Search for Zc(3900) via Quantum Computing Machine Learning

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Outline

Introduction

Data Set

- Zc(3900) decay chain
  $e^+e^- \to Zc(3900)^{\pm}\pi^{\mp}$
  $Zc(3900)^{\pm} \to J/\psi\pi^{\pm}$
  $J/\psi \to e^+e^-(\mu^+\mu^-)$
- Signal MC sample (BOSS 7.0.3)

decay tree	**decay model**
$e^+e^- \to Zc(3900)^{\pm}\pi^{\mp}$	PHSP
$Zc(3900)^{\pm} \to J/\psi\pi^{\pm}$	PHSP
$J/\psi \to e^+e^-(\mu^+\mu^-)$	VLL

- Data Samlpe (BOSS 7.0.3)
  4.260 GeV Data at BESIII of 2013

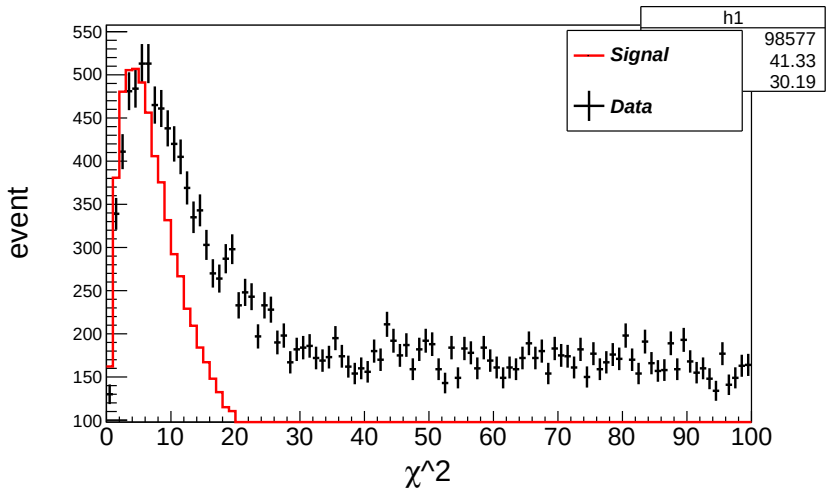
sample	**luminaance**	**center-mass energy**	**Run number**
4260	828.4±0.1±5.5	4257.97±0.04±0.66	29677-30367 31561-31981

Classical Data Processing Procedure

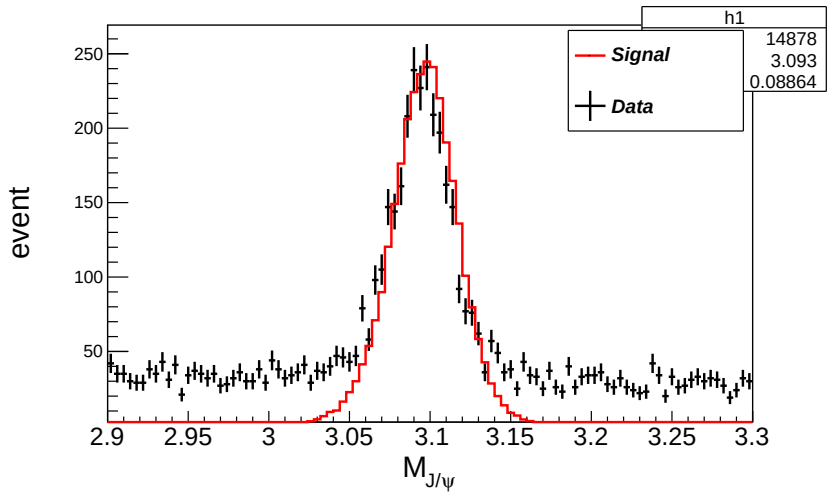
- Good charged track selection
  - $|cos\theta| < 0.93, |V_z| < 10cm, |V_r| < 1cm$
  - Four good tracks and zero net charge
- particle identification
  - $p > 1$ Gev/c identified as lepton
  - $p < 1$ Gev/c identified as π
  - The number of pions and that of leptons should be two in each event with zero net charge.
  - $E_{EMC} > 1.1$ GeV identified as e
  - $E_{EMC} < 0.35$ GeV identified as μ
- remove gamma-conversion background
  - $\cos(\pi^+\pi^-) < 0.98$
  - $\cos(\pi^\pm e^\mp) < 0.98$

Classical Data Processing Procedure

- 4C kinematic Fit: $\chi^2 < 60$
- J/ψ mass window :
  $3.08 < M(l^+l^-) < 3.12$ GeV$/c^2$
- sideband :
  $3.0 < M(l^+l^-) < 3.06$ and $3.14 < M(l^+l^-) < 3.20$ GeV$/c^2$



