Status of $h \to \mu^+\mu^-$ at 500 GeV ILC

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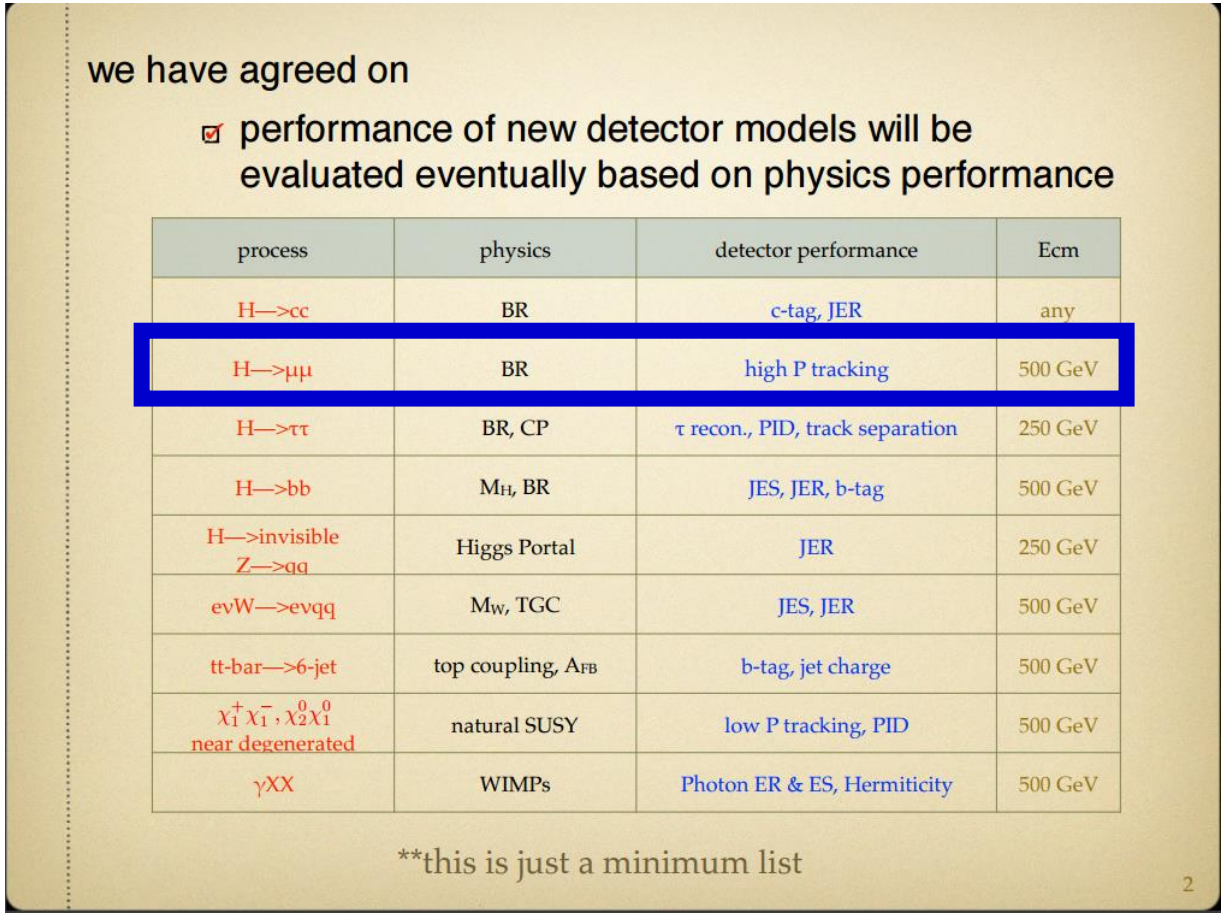
Quick introduction

This process is selected as
one of the physics benchmark process of ILD optimization.



we have agreed on

- ☑ performance of new detector models will be evaluated eventually based on physics performance

