XFEL
X-Ray Free-Electron Laser

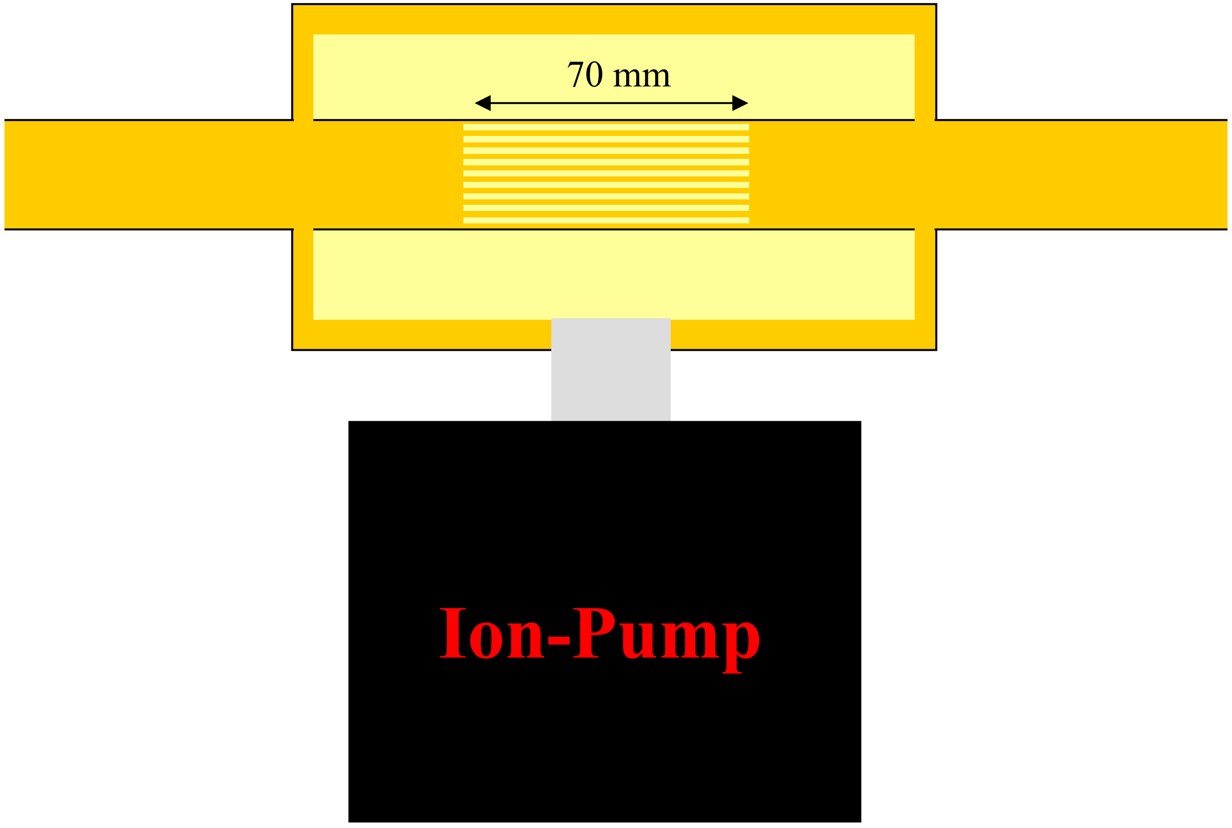
Wakefields of different elements

Igor Zagorodnov

28.04.07

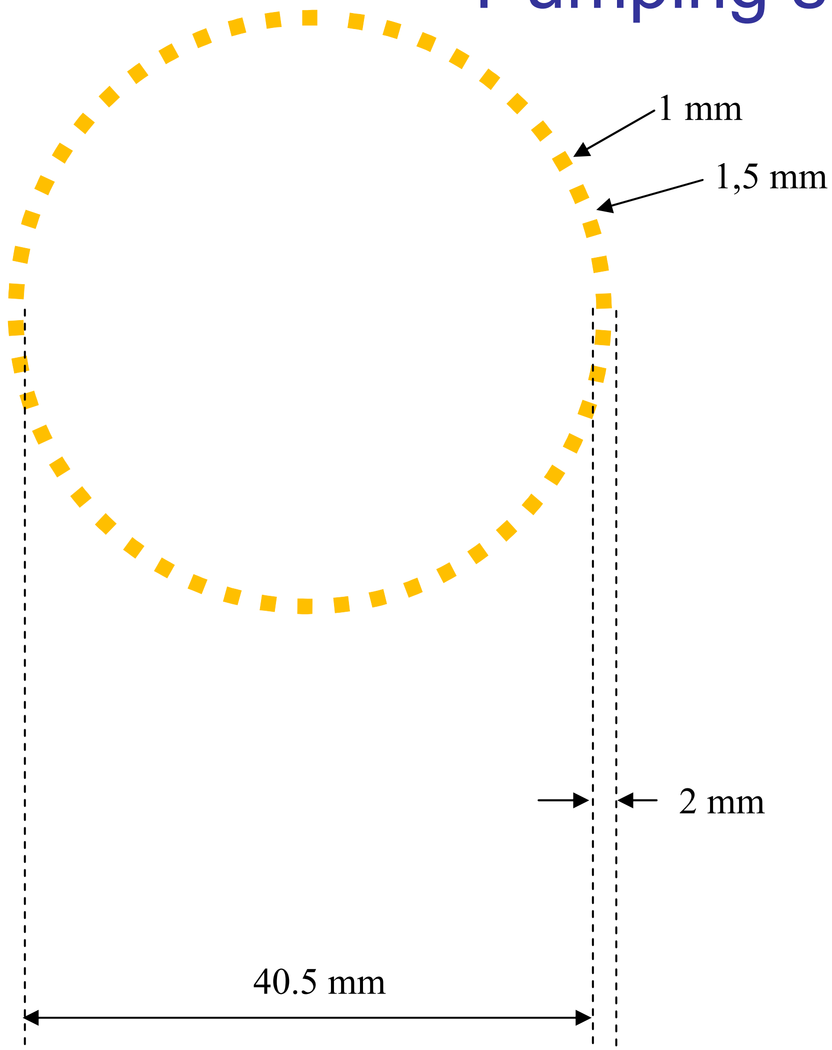
BD meeting, DESY

Pumping slots



Boris Nagorny

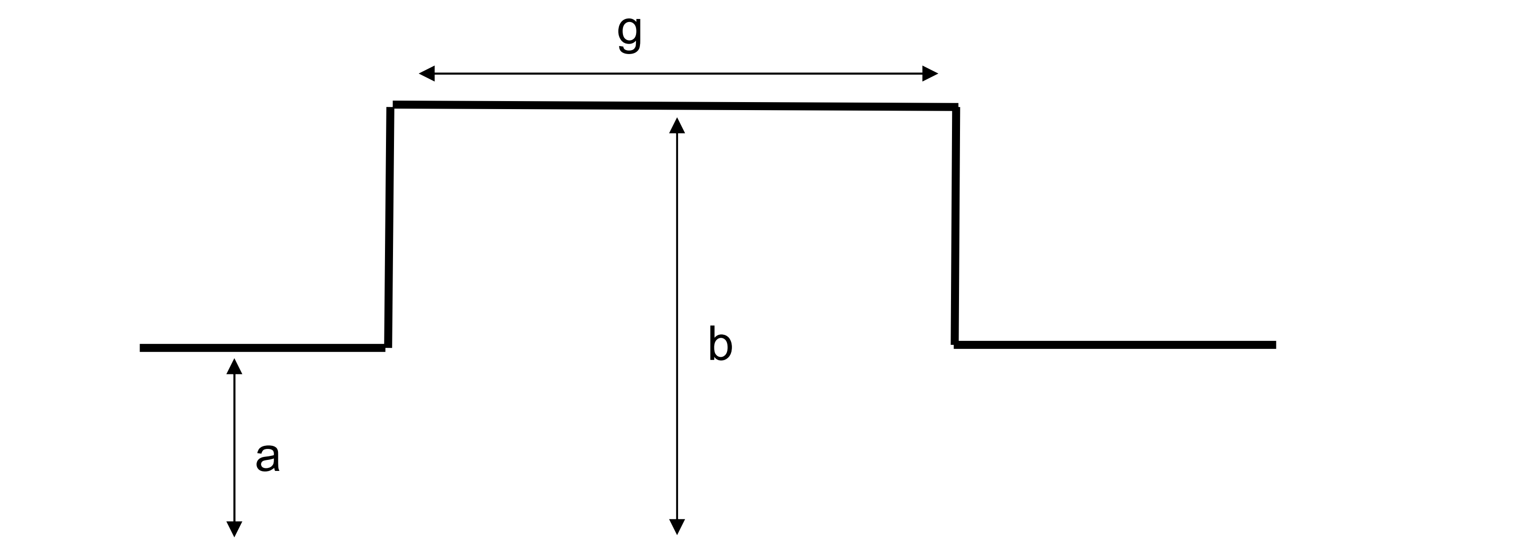
Pumping slots



78 items after LINAC

Boris Nagorny

Pumping slots: cavity model



Pumping slots: cavity model

(1) Analytical estimation for cavity (g - finite)

$$w_{\|}^{\delta}(s) = \frac{Z_0 c}{\sqrt{2}\pi^2 a}\sqrt{\frac{g}{s}}$$

$$k_{\|} = \frac{Z_0 c}{4a\pi^{2.5}}\Gamma\left(\frac{1}{4}\right)\sqrt{\frac{g}{\sigma_z}}$$

$$\mathrm{k_{rms}} = \frac{k_{\|}}{2.467}$$

$$w_{\perp}^{\delta}(s) = \frac{2}{a^2}\frac{\sqrt{2}Z_0 c}{\pi^2 a}\sqrt{gs}$$

$$k_{\perp} = \frac{2}{a^3}\frac{Z_0 c}{\pi^{2.5}}\Gamma\left(\frac{3}{4}\right)\sqrt{g\sigma_z}$$

