Polarization measurement from W^+W^- production

Ivan Marchesini (DESY), Zeuthen 2008-04-11

Overview

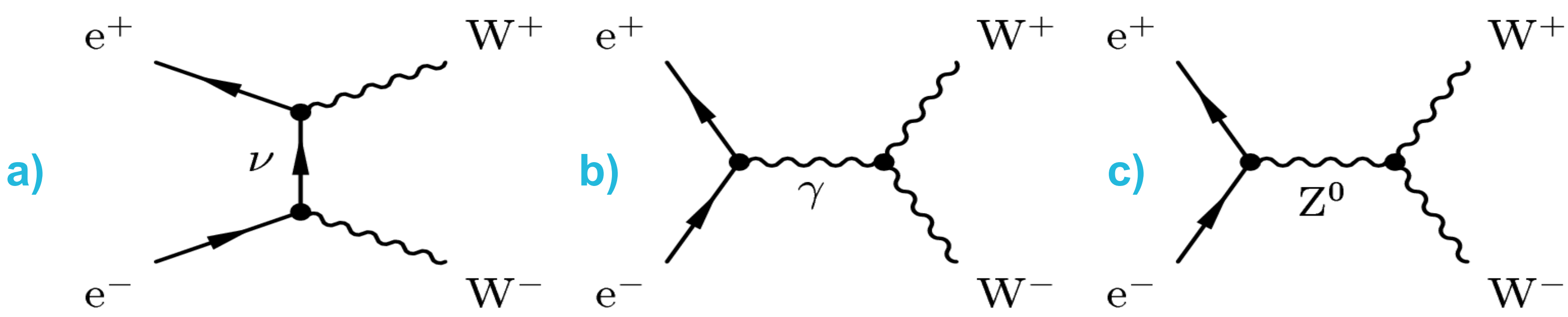
- Data driven polarization measurements are necessary:
  - Polarimeters need to be calibrated;
  - Data driven measurements allow to obtain a better precision than the polarimeters, necessary for various analysis.

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

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

- The analysis is currently at the first steps, since we are burdened with the mass production organization. In the following I will show what we have done so far and how we plan to continue.

W^+W^- production and polarization - 1

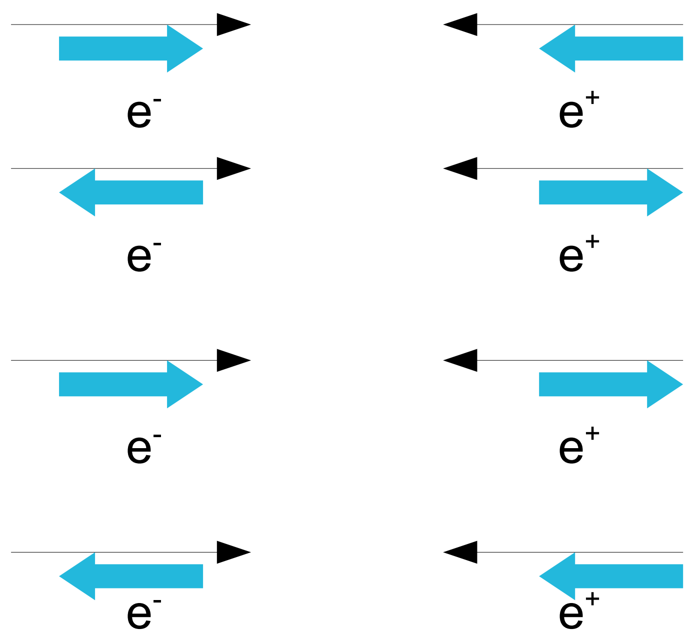


b) c) s-channel: e^+ and e^- must have opposite polarizations, to give the vector boson.

J_z=1 allows vector mediator

a) t-channel: same polarizations for e^+ and e^- are allowed. The W^- can couple only to e^-_L and e^+_R: this channel can be completely switched off by choosing the wrong polarization.

W^+W^- production and polarization - 2



σ_{RR}	$0.25\,(1+P_{e-})(1+P_{e+})$	$J_Z=0$
σ_{LL}	$0.25\,(1-P_{e-})(1-P_{e+})$	
σ_{RL}	$0.25\,(1+P_{e-})(1-P_{e+})$	$J_Z=1$
σ_{LR}	$0.25\,(1-P_{e-})(1+P_{e+})$	

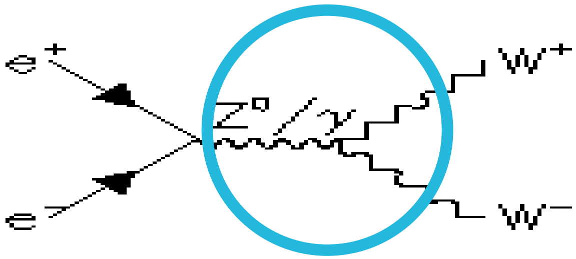
- The total cross section is therefore influenced by the beam polarizations:

$$\sigma(P_{e-},P_{e+}) = 0.25\,\{(1+P_{e-})(1+P_{e+})\sigma_{RR}+(1-P_{e-})(1-P_{e+})\sigma_{LL} + (1+P_{e-})(1-P_{e+})\sigma_{RL} + (1-P_{e-})(1+P_{e+})\sigma_{LR}\}.$$

- Measuring the cross section for different combinations of polarization we want, vice versa, to deduct the polarization.

