$e^+ e^-$ "Higgs Factory" Parameter Relations

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BASICs Recap

- Luminosity Equation:

$$Lum0 := \frac{3}{8} \frac{P0\,\rho\,(byIP\,xix + bxIP\,xiy)}{m\_e\,\pi\,r\_e^2\,gammar^3\,e\,bxIP\,byIP}$$

- Beamstrahlung lifetime:

$$tau\_ng := \frac{1}{6} \frac{\sqrt{C}\,\sqrt{2}\,\sqrt{3}\,m\_e\,(byIP\,xix + bxIP\,xiy)\,\sqrt{nb}\,\sqrt{u}\,e^u}{\sqrt{Lum00}\,\sqrt{bxIP}\,\sqrt{byIP}\,c^{3/2}\,\sqrt{xiy}\,\sqrt{xix}\,\alpha^2\,hbarMeVs}$$

  - where u is:

$$u0\_ng := \frac{1}{9} \frac{\eta\,m\_e^{4/3}\,e^{1/3}\,3^{2/3}\,(byIP\,xix + bxIP\,xiy)^{2/3}\,sigz\,\sqrt{nb}}{Lum00^{1/6}\,\pi^{1/6}\,r\_e^{1/3}\,bxIP^{1/6}\,byIP^{1/6}\,P0^{1/3}\,\rho^{1/3}\,\sqrt{C}\,\sqrt{c}\,\sqrt{xiy}\,\sqrt{xix}\,hbarMeVs}$$

Observations

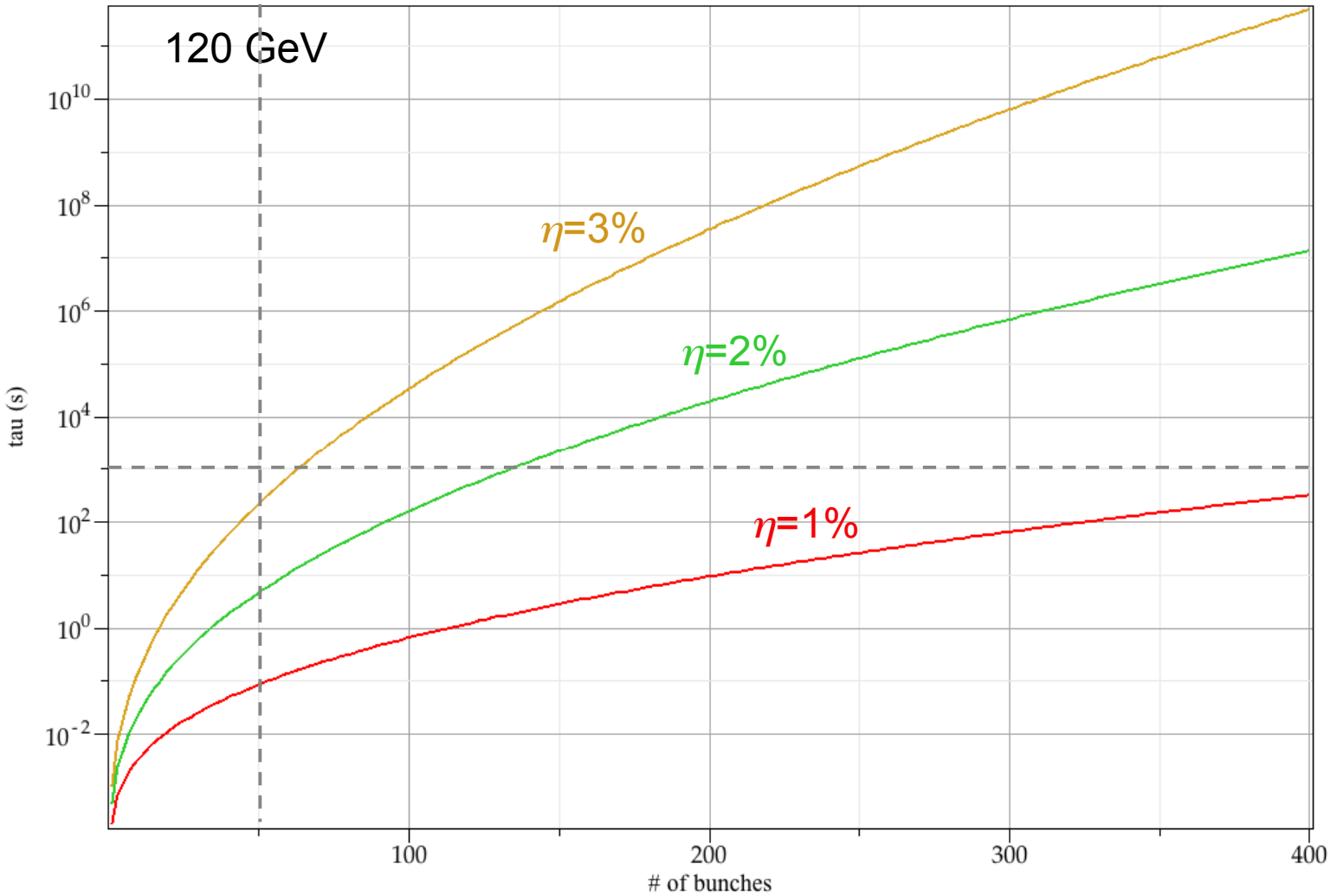
- For the “free” parameters, beamstrahlung lifetime is proportional to…
  $\sqrt{nb}$, $\sqrt{ß_x}$, $e^{\sigma z}$, e^{η}
- and inversely proportional to
  $\sqrt{\xi_x}$