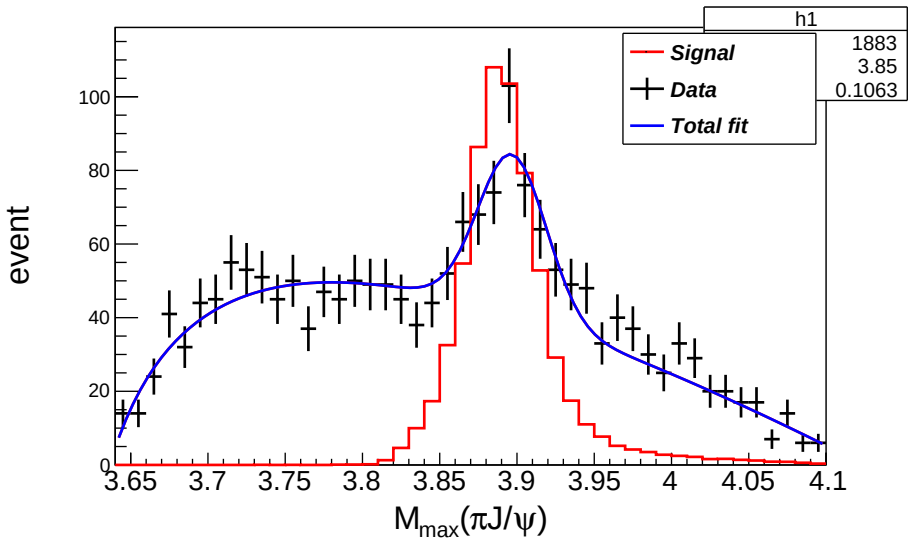
4C Kinematic fit χ^2 distribution



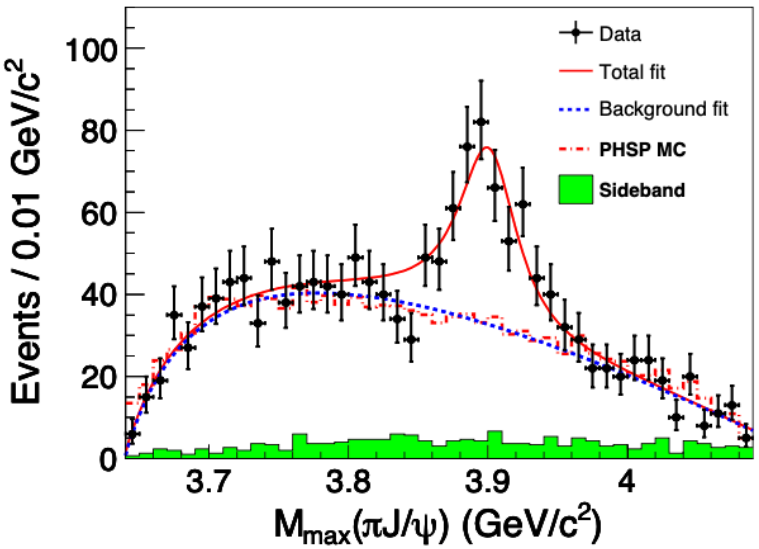
$M(l^+l^-)$ invariant mass distributions.

Classical Data Processing Procedure

We use events from the J/ψ mass window and select the maximum of $M(\pi^+ J/\psi)$ and $M(\pi^- J/\psi)$ as variables, then fit this to obtain the signal



$M_{max}(\pi J/\psi)$ invariant mass distributions.



$M_{max}(\pi J/\psi)$ @BESIII

Quantum Transform Introduction

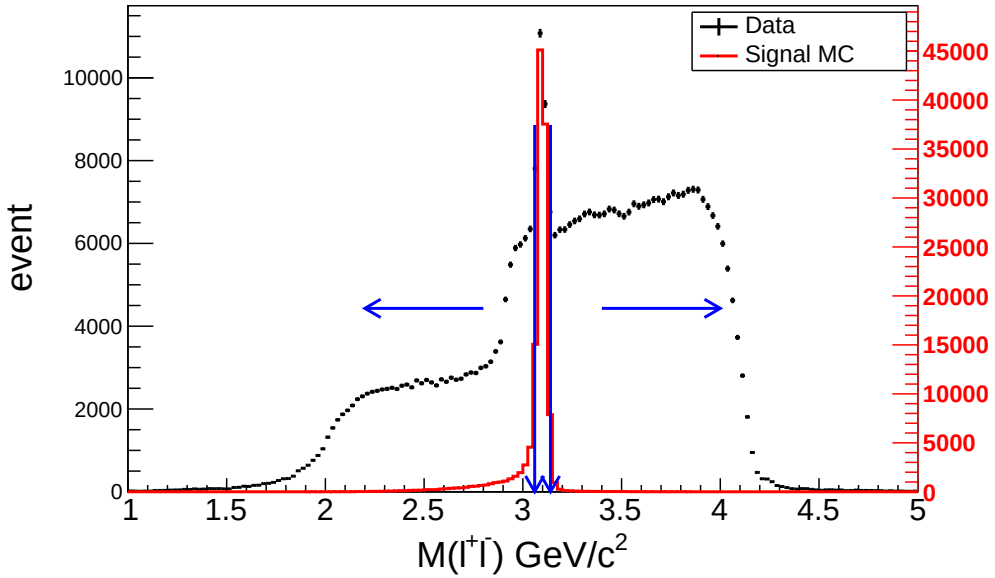
Quantum Transform

Preliminary Selection

- Four good tracks, zero net charge
- π: $p < 1$ Gev/c
- lepton :$p > 1$ Gev/c
  - e : $p > 1$ Gev/c and $E_{EMC} > 0.8 GeV$
  - μ: $p > 1$ Gev/c and $E_{EMC} < 0.6 GeV$

