Polarization measurement from W^+W^- production

Philip Bechtle, Wolfgang Ehrenfeld, Ivan Marchesini - DESY

Ivan Marchesini, ILD Workshop Seul, 2009-02-16

Overview

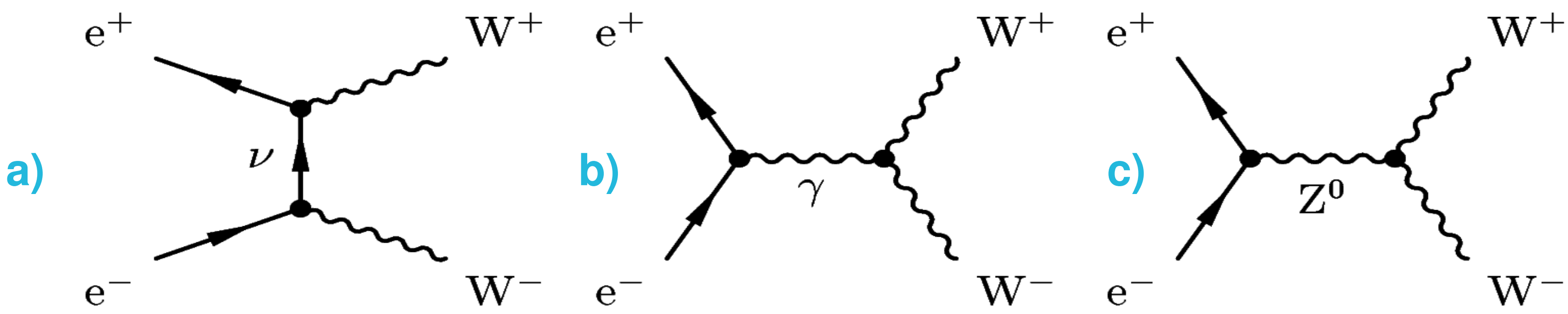
- The aim of data driven polarization measurements at the ILC is to reduce the error on the average polarization respect to the polarimeters, on the long time scale (high luminosity demanding), reaching the precision ~ 0.2%, aimed for some studies.

- W^+W^- production is sensitive to polarization and has an high cross section: fits in this purpose.

- I will show two ways to measure the polarization:
  - From the total cross section measurement (Blondel scheme);
  - From the $\cos\theta_W$ distributions (MC templates fit).

- Using data, eventual new physics is involved and its contribution has to be evaluated.

W^+W^- production and polarization



b) c) **s-channel**: e^+ and e^- must have opposite polarizations, to give the vector boson.

J_z=1 allows vector mediator

a) **t-channel**: same polarizations for e^+ and e^- are generally allowed. But the W can couple only to e^-_L and e^+_R: so for the WW production only the combination $e^-_L e^+_R$ is allowed.

Analysis: selection.

Selection

Simulation:

- ILD_00 mass production run 04 DSTs.
- 20 fb^{-1} for each polarization (here shown +30% e^+, -80% e^-);

Background:

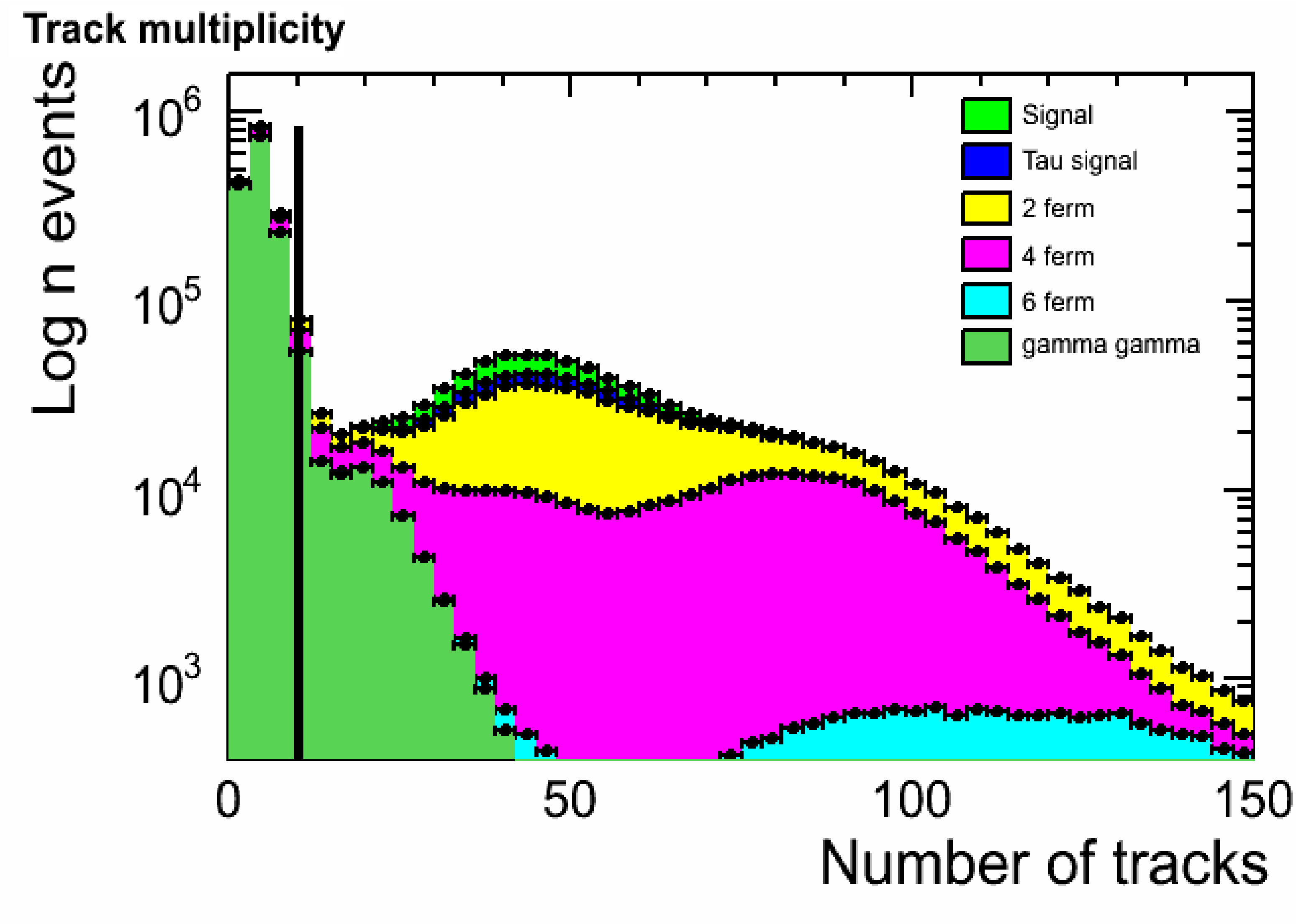
- Complete 2, 4 and 6 fermions backgrounds. Complete gamma background.

W^+W^- decays:

- Leptonic (10%): l ν l ν;
- Semileptonic (43%): q q l ν;
- Hadronic (47%): q q q q.

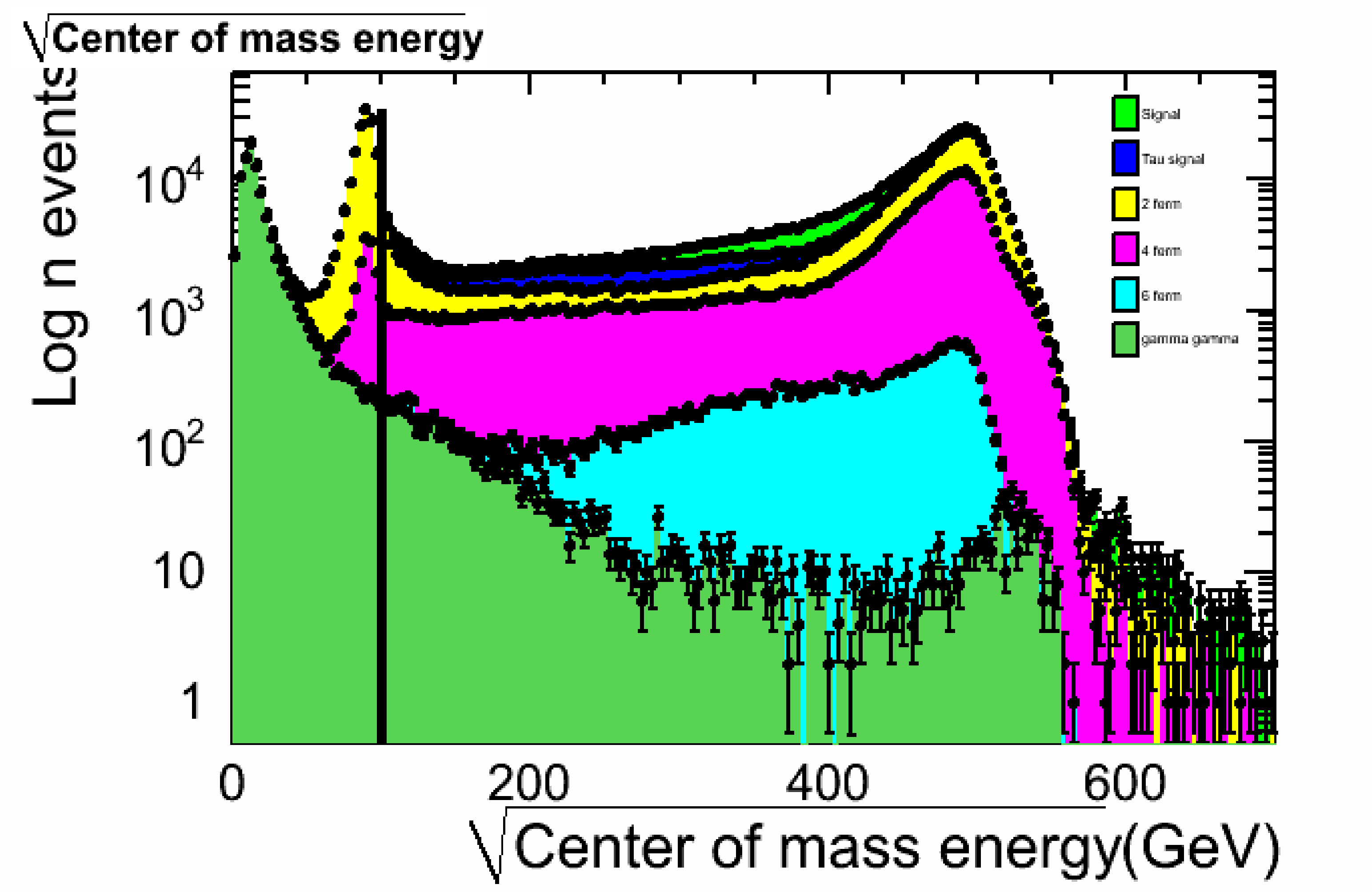
We select only the semileptonic final state, for the muon and electron channel. We currently exclude the tau channel, to have a signal as clean as possible.

