Status slow extraction and spill structure: plans for SIS18

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FAIR Experiments and Accelerators

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Outline

- Introduction
- Status of slow extraction
  - Machine experiments 2016
  - Theoretical understanding
- Plans for 2018
  - Further studies
  - VHF cavity for spill smoothing
- SIS18 VHF cavity
- Summary

Introduction

- HIC4FAIR Workshop I (07/2015, Hamburg)
  - Spill structure issue brought up
  - Efforts to improve SIS18 spill structure recommended
- HIC4FAIR Workshop I Follow-Up (02/2016, Darmstadt)
  - Presentation of status of SIS18 spill structure
  - Review of past attempts at improving it
  - Long-term: strategy for better understanding
    - Extended machine experiment campaign
    - Identification of origin of spill ripple
    - Theoretical modeling
  - Mid-term: technical measures
    - High-frequency cavity for spill smoothing
    - Spill feedback at kHz scales using KO exciter
  - Short-term: machine experiments (2016)
    - Origin of spill ripples
    - Influence of machine parameters on sensitivity

Proposed ‘Next Steps’ from H4F Follow-Up

Machine Experiments 2016
Simultaneous ripple measurements
Comparison of extraction methods
Influence of chromaticity and res. strength
Spill feedback using KO?

Status: Machine Experiments 2016

- Measurement campaign
  (P. Forck, P. Schmid, H. Welker, et al.)
- Influence of res. sextupole strength on ripple sensitivity
  - Sensitivity increases with res. strength
  - More details in S. Sorge's talk
- Comparison of quad driven and KO extraction
  - Unsuccessful due to technical problems
- Artificial ripple on main power converters (dipole and quadrupole)
  - Clear correlation seen
  - Quad more sensitive than dipole as expected
  - Natural ripple not fully understood quantitatively
- Spill feedback using KO
  - Not possible due to resource limitations

Success of Machine Experiments 2016	
Simultaneous ripple measurements	+
Comparison of extraction methods	–
Influence of chromaticity and res. strength	–/+
Spill feedback using KO	–

Main conclusions from experiments

- Origin of natural spill ripple not clearly identified
- Lower sextupole strength preferable, but little margin due to impact on extraction efficiency
- Further investigations necessary

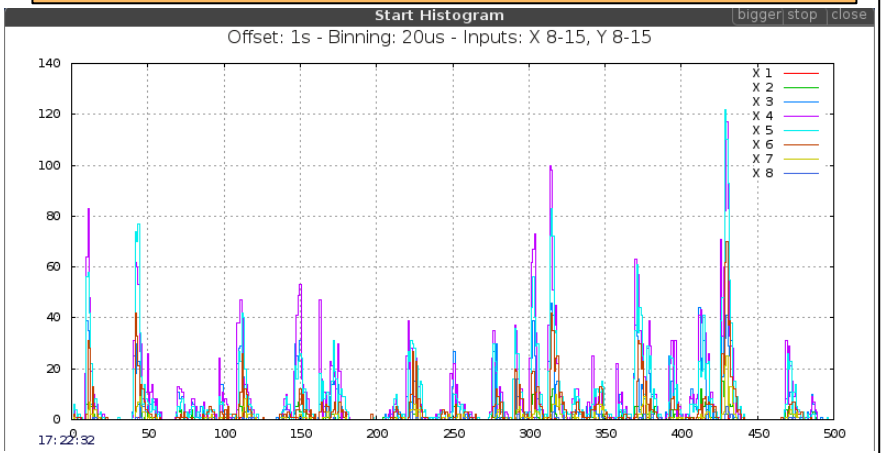
Status: Theoretical Understanding

- Exchange with other labs
  - Slow extraction workshops
    - Darmstadt, 06/2016
    - CERN, 11/2017
  - Common knowledge base
  - Common effort on modeling/simulation
- BMBF proposal by beam physics group
  - PhD students for theoretical modeling
  - Benchmarking with machine experiments
- First studies by S. Sorge
  - Simulation of ripple sensitivity as function of resonance sextupole amplitude
  - See next talk

Plans for 2018: Slow Extraction from SIS18

- Status quo
  - Detectors with high time resolution suffer from pile-up
  - Breaks in the spill are a major issue
  - Diamond detectors can resolve 100ps time structure
  - Stability of power supplies cannot be improved by a reasonable amount
  - Substantially improving the spill structure with the available knobs has been unsuccessful
- Plans for 2018
  - Continuation of machine experiments for determination of ripple origin
  - Continuation of theoretical studies
  - Installation of a VHF cavity for spill smoothing

