ZZ→4l : Status and future plans

1st Artemis Annual Meeting

27-28 September 2007

Chalkidiki, Greece

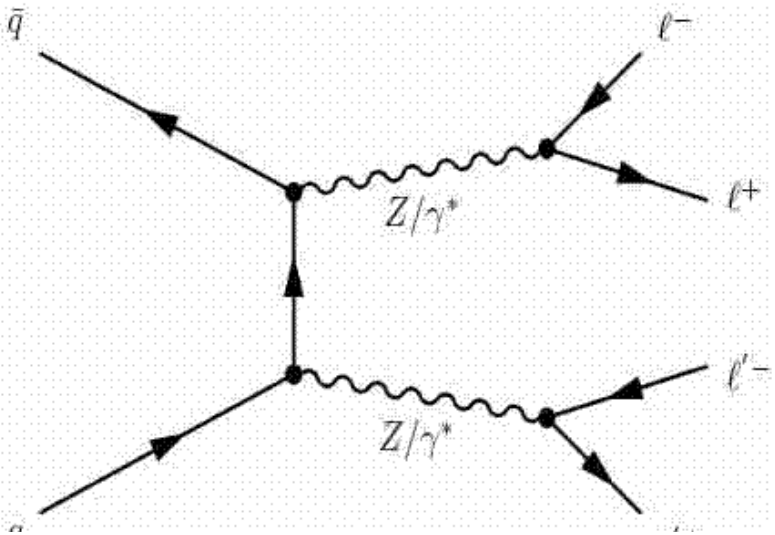
For the AUTh group:
Ilektra Christidi

Overview

- Current analysis status (work done for CSC note using AOD w/ straight cuts)
  - Muon & electron selection
  - Single lepton efficiency & fake rates
  - Lepton pairing and cuts on pairs
  - Results
- Things to be done for current analysis
- Further future plans
  - TGC limits
  - Measurement of $Zb\bar{b}$

Motivation

- SM cross section not measured yet
- Irreducible background to H→4l
- Develop tools for detector calibration using Z→2l
- Beyond the SM: Triple Gauge Couplings (TGCs)



- Backgrounds: $Zb\bar{b}$, $t\bar{t}$

Preselection cuts

Muons (STACO):

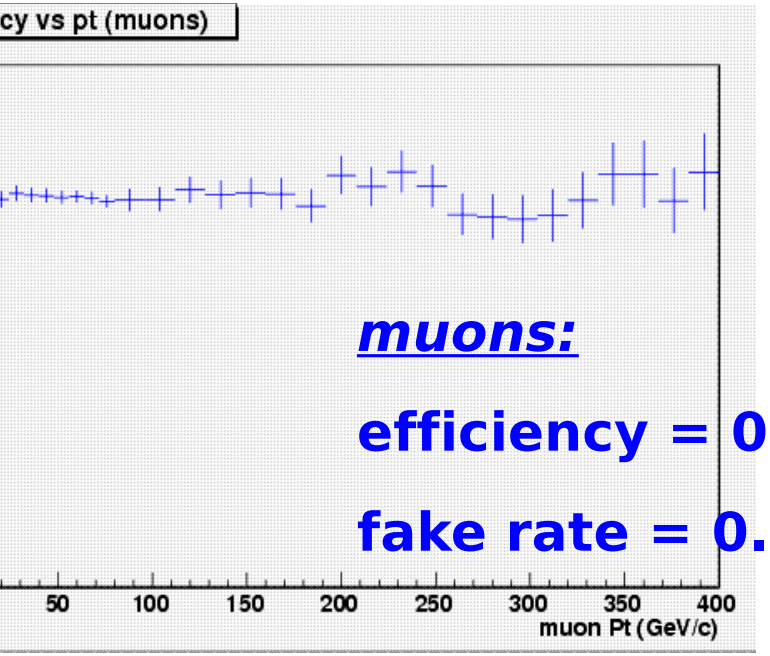
- Combined Track OR (Standalone Track AND |η|>2.5)
- chisq/DOF < 15 on match
- chisq/DOF < 15 on fit
- Pt > 6 GeV/c, |η|<2.7

Electrons

- Author Egamma OR EgammaSoft
- 0.5 < E/P < 3.0
- Pt > 6 GeV/c, |η|<2.7

Create opposite charge pairs with lepton dR>0.2

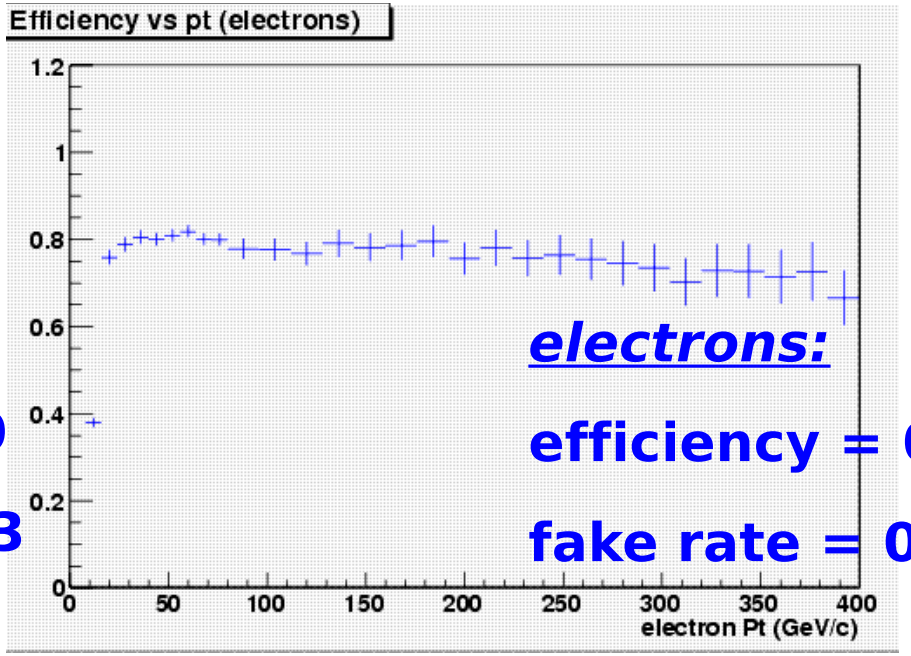
Single lepton effic./fakes



muons:

efficiency = 0.90

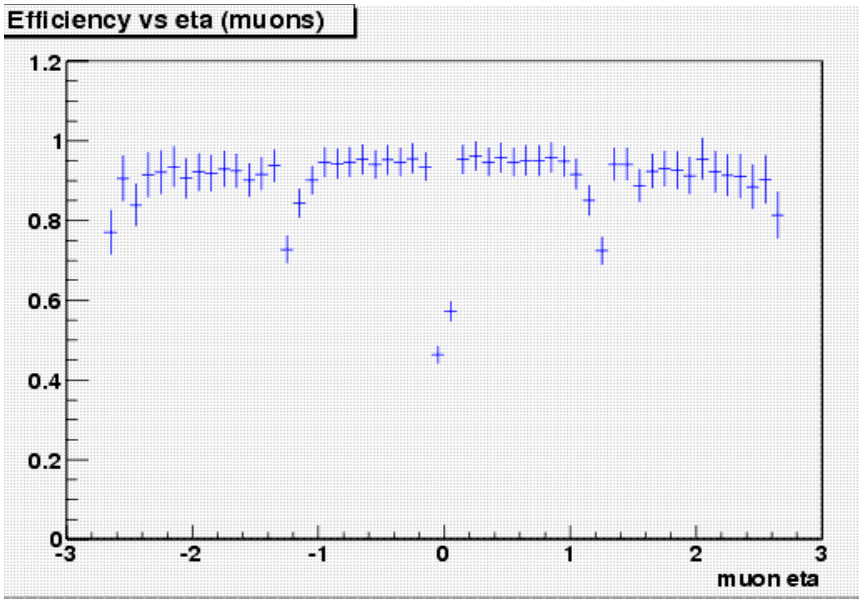
fake rate = 0.003

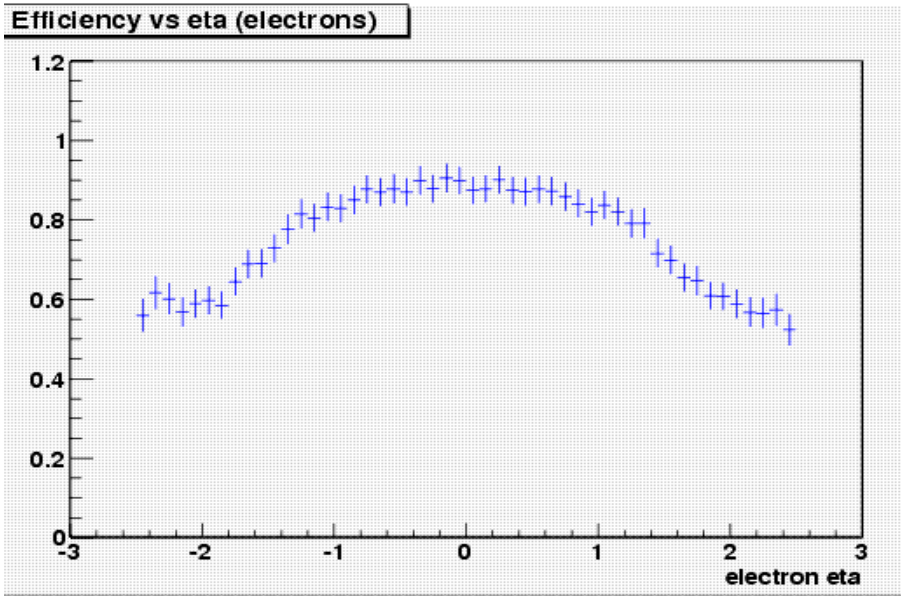


electrons:

