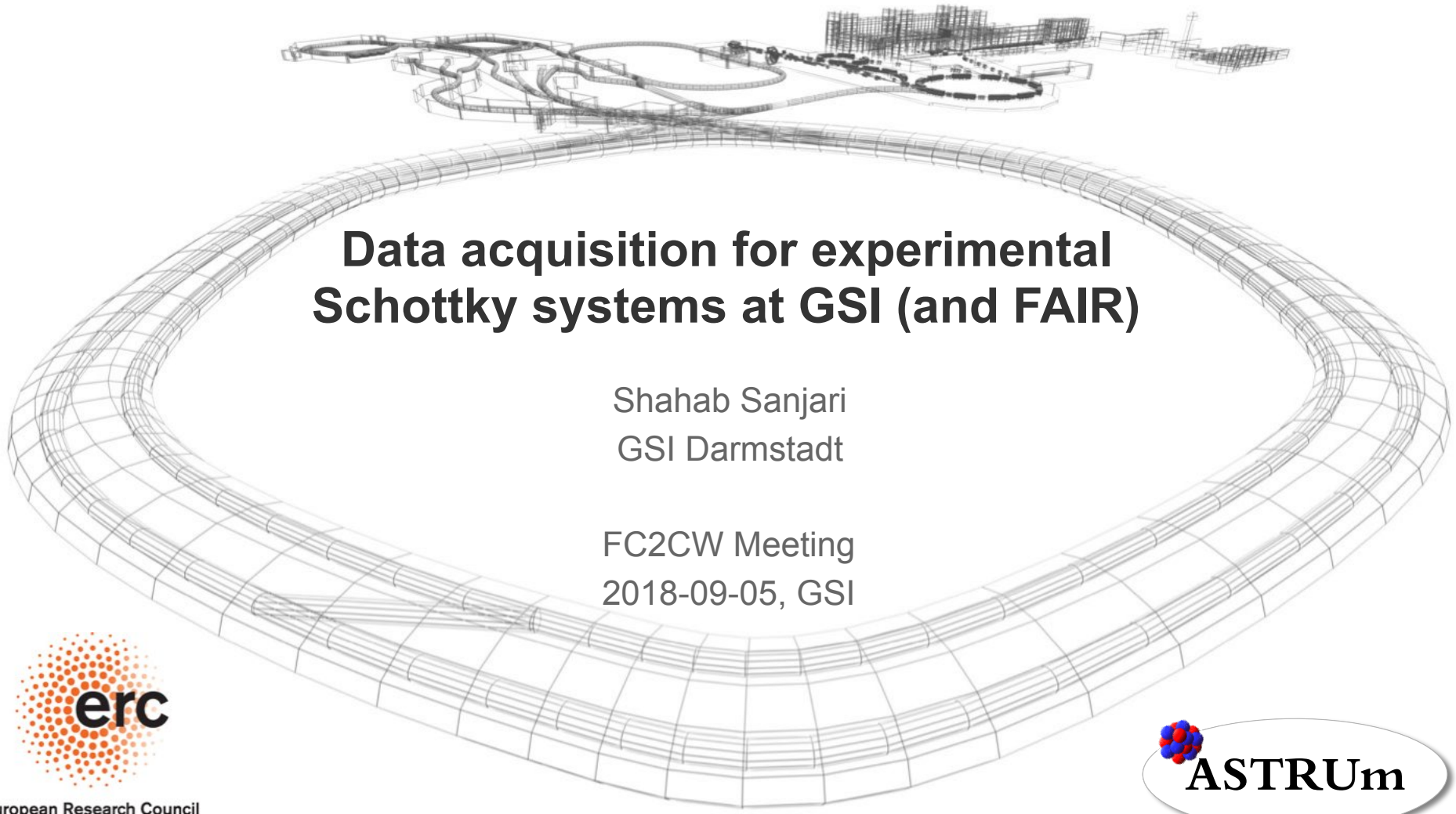
GSI Helmholtzzentrum für Schwerionenforschung GmbH



Data acquisition for experimental Schottky systems at GSI (and FAIR)

Shahab Sanjari
GSI Darmstadt

FC2CW Meeting
2018-09-05, GSI

European Research Council
Established by the European Commission

ASTRUm

Outline

- Application of Schottky analysis in Storage ring experiments
- Design of different Schottky detectors
- Data acquisition and processing

GSI and FAIR

- The Four Pillars of Physics at FAIR

1. APPA Physics (Atomic, Plasma Physics and Applications)
   - SPARC - Stored Particles Atomic Research Collaboration
2. Nuclear Matter Physics
3. NUSTAR Physics (Nuclear Structure, Astrophysics and Reactions)
   - ILIMA - Isomeric Beams, Lifetimes and Masses
4. Physics with High Energy Antiprotons

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ESR

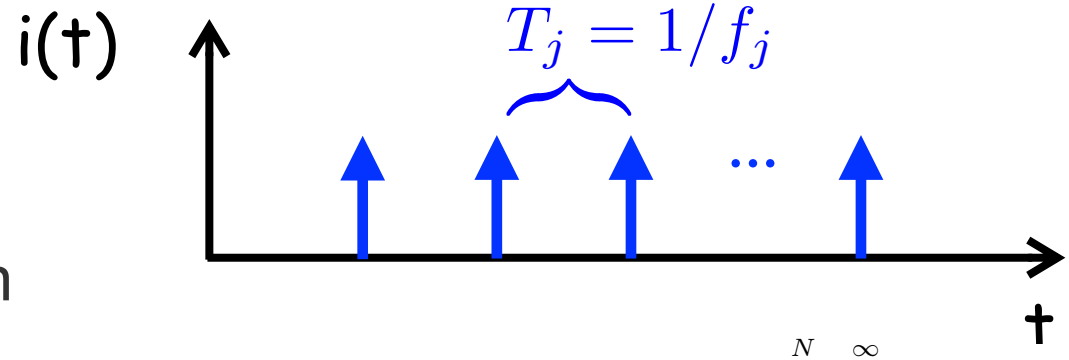
HESR

CRYRING

CR

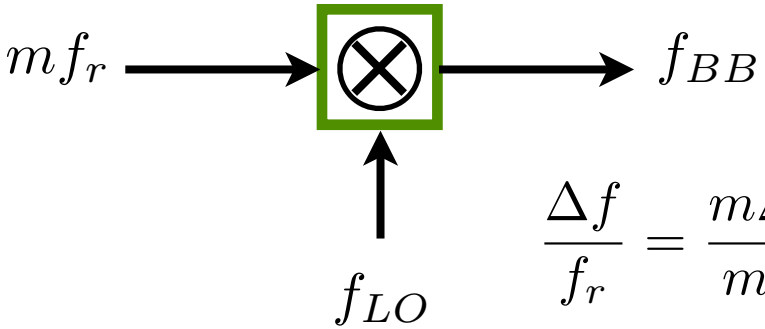
Longitudinal Schottky analysis

- Schottky “signals”
  - “Bands” in spectrum
  - Total power constant in each band
  - Mixing into base band
  - Rev. freq., beam intensity etc..

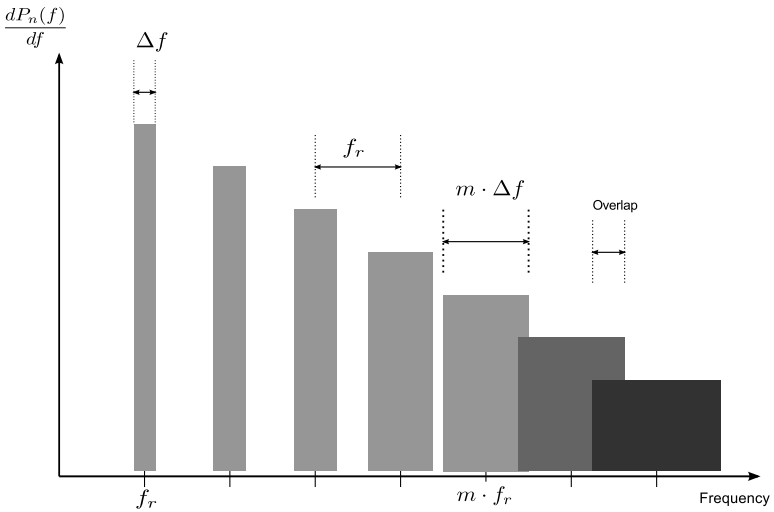


$$r_{ii}(t+\tau,t) = \cdots = (Ze)^2 f_r^2 N^2 + 2(Ze)^2 f_r^2 \sum_{j=1}^{N}\sum_{m=1}^{\infty} \cos(m\omega_j \tau)$$

$$\langle \delta i_{\parallel}^2 \rangle = 2(Ze)^2 f_r^2 N = 2Ze f_r I_{beam}$$



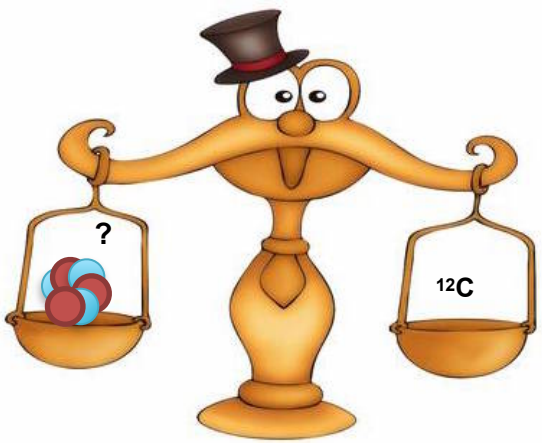
$$\frac{\Delta f}{f_r} = \frac{m\Delta f}{mf_r} < \frac{m\Delta f}{f_{BB}}$$



Applications (1)

- Schottky Mass Spectroscopy

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



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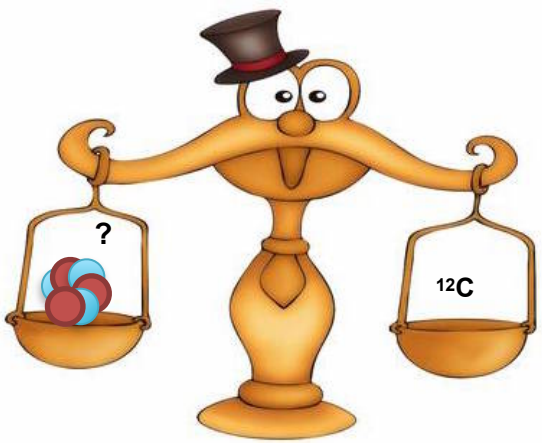