Preselection - 1



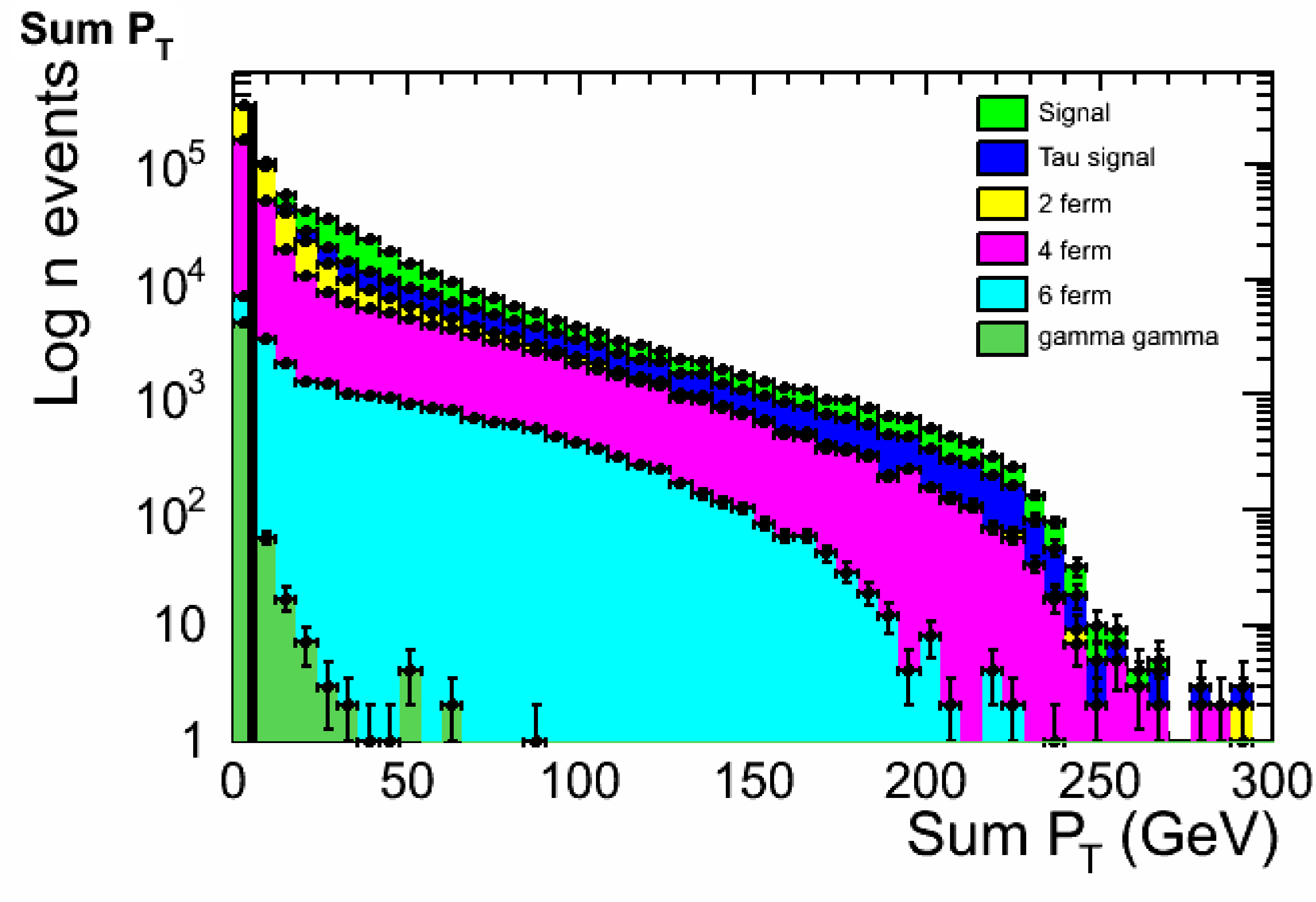
- Tracks < 10.

Preselection - 2



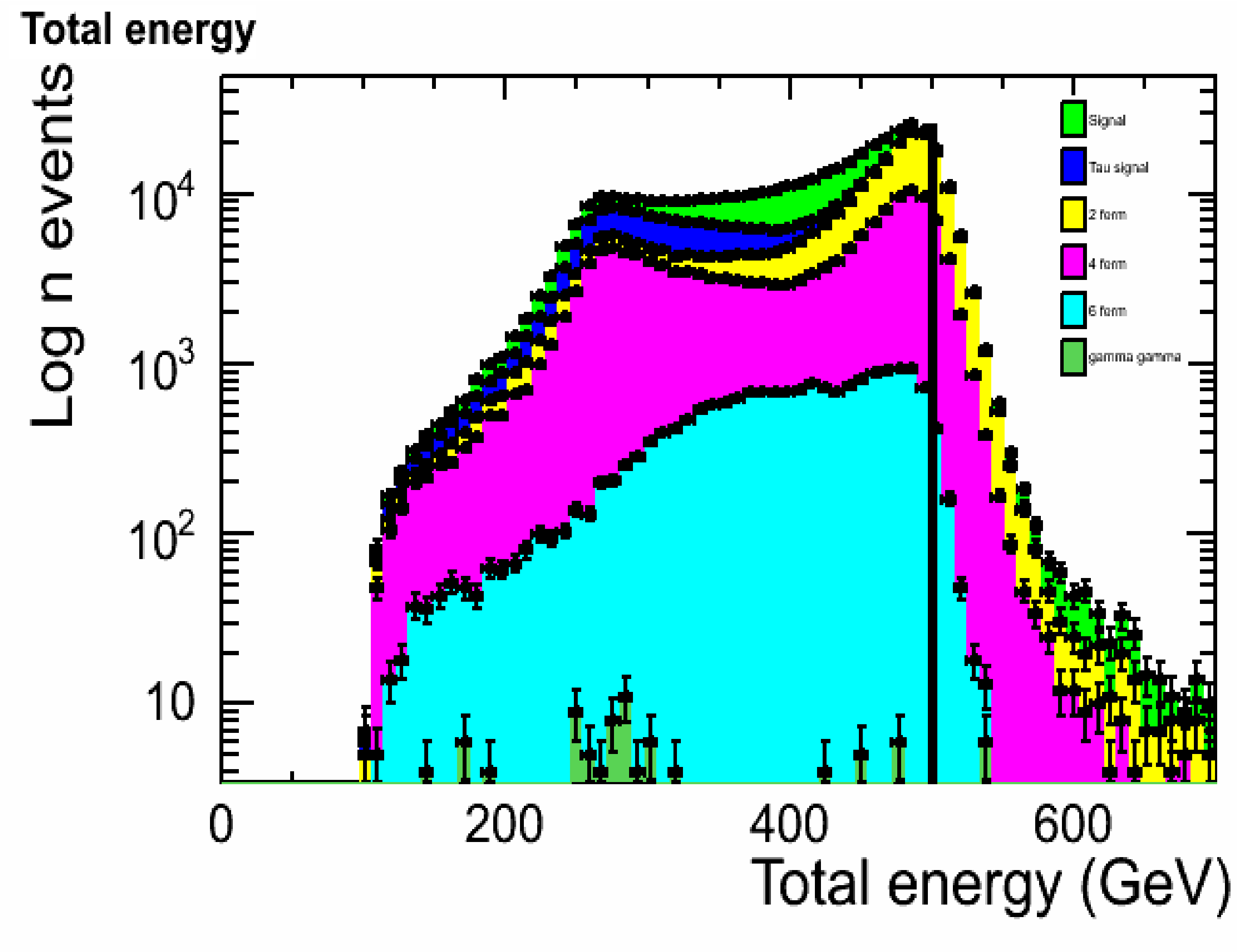
- SqrtS > 100 GeV.

Preselection - 3



- Total transvers momentum > 5 GeV.

Preselection - 4



- Total energy < 500 GeV.

Selection on the leptonic jet

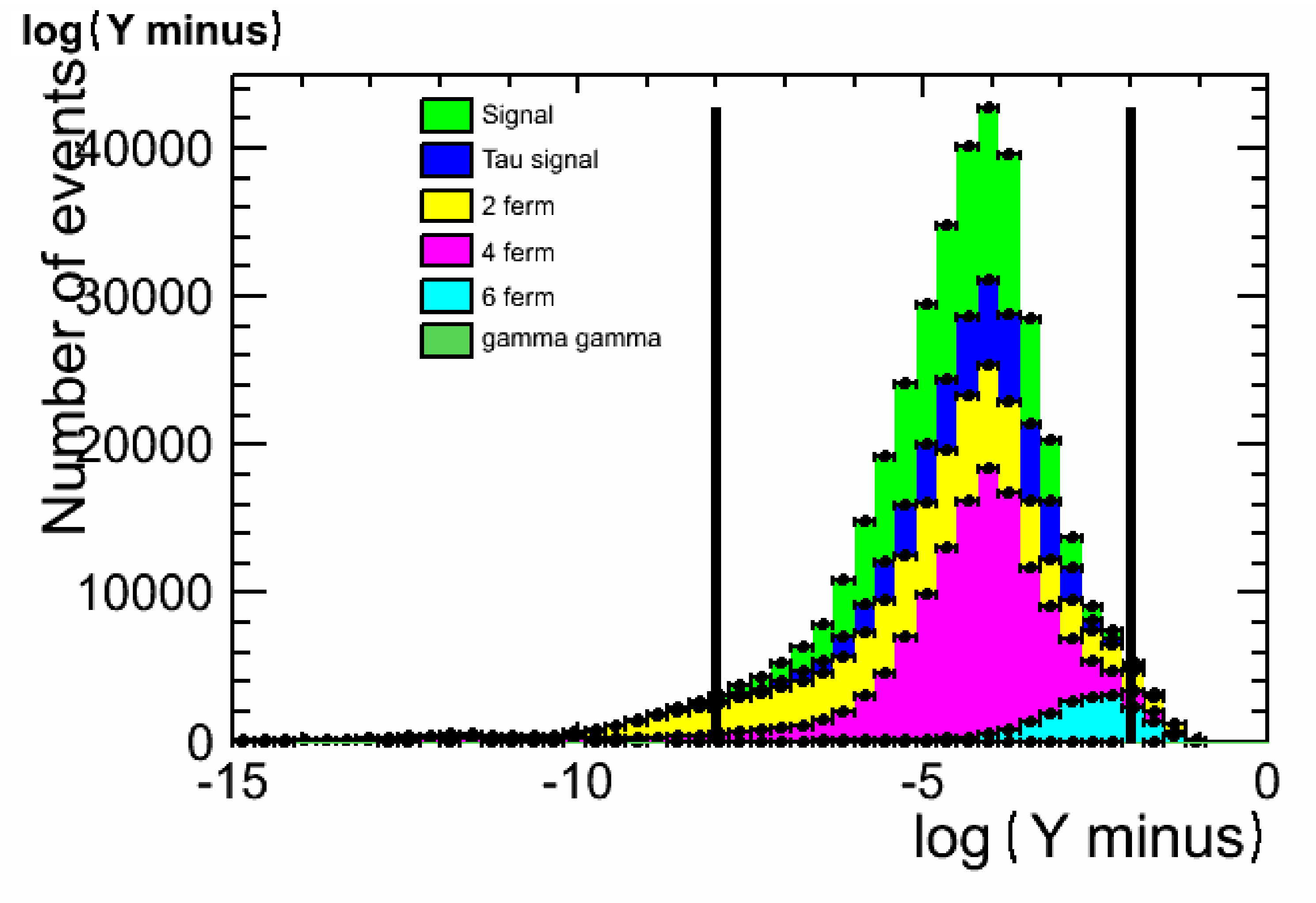
- We force 3 jets (Durham). Two jets are for the hadronic decay. One jet is the lepton. The jet with less multiplicity is taken as the leptonic jet.

- Requirement on the leptonic jet:
  - Isolated (theta-phi isolation > 0.5).
  - One and only one track with $p_T > 10$ GeV.
  - If more than one track:
    - Three tracks: electron radiating photon converting to pair. Two tracks must have invariant mass → 0.

      The third track must be an electron: E/p → 1.
    - In case of muon (E/p → 0) only one track allowed.
  - Lepton track must be charged.

