Acceptance Problems of Positron Capture Optics

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DESY

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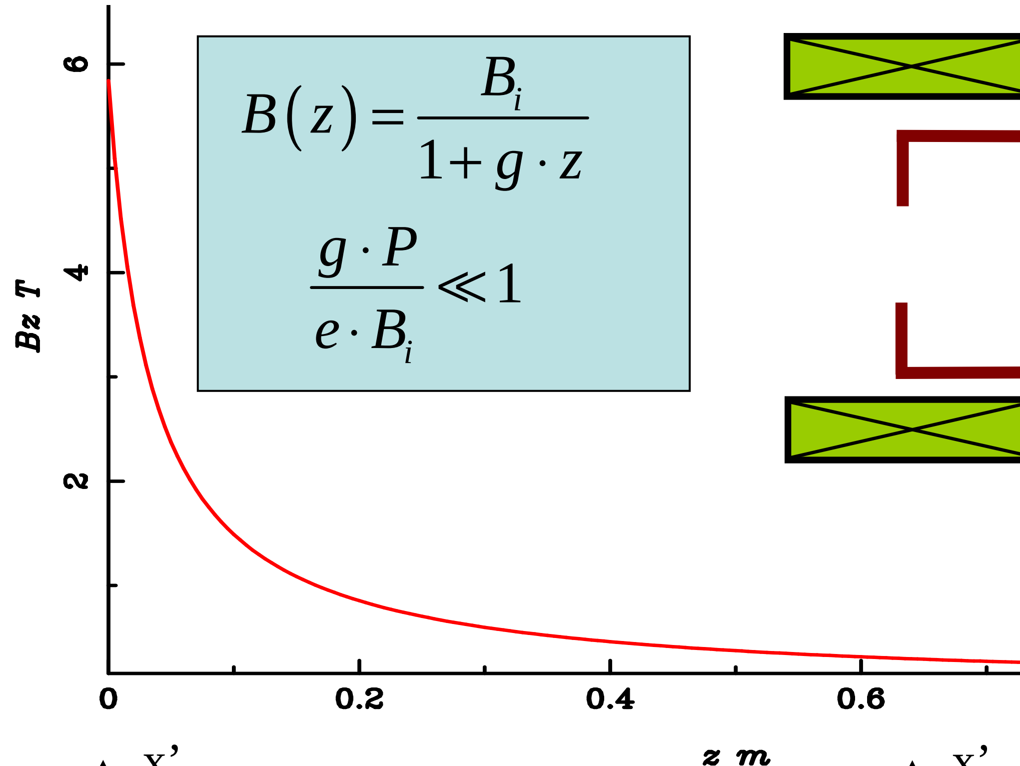
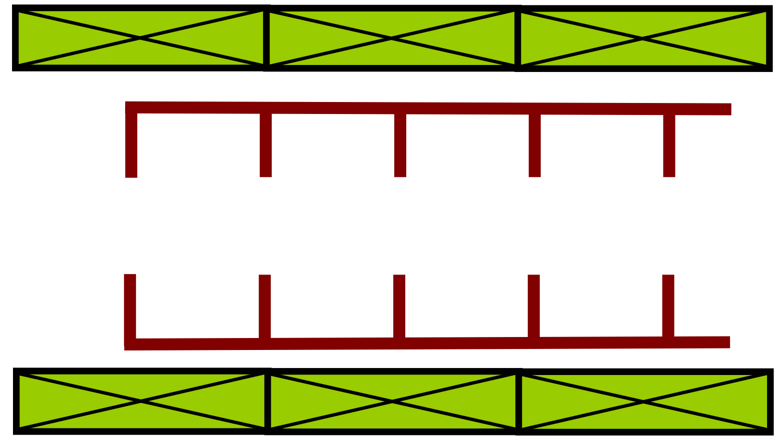
- Basics
- Capture efficiencies for conventional source and undulator source

The capture optics



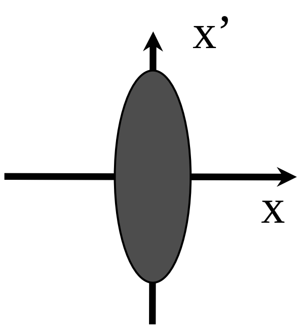
$$B(z) = \frac{B_i}{1 + g \cdot z}$$

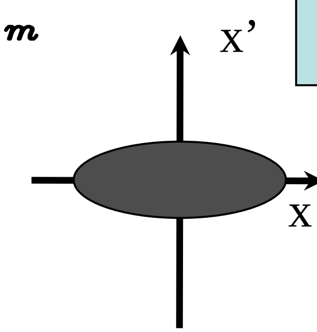
$$\frac{g \cdot P}{e \cdot B_i} \ll 1$$



low frequency (L-band)

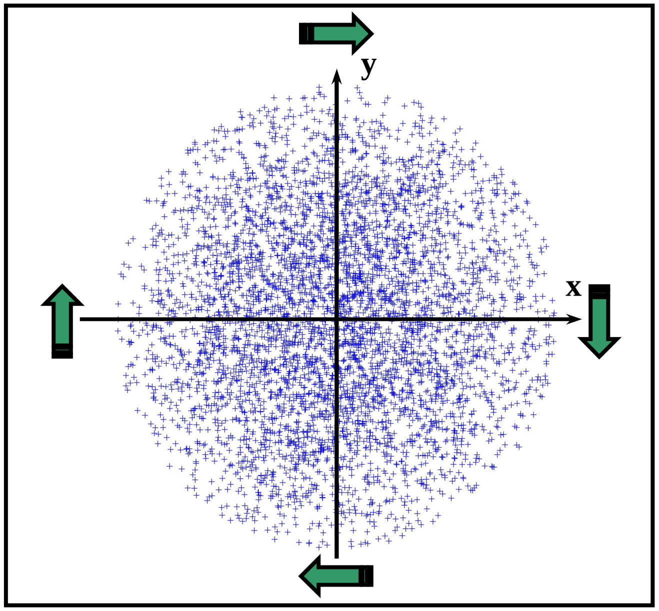
- ➢ large iris radius
- ➢ long wave length





What is the Effect of a Solenoid Field on the Target location?

When a beam is created inside a solenoid field it retains an angular momentum when exiting the solenoid:



Vortex motion of an electron beam with angular momentum

$$\varepsilon_{mag} = \frac{e \cdot B_z}{8 \cdot m_0 c} \cdot R^2$$

$B_z =$ solenoid field at the cathode position

$R =$ cathode radius

The angular momentum acts as an emittance contribution, thus diluting the beam quality.

What is the Effect of a Solenoid Field on the Target location?

