WW Scattering in the LDC00Sc Detector Model

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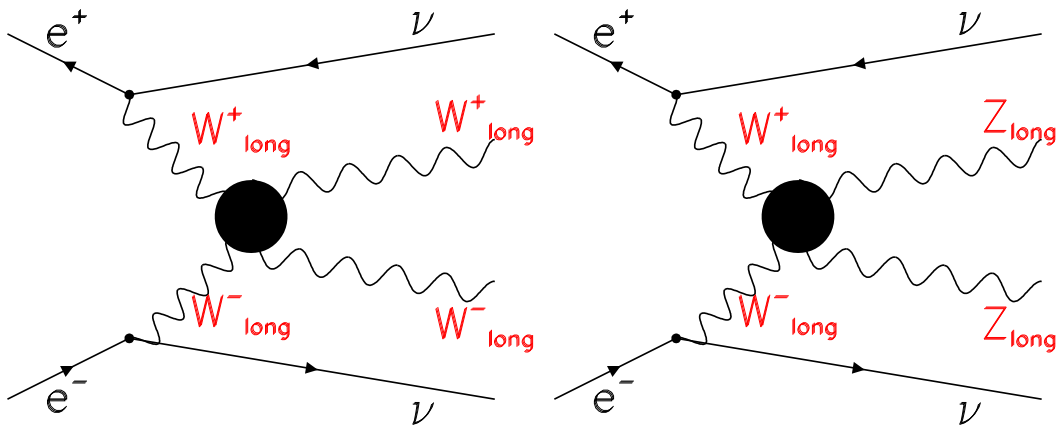
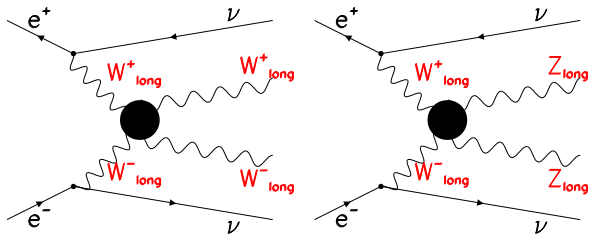


Motivation

- **Strong WW scattering**
  - **Electroweak symmetry breaking due to a light Higgs boson: no strong WW scattering**
  - **no Higgs below about 0.8 TeV, interaction among gauge bosons becomes strong at high energy.**

- **WW scattering @ e^+e^-**



- **For the weak boson scattering, there are two dimension four operators in the effective lagrangian at SU(2)$_c$ conserving**
  $L_4 = \frac{\alpha_4}{16\pi^2} tr(V_\mu V_v) tr(V^\mu V^v) \qquad L_5 = \frac{\alpha_5}{16\pi^2} tr(V_\mu V^\mu) tr(V_v V^v)$
  anomalous couplings α_4 & α_5 are related to the scale of new physics

Motivation

- α_4 & α_5 are zero in the SM, and are model dependent
- The sensitivity of α_4 & α_5 at linear collider ?
  - LC-PHSM-2001-038: SIMDET for TESLA @ 800 GeV
  - hep-ph/0604048: SIMDET for TESLA @ 1000 GeV
  - Andres F. Osorio's thesis: SIMDET for TESLA @ 800 GeV
- Motivation @ this work
  - WW/ZZ separation
  - Extract α_4 & α_5:
    - Detector model: LDC00, LDC00Sc, LDC01, LDC01Sc
    - PFA: PandoraPFO PFA vs. Wolf PFA
- This talk: We use PandoraPFO PFA to study WW with LDC00Sc detector model, and extract α_4 & α_5.

WW/ZZ MC production

- **LC-PHSM-2001-038: 800 GeV @ TESLA**

Channel	Events (ZZ$\nu\nu$)	Events (WW$\nu\nu$)
$e^+e^- \to ZZ\nu\nu \to qqqq\nu\nu$	2168 $\pm$ 10	
$e^+e^- \to WW\nu\nu \to qqqq\nu\nu$		5077 $\pm$ 23
$e^+e^- \to qqqq\nu\nu$ (background)	174 $\pm$ 5	509 $\pm$ 8
$e^+e^- \to WZe\nu \to qqqq\nu\nu$	993 $\pm$ 20	1728 $\pm$ 34
$e^+e^- \to WWe^+e^-, ZZe^+e^- \to qqqq\nu\nu$	250 $\pm$ 60	257 $\pm$ 57
$e^+e^- \to WW/ZZ \to qqqq$	negl.	negl.
$e^+e^- \to t\bar{t} \to X$	143 $\pm$ 20	444 $\pm$ 75
$e^+e^- \to q\bar{q} \to X$	negl.	negl.