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.

Current simulation

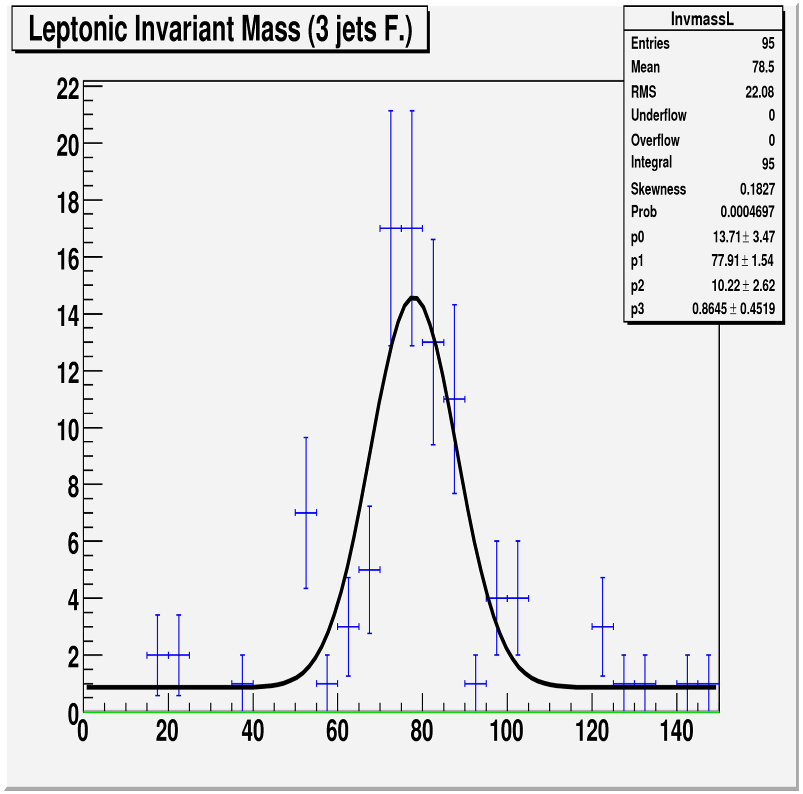
- **Simulation**: Old Mokka 5.4, LDC00Sc, B=4T files.
- **Tracking**: LEPTracking and TrackwiseClustering.
- **Particle flow**: Wolf.
- **Background**: at the moment using only qq.
- **W^+W^- decays** (at the moment only semileptonic analyzed):
  - Leptonic (10%): l ν l ν;
  - Semileptonic (43%): q q l ν;
  - Hadronic (47%): q q q q

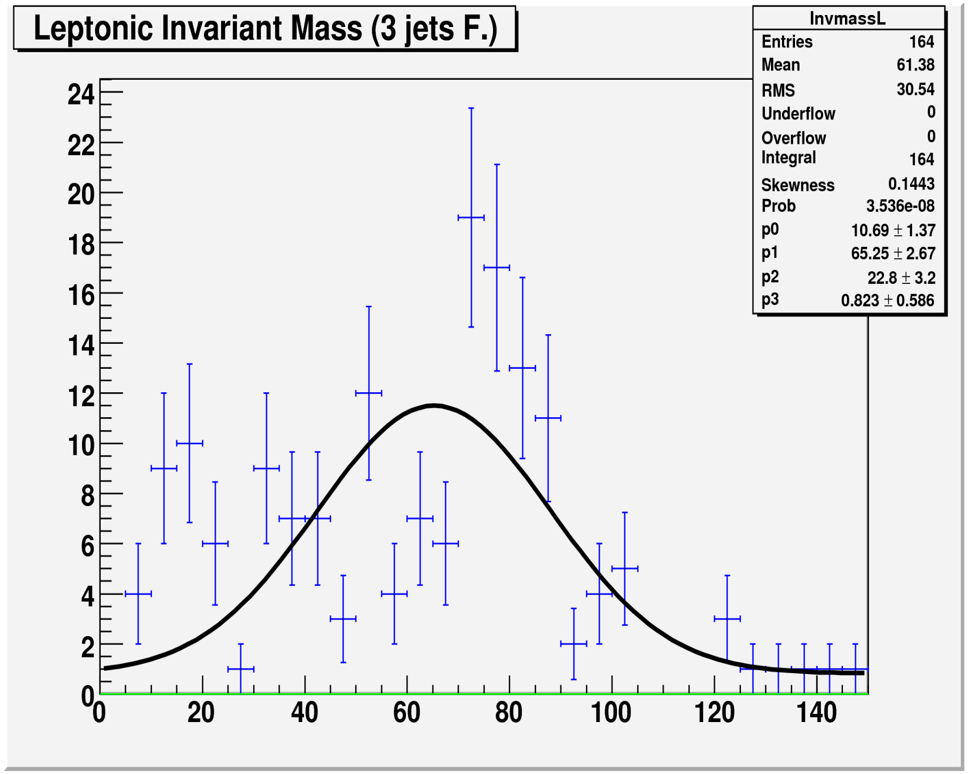
Current selection

- Preselection cuts:
  - Ntracks ≥ 5.
  - Neutrino: P_T>5 GeV, $\sum E$ < 450 GeV.
  - Isr: M_{vis}>100 GeV.

