Reconstruction of tau using TAURUS on CEPC

Speaker: Chuyi Kong

Achknowlodgement: Manqi Ruan

Young Scientist Forum, YangZhou, 2021.4.16

Content

Motivation

Introduction of TAURUS

Software and samples

Implementation on different channels

Conslusion

Why tau finding?

- Channels containing tau could be a sensitive probe to new physics.
- Example:

$\mathrm{H} \rightarrow \tau\tau$, τ plays a crucial role in searching SM Higgs bosons.

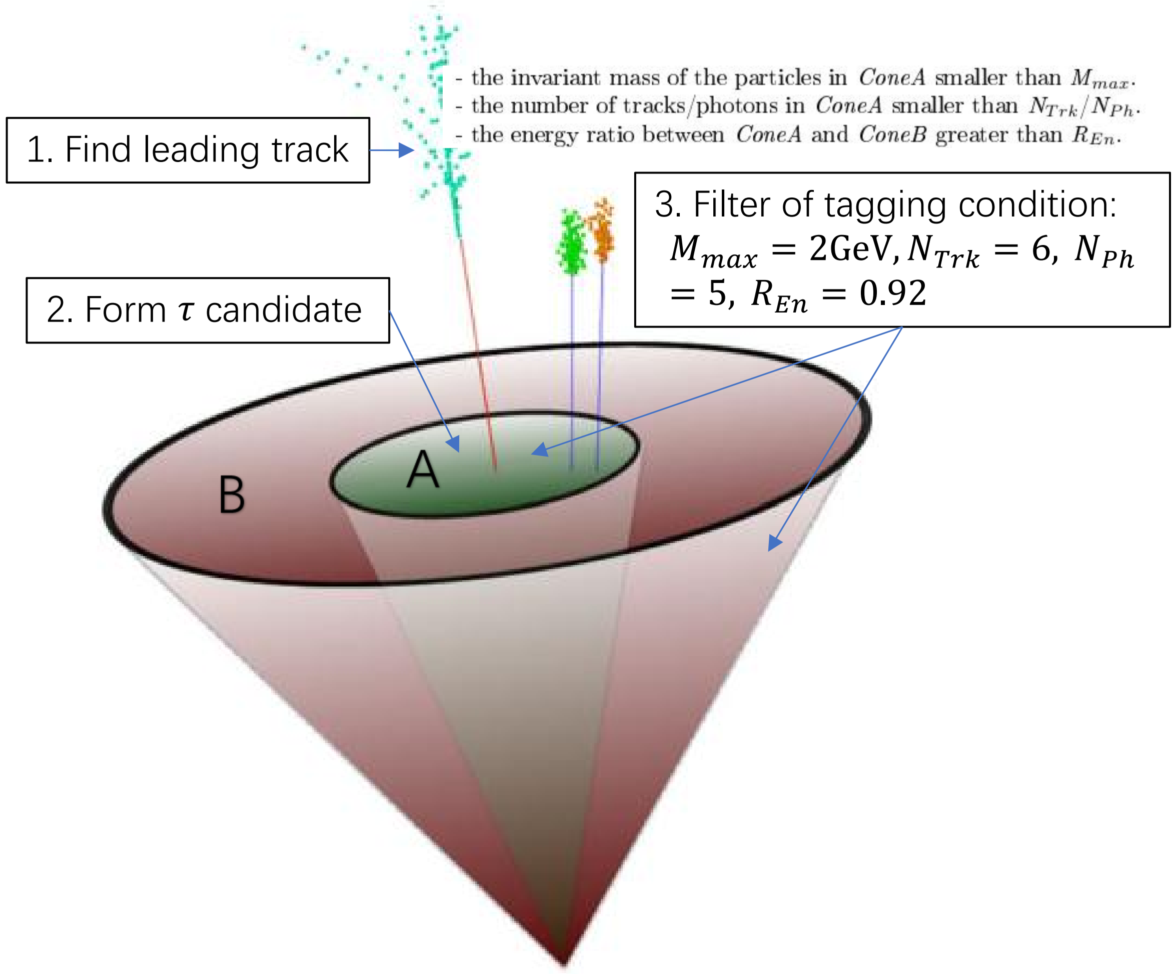
$\mathrm{WW} \rightarrow \tau\upsilon qq$, τ reconstruction is necessary for the measurement of Higgs total width using WW mode.

τ also presents in various B meson decay channels, B_c mesons for instance provides opportunity to discover dark matter candidates

- In CEPC, a good performance is expected.

Algorithm of TAURUS

- Double-cone based algorithm
- Sensitive parameter: Outer cone & Inner cone
- Parameter settings are optimized along with energy for different physics process



Double cone based τ finding algorithm in a $\tau \to \pi^- \pi^0$ event

Yu, D., Ruan, M., Boudry, V. *et al.* The measurement of the H→ττH→ττ signal strength in the future e+e−e+e− Higgs factories . *Eur. Phys. J. C* **80,** 7 (2020).

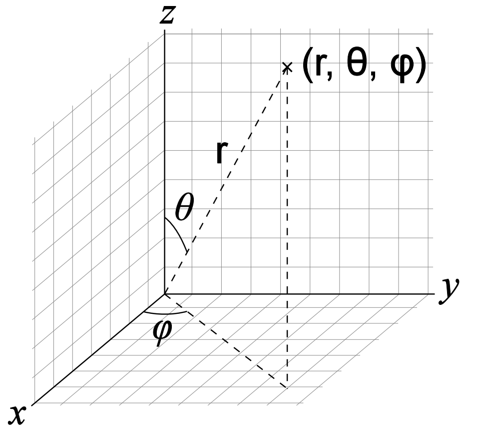
Implementation

Channel	$\mathbf{H \to \tau\tau}$	$\mathbf{WW \to \tau\upsilon qq}$	$\mathbf{B_C \to \tau\upsilon}$	$\mathbf{B_S \to \tau\tau}$
Event Number	18000	19000	17400	19500

- Detector model: CEPC baseline detector
- The reconstruction starts from ArborPFO final state particles.(Hadronic decay:$\pi^+, \pi^-, \pi^0 \to \gamma\gamma$ Leptonic decay: e, μ)
- Tau is tagged with visible energy and momentum reconstructed. The information can be used for further analyses.

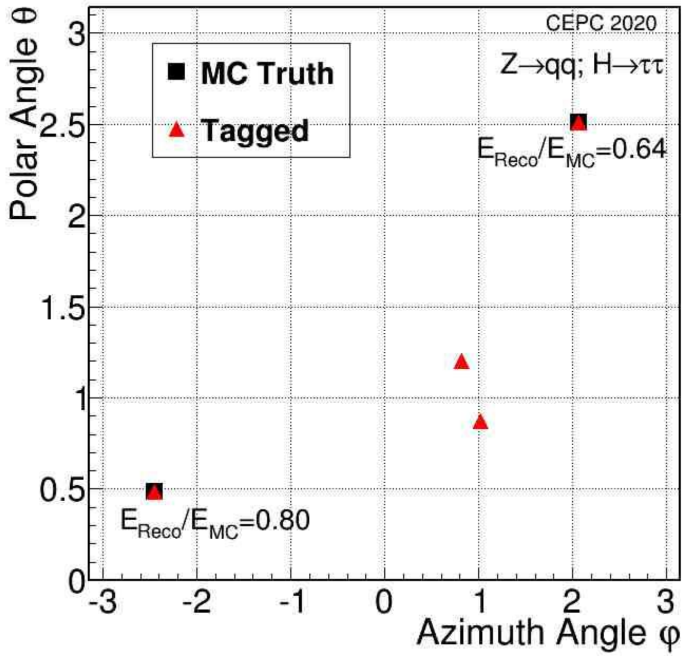
Higgs Channel-Event Display

- Efficiency: $\frac{\text{Number of tagged truth tau}}{\text{Number of truth tau}}$
- Purity: $\frac{\text{Number of tagged truth tau}}{\text{Number of tagged tau}}$