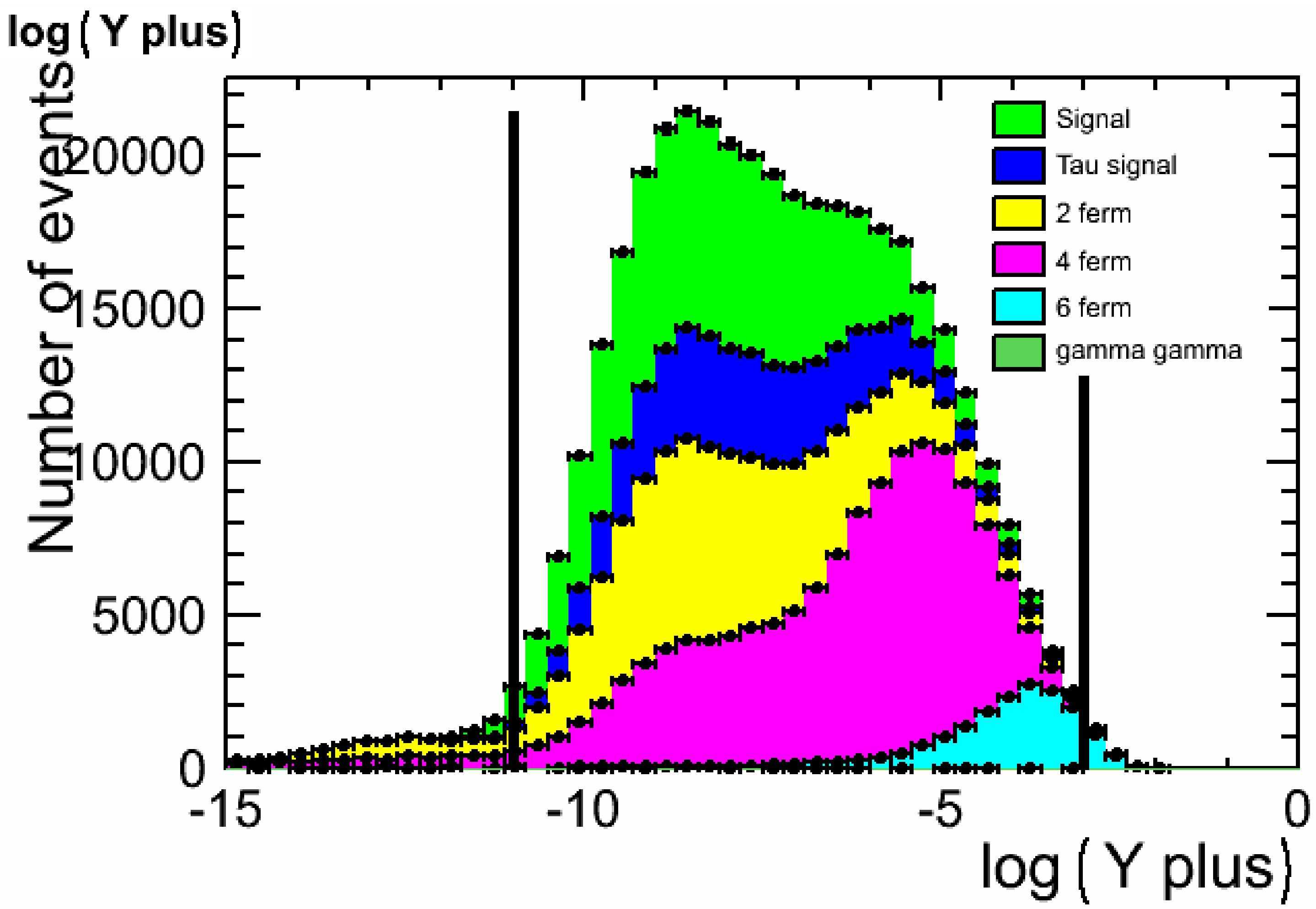
- PFOID not implemented, with this set-up selection it leads to an efficiency loss.

Jet finder Y minus cut



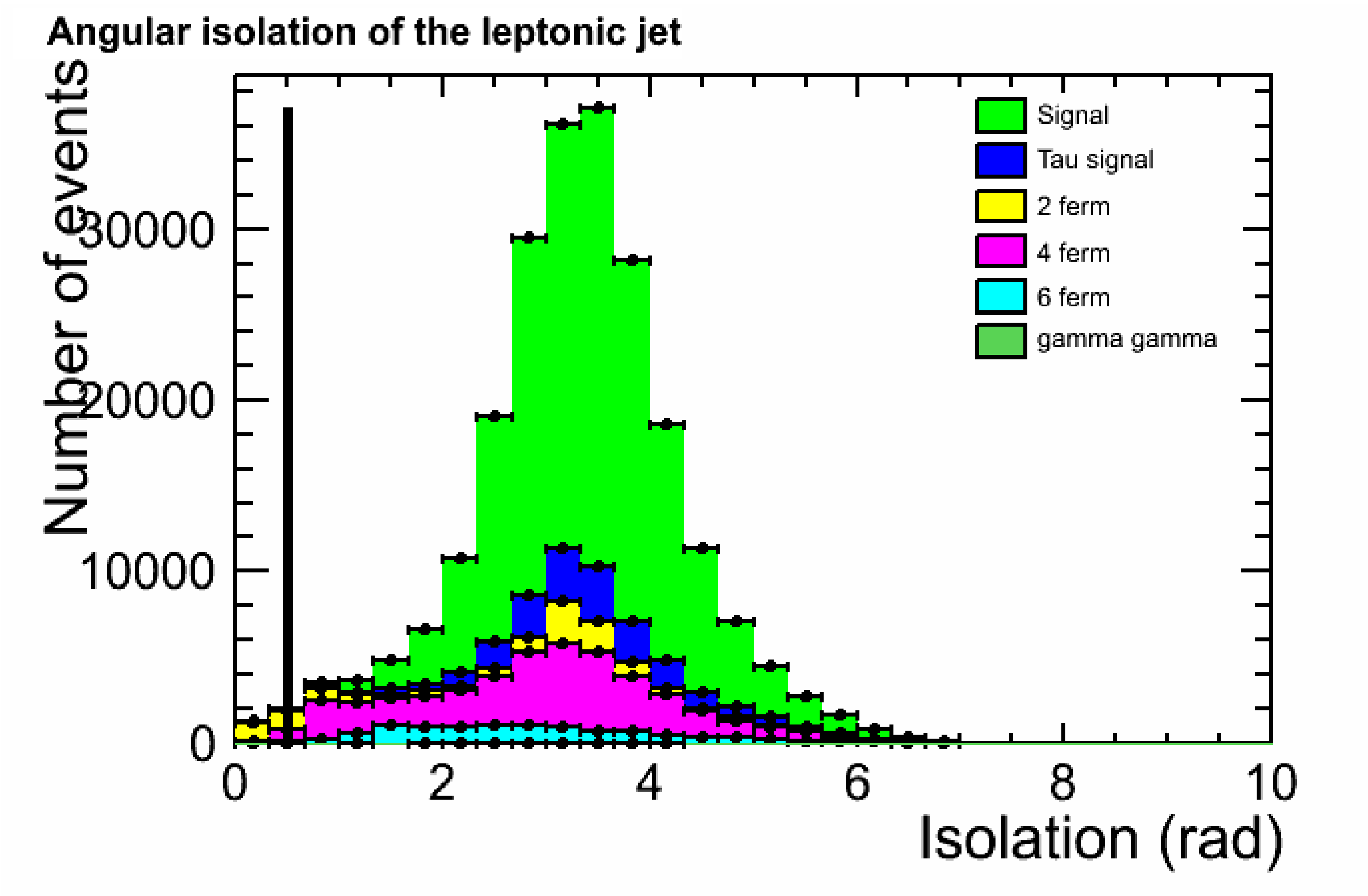
- Yminus -8<<-2.

Jet finder Y plus cut



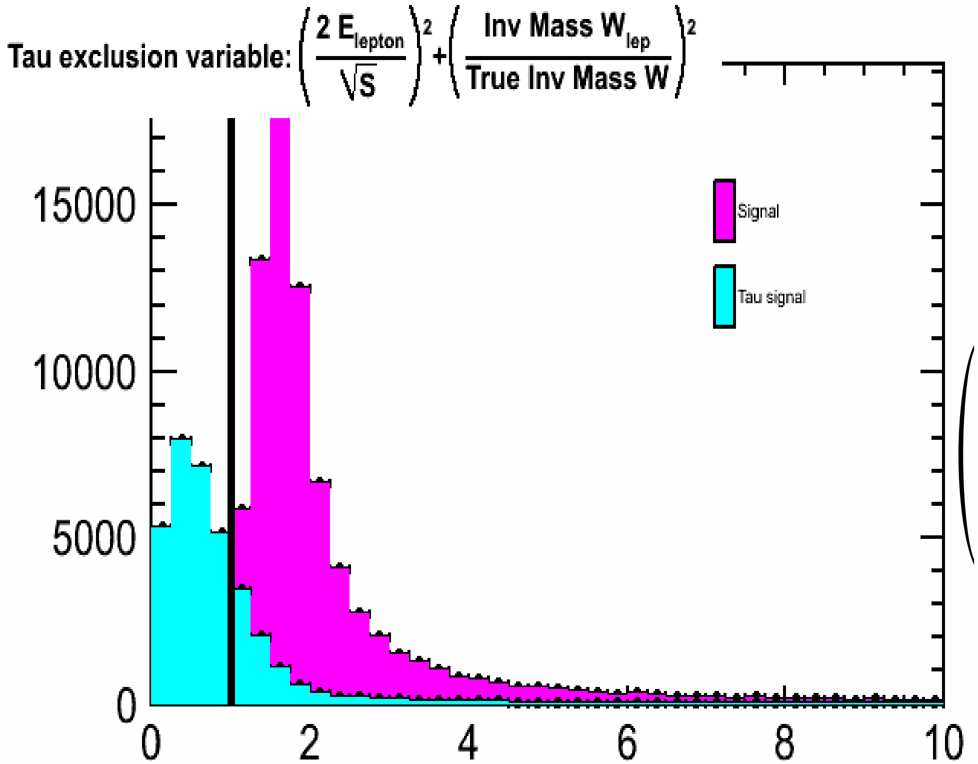
- Yplus -11<<-3.

Lepton jet isolation



- Theta-phi cone isolation > 0.5 rad.

