Slice energy spread measurement at PITZ

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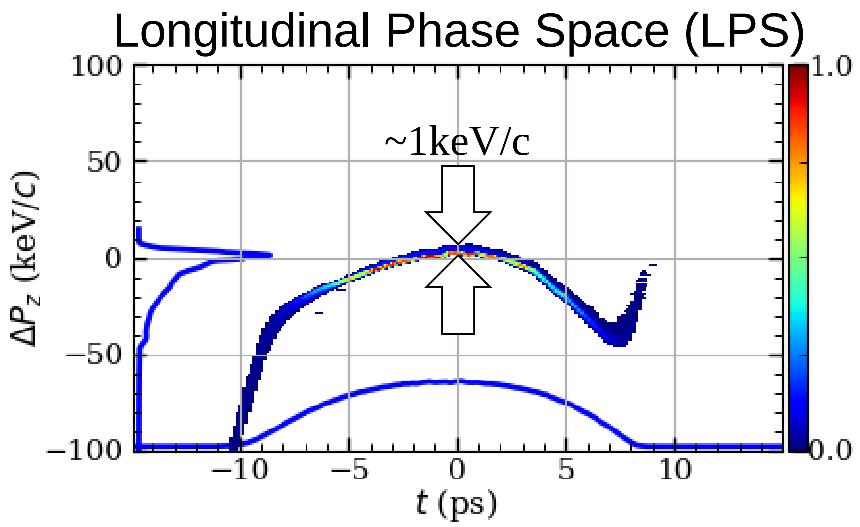


➔Critical parameter in FEL optimization

SASE FEL:

- $\frac{\sigma_E}{E} < \rho_{FEL}$ (e.g. 1e-4, 5 kA/1.4 MeV → 20 A/5.6 keV)
- If σ_E too low → microbunching instability (MBI)
  → Laser heater (LH) to suppress MBI (e.g. LCLS→20 keV by LH)

Seeded FEL:

Bunching factor and harmonic number

e.g. HGHG@ FERMI: 100 keV→40 keV ➔16 nm (n=15) → 10 nm (n=25)

Slice energy spread measurements

Method = Transverse Deflecting System (TDS) + Dipole

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

	SwissFEL	EuXFEL	Unit
Q	200	250	pC
Ek	100-400	130	MeV
Ipeak	20	20	A
dE	15	6	keV
Ipeak/dE	**1.3**	**3.3**	A/keV

Why is the energy spread results so different?

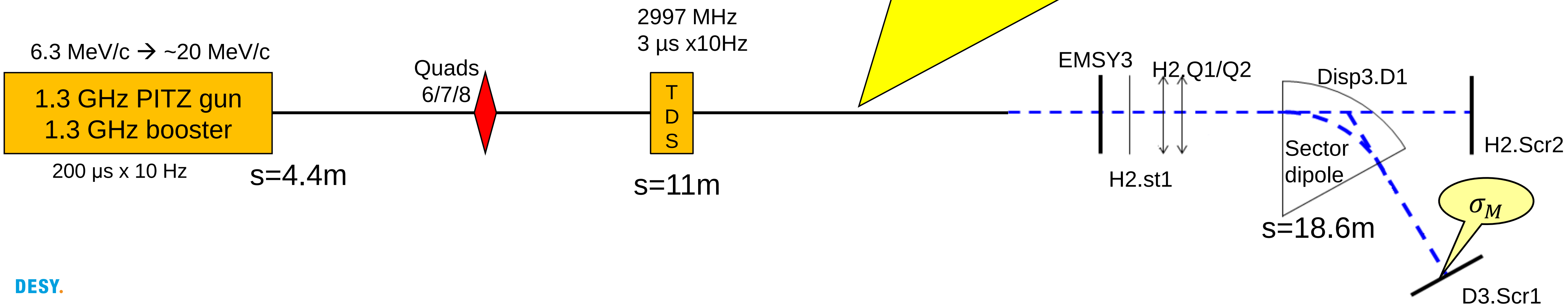
- Cathode effect (Cu vs Cs_2Te) due to response time
- Laser temporal noise
- Lattice, IBS
- Or measurement effects?