Success

- Efficiency=1,Purity=1

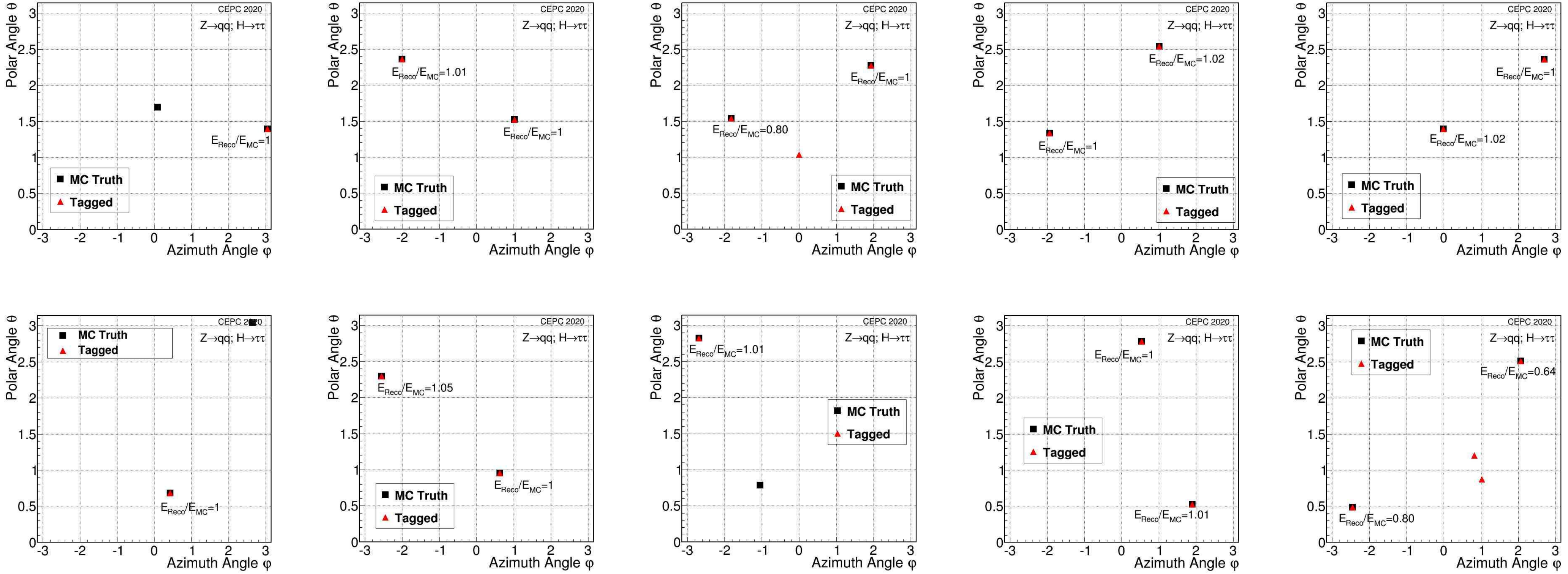


Failure-Misidentification

- Efficiency=1,Purity=0.5

Failure-Loss

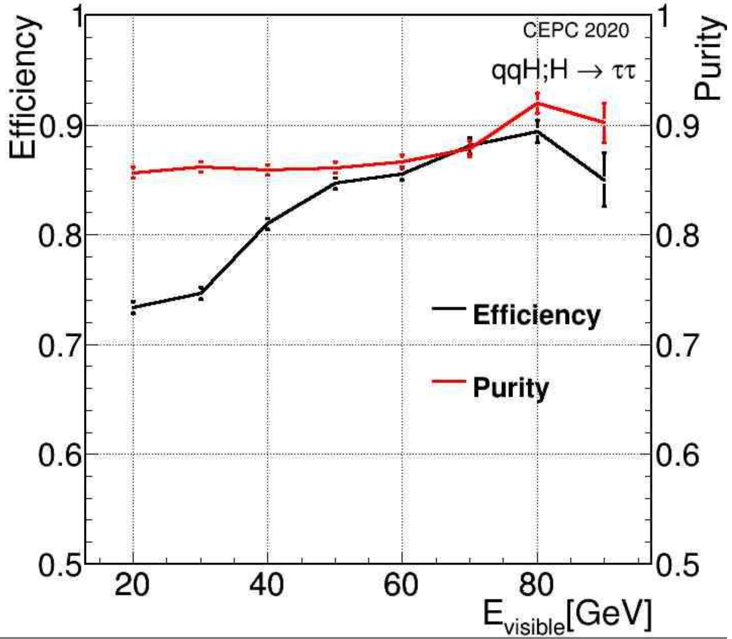
- Efficiency=0.5,Purity=1



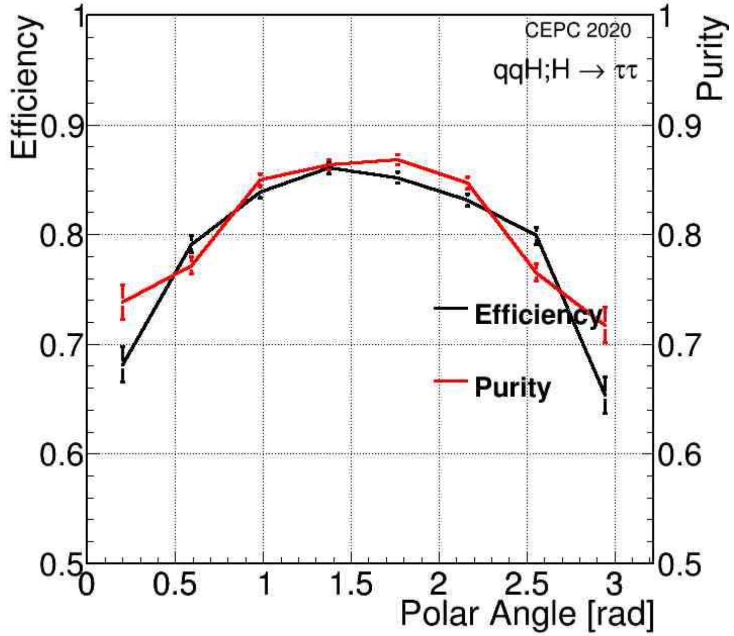
Higgs Channel-Event Display

Higgs Channel-Performance

- Overall efficiency/purity: 0.80/0.86
- Performance over energy: Parameters are optimized to reach a maximum $\mathbf{Efficiency} \times \mathbf{Purity}$
- Performance over polar angle: Fixed parameters are used, to be optimized in future



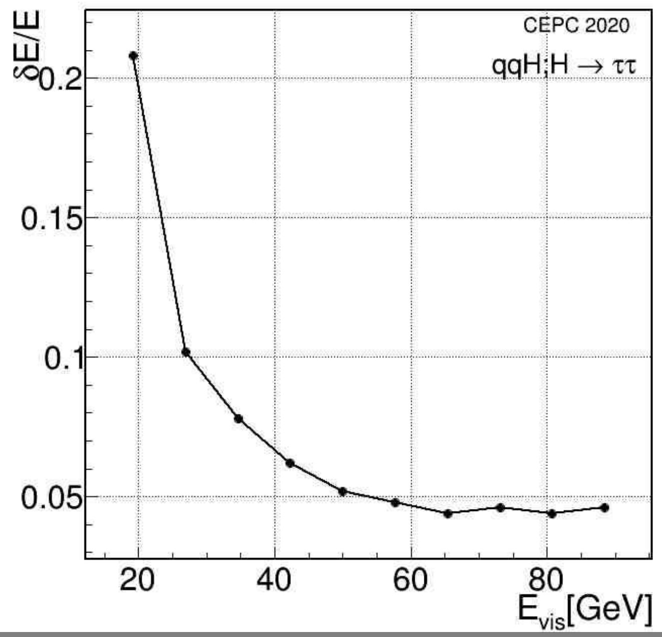
Performance over energy, optimized



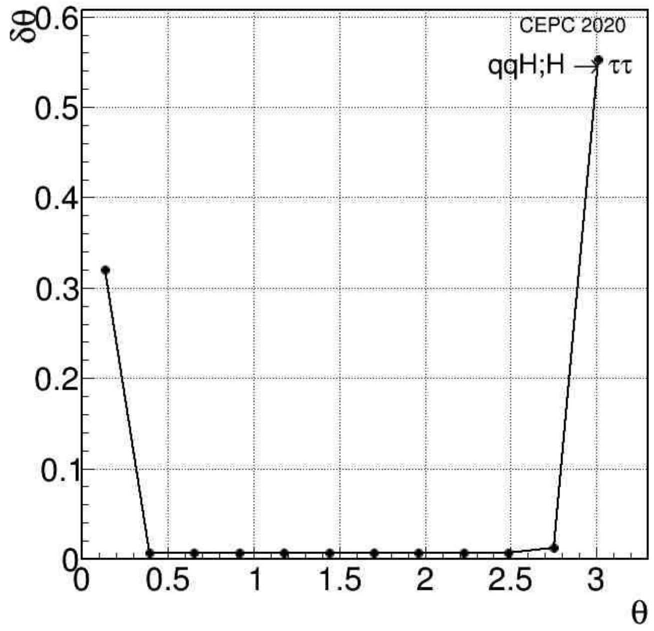
Performance over polar angle

Higgs Channel-Resolution

- Overall energy resolution: 0.09. Performance limited in low energy range
- Overall polar angle resolution: 0.01 Performance limited in endcap region
- Energy and polar angle are sliced into equal intervals, $\delta E/E$ and $\delta\theta$ is the 1-sigma peak width of each interval.



