# ILIMA Technical Status

Helmut Weick, GSI
NUSTAR Week Helsinki, 10th Oct. 2013

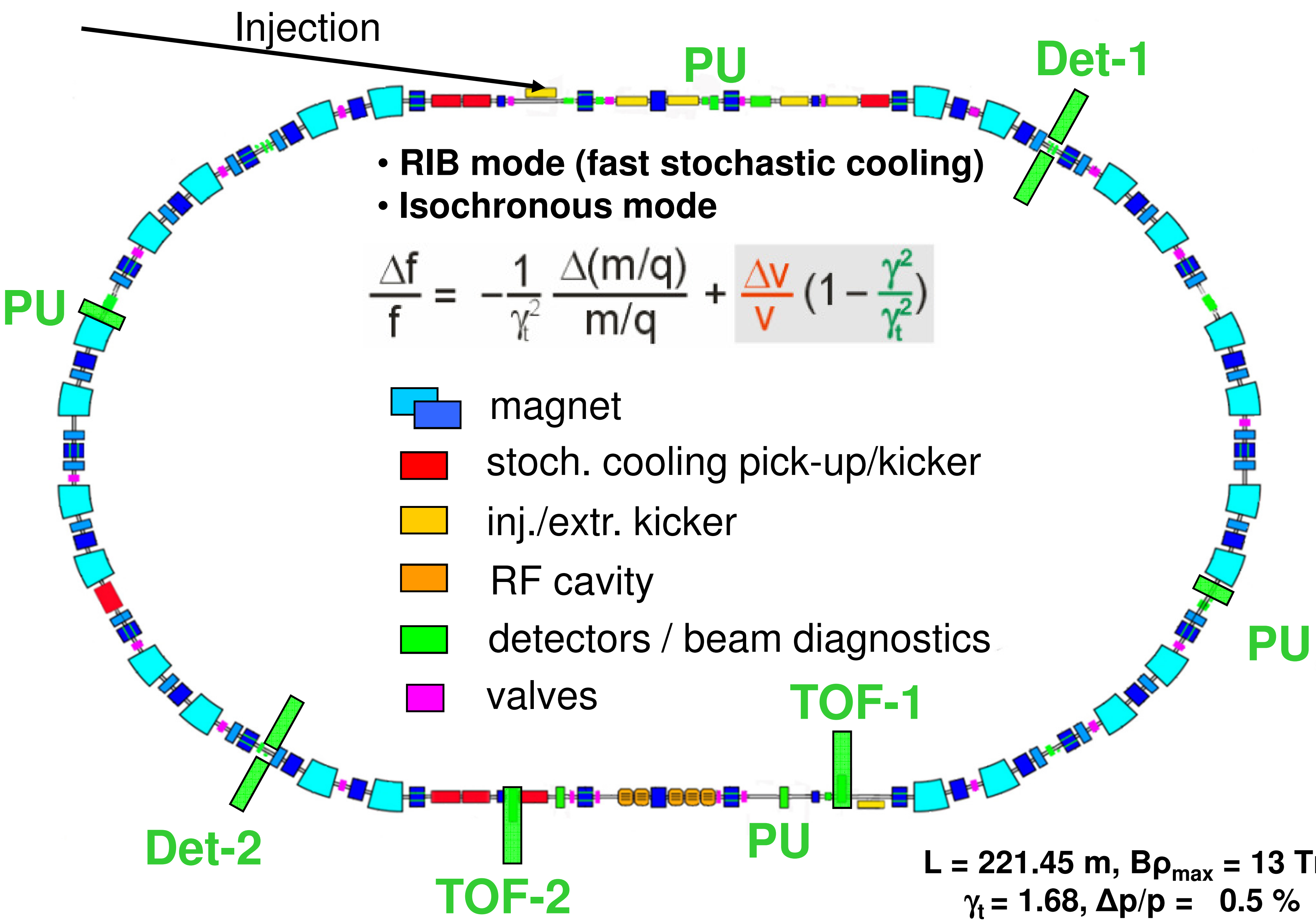
- ILIMA Working Groups
- ToF-Detectors
- Schottky Detection
- Particle Detectors in Ring
- The ring itself (CR)

# Working Groups

## ILIMA Technical Board

| Sub-Project | Group Leader | | Institute |
|---|---|---|---|
| **Project Manager, Chair** | **H** | **Weick** | GSI, Darmstadt |
| Simulation and Beam Handling | H | Weick | GSI, Darmstadt |
| Evaluation Software | Yu | Litvinov | GSI, Darmstadt |
| Physics and Theory Programs | Z | Patyk | Soltan Inst + Univ. Warsaw |
| ToF Detectors | W | Plaß | GSI, Darmstadt |
| Schottky Detectors | C | Kozhuharov | GSI, Darmstadt |
| Other Detectors | I | Dillmann | Univ. Giessen / TRIUMF |
| *Spokesperson* | P | Walker | Uni. Surrey |
| *Deputy-spokesperson* | Yu | Litvinov | GSI, Darmstadt |

