Pre-linac collimation in the CLIC RTML

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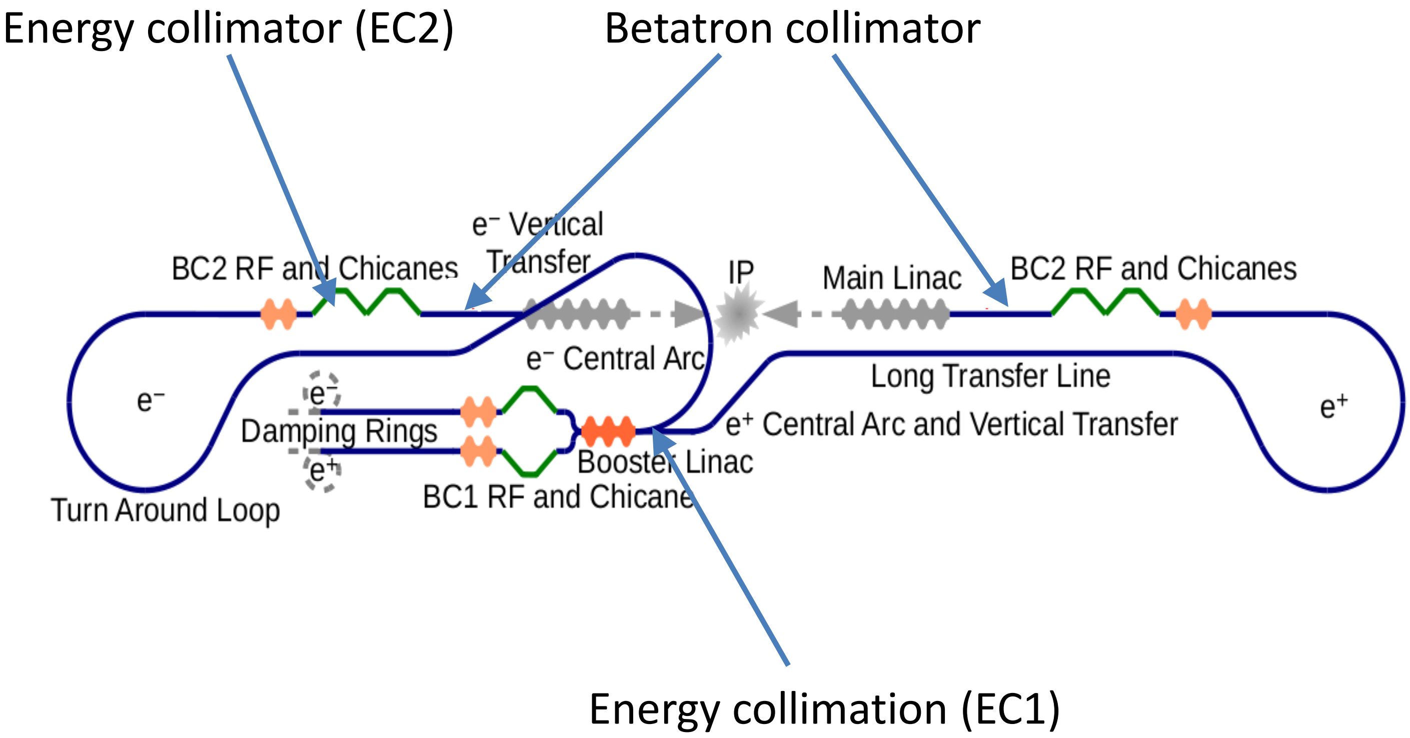
Proposed collimator locations



Energy collimator (EC2)

