Commissioning of the LEB Stopping Cell at the FRS Ion-Catcher

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Overview

Motivation

Results from a first generation stopping cell at the FRS (S258)

Development of a second generation, cryogenic stopping cell

Plans for an on-line test at the FRS Ion Catcher

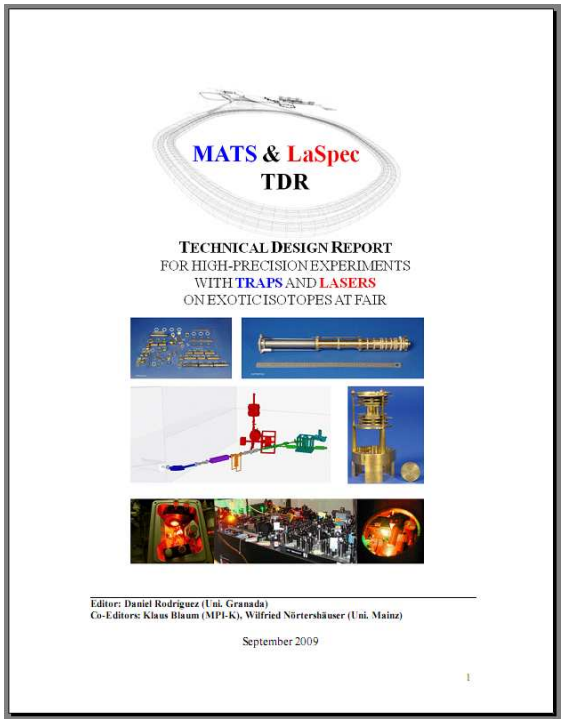
Conclusions

Motivation: Low Energy Branch at FAIR

Low Energy Brach of the Super-FRS at FAIR

High-precision experiments with in-flight separated exotic nuclei almost at rest, (production by projectile fragmentation / fission)

- universal and fast production
- high selectivity
- cooled exotic nuclei



MATS

(Precision Measurements of very short-lived nuclei using an Advanced Trapping System for highly charged ions)

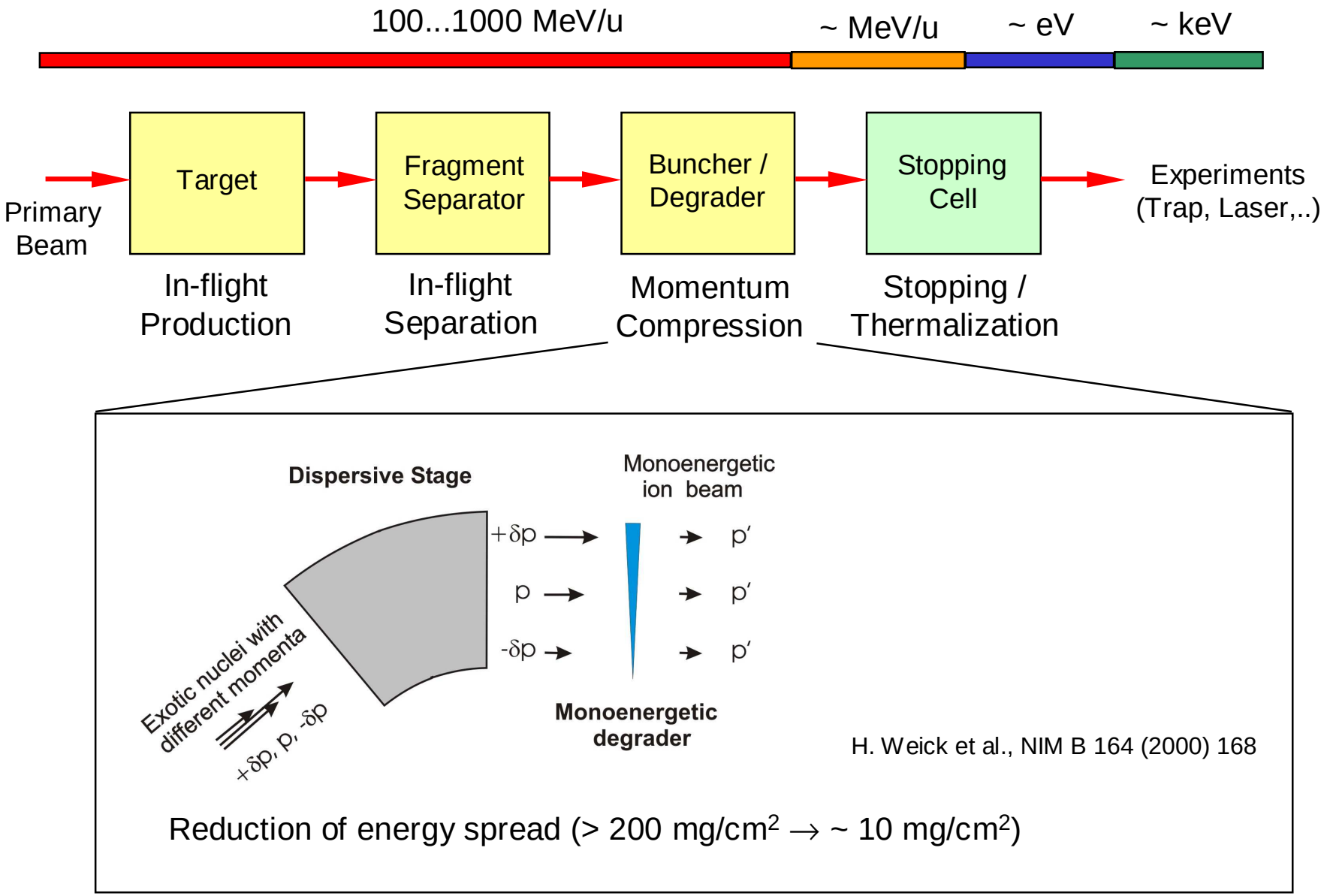
- High accuracy mass measurements
- In-trap conversion electron and alpha spectroscopy
- Trap assisted spectroscopy

