ZH Cross-section measurement at 365 GeV

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Higgs Performance meeting
May 13th, 2024

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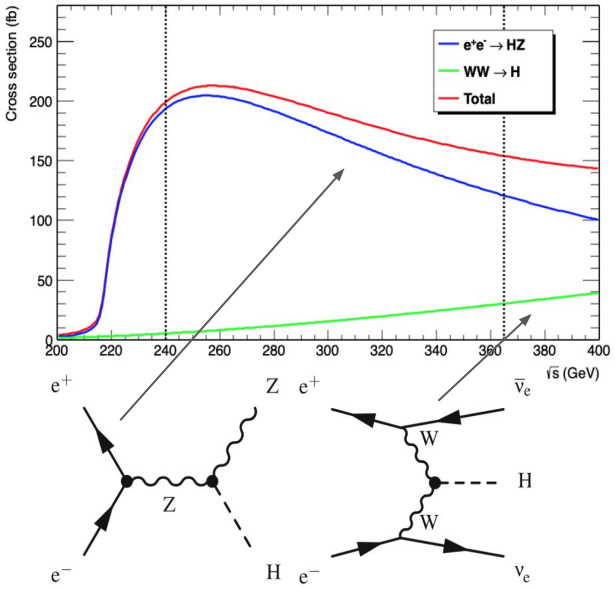
FUTURE CIRCULAR COLLIDER

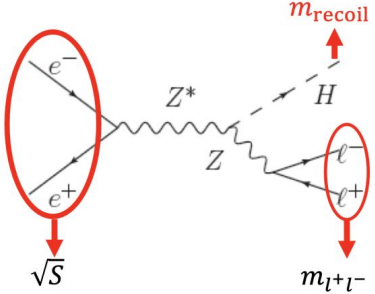
- Introduction
- Comparative analysis between 240 and 365 GeV
- Boosted decision Tree
- Conclusion/Future steps

Introduction



- **Goal: measurement of the ZH cross-section at 365 GeV following 240 GeV methodology**
- **Signal:** $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^- + X$ **(focus on muons)**
  $e^+e^- \rightarrow ZH \rightarrow e^+e^- + X$
- **Z decaying leptonically and use of the recoil mass method:**

$$M^2_{recoil} = (\sqrt{s} - E_{l\bar{l}})^2 - p^2_{l\bar{l}} = s - 2E_{l\bar{l}}\sqrt{s} + m^2_{l\bar{l}}$$



- **Uncertainties at 240 GeV:**
  - **Cross-section: 0.69 %**
  - **Higgs mass: 4.0 MeV**

	Z, years 1-2	Z, later	WW, years 1-2	WW, later	ZH	$t\bar{t}$	
$\sqrt{s}$ (GeV)	88, 91, 94		157, 163		240	340-350	365
Lumi/IP ($10^{34} cm^{-2} s^{-1}$)	70	140	10	20	5.0	0.75	1.20
Lumi/year (ab^{-1})	34	68	4.8	9.6	2.4	0.36	0.58
Run time (year)	2	2	2	0	3	1	4
Number of events	6×10^{12} Z		2.4×10^8 WW		1.45×10^6 HZ $+4.5 \times 10^4$ $WW \rightarrow H$	1.9×10^6 $t\bar{t}$ $+3.3 \times 10^5$ HZ $+8 \times 10^4$ $WW \rightarrow H$	

1.45×10^6 ZH at 240 GeV
0.33×10^6 ZH at 365 GeV

Include 365 GeV
Gain ~23% ZH events

Monte Carlo samples and events selection

➢ **Signal:**

- $Z(\mu^+\mu^-)H$ (Whizard/Pythia)

➢ **Background:**

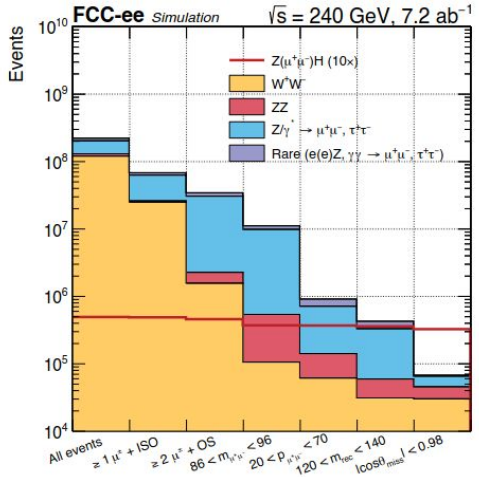
- W^+W^- (Pythia)
- $\gamma\gamma \rightarrow \mu\mu$ (Whizard/Pythia)
- e^+e^-Z (Whizard/Pythia)
- ZZ (Pythia)
- $Z/\gamma \rightarrow \mu^+\mu^-$ (Whizard/Pythia)

➢ **Rare backgrounds:**

- $Z(qq)$ (Pythia)
- $Z(\tau^+\tau^-)H$ (Whizard/Pythia)
- $Z(\nu\nu)H$ (Whizard/Pythia)
- $\gamma\gamma \rightarrow \mu^+\mu^-$ (Whizard/Pythia)
- $\gamma\gamma \rightarrow \tau^+\tau^-$ (Whizard/Pythia)

➢ **Events basic selection:**

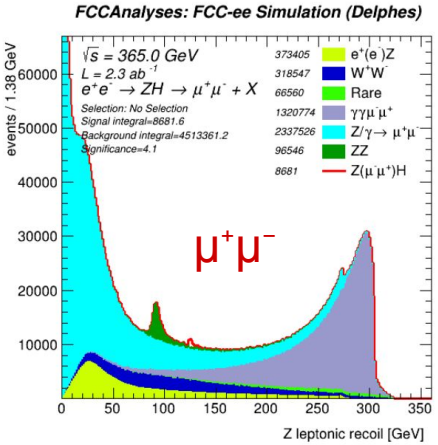
1. Preselection: Select at least 2 leptons with:
   - Momentum $p_l > 20$ GeV
   - Opposite sign
   - One lepton required to be isolated
2. $m_{l^+l^-} \in [86, 96]$ GeV
3. $p_{l^+l^-} \in [20, 70]$ GeV
4. $m_{recoil} \in [120, 140]$ GeV

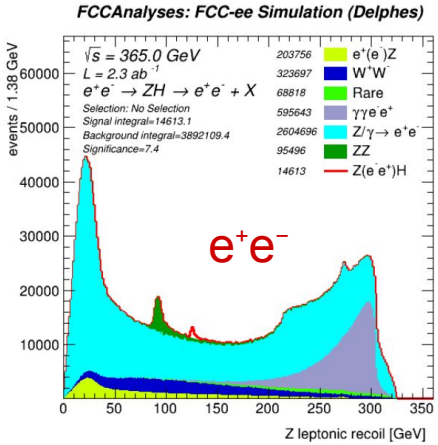


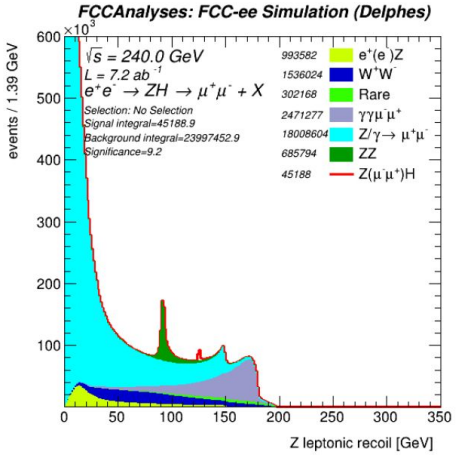
Comparison 240/365 GeV with Preselection Cuts

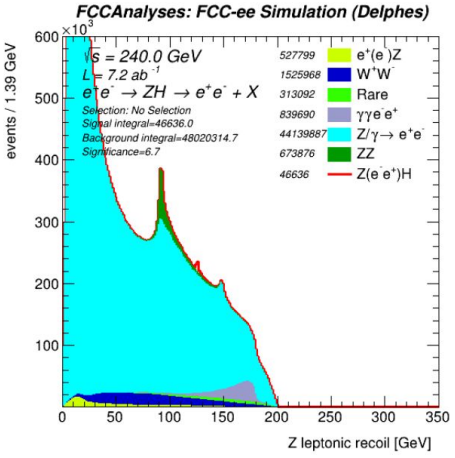
365 ⇒

240 ⇒









➢ **Preselection cuts**

- Select at least 2 leptons:
  - Momentum p_ℓ > 20 GeV
  - Opposite sign
  - One lepton required to be isolated

➢ **Differences**

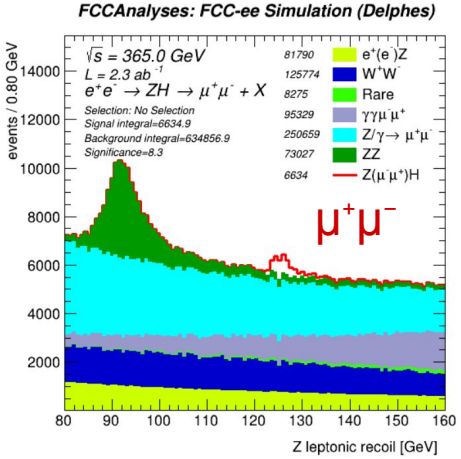
- Luminosity from **7.2** to **2.3** ab^{-1}
- Signal yields **~5** times lower for $\mu^+\mu^-$ corresponding to lower luminosity and cross-section

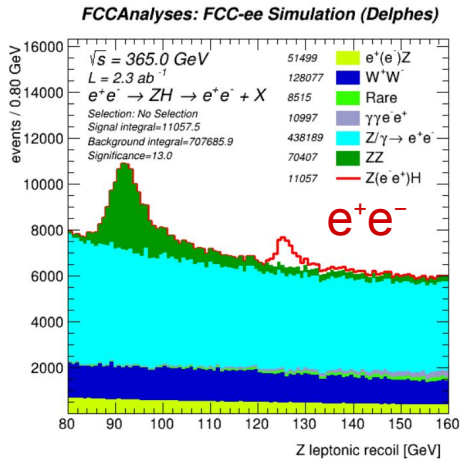
Comparison m_{recoil} distribution at 365 GeV (top) and 240 GeV (bottom) for the $\mu^+\mu^-$ and e^+e^- channel with preselection cuts

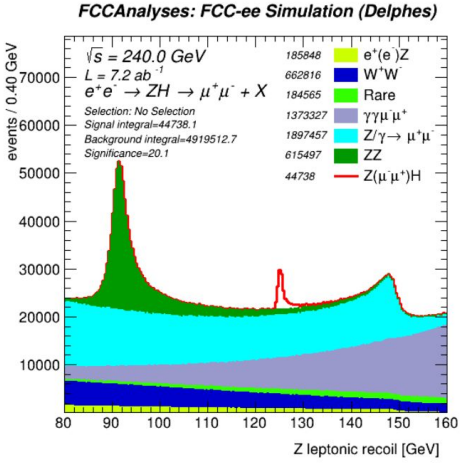
Comparison 240/365 GeV with Preselection Cuts

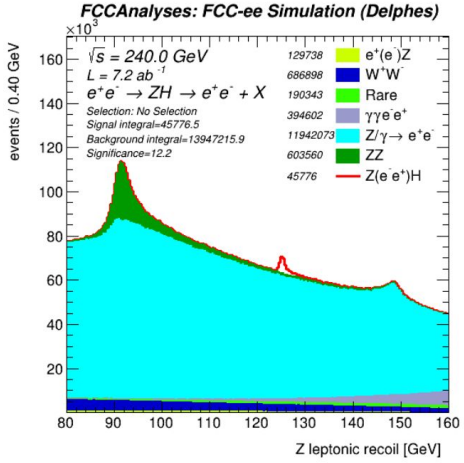
365 ⇒

240 ⇒









➢ **Zoom between 80 and 160 GeV**

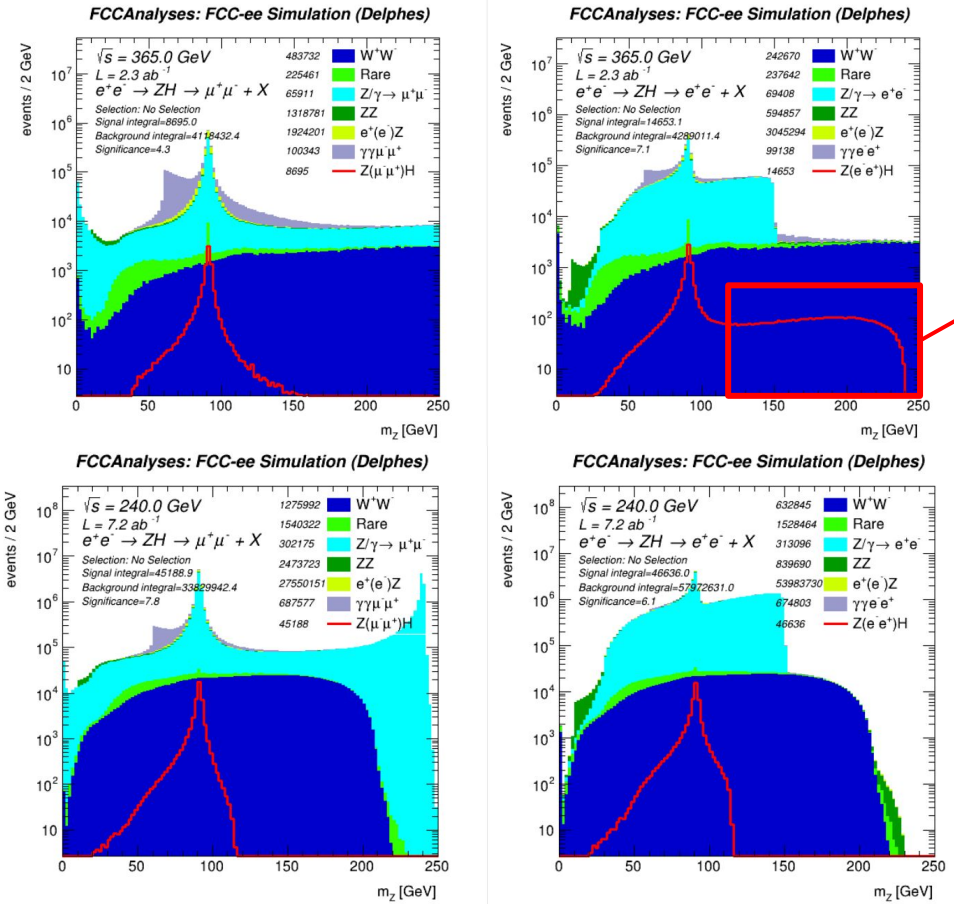
- Luminosity from **7.2** to **2.3** ab^{-1}
- Signal yields **5** times lower for $\mu^+\mu^-$ corresponding to lower luminosity and cross-section
- **Shape** of the background
- Signal peak with **lower resolution** but significantly less background at 365 GeV

Comparison m_{recoil} distribution at 365 GeV (top) and 240 GeV (bottom) for the $\mu^+\mu^-$ and e^+e^- channel with preselection cuts

Reconstructed Z Mass with preselection cuts at 240/365 GeV

365 ⇒

240 ⇒



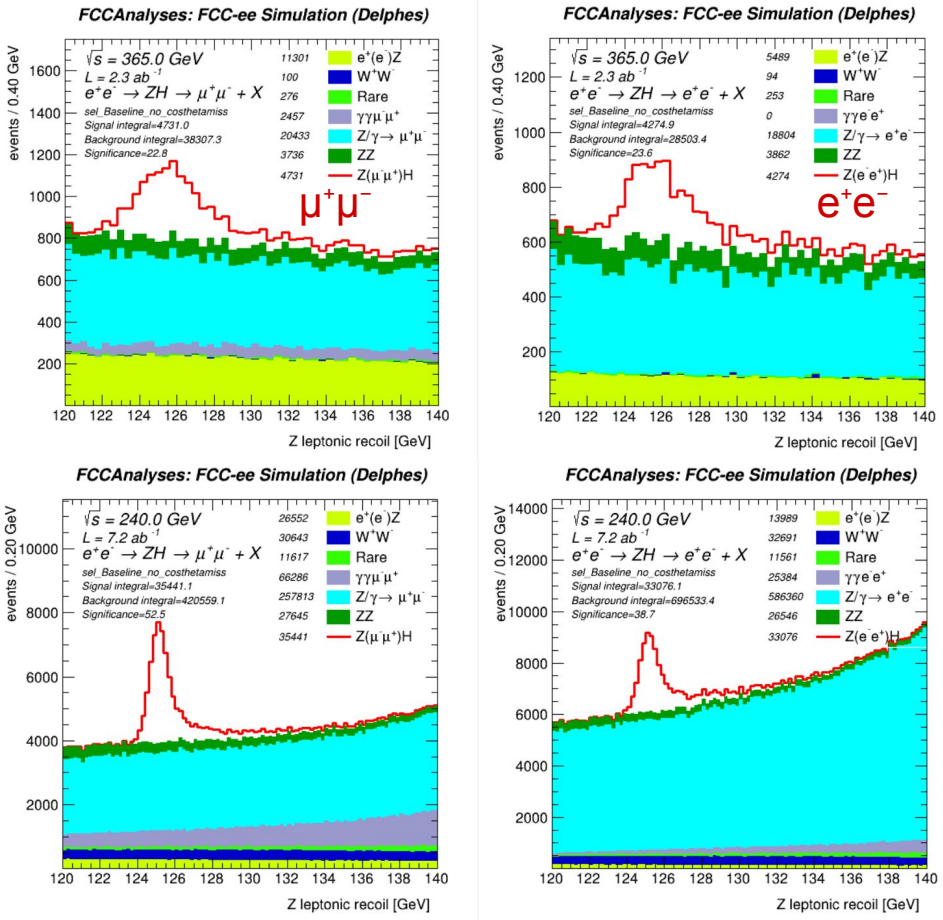
- At **higher energy**, the cut on the **Z mass** is removing **ZH events** which are not genuine **signal events** with a Z for **e^+e^-** channel
- Interpretation of false **e^+e^- reconstructed into Z** with one fake-e coming from H decay (for instance to tautau) or from **e^+e^-** pairs not coming from a Z in the eeH final state
- Afte $m_{l^+l^-} \in [86, 96]$ GeV mass:

Reconstructed Z mass comparison at 240/365 GeV for $\mu^+\mu^-$ and e^+e^- channel with preselection cuts

Mass recoil of the Z leptons with basic selection cuts

365 ⇒

240 ⇒



- **Momentum Cut < 70 GeV** removed at 365 GeV
- **WW negligible** at 365 GeV
  - The cut on the mass is removing them
- Resolution **3.5** times wider at 365 GeV
- **Significance** (S/sqrt(B)) is **~23** at **365 GeV**, vs. **~53** at **240 GeV** for $\mu^+\mu^-$ and **~24 vs ~39** for e^+e^- channel with the basic selection cuts.
- **Selection** used for **ZH cross-section measurement with BDT**

m_{recoil} distribution comparison at 240 GeV (left) and 365 GeV (right) for $\mu^+\mu^-$ and e^+e^- channel without cos θ_{miss} selection cut

