Higgs to di-photon analysis and photon energy reconstruction

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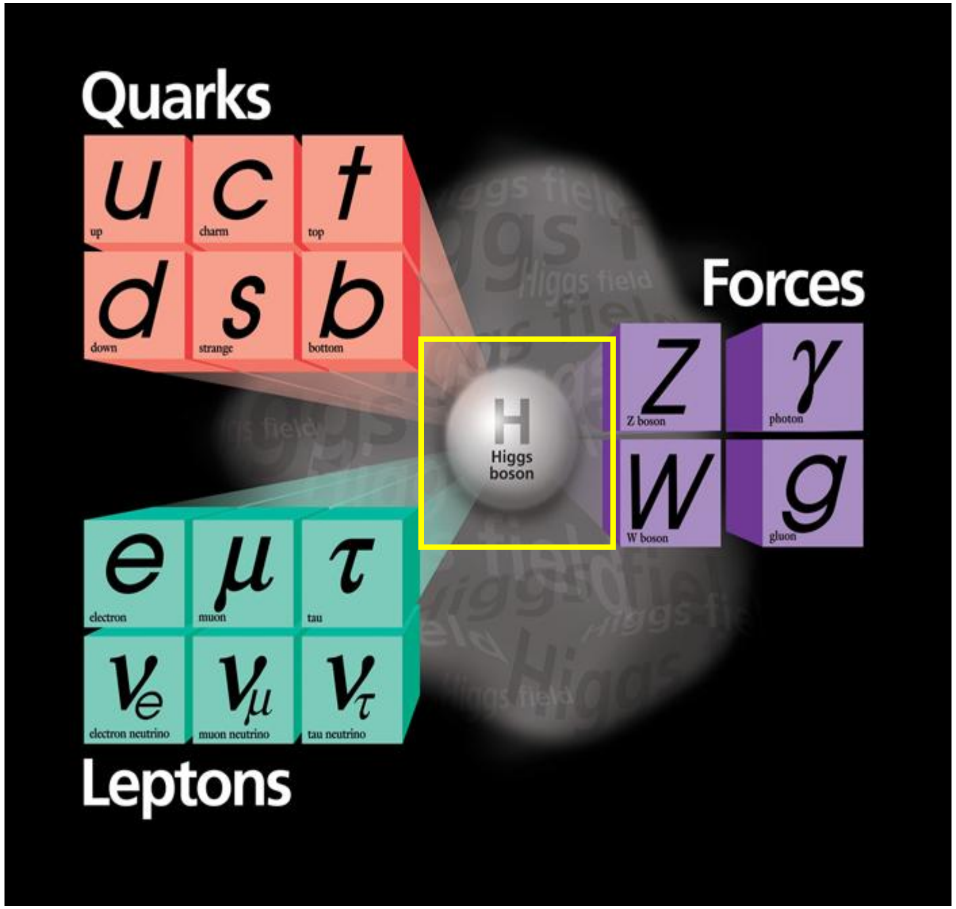
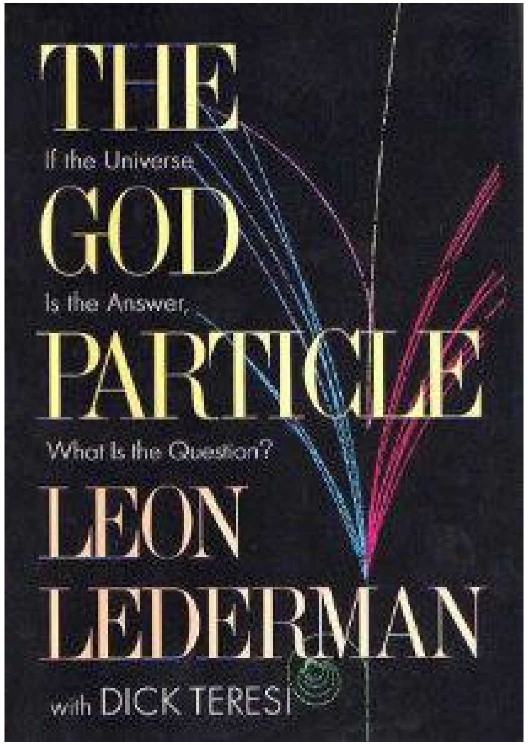
Outline

- From the Higgs to CEPC
- Analysis of Higgs to di-photon with fast simulation
- Photon reconstruction with full simulation
- Summary and plan

Stand model & Higgs

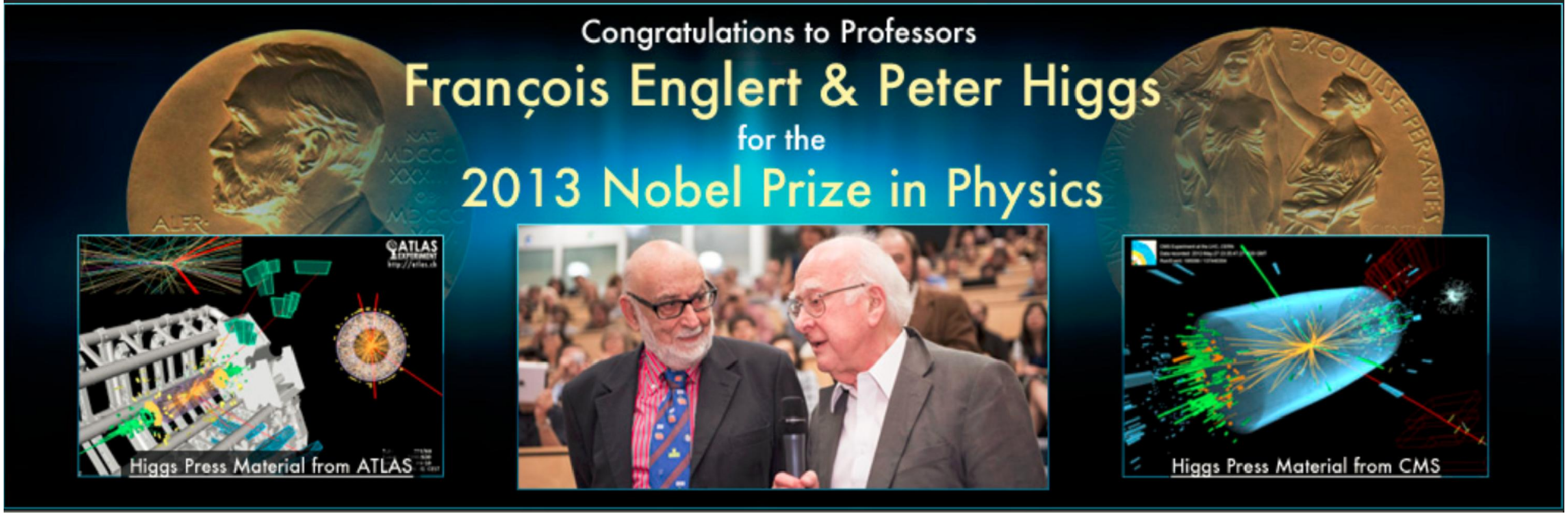


➔**Higgs** explants origin of mass, and is regarded as "the God particle".



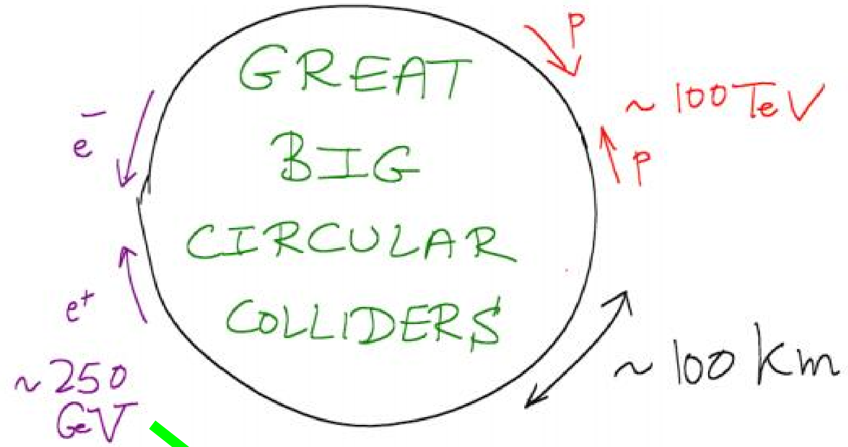
➔Looking for **Higgs** is a main objective at (LEP, Tevatron, LHC) .

Nobel Prize in Physics in 2013



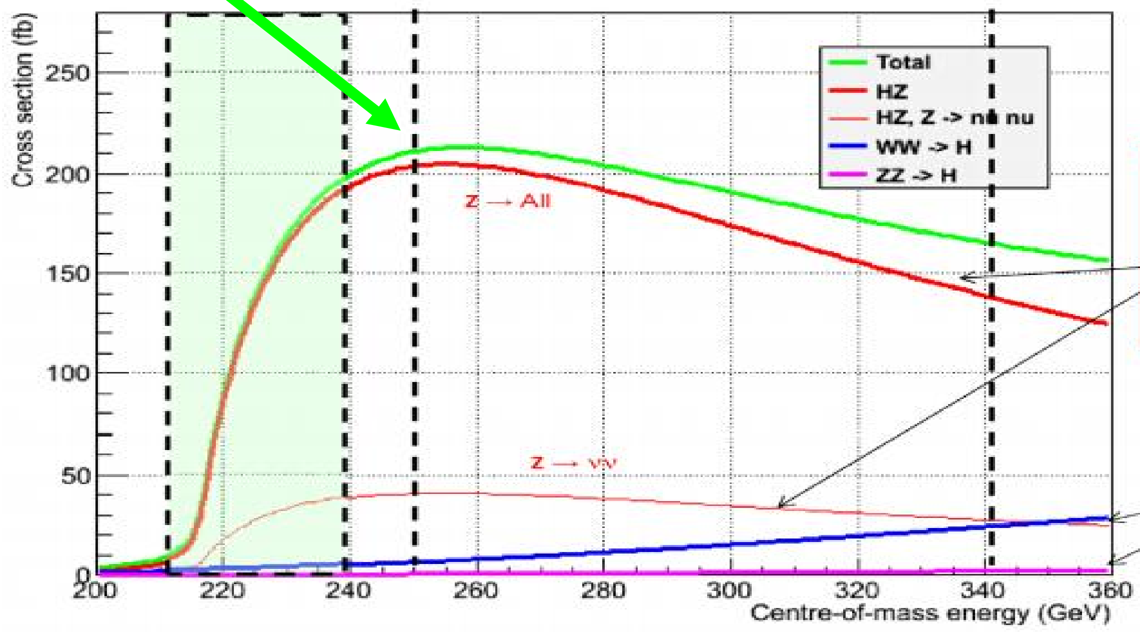
The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs ***" for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"***

