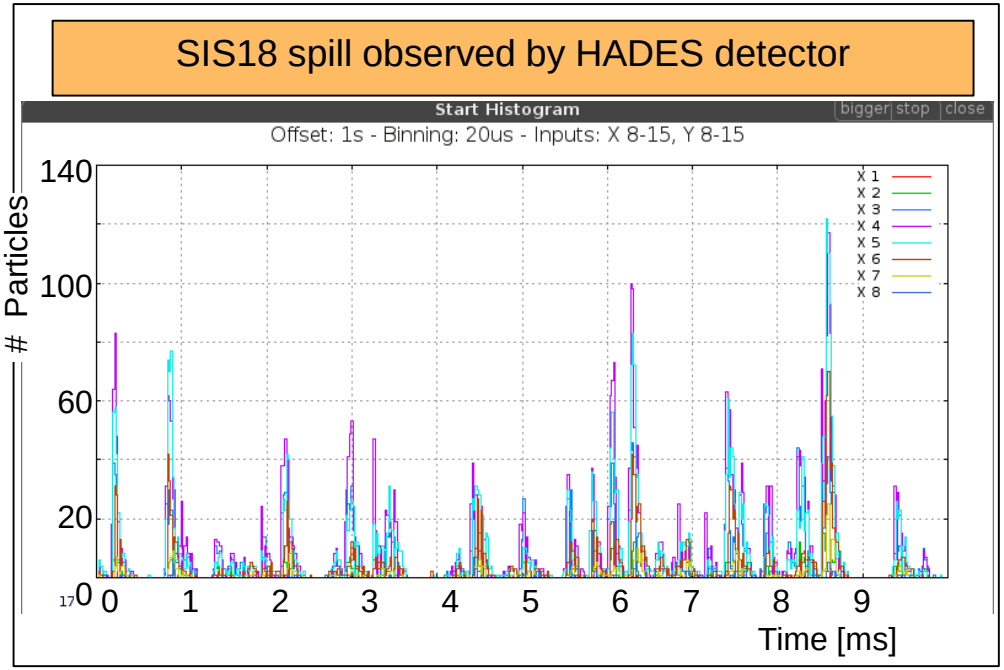
Planned measures for improving the SIS18 spill quality

Slow extraction workshop, CERN, Nov. 2017

Peter Schmid, GSI

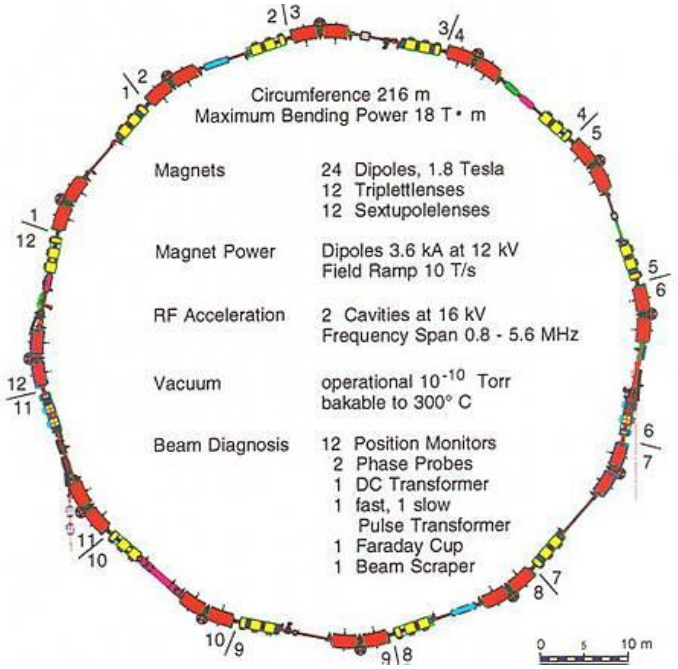
Introduction

- Current situation
  - 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



SIS18
Heavy Ion Synchrotron

- Basic parameters
  - Circumference 216m
  - Top beam rigidity 18.5Tm
  - Ramp rate 4T/s (10T/s)
- Optical layout
  - Twelve identical cells
  - Triplet focusing at injection
  - Doublet focusing at extraction
  - Optics change during ramp



