# Cost model for Higgs factory based on circular collider

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# CEPC Cost model

$$N(higgs) = N_{IP} \cdot L \cdot \sigma\left(year \times month_{physics} \times 30 \times 24 \times 60 \times 60\right) \qquad \left(month_{physics} = 6\right)$$

$$\mathrm{Cost}_{total} = \mathrm{Cost}(machine) + \mathrm{Cost}(\mathrm{detector}) + \mathrm{Cost}(\mathrm{elect}) + \mathrm{Cost}(\mathrm{repair}) + \mathrm{Cost}\left(\mathrm{staff}\right)$$

$$\mathrm{Cost}(machine) = \frac{C}{100} \bullet 240\left(亿\right) + 60\left(亿\right)$$

$$\mathrm{Cost}(\mathrm{detector}) = 20\left(亿\right) \times N_{IP}$$

$$\mathrm{Cost}(\mathrm{elect}) = P_{SR} \times 10 \times year \times month_{operation} \times 30 \times 24 \times 0.5 \qquad \left(month_{operation} = 9\right)$$

$$\mathrm{Cost}(\mathrm{repair}) = \mathrm{Cost}(machine) \times 10\% \times year$$

$$\mathrm{Cost}\left(\mathrm{staff}\right) = \left(\mathrm{Cost}(machine) \times 3\% + 2\left(亿\right)\right) \times year$$

$$L\left(N_{IP}\right) = L\left(2IP\right) \frac{\sqrt{\frac{2}{N_{IP}}}}{\sqrt{1 + \frac{4*\left(N_{IP} - 2\right)}{C}}}$$

