ILIMA Status and Perspectives

Helmut Weick, GSI
NUSTAR Week Valencia, 25th Sept. 2014

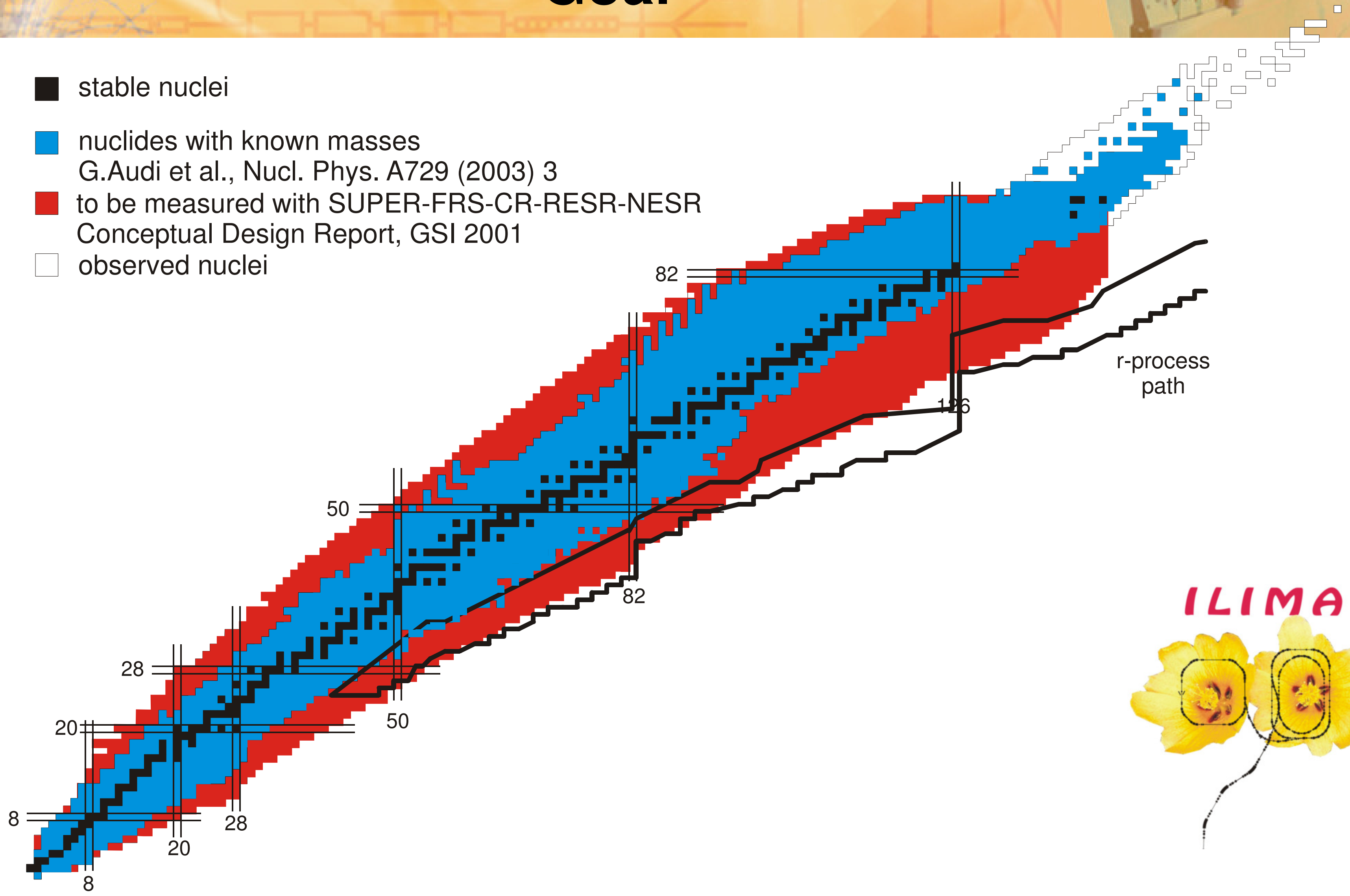
- **CR Facility**
- **Isochronous Mass Measurement Analysis**
- **ToF Detector Development**
- **Schottky Detection, Developments**
- **The Case for Particle Detectors in Ring**
- **Perspectives for HESR and ...**

ILIMA

GSI

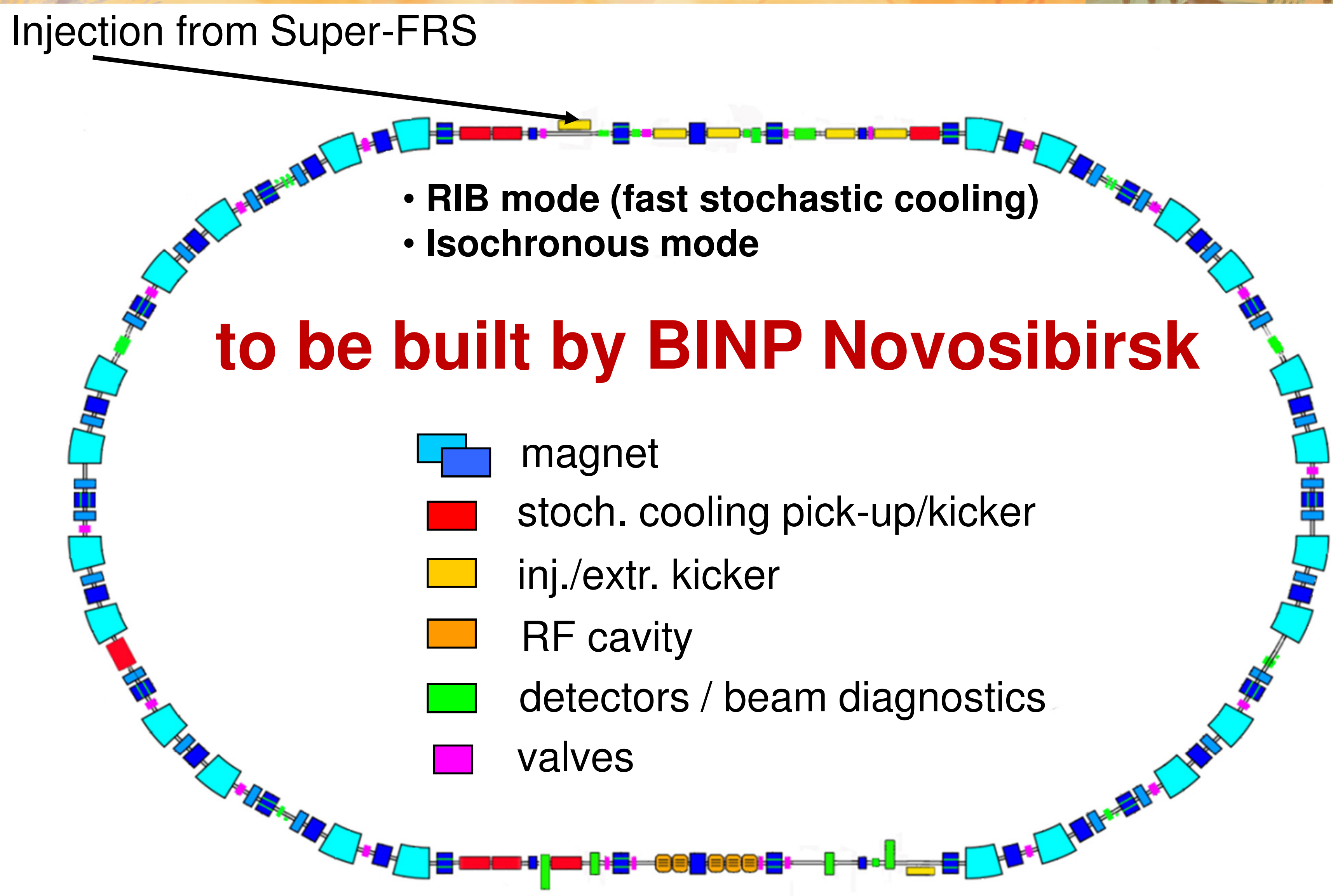
FAIR

ILIMA = Isomeres, LIfetimes and Masses
- Goal -



ILIMA

Collector Ring CR



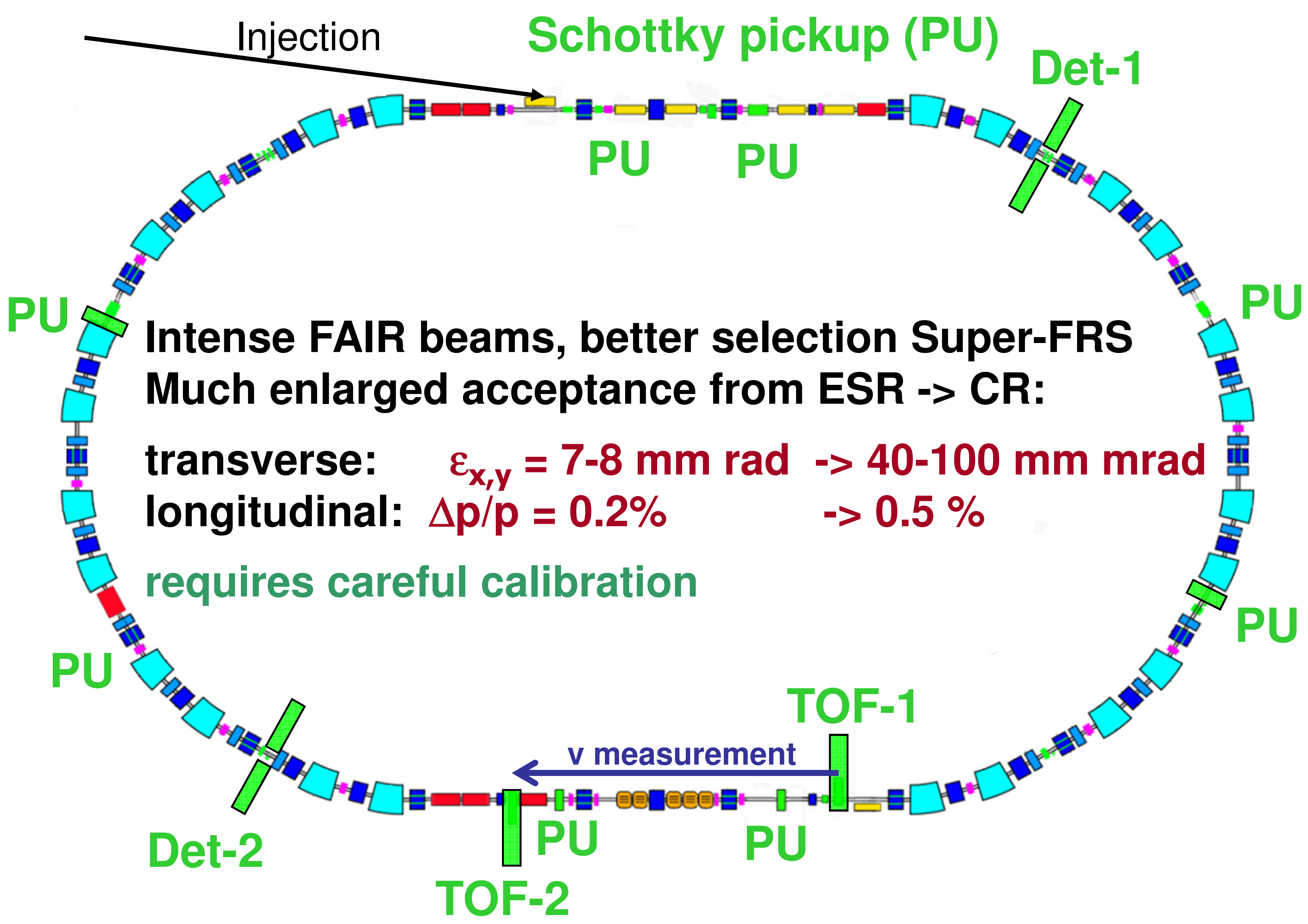
- **RIB mode (fast stochastic cooling)**
- **Isochronous mode**

to be built by BINP Novosibirsk

$L = 221.45$ m, $B\rho_{max} = 13$ Tm
$\gamma_t = 1.68$, $\Delta p/p = \pm 0.5$ %
$\varepsilon_x = \varepsilon_y = 100$ mm mrad

