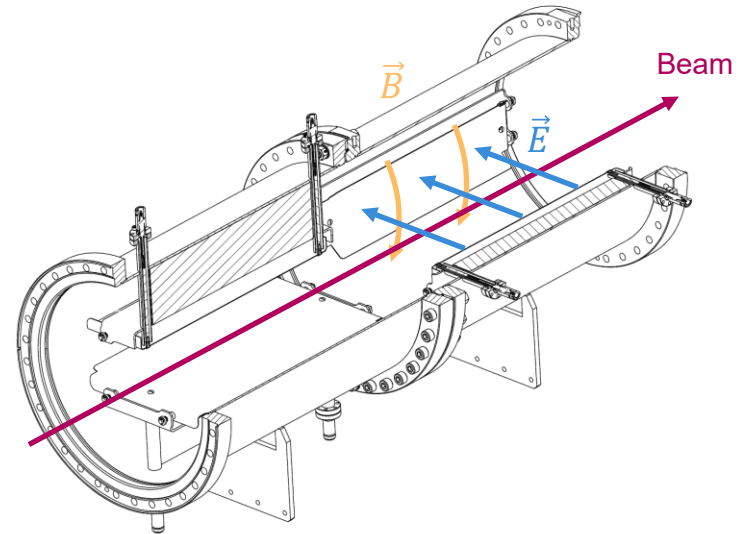


An aerial photograph of the FAIR GSI facility, showing a large complex of buildings and construction sites surrounded by green fields and forests. The facility is situated in a valley, with a road and parking areas visible. The construction sites are marked with yellow cranes and orange earth.

# Software Defined Radio Based Feedback System for Transverse Beam Excitation

Philipp Niedermayer (GSI)

- 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**



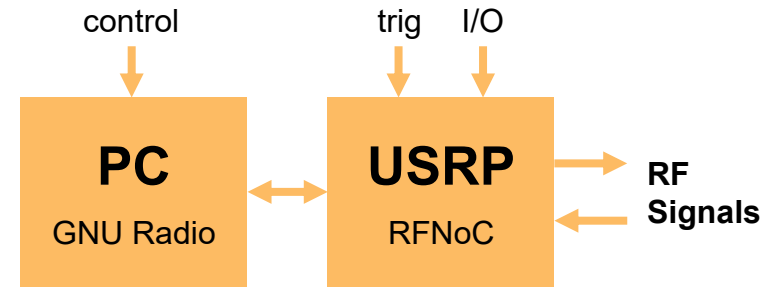
Stripline Exciter

- 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)

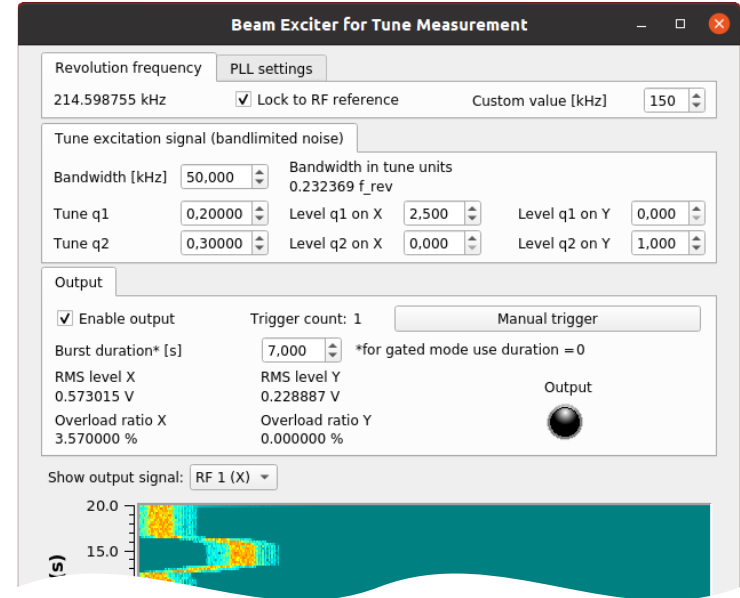
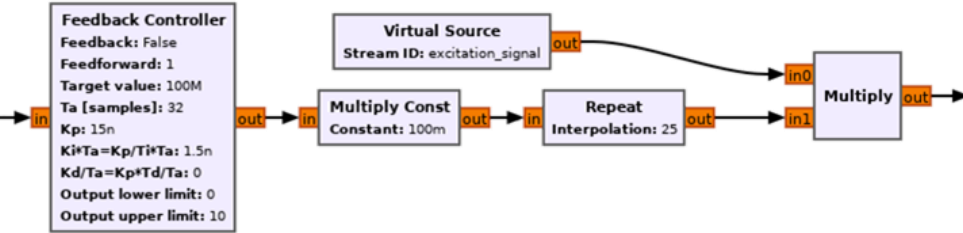
- Digital signal processing on FPGA + CPU
- Commercial front-end hardware (USRP)
- Large flexibility & on demand changes
- Widely used in radio communication