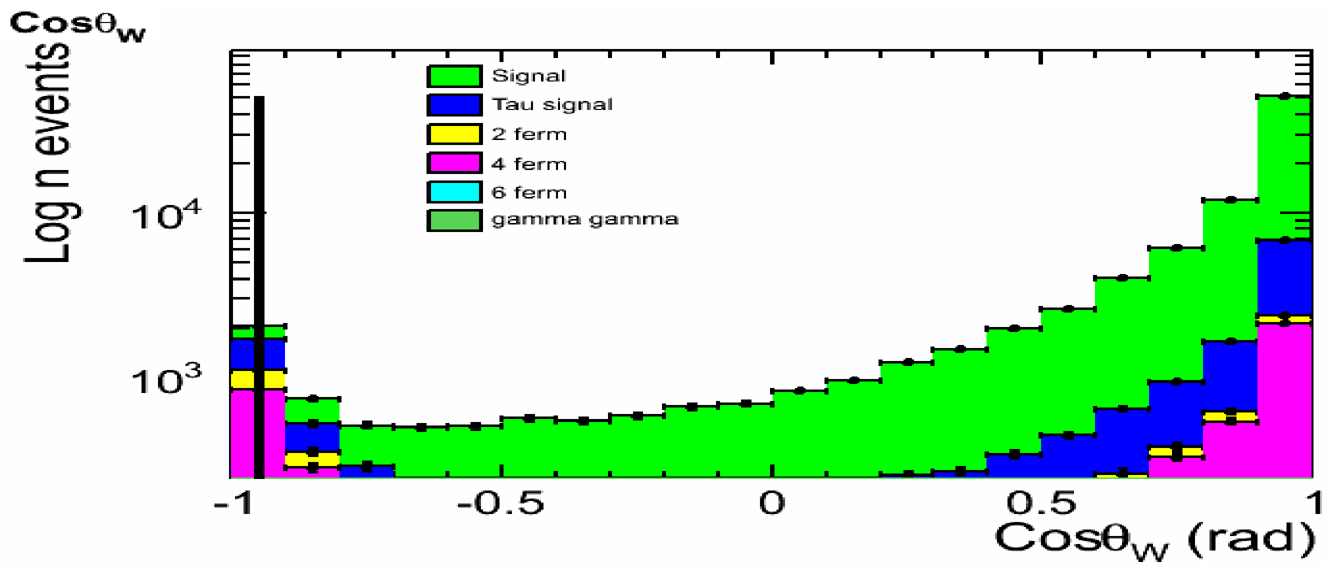
Tau selection

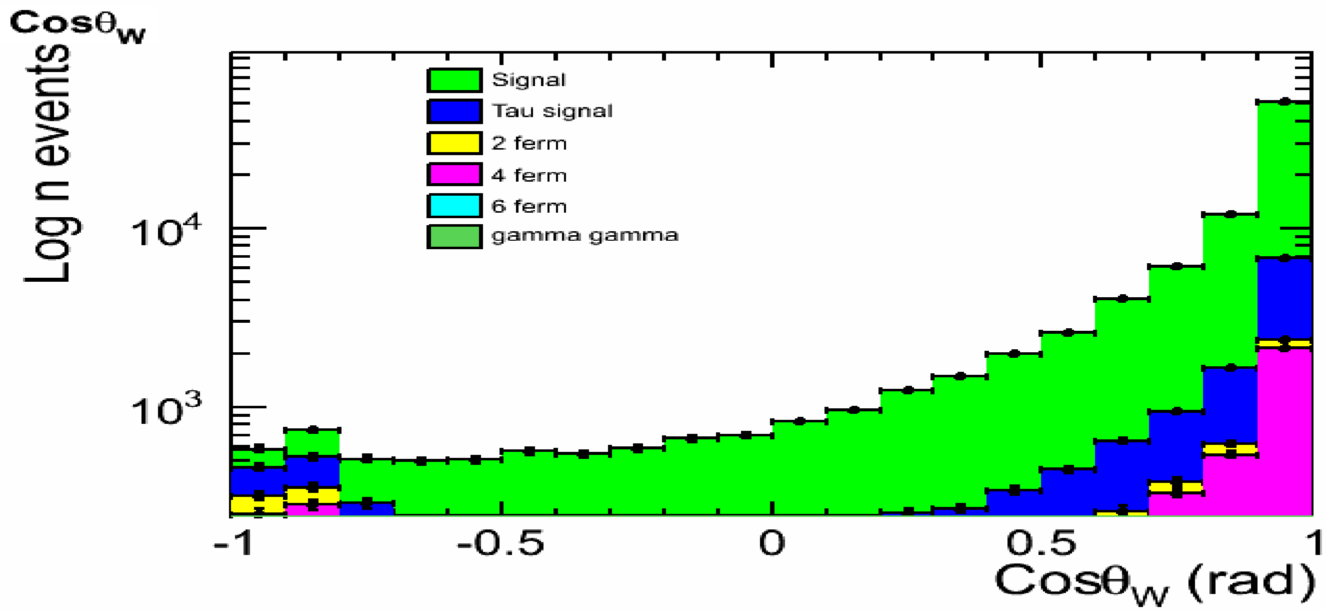


$$\left(\frac{2\,E_{lepton}}{\sqrt{S}}\right)^2+\left(\frac{Inv\ Mass\ W}{W\ mass}\right)^2<1$$

- Tau can decay, and more neutrinos are present in the final state.
- This disturbs the reconstruction of the W "leptonic" invariant mass from the lepton+missing momentum.
- Tau contribution suppressed.

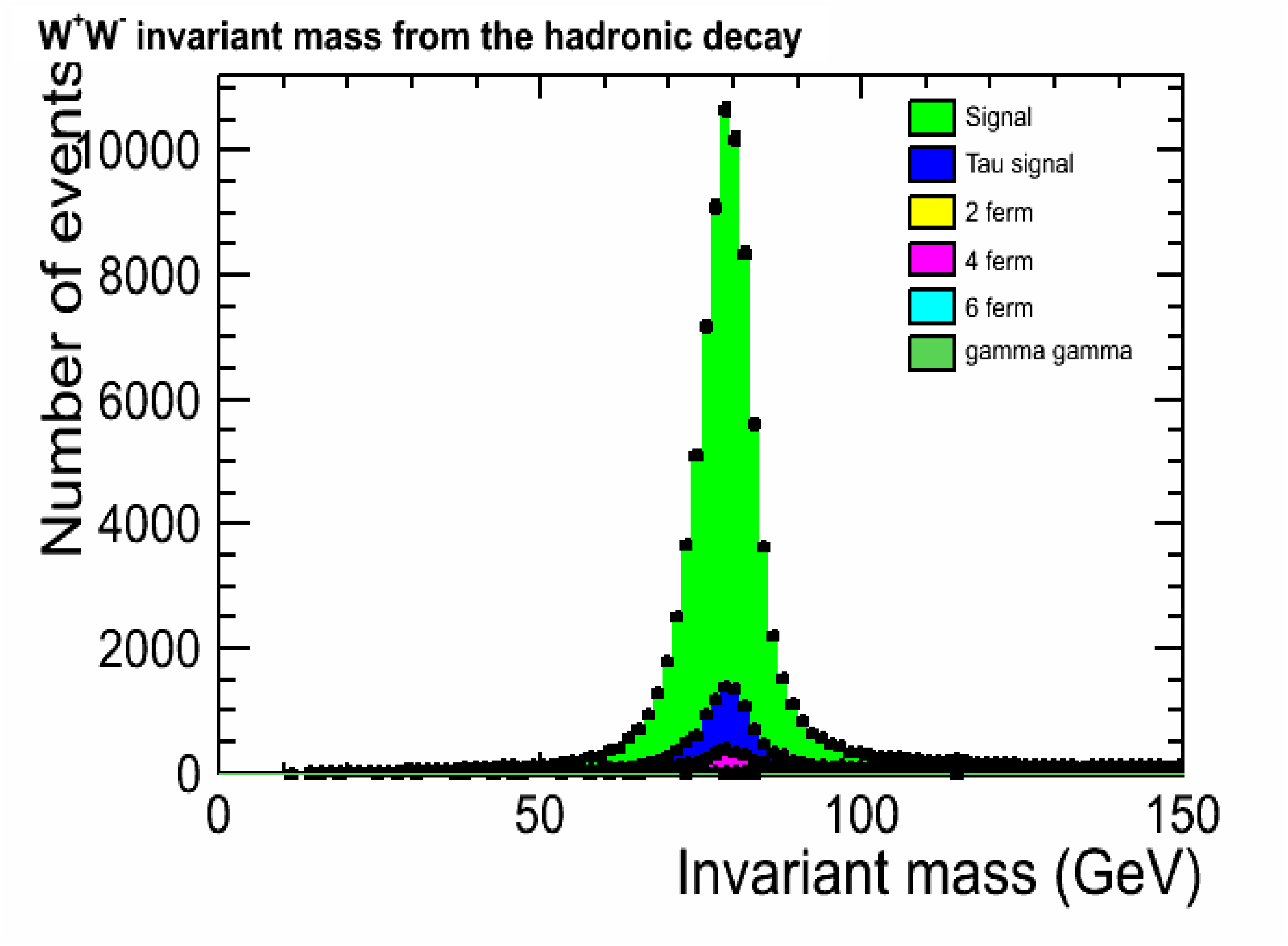
$Cos\theta_W$





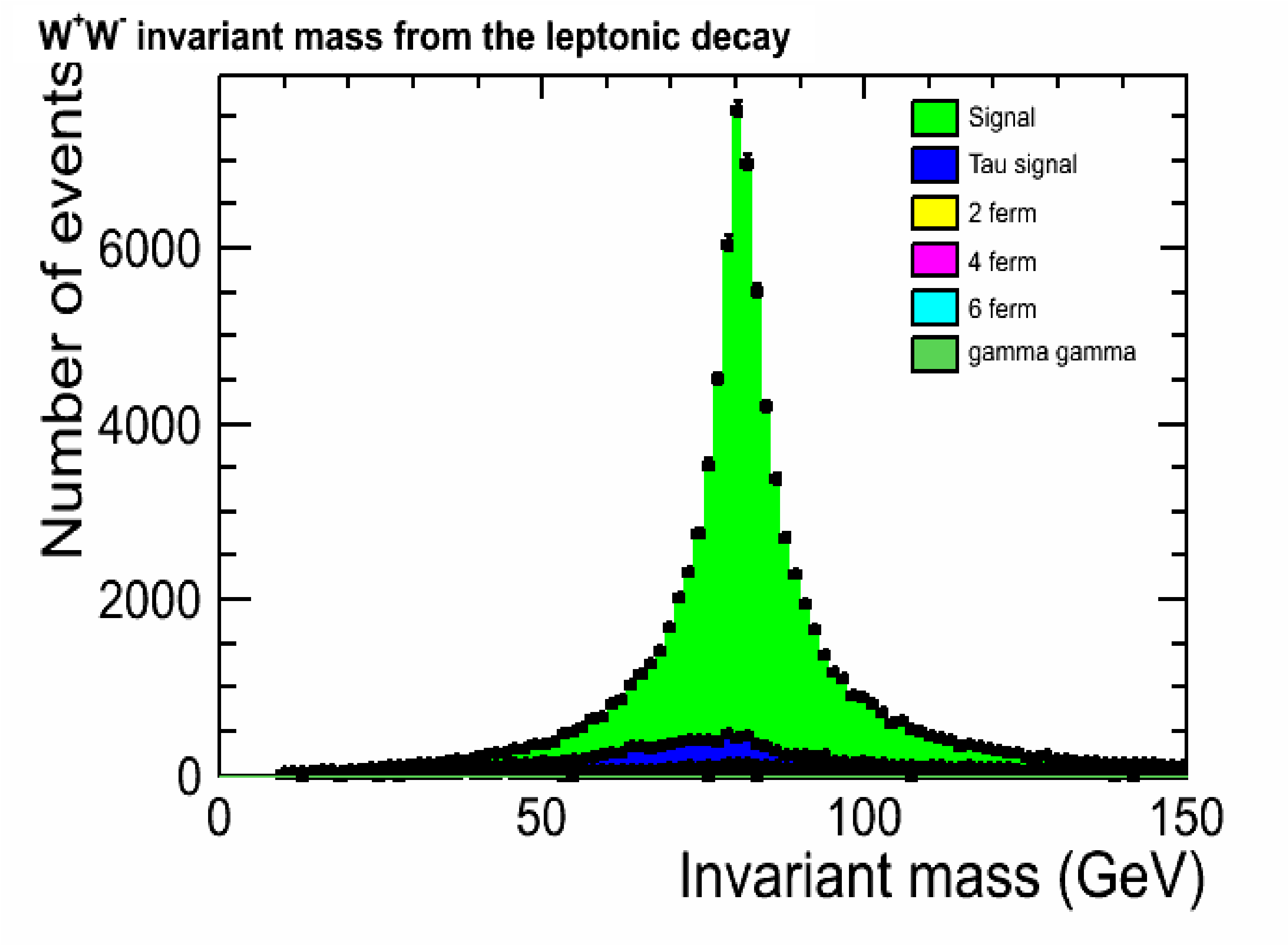
- Cut at -0.95 to clean the first bin.

Hadronic invariant mass



- Invariant mass from the hadronic decay 10<<150.

Leptonic invariant mass



- Invariant mass from the leptonic decay 10<<150.

Results

- The final results for the selection are:
  - Signal efficiency: 68.7%.
  - Purity: 84%.

	Signal	Tau	2f	4f	6f	Gamma
Initial Events	107490	52926	454996	430990	20805	$1.5*10^6$
Final Events	73893	8150	1178	4506	524	6
Efficiency	68.7%	15.4%	0.26%	1.05%	2.52%	0%

The total cross section and the Blondel scheme.