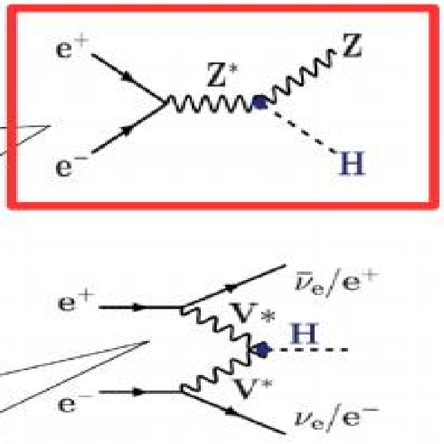
Circle Electron Positron Collider



1.The Higgsstrahlung process（ZH process）

2.The weak boson (WW or ZZ) fusion reactions

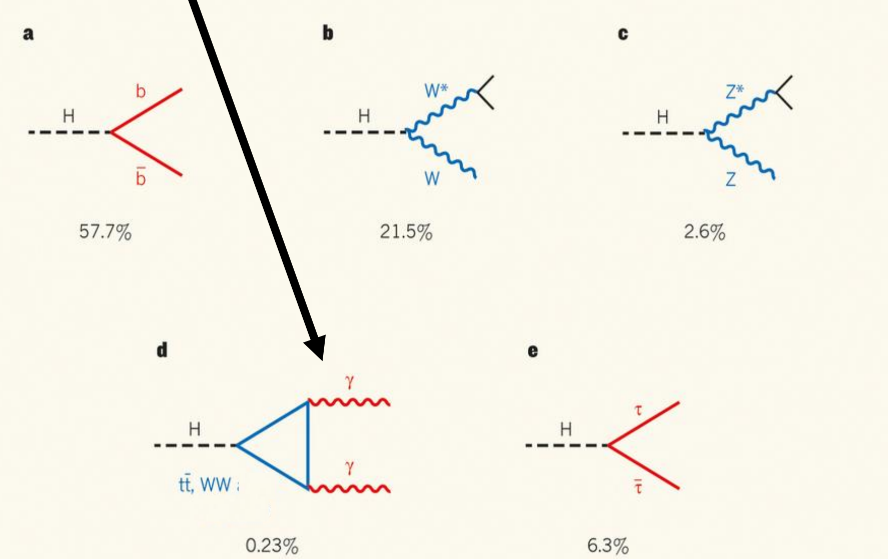




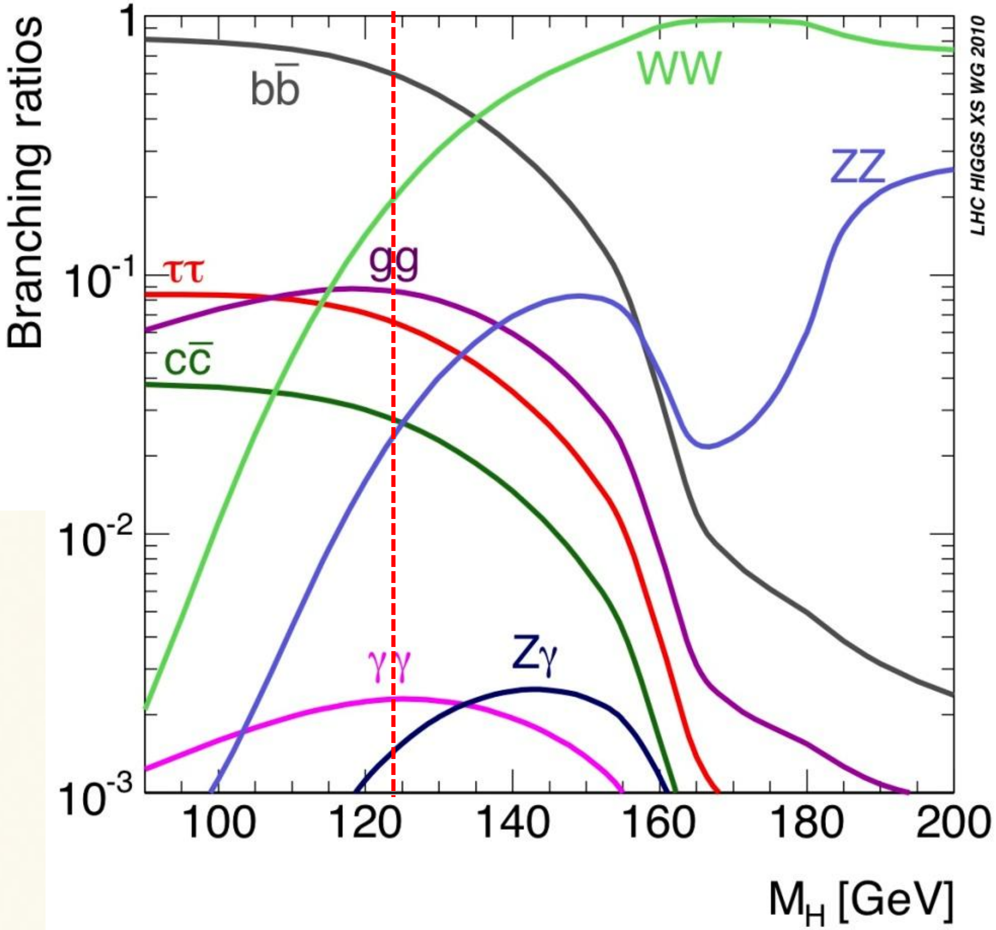
Higgs Boson Decay

Higgs decay branching ratio at m_H=125 GeV

- bb: 57.7%
- WW: 21.5%
- ττ: 6.3%
- ZZ*: 2.6%
- γγ: 0.23%



Nature,496,439–441(25 April 2013)



Signal

- Information

  Integrated luminosity: 5 ab^{-1}

  Generator：Whizard 1.95

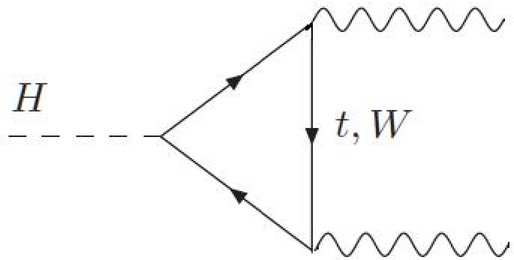
- ZH→(νν,ll,qq) γγ event:

Mode	*qq*	νν	ll
BR(%)	70	20	10

four final state particles

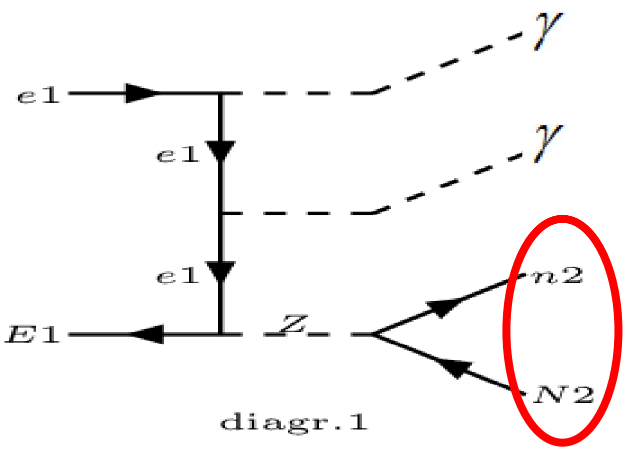
two final state particles

The Higgs decay into two photons through massive charged particle



Background

Main background: $e^+e^- \to \left(q\bar{q}, \nu\bar{\nu}, l\bar{l}\right)\gamma\gamma$



\+ topology

Can be replaced by qq & ll

other background: $e^+e^- \to ww, zz$

Analysis

- Signal

  large photon energy

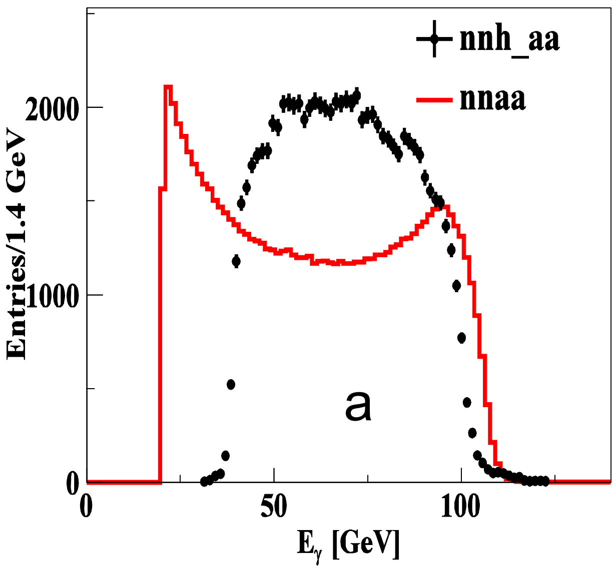
  the largest two-photon invariant mass

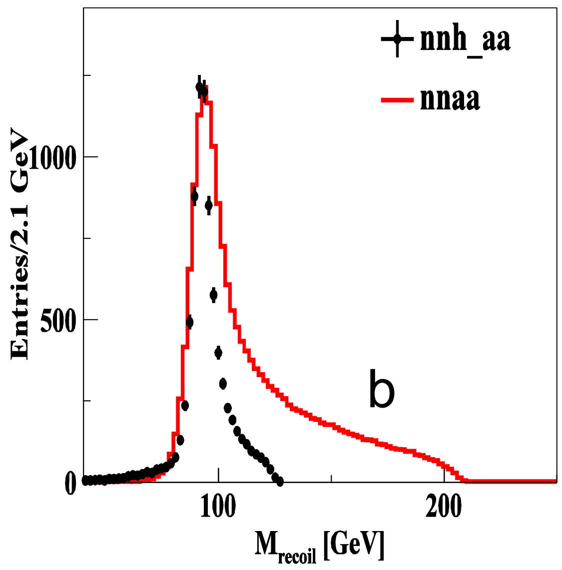
- Background

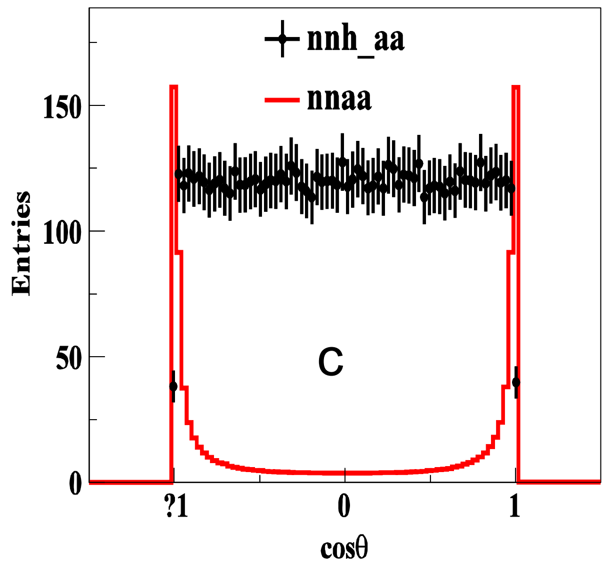
  almost along the beam direction

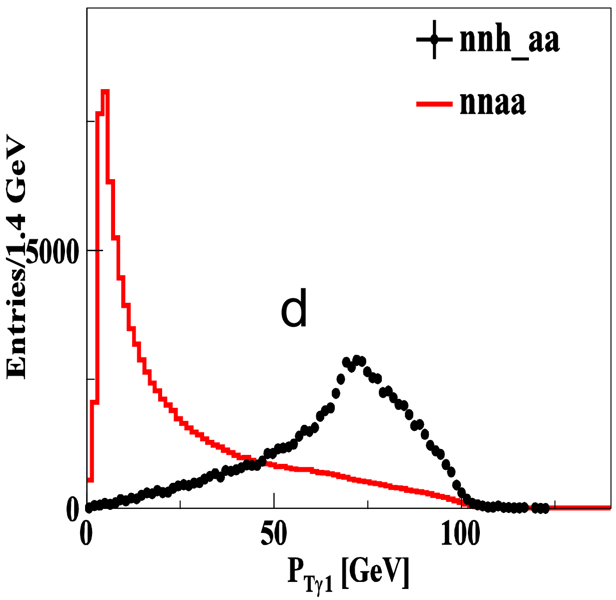
  low transverse momentum

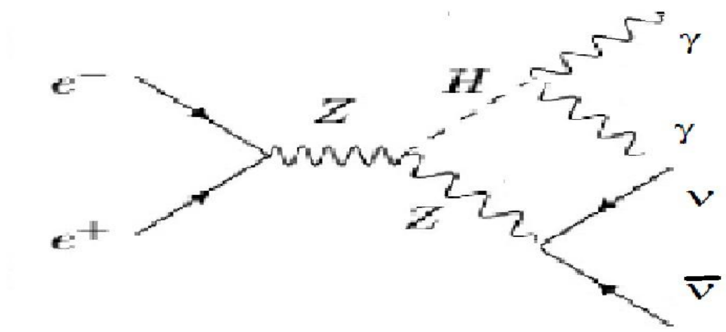
Two final state objects











Cut chain

Beam without pol.		Events			
Channel	Generate	cut1	cut2	cut3	cut4
nnH_aa	Efficiency	100%	82.94%	61.22%	57.45%
nnH_aa	557	557	462	341	320
nnaa	1276400	401626	105008	16182	13231

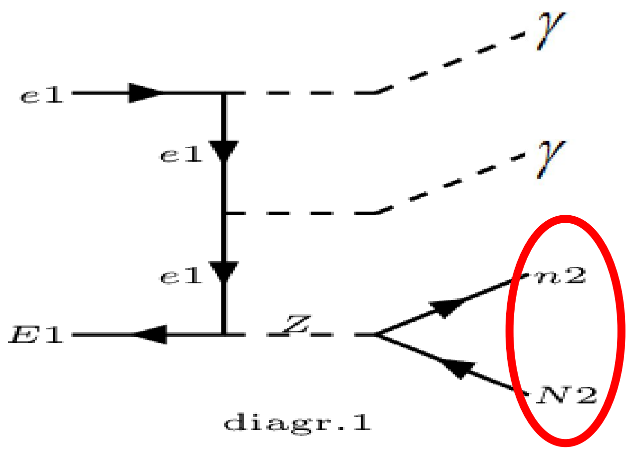
Cut1： $E_\gamma > 35GeV$

Cut3： $\begin{cases} P_{Tlow} > 48GeV \\ P_{Thigh} > 37GeV \end{cases}$

Cut2： $|\cos\theta_p| < 0.84$

Cut4： $M_{reco} < 110GeV$

Four final state objects



$$e^+e^- \rightarrow \left(q\bar{q}, l\bar{l}\right)\gamma\gamma$$

- Kinematic fitting

  In four final state objects channel, kinematic fitting are used to improve the performance.

