

UPDATE TO ZZ→4l ANALYSIS

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PART I

Z+Jets on Generator Level

General Information

PROBLEM: Photons of the Z boson decay (final state radiation of electron or positron) can be wrongly identified as different particles (electron or positron)

Number of events: 135 915

Total number of electrons: 247 118
Number of electrons with mother Z boson:135915 → 55% of the total electrons have mother Z boson

Total number of positrons: 247 059
Number of positrons with mother Z boson:135 915 → 55.01% of the total positrons have mother Z boson

Total number of photons: 18 028 792
Number of photons with mother Z boson: 223 470 → on average 2 photons per event result from Z decay

↓

Photons percentage after pT>5GeV/c and deltaR>0.1 (in respect to electron or positron) cut: 2.50%

Number of photons (from the total number of photons) with pT>5GeV is 56 088 → 0.31%

Mother of Electrons

Electrons from Z boson:
Number of electrons with mother Z boson:135 915 → 55% of electrons result from Z boson

Electrons from light I=0 mesons:
Number of electrons with mother η meson: 6145
Number of electrons with mother ω meson: 88

Electrons from light I=1 mesons:
Number of electrons with mother π^0 meson: 97 278

→ 41.89% of electrons result from Dalitz decay

Electrons from c quark:
- **Mesons**

Number of electrons with mother D^0 meson: 3012
Number of electrons with mother D^- meson: 2137
Number of electrons with mother D^+_s meson: 698

- **Baryons**

Number of electrons with mother Λ^-_c baryon: 226
Number of electrons with mother Ξ^0_c baryon: 24

→ 2.47% of electrons result from c quark

Electrons from b quark:
- **Mesons**

Number of electrons with mother B^0 meson:180
Number of electrons with mother B^- meson: 519
Number of electrons with mother B^0_s meson:180

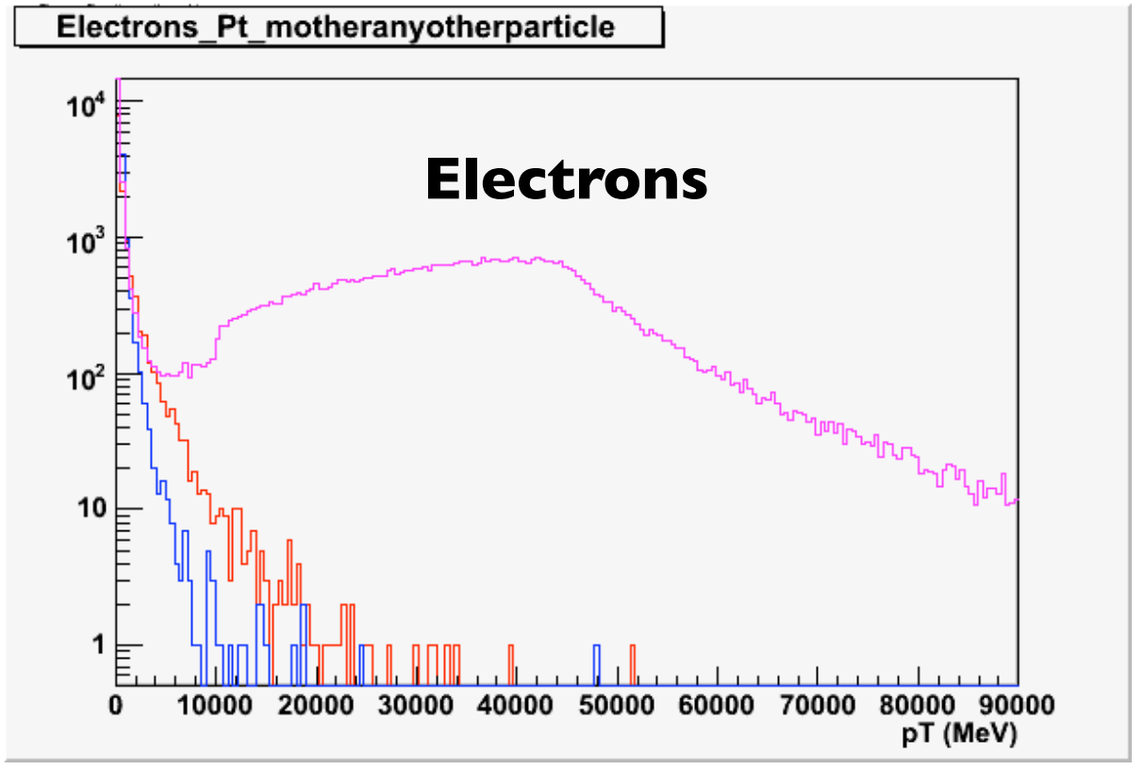
- **Baryons**

Number of electrons with mother Λ^0_b baryon: 115
Number of electrons with mother Ξ^0_b baryon: 6

→ 0.41% of electrons result from b quark

★For positrons similar results can be obtained

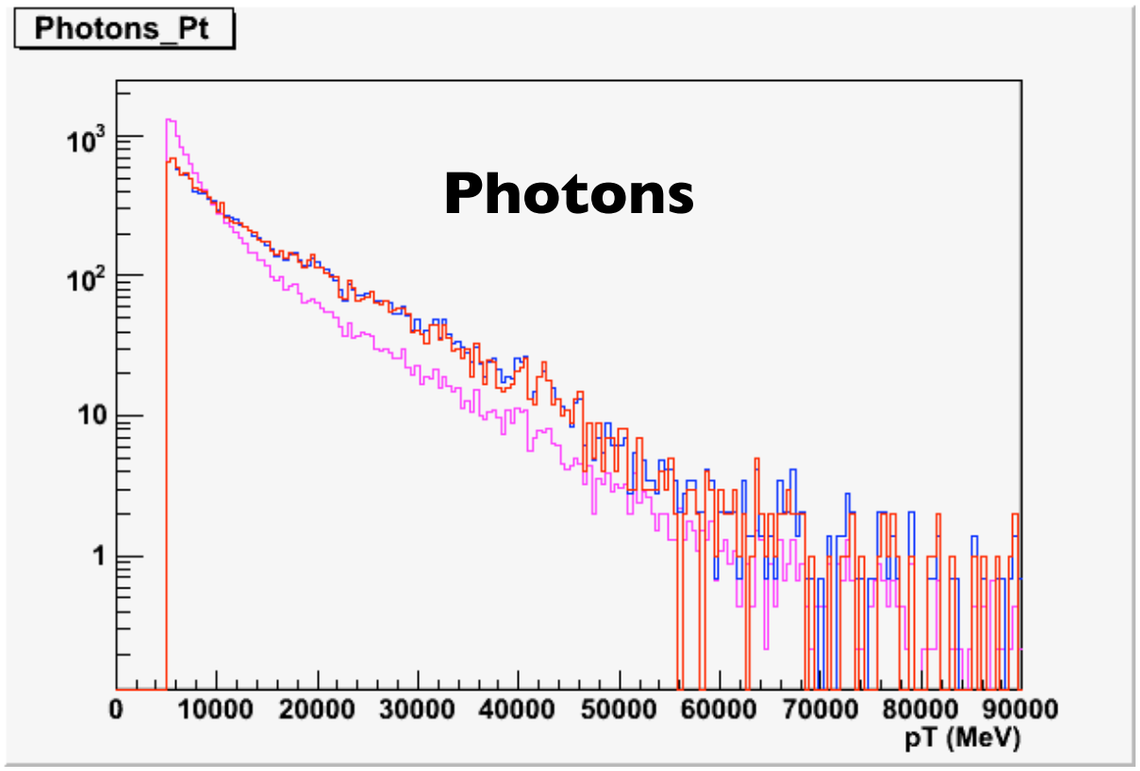
Electrons & Photons pT



---- All
---- Mother any other particle except Z^0, π^0
---- Mother π^0

The histogram is normalized to the same number of entries.

