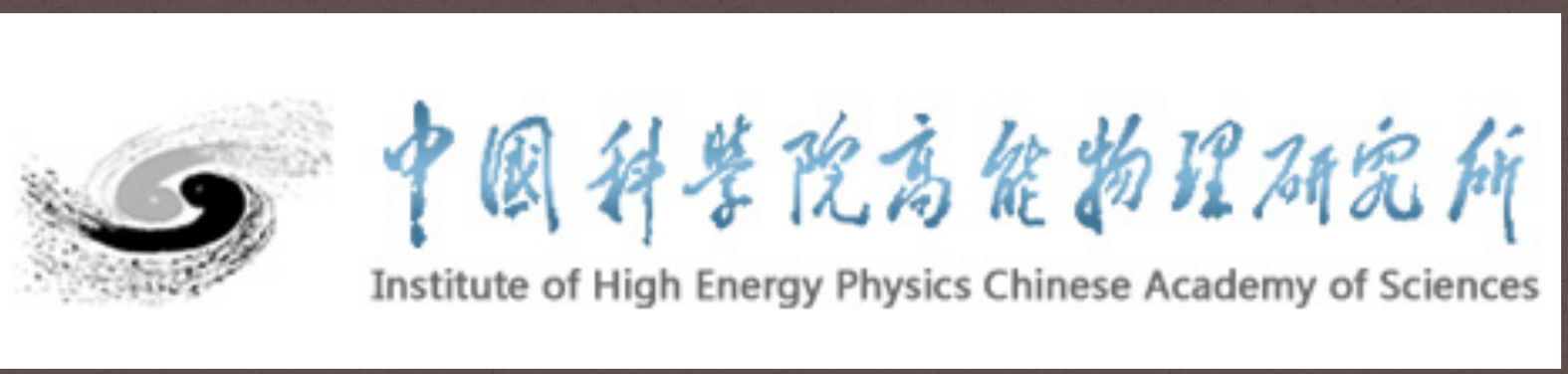
Lepton Reconstruction & H→ττ Measurement at CEPC

FCC Workshop 2020

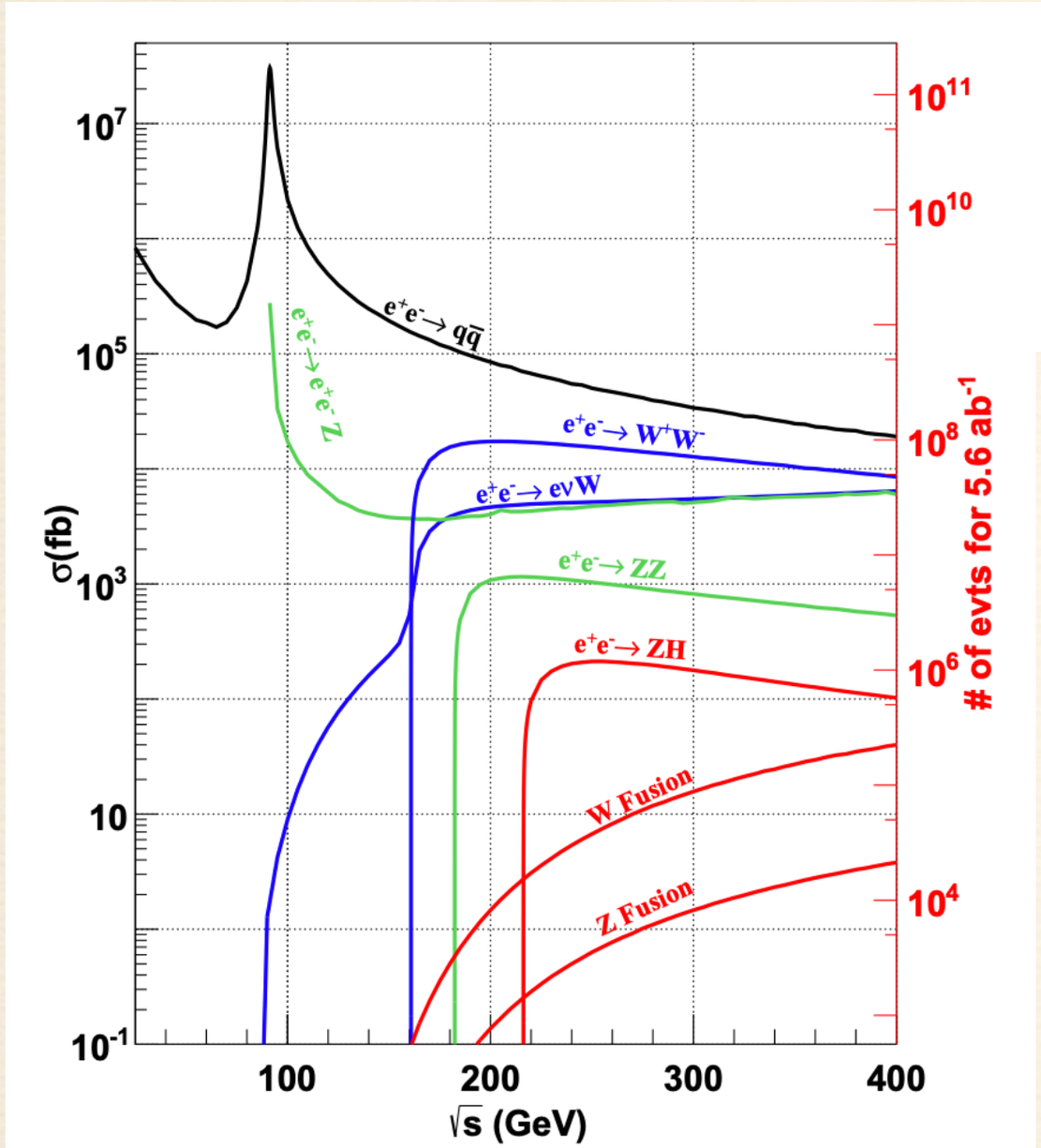
Dan YU, Manqi RUAN

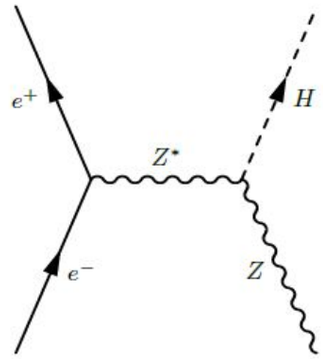


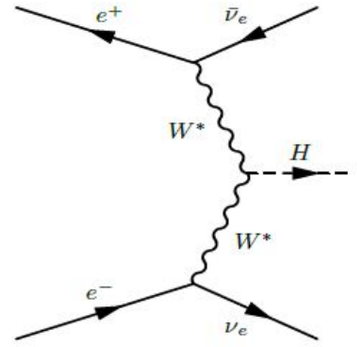
Plan

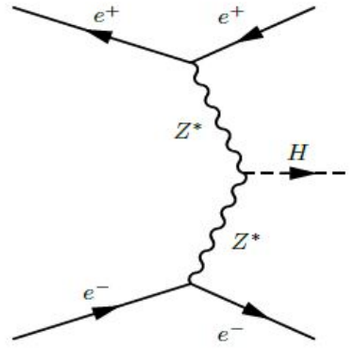
- Introduction
- Lepton Identification
  - Single lepton
  - Lepton in jets
- τ Identification
  - Signal strength analysis
  - τ decay
- Summary