efficiency = 0.76

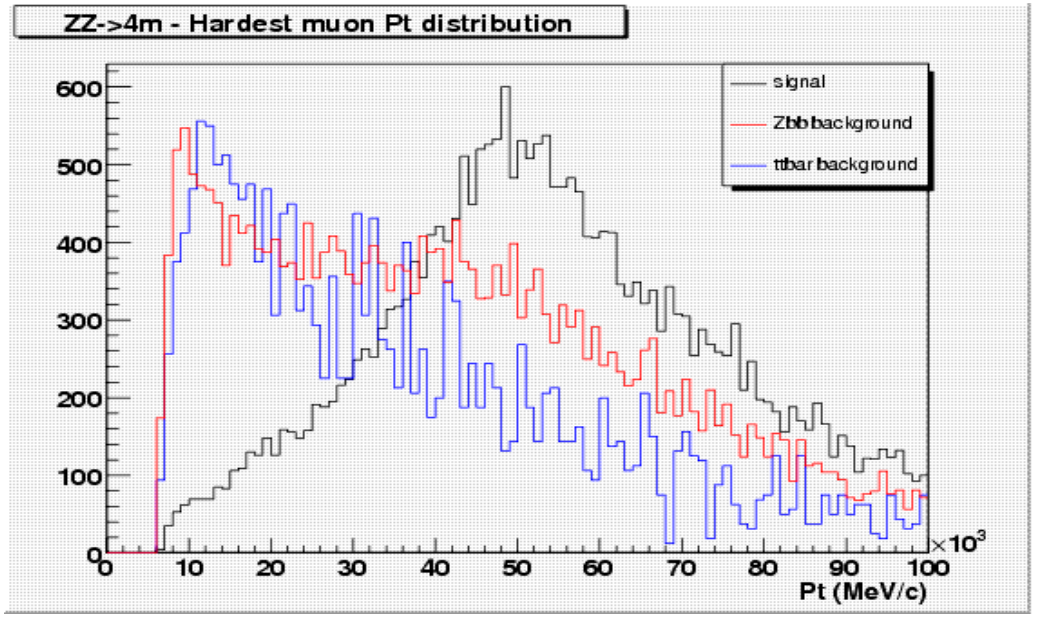
fake rate = 0.001

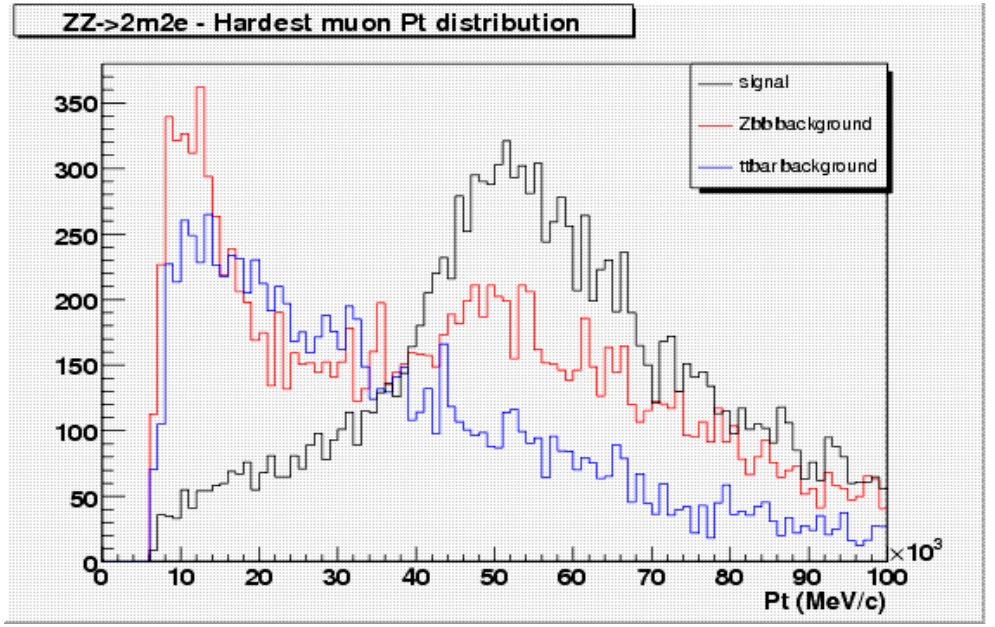


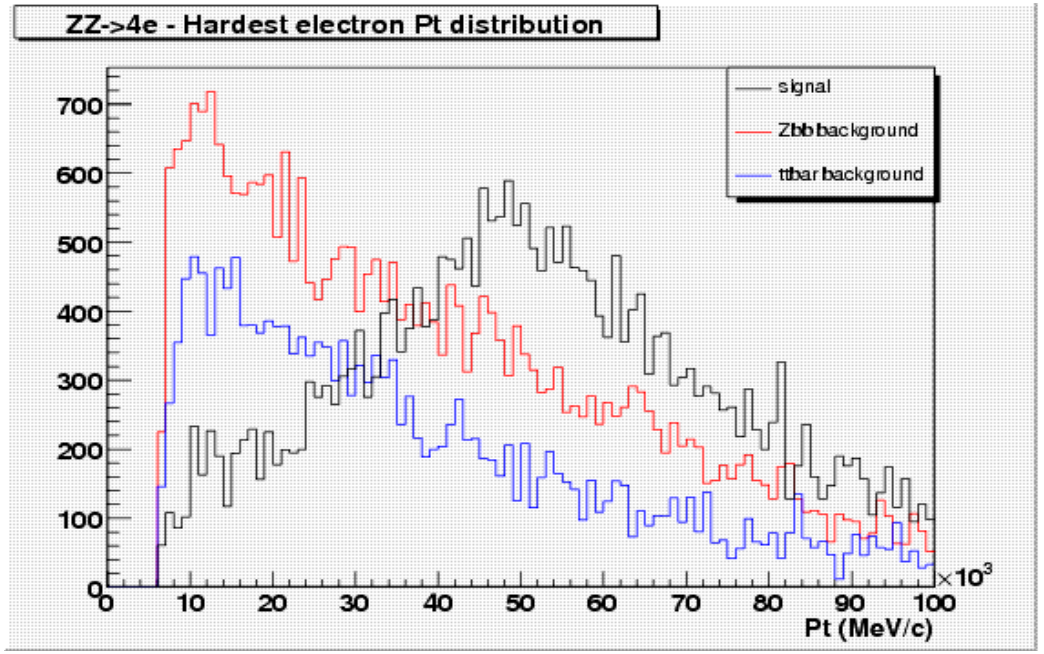


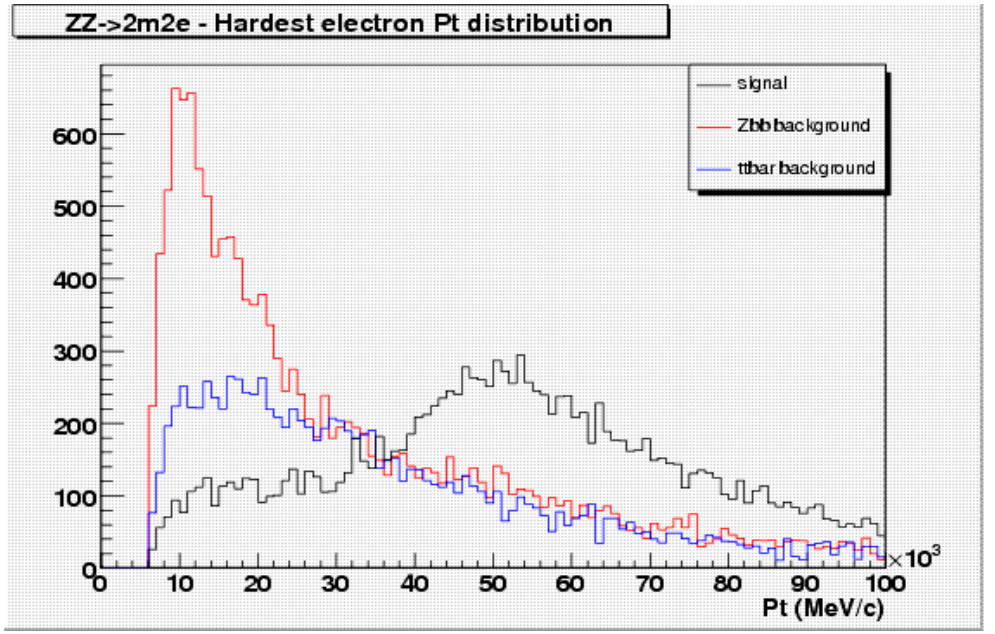
After Preselection: Pt

At least one lepton in each pair with Pt > 20 GeV/c



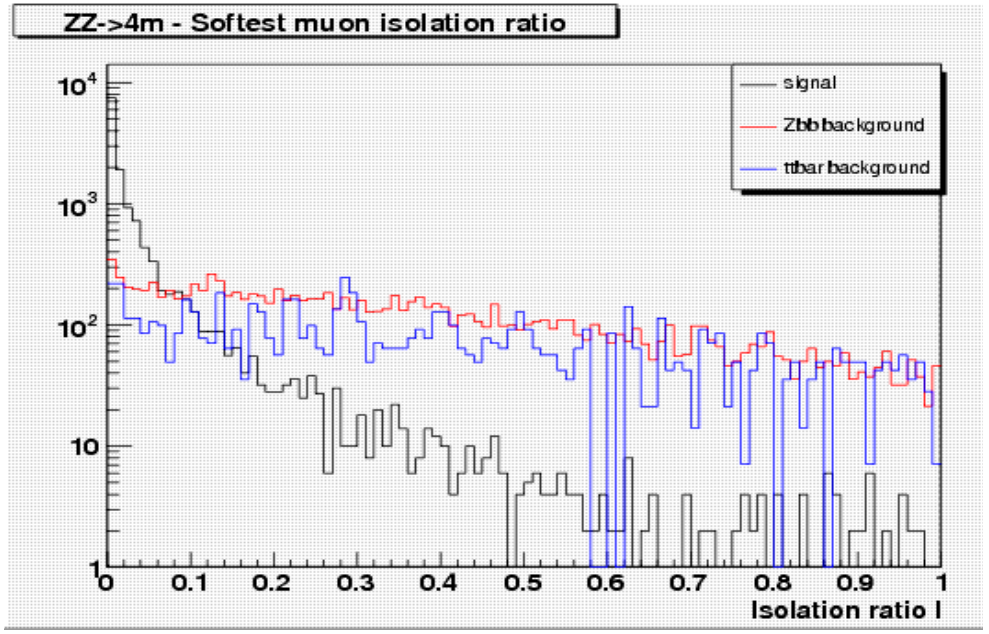


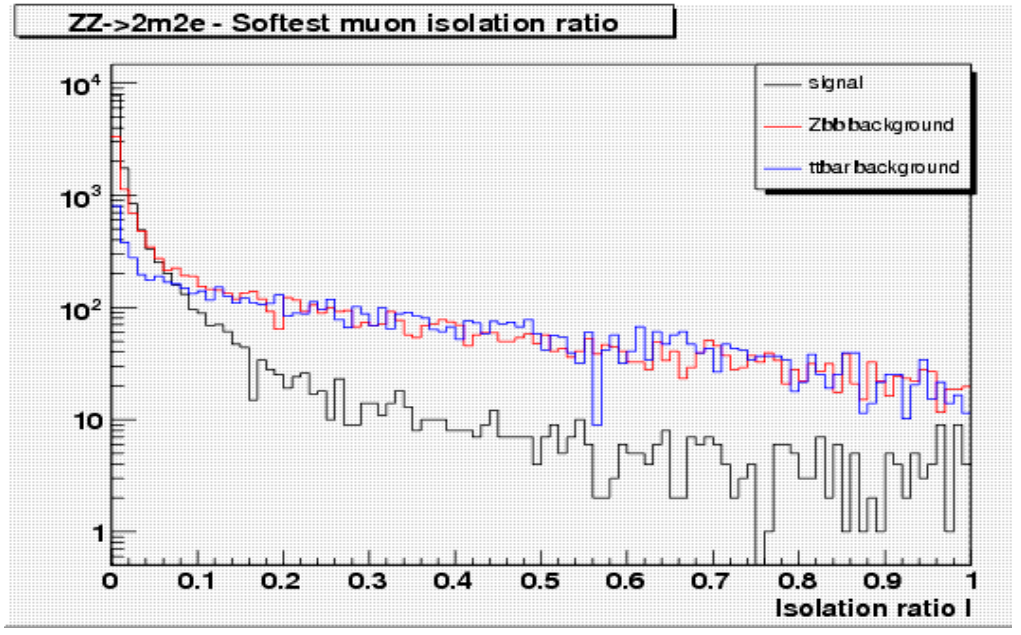


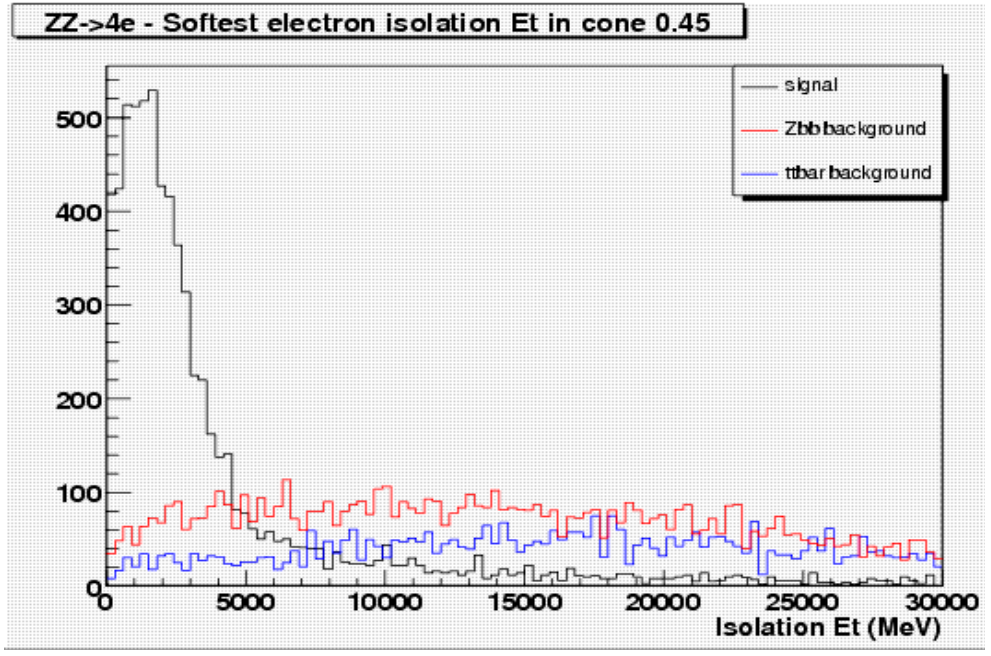


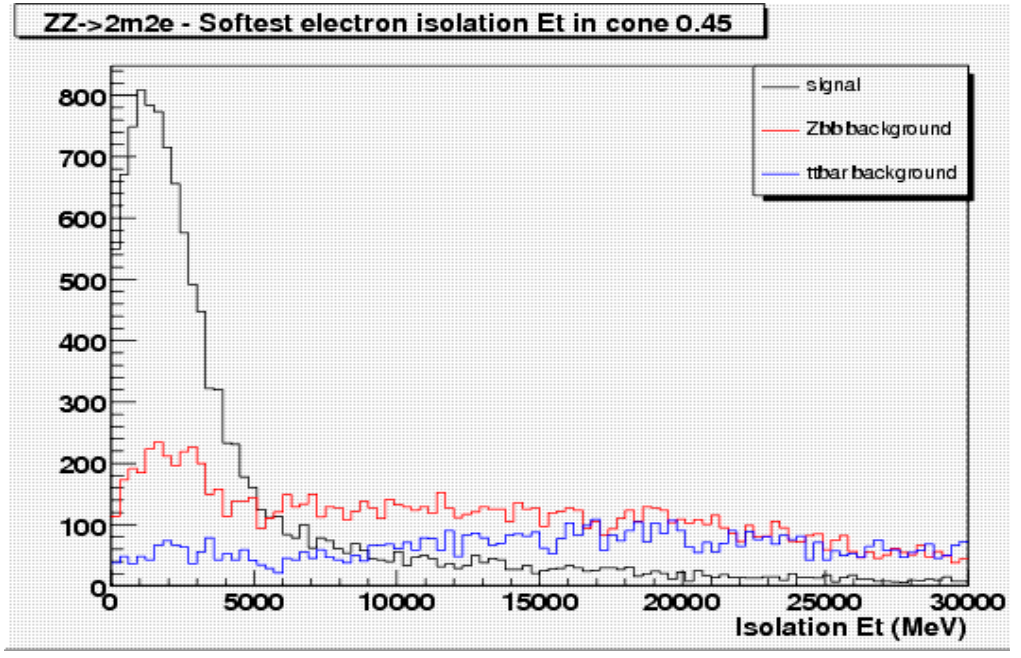
After Preselection: Isolation

Muon: Isol. Ratio < 0.3, Electron: Et in 0.45 cone < 10 GeV



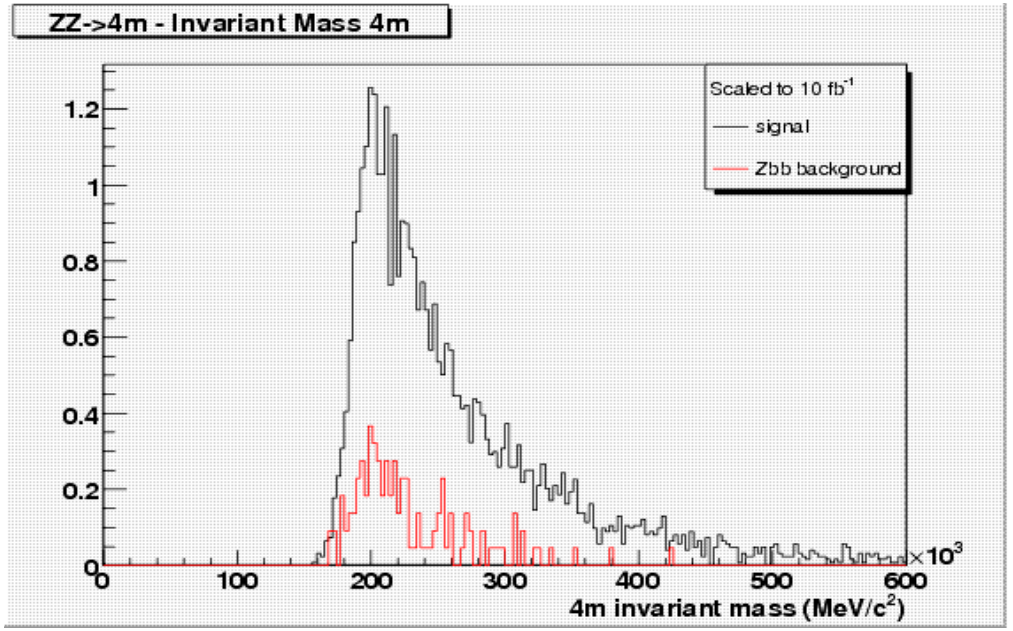


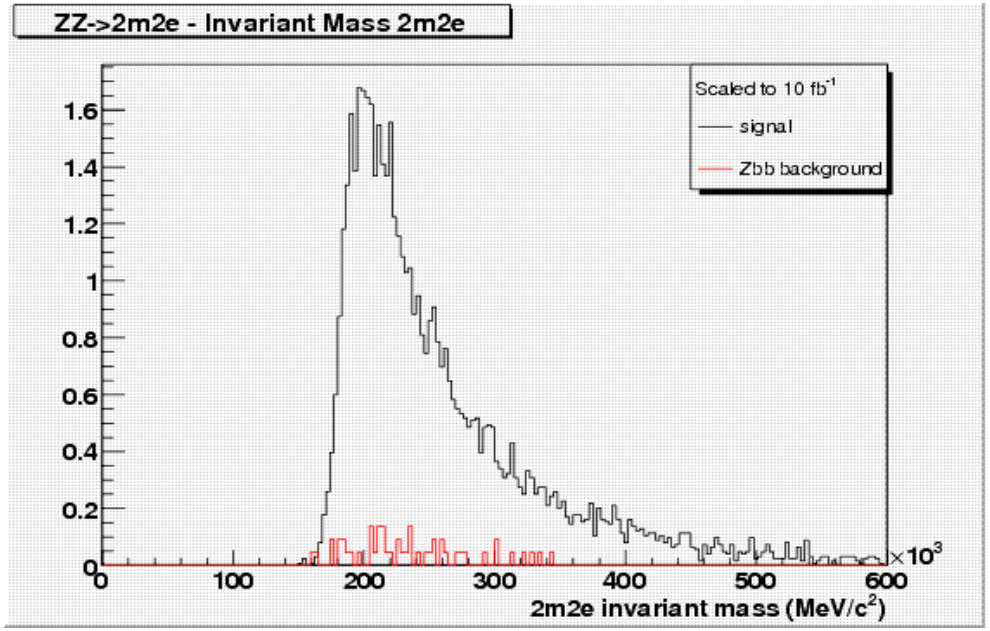


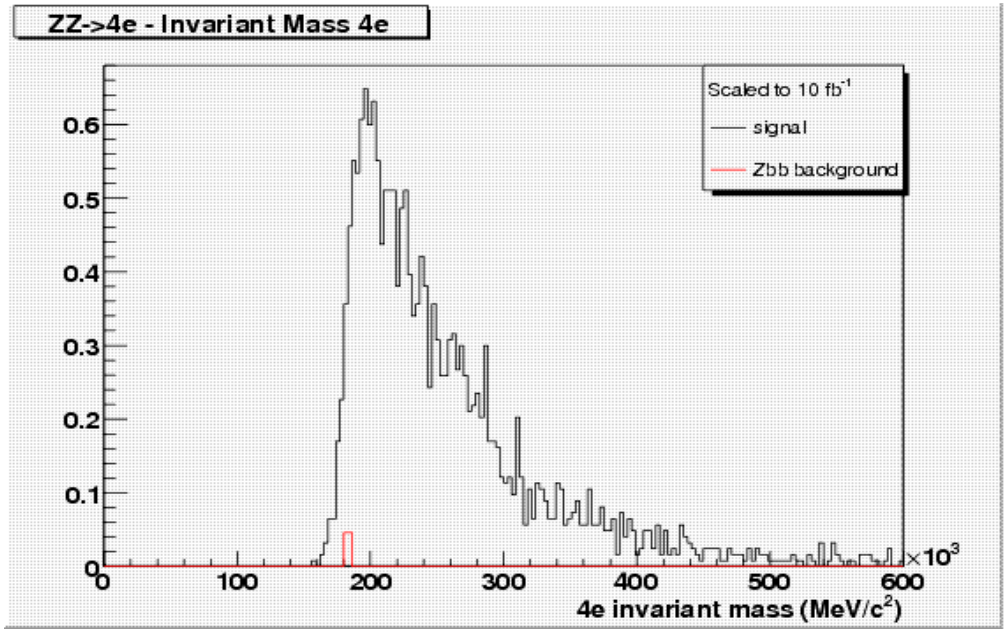


Final 4l Invariant Masses

After Z invariant mass cut: 70 GeV/c² < m(Z) < 110 GeV/c²







$\bar{t}t$ bg not shown, because of lack of statistics

Effic./rejection: summary

Signal

	$ZZ \to 4\mu$ (%)	$ZZ \to 4e$ (%)	$ZZ \to 2\mu 2e$ (%)
Lepton Preselection	70.7	62.3	65.4
Pair formation,dR	99.3	88.0	93.4
Isolation, P_t^{max}	92.3	62.2	70.5
Z Mass region	71.1	73.0	76.1
Total	46.1±0.8	24.9±0.6	32.8±0.5