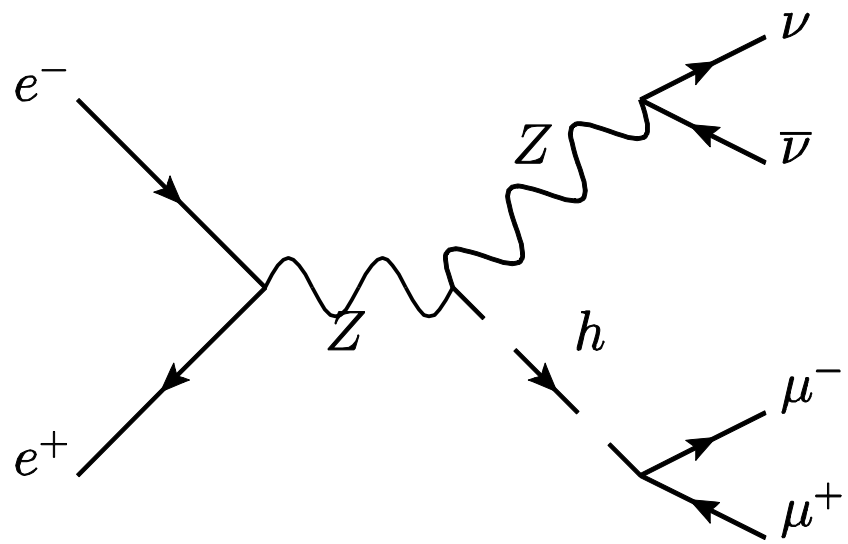
process	physics	detector performance	Ecm
H—>cc	BR	c-tag, JER	any
H—>μμ	BR	high P tracking	500 GeV
H—>ττ	BR, CP	τ recon., PID, track separation	250 GeV
H—>bb	M_H, BR	JES, JER, b-tag	500 GeV
H—>invisible Z—>qq	Higgs Portal	JER	250 GeV
evW—>evqq	M_W, TGC	JES, JER	500 GeV
tt-bar—>6-jet	top coupling, A_{FB}	b-tag, jet charge	500 GeV
$\chi_1^+\chi_1^-$, $\chi_2^0\chi_1^0$ near degenerated	natural SUSY	low P tracking, PID	500 GeV
γXX	WIMPs	Photon ER & ES, Hermiticity	500 GeV

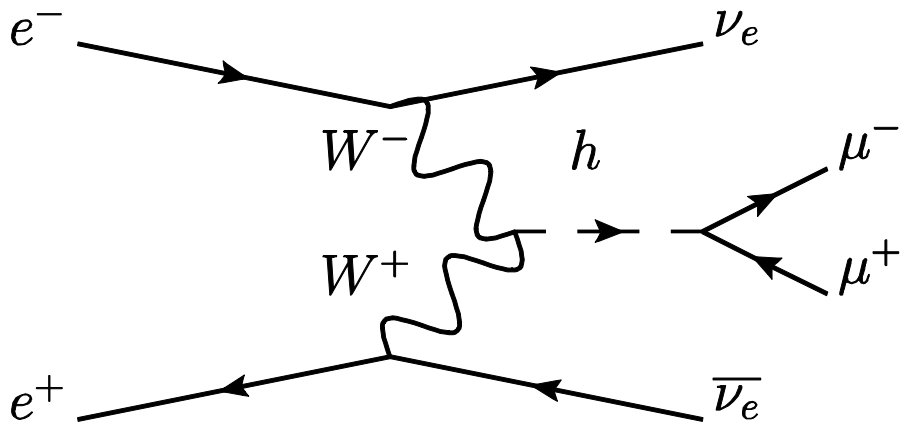
**this is just a minimum list

2

Signal

signal: $e^+e^- \to \nu\bar{\nu}h, h \to \mu^+\mu^-$





BR($h \to \mu^+\mu^-$) ~ **2.2*10^{-4}**

expected # events: **~60**

with 1600 fb^{-1}, $P(e^-, e^+)$ = (-0.8, +0.3) (“H20” scenario)

(other beam pol. cases are hopeless)

Current analysis setting

- ILCSOFT: v01-17-09
- MC samples: DBD + additional, DBD configuration, most of them are fully-simulated
  - Signal: **ffh_mumu**
  - Background: 2f, 3f, 4f, 5f, aa_2f, aa_4f, higgs_ffh + **additional**
  - MC production information of **blue colors** can be found at: https://confluence.desy.de/display/ILD/Monte+Carlo+Production
    - Additional 4f_ZZ_leptonic is not included

Analysis

- Everything based on cut-based analysis
  - Muon reconstruction
  - Precuts: only selecting signal signature
  - Optimization: maximize signal significance $\frac{S}{\sqrt{S+B}}$
  - See backup for details

Results

Table 2: The cut statistics using fully-simulated samples.

	$\nu\nu h$ $h \to \nu\nu$	$qqh+\ell\ell h$ $h \to \nu\nu$	ffh $h \to$ other	2f	$\gamma\gamma \to$ 2f	3f	4f	$\gamma\gamma \to$ 4f	5f
No cut	57.53	31.13	4.116×10^5	4.224×10^7	4.283×10^9	4.269×10^8	4.592×10^7	3.356×10^5	2.209×10^5
# $\mu^{\pm}$	54.39	27.39	6895.00	2.071×10^6	62.62	299.75	1.209×10^6	1.131×10^4	6125.00
# $N^{\text{track}}_{P_t>5\text{GeV}}$	54.27	4.89	1425.76	2.014×10^6	31.28	0	9.826×10^5	9544.48	4411.00
$M_{\mu\mu}$	44.61	3.94	0	3741.41	0	0	2407.24	21.81	31.63
E_{vis}	43.88	0.17	0	2390.68	0	0	1529.57	18.66	24.10
P_t	25.97	0.07	0	64.20	0	0	457.80	6.07	3.68
thrust	20.48	0.05	0	20.60	0	0	118.92	0	0
θ_{thrust}	19.84	0.05	0	20.60	0	0	102.07	0	0

I obtained $N_{\text{sig}} = 19.84$ and $N_{\text{bkg}} = 122.72$. The significance is $\frac{19.84}{\sqrt{19.84+122.72}} = 1.66$, and the precision is $\frac{\Delta(\sigma \times \text{BR})}{(\sigma \times \text{BR})} = 60\%$.