Universal Software Radio Peripheral (USRP)



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



**Beam Exciter for Tune Measurement**


Revolution frequency: 214.598755 kHz  
PLL settings:  Lock to RF reference | Custom value [kHz]: 150

Tune excitation signal (bandlimited noise)  
Bandwidth [kHz]: 50,000 | Bandwidth in tune units: 0.232369 f\_rev

Tune q1: 0,20000 | Level q1 on X: 2,500 | Level q1 on Y: 0,000  
Tune q2: 0,30000 | Level q2 on X: 0,000 | Level q2 on Y: 1,000

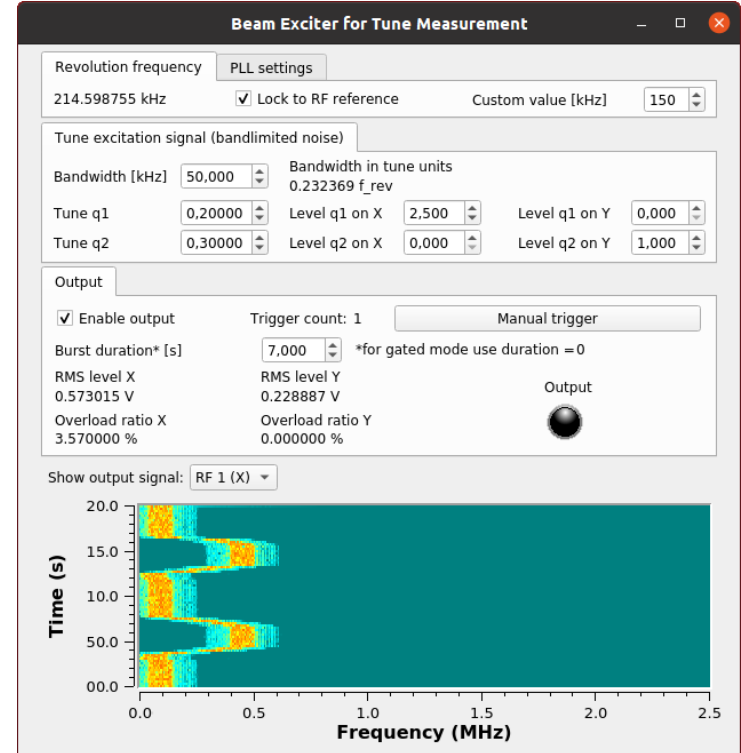
Output  
 Enable output | Trigger count: 1 | Manual trigger  
Burst duration\* [s]: 7,000 | \*for gated mode use duration = 0  
RMS level X: 0.573015 V | RMS level Y: 0.228887 V  
Overload ratio X: 3.570000 % | Overload ratio Y: 0.000000 %

Show output signal: RF 1 (X)