(2) Analytical estimation for step-out transition (g - infinite)

$$Z_{\|} = \frac{Z_0}{\pi}\ln\left(\frac{b}{a}\right)$$

$$w_{\|}^{\delta}(s) = Z_{\|} c \delta(s)$$

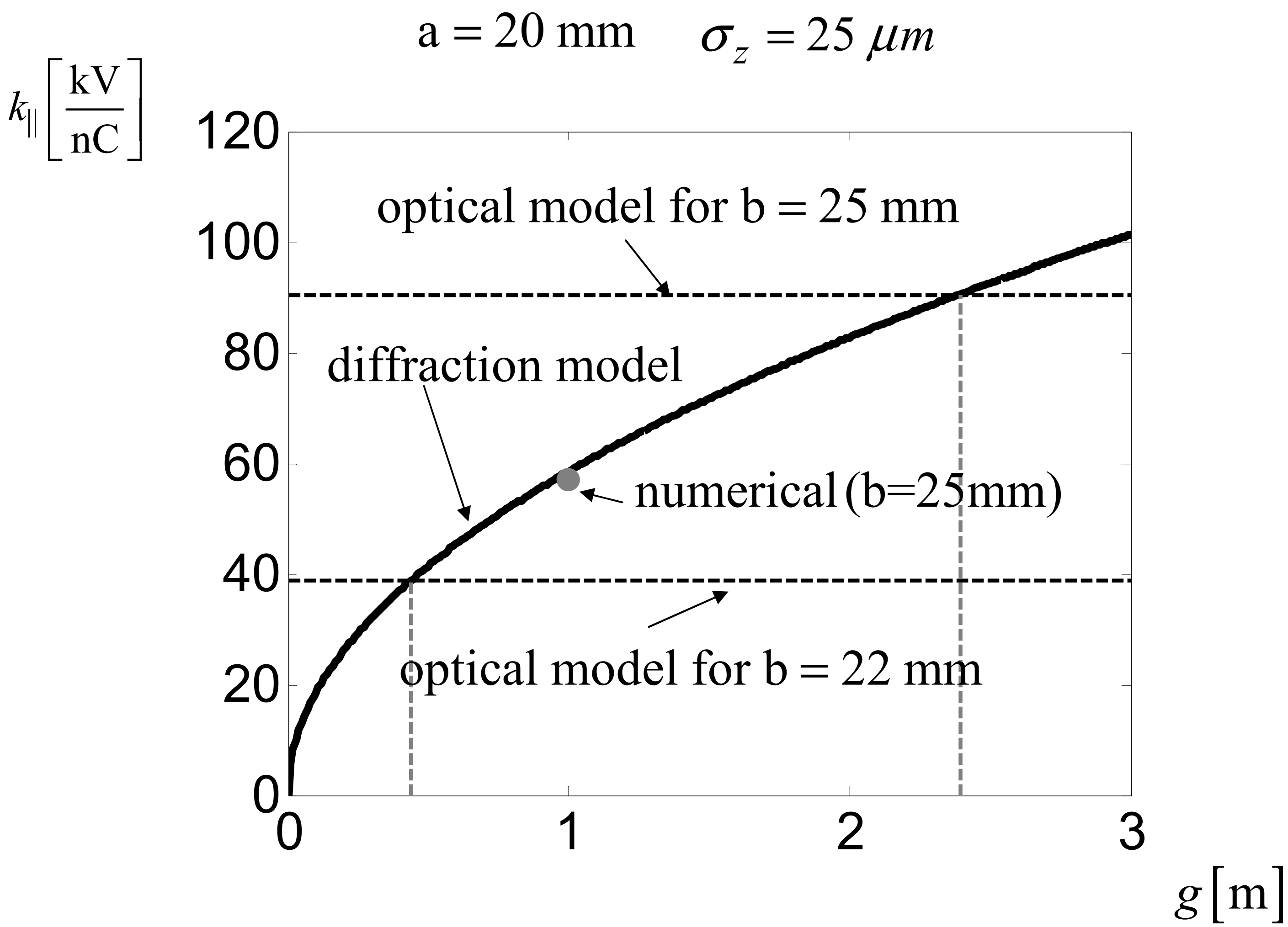
$$k_{\|} = \frac{Z_{\|} c}{2\sqrt{\pi}\sigma_z}$$

$$\mathrm{k_{rms}} = k_{\|}\sqrt{\frac{2}{\sqrt{3}} - 1} \approx 0.4\, k_{\|}$$

$$w_{\perp}^{\delta}(s) = 2 * k_{\perp} * \theta(s)$$

$$k_{\perp} = \frac{Z_0 c}{2\pi}\left(\frac{1}{a^2} - \frac{1}{b^2}\right)$$

Pumping slots: cavity model



$g = 70\,\text{mm}$ ⇨ diffraction model (g -finite)

Pumping slots

$$\mathrm{a} = 20\ \mathrm{mm}$$

$$\sigma_z = 25\ \mu m$$

$$g = 70\,\mathrm{mm}$$

$$\theta = \frac{3}{5} 2\pi$$

$$k_{\|} = \frac{Z_0 c}{4 a \pi^{2.5}} \Gamma\left(\frac{1}{4}\right) \sqrt{\frac{g}{\sigma_z}}$$

$$\mathrm{Spread} = \frac{k_{\|}}{2.467}$$

$$k_{\|}{}^{cavity} = 15.5 \frac{\mathrm{kV}}{\mathrm{nC}}$$

$$\mathrm{Spread}^{\mathrm{cavity}} = 6.3 \frac{\mathrm{V}}{\mathrm{pC}}$$

$$k_{\|}{}^{pump} \approx k_{\|}{}^{cavity} \frac{\theta}{2\pi} = 9.3 \frac{\mathrm{kV}}{\mathrm{nC}}$$

$$k_{rms}{}^{pump} \approx Spread^{cavity} \frac{\theta}{2\pi} = 3.8 \frac{\mathrm{kV}}{\mathrm{nC}}$$

$$k_{\|}{}^{pump,total} = k_{\|}{}^{pump} * 78 = 725 \frac{\mathrm{kV}}{\mathrm{nC}}$$

$$k_{rms}{}^{pump,total} = k_{rms}{}^{pump} * 78 = 296 \frac{\mathrm{kV}}{\mathrm{nC}}$$

