Higgs → Invisible

Maoqiang Jing [a]

X. Shi [a], X. Mo [a], G. Li [a], M. Ruan [a], X. Lou [a,b,c], W. Yao [d], S. Jyotishmati [b], Z. Chen [e], D. Wang [e], M. Wang [e]

a: IHEP, CAS, China
b: U. Dallas, USA
c: UCAS, China
d: LBNL, USA
e: Peking U, China

2018.06.27

IHEP, Beijing

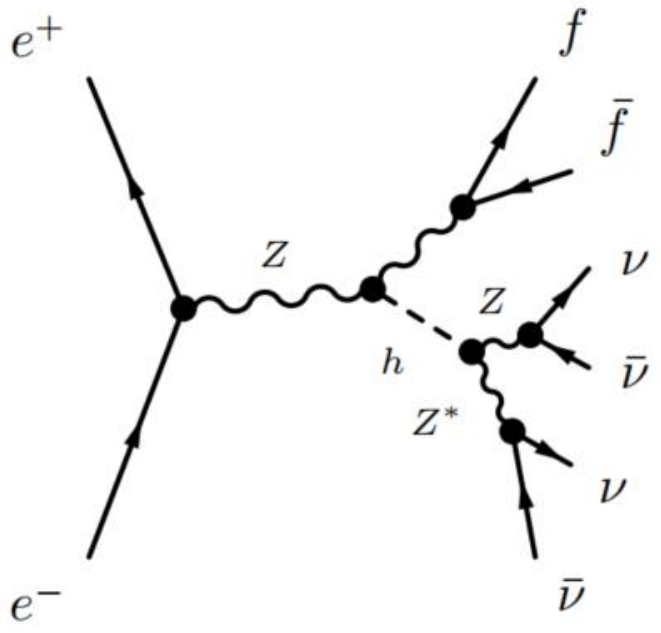
Outline

- Motivation
- CEPC conceptual detector
- Monte Carlo Simulation
- Dynamic channels
- $Z(\mu^+\mu^-)H(inv)$ Selection Criteria
- $Z(\mu^+\mu^-)H(inv)$ Selection Results
- Background
- Next Plan
- Backup

Motivation

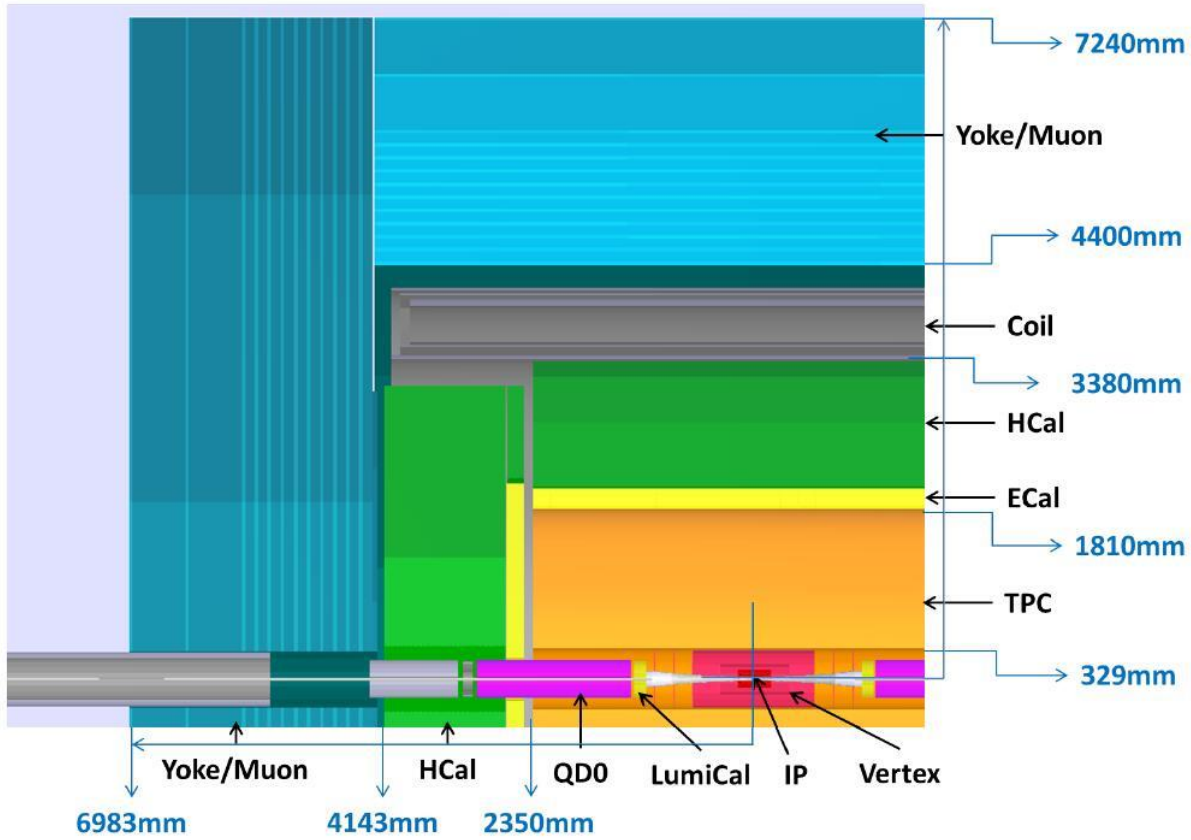
- Higgs decays invisibly in SM via four neutrinos with BR ~ 10^{-3}
- Many extensions of SM suggest an enlarged BR of invisible channel of Higgs boson
- Invisible decay of Higgs boson is a sensitive probe for new physics
- LHC searched invisible Higgs decay through VH(V for W or Z) or VBF (Vector boson fusion)

  ATLAS~UL 23%, CMS~UL 24%



CEPC conceptual detector

- CEPC conceptual detector is based on the proposed International Large Detector(ILD) at ILC
- With respect to ILD:
  - L* reduced to 1.5m(ILD: 4.5m), could achieve a higher luminosity
  - Has multiple interaction points, thickness of return yoke is reduced by 1 meter

