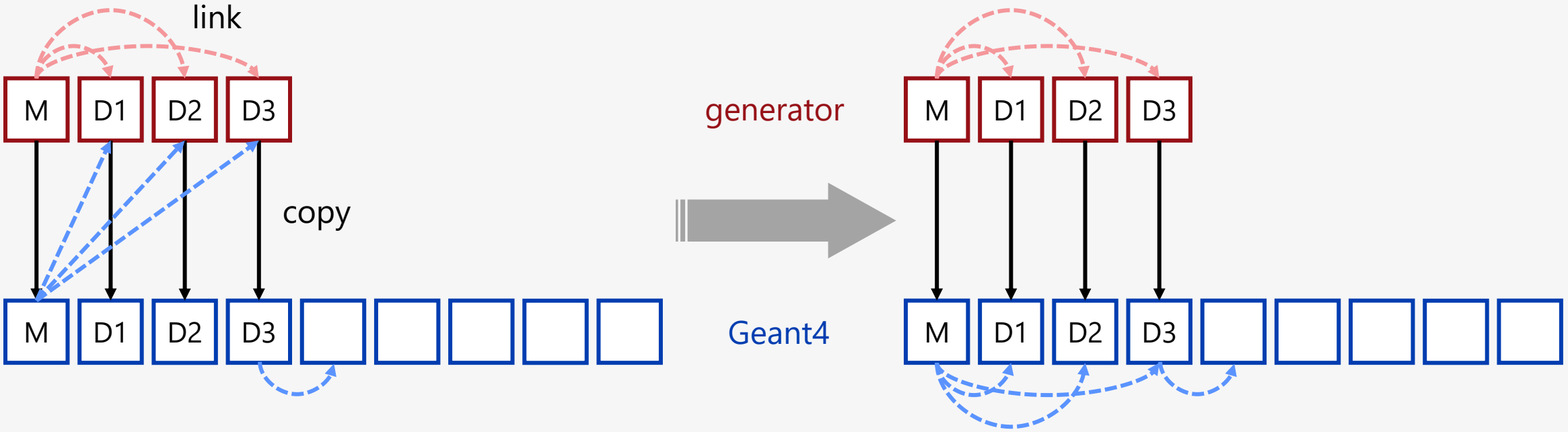
Truth Vertexing at CEPC

Wang Xinzhu, Wu Jingfei, Zhang Chenguang, **Zhu Yifan**

Wang Tao, Huan Yanping

Bug Shooting in Truth Tracing

- Truth tracing in TDR 25.3.2
  - Fix truth particle links when copying from generator to Geant4
  - Secondary particles are linked to parents from generator correctly



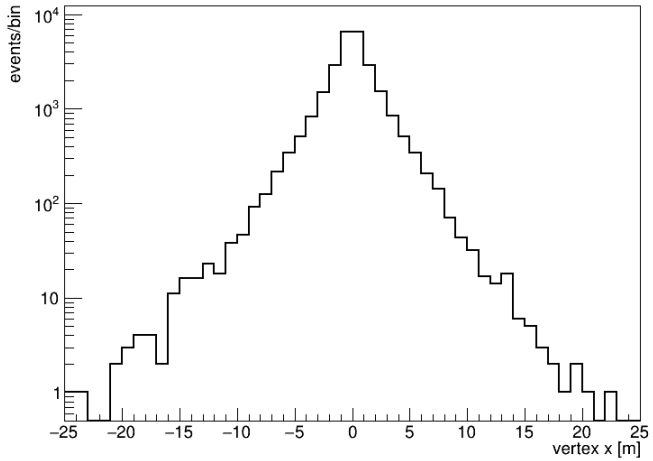
Truth Particle Chain

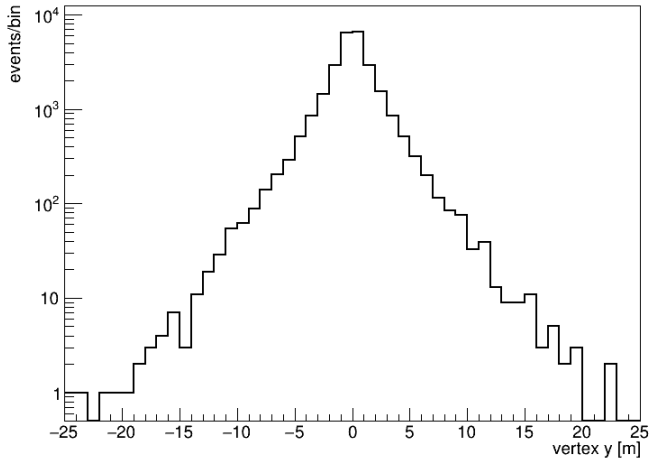
- A truth particle chain tool is available
- Extract truth vertices from a tree structure

