Software Defined Radio Based Feedback System for Transverse Beam Excitation

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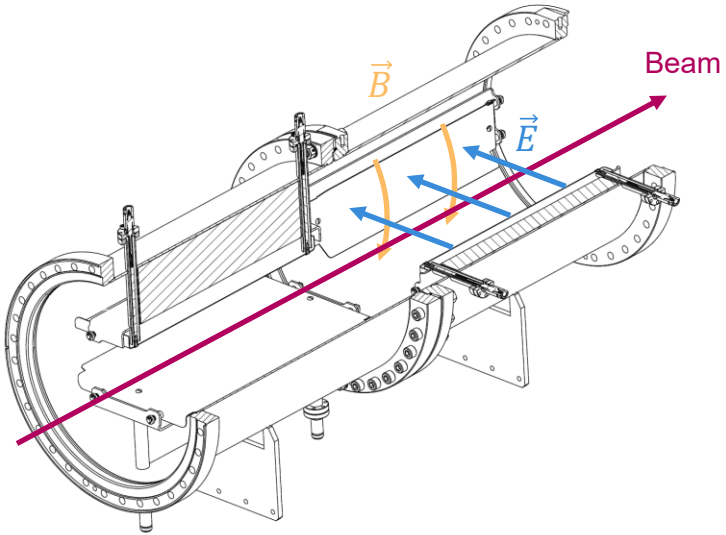
Bild: GSI Helmholtzzentrum für Schwerionenforschung, D. Fehrenz, 2022

Motivation

- Beam excitation with stripline kickers
  - Tune & chromaticity measurement
  - Slow extraction (nonlinear machine)
- RF signal generation
  - Flexible
  - Interconnectable
  - Maintainable

  - ~~Arbitrary waveform generator~~
  - ~~Custom hardware design~~
  - **Software-defined radio**



Stripline Exciter

Image: P. Kowina / JHAASS

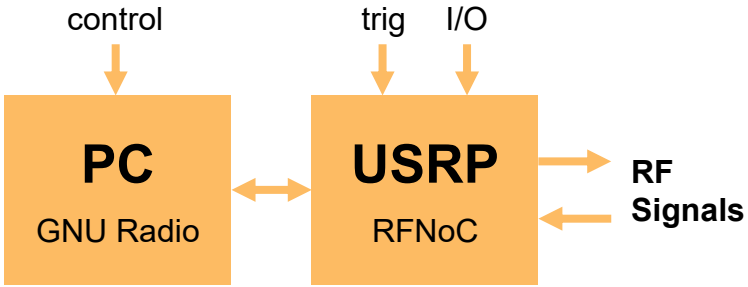
Outline

- Software-defined radio (SDR)
  - GNU Radio
  - Digital signal processing
- Beam excitation for slow extraction
  - Process & requirements
  - Software radio approach
- Commissioning
  - COSY Accelerator
  - Feedback system performance

Software-Defined Radio (SDR)

Software-Defined Radio (SDR)

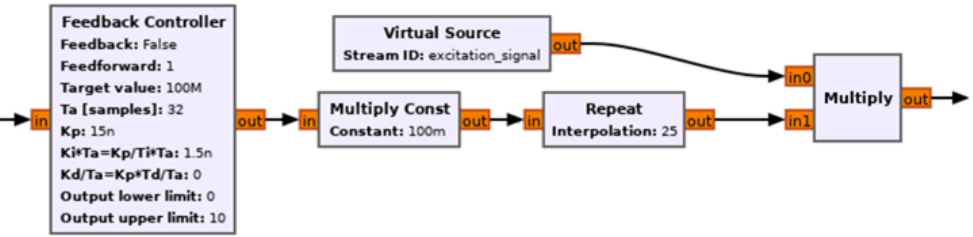
- Digital signal processing on FPGA + CPU
- Commercial front-end hardware (USRP)
- Large flexibility & on demand changes
- Widely used in radio communication