Major background: $\nu\nu\mu\mu$ and $\nu\nu\tau\tau$ from 4f (as expected), mostly from WW
Now working on more suppression...

Comparison

Ref.: ILC operating scenario (arXiv:1506.07830 [hep-ex])

$\int \mathcal{L} dt$ at $\sqrt{s}$	250 fb^{-1} at 250 GeV		330 fb^{-1} at 350 GeV		500 fb^{-1} at 500 GeV		
$P(e^-, e^+)$	(-80%,+30%)						
production	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	Zh	$\nu\bar{\nu}h$	$t\bar{t}h$
decay	$\Delta(\sigma \cdot BR)/(\sigma \cdot BR)$						
$h \to \mu^+\mu^-$ [45]	72%	-	76%	140%	88%	72%	-

[45] C. Calancha, private communication.

scale to 1600 fb^{-1}:
~40% expected

I don't know how exactly Tino evaluated...
(his analysis is 1 TeV $\nu\nu h$)
Relatively ~50% worse than extrapolation

Summary / Plans

- Performed analysis for $h \to \mu^+\mu^-$ at 500 GeV
  - Very challenging due to small BR($h \to \mu^+\mu^-$)
  - Current precision is **60%**

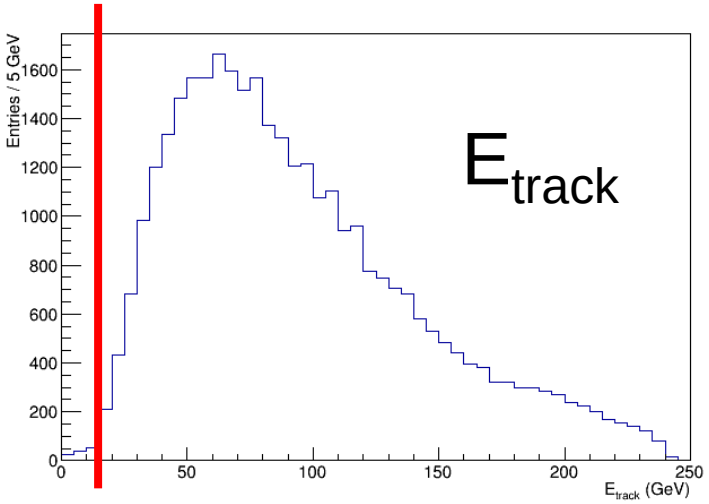
- Need some work to suppress more backgrounds, especially $\nu\nu\mu\mu$ backgrounds
  - Now try to find useful variables...
- Re-weighting by $\frac{1}{\sigma}$ (still work in progress)