CEPC





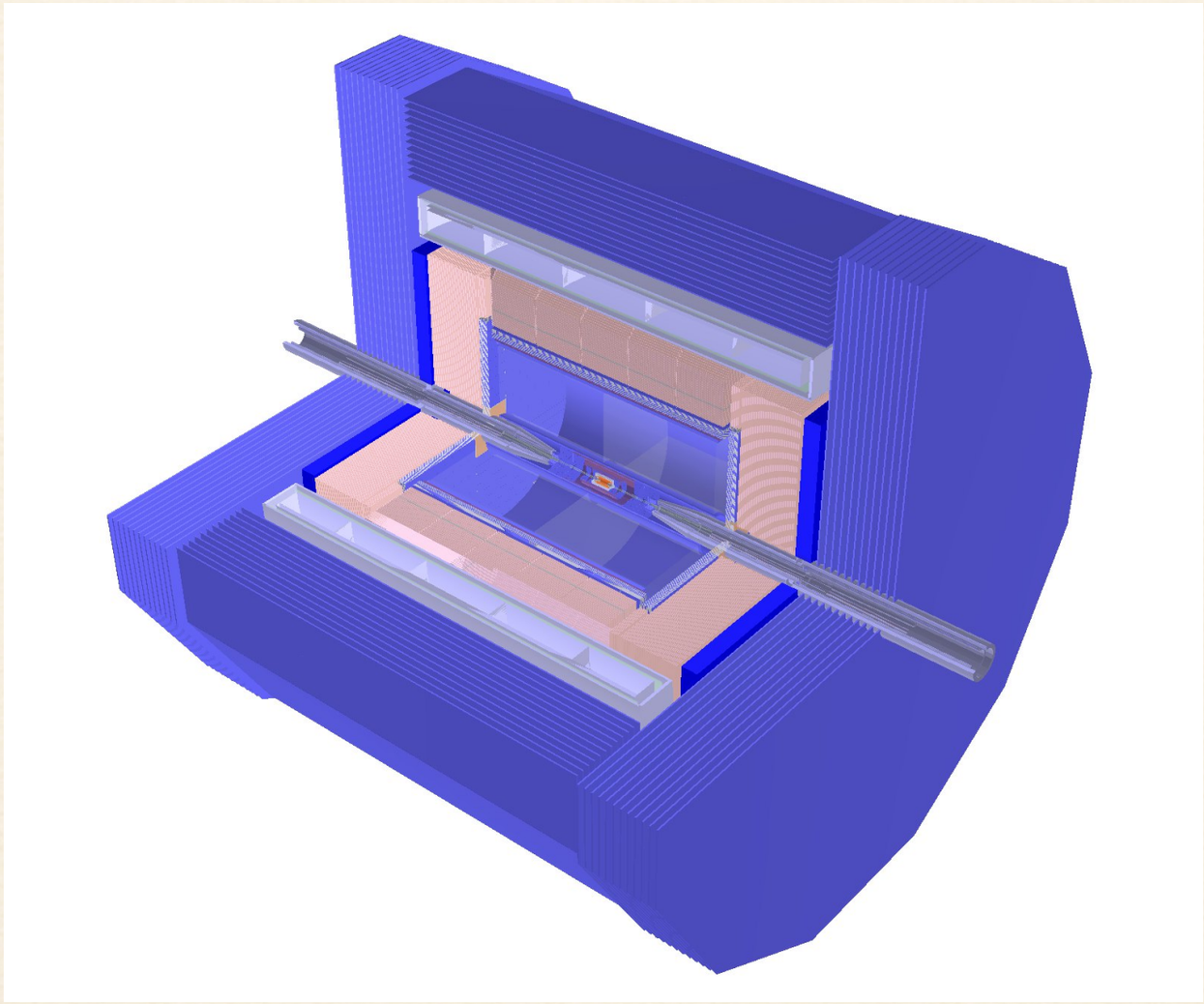




- Higgs factory: 240 GeV, 10^6 Higgs,
  - Advantage: Clean, Known initial states
  - Measurements: Higgs boson mass, cross section, decay modes, branching ratio
- Z factory: 91 GeV, 6×10^{11}
  - EW precision physics
- WW threshold runs, ~160GeV, 10^8
  - W mass/width measurement
- PFA Oriented detector

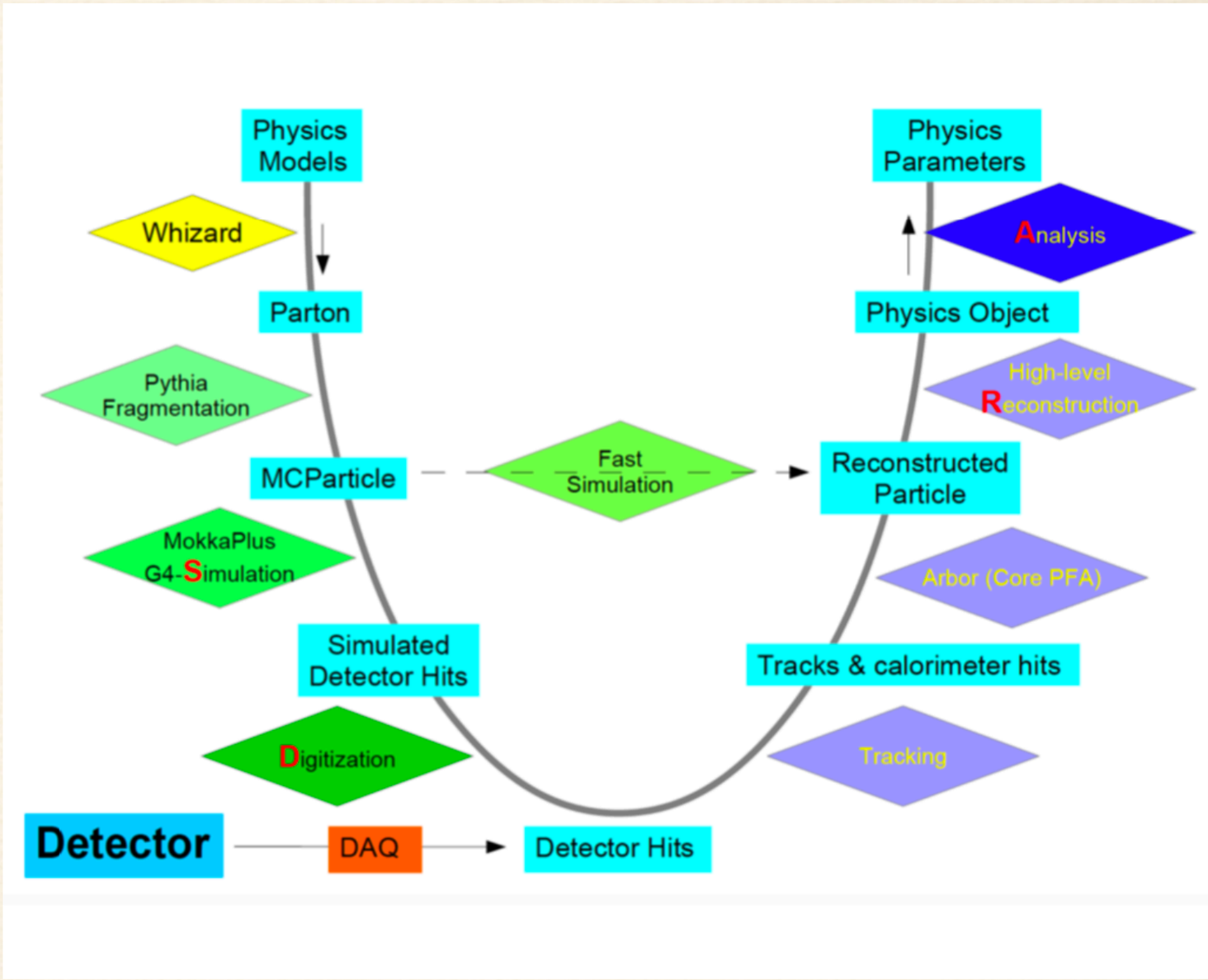
CEPC Detector Baseline

- PFA Oriented concept using High Granularity Calorimeter + TPC (*Option: full silicon tracker*)
- Alternative: Innovative Detector for Electron-positron Accelerator (IDEA)



CEPC Full Simulation

- Software chain
- CDR Samples:
  - Full simulated Higgs signal
  - small cross-section(<20 fb): simulated to a minimal statistic of 100k
  - 4 fermion background Full simulated
  - 2 fermion background: 20% simulated