- Forcing 3 jets (Durham). Two jets are for the hadronic decay. One jet is the lepton:
  - Isolated (5 degrees theta-phi).
  - 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.

Tau selection



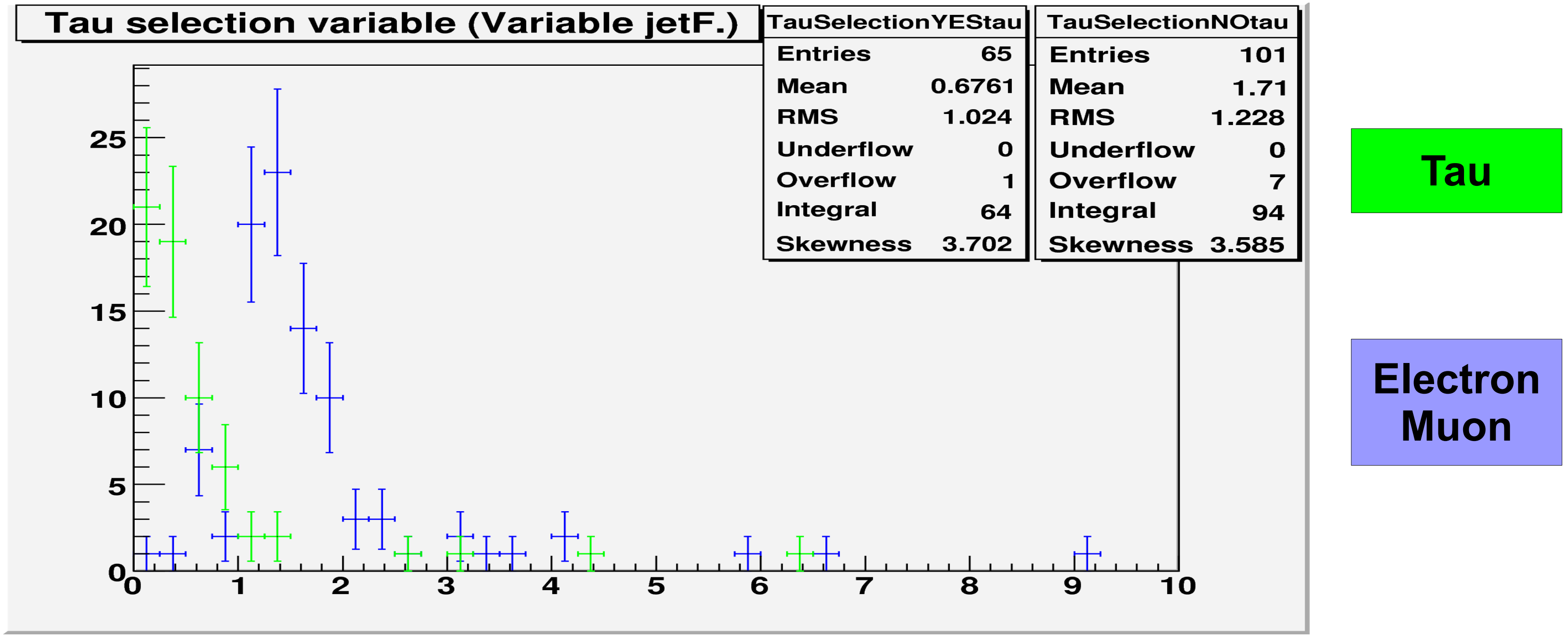


- Tau can decay, and more neutrinos are present in the final state.
- This disturbs the reconstruction of the W “leptonic” invariant mass from the lepton+missing momentum.
- Tau contribution suppressed.