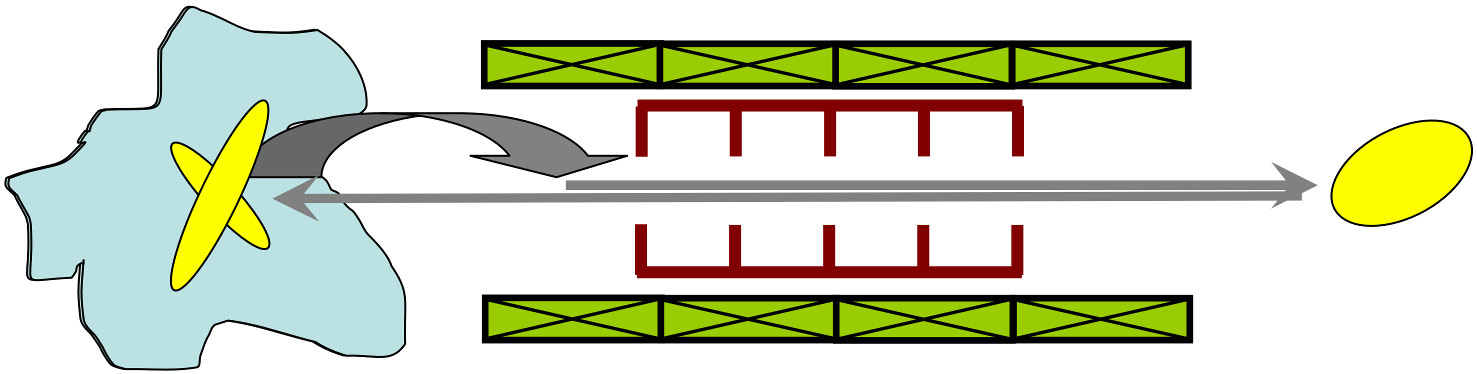
In case of the positron capture section the beam quality does not chance significantly when comparing a case with and without solenoid field on the target!

WHY?

What is the Effect of a Solenoid Field on the Target location?

Initial phase space

Solenoids & Apertures



I Start inside the solenoid field and track through the structure

II Some fraction survives, i.e. a part of the initial phase space can be mapped into the final phase space without losses

III Track back through the entrance field of the solenoid

⇨ when starting inside/outside the solenoid the beam looks the same at the exit.

How to calculate the Acceptance of the Capture Optics?

Try to calculate the maximum phase space volume which can be transmitted:

$$V = \pi^2 \frac{2}{3} \left(\frac{eB_z}{2m_0 c\gamma} R^2 \right)^2$$

R. Helm, 1962,
4D Volume, canonical momenta

$$\gamma A = \frac{eB_z}{2 \cdot m_0 c} R^2$$

SLAC, Projection

$$\gamma A = \frac{eB_z}{m_0 c} R^2$$

DESY, Projection

Scaling with $B_z R^2$

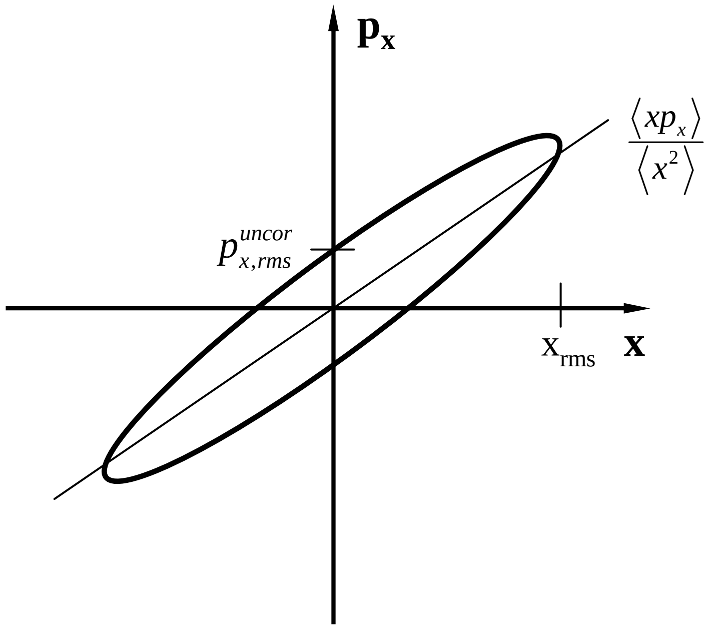
How to calculate the Acceptance of the Capture Optics?

Since the beam has to be matched into the Damping Ring, we have to relate the individual particle coordinates to the rms parameters of the beam:

I Take out correlated beam divergence: $$\tilde{p}_{x,i} = p_{x,i} - \frac{\langle x p_x \rangle}{\langle x^2 \rangle} x_i$$

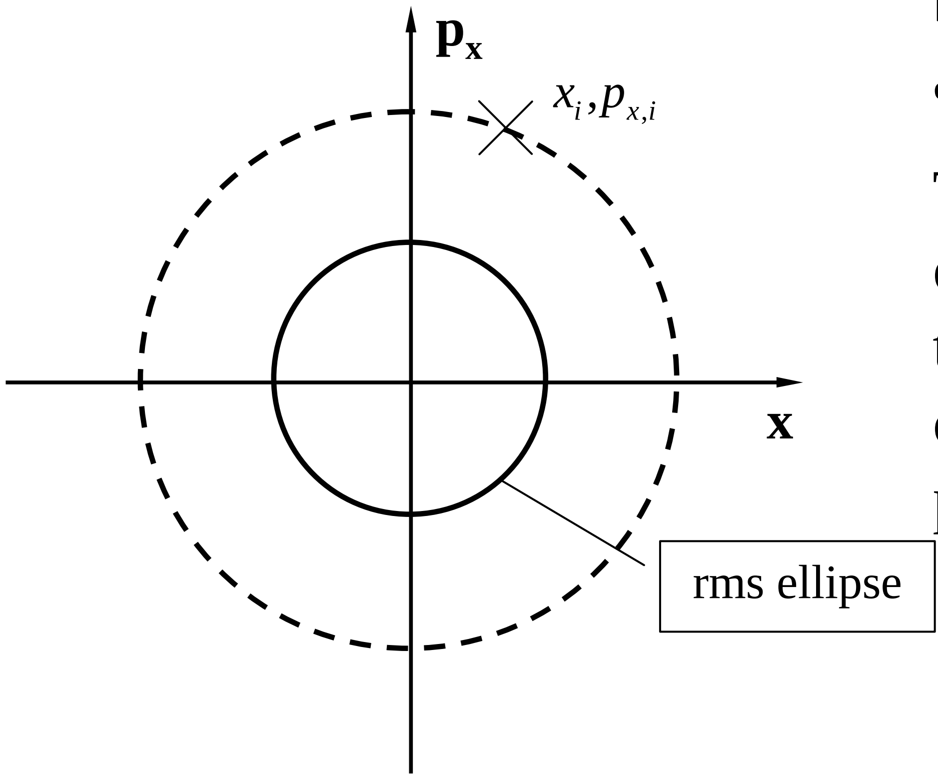
II Calculate 'single particle emittance':

With $$\beta_x = \sqrt{\frac{x_{rms}^2}{\varepsilon_{rms}}} = \frac{x_{rms}}{p_{x,rms}^{uncor}}$$



‘Single Particle Emittance’

