$\mathrm{H} \longrightarrow \mu\mu$ @ 1 TeV Update

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Weekly Physics & Software Meeting

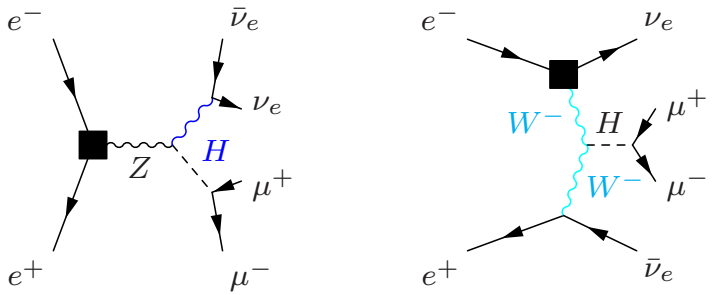
December 07th, 2012

Today

1. Final State Radiation (FSAR) of the muons from $\mathrm{H} \rightarrow \mu\mu$
2. Signal efficiency after reconstruction/preselection
   - Purity not checked but expected high (based on previous preliminary studies).
3. Debugged my optimization algorithm.
   - Smooth distributions: used sidebands for extract background.
   - Added Signal/background distributions in the scans plots.
   - Decided best value taking in account signal (not only significance distribution).
   - Expected significant improvement.

- All the plots shown were made using full simulated and reconstructed $\mathrm{H} \rightarrow \mu\mu$ samples.
- Used `RecoMCTruthLink` and `MCParticlesSkimmed` Collection to find the real $\mu^{\pm}$.

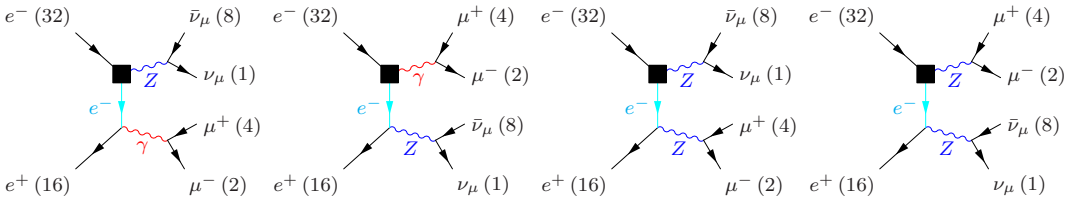
$H \to \mu\mu$



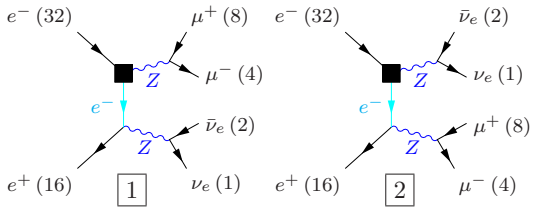
$H \to \mu\mu$

- E=1 TeV
- cross section: 748.4 fb^{-1}(lr), 5.905 fb^{-1}(rl)
- branching ratio: 0.000221
  - $\approx$ 45 events with L=500 $\mathrm{fb}^{-1}$and (e^{-1},e^{+1})=(-0.8,$+0.2$)
  - $\approx$ 4 events with L=500 $\mathrm{fb}^{-1}$and (e^{-1},e^{+1})=($+0.8$,-0.2)
- ILCSOFTv16
- Included overlay $\gamma\gamma \to$ hadrons

Main Background Sources



$$ZZ(WW) \rightarrow \nu\nu\mu\mu$$



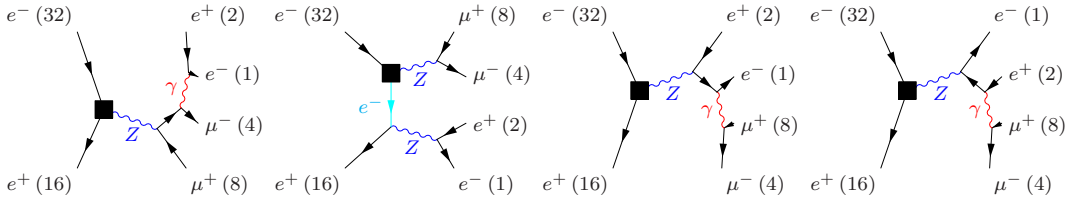
$$Z \rightarrow \nu\nu\mu\mu$$

- same final state as the signal.
- Only showed a few of the total Feynman diagrams.

