Experimental Reports:
CTR Transverse Profile Measurements

Prach Boonpornprasert

PITZ Physics Seminar

08.04.2021

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

PITZ Photo Injector Test Facility Zeuthen

DESY

Outline

- Overview of the Experiments
- Realignment of the THz Measurement Station
- Experimental Results
  - Pulse Energy Measurements (beam transport preaparation)
  - Transverse Profile Measurements
  - Polarization Measurements
- Checking for Near-Filed and Far-Field Regions
- Roughly Checking with THzTransport Simulation
- Issues with Booster Phase
- Summary & Outlook

Overview of the Experiments

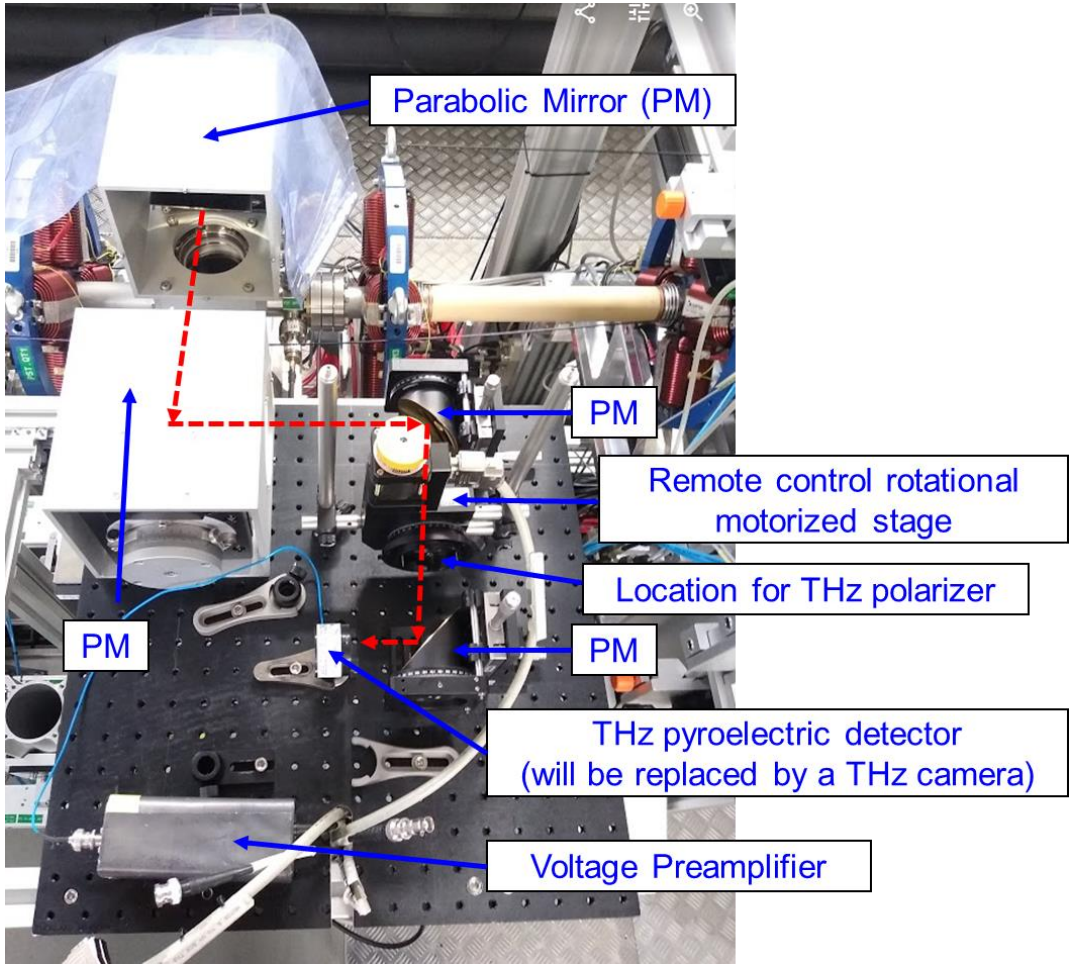
- Time in total ➔ 6 shifts (20210321N, 20210322M, 20210322A, 20210322N (0.25), 20210323A(0.25), 20210323N, 20210324A (0.5), 20210325N)
- Machine & beam parameters
  - MBI laser, BSA = 2.0 mm, ~~temporal short Gaussian (~ 2.5 ps)~~ ➔ long Gaussian (~7 ps)
  - Maximum beam momenta: 6.6 MeV/c and 21.8 MeV/c
  - Φ_{gun} is fixed at MMMG phase, $\Phi_{booster}$ is scanned for velocity bunching
  - Bunch charge of 250 pC and 1 nC

1. Pulse energy measurements (beam transport preparation)
   - CTR, CDR (hole), CDR (gap)
   - 250 pC, 1 nC
   - $\Phi_{booster}$ SP = MMMG, MMMG+30°, MMMG+60°, MMMG+80°
2. Transverse profile measurements
   - CTR, CDR (hole), CDR (gap)
   - 1 nC
   - $\Phi_{booster}$ SP = ~MMMG+77° (full compression phase)
3. Polarization measurements
   - CTR, CDR (hole)
   - 1 nC
   - $\Phi_{booster}$ SP = ~MMMG+77° (full compression phase)