Pumping slots

$a = 20 \text{ mm}$

$\sigma_z = 25\ \mu m$

$g = 70\text{ mm}$

$\theta = \frac{3}{5} 2\pi$

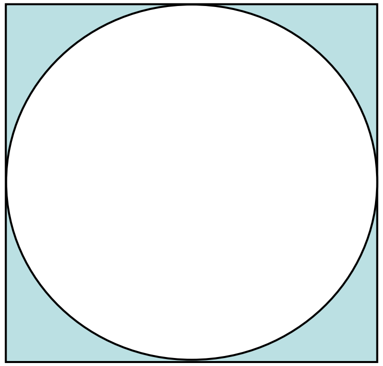
$$k_{||}^{pump,total} = k_{||}^{pump} * 78 = 725 \frac{\text{kV}}{\text{nC}} \quad \%$$

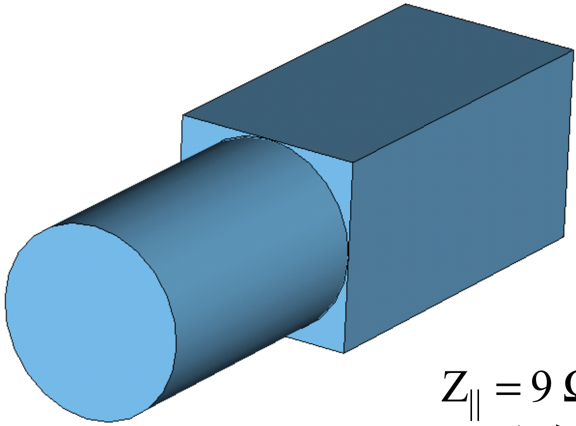
$$k_{rms}^{pump,total} = k_{rms}^{pump} * 78 = 296 \frac{\text{kV}}{\text{nC}}$$

TOTAL (LINAC to SASE2)

	Pipe (456m)	Collimators (4 items)	Kickers (3*10m)	Pumps (78 items)	Total
Loss	3430	4343	2659	725 (6%)	10432+725 (+7%)
Spread	**4332**	**3164**	**1557**	**296 (3%)**	**8763+296 (+3%)**
Peak	-9048	-9088	-4633		

Round to square transition in bunch compressor





$$w_{\|}^{\delta}(s) = Z_{\|} c \delta(s)$$

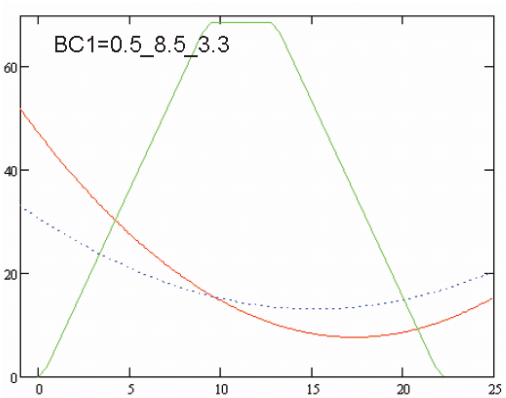
$$k_{\|} = \frac{Z_{\|} c}{2\sqrt{\pi}\sigma}$$

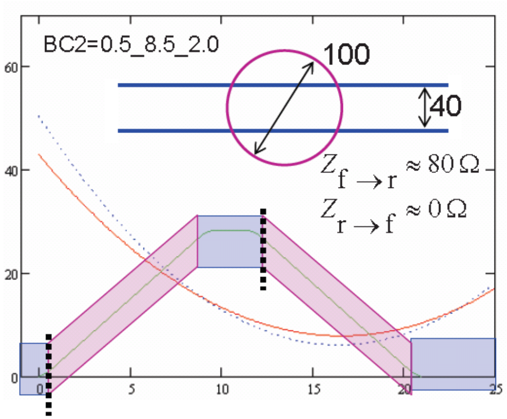
$$k_{rms} = k_{\|}\sqrt{\frac{2}{\sqrt{3}} - 1}$$

$Z_{\|} = 9\ \Omega$

„size independent“

$Z_{\|} = 80\ \Omega$





flat chamber in BC1

“2x20” cu	Ipeak/A=1002 emit_hor/um=1.56
“inf”	Ipeak/A=996 emit_hor/um=1.61
“2x20” st	Ipeak/A=1001 emit_hor/um=1.31