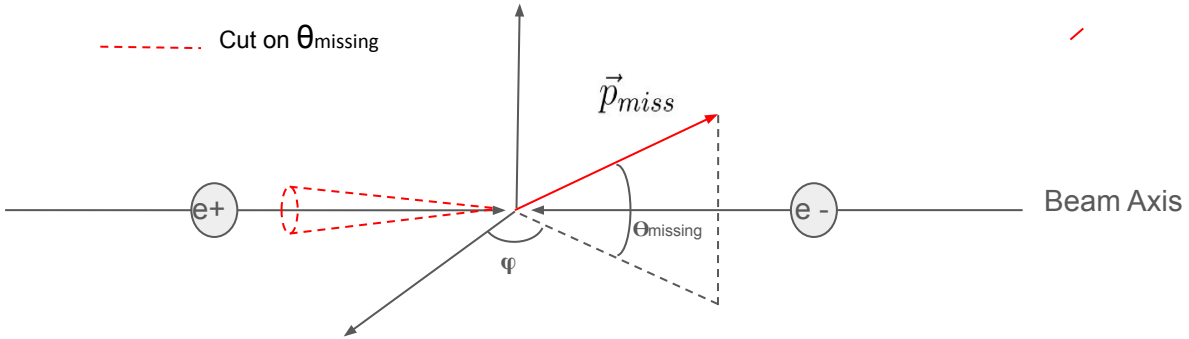
Missing momentum

- The **missing momentum** is defined by the **negative vectorial sum** of the momenta of all reconstructed particles:

$$\vec{p}_{miss} = -\sum_{n_{part}} \vec{p}_{rec}$$

- **θmissing** is the **polar angle** of the **missing momentum vector** with respect to the **beam axis**

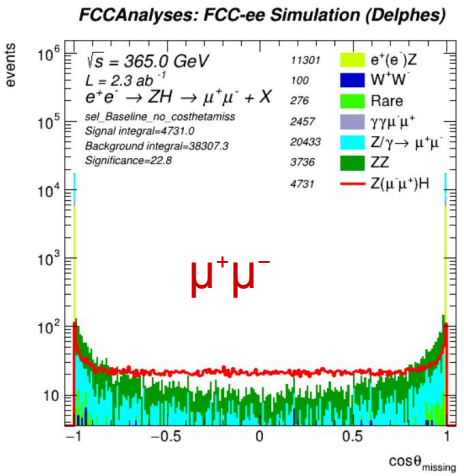
- The requirement $|\cos \theta_{missing}| < \mathbf{0.98}$ is used for the **mass analysis only,** which means that we are removing events mostly collinear to the beam axis

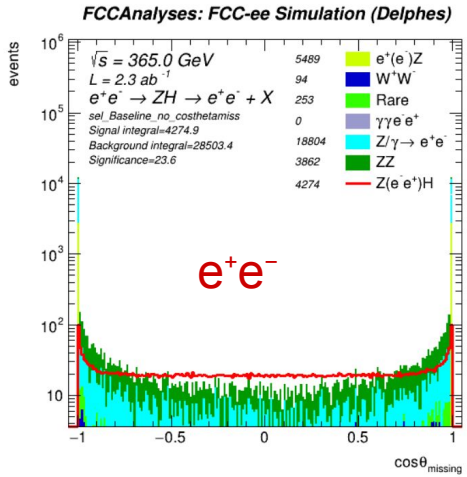


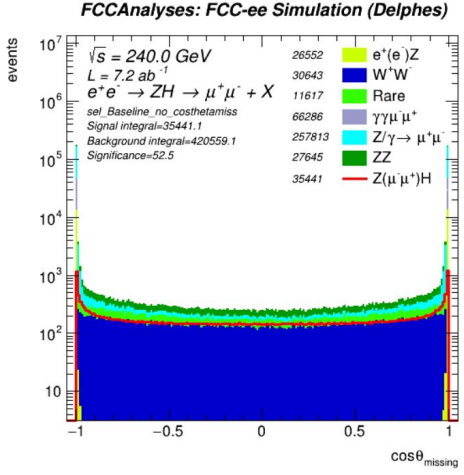
Cos θmissing selection cut

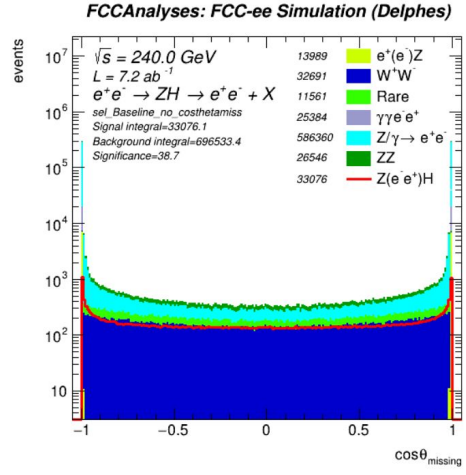
365 ⇒

240 ⇒









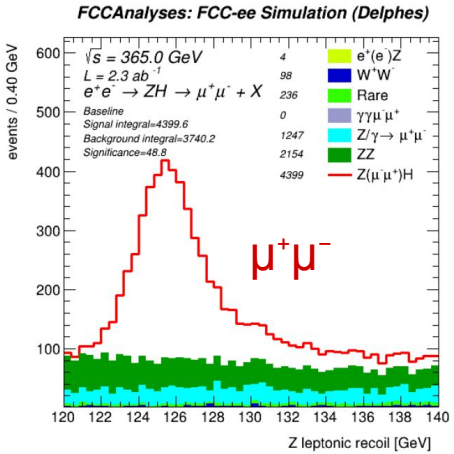
- Cut $|\cos\theta_{missing}| < 0.98$ used for **mass analysis only**
- This cut is removing a lot of background concentrated in the **last bins**

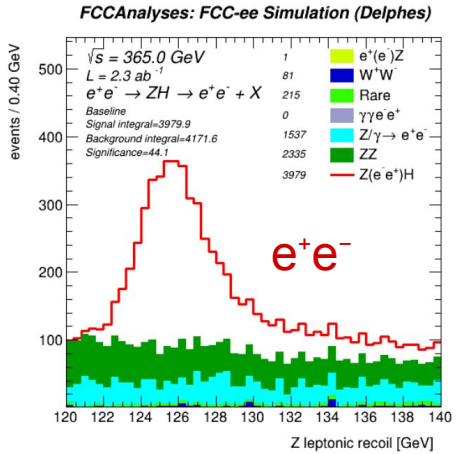
Cos θmissing distribution at 365/240 GeV for $\mu^+\mu^-$ and e^+e^- channel with basic selection cuts

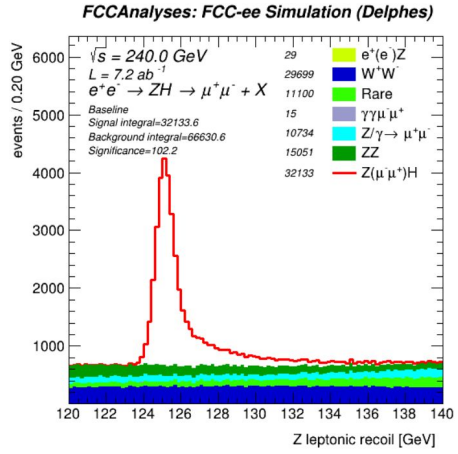
Mass recoil of the Z leptons with cos θmiss selection cut

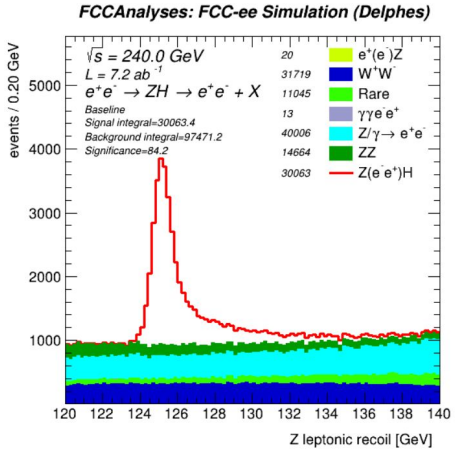
365 ⇒

240 ⇒









- Cut $|\cos\theta_{miss}| < 0.98$ used for **mass analysis only**
- **Significance** (S/sqrt(B)) is **~49** at **365 GeV**, vs. **~102** at **240 GeV** for $\mu^+\mu^-$ and **~44 vs ~84** for e^+e^- channel

m_{recoil} distribution comparison 240 GeV (left) and 365 GeV (right) for $\mu^+\mu^-$ and e^+e^- channel with selection cuts

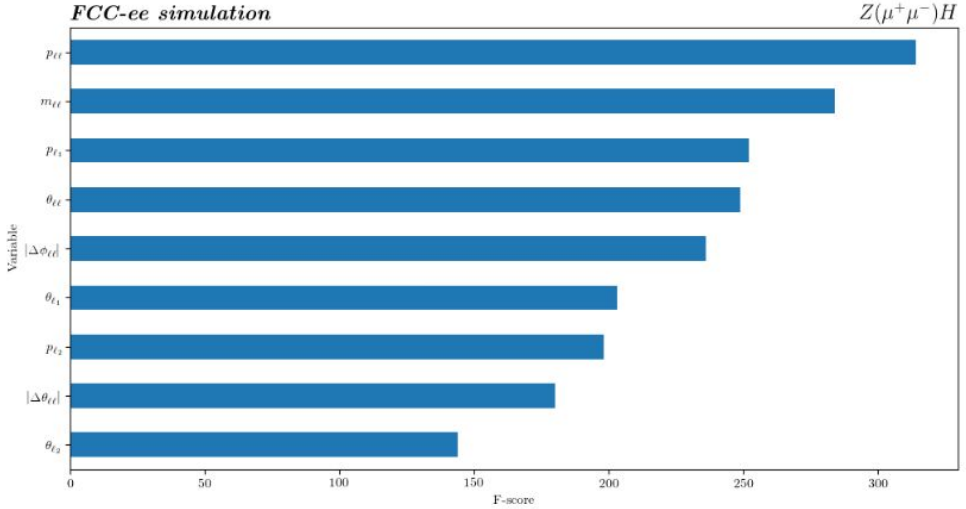
Boosted Decision Tree

Boosted Decision Tree

- Machine learning algorithm that separates signal and background by giving a BDT score
- BDT offers model independent analysis
- Nominal samples (winter 2023) are used to train the BDT
- Training_variables for BDT:

Variable	Description
$p_{\ell^+\ell^-}$	Lepton pair momentum
$\theta_{\ell^+\ell^-}$	Lepton pair polar angle
$m_{\ell^+\ell^-}$	Lepton pair invariant mass
$p_{l_{\text{leading}}}$	Momentum of the leading lepton
$\theta_{l_{\text{leading}}}$	Polar angle of the leading lepton
$p_{l_{\text{subleading}}}$	Momentum of the subleading lepton
$\theta_{l_{\text{subleading}}}$	Polar angle of the subleading lepton
$\pi - \Delta\phi_{\ell^+\ell^-}$	Acoplanarity of the lepton pair
$\Delta\theta_{\ell^+\ell^-}$	Acolinearity of the lepton pair

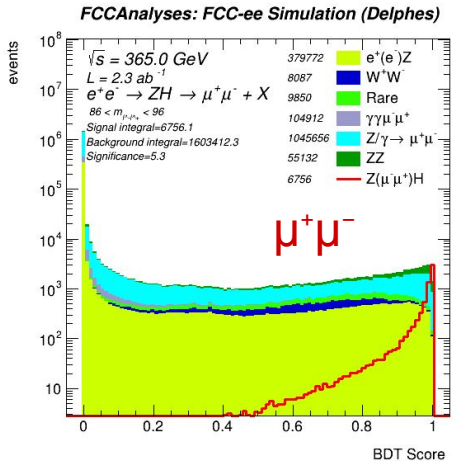
- Number of events for BDT training:
  - All signals passed the basic selection
  - Total Number of backgrounds = Total Number of Signals
  - Number of events of each process is proportional to their cross-section×cut efficiency
  - 1/2 of events for training
  - 1/2 of events for testing

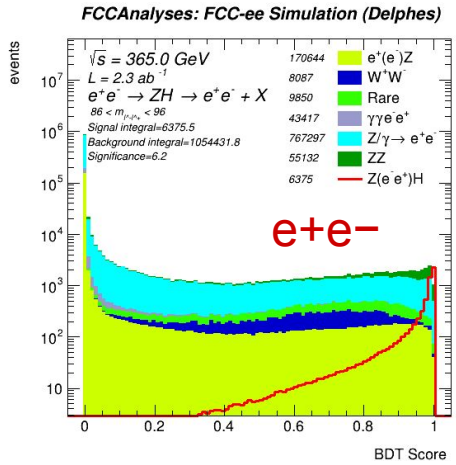


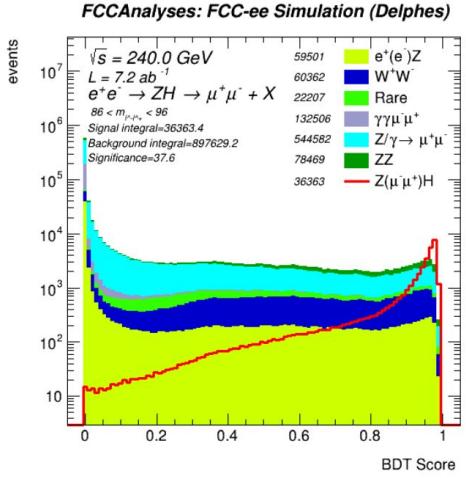
BDT score for mumu and ee at 365/240 GeV

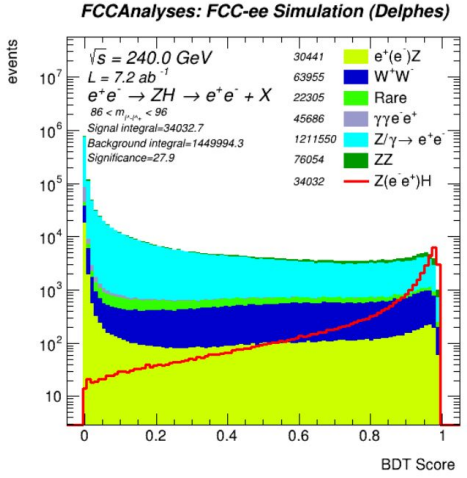
365 ⇒

240 ⇒









➢ **Cut used:**

- two leptons
- opposite sign
- one lepton required to be isolated
- cut on Z mass [86,96]
- cut Z momentum > 20 GeV

➢ **Without mass recoil selection cut:**

$$m_{recoil} \in [120, 140]\ \text{GeV}$$

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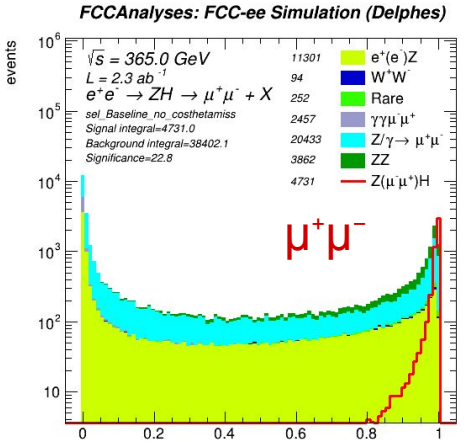
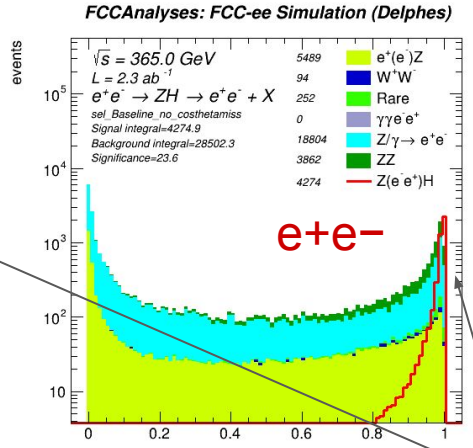
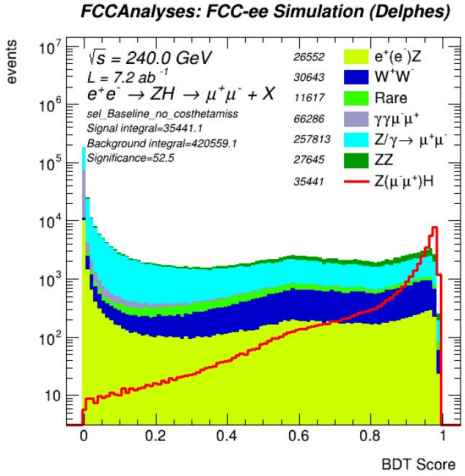
BDT score for mumu and ee at 365 GeV

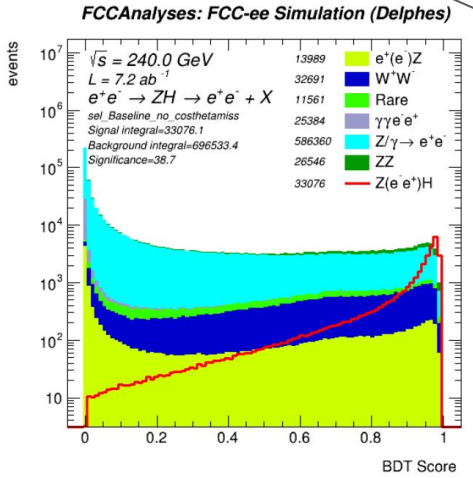
365 ⇒

240 ⇒









➢ **Cut used:**

- two leptons
- opposite sign
- one lepton required to be isolated
- cut on Z mass [86,96]
- cut Z momentum > 20 GeV

➢ **With mass recoil selection cut:**

$$m_{recoil} \in [120, 140]\ \text{GeV}$$

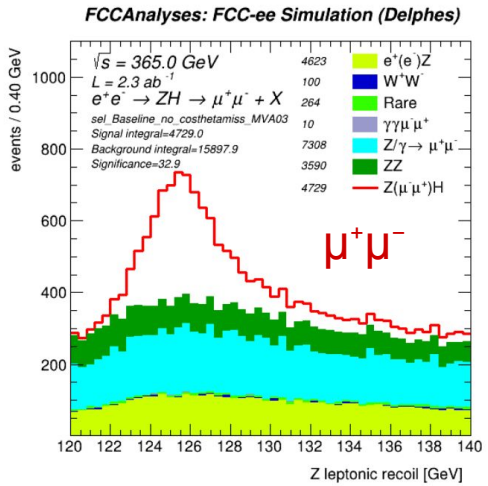
➢ **Rise towards 1 at 365 GeV**

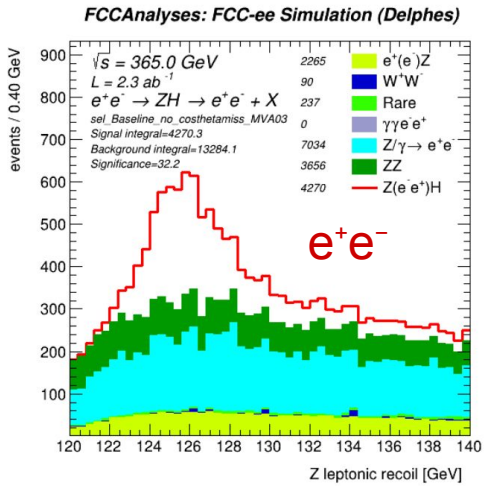
➢ This **BDT score** is **fitted** to measure the **ZH cross-section**