Tau selection

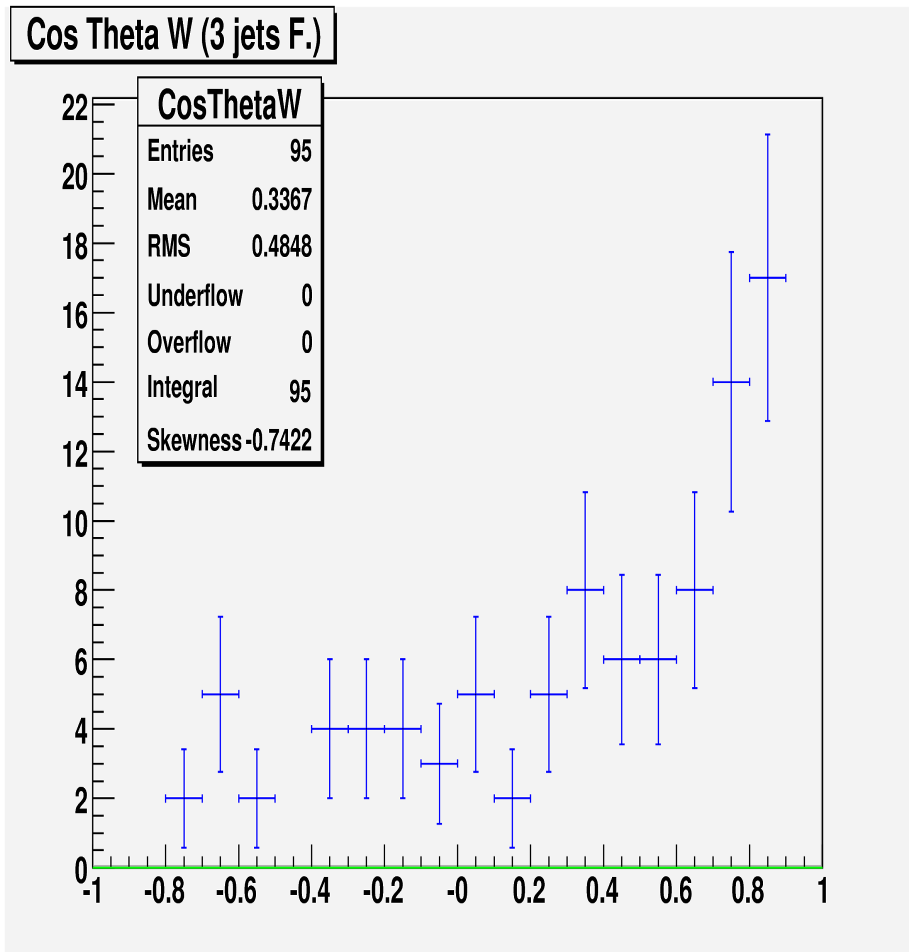
- At the moment using a cut-oriented tau selection:

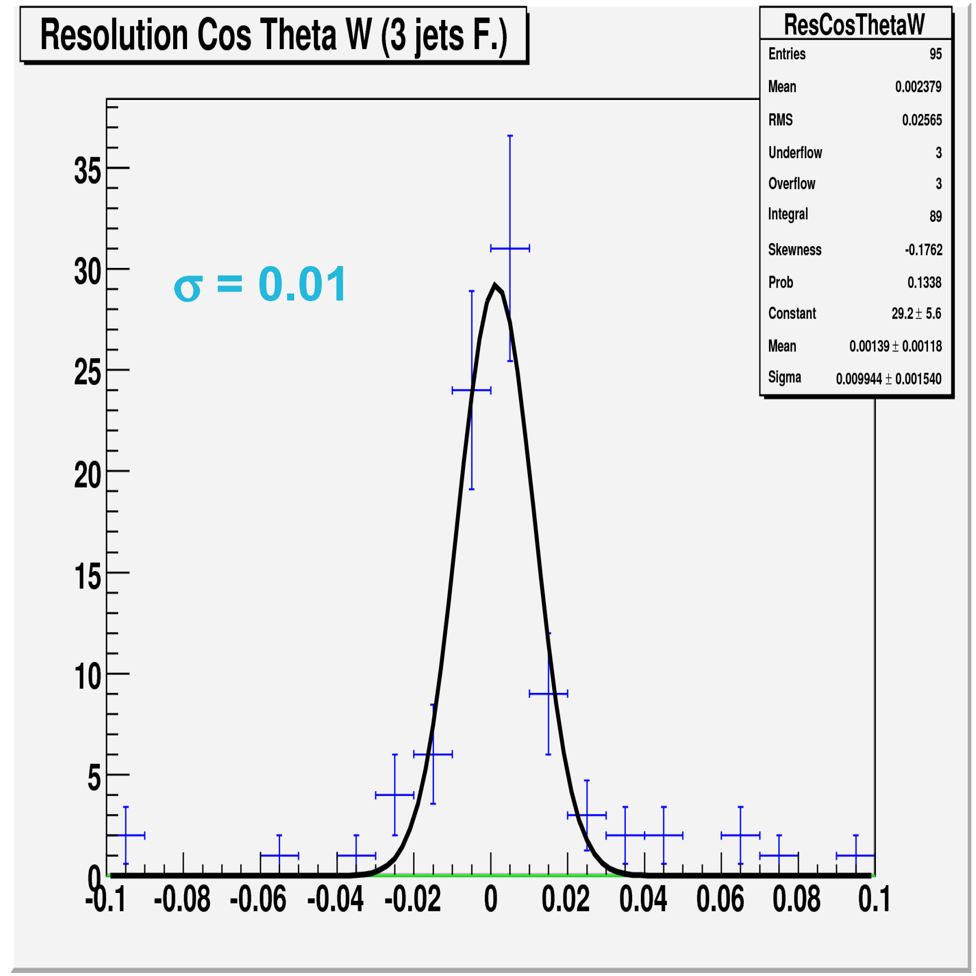
$$\left(\frac{E_{VIS}}{E_{CM}}\right)^2 + \left(\frac{E_{lepton}}{E_{beam}}\right)^2 < 1$$



