Higgs Recoil Mass Study

ILC Physics Meeting

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What 's NEW this week

◆ continue **study of Higgs decay mode dependence** using high statistics sample generated for EACH DECAY MODE

this time also include **H→γγ**

◆ **improve isolated lepton finder**

in order to resolve bias due to pairing leptons not from prompt Z decay

❖Previous "pairing method #1" :

- **select lepton pair with invariant mass closest to Z mass**
- Shortcoming: sometimes pairs lepton from Higgs decay (H→zz, ww , tau tau)

❖NEW "pairing method #2" :

- **select lepton pair which yields smallest chi^2 formed using invariant mass and recoil mass**

comparison between performance of the two lepton finders.

- some improvement in the "mistake" of H→ zz, ww, tau tau , gamma gamma

  pairing mistake for H→zz is reduced by about 15%

  without additional bias on other modes.

•similar improvement for WW, tau tau, gamma gamma as well. Now bb is perfect also.

•the remaining bias on H-->zz is still not trivial

wrong pairing happens 4.2 % of the time

However H→zz mode BR is very small , so overall 4.2% x 2% ∼ 0.08 %

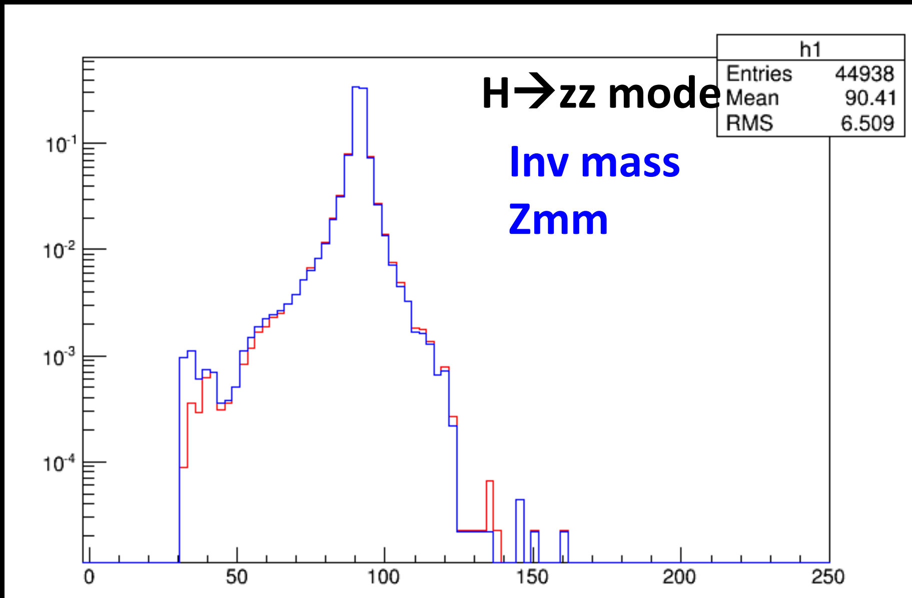
• the slight bias in this early stage of selection will mostly be "evened out" by other final cuts (e.g. tighter inv mass cut, recoil mass window, ect…)

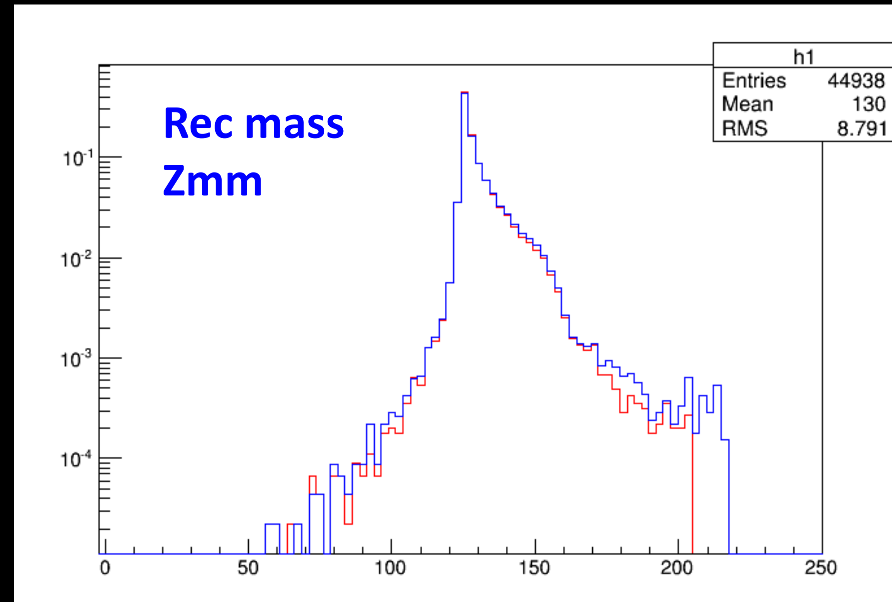
how does new processor affect overall efficiency ?

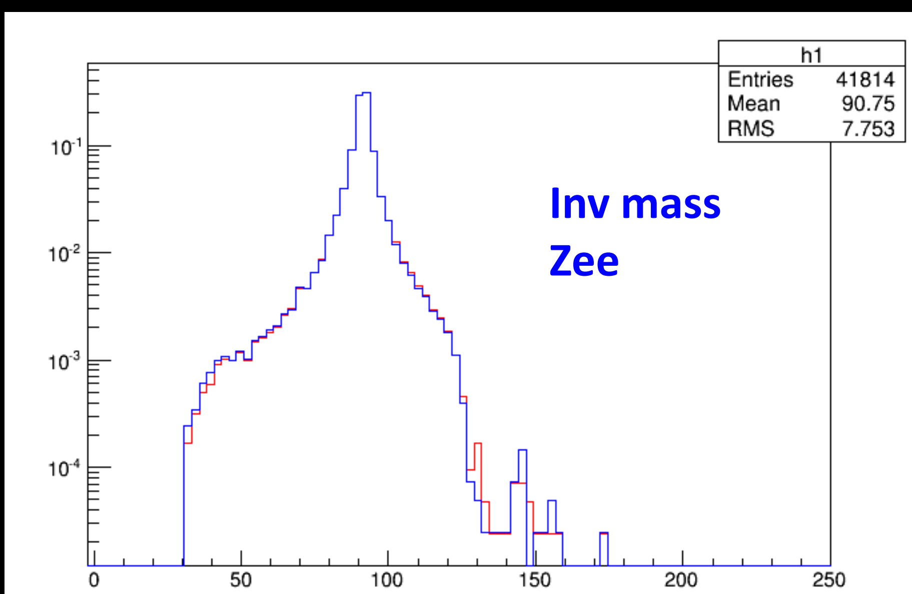
next page compares efficiency for each cut

