Beam dynamics simulations for the European XFEL photo injector

Cathode laser pulse shape influence

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DESY-TUD Meeting
Hamburg, August 9, 2013

HELMHOLTZ ASSOCIATION

DESY

“Nominal” XFEL Photo Injector (PI) setup for BD simulations

- RF gun:
  - Gun-4.1 field profile (FB=1.08) and Ecath=60.58MV/m*
  - Main solenoid centered at z=0.276m, bucking at compensation
- Cathode laser:
  - Temporal: flat-top 2ps/21.5ps\2ps*
  - Transverse: radial homogeneous

To be compared with Gaussian temporal profile and 3D ellipsoidal pulses

- Booster: ACC1=8xTESLA cavities:
  - 1st cavity is centered at z~4.04m from the cathode
    (1st iris of the 1st TESLA cavity → z=3.637m ←→CDS at PITZ z=3.24m)
  - Epeak=33.5MV/m
  - Phase → on-crest
- ASTRA optimization
  - 200k particles
  - Minimized transverse projected transverse emittance at z=15m
  - Tuned parameters: laser rms spot size, main solenoid peak field, gun launch phase, rms bunch length**

* M. Krasilnikov, et al., Phys. Rev. ST Accel. Beams 15, 100701 (2012).

** used for the Gaussian and 3D ellipsoid laser pulse optimization for the second comparison option

Different cathode laser pulse shapes: strategy of comparison

same σ_t^{laser}

Gauss

Flat-top

Ellipsoid

➔ comparison-1 (various $\sigma_z^{e-bunch}$)