Cut chain

Beam without pol.		Events					
Channel	Generate	cut1	cut2	cut3	cut4	cut5	cut6
qqH_aa	Efficiency	100%	88.38%	74.94%	53.75%	34.38%	34.38%
qqH_aa	1652	1652	1460	1238	888	568	568
qqaa	11011914	2027271	803856	228018	93878	24390	19184
ww	42455430	46318	20339	6616	17	0	0
zz	5805561	15716	2913	990	51	17	11
wworzz	19700221	18953	8723	3630	14	14	14

cut1= $E_\gamma > 35GeV$

cut2= $|\cos\theta_p| < 0.9$

cut3= $\begin{cases} 20GeV < P_{Tlow} < 97GeV \\ 26GeV < P_{Thigh} < 100GeV \end{cases}$

cut4= $85GeV < M_{reco} < 100GeV$

cut5= $P_{T\gamma 1} + P_{T\gamma 2} > 118GeV$

cut6= $130GeV < E_{\gamma 1} + E_{\gamma 2} < 150GeV$

Cut and fit

- **Cut**

  cut chain optimized to maximize signal to background ratio $\frac{S}{\sqrt{S+B}}$

  efficiency for

  $\nu\nu h\_\gamma\gamma$ channel: 54.5%

  $qqh\_\gamma\gamma$ channel: 34.3%

  $\mu\mu h\_\gamma\gamma$ channel: 42.2%

  $\tau\tau h\_\gamma\gamma$ channel: 41.9%

- **Fit**

  Gaussian function for sig

  Polynomial for bkg

Fast simulation result

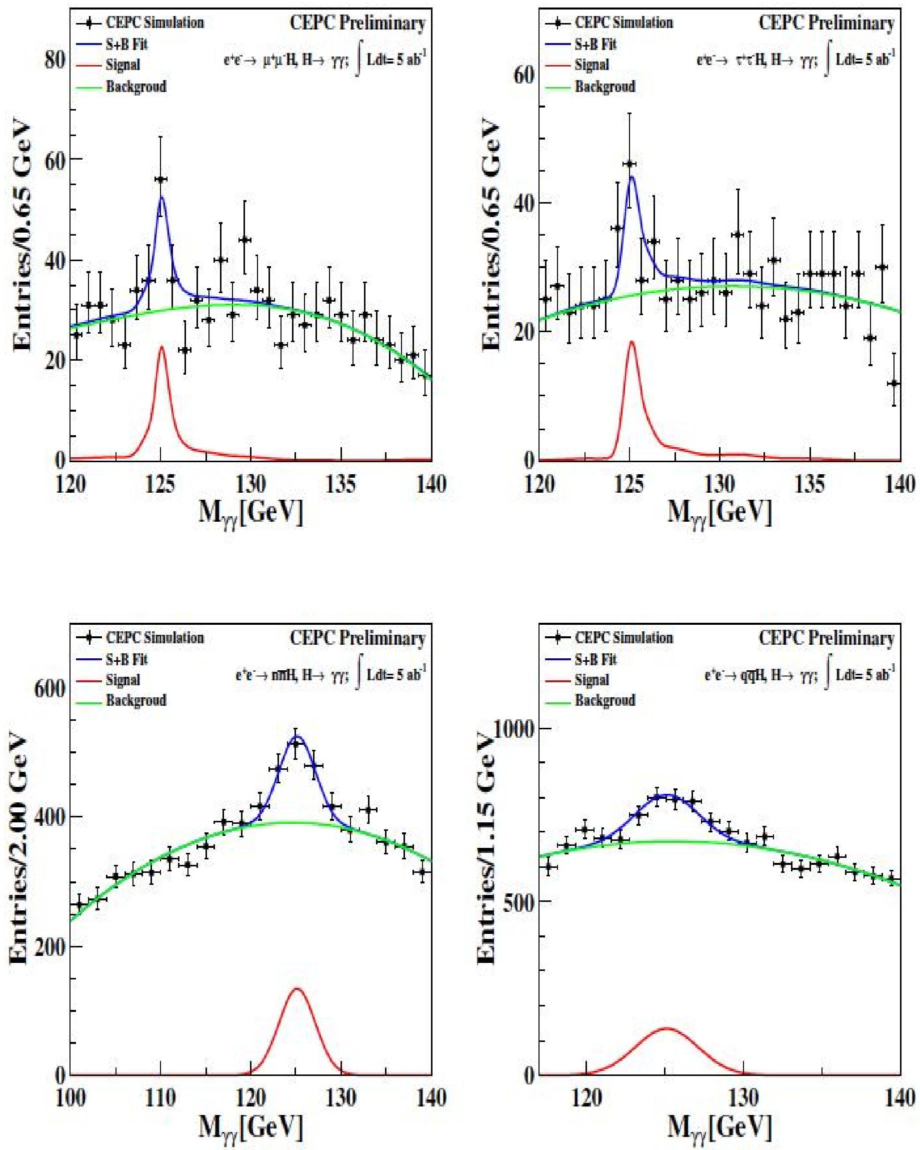
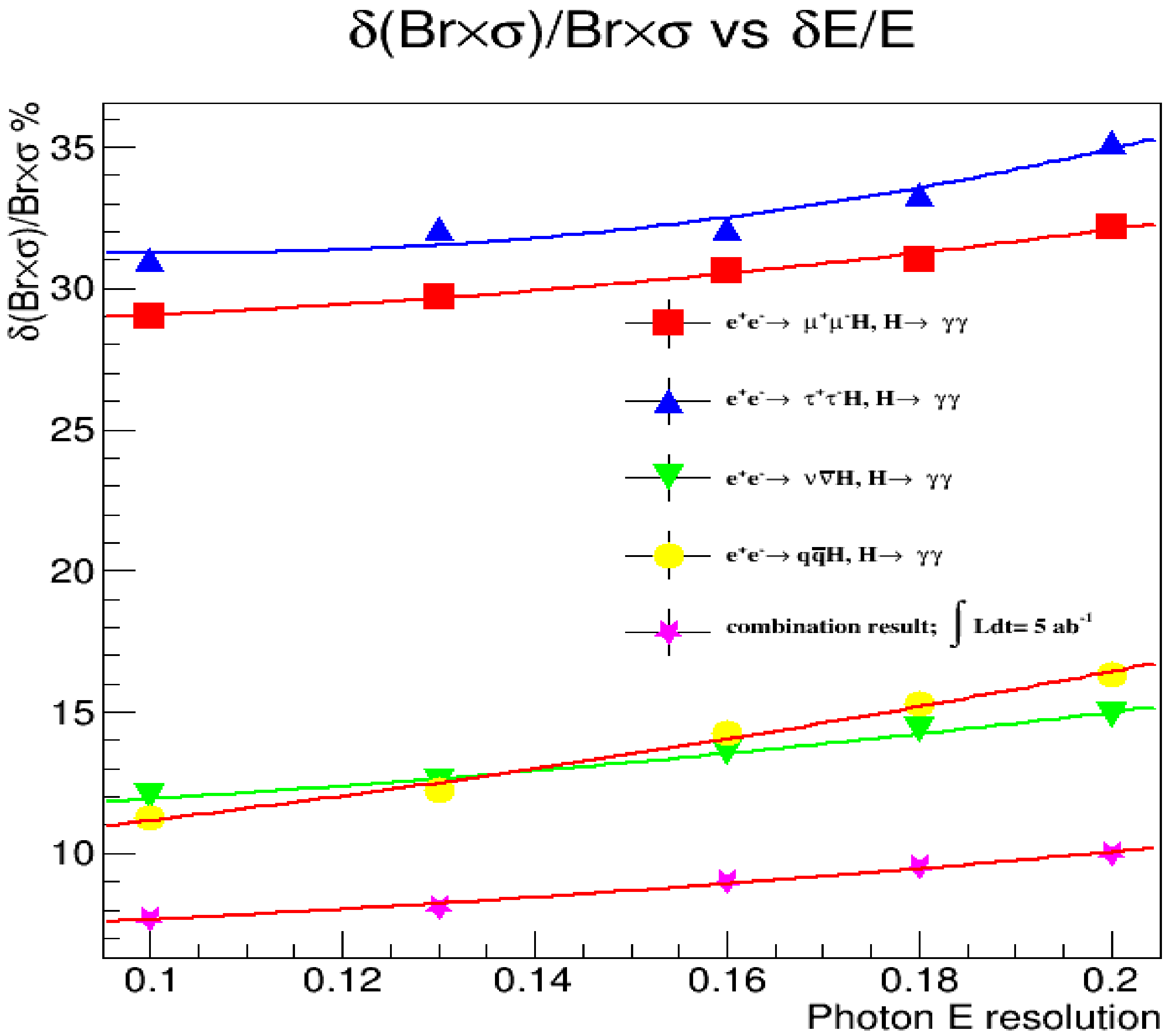


Table 12: Expected event yields for signal and backgrounds in $H \to \gamma\gamma$ channel, normalized to 5 ab^{-1}.

Channel		$\frac{\delta(E)}{E} = \frac{10\%}{\sqrt{(E)}} \oplus 1\%$	$\frac{\delta(E)}{E} = \frac{16\%}{\sqrt{(E)}} \oplus 1\%$	$\frac{\delta(E)}{E} = \frac{20\%}{\sqrt{(E)}} \oplus 1\%$
$Z \to \mu^+\mu^-$	Signal/efficiency	$62 \pm 18/42.2\%$	62 ± 19	59 ± 19
	background	832 ± 33	831 ± 34	826 ± 33
	$\delta(Br \times \sigma)/(Br \times \sigma)$	29.03%	30.64%	32.20%
$Z \to \tau^+\tau^-$	Signal/efficiency	$58 \pm 18/41.9\%$	56 ± 18	54 ± 19
	background	760 ± 32	757 ± 32	762 ± 32
	$\delta(Br \times \sigma)/(Br \times \sigma)$	31.03%	32.14%	35.18%
$Z \to \nu\nu$	signal	$334 \pm 40/57.5\%$	339 ± 46	342 ± 51
	background	7059 ± 91	7053 ± 94	7047 ± 96
	$\delta(Br \times \sigma)/(Br \times \sigma)$	11.98%	13.56%	14.91%
$Z \to qq$	signal	$594 \pm 67/34.3\%$	582 ± 83	575 ± 94
	background	13053 ± 130	12831 ± 138	12566 ± 144
	$\delta(Br \times \sigma)/(Br \times \sigma)$	11.28%	14.26%	16.35%
Total	$\delta(Br \times \sigma)/(Br \times \sigma)$	7.7%	9.0%	10.0%

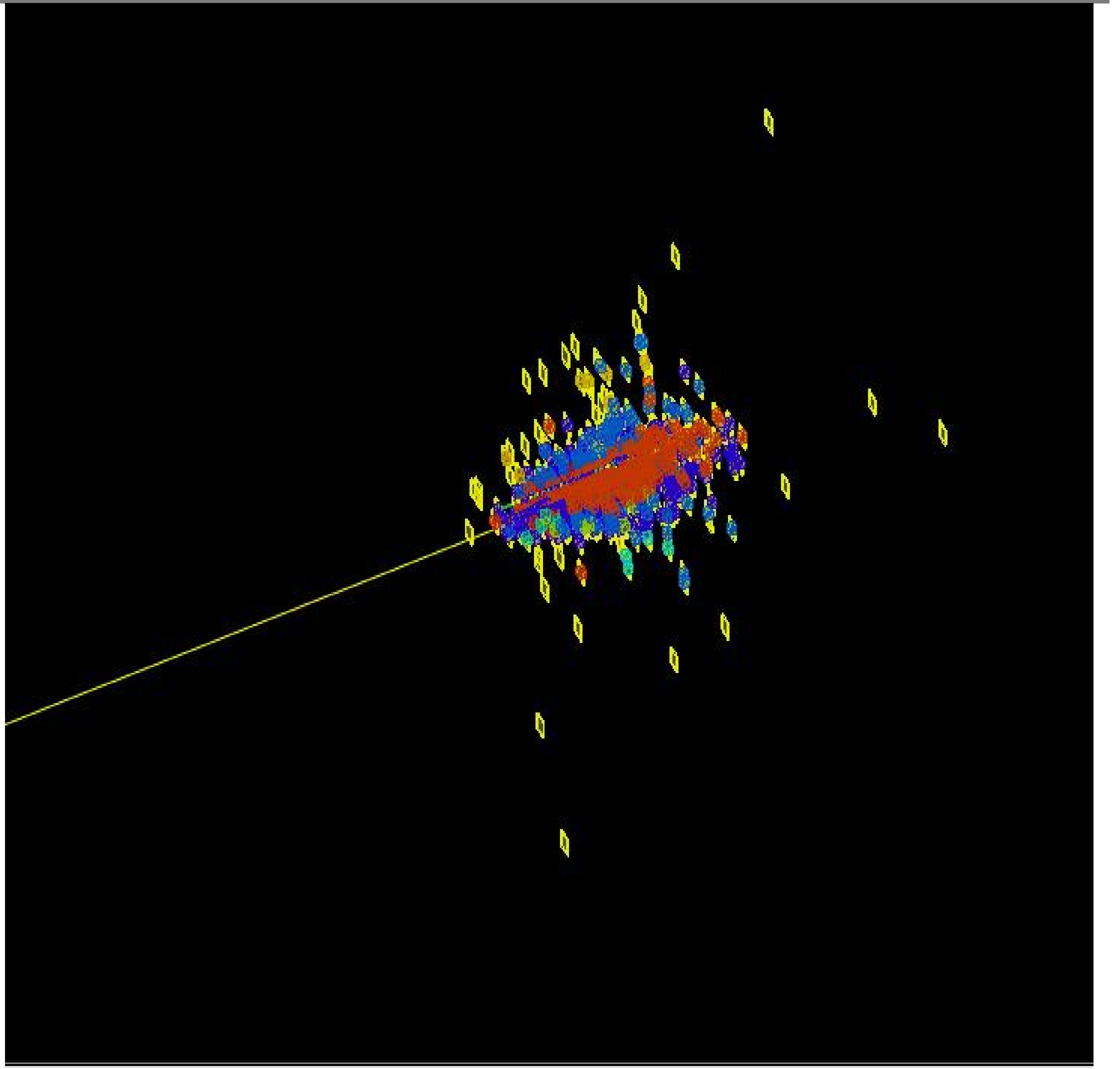
A relative precision of 9.0% can be obtained

