First Experimental Characterization of Electron Beams for THz Studies at PITZ.

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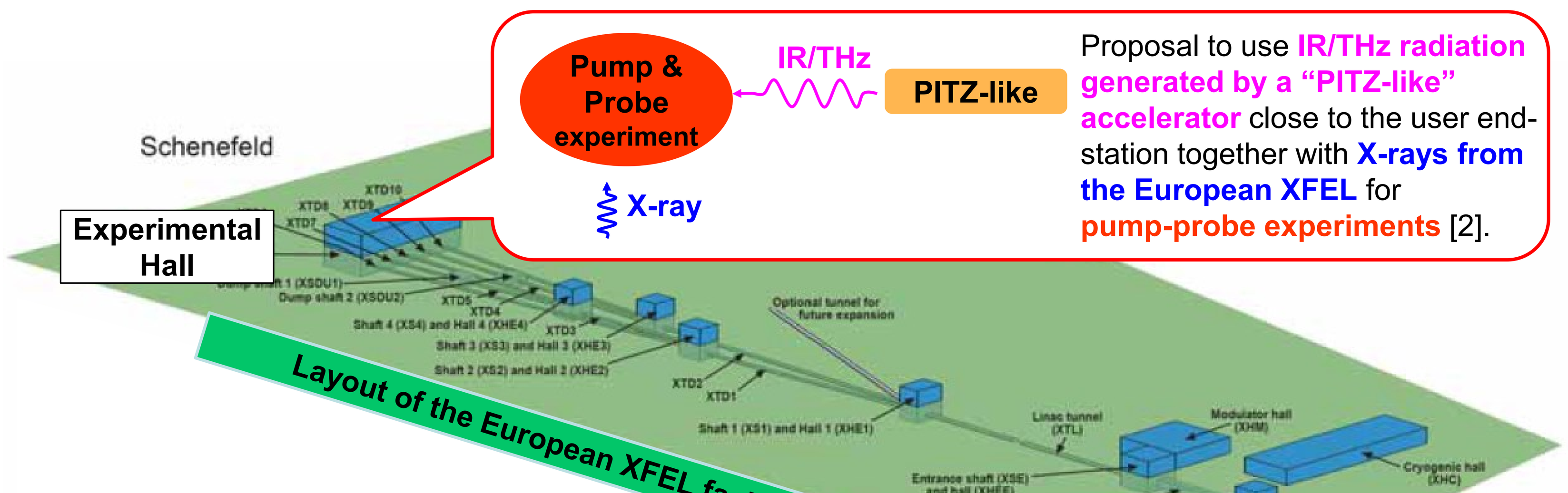
Introduction



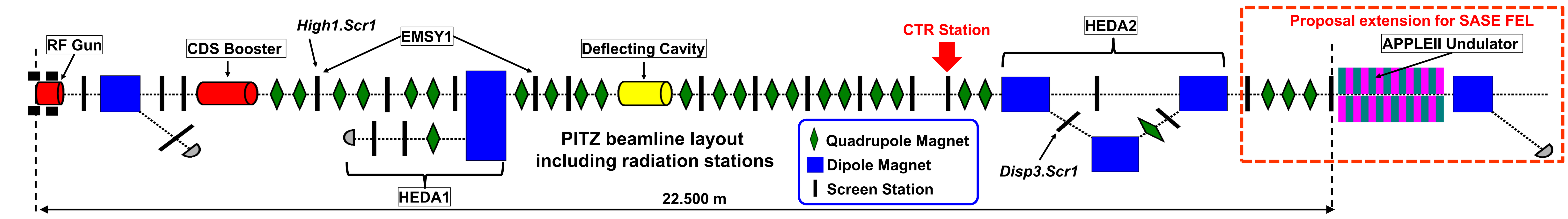
Proposal to use IR/THz radiation generated by a "PITZ-like" accelerator close to the user end-station together with X-rays from the European XFEL for pump-probe experiments [2].

References
[1] Eu XFEL Tech. Design report 2007
[2] E.A.Schneidmiller et. al, WED55, FEL2012

Advantages of this concept

- The proposed facility can be located next to the user end-stations allowing to conduct pump-probe experiments with **X-ray, IR/THz, optical laser** and **ultra-short electron pulses**.
- Time synchronization accuracy with the X-ray pulses ~$\sigma(100\text{ fs})$.
- Possible to generate IR/THz radiation with
  - Different methods
  - Different temporal and spectral patterns
  - Different polarizations
  - Wide wavelength tunability
  - high pulse energy

