Status of the XFEL OTR stations and Emittance Growth due to off-axis screen Wakefields

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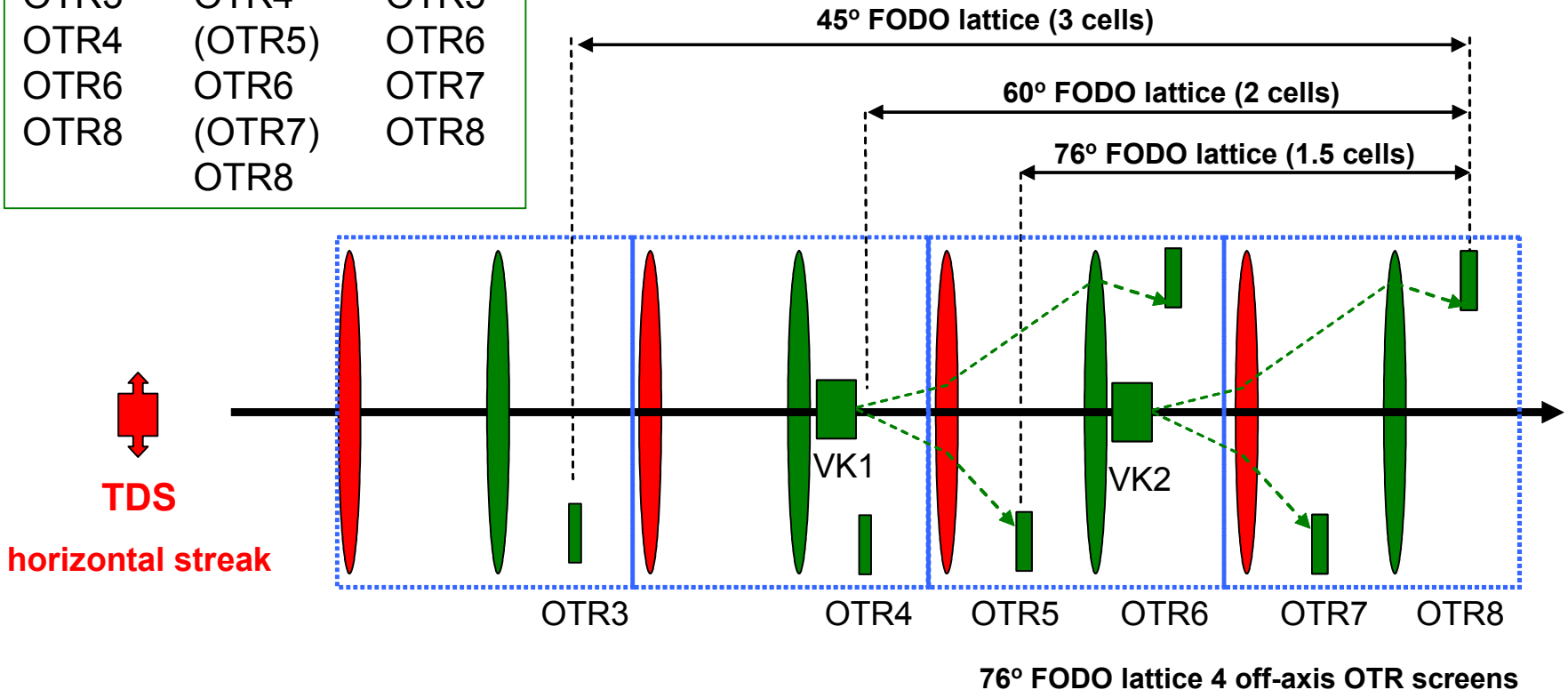
BD meeting, DESY

Diagnostic sections:

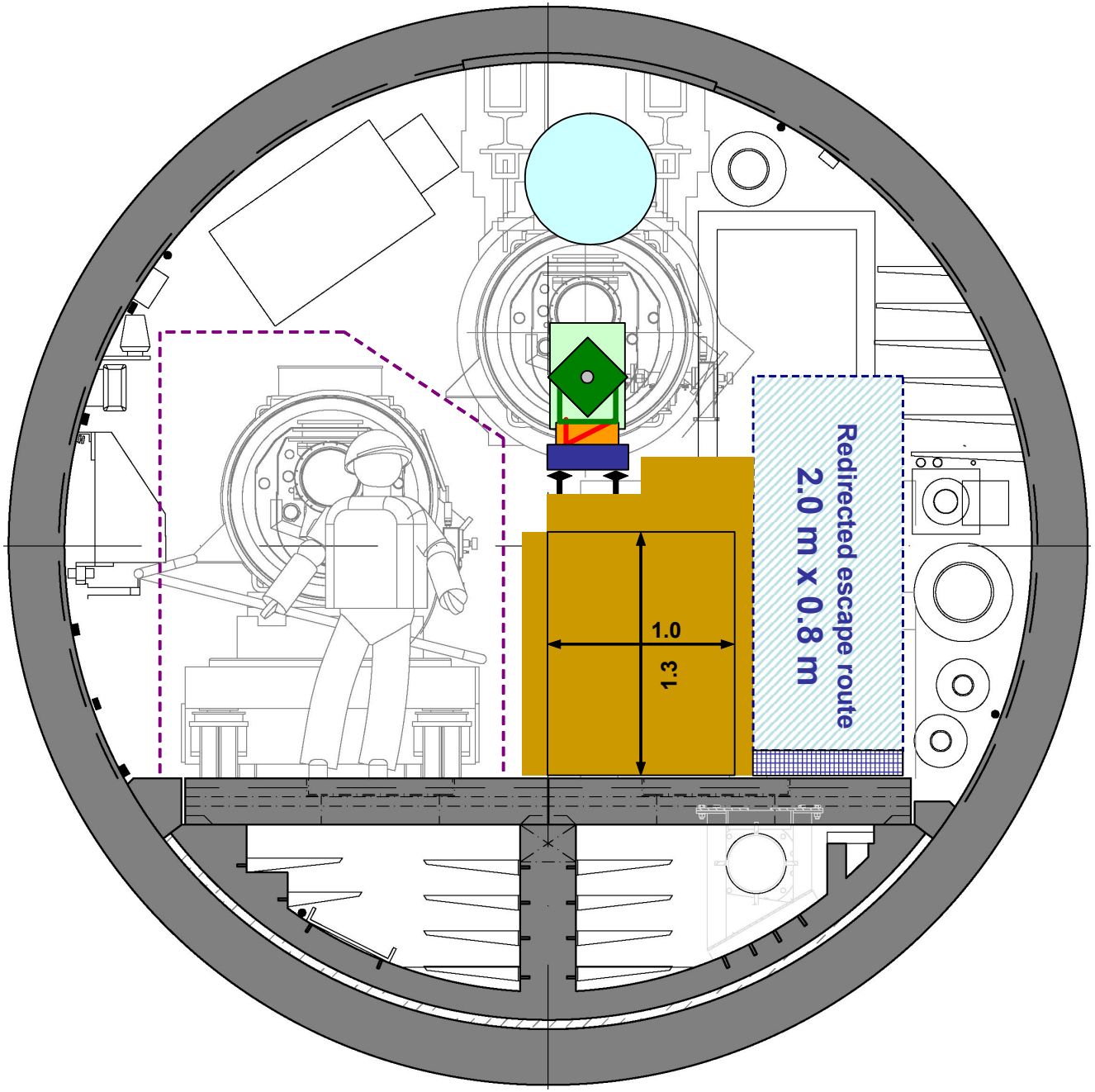
- Injector
- Downstream BC1 chicane
- Downstream BC2 chicane

