Invisible Z estimation in the monojet final state

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CMS, CERN Summer Student Program 2014

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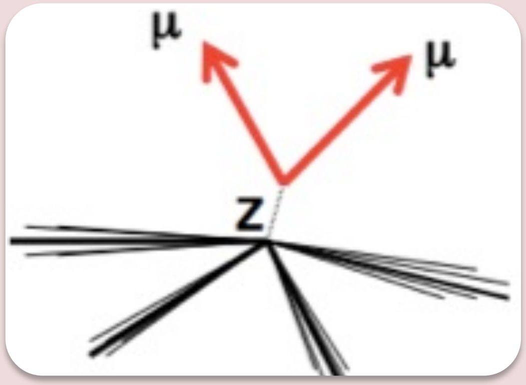
Objective

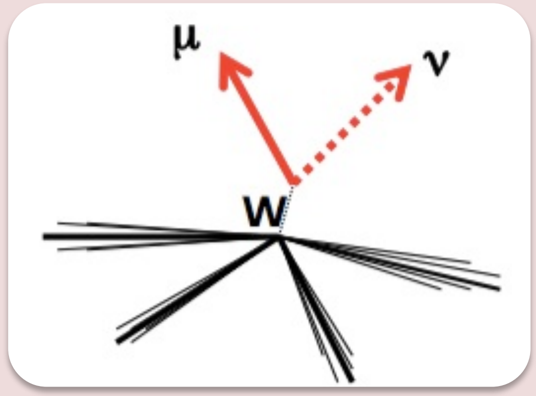
To estimate number of irreducible invisible Z background contribution in the monojet final state and obtain the exclusion limit in the study

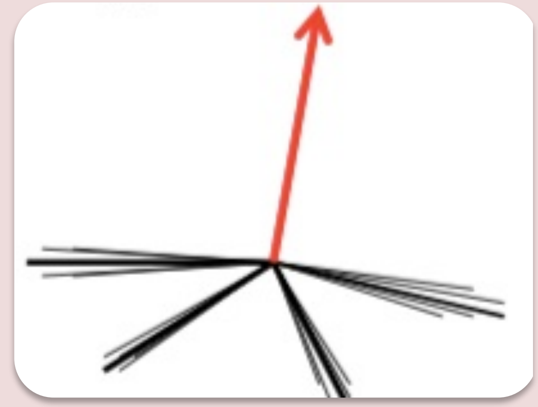
Motivation

- Large missing transverse energy (MET) + jets has a great potential for discovery of new physics
- Invisible Z is one of dominant backgrounds remaining after applying monojet selection cuts.
- Z($\mu\mu$) sample is used to predict Z($\nu\nu$)
  - High uncertainty because of small statistic

Candidates for invisible Z estimation







Z(μμ)+jets	W(μν)+jets	γ+jets
• Clean • Easy to select • Small statistic	• Not so clean • Larger statistic	• Clean for high E • Large statistic • (Not so clean for < 100 GeV)

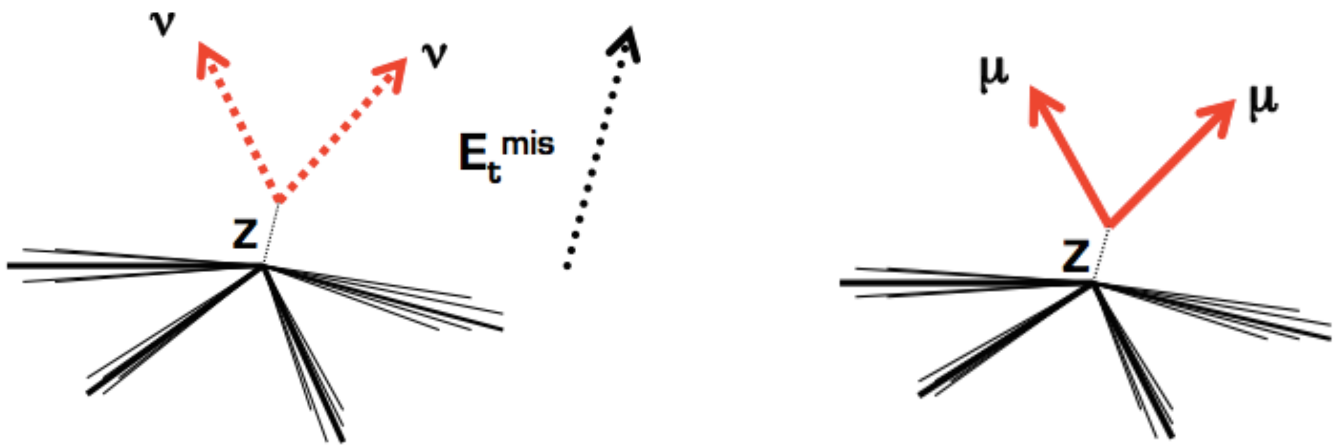
Meenakshi Narain, Searches with Missing E_T at the LHC, (2009).