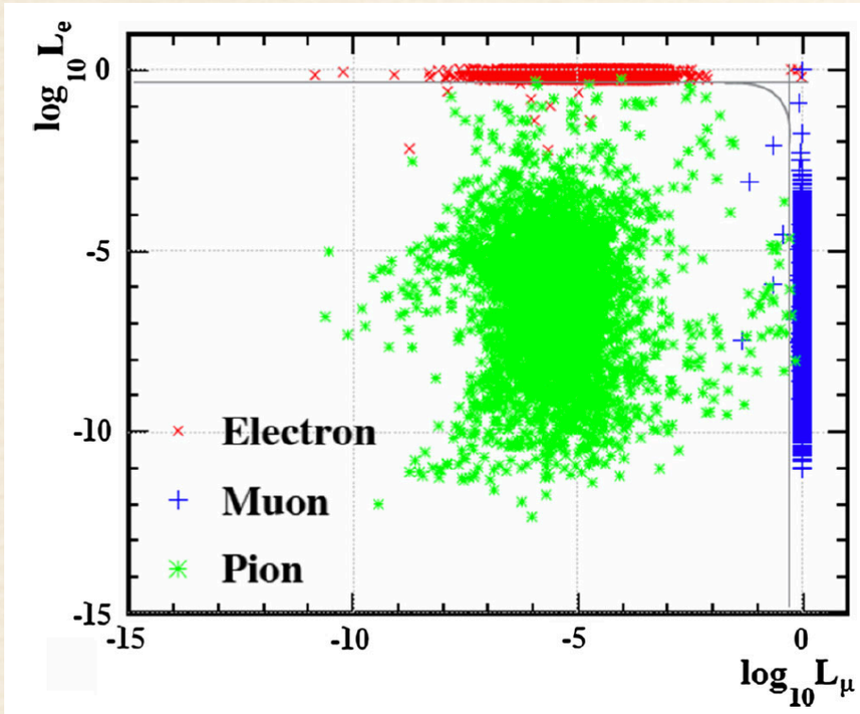


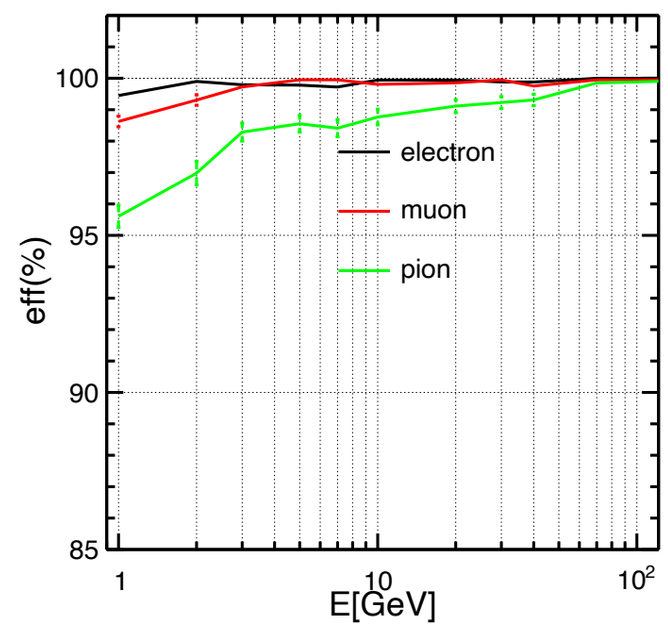
Light Lepton

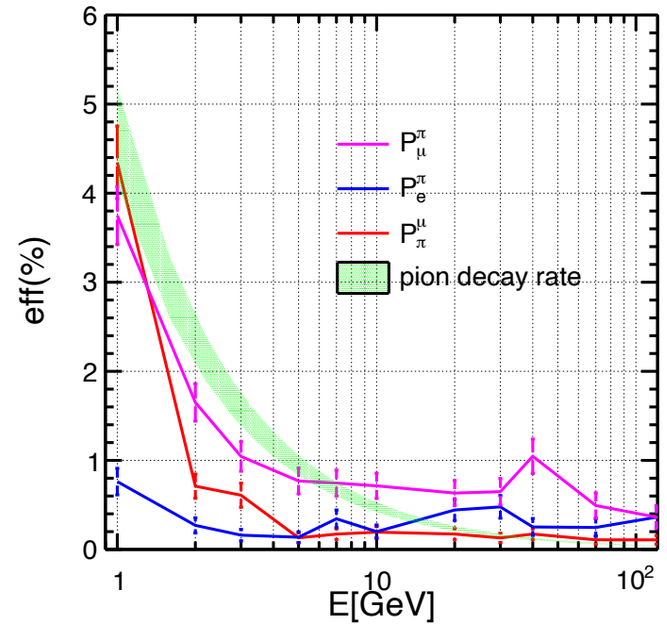
Essential to the precise Higgs measurements
jet flavor tagging and the jet charge measurement

Light Lepton Identification

- LICH uses TMVA methods to summarize 24 input variables into two likelihoods, corresponding to electrons and muons.
- The efficiency for electron and muon is higher than 99.5% (E>2 GeV). Pion efficiency ~ 98%.







Migration Matrix at 40GeV (LICH)

Type	e^- like	μ^- like	π^+ like
e^-	99.71 ± 0.08	< 0.07	0.21 ± 0.07
μ^-	< 0.07	99.87 ± 0.08	0.05 ± 0.05
π^+	0.14 ± 0.05	0.35 ± 0.08	99.26 ± 0.12

Migration Matrix for ALEPH PID ($> 2GeV$)(*Eur.Phys.J.C20:401-430,2001*)

Type	e^- like	μ^- like	π^+ like	undefined
e^-	99.57 ± 0.07	< 0.01	0.32 ± 0.0	0.09 ± 0.04
μ^-	< 0.01	99.11 ± 0.08	0.88 ± 0.08	0.01 ± 0.01
π^+	0.71 ± 0.04	0.72 ± 0.04	98.45 ± 0.06	0.12 ± 0.03

