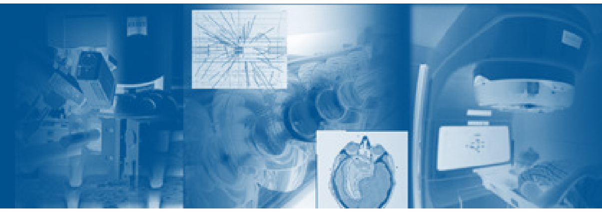
R&D for Hadron Storage Rings

Dieter Prasuhn, FZJ



Topics:

- (polarized) Ion sources for hadron storage rings FZJ
- Combined electrostatic and magnetic deflectors FZJ
- High energy beam cooling FZJ
- New accumulation schemes for storage rings GSI
- Cavity design GSI
- Diagnostic tools for ion beams of extreme low intensities GSI

(polarized) Ion sources for hadron storage rings

Motivation:

- Assure high intensity beams for COSY
- Possible later experiments at FAIR with polarized beams

Leading lab: FZJ

Collaboration partners:

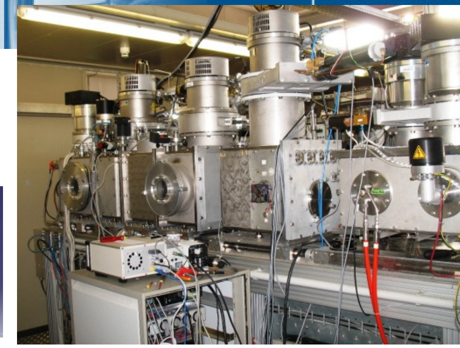
- BNL Brookhaven
- IUCF Bloomington
- INR Moscow

Abstract

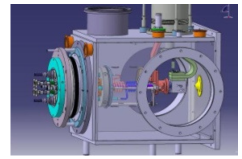
At FZJ the availability of polarized beams with the maximum possible intensity and quality has to be assured. For the planned FAIR project the potential will be enhanced by providing polarized beams. First, an analysis of existing sources and subsystems will be pursued. According to the results of this analysis a new polarized ion source can be designed and built in the period 2015-2019. The developments will be carried out with partners Brookhaven BNL, IUCF Bloomington, INR Moscow, and cooperating universities. An ion source, based on the proven concept of resonant charge exchange of a pulsed, nuclear spin-polarized atomic beam with an intense plasma beam, appears as the appropriate approach.

Projects, with cooperation contracts or intentions:

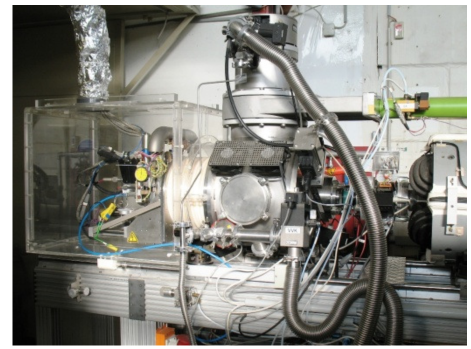
- Improvement of the atomic beam intensities
- Plasma ionizer with partners
- Testing and validation of the performance and long-term behavior at FZJ
- Development and improvement of diagnostic tools



- Investigation of pulsed (polarized) atomic H and D beams
  - Production of intense pulses
  - Determination of intensity and beam characterization
  - Needed input for transport optimization

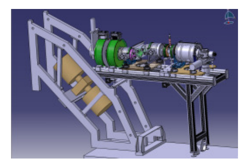


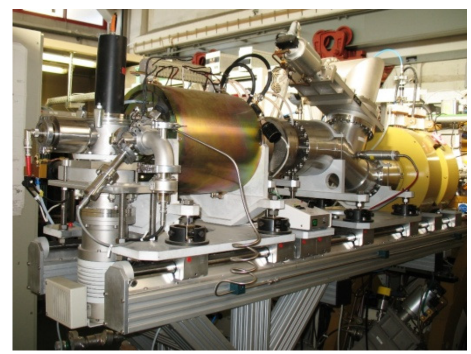
- Next steps
  - Design magnet system, purchase it and verify the performance
  - Beam studies Q2-Q3/2012



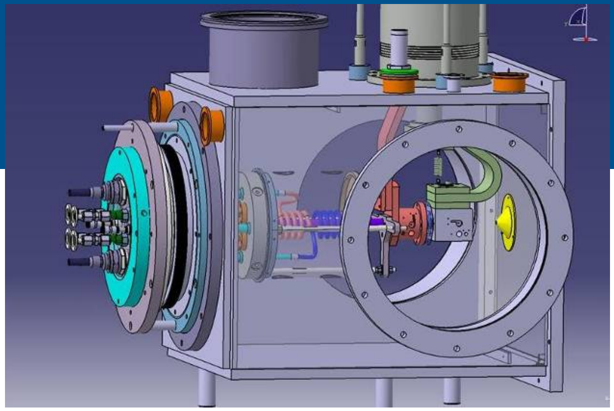
- Pulsed $Cs^{+/0}$ beams with improved brightness
  - Enabling the operation of a second ionizer with diagno
  - Design of a pulsed extractor for increased intensity

- Next steps
  - Finalizing control system and diagnostic elements
  - Ionizer modules will be available soon
  - First beams in Q3/2012



