Benchmarking Overview and the WW Benchmark

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Jan 16, 2013

DBD Benchmarking + SimReco Personnel

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  - Stephane Poss
  - Philipp Roloff
  - Jan Strube
- DESY
  - Alexander Grohsjen
  - Marcel Stanitzki
- PNNL
  - David Asner
  - David Cowley
  - Brock Erwin
  - Malachi Schram
- SLAC
  - Tim Barklow
  - Norman Graf
  - Jeremy McCormick
  - Homer Neal

2

Software Chain for the DBD

- Event Generation
  - Whizard, physsim, Guineapig
- Detector response simulation (slic)
- Event Reconstruction
  - Event overlay
  - lcsim tracking
  - slicPandora PFA
  - LCFI vertex finding
- Analysis
  - LCFI+ flavor tagging
  - Everything else

3

Fully Simulated and Reconstructed Events

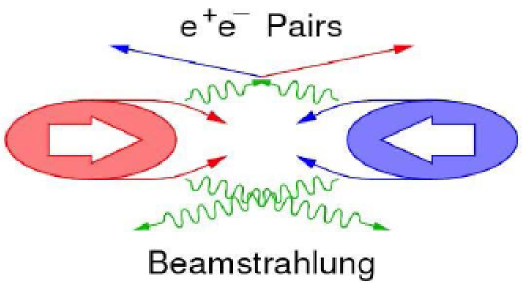
Process	$\sqrt{s}$ (GeV)	# Events (10^6)	$\mathscr{L}$ ab^{-1}
$t\bar{t}h$	1000	0.4	52
$ttZ, ttbb$	1000	0.4	15
tt	1000	1.0	2.0
$\nu\bar{\nu}h,\ h \to b\bar{b}, c\bar{c}, WW^*, gg$	1000	3.1	7.4
$\nu\bar{\nu}h,\ h \to \mu^+\mu^-$	1000	0.5	6400
$e\nu W, eeZ, \nu\nu Z \to e\nu qq, eeqq, \nu\nu qq$	1000	4.0	0.034
$eeZ, \nu\nu Z, WW \to ee\mu\mu, \nu\nu\mu\mu$	1000	1.0	0.004
WW	1000	6.0	2.0
all other SM processes	1000	6.0	$1 \cdot 10^5 - 1.0$
$t\bar{t}$	500	2.0	1.0 per m_{top}
$t\bar{t}$ background SM processes	500	2.0	varies
TOTAL		26	

Table 11.1.2: Contents of "all Other SM Processes" Mixed File.

Process	$\mathscr{L}$ ab^{-1} per pol.	# Events (10^5) P(e^-/e^+) -0.8/+0.2	# Events (10^5) P(e^-/e^+) +0.8/-0.2	Weight
$e\gamma \to e\gamma$	$4 \cdot 10^{-5}$	0.5	0.5	$2.5 \cdot 10^{+4}$
$e^+e^- \to 2f, 4f$	0.034	3.7	2.0	29
$e\gamma \to 3f$	0.003	3.5	3.1	330
$e\gamma \to 5f$	0.25	3.1	2.1	4
$e^+e^- \to 6f$	1.0	1.8	0.6	1
$\gamma\gamma \to 2f$	0.001	5.7	5.7	7700
$\gamma\gamma \to 4f$	0.083	2.5	2.5	12
$\gamma\gamma \to$ minijets:				
$4 < p_T < 40$ GeV	0.012	9.2	9.2	$80 - 9000$
$p_T > 40$ GeV	0.105	2.3	2.3	12

