R/Z optimization for the tracker at the CEPC

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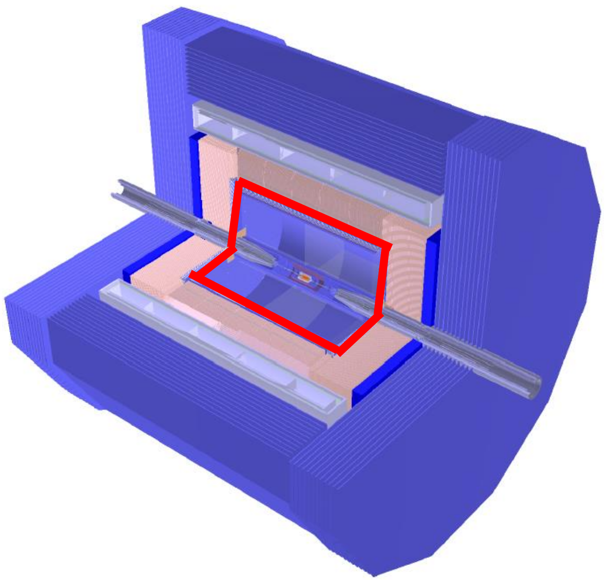
Introduction



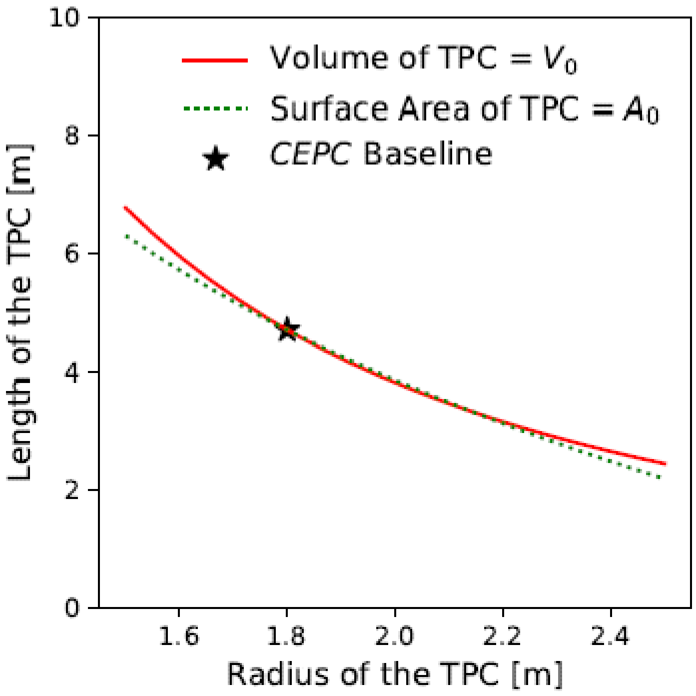
- CEPC
  - $\sim 10^{12}$ Z boson on the Z-pole
  - 1 Million Higgs bosons at 240GeV
- Physics objects:
  - Tracks
  - Jets
- Tracking system of the CEPC
  - Cylindrical configuration
  - Characterized by its radius (R) and length (Z)
- Why Optimal R & Z?
  - The performance depends on the R & Z (with sub-systems tuned to be the best)
  - Construction cost also depends on them

Methodology

- "**phenomenal**" study
- 1. Deferential performance parameterization for tracks and jets
  - as function of kinematic parameters
  - Parameterizations should be done for any radius (R) and any length (Z) of the tracking system

Methodology

- 2. Performance evaluation
  - p_T or E Resolutions averaged over kinematic phase space
- Construction cost
  - Surface area of the TPC (proportional to the volume of ECAL with fix thinness)
  - Volume
- Optimize the R/Z
  - With construction cost as constraint



Track p_T resolution parameterization

- The effective radius (r) is important to determine p_T

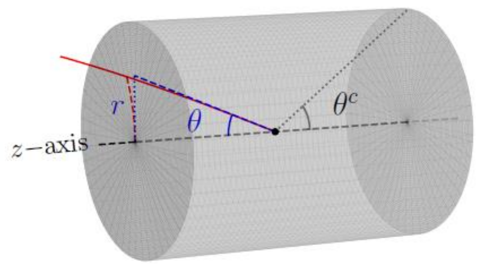


Figure 2: Skeleton diagram of a sideview of the TPC and a trajectory of one particle (marked by the solid red line) hitting its endcap, which has a p_T of 1.8 GeV/c and a θ of 21°.