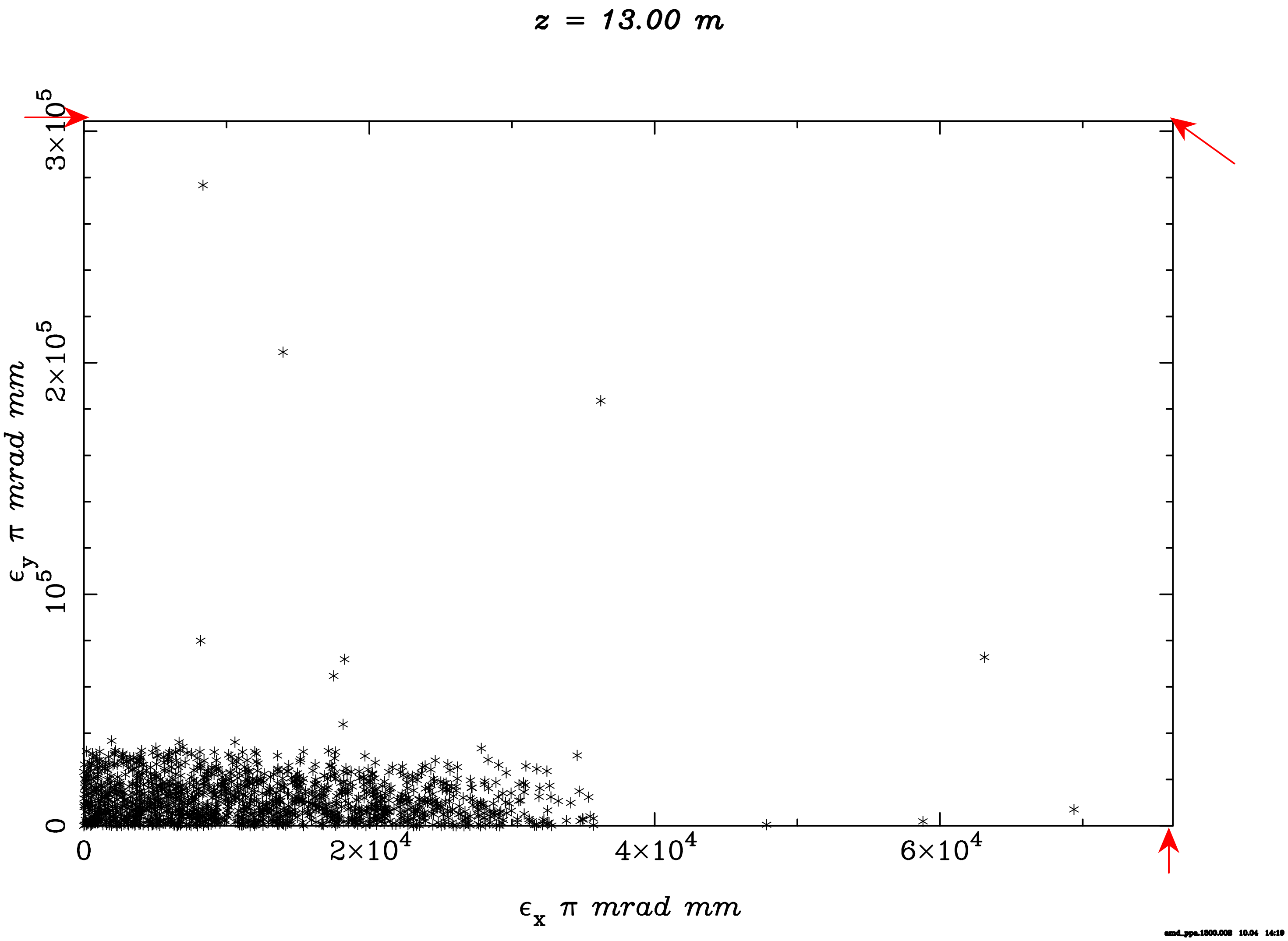
$$\varepsilon_{x,i} = \frac{x_i^2}{\beta_x} + p_{x,i}^2 \beta_x$$



The rms ellipse of the beam is transformed into a circle.

The square of the radius of a coaxial circle through the particle coordinates is the single particle emittance.

Example: Single Particle Emittance Plot



Capture Efficiency Calculations

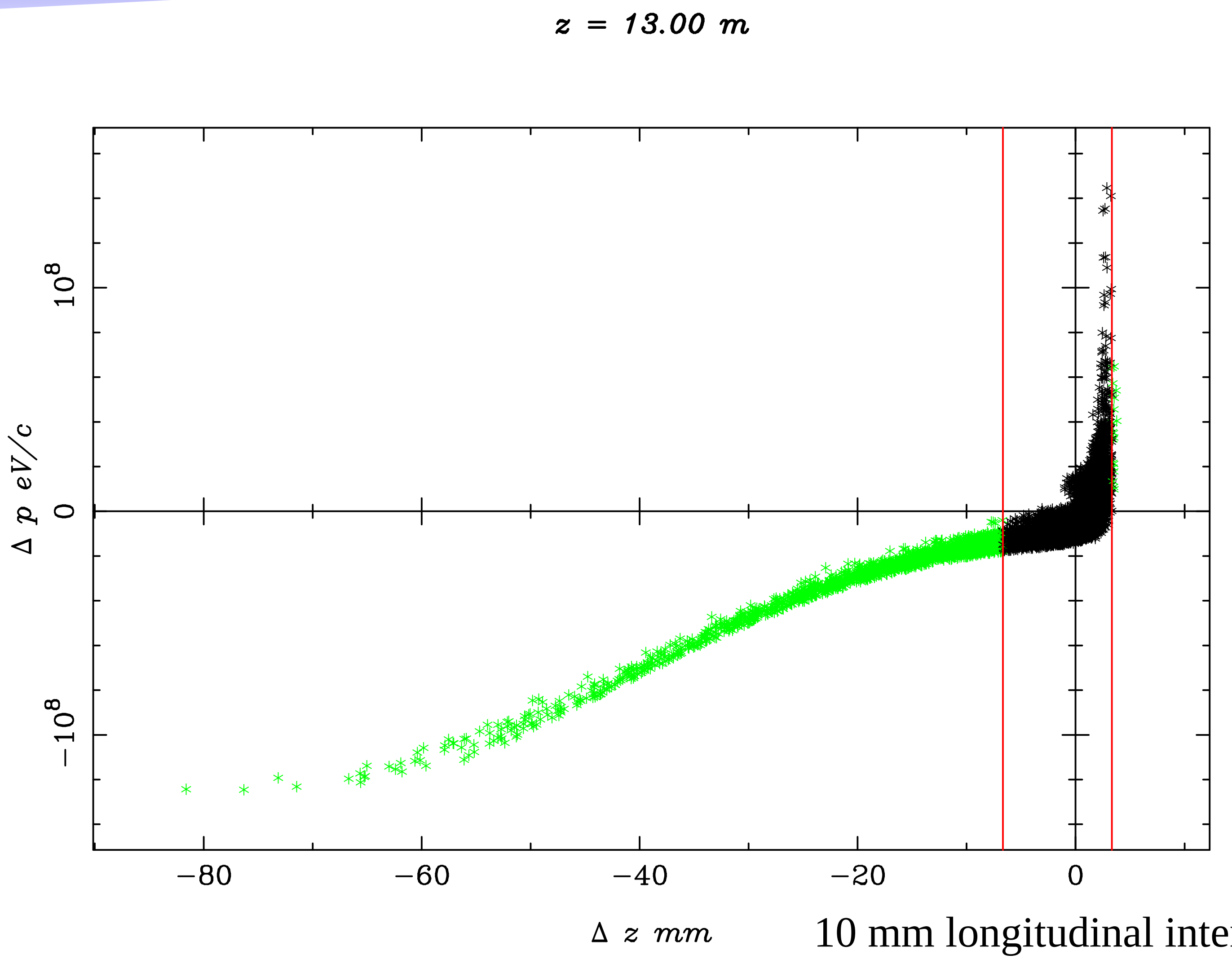
Input:

- Photons from a helical undulator E_1 = 20 MeV onto a 0.4 X_0 Ti target, σ = 0.7 mm
- 6.2 GeV electrons onto a 4.5 X_0 W target, σ = 3 mm

Capture Optics

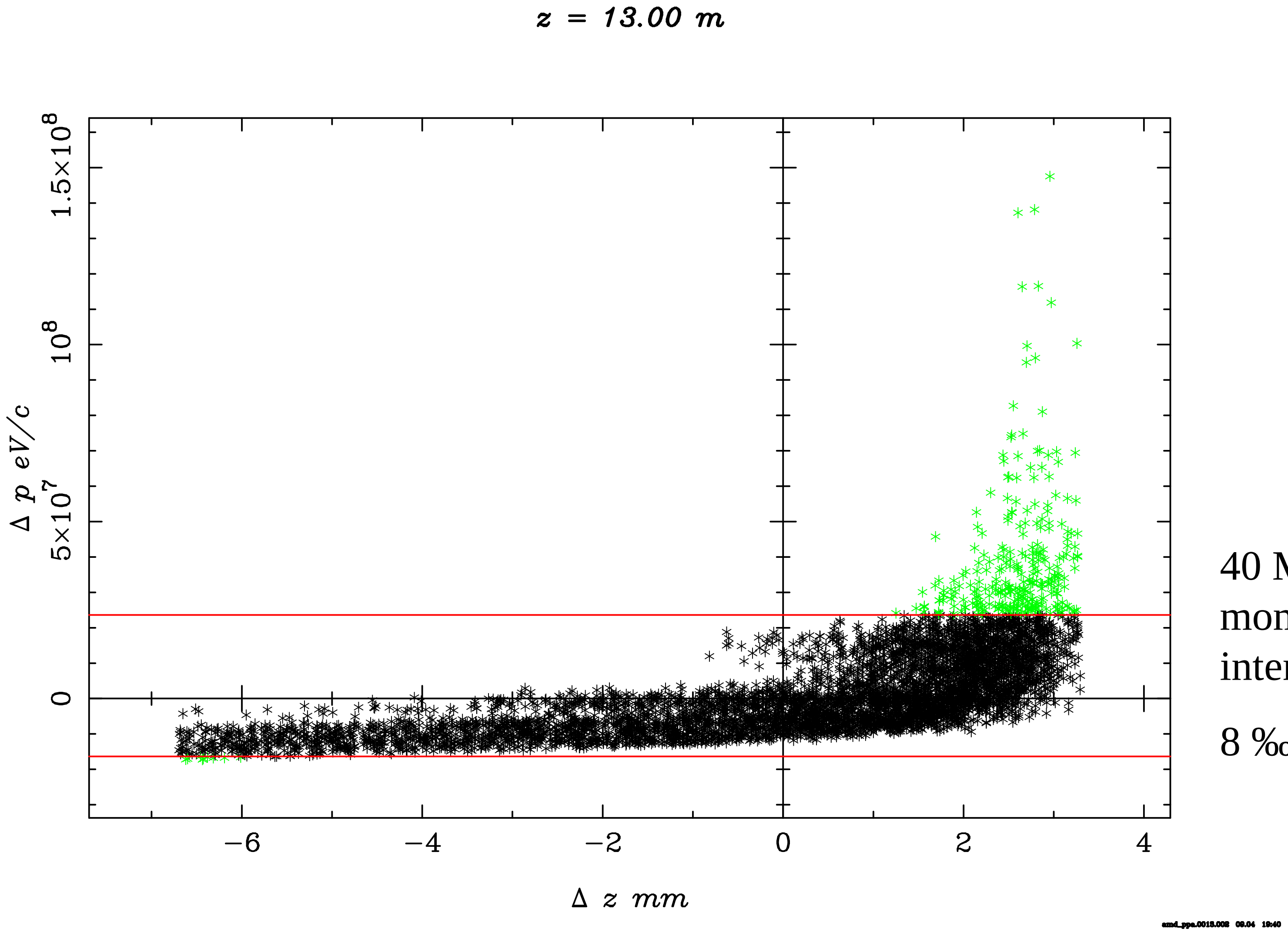
- AMD starting at 6 T, end field Bz varied
- taper parameter g = 30 m^{-1} for undulator source, g = 60 m^{-1} for conv. Source
- CDS acceleration section as in TDR up to ~120 MeV
- cavities start 0.2 m behind the target in all cases
- aperture radius = 23 mm
- ideal fields, no misalignments
- tracking program ASTRA