- A starting parameter set was given by F. Zimmermann & modif. by Cai et al.:
  - P=50 MW, C=26700 m, r=2625 m, $ß_x$=0.05 m, $ß_y$ = 0.001 m, xix=0.035, xiy=0.07, eta=0.03, sigz=0.0015, nb=50, gammar=2.35E5 (120 GeV).
  - Lum=1.32E34 * 0.76; emitx=4.3E-9 mr; emity=21E-12 mr,

Parameter Table (Y. Cai, F.Z.)

	LEP2	LEP3	TTEV	TLEP
Beam Energy [GeV]	104.5	120	120	175
Circumference [km]	26.7	26.7	18.9	82.4
Beam current [mA]	4	7.2	5.0	6.4
Number of bunches	4	50	20	466
Bunch population [10^{10}]	57.5	8.0	10.0	2.36
Horizontal emittance [nm]	48	4.3	4.4	1.03
Vertical emittance [nm]	0.25	0.02	0.022	0.005
β_x* [mm]	1500	50	50	50
β_y* [mm]	50	1	1	1
Hourglass factor	0.98	0.76	0.72	0.80
SR power [MW]	11	50	50	50
Bunch length [mm]	16.1	1.5	1.86	1.32
Momentum acceptance [%]	1.25	3.0	3.0	3.0
Beam-beam parameter	0.07	0.07	0.09	0.06
Luminosity [10^{34} $cm^{-2}s^{-1}$]	0.0125	1.01	0.77	1.16