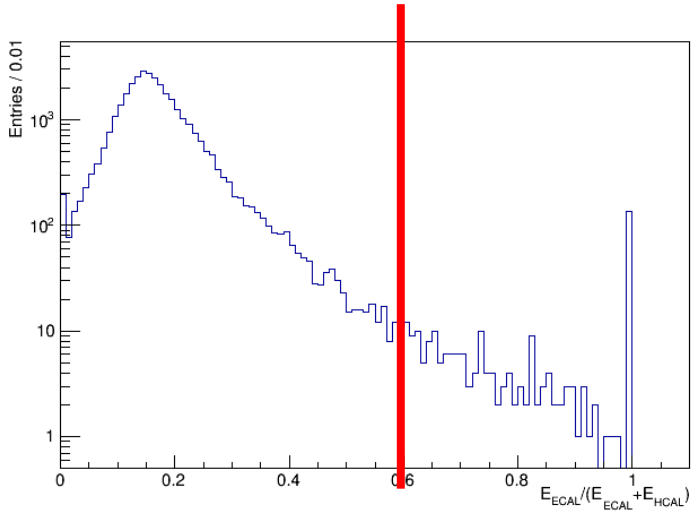
BACKUP SLIDES

Muon Reconstruction

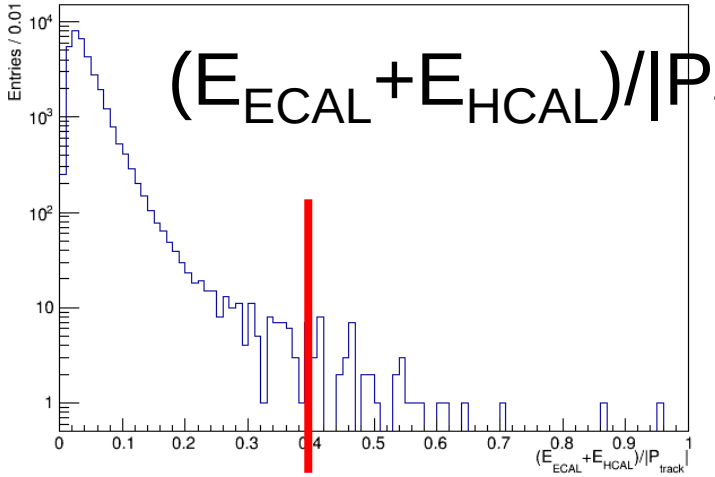
- almost not changed
  - $E_{track} > 15$ GeV
  - $E_{ECAL}/(E_{ECAL}+E_{HCAL}) < 0.6$
  - $(E_{ECAL}+E_{HCAL})/|P_{track}| < 0.4$
  - ~~$E_{yoke} > 1$ GeV~~ <--- 3f and aa_2f are SGV samples, cannot use this information
  - $|d_0/\mathrm{sigma}(d_0)| < 5$

