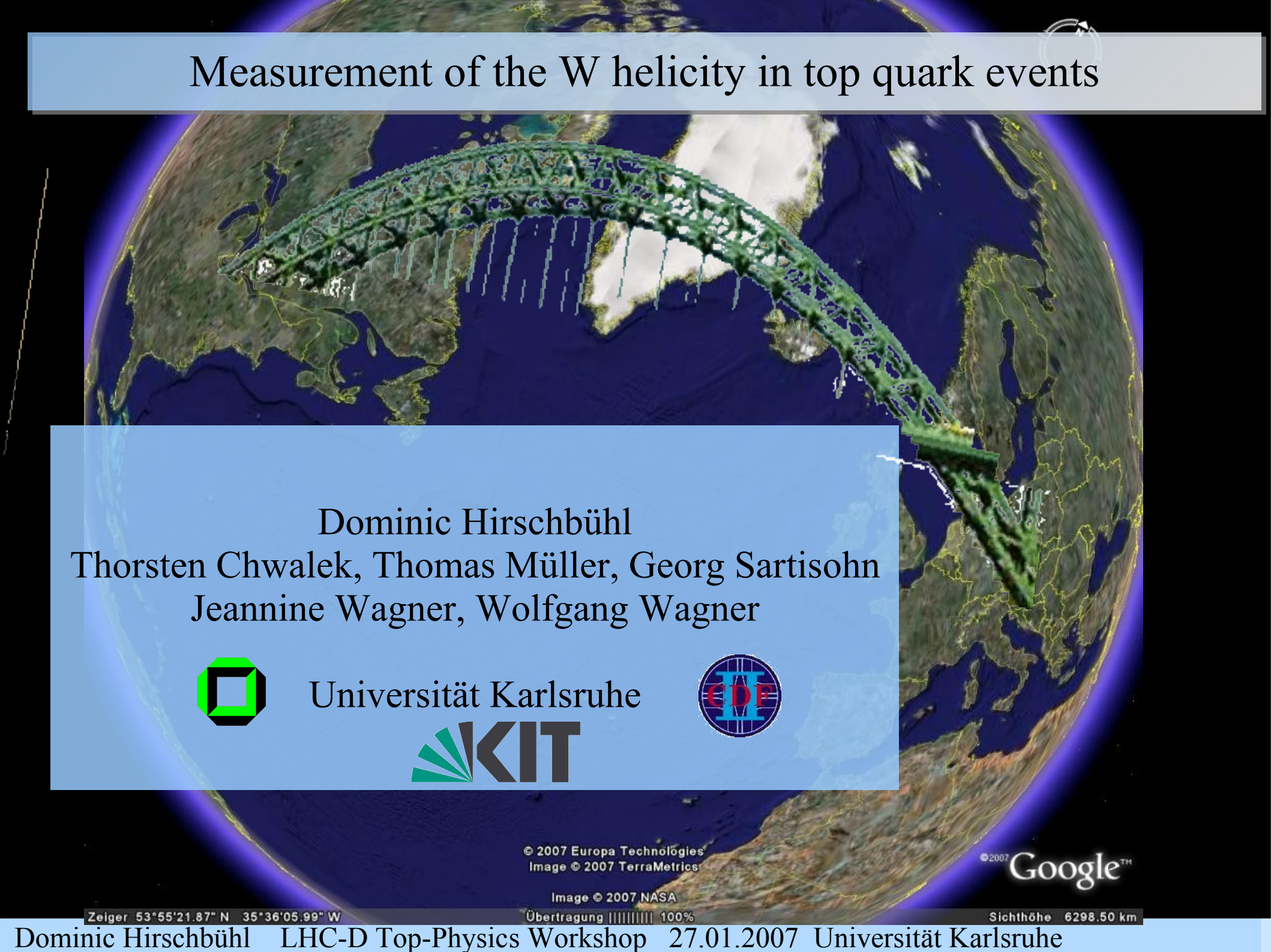
Measurement of the W helicity in top quark events



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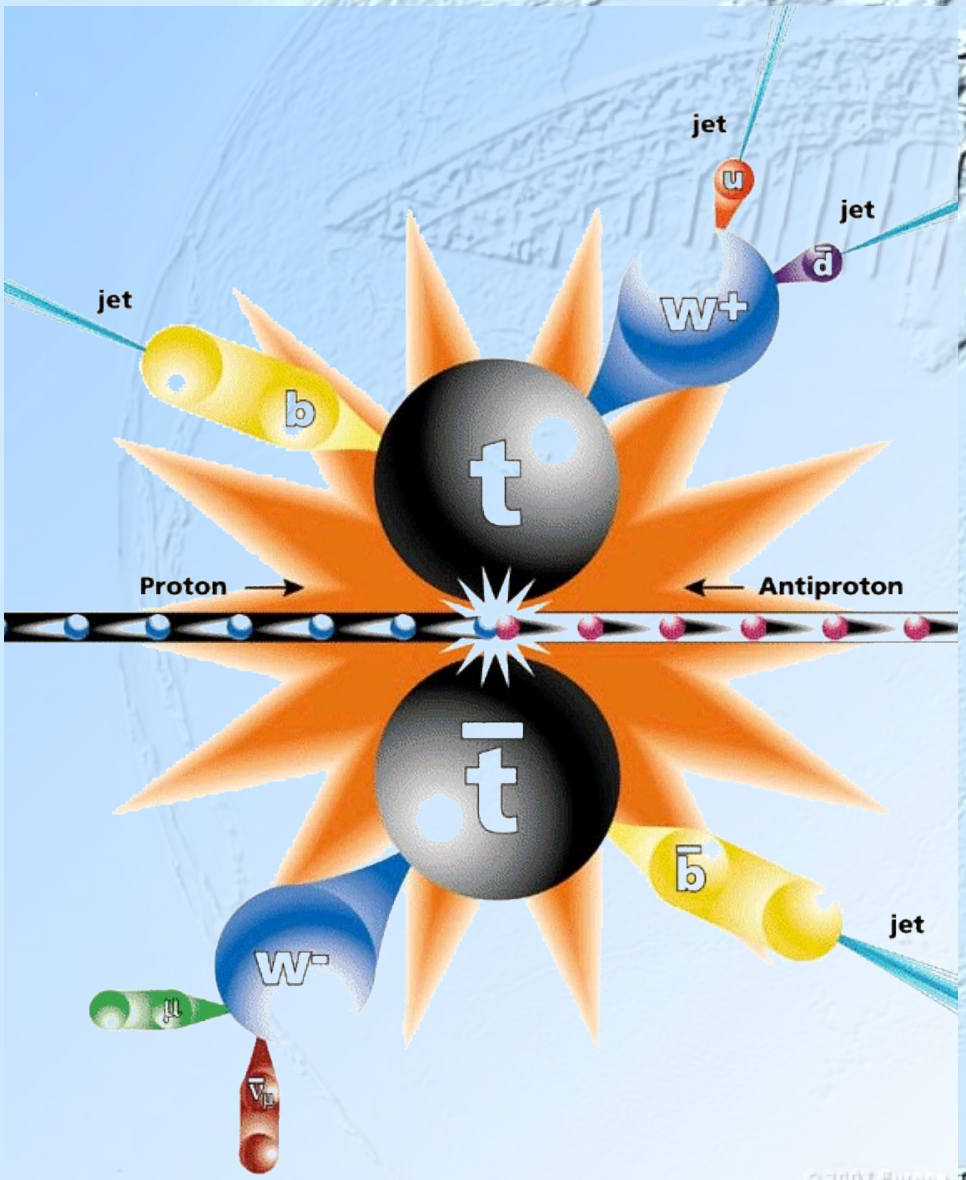
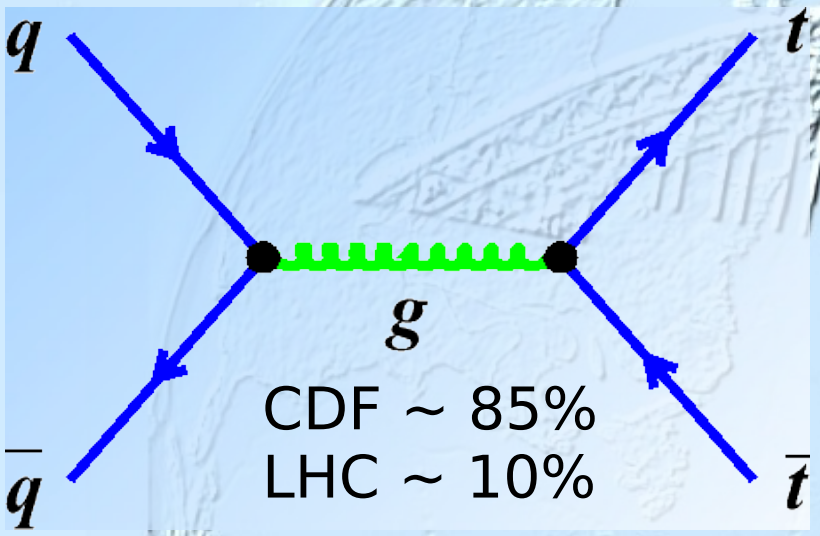
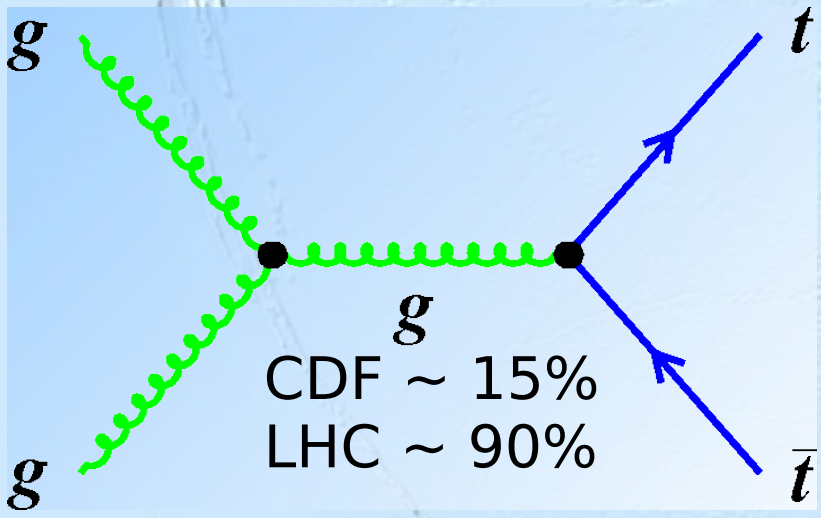
Motivation