LaSpec (Laser Spectroscopy)

- Collinear laser spectroscopy of ions and atoms
- β-NMR
- Resonance ionization spectroscopy

MATS - LaSpec TDR submitted in September 2009

Motivation: Stopping Cell

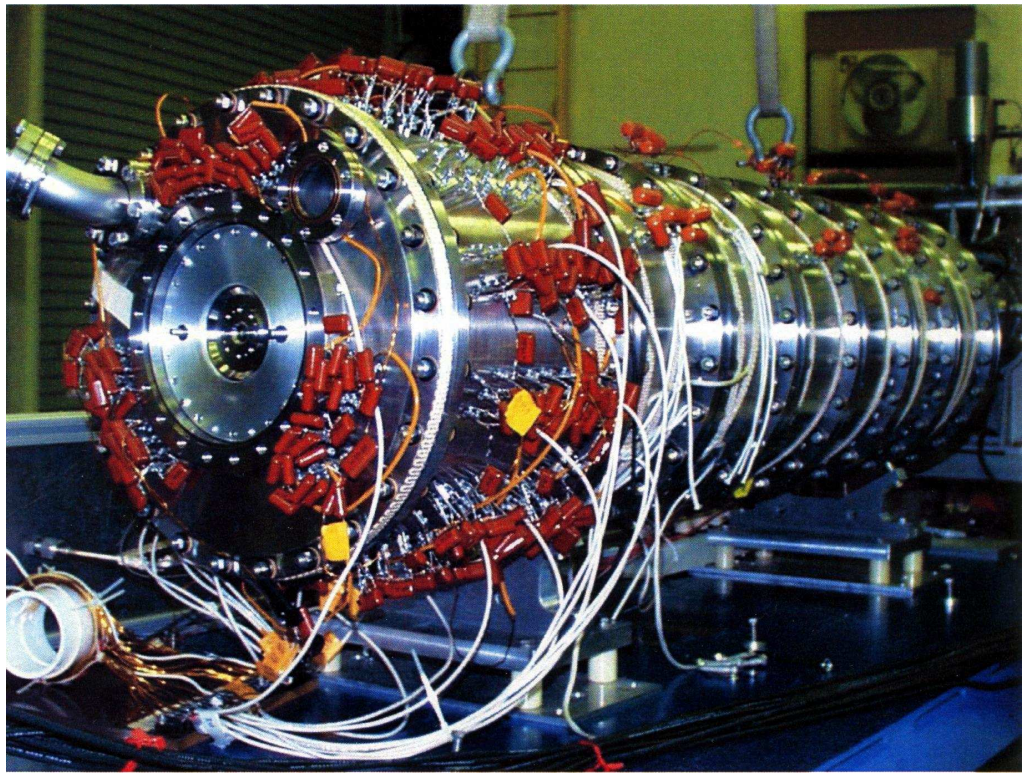


Reduction of energy spread (> 200 mg/cm^2 → ~ 10 mg/cm^2)

First Generation Stopping Cell (S258)