5

Beam-Induced Background

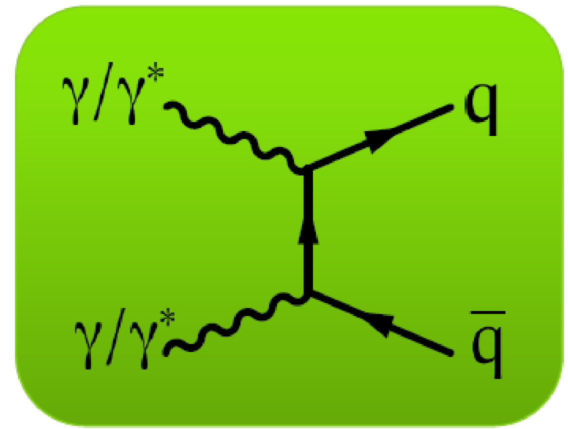


Pair background
1 event per BX
450k particles

Generated by GuineaPig
ascii → hepevt → stdhep

Merged with every "physics" event

MCParticles that don't make hits will be dropped

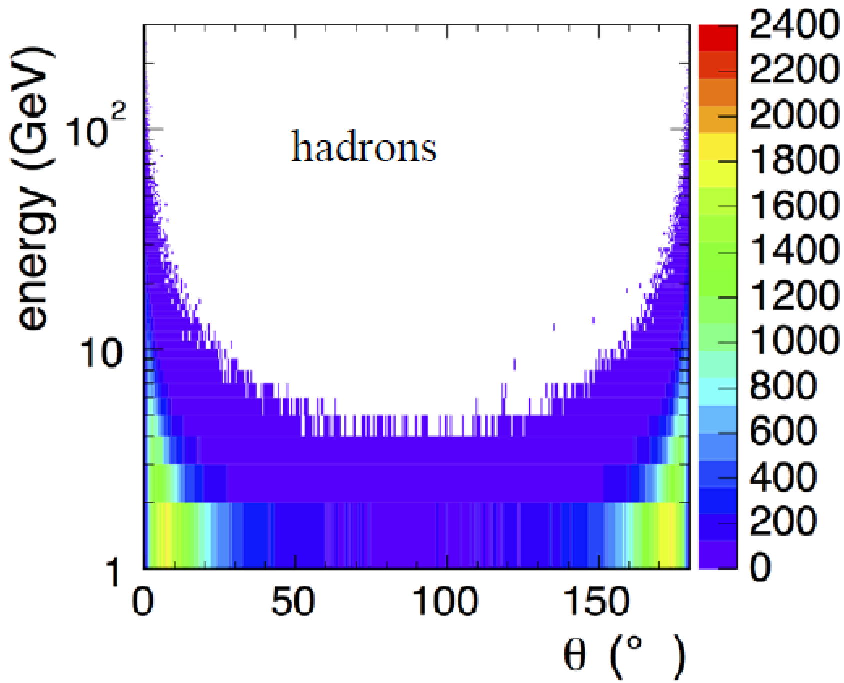


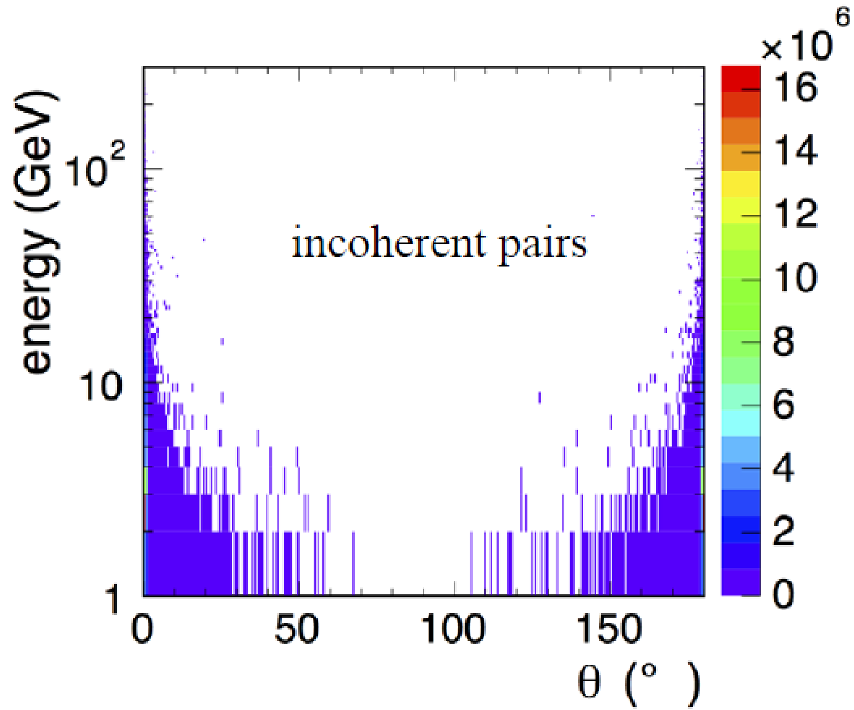
γγ interactions
4.1 events per BX @ 1 TeV
1.7 events per BX at 500 GeV

Generated by Whizard

6

Angular distribution of background





Incoherent pairs affect mostly occupancies and tracking efficiencies

Hadrons have enough energy to reach the calorimeter

- Physics Benchmarking
  - WW   T.B.
  - $\nu\bar{\nu}H$ Homer Neal
  - $t\bar{t}$ Malachi Schram
  - $t\bar{t}H$ Philipp Roloff (tomorrow)

$e^+e^- \to W^+W^- \quad \sqrt{s} = $ **1 TeV**

Four Jet Topology (0.8<cosΘ<1 only)

Two Jets Plus Lepton Topology (0.8<cosΘ<1 and -1<cosΘ<1)

Beam Polarization Measurement Only

Use 50%/50% lumi at $Pol(e^- / e^+) = (-0.8 / +0.2) / (+0.8 / -0.2)$

$e^+e^- \to W^+W^-$ $\sqrt{s} =$ **1 TeV**

Count events in bins of ($\cos\Theta, \cos\theta$)

where Θ **is polar angle of** W^- **in lab frame and**

θ **is either the polar angle of the lepton in** W^- **rest frame or an average of all four quark angles in their parent** W **rest frame in the case of the fully hadronic topology.**

To account for detector efficiency and resolution do template fit of parameters a **&** b **where for each bin** i

$$N_i = a\int d\vec{x}_i d\vec{x}\,'\eta(\vec{x}\,')\Omega(\vec{x},\vec{x}\,')\frac{d\sigma_{LR}}{d\vec{x}\,'} + b\int d\vec{x}_i d\vec{x}\,'\eta(\vec{x}\,')\Omega(\vec{x},\vec{x}\,')\frac{d\sigma_{RL}}{d\vec{x}\,'}$$

