Preliminary studies Higgs boson invisible decay

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Feb. 24th, 2025

Outlines

- Samples
- Updates on lepton ID
- Event selection
- Preliminary results

Samples

More samples are being produced

- Produced with the latest version (including updates of Fangyi)
- See slides from Kaili for explanation and cross sections: /cefs/higgs/zhangkl/stdhep/Sample generation for CEPC.pdf

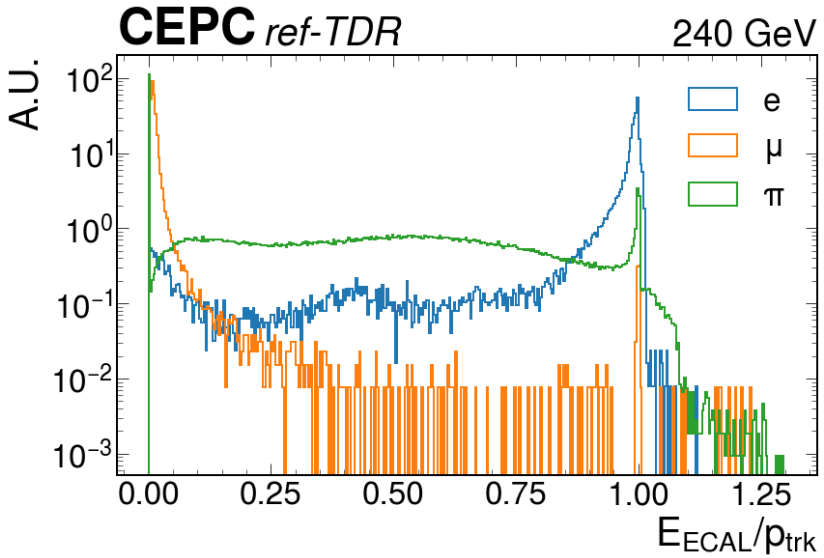
	Processes	Location	Events
Signal	Z(→ee/μμ/qq)H(→4ν)	/cefs/higgs/liugeliang/CEPC/202501/Production/Hinvi	20k per final state
4-fermion bkg	single-Z, single-W, Z-or-W, ZZ, WW, ZZ-or-WW	/cefs/higgs/liugeliang/CEPC/202501/Production/4fermions	20k per final state
2-fermion bkg	qq	/cefs/higgs/liugeliang/CEPC/202501/Production/2fermions	100k
ZH	Z(→ee/μμ/ττ/νν/qq) H(→incl)	/cefs/higgs/liugeliang/CEPC/202501/Production/HX	10k per final state

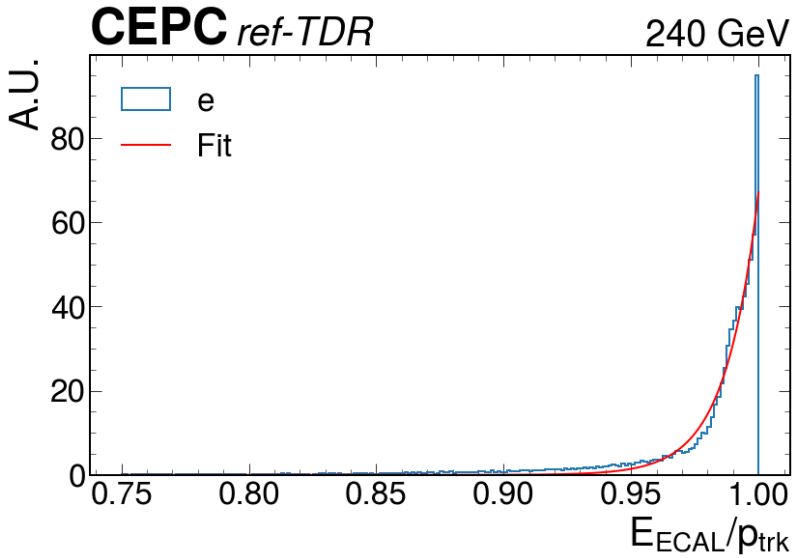
Lepton ID

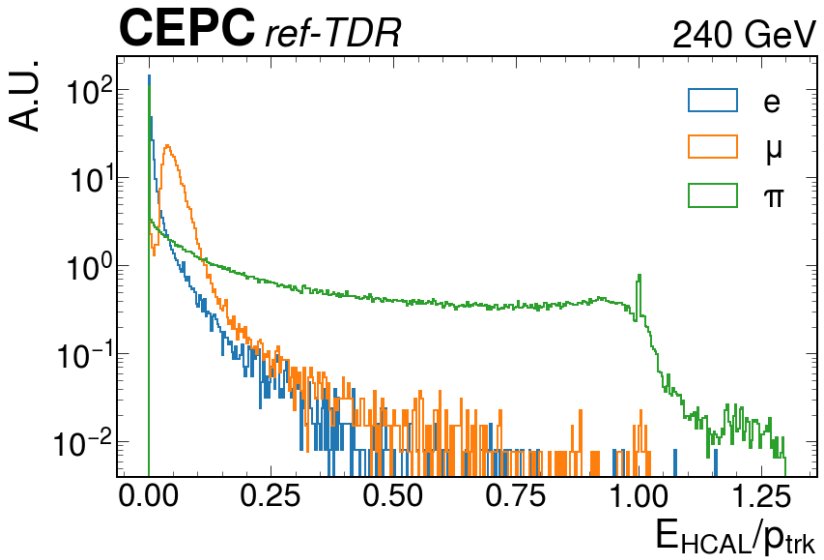
- Combination of E_{ECAL}, E_{HCAL}, TOF, TPC information
- Keep roughly a 90% WP

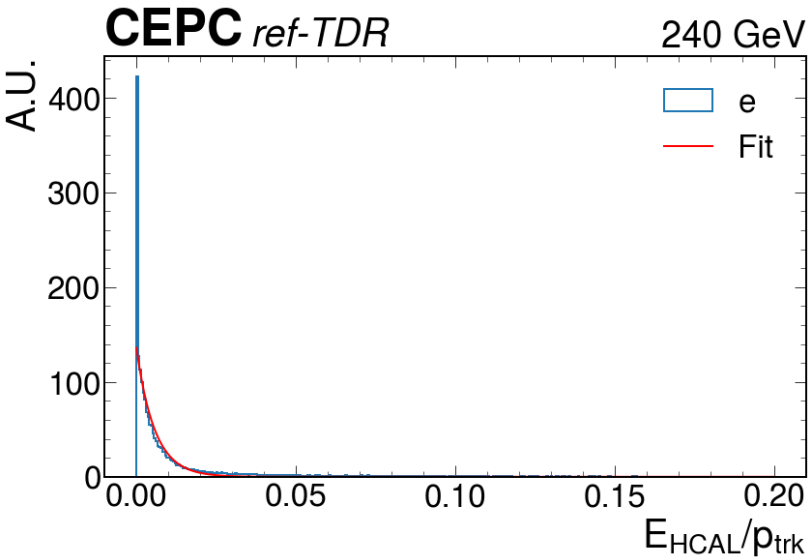
➢ Electron

- E_{ECAL}/p_{track} + E_{HCAL}/p_{track} + TOF + TPC
- E_{ECAL}/p_{track}, E_{HCAL}/p_{track} not Gaussian like: fit with exponential function
- $\chi^2 = \frac{(TPC-\mu_{TPC})^2}{\sigma^2_{TPC}} + \frac{(TOF-\mu_{TOF})^2}{\sigma^2_{TOF}} + 2\mu_{E_E/p}E_E/p + 2\mu_{E_H/p}E_H/p$









