Beam Polarization from $W^+W^- \rightarrow qq\ell\upsilon$

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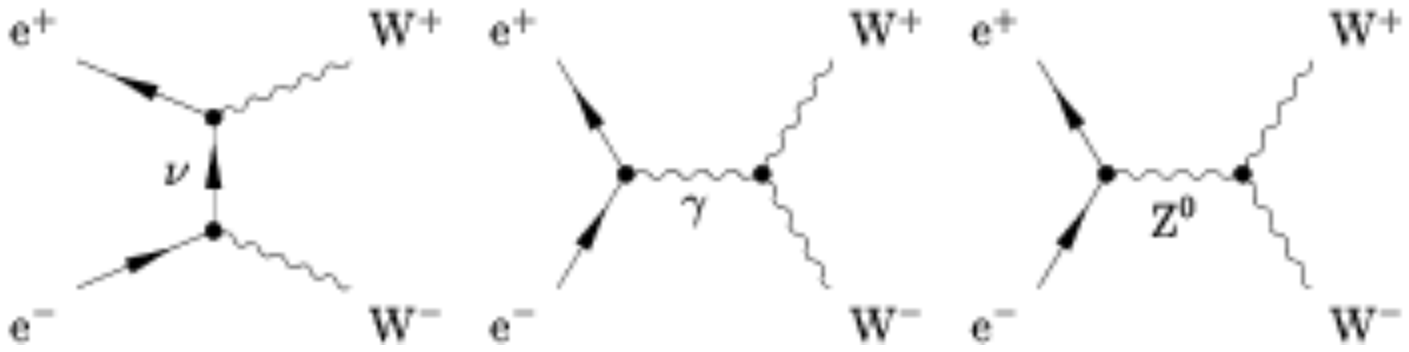
Introduction

- Beam polarization can be measured with polarimeters to a precision of $2.5 \cdot 10^{-3}$.
  - however, not the luminosity-weighted polarization

- Large luminosity at a LC allows an accurate measurement of the luminosity-weighted polarization from the data, for example using the process $e^+e^- \rightarrow W^+W^- \rightarrow qq\ell\upsilon$.
  - also, calibration of the absolute polarization scale

W-pair Production and Decay

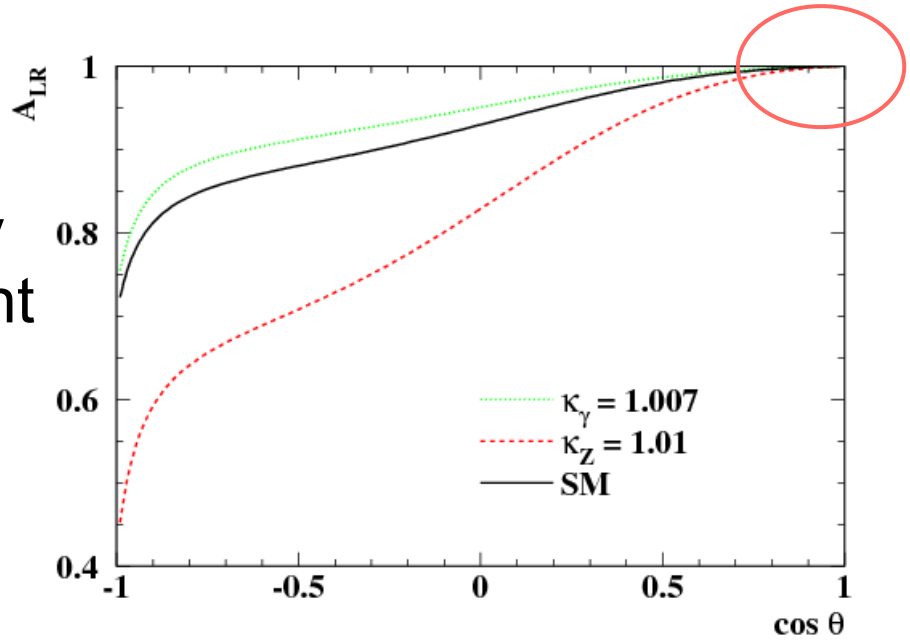


- Mixture of υ t-channel and Z, γ s-channel exchange.
- Cross section σ = 7 – 3 pb at E_{CM} = 500 GeV - 1 TeV.
- Decay modes:

# channels	process	BR
1	$W^+W^- \rightarrow qqqq$	45.6%
3	$W^+W^- \rightarrow qq\ell\upsilon$	43.8%
6	$W^+W^- \rightarrow \ell\upsilon\ell\upsilon$	10.6%

Polarization Measurement with W-pairs

- Total cross section and differential cross section $d\sigma/d\theta_W$ strongly sensitive to the polarization:
  - use the Blondel technique
  - fit the W production angle
- Forward peak dominated by ν exchange and independent of anomalous couplings:
  - fit simultaneously the polarisation and anomalous couplings



Blondel Scheme with Ws - Reminder

- Four independent measurements: σ_{RR}, σ_{LL}, σ_{RL}, σ_{LR}.
- Can measure $\mathcal{P}_{e^+}$ and $\mathcal{P}_{e^-}$, if $|\mathcal{P}^R| = |\mathcal{P}^L|$ for each beam:

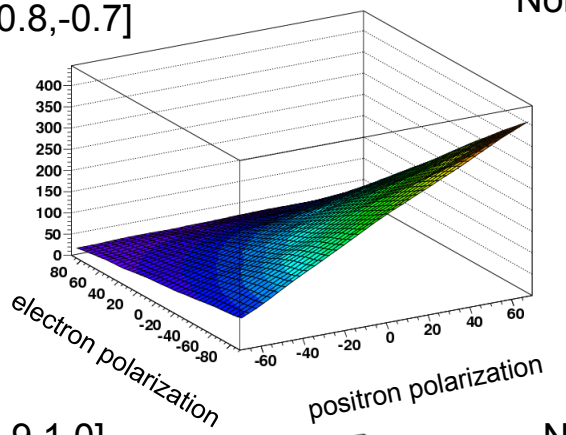
$$\mathcal{P}_{e^\pm} = \sqrt{\frac{(\sigma_{RL} + \sigma_{LR} - \sigma_{RR} - \sigma_{LL})(\mp\sigma_{RL} \pm \sigma_{LR} - \sigma_{RR} + \sigma_{LL})}{(\sigma_{RL} + \sigma_{LR} + \sigma_{RR} + \sigma_{LL})(\mp\sigma_{RL} \pm \sigma_{LR} + \sigma_{RR} - \sigma_{LL})}}$$

- Polarisation asymmetry $|\mathcal{P}^R_{e^\pm}|$ - $|\mathcal{P}^L_{e^\pm}|$ needs to be measured by polarimeters.

