Overview of the REGAE Beamline Upgrade

Ultrafast Beams and Applications 2019

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CFEL, UHH

CFEL SCIENCE

GEFÖRDERT VOM

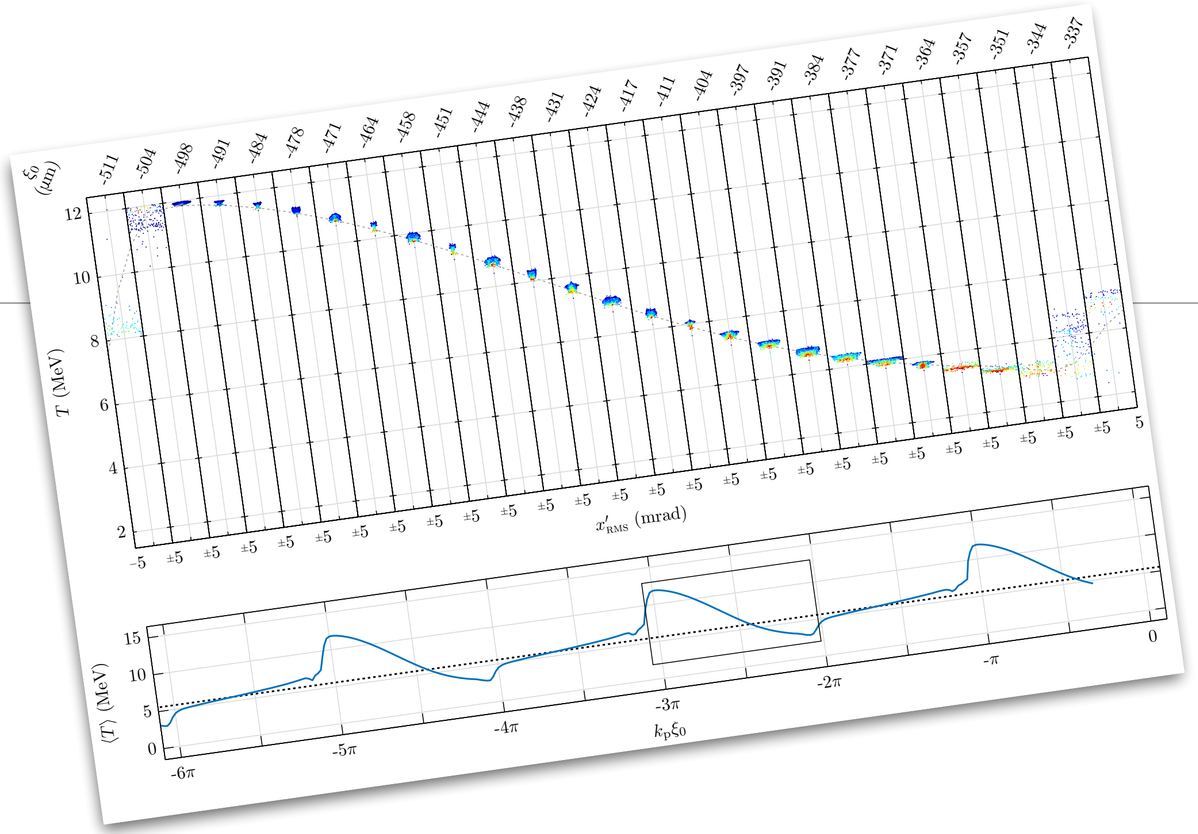
Bundesministerium für Bildung und Forschung

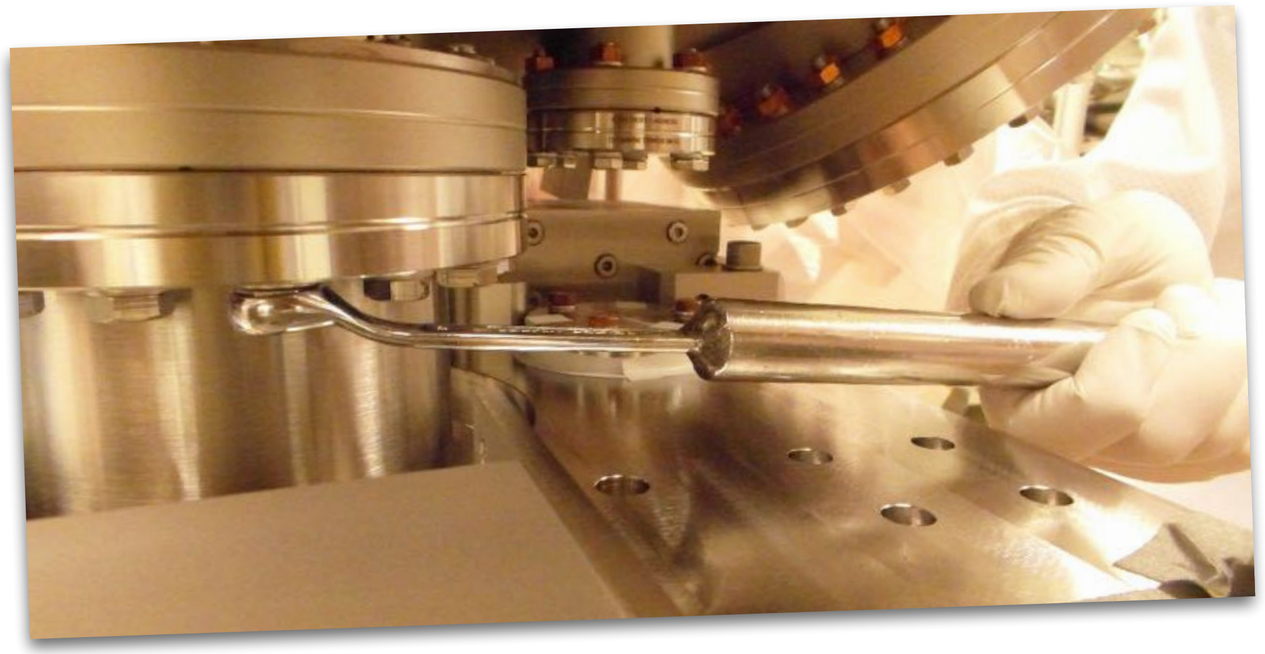
05K16GUB

UHH DESY

REGAE

- projects & goals
  - (time-resolved electron diffraction)
  - external injection of electron bunches into laser-driven plasma wakefields
  - linearization of the longitudinal phase space without higher harmonic field
  - THz-based acceleration
- REGAE beamline upgrade
  - REGAE beamline
  - laser transport beamline
  - commissioning