Other Background Sources

Other sources considered:

- $\mu\mu e^+e^-$ (leptons being forward)

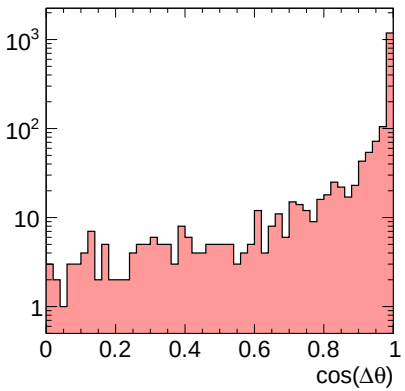


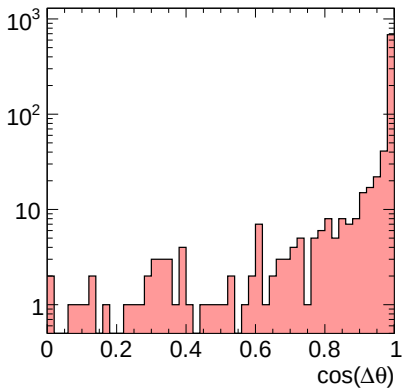
- $Z \longrightarrow \mu\mu$
- 4f_sw_l
- 4f_ww_l
- 4f_zz_l

Final State Radiation (FSAR)

FSAR in $H \to \mu\mu$ (probability 63 %)

- μ^+,μ^-(or both) emit γ's
- That causes low tails in Higgs mass distribution
  - emited γ carries a fraction of E/P of the muon.
- Tipicaly angle between emited γ and μ very small $\cos(\Delta\theta) \approx 1$
  - left plot: cos(μ, γ) distribution
  - right plot: cos(μ, γ) distribution E(γ)$>$ 500 MeV
- Recovering adding to muon P/E from γ's inside cone (semiangle 11.48^o)





Muons FSAR

- Checked MCTruth information
- In 10^4 signal events 6270 events showed FSAR

FSAR

- Muon (PDG=13) stable.
- Anti-muon (PDG=-13) emit γ.

PDG	gen Status	energy	P_T	cosθ
22	2	0	0	1
22	2	1.33953	1.33811	-0.0461053
25	2	262.186	143.788	0.78151
22	1	0	0	1
22	1	1.33953	1.33811	-0.0461053
25	2	262.186	143.788	0.78151
13	2	214.899	145.462	0.736086
-13	2	47.2871	41.8939	0.46378
13	1	214.876	145.447	0.736086
-13	2	47.3096	41.8911	0.464079
-13	1	47.1372	41.7619	0.463747
22	1	0.17236	0.14843	0.508333

FSAR

- Muon (PDG=13) emit γ.
- Anti-muon (PDG=-13) stable.

PDG	gen Status	energy	P_T	cosθ
22	2	5.47783e-14	3.58122e-16	0.999979
22	2	4.76897e-06	2.51788e-08	-0.999986
25	2	209.414	63.331	0.926239
22	1	5.47783e-14	3.58122e-16	0.999979
22	1	4.76897e-06	2.51788e-08	-0.999986
25	2	209.414	63.331	0.926239
13	2	144.678	14.1117	0.995232
-13	2	64.736	63.6818	0.179721
13	2	144.678	14.1117	0.995232
-13	1	64.736	63.6818	0.179721
13	1	144.314	14.0767	0.995231
22	1	0.363252	0.0351287	0.995313

FSAR

- Both, muon a-muon stable (status = 1)