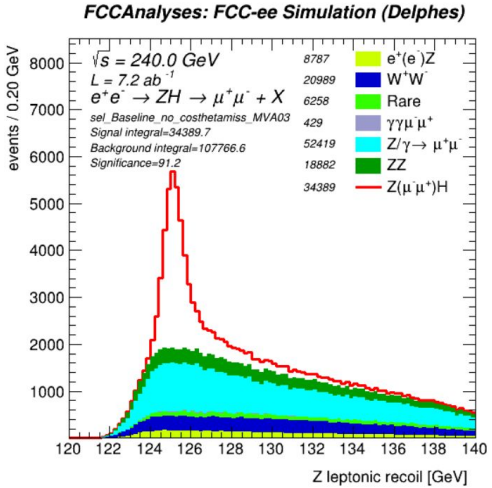
Mass recoil of the Z leptons with BDT requirement

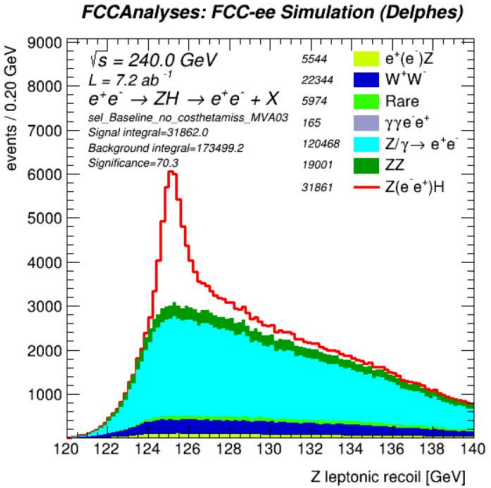
365 ⇒

240 ⇒









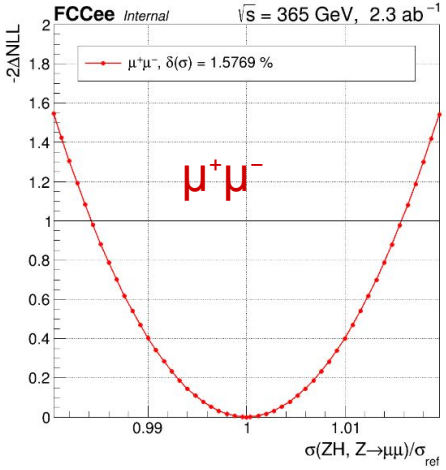
- We apply a **cut** on the **BDT score** to see its **performance**.
- **Significance** from **22** to **33** for $\mu^+\mu^-$ and from **24** to **32** for e^+e^- channel
- **Significance** (S/sqrt(B)) is **~33** at **365 GeV**, vs. **~91** at **240 GeV** for $\mu^+\mu^-$ and **~32 vs ~70** for e^+e^- channel
- With **BDT score > 0.3**, background is divided by **2**

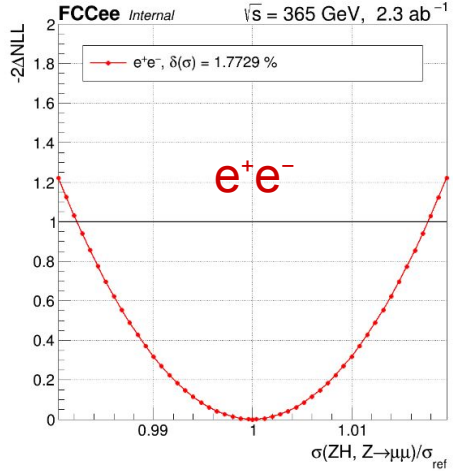
m_{recoil} distribution comparison at 240/365 GeV for $\mu^+\mu^-$ and e^+e^- channel with BDT score selection cut > 0.3

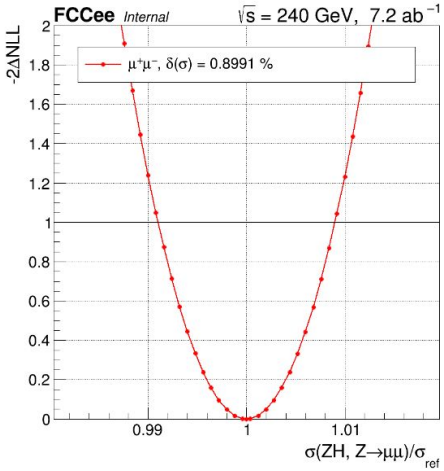
μ+μ− and e+e− statistical uncertainties on cross-section measurement at 365/240 GeV

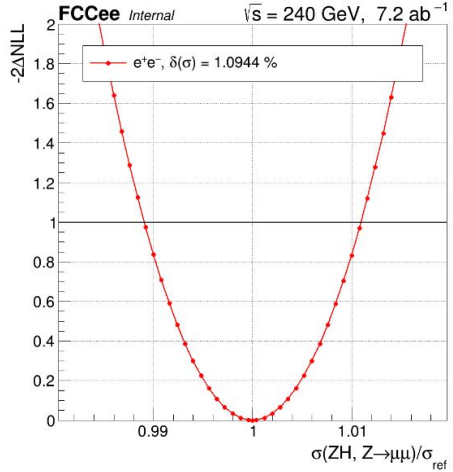
365 ⇒

240 ⇒









- The statistical uncertainties are **1.58%** for **$\mu^+\mu^-$** and **1.77%** for **e+e-** at **365 GeV**
- The statistical uncertainties are **0.90%** for **$\mu^+\mu^-$** and **1.09%** for **e+e-** at **240 GeV**
- NB: If we would have the **same luminosity**, the uncertainty on ZH cross-section in the **$\mu^+\mu^-$** final state is the **same** at **240** and **365 GeV** and it is better by **9% (1.002%)** in the **e+e-** final state at 365 GeV
- The distance between the **two statistical uncertainties** of **$\mu^+\mu^-$** and **e+e-** have been reduced by **8%** at **365 GeV**

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Conclusion

With same luminosity ⇒

	significance		resolution (FWHM)		Statistical uncertainties	
$\sqrt{s}$	240 ($7.2\ ab^{-1}$)	365 ($2.3\ ab^{-1}$)	240	365	240 ($7.2\ ab^{-1}$)	365 ($2.3\ ab^{-1}$)
$\mu^+\mu^-$	52,5	22,8	1,5	3,5	0.8991	1.5769
e^+e^-	38,7	23,6	1,5	3,5	1.0944	1.7729

	significance		resolution (FWHM)		Statistical uncertainties	
$\sqrt{s}$	240 ($7.2\ ab^{-1}$)	365 ($7.2\ ab^{-1}$)	240	365	240 ($7.2\ ab^{-1}$)	365 ($7.2\ ab^{-1}$)
$\mu^+\mu^-$	52,5	40.3	1,5	3,5	0.8991	0.8913
e^+e^-	38,7	41.8	1,5	3,5	1.0944	1.0020

- **With the same luminosity,** we have **1.3** times less significance for **$\mu^+\mu^-$** & **1.08** times more for **e+e−** at **365 GeV** compared to **240 GeV**, because the background is smaller for e^+e^-
- **2.3** times less resolution for each channel at **365 GeV**
- Statistical uncertainties with 7.2 ab^{-1} would be **0.891%** for **$\mu^+\mu^-$** and **1.002%** for **e+e−**
  ⇒ **Same** statistical uncertainty for **$\mu^+\mu^-$** but a **9%** improvement for **e+e−** at **365 GeV**

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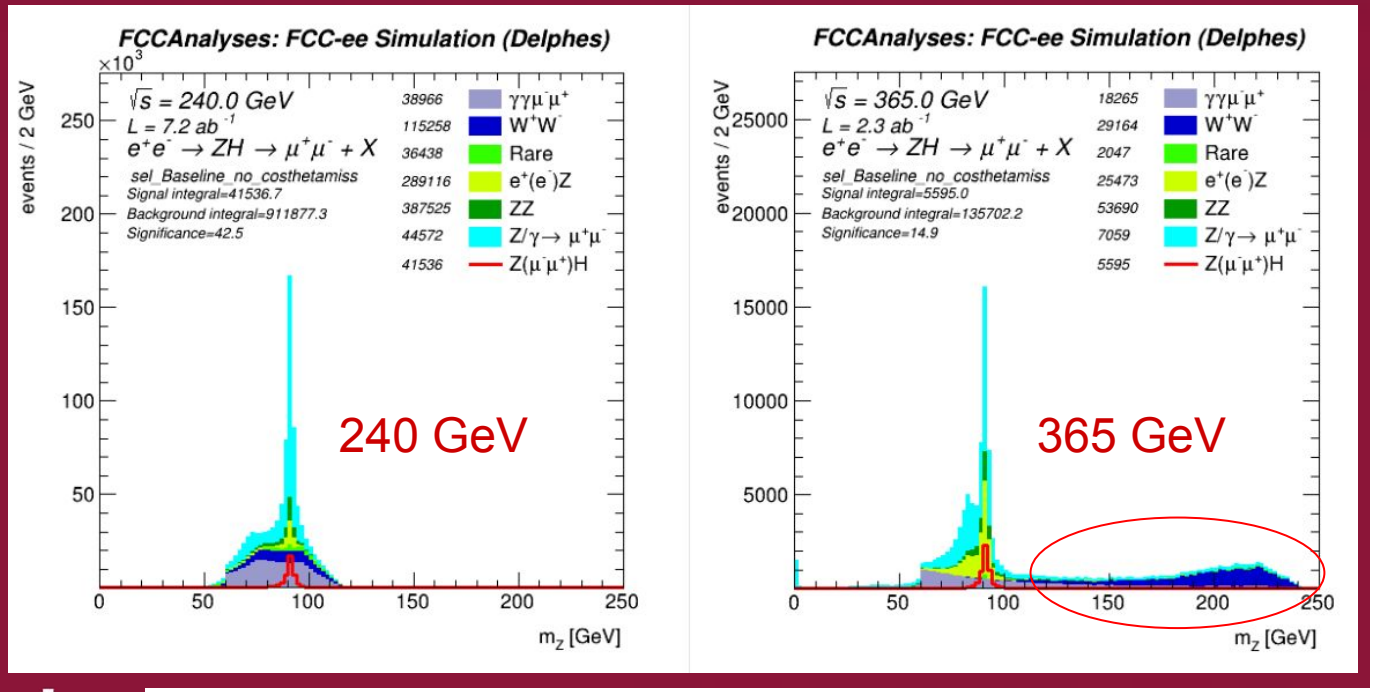
Future steps

- **Improve the BDT training model**
  - Waiting for samples that have been with “Winter_training” label

- Do the systematic uncertainties with Combine (lepton, BES, sqrt(s))
  - Being able to estimate sqrt(s) uncertainty at 365 GeV
  - Check the requirement for the BES samples request

Back up

Reconstructed Z Mass (without Z mass selection cut)

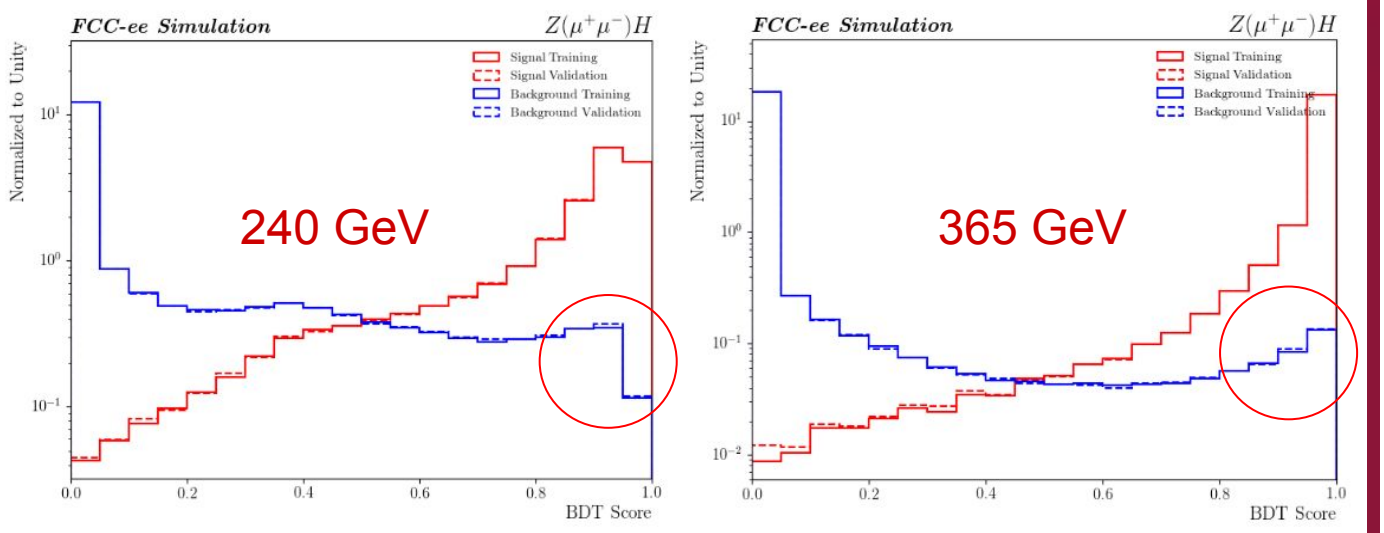


Reconstructed Z mass comparison at 240 GeV (left) and 365 GeV (right) for mumu channel without zll mass selection cut

- **WW background** is moved to **higher energy** for 365 GeV
- The **cut** $m_{l^+l^-} \in [86, 96]$ GeV is **removing it**
- **Better signal** over background at 365 GeV

Dois je garder ce plot ? peut être en back up

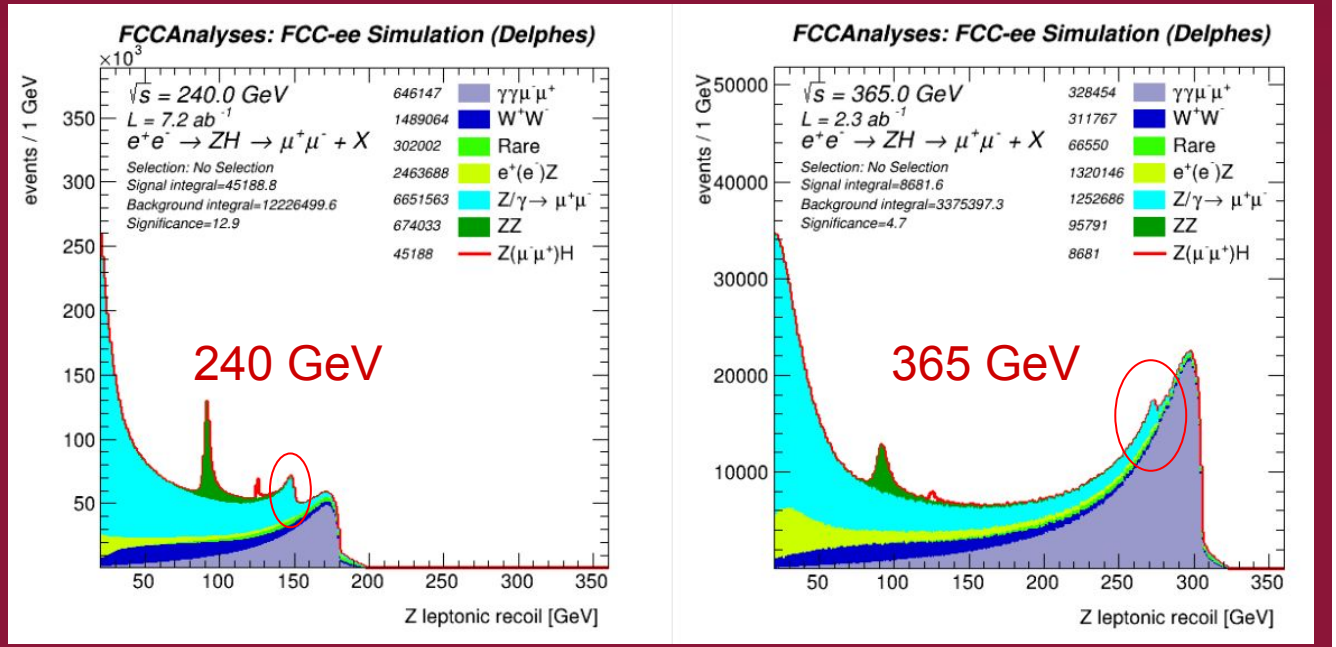
BDT score comparison



- **Prove** the **universality** of the **BDT model** used
- At 365 GeV, we are **investigating** why **background** is **rising** at **high score**

BDT score comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Comparison 240/365 GeV without selection

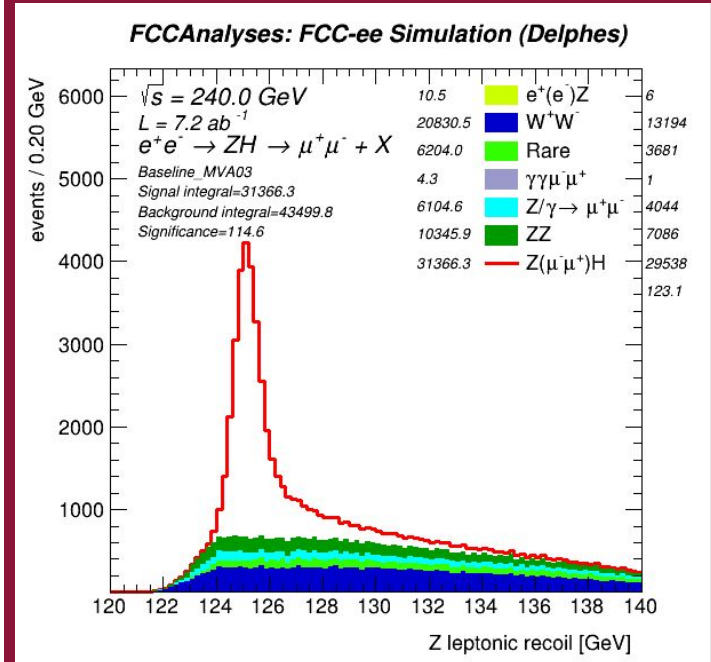


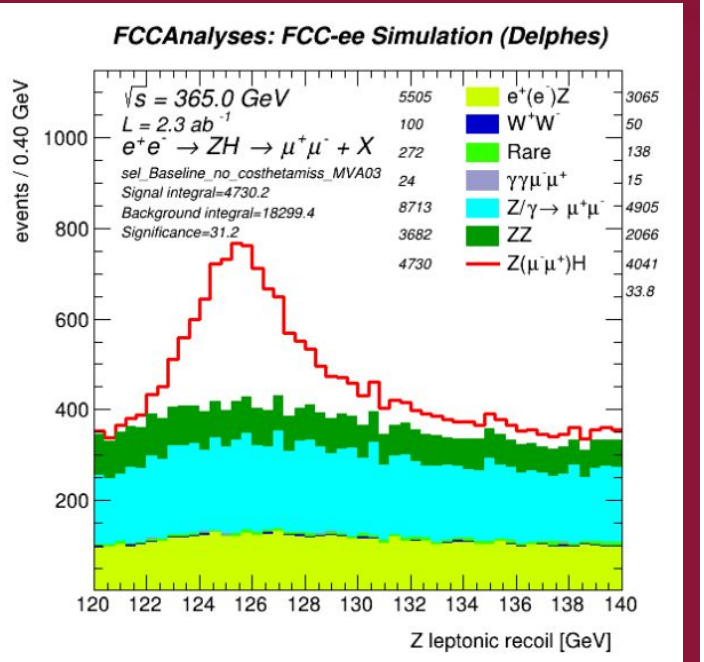
Comparison m_{recoil} distribution at 240 GeV (left) and 365 GeV (right) for the $\mu^+\mu^-$ channel in linear scale without selection