<u>Normalization method:</u>
Entries_Mother_ π^0/Entries_All
Entries_Mother_ π^0/Entries_ Mother any other particle except Z^0, π^0

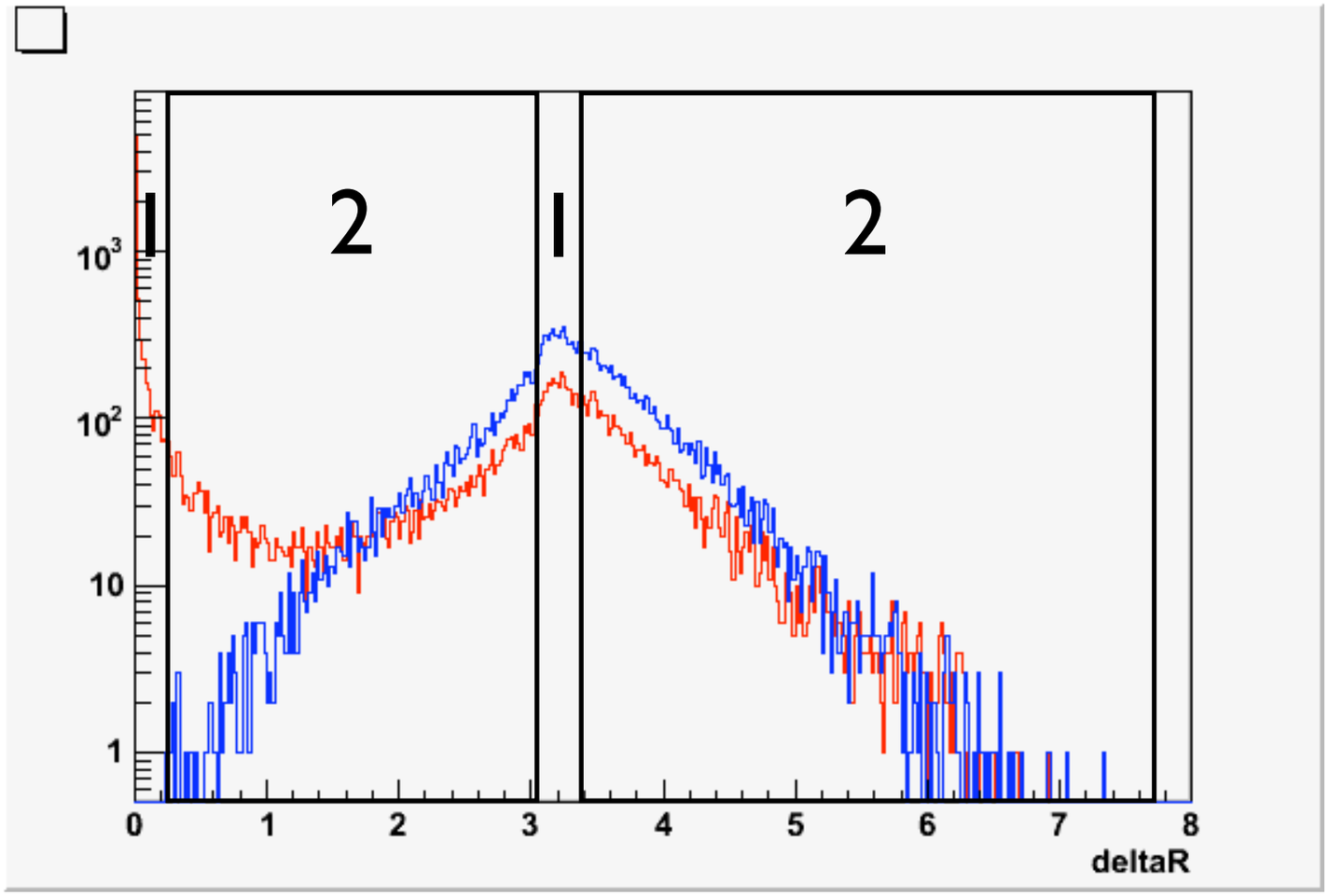


---- All
---- Mother Z^0
---- Photons colinear with electrons or positrons

The histogram is normalized to the same number of entries.

<u>Normalization method:</u>
Entries_Photons_colinear/Entries_All
Entries_Photons_colinear/Entries_Mother_Z