Linear Stopping Cell

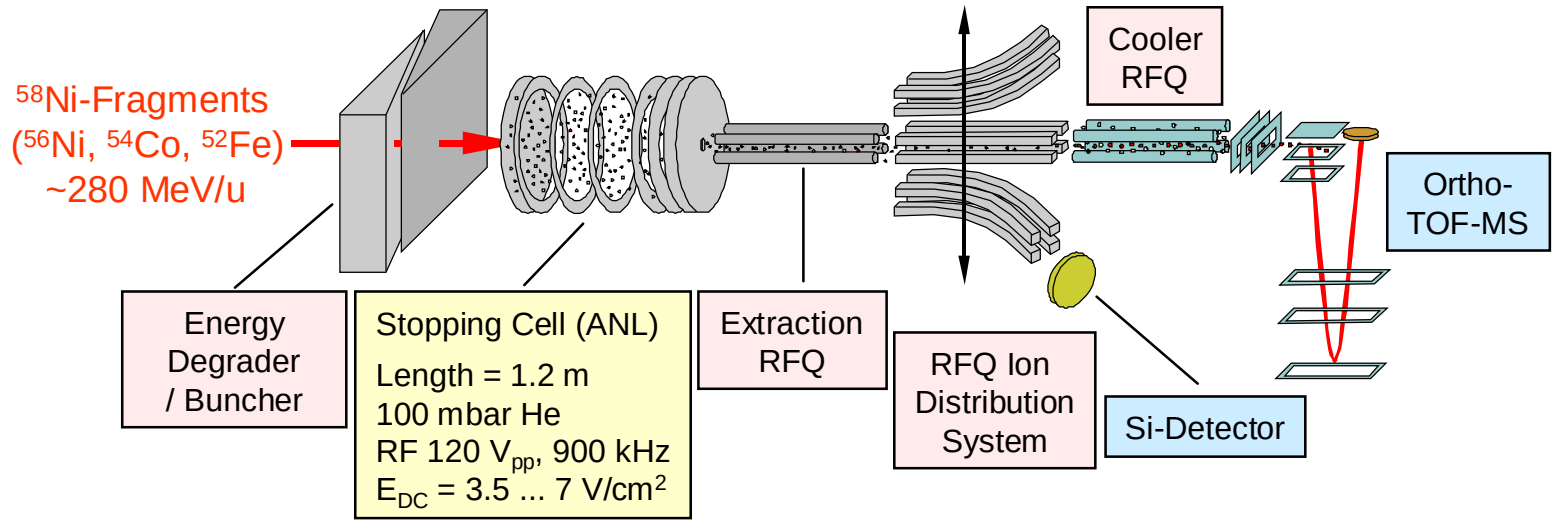
- Overall length: 1.4 m
- Pressure: 100 mbar helium
- RF fields (120 V_{pp} @ 900 kHz)
  DC fields (~7 V/cm) for extraction



G. Savard et al., NIM B 204 (2003) 582

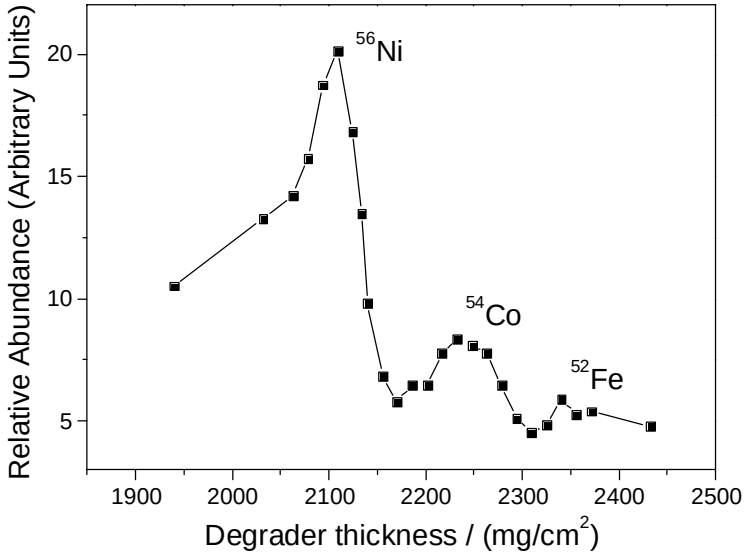
ANL Physics Division

On-line Test of the FRS Ion-Catcher (S258)



Results of on-line test in 2005:

- Successful demonstration of range-bunching, stopping, and extraction from a gas cell of relativistic exotic nuclei
- Extraction efficiency: ~ 45%
- Extraction times: ~ 20 ... 50 ms



M. Petrick et al., NIMB 266 (2008) 4493

Issues:

- Molecule formation (contaminants)
- Stopping efficiency ~ 5% (limited by pressure of 100 mbar)