# Beam-beam limit

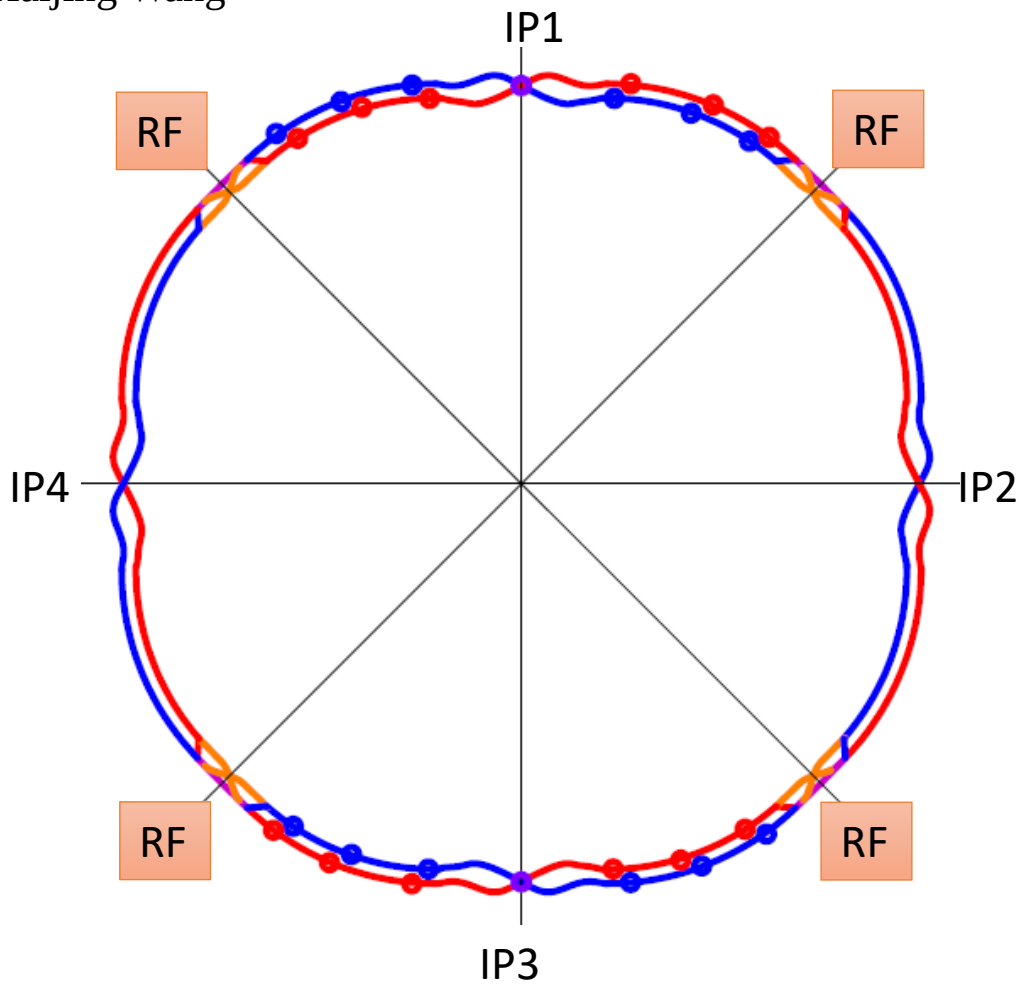
Jie Gao

$$\xi_{y,\max} \propto \sqrt{\frac{U_0}{N_{IP}}}$$

$$L \propto \xi_{y,\max} I_b \propto \xi_{y,\max} / U_0$$

# CEPC 4IP scheme*

Haijing Wang

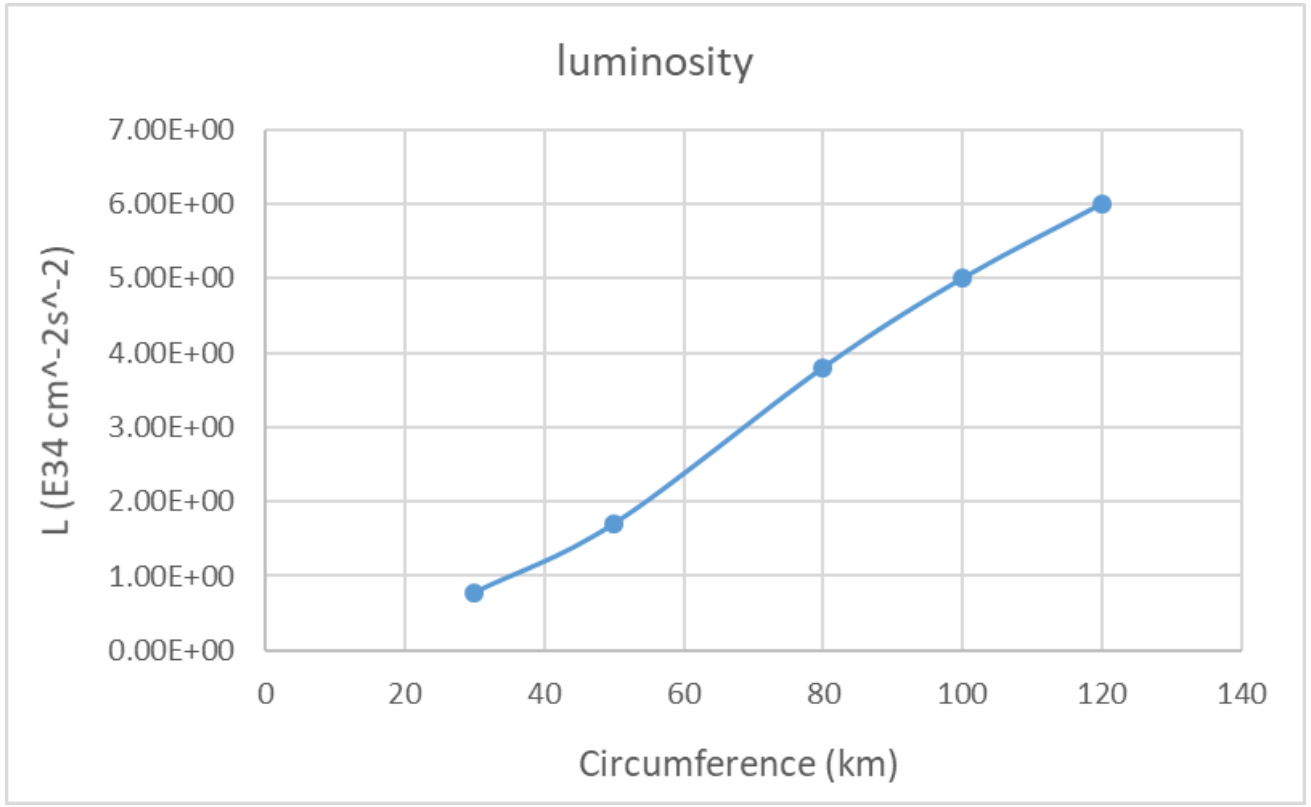



- 4 IPs
  - Equal spacing between IPs
- 4 RFs
  - RF at the midpoint of 2 IPs
  - shared RFs
- 2×2 collision
  - 2 trains/beam

* Dou Wang, et. al., "CEPC 4 IP discussions", CEPC day, A419, IHEP, Aug. 16th 2019.