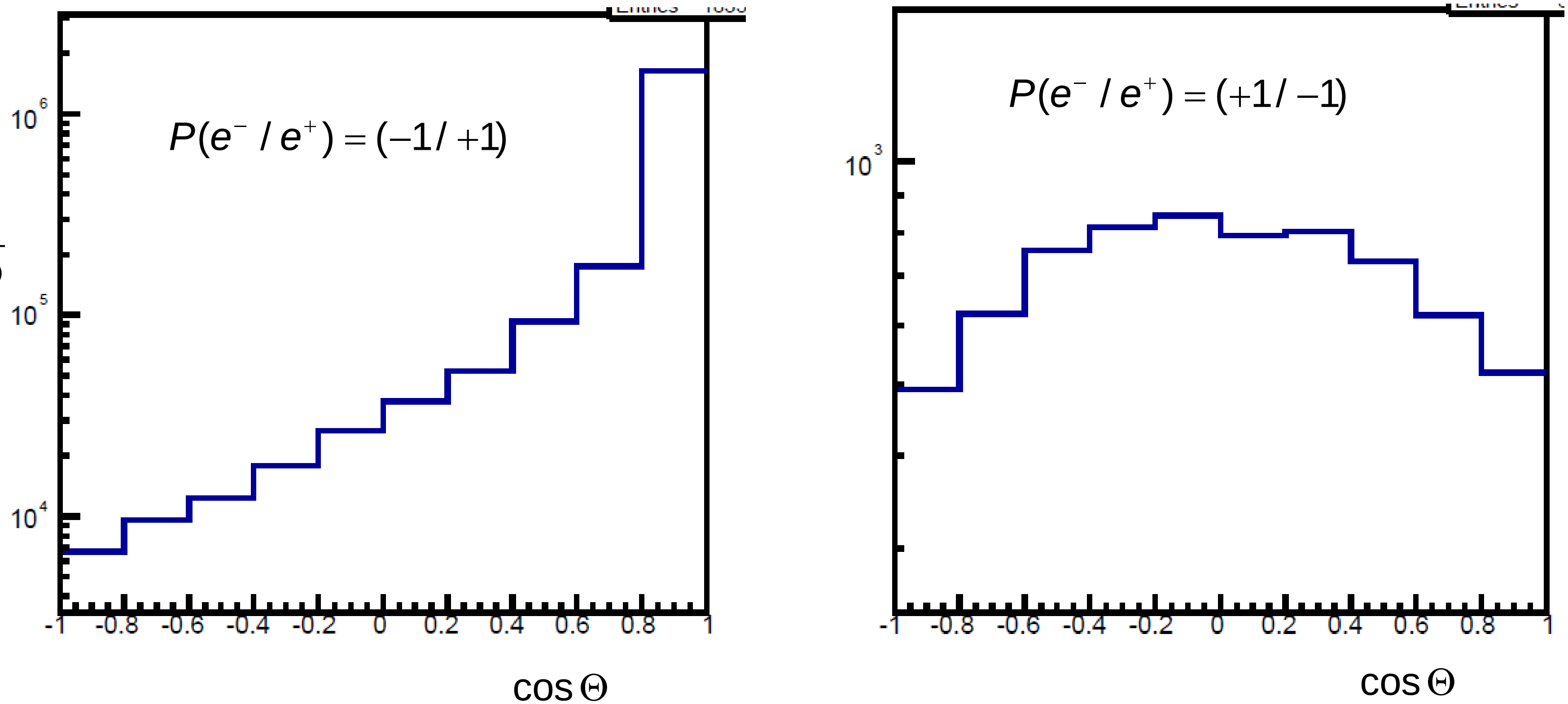
$$a = \frac{(1-P(e^-))(1+P(e^+))}{4}$$

$$b = \frac{(1+P(e^-))(1-P(e^+))}{4}$$

(then convert a **&** b **meas. to** $P(e^-)$ **&** $P(e^+)$ **)**

$e^+e^- \to W^+W^- \quad \sqrt{s} = $ **1 TeV**

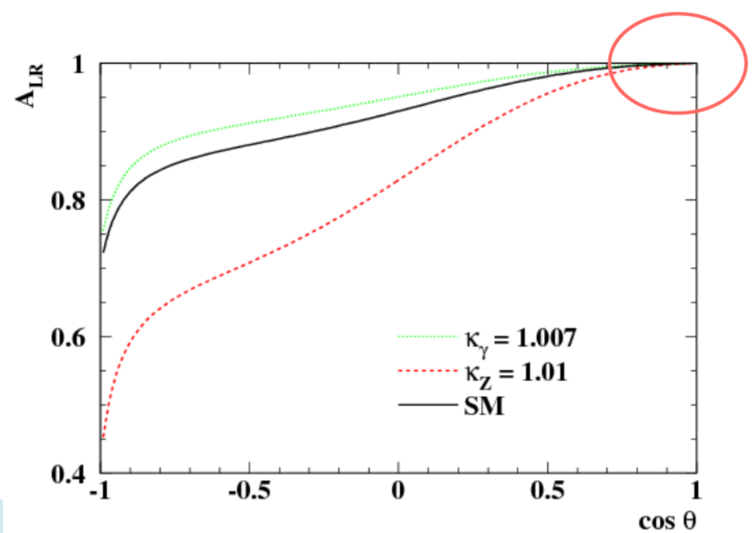
$\frac{d\sigma}{d\cos\Theta}$



Either fit over entire $\cos\Theta$ **range and assume SM**

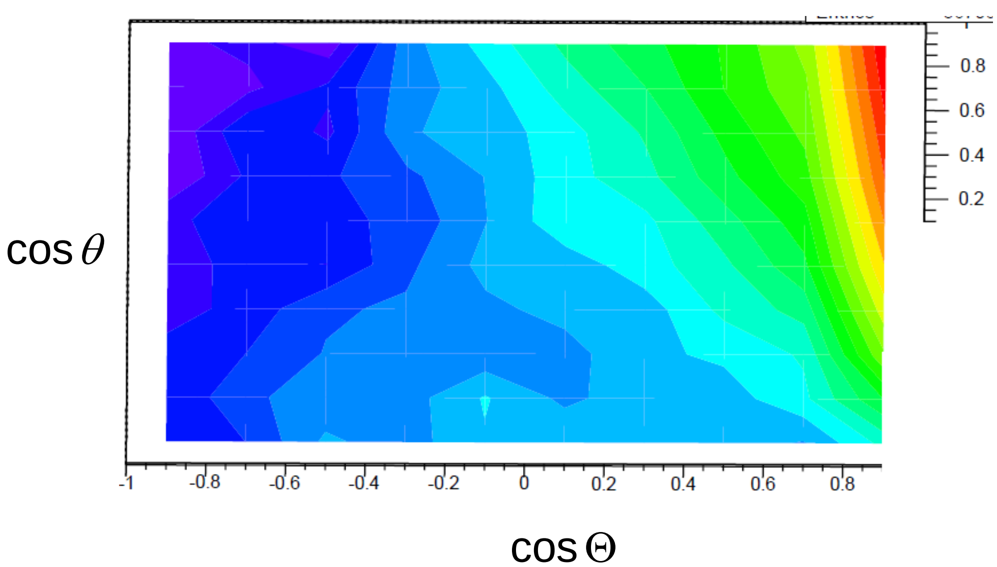
or

restrict fit to $1-\varepsilon < \cos\Theta < 1$

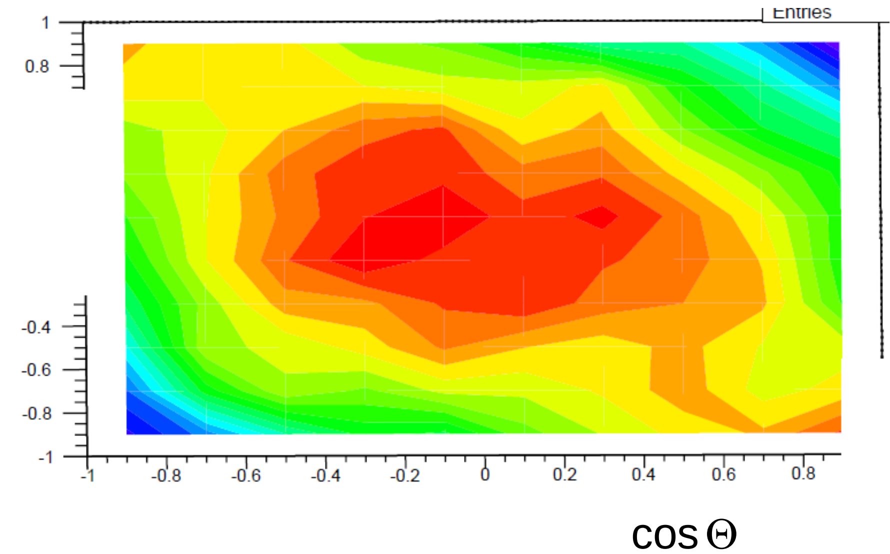


$$e^+e^- \to W^+W^- \quad \sqrt{s} = \mathbf{1\ TeV}$$

$P(e^- / e^+) = (-1/+1)$



$P(e^- / e^+) = (+1/-1)$



Four Jet Topology (0.8<cosΘ<1 only)

Two Jets Plus Lepton Topology (0.8<cosΘ<1 and -1<cosΘ<1)

Analysis for $e^+e^- \to WW \to \nu\mu qq$

Require 1 **isolated muon, 0 isolated electron & 0 isolated photon**

Set isolated muon aside and perform jet analysis on remaining PFO's using the kt-algorithm in exclusive mode with 2 jets with ∆R=0.7. This algorithm will identify beams jets and group everything else into 2 jets.

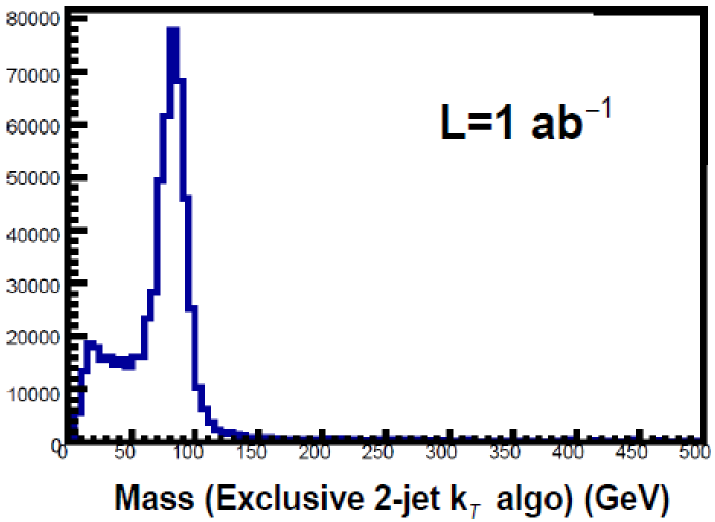
The 2 jets that remain after discarding the beam jets represent the jets from the hadronically decaying W.