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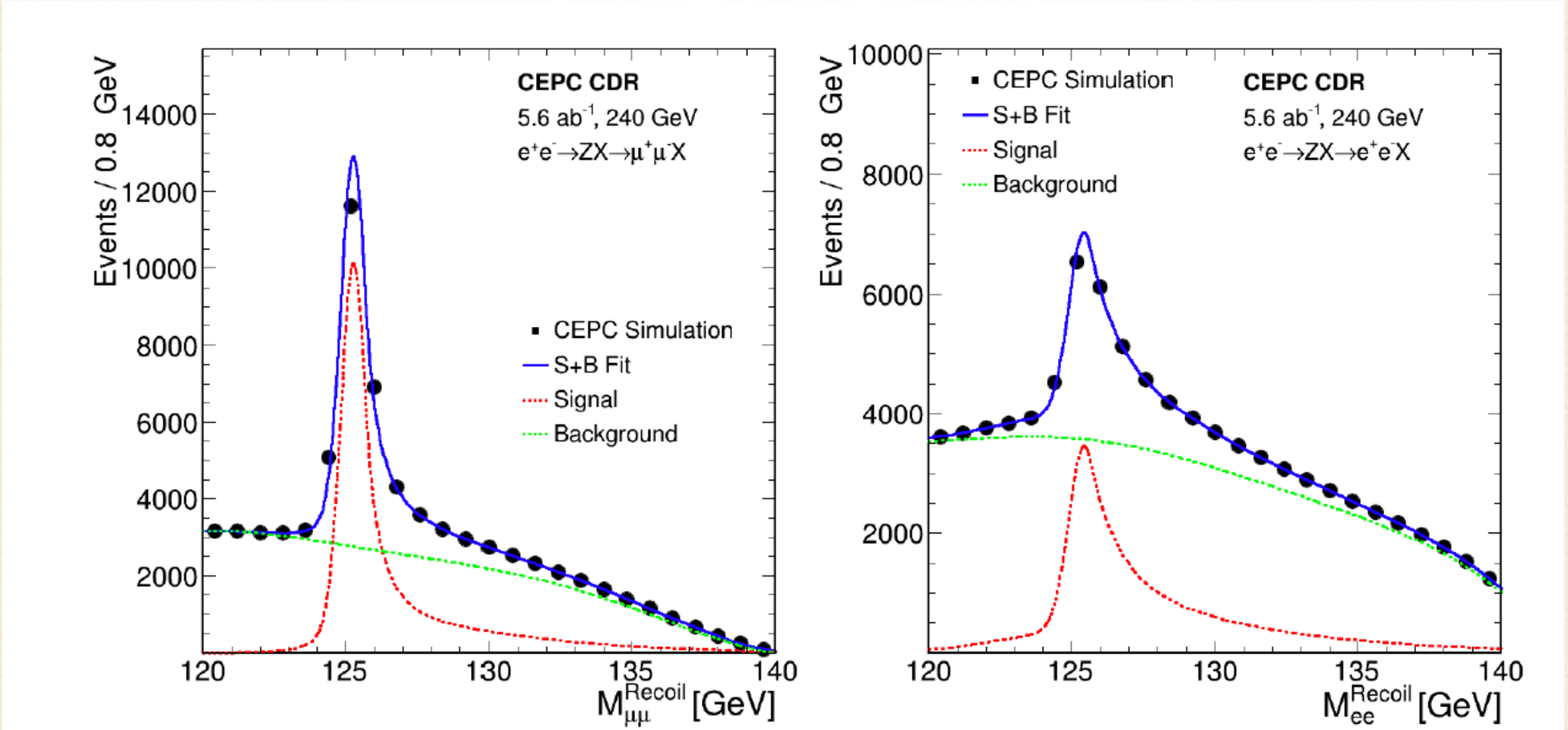
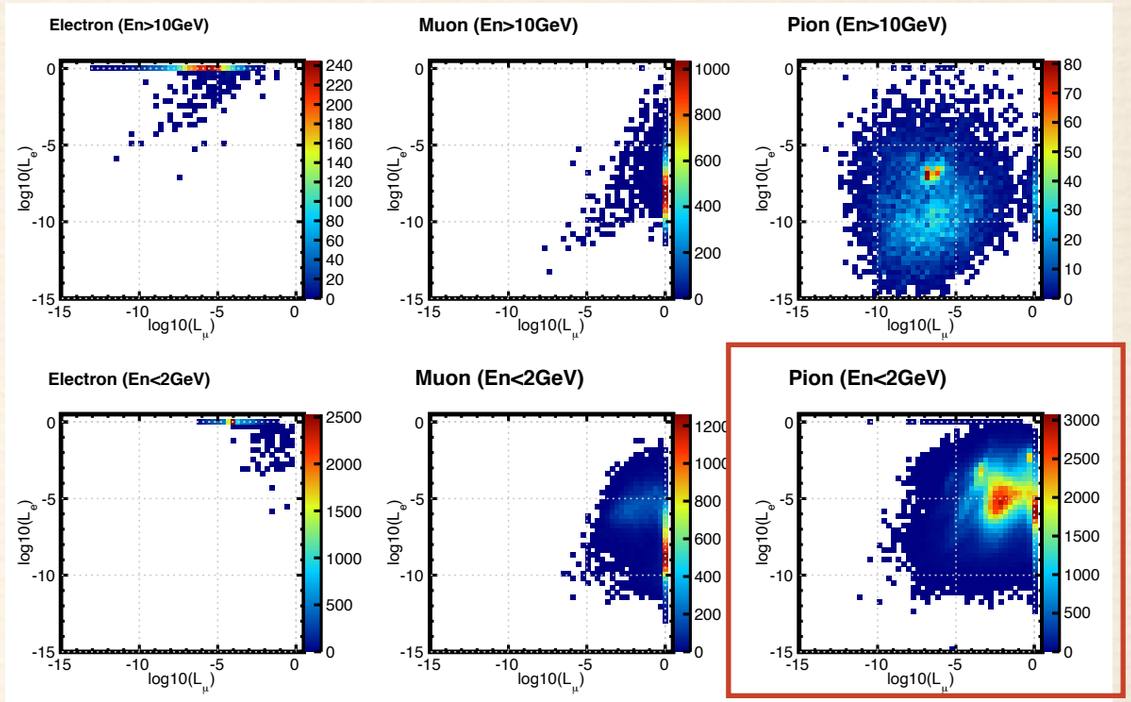
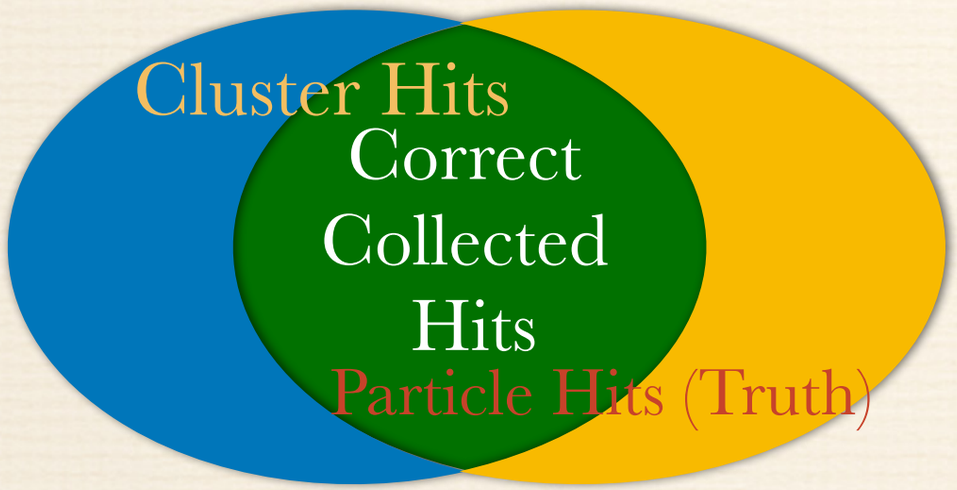
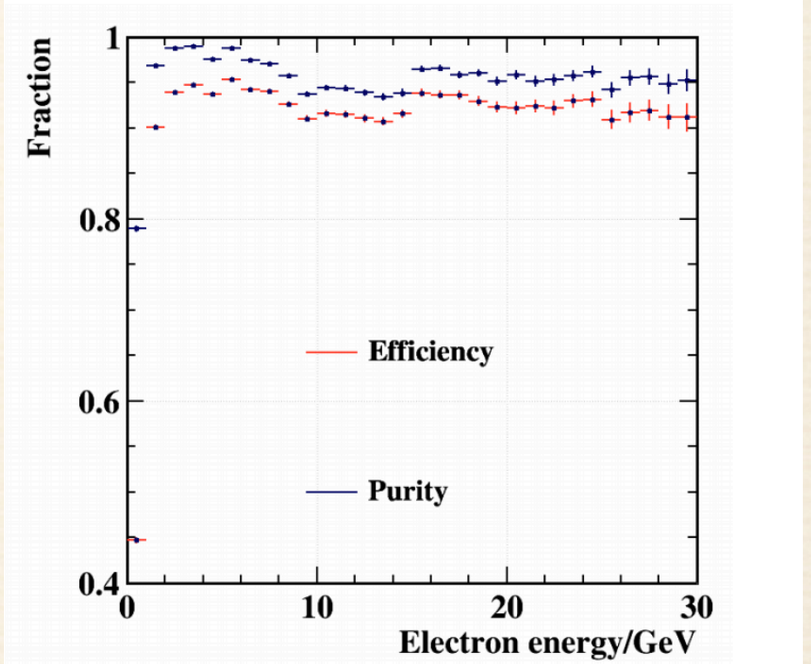


Lepton Identification in Jets

- The performance for lepton in jets degrades comparing to the single particle results because of the high statistics of background and the clustering
  - For higher energy, still nice separation
  - For lower energy, pion mixed with muon
- Correlation between lepton id performance and the calorimeter clustering performance identified
  - For inclusive leptons ~90% level
  - For the objects with better clustering performance (about 40%), performance ~ isolated case







electron efficiency and purity in Bc→τν evnets
(*by Taifan ZHENG*)

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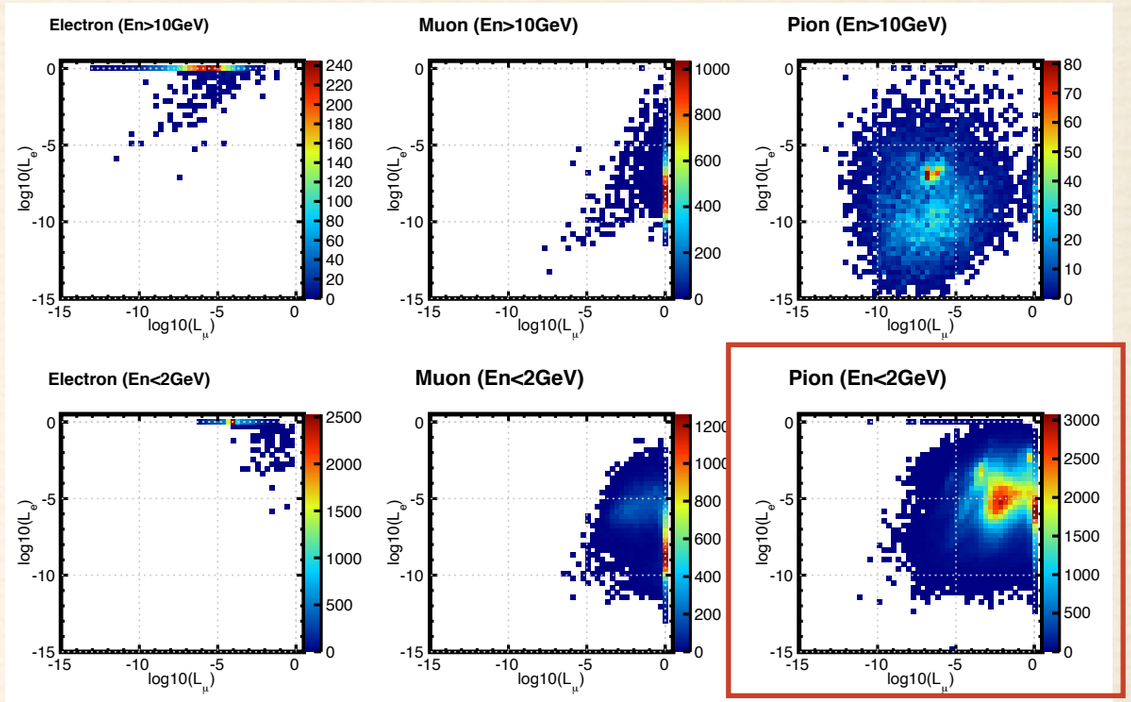
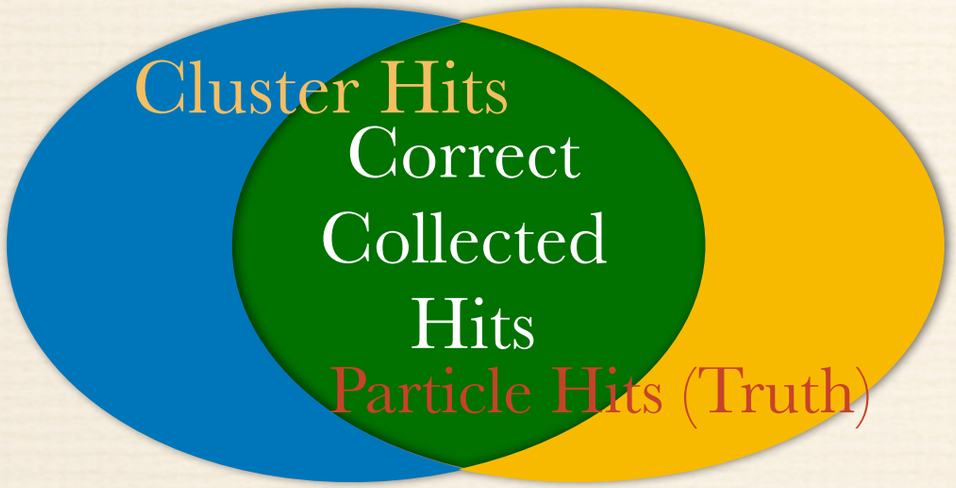
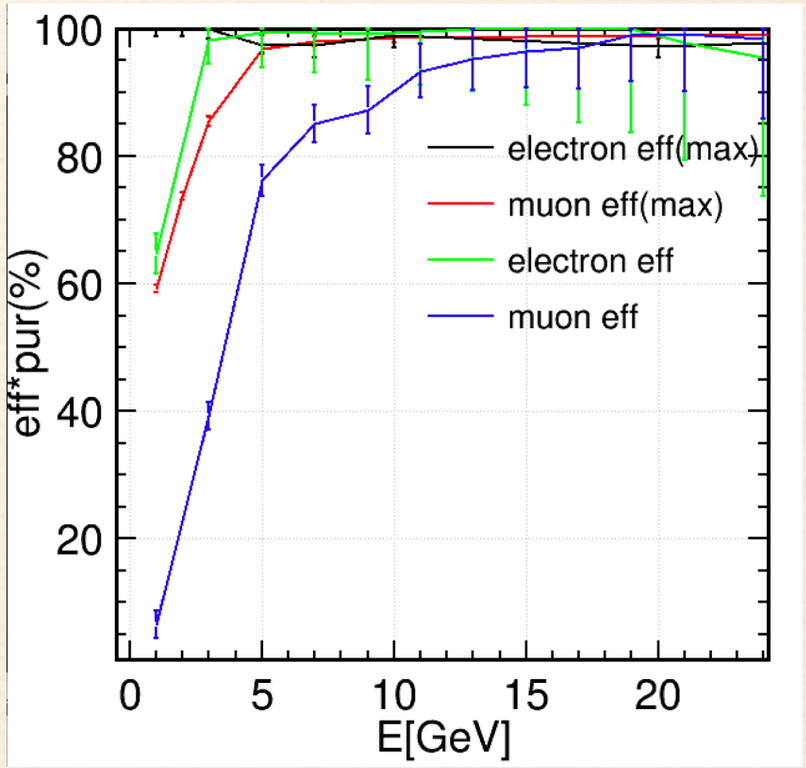