$t\bar{t}$

	4μ	$4e$	$2\mu 2e$
Lepton Preselection	32.1	3.8	2.7
Pair formation,dR	1.6	1.8	2.3
Isolation, P_t^{max}	8.4	846.3	70.0
Z Mass region	20.8	>12	23.4
Total	8973.6 ± 3165.6	$69464.3 \pm 100\%$	10172 ± 3820.5

$Zb\bar{b}$

	4μ	$4e$	$2\mu 2e$
Lepton Preselection	16	9.5	5.4
Pair formation,dR	1.3	1.7	2.1
Isolation, P_t^{max}	3.6	24.1	28.9
Z Mass region	11.0	138	6.8
Total	823.7 ± 72.3	53711.7 ± 38117.0	2228.5 ± 322.1

Results: signal/bg

Results below are normalized to $10fb^{-1}$

	4μ events	$4e$ events	$2\mu 2e$ events	Total
Signal	3.74 ± 0.06	1.95 ± 0.06	5.34 ± 0.08	11.03 ± 0.12
$Zb\bar{b}$	0.60 ± 0.05	0.009 ± 0.006	0.23 ± 0.03	
$t\bar{t}$	0.69 ± 0.24	0	0.67 ± 0.22	
Total bgr	1.29 ± 0.25	0.009 ± 0.006	0.90 ± 0.22	2.20 ± 0.11

To be done (1)

- Move to Athena 13
  - use AthenaRootAccess ?
- Need more statistics to measure bg properly
  - there are more $t\bar{t}$, how about $Zb\bar{b}$?
- Investigate isolation cut (rejection suspiciously high for 4e $t\bar{t}$ bg...)
  - which definition ? track or energy ? optimize, correlations...
- Use also MuTag ?

