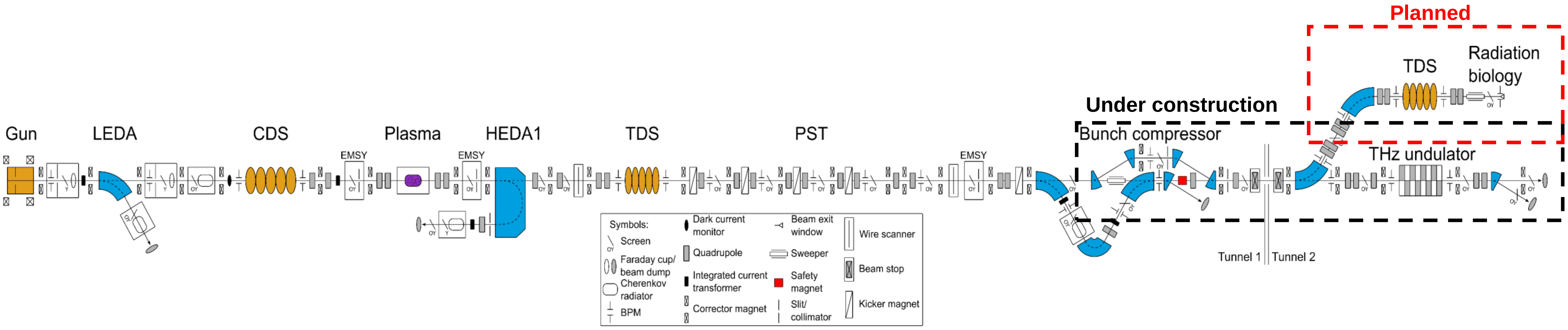
PITZ facility overview and plans

Photo Injector Test Facility at DESY in Zeuthen

Tobias Weilbach on behalf of the PITZ collaboration
MT ARD ST3 Meeting 2021, 29.09.2021



HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Photo Injector Test Facility at DESY in Zeuthen (PITZ)

High brightness photo injector development, optimization and applications

- Started again in 02/2021 with 2+2 schedule
  → several run periods with extensive measurement program
- **Gun4.2** run was finished successfully in 08/2021 after ~36 months of operation (200 µs, ~60 MV/m), Gun4.2 dismounted
  - Progress on new **ELLA photocathode laser system**
  - **First Green cathodes** in PITZ gun
  - Test of different scintillator screen materials (**non proportionality**)
  - **Slice energy spread** measurements
  - …
- **Gun 5.1** installation and time line
- **THz@PITZ update:** Status of installation process
- Future plans on **FLASH radiation therapy**

Talk 30.09. 14:25

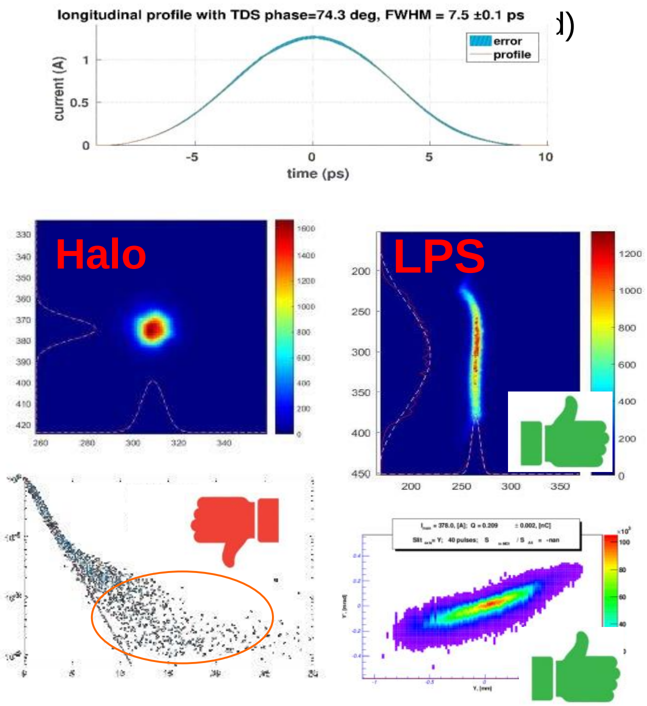
Progress on ELLA photocathode laser system

Photo cathode laser for broad range of applications

UV-stretcher:

Var. Gaussian

- 50nJ UV pulse energy (~1nC@Cs:Te)
- 1MHz repetition rate
- **Gaussian shape** at variable pulse d)

