Further studies on WW

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KEK, December 2018

- Further look at kinematics
- First look at background

The WW process

Starting point: analysis in the note LC-DET-2009-003

Triple Gauge Couplings and Polarization at the ILC

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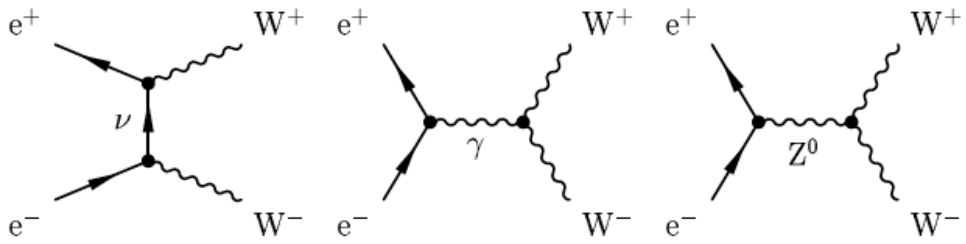
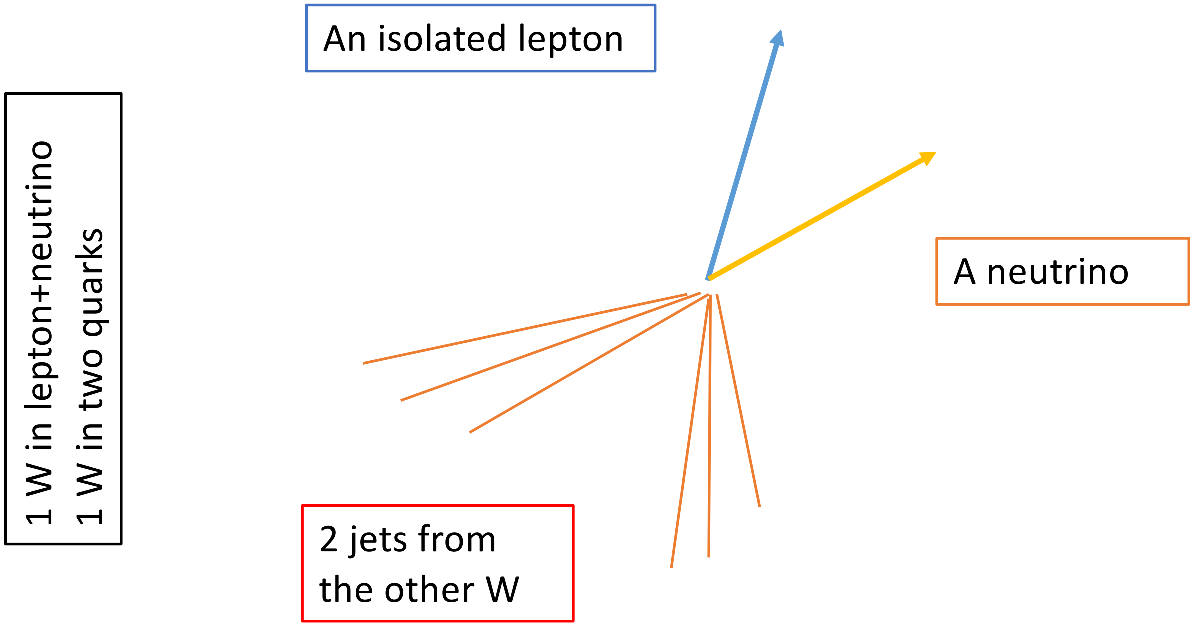
Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany



- WW production is sensitive to the triple gauge couplings, predicted by the SM due the non-abelian nature of the electroweak interaction.
- Precise measurements could determine if anomalous TCG (aTGC) are present
- Study in WW semi-leptonic samples
- Process has also strong dependence

on polarization (suppressed in eRpL) and can be used to measure P

Reminder on selection



Pre-selection:

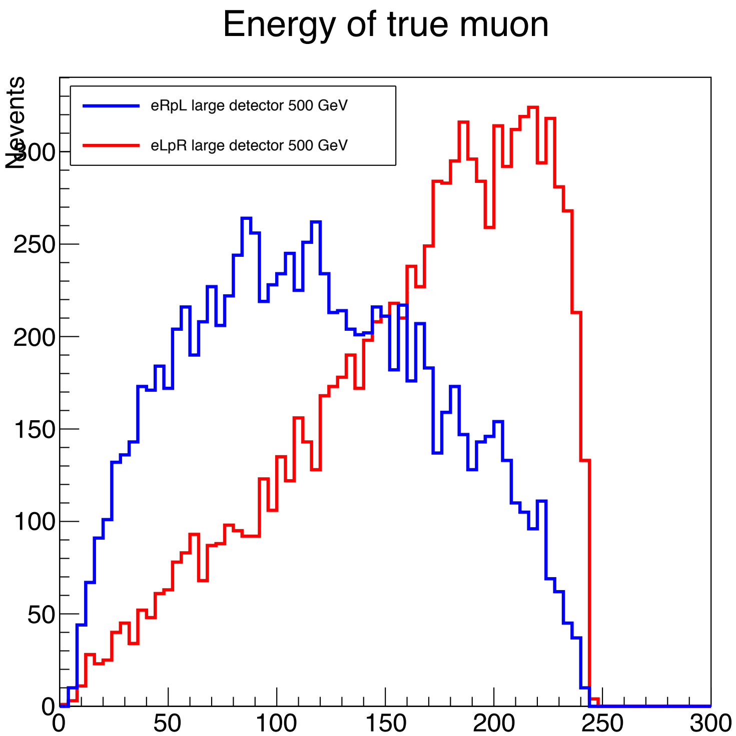
- Require an isolated lepton – only muon (processor IsolatedLeptonTaggingProcessor)
- Exclude isolated lepton from PFOs
- Run jet cluster on PFOs without isolated lepton, require 2 jets with E>10 GeV
- (processor JetClustering, kt vertex with R parameter=1.4)