- **$\sqrt{s} =$ 800 GeV; polarization RL 40% 80%; with ISR; w/o beamstrahlung**

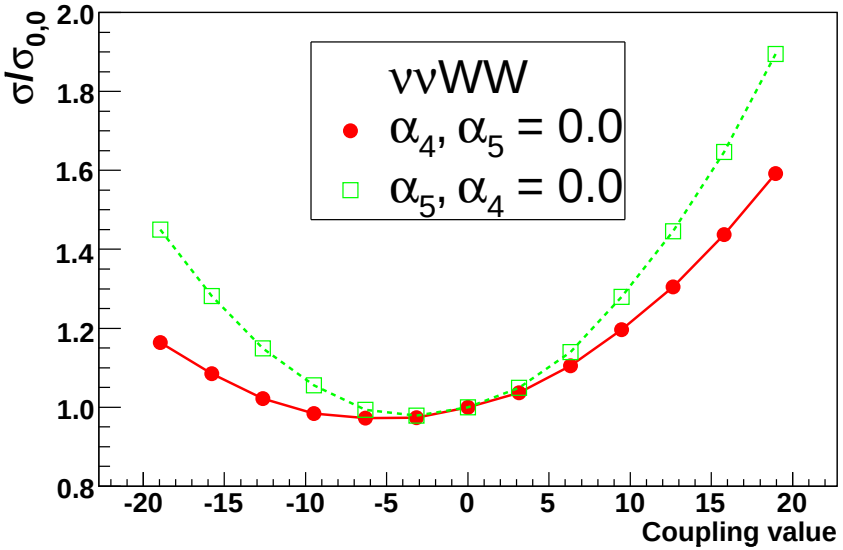
Channel	Luminosity (fb^{-1})	Generator	
$\nu_e\bar{\nu}_eWW/ZZ$	1000	Whizard 1.50	
$e\nu_eWZ$	1000	Whizard 1.50	
$eeWW/ZZ$	500	Whizard 1.50	
$t\bar{t} \to X$	500	PYTHIA 6.1	no polarization
$\nu_e e^{\pm}W^{\mp}$	500	Whizard 1.50	hep-ph/0604048
$\nu_{\mu,\tau}\bar{\nu}_{\mu,\tau}WW$	1000	Whizard 1.50	hep-ph/0604048

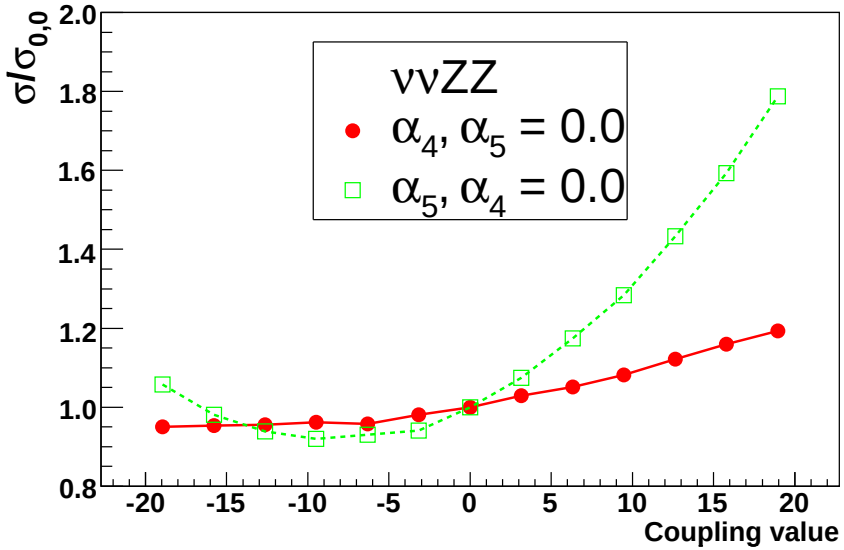
Event reconstruction

- **Detector simulation: LDC00Sc detector model @ Mokka v6.2;**
- **Marlin v00-09-06; MarlinReco v00-02; MarlinUtil v00-02**
- **Pandora PFA v01-00**
- **Processors for Digitization**
  - **VTXDigi FTDDigi TPCDigi**
  - **SimpleCaloDigi**
- **Processors for Pandora PFA**
  - **tracking finding: TrackCheater**
  - **cluster finding & track-cluster match: PandoraPFAProcessor**

Sensitive variables

- **WW/ZZ Signal events**
  - $147.0 < m^1_{qq} + m^2_{qq} < 171.0$ **GeV: WW**
  - $171.0 < m^1_{qq} + m^2_{qq} < 195.0$ **GeV: ZZ**
  - $|m^1_{qq} - m^2_{qq}| <= 20.0$ **GeV**
  - $m_{\nu_e\bar{\nu}_e} >= 100.0$ **GeV**

