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ML Feedback for HI Jena Laser plasma accelerators

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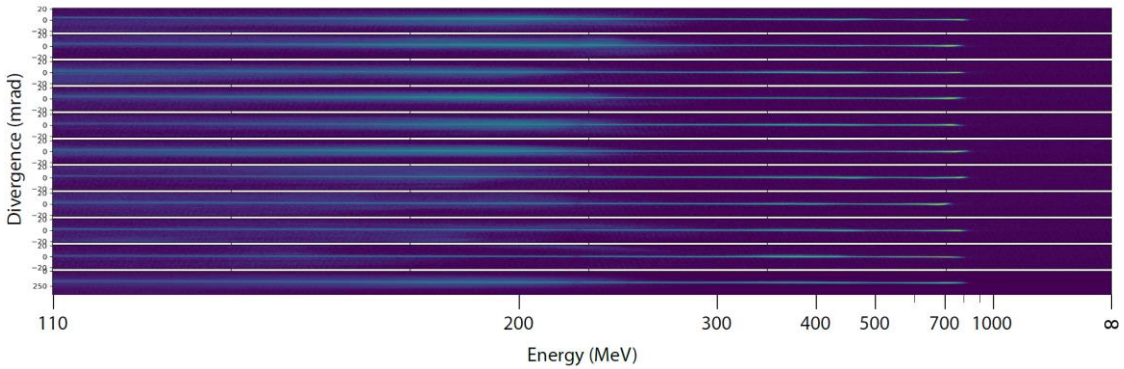
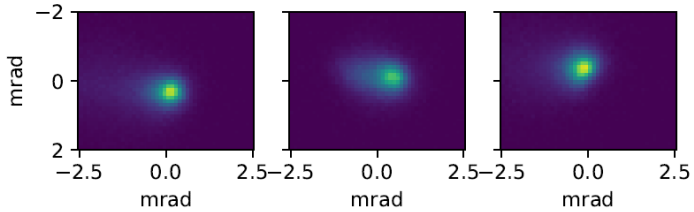
Acceleration electron bunches to GeV level

Electron bunch spectrum



Optimization parameter for particle beams

- peak energy
- bandwidth
- charge
- pointing



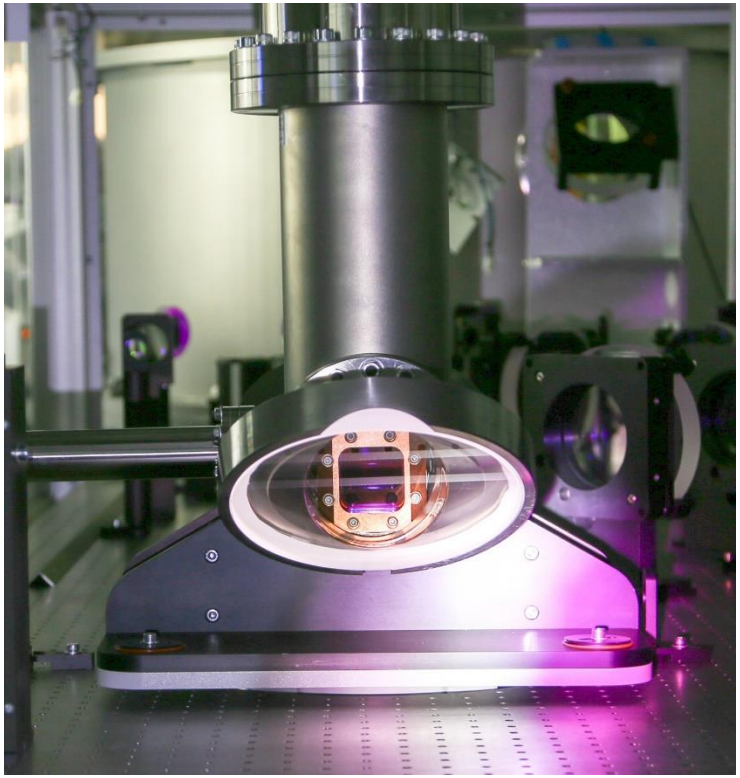
- GeV beams with ultra low beam divergence < 0.5 mrad^2
- pointing fluctuations on same order as divergence

