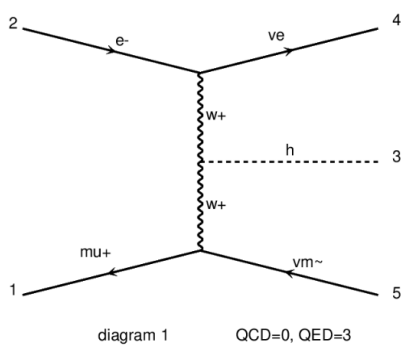
MUON COLLIDER

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

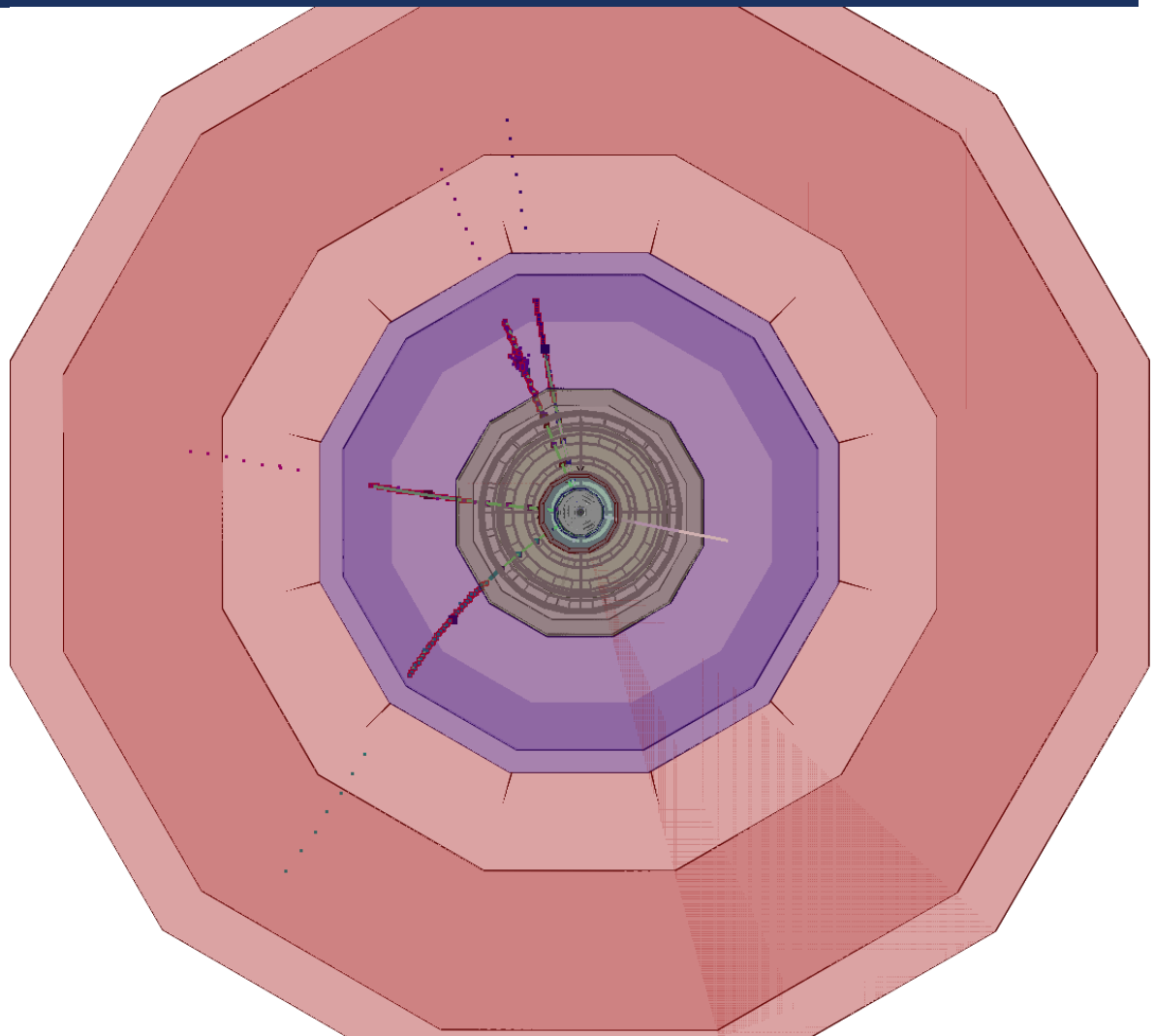
INFN Istituto Nazionale di Fisica Nucleare

$$\mu^+\mu^- \rightarrow \mathrm{H} \rightarrow \mathrm{ZZ} \rightarrow 4\mu$$

$$WW fusion$$



Preliminary results



Angela Zaza, Anna Colaleo, Filippo Errico,
Paola Mastrapasqua, Rosma Venditti

Samples

	Physical process	#Events	Cross section (pb)
Signal	$\mu^+\mu^- \rightarrow \mathrm{H} \rightarrow \mathrm{ZZ} \rightarrow 4\mu$	4000	$9.291 \cdot 10^{-6}$
Irreducible bkg	$\mu^+\mu^- \rightarrow \mathrm{Z}\mu^+\mu^-\nu_\mu\overline{\nu_\mu}$ (*) $\mathrm{Z} \rightarrow \mu^+\mu^-$	4000	$7.972 \cdot 10^{-5}$
(F. diagrams in backup slides)	$\mu^+\mu^- \rightarrow \mathrm{Z}\mu^+\mu^-$ $\mathrm{Z} \rightarrow \mu^+\mu^-$	4000	$1.877 \cdot 10^{-3}$

$\sqrt{s}$ = 1.5 TeV

Software release: v02-05-MC

Magnetic Field: 3.57 T

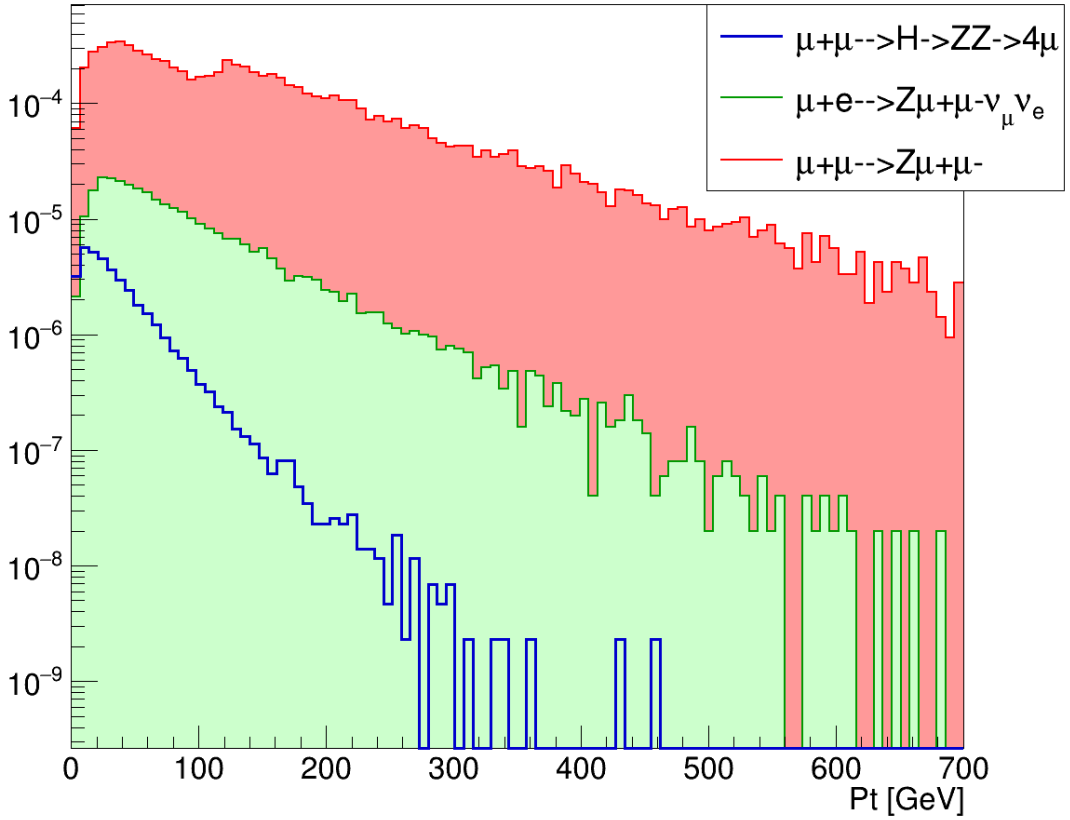
Muon Barrel: -1.34 T

Double Layer Filter not enabled

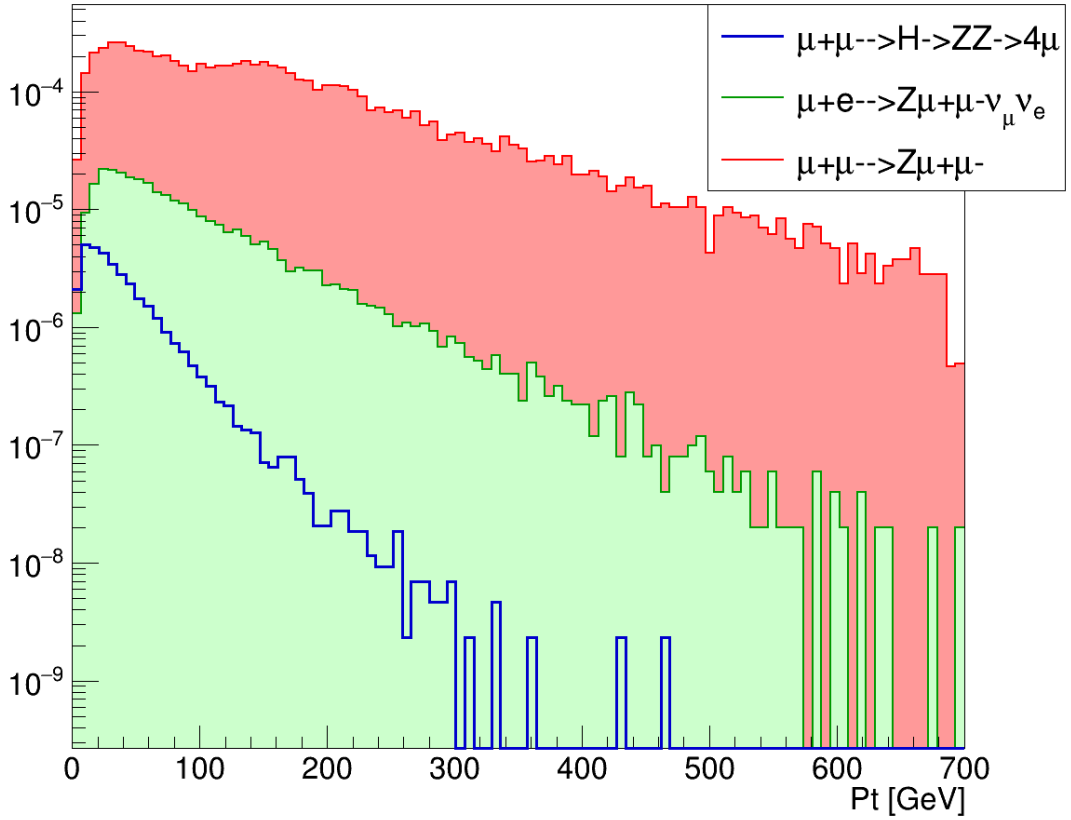
(*) in order to avoid $\mu^+\mu^-$ annihilation, we produced $\mu^+e^- \rightarrow \mathrm{Z}\mu^+\mu^-\nu_e\overline{\nu_\mu}$ with MadGraph (Fabio Maltoni suggestion)

Transverse Momentum: comparison between Generated and Reconstructed Muons

Generated muons after interaction with detector: Pt histogram



Reconstructed Muons: Pt histogram

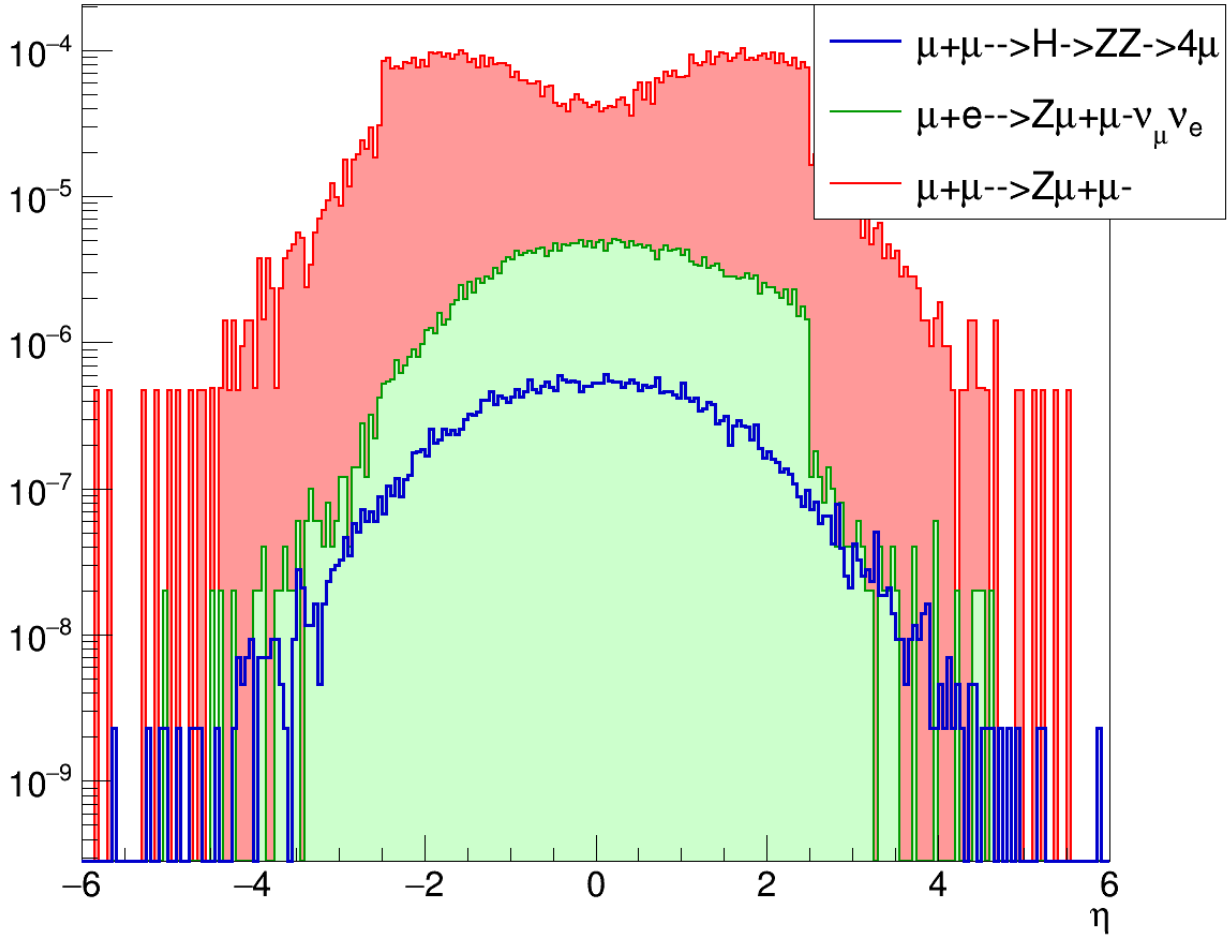


Reconstructed Muons: Particle Flow output collection.