➢ **Differences**

- From **7.2** to **2.3** ab^{-1} luminosity
- Event Number divided by **10**
- Find the recoil mass peak from calculation at higher energy

Mass recoil of the Z leptons with trained BDT machine learning





- Boosted decision Tree (BDT) machine learning used to extract signal and background by giving them a score.
- Backgrounds have low scores
- For the moment nominal samples are used to trained the BDT
- We ordered the training samples

m_{recoil} distribution comparison 240 GeV (left) and 365 GeV (right) for mumu channel with BDT score > 0.3 selection cut

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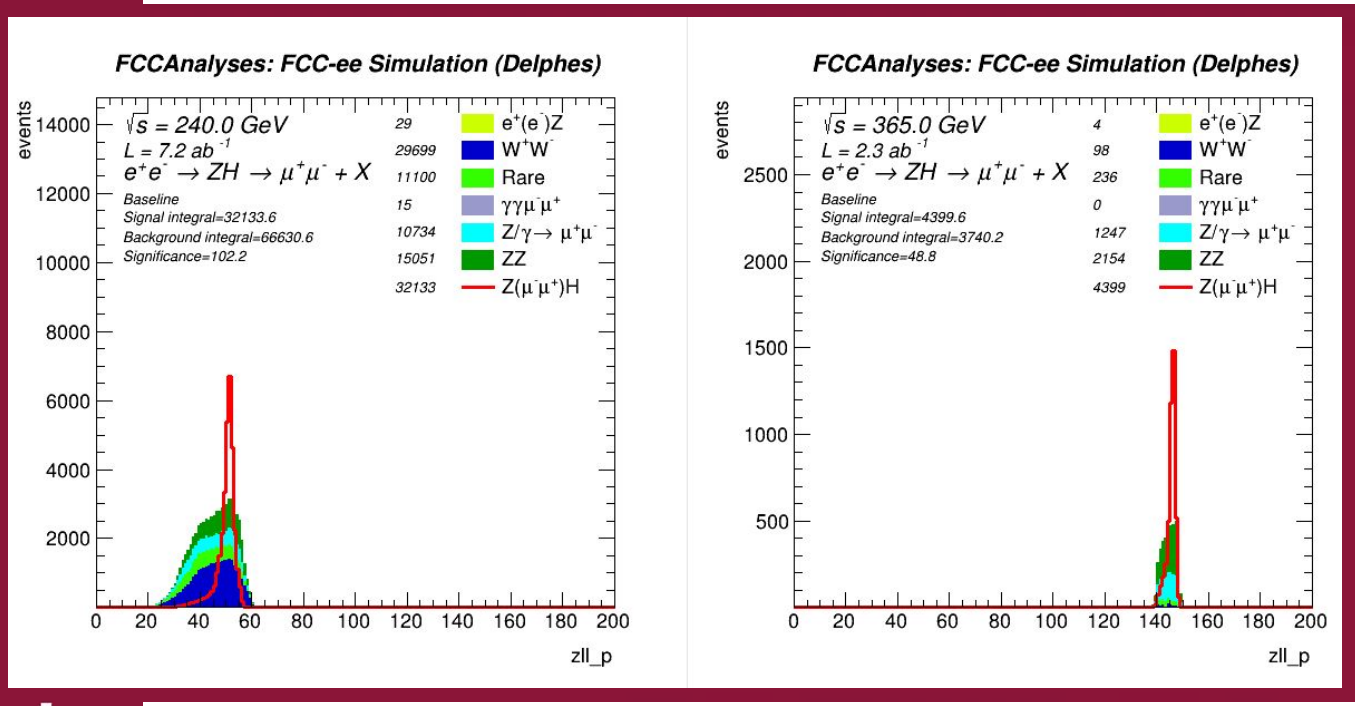
Momentum of the reconstructed Z boson

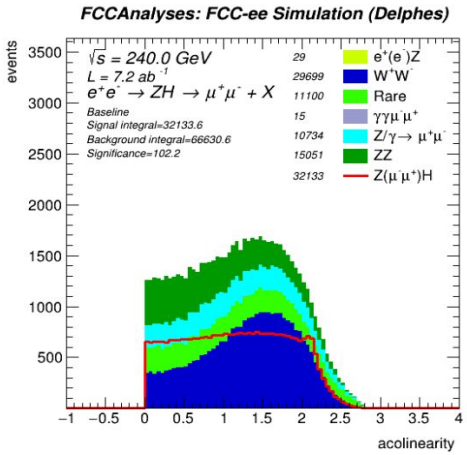


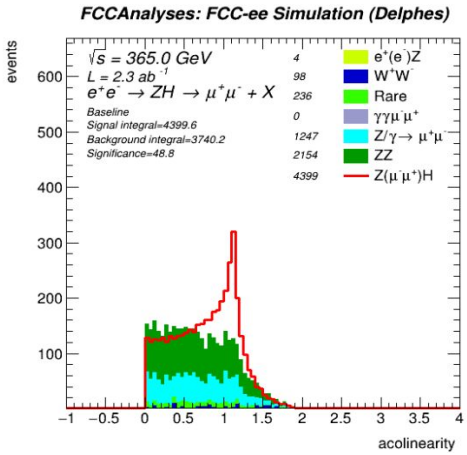
- Z momentum higher by about 100 GeV at 365 GeV
- less background but more concentrated at 365 GeV
- System boosted at 365 GeV

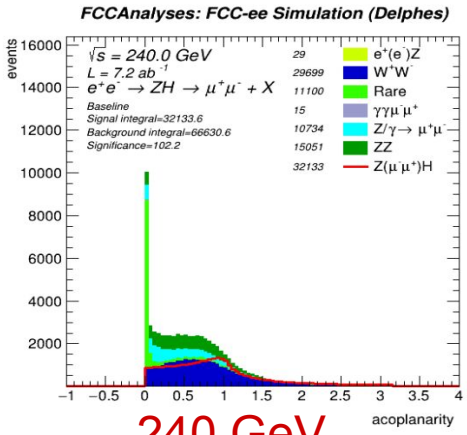
Momentum of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

DEWYSPELAERE Kevin

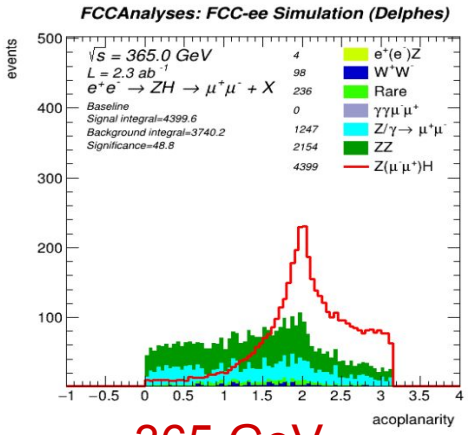
Acollinearity and acoplanarity of the reconstructed Z boson







240 GeV



365 GeV

- **Acollinearity:**

$$\Delta\theta_{\ell^+\ell^-}$$

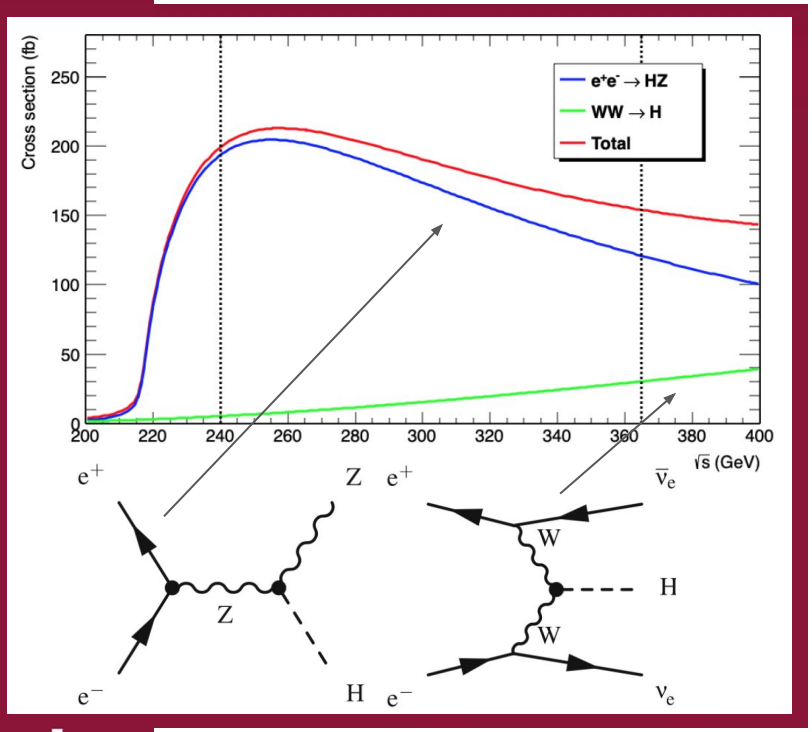
- **Acoplanarity:**

$$\pi - \Delta\phi_{\ell^+\ell^-}$$

- **Boosted system**
- **At 365 GeV, we have sharp peaks appearing at ~1 (acolinearity) and at ~2 (acoplanarity) for the signal**

Acollinearity (up) and acoplanarity (down) of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θ_{miss} selection cut

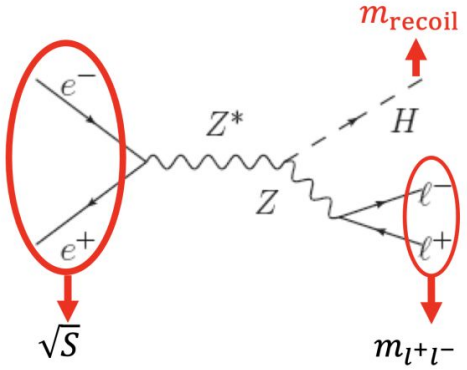
Introduction



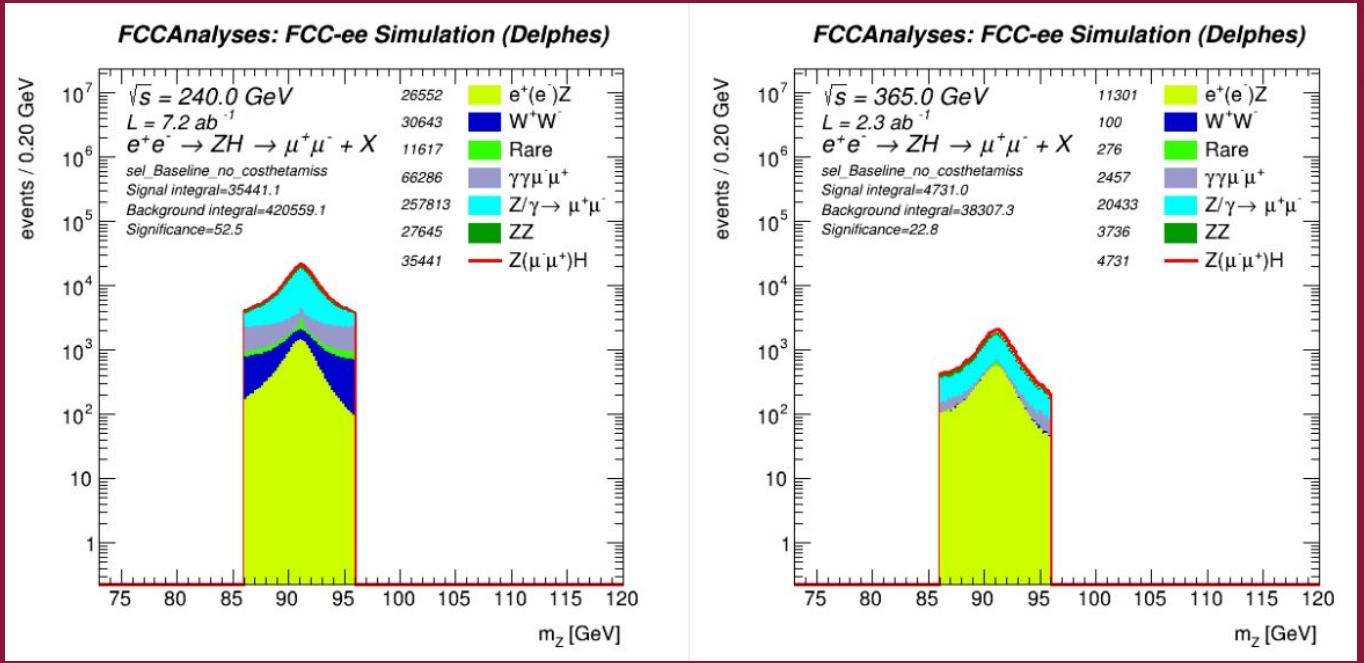
Improved-Born Higgs production cross-sections for the Higgsstrahlung process and the WW fusion process, incorporating initial state radiation, are predicted by HZHA

- **Goal: measurement of the ZH cross-section at 365 GeV**
- **Signal:** $e^+e^- \rightarrow ZH \rightarrow \mu^+\mu^- + X$
- **Use of events with a Z decaying leptonically and reconstruction of the mass recoil without considering Higgs products:**

$$M^2_{recoil} = (\sqrt{s} - E_{l\bar{l}})^2 - p^2_{l\bar{l}} = s - 2E_{l\bar{l}}\sqrt{s} + m^2_{l\bar{l}}$$



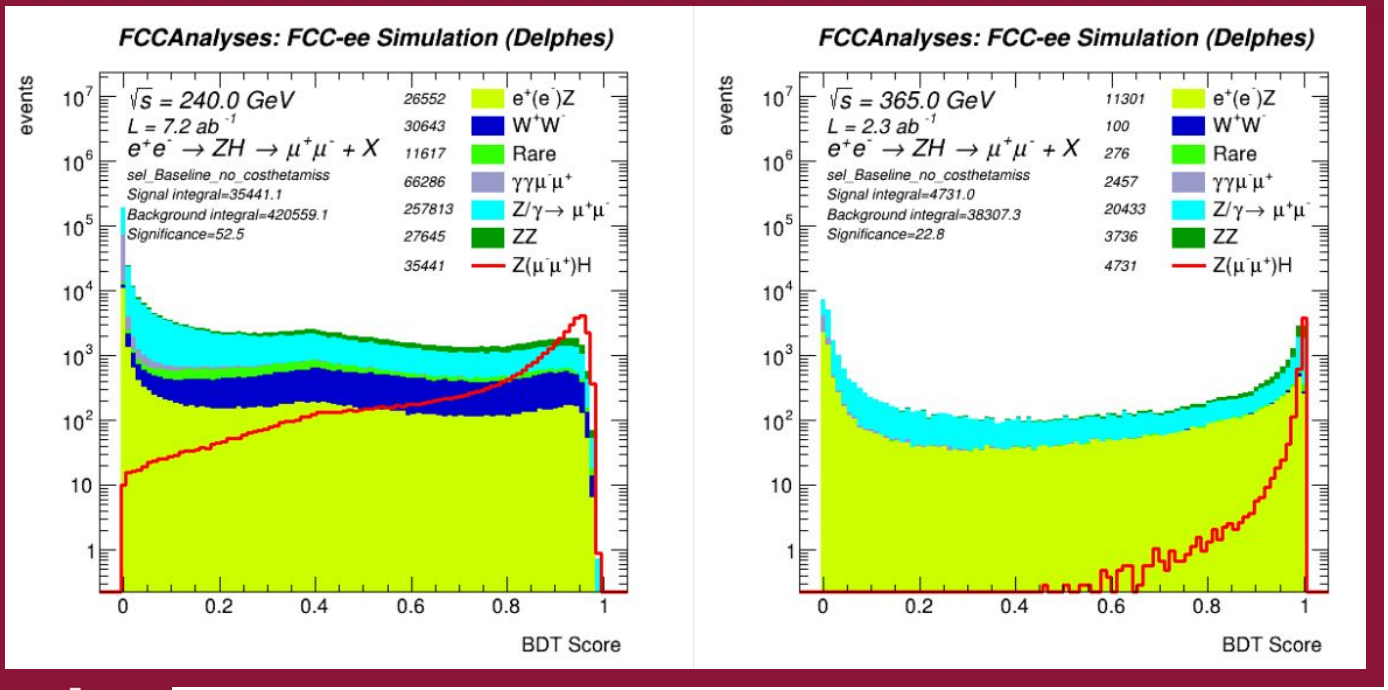
Reconstructed Z Mass without selection



➢ C

Reconstructed Z mass comparison at 240 GeV (left) and 365 GeV (right) for mumu channel without zll mass selection cut

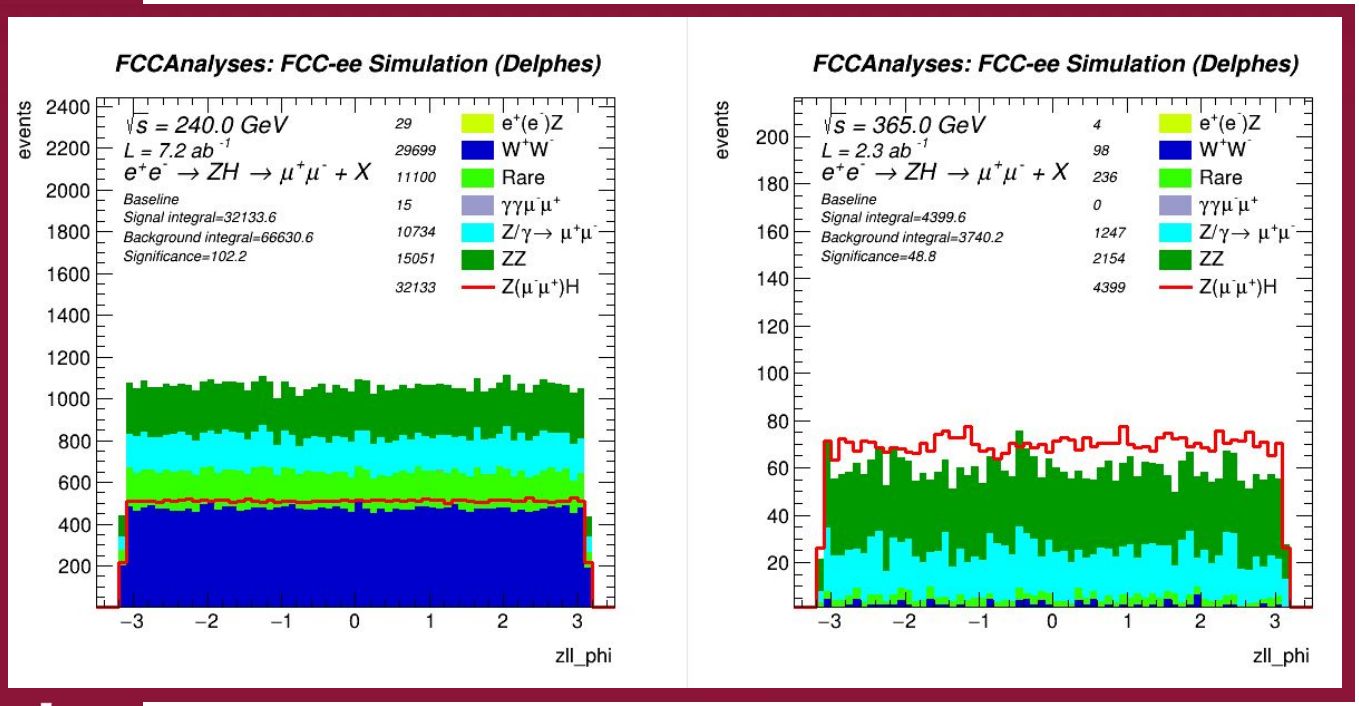
BDT Score comparison



BDT score comparison 240 GeV (left) and 365 GeV (right) for mumu channel

- **BDT score** comparison for **signal** and **background**
- At 365 GeV, we're **investigating** to know why **background** is **rising** at **high score**
- This BDT score will be used in the **final ZH cross-section fitting**