Quantum Transform

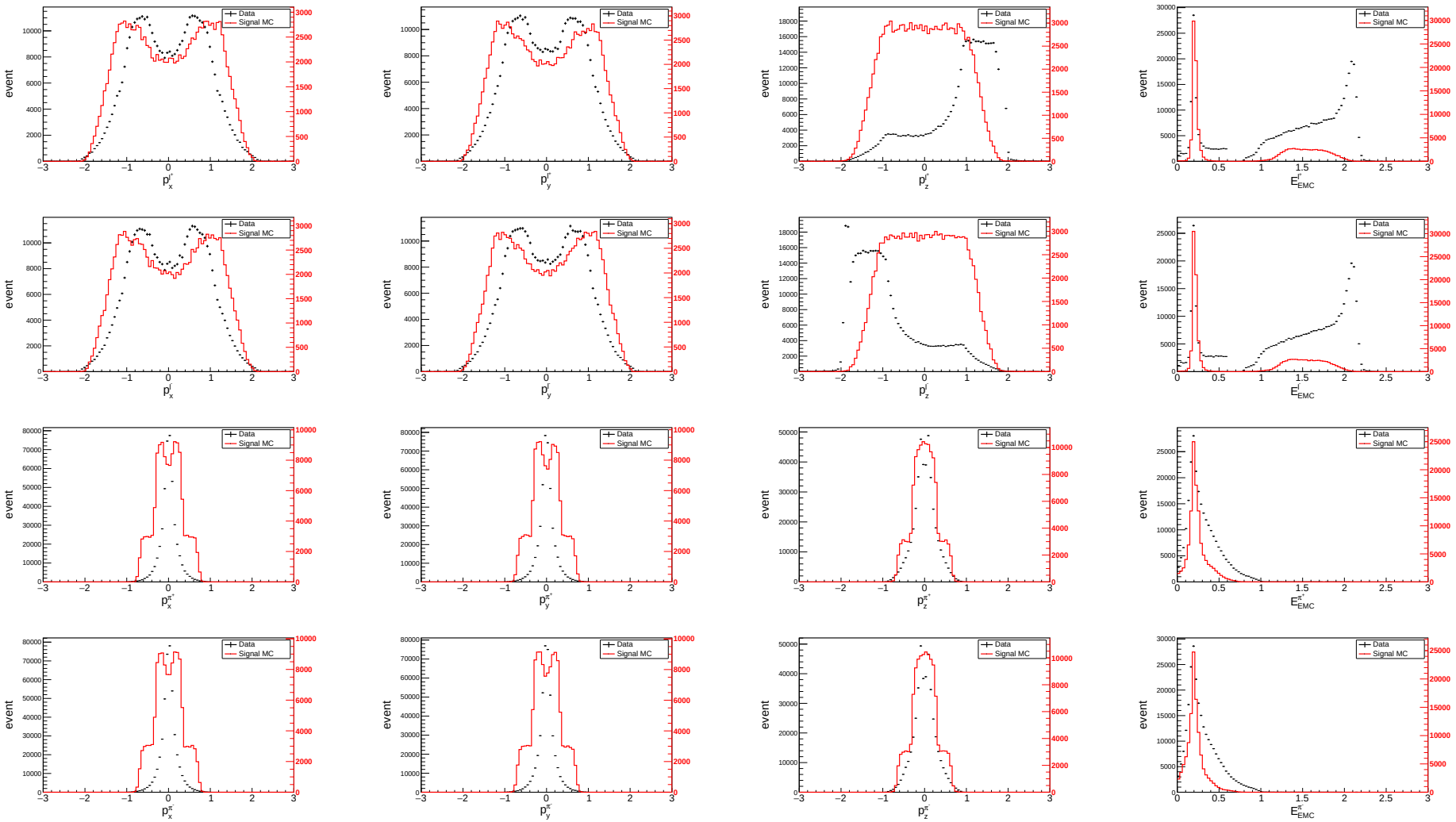
- Model : Transform and Quantum Transform
- Parameter Set:17 variables
  - 16 variables: p_x, p_y, p_z and E_{EMC} of 4 charge tracks
  - χ^2 (4C kinematic fit)
- Signal : Signal MC
- Background is form data :
  $M(l^+l^-) \in (0, 3.06) \bigcup (3.14, 5)$ GeV$/c^2$