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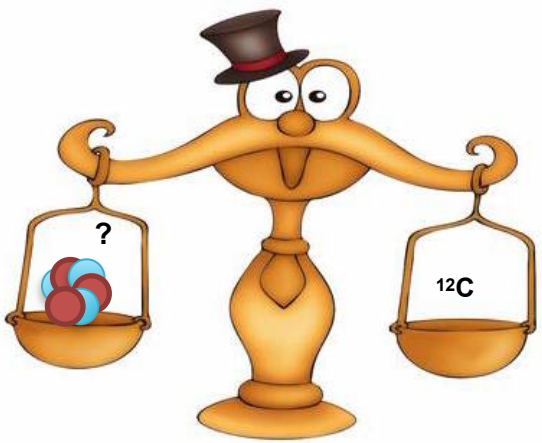
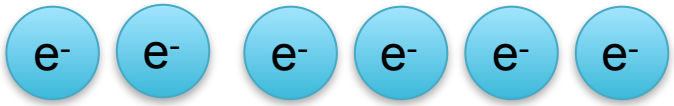
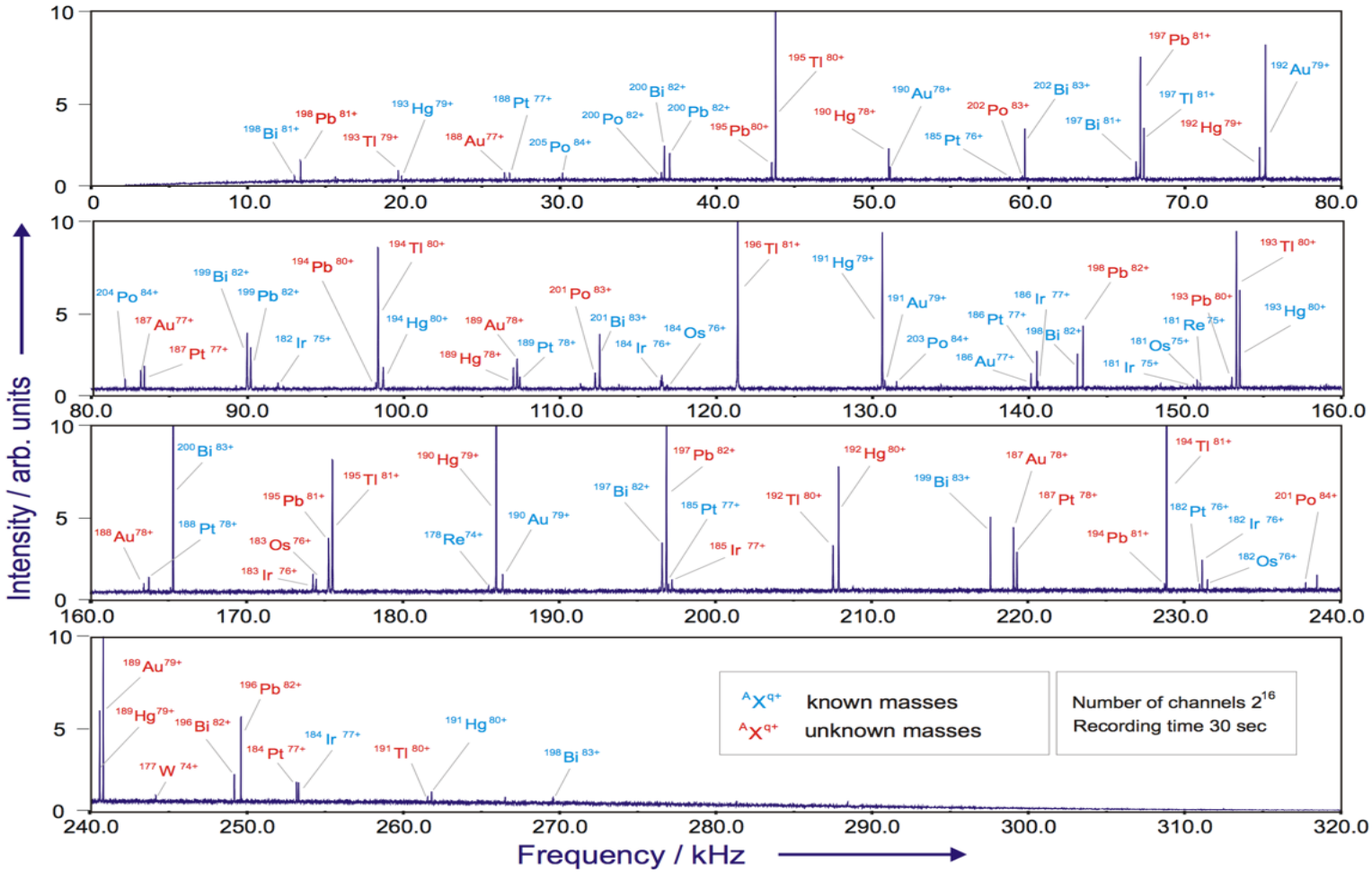




Slide courtesy of Y. Litvinov



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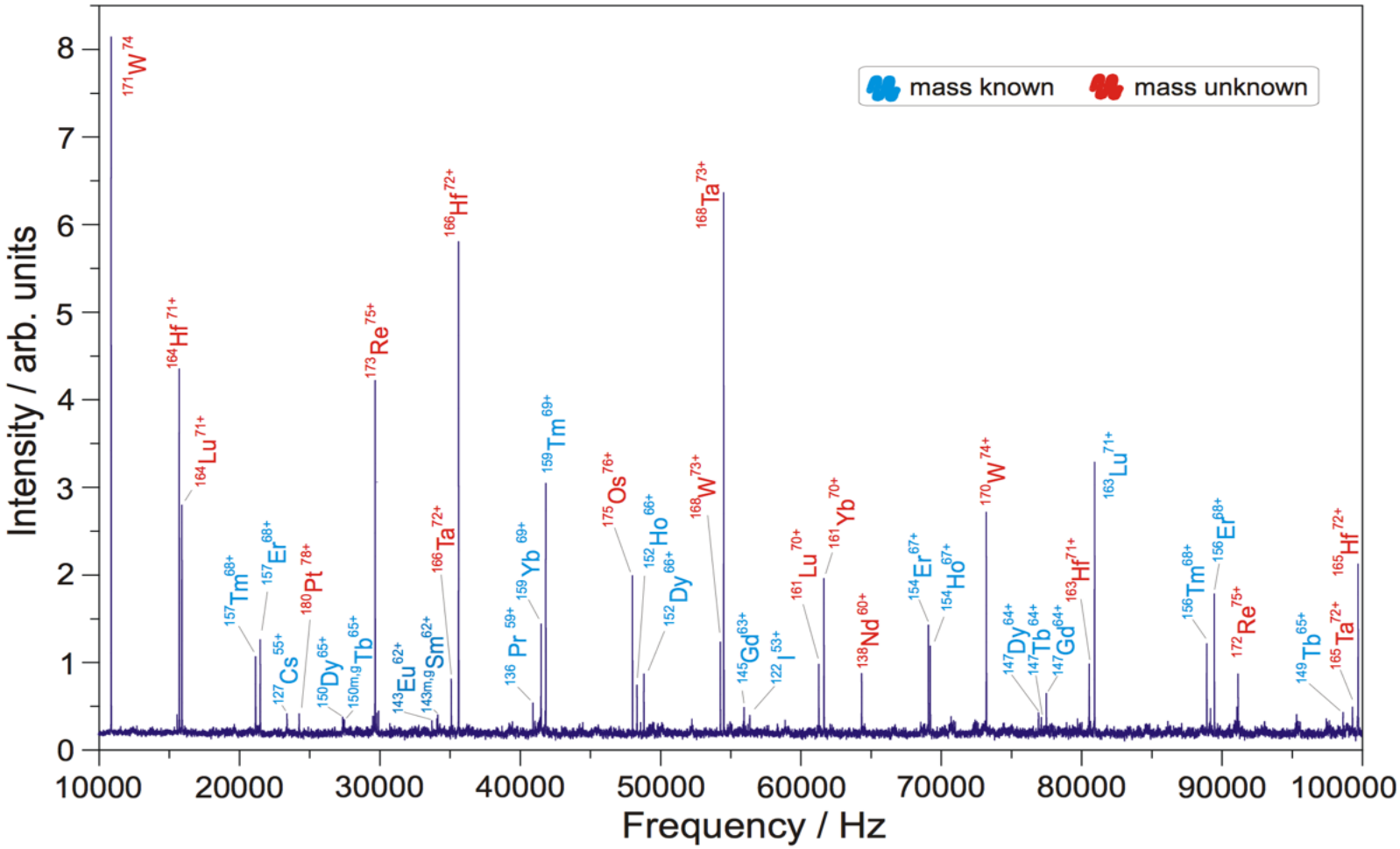

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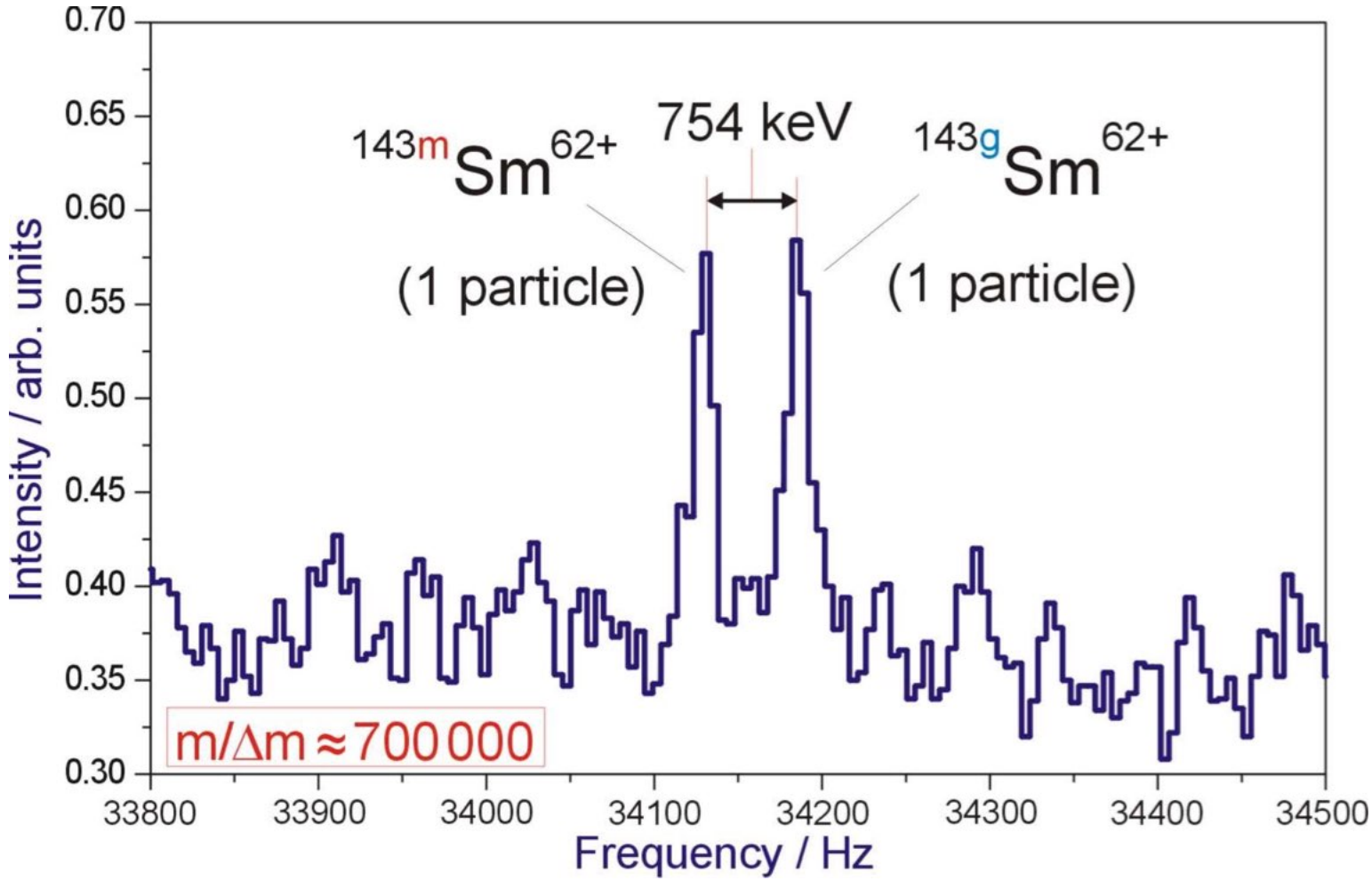
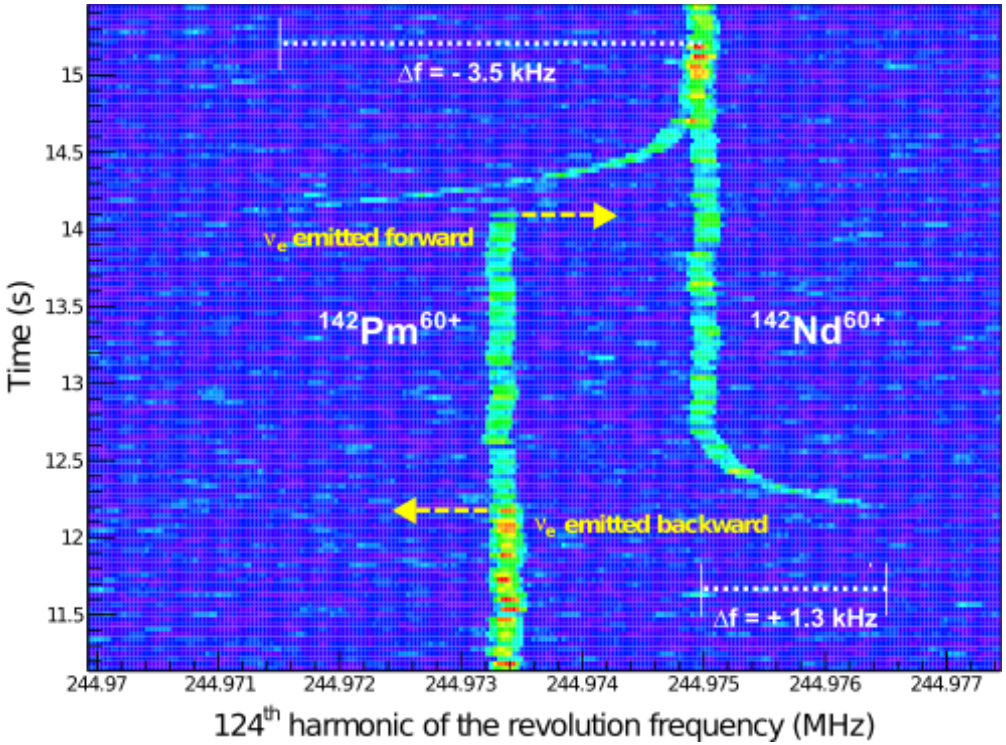