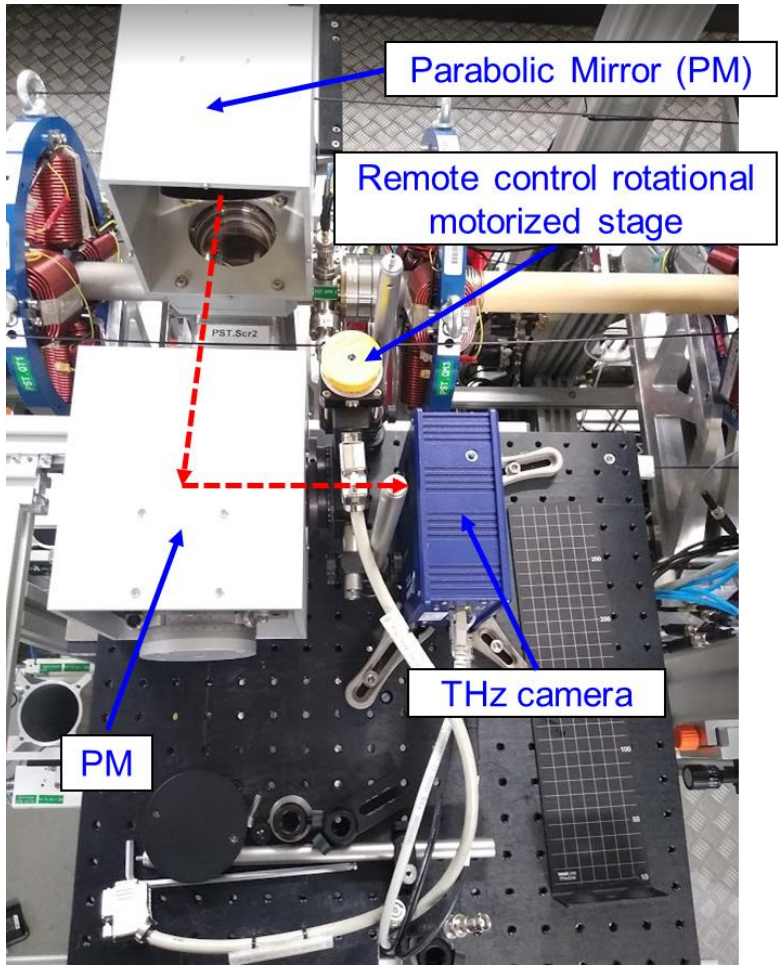
Realignment of the THz Measurement Station

- **Unsuccessful measurements with the 4-parabolic-mirrors layout, no THz beam found on Pyrocam**
- **Realigned to be the 2-parabolic-mirrors layout, found THz beams and finished the program**

The 4-parabolic-mirrors layout



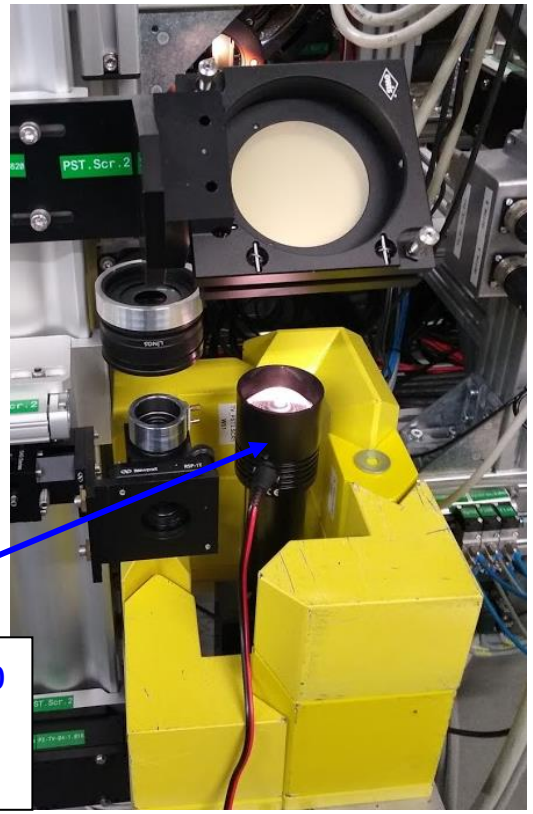
The 2-parabolic-mirrors layout



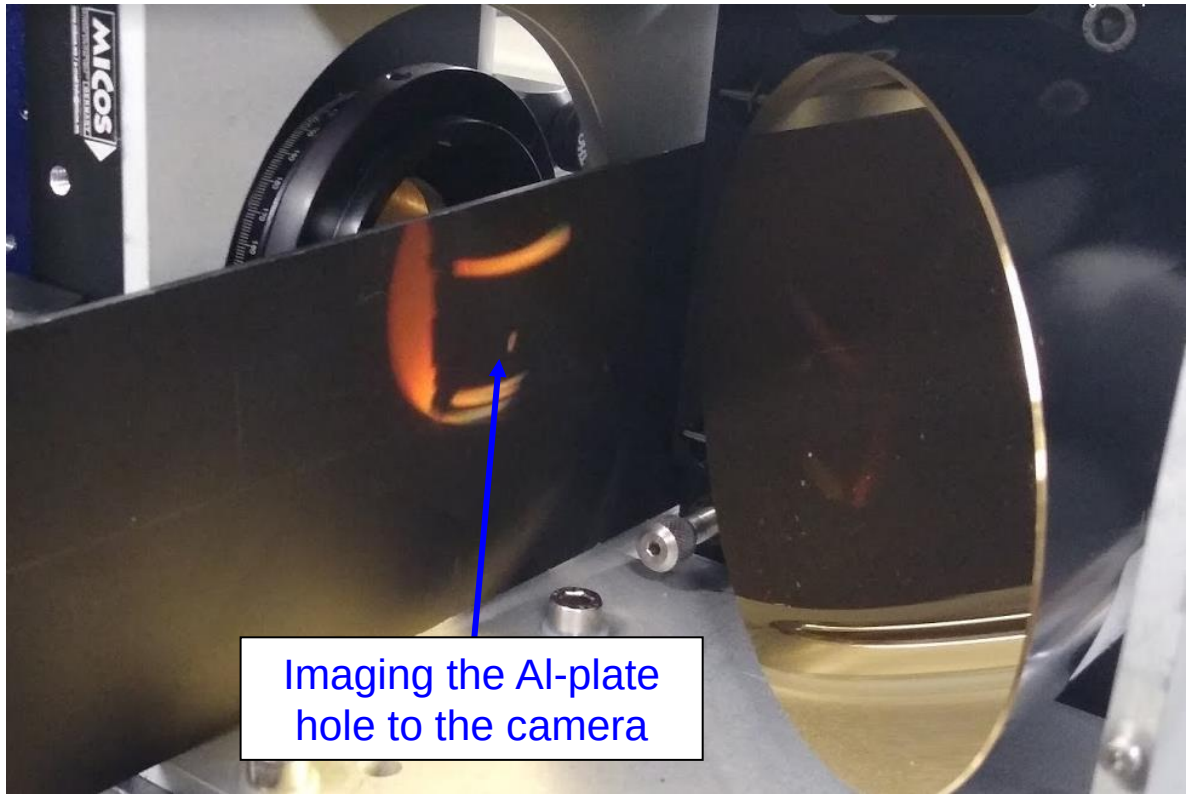
Realignment of the THz Measurement Station