τ Identification and Reconstruction

Tau is the heaviest SM lepton - large coupling to Higgs boson Br(H → ττ): 6.27%

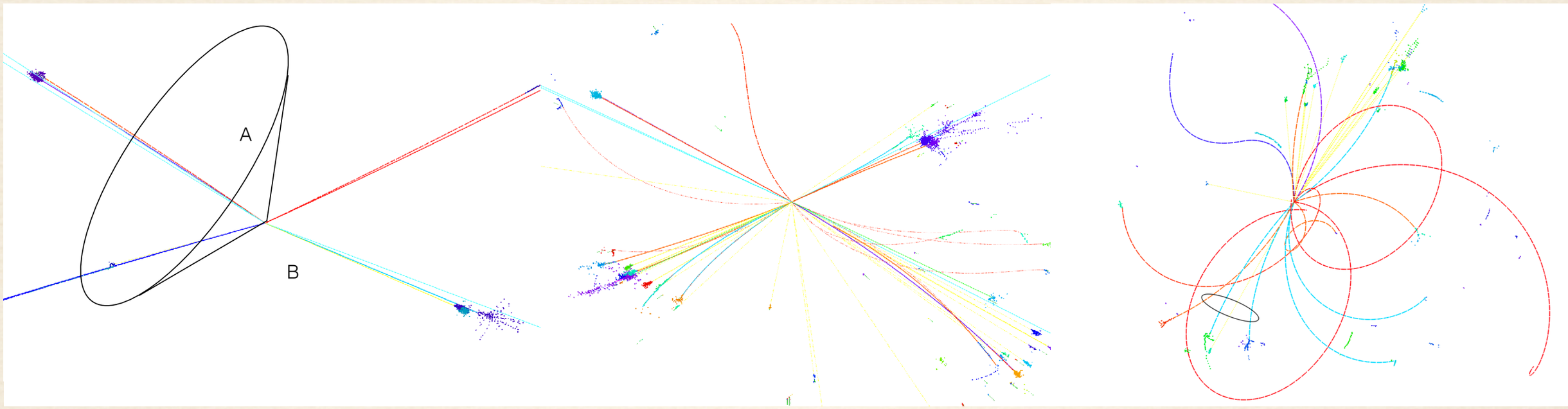
Rich relevant physics

Performance rely on particle separation

Testbed for PFA/Objectives for detector optimization

Event topology

- llH channel / Z→ττ
- qqH (isolate τ with jets)
- τ inside jets

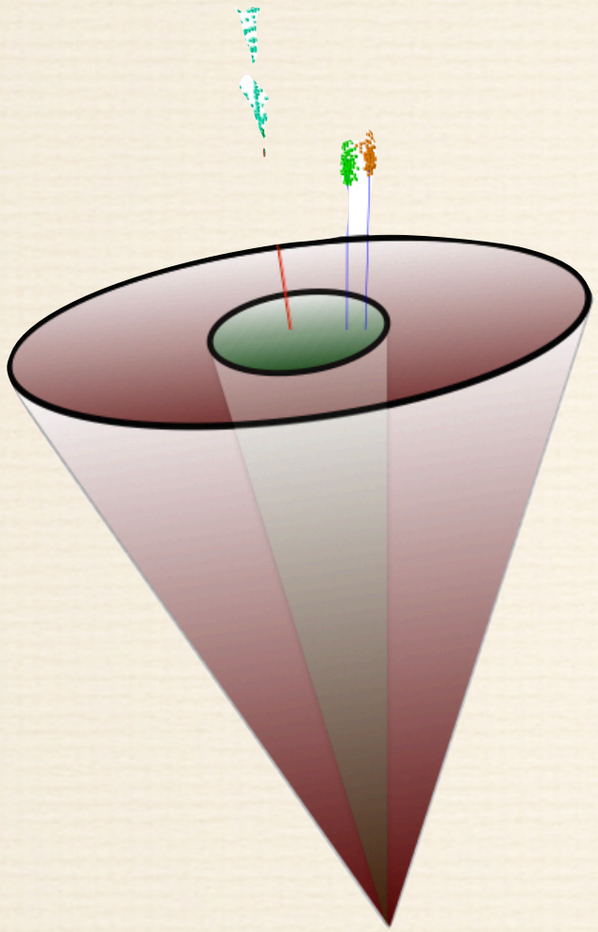


- (Veto the two isolate lepton)
- Divide the whole space into 2 part
- Multiplicity & Impact parameter