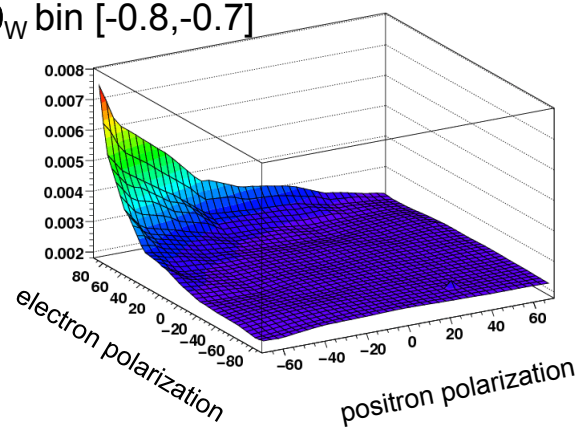
Angular Fit Method

Look at the polarization dependence in bins of $\cos\theta_W$. Obtain templates of $d\sigma(\cos\theta,Pe-,Pe+)$ and fit data extracted from the templates for given Pe-,Pe+.

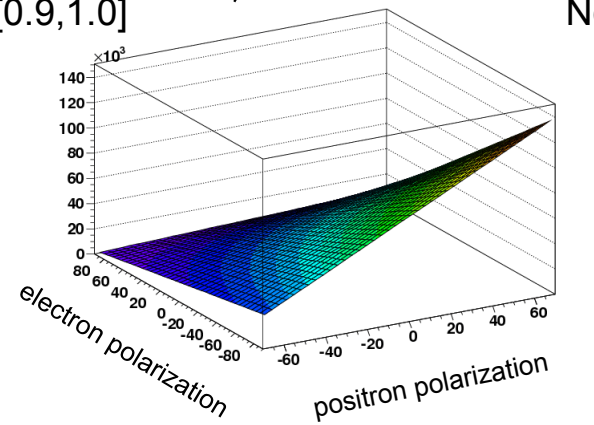
$\cos\theta_W$ bin [-0.8,-0.7]



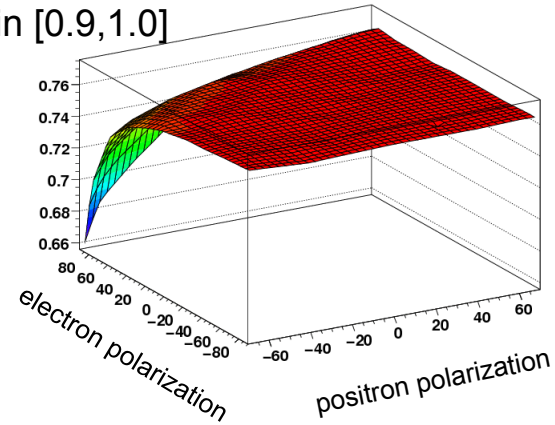
Norm $\cos\theta_W$ bin [-0.8,-0.7]



$\cos\theta_W$ bin [0.9,1.0]

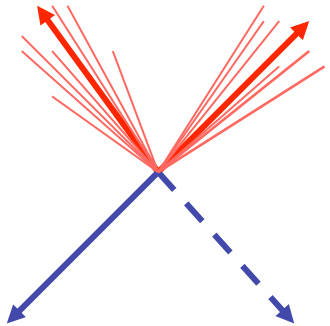


Norm $\cos\theta_W$ bin [0.9,1.0]



Selection of Semileptonic Final State

- Event topology



  - 2 jets
  - 1 charged lepton
  - 1 neutrino
- Straightforward reconstruction
- Low background

- Event selection
  - Cut based selection
  - Preselection
  - Dedicated lepton ID
  - Force event in two jets
  - Kinematic fit with 2C
  - Anti-tau discriminant variable
  - Cut on the reconstructed W mass
  - Cut on the W production angle

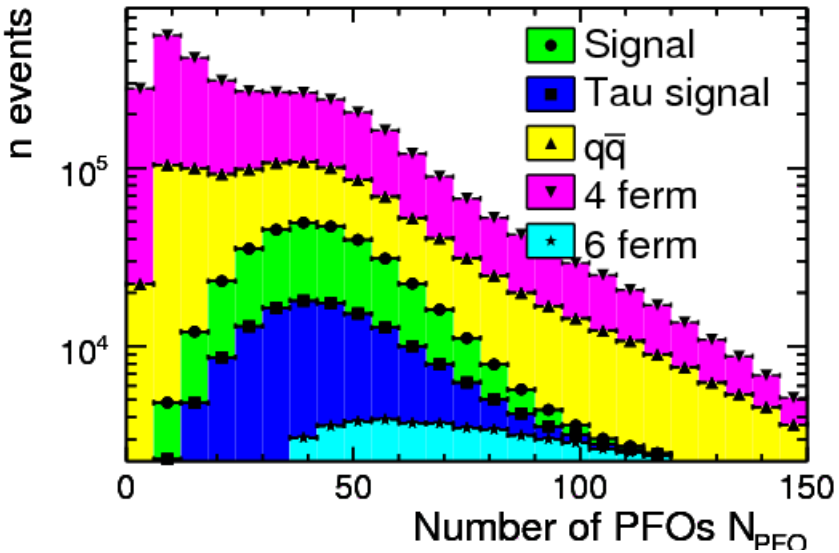
Analysis at E_{CM} = 1 TeV

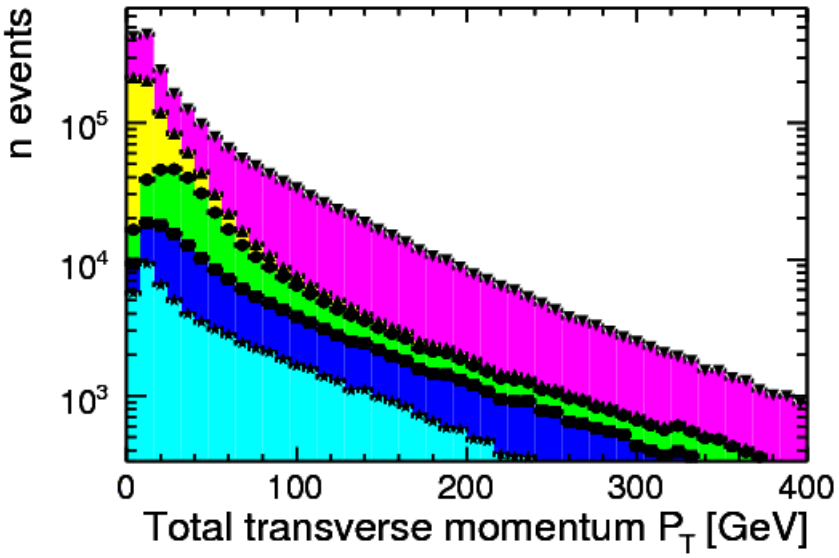
- ILC operated at E_{CM} = 1 TeV and $\mathcal{L}$ = 100 fb^{-1} for each polarization; results extrapolated at 1000 fb^{-1}.
- Longitudinal polarization:
  - 80% electron polarization
  - 20% positron polarization
- SM Backgrounds: 2f, 4f, 6f, $\gamma\gamma/e\gamma$ (not yet accounted for)
  - generation with Whizard version 1.95.
  - full simulation and reconstruction with ILCSoft version v01-16 and detector model ILD_o1_v05.
- Beam background: 4.1 $\gamma\gamma$ -> hadrons events/BX
- Signal: only semi-leptonic channel with $\ell = e^-, \mu^-$.