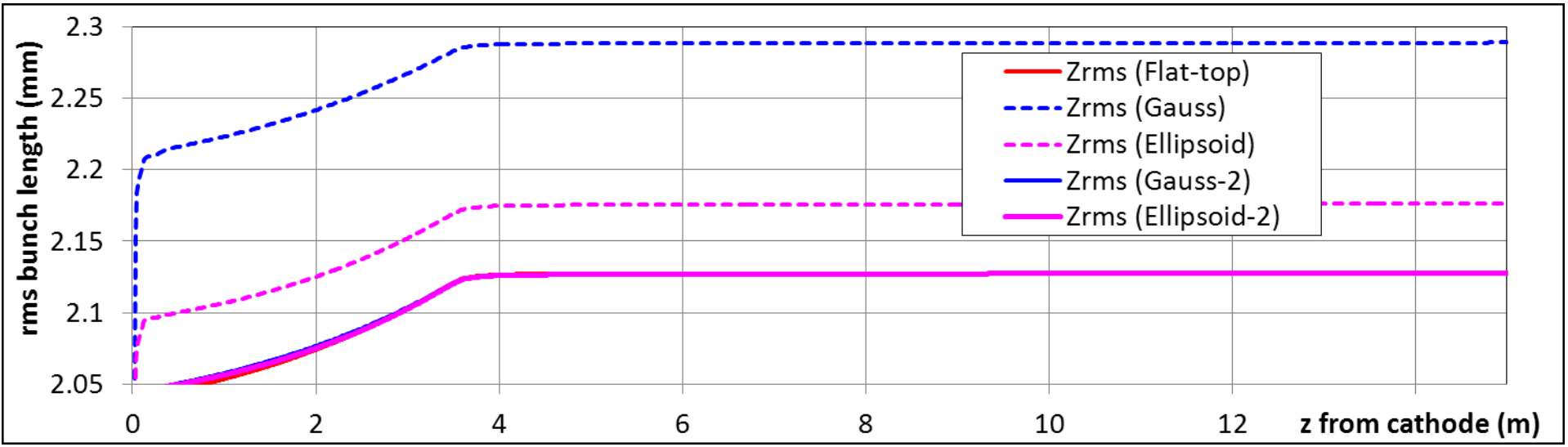
same $\sigma_t^{e-bunch}$

Gauss-2

Ellipsoid-2

➔ σ_z^{laser} to be tuned

comparison-2



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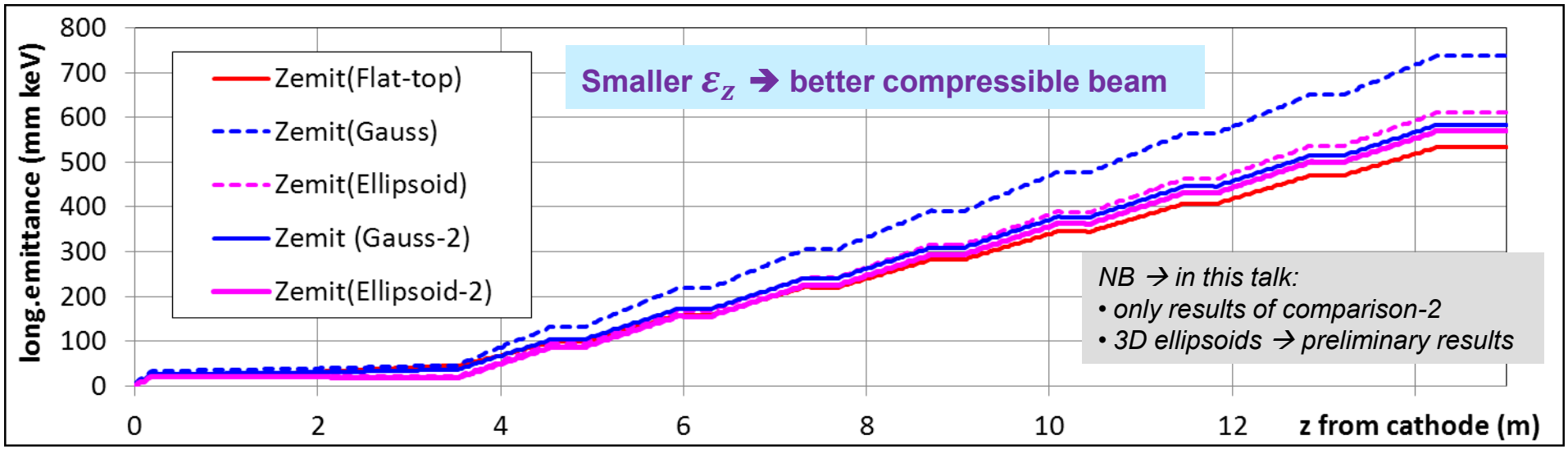
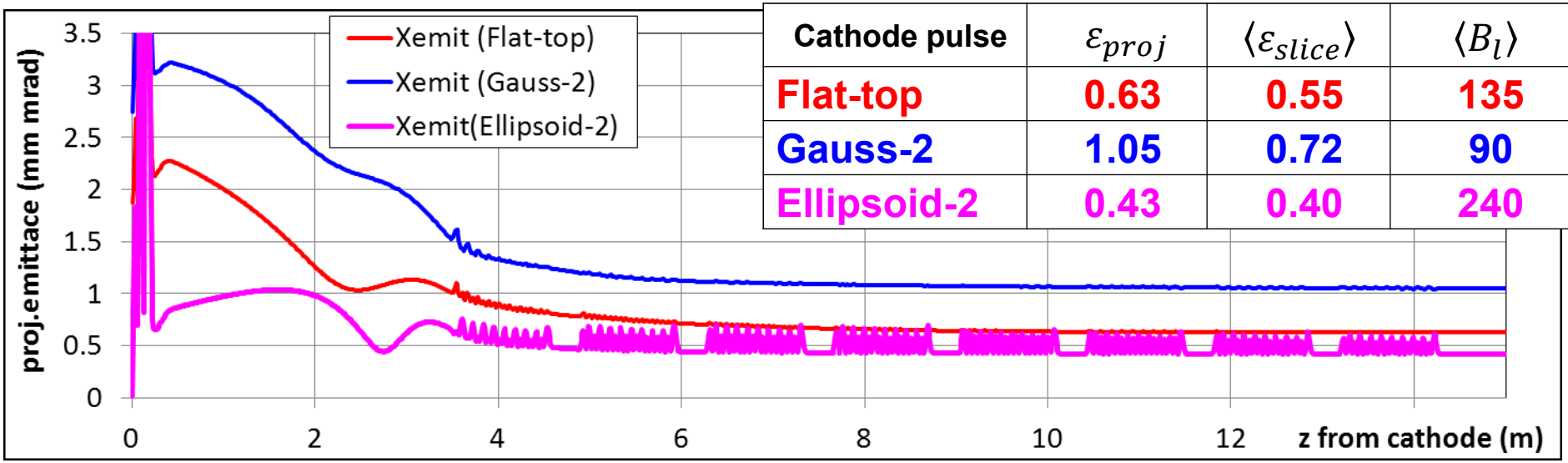