Longitudinal Cut



10 mm longitudinal interval ≙
15° Phase in L-Band

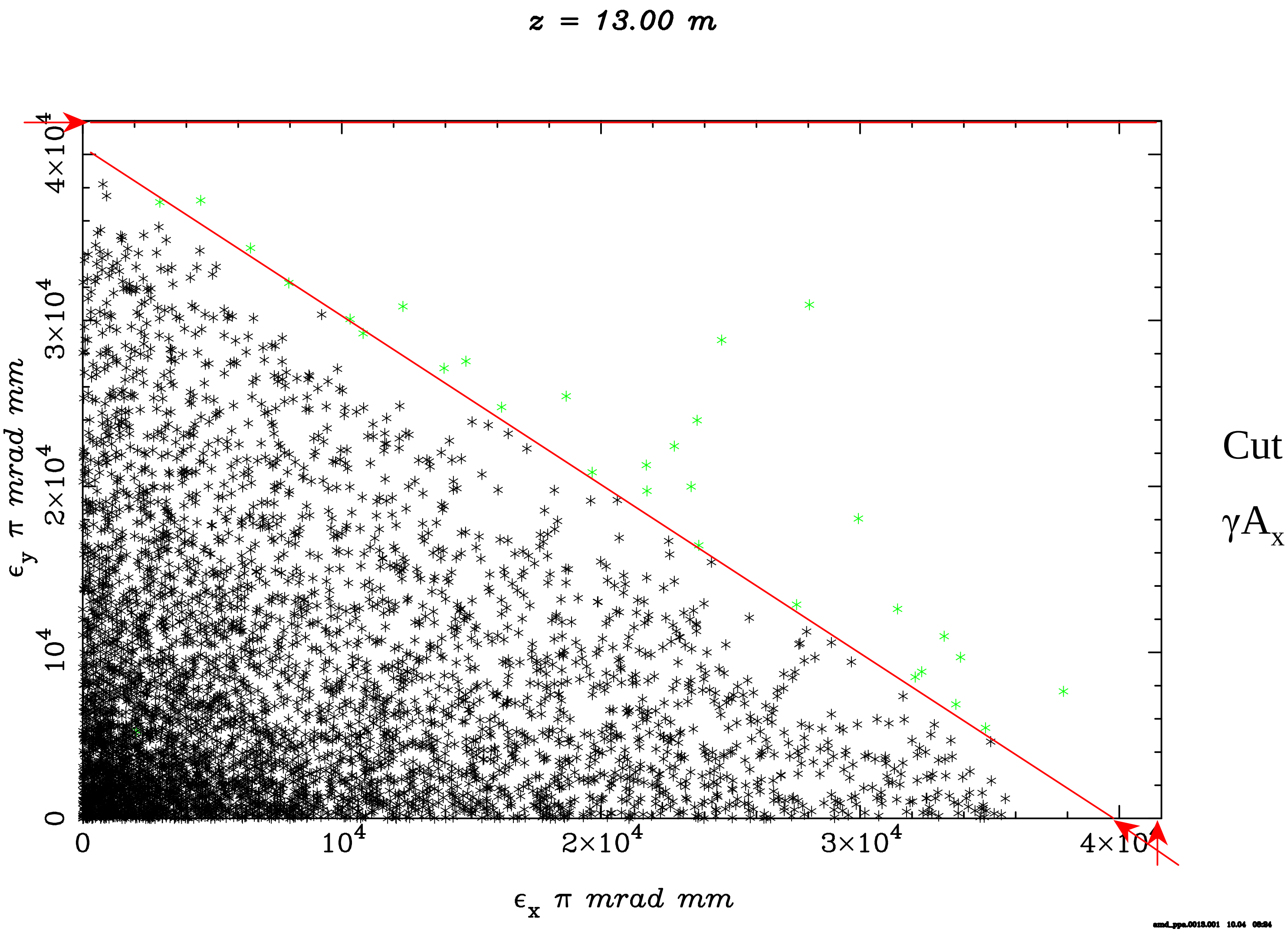
Momentum Cut



40 MeV momentum interval ≙

8 ‰ at 5 GeV

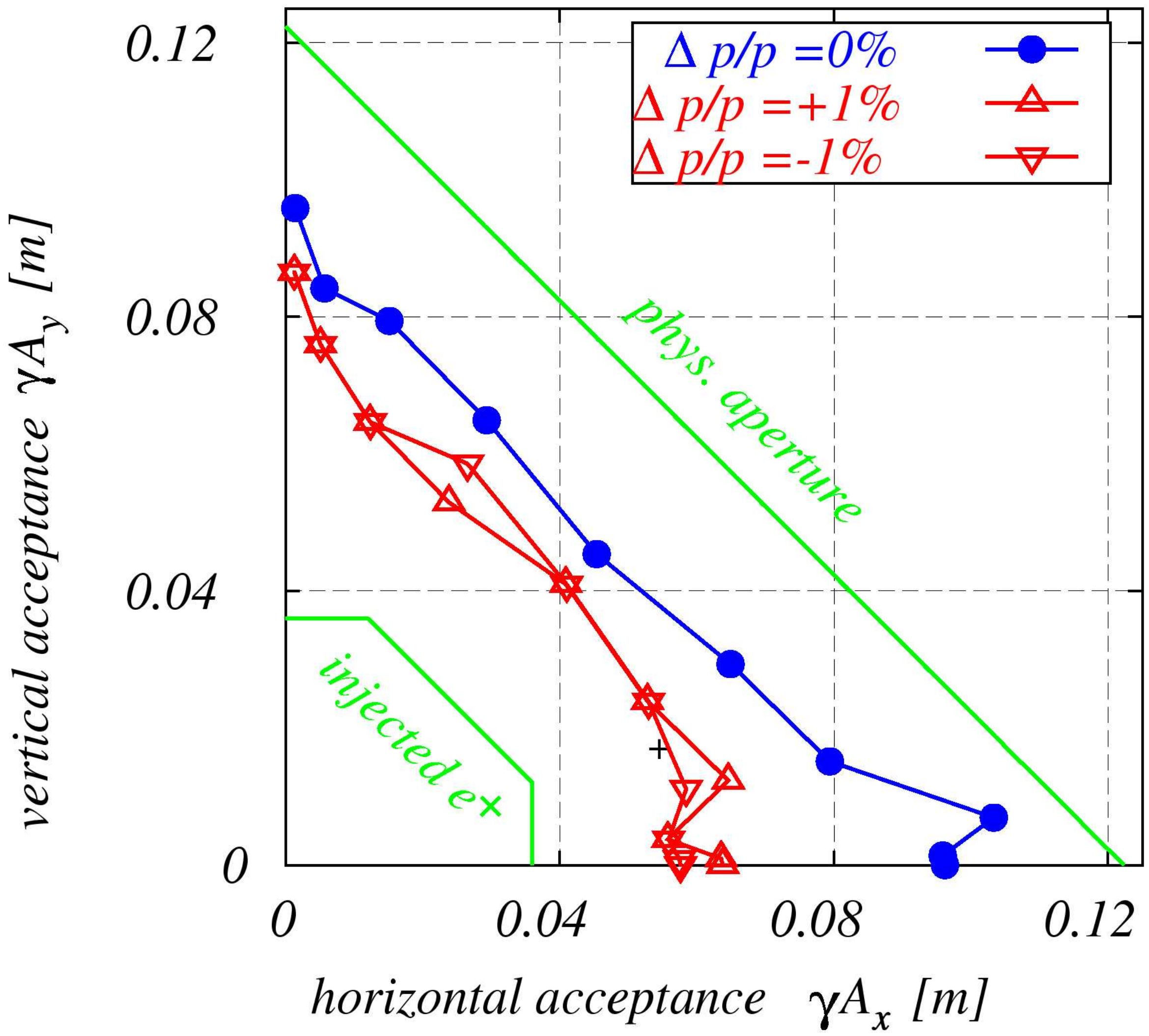
Transverse Acceptance Cut



Cut at

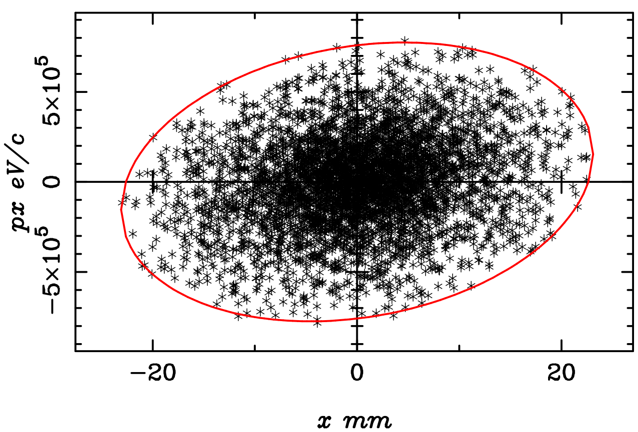
$\gamma A_x + \gamma A_y = 0.04$

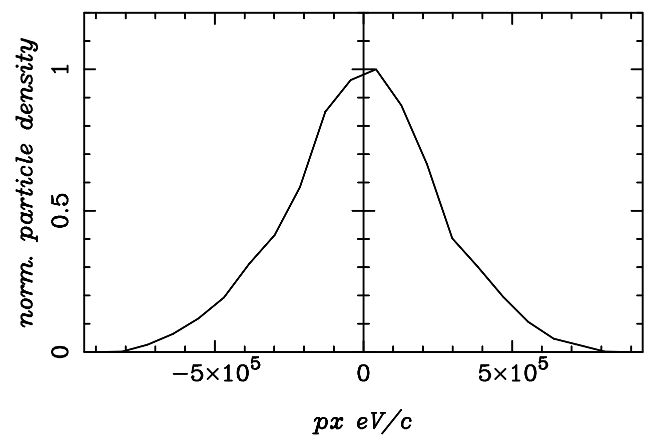
Dynamic Aperture of a Damping Ring (TDR)

