Witness radius matching revisited

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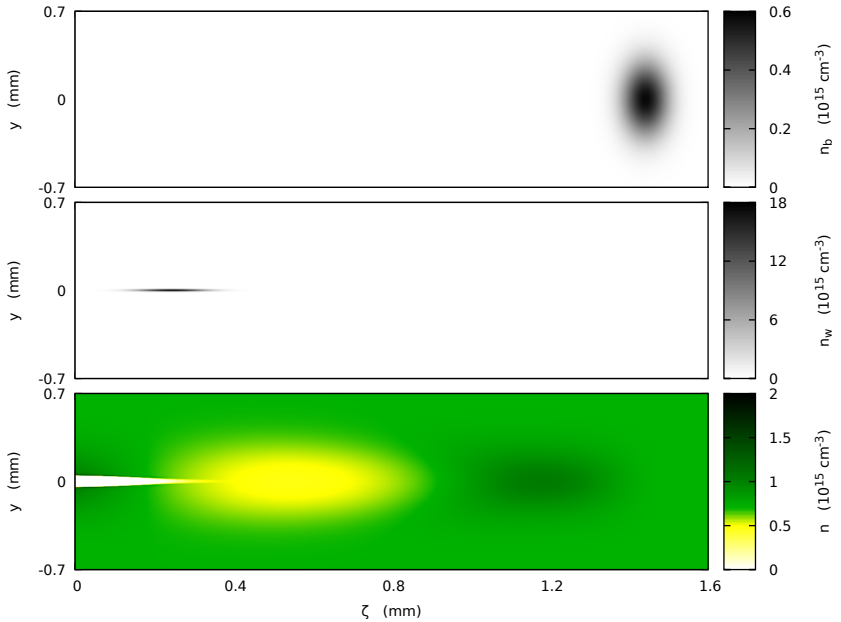
Matched witness

Ideally, the witness beam should drive a blowout (bubble)

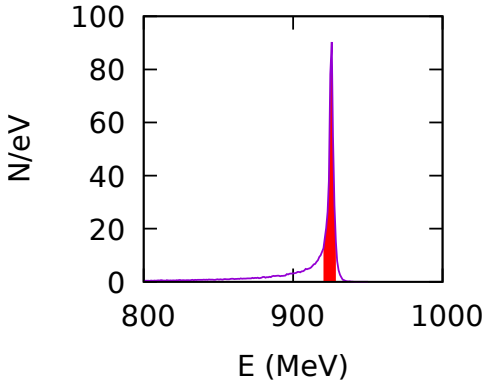


The matching condition is then

$$\sigma_x' = \left(\frac{2c^2 {\epsilon_{x,0}^*}^2}{\gamma \omega_p^2} \right)^{1/4}, \tag{1}$$

Defining the core

Q_E is the fraction of the beam within a 1% energy range.



Q_t is the fraction of the beam within the 4D hypersphere of radius $2\sigma_{\mathrm{matched}}$