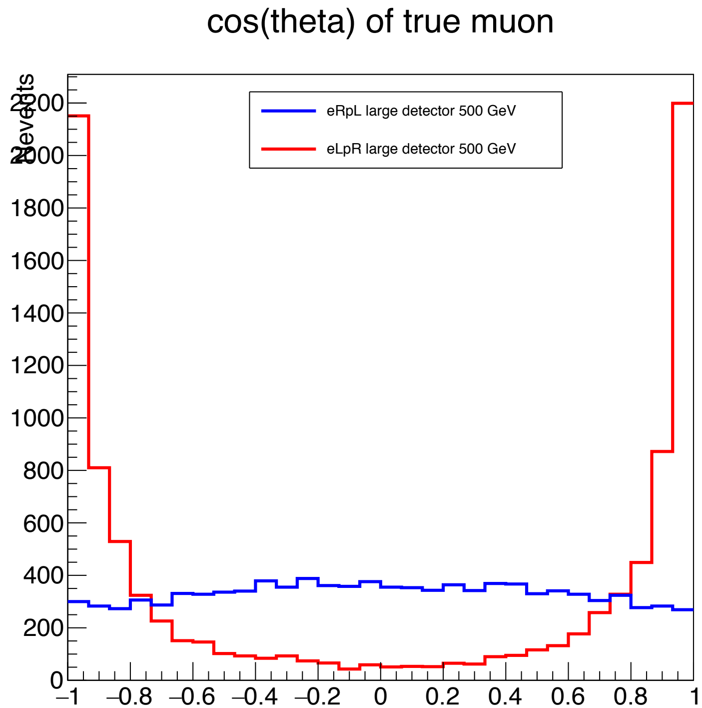
Samples used

- Samples* in
  - /pnfs/desy.de/ilc/prod/ilc/mc-opt-3/ild/dst-merged/500-TDR_ws/4f_WW_semileptonic/ILD_**l5**_o1_v02/
  - /pnfs/desy.de/ilc/prod/ilc/mc-opt-3/ild/dst-merged/500-TDR_ws/4f_WW_semileptonic/ILD_**s5**_o1_v02/
  - **For eRpL and eLpR**

* Samples contain W->mu nu and W-> tau nu decays+overlays

Kinematics eRpL vs eLpR is very different





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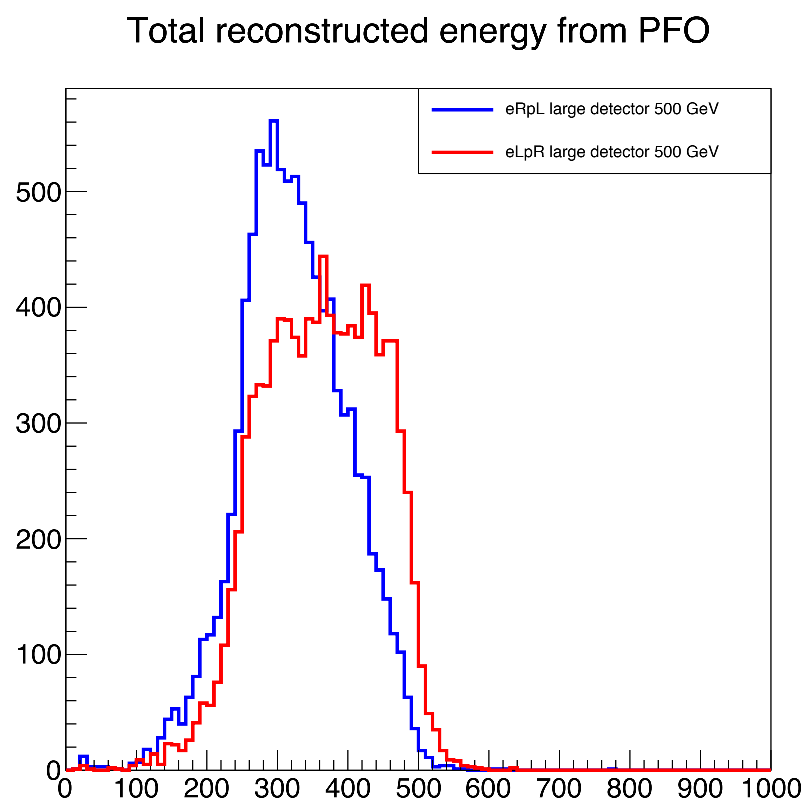