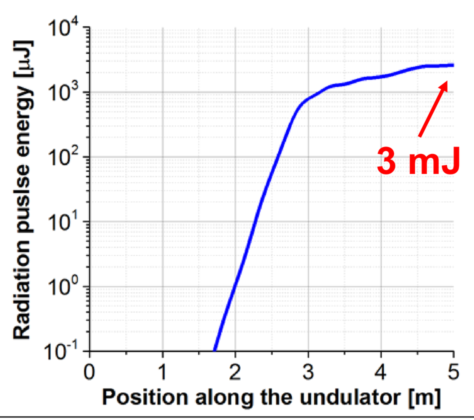
PITZ accelerator is an ideal machine for the development of such IR/THz source → **2 options of radiation have been studied:**
- **SASE FEL**
- **Coherent Transition Radiation (CTR)**



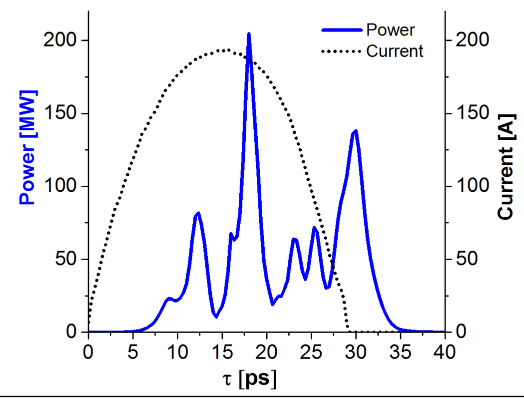
Radiation Calculations from Start-to-End Beam Dynamics Simulations

SASE FEL radiation for a radiation wavelength of **100 µm (3 THz)** was calculated using the GENESIS1.3 code. An electron beam with **4 nC** bunch charge, **~20 ps** pulse length (FWHM) and **15 MeV/c** mean momentum and a helical undulator with **40 mm** period length were used for the calculation.

Pulse energy along the undulator axis.

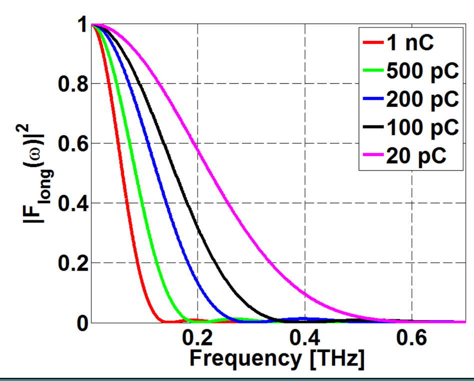


Temporal profiles of the radiation pulses at the saturation points (the dash line represents the beam current profile at the undulator entrance).

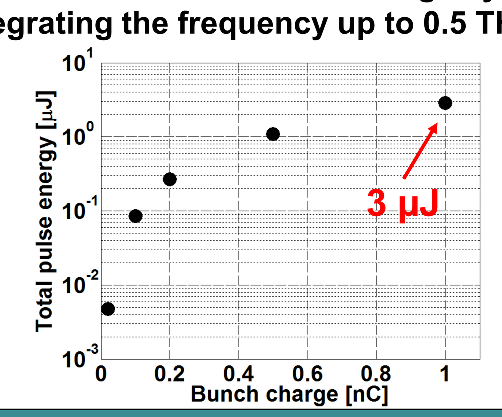


CTR was calculated by the generalized Ginzburg-Frank formula [S.Casalbuoni, TESLA Report 2005-15]. A short-bunch (**~2.5 ps** FWHM) electron beams compressed by velocity bunching using the booster and a circular metallic screen with a radius of **15 mm** were used for the calculation.

Square of the form factors of the compressed bunch at the CTR station.



Calculated total radiation energy as a function of the bunch charge by integrating the frequency up to 0.5 THz.



Velocity Bunching Measurements for CTR Option

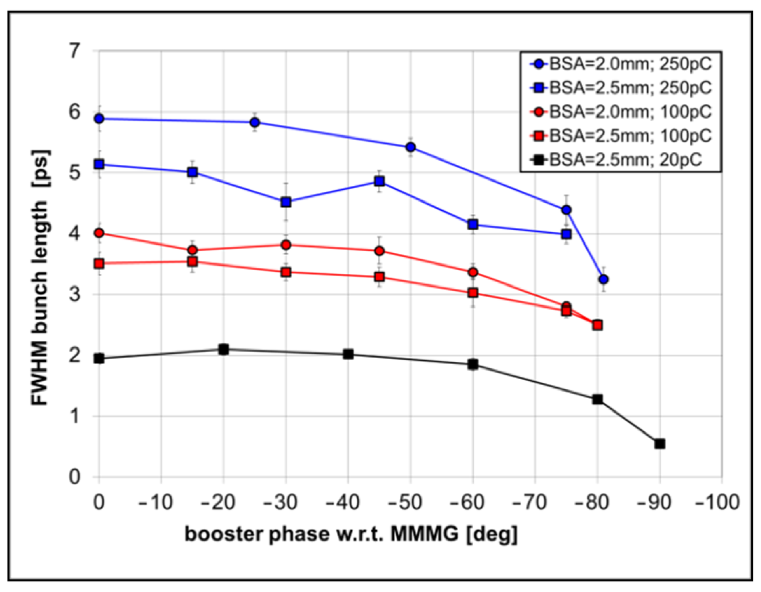
Machine Parameters	
Laser pulse shape	Gaussian
Laser temporal length	~2.5 ps FWHM
BSA	2.0, 2.5 mm
Peak power of RF in the gun	6.3 MW
Peak power of RF in the booster	2.7 MW
Gun phase*	0 degree
Booster phase*	0 to -90 degree
Bunch charge	20, 100, 250 pC

