

W Helicity Measurement in Top Quark Decays at DØ



DPF 2004 - Riverside

Christian Schmitt

University of Wuppertal

On behalf of the DØ Collaboration



Outline:

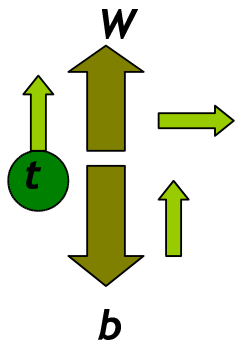
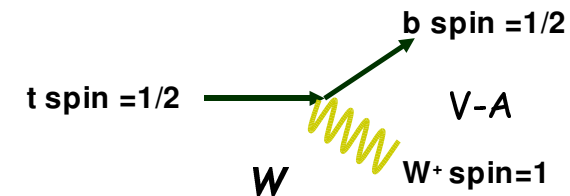
- Introduction
- Measurement of the W Helicity
- Summary & Outlook

W Helicity



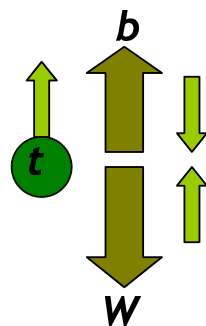
- Top decay in the Standard Model: V-A interaction (as all other fermions)

- Helicity states of the W Boson:

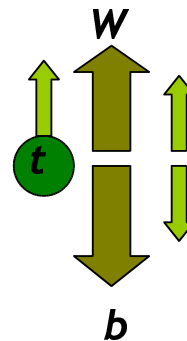


longitudinal
fraction: f_0

$$f_0 = \frac{m_t^2}{2M_W^2 + m_t^2 + m_b^2} = (70.1 \pm 1.6) \%$$



Left handed
fraction: f_-



Right handed
fraction: f_+

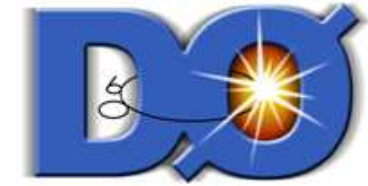
$f_- \approx 30\%$ V-A, $f_+ \approx 0\%$
 $f_- \approx 0\%$ V+A, $f_+ \approx 30\%$