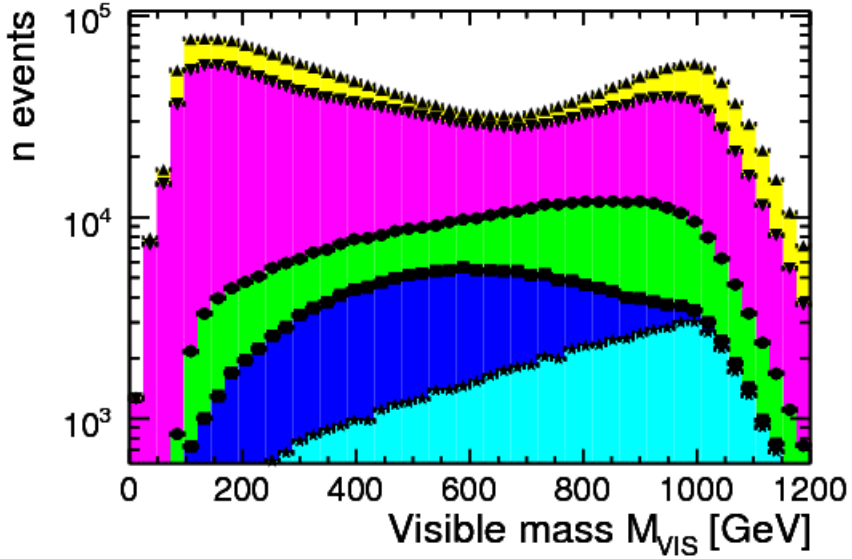
Selection Cuts

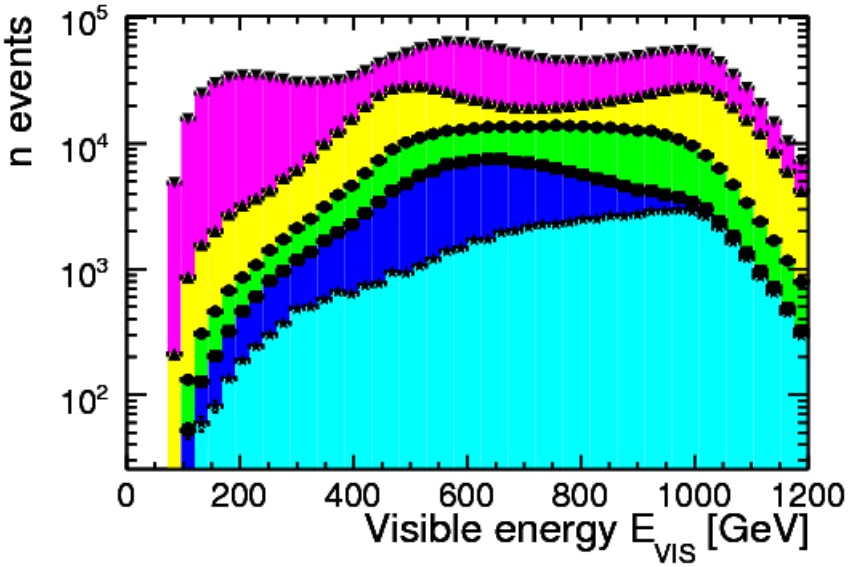
- Number of reconstructed PFOs > 15
- Visible energy < 1200 GeV
- Visible mass > 100 GeV
- Transverse momentum > 5 GeV
- One isolated lepton (muon or electron)
- Two jets reconstructed with the kt algorithm in the exclusive mode with R=1.3
- 2C kinematic fit
- $\tau_{\text{discr}} > 1$
- $40 < M_W^{\text{fit}} < 120\ \text{GeV}$
- $\cos\theta_W > -0.95$

Preselection







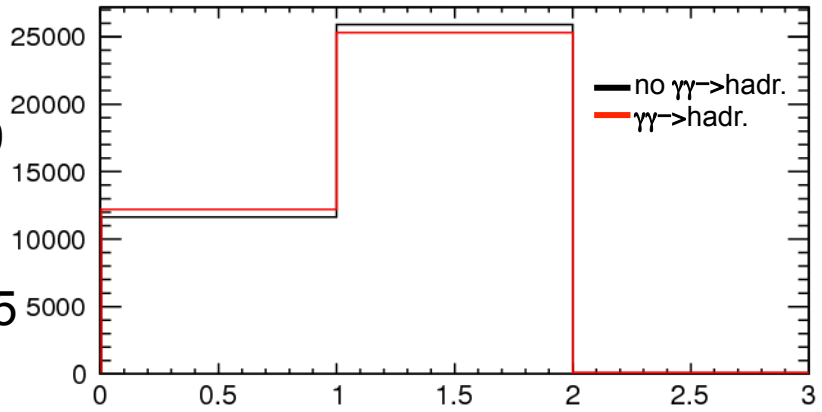


Lepton Identification

- Lepton ID

For e+/e- : $(En_{ECAL}+En_{HCAL})/P > 0.8$
$En_{ECAL}/(En_{ECAL}+En_{HCAL})>0.9$
Charge not-zero

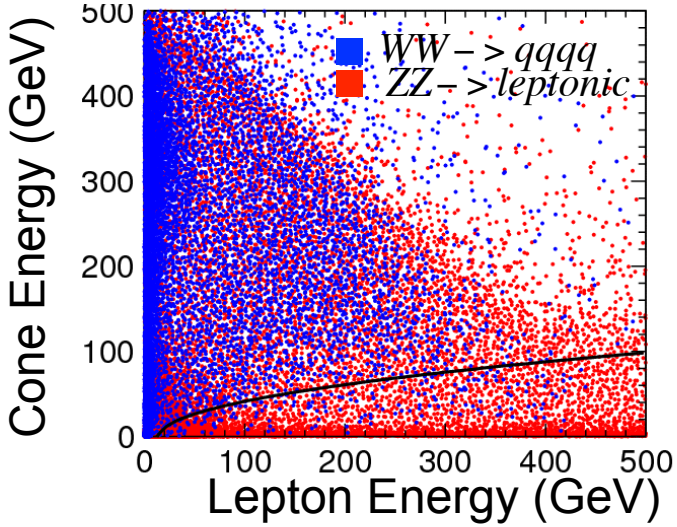
For μ+/μ-: $(En_{ECAL}+En_{HCAL})/P < 0.4$
$En_{ECAL}/(En_{ECAL}+En_{HCAL})<0.5$
Charge not-zero