Layout: A. Dolinskii, S. Litvinov

CR for ILIMA

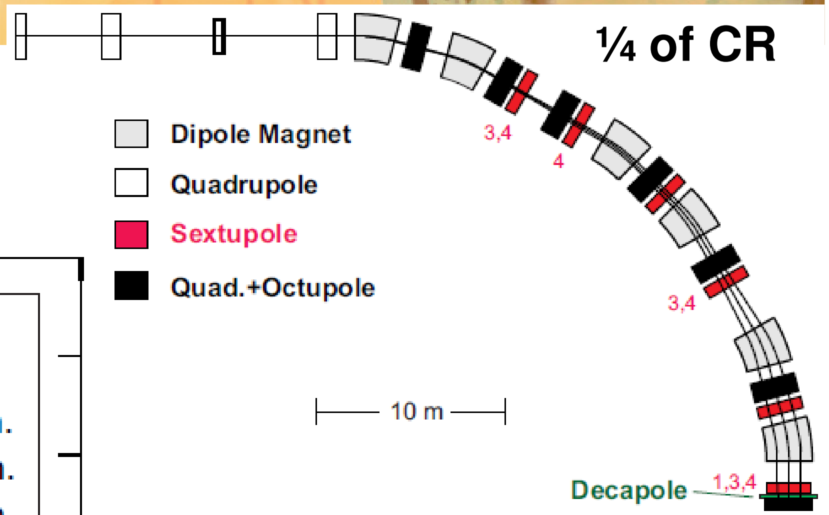


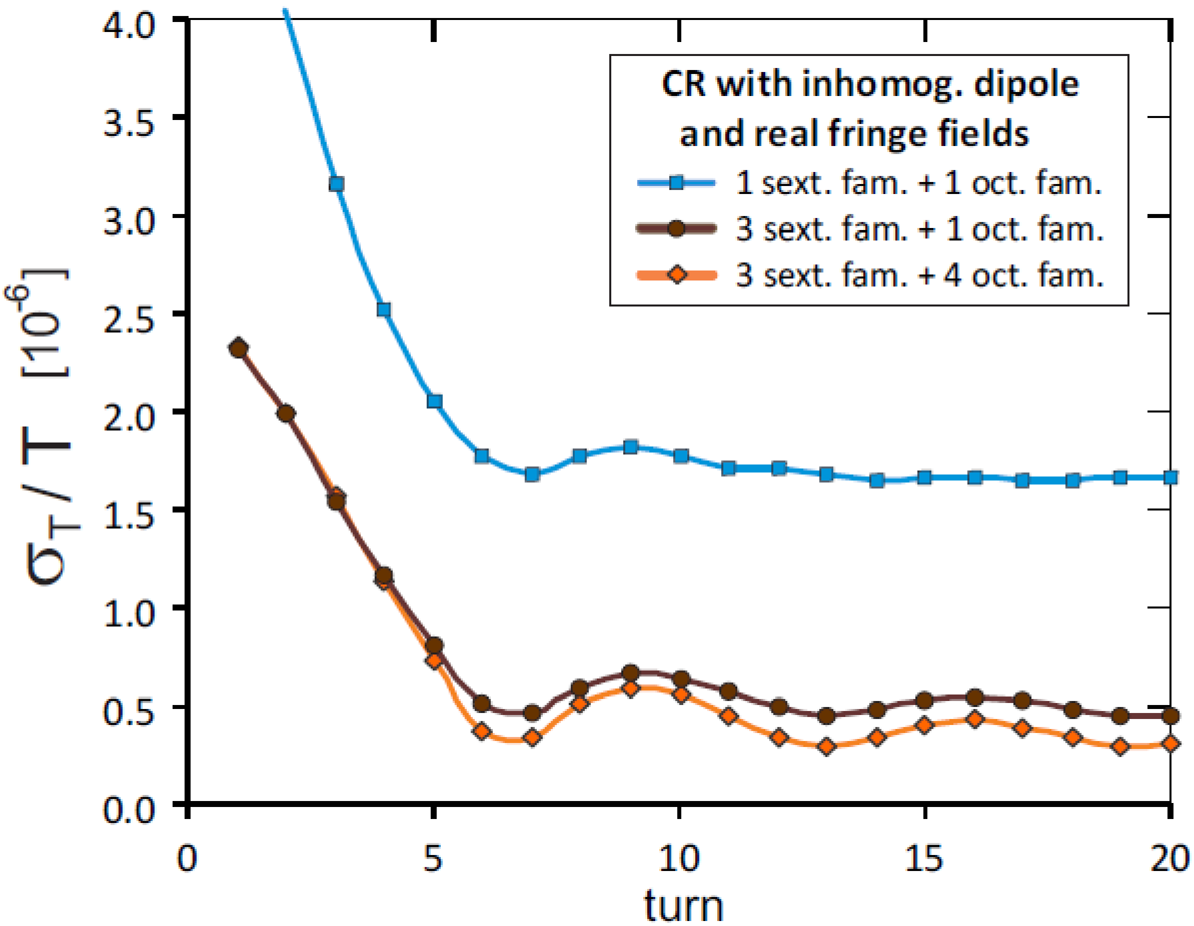
Intense FAIR beams, better selection Super-FRS
Much enlarged acceptance from ESR -> CR:

transverse: $\varepsilon_{x,y}$ = 7-8 mm rad -> 40-100 mm mrad
longitudinal: $\Delta p/p$ = 0.2% -> 0.5 %

requires careful calibration

CR Simulation of Isochronous Mode

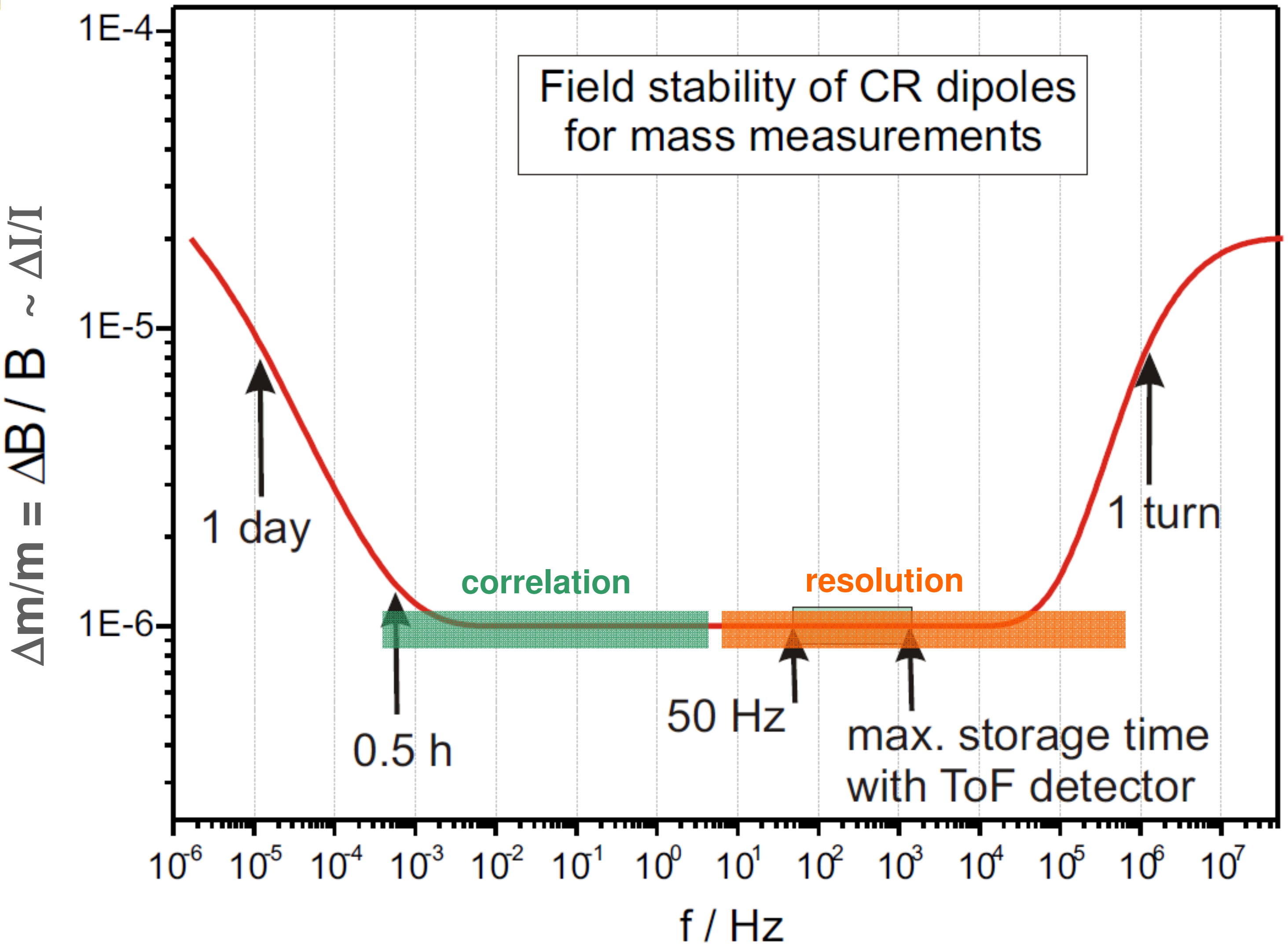




Simulation: full phase space in x,y (100 mm mrad), $\delta=\pm0.5\%$ including realistic fringe fields and field imperfections.