Test of the **SM**

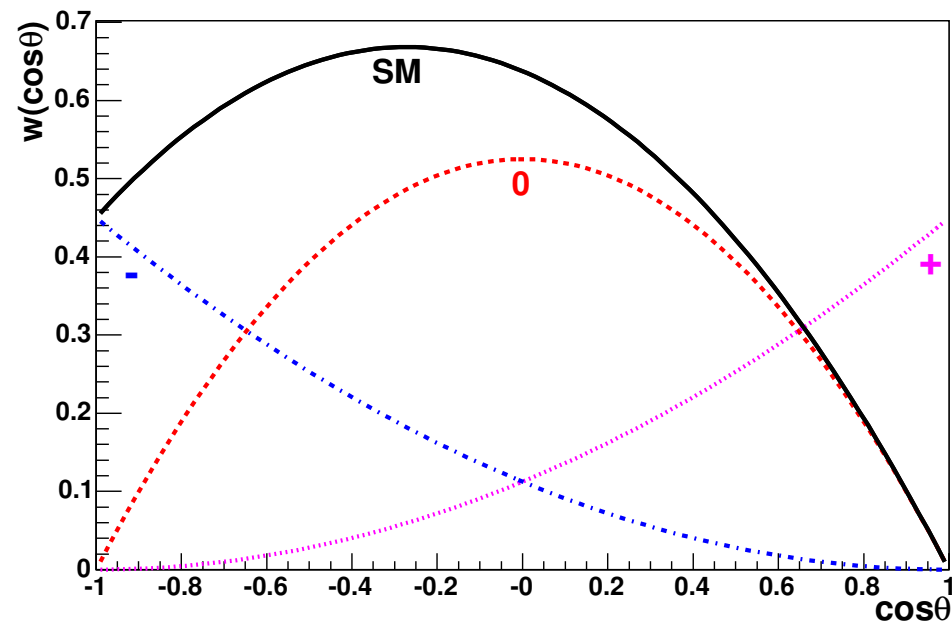
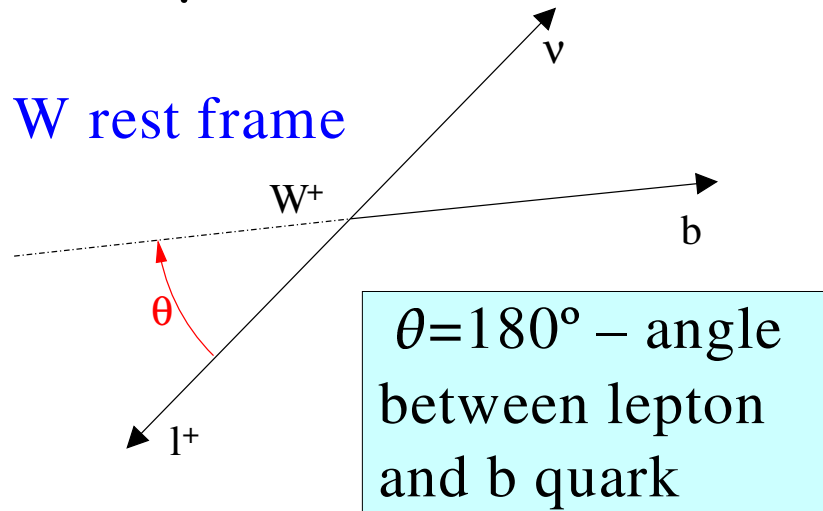
Opportunity to
look for **new**
physics

Suppressed by
factors of order
 m_b^2/m_t^2

W Helicity



- Separation between different Helicity states:



$$\omega(\cos \theta) = f_- \frac{3}{8} (1 - \cos \theta)^2 + f_0 \frac{3}{4} \sin^2 \theta + f_+ \frac{3}{8} (1 + \cos \theta)^2$$

- Previous RunI measurements:
 - CDF: $f_0 = 0.91 \pm 0.5$ (stat+syst), $f_+ = 0.15 \pm 0.11$ (stat)
 - D0: $f_0 = 0.56 \pm 0.38$ (stat+syst)

Outline of the Analyses



- Two analyses:

- topological
- b-tagging

Integrated Luminosity:

- e+jets: 169 pb⁻¹
- μ +jets: 158 pb⁻¹

- Lepton+Jets preselection

- Top quark selection and reconstruction

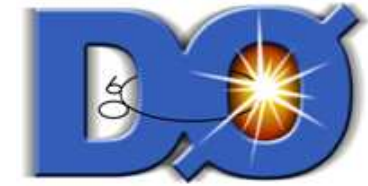
- Topological discriminant -> Separation from W+jets
- Kinematic fit -> Reconstruct both top quarks

- Compare measured $\cos(\theta)$ distribution with expectation

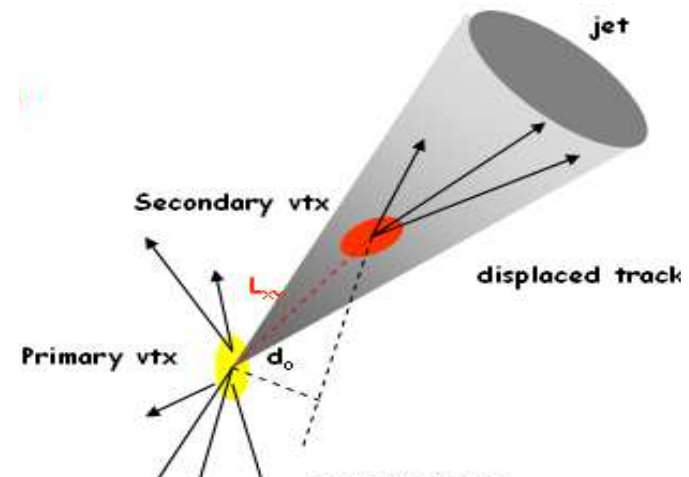
- Determination of f_+

- Binned likelihood fit to $\cos(\theta)$ distribution
- Bayesian limit calculation