- Isolation

$$\cos\theta = 0.98$$

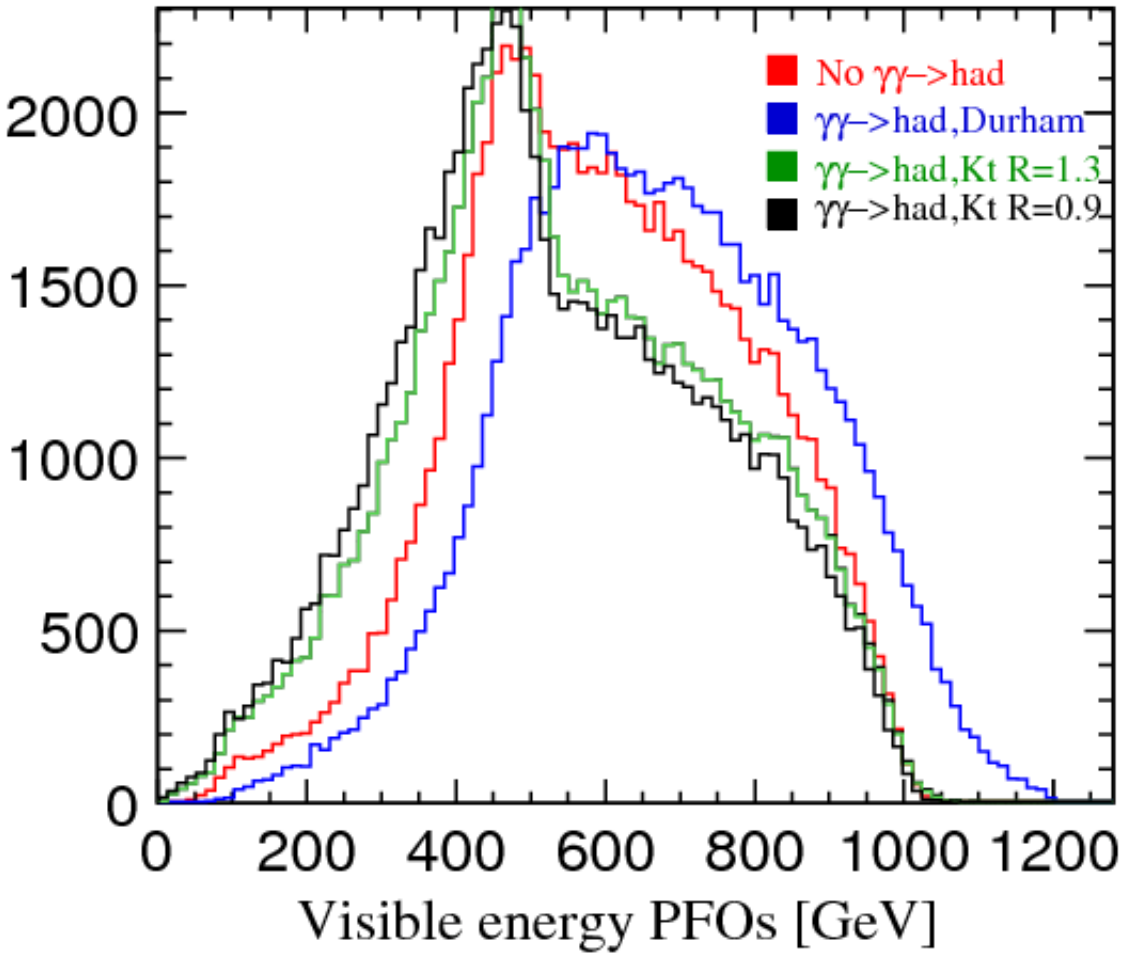
$$E_{cone} < \sqrt{20E_{\ell} - 300}$$



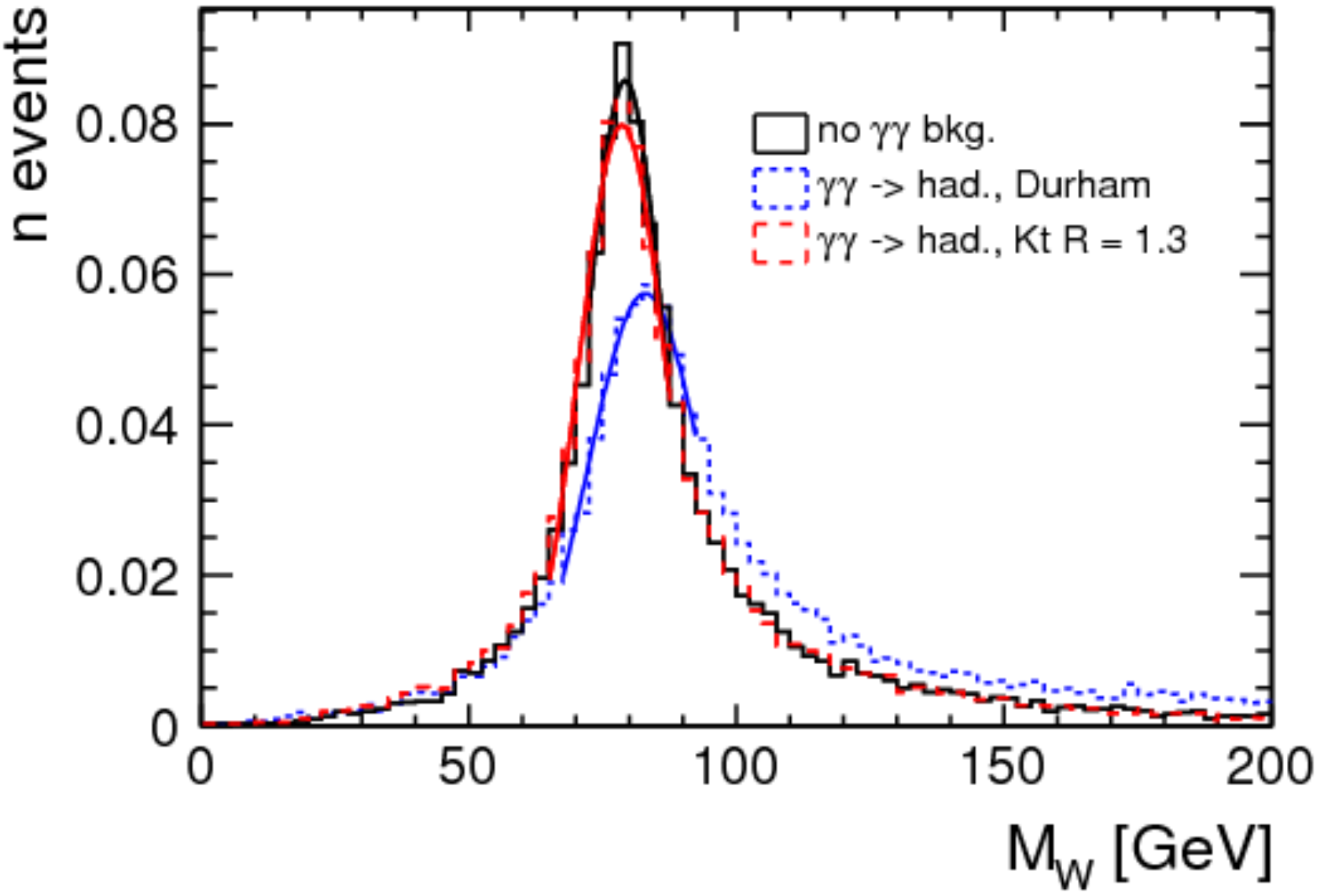
Efficiency: 93%

Jet Clustering and Suppression of $\gamma\gamma \rightarrow$ hadrons

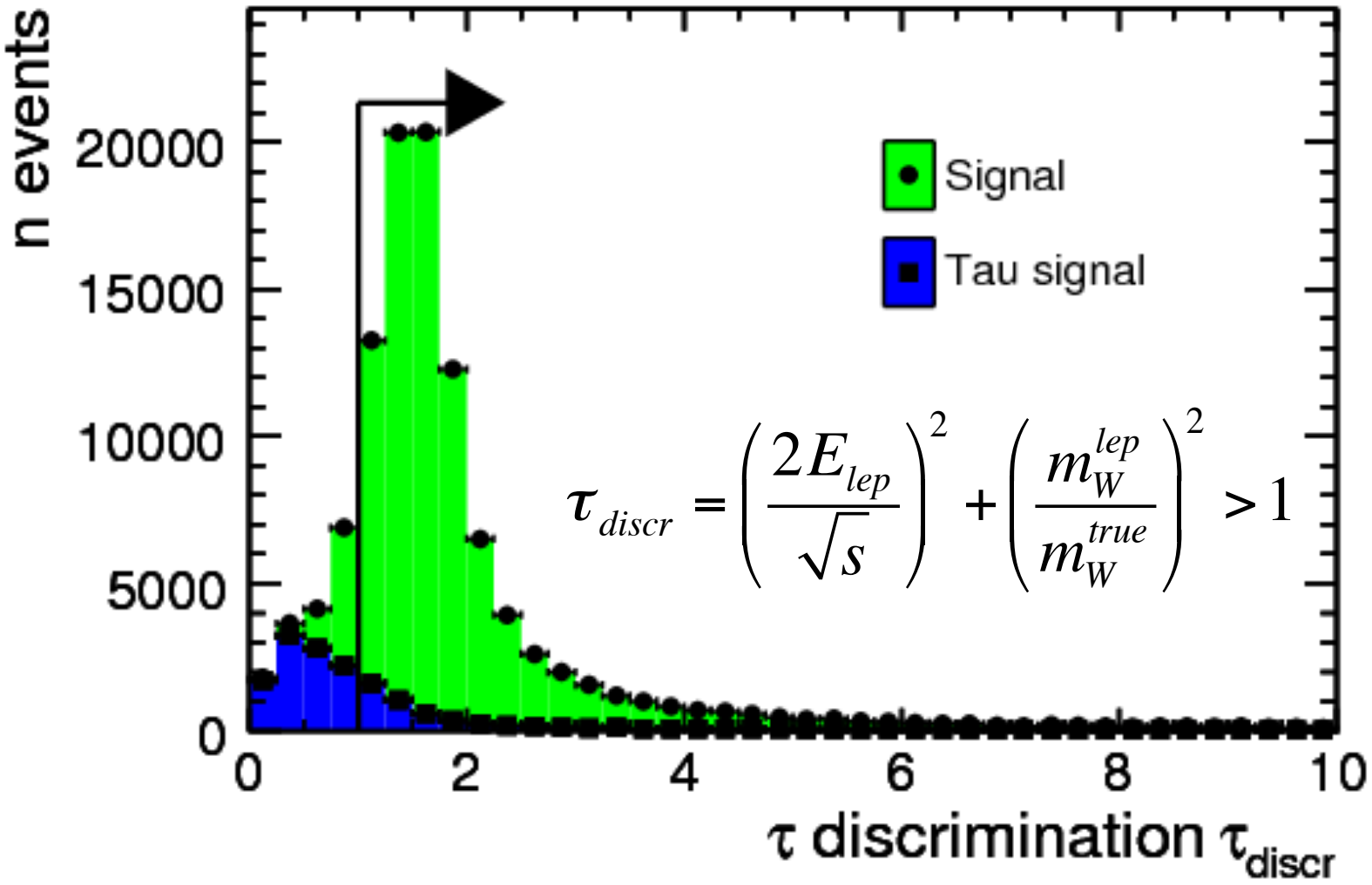
Jet clustering with kt algorithm, R=1.3



W Invariant Mass