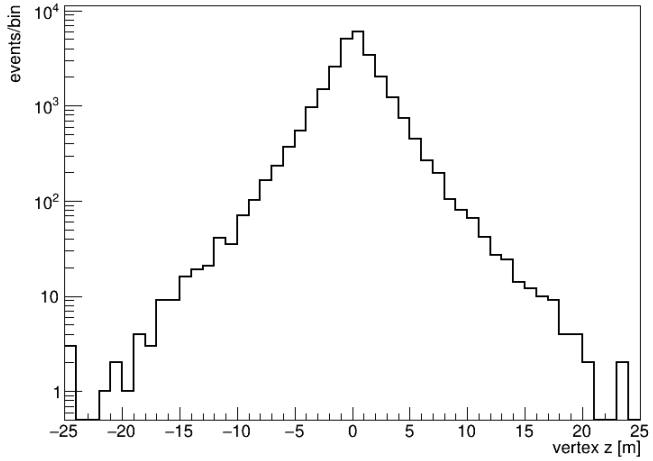
```
    auto select_D0 = [](const edm4hep::MCParticle &mcp){ return mcp.getPDG() == 421 /*D0*/; };
    [[maybe_unused]] auto reject_K  = [](const edm4hep::MCParticle &mcp){ return std::abs(mcp.getPDG()) != 321; };

    TruthChain chains(mcpCols);
    chains.FilterRoot(select_D0); // Select root particles, D0 as an example
    for(const auto &root_index : chains.RootIndexs())
    {
        auto mcp = mcpCols->at(root_index);
        truth_vtx1_x_.push_back(mcp.getVertex().x);
        truth_vtx1_y_.push_back(mcp.getVertex().y);
        truth_vtx1_z_.push_back(mcp.getVertex().z);

/* Depth
 * 0             1              2
 * D0 ----------> K-  ----------> ...
 *          |--> pi+ ----------> ...
 */
        auto vertex_indexs = chains.SelectVertexDepth(root_index, 1); // Get indexes of particles with decay depth 1, For release after TDR 25.3.2
//        auto vertex_indexs = chains.SelectVertexDepth(root_index, 1, reject_K); // Reject particles not interested in, e.g., K
//        auto vertex_indexs = chains.SelectVertexDepth_old(root_index, 1);       // For release before TDR 25.3.2
TruthVertexing       INFO
   |_____ depth: 0 id:  620d57085 genstatus: 2 pdg: 421 vertex: -0.711111 0.0667151 -0.189687  endpoint: -0.716489 0.0676606 -0.190812
          |_____ depth: 1 id:  620d57094 genstatus: 2 pdg: -313 vertex: -0.716489 0.0676606 -0.190812  endpoint: -0.716489 0.0676606 -0.190812
                 |_____ depth: 2 id:  620d570103 genstatus: 2 pdg: -311 vertex: -0.716489 0.0676606 -0.190812  endpoint: -0.716489 0.0676606 -0.190812
                        |_____ depth: 3 id:  620d570107 genstatus: 1 pdg: 130 vertex: -0.716489 0.0676606 -0.190812  endpoint: -2414.61 891.278 -609.028
                 |_____ depth: 2 id:  620d570104 genstatus: 2 pdg: 111 vertex: -0.716489 0.0676606 -0.190812  endpoint: -0.716564 0.0676678 -0.190837
                        |_____ depth: 3 id:  620d570108 genstatus: 1 pdg: 22 vertex: -0.716564 0.0676678 -0.190837  endpoint: -1712 679.005 -278.097
                               |_____ depth: 4 id:  620d570112 genstatus: 0 pdg: 11 vertex: -1712 679.005 -278.097  endpoint: -1723.63 680.708 -276.212
                               |_____ depth: 4 id:  620d570113 genstatus: 0 pdg: -11 vertex: -1712 679.005 -278.097  endpoint: -1723.8 683.703 -278.348
                        |_____ depth: 3 id:  620d570109 genstatus: 1 pdg: 22 vertex: -0.716564 0.0676678 -0.190837  endpoint: -1883.52 149.586 -645.868
                               |_____ depth: 4 id:  620d570110 genstatus: 0 pdg: 11 vertex: -1883.52 149.586 -645.868  endpoint: -1931.47 148.945 -668.714
                               |_____ depth: 4 id:  620d570111 genstatus: 0 pdg: -11 vertex: -1883.52 149.586 -645.868  endpoint: -1905.65 148.838 -657.135
          |_____ depth: 1 id:  620d57095 genstatus: 2 pdg: 113 vertex: -0.716489 0.0676606 -0.190812  endpoint: -0.716489 0.0676606 -0.190812
                 |_____ depth: 2 id:  620d570105 genstatus: 1 pdg: 211 vertex: -0.716489 0.0676606 -0.190812  endpoint: -1494.35 1109.17 -239.629
                 |_____ depth: 2 id:  620d570106 genstatus: 1 pdg: -211 vertex: -0.716489 0.0676606 -0.190812  endpoint: -1869.62 -291.595 -341.436
```