Experiment

Online laser diagnostic & control

PIC simulations

Cryo cooled power amplifier



- 100 W pumping power @532 nm
- target temperature 90 K to reduce the thermal lens of the Ti:Sapphire crystal
- Helium expander cryo head

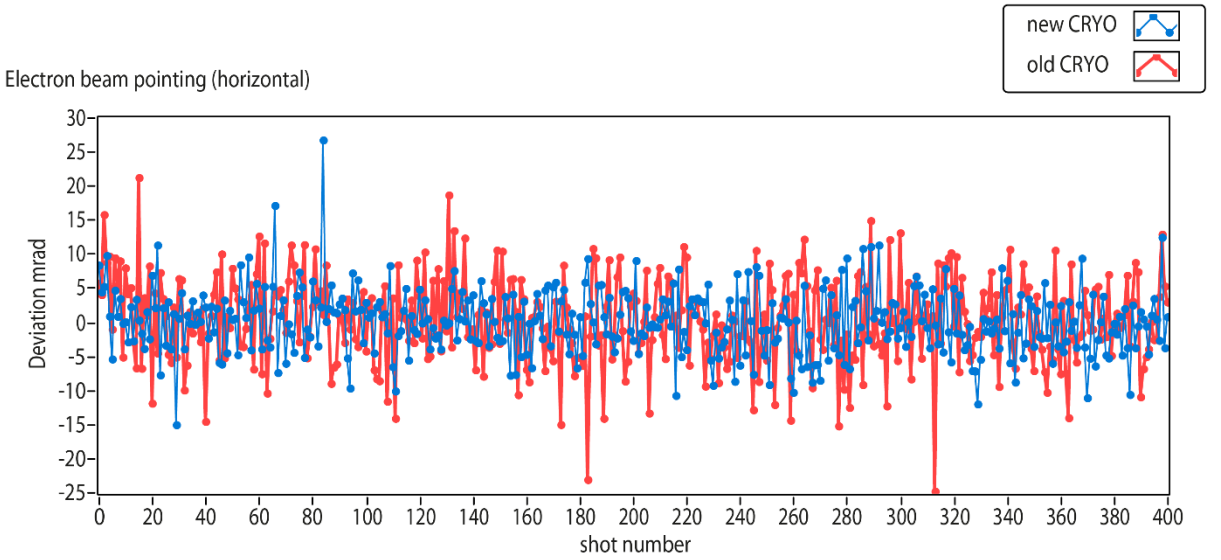
New Cryo head (installation summer 2022)