PDG	gen Status	energy	P_T	cosθ
22	2	74.5424	21.9292	0.955749
22	2	0.0134528	0.000106008	-0.999969
25	2	231.598	142.949	-0.680024
22	1	74.5424	21.9292	0.955749
22	1	0.0134528	0.000106008	-0.999969
25	2	231.598	142.949	-0.680024
13	1	200.504	160.48	-0.599486
-13	1	31.094	28.5214	-0.398268

FSAR

- Both, muon a-muon unstable (status = 2)

PDG	gen Status	energy	P_T	cosθ
22	2	0.0021251	0.000231734	0.994037
22	2	4.99517e-07	3.4965e-09	-0.999976
25	2	231.093	159.696	-0.57004
22	1	0.0021251	0.000231734	0.994037
22	1	4.99517e-07	3.4965e-09	-0.999976
25	2	231.093	159.696	-0.57004
13	2	20.1112	20.1108	0.0034987
-13	2	210.982	179.504	-0.525486
13	2	20.091	20.0899	0.00348981
-13	2	211.002	179.483	-0.525528
13	2	20.0225	20.0221	0.00343475
22	1	0.068509	0.0684959	0.0195483
-13	1	210.136	178.649	-0.526524
22	1	0.866272	0.836249	-0.260987
13	1	20.0224	20.022	0.0034356
22	1	3.47889e-05	3.04306e-05	-0.48463

Preselection

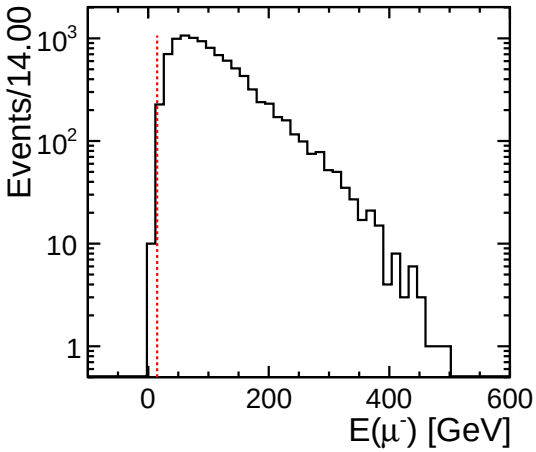
2 Muons

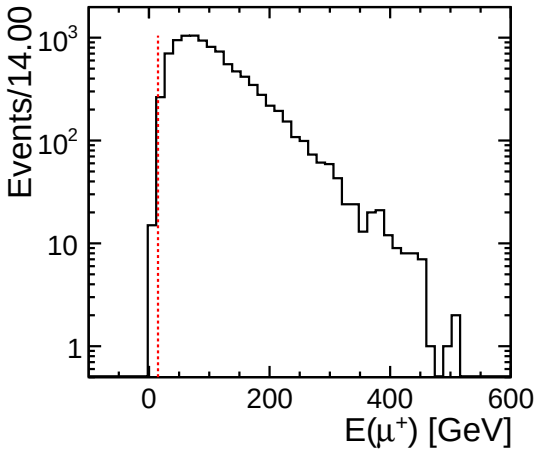
- $E > 15$ GeV
- $E_{calE}/(E_{calE} + E_{calH}) < 0.5$
- $(E_{calE} + E_{calH})/|\vec{P}| < 0.3$

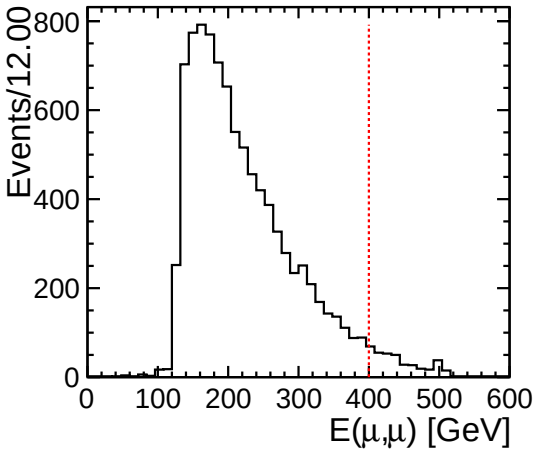
H candidate

- $E_{muon1} + E_{muon2} < 400$ GeV
- $|M(\mu^+, \mu^-) - 125| < 30\ \mathrm{GeV/c^2}$