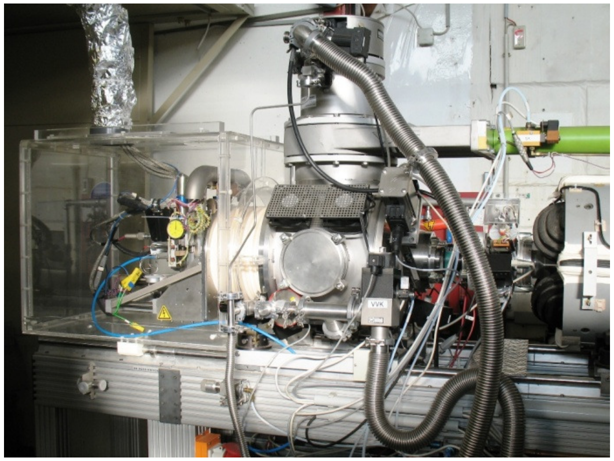


- Plasma Ionizer/ Charge exchange and extraction
  - Continue design studies



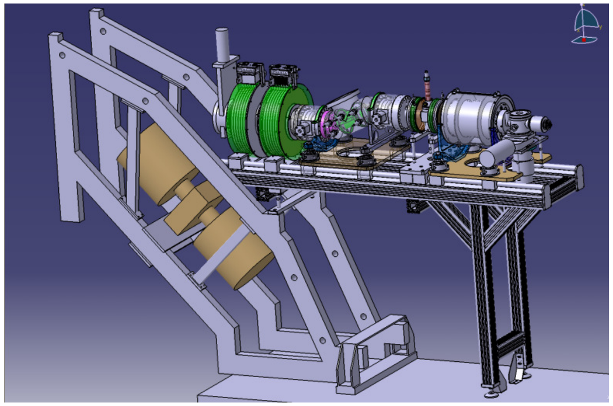
Atomic beam studies

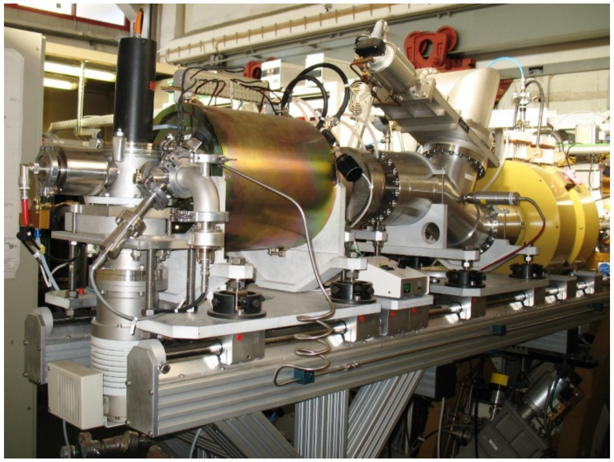
- Intensity
- Density, profiles
- Velocity distribution



Cs beam studies

- Intensity
- Profile/ Brightness





Beam diagnostics

- Polarization

Motivation:

- Search for an electric dipole moment in p and d

Leading lab: FZJ

Collaboration partners:

- BNL Brookhaven
- Technical University Aachen

Abstract

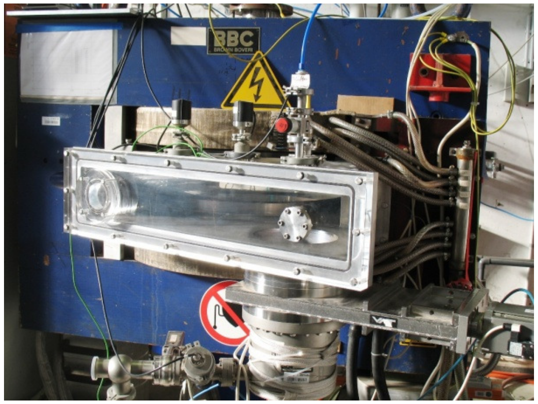
Modern interest in elementary particle and bound-state electric dipole moments (ÉDM) stems from the pioneering work of more than 50-year quest to find a neutron EDM anticipated parity (P) and time-reversal (T or CP) violation, necessary ingredients for the existence of a non-zero EDM. The standard model predicts non-vanishing EDMs; however, their magnitudes are expected to be unobservably small. Hence, discovery of a non-zero EDM between the current bounds and standard model predictions would signal “new physics” CP violation. Uncovering such a phenomenon could prove crucial in understanding the matter-antimatter asymmetry of our universe which seems to require (suggest) new large sources of CP violation beyond standard model expectations. A novel method has been propose within an international collaboration using dedicated storage rings to determine the electric dipole moment of protons and deuterons with a one sigma sensitivity of 10–29 e cm. per 10^7 s running time. At this level it will be the best experiment among current and currently planned EDM experiments. The main bending field for the proposed proton EDM experiment has to be purely electrostatic whereas combined electrostatic and magnetic field deflectors are essential to perform a deuteron EDM experiment, which is complimentary to the proton EDM measurement. The proposed techniques are presently tested and perfected by running very important hardware tests at KVI (the Netherlands) and COSY (Germany), where polarized protons and deuteron beams are available.

R&D work for deflectors with combined electrostatic and magnetic bending fields:

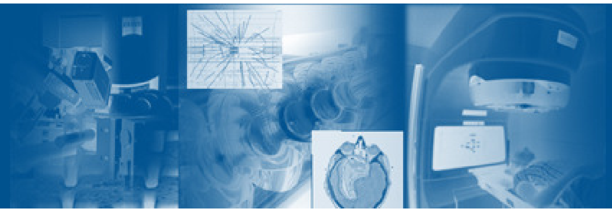
- Layout: field calculations to optimize the coil and conductor plate arrangement
  with respect to filed quality and stability
- Design: mechanical design of the deflector
- Prototype: development of a deflector prototype
- Test bench: Development of a test bench to study field quality and stability of the prototype

R&D for E/B deflectors

- Review and investigation of electrostatic and magnetic deflector designs
  - Electrostatic bends for GeV/c beams
  - Beam and spin dynamics
  - Collaboration started / kick-off
  - Upgrade the existing test bench for E/B deflectors
- Pulsed / RF deflectors
  - Design of an RF deflector and test in COSY
- Next steps 2012
  - Conceptional design of E/B deflector
  - Realizing control system and diagnostic elements



High energy beam cooling



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Motivation:

- **Electron cooling at COSY up to maximum momentum**
- **Electron cooling at HESR up to maximum momentum**
- **Fast stochastic cooling at differet energies**

Leading lab: FZJ

Collaboration partners:

- **GSI**
- **HIM, Mainz**
- **JINR, Dubna**
- **BINP, Novosibirsk**

Topics:

- High energy electron cooling
- Broad band stochastic cooling

Goal: magnetized electron cooling up to 8 MeV electron energy

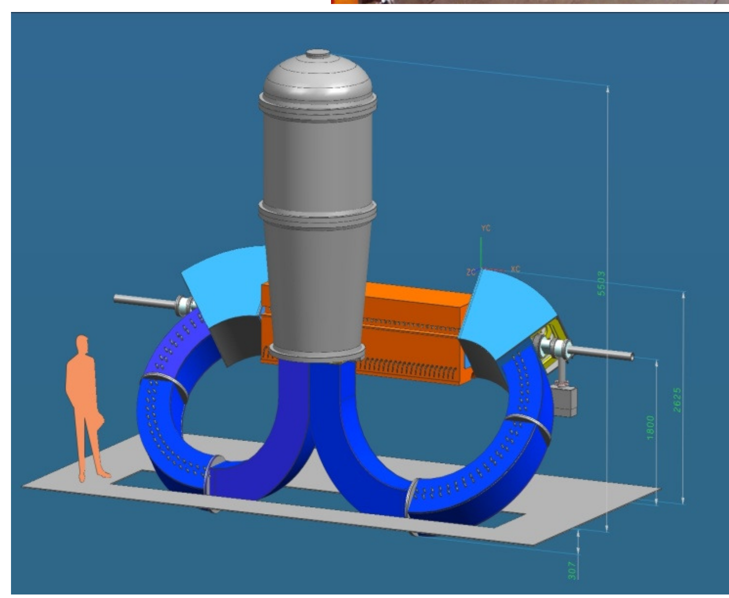
HESR: 4.5 MeV

Upgradeable
to 8 MeV

at COSY:

from 0.1 MeV

to 2 MeV



Parameters for the HESR stochastic cooler:

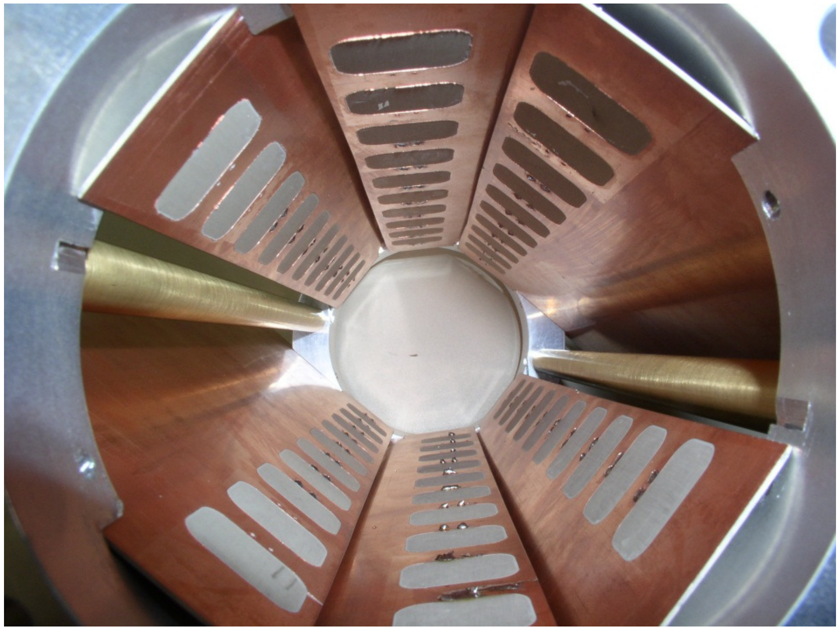
Momentum range (antiprotons): 1.5 - 15 GeV/c

Band width: 2 - 4 GHz, high sensitivity

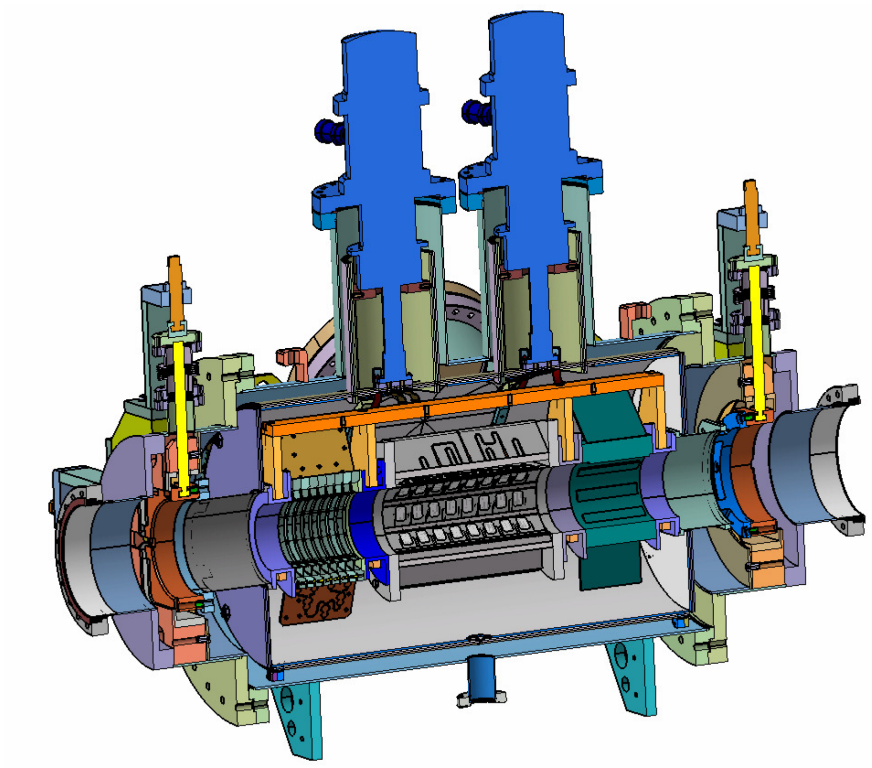
Longitudinal cooling: Notch-Filter, ToF

Aperture of couplers: 89 mm

Octagonal Printed-Loop Coupler



Stochastic cooling pickup (prototype) installed in COSY



Slot couplers with fixed aperture show the same sensitivity as movable λ/4 structures

JINR (Dubna) has ordered the structures for NICA

Motivation:

- **Accumulation in HESR for the FAIR-Modularized Start Version**
- **Accumulation in the RESR**

Leading lab: GSI

Collaboration partners:

- **FZJ**

Simulation of Barrier Bucket Accumulation

Barrier Bucket Scheme for Beam Compression in ESR

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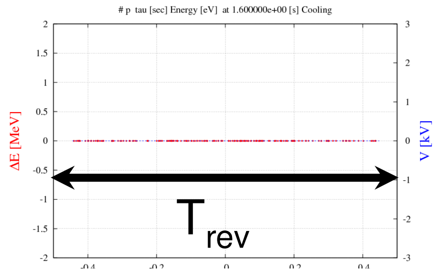
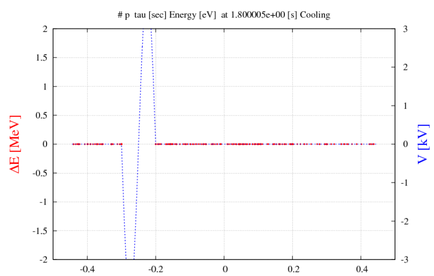
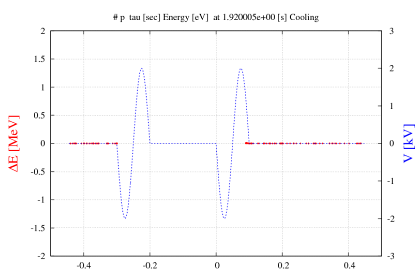
Electron cooling always ON.