New method for the alignment: Imaging method

- **Previously, alignments were done by inverse-transport a laser beam from the detector position to the radiator**
- **Imaging method ➔ Project the image of the radiator to the image plane of the THz camera**



Place a halogen lamp in front of the PST.SCR2 camera

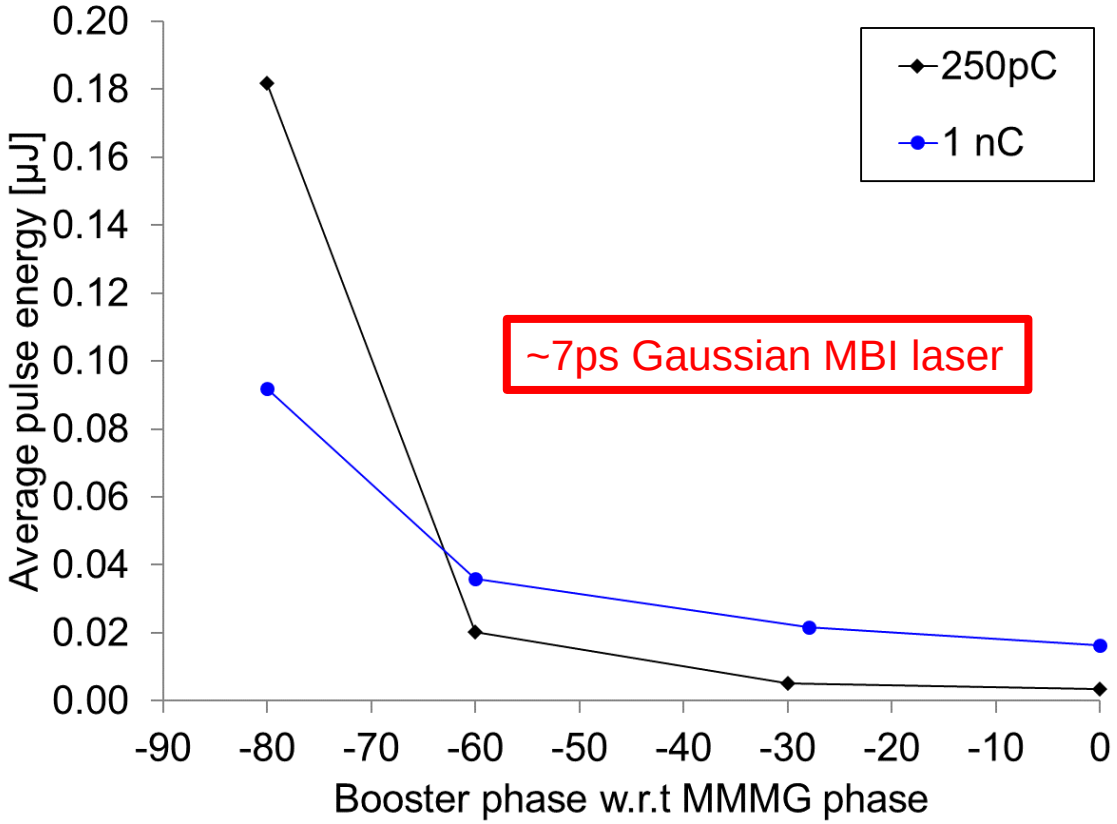


Imaging the Al-plate hole to the camera

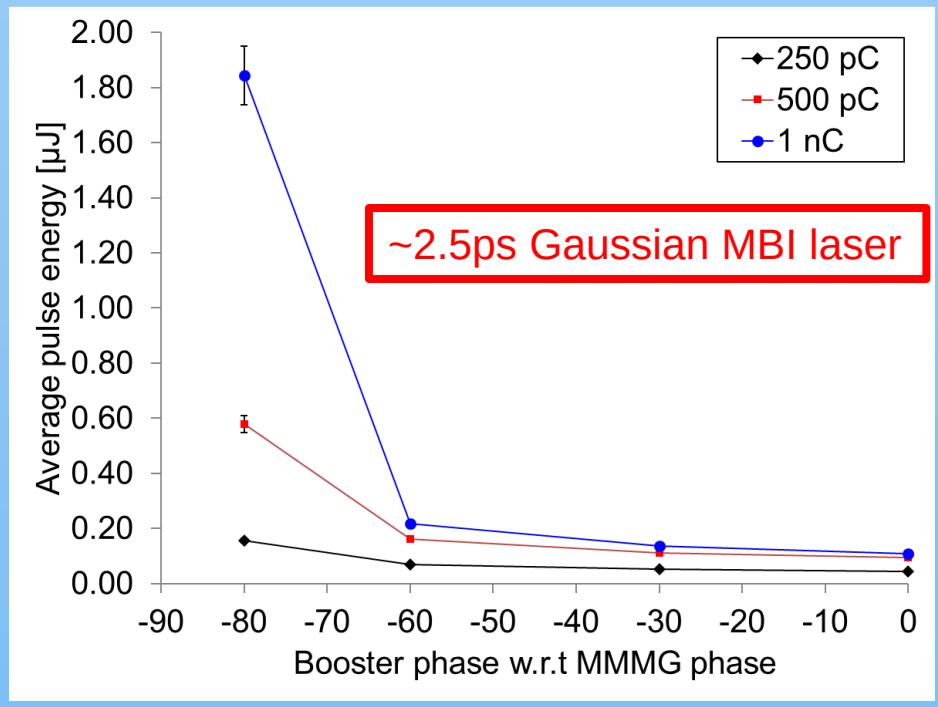
Experimental Results

CTR pulse energy measurements (beam transport preparation)

- The 4-parabolic-mirrors layout was used
- At -80°, P.E. with 250 pC is higher than P.E. with 1 nC
  ← Bad alignment & transport, overcompression
- Much lower than measurements in 2017



