

Status and future plans of PITZ

Photo Injector Test Facility at DESY in Zeuthen

Mikhail Krasilnikov for PITZ team
Virtual ARD ST3 Workshop, 23.09.2020

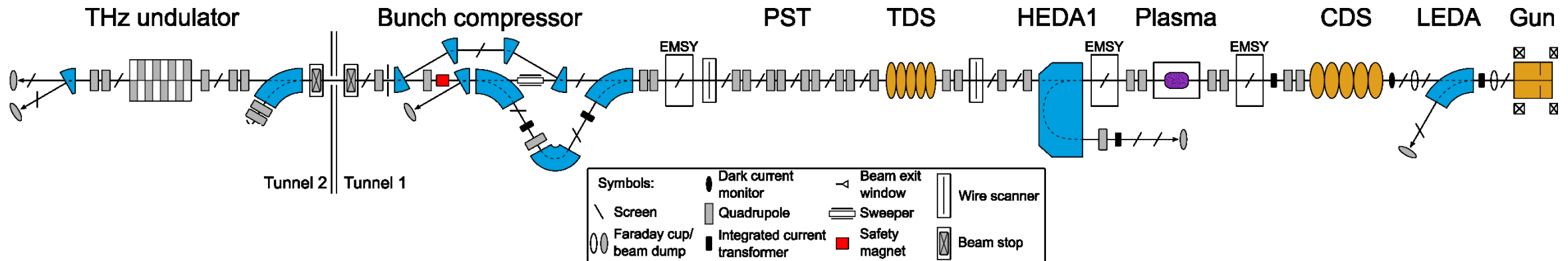


Photo Injector Test Facility at DESY in Zeuthen (PITZ)

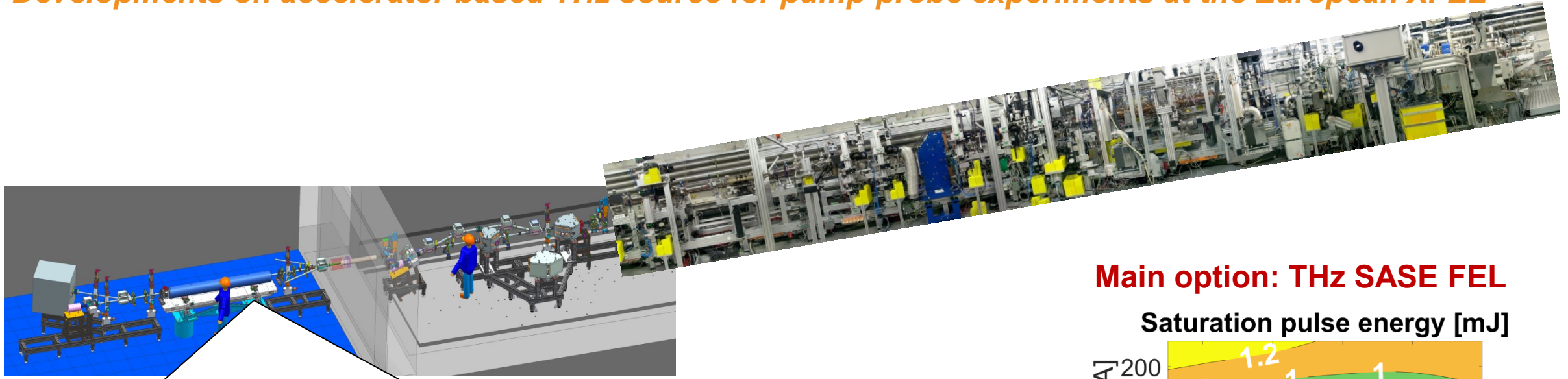
High brightness photo injector development, optimization and applications

- As **first machine @DESY: restarted operation** after COVID19 lock-down on 20.4.2020: efficiency of shift work is lower than before, e.g. due to separation of both shift persons, but → several run periods with extensive measurement program:
 - **Gun4.2** is running **stably**, usually 200 μs RF pulse length, up to 60 MV/m, >92% up time
 - Emittance reduction with **truncated Gaussian**
 - **THz@PITZ** → application of PITZ for THz SASE FEL, design finalized + several beam measurements
 - **Progress** on new **ELLA system**, also during COVID19 lock-down
 - **Cathode response time measurements**
 - **Thermal emittance measurements** at fresh and used Cs₂Te cathodes
 - ...
- **TDS klystron** was **exchanged** and put back into **operation**
- Further installations in the PITZ **tunnel annex (THz@PITZ)**



THz R&D at PITZ

Developments on accelerator based THz source for pump-probe experiments at the European XFEL

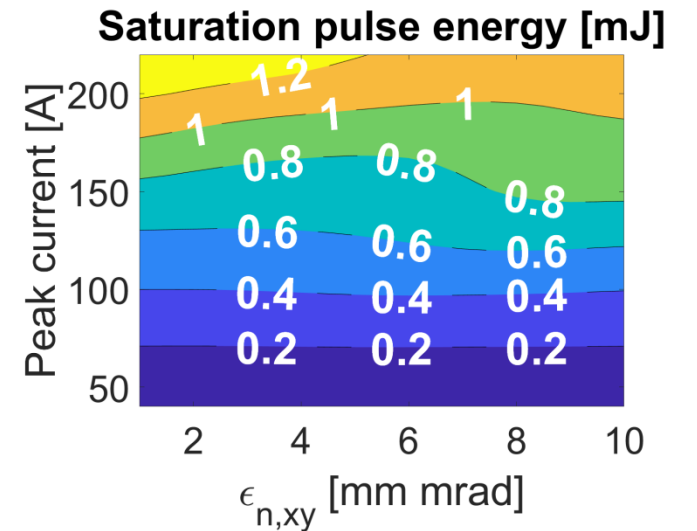


LCLS-I undulators (on load from SLAC)