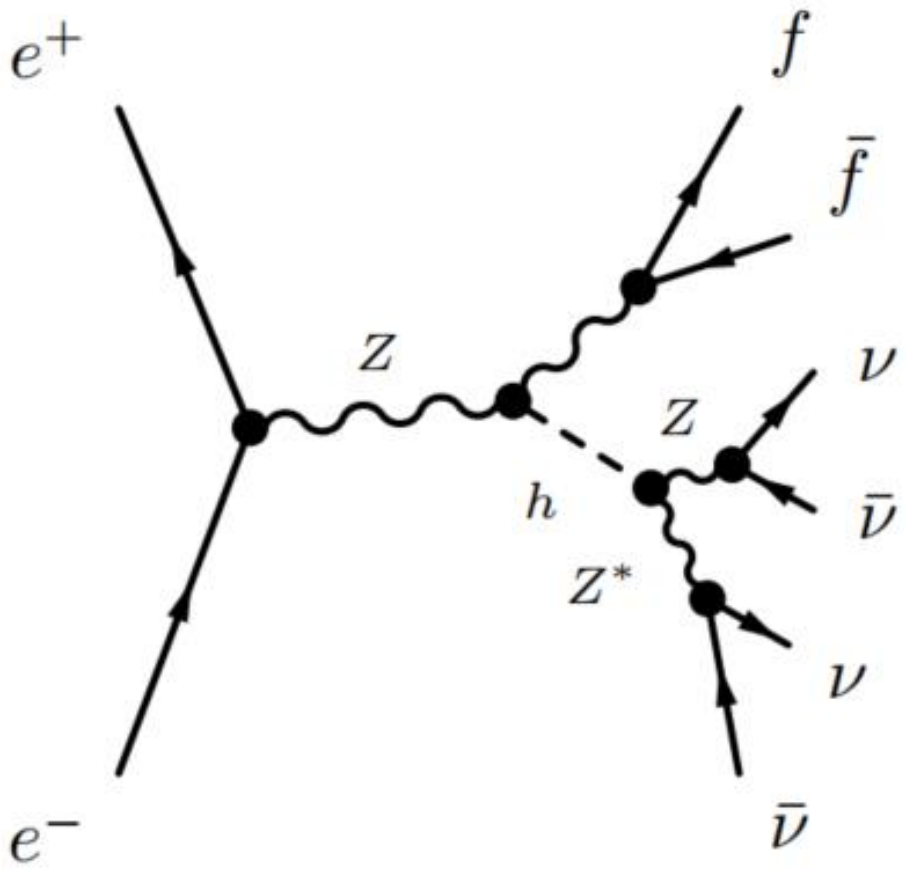


Monte Carlo Simulation

- CEPC_v1(250GeV, 3.5T)
- Generator: Whizard 1.95(with ISR, Luminosity $5ab^{-1}$, M_H=125GeV)
- Simulation: Geant4 and Mokka with ISR and bremsstrahlung effects
- Reconstruction: Marlin and ArborPFA

Decay channels

- **Leptonic:**
  - Z(μμ)H(*inv*)
  - Z(ee)H(*inv*)
- **Hadronic:**
  - Z(qq)H(*inv*)

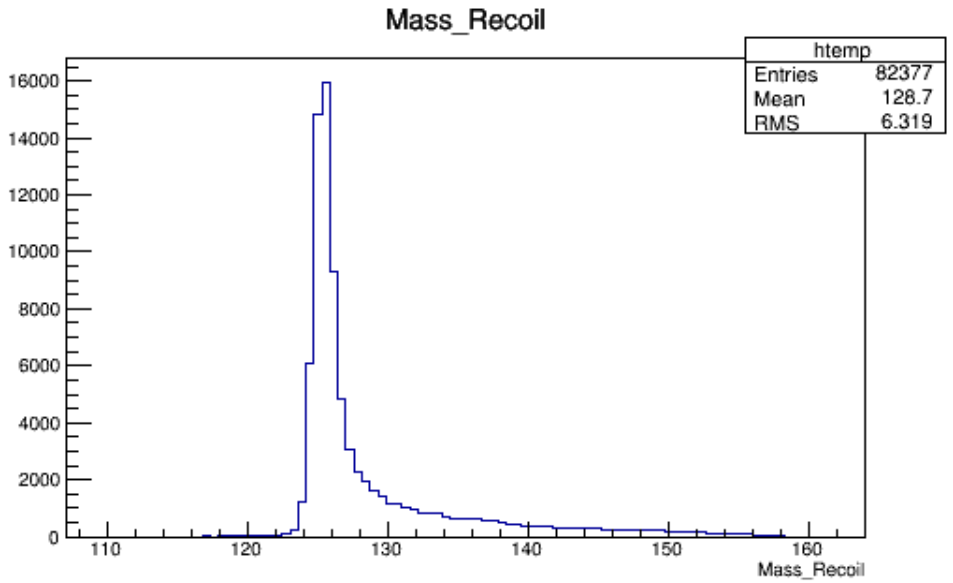


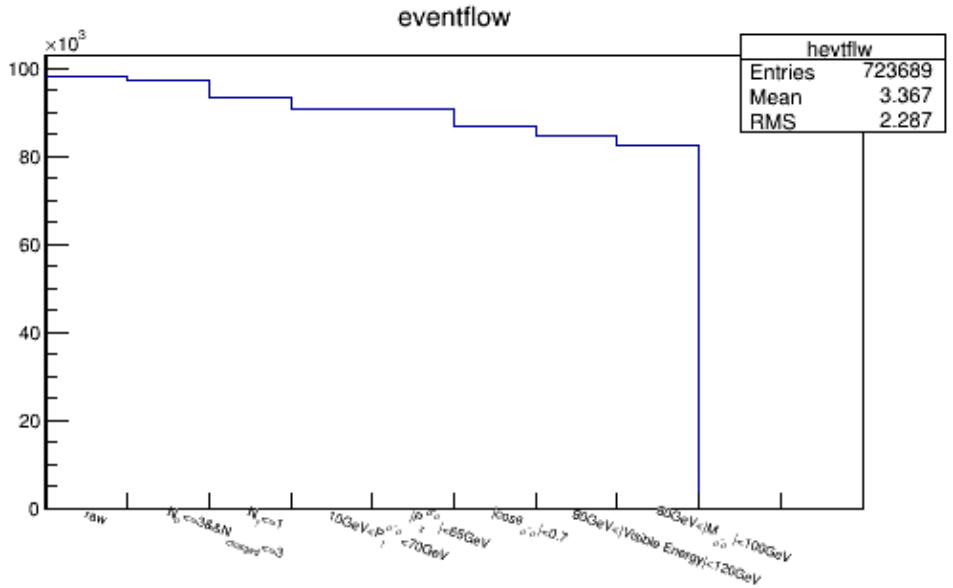
$Z(\mu^+\mu^-)H(inv)$ Selection Criteria

- $Z(\mu^+\mu^-)H(inv)$
  - In order to save more signal events, we require $N_\mu \leqslant 3$, $N_{ch} \leqslant 3$
  - Because Higgs decays invisibly for the signal, only one photon is allowed, which may come from ISR($N_\gamma \leqslant 1$)
  - $10GeV < P_t^{\mu+\mu-} < 70GeV$
  - $|P_z^{\mu+\mu-}| < 65GeV$
  - $|\cos\theta_{\mu+\mu-}| < 0.7$
  - $90GeV < |\text{Visible Energy}| < 120GeV$
  - $80GeV < M_{\mu+\mu-} < 100GeV$

These ranges rely on the resolution of the momentum

$Z(\mu^+\mu^-)H(inv)$ Selection Results





Cut	Efficiency	Xin's Results
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	97242/98155=99.1%	89919/92433=97.3%
$N_\gamma<=1$	93074/98155=94.8%	88865/92433=96.1%
$10GeV<P_t^{\mu+\mu-}<70GeV$	90791/98155=92.5%	86791/92433=93.9%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	90535/98155=92.2%	86591/92433=93.7%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	86855/98155=88.5%	85674/92433=92.7%
$90GeV<M_{\mu+\mu-}<120GeV$	84660/98155=86.3%	84960/92433=91.9%
80GeV<Energy Visible<100GeV	82377/98155=83.9%	80049/92433=86.6%

Background

- There are no events left in Bhabha, sze_l0nunu, szeorsw_l0l, ww_h_ccbs, ww_h_ccds, ww_h_cuxx, ww_h_uubd, ww_h_uusd, ww_sl0muq, ww_sl0tauq and zz_h processes
- There are still events left in some processes