=> Projected and slice emittance measurements and matching

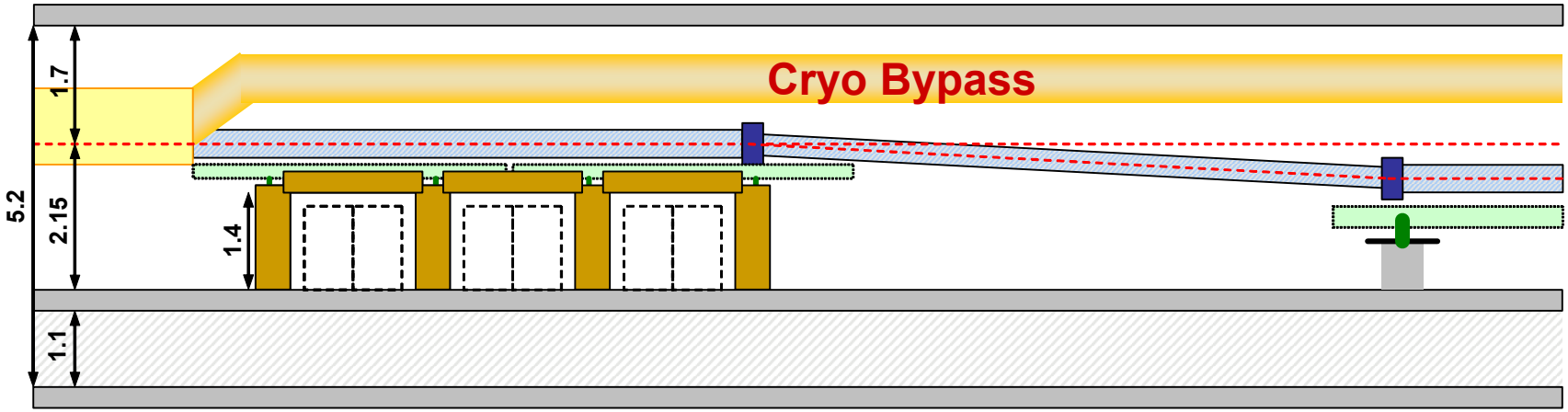
45deg	60deg	76deg
OTR3	OTR4	OTR5
OTR4	(OTR5)	OTR6
OTR6	OTR6	OTR7
OTR8	(OTR7)	OTR8
	OTR8	



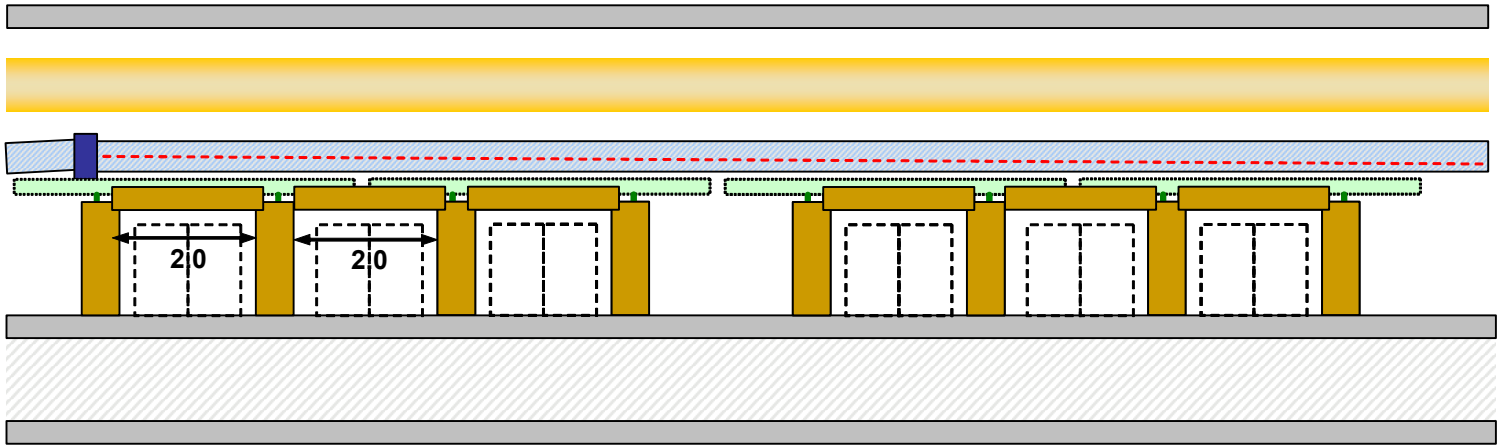
1. Baseline Layout BC Sections: XTL Cross section



1. Baseline Layout BC Sections: Side view



Konstruktionszeichnung Girder: G. Weichert



Meeting on OTR/WS 7.4.2008

- Kickers and off-axis screens available In INJ, BC1, BC2
- Fast WS not required

Advantage:
- Select bunch out of bunch train
- Single bunch resolved (compared to averaged profiles)
- 2D beam shapes