Properties	Details
Type	fixed gap planar hybrid (NeFeB)
Nominal gap	6.8 mm
K-value	3.49
Support diameter / length	30 cm / 3.4 m
Vacuum chamber	11 mm x 5 mm
Period length	30 mm
Poles / a module	226 poles (= 113 periods)
Total weight w/o vac. chamber	1000 kg



Main option: THz SASE FEL



Sat. pulse energy: 0.1 – 1.2 mJ
Sat. length: 3.5 – 8 m

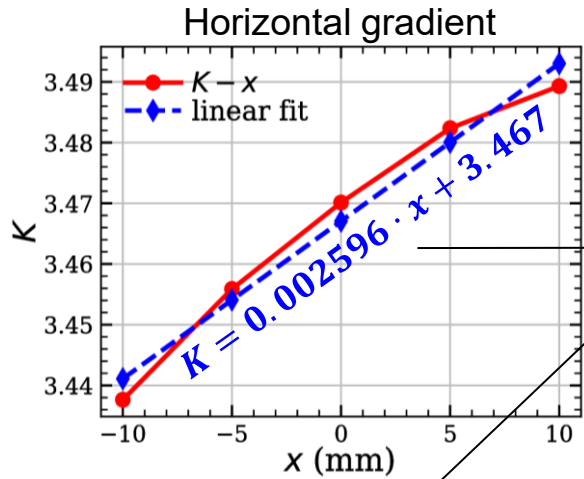
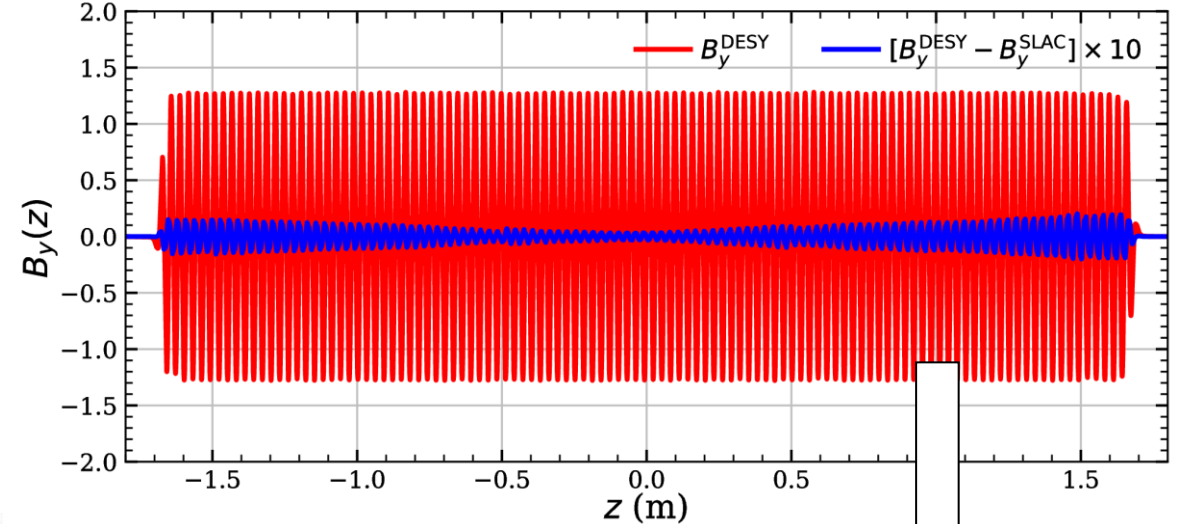
LCLS-I undulator field measurement at DESY in Hamburg



Horizontal field gradient implementation

- Two **LCLS-I** undulators have arrived at Hamburg in August 2019
- The fields of the undulator **L143-112000-26** have been re-measured at DESY Hamburg and are **consistent** with SLAC measurement (discrepancy < 0.02 T)
- However, the **transverse gradient** will lead to an off-axis (~25 mm) trajectory in the horizontal plane; **steering coils** will be considered to correct it

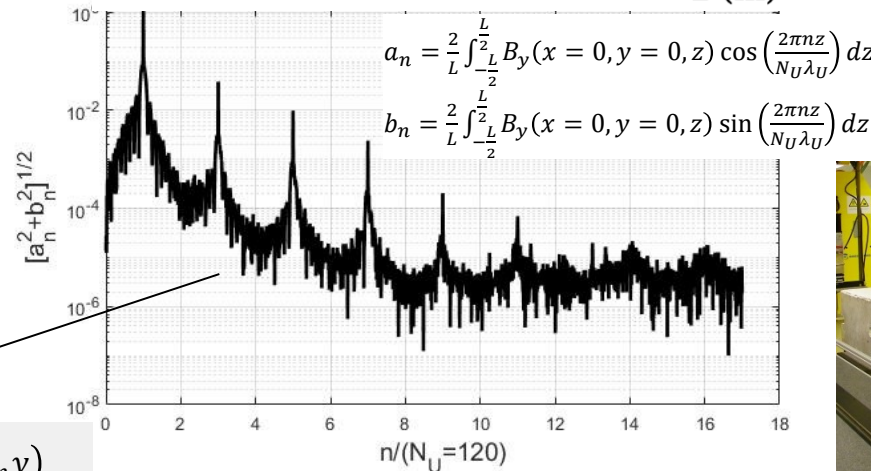
On-axis B_y along the 3.4 m undulator



$$\frac{B_y(x, y, z)}{B_0} \propto \frac{\cosh[k_x(x_0 + x)]}{\cosh[k_x x_0]}$$

$$x_0 \approx 1.33\text{m}$$

$$k_x \approx 0.916\text{ m}^{-1}$$



$$a_n = \frac{2}{L} \int_{-\frac{L}{2}}^{\frac{L}{2}} B_y(x=0, y=0, z) \cos\left(\frac{2\pi n z}{N_U \lambda_U}\right) dz$$

$$b_n = \frac{2}{L} \int_{-\frac{L}{2}}^{\frac{L}{2}} B_y(x=0, y=0, z) \sin\left(\frac{2\pi n z}{N_U \lambda_U}\right) dz$$