# Collector Ring (CR68)



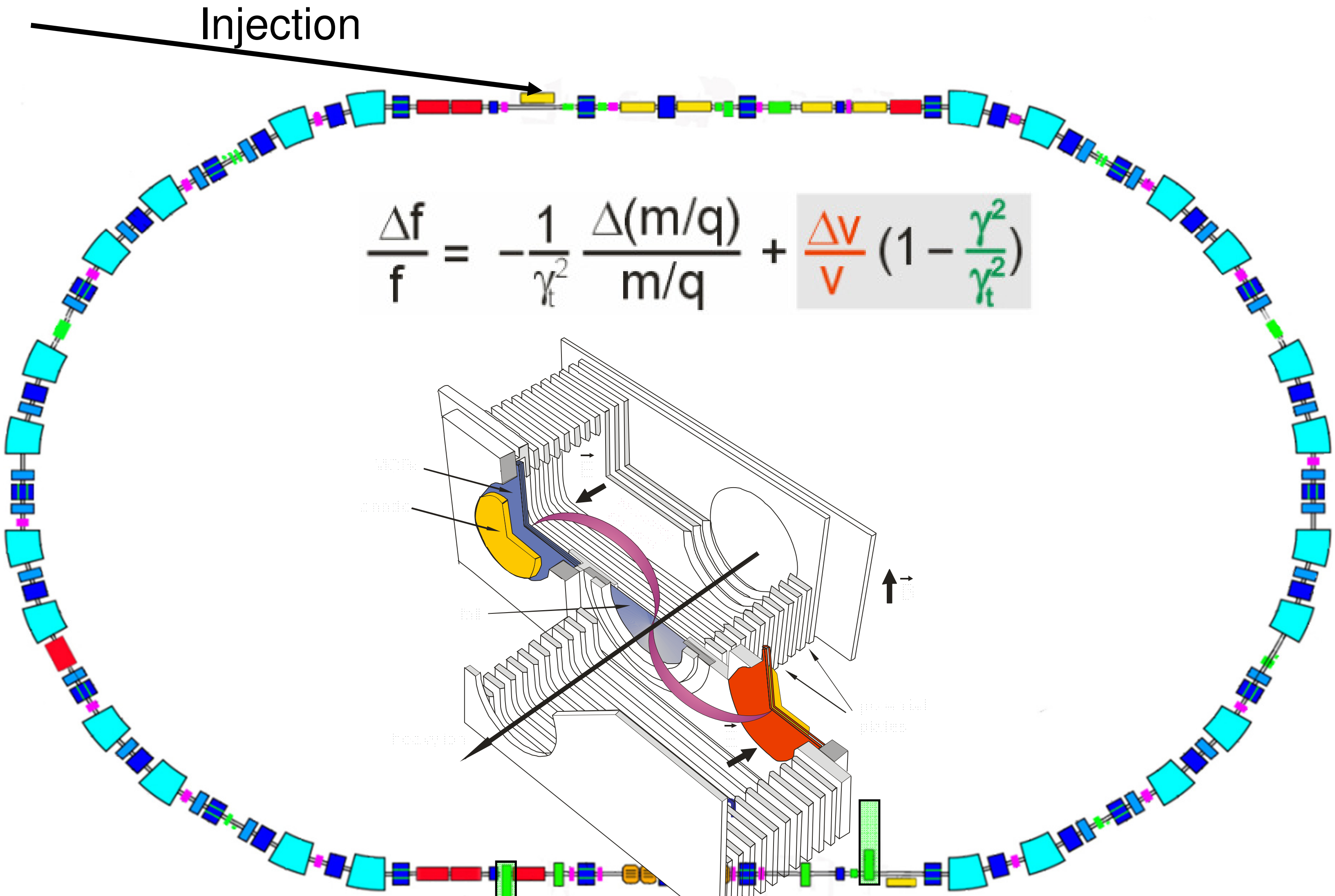

- **RIB mode (fast stochastic cooling)**
- **Isochronous mode**

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

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

**Layout: A. Dolinskii**

# Collector Ring (CR68)

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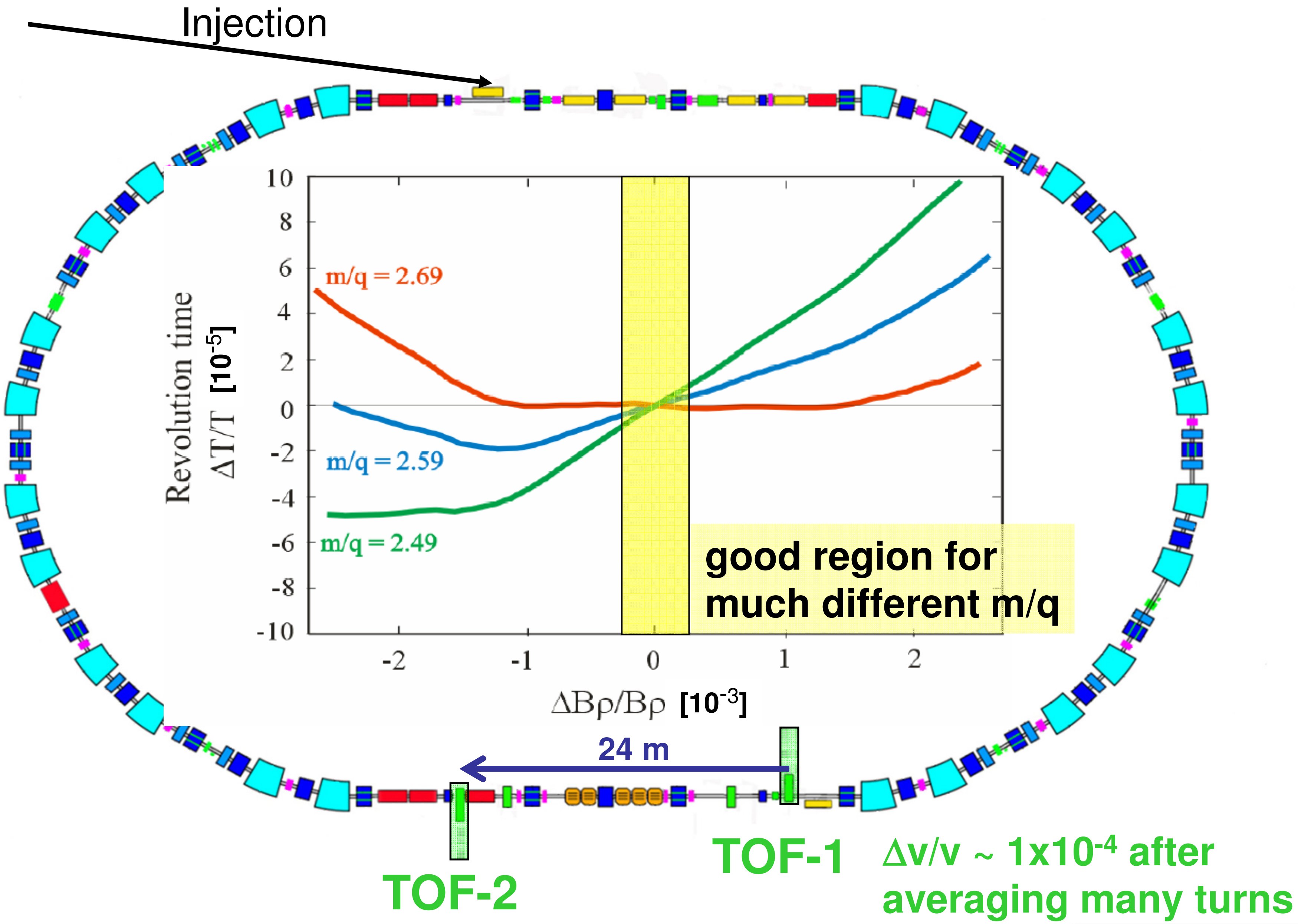
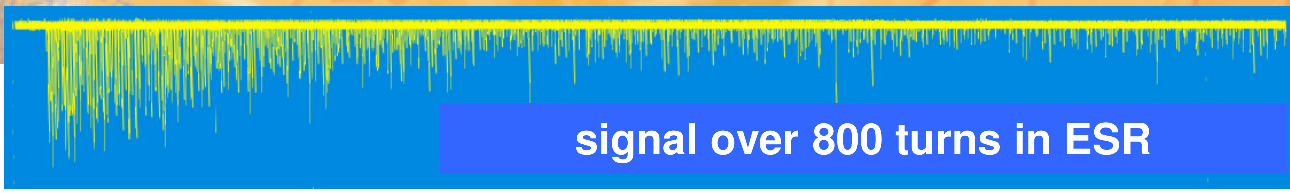
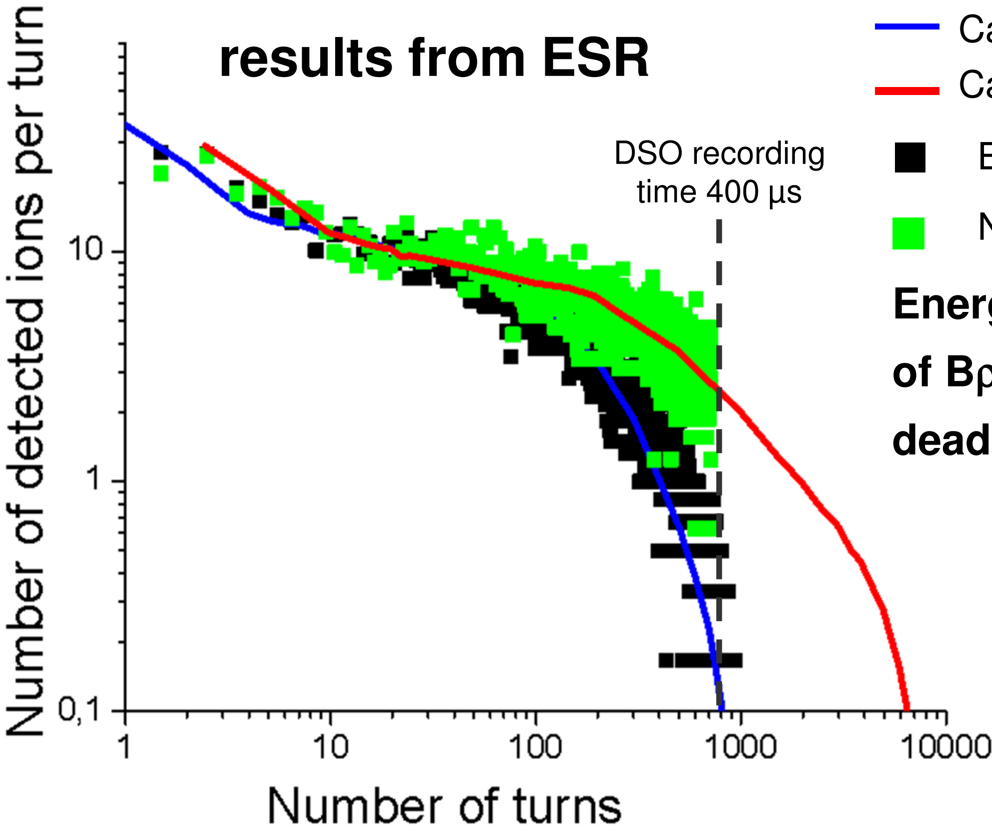
# Collector Ring (CR68)



# Detector Efficiency



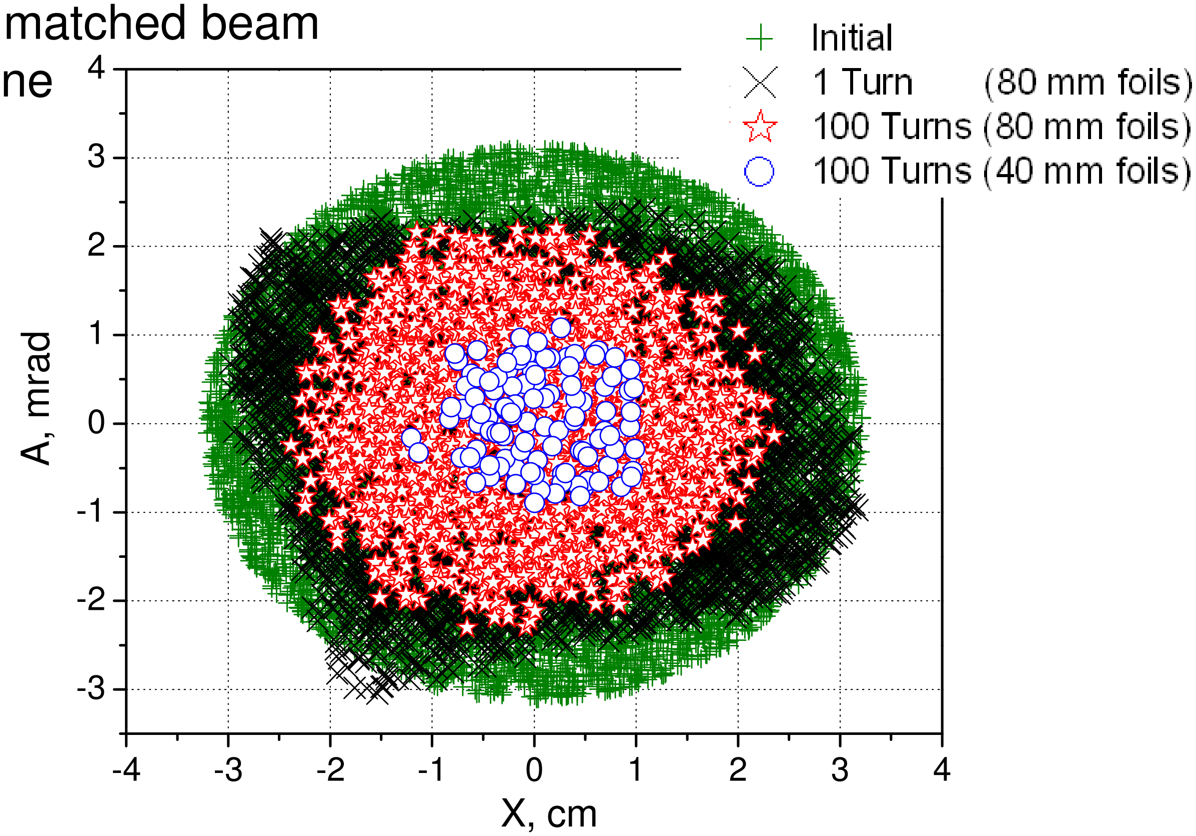

**Energy loss in foil causes shift out of Bρ acceptance and saturation / dead time of MCP**

**Up to 8 times larger number of turns**
**→ Higher mass measurement accuracy**
**In CR many more turns possible due to larger acceptance**

**Lower amplification, less saturation also possible,**
**Even pulse height for additional ID could be used, same time resolution.**
**Bo Mei, XiaoLin Tu, Meng Wang, et al., IMS Lanzhou**

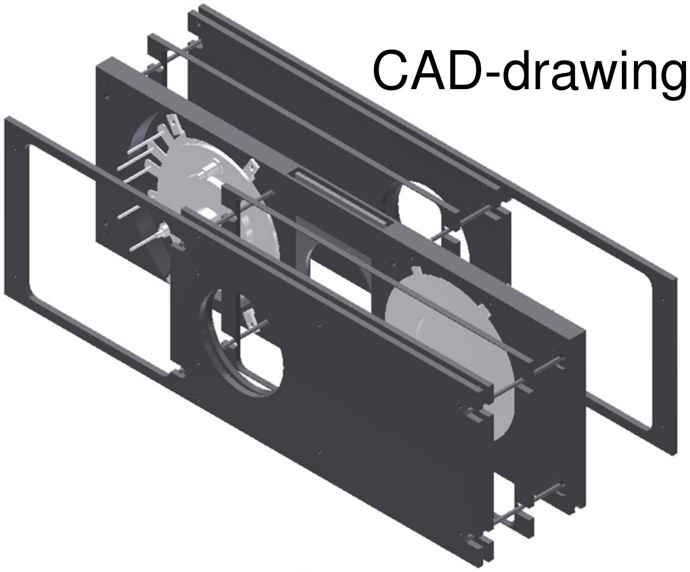
# ToF Detector – CR Acceptance

phase space of matched beam
in symmetry plane

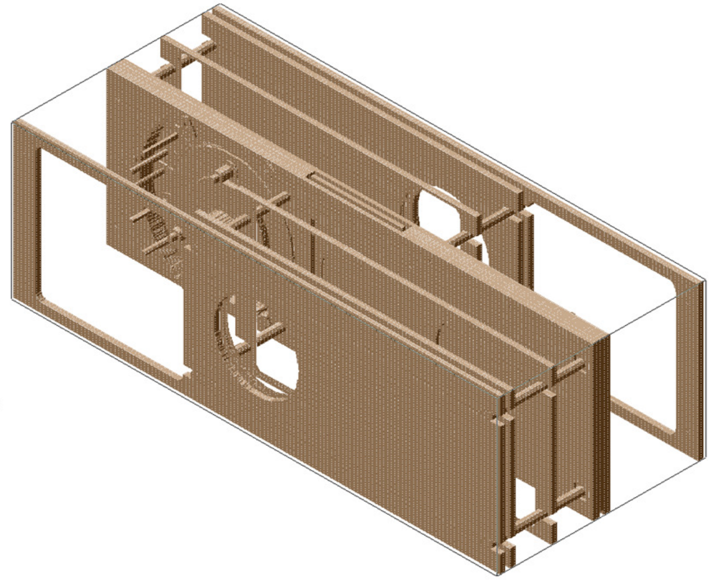



Present Ø=40 mm foil is too small for good acceptance
⇒ 80 mm diameter of foil
(phase space area ~ Ø^4)

