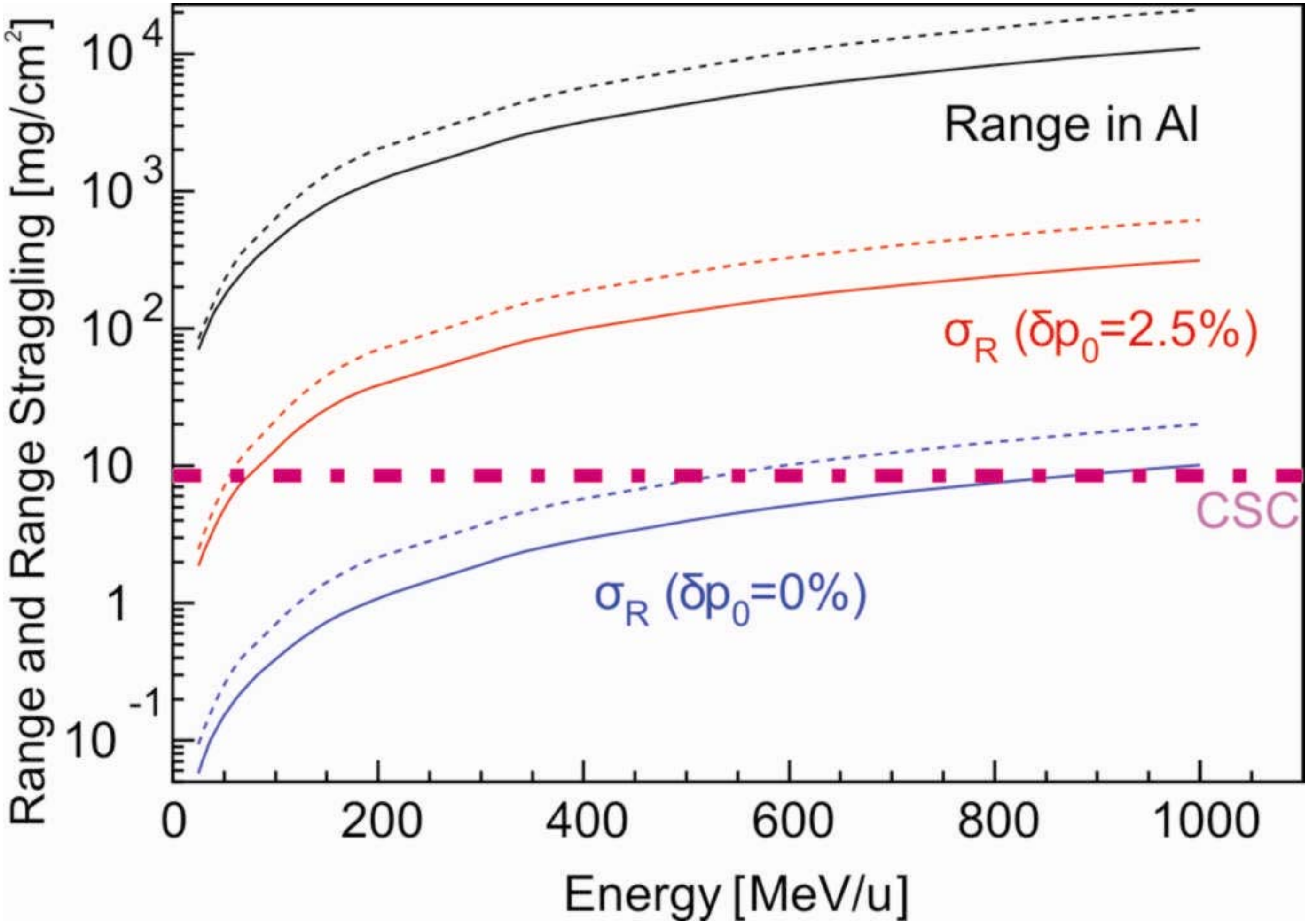


length(TA-LF6) = 250m

Investigation of the Layout of the E-Buncher

J. Winfield, HG

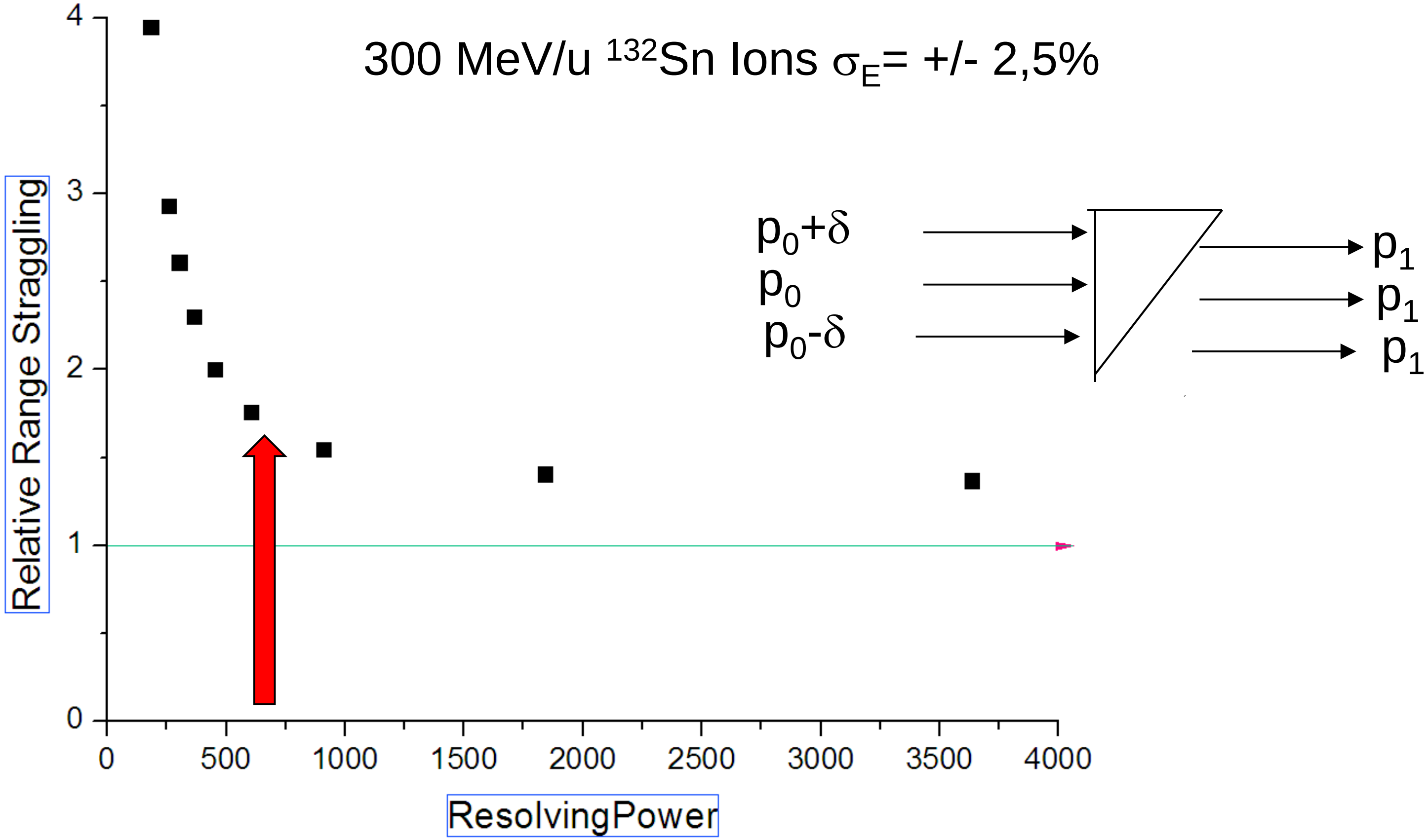
U, Xe Fragments in Al



Investigation of the Layout of the E-Buncher

H.G., J. Winfield

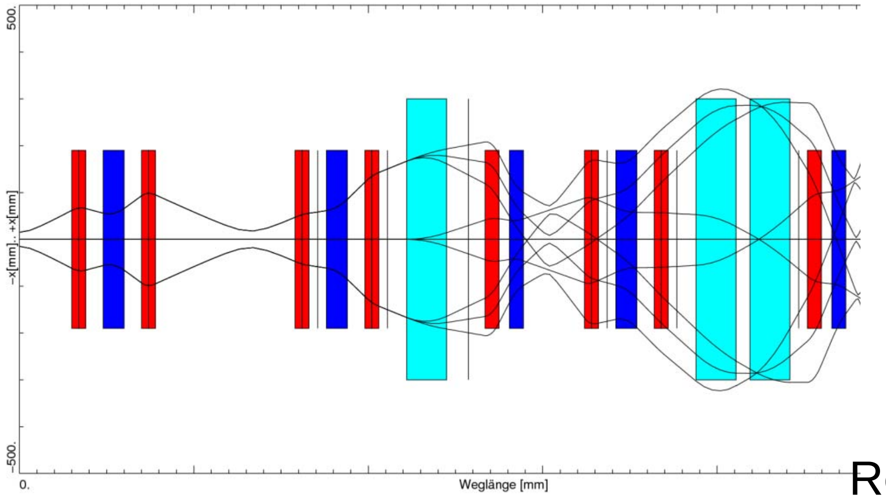
