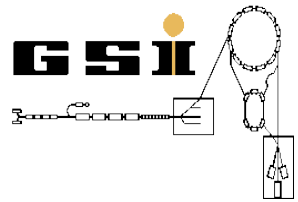
First operation of a cryogenic stopping cell at the FRS Ion Catcher

Sivaji Purushothaman

GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt

for the FRS Ion Catcher Collaboration

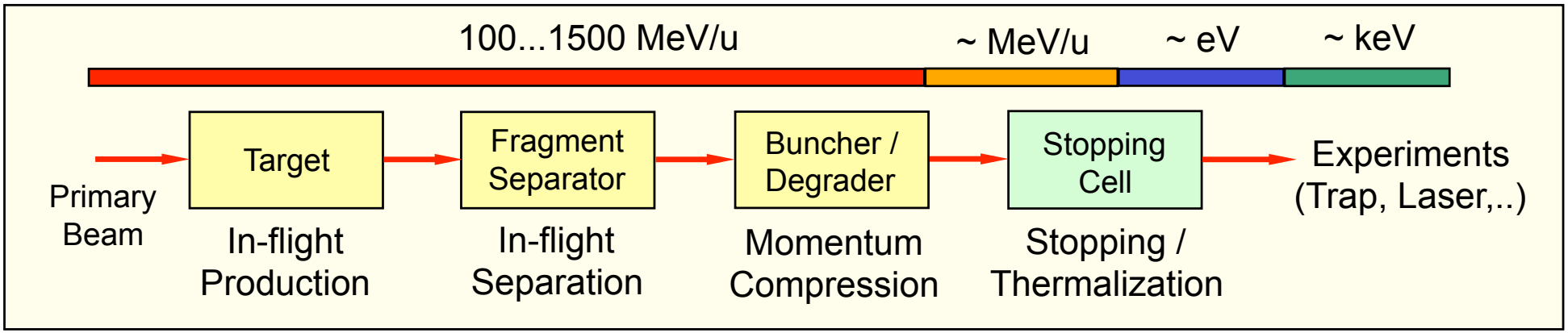


FRS-user meeting 2011

Motivation: Low Energy Branch of the Super-FRS

LEB: 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



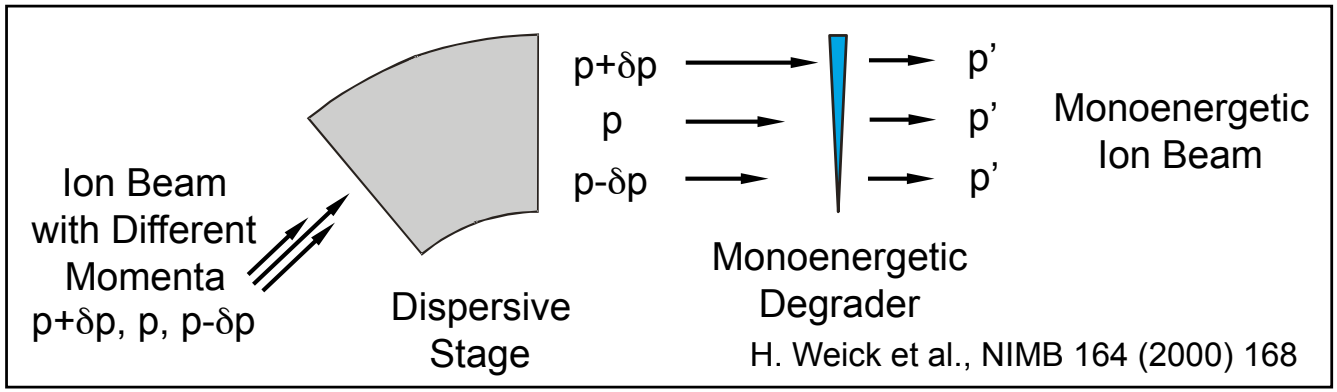
MATS (Precision Measurements of very short-lived nuclei using an Advanced Trapping System for highly charged ions)

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

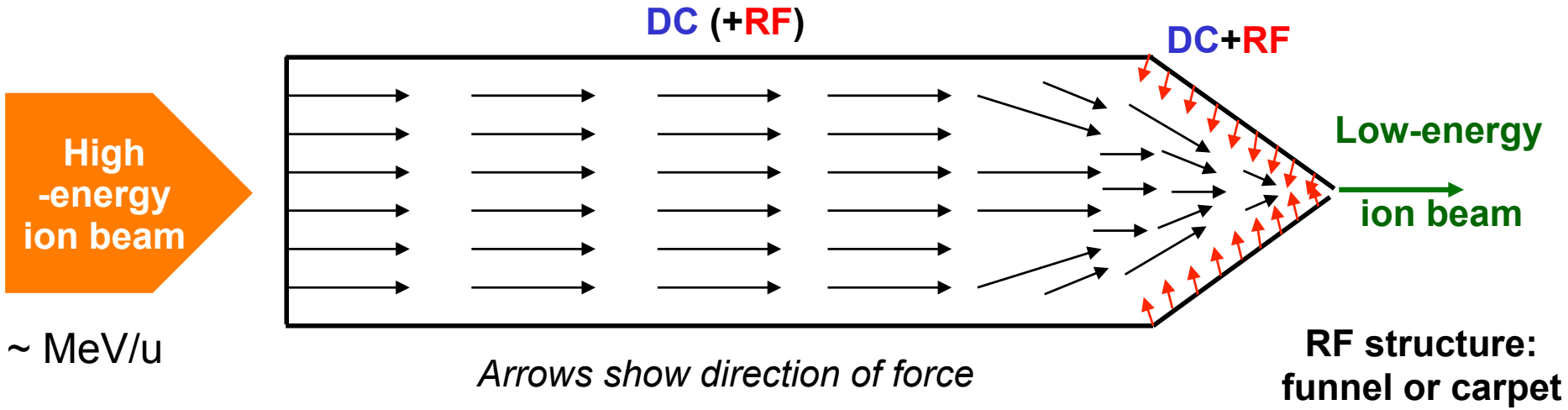
LaSpec (Laser Spectroscopy)

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

Stopping Cell Principles



Stopping Cell



- High-energy ions stopped in noble gas
- Stopped ions transported using DC and RF fields to exit-hole
- Extraction by gas flow

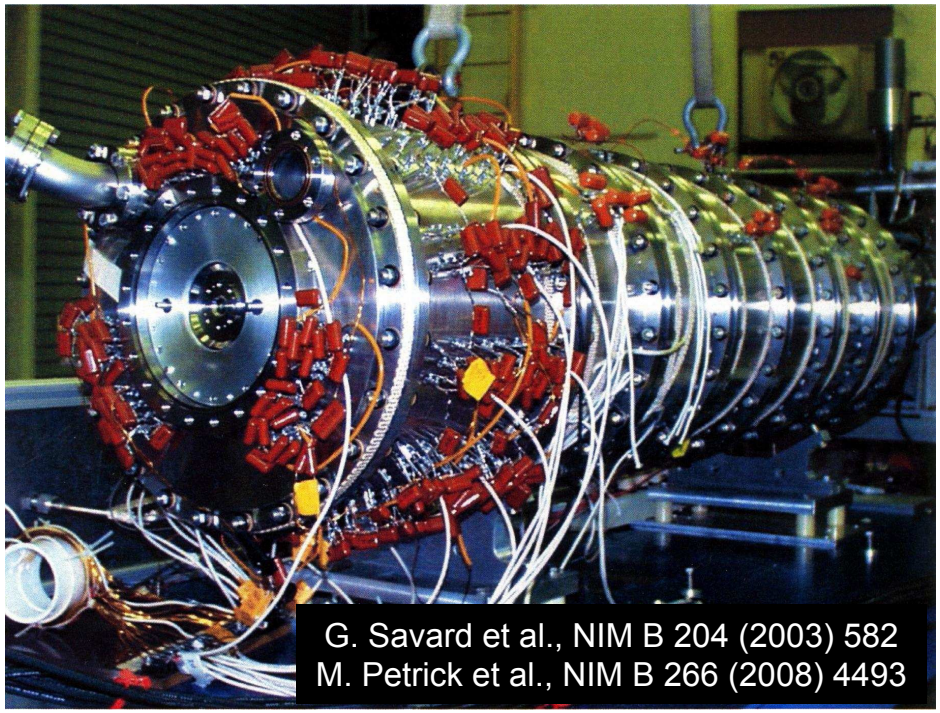
Stopping Cell for Relativistic Exotic Nuclei