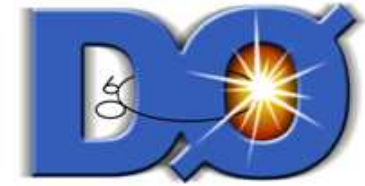
Event Preselection



- Lepton (e, μ)
 - $p_T > 20 \text{ GeV}$, $|\eta| < 1.1$ (2.0)
 - veto on second lepton with $p_T > 15 \text{ GeV}$
- Missing transverse Energy > 20 (17) GeV
- Jets
 - ≥ 4 jets with $p_T > 15 \text{ GeV}$, $|\eta| < 2.5$
 - ≥ 1 b-tagged jet (Secondary Vertex Algorithm)
- Event
 - kinematic fit has to converge
 - constraints on mass of W boson and top quark

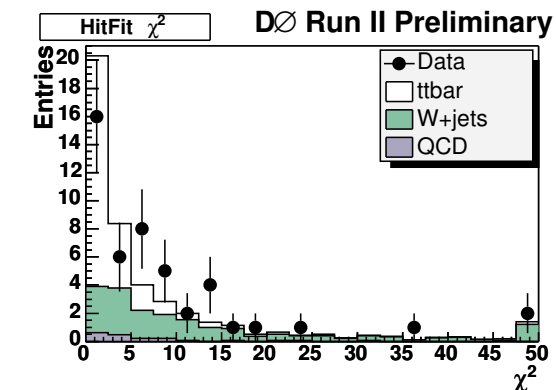
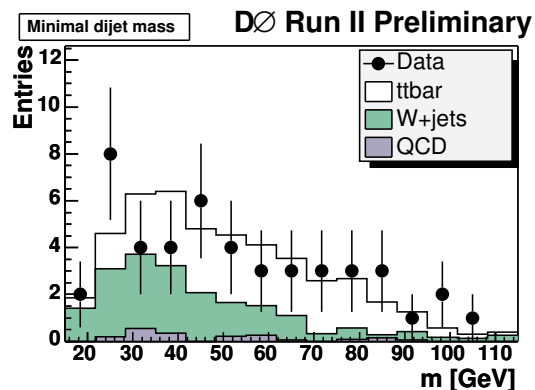
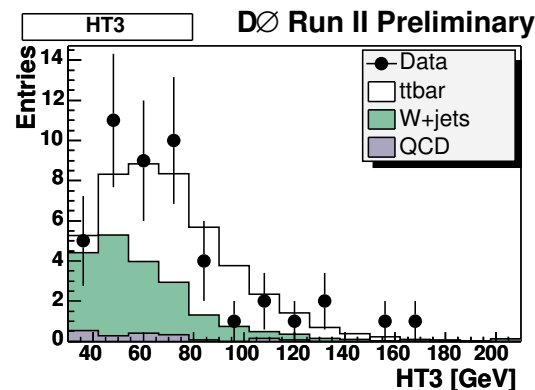
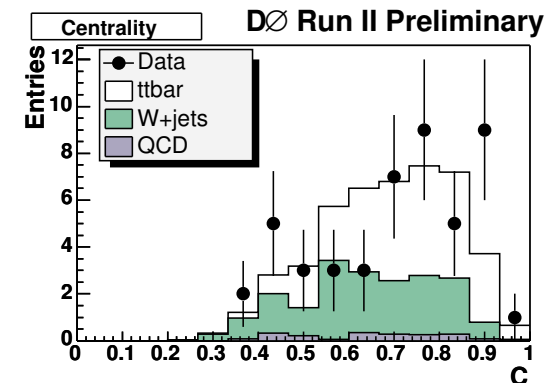
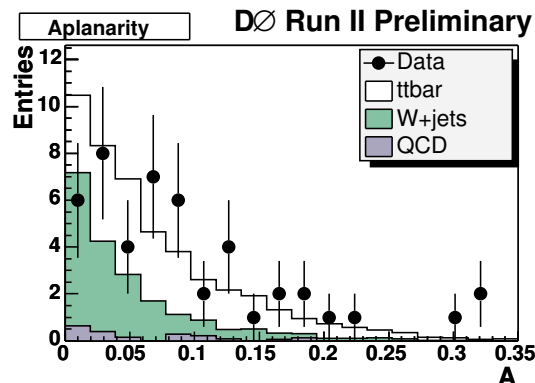
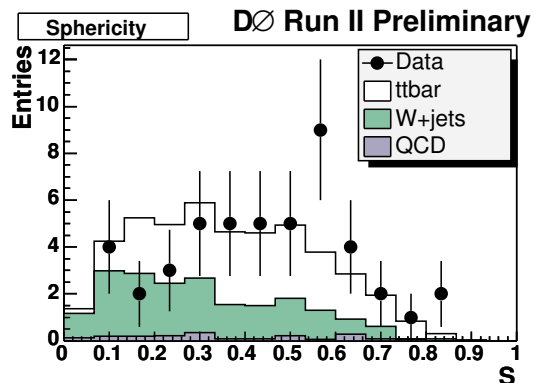