Role of the Ion-optical Resolving Power



Investigation of the Layout of the E-Buncher

Under Investigation

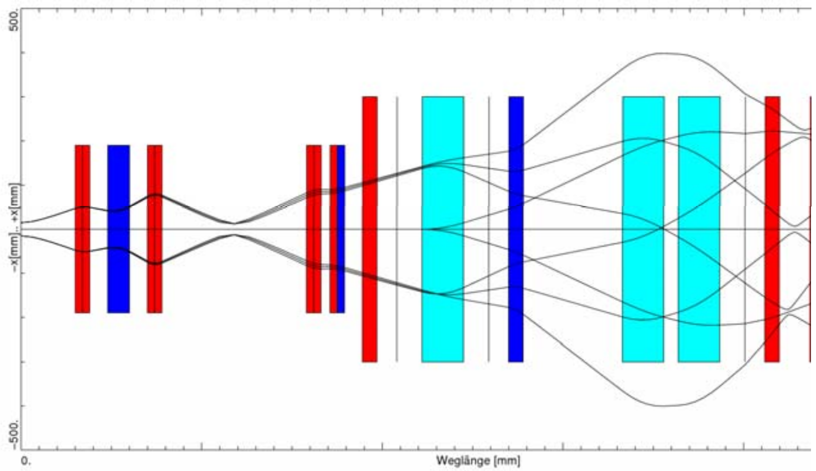
ca. 20-30% Transmissions-verminderung



S--EB

Dispersion = 4 cm/%

Resolving Power = 600
ε_x= 300 π mm mr
ε_y= 300 π mm mr