Cos θ_w

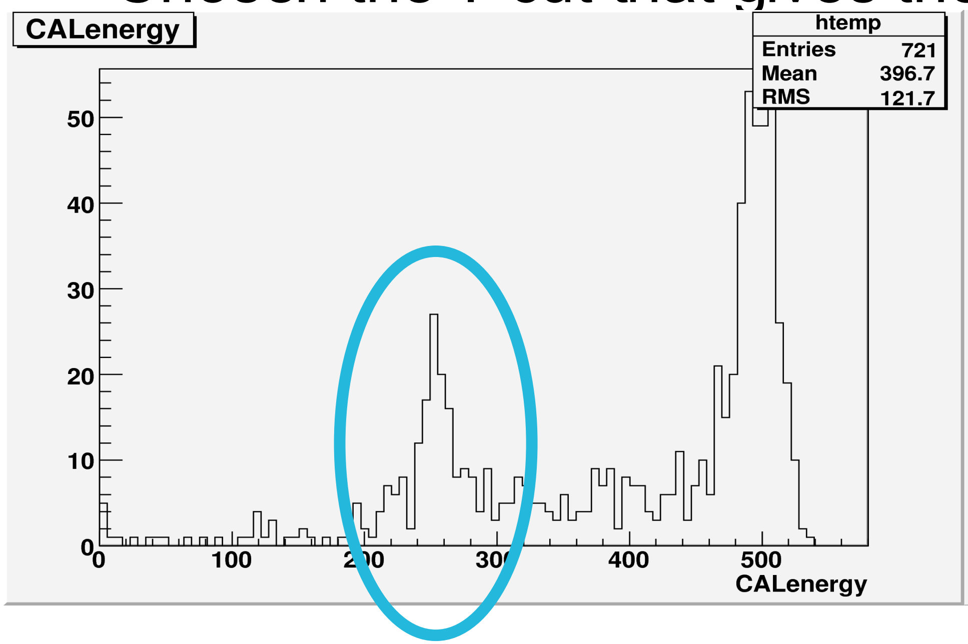
Results for **Cos θ_w** with the resolution obtained using the true MC information.