# 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

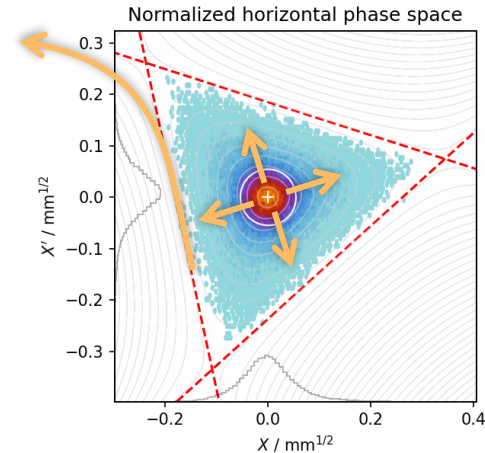
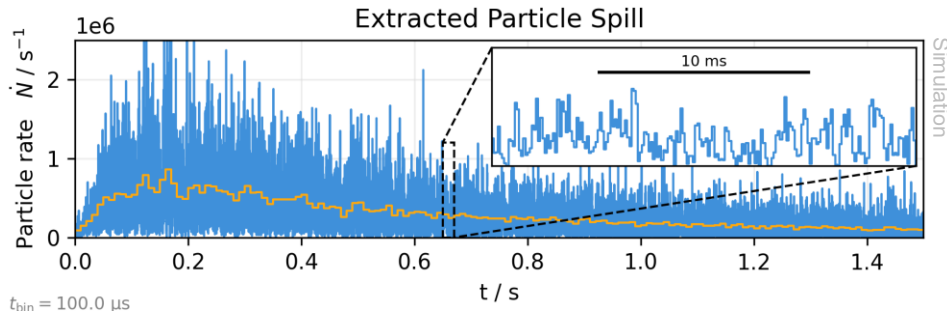
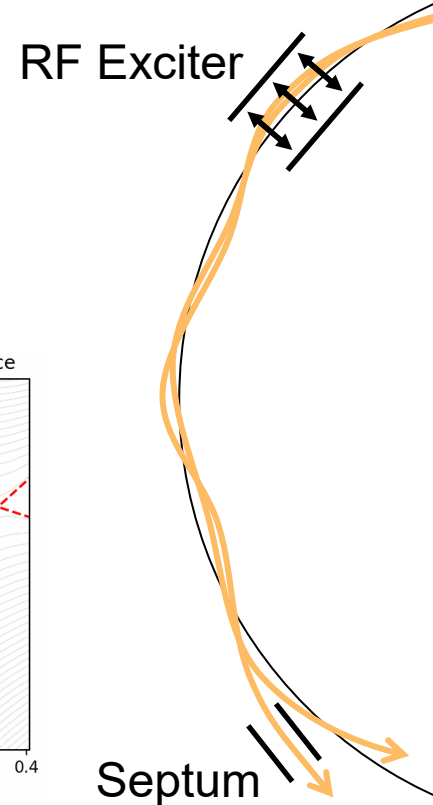


# Beam Excitation for Slow Extraction

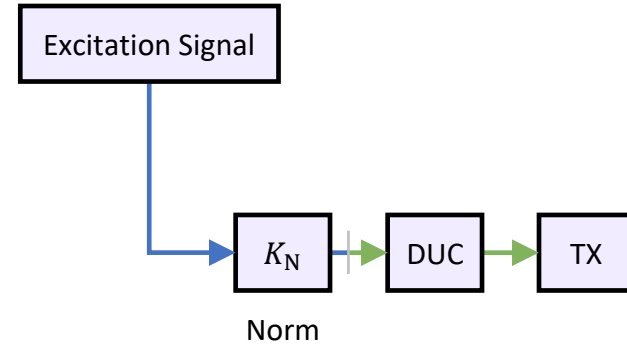
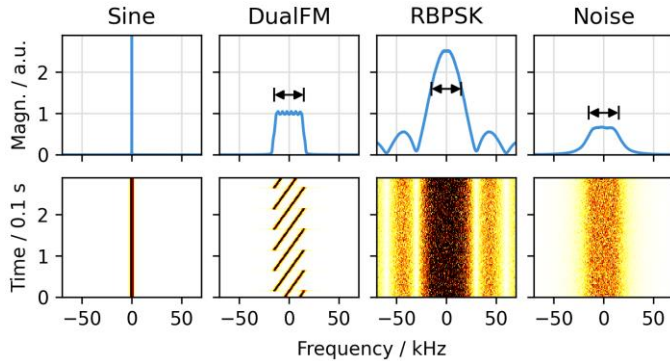