Fast simulation result

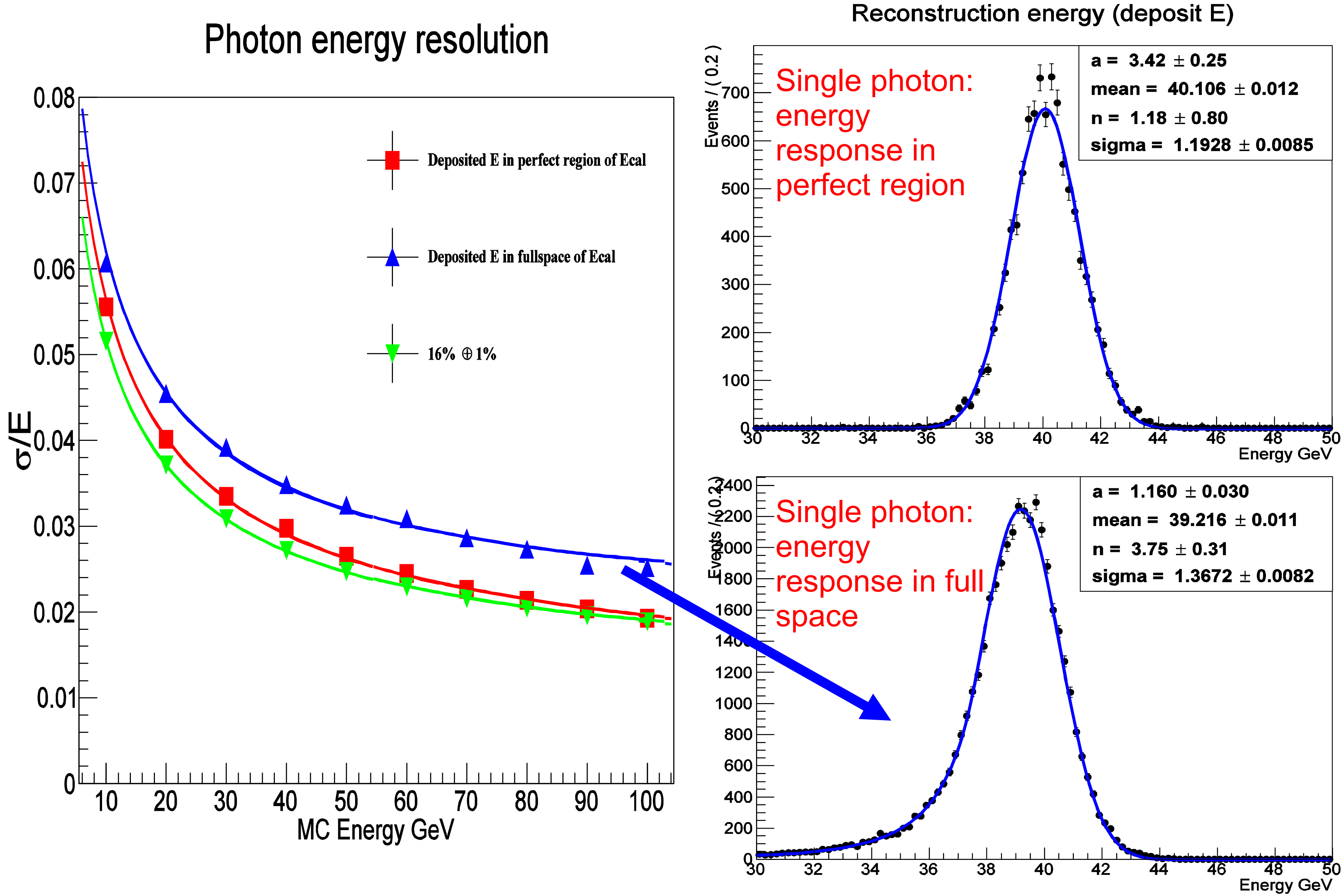


Photon reconstruction with full simulation

- 1.Photon energy estimator
- 2.Photon energy estimator correction according to Ecal geometry
- 3.Photon conversion