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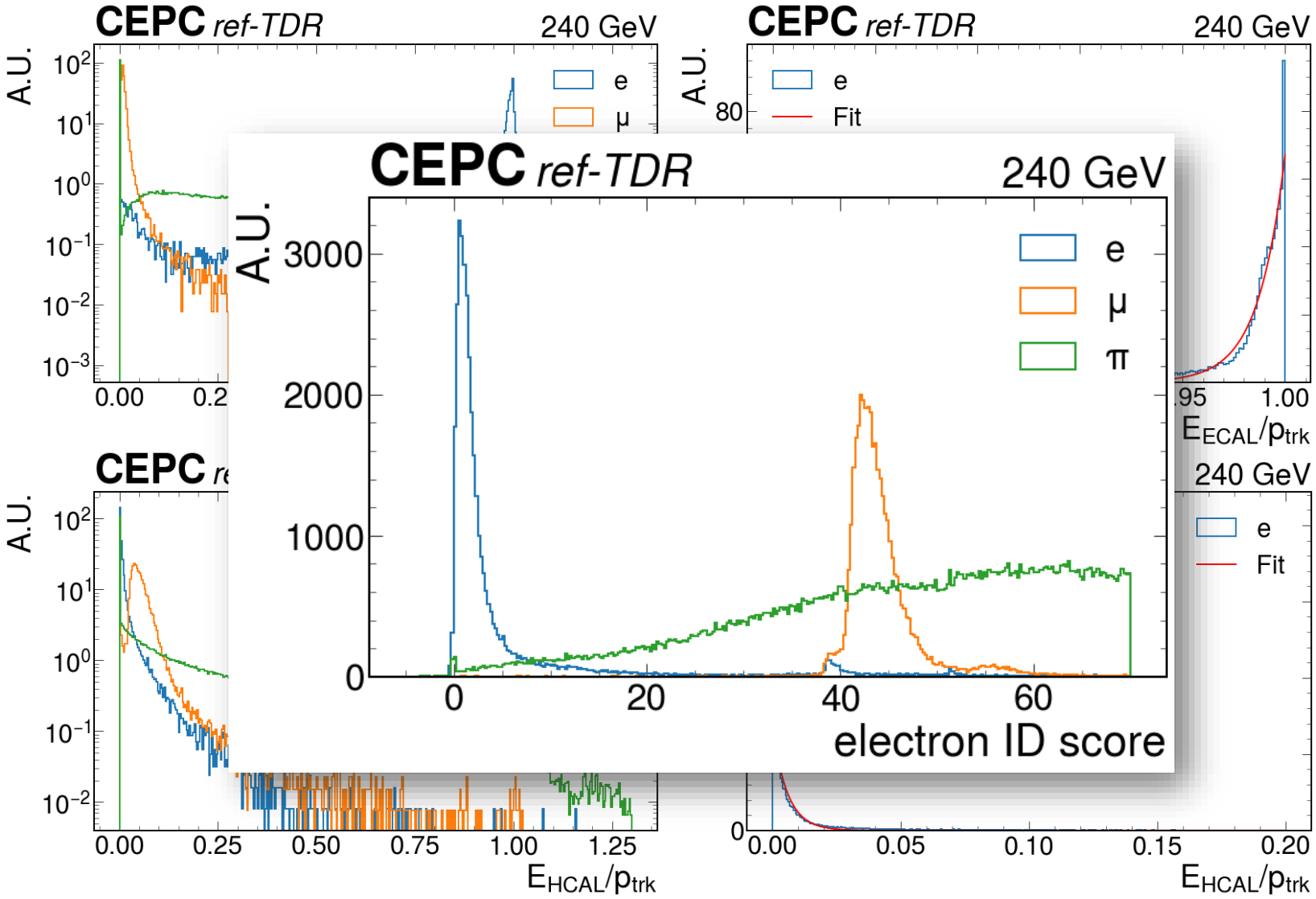
- p(e→e)=90.0%, p(μ→e)=0.03%, p(π→e)=4.6%



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➢ Muon

- E_{ECAL}/p_{track} + E_{HCAL}/p_{track} + TOF + TPC
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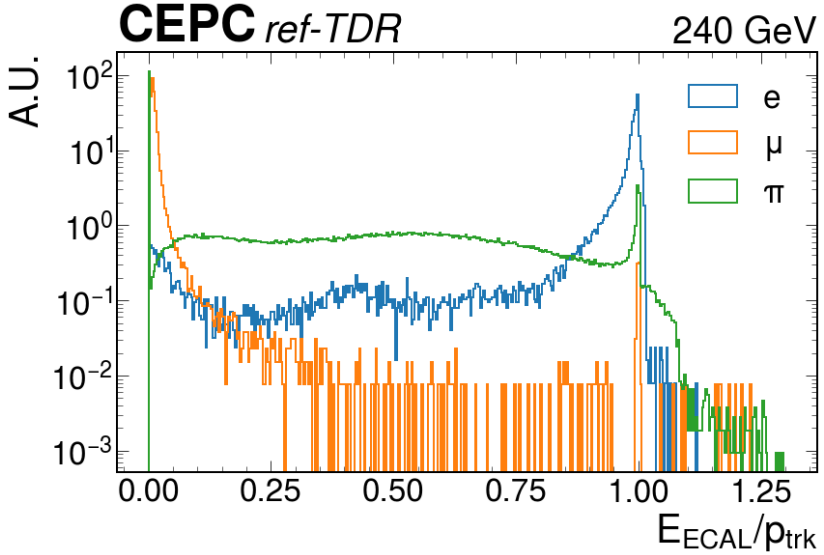
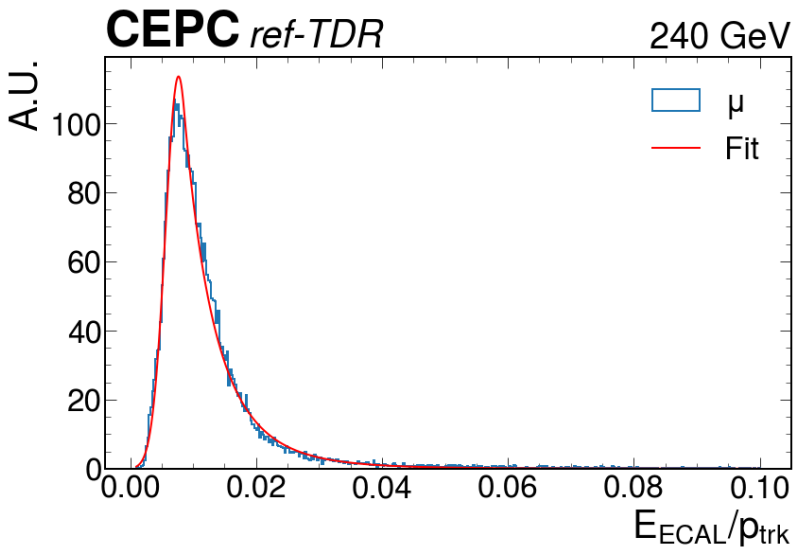
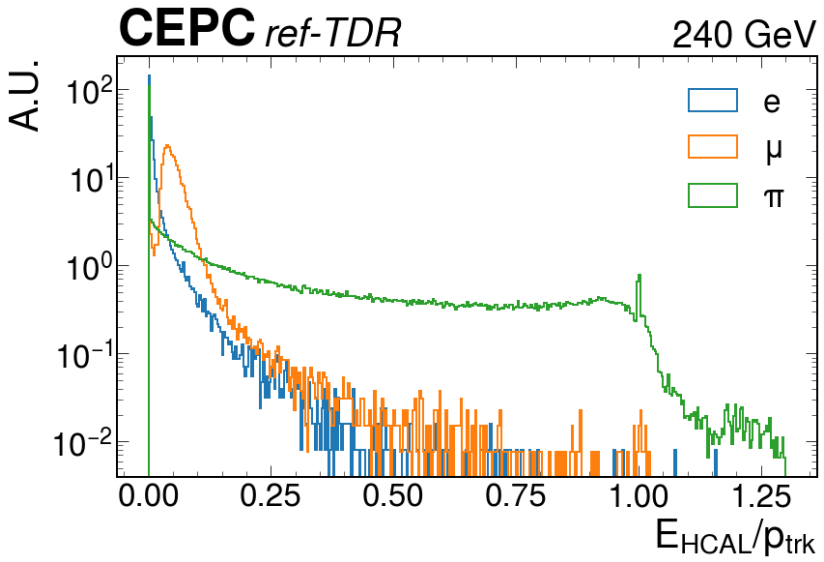
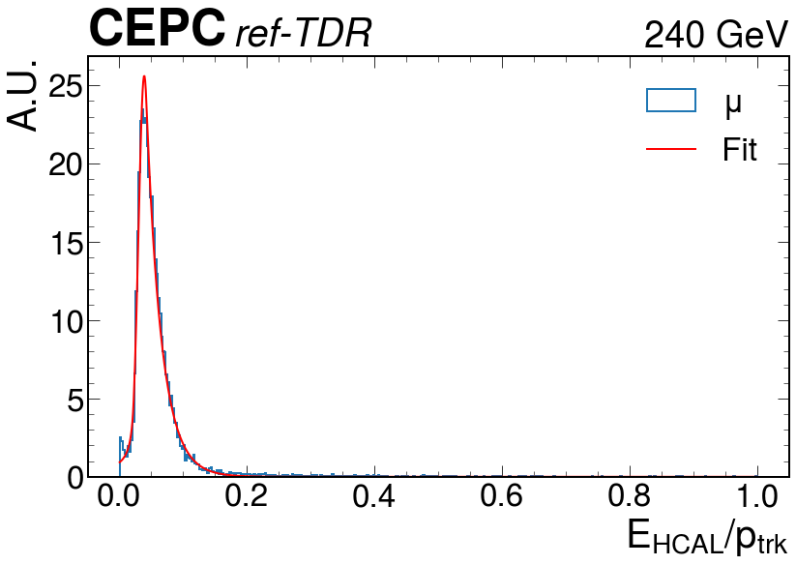
- $\chi^2 = \frac{(TPC-\mu_{TPC})^2}{\sigma^2_{TPC}} + \frac{(TOF-\mu_{TOF})^2}{\sigma^2_{TOF}} + \frac{(E_E/p-\mu_{E_E/p})^2}{\sigma^2_{E_E/p}} + \frac{(E_H/p-\mu_{E_H/p})^2}{\sigma^2_{E_H/p}}$