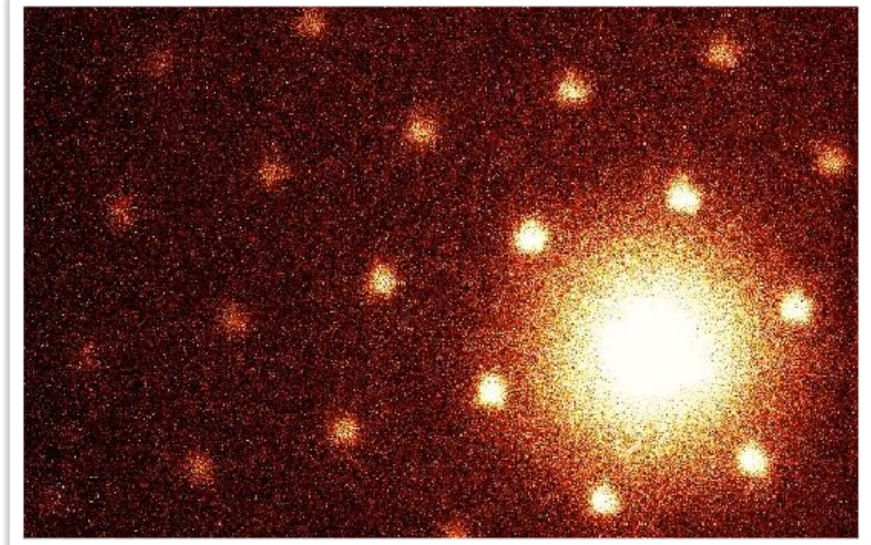


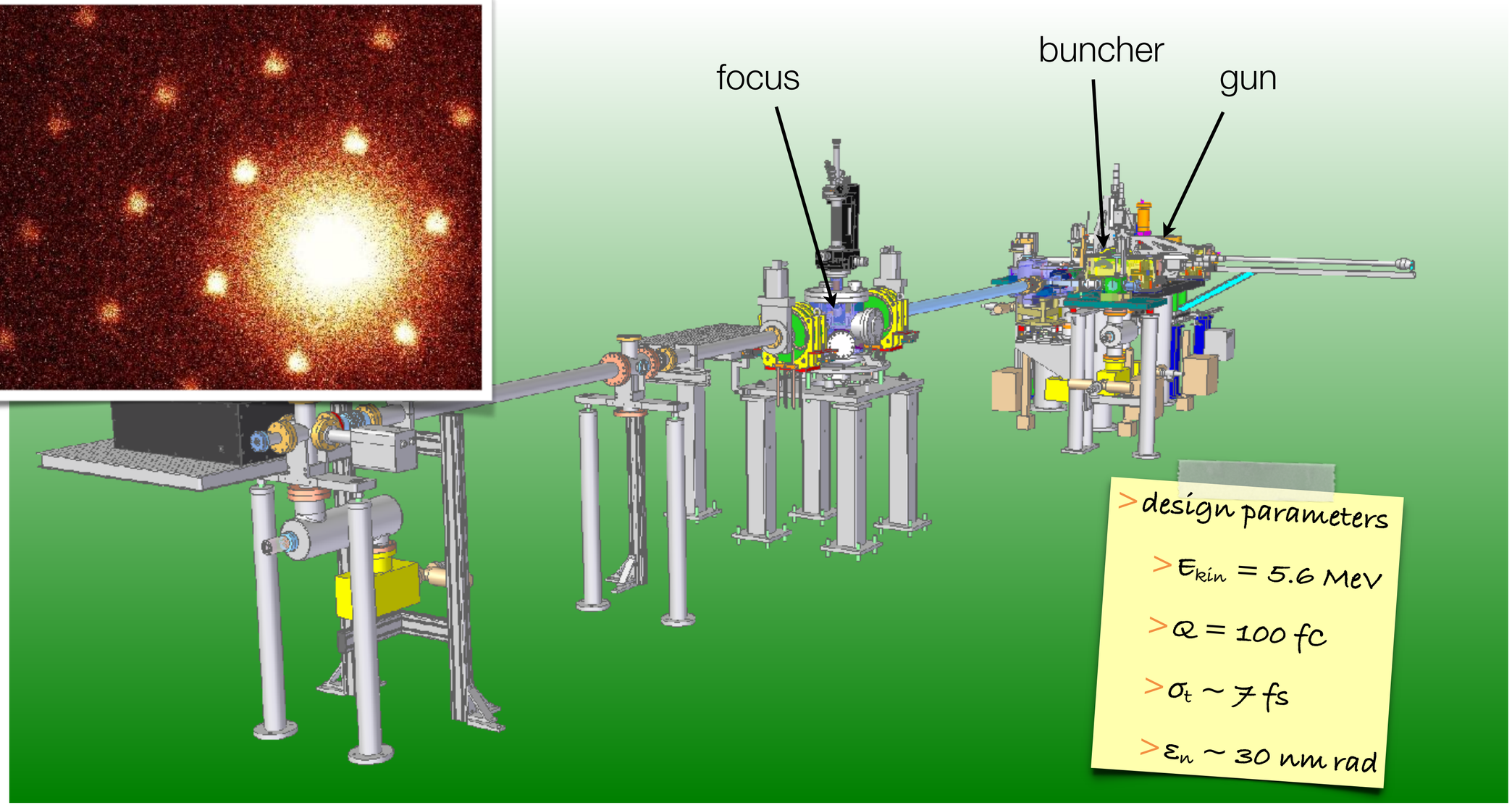


REGAE — Relativistic Electron Gun for Atomic Exploration

Projects & Goals

REGAE — Relativistic Electron Gun for Atomic Exploration





> design parameters

> E_{kin} = 5.6 MeV

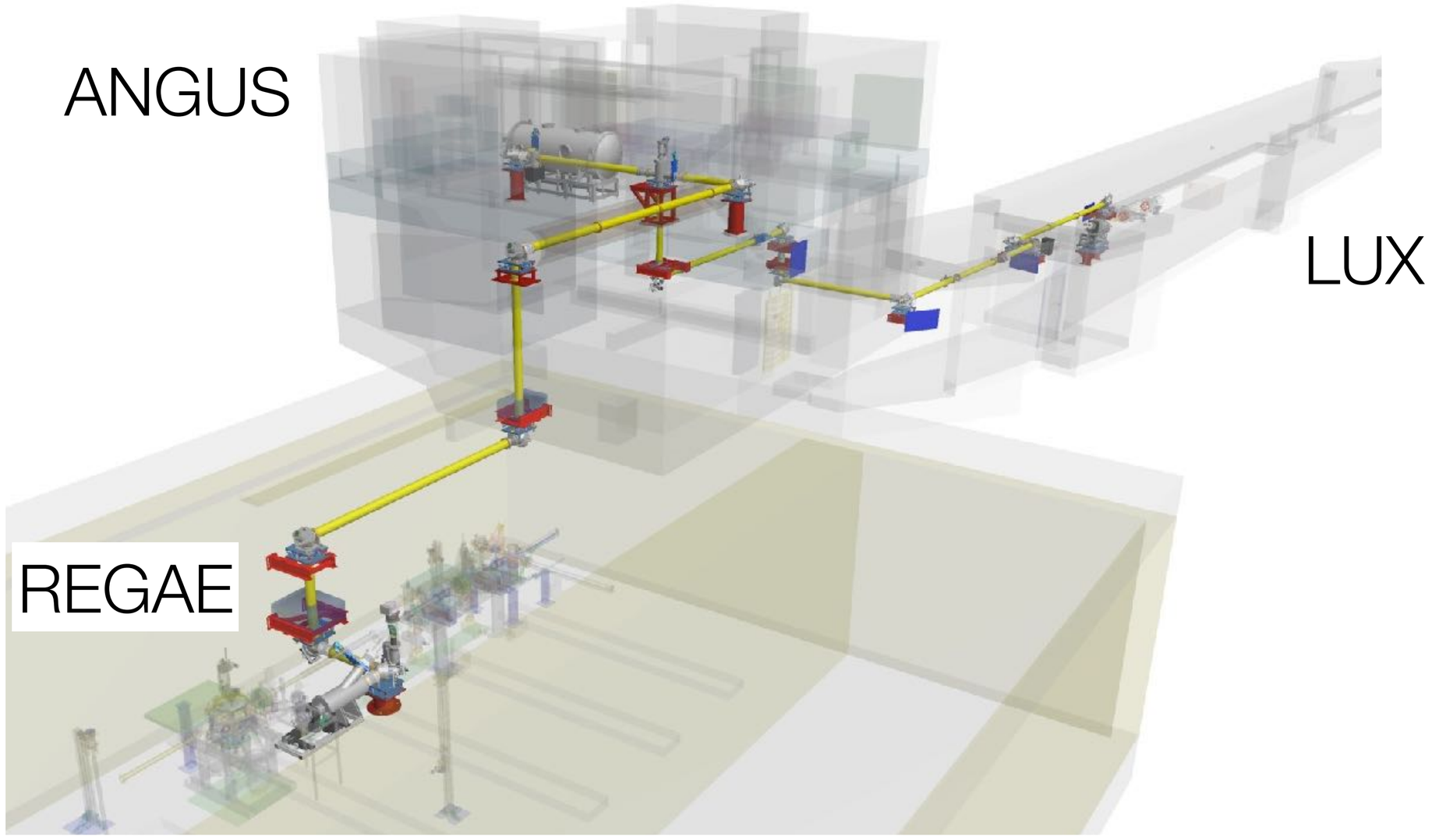
> Q = 100 fC

> σ_t ~ 7 fs

> ε_n ~ 30 nm rad

External Injection at REGAE: Facilities

ANGUS



LUX

External Injection at REGAE: Concept

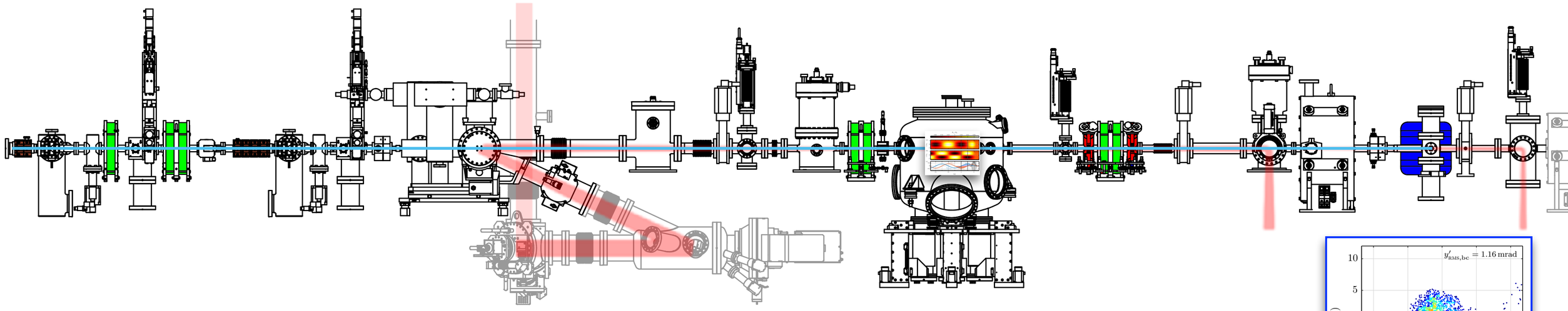
Joint DESY / UHH Project
DESY funding (ARD/POF)
UHH funding
Third party EU funding

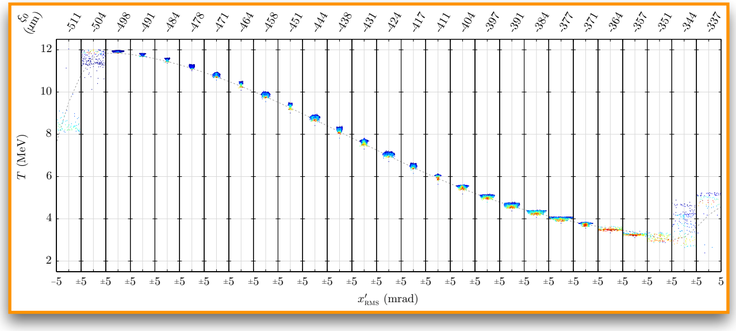
External Injection at REGAE forms an ARD milestone

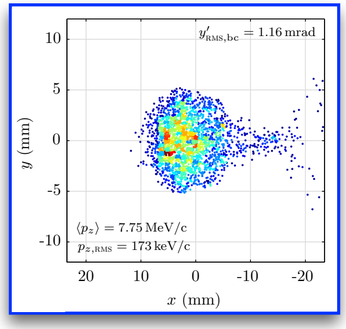
REGAE ⟷ synchronization* Δt < 50 fs ⟷ ANGUS

wakefield

eSpec



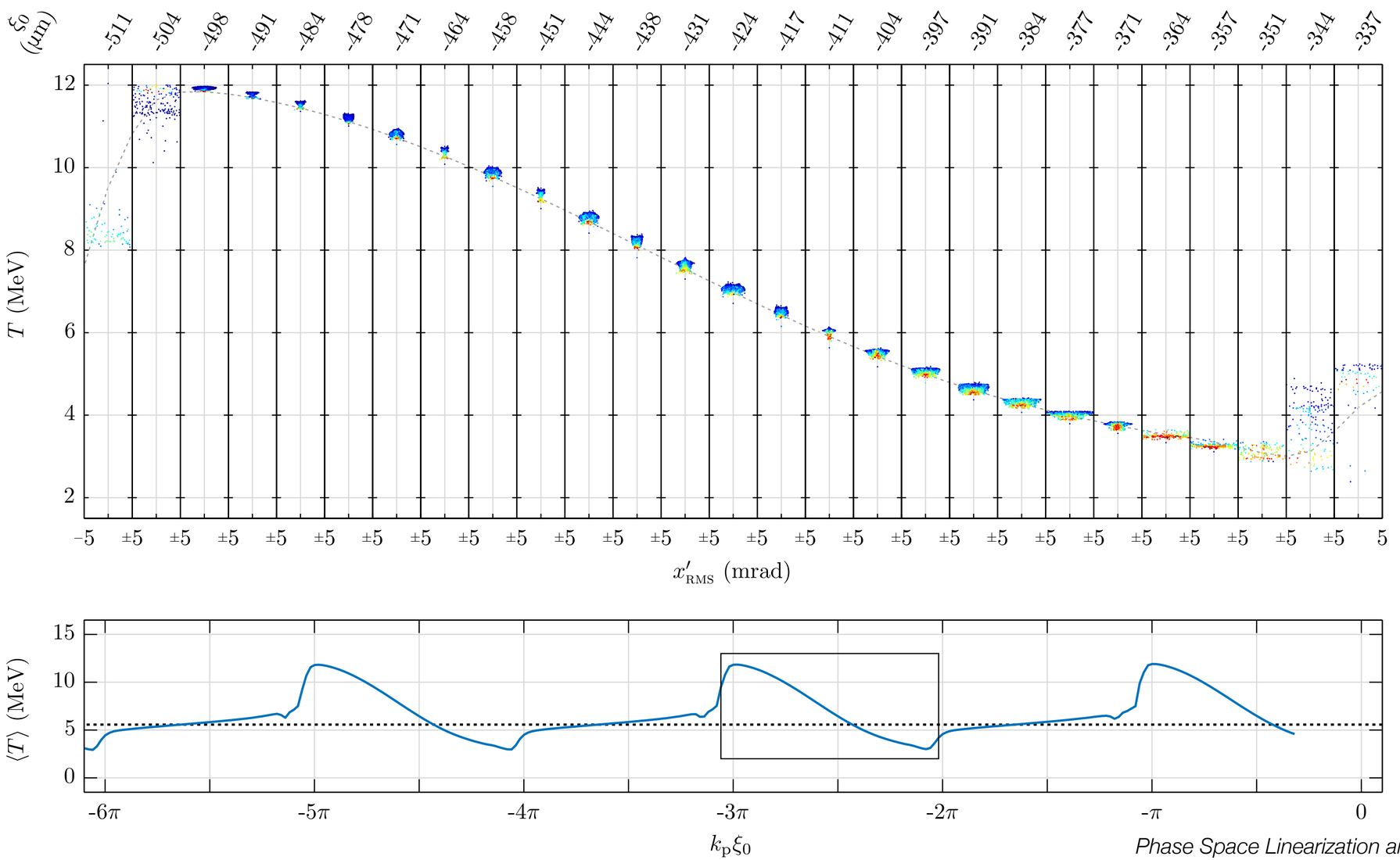




z

* M. Titberidze, *Pilot Study of Synchronization on a Femtosecond Scale between the Electron Gun REGAE and a Laser-Plasma Accelerator*, PhD Thesis, University of Hamburg, 2016