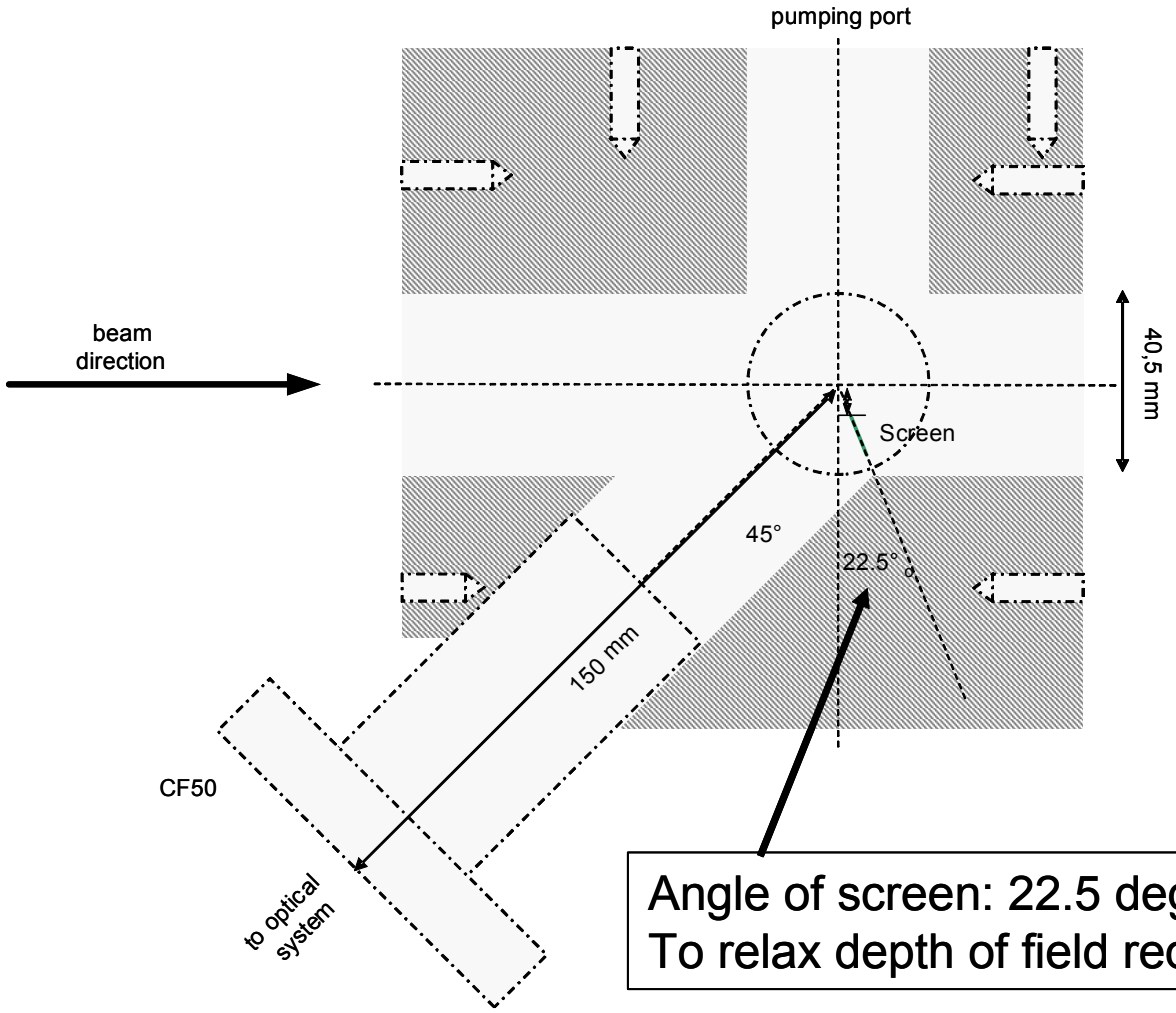
Risks:
- SR from kicker => measurements at FLASH
- COTR => measurements at FLASH

Section	OTR/WS old	OTR	OTR-off-axis	WS	Comment
Injector[1]	**5/5**	**1+1**	**4**	**0**	**WS taken out/ space reserved Laser Heater OTRs not included**
BC1	**9/9**	**4+1**	**4**	**0**	**WS taken out/ space reserved**
BC2	**9/9**	**4+1**	**4**	**0**	**WS taken out/ space reserved**
Collimator	**4/4**	**4**	**0**	**4**	**Screens to detect the beam, wire scanners for precise measurements**
Beam distribution	**0/0**	**3**	**0**	**4**	**1 before the switch and 1 in each branch**
Undulator beamlines	**0/4**	**0**	**0**	**8**	**1 before the SASE undulator in each line**
Dump	**2/2**	**3**	**0**	**3**	**1 for every dump**
Total	**29/33**	**21**	**12**	**19**	

[1] The gun screens are not included here.

First Conceptual Design

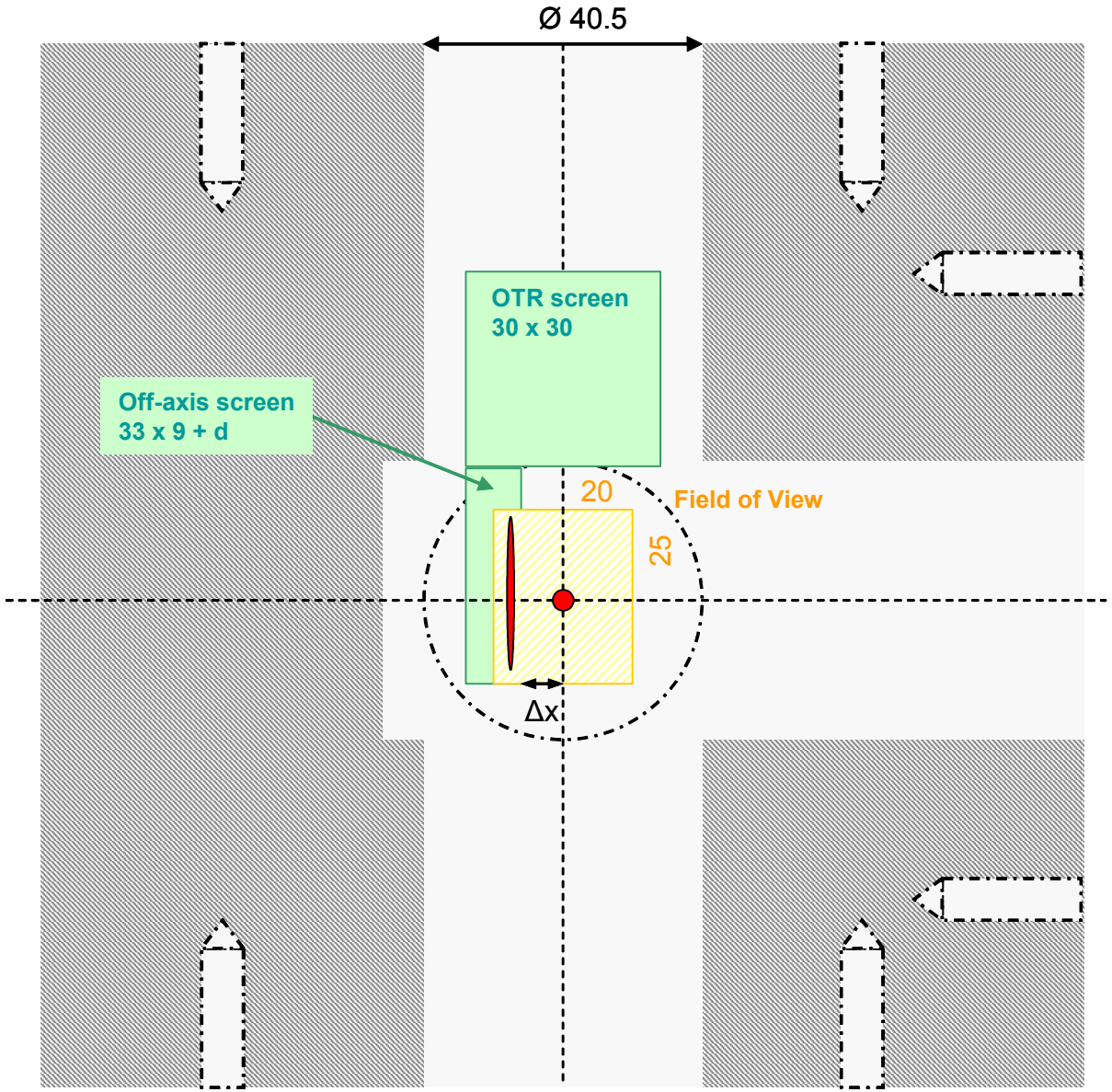
BC1 & BC2: Horizontal streak
=> reflect up or down due to depth of field requirements



