Beam Diagnostics for the Multi-Turn ERL Operation at the S-DALINAC*

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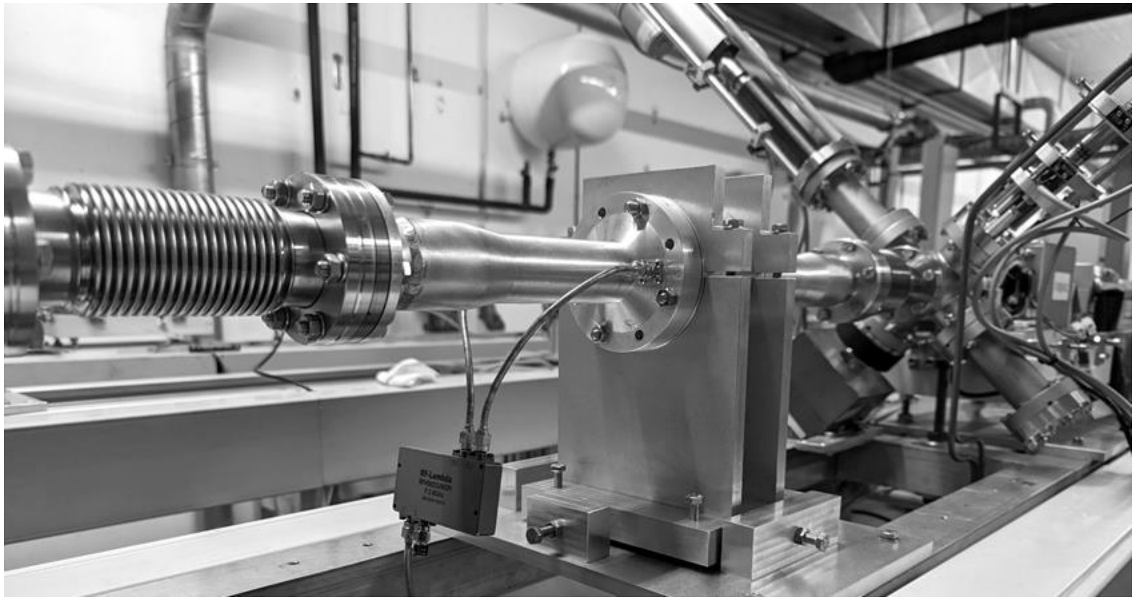
M. Dutine, M. Arnold, A. Brauch, R. Grewe, L. Jürgensen, N. Pietralla, F. Schliessmann, D. Schneider



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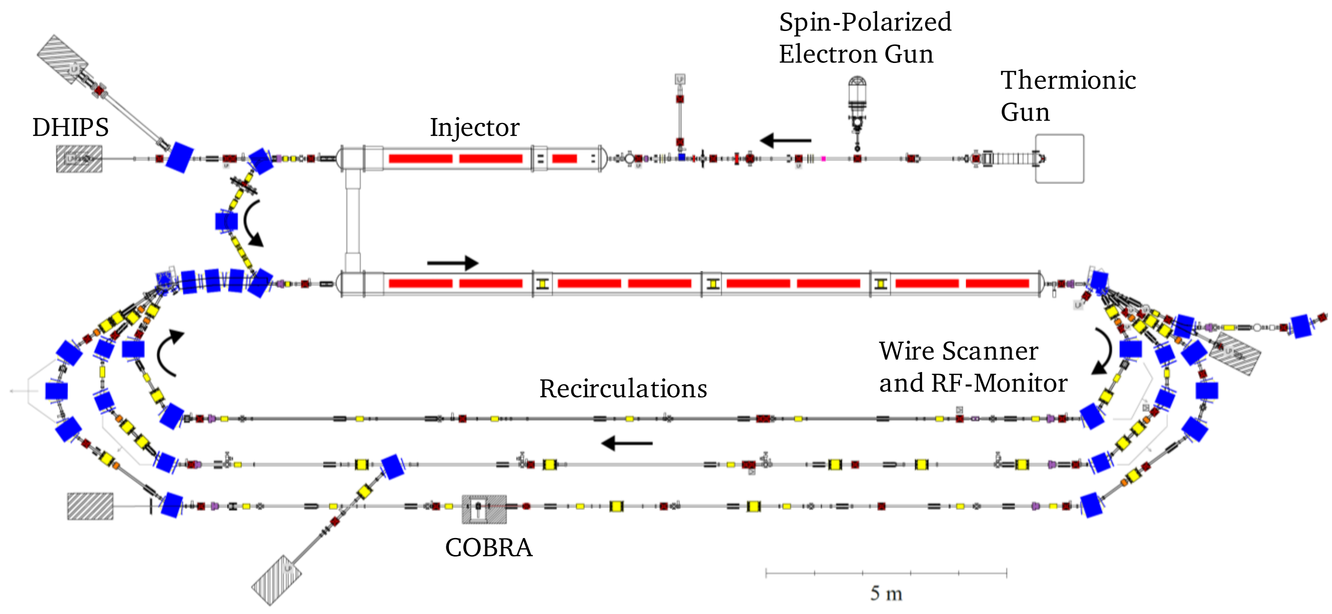
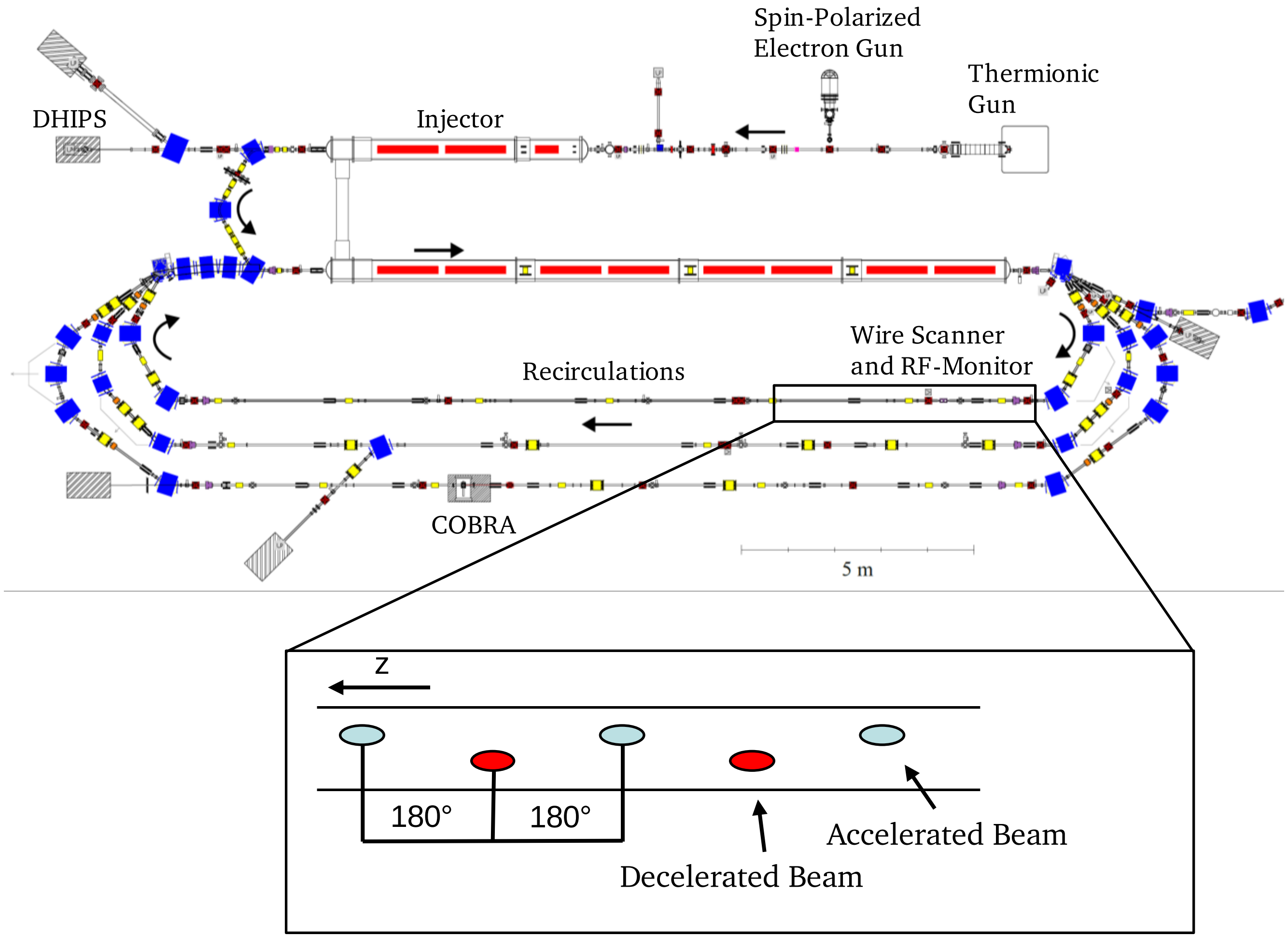
*Work supported by DFG (GRK 2128), BMBF (05H21RDRB1), the State of Hesse within the Research Cluster ELEMENTS (Project ID 500/10.006) and the LOEWE Research Group Nuclear Photonics.