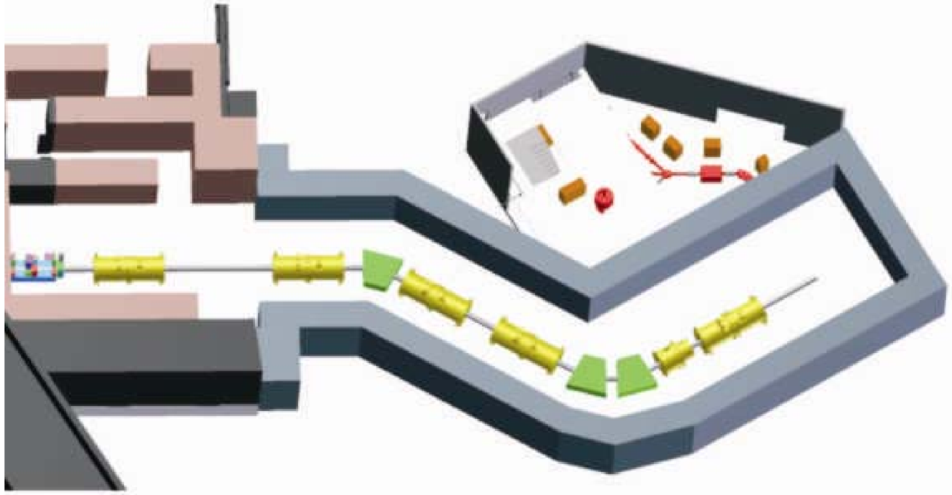
Dispersion = 8 cm/%

C--EB

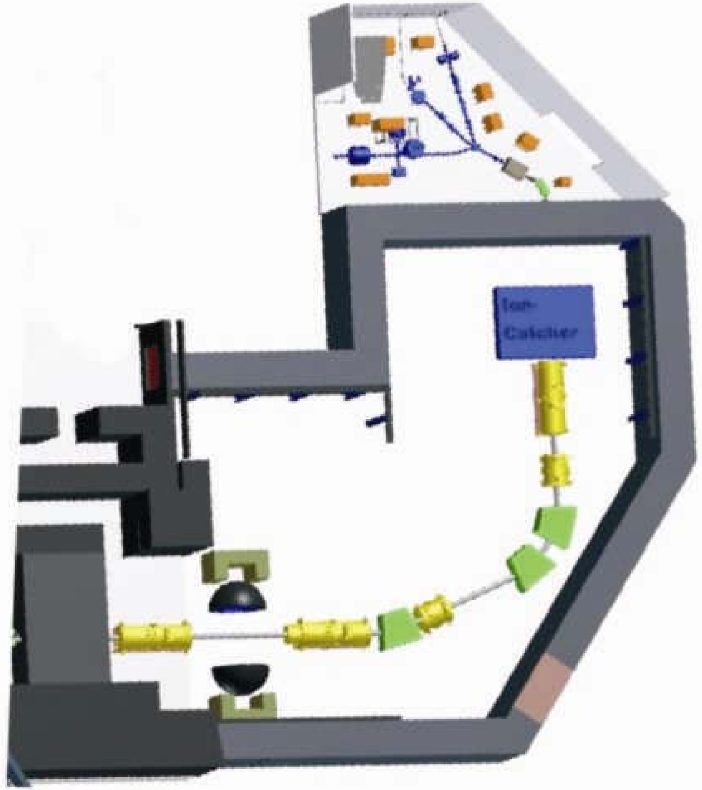
Previous Standard Version

Hans Geissel, EMIS . 2012

Investigation of the Layout of the E-Buncher



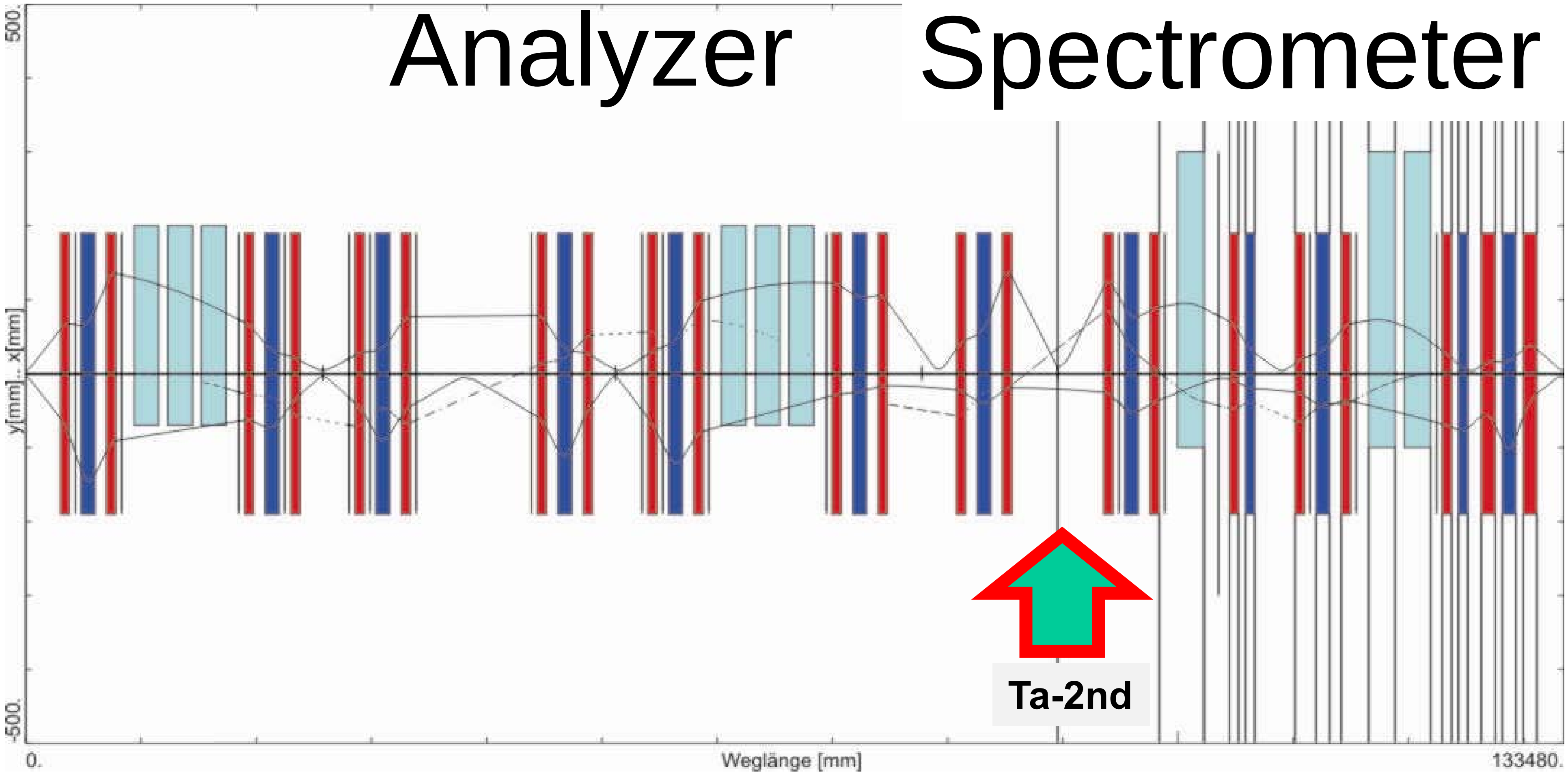
S-Energy Buncher



C-Energy Buncher