External Injection at REGAE: S2E(nd of Plasma) Simulation



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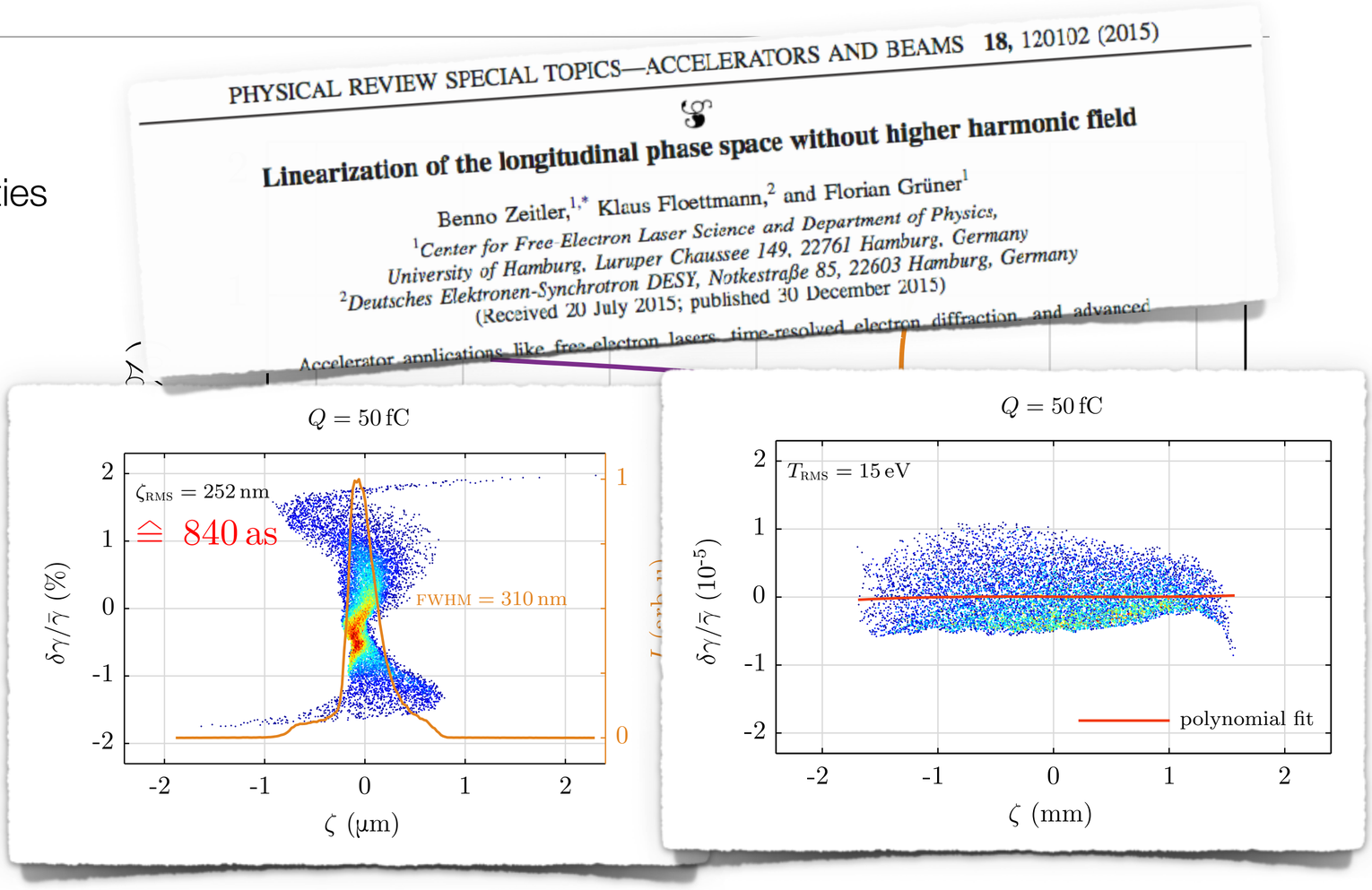
Linearization of the Longitudinal Phase Space

> … without higher harmonic fields
  > bunch length minimum limited by non-linearities
  > typical approach: higher harmonic cavity
  > new concept: stretcher mode
    > no additional cavity required

> promising simulation results for REGAE
  > possible bunch length (well) below 1 fs
  > energy spread compensation: $\Delta E/E < 10^{-5}$

> REGAE: proof of principle experiment
  > step 1: energy spread compensation
  > step 2: phase space analysis using TDS



Benno Zeitler,
Phase Space Linearization and External Injection of Electron Bunches into Laser-Driven Plasma Wakefields at REGAE,
PhD thesis, University of Hamburg, 2016

THz-based Acceleration at REGAE

> use THz fields instead of RF for…

> acceleration: similar to external injection

> *(almost) everything is there anyways!*

> diagnostics: THz-based TDS

> resolution on fs scale (and better)

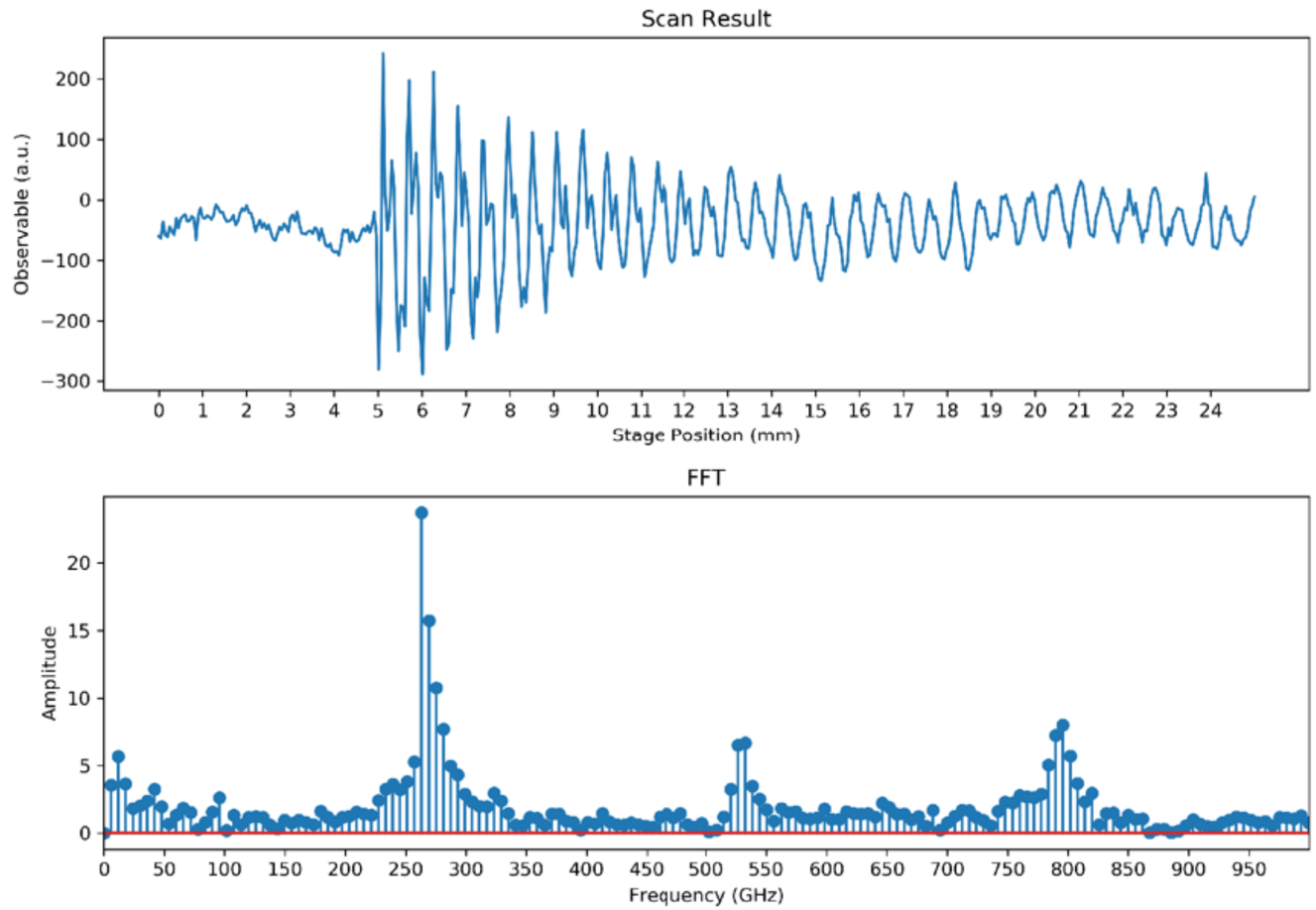
> synergy with linearization

> THz pulses created by REGAE gun laser

> pulse energy: ~200 nJ

> frequency: 270 GHz

> 3D printed THz cavities



Courtesy: F. Lemery, F. Mayet

REGAE Beamline Upgrade

REGAE Beamline Upgrade: Team

LUX and ANGUS
crew
ft. Theresa Staufer*

Ryan Stark*

Christian Werle*

Benno Zeitler*

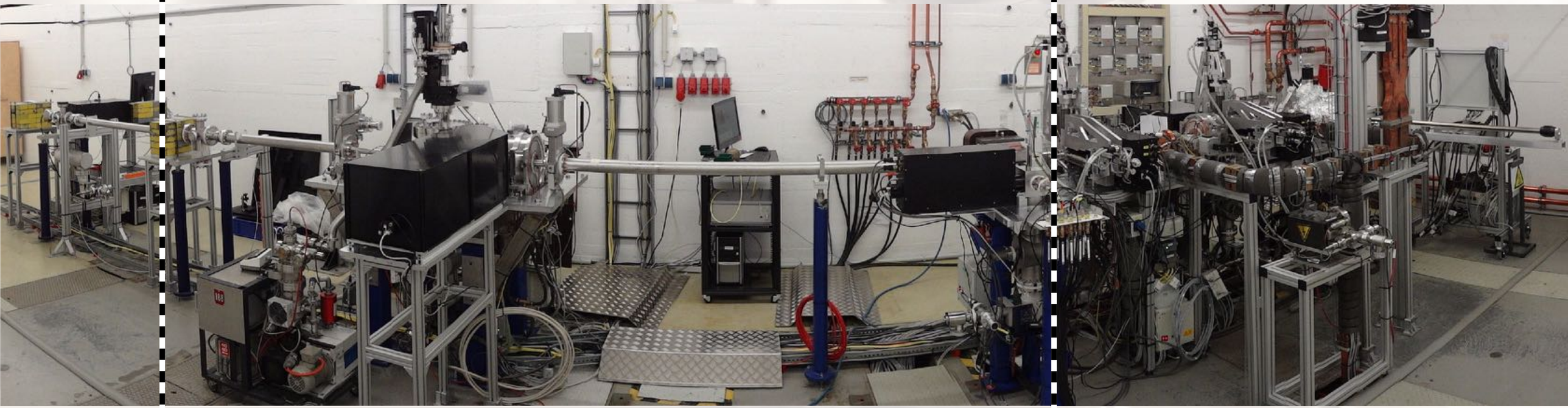
Klaus Flöttmann
Hossein Delsim-Hashemi
Max Hachmann

Nick Guse

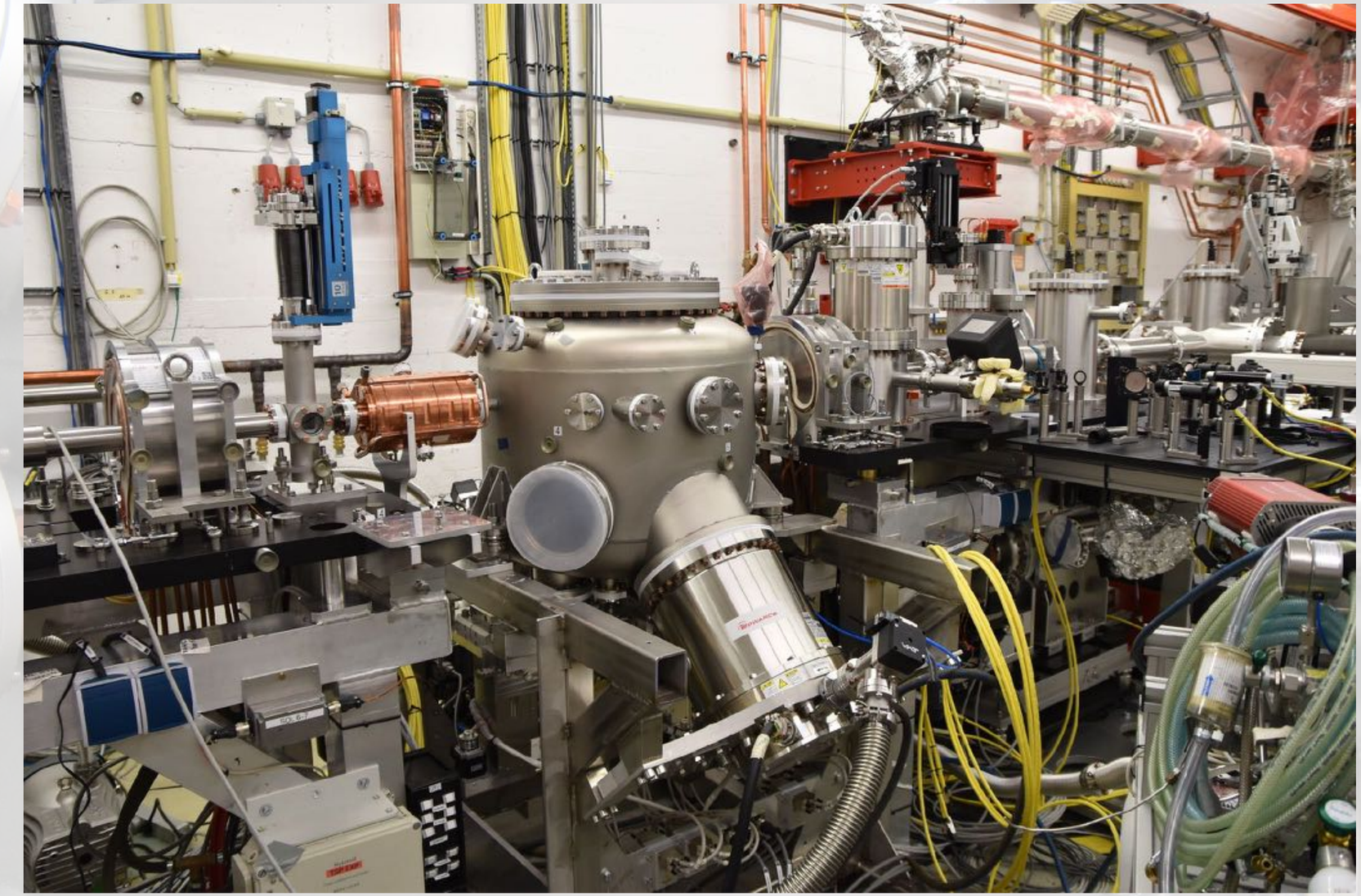
technical groups
(DESY, UHH, MPSD)