Betatron collimator

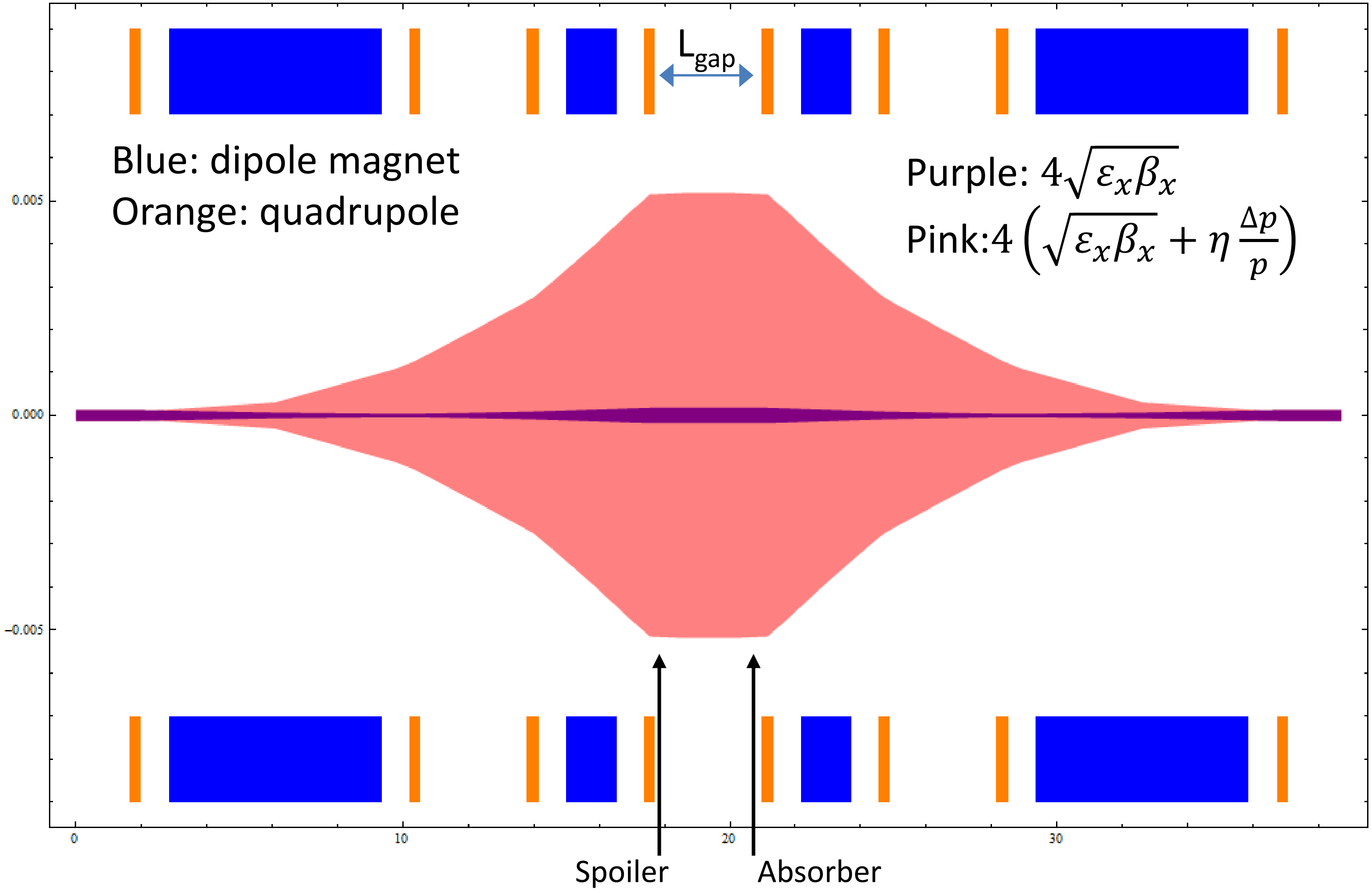
Energy collimation (EC1)

Energy collimator assumptions

- Minimise beam impedance:
  - Spoiler aperture $a_x = N_\sigma D_x \sigma_E \geq \pm 5$ mm
- Energy spread
  - EC1: ±0.33%
  - EC2: ±1.7%
  - Cut at $4\sigma_E$
    - Assumed main linac acceptance
- Required dispersion:
  - EC1: $D_x \geq 0.375$ m
  - EC2: $D_x \geq 0.073$ m