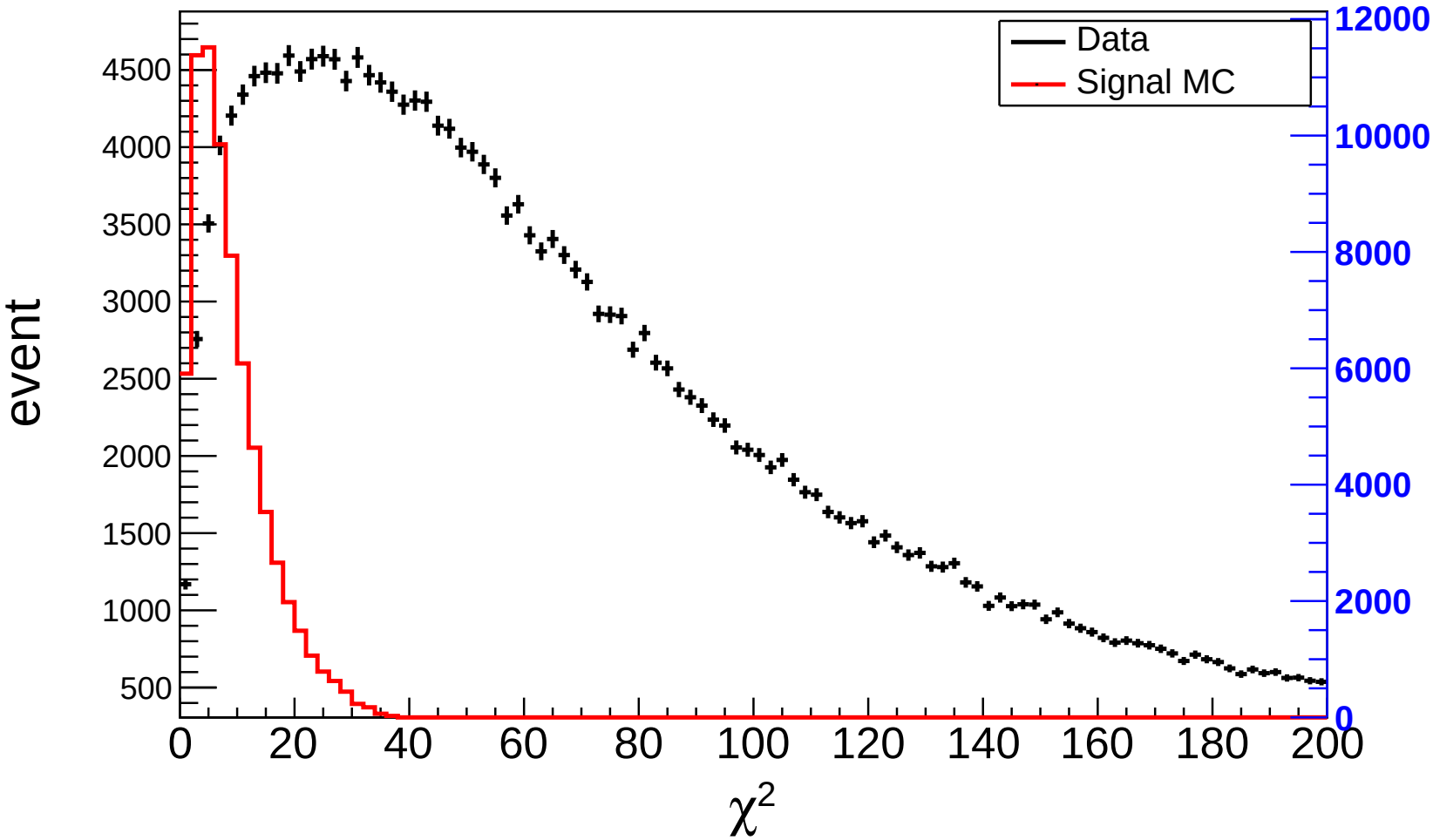
Train data set

- Signal: background = 1:1
- Classical Transform :
  - 130k events (65k for train, 65k for validation)
  - 300 epochs
  - Learning rate : 0.0007 or 0.0009
- Quantum Transform :
  - 20k events (10k for train , 10k for validation)
  - 8 epochs
  - Learning rate : 0.0007 or 0.0009