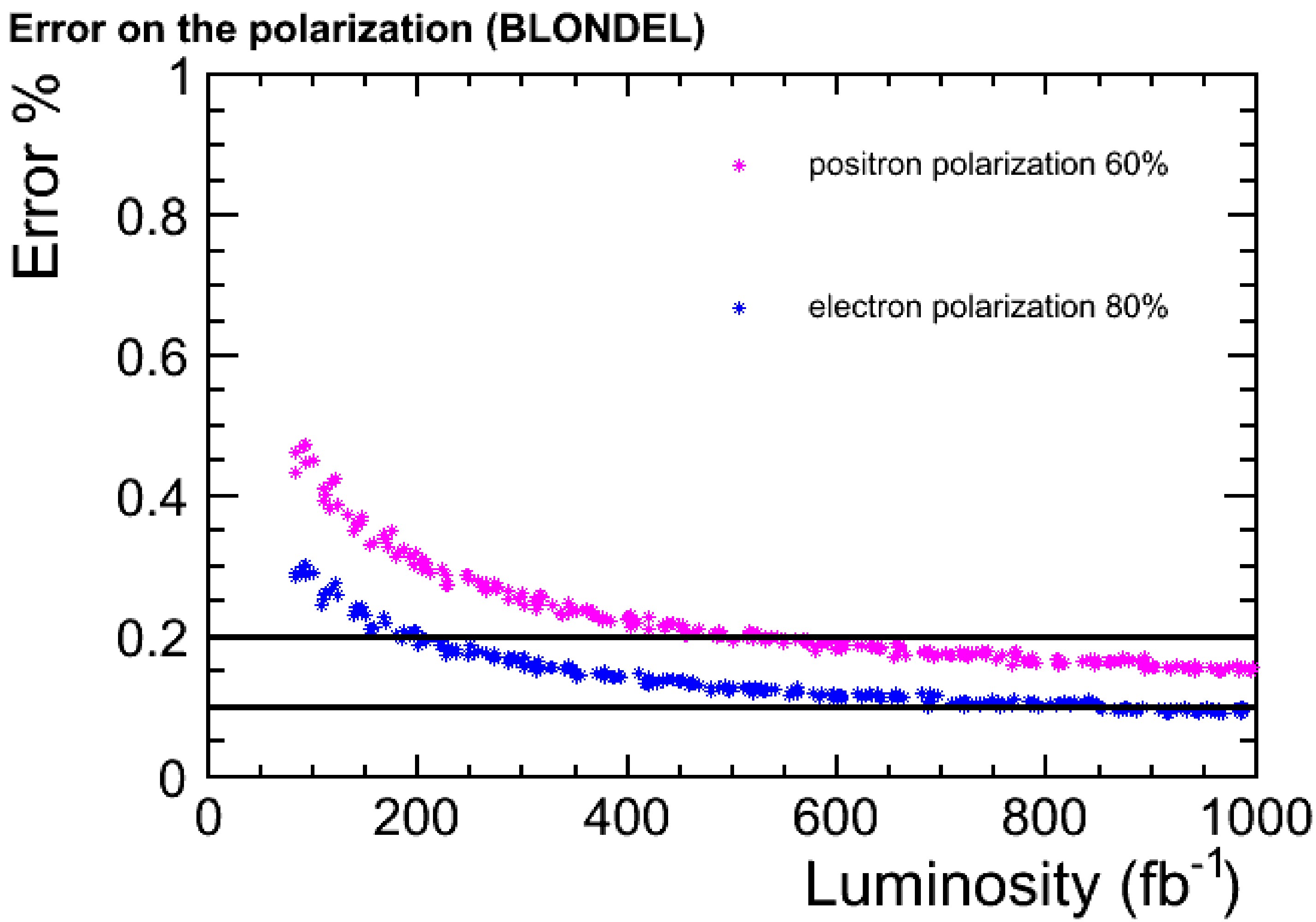
First way to get the polarizations: The Blondel Scheme

- Needed all the four combinations of polarization: ++, --, +- and -+.
- Assumption: $|+P_{e-}| = |-P_{e-}|$ and $|+P_{e+}| = |-P_{e+}|$ (polarimeters necessary to get deviations).
- From the cross sections for the different polarization signs:

$$|P_{e^\pm}| = \sqrt{\frac{(\sigma_{-+} + \sigma_{+-} - \sigma_{--} - \sigma_{+})(\pm\sigma_{-+} \mp \sigma_{+-} + \sigma_{--} - \sigma_{+})}{(\sigma_{-+} + \sigma_{+-} + \sigma_{--} + \sigma_{+})(\pm\sigma_{-+} \mp \sigma_{+-} - \sigma_{--} + \sigma_{+})}}$$

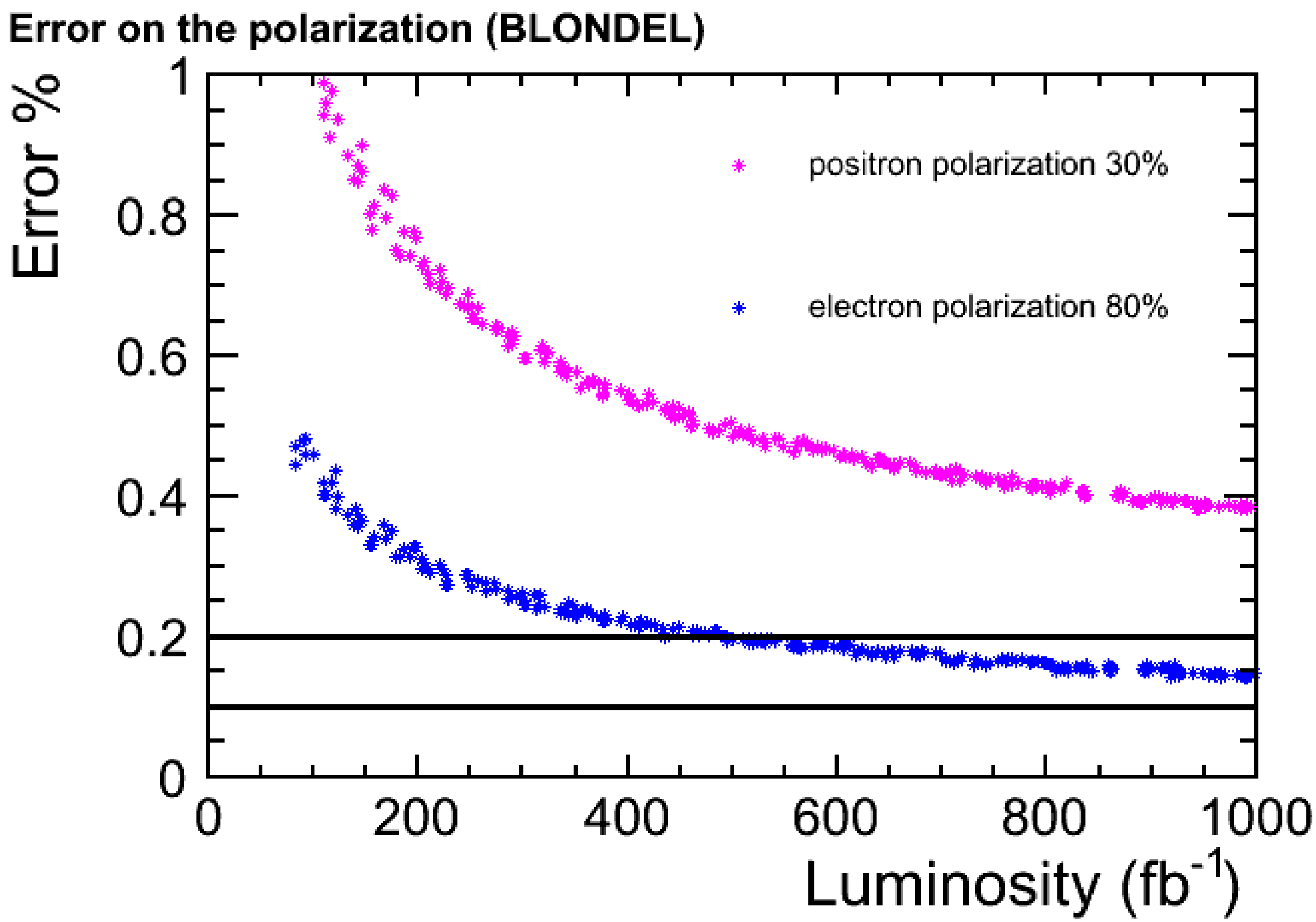
- With 20fb-1 on each sign combination (80fb-1 total), for 60% positron and 80% electron polarizations, the statistical errors on the polarizations are:
  - **0.30**% on the electron;
  - **0.47**% on the positron.
- These errors include 10% systematic error which was added to the non-background.

Propagation at higher luminosities



- 500 fb^{-1} of statistics would give an error on the electron polarization of ~0.1%, and 0.2% on the positron one.

Positron polarization 30%



▶ Up to 1000 fb^{-1} of total luminosity the error on e^+ polarization doesn't reach the aimed value. Worsening also for e^-.

Comments

- The estimate of the luminosity required by the Blondel scheme is of around 500 fb^{-1} of luminosity to be shared equally between the four helicity combinations, in the case of 60% positron polarization. This gives an error of around 0.1% on the electron polarization and ~0.2% on the positron one.

- The Blondel scheme does not give convergence to the aimed polarization errors up to 1000 fb^{-1} of luminosity, in case the positron polarization should be 30%. In this case there is a worsening also of the error on the electron polarization.

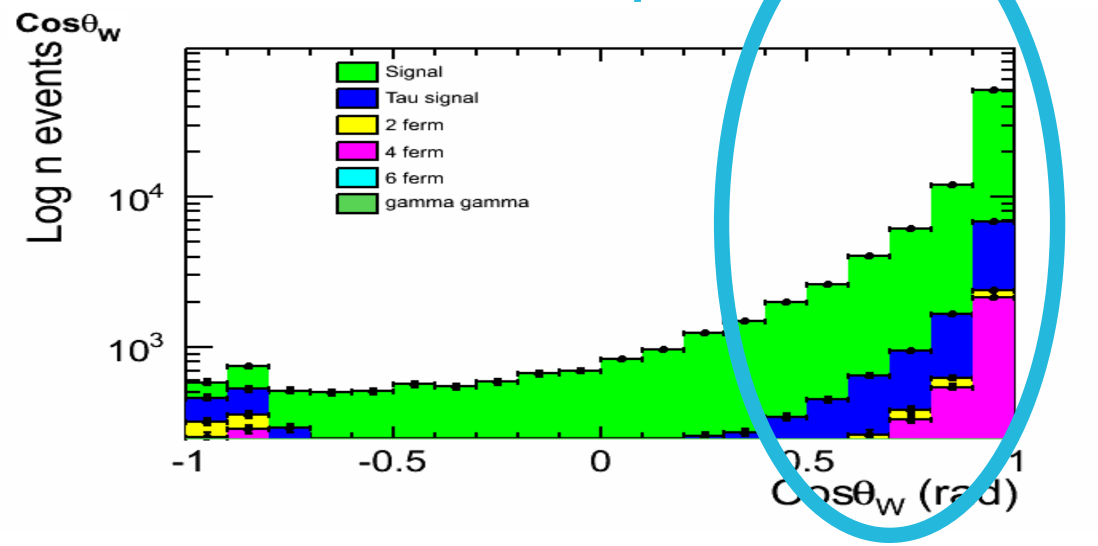
The angular distributions and the MC templates method.

Angular distributions - introduction

- The t-channel cannot occur in the case of $e^-_R e^+_L$, while the s-channel can.

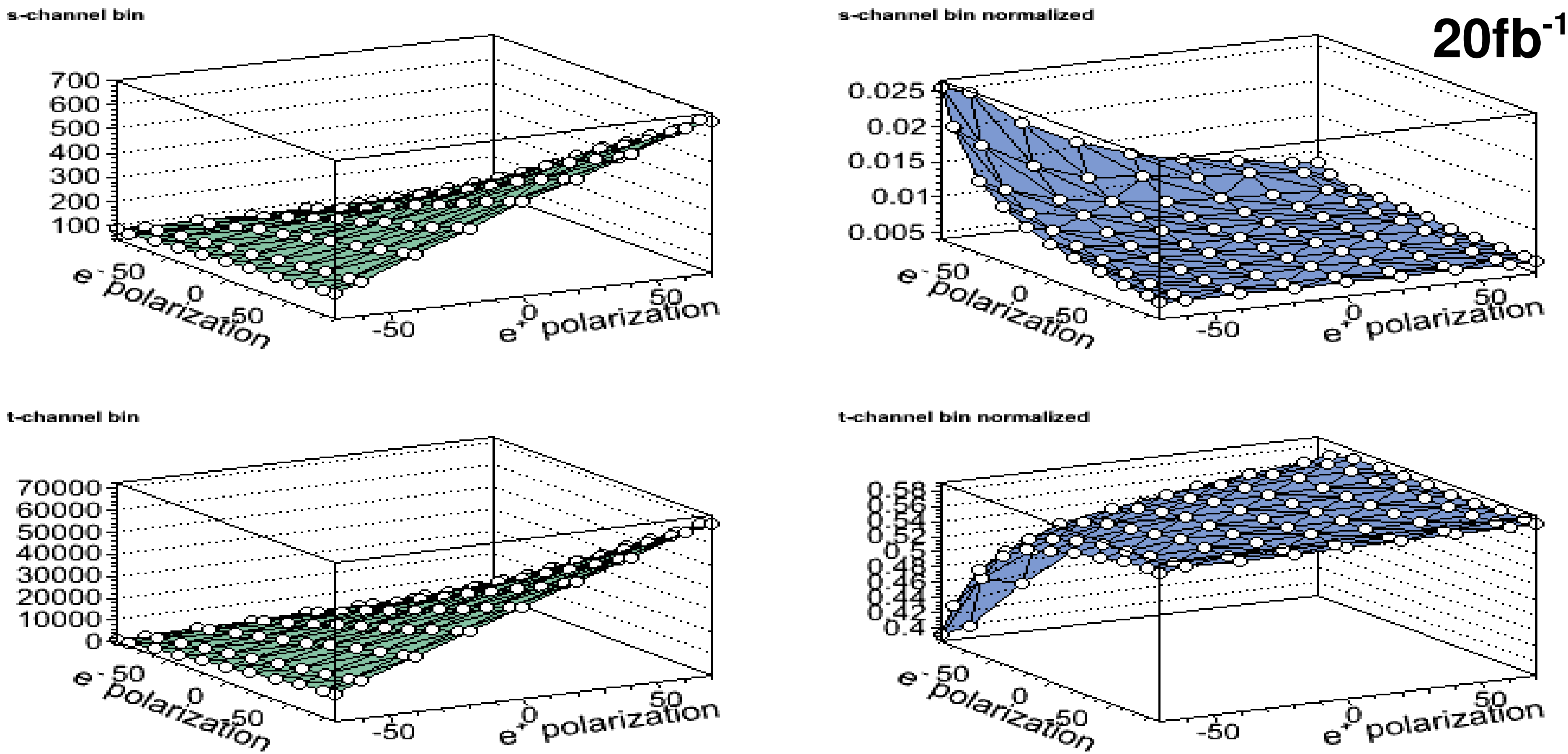
- Since the s and t channels have very different topologies (t-channel is concentrated in the forward region), an angular dependency of the $\cos\theta_W$ distribution from the polarization is expected.