# CEPC higgs luminosity vs. circumference

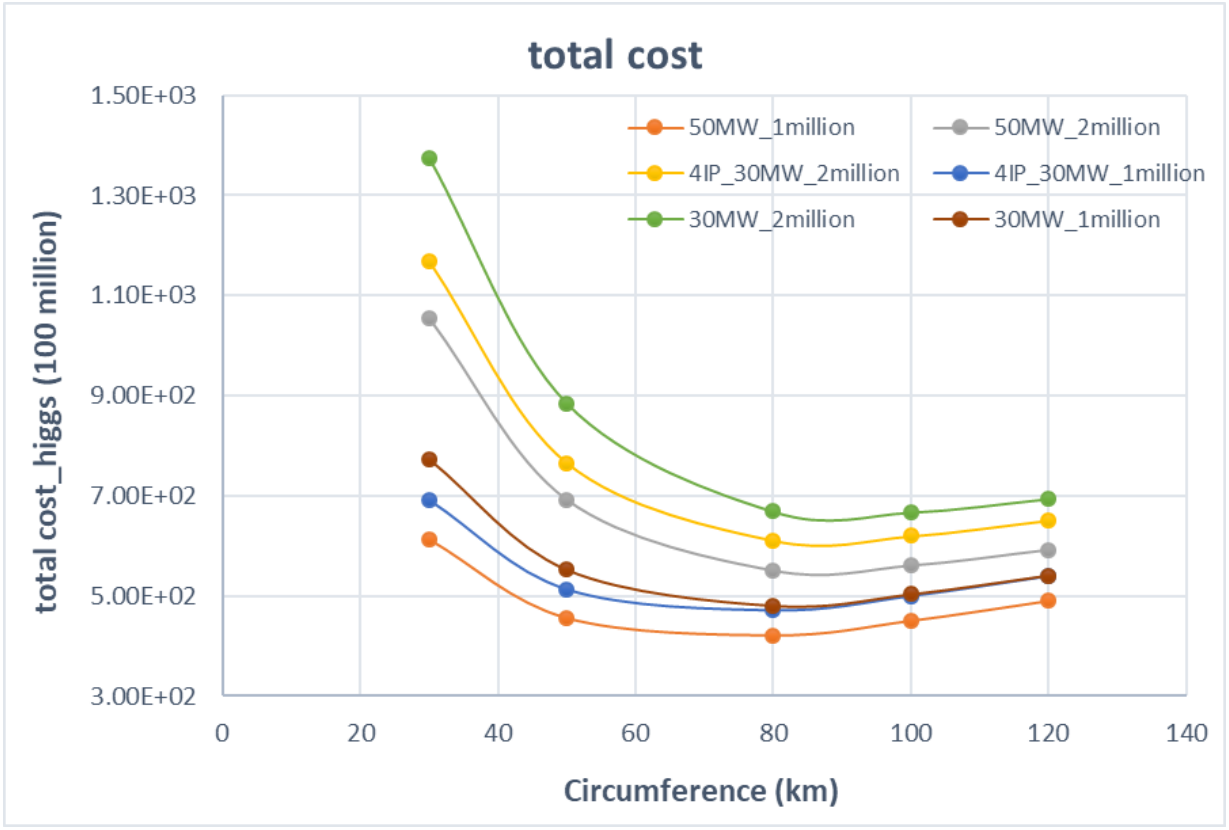
- $P_{SR}$=30MW



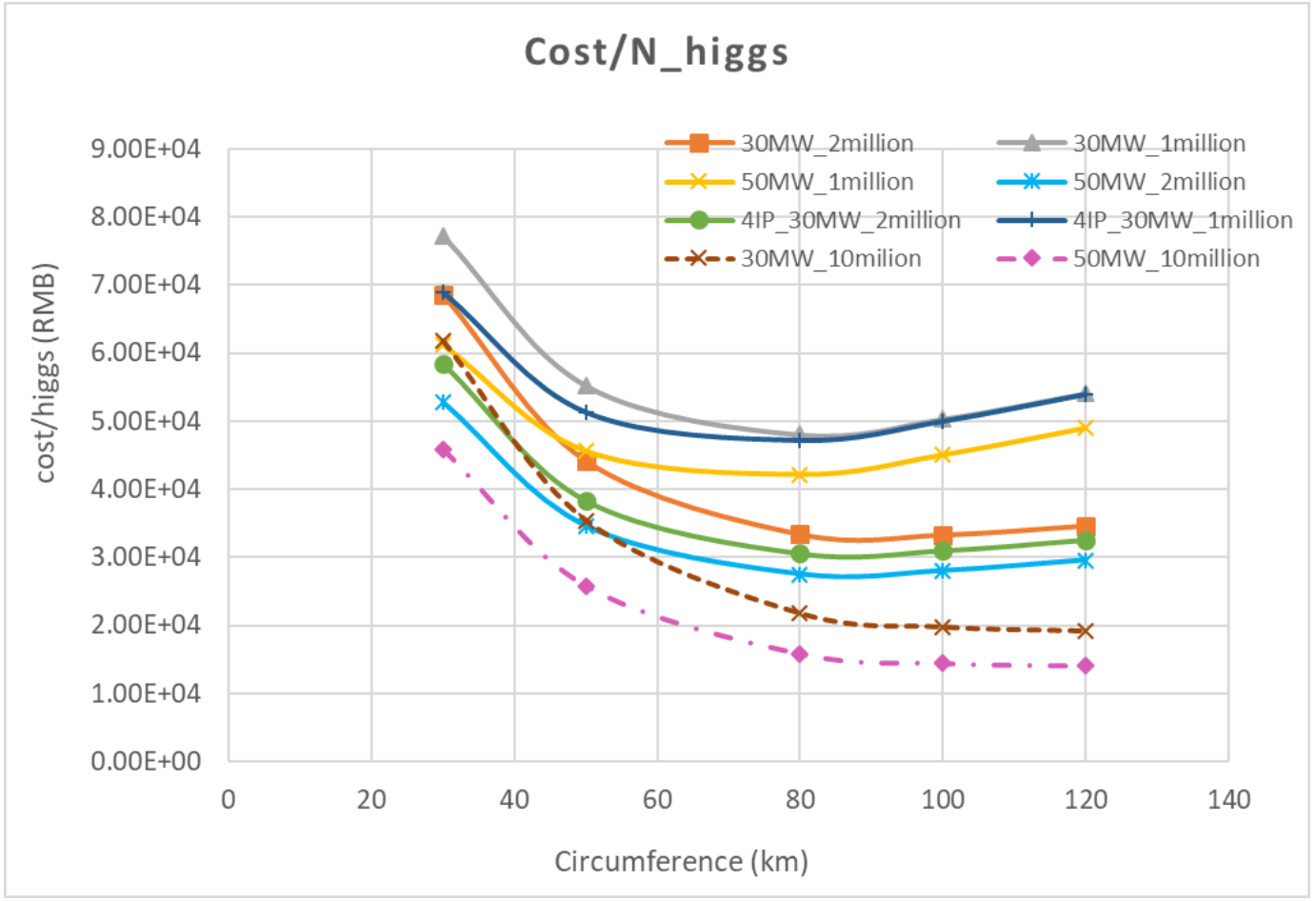

$$L = 9.35 + 0.40 * C - 3.64 * \sqrt{C}$$

# Total cost vs. circumference- higgs only

- Cross section @240GeV=200fb



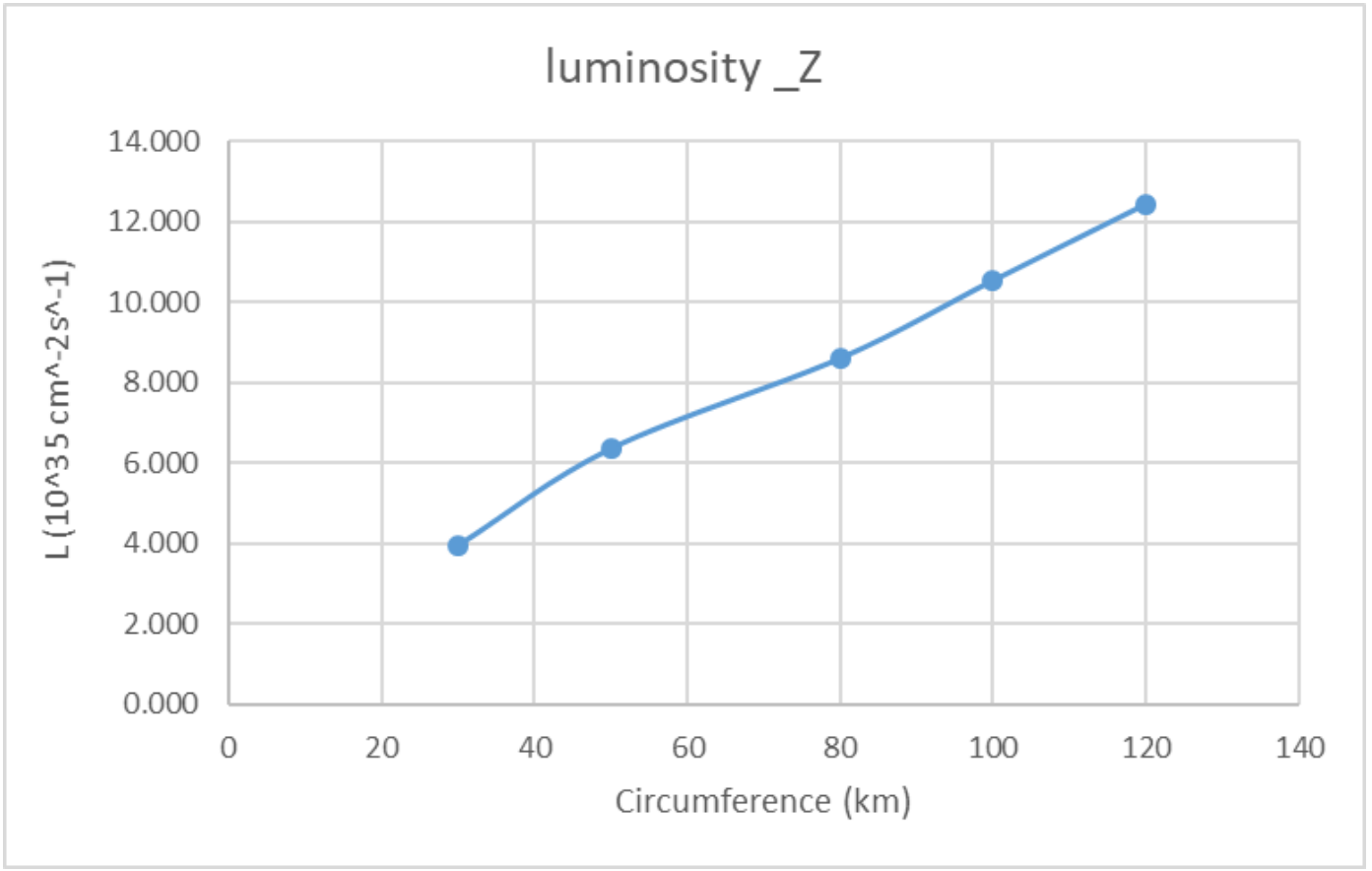
# Cost per higgs vs. circumference




- Higgs number↑, cost/H↓
- Higgs number↑, C↑
- Higgs number>1 M, $cost_{4IP}$↓
- 50MW is more efficient.