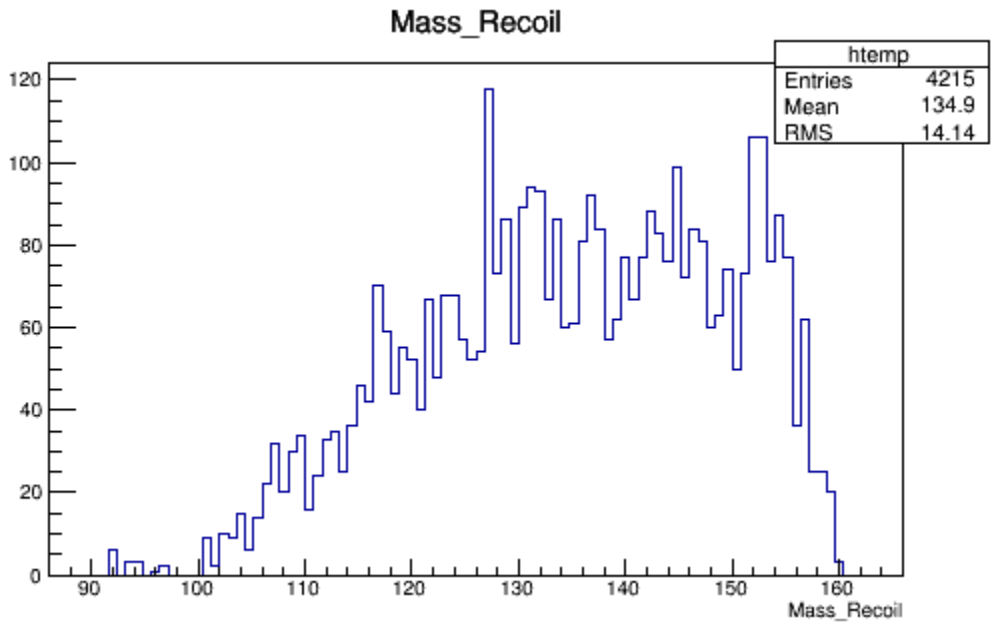
Process	Base Cut Efficiency
e2e2	4215/328311=1.3%
e3e3	25193/1484572=1.7%
sze_l0mu	9260/1069667=0.9%
sze_l0tau	6374/1763181=0.4%
sze_sl0_dd	360/505642=0.1%
sze_sl0_uu	821/722891=0.1%
zz_l0mumu	6078/100000=6.1%
zz_l0mu	8707/200000=4.4%
zz_l0taumu	1392/100000=1.4%
zz_l0tau	1999/299800=0.7%
zz_l0tautau	194/100000=0.2%

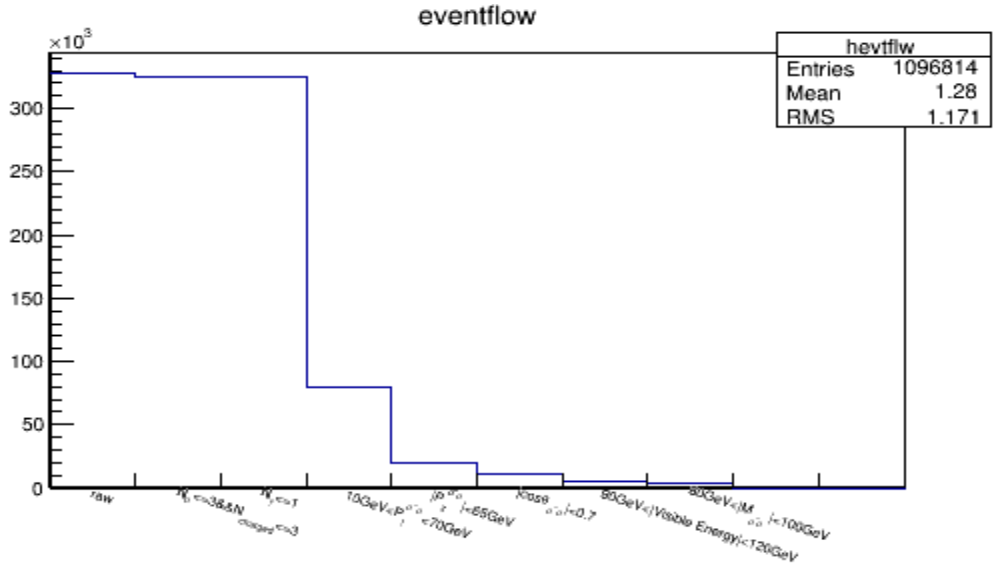
Next Plan

- Add BDT cut to suppress background level
- Calculate S/B for every cut

Backup

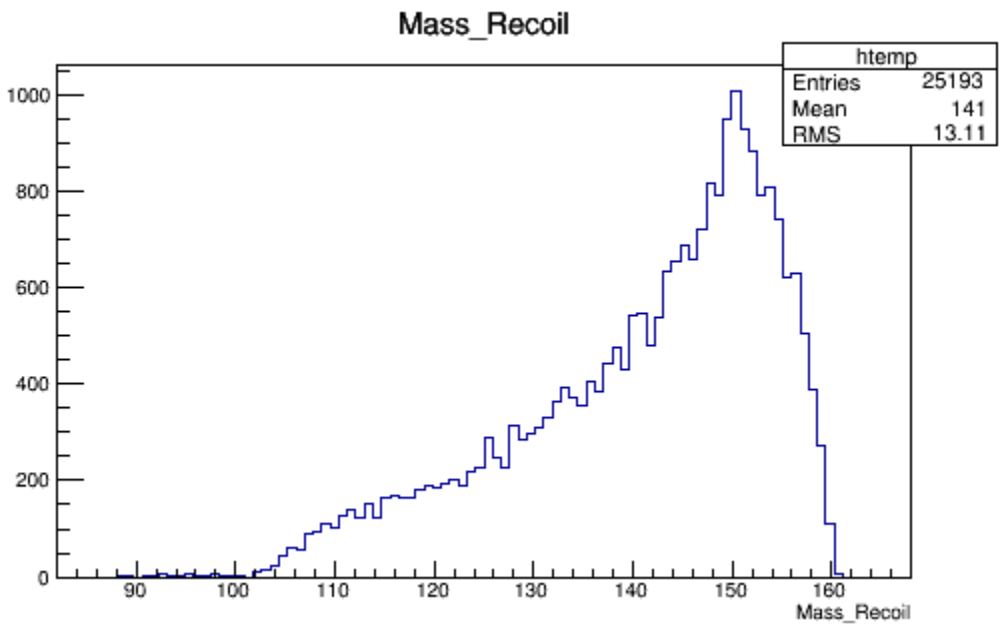
e2e2

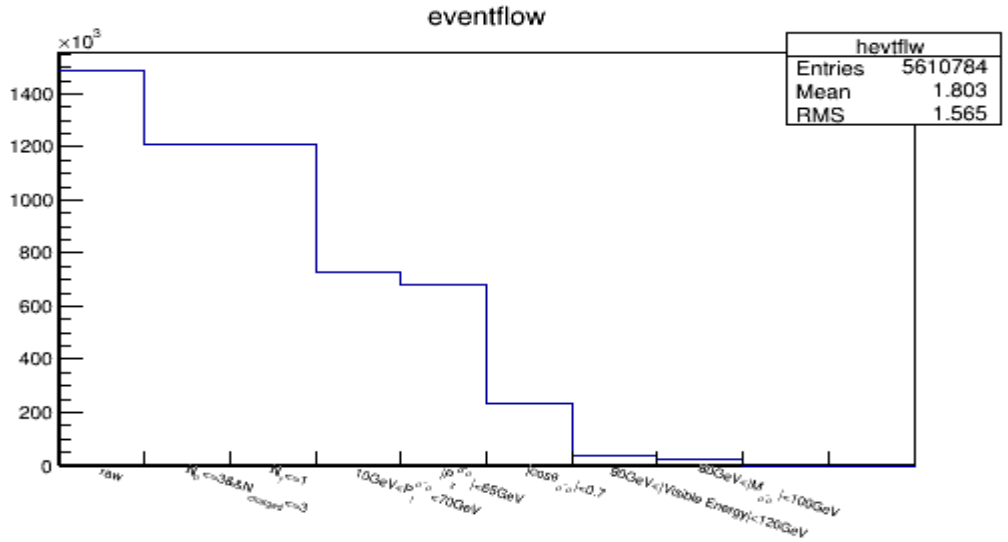




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	324367/328311=98.8%
$N_{\gamma}<=1$	324367/328311=98.8%
$10GeV<P_t^{\mu+\mu-}<70GeV$	80276/328311=24.5%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	20212/328311=6.2%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	10371/328311=3.2%
$90GeV<M_{\mu+\mu-}<120GeV$	4695/328311=1.4%
80GeV<Energy Visible<100GeV	4215/328311=1.3%