Motivation


Spin-Polarized
Electron Gun
Thermionic
Gun
DHIPS
Injector
Recirculations
Wire Scanner
and RF-Monitor
COBRA
5 m

Motivation


Spin-Polarized
Electron Gun
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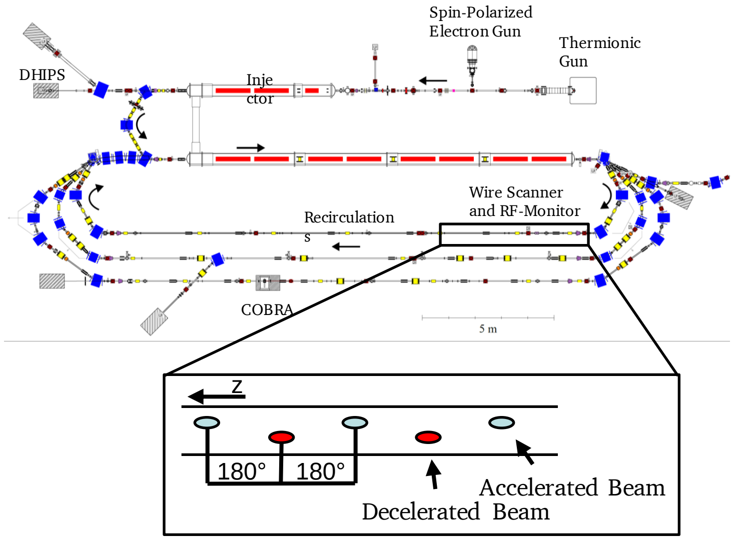
Recirculations
Wire Scanner
and RF-Monitor
COBRA
5 m
z
180°
180°
Accelerated Beam
Decelerated Beam

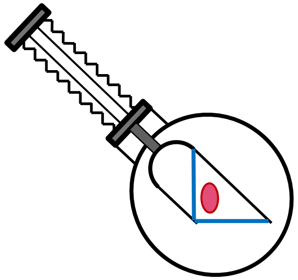
Motivation



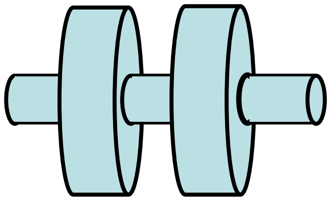
Requirements for a new position measurement

- Simultaneous measurement of both beams
- Non-destructive
- Can be used during beam tuning
  (100 nA ≙ 30 aC)