To be done (2)

- Look into more ways to reduce bg
  - Vertexing/IP for $Zb\bar{b}$
  - Et(miss) for $t\bar{t}$
- Assess & correct lepton-to-Z mis-assignment
  - preliminary study shows ~7% mis-assignment!
- Study ZZ*→4l, relevant for low Higgs mass
  - Different cuts needed ?
- Refine Z mass cut for on-shell Z
  - constrained fit ?
- Calculate cross-sections/sensitivities, combine errors
  - Use standard tools ? ROOFIT ? ....

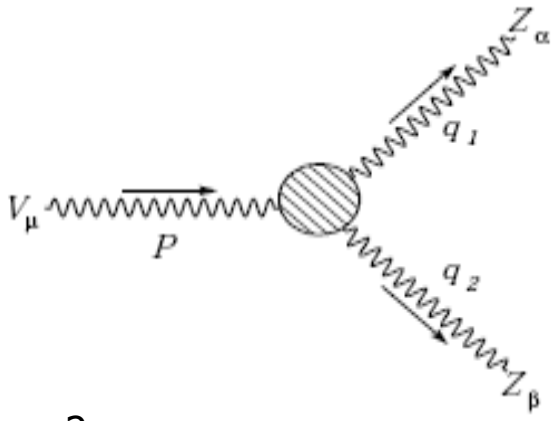
Systematic errors

Bing Zhou, University of Michigan, & Chara Petridou

From **MC** and **data**

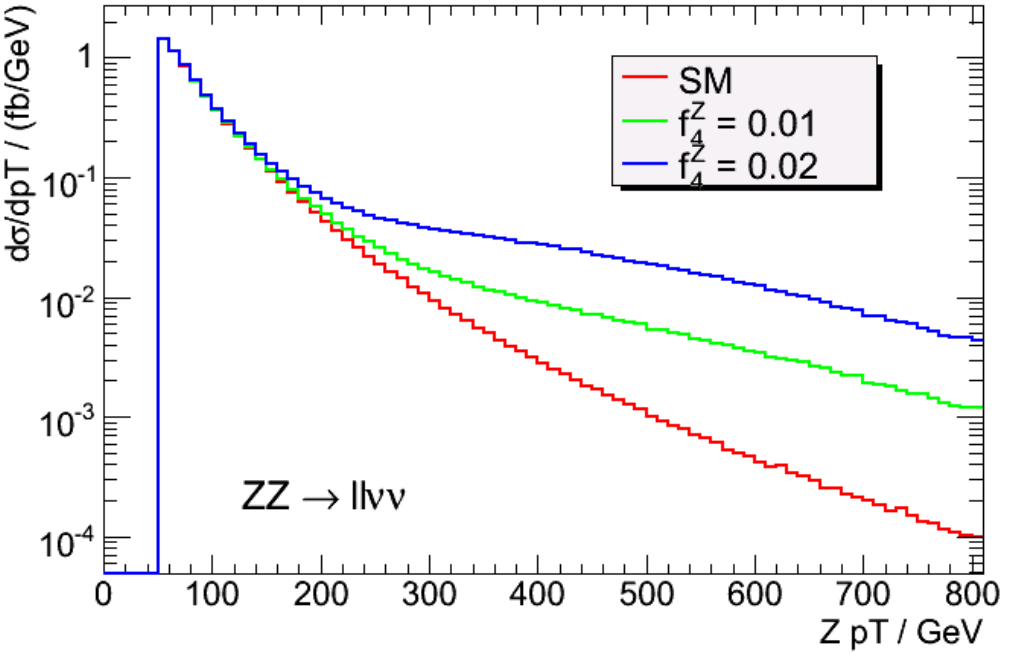
- Luminosity: 5-10% (Tevatron: 6.5%, and got less)
- Trigger efficiency: ?
- Lepton identification efficiency: 3% (MC data with pileup and cavern backgrounds)
- Background estimate: 20-25% (from MC statistics, will get better with more samples & real data)
- PDFs: 3% (run Pythia with different structure functions)
- QCD corrections (scaling uncertainty for NLO calculations): 5%
- Jet & lepton energy scale: 5% (from WW & WZ BDT study, have to re-think...)