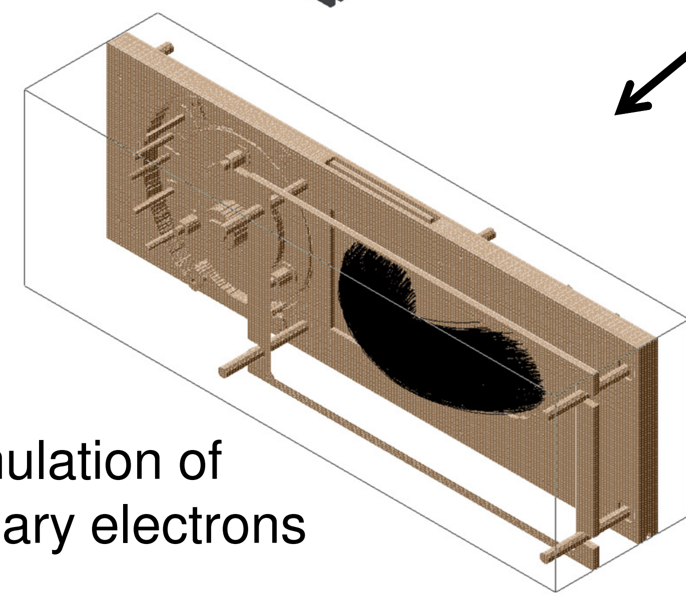
# Detector Simulation



CAD-drawing



SIMION grid creation and calculation of electrical fields

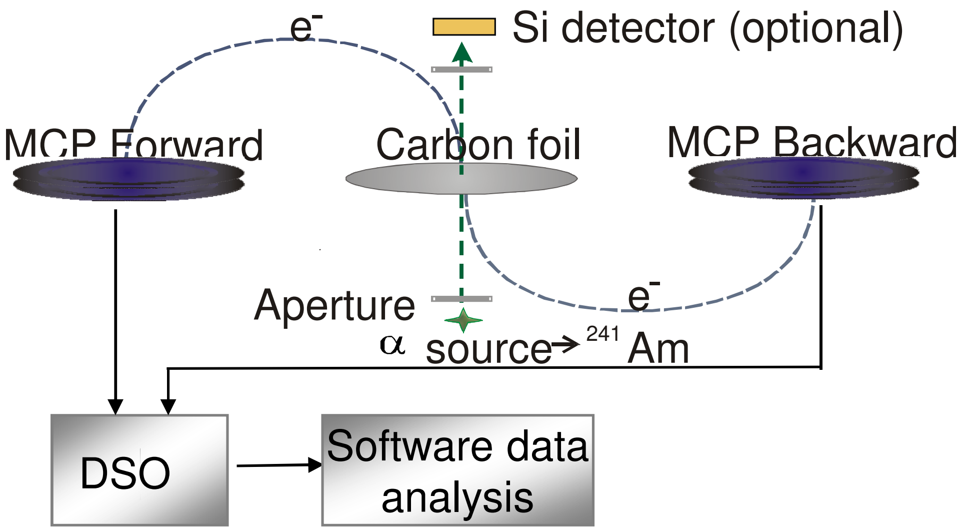


Simulation of secondary electrons

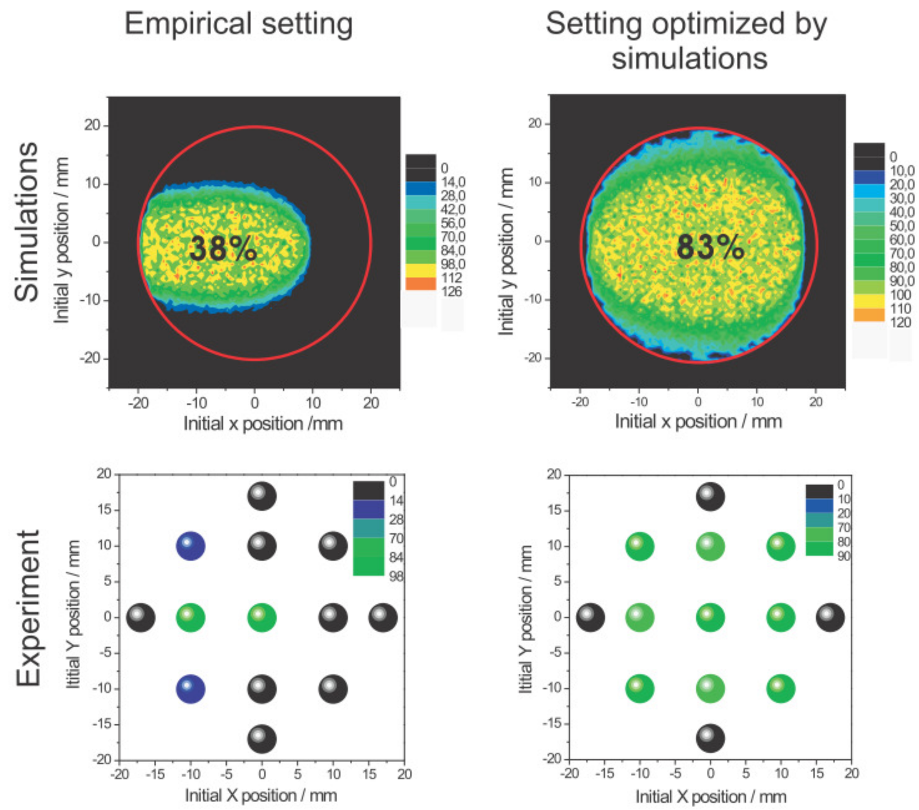
| | |
|---|---|
| <sec.electron ToF> | 4378 ps |
| $\sigma_{transport}$ | 28 ps |
| Efficiency | 98,0 % |
| B-Field | 7.33 mT |
| E-Field | 207 V/mm |

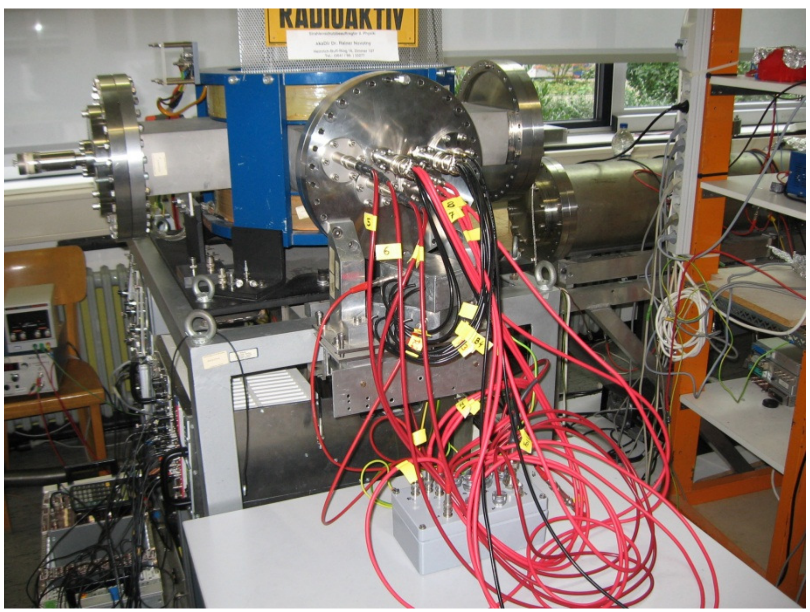
**Marcel Diwisch, Univ. Giessen**

# Improvements of the TOF Detector




Position dependent test with
α-source or laser pulses

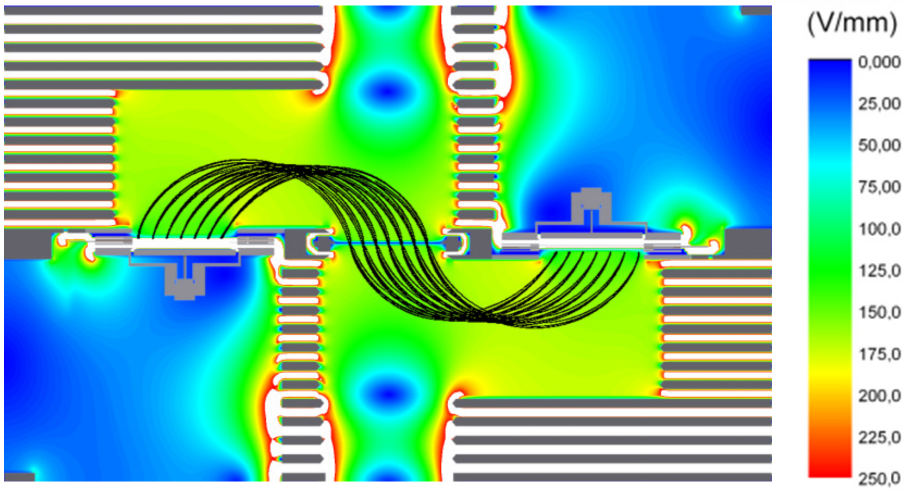


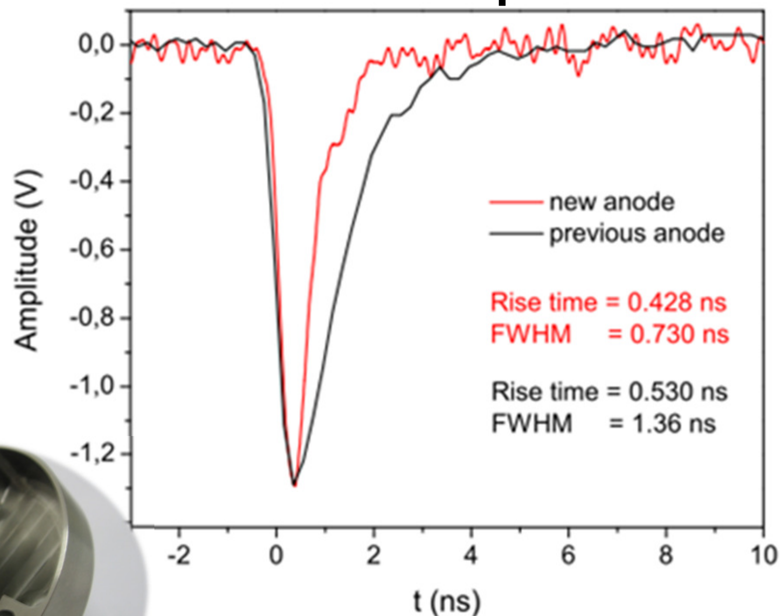
Offline setup of TOF detector in Giessen