S. Litvinov et al. NIM A724 (2013) 20.

Power Supply Stability



updated specs for BINP Novosibirsk: $\Delta I / I = \pm 0.5 \times 10^{-5}$

First Order has a Limited Validity for Isochronous Mass Measurements

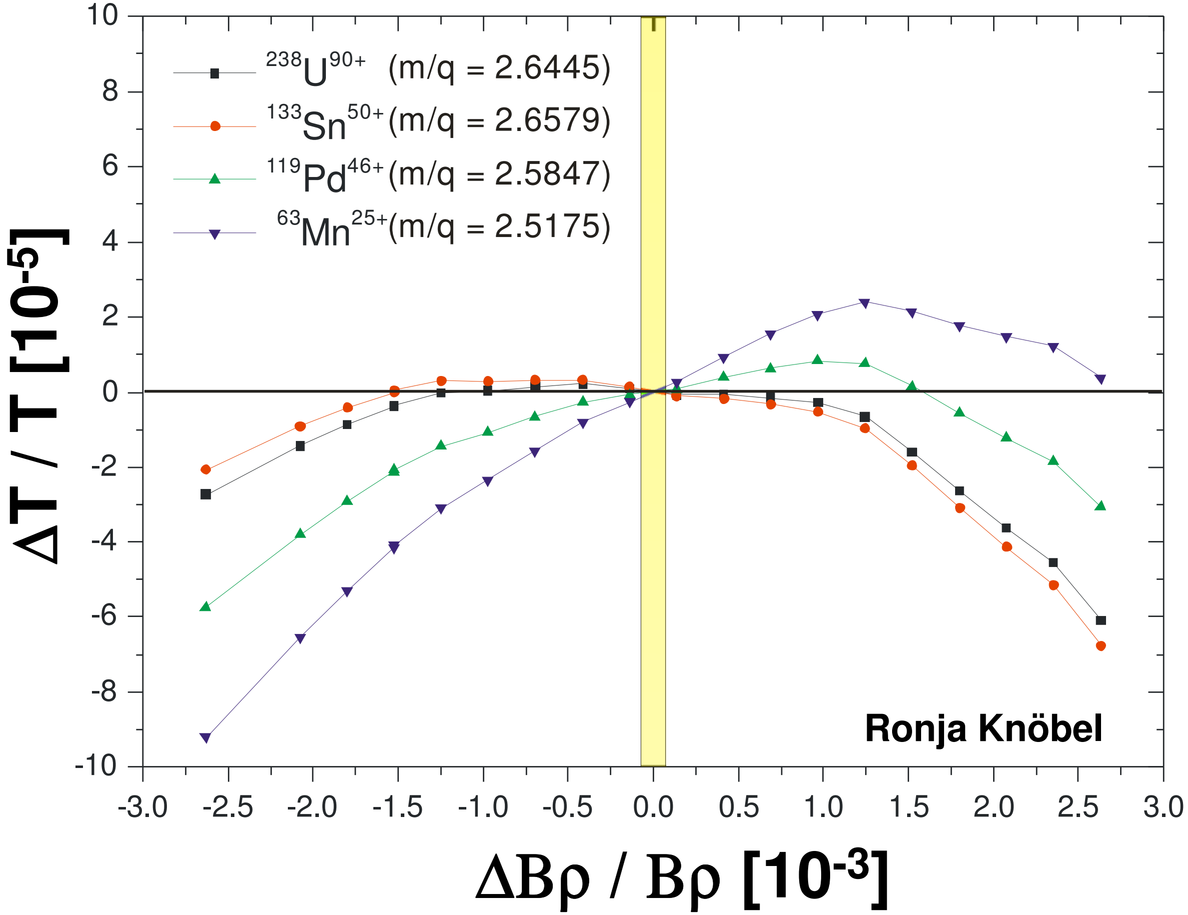
$\gamma_t \rightarrow \gamma$

$$\frac{\Delta f}{f} = -\frac{1}{\gamma_t^2}\frac{\Delta(m/q)}{m/q} + \frac{\Delta v}{v}\left(1 - \frac{\gamma^2}{\gamma_t^2}\right)$$

Revolution frequency **f** of ions with **m/q** and velocity v, γ.

γ_t = transition point of ring

Region of good Isochronicity



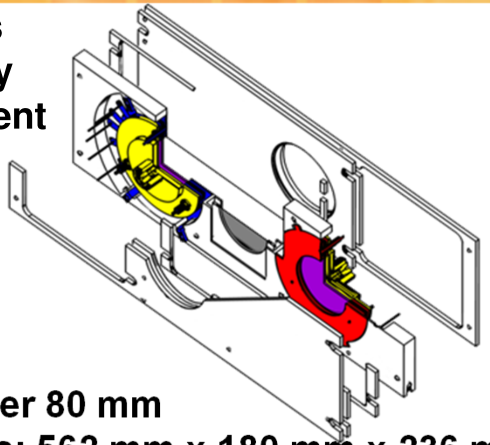
FRS for Bρ determination by narrow slit

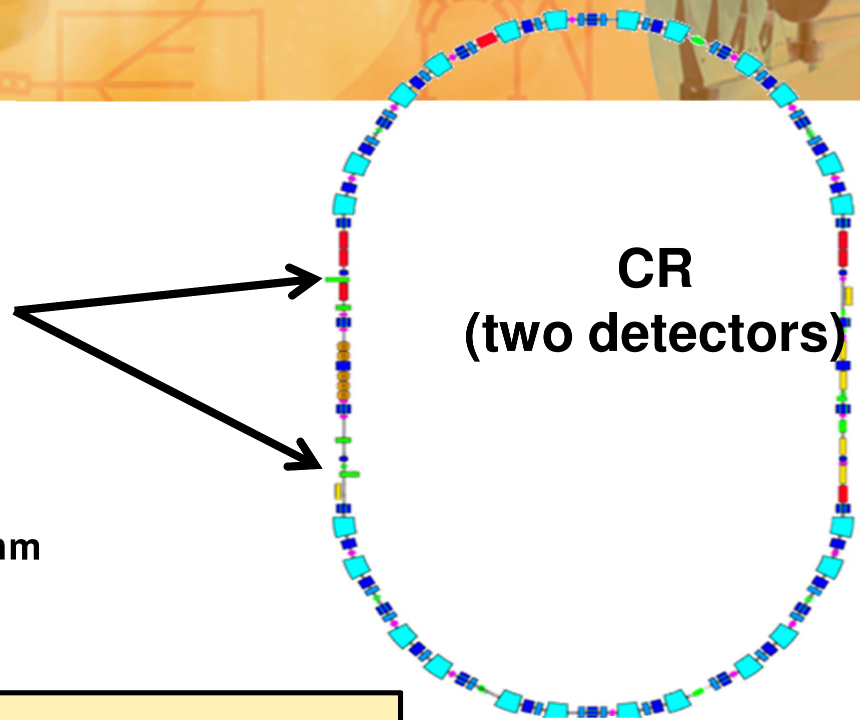
Isochronicity has a limited interval

⇒ Solution: Determine Bρ in addition

TOF Detector System for CR

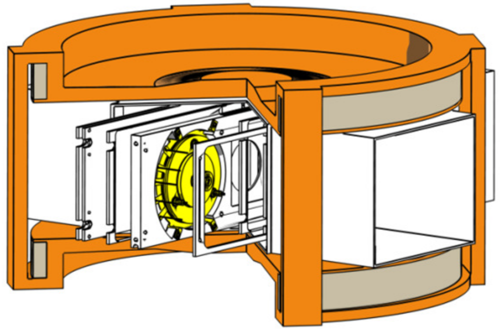
2 detectors
for velocity
measurement





Foil diameter 80 mm
Dimensions: 562 mm x 180 mm x 236 mm
Electron transport efficiency ≈ 98%
Timing accuracy ≈ 35 ps

Main challenges for new detector:
- Active area x 4 required
- Very limited space in the ring
  → scaling up the detector not possible



Achievements:
- Simulations for the CR and the TOF detector
  (M. Diwisch PhD Thesis, University Gießen, in preparation; GSI Scientific Report 2012, p. 212)
- Simulated performance of the TOF detector even surpasses the performance parameters of the existing detector
- CAD drawings exist

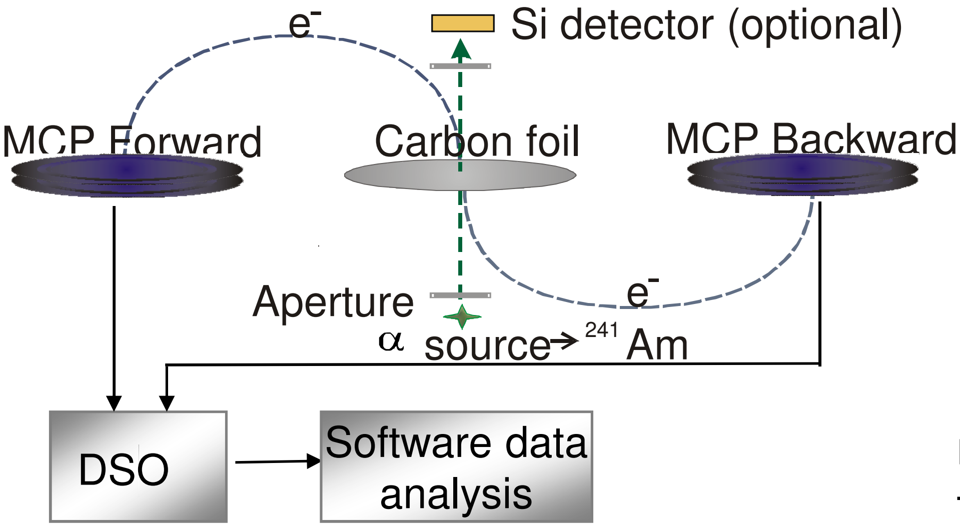
TOF Detector Test Bench

Electron Transport efficiency x2
(B. Fabian PhD Thesis, University Gießen, 2008)

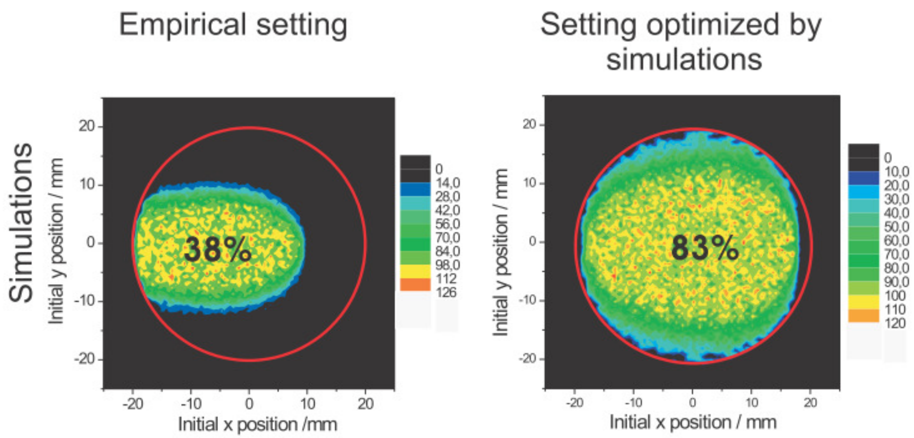
Larger turn number possible (x 10)
(GSI Scientific Report 2010, p.141)

Better timing accuracy (σ_{Timing}: 45 ps → 38 ps)
(N. Kuzminchuk PhD Thesis, University Gießen, 2011)

MCP signal shape improved by anode shape; width x 0.5 **(GSI Scientific Report 2010, p.141)**