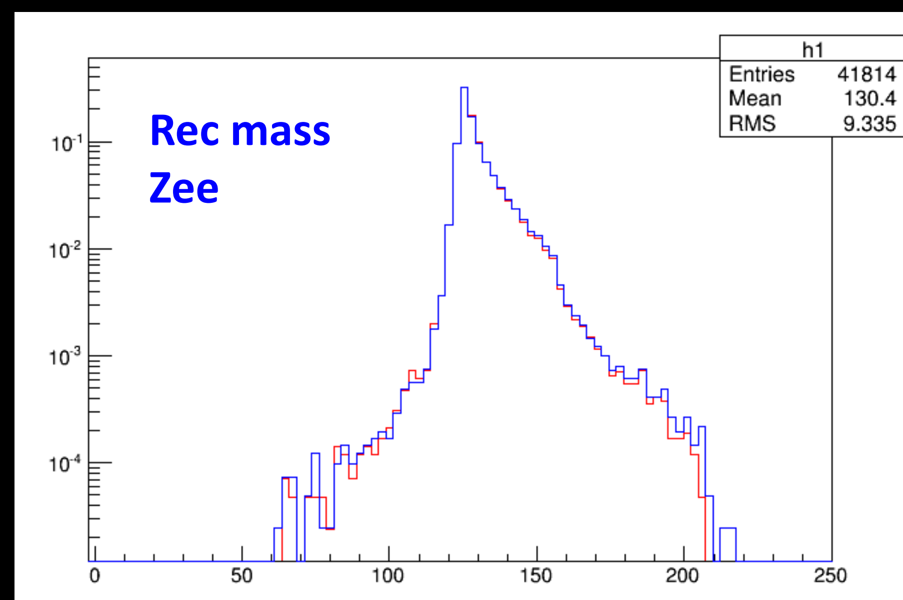
Blue : old

Red: new : inv mass and recoil mass are not as spread out









Check lepton pairing mistake is reduced : Zmm channel

OLD

250 GeV	bb	cc	zz	ww	tautau	gg	aa
Total	100.00%	100%	100.00%	100.00%	100.00%	100%	100.00%
C1	100.00%	100%	94.66%	98.13%	99.35%	100%	99.94%
C2	0.00%	0	4.97%	1.46%	0.51%	0.00%	0.06%
C3	0.00%	0	4.63%	0.46%	0.26%	0.00%	0.00%
C4	0.00%	0	0.36%	0.41%	0.14%	0.00%	0.00%
C5	0.00%	0	0.00%	0.00%	0.00%	0.00%	0.00%

NEW

250 GeV							
Total	100.00%	100%	100.00%	100.00%	100.00%	100%	100.00%
C1	100.00%	100%	95.43%	98.27%	99.39%	100%	99.96%
C2	0.00%	0	4.21%	1.33%	0.47%	0.00%	0.04%
C3	0.00%	0	3.82%	0.46%	0.26%	0.00%	0.00%
C4	0.00%	0	0.36%	0.41%	0.14%	0.00%	0.00%
C5	0.00%	0	0.00%	0.00%	0.00%	0.00%	0.00%

C1: correct

Pairing mistake — C2: two real leptons exist, but at least one wrong lepton

C3: both leptons wrong

C4: only 1 real lepton

C5: no real lepton

Check lepton pairing mistake is reduced : Zee channel

OLD

250 GeV	bb	cc	zz	ww	gg	aa
total muons	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
C1	99.90%	99.92%	97.29%	96.89%	99.95%	98.40%
C2	0.04%	0.01%	1.93%	2.12%	0.00%	1.19%
C3	0.00%	0.00%	1.16%	0.01%	0.00%	0.02%
C4	0.02%	0.01%	0.72%	0.96%	0.00%	0.37%
C5	0.00%	0	0.01%	0.00%	0.00%	0.00%

NEW

250 GeV	bb	cc				
total muons	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
C1	99.91%	99.92%	97.71%	96.90%	99.95%	98.35%
C2	0.02%	0.01%	1.52%	2.11%	0.00%	1.25%
C3	0.00%	0.00%	0.64%	0.01%	0.00%	0.01%
C4	0.02%	0.01%	0.72%	0.96%	0.00%	0.37%
C5	0.00%	0.00%	0.01%	0.00%	0%	0.00%

C1: correct

Pairing mistake — C2: two real leptons exist, but at least one wrong lepton

C3: both leptons wrong

C4: only 1 real lepton

C5: no real lepton

Efficiency of each Higgs decay mode (after each cut)

250 GeV, $Z\mu\mu$ mode

OLD processor

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.27 +/-0.081	92.67 +/-0.083	93.01 +/-0.082	92.84 +/- 0.07
Cut1 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.24 +/-0.081	92.64 +/-0.083	92.77 +/-0.083	92.83 +/- 0.07
Cut2 :	90.85 +/-0.094	90.84 +/-0.095	90.05 +/-0.098	91.37 +/-0.091	90.56 +/-0.093	90.6 +/-0.094	90.48 +/- 0.08
Cut3 :	88.92 +/- 0.1	89.07 +/- 0.1	88.23 +/- 0.11	89.39 +/-0.099	88.53 +/- 0.1	88.49 +/- 0.1	88.69 +/-0.086
Cut4 :	88.71 +/- 0.1	88.88 +/- 0.1	88.03 +/- 0.11	89.2 +/- 0.1	88.29 +/- 0.1	88.24 +/- 0.1	88.52 +/-0.087
Cut5 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.73 +/- 0.1	88.18 +/- 0.1	88.13 +/- 0.1	86.7 +/-0.092
Cut6 :	88.16 +/- 0.1	88.47 +/- 0.1	87.82 +/- 0.11	87.99 +/- 0.1	87.43 +/- 0.11	87.3 +/- 0.11	73.14 +/- 0.12
Cut7 :	81.72 +/- 0.13	81.74 +/- 0.13	81.23 +/- 0.13	81.62 +/- 0.13	81.04 +/- 0.13	81.14 +/- 0.13	67.98 +/- 0.13
Cut8 :	81.55 +/- 0.13	81.59 +/- 0.13	81.07 +/- 0.13	81.42 +/- 0.13	80.85 +/- 0.13	80.87 +/- 0.13	67.89 +/- 0.13

NEW

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.27 +/-0.081	92.67 +/-0.083	93.01 +/-0.082	92.84 +/- 0.07
Cut1 :	92.41 +/-0.086	92.43 +/-0.087	91.66 +/- 0.09	93.24 +/-0.081	92.64 +/-0.083	92.77 +/-0.083	92.83 +/- 0.07
Cut2 :	90.85 +/-0.094	90.84 +/-0.095	90.05 +/-0.098	91.4 +/-0.091	90.64 +/-0.093	90.65 +/-0.094	90.48 +/- 0.08
Cut3 :	88.92 +/- 0.1	89.07 +/- 0.1	88.23 +/- 0.11	89.4 +/-0.099	88.53 +/- 0.1	88.5 +/- 0.1	88.69 +/-0.086
Cut4 :	88.71 +/- 0.1	88.88 +/- 0.1	88.03 +/- 0.11	89.21 +/- 0.1	88.3 +/- 0.1	88.27 +/- 0.1	88.52 +/-0.087
Cut5 :	88.66 +/- 0.1	88.8 +/- 0.1	87.97 +/- 0.11	88.74 +/- 0.1	88.19 +/- 0.1	88.16 +/- 0.1	86.7 +/-0.092
Cut6 :	88.16 +/- 0.1	88.47 +/- 0.1	87.82 +/- 0.11	87.99 +/- 0.1	87.44 +/- 0.11	87.32 +/- 0.11	73.14 +/- 0.12
Cut7 :	81.72 +/- 0.13	81.74 +/- 0.13	81.23 +/- 0.13	81.62 +/- 0.13	81.03 +/- 0.13	81.12 +/- 0.13	67.98 +/- 0.13
Cut8 :	81.55 +/- 0.13	81.59 +/- 0.13	81.07 +/- 0.13	81.42 +/- 0.13	80.85 +/- 0.13	80.87 +/- 0.13	67.89 +/- 0.13