FT

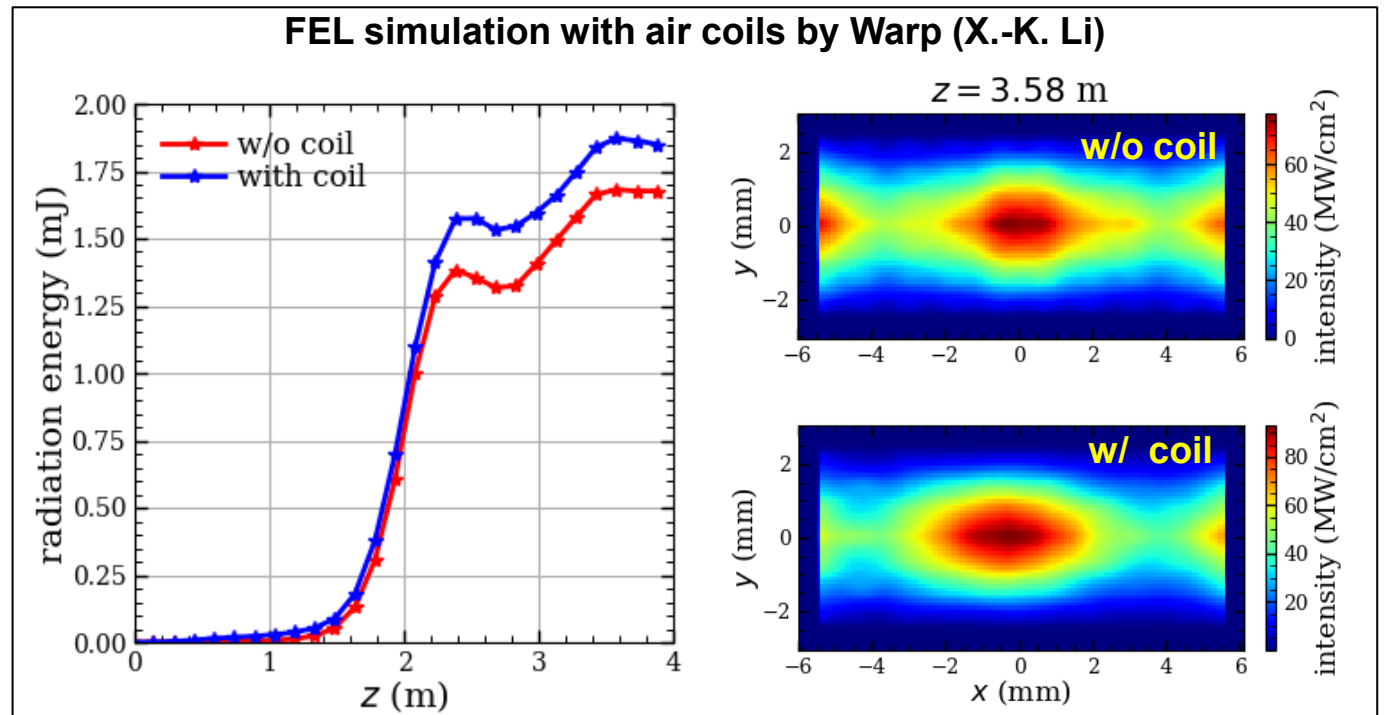
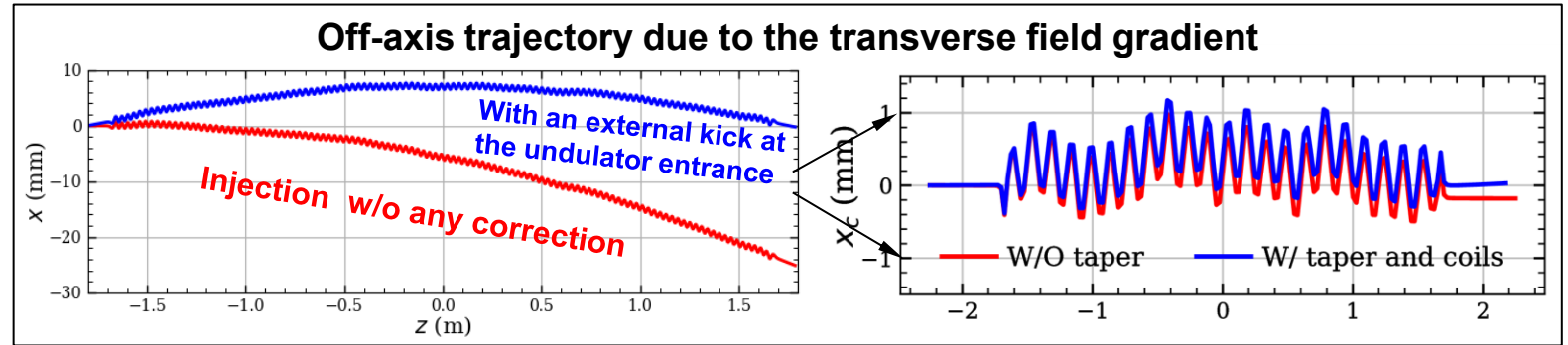
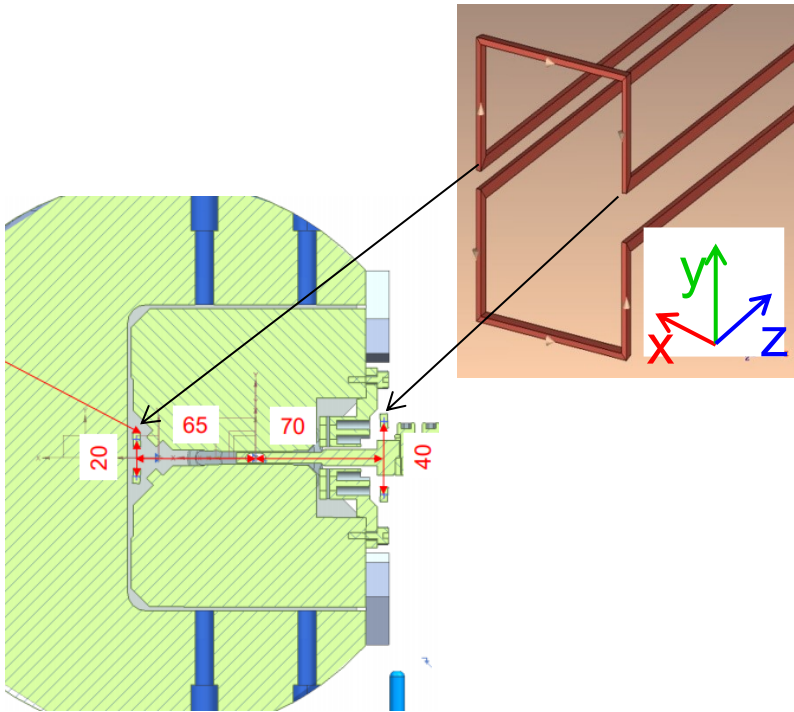