- $r \sim \min(R, Z/2 \ \tan(\theta))$
- Bending radius of the track
  - $\rho \sim 1.1 E \ \sin\theta \ \mathrm{m/GeV}$ for a B-field of 3T
- With the case of $r \ll \rho$
  - $\sigma_{p_T} \propto r^{-2}$

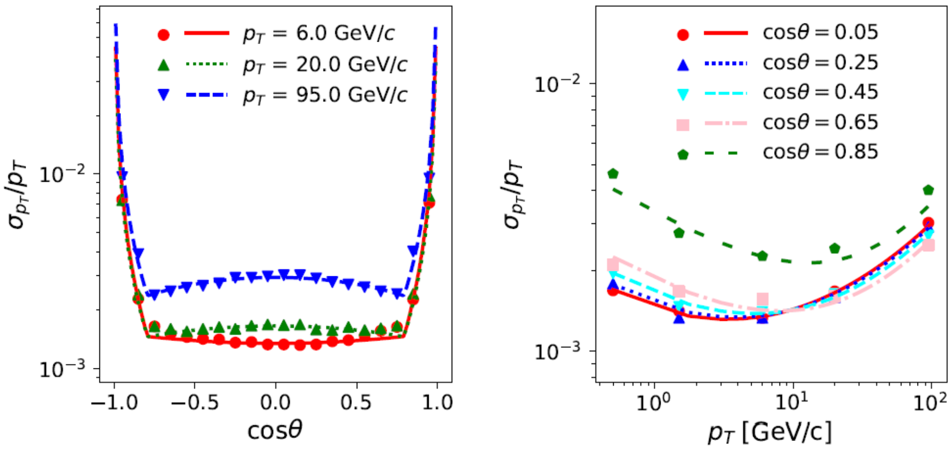
Track p_T resolution parameterization

- Taking account into the dependency on the p_T and the remaining dependency on the polar angle
- Parameters determined from the full simulation data at baseline detector

$$\sigma_{p_T}/p_T = \frac{r^{-2}}{R_0^{-2}}(c_0 + c_1 \cos^2\theta),$$

$$\ln c_0 = a_0 + b_0 \ln p_T + d_0 \ln^2 p_T,$$

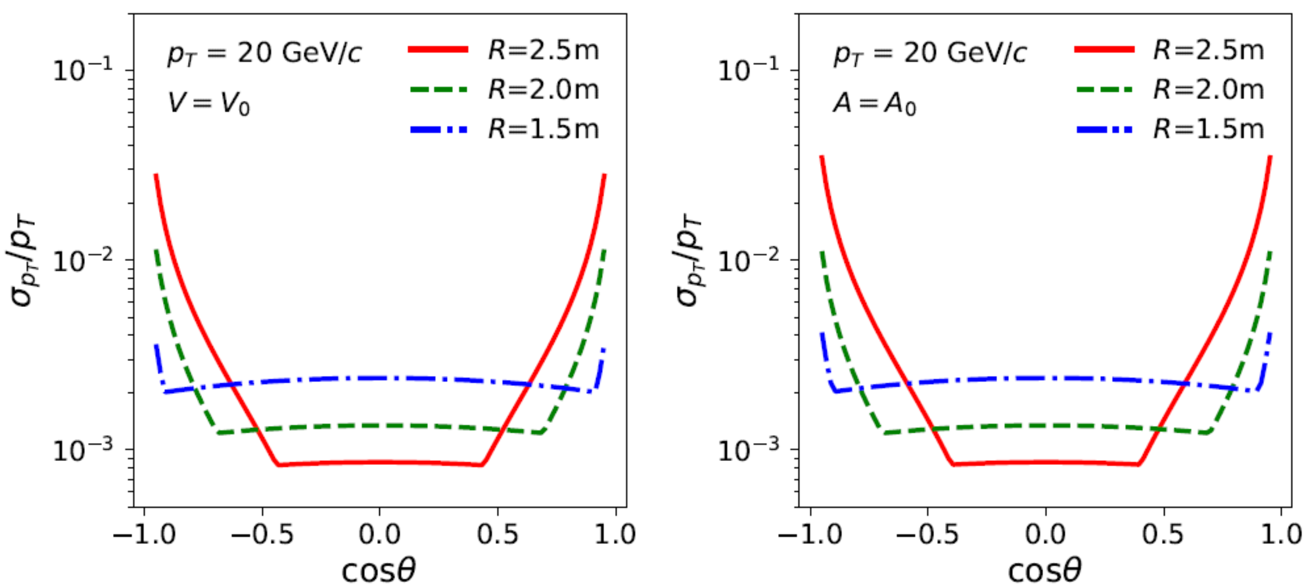
$$c_1 = a_1 + b_1 \ln p_T + d_1 \ln^2 p_T.$$