EC1 design

Design matched to existing optics



Blue: dipole magnet
Orange: quadrupole

Purple: $4\sqrt{\varepsilon_x \beta_x}$
Pink: $4\left(\sqrt{\varepsilon_x \beta_x} + \eta \frac{\Delta p}{p}\right)$

Summary of EC1 parameters

Optics parameters	Value
Quad length	0.35m
Quad aperture	0.12m
BEND1 length	6.51m
BEND2 length	1.52m
Q1 strength (T/m)	0.34
Q2 strength (T/m)	-0.25
Q3 strength (T/m)	0.40
L_{gap}	3.26m
Total length	38.70m

Spoiler parameters	Value
Taper length	90mm
Flat part length	18mm (0.05X_0)
Material	Be
Radiation length (X_0)	0.353m
Spoiler length	0.198m

Absorber parameters	Value
Taper length	27mm
Flat part length	0.65m (18X_0)
Material	Ti
Radiation length (X_0)	0.036m
Spoiler length	0.702m

EC2 design

- Propose placing absorber in BC2 chicane
  - D_x = 0.29m (chicane 1) and 0.19m (chicane 2)
    - D_x > 0.073m, both chicanes suitable for aperture
  - No space for spoiler: absorber survivability?
    - $\sigma_r = \sqrt{\sigma_x \sigma_y} \geq 600\mu m$
    - Chicane 1: $\sigma_r = 260\mu m < 600\mu m$
    - Chicane 2: $\sigma_r = 210\mu m < 600\mu m$
    - Need spoiler to ensure absorber survival
    - In comparison, for EC1: $\sigma_r \approx 6mm$
  - Consider modifications of chicane?

Betatron collimation design

- Apply cuts at $8\sigma_x$and $50\sigma_y$
  - Currently no main linac dynamic aperture study
    - The betatron cuts are therefore assumed
- Spoiler aperture
  - Of the order of 1mm
- Emittance growth due to spoiler wakefields
  - Serious problem
  - Redefine collimator parameters to optimise

Emittance growth (1)

- Emittance growth budget for RTML:

	Design	Static	Dynamic
$\Delta\varepsilon_{x,norm}$	60nm	20nm	20nm
$\Delta\varepsilon_{y,norm}$	1nm	2nm	2nm

- Emittance growth depends on many parameters
    - See arXiv:1212.6023v1, J. Resta-Lopez et al. for more details
  - Contributions from geometric and resistive wakefields
    - Depends on spoiler and beam pipe geometry
    - Electrical properties of spoiler
    - Bunch length and beam size