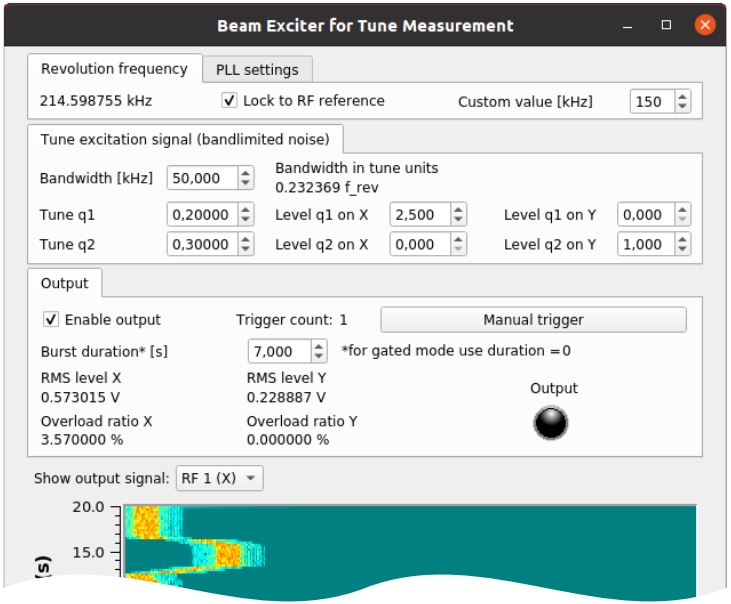


Universal Software Radio Peripheral (USRP)

GNU Radio & RFNoC

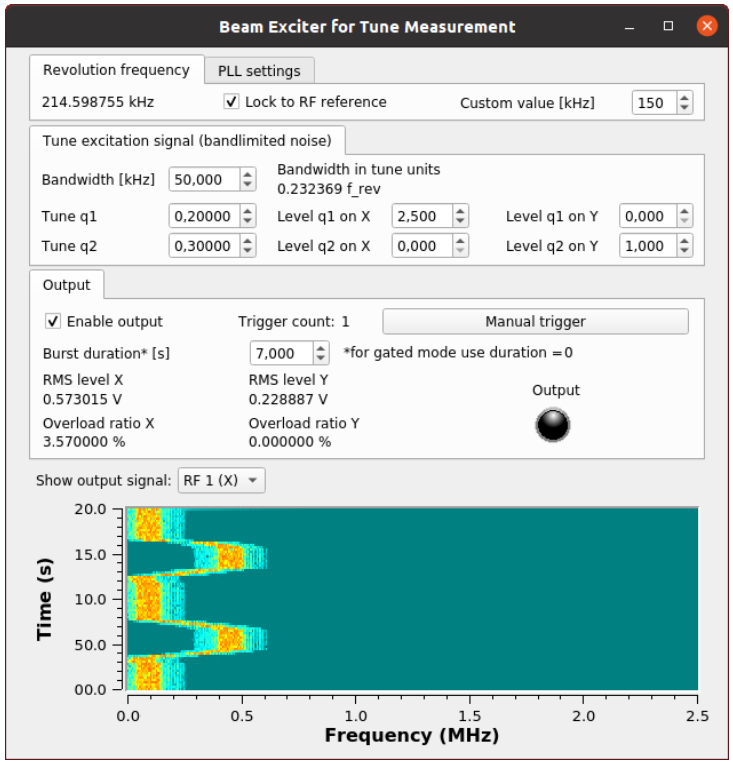
- Framework for signal processing
- Flow graph design
- Predefined and custom blocks
  - CPU (Python, C++)
  - FPGA (Verilog, VHDL)
  - Parametrized → GUI





Software Radio for Beam Excitation

- Generate excitation signals
  - Baseband: DC to 10 MHz
  - Triggered operation mode
- Process signals
  - Up to 200 MHz on FPGA
  - Acquisition and real-time evaluation
  - Overall latency of 1 – 2 ms