SIS18 optical parameters	
Q_h / Q_v	4.29 / 3.28
Q'_h / Q'_v	-6.4 / -4.1
α_p (inj. / ext.)	0.042 / 0.032
γ_t (inj. / ext.)	4.9 / 5.6

Experimentalists' Requests

- Avoid pile-up
  - Detector not designed for such a high rate (intensity spikes)
    - Overloads detector, 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 is required
- Provide no more than one particle per bunch
  - Otherwise detector cannot discriminate signals (T_0 determination)
- By reducing the voids and the pile-up J. Pietraszko estimates that the total number of detectable events can be increased by up to a factor of 6

Information by courtesy of J. Pietraszko

Mitigation measures

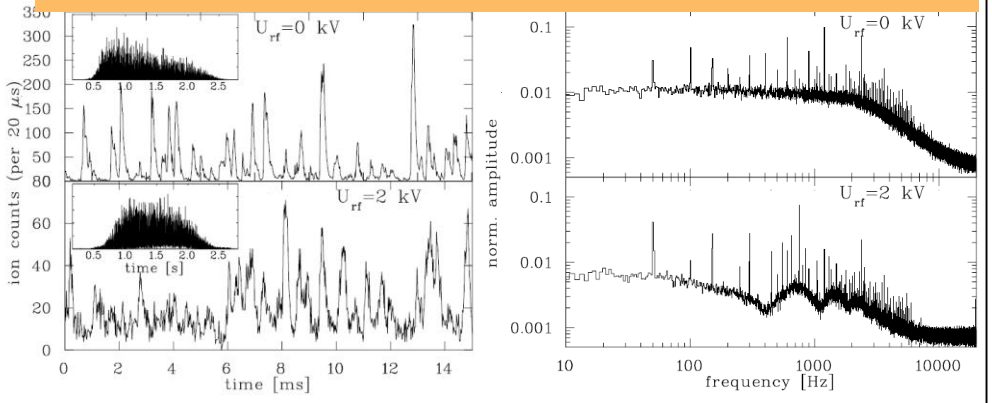
- Making the spill structure less sensitive to ripple
  - stochastic excitation
  - air coil quadrupole
  - spill smoothing cavity (VHF)
- Minimizing breaks in the spill
  - Bunching the beam

    (Experiments require bunching at high frequency > 40MHz)

Bunched Beam Extraction

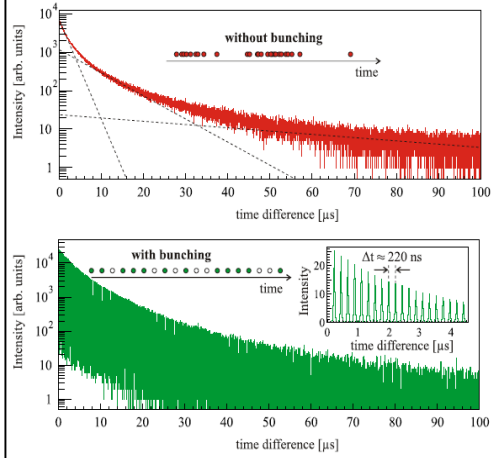
- Bunching with existing cavity (≈5MHz)
  - Smoothing effect because of synchrotron oscillation
  - Broadening of sharp peaks in spill created by tune ripple
  - Number of breaks is substantially reduced
- Experimentally verified at SIS18
  - Used extensively for therapy at GSI
  - Works well for experiments with sufficiently long integration times
- Problems with pile-up remain
  - Significant perturbations in the spill structure persist
  - VHF RF System with frequency > 40MHz is required otherwise experiments run at reduced performance

