

Beam dynamics simulations for the European XFEL photo injector

Cathode laser pulse shape influence

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

- RF gun:
 - **Gun-4.1** field profile (FB=1.08) and $E_{\text{cath}}=60.58\text{MV/m}^*$
 - Main solenoid centered at $z=0.276\text{m}$, bucking at compensation
- Cathode laser:
 - Temporal: **flat-top** 2ps/21.5ps\2ps*
 - Transverse: radial homogeneous
- Booster: **ACC1**=8xTESLA cavities:
 - 1st cavity is centered at $z\sim 4.04\text{m}$ from the cathode
(1st iris of the 1st TESLA cavity $\rightarrow z=3.637\text{m}$ \leftrightarrow CDS at PITZ $z=3.24\text{m}$)
 - $E_{\text{peak}}=33.5\text{MV/m}$
 - Phase \rightarrow on-crest
- ASTRA optimization
 - 200k particles
 - Minimized transverse projected transverse **emittance** at $z=15\text{m}$
 - Tuned parameters: laser rms spot size, main solenoid peak field, gun launch phase, rms bunch length**

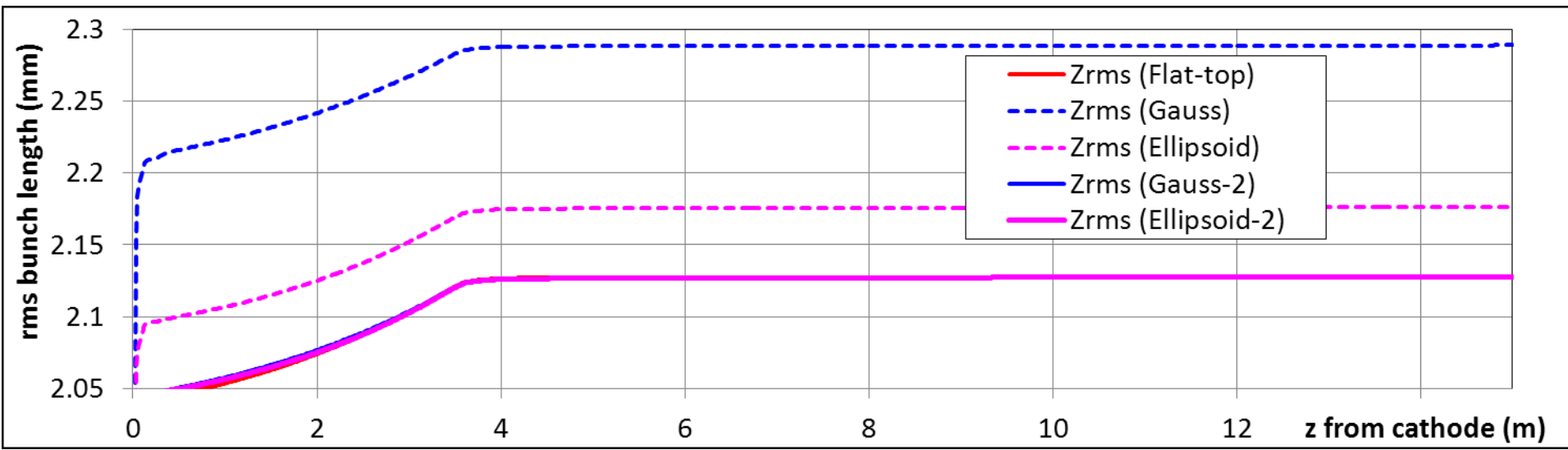
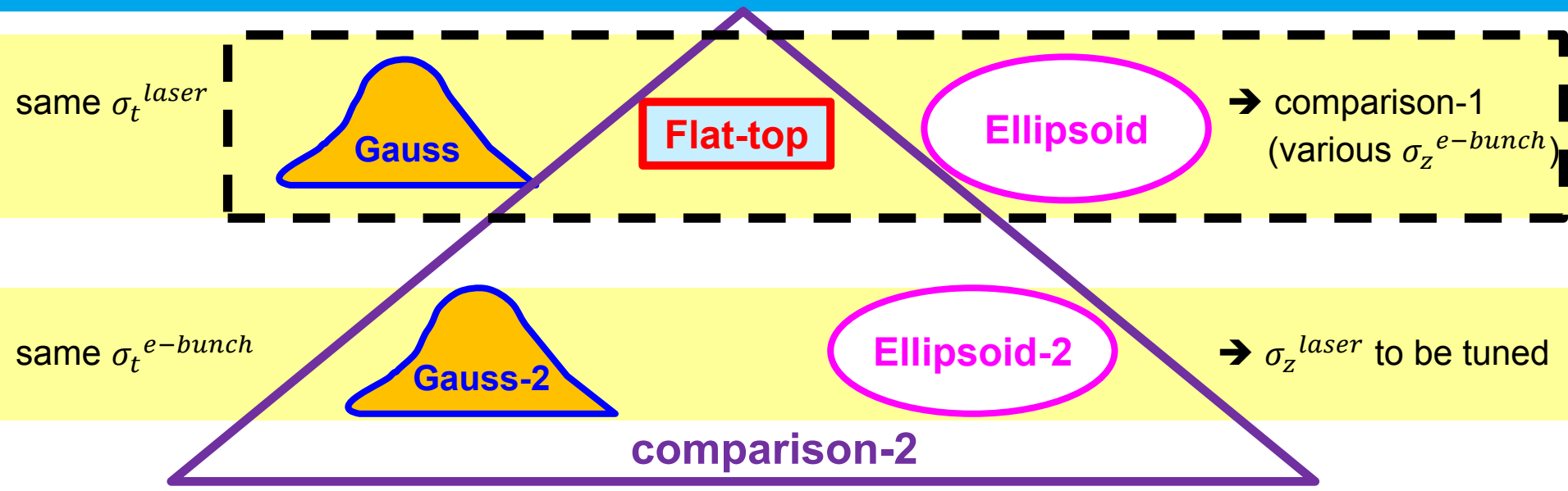
← To be compared with Gaussian temporal profile and 3D ellipsoidal pulses