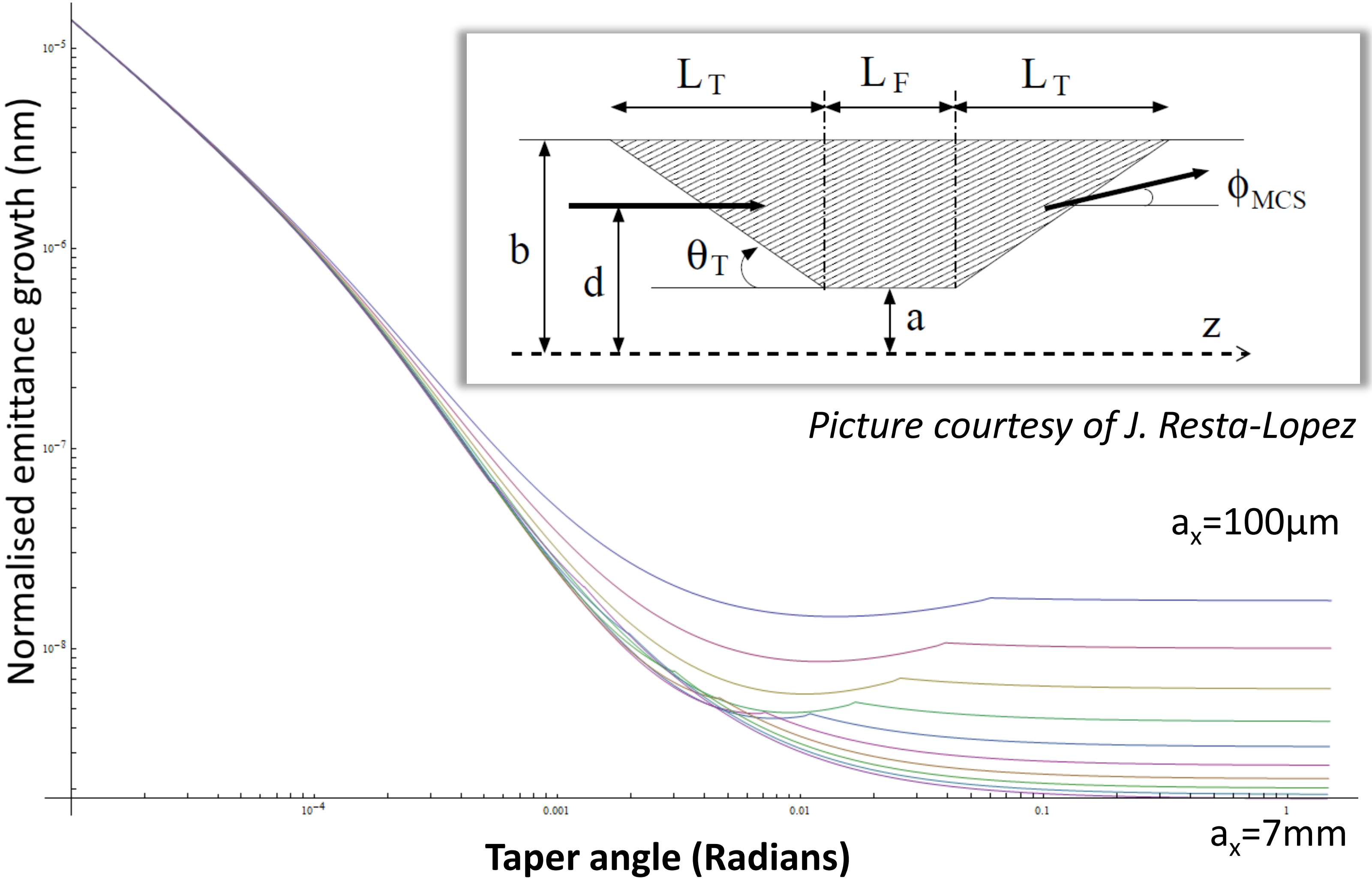
Emittance growth (2)

- Total emittance growth for betatron collimator

	#σ cut	**$\Delta\varepsilon_x$ (Be with/without Cu coating) 1σ offset**	**$\Delta\varepsilon_x$ (Be with/without Cu coating) 0.25σ offset**
x	8	110nm/115nm	7.02nm/7.38nm
y	50	4.2nm/4.4nm	0.276nm/0.289nm

- What does this mean?
  - This is theoretical minimum emittance growth
  - Only solution is maintain beam stability in collimator to better than 0.25σ (including alignment)
    - This will probably require some form of dynamic correction
      - E.g. feed-forward train (or maybe even bunch) position correction

Theoretical emittance growth (per spoiler)



Picture courtesy of J. Resta-Lopez

Optimised collimator parameters

Parameter	Range
θ_T	> 80mRad
Spoiler aperture	> 1.8mm
Beam jitter	$< 0.25\sigma_{x,y}$

These parameters have been determined by the wakefield study.