cut definition

```
------------------------
Process: ZH --> mu+ mu- H
Polarization: (e-,e+) = (-0.8,+0.3)
----------Cuts----------
Cut  0 :
Cut  1 :    leptype==13
Cut  2 :    Ptdl>10&&abs(Minv-91.18)<40&&Mrec>100&&Mrec<300
Cut  3 :    Minv>73&&Minv<120
Cut  4 :    Ptdl>10&&Ptdl<70
Cut  5 :    (Ptsum<0||Ptsum>10)
Cut  6 :    !((Evis-Elep1-Elep2-Ephotonmax)<10&&Ephotonmax>0&&abs(cosmis)>0.98)
Cut  7 :    abs(cosz) < 0.9
Cut  8 :    Mrec>100&&Mrec<160
```

- Bias related to loose cuts on Mrec and Minv (cut2, cut3) are smoothed out between H→zz, ww, tau tau
- Efficiency for H→zz slightly higher after cut2, cut3
- Final efficiency not changed

Efficiency of each Higgs decay mode (after each cut)

250 GeV, Zee mode

OLD processor

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	87.88 +/- 0.11	87.73 +/- 0.11	87.02 +/- 0.11	88.73 +/- 0.1	88.83 +/- 0.1	89 +/- 0.1	89.19 +/-0.081
Cut1 :	87.88 +/- 0.11	87.73 +/- 0.11	87.02 +/- 0.11	88.66 +/- 0.1	88.68 +/- 0.1	85.94 +/- 0.11	89.19 +/-0.081
Cut2 :	86.23 +/- 0.12	86.13 +/- 0.11	85.33 +/- 0.11	86.7 +/- 0.11	86.78 +/- 0.11	84.09 +/- 0.12	85.8 +/-0.092
Cut3 :	84.14 +/- 0.12	84.06 +/- 0.12	83.28 +/- 0.12	84.11 +/- 0.12	83.99 +/- 0.12	81.75 +/- 0.12	83.53 +/-0.097
Cut4 :	84.04 +/- 0.12	83.97 +/- 0.12	83.2 +/- 0.12	83.98 +/- 0.12	83.84 +/- 0.12	81.64 +/- 0.12	83.42 +/-0.098
Cut5 :	83.99 +/- 0.13	83.89 +/- 0.12	83.13 +/- 0.12	83.52 +/- 0.12	83.73 +/- 0.12	81.52 +/- 0.12	81.7 +/- 0.1
Cut6 :	83.5 +/- 0.13	83.54 +/- 0.12	82.95 +/- 0.12	82.84 +/- 0.12	82.95 +/- 0.12	80.75 +/- 0.13	69.68 +/- 0.12
Cut7 :	77.4 +/- 0.14	77.53 +/- 0.14	76.82 +/- 0.14	77.04 +/- 0.14	76.91 +/- 0.14	75.16 +/- 0.14	64.82 +/- 0.13
Cut8 :	77.21 +/- 0.14	77.3 +/- 0.14	76.57 +/- 0.14	76.8 +/- 0.14	76.65 +/- 0.14	74.89 +/- 0.14	64.65 +/- 0.13

NEW

Eff. (%)	bb	cc	gg	tt	ww	zz	aa
Cut0 :	87.88 +/- 0.11	87.73 +/- 0.11	87.02 +/- 0.11	88.73 +/- 0.1	88.83 +/- 0.1	89 +/- 0.1	89.19 +/-0.081
Cut1 :	87.88 +/- 0.11	87.73 +/- 0.11	87.02 +/- 0.11	88.66 +/- 0.1	88.68 +/- 0.1	85.94 +/- 0.11	89.19 +/-0.081
Cut2 :	86.24 +/- 0.12	86.13 +/- 0.11	85.33 +/- 0.11	86.73 +/- 0.11	86.82 +/- 0.11	84.12 +/- 0.12	85.86 +/-0.091
Cut3 :	84.14 +/- 0.12	84.06 +/- 0.12	83.28 +/- 0.12	84.04 +/- 0.12	83.86 +/- 0.12	81.72 +/- 0.12	83.5 +/-0.097
Cut4 :	84.04 +/- 0.12	83.96 +/- 0.12	83.2 +/- 0.12	83.92 +/- 0.12	83.71 +/- 0.12	81.58 +/- 0.12	83.38 +/-0.098
Cut5 :	83.99 +/- 0.13	83.88 +/- 0.12	83.13 +/- 0.12	83.45 +/- 0.12	83.6 +/- 0.12	81.47 +/- 0.12	81.66 +/- 0.1
Cut6 :	83.5 +/- 0.13	83.54 +/- 0.12	82.95 +/- 0.12	82.77 +/- 0.12	82.83 +/- 0.12	80.67 +/- 0.13	69.67 +/- 0.12
Cut7 :	77.4 +/- 0.14	77.53 +/- 0.14	76.82 +/- 0.14	76.97 +/- 0.14	76.79 +/- 0.14	75.08 +/- 0.14	64.79 +/- 0.13
Cut8 :	77.21 +/- 0.14	77.3 +/- 0.14	76.56 +/- 0.14	76.75 +/- 0.14	76.54 +/- 0.14	74.83 +/- 0.14	64.63 +/- 0.13

cut definition

```
------------------------
Process: ZH --> e+ e- H
Polarization: (e-,e+) = (-0.8,+0.3)
----------Cuts----------
Cut  0 :
Cut  1 :    leptype==11
Cut  2 :    Ptdl>10&&abs(Minv-91.18)<60&&Mrec>100&&Mrec<300
Cut  3 :    Minv>73&&Minv<120
Cut  4 :    Ptdl>10&&Ptdl<70
Cut  5 :    (Ptsum<0||Ptsum>10)
Cut  6 :    !((Evis-Elep1-Elep2-Ephotonmax)<10&&Ephotonmax>0&&abs(cosmis)>0.98)
Cut  7 :    abs(cosz) < 0.9
Cut  8 :    Mrec>100&&Mrec<160
```

- Smoothing out of bias related to loose cuts on Mrec and Minv (cut2, cut3) are not apparent
- Efficiency for H→zz, ww, tau tau lowered by about 0.1%
-

Conclusion on mode dependence study

Tried to improve isolated lepton finder to resolve the slight mode dependence related to the early stage loose requirements on Invariant mass and recoil mass

For Zmm channel :

- We see pairing mistake reduced, esp for H→ zz mode
- bias in early stage smoothed out between different modes
- **No effect on final efficiency (after all other cuts)**

  ➔ we still need other ways of improving

- **use MC truth to study if other cuts affect "correct pairs" and "wrong pairs" differently**

For Zee channel, :

- pairing mistake reduced for H→ zz, ww
- However mistake increased slightly for other modes (γγ、 ττ) need investigation
- Final efficiency is slightly reduced (by ∼ 0.1%)

Maybe : width used in denominator of chi^2 function was too tight due to contribution from longer tail recoil mass tail (and wider inv mass distr due to brem ?)

