Summary and Plans: Electroweak and alternative Theories

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WG conveners:

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Montpellier, ECFA LC Study, Nov 13-16, 2004

New LC notes since 2003 summer

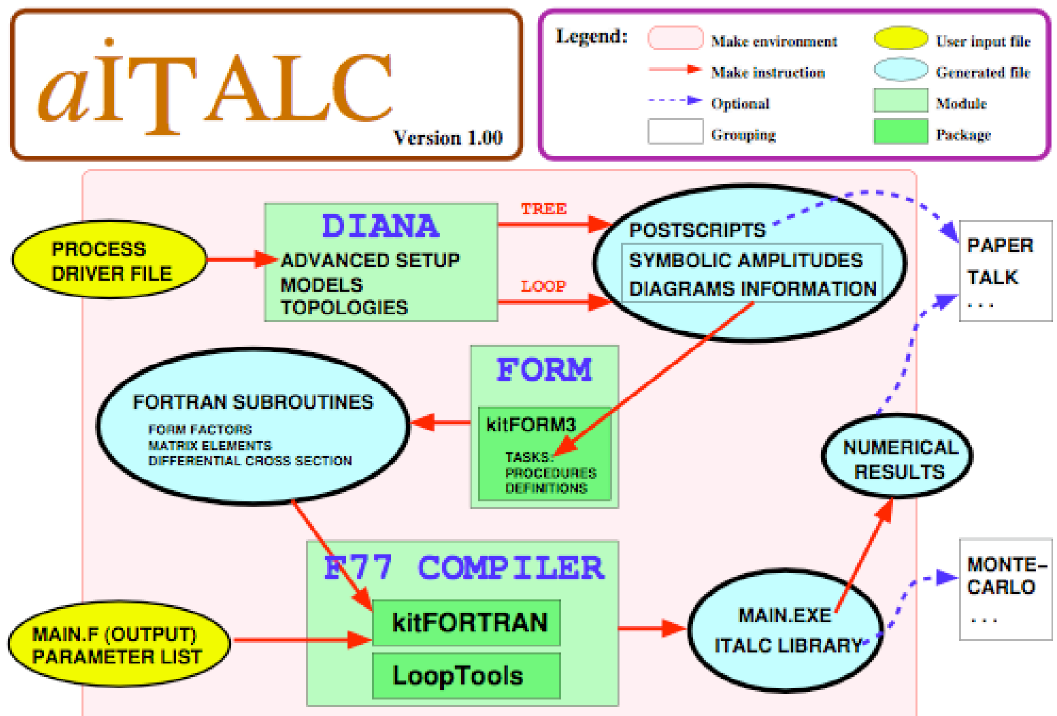
- I. Marfin, V. Mossolov, T. Shishkina: Anomalous quartic boson couplings via □□□ WW and □□□ WWZ at the TESLA kinematics
- K.Mönig, J.Sekaric: A Study of Charged Current Triple Gauge Couplings at e□collider
- O. Nachtmann, C. Schwanenberger: CP Violation in the 3 Jet and 4 Jet Decays of the Z-Boson at GigaZ
- M. Czakon, J. Gluza, J. Hejczyk: Tree and one-loop level tests of the minimal LR-symmetric model
- M. Diehl, O. Nachtmann, F. Nagel: Probing triple gauge couplings with transverse beam polarization in e^+e^- □ W^+W^-
- S. De Curtis: Electro-weak Fits at CLIC
- P. Osland, A.A. Pankov, N. Paver: Discriminating graviton exchange effects from other new physics scenarios in e^+e^- collision

Presentations in Montpellier

- Francois Richard: Benefits of an improved e^- polarization accuracy
- Jadranka Sekaric: TGCs from e□□ W□
- Felix Nagel: TGCs with transverse polarization
- Alejandro Lorca: Complete O(□) massive corrections to Bhabha scattering; automatization with aITALC
- Christian Schwanenberger: CP violation in 3- and 4-jet decays of the Z boson at GigaZ