# CEPC Z luminosity vs. circumference

- $P_{SR}$=30MW



# Cost per Z vs. circumference

- Cross section @91GeV=30nb

$$Cost(\text{elect}) = P_{SR} \times 10 \times year \times month_{operation} \times 30 \times 24 \times 0.5$$

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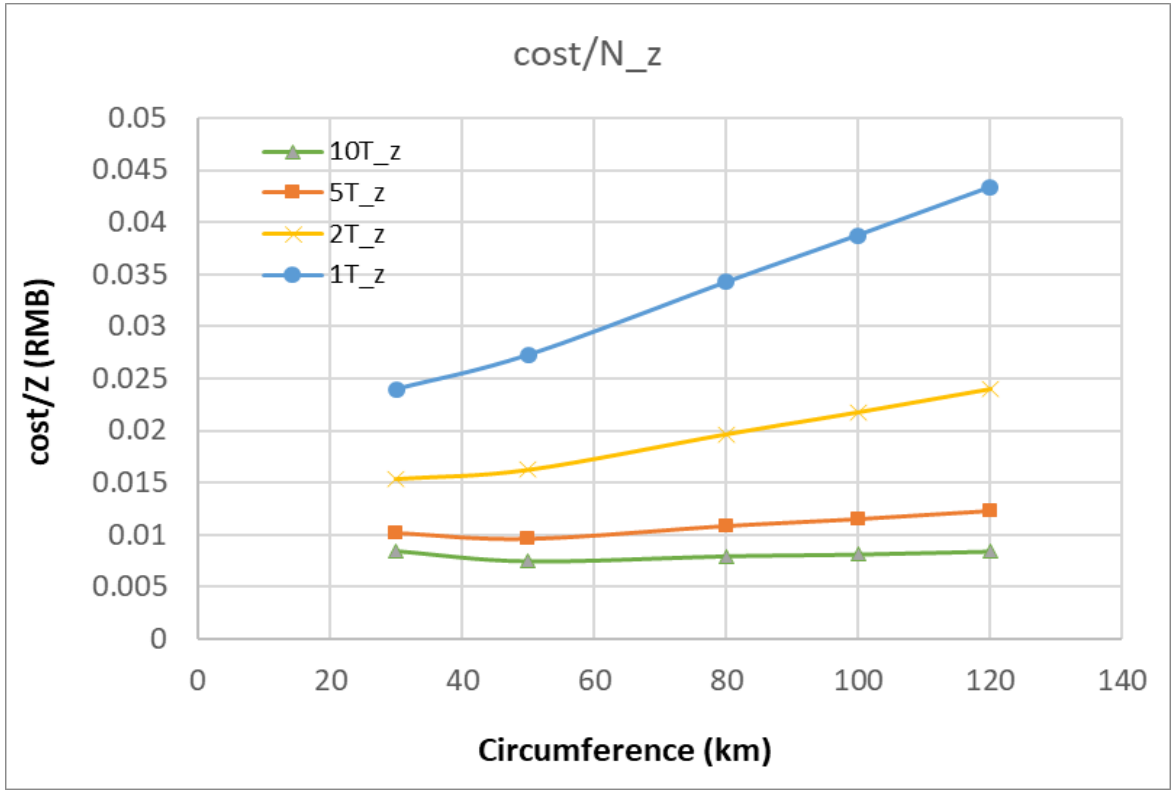
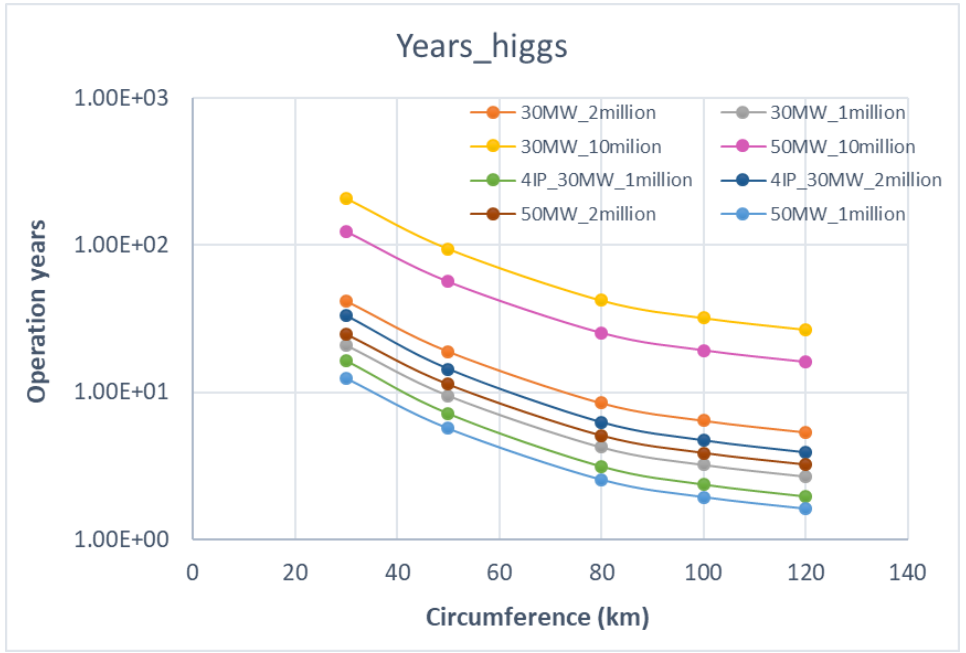
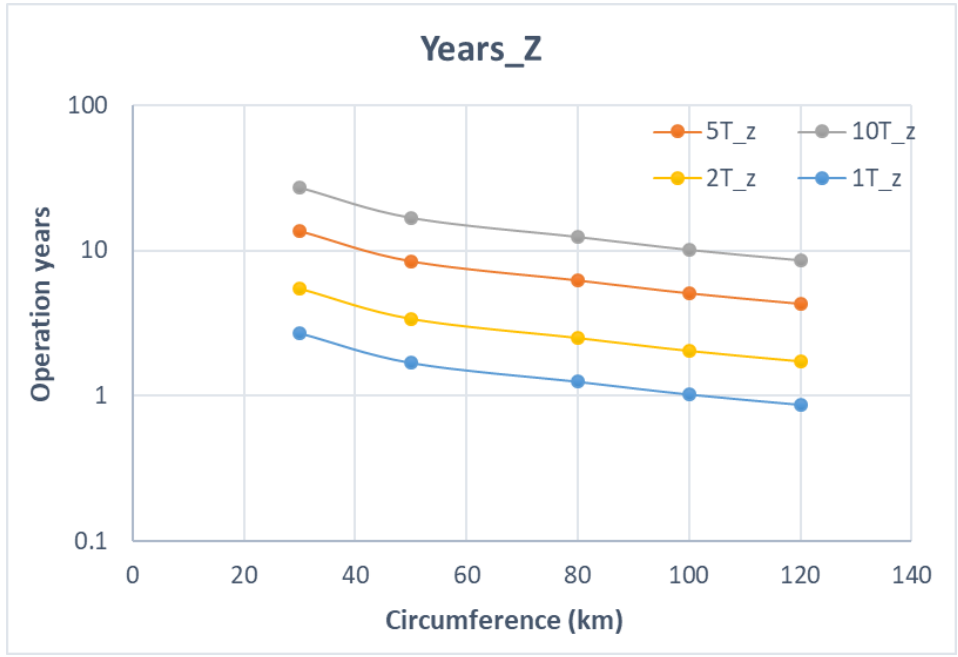