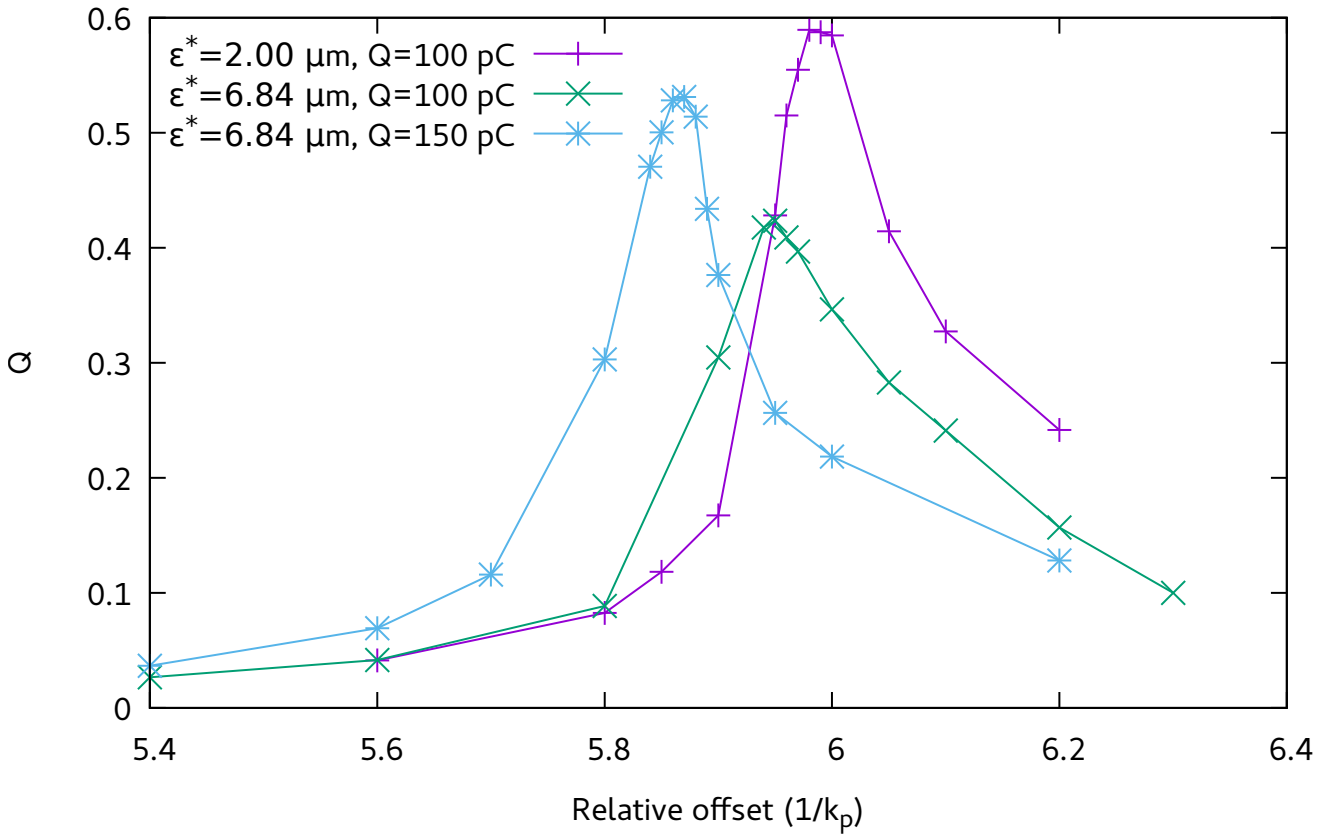
$$\frac{x^2}{\sigma_x'^2} + \frac{y^2}{\sigma_y'^2} + \frac{p_x^2}{\sigma_{p_x}'^2} + \frac{p_y^2}{\sigma_{p_y}'^2} < 4 \qquad (2)$$

(normalised to the 0.594 for a matched Gaussian beam)