(a) (b)

Optimal R/Z of the Tracker for the Track

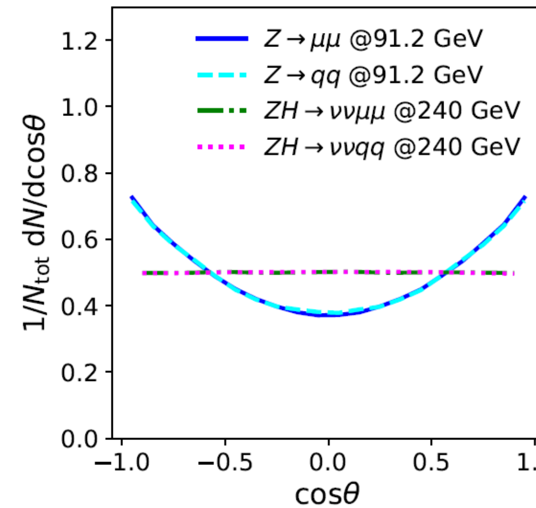
- Formula employed to general R and Z
- Fix cost
  - Larger R/Smaller Z → better performance at the barrel, worse performance at the end-cap
  - Optimal R/Z should balance performance at barrel and end-cap

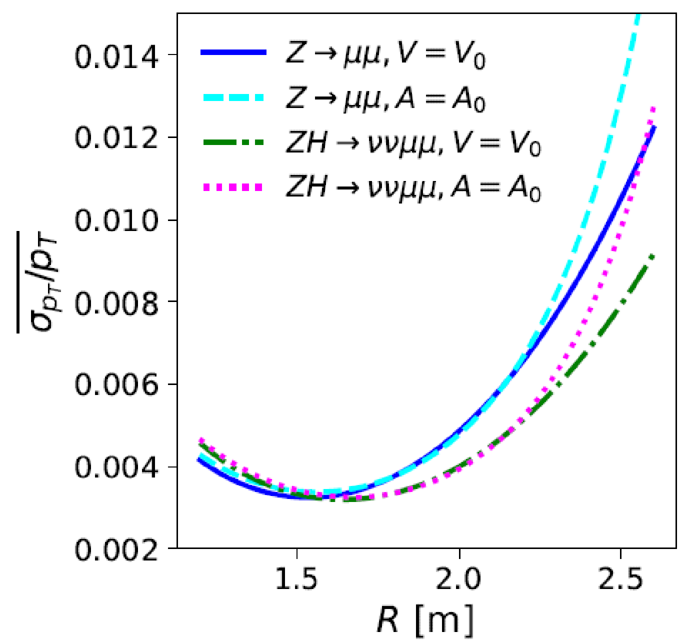


(a) (b)