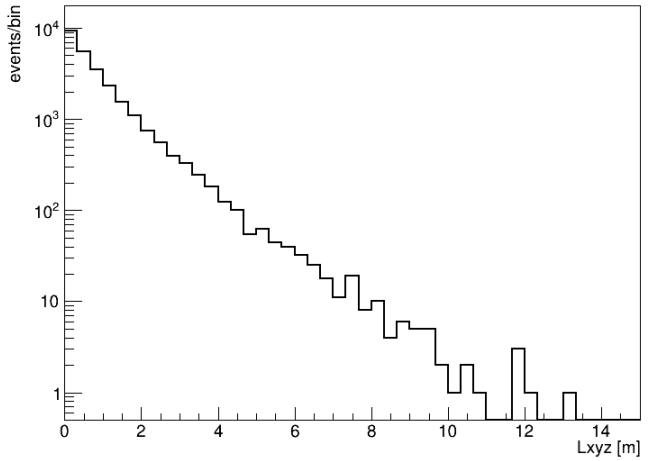
Example: D0 truth Vertex

- $\sqrt{s}$ = 91.2GeV









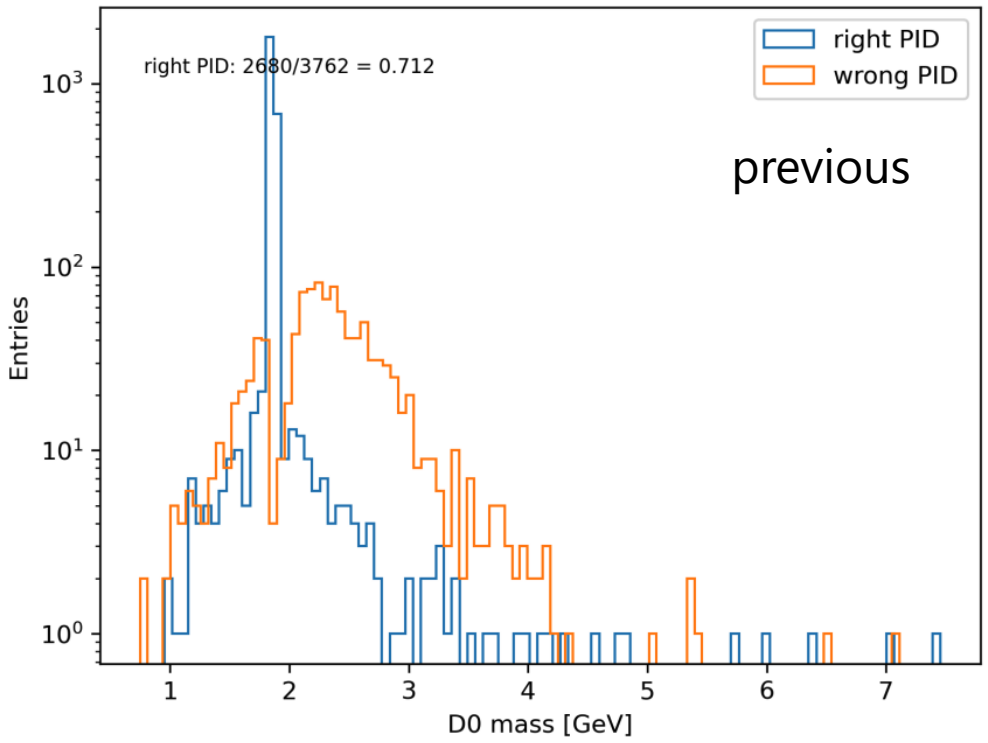
D_0 Vertex Reconstruction

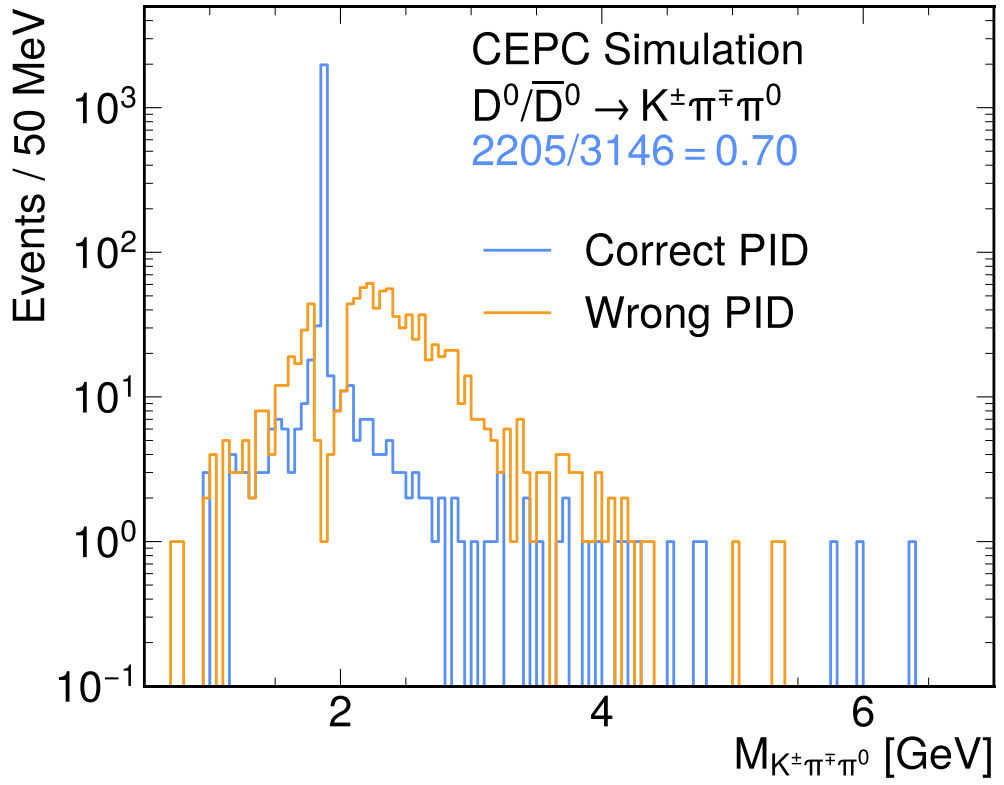
- Select $D^0/\bar{D}^0 \to \pi^+\pi^-\pi^0$ to check PID and vertex fit performance @ √s = 91.2GeV
- Several small bugs fixed (such as m_{π^0}, selection of neutral objects)
- Blue: previous; Red: reproduction
  - Similar purity with higher efficiency (different definition?)

Cuts	Efficiency [%]		Purity [%]	
2 tracks reconstructed	94	97	-	-
Vertex reconstructed	87	96	-	-
$1.85 < M_D < 1.88$ GeV	64	73	1.5	1.6
charged pair	64	73	1.8	1.8
Kinematic > 0	63	72	1.8	1.9
Chi2 < 4	58	67	2	2.1
Only 1 π^0	58	67	12	5.8
PID	58	67	91	11.4
0 other neutral object	-	67	-	91.2

D_0 Vertex Peformance

- Distribution of $M_{K^{\pm}\pi^{\mp}\pi^0}$ in $D^0/\overline{D}_0 \to K^{\pm}\pi^{\mp}\pi^0$
- Similar shape & wrong PID rate