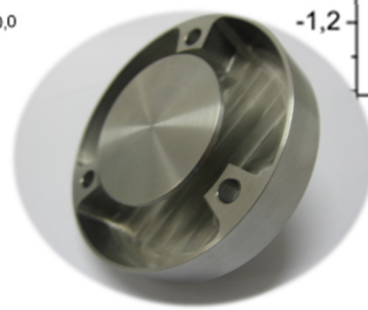
# Improvements of TOF detector

**M. Diwisch, Master thesis (2011)**

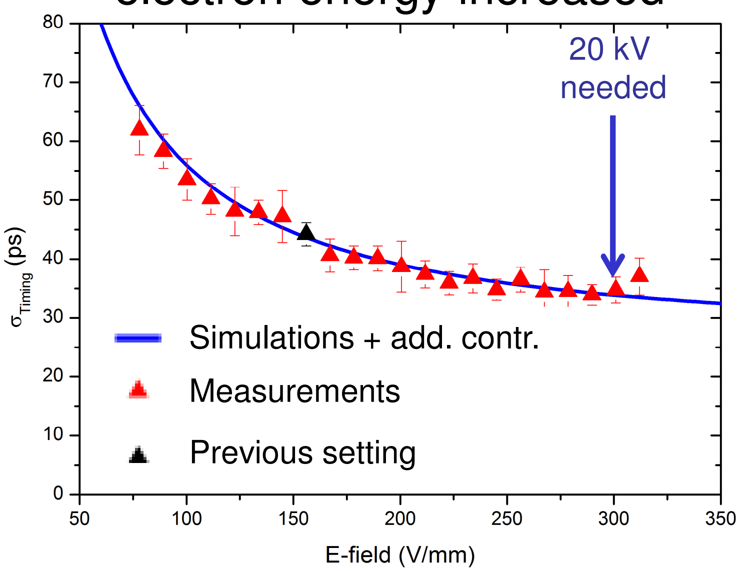



## anode shape



## electron energy increased




$$\sigma = \sqrt{\sigma^2(\mathrm{Transport}) + \sigma^2(\mathrm{MCP}) + \sigma^2(\mathrm{ETD})}$$

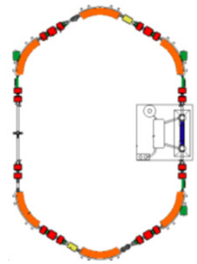
**Timing accuracy increased from 45 ps to 33 ps**

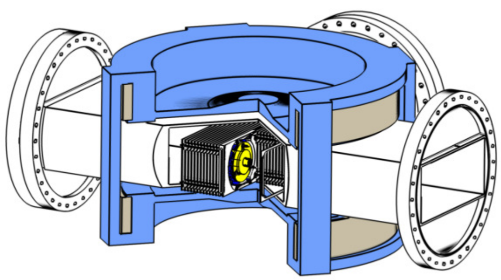
# Detector Comparison

## ESR

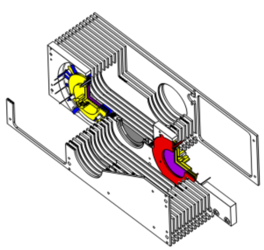
L = 108.36 m
$B\rho$ = 8-10 Tm
$\gamma_t$ = 1.4
$\Delta p/p$ = 0.2 %
$\varepsilon_x$ = 7 mm mrad

TOF detector (1x)





B-field homogeneity radius 100 mm

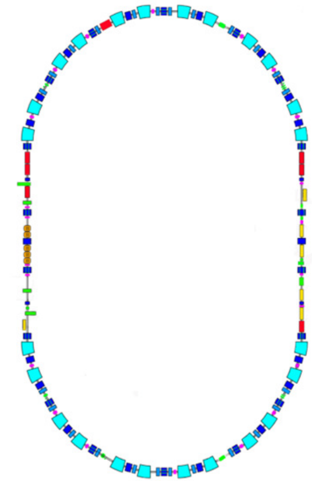


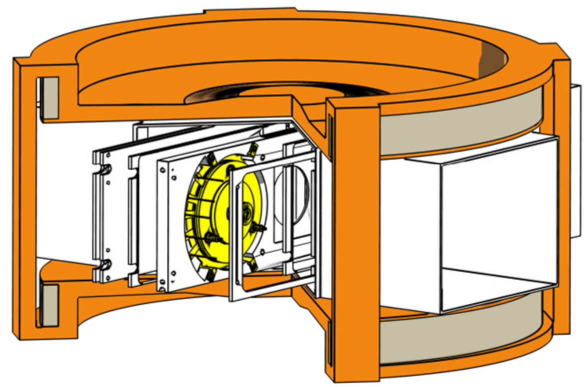
Foil diameter 40 mm
Efficiency ≈ 38%
Timing accuracy ≈ 45 ps

## CR

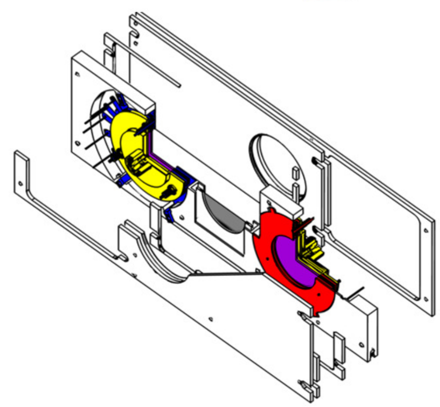
L = 221.45 m
$B\rho$ = 13 Tm
$\gamma_t$ = 1.68
$\Delta p/p$ = 0.5 %
$\varepsilon_x$ = 100 mm mrad

TOF detector (2x)





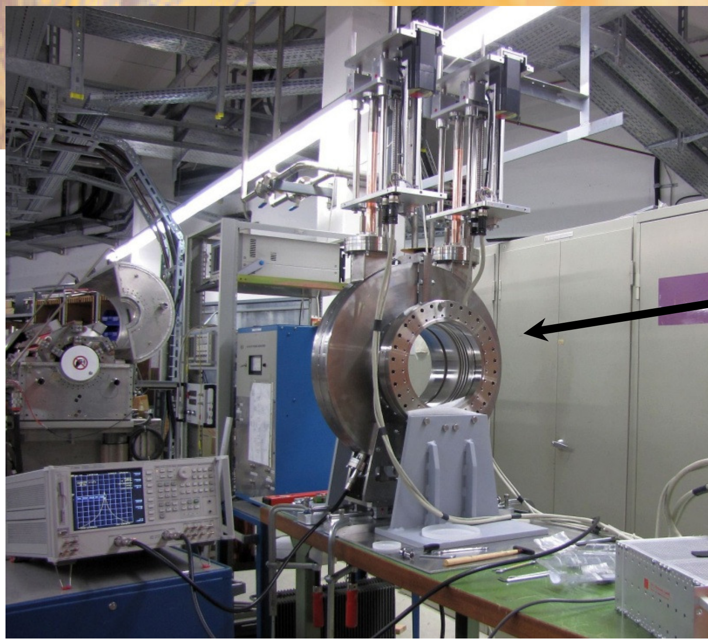
B-field homogeneity radius 200 mm



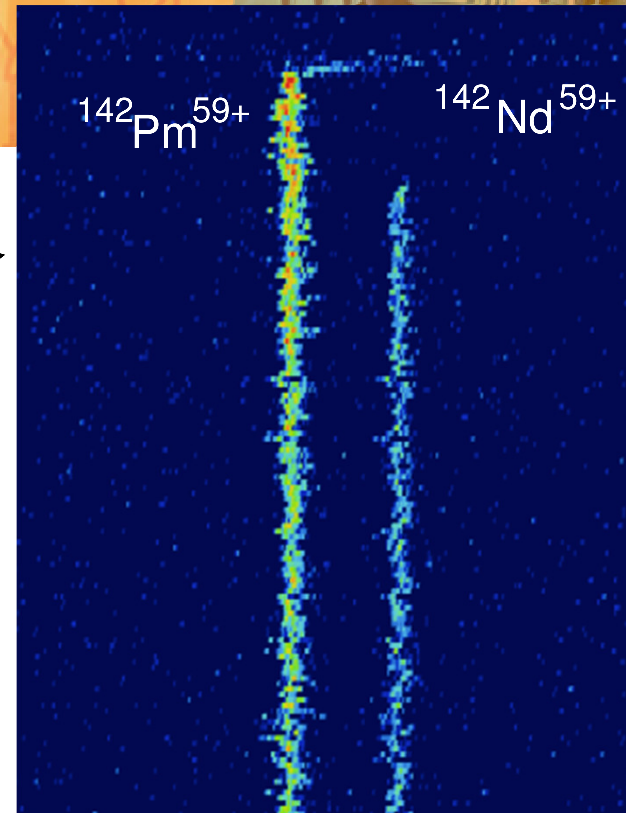
Foil diameter 80 mm
Efficiency ≈ 98%
Timing accuracy ≈ 37 ps

$$\sigma = \sqrt{\sigma^2(\text{Transport}) + \sigma^2(\text{MCP}) + \sigma^2(\text{ETD})}$$

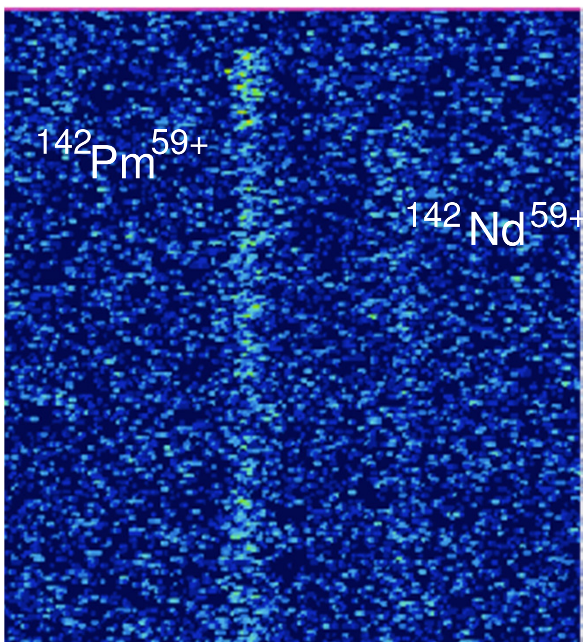
# First EC-decay of He-like $^{142}$Pm ions measured in E082 experiment