Bunches Scaling



Emittance vs # of Bunches

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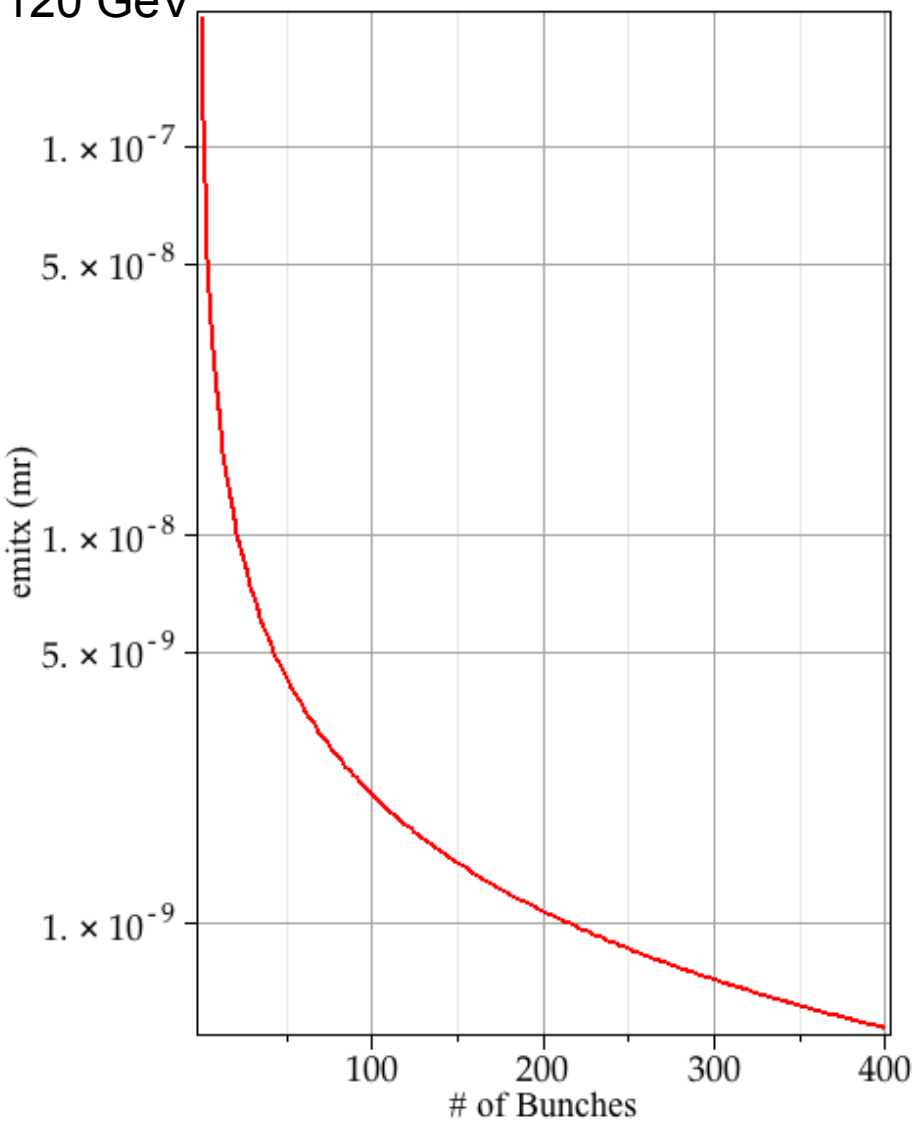
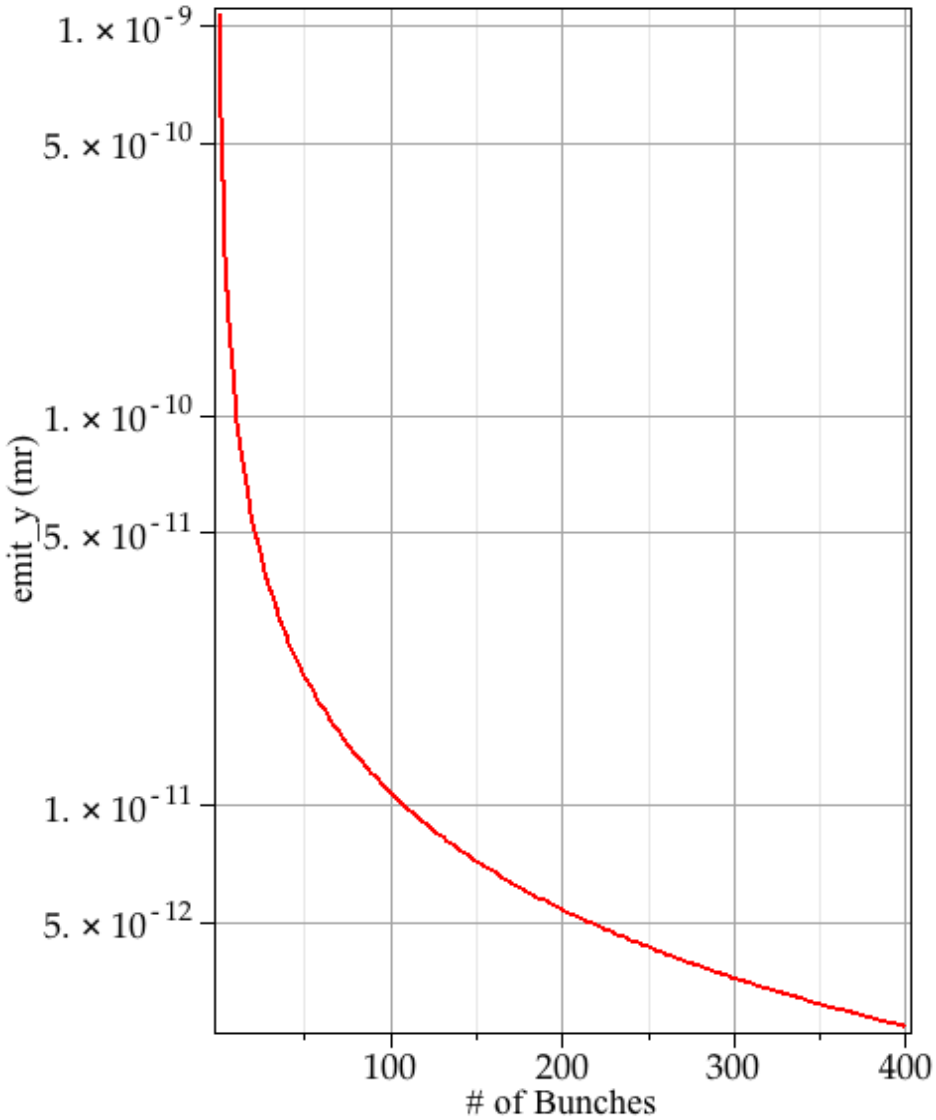
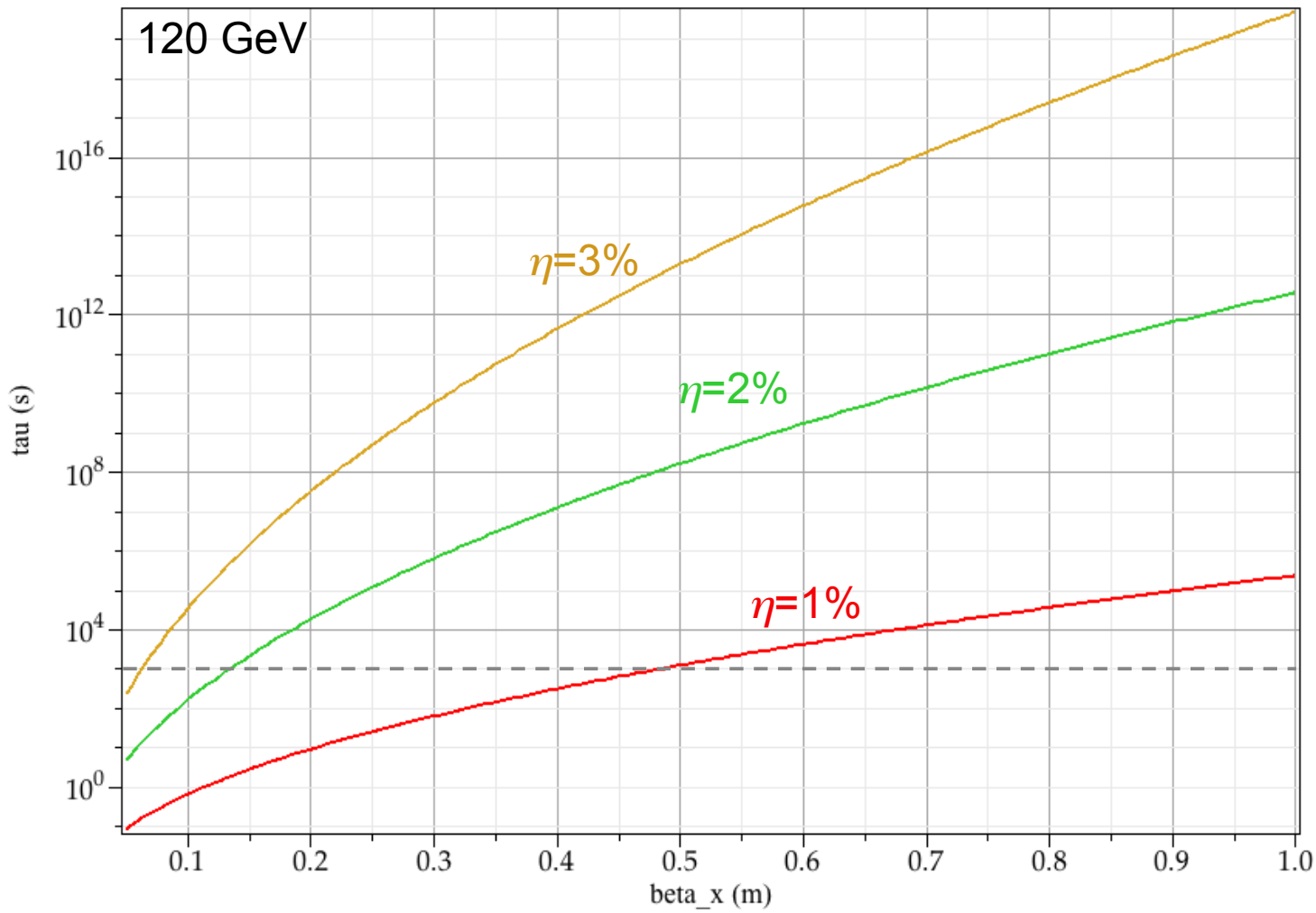
120 GeV