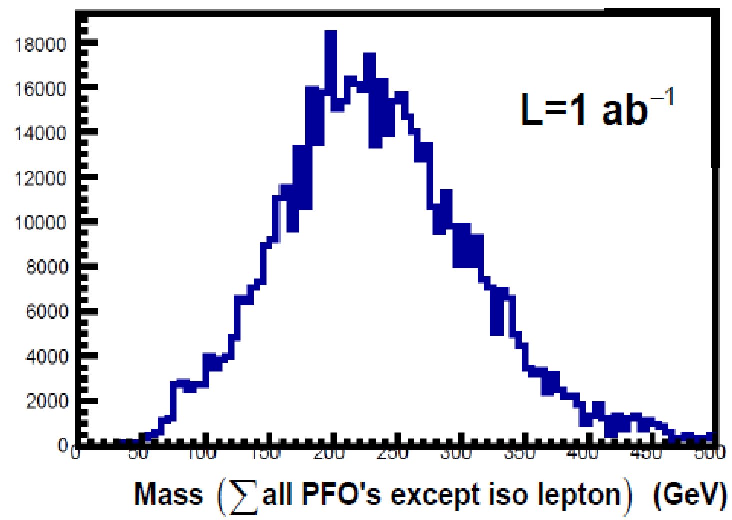
Require

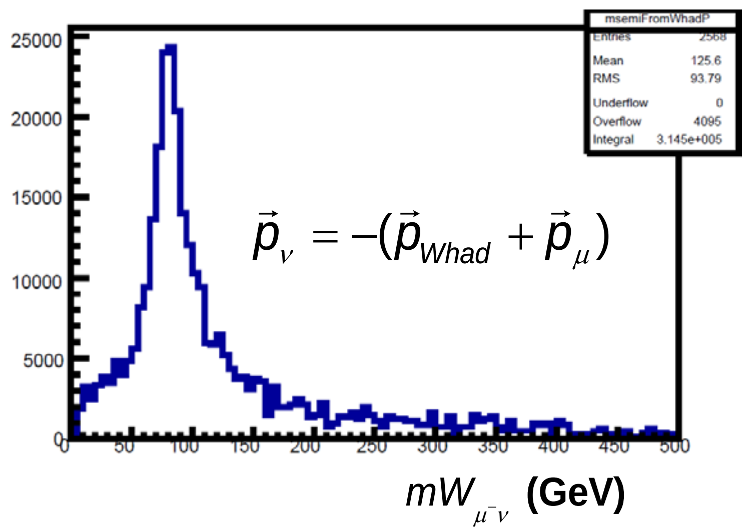
$N_{PFO}(remaining)$ **> 12**

$60 < M_{2j} < 100$ **GeV** $\quad E_{2j} > 300$ **GeV**

$$e^+e^- \to WW \to \nu\mu qq$$

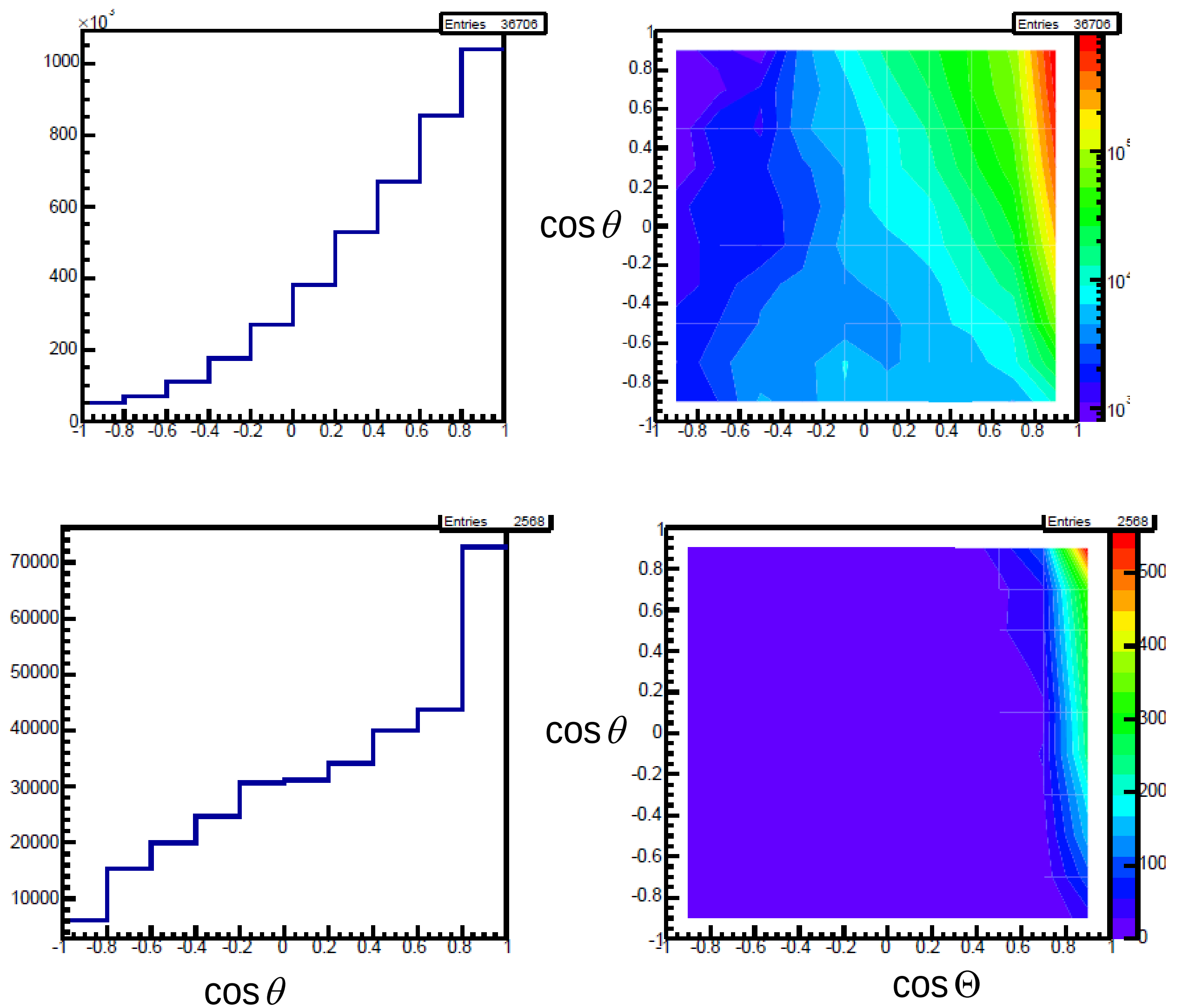






14

$$e^+e^- \to WW \to \nu\mu qq$$

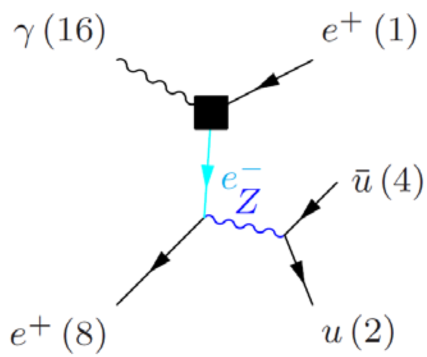