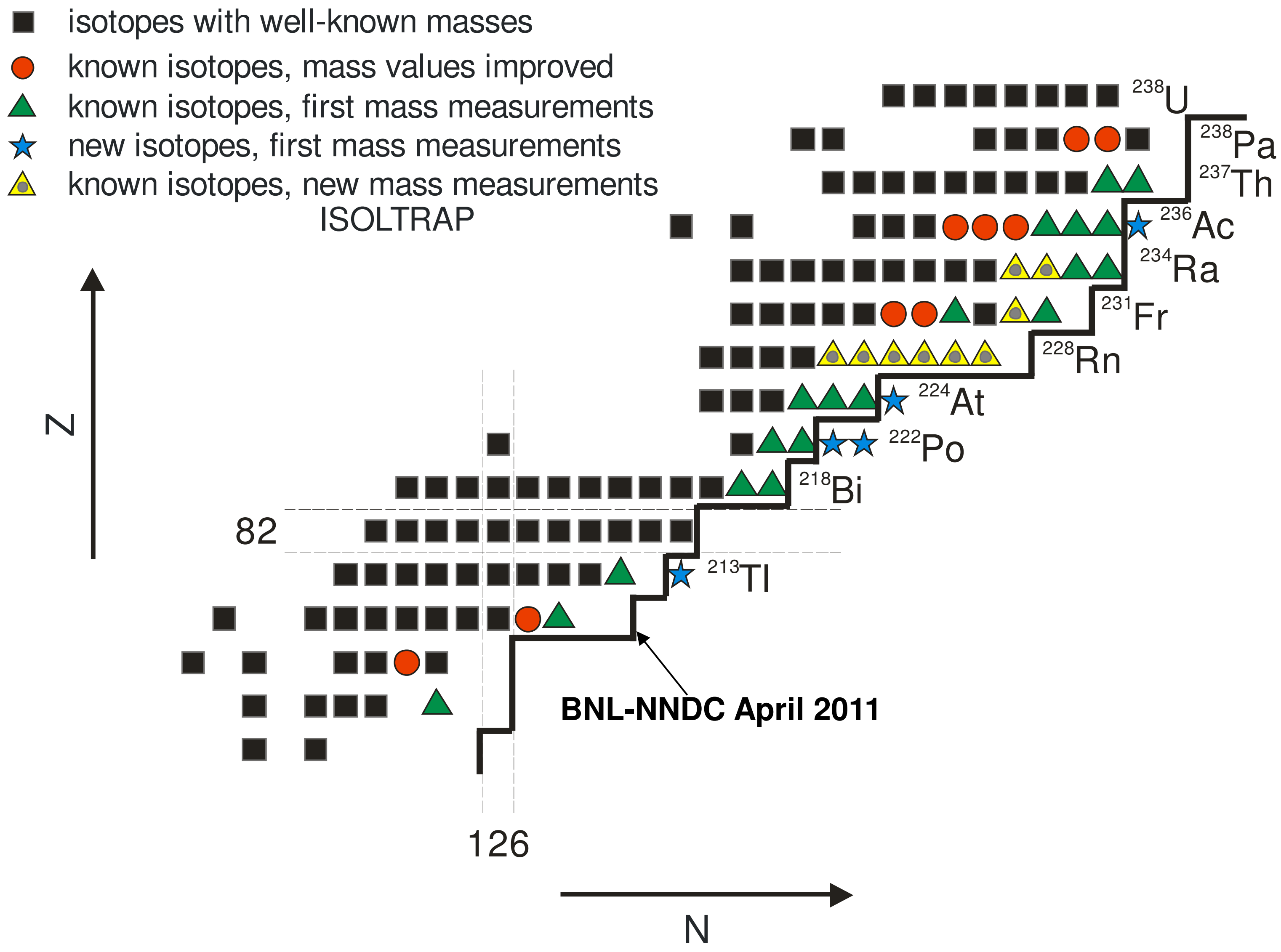


Position dependent test with α-source or laser pulses



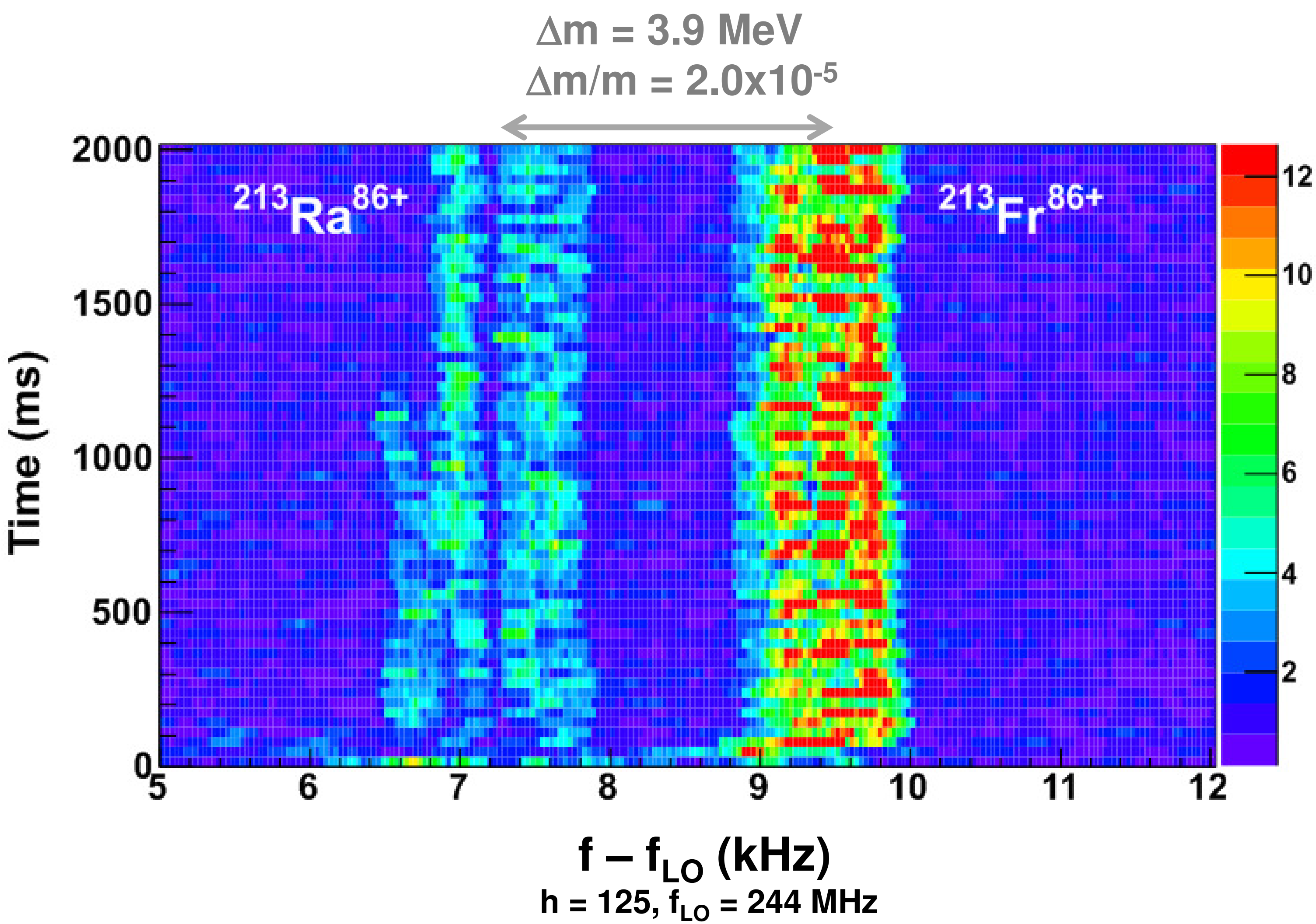
now testing with 80mm diameter carbon foils from TU Munich

Schottky Mass Spectrometry (SMS)



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

Schottky in isochronous ESR (uncooled)



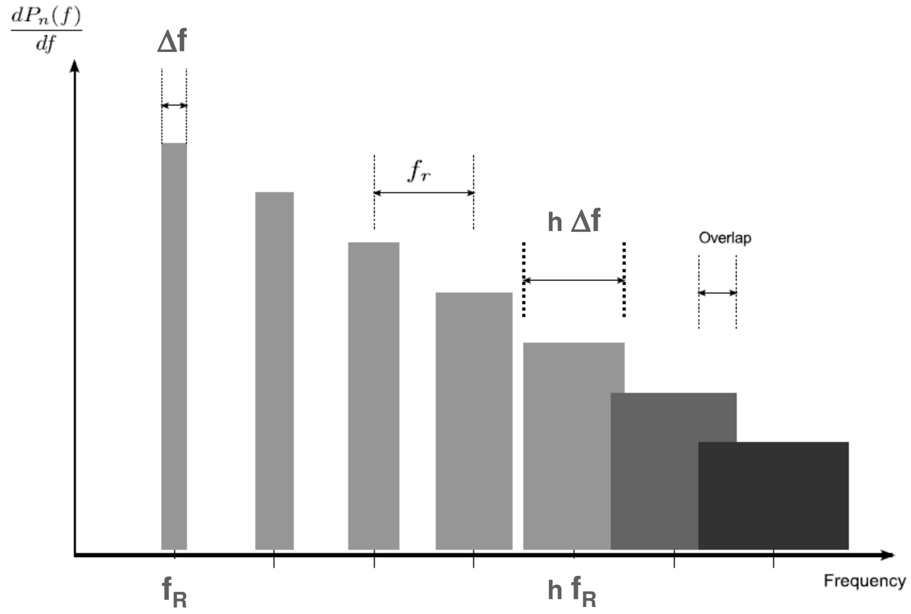
Many Pickups in Isochronous CR

High harmonic for better frequency resolution and faster measurement (sampling theorem), but more noise.

$$T_{min} = 2/(f_2 - f_1) = 2/\Delta f$$

Acceptance ΔBρ/Bρ limited (1% full width), but ions come with larger spread in m/q depending on production and separation.

$$\frac{\Delta f}{f} = -\frac{\Delta T}{T} = -\frac{1}{\gamma_t^2} \cdot \frac{\Delta(m/q)}{m/q} + \left(1 - \frac{\gamma^2}{\gamma_t^2}\right)\frac{\Delta v}{v}$$

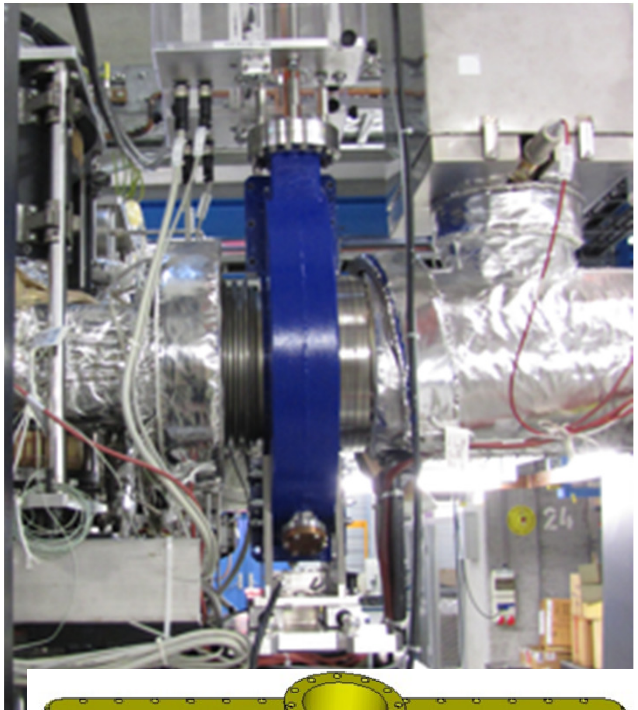


noise power at different harmonics (h)

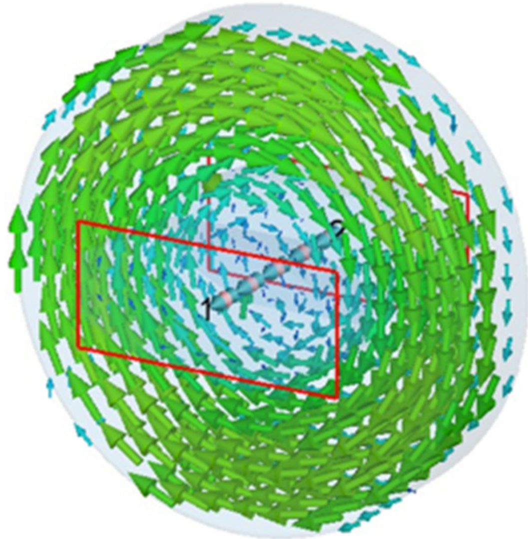
Large spread in Δf/f requires large band width, and limits harmonic to avoid overlap of frequency bands and ambiguity.
For Δm/m = 5%, γ_t = 1.68, CR68 → h_{max} = 56. We want h ~ 125, f_R = 109 MHz.

Use 3 pick ups to cover full range. Still amibiguity due to overlap of different harmonics -> use 2x3 pickups at other harmonic, fits in CR.