SIS18 spill observed by HADES detector



J. Pietraszko, HIC4FAIR WS, 2016

Plans for 2018: HADES Requirements

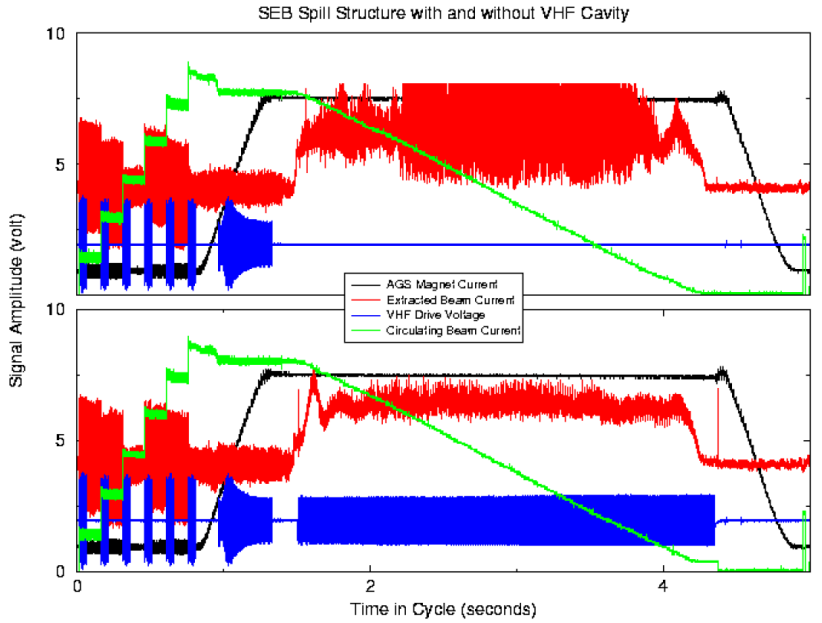
- Avoid pile-up
  - Detector not designed for such a high rate (intensity spikes)
    - Detector overload and aging
    - Could potentially destroy detector
- Reduce voids
  - Distribute particles more evenly across the spill
  - Decrease fluctuations around mean value
  - Provide more average intensity (crank up beam current)
- Bunching with the available cavities improves spill quality
  - But bunches can be occupied by two particles with a probability of 25%
  - **Bunching at higher frequency (≥ 40MHz) is required**
- Provide no more than one particle per bunch
  - Otherwise detector cannot discriminate signals (T0 determination)
- Increase of total number of detectable events by up to factor 6 estimated by reducing the voids and the pile-up

Information by courtesy of J. Pietraszko

Plans for 2018:
Spill Smoothing by VHF Cavity

- Successfully used at AGS
- Spill smoothing techniques
  - Empty bucket channeling
  - Bunching at higher harmonics
- Bunched extraction at SIS18
  - Maximum bunching frequency limited to 5 MHz
  - Insufficient for experiments HADES and FRS
  - Higher frequencies (≥40MHz) require new cavity
- Installation of VHF cavity in SIS18 foreseen
  - Hardware is procured
  - Installation is scheduled for April 2018

Improved spill at AGS with channeling



K. Brown, BNL, 1999

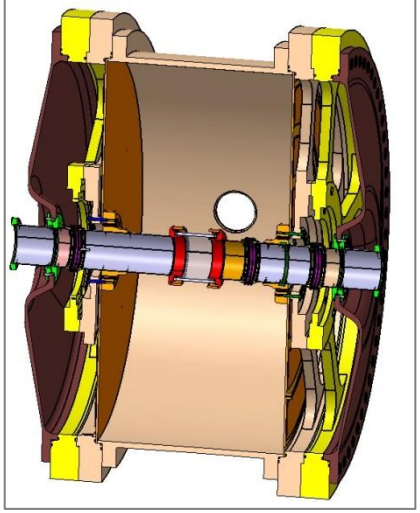
SIS18 VHF Cavity: Status

- Project lead by Ring RF Group
- Cavity based on refurbished pill box resonator
- Introduction of a beam tube
  - Bakeable ceramic gap for UHV requirements
- Internal beam pipe reduces fundamental frequency from 108.5MHz to 79.6MHz (simulations using CST)
- Cavity can be made transparent
  - Fast detuning and reduction of shunt impedance by three orders of magnitude
  - Ceramic gap can be shorted as last resort
- Total RF power of 3kW
  - Provided by solid state amplifier
  - Calculated RF voltage 85kV (unloaded)
  - Sufficient to bunch beam completely