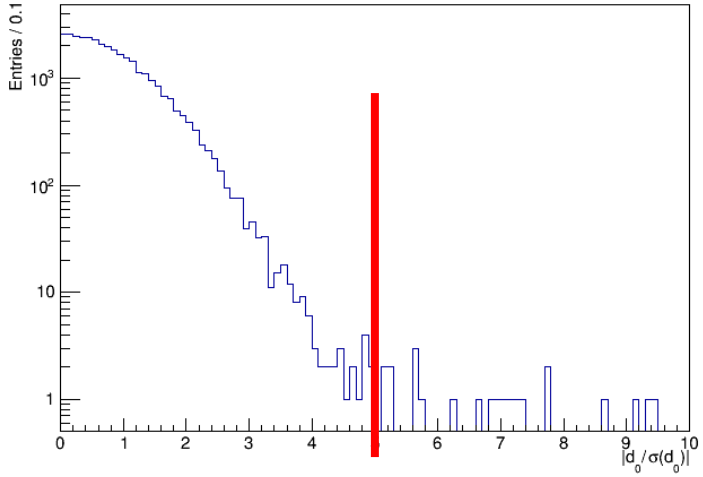
Muon Reconstruction





$E_{ECAL}/(E_{ECAL}+E_{HCAL})$

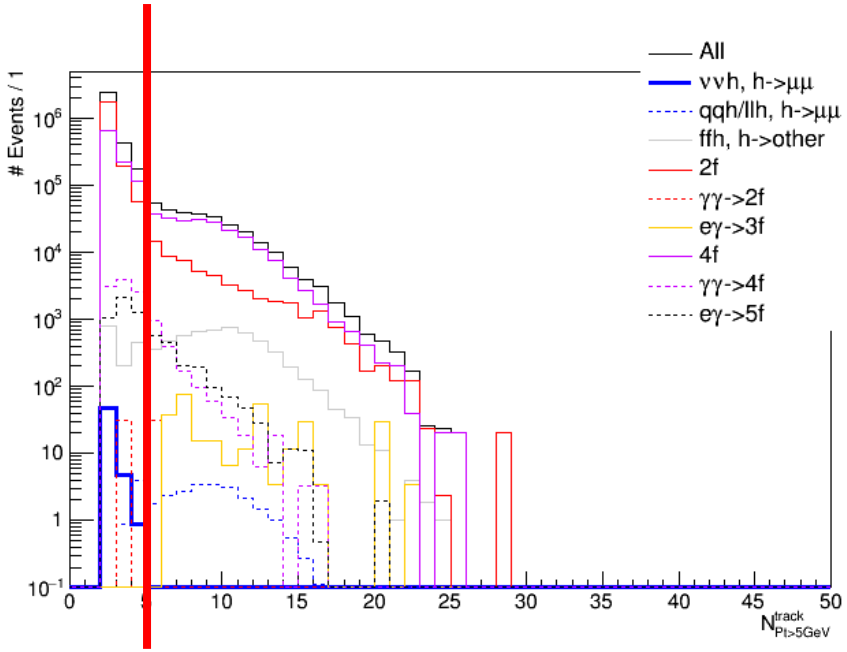


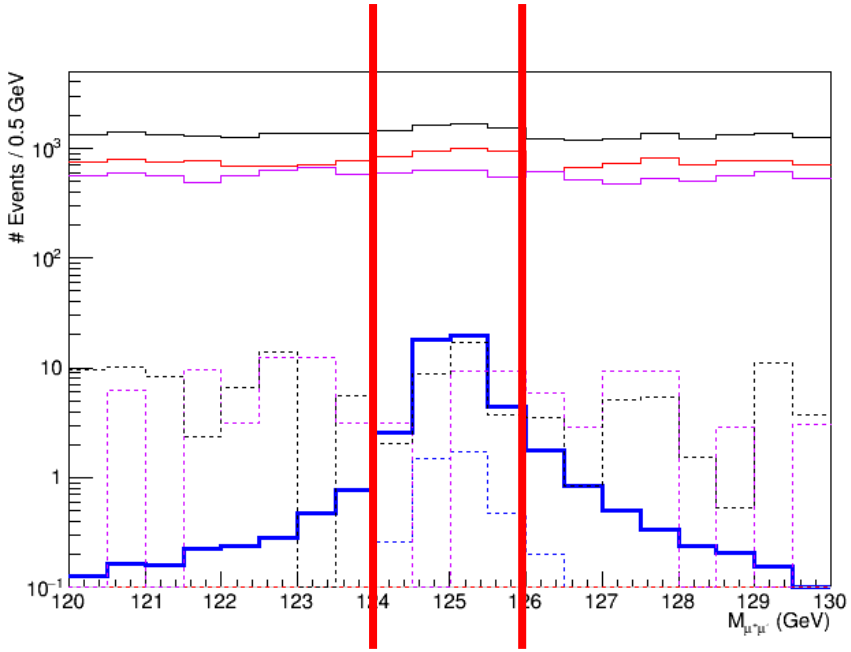


$|d_0/sigma(d_0)|$

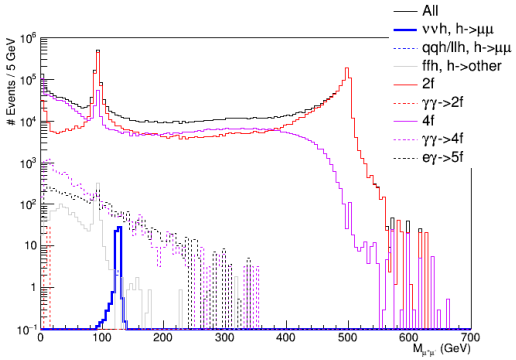
Precuts

$\# \mu^{\pm} = 1$, $N^{track}_{Pt > 5\ GeV} <= 4$, $124 < M_{\mu\mu} < 126$ GeV



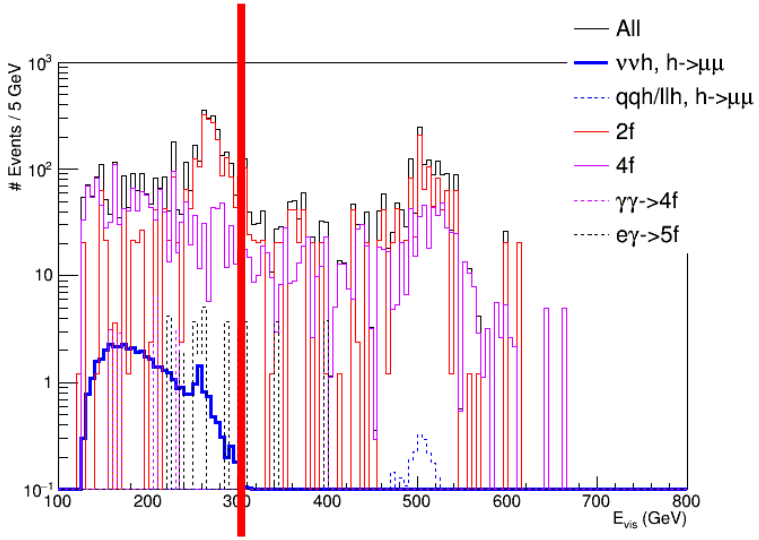


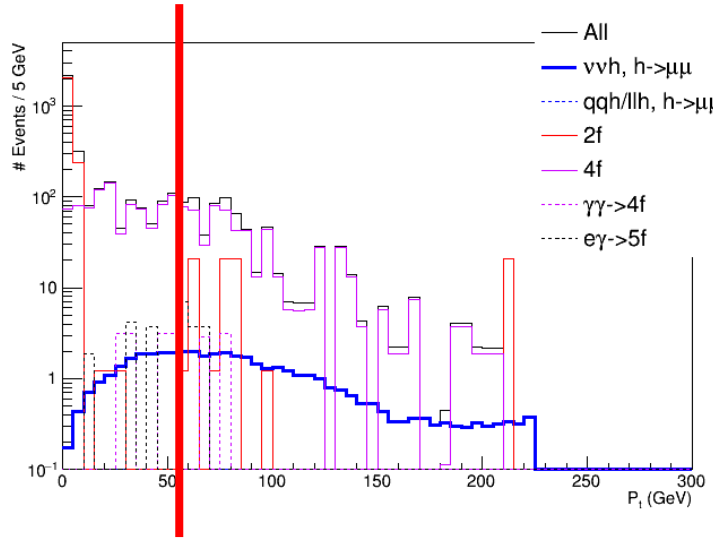
zoom up
around signal region