- No isolation requirement.
- Table signal Efficiency next slide



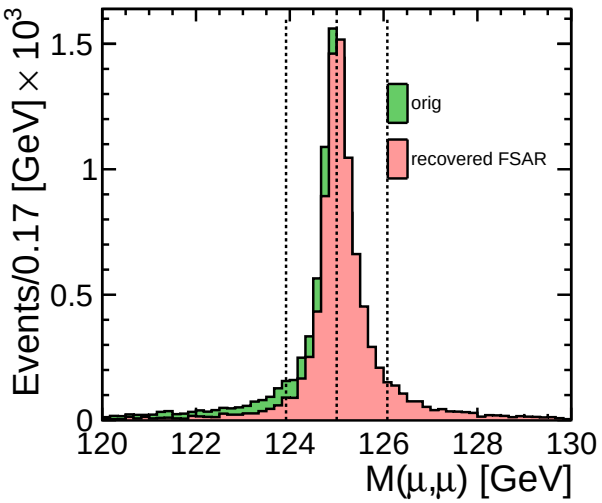




Signal Efficiency

Signal Efficiency (%), $\sigma = 0.36\ \mathrm{GeV/c^2}$

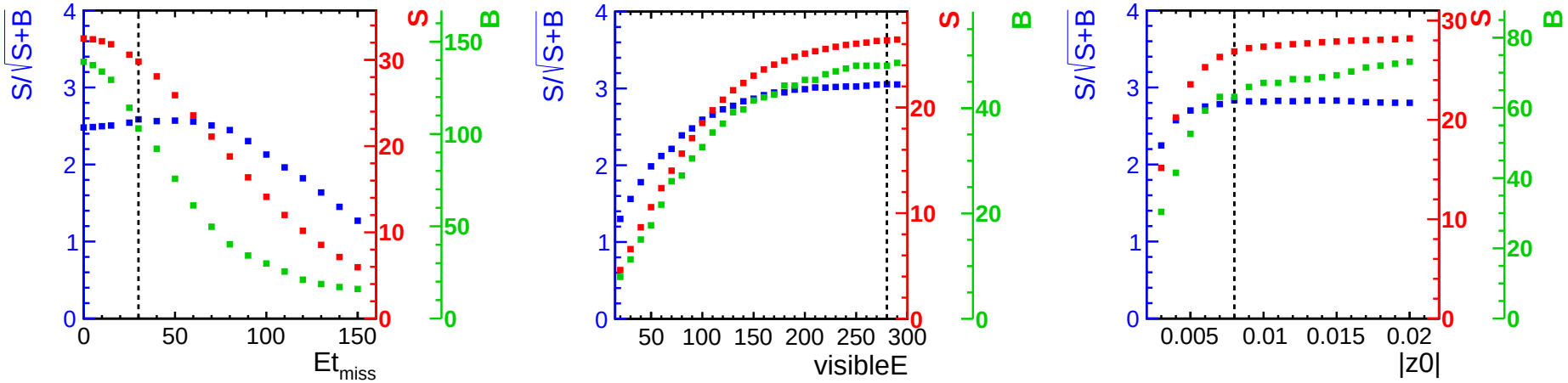
Selection	Efficiency	# Events
0) Nature	1.00	45
1) reco	94.09 (94.09)	42.3
2) μ selec.	96.31 (90.62)	40.78
3) $\lvert mH - 125\rvert < 30, eH < 400$	95.53 (86.57)	38.96
x) $\lvert mH - 125\rvert < 3 * \sigma$	82.86 (71.73)	32.28



- Signal efficiency after reconstruction/preselection: 86.6 %
- Events with $\mu^{\pm} \rightarrow \gamma$: 62.7 % (MCTruth)
- Added P/E of γ inside μ cone of semiangle 11.48^o
- Area 3 σ around peak just 83 %

Optimization

- Previously defining S/B in every scan as # events inside signal window
- That's ok for signal (enough statistics) but back fluctuates and makes funny distribution shapes
- Now B is defined using long enough sidebands, and normalizing # events with the signal region size.