DeltaR

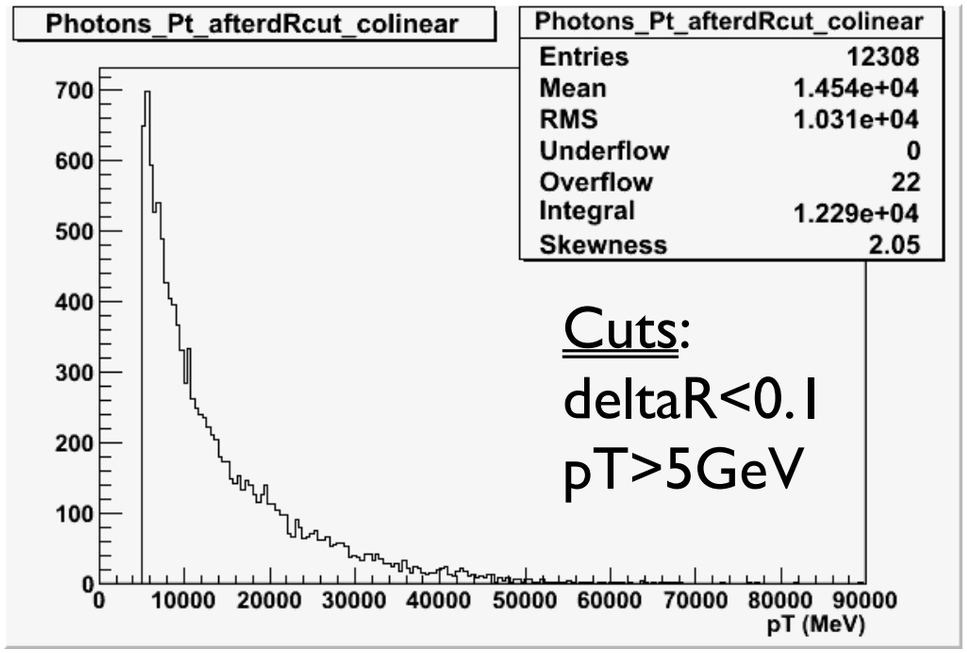


---- Electrons_Photons_deltaR
---- Electrons_Positrons_deltaR

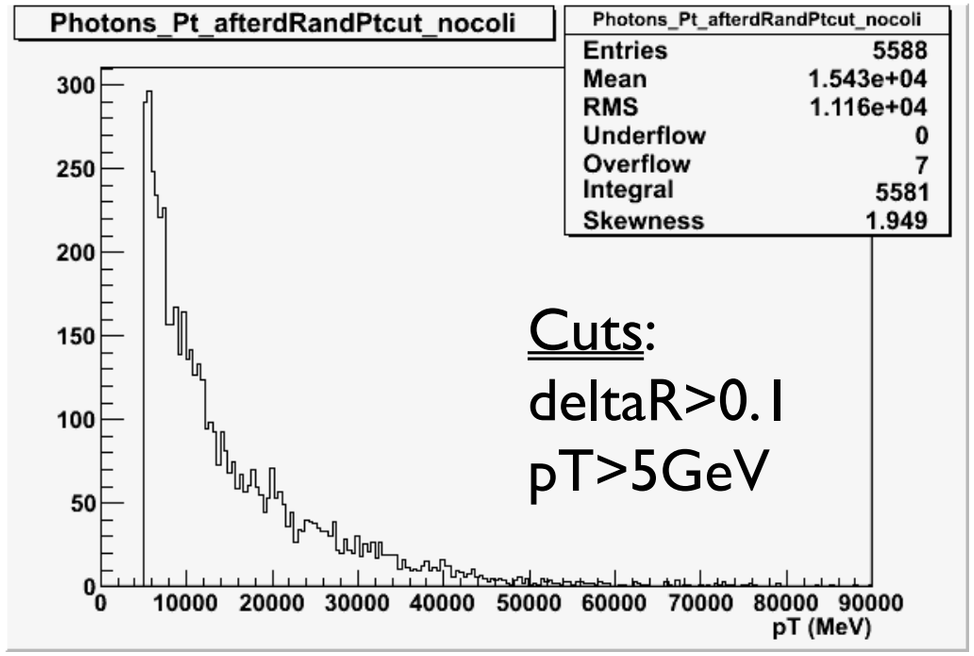
Area 1: photons which are colinear with electrons or positrons

Area 2: photons which are not colinear with electrons or positrons

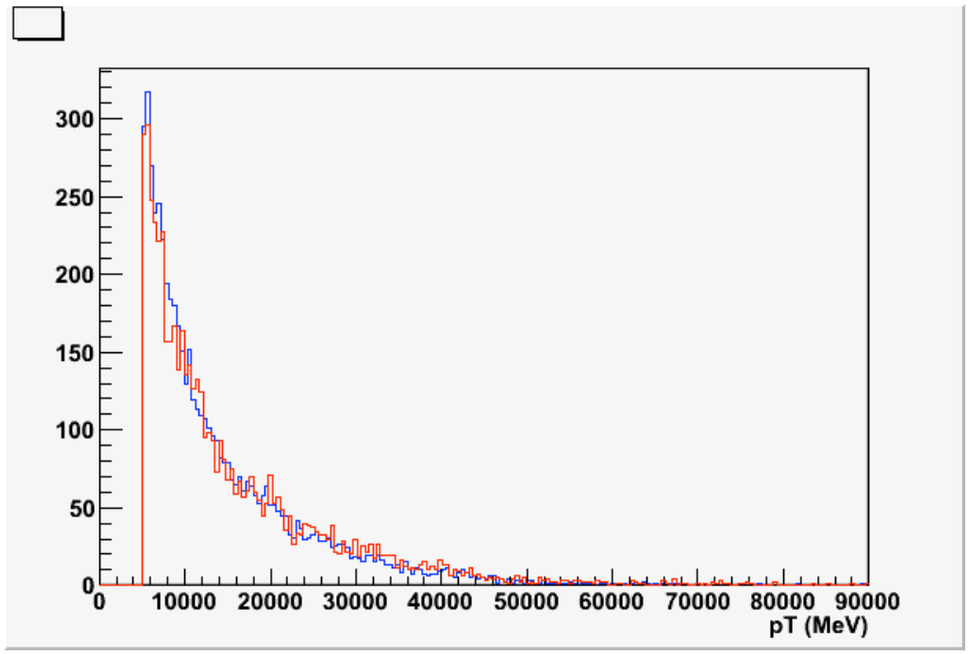
pT Distributions



1: Colinear Photons



2: Non-Colinear Photons



---- Non-Colinear Photons
---- Colinear Photons

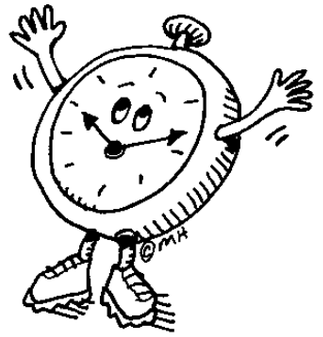
The histogram is normalized to the same number of entries.

Future Plans

★ The next step of this study is to run for full simulated Monte Carlo events in order to see:

a) The probability of the non collinear photons with p_t > 5GeV/c

b) whether these non colinear photons affect our results on the ZZ→4l analysis



PART II

Status of ZZ→ 4l measurement

Cuts Of Our Analysis

This analysis is with Athena **13.0.40** using **AthenaRootAccess**.

Preselection Cuts:

Electrons

★ Duplicates Removal: Duplicate effect occurs in the case of electrons. Two reconstructed electrons with the same track give different shower to the electromagnetic calorimeter. If in the same electron belongs two clusters of energy at the electromagnetic calorimeter we choose the cluster of energy with the largest value of E_t (**new**)

★ Author Egamma or EgammaSoft

★ p_t > 5 GeV & |η| < 2.5

STACO Muons

★ Combined Track OR Standalone Track for |η| > 2.5

★ χ^2/DOF < 15 on match

★ p_t > 6 GeV/c , |η| < 2.7

More detailed comparison with 12.0.6 in indico (http://indico.cern.ch/conferenceDisplay.py?confId=32796 Ilektra Christidi)

Cuts Of Our Analysis

After Preselection:

Electrons - Muons

★ deltaR>0.2 (angle between the two leptons of the pair)

★ At least one electron in each pair with p_t > 20 GeV

★ Isolation:

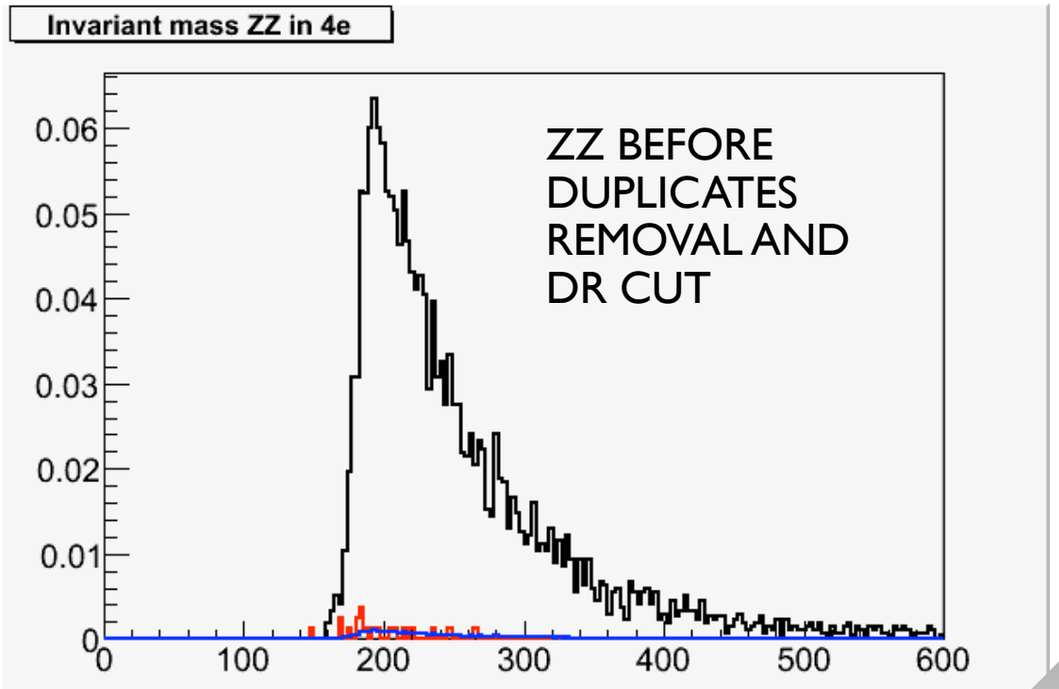
- Electrons: IsEM = 0xFFFF (Something between Medium and Tight)
- Muons: Isolation Ratio < 0.2 (energy in a cone of deltaR<0.4 around the muon divided by E_t)

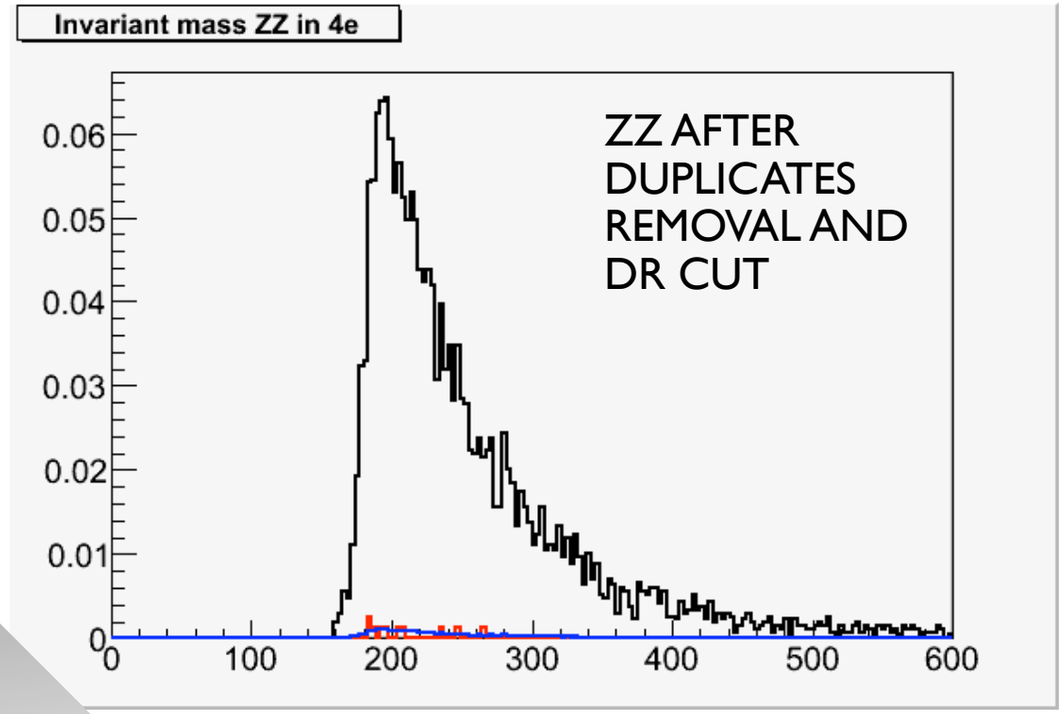
★ 2l invariant mass

- **ZZ:** 70 < m(pair1) < 110 GeV/c
  70 < m(pair2) < 110 GeV/c

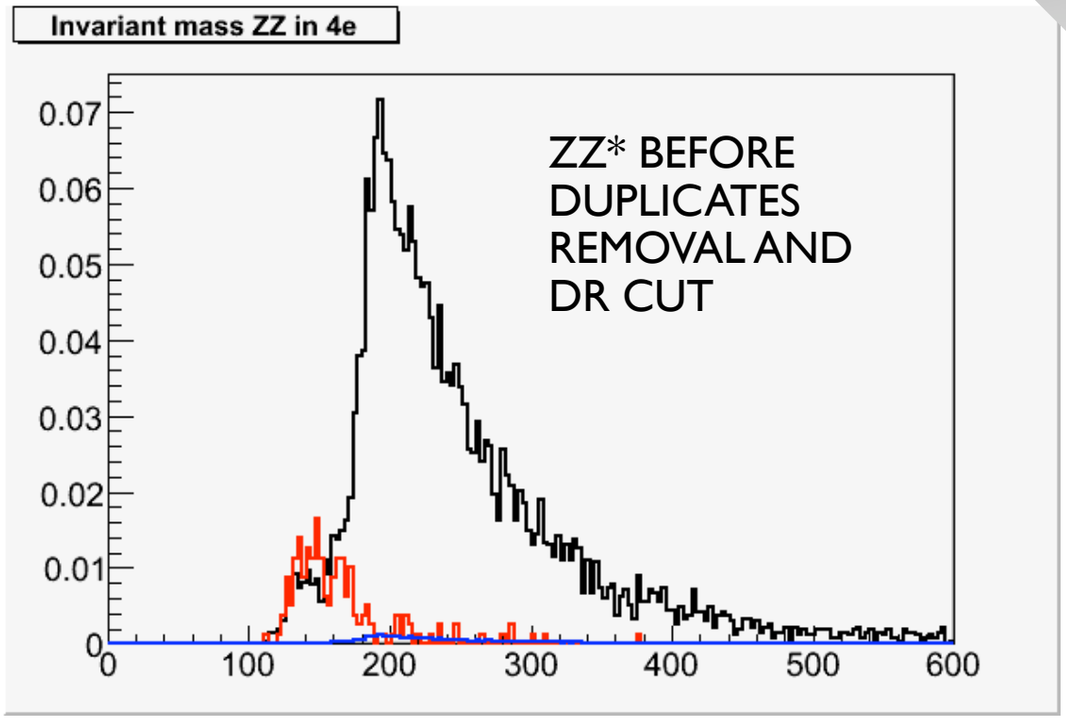
- **ZZ*:** 70 < m(pair1) < 110 GeV/c
  m(pair2) > 20 GeV/c