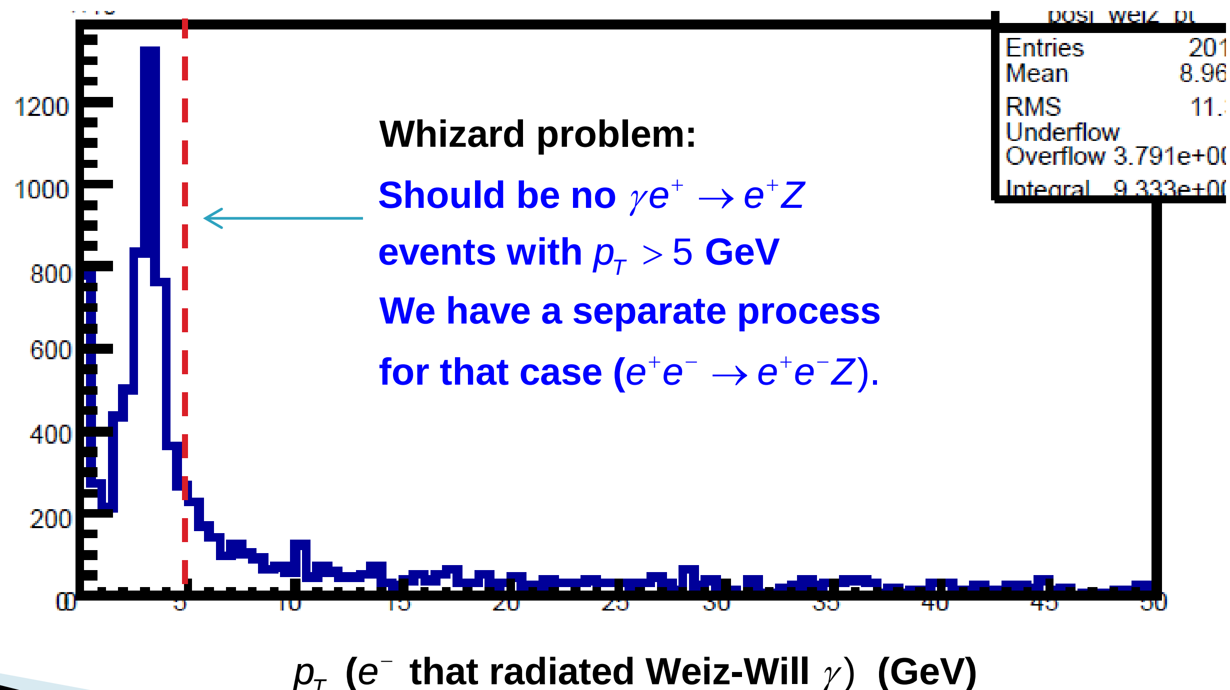
True angles

Reco angles

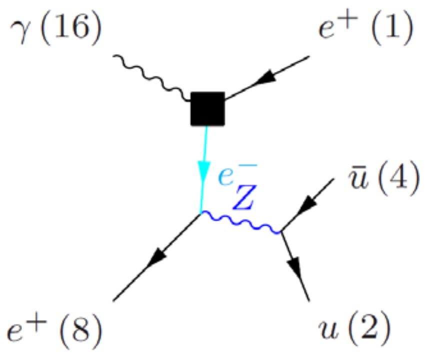
$$e^+e^- \to WW \to \nu eqq$$

Electron background very different from muon





$$e^+e^- \to WW \to \nu eqq$$



Compton scattering problem:

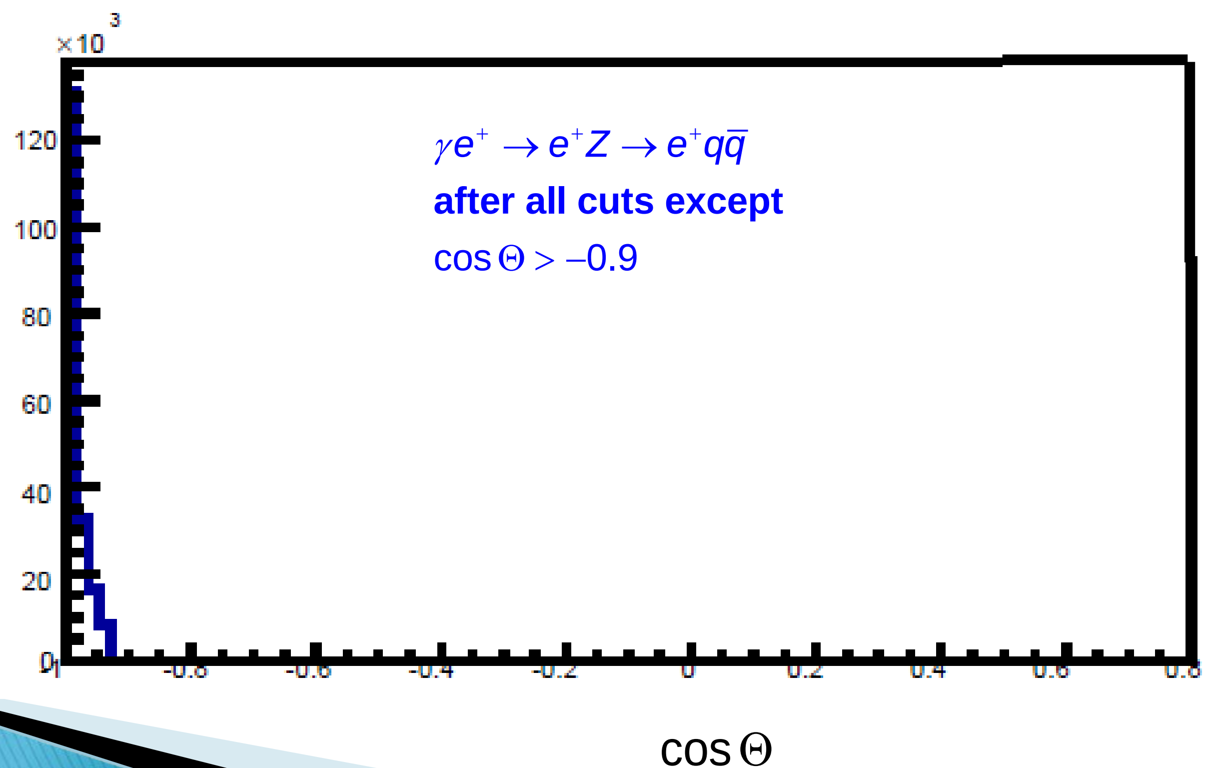
$\gamma e^+ \to e^+ Z$

leads to events with e^+ / e^-

in backwards direction.