t-channel peak



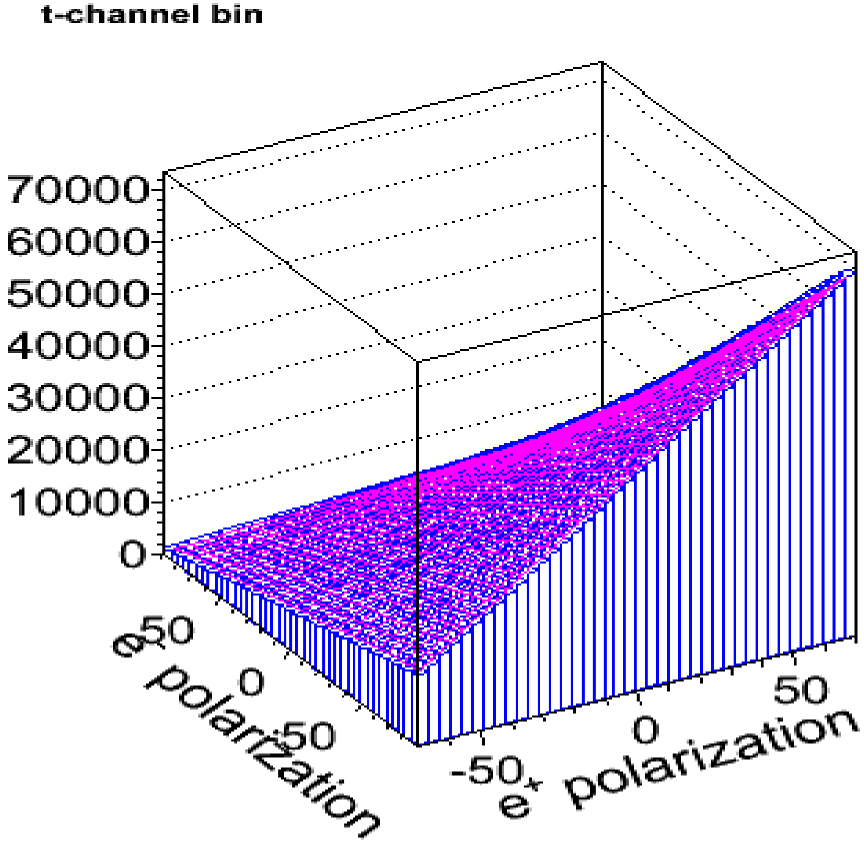
- To observe the dependency, we plot each bin of the $\cos\theta_W$ distribution as a function of the polarizations.

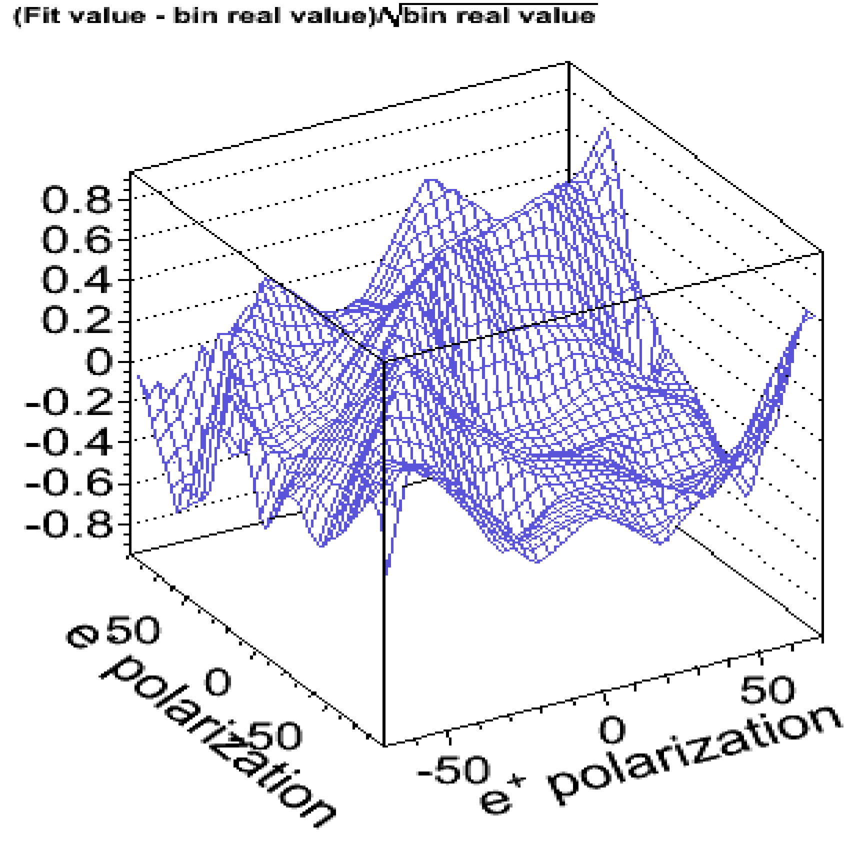
Angular distributions - templates



Plots on the right are for normalized cosθ distributions, to cancel the cross-section dependency. Expected relative suppression of the t-channel for e^-_R and e^+_L.

Angular distributions - templates





Templates are fitted with a surface which is used as input for the polarization fit from the “data”. Deviation of the fit surfaces from the templates below 1 sigma. No need to subtract the background.

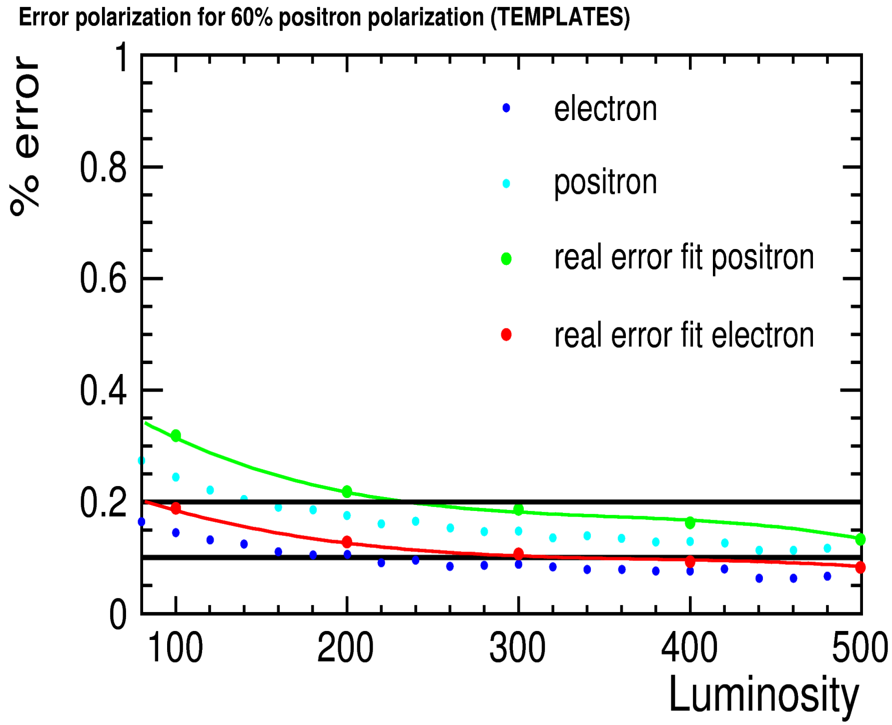
Angular distributions – fit

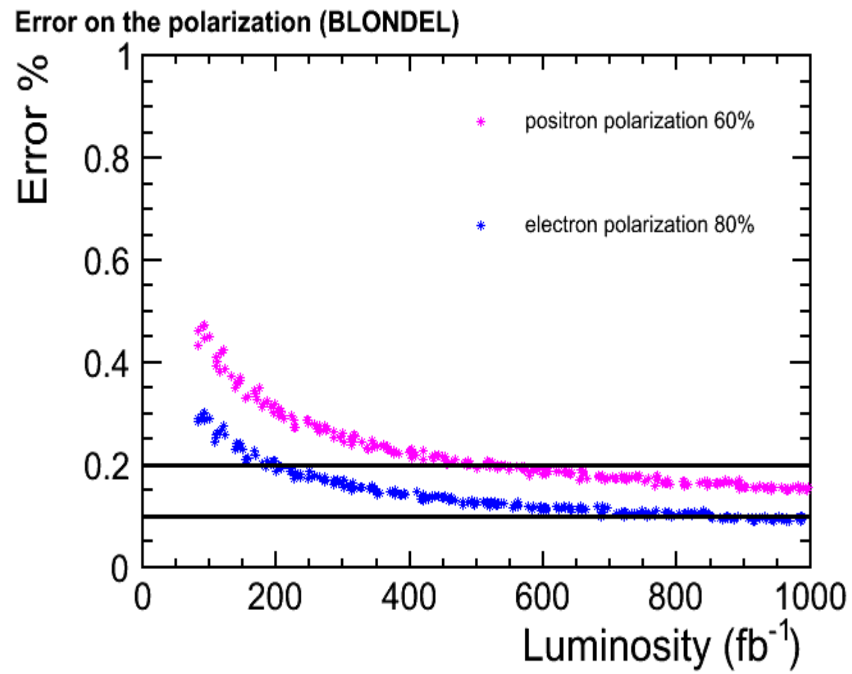
- 4 samples of "data" for ++, --, +-, -+ 60(30)% e^+ / 80% e^- polarization combinations created for 20fb^{-1}. Data sample is obtained from a random, poissonian, variation of the templates. Total luminosity (80fb^{-1}) shared equally between the four sign combinations of the polarizations.

- **60%**.
  - Fitted positron polarization: 59.98 +- 0.16 (**0.27%**);
  - Fitted electron polarization: 80.02 +- 0.13 (**0.15%**);
  - 10% systematic on the non-tau background included.
- **30%**.
  - Fitted positron polarization: 30.01 +- 0.19 (**0.63%**);
  - Fitted electron polarization: 79.96 +- 0.13 (**0.16%**).

Correlation e^+/e^- polarizations: 1.5%.