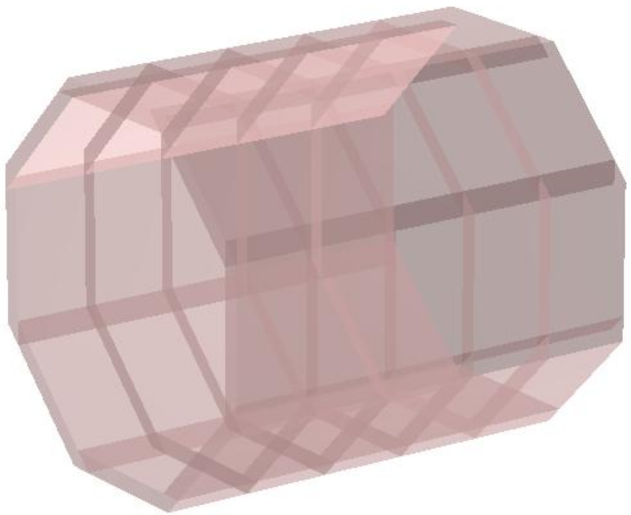


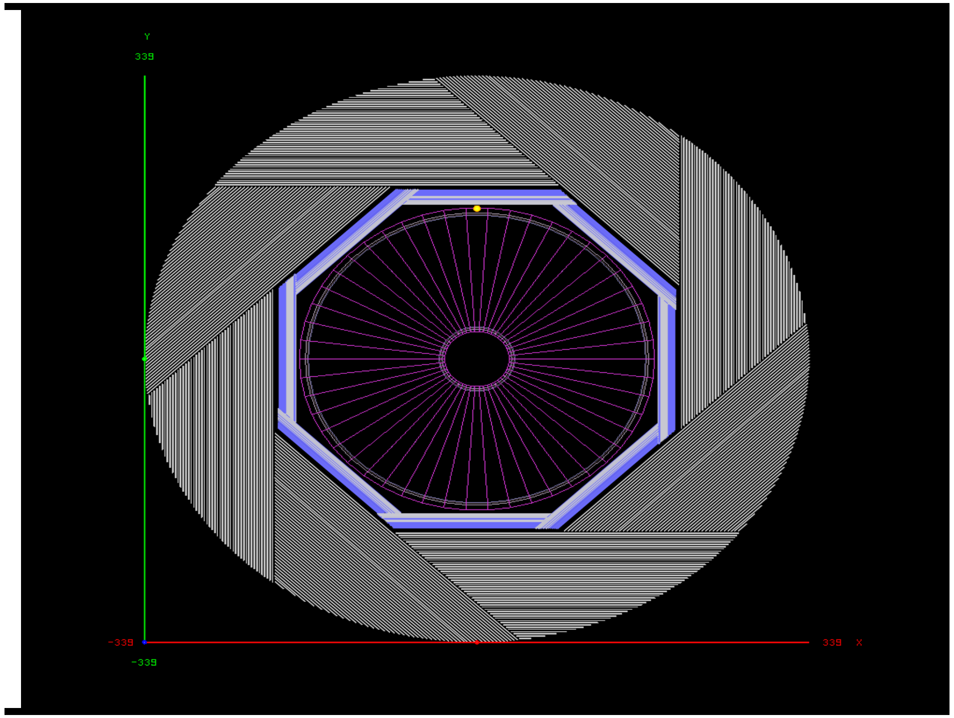
Photon energy estimator



Photon angular resolution correction

Theta & Phi Dependence

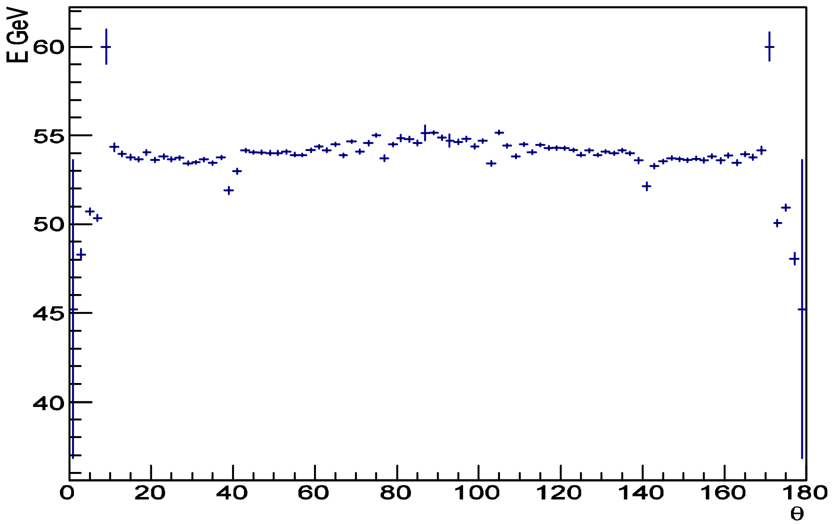




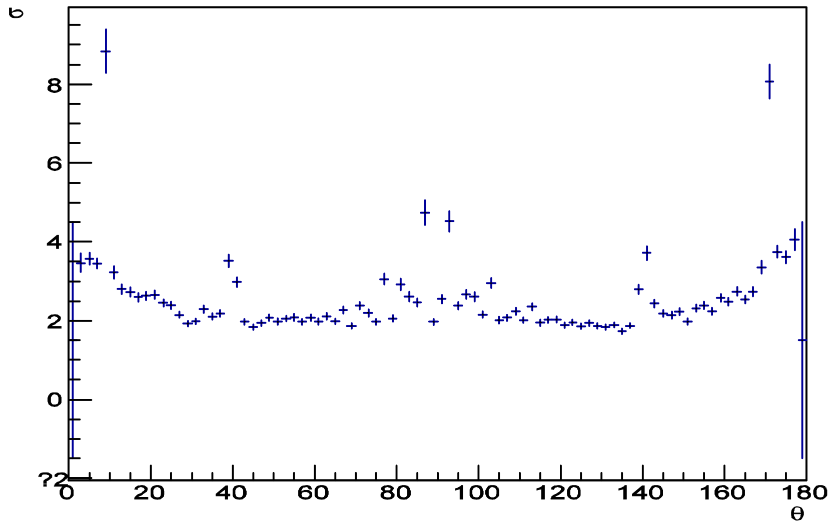
Photon angular resolution correction

（no gamma conversion）

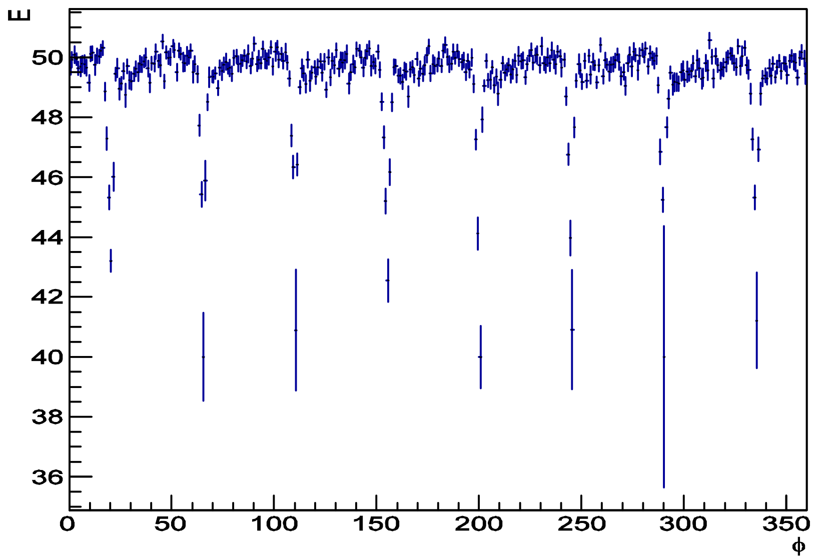
E vs θ



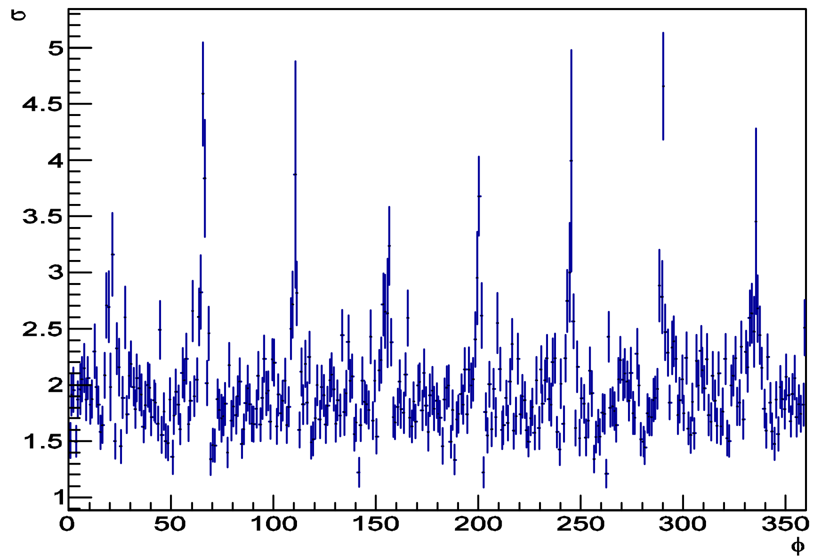
σ vs θ



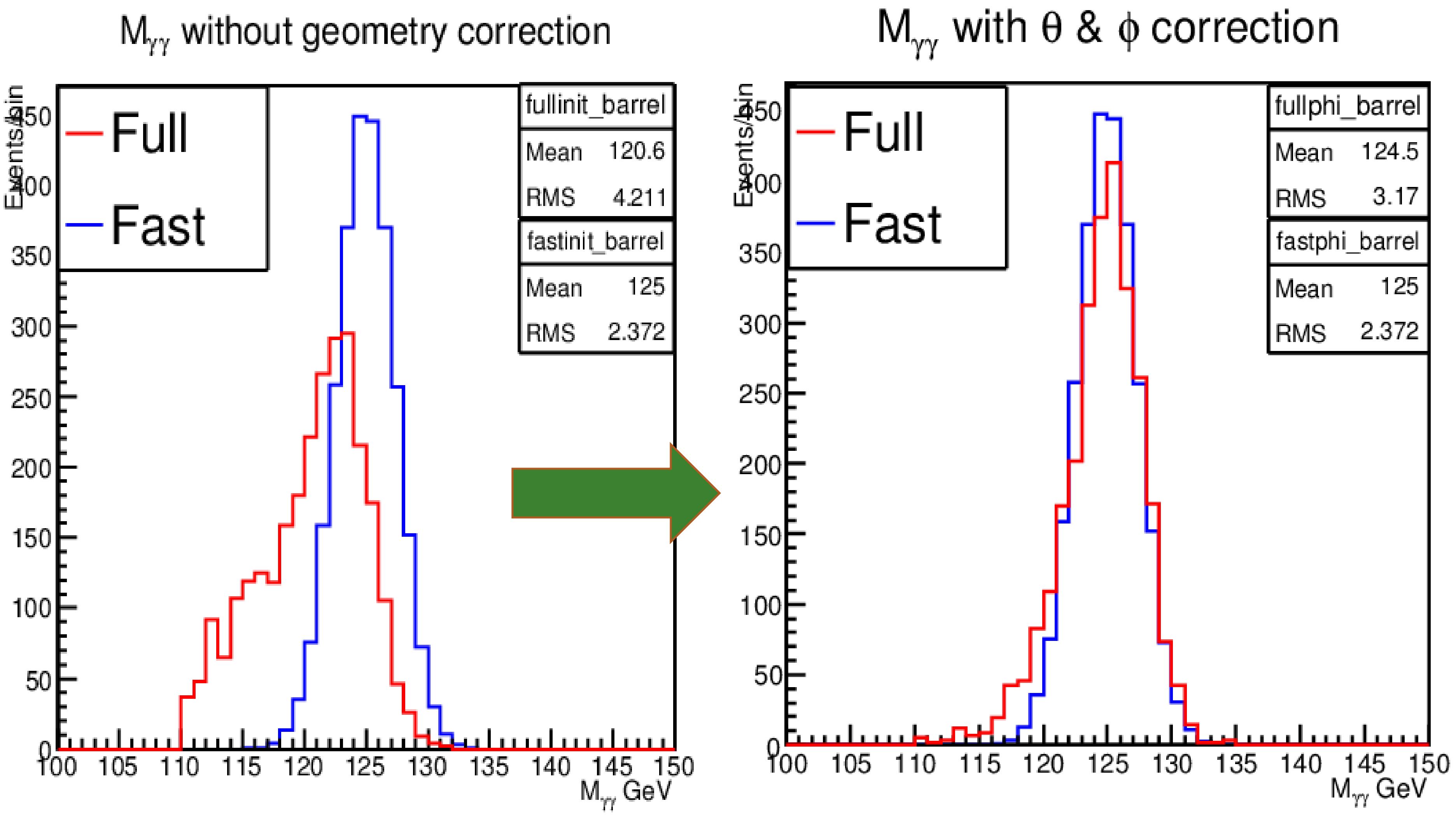
E vs ϕ



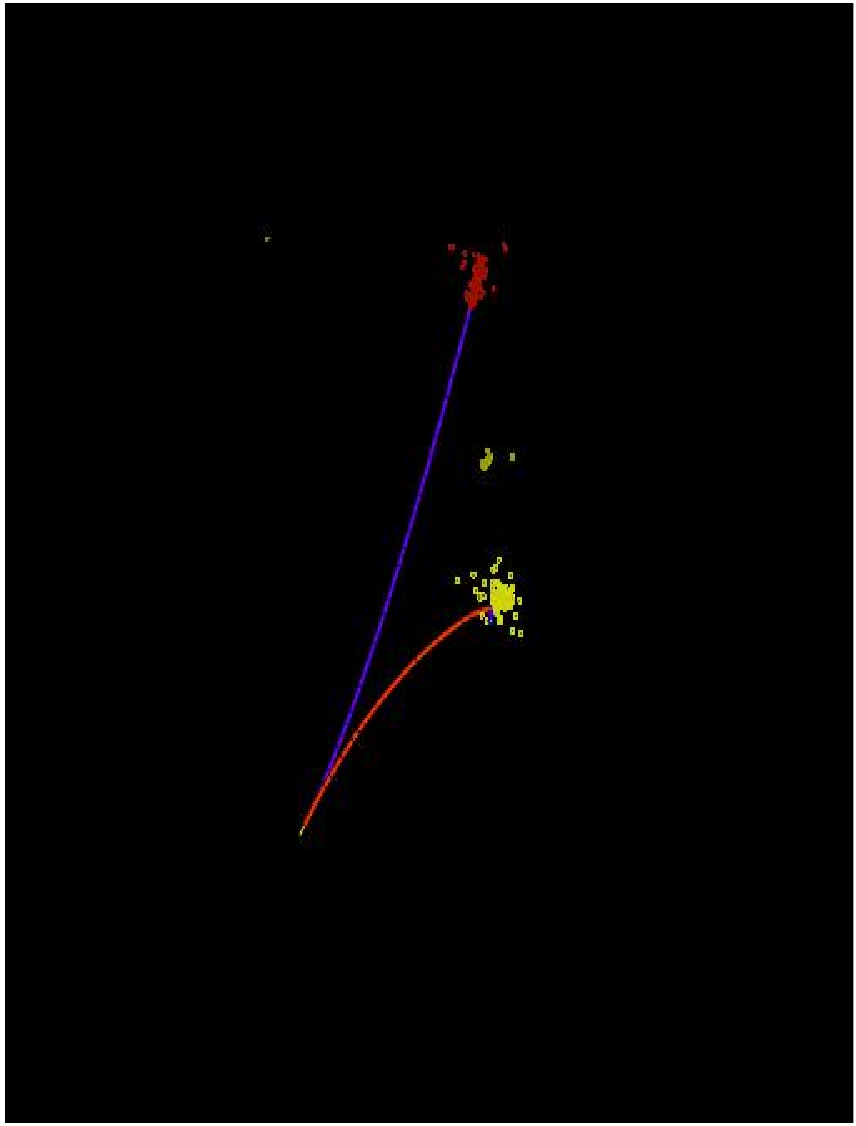
σ vs ϕ

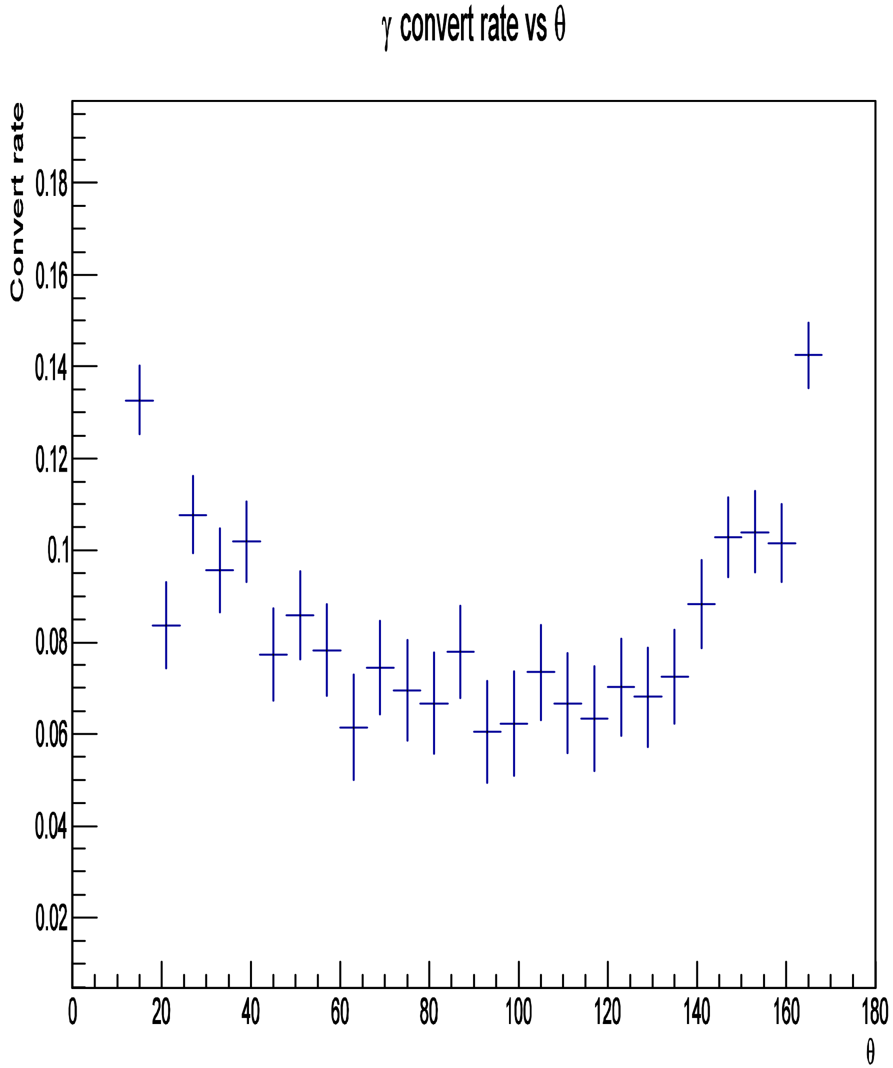


Photon angular resolution correction

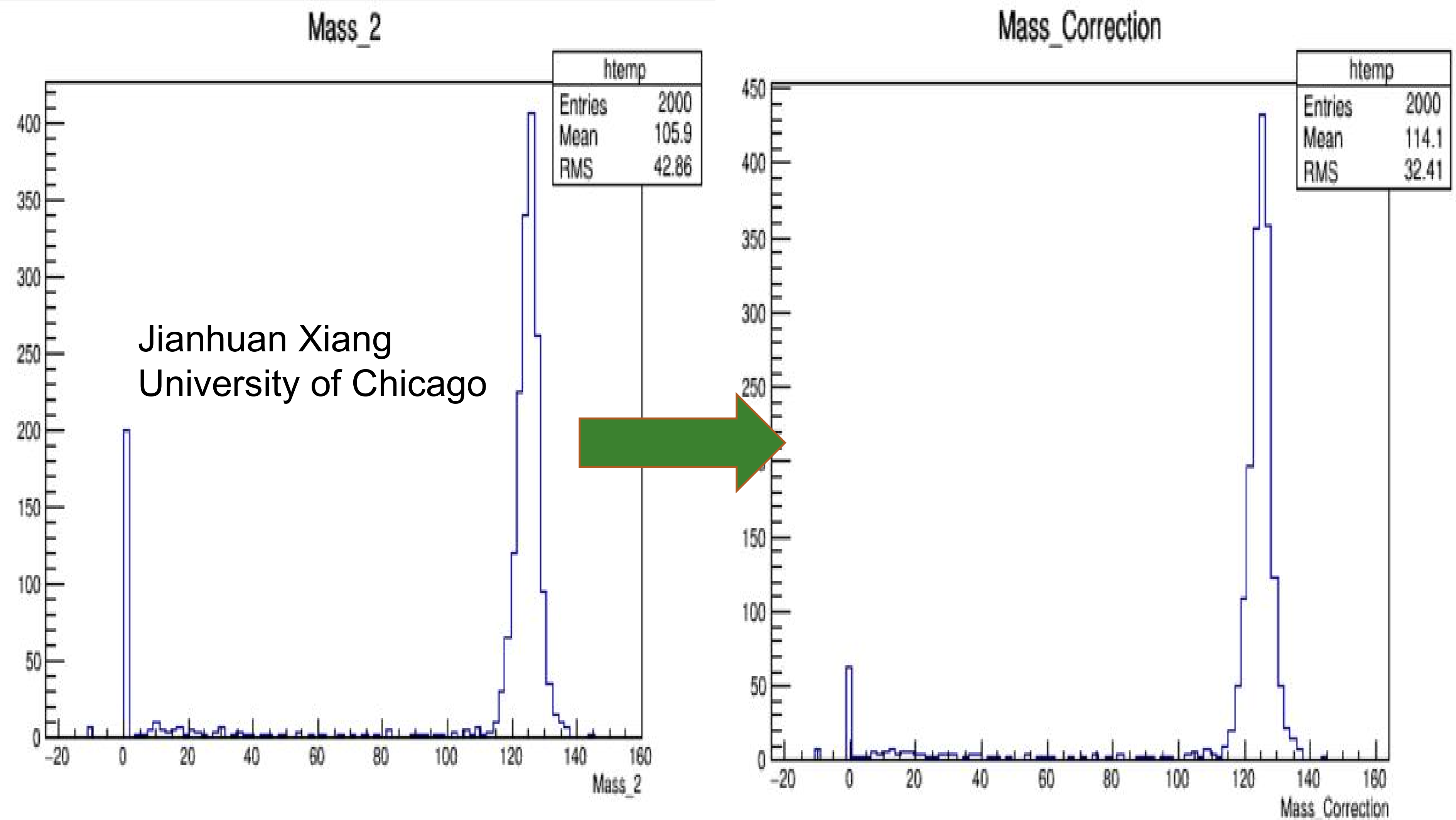


Gamma conversion





Gamma conversion