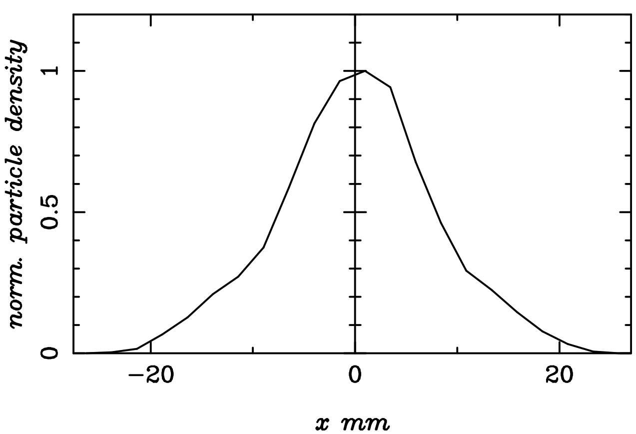


Transverse Phase Space after Cuts

$z = 13.00\ m$



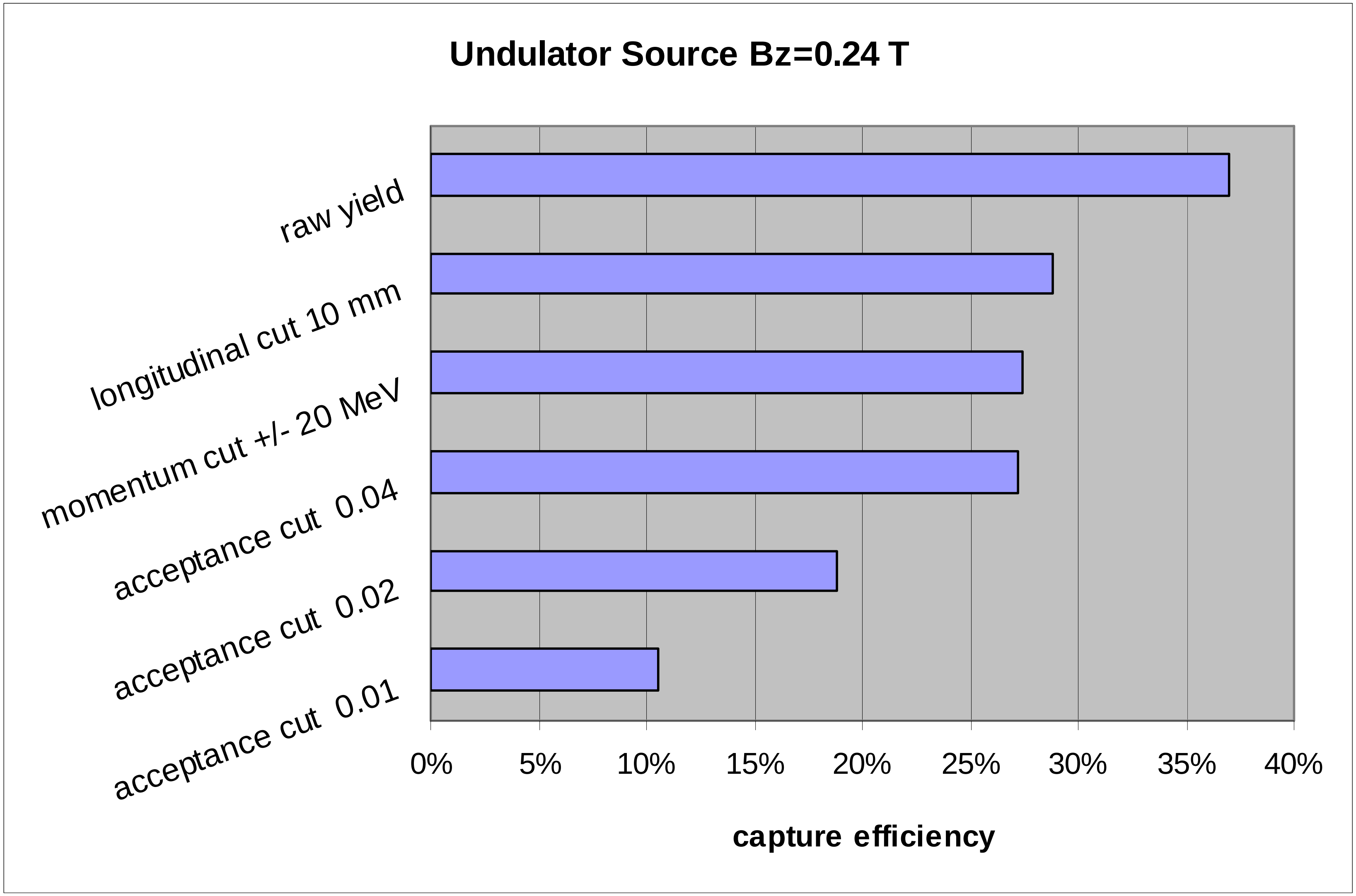




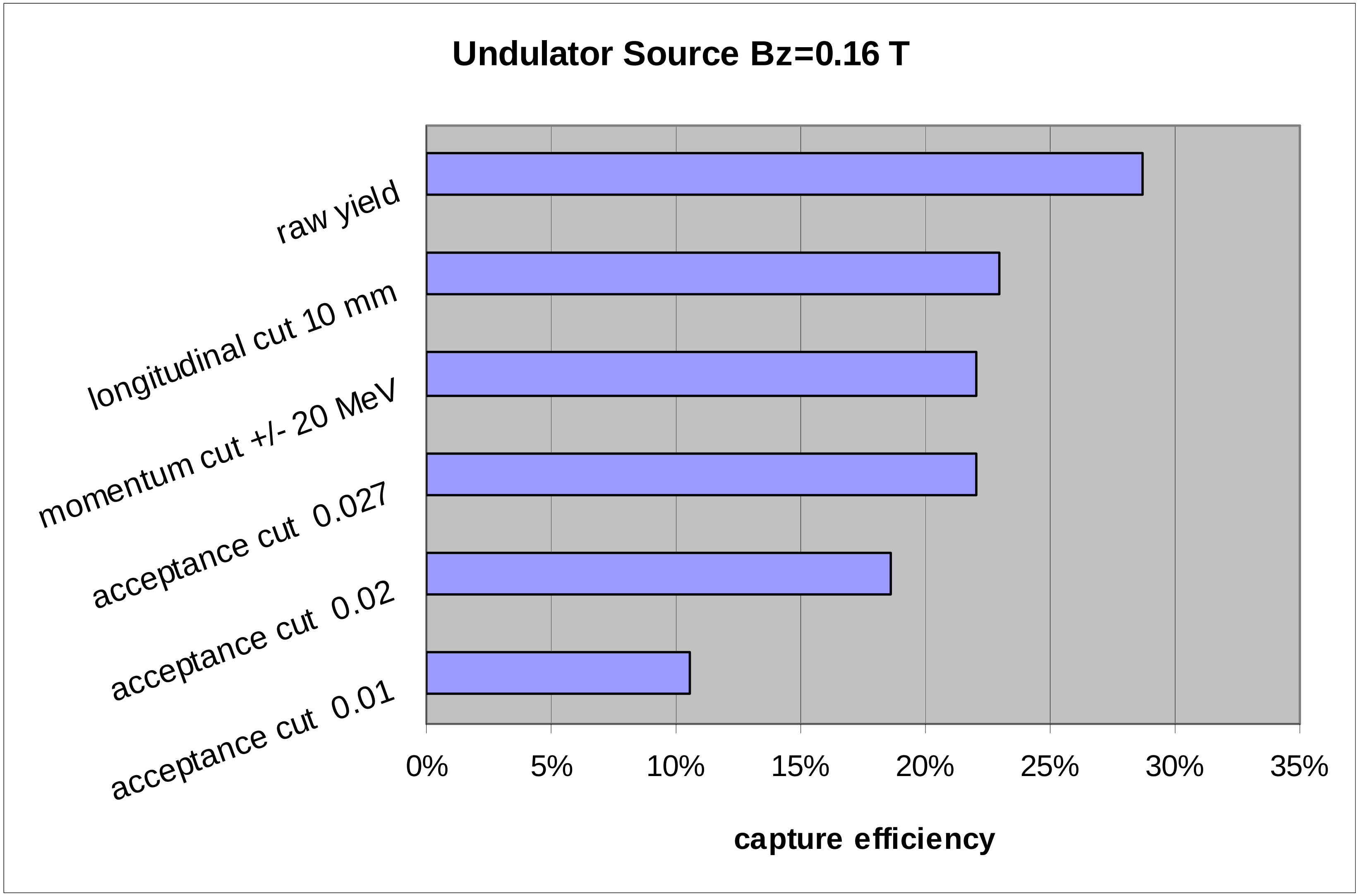
$\gamma\varepsilon_{rms} = 0.004$, no particles outside a 3 sigma ellipse

