HELMHOLTZ

MATTER AND THE UNIVERSE

Topic: Ion Facilities

Enhancing Spill Quality in Slow Extraction

M. Block for the GSI/FAIR research and accelerator departments

Introduction

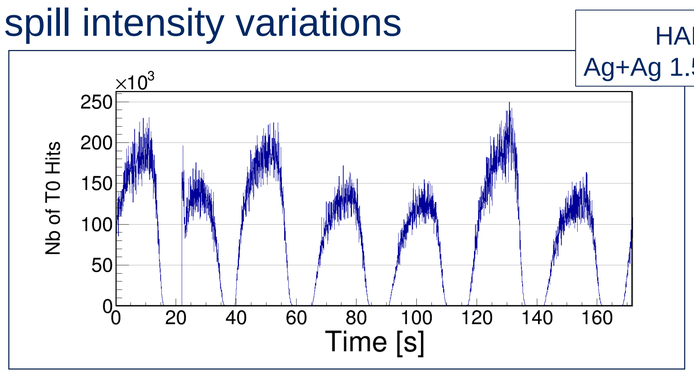
GSI offers access to a unique accelerator facility for ions enabling research on the fields of nuclear reactions and structure, nuclear astrophysics and hadron physics. The linear accelerator **UNILAC** provides beams of nearly all ion species from protons to uranium up to 11.4 MeV/u. The beam serves different experimental facilities and/or is injected into the SIS18 synchrotron. With 18 Tm rigidity, the **SIS18** can accelerate protons to 4.7 GeV and of uranium ions to 1 GeV/u. Eight experimental stations are served by SIS18 beams, one of them is **HADES** (High Acceptance DiElectron Spectrometer).

Challenge

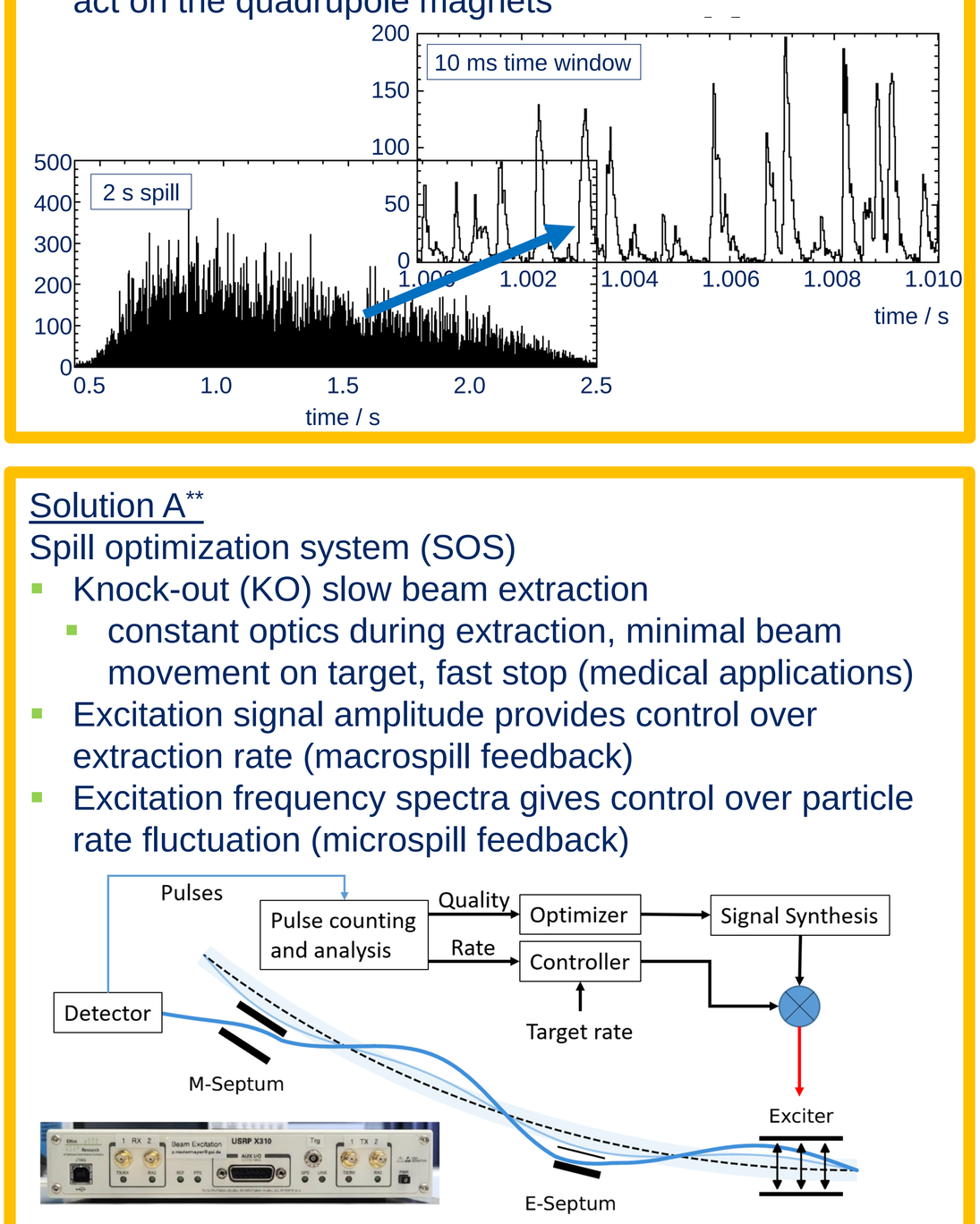
Slow beam extraction from a synchrotron is a critical step requiring precise control and optimization

