A new approach to longitudinal Schottky characterization

Simon Hirlaender

MSWG meeting #15

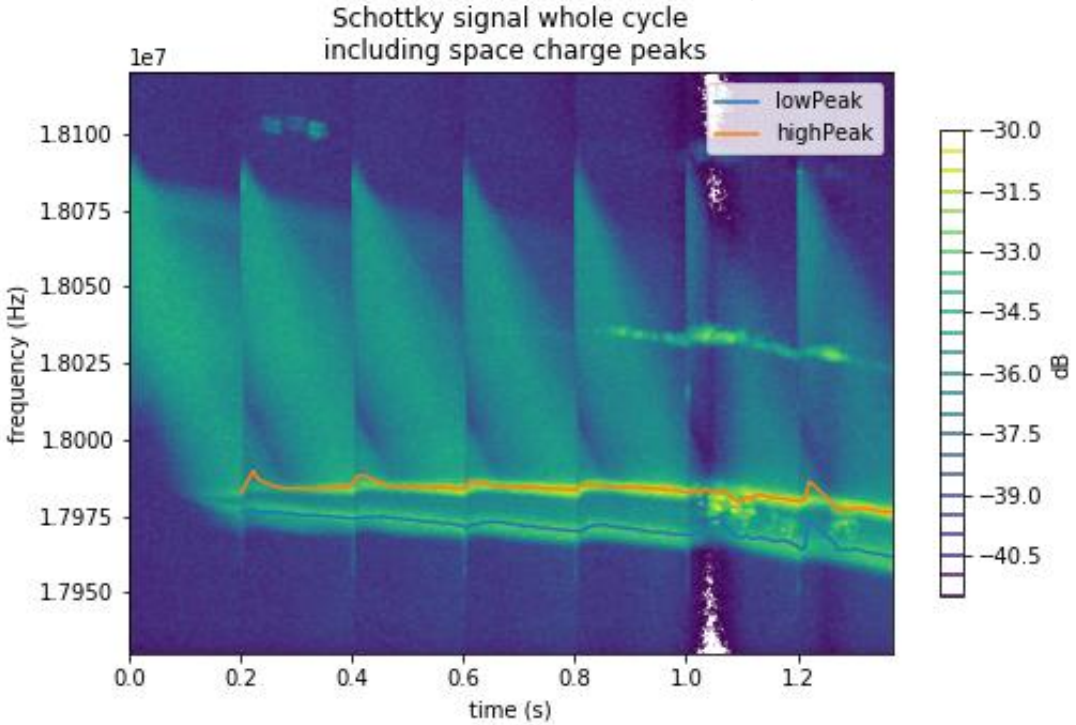
Acknowledgements to all contributors:
H. Bartosik, G. Bellodi, N. Biancacci, F.Caspers, A. Huschauer, V. Kain, R. Scrivens, M. Wendt.

Why? What you can expect?

- Overview of achievements
- Short intro into challenges of the Schottky analysis
- Short description of new strategy
- Two new applications:
    1. Multiple injection LEIR-Nominal
    2. Cooling LEIR-Early
- Conclusion - outlook

Overview: Longitudinal Schottky acquisition advances -LEIR:

Related to momentum of particles:



→ Injection efficiency:
- Cooling efficiency/time
- Dragging
- Scraping mechanism

→ LINAC3:
- Initial beam characterization
- Influence of specific parameters as: RampingCavity/DeBunching – phases, amplitudes…

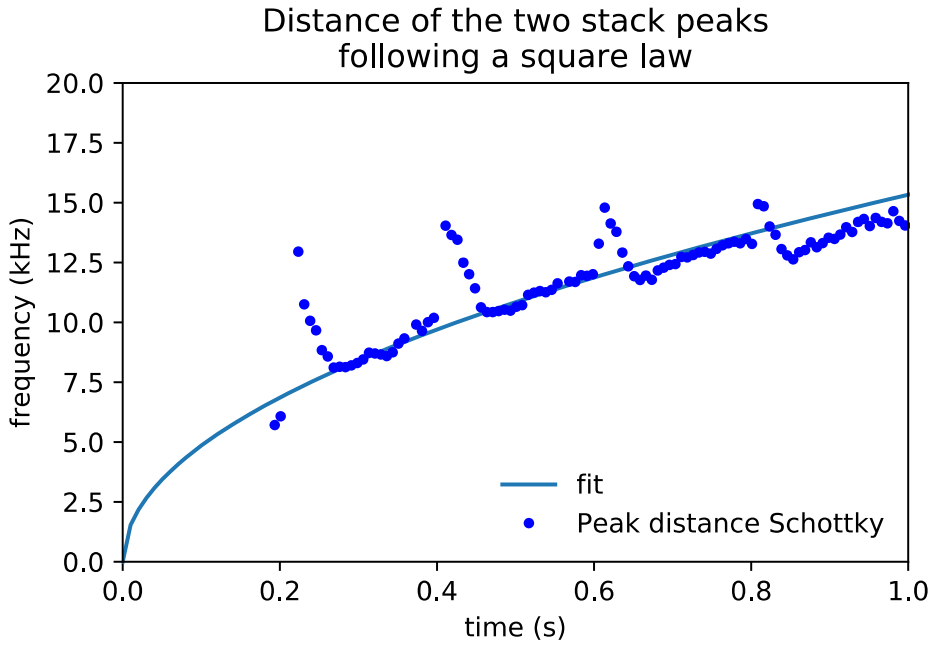
→ Space charge:
- Double peak effect (left plot)

- Improvement of signal quality and resolution.
- Improvement of analysis quality by a new ansatz and techniques.
- Improvement of software (Iphyton – open source) to analyze the data directly- run parameter scans

Main Problem:

Fundamental properties of Schottky spectrum

- The Schottky signal is usually given in the absolute value of the Fourier coefficients of the FFT in decibel or linear.
- The parameters one looks at should be invariant under the nonlinear transformation
- The intensity is not invariant under these transformations
  - meaning even the the mean is distorted!
  - nevertheless the trend is evident
- Only peak detection makes sense…. e.g. (new) double peak detection! – right plot



The proposed cure:

Fundamental properties of Schottky spectrum

- We try to add the dimension of the intensity to analysis
- This has several advantages e.g.:
  - Spectrum can be interpreted as PDF
    statistics is correct
  - Particle population within specific momentum range
  - Identify beam losses within energy range
  - Leveling to compare different signals

Key ingredient:
Paseval's Theorem

- The power P_m of one acquisition period is proportional to the sum of the square of the absolute values of the Fourier coefficients c_k:

$$P_m \propto \sum_k^N |c_k|^2$$

- The current *I* is proportional to the power and hence to

$$I \propto P_m \propto \sum_k^N |c_k|^2$$

- The area of the Schottky spectrum A_{spec} can be made proportional to the intensity by regarding $|c_k|^2$:

$$A_{spec} \propto \sum_k^N |c_k|^2$$

Remaining challenges:

- Signal is pre-filtered to avoid overlap of sidebands…
- Attenuation transforms amplitudes
- Threshold cuts off amplitudes

- frequency window

- only small ranges

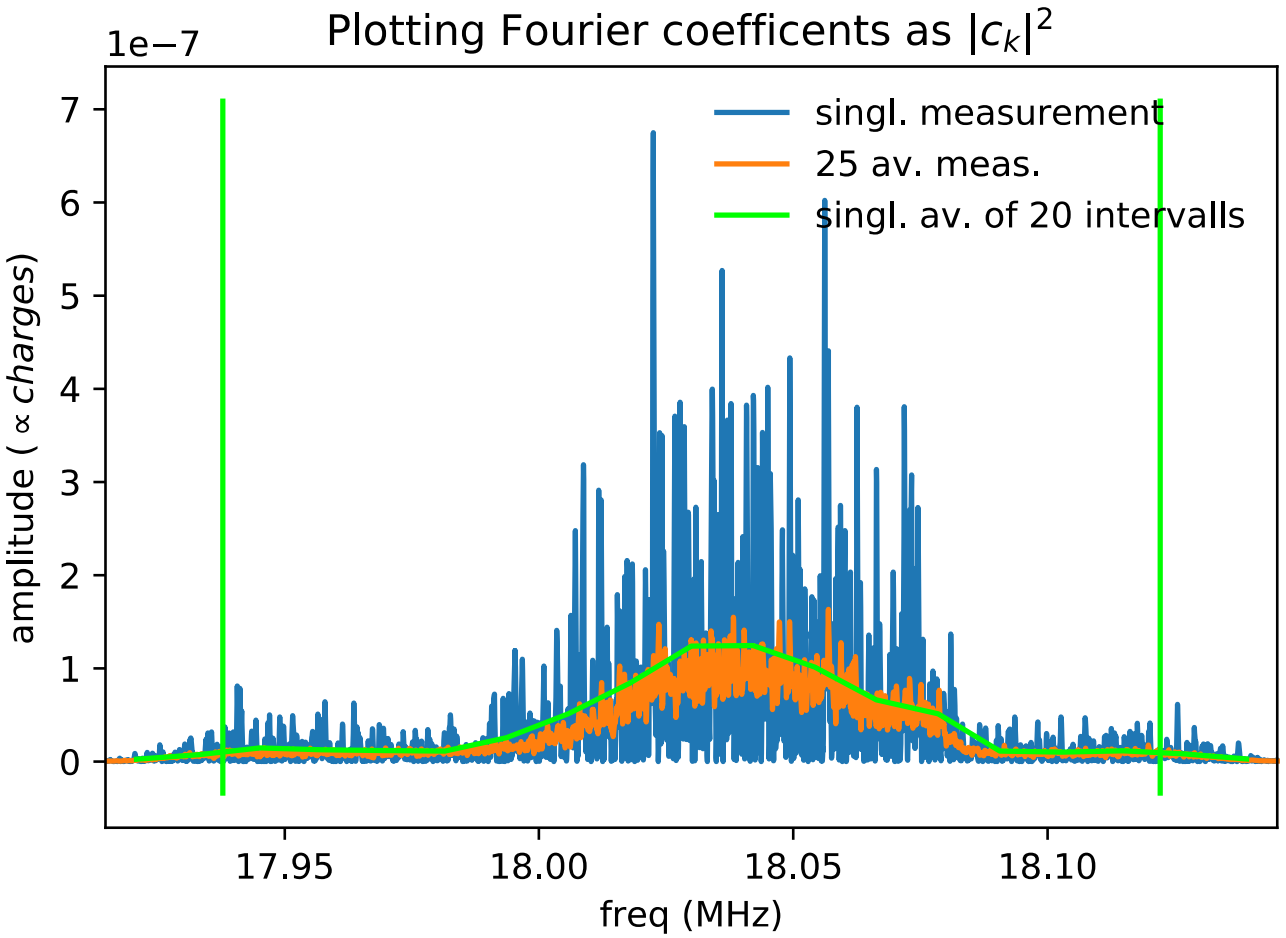
- shift taken into account

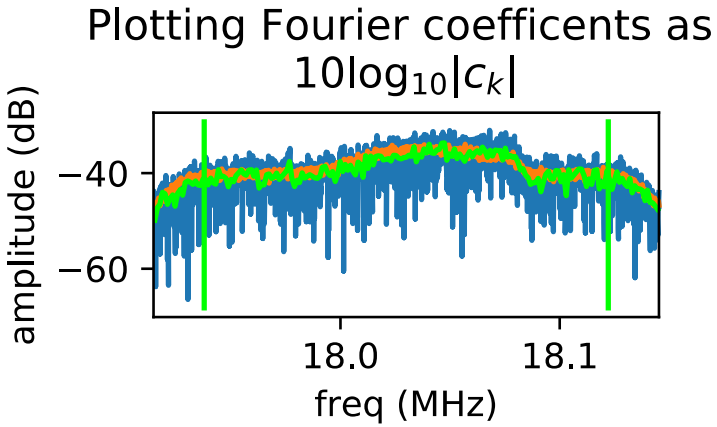
And to be operational…:

- Fast acquisition -> Single measurement
- Fast algorithms -> Simple - no over-engineering

New Analysis:

Change coefficients and use Interval averaging vs. multiple independent measurements

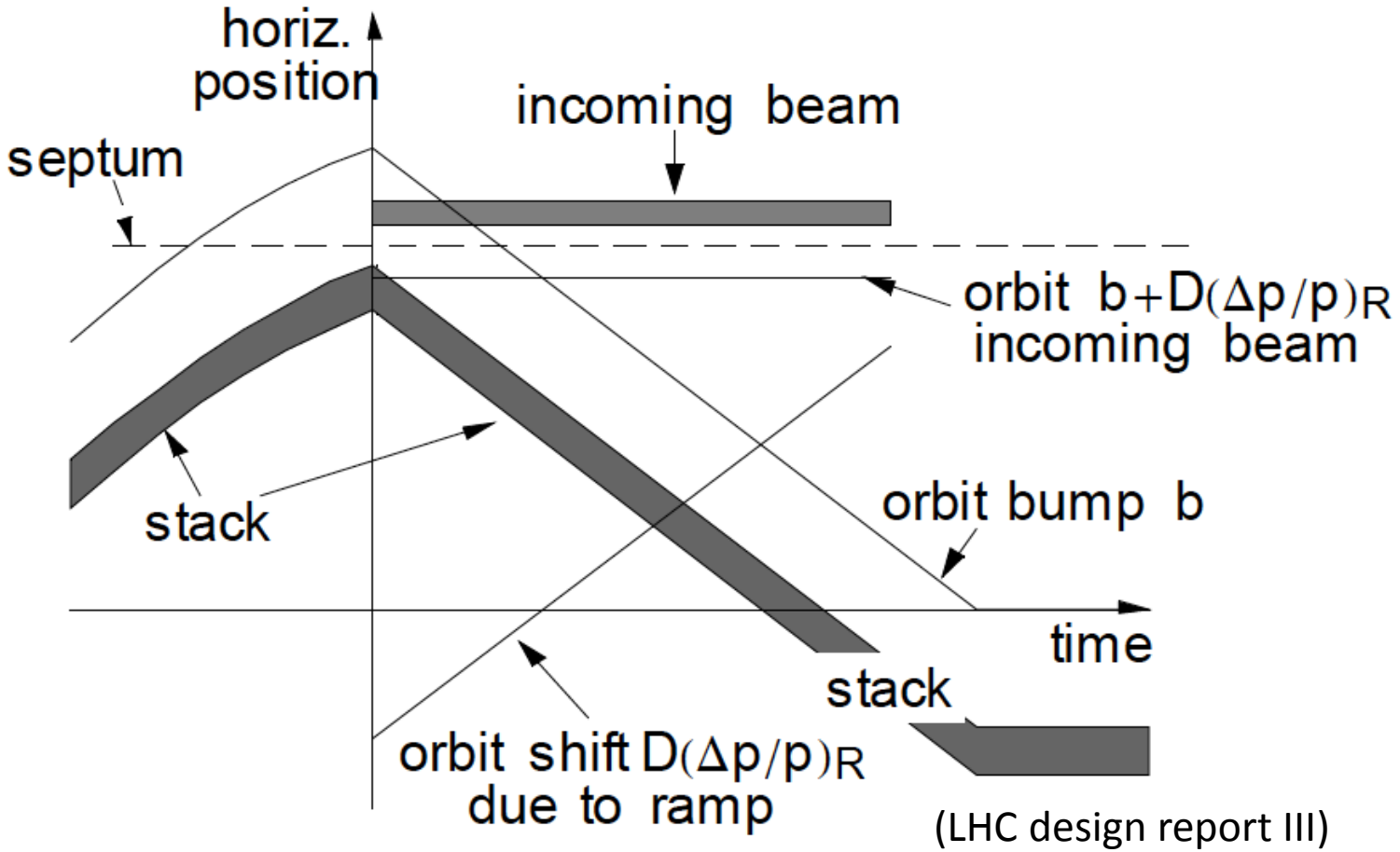




- Fast analysis
- No offset problem
- Good quality even from single measurements
- Detection of data with statistical method

A first application:

Multi turn injection in LEIR - short primer



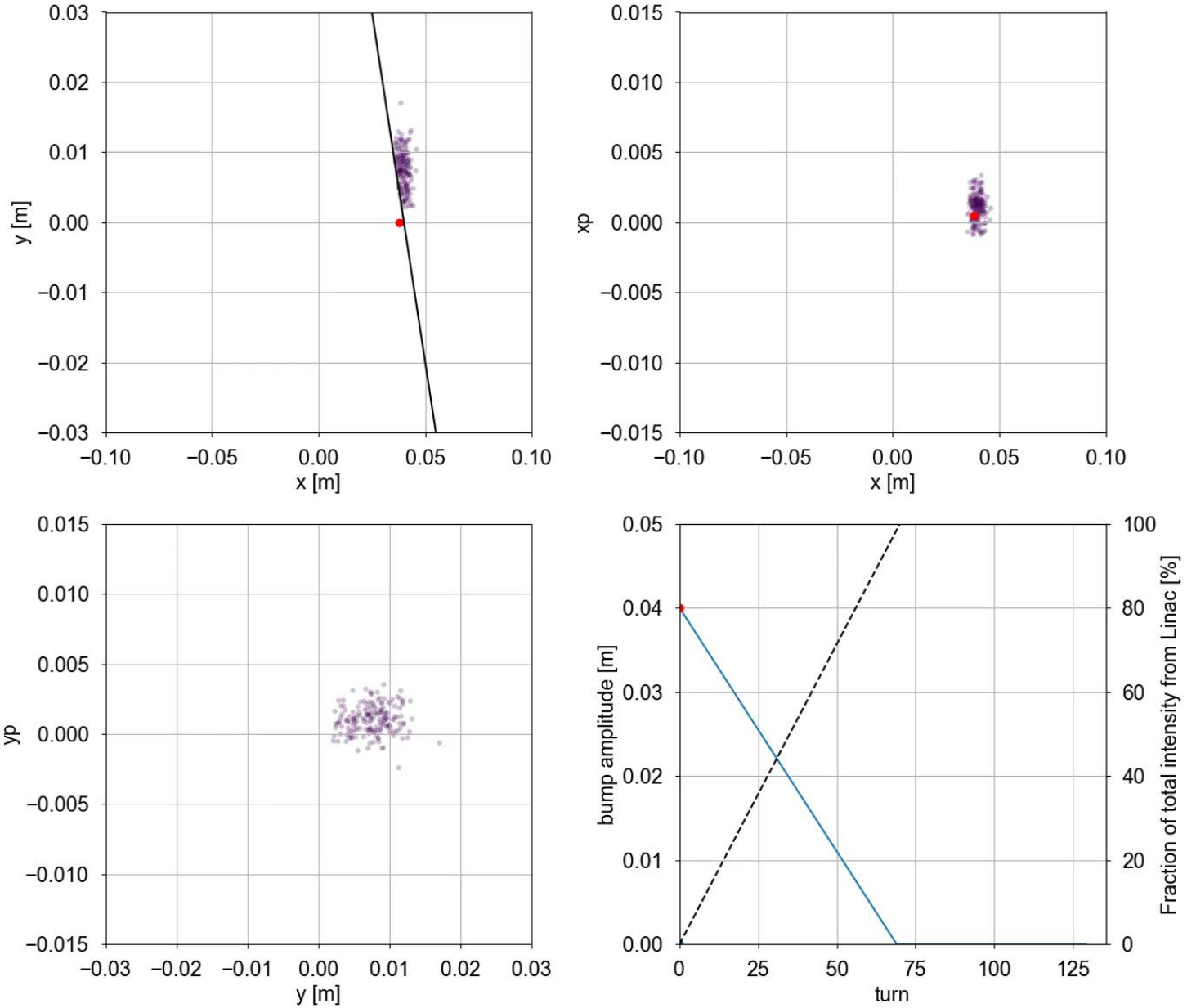
(LHC design report III)

- 7 pulses-each 200us from LINAC3/70 turns
- Extension of the conventional multi turn injection
- Additionally the momentum is ramped during pulse
- Advantage: small transverse emittance – high injection efficiency

A first application:

Multi turn injection in LEIR - short primer

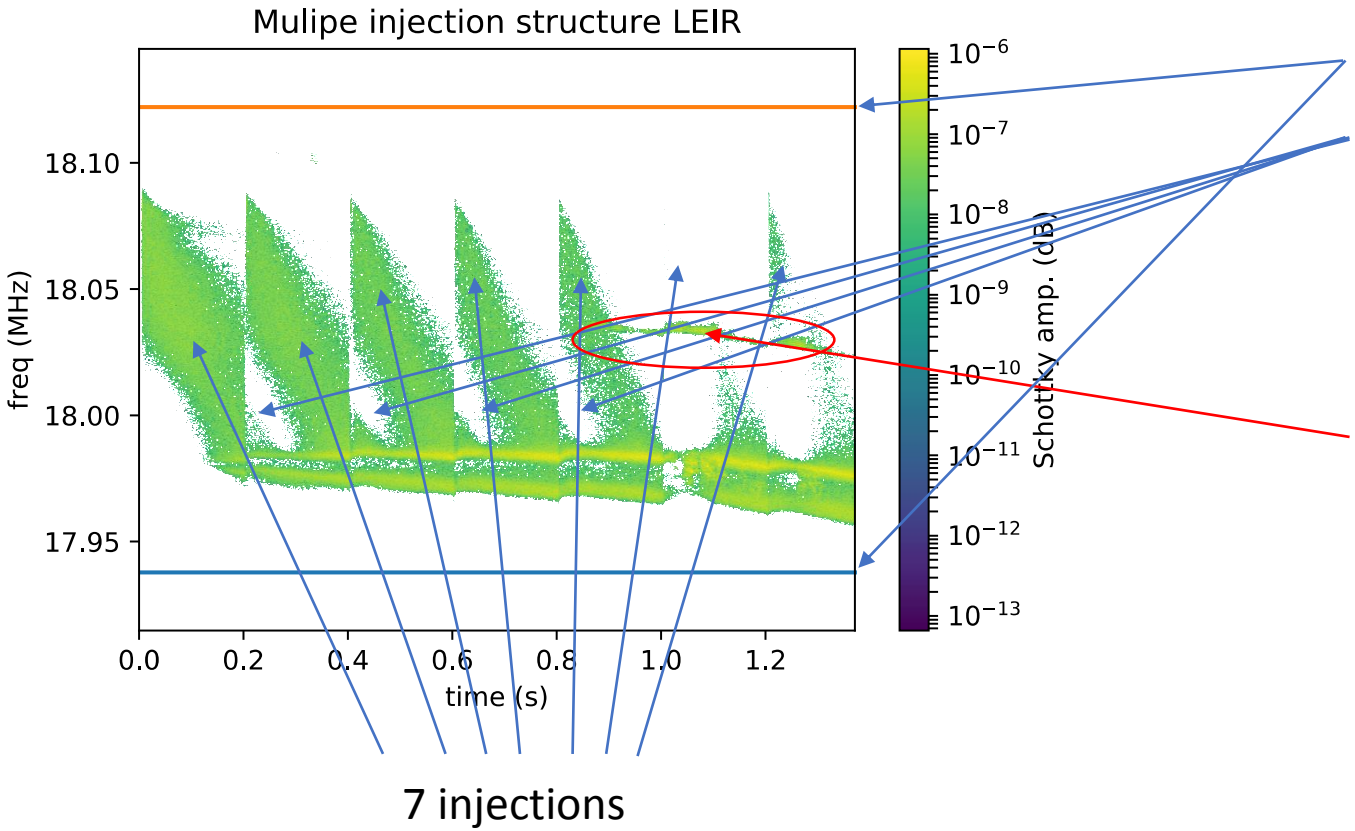
Large momentum spread
Cooling afterwards
shrinks momentum



(by Bartosik H.)