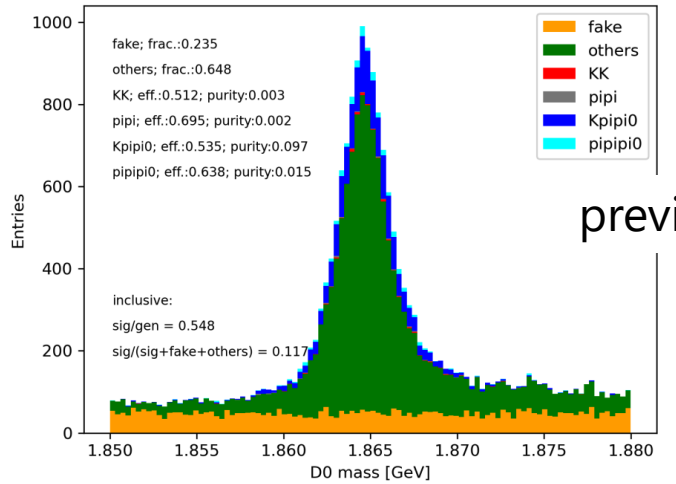


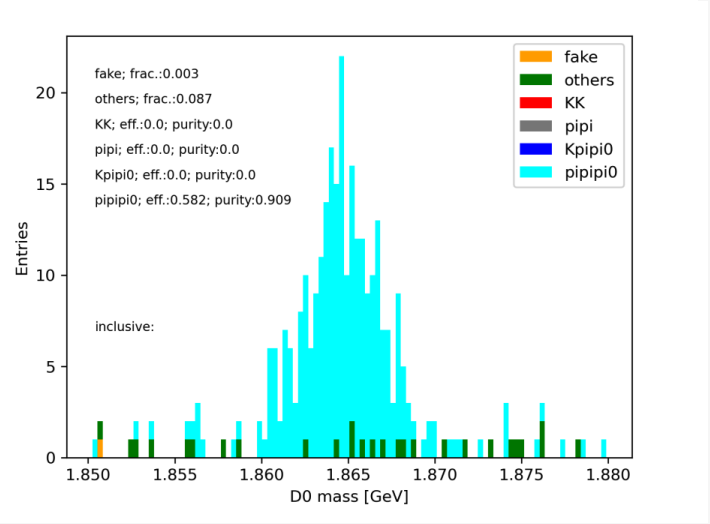


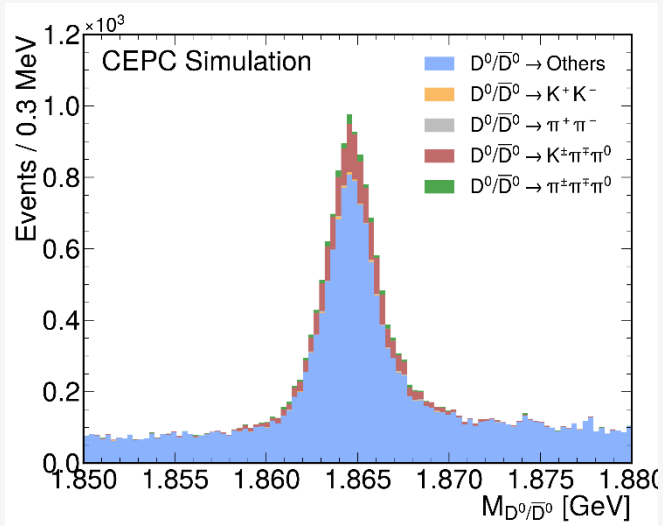
D_0 Vertex Performance

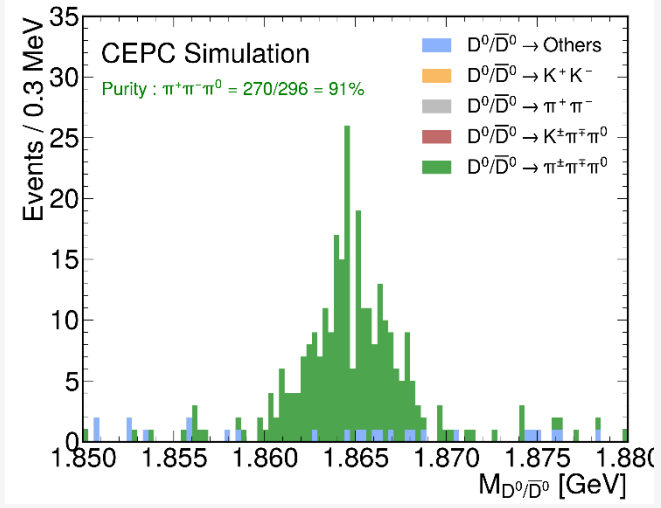
- Distribution of M_{D_0} in $D^0/\bar{D}_0 \rightarrow$ inclusive

previous









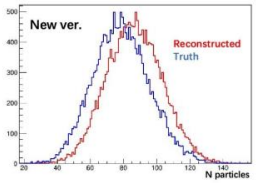
Jet Vertex Reconstruction

- One-to-one match for jets possible @ TDR 25.3.2
- Particle level second vertices ↔ reco level

Kaili

PFO matching in 25.3

- Typically, one bb jet with 36PFOs, 14 tracks, 32 truth particles.
  - Consistent with @Fangyi N_PFO=1.1 N_truth conclusion.
  - Possible for 1-1 correspondence.
  - In truth level, photon/Klong matching possible. Ability to match 43 GeV photon.