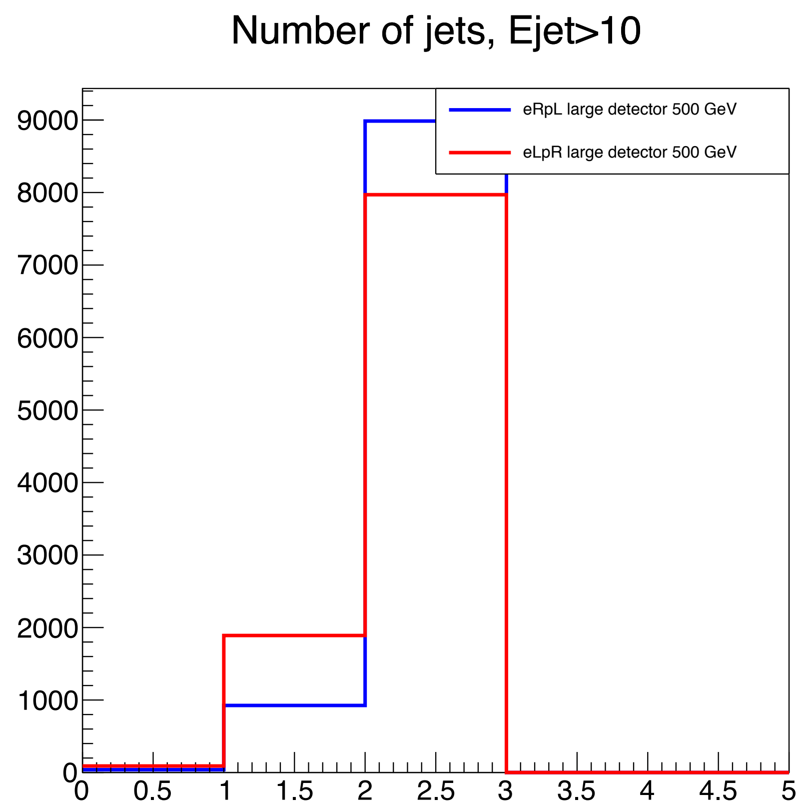

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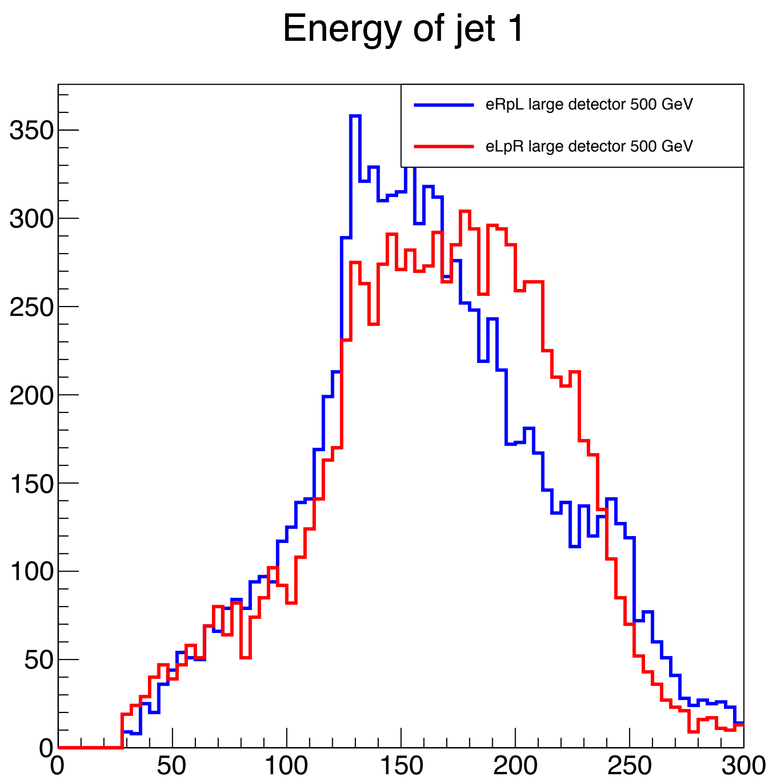

