

P7 Accelerator Physics
WP 2 Extraction Mechanism

SLOW EXTRACTION OPTIMISATION AS PART OF THE NON-CLINICAL RESEARCH PROGRAMME AT MEDAUSTRON

Symposium on Non-Clinical Ion Beam Research at MedAustron
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WHY EXTRACTION?

From here...



... to there!



WHY **SLOW** EXTRACTION?

Controllable,
repeatable
extraction

Constant
dose rates
for >10s

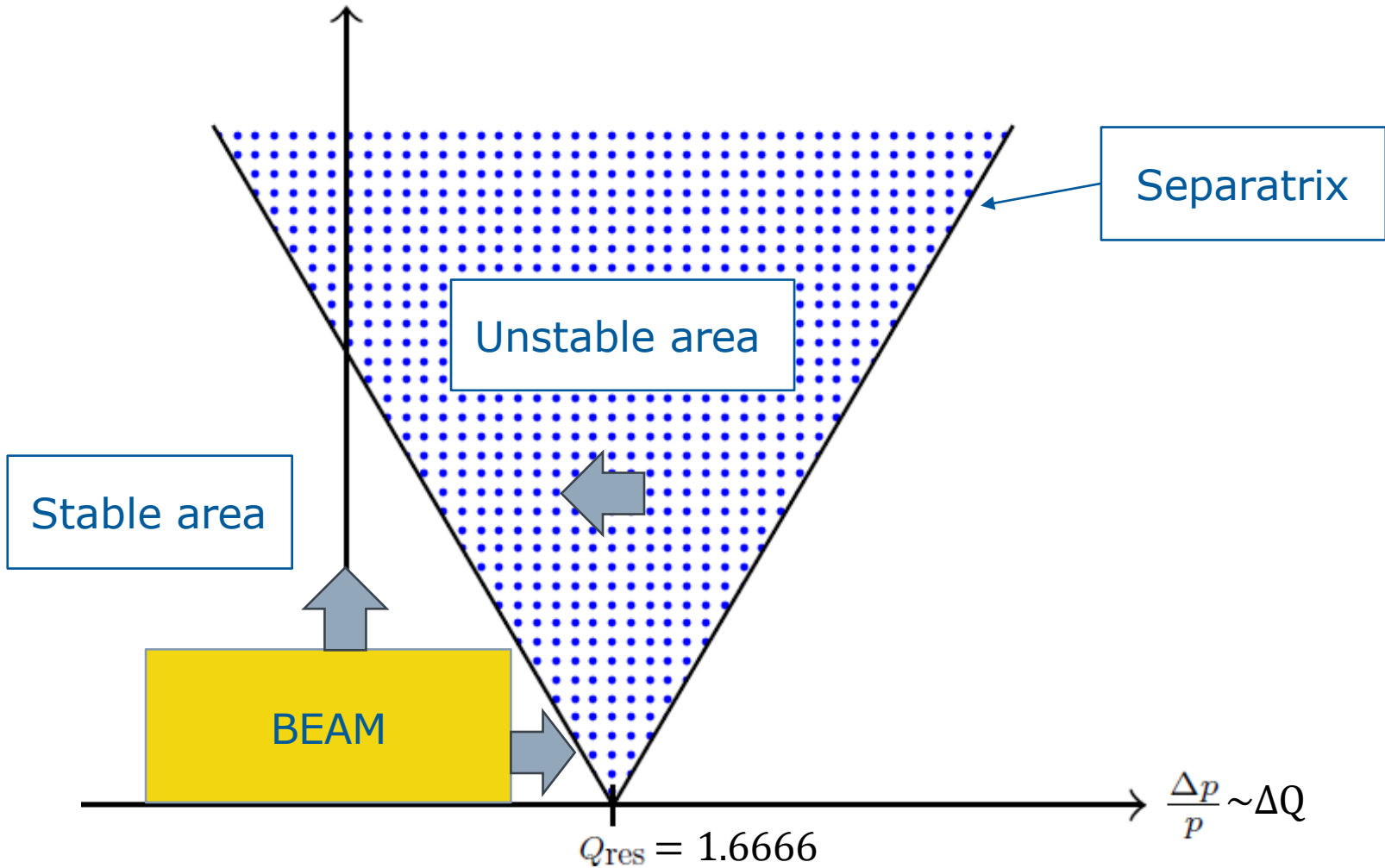
DDS to scan
beam over
the tumour

Safety
aspects

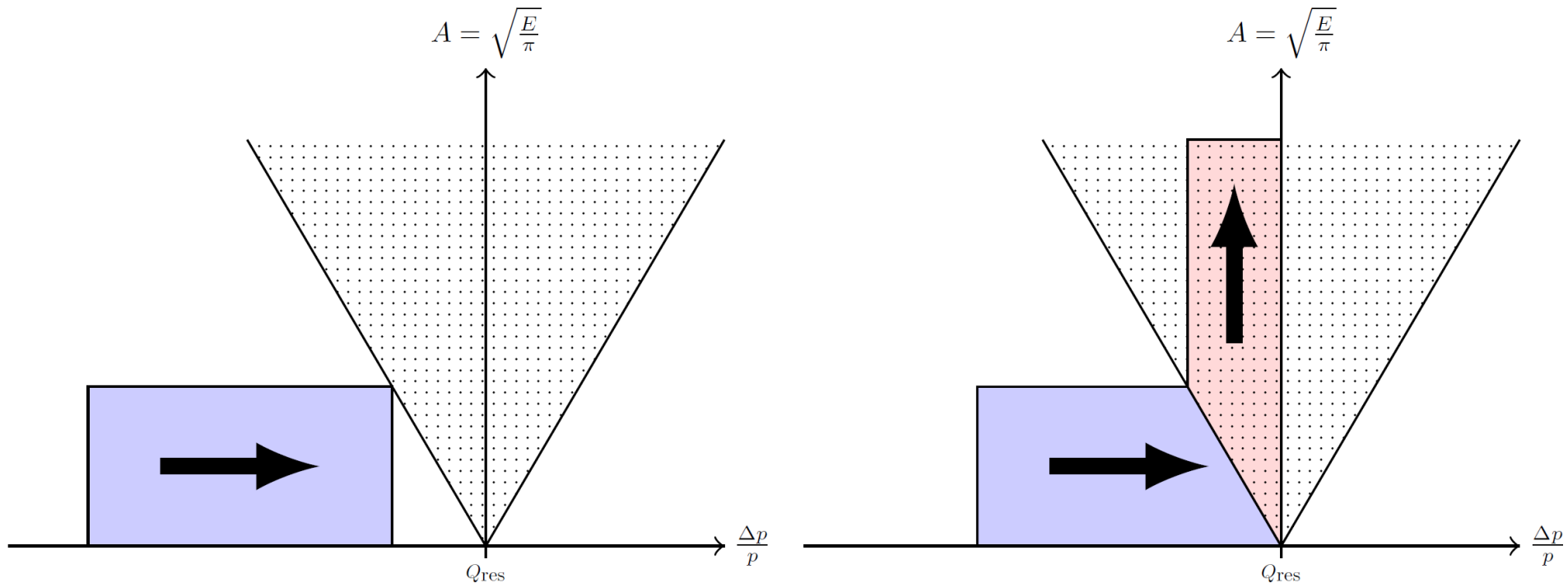
Different extraction methods available for Slow Extraction:

- **Betatron Core Extraction**
- **Radio-frequency Knock Out (RFKO)**
- Tune Sweep
- **Constant Optics Slow Extraction (COSE)**
- RF noise
- **Phase displacement extraction**

STEINBACH DIAGRAM

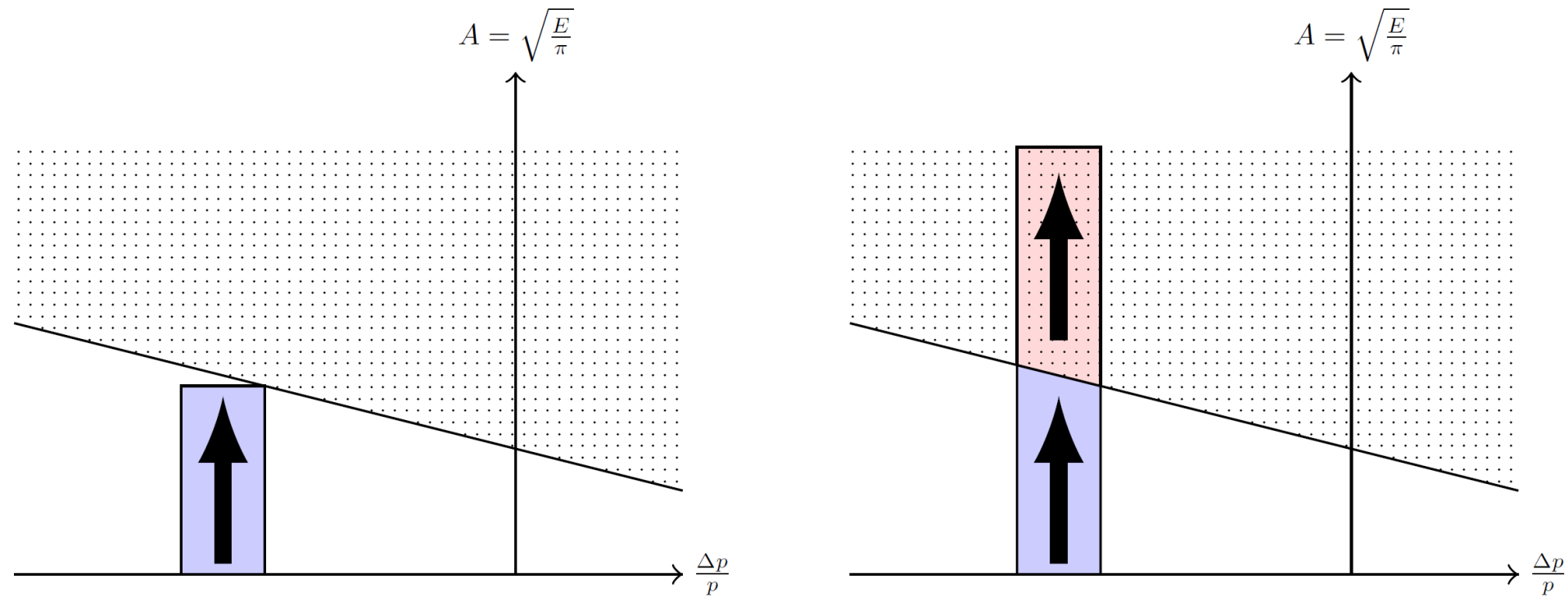


BETATRON CORE EXTRACTION



- Betatron Core accelerates particles
- Particle momentum is increased
- Beam is pushed into resonance