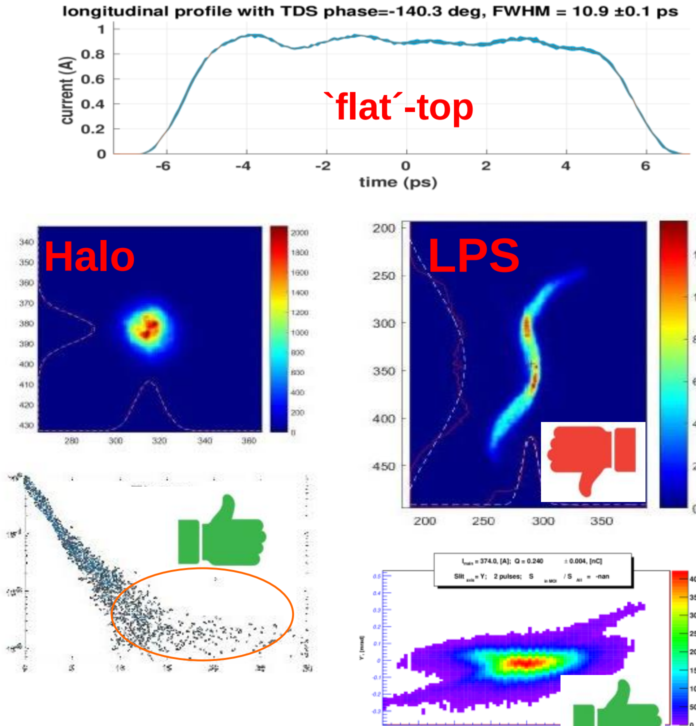


emittance ~0.57 mm mrad

Longitudinal Shaping:

by spectrum control of chirped laser pulses

- Shaper setup with spatial filters (IR & UV)
- Depends on shape, but typically 50nJ UV @1MHz
- Variable shapes and compressions
- Capability to control longitudinal phase space (LPS)

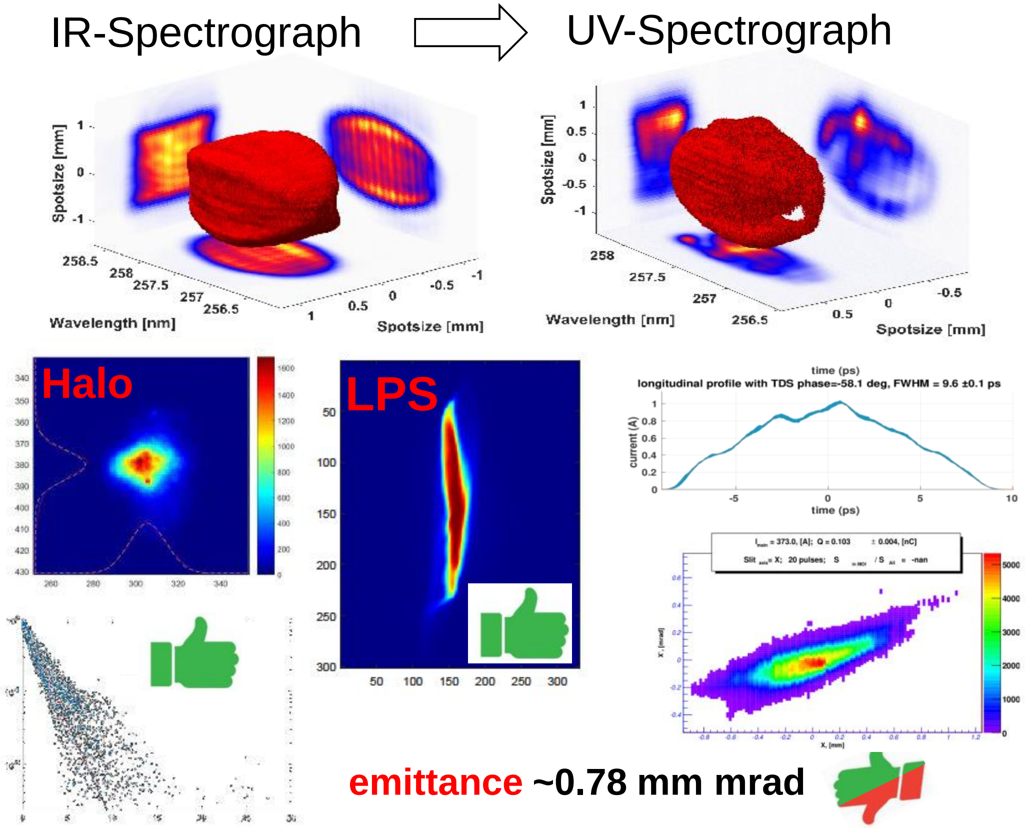


emittance ~0.56 mm mrad

Temporal-Spatial Tapering:

Temporal Shaping by transverse tapering

- Shaper setup with compromise for 20nJ @ 0.125MHz
- **Balance 3D Shape preservation versus conversion efficiency**
- Limited targeting of electron distribution possible in all 3 directions



emittance ~0.78 mm mrad

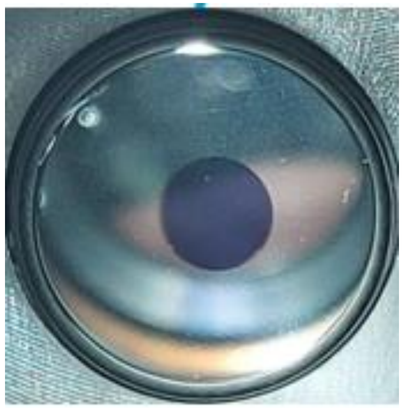
Courtesy of: C. Koschitzki

Speed talk 30.09 11:05

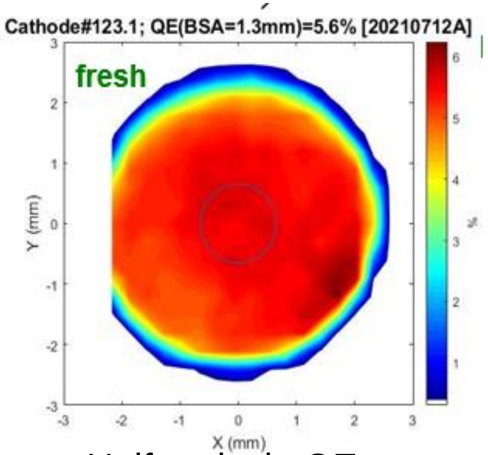
Green photocathodes for high-brightness RF photoinjectors

KCsSb Photocathode

- Successfully produced the first batch of green cathodes (3) in “new production system” at INFN LASA with sequential deposition
  - ✓ Out of which 1 thick (147.1) (Sb= 10 nm) and 2 thin (112.1, 123.1) (Sb = 5 nm) cathodes
  - ✓ Q.E @514 nm is recorded 3-7 % for thick and thin cathodes respectively after the production



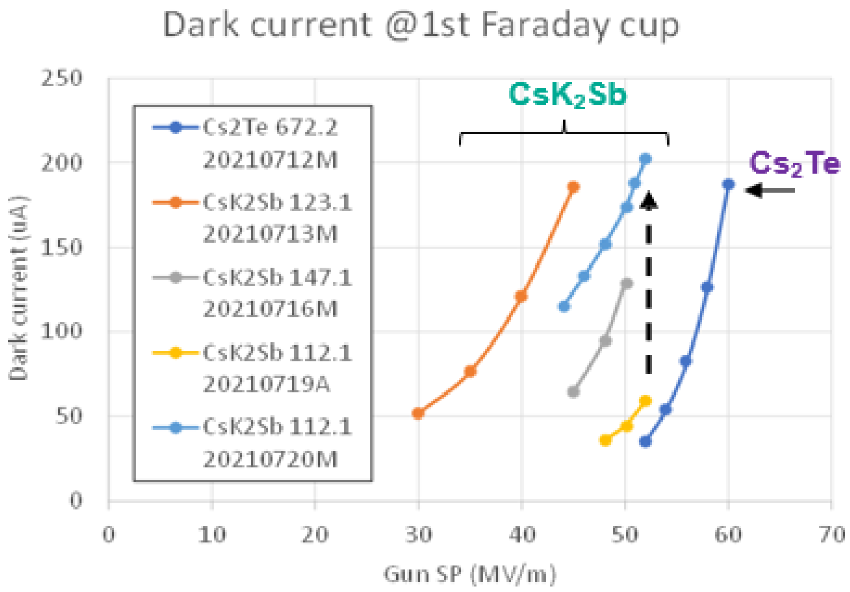
• KCsSb cathode



• Uniformity in QE map

- Results:

- Above 30-40 MV/m, much more vac events than Cs2Te conditioning → degrades QE significantly
- QE drops from 3-6% to below 1% within 2 days
- Thermal emittance
  - Green 2.4eV @19 MV/m, ~0.6 mm.mrad/mm
  - UV 4.8eV @19 MV/m, ~1 mm.mrad/mm
- Response time
  - One good dataset for #147.1, analysis ongoing
- Higher dark current observed compared to Cs2Te photocathode



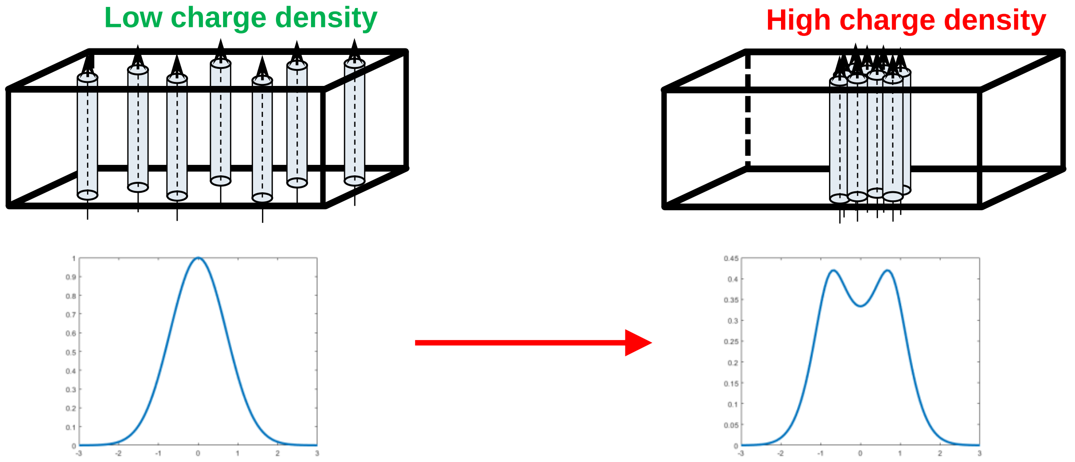
Courtesy of: Sandeep Mohanty, Houjun Qian