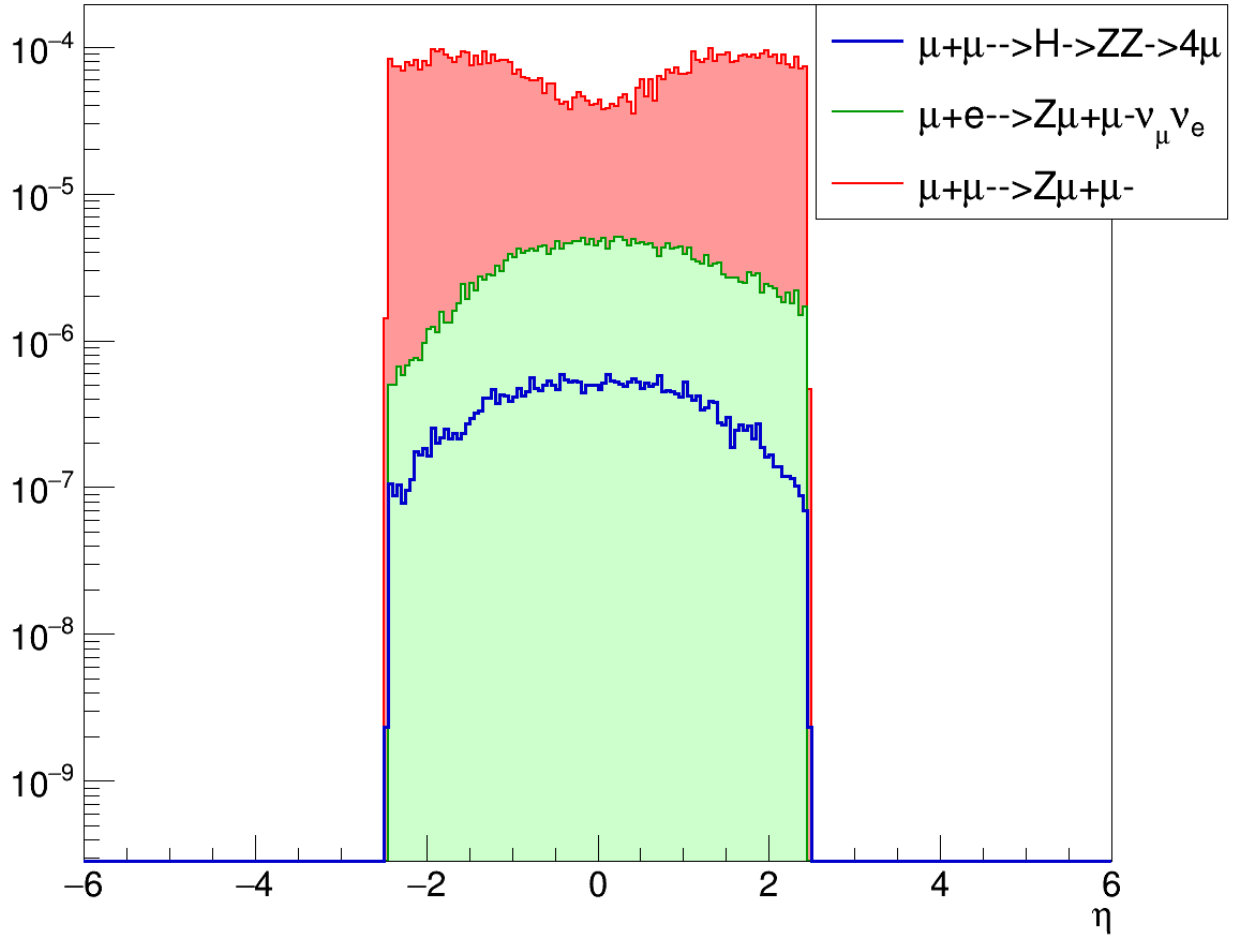
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Pseudorapidity: comparison between Generated and Reconstructed Muons

Generated muons after interaction with detector: η histogram



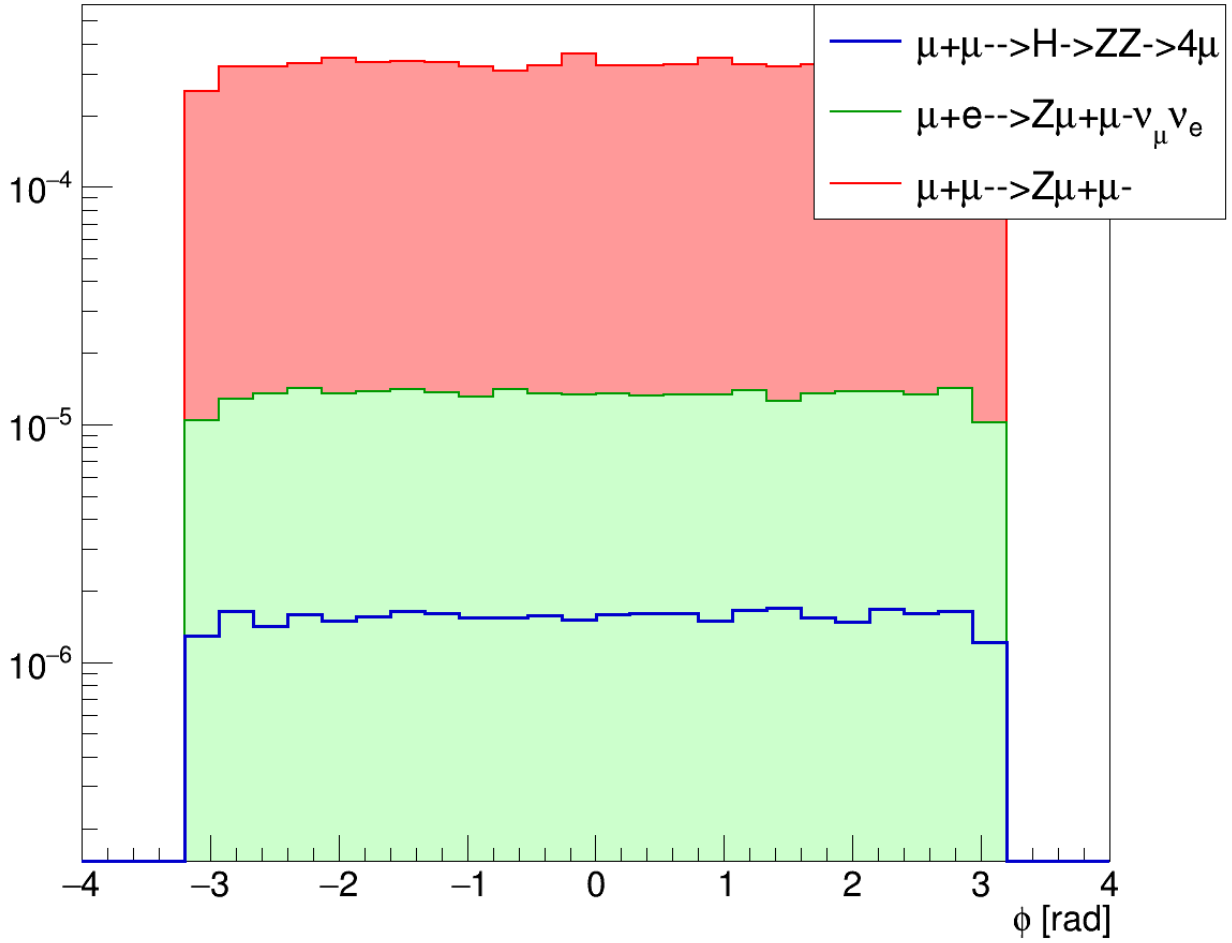
Reconstructed muons: η histogram



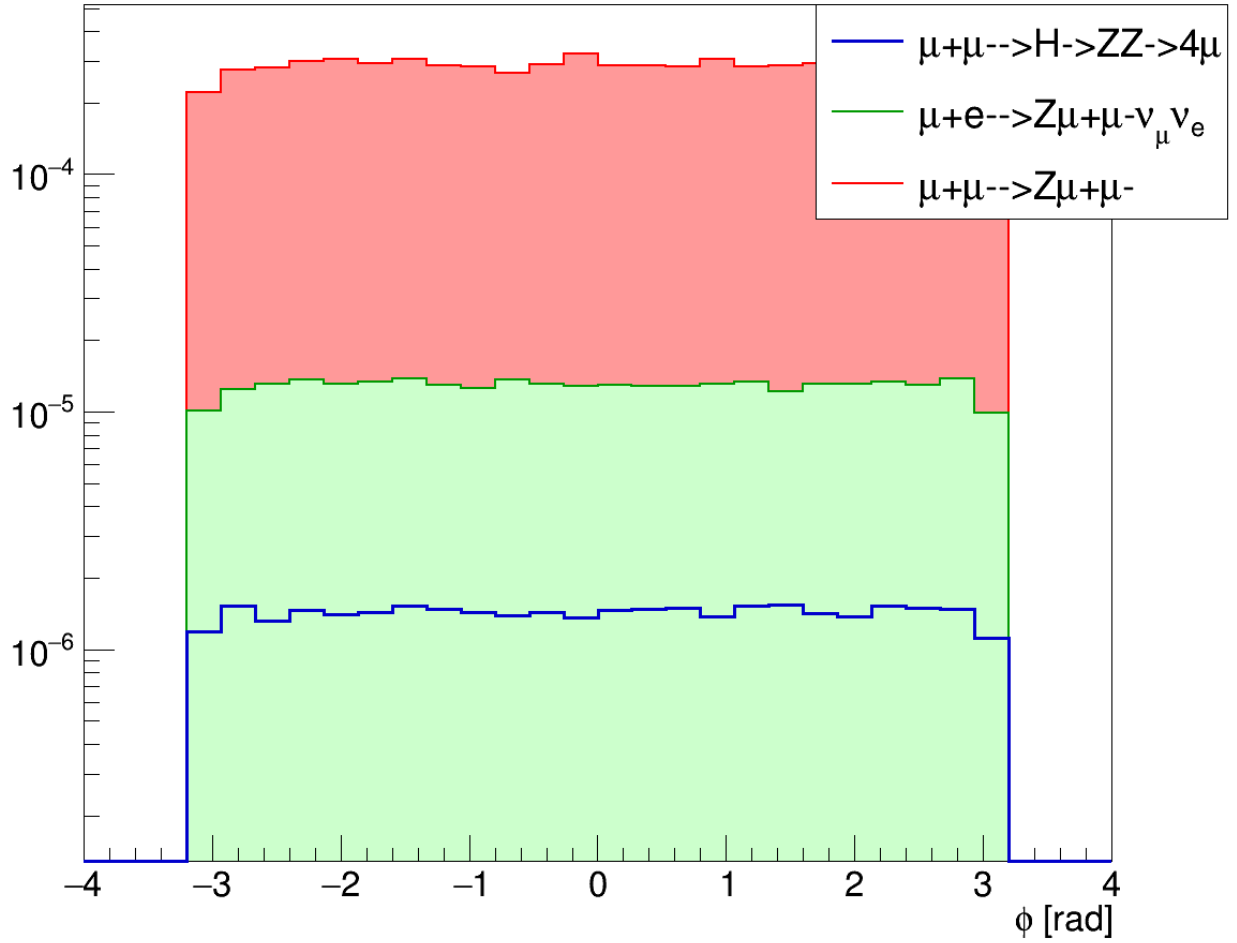
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Φ: comparison between Generated and Reconstructed Muons