Q is the fraction of the beam satisfying both

Beamloading

Correct phase is important to maximize the beam quality



Beamloading

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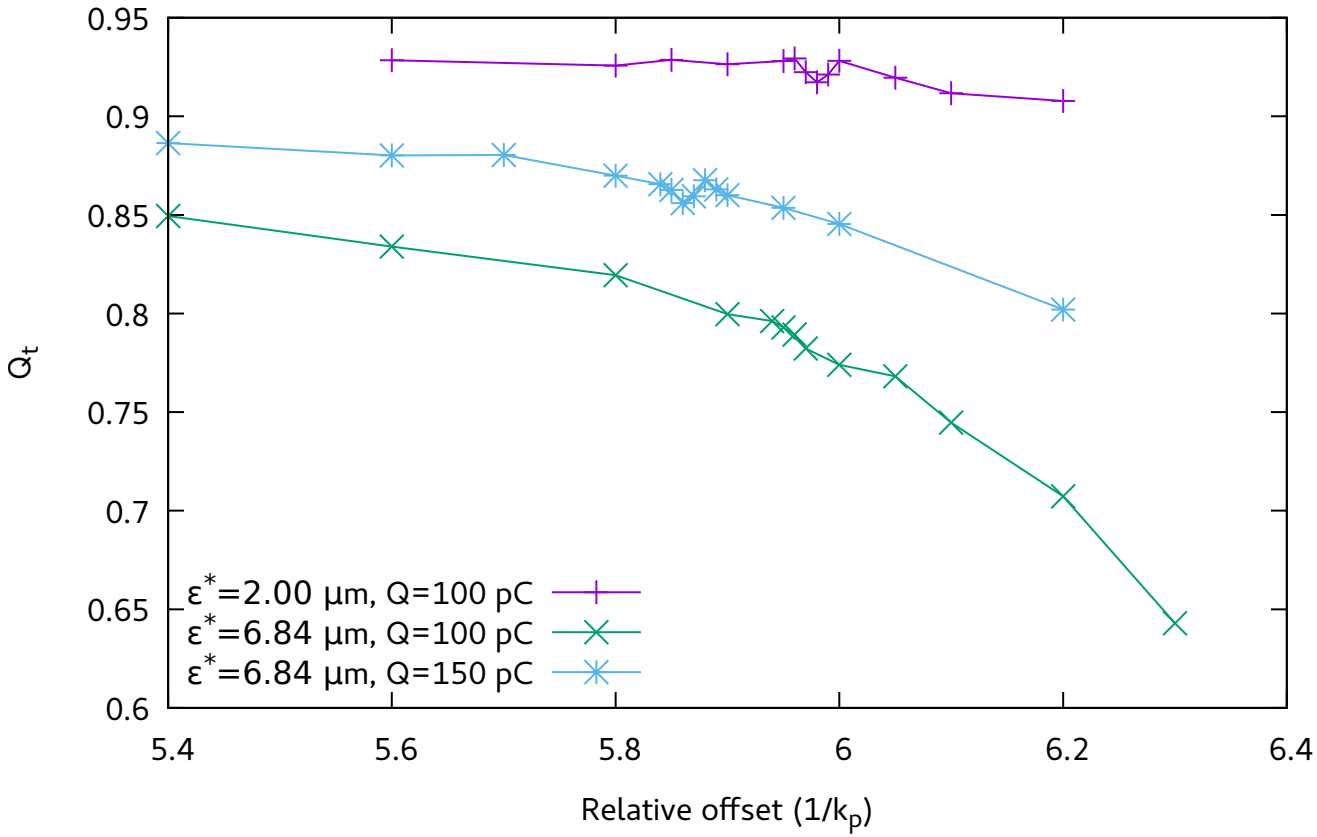
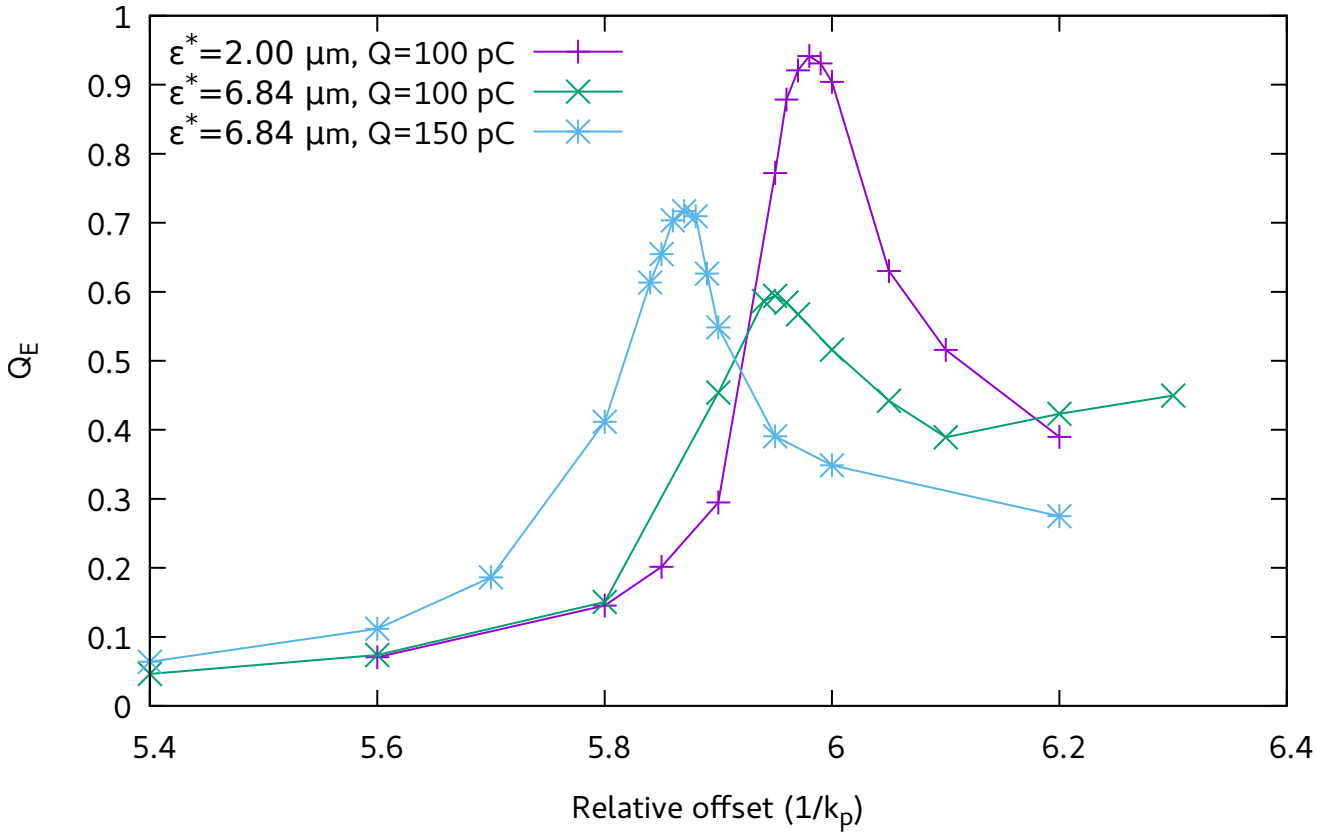