Slide courtesy of Y. Litvinov

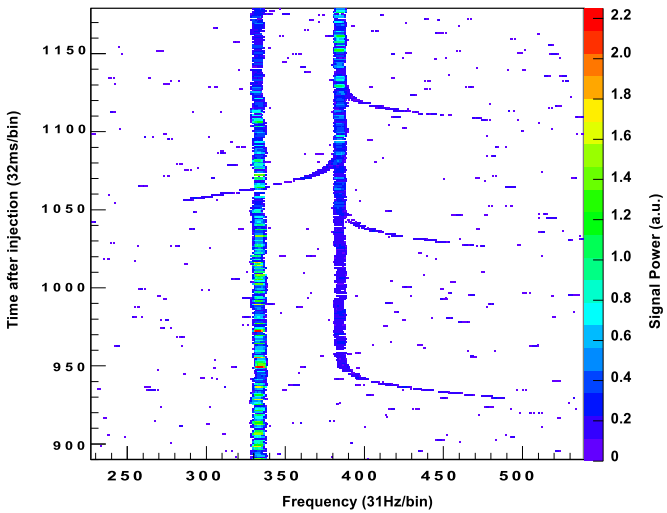
Applications (2)

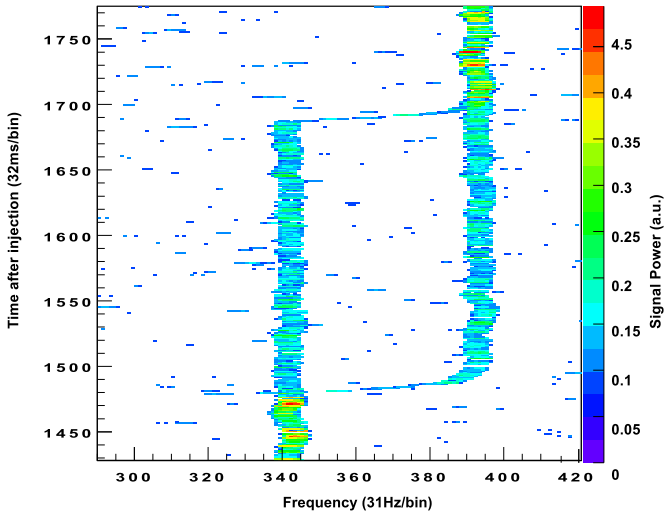
- Lifetime measurement
- e.g. single ion 2 body decay study
- approx. same m/q ratio

$$^{142}_{61}\mathrm{Pm}^{60+} \longrightarrow {}^{142}_{60}\mathrm{Nd}^{60+} + \nu_e$$



Kienle, Bosch et. al., Phys. Lett. B 726 (2013) 4–5, p.638


Time after injection (32ms/bin)
Frequency (31Hz/bin)
Signal Power (a.u.)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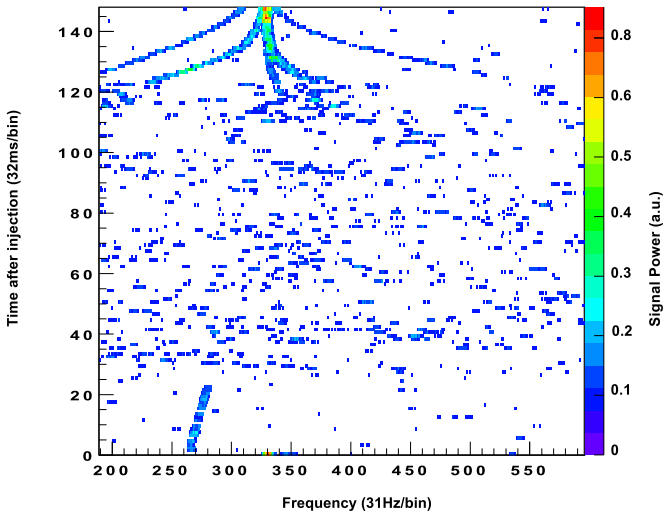
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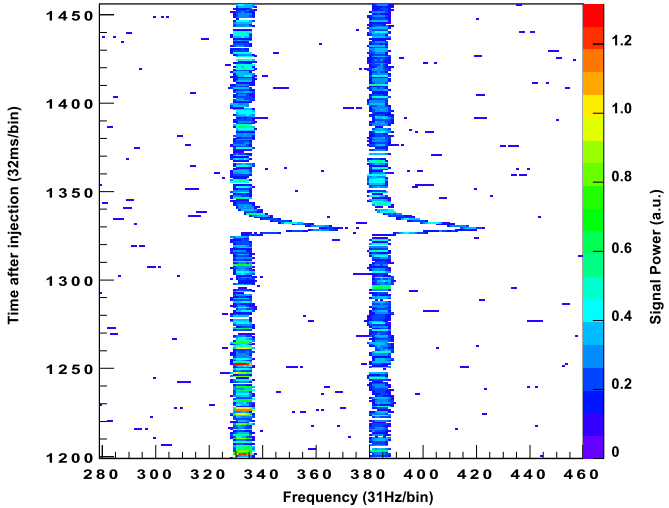
Time after injection (32ms/bin)
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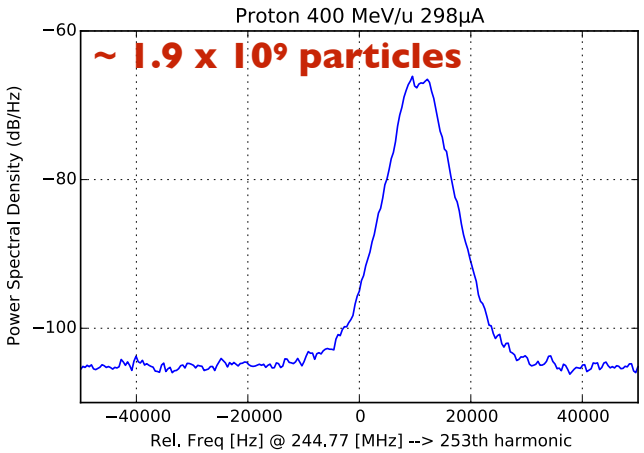
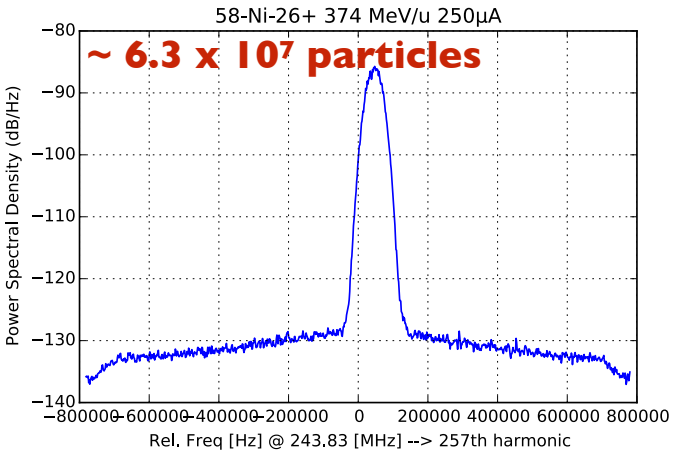
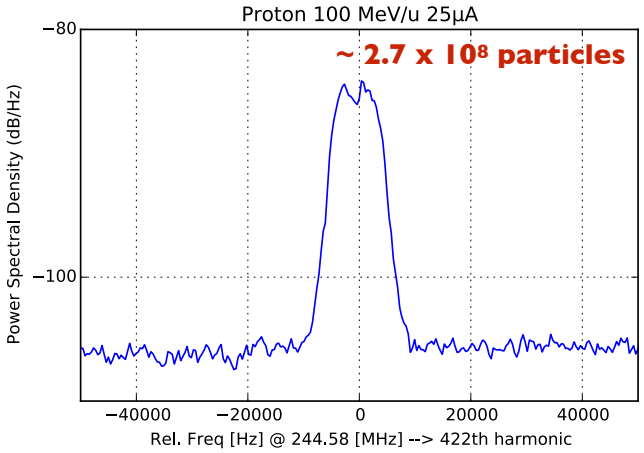
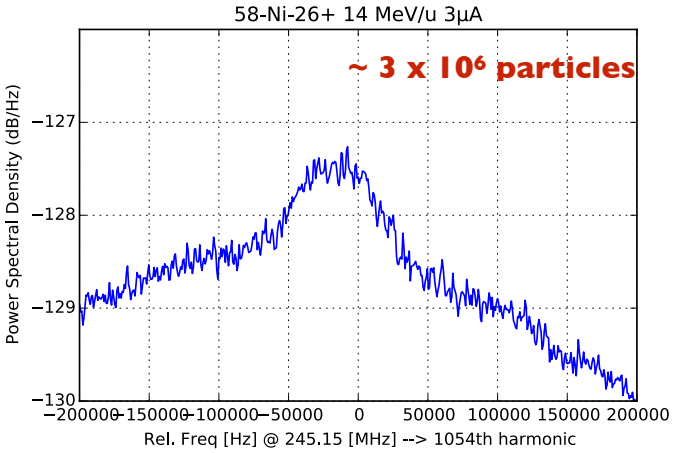
Applications (3)