Inputs for Jet Tagging

- Definitions from ILD

Name	Description	Normalization factor	Used by category
trk1d0sig	d0 significance of track with highest d0 significance	1	A, B, C, D
trk2d0sig	d0 significance of track with second highest d0 significance	1	A, B, C, D
trk1z0sig	z0 significance of track with highest d0 significance	1	A, B, C, D
trk2z0sig	z0 significance of track with second highest d0 significance	1	A, B, C, D
trk1pt	transverse momentum of track with highest d0 significance	$1/E_{\text{jet}}$	A, B, C, D
trk2pt	transverse momentum of track with second highest d0 significance	$1/E_{\text{jet}}$	A, B, C, D
jprobr	joint probability in the r-phi plane using all tracks	1	A, B, C, D
jprobr5sigma	joint probability in the r-phi plane using all tracks having impact parameter significance exceeding 5 sigma	1	A, B, C, D
jprobz	joint probability in the z projection using all tracks	1	A, B, C, D
jprobz5sigma	joint probability in the z projection using all tracks having impact parameter significance exceeding 5 sigma	1	A, B, C, D
d0bprob	product of b-quark probabilities of d0 values for all tracks, using b/c/q d0 distributions	1	A, B, C, D
d0cprob	product of c-quark probabilities of d0 values for all tracks, using b/c/q d0 distributions	1	A, B, C, D
d0qprob	product of q-quark probabilities of d0 values for all tracks, using b/c/q d0 distributions	1	A, B, C, D
z0bprob	product of b-quark probabilities of z0 values for all tracks, using b/c/q z0 distributions	1	A, B, C, D
z0cprob	product of c-quark probabilities of z0 values for all tracks, using b/c/q z0 distributions	1	A, B, C, D
z0qprob	product of q-quark probabilities of z0 values for all tracks, using b/c/q z0 distributions	1	A, B, C, D
nmuon	number of identified muons	1	A, B, C, D
nelectron	number of identified electrons	1	A, B, C, D
trkmass	mass of all tracks exceeding 5 sigma significance in d0/z0 values	1	A, B, C, D

Table 5: Flavor tagging input variables. The category is defined in Tab. 4.