$$\chi(x, y, z) = -\frac{\cosh[k_x(x_0 + x)]}{\cosh[k_x x_0]} \cdot \sum_{n=1}^{N_h \cdot N_U} \{a_n \cos(k_{zn} z) + b_n \sin(k_{zn} z)\} \cdot \frac{\sinh(k_{yn} y)}{k_{yn}}$$

3D Field map $\vec{B} = -\frac{\partial \chi}{\partial \vec{r}}$, including horizontal gradient

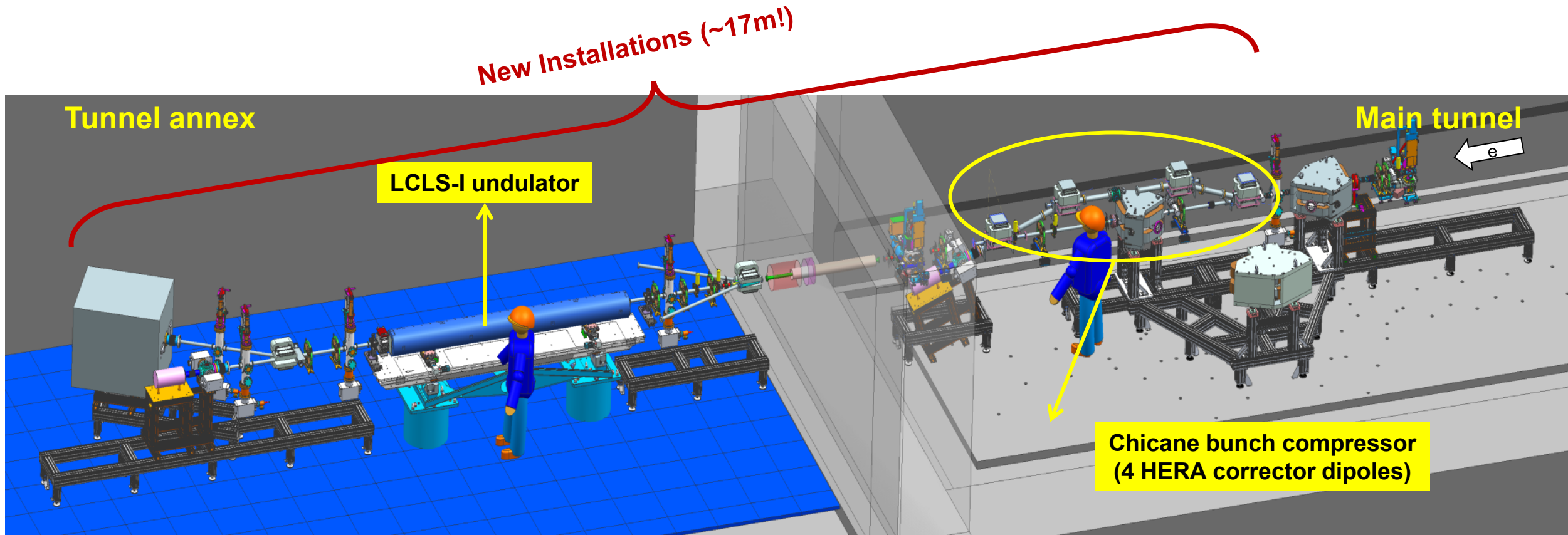
Design and modeling of correction coils

Horizontal undulator gradient impact onto beam transport and FEL



PITZ-4 Setup for THz generation

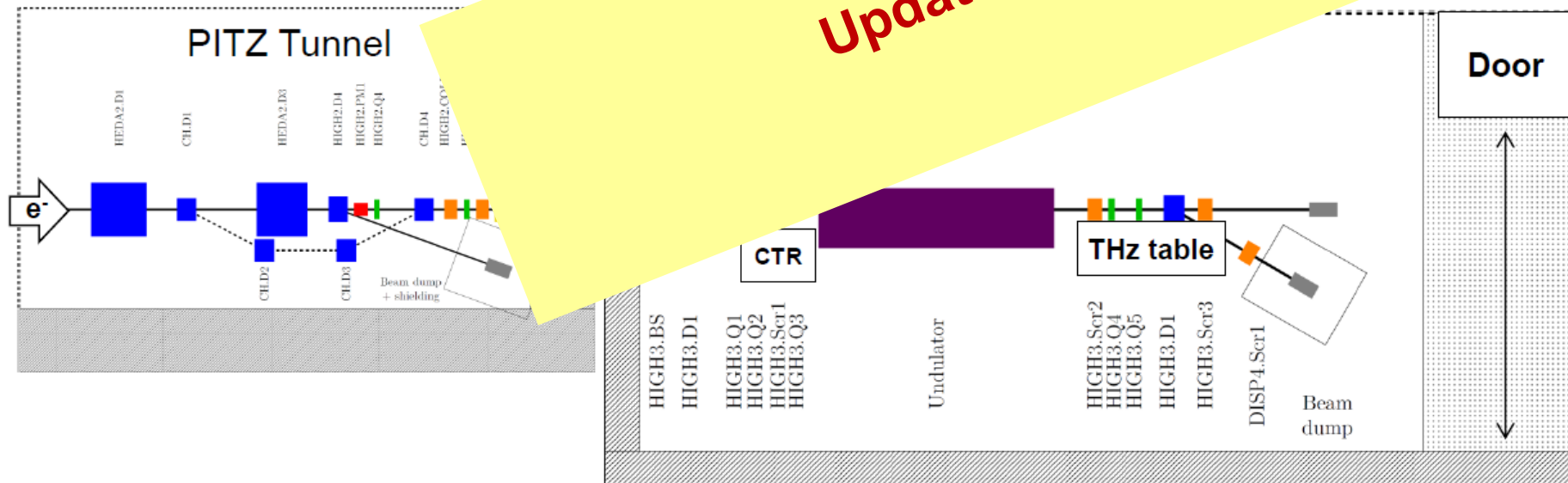
PITZ Beamline Upgrade for THz Proof-of-principle Experiments