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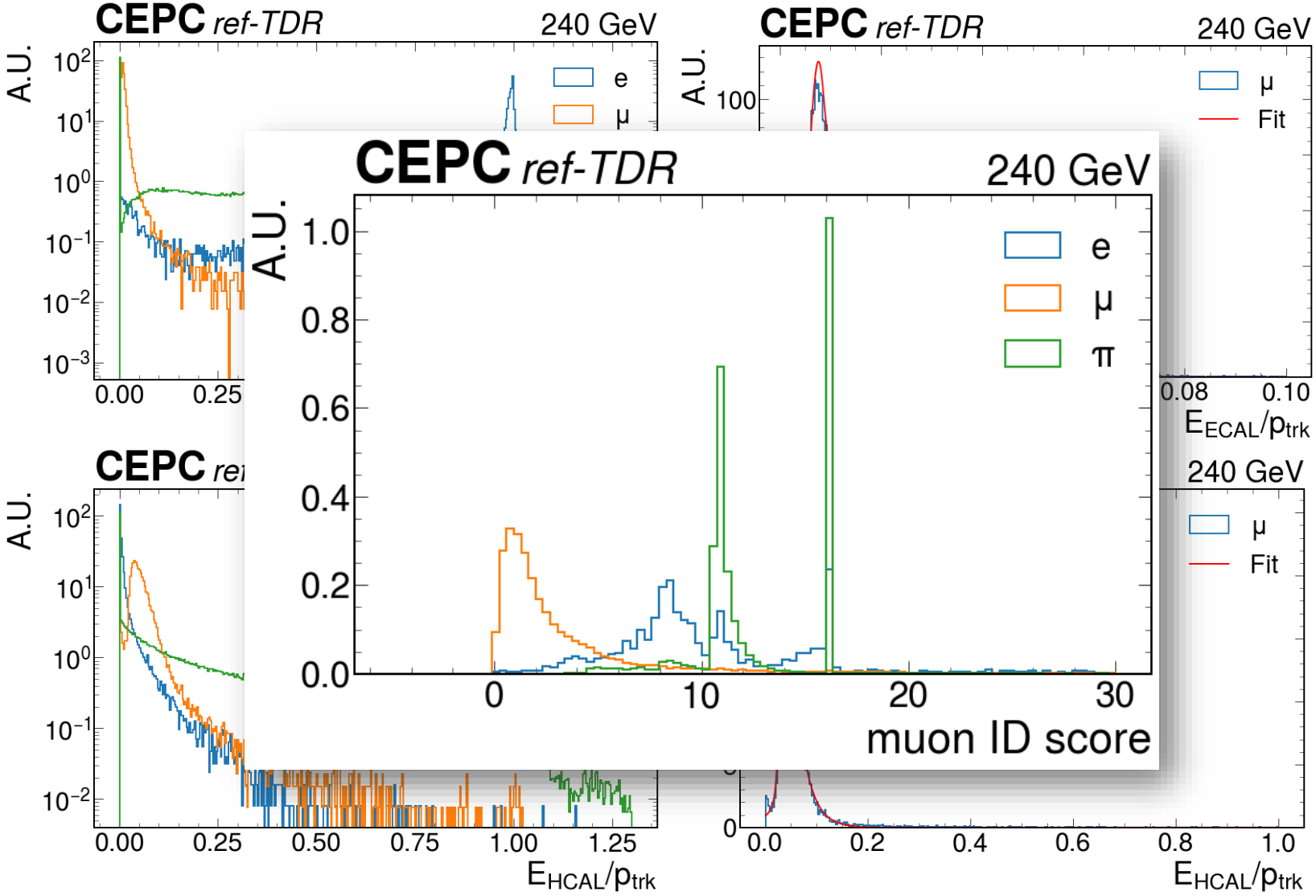
- p(μ→μ)=90.0%, p(e→μ)=3.6%, p(π→μ)=33.2%



Baseline selection

- **μμ final state:**
  - Two PFOs passing $|\cos\theta| < 0.99$, muon ID
  - Opposite charge