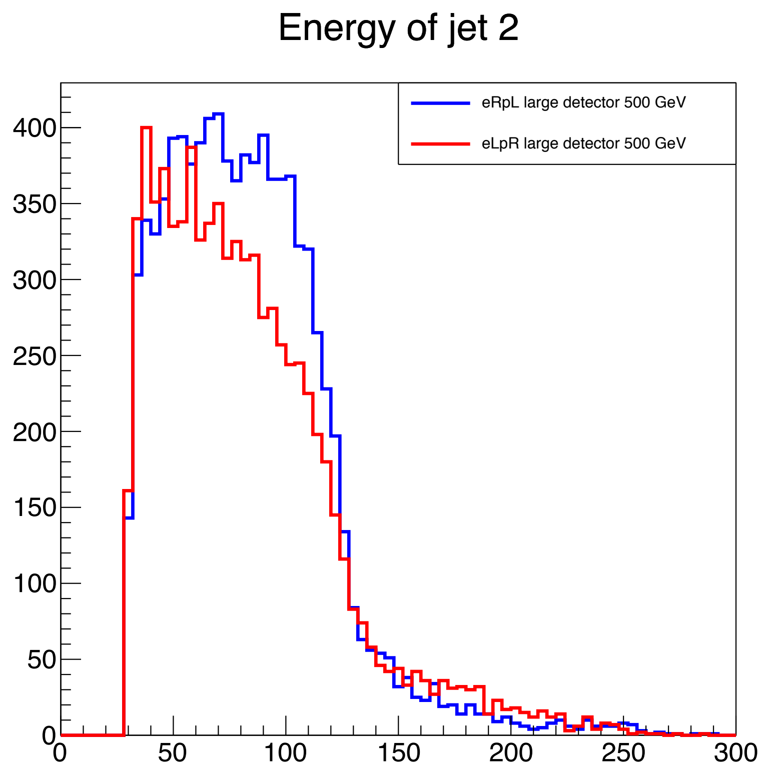

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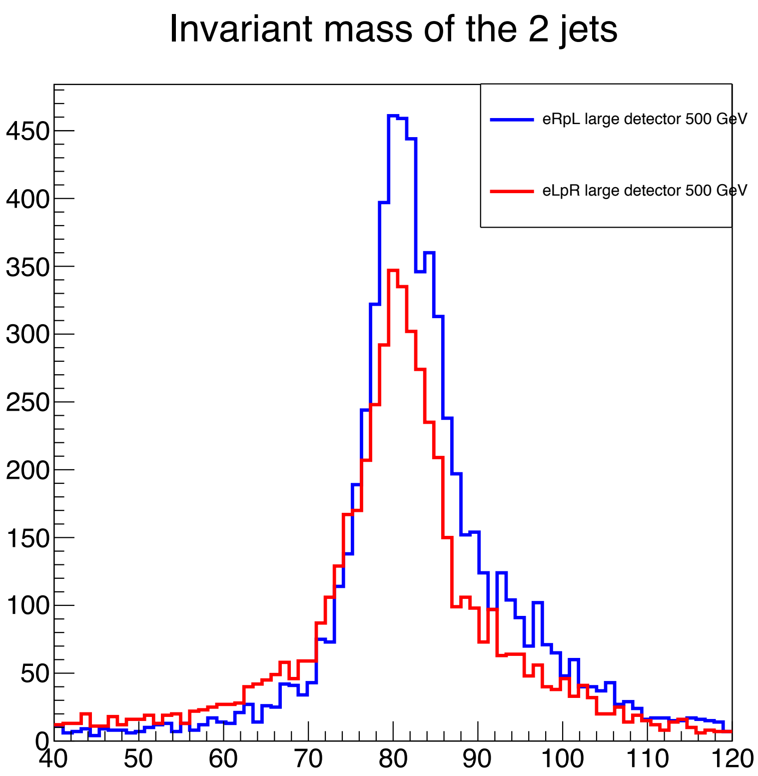
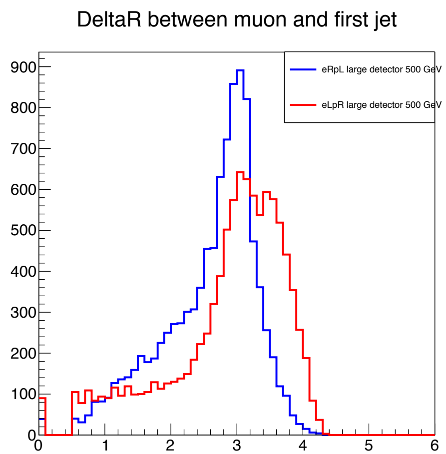
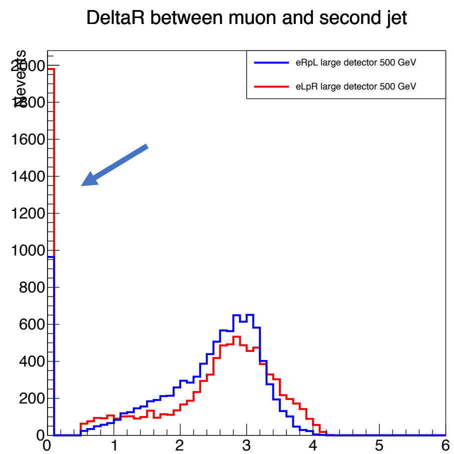
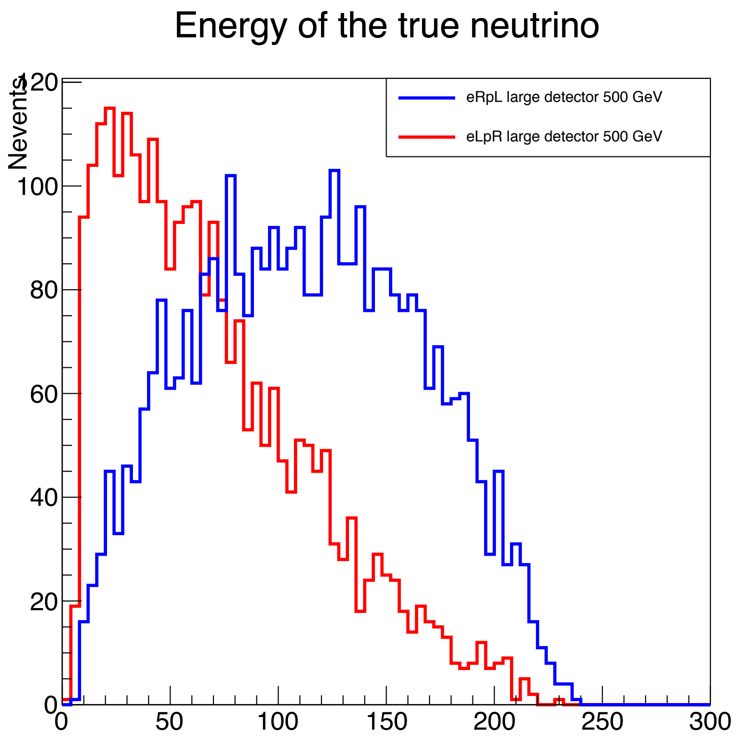