E-Loss Spectrometer

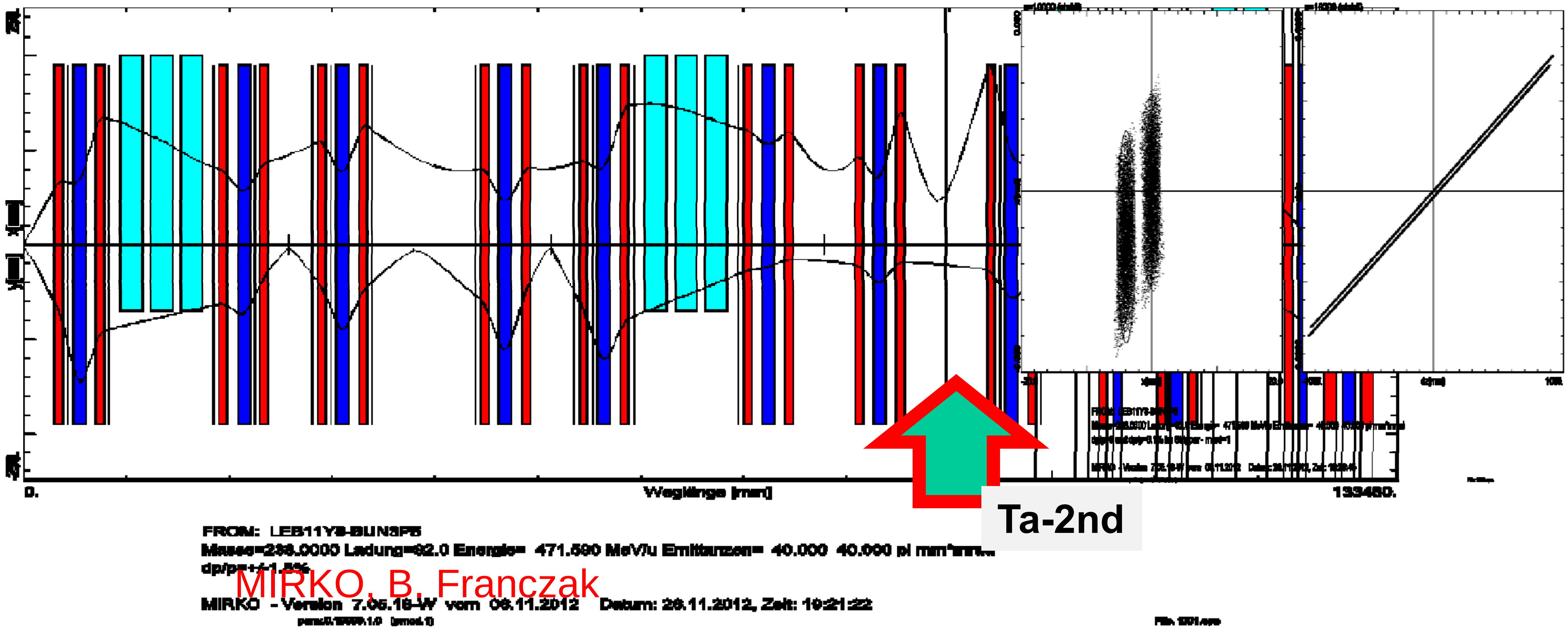
LEB-C-EB-Dispersion-Matched



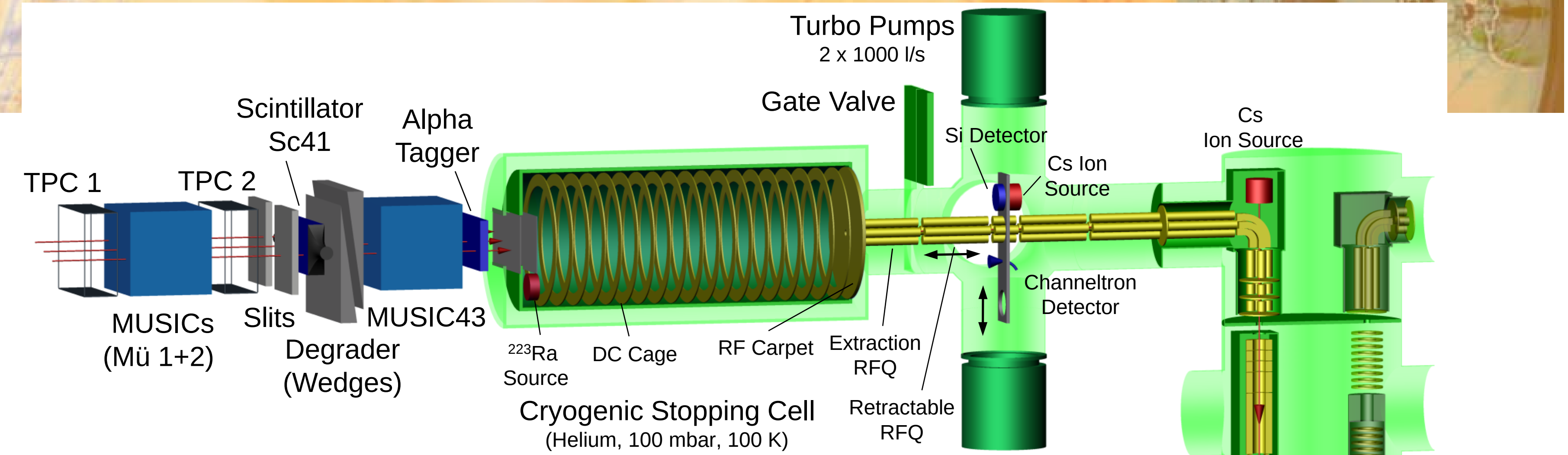
E-Loss Spectrometer

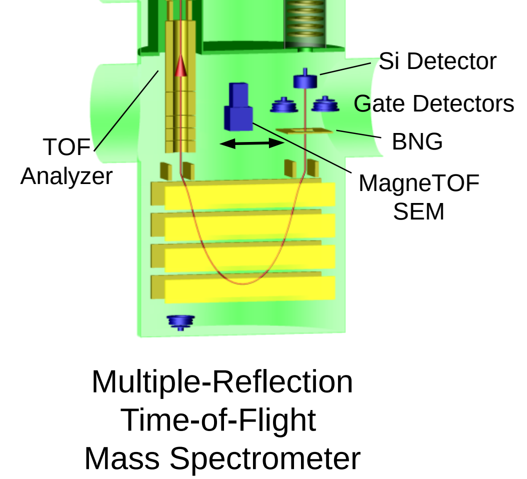
LEB-C-EB-Dispersion-Matched

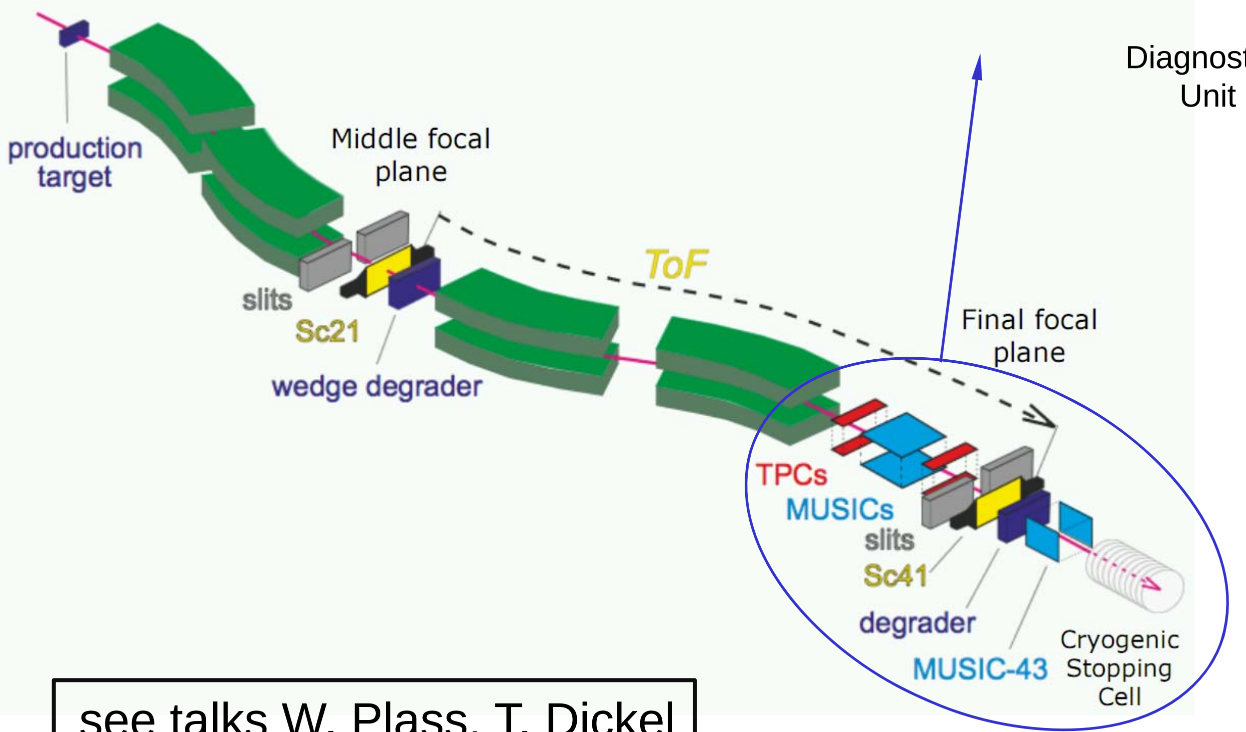