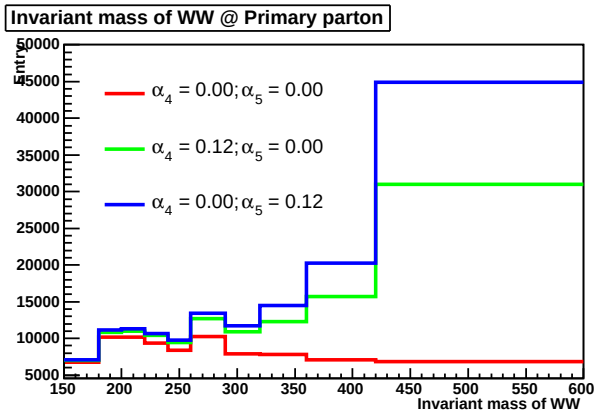


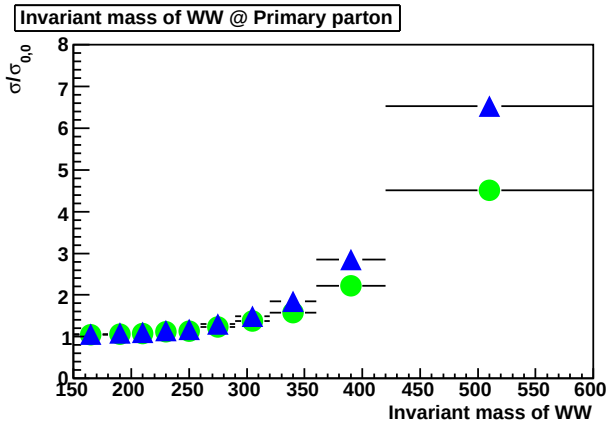


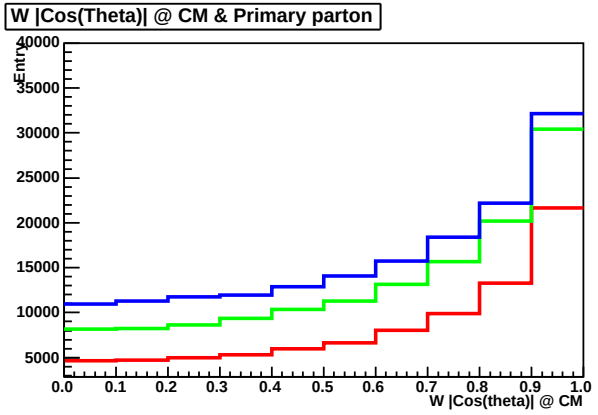
- $\nu\nu WW$ **events are more sensitive than** $\nu\nu ZZ$ **events**
- α_5 **is more sensitive than** α_4

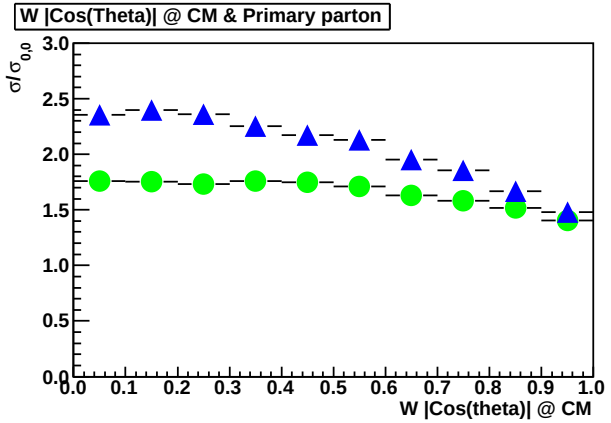
Sensitive variables

- **Interesting variables: $d\sigma/dM_{WW}$ and $d\sigma/d|\cos\theta^{\star}_{W}|$**
- **$\theta^{\star}_{W}$: W's θ @ WW rest frame**