“Tau-signal” Suppression



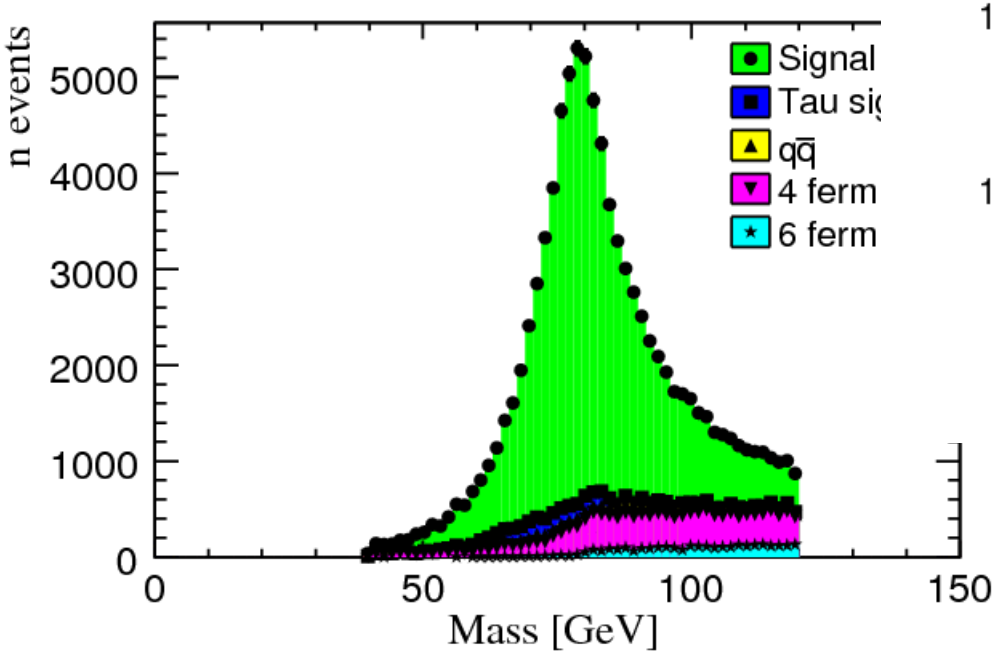
Data Reduction

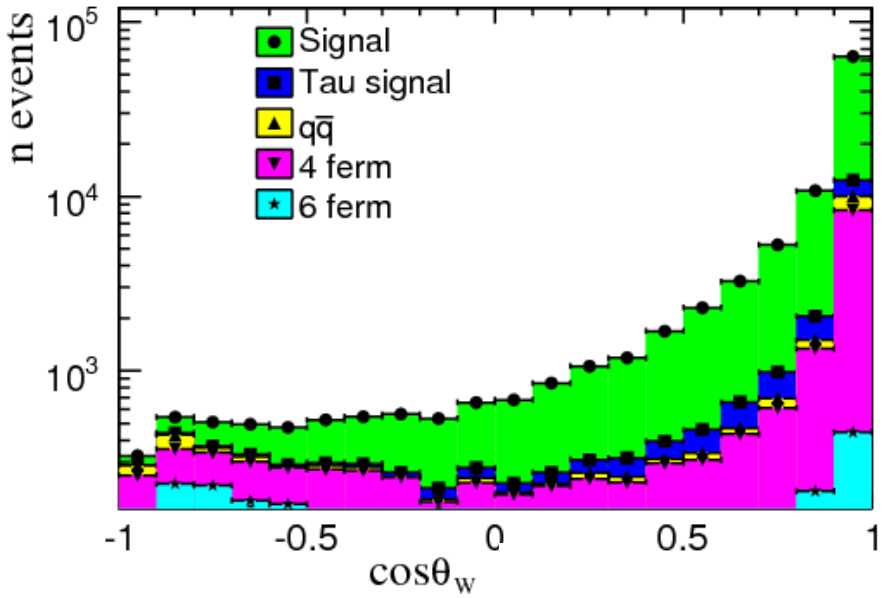
Cut	qqlv	qqτv	2 ferm	4 ferm	6 ferm
Initial events	210841	104698	776759	2369330	69277
Preselection	192577	95783	427708	1130853	63785
One isolated lepton	117452	20010	19168	234110	22697