RADIO FREQUENCY KNOCK OUT (RFKO) EXTRACTION

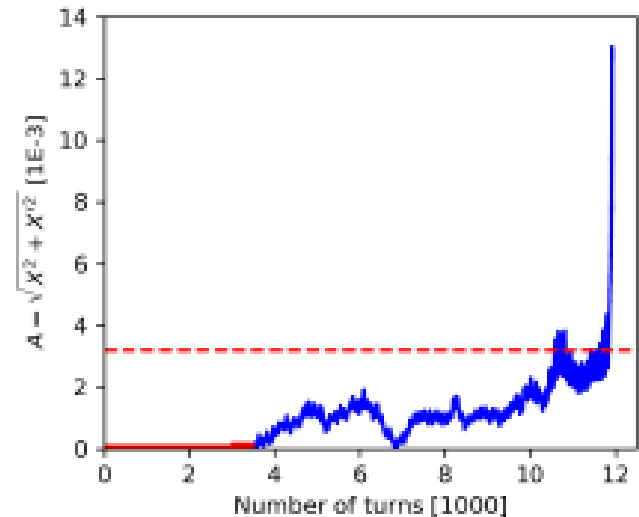
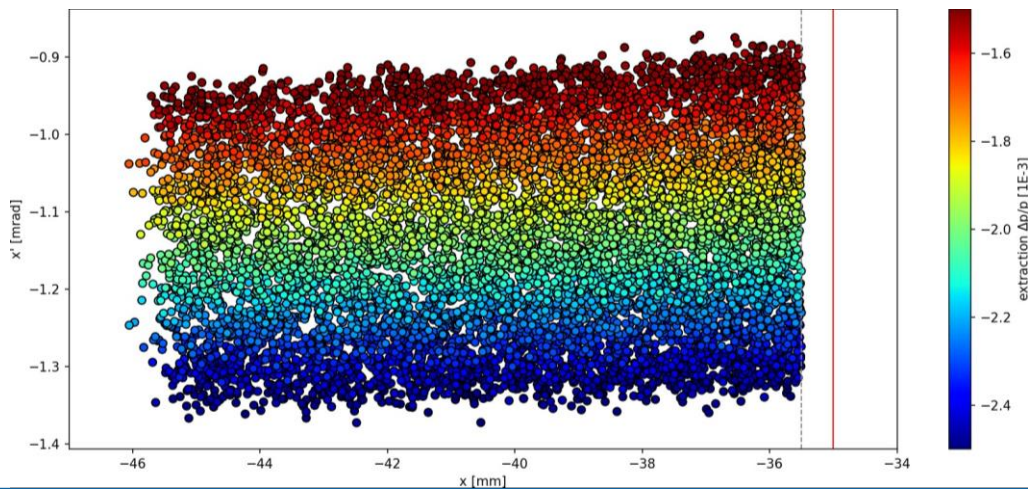
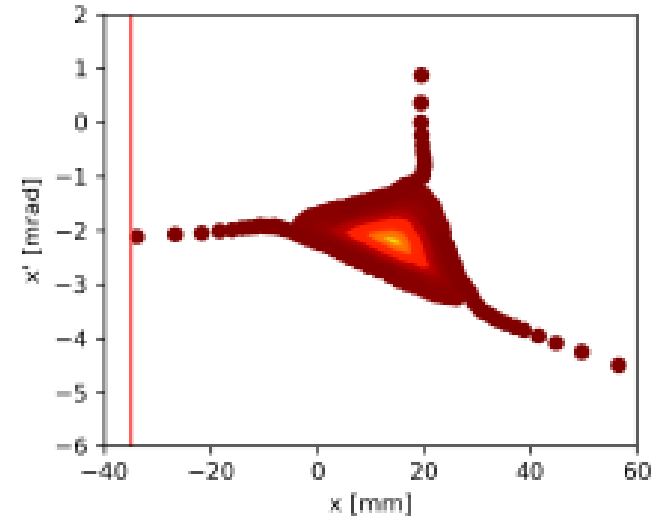
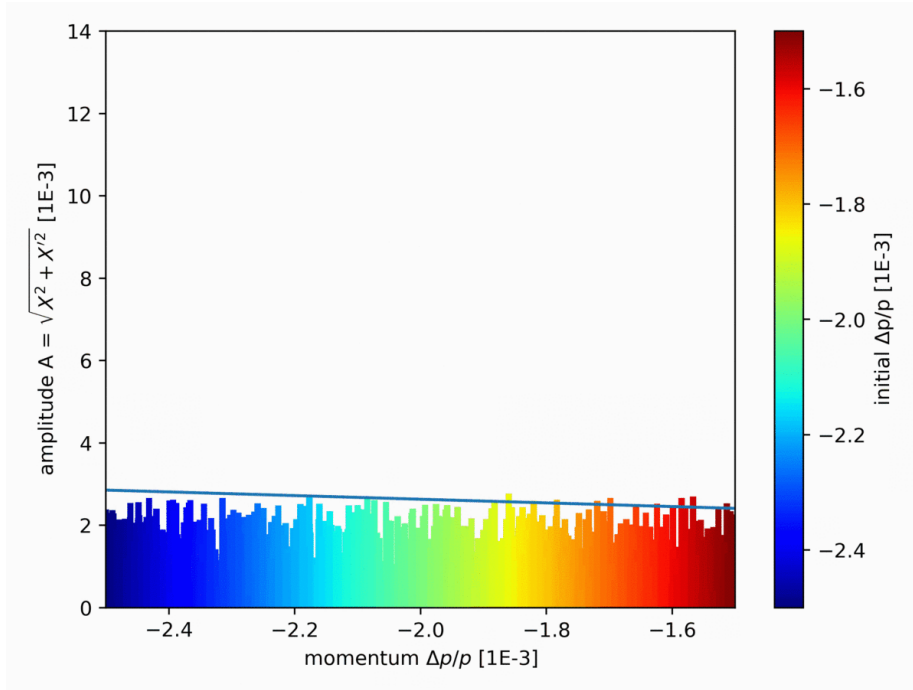


- Particle amplitude is increased
- Transverse kicker with AC
- Frequency matched to beam revolution