Spill structure of coasting and bunched beam in SIS18



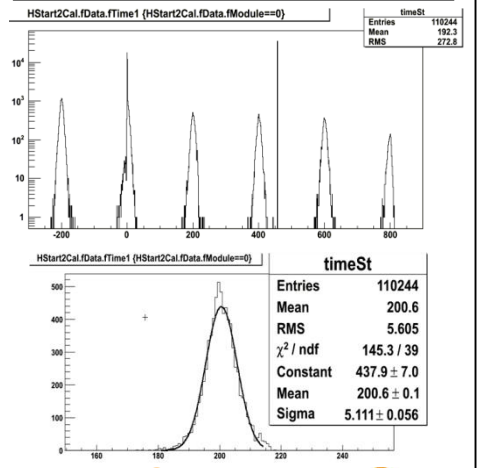
P. Forck, 2000

Bunched extr. at FRS



C. Stahl, PhD Thesis, 2015

Bunched extr. at HADES

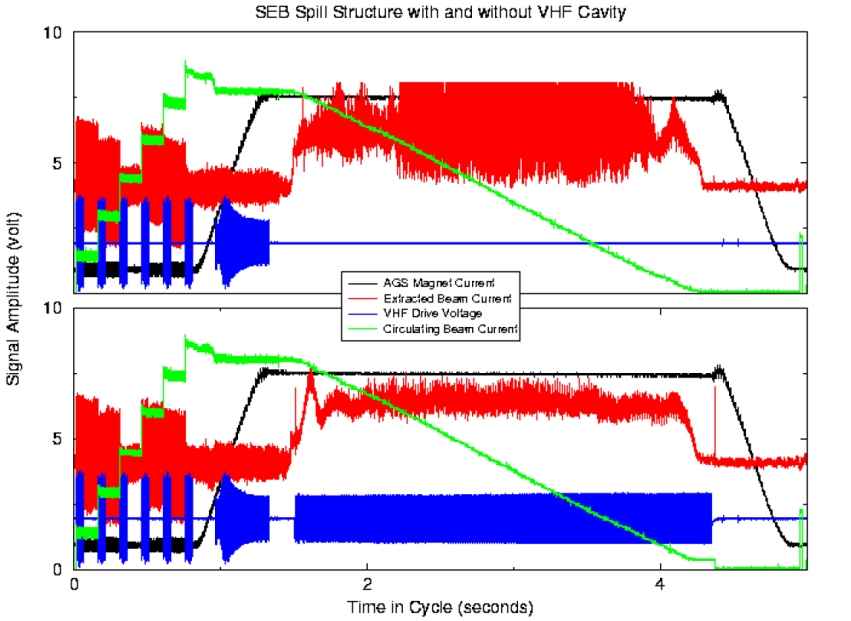


Data courtesy W. König

Very High Frequency Cavity

- Spill smoothing
  - 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 require new RF cavity (≥ 40MHz)
  - Theoretical studies for SIS18 are ongoing
  - Hardware is procured
  - Installation is scheduled for April 2018

Improved spill at AGS with channeling



K. Brown, BNL, 1999

VHF Cavity for SIS18

A spare pill box resonator is currently being refurbished (see Fig. 1).
To adapt the cavity for UHV, a beam tube with a ceramic gap was designed (see Fig. 2).
Simulations predict that the internal beam pipe changes the fundamental frequency from 108.5MHz to 79.6MHz (CST-Microwave-Studio).
An external device will be provided for detuning and reducing the shunt impedance by three orders of magnitude. Additionally, the ceramic gap can be shorted.
A total RF power of 3kW provided by a solid state amplifier will be available.