Optimization

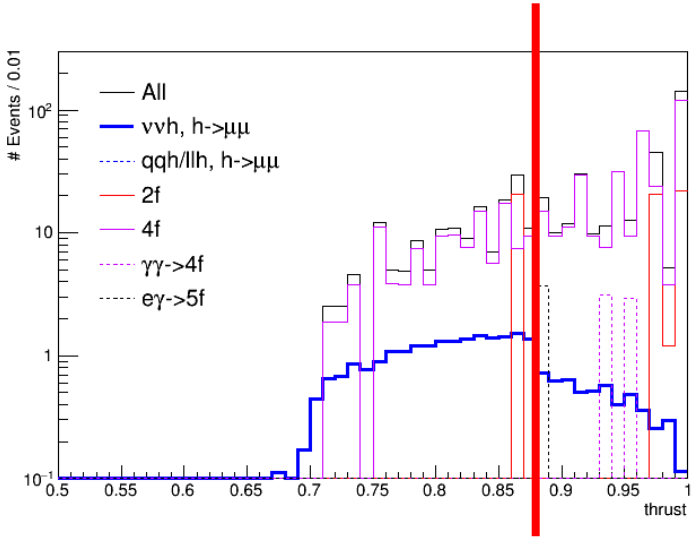
E_{vis}
< 315 GeV

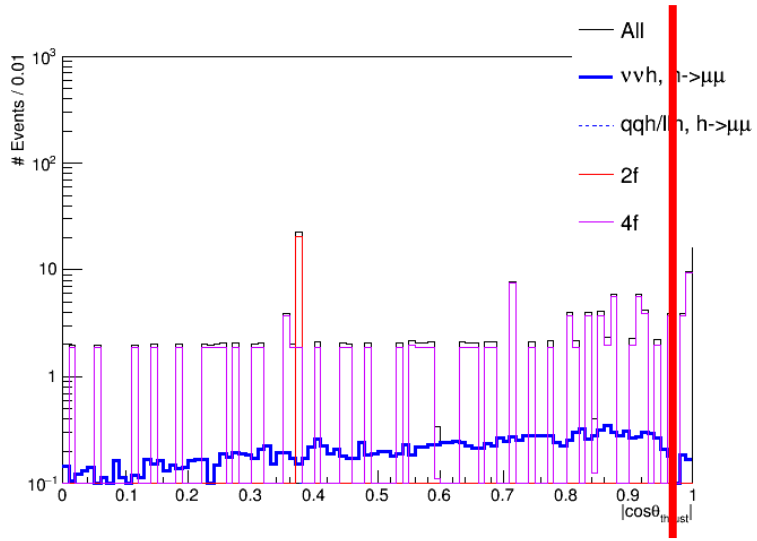




P_t
> 65 GeV

thrust
< 0.88





$|\cos\theta_{\text{thrust}}|$
< 0.96

Results

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Results are relatively ~10% worse than previous.
New processes such as 3f and aa_2f are completely suppressed.
Major 4f backgrounds were $\nu\nu\mu\mu$ and a bit $\nu\nu\tau\tau$ (as expected).