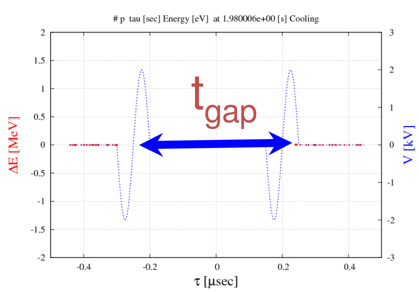
1. After injection, debunching and ecool of the coasting beam



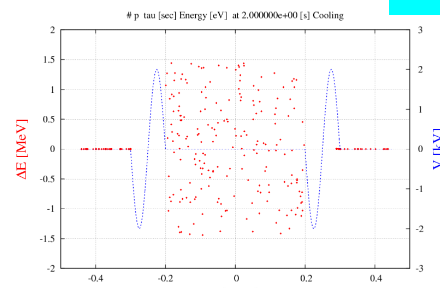
2. BB pulses ON, Δt ~0.5 s



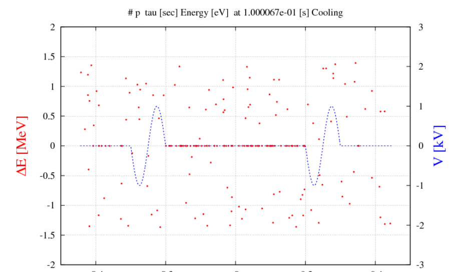
3. Compress the stack to create the gap: Moving the BB pulse Δt ~0.5 s



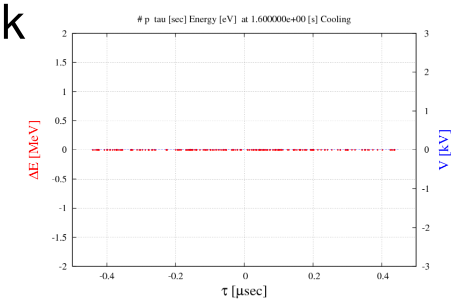
4. Gap ready for new injection (gap peak to peak adjustable 0-600 ns)



5. New injection. Beam not captured by the BB voltage (170 V) and starts to fill the ring.



6. Decrease BB voltage (Δt ~ ns; negligible). Debunching into a coasting beam

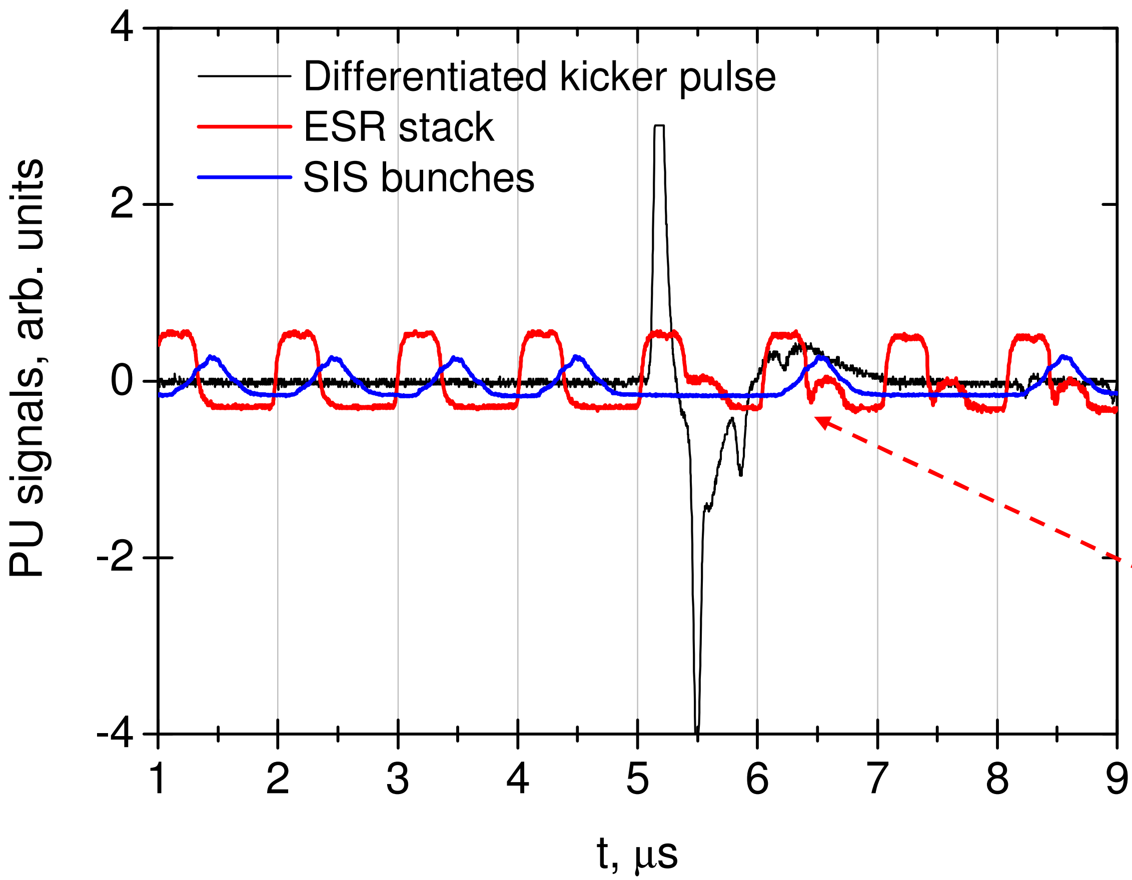


7. BB pulses OFF. Ecool the beam and back to step 1.

$$\boxed{T_{rev} = t_{kicker} + T_{BB} + t_{gap} + t_{accu}}$$

T_{rev}	t_{kicker}	T_{BB}	t_{gap}	t_{accu}	
≥1000	2x100	200 @ 5 MHz	400	≥200	ns

V_{BB}=120 V, T_B=200 ns (f_{rf} =5 MHz), I_e=0.1 A, stacking cycle=9 s

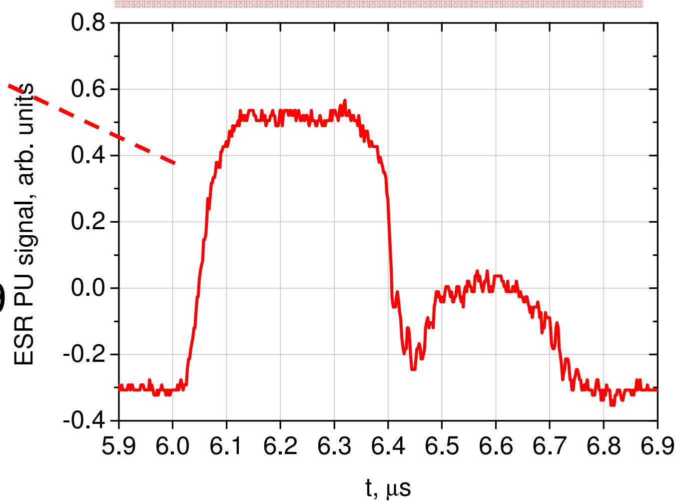


signals not corrected for cable delays

Injection kicker: total pulse ~500 ns

SIS bunch length: 300-350 ns(FWHM)

ESR stack length: T_{stack}= 400 ns (75% of uniform distribution)