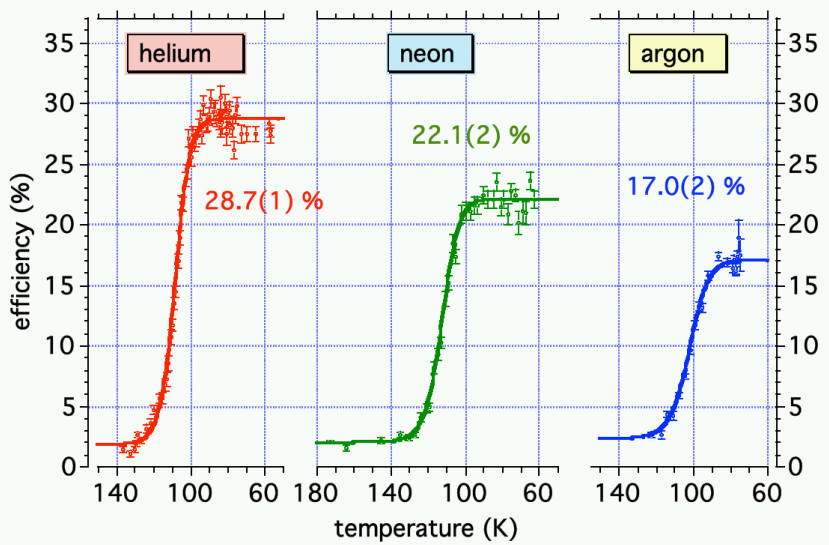
Cryogenic Stopping Cell: Conceptual Design

New concept: Operate He-filled stopping cell at cryogenic temperature (~70 K)