- Tau jet reconstruction package: TAURUS

- TAURUS with different parameters

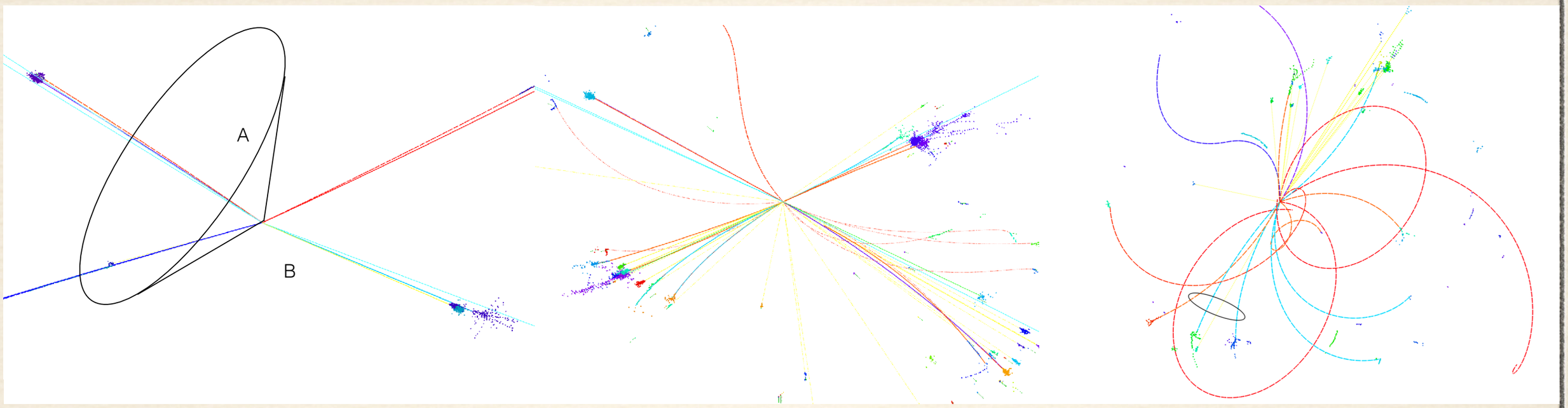
Taurus



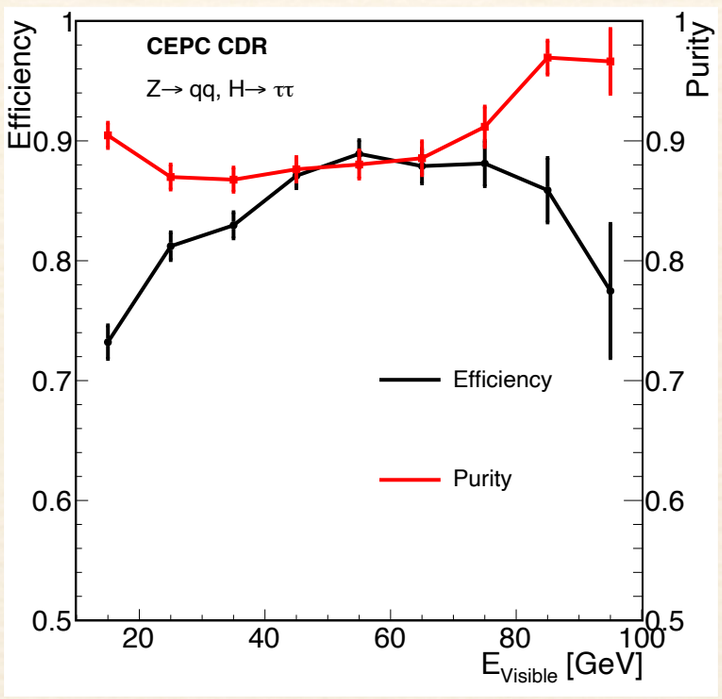
- Double cone based algorithm
  - Find seeds(Tracks with enough energy)
  - Collect particle in two cones
  - Use the multiplicity, energy ratio between two cones, invariant mass for τ tagging

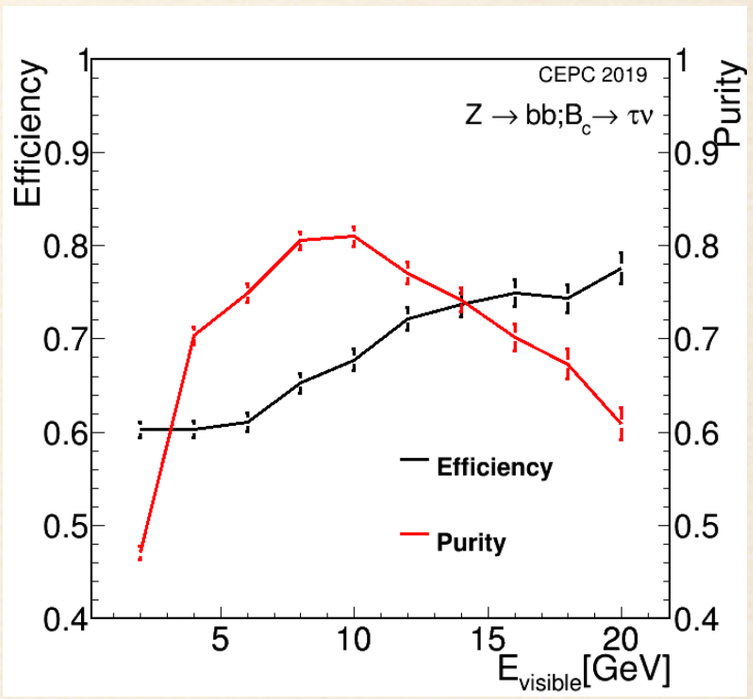
Event topology

- llH channel / Z→ττ
- qqH (isolate τ with jets)
- τ inside jets



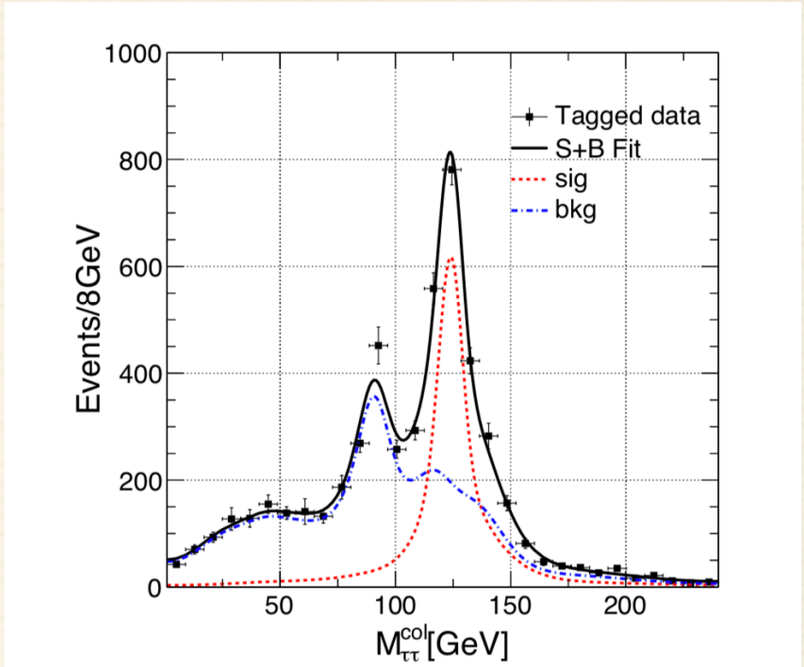
- (Veto the two isolate lepton)
- Divide the whole space into 2 part
- Multiplicity & Impact parameter
- Efficiency > 90%





Signal Strength Analysis (without jets)

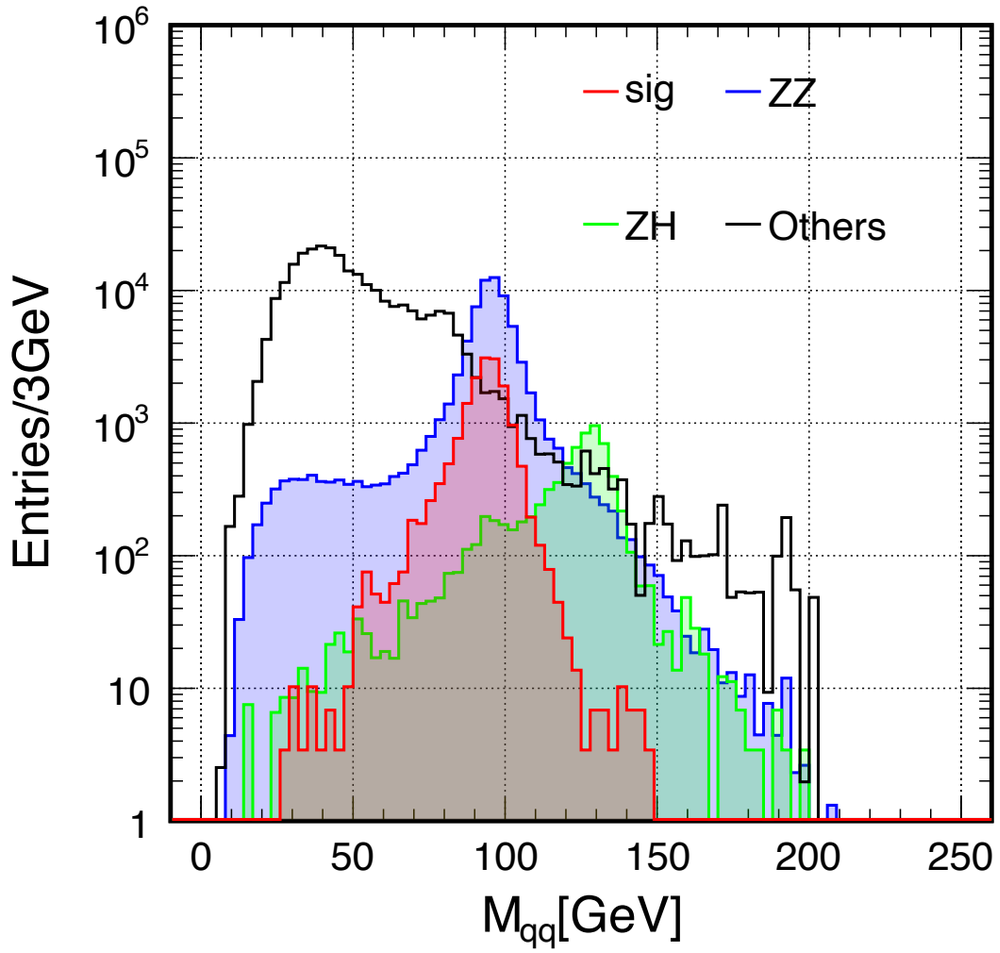
- (μμ/ee information)
- Use the multiplicity and impact parameter for ττ event selection.
- Fit the collinear mass for signal and background statistics