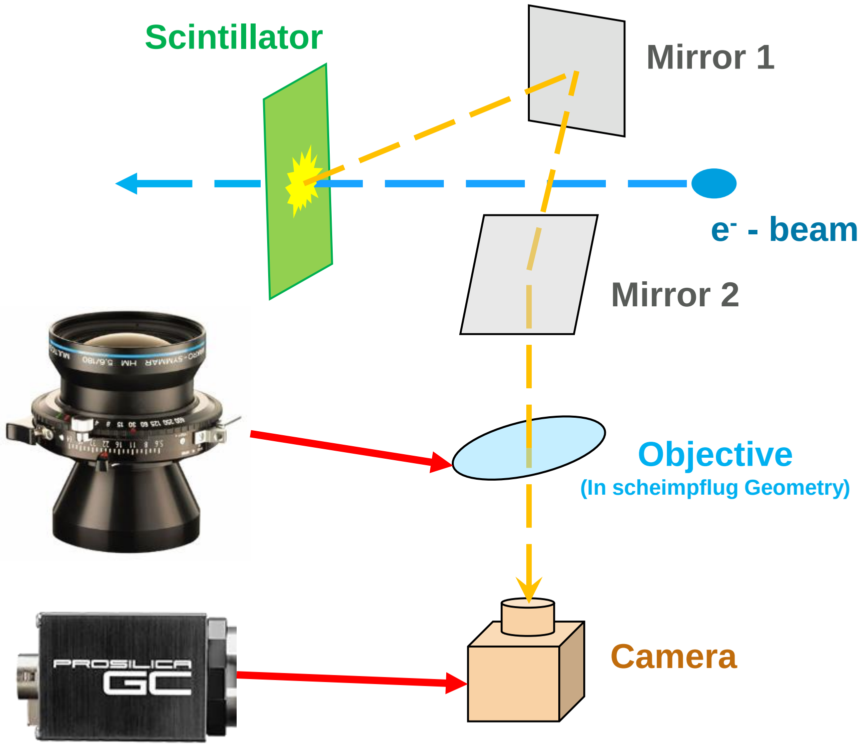
Speed talk 01.10. 12:40

Scintillators Nonproportionality Studies

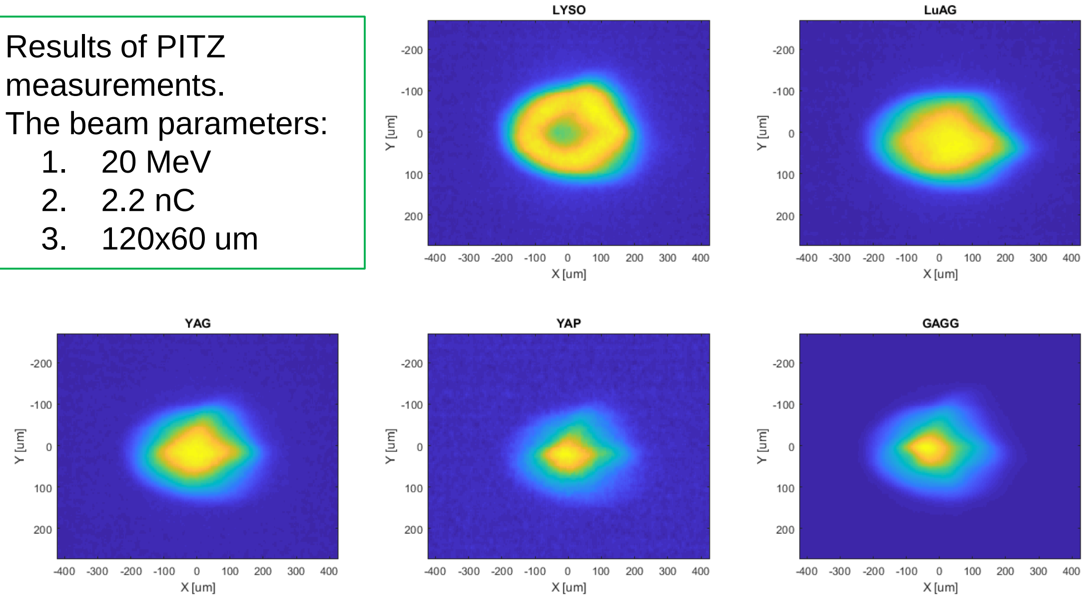
Light output from different scintillators

- In high energy physics it's well-known that a scintillator light output depends on the energy deposited.
- In case of beam diagnostics the light output of a scintillator depends on the charge density.
- The were 5 different scintillator materials: **LYSO, YAG,YAP, LuAG, GAGG.**