For e^+ / e^- only require

$\cos\Theta > -0.9$



Number of Events Simulated Vs. Analyzed

Process	Polarization	N_fullsim	N_analyzed	% Analyzed
$4f\_WW$	$m80p20$	5135540	2303440	45%
evW	$m80p20$	6570290	4046170	62%
tt	$m80p20$	566450	565100	100%
all_other	$m80p20$	3232670	2212120	68%
$4f\_WW$	$p80m20$	436590	432130	99%
evW	$p80m20$	5080160	3094260	61%
tt	$p80m20$	566494	567990	100%
all_other	$p80m20$	2814720	1845900	66%

18

$$e^+e^- \rightarrow WW \rightarrow \nu lqq$$

Table 11.4.3: Number of events passing semileptonic W^+W^- cuts for 500 fb^{-1} luminosity.

Type	Solid Angle	$P(e^-)$	$P(e^+)$	Number of events
Signal	$0.8 < \cos\Theta < 1.0$	-80%	+20%	122300
Signal	$-1 < \cos\Theta < 0.8$	-80%	+20%	37040
Signal	$0.8 < \cos\Theta < 1.0$	+80%	-20%	8490
Signal	$-1 < \cos\Theta < 0.8$	+80%	-20%	3216
Background	$0.8 < \cos\Theta < 1.0$	-80%	+20%	3547
Background	$-1 < \cos\Theta < 0.8$	-80%	+20%	5050
Background	$0.8 < \cos\Theta < 1.0$	+80%	-20%	3985
Background	$-1 < \cos\Theta < 0.8$	+80%	-20%	3699

Low MC Stat

Table 11.2.5: Number of events passing semileptonic W^+W^- cuts for 500 fb^{-1} luminosity.

Type	Solid Angle	$P(e^-)$	$P(e^+)$	Number of events
Signal	$0.8 < \cos\Theta < 1.0$	-80%	+20%	115400
Signal	$-1 < \cos\Theta < 0.8$	-80%	+20%	35015
Signal	$0.8 < \cos\Theta < 1.0$	+80%	-20%	8585
Signal	$-1 < \cos\Theta < 0.8$	+80%	-20%	3115
Background	$0.8 < \cos\Theta < 1.0$	-80%	+20%	9097
Background	$-1 < \cos\Theta < 0.8$	-80%	+20%	7965
Background	$0.8 < \cos\Theta < 1.0$	+80%	-20%	6303
Background	$-1 < \cos\Theta < 0.8$	+80%	-20%	5727