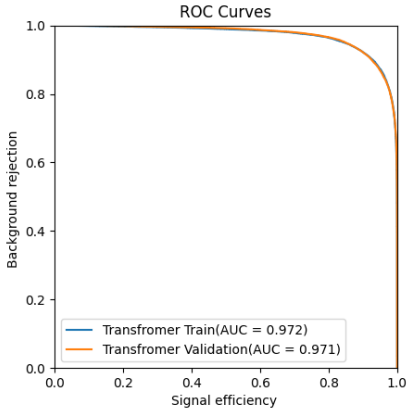
Distribution of variables



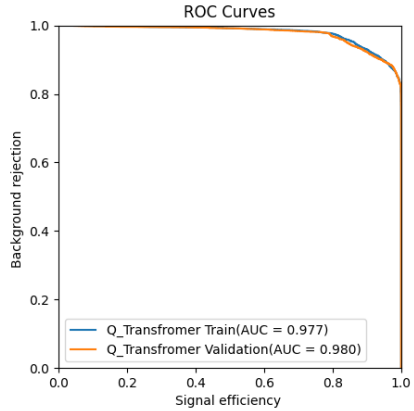
Distribution of varisbles



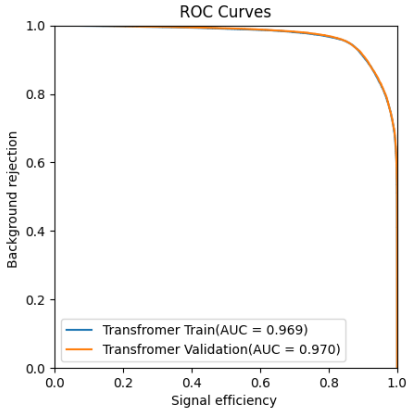
ROC Curve



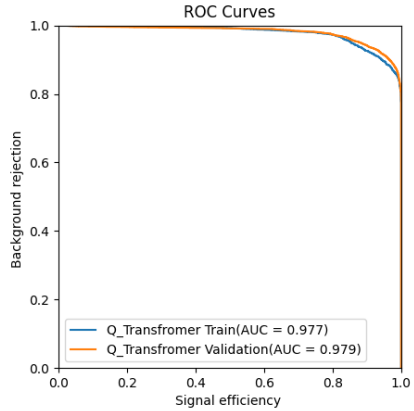
Classical, Lr: 0.0007



Quantum, Lr: 0.0007

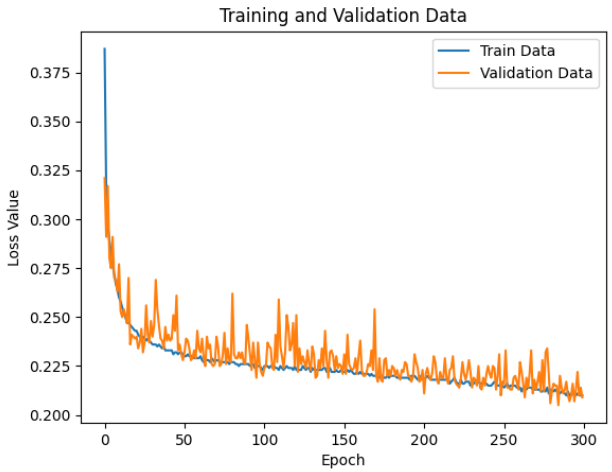


Classical, Lr: 0.0009



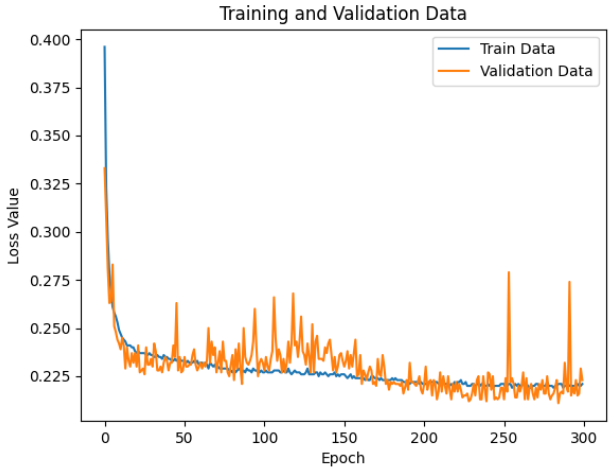
Quantum, Lr: 0.0009

Loss

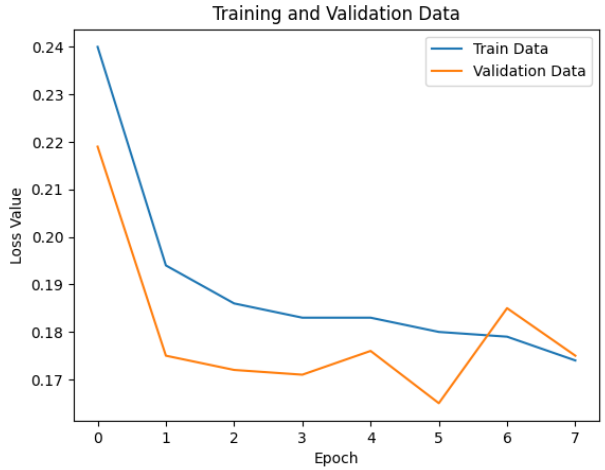


Classical, Lr: 0.0007

Quantum, Lr: 0.0007

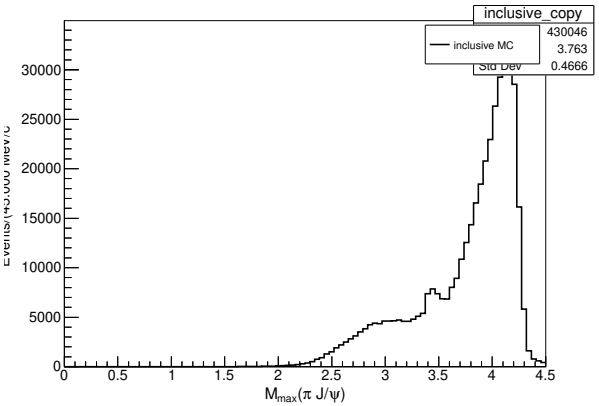


Classical, Lr: 0.0009

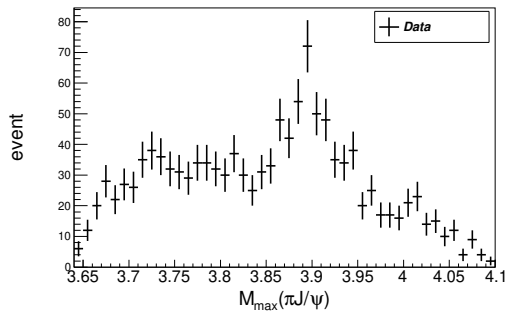


Quantum, Lr: 0.0009

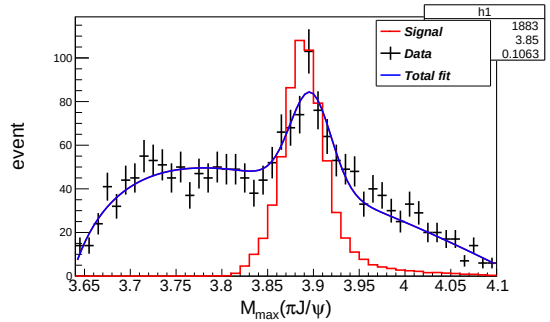
Real data distribution



data with preliminary cut



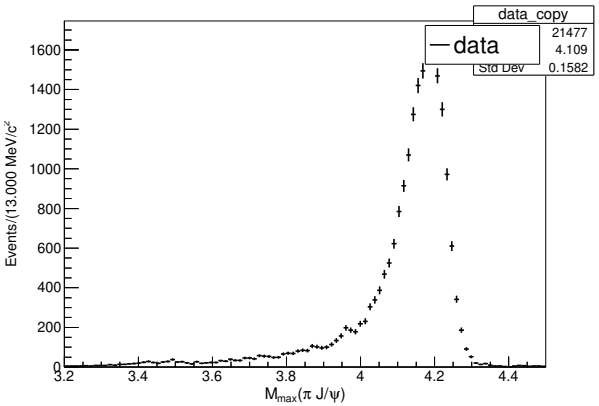
data with all cut



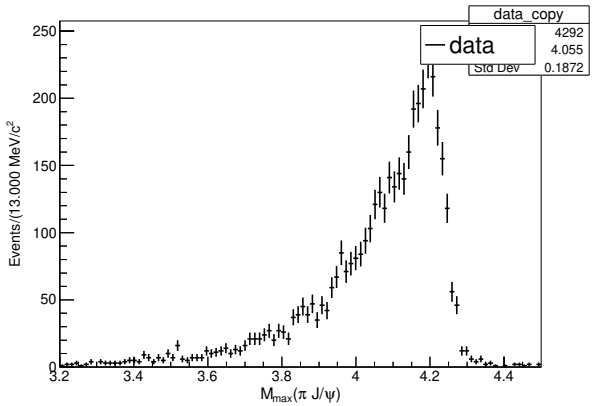
Signal with all cut

Test model

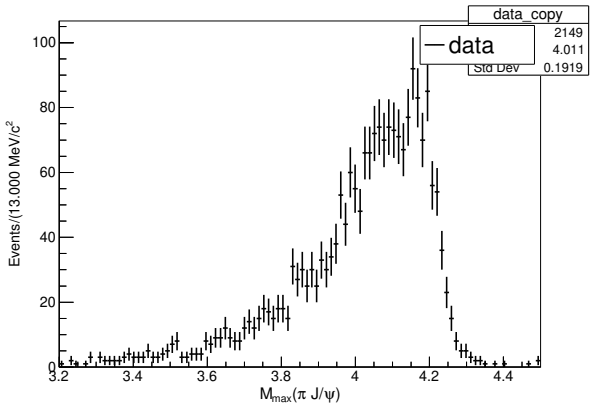
We apply the model to real data and set different background rejection rates.