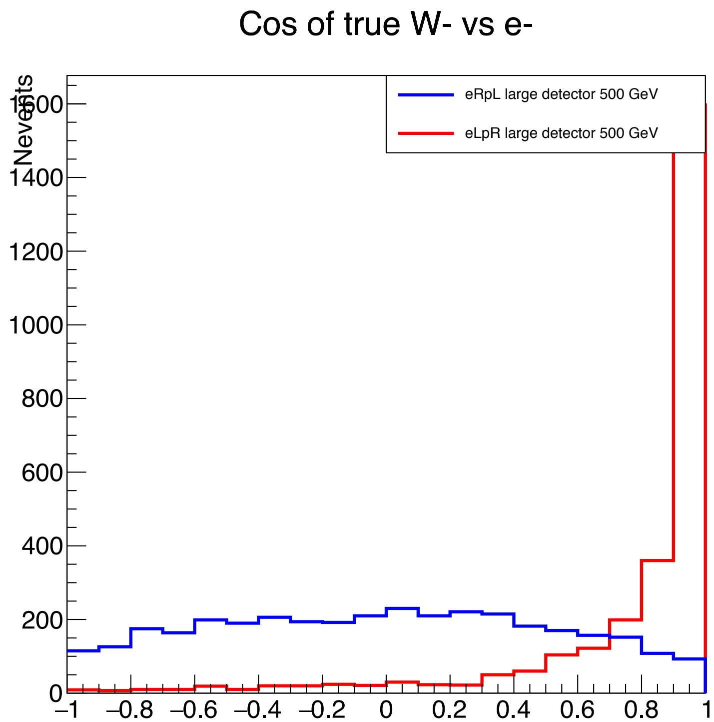




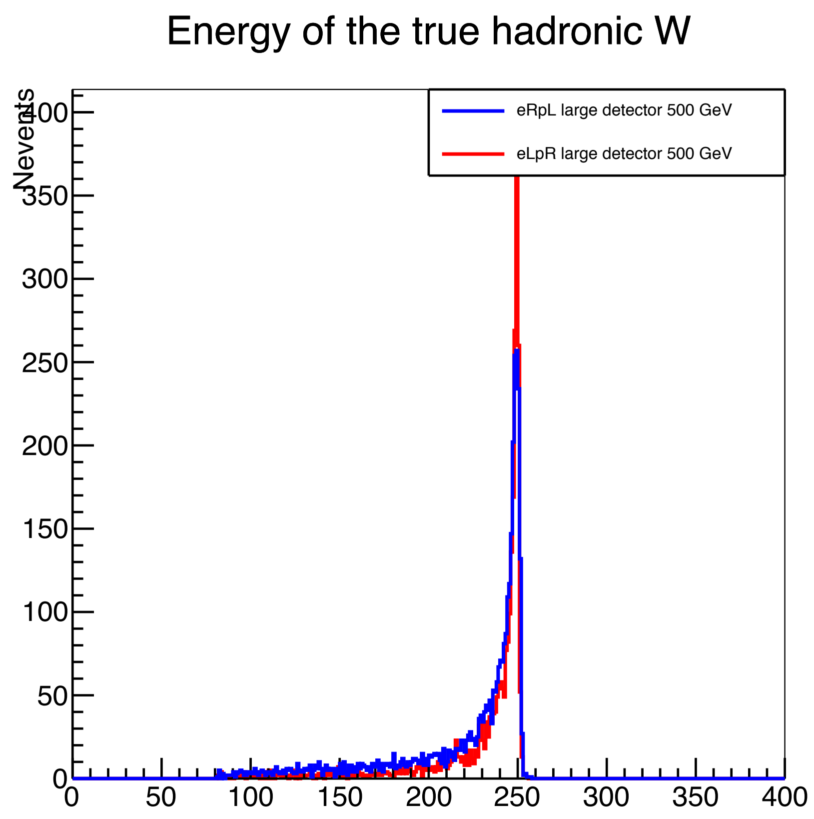
Less energetic
second jet in eLpR?
makes slightly lower
efficiency for eLpR