Generated muons after interaction with detector: ϕ histogram



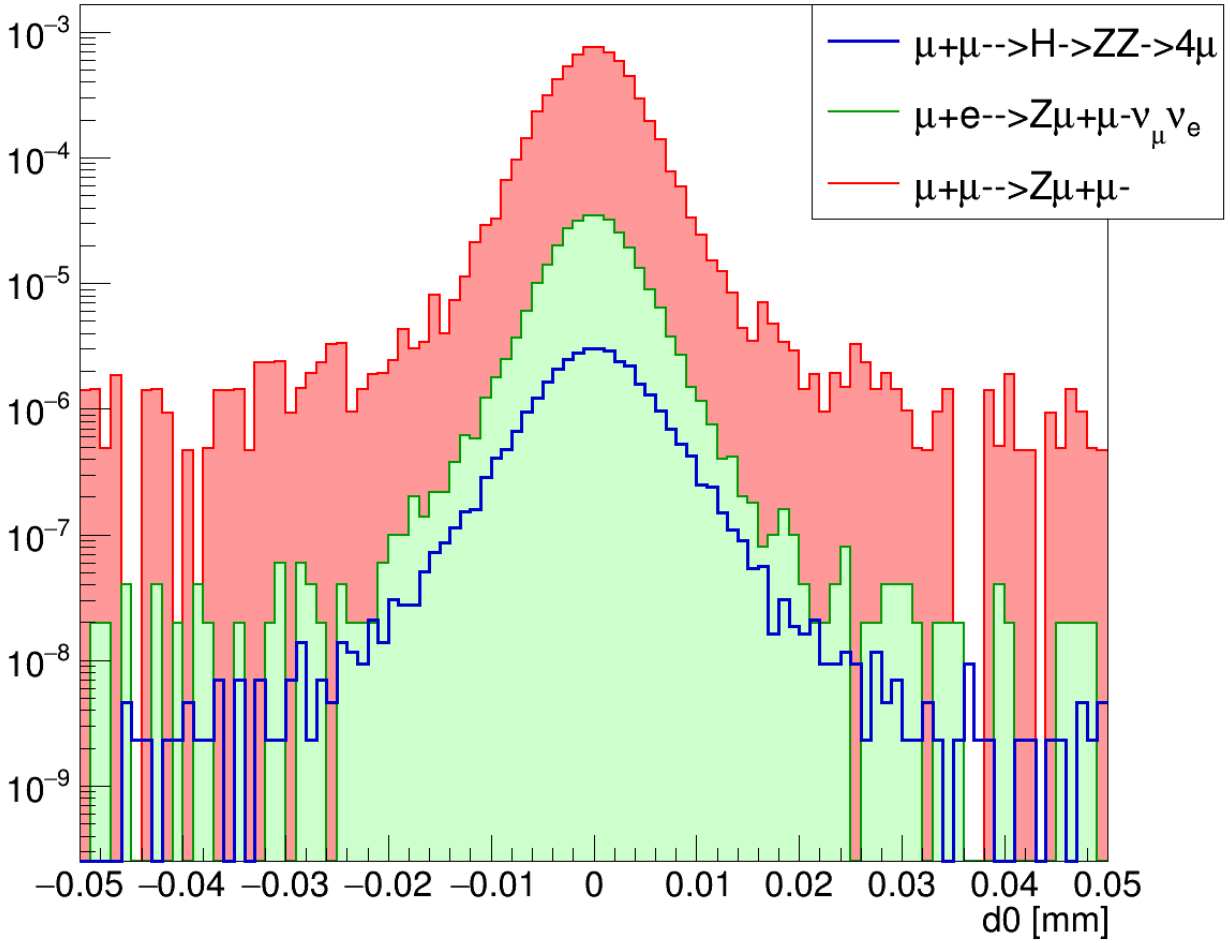
Reconstructed muons: ϕ histogram



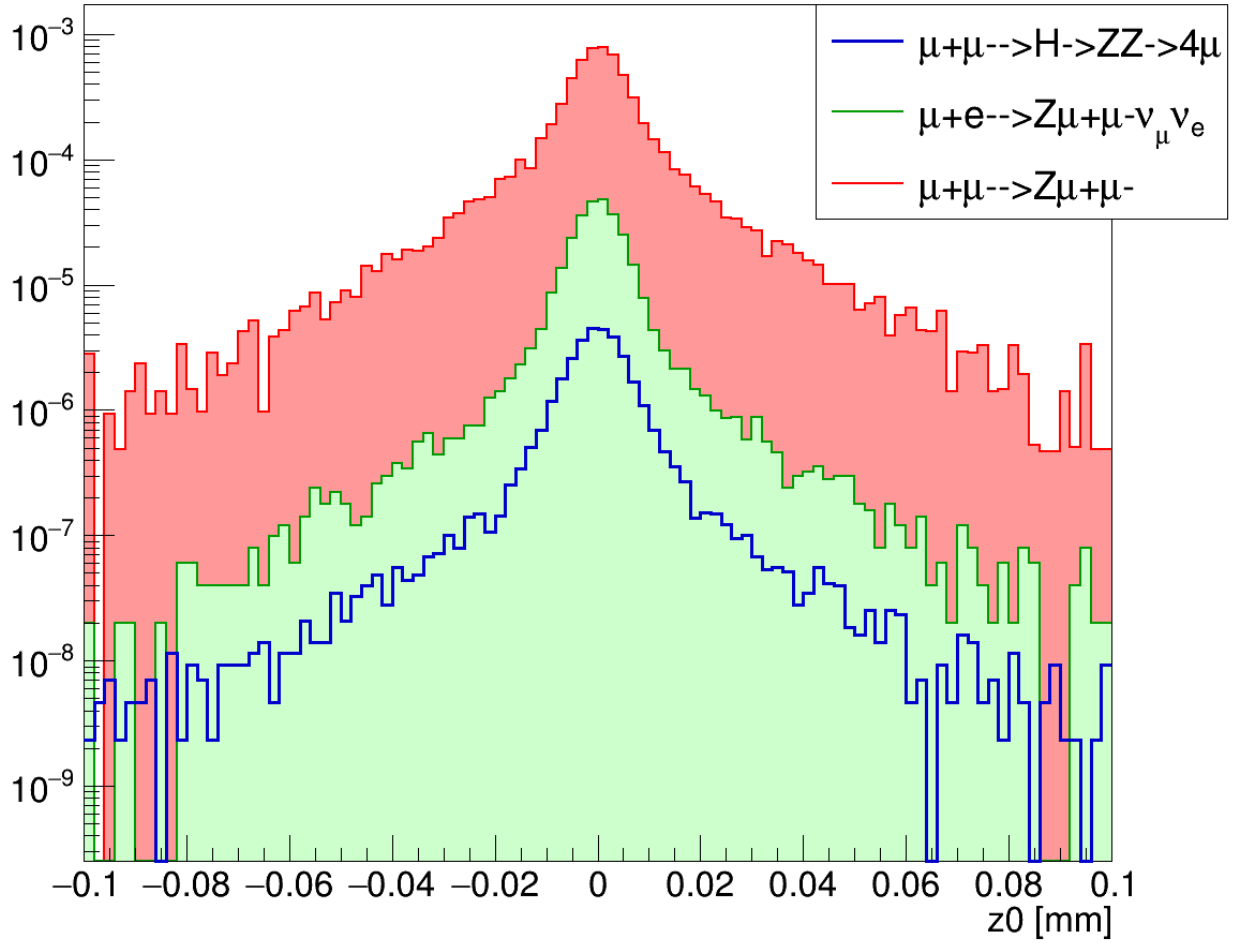
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Muon trak Parameters: D0 and Z0

Reconstructed muons: d0 histogram



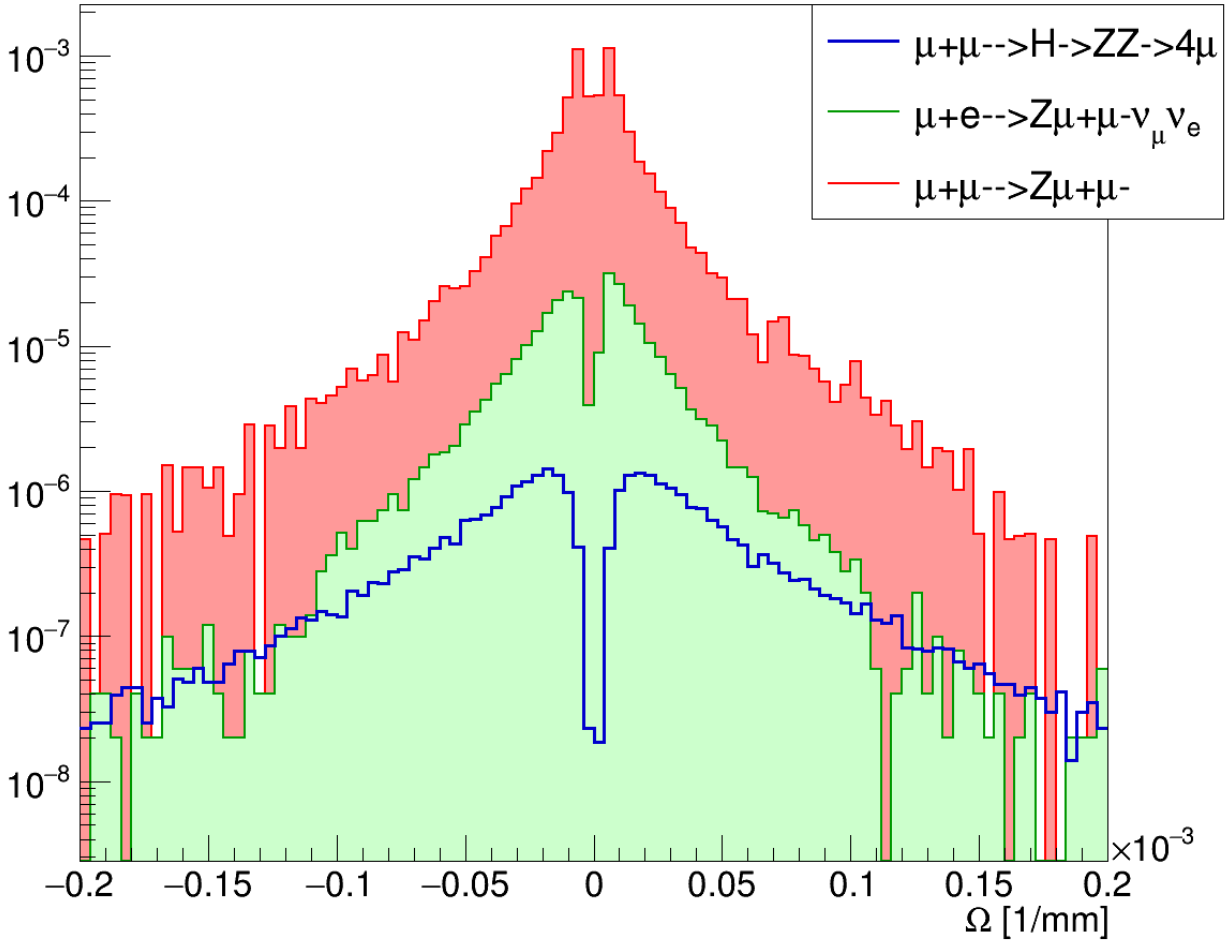
Reconstructed muons: z0 histogram



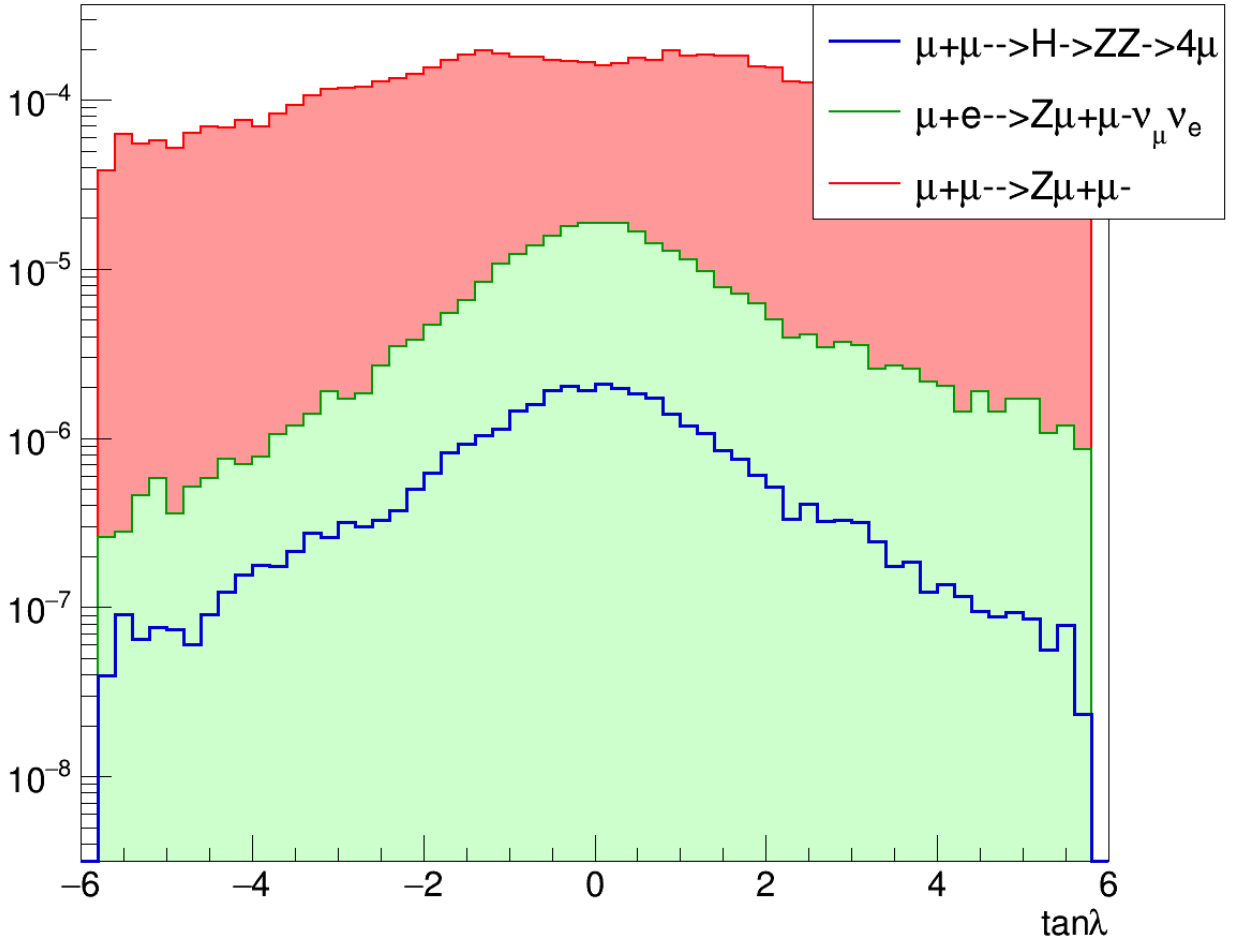
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Muon trak Parameters: Ω and tanλ