# Operation years

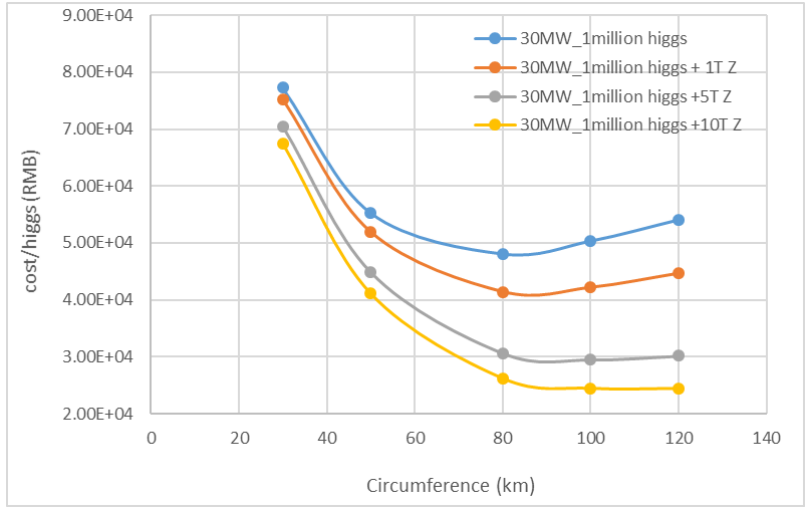


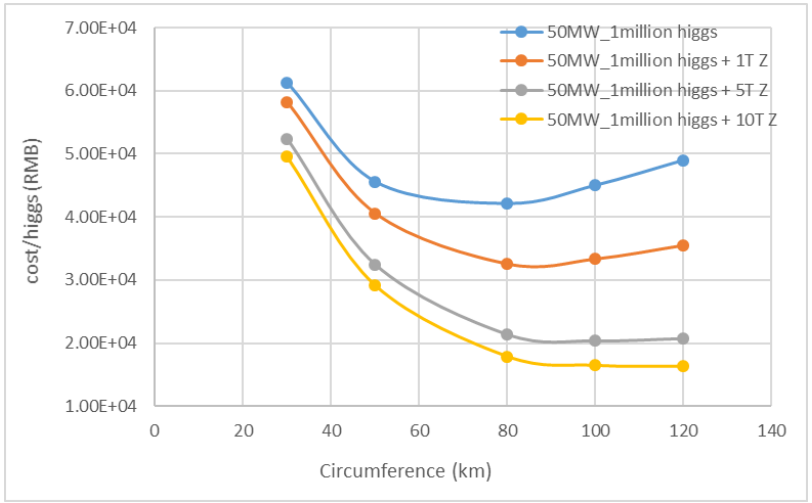



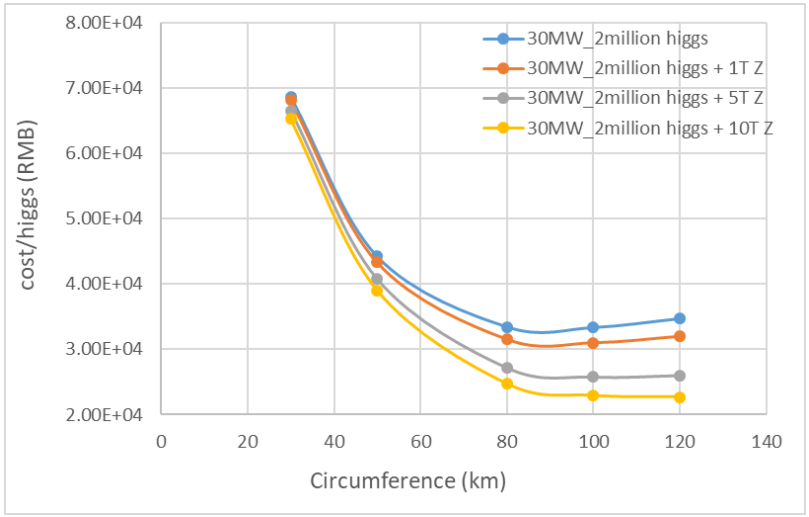

$$F_{higgs} = \frac{Year_{higgs}}{Year_{higgs} + Year_{Z}}$$

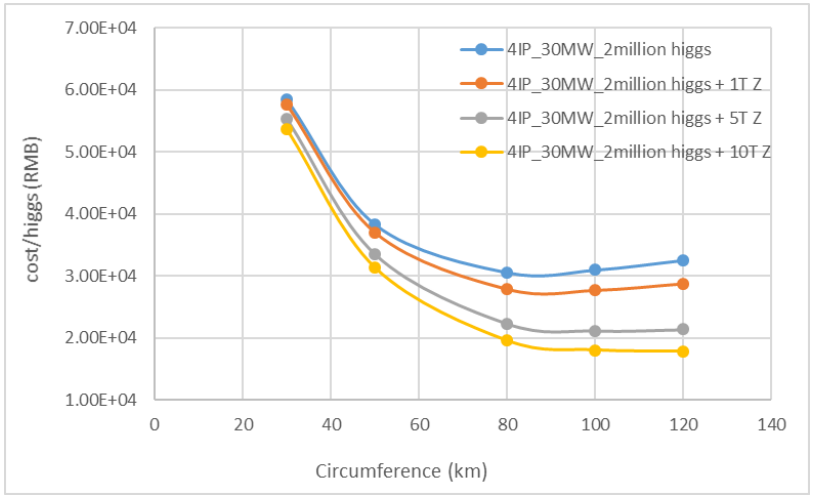
$$\mathrm{Cos}\,t_{higgs}(machine) + \mathrm{Cos}\,t_{higgs}(\mathrm{det\,ector}) = \left(\mathrm{Cos}\,t(machine) + \mathrm{Cos}\,t(\mathrm{det\,ector})\right) \times F_{higgs}$$