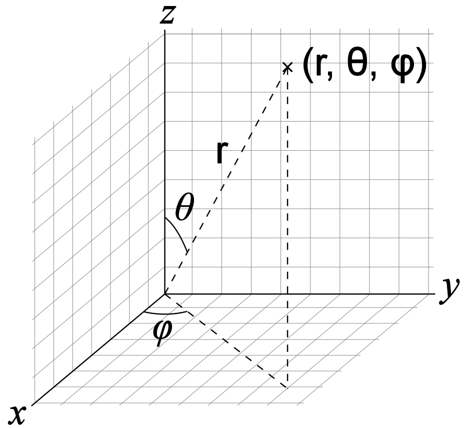
Resolution of energy

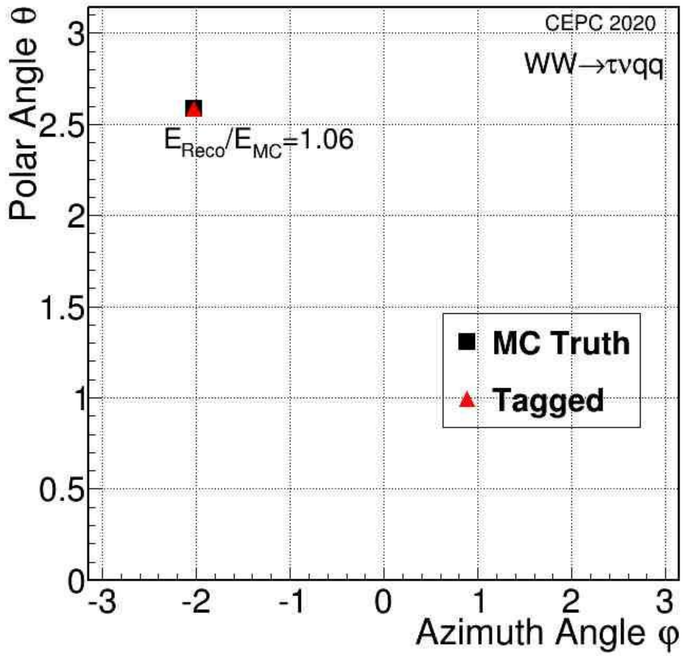


Resolution of polar angle

$WW \rightarrow \tau\upsilon qq$ -Event Display

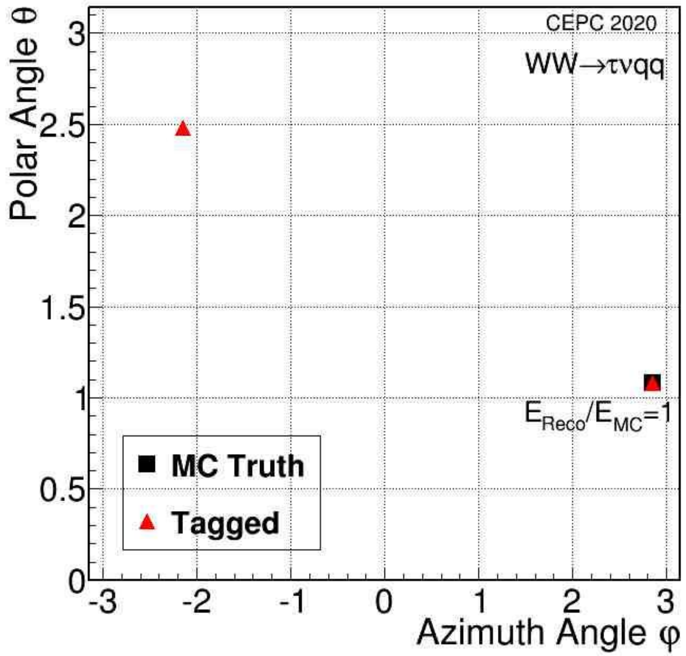
- Efficiency: $\frac{\text{Number of tagged MC particles}}{\text{Number of MC particles}}$
- Purity: $\frac{\text{Number of tagged MC particles}}{\text{Number of tagged particles}}$





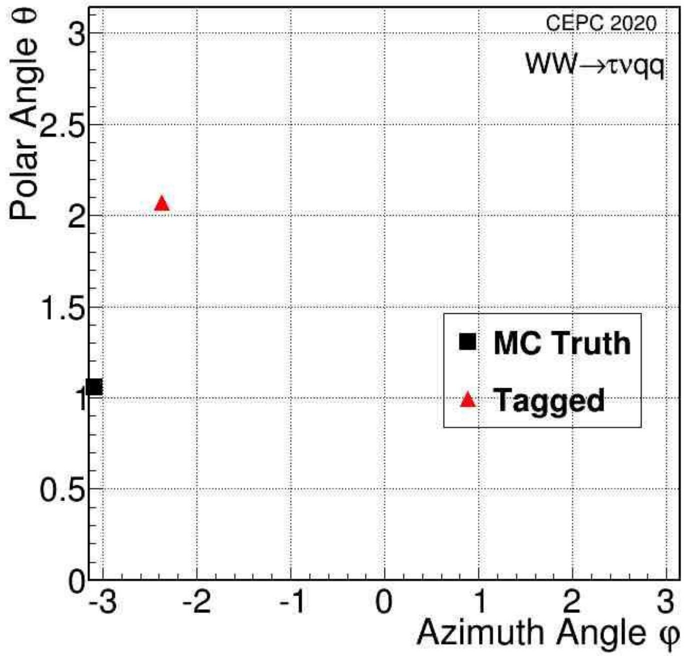
Success

- Efficiency=1,Purity=1



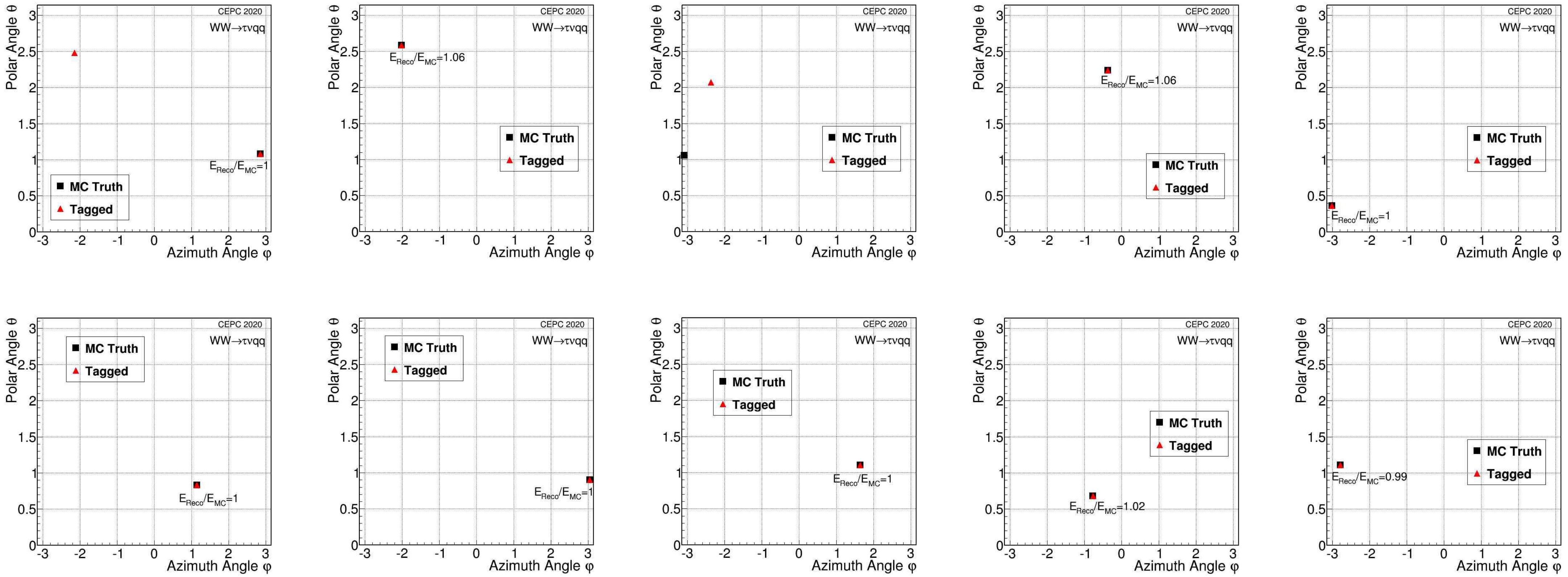
Failure-Misidentification

- Efficiency=1,Purity=0.5



Failure-Loss

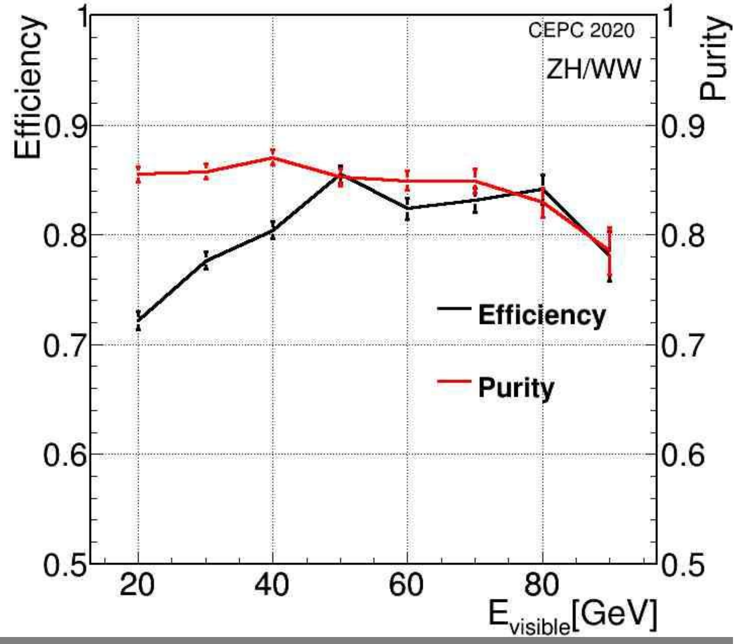
- Efficiency=0,Purity=0



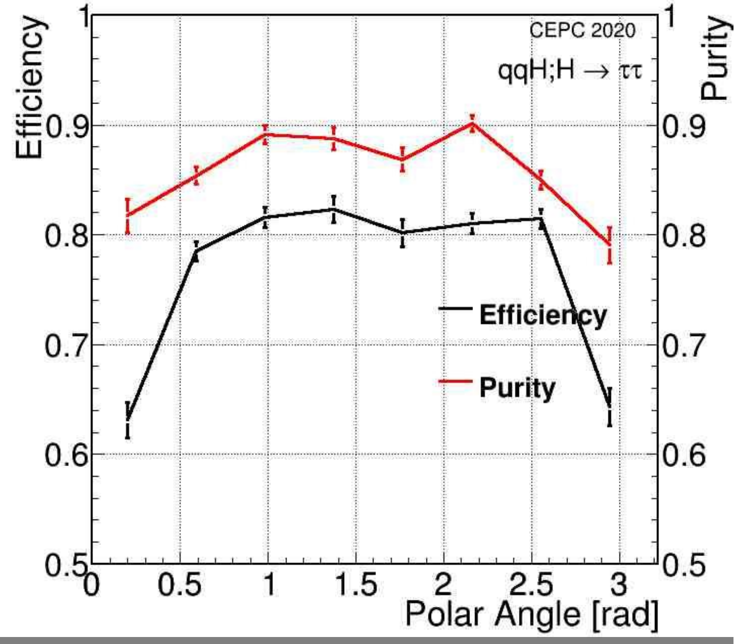
$WW \rightarrow \tau\upsilon qq$ -Event Display