Reconstructed muons: Ω histogram

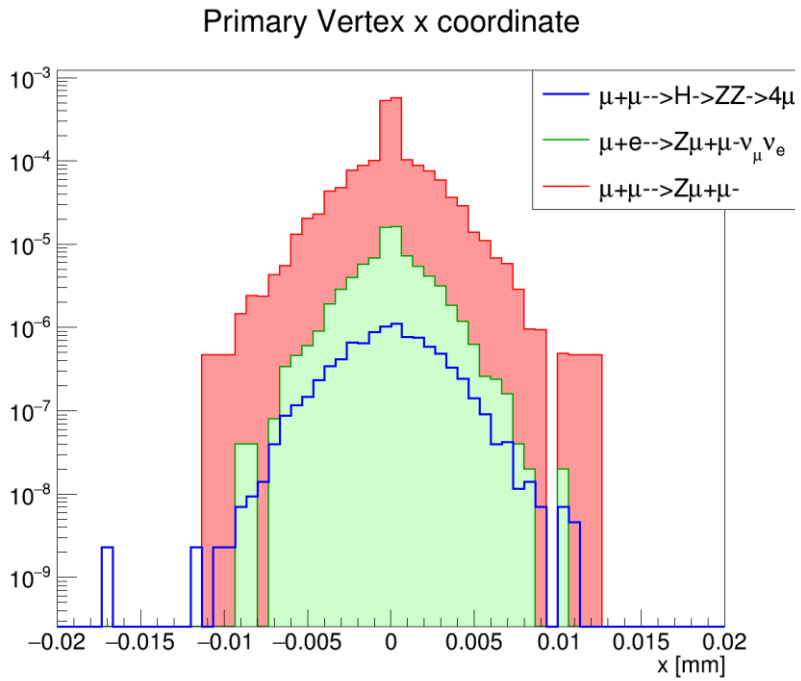


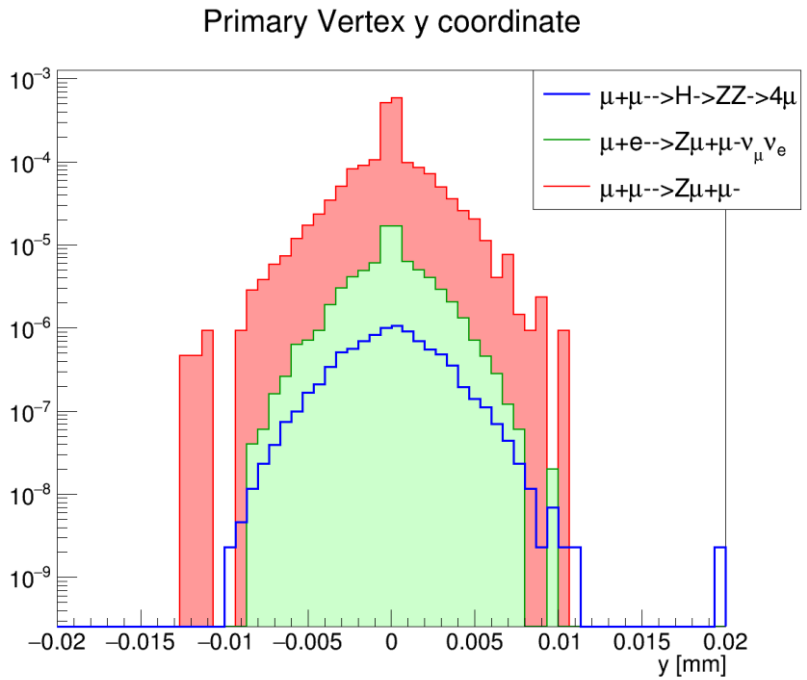
Reconstructed muons: tanλ histogram

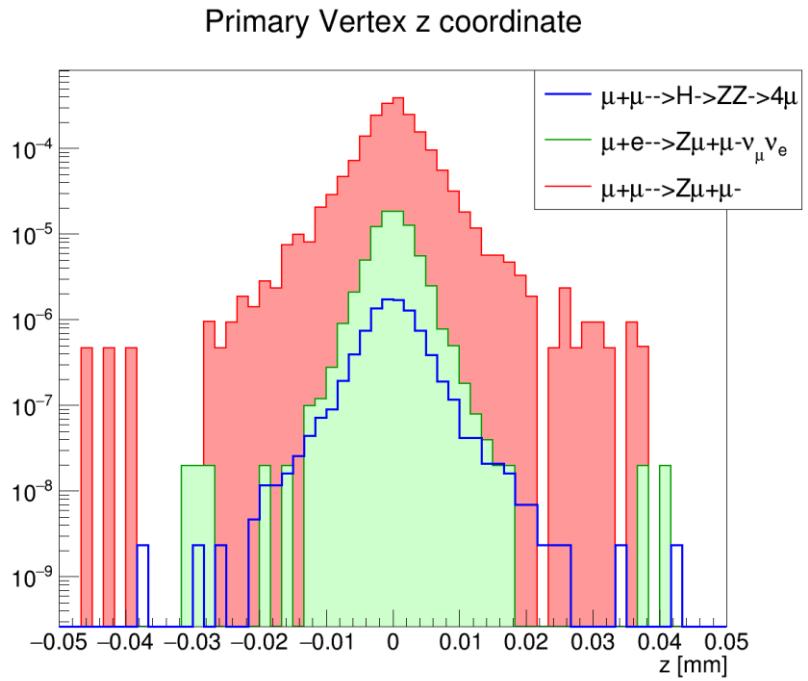


Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Primary Vertex Position





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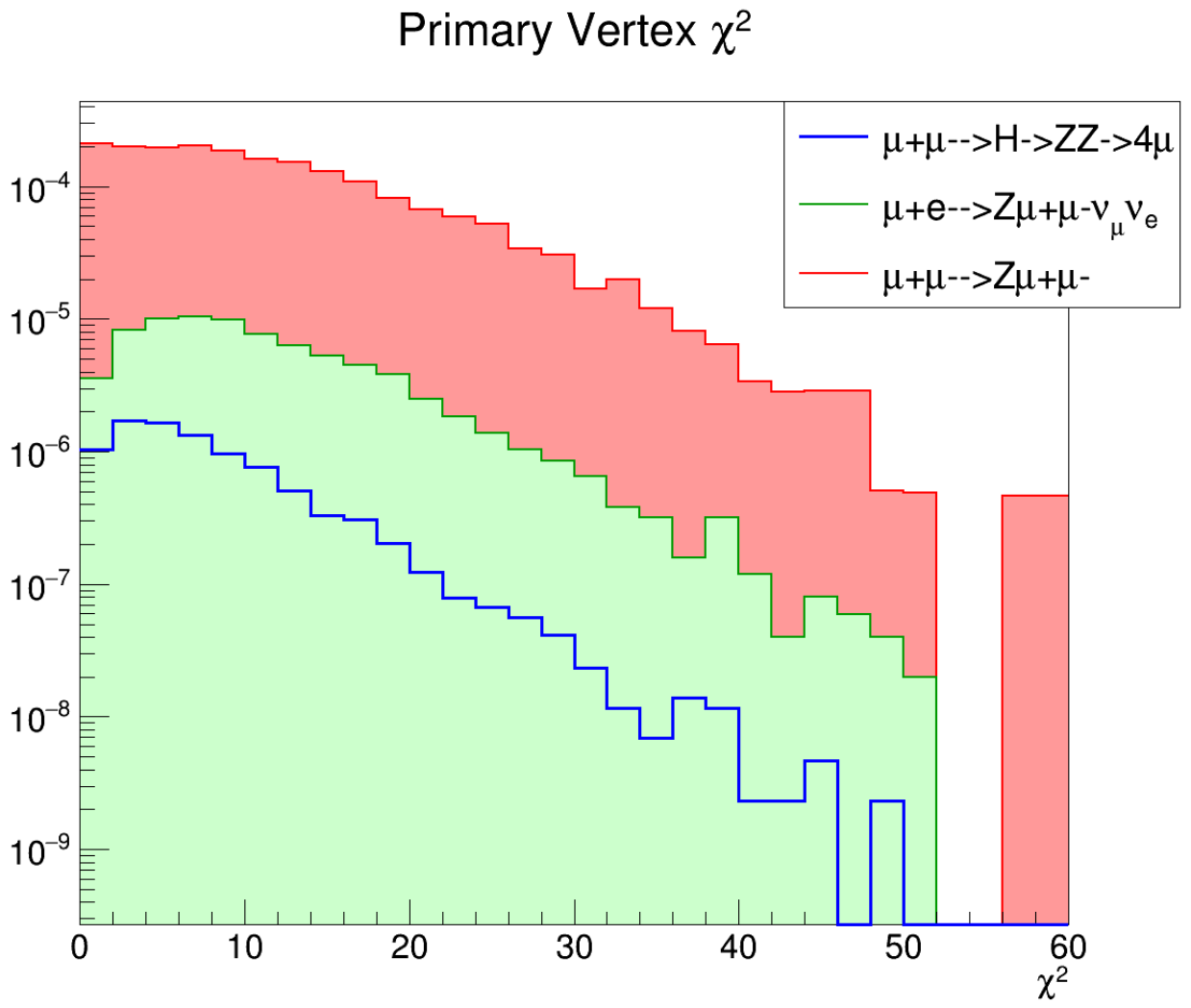
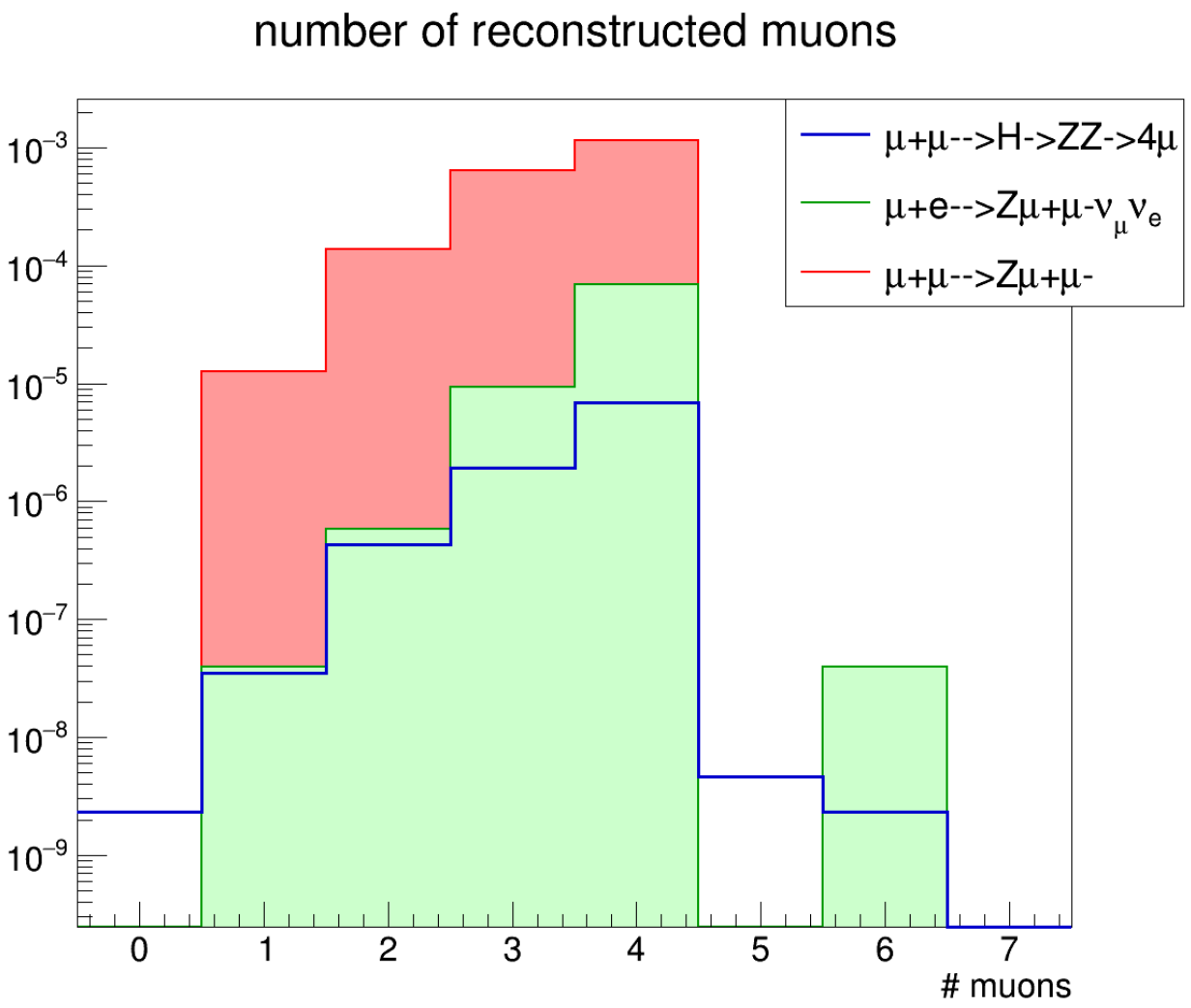
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Primary Vertex Chi Square



Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Number of Reconstructed Muons per event



# Reco muons	signal	bkg
0	1	0
1	15	29
2	187	320
3	823	1820
<4	1026	2169
% wrt the total number of Gen events	**25.65%**	**27.11%**

SIGNAL

GEN level: 16000 final state muons

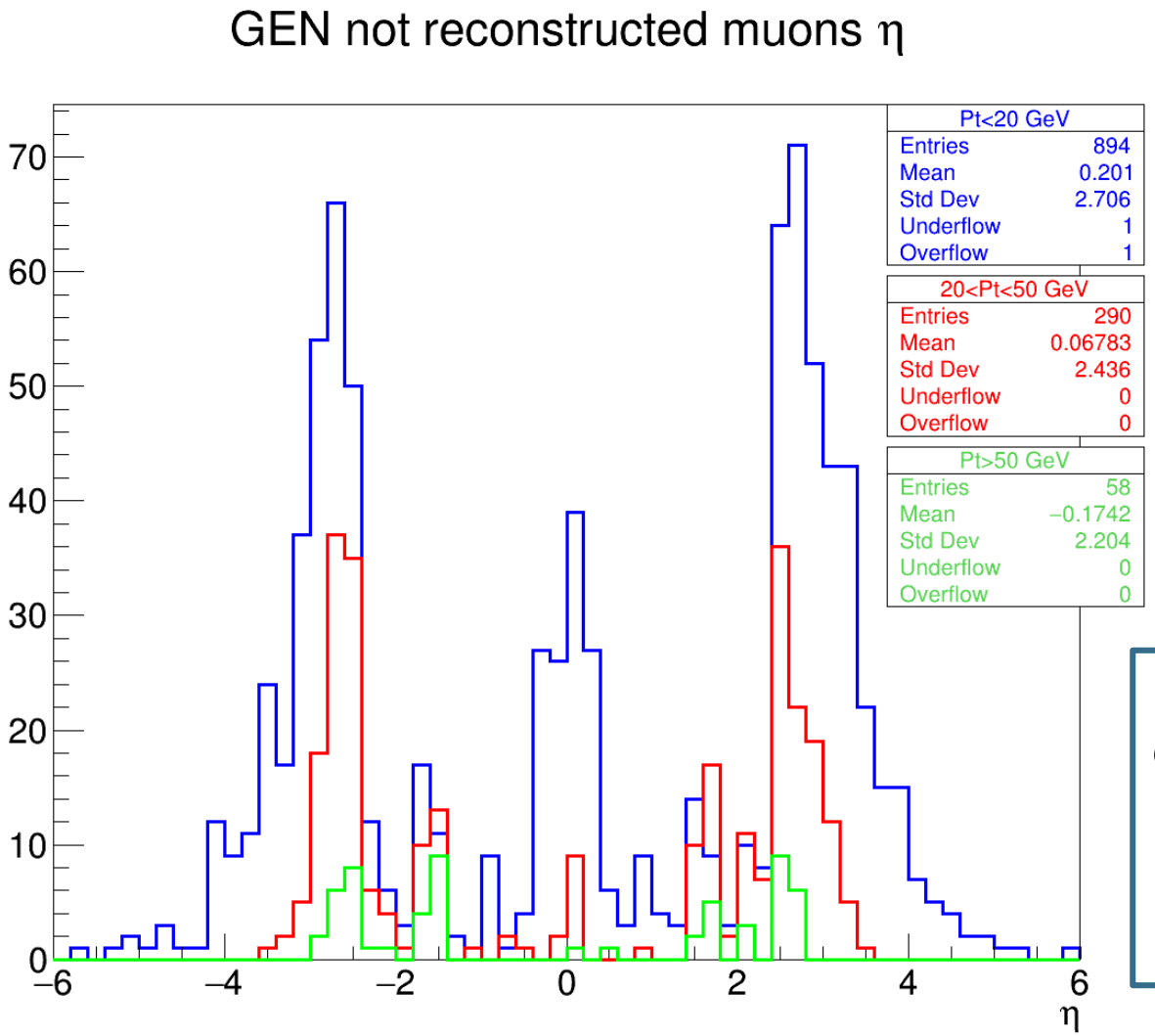
RECO level: 14758 reconstructed as muons

499 wrongly reconstructed as:

neutrons(255), pions(185), photons(9)

Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

GEN level: muons that have not been reconstructed



SIGNAL

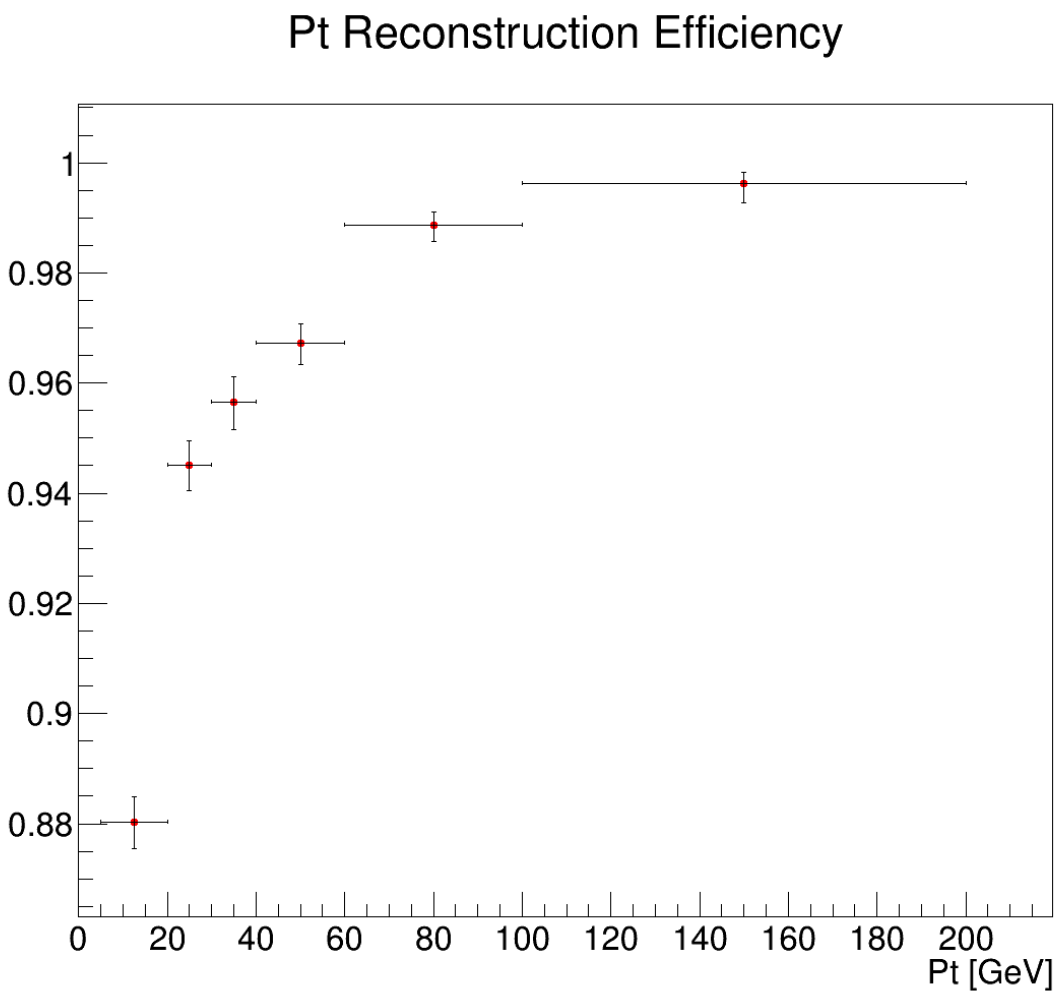
GEN level: 16000 final state muons

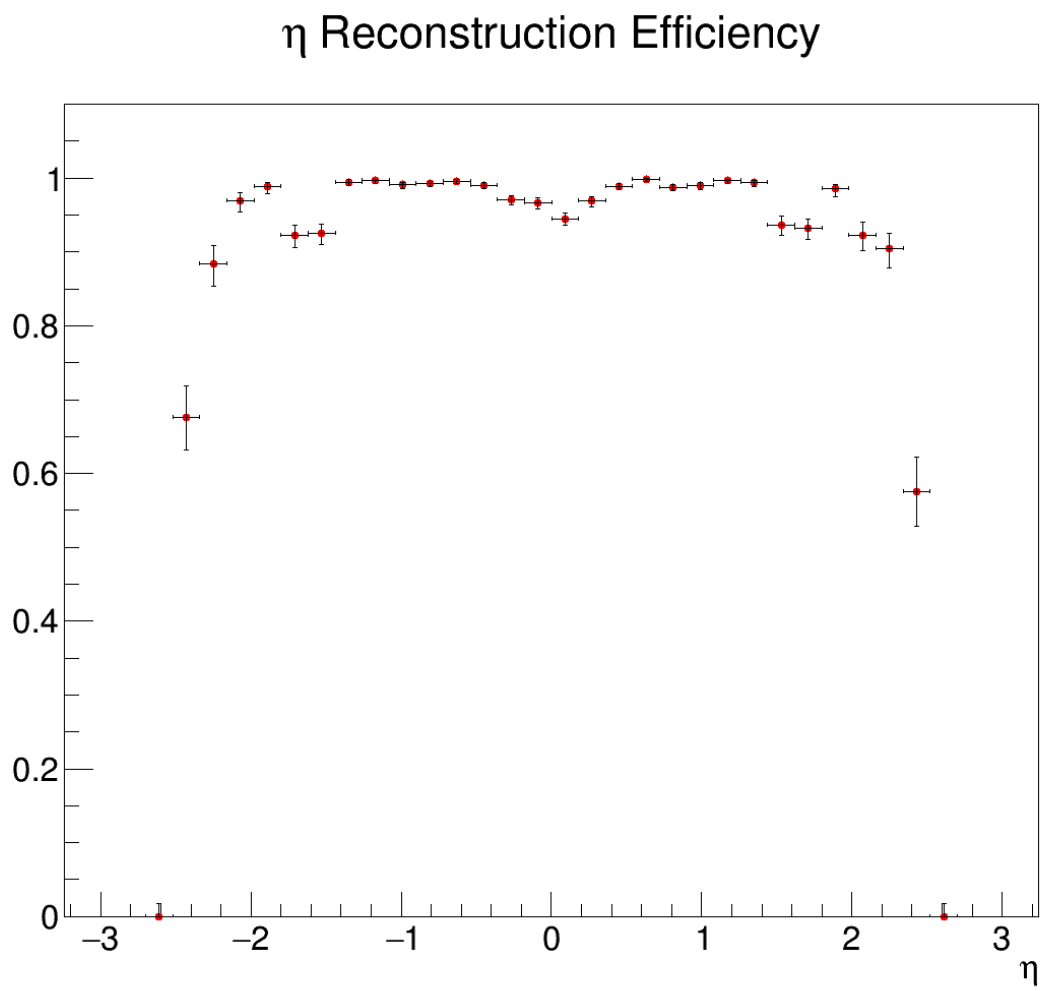
RECO level: 14758 reconstructed as muons

499 wrongly reconstructed as:

neutrons(255), pions(185), photons(9)

Reconstruction Efficiency: ONLY SIGNAL

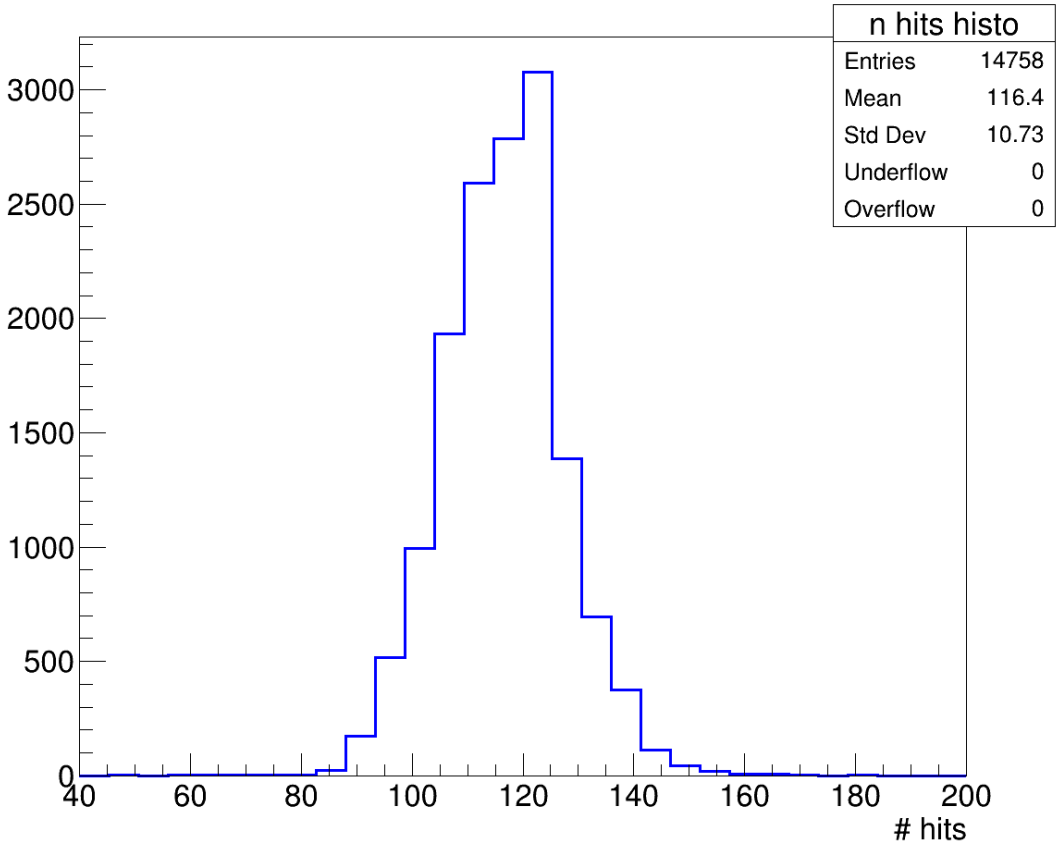




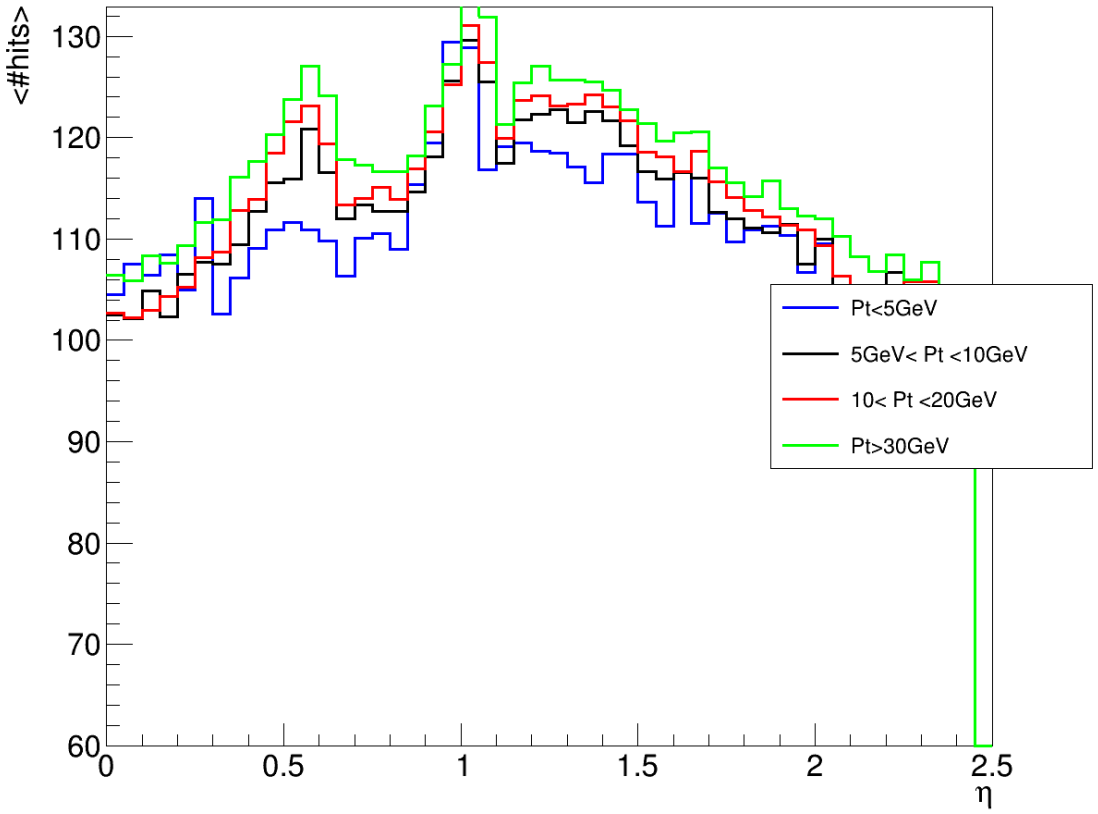
Reconstructed Muon Hits: ONLY SIGNAL

RECO MUON → track → tracker hits
RECO MUON → cluster → calorimeter and muon system hits

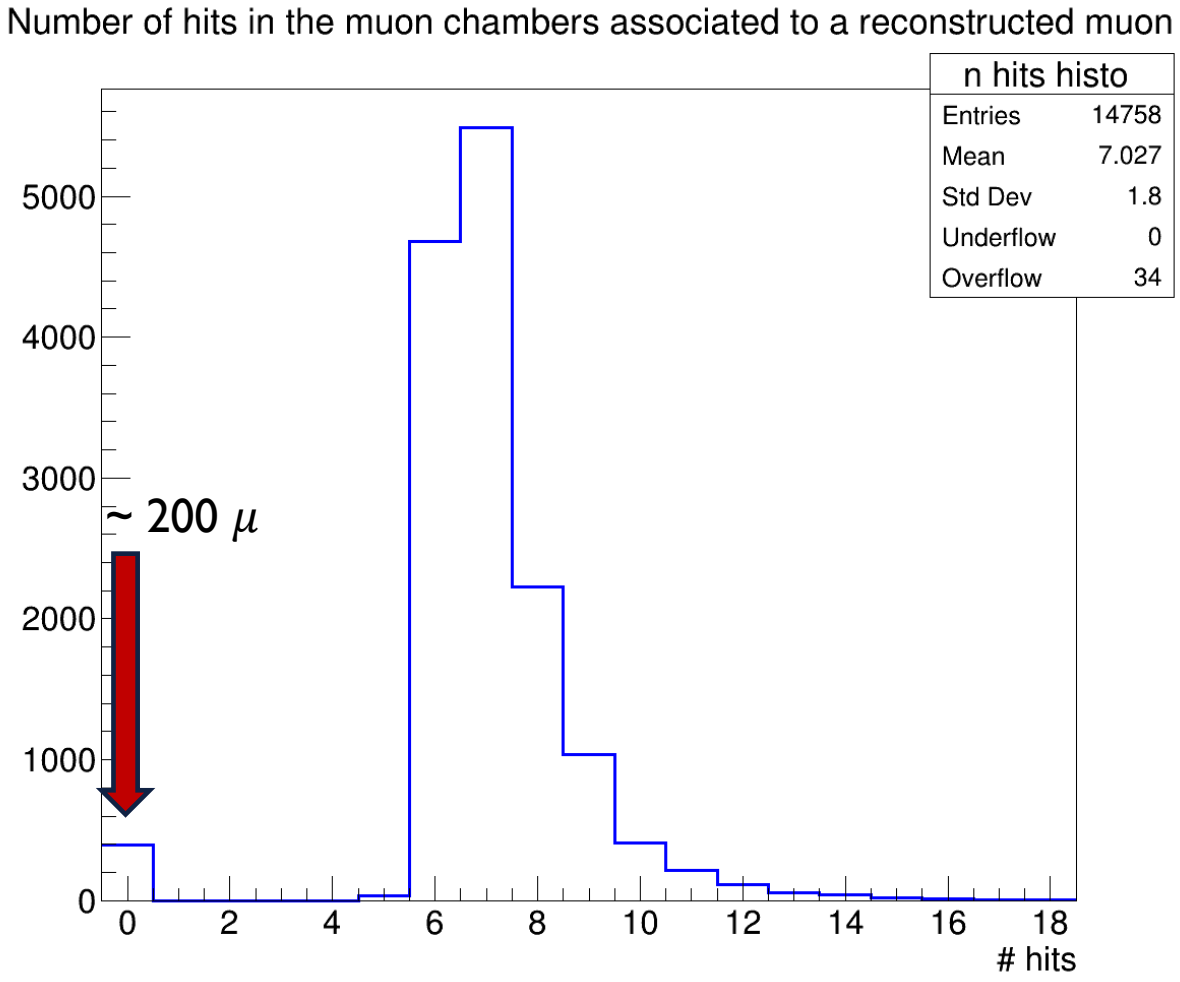
Number of hits associated to a reconstructed muon