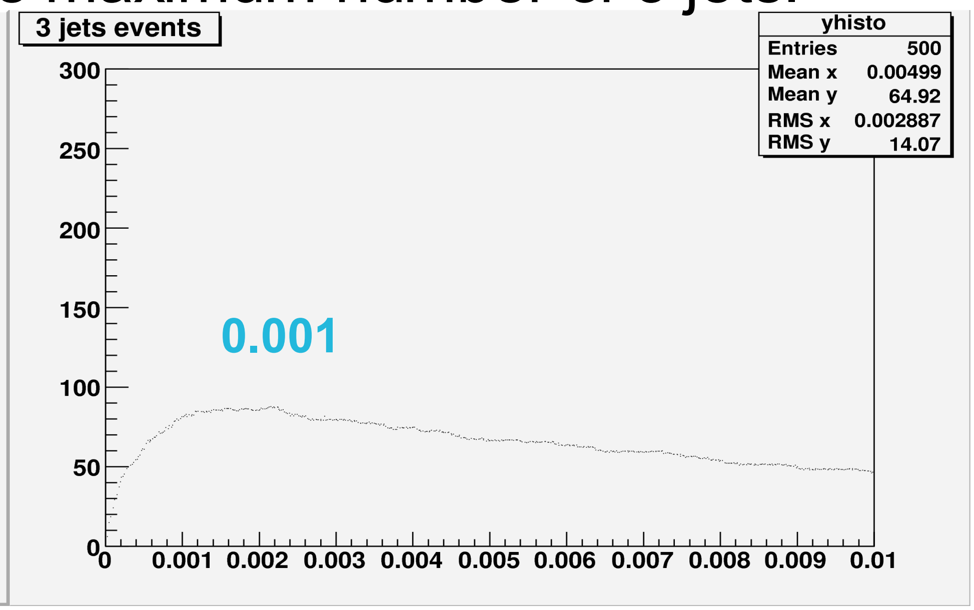




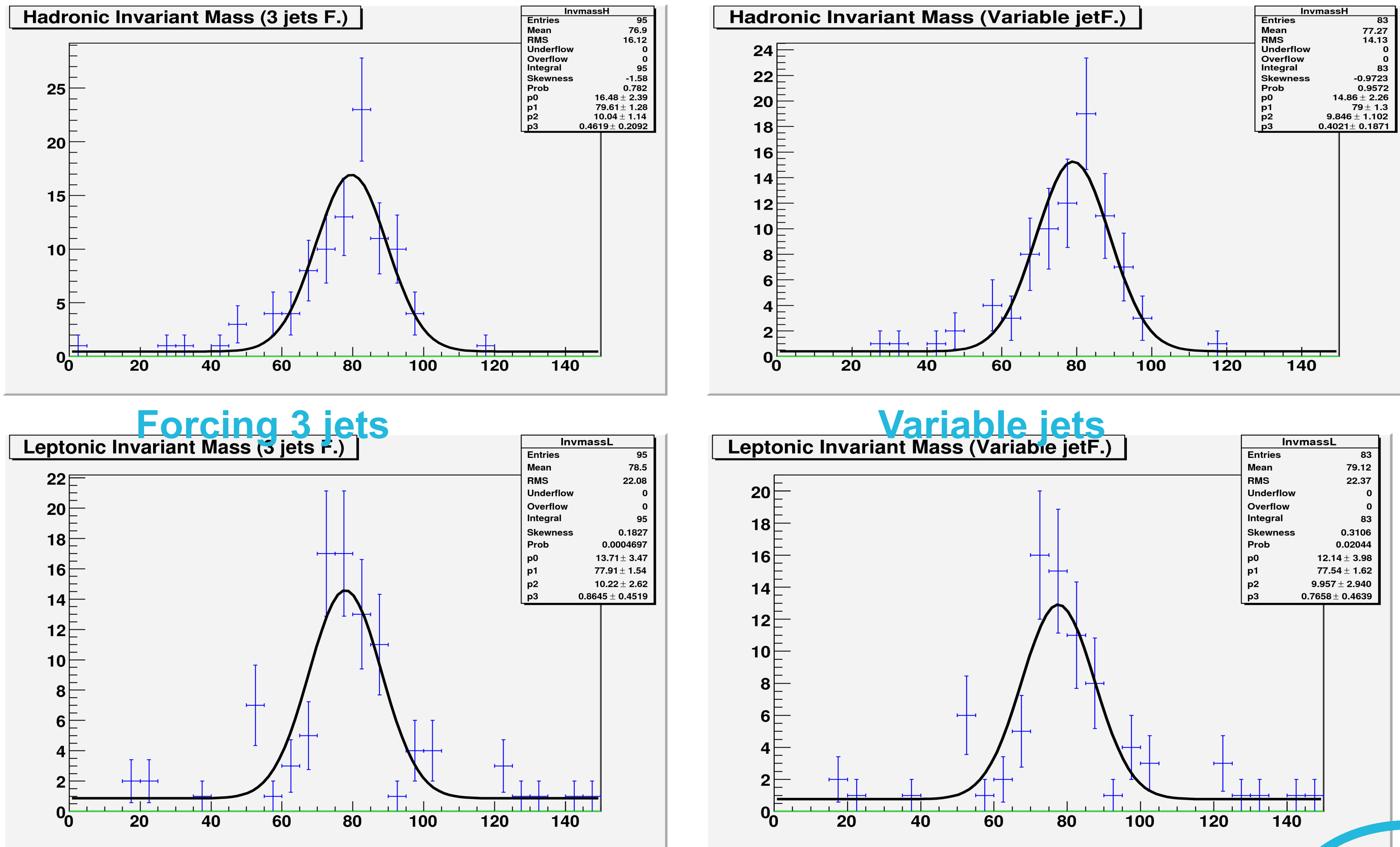
Variable jets finder: Y cut

- The same analysis has been repeated with the variable jet finder, asking for and not imposing three jets.
- Y cut choice:
  - W^+W^- events with $200 < E_{CAL} < 300$ GeV is expected to be a very pure semileptonic sample: μ penetrates all the calorimeter without leaving an energetic deposit.
  - Chosen the Y cut that gives the maximum number of 3 jets.





3 jets vs variable jets



Results obtained not forcing the jet finder to 3 jets are reported: they are compatible with the 3 jets results.

$\sigma = 10$

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 still necessary to get deviations).
- From the cross section for the unpolarized case (σ_u), and those for the different polarizations combinations it is possible to get:

$$\sigma = \sigma_u \left[1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + A_{\rm LR}(\mathcal{P}_{e^+} - \mathcal{P}_{e^-})\right]$$

$$A_{\rm LR} = \sqrt{\frac{(\sigma_{++} + \sigma_{-+} - \sigma_{+-} - \sigma_{--})(-\sigma_{++} + \sigma_{-+} - \sigma_{+-} + \sigma_{--})}{(\sigma_{++} + \sigma_{-+} + \sigma_{+-} + \sigma_{--})(-\sigma_{++} + \sigma_{-+} + \sigma_{+-} - \sigma_{--})}}$$

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

the cross sections for the polarized case, the left-right asymmetry and the polarizations.