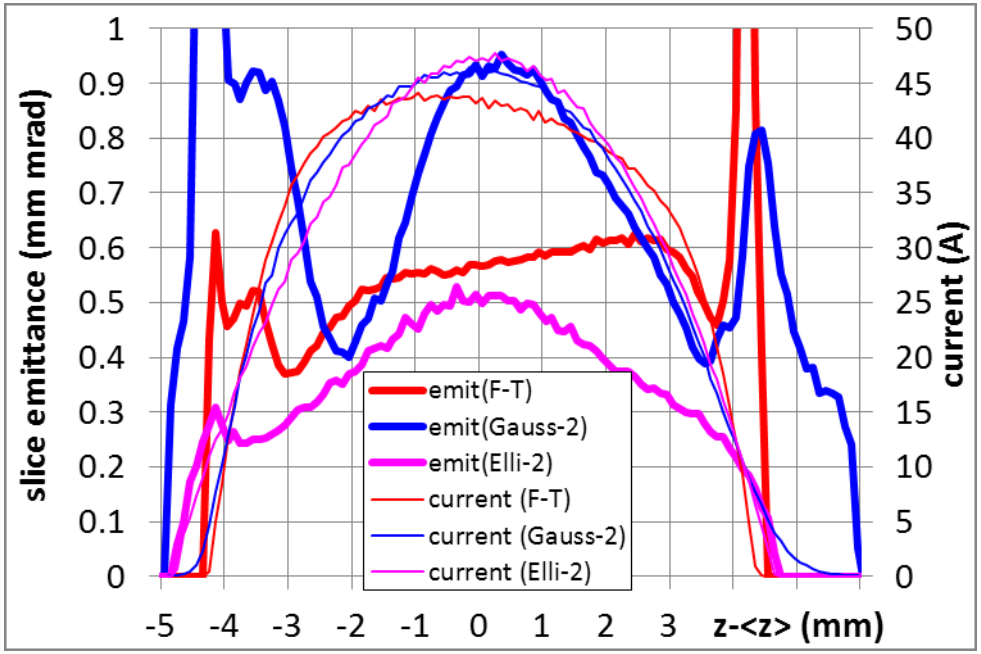
Comparison-2: Optimized machine parameters