First Generation Stopping Cell (S258)

Successful proof-of-principle

Suffered from:

1. Poor stopping efficiency
2. Presence of impurities

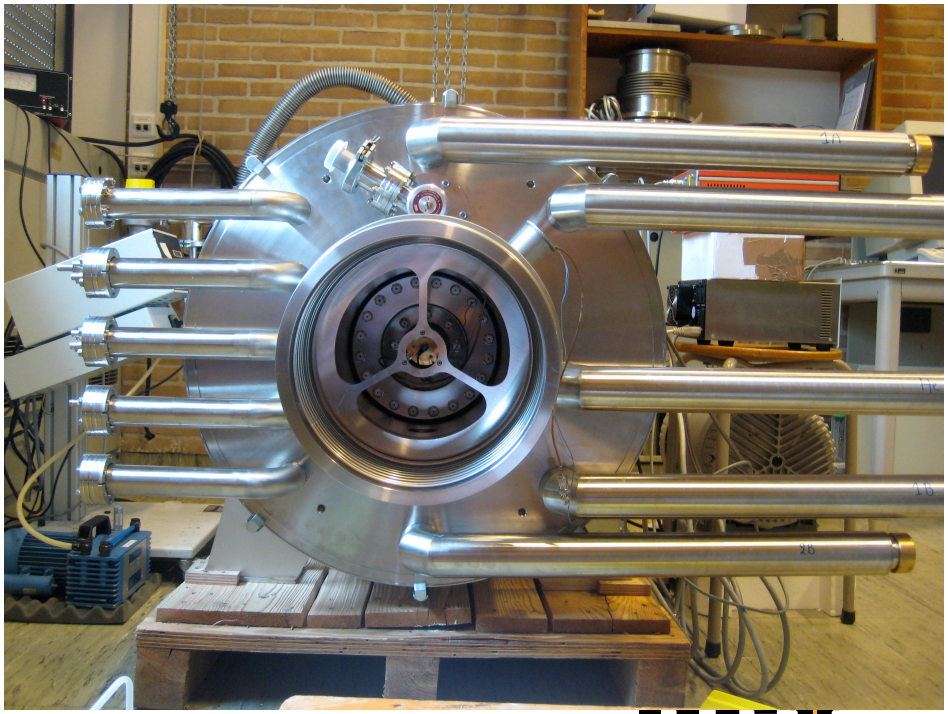


G. Savard et al., NIM B 204 (2003) 582
M. Petrick et al., NIM B 266 (2008) 4493

Second Generation Stopping Cell (S411)

Solutions now implemented:

1. High-density operation
2. Cryogenic operation

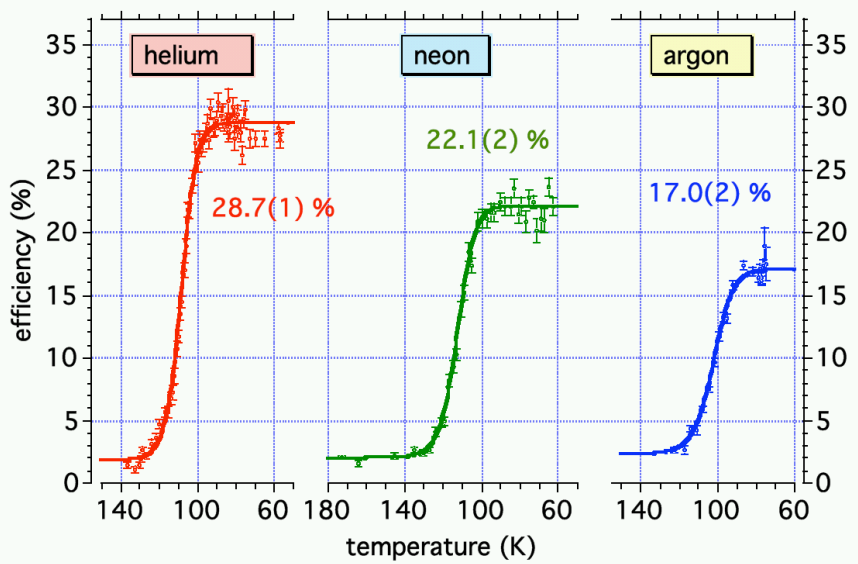


Stopping Cell: Cryogenic Operation

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

Advantages

- Ultra-pure helium (freezing-out of contaminants)
  - Ideal for ion survival
  - 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



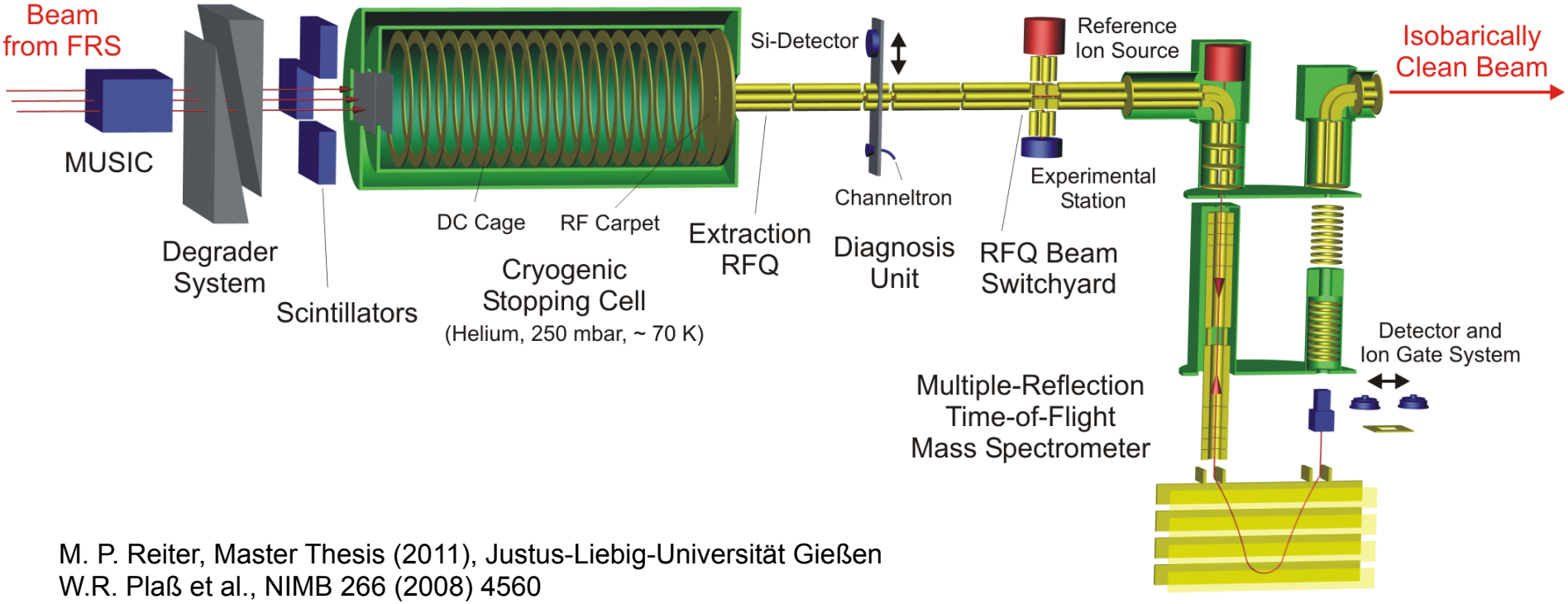
Transport efficiency
of α-decay recoil ions
in a closed gas cell