$\delta p_0 = 2$ % Analyzer $\delta p = 0.2$ % Spectrometer



FRS Ion Catcher Setup (Final Focal Plane)



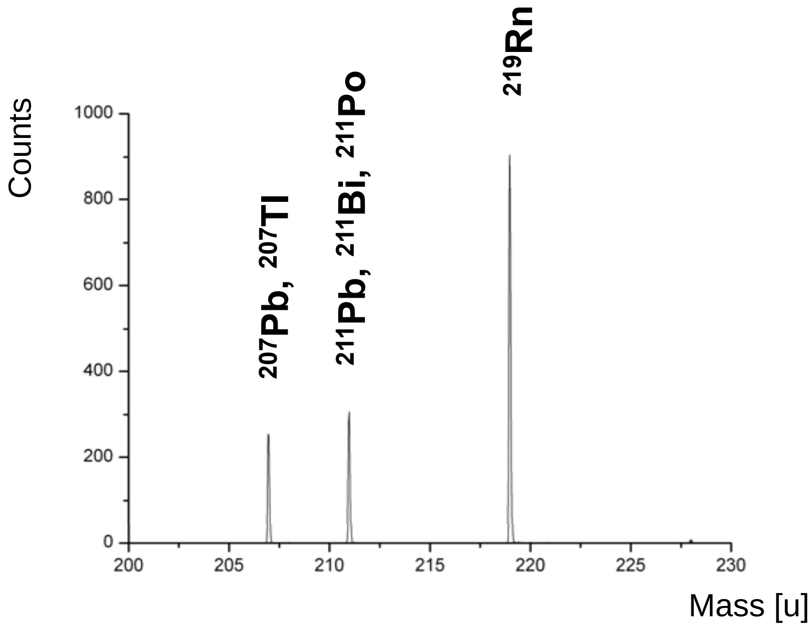




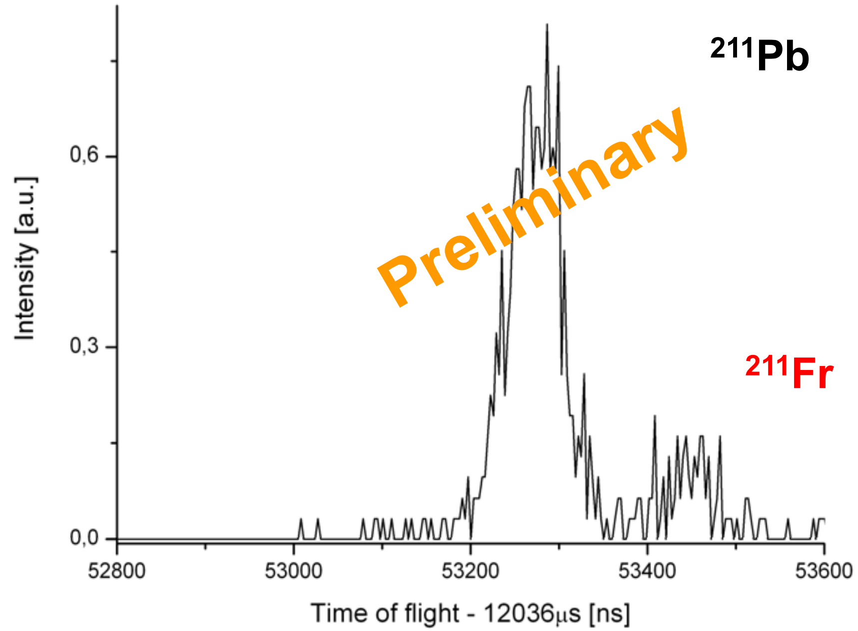
see talks W. Plass, T. Dickel

MR-TOF-MS Measurements

Cleanliness of stopping cell
(Broadband measurement)