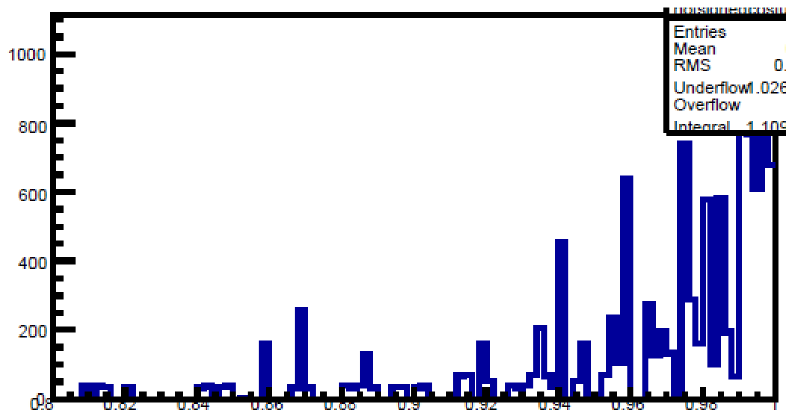
High MC Stat

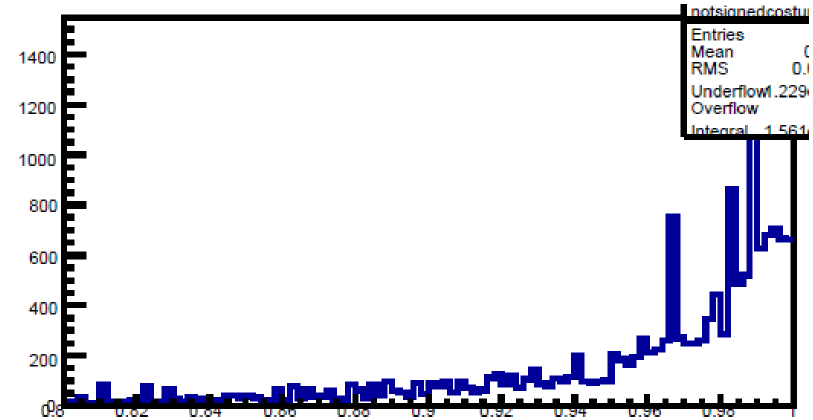
19

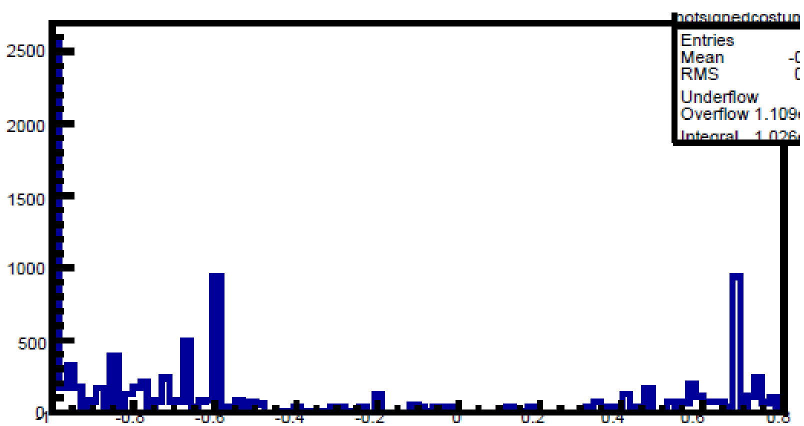
All other background m80p20

Low stat

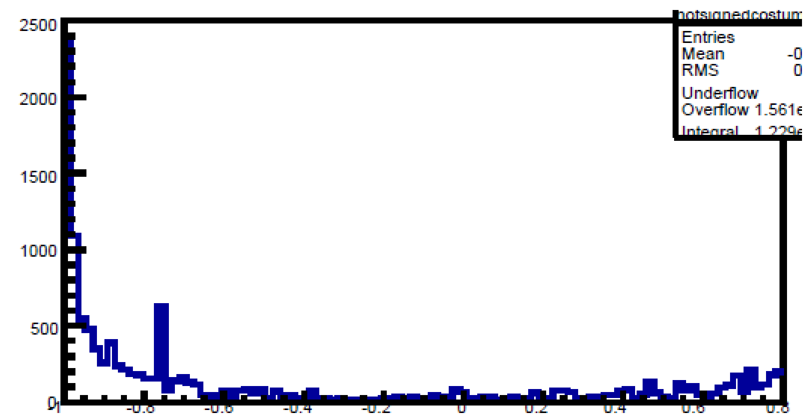
High stat







cos Θ

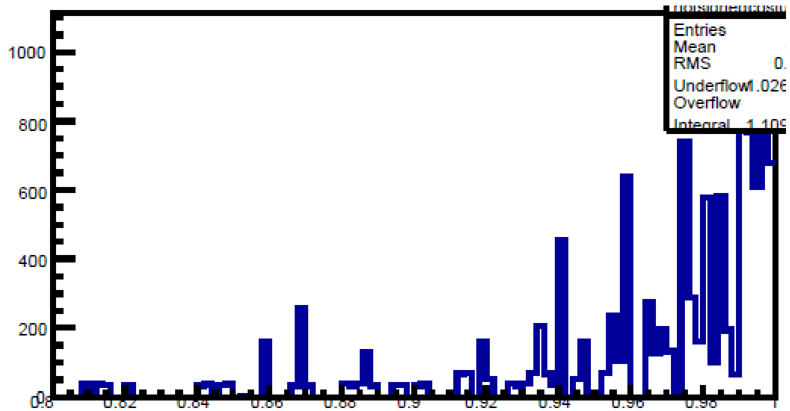


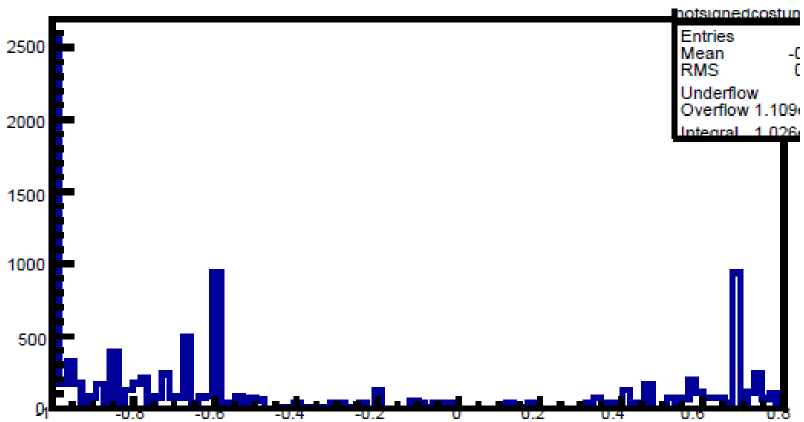
cos Θ

Before identifying additional processes with Weiz-Will problem

All other background m80p20

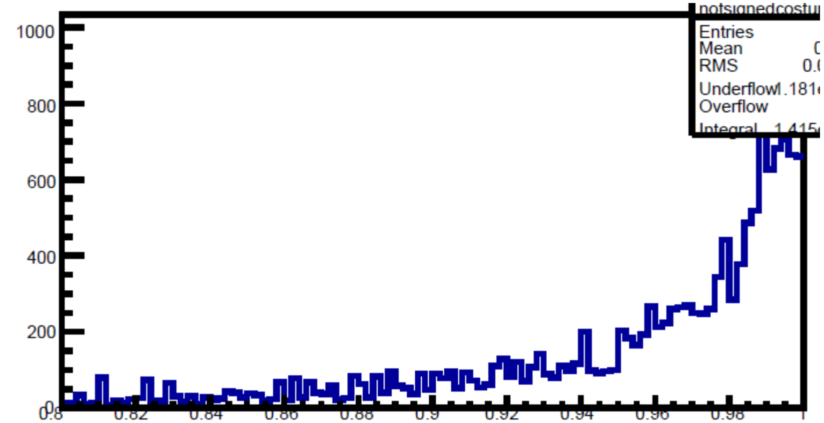
Low stat

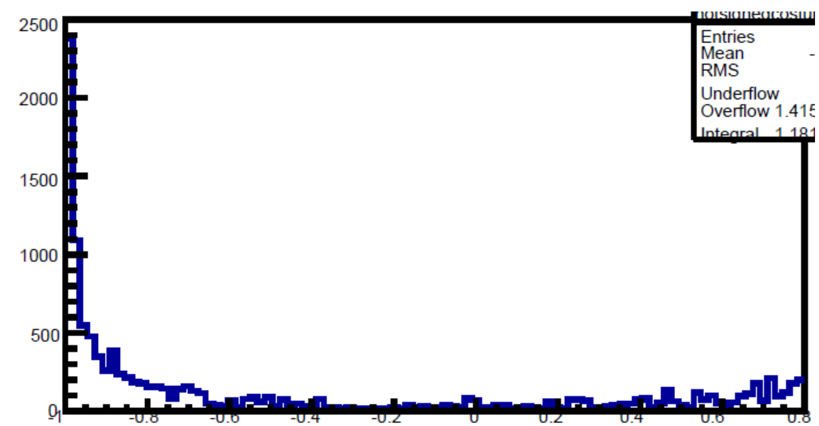




cos Θ

High stat





cos Θ

After identifying additional processes with Weiz-Will problem

Analysis for $e^+e^- \to WW \to qqqq$

Require 0 isolated muons, electrons, & photons

Perform jet analysis using the kt-algorithm in exclusive mode with 4 jets with ΔR=0.7. This algorithm will identify beams jets and group everything else into 4 jets.

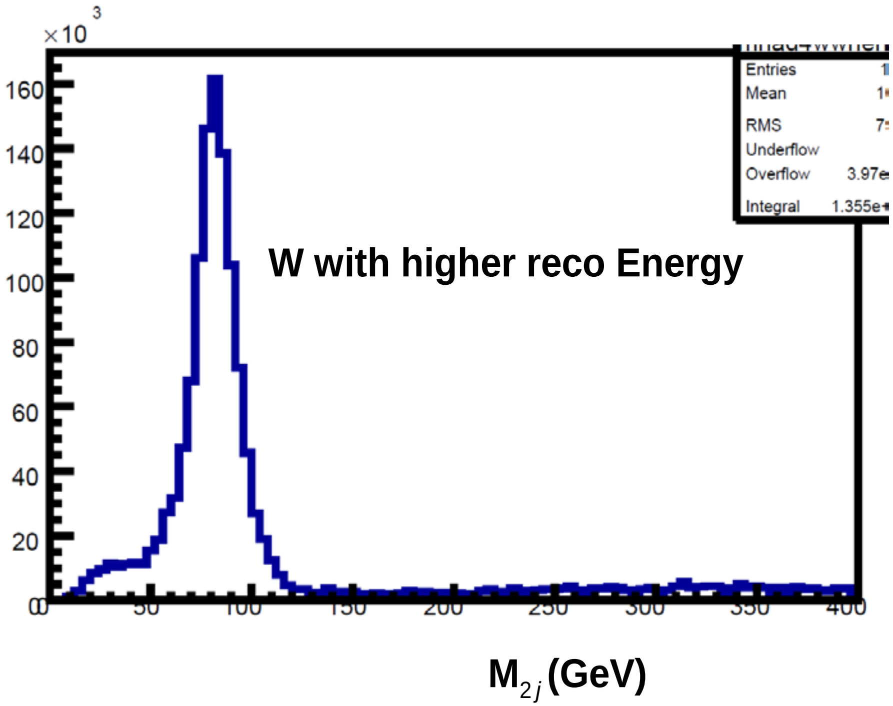
The 4 jets are divided into two 2-jets systems using a chisquare minimization similar to that used in $t\bar{t}h$ analysis