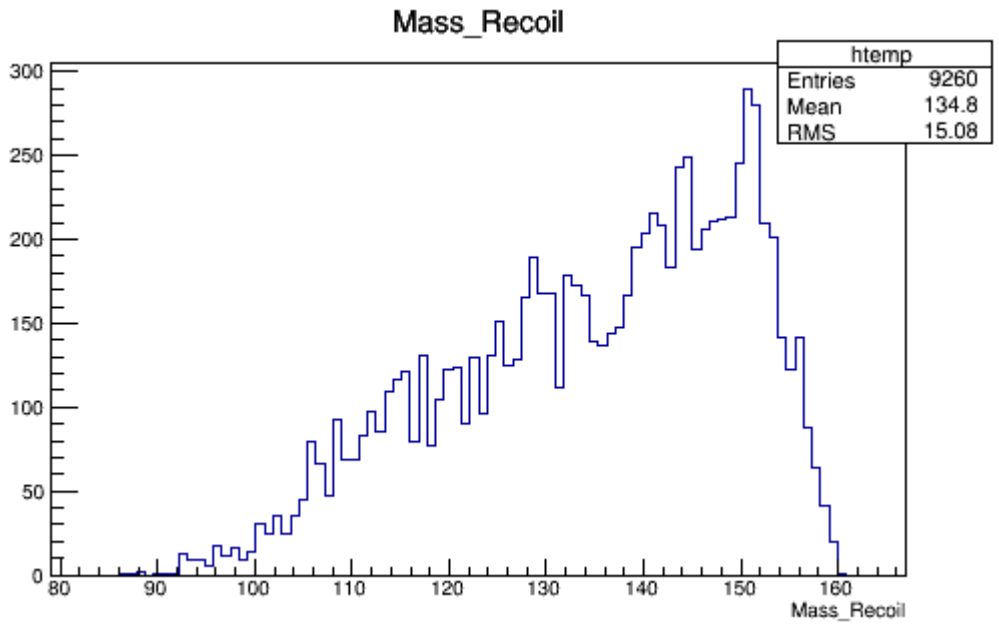
e3e3

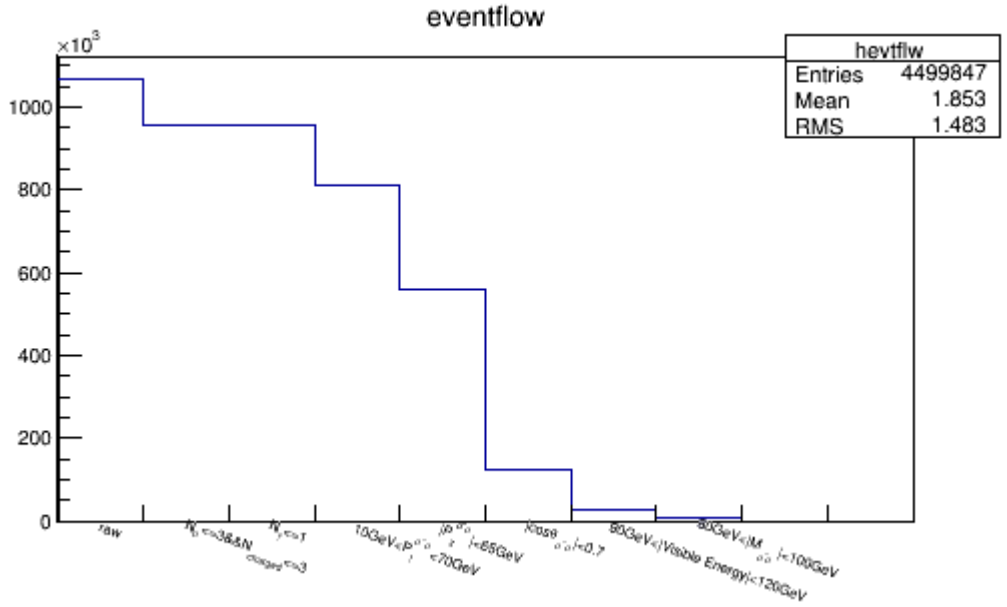




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	1209497/1484572=81.5%
$N_{\gamma}<=1$	1209497/1484572=81.5%
$10GeV<P_t^{\mu+\mu-}<70GeV$	727556/1484572=49.0%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	682618/1484572=46.0%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	231229/1484572=15.6%
$90GeV<M_{\mu+\mu-}<120GeV$	40622/1484572=2.7%
80GeV<Energy Visible<100GeV	25193/1484572=1.7%

