TGC in WW events

Christoph Burgard
Silke Petzold

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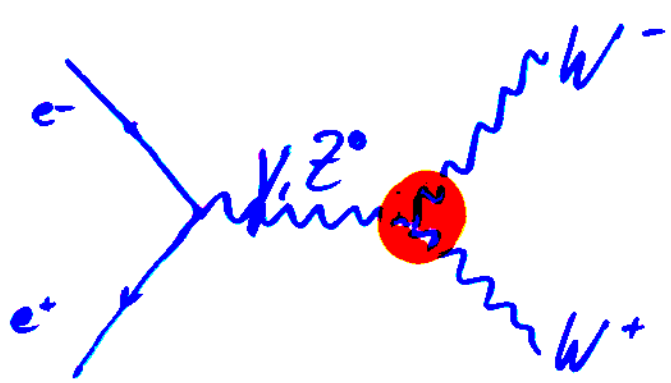
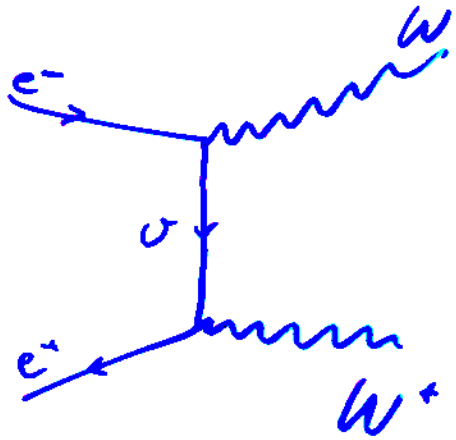
- Status of studies on detector, ISR & beam-strahlung effects

- WWγ vs. WWZ with polarized beams

useful cross-checks from the work of Reso Shanidze

Measurement of TGC (in WW)

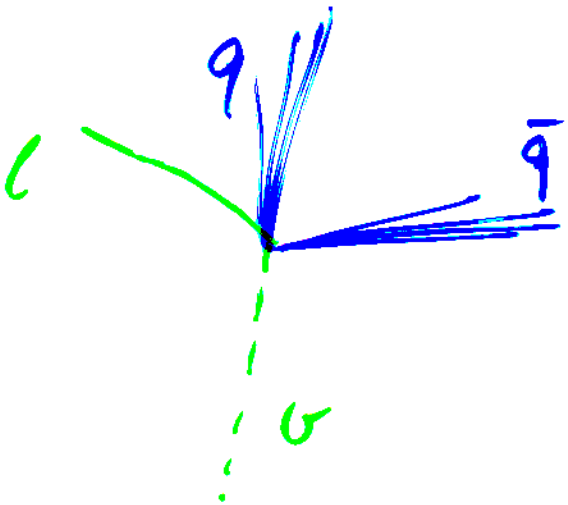




- total cross-section
- W production angle $\cos\Theta_W$
- polarisation of the W boson → use W-decay as polarisation analyser

{ for example: $(\tau_-\tau_+) = (-+), (+-)$ possible in t-channel only

Golden Channel : $WW \to qq\ell\nu$



→ best reconstruction of 5 angles

→ W production angle $\cos\theta_W$

→ W decay angles θ^*, ϕ^*
(in W restframe)

of leptonically decaying W: $\cos\theta^*_\ell$, ϕ^*_ℓ

" hadronically " " : $(\cos\theta^*_q)^{folded}$, $(\phi^*_q)^{folded}$

Status @ Tracod:

Measurement of the $WW(Z/\gamma)$ Couplings in $WW \to qq\ell\nu$ events with the Spin Density Matrix Method

Fits on generator level

use WW (CC03) events only !

Results so far: for example

Fit to 500 fb^{-1} @ 500 GeV

$\sigma(\Delta\kappa_\gamma) = 2.5 \cdot 10^{-4}$

$\cos\Theta_W$ only: $\sigma(\Delta\kappa_\gamma) = 3.4 \cdot 10^{-4}$
lepton. decay: $\sigma(\,\cdot\,) = 5.1 \cdot 10^{-4}$
+ had. decay + total X-sec

+ first estimates of detector effects ...
(angle resolution etc)

systematics

statistical error

$\mathcal{O}(10^{-4})$

compared to LEP2

/ 10 from greater sensitivity $\leq$ 500 GeV

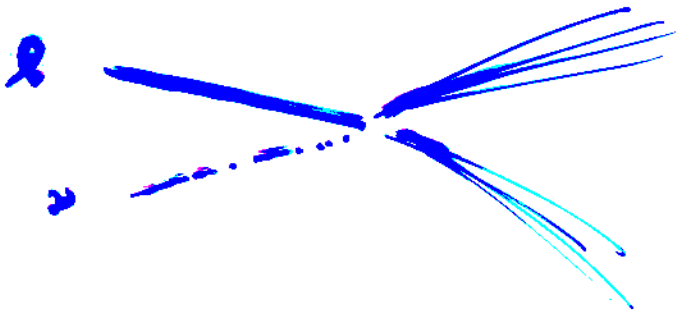
/ $\sqrt{1000}$ from greater lumi

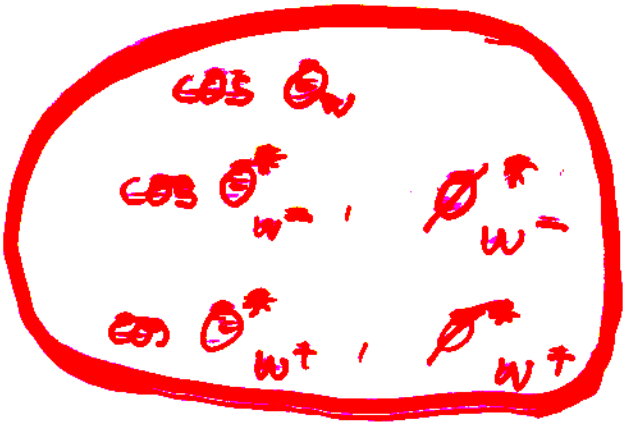
systematic errors need to be reduced by factor ~10 compared to LEP2

important ones:

- jet/ angular resolution, detector effects
- ISR / beam-strahlung
- event selection
- generators

Detector Effects





- jetfinding: force to 2 jets ($\neg \ell$)
- kinematics:

"measured" $\vec{p}_\nu = \vec{\not{p}}_{missing}$

OR

"kinematic fit"

3 missing dof (ν)

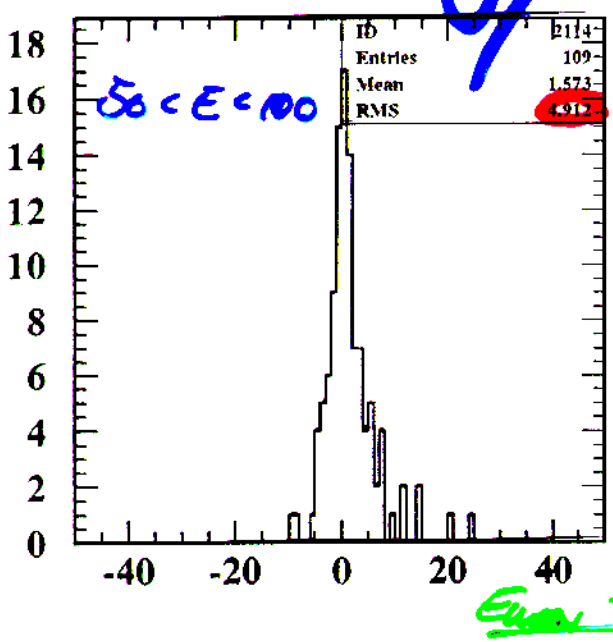
4 constraints $\vec{\not{p}} = 0$, $E = \sqrt{s}$

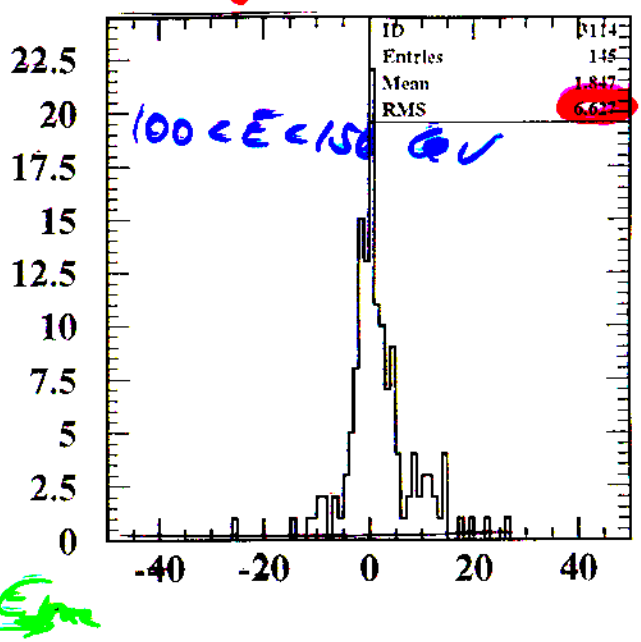
(or 6 for $M_W = M_{jj} = M_{\ell\nu}$)

$\Rightarrow$ need error parametrisation

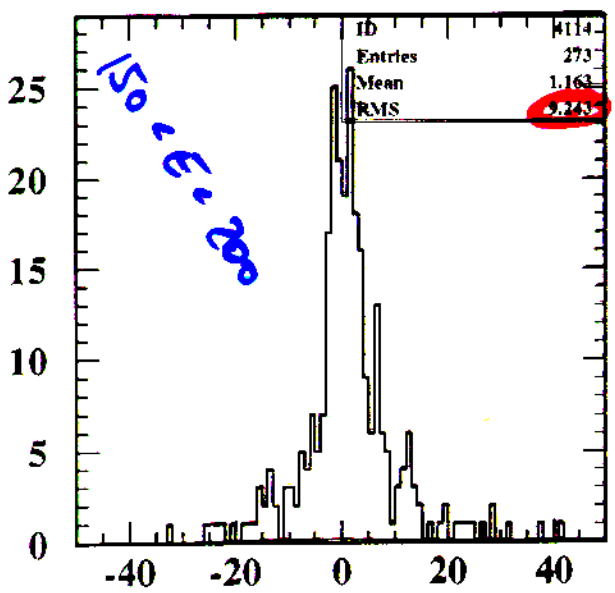
ERROR - PARAMETRISATION

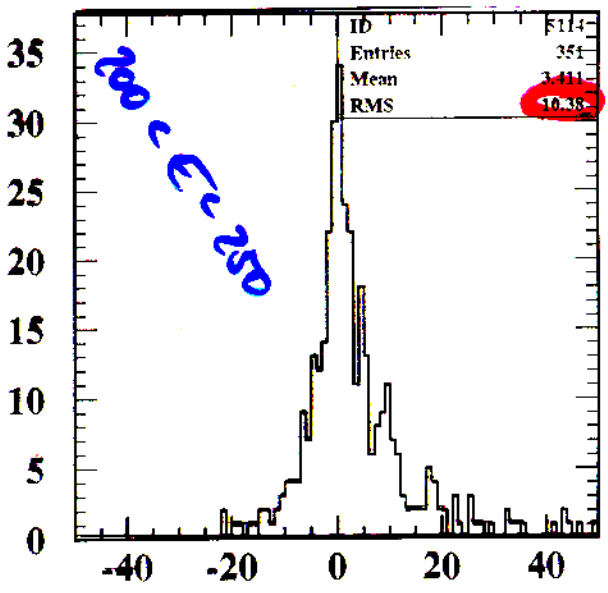
Energy (JETS)





$E_{meas} - E_{true}$





$E_{meas} - E_{true}$

$$\sigma_E = 0.25 \cdot E^{0.7}$$

$$\sigma_{\cos\theta} = 0.3 \cdot \sin\theta / E$$

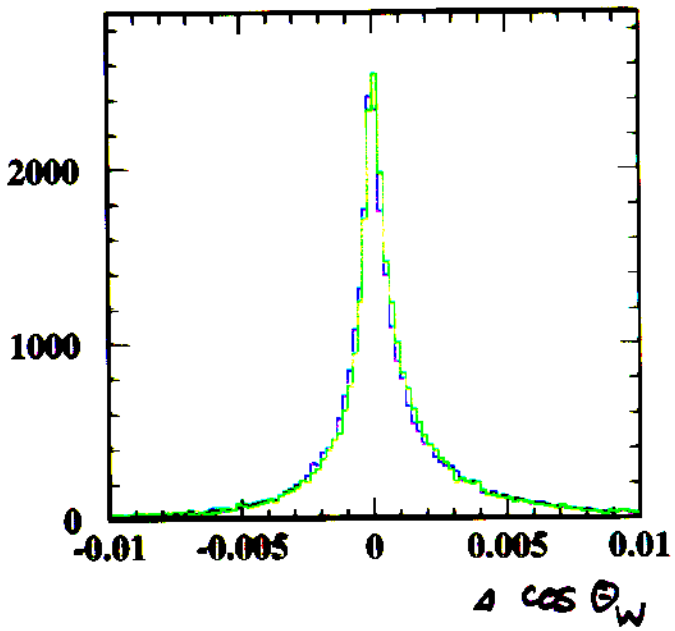
$$\sigma_\phi = 1.1 / \sin\theta \cdot E$$

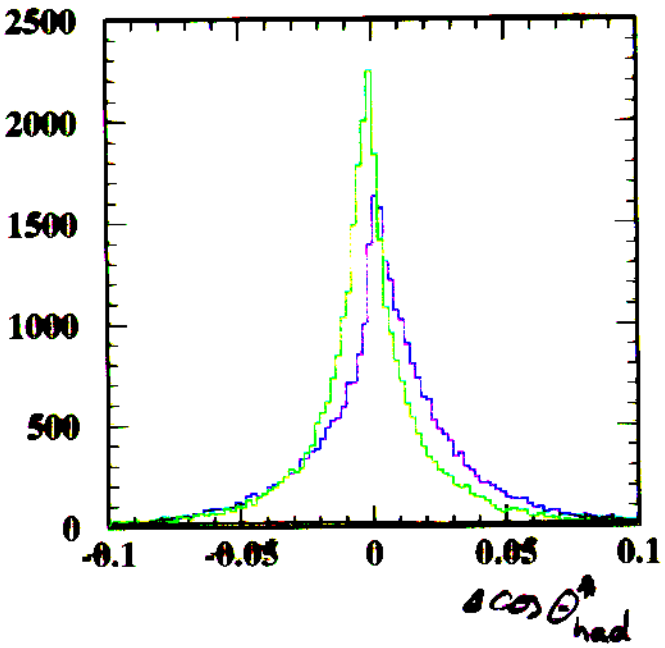
without ISR, beam-strahlung

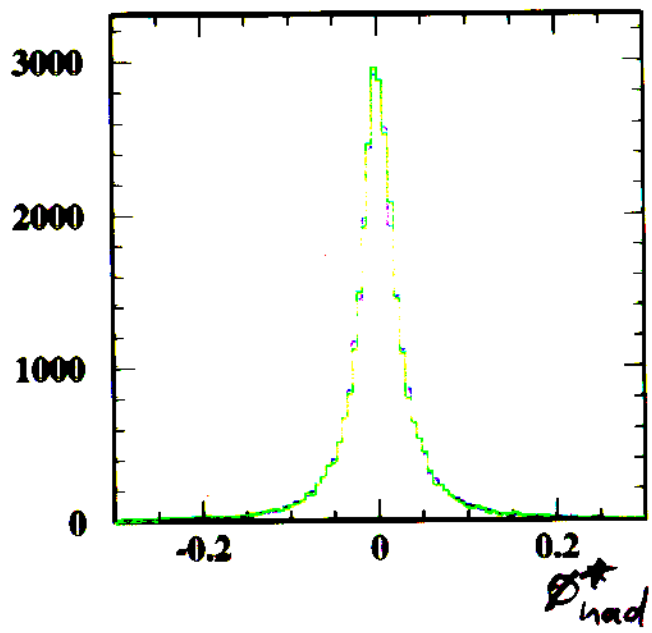
RESOLUTIONS

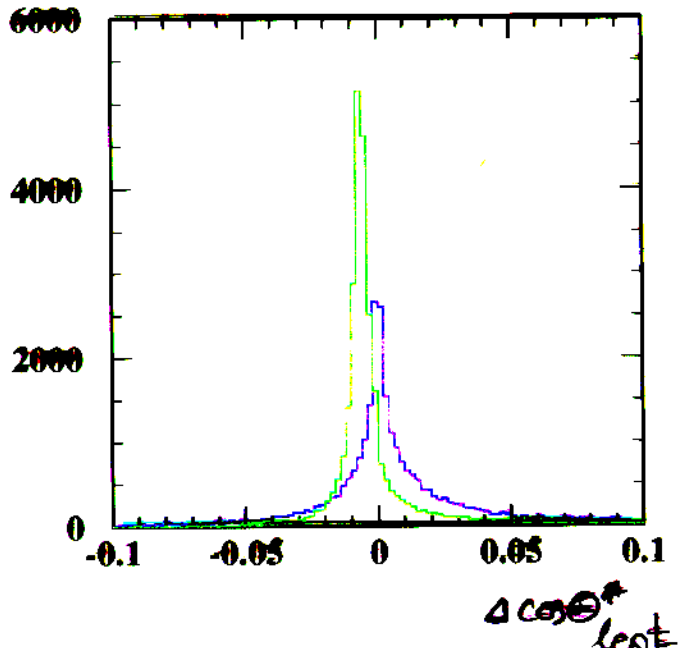
Z measured

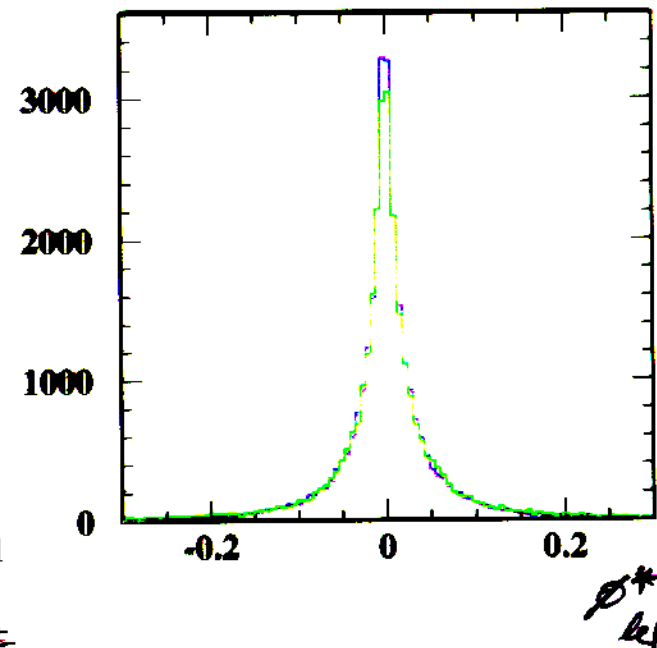
Z 1c kinematic fit

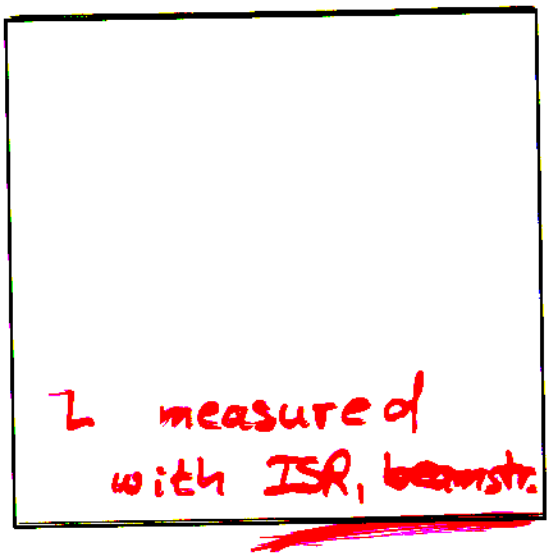


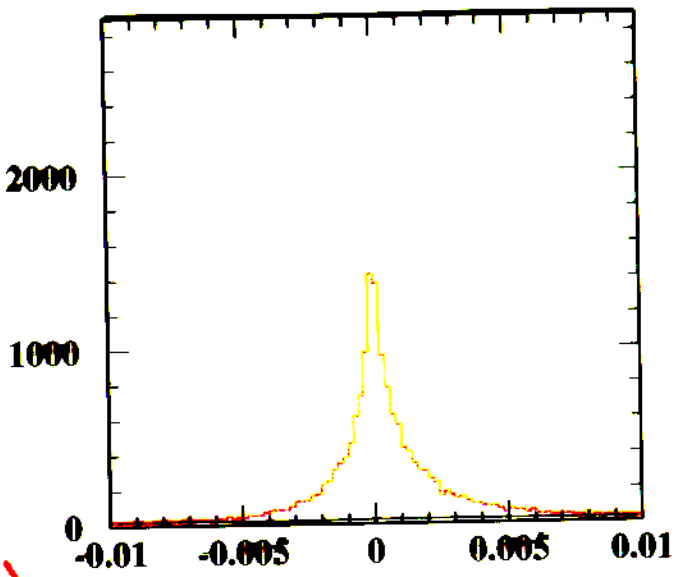


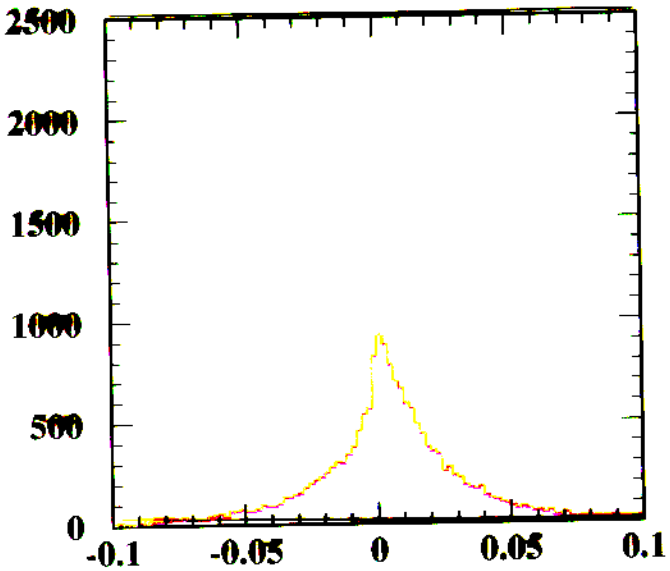


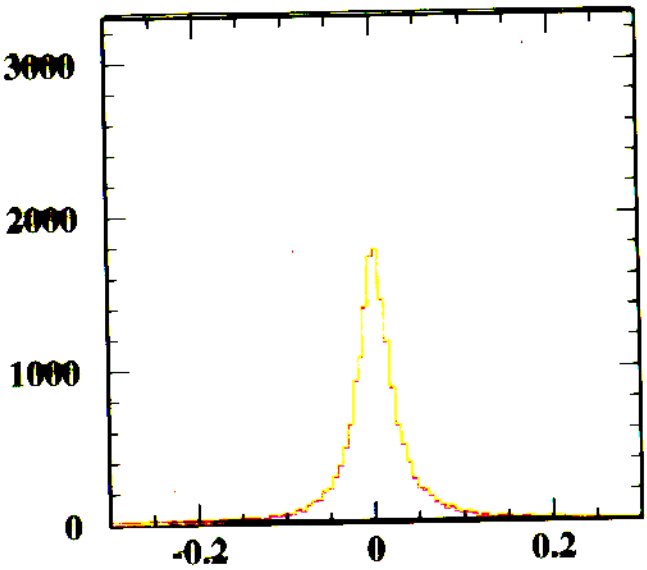


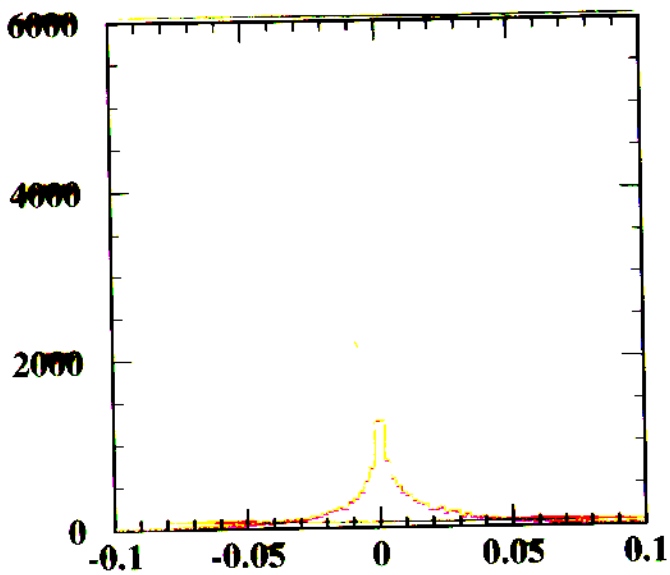


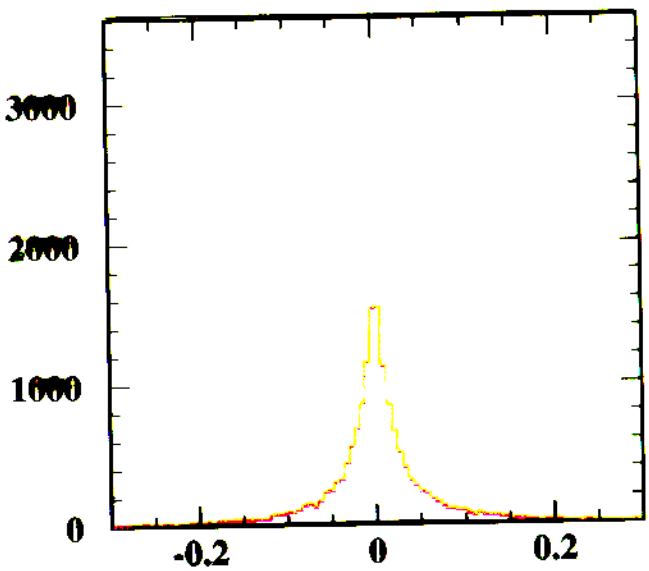

L measured
with ISR, beamstr.
(from Pythia & Circe)


2000
1000
0
-0.01
-0.005
0
0.005
0.01


2500
2000
1500
1000
500
0
-0.1
-0.05
0
0.05
0.1


3000
2000
1000
0
-0.2
0
0.2

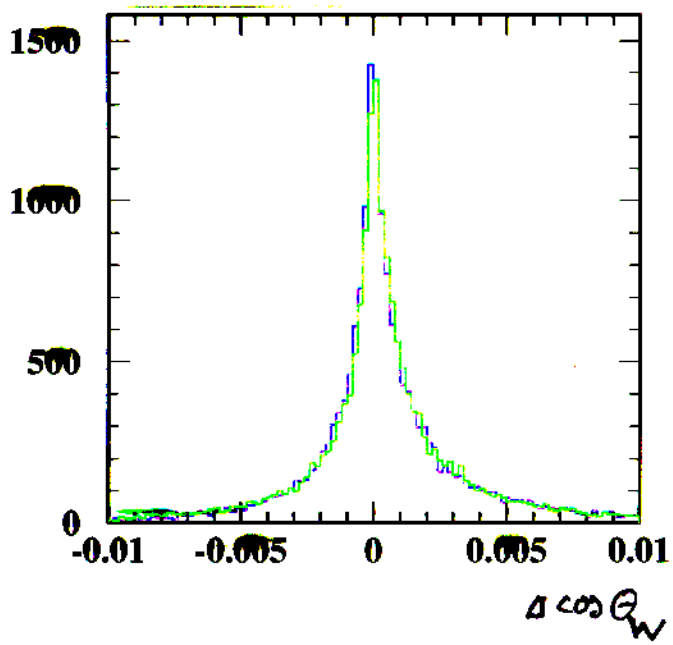

6000
4000
2000
0
-0.1
-0.05
0
0.05
0.1

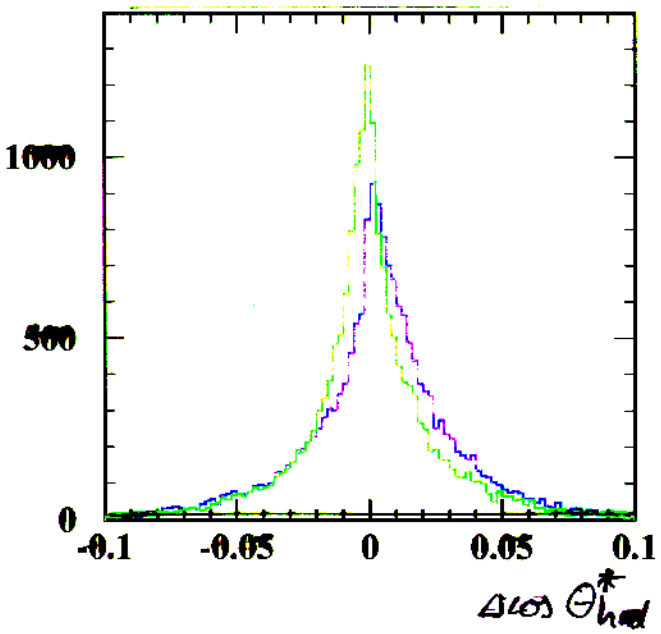

3000
2000
1000
0
-0.2
0
0.2

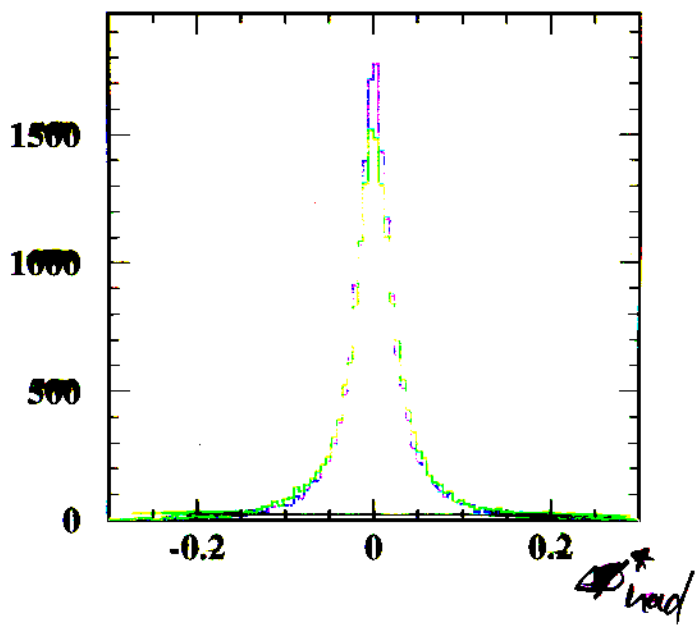
with ISR, ~~beam~~ strahlung

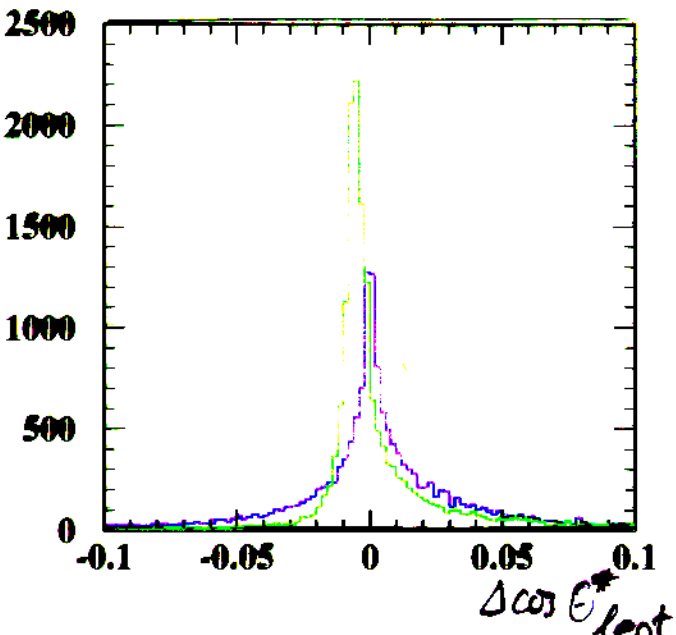
RESOLUTIONS

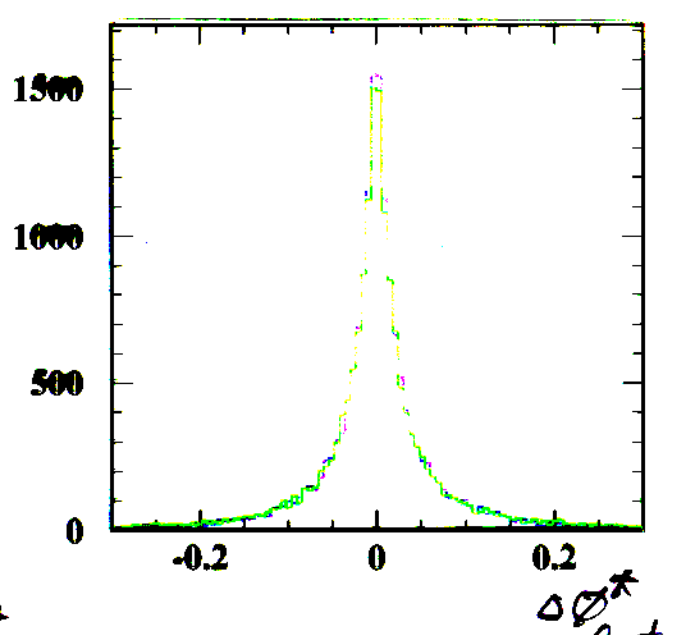
- measured
- 1C kinematic fit ($\vec{p}=0$, $E=\sqrt{s}$)











Detector, ISR & ~~beam~~-Strahlung

Effect on fit errors :

	$\sigma_{\mathcal{A}_{FB}}$
generator level	$3.52 \cdot 10^{-4}$
"measured" ($\bar{P}_e = \bar{P}_{min}$)	$3.54 \cdot 10^{-4}$
kinematic fit	$3.55 \cdot 10^{-4}$

⇒ no large effects on TGC measurement

- need to study that a bit more for various anomal. couplings

TGC ($WW\gamma$ / WWZ) @ LC

$e^+e^- \to W^+W^-$:

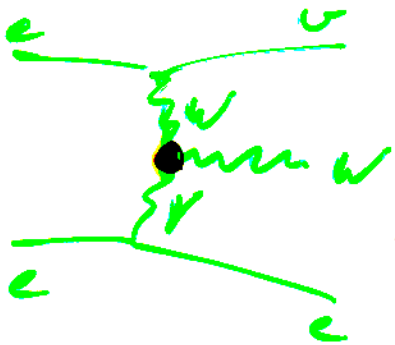
both ($WW\gamma$ and WWZ) couplings

@ LEP 2: measure one coupling parameter

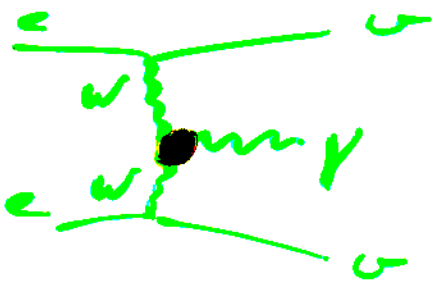
assume gauge invariance to assign them to $\begin{cases} WW\gamma \\ WWZ \end{cases}$

How to disentangle WWZ / WWγ

- alternative reactions :

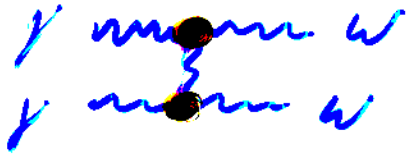


Single W



νWγ

- γ collisions :

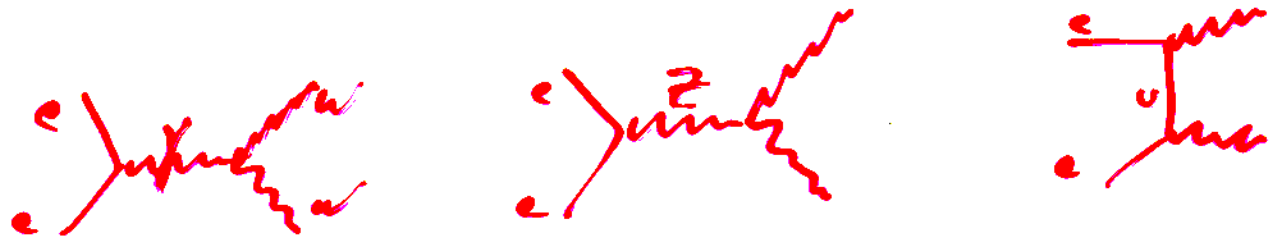


γγ

eγ

... disentangle $WW\gamma$ / WWZ ...

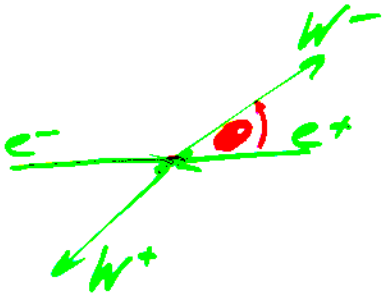
- polarised beams

e^-_L 

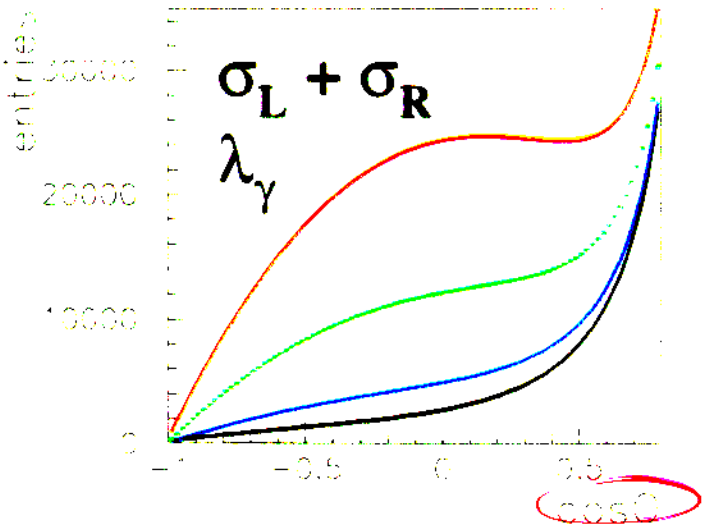
e^-_R 

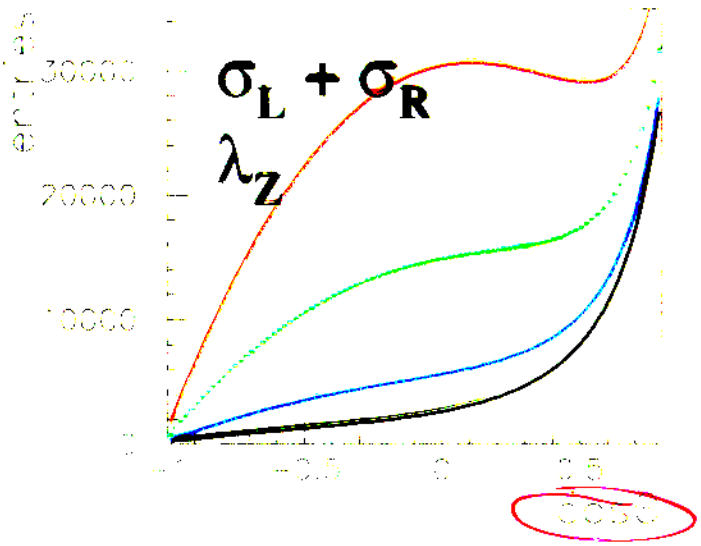
→ Difference $(e^-_L - e^-_R)$: γ cancels (... some interference eff.
→ measure WWZ only

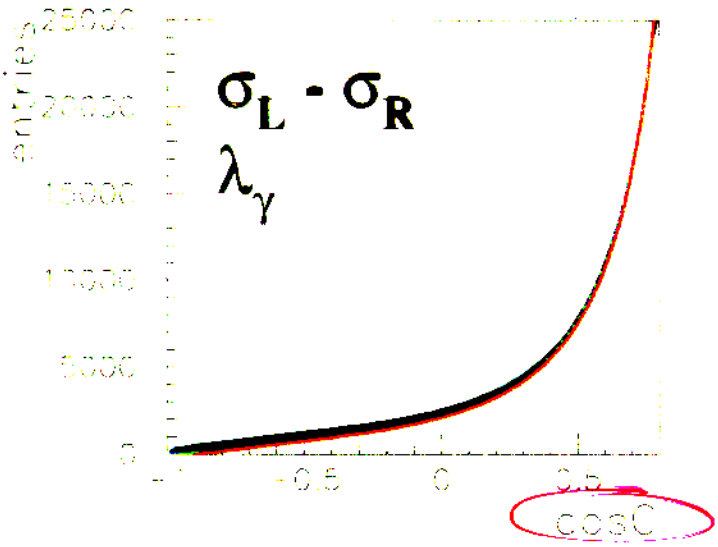
... to illustrate ...

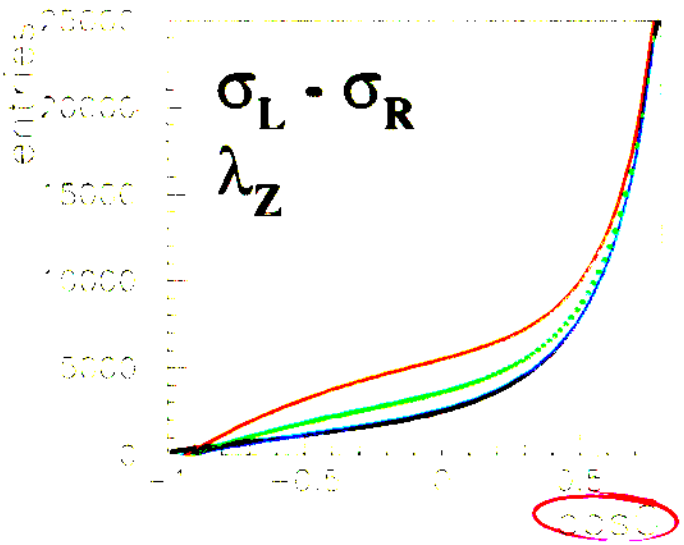


$\lambda_{\gamma/Z} = 0,\ 0.1,\ 0.2,\ 0.3$







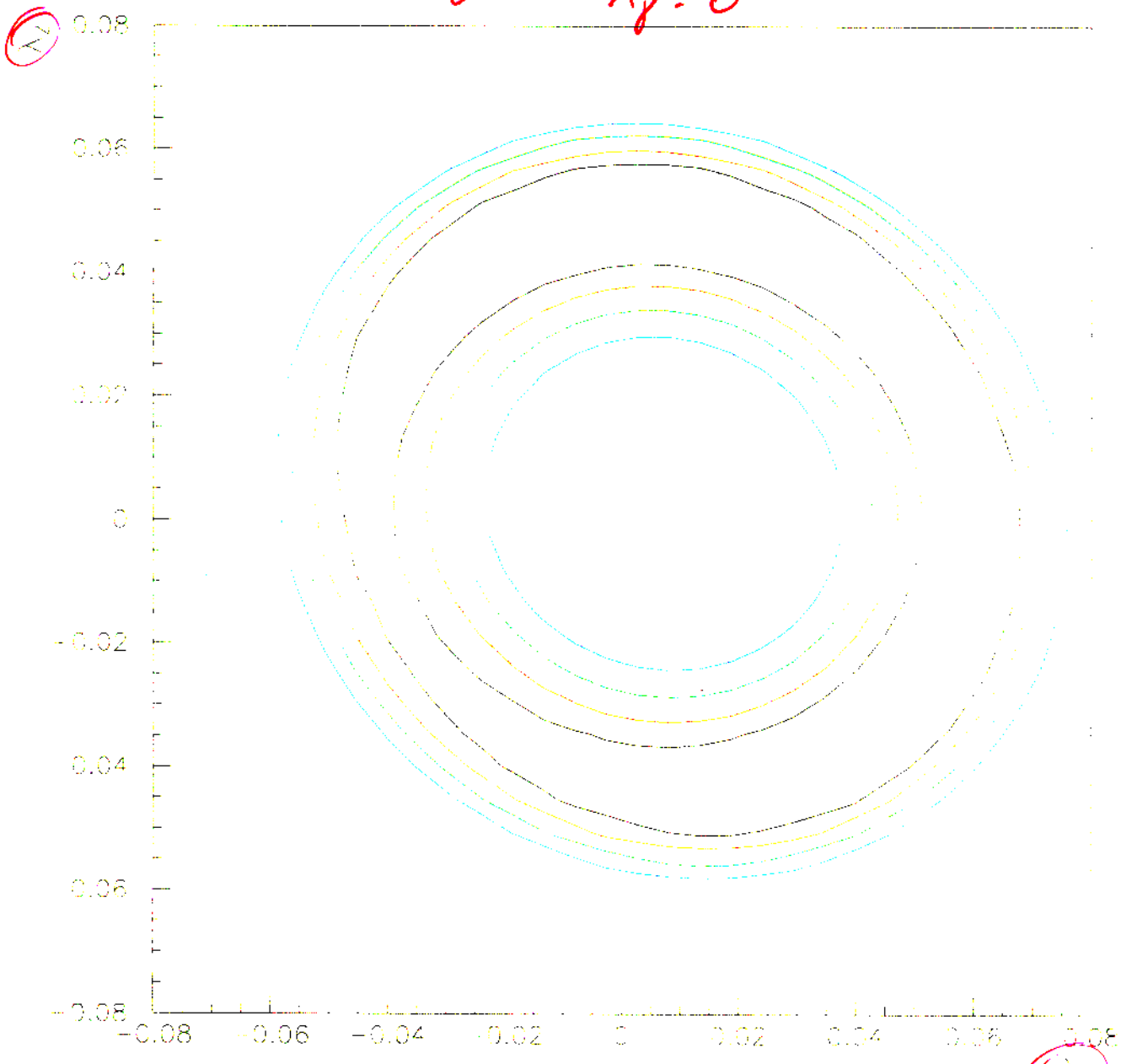


† statistical errors expected for 500 fb^{-1} @ 500 GeV

Fit TGC with unpolarised beams

@ 500 GeV (Born level), $\int \mathcal{L} = 500\ fb^{-1}$

anomalous coupling: $\lambda_z = 0.05$
$\lambda_\gamma = 0$



— $\chi^2 = 100$
— $\chi^2 = 400$
— $\chi^2 = 900$
— $\chi^2 = 1600$

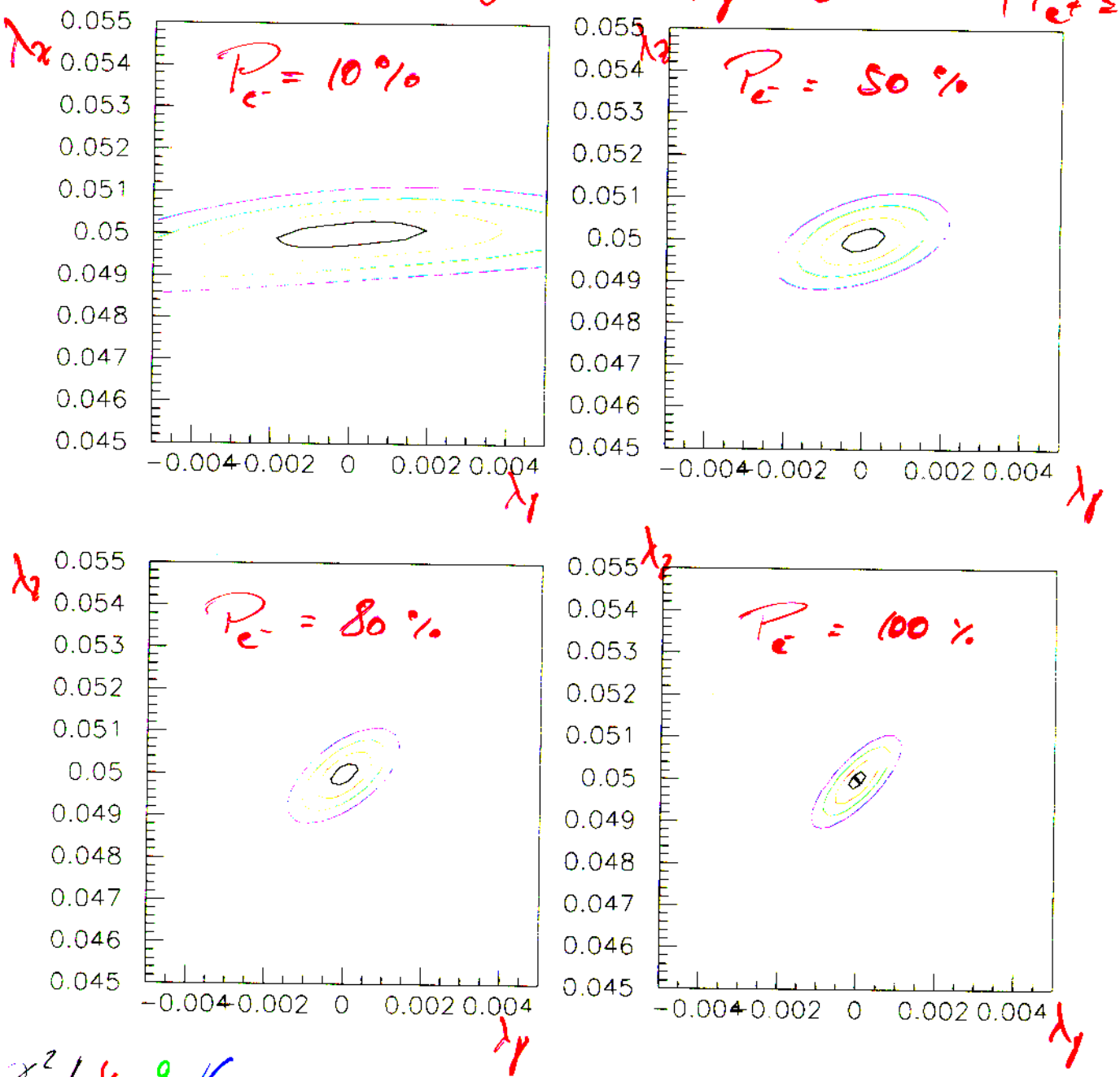
Fit to W production angle only !

⇒ cannot distinguish λ_z / λ_γ

Fit TGC with polarised e⁻ beam @ 500 GeV

$\int \mathcal{L} = 2.5\,\text{fb}^{-1}$ with e^-_L
$\int \mathcal{L} = 250\,\text{fb}^{-1}$ with e^-_R

anomalous couplings: $\lambda_z = 0.05$, $\lambda_\gamma = 0$ ($P_{e^+} = 0$)



$\chi^2 = 1, 4, 9, 16$

clearly distinguish λ_z and λ_γ

Summary WWγ ↔ WWZ

- Polarisation allows to disentangle WWγ/WWZ
  - → confirmed with generator level study
  - → working on implementation of polarisation into WHIZARD → detector level

- One polarised beam would be enough (statistical losses with two polarised beams)

- not studied how good TGC measurement in γγ collider would be, but

- γγ option not mandatory to disentangle WWγ/WWZ couplings

  .. but would be nice to have additional statistics & alternative reactions..

Conclusions

- stat. errors on anomalous couplings
  $\mathcal{O}$(few. 10^{-4})
  - main contribution from $\cos\theta_W$ ↑ well measured due to W boost
  - syst. errors from detector, ISR, beam-strahlung look controlable (study that for CP couplings)

- WWγ ⇔ WWZ anomalous couplings can be disentangled with polarized beams