bkg rejection rate : 95%

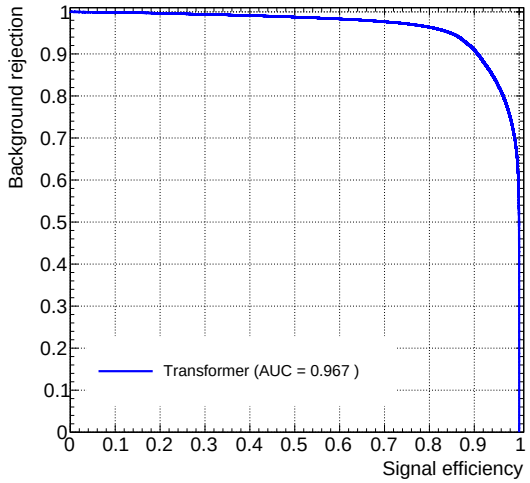


bkg rejection rate : 99%

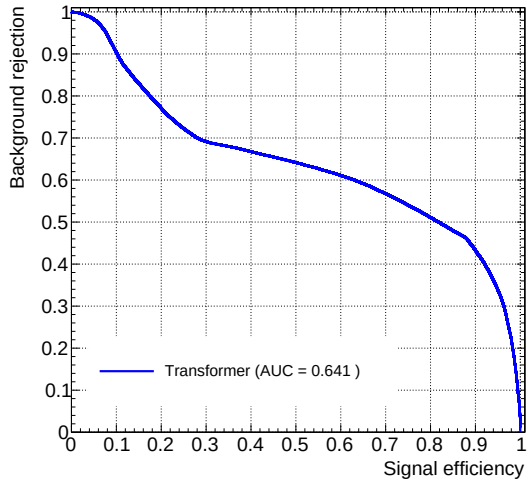


bkg rejection rate : 99.5%

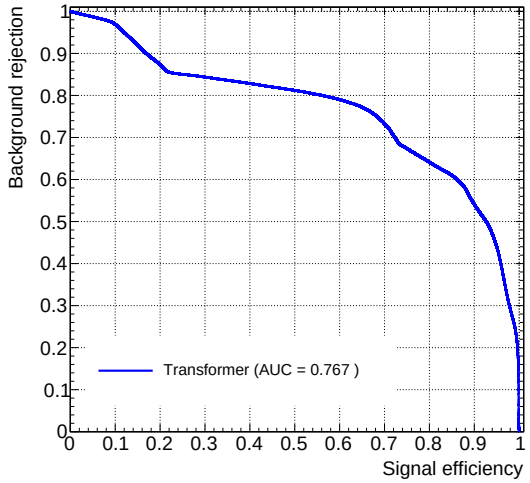
ROC curve



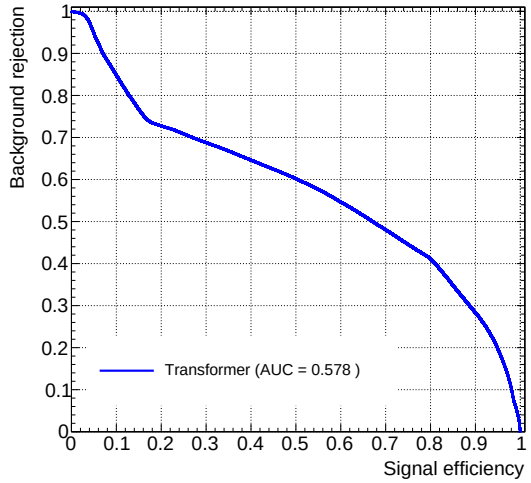
Sig:130k; data:130k



Sig:130k; data:250k



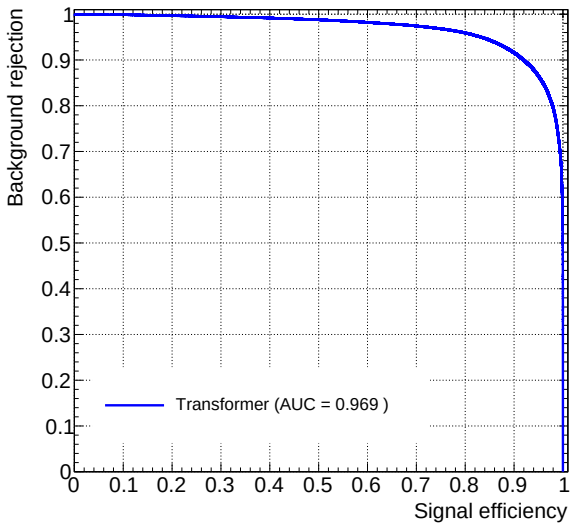
Sig:130k; data:200k



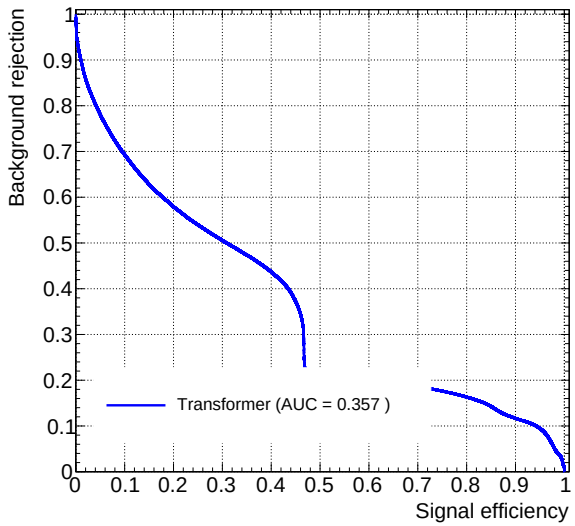
Sig:130k; data:430k

ROC curve

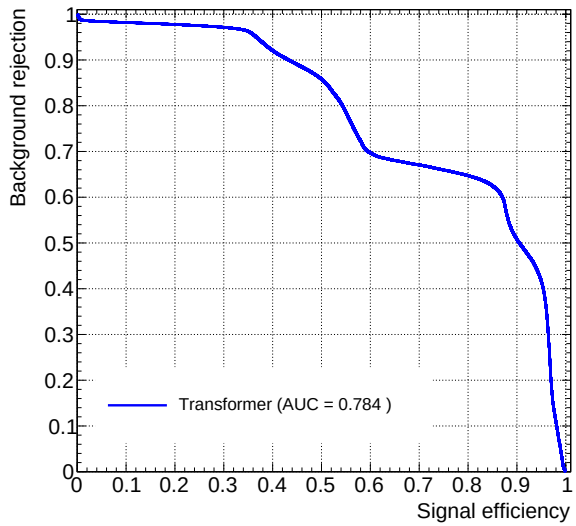
We divided the data into three parts and then applied the model to each part separately.
Signal : 130k
Data : 130k



Prat 1 : 130k