BC2: flat & round

Ipeak/A=5076
emit_hor/um=1.36

Ipeak/A=5005
emit_hor/um=1.12

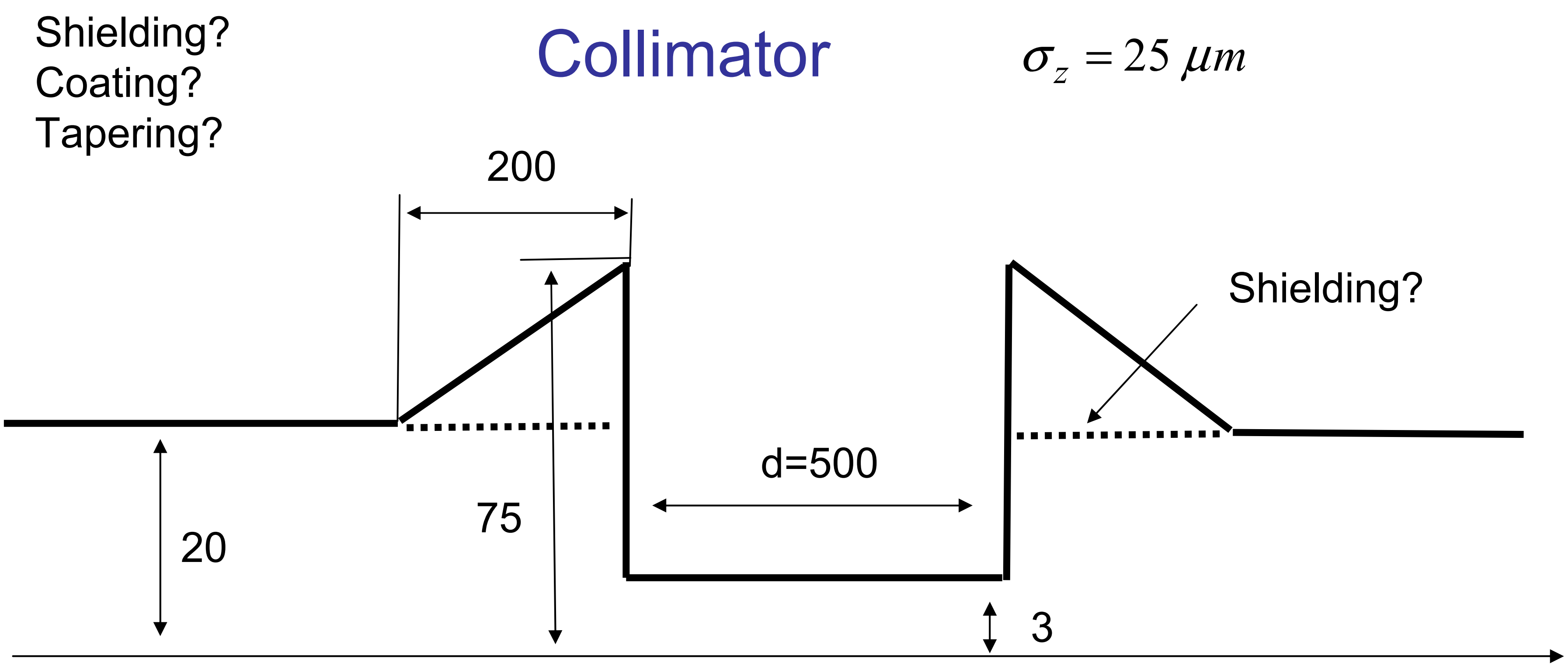
Ipeak/A=5065
emit_hor/um=1.59

XFEL BC System
BC lattice & chamber geometry

Martin Dohlus,
BDM, 03.09.2007

Collimator

$\sigma_z = 25\ \mu m$



	Analytical (optical)	Numerical (ECHO)	
	Step-out	Collimator with shielding	Collimator without shielding
Loss, kV/nC	934	929	929
Kick, kV/nC/mm	4.5	4.2	4.2

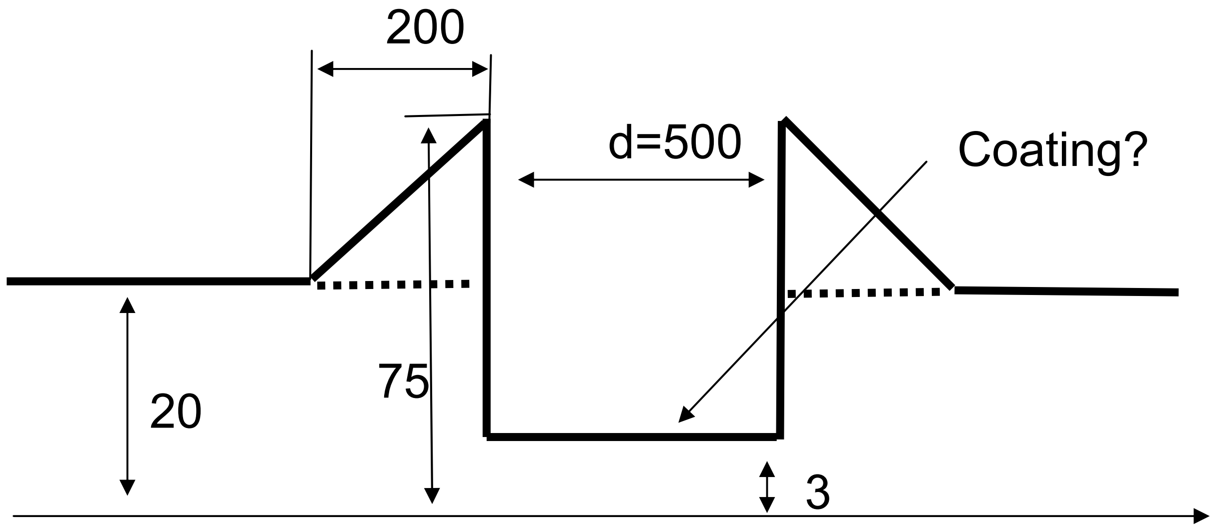
The shielding has no effect on short range wake