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

FRS - Cryogenic stopping cell – MR-TOF beam line

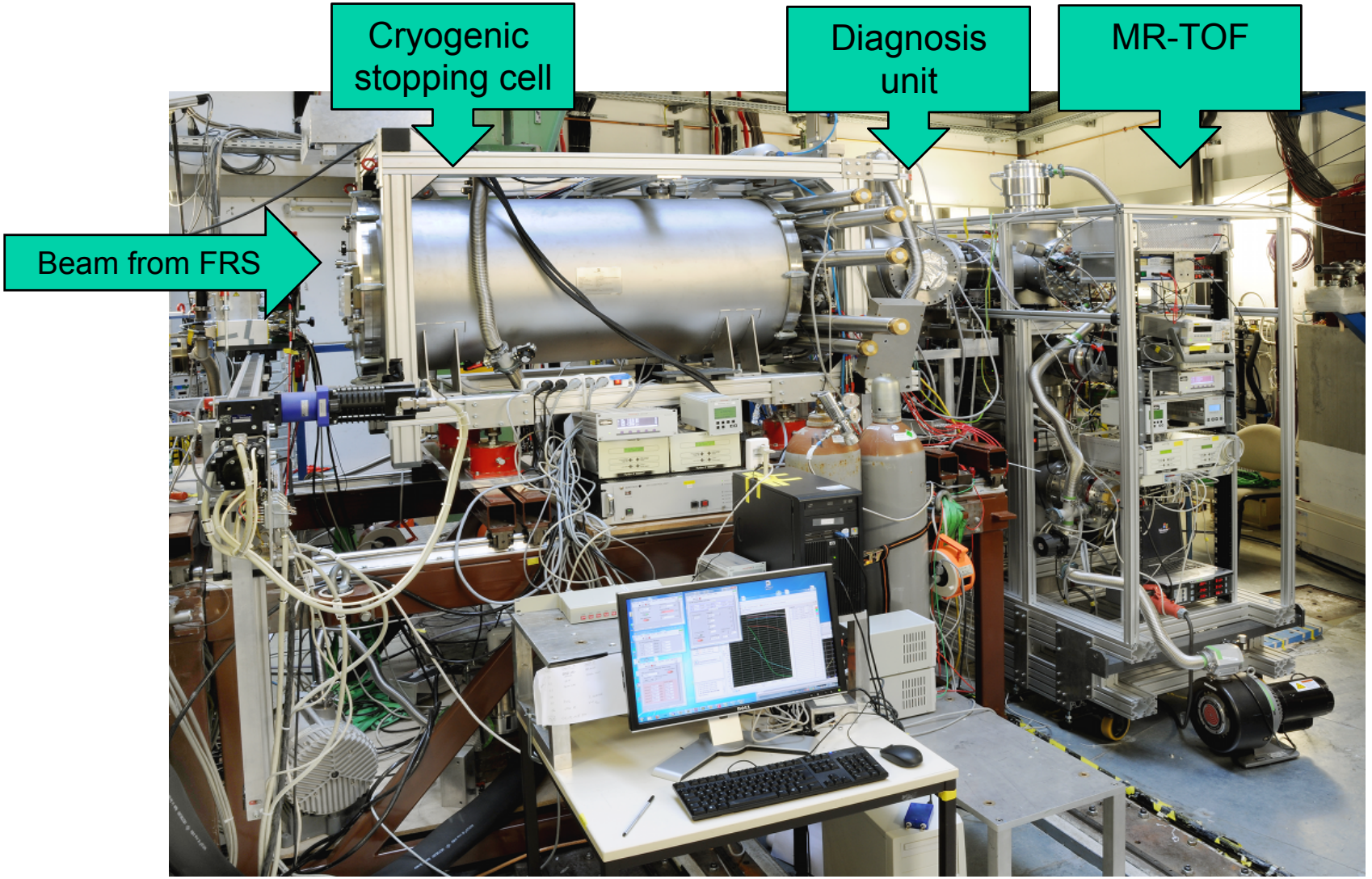
~ GeV/u | ~ MeV/u | ~ eV | ~ keV

Fragment Separator FRS Production, separation and range-bunching	**Cryogenic Stopping Cell** Stopping, thermalization, extraction	**RFQ Beam Line** Ion cooling, transmission, differential pumping, isotope separation, diagnosis, beam distribution introduction of reference ions	**Multiple-reflection TOF-MS** Ion identification, isobar separation direct mass measurements