Outline

- Theoretical Background
- Event Selection
- Invisible Z prediction
- Result
- Summary
- Future Plans

Z+jets background estimation

$Z(\nu\nu)$ prediction using



The process of Z(*νν*) is mimicked by removing muons in the Z($\mu\mu$) event to missing transverse energy.

Meenakshi Narain, Searches with Missing E_T at the LHC, (2009).

Z+jets background estimation

Use Z($\mu\mu$) as control sample to estimate Z($\nu\nu$)

$$N(Z \to \nu\nu) = \frac{(N_{Obs} - N_{Bgd})}{A \cdot \varepsilon} R\left(\frac{Z \to \nu\nu}{Z \to \mu\mu}\right)$$

N_{obs}= Number of observed Z($\mu\mu$) event
N_{bgd}= Number of estimated Z($\mu\mu$) background
A = Acceptance
ε = Selection efficiency

Acceptance and Efficiency

All generated events = X

↓ cuts

Y events

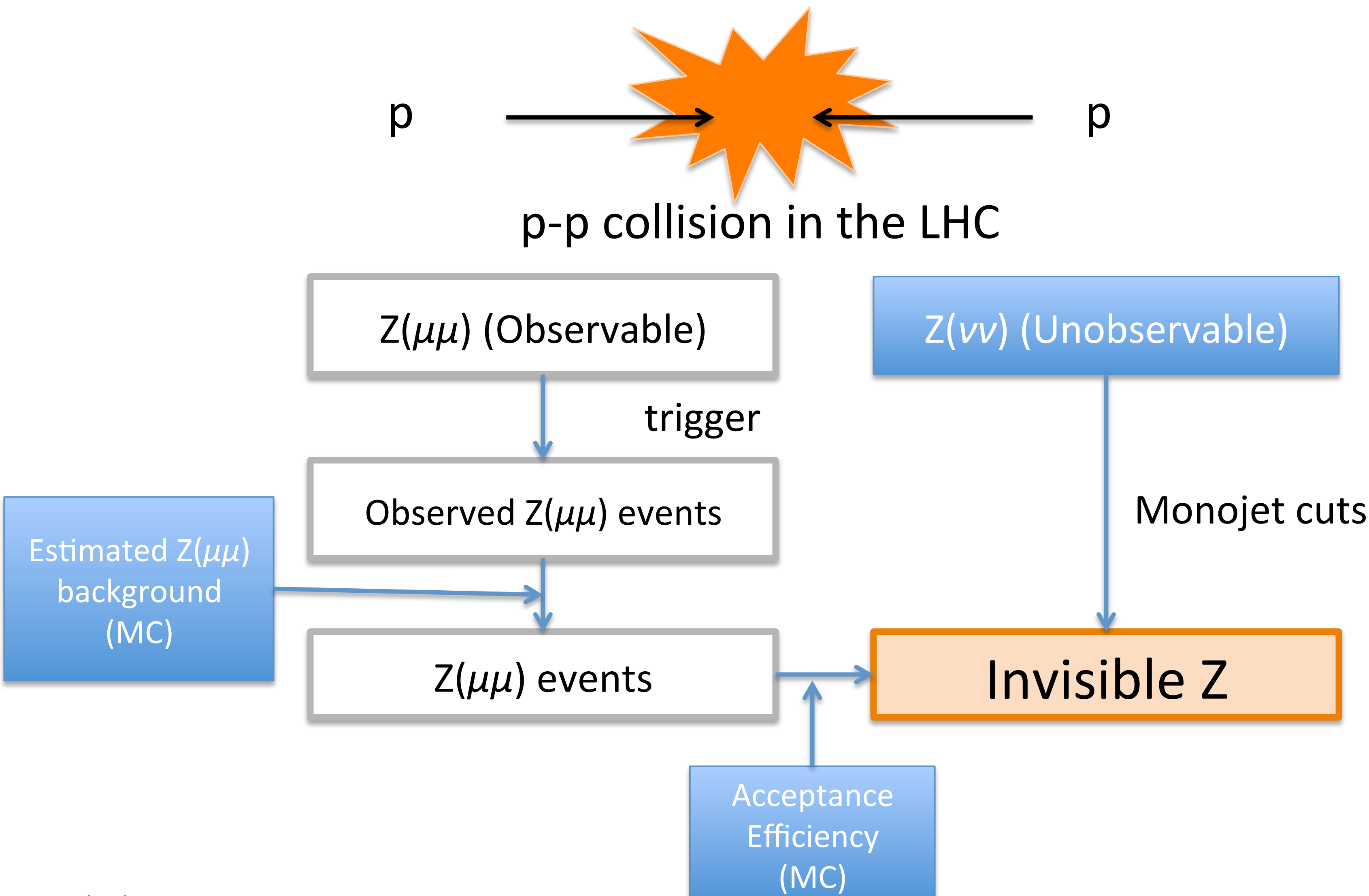
↓ muon identification & isolation

Z events

Acceptance = Y/X

Efficiency = Z/Y