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Summary & plan

Fast simulation

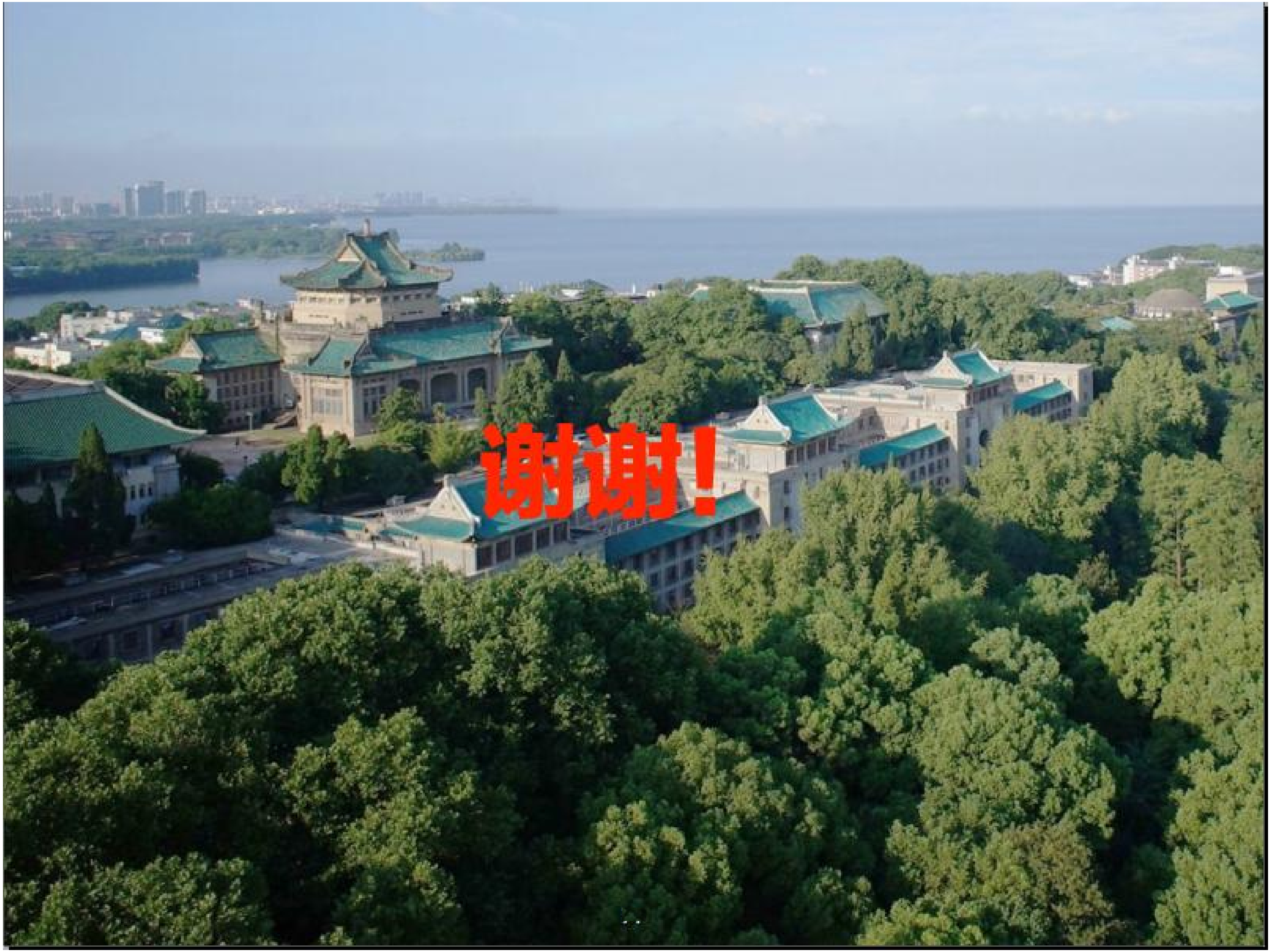
1. A relative precision of 9.0% can be obtained for the σ(ZH) $\times$BR(H->$\gamma\gamma$) measurement.
2. By varying the stochastic term of the ECAL energy resolution, its impact on the expected precision has been evaluated.

Photon reconstruction

1. Energy estimator
2. Energy anglur resolution correction
3. Gamma conversion correction

Plan

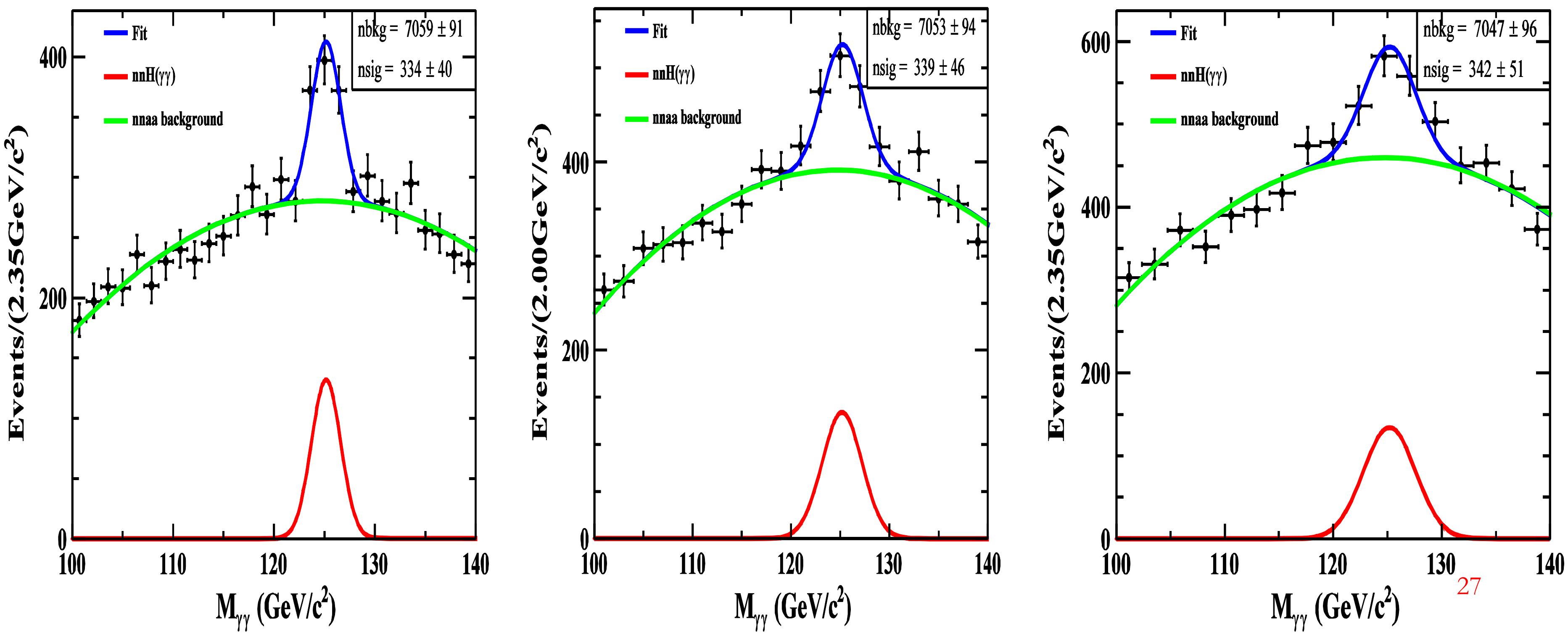
Analysis of Higgs to di-photon with full simulation.


谢谢！

Back up

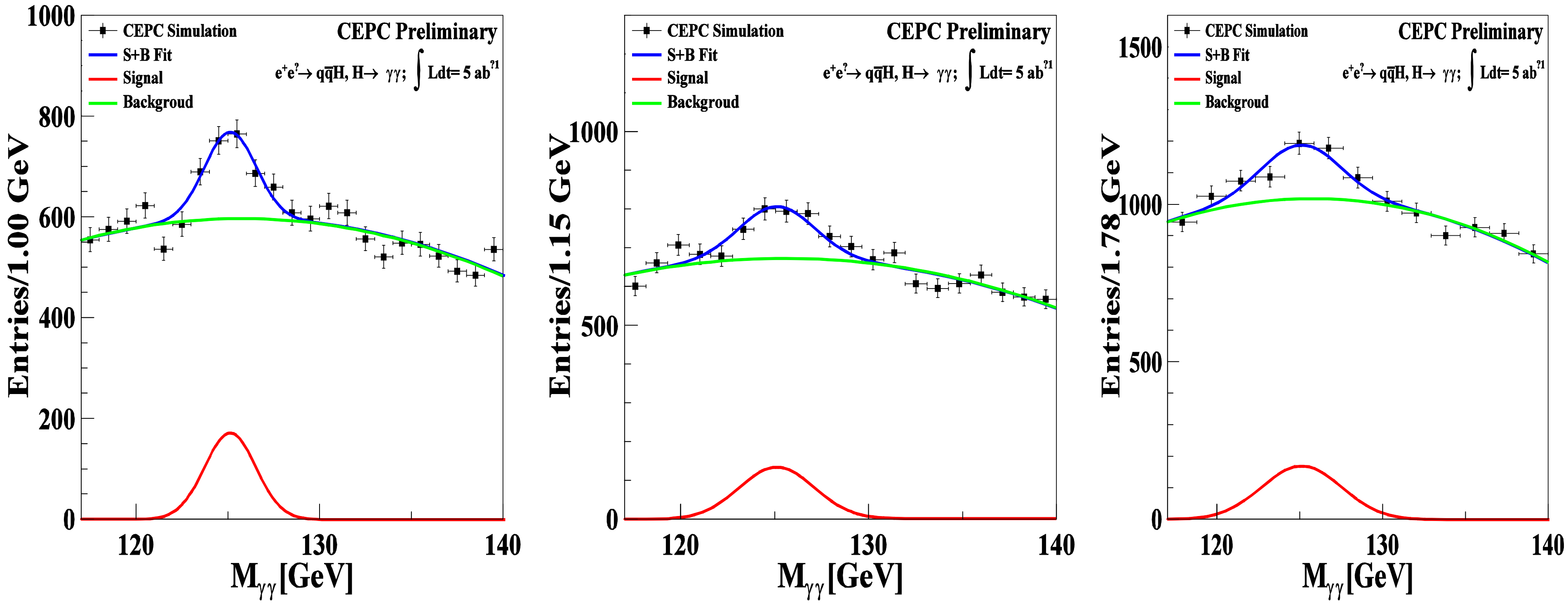
ZH->nnγγ : performance under the different Ecal energy resolution