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

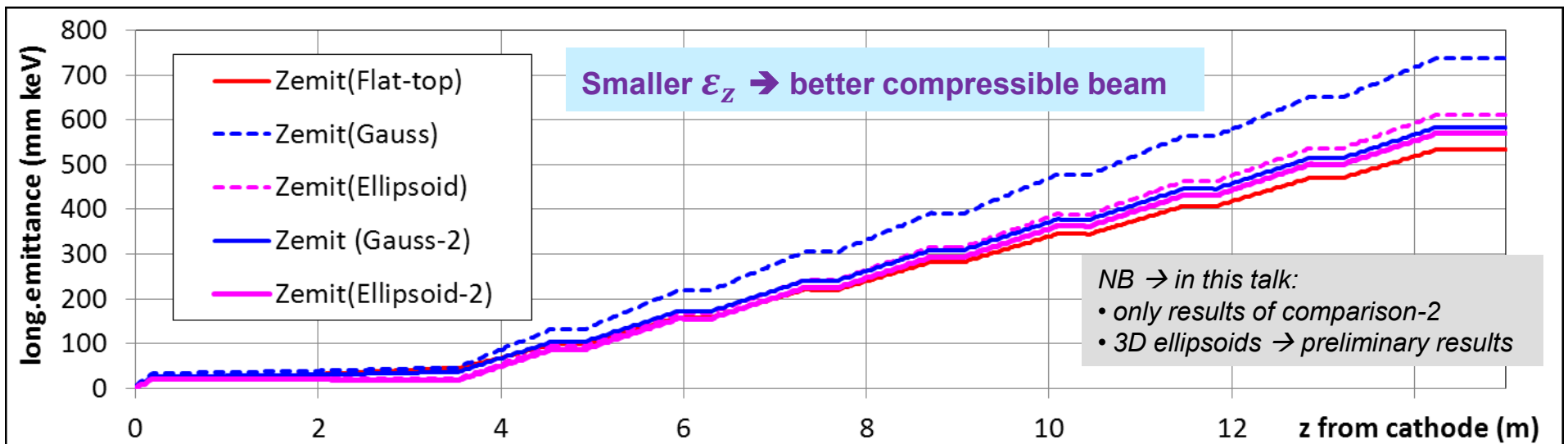
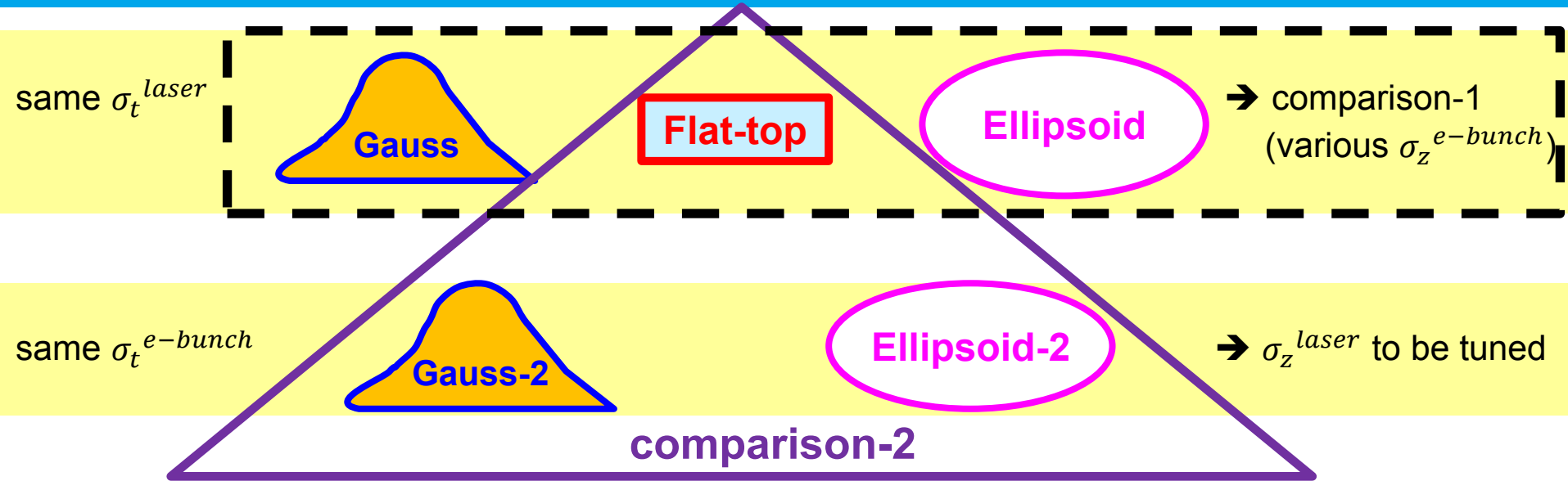
** used for the Gaussian and 3D ellipsoid laser pulse optimization for the second comparison option