Mass measurement
(High resolution mode)

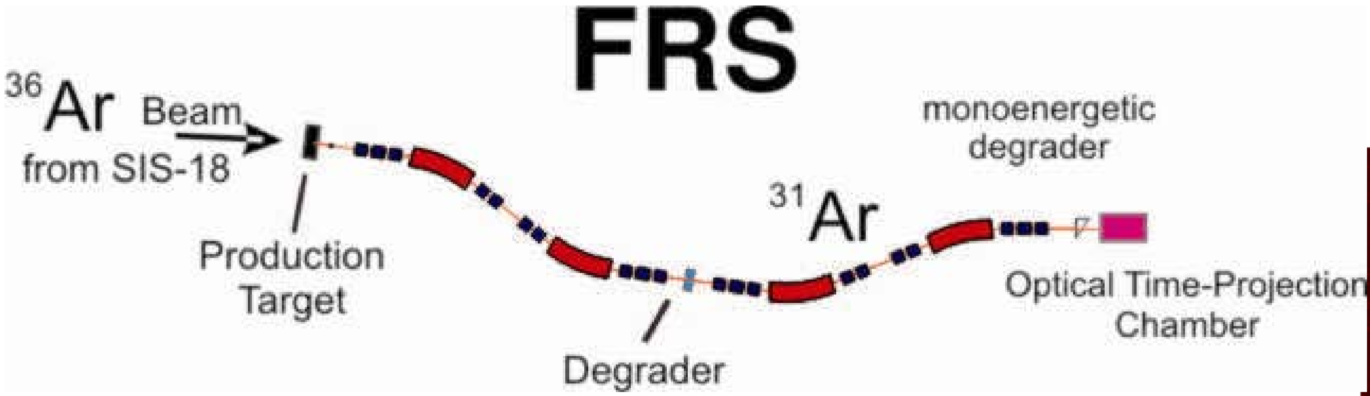


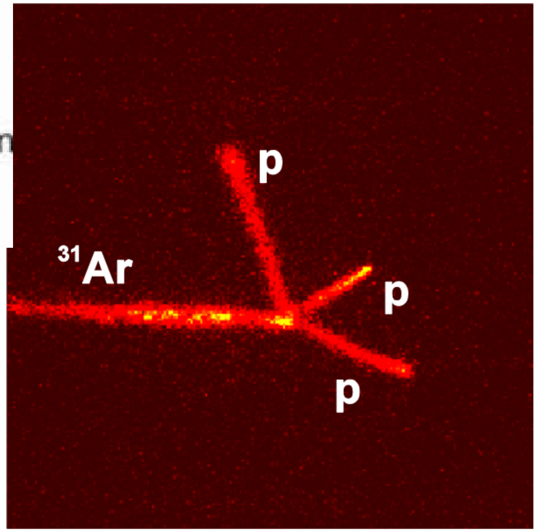
see Talk W. Plass

First time, direct mass measurement of projectile fragments with an MR-TOF-MS:

- **Isobars ^{211}Ra, ^{211}Po and ^{211}Fr**
- **^{213}Rn with half-life of 19.5 ms**

Discovery of Rare Decay Modes
M. Pfützner



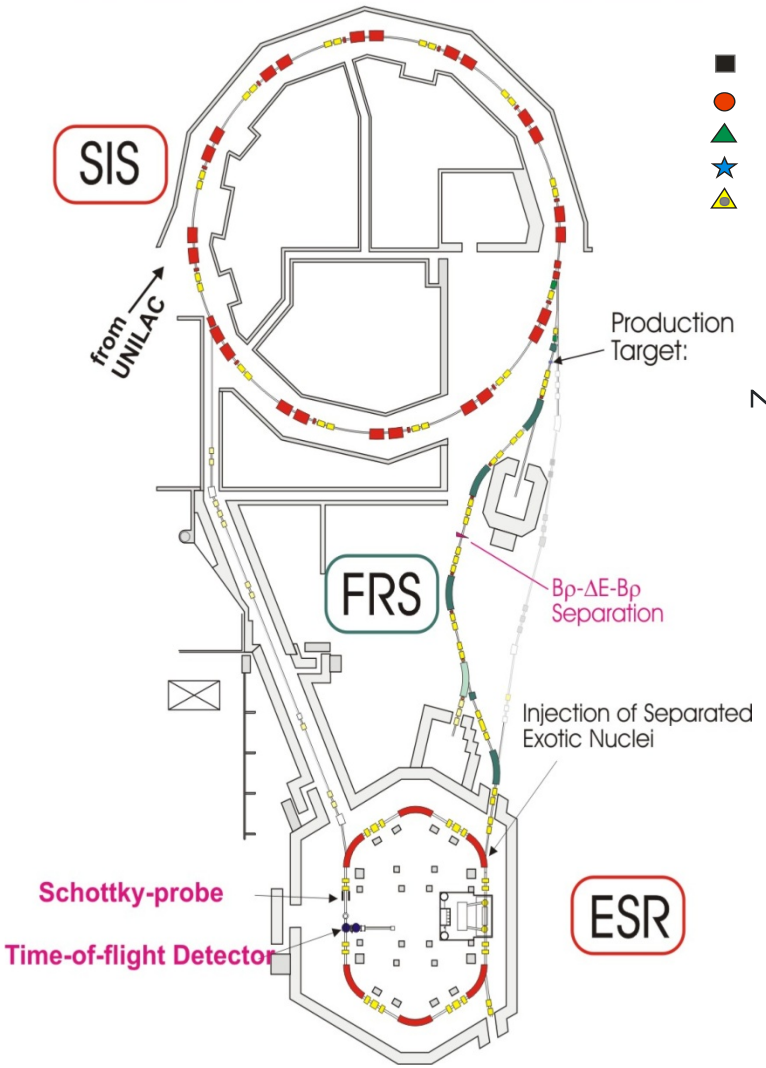


e.g. True Ternary Fission, cluster decay emission
neutron emission from the ground state