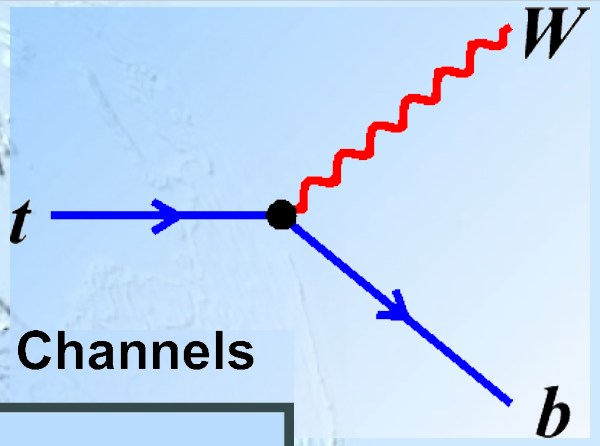
- Top quark discovered in 1995 at CDF & D0
- Top quark mass known with a precision of ~1.5%
- Other properties not know with high precision:
  - lifetime
  - charge
  - tWb – Vertex
- Still enough room for new physics.

Top Quark Pair Production





Top Quark do not hadronize
→ decay almost into W and b quark



Top Pair Decay Channels

W decay	e^+	μ^+	τ^+	$u\bar{d}$	$c\bar{s}$
e^-	ee	eμ	eτ	electron+jets	
μ^-	eμ	μμ	μτ	muon+jets	
τ^-	eτ	μτ	ττ	tau+jets	
$\bar{u}d$	electron+jets	muon+jets	tau+jets	all-hadronic	
$\bar{c}s$					

dileptons

Choose lepton + jets channel:
- ~ 30% BR and moderate background
- need lepton to analyze top decay

Helicity of W bosons in top quark decays

$$\text{Helicity}: h = \frac{\sigma \cdot p}{|p|}$$

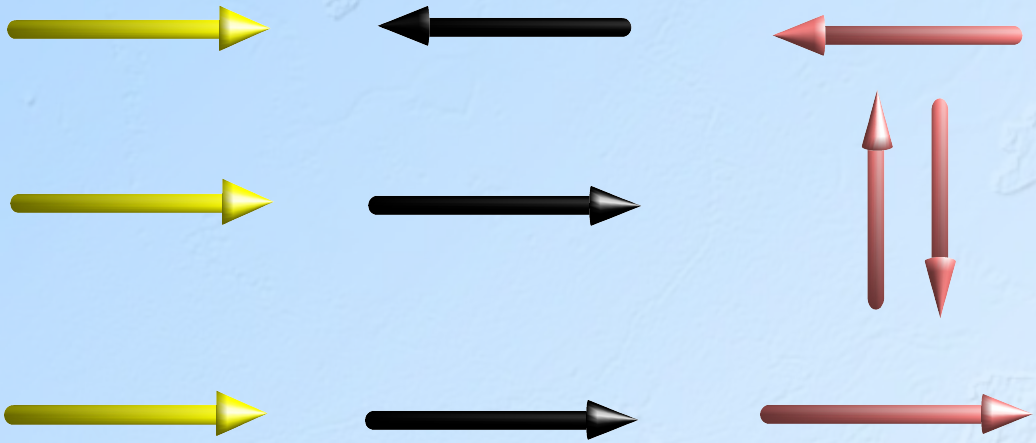
Spin : $s_b = ½$ $s_{top} = 1/2$ $s_W = 1$