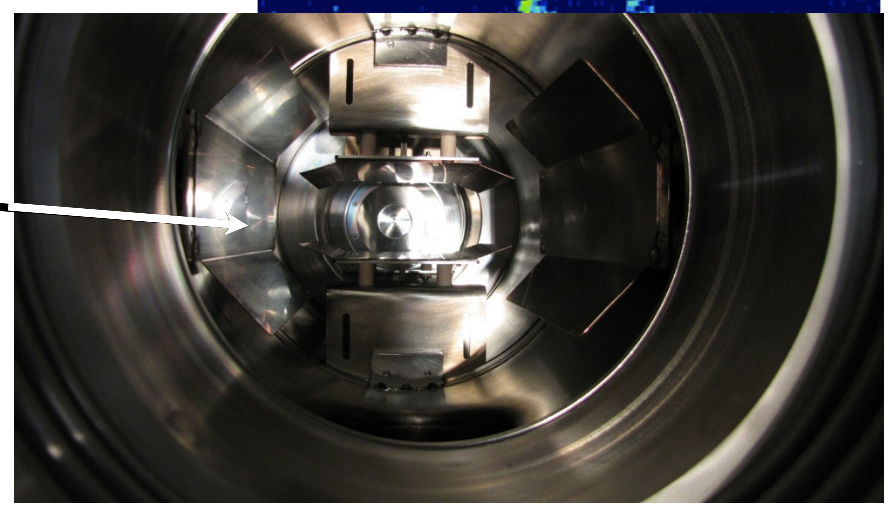
New resonator cavity (2010)
$124^{th}$ harmonic




**the same decay:**
**improvement by**
**a factor of about 100**

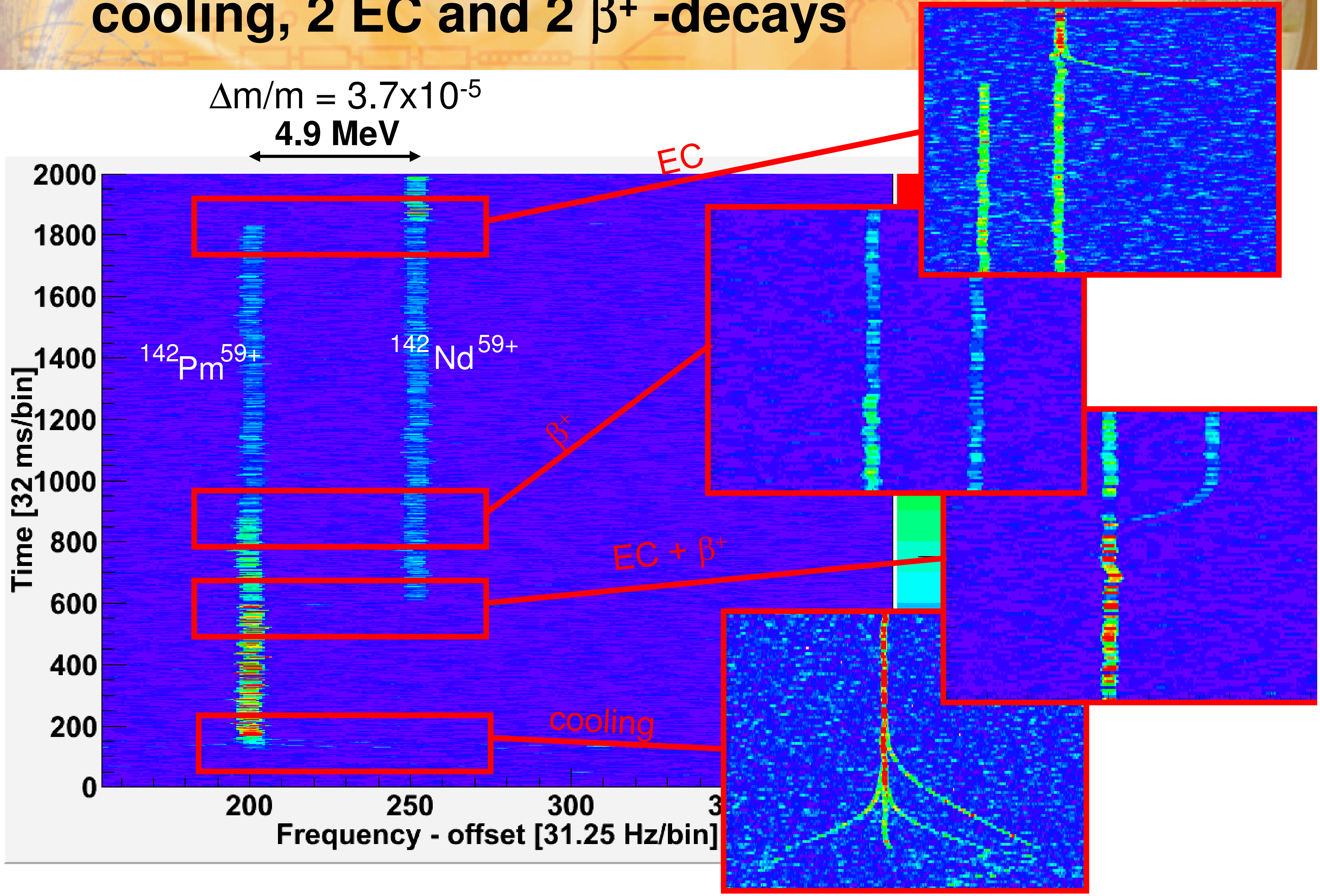



Old Schottky pickup (1992)
$30^{th}$ harmonic

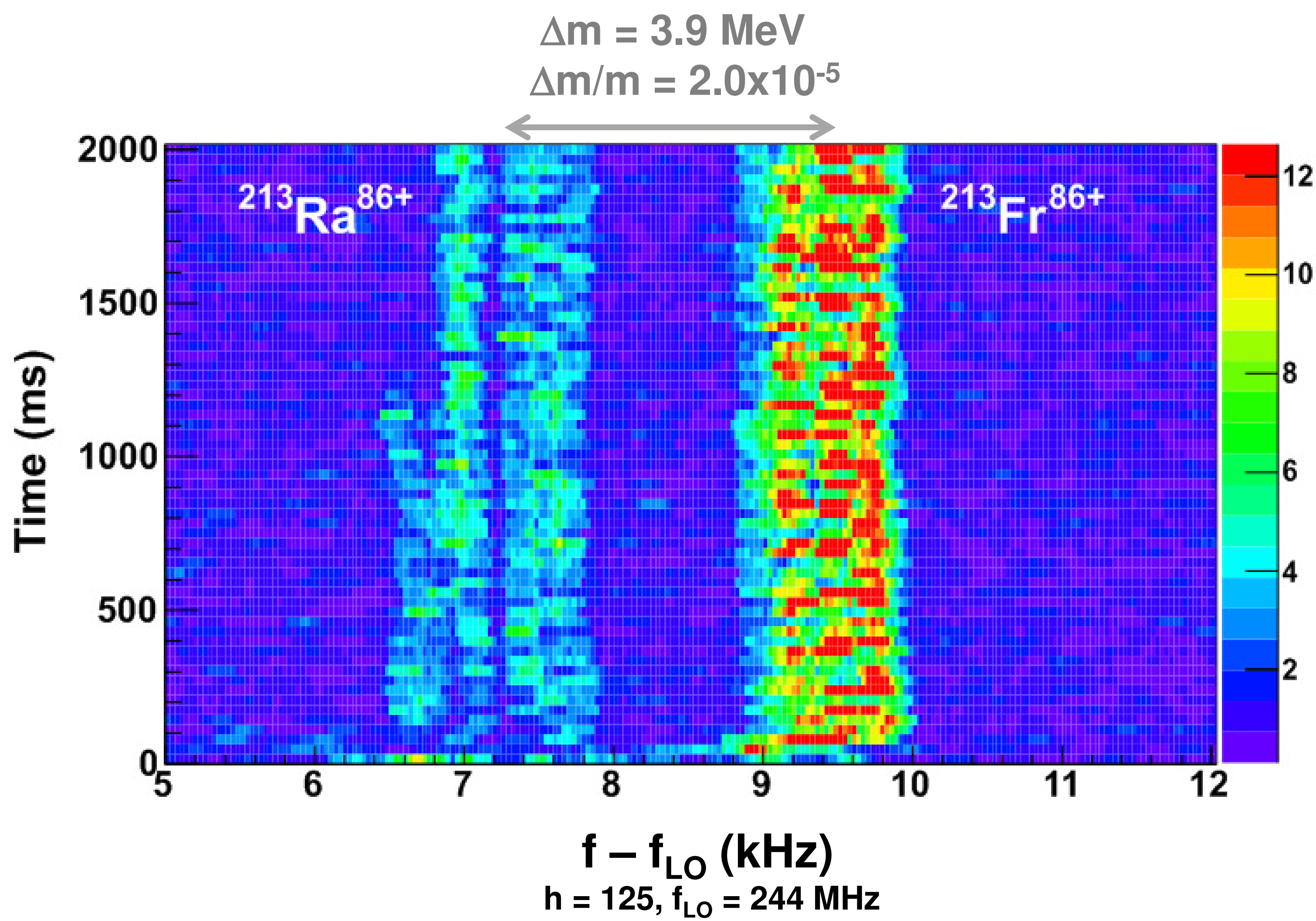


***F. Nolden,***
***P. Hülsmann, et al.,***
**NIM A 659 (2011) 69.**

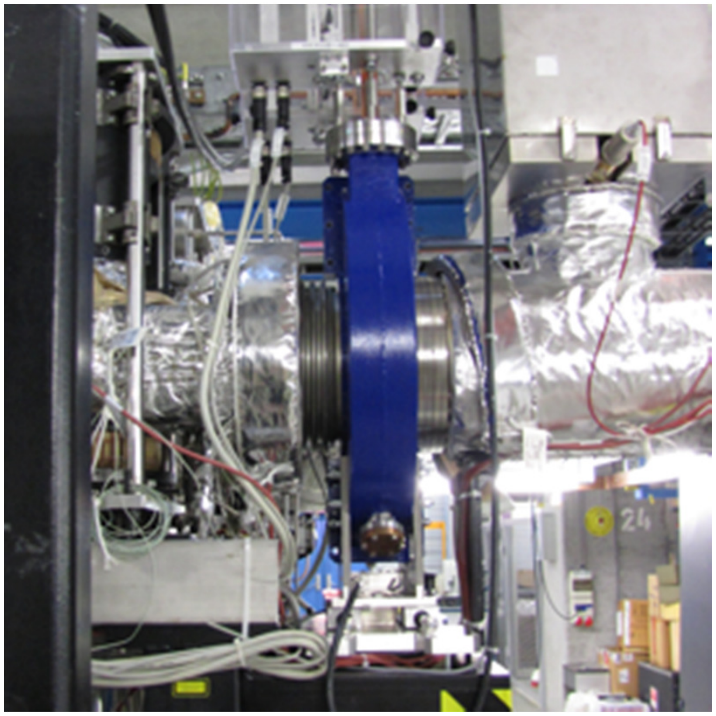
# EC decay in ESR
# cooling, 2 EC and 2 $\beta^+$ -decays