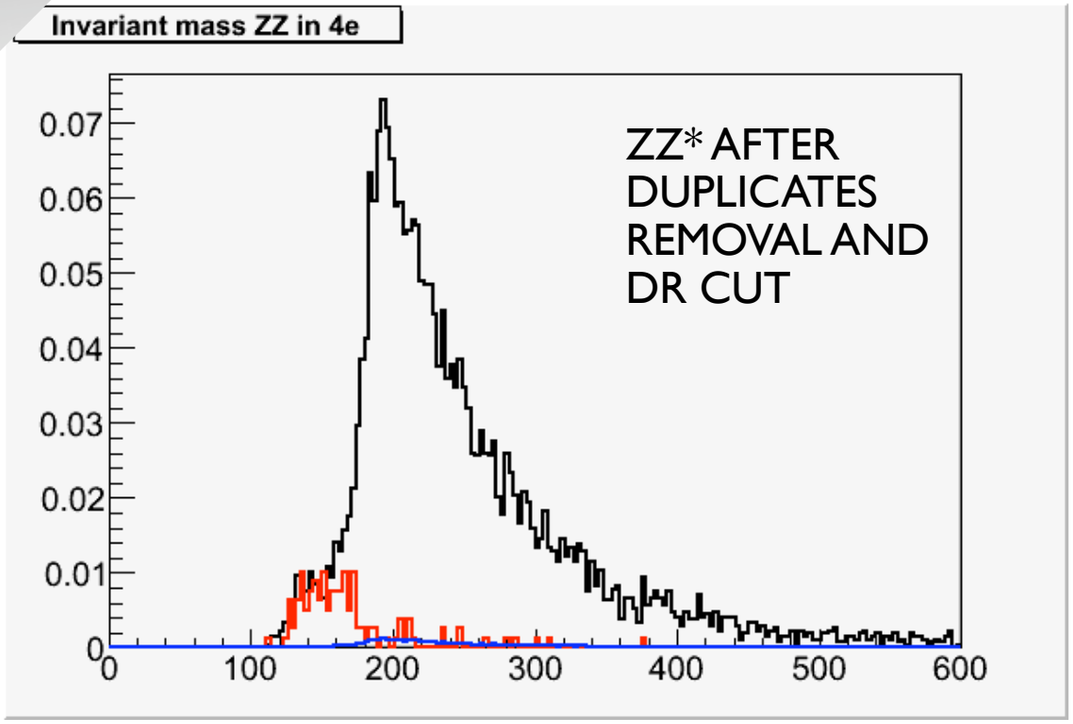
Final 4e Invariant Masses ZZ & ZZ*





Scaled to 1fb^{-1}
ZZ→4e signal
Zbb (bg)
ttbar (bg)





Results for electrons: signal/background

Normalized to 1fb^{-1}

Before Duplicates Removal & deltaR cut

13.0.40	ZZ	ZZ*
Signal	2.54±0.03	3.16±0.03
Zbb tt *Z+Jets*	0.064±0.009 0.048±0.028 *51*	0.467±0.024 0.366±0.076 *127*
Total background	0.112±0.029	0.833±0.080

ZZ: Signal/Background = 22.67

ZZ*: Signal/Background = 2.91

After Duplicates Removal & deltaR cut

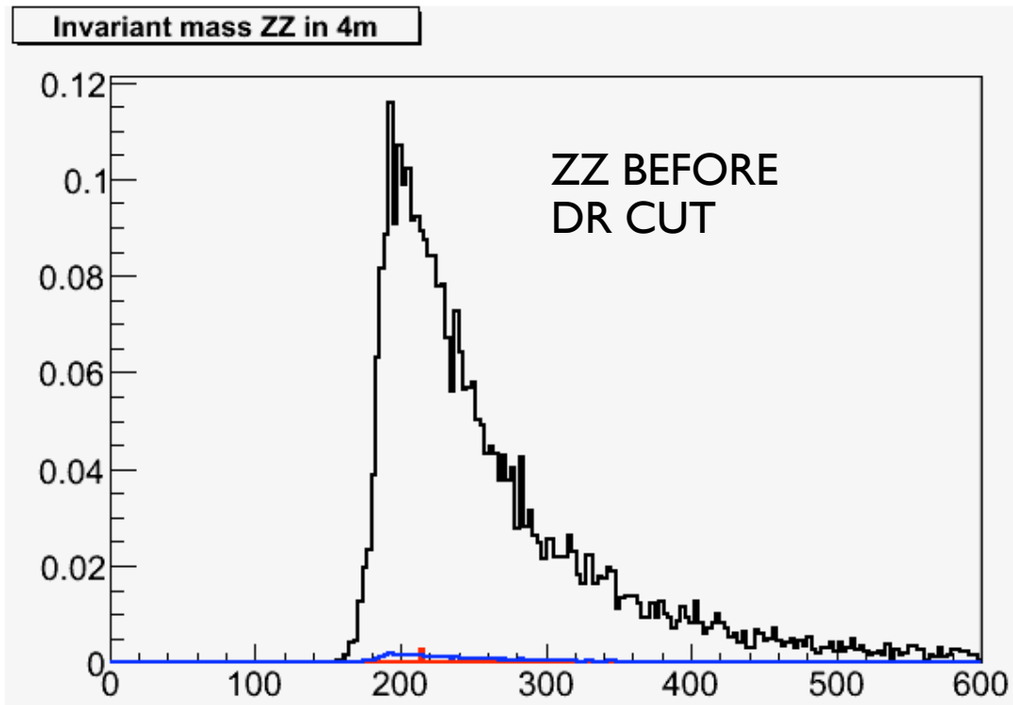
13.0.40	ZZ	ZZ*
Signal	2.50±0.03	3.10±0.03
Zbb tt Z+Jets	0.021±0.005 0.032±0.023 1.424	0.247±0.018 0.271±0.066 4.237
Total background	0.053±0.023	0.518±0.068