Energy resolution	$\frac{10\%}{\sqrt{E}} \oplus 1\%$	$\frac{16\%}{\sqrt{E}} \oplus 1\%$	$\frac{20\%}{\sqrt{E}} \oplus 1\%$
Signal yield	334 ± 40	339 ± 46	342 ± 51
Significance	8.65σ	7.11σ	6.37σ
δ(Br×σ)/Br×σ	**11.98%**	**13.56%**	**14.91%**



ZH->qqγγ : performance under the different Ecal energy resolution

Energy resolution	$\frac{10\%}{\sqrt{E}} \oplus 1\%$	$\frac{16\%}{\sqrt{E}} \oplus 1\%$	$\frac{20\%}{\sqrt{E}} \oplus 1\%$
Signal yield	594 ± 67	582 ± 87	575 ± 94
Significance	8.14σ	5.90σ	4.87σ
Precision	**11.28%**	**14.26%**	**16.35%**



Cut chain

Beam without pol.		Events					
Channel	**Generate**	**cut1**	**cut2**	**cut3**	**cut4**	**cut5**	**cut6**
μμH_aa	**Efficiency**	**100%**	**91.56%**	**72.28%**	**55.42%**	**54.21%**	**42.17%**
μμH_aa	**83**	**83**	**76**	**60**	**46**	**45**	**35**
μμaa	**1135659**	**214725**	**66703**	**23786**	**6427**	**1884**	**1026**

cut1= $E_\gamma > 35GeV$

cut2= $|\cos\theta_p| < 0.9$

cut3= $\begin{cases} 93GeV > P_{Tlow} > 20GeV \\ 100GeV > P_{Thigh} > 30GeV \end{cases}$

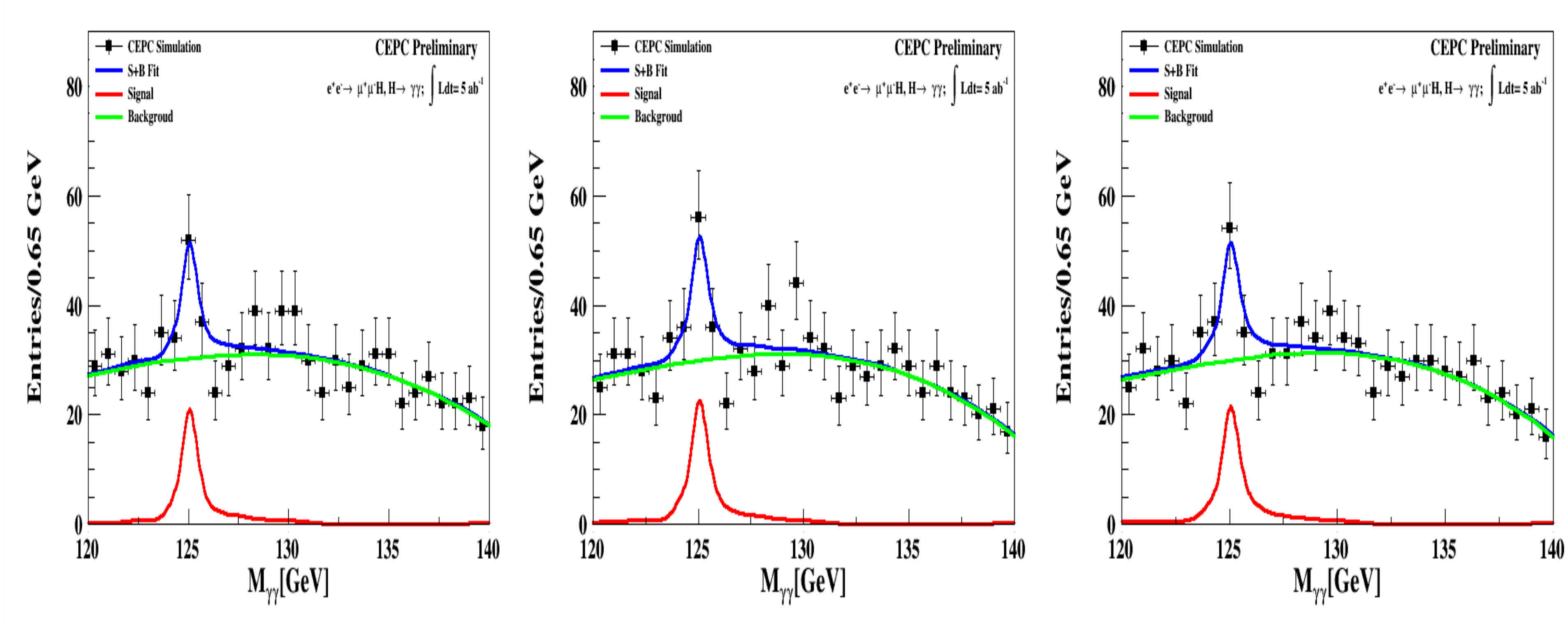
cut4= $86\text{GeV} < M_{reco} < 100GeV$

cut5= $136GeV < M_{\gamma\gamma} < 148GeV$

cut6= $|\cos\theta_{\mu\gamma}| < 0.9$

ZH->e2e2γγ : performance under the different Ecal energy resolution

Energy resolution	$\frac{10\%}{\sqrt{E}} \oplus 1\%$	$\frac{16\%}{\sqrt{E}} \oplus 1\%$	$\frac{20\%}{\sqrt{E}} \oplus 1\%$
Signal yield	59 ± 19	61 ± 19	62 ± 18
Significance	3.18σ	3.21σ	3.23σ
δ(Br×σ)/Br×σ	**31.03%**	**32.14%**	**35.18%**



Cut chain

Beam without pol.		Events					
Channel	Generate	cut1	cut2	cut3	cut4	cut5	cut6
ττH_aa	Efficiency	98.67%	89.33%	61.33%	48.00%	46.67%	41.89%
ττH_aa	75(0.9)	74	67	46	36	35	31
ττaa	429975	146922	49424	14533	3562	1778	1410

cut1= $E_{\gamma} > 35GeV$

cut2= $|\cos\theta_{p}| < 0.9$

cut3= $\begin{cases} 93GeV > P_{Tlow} > 30GeV \\ 100GeV > P_{Thigh} > 36GeV \end{cases}$

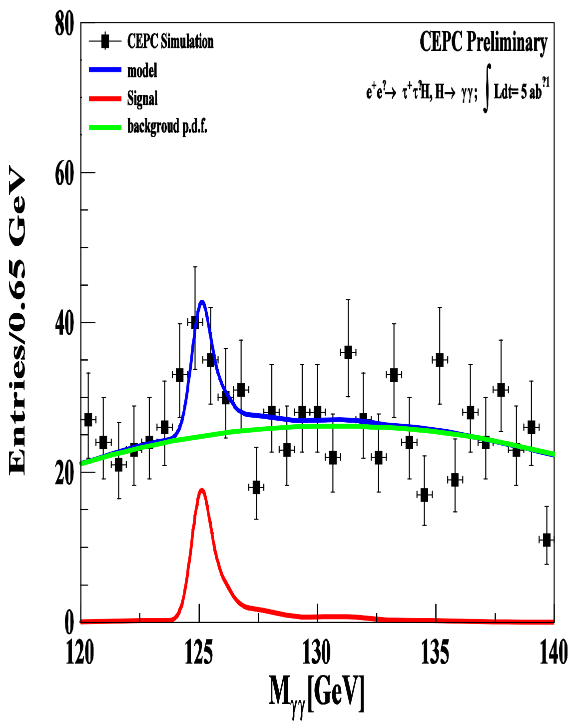
cut4= $86\text{GeV} < M_{reco} < 100GeV$

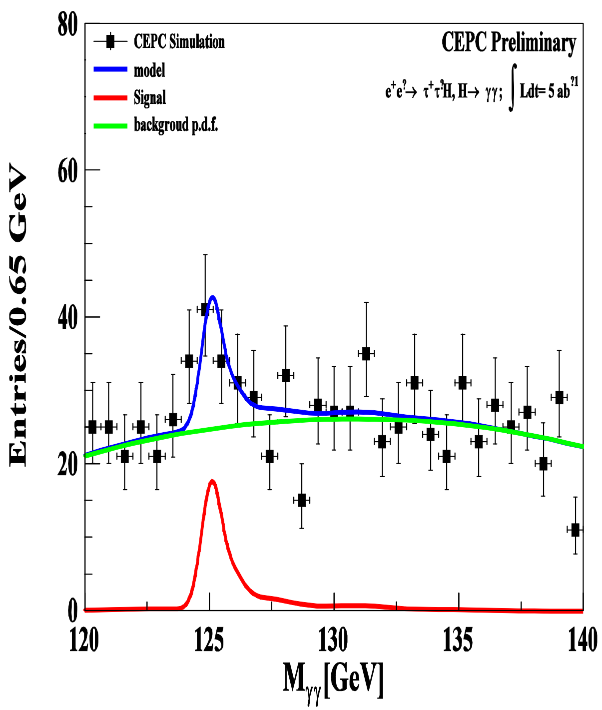
cut5= $130GeV < M_{\gamma\gamma} < 148GeV$