'gaussian' distribution in x and px

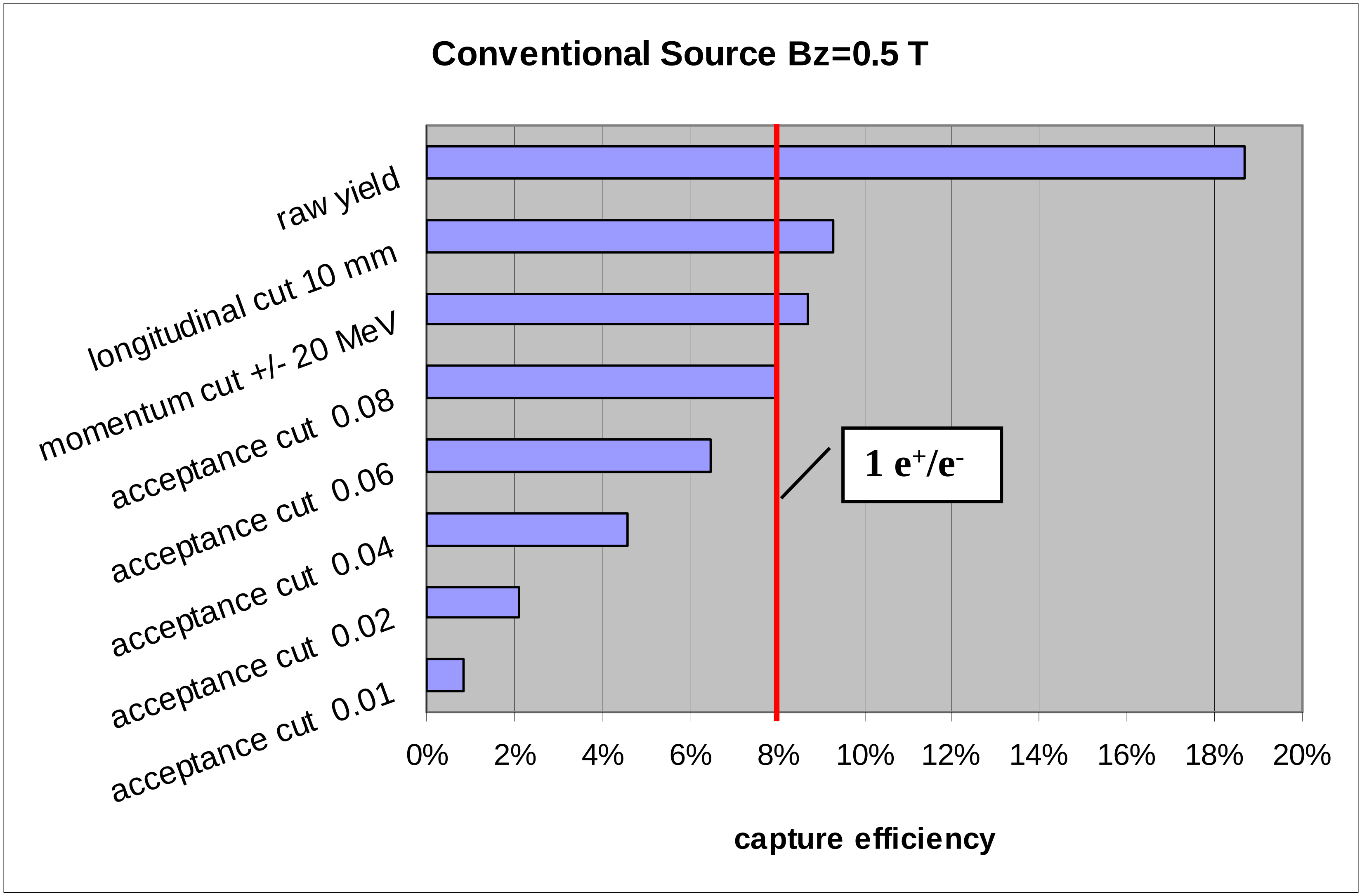
Undulator Source, Bz = 0.24 T



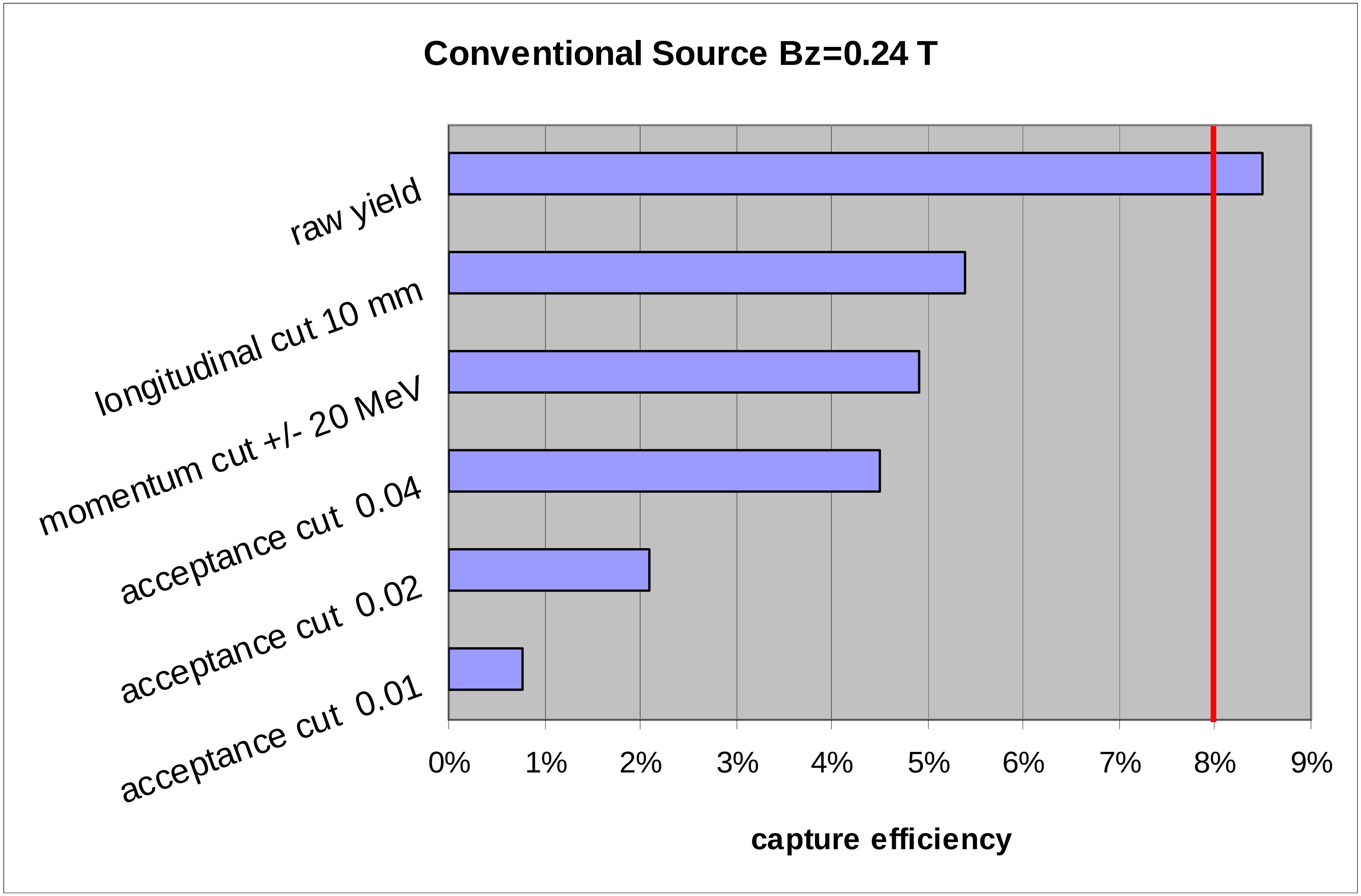
Undulator Source, Bz = 0.16 T