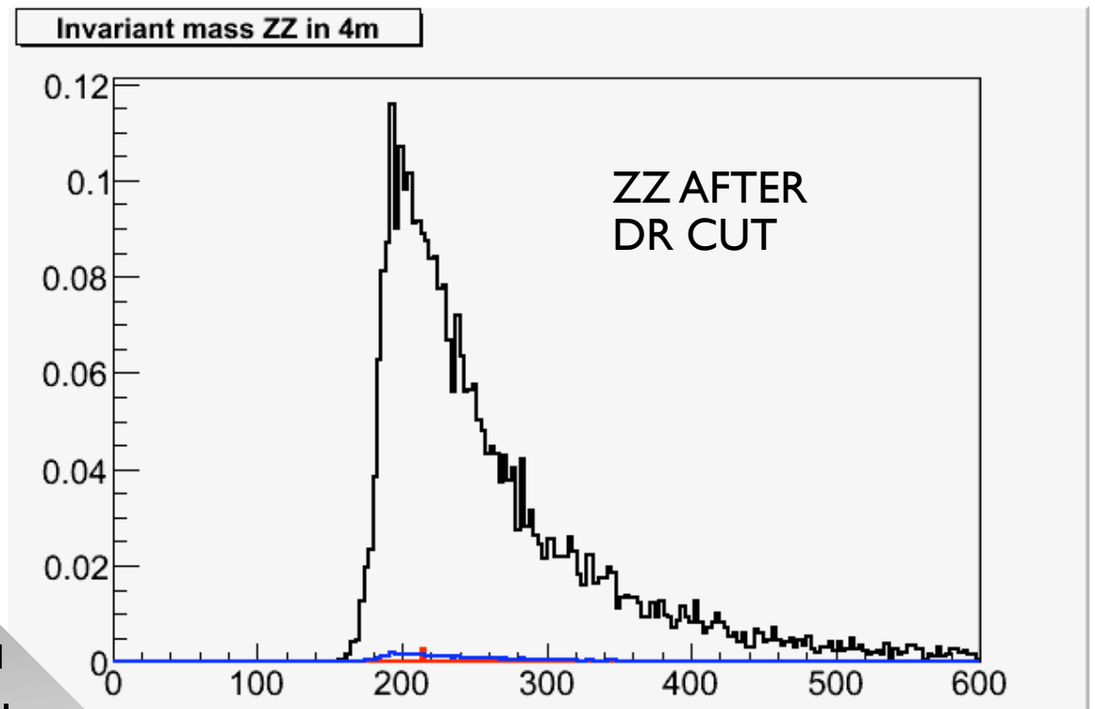
ZZ: Signal/Background = 47.17

ZZ*: Signal/Background = 5.98

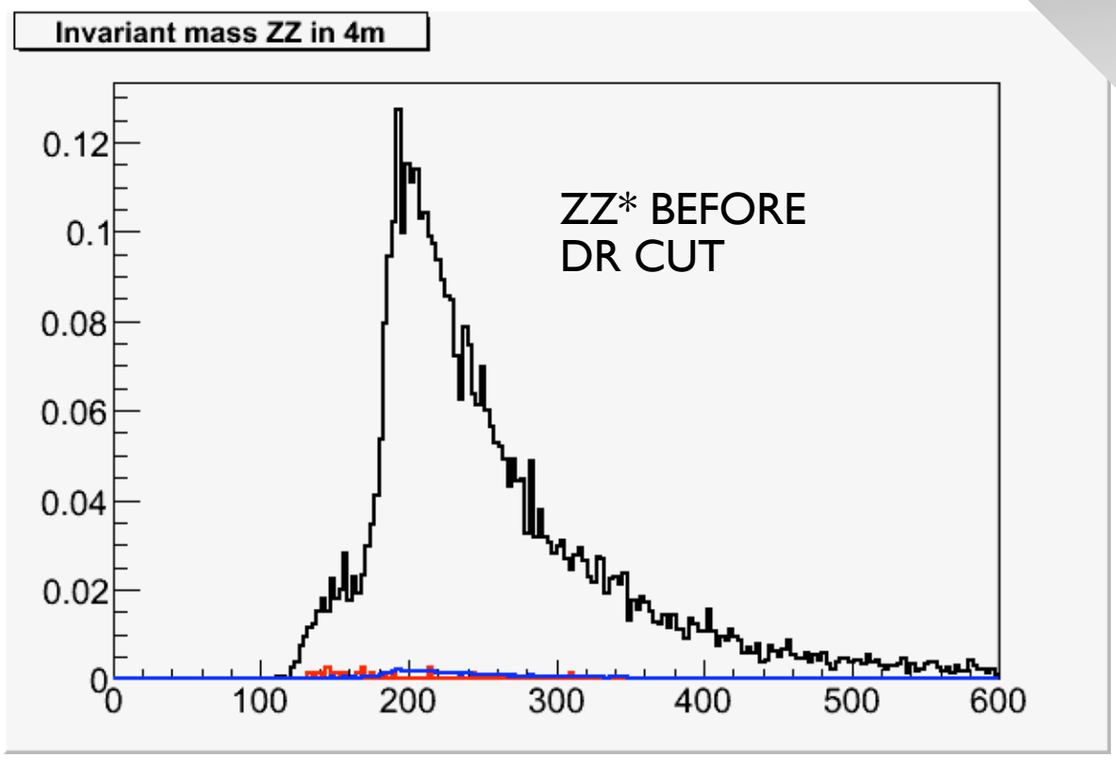
★We have to increase our statistics for Z+jets. It is an upper estimated for the Z+jets

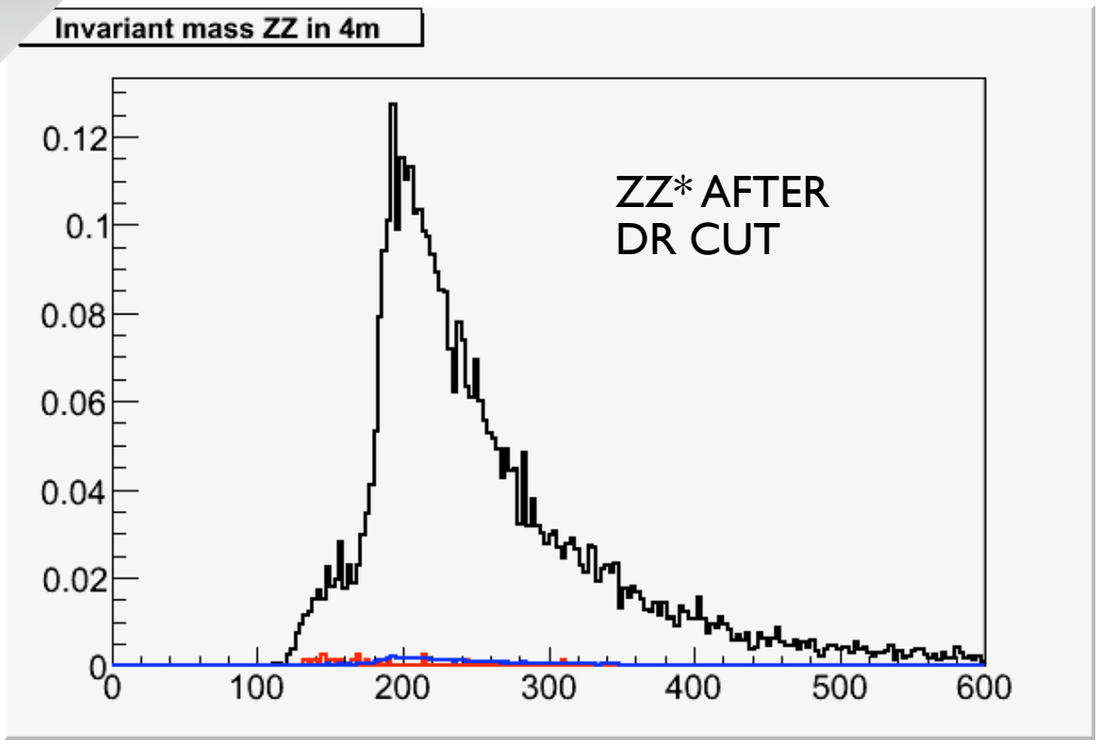
Final 4μ Invariant Masses ZZ & ZZ*





Scaled to 1fb^{-1}
ZZ→4μ signal
Zbb (bg)
ttbar (bg)





Results for muons: signal/background

Normalized to 1fb^{-1}

Before deltaR cut

13.0.40	ZZ	ZZ*
Signal	3.43±0.03	4.27±0.03
Zbb tt	0.003±0.002 0.0007±0.0005	0.021±0.005 0.032±0.023
Total background	0.003±0.002	0.053±0.023