Fig. 1: The original pill box cavity

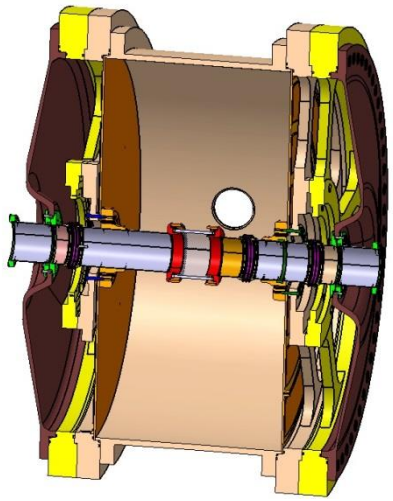


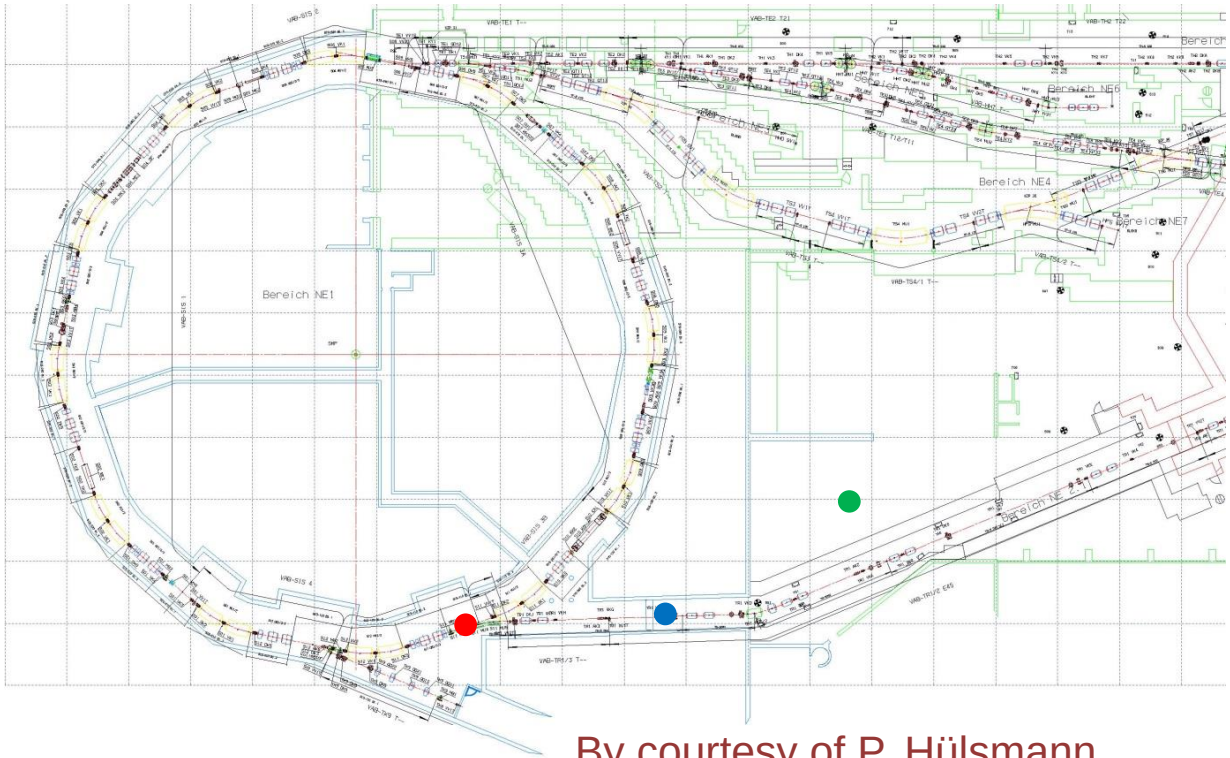
Fig. 2: A beam tube with a ceramic gap is added to the cavity

Some basic parameters	
Frequency	79.6±1.4MHz
Harmonic number	h = 60 - 61
Available Gap Voltage	85kV
Unloaded Shunt impedance	5kΩ-5MΩ
Unloaded Quality factor	3000-30.000
Vacuum Requirements	10^{-11} mbar inside the beam tube

By courtesy of P. Hülsmann

A VHF Cavity for SIS18

Integration of the cavity into period 11 (S011) is foreseen for April 2018 (location: red dot)
The 3kW solid state amplifier will be located next to the former reinjection channel, 25m away from the cavity (blue dot)
The PLC, the steering- and control racks will be located in the RRF-supply-room, BG1.016 (green dot)
The ceramic gap in the cavity will be bakeable because of the vacuum requirements in SIS18



By courtesy of P. Hülsmann

Currently the installation of the cables for the VHF system takes place.
For the phase- and amplitude loop some components from the UNILAC-LLRF will be adapted for the fundamental frequency of about 80MHz.
Modifications of the components necessary for the integration of the beam tube are currently underway.
The beam pipe including the ceramic gap is presently under construction.

Intention of the project

- Proof of principle
- Machine experiment
- Work out in collaboration with experimenters what quantities are of most importance
- Show that for small to moderate intensities ($10^6 - 10^7$ particles/s)
  - the pile-up and the spill quality can be improved
  - breaks can be avoided
- If the pilot study proves successful (at low current) design a dedicated VHF cavity

Acknowledgement

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