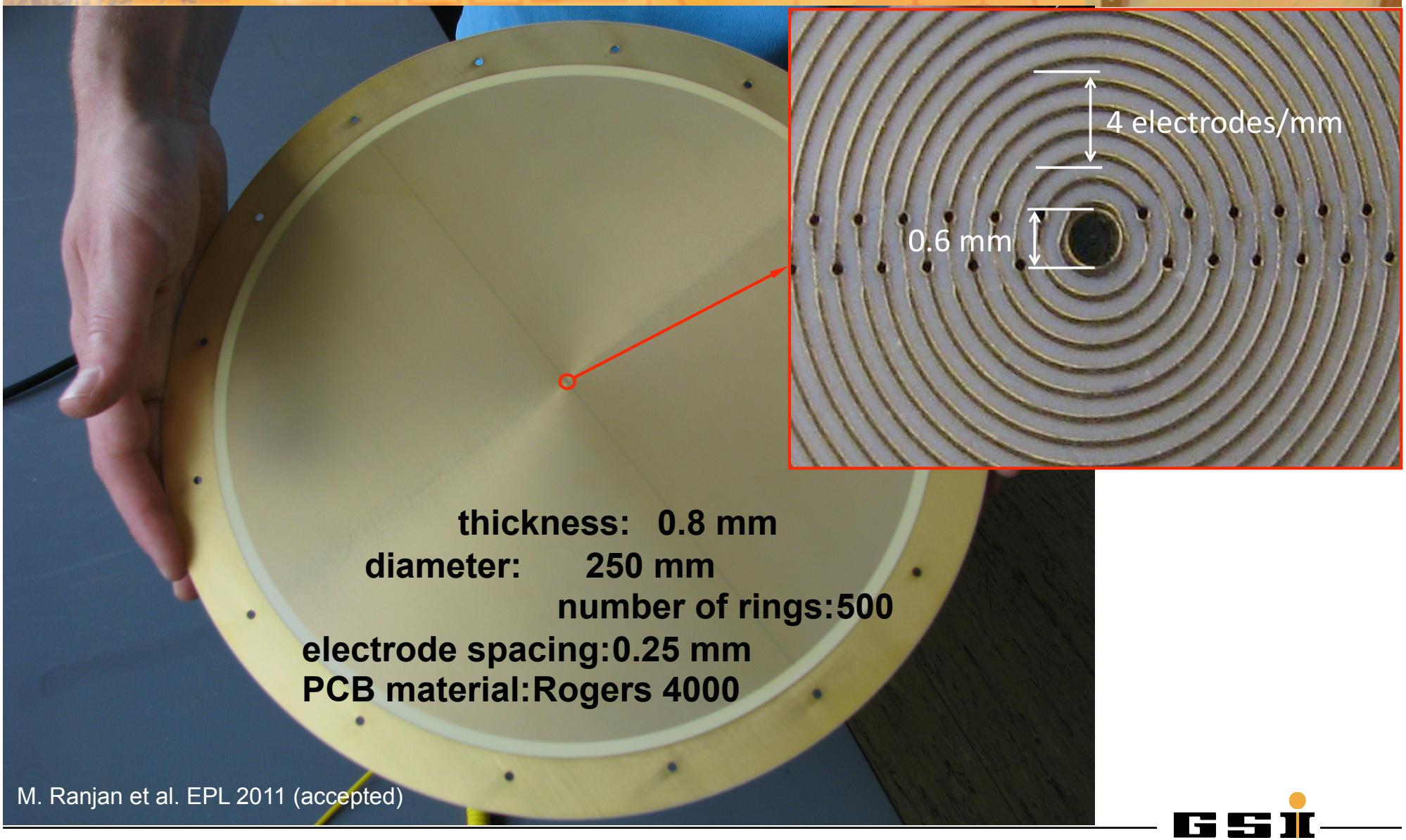


M. P. Reiter, Master Thesis (2011), Justus-Liebig-Universität Gießen
W.R. Plaß et al., NIMB 266 (2008) 4560

Cryogenic stopping cell & MR-TOF at S4

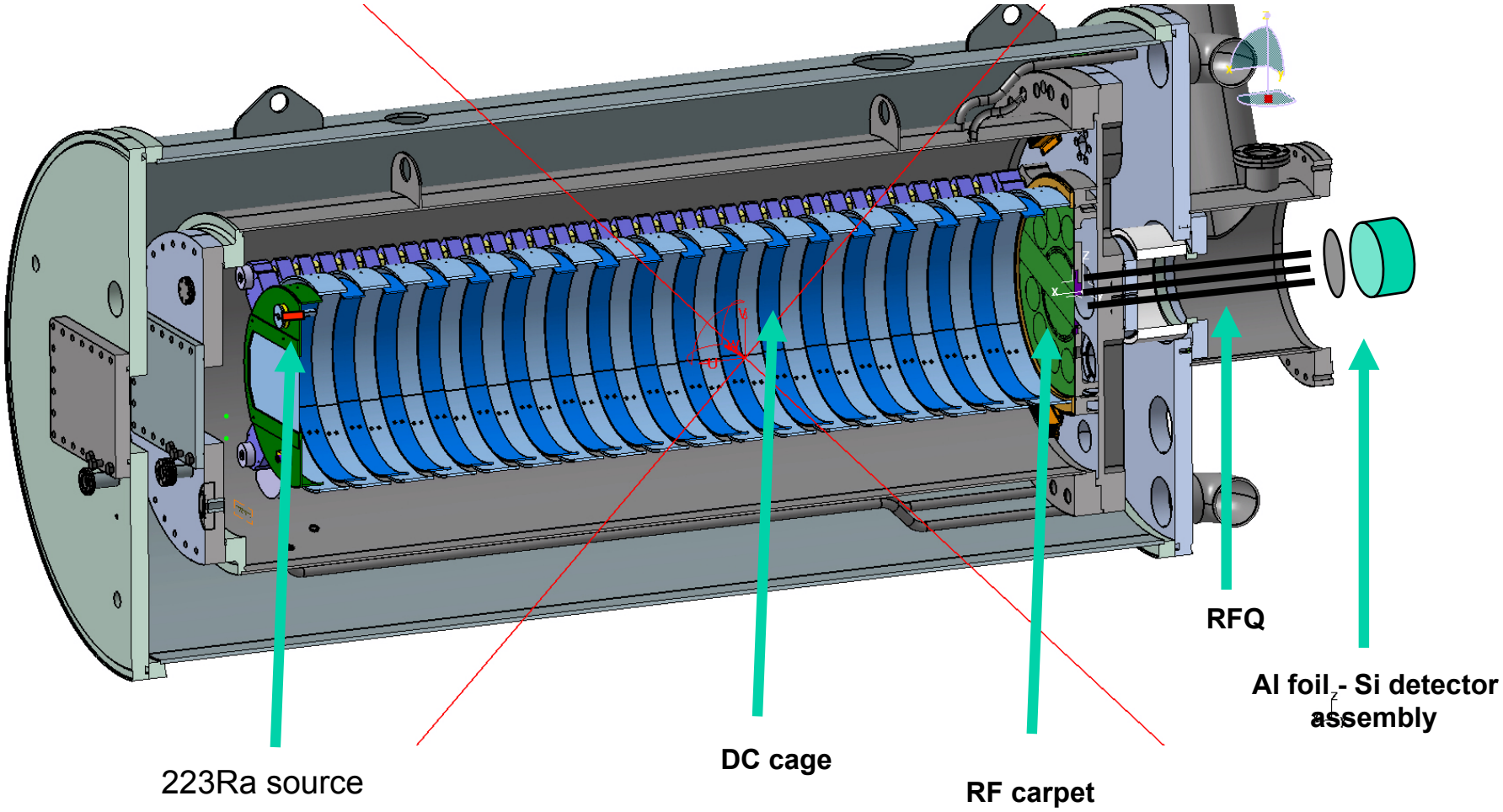


Cryogenic Stopping Cell: RF Carpet



M. Ranjan et al. EPL 2011 (accepted)

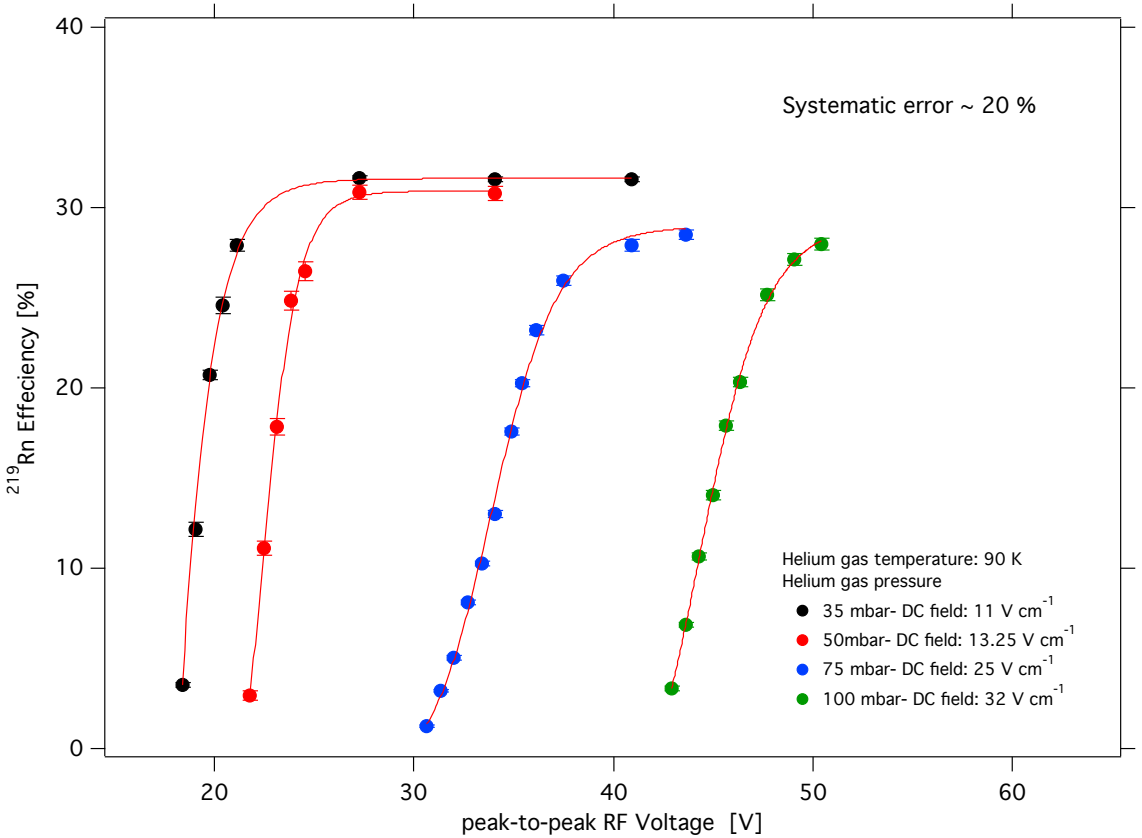
Cryogenic stopping cell - offline test



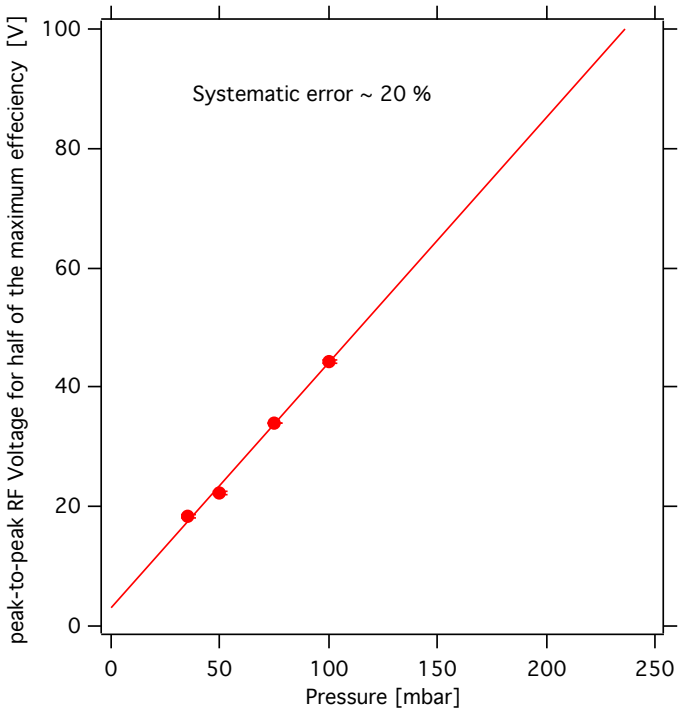
M. Ranjan PhD Thesis, University of Groningen (in preparation)
M. P. Reiter, Master Thesis (2011), Justus-Liebig-Universität Gießen