- Results of PITZ measurements.
- The beam parameters:
  1. 20 MeV
  2. 2.2 nC
  3. 120x60 um



Courtesy of: A. Novokshonov, G. Kube

Slice energy spread measurement in low energy injector

Speed talk 30.09. 16:10

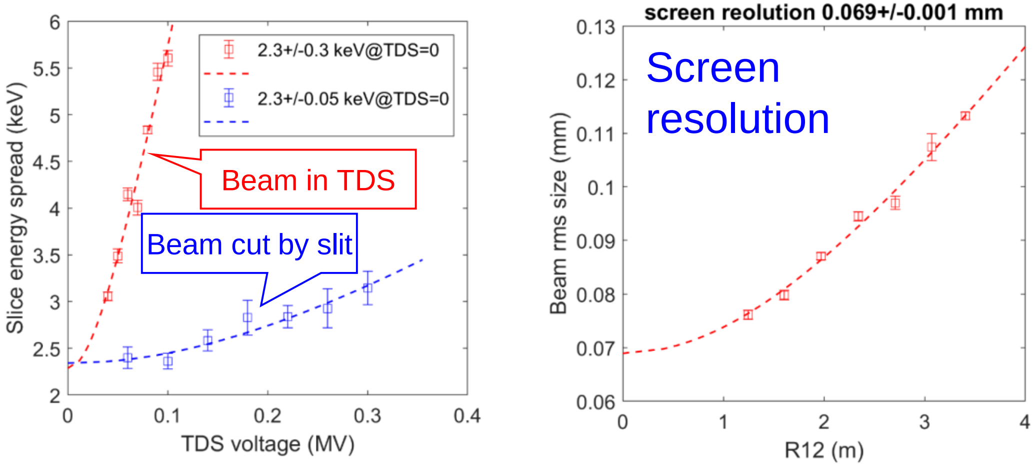
Use a slit mask to measure emittance contribution and screen resolution

- Slice energy spread measurement by TDS + dipole

$$\sigma_M^2 = \left(D\frac{\sigma_{E,TDS}}{E}\right)^2 + \sigma_{scr}^2 + \sigma_{emit}^2 + \left(D\frac{\sigma_E}{E}\right)^2$$

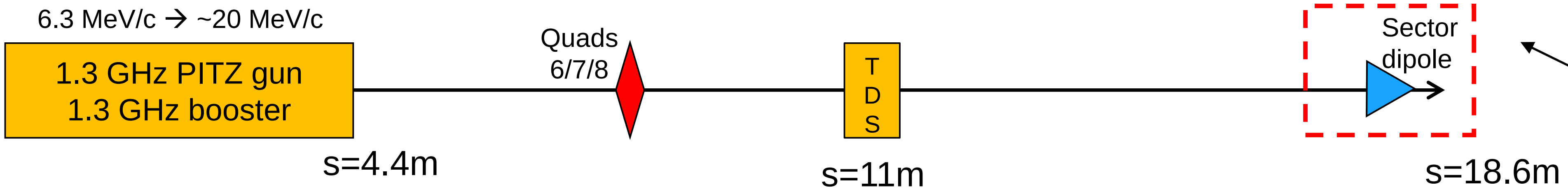
  - Previous methods (require constant beam β function)
    - Scan TDS voltage + Scan beam energy **E** (SwissFEL)
    - Scan TDS voltage + Scan dipole dispersion **D** (Eu-XFEL)
    - Fits better for high energy machine
  - Our new method (does not require constant β function)
    - Scan TDS voltage, then measure $\sigma_{scr}^2 + \sigma_{emit}^2$ independently with a slit mask by scanning R12
    - Fits better for low energy injector (closer to electron source)

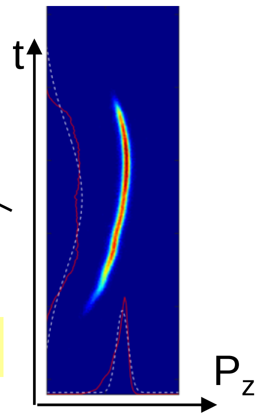
TDS scan



Total	$\sigma_M = 107\mu m$	2.33 keV
Screen resolution	$\sigma_{scr} = 70\mu m$	1.52 keV
Beam emittance term	$\sigma_{emit} = 30\mu m$	0.65 keV
Slice energy spread	$\sigma_E = 76\mu m$	**(1.65±0.05) keV**

1.3 keV Astra Simulations





Courtesy of: H. Qian, M. Krasilnikov

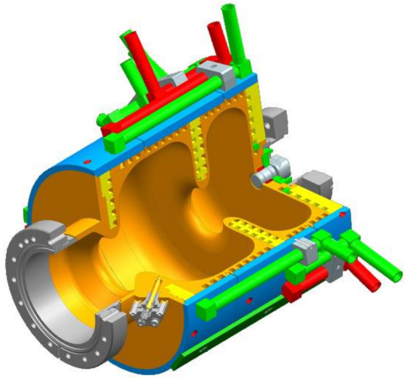
(Near) Future Plans: Gun5 at PITZ

Gun5 installation and time line

- 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**, extended cooling, new rf pickup)
- Some delays due to COVID-19