Fit probability	100232	17607	12491	68277	17983
Tau rejection	91282	5651	10295	52409	16445
Mass cuts	76415	4120	2550	14052	3010
Cosθ>-0.95	76102	4100	2370	12443	2887

Efficiency: 36% (100 fb^{-1} for Pol(e^-/e^+) = -80%,+20%)
Purity: 82%

W Invariant Mass and Production Angle

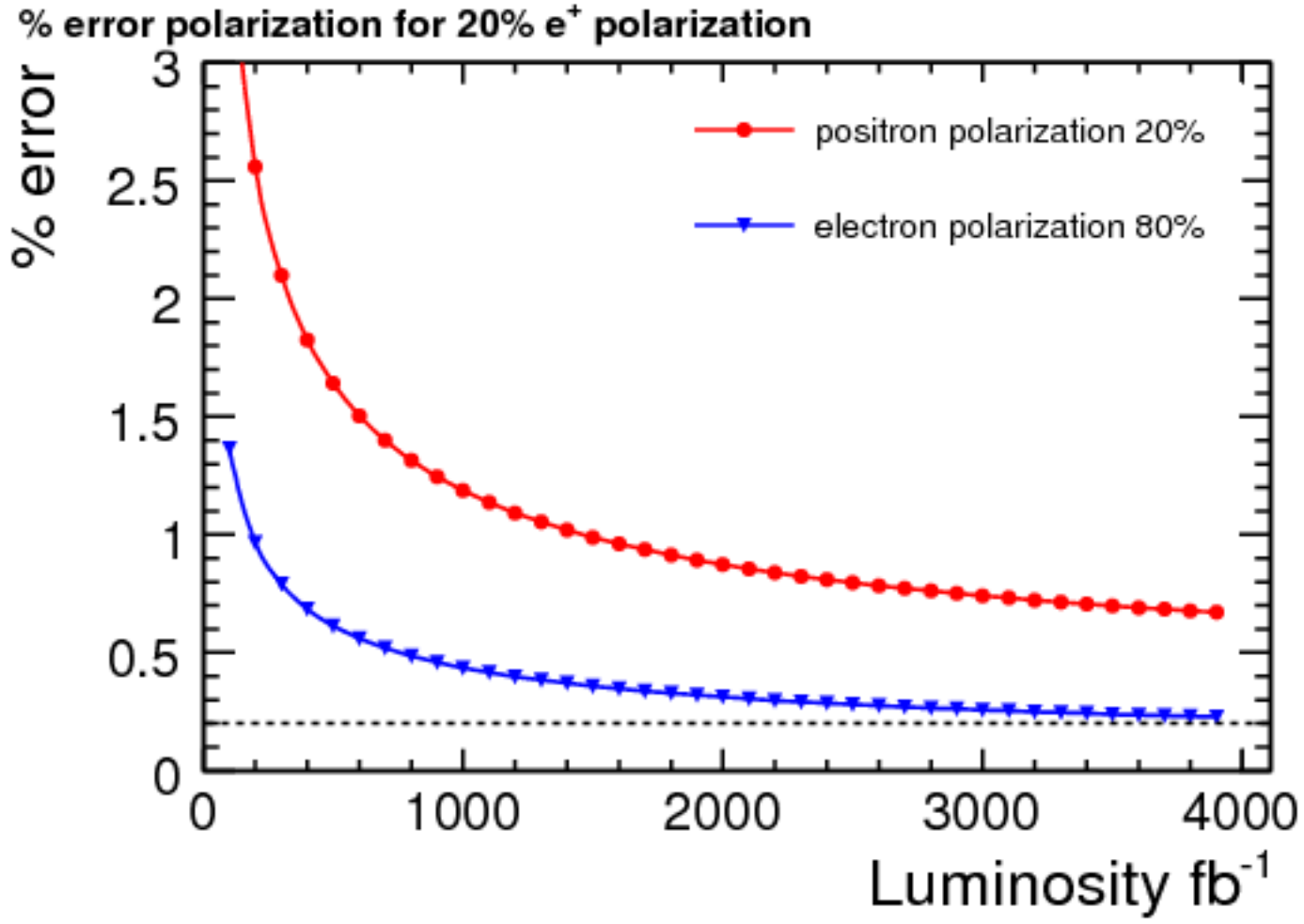
100 fb^{-1} for Pol(e^-/e^+) = -80%,+20%