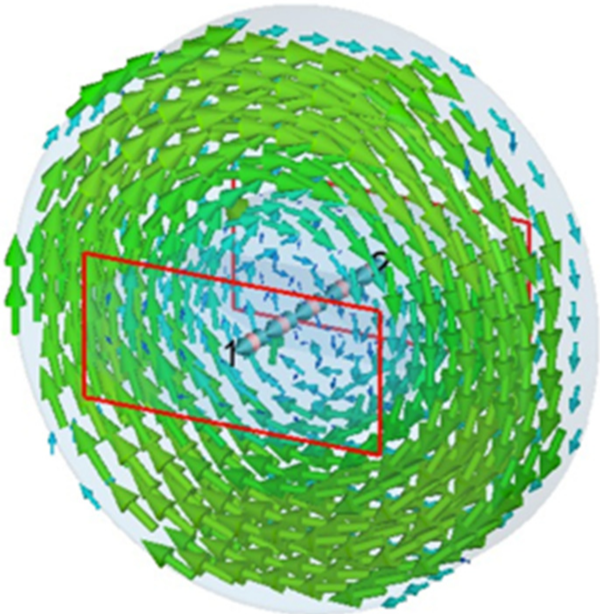
# Schottky in isochronous ESR (uncooled)

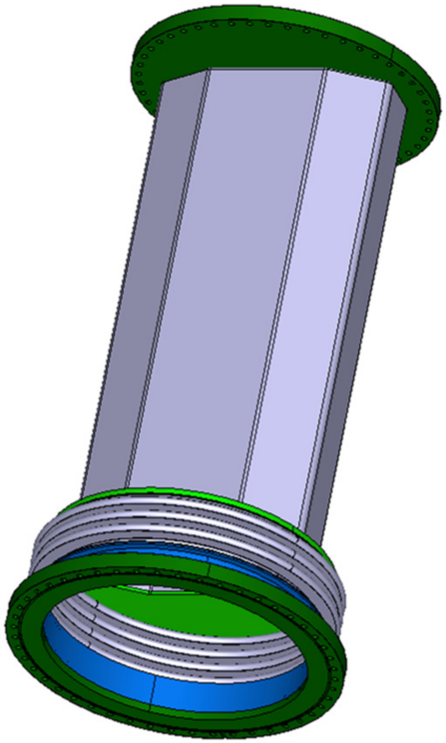


# Resonant Schottky Pickup

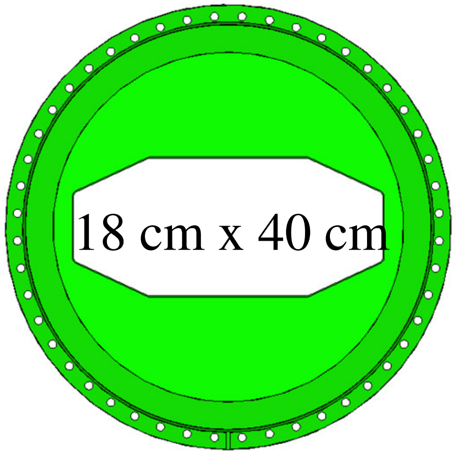


**use pill box cavity**
**single mode T010**
**$f_R$ tunable,**
**quality factor Q**
**also tunable.**



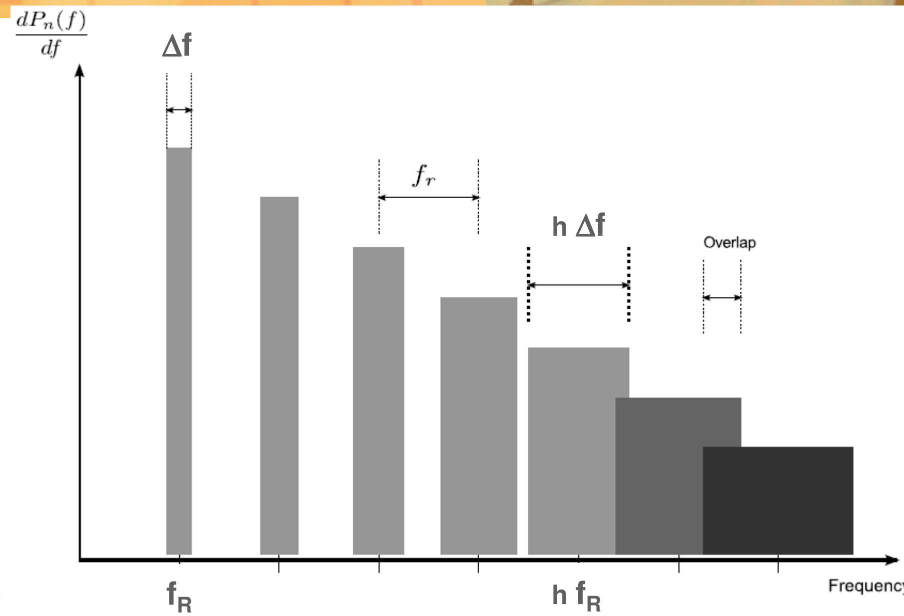
**CR beam pipe**



# Many Pickups in Isochronous CR

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

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



*noise power at different harmonics (h)*

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

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

Large spread in Δf/f requires large band width, and limits harmonic to avoid overlap of frequency bands and ambiguity.
For $\Delta m/m = 5\%$, $\gamma_t = 1.68$, 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.

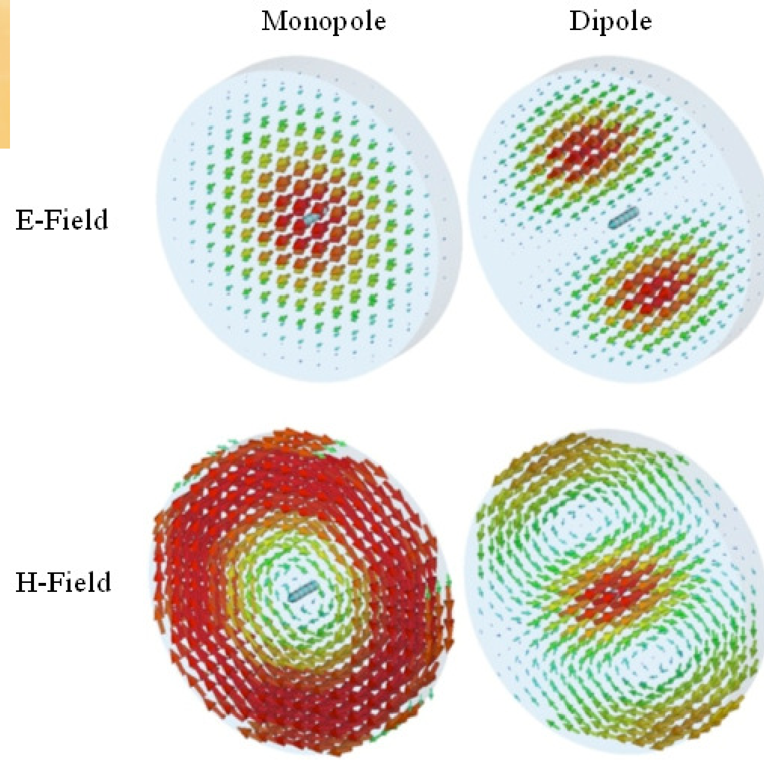
For isobars h=10^5 possible, but far beyond cut off frequency.

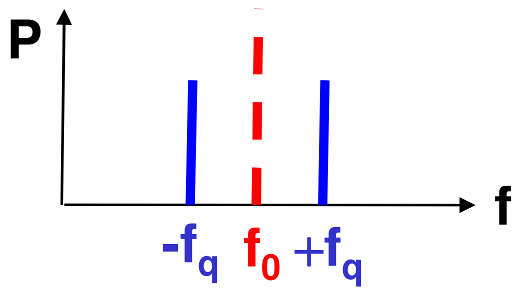
# Transverse Pickup

**Good isochronicity needs definition of m/q also for testing as function of velocity.**

**Pickup sensitive to position for single ions.**

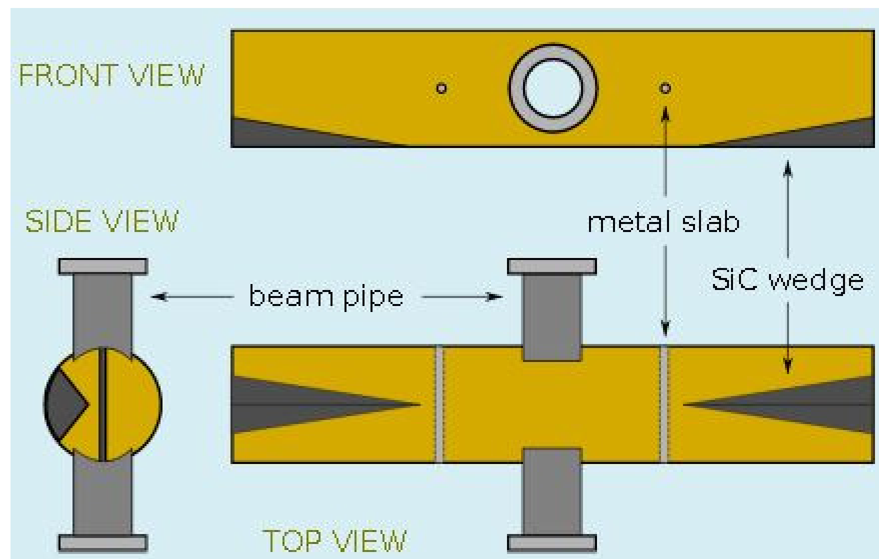
**Position dependence by dipole mode of resonator. Betatron oscillations introduce sidebands shifted by tune frequency. Intensity of side bands gives position, calibrate with known position.**