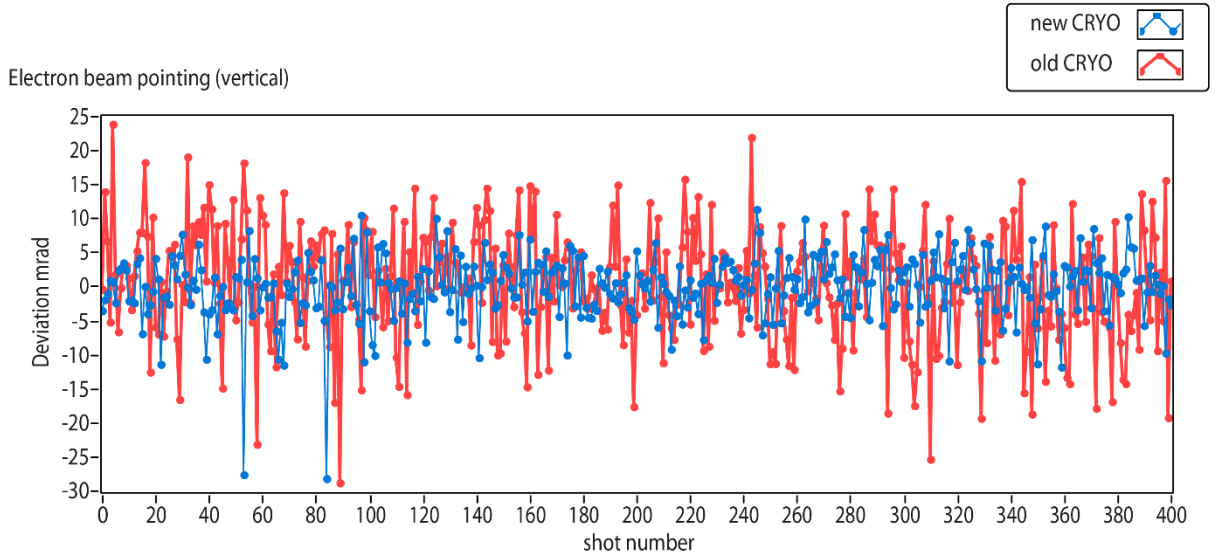
- no vibrations anymore

recent LWFA experiments beam pointing

- LWFA with ionization injection (95% helium, 5% nitrogen)
- super sonic gas jet

Jitter for electron bunches is **m**rad while for the laser beam is **µ**rad.

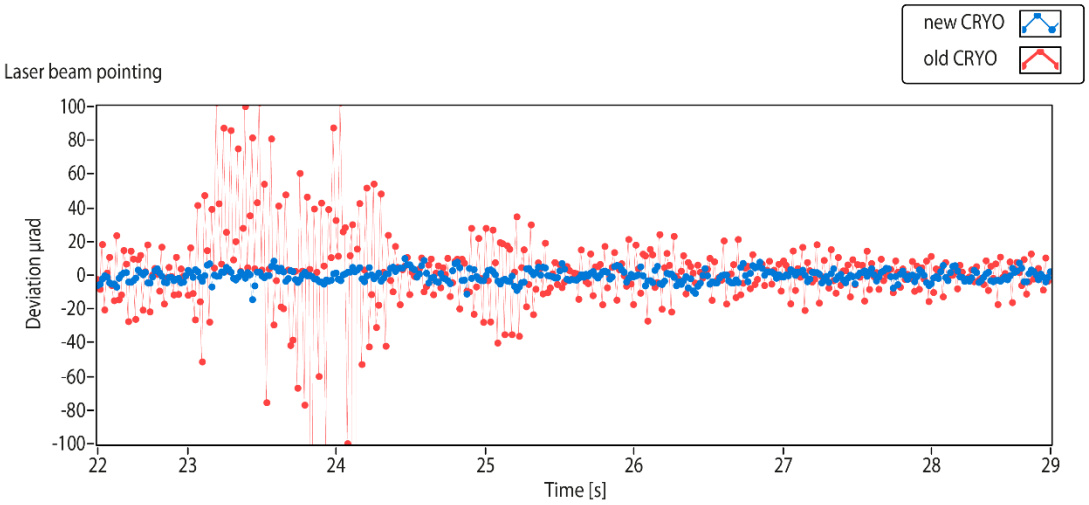


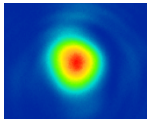


horizontal direction
old CRYO jitter: 6.5 mrad (rms)
new CRYO jitter: 4.7 mrad (rms)