* group of
Florian Grüner

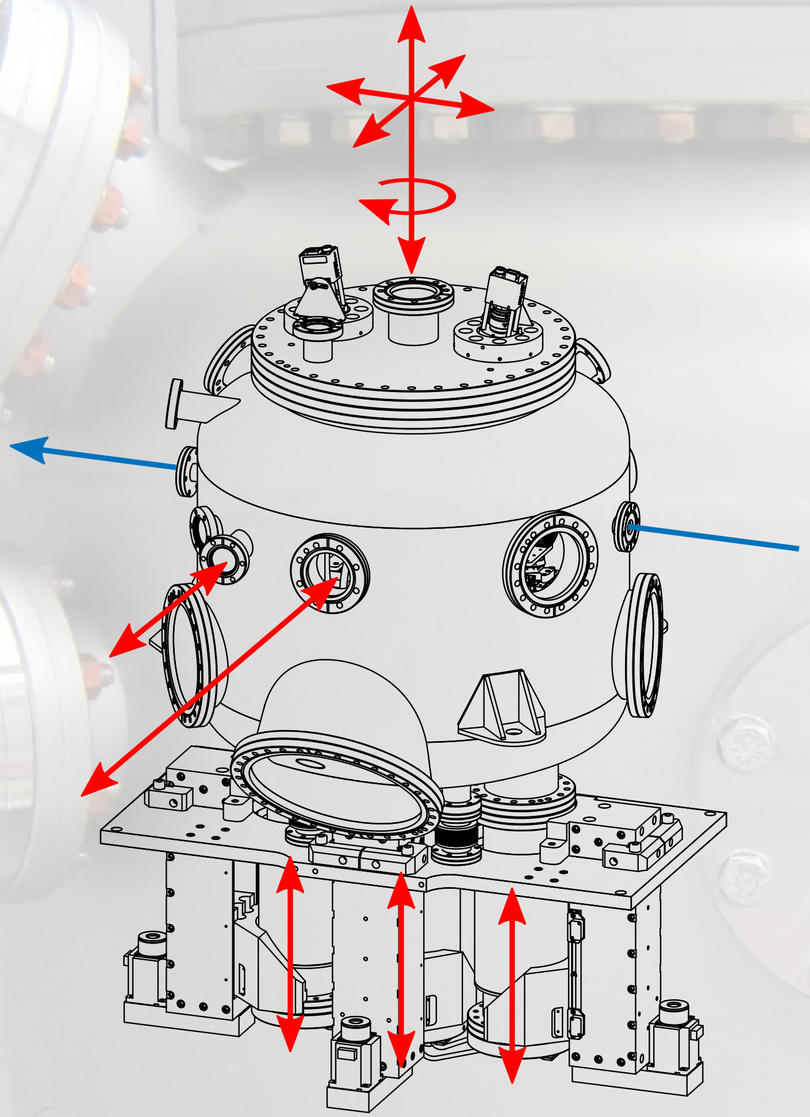
REGAE Beamline Upgrade: Dismantling

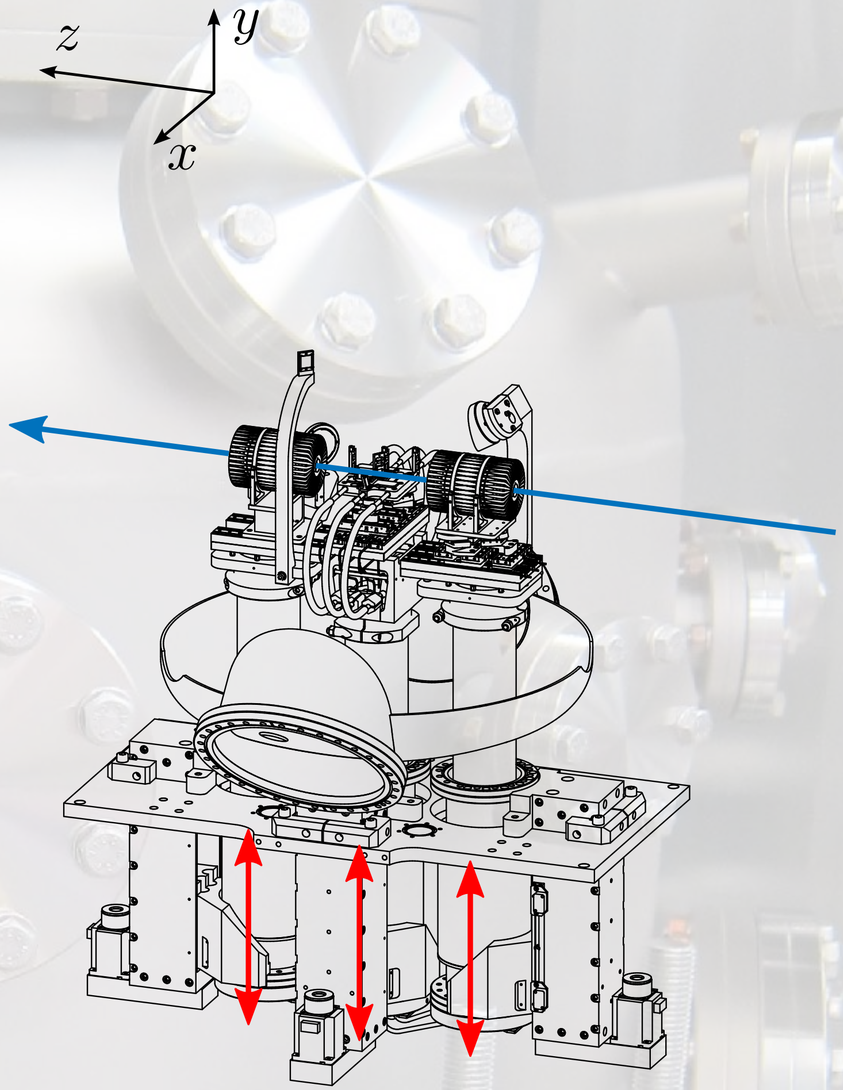


REGAE Beamline Upgrade

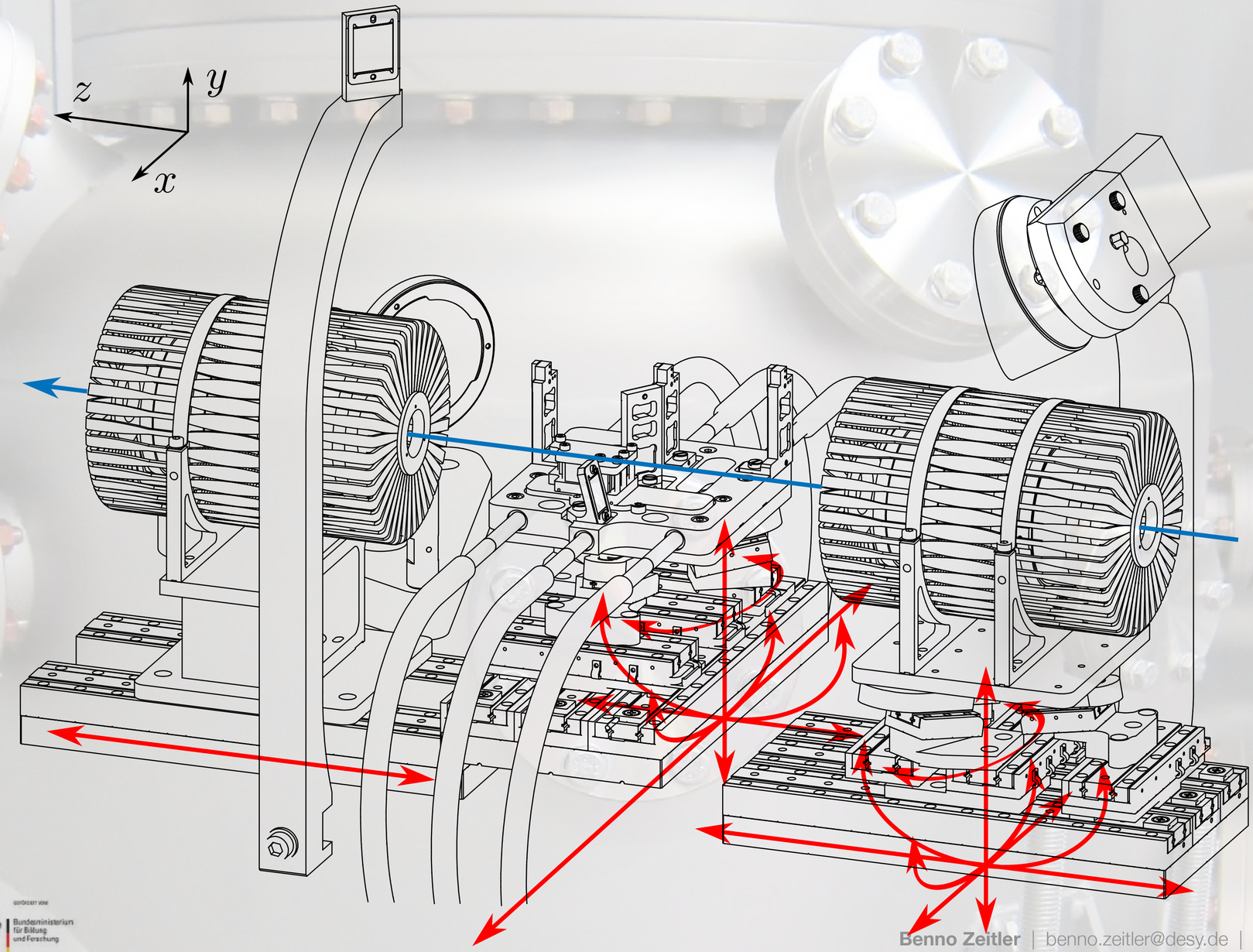