- Intensity measurements

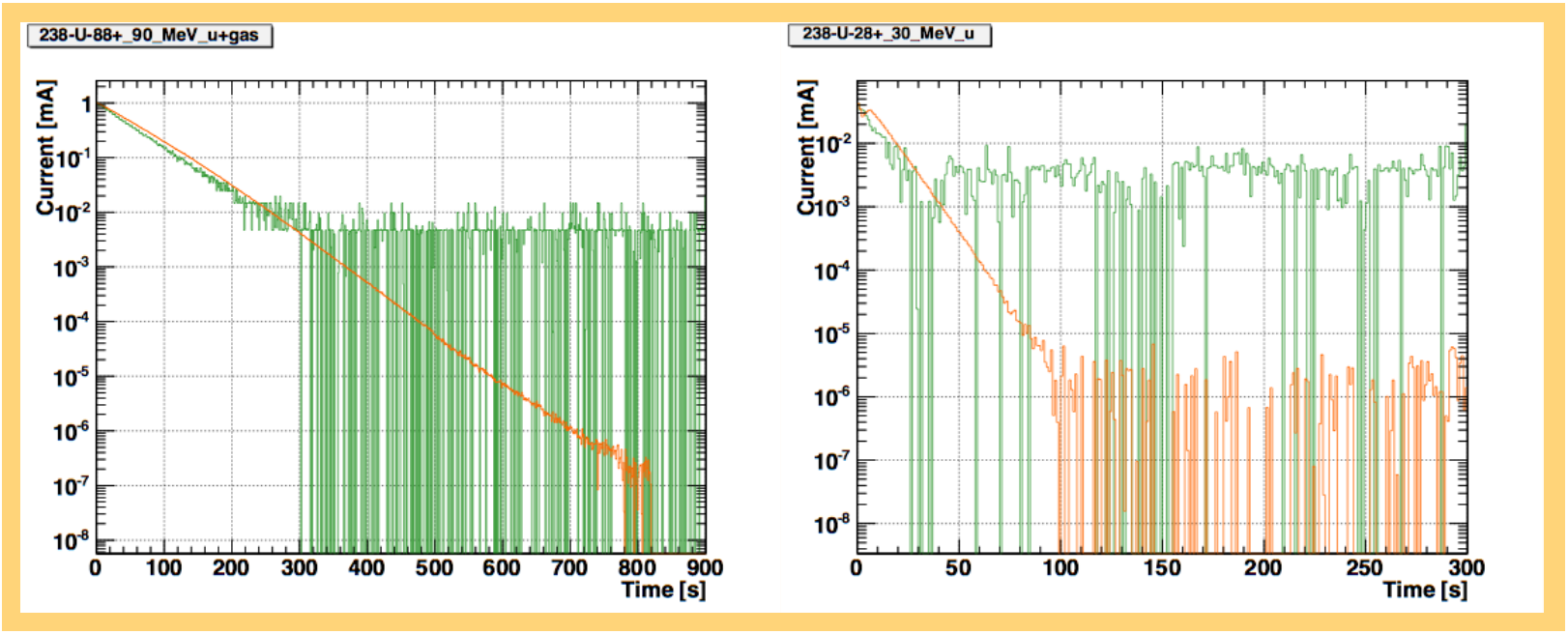








- Calibrate the integral Schottky power using e.g. a DCCT



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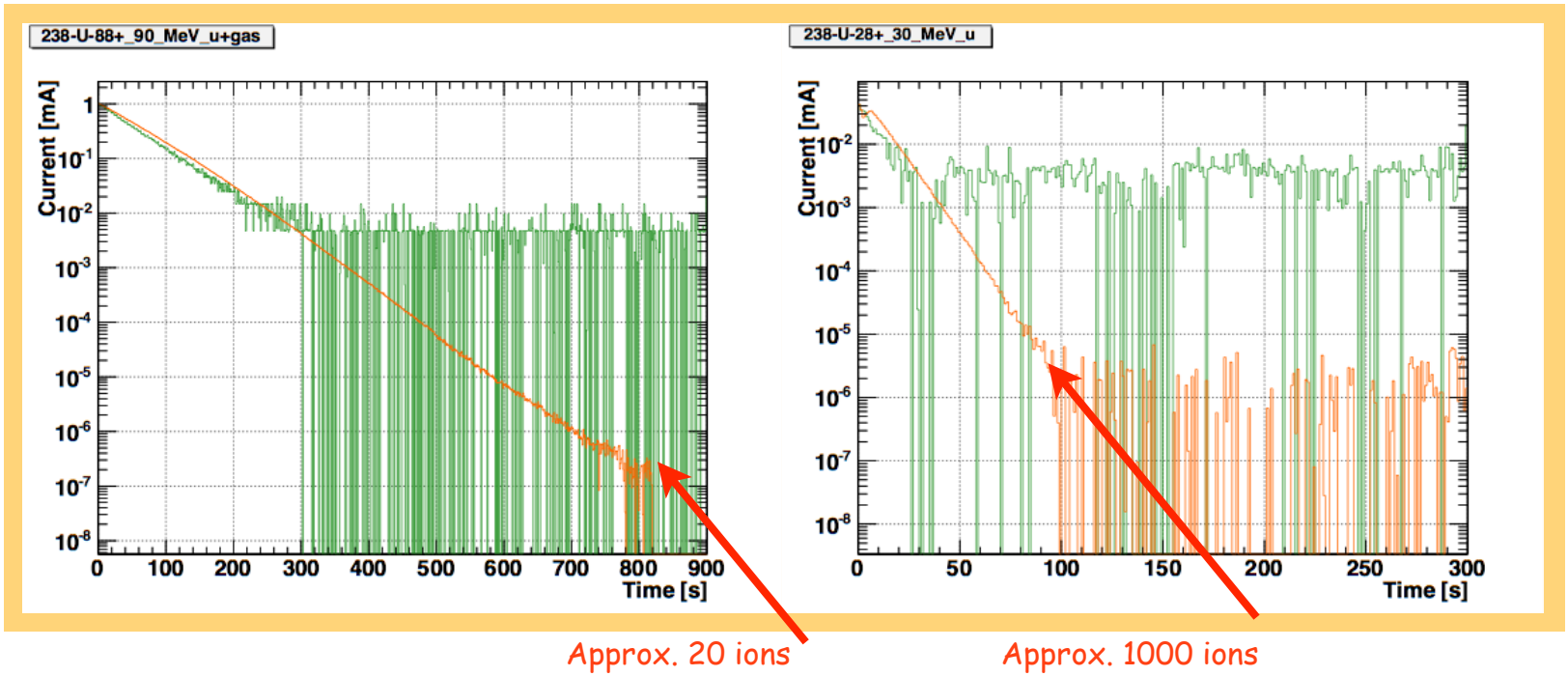

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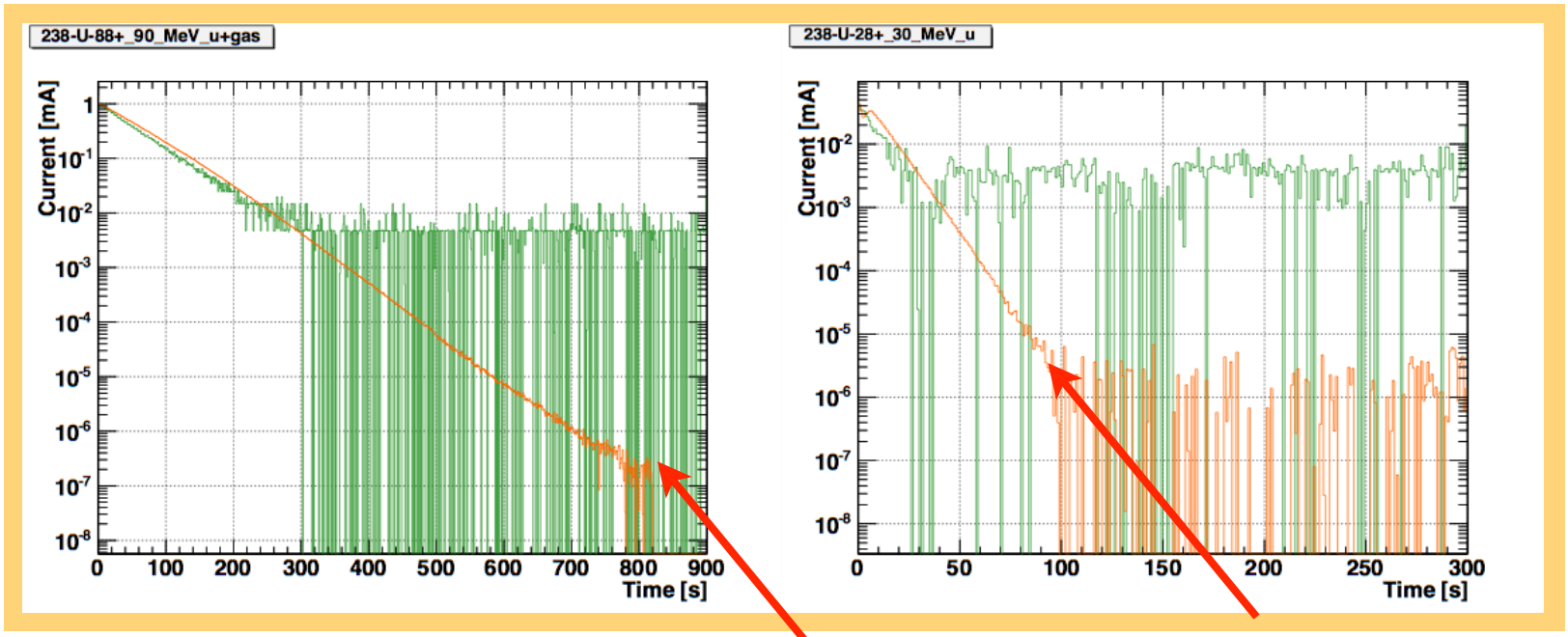

Approx. 20 ions

Approx. 1000 ions

- Limited by DCCT error (±1μA)
- Non-linear at high intensities

Applications (4)

- Exact frequency for deceleration
- Fine tune of e-cooler
  - Precision measurement of ion velocity

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- Exact frequency for deceleration

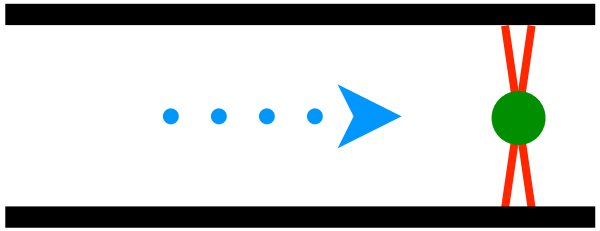
$$v_{ion} = c \cdot \sqrt{1 - \frac{1}{\left(\frac{eU_c^{corr}}{m_e c^2} + 1\right)^2}}$$

- Fine tune of e-cooler
  - Precision measurement of ion velocity

$$U_c^{corr} = U_c - \frac{113 \cdot I_c}{\sqrt{1 - (\frac{eU_c}{m_e c^2} + 1)^{-2}}}$$

“Non-resonant” structures

- Parallel plates
  - Primary fields
  - External resonant circuit



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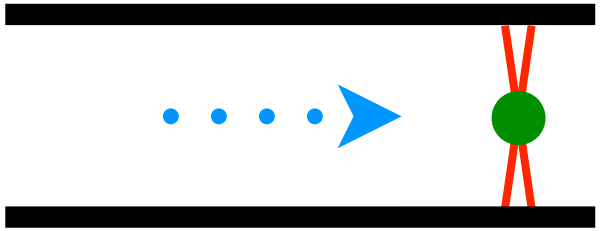
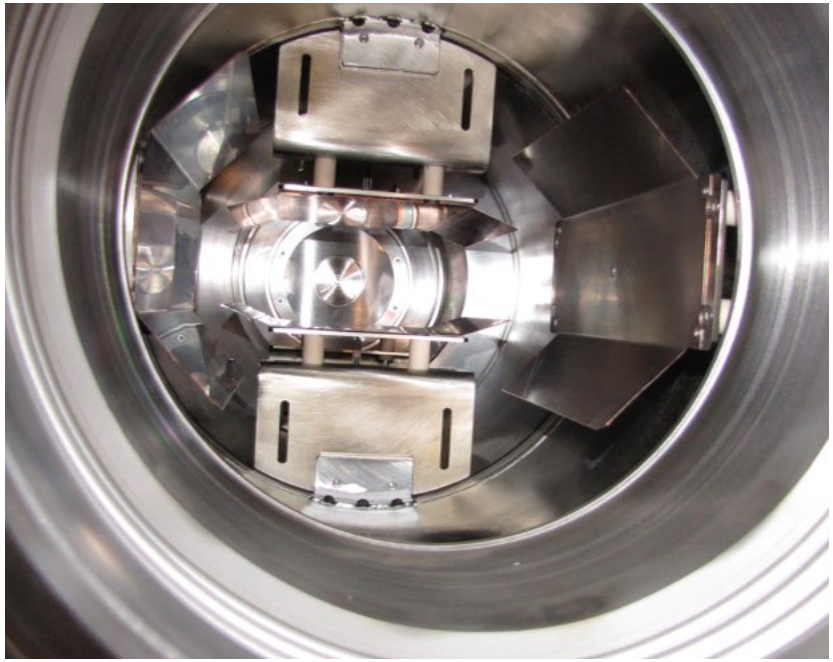
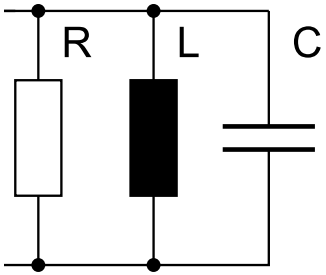