Offline test

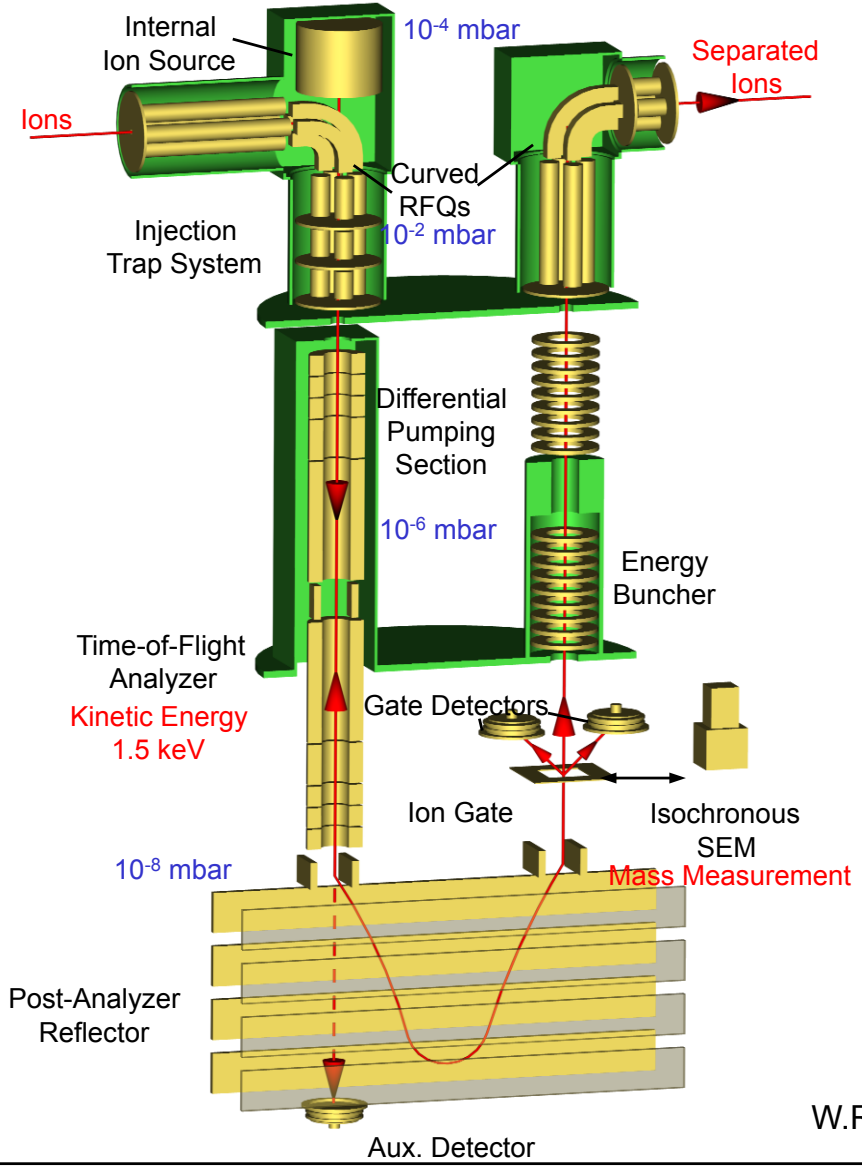
Survival and extraction efficiency measurement with a ^{223}Ra source

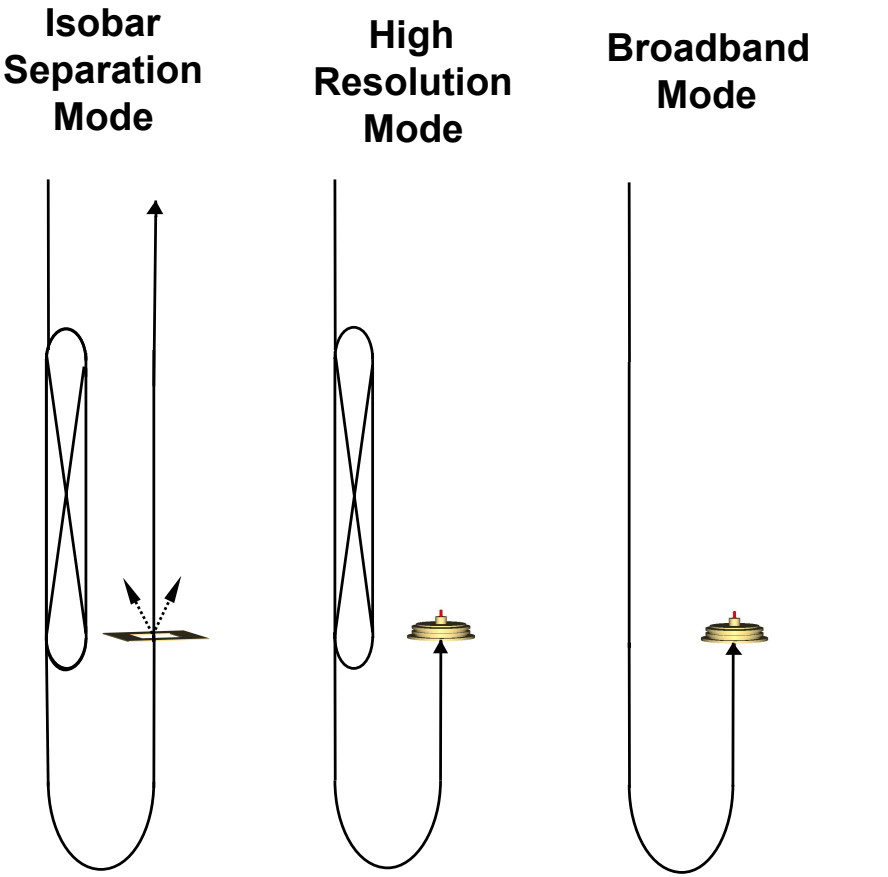


Peak-to-peak RF voltage required to achieve the half value of the maximum efficiency



Multiple-Reflection Time-of-Flight Mass Spectrometer





W.R. Plaß et al., NIMB 266 (2008) 4560

Performance Characteristics of the MR-TOF-MS

Universal mass spectrometer and mass separator
(works for all elements, stable and unstable ions)