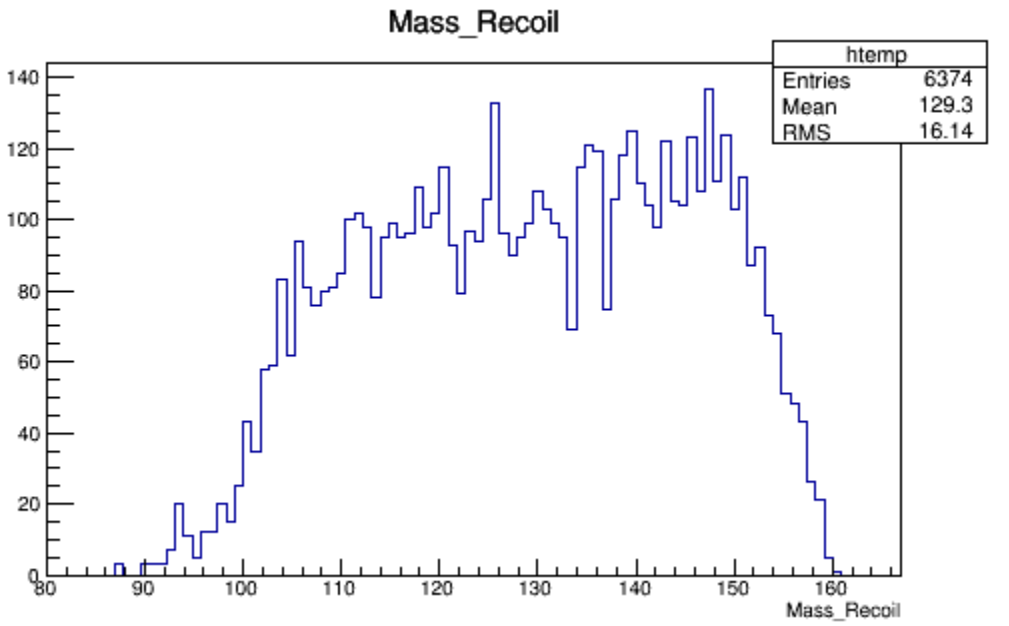
sze_l0mu

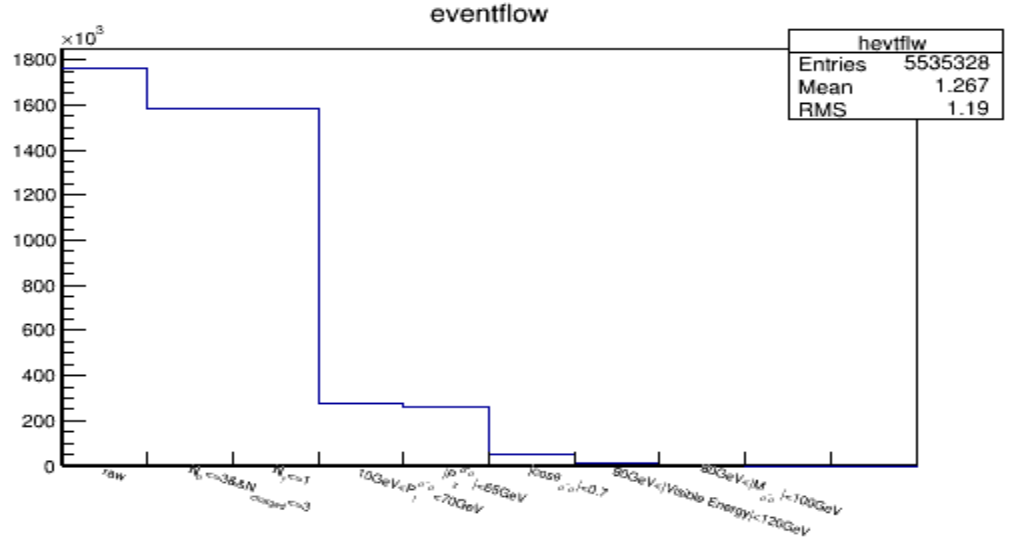




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	954135/1069667=89.2%
$N_{\gamma}<=1$	954135/1069667=89.2%
$10GeV<P_t^{\mu+\mu-}<70GeV$	809255/1069667=75.7%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	556906/1069667=52.1%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	121947/1069667=11.4%
$90GeV<M_{\mu+\mu-}<120GeV$	24542/1069667=2.3%
80GeV<Energy Visible<100GeV	9260/1069667=0.9%

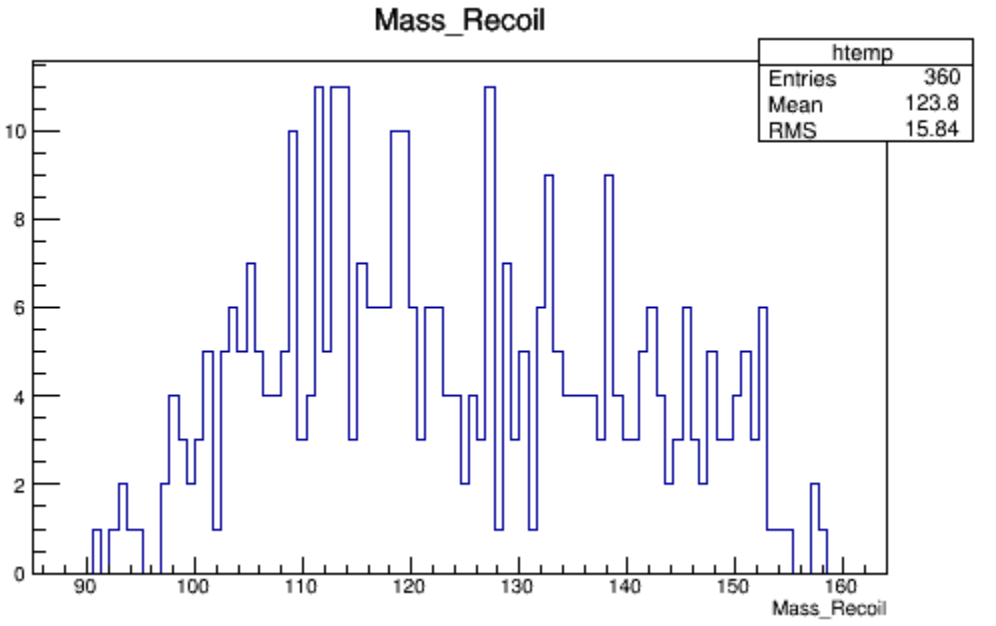
sze_l0tau

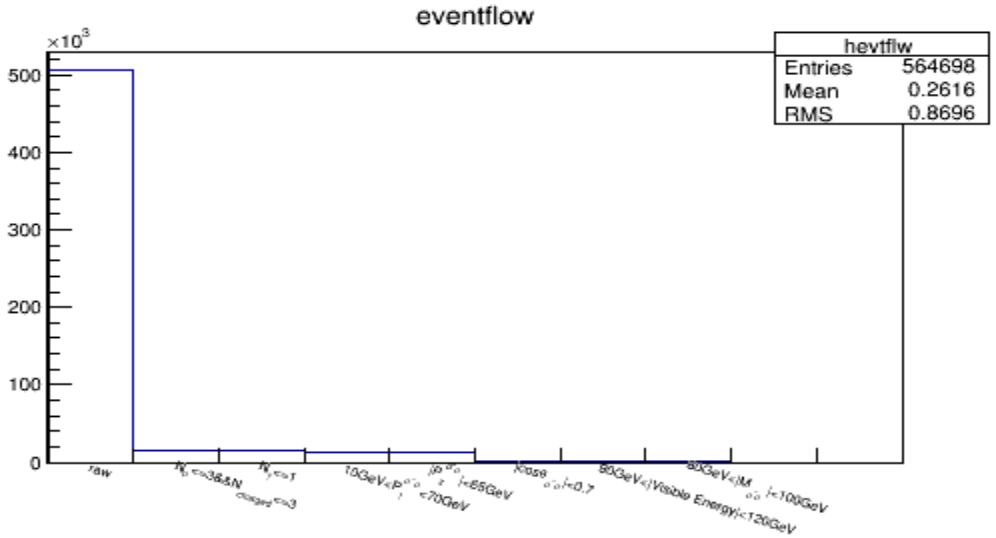




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	1579584/1763181=89.6%
$N_{\gamma}<=1$	1579584/1763181=89.6%
$10GeV<P_t^{\mu+\mu-}<70GeV$	277968/1763181=15.8%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	261553/1763181=14.8%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	53657/1763181=3.0%
$90GeV<M_{\mu+\mu-}<120GeV$	13427/1763181=0.8%
80GeV<Energy Visible<100GeV	6374/1763181=0.4%