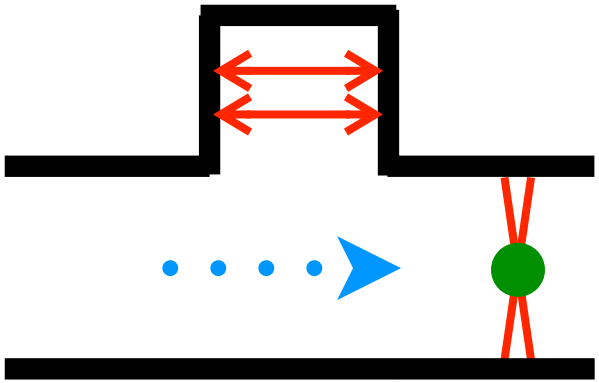


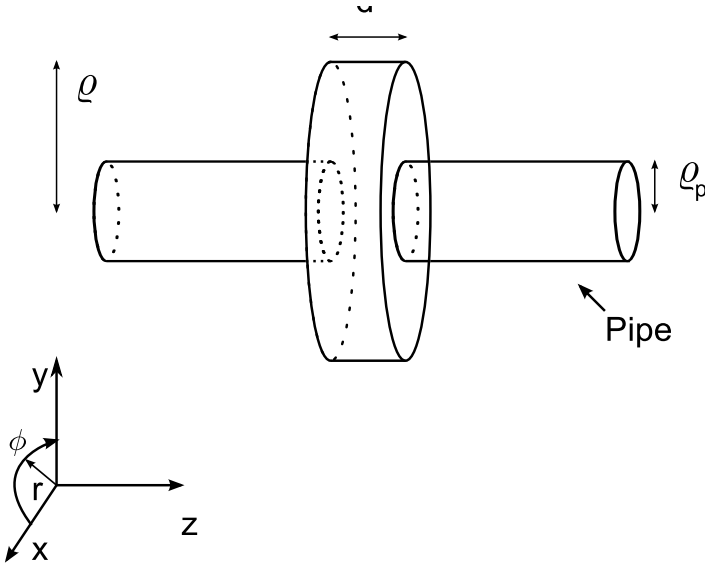


B. Schlitt, PhD Thesis 1997

Resonant Cavity Pickups

- Resonant cavities
  - Wake fields
  - Surface current
  - Shape modes using proper design





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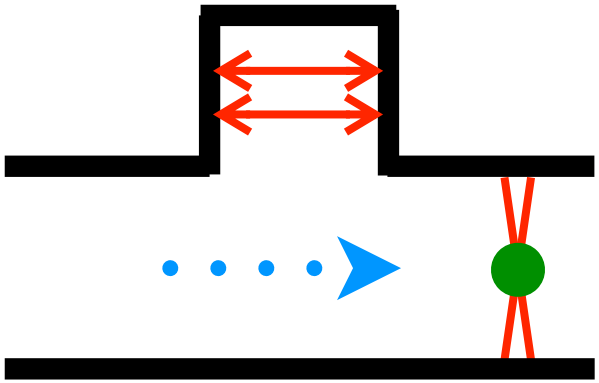
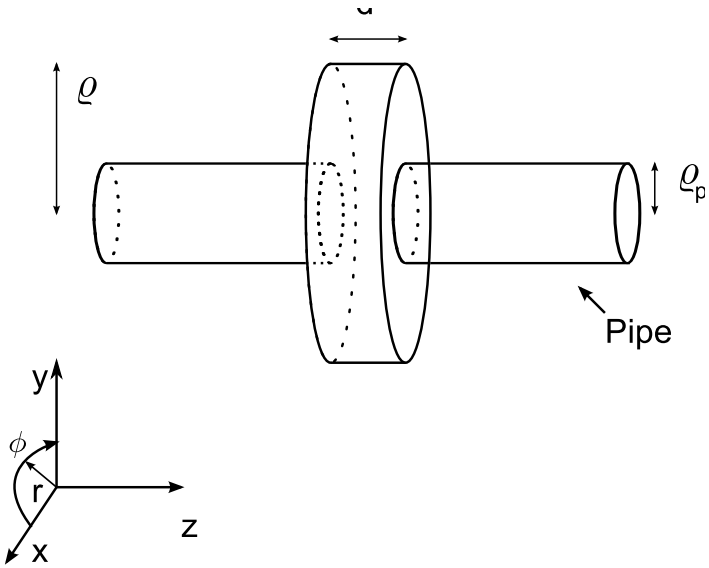
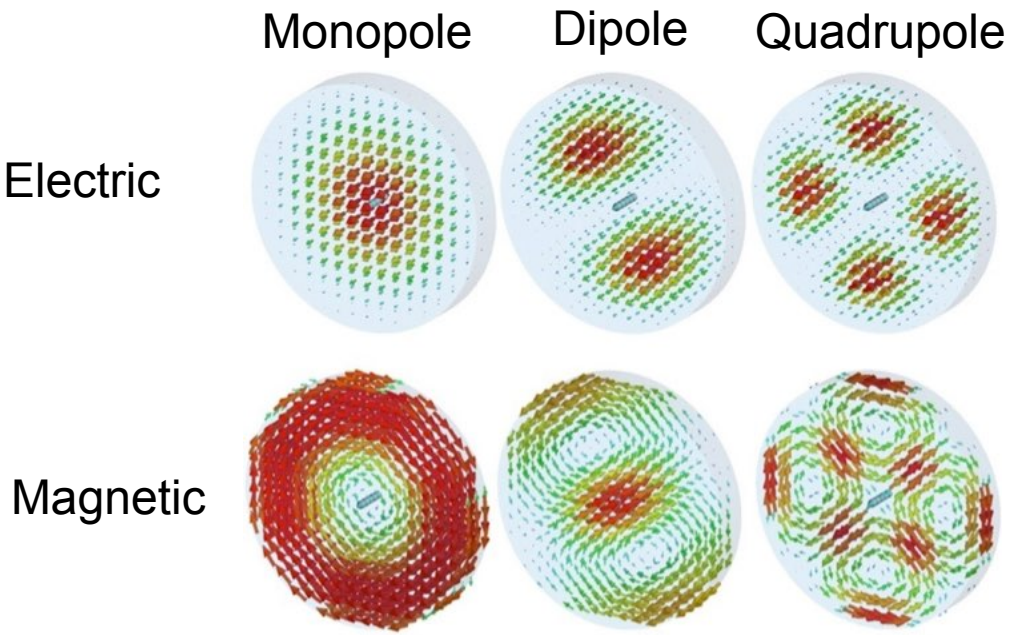
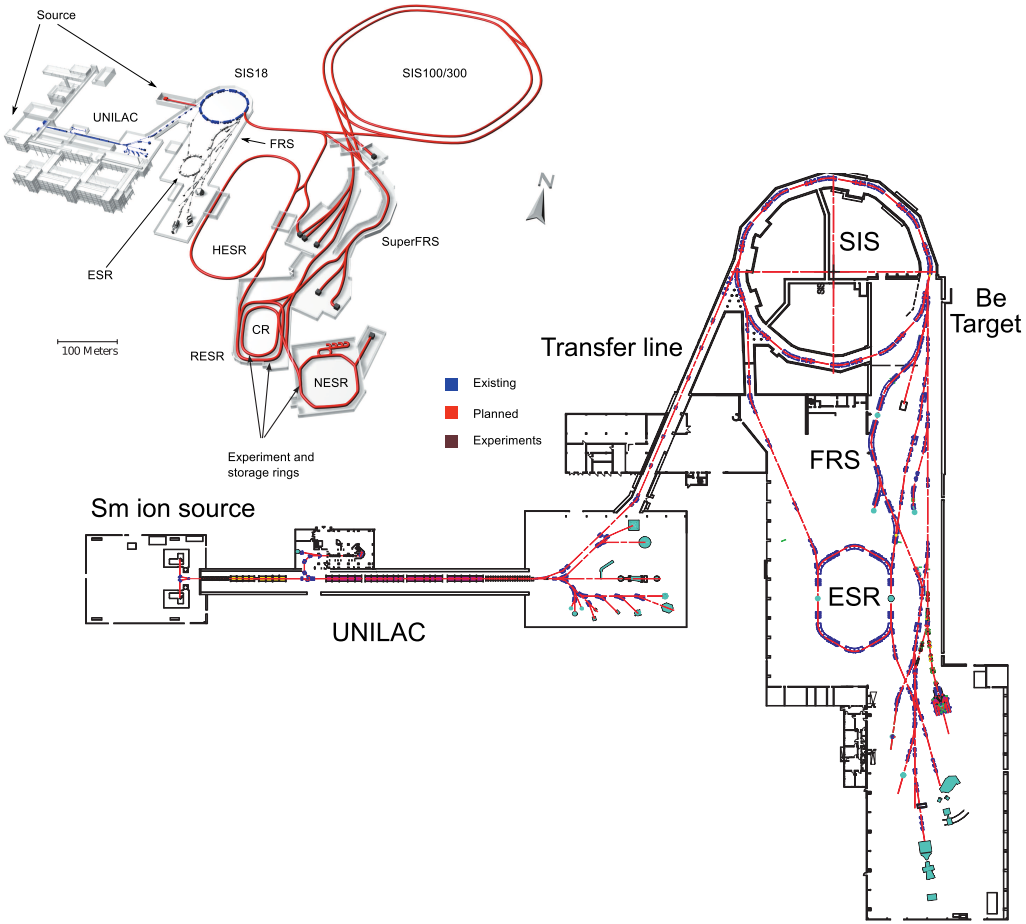