Summary

$\mathrm{H} \rightarrow \mu\mu$

- Checked FSAR: probability of μ emitting γ 63 %
- Studied signal efficiency: after reco/pre-selection, efficiency = 86.6 %
- Improve optimization algorithm.

Back up

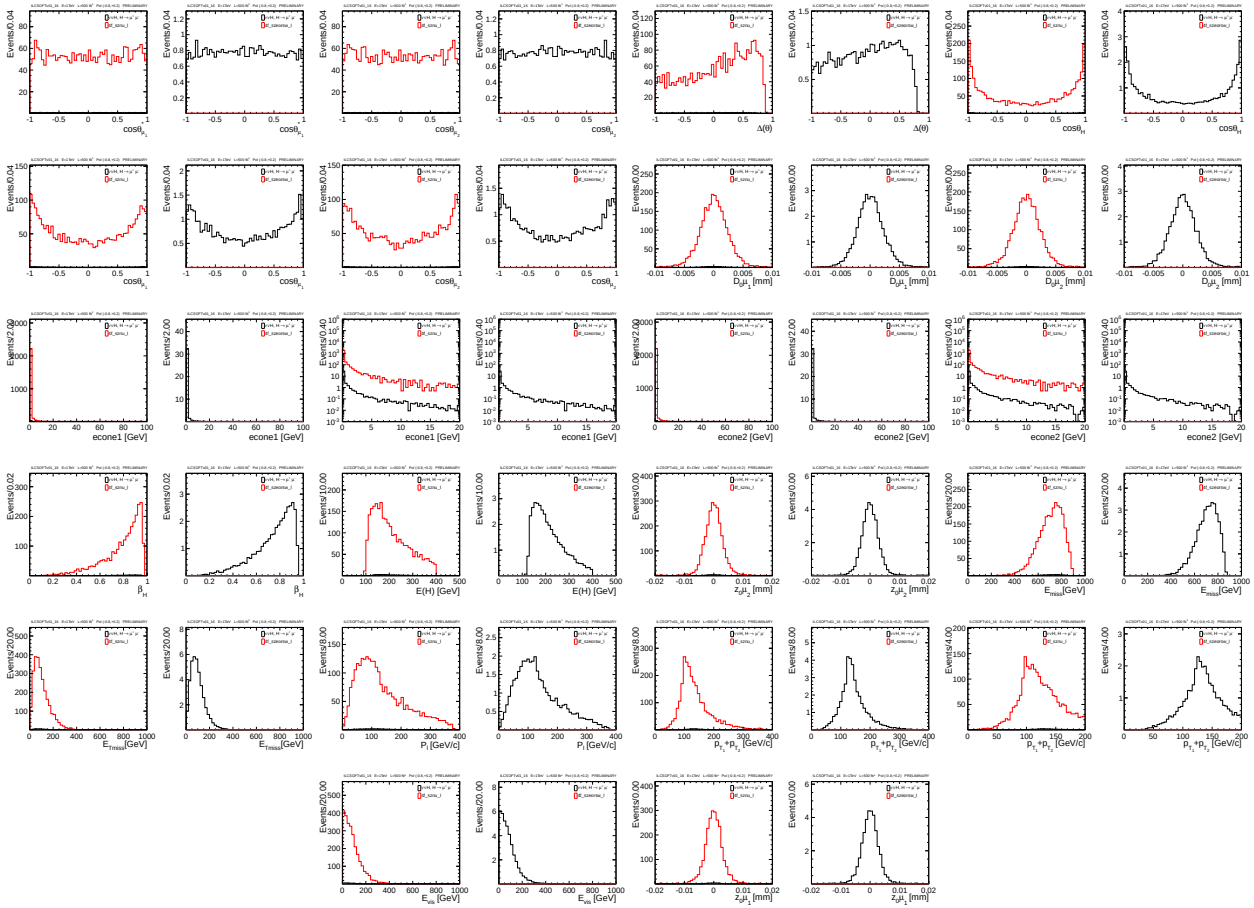
Muon Selection Efficiency/Purity

process	effi (%)	purity(%)
signal	98.1747	99.8674
2f_z_bhabhag	NA	0
2f_Z_hadronic	95	37.2549
2f_Z_leptonic	95.4683	95.4683
4f_WW_leptonic	98.1707	95.2663
4f_ZZWWMix_hadronic	92.3077	21.0526
4f_ZZWWMix_leptonic	97.4763	96.5625
4f_ZZ_hadronic	94.7368	45.5696
4f_ZZ_leptonic	96.1123	97.8022