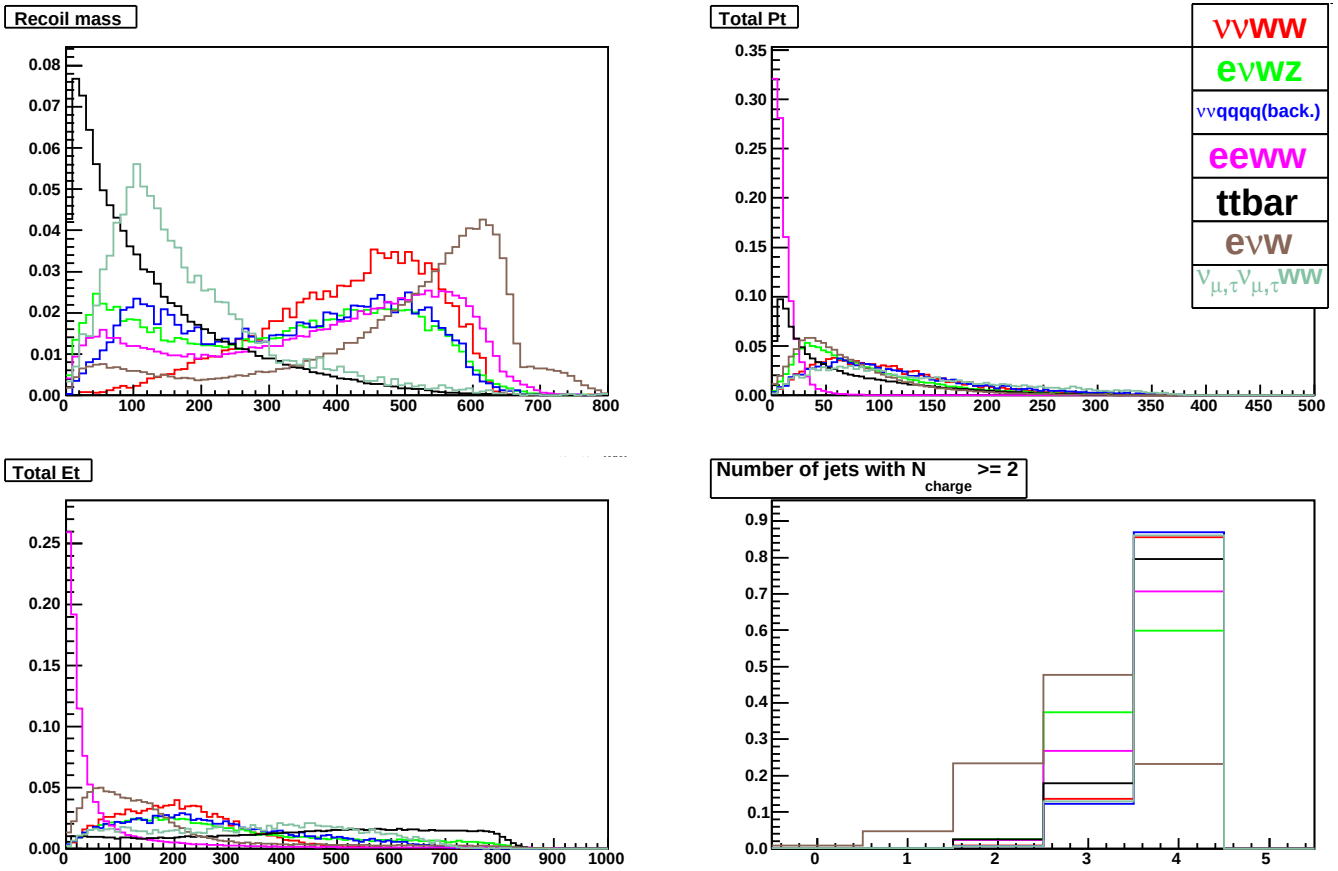


WW/ZZ event selection

- We follow LC-PHSM-2001-038, and unify selection cuts for WW/ZZ
- Event selection: select events with a significant fraction of neutrinos
  - Recoil mass: $M_{recoil} >= 200.0$ GeV
  - Total transverse momentum: $P_T >= 40$ GeV
  - Total transverse energy: $E_T >= 150$ GeV
  - Total missing momentum and most energetic track: $|\cos\theta| < 0.99$
  - Energy in a 10^o cone of most energy track: $E_{cone} >= 2.0$ GeV
  - Force events to have 4 jets, and $Y_{34} > 0.0001$
    - Ktjet package for jet finding
    - Jet selection: $E_{jet} > 10.0$ GeV and $|\cos\theta_{jet}| < 0.99$
- WW/ZZ selection
  - WW: $60 < M_W < 88$ GeV
  - ZZ: $85 < M_Z < 100$ GeV