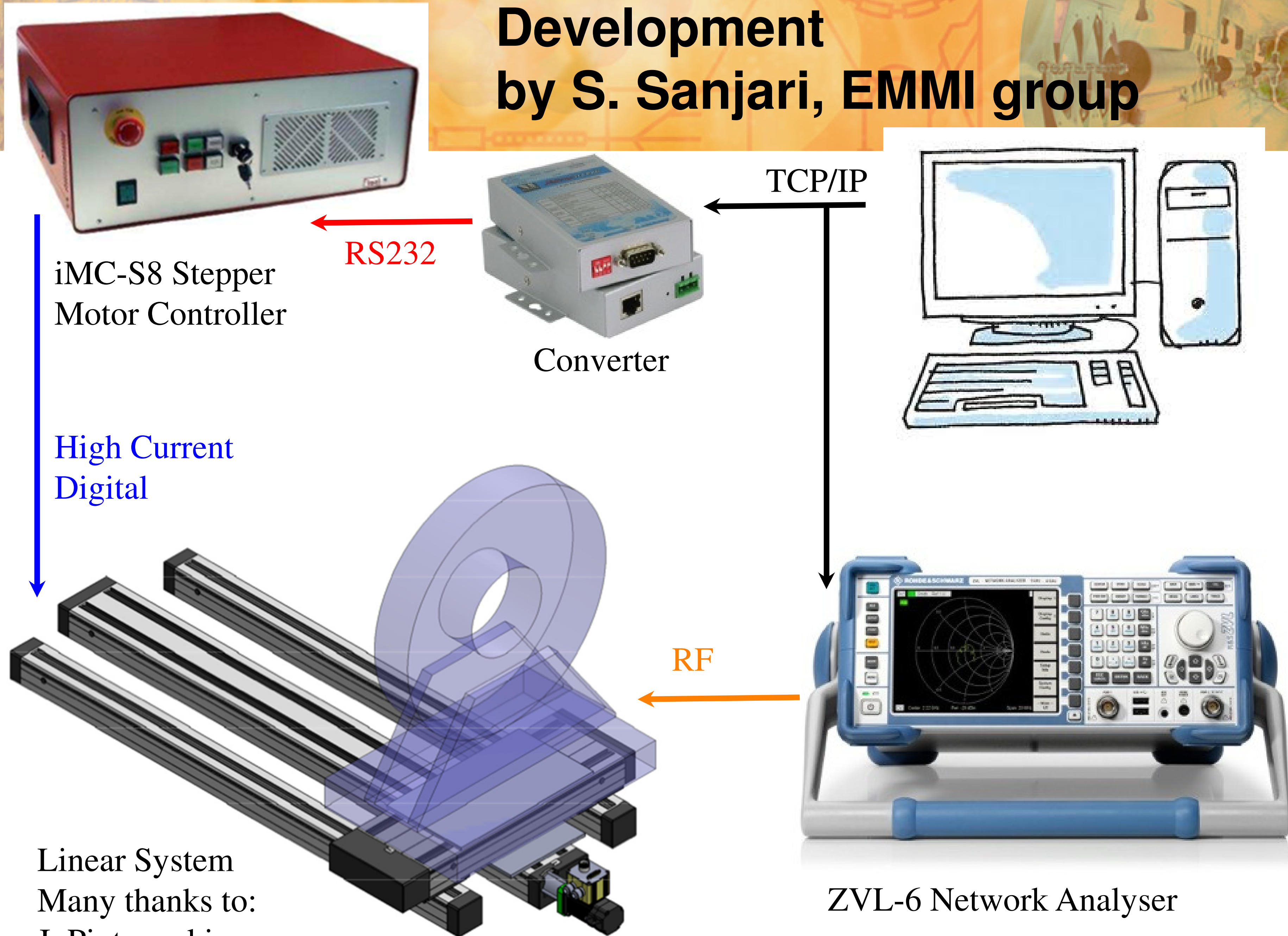




**in arc to observe shift by dispersion -> $B\rho$ of ion, needed $\Delta B\rho/B\rho < 10^{-3}$ -> $\Delta x \sim$ 1-2 mm.**

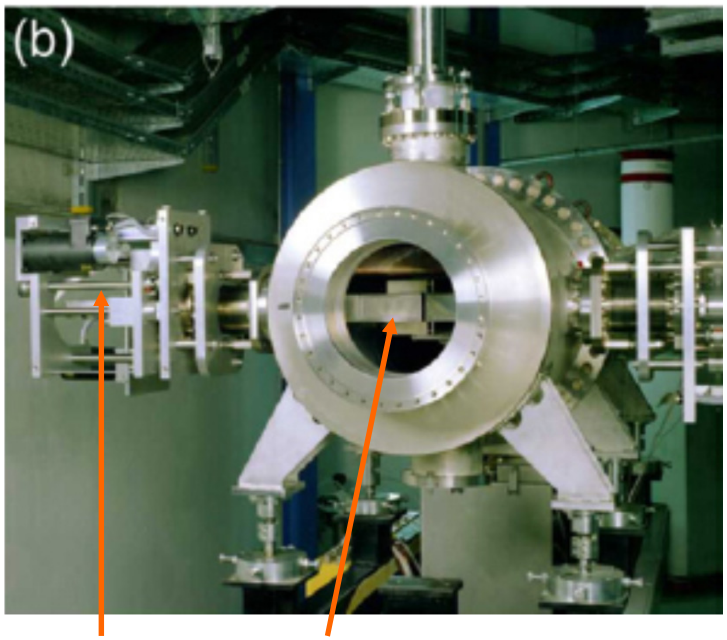
**Different shape of resonator needed.**



# Development
# by S. Sanjari, EMMI group



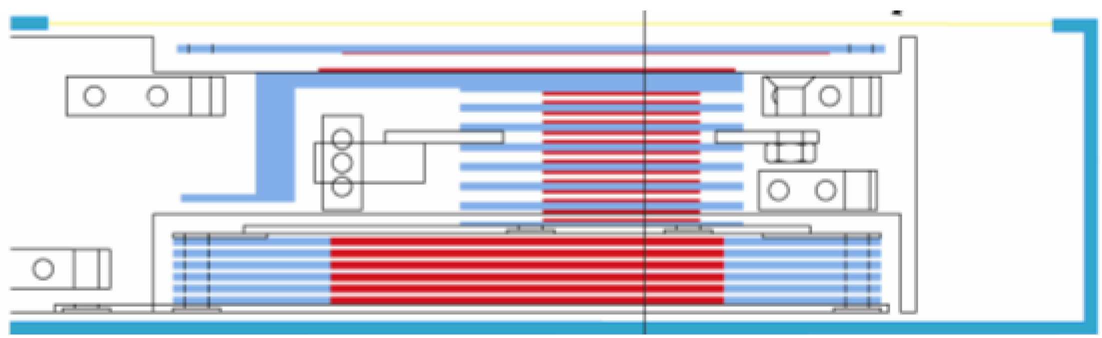
# Detectors after Decays




**Detect after spontaneous decay.**
**Afterwards also identification.**
**Example: beta delayed neutrons**

**Sometimes also after target.**
**Use target as stripper to separate.**
**In ESR intense $^{205}\mathrm{Tl}^{81+}$ from $^{205}\mathrm{Pb}^{81+}$,**
**(bound state $\beta$-decay of $^{205}\mathrm{Tl}$).**
**→ HESR at FAIR**

**Si stack + passive absorbers,**
**or CsI for $\Delta E$, E**



L. Mayer, TU München

**First investment 3 pockets, detectors later.**

# CR Correction Scheme

$$\frac{\Delta T}{T} = \frac{T - T_0}{T_0} = \cancel{(t|x)_c x} + \cancel{(t|a)_c a} + \cancel{(t|\delta)_c \delta} \qquad \text{=0 (first order)}$$

$$+ (t|xx)_c x^2 + (t|xa)_c xa + (t|aa)_c a^2 + (t|yy)_c y^2 + (t|yb)_c yb$$

$$+ (t|bb)_c b^2 + (t|x\delta)_c x\delta + (t|a\delta)_c a\delta + (t|\delta\delta)_c \delta^2$$

**Full correction of order n ≥ 2 not possible in ring with non-zero phase advance, but is needed for large acceptance. Would impose strong acceptance limit (factor ~25 less).**

$$\lim_{n\to\infty} \frac{(t|aa)}{nT_0} = 0$$

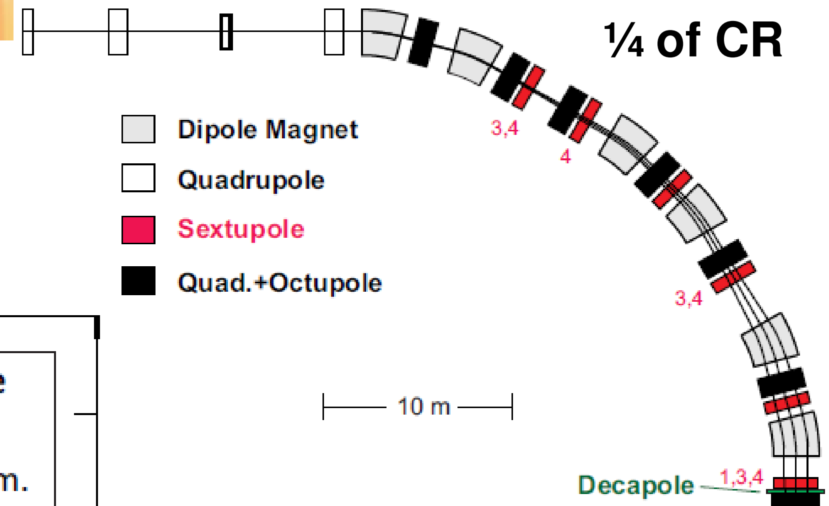
$$\lim_{n\to\infty} \frac{(t|xx)}{nT_0} = 0$$