# Cost per higgs vs. circumference (combining higgs & Z)

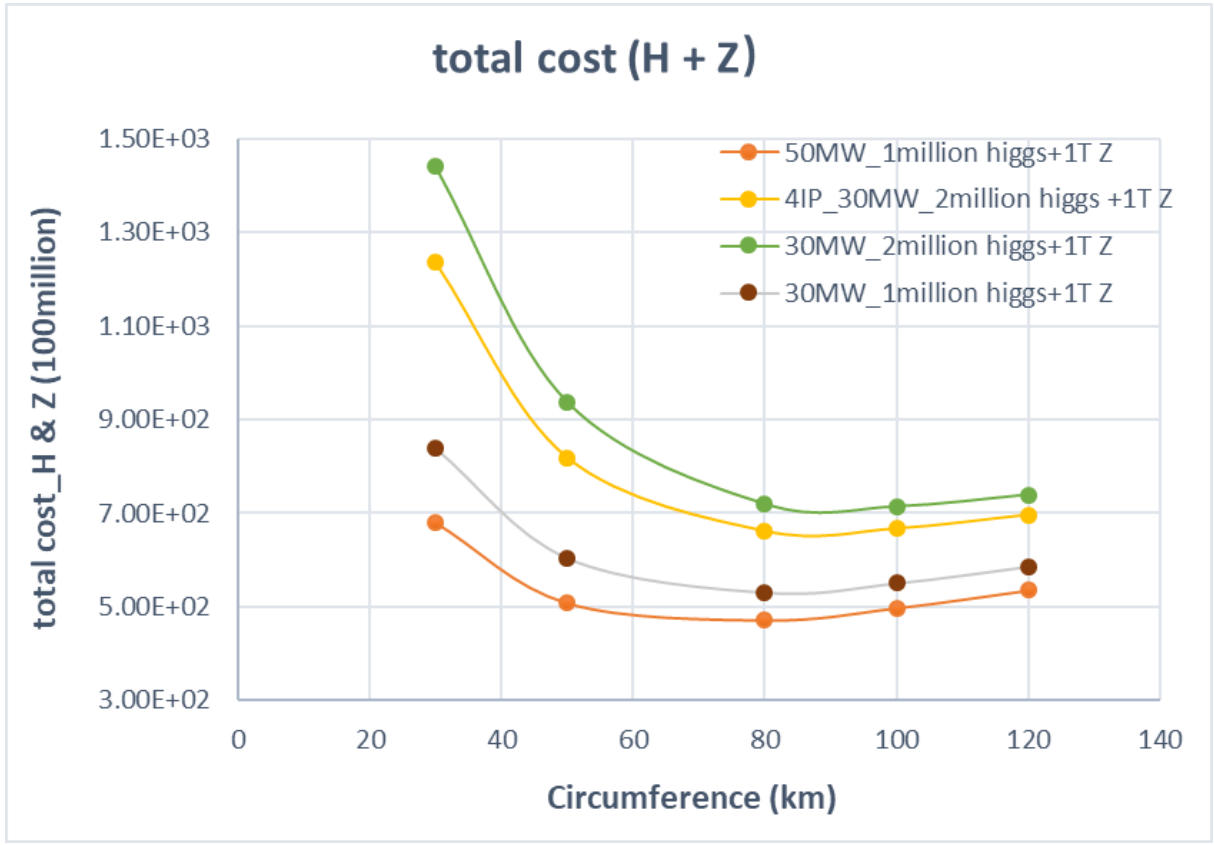


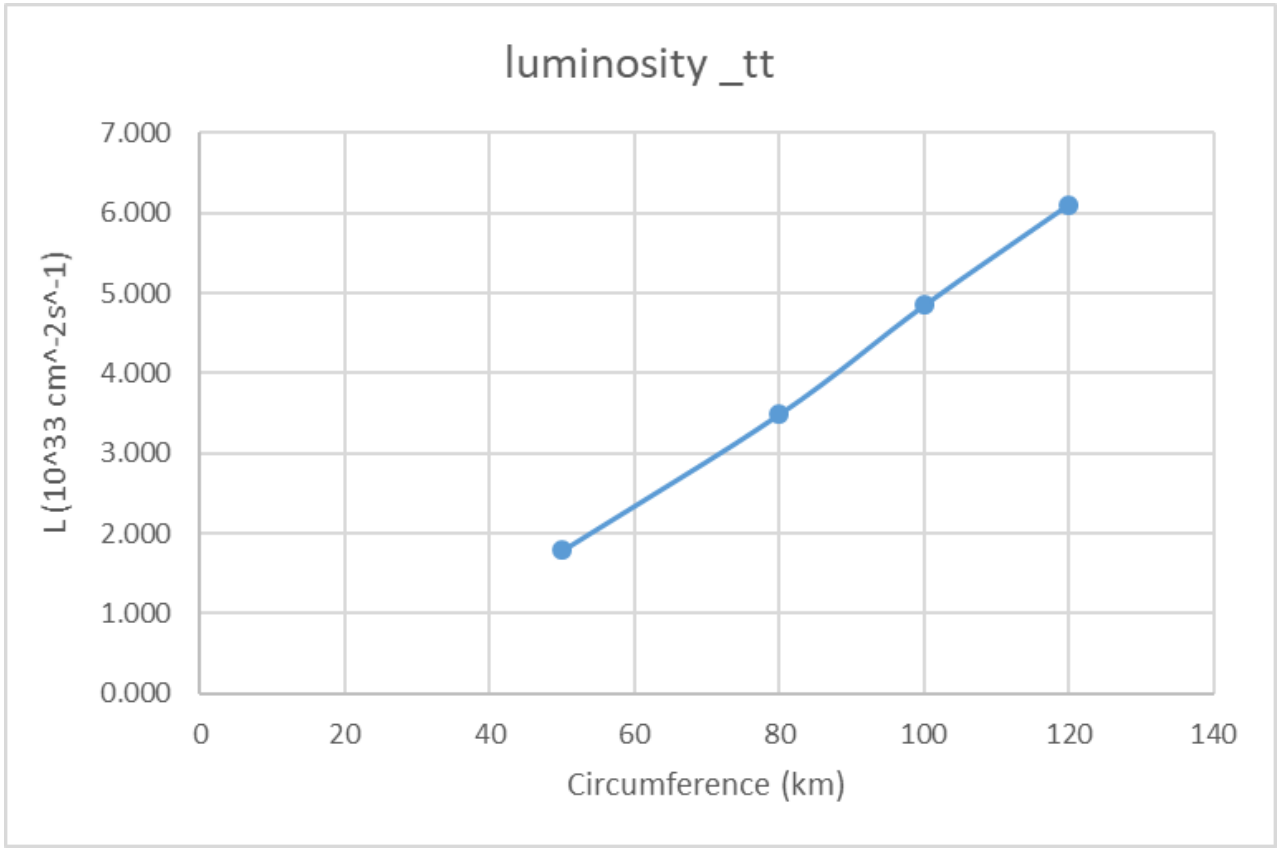



# Total cost vs. circumference (combining higgs & Z)



# CEPC tt luminosity vs. circumference

- $P_{SR}$=30MW



# Cost per top quark vs. circumference

- Cross section @360GeV=500fb

$$Cost(machine) = \frac{C}{100} \bullet 240(亿) + 60(亿) \quad + k \times 60 \quad (亿)$$

$$Cost(elect) = P_{SR} \times 10 \times year \times month_{operation} \times 30 \times 24 \times 0.5$$