Different cathode laser pulse shapes: strategy of comparison



Different cathode laser pulse shapes: strategy of comparison

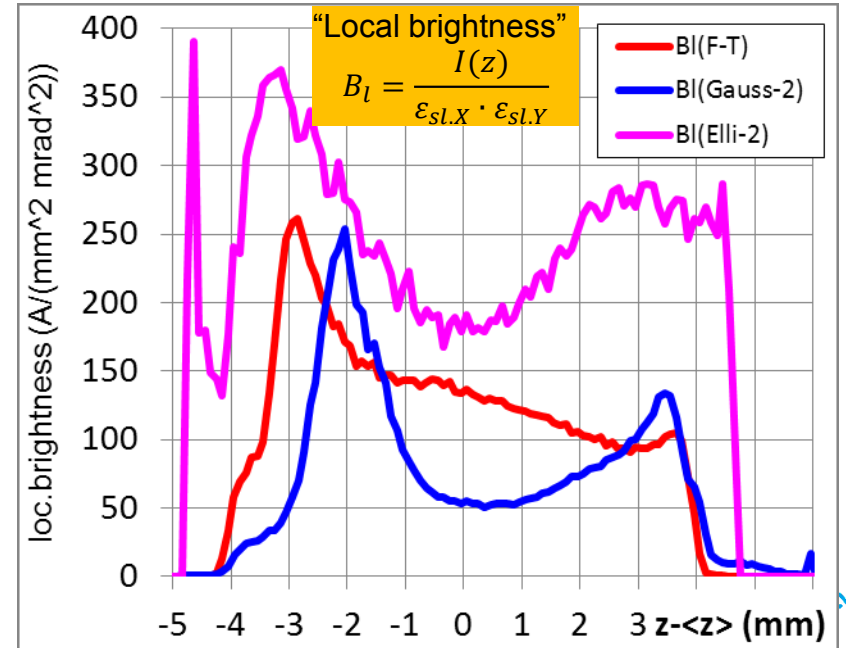
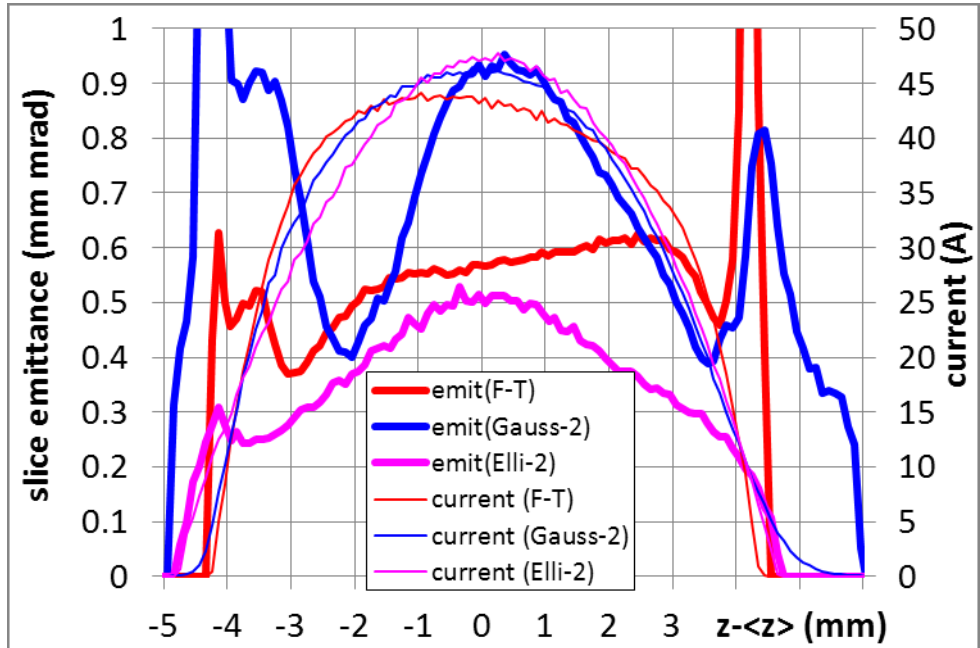
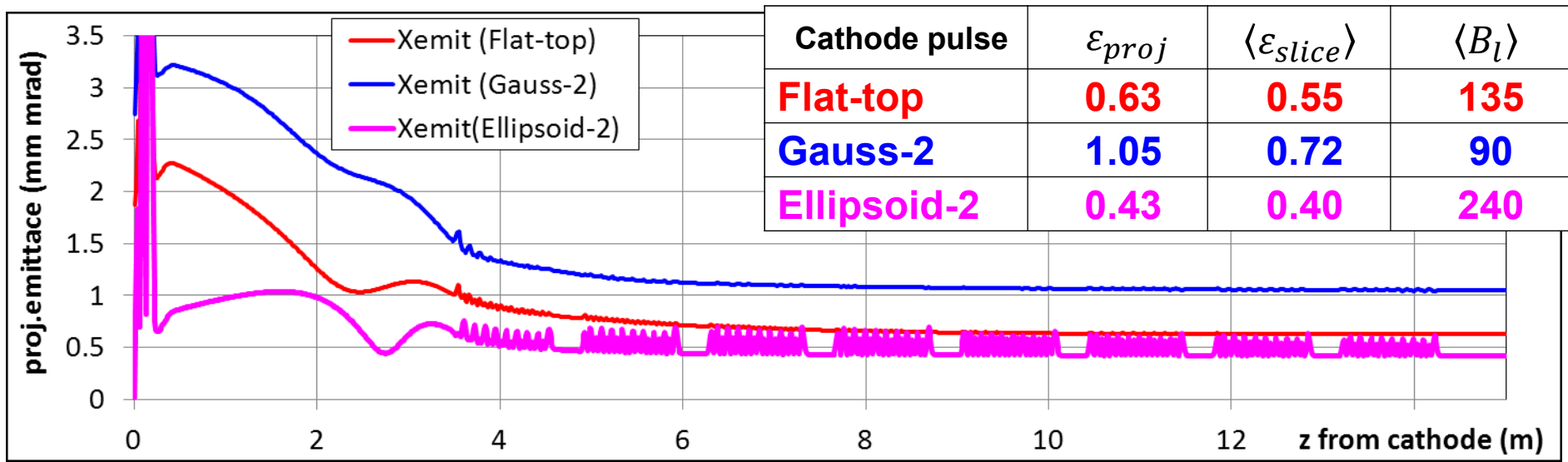