$WW \rightarrow \tau\upsilon qq$- Performance

- Overall efficiency: 0.79
- Overall purity: 0.85



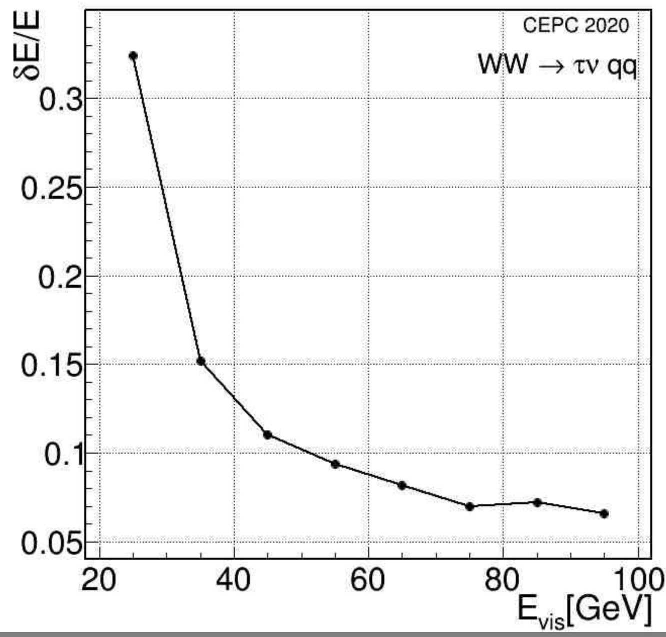
Performance over energy, optimized



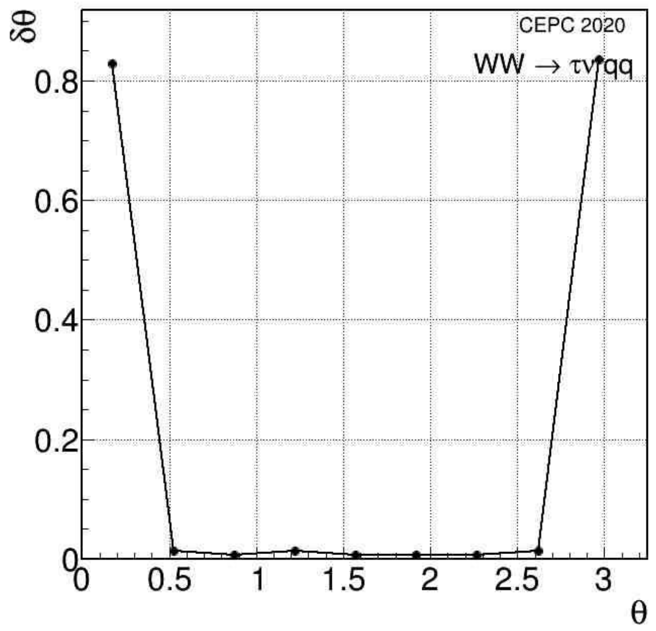
Performance over polar angle

WW Channel-Resolution

- Overall energy resolution: 0.14
- Overall polar angle resolution: 0.01
- Limited performance in low energy range and endcap section



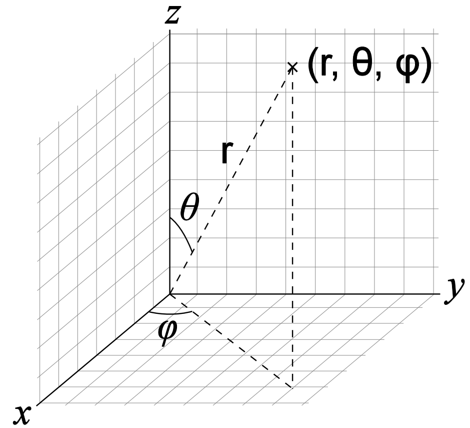
Resolution of energy

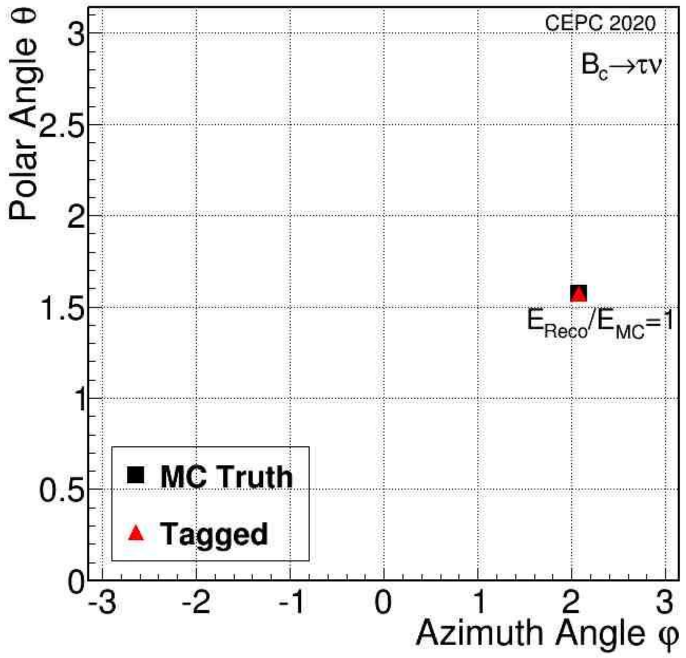


Resolution of polar angle

B_c Channel-Event Display

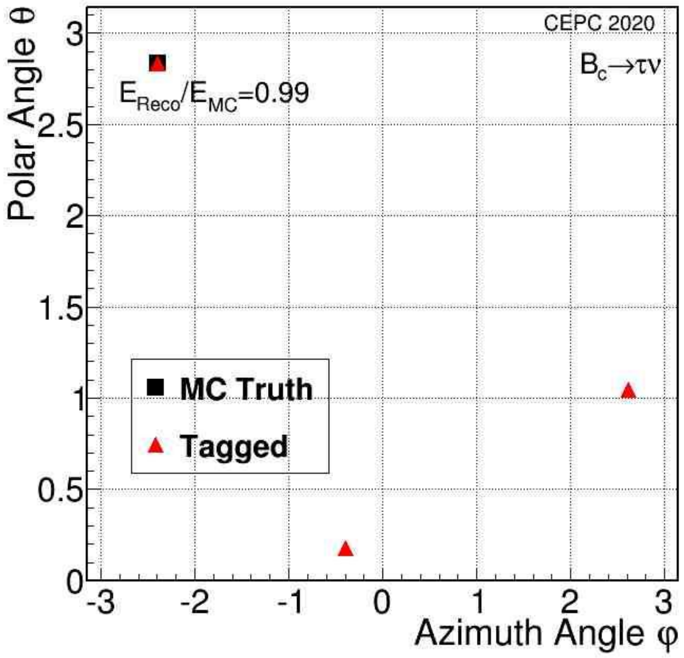
- Efficiency: $\frac{\text{Number of tagged MC particles}}{\text{Number of MC particles}}$
- Purity: $\frac{\text{Number of tagged MC particles}}{\text{Number of tagged particles}}$