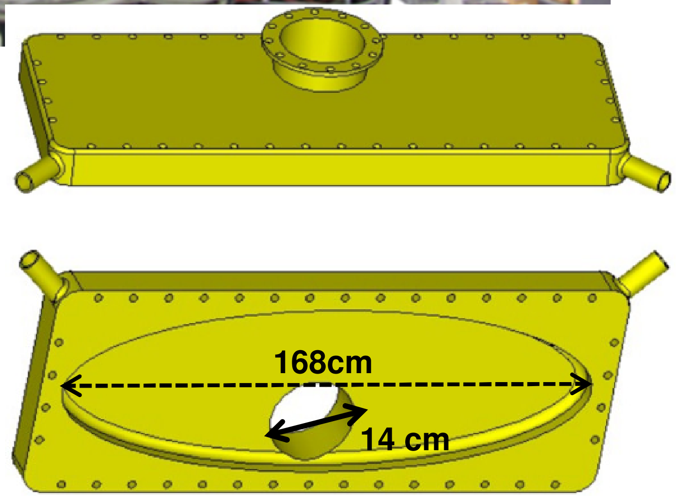
Resonant Schottky Pickup (with transverse position measurement)

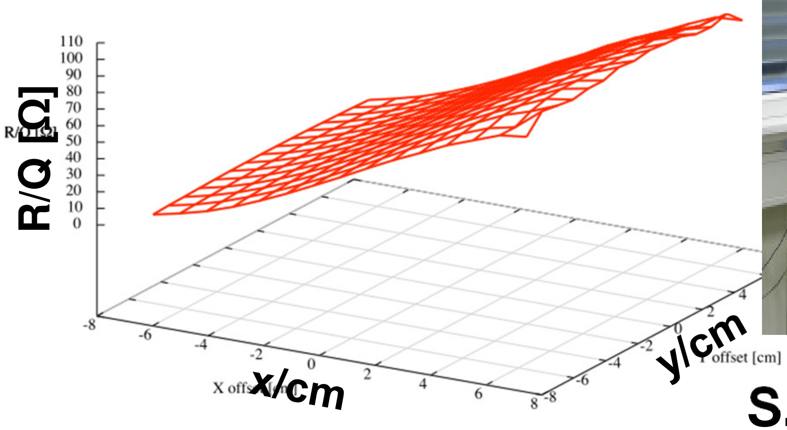


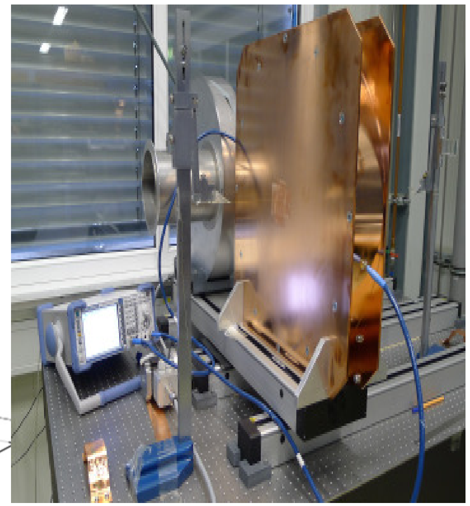
Use pill box cavity in
T010 monopole mode
f_R tunable,
quality factor Q
also adjustable.



Elliptical cavity possible
to introduce gradient in R/Q,
signal strength gives position







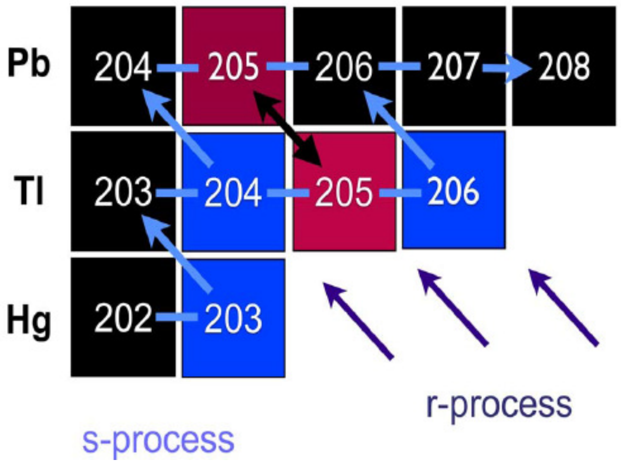
S. Sanjari, X. Chen

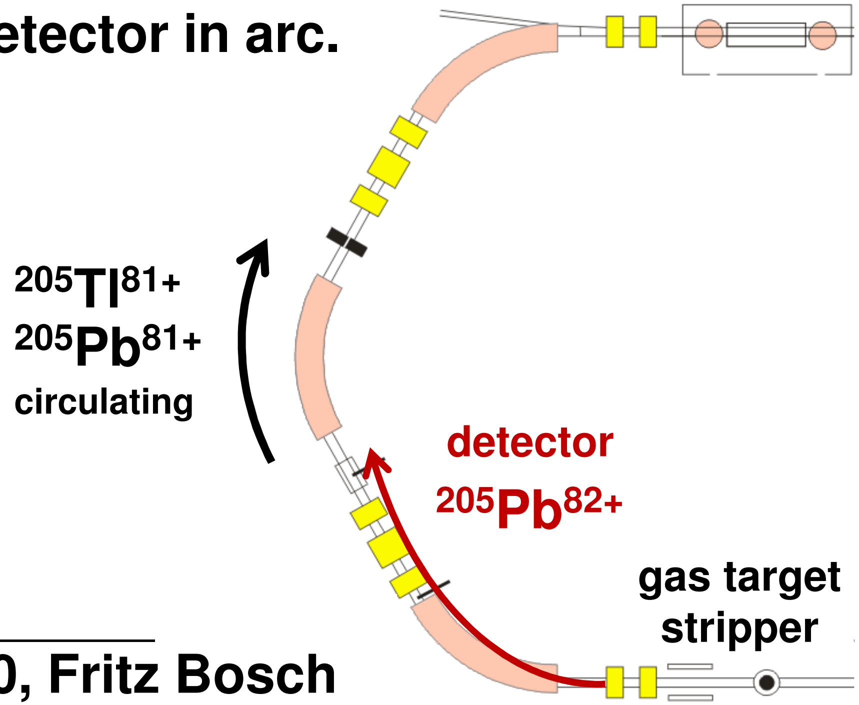
Applications for Particle Counters

Lifetime of ^{205}Tl for bound-state β-decay

Calibrate neutrino capture cross section in Tl for solar neutrino flux,
Influence on cosmic clock for S-process ^{205}Pb ($T_{1/2}$=1.7x10^7 y)

^{205}Pb EC Q-value so small that inverse is possible with highly ionised ions and bound-state β-decay (Q=+31 keV, $T_{1/2}$ ~120d ?).
Intense beam needed, no separation in Schottky possible.
But after gas stripper nicely visible on detector in arc.





GSI experiment proposal E100, Fritz Bosch

Applications for Particle Counters

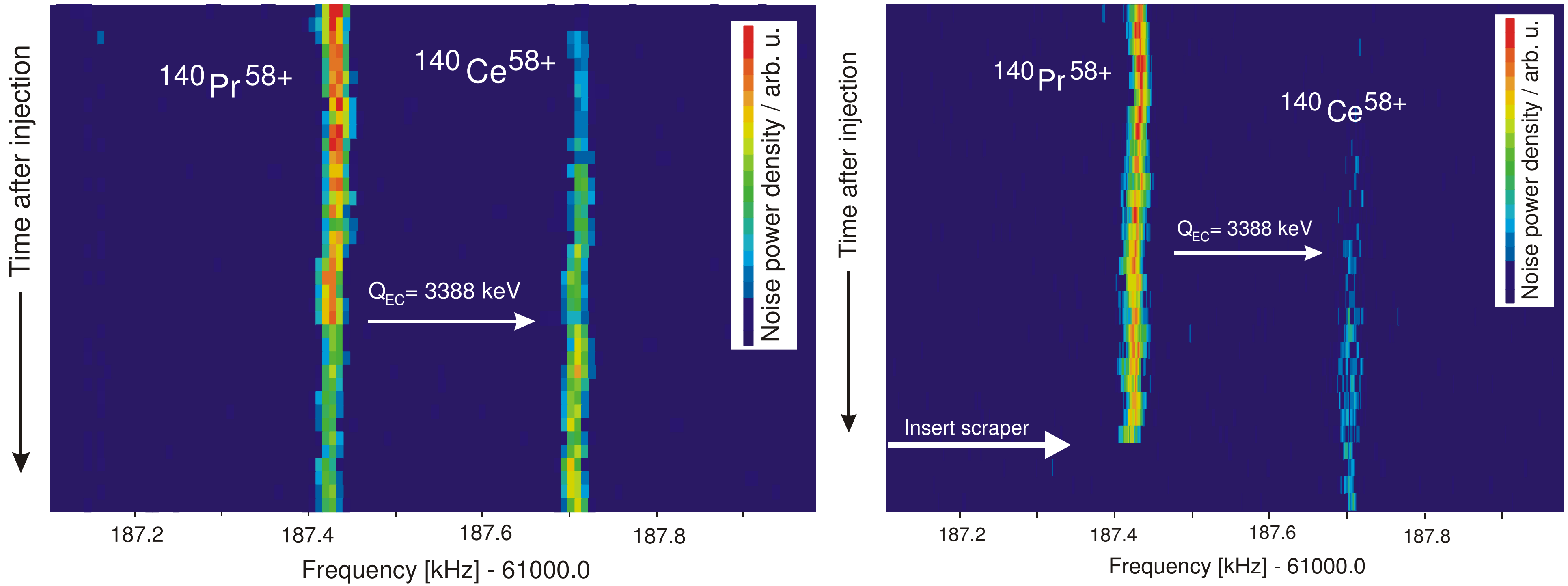
Beta delayed neutrons

Ions can so spontaneous β-decay in ring -> changed orbit
different position on detector with n emission
+ particle (mass) identification to find ratio.

