1) The energy lost per turn for a single electron is given by:

electron energy

$$\boxed{U_0(\text{keV}) = \frac{e^2\gamma^2}{3\varepsilon_0\rho} = 88.5 \cdot \frac{E^4(\text{GeV})}{\rho(\text{m})}}$$

← bend radius 11×10^3 for 0.84 fill factor

The FCC energy range is 45 → 175 GeV.

The corresponding energy lost per turn is:

$$\frac{88.5\times45^4}{11\times10^3} = 3.299\times10^4 \text{ keV} \quad [45\text{ GeV}]$$

$$= \underline{0.03299\text{ GeV}}$$

$$\frac{88.5\times175^4}{11\times10^3} = 7.546\times10^6 \text{ kev} \quad [175\text{ GeV}]$$

$$= \underline{7.55\text{ GeV}}$$

- This confirms the data in the parameters table

$$\frac{88.5\times120^4}{11\times10^3} = 1.6683\times10^3 \text{ keV}$$

$$= \underline{1.668\text{ GeV}}$$

This loss per turn per electron can be converted into total power loss.

- Power = $\frac{\text{Energy}}{\text{Time}}$ – if we have E (per electron per turn) then for N electrons in a beam: $E_{\text{beam per turn}} = N E_{\text{elect per turn}}$

- Then a current can be defined as the rate of flow of charge:
  - per beam there are N electrons of charge e, so total charge Ne.
  - They circuit it time T

$$I_b = \frac{Ne}{T}$$

Therefore, the power $\boxed{P[W] = U_0[eV] \cdot I_b[A]}$

$P_{45} = 0.03299 \times 10^9 [eV] \times 1.450 [A]$
$= 47.84\ MW$

$P_{175} = 1.668 \times 10^9 [eV] \times 30 \times 10^{-3} [A] = 50.04 \times 10^6\ W$
$= 50.04\ MW$

Again, this confirms the data in the table
Also, All values for P_{beam} are 50 MW-
because of the limit set on sych ~~raction~~ radiation
Power.

- The rf system must compensate for this power loss. Therefore, per turn, the rf must provide:

50 MW of power to each beam

- Then converting that power to energy

$$E = 50MW \times T_{rev} = 50MW \times 3.33 \times 10^{-4} [s]$$
$$= 1.665 \times 10^{4} J$$
$$= 16.65 kJ$$

This is assuming an even distribution.
In the end, the sychroton radiation is "collimated" in a specific direction for $\beta = 1$ so maybe the heating on the outer side will be greater.

- you could change this to temp using specific heat.

2) Any angle greater than the critical angle has a small contribution. The radiation peaks at $\sim 0.3\theta_c$.

$$\theta_c = \frac{1}{\gamma}\left(\frac{w_c}{w}\right)^{1/3} \qquad w_c = \frac{3}{2}\frac{c}{\rho}\gamma^3$$

$$w_c = \frac{3}{2} \times \frac{3\times10^8}{11\times10^3} \cdot \left(\frac{46.5}{0.5005}\right)^3 = \cancel{1.798\times10^6\ HZ} = \underline{3.08\times10^{19}}$$

$$\cancel{= 1.798\ MHZ}$$

$$f_c = \frac{w_c}{2\pi} = 4.9019\times10^{18}\ HZ,\quad \lambda_c = \frac{3\times10^8}{4.9019\times10^{18}} = \underline{6.12\times10^{-11}\ m}$$

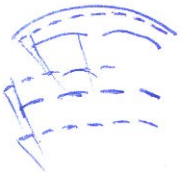
3) The dipole filling factor is the factor of the lattice cell that is filled with depoles.

$$\text{filling factor} = \frac{L_{dipoles}}{L_{cell}}$$

There is a trade off between the requirements of low beta and the requirements of less synchrotron radius. Ideally a fill factor of 1 would reduce the magnet field strength. However, there need to be insertion devises and diagnostics.

$L\uparrow \theta\uparrow$, ~~$N\uparrow$ $L\downarrow \theta\downarrow$~~

1 dipole



~~filling factor ∝ L dipole, N dipoles~~, θ

~~well you should argue for a fill factor 1 there is 1 dipole and the more dipoles, the lower the fill factor~~

fill factor ∝ L, θ, N

AT5073 But the more magnets, the less consistent the field will be.

4) $\varepsilon_{min} = \frac{F C_j \cancel{\Theta}^3 \gamma^2}{J_x \cdot \sqrt{15} \cdot 12}$ if $N \uparrow$ then $\Theta \downarrow$ $\Theta = \frac{2\pi}{N}$

100 Fodo F^2

$\Rightarrow \varepsilon_{min} \propto \frac{1}{N^3}$ $\Theta^3 = \frac{(2\pi)^3}{N^3}$

$$\varepsilon_{min} = \frac{(2\pi)^3 C_j \gamma^2}{J_x N^3}$$

$C_j = 3.84 \times 10^{-13}$ m

$1 - \cancel{\beta}$ Damping; $J_x \sim 1$

$\gamma = \frac{175 \times 10^9}{0.5 \times 10^6}$ $\Rightarrow \varepsilon_{min} = \frac{(2\pi)^3 \times 3.84 \times 10^{-10}\,\text{mm} \cdot \left(\frac{175\times10^9}{0.5\times10^6}\right)^2 \times 100}{12 \cdot \sqrt{15} \quad N^3}$

$= \cancel{\frac{1166.8 \times 100}{12\sqrt{15}\,N^3}[\text{mm}]}$ $\frac{25106}{N^3}$ [mm]

The target emmittance at 175 GeV is 2nm. So, as the fill factor increases with increasing N, which intum decreases the sychrotron radiation, the largest N possible should be chosen, as to minimise the emmitance, bearing in mind that the fill factor $\not>$ 1 and there needs to be space for deagnostic and experments.

for $\varepsilon_x = 2$nm ~~N = 1800~~   ~~This seems to low?~~

~~$\varepsilon \leq 2$pm~~   2324 = N   ~~for the prososed fill facto~~

$N = \frac{12 \times 6.4 \times 0.84 \times 10^3}{10\text{m}} = 6854$

$- \varepsilon_{min} = 36$ Pm at 175 GeV

just for the minimum horizontal ε_x
$N = 2324$, but we have not counted
for the vertical ε_y. ~~If the same~~
~~formula applies: $N_{\varepsilon y}$ =~~ for the N and a
length of 10m, the fill factor is quite low
at ~ 0.37