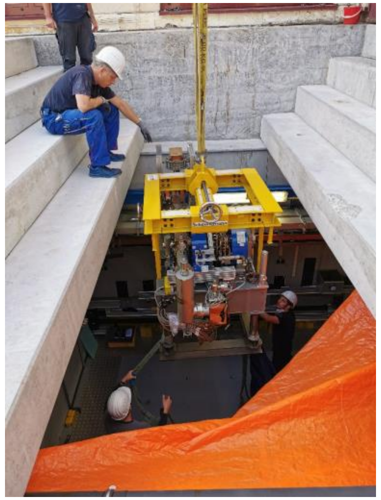
- Status:
  - Gun 5.1 moved to PITZ tunnel
  - Vacuum, water and RF connections done
  - Currently preparations for bake out procedure

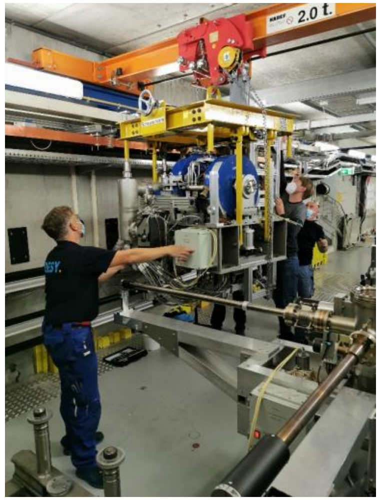
- Timeline:
  - Alignment after bake out (new cathode box)
  - Start conditioning in week 42
  - First beam (short rf pulse) end of 2021 / beginning of 2022