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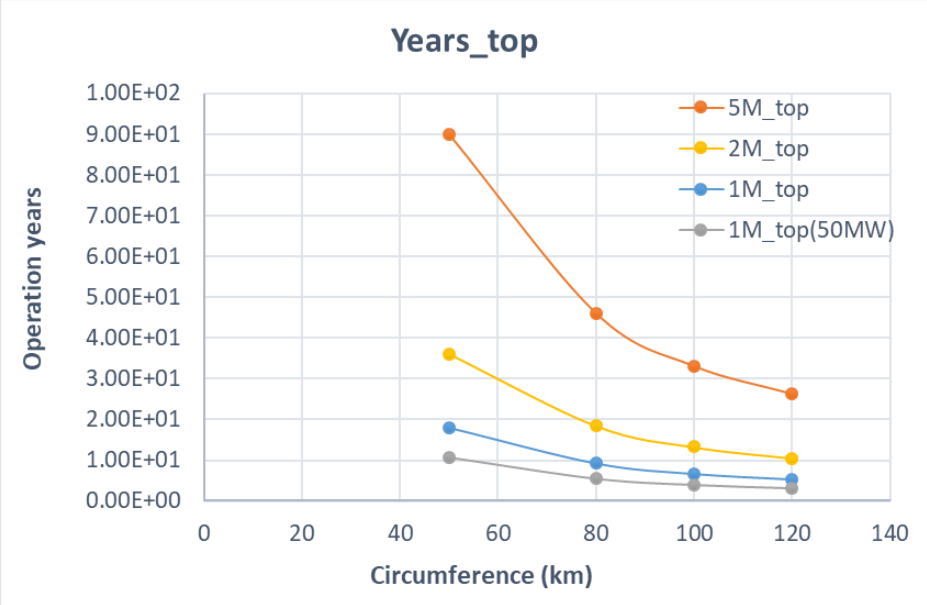
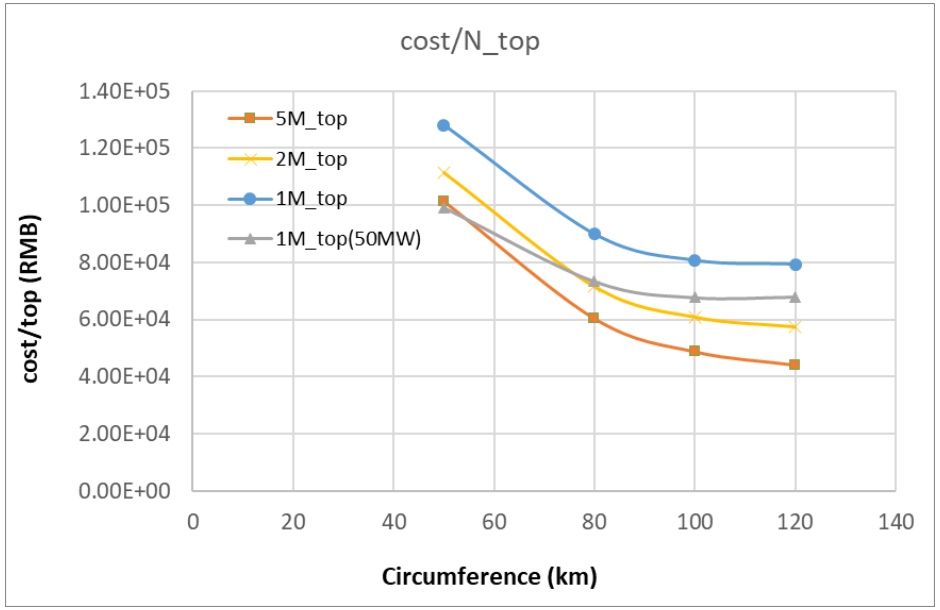
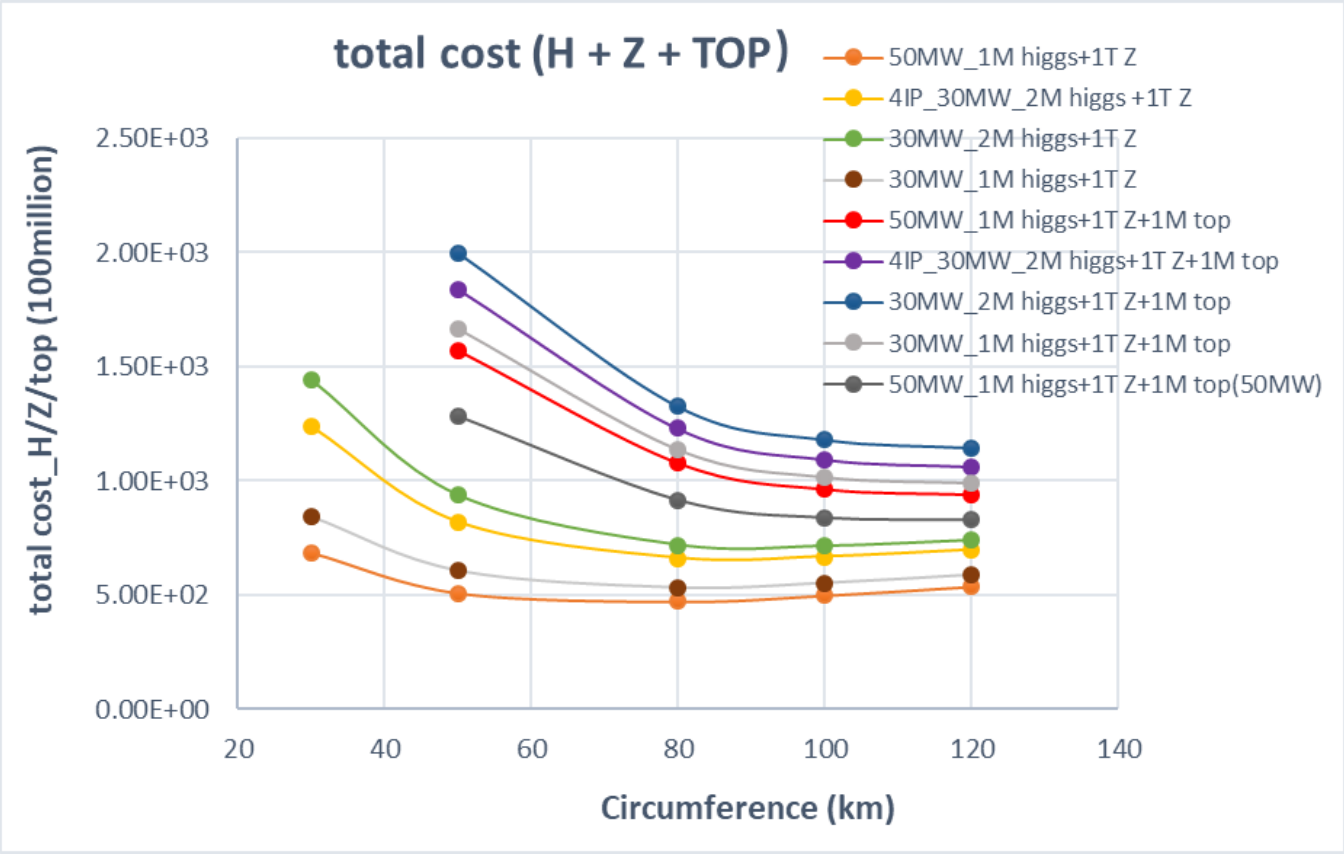