Check for oscillations in bound-state beta decay

Neutrino recoil large enough to deflect ions onto detector

Separation of Isobars



time span 520s after injection
populate $^{140}Ce^{58+}$ by EC

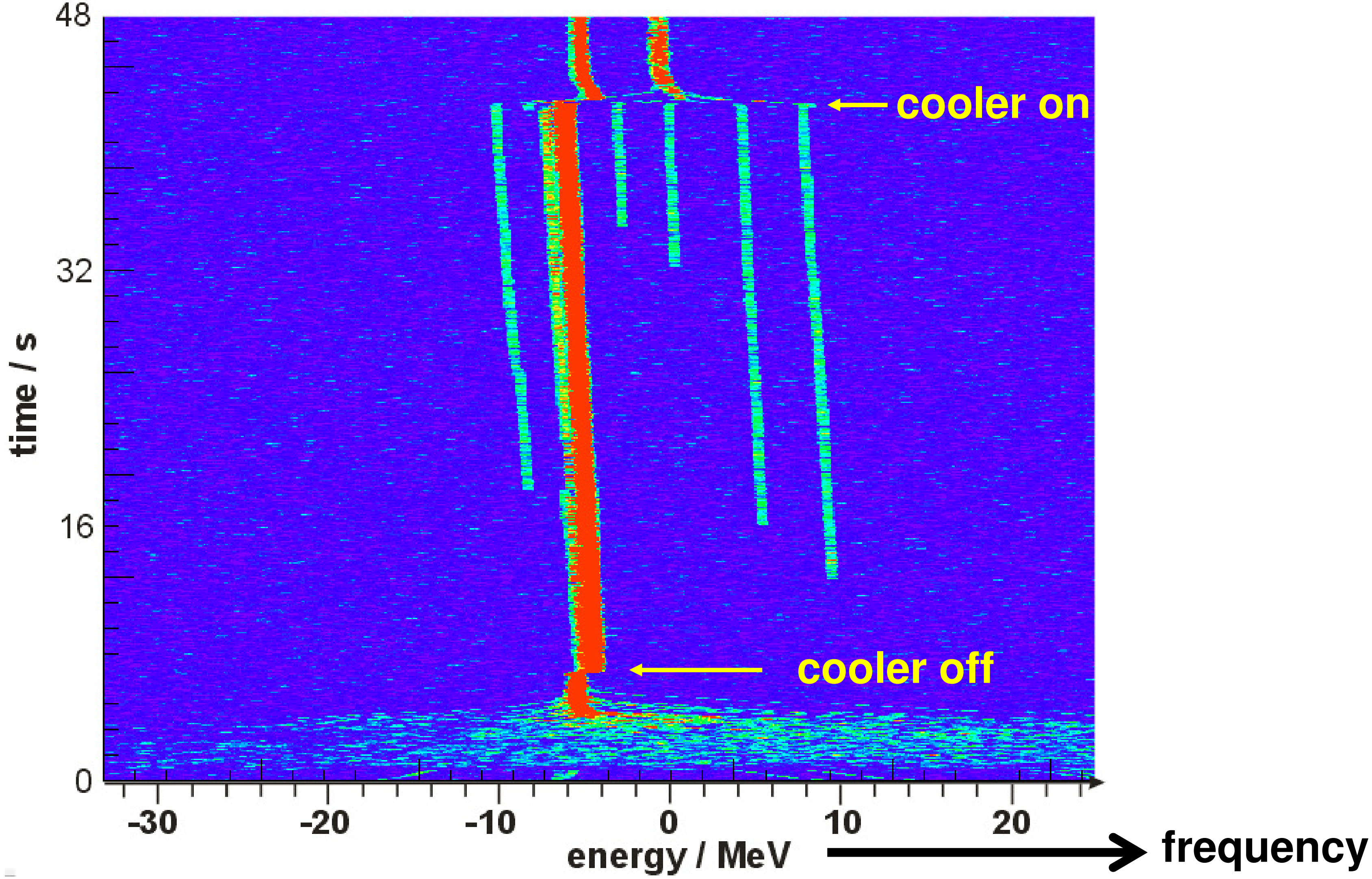
170s after injection
mechanical scraper removes $^{140}Pr^{58+}$

$\Delta m/m = 1.5 \cdot 10^{-5}$
distance between the two lines
in arc of ESR: **$\Delta x \sim 50\ \mu m$**

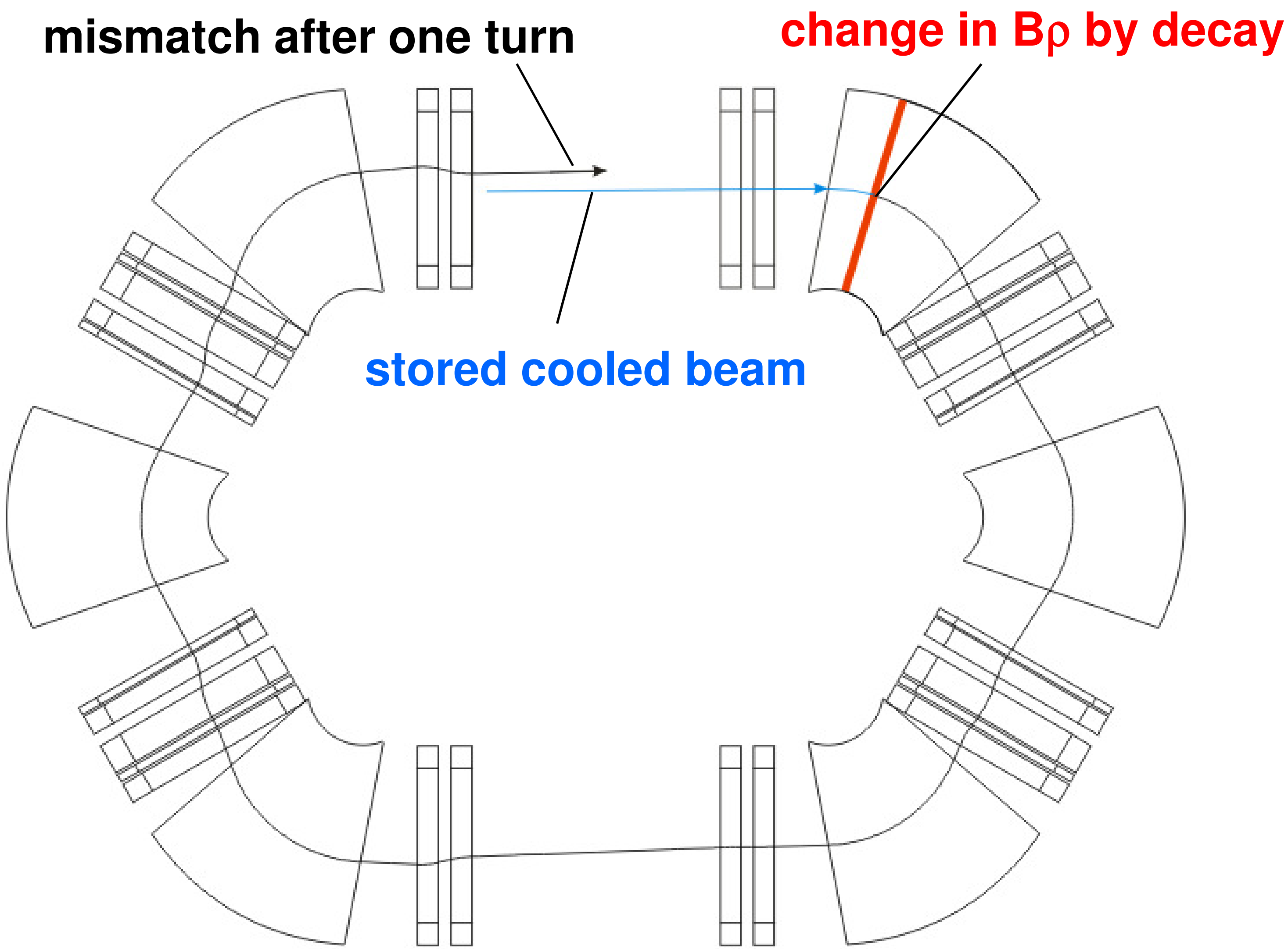
H. Weick et al., GSI annual report 2005.

Frequency Shift by Longitudinal Neutrino Recoil

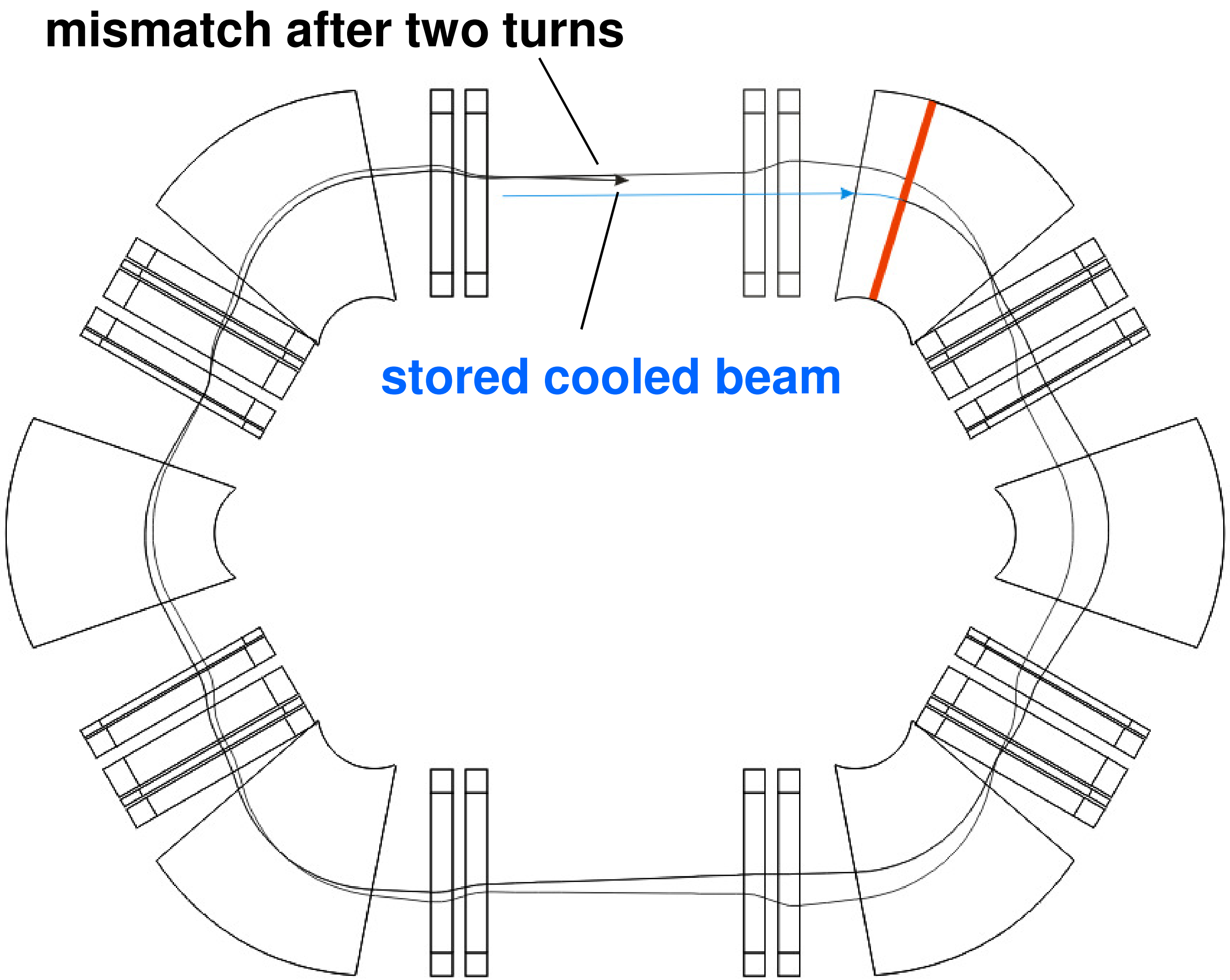
EC decay of ^{142}Pm, cooling switched off