*w.r.t. Maximum Mean Momentum gain (MMMG) phase

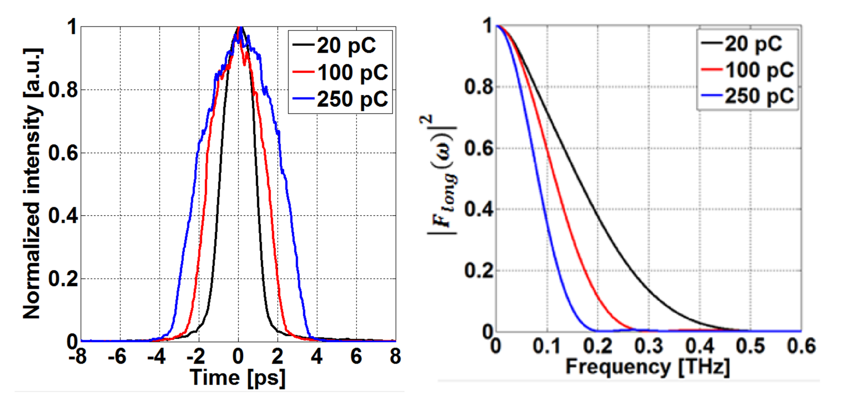
- The electron bunches are compressed by velocity bunching using the booster cavity.
- The deflecting cavity is used for measuring the electron bunch lengths.
- The radiation energy from CTR is directly proportional to the square of the longitudinal form factor of the electron bunch (F_{long}) which is the Fourier transform of the function that describes the longitudinal charge profile (ρ_{long}) and can be calculated by the following equation:

$$F_{long}(\omega) = \int_{-\infty}^{\infty} \rho_{long}\, exp(-i\omega t)dt$$

The measured FWHM bunch length as a function of booster phase for the different bunch charges and the different BSA sizes.



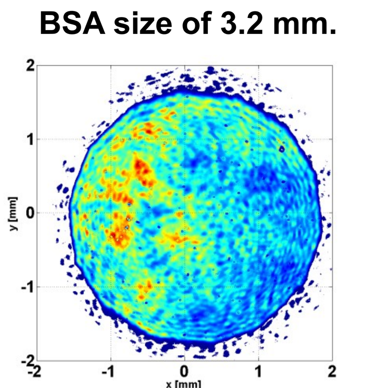
The selected longitudinal beam profiles measured by using the deflecting cavity (20,100 and 250 pC for BSA size of 2.5 mm and booster phase of -60 degree) and the corresponding calculated square of the form factors.



4nC Electron Beam Measurements for SASE FEL Option

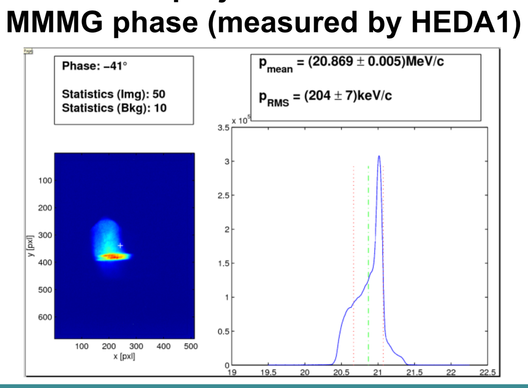
Machine Parameters	
Laser pulse shape	Gaussian
Laser temporal length	~11 ps FWHM
Laser BSA size	3.2 mm
Peak power of RF in the gun	6.0 MW
Peak power of RF in the booster	2.8 MW
Gun phase w.r.t. MMMG phase	0 degree
Booster phase w.r.t. MMMG phase	0 degree

The transverse profile of laser on VC2 camera for the BSA size of 3.2 mm.