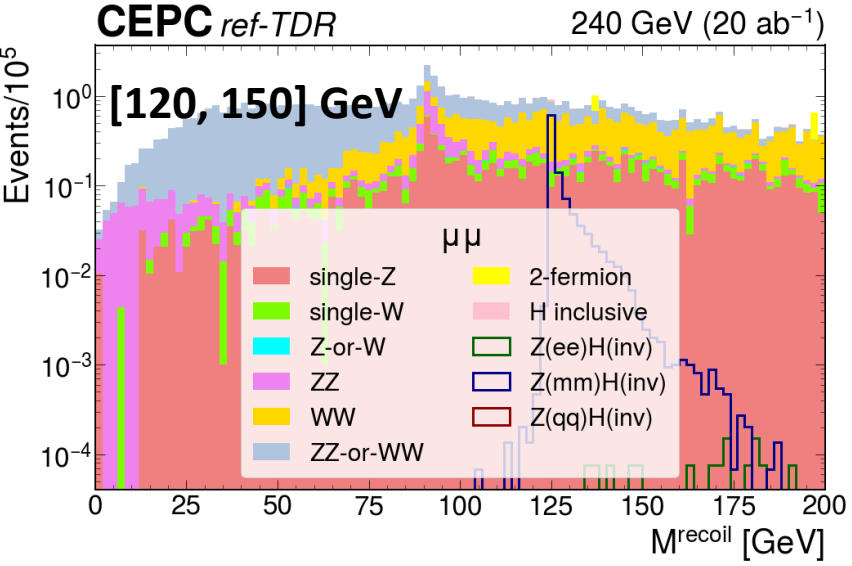
- **ee final state:**
  - Events not passing μμ baseline selection (orthogonality)
  - Two PFOs passing $|\cos\theta| < 0.99$, electron ID
  - Opposite charge

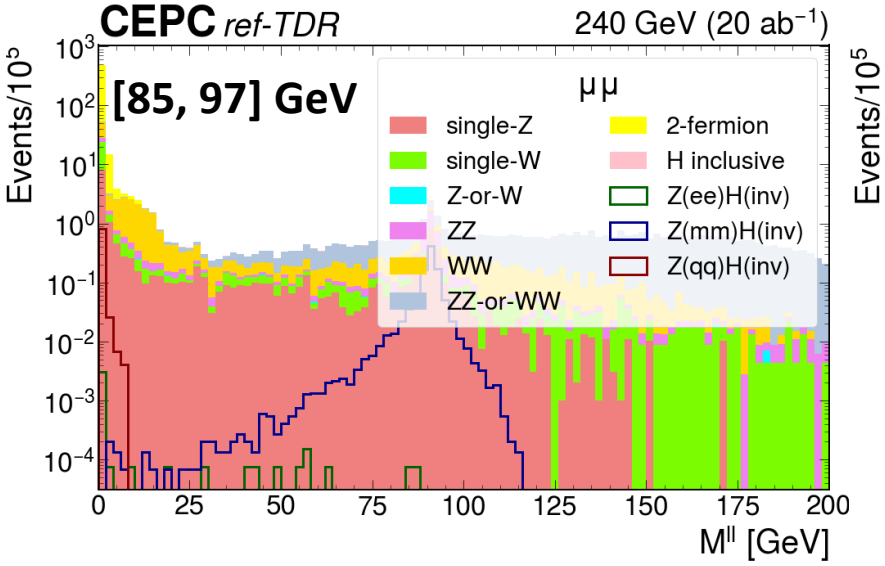
- **qq final state:**
  - Number of PFOs >= 2

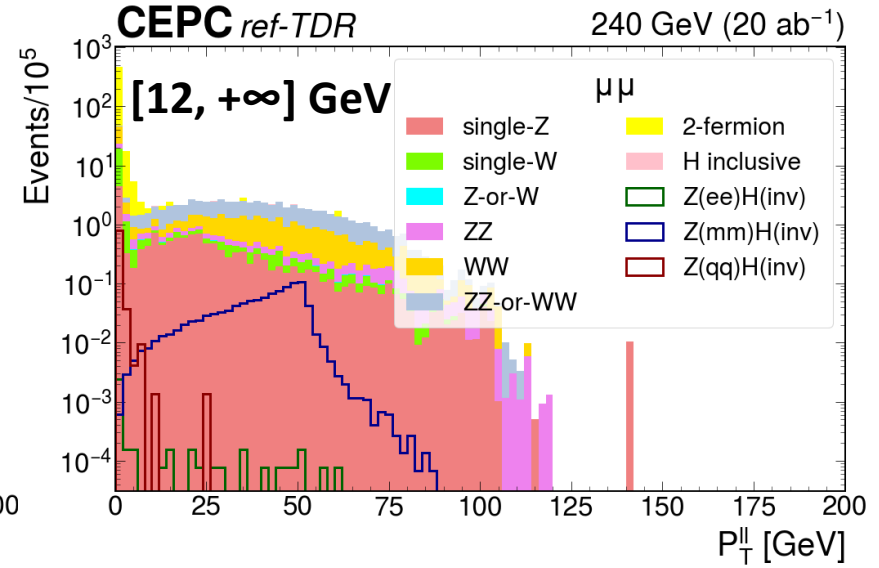
Kinematic selection

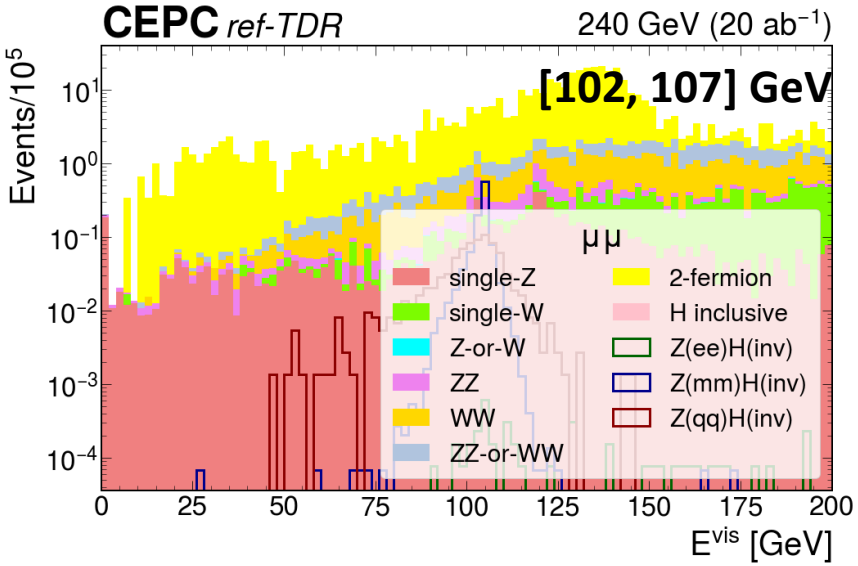
Copy the selection criteria from Chinese Phys. C 44 123001