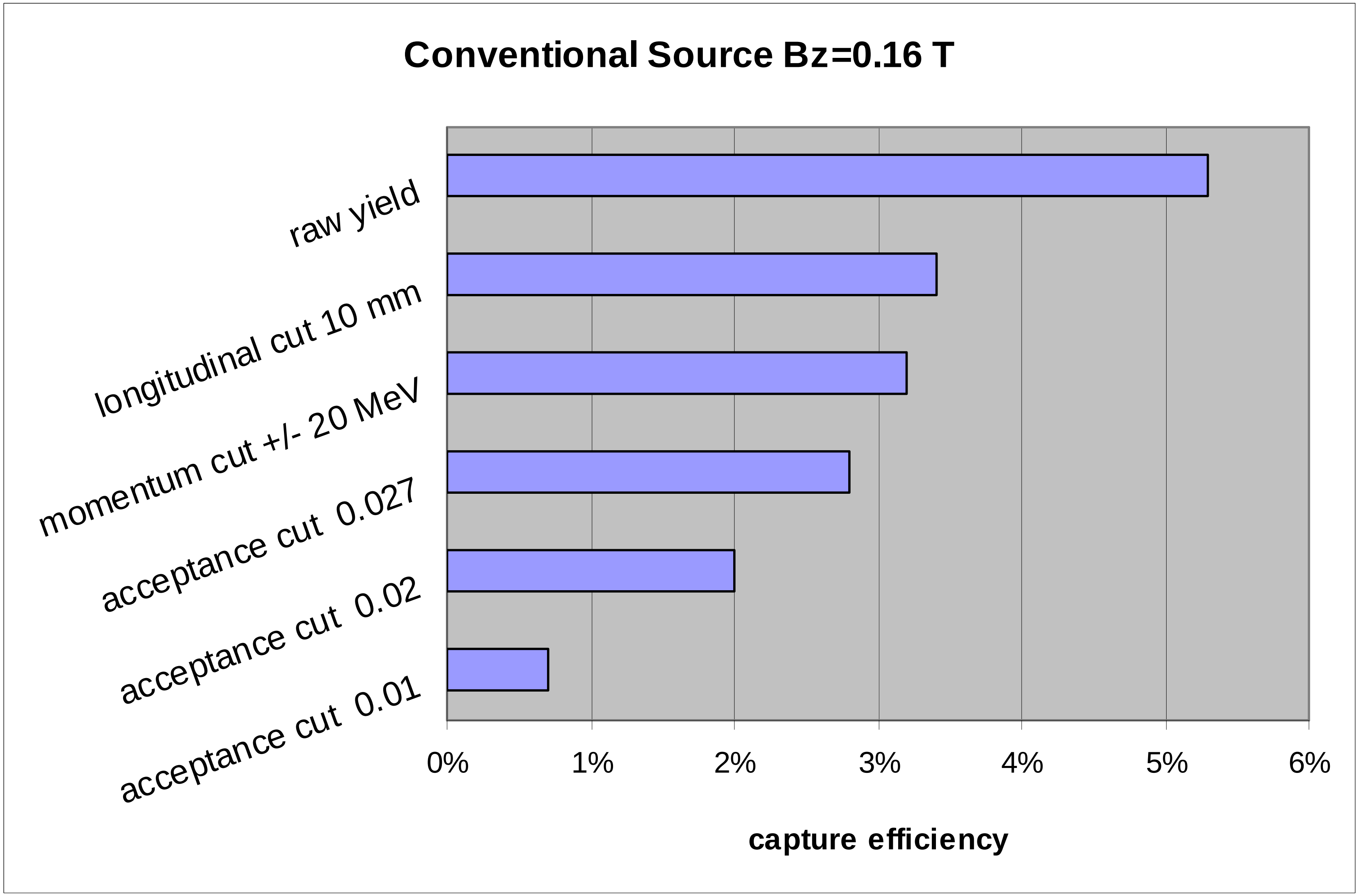
Conventional Source, Bz = 0.5 T



Conventional Source, Bz = 0.24 T



Conventional Source, Bz = 0.16 T



Conventional & Undulator Source Bz = 0.24 T