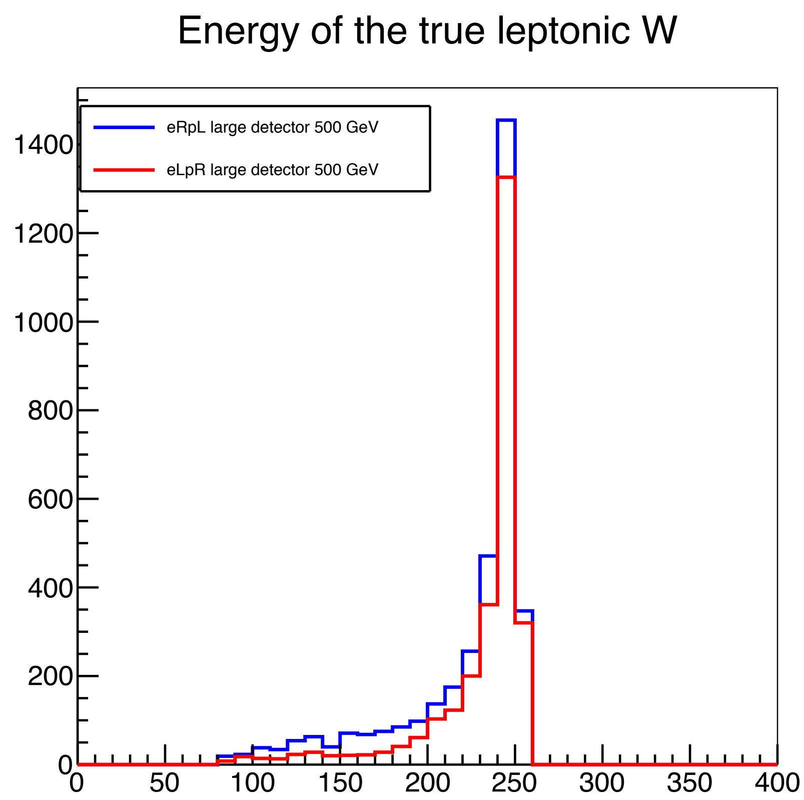
Kinematics eRpL vs eLpR is very different





Kinematics eRpL vs eLpR is very different



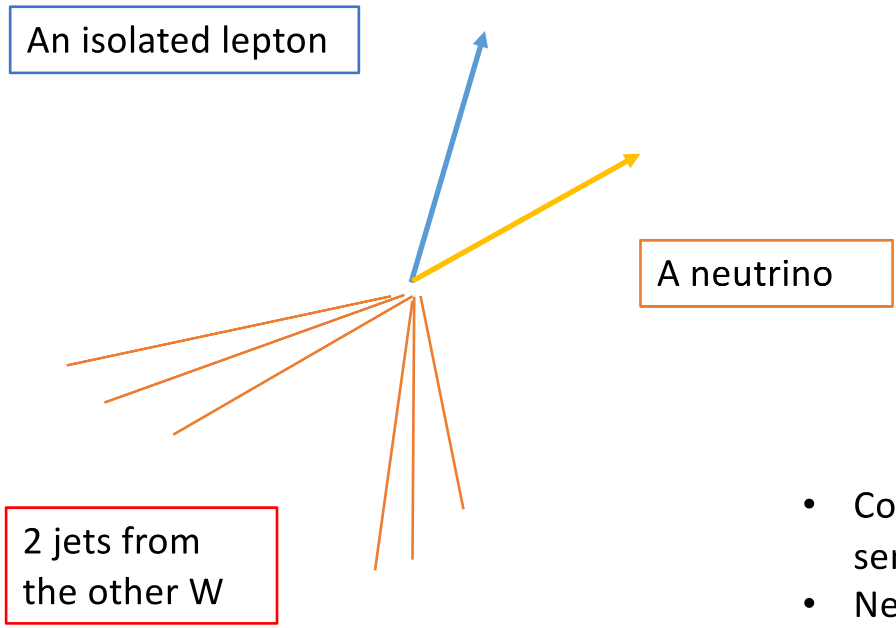


Comparison eRpL - eLpR (large detector used)

Cut on W->mu nu	**eRpL Start 9950**	**%**
Ntracks>10 $(\gamma\gamma\ backg)$	9913	99.6
Etot<500 GeV (overlays)	9868	99.2
Emuon>30 GeV (W->tau->mu)	4659	46.8
2 jets, E>30 DeltaR>0.5	4032	40.5
No 2^{nd} lepton (Z, top)	4028	40.5
60< m12(jets) <110	3509	35.3

Cut on W->mu nu	**eLpR Start 9950**	**%**
Ntracks>10 $(\gamma\gamma\ backg)$	9886	99.4
Etot<500 GeV (overlays)	9667	97.2
Emuon>30 GeV (W->tau->mu)	4516	45.4
2 jets, E>30 DeltaR>0.5	3414	34.3
No 2^{nd} lepton (Z, top)	3409	34.3
60< m12(jets) <110	2717	27.3