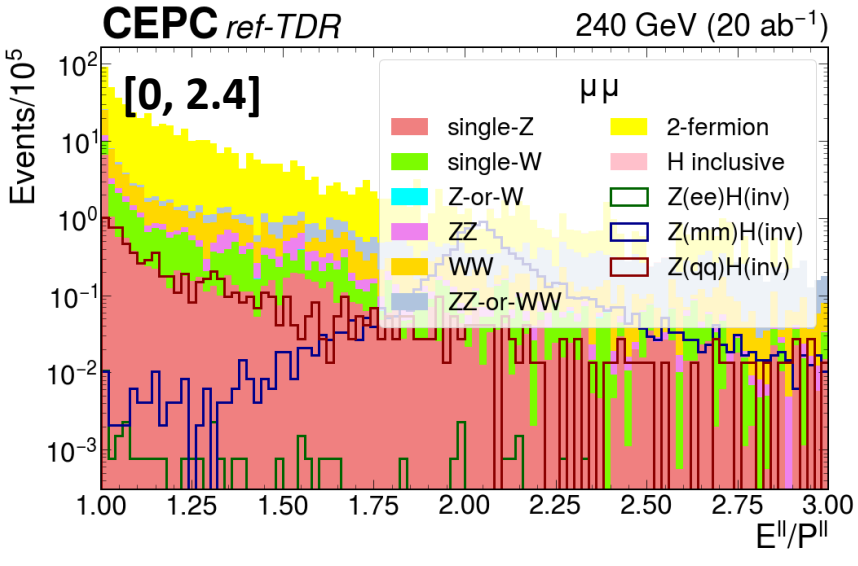
➢ μμ final state









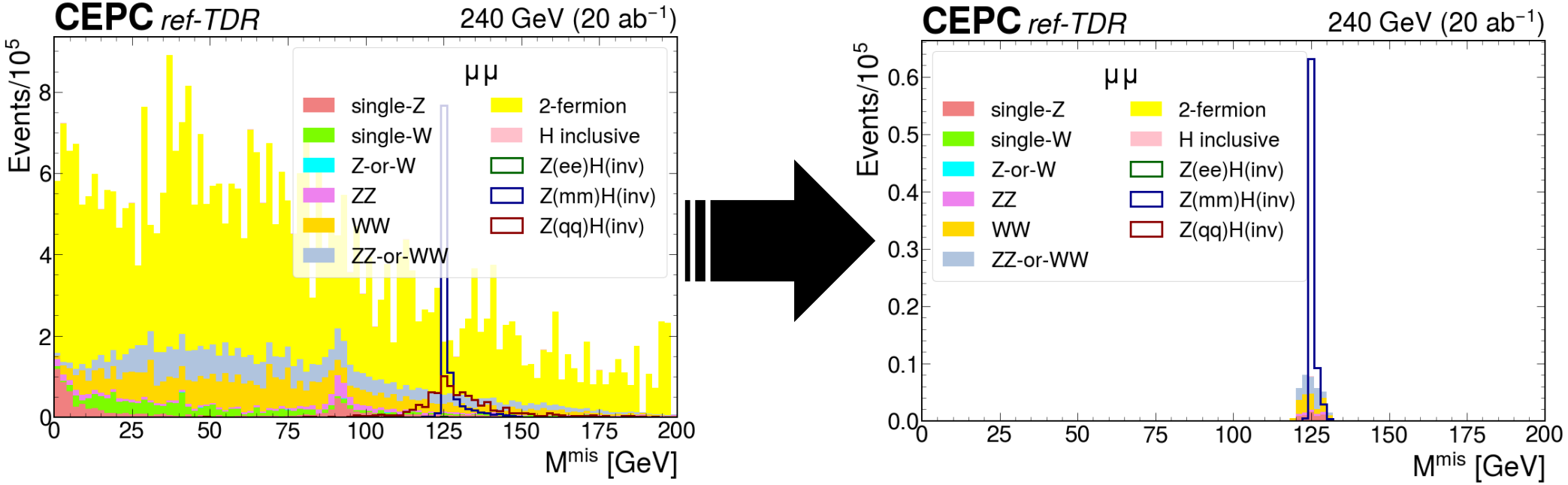


Kinematic selection

Copy the selection criteria from Chinese Phys. C 44 123001

➢ μμ final state

Process	eeH	mmH	qqH	sz	sw	szw	zz	ww	zzww	2f	Hincl	All bkg
Total yield	140800	135400	2736200	32403400	69705000	4989600	22819400	181522200	73003000	1082137200	4073200	1470653000
Base sel	406	106555	85917	1558339	1893099	14293	791039	4331596	3576077	44002567	34049	56201059
Kin sel	0	76004	0	5358	0	0	2188	12917	13525	0	47	34035
eff (%)	0.000	56.133	0.000	0.017	0.000	0.000	0.010	0.007	0.019	0.000	0.001	0.002
eff CDR (%)	-	59.17	-	0.01	0.00	0.00	0.01	0.01	0.02	0.000	0.00	0.00