- **Maybe we should use different lepton pairing strategies for Zee and Zmm.**
- **Other cuts need to be investigated in the same way**

BACKUP

Efficiency of each Higgs decay mode (after each cut)

250 GeV, Zμμ mode

250 GeV	bb	cc	tt	gg	ww	zz
cut0	92.41+/−0.09%	92.43+/−0.09%	93.27+/−0.08%	91.66+/−0.09%	92.64+/−0.08%	92.77+/−0.08%
cut1	90.85+/−0.09%	90.84+/−0.09%	91.40+/−0.09%	90.06+/−0.10%	90.72+/−0.09%	90.76+/−0.09%
cut2	88.92+/−0.10%	89.07+/−0.10%	89.39+/−0.09%	88.23+/−0.11%	88.53+/−0.10%	88.49+/−0.10%
cut3	88.71+/−0.10%	88.88+/−0.10%	89.20+/−0.10%	88.03+/−0.11%	88.29+/−0.10%	88.24+/−0.10%
cut4	88.66+/−0.10%	88.80+/−0.10%	88.73+/−0.10%	87.97+/−0.11%	88.18+/−0.10%	88.13+/−0.10%
cut5	88.16+/−0.10%	88.47+/−0.10%	87.99+/−0.10%	87.82+/−0.11%	87.43+/−0.11%	87.30+/−0.11%
cut6	81.72+/−0.13&	81.74+/−0.13%	81.62+/−0.13%	81.22+/−0.13%	81.04+/−0.14%	81.14+/−0.13%
cut7	72.4+/−0.15%	72.29+/−0.15%	72.33+/−0.14%	71.91+/−0.15%	71.67+/−0.14%	71.29+/−0.15%

Cut0: isolated μ selection
Cut1: loose Minv and Mrec window
Cut2: 73<Minv<120 GeV
Cut3: 10 < Pt_dl < 70 GeV
Cut4: Ptsum > 10 GeV
Cut5: cos(θ missing) < 0.98
Cut6: cos(θ Z) < 0.9
Cut7: 100 < Mrec 160 GeV

- tt, ZZ, WW affected by "mistaken lepton selection"
  c.f gg mode receive no particular bias (?)
- tt more biased by Ptsum cut
- diverse effect from cos(θ missing) cut

Efficiency of each Higgs decay mode (after each cut)

250 GeV, Zee mode

250 GeV	bb	cc	tt	gg	ww	zz
cut0	86.00+/−0.12%	85.86+/−0.11%	86.84+/−0.10%	85.16+/−0.11%	86.79+/−0.11%	84.11+/−0.11%
cut1	84.28+/−0.12%	84.22+/−0.12%	84.71+/−0.11%	83.43+/−0.12%	84.77+/−0.12%	82.15+/−0.12%
cut2	82.35+/−0.13%	82.27+/−0.12%	82.31+/−0.12%	81.50+/−0.12%	82.20+/−0.12%	80.01+/−0.13%
cut3	82.24+/−0.13%	82.18+/−0.12%	82.20+/−0.12%	81.43+/−0.12%	82.05+/−0.12%	79.90+/−0.13%
cut4	82.20+/−0.13%	82.10+/−0.12%	81.74+/−0.12%	81.36+/−0.12%	81.95+/−0.12%	79.79+/−0.13%
cut5	81.72+/−0.13%	81.76+/−0.12%	81.07+/−0.12%	81.18+/−0.12%	81.19+/−0.13%	79.03+/−0.13%
cut6	75.75+/−0.14%	75.88+/−0.14%	75.40+/−0.14%	75.19+/−0.14%	75.27+/−0.14%	73.56+/−0.14%
cut7	54.65+/−0.17%	54.86+/−0.16%	54.21+/−0.16%	54.38+/−0.16%	53.83+/−0.16%	52.83+/−0.16%

Cut0: isolated μ selection
Cut1: loose Minv and Mrec window
Cut2: 73<Minv<120 GeV
Cut3: 10 < Pt_dl < 70 GeV
Cut4: Ptsum > 10 GeV
Cut5: cos(θ missing) < 0.98
Cut6: cos(θ Z) < 0.9
Cut7: 100 < Mrec 160 GeV

- Similar trends as observed for Zmm
- larger loss due to Minv cut

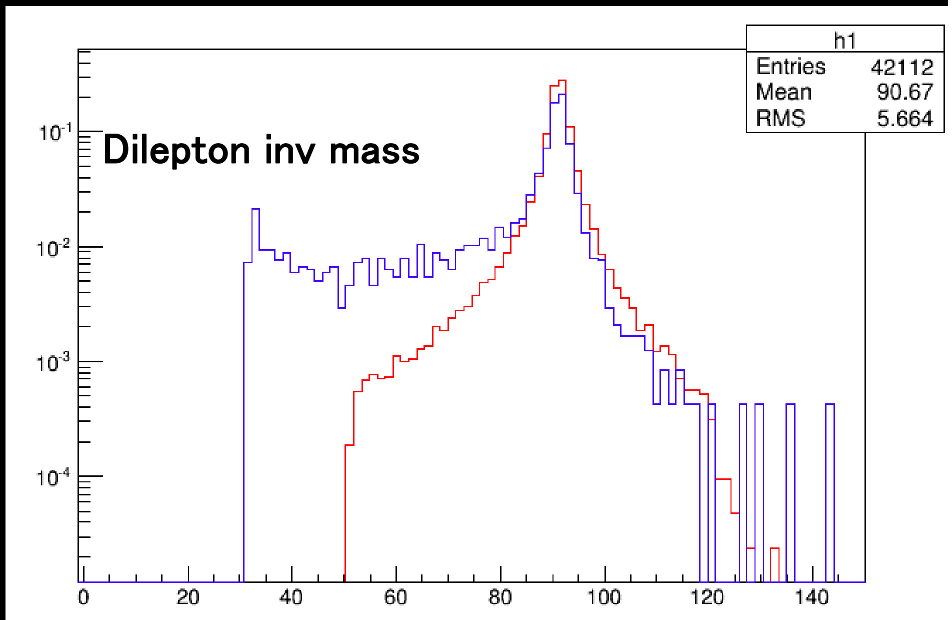
250 GeV	e2e2_Lpol				deviation	deviation
	N(100-160)	N_err	eff	eff_err	from avg	from ALL
bb	1885	5	72.40%	0.15%	0.42%	0.21%
cc	1882	5	72.29%	0.15%	0.31%	0.10%
tt	1883	5	72.33%	0.14%	0.35%	0.15%
gg	1872	5	71.91%	0.15%	-0.08%	-0.28%
ww	1866	5	71.67%	0.14%	-0.31%	-0.51%
zz	1856	5	71.29%	0.15%	-0.69%	-0.90%
all modes	1883	9	72.19%	0.27%		
		avg of 6	71.98%			