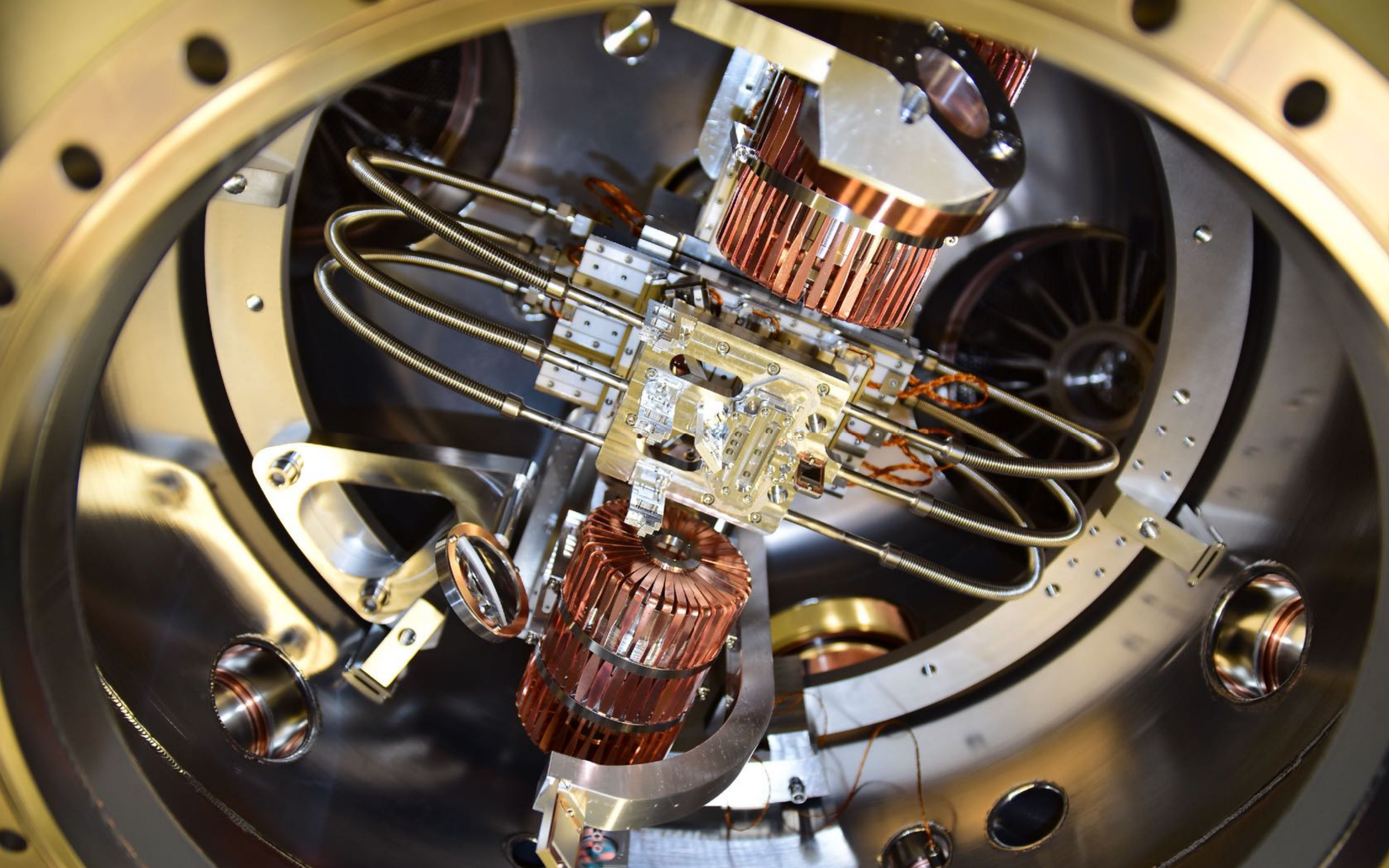
Interaction Chamber: *Sancho Panza*



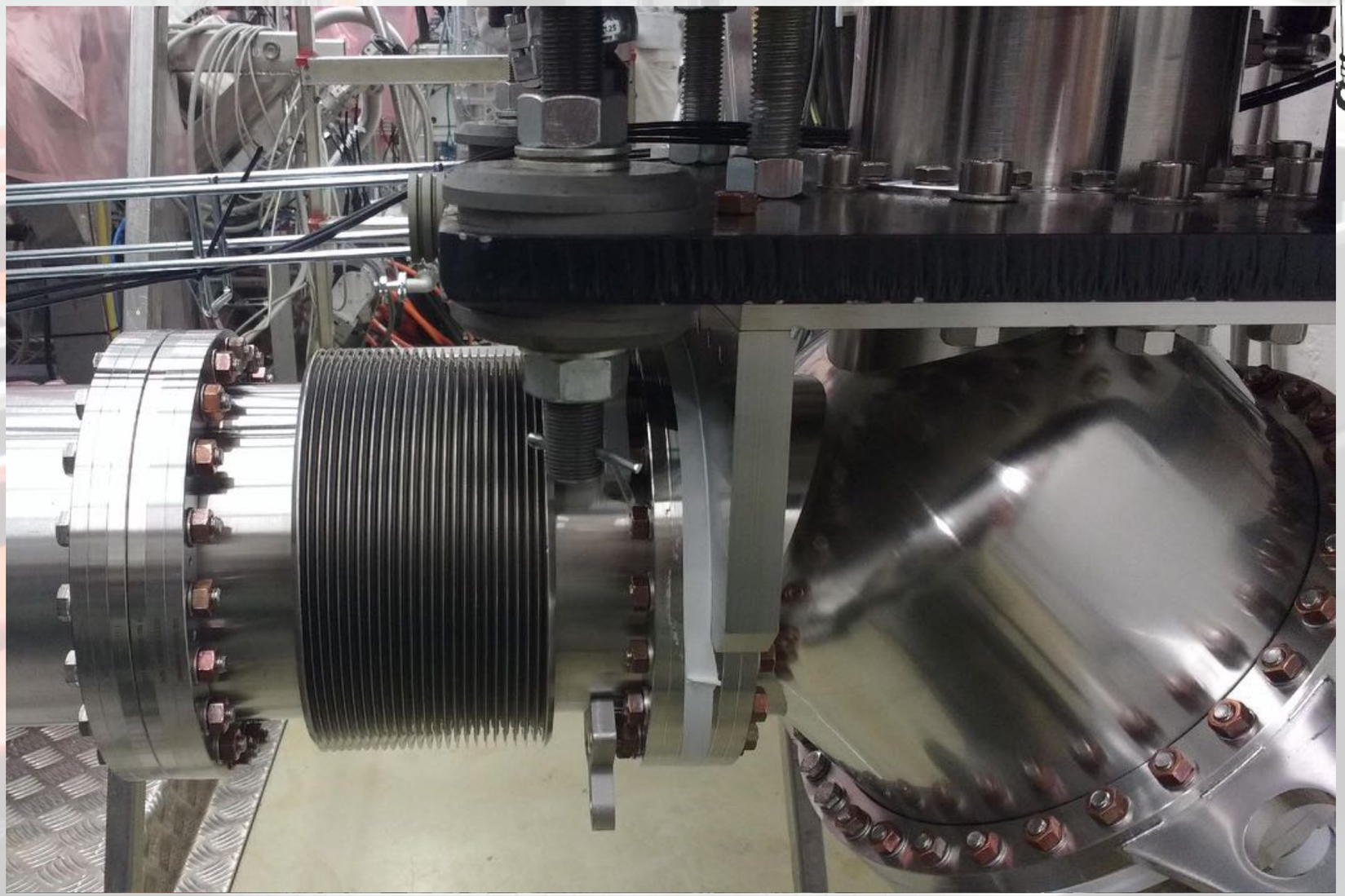


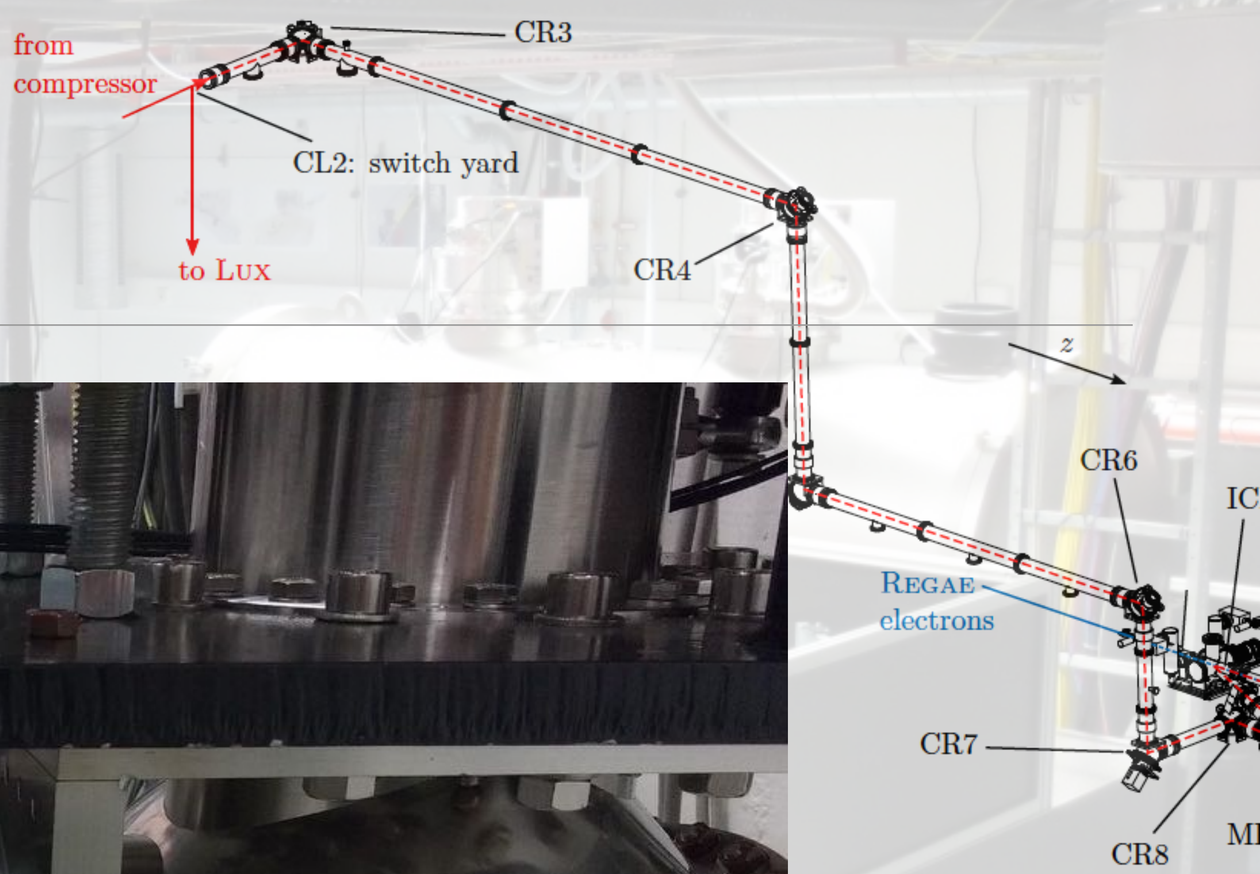
Interaction Chamber: Inside *Sancho Panza*