- Large range of extraction times (0.2 – 20 s)
- Momentum dependence of extraction parameters
- Variation of beam spot on target
- Spill to spill intensity variations

HADES
Ag+Ag 1.5 AGeV



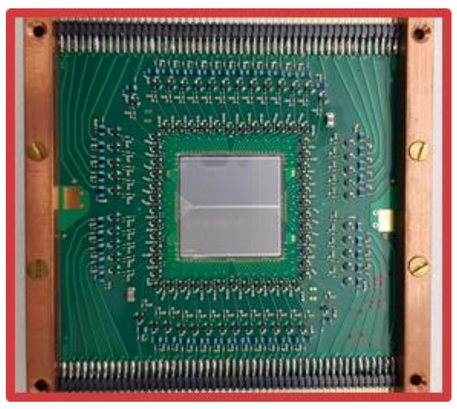
- Microspill structure related to power supply ripples that act on the quadrupole magnets



Consequences

- Instantaneous high beam intensities (macro structure) produce high loads in detectors
- Beam micro structure limits data acquisition rates and enhances the probability of pileup events

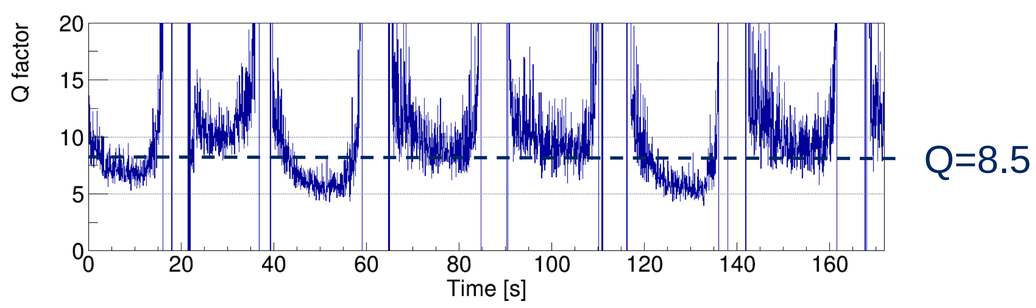
Means to quantify the beam microstructure:



Fast beam detectors based on LGAD technology

Quality factor Q* of the beam defined as ratio of peak to average intensities:

$$Q = \frac{N_{max}(20\mu s)}{N_{mean}(40\ ms)}$$



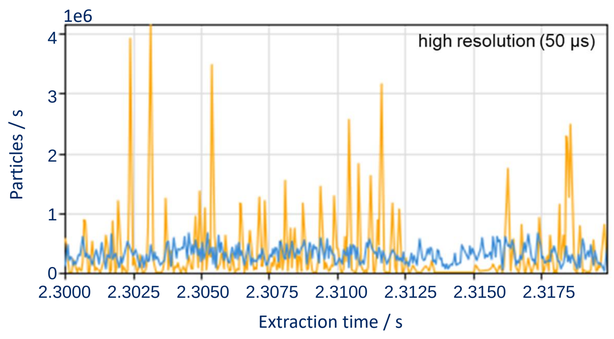
Q=8.5

Solution A**

Spill optimization system (SOS)

- Knock-out (KO) slow beam extraction
  - constant optics during extraction, minimal beam movement on target, fast stop (medical applications)
- Excitation signal amplitude provides control over extraction rate (macrospill feedback)
- Excitation frequency spectra gives control over particle rate fluctuation (microspill feedback)

Result of beam test at COSY

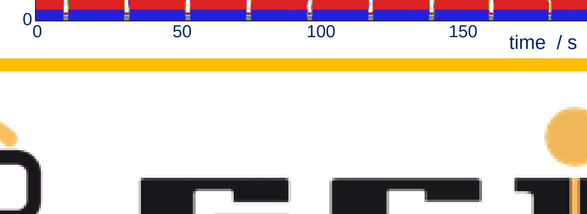


without SOS
with SOS

Solution B

Spill smoothing by bunching using radiofrequency fields

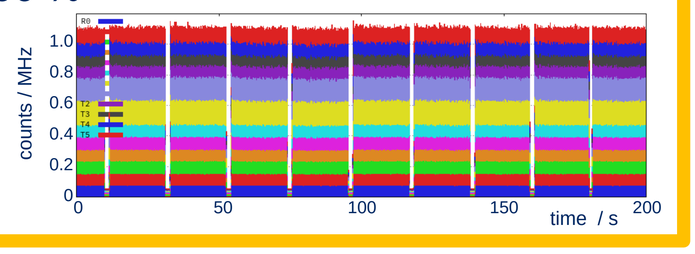
- Demonstration of spill smoothing using dedicated cavities at AGS (BNL) in different operation modes
- Test cavity installed in SIS18



- High shunt impedance limits the use of test cavity and probably also the beam intensity
- Special cavity for SIS100@FAIR under development

Result: Feedback system + HF Cavity

- Significantly improved spill shape stability
- Substantial reduction of microspill structure, Q<5!
- Duty factor close to 90 %
- **Important for all experiments using long extraction at FAIR**



* Rost, A., et al., Performance of the CVD diamond based beam quality monitoring system in the HADES experiment at GSI, IPAC 2019, doi:10.18429/JACoW-IPAC2019-WEPGW019
** Niedermayer, P., Singh, R. Excitation signal optimization for minimizing fluctuations in knock out slow extraction. *Sci Rep* **14**, 10310 (2024). https://doi.org/10.1038/s41598-024-60966-y

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