Angle of screen: 22.5 deg
To relax depth of field requirements

OTR Screen: XFEL Injector

Front view (1:1) - Intersection B in top view

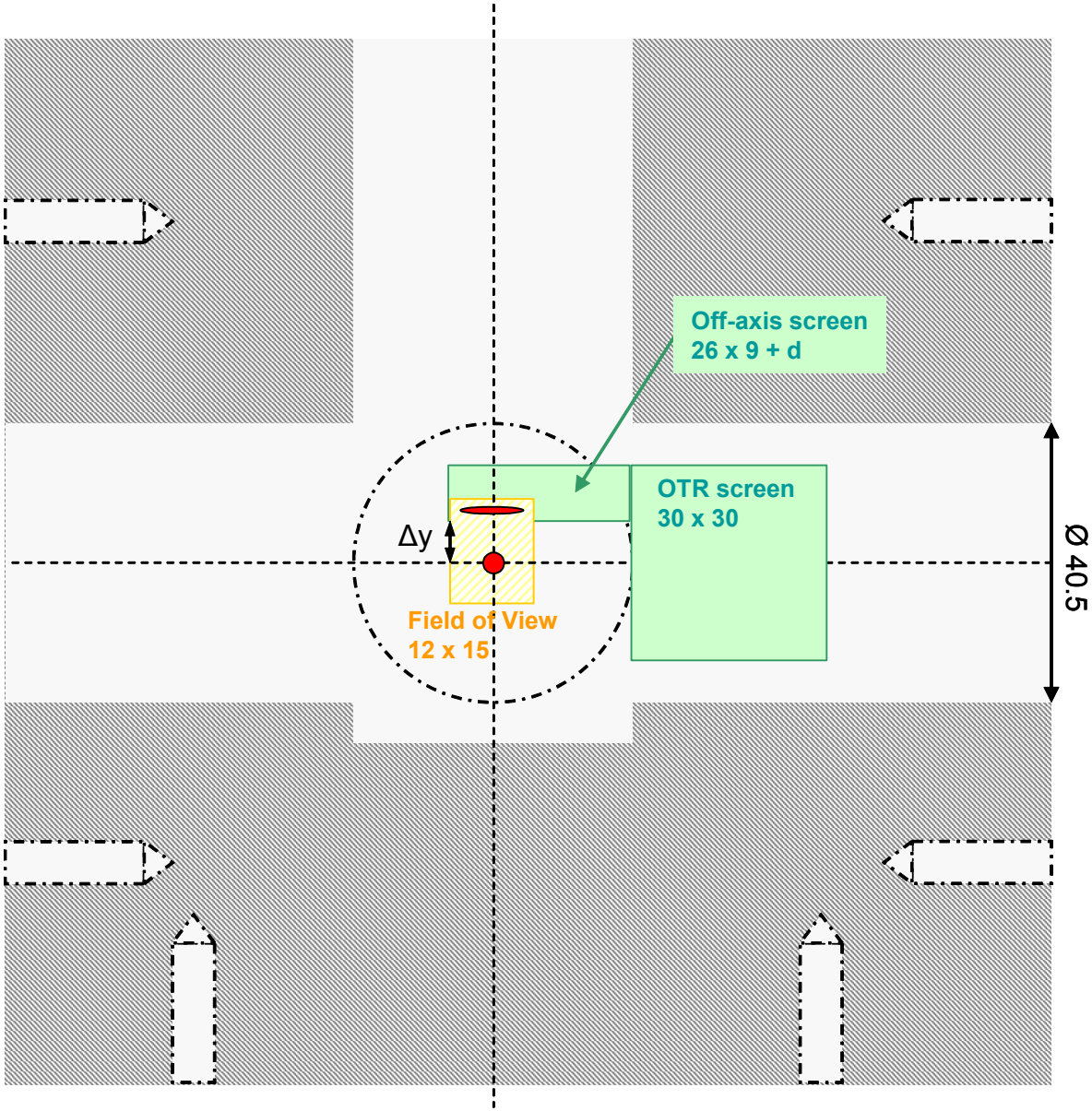


Field of View: 20 x 25 mm²
Off- axis screen: Δx = 6 mm - d
Resolution : 25 µm
Beam size (rms): 130 µm
Streaked beam : 22 mm
Beam energy : 0.13 GeV
Bunch length : 2.0 mm

