Polarization at TESLA:
the Transverse Polarization Option

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Abstract: Some results concerning the transverse polarization are outlined.

References:

TRANSVERSE VERSUS LONGITUDINAL POLARIZATION EFFECTS IN $e^+e^- \to W^+W^-$. J. Fleischer, K. Kołodziej, F. Jegerlehner, Phys.Rev.D49:2174-2187,1994

EEWW: A GENERATOR FOR $e^+e^- \to W^+W^-$ INCLUDING ONE LOOP AND LEADING PHOTONIC TWO LOOP CORRECTIONS. J. Fleischer, F. Jegerlehner, K. Kołodziej, G. J. van Oldenborgh, Comput.Phys.Commun.85:29-39,1995, hep-ph/9405380

SEARCH FOR ANOMALOUS GAUGE BOSON COUPLINGS. F. Jegerlehner, Nucl.Phys.Proc.Suppl.37B:129-140,1994

Transverse polarization

Electron: polarization angle ϕ.
$\vec{P} = (P_T\ \cos\phi,\ P_T\ \sin\phi,\ P_L)$,

P_L **longitudinal polarization**

P_T **magnitude of transversal polarization**

Positron: $P \to P'$, $\phi \to \phi'$

$|\vec{P}| = ((P_T)^2 + (P_L)^2)^{1/2} \leq 1$
$|\vec{P}| = 1$ **for a pure state of complete polarization in a given direction**

For natural polarization in a storage ring we have $\vec{P}_\perp \parallel -\vec{H}$ **and** $\vec{P}'_\perp \parallel \vec{H}$ **such that** $\phi = \phi' = \frac{\pi}{2}$

ϕ_W: W^- **production angle**

Polarized square matrix element

In the limit $m_e \to 0$: only the amplitudes $M_- = M_{-+}$ and $M_+ = M_{+-}$ are non-zero

$$\Downarrow$$

$$\begin{aligned}\overline{|M|^2} \;\; &= \;\; \frac{1}{4}\Big[(1 - P_L P_L')\left(|M_+|^2 + |M_-|^2\right) + (P_L - P_L')\left(|M_+|^2 - |M_-|^2\right) \\ &\quad + \; (2\, P_T P_T')\left(\cos(2\phi_W)\ \mathrm{Re}(M_+ M_-^*) - \sin(2\phi_W)\ \mathrm{Im}(M_+ M_-^*)\right)\Big]\end{aligned}$$

Unpolarized beams

$\Rightarrow |M_-|^2 + |M_+|^2$ **via total cross section** σ

$$\frac{d\sigma}{d\cos\theta} = \frac{1}{2}\left(\frac{d\sigma_L}{d\cos\theta} + \frac{d\sigma_R}{d\cos\theta}\right) = \frac{\beta_W}{64\pi s}\left(|M_-|^2 + |M_+|^2\right) \quad ,$$

Longitudinally polarized beams

$\Rightarrow |M_-|^2 - |M_+|^2$ **via left-right asymmetry** A_{LR}

$$\frac{d(\sigma A_{LR})}{d\cos\theta} = \frac{1}{2}\left(\frac{d\sigma_L}{d\cos\theta} - \frac{d\sigma_R}{d\cos\theta}\right) = \frac{\beta_W}{64\pi s}\left(|M_-|^2 - |M_+|^2\right) \quad ,$$

Transversely polarized beams

$\Rightarrow \mathrm{Re}(M_+ M_-^*)$ **via azimuthal asymmetry** A_T

$$\frac{d(\sigma A_T)}{d\cos\theta} = \int_0^{2\pi} \frac{d^2\sigma}{d\cos\theta d\cos\phi}\cos 2\phi \; d\phi = \frac{\beta_W}{64\pi s}\, 2\mathbf{Re}(M_+ M_-^*) \quad .$$

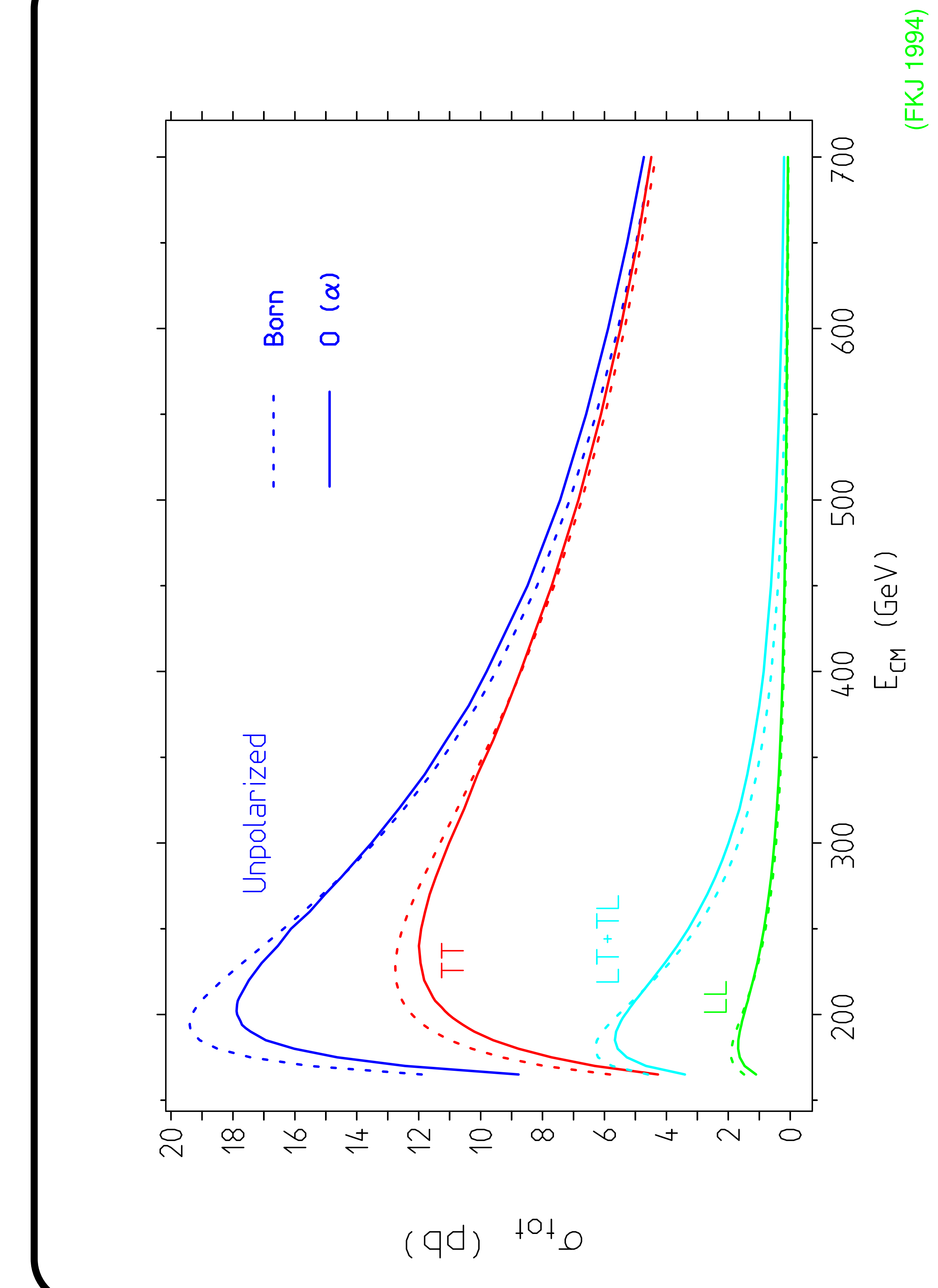
Here and in the following we denote $\phi \equiv \phi_W$**.**

Main feature of σA_T

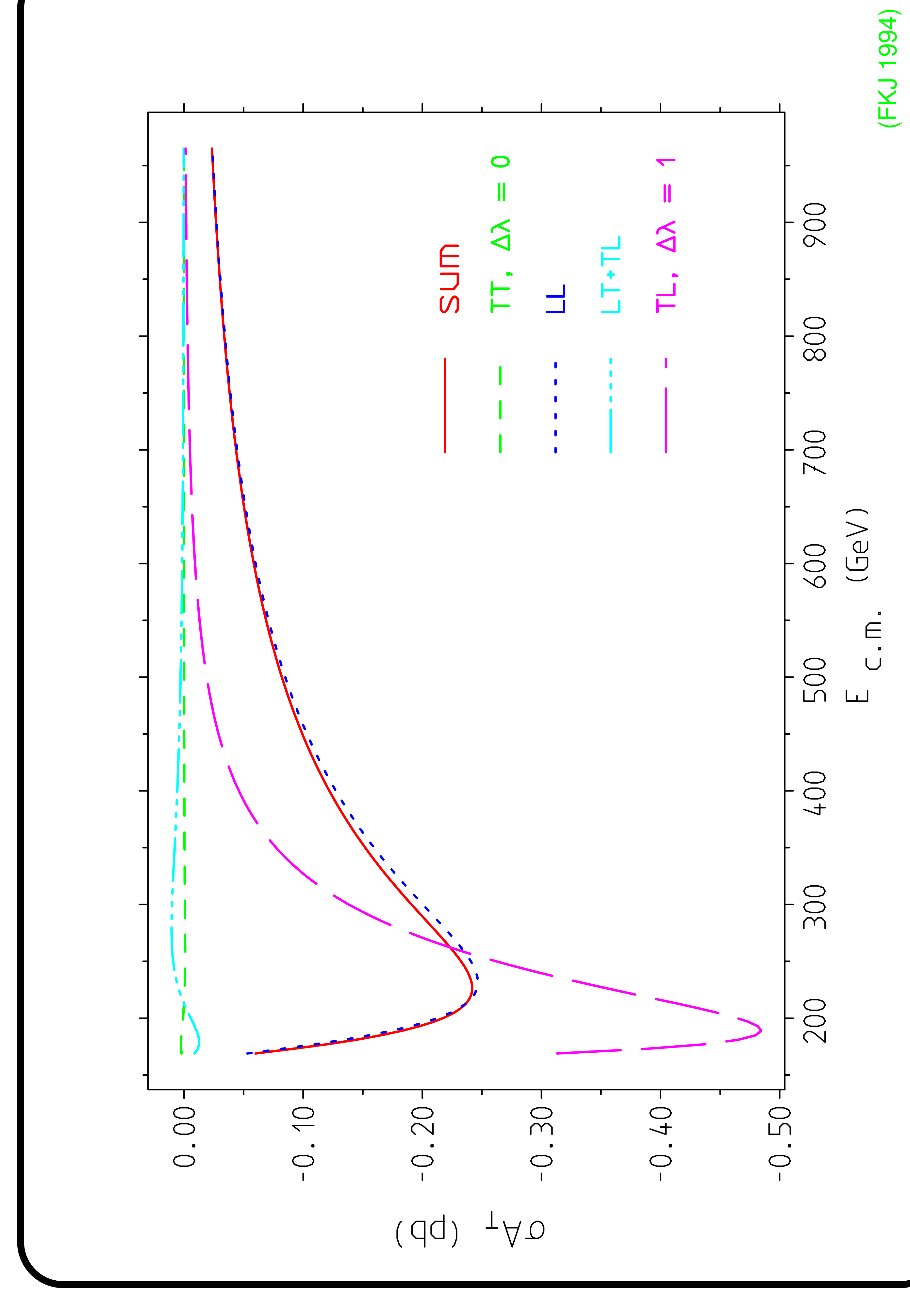
- **no TT $|\Delta\lambda| = 2$ final state contribution**
  as $M(+;\pm\mp) = 0$
- **!!! sum over final state spins: almost pure LL**
  (see Fig σA_T)
- **TL and LT large but cancel in sum**
- **rather small at 1% level**
  (size similar to σ_R; probe different physics)
- **note $\sigma A_{LR} \simeq \sigma_L/2 \simeq \sigma_{tot}^{\mathrm{unpol}}$**
  dominated by TT; probe different physics

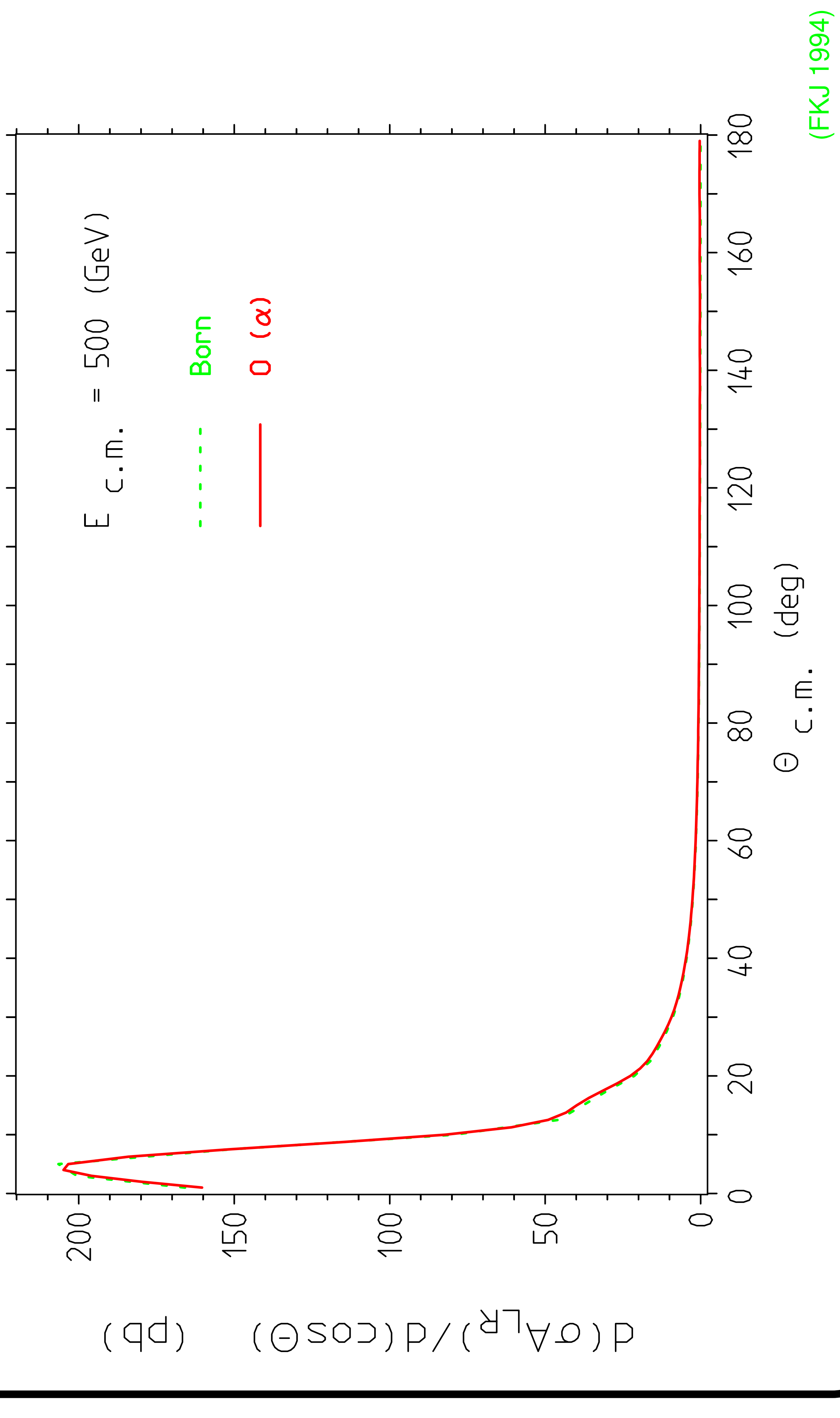
transversal polarization provides an important tool for investigation of $W_L W_L$ physics, probing electroweak symmetry breaking; clean, no background !

without transversal polarization: $W_L W_L$ is small contribution which can only be digged out be angular cutting (background problem).



Unpolarized
Born
O (α)
TT
LT+TL
LL
E_{CM} (GeV)
σ_{tot} (pb)
(FKJ 1994)


(FKJ 1994)
SUM
TT, Δλ = 0
LL
LT+TL
TL, Δλ = 1
E c.m. (GeV)
σA_T (pb)
200
300
400
500
600
700
800
900
0.00
-0.10
-0.20
-0.30
-0.40
-0.50


d(σ_LR)/d(cosΘ) (pb)
Θ c.m. (deg)
E c.m. = 500 (GeV)
Born
O (α)
(FKJ 1994)
0
50
100
150
200
0
20
40
60
80
100
120
140
160
180

HOW TO DISENTANGLE TRIPLE GAUGE COUPLINGS

The dependence of the cross section on the VWW form–factors shows up directly in the helicity amplitudes:

$$M(-;\lambda,\bar{\lambda}) = \sqrt{2}\beta_W \gamma^{2-|\lambda|-|\bar{\lambda}|}\, d^{J_0}_{\Delta\sigma,\Delta\lambda}(\theta)$$
$$\left\{ e^2\,(H_i^\gamma - \frac{H_i^Z}{1-M_Z^2/s}) + \frac{g^2}{2}\frac{H_i^Z}{1-M_Z^2/s} \right.$$
$$\left. - \quad \frac{\hat{M}_{T_1}(-;\lambda,\bar{\lambda})}{\beta_W}\,\frac{g^2}{\frac{1+\beta_W^2}{2}-\beta_W\cos\theta} \right\}$$
$$M(+;\lambda,\bar{\lambda}) = \sqrt{2}\beta_W \gamma^{2-|\lambda|-|\bar{\lambda}|}\, d^{J_0}_{\Delta\sigma,\Delta\lambda}(\theta)$$
$$\left\{ e^2\,(H_i^\gamma - \frac{H_i^Z}{1-M_Z^2/s}) \right\}$$

with the correspondence

amplitude	state	
H_l^V	LL	
H_0^V	TT	; $\Delta\lambda = 0$
H_{-1}^V	TL, LT	; $\Delta\lambda = -1$
H_{+1}^V	TL, LT	; $\Delta\lambda = +1$

Radiative corrections:

$$
\begin{aligned}
H_l^V &= (2+\gamma^{-2})A_1^V + 2A_2^V - \beta_W^2 A_3^V \\
H_0^V &= A_1^V \\
H_{-1}^V &= 2A_1^V + A_2^V + \beta_W A_4^V \\
H_{+1}^V &= 2A_1^V + A_2^V - \beta_W A_4^V \quad .
\end{aligned}
$$

With A_i^V vertex corrctions ($V=\gamma,\ Z$).

Anomalous couplings:

$$
\begin{aligned}
H_l^V &= 2\{(1+\tfrac{2M_W^2}{s})\delta_V + \delta\kappa_V + (1-\tfrac{M_W^2}{s})\lambda_V\} \\
H_0^V &= \delta g_V + \tfrac{s}{2\Lambda^2}\lambda_V \\
H_\mp^V &= 2\delta_V + \delta\kappa_V + \lambda_V \mp \beta_W \tfrac{s}{\Lambda^2}\xi_V \quad .
\end{aligned}
$$