# Beam Excitation for Slow Extraction

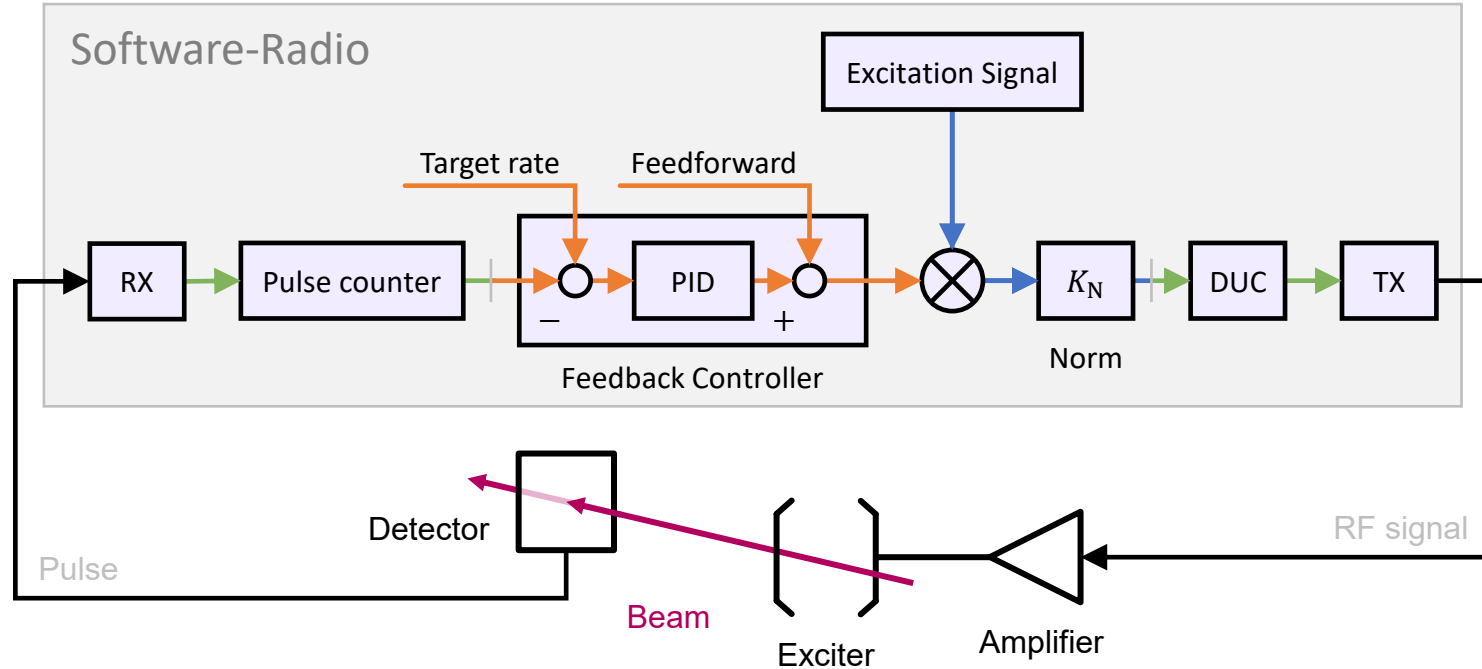
- Sextupole driven 3<sup>rd</sup> order resonance
- Transverse excitation to control particle amplitude
- Particles become instable and are extracted → Spill
- ▶ **Excitation signal controls spill**