TGCs: the principle



$$\Gamma^{\alpha\beta\mu}_{ZZV} = \frac{i(\hat{s} - M_V^2)}{M_Z^2}\left[f_4^V\left(P^\alpha g^{\mu\beta} + P^\beta g^{\mu\alpha}\right) - f_5^V \varepsilon^{\mu\alpha\beta\rho}(q_1 - q_2)_\rho\right]$$

$$(V = Z, \gamma)$$



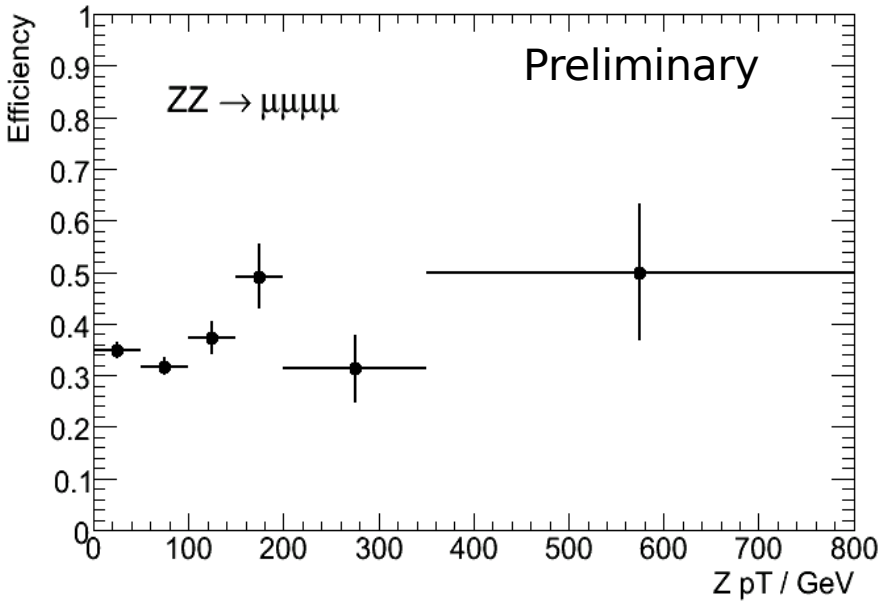
Tom Barber, Pat Ward, University of Cambridge

- $f_4^V = f_5^V = 0$ at tree level in the SM
- 4 parameters accessible with ZZ→4l: $f_4^Z, f_5^Z, f_4^\gamma, f_5^\gamma$
- 4 observables change with anomalous TGC: cross-section vs Pt(Z), M(ZZ), lepton angle, Z angle
- Started collaboration with Cambridge group for f_4^Z with Pt(Z)

TGCs: the method

Tom Barber, Pat Ward, University of Cambridge

- Use LO Baur-Rainwater (BR) MC to generate Pt(Z) distributions for different f_4^Z
- Fit cross-section to quadratic function of f_4^Z in bins of Pt(Z)
- Find efficiency from full MC (events after all cuts/truth events)
- Expected events = BR cross-section × efficiency × luminosity
- Generate fake event samples based on this expectation for signal and Zbb background
- Binned Likelihood fit of Pt(Z) distribution to one parameter ($(f_4^Z)^2$)

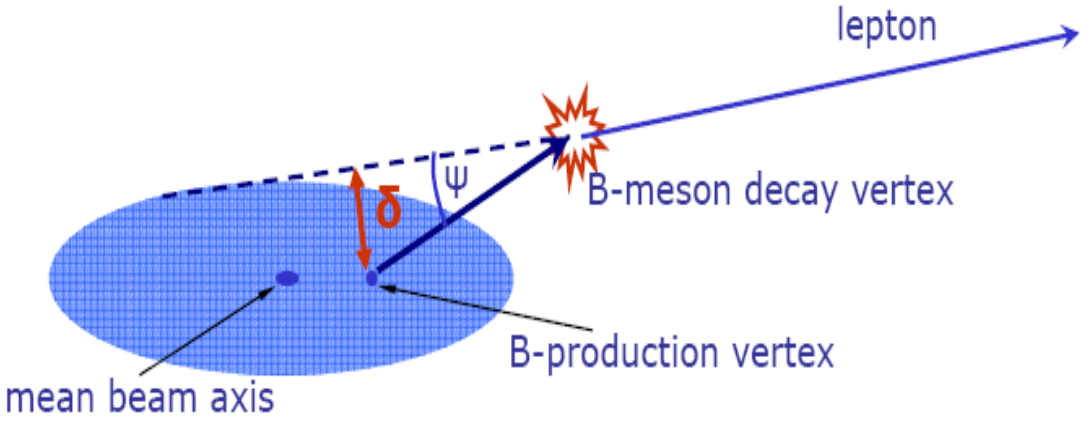


TGCs: to be done

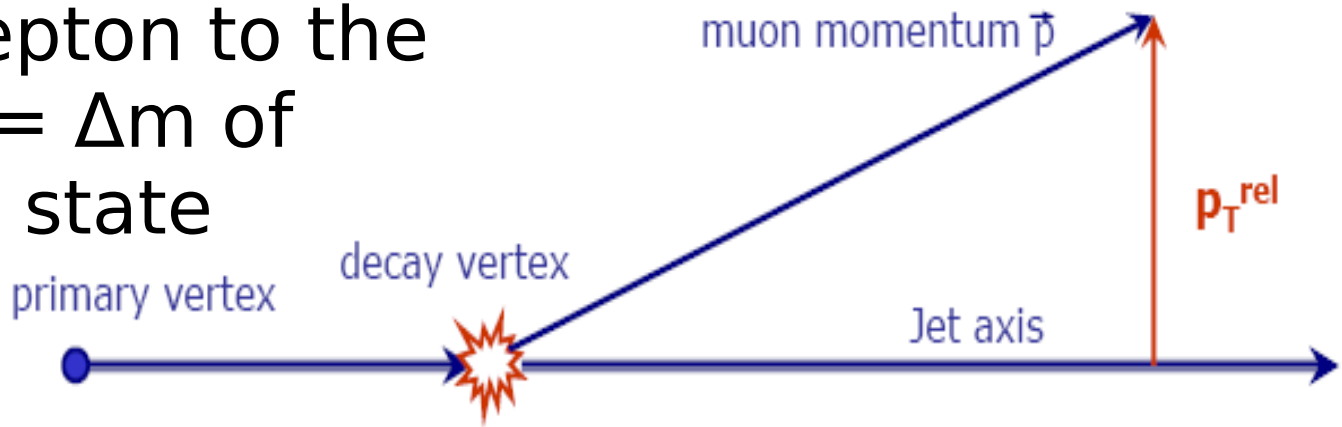
- Take over part of the BR MC generation
- Use the rest of the observables to improve limit (advantage over the ZZ→llνν channel)
- Set limits for the rest of the parameters
- Multi-dimensional fits ?

Measurement of $Zb\bar{b}$

- Tagging:
  - isolation
  - lepton IP/vertexing
  - (lifetime fit ? $\tau(B)=1.4ps$, $\tau(D)=1ps$)



- Background ($Zc\bar{c}$):
  - Pt-relative of lepton to the associated jet = Δm of initial and final state



b-tagging methods for inclusive b cross-section measurement:
S. Jetter, M. Volkmann and M. zur Nedden, HU Berlin

Conclusions

- Baseline ZZ→4l signal & background expectation done
- Many ideas for improvements/optimizations
- Systematic errors far from understood
- TGC limit measurement is beginning and looks promising
- $Zb\bar{b}$ measurement needs a lot of study and feedback