The next stage is to optimise the optics of the betatron collimation system to meet these constraints

Conclusions

- EC1
  - System designed and optimised
    - Now need to run tracking simulations
- EC2
  - Designs need to be considered and finalised
    - Redesign chicane to allow for spoiler?
- Betatron collimation
  - Design parameters optimised
    - Beam jitter must stay within tolerances
  - Need to design optics

Back-up slides

Mathematical description

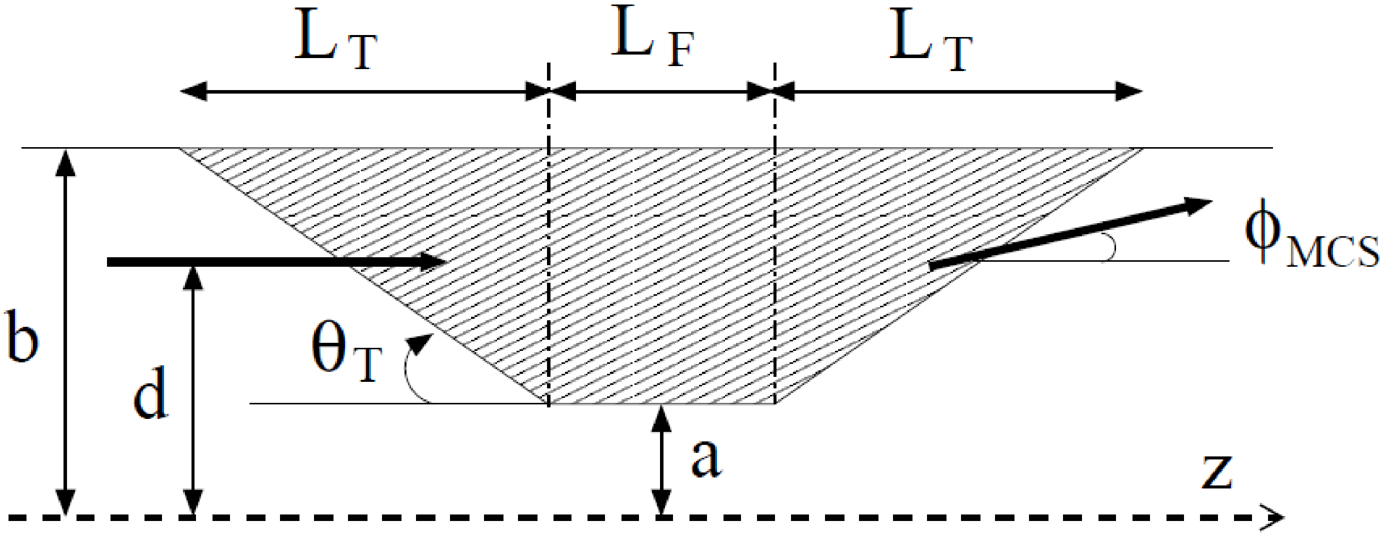
$$\langle y'_{RMS} \rangle = \frac{r_e N_b}{\sqrt{3}\gamma} \kappa y_0$$