$\sigma_z = 25\ \mu m$

Collimator

$\tau = 0[\sec]$

$\Delta_{rough} = 300[\mathrm{nm}]$ $\Delta_{oxid} = 5[\mathrm{nm}]$



TIMETAL (Titanium)

$\sigma = 0.6 \cdot 10^6 \Omega^{-1} m^{-1}$

TiN (SLAC-PUB-7261)

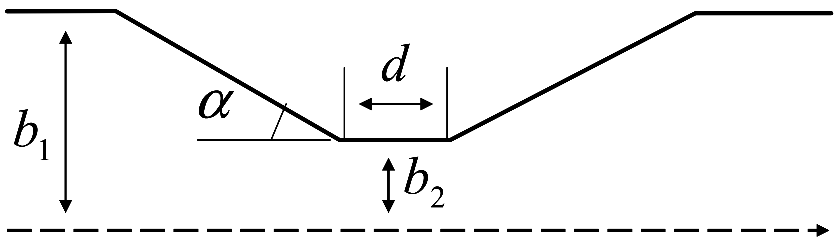
$\sigma = 4.5 \cdot 10^6 \Omega^{-1} m^{-1}$

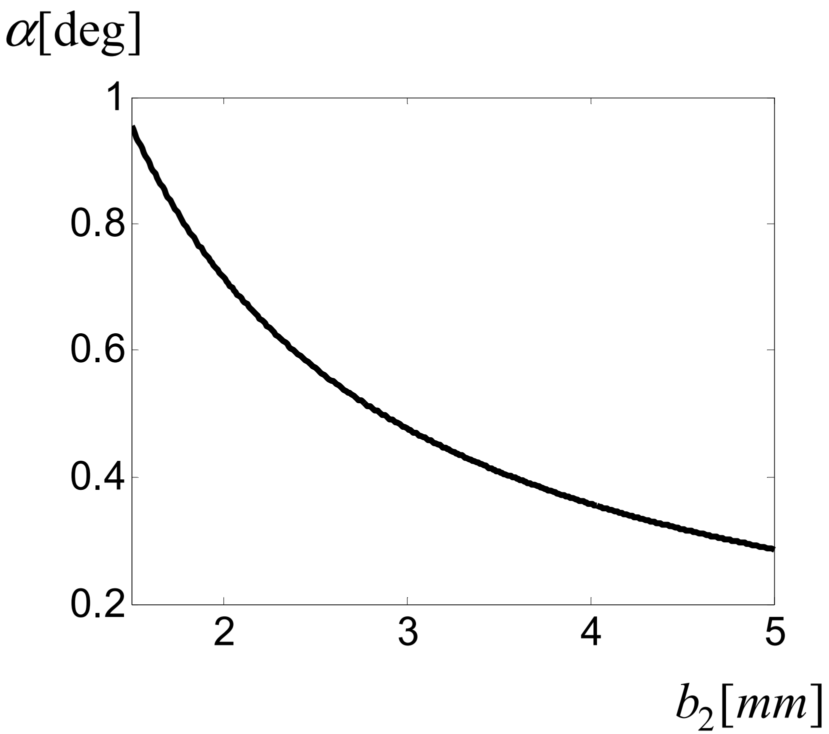
	Geometrical	Resistive	
		TIMETAL (Titanium)	TiN
Loss, kV/nC	934	491	151
Spread, kV/nC	367	333 →	152 (-55%)

Coating reduces the energy spread due to resistive part by 55%.

Transverse kick?

XFEL collimators. Tapering





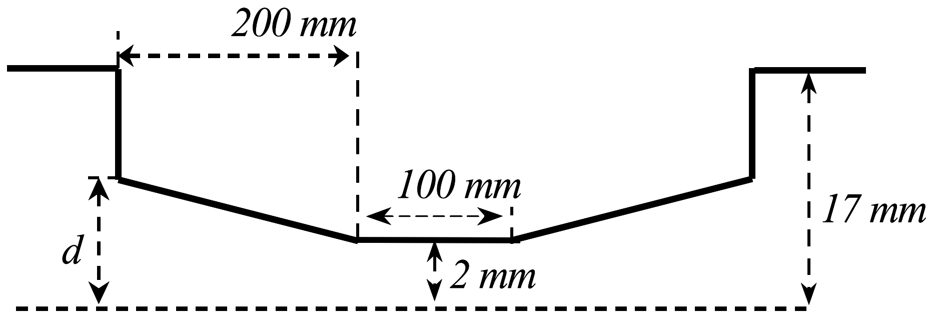
When a short bunch passes by an out-transition, a significant reduction in the wake will not happen until the tapered walls cut into the cone of radiation, i.e until