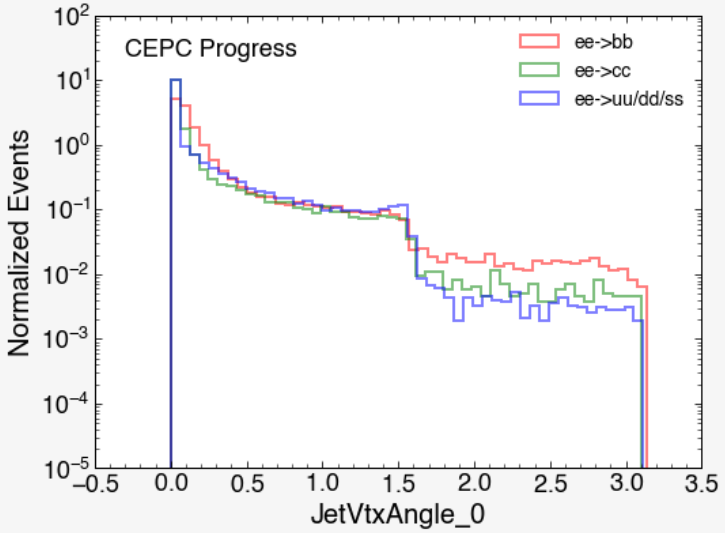
Inputs for Jet Tagging

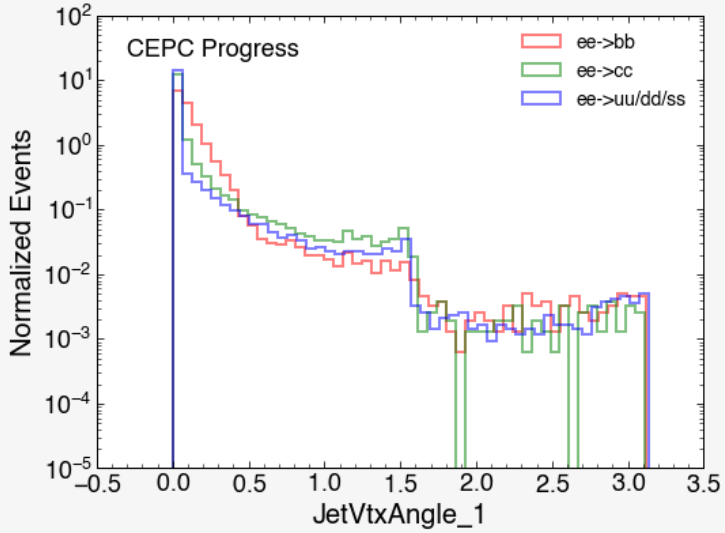
- Definitions from ILD

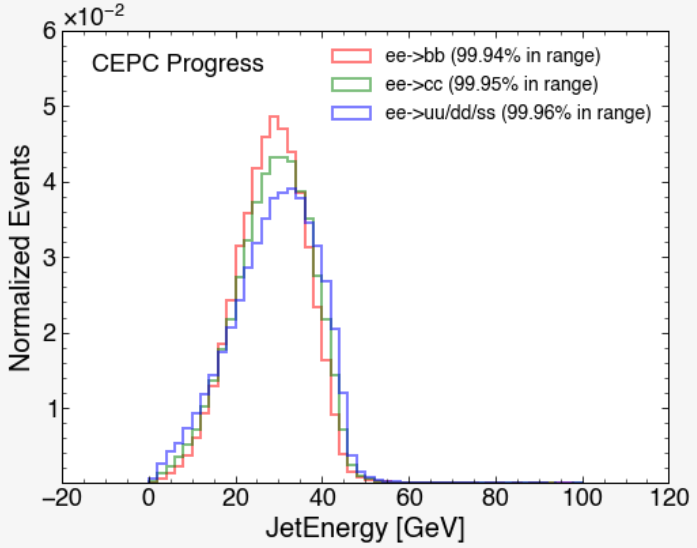
Name	Description	Normalization factor	Used by category
1vtxprob	vertex probability with all tracks associated in vertices combined	1	B, C, D
vtxlen1	decay length of the first vertex in the jet (zero if no vertex is found)	$1/E_{\text{jet}}$	B, C, D
vtxlen2	decay length of the second vertex in the jet (zero if number of vertex is less than two)	$1/E_{\text{jet}}$	D
vtxlen12	distance between the first and second vertex (zero if number of vertex is less than two)	$1/E_{\text{jet}}$	D
vtxsig1	decay length significance of the first vertex in the jet (zero if no vertex is found)	$1/E_{\text{jet}}$	B, C, D
vtxsig2	decay length significance of the second vertex in the jet (zero if number of vertex is less than two)	$1/E_{\text{jet}}$	D
vtxsig12	vtxlen12 divided by its error as computed from the sum of the covariance matrix of the first and second vertices, projected along the line connecting the two vertices	$1/E_{\text{jet}}$	D
vtxdirang1	the angle between the momentum (computed as a vector sum of track momenta) and the displacement of the first vertex	E_{jet}	B, C, D
vtxdirang2	the angle between the momentum (computed as a vector sum of track momenta) and the displacement of the second vertex	E_{jet}	D
vtxmult1	number of tracks included in the first vertex (zero if no vertex is found)	1	B, C, D
vtxmult2	number of tracks included in the second vertex (zero if number of vertex is less than two)	1	D
vtxmult	number of tracks which are used to form secondary vertices (summed for all vertices)	1	D
vtxmom1	magnitude of the vector sum of the momenta of all tracks combined into the first vertex	$1/E_{\text{jet}}$	B, C, D
vtxmom2	magnitude of the vector sum of the momenta of all tracks combined into the second vertex	$1/E_{\text{jet}}$	D
vtxmass1	mass of the first vertex computed from the sum of track four-momenta	1	B, C, D
vtxmass2	mass of the second vertex computed from the sum of track four-momenta	1	D
vtxmass	vertex mass as computed from the sum of four momenta of all tracks forming secondary vertices	1	B, C, D
vtxmasspc	mass of the vertex with minimum pt correction allowed by the error matrices of the primary and secondary vertices	1	B, C, D
vtxprob	vertex probability; for multiple vertices, the probability P is computed as 1-P = (1-P1)(1-P2)...(1-PN)	1	B, C, D

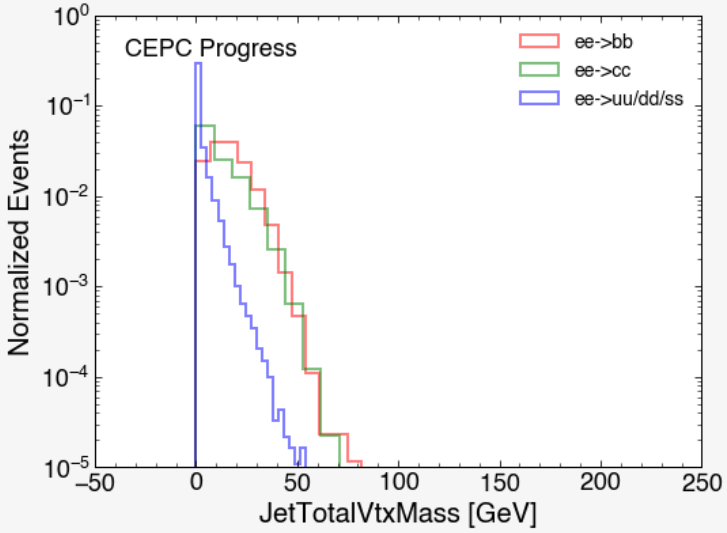
Table 6: Flavor tagging input variables (continued).