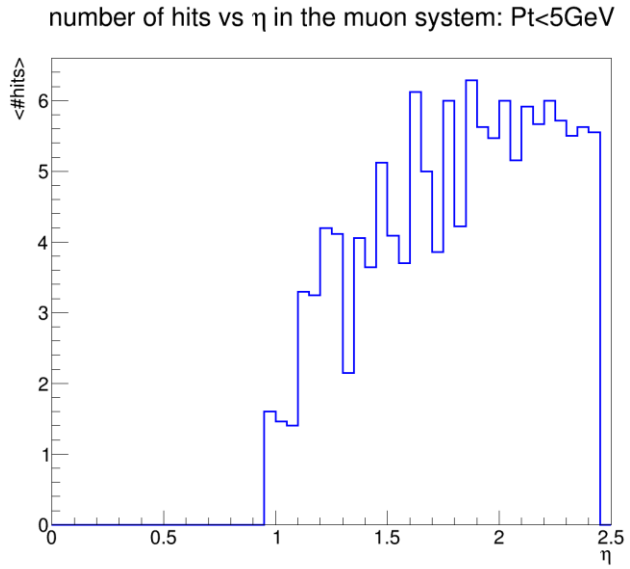


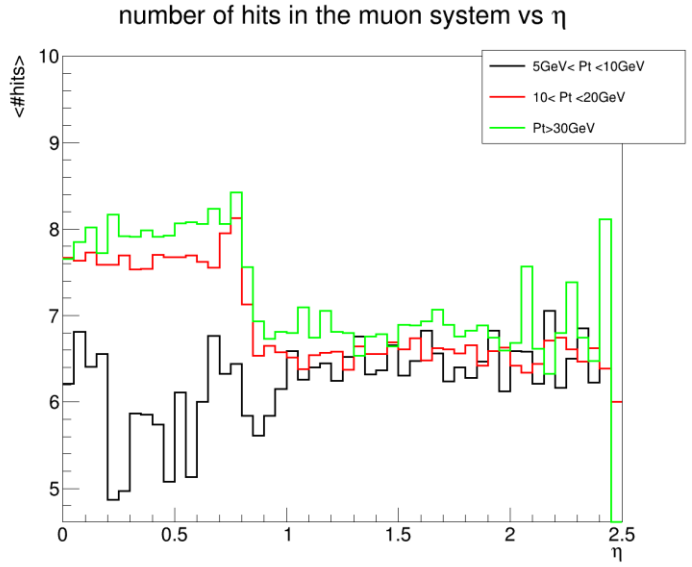
number of hits vs η



Hits in the muon system: ONLY SIGNAL







ONGOING STUDIES

Selection of good final state muons

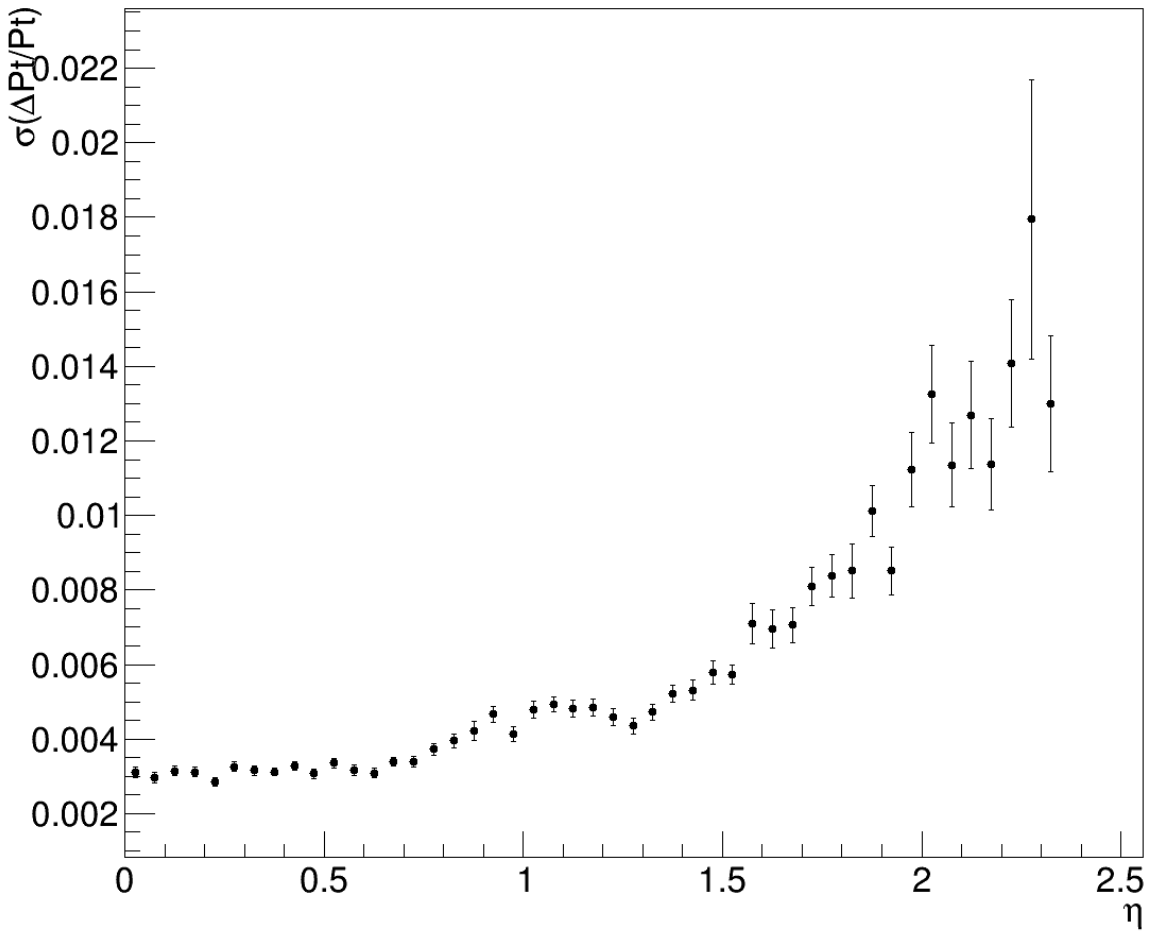
Table A

	SIGNAL			BACKGROUND		
Selection	**#muons**	**Absolute efficiency**	**Relative efficiency**	**#muons**	**Absolute efficiency**	**Relative efficiency**
GEN	16000			32000		
$\|\eta\| < 2.5$	14758 ± 121	0.9224 ± 0.0021	0.9224 ± 0.0021	29457 ± 172	0.9205 ± 0.0015	1.00 ± 0.00
$P_T > 5GeV$	14293 ± 120	0.8933 ± 0.0024	0.9684 ± 0.0014	29406 ± 171	0.9189 ± 0.0015	0.9983 ± 0.0002
$D_0 < 2\ mm$	14291 ± 120	0.8932 ± 0.0024	0.9999 ± 0.0001	29404 ± 171	0.9189 ± 0.0015	0.9999 ± 0.0001
$Z_0 < 10\ mm$	14288 ± 120	0.8930 ± 0.0024	0.9998 ± 0.0001	29404 ± 171	0.9189 ± 0.0015	1.00 ± 0.00

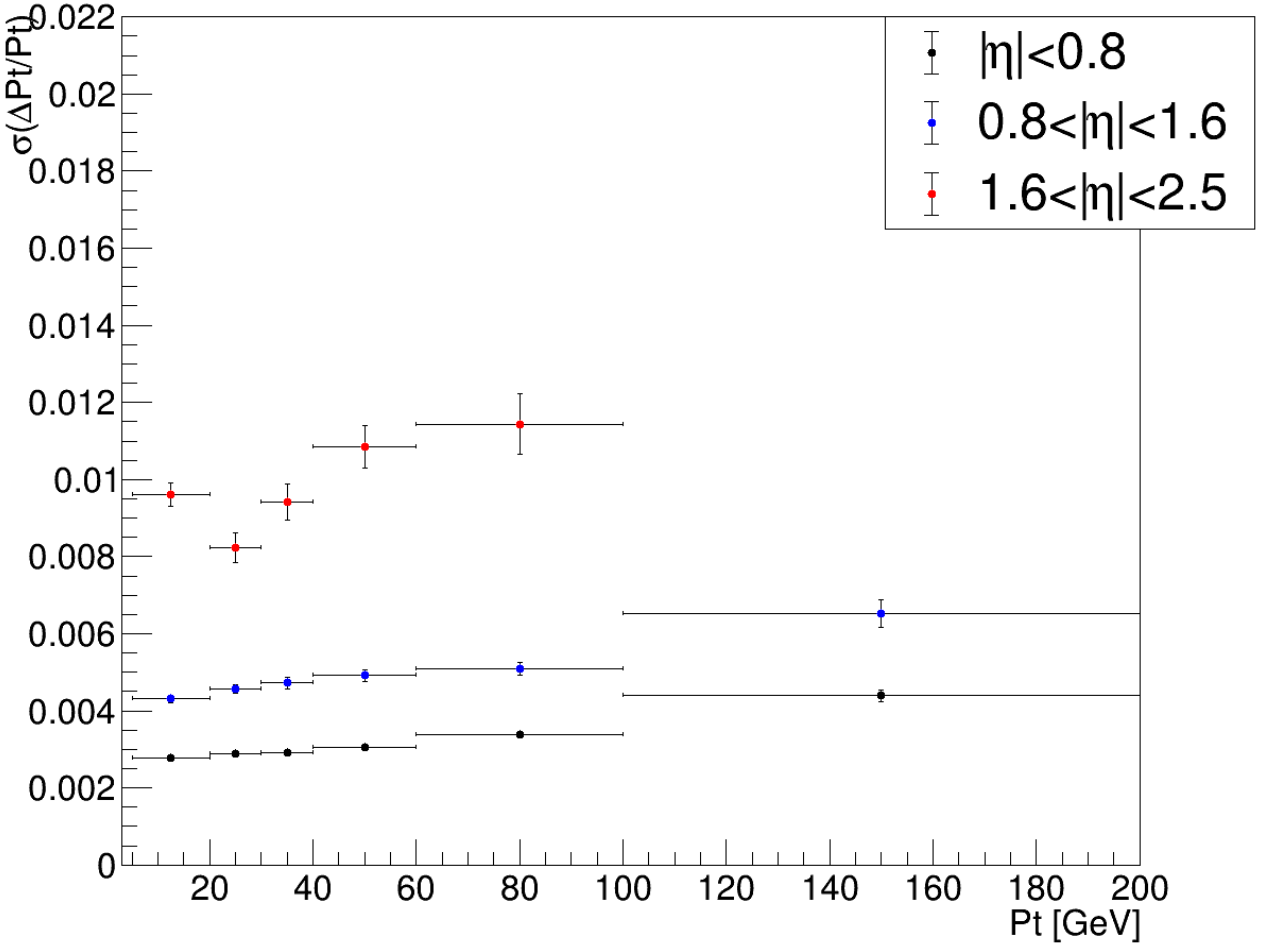
From now on, only reconstructed muons passing the selection in Table A will be considered.

Transverse Momentum Resolution

Pt resolution vs η



Pt Resolution vs Pt



ZZ Candidate Selection: inspired to CMS analysis

- Z candidates: pairs of selected muons of opposite charge that satisfy
  $12 < InvMass\ (\mu^+\mu^-) < 120\ GeV$

- ZZ candidates: pairs of non-overlapping Z candidates
  Z_1: Z candidate with reconstructed mass $m_{\mu^+\mu^-}$ closest to the nominal Z boson mass
  Z_2: the other Z candidate

  ZZ candidates are required to satisfy:
  - $\Delta R > 0.02$ between each of the 4 muons
  - At least 2 muons with:
    $P_{T,i} > 20\ GeV$
    $P_{T,j} > 10\ GeV$
  - $Z_1 mass > 40\ GeV$
  - $InvMass\ (4\mu) > 70\ GeV$