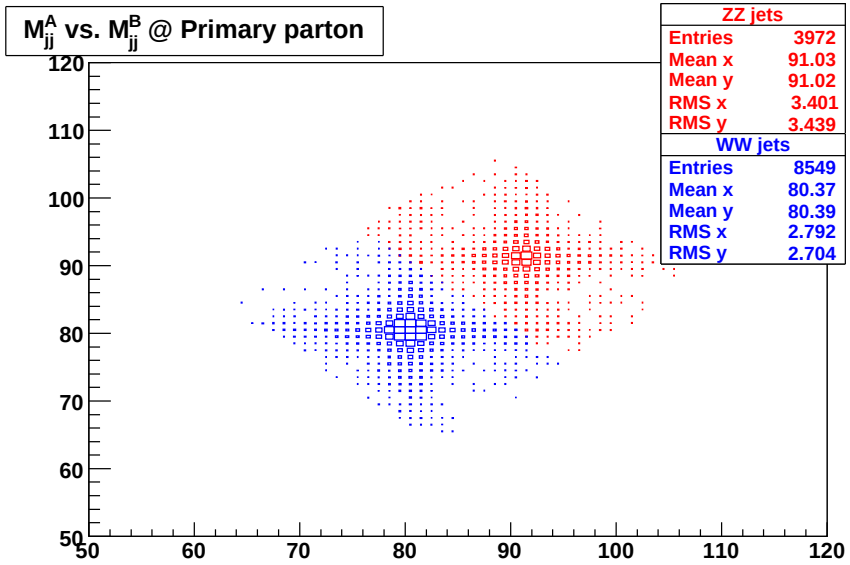
Control plots @ detector level

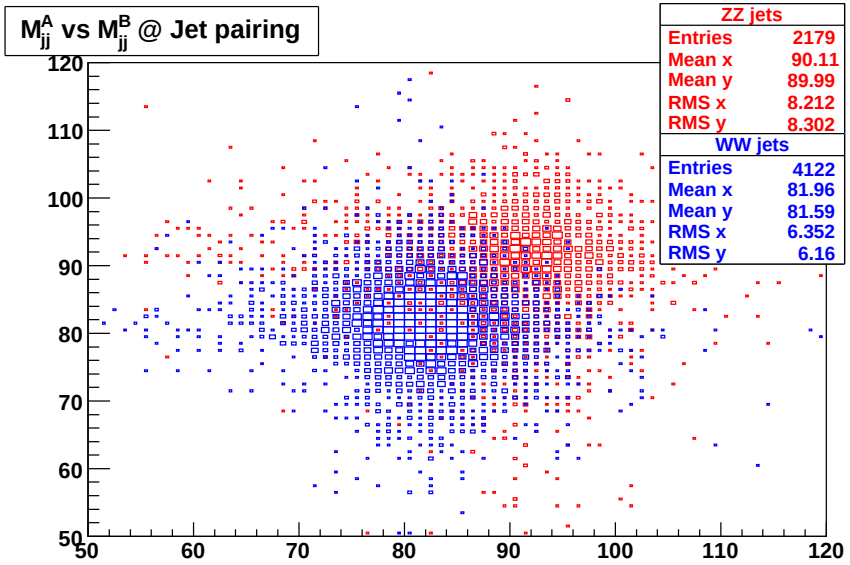
- **Before event selection, histograms are normalized to one.**