PITZ-4 Setup for THz@PITZ

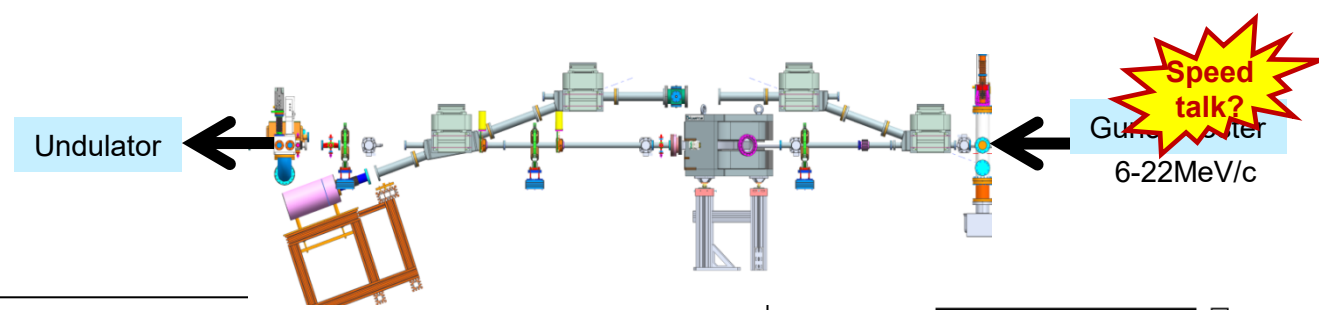
Beamline technical design and Infrastructure

- **Layout of beam line fixed, parts are being built**
 - Design of screen stations and THz diagnostic setup started
 - **Crane** installed, infrastructure setup ongoing (cabling, network and gas distribution)
 - **Personal interlock** installed & tested, waiting for TÜV approval
 - Magnetic field of **LCLS-I undulator** was measured in HH
 - New support structure for undulator designed, order placed
 - First stage of **radiation safety concept** for screen stations and THz table, design of components (e.g. beam shutters)
 - Simulations on radiation safety concept
- department in HH,

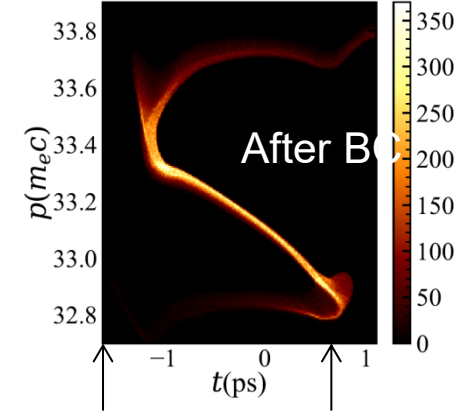
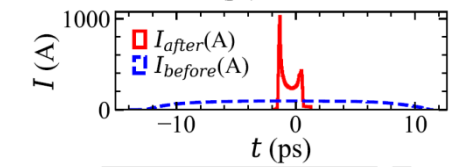
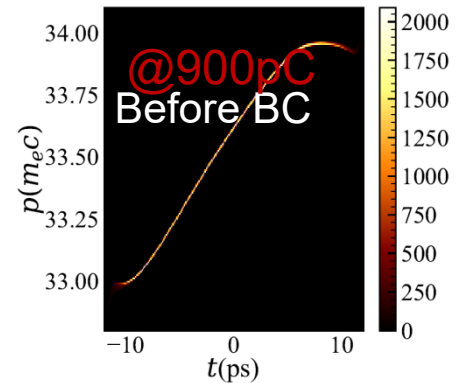
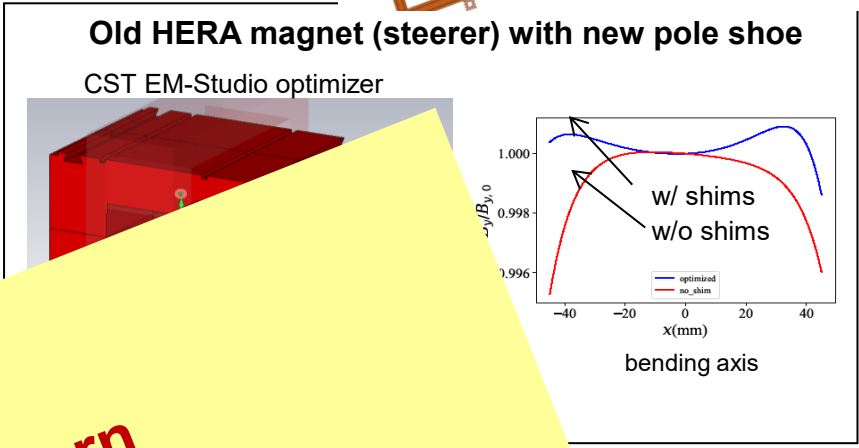