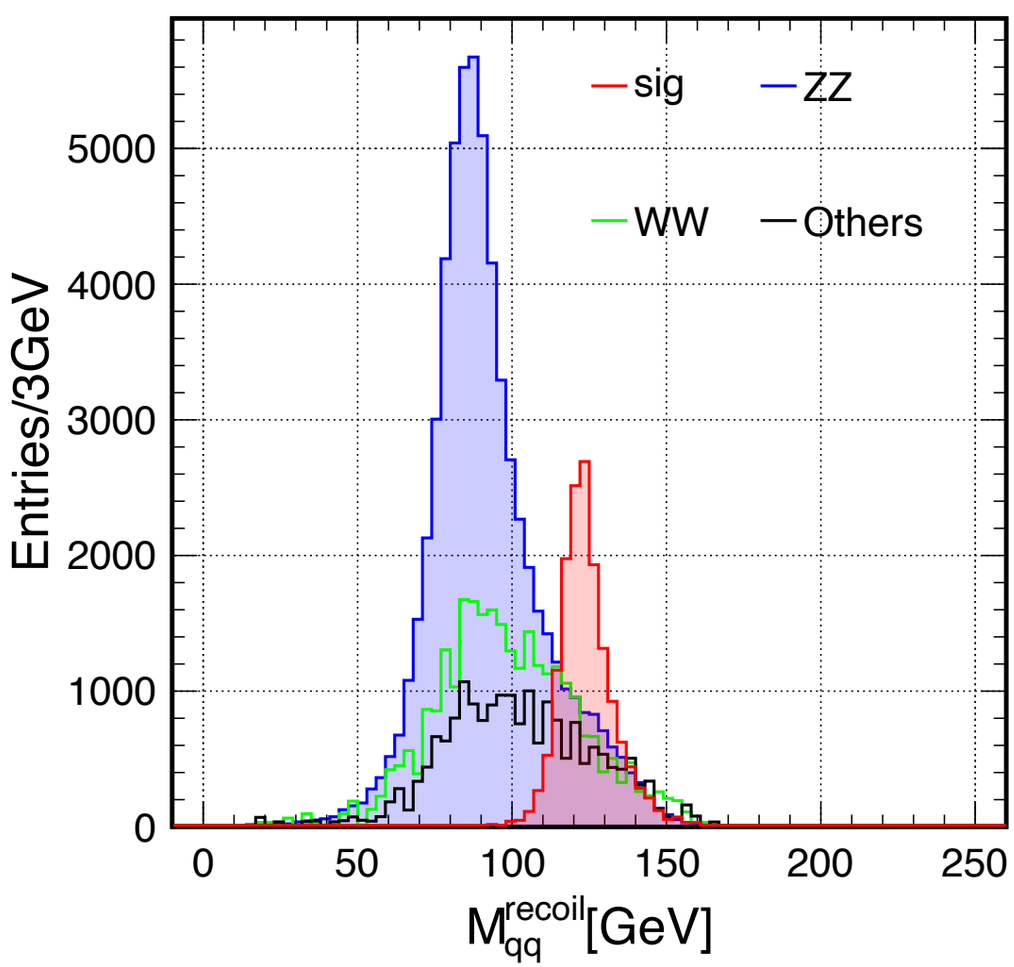


	$\mu\mu H\tau\tau$	$2f$	SW	SZ	WW	ZZ	mixed	ZH	total Bkg	$\sqrt{S+B}/S(\%)$
total generated	2388	801152078	19517399	9072946	50826211	6389424	21839941	1102582	909900581	1263.17
$N_{\mu^+} > 1, N_{\mu^-} > 1$	2341	22894549	37923	720547	1335231	831861	1251657	567636	27639404	233.56
$115GeV < M_{recoil} < 160GeV$	2186	864849	154	155502	396485	112837	164225	3114	1697166	61.75
$60GeV < M_{invariant} < 105GeV$	2118	662042	0	31145	111376	56642	99874	987	962066	48.08
$E_{Le} < 65GeV$	2101	658199	0	17760	111340	56516	99822	957	944594	48.02
$N_{Trk}(A/B) < 6$ & $N_{Ph}(A/B) < 7$	1977	78	0	996	2576	8019	29	105	11803	6.16
BDT>0.78	1891	0	0	264	231	3682	9	39	4225	4.26
$M_{\tau\tau}^{col} > 0$	1853	0	0	259	88	3099	9	35	3490	4.07
$\tau\tau$ collinear mass fit result										2.75

Signal Strength Analysis (with jets)

- Strategy:
  - τ pair selection
  - Jet system information
  - Fit on impact parameter

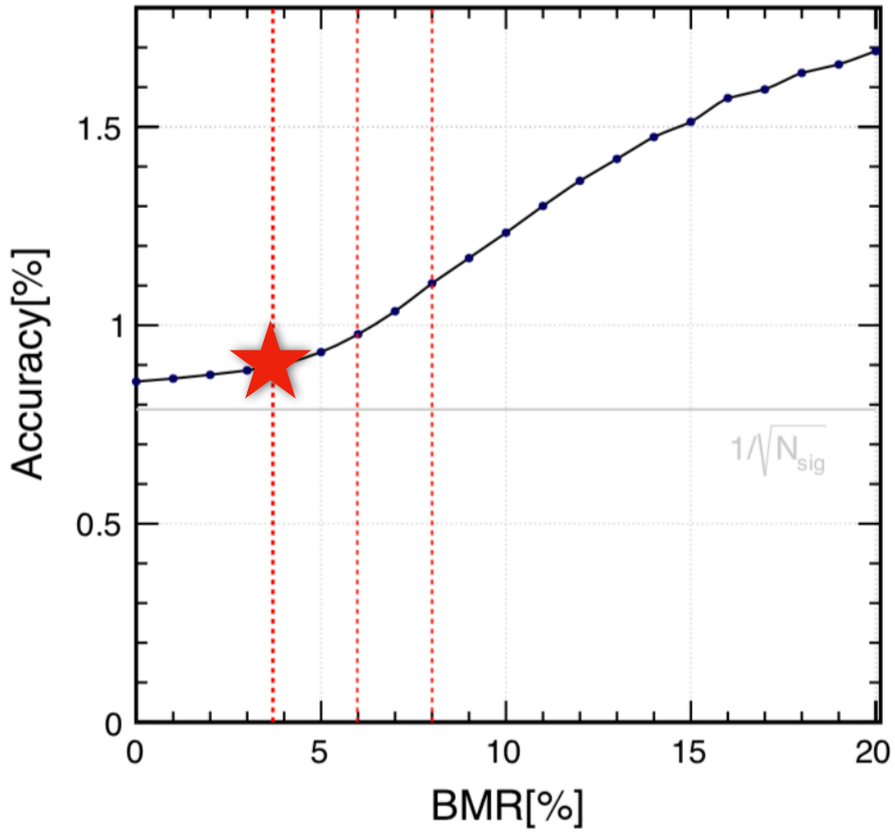




Results & BMR Dependency

- Combined Accuracy: 0.8%
- BMR: boson mass resolution, Separate W/Z/H in hadronic decays
- 3.8% for the current Detector+PFA
- qqH signal strength accuracy degrades by 20% if the boson mass resolution degrades from 3.8% to 8%.