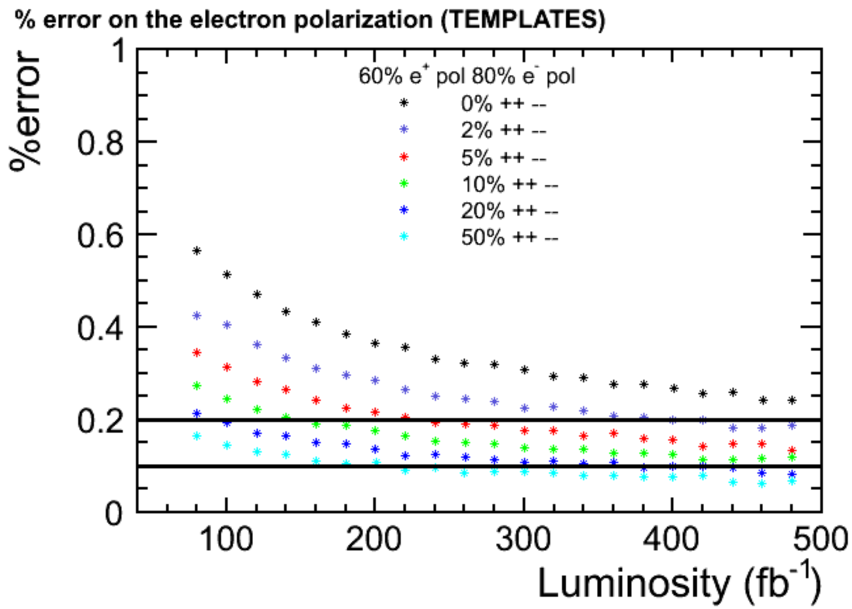
Correction on the fit error – 60% e^+ case

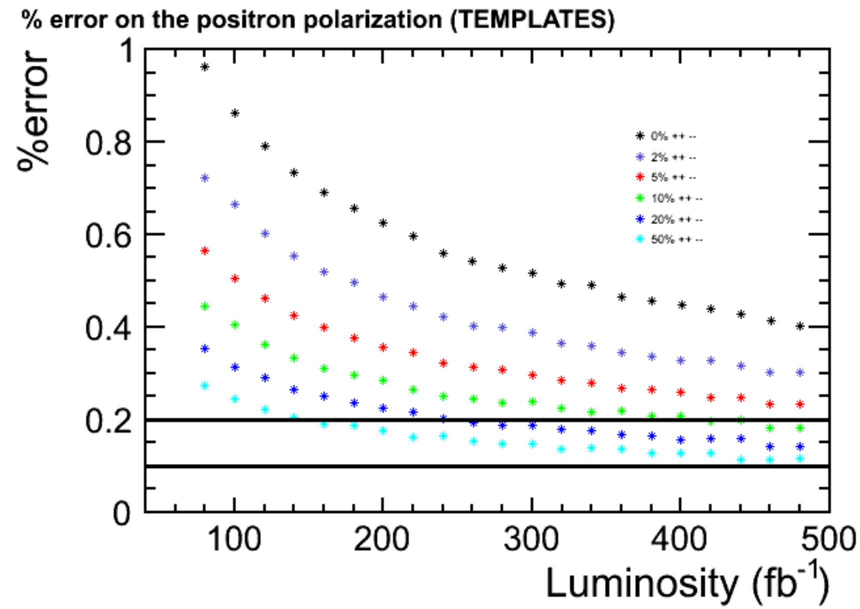




To check the correctness of the error given by the fit we have iterated the fit and taken the sigma of the gaussian distribution of the measured polarizations as the real error of the fit. There is a slight increasment of the error, respect to the one given by the fit. For 60% positron polarization, the final luminosity esitmate is 220fb^{-1} (Blondel: 500 fb^{-1}).

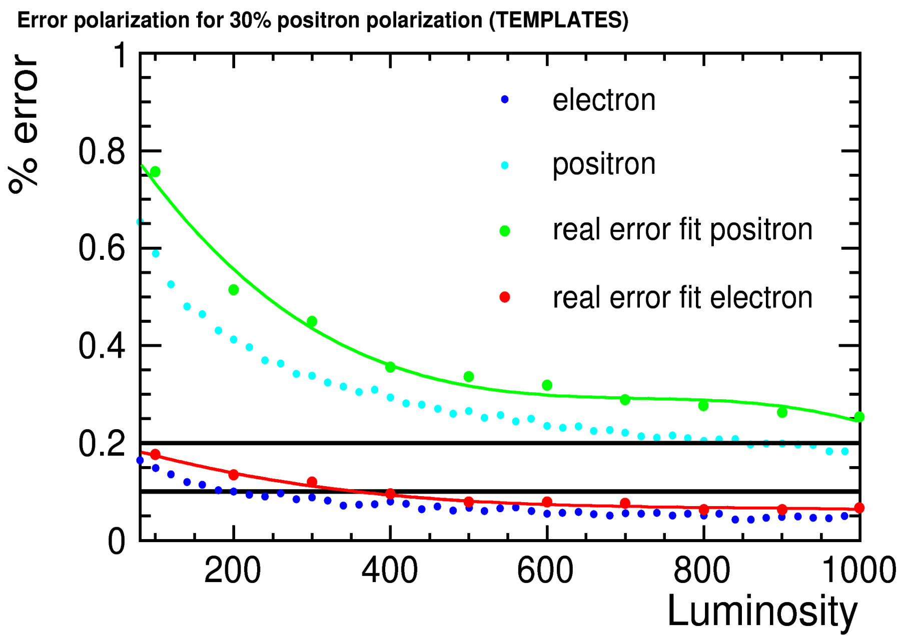
Reducing ++ -- combinations – still fit error

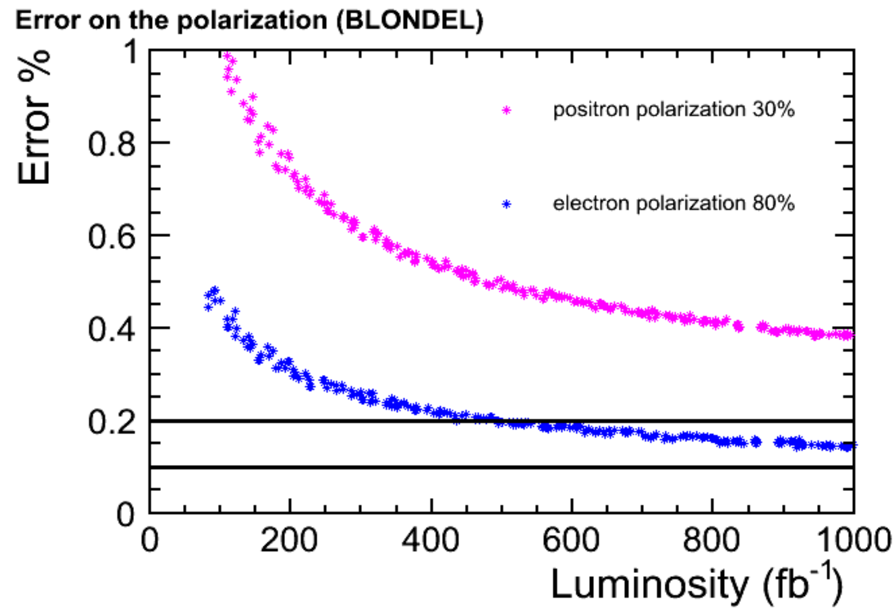




- The lower luminosity demand respect to the Blondel tecnique leaves room for reducing the time spent on the “less-interesting” physics combinations (++ --).
- Plots currently ready only for the fit error, underestimated. Dedicating only the 20% of the luminosity to the ++ -- combinations we move to a request of 240 (300?)fb^{-1} in total, and to 400 (500?)fb^{-1} in the case of further reduction to 10% (correcting the fit error).

Case 30% e^+ polarization





In the case of 30% positron polarization, we have for this tecnique no worsening for the electron polarization, respect to the 60% case. Error on the positron polarization lower respect to the Blondel scheme, but still high. Luminosity demand to reach the 0.2% error > 1000fb^{-1}.

Angular distributions - conclusions

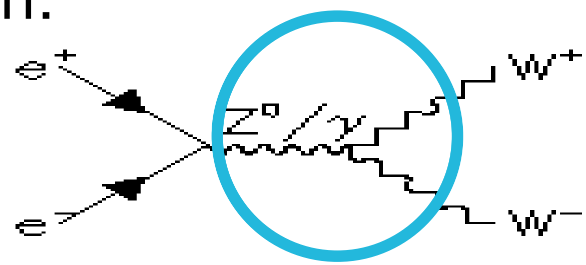
- This fitting tecnique reduces the demand respect to the Blondel scheme.

- Possibility to reduce significantly the luminosity spent on the ++ - - polarization combinations.

Coming next.

Triple Gauge Couplings

- The nonabelian nature of SU(2) group allows triple gauge bosons couplings (TGC) in the SM, which appear in the s-channel of the WW production:



- In the SM the TGCs g_1^Z, g_1^γ, κ_γ, and κ_z = 1 at tree level, and all the others are 0.
- Small deviations from this values are predicted also in the SM as loop effects.
- Many extensions of the SM predict anomalous TGCs via loop effects: they might influence the cross section and the angular distributions of the WW production.
- t-channel is TGCs-free.

Following steps

- We will evaluate the TGCs influence on the fit, as a systematic error.
- We will afterwards try to fit simultaneously the polarization and the TGCs.
- To study the fitting procedure necessary to work with several polarizations and TGC constants values. In order to do that we will weight the events as a function of the couplings.
- The total cross section as a function of the anomalous couplings will be given by:

$$\sigma_{reweighted} = \frac{\sigma_{gen}}{N_{gen}} \sum_i w_i$$

where *w* is the weight as a function of the TGCs.

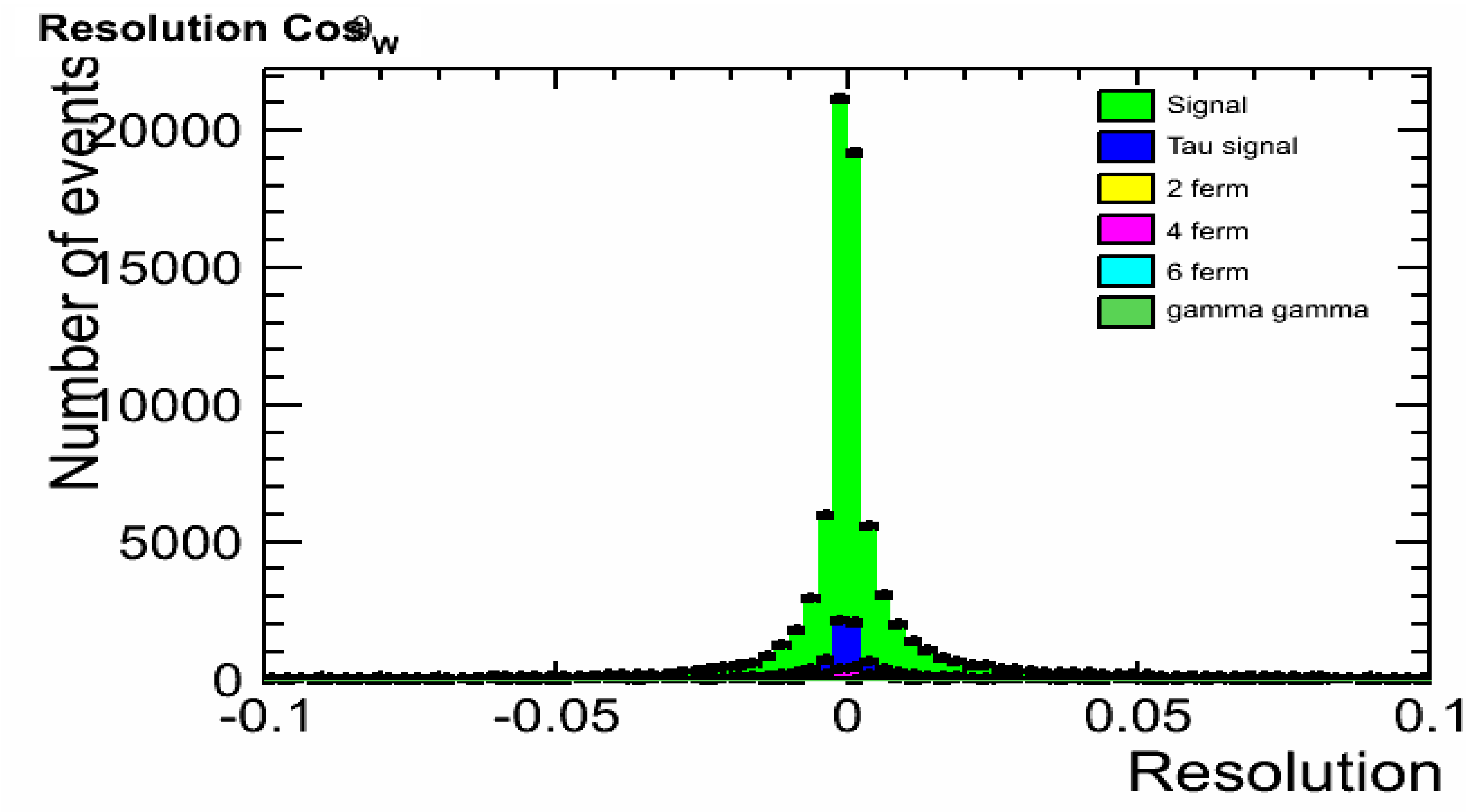
Current status

- Adaptation of the fortran code used by Wolfang Ehrenfeld in his 2003 study, to calculate the event-weights for the TGCs, is ongoing.