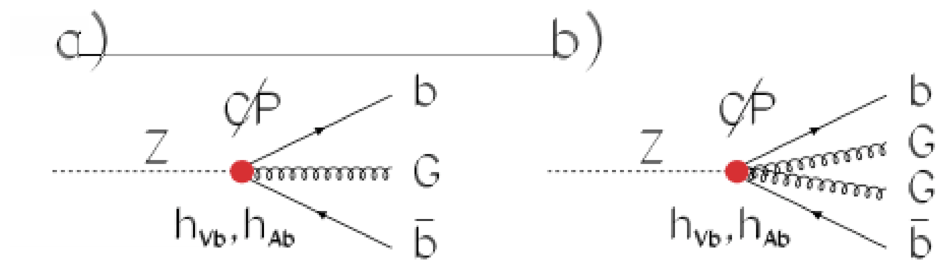
$O(\alpha)$ massive Bhabha scattering calculation with aITALC

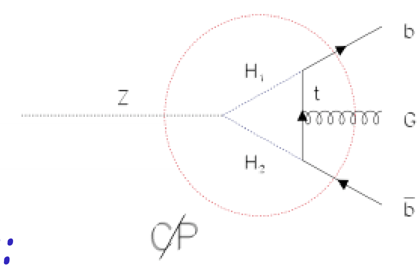
- *aITALC: automatic tool to compute $2 \to 2$ processes, planned launch 2004 February (A. Lorca, T. Riemann)*
- *Agreement with FeynArts + FormCalc + LoopTools calculation (T. Hahn) to 14 digits*
  ~double precision



CP violation in Z → 3, 4 jets

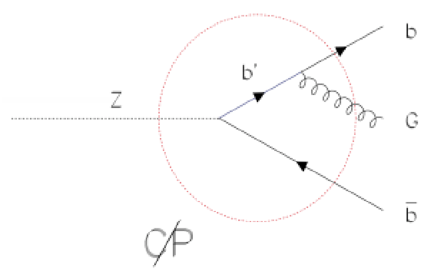
- ✘ *Search for CP-violating Zbbg and Zbbgg couplings using CP-odd vector and tensor observables constructed from the momentum vectors of the b and anti-b quarks*

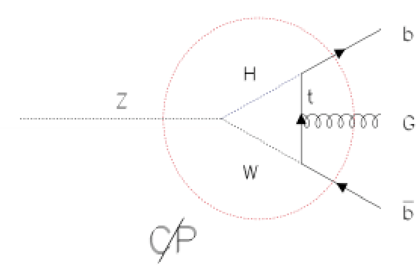




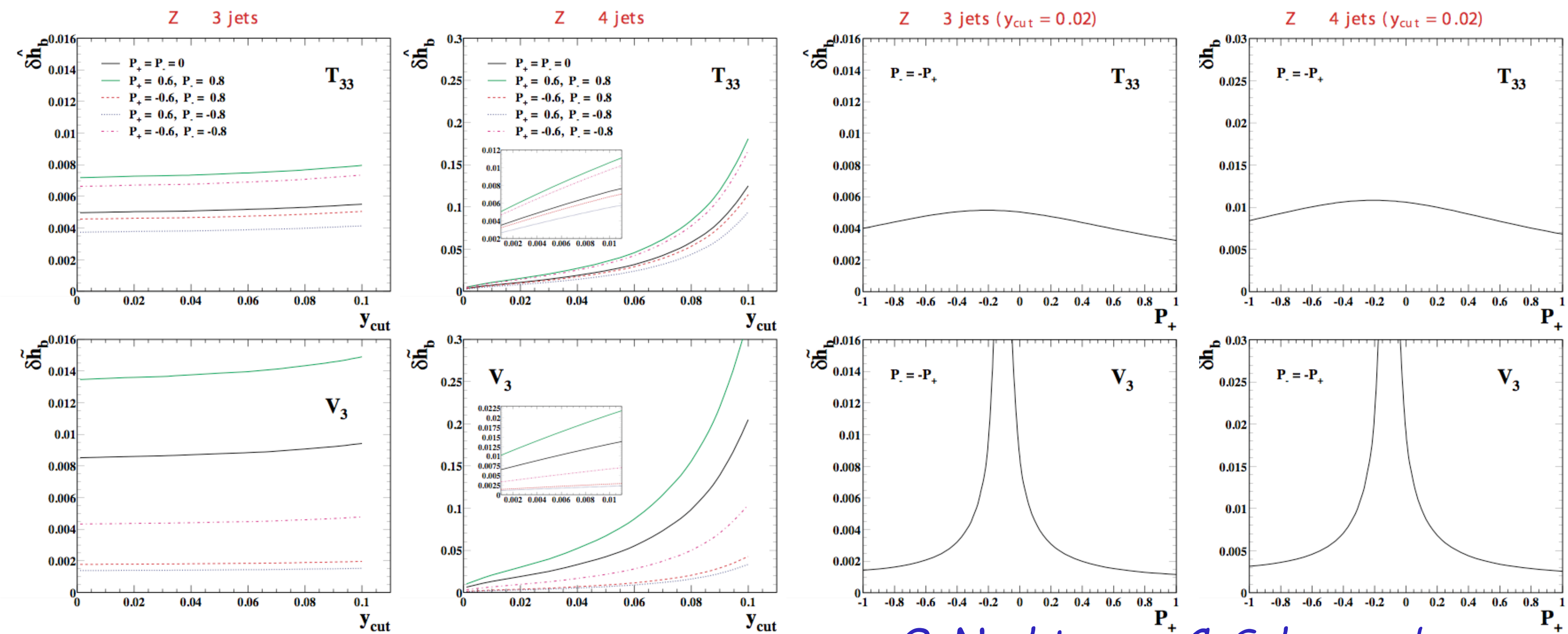
- ✘ *Sensitive to different new physics scenarios: excited b′ quarks, charged Higgs, …*

e.g. charged Higgs





CP violation in Z 3, 4 jets



O. Nachtmann, C. Schwanenberger

- GigaZ can increase sensitivity by a factor of 10 with respect to LEP
- Choice of polarization effects sensitivity greatly for vector observable
- Code for MC reweighting available for interested experimentalists

e^- polarization systematics

- Precision measurements limited by systematics on $P(e^-)$ using polarimeters dP~0.5% (SLC) $\to$ 0.25% $\to$?
- De-polarization effects of 0.2% @ 500 GeV
  - How well is it understood?
- If $P(e^+)$ also available, systematics on effective polarization is much reduced due to favorable error propagation
  - Need to know correlated time variations from polarimeters
- At GigaZ: Blondel scheme based on ee $\to$ ff with pure s-channel vector exchange
  - De-polarization accounted for
  - Automatically luminosity weighted
  - Assumed: only sign flips, absolute value of P remains the same, polarimeters needed for relative measurements
  - Need to know correlated time variations
  - Luminosity needs to be spent on less interesting polarization combinations

e^- polarization systematics

- *Blondel scheme can be used at high energy using ff with s=s' (5-2 pb at 350-500 GeV, A_{LR}~0.5) or radiative return ff□(17-7 pb, A_{LR}~0.2, need to reject Zee background: ~10% efficiency)*
- *W couples to L-handed e^-: WW, We□natural tools to measure P large forward peak in WW dominated by t-channel □exchange: A_{LR} in this region not sensitive to anomalous couplings*
- *Typically a factor 3-4 improvement w.r.t. polarimeter measurement*

K. Mönig, Snowmass 2001 proceedings (for 500 GeV errors a factor of   2 larger)

A_{LR} with s-channel vector exchange

□ suppression / enhancement for s-channel vector exchange

… for t-channel WW production

L=500 fb^{-1} E_{cm}=350 GeV	value	Rel. error [%]							
		$L_{\pm\pm}/L$ = 0.5			$L_{\pm\pm}/L$ = 0.1			Polarimeter	
		HE	ff	WW	HE	ff	WW	= 0	= 0.5
P_{e^-}/P_{e^-} [%]	0.8	0.10	0.51	0.07	0.21	1.11	0.11	0.25	0.25
P_{e^+}/P_{e^+} [%]	0.6	0.12	0.53	0.11	0.15	1.13	0.21	0.25	0.25
corr		ã 0.49	ã 0.91	0	ã 0.56	ã 0.93	ã 0.52	0	0.50
$(P_{e^-} + P_{e^+})/(1 + P_{e^-}P_{e^+})$	0.95	0.02	0.08	0.02	0.05	0.17	0.02	0.07	0.08
$P_{e^-}P_{e^+}$	0.48	0.11	0.22	0.13	0.18	0.42	0.18	0.35	0.43
$P_{e^-} + P_{e^+}$ ã $P_{e^-}P_{e^+}$	0.92	0.03	0.12	0.03	0.06	0.25	0.03	0.09	0.11

e^- polarization systematics

- *WW can also be used in the absence of $P(e^+)$ to recover sensitivity for A_{LR}*
- *F. Richard 's quick estimate for 1 ab^{-1} at 1 TeV:*
  gain of 14 on dP □ gain of 5 on A_{LR} accuracy (w.r.t. dP=0.5%) □
  discriminate between Z' models and measure Z' mass with <10% error up to 7 TeV (LHC: direct observation up to 5 TeV, identification up to 2 TeV)

Open questions:

- *No study at all for We□*
- *F.R.'s estimate does not take into account any detector effect*
- *K.M.'s WW study based on tree-level analytic calculation only*
- *Radiative corrections?*
- *New physics (e.g. KK towers…) can contribute*
  angular distribution can be used to estimate / handle this effect

Common interest with machine experts!

TGCs from ee→ WW

- *New phenomenological study using semi-leptonic WW*
- *Most general Lorentz invariant parametrization: 28 real parameters*
  7-7 γWW, ZWW couplings (4 CP conserving, 3 CP violating)
  $CP\tilde{T}$ symmetry: real and imaginary parts
- *In SM $g_1^\gamma=g_1^Z=\kappa_\gamma=\kappa_Z=1$, others=0*
- *Only loose constraints from LEP*
- *6 experimental observables: W production and decay angles*
- *Construct optimal observables to get highest statistical sensitivity*
- *4 symmetry classes of couplings (CP, $CP\tilde{T}$) with no correlation between classes*
- *Fit all 28 couplings simultaneously*

TGCs from $ee\to WW$

Errors in units of 10^{-3}

M. Diehl, O. Nachtmann, F. Nagel

CP conserving, real part	Δg_1^γ	Δg_1^Z	$\Delta\kappa_\gamma$	$\Delta\kappa_Z$	λ_γ	λ_Z	g_5^γ	g_5^Z
No polarization	6.5	5.2	1.3	1.4	2.3	1.8	4.4	3.3
$(P_l^-,P_l^+)=(\pm 80\%,0)$	3.2	2.6	0.61	0.58	1.1	0.86	2.2	1.7
$(P_l^-,P_l^+)=(\pm 80\%, \pm 60\%)$	1.9	1.6	0.40	0.36	0.62	0.50	1.4	1.1
$(P_t^-,P_t^+)=(80\%,60\%)$	2.8	2.4	0.69	0.82	0.69	0.55	2.5	1.9

Similar sensitivity for all classes (e.g. 0.36-2.5 with e^+,e^- polarization)

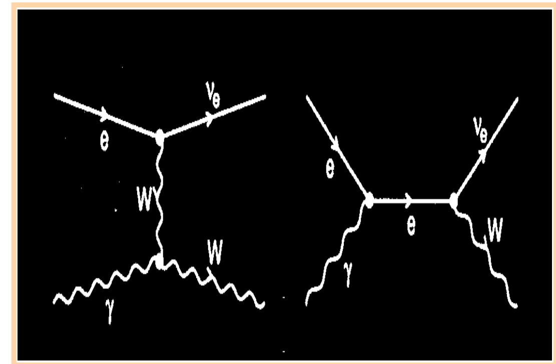
Large correlations $\Rightarrow$ use LR basis to reduce correlation

$h_+=Im(g_1^R+\kappa_R)/\sqrt{2}$ only measurable with transverse polarization!

- ✘ No polarization: 27 couplings measurable
- ✘ e^- polarization: factor 2 improvement on sensitivity
- ✘ e^-, e^+ polarization: factor 3-4 improvement
- ✘ Transverse polarization: factor 2-4 improvement, access to $Im(g_1^R+\kappa_R)/\sqrt{2}$

TGCs from $e\gamma \to W\nu$

- L-handed e, R-handed γ to suppress s-channel e exchange
- Pythia for event generation at 450 GeV
  SIMDET v3 for detector simulation
- Hadronic W decays only
- Real $e\gamma$ mode: main background $e\gamma \to eZ$, $(e)\gamma\gamma \to qq$
  Parasitic $e\gamma$ mode at $\gamma\gamma$ collider:
  new backgrounds $\gamma\gamma \to WW$ (semi-leptonic), $\gamma\gamma \to qq$
- High ~90% efficiency with 82% / 73% purity
- 3 kinematic variables: W polar angle, W decay polar & azimuthal angles
- WHIZARD ME to reweight distributions for TGCs
- Only κ_γ and λ_γ considered in the fit



TGCs from e□□ W□

Errors in units of 10^{-3}

K.Mönig, J.Sekaric

Real / Parasitic	□□$_□$			□$_□$		
dL	1%	0.1%	0%	1%	0.1%	0%
Generator level	3.3/3.4	1.0/1.0	0.4/0.4	0.29/0.31	0.27/0.29	0.27/0.29
Efficiency	3.4/3.5	1.0/1.0	0.5/0.5	0.33/0.34	0.30/0.32	0.30/0.32
Variable E_{beam}, WHIZARD	3.6/3.7	1.0/1.0	0.5/0.5	0.44/0.45	0.40/0.41	0.39/0.40
Background	3.6/3.7	1.0/1.0	0.5/0.5	0.44/0.45	0.40/0.41	0.39/0.40

Systematics (for dL=0.1%)

- ✘ 1% change in photon polarization at P=+90%: □$_□$~5□, □$_□$~1□ effect
- ✘ 50 MeV error on W mass: □$_□$, □$_□$~1□ effect
- ✘ Beam energy spectrum: no effect

Ongoing study of low energy □□ events (beam strahlung)

Remarks on charged TGCs

- □□□ WW phenomenological study on its way but using a different effective Lagrangian, will be difficult to compare with ee results
- Understand differences for non-polarized ee □ WW results between TDR spin-density matrix and new OO analyses (□□$_V$)
- Physics interpretation of measured anomalous couplings depends on process
  - ee □ WW sensitive to vector resonances
  - □□□ WW sensitive to scalar and tensor resonances
  - e□□ W□ no effect from close by resonances

need all information to understand the nature of new physics

Possible subjects for the group

Suggestions to initiate the discussion in Montpellier:

- *Definition of suitable pseudo-observables for W pair-production that allow to interpret published data within different models*
  - SUSY: WW production through chargino box… no TGC involved
  - Expectation from loop corrections ~ $3 \cdot 10^{-3}$ but sensitivity to ~10^{-4}: able to test SM in the same way as $\sin^2\theta_{eff}$ and m_W do now
- *A complete evaluation of Strong EWSB signals ($ee \to WW$, VVV, $VV\nu\nu$; $\gamma\gamma \to WW$, WWZ; $e\gamma \to W\nu$, $WZ\nu$, …). Which parameters can we extract with which accuracy?*
  - Interaction among gauge bosons given by gauge structure
  - Longitudinal gauge bosons connected to the EWSB mechanism: their interactions can teach us about this mechanism if there is no elementary Higgs
  - In strongly interacting theory longitudinal gauge bosons expected to have similar interactions to pions in QCD: expect to see effects from the dynamics of the new theory

Possible subjects for the group

- *Which signals can we expect from Little Higgs theories?*
  - *Z', W' , vector-like fermion states, new scalars*
  - *Direct detection is not very probable at LC look for indirect effects: contact interactions, TGCs*
- *Are we able to observe and analyze the unexpected (BBSM ~ Beyond 'traditional' BSM)?*
  - *Non-commutative QED? …*
- *ED theories*
  - *KK excitations, stringy effects, …*
  - *Radions (studied in the Higgs group)*
- *Tree vs. one-loop level*
  - *Recent study on minimal LR symmetric model (M. Czakon, J. Gluza, J. Heyczyk) shows that corrections from SM particles have a different structure from their SM counterpart: in fits it is not sufficient to use only tree-level couplings modified by SM radiative corrections… where does this happen in other models?*

Possible subjects for the group

- Lack of realistic experimental studies… especially on fermion-pair production: studies by experimentalists so far ~ phenomenological studies including some experimental systematics
- A lot to learn and give as input to the machine design
  Example: What precision do we really need on luminosity?
  - If decision on crossing angle, we need new mask design which has an influence on luminosity measurement
  - WW self-calibrating due to large forward peak but 2f sensitive… at what extent?
  - Can we use large angle Bhabha scattering? Effect of new physics…