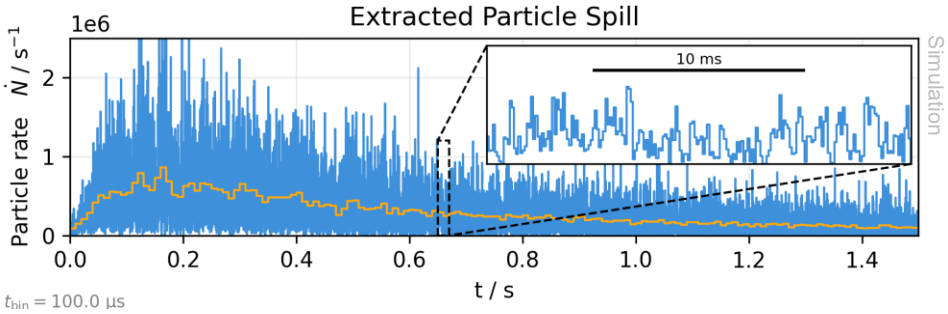


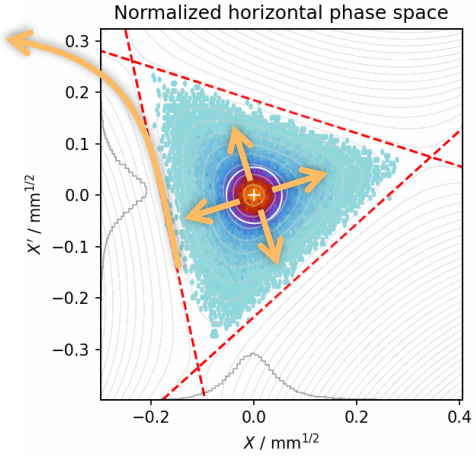
Beam Excitation for Slow Extraction

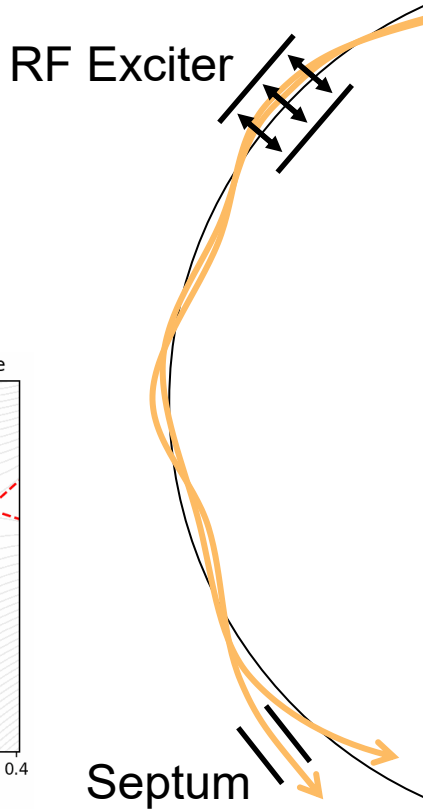
Beam Excitation for Slow Extraction

- Sextupole driven 3rd order resonance
- Transverse excitation to control particle amplitude
- Particles become instable and are extracted → Spill