Comparison-2: Optimized machine parameters

		PITZ-1.8 (talk of M.Khojayan)			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	Temporal profile/shape →		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	



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



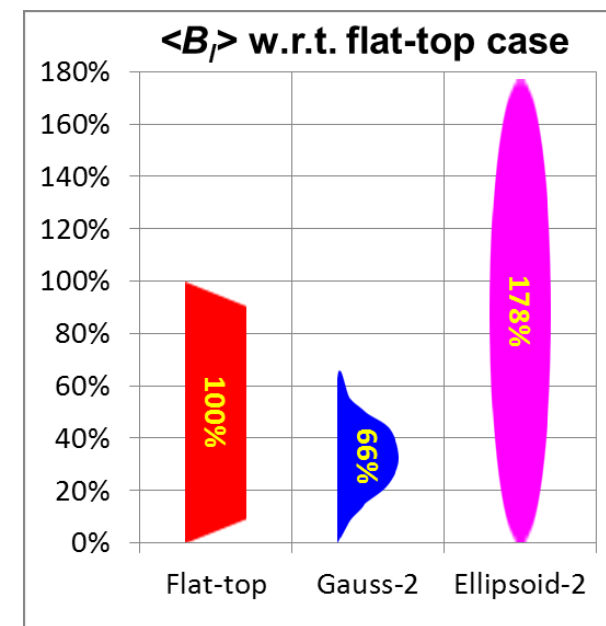
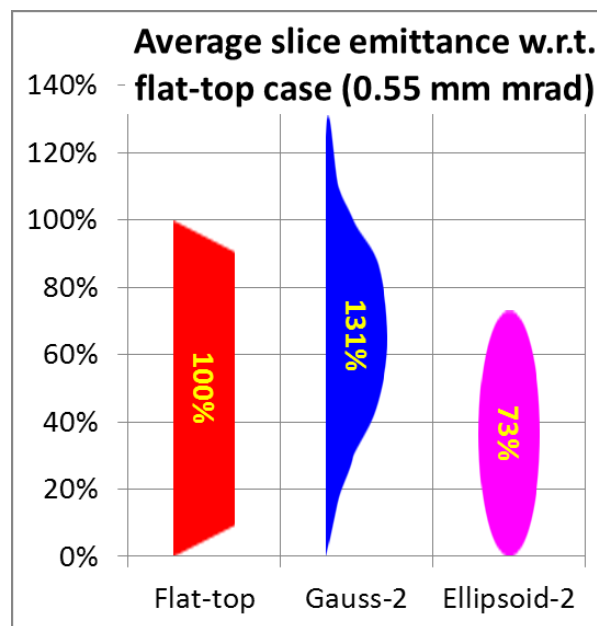
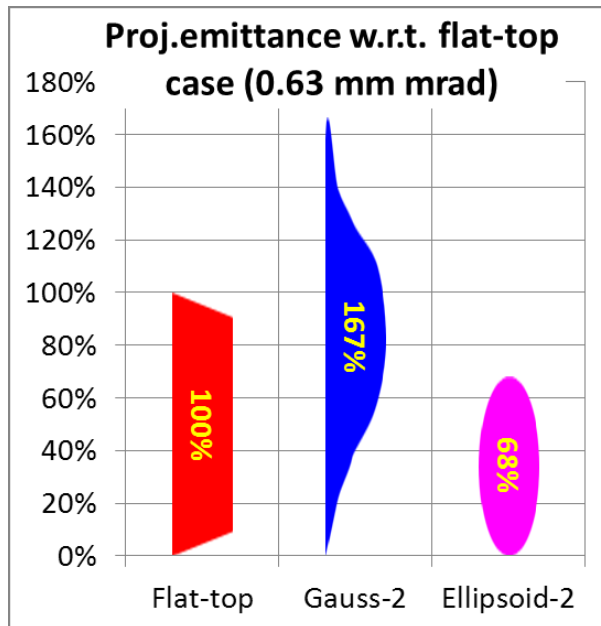
Conclusions

> 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 ($E_{\text{cath}}=60.6\text{MV/m}$)
- ACC1 as a booster + further acceleration ($\sim 150\text{MeV}$)
- Solenoid and booster positions were not varied

> 3 cathode laser pulse shapes were simulated to reach the smallest projected emittance after the injector:

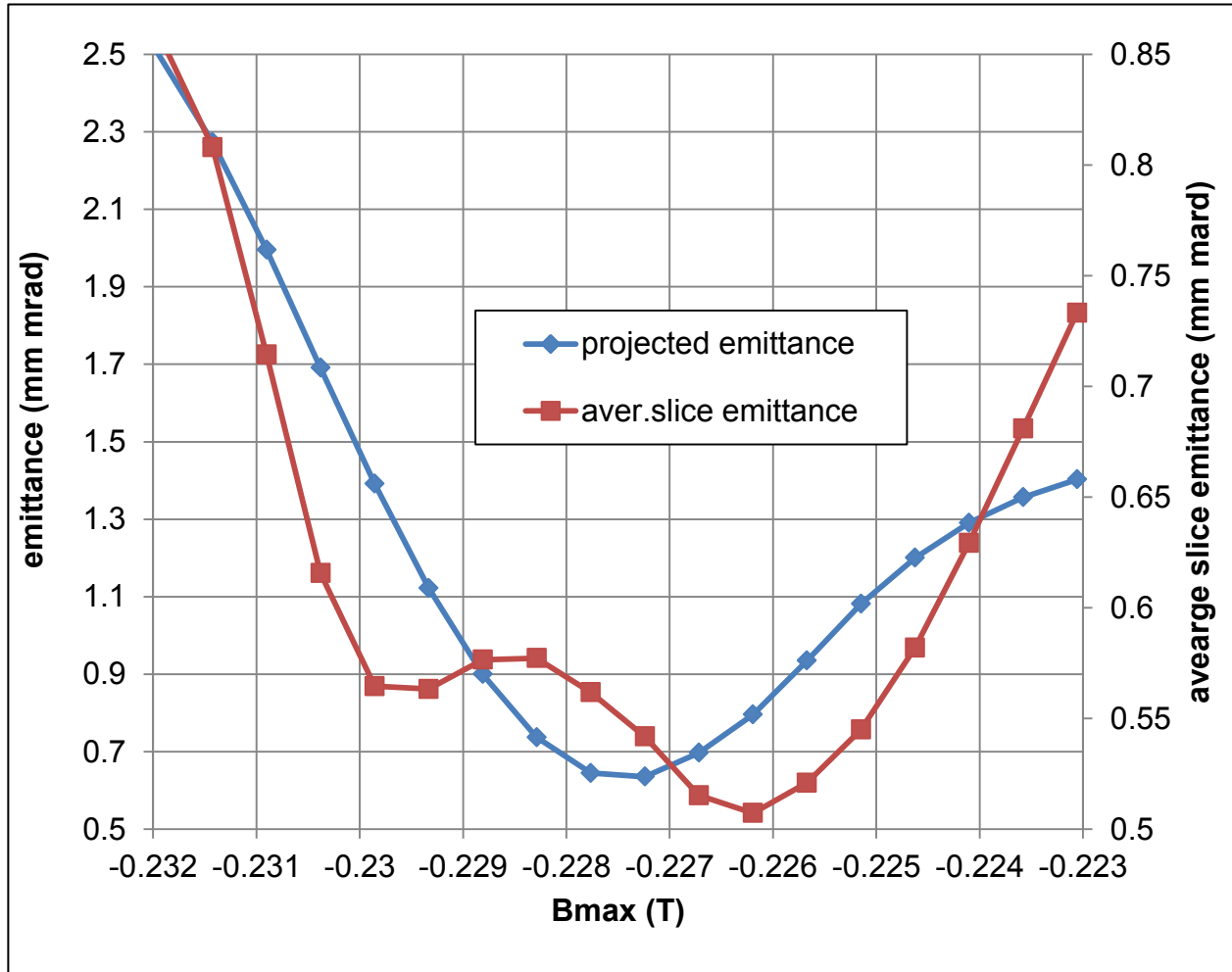
- Flat-top (2/21.5\2ps), Gaussian and 3D ellipsoid (preliminary)
- Comparison-2 option discussed → tuning Gaussian and ellipsoid laser duration to yield the same rms electron bunch length