Beamloading

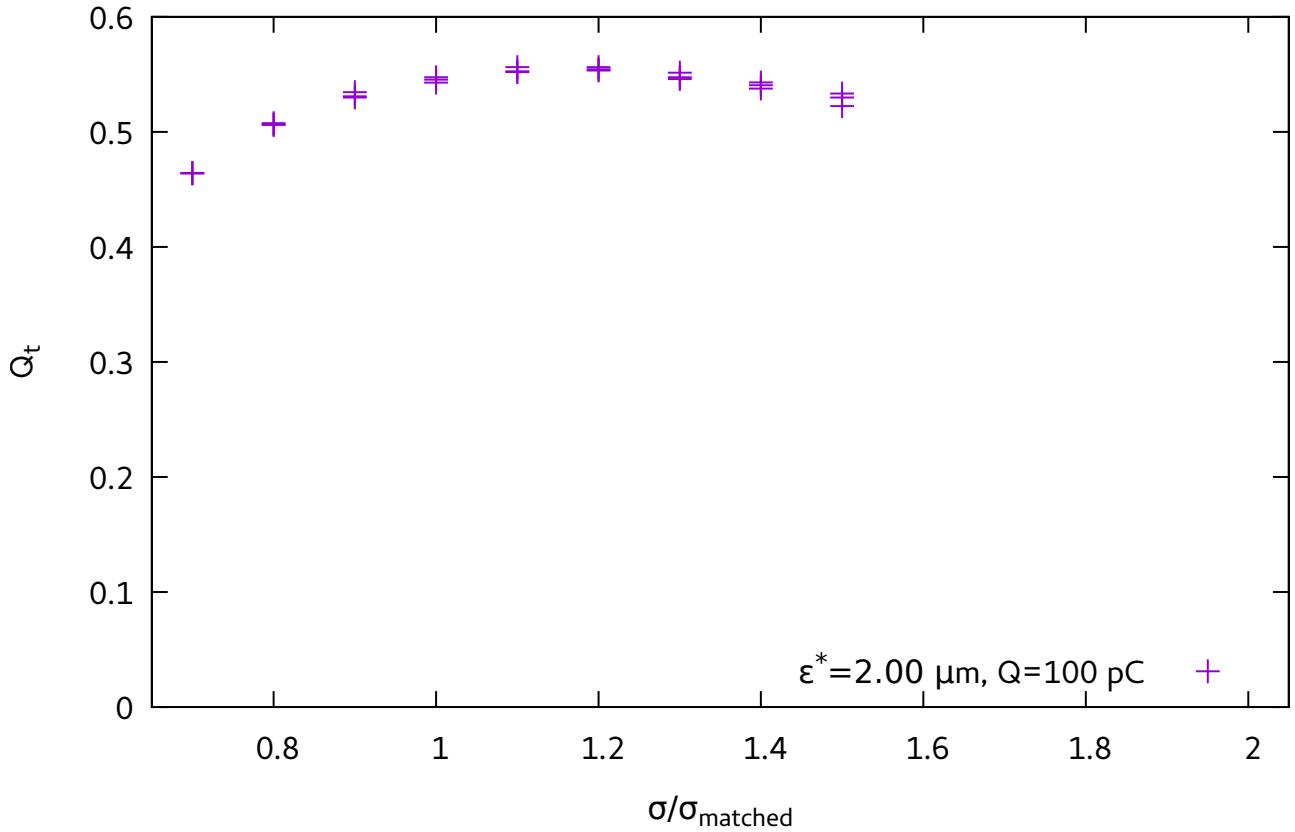
Correct phase is important to maximize the beam quality