ATLAS selection algorithm will also be considered

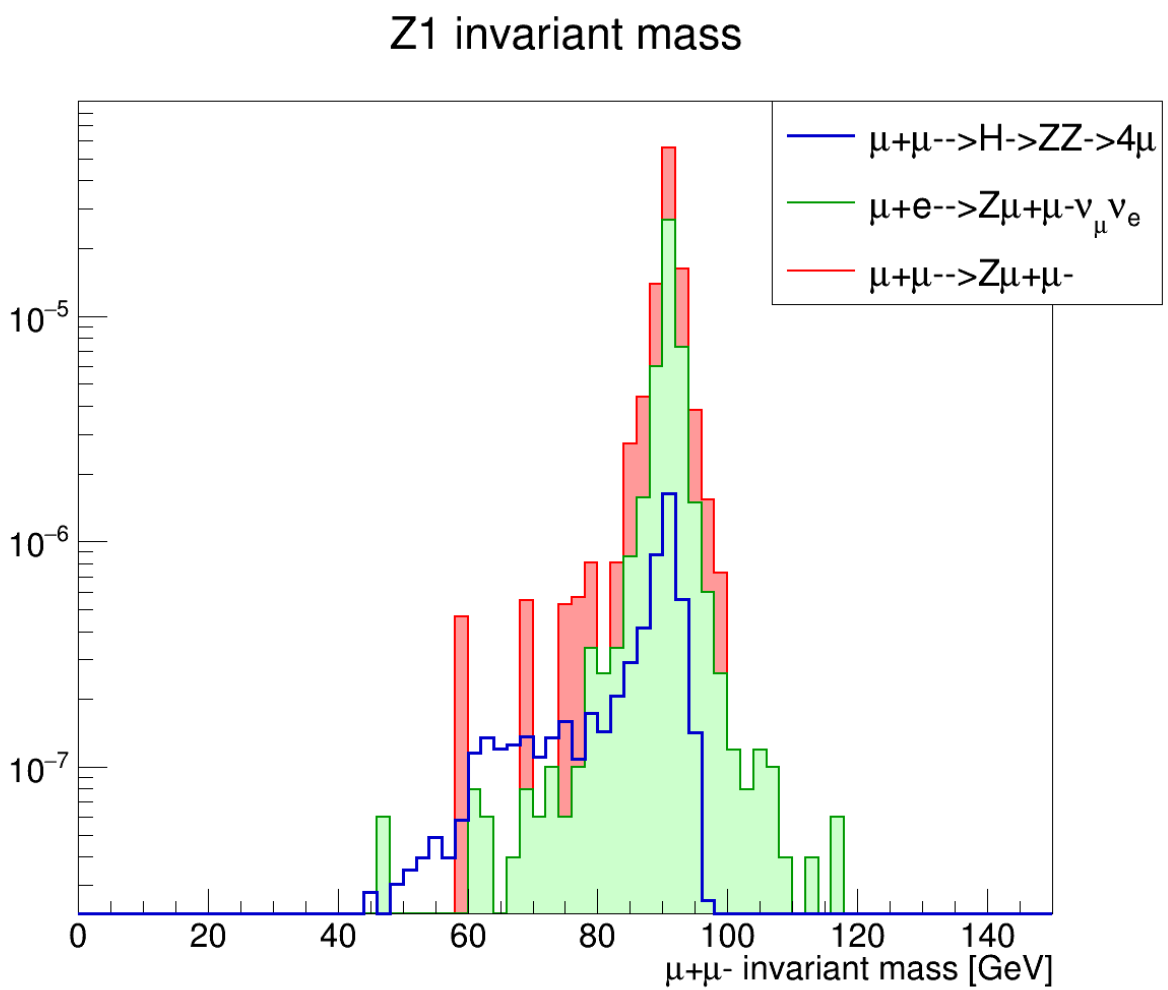
Selection of Events

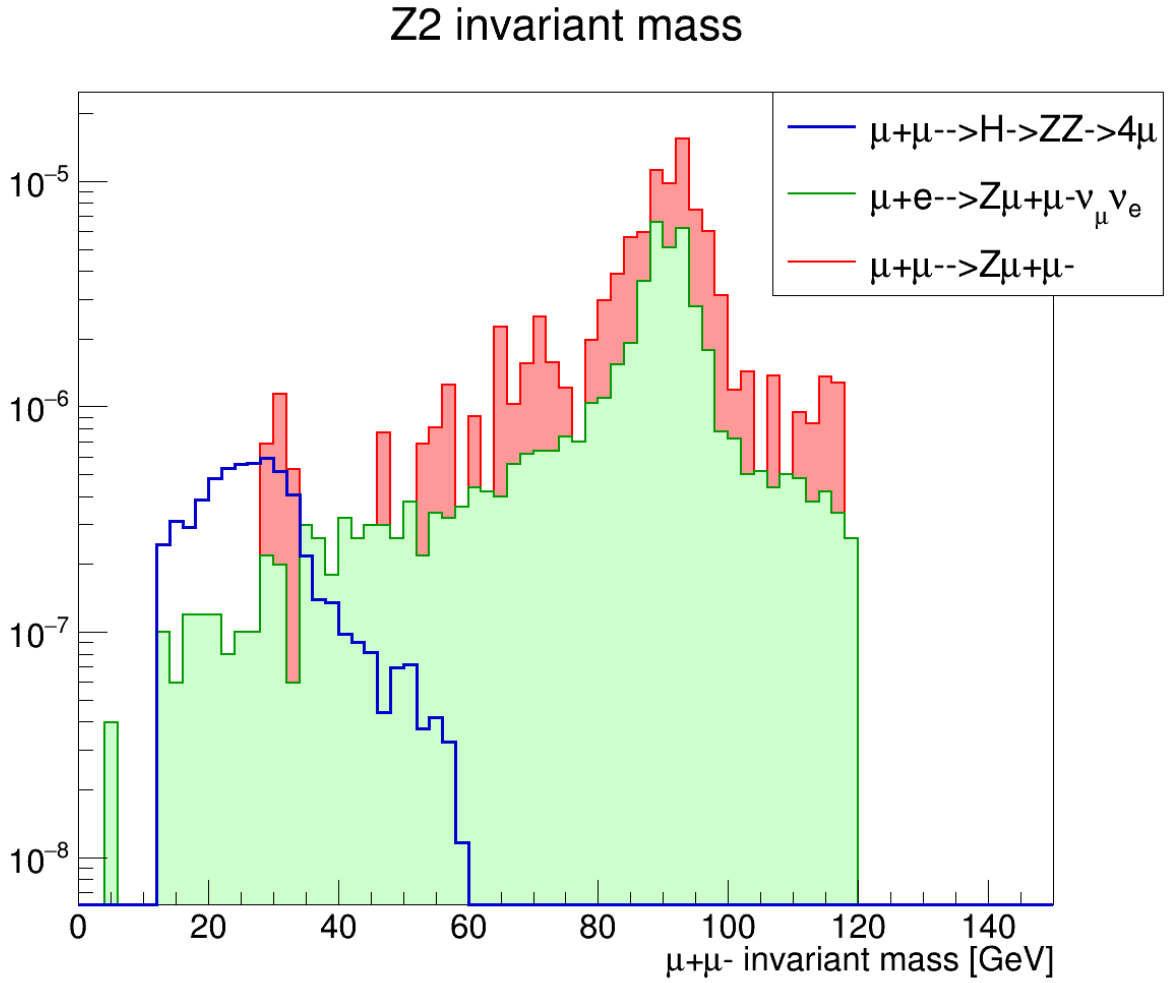
Table B

Selection	SIGNAL #events	SIGNAL Absolute efficiency	SIGNAL Relative efficiency	BACKGROUND #events	BACKGROUND Absolute efficiency	BACKGROUND Relative efficiency
GEN	4000			8000		
At least 4 good final state muons	2592			5791		
Opposite sign muon pairs	2592 ± 51	1.00 ± 0.00	1.00 ± 0.00	5791 ± 76	1.00 ± 0.00	1.00 ± 0.00
$\Delta R > 0.02$ between each of the 4 muons	2586 ± 51	0.9977 ± 0.0010	0.9977 ± 0.0010	5790 ± 76	0.9998 ± 0.0002	0.9998 ± 0.0002
At least 2 muons with: $P_{T,i} > 20\ GeV$ $P_{T,j} > 10\ GeV$	2585 ± 51	0.9973 ± 0.0010	0.9996 ± 0.0004	5790 ± 76	0.9998 ± 0.0002	1.00 ± 0.00
$12 < InvMass\ (\mu^+\mu^-) < 120\ GeV$	2581 ± 51	0.9958 ± 0.0013	0.9985 ±0.0008	2477 ± 50	0.4277 ± 0.0065	0.42781 ± 0.0065
$Z_1 mass > 40\ GeV$	2562 ± 51	0.9884 ±0.0021	0.9926 ± 0.0017	2476 ± 50	0.42756 ± 0.0065	0.9996 ± 0.0004
$InvMass\ (4\mu) > 70\ GeV$	2561 ± 51	0.9880 ±0.0021	0.9996 ± 0.0004	2476 ± 50	0.42756 ± 0.0065	1.00 ± 0.00
After normalization ($L = 500 fb^{-1}$)	2.97			52.31		

From now on, only events passing the selection in Table B will be considered.

Z_1 and Z_2 Mass

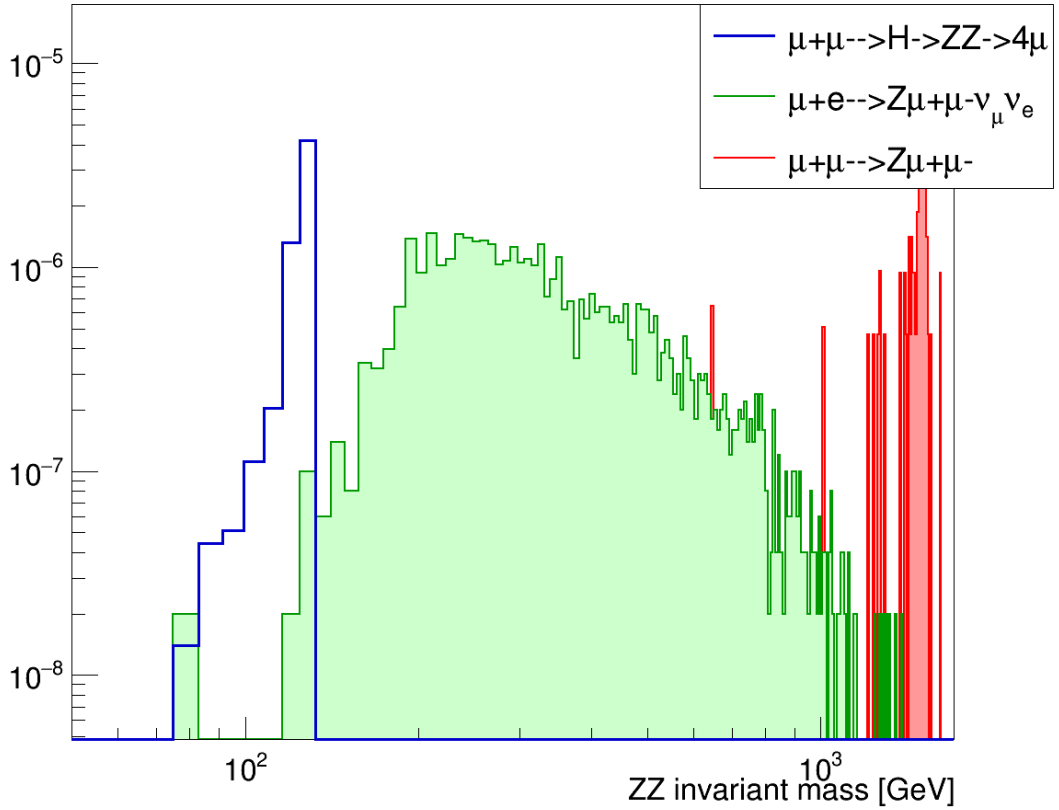




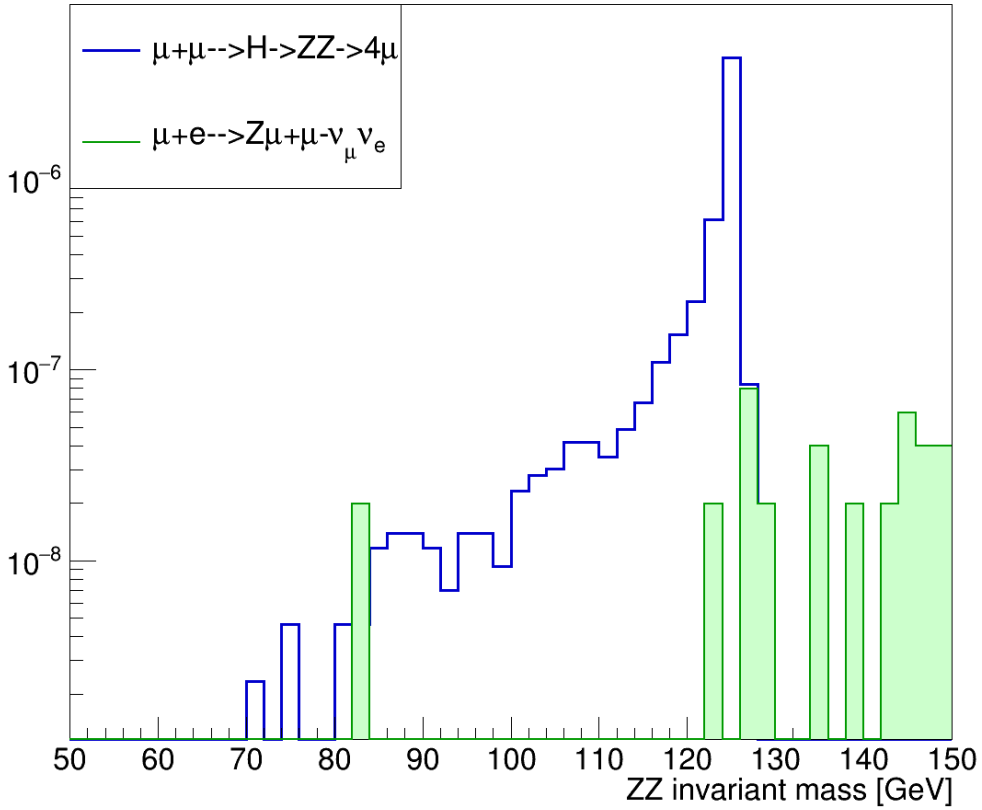
Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Higgs Mass

Higgs invariant mass



Higgs mass zoom



The analyzed channel appears to be background free. A much higher number of bkg events need to be generated in order to confirm this preliminary result.

Histograms are normalized to the number of events and cross section, assuming L=$1pb^{-1}$ for all the samples

Next steps

- Increase the samples size for a better statistics
- Optimize muons reconstruction and identification
- Add BIB events
- Implement muon ID
- Analyse Higgs production in s channel
- Perform the same study for $\sqrt{s}$ = 3 TeV ⟶ BIB available ?

Many thanks to Massimo, Laura, Lorenzo, Nazar and Chiara for helping.

THANK YOU!