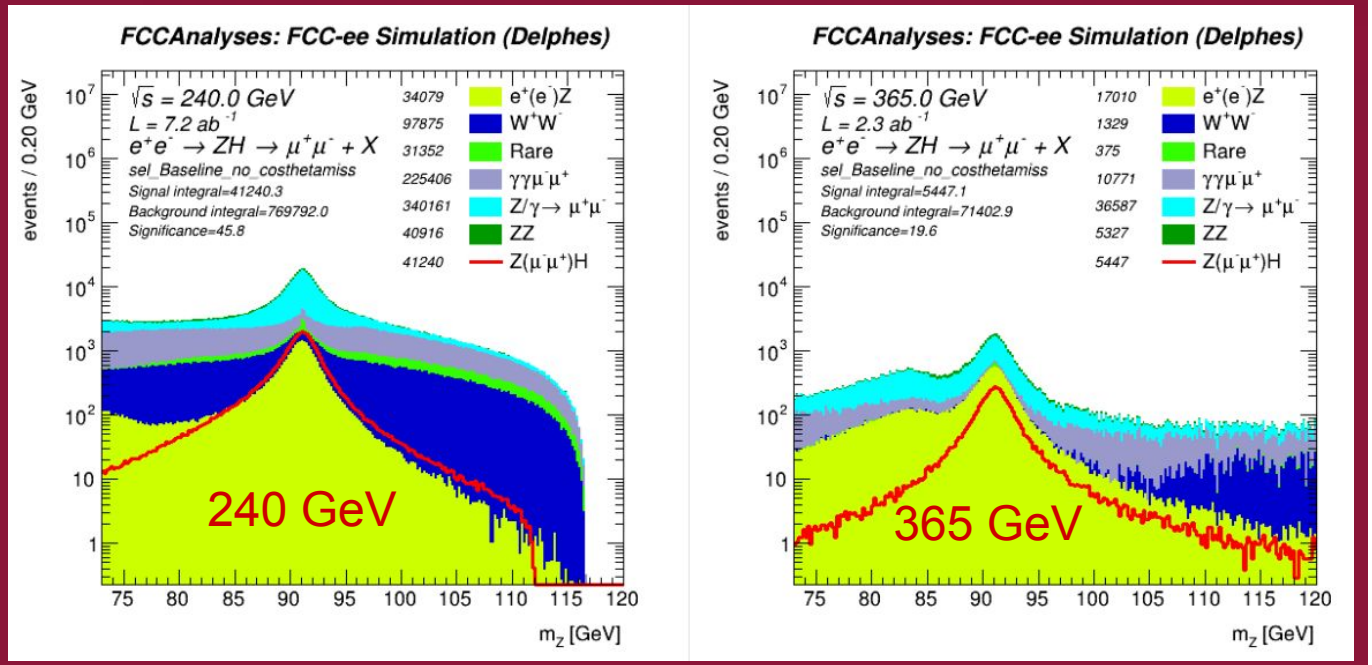
Phi angle of the reconstructed Z boson



➢ At 365 GeV Z/γ and ZZ backgrounds are dominant

Phi angle of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

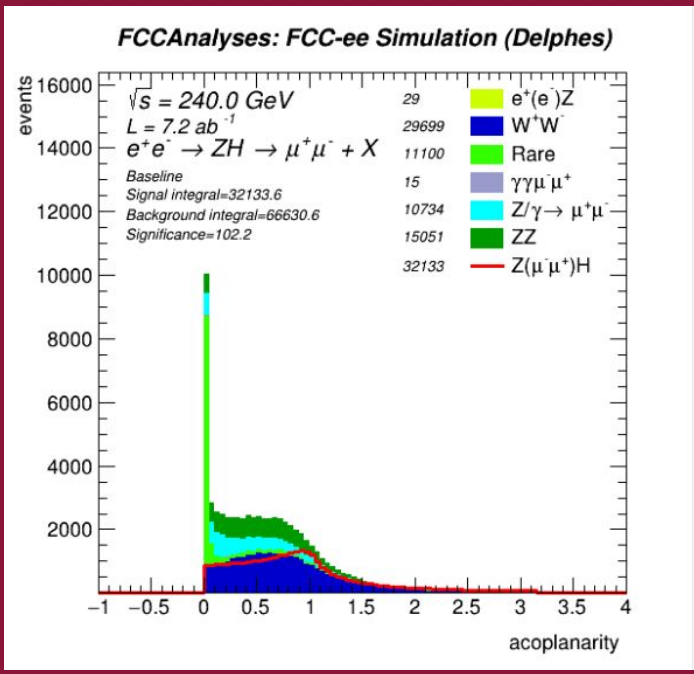
Reconstructed Z Mass without zll mass selection cut

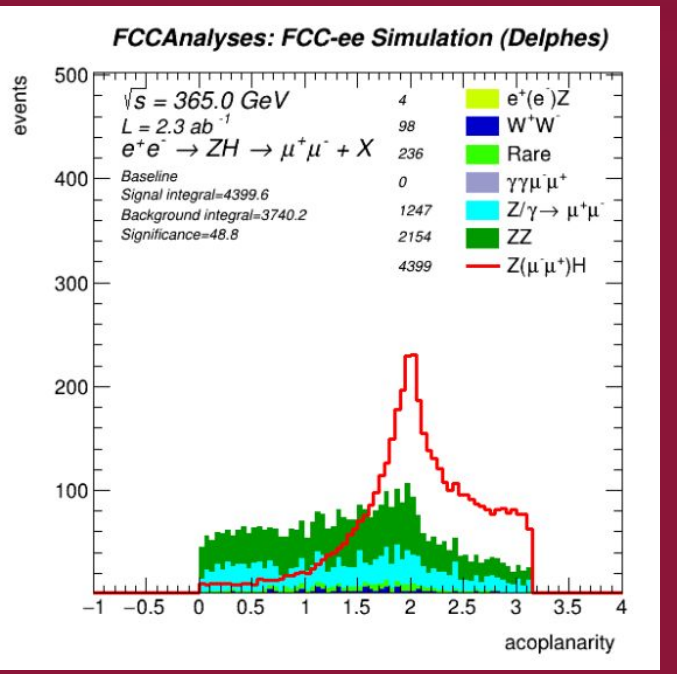


- WW background is moved to higher energy for 365 GeV
- The cut at 86 < zll mass < 96 GeV is removing them

Reconstructed Z mass comparison at 240 GeV (left) and 365 GeV (right) for mumu channel without zll mass selection cut

Acoplanarity of the reconstructed Z boson

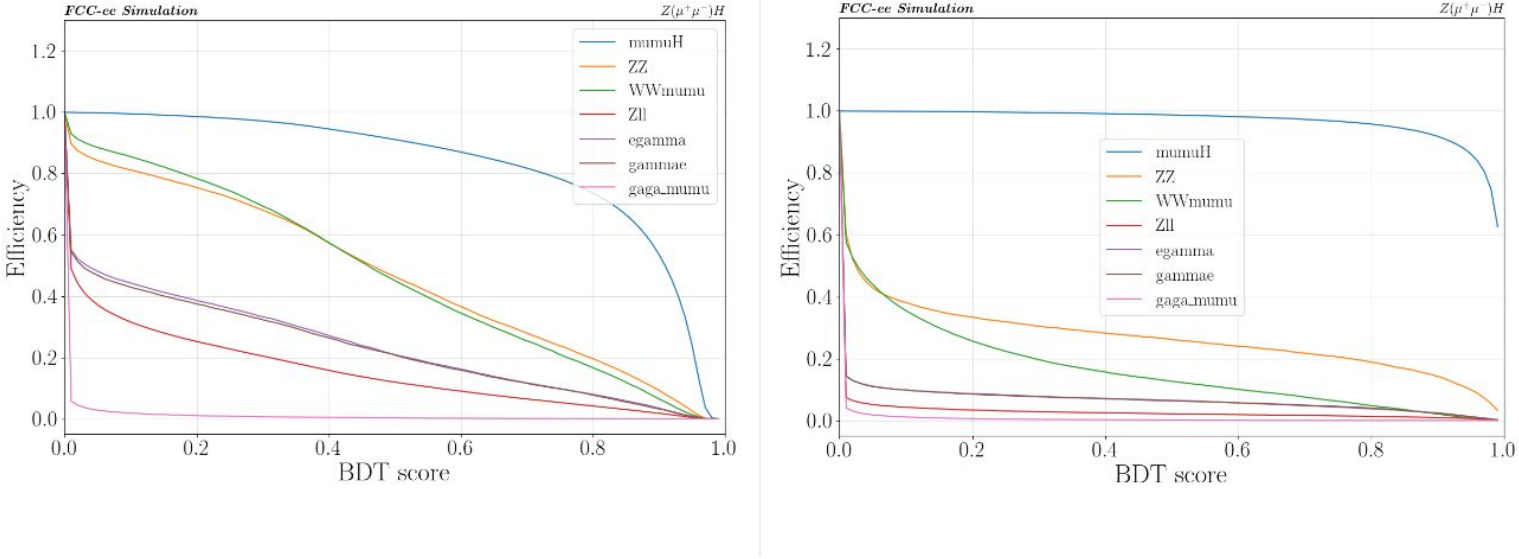




- Higher acoplanarity for signal at 365 GeV
- Peak at 2

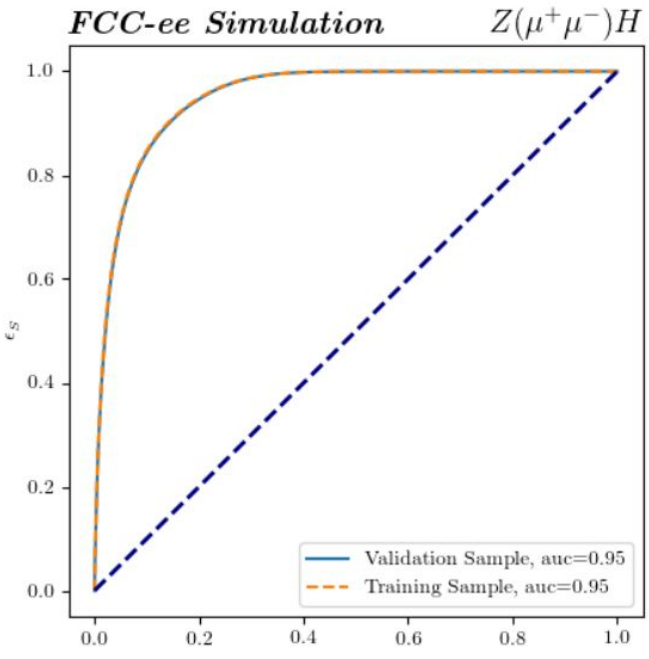
Acoplanarity of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

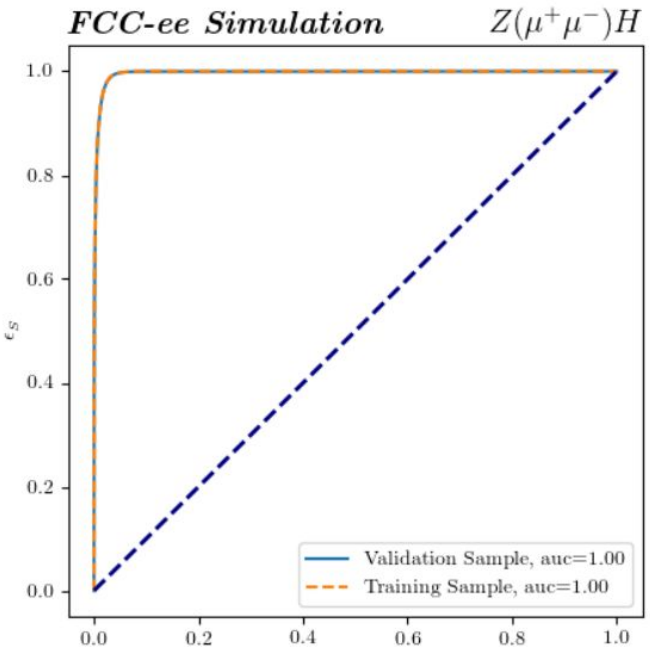
Efficiency of the BDT



Efficiency comparison 240 GeV (left) and 365 GeV (right) for mumu channel

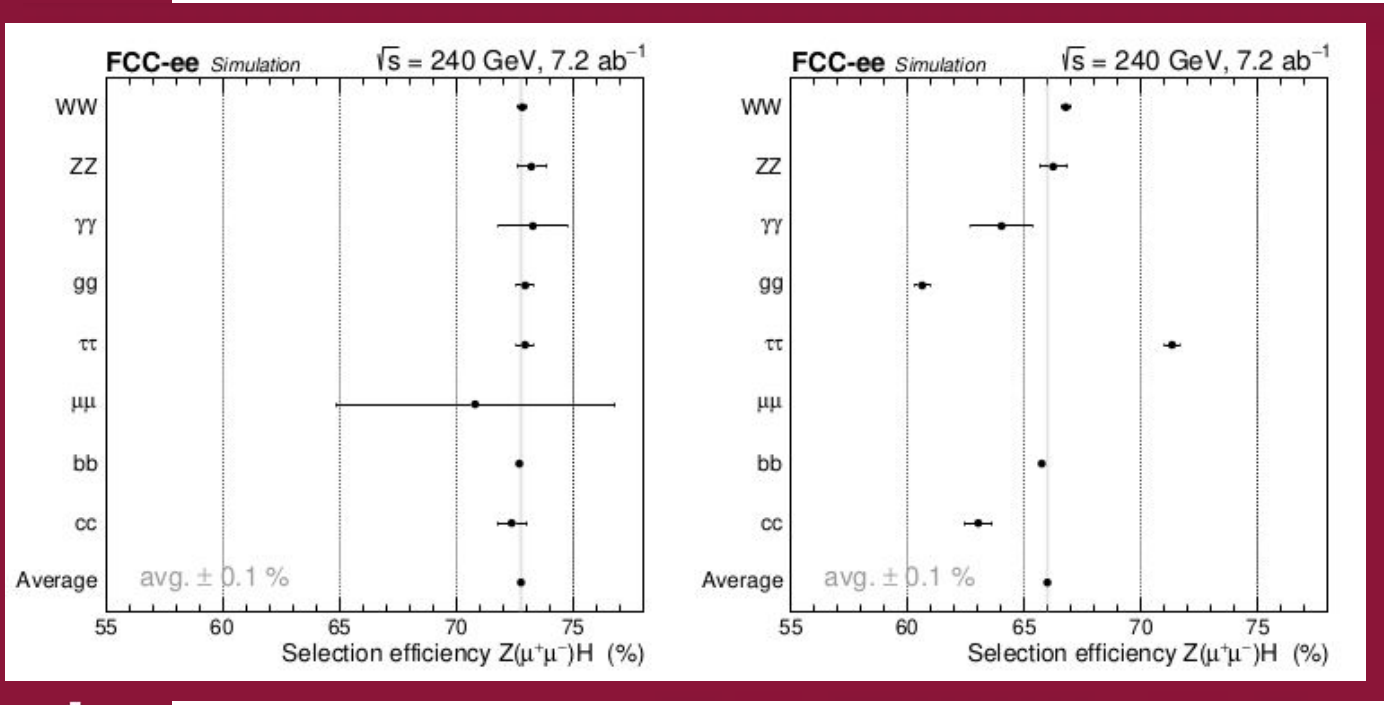
Efficiency of the BDT





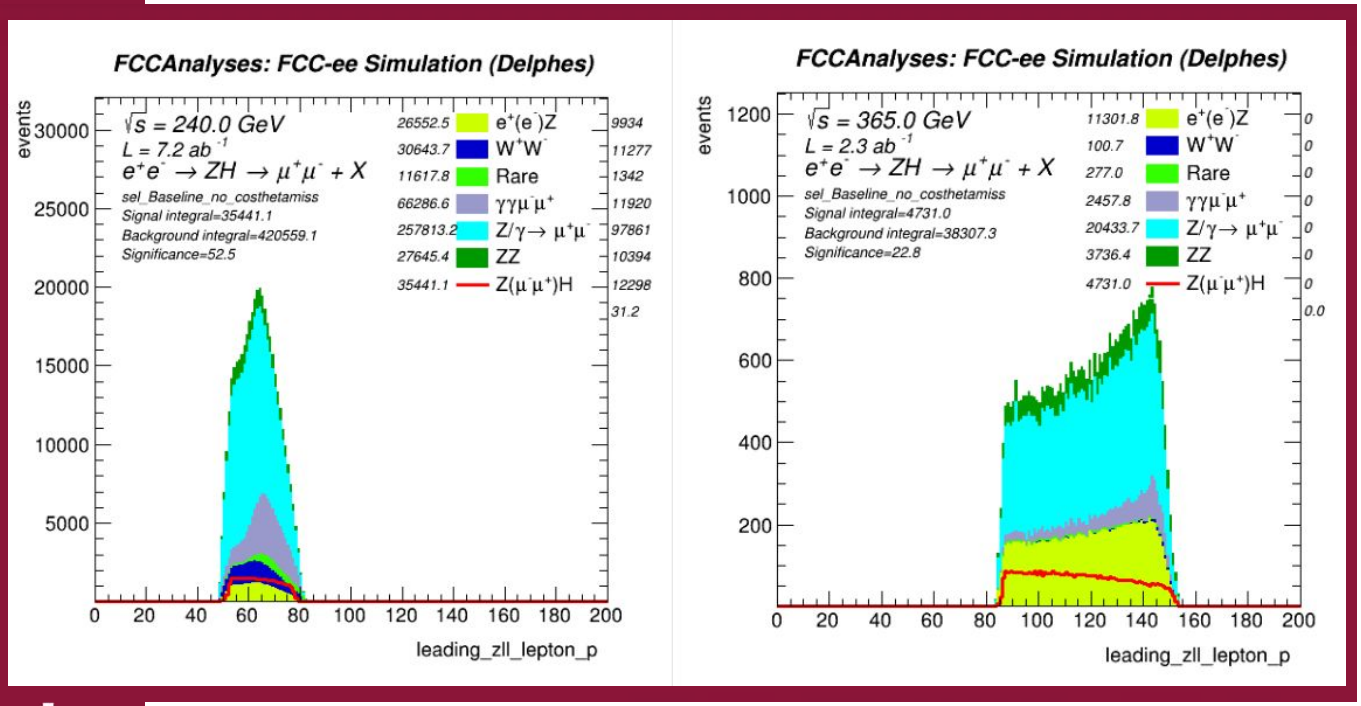
Efficiency comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Training_variables for BDT