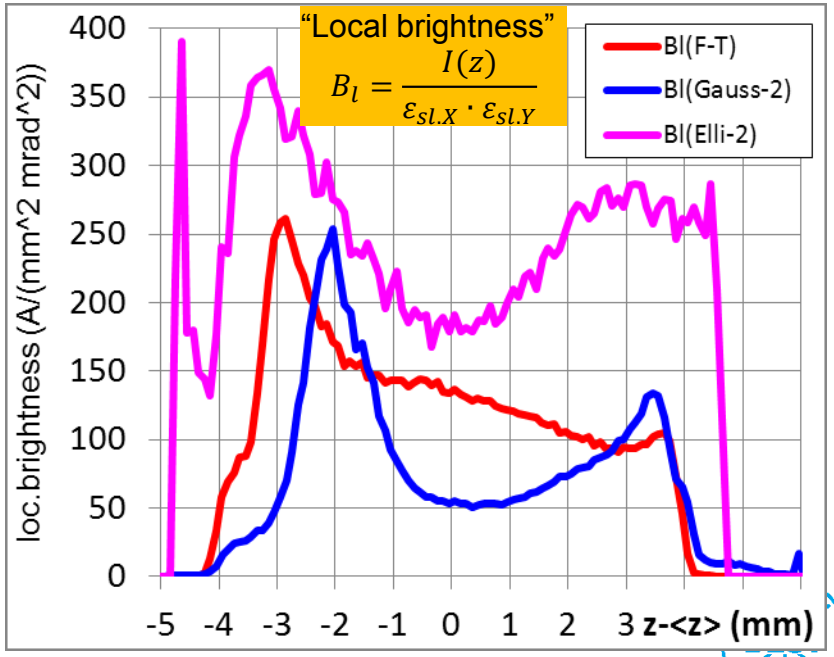
	Temporal profile/shape →		PITZ-1.8 (M.Khojoyan)			European XFEL photo injector*		
			cylindrical		3D ellipsoidal	cylindrical		3D ellipsoidal
			Gaussian	Flat-top PRSTAB-2012	3D homogeneous	Gaussian	Flat-top [PITZ gun+laser]	3D homogeneous
Cathode Laser	Transverse duistribution		radial homogeneous		3D homogeneous	radial homogeneous		3D homogeneous
	Trms	ps	5.4	**6.272**	6.1	5.29	**6.272**	5.995
	XYrms	mm	0.385	0.401	0.39	0.389	0.415	0.395
RF gun	Th. emit.	mm mrad	0.326	0.339	0.33	0.329	0.351	0.335
	Ecath.	MV/m	**60.58**					
	Phase	deg	~ on-crest	~ on-crest	~ on-crest	-2.33	-1.5	-2.29
	MaxBz	T	0.2275	0.2279	0.2297	0.2269	0.2275	0.2295
Booster	MaxE	MV/m	**19.76**			**ACC1=8x33.5, on-crest**		
Electron beam	Charge	nC	1					
	Momentum	MeV/c	23.96	23.96	23.96	151.1	151.1	151.1
	Proj. emittance	mm mrad	1.08	0.639	0.419	1.05	0.629	0.431
	Th. / proj.	%	30	53	79	31	56	78
	<Sl. emit.>	mm mrad	0.778	0.572	0.392	0.722	0.550	0.402
	Rms bunch length	mm	2.163	2.163	2.162	2.127	2.128	2.127
	Peak current	A	45.4	43.2	46.8	46	43.8	47.3
	Long. emittance	mm keV	107	98	88	583	533	224

$\varepsilon_{projected}$ along the beam line and $\varepsilon_{slice}(z = 15m)$



Cathode pulse	ε_{proj}	$\langle\varepsilon_{slice}\rangle$	$\langle B_l \rangle$
Flat-top	0.63	0.55	135
Gauss-2	1.05	0.72	90
Ellipsoid-2	0.43	0.40	240





Conclusions

- Beam dynamics simulations for the European XFEL photo injector have been performed:
  - Gun and laser input → from PITZ-1.8 experimental data, comparing the PITZ-1.8 setup (Ecath=60.6MV/m)
  - ACC1 as a booster + further acceleration (~150MeV)
  - Solenoid and booster positions were not varied
- 3 cathode laser pulse shapes were siumulated to reach the smallest projected emittance after the injector:
  - Flat-top (2/21.5\2ps), Gaussian and 3D ellipsoid (preliminary)
  - Comparison-2 option discussed➔ tuning Gaussian and ellipsoid laser duration to yield the same rms electron bunch length