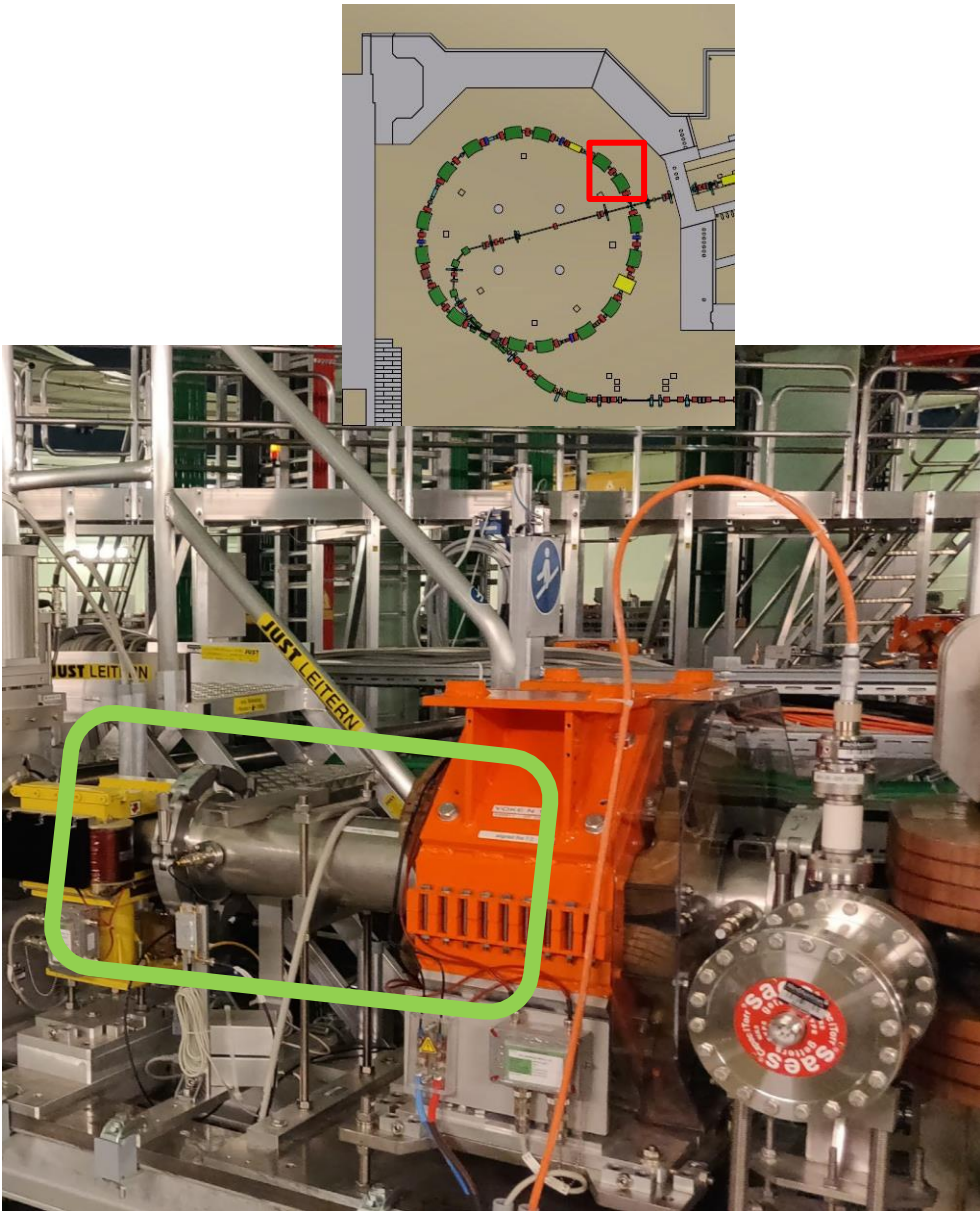
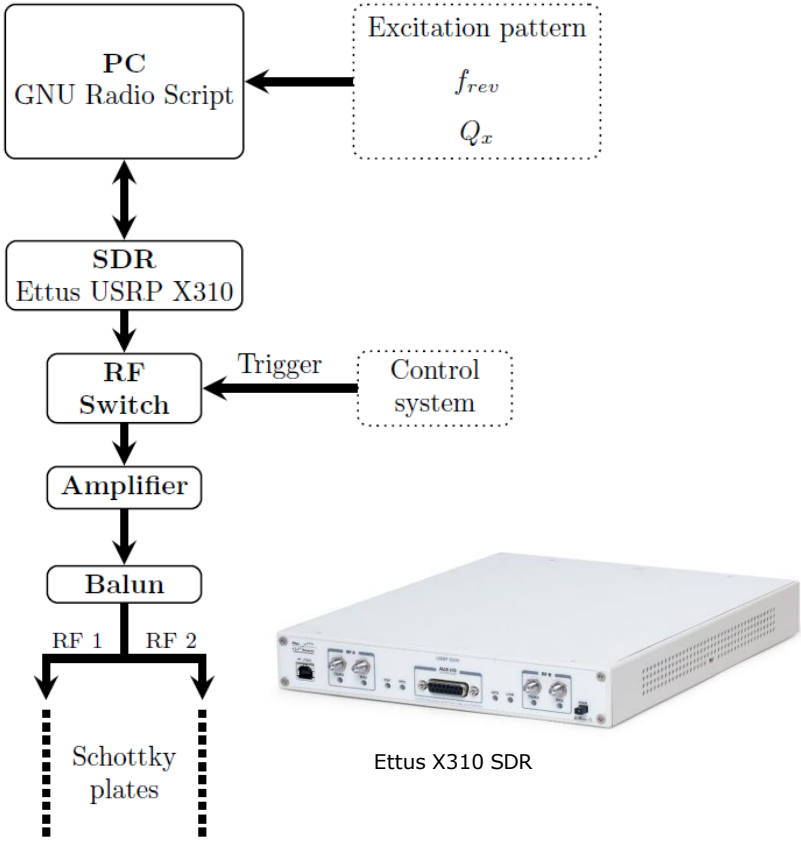
ADVANTAGES OF RFKO

- ✓ Compatible with bunched beam extraction
- ✓ Changing the beam energy during the spill
→ Multi Energy Extraction
- ✓ Sub-millisecond adaptation of the beam intensity
→ Dynamic Intensity Control
→ Irradiation Gating
- ✓ Compatible with FLASH treatment (?)
- ✓ Ripple reduction by adjusting the excitation pattern and introducing a closed-loop feedback regulation