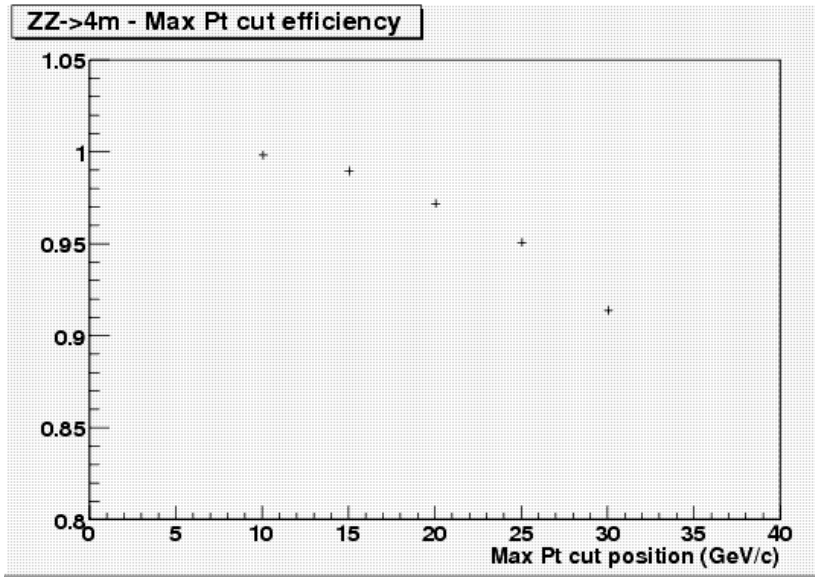
Extras

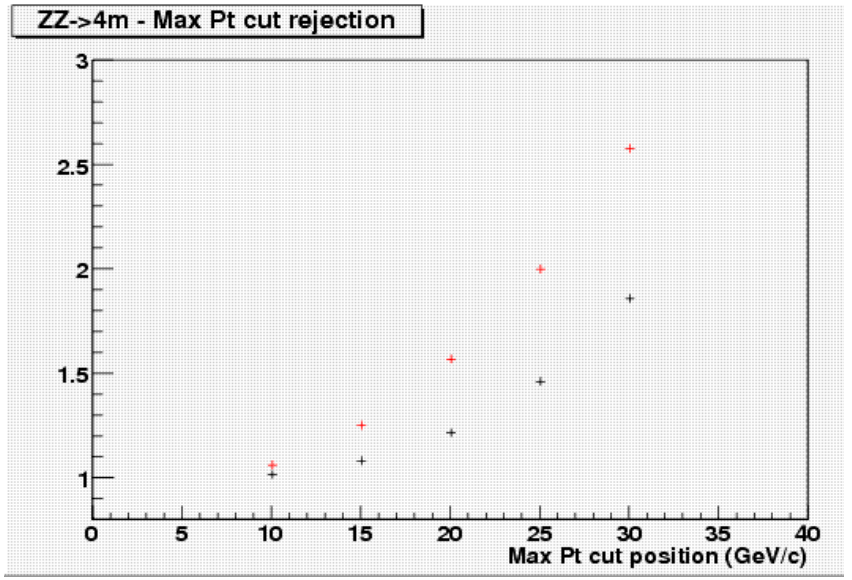
MC Samples

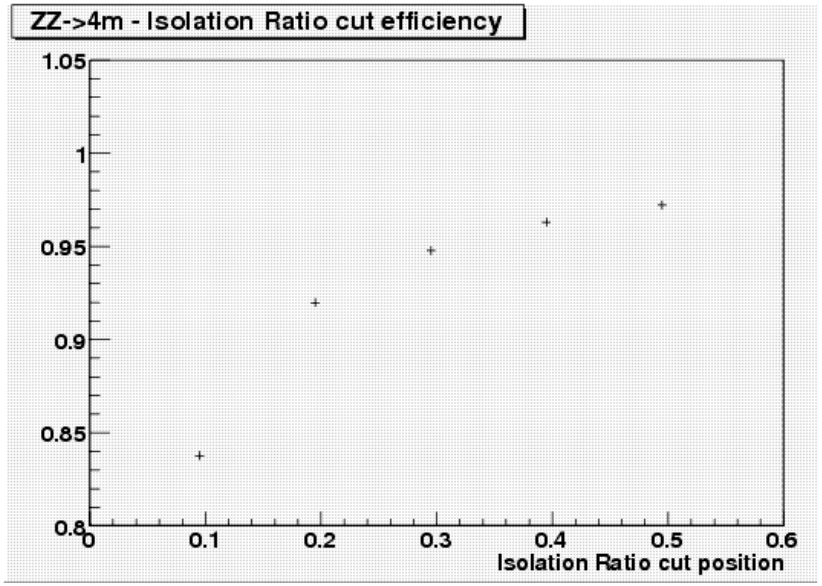
- Pythia signal & Zbb at LO (no K factors included!), Jimmy signal & ttbar at NLO
- Control plots of MC truth 4l and Z invariant masses ok

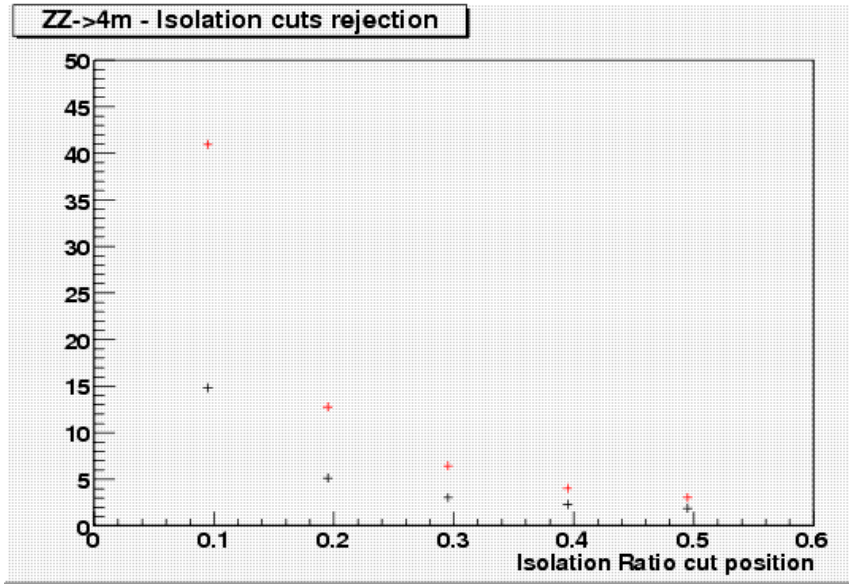
Channel	Generator	Events	Filter eff.	x-sec
ZZ to 4l	Pythia	43000	0.21900	159fb
ZZ to 4l(v11.0.42)	Pythia	154450	0.21900	159fb
ZZ to 4l	MC@NLO/Jimmy	11500	1.00000	?
Zbb(bar)	Acer/Pythia	106650	0.00942	52pb
tt(bar)	MC@NLO/Jimmy	72100	0.00728	833pb