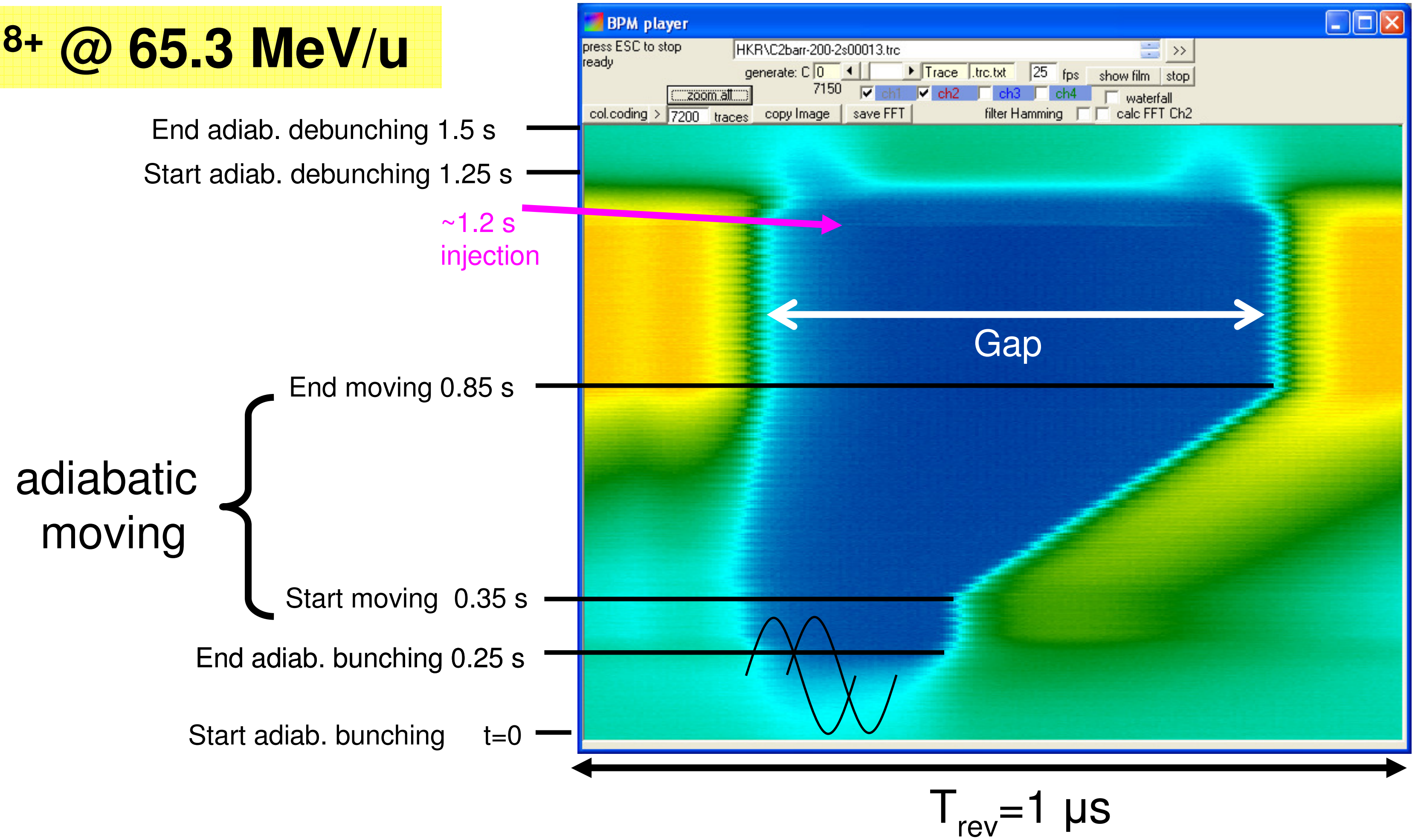
in combination with electron cooling

$^{40}Ar^{18+}$ @ 65.3 MeV/u

Beam signal in the ESR Pickup

(1 frame/ 200 revolutions for a total time of 1.46 s)

V_{BB}=120 V, T_B=200 ns (f_{rf}=5 MHz), I_e=0.1 A



Limitation of Intensity during Accumulation

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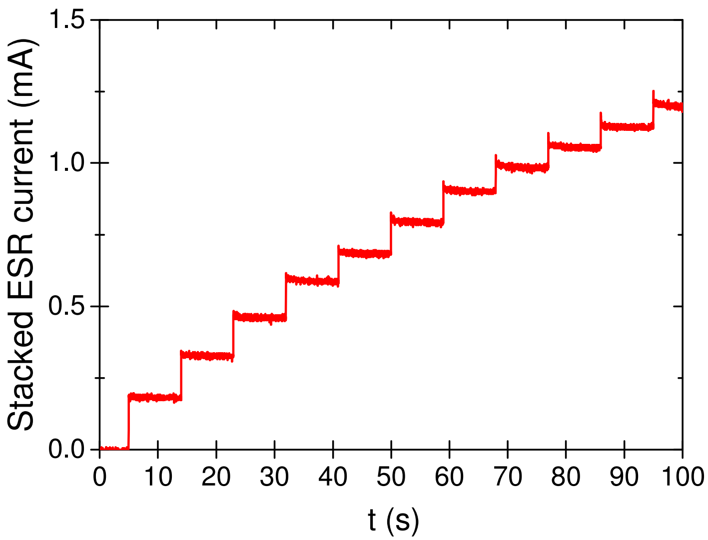
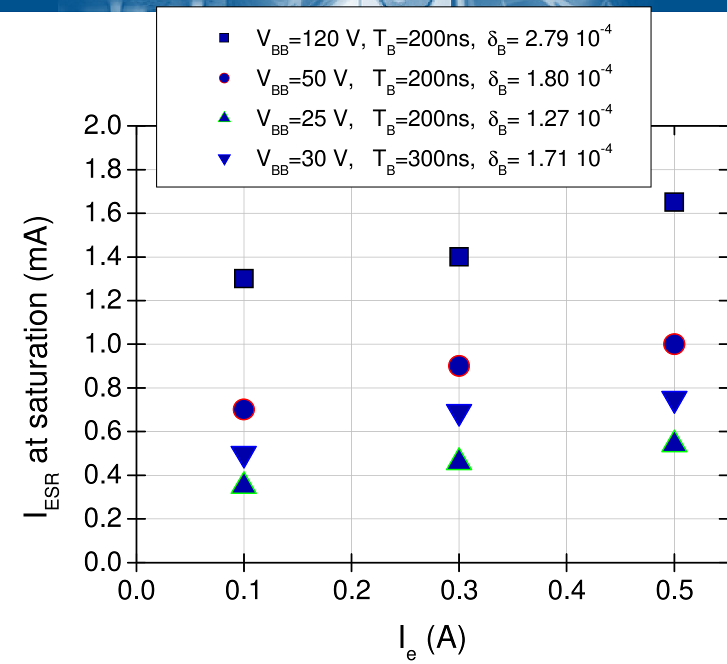
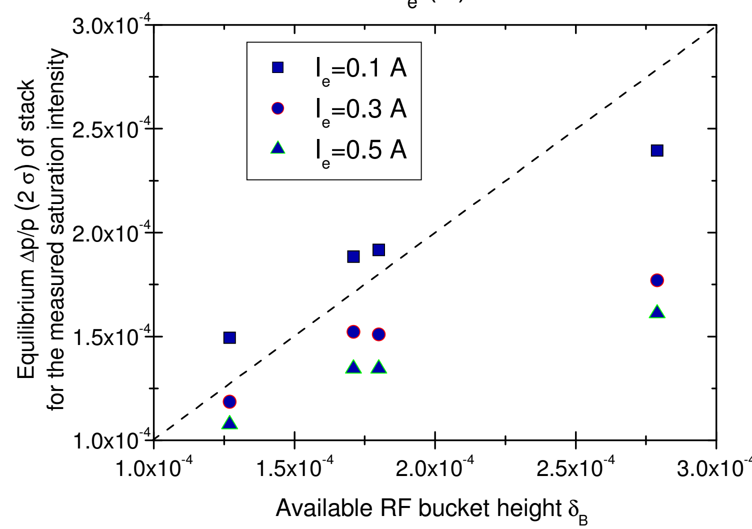
Stored ion current