Information by courtesy of P. Hülsmann

Original pill box cavity

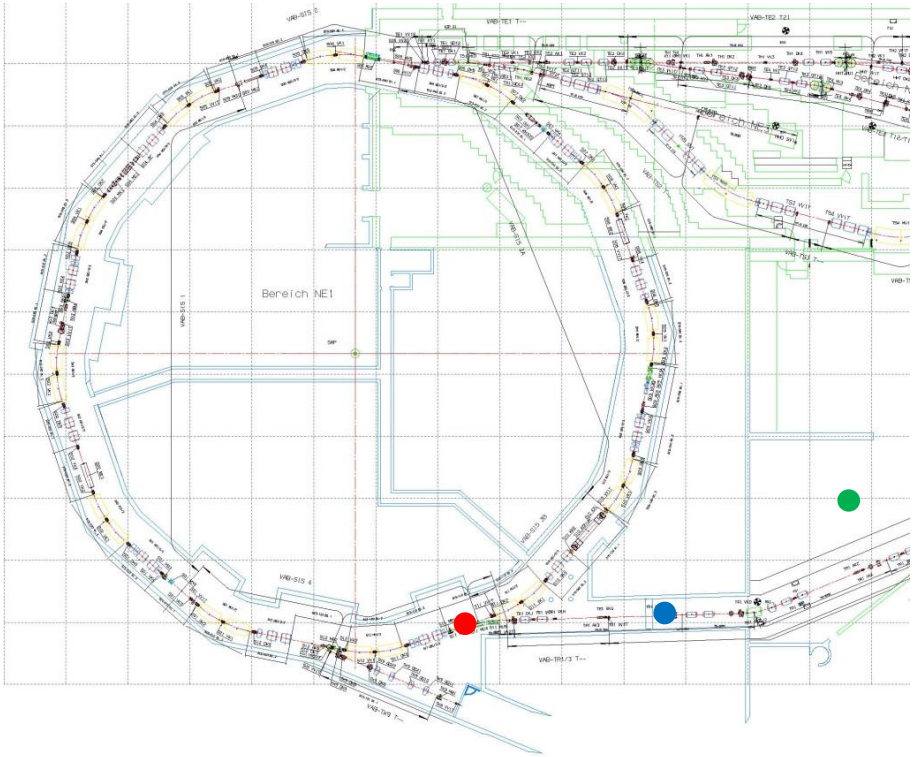
Beam tube added



Basic parameters of VHF cavity	
Frequency	79.6±1.4MHz
Harmonic number	h = 60 - 61
Gap voltage	85kV
Unloaded shunt impedance	5kΩ-5MΩ
Unloaded quality factor	3000-30.000
Vacuum pressure in beam tube	10^{-11} mbar

SIS18 VHF Cavity: Installation

- Cavity installation in period S11(red dot)
  - Installation scheduled for 04/2018
- Power amplifier in reinjection channel (blue dot)
  - 25m distance to cavity
- Control racks in RRF supply room (green dot)
- Phase- and amplitude loops
  - UNILAC-LLRF components adapted to 80MHz
- Present status
  - Mechanical modifications of pill box cavity ongoing
  - Beam pipe with ceramic gap under construction
  - Installation of cables for VHF system ongoing



Information by courtesy of P. Hülsmann

SIS18 VHF Cavity: Beam Time 2018

- Proof of principle
  - Beam manipulations to be tested in machine experiments
  - Effect on spill structure to be measured with accelerator and experiment detectors
  - Operation with small to moderate intensities (10^6 – 10^7 particles/s)
- Main criteria for success
  - Reduction of pile-up
  - Reduction of spikes and voids
  - Improvement of max/average
- Collaboration with experimentalists
  - Identify their criteria on spill quality
  - Test influence of VHF cavity on those
- Next steps
  - If the pilot study proves successful design a dedicated VHF cavity

Summary

- Status of slow extraction from SIS18
  - Machine experiments performed in 2016
  - Theoretical studies resulted in better understanding of ripple sensitivity
  - Origin of spill ripple not completely understood
  - Exchange with other labs to improve understanding and tools
- Plans for 2018
  - Continuation of spill ripple investigations
  - Increased efforts for modeling through PhD students
  - Installation of spill smoothing cavity
- SIS18 VHF cavity for spill smoothing
  - Presently under construction
  - Installation foreseen for April 2018
  - To be tested in collaboration with experiments

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