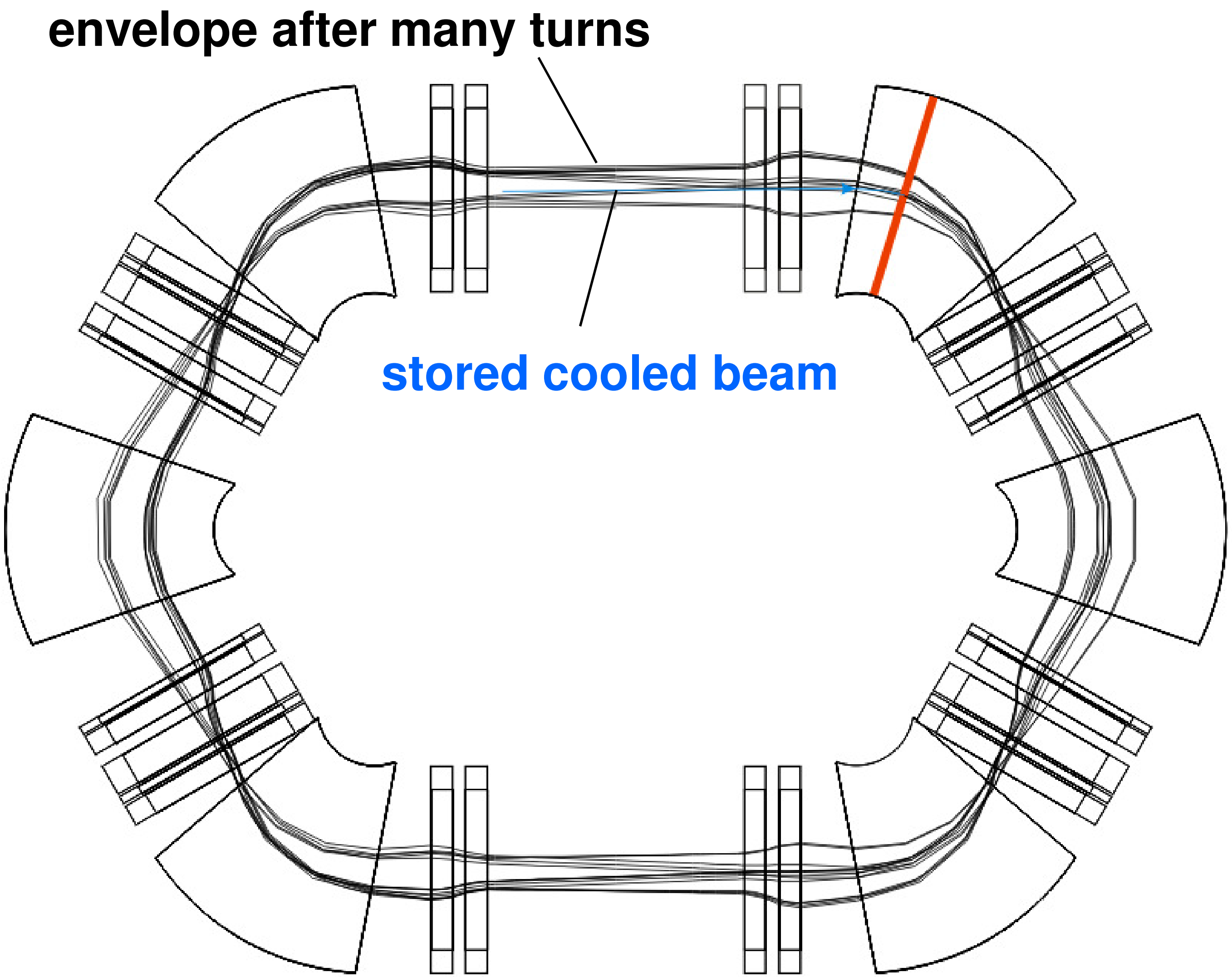
Decay in ESR → Mismatch



Mismatch after two turns



Mismatch after many turns



Separation of Daughters

Increased betatron motion amplitude helps to get daughter ions on detector

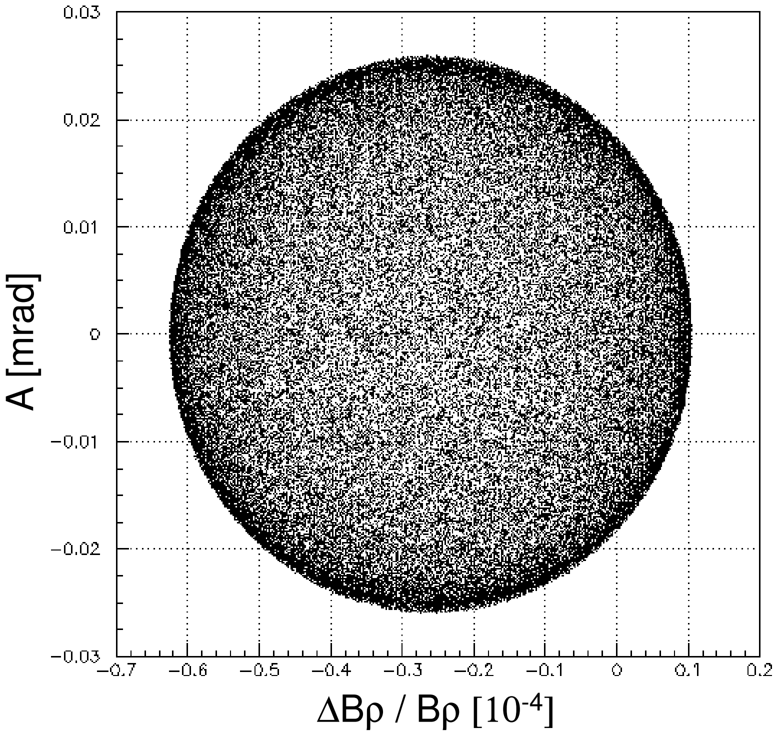
<u>for ^{140}Pr EC</u>

$\Delta p/p \;\; = \pm 3.6 \times 10^{-5}$

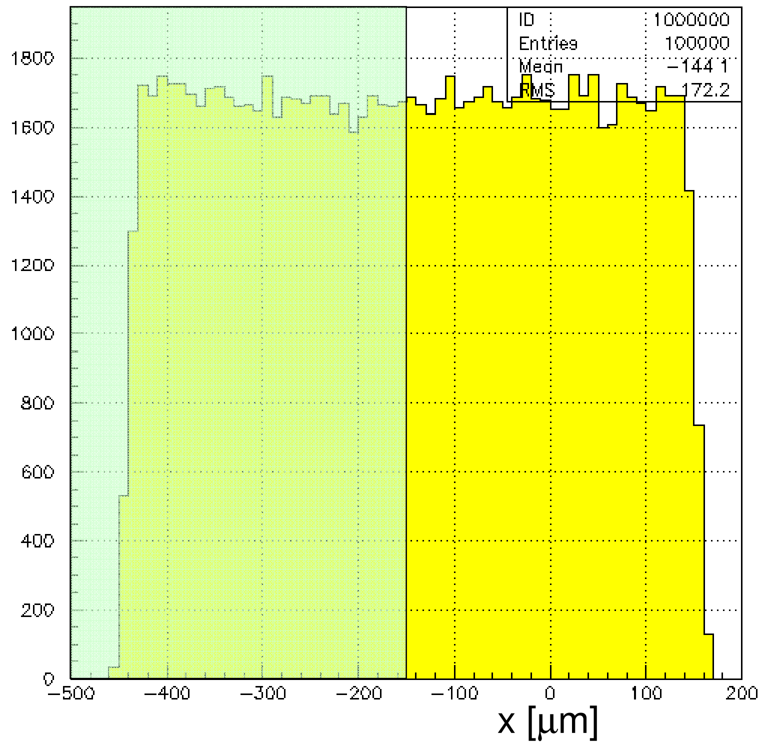
$\Delta m/m = \; -2.6 \times 10^{-5}$

$\Delta A \;\;\; = \pm\, 0.0255$ mrad

distribution directly after decay

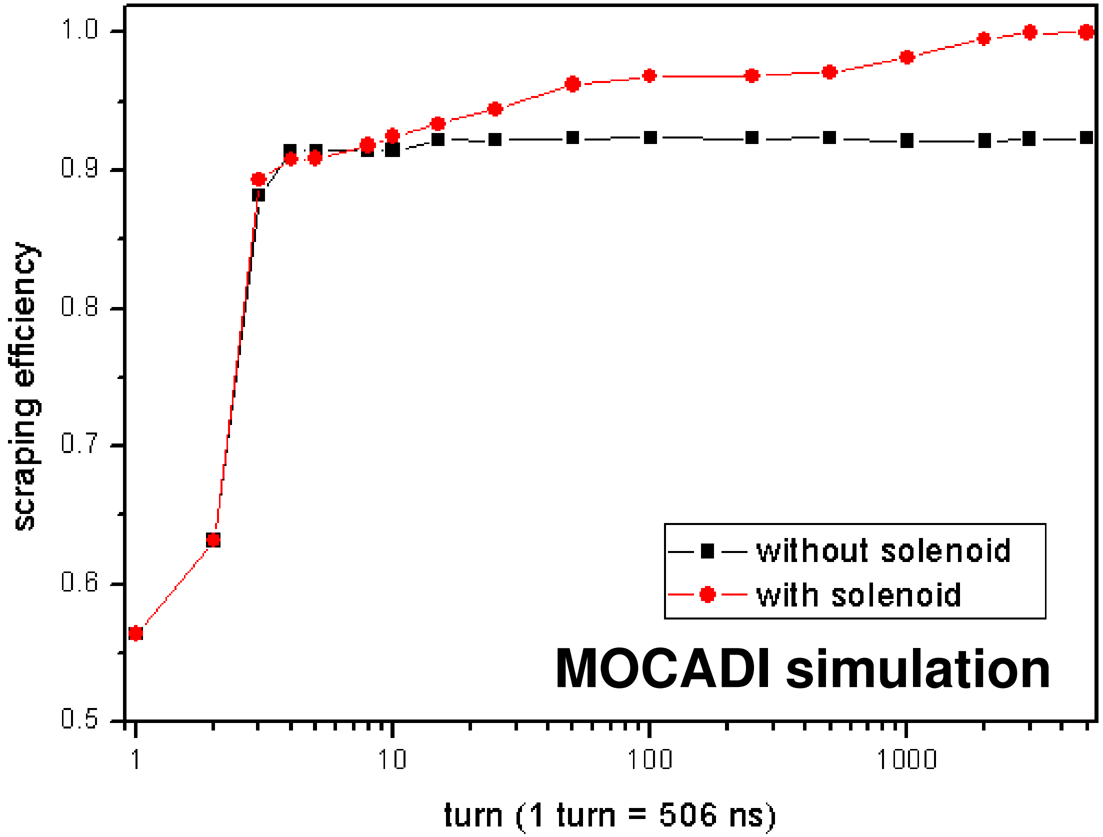


decay on straight section
measure at usual detector
in arc after one turn.



Scraper Efficiency Simulation

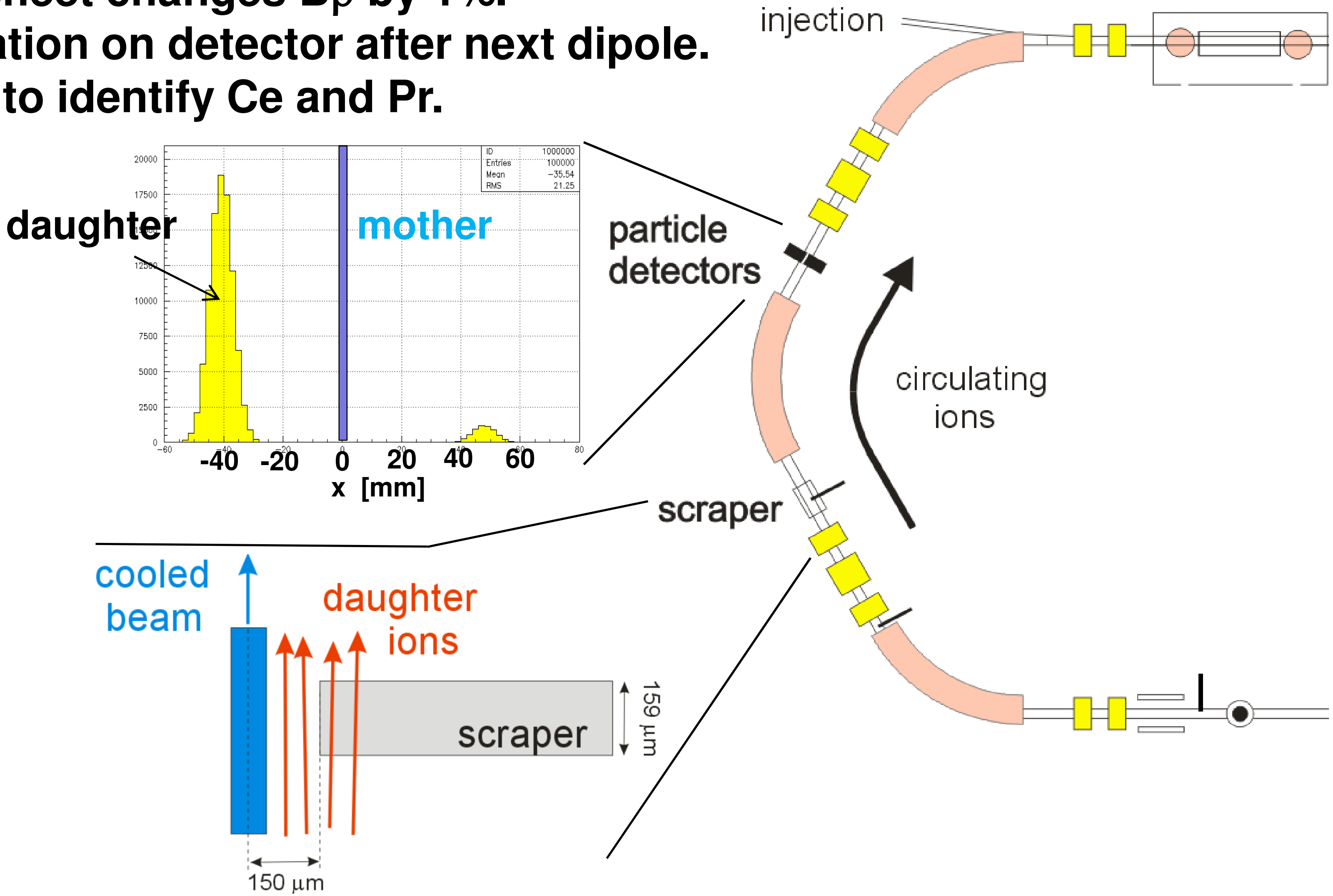
Already after a short time daughters will be detected.
→ well defined decay time (Δt ~ 0.5 - 3 μs) with a bit of tail, not 100% (in safe setting) but also not required.