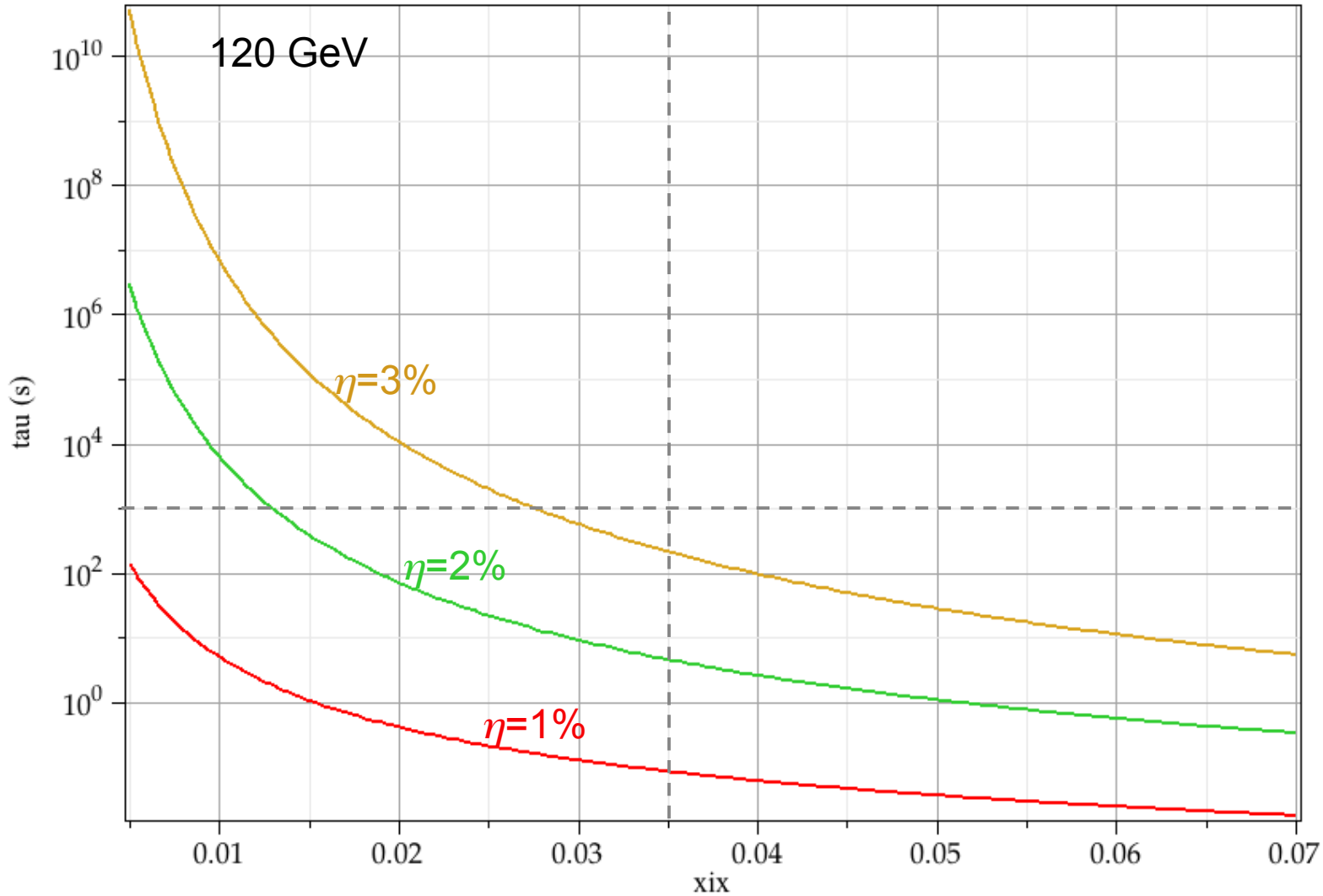




ßx Scaling


120 GeV
η=3%
η=2%
η=1%
tau (s)
10^{16}
10^{12}
10^{8}
10^{4}
10^{0}
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
beta_x (m)

ξ_x Scaling


120 GeV
η=3%
η=2%
η=1%
tau (s)
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
0.01
0.02
0.03
0.04
0.05
0.06
0.07
xix

Aspect Ratio

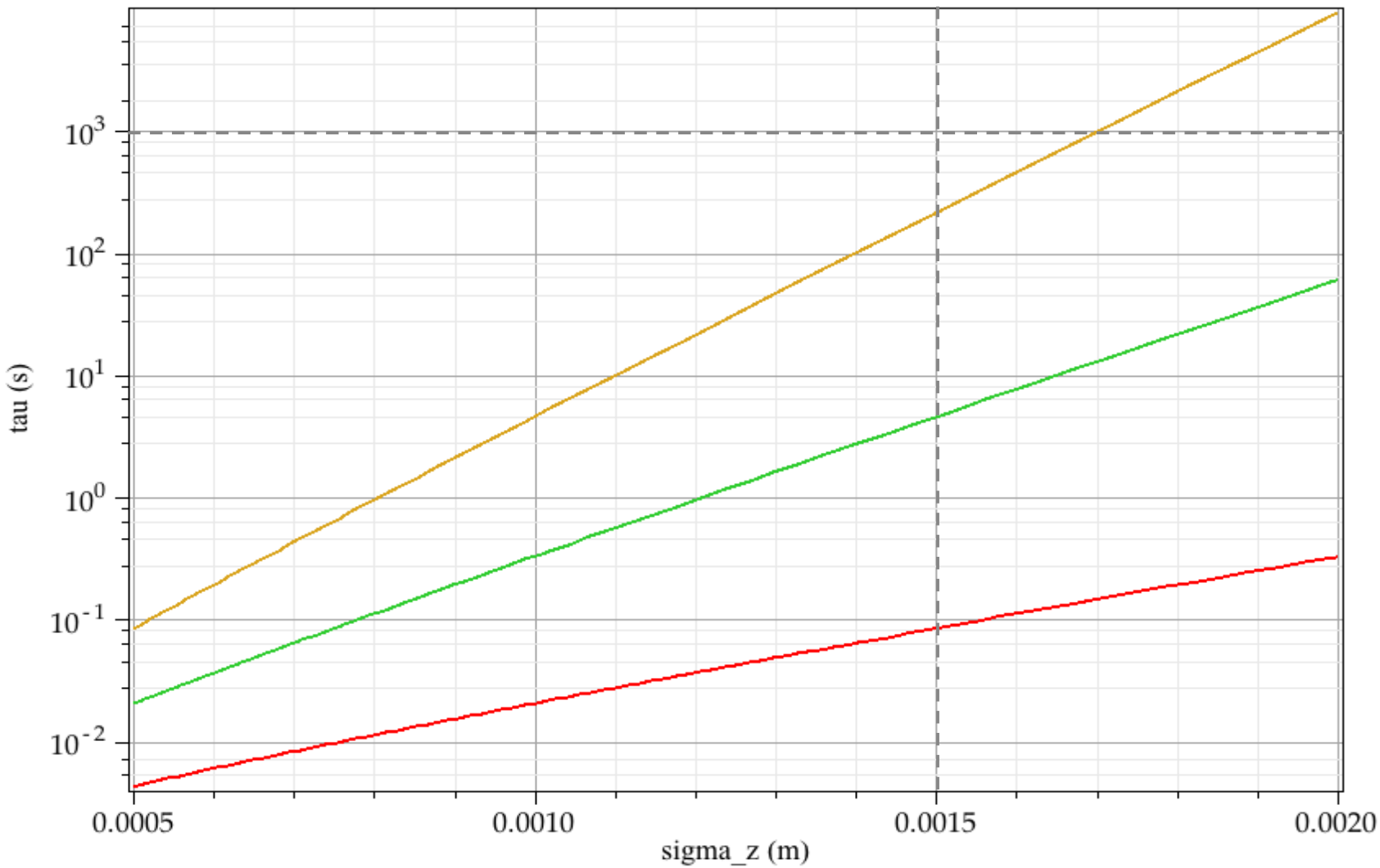
- Aspect ratio scales as:

$$\frac{\varepsilon_y}{\varepsilon_x} = \frac{0.204081632653061\ xix^2}{betax}$$

- Want ξ_x small, $ß_x$ large => extreme aspect ratio

- Note: changing ξ_y or $ß_y$ changes luminosity; not the beamstrahlung lifetime

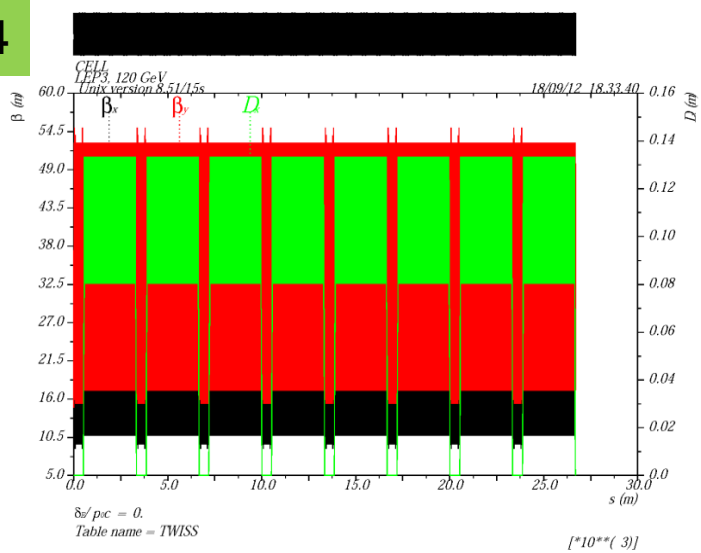
σ_z Scaling



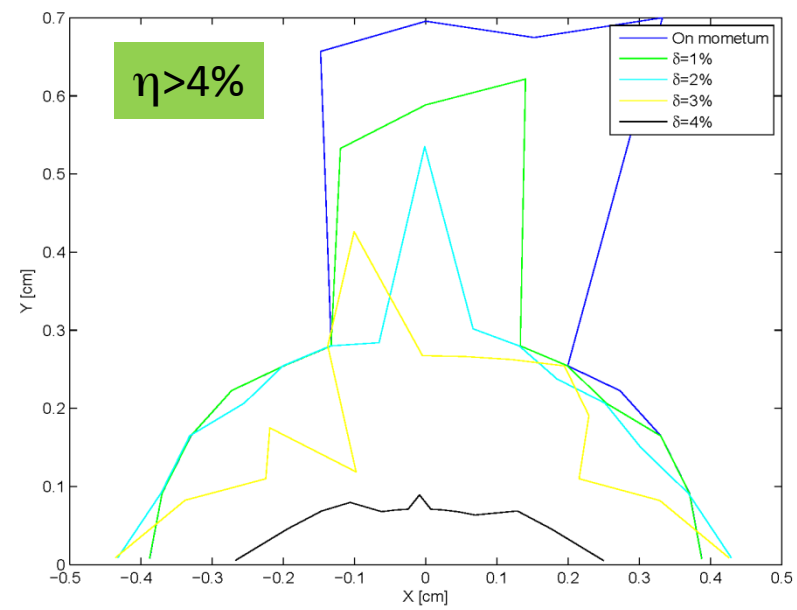
Arc Lattice for 120 GeV in LEP Tunnel (Y. Cai)

$90^0/60^0$ FODO Lattice

ß≤50m
D≤0.14



Dynamic Aperture



Emittance:

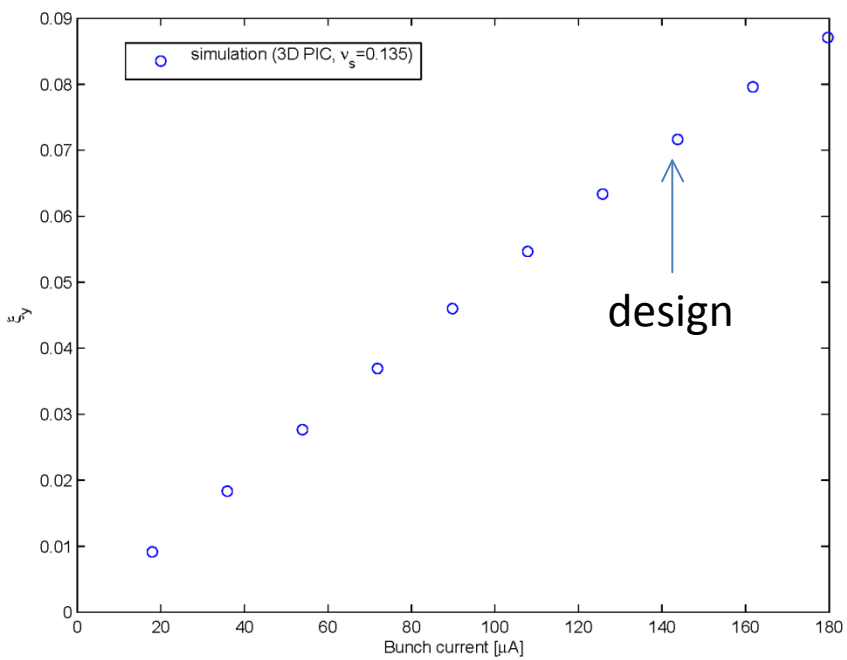
$$\varepsilon_x = F_c \frac{C_q \gamma^2}{J_x} \theta^3$$

where θ is the bending angle in a cell.

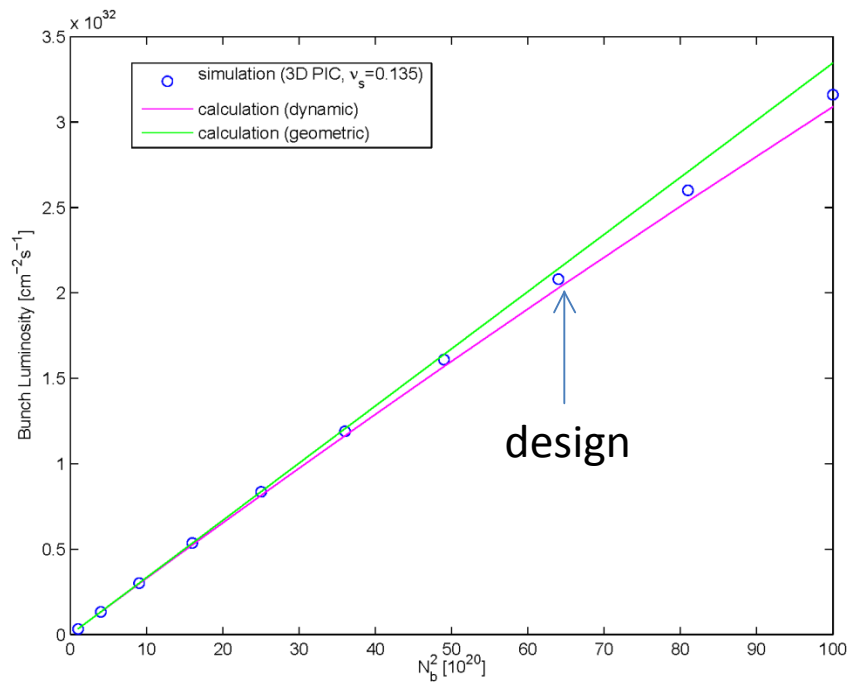
Design: ε_x=4.3 nm
and cell length is 28.28 m

Beam-Beam Calculations (Y. Cai)

Beam-beam parameter



Bunch luminosity



There is no surprise. It simply confirms calculations.

Conclusion (so far)

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- Increasing the # of bunches allows to maintain a reasonable aspect ratio of the beam
  - emittances do get very small.
  - for 150 bunches (2% energy acceptance needed); cell length approaches 20 m.
- $ß_x$ and ξ_x control beamstrahlung lifetime with little effect on luminosity.
- $ß_y$ and ξ_y control luminosity with little effect on beamstrahlung lifetime
- σ_z has significant effect on beam lifetime
- Varying $ß_x$ and/of ξ_x allows to increase beam lifetime at the expense of beam aspect ratio.
  - may not be a route to success