P. Dendooven et al., NIM A 558 (2006) 580
S. Purushothaman et al., NIM B 266 (2008) 4488

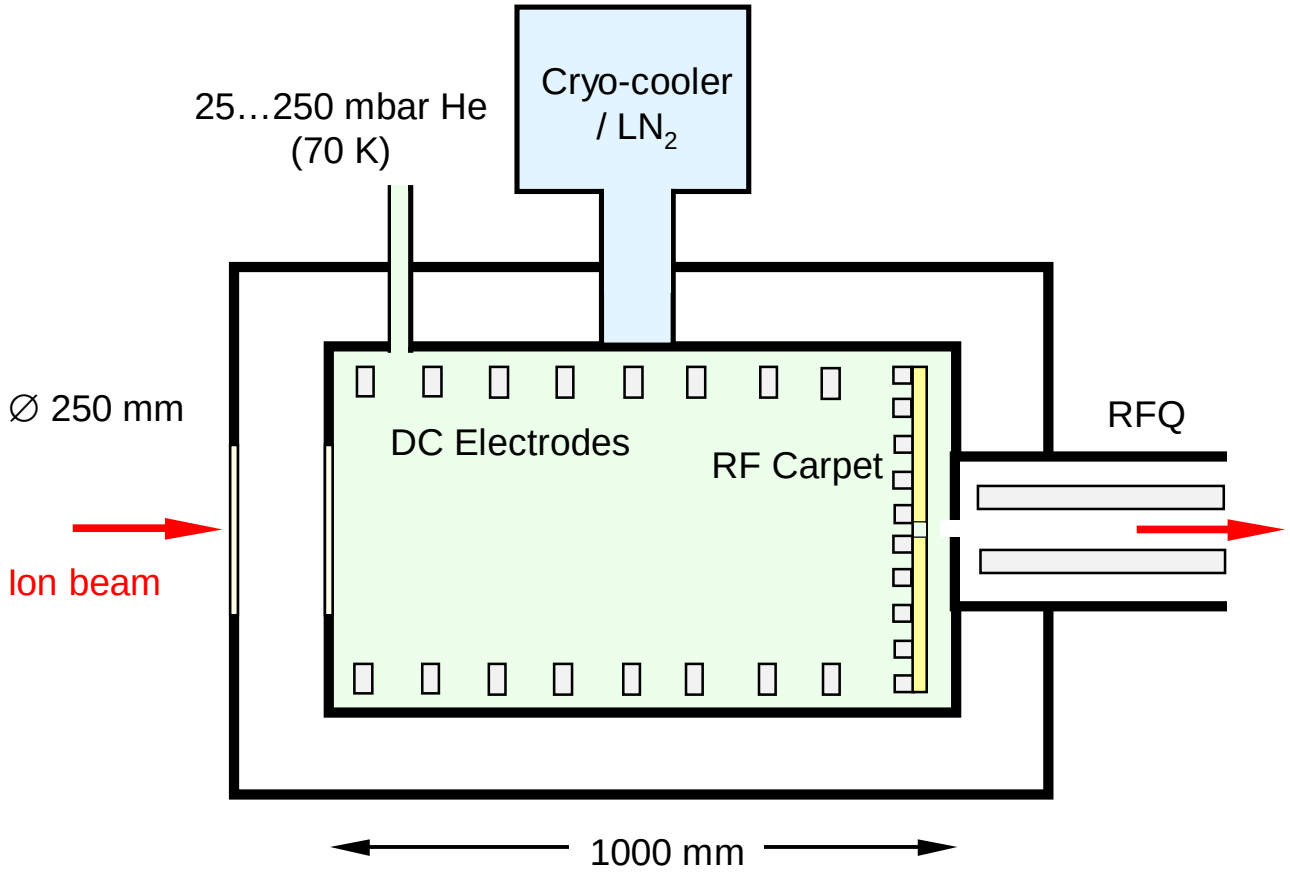
Advantages

- Ultra-pure helium (freezing-out of contaminants)
  - Reduced ion losses
  - No formation of molecules/adducts
- Reduced radial ion diffusion
- 2+ charge state (?) → shorter extraction times
- Reduced requirements for cleanliness → easier, more flexible construction
- Operational reliability



Transport efficiency of α-decay recoil ions in a closed gas cell

Cryogenic Stopping Cell: Conceptual Design



Collaboration

KVI / university of groningen

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

GSI

UNIVERSITY OF JYVÄSKYLÄ

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

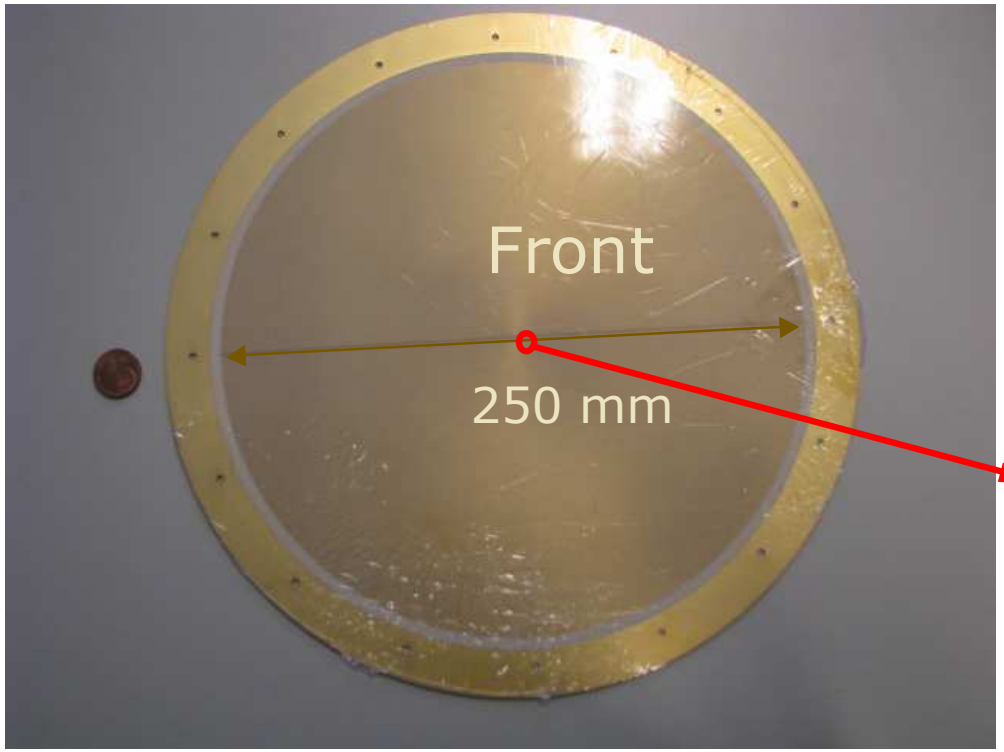
Challenges:

Fast ion extraction at high buffer gas density
→ high axial electric DC field

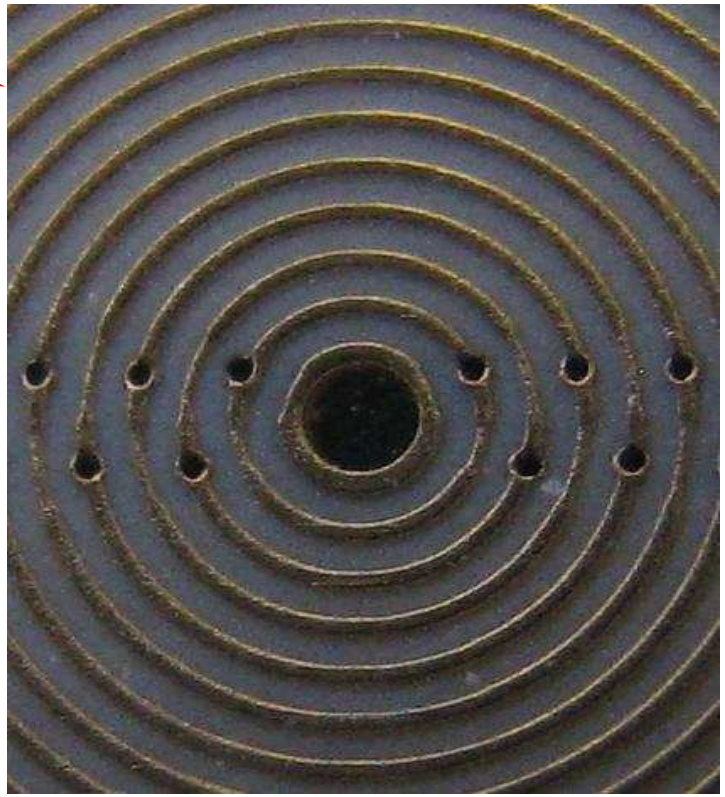
Efficient ion extraction at high buffer gas density
→ high repelling electric RF field (RF carpet)