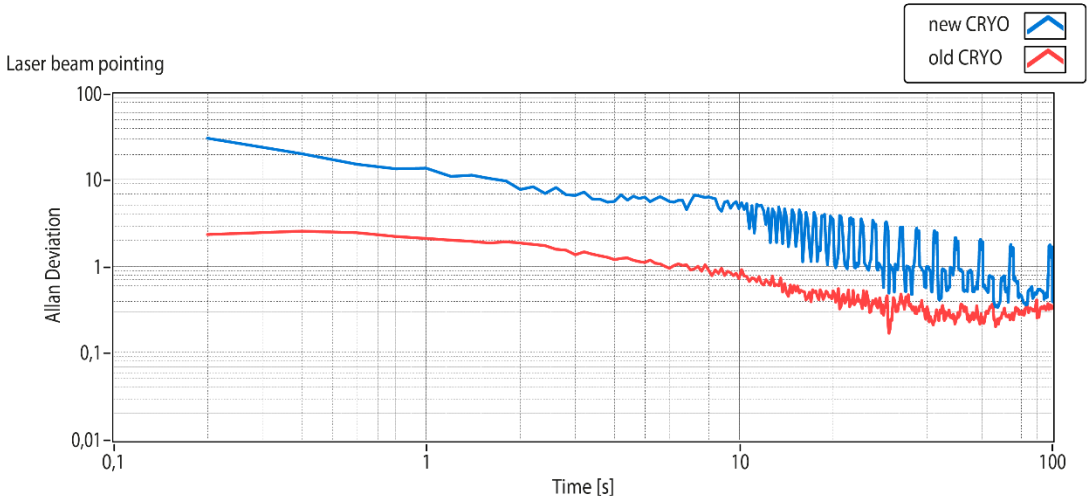
vertical direction
old CRYO jitter: 30 µrad (rms)
new CRYO jitter: 4 µrad (rms)

Comparison CRYO cooler (vertical direction)





Focal spot diameter: ~10 µrad
old CRYO jitter: 30 µrad (rms)
new CRYO jitter: 4 µrad (rms)



Long term drift only depends on environment. (temperature, humidity, air pressure)

Data from old CRYO too erratic for ML. Need for higher sampling rate.

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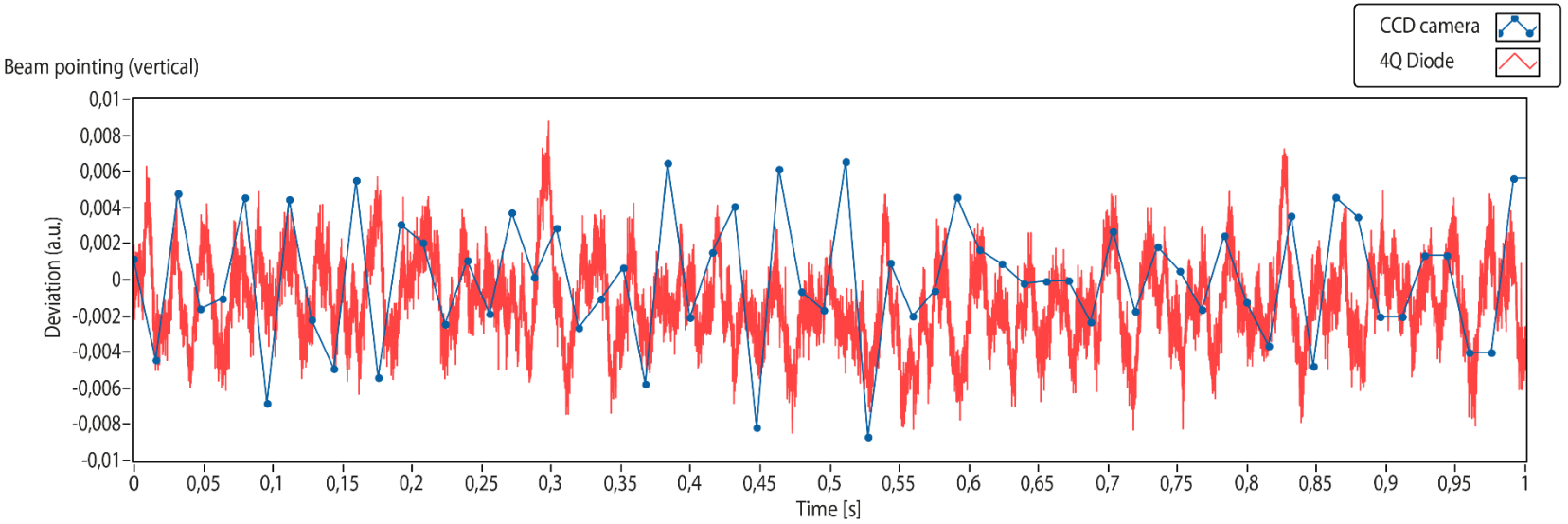
Active beam stabilization