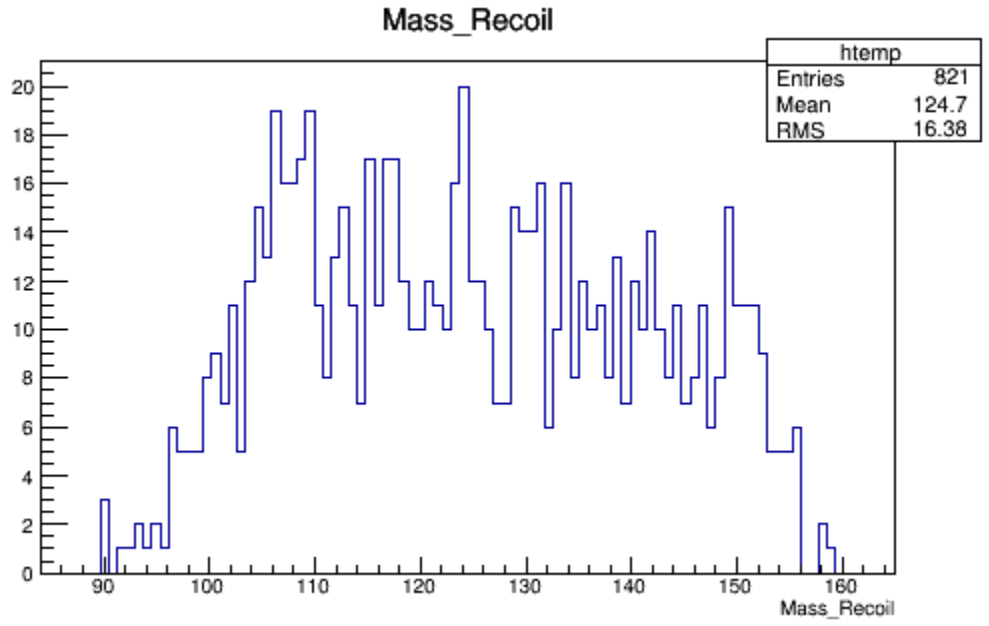
sze_sl0_dd

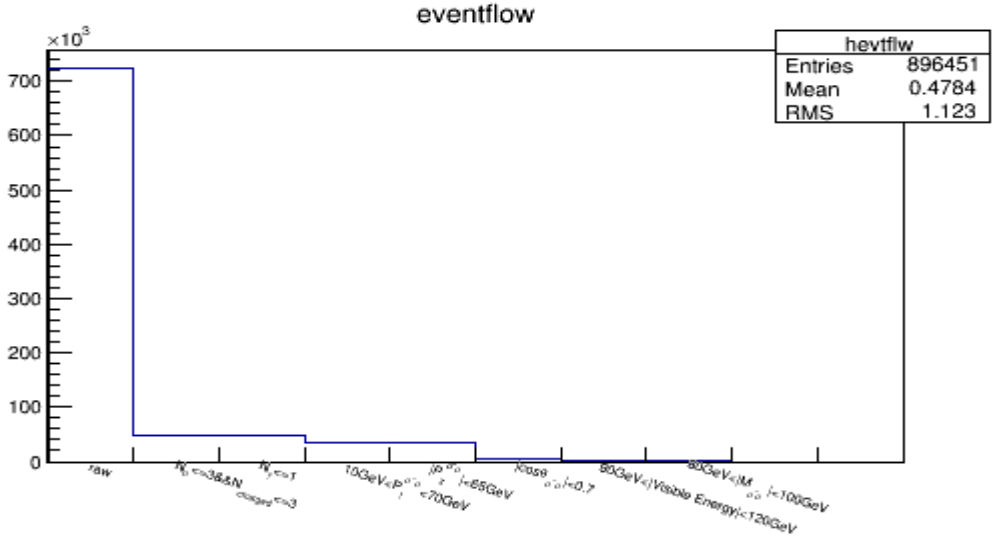




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	16077/505642=3.2%
$N_{\gamma}<=1$	16077/505642=3.2%
$10GeV<P_t^{\mu+\mu-}<70GeV$	12188/505642=2.4%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	11903/505642=2.4%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	1880/505642=0.4%
$90GeV<M_{\mu+\mu-}<120GeV$	571/505642=0.1%
80GeV<Energy Visible<100GeV	360/505642=0.1%

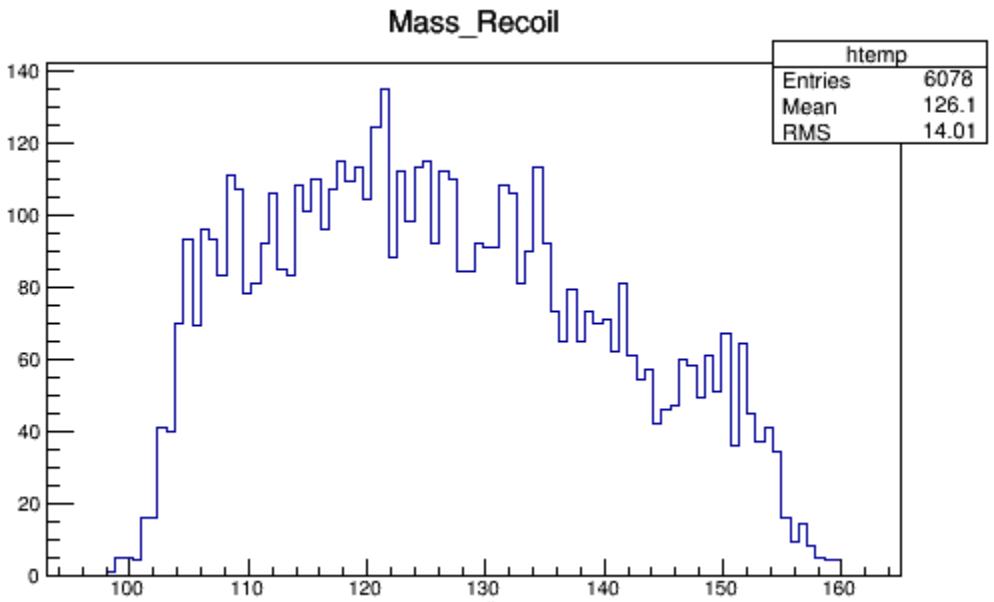
sze_sl0_uu





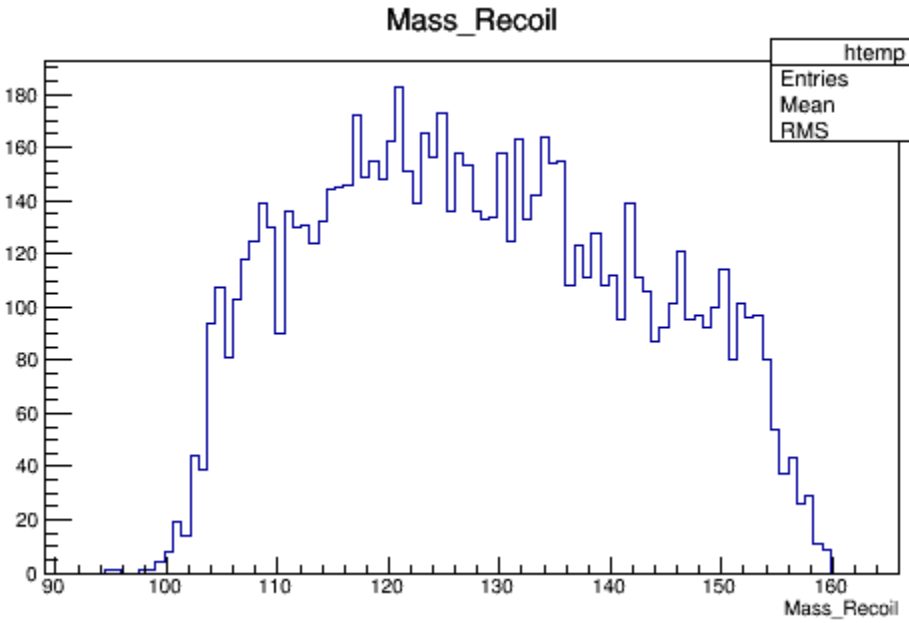
Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	48311/722891=6.7%
$N_{\gamma}<=1$	48311/722891=6.7%
$10GeV<P_t^{\mu+\mu-}<70GeV$	34763/722891=4.8%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	34370/722891=4.8%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	5522/722891=0.8%
$90GeV<M_{\mu+\mu-}<120GeV$	1462/722891=0.2%
80GeV<Energy Visible<100GeV	821/722891=0.1%