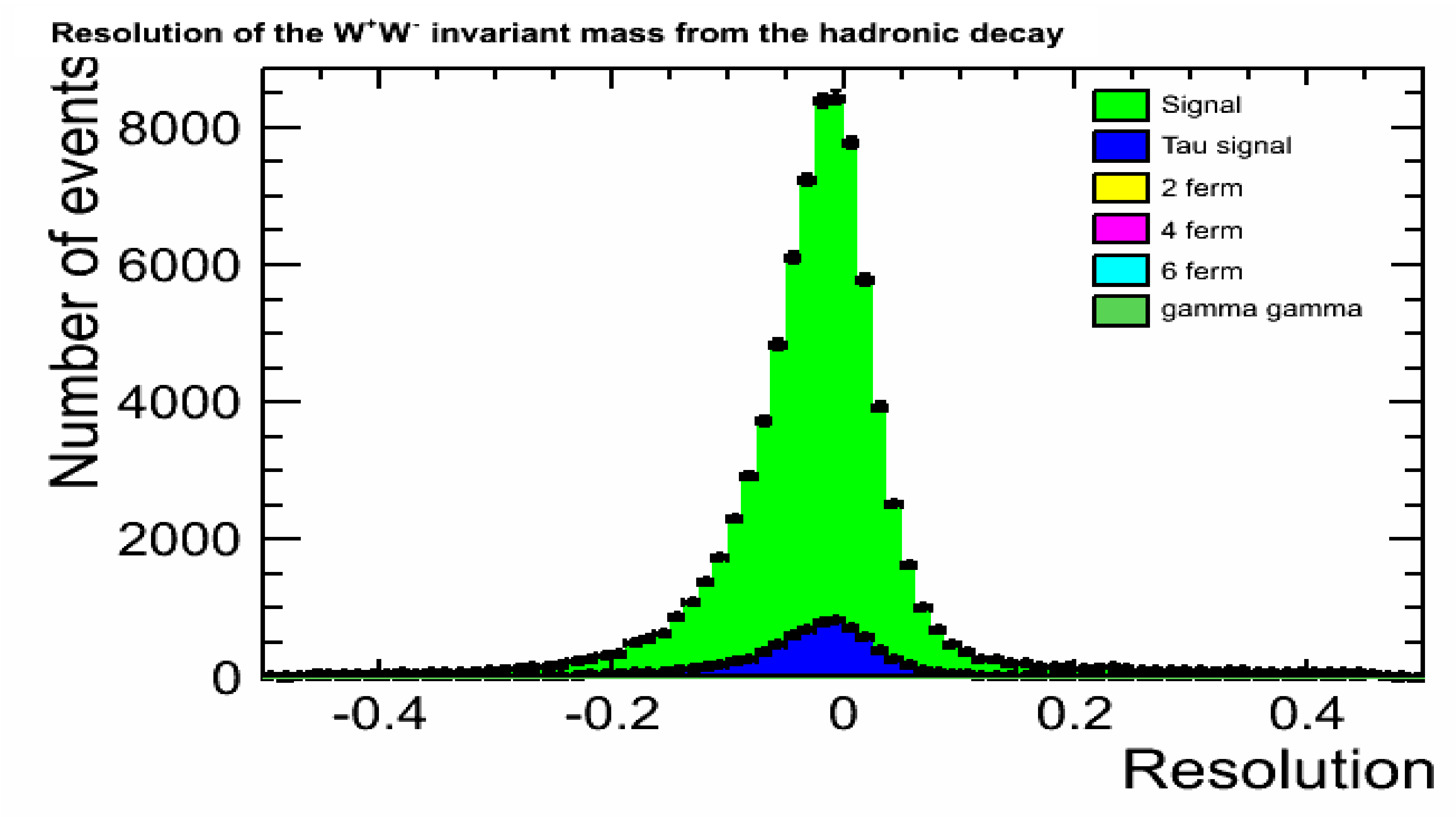
- Evaluation of the TGCs influence as a systematic error should be possible in a short time scale.

- First draft of the analysis note available from today.

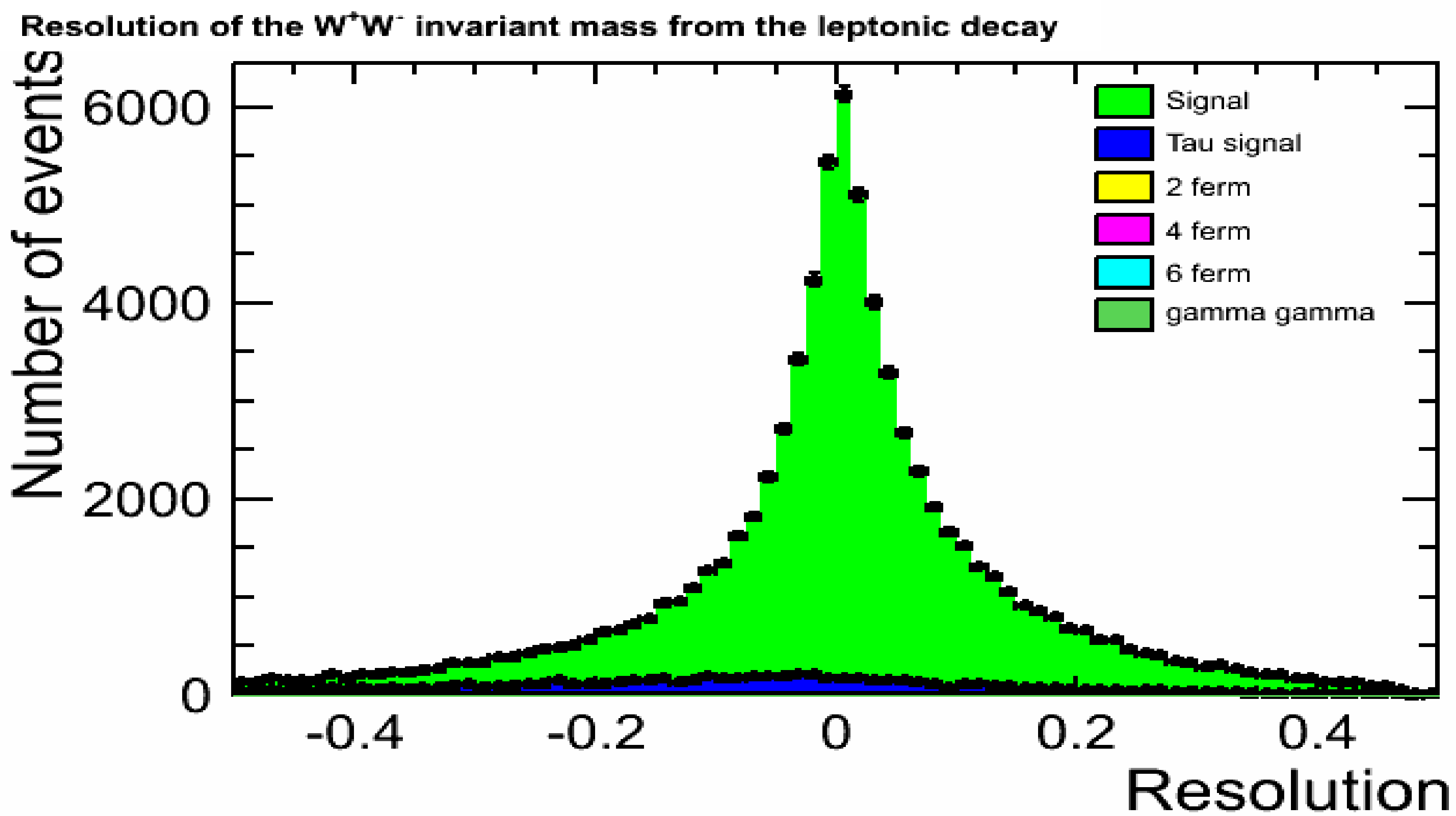
Resolution Cos θ_W



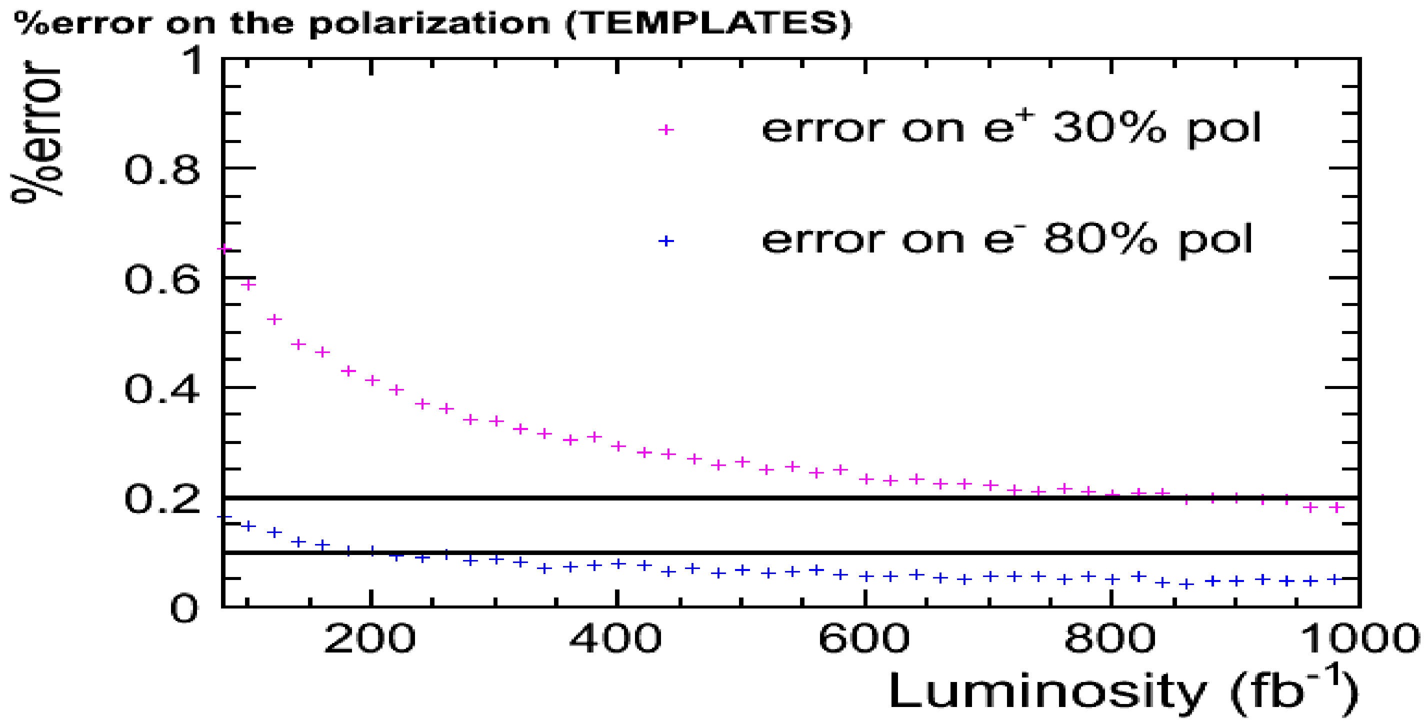
Resolution hadronic invariant mass



Resolution leptonic invariant mass



Angular distributions – fit error



For the 30% e$^+$ polarization option things get worse for the positron, while remain inaltered for the electron. Convergence to 0.2% error on the positron polarization reached at 1000fb^{-1}.