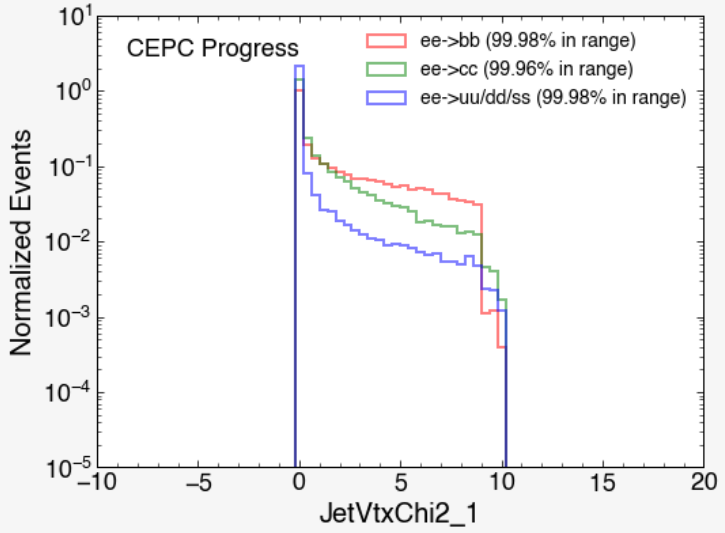
Jet Tagging Var Distribution

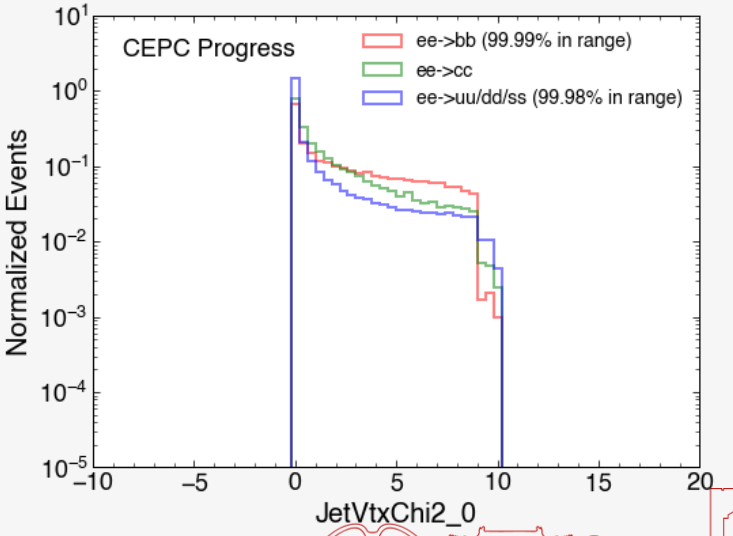




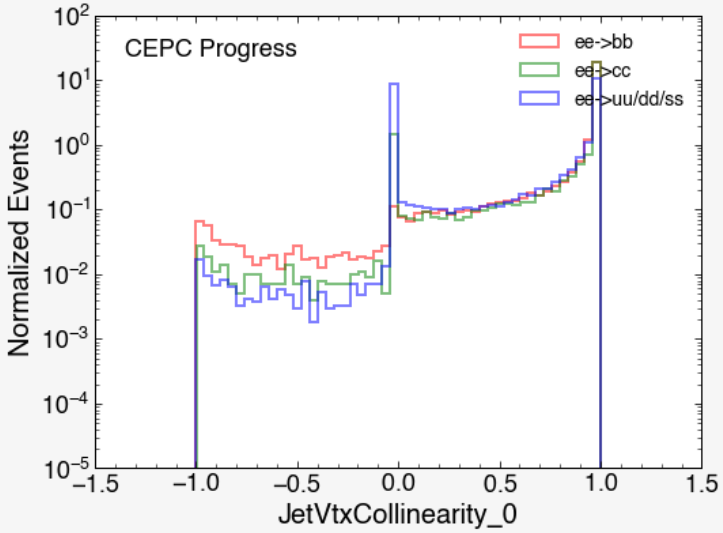


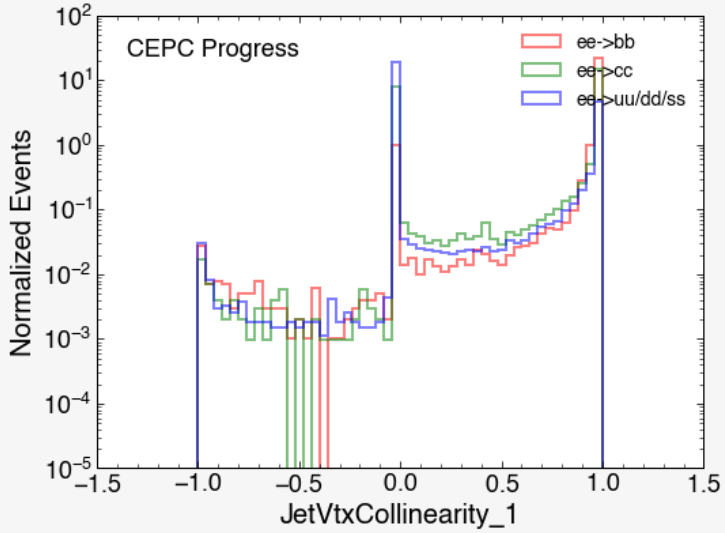


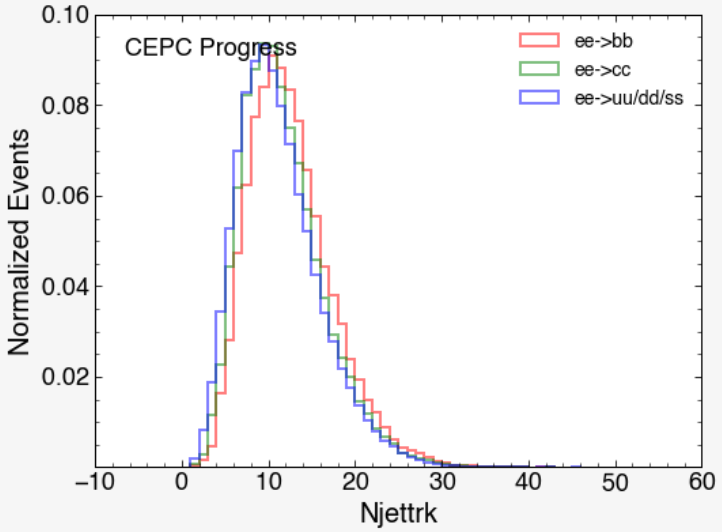


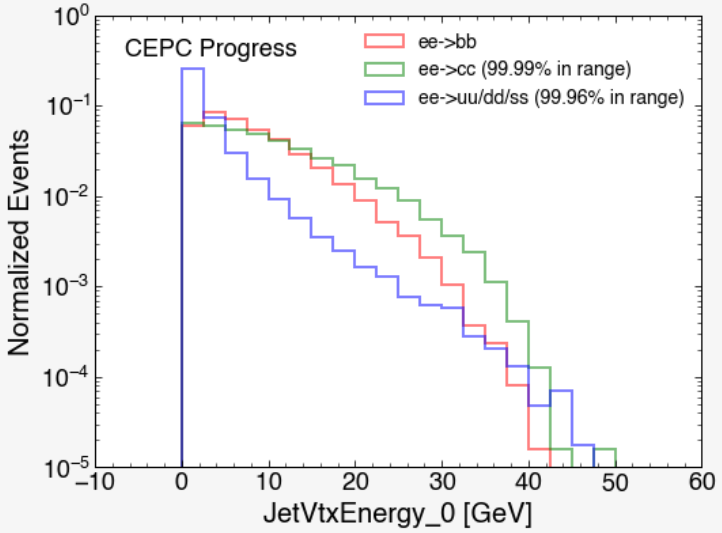


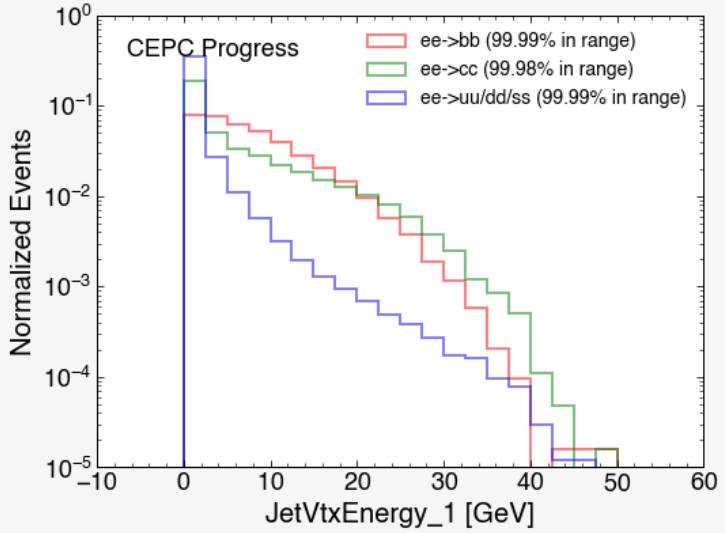
Jet Tagging Var Distribution

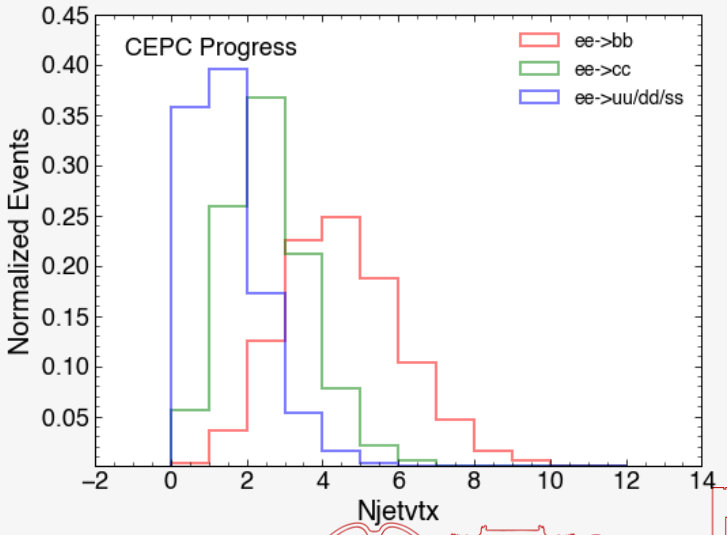




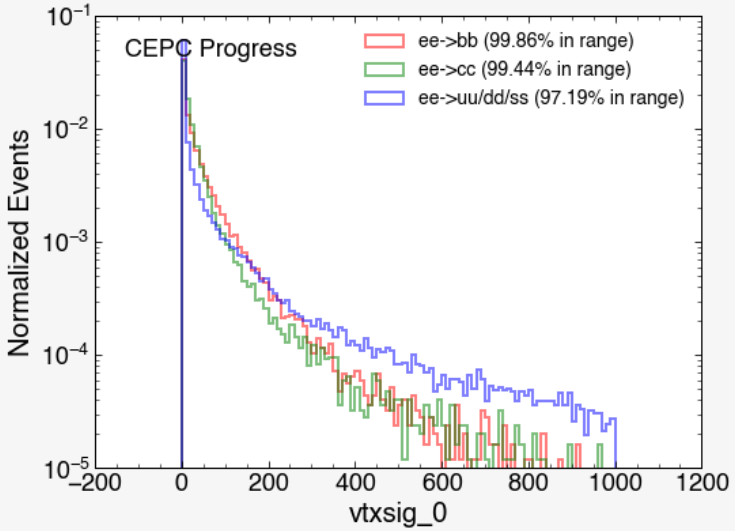


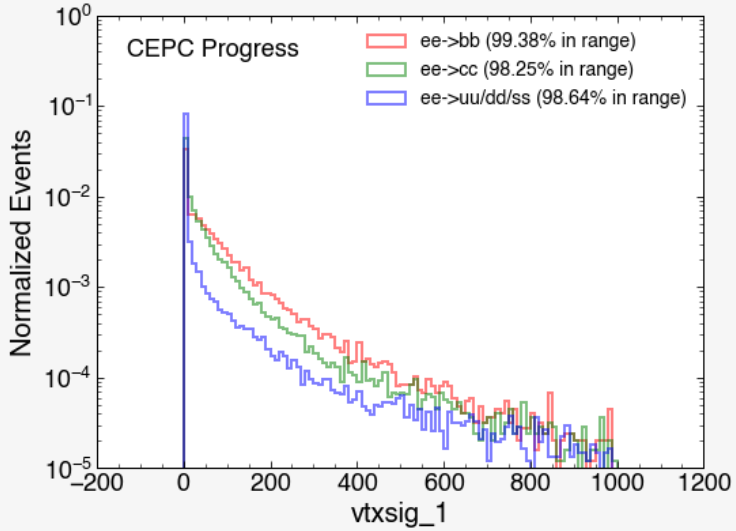






Jet Tagging Var Distribution





Conclusions & to-do

- Truth tracing available in newest release
- D0 vertex reconstruction ready
- Inputs for jet flavor tagging ready

- Based on current vertex reconstruction, performance check by 13th
  - **March D0 construction with reconstructed pi0** (Jinfei) by this Wednesday: difference in efficiency and how to suppress fake rate
  - **Check truth vertex behavior** (Yifan) by this Tuesday
  - **Complete the variable comparison among different jet flavors** (Xinzhu) by this Tuesday
  - **Comparison between truth variables and rec. variables with match** (Yifan & Xinzhu) by this Wednesday
  - **Flavor tagging efficiency** (Yifan) by this Thursday
- Sample list (signal and background) by 12AM 12th March:
  - **D0** (Peng Zhang)
  - **Higgs-hadronic decay** (Zuofei)
  - **Produce all signal/background samples in time**: discussion this Wednesday afternoon

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Thank You

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