Backup slides



Projected and average slice emittance vs. solenoid peak field

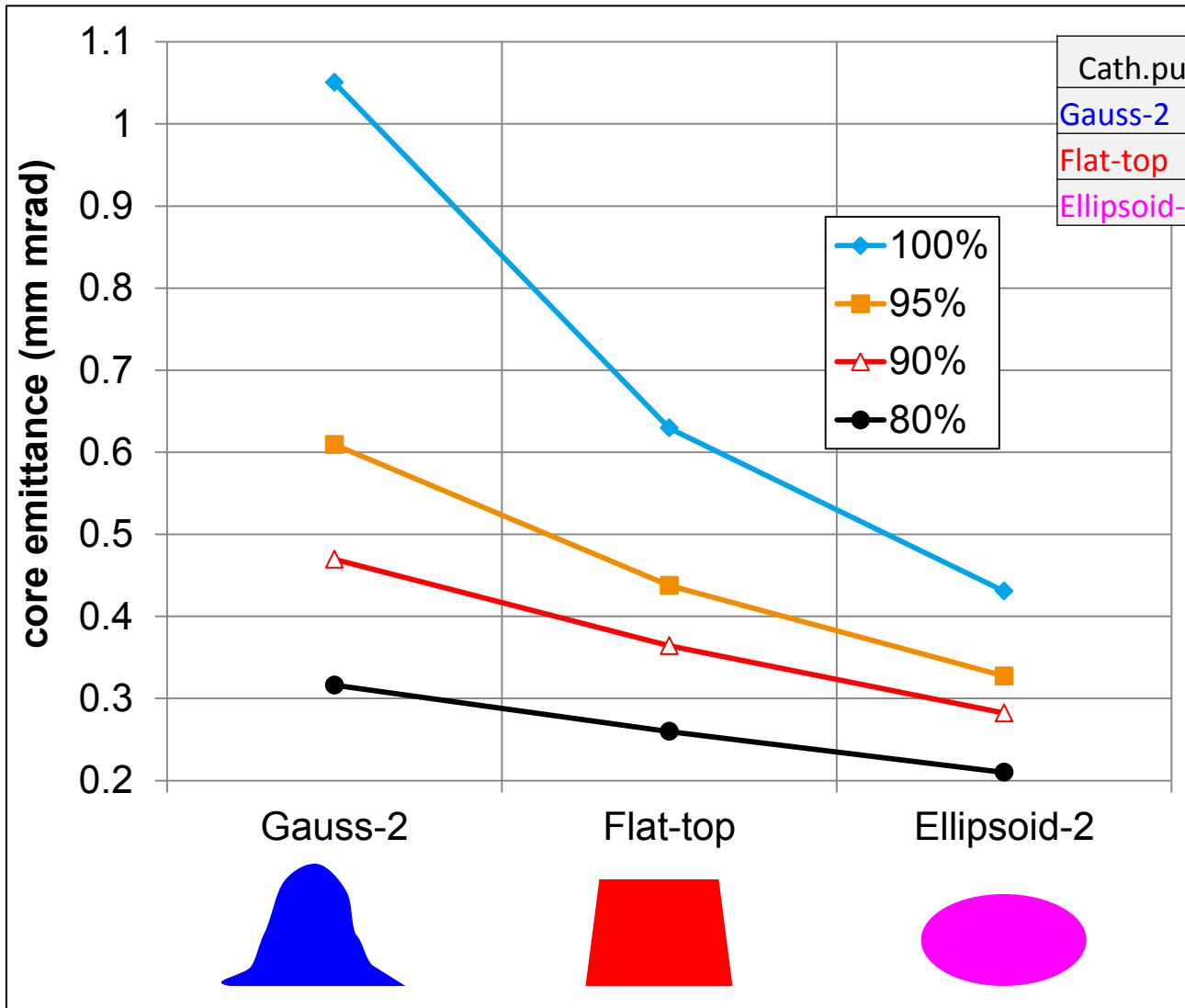


PITZ → XFEL PI: → (%)

	Temporal profile/shape →		PITZ-1.8			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 distribution		radial homogeneous		3D homogeneous	radial homogeneous		3D homogeneous
	Trms	ps	5.4	6.272	6.1	98%	100%	98%
	XYrms	mm	0.385	0.401	0.39	101%	103%	101%
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	99.7%	99.8%	99.9%
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	97.3%	98.5%	102.8%
	Th. / proj.	%	30	53	79	34	36	33
	<Sl. emit.>	mm mrad	0.778	0.572	0.392	92.8%	96.2%	102.6%
	Rms bunch length	mm	2.163	2.163	2.162	98.4%	98.4%	98.4%
	Peak current	A	45.4	43.2	46.8	46	43.8	47.3
	Long. emittance	mm keV	107	98	88	583	533	224



Core emittance (XFEL PI, comparison-2)



Cath.pulse	100%	95%	90%	80%
Gauss-2	1.05	0.61	0.47	0.32
Flat-top	0.63	0.44	0.36	0.26
Ellipsoid-2	0.43	0.33	0.28	0.21

Phase space at z=15m