Wire Scanner Measurement

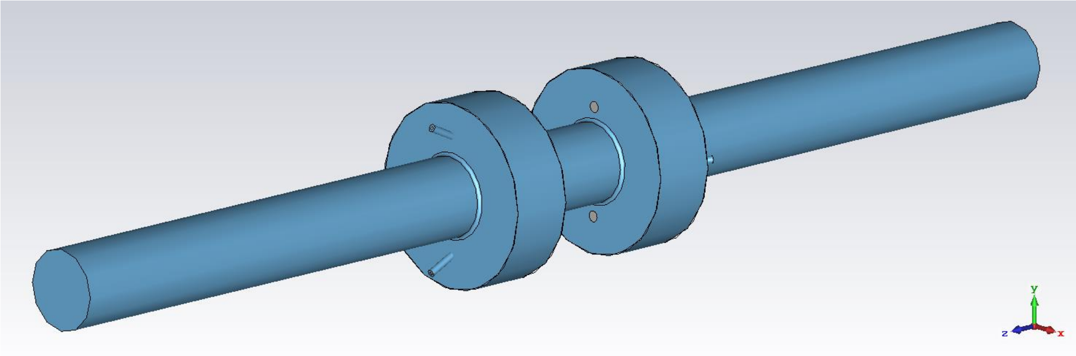


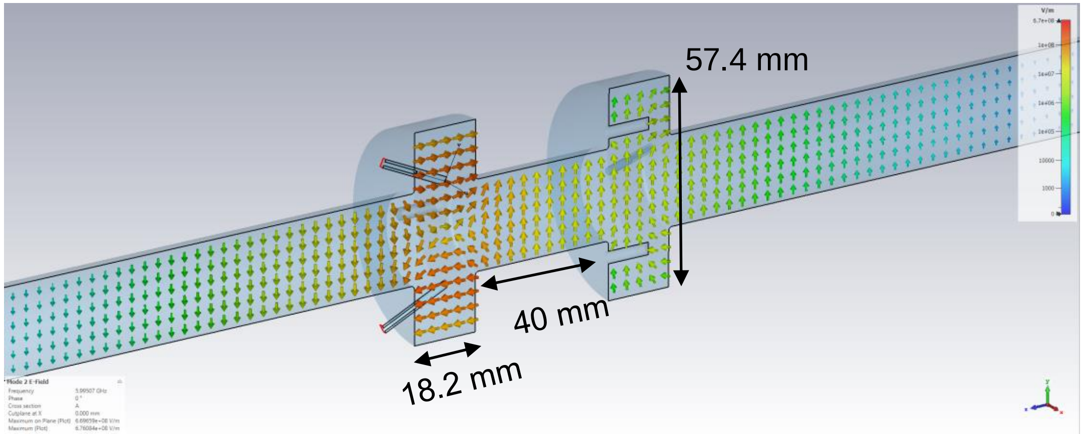
6 GHz RF-Monitor



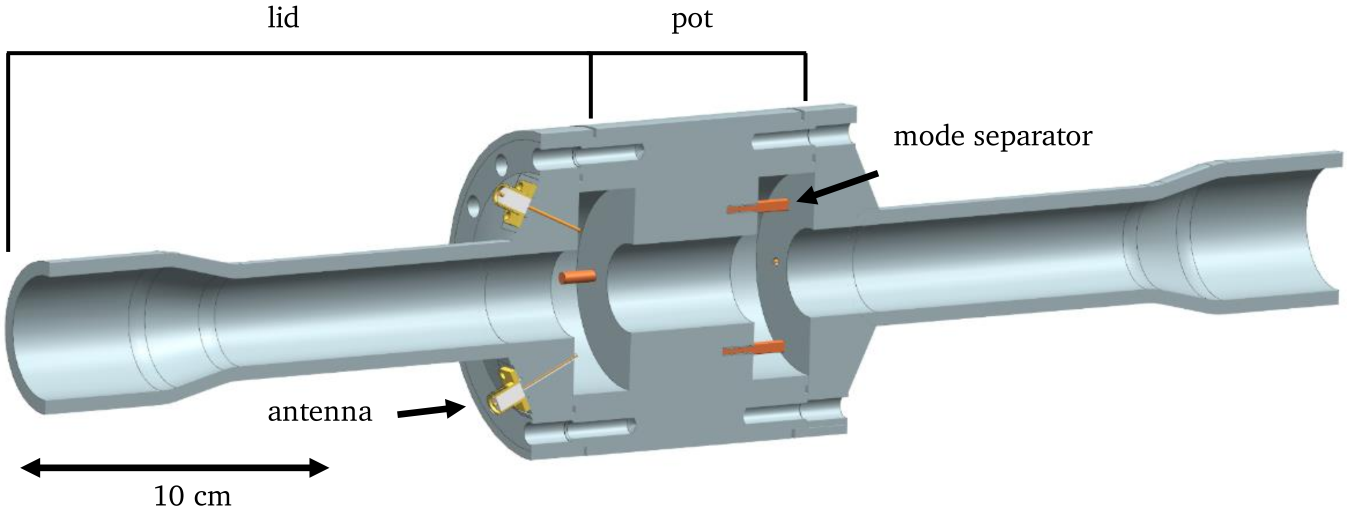
Design of the RF-Monitor

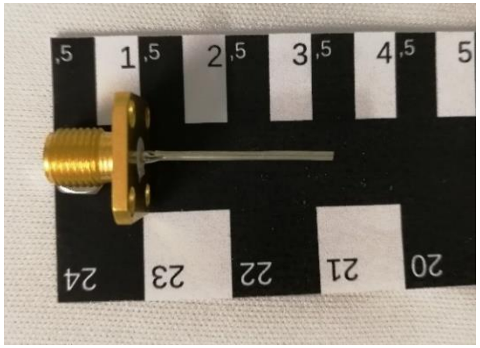
- In a cavity BPM: TM110 is excited → linearly dependent on beam current and transverse beam offset
- Design with dedicated cell for x and y measurement
- Excitation orientation by mode separators
- Outcoupling through capacitive antennas
- Material: Aluminum
- Determination of geometric parameters by simulation (CST)





Construction of the RF-Monitor





Conception of the Wire Scanner

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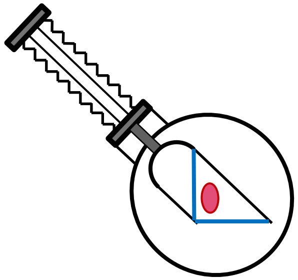
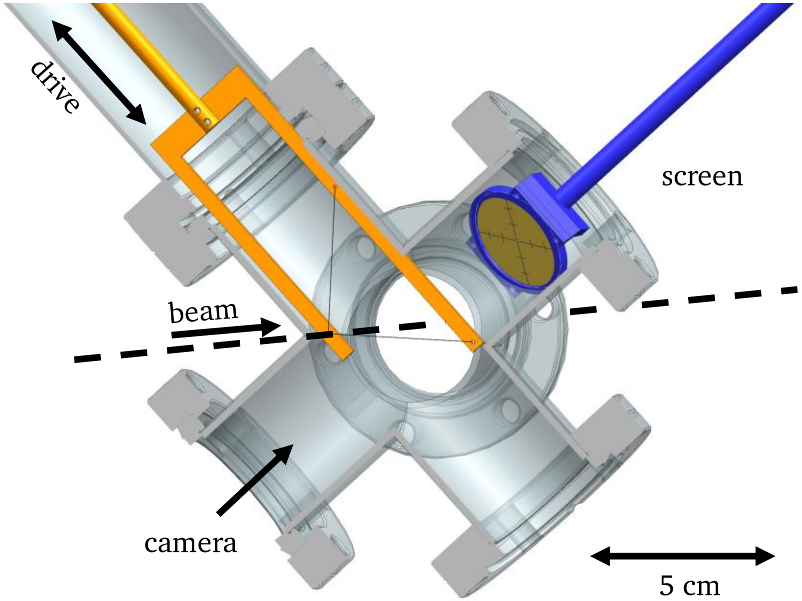
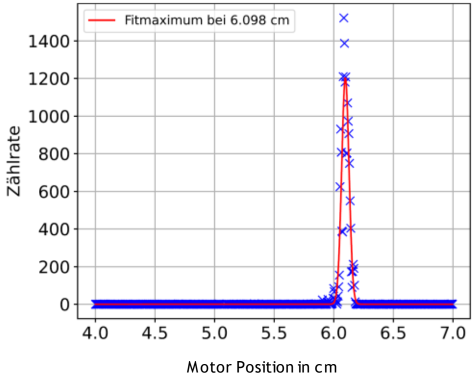
Wire Scanner Measurement