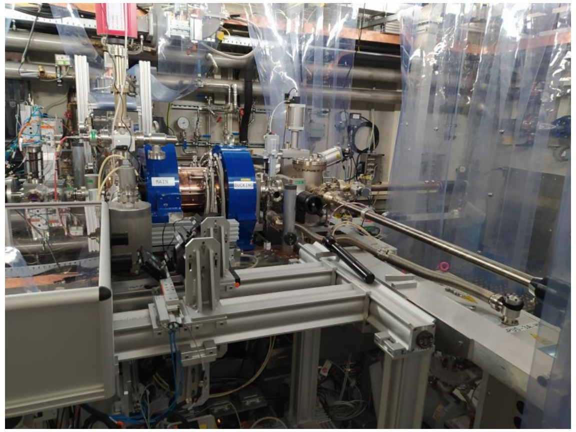


Courtesy of: S. Philipp

Final machined cathode body of Gun5

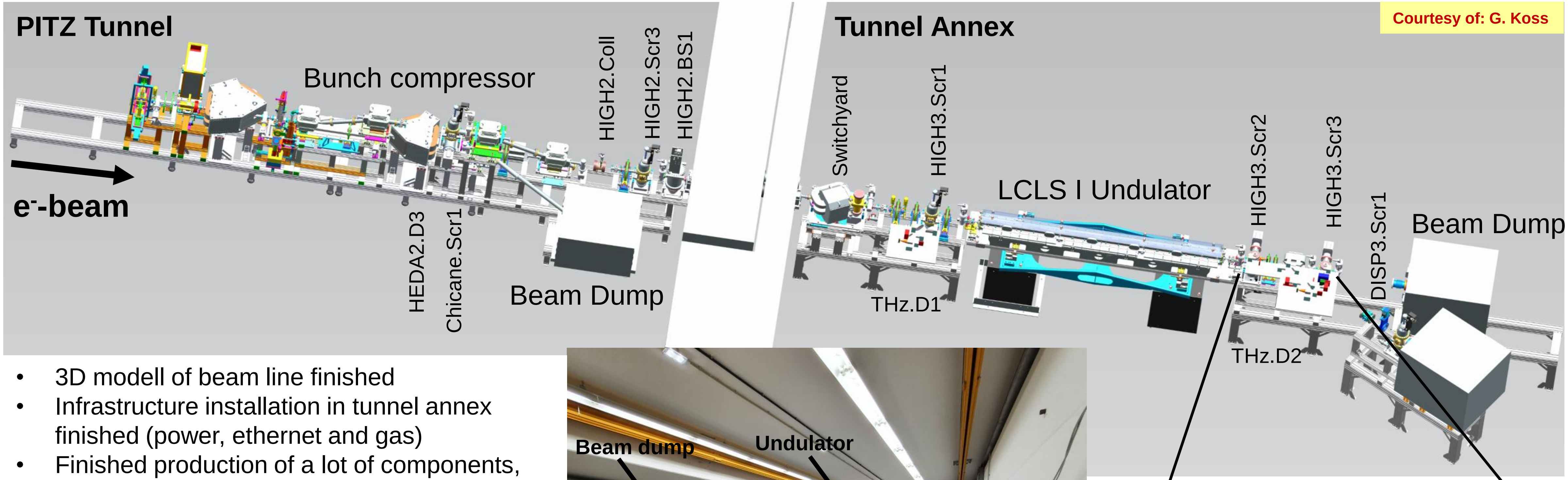




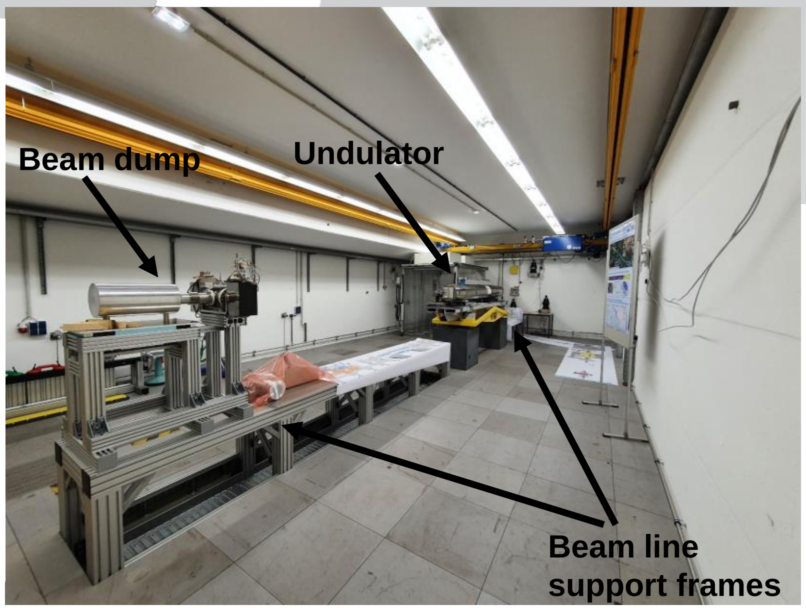


(Near) Future Plans: THz@PITZ

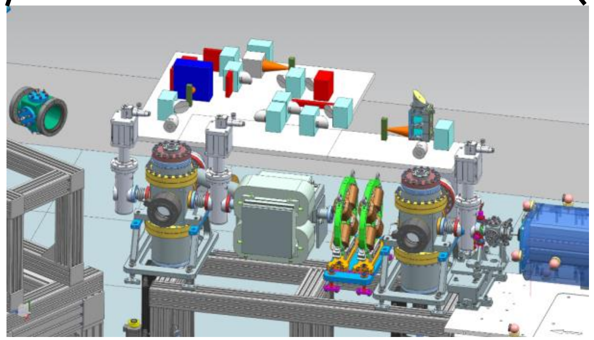
Developments on accelerator based THz source for pump-probe experiments at the European XFEL



- 3D modell of beam line finished
- Infrastructure installation in tunnel annex finished (power, ethernet and gas)
- Finished production of a lot of components, e.g. dipole chambers, screen stations, beam shutter,…
- Production ongoing for magnet alignment support structures, connecting bellows, rotational steerers
- Detailed design of THz diagnostic boards ongoing (incl. actuators, detectors and THz camera)



THz diagnostic setup (THz.D2)