Estimating the luminosity needed - 1

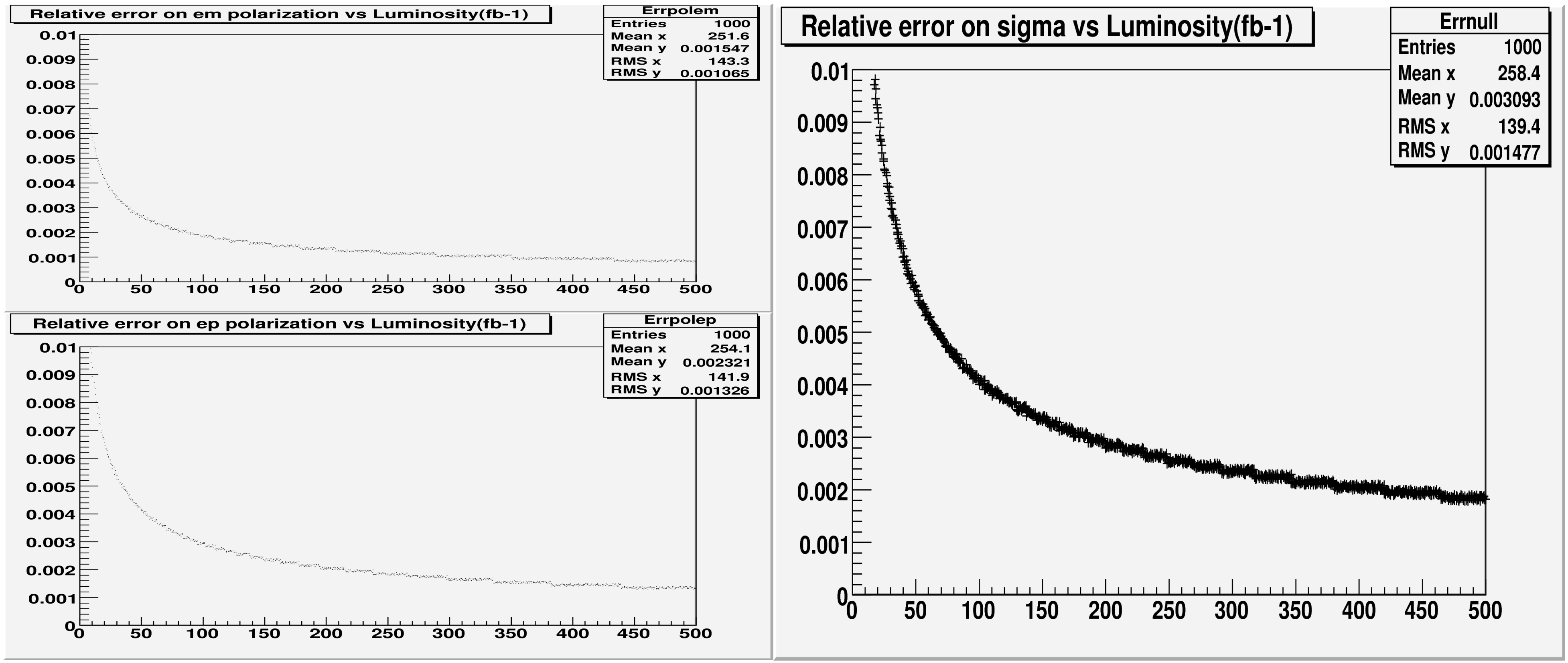
- Currently only the non-polarized cross section available, and a very low statistic.
- To get a rough idea of the luminosity needed to get the desired precision from the Blondel scheme, we have estimated the cross sections for 0.8% e^- and 0.6% e^+ polarizations, from:

$$\sigma=\sigma_u\left[1-P^-P^++\left(P^+-P^-\right)A_{LR}\right]$$

and propagated the errors.

- We have recalculated iteratively varying the luminosity in the interval 1-500 fb^{-1} for each polarization combination, to study the dependence of the error on the polarizations with the luminosity.
- We have applied the Blondel scheme.

Estimating the luminosity needed - 2



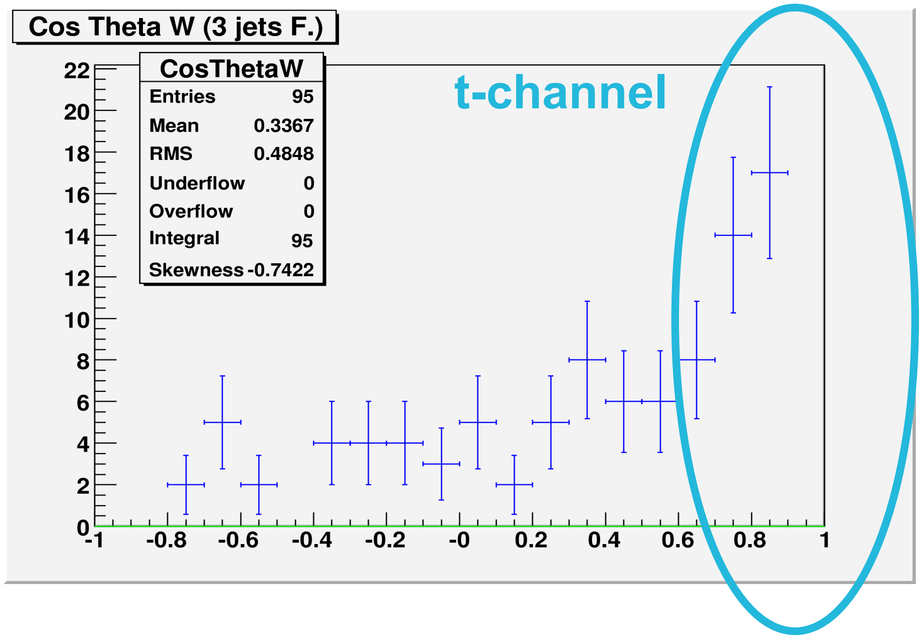
- For a luminosity of ~215 fb^{-1} x 4 the errors on the e^- polarization is ~0.1% and 0.2% for the e^+.
- This corresponds to an error on σ of ~ 0.25%.
- Blondel is only the first method we will apply and currently using old software: conservative.