BACK UP

Feynman Diagrams

$$\mu^+ e^- \rightarrow Z\mu^+\mu^-\nu_e\overline{\nu_\mu}$$

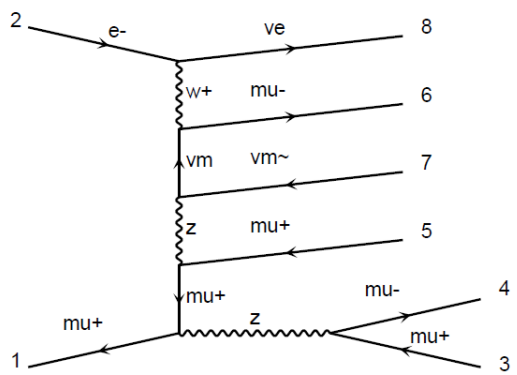


diagram 1 QCD=0, QED=6

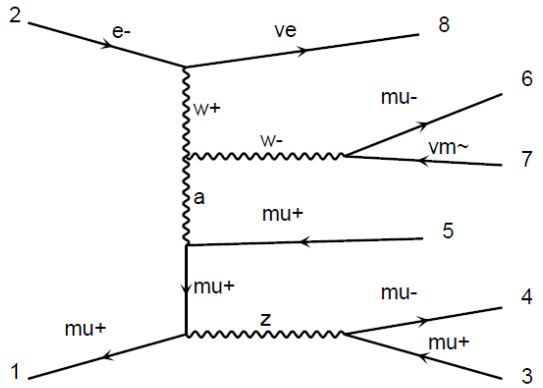


diagram 11 QCD=0, QED=6

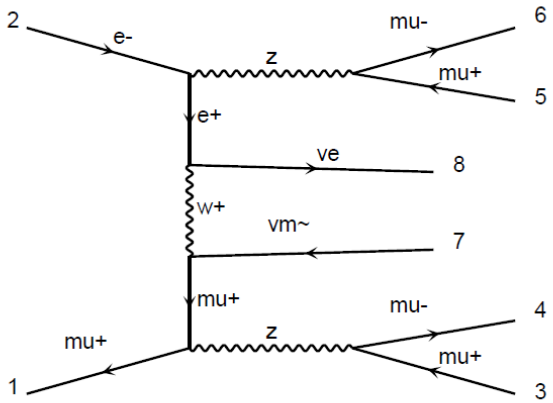


diagram 14 QCD=0, QED=6

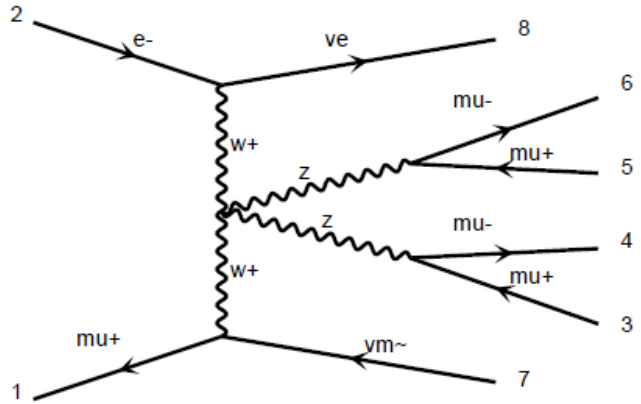


diagram 87 QCD=0, QED=6

Feynman Diagrams

$$\mu^+\mu^- \rightarrow Z\mu^+\mu^-$$

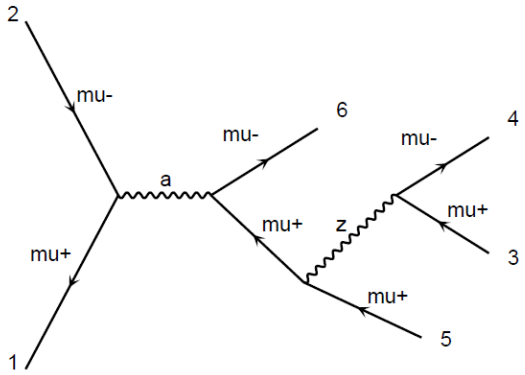


diagram 1 QCD=0, QED=4

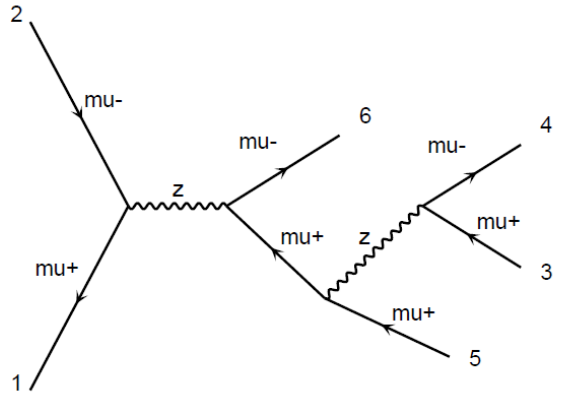


diagram 2 QCD=0, QED=4

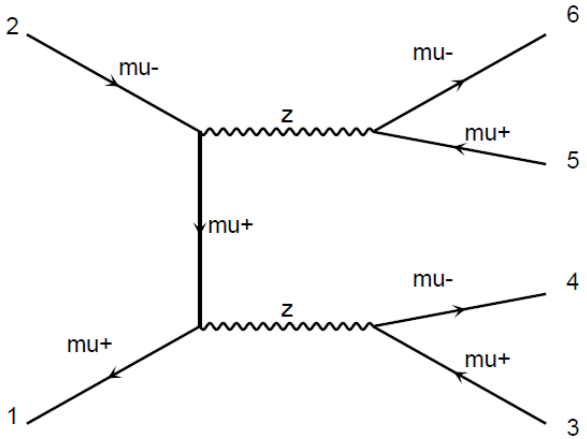


diagram 8 QCD=0, QED=4

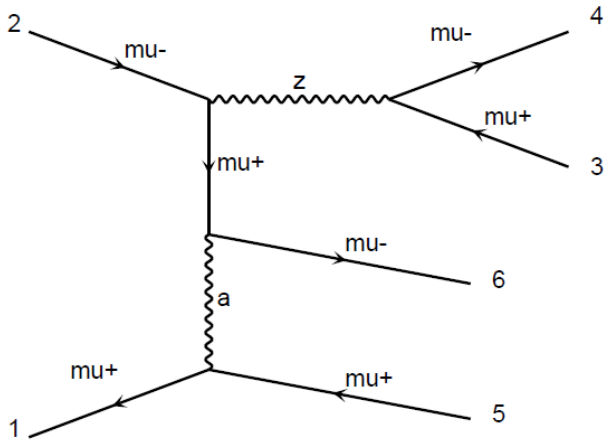
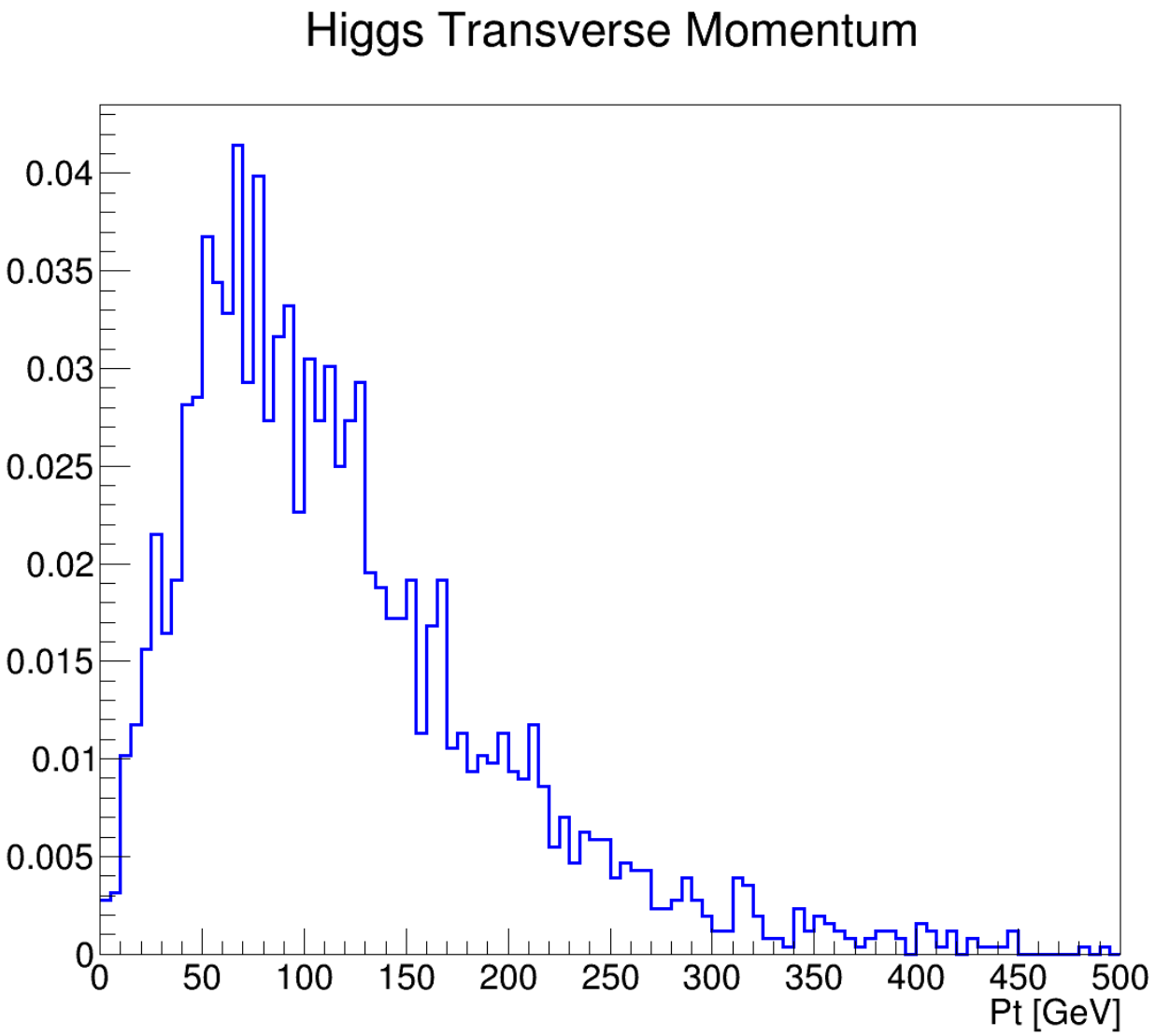


diagram 9 QCD=0, QED=4

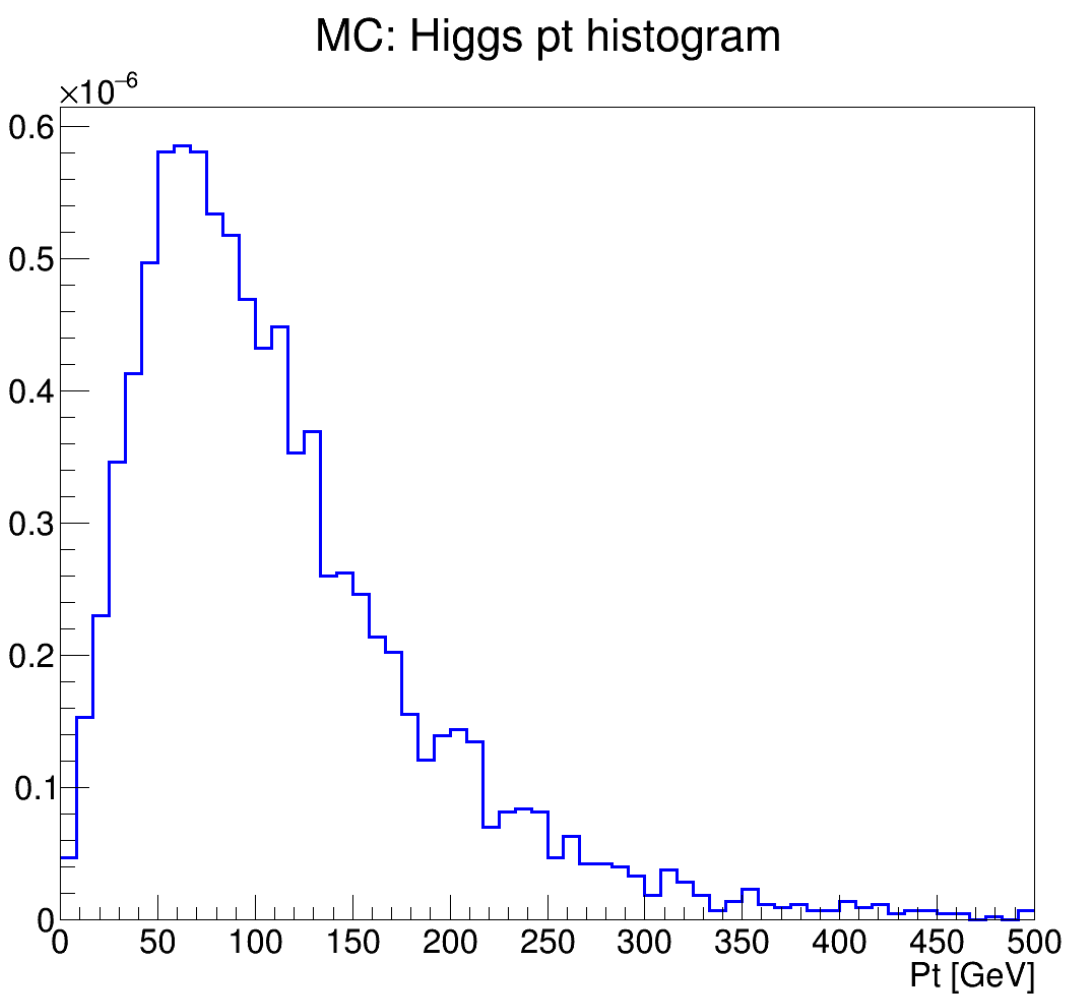
Track Parameters

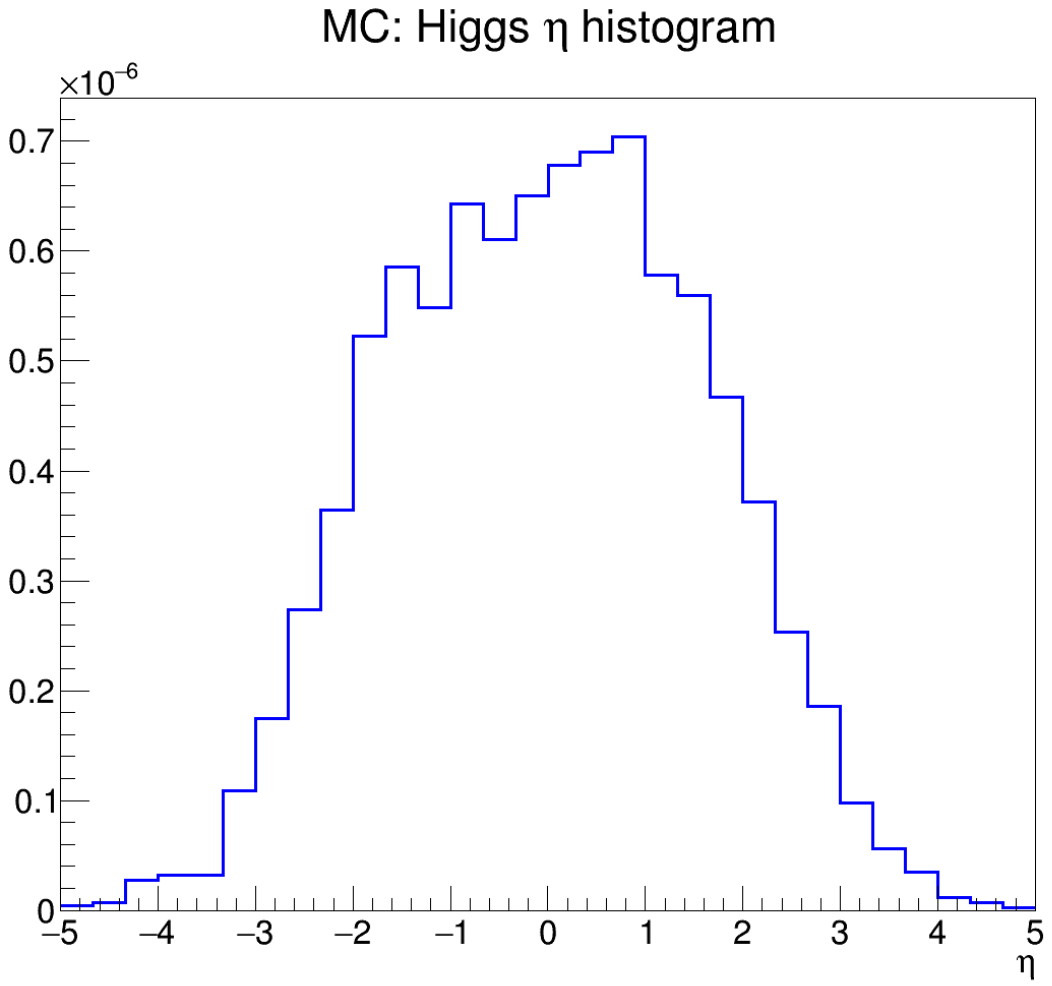
Track parameters	
d0	The distance between the helix and the reference point in the x-y plane.
z0	The distance between the helix and the reference point in the z direction.
Ω	The signed curvature of the track, defined as $\Omega = Pt/(cBq)$, where B is the magnetic field and q the charge of the particle.
tanλ	The angle of the helix to the x-y plane.

Higgs Transverse Momentum

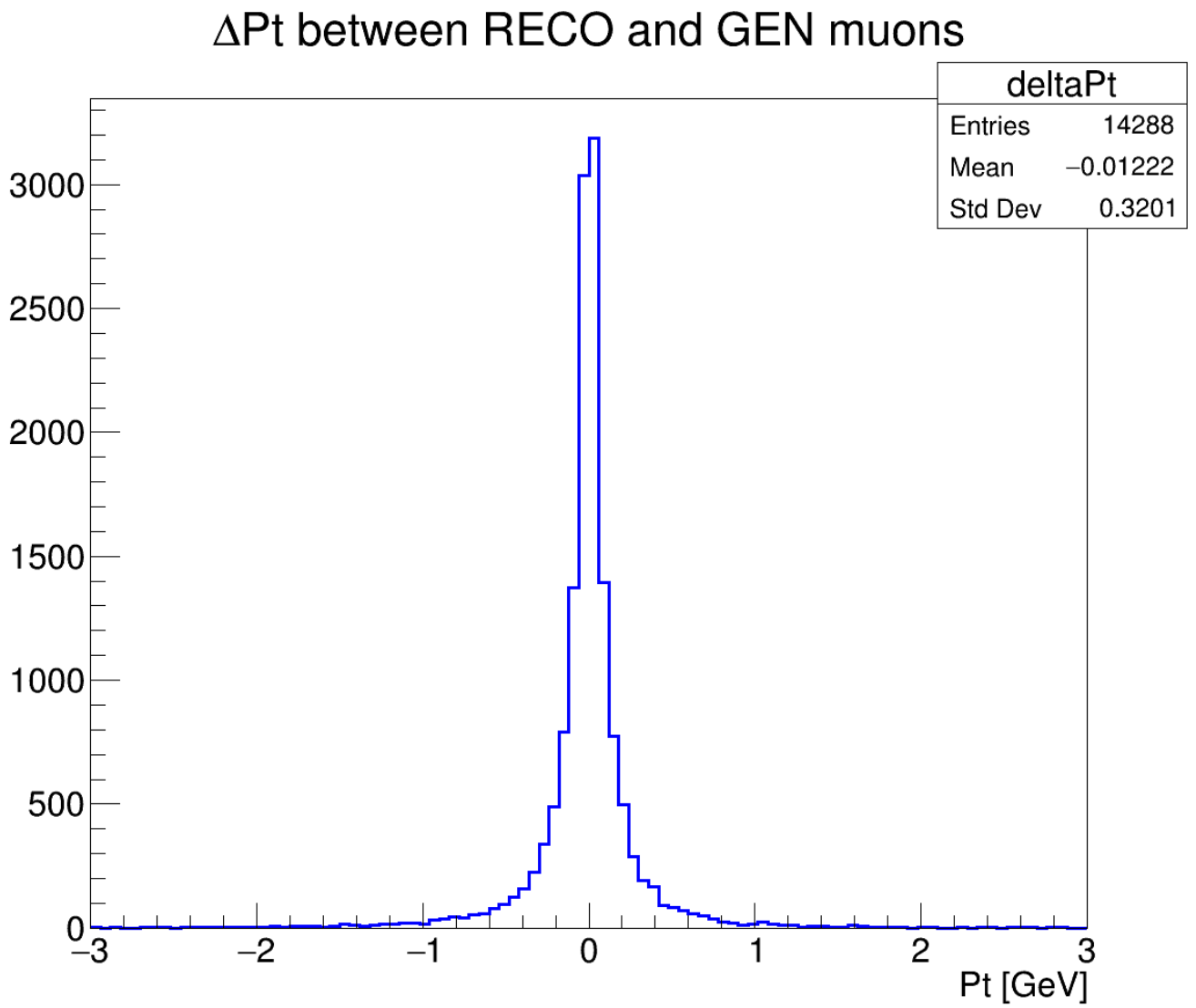


GEN level: Higgs Pt and eta





Transverse Momentum difference between Reconstracted and Generated Muons



Good reconstructed muons