- Excitation signal controls spill



# Software Radio Based Feedback System

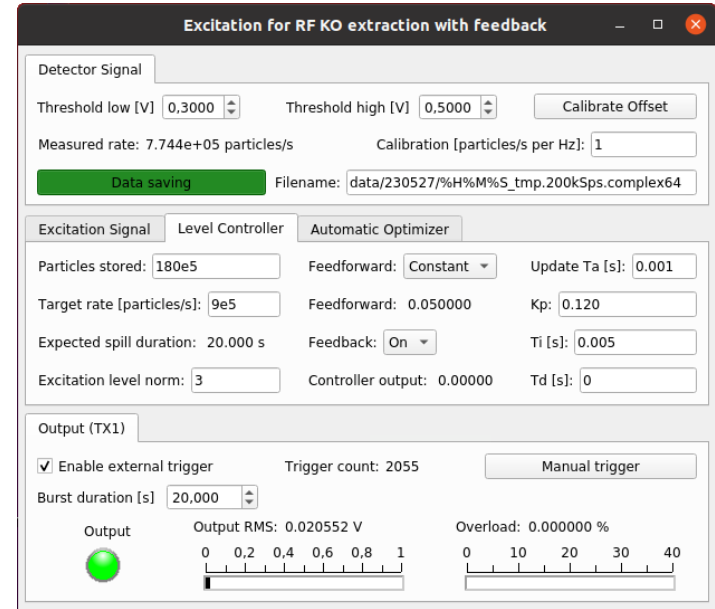


# Software Radio Based Feedback System

- 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

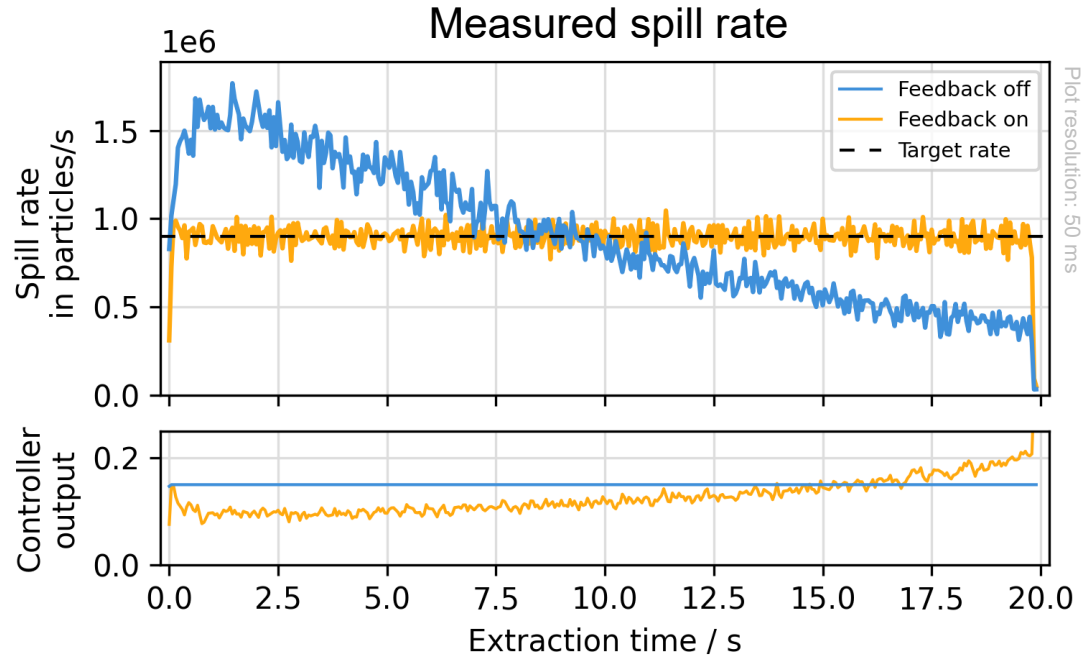


[git.gsi.de/p.niedermayer/exciter](https://git.gsi.de/p.niedermayer/exciter)