Angular distributions

▶ The total cross section is not the only observable.

▶ Also the angular distributions can be exploited:

- W production angle θ: the polar angle of the outgoing W with respect to the e^- beam direction.
- Decay fermion angles in the W rest frame:
  - Polar θ^*;
  - Azimuthal ϕ^*.



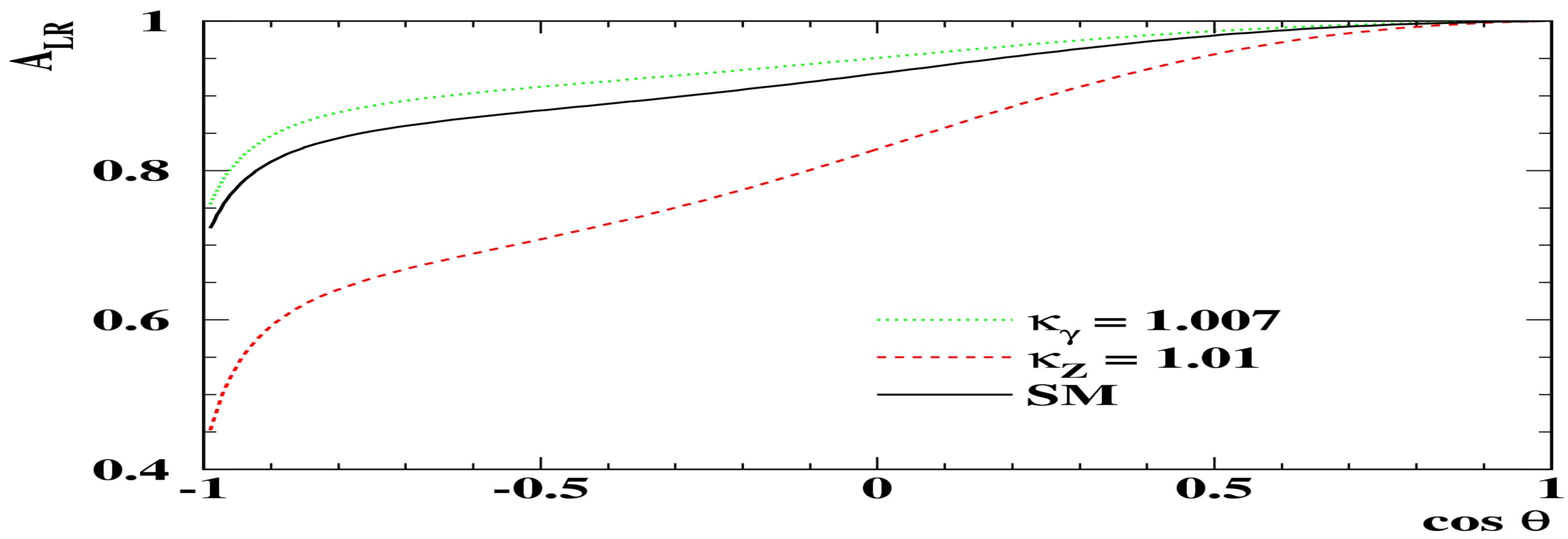
▶ Cosθ: the forward peak is due to the t-channel contribution.

▶ The second step of the analysis will be to fit simultaneously polarizations and TGCs, making use also of the angular distributions.

Example

▶ The A_{LR} asymmetry as a function of the $\cos\theta_W$, for different anomalous couplings:

• the t-channel is independent from the TGCs.



Following steps - 1

- To study the fitting procedure necessary to work with several polarizations and TGC constants values:
  - 100% pure polarization files to be combined to get several polarizations;
  - Not convenient to generate different files for several different values of the couplings, better to 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.

Following steps - 2

- The SDM, spin density matrices will be used for the fit. The SDM describe the polarization of the W bosons, and can be extracted form the data using projection operators.

- The inputs for the fit will then be:
  - The total cross sections for the different polarizations;
  - The SDM;
  - The normalized $\cos\theta$ distribution.

- A previous study has been performed by Wolfgang Menges in 2003, in fast simulation:

  - For one anomalous coupling and 60% e^+ 80% e^- polarizations, for $\Delta\sigma/\sigma$ = 1% to 0.25 %, $\Delta P^-/P^-$ = 0.2% to 0.05% and $\Delta P^+/P^+$= 0.31% to 0.08% at 800 GeV.

Conclusions

- Necessary to benefit from the results of the mass production:
  - **Simulation**:
    - New samples: moving therefore to more statistic, to a complete background, to the new detector model and the latest software version.
  - **Reconstruction**:
    - Pandora algorithm;
    - Lepton-ID.
- **Analysis**:
  - Upgrade the cut selection and evaluate whether selecting also the fully hadronic decay channel.
  - As shown the Blondel scheme makes some assumptions, to be evaluated.
  - An improvement is expected from the second method, which considers the TGCs influence on the measurement.