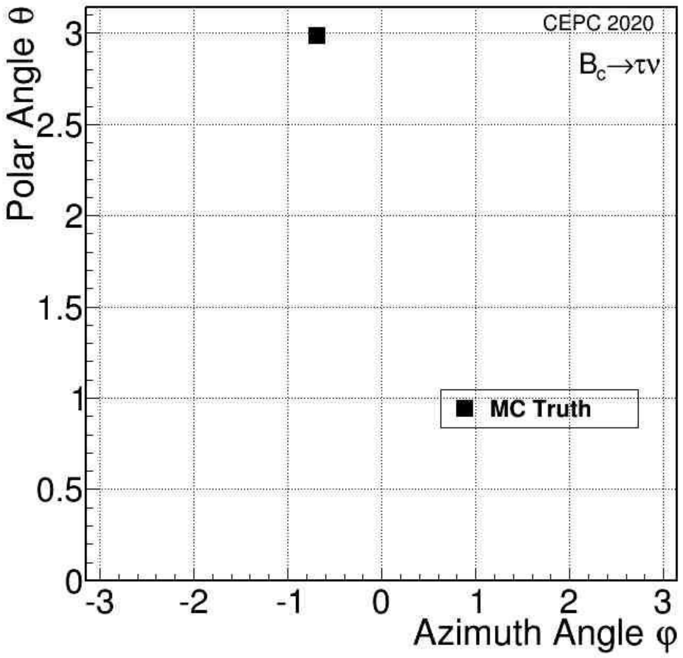
Success

- Efficiency=1,Purity=1



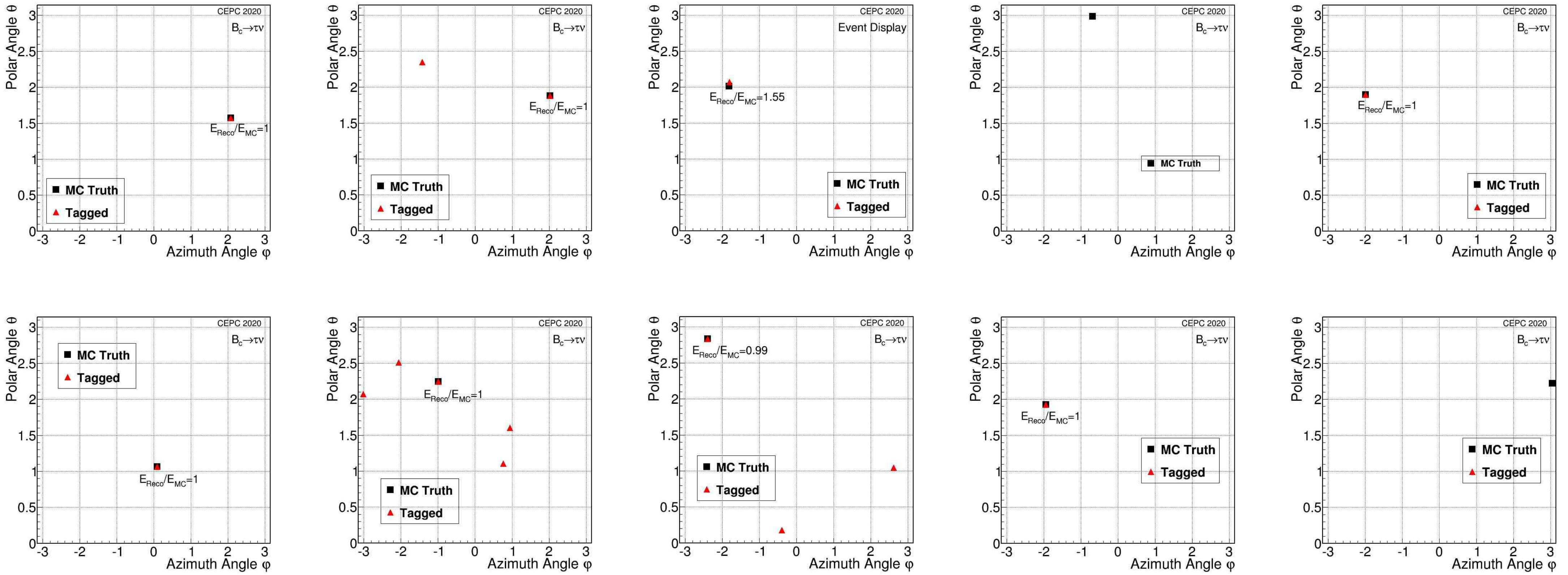
Failure-Misidentification

- Efficiency=1,Purity=0.5



Failure-Loss

- Efficiency=0,Purity=0

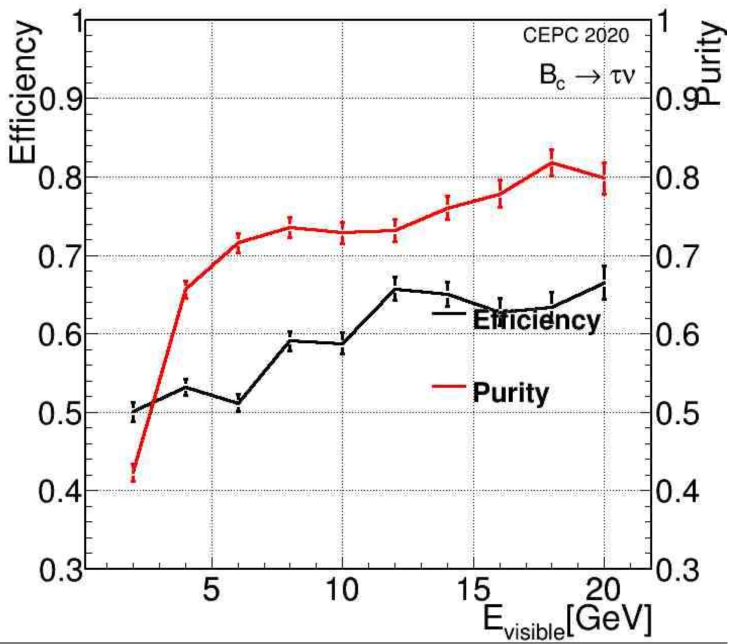


B_c Channel-Event Display

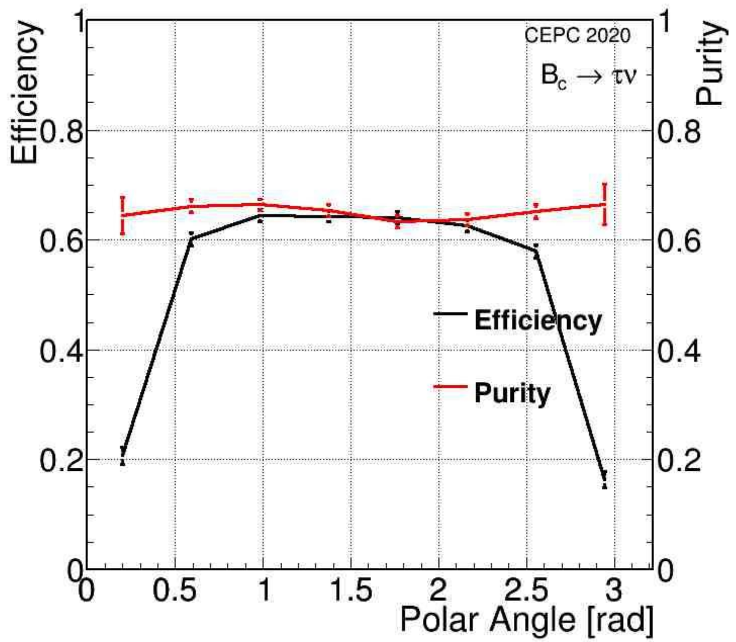
B_C Channel-Performance

- Overall efficiency: 0.57
- Overall purity: 0.67
- Impact parameter cut is used for optimization, IP>1.3

  $IP = log((D_0/\sigma_{D_0})^2 + (Z_0/\sigma_{Z_0})^2)$
- Drastic drop of purity below 5 GeV