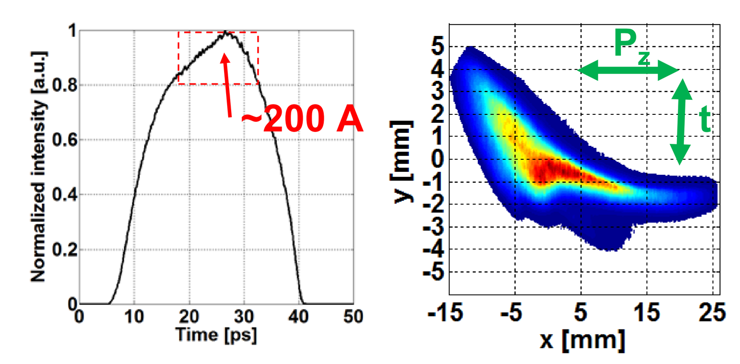
Momentum Measurement

Momentum projection at the booster MMMG phase (measured by HEDA1)



Measurements of Longitudinal Profiles

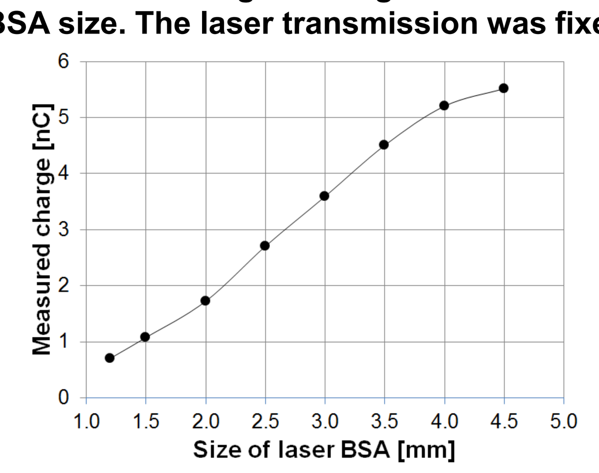
Measured by the deflecting cavity and HEDA2



The measured longitudinal profile of the 4 nC electron beam (left) and the image of the streaked beam at Disp3.Scr1 in the HEDA2 section (right).

Test of Generating High Bunch Charge

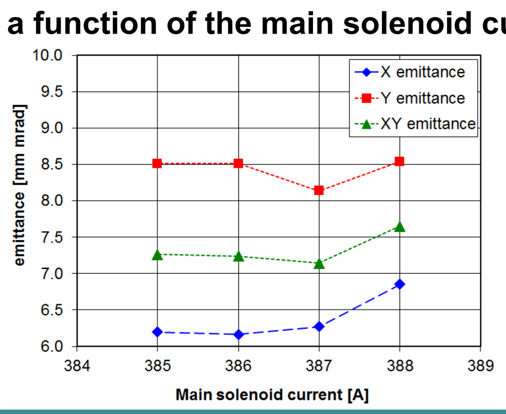
Measured bunch charge at the gun exit as a function of laser BSA size. The laser transmission was fixed at 70%.



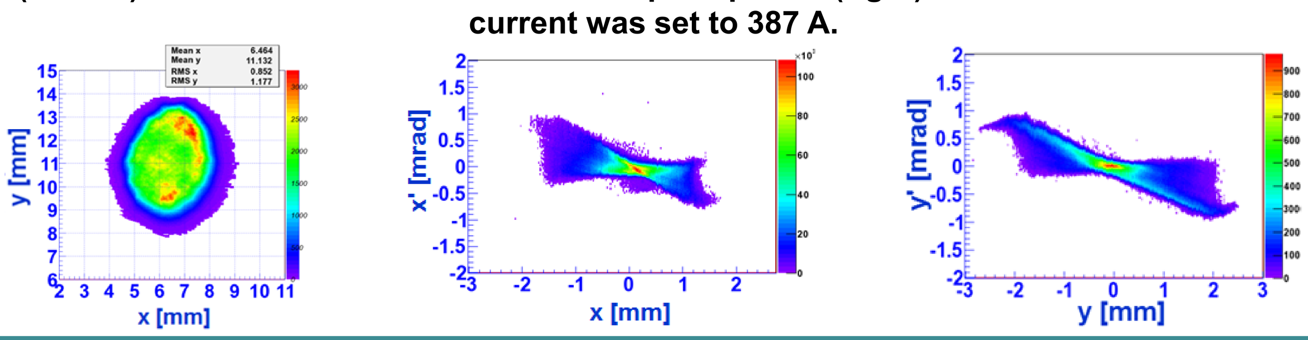
Transverse Emittance Measurement

Measured by EMSY1 (single Slit Scan Technique)

Measured normalized transverse emittance as a function of the main solenoid current.



The electron beam profile at High1.Scr1 (left), the measured horizontal trace space profile (middle) and the measured vertical trace space profile (right) when the main solenoid current was set to 387 A.



PITZ Photo Injector Test Facility Zeuthen
HELMHOLTZ GEMEINSCHAFT

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