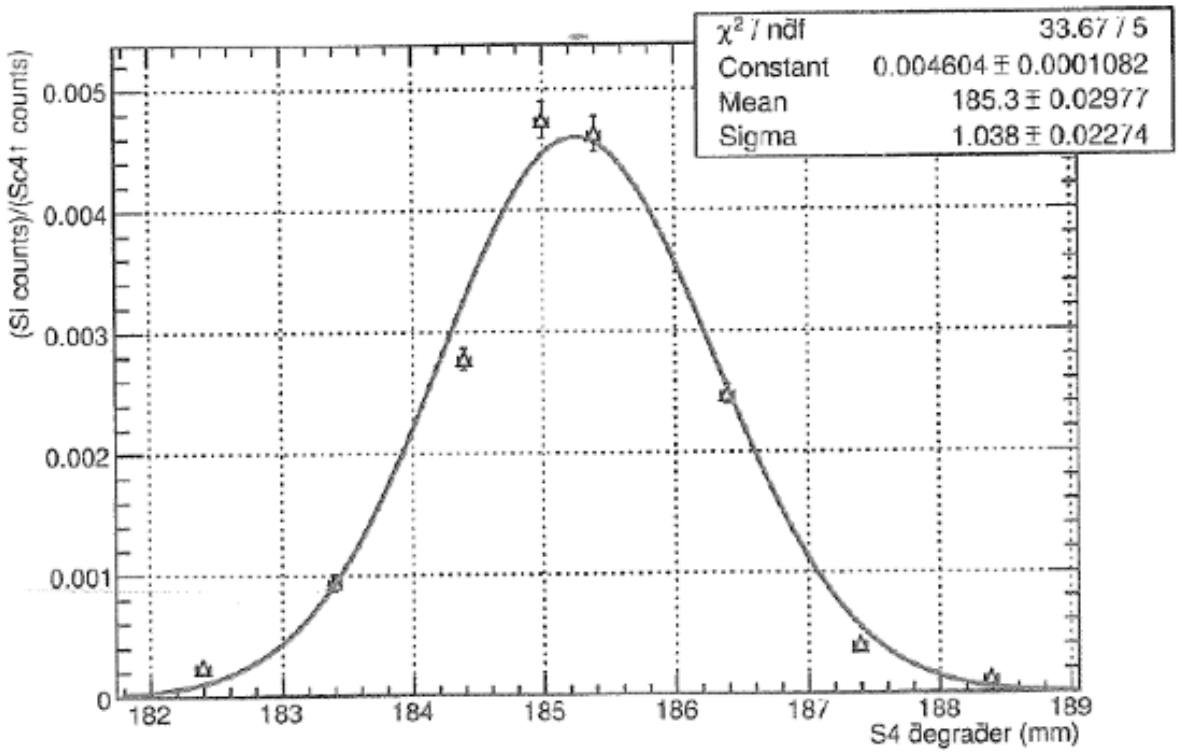
Mass Resolving Power	Mass Range
600,000	~% - full
Mass Measurement Accuracy	Transmission efficiency
~10^{-7}	up to 70%
Measurement Duration	Ion Capacity
~10 ms	> 10^6 ions / s
Sensitivity	Calibration
~10 ions	external / internal

World-wide unique combination of performance characteristics!

T. Dickel, PhD Thesis (2010), Justus-Liebig-Universität Gießen

FRS range bunching

S4 degrader thickness scan for ^{223}Th

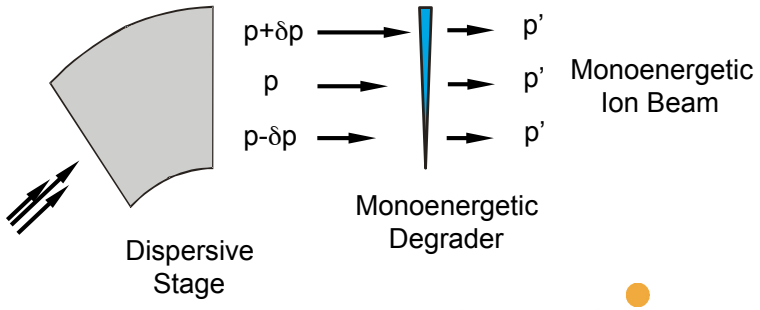


length gas cell =	4.80	mg/cm2 He
sigma range distribution =	1.038	mm step motor
sigma range distribution =	16.608	mg/cm2 Al
sigma range distribution =	12.78	mg/cm2 He
fraction stopped inside =	0.149015	

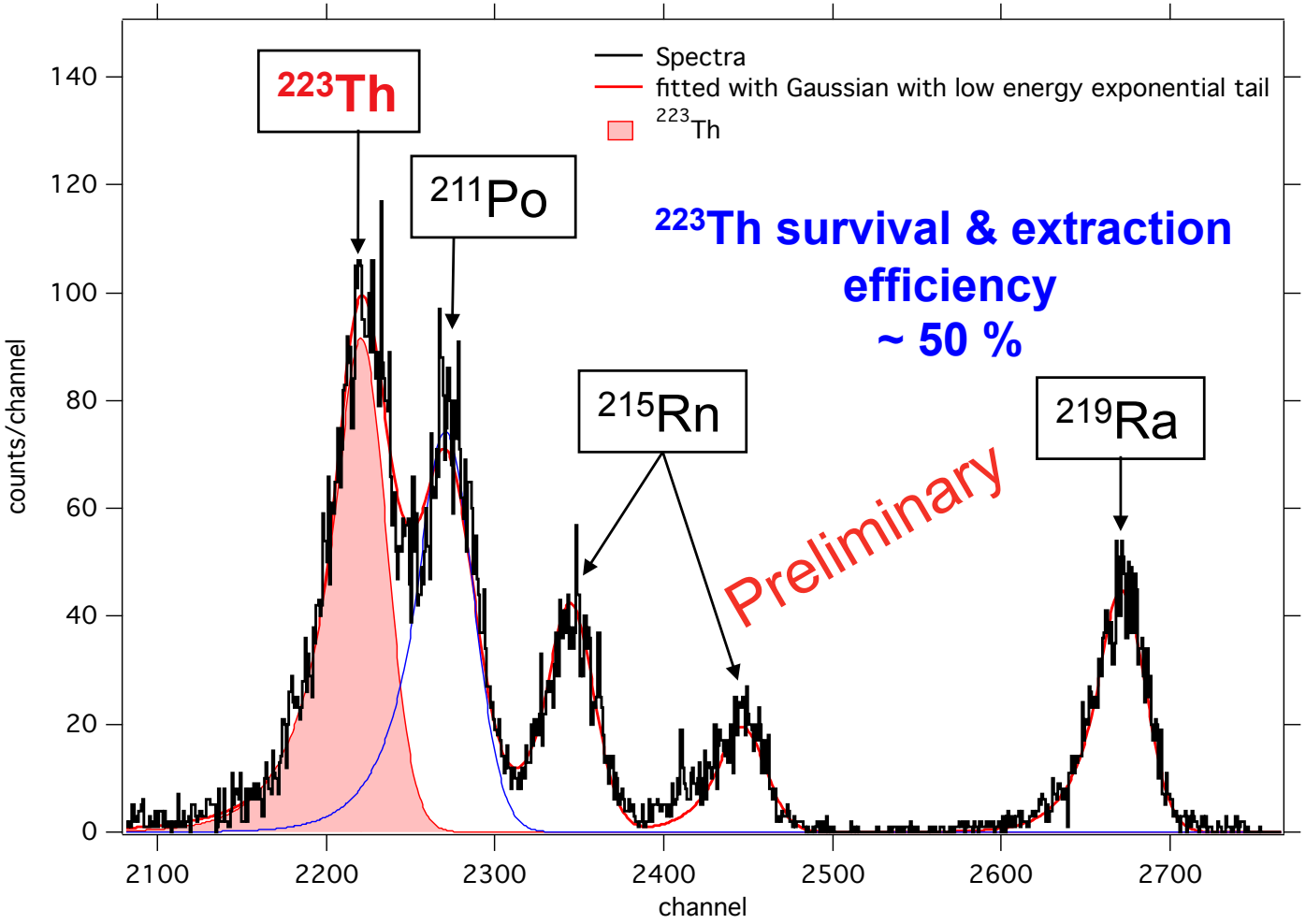
^{238}U projectile fragments produced at 1 GeV/u and separated and range-bunched in the FRS

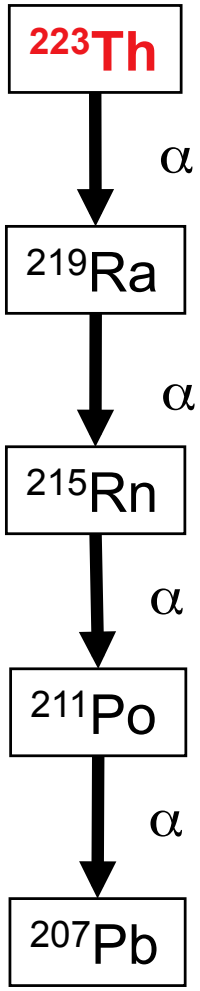
Helium areal density used
4.8 mg cm^{-2}
100 mbar at 100 K
300 mbar at 300K