RFKO SIMULATION - PROOF OF PRINCIPLE

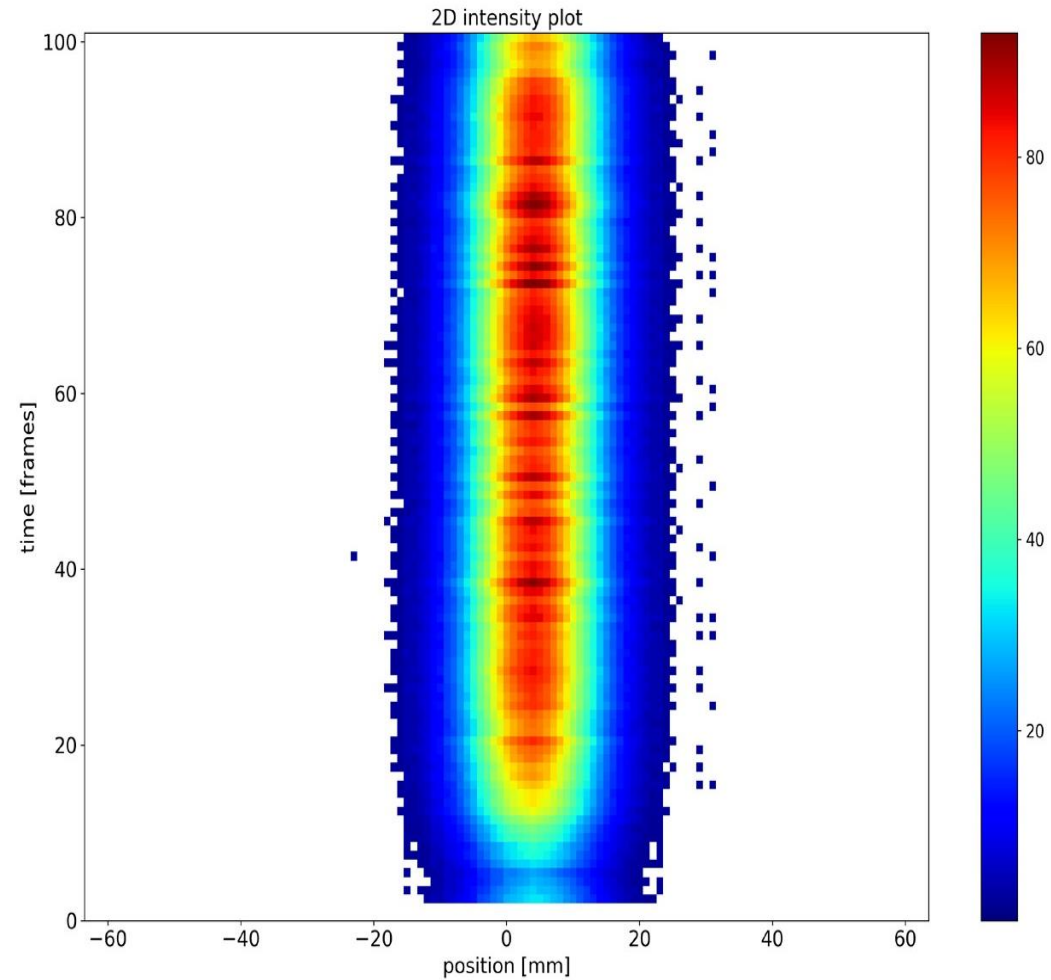
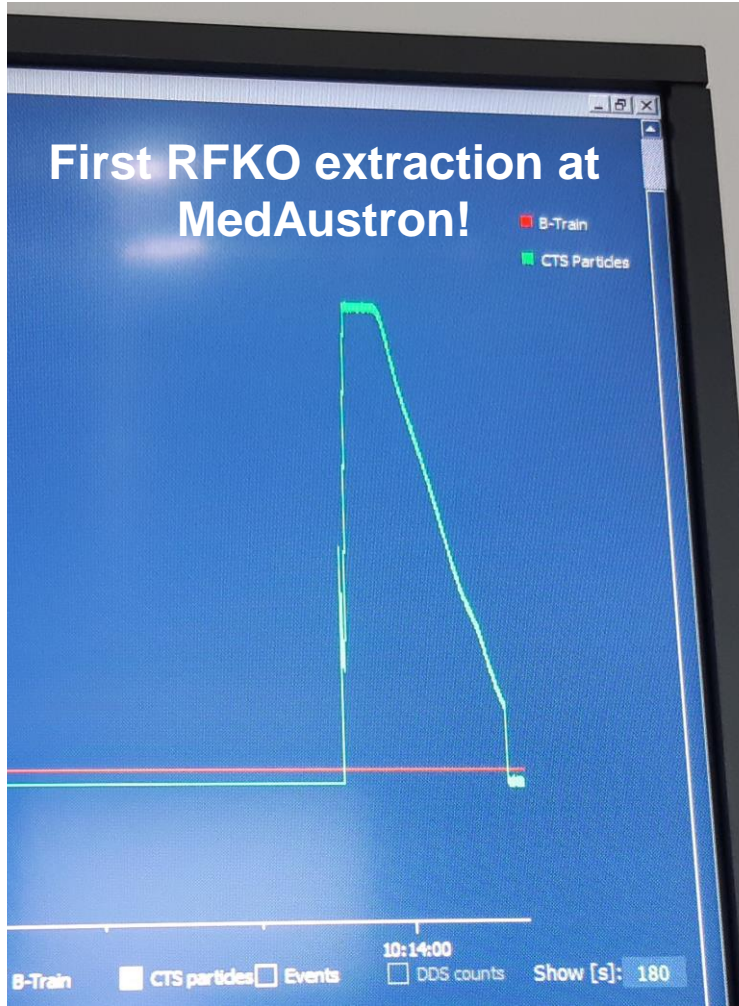