M. Wada, NIMB 204 (2003) 570

Cryogenic Stopping Cell: RF Carpet



Thickness:	0.8 mm
Diameter:	250 mm
Number of rings	500
Electrode spacing:	0.25 mm
Exit hole:	0.6 mm



P. Dendooven, M. Ranjan et al.

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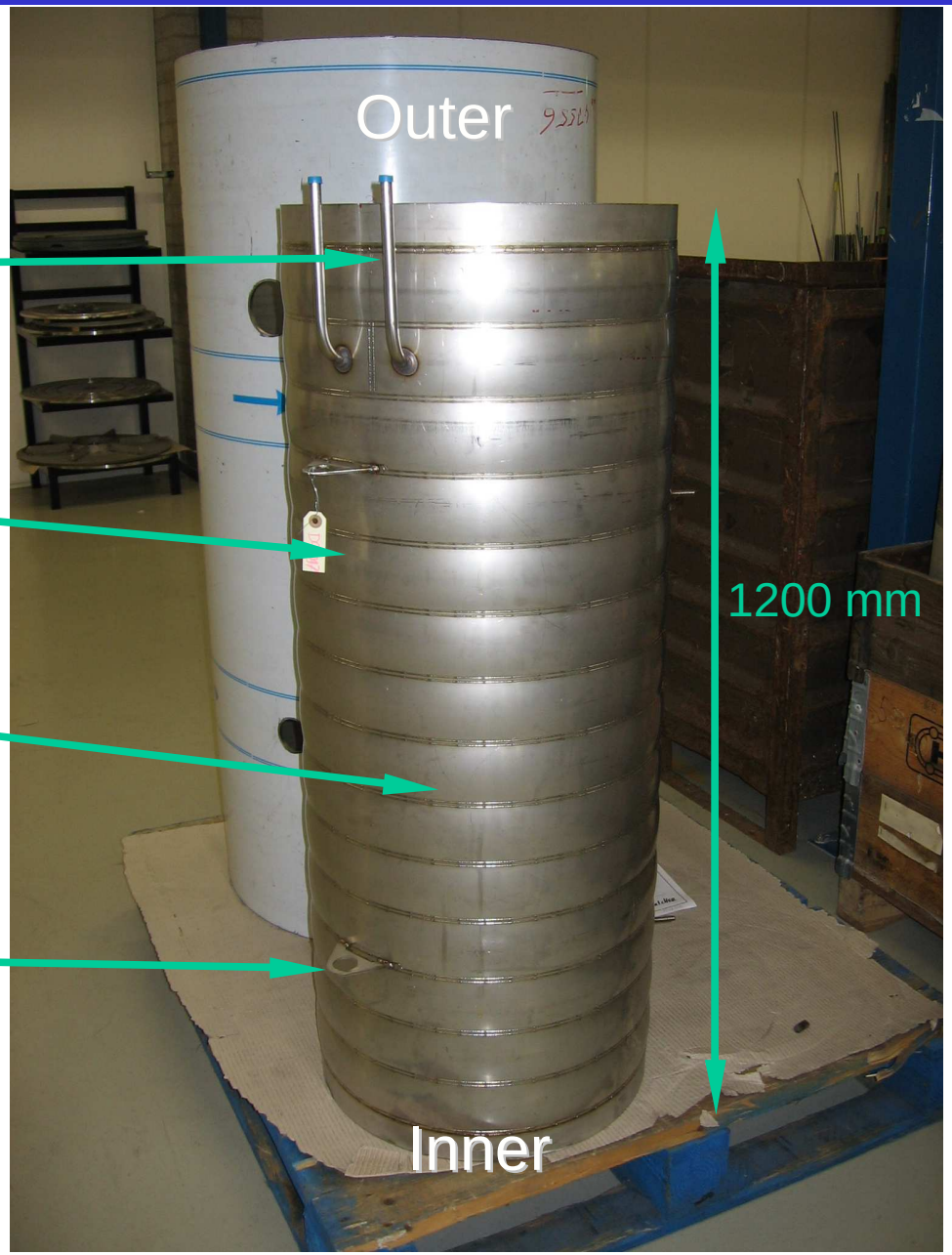
Cryogenic Stopping Cell: Vacuum chambers