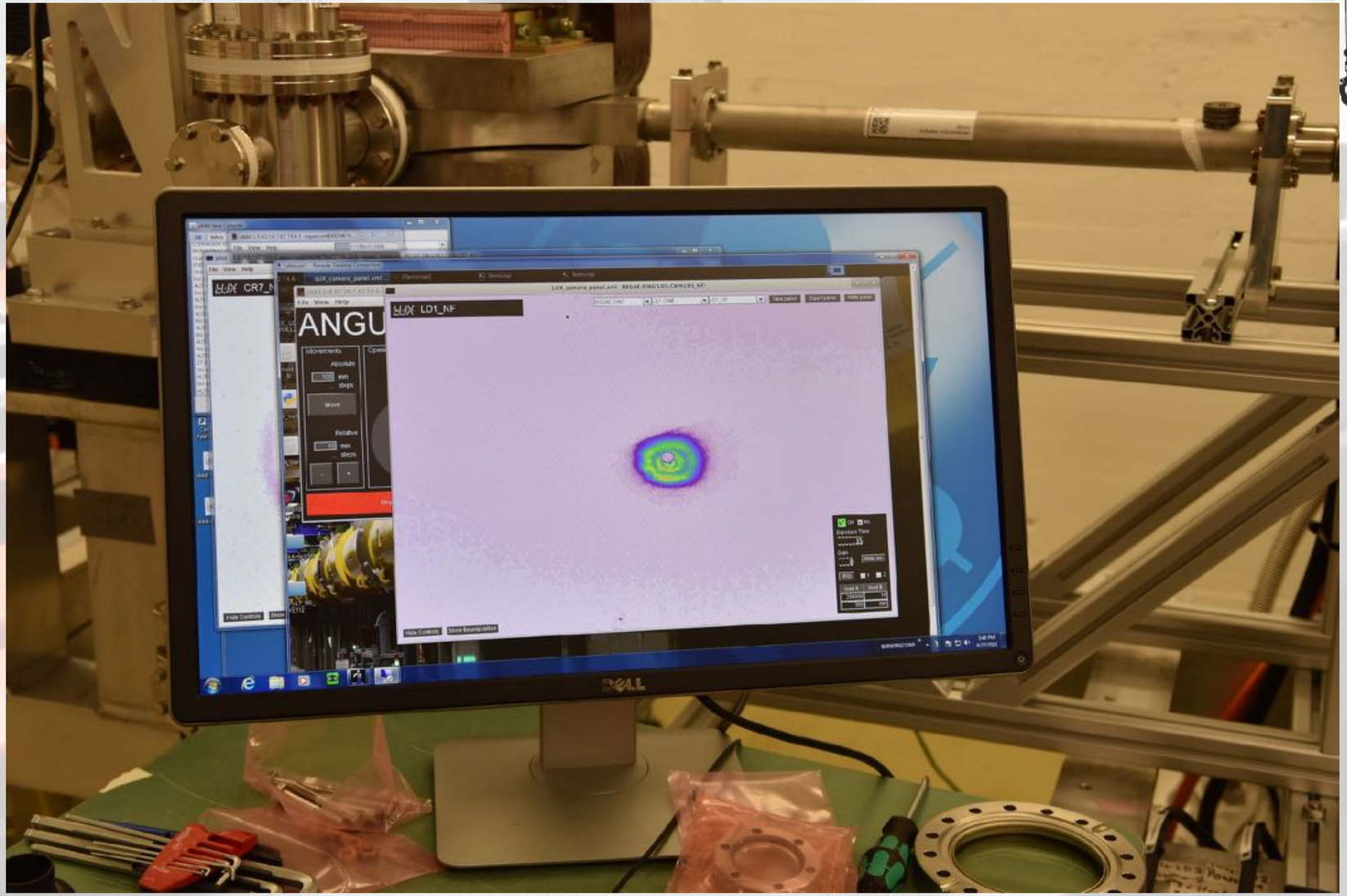


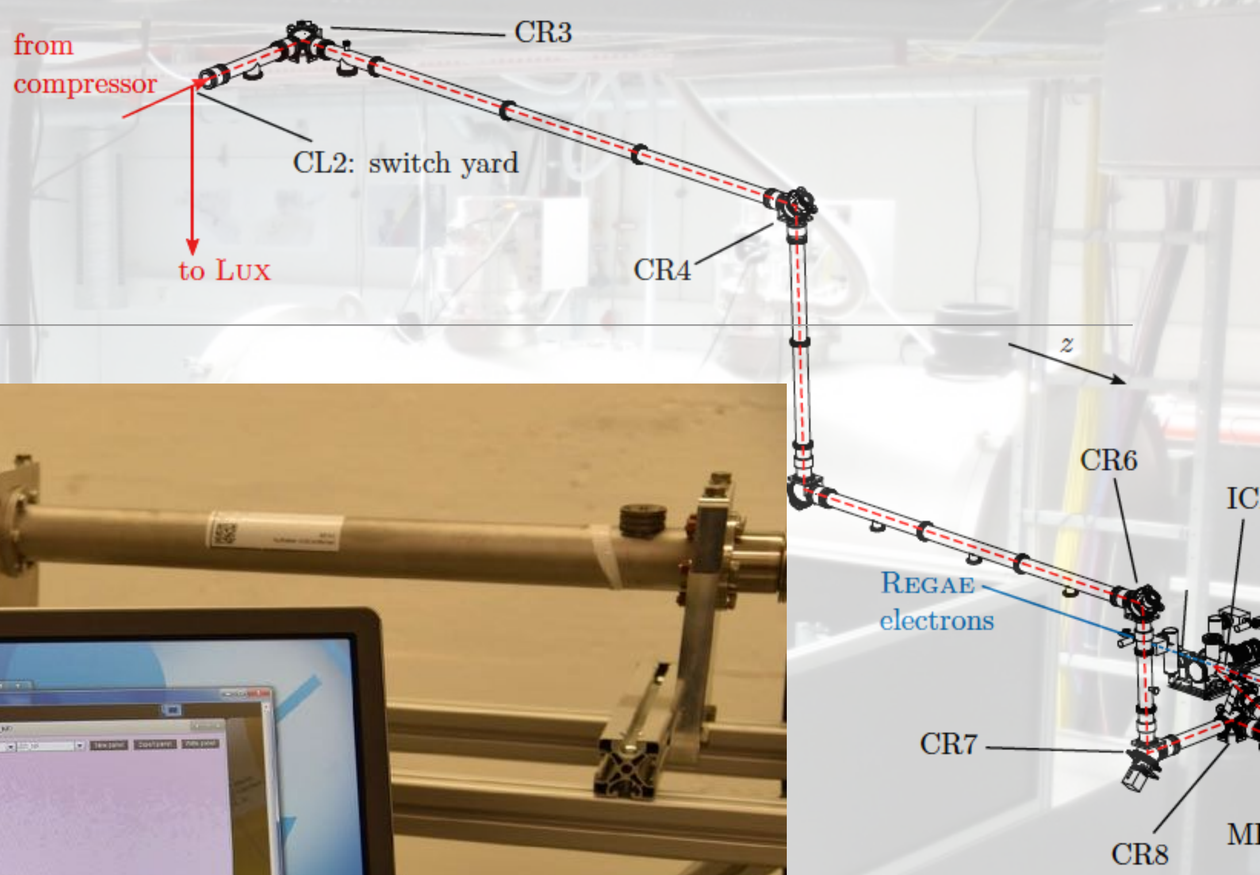
Laser Transport Beamline

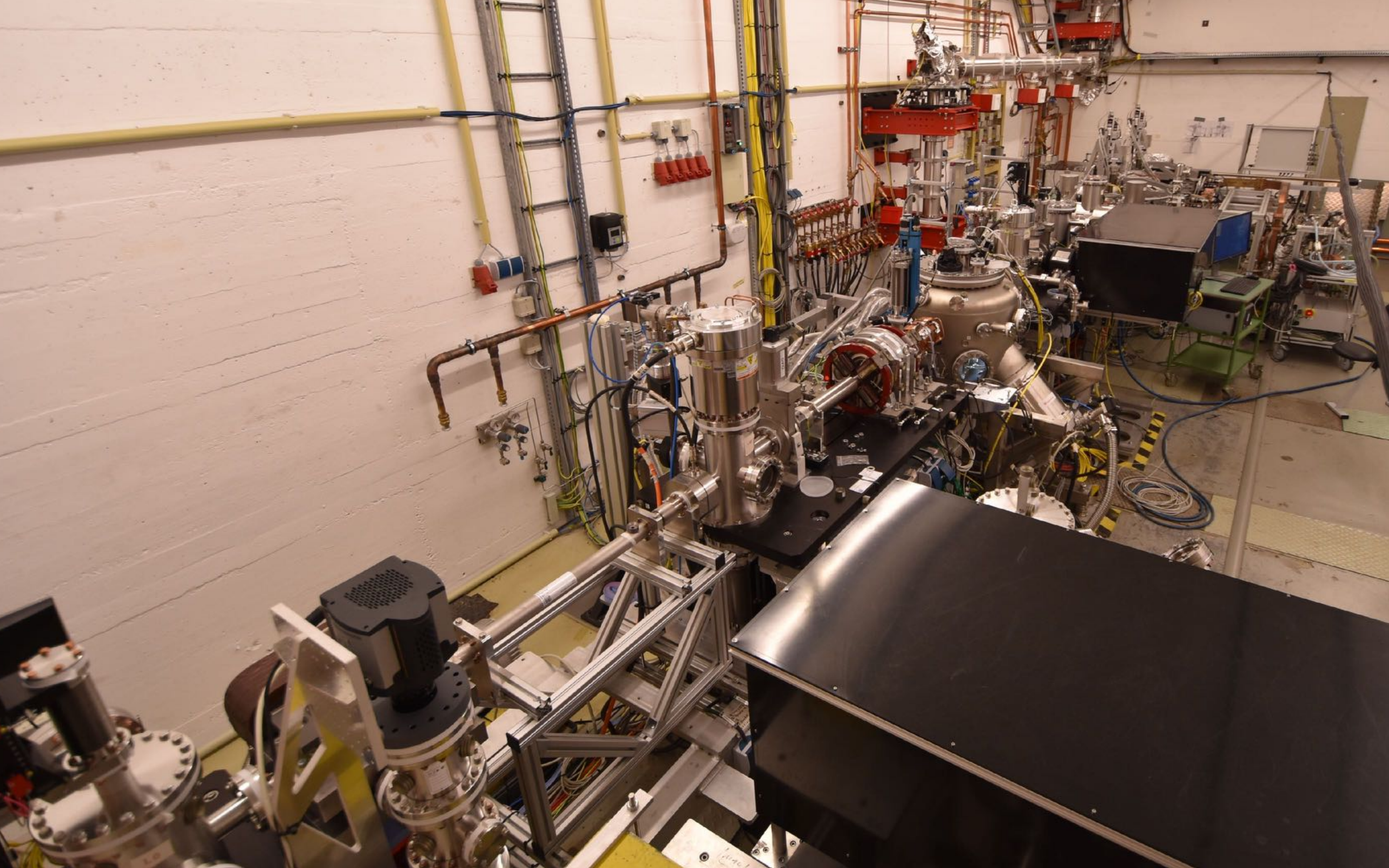




Laser Transport Beamline



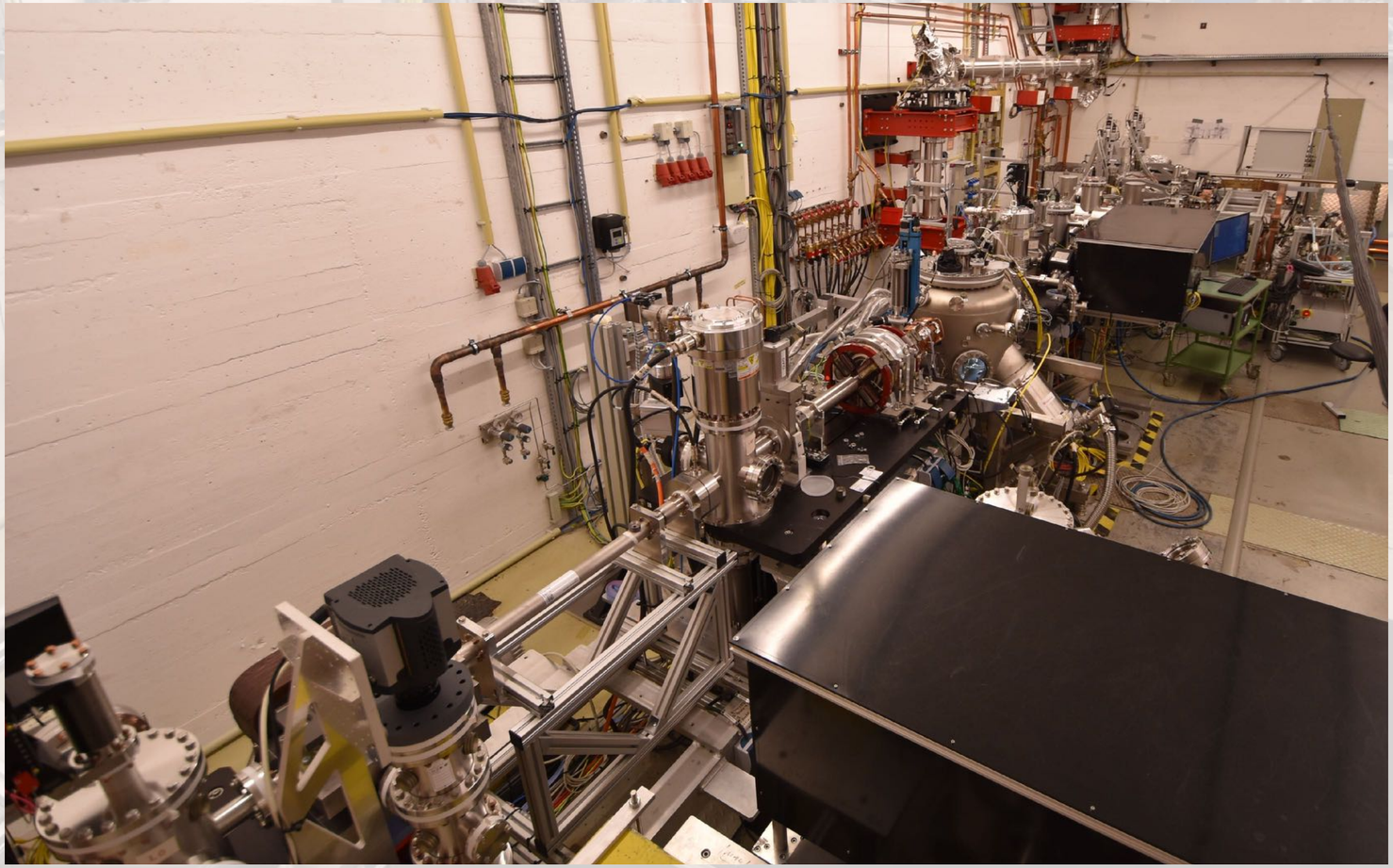




REGAE Beamline Upgrade: Summary

- REGAE beamline
  - interaction chamber
  - differential pumping
  - transverse deflecting structure
  - beam arrival cavity
  - additional klystron & modulator