Analysis workflow



Event Selection

For Z($\mu\mu$)

- Monojet selection
- $p_T > 20\, GeV$
- $|\eta| < 2.4$
- Transverse invariant mass between 60 – 120 GeV

Require 2 muons and at least one of these has to be well identified and isolated.

$$M_T = \sqrt{2 p_T^{\mu} E_T^{miss} \left(1 - \cos \Delta\phi\right)}$$

p_T^{μ} - transverse momentum of the muon
$\Delta\phi$ - angle between the muon p_T and the E_T^{miss} vectors.

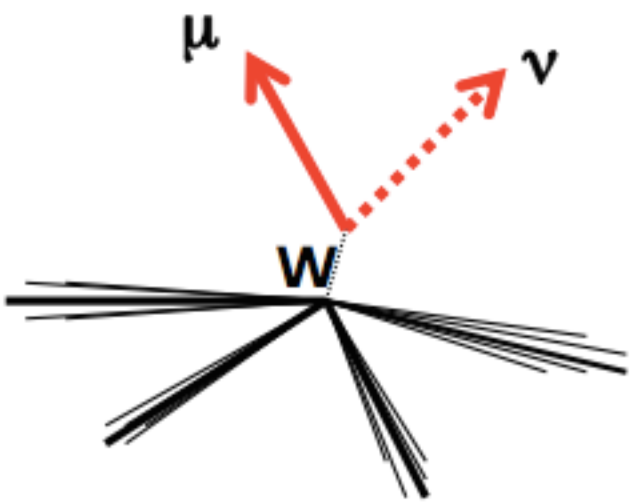
$Z(\nu\nu)$ Prediction

MET	N_{obs}	N_{bgd}	Acceptance	Efficiency	$Z(\upsilon\upsilon)$
$>$ 250 GeV	3695	288	0.89±0.02	0.74±0.02	30700±1898
$>$ 300 GeV	1538	128	0.91±0.02	0.75±0.02	12199±831
$>$ 350 GeV	685	70	0.93±0.02	0.76±0.02	5174±423
$>$ 400 GeV	348	31	0.94±0.02	0.76±0.02	2630±238
$>$ 450 GeV	183	15	0.94±0.02	0.75±0.03	1420±152
$>$ 500 GeV	96	7.7	0.94±0.02	0.76±0.03	732±98
$>$ 550 GeV	47	5.1	0.95±0.02	0.75±0.04	349±66