Cooling pipe lines

Cooling spiral

Place for heating wire

Handle



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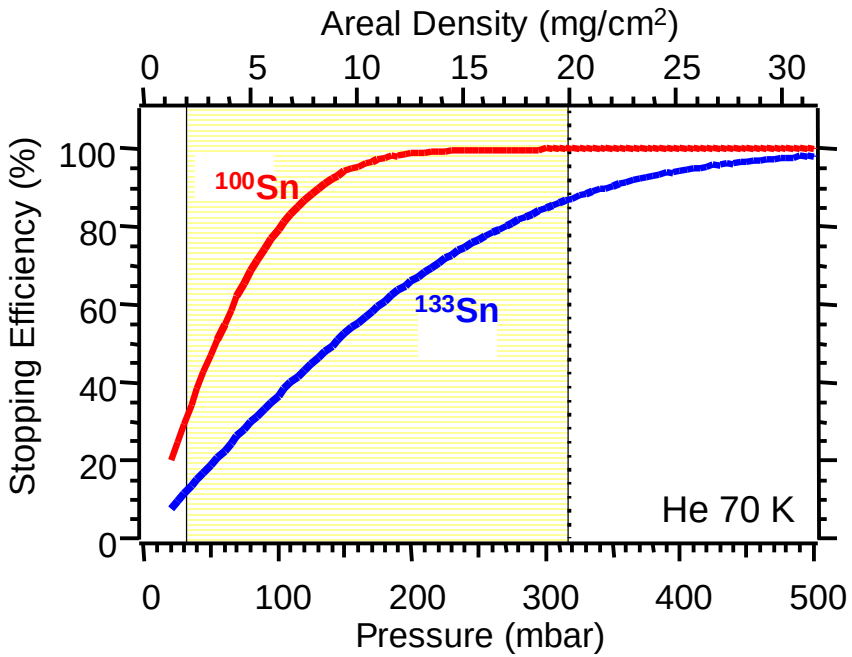
Cryogenic Stopping Cell: Expected Performance

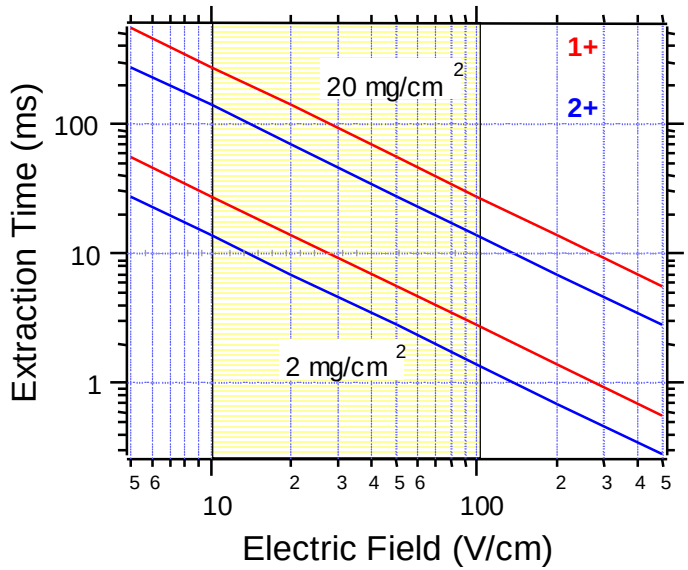
Efficiency

Stopping	10...100%
Stopped as ion	30...50%
Transport	100%
Total	5...50%



Extraction Time

10...100 ms



LEB of the Super-FRS

Range straggling (rms) in helium

^{100}Sn: σ_R = 2.5 mg/cm^2

^{133}Sn: σ_R = 6.6 mg/cm^2

H. Weick

Off-line / On-line Test at the FRS Ion-Catcher

Time schedule
- Development in 2008/2009
- Construction in 2009
- Off-line / on-line test at GSI in 2010/2011