beam direction
into slide

OTR Screen: XFEL BC1

Front view (1:1) - Intersection B in top view

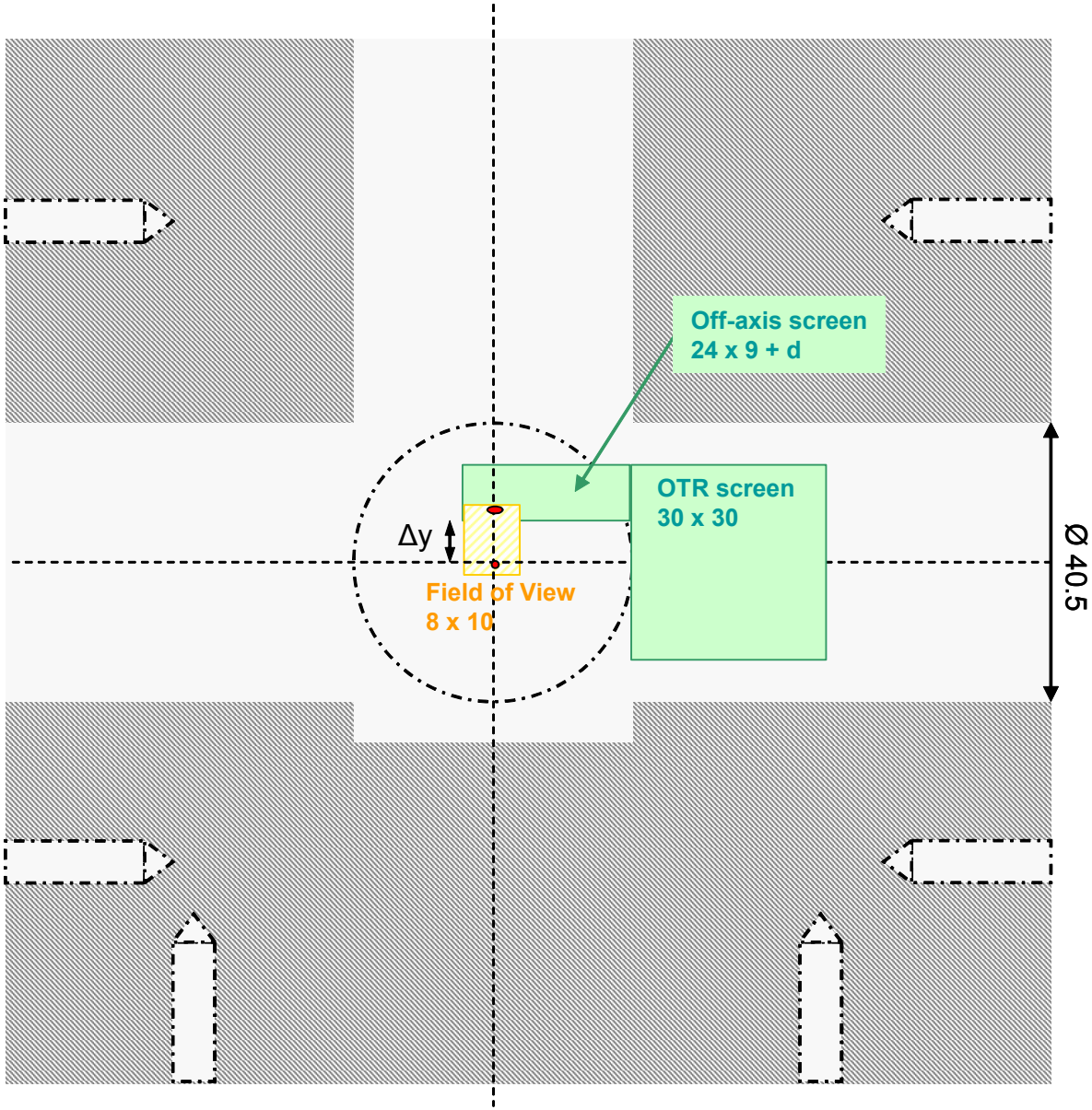


Field of View : 12 x 15 mm²
Off- axis screen: Δy = 6 mm - d
Resolution : 15 µm
Beam size (rms): 70 µm
Streaked beam : 9 mm
Beam energy : 0.5 GeV
Bunch length : 110 µm

beam direction
into slide

OTR Screen: XFEL BC2

Front view (1:1) - Intersection B in top view



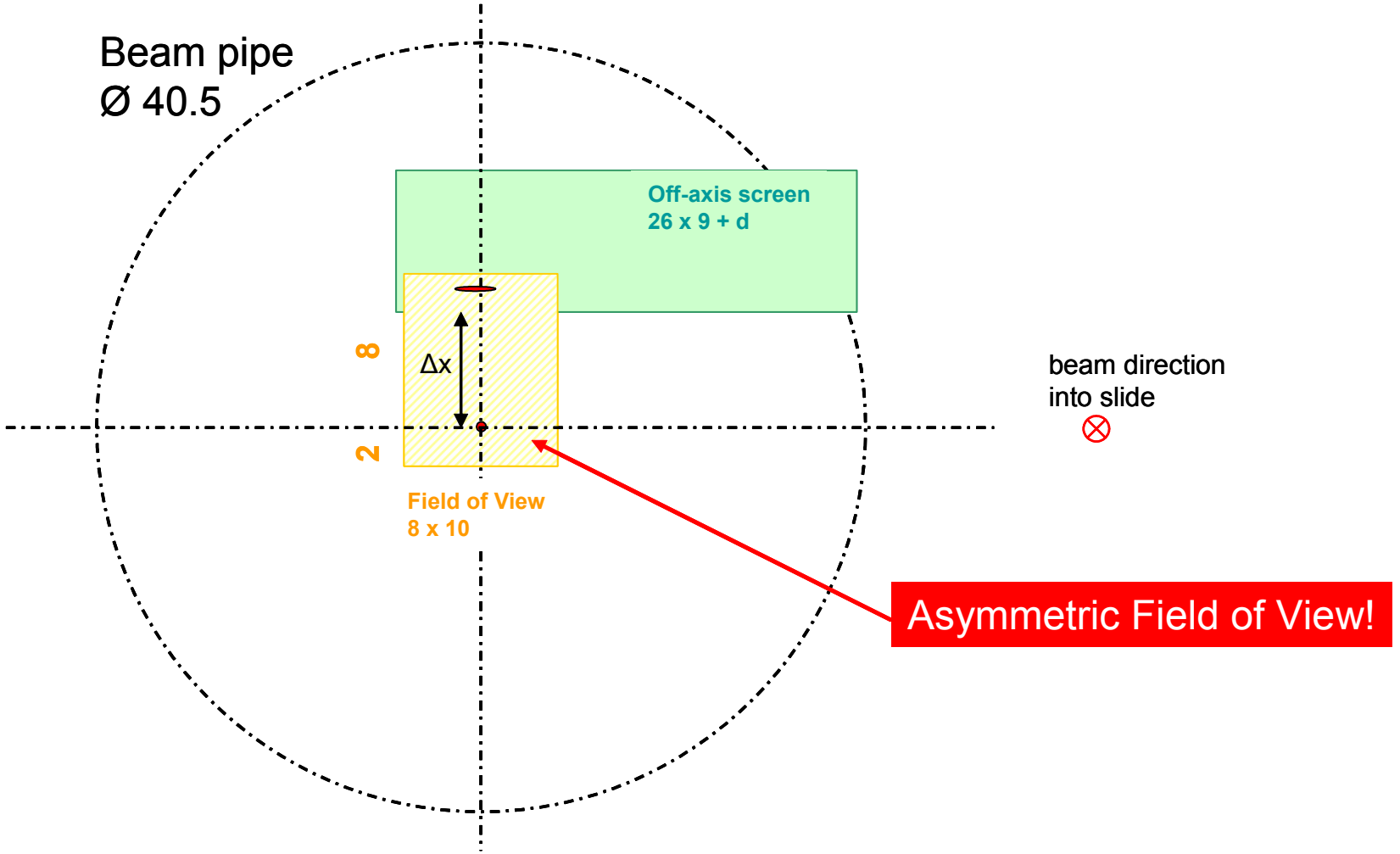
Field of View : 8 x 10 mm²
Off- axis screen: Δy = 6 mm - d
Resolution : 10 µm
Beam size (rms): 40 µm
Streaked beam : 2.1 mm
Beam energy : 2.0 GeV
Bunch length : 25 µm