RFKO SETUP



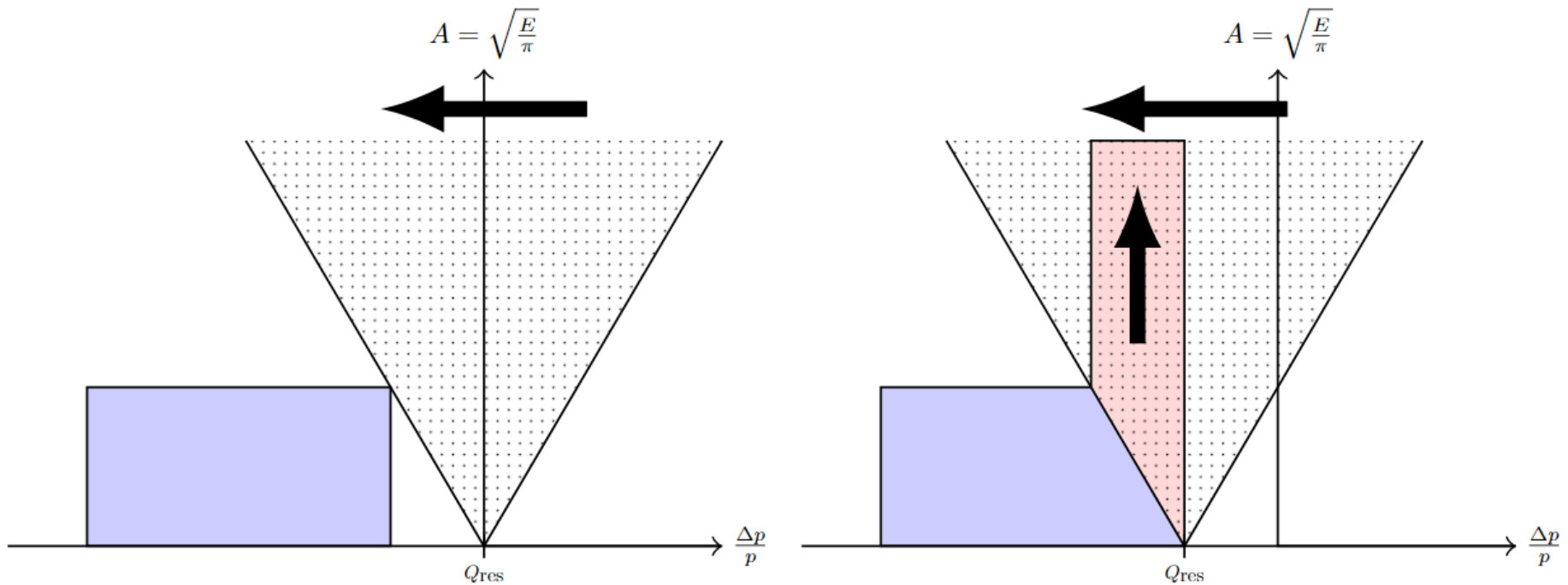
Courtesy of X. German

MEASUREMENT RESULTS



Courtesy of D.A. Prokopovich

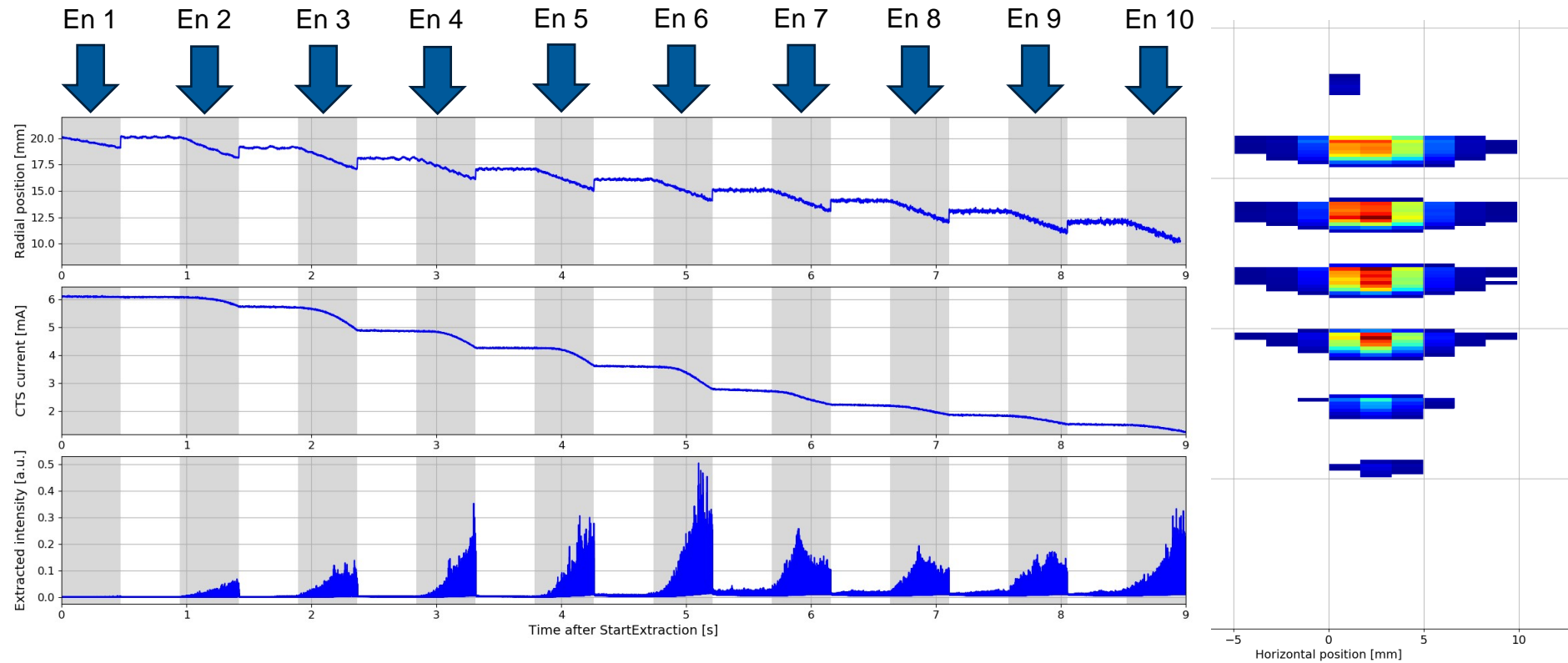
CONSTANT OPTICS SLOW EXTRACTION (COSE)