A first application:

Beam scraping and injection quality on the multiple injection process in LEIR



- Frequency window
- Scraping (white area below new injections)
- Injections not the same
- Instabilities distort results
- BCT comparison

A first application:

Beam scraping and injection quality on the multiple injection process in LEIR

From Schottky:

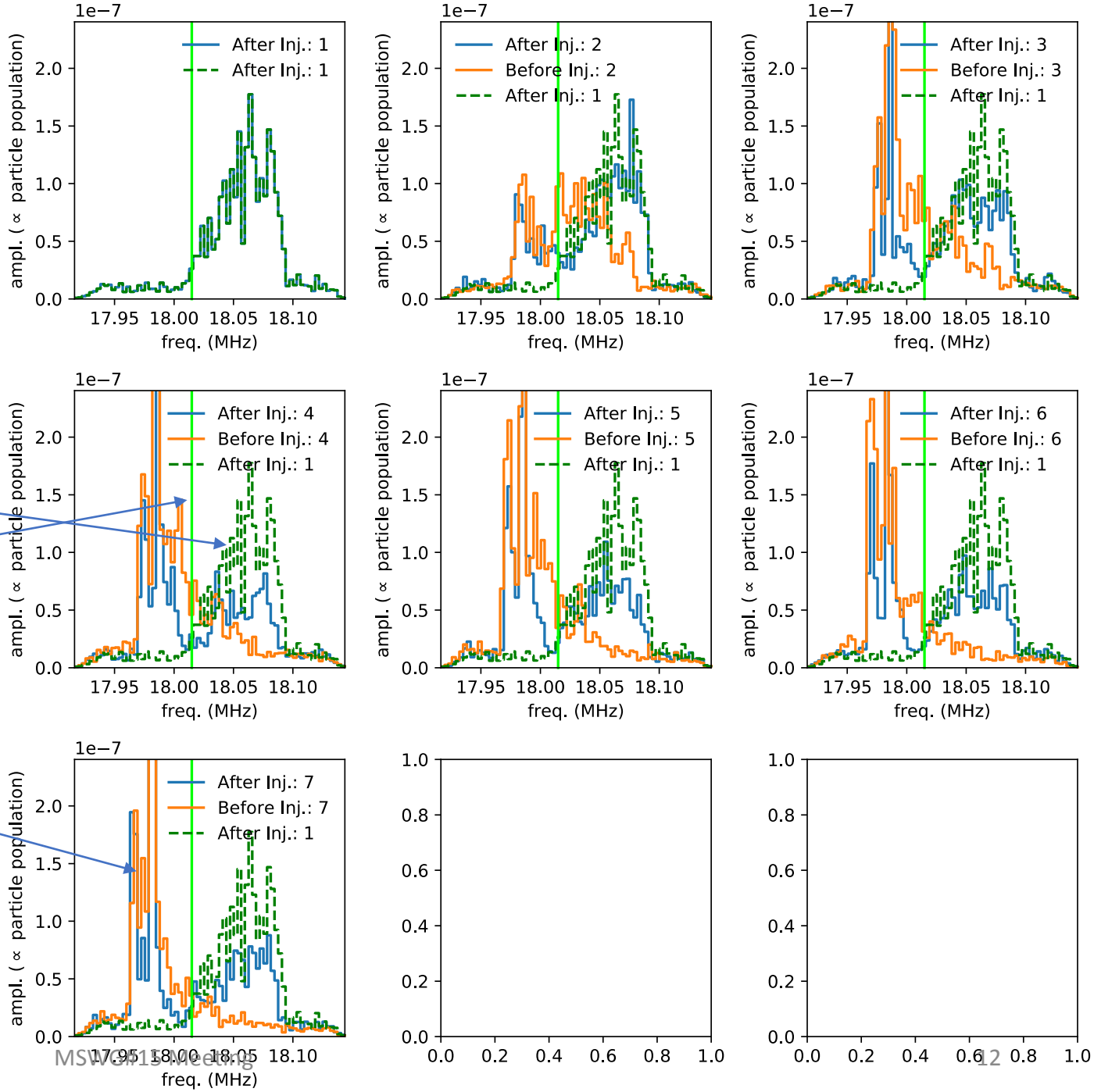
Taken shortly before (orange) after injection (blue).

Reference 1. injection (green dashed)

Shaded area is acceptance area estimation, boundary: green line

All in the shaded area is scraped off during injection process.