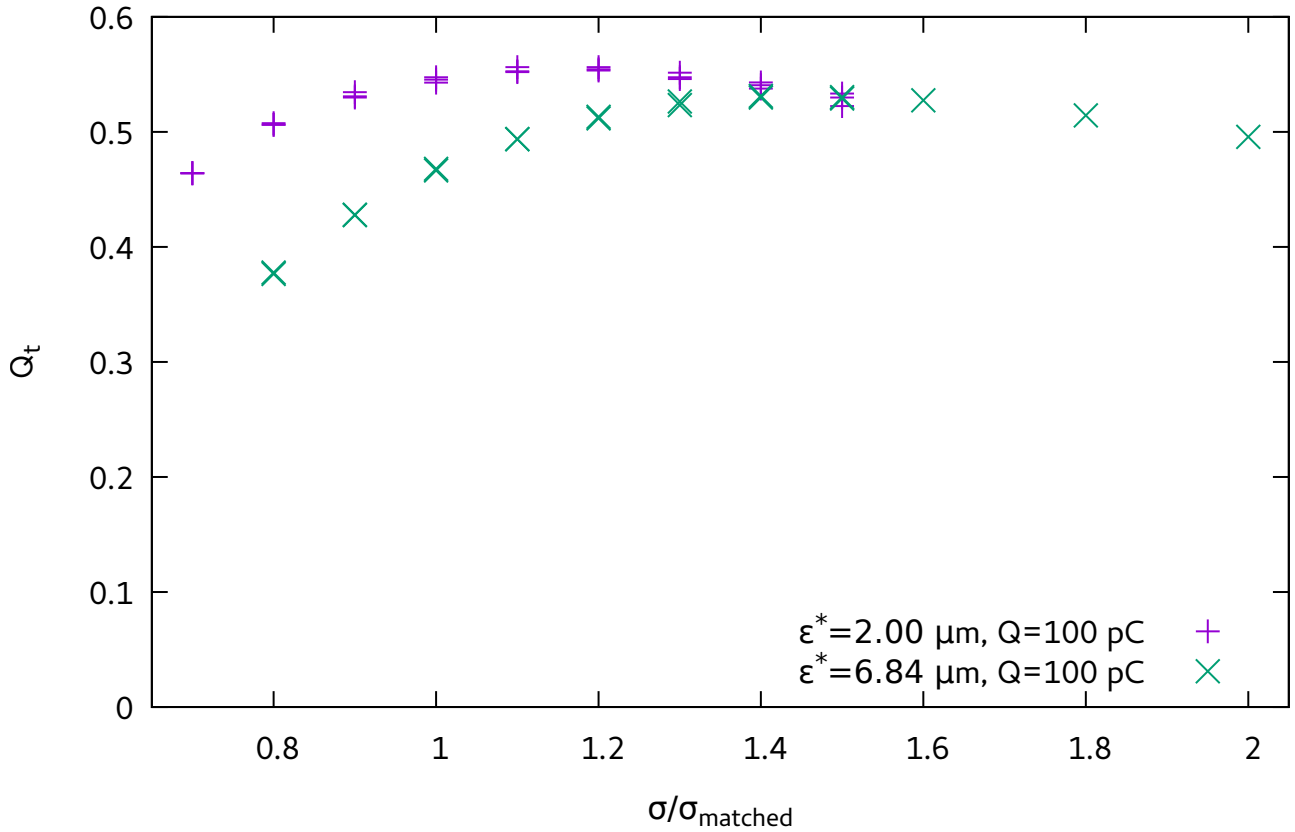
Radius scan

Beamloading depends (weakly) on witness radius, so comparison limited to Q_t for simple 1D scan.