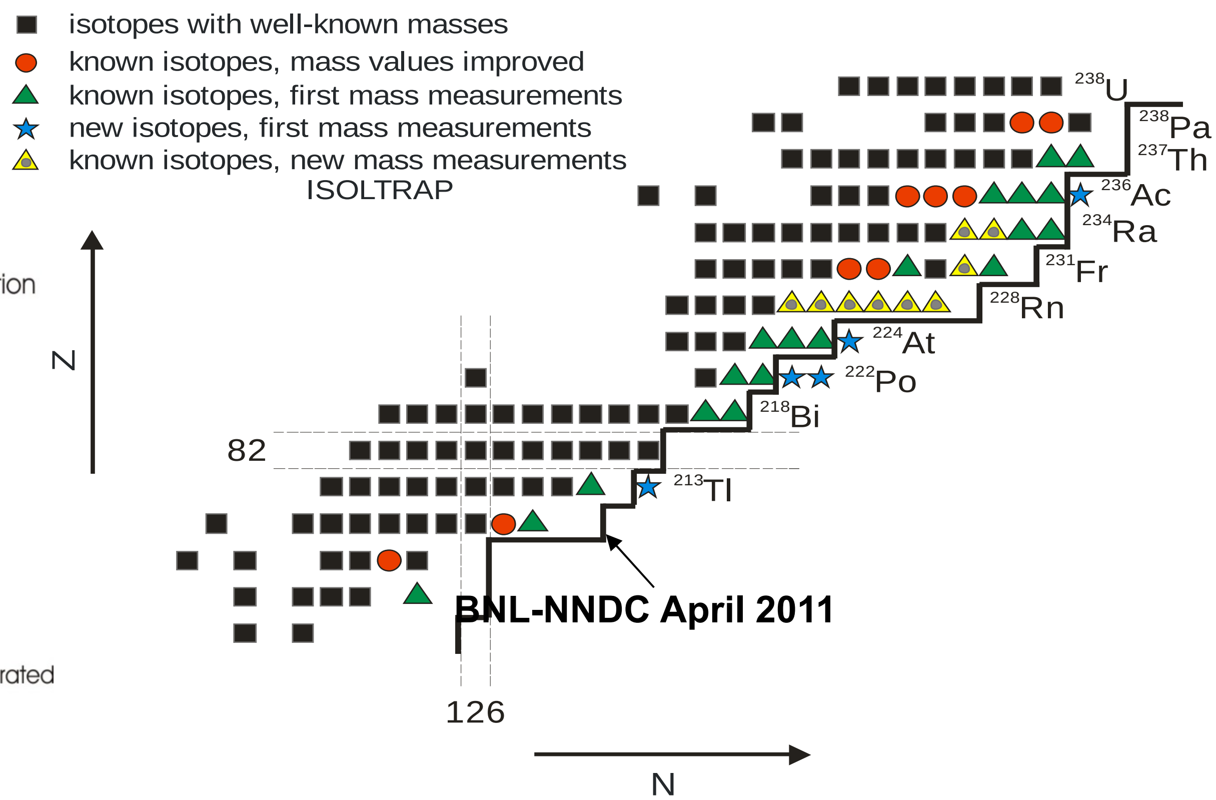
I. Mukha, L. Grigerenko, C. Scheidenberger

FRS-ESR Experiments

Precision Experiments with the combination of the FRS and the ESR



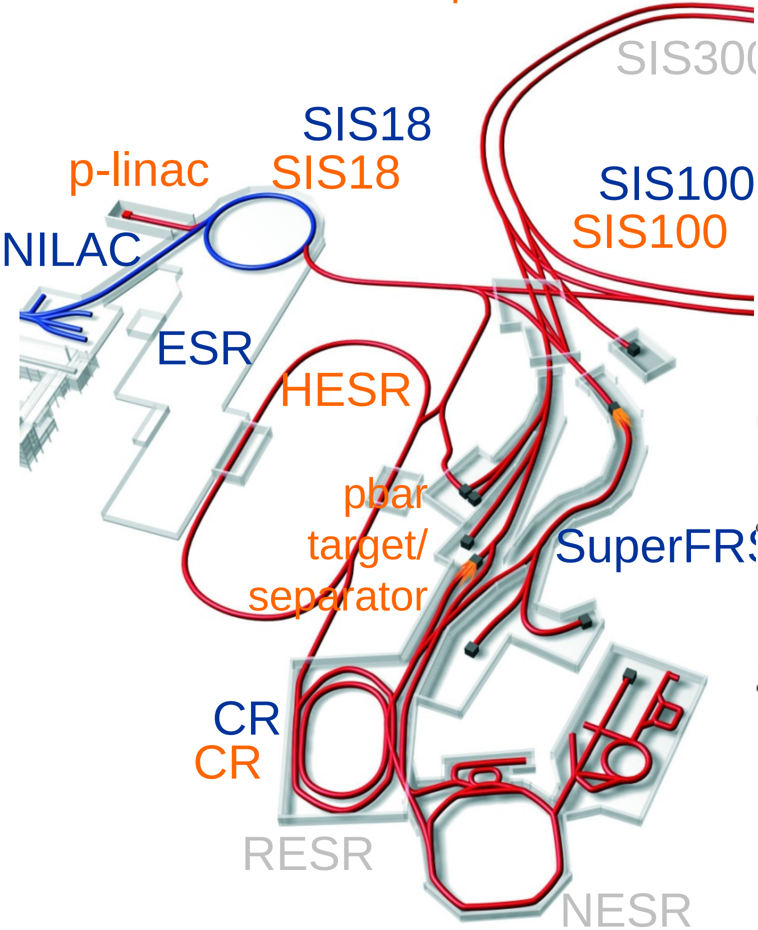
L. Chen et al., Nucl. Phys. A 882 (2012) 71.