CTR pulse energy measurements in 2017
(the copper cone collector was used)

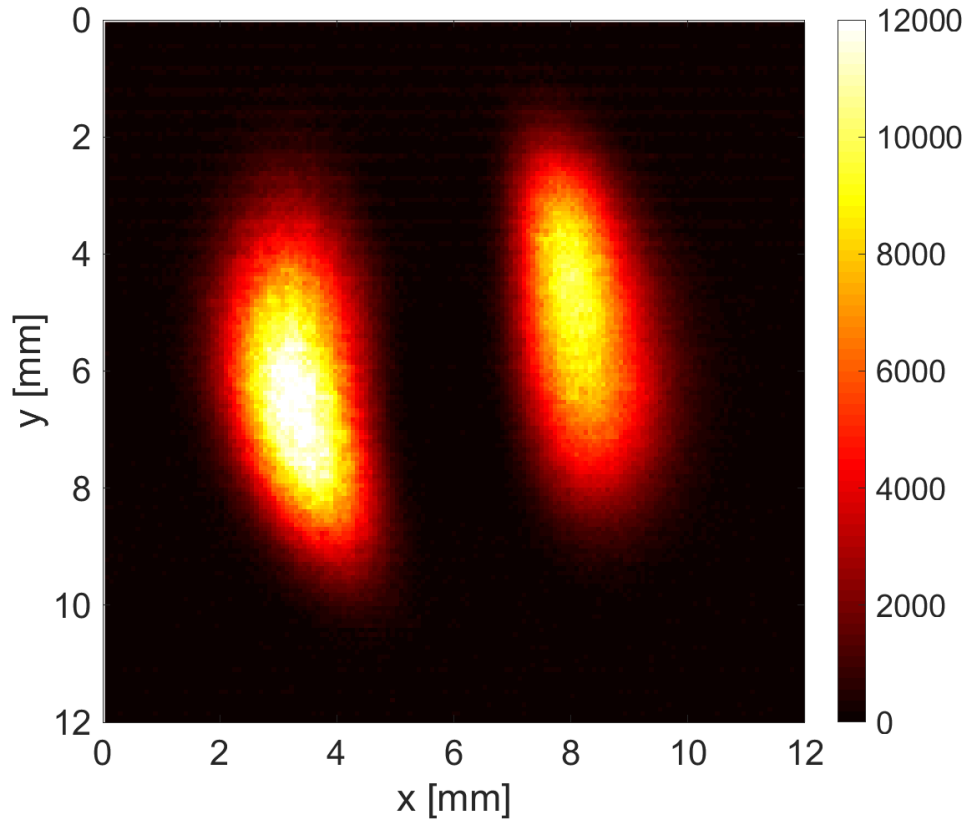


Experimental Results

Transverse Profile Measurements

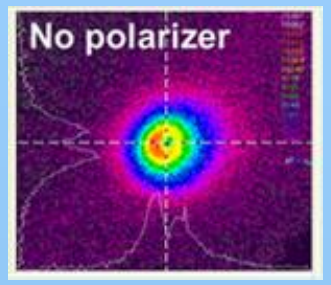
- The 2-parabolic-mirrors layout was used

First measured THz CTR image (with its signature) at PITZ



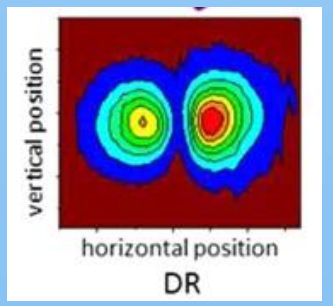
A measured CTR transverse profile from Chiang Mai University, Thailand

https://accelconf.web.cern.ch/FEL2012/papers/wepd52.pdf



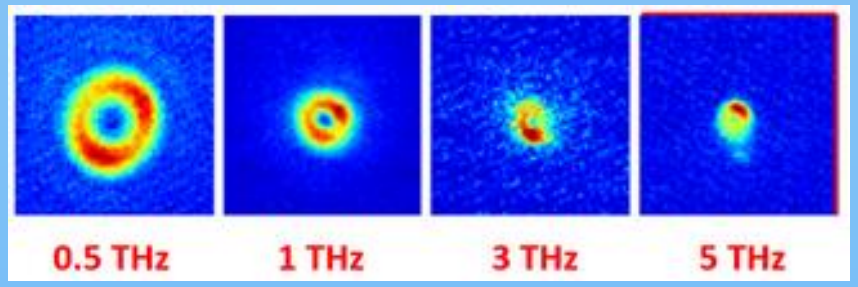
A measured "DR" transverse profile from TELBE, HZDR, Germany

https://www.nature.com/articles/srep22256



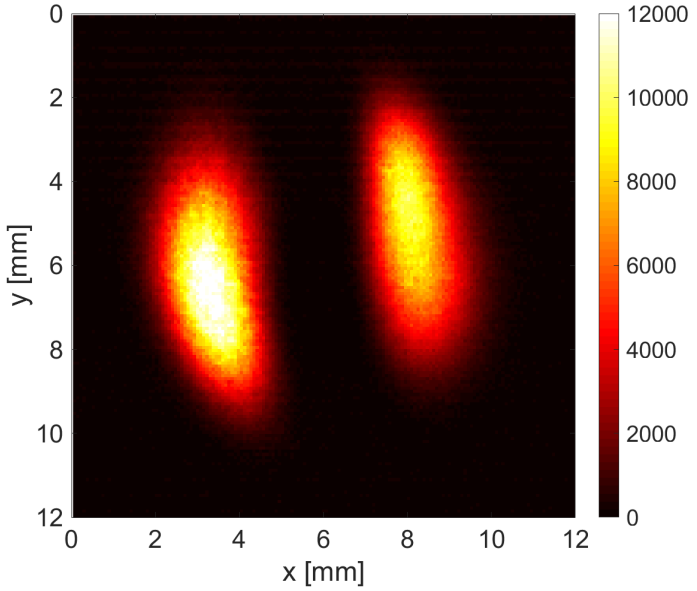
A measured CTR transverse profile (comb beam) from SPARC_LAB, INFN, Italy