WW aTGC couplings



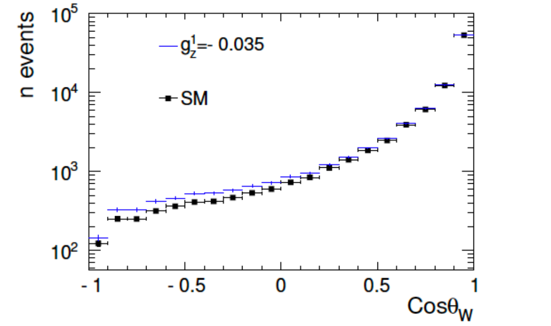


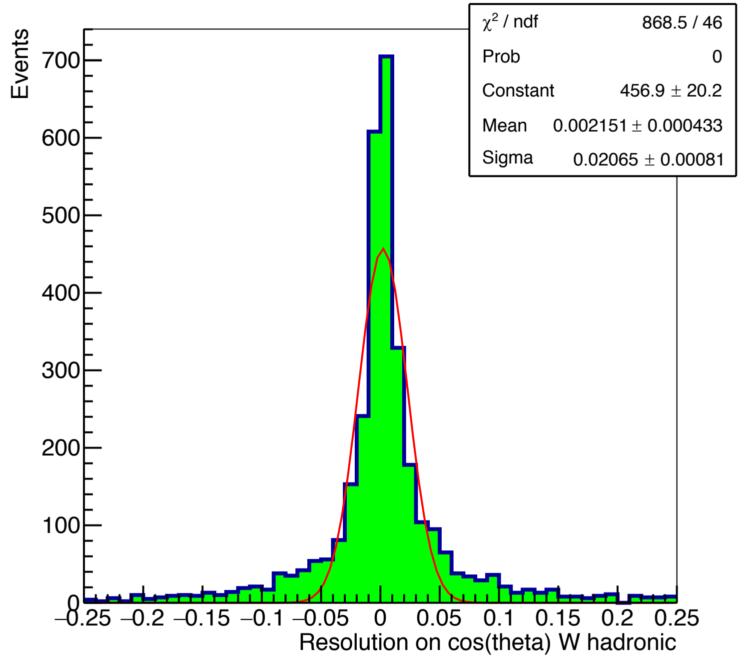
Figure 22: Comparison of two $\cos\theta_W$ distributions: the black squares show the SM distribution, while the blue markers show the distribution obtained for a simulated anomalous value of the g_1^Z coupling, namely $g_1^Z = -0.035$.

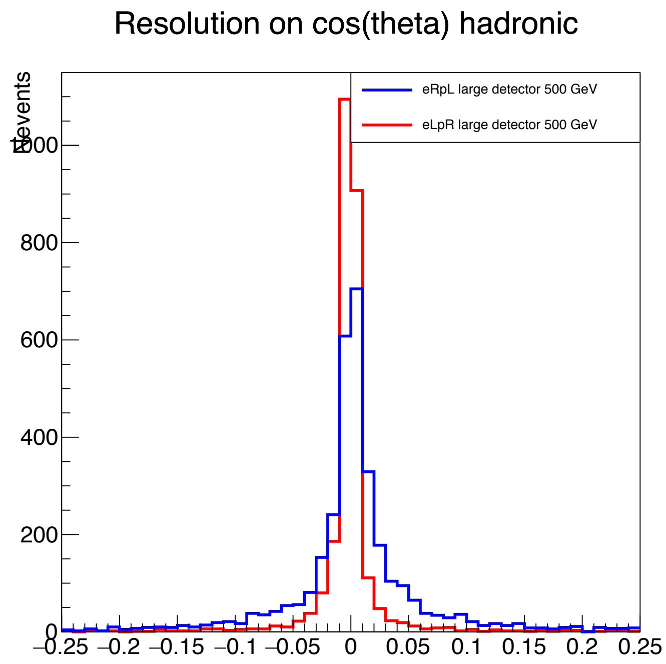
- Cos(theta$_W$) of the negative W is sensitive to aTCG
- Need to reconstruct direction of the W's, charge comes from the lepton
- For the leptonic W, require momentum conservation
- For the hadronic W, use the two jets

Reconstruction of hadronic theta(W)

First method: reconstruct theta(W) from the hadronic W, i.e. from the momentum of the 2 jets

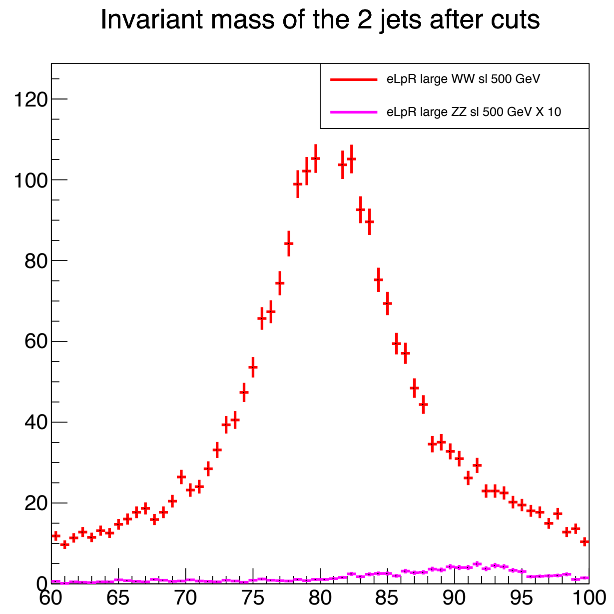
Large eRpL





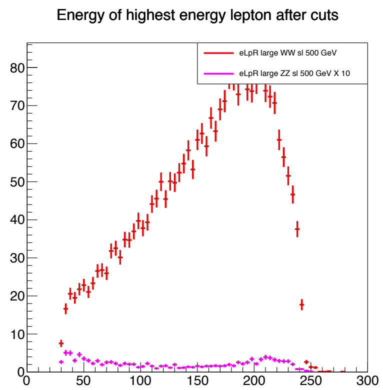
Background studies: 4f_ZZ_semileptonic

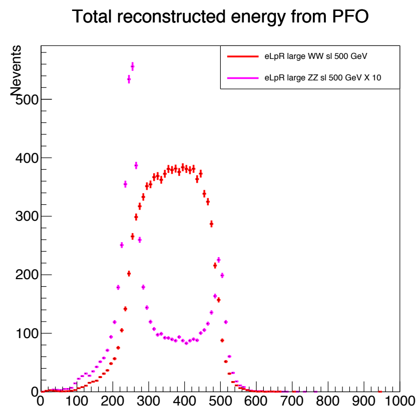
Cut on ZZ->qqll	eLpR Start 62082	%
Ntracks>10 ($\gamma\gamma$ $backg$)	61351	98.8
Etot<500 GeV (overlays)	56693	91.3
Emuon>30 GeV (W->tau->mu)	8727	14.1
2 jets, E>30 DeltaR>0.5	6708	10.8
No 2nd lepton (Z, top)	2263	3.7
60< m12(jets) <110	1255	2.0