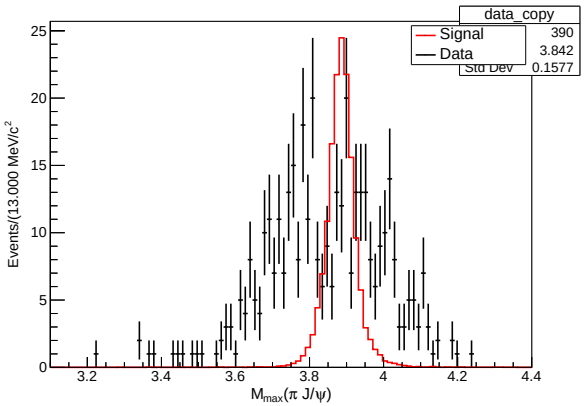
Part 2 : 130k



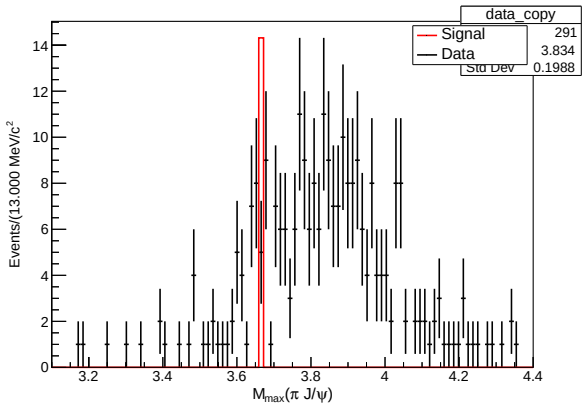
Part 3 : 130k

Test model

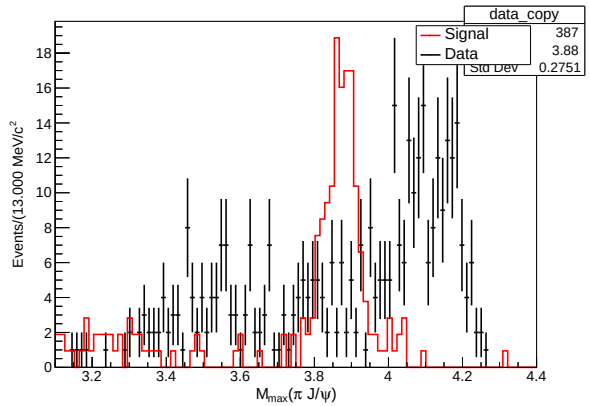
We divided the data into three parts and then applied the model to each part separately.
Signal : 130k
Data : 130k
Background rejection rate :99.7%



Part 1
Data : 390
Signal :25173



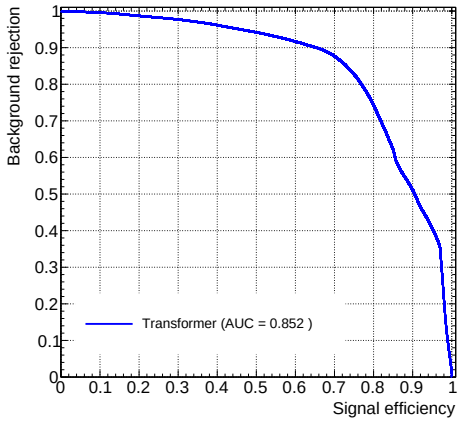
Part 2
Data : 291
Signal : 1



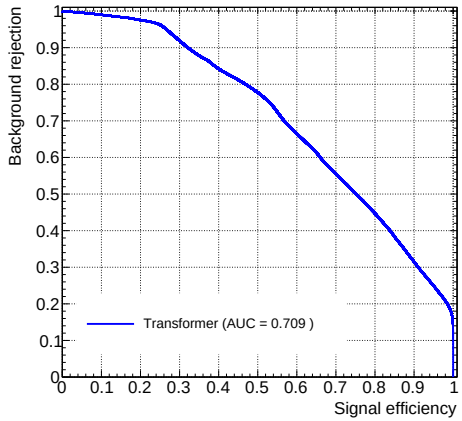
Part 3
Data : 387
Signal : 210

Test model

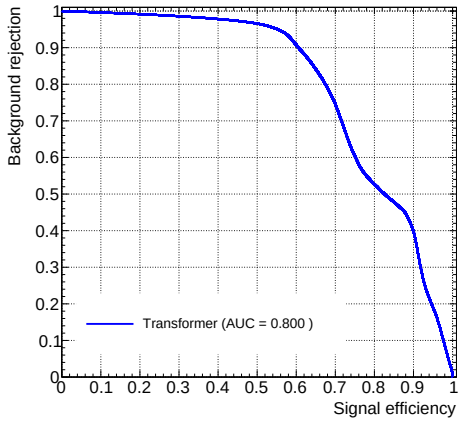
We reduce the number of epoch to train the model, and then apply the model.