beam direction
into slide

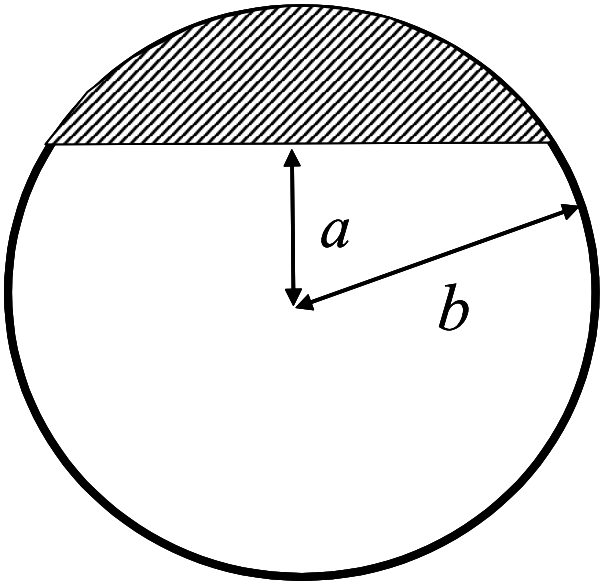
Geometry

OTR Screen: Injector (BC1, BC2)

Front view



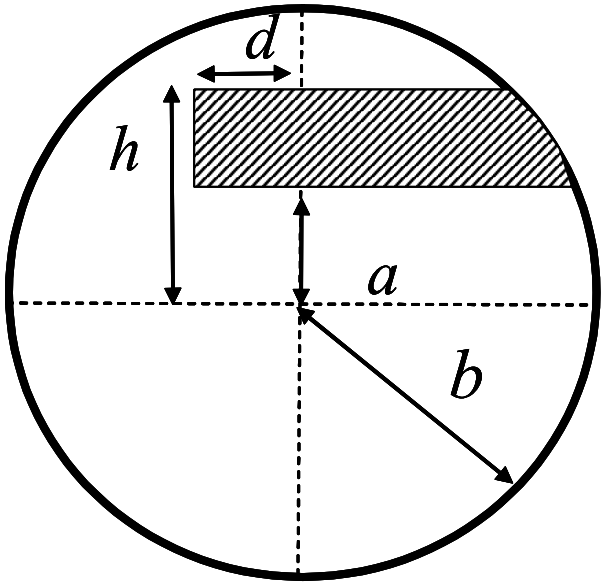
Simple model (overestimation)



$$k^0(0,0) = \frac{c\,Z0\left(a\sqrt{-a^2+b^2}+\left|-2a^2+b^2\right|\mathrm{ArcCot}\left[\frac{a}{\sqrt{-a^2+b^2}}\right]\right)}{4\,a\,b^2\,p^2}$$