Left of shaded area: stacked beam -> peaks are transformed nonlinear…

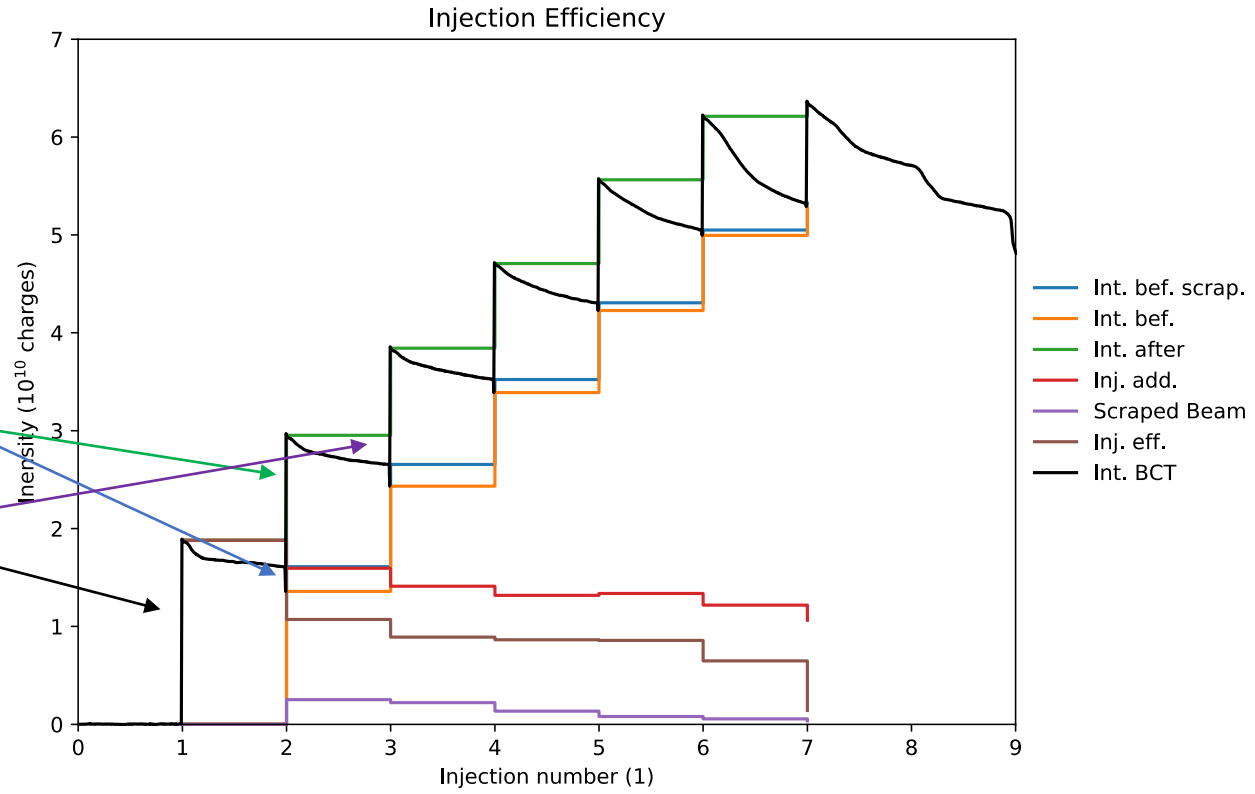


First application:

Beam scraping and injection quality on the multiple injection process in LEIR
From BCT: true intensities for multi injection

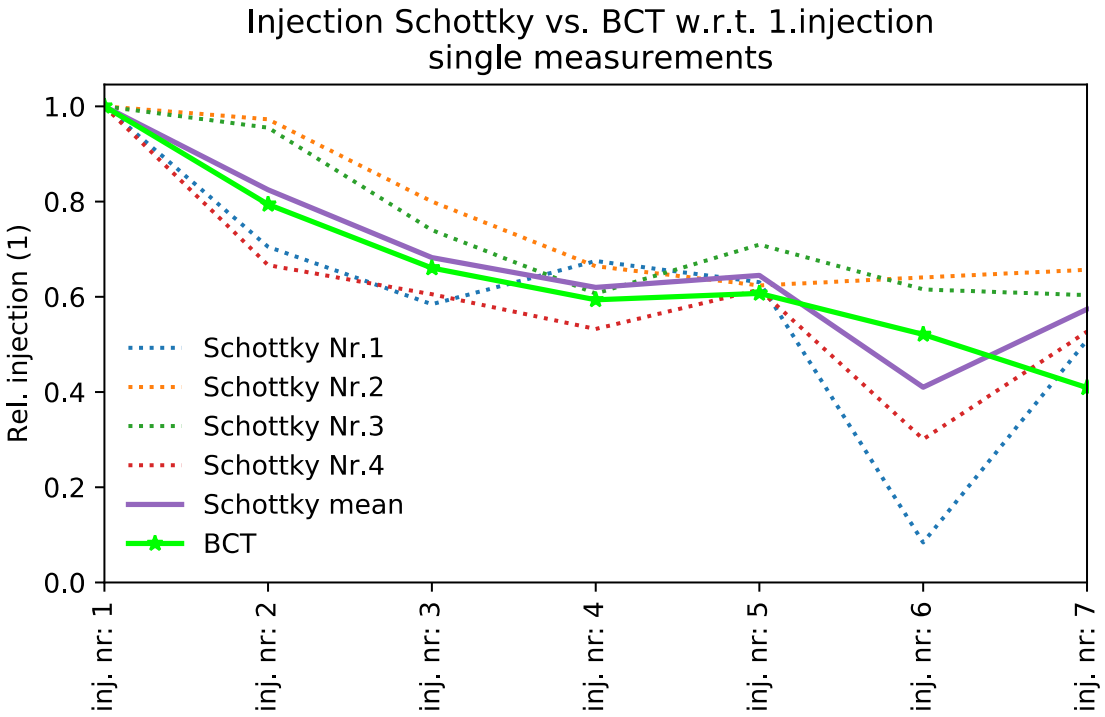
BCT-Intensity contains:

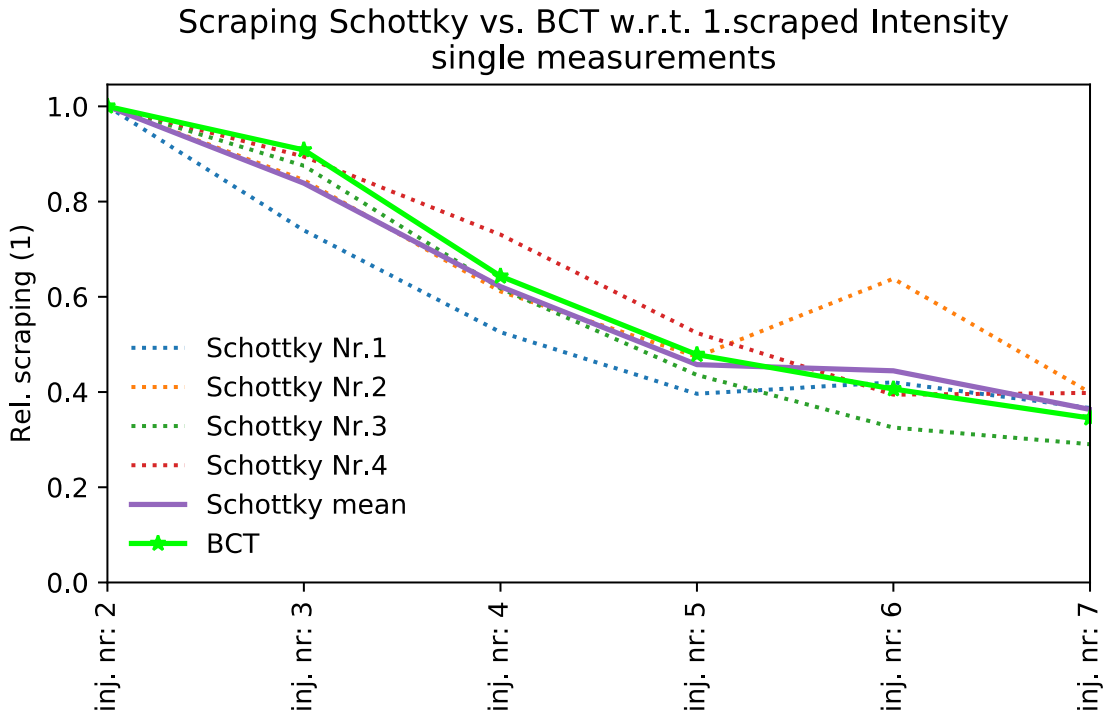
- Scraped beam
- Stacked beam
- Injected beam
- Other losses



Comparison of new method with BCT

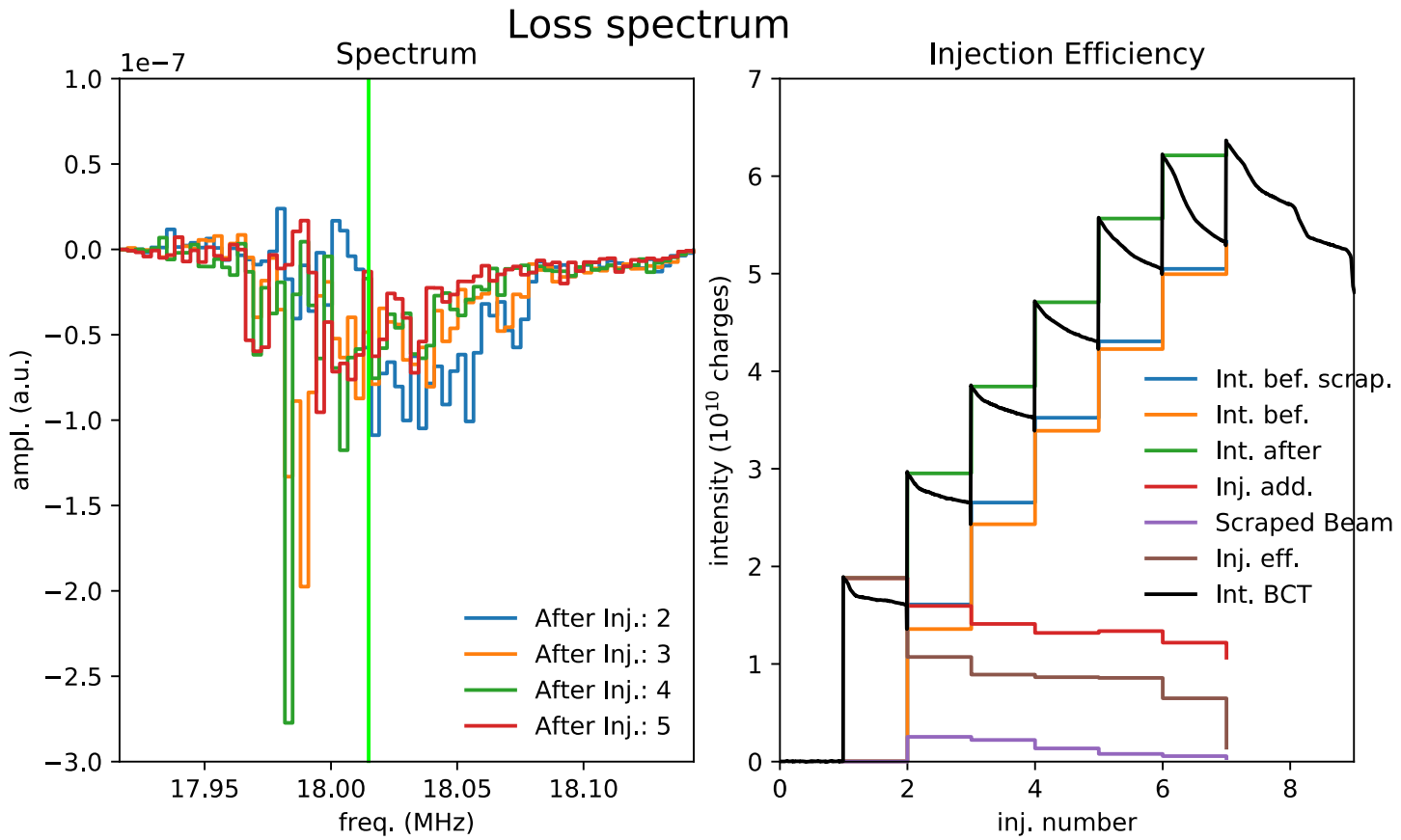
shot to shot variations from LINAC3-good agreement