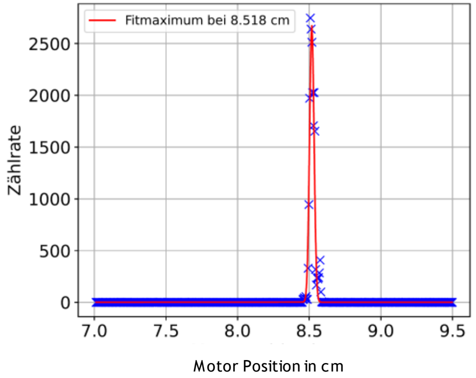


Conception of the Wire Scanner

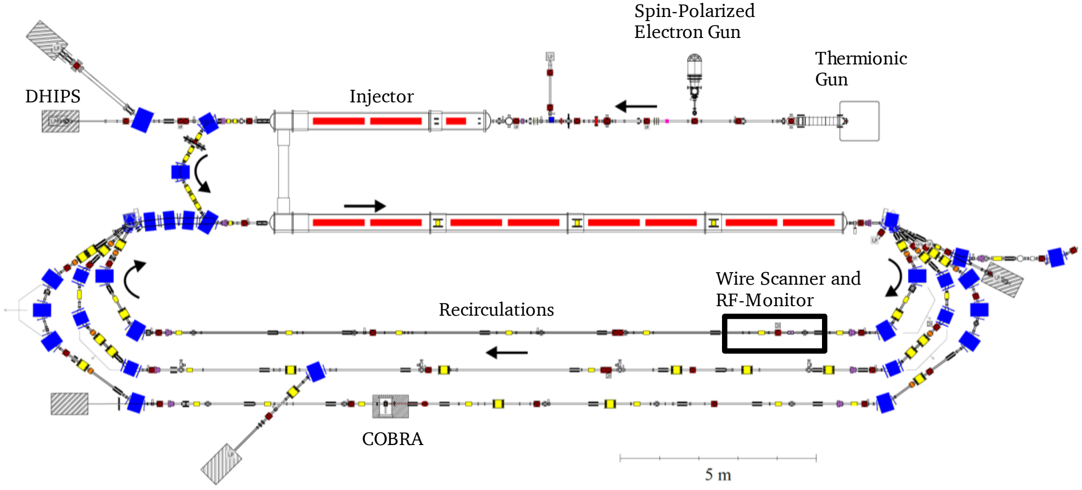
- Two wires (100 µm) are driven through the beam
- Count rate of secondary particles is measured by beam loss detectors (proportional to beam intensity)
- Knowledge of the wire position (through calibration using a fluorescent screen) allows conclusions to be drawn about the beam position and shape

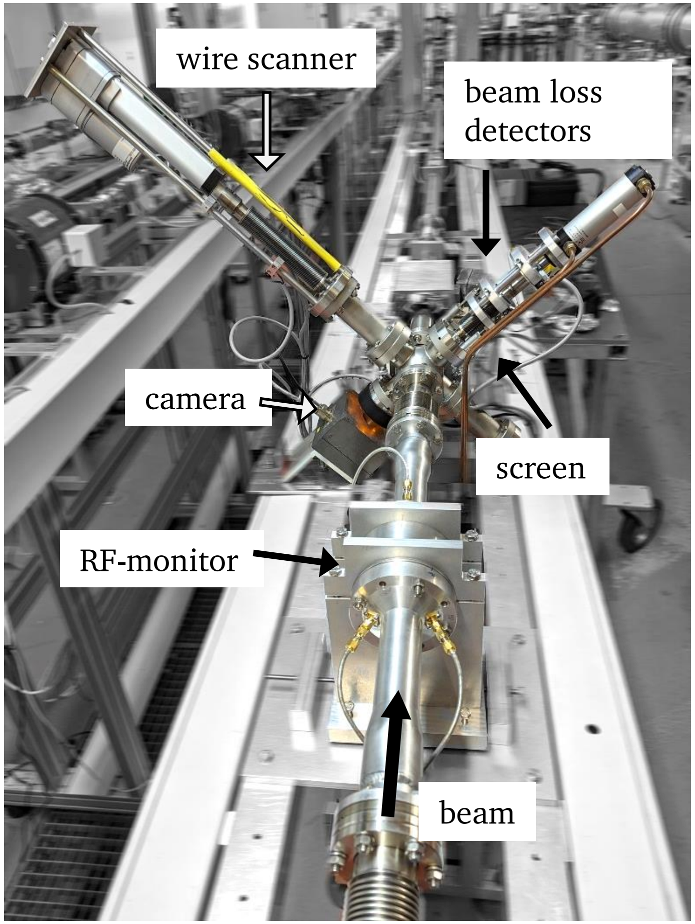






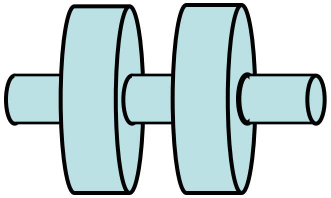
Experimental Setup



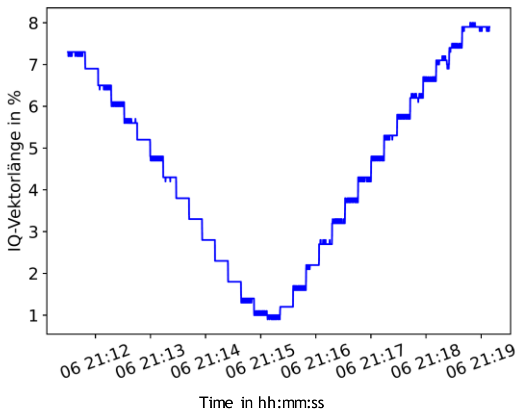


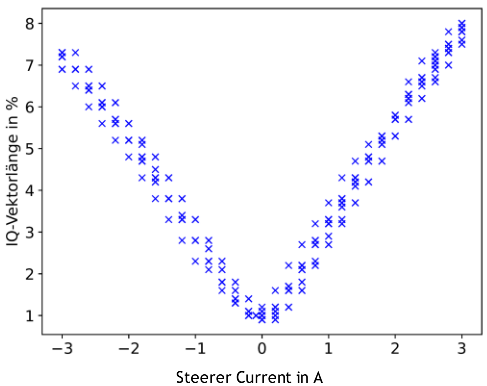
6 GHz RF-Monitor
Measurement Method

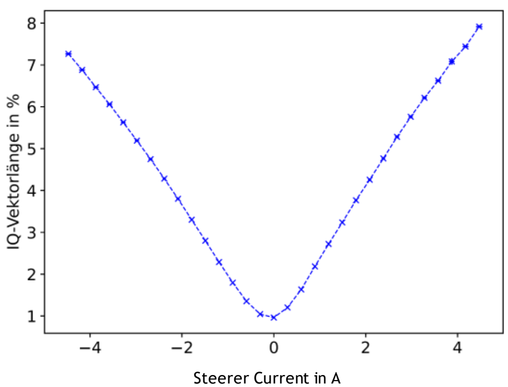
6 GHz RF-Monitor



6 GHz RF-Monitor
Measurement Method







- Steerer sweep
  → 10 sec per step, ca. 10 data points per sec
- IQ-Vector length als measure for excitation

- Sort data by steerer current

- Each data point determined by mean
- Uncertainty determined by standard deviation
- Calculating position by calibration