► **Excitation signal controls spill**

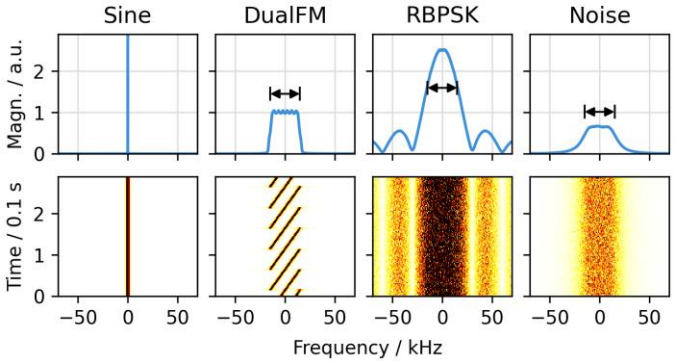


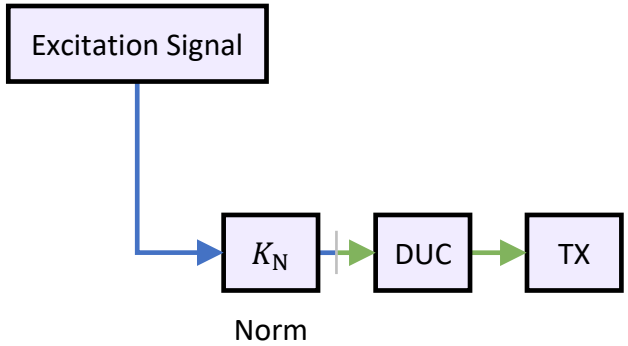




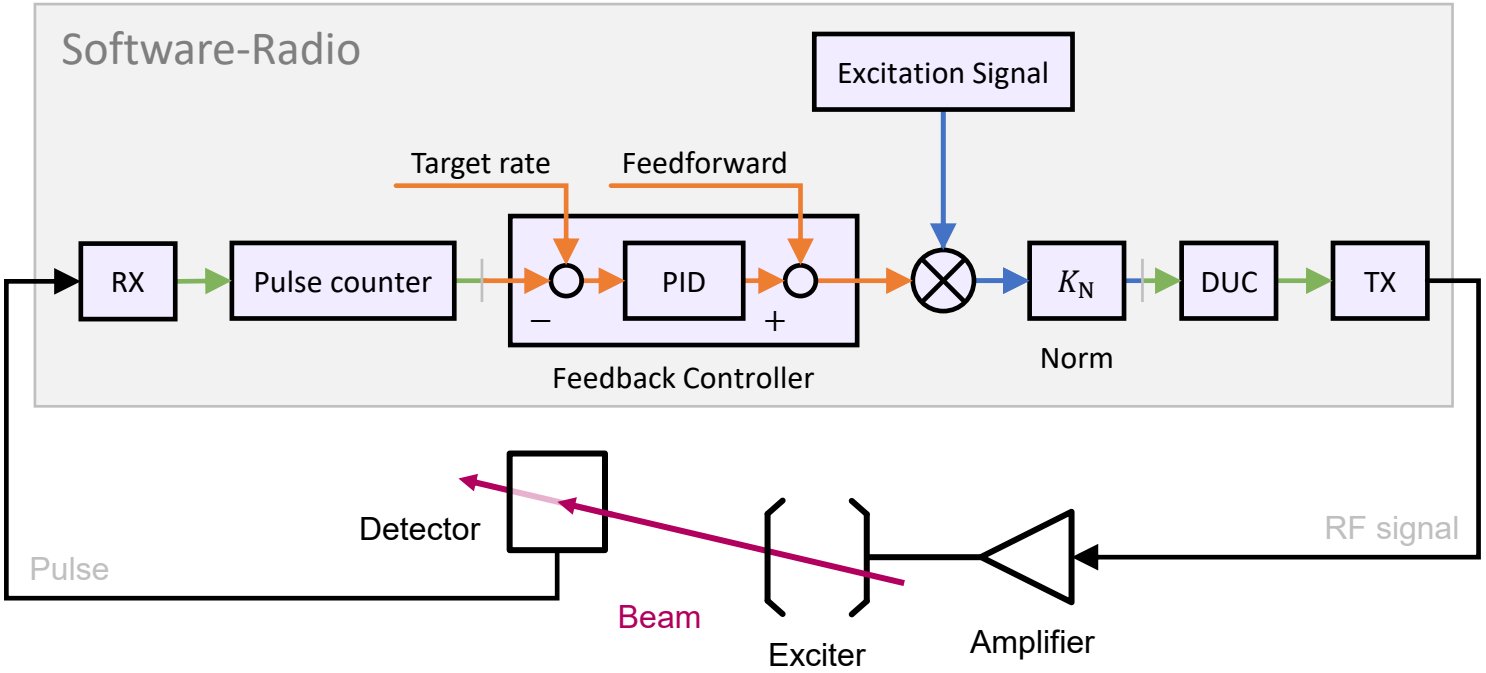
Software Radio Based Feedback System

- Excitation signal controls spill





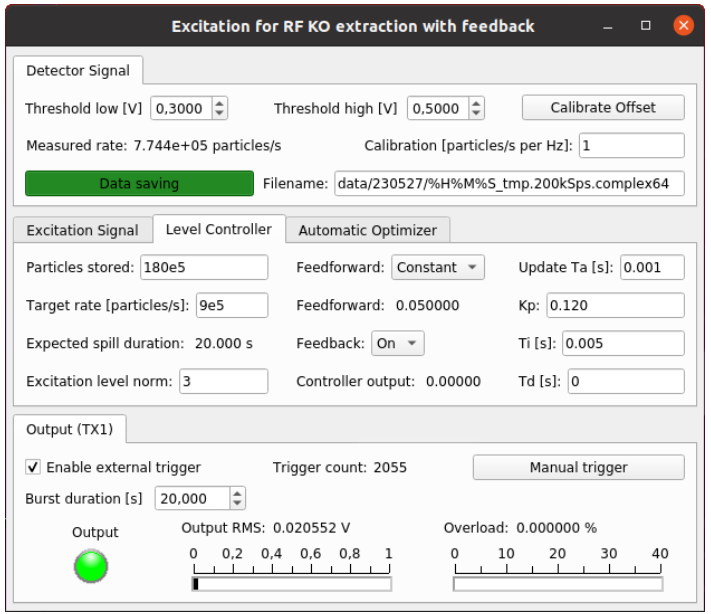
Software Radio Based Feedback System



Software Radio Based Feedback System

- Portable single-device solution
  - Digitizes detector signals (ns)
  - Generate RF signals (kHz ~ MHz)
- Spill control with feedback
  - PID controller for amplitude (ms)
  - Automatic optimizer for parameters (cyclic)
- Open source software
  - Flow graphs & GUIs
  - Custom blocks