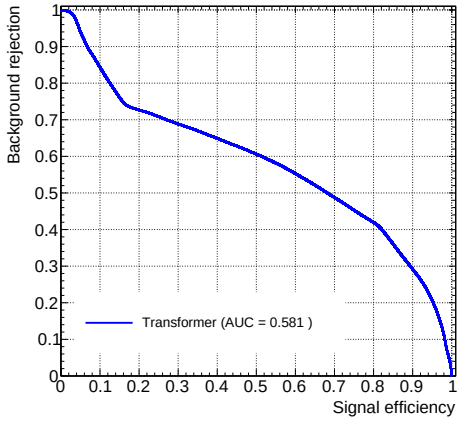
eopch :10



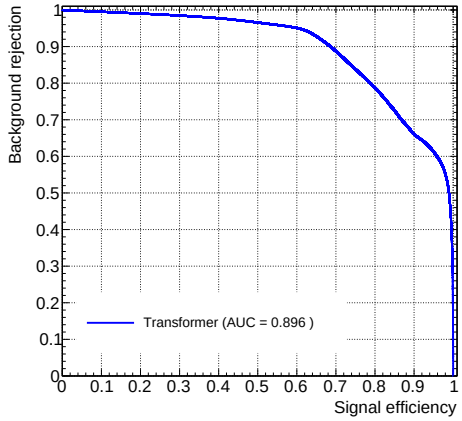
eopch :20



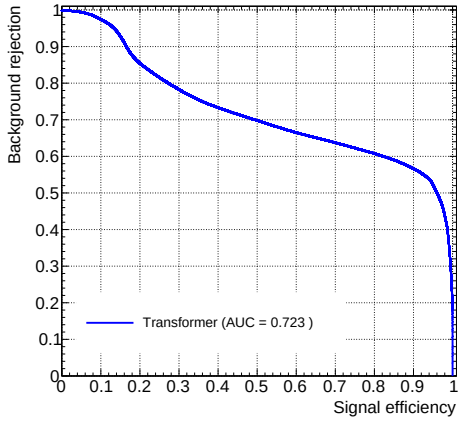
eopch :30



eopch :40



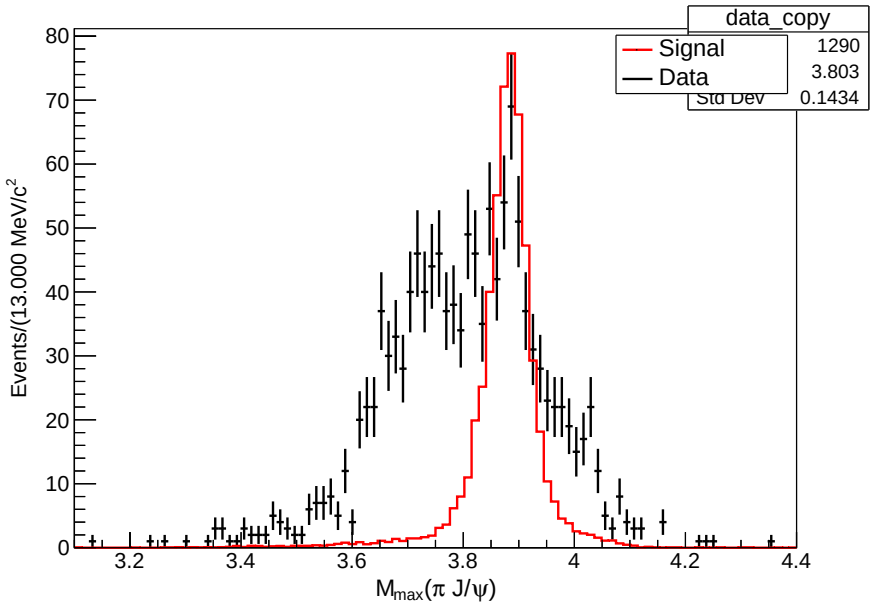
eopch :50



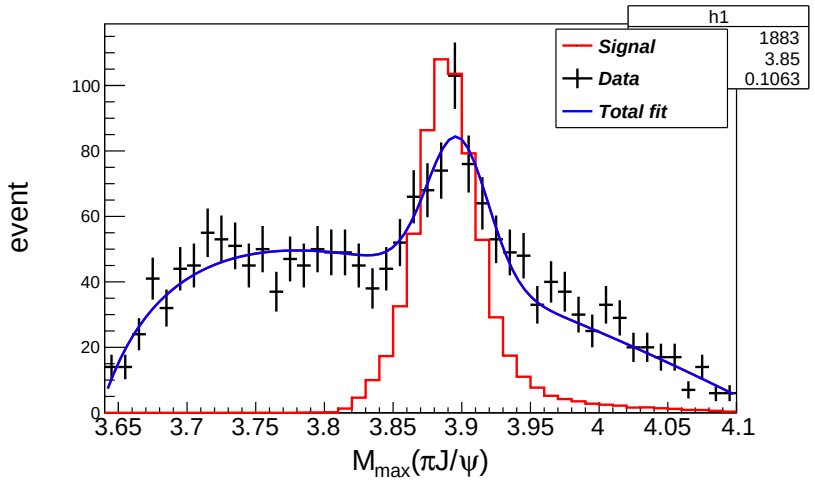
eopch :60

Test Model

Signal : 130k
Data : 430k
Background rejection rate :99.7%



Epoch : 50
Data : 1290
Signal :20146



by Cut
Data : 1883
Signal : 55474

Result

Transform 1 : use 130k sideband data to train.
Transform 2 : use all sideband data (400k) to train.

	Transform 1	**Transform 2**	**Cut**
signal	7442(5.7%)	20146(15.5%)	55474(42.6%)
Data	1290(99.7%)	1290(99.7%)	1883(99.5%)