ZZ: Signal/Background = 1143.3

ZZ*: Signal/Background = 80.6

After deltaR cut

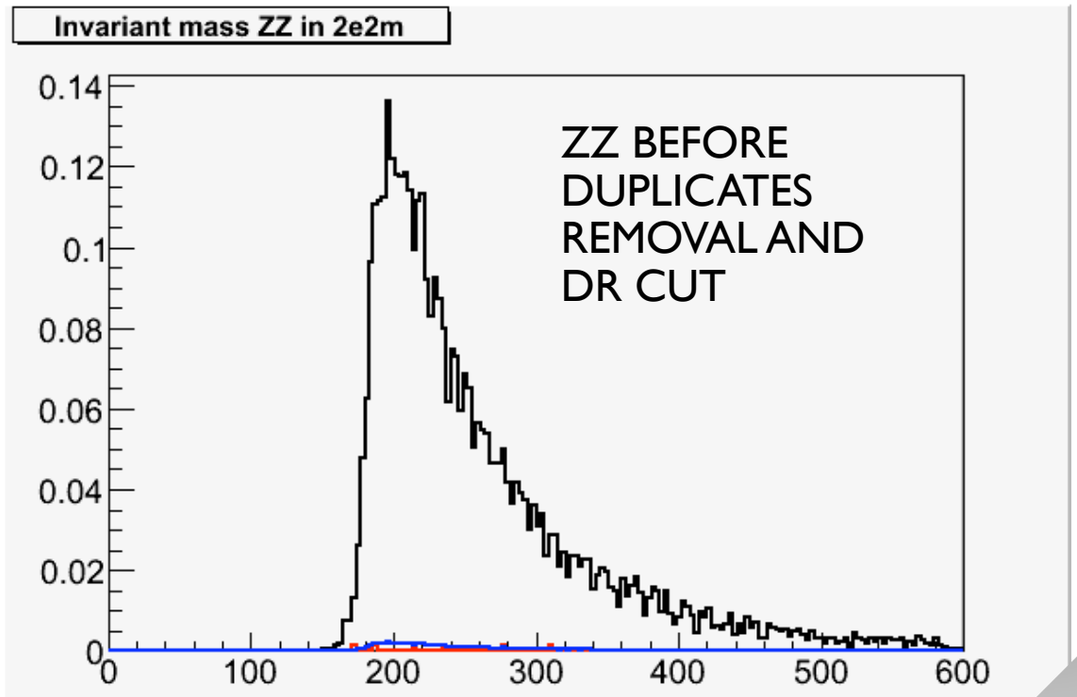
13.0.40	ZZ	ZZ*
Signal	3.42±0.03	4.26±0.03
Zbb tt	0.003±0.002 0.0007±0.0005	0.021±0.005 0.032±0.023
Total background	0.003±0.002	0.053±0.023

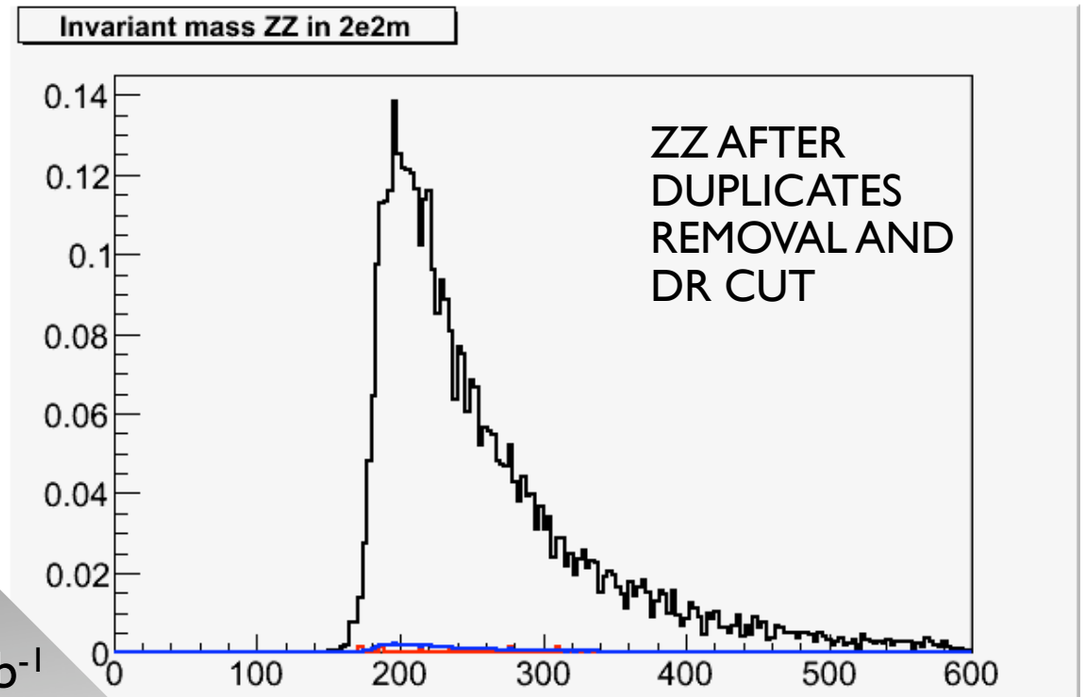
ZZ: Signal/Background = 1140

ZZ*: Signal/Background = 80.4

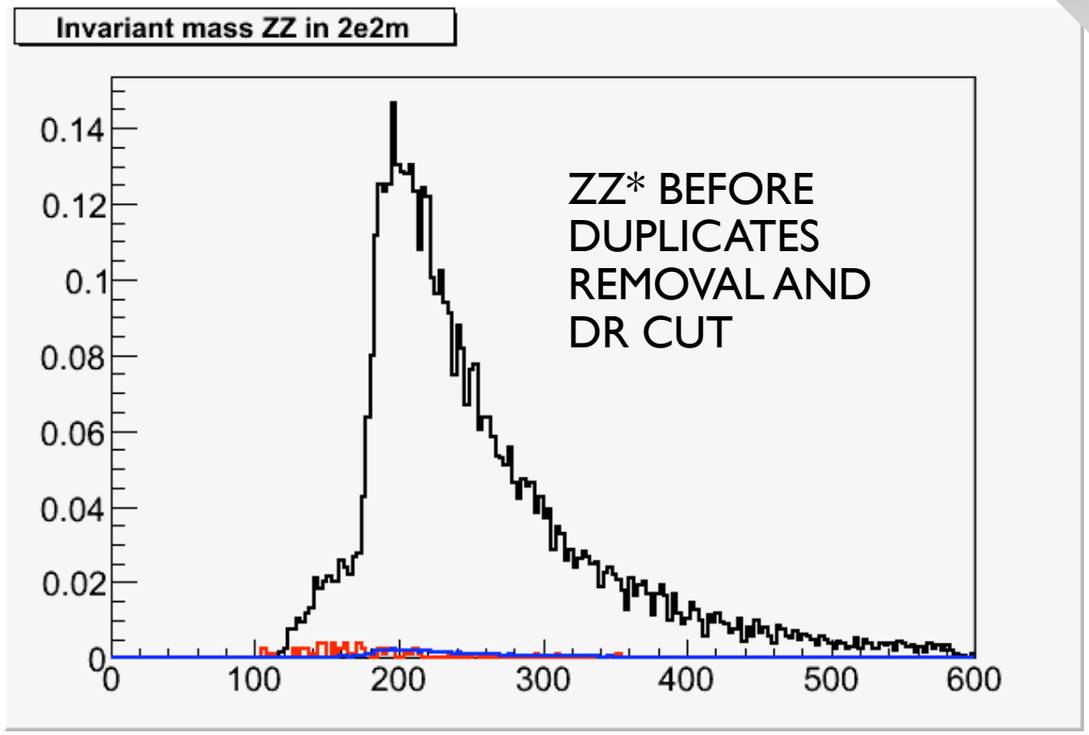
★ No estimate available for Zμμ+jets because of lack of statistics