Topological Discriminant



- 6 variable topological likelihood to discriminate $t\bar{t}$ from background (W+jets, QCD)
- Optimized cut on this discriminant
 - topological analysis: $L > 0.6$
 - b-tagged analysis: $L > 0.1 (\mu) L > 0.3 (e)$

Input Variables



Sample composition

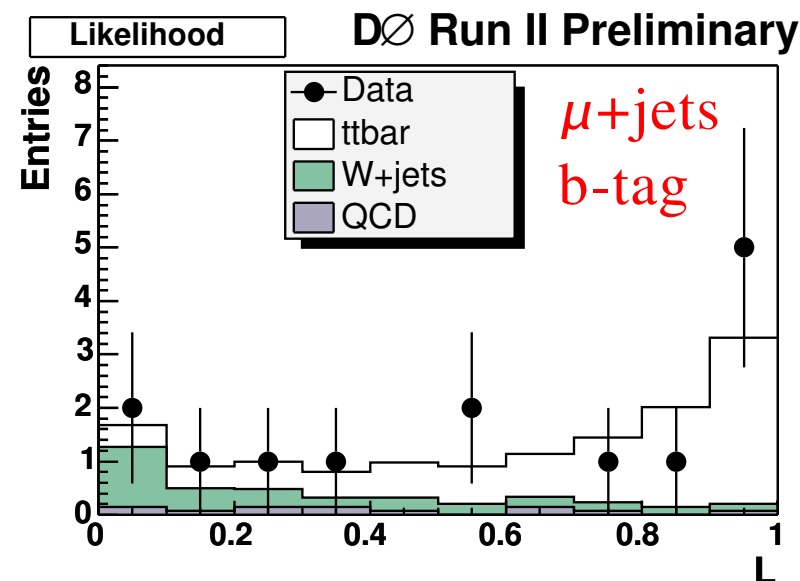


- Multijet ("QCD") background determined from data using the difference in the lepton efficiency (compared to $t\bar{t}$ and W +jets)
- The number of $t\bar{t}$ and W +jets events is extracted from the topological discriminant
 - by using the cut efficiency determined on MC (topological)