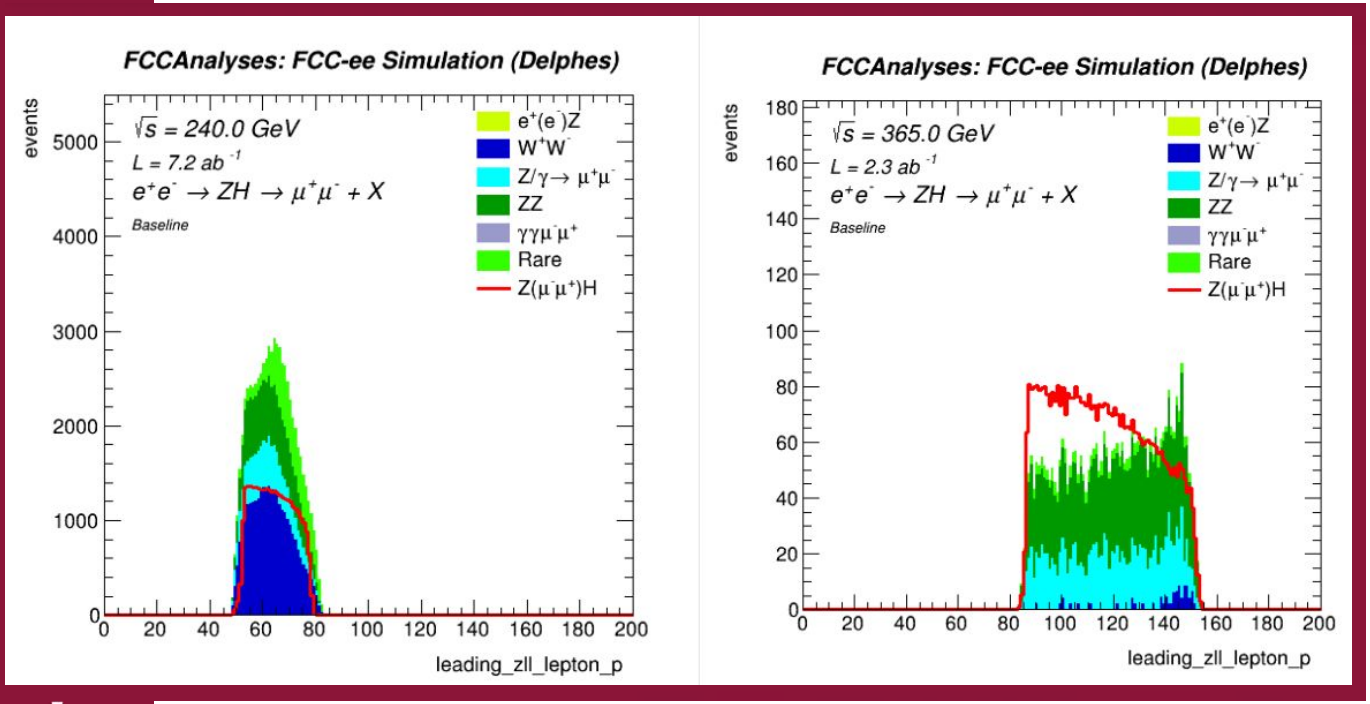
Selection efficiency of the different Higgs decay modes with Z ⇒ mumu, The left column shows the selection efficiency with the basic selection (without cos(θmiss) cut), and the right column shows selection efficiency with baseline selection (with cos(θmiss) cut).

Momentum of the leading lepton coming from the Z decay



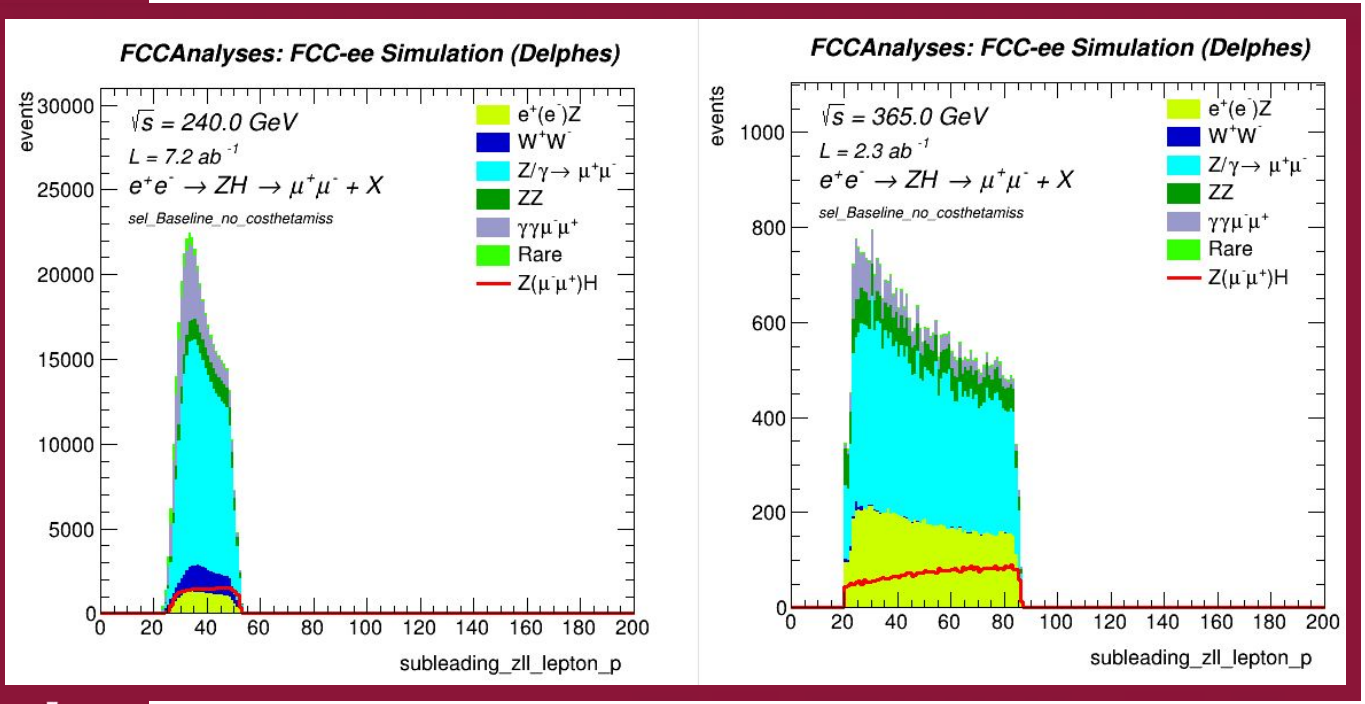
Momentum of the leading lepton coming from the Z decay comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Momentum of the leading lepton coming from the Z decay



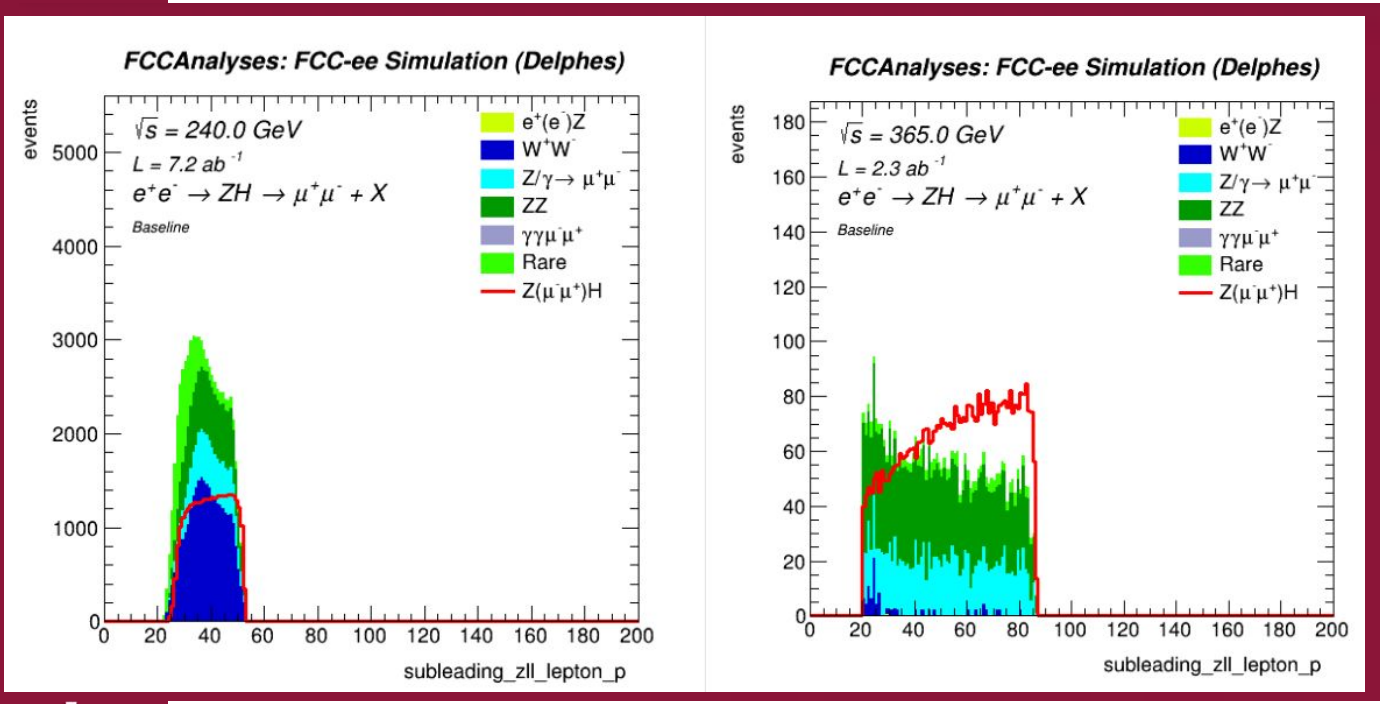
Momentum of leading lepton coming from the Z decay comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Momentum of the subleading lepton coming from the Z decay



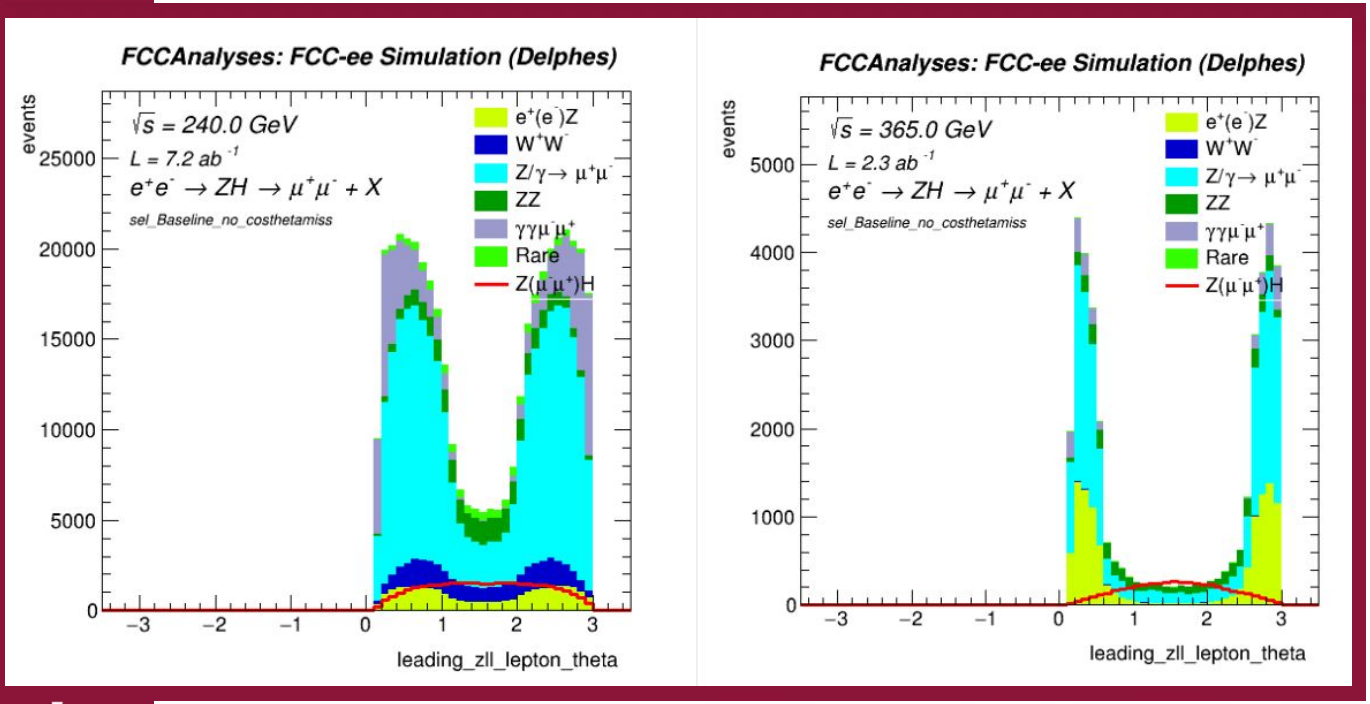
Momentum of the subleading lepton coming from the Z decay comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Momentum of the subleading lepton coming from the Z decay



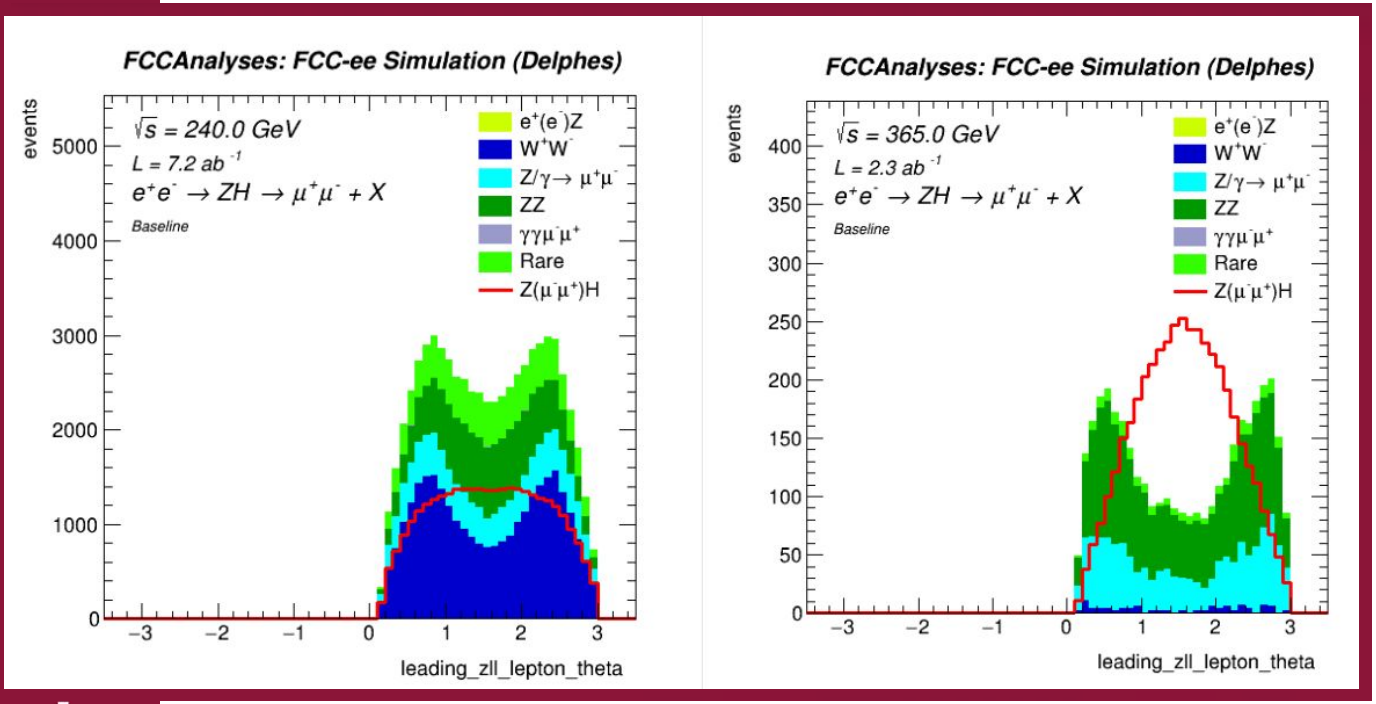
Momentum of the leading lepton coming from the Z decay comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Theta angle of the leading lepton coming from the Z decay



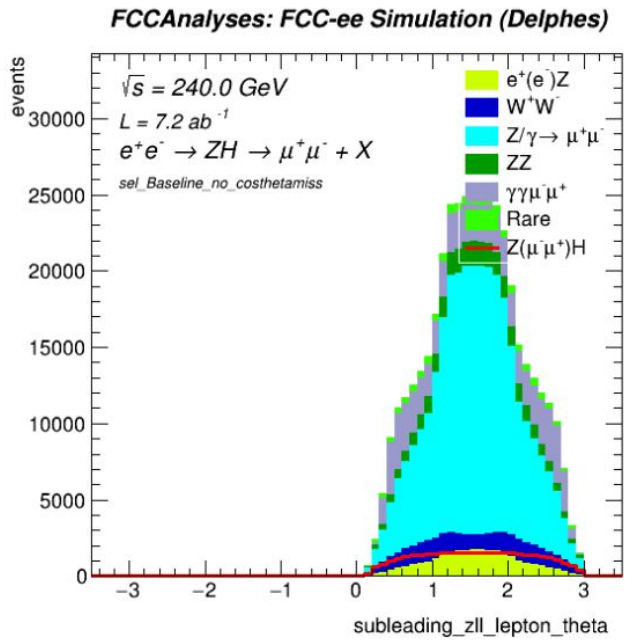
Theta angle of the leading lepton coming from the Z decay comparison at 240 GeV (left) and 365 GeV (right) for mumu channel

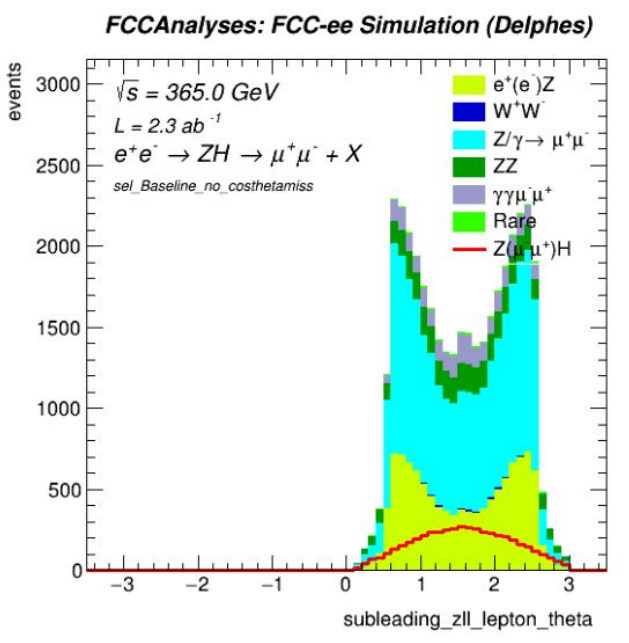
Theta angle of the leading lepton coming from the Z decay