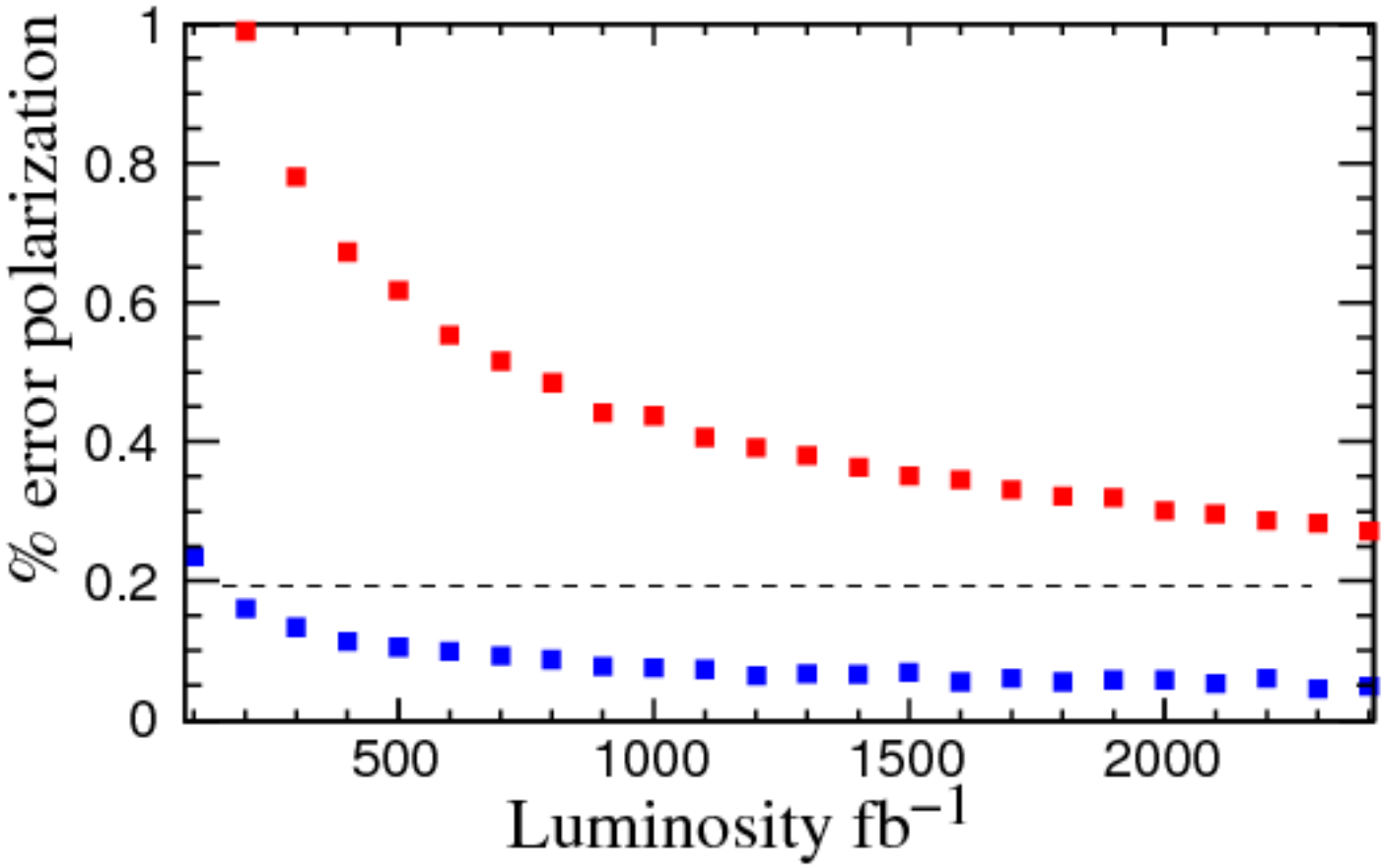
Polarization Measurement: Blondel Method

25%/25%/25%/25% (-0.8,-0.2)/(-0.8,+0.2)/(0.8,-0.2)/(0.8,0.2)