Efficiencies: 4m





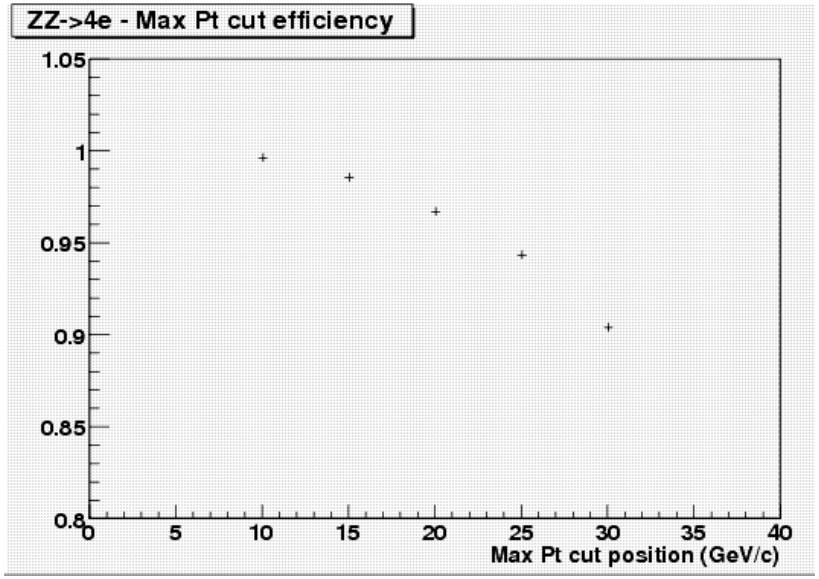


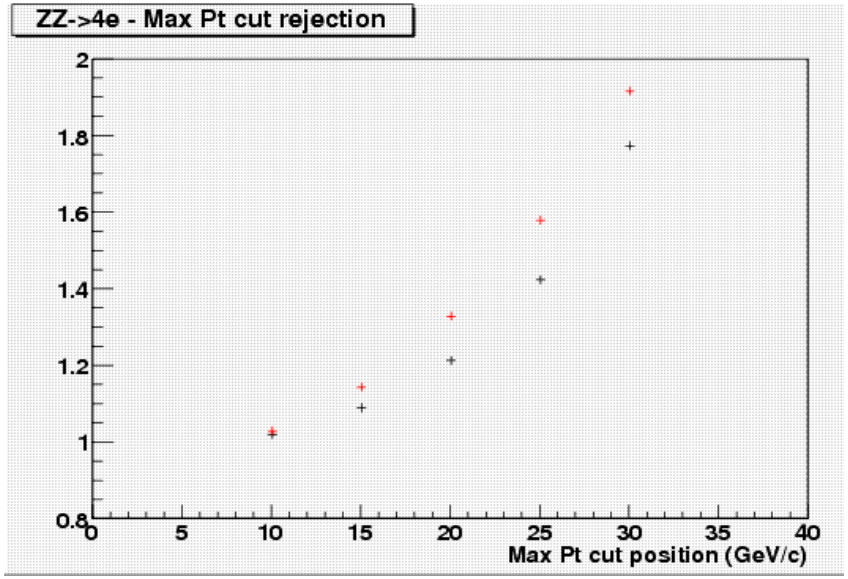


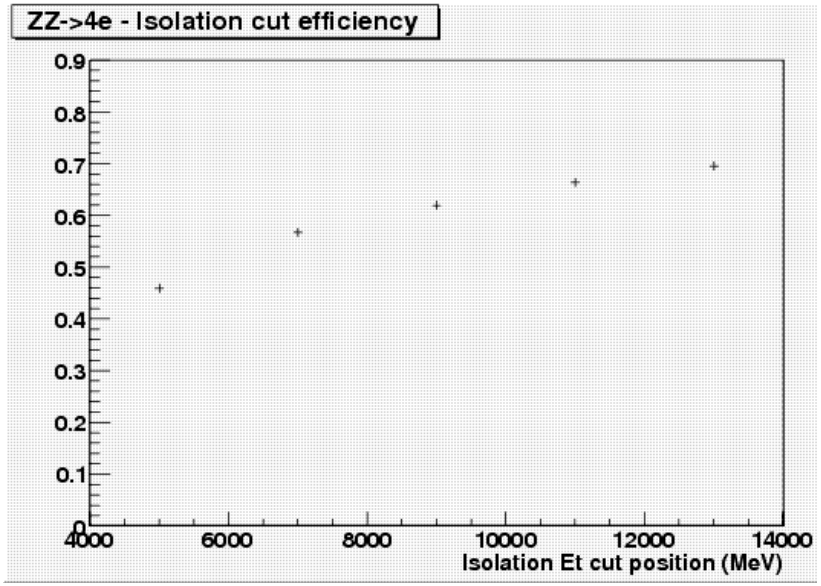
signal

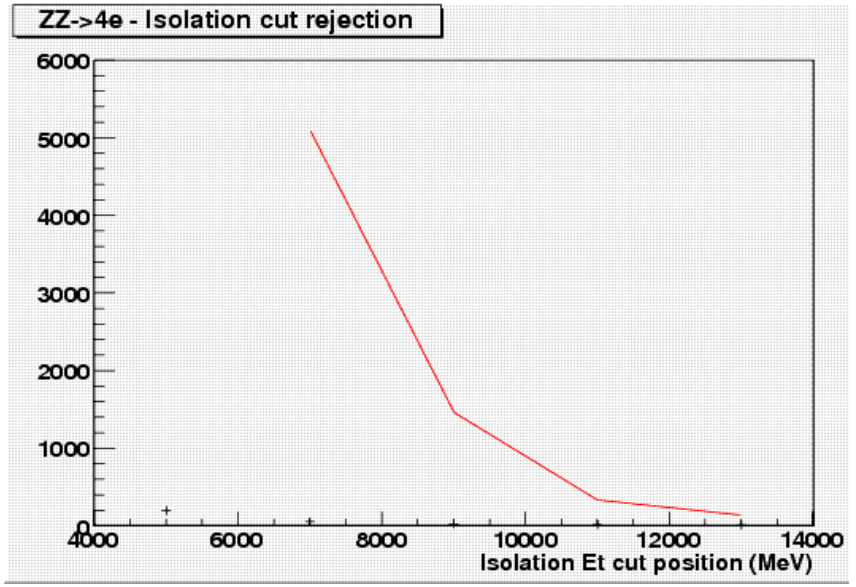
black: Zbb, red: ttbar

Efficiencies: 4e







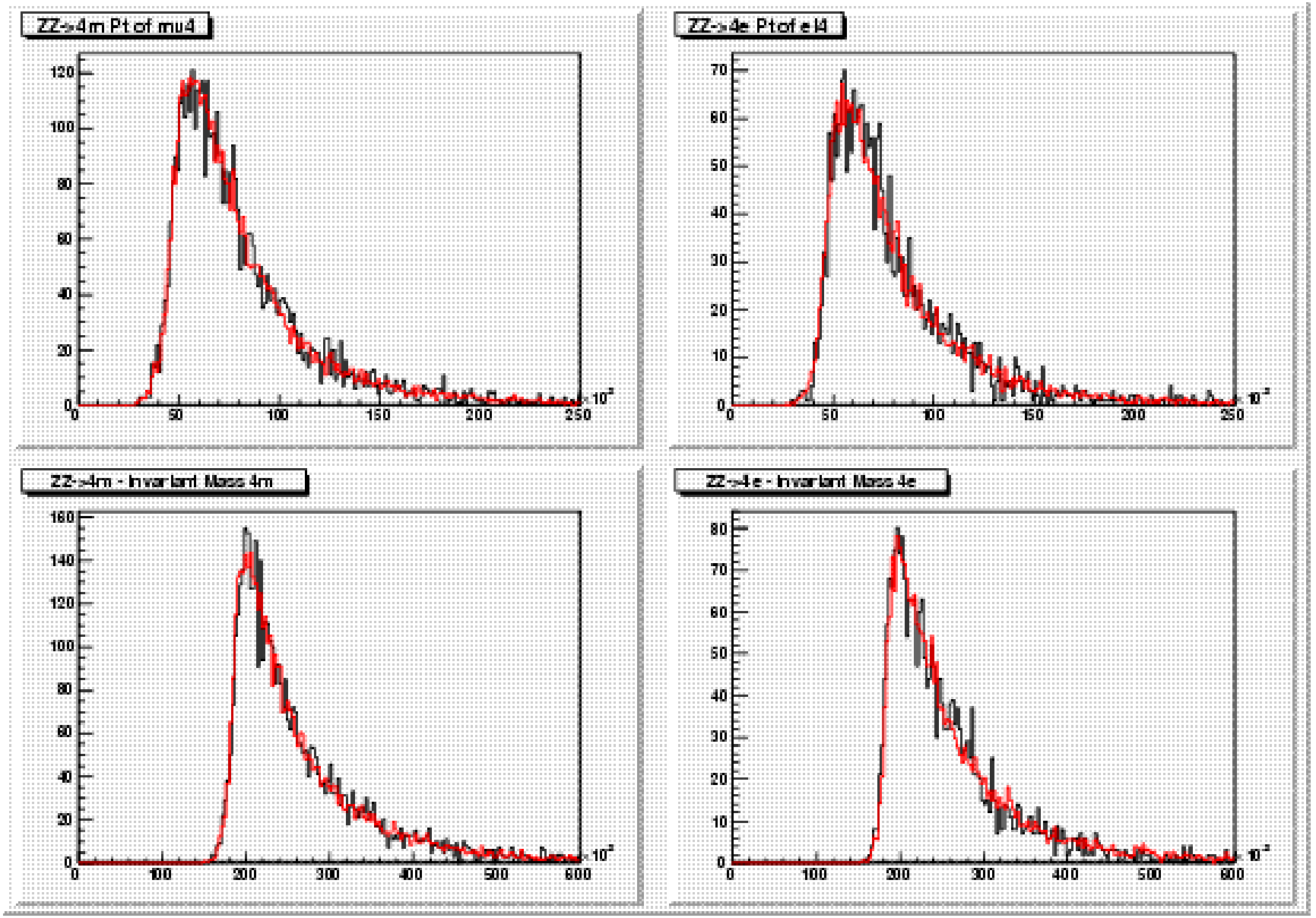


signal

black: Zbb, red: ttbar

12.0.6 – 11.0.42 Comparison

Pt & Inv. Mass distributions



12.0.6 – 11.0.42 Comparison

Cut efficiencies

	$ZZ \to 4\mu$ (%)	$ZZ \to 4e$ (%)	$ZZ \to 2\mu 2e$ (%)
Preselection	70.7 (77.0)	62.3 (67.4)	65.4 (72.4)
Create pairs,dR	99.3 (99.4)	88 (91.1)	93.4 (95.3)
Isolation,Pt	92.3 (92.9)	62.2 (68.3)	70.5 (74.4)
Mass	71.1 (71.5)	73.0 (73.6)	76.1 (76.3)
Total	46.1 (50.8)	24.9 (30.9)	32.8 (39.2)