Kinematic selection

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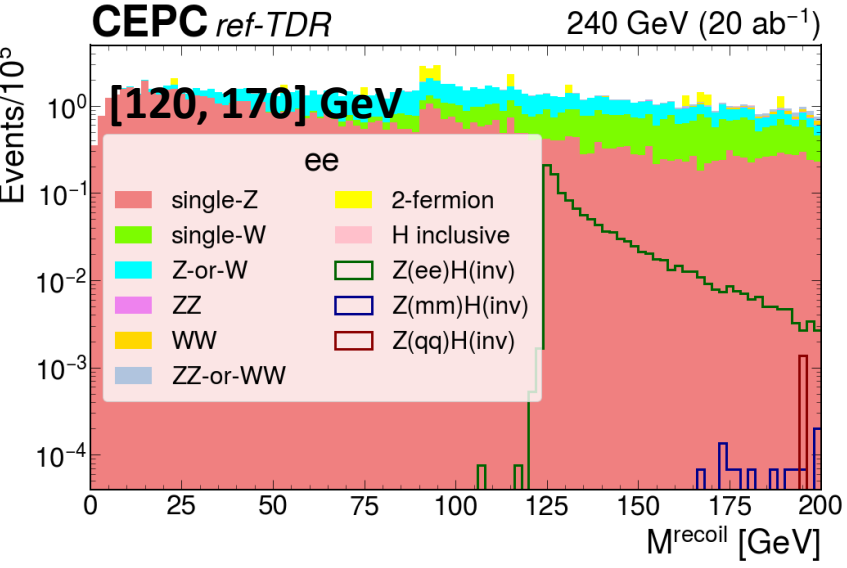
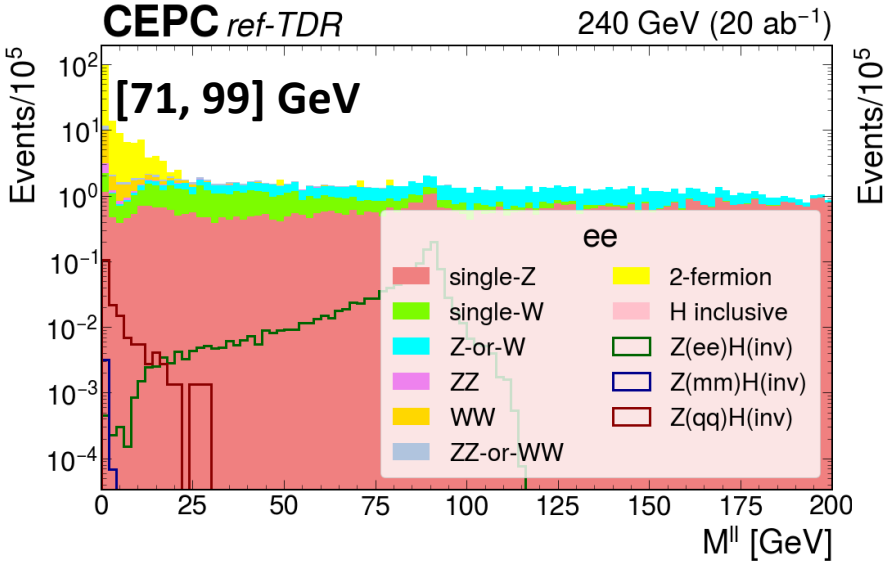
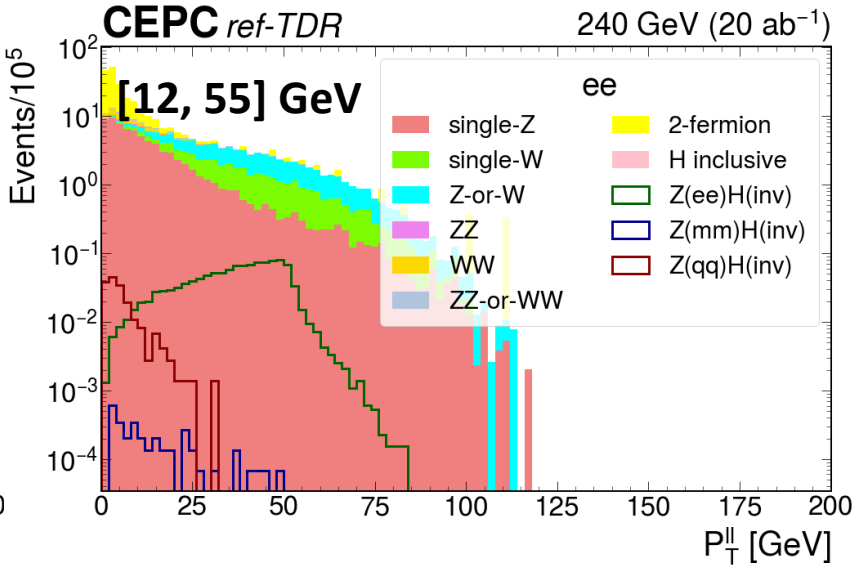
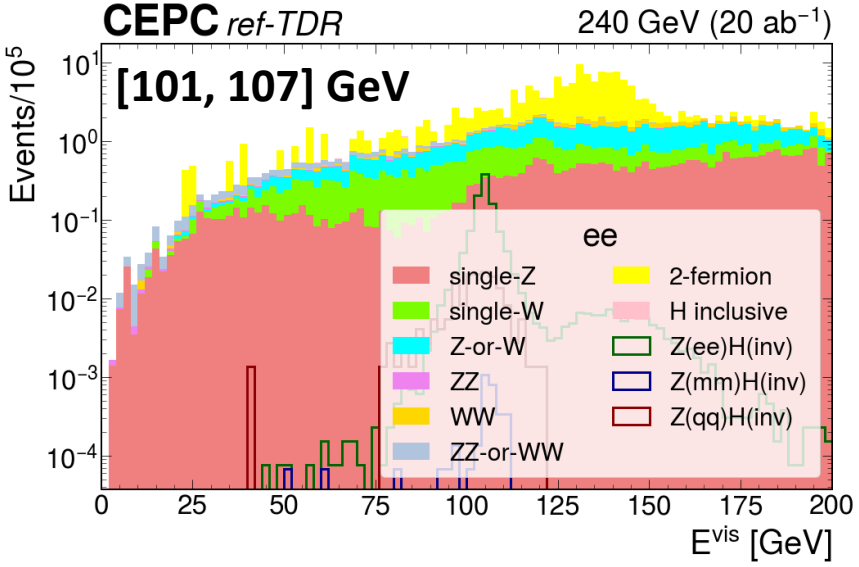
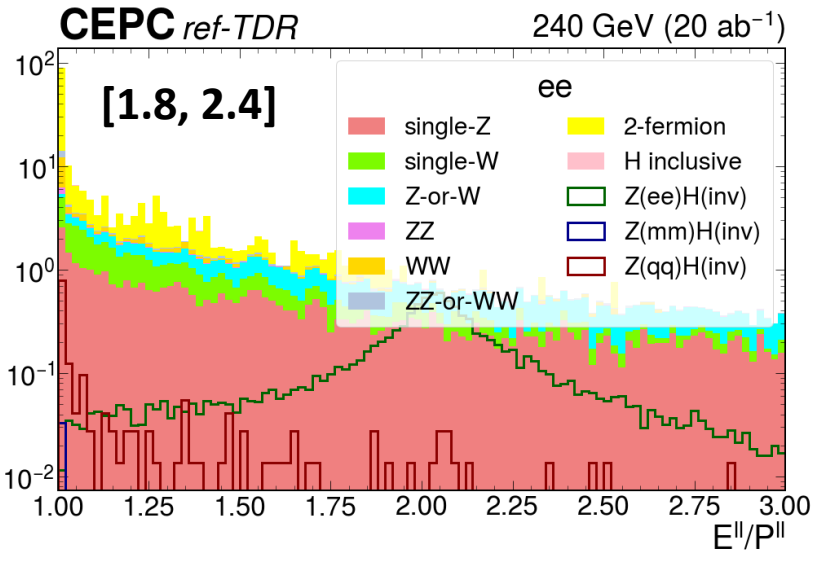
- ee final state











Kinematic selection

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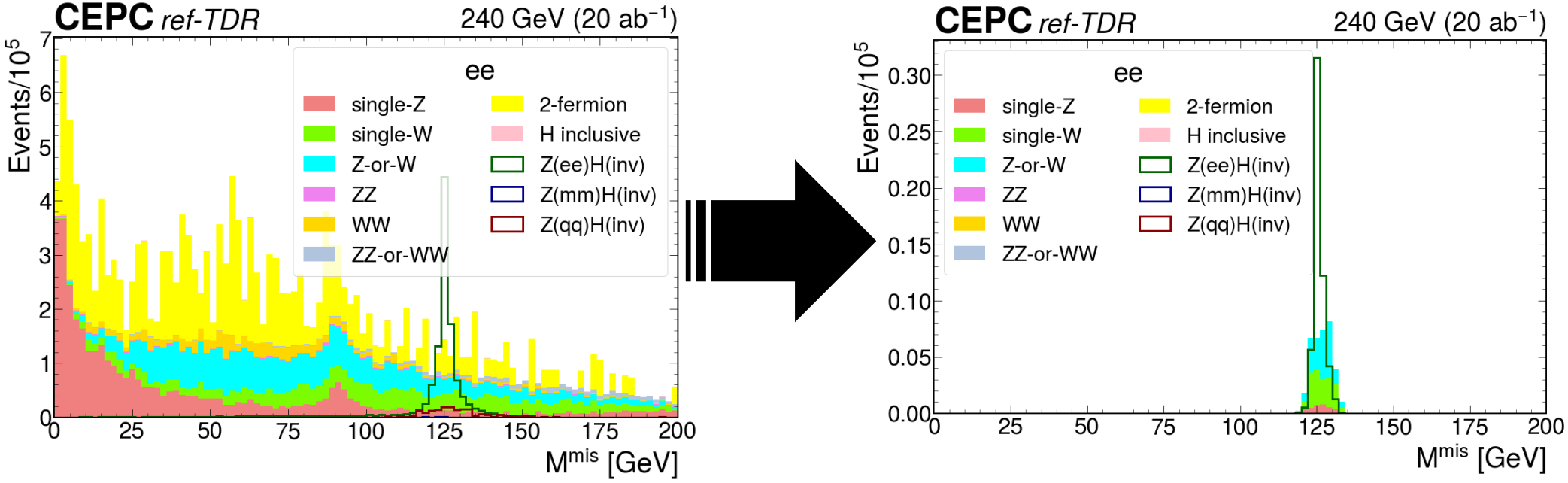
➢ ee final state

Process	eeH	mmH	qqH	sz	sw	szw	zz	ww	zzww	2f	Hincl	All bkg
Total yield	140800	135400	2736200	32403400	69705000	4989600	22819400	181522200	73003000	1082137200	4073200	1470653000
Base sel	118165	333	17785	7595862	2750212	4080038	161423	1092489	451954	12614069	23692	28769739
Kin sel	55517	0	0	3449	14227	17931	0	0	211	0	54	35872
eff (%)	39.429	0.000	0.000	0.011	0.020	0.359	0.000	0.000	0.000	0.000	0.001	0.002
eff CDR (%)	35.34	-	-	0.01	0.01	0.43	0.00	0.00	0.00	0.000	0.00	0.00