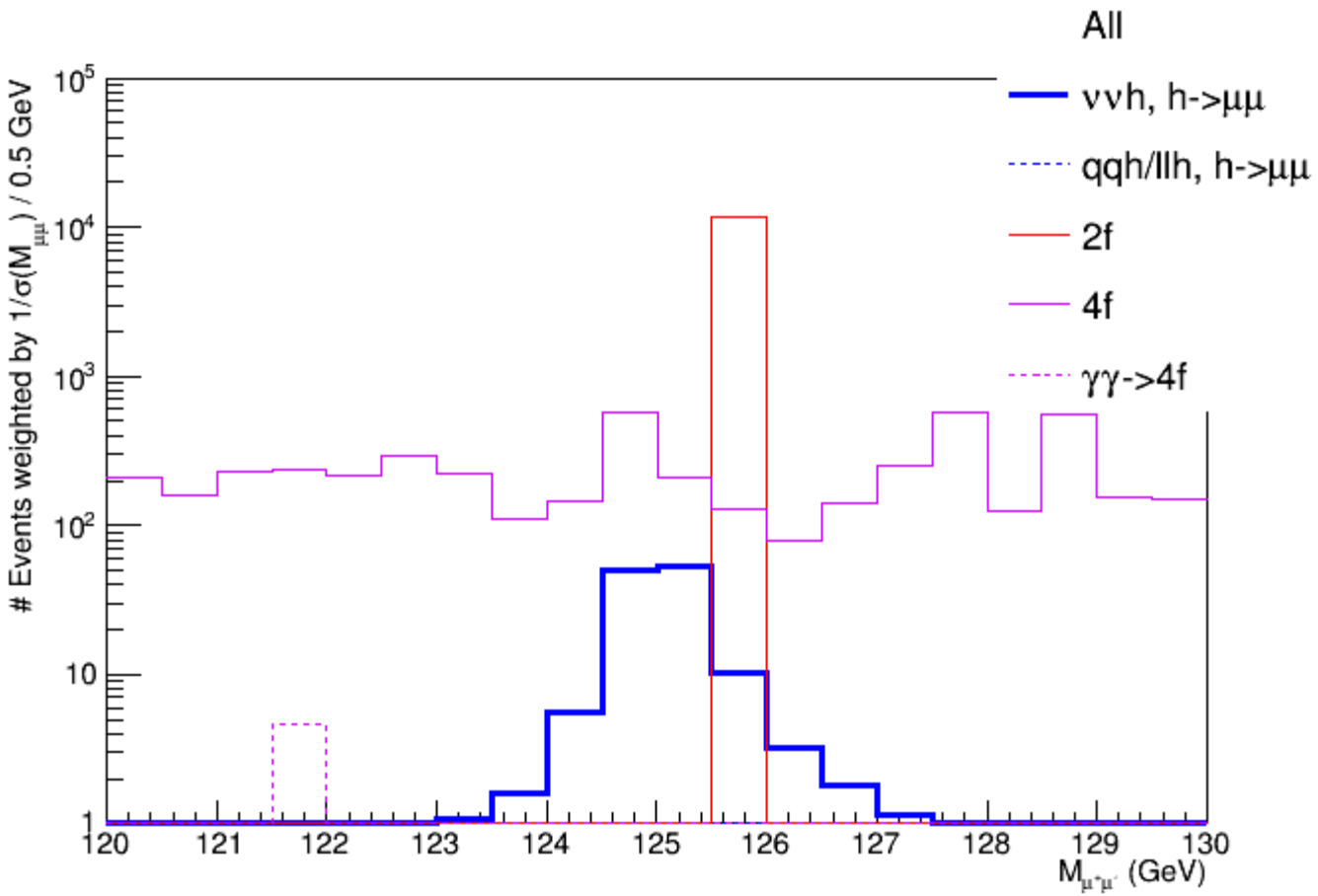
Remained background

- 4f
  - ZZWWMix_leptonic (ID: 250030, 250032)
  - SingleZnunu_leptonic (ID: 250054, 250056)
- 2f
  - 2f_Z_leptonic (ID: 250106)

Re-weighting

- Mikael’s suggestion
- Apply $\frac{1}{\sigma(M_{\mu\mu})}$ as a re-weighting factor
  - Signal will grow up in signal region
  - Backgrounds will not so grow up or even decrease

Re-weighting plot



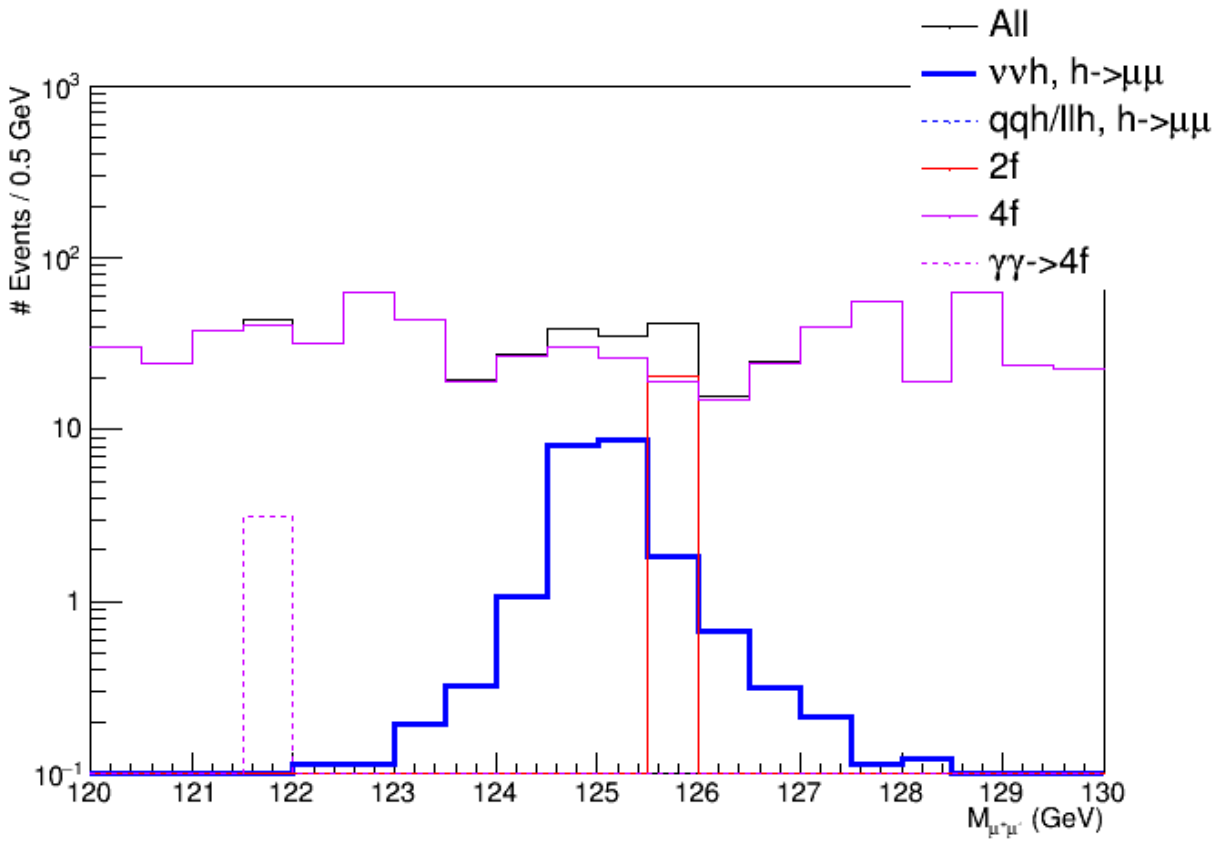
All events after optimum cuts except $M_{\mu\mu}$ cut range changed to 120 - 130 GeV are plotted.