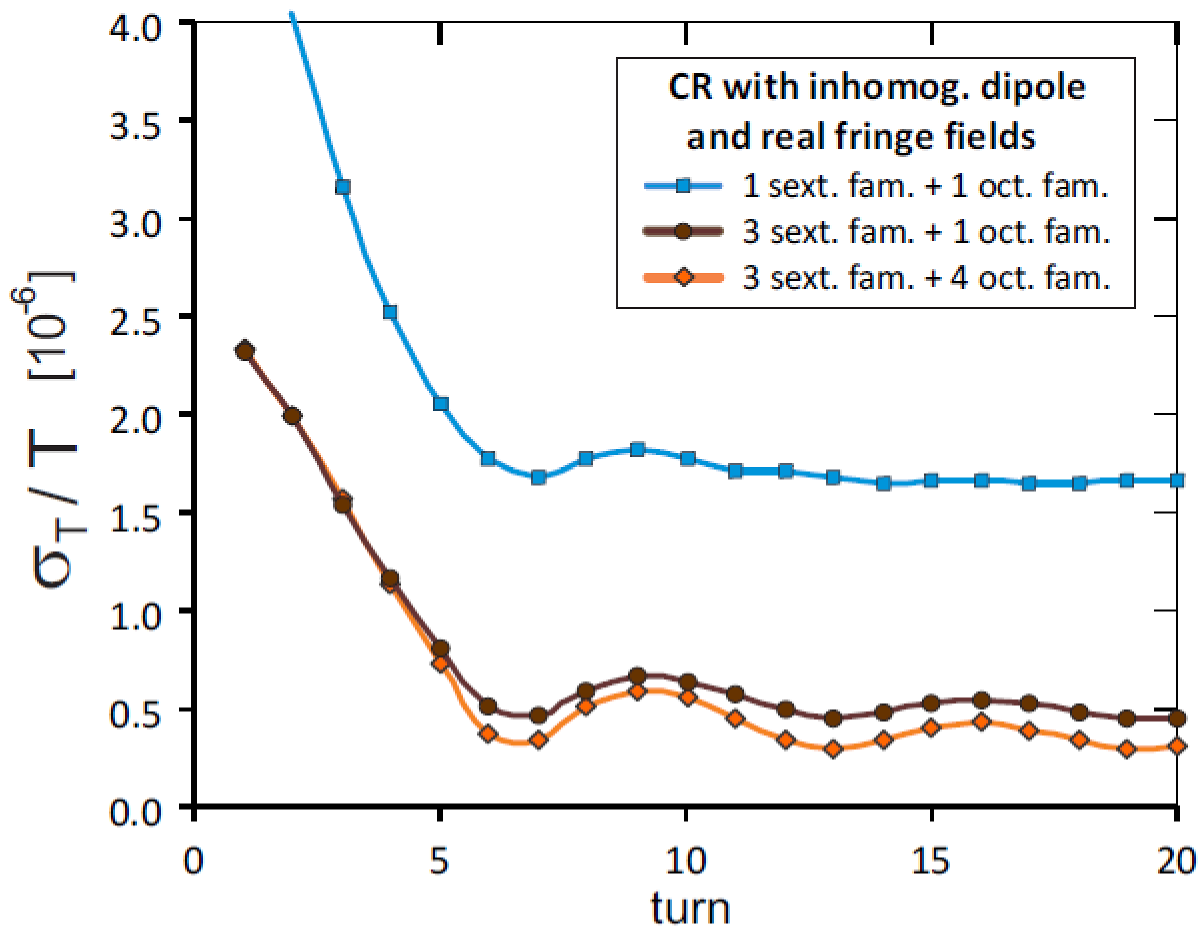
$$\lim_{n\to\infty} \frac{(t|xa)}{nT_0} = 0$$

**by sextupole tuning, correct only that much that remaining deviations average out.**

*S. Litvinov, D. Toprek, H. Weick, A.Dolinskii,*
**Isochronicity Correction in the CR Storage Ring,**
Nuclear Instruments and Methods in Physics Research A 724 (2013) 20.

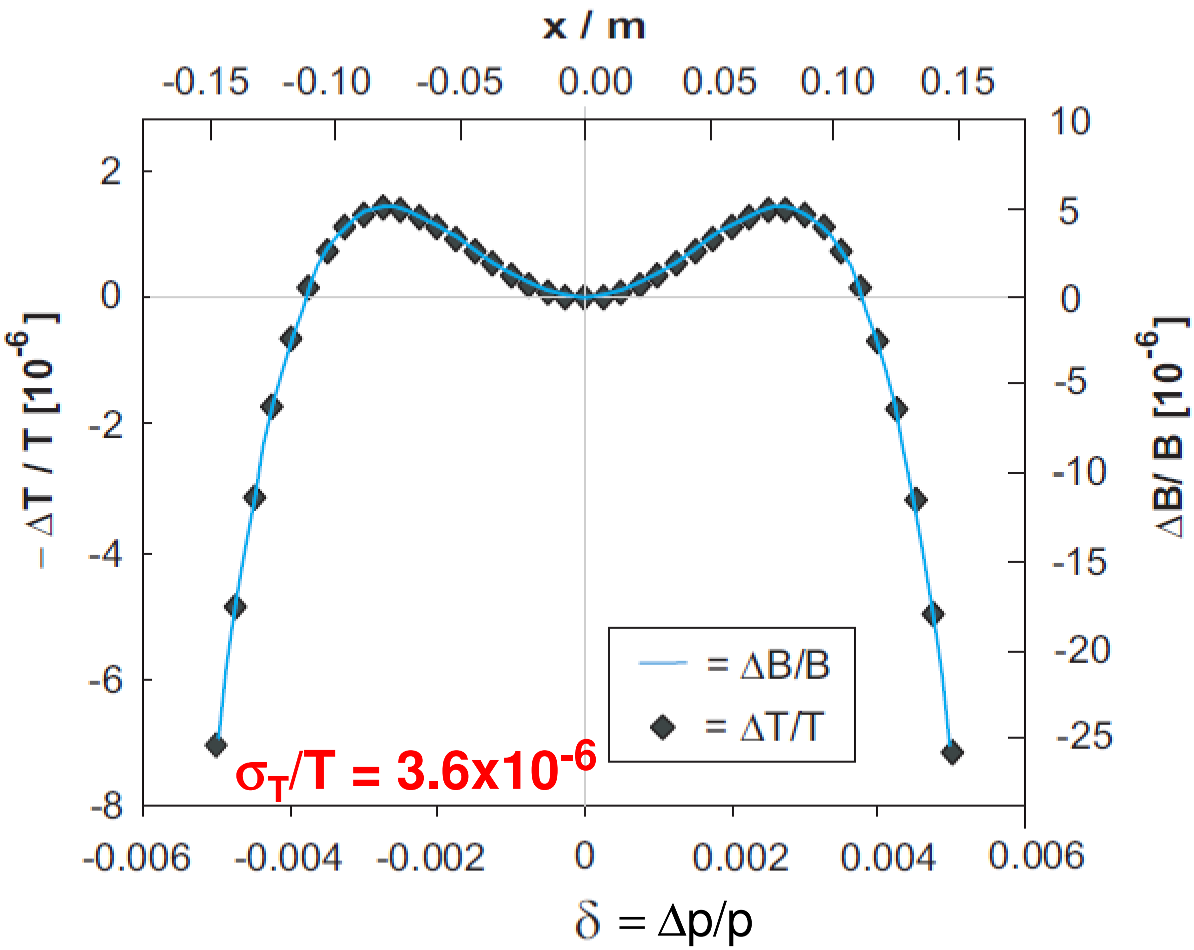
# CR Simulation




**Simulation: full phase space in x,y (100 mm mrad), δ=±0.5% including realistic fringe fields and field imperfections.**

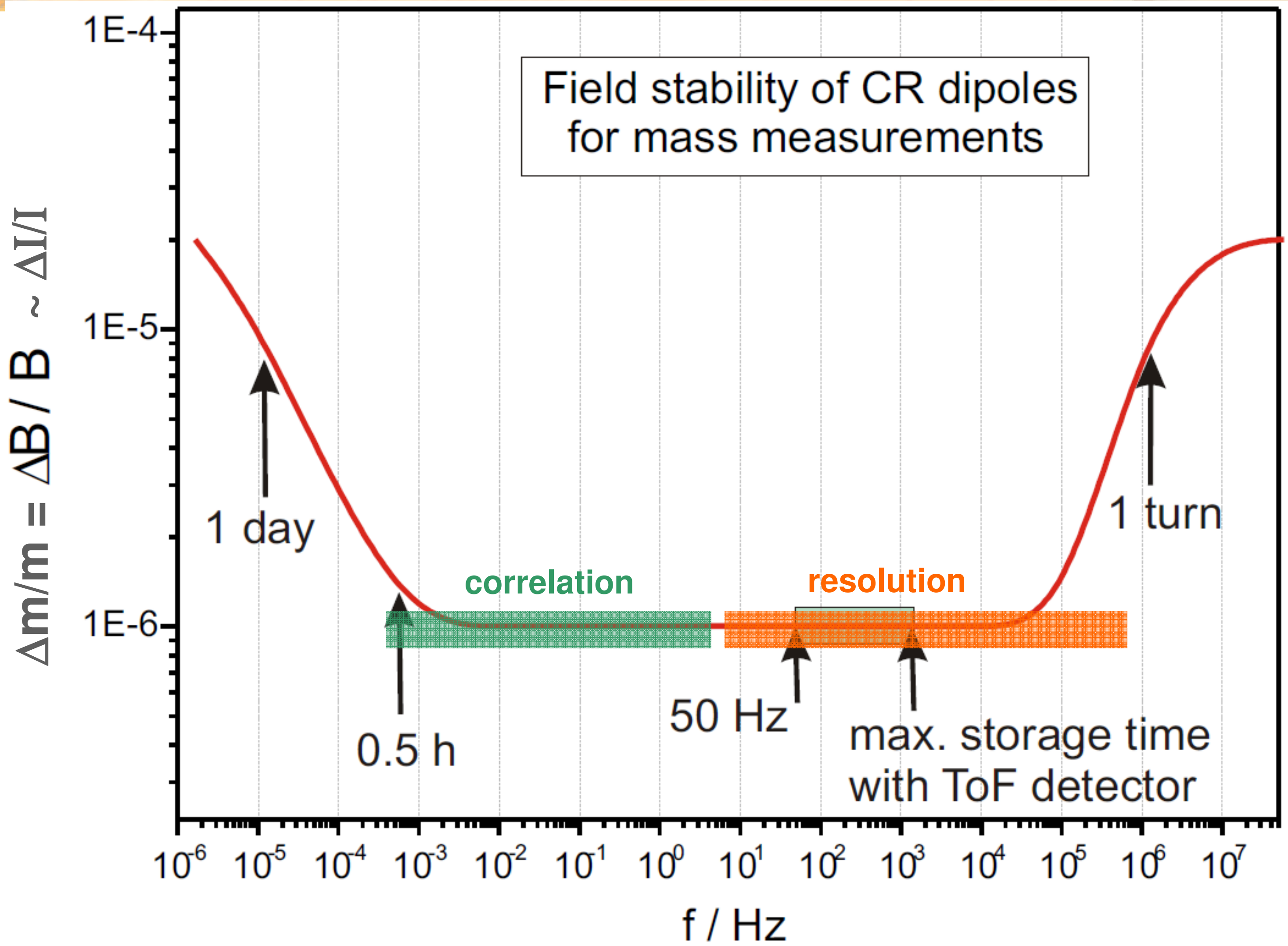
# CR Dipole Homogeneity




**without sextupole/octupole correction only $\sigma_T/T = 1.2\text{x}10^{-4}$**

**decapole could help for further improvement**

# Power Supply Stability




**but in update of CR TDR only $\Delta I / I = \pm 0.5 \times 10^{-4}$**

# Summary

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

**Schottky also possible in isochronous CR.**
**Less limited in beam intensity, but still fast.**
**Transverse pickup still needs development.**

**Particle detectors also have a case/place in CR.**

**Experiments with cooling possible in HESR.**
**Lifetime, decay modes, …**

**The CR itself is consolidated, even manufacturing seems distributed (BINP Novosibirsk). Magnet homogeneity on needed level impossible, but higher order correction is required.**
**Power supply stability is critical, specification so far are not sufficient.**