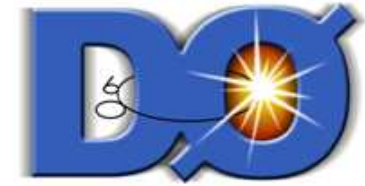
Channel	$t\bar{t}$	W +jets	QCD
μ +jets	11.3 ± 1.3	17.6 ± 1.2	2.1 ± 0.5
e +jets	25.9 ± 1.5	20.3 ± 1.5	2.7 ± 0.5

- by performing a fit (b-tag)

Channel	$t\bar{t}$	W +jets	QCD
μ +jets	10.2 ± 2.9	3.1 ± 2.2	0.9 ± 0.2
e +jets	16.9 ± 4.1	14.9 ± 4.0	1.0 ± 0.3



$\cos(\theta)$ Templates



- Reconstruct full event using a constrained kinematic fit:

- mass of W boson is set to 80.4 GeV
- mass of top quark is set to 175 GeV

Fit reconstructs four vectors of particles:
 t, b, W
 $\Rightarrow$ calculate $\cos\theta$

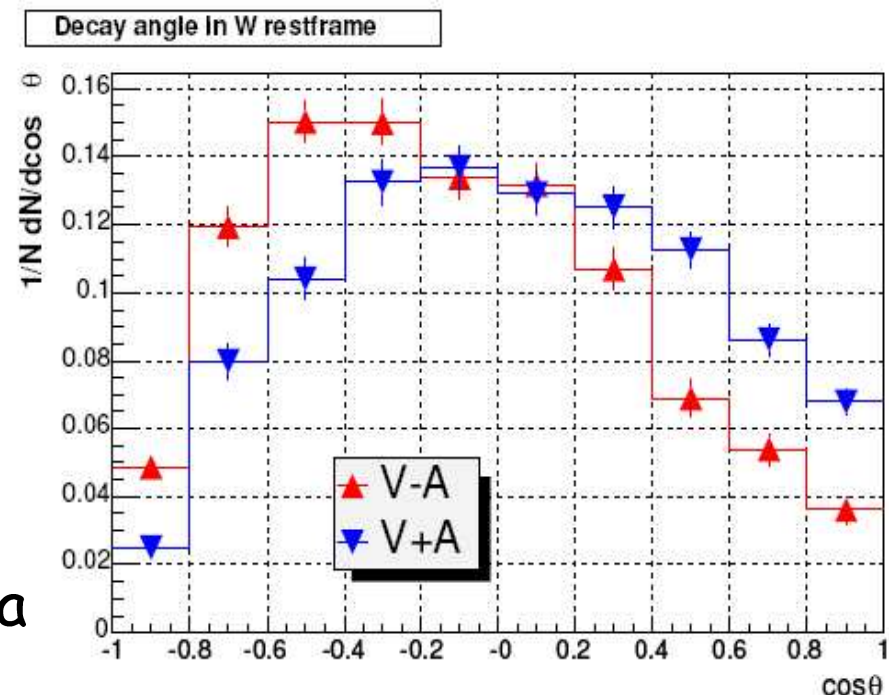
- Among the 12 possible solutions the one with the minimal χ^2 is chosen