git.gsi.de/p.niedermayer/exciter



Commissioning at COSY Accelerator

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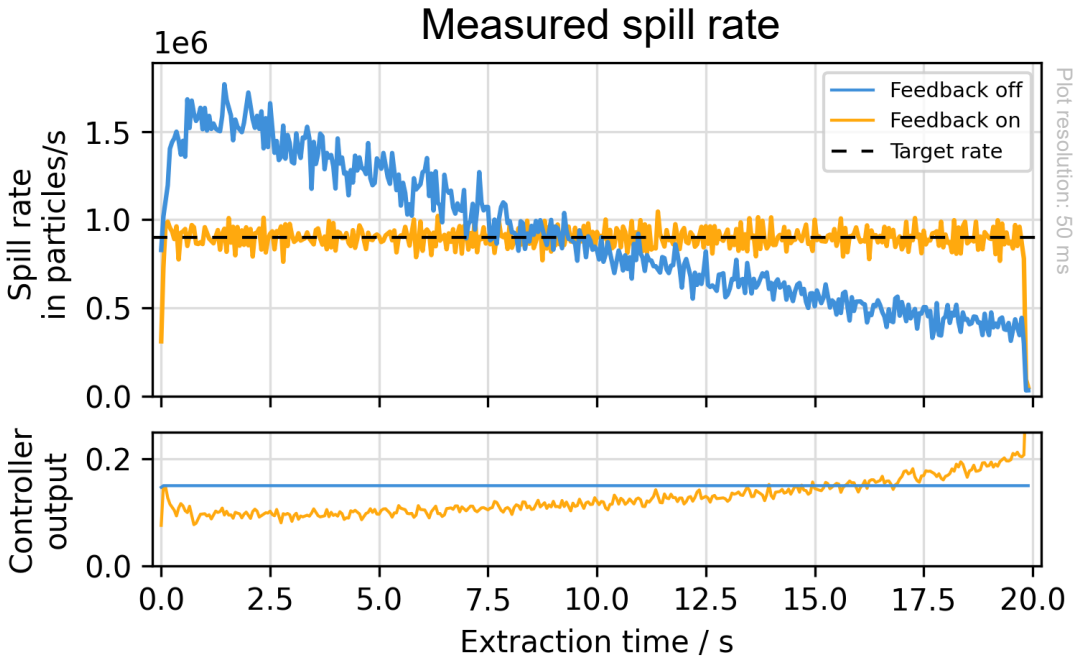
- Joint beamtime in May 2023
- Spill detectors
  - HADES LGAD
  - Scintillator BC400
  - Ionisation chamber + IFC
- Feedback system
  - Corrects drift
  - Maintains spill rate



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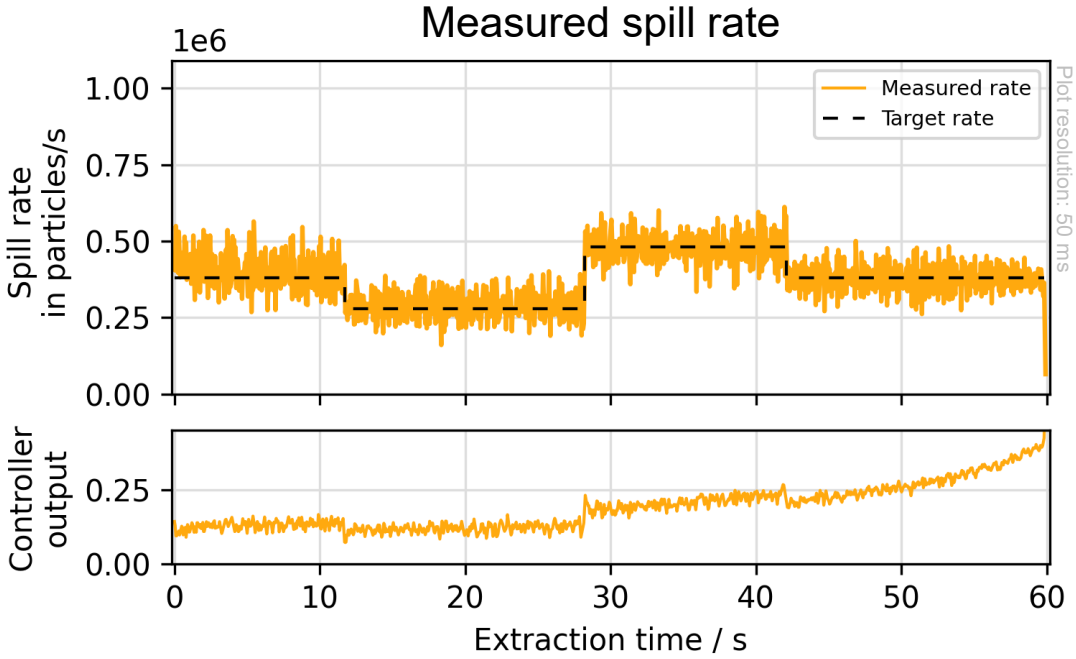