G.Stupakov, K.Bane, I.Zagorodnov, Optical Approximation …, PR-STAB, 2007

Improved model



$b = 20.25$ mm

$h = 15$ mm

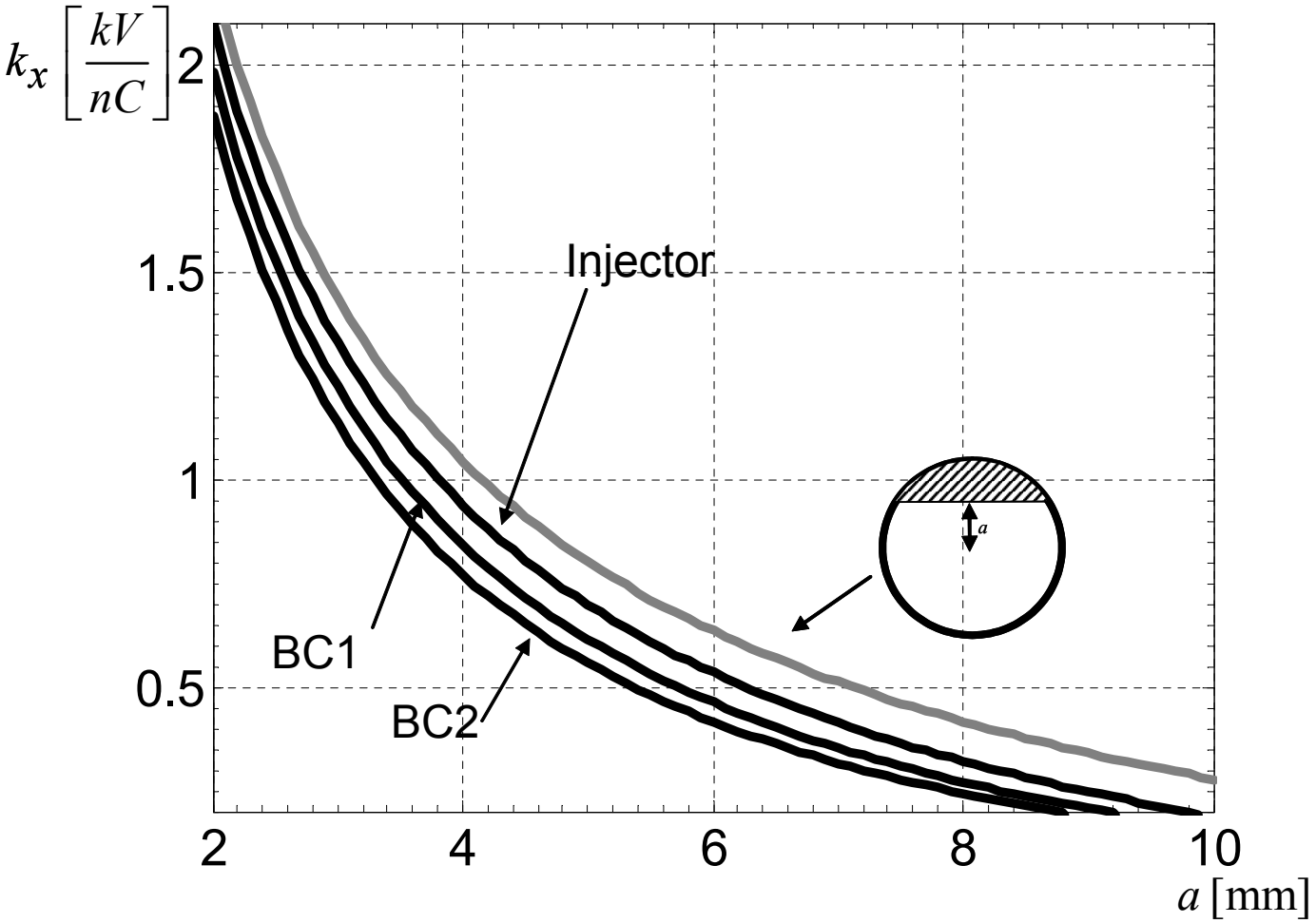
$d = 12.5$ mm - in Injector

$d = 6$ mm - in BC1

$d = 4$ mm - in BC2

$$k^1(0,0) = \frac{1}{8\,a\,b^2\,h\,p^2}\,c\,Z0\left(\left(-2a^2+b^2\right)h\,\mathrm{ArcCot}\left[\frac{a}{\sqrt{-a^2+b^2}}\right] - a\sqrt{b^2-2h^2}\,\mathrm{ArcCot}\left[\frac{h}{\sqrt{b^2-h^2}}\right] + \left(-2a^2+b^2\right)h\,\mathrm{ArcTan}\left[\frac{d}{a}\right] + a\left(-\sqrt{b^2-2h^2}\,\mathrm{ArcTan}\left[\frac{d}{h}\right] + h\left(\sqrt{-a^2+b^2} - \sqrt{b^2-h^2} + d\,\mathrm{Log}\left[\frac{d^2+h^2}{a^2+d^2}\right]\right)\right)\right)$$

Kick factor



Emittance Growth

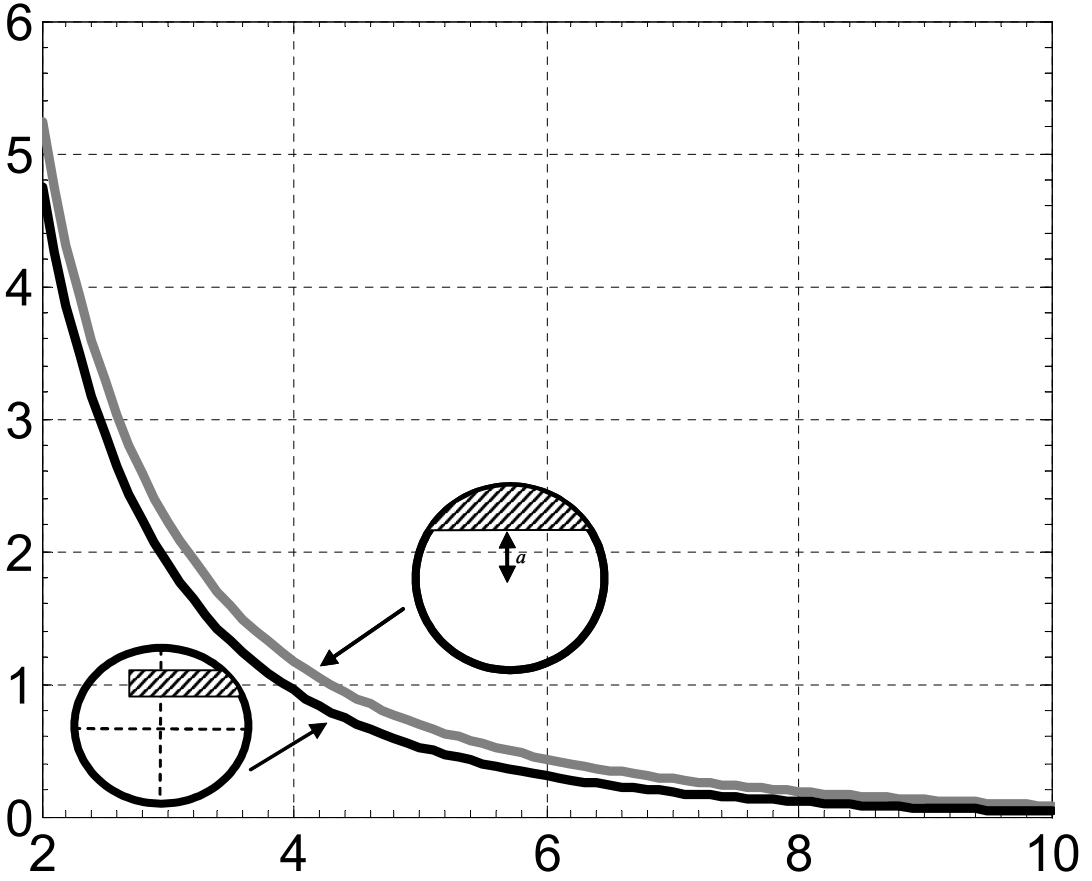
$$S = \frac{eQk_x}{\beta_z^2 E}$$

$$\varepsilon_x = \sqrt{\varepsilon_{0x}{}^2 + S^2 \frac{\varepsilon_{0x}\beta}{3}} \approx \varepsilon_{0x} + S^2 \frac{\beta}{6}$$

$$\frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}} = \sqrt{1 + S^2 \frac{\beta}{3\varepsilon_{0x}}} - 1 \approx S^2 \frac{\beta}{6\varepsilon_{0x}}$$