Defining a Loss spectrum

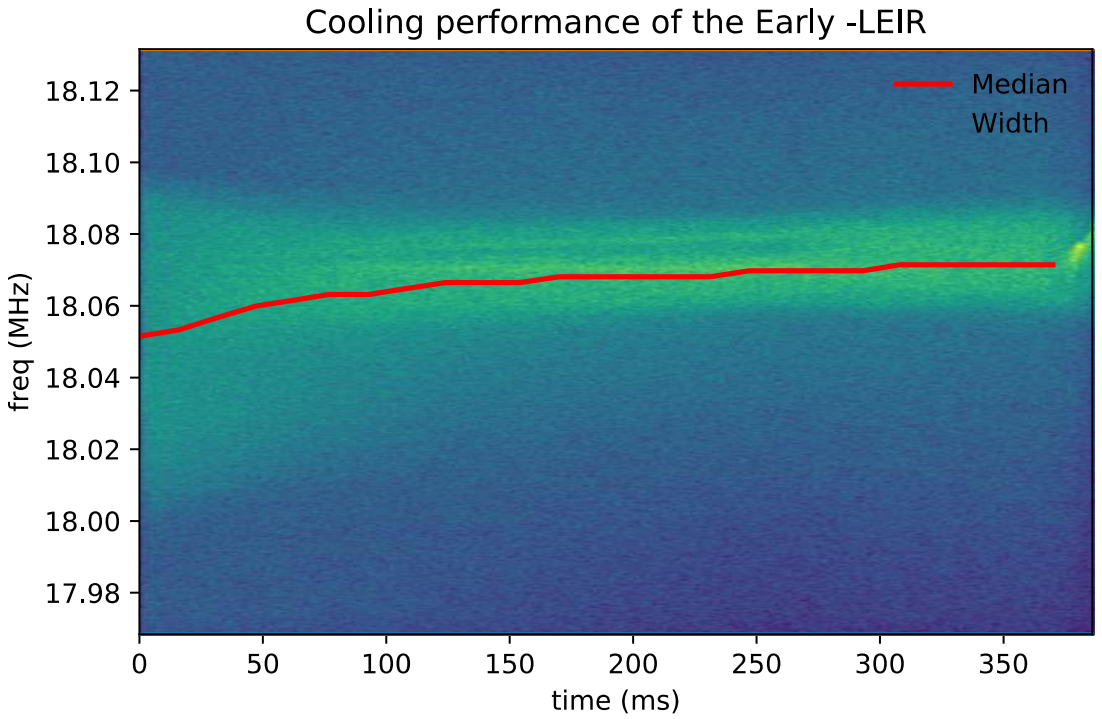
Monitor losses in specific energy ranges

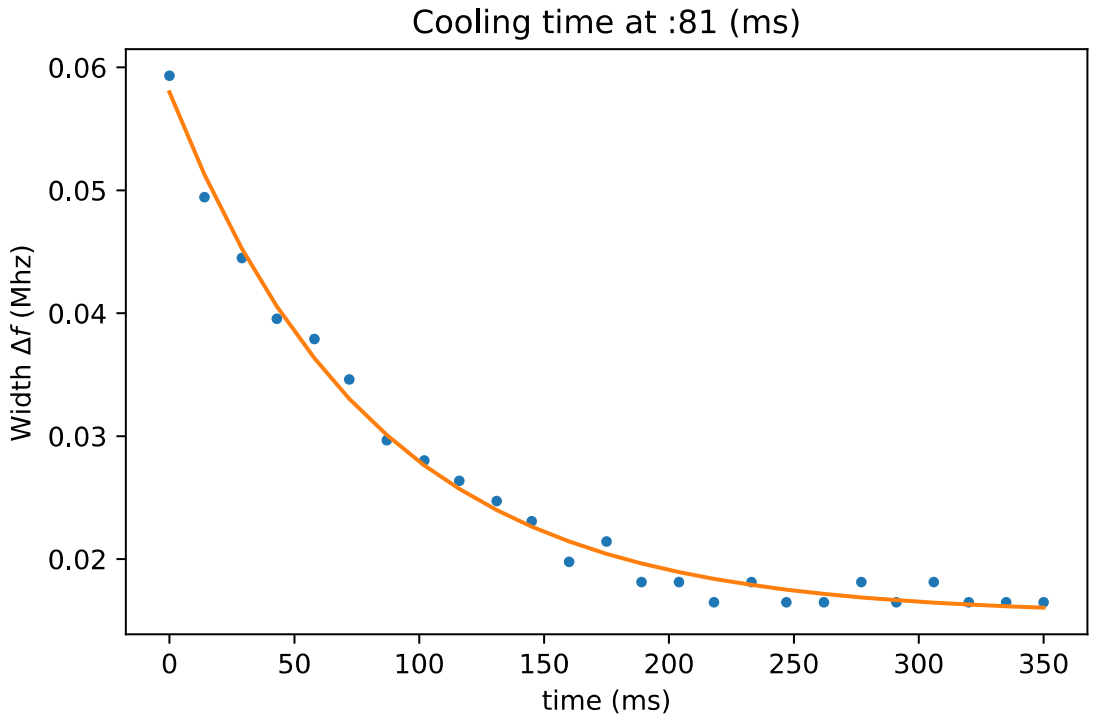


- Spectrum in shaded area area is proportional to Intensity!
- Additional information which energy is lost
- Left of shaded area shows changes of spectrum within timespan of acquisitions

Second application: Cooling performance

LEIR –Early single acquisition, median, 60% of particles in defined width, accurate even with fewer points down to ~ 10 (fast)





Conclusion

- New single acquisition characterization possible
- Change of coefficients show expected behavior
- Spectral analysis of multiple injection possible
- Cooling time estimates can be obtained from single shot
- Looking forward to many new possible applications…