$$\tan\alpha \sim \sigma_z / b_2$$

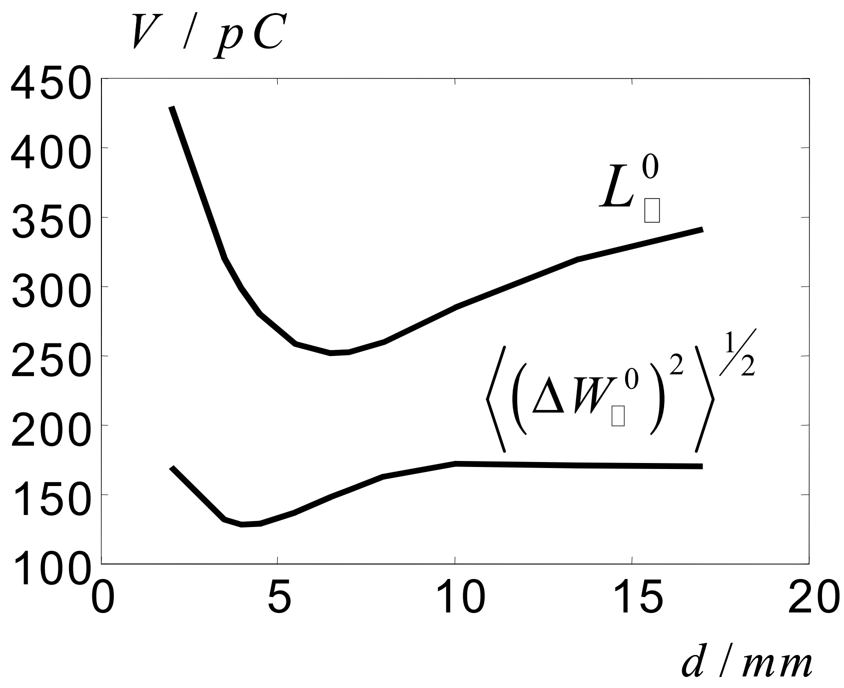
$$\sigma_z = 0.025 \text{ mm}$$

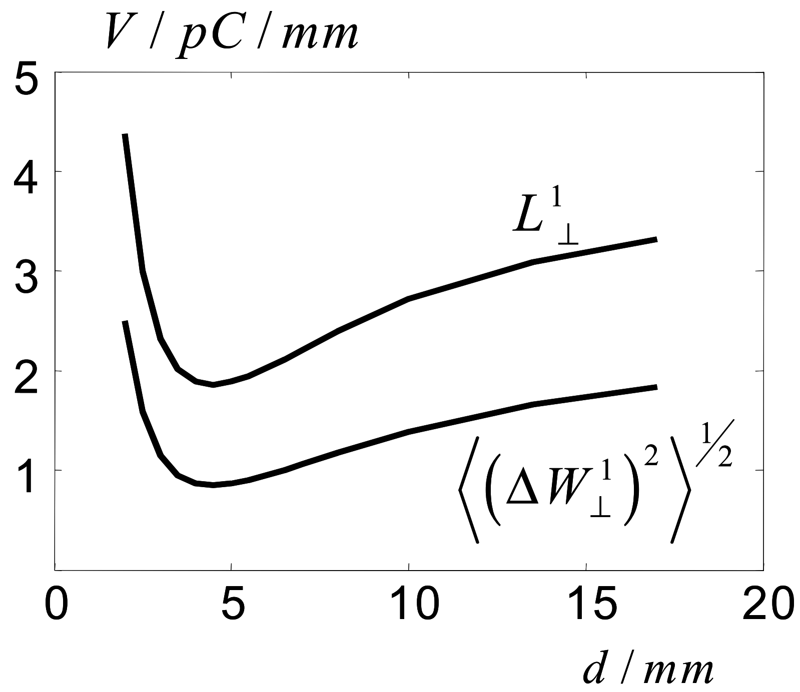
XFEL collimators. Tapering

Geometry of the “step+taper” collimator for TTF2



$\sigma_z = 50\ \mu\text{m}$

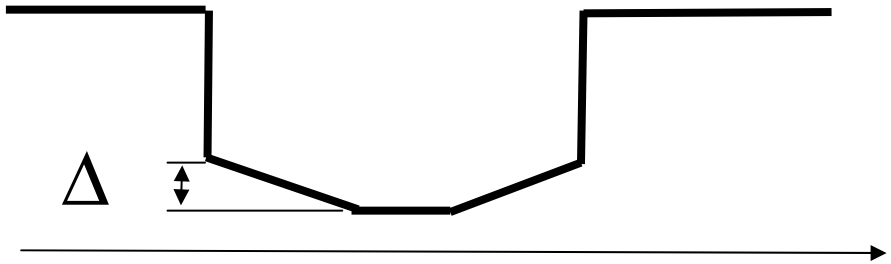




Collimator geometry optimization.
Optimum d ~ 4.5mm

TESLA Report 2003-23

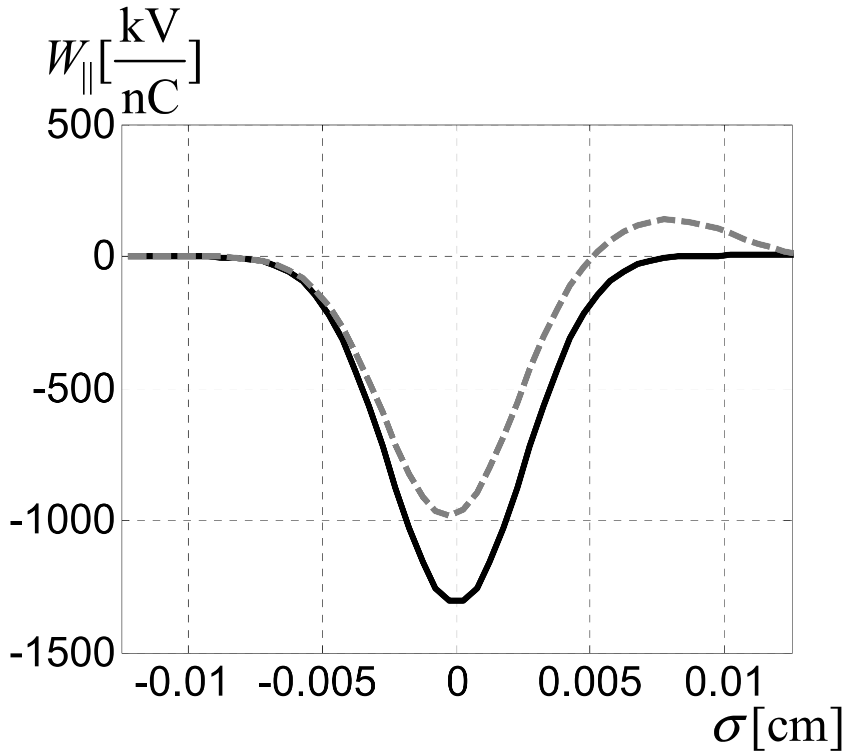
XFEL collimators. Tapering