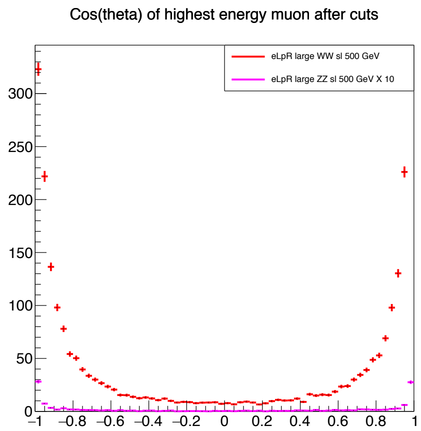


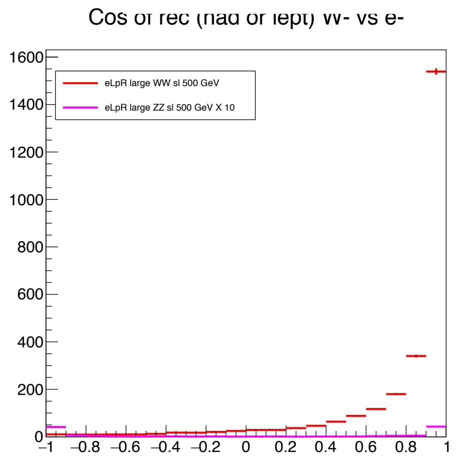
Events normalized to arbitrary lumi, ZZ multiplied by 10

Background studies: 4f_ZZ_semileptonic









Events normalized to same arbitrary lumi (ZZ here X10)

This background is small at least in eL pR and the kinematics is very different, so not a real problem.

Background studies: 4f_WW_fully hadronic

Cut on WW->qqqq	**eLpR Start 9520**	**%**
Ntracks>10 ($\gamma\gamma$ $backg$)	9520	100
Etot<500 GeV (overlays)	6478	68
Emuon>30 GeV (W->tau->mu)	6	0.063
2 jets, E>30 DeltaR>0.5	5	0.053
No 2nd lepton (Z, top)	5	0.053
60< m12(jets) <110	1	0.011

Background is negligible

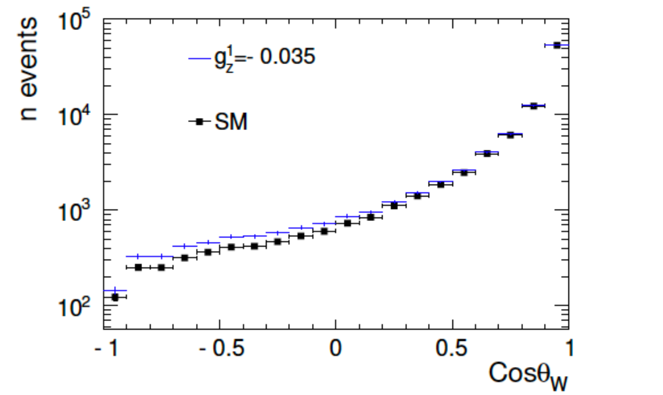
Summary and plans

- Summary:
  - Started to look at eL pR, kinematics is different, resolution on cos(theta)W seems to be slightly better
  - Cuts are to be optimized with background
  - Started to look at the background

Backup

Angular variables sensitive to aTGC:

- the angle θ_W between the W^- and the e^- beam;
- the polar and azimuthal angles of the fermion in the decay $W^- \to f\bar{f}$ calculated in the rest frame of the W^-;
- the corresponding polar and azimuthal angles of the fermion in the decay of the W^+.



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Reconstruction of leptonic theta(W)

Second method: reconstruct theta(W) from the leptonic W, i.e. from the neutrino and the lepton, with some assumptions (from the note):

$$
\begin{aligned}
P_x + P_{\nu,x} &= 0, \\
P_y + P_{\nu,y} &= 0, \\
P_z + P_{\nu,z} + P_\gamma &= 0, \\
E_\nu &= \sqrt{P_{\nu,x}^2 + P_{\nu,y}^2 + P_{\nu,z}^2}, \\
E_\gamma^2 &= P_\gamma^2, \\
E + E_\nu + E_\gamma &= 500,
\end{aligned}
$$

i.e. missing pT is due to the neutrino;
ISR photon only in Z direction

$$
E_\gamma = \frac{(500 - E)^2 - P_x^2 - P_y^2 - P_z^2}{1000 - 2E - 2P_z}
$$

$$
E_\gamma = \frac{(500 - E)^2 - P_x^2 - P_y^2 - P_z^2}{1000 - 2E + 2P_z}
$$

It leads to 2 possible solutions for the ISR energy, and therefore for the neutrino energy. Take the solution which gives the W mass closer to the nominal