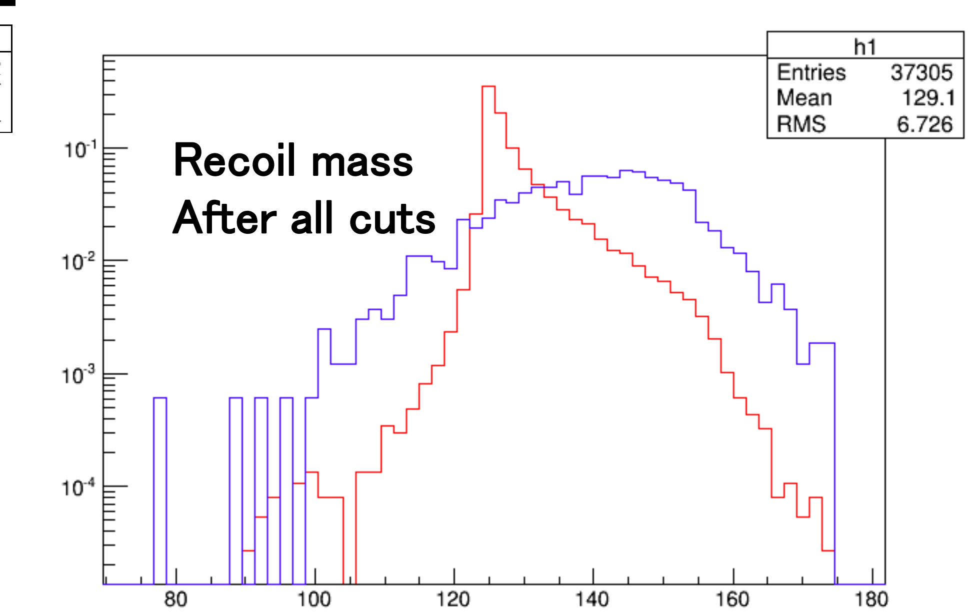
Efficiency of each Higgs decay mode (after all cuts)

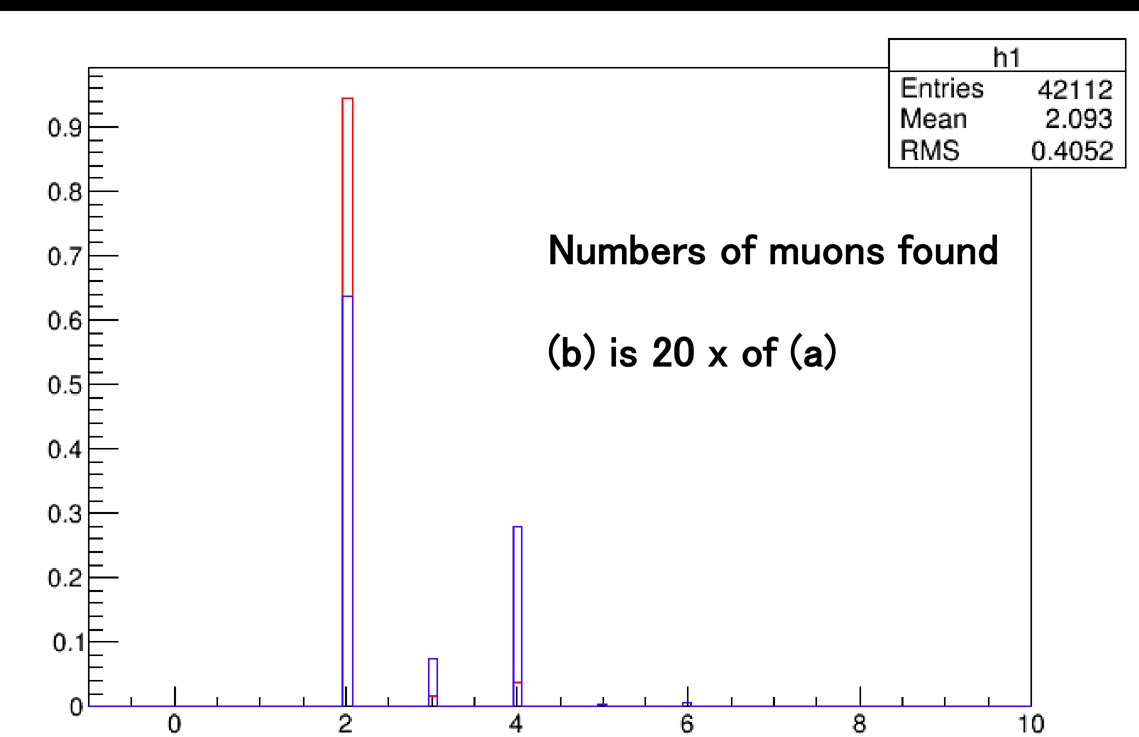
- systematic bias is < **1.3% for Zmm. < 4.2% for Zee**
- **H→zz, H→ww most affected**

(lepton pair containing lepton not from prompt Z decay)

250 GeV	e1e1_Lpol				deviation	deviation
	N(100-160)	deltaN	eff	eff_err	from avg	from ALL
bb	1491	6	54.65%	0.17%	-1.15%	-0.39%
cc	1497	6	54.86%	0.16%	-0.94%	-0.18%
tt	1480	6	54.21%	0.16%	-1.58%	-0.83%
gg	1484	6	54.38%	0.16%	-1.42%	-0.66%
ww	1469	6	53.83%	0.16%	-1.96%	-1.21%
zz	1442	6	52.83%	0.16%	-2.96%	-2.21%
all modes	1502	10	55.04%	0.28%		
		avg of 6	54.13%			