- Signal templates

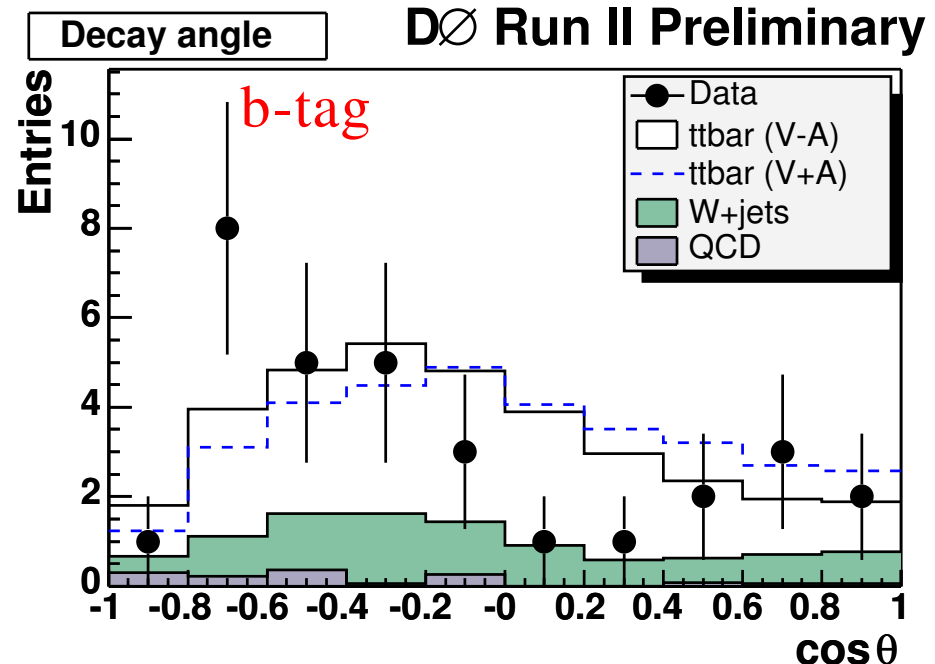
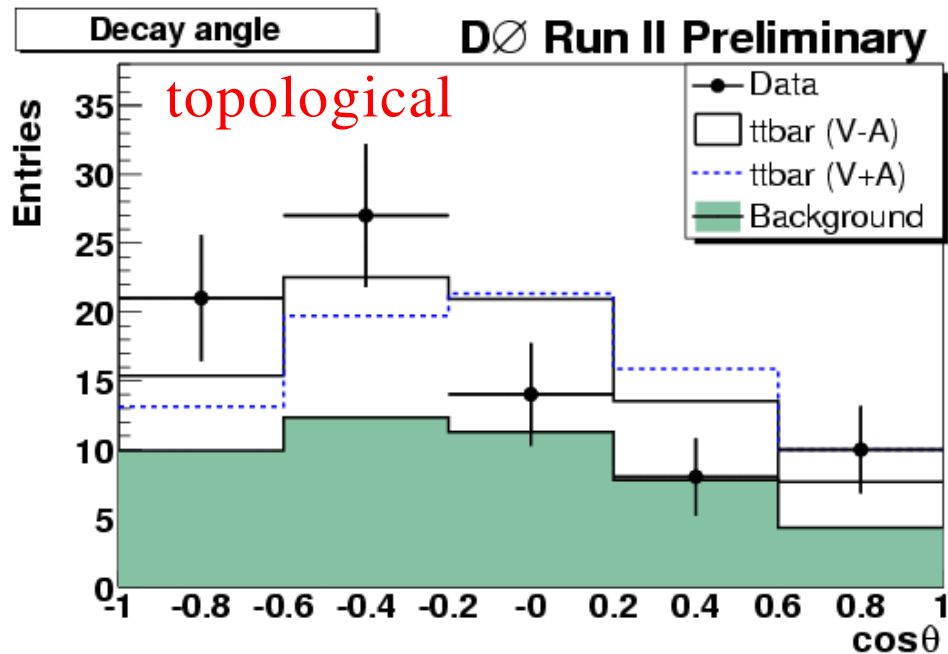
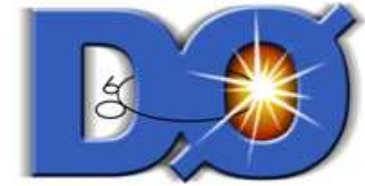
- f_0 fixed at 0.7
- f_+ varied from 0.0 .. 0.3

- Background templates

- W +jets: taken from MC
- Multijet: taken from data by reversing identification criteria on leptons