6 GHz RF-Monitor
Single Beam Measurement

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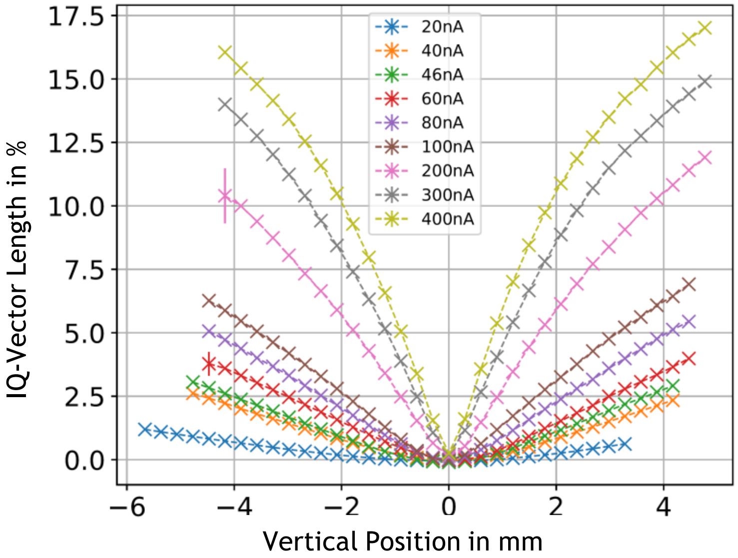
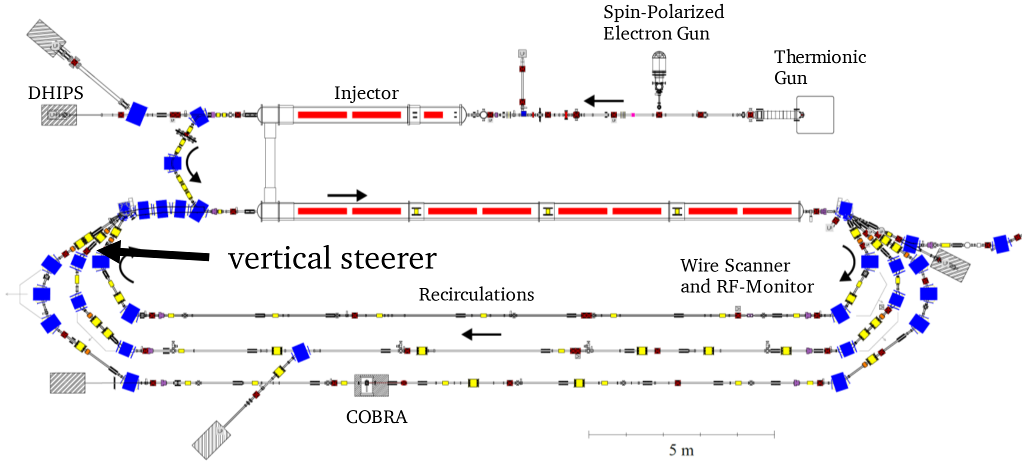
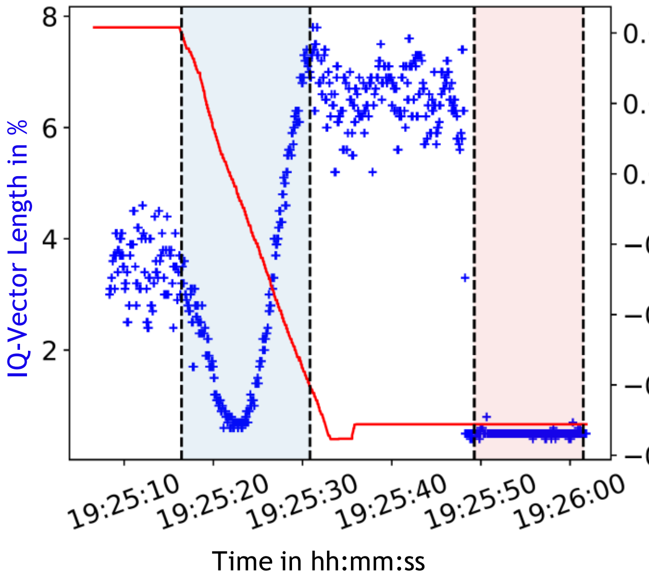


Measurement principle of the ERL-Measurement

- Measurement of once accelerated beam
- Measurement of both beams
- Determine position of once decelerated (ERL) beam from both

6 GHz RF-Monitor
ERL-Measurement

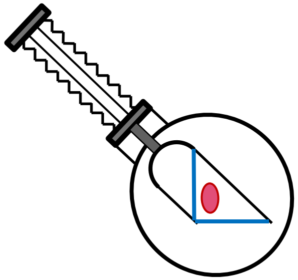




- Only one usable measurement during commissioning (due to low beam quality)
- Steerer in second recirculation used for change in vertical position
- Correlation between monitor signal and steerer current clearly visible
- Once accelerated beam at $y = (-0.70 \pm 0.04)$ mm
- No position determination of ERL-beam possible (due to missing current information)