	$\delta(\sigma\times BR)/(\sigma\times BR)$
$\mu\mu H$	2.8%
eeH	5.1%
$\nu\nu H$	7.9%
qqH	0.9%
combined	0.8%



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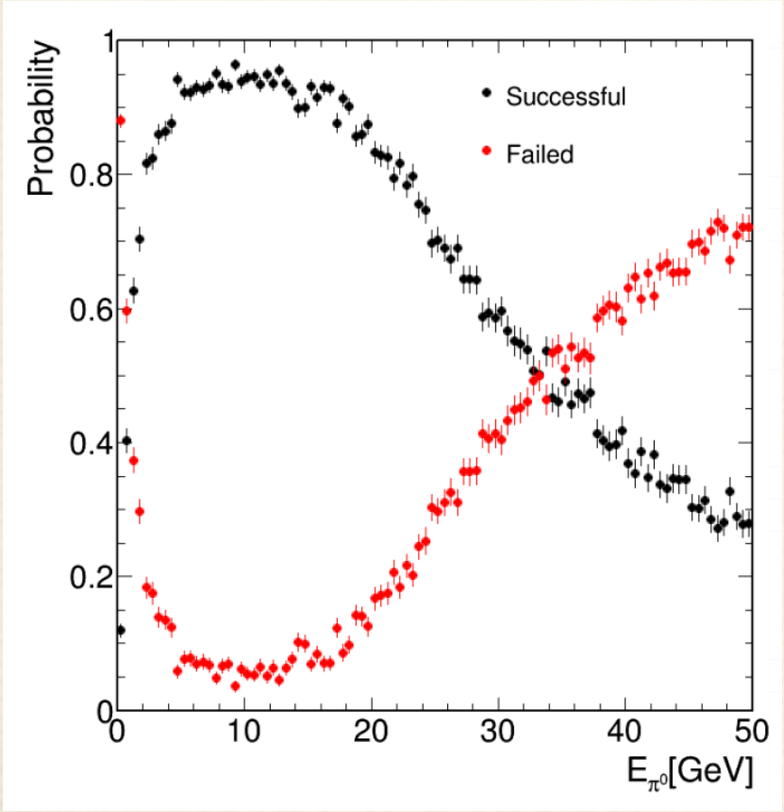
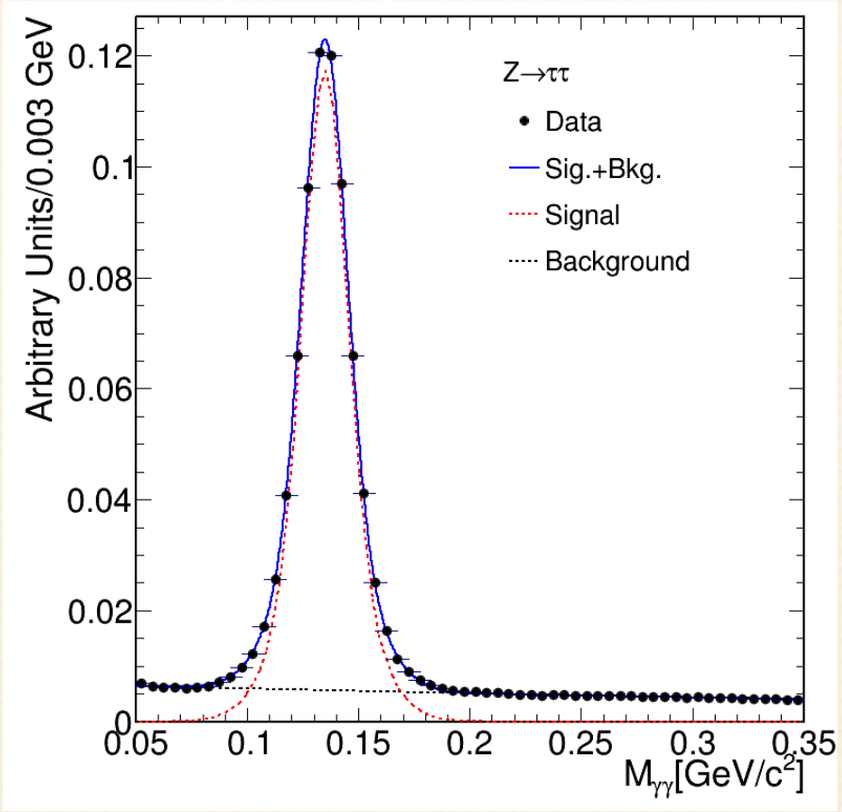
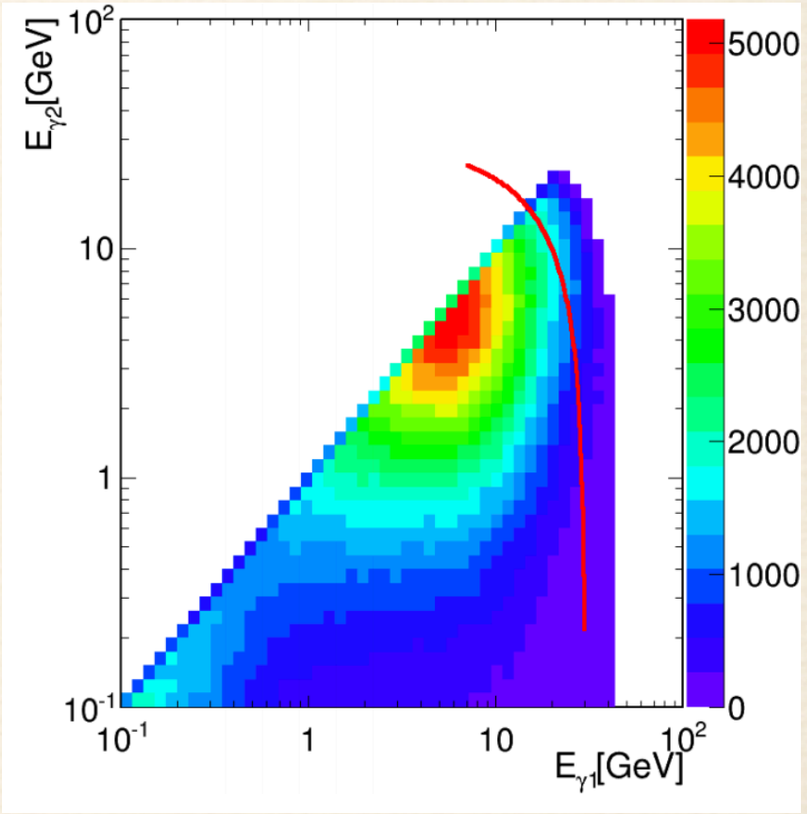
π0 Reconstruction

- Important for τ decay mode identification
- Difficulty: low energy photon reconstruction & merging
- most π0 in τ with energy < 30GeV







By Yuqiao SHEN

Summary

- TMVA based lepton identification has been developed with high efficiency
  - For >2GeV isolate lepton: 99.5%
  - For leptons in jets, at clustering eff*purity > 90%, identification performance converge to isolated lepton cases
- Inclusive τ identification developed with efficiency ~ 80%
  - PFA plays important role in Higgs to ττ analysis (final relative accuracy: 0.8%)
  - Decay modes identification ongoing
  - Better photon/π0 reconstruction needed (ongoing)
- Plan
  - τ in jets
  - CP
  - Exotic decay

Thank you for your attention!

Backup

Signal Strength Analysis (with jets)

- Event selection: qq system information

	$qqH\tau\tau$	$2f$	SW	SZ	WW	ZZ	mixed	ZH	total Bkg	$\sqrt{S+B}/S$ (%)
Total Statistic	48266	801152078	19517399	9072946	50826211	6389424	21839941	374357	909679268	62.43
NCh>10	47347	272992986	13765307	1969972	47052263	5756249	18020636	331843	359889260	40.07
$110GeV < E_{tot} < 235GeV$	46183	173589861	13159096	942644	31297172	3239464	5154115	264535	227646887	32.67
$E_{Le} < 45GeV, E_{L\mu} < 65GeV$	44093	169589868	3413790	707027	22428227	2911836	4985026	237240	204273014	32.41
$N_{\tau+} > 0, N_{\tau-} > 0$	24214	401147	212183	13999	1129502	171380	193055	16821	2138087	6.55
$90GeV < M_{\tau\tau}^{col} < 160GeV$	17176	9717	21483	1689	135538	62721	7722	5305	244175	2.97
$70GeV < M_{qq} < 110GeV$	16257	1596	4119	1012	26823	52307	1818	717	88392	1.98
$M_{qq}^{rec}(GeV) > 100GeV$	16211	0	1463	637	11071	13814	1265	647	28897	1.31
2-D impact parameter fit result										0.93

Tau decay mode analysis

	No Trk	1-prong(l)	1-prong(h)	1prong + 1photon	1prong + 2photon	1prong + 3photon	1prong + 4photon	1prong + 5photon	3prong	3prong+ 2photon	other
1-prong(l)	3.58	88.42	3.17	2.58	0.04	0	0	0	0.35	0	Ntrk>1
1-prong(h)	5.90	5.76	78.17	4.49	0.82	0.20	0.06	0	1.16	0	Ntrk>1
1prong + 2photon	2.47	1.31	0.88	29.01	58.34	3.27	0.21	0.01	0.03	1.59	Ntrk>1
1prong + 4photon	1.93	1.23	0.17	1.78	9.75	31.07	45.01	3.24	0	0.19	Ntrk>1
3prong	1.34	1.93	0.34	0.15	0.05	0	0	0	88.44	0.24	Ntrk=2
3prong + 2photon	1.12	1.68	0.14	0.10	0.33	0.10	0.02	0.01	1.08	63.94	Nph=1