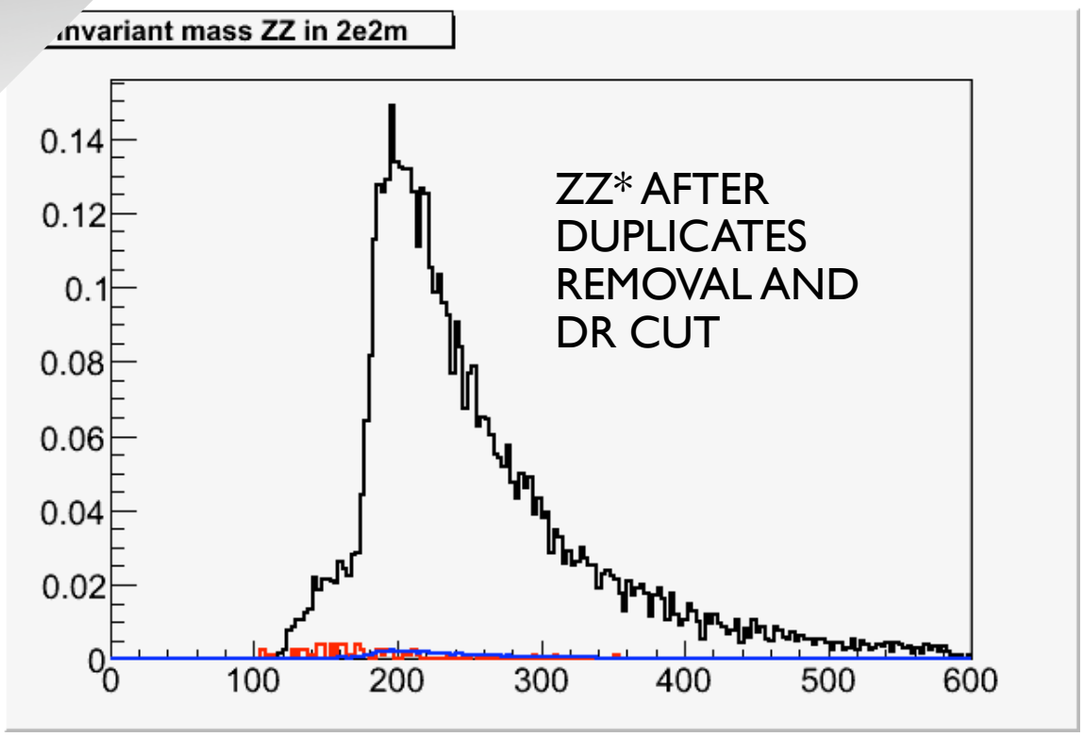
Final 2e2μ Invariant Masses ZZ & ZZ*





Scaled to 1fb^{-1}
ZZ→2e2μ signal
Zbb (bg)
ttbar (bg)





Results for 2e2μ: signal/background

Normalized to 1fb^{-1}

Before Duplicates Removal & deltaR cut

13.0.40	ZZ	ZZ*
Signal	5.53±0.04	6.78±0.04
Zbb tt	0.016±0.005 0.016±0.016	0.156±0.014 0.191±0.055
Total background	0.032±0.017	0.350±0.057

ZZ: Signal/Background = 172.8

ZZ*: Signal/Background = 19.4

After Duplicates Removal & deltaR cut

13.0.40	ZZ	ZZ*
Signal	5.52±0.04	6.68±0.04
Zbb tt	0.016±0.005 0.016±0.003	0.155±0.014 0.191±0.055
Total background	0.032±0.005	0.346±0.057

ZZ: Signal/Background = 172.5

ZZ*: Signal/Background = 19.3

Summary & Future Plans

☑ Analysis fully migrated to Athena 13.0.40 and is now done with ARA on DPDs

☑ Improved our results (in the case of 4e) after removing the duplicates and adding the deltaR cut during the process of making pairs

☑ Not significant changes in the case of 4μ and 2e2μ

★ Started looking at background from Z+jets and it could be considerable (work in progress)

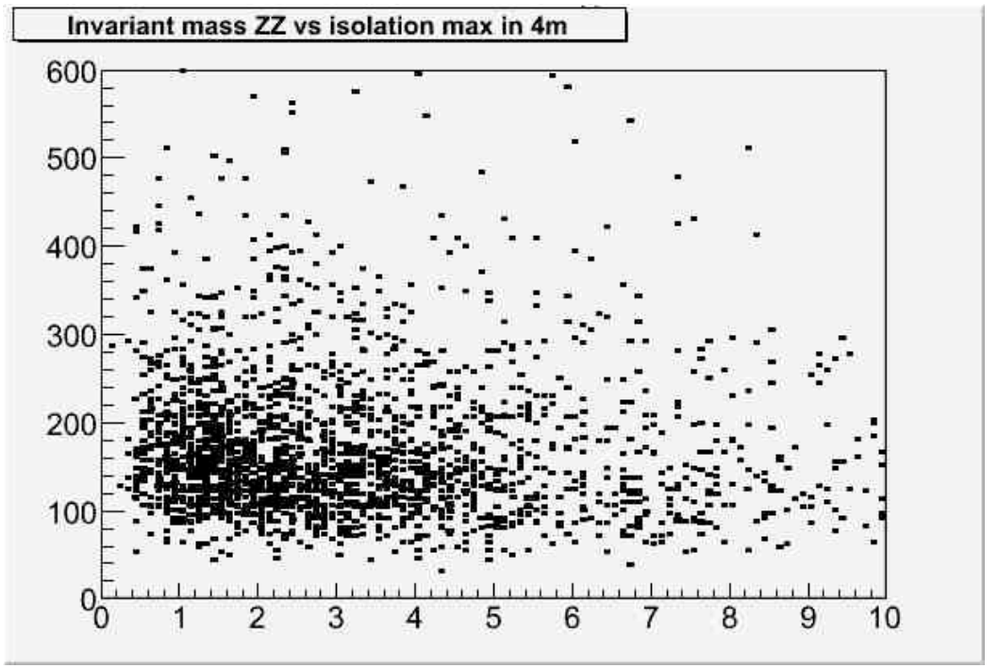
1. pT>10 GeV/c
2. Investigate isolation definitions shown in the last Artemis Monthly Meeting by Christos Anastopoulos (http://indico.cern.ch/getFile.py/access?contribId=15&sessionId=3&resId=1&materialId=slides&confId=32796)

★ Improve truth matching studies still in progress by Dimitris Iliadis.

Back-up

Technical Issues

For ttbar background



Invariant mass is uncorrelated with isolation

In order to calculate the final number of events in the case of 4m, we first calculate the efficiency of the isolation cut and then we run the algorithm without isolation cut and we multiply the final result with the efficiency of the isolation cut.

For Z+jets background

We use similar logic in the case of Z+jets. Actually, in the case of Z+jets we use the final mass cut efficiency of Zbb (Zbb is a subset of Z+jets), in order to calculate the final number of 4e events.