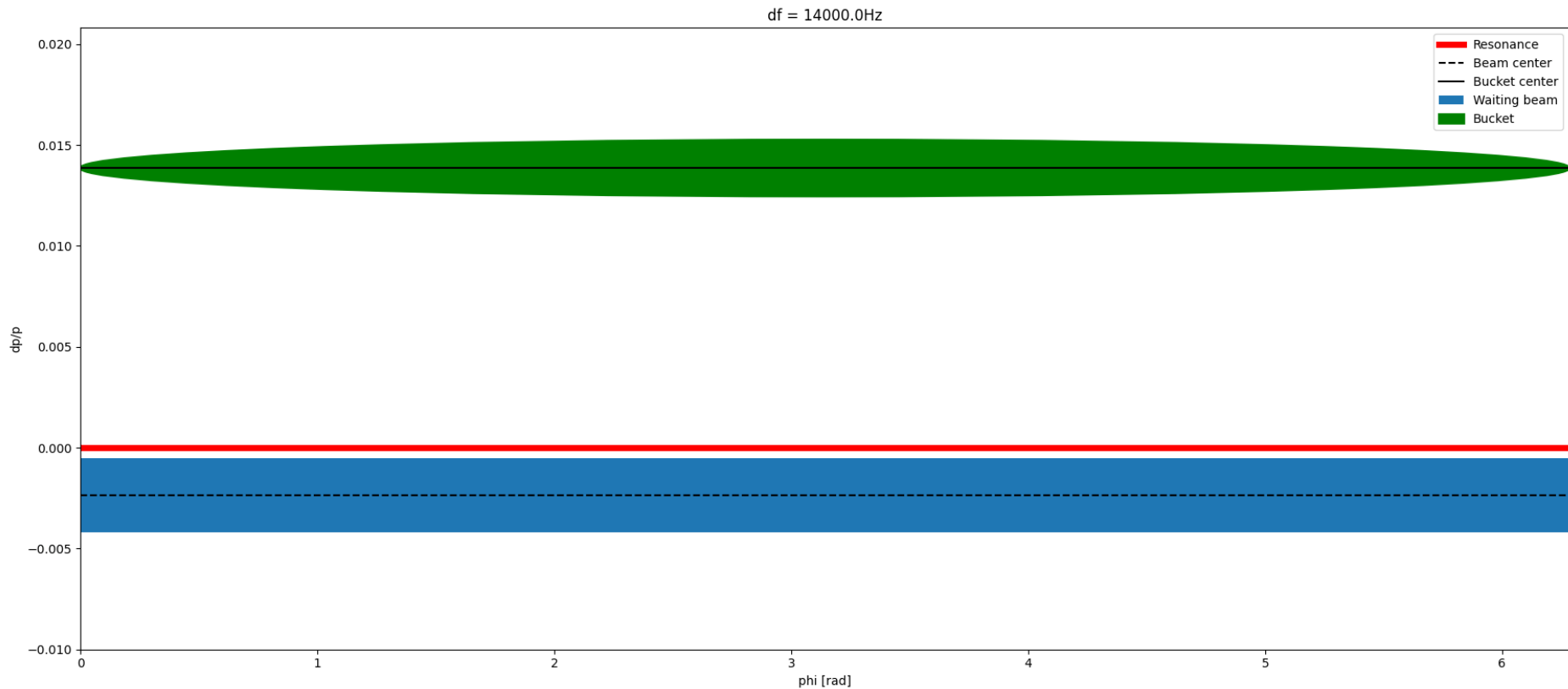
- Resonance is moved into the beam
- Linear ramp of all MR magnets
- Synchronized ramp of radial beam position

- ✓ **Bunched operation**
- ✓ **Multi Energy Extraction**

MULTI ENERGY EXTRACTION WITH COSE



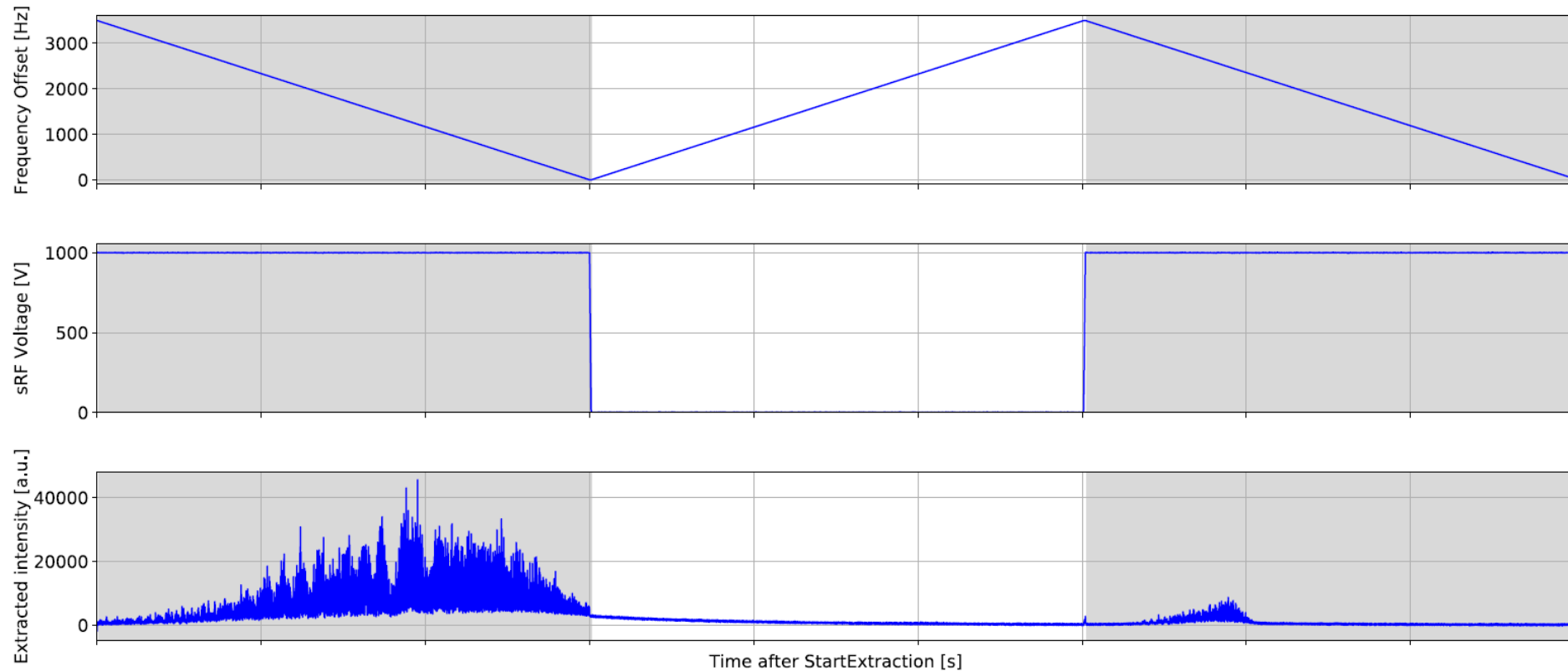
PHASE DISPLACEMENT EXTRACTION (PDE)