Emittance Growth (OTR screen in XFEL Injector)

$$\frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}}[\%]$$

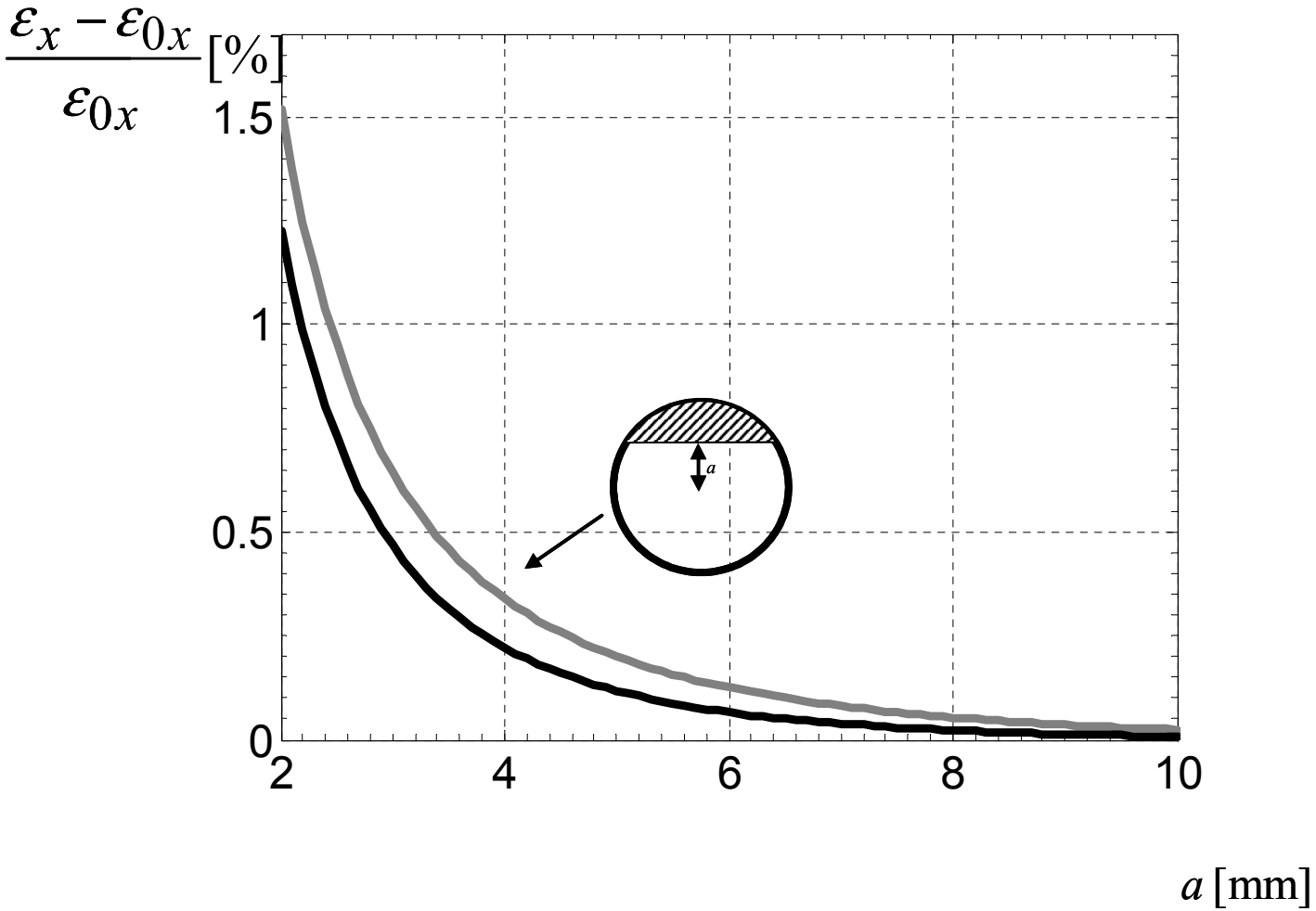


Transverse beam size (rms): 130 mm

Energy: 0.13 GeV

$\varepsilon_{0x} = 1\,\text{mm}\times\text{mrad}$

Emittance Growth (OTR screen in XFEL BC1)



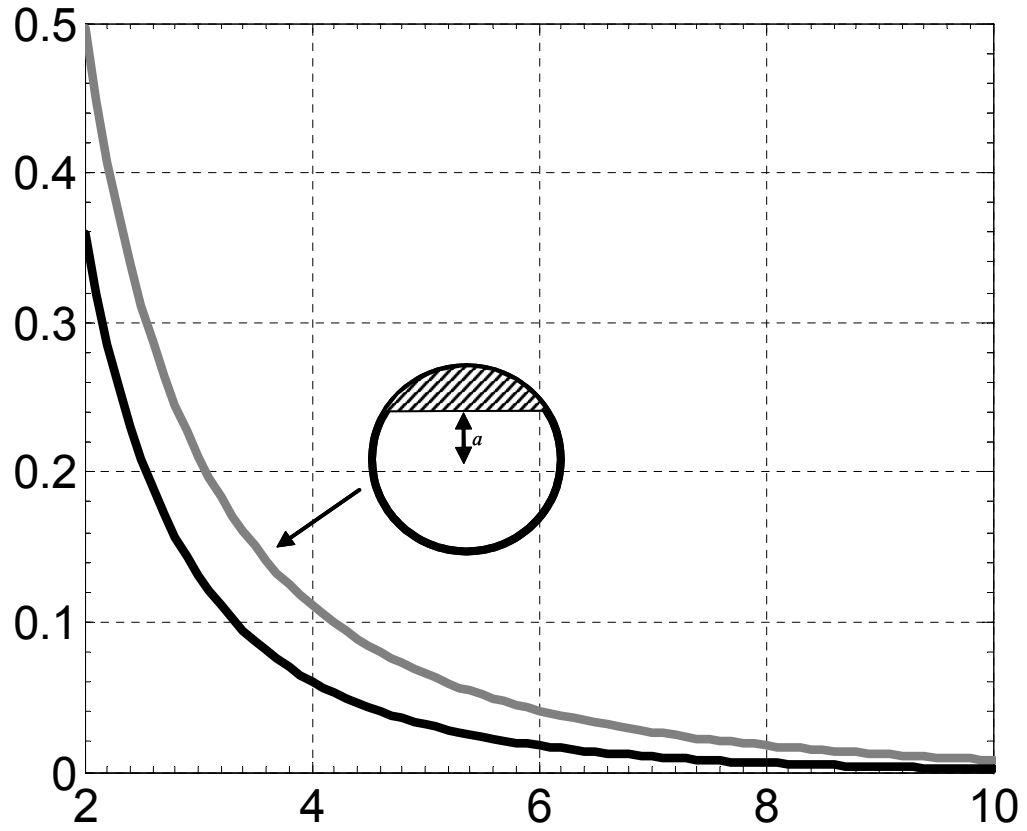
Transverse beam size (rms): 70 mm

Energy: 0.5 GeV

$\varepsilon_{0x} = 1$ mm×mrad

Emittance Growth (OTR screen in XFEL BC2)

$$\frac{\varepsilon_x - \varepsilon_{0x}}{\varepsilon_{0x}}[\%]$$



Transverse beam size (rms): 40 mm

Energy: 2 GeV

$\varepsilon_{0x} = 1$ mm×mrad