SwissFEL and EuXFEL:

- use energy scan or dispersion scan to fit contribution from screen and emittance
- require a **constant** central slice β function at dipole screen during scan
- fits better **high** beam energies

Method used at PITZ:

- 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 **low energy** injector (closer to electron source)

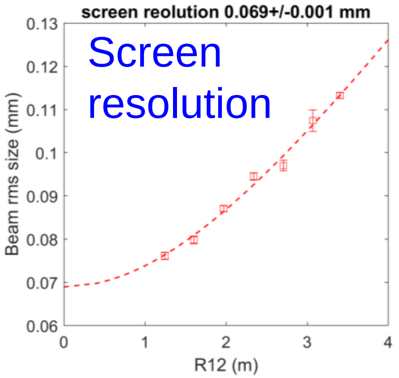


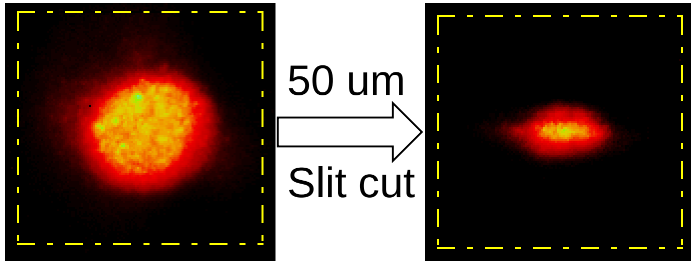
Slice energy spread measurements at PITZ

TDS voltage scan with and without vertical emittance reduction

Slits were used to:

- cut emittance to improve TDS time and energy resolution:
  - $\varepsilon_y \sim 0.4\ mm\ mrad\ \rightarrow 0.04\ mm\ mrad$
  - a factor of ~10 improvement on LPS resolution, reduces the error bar

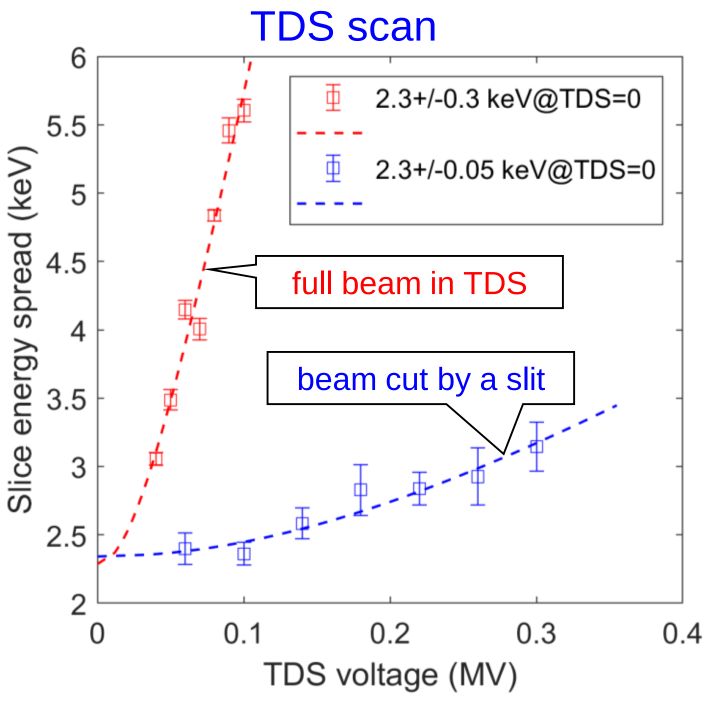




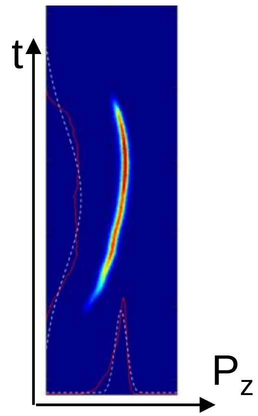
Full beam

Beamlet

- measure dispersion screen resolution
- measure beam size @dispersion screen due to emittance



TDS 0.1MV



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

Total	$\sigma_M = 107\ \mu m$	$\rightarrow 2.33\ keV$
screen resolution	$\sigma_{scr} = 70\ \mu m$	$\rightarrow 1.52\ keV$
beam emittance term	$\sigma_{emit} = 30\ \mu m$	$\rightarrow 0.65\ keV$
slice energy spread	$\rightarrow 76\ \mu m$	$\sigma_E = (1.65 \pm 0.05)\ keV$

ASTRA Simulation value **1.3 keV**

$\sigma_E(t \sim 0) = 1.65 \pm 0.05\ keV$ was measured for the XFEL nominal working point, slightly higher than ASTRA simulations 1.3 keV, but much lower than high energy injectors