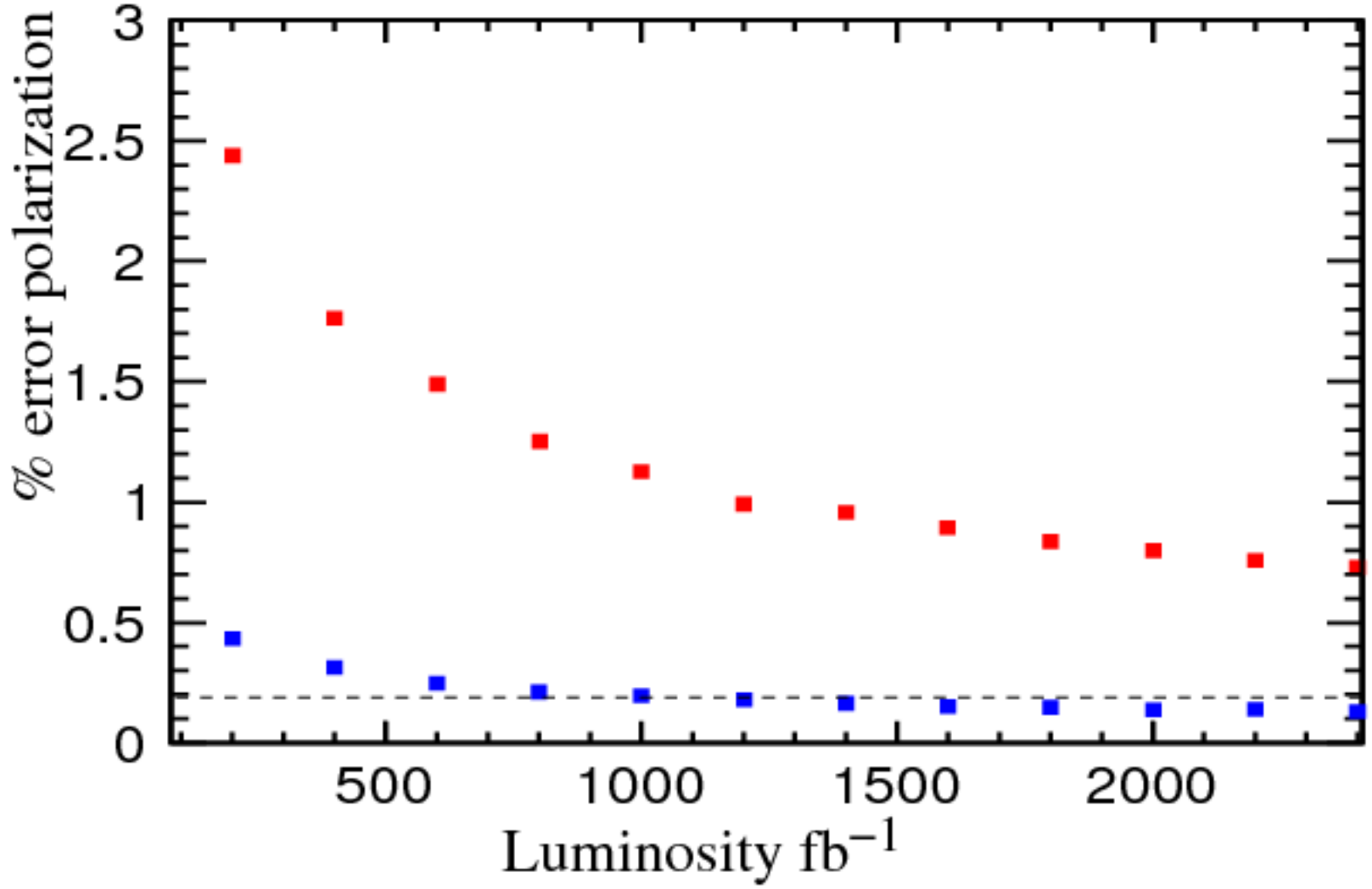
Polarization Measurement: Fit Method

25%/25%/25%/25% (-0.8,-0.2)/(-0.8,+0.2)/(0.8,-0.2)/(0.8,0.2)



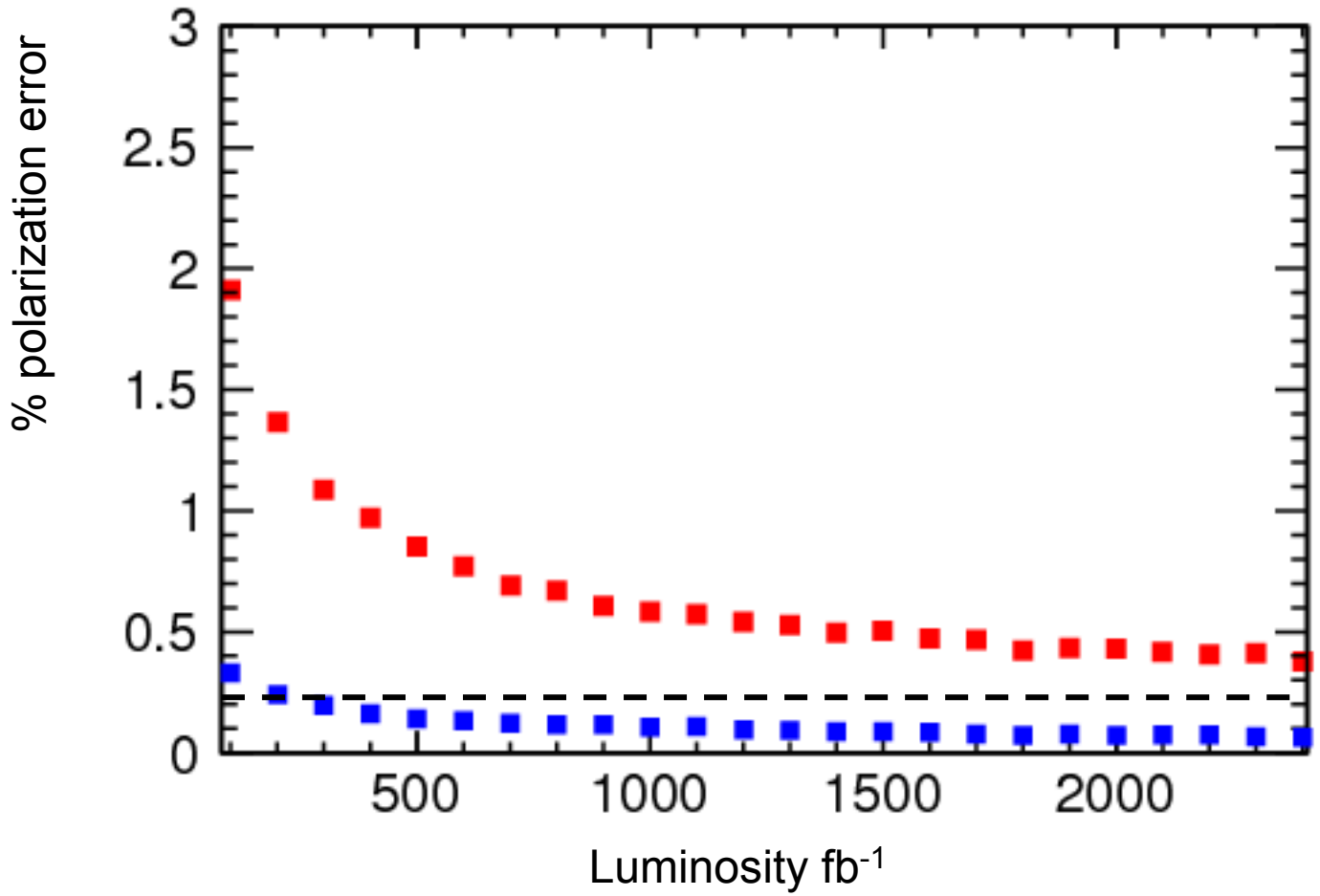
Polarization Measurement: Fit Method

50%/50% (-0.8,+0.2)/(0.8,-0.2)



Polarization Measurement: Fit Method

10%/40%/40%/10% (-0.8,-0.2)/(-0.8,+0.2)/(0.8,-0.2)/(0.8,0.2)



Polarization Errors

$qq\ell\upsilon$ events, $\sqrt{s} = 1$ TeV, lumi 1000 fb^{-1}

efficiency 36%, purity 82%

	P_{e-}	ΔP_{e-}	$\Delta P_{e-}/P_{e-}$	P_{e+}	ΔP_{e+}	$\Delta P_{e+}/P_{e+}$
Blondel method (25% --/-+/+-/--)	0.8	0.00351	0.44%	0.2	0.00239	1.19%
Fit method (25% --/-+/+-/--)	0.8	0.00060	0.07%	0.2	0.00086	0.43%
Fit method (10% --/++) (40% -+/+-)	0.8	0.00084	0.105%	0.2	0.00120	0.6%
Fit method (50% -+/+-)	0.8	0.00155	0.19%	0.2	0.00227	1.13%

Summary

- Beam polarization can be measured from data themselves, using the process of semi-leptonic decay of W-pair,

$$e^+e^- \rightarrow W^+W^- \rightarrow qq\ell\upsilon.$$

- Fit of the W^- production angle is more powerful than the Blondel scheme.
  - Need to address the dependence of the TGCs, to be done in the future.