$$\kappa = \kappa_g + \kappa_r$$

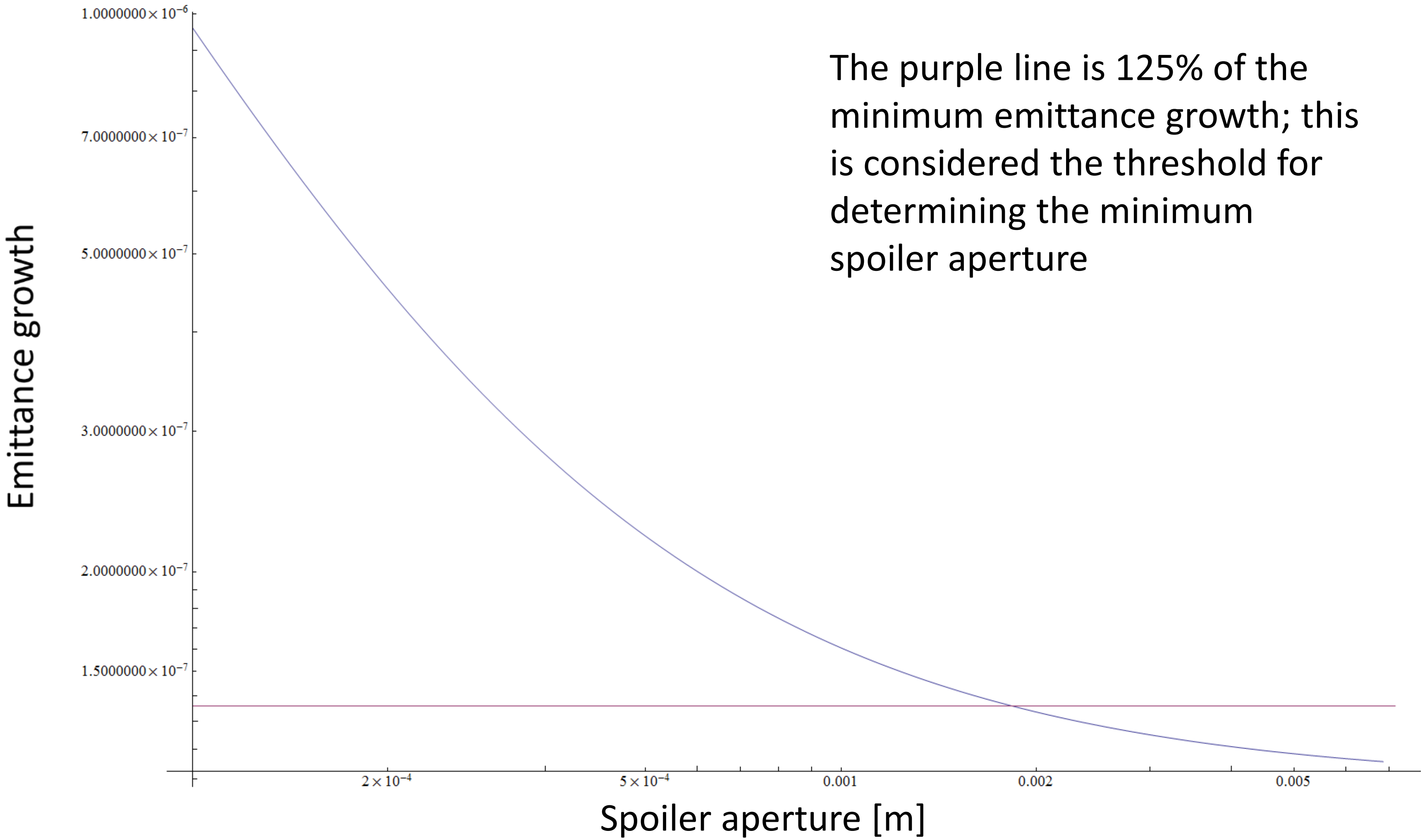
$$\frac{\delta\varepsilon_y}{\varepsilon_y} = \sqrt{1 + \frac{\beta_y}{\varepsilon_y}\langle y'_{RMS} \rangle^2} - 1$$

$$\kappa_g = \begin{cases} \dfrac{\pi\theta_T h}{2\sigma_z}\left(\dfrac{1}{a^2} - \dfrac{1}{b^2}\right) & \theta_T < 3.1^2 \dfrac{a\sigma_z}{h^2} \\ \dfrac{8}{3}\sqrt{\dfrac{\theta_T}{\sigma_z a^3}} & 3.1^2 \dfrac{a\sigma_z}{h^2} < \theta_T < 0.37^2 \dfrac{\sigma_z}{a} \\ \dfrac{1}{a^2} & \theta_T > 0.37^2 \dfrac{\sigma_z}{a} \end{cases}$$

$$\kappa_r = \frac{\pi}{8a^2}\Gamma(1/4)\sqrt{\frac{2}{\sigma_z \sigma Z_0}}\left[\frac{L_F}{a} + \frac{1}{\theta_T}\right]$$



Emittance growth vs aperture



The purple line is 125% of the minimum emittance growth; this is considered the threshold for determining the minimum spoiler aperture

Emittance growth vs offset