- Empty bucket is moved through the waiting beam
- Sweep can be repeated multiple times

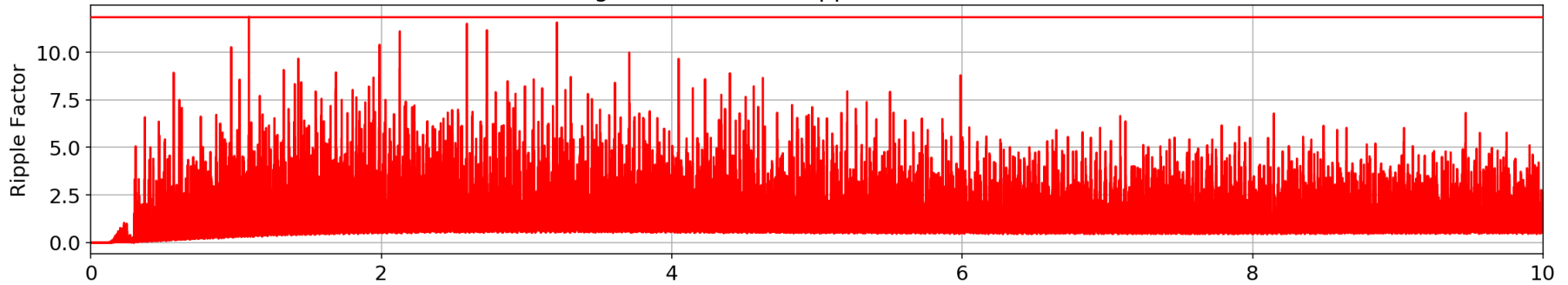
✓ **Fast extraction times**
✓ **FLASH**

PDE MEASUREMENTS

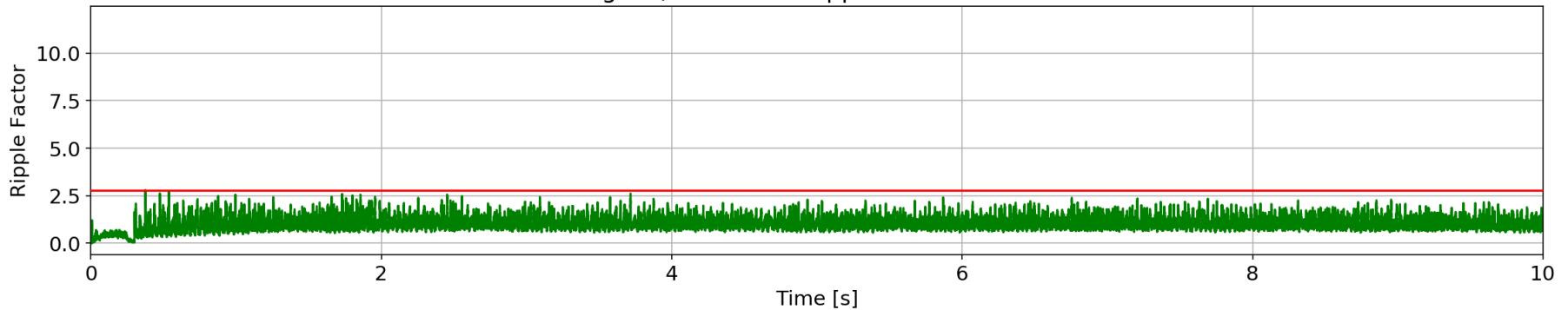


RIPPLE REDUCTION

REFERENCE: C6+, DEG 100, 10s, 402.8MeV, Chan OFF
Original, Maximum Ripple Factor = 11.872



CHANNELLING CANDIDATE: $dF = 3\text{kHz}$, $V = 2.1\text{kV}$
Original, Maximum Ripple Factor = 2.795



Less ripples

Less
intensity
fluctuations

Constant
dose rate

Faster
treatment

SUMMARY

Successful testing of alternative extraction methods (RFKO, COSE and PDE)

Proof of principle: extraction of the circulating beam into the treatment room

Understanding of complex beam dynamics during extraction

Further optimization and ongoing developments needed

	Extraction method		
	RFKO	COSE	PDE
Bunched beam	✓	✓	✗
MEE	✓	✓	✗
FLASH	(✓)	(✓)	✓

SUMMARY



From your perspective, in which direction will this field move in the next 5 years and what are the key questions?

Application of techniques such as FLASH and Multi Energy Extraction and novel extraction methods to improve treatment quality

Going to even faster treatment times by utilising advanced ripple reduction methods



What are potential synergies with other NCR research groups for filling these gaps?

Expansion of alternative extraction methods to other particle species (e.g. RFKO with helium ions)

Development of new detector systems and testing setups for advanced extraction techniques

THANK YOU



RFKO Team:



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Laurids Adler



Felix Feichtinger



Lorenz Fischl



Greta Guidoboni



Katrin Holzfeind



Clemens Maderböck



Thomas Margreiter



Mauro Pivi



Elisabeth Renner



Valeria Rizzoglio



Claus Schmitzer



Ivan Strasik



Michael Benedikt



Rebecca Taylor



Pablo Arrutio



Matthew Fraser

THANK YOU FOR YOUR ATTENTION!