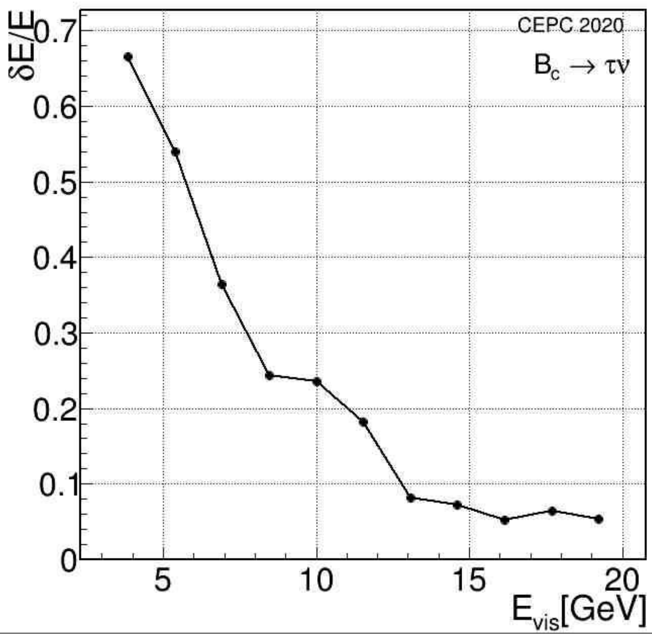
Performance over energy, optimized



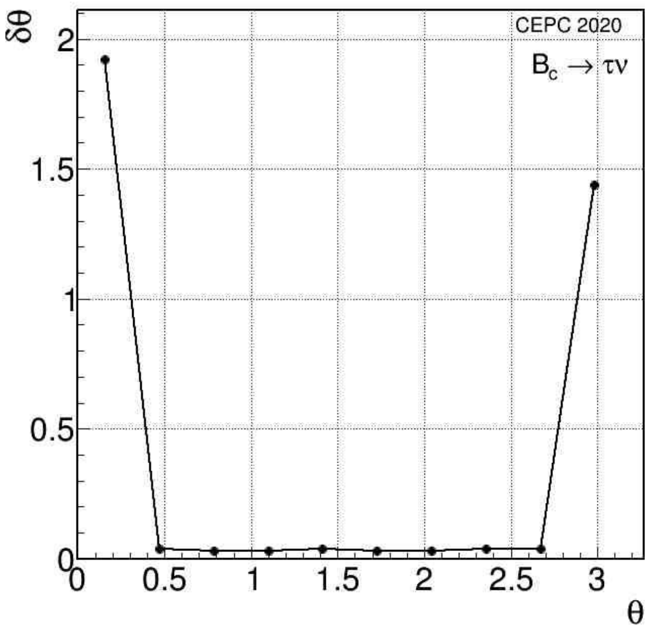
Performance over polar angle

B_c Channel-Resolution

- Overall energy resolution: 0.31
- Overall angle resolution: 0.07



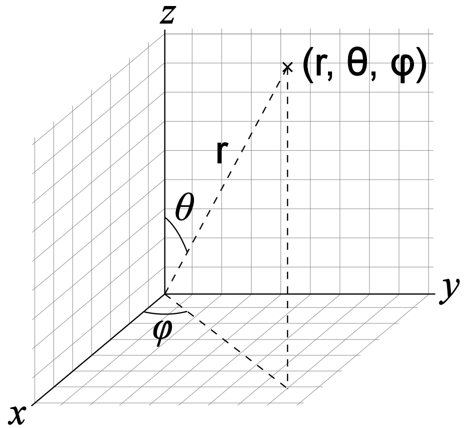
Resolution of energy



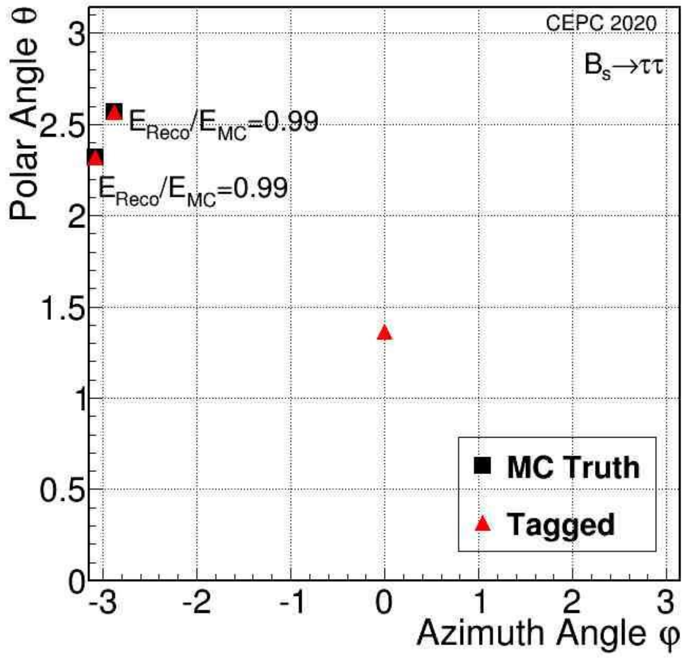
Resolution of polar angle

B_S Channel-Event Display

- Efficiency: $\frac{\text{Number of tagged MC particles}}{\text{Number of MC particles}}$
- Purity: $\frac{\text{Number of tagged MC particles}}{\text{Number of tagged particles}}$

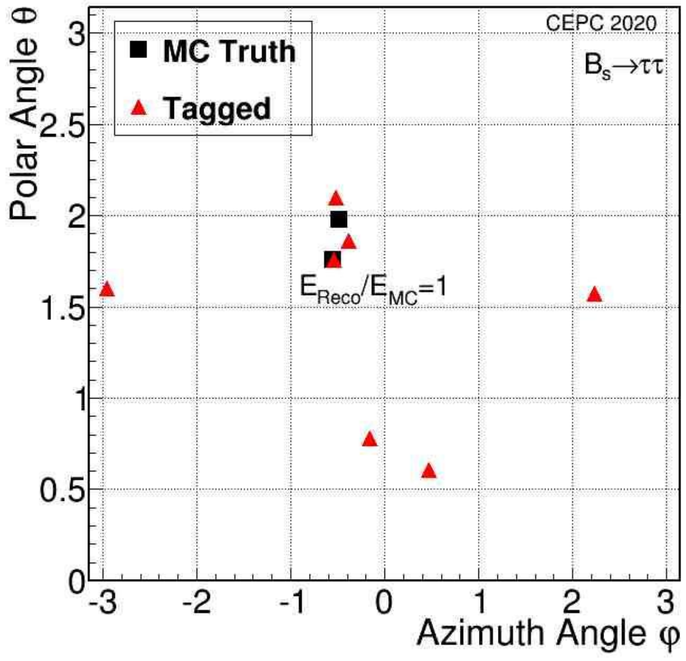


Successful event with exactly two tau leptons tagged&matched is rare.