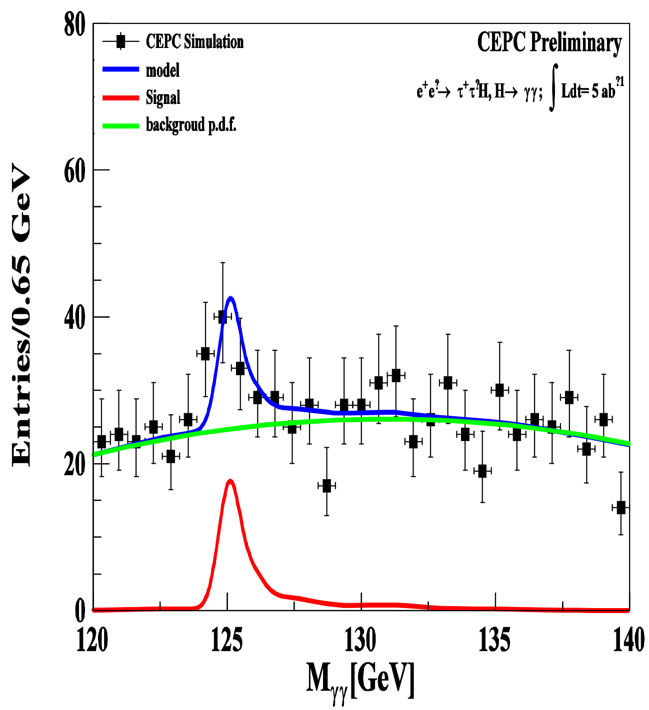
cut6= $|\cos\theta_{\mu\gamma}| < 0.99$

ZH->e3e3γγ : performance under the different Ecal energy resolution

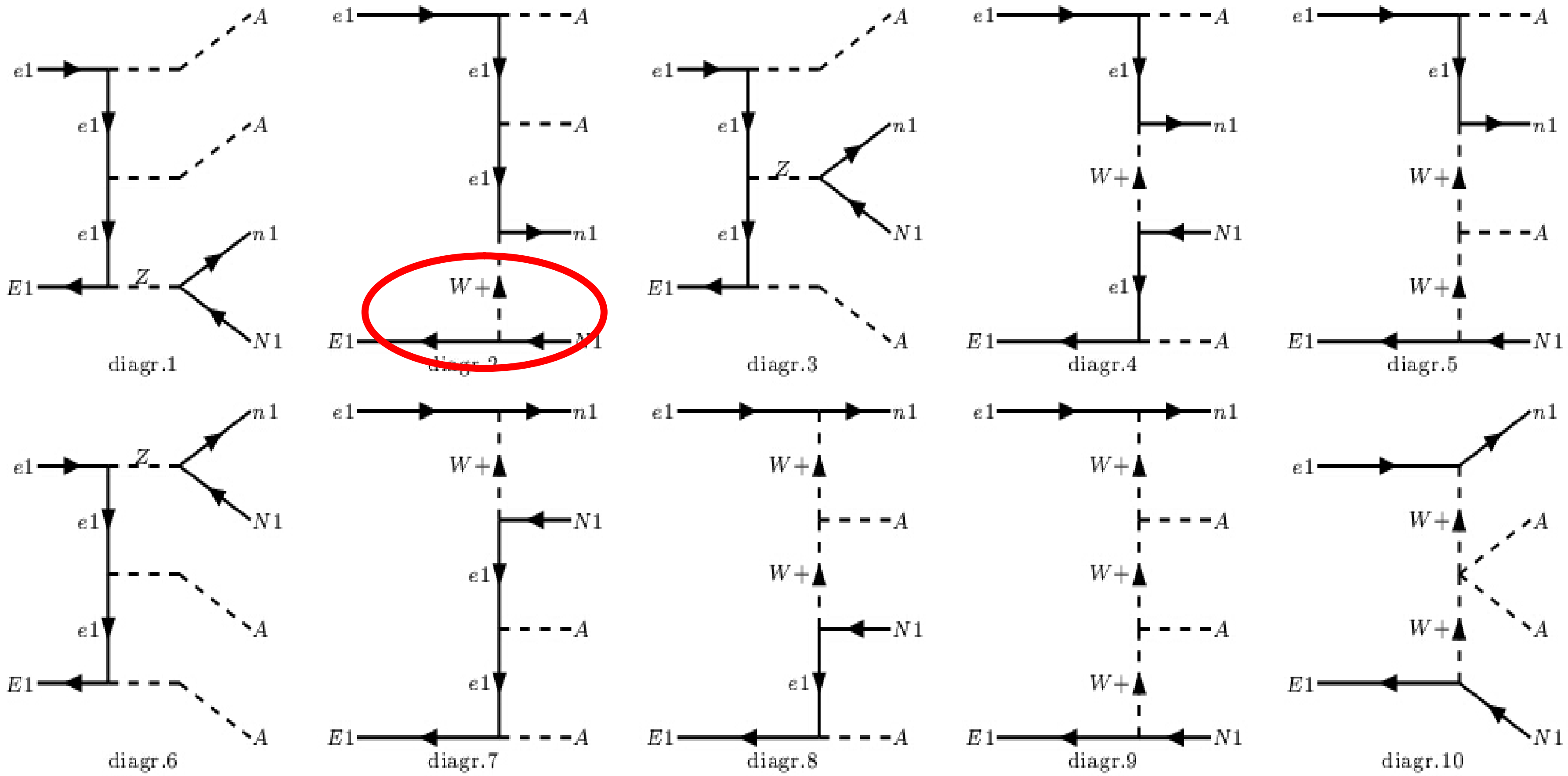
Energy resolution	$\frac{10\%}{\sqrt{E}} \oplus 1\%$	$\frac{16\%}{\sqrt{E}} \oplus 1\%$	$\frac{20\%}{\sqrt{E}} \oplus 1\%$
Signal yield	58 ± 18	56 ± 18	54 ± 19
Significance	3.23σ	3.21σ	3.18σ
δ(Br×σ)/Br×σ	**31.03%**	**32.14%**	**35.18%**



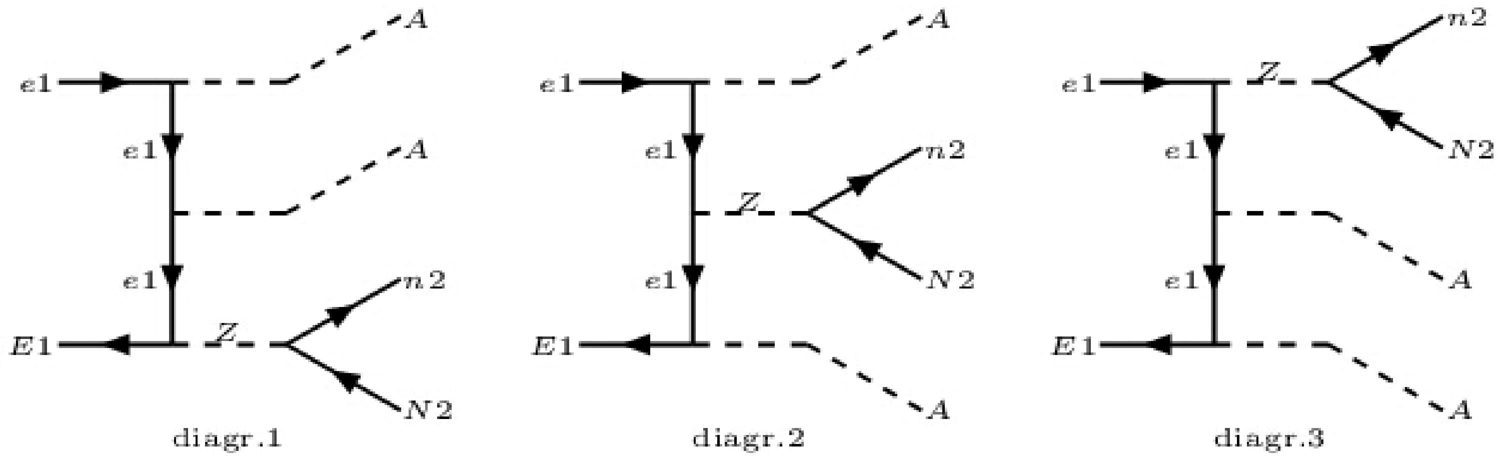




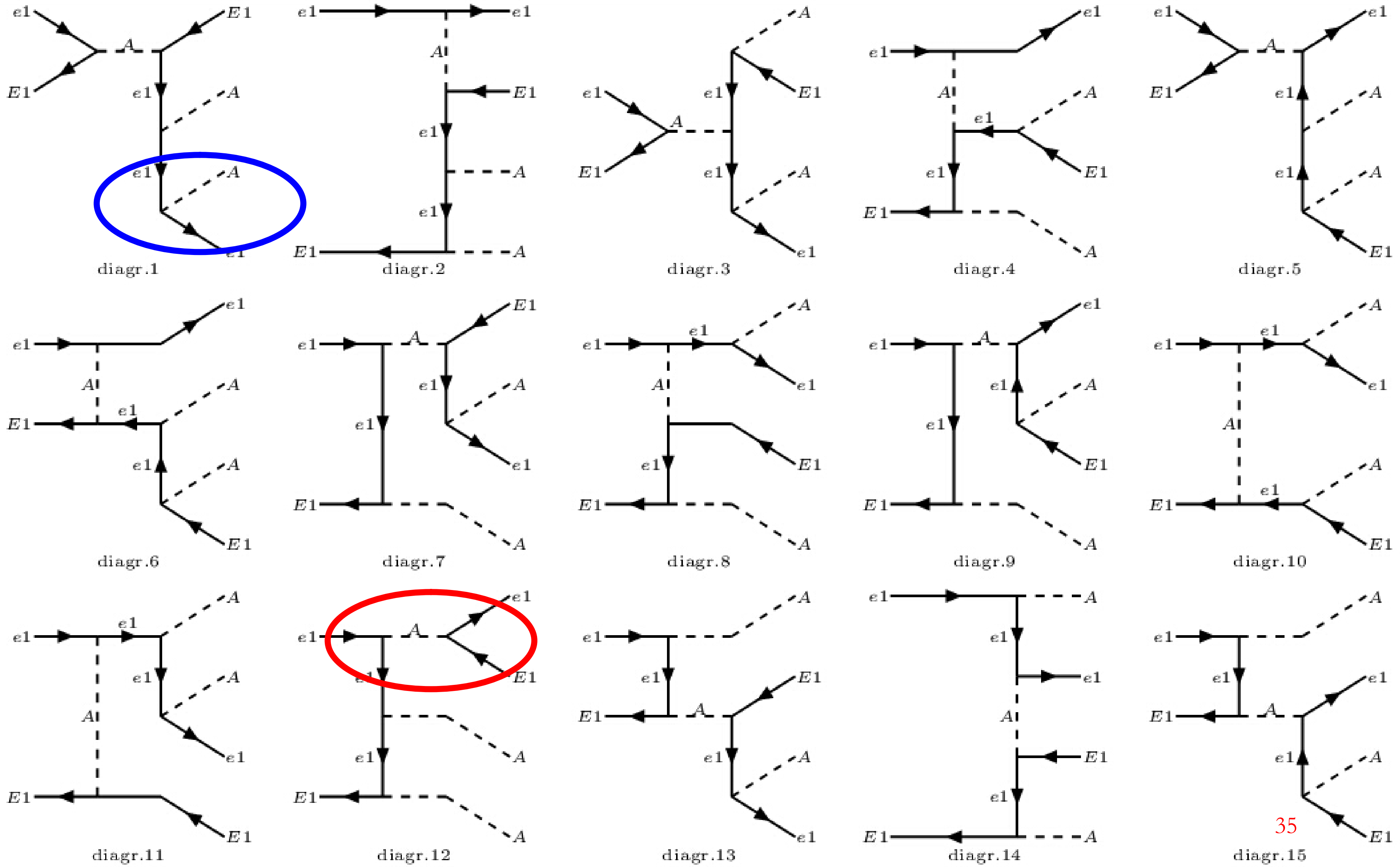
Feynman Diagrams for $\nu_{e+}\nu_{e-}aa$



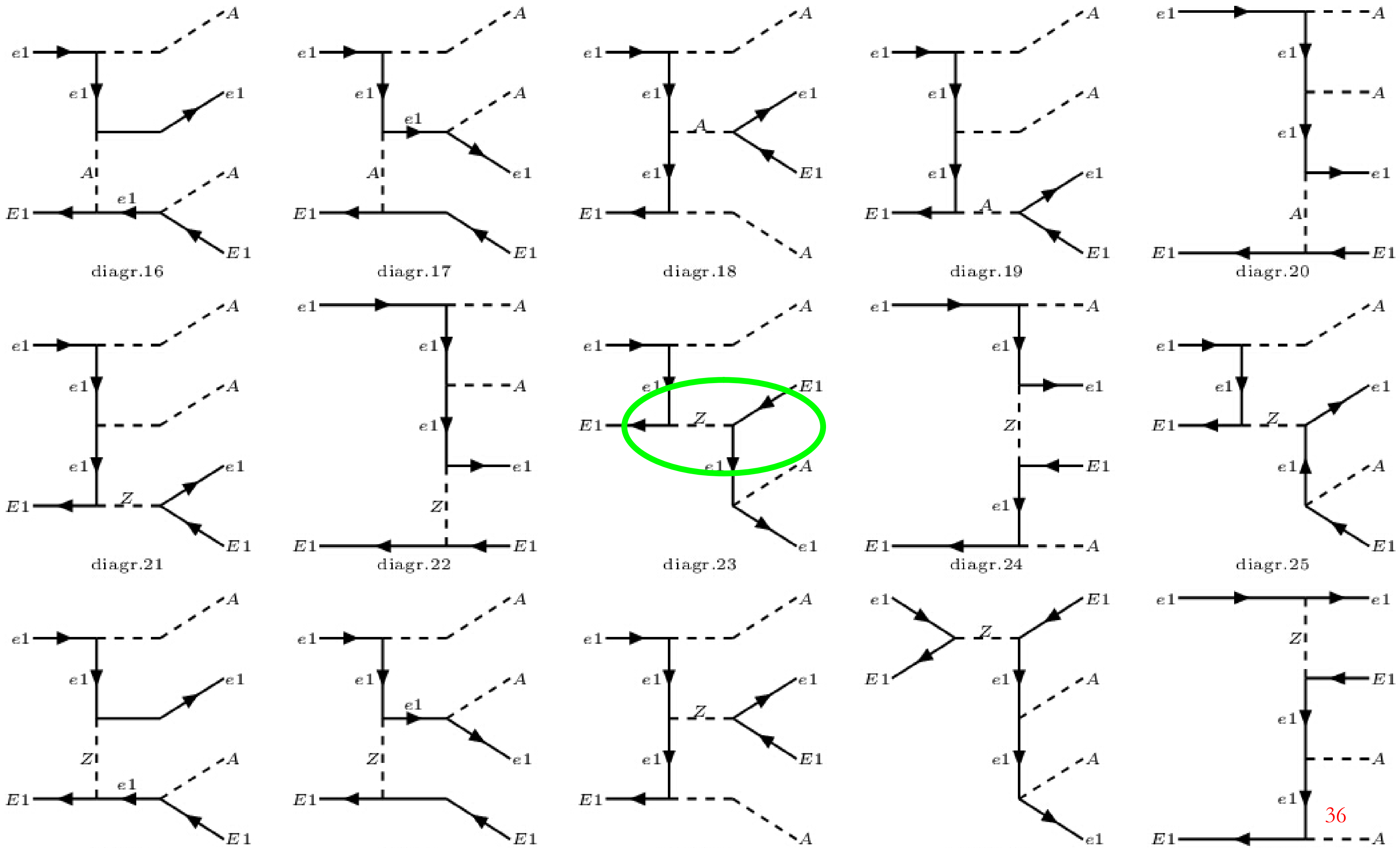
Feynman Diagrams for $\nu_{\mu+}\nu_{\mu-}aa$



Feynman Diagrams for e+e-aa



Feynman Diagrams for e+e-aa



diagr.16 diagr.17 diagr.18 diagr.19 diagr.20

diagr.21 diagr.22 diagr.23 diagr.24 diagr.25

diagr.26 diagr.27 diagr.28 diagr.29 diagr.30

Feynman Diagrams for uuaa