Kinematic selection

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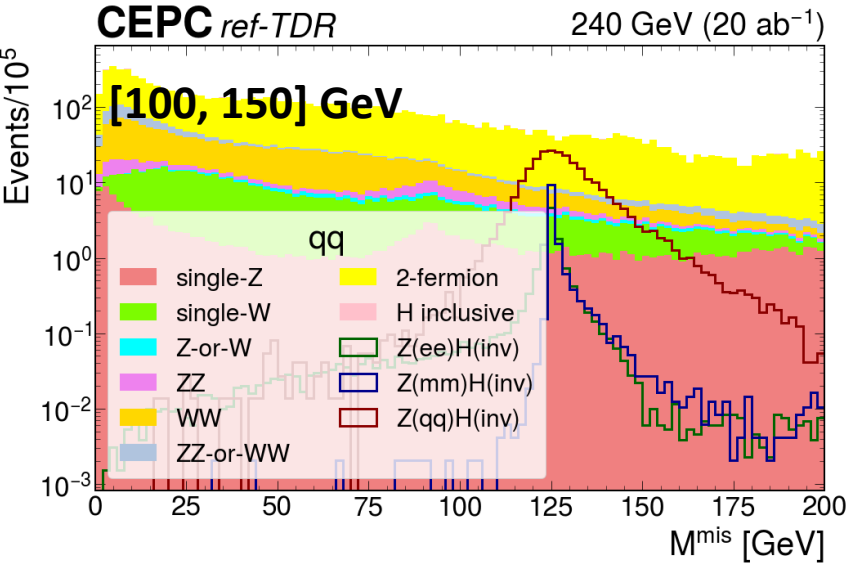
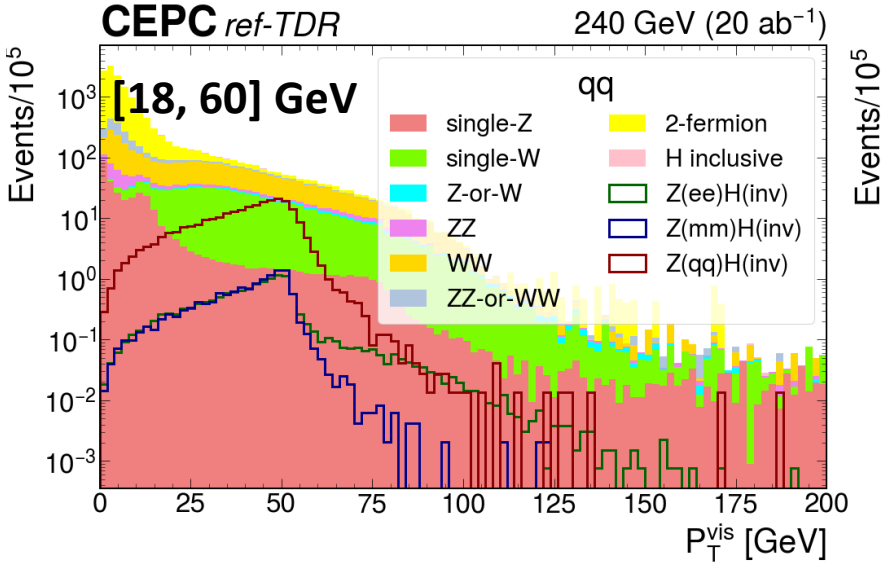
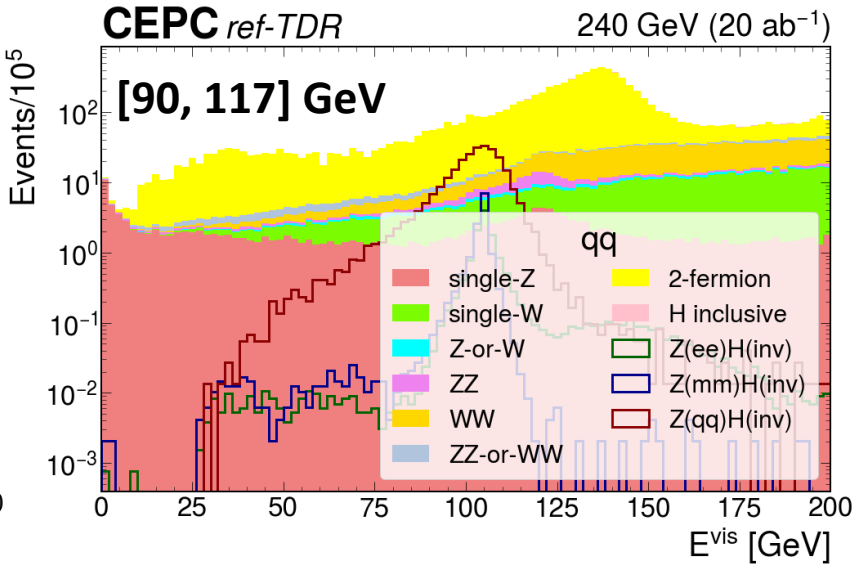
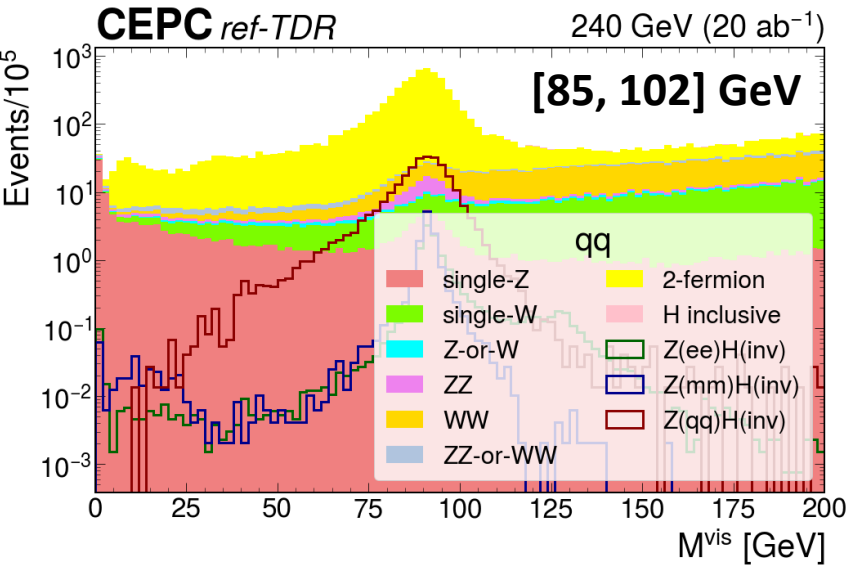
A cut on decay vertex is missed !!!