PITZ Bunch compressor

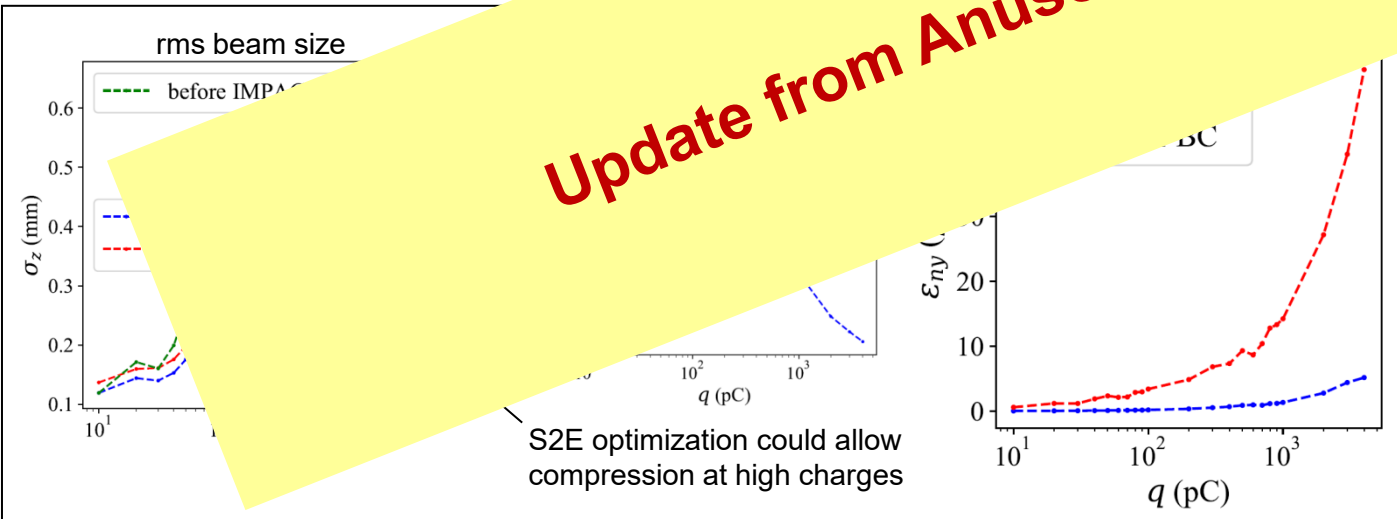
Magnetic chicane based on HERA steerers



- To optimize for **SASE**
 - high averaged currents, longer than cooperation length
 - high charge, longitudinal flat-top and Gaussian
- To support tuning **seeded FEL** (by Photocathode laser pulse modulation)
- To optimize for **superradiant**
 - short bunch length
 - relatively low charge 10pC-1nC, longitudinal Gaussian
- To optimize for low-Q sub-ps high-repetition application (~1pC)



Update from Anusorn

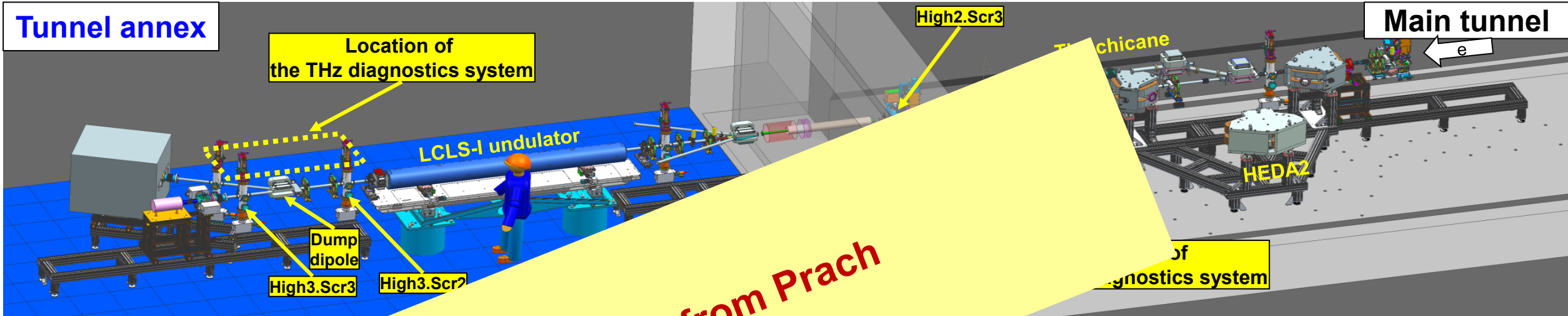


Conclusions and outlook:
...

Simulations:
Anusorn Lueangaramwong

THz Radiation Diagnostics systems for PITZ-4

Design considerations are ongoing



- ### The THz diagnostics system in the tunnel annex
- Two screen stations for electron bunch length and energy spread measurements for coupling FEL radiation to the THz diagnostics system:
 - Radiation power / energy
 - Transverse distribution / polarizations
 - Spectral distributions (interferometer setup)