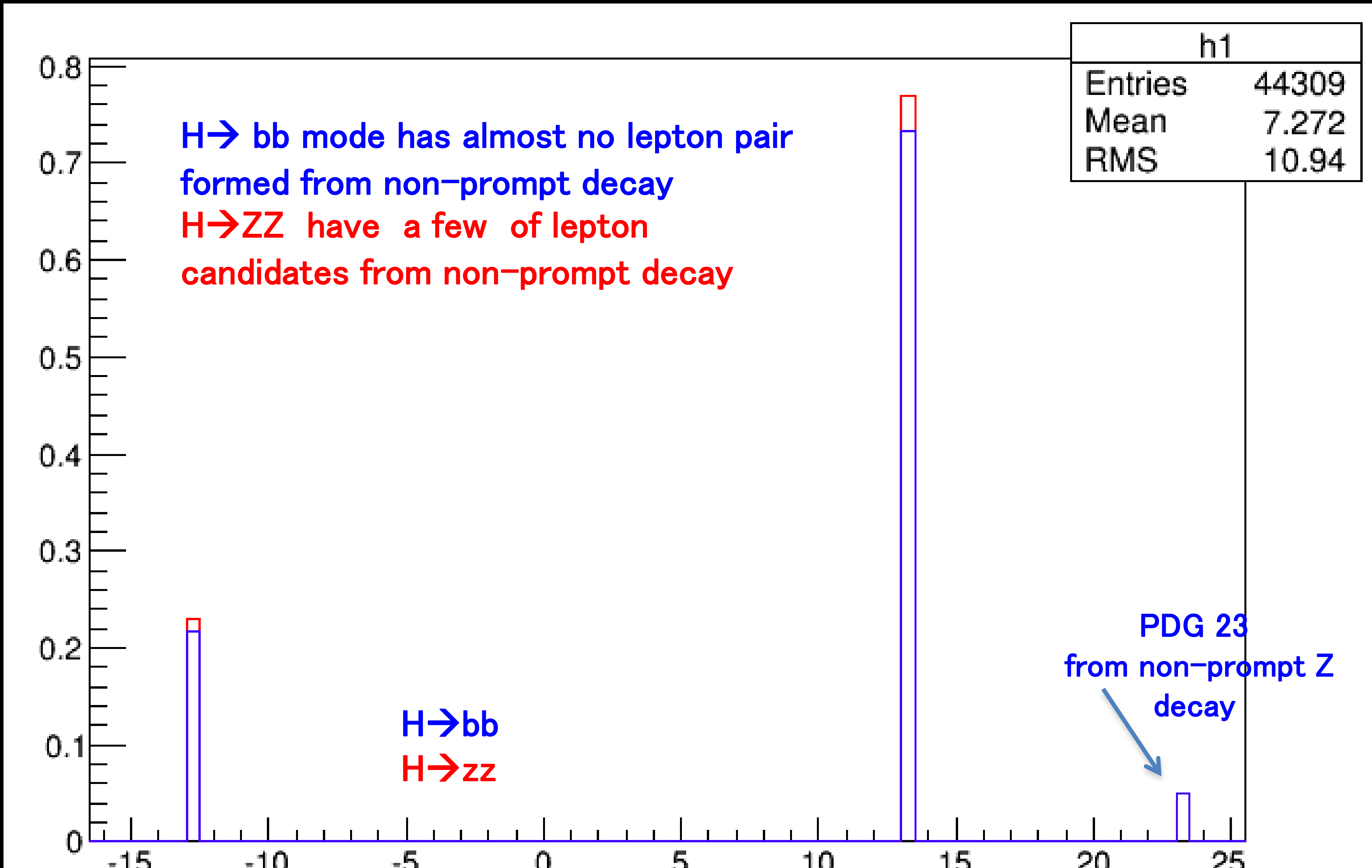


Z→mm, H→zz mode

(a) at least one lepton is not from prompt Z decay

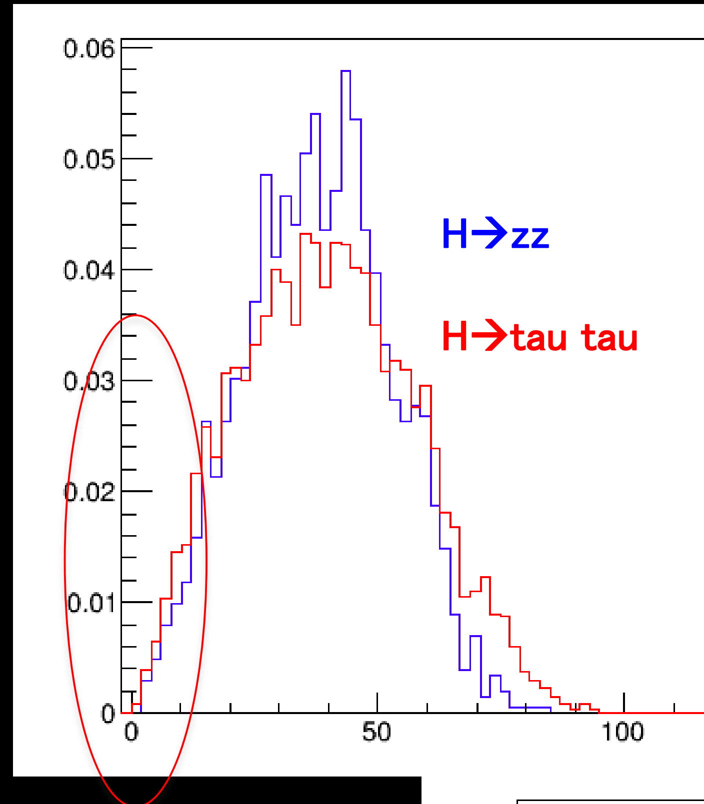
(b)both leptons from prompt decay

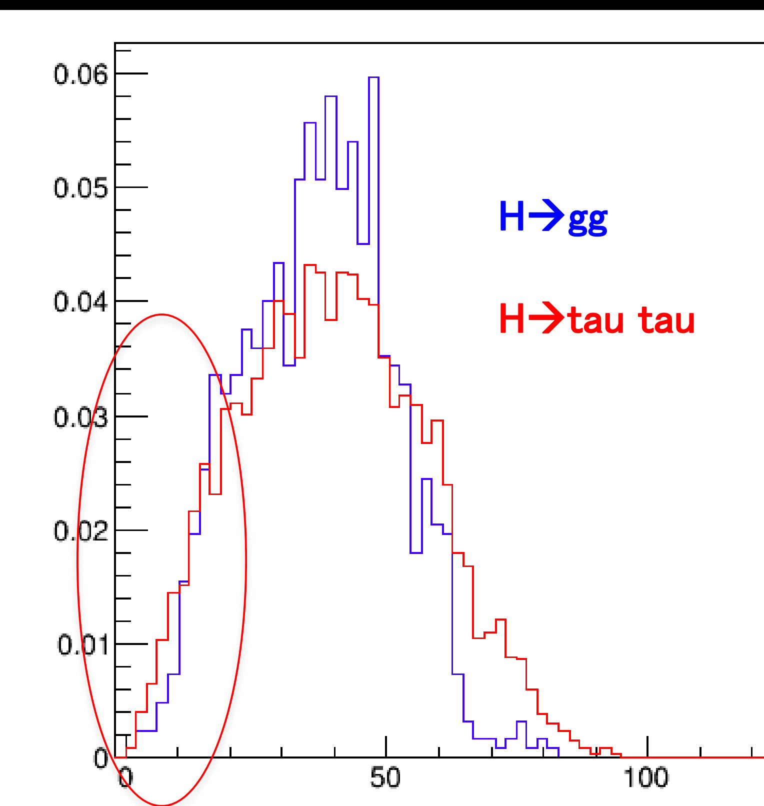
Use MC truth to investigate parent PDG of feptons in “selected pair” Z→mm