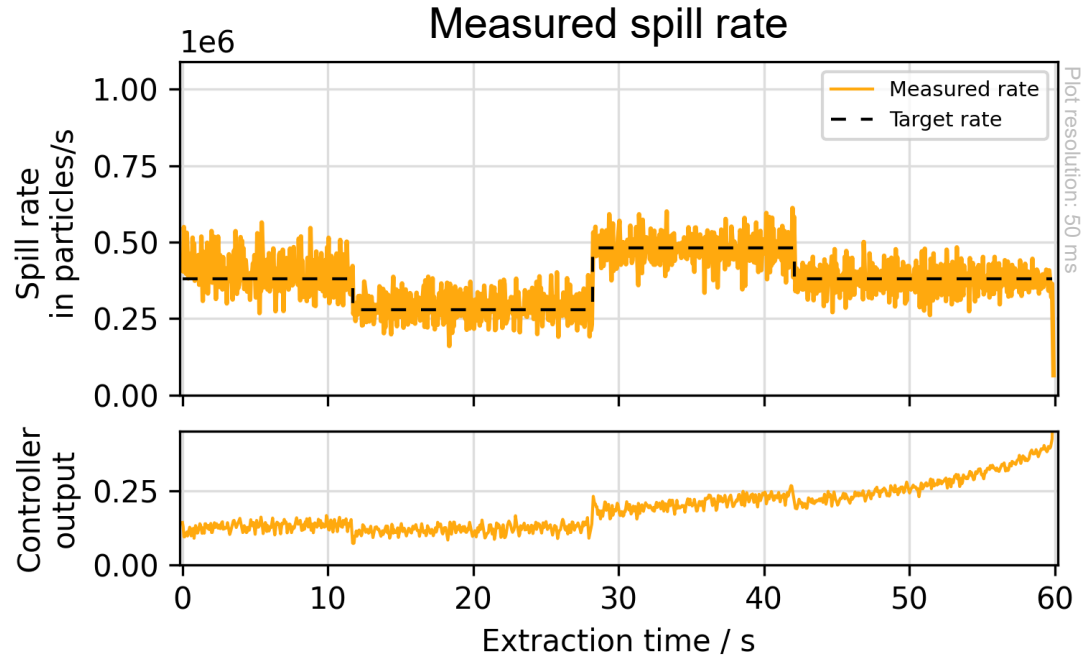


# Commissioning at COSY Accelerator

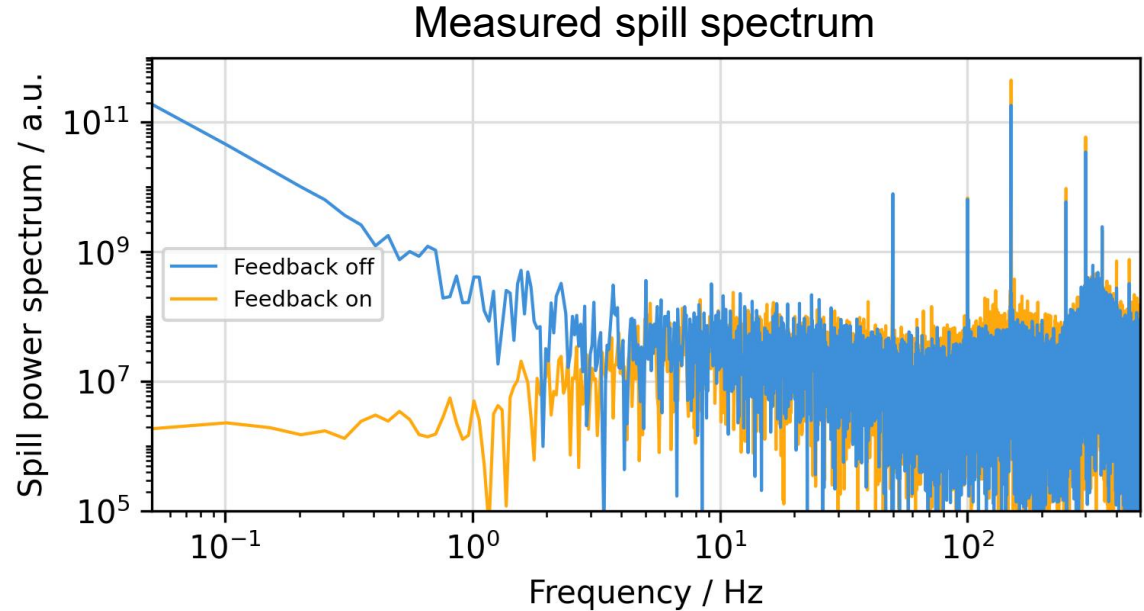
- Joint beamtime in May 2023
- Spill detectors
  - **HADES LGAD**
  - Scintillator BC400
  - Ionisation chamber + IFC
- Feedback system
  - Corrects drift
  - Maintains spill rate



- Joint beamtime in May 2023
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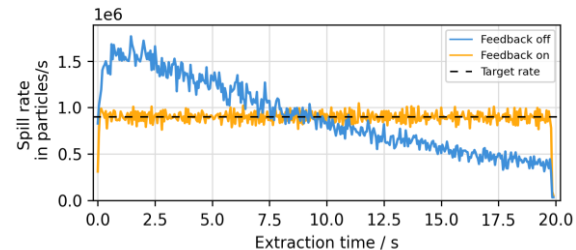
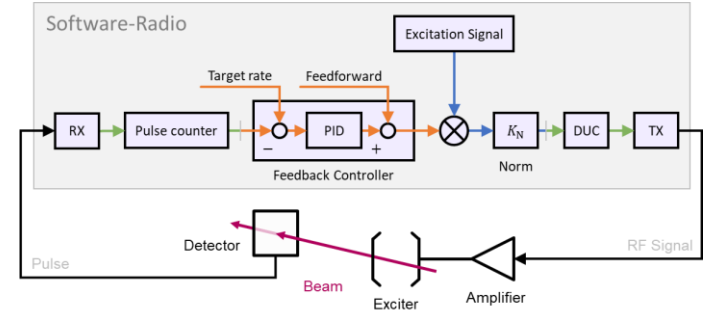
- Joint beamtime in May 2023
- Spill detectors
  - **HADES LGAD**
  - Scintillator BC400
  - Ionisation chamber + IFC
- Feedback system
  - Corrects drift
  - Maintains spill rate
  - Works up to  $\sim 5$  Hz





# 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 ( $\leq 5$  Hz)
  - Twin system in operation at COSY Jülich



[git.gsi.de/p.niedermayer/exciter](https://git.gsi.de/p.niedermayer/exciter)

# Thank you!



COSY Control Room

## Special thanks to

Team of the COSY accelerator in Jülich

HADES LGAD group

Beam instrumentation department at GSI