Theta angle of the leading lepton coming from the Z decay comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Theta angle of the subleading lepton coming from the Z decay

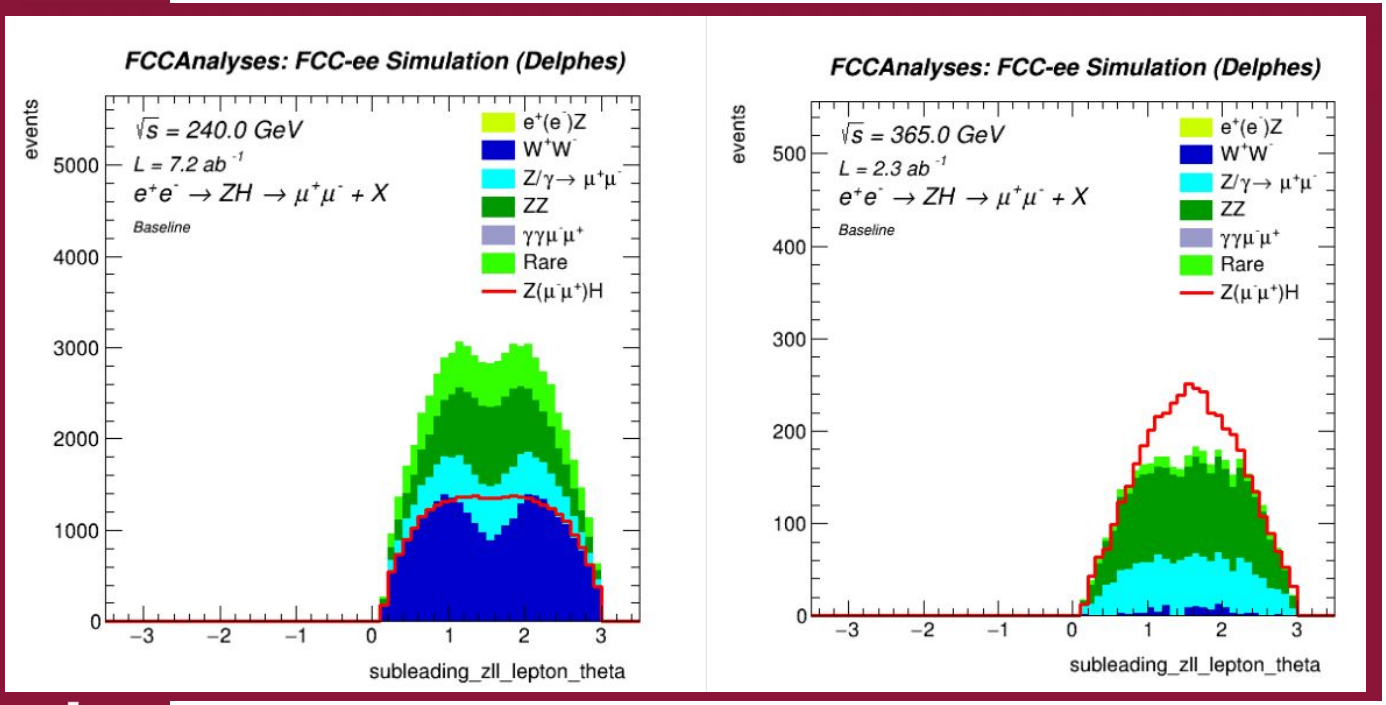




Theta angle of the subleading lepton coming from the Z decay comparison at 240 GeV (left) and 365 GeV (right) for mumu channel

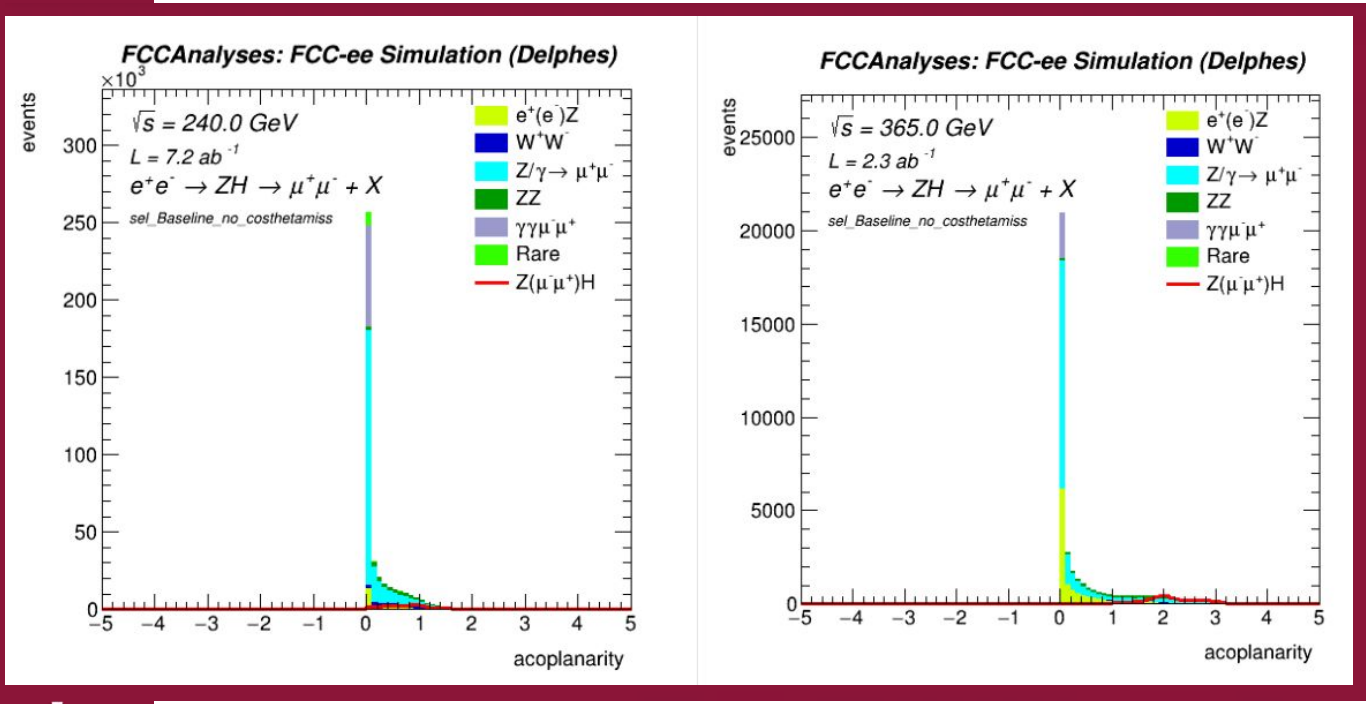
DEWYSPELAERE Kevin

Theta angle of the subleading lepton coming from the Z decay



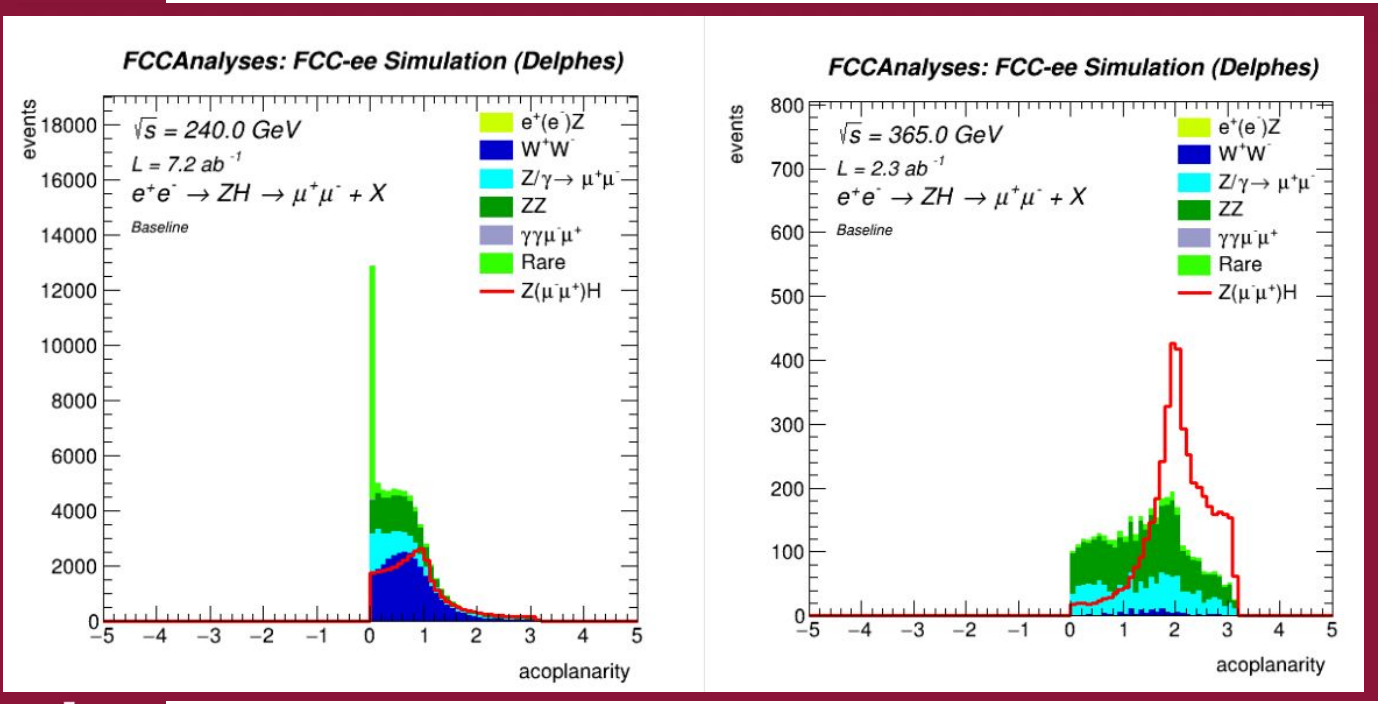
Theta angle of the subleading lepton coming from the Z decay comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Acoplanarity of the reconstructed Z boson



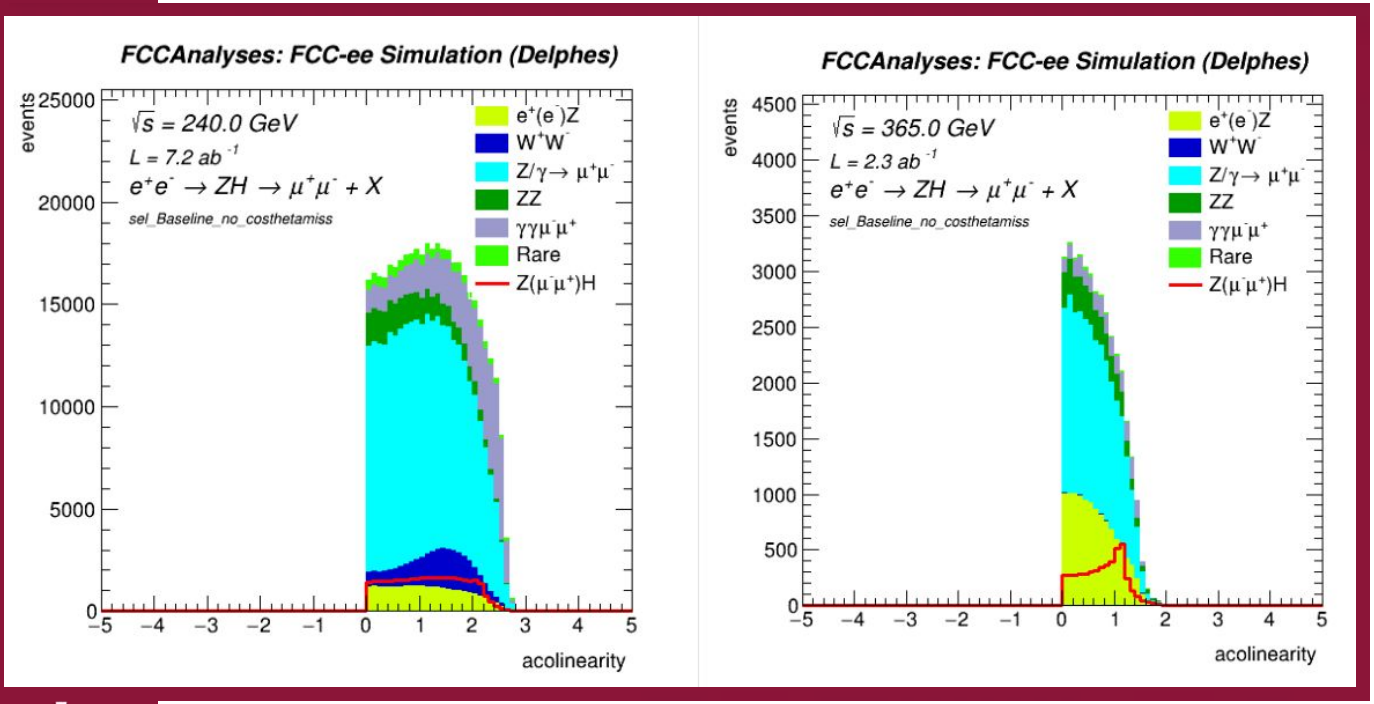
Acoplanarity of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Acoplanarity of the reconstructed Z boson



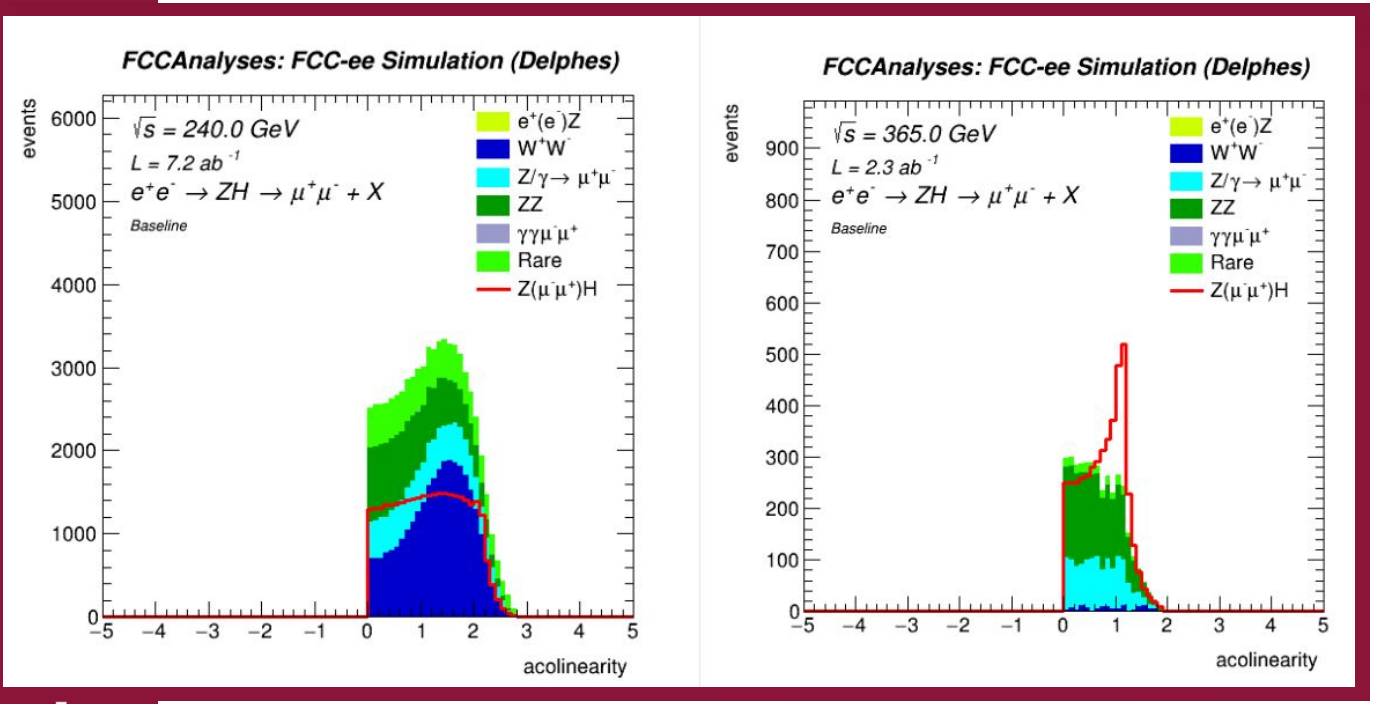
Acoplanarity of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Acollinearity of the reconstructed Z boson



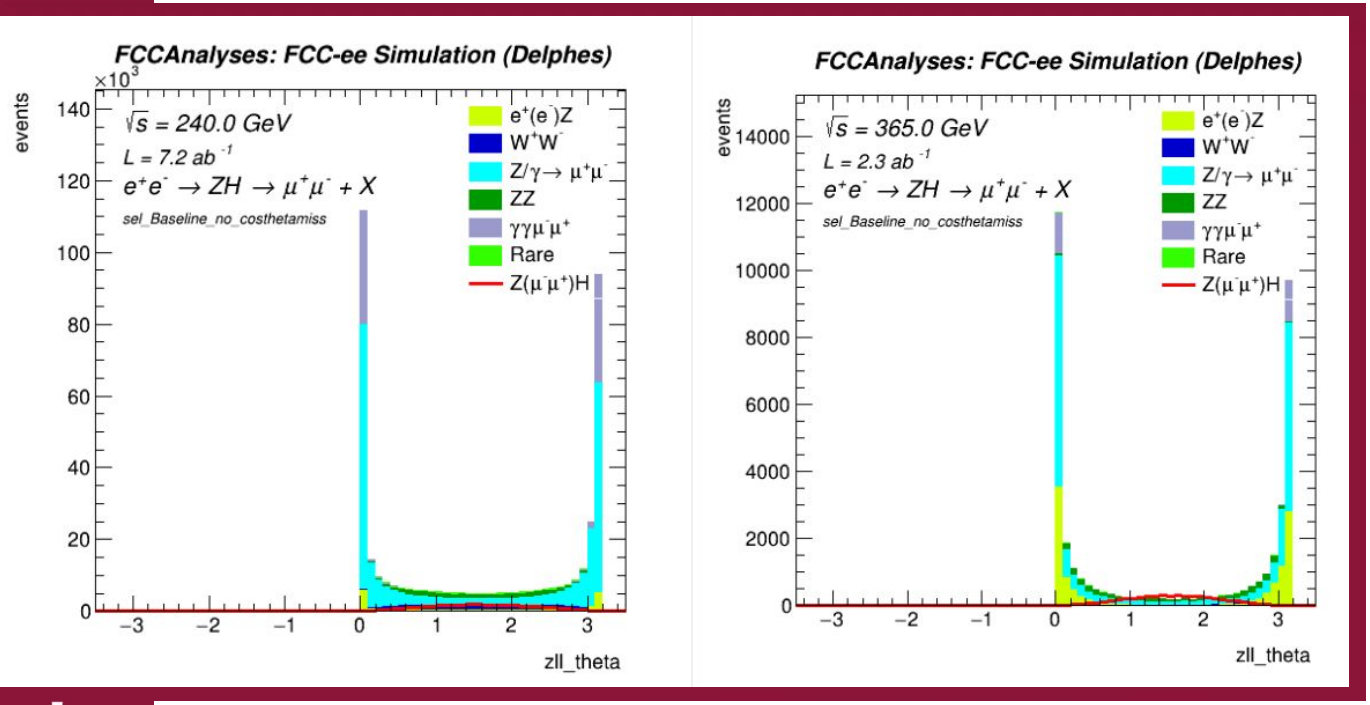
Acollinearity of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel

Acollinearity of the reconstructed Z boson



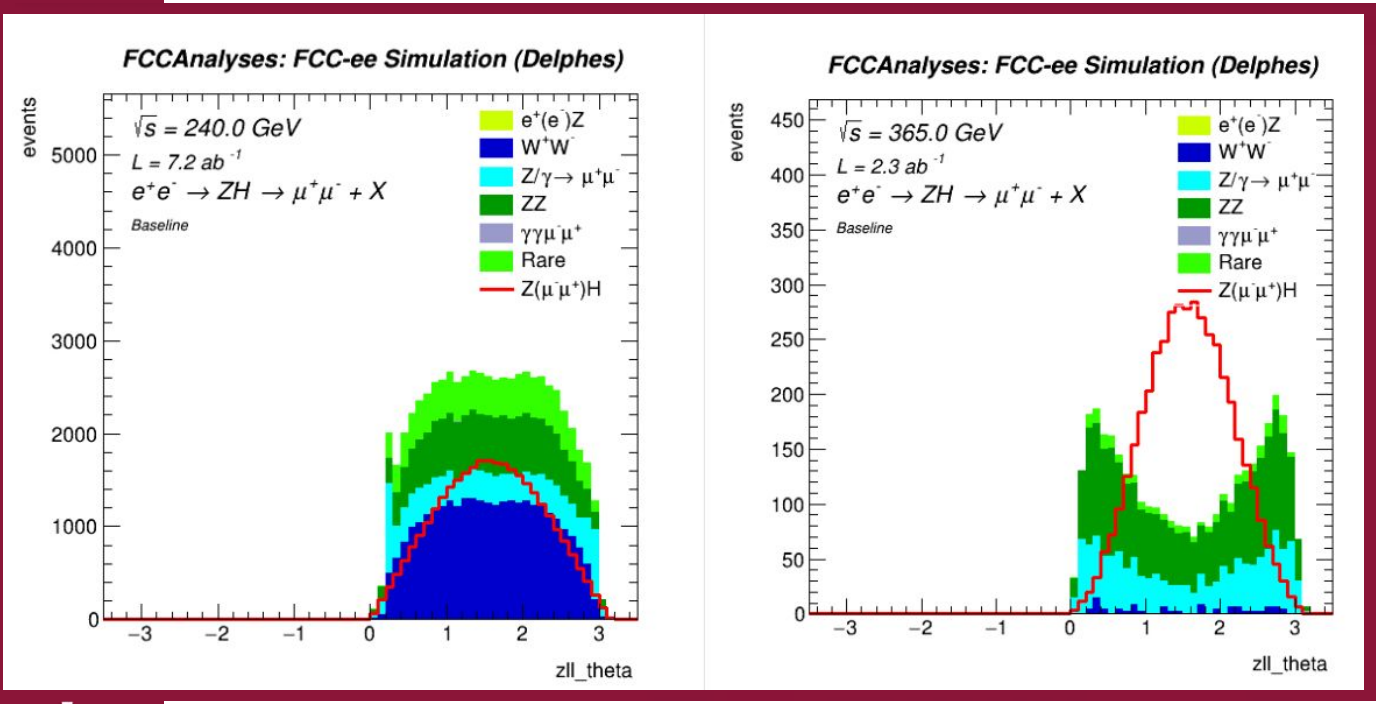
Acollinearity of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Theta angle of the reconstructed Z boson



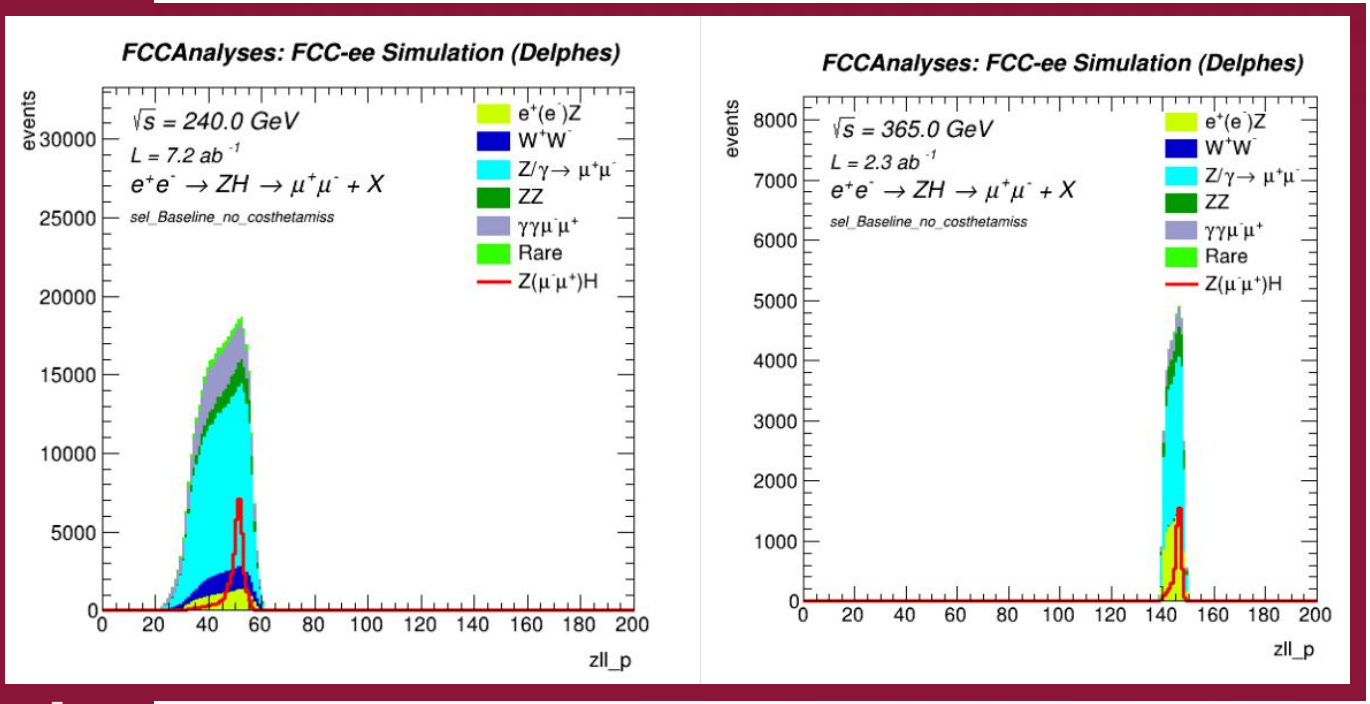
Theta angle of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel

Theta angle of the reconstructed Z boson



Theta angle of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

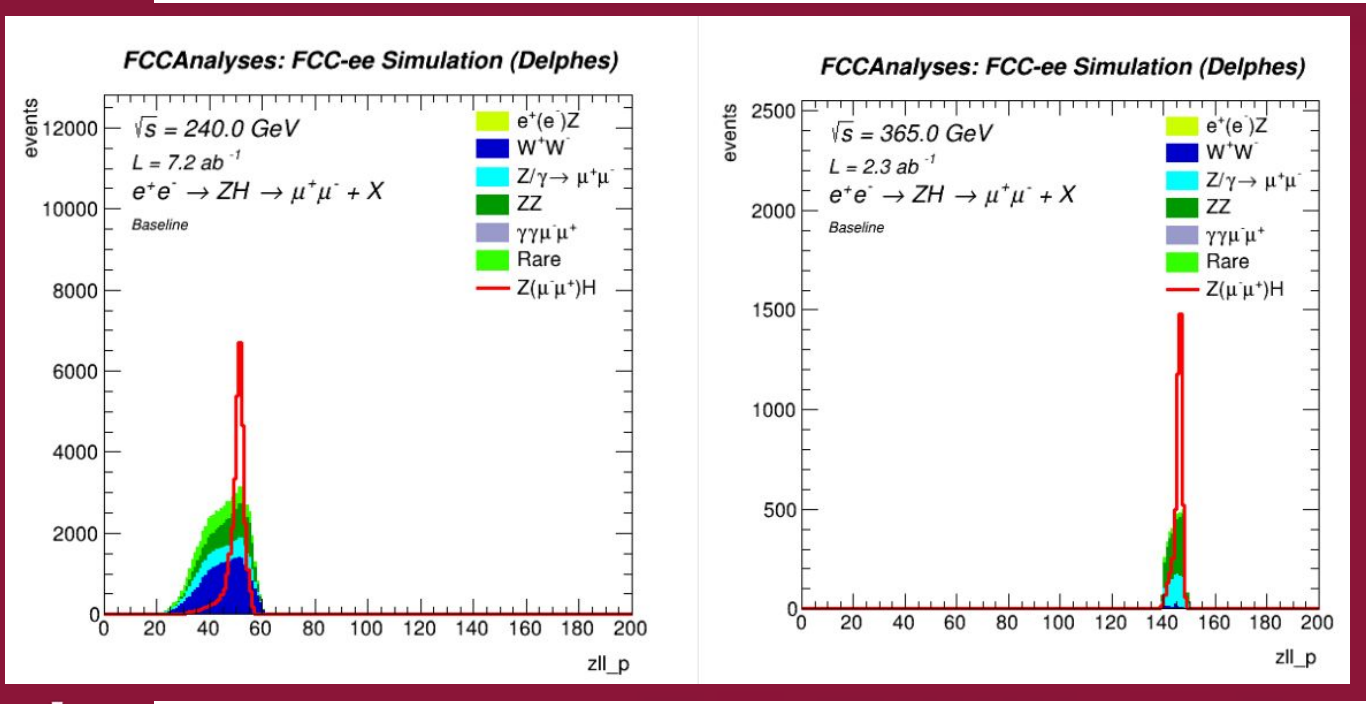
Momentum of the reconstructed Z boson



➢ **Z momentum gain 100 GeV at 365 GeV**

Momentum of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel

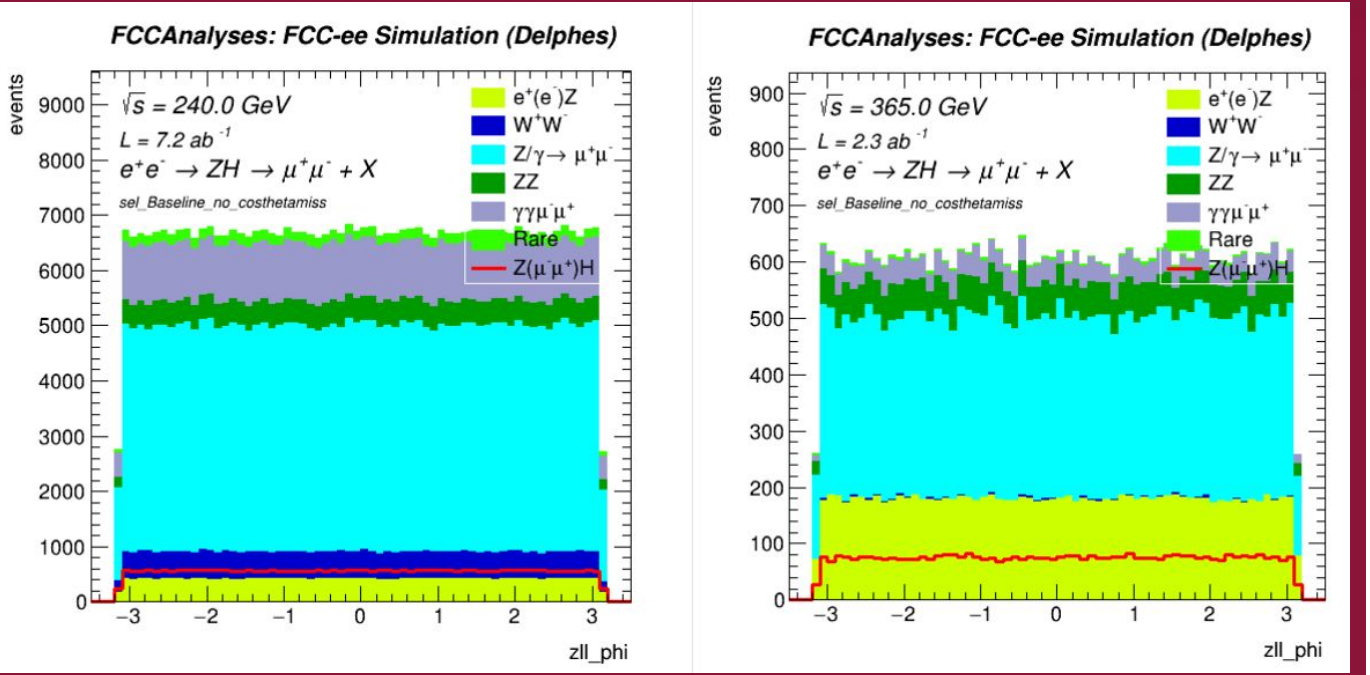
Momentum of the reconstructed Z boson



- **Z momentum gain 100 GeV at 365 GeV**

Momentum of the reconstructed Z boson comparison 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

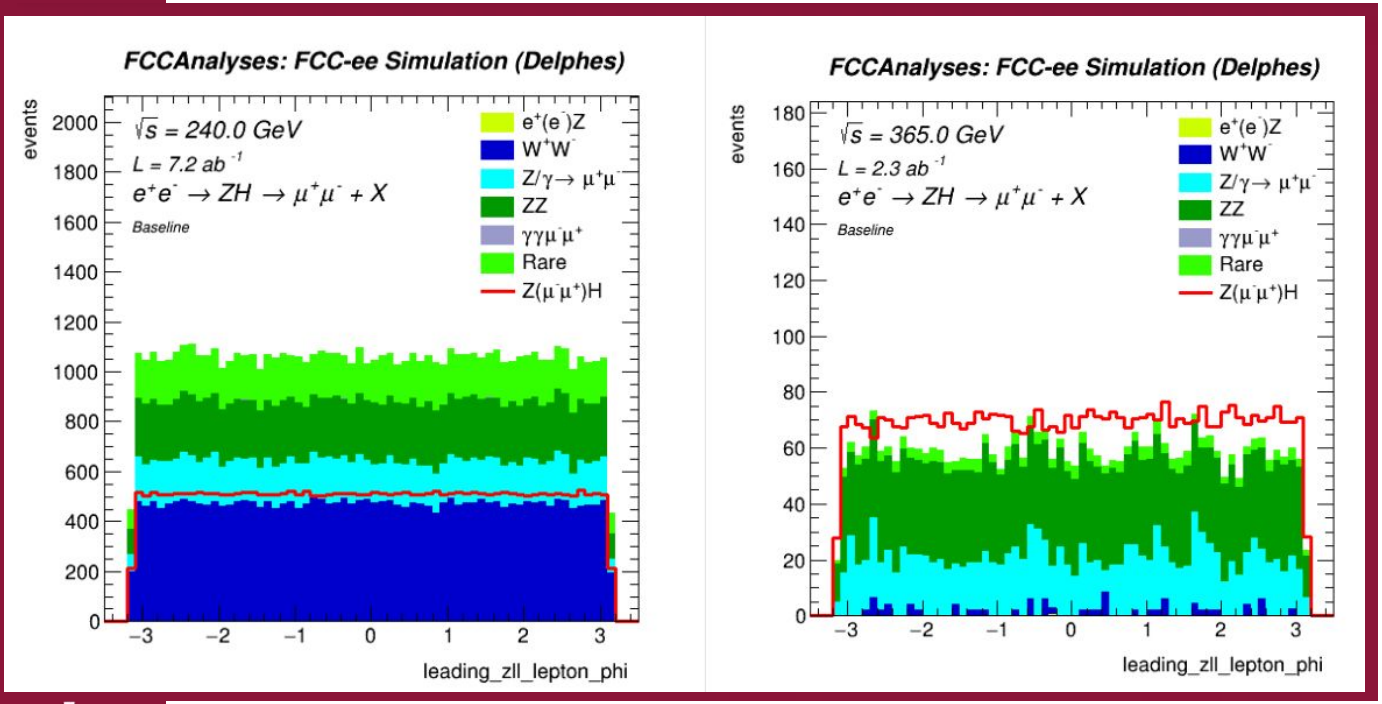
Phi angle of the reconstructed Z boson



- Number of events divided by 3
- We gain a bit of signal noise ratio
- Need to add integrals and SNR number on the plot

Phi angle of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel

Phi angle of the reconstructed Z boson



- Number of events divided by 3
- We gain a bit of signal noise ratio
- Need to add integrals and SNR number on the plot

Phi angle of the reconstructed Z boson comparison at 240 GeV (left) and 365 GeV (right) for mumu channel with cos θmiss selection cut

Sample used for BDT training

Sample Name	Process	Generator	Training + Validation	cross-section (pb)
Higgs Processes				
wzp6_ee_mumuH	$e^+e^- \to \mu^+\mu^- H$	WHIZARD + PYTHIA6	873007	0.0067643
Diboson Processes				
p8_ee_ZZ	$e^+e^- \to ZZ$	PYTHIA8	59261	1.35899
p8_ee_WW_mumu	$e^+e^- \to WW \to \mu^+\nu_\mu\mu^-\bar{\nu_\mu}$	PYTHIA8	62966	0.25792
Dilepton Processes				
wzp6_ee_mumu	$e^+e^- \to \mu^+\mu^-$	WHIZARD + PYTHIA6	551655	5.288
Electron Photon Processes				
wzp6_egamma_eZ_Zmumu	$e^-\gamma \to e^- Z(\mu^+\mu^-)$	WHIZARD + PYTHIA6	28662	0.10368
wzp6_gammae_eZ_Zmumu	$e^+\gamma \to e^+ Z(\mu^+\mu^-)$	WHIZARD + PYTHIA6	28512	0.10368
Photon Photon Processes				
wzp6_gaga_mumu_60	$\gamma\gamma \to \mu^+\mu^-$	WHIZARD + PYTHIA6	141949	1.5523

Sample Name	Process	Generator	Training + Validation	cross-section (pb)
Higgs Processes				
wzp6_ee_eeH	$e^+e^- \to e^+e^- H$	WHIZARD + PYTHIA6	769907	0.0067643
Diboson Processes				
p8_ee_ZZ	$e^+e^- \to ZZ$	PYTHIA8	29894	1.35899
p8_ee_WW_ee	$e^+e^- \to WW \to e^+\nu_e e^-\bar{\nu_e}$	PYTHIA8	34874	0.25792
Dilepton Processes				
wzp6_ee_ee_Mee_30_150	$e^+e^- \to e^+e^-$ (30-150 GeV)	WHIZARD + PYTHIA6	660832	8.305
Electron Photon Processes				
wzp6_egamma_eZ_Zee	$e^-\gamma \to e^- Z(e^+e^-)$	WHIZARD + PYTHIA6	7883	0.05198
wzp6_gammae_eZ_Zee	$e^+\gamma \to e^+ Z(e^+e^-)$	WHIZARD + PYTHIA6	7887	0.05198
Photon Photon Processes				
wzp6_gaga_ee_60	$\gamma\gamma \to e^+e^-$	WHIZARD + PYTHIA6	28534	0.873

Samples used for the BDT analysis, $\mu^+\mu^-$ (up) and e^+e^- (down)