Systematic Error
$\sigma^{syst} \approx 10$ keV

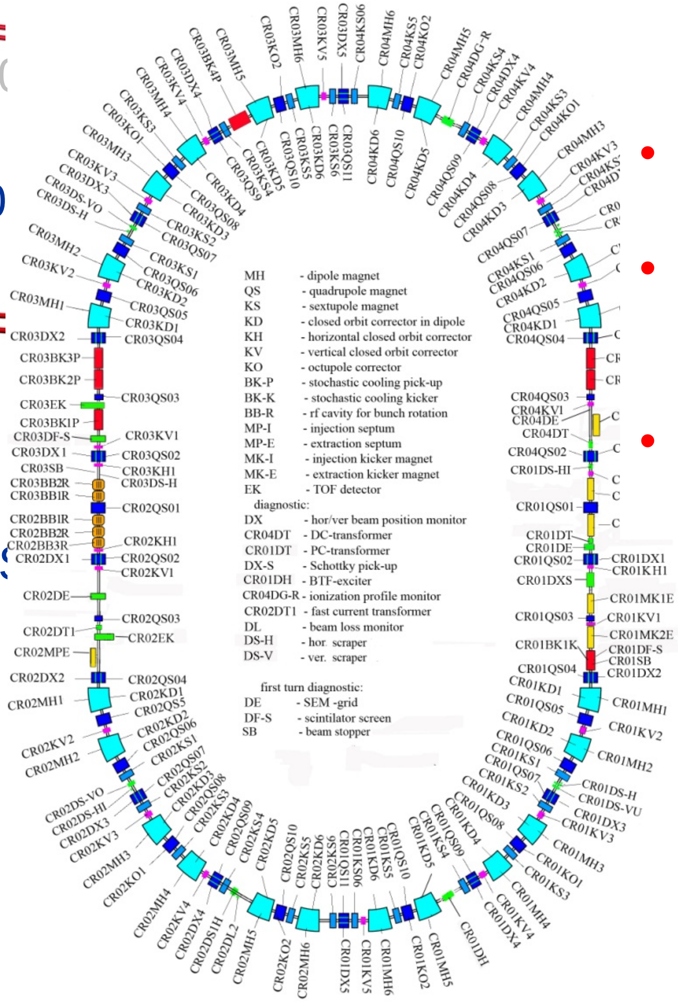
Super-FRS combined with Collector Ring
M. Steck

Modularized Start Version (MSV)



RESR and NESR will be added

For Exotic Nuclei:



- Stochastic Precooling
- Isochronous Mass Measurement
- Lifetime Measurements

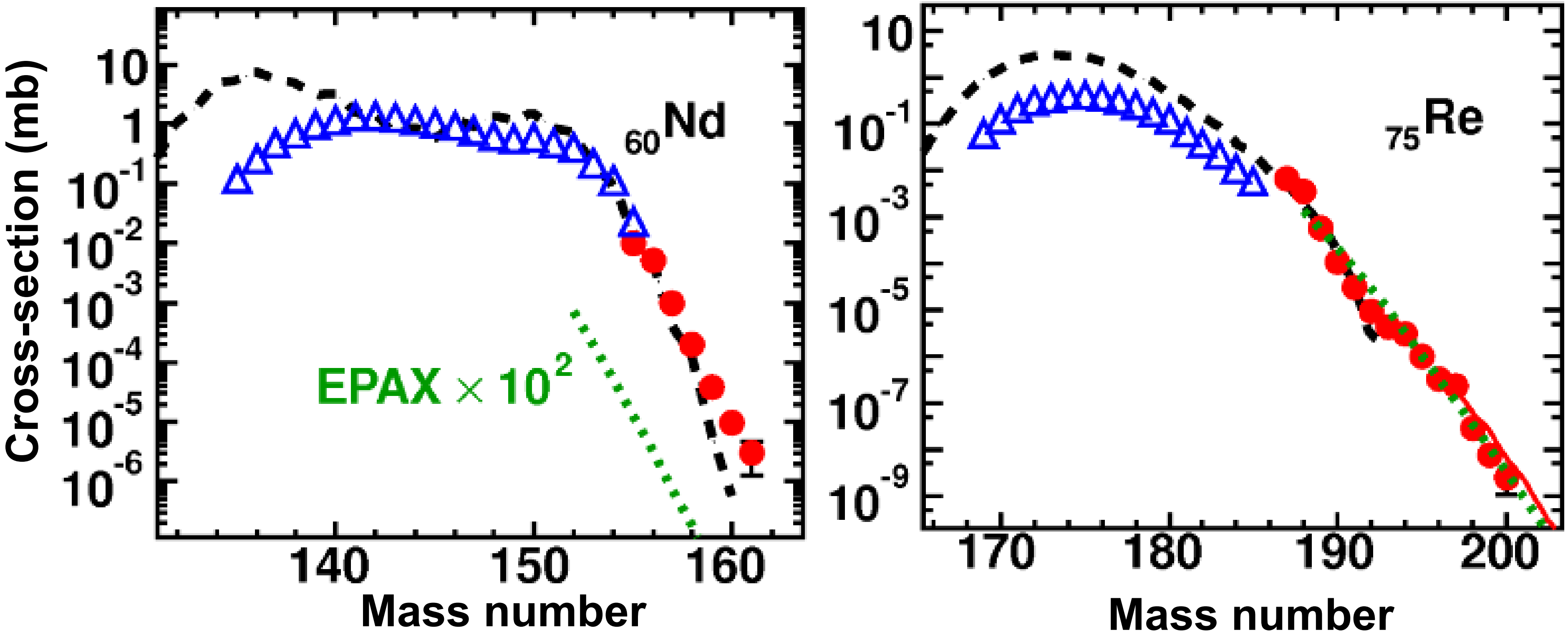
see Talk Yu. Litvinov

Scientific Goals
for Experiments directly with the Super-FRS

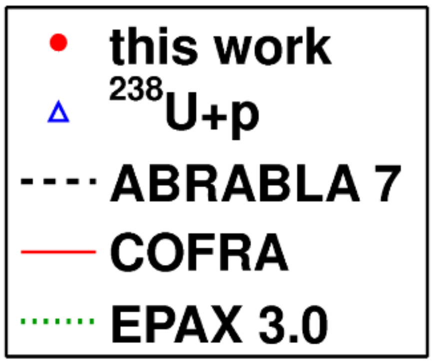
Separator Experiments:

- Search for New Isotopes, map the Driplines
- Measure Production Cross Sections,
- Reaction Kinematics,
- Mass
- Rare Decay Modes (In-Flight Decay)
- Interaction, nucleon removal, charge-changing cross sections

Measured Cross-Sections compared with Models



J. Kurcewicz et al. Phys. Lett. B217 (2012) 371



EPAX 3.0: K. Sümmerer to be published in Phys. Rev. C (2012), arXiv id 1205.5436.

COFRA: J. Taieb et al., Nucl. Phys. A 724 (2003) 413-430.

Scientific Goals
for Experiments directly with the Super-FRS

Spectrometer Experiments

- **Measure Precise Momentum Distributions e.g., after knockout, charge-changing reactions**
- **Atomic Collisions, Channeling, Resonant Coherent Excitation**
- **Exotic Atoms In-medium effects of mesons, mass of eta-prime**


Thank You!
NuSTAR Annual Meeting