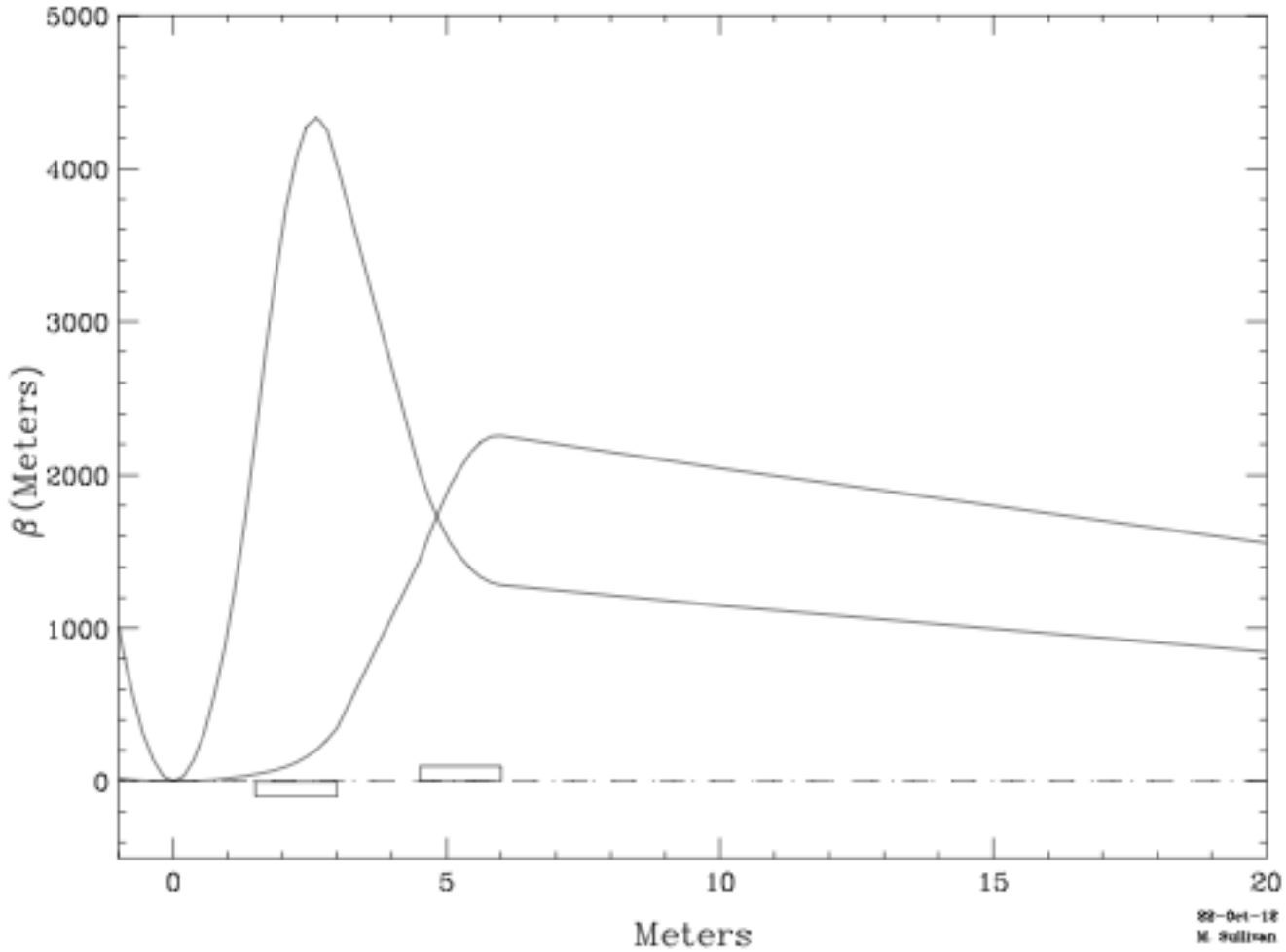
IR Parameters (M. Sullivan)

- Expts. would like 4 m L*
  - > 22000 m $ß_y$ in the first quadrupole, for 2 m length. $ß_x$ would be 7000 m
  - this requires 110 mm pole radius (15σ BSC); 7.3T tip field.
  - such a quad throws about 12 kW of synch rad. at E_c=10s of MeV.
    this will require a beam pipe radius of ≥ 20 mm to avoid intercept.

- If we move the 1st quad in to 1.5 m:
  - 4400 m $ß_y$ for a 1.5 m long magnet; $ß_x$ ≈ 2200 m
  - 50 mm pole radius and 9.6 T tip field; 17 kW of s.r. power

- In either case a 20-mm-radius pipe may be too small to avoid intercepting.

IR Doublet (M. Sullivan)



Summary

- Simple scaling suggests a larger number of bunches will be beneficial to mitigate beamstrahlung effects on beam lifetime
  - Can we fit 100...150 in without having two rings??
- The s.r. power limits beam current and thus forces low emittance
- Aspect ratios of 1:200 or higher are highly desirable.
- S.R. from the IR quadrupoles will need to be watched carefully.