Helicity of the W boson

left-handed
$h_w = -1$

longitudinal
$h_w = 0$

right-handed
$h_w = -1$



$$F_-(W) = \frac{2m_W^2}{2m_W^2 + m_{top}^2} \simeq 0.3$$

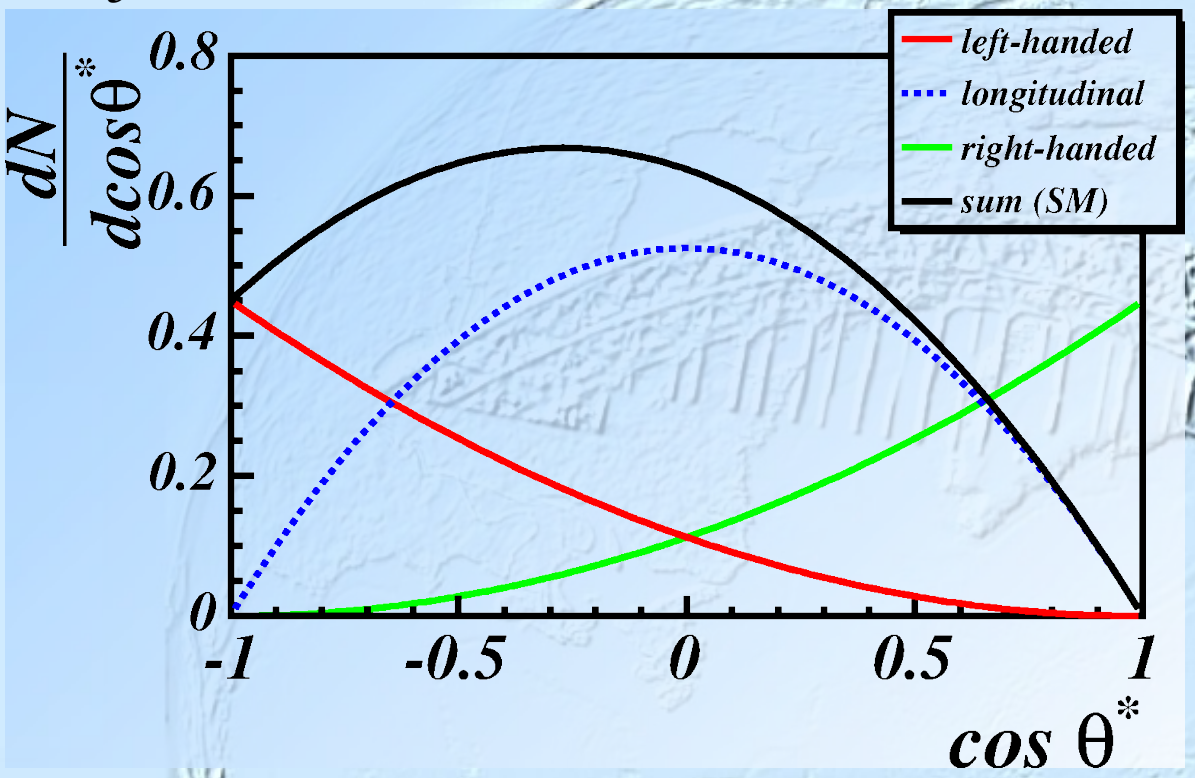
$$F_0(W) = \frac{m_{top}^2}{2m_W^2 + m_{top}^2} \simeq 0.7$$

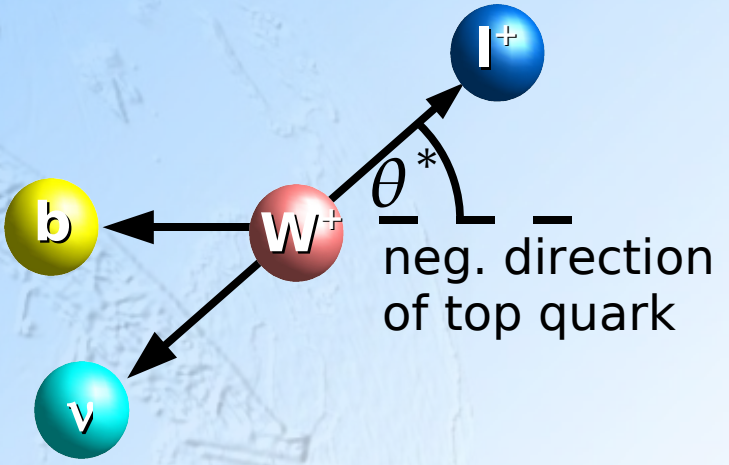
forbidden in the SM

Deviations from SM values will indicate new physics:

- V+A coupling → altered F_+
- Non SM EW symmetry breaking → altered F_0

Sensitive Observable





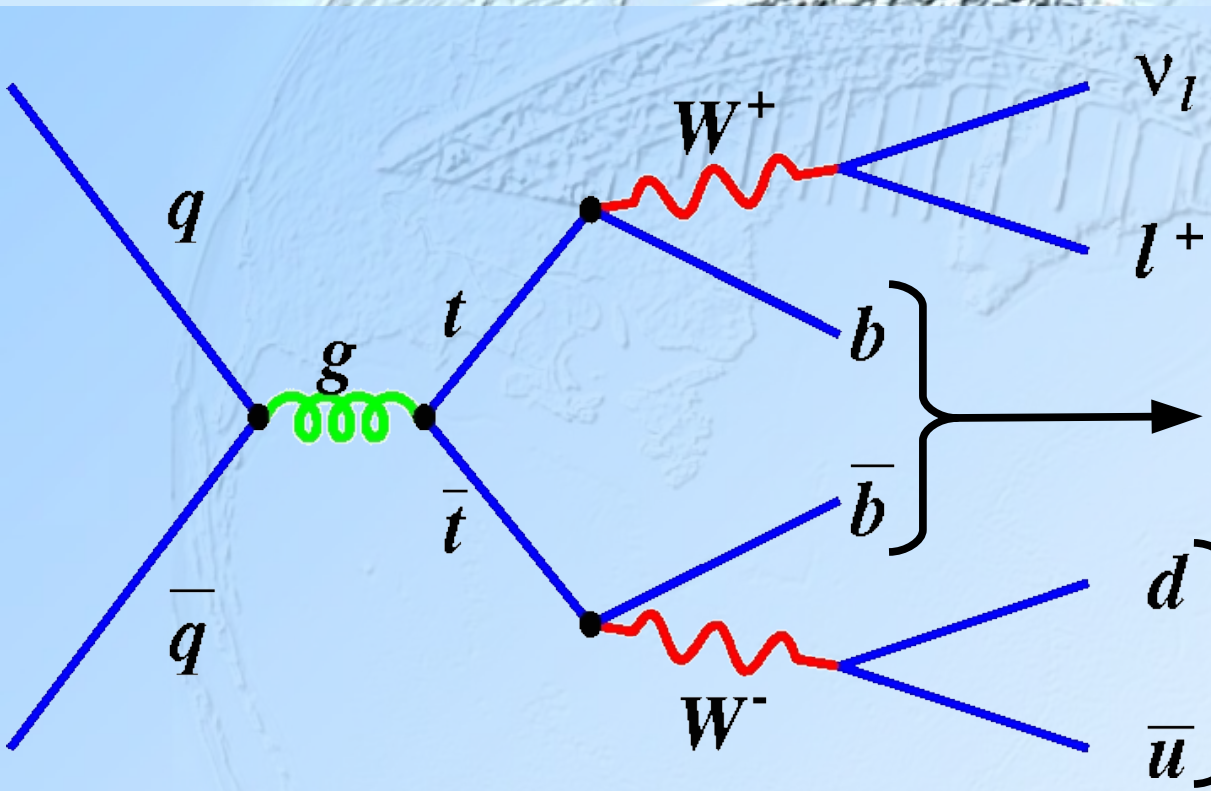
$$\frac{dN_{h_W=-1}}{d(\cos\theta^*)} \sim \frac{3}{8}(1-\cos\theta^*)^2$$

$$\frac{dN_{h_W=0}}{d(\cos\theta^*)} \sim \frac{3}{4}(1-\cos^2\theta^*)$$

$$\frac{dN_{h_W=+1}}{d(\cos\theta^*)} \sim \frac{3}{8}(1+\cos\theta^*)^2$$

Needs full reconstruction of tt events.