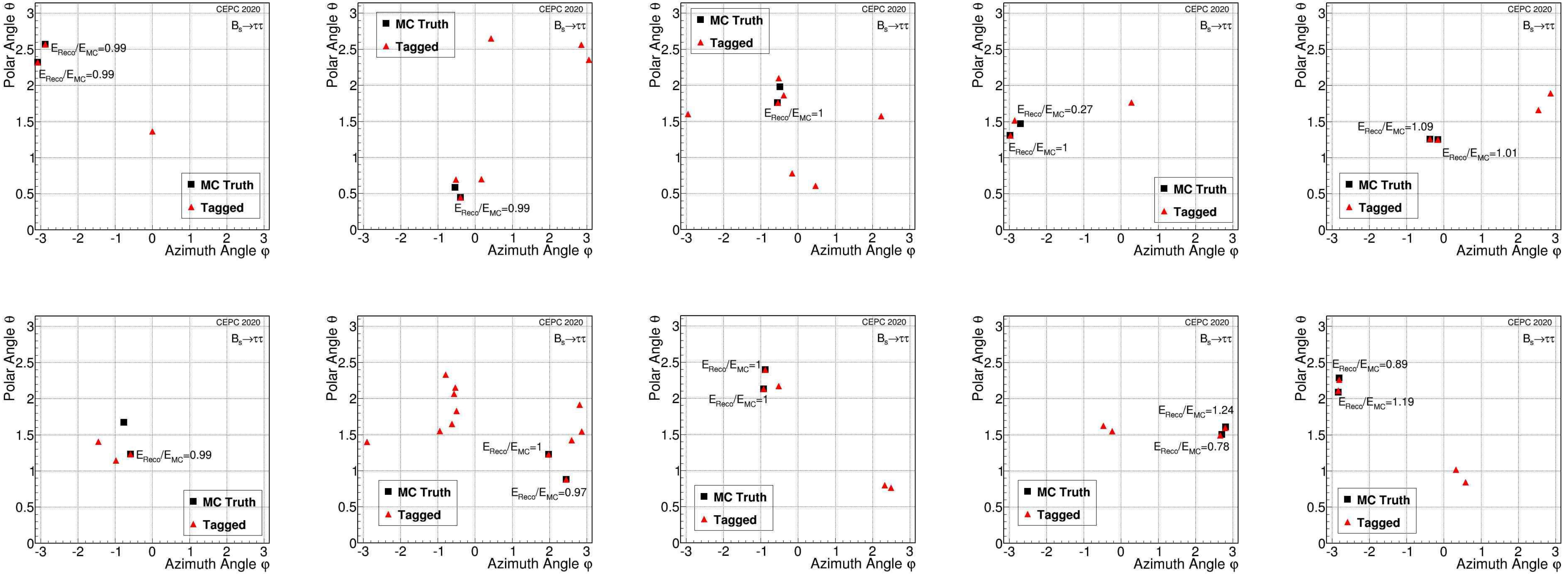
Failure-Misidentification

- Efficiency=1,Purity=0.667



Failure-Loss+Misidentification

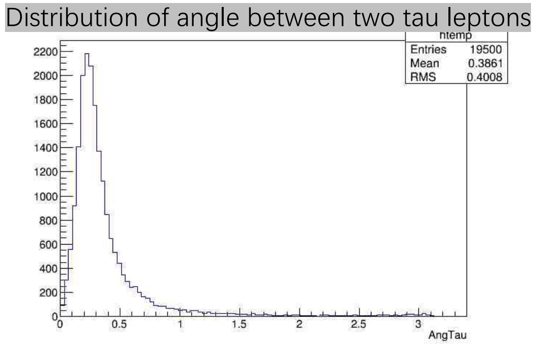
- Efficiency=0.5,Purity=0.143

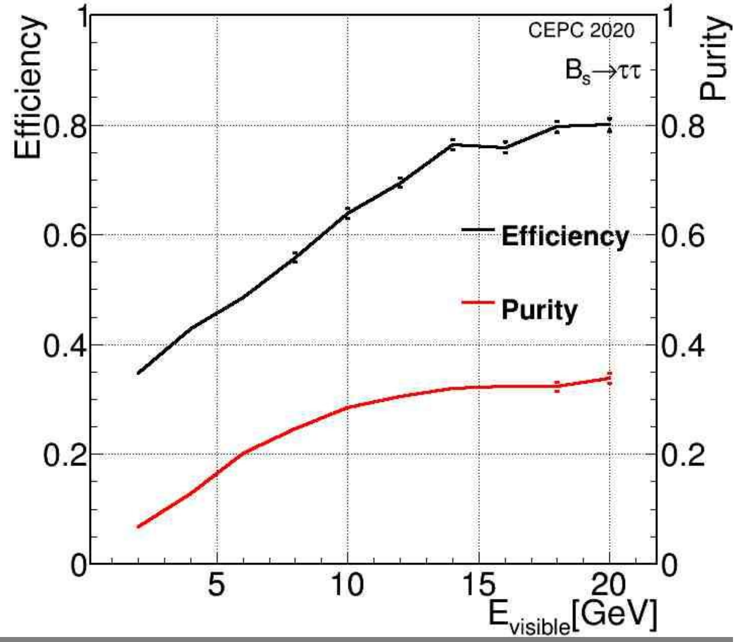


B_s Channel-Event Display

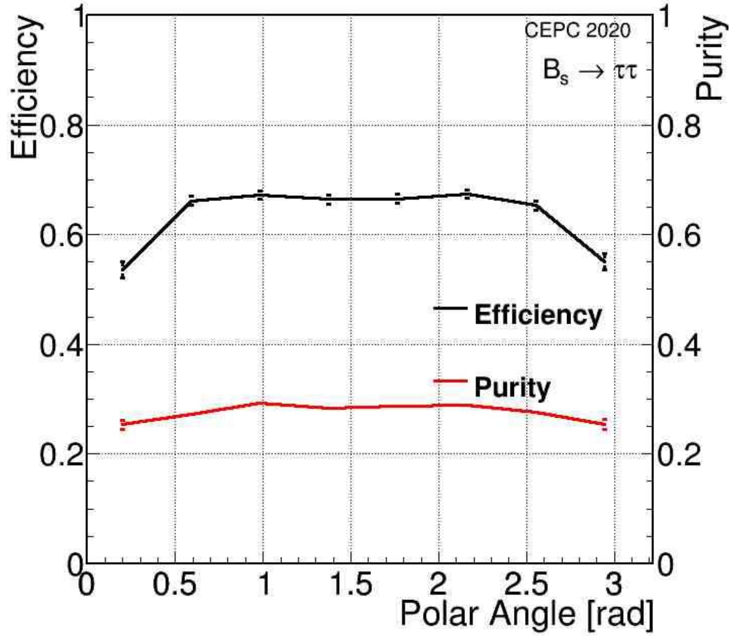
B_S Channel-Performance

- Overall efficiency: 0.55
- Overall purity: 0.18





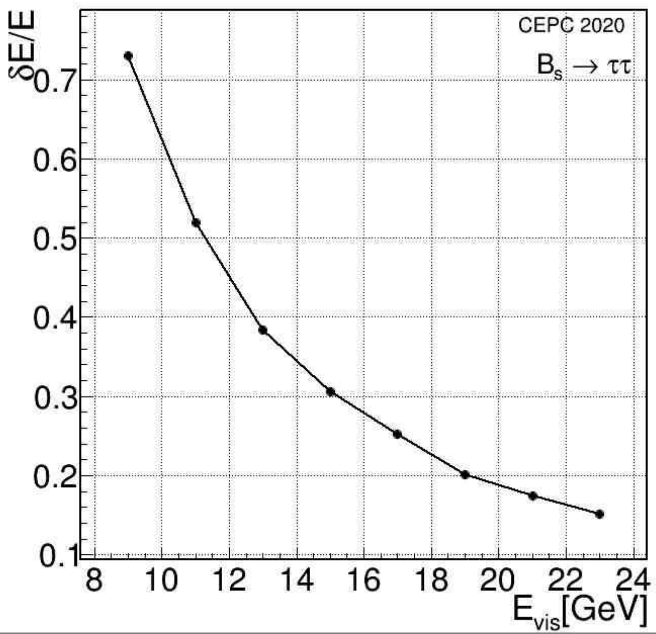
Performance over energy



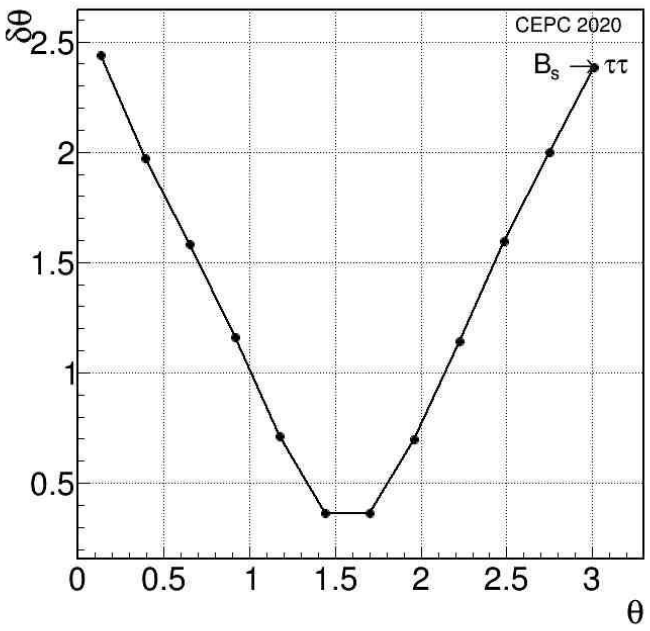
Performance over polar angle

B_S Channel-Resolution

- Overall energy resolution: 0.43
- Polar angle resolution: 1.11
- Double cone based algorithm is not suitable for Bs channel



Resolution of energy



Resolution of polar angle

Conclusion

	Higgs(isolated)	WW(isolated)	Bc(jet)	Bs(jet)
Efficiency	0.80	0.79	0.57	0.55
Purity	0.86	0.85	0.67	0.18
Energy Resolution	0.09	0.14	0.31	/
Polar Angle Resolution	0.01	0.01	0.07	/

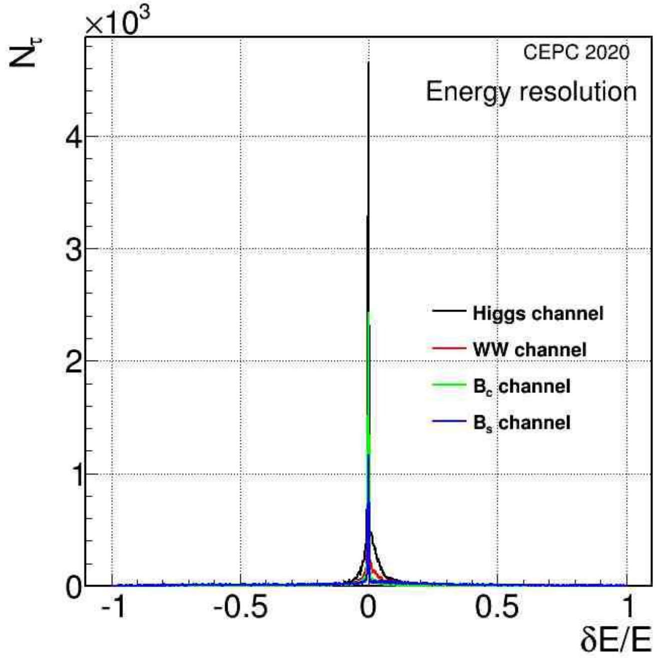
Work for future:

- Develop an optimized parameter set for performance over polar angle.
- PID information of charged particles could be of use for tau of hadronic decay mode
- For tau leptons in jets:
  - Reconstruction of tau leptons of low energy.(Bc)
  - Reconstruction of tau pairs close to each other.(Bs)

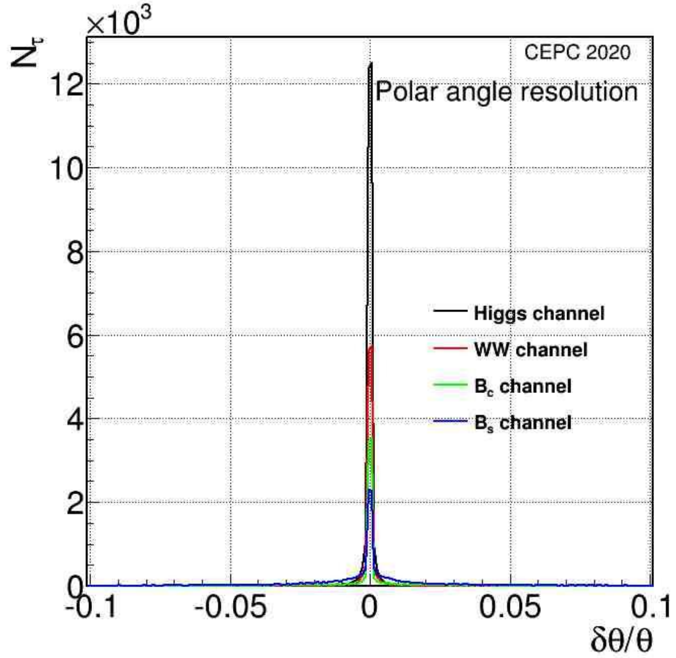
Thank you for the listening!