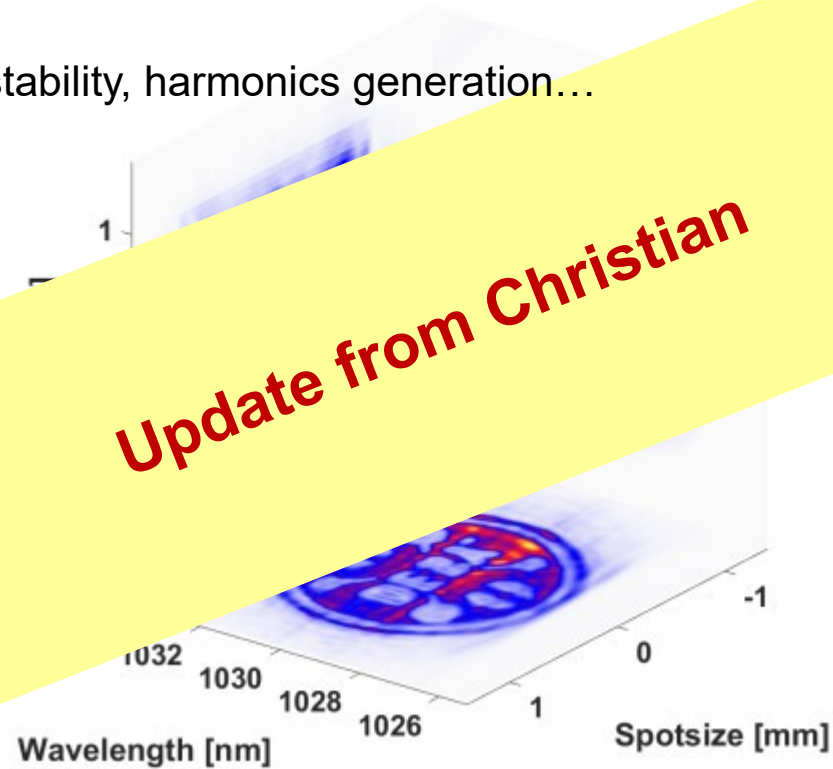
- ### The THz diagnostics system in the main tunnel
- A screen station (High2.Scr3) located downstream from the chicane is used as a CTR station for electron bunch length and compression efficiency measurements:
 - *Relative* radiation power / energy
 - Spectral distributions (interferometer setup)

ELLA Progress

R&D on Photocathode laser system for 3D pulse shaping

- Motivation (short)
- 2 setups (SLM and VBG)
- Challenges: shape preservation, stability, harmonics generation...
- Resent findings/results
- Outlook (plans)

Update from Christian

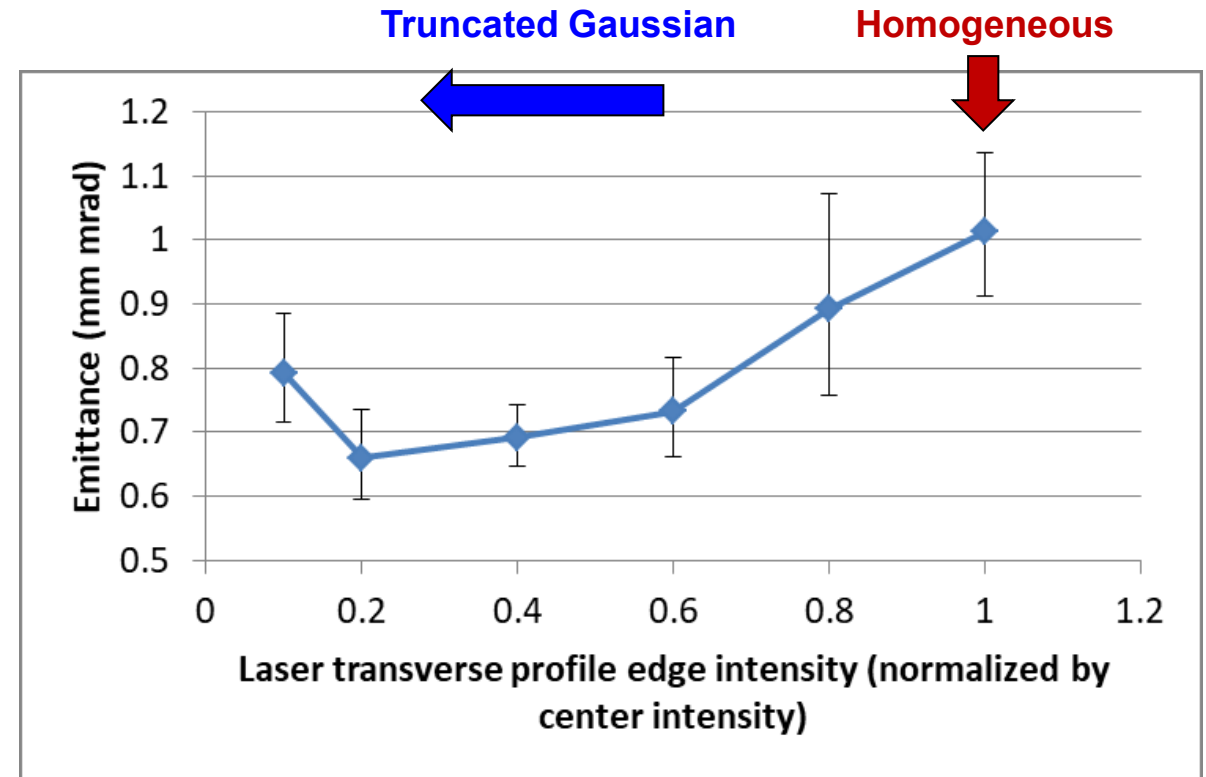
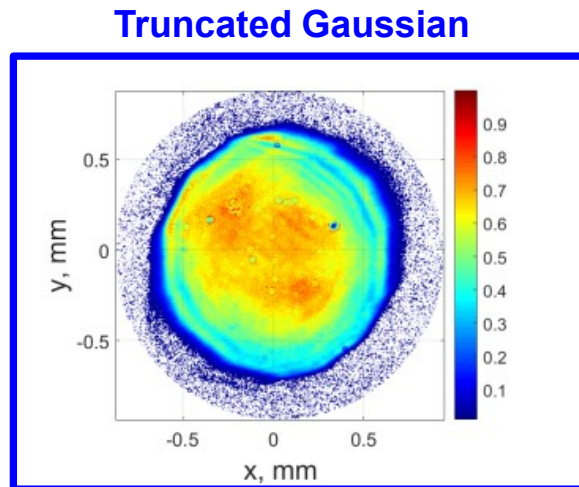
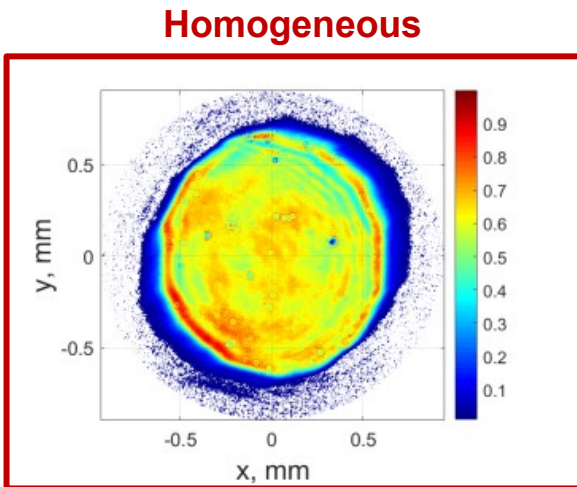
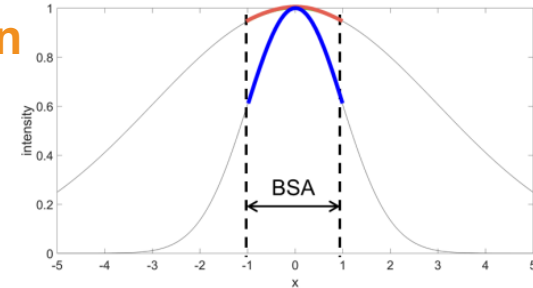