4f_ZZ_semileptonic	98.1595	85.5615
4f_singleW_leptonic	99.0741	99.0741
4f_singleZnunu_leptonic	98.0831	99.3528
4f_singleZnunu_semileptonic	100	52.381
4f_singleZsingleWMix_leptonic	NA	0
4f_singleZee_semileptonic	100	27.2727
4f_singleZee_leptonic	97.7778	95.6522
4f_WW_semileptonic	96.4103	87.4419
4f_singleW_semileptonic	100	31.25

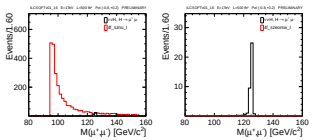
- High efficiency/purity for the relevant modes (leptonic final states).

Signal VS sznu_l Distributions

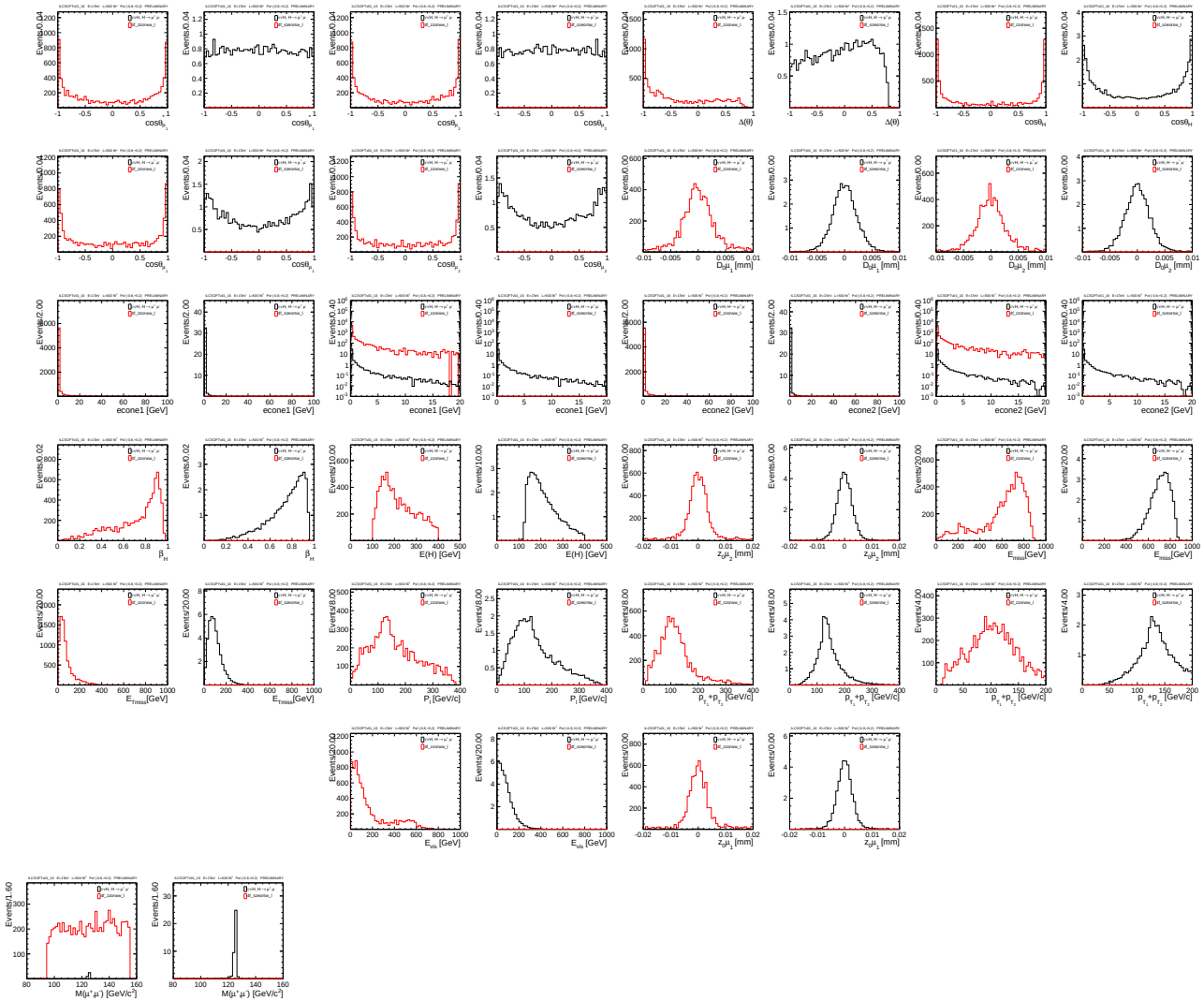
- Event Variables looks very similar.