Stopping efficiency
~ 15%



^{223}Th – Online measurement

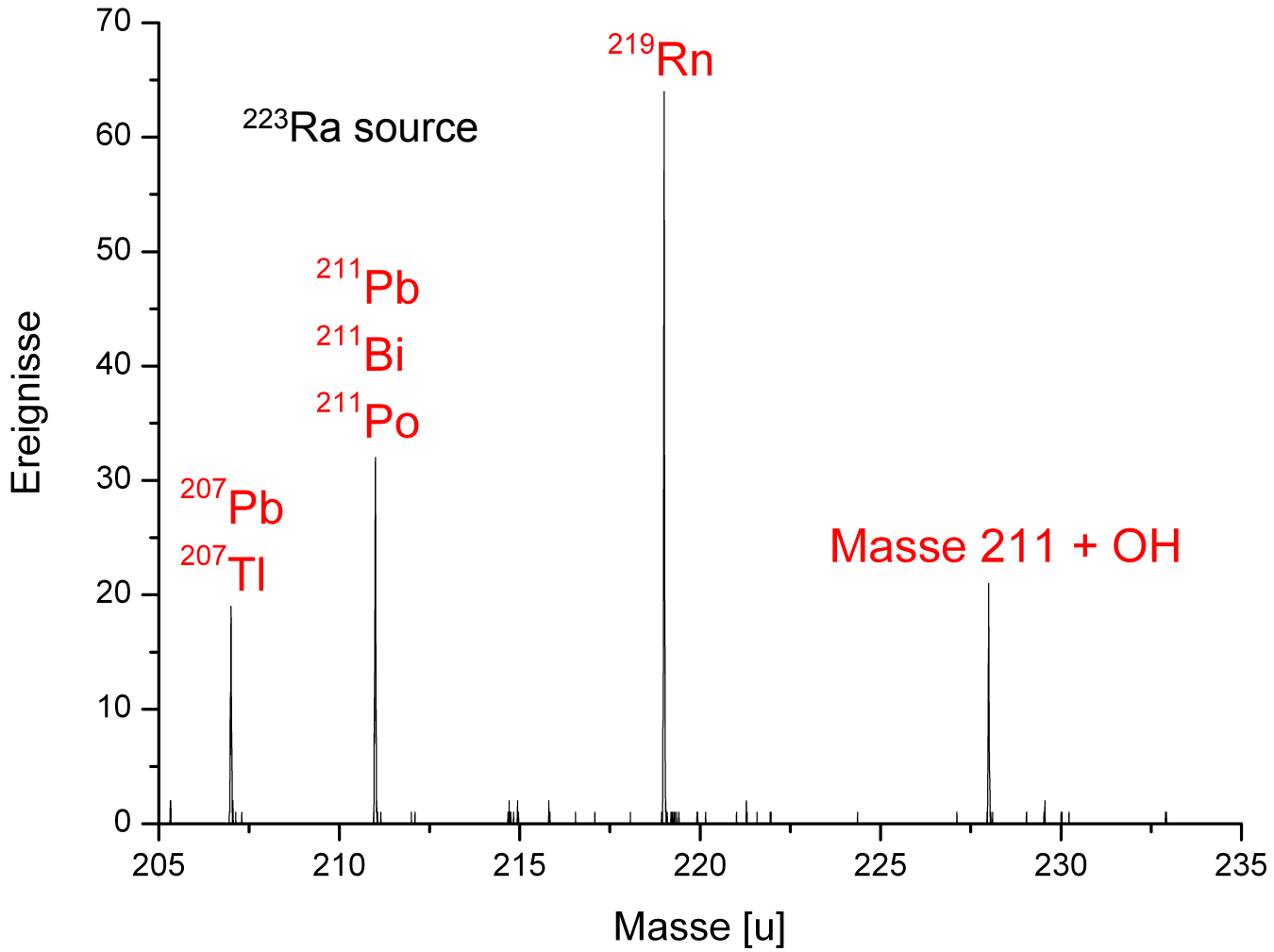




First on-line operation of a cryogenic stopping cell!

^{223}Th: total efficiency (stopping + extraction) ~ 8%

Mass scan with MR-TOF



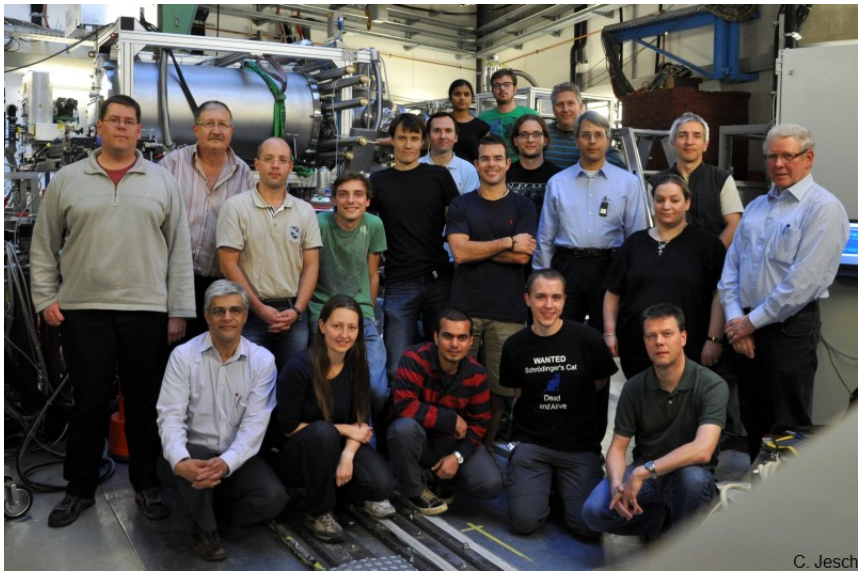
J. Ebert, Master Thesis, Justus-Liebig-Universität Gießen (2011)

Plans for next beam time (Spring 2012)

- Systematic study of
  - intensity limitations
  - temperature/cleanliness
- Test mass measurement