Optimal R/Z of the Tracker for the Track

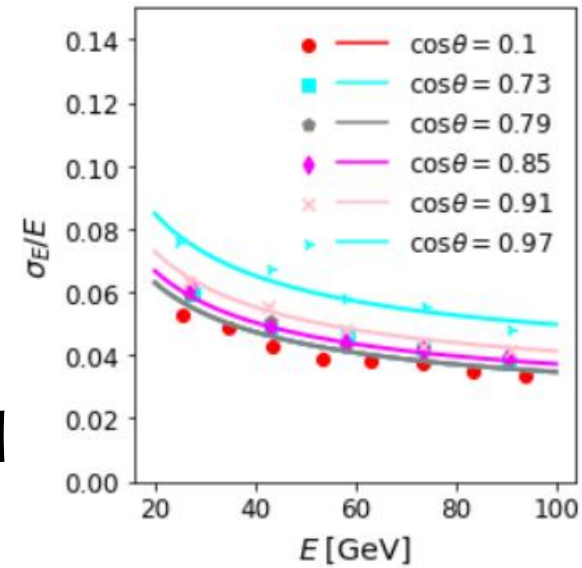
- Average over kinematic phase space (p_T,θ) weighted by objects distribution
  - $|\cos\theta| < 0.99$
  - Benchmark channels
    - $Z \to \mu\mu$ @91GeV
    - $\nu\nu H \to \nu\nu H(\mu\mu)$ @ 240GeV
- Optimal R/Z obtained
  - Optimal R/Z on Zpole < the one for Higgs Run
  - Fixing volume or surface area result in similar results





Jet energy resolution (JER) parameterization

- Similar parameterization strategy adopt to jet
- What influence the accuracy with FPA
    - The p_T resolution of the track
    - Track and neutral particles separation
- $\mathrm{JER} = \sqrt{b_1(E) + \frac{b_2(E)}{r+b_3}}$
    - $b_i(E) = c + \frac{d_i}{E}, i = 1,2$
- Parameters in the formula extracted from full simulation data at baseline