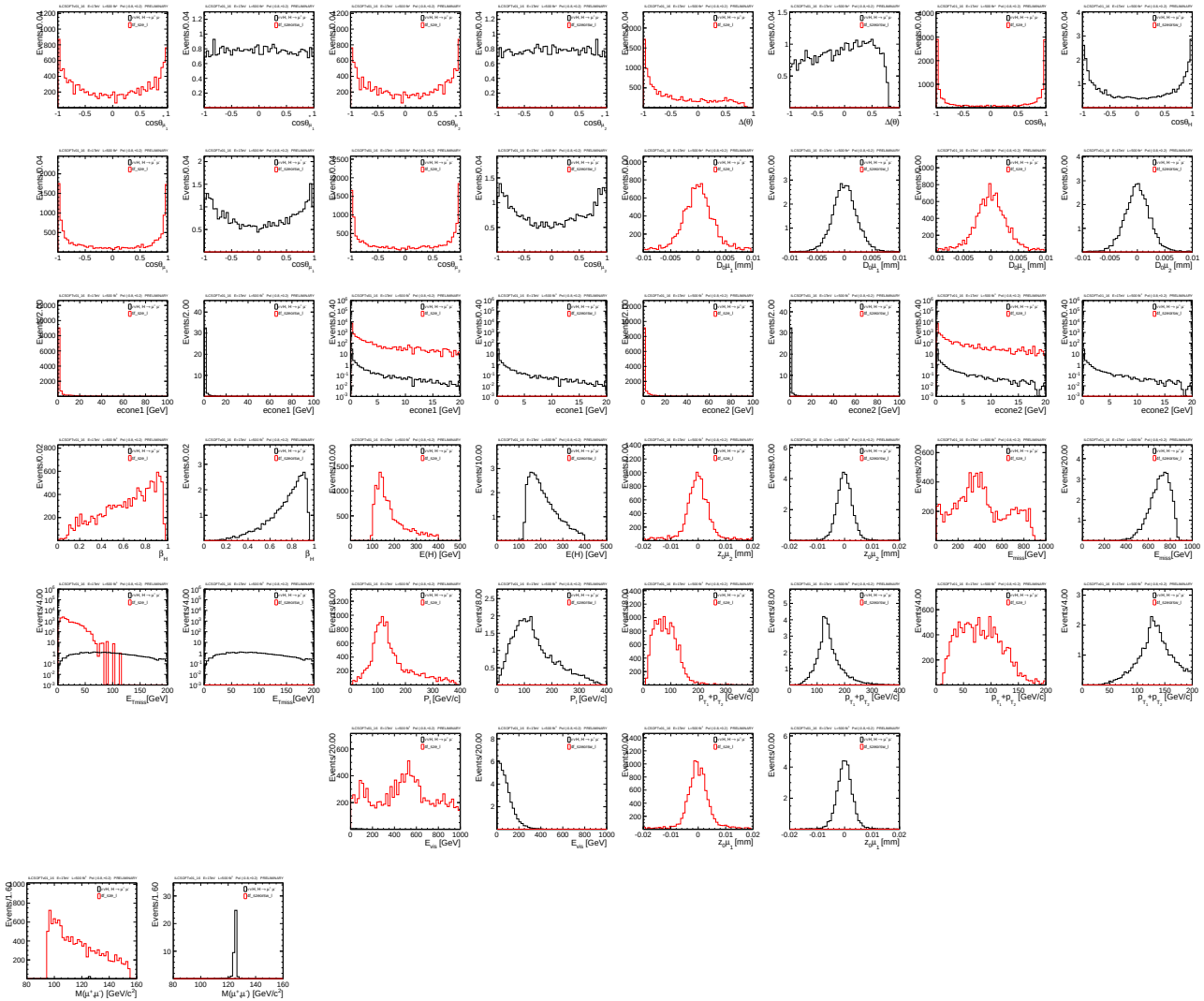
- Only the mass looks different.