Require

N_{PFO} **> 28**

55 $< M_{2j} < 105$ **GeV** $E_{4j} > 600$ **GeV**

$$e^+e^- \to WW \to qqqq$$



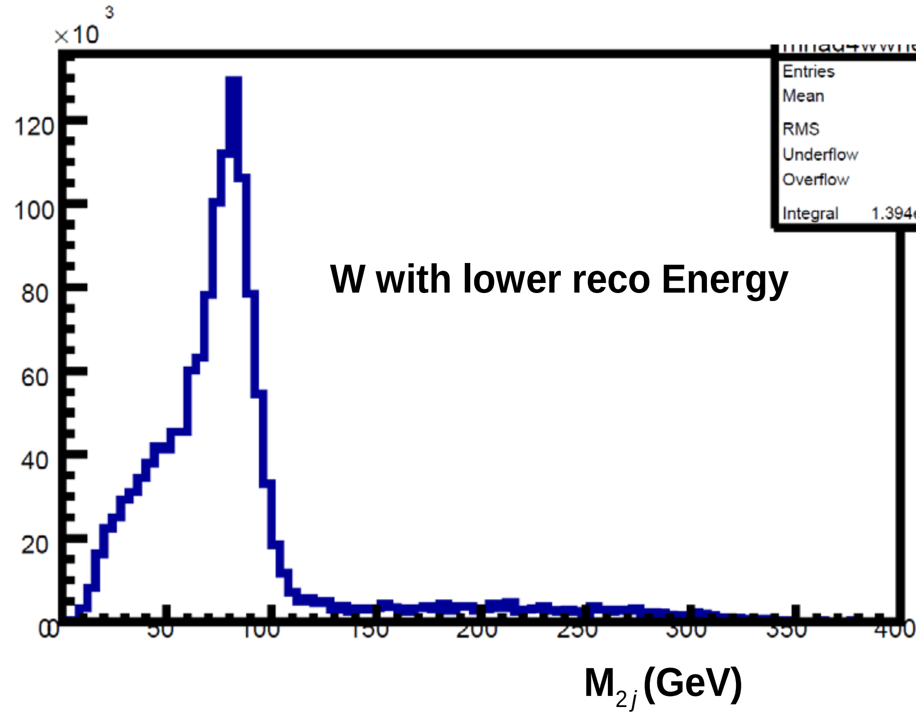


Table 11.2.6: Number of events passing fully hadronic W^+W^- cuts for 500 fb^{-1} luminosity.

Type	Solid Angle	$P(e^-)$	$P(e^+)$	Number of events
Signal	$0.8 < \|\cos\Theta\| < 1.0$	-80%	+20%	296800
Signal	$0.8 < \|\cos\Theta\| < 1.0$	+80%	-20%	22970
Background	$0.8 < \|\cos\Theta\| < 1.0$	-80%	+20%	32507
Background	$0.8 < \|\cos\Theta\| < 1.0$	+80%	-20%	13186

$e^+e^- \to W^+W^- \quad \sqrt{s} =$ **1 TeV**

Beam Polarisation Measurements

The effective polarisation parameters a and b are extracted by counting events in bins of $(\cos\Theta, \cos\theta)$ and fitting for a and b with a linear least squares fit:

$$\chi^2 = \sum_i \frac{(N_i - (a\mu_i + b\nu_i)L)^2}{N_i}$$

where N_i is the number of events in bin i, L is the integrated luminosity

$$\mu_i = \int d\vec{x}_i d\vec{x}' \eta(\vec{x}') \Omega(\vec{x}_i, \vec{x}') \frac{d\sigma_{LR}}{d\vec{x}'}$$

$$\nu_i = \int d\vec{x}_i d\vec{x}' \eta(\vec{x}') \Omega(\vec{x}_i, \vec{x}') \frac{d\sigma_{RL}}{d\vec{x}'}$$

Let M_{ki} be the number of events in bin i from a Monte Carlo sample produced with effective beam polarisations a_k and b_k and luminosity L_k.

$$\mu_i = \frac{1}{a_1 b_2 - a_2 b_2}\left[b_2 \frac{M_{1i}}{L_1} - b_1 \frac{M_{2i}}{L_2}\right], \qquad \nu_i = \frac{1}{a_1 b_2 - a_2 b_2}\left[-a_2 \frac{M_{1i}}{L_1} + a_1 \frac{M_{2i}}{L_2}\right].$$

$e^+e^- \to W^+W^- \quad \sqrt{s} = $ **1 TeV**

Table 11.4.5: Polarisation errors assuming 500 fb^{-1} luminosity for each initial state polarisation configuration.

$\cos\Theta$ range	P_{e^-}, P_{e^+}	Δa	Δb	ΔP_{e^-}	ΔP_{e^+}
$0.8 < \cos\Theta < 1$	-0.8,+0.2	0.0011	0.62	3.77	2.51
$0.8 < \cos\Theta < 1$	+0.8,-0.2	0.00030	0.20	0.13	0.27
$-1 < \cos\Theta < 1$	-0.8,+0.2	0.0010	0.084	0.51	0.32
$-1 < \cos\Theta < 1$	+0.8,-0.2	0.00027	0.032	0.020	0.08
$\cos\Theta$ range	P_{e^-}, P_{e^+}	$\Delta\alpha$	$\Delta\beta$	$\Delta\lvert P_{e^-}\rvert$	$\Delta\lvert P_{e^+}\rvert$
$-1 < \cos\Theta < 1$	sum	0.00097	0.00027	0.0017	0.0027

old low stat PAC numbers

$\cos\Theta$ range	P_{e^-}, P_{e^+}	Δa	Δb	ΔP_{e^-}	ΔP_{e^+}
$0.8 < \cos\Theta < 1$	-0.8,+0.2	0.0011	0.020	0.12	0.077
$0.8 < \cos\Theta < 1$	+0.8,-0.2	0.00037	0.0090	0.0046	0.023
$-1 < \cos\Theta < 1$	-0.8,+0.2	0.0011	0.0097	0.058	0.038
$-1 < \cos\Theta < 1$	+0.8,-0.2	0.00037	0.0071	0.0041	0.018
$\cos\Theta$ range	P_{e^-}, P_{e^+}	$\Delta\alpha$	$\Delta\beta$	$\Delta\lvert P_{e^-}\rvert$	$\Delta\lvert P_{e^+}\rvert$
$-1 < \cos\Theta < 1$	sum	0.0010	0.00032	0.0020	0.0029

new high stat numbers

↑ **Δb better because bgnd polarization dependence included in new results**