Intensity limit is related to available rf amplitude

Highest intensities cannot be achieved with modified ESR cavity

Accumulation with Stochastic Cooling

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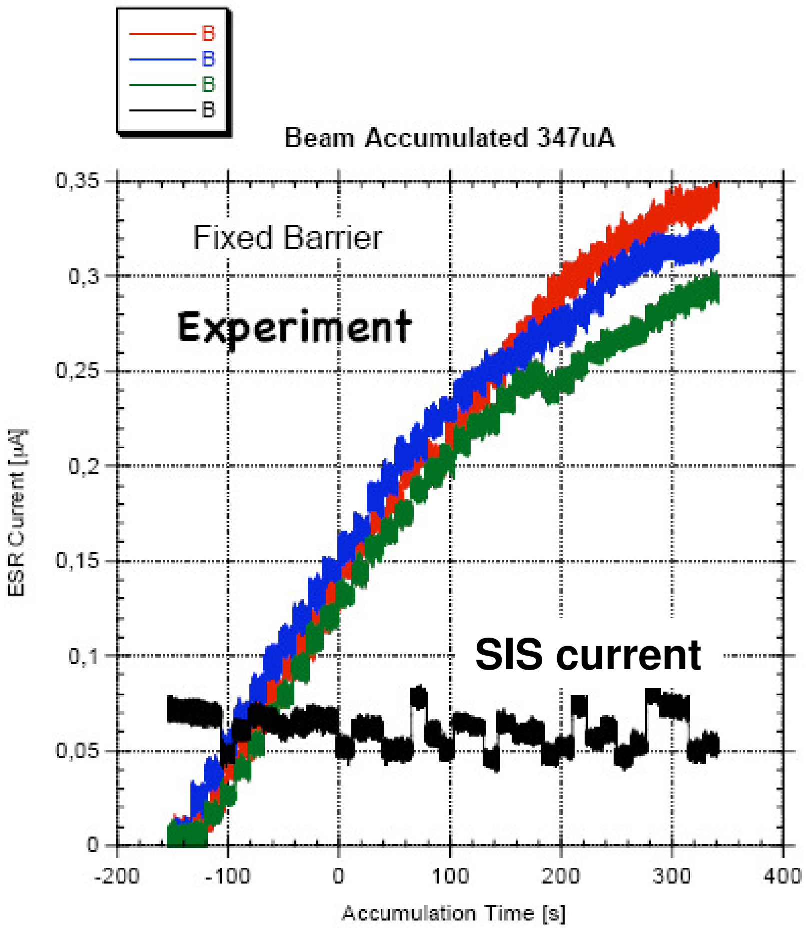
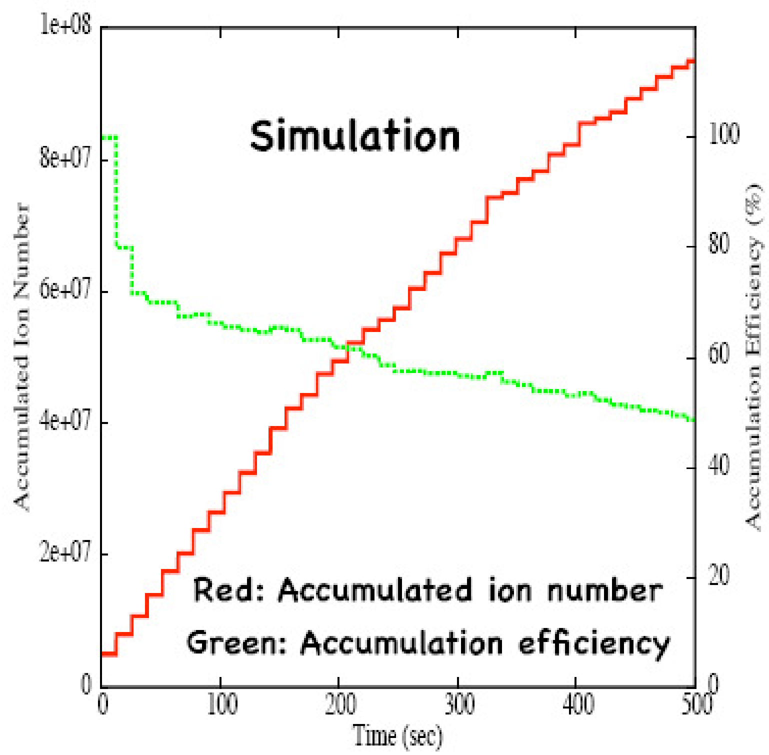
Fixed barrier bucket at ESR POP experiment

Ar^{18+} 400 MeV/u





Cavity design

Leading lab: GSI

Collaboration partners:

- FZJ

ESR Prototype Cavity

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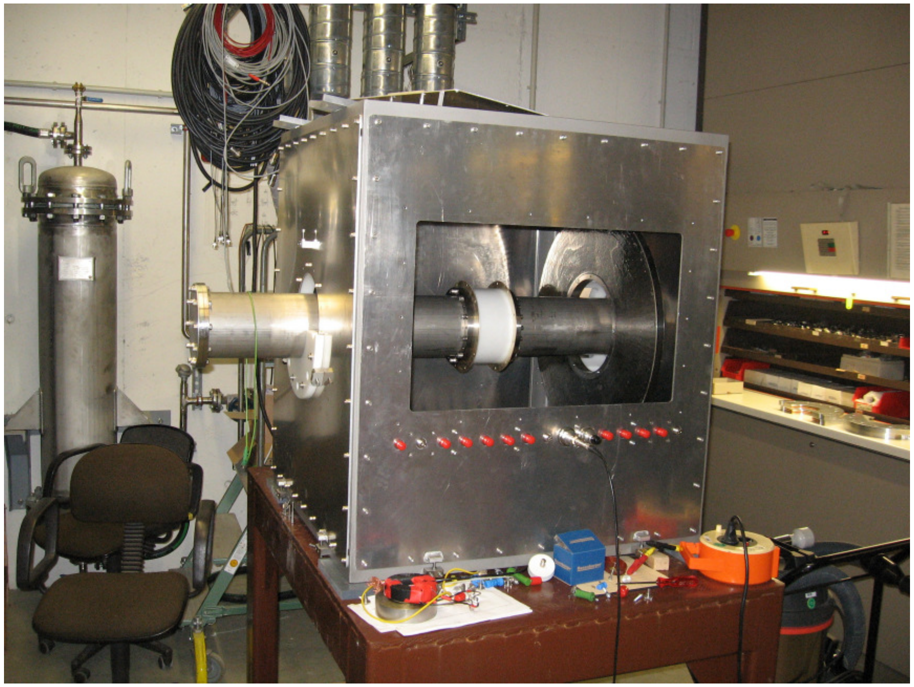

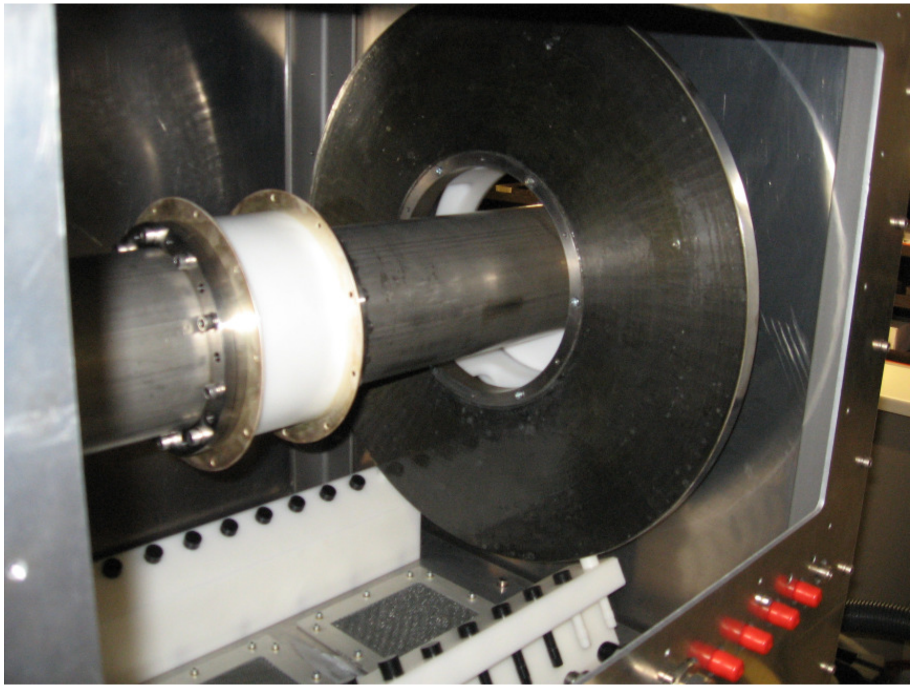

Will be equipped with vacuum chamber and prepared for installation in the ESR

Þ **Increased barrier voltages will be available for beam accumulation**
Investigation of intensity limits for accumulated ion beams

Diagnostic tools for ion beams of extreme low intensities

Leading lab: GSI

Resonant Schottky Pick-up

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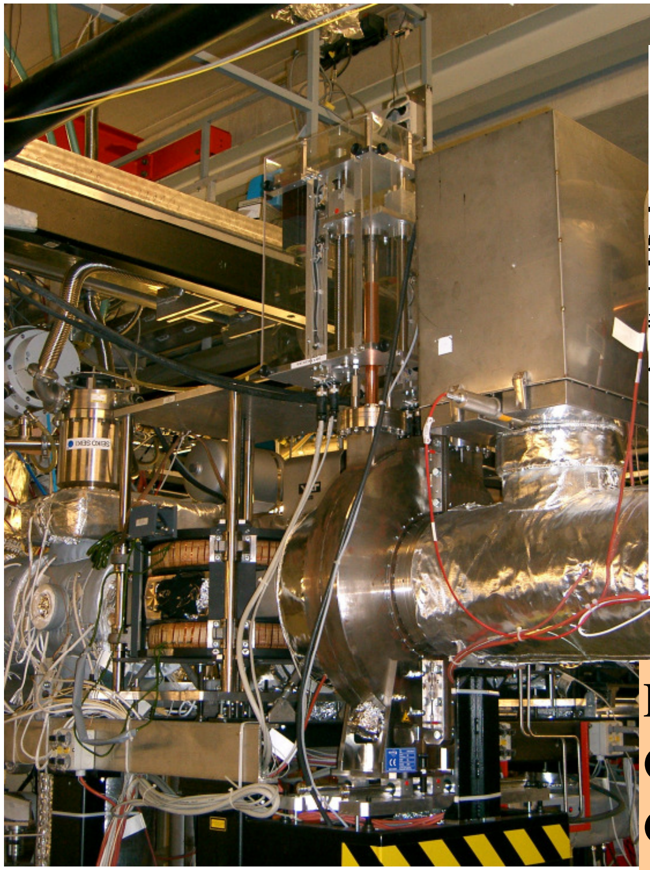
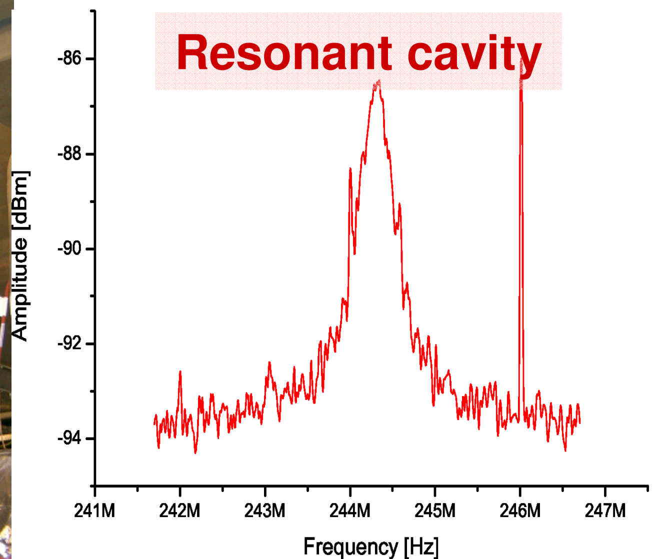
goal: high sensitivity for single ion detection