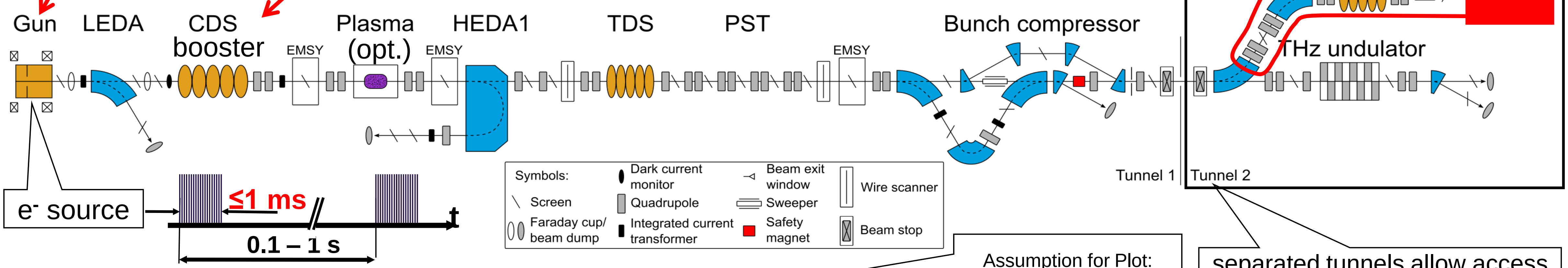


Future Plans: eFLASH RT setup at PITZ

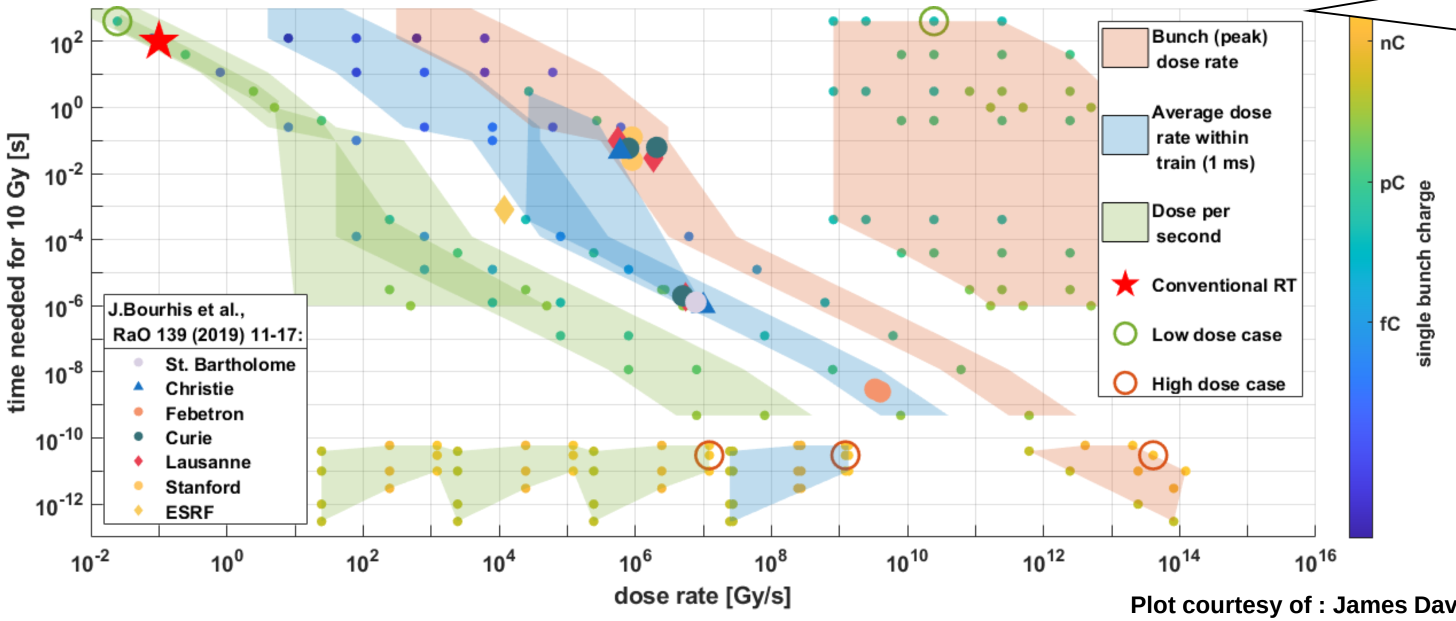
R&D in cancer research

free space for eFLASH RT R&D area: **> 6 x 2 x 3 m³** (l x w x h)

lots of beam diagnostics and beam manipulation



separated tunnels allow access to treatment area while accelerator is running



Assumption for Plot: ~20 MeV electron beam in water with **1mm³** irradiation volume.

- Use **unique capabilities of PITZ** (flexible bunch pattern and charge) **for FLASH R&D**
- Define optimum **clinical beam parameters** for curing different **types of tumor** in human body

Courtesy of: F. Stephan

Plot courtesy of : James David Good, Marie-Catherine Vozenin, Jean-Francois Germond

Conclusions and Outlook

Status and future plans of PITZ

☼=speed talk

- **Gun 4.2 run was completed successfully**
  - 3D ellipsoidal pulses (in progress → IR, UV, spatial filtering) ☼
  - First green cathode in PITZ Gun ☼
  - Scintillator material studies (nonlinearity in light output) ☼
  - Developed improved method for slice energy spread measurements at low energies ☼

- Status of **GUN 5.1**:
  - Installation is close to finish (transport to tunnel, connecting vacuum, water and rf)
  - Conditioning planned to start in week 42

- **THz@PITZ** (developments on accelerator based THz source for pump-probe experiments at the EXFEL):
  - Beam line technical design and Infrastructure (infrastructure ready, component production ongoing, installation started)
  - THz diagnostics (design is under finalization)

- **eFLASH at PITZ** (radiation therapy with high dose rates):
  - Future plans to use unique capabilities of PITZ for R&D for cancer therapy

Thank you!

DESY:
T. Weilbach, G. Adhikari, N. Aftab, P. Boonpornprasert, M. E. Castro Carballo, G. Georgiev, J. Good, M. Groß, C. Koschitzki, G. Koss, M. Krasilnikov, G. Kube S. Lederer, X. Li, O. Lishilin, A. Lueangaramwong, S. Mohanty, F. Mueller, R. Niemczyk, A. Novokshonov, A. Oppelt, S. Philipp, H. Qian, F. Stephan and G. Vashchenko

INFN LASA:
L. Monaco, G. Rocco, D. Sertore

Contact

DESY. Deutsches Elektronen-Synchrotron

www.desy.de

Tobias Weilbach
PITZ
tobias-.weilbach@desy.de
+49 33762 77494