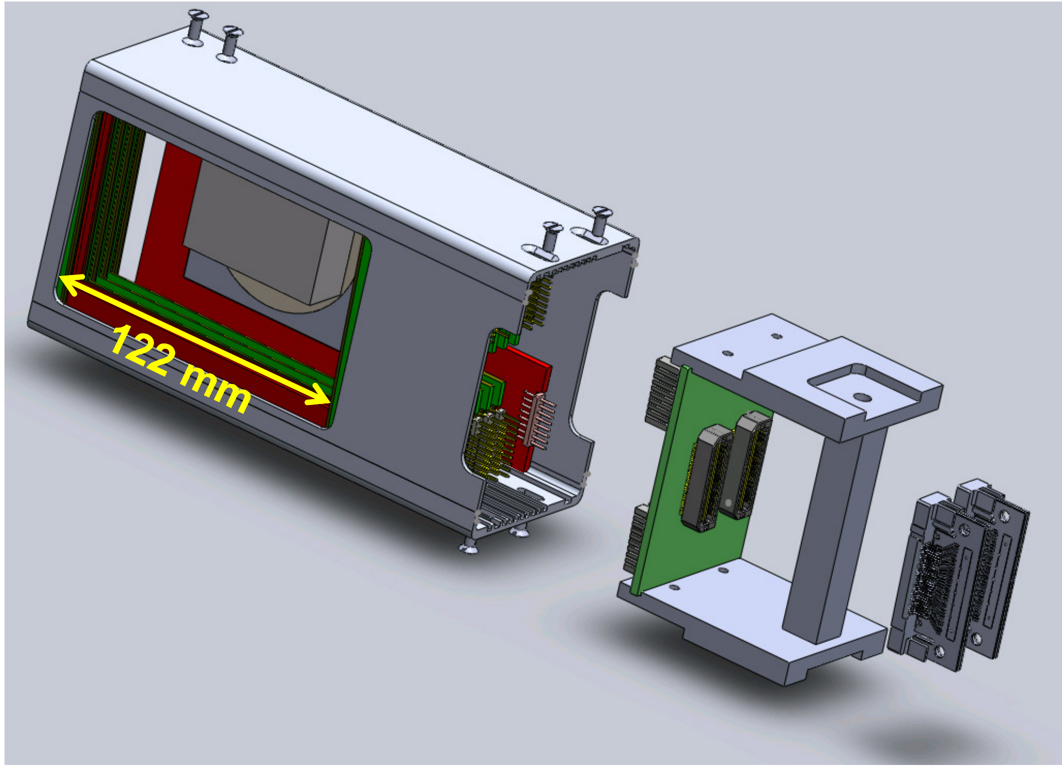
ESR in standard mode with / w.o. solenoid, EC decay of ^{142}Pm. Scraper in arc at Δx=150 μm from centered beam.

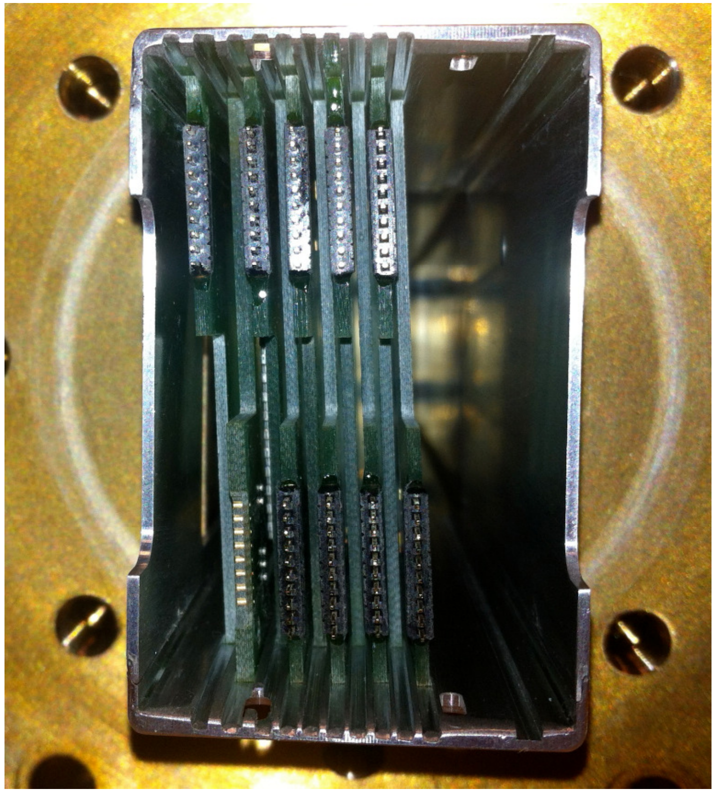
Position of Scraper/Degrader and Detector

Magnify separation by a degrader as scraper.
Thin steel sheet changes Bρ by 1%.
Nice separation on detector after next dipole.
ΔE counter to identify Ce and Pr.



New Detector Setup for ESR





DSSD stack for ΔE-E measurement for heavy ions,
active area 40mm x 60mm, also with CsI calorimeter + Si photo diode,
identity Z and mass.

Ali Najafi

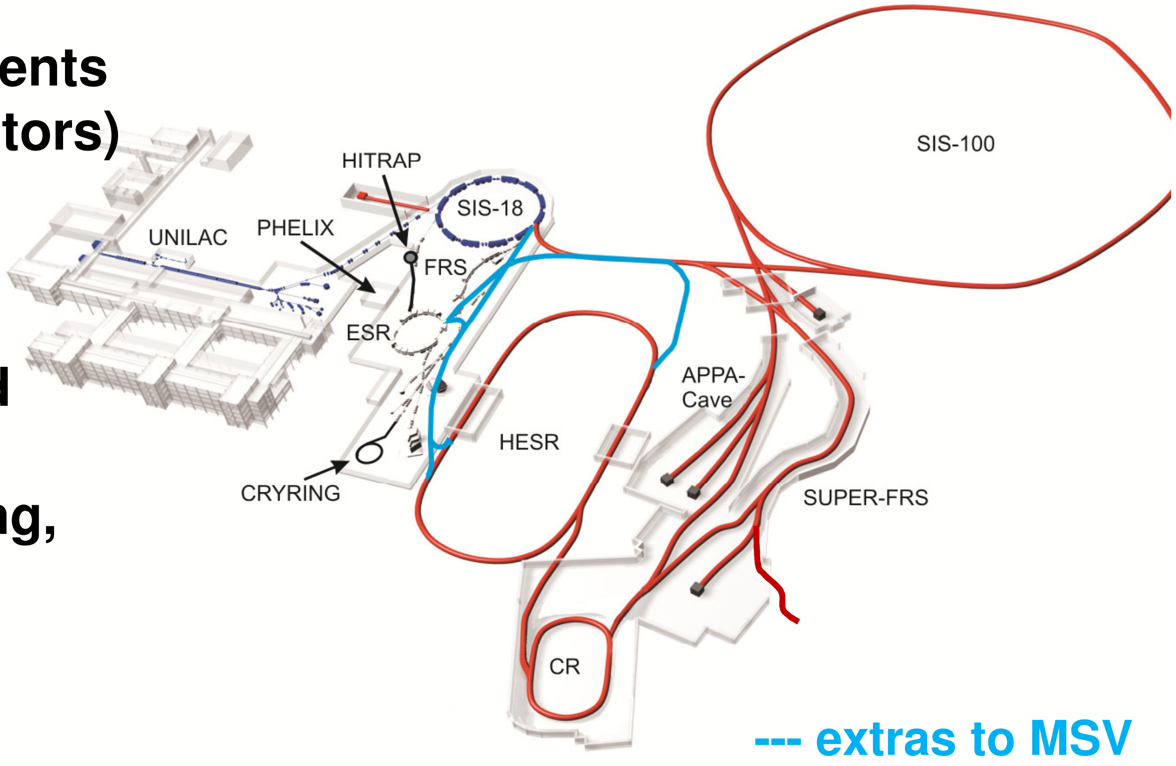
HESR Perspectives

no NESR.

But HESR with stochastic and electron cooling
HESR E_{min} = 740 MeV/u, possible with SIS-18

Good for lifetime measurements
(Schottky and particle detectors)

No better acceptance of
secondary beams compared
to ESR.
Also lower acceptance in ring,
then better transfer to ESR.



Summary

CR will be build by BINP Novosibirsk considering our needs,
but large acceptance is challenge, extras required.

Consider also correlations from measurement itself
in mass analysis (limited isochronicity).

Development for ToF Detector in progress.
Timing and efficiency of detector good enough.

Schottky also possible in isochronous CR.
New development for position sensitivity.

Particle detectors can do things not possible otherwise, new detector.

Some experiments with cooling possible in HESR:
lifetime, decay modes, …

ILIMA Collaboration

100 scientists
29 institutes
16 countries

GSI, Germany: E. Badura, F. Bosch, C. Brandau, C. Dimopoulou, A. Dolinski, P.Egelhof, A. Evdokimov, B. Franczak, B. Franzke, H. Geissel, F. Herfurth, J. Hoffmann, H.-J. Kluge, R.K. Knöbel, C. Kozhuharov, N. Kurz, S.A. Litvinov, Yu.A. Litvinov, M. Marta, G. Münzenberg, F. Montes, F. Nickel, F. Nolden, C. Nociforo, W. Quint, S. Sanjari, C. Scheidenberger, D. Shubina, H. Simon, A. Sobiczewski, M. Steck, Th. Stöhlker, S. Typel, G.K. Vorobjev, H. Weick, N. Winckler, M. Winkler

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Frankfurt,Germany: Th. Bürvenich

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Tsukuba, Japan: A. Ozawa

ANU Canberra, Australia: M.W. Reed