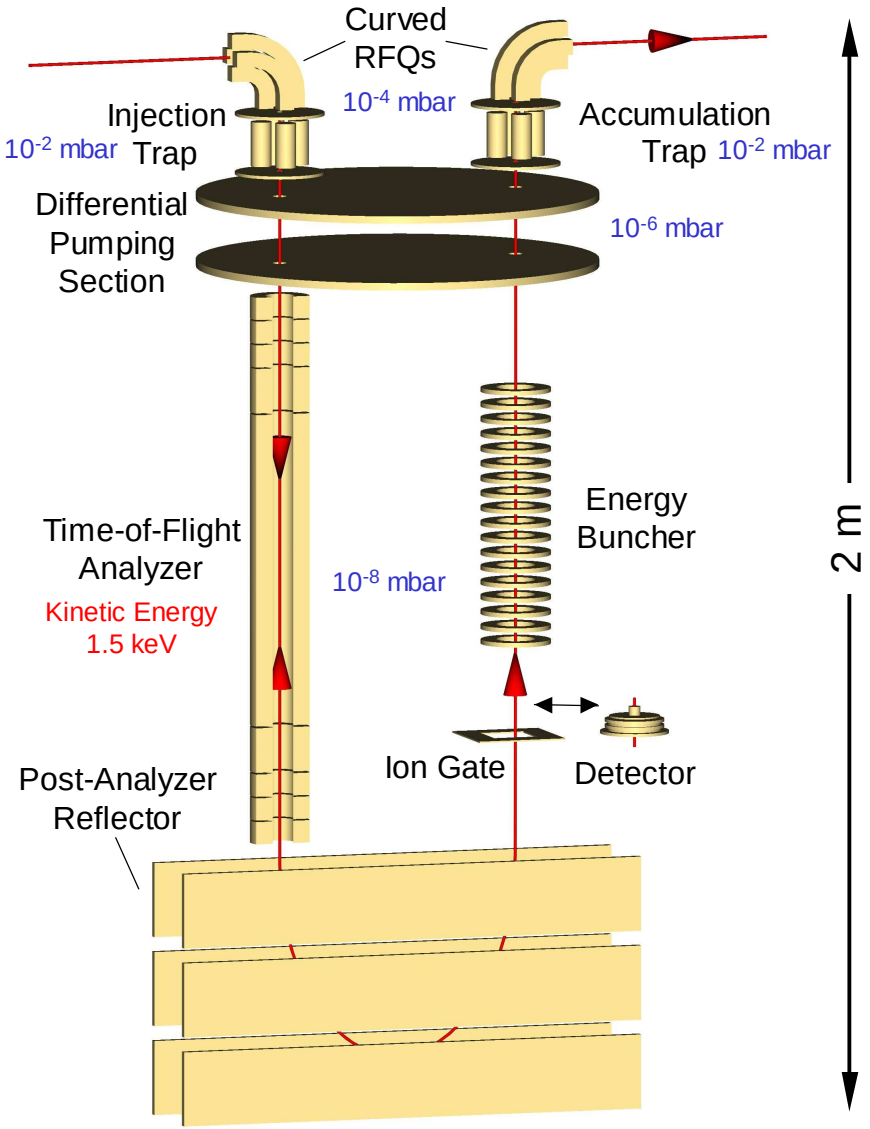
Performance characterization
- Test cryogenic operation
- Demonstrate stopping and extraction
- Investigate cleanliness / contamination
- Measure extraction efficiency and extraction times
- Determine intensity limitations

Off-line
- ^{223}Ra recoil ion source
- Fission source

On-line
- Stable beam
- Projectile fragments

Issue: Space at F4

Multiple-Reflection Time-of-Flight Mass Spectrometer



W.R. Plaß et al., *Nucl. Instrum. Methods B* **266** (2008) 4560

Mass resolving power
- m/Δm > 300,000 (FWHM)
- m/Δm > 50,000 (1%)
- m/Δm > 20,000 (0.1%)

Mass accuracy
- 0.1...1 ppm

Transmission efficiency
- up to (70 ± 30)%

Repetition frequency
20…100 Hz

Ion capacity
- up to 10^4 ions/cycle → 10^6 ions/s

Isobar separation
- demonstrated for C_6H_6 and $^{13}C^{12}C_5H_5$ (Intensity ratio 200:1, Δm = 4 mu)

Fast, high-resolution, broadbad, efficient, detects stable and radioactive ions
→Ideal tool for the commissioning of the FRS Ion-Catcher

Conclusions and Outlook

Stopping cell for the Low Energy Branch of the Super-FRS

- Key device for operation of MATS and LaSpec

First generation stopping cell (S258)

- Successful on-line test; proof-of-principle for stopping and extraction of relativistic projectile fragments
- High extraction efficiency
- Issues: Low pressure (stopping), molecule formation

Cryogenic stopping cell

- Goal: overcome problems of first generation device
- Cryogenic operation: many advantages
- Challenges: achieve high electric fields
- Design has been completed; contruction is underway
- First test in 2010

LEB Stopping Cell Collaboration

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