Optimal R/Z of the Tracker for the Jet

- Formula employed to general R and Z
- Fix cost
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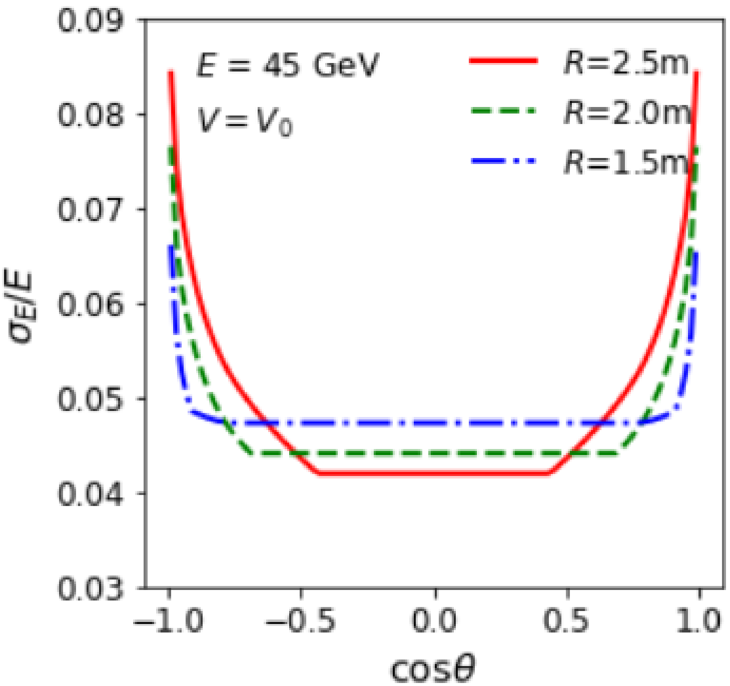
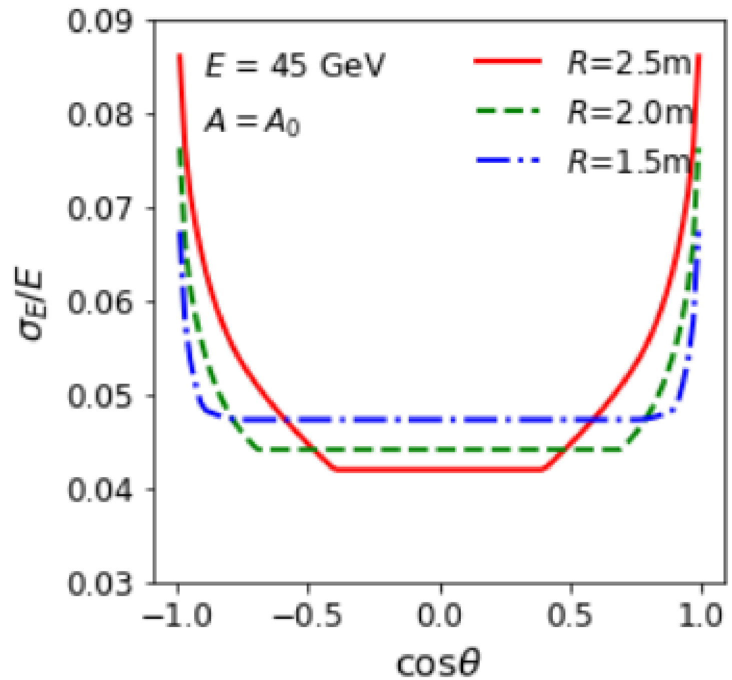
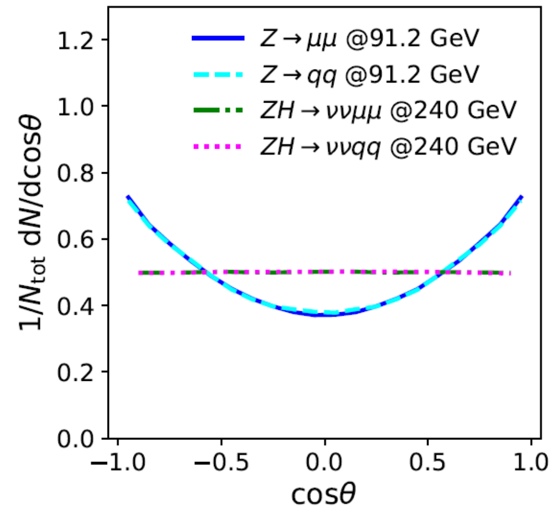
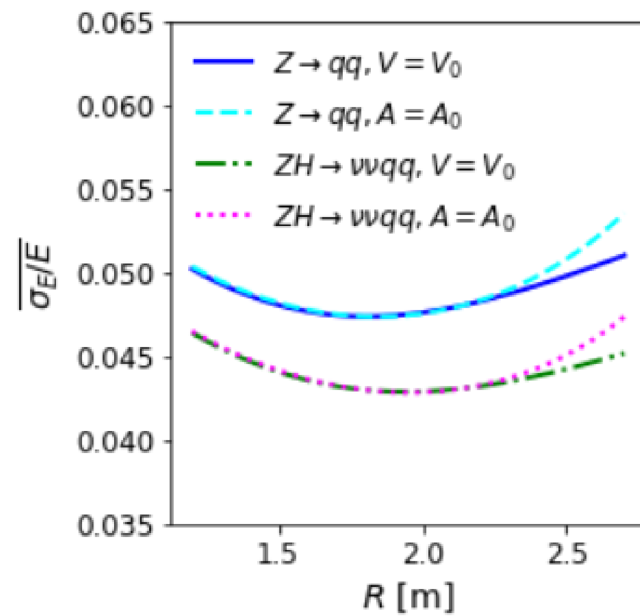