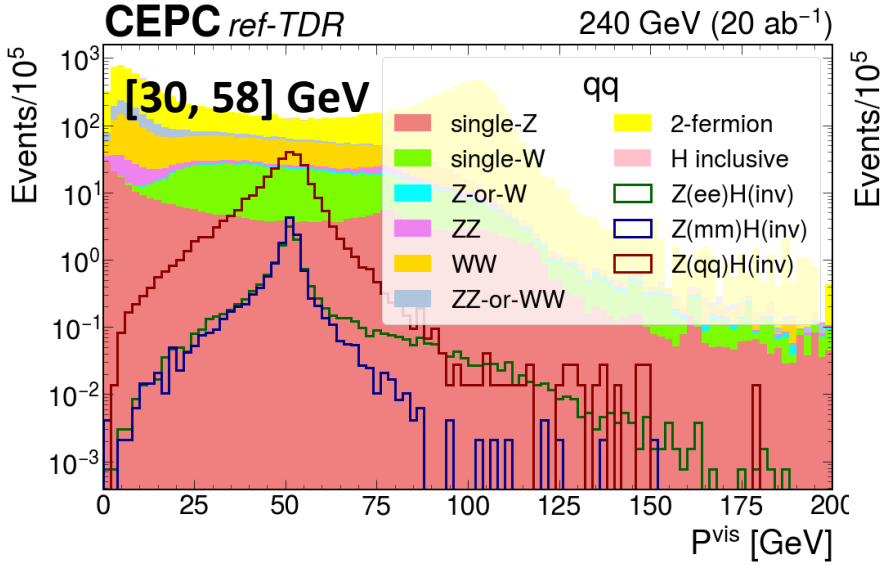
- qq final state

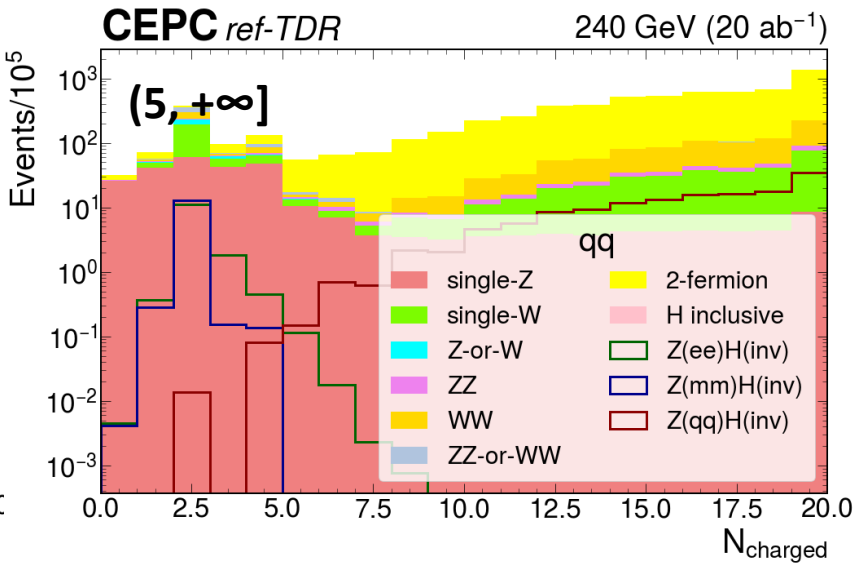












Kinematic selection

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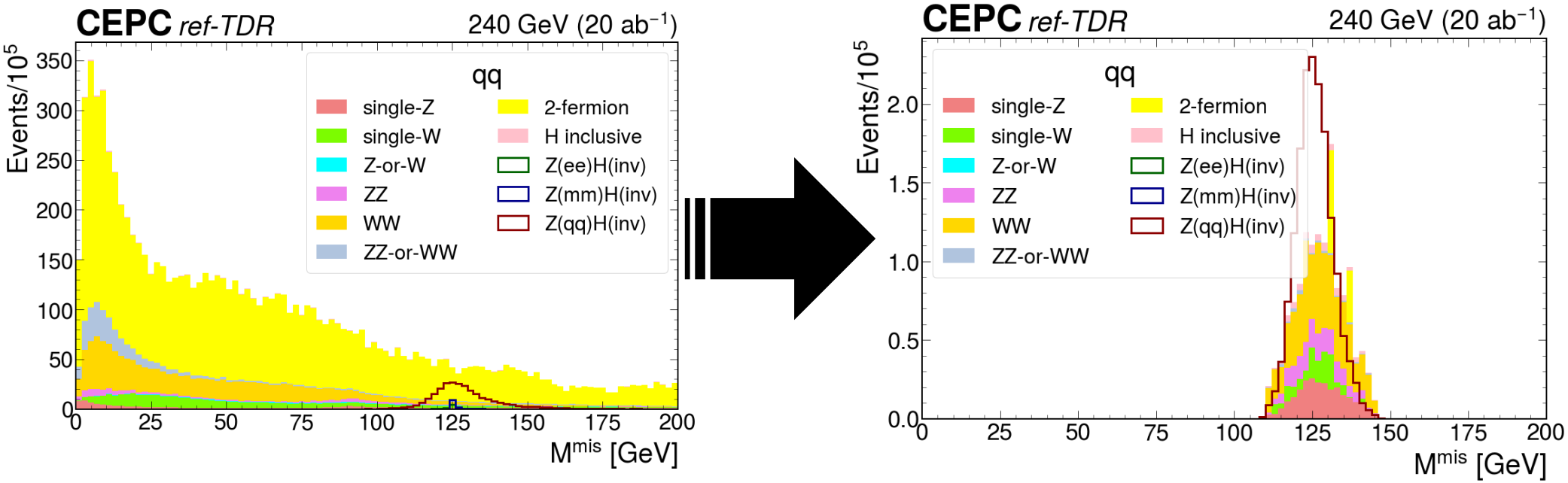
➢ qq final state

Process	eeH	mmH	qqH	sz	sw	szw	zz	ww	zzww	2f	Hincl	All bkg
Total yield	140800	135400	2736200	32403400	69705000	4989600	22819400	181522200	73003000	1082137200	4073200	140800
Kin sel	23	0	1626945	244397	128022	0	182434	601706	20246	97783	55033	23
eff (%)	0.0163	0.000	59.460	0.754	0.184	0.000	0.800	0.332	0.028	0.009	1.351	0.0163
eff CDR (%)	-	-	60.81	0.66	0.06	0.00	0.64	0.21	0.02	0.00	0.97	0.03



Preliminary results

- With 5.6 ab-1 or 20 ab-1
- Fit M_{mis}
- No systematic uncertainties
- Compute **expected** BR(H→invisible)
  - SM BR(H→invisible)≈0.1%

5.6 ab-1

Final state	Uncertainty	Upper limit	Upper limit (CDR)
ee	$(1.00^{+4.68}_{-1.00}) \cdot 0.1\%$	0.921%	1.08%
μμ	$(1.00^{+2.53}_{-1.00}) \cdot 0.1\%$	0.495%	0.55%
qq	$(1.00^{+1.21}_{-1.00}) \cdot 0.1\%$	0.237%	0.27%
All	$(1.00^{+1.05}_{-0.92}) \cdot 0.1\%$	0.202%	0.26%

20 ab-1

Final state	Uncertainty	Upper limit
ee	$(1.00^{+2.46}_{-1.00}) \cdot 0.1\%$	0.483%
μμ	$(1.00^{+1.28}_{-0.86}) \cdot 0.1\%$	0.234%
qq	$(1.00^{+0.64}_{-0.64}) \cdot 0.1\%$	0.125%
All	$(1.00^{+0.55}_{-0.53}) \cdot 0.1\%$	0.102%

Next steps

- **Samples**
  - Add ee->ll backgrounds
  - More sample production after new release of CEPCSW

- **Optimization of selection criteria**
  - In ee/μμ final states: isolation, number of charged PFOs, etc
  - In qq final states: jet substructure, vertex

- **Categorization (not necessary)**
  - Based on jet flavor

- **Consideration of systematic uncertainties**
  - Beam-induced background
  - Luminosity measurement
  - Efficiency / resolution uncertainties