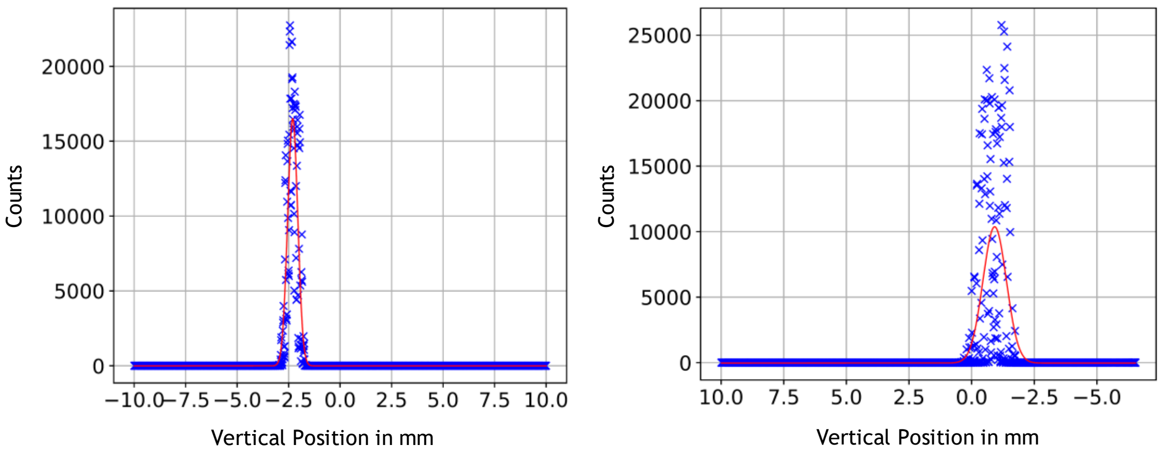
Wire Scanner
ERL-Measurement

Wire Scanner Measurement



Wire Scanner
ERL-Measurement

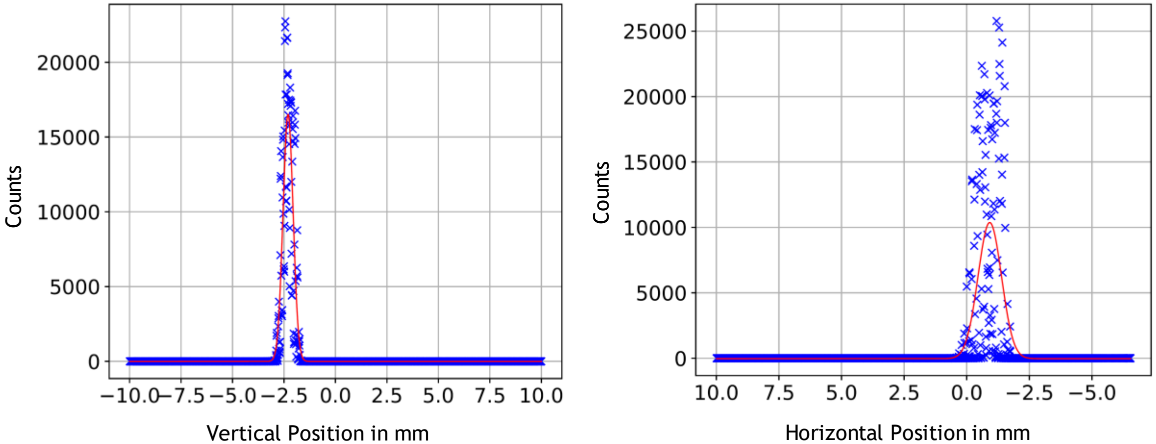
once accelerated beam



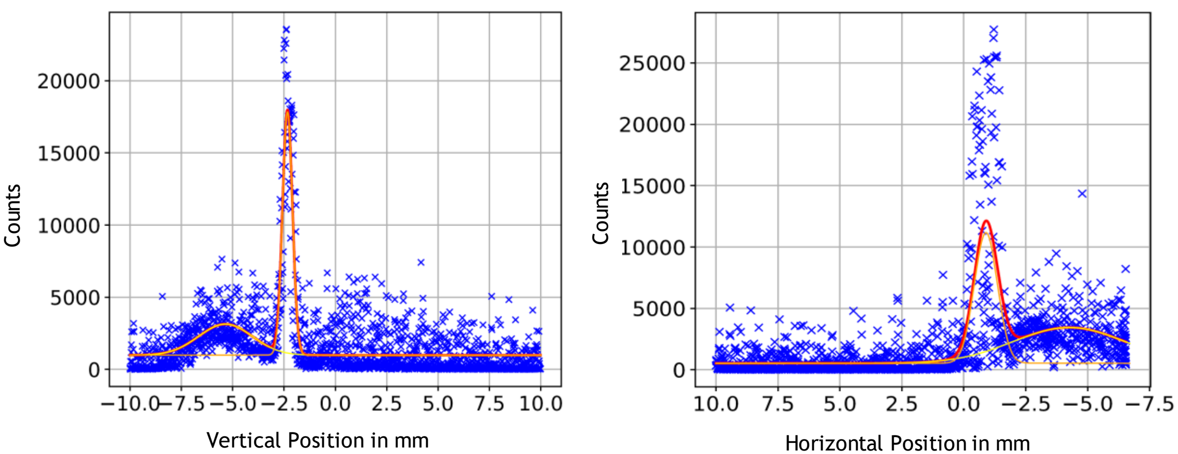
- Once accelerated beam:
  $\sigma_y = (0.22 \pm 0.01)$ mm
  $\sigma_x = (0.46 \pm 0.03)$ mm

Wire Scanner
ERL-Measurement

once accelerated beam



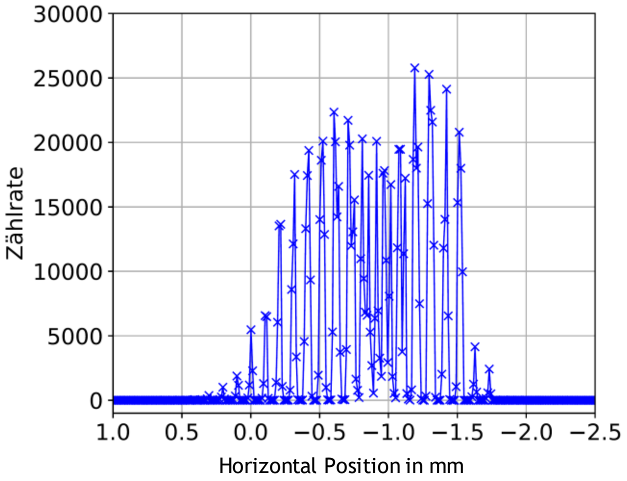
both beams



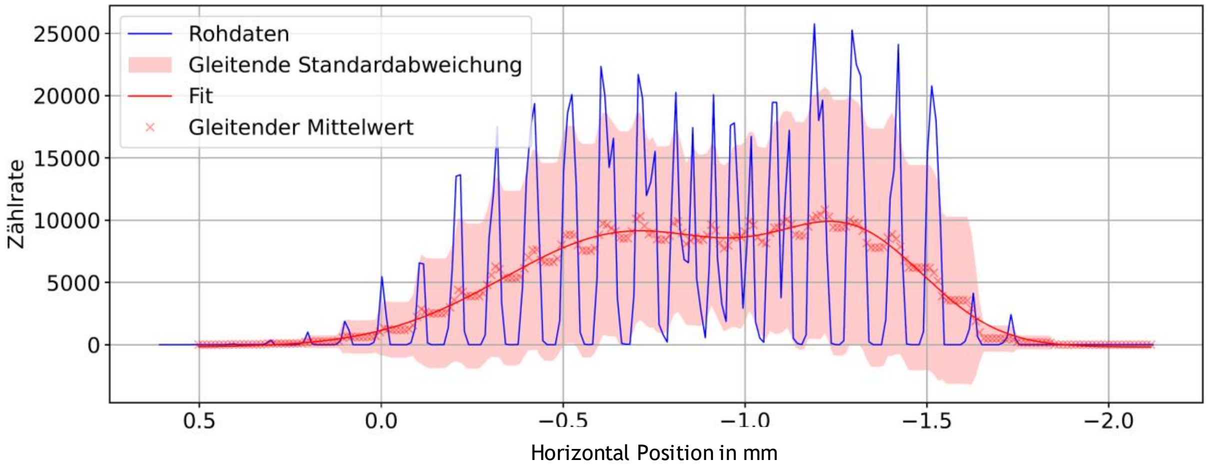
- Once accelerated beam:
  $\sigma_y = (0.22 \pm 0.01)$ mm
  $\sigma_x = (0.46 \pm 0.03)$ mm
- ERL-beam:
  $\sigma_y = (1.31 \pm 0.11)$ mm
  $\sigma_x = (2.25 \pm 0.38)$ mm
- High background
  → beam loss
- Comparisson of peak area
  vertical: (69.4 ± 10.9) %
  horizontal: (132.3 ± 33.3) %

Wire Scanner
50 Hz Disturbence

once accelerated horizontal beam

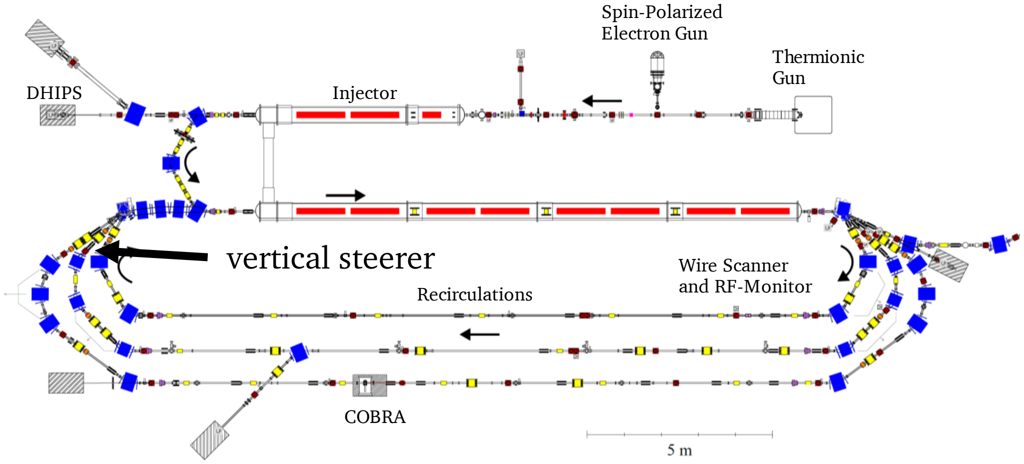


- Zoom on peak of once accelerated horizontal beam
  →Micro structure within the peak
- Frequency of (52 ± 3) Hz
  → 50 Hz disturbence
  (german grid frequency)