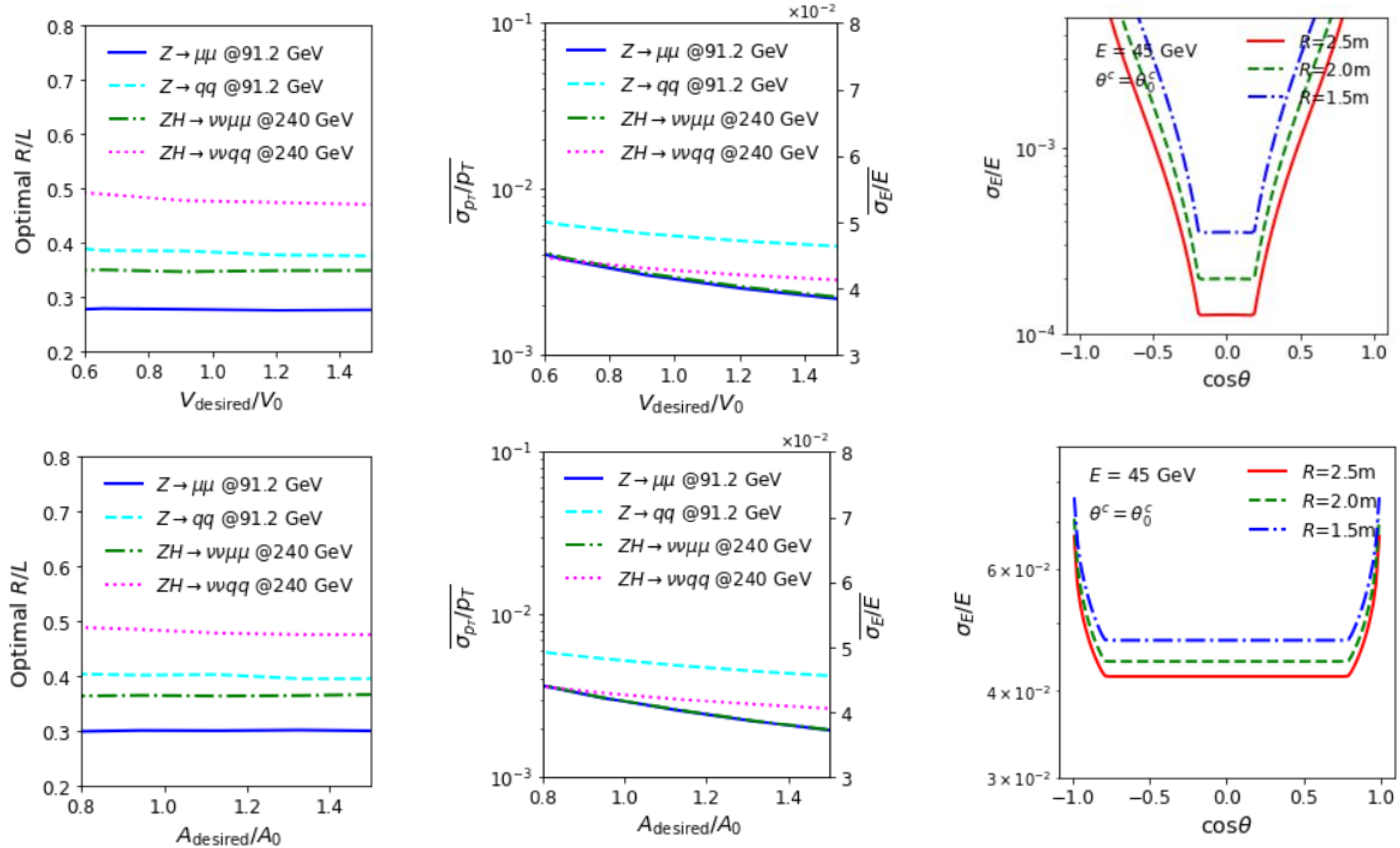
Optimal R/Z of the Tracker for the Jet

- Average over kinematic phase space (E, θ) weighted by objects distribution
  - Benchmark channels
    - $Z \rightarrow qq$ @91GeV
    - $\nu\nu H \rightarrow \nu\nu H(qq)$ @ 240GeV
- Optimal R/Z obtained
  - Optimal R/Z on Zpole < the one for Higgs Run
  - Fixing volume or surface area result in similar results





Changing the cost



Summary

- Optimal R/Z/(R/Z)

Physics process	Constraint	Optimal R (m)	Optimal L (m)	Optimal R/L	Yielded resolutions (%)
$Z \to \mu\mu$	volume of TPC	1.62	5.80	0.279	0.285
$\sqrt{s} = 91$ GeV	surface area of TPC	1.65	5.59	0.295	0.292
$ZH \to \nu\nu\mu\mu$	volume of TPC	1.74	5.03	0.346	0.292
$\sqrt{s} = 240$ GeV	surface area of TPC	1.77	4.86	0.364	0.294
$Z \to qq$	volume of TPC	1.81	4.65	0.389	4.73
$\sqrt{s} = 91$ GeV	surface area of TPC	1.84	4.50	0.409	4.73
$ZH \to \nu\nu qq$	volume of TPC	1.94	4.05	0.479	4.28
$\sqrt{s} = 240$ GeV	surface area of TPC	1.95	4.00	0.487	4.28

  - Benchmark nn Z-pole channel prefer smaller radius
  - Jets prefer larger radius than tracks
- Provide the understanding of how the shape/sizes of detector affect the track and the jet performance