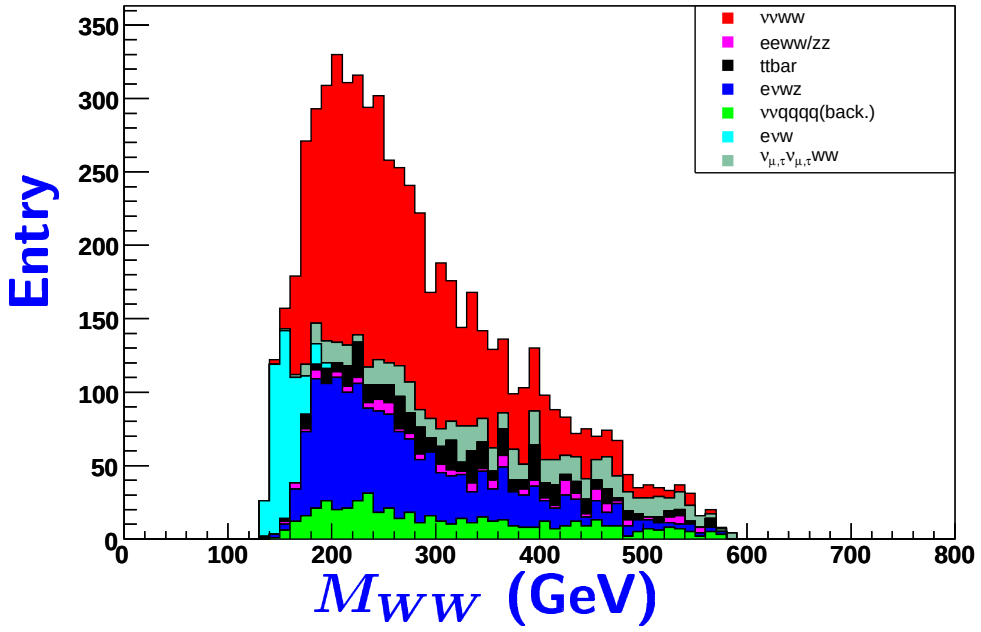
WW/ZZ separation

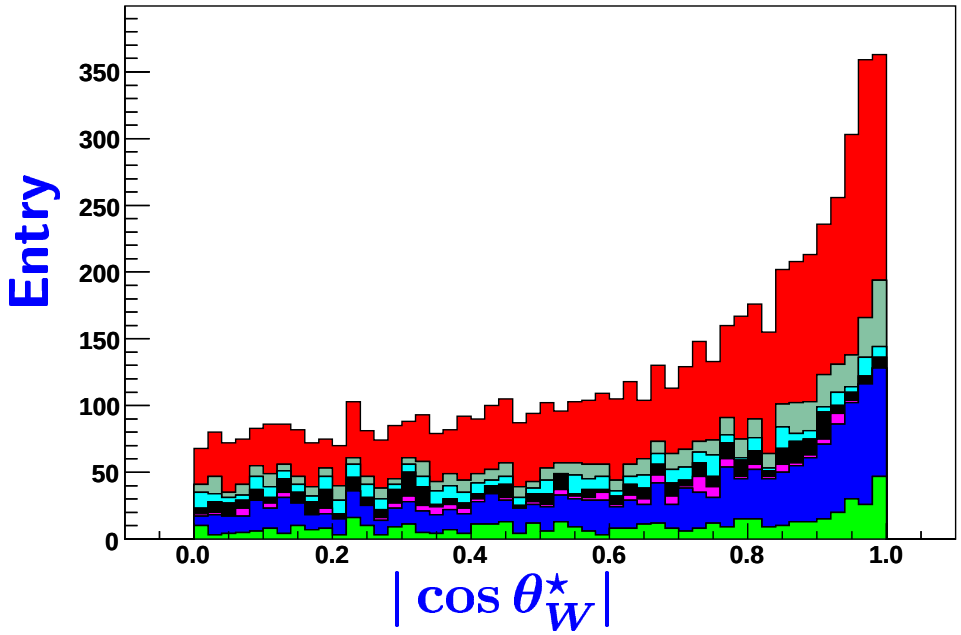
- **WW/ZZ: SAME selection @ detector level; without WW/ZZ selection**





Fit distributions



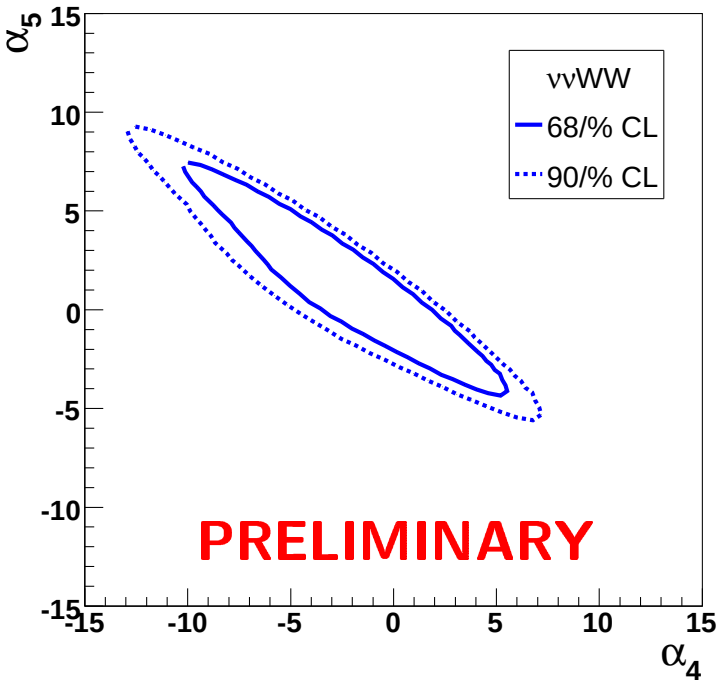


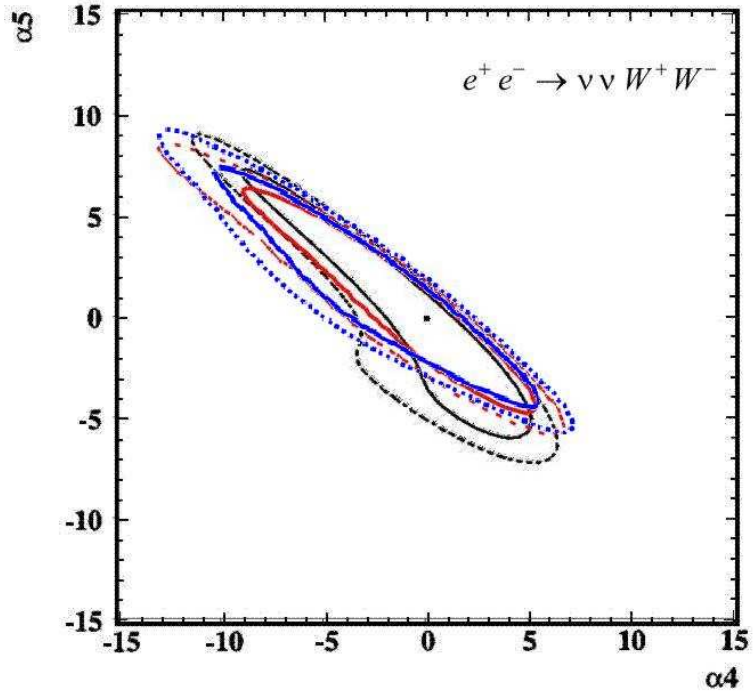
- **fit distribution:** $d^2\sigma/(dM_{WW}d|\cos\theta^{\star}_{W}|)$
- $150 < M_{WW} < 600$ **GeV; 10 bins for** M_{WW}**; 10 bins for** $|\cos\theta^{\star}_{W}|$

Binned maximum likelihood fit

- **Fitting for 10×10 bins $d^2\sigma/(dM_{WW}d|\cos\theta^{\star}_{W}|)$ at detector level**
  - **SM sample with (0.0, 0.0) as "data"**
  - **each bin $p(n) = e^{-\lambda}\lambda^n/n!$**
    - **n: observed number @ "data" sample and background event samples**
    - **λ: expected number; $\lambda = m^{signal}(\alpha_4, \alpha_5) + m^{bcg1}(\alpha_4, \alpha_5) + m^{bcg2}$**
  - **$-\ln\mathcal{L} = -\sum p(n_i) = -\sum n_i \ln\lambda_i + \sum\lambda_i$**
- **$m^{signal}(\alpha_4, \alpha_5)$ and $m^{bcg1}(\alpha_4, \alpha_5)$**
  - **Each MC event (ith event) is weighted by**
    $R_i(\alpha_4, \alpha_5) = 1.0 + A_i\alpha_4 + B_i\alpha_4^2 + C_i\alpha_5 + D_i\alpha_5^2 + E_i\alpha_4\alpha_5$
    R_i is the ratio of matrix element to SM sample with (0.0, 0.0)
  - **Decide A_i, B_i, C_i, D_i, E_i @ each event**
    - **Using generated SM sample with (0.0, 0.0), we recalculate matrix elements for each events with 20 sets of (α_4, α_5) value, and decide $(A_i, B_i, C_i, D_i, E_i)$ by TMinuit fitting to 20 R for ith event.**
  - **Count selected events with $R_i(\alpha_4, \alpha_5) \rightarrow m^{signal}(\alpha_4, \alpha_5)$**
- **Selection performance independent of (α_4, α_5)**

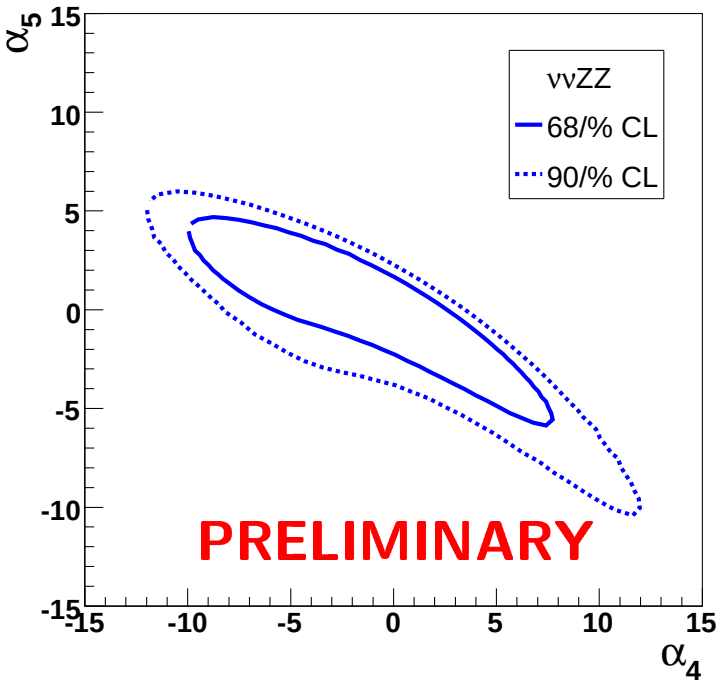
Likelihood from WW

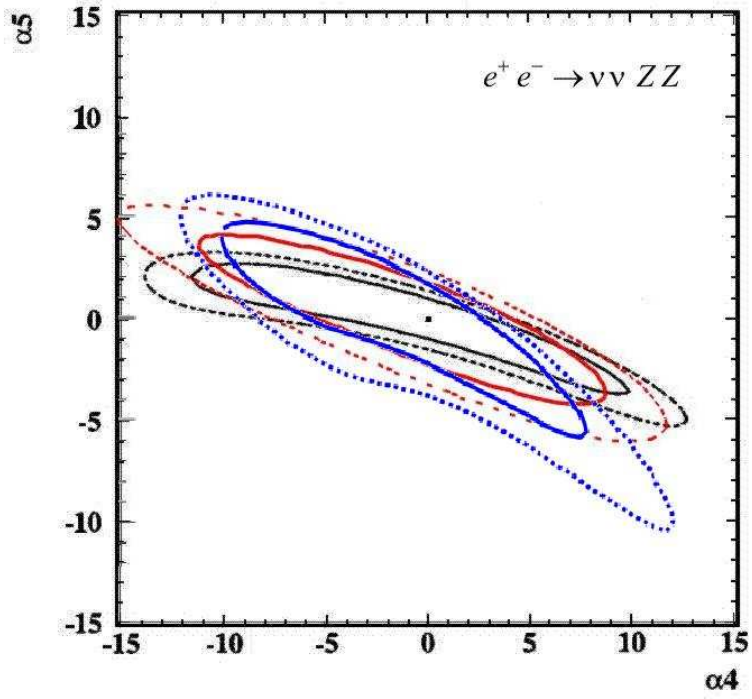




- **Blue: our results on LDC00Sc detector model**
- **Red: Predrag Krstonosic's results @ LCWS 2005 on TESLA fast simulation**
- **Black: LC-PHSM-2001-038 on TESLA fast simulation**

Likelihood from ZZ





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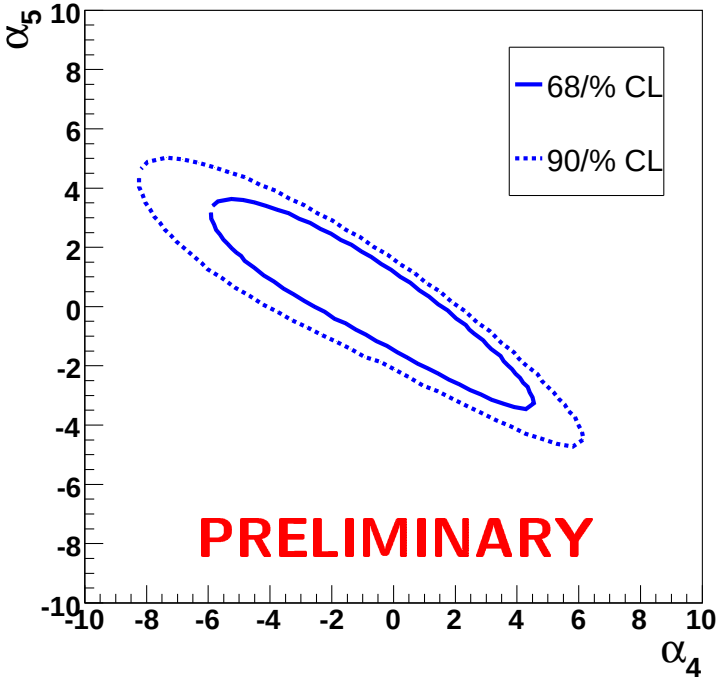
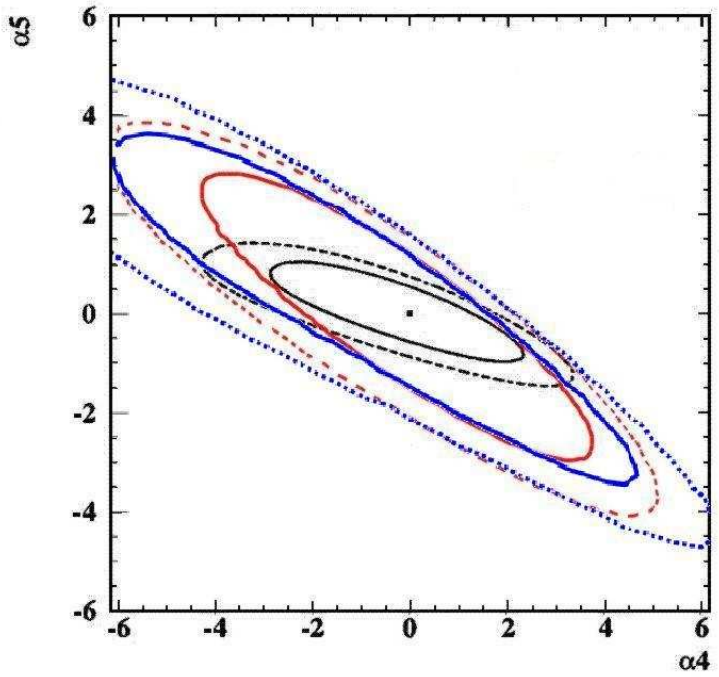
Likelihood from combined WW/ZZ





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Summary and outlook

- **We study WW scattering with LDC00Sc detector model, and extract α_4 & α_5, which are comparable with that of TESLA fast simulation.**

- **Possible improvements**
  - **b-tag $\rightarrow t\bar{t}$ events**
  - **lepton identification $\rightarrow e\nu WZ$**

- **Plans for future**
  - **Track finding: TrackCheater $\rightarrow$ full LDC tracking**
  - **Different PFAs: Pandora PFA vs. Wolf PFA**
  - **Different detector models: LDC00Sc, LDC01Sc, LDC00 and LDC01**