https://www.mdpi.com/2076-3417/6/2/56/htm

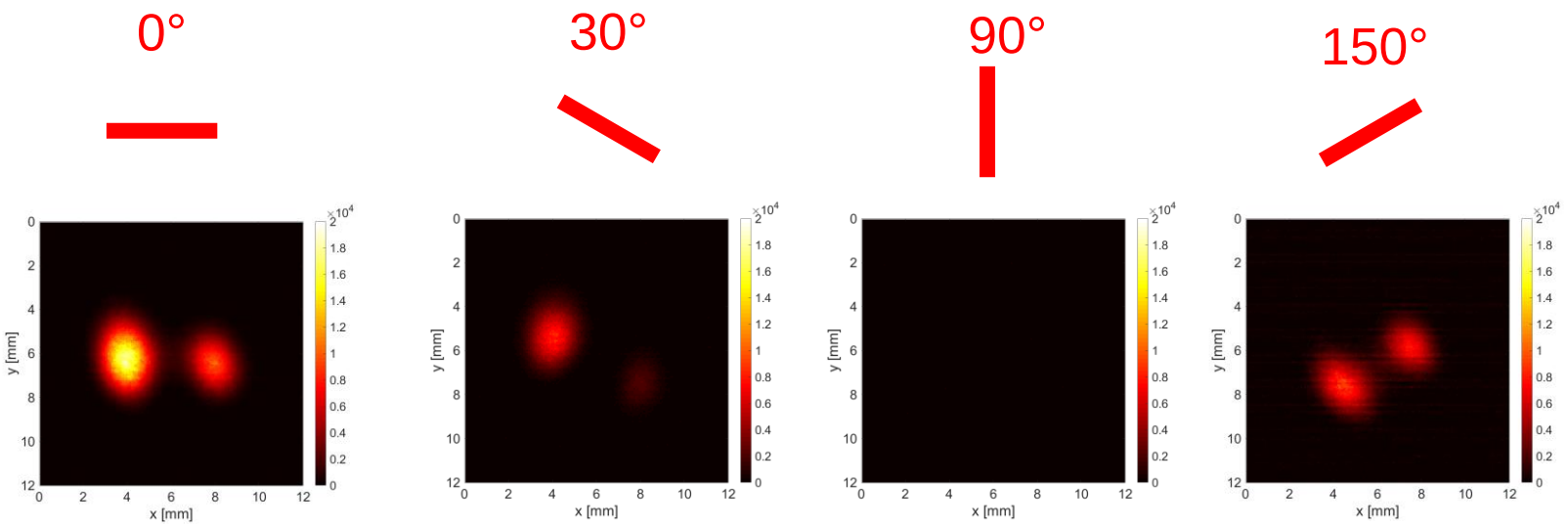


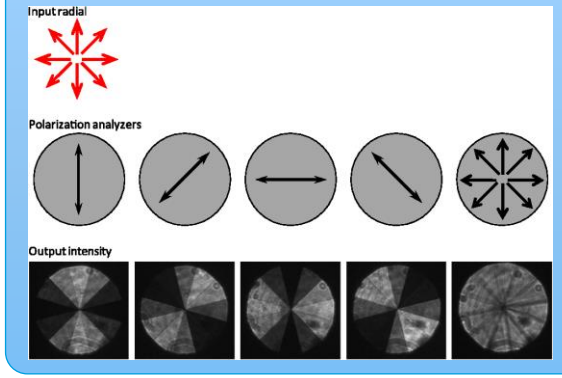
Experimental Results

Polarization Measurements



CTR polarization measurement using a THz linear HDPE polarizer





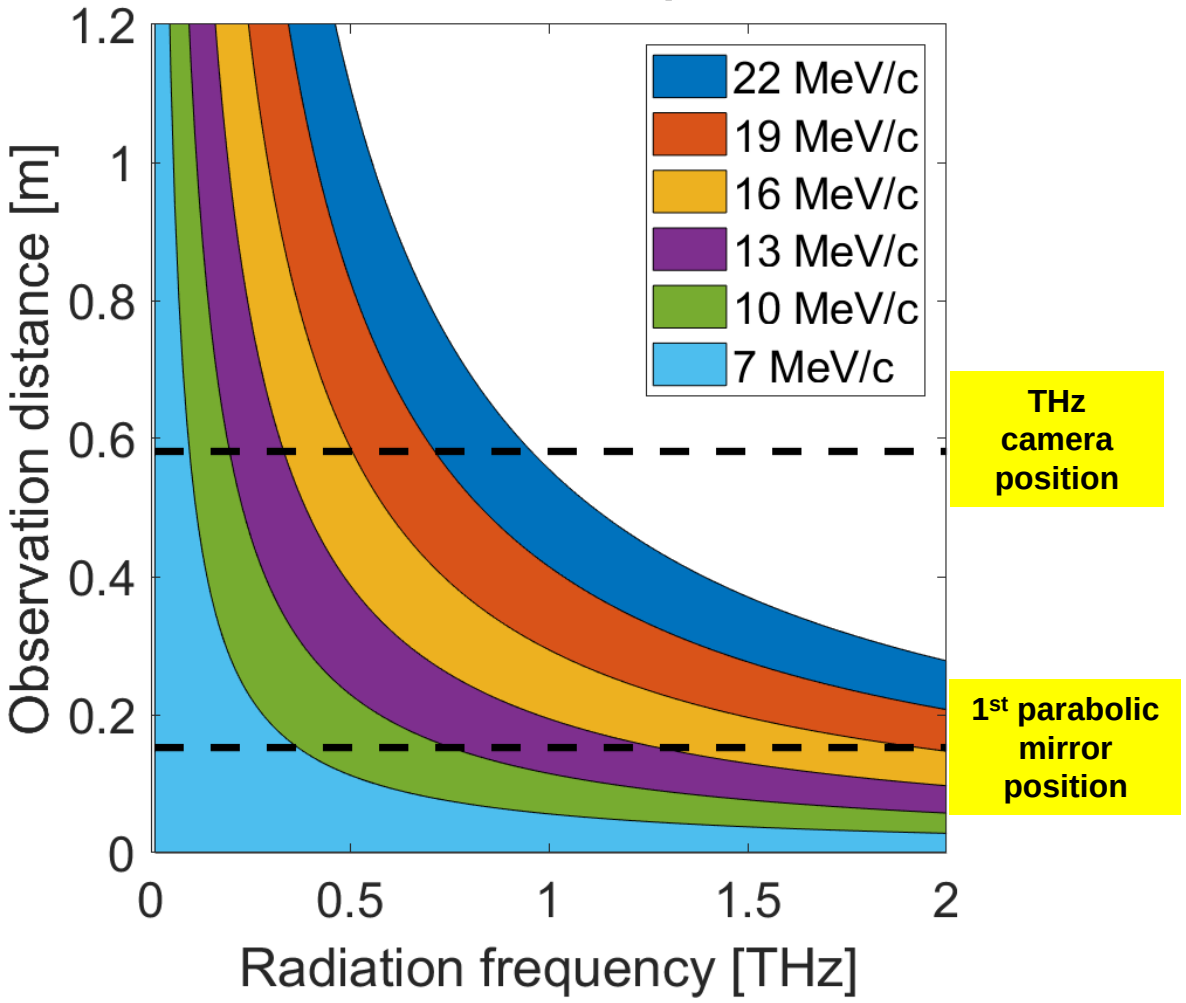
Example:
Experimental transmission when the input beam is radially polarized and the beam is analyzed with a linear or a radial analyzer.