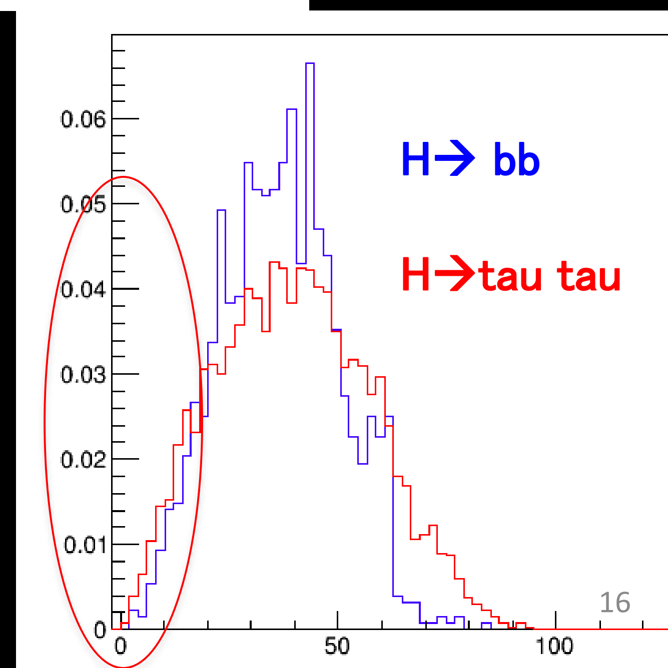


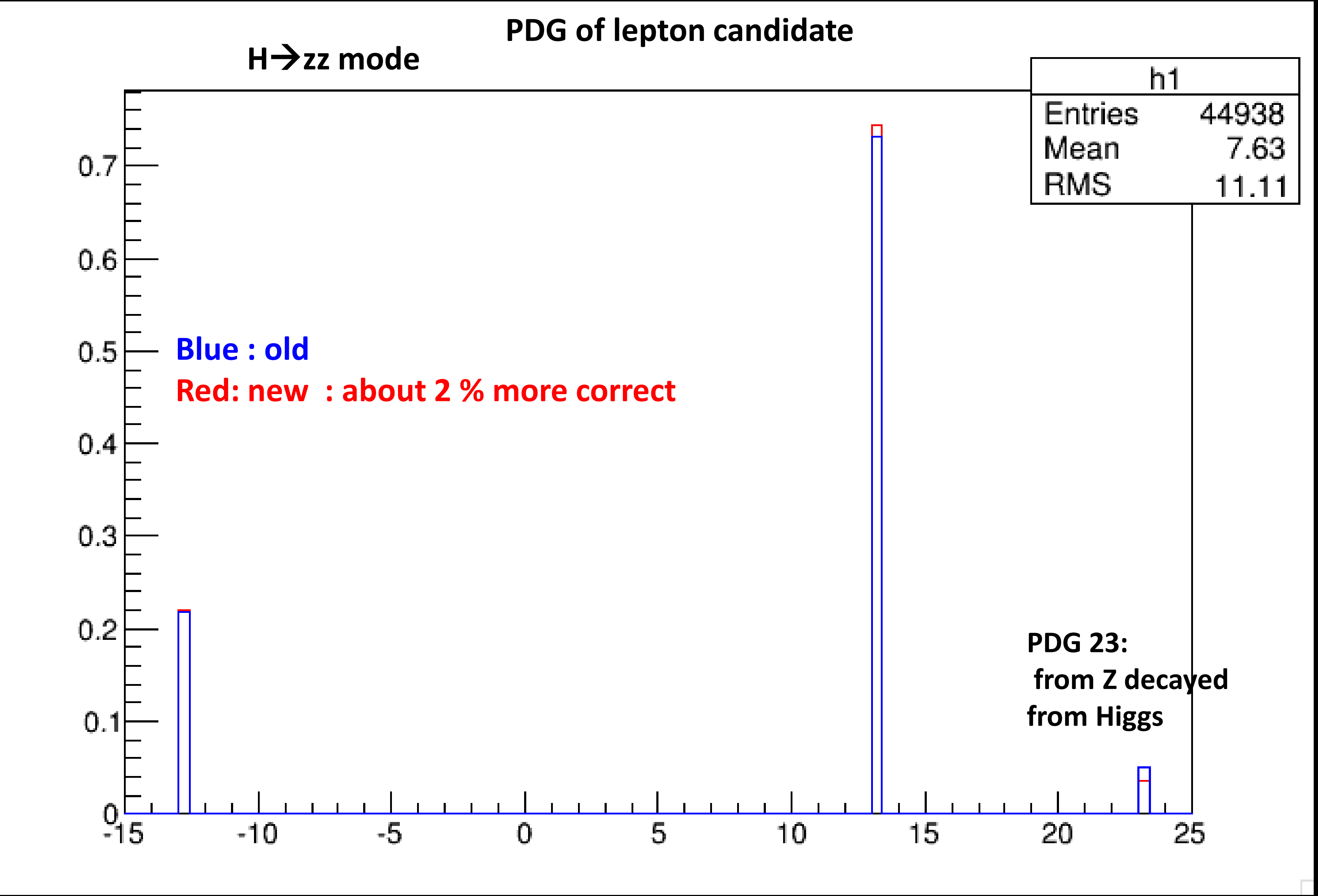
observation of Ptsum distr
(at stage just before Ptsum cut)
Zmm channel

Compare to other modes,
H→tau tau seem very slightly biased in region of Ptsum < 10








PDG of lepton candidate
H→zz mode
h1
Entries 44938
Mean 7.63
RMS 11.11
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-15
-10
-5
0
5
10
15
20
25
Blue : old
Red: new : about 2 % more correct
PDG 23:
from Z decayed
from Higgs

Statistical error study results
Z→μμ and Z→ee combined

(−0.8,+0.3)		xsec err	mass err [MeV]
250GeV	Zmm	3.35%	40.4
	Zee	4.76%	109
	Total	**2.74%**	**37.9**
350GeV	Zmm	3.90%	101
	Zee	5.63%	327
	Total	**3.21%**	**96.5**
500GeV	Zmm	6.95%	474
	Zee	9.89%	1540
	Total	**5.69%**	**453**

xsec error

- 350 GeV is 17 % worse w.r.t. 250 GeV
- 500 GeV is much worse
- Zee is worse by > 40% w.r.t. Zmm
- right hand pol is worse by 5 – 10 % w.r.t. left hand

Mass error

- 350 GeV is worse by factor of slightly less than 3 w.r.t. 250 GeV
- Zee is worse by a factor of 2 – 3 w.r.t. Zmm
- Systematic error of fitted recoil mass is negligible (< few MeV for 250 , 350 GeV)

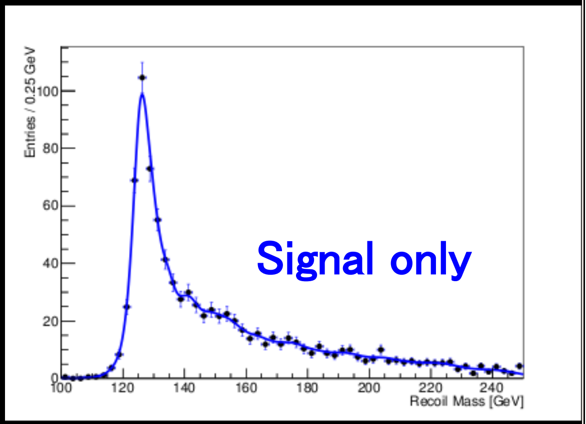
(+0.8,−0.3)		xsec err	mass err [MeV]
250GeV	Zmm	3.57%	40.5
	Zee	5.14%	121
	Total	**2.93%**	**38.4**
350GeV	Zmm	4.31%	112
	Zee	6.26%	296
	Total	**3.55%**	**105**
500GeV	Zmm	8.36%	613
	Zee	9.85%	1510
	Total	**6.37%**	**568**

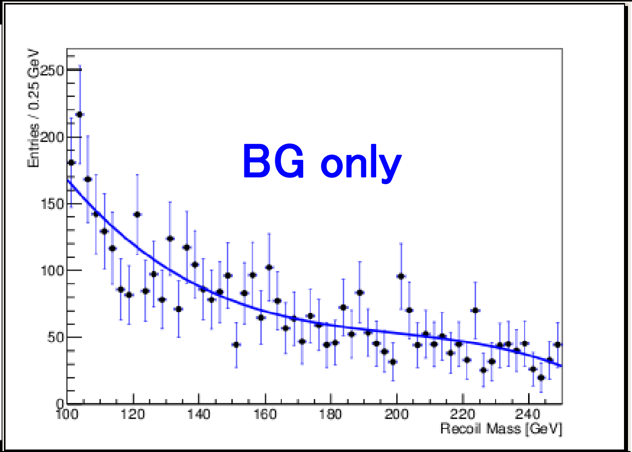
xsec error almost same as past results using GPET