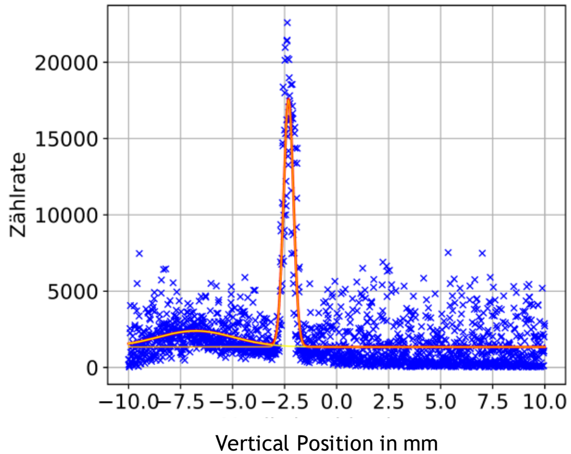


- Moving average of 20 data points
- Two beam maxima in distance of ca. 0.6 mm
- $\overline{\sigma_x} = (0.26 \pm 0.01)$ mm

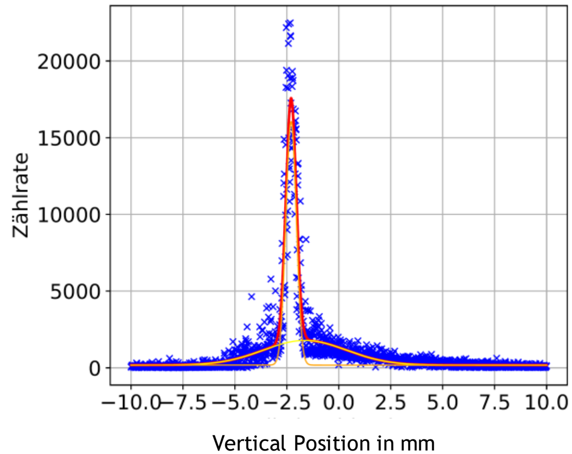
Wire Scanner
ERL-Measurement



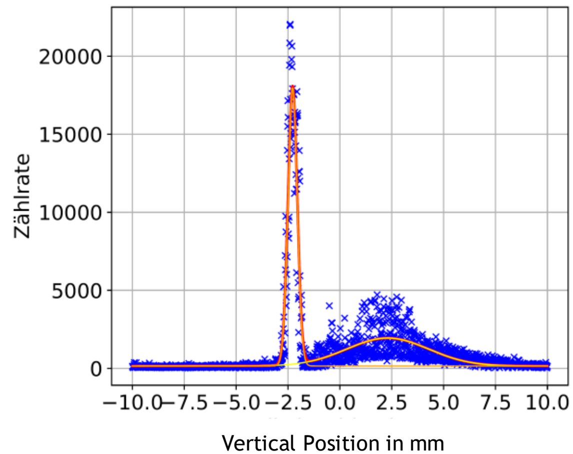
- beam position change of 9.1 mm with 0.4 A change of steerer current
- destruction of ERL mode → significant reduction of background



steerer: 1.198 A



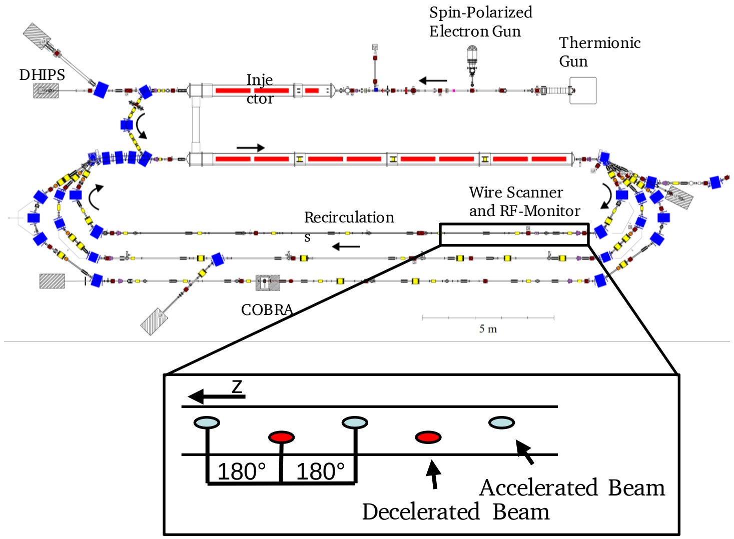
steerer: 1.218 A



steerer: 1.238 A

THANK YOU FOR YOUR ATTENTION

Motivation

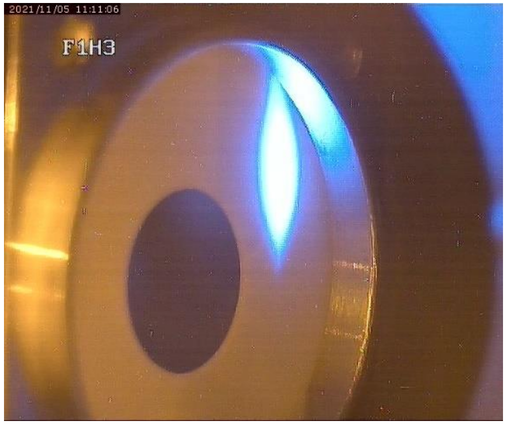


Previous ERL diagnosis

- Screens with hole
  → not non-destructive

Previous non-destructive diagnosis

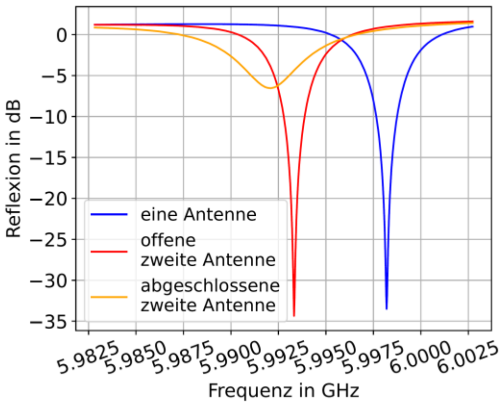
- RF-Monitor
  → Designed for 3 GHz

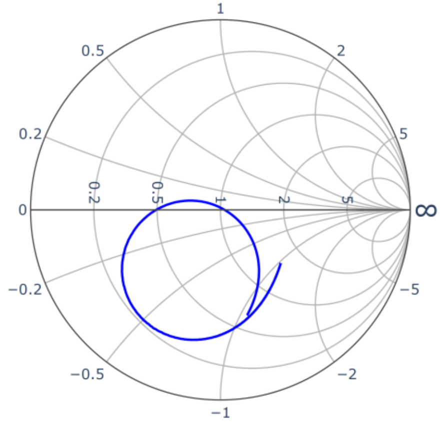


Frequency Tuning and Coupling

Iterative setup:

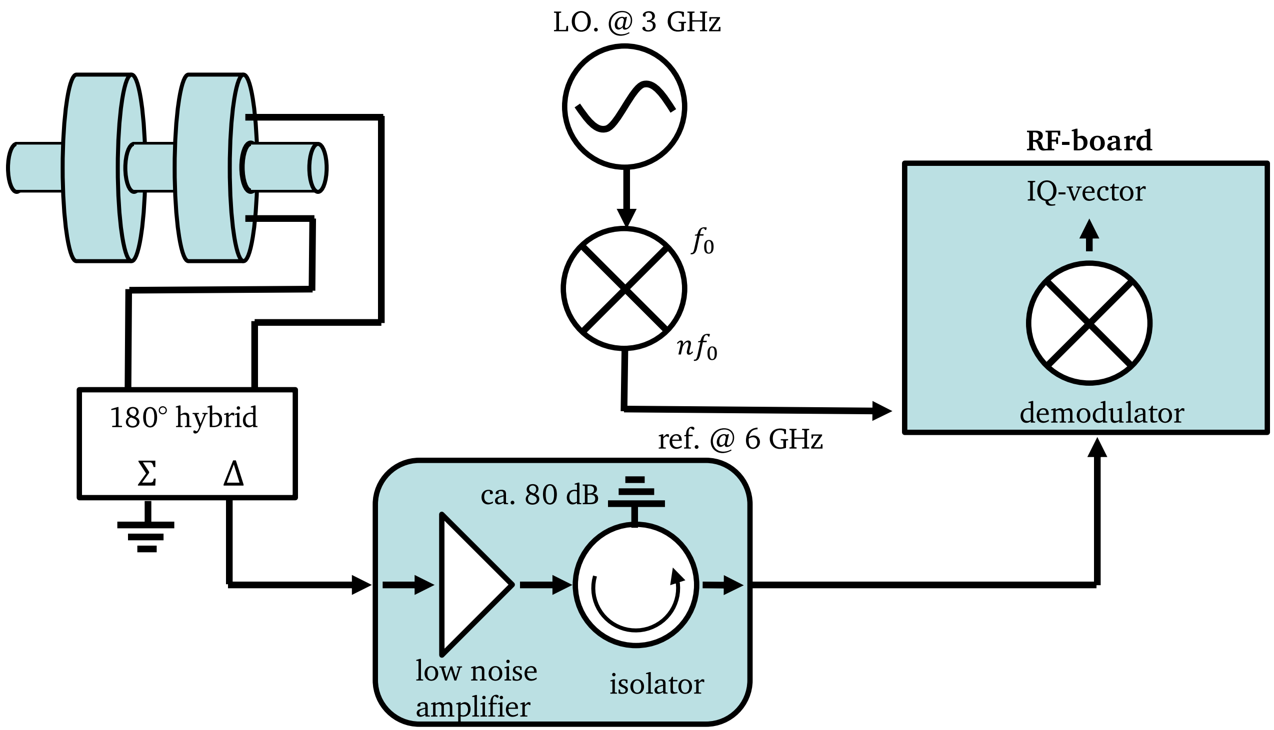
- Measurement of S11 with one antenna for coupling and Q_0
- Verification with second (open) Antennea
  → Strong change in resonant frequency
- Measurement of the resonant frequency and Q_L with second (closed) Antennea
  → Change in resonant frequency
- Tuning the resonant frequency using mode separators
  → Change of coupling





monitor parameter	horizontal cell	vertical cell
resonant frequency	5.9923 GHz	5.9923 GHz
unloaded qualiy factor Q_0	2763	2485
loaded qualiy factor Q_L	876	842
coupling κ	0.893	0.929

Signal Processing



Conception of the Wire Scanner

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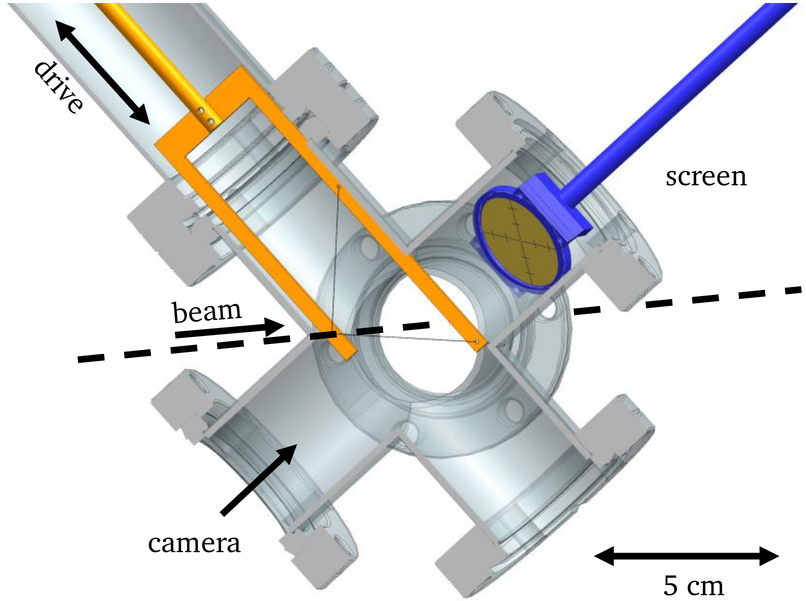
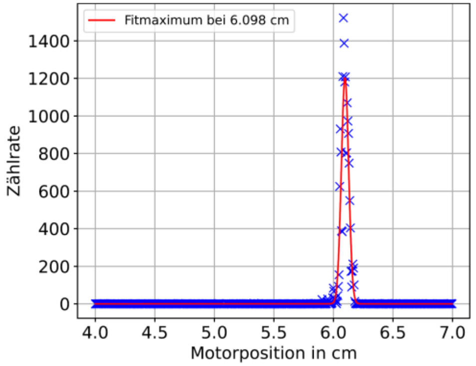
- Two wires (100 µm) are driven through the beam

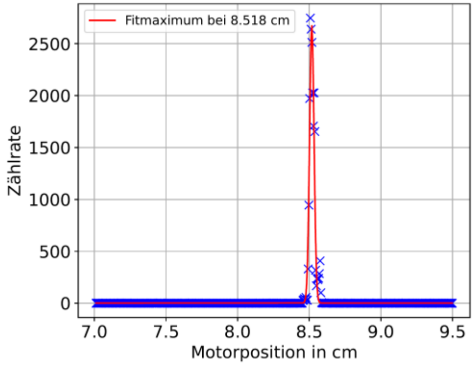
- Count rate of secondary particles is measured by beam loss detectors (proportional to beam intensity)

- Knowledge of the wire position (through calibration using a fluorescent screen) allows conclusions to be drawn about the beam position and shape

- Position accuracy:
vertical: 120 µm
horizontal: 80 µm







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6 GHz RF-Monitor Resolution

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- Measurement in small steps around signal minima (with 100 nA beam)
- Resolution depends on position
  - poor resolution around center:
    vertical: 380 µm
    horizontal: 320 µm
  - Good resolution on the slopes:
    vertical: 30 µm
    horizontal: 50 µm