For online measurement: Use transmitted light through high reflective mirrors and focus the beam on the CCD (already used for data logging)

Data recording

- using 4Q Diode for high temporal resolution (10 kHz) instead of CCD camera (100 Hz)
- no post evaluation necessary

Data recording

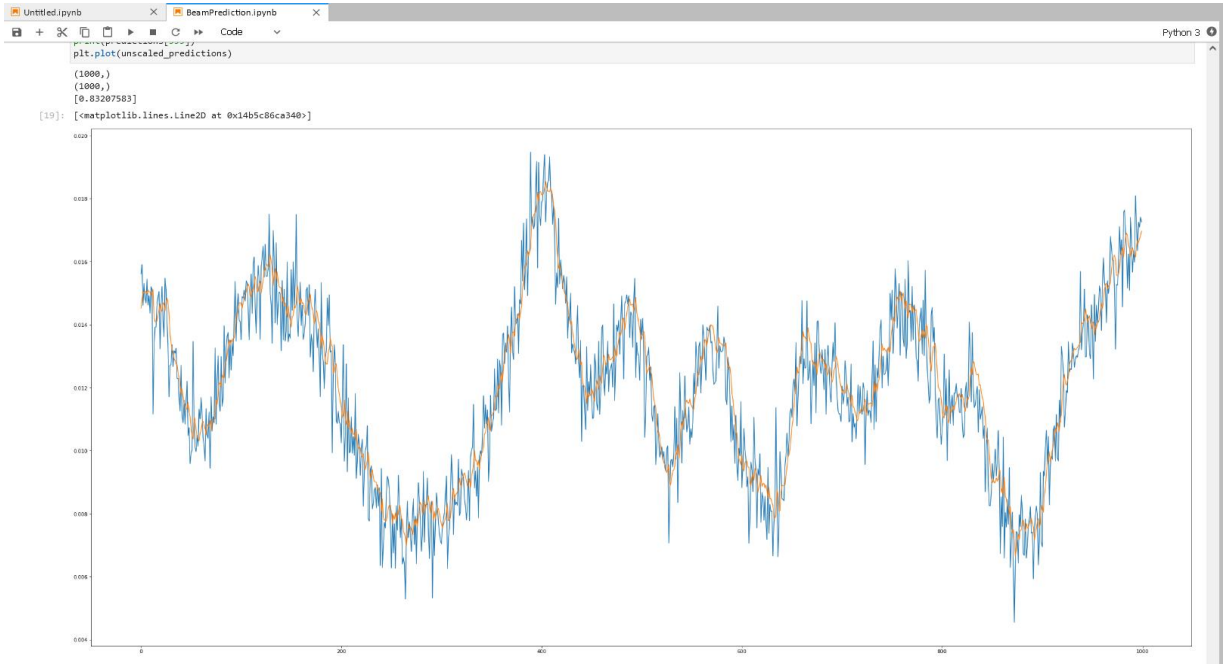


Much better training data but much computation time increases significantly.
Long term prediction (> 1 seconds) gets difficult.

ML algorithm

Switching from first demonstration with selfwritten Labview program to python and tensorflow. Computational acceleration by GPUs.

Good news: It works!



Bad news: prediction not accurate for different times of the day (morning vs. afternoon)

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Outlook for 2022/23

- Online measurement of beam fluctuations with > 10 kHz
- establish reliable model for beam prediction