Reference: *I. Moreno Optical Engineering, 51(12), 128003 (2012)*

Checking for Near-Filed and Far-Field Regions

Reference: G. Kube, TESLA-FEL 2008-01

Plots of $a = \lambda\gamma^2$



- Near-field (Fresnel, pre-wave) region condition:

$$a \leq \lambda\gamma^2$$

where: a is the observation distance
λ is the radiation wavelength
γ is the Lorentz factor

- Far-field (Fraunhofer, wave) region condition :

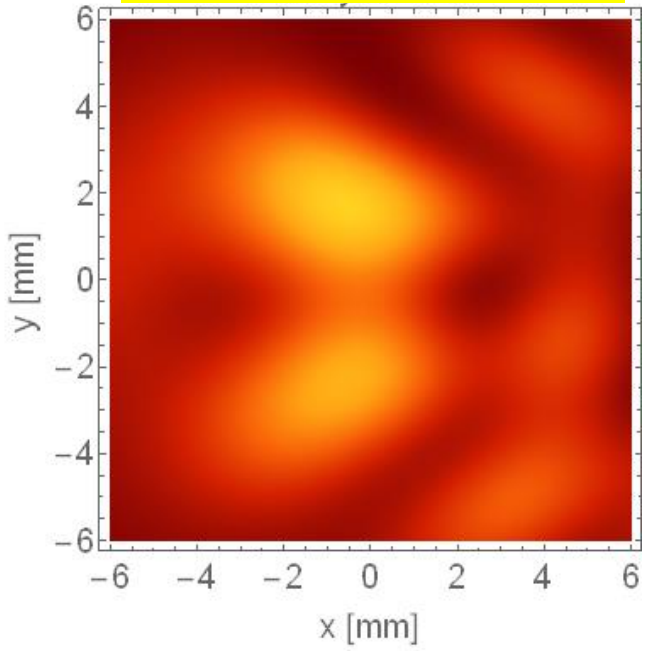
$$a \gg \lambda\gamma^2$$

- PITZ case: 7 MeV/c, f < 0.5 THz ← Near-field region
- 1st parabolic mirror position is in the near-field region → near-field radiation profiles are also projected to the THz camera
- Impossible to purely measure far-field radiation profiles, unless changing position of 1st parabolic mirror
  → re-design the whole THz station

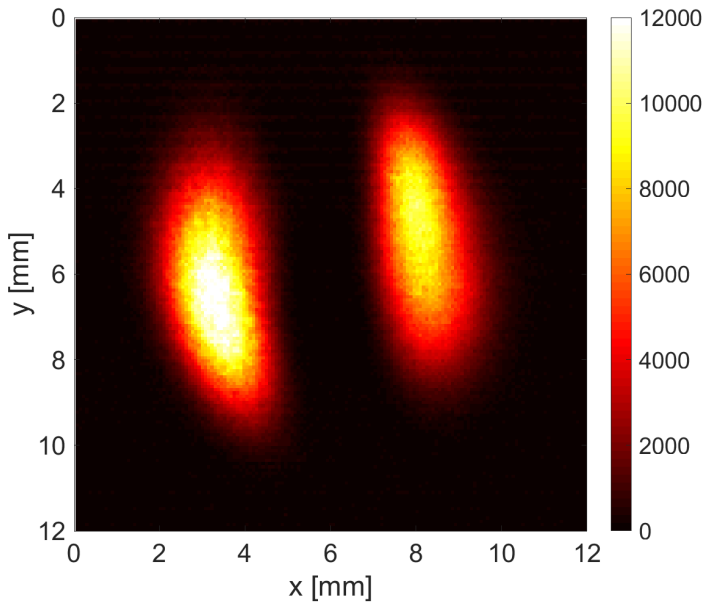
Roughly Checking with THzTransport Simulation

THzTransport Mathematica Application [B. Schmidt, DESY Hamburg, Version 21.2.2017]