→ High uncertainty at high energy

$Z(\nu\nu)$ Prediction

Using W+jets



$$N(Z \to \nu\nu) = \frac{(N_{Obs} - N_{Bgd})}{A \cdot \varepsilon} R\left(\frac{Z \to \nu\nu}{W \to \mu\nu}\right)$$

Event selection

- Monojet selection
- $p_T > 20\ GeV$
- $|\eta| < 2.4$
- Well identified and isolated transverse invariant mass between 50 – 100 GeV

$Z(\nu\nu)$ Prediction

MET	N_{obs}	N_{bgd}	Acceptance	Efficiency	$Z(\nu\nu)$
$>$ 250 GeV	17191	1816	0.86±0.02	0.39±0.02	21874±1090
$>$ 300 GeV	6955	712	0.89±0.02	0.39±0.02	8719±444
$>$ 350 GeV	3104	319	0.90 ±0.02	0.38±0.02	3860±210
$>$ 400 GeV	1484	148	0.91±0.02	0.38±0.02	1851±109
$>$ 450 GeV	780	76	0.92±0.02	0.37±0.03	990±66
$>$ 500 GeV	402	44	0.93±0.02	0.37±0.03	521±43
$>$ 550 GeV	228	31	0.94±0.02	0.38±0.04	287±31

➡ Lower uncertainty in Z(*νν*) prediction

Exclusion limit

MET (GeV)	> 250	> 300	> 350	> 400	> 450	> 500	> 550
Z($\nu\nu$)+jets	26287±1094	10459±471	4517±236	2241±131	1205±83	626±53	318±36
W+jets	17177±1030	5908±365	2333±154	1012±72	495±39	247±24	119±14
$t\bar{t}$	446±223	167±84	69±35	31±16	15±7.7	6.6±2.3	2.8±1.4
Z(ll)+jets	134±67	43±21	17±8.7	8.4±4.2	4.7±2.3	2.3±1.2	1.0±0.5
Single t	155±77	53±26	18±9.1	6.1±3.1	0.9±0.4	0.0±0.0	0.0±0.0
QCD Multijets	462±231	101±51	32±16	5.5±2.7	2.3±1.2	1.2±0.6	0.6±0.3
Diboson	3421±1710	1396±698	641±320	305±153	165±83	88±44	55±28
Total SM	48081±2302	12600±924	7628±429	3609±214	1889±124	971±73	497±48
Data	52157	19783	8324	3825	1828	934	519
Exp limit	4225	1707	787	368	199	122	90
Obs limit	7627	3103	1360	564	170	102	107

Summary

- One of useful methods to estimate the Z($\nu\nu$) is the use of W($\mu\nu$)+jets data.
- Taking the advantage of the similar kinematics of Z($\nu\nu$) and W($\mu\nu$)
- Using W($\mu\nu$) control samples, the uncertainty was reduced.

Future Plans

- Expand range of event selection in order to reduce statistic uncertainty
- Invisible Z Estimation by using γ+jets.

References

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Cr. CERN Summer Student Team

Monojet

- One jet plus nothing else
- Nothing is not well-identified in a real experiment.
  - The region that identification process is not reliable
- Monojet final state
  - parton + undetectable particles

Patrick Eraerds,"Analysis of Mono-jet" Events at Tevatron, *Diploma Thesis in Physics*.(2006)

Monojet Selection

- Exactly one quality-jet
- Without …
  - second-quality jet above thresholds
  - Isolated electrons and muons above thresholds
  - No bad-jets above threshold

Patrick Eraerds,"Analysis of Mono-jet" Events at Tevatron, *Diploma Thesis in Physics*.(2006)