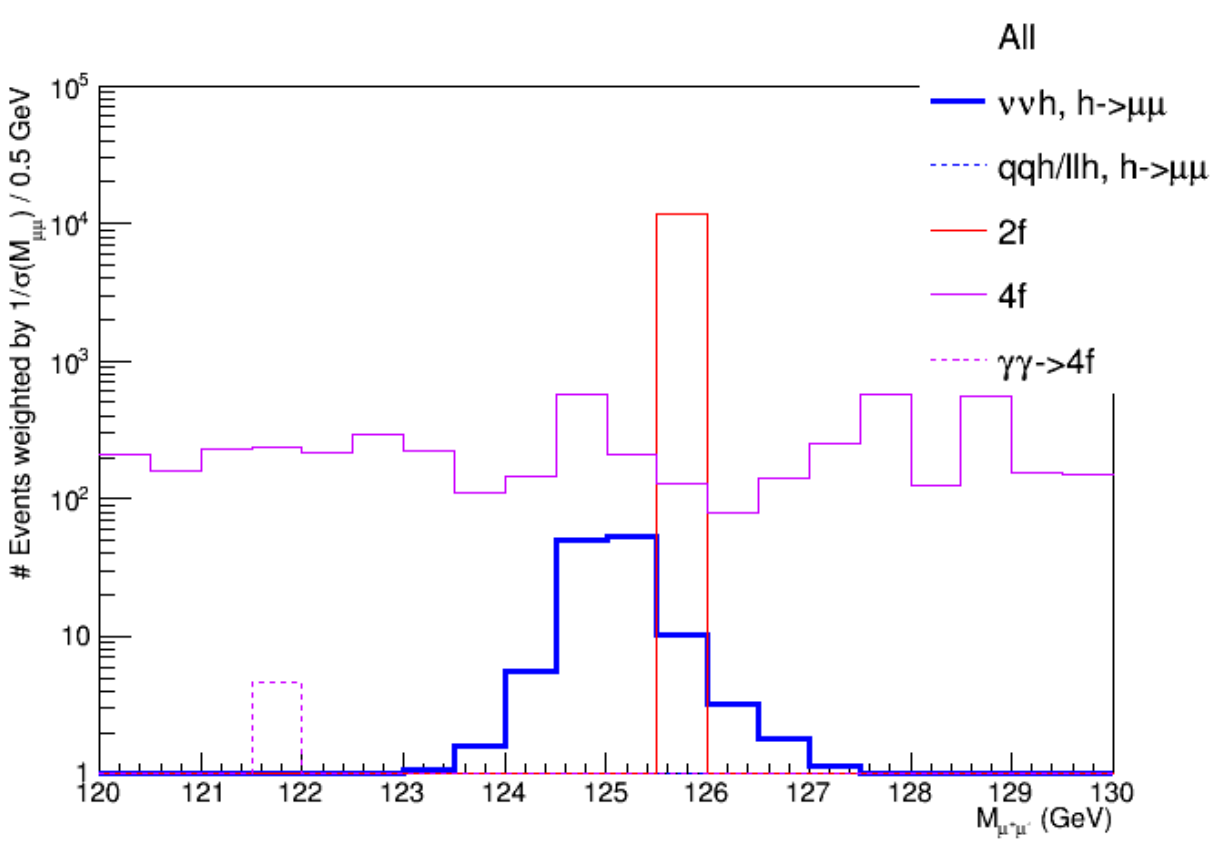
Re-weighted by $\frac{1}{\sigma(M_{\mu\mu})}$.

2f in only one MC event

4f looks flat (in log plot)

Comparison





Usual # events

Re-weighted by $\frac{1}{\sigma(M_{\mu\mu})}$