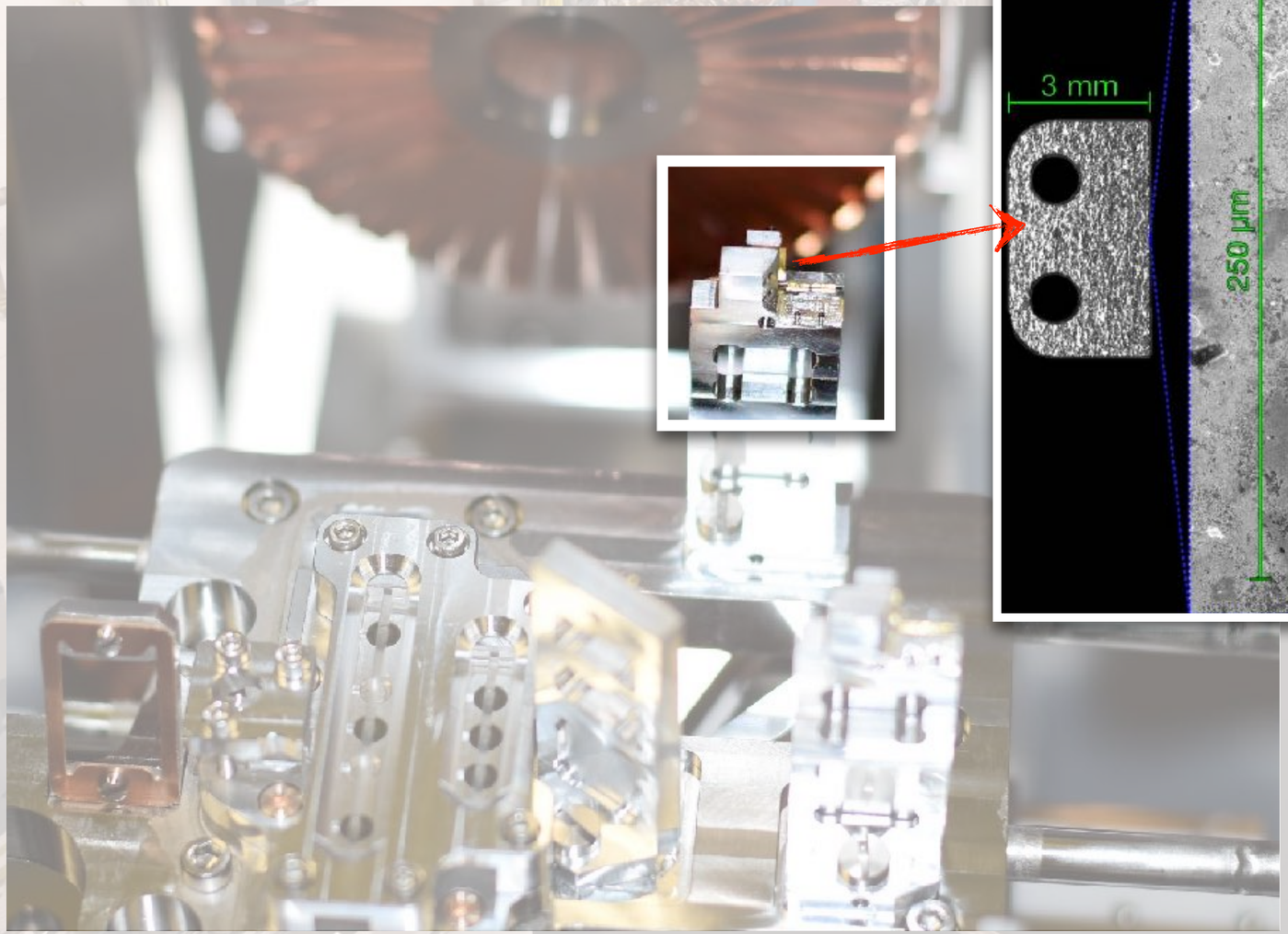
- laser transport beamline
  - connection to ANGUS vacuum system
  - final focusing chamber
  - in-coupling chamber
  - ANGUS beam in the tunnel
  - synchronization



First Shots: Knife Edge Scan

> transverse bunch profile diagnostics
  > similar to wire scanner
  > small beam diameters < 10 µm
    > high quality edges
    > high precision movement

> complementary diagnostics
  > transmitted signal
  > scattered signal



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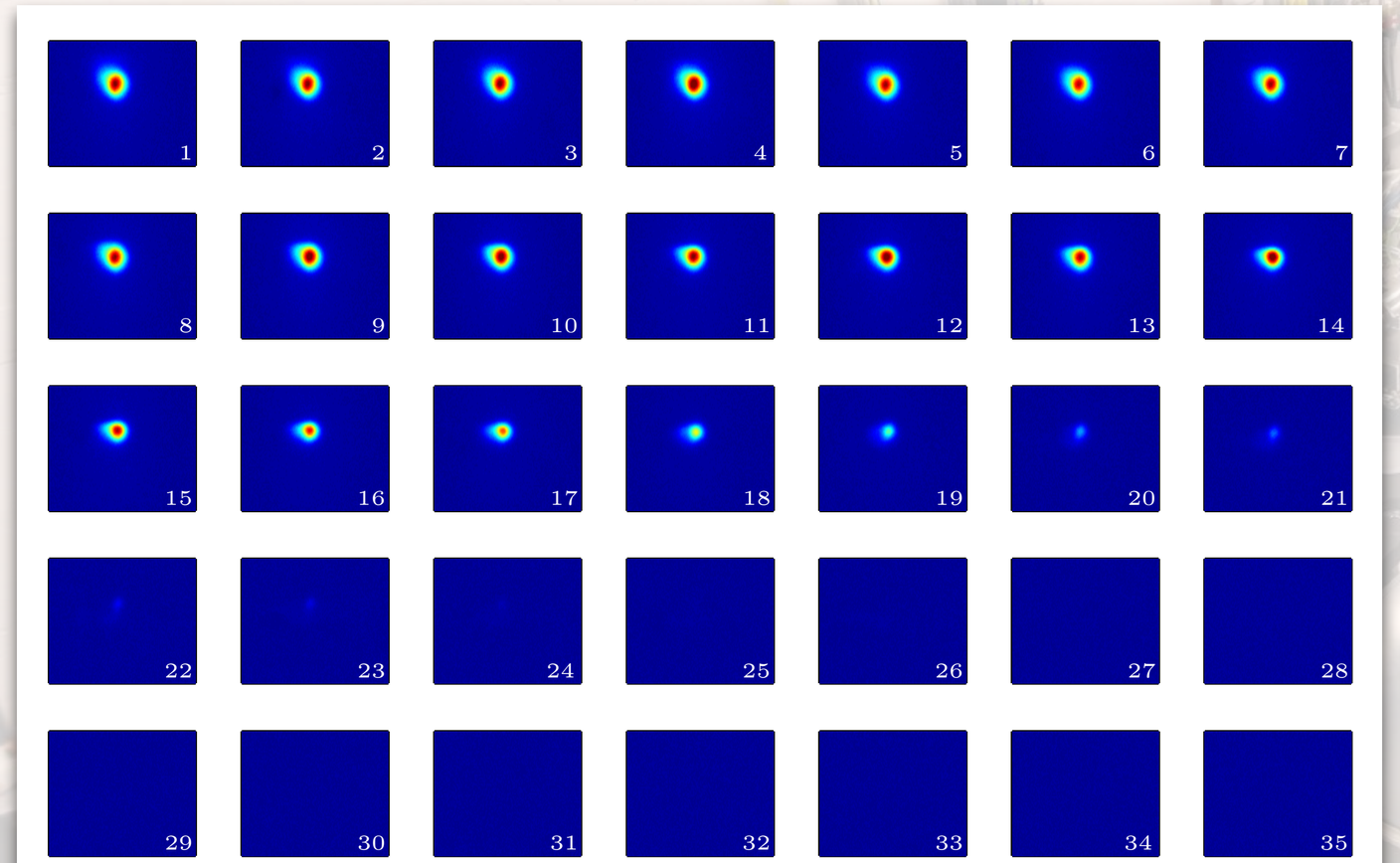
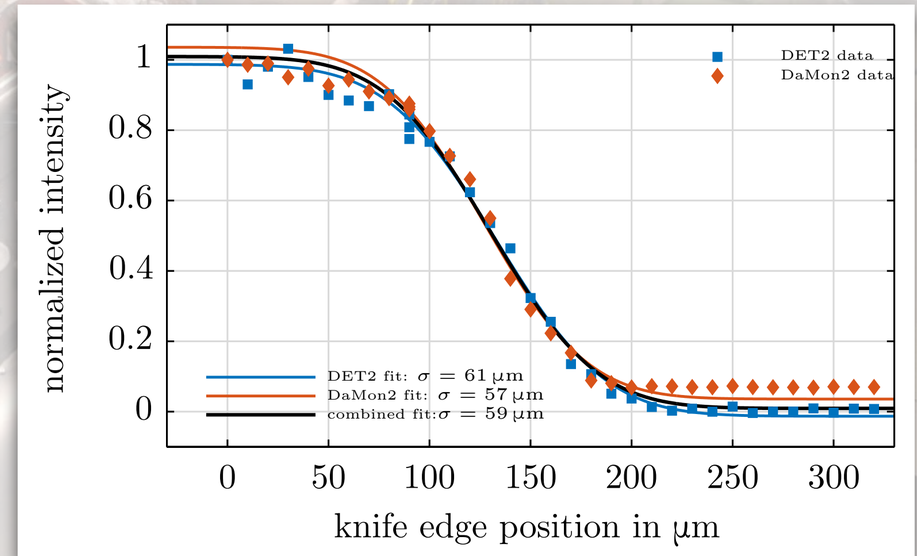




First Shots: Transverse Deflecting Structure

> collaboration with CANDLE

> parts machined at CANDLE

> cavity brazed at DESY

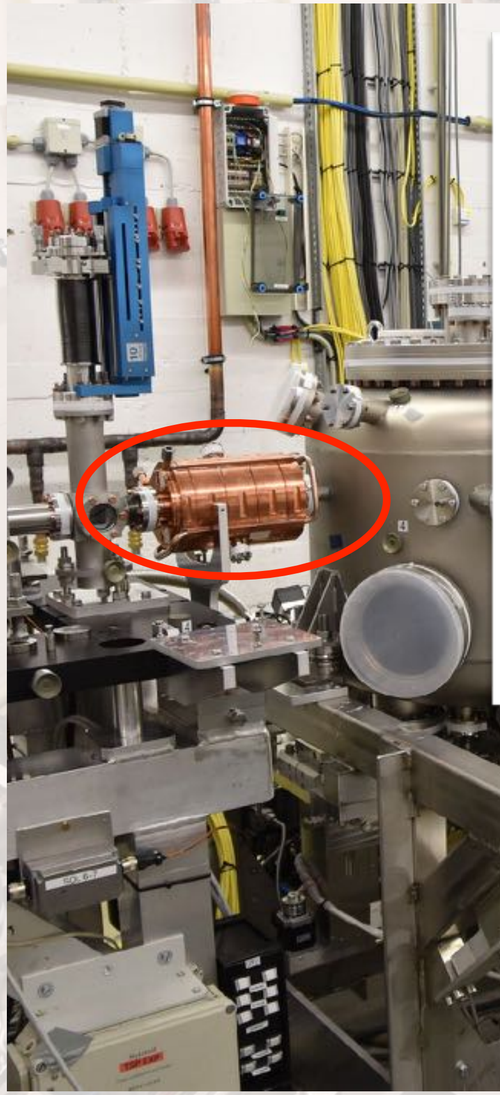
> design resolution: ~10 fs at 5 MeV

> no klystron: amplifier driven

> streaking voltage ~150 kV

> measurements:

> Ryan Stark & Max Hachmann



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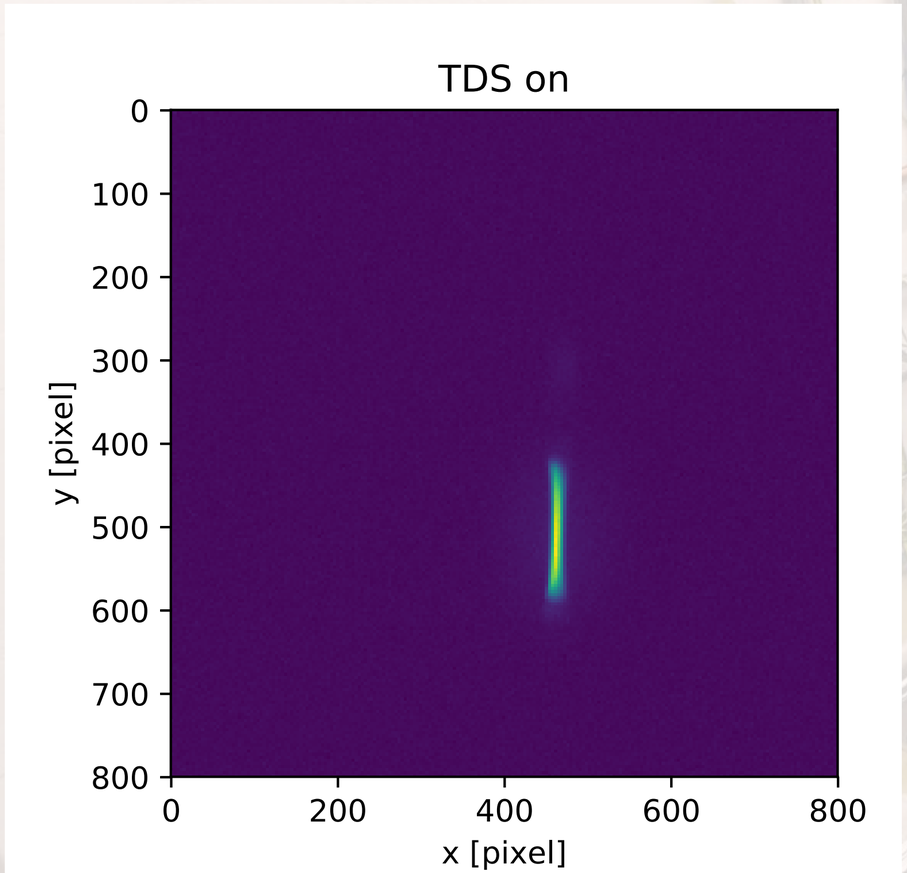
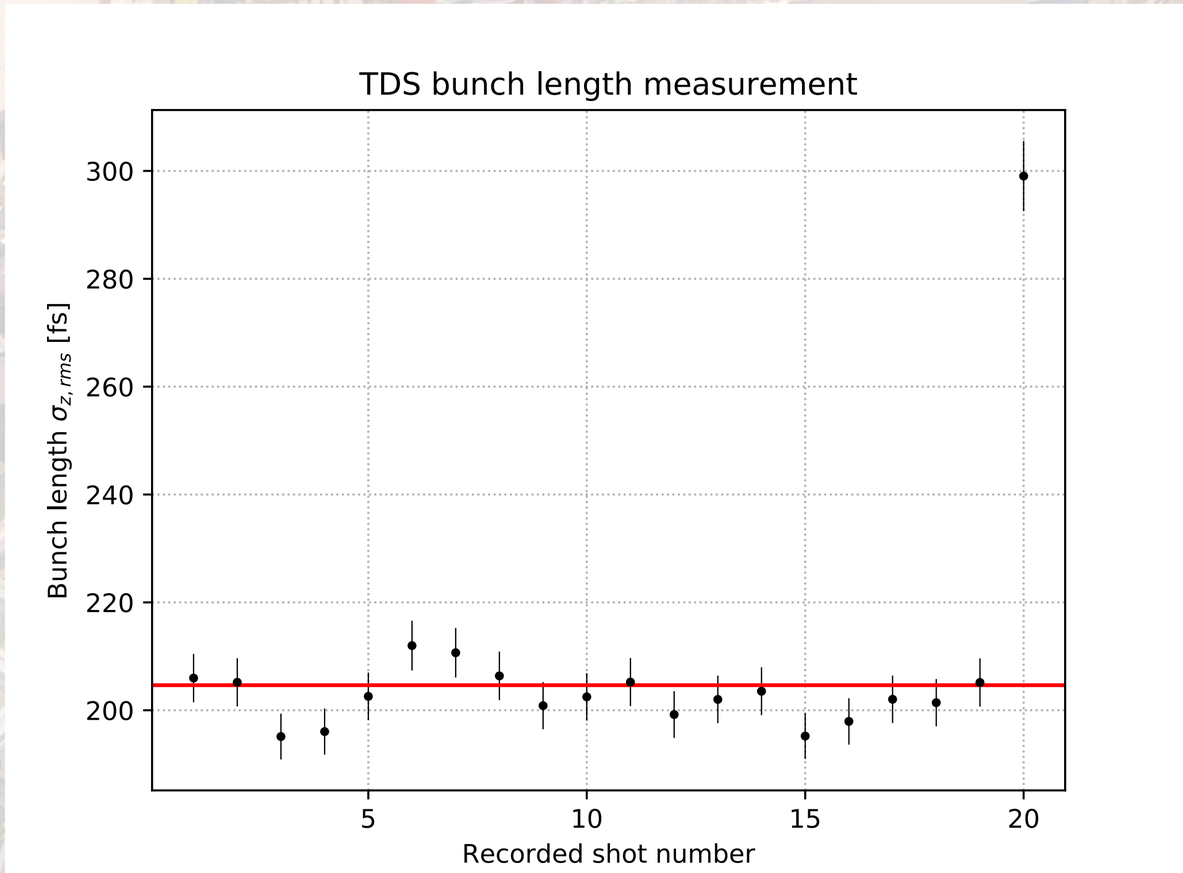




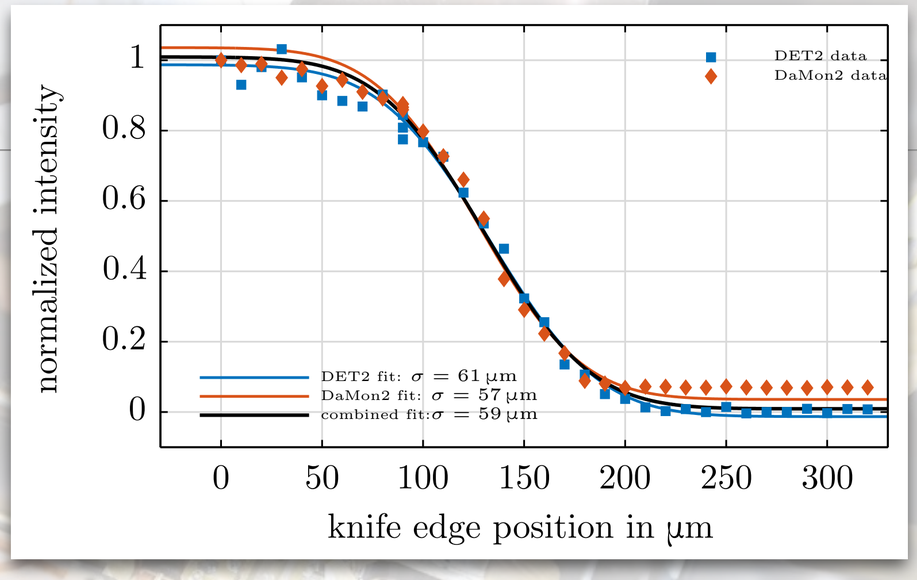
courtesy: Ryan Stark

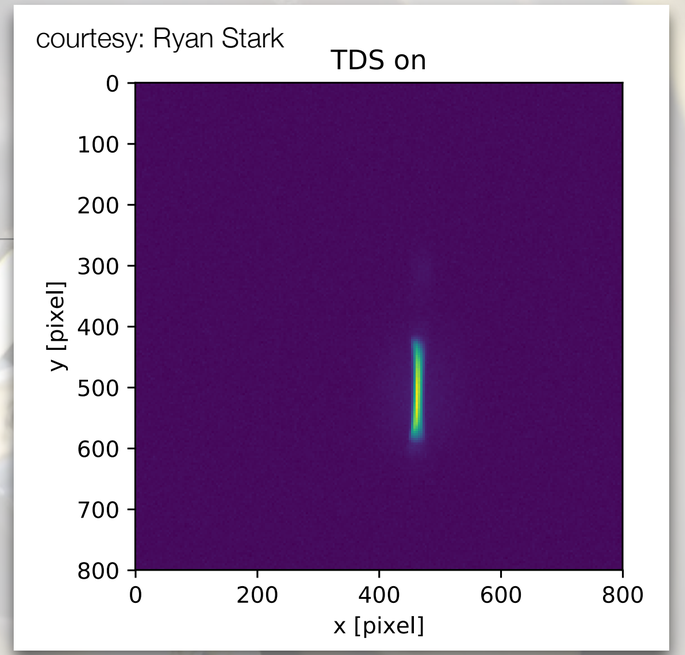
Conclusion

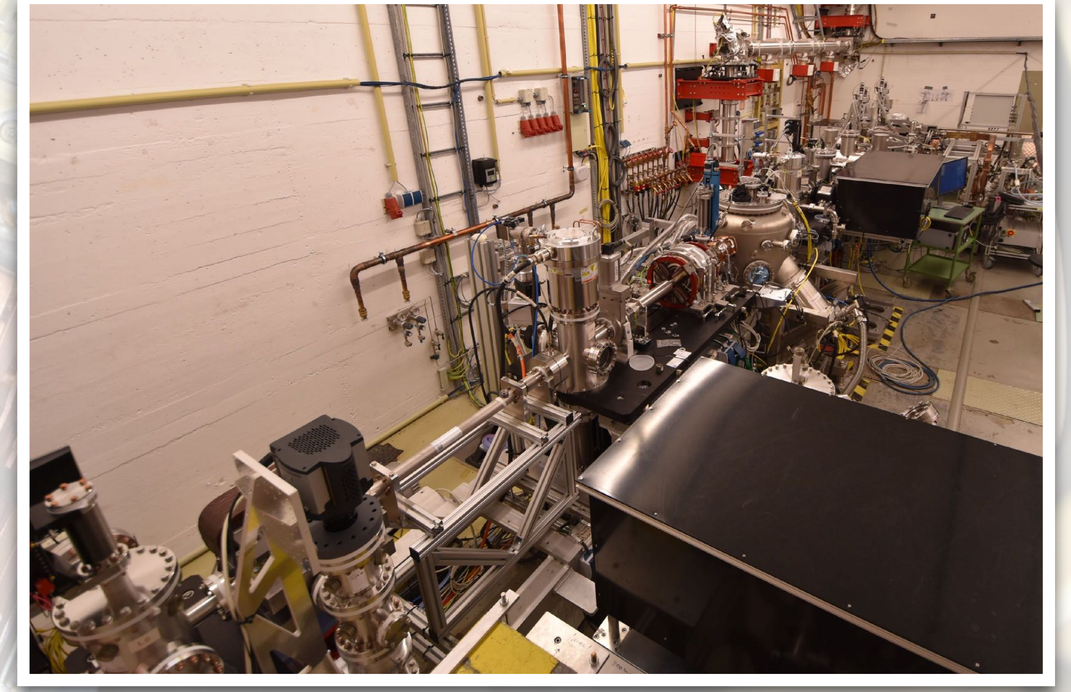
- REGAE beamline upgrade completed
  - commissioning in progress

- projects
  - external injection project
    - phase space linearization
    - (THz acceleration/diagnostics)

- test bed for future injection experiments
  - components: BAC, hexapods, (Si-)mirrors, …
  - concepts: synchronization, matching, electron-laser-overlap, in-coupling, differential pumping, THz, …







Thank you for your attention

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eli beamlines

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