Simulated CTR image



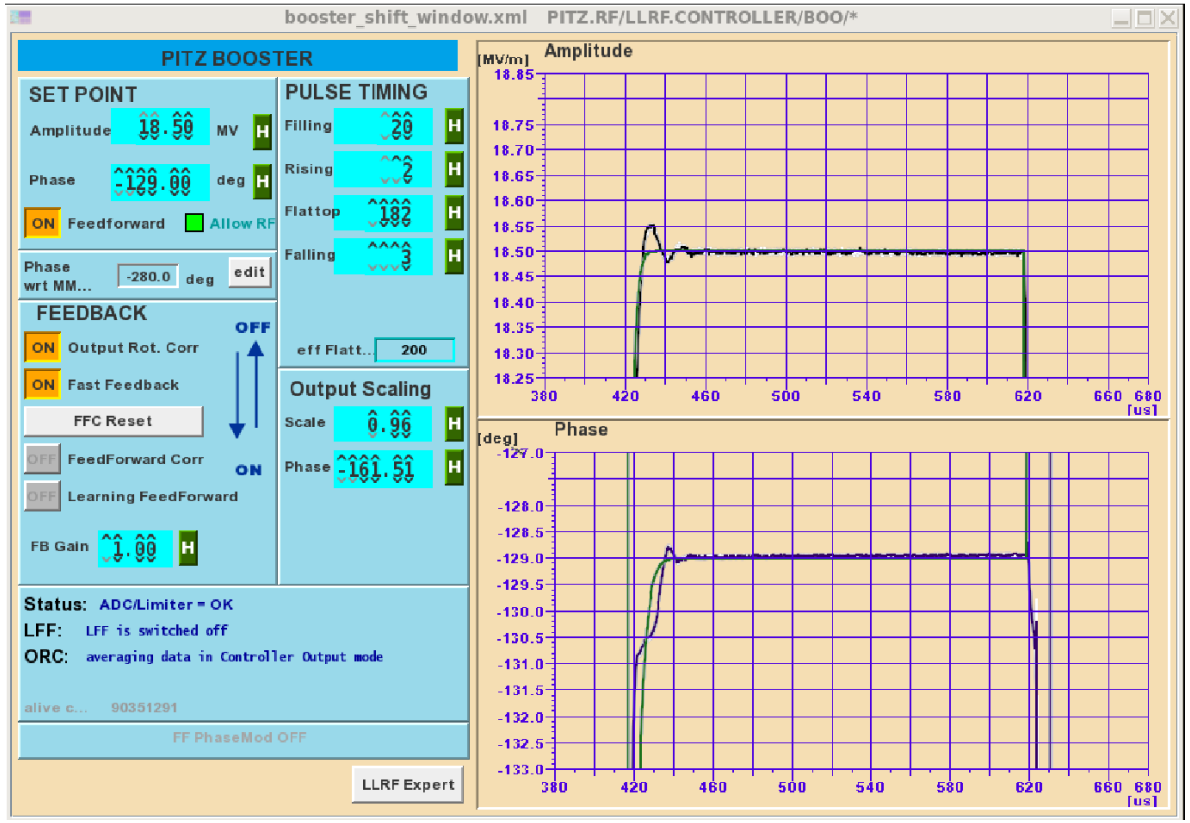
Measured CTR image



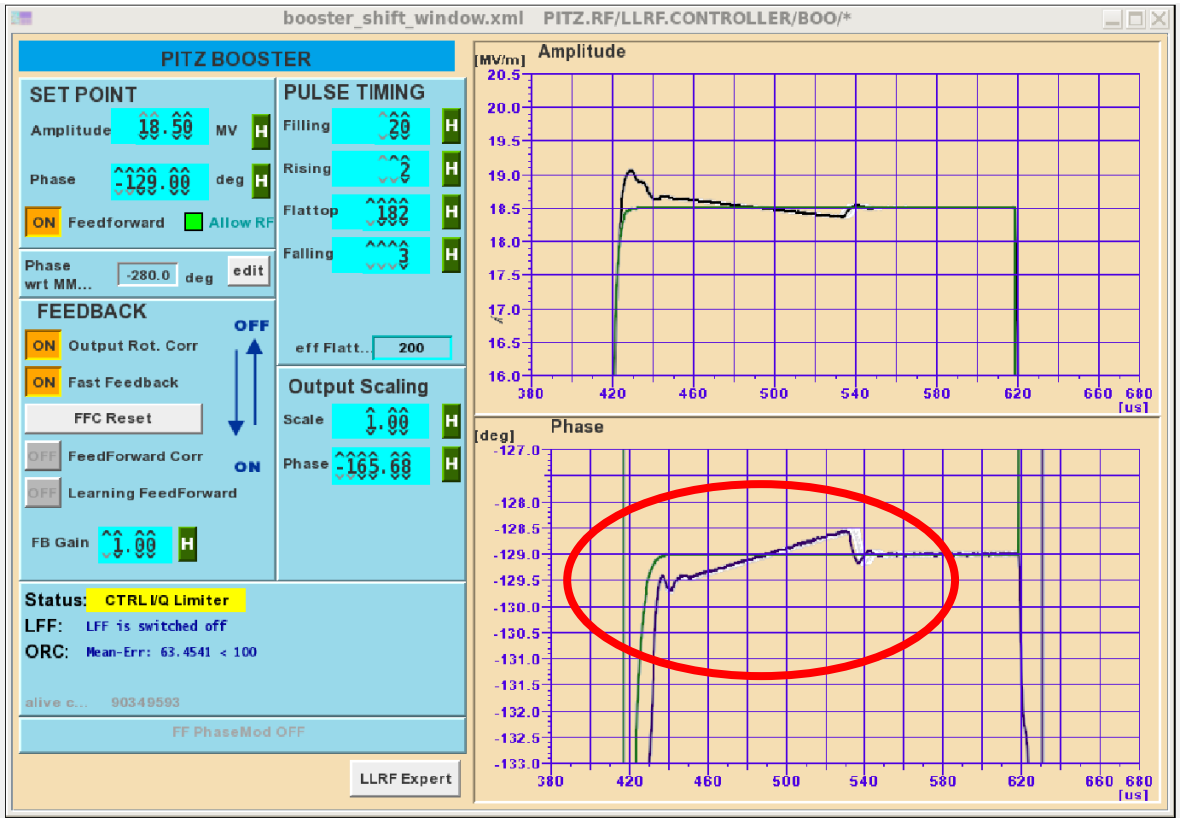
- Position and angle errors were manually tuned
- Different orientation ← only 2D transport in simulation (3D in practical), camera orientation
- The two-lobes signature is possible to appear in simulated profiles
- Detailed simulations can be performed (tilting, position errors, vacuum window, etc.)