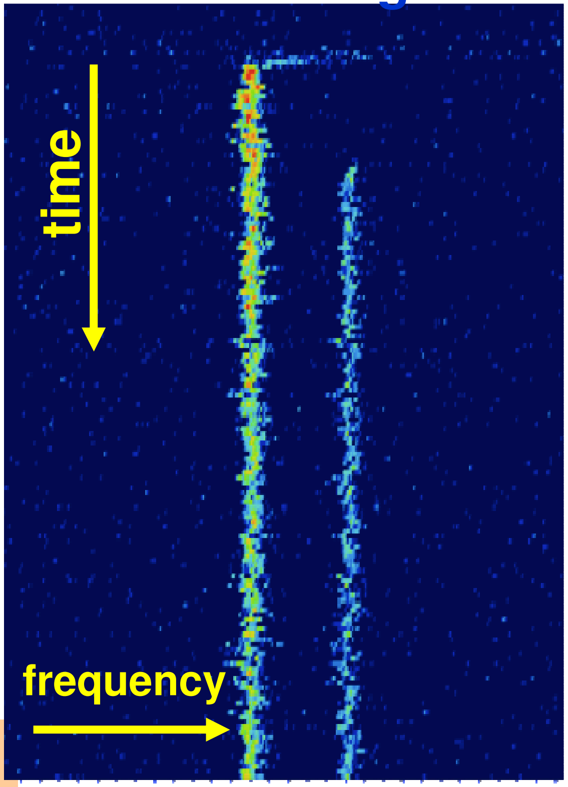


new Schottky resonator installed in the ESR



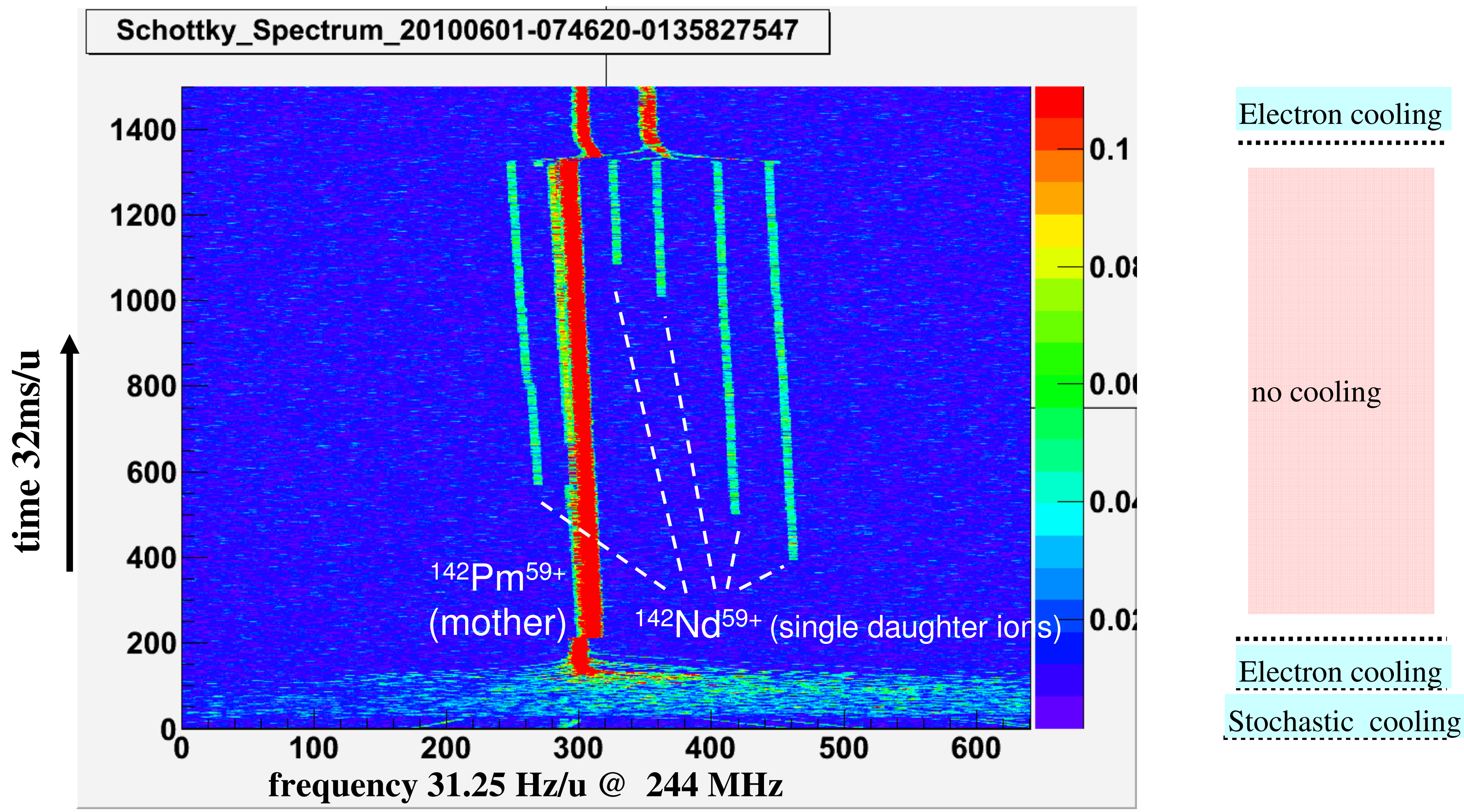
Frequency	244 $\pm$ 2.5 MHz
Quality factor measured	1130
Quality factor calculated	1940
R/Q exper.	50.7 Ω
R/Q theor.	50.3/43.1 Ω

Detection of single ions

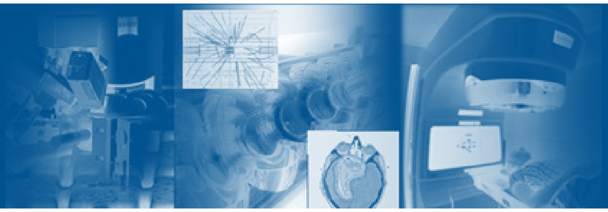


Observation of daughter nucleus after beta decay with high sensitivity and good time resolution (32 m

New Schottky Resonator



improved time resolution (32 ms) due to higher sensitivity and higher frequency



Thank you for your attention.

And thanks to all collaborators from GSI and FZJ for their support!