Lepton + jet events
event signature and cuts



missing transverse energy
$E_{T,miss} > 15$ GeV

isolated lepton (e, μ)
$p_T > 20$ GeV/c

b quark jets, $E_T > 15$ GeV
at least one with
secondary vertex tag

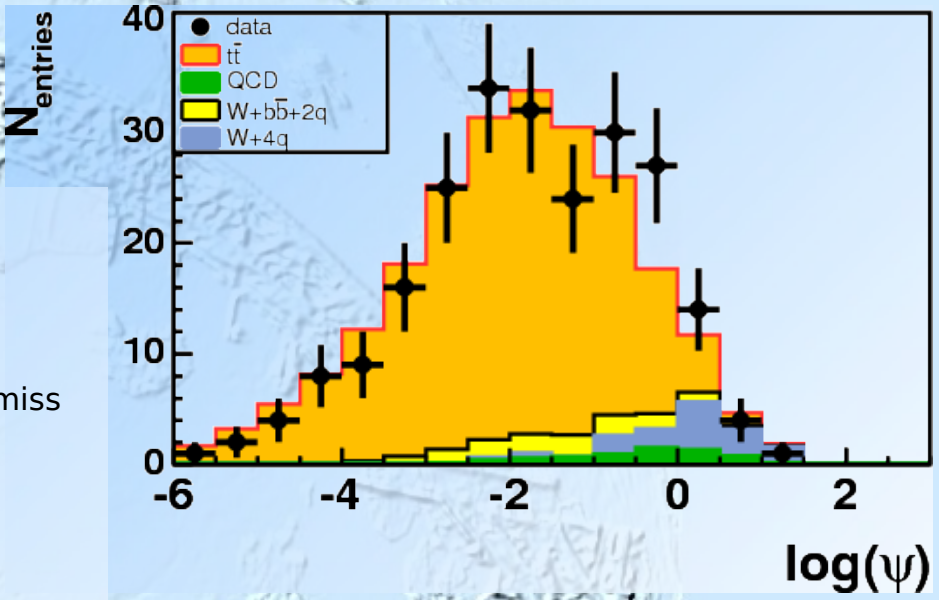
light quark jets
$E_T > 15$ GeV

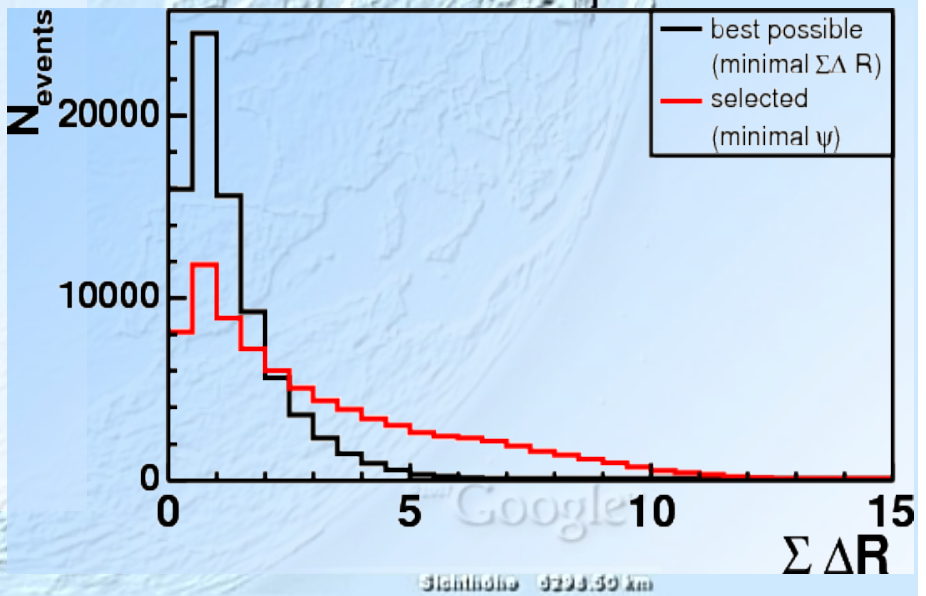
Reconstruction of top quarks, has to deal with a lot of combinations
→ Development of a method to choose one combination

Full reconstruction of tt events

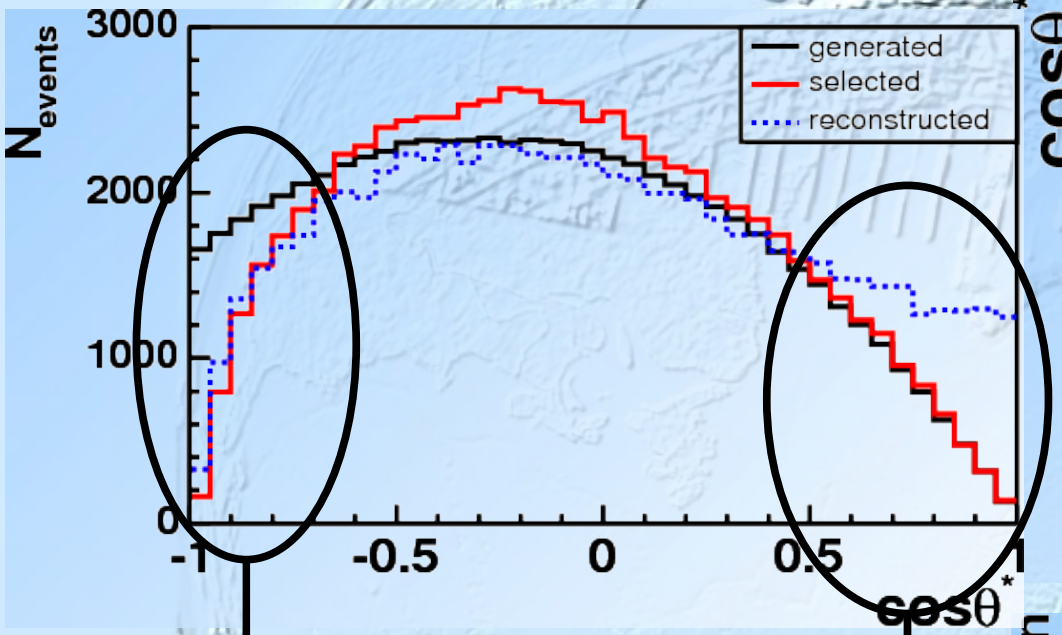
$$\Psi = P_\nu \cdot \chi^2 \cdot P_{b-light}$$

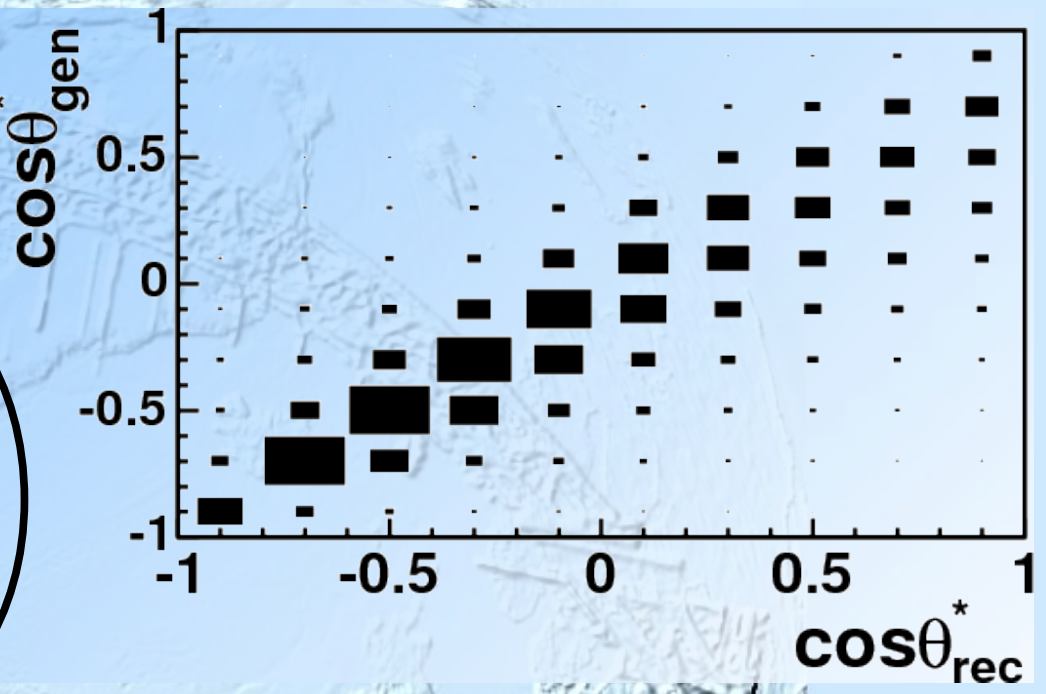
- Neutrino momentum z component solution: P_z
  - using m_W mass constraint, and fit $E_{T,miss}$ to avoid complex soultions
- Mass and energy constraints: χ^2
  - mass of hadronically decay W boson
  - difference of top quark masses
  - transverse energy sum
- b probability of b Jets: $P_{b\text{-light}}$
  - Neural Net b-tagger (based on secondary vertex tag)
  - probability belonging to the primary vertex