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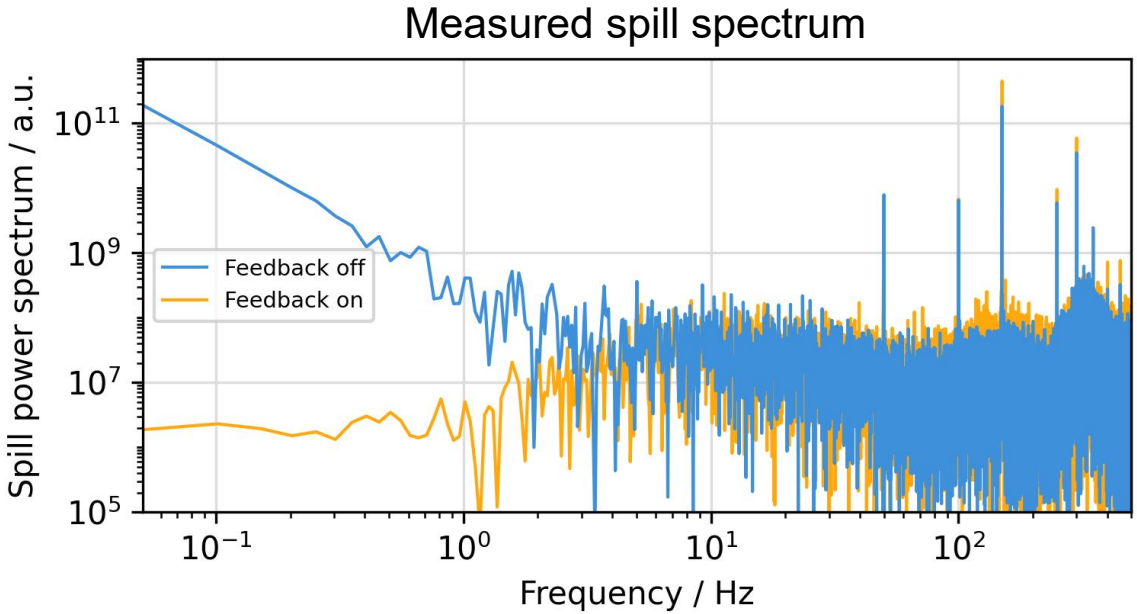
  - Works up to ~ 5 Hz



Summary

- Software-defined radio
  - Signal generation, acquisition & processing
  - Flexible flow graph design
- Excitation and feedback system
  - Portable single-device solution
  - Feedback from spill detector signal
- Commissioning
  - Spill rate maintained (≤ 5 Hz)
  - Twin system in operation at COSY Jülich

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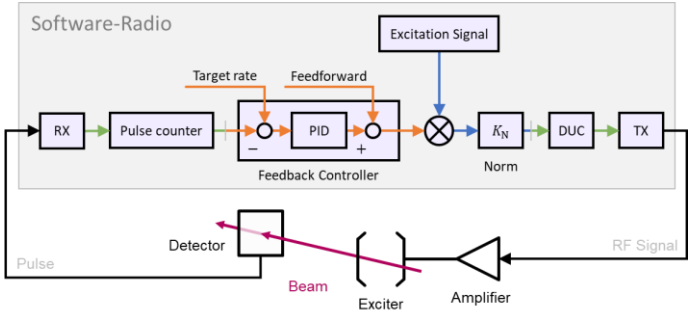

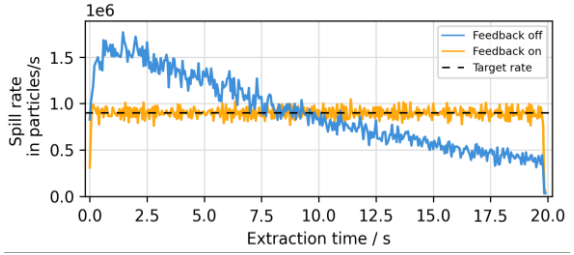

Acknowledgements

Thank you!

COSY Control Room

Special thanks to

Team of the COSY accelerator in Jülich

HADES LGAD group

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