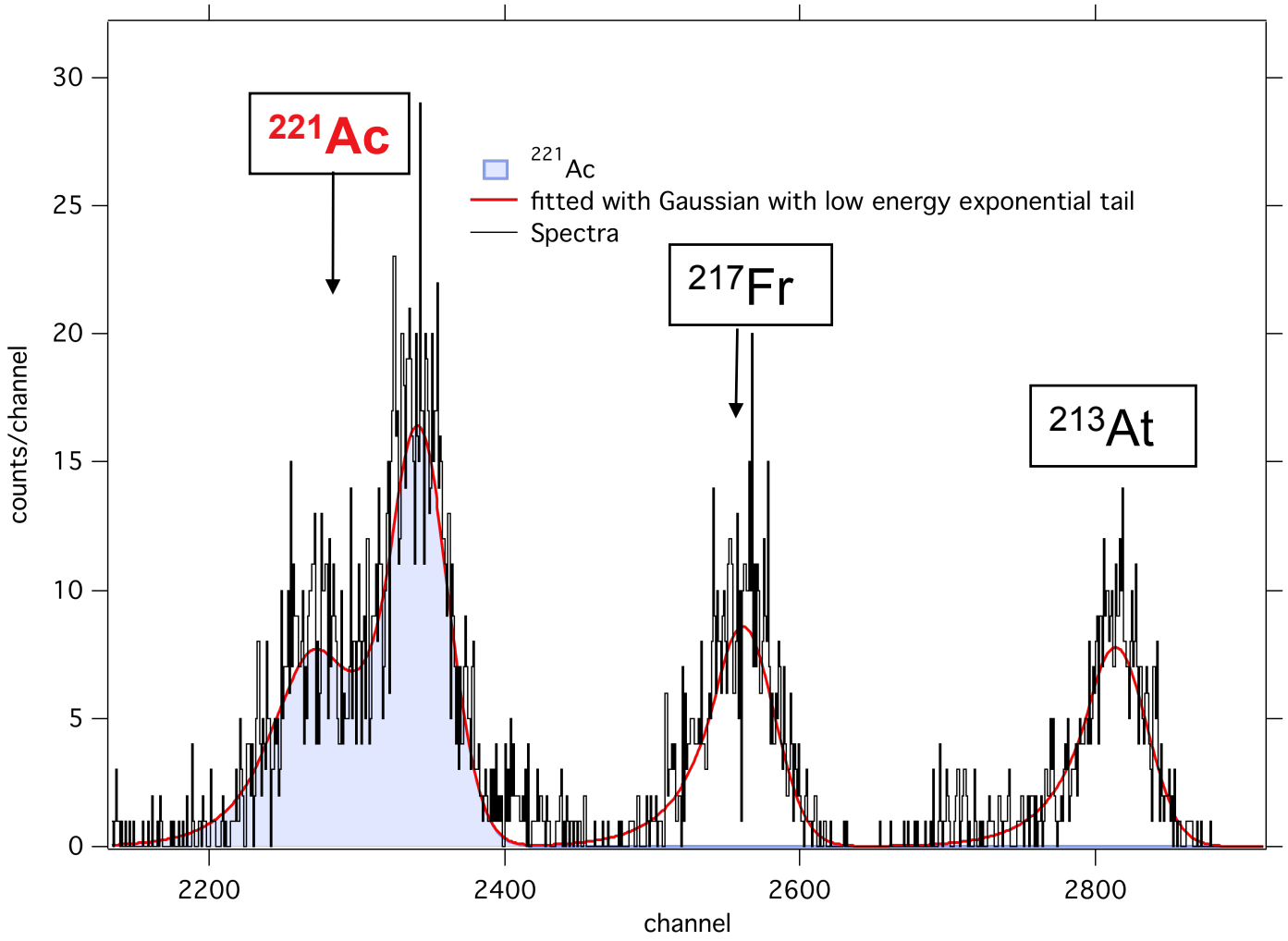
S411 / FRS Ion Catcher Collaboration

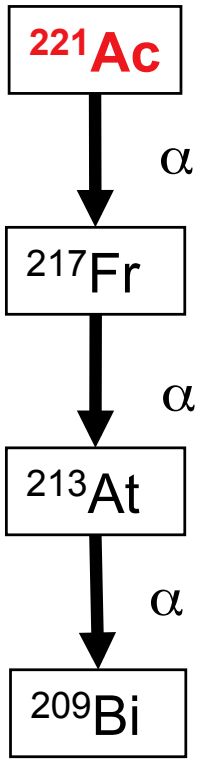
Spokesperson:	P. Dendooven	KVI – Univ. Groningen
Co-spokesperson:	W.R. Plaß	GSI, JLU Gießen
GSI contact person:	S. Purushothaman	GSI
	T. Dickel	JLU Gießen
	J. Ebert	JLU Gießen
	H. Geissel	GSI, JLU Gießen
	E. Haettner	JLU Gießen
	C. Jesch	JLU Gießen
	N. Kalantar	KVI-Univ. GRoningen
	R. Knöbel	GSI, JLU Gießen
	J. Kurcewicz	GSI
	I.D. Moore	Univ. Jyväskylä
	C. Nociforo	GSI
	H. Penttilä	Univ. Jyväskylä
	S. Pietri	GSI
	M. Ranjan	KVI – Univ. Groningen
	M. P. Reiter	JLU Gießen
	S. Rinta-Antila	Univ. Jyväskylä
	C. Scheidenberger	GSI, JLU Gießen
	M. Takechi	GSI
	P. Thirolf	LMU
	H. Weick	GSI, JLU Gießen



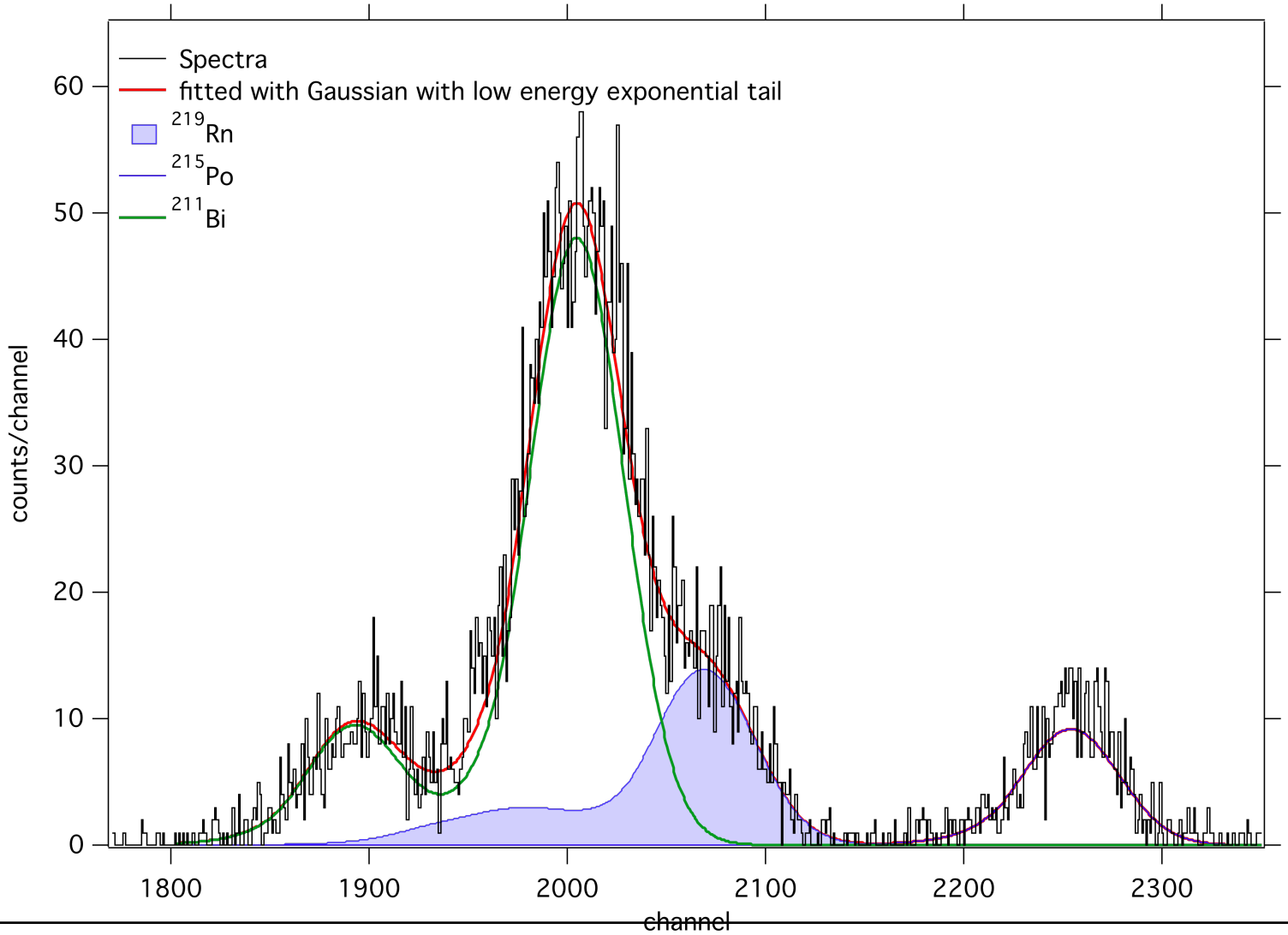
Kernfysisch Versneller Instituut
university of groningen
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN
GSI
UNIVERSITY OF JYVÄSKYLÄ
LMU

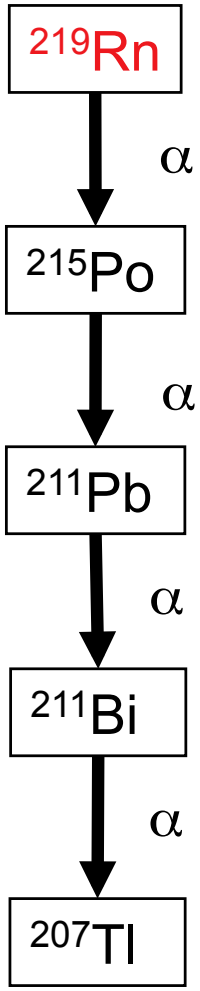
^{221}Ac – Online measurement





^{219}Ra – Online measurement





Offline test - ^{223}Ra - Source

Offline alpha recoil source