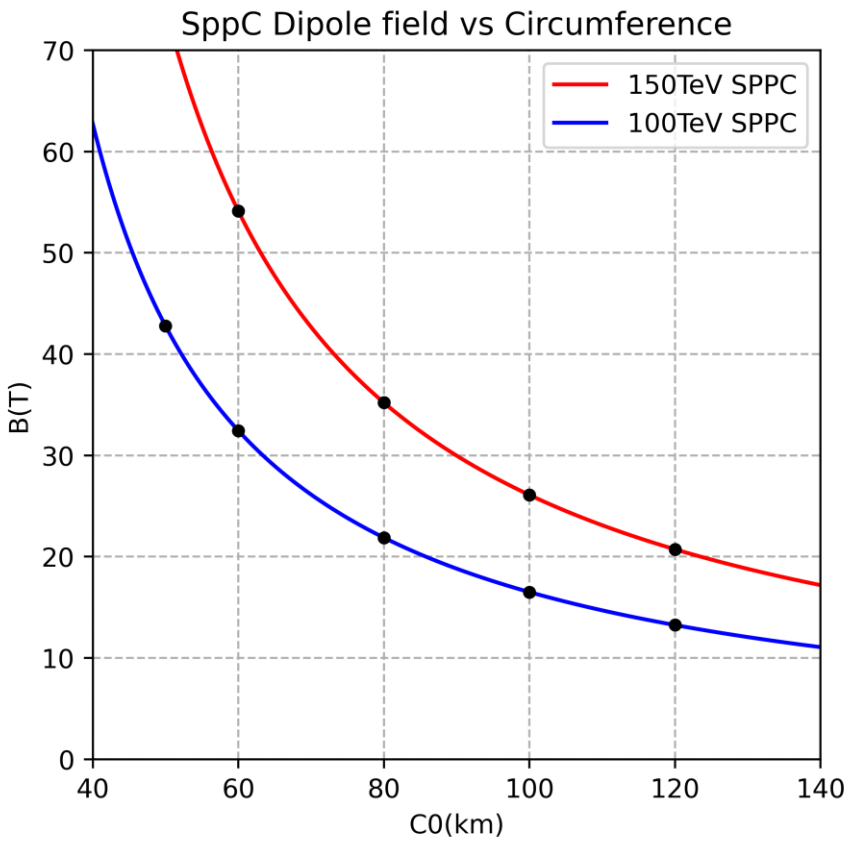



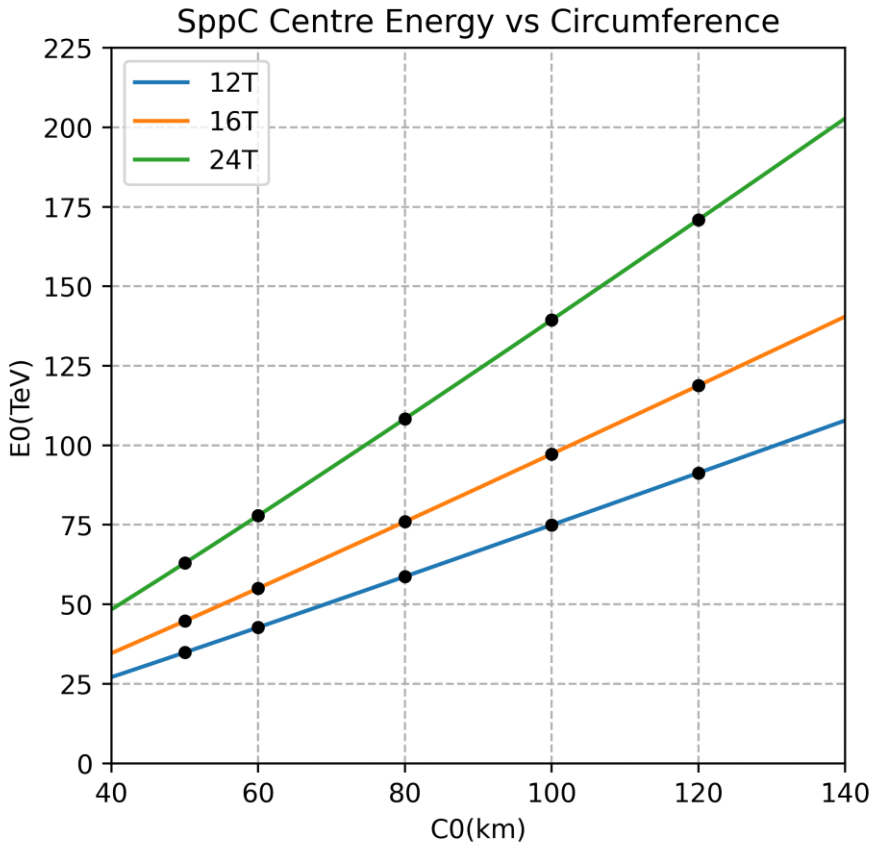
# Total cost vs. circumference (combining higgs/Z/ tt)



# Dipole strength & energy potential of SPPC

Hao Cheng Xu



# Summary

- CEPC cost performance is studied based on a rough cost model.
- Higgs physics is the first goal of CEPC
  - Requirement of total higgs: 1million $\rightarrow$ 80km is a good choice
  - Requirement of total higgs: $\geq$2million $\rightarrow$ 80km and 100km almost same
  - Combining higgs and ttbar: $\rightarrow$ 100km is the best choice
- 100 km circumference is a good choice for CEPC with consideration of the potential at ttbar, Z and SPPC.

# Back up

# Higgs Cost vs. circumference (combining higgs & Z)