Resonant Pickups



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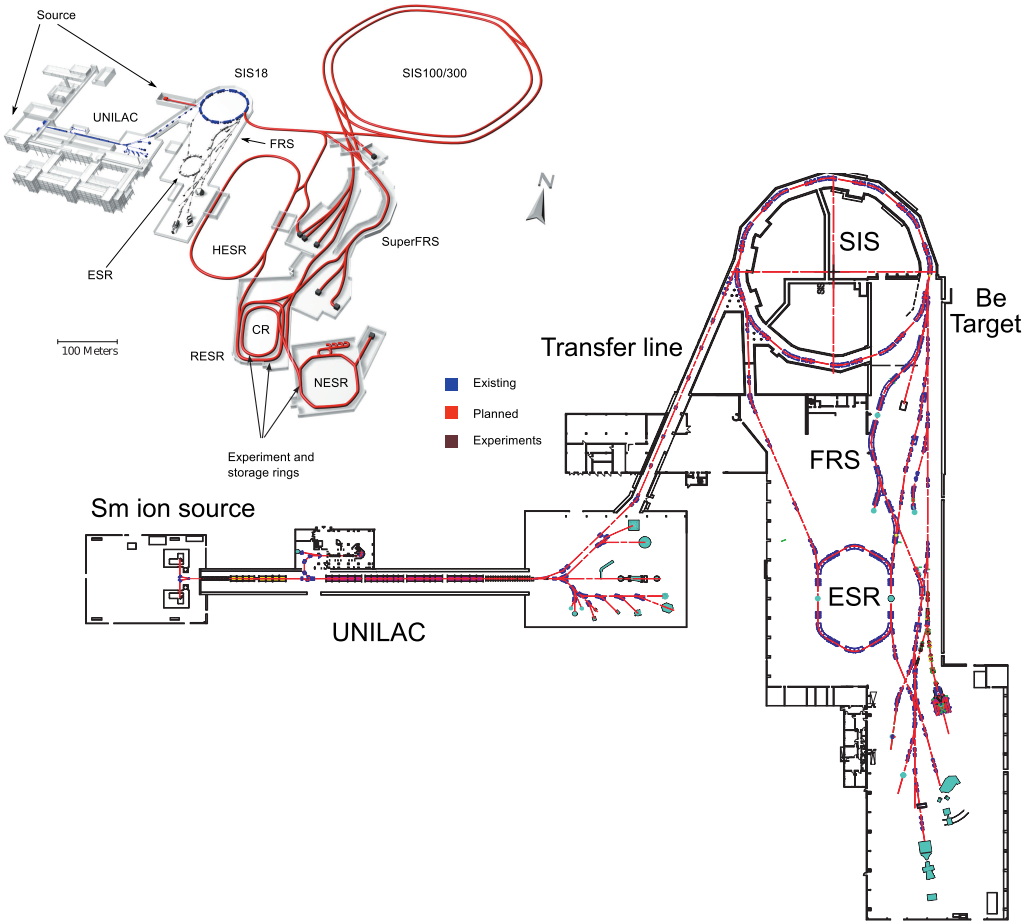
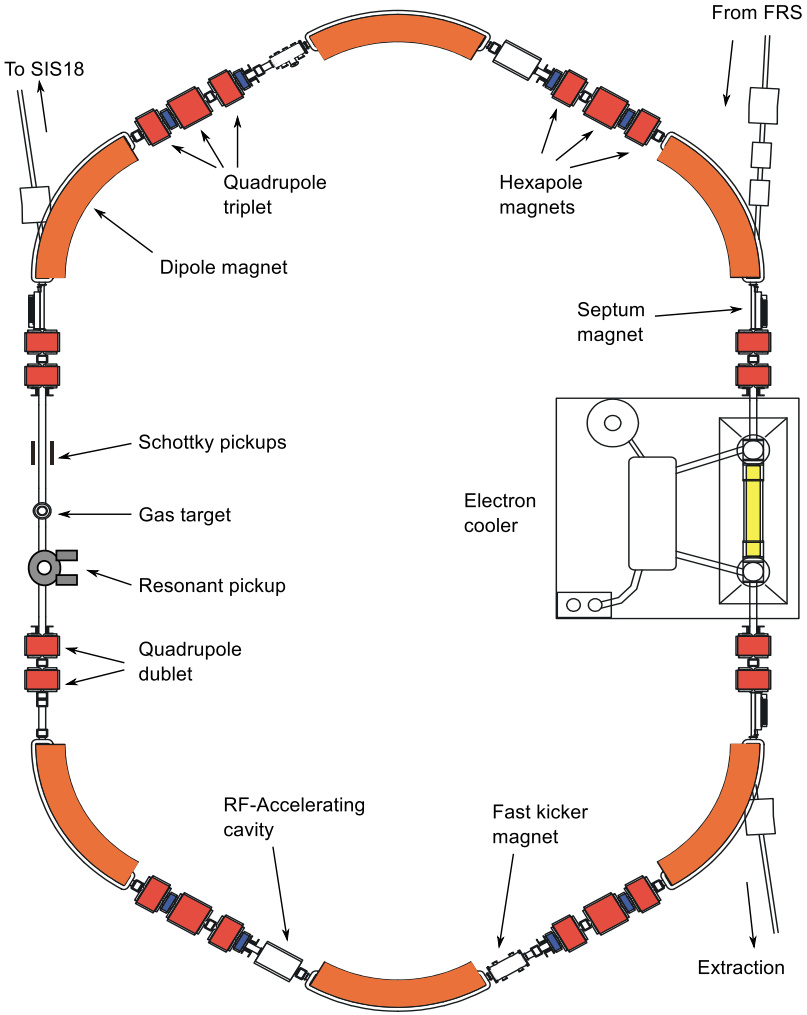
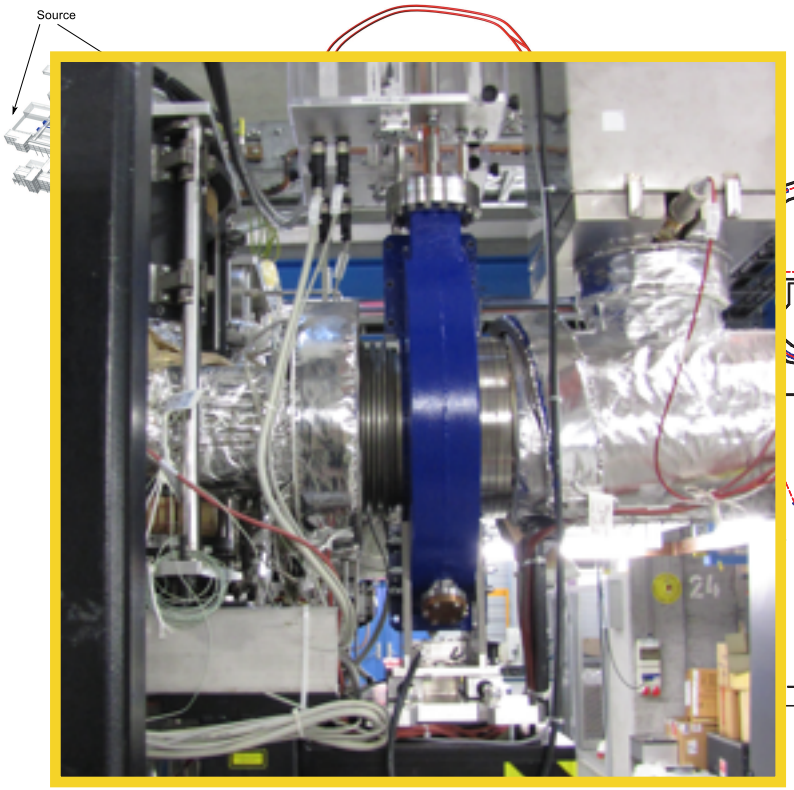
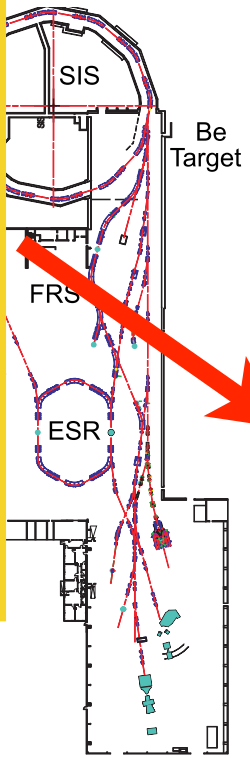
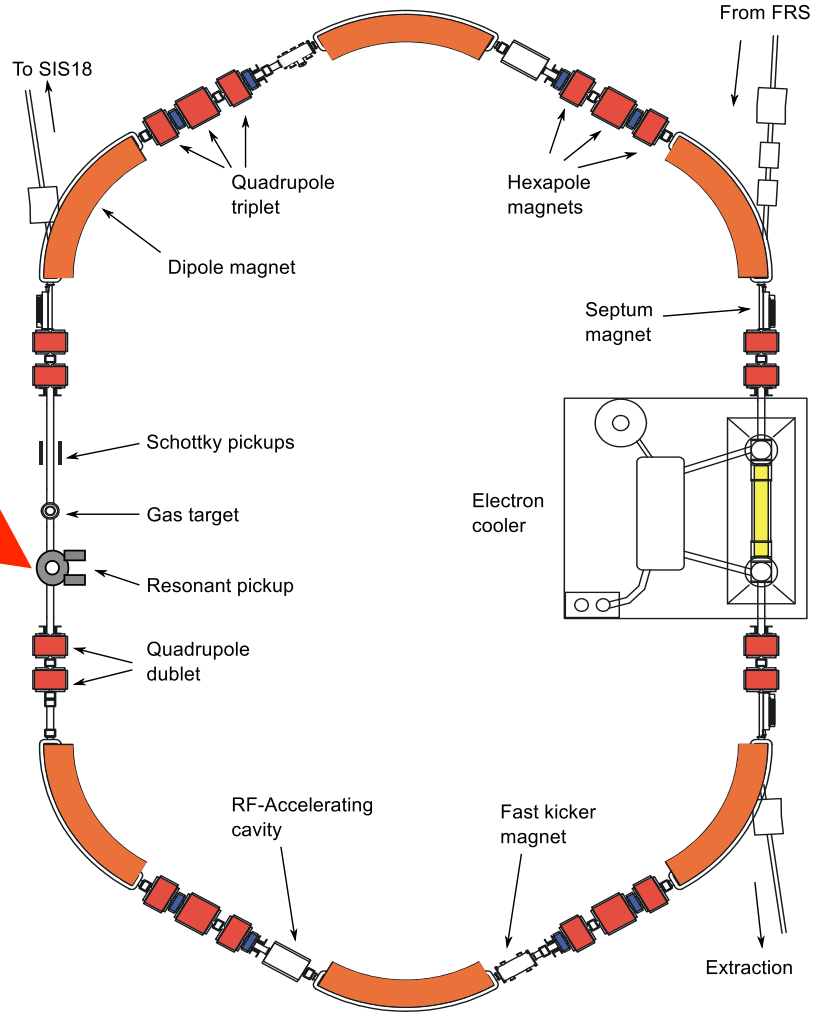




Resonant Pickups



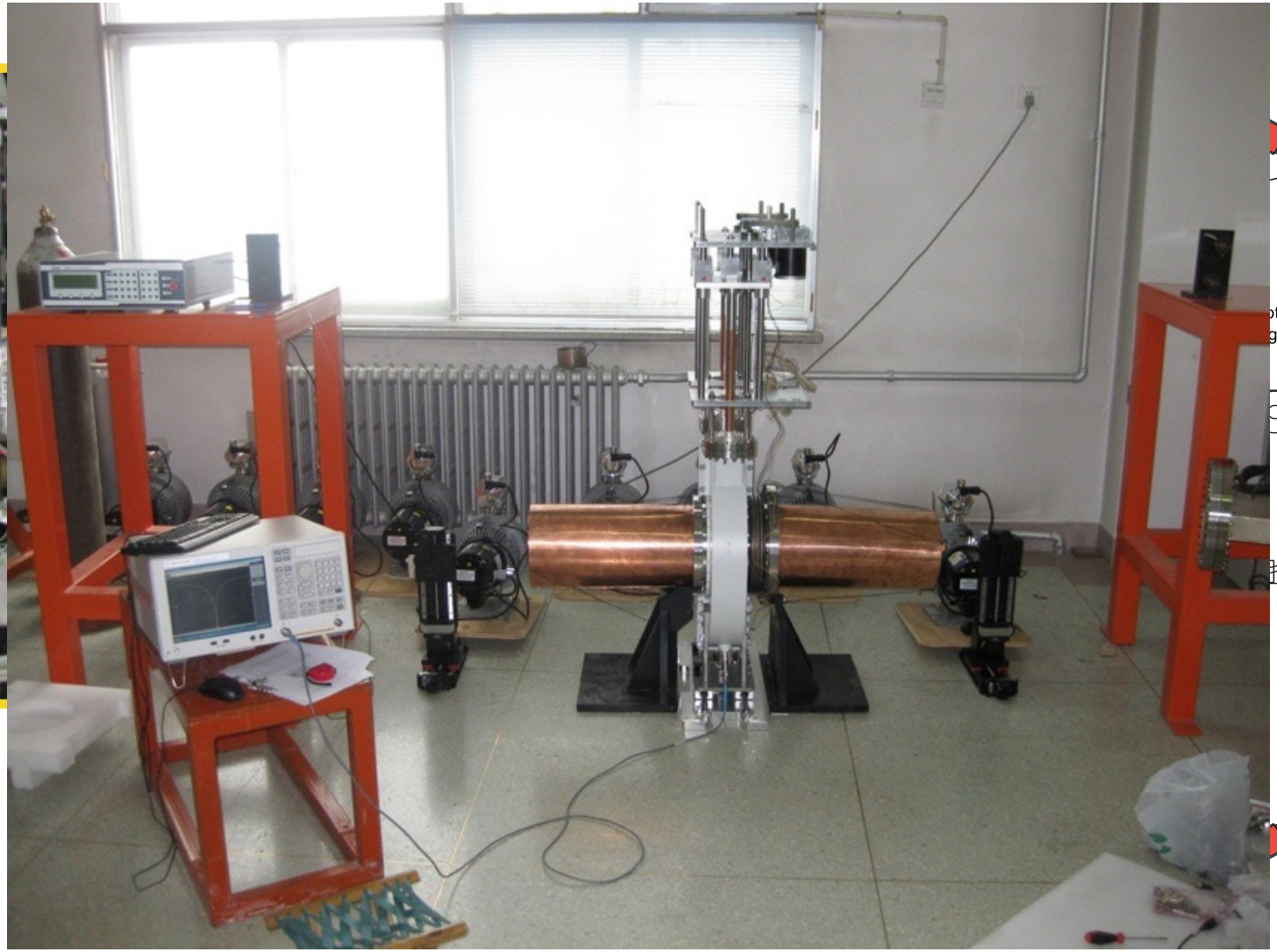


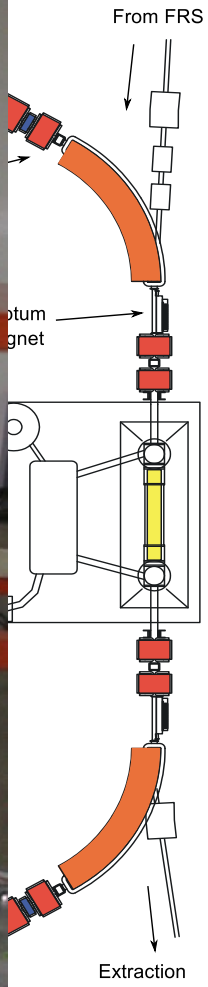


Noden et. al. NIM-A, v. 659 No. 1 pp. 69–77 (2011)

Sanjari et. al. Phys. Scr. 014088 (2013)

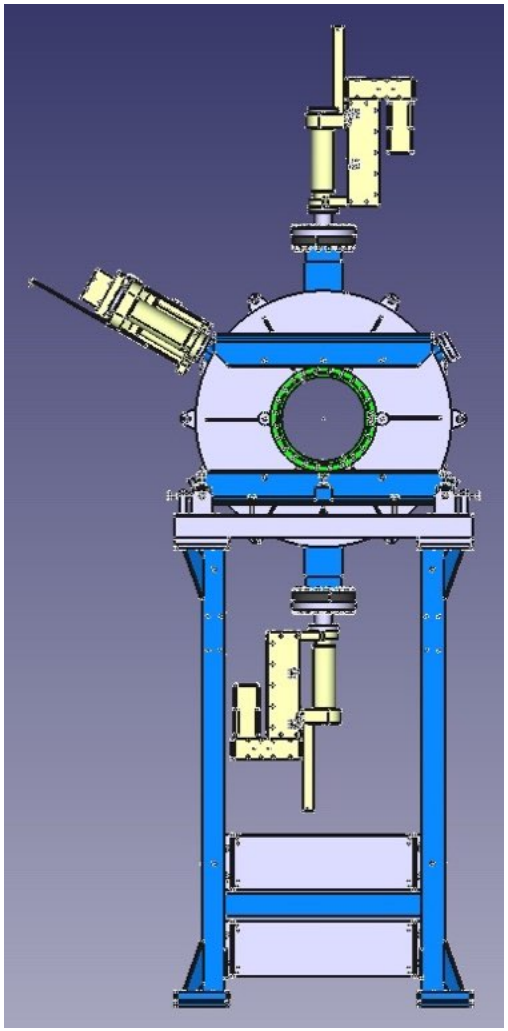
Resonant Pickups





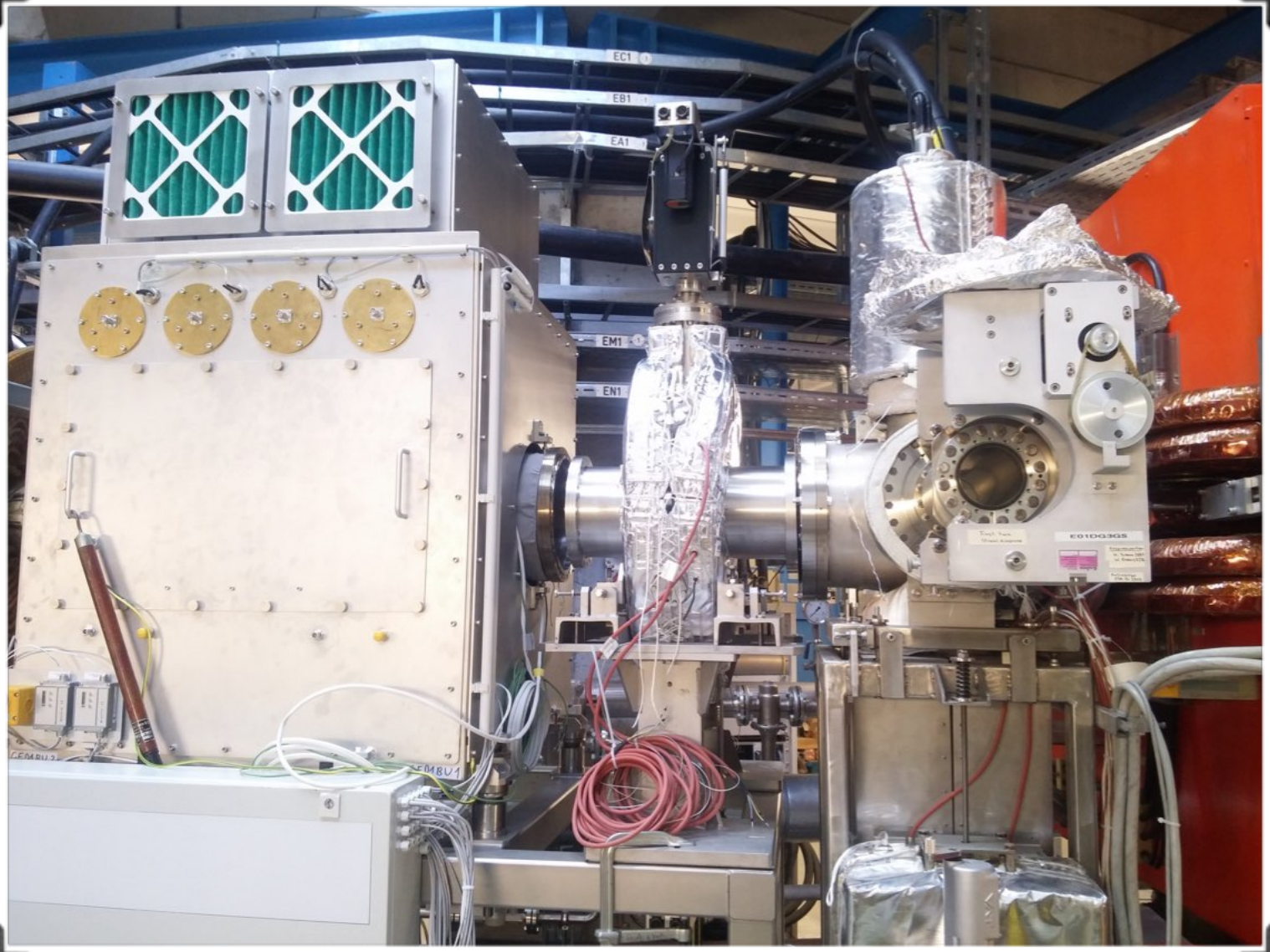
New prototype

- Symmetric design
- Made of 100% stainless steel
  - Vacuum friendly
  - Easy construction
  - No movable parts in the support
- No ceramic gap (hence no reliance on ceramic spec)
- Variable Frequency (ca. 4 MHz at 410 MHz)
- Variable sensitivity (Q value)
  - “follow” the beam during cooling
  - Dynamic loading

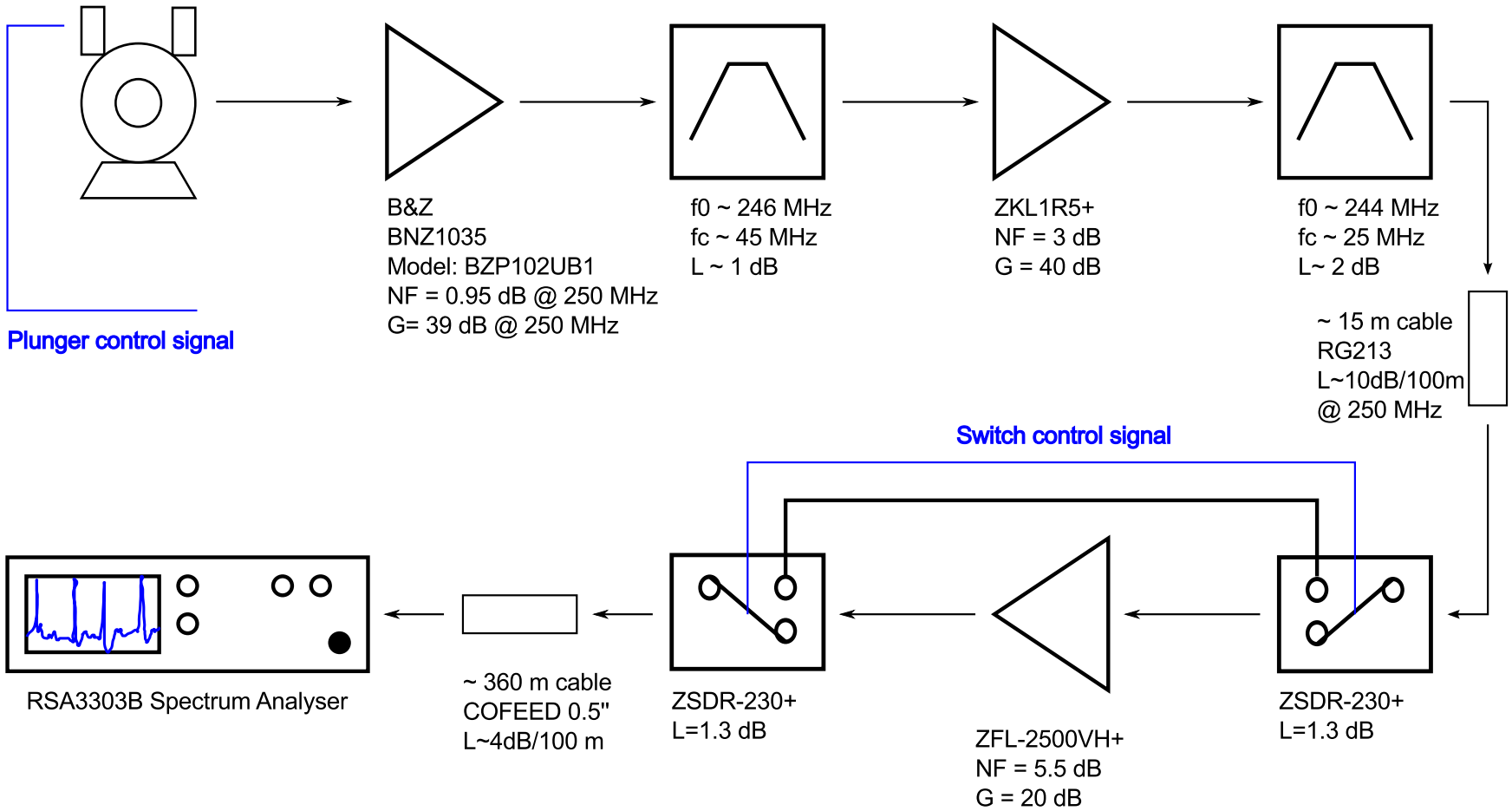


Ne

- S
- M
- N
- V
- V

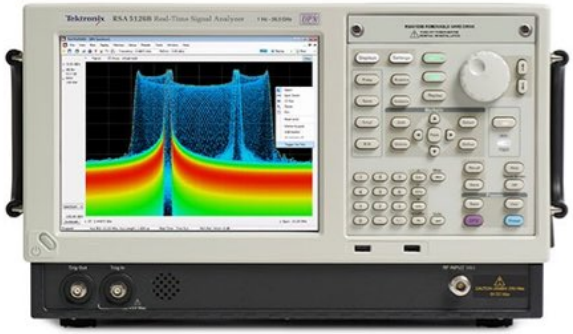


RF Signal flow

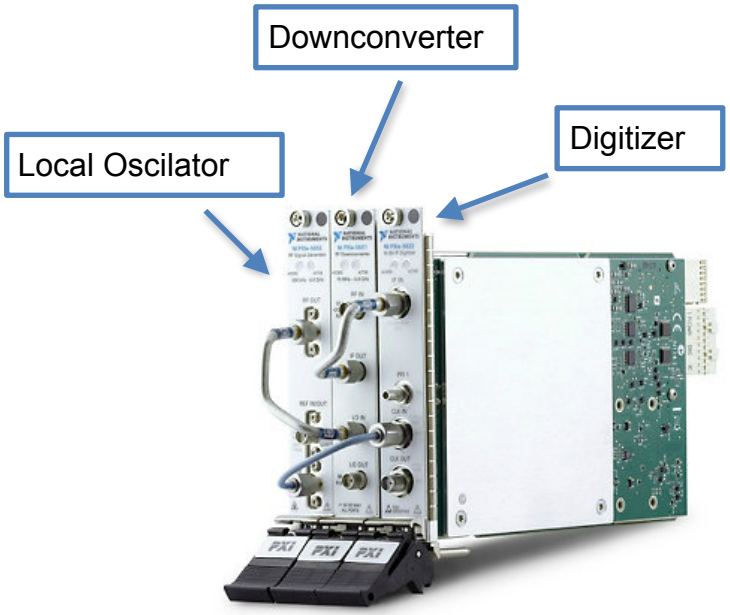


Data acquisition

- Spectrum analyser
  - Setup and configuration
  - Narrowband recording per injection

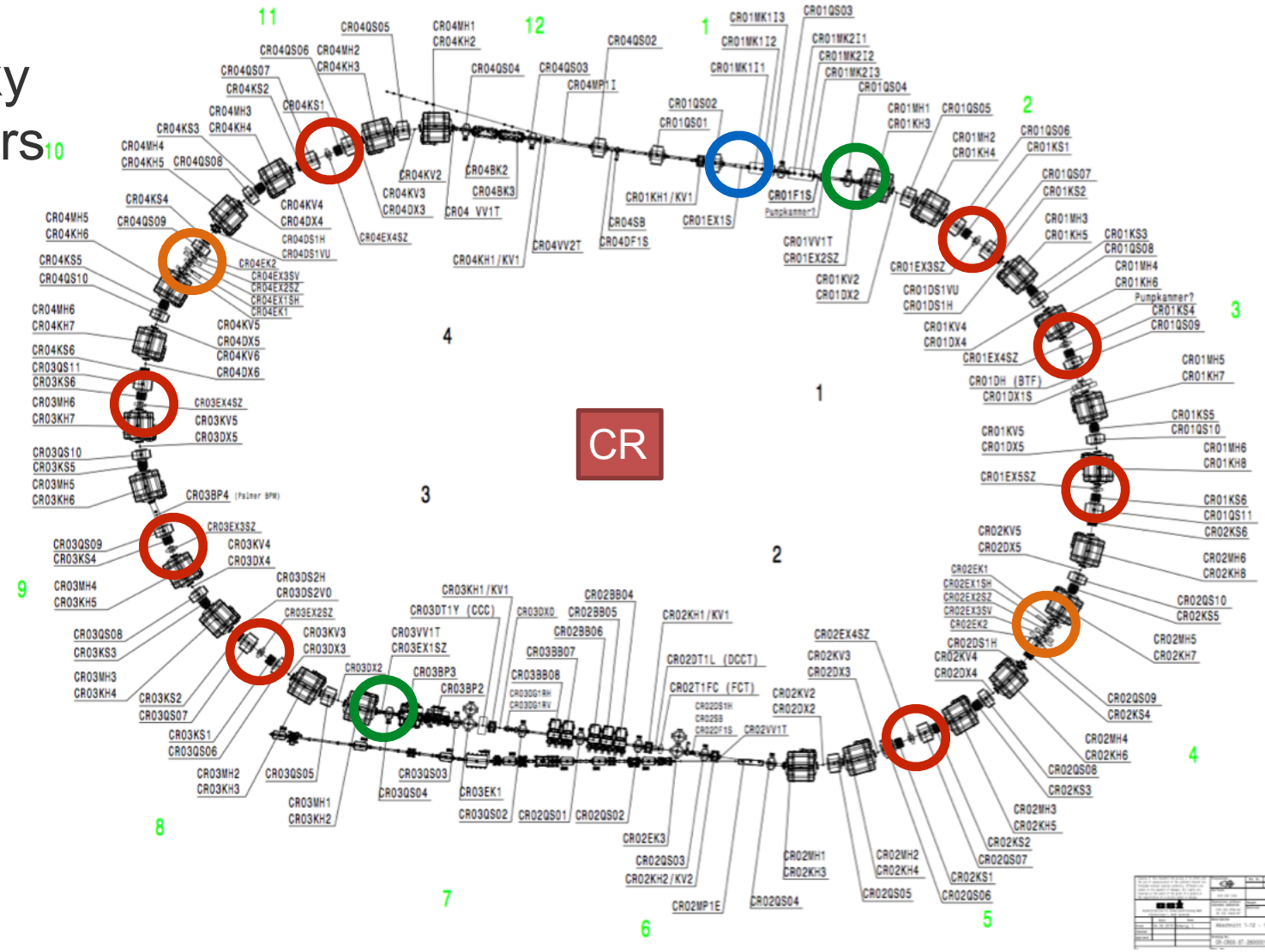


- NTCAP (C. Trageser, PhD Thesis):
  - broadband recording
  - Continuous write
  - 2 to 70 Msps
  - Local / Network write

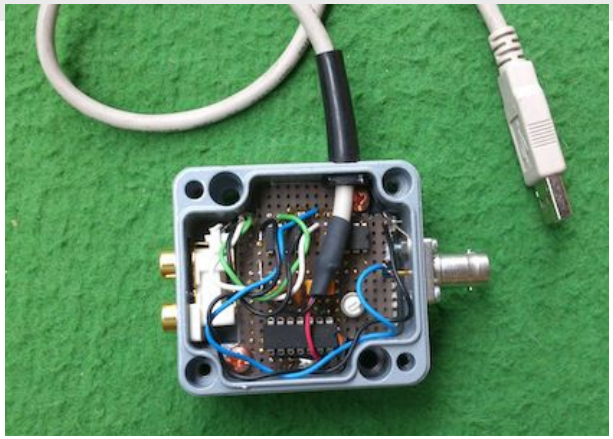


Example of several Schottkies

- Schottky detectors in CR



- Software defined radio
  - (Relatively) low cost
  - Narrowband
  - Open source tools (i.e. gnuradio)
- Additional compatibility with FAIR control system



“Experimental” SDR tasks

- Creating online control spectra
- Creating combined spectra
  - Super broadband
  - Averaging
  - Other mathematical operations

- File sink
  - Local drive
  - HPC cluster
  - Network (ZMQ, etc…)

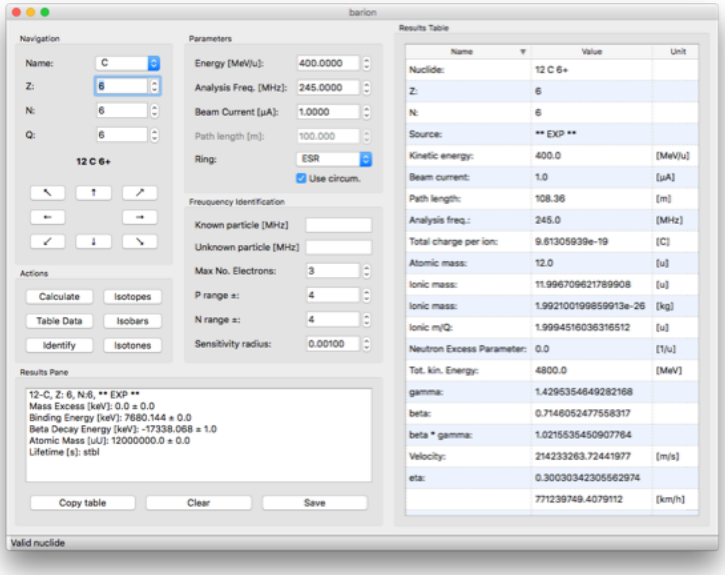
- Future special operations related to transverse Schottkies

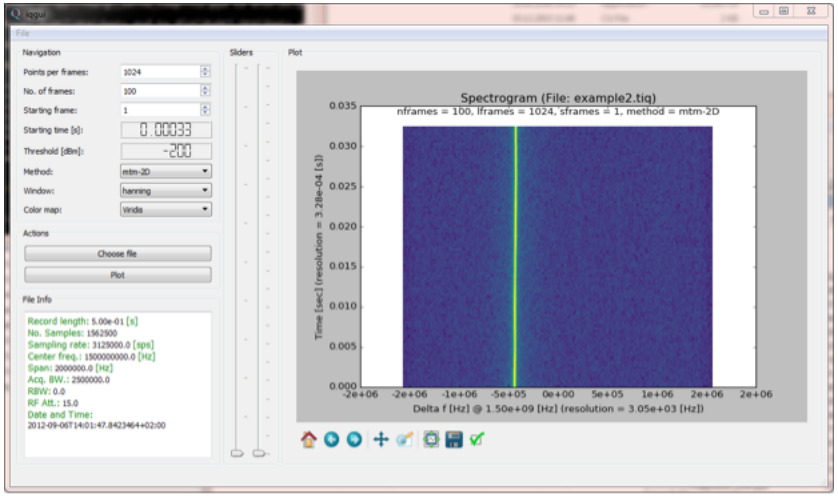
Current developments

- Resonant Schottky detectors with transverse sensitivity
- Broad band experimental detectors based on slow wave principle
- Open source tools and libraries for data analysis
- Nuclidic Identification based on deep neural networks (DNN) on GPU workstation
  - Learning on Schottky data
  - Work in progress

Fork me on GitHub

https://github.com/xaratustrah





Thank you!