Backup

Deviation distribution



Energy deviation distribution



Polar angle deviation distribution

Matching Condition

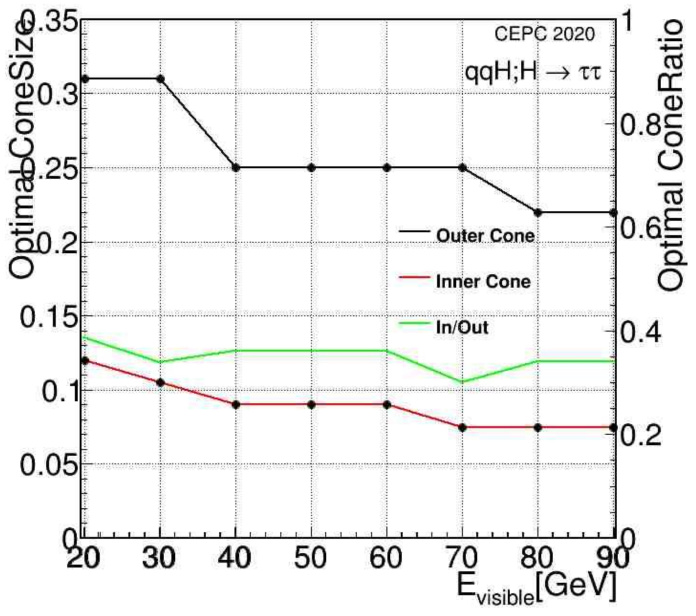
$$DE = \frac{|E_{MC} - E_{Reco}|}{E_{MC} + E_{Reco}}, DR = \arccos \frac{\vec{P_{MC}} \cdot \vec{P_{Reco}}}{|\vec{P_{MC}}||\vec{P_{Reco}}|}$$

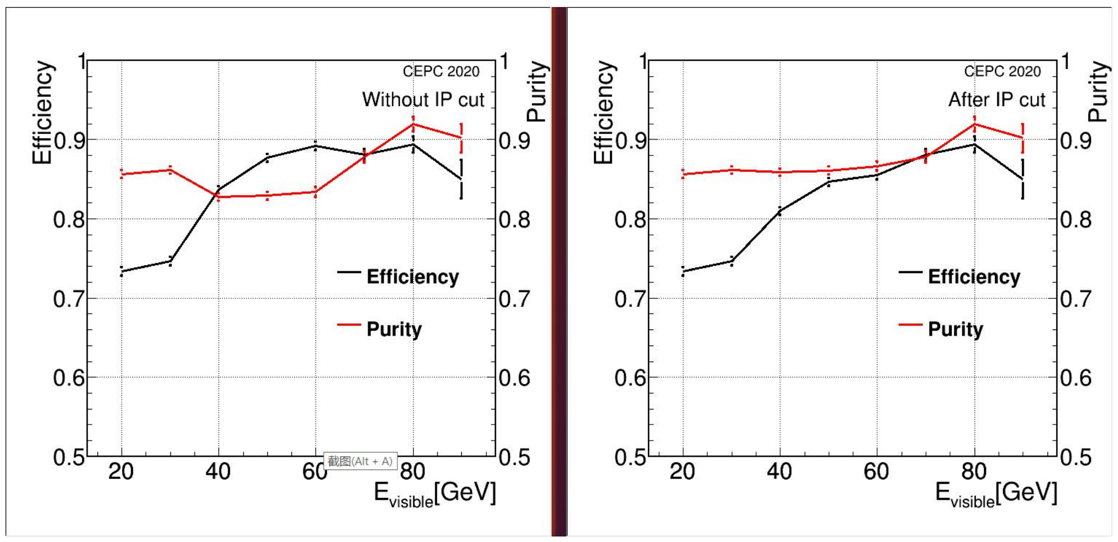
	Higgs Channel	WW Channel	Bc Channel	Bs Channel
Maximum DE	0.2	0.2	0.2	0.2
Maximum DR	0.1	0.1	0.1	0.1

A stricter matching condition is adopted (In comparison with DE<0.8&&DR<0.5 in the plots of previous talks) for optimization.

Optimization, Higgs channel as example

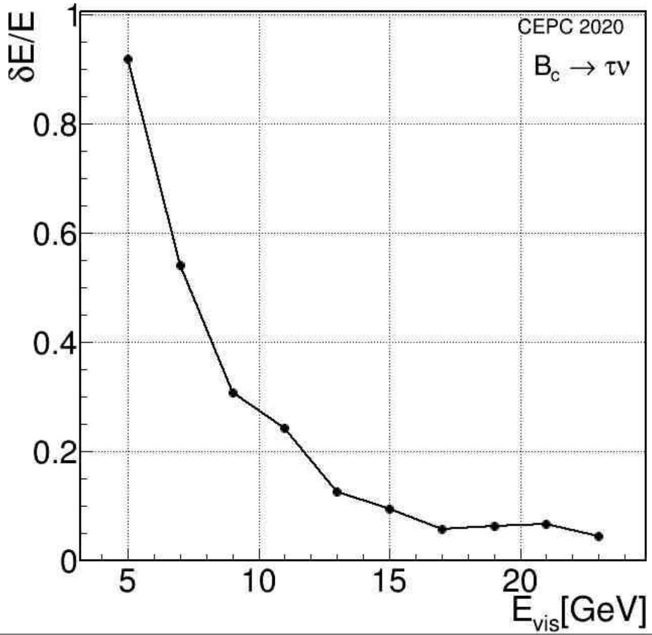
- Parameters sensitive to visible energy: Outer/Inner cone value
- Evaluation: maximal **efficiency × purity**
- Impact parameter cut is also used to ameliorate the purity.



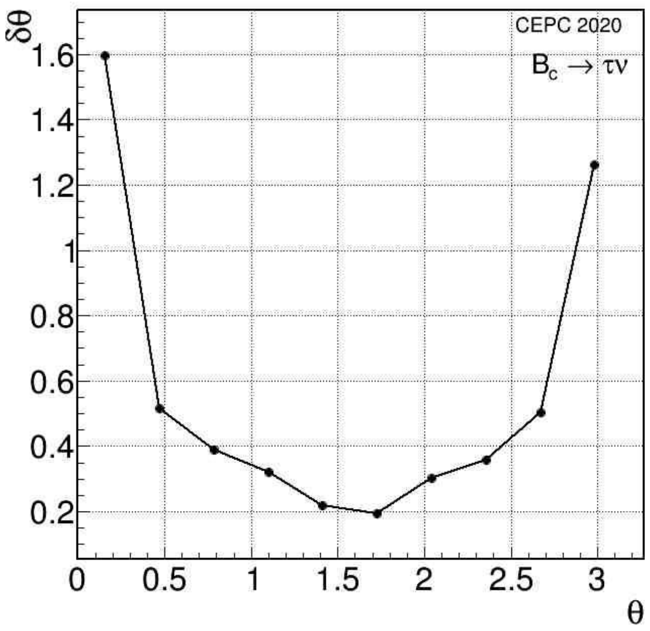


B_C Channel- Resolution, no IP cut

- Without impact parameter cut, the resolution become worse especially for polar angle.



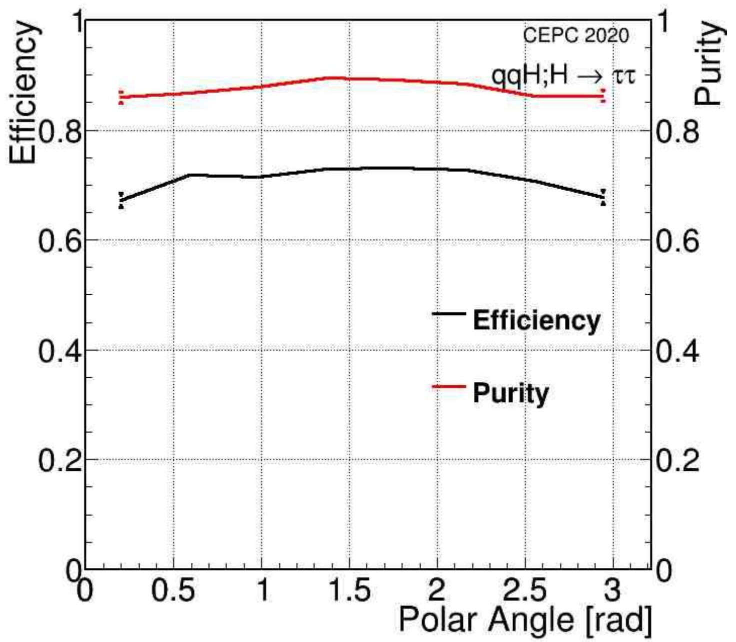
Resolution of energy



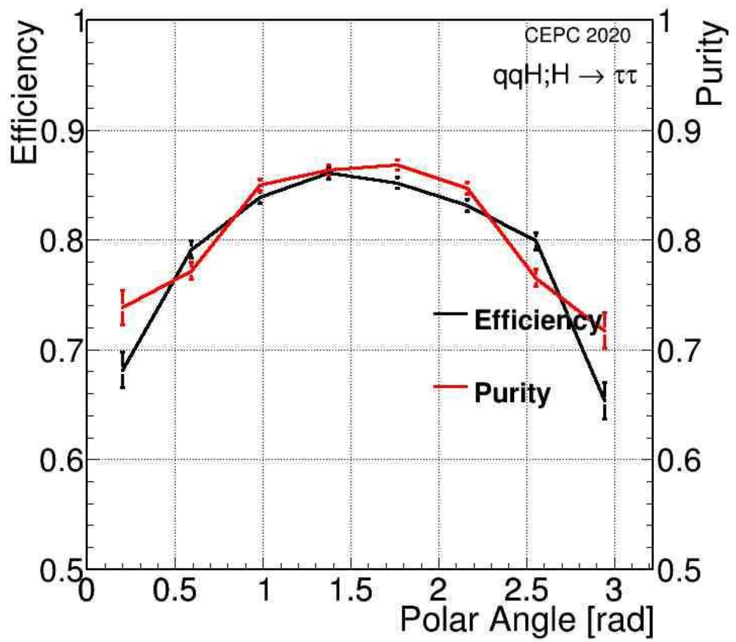
Resolution of polar angle

Factors of endcap drop

- The performance on generator is flat line, indicating that ArborPFO performance in endcap region limits TAURUS performance.



Performance on generator



Performance in full simulation