Issues with Booster Phase

RF1 Feedback



- FB worked normally



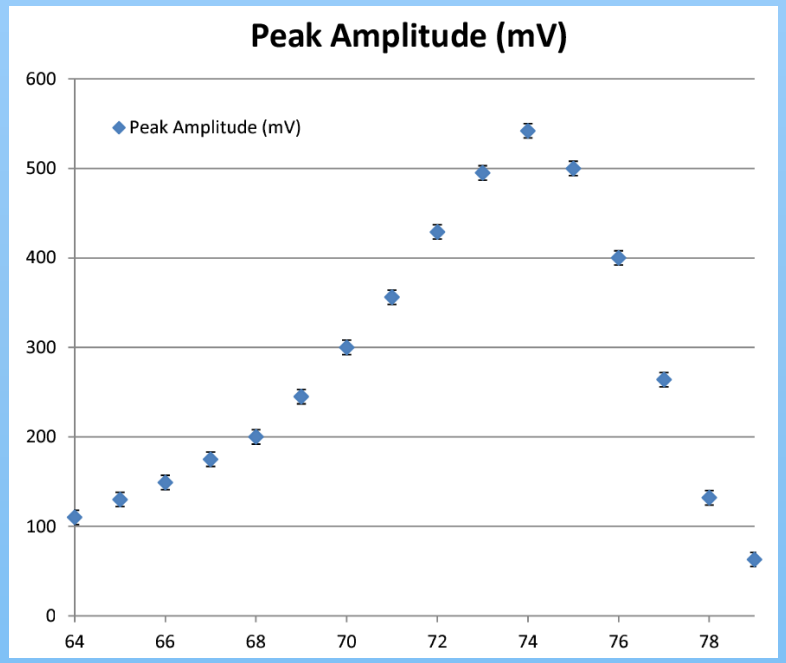
- The RF feedback failed when changing the booster phase setpoint with too big step or too fast
- Way to solve:
  switch off FB ➔ change phase ➔ switch on FB

Issues with Booster Phase

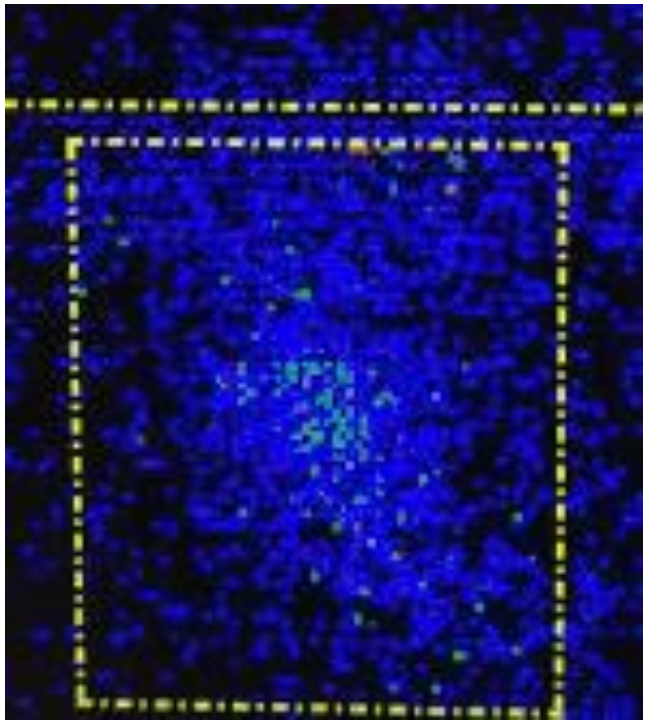
CTR intensity oscillation

Measured CTR voltage vs booster phase

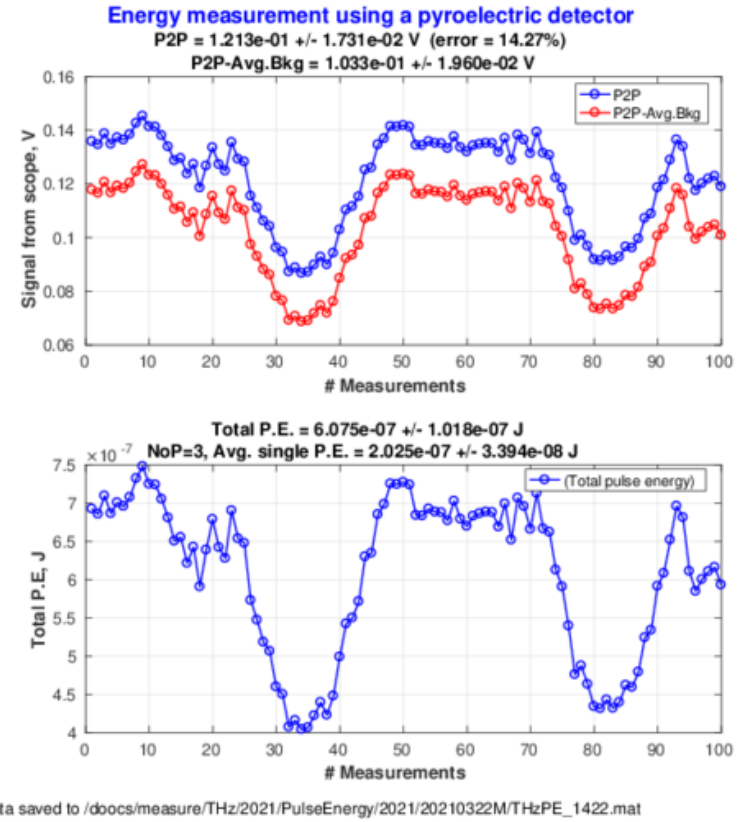
20.12.2018 22:38



~2.5ps Gaussian MBI laser was used



CTR@THz camera from the videoclient



Could be the cause of this behavior

Summary and Outlook

Summary

- Transverse profiles and polarizations of CTR generated from a compressed 1 nC beam were measured
- CTR intensity is very sensitive to the booster phase around the full compression
- Less mirrors less complications
- Alignment with the imaging method worked well

Outlook

- Repeat measurements with the THz camera in the next run (3 shifts)
  - Optimize CTR images with better experiences (1)
  - Investigate CTR intensity vs booster phase around the full-compression phase (1)
  - Michelson interferometer measurements for the full-compression beam (1)
- Detailed follow-up CTR simulations

Near-Filed and Far-Field Regions