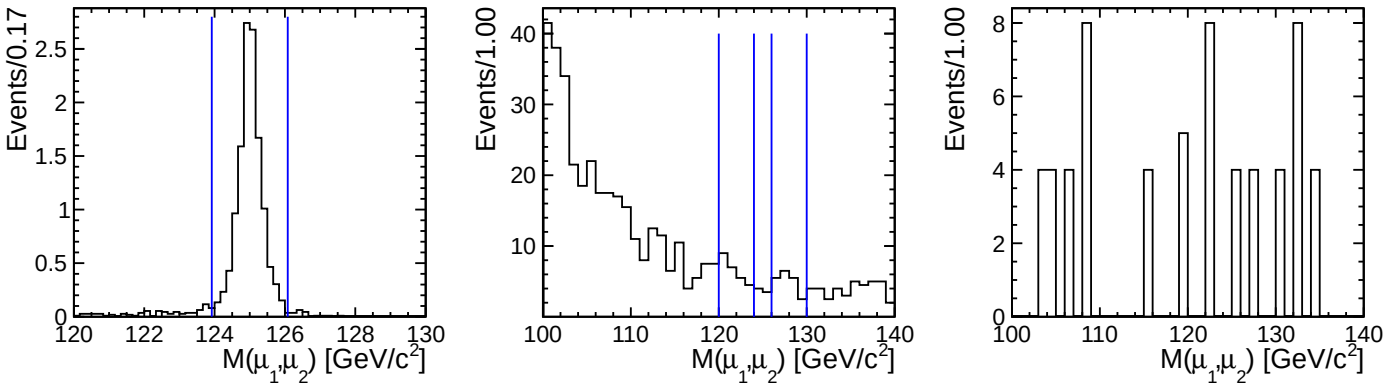
Signal VS zzorww_l Distributions



Signal VS sze_l Distributions



Naive Estimation of $\Delta(\sigma \cdot Br)/\sigma \cdot Br$



- Signal: 3 σ ($\sigma \approx 0.36\ \mathrm{GeV/c^2}$) around peak
- sznu: sidebands (120,124) & (126,130)
- zzorww: assumed flat, averaged over (100,140)

$\longrightarrow$ Normalized number of background events to signal window size

Yields

- Signal: 12.4
- sznu: 6.21
- zzorww: 1.62

- $\frac{\Delta(\sigma \cdot Br)}{\sigma \cdot Br} = \frac{\sqrt{S+B}}{S} = 36.3\ \%$

(This is for $L = 500\ \mathrm{fb}^{-1}$)

Estimation of $\Delta(\sigma \cdot Br)/\sigma \cdot Br$

- Alternative calculation provides 34 %
  - Fitting sznu and extrapolatin integral in region (124.53, 125.47)
  - Previous slide used bigger signal region definition (123.92, 126.08)
- Method using toy MC stil under development
- No good fit to the data, so no realistic templates to generate toy samples. :-(