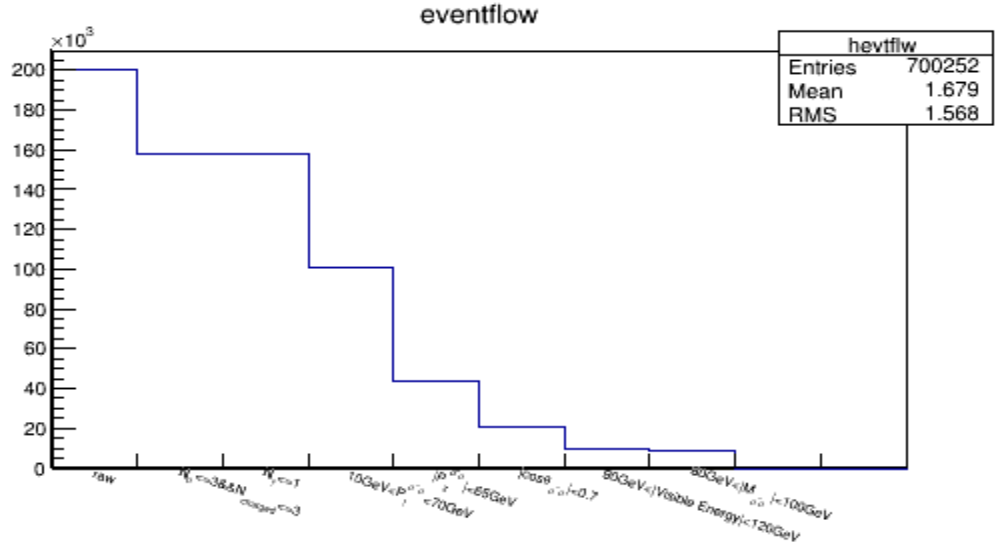
zz_l0mumu



Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	99488/100000=99.5%
$N_{\gamma}<=1$	99488/100000=99.5%
$10GeV<P_t^{\mu+\mu-}<70GeV$	69807/100000=69.8%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	28669/100000=28.7%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	14055/100000=14.1%
$90GeV<M_{\mu+\mu-}<120GeV$	6316/100000=6.3%
80GeV<Energy Visible<100GeV	6078/100000=6.1%

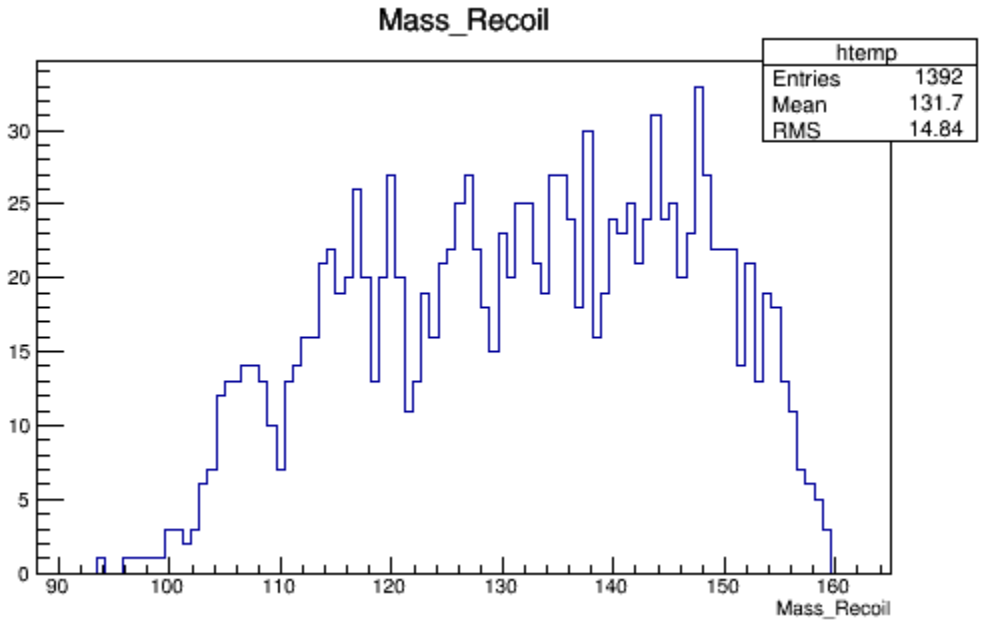
zz_l0mu

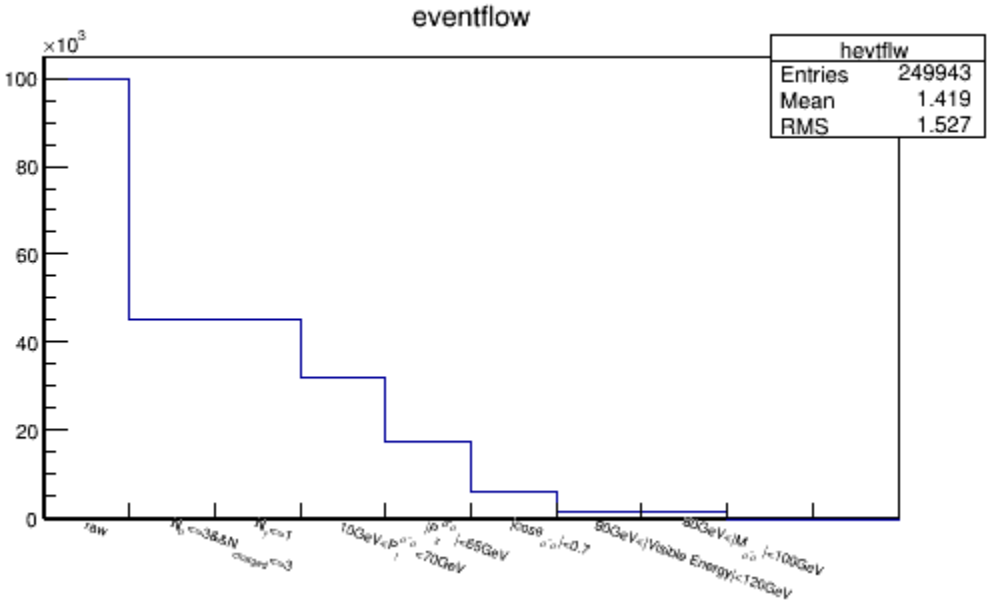




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	158146/200000=79.1%
$N_{\gamma}<=1$	158146/200000=79.1%
$10GeV<P_t^{\mu+\mu-}<70GeV$	100688/200000=50.3%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	44082/200000=28.7%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	21063/200000=10.5%
$90GeV<M_{\mu+\mu-}<120GeV$	9420/200000=4.7%
80GeV<Energy Visible<100GeV	8707/200000=4.4%