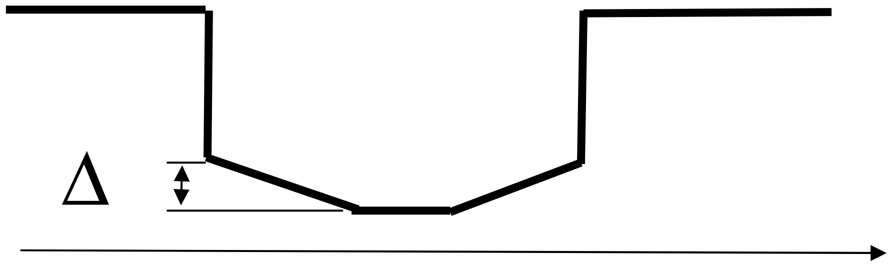
$$\sigma_z = 25\ \mu\text{m}$$?

Δ, mm	Loss, kV/nC	Spread, kV/nC
3.5	656	311
3	661	299
2.5	674	**294**
2	696	296
1.5	729	301
0	929	365

The tapering can reduce the energy spread only by 20%.

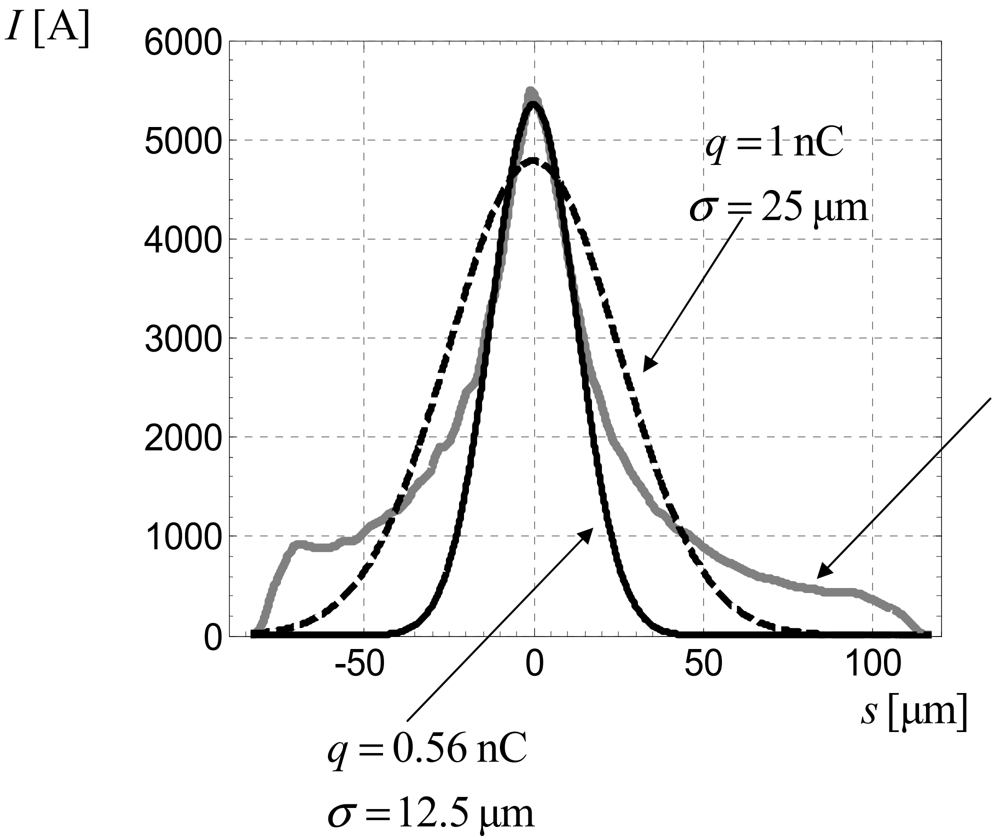


XFEL collimators. Tapering



$$\sigma_z = 12.5\ \mu m$$?

The tapering **does not reduce** the energy spread



Bunch shape from S2E simulations by Martin Dohlus