Radius scan


0.6
0.5
0.4
0.3
0.2
0.1
0
Q_t
0.8
1
1.2
1.4
1.6
1.8
2
$\sigma/\sigma_{matched}$
ε^*=2.00 μm, Q=100 pC

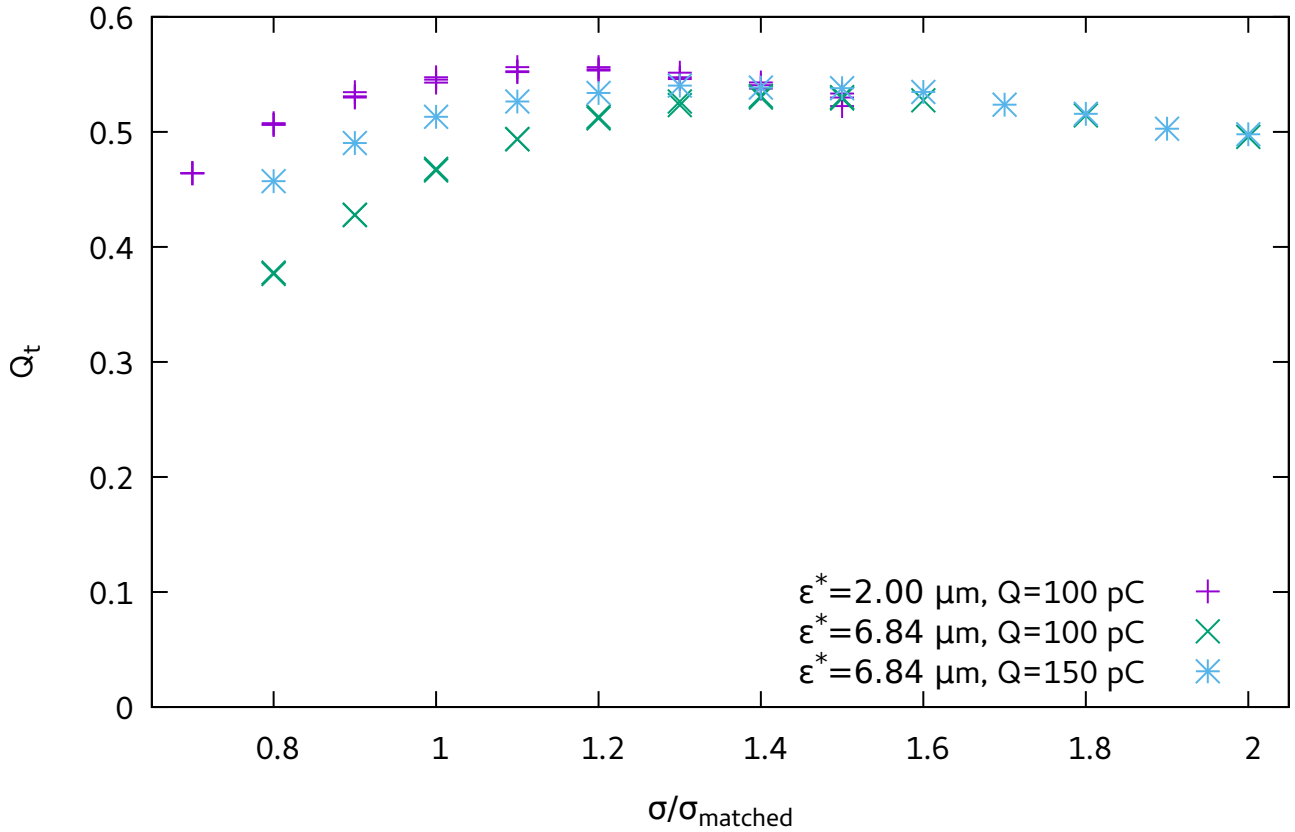
Radius scan


0.6
0.5
0.4
0.3
0.2
0.1
0
Q_t
0.8
1
1.2
1.4
1.6
1.8
2
$\sigma/\sigma_{matched}$
ε^*=2.00 µm, Q=100 pC
ε^*=6.84 µm, Q=100 pC

Higher emittance witness gives higher quality acceleration (Q_t) for $\sigma > \sigma_{\mathrm{matched}}$

Incomplete blowout? (smaller focussing field)

Radius scan


0.6
0.5
0.4
0.3
0.2
0.1
0
Q_t
0.8
1
1.2
1.4
1.6
1.8
2
$\sigma/\sigma_{matched}$
ε^*=2.00 μm, Q=100 pC
ε^*=6.84 μm, Q=100 pC
ε^*=6.84 μm, Q=150 pC

Physics

Higher emittance witness gives higher quality acceleration (Q_t) for $\sigma > \sigma_{\mathrm{matched}}$

Consistent with incomplete/slow blowout.

Larger beams drive smaller wake, improves matching for larger beams.

Conclusion

Good news?

Large range of radii give comparable acceleration quality (Q_t).

BUT complicated, needs simulations.