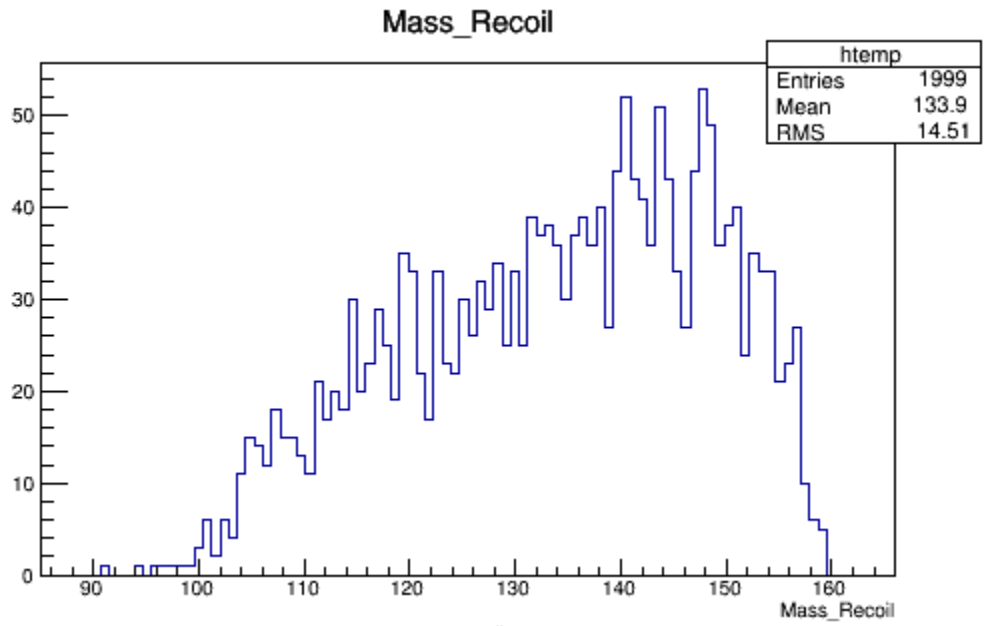
zz_l0taumu

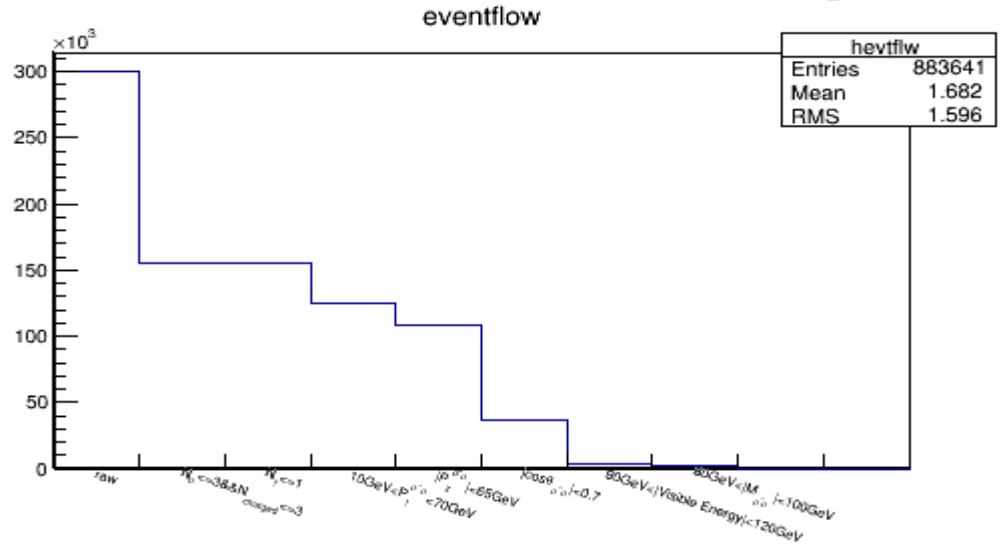




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	45443/100000=45.4%
$N_{\gamma}<=1$	45443/100000=45.4%
$10GeV<P_t^{\mu+\mu-}<70GeV$	31904/100000=31.9%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	17717/100000=17.8%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	6323/100000=6.3%
$90GeV<M_{\mu+\mu-}<120GeV$	1721/100000=1.7%
80GeV<Energy Visible<100GeV	1392/100000=1.4%

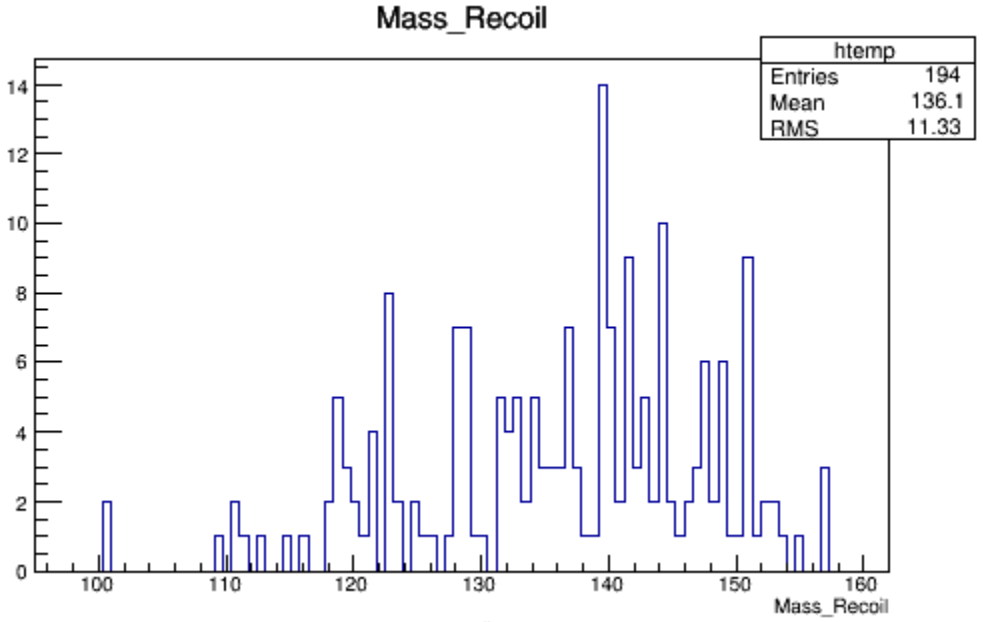
zz_l0tau

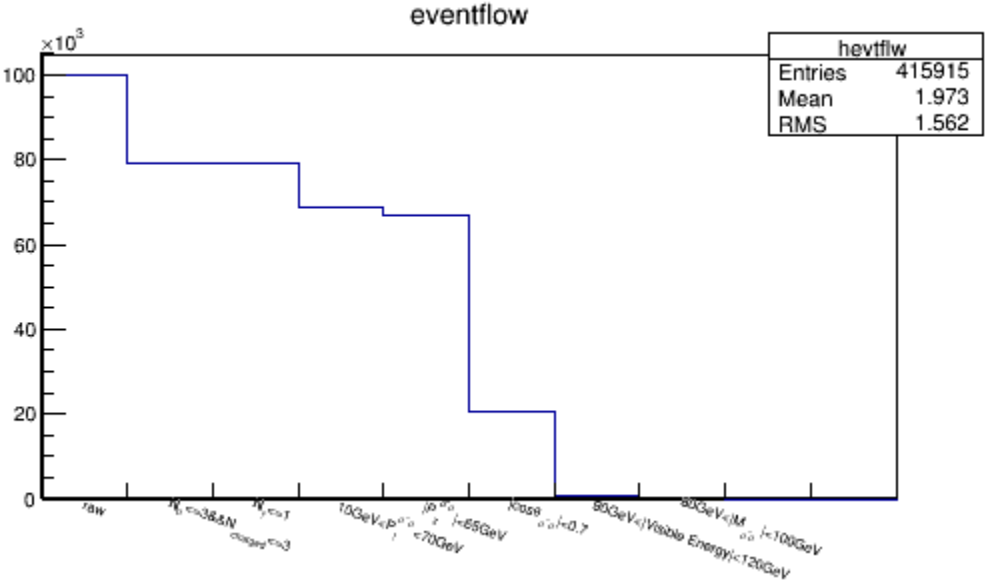




Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	154663/299800=51.6%
$N_{\gamma}<=1$	154663/299800=51.6%
$10GeV<P_t^{\mu+\mu-}<70GeV$	124646/299800=41.6%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	107914/299800=36.0%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	37081/299800=12.4%
$90GeV<M_{\mu+\mu-}<120GeV$	2875/299800=1.0%
80GeV<Energy Visible<100GeV	1999/299800=0.7%

zz_l0tautau





Cut	Efficiency
$(N_{\mu+}+N_{\mu-})<=3$, $N_{charged}<=3$	79278/100000=79.3%
$N_{\gamma}<=1$	79278/100000=79.3%
$10GeV<P_t^{\mu+\mu-}<70GeV$	68930/100000=68.9%
$\lvert P_z^{\mu+\mu-}\rvert<65GeV$	67100/100000=67.1%
$\lvert\cos\theta_{\mu+\mu-}\rvert<0.7$	20657/100000=20.7%
$90GeV<M_{\mu+\mu-}<120GeV$	478/100000=0.5%
80GeV<Energy Visible<100GeV	194/100000=0.2%