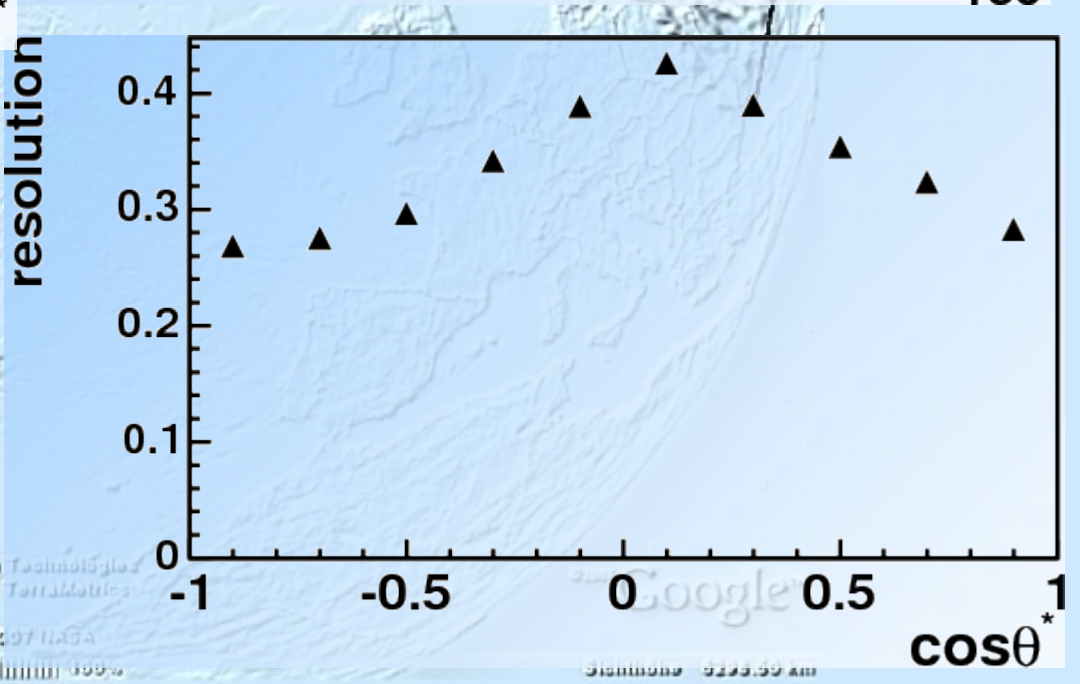
Resolution of cosθ*





Mis-measuremt of missing ET

isolation cut of lepton



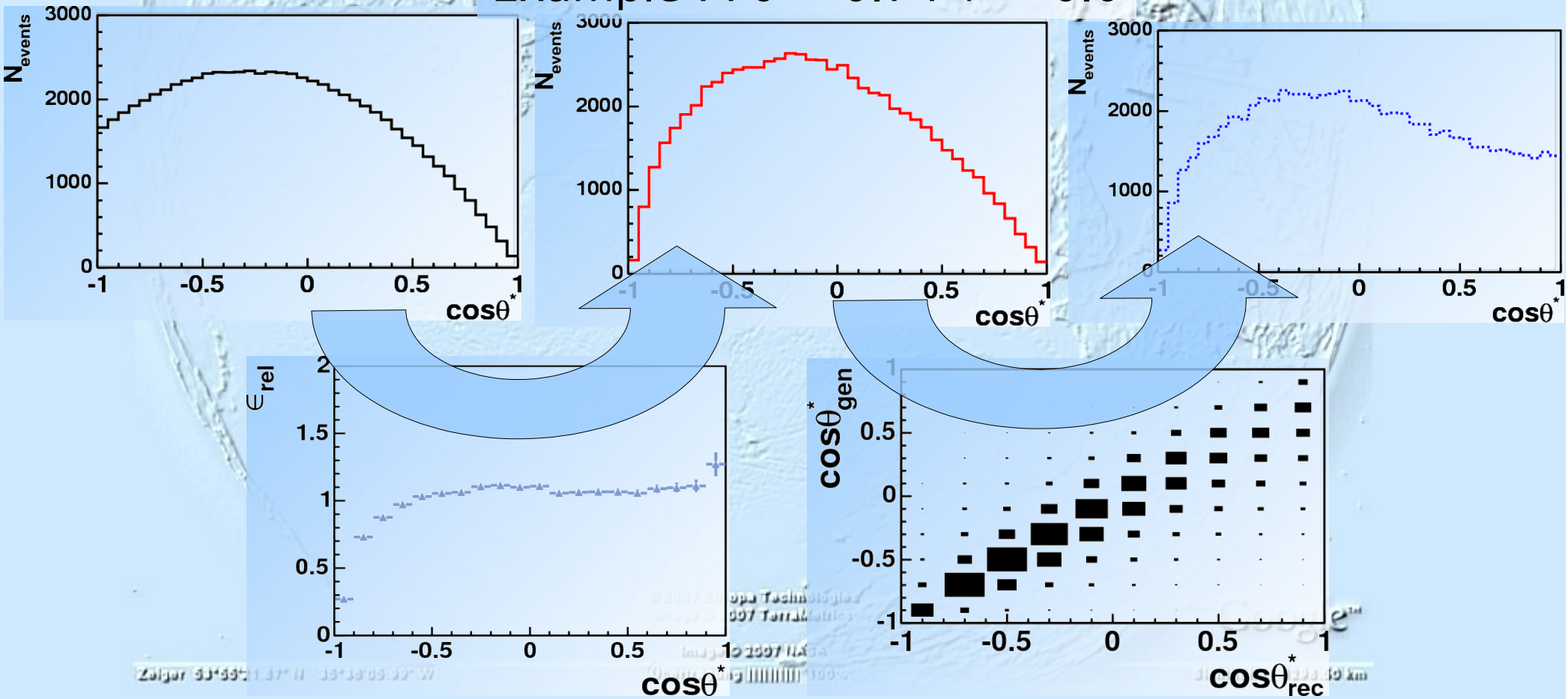
Fitting method

Using a likelihood method:

$$L(F_{0/+}) = \prod_{k=1}^{N_{bins}} \frac{\mu_k (F_{0/+})^{n_k} \cdot e^{-\mu_k}}{n_k!}$$

Idea: Calculate expected number of events μ_k from theory distribution include efficency and migration effects