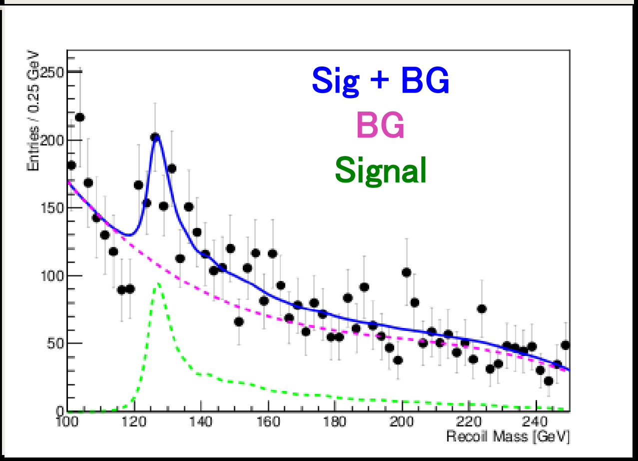
Can precision can be slightly improved if we fit over a wider range ?
assuming we can neglect the H*→WW bump beyond 160 GeV

500 GeV, Zee (-0.8,+0.3)

fit in 100 – 250 GeV (c.f. 100-160 GeV)



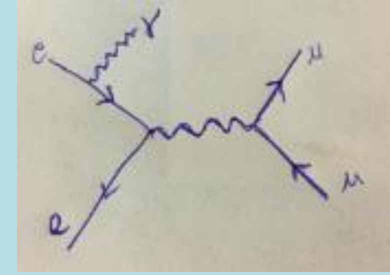




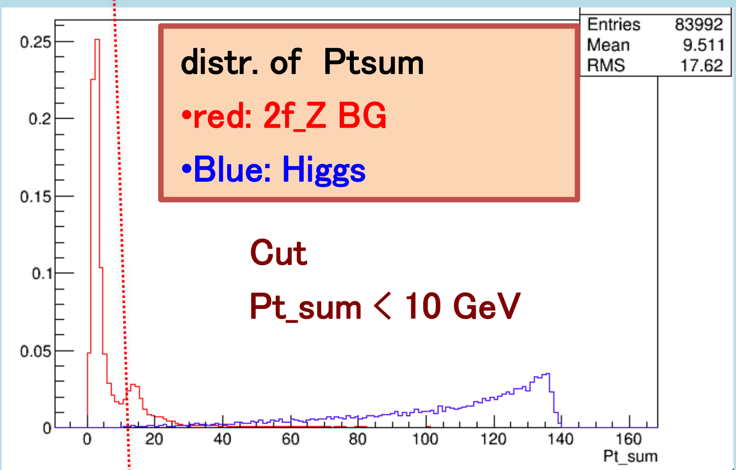
		xsec error (%)		mass error (MeV)	
(−0.8,+0.3)		narrow	wide	narrow	wide
500GeV	Zmm	6.95%	6.50%	474	468
	Zee	9.89%	7.86%	1540	1540
	Total	**5.69%**	**5.01%**	**453**	**448**
(+0.8,−0.3)					
500GeV	Zmm	8.36%	7.27%	613	572
	Zee	9.85%	7.86%	1510	1530
	Total	**6.37%**	**5.33%**	**568**	**536**

10-20 % improvement on xsec and a few % on mass precision

Prevention of signal bias i.e. Higgs decay mode dependence



- the "traditional" dptbal (= |Pt,dl | − |Pt, γ |) cut for removing 2f BG (γ back–to back w.r.t. di–lepton) caused signal bias (esp. H → τ τ , γ γ)

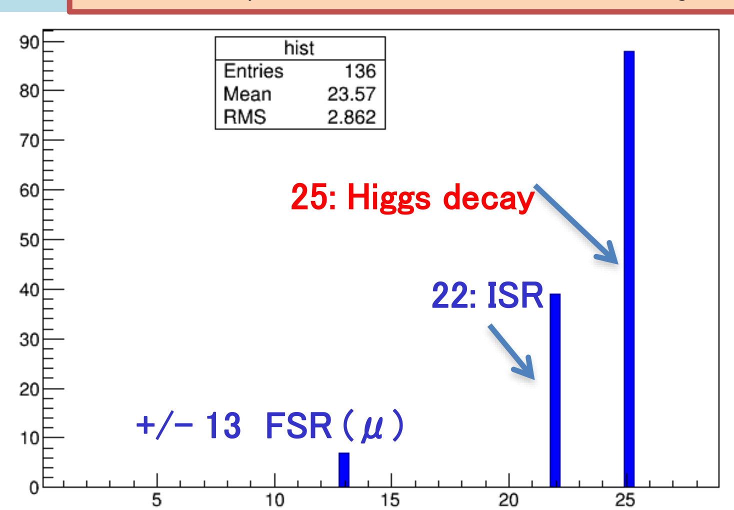


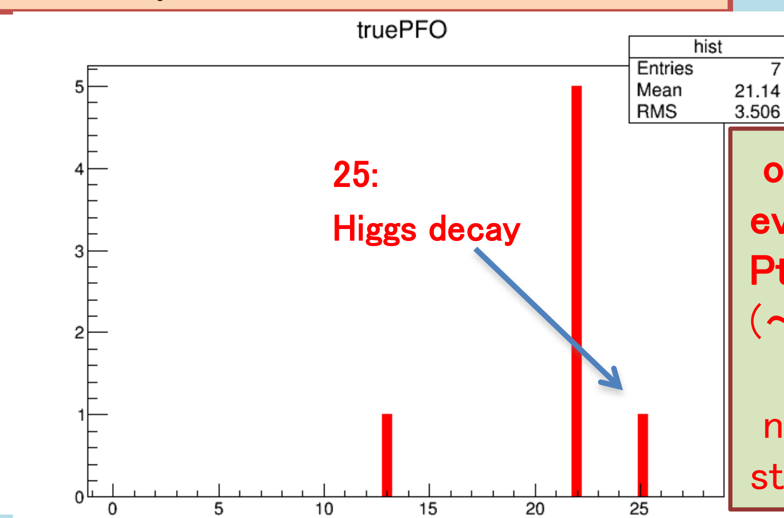
NEW #1 isolated photon finder: γ we look at have small cone energy) not from Higgs decay

NEW #2 Now use $\left|\overrightarrow{P_{t,sum}}\right| \circ \left|\overrightarrow{P_{t,g}}+\overrightarrow{P_{t,dl}}\right|$ (instead of dptbal)

vector direction info singles out back to back events

PDG of γ for events removed by Ptsum /dptbal cut (250 GeV Zmm)





only < few unweighed events removed by Ptsum cut (∼ 0 weighed events)

negligible compared to statistical uncertainties

∼100 Higgs decay related γ events removed by dptbal cut !!

need more careful study of Higgs decay mode bias using high stat sample