Emittance measurements with truncated Gaussian pulses

Idea: transverse truncation leads to lower emittance and better efficiency (less cutting)

Projected emittance measurements:

- Laser temporal: 6 ps (FWHM) Gaussian
- Bunch charge: 500pC
- Gun: 6.3 MW_p (~60 MV/m)
- Electron momentum after booster: 20 MeV/c
- Beam shaping aperture (BSA) diameter: 1.3mm



34% emittance improvement!

- 15% for 250 pC bunch charge



Slice Emittance Measurements at PITZ

Slit scan with TDS and quads applied

- Method
- Challenges
- Recent results

Update from Raffael

Cathode Response Time measurements



Measuring electron bunch lengthening during emission

- Method (single shot, interferometer in Pharos, ...)
- Challenges (low charge, thorough beam transport/focusing...)
- Recent results: **Cathode response time measurements** for 5 Cs₂T (5, 10, 15 nm from INFN, 10nm fresh and used from ... and 2 metal cathodes (Mo and Au))

? Disclaimer for not published results ?

Update from Gregor, Houjun

(Near) Future Plans: Gun5 at PITZ

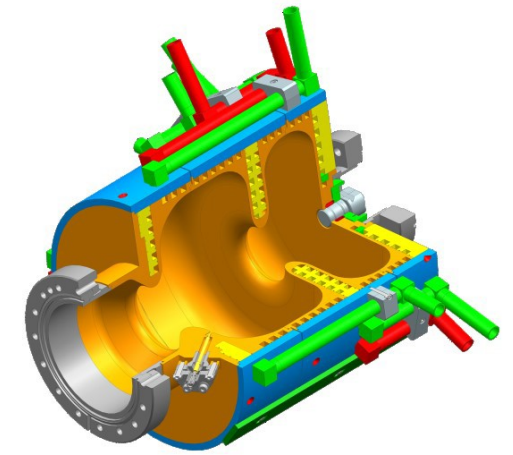
Gun5 fabrication, installation and tests

- Gun5 allowing longer bunch trains for FLASH and XFEL has high priority to reach longer RF flat-tops (up to **1 ms**) for providing more bunches to users at FLASH and European XFEL.
- New cavity **design** (**elliptic** shape including **cathode hole transition** and extended cooling)
- Further developments of the LLRF system (**RF pick**)
- Due to COVID-19 workflows had to be re-organized (reduced communication etc.) → slow progress

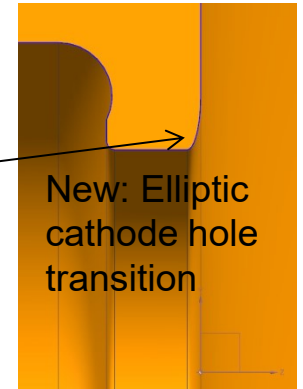
Status:

- RF-surface for cathode
- Stainless steel jacket delivered for final machining
- Vacuum flanges waiting for delivery
- Timeline:
 - ??September: final braze, tuning → dry ice cleaning,
 - ??October: start of set up, Leuthen, installation at PITZ

Update from Sebastian (and Frank)



and cathode



New: Elliptic cathode hole transition



Central iris part with outer machining before brazing stainless steel jacket

Conclusions and Outlook

Status and future plans of PITZ

Thank you

Plan of the Talk

+ Speed talks proposals



- Short introduction to PITZ facility (1-2 slides):
 - operation during COVID-19
 - main current activities
- THz at PITZ project progress (5-6 slides):
 - Introduction (proof of principle for pump-probe THz source) =1 slide
 - LCLS-I undulator measurements in Hamburg, horizontal gradient modeling, compensation coil design) =2 slides [Speedtalk?]
 - PITZ-4 Setup for THz@PITZ (layout, 3D view, installations in tunnel, technical status) = 1 slide → Tobias
 - Bunch compressor design = 1 slide → Anusorn [Speedtalk?]
 - THz diagnostics design = 1 slide → Prach [Speedtalk?]
- ELLA progress =1 slide → Christian
- Truncated Gaussian shaping =1 slide → Matthias [Speedtalk]
- Slice emittance =1 slide → Raffael
- Cathode response time (1-2 slides) → Houjun, Gregor, Ye [Speedtalk?]
 - Setup
 - Highlight results
- Upcoming: gun5 highlights and installation plans = 1 slide → Sebastain (+Frank)
- Conclusions and outlook = 1 slide