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High sensitive Schottky analysis for the GSI storage rings

Shahab Sanjari MT ARD ST3 Annual meeting

2019-10-16, GSI







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





- 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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Longitudinal Schottky analysis

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







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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Applications (1)



Schottky Mass Spectroscopy



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Slide courtesy of Yu. A. Litvinov





Slide courtesy of Yu. A. Litvinov





Applications (2)



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

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





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



MSS, PhD Thesis 2013

Applications (3)

- Absolute current measurement
 - Calibration needed using e.g. a DCCT (or a CCC)







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- Better results by using CCC - Non-linear at high intensities

M Chahah Cariari 2010 10

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MSS, PhD Thesis 2013



"Non-resonant" structures

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- 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

 A similar cavity was tested and built into CSRe in Lanzhou

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MSS et. al. TDR 2018. MSS et. al. D

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Improved design

- Symmetric design
- Made of 100% stainless steel
 - Vacuum friendly
 - Manufacturing friendly
 - No movable parts in the support
- No ceramic gap (hence no reliance on ceramic spec)
- Variable Frequency (ca. 4 MHz at 410 MHz)
- Variable Q_u value between 1600 3100

- Preliminary short test beam 2018-12 and 2019-04:
 - ¹⁰⁷Ag⁴⁵⁺ @ 232 MeV/u
 - ca. 2.5 x 10⁷ particles
 - e-cooler on
- Single particle setup not available

Cavity pickups with transverse sensitivity

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Bergere et. al. 1962

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Ursic et. al. 1997

Goldberg et. al. 1987

Schnell et. al. 1992

Inoue et. al. 2008

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Hansli, Hülsmann et. al. 2011

Cavity pickups with transverse sensitivity

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MSS et. al. Phys. Scr. 014060 (2015)

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Chen et. al. Nucl. Instrum. Meth. A, 826 (2016) 39-47

- Position determination
 - Comparison with circular reference
 - Same Depth (TTF)
 - Same f₀

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Slow wave pickups

- Situation: Slow heavy ions
- Plate resonators:
 - Charge redistribution too fast
- Cavity pickups:
 - Effect of transit time factor

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RF Signal flow

- Continuous
- 2 to 70 Msps
- Local / Network access

Data acquisition

- Spectrum analyzer
 - Ring / cooler setup and configuration
 - Narrowband recording for each injection
- Old-TCAP system: (90's ca. 2010)
- New-TCAP system:
 - broadband recording

Software defined radio (SDR)

- Hardware is (relatively) low cost
- Usually narrowband
- Signal processing in software
 - VHDL on FPGA
 - C++ / Python on PC
- Open source tools available (i.e. GNU-Radio)
- Additional compatibility with FAIR control system is possible / desirable

Some SDR history @ GSI

MSS et. al. GSI Scientific Report GSI-ACCELERATORS-07 (2009)

Commercial variants

- Preliminary tests:
 - Stream recording works fine
- Time stamp?
 - Needed for FAIR-DAQ
 - FAIR Commissioning & Control Working Group (FC2WG)
 - USB-3 bus interrupt polling mode only

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Related activities

- Open source tools and libraries for Schottky data analysis
- Nuclidic identification based on deep neural networks (DNN) on GPU workstation
 - Learning on Schottky data
 - Work in progress

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![](_page_46_Picture_7.jpeg)

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# Thank you!

![](_page_47_Picture_2.jpeg)

GSI Helmholtzzentrum für Schwerionenforschung GmbH