Example : F0 = 0.7 F+ = 0.0



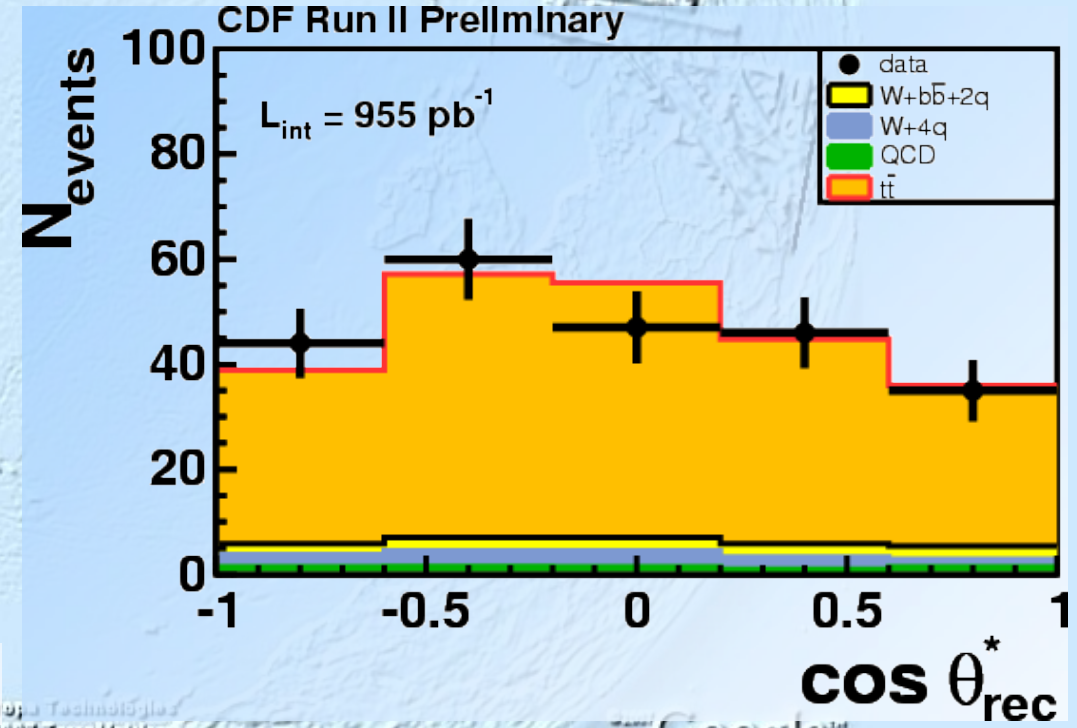
Background estimation and observed cosθ* distribution

QCD (nonW)	6.8 ± 1.8
Mistags	12.3 ± 1.8
W + c	0.6 ± 0.2
W +cc	3.0 ± 1.0
W + bb	6.4 ± 1.8
Diboson	1.6 ± 0.3
Single-Top	0.6 ± 0.1
Sum	12.3 ± 2.5
Total	31.3 ± 3.8

→ Modeled using data

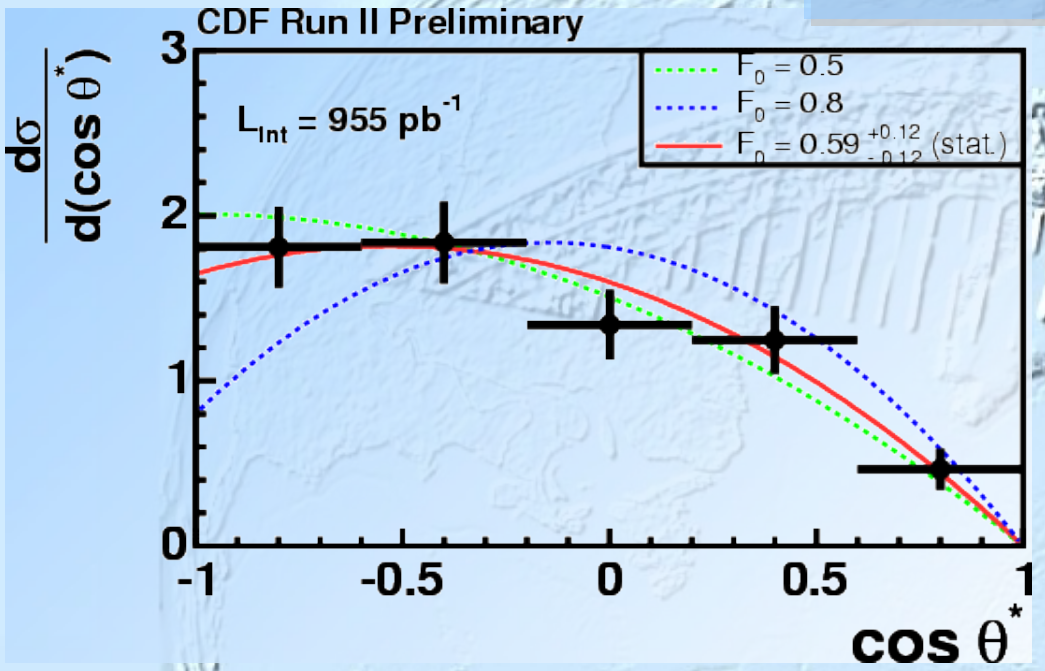
→ Modeled using W+qq MC

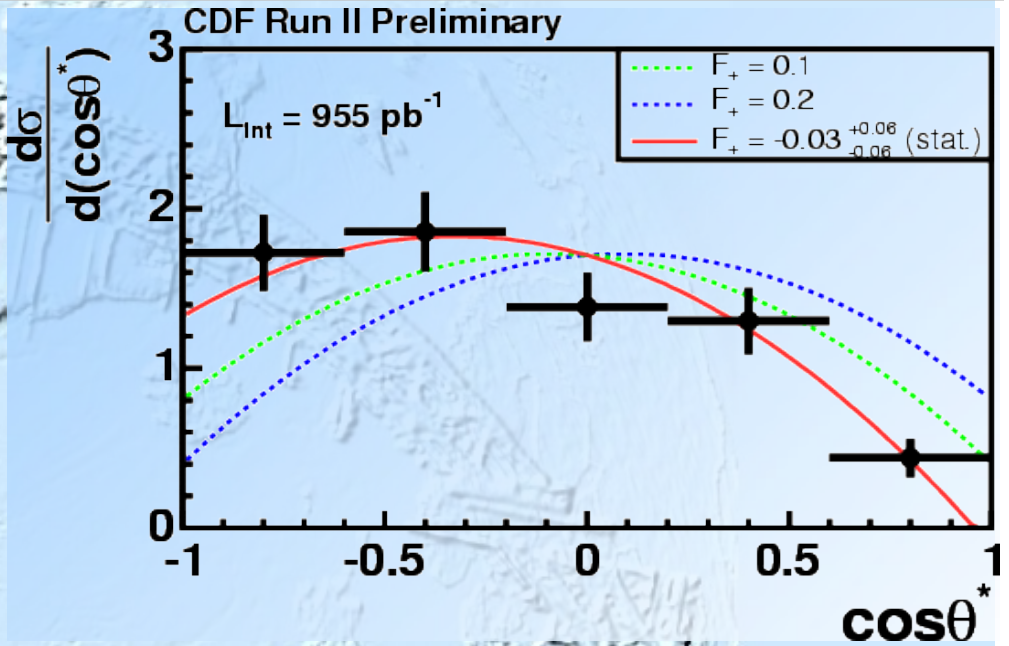
→ Modeled using W+qq MC

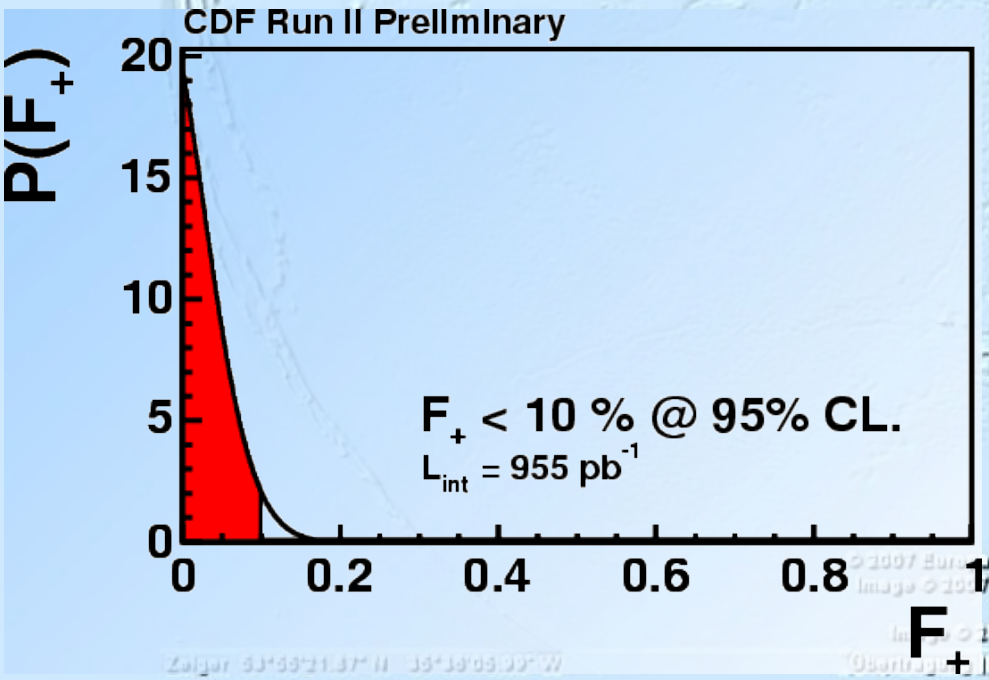


Observed data : 232 events

Result







Unfolded distribution using the result of the fit.

$F_0 = 0.59 \pm 0.12\ (stat) \pm 0.07\ (sys)$

$F_+ = -0.03 \pm 0.06\ (stat) \pm 0.04\ (sys)$

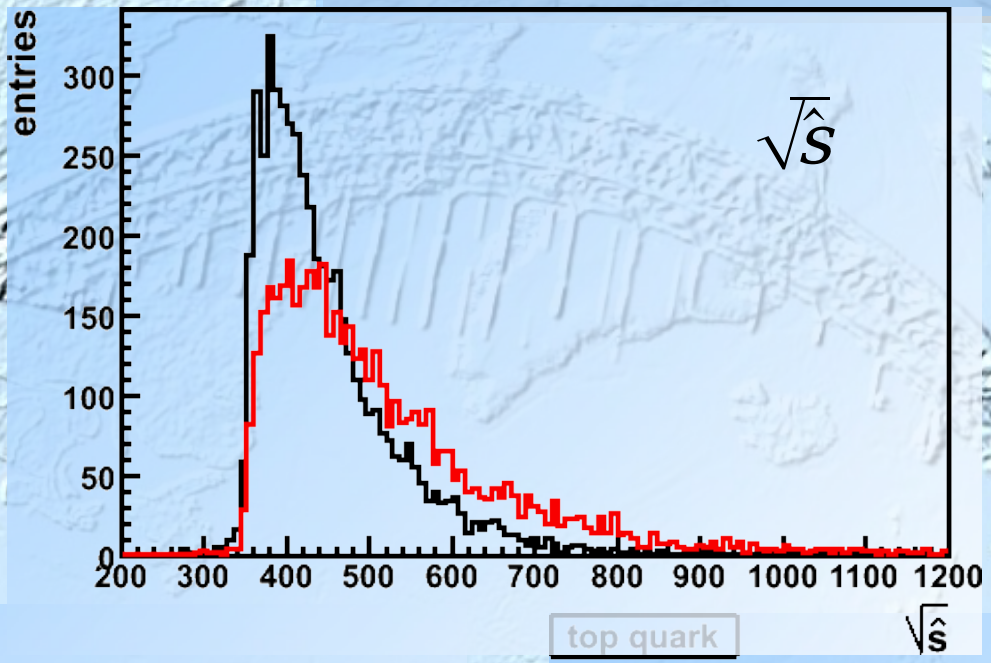
Systematic uncertainties

Determined with pseudo experiments

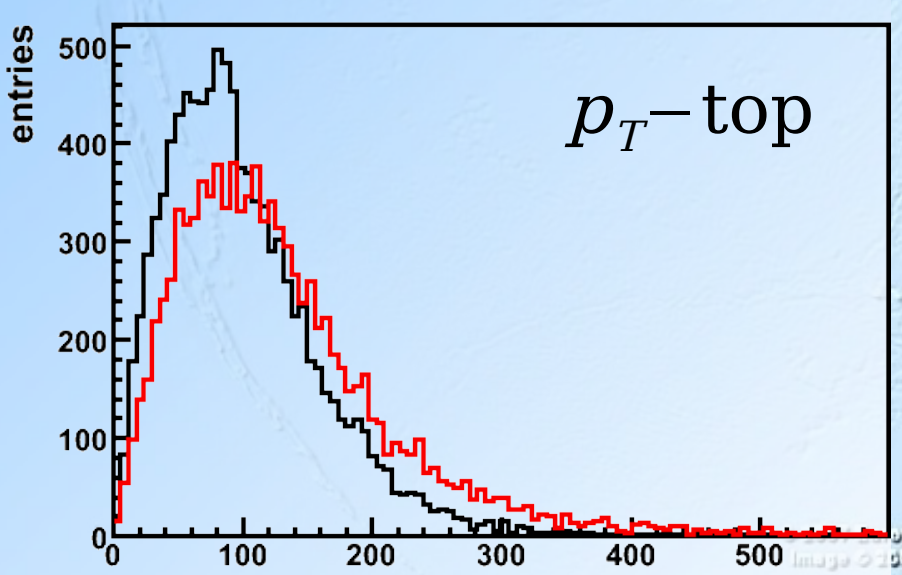
CDF Run II Preliminary

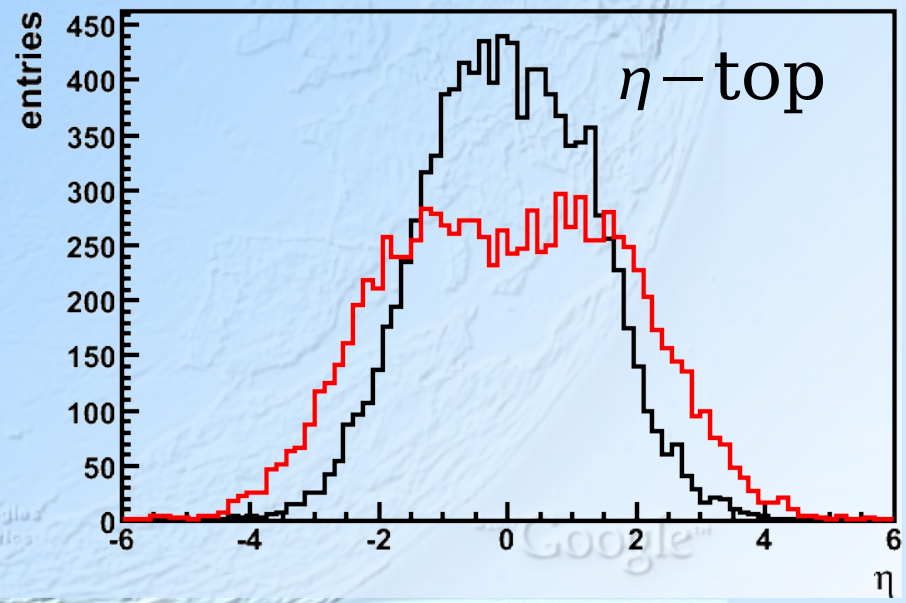
Source	Uncertainties $[10^{-2}]$ $-\Delta F_0$	$+\Delta F_0$	$-\Delta F_+$	$+\Delta F_+$
Monte Carlo gen.	0.61	0.61	0.08	0.08
Parton density functions	0.71	0.71	0.16	0.16
Initial state radiation	0.01	0.01	0.24	0.24
Final state radiation	1.31	1.31	0.77	0.77
Jet energy scale	5.68	6.34	3.01	3.61
b likeness	1.40	1.40	0.88	0.88
Background normalization	0.60	0.60	0.18	0.18
Background shape	1.00	1.13	0.72	0.89
Lepton energy	0.20	0.20	0.05	0.05
Total	6.18	6.81	3.32	3.91

Generator level studies with LHC

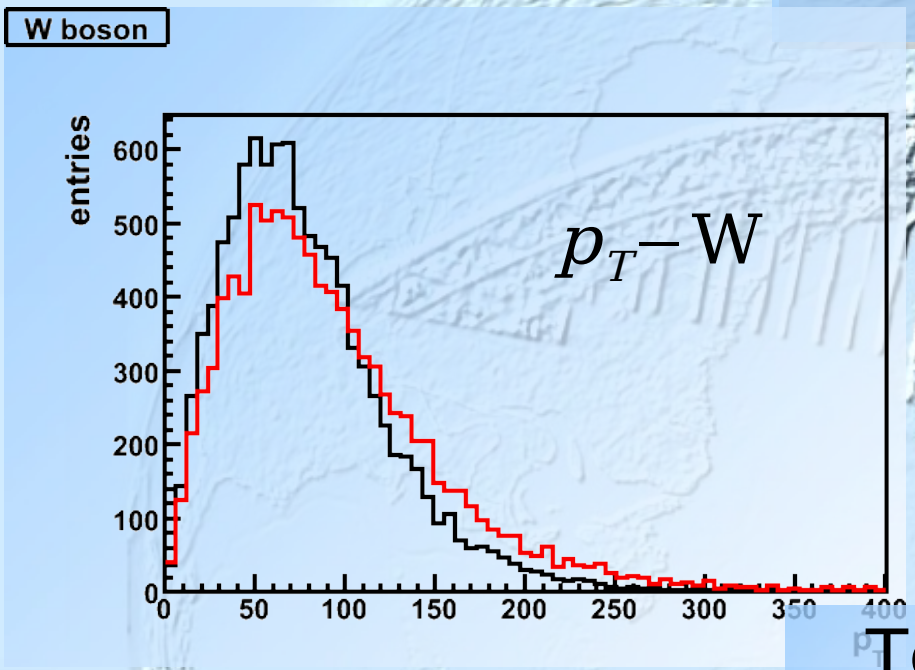


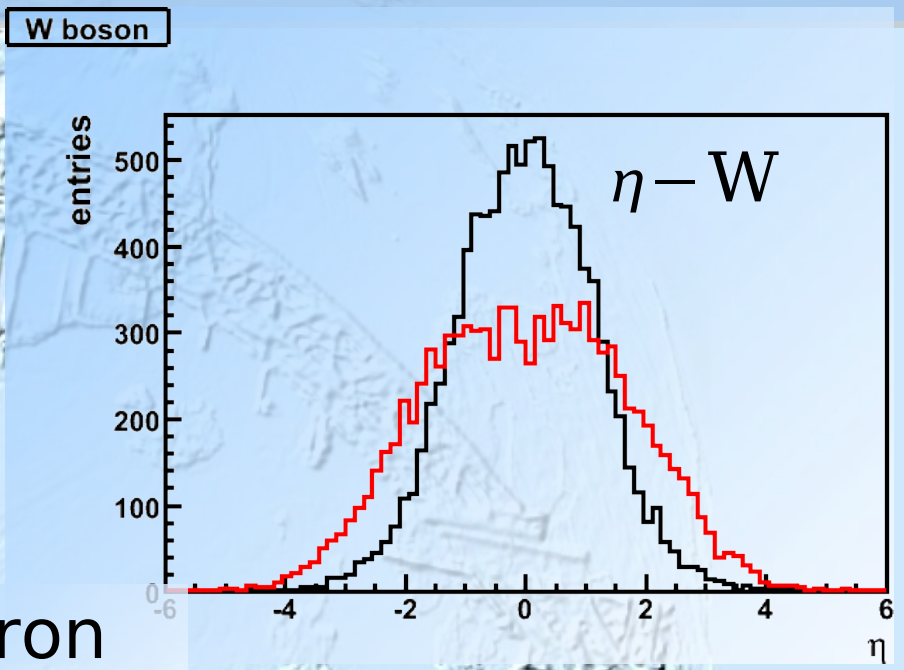
Tevatron
LHC





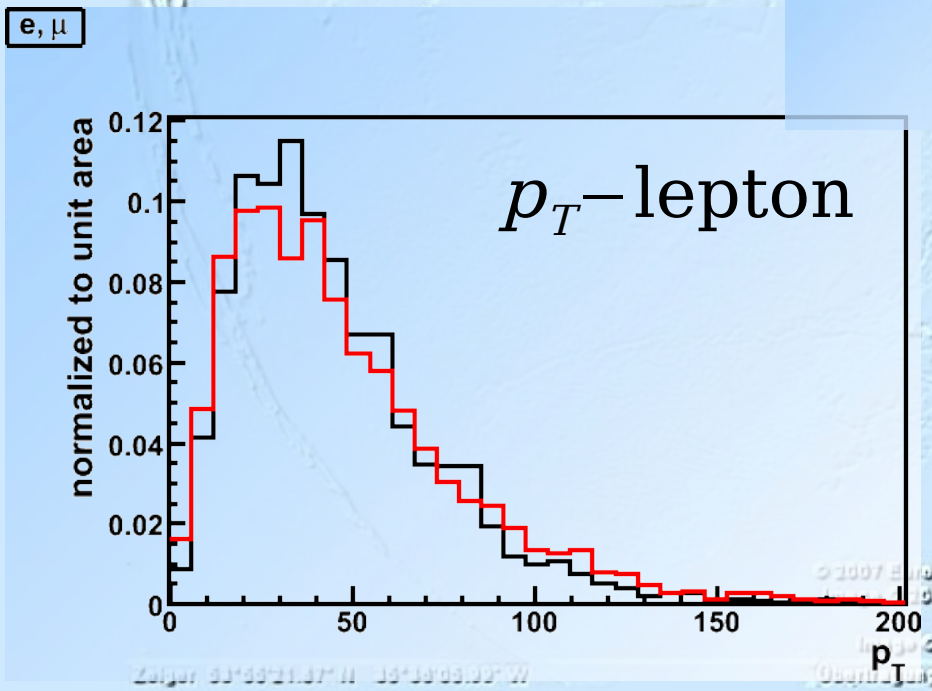
Generator studies with LHC

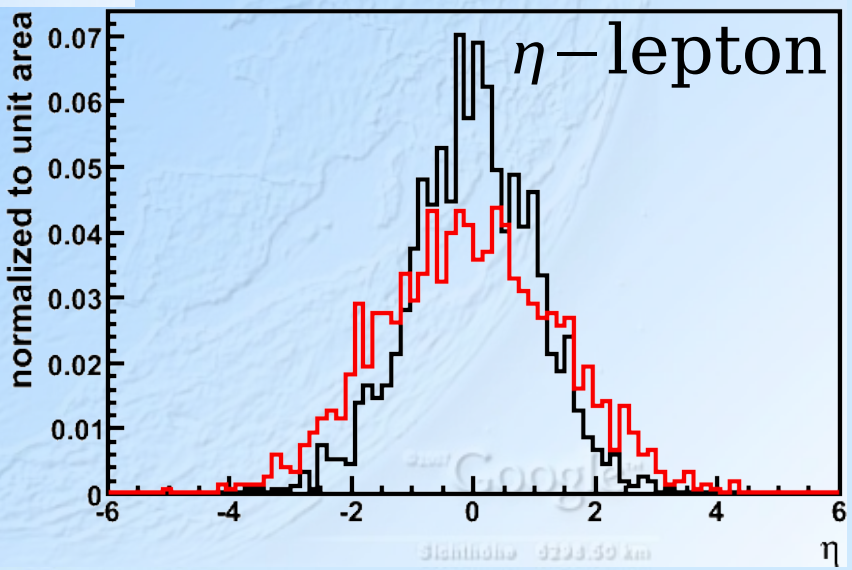




Tevatron

LHC





Conclusion

- We have developed a transparent method to reconstruct tt event fully
- Applied to the W helicity measurement at CDF
- Results are compatible with the SM predictions
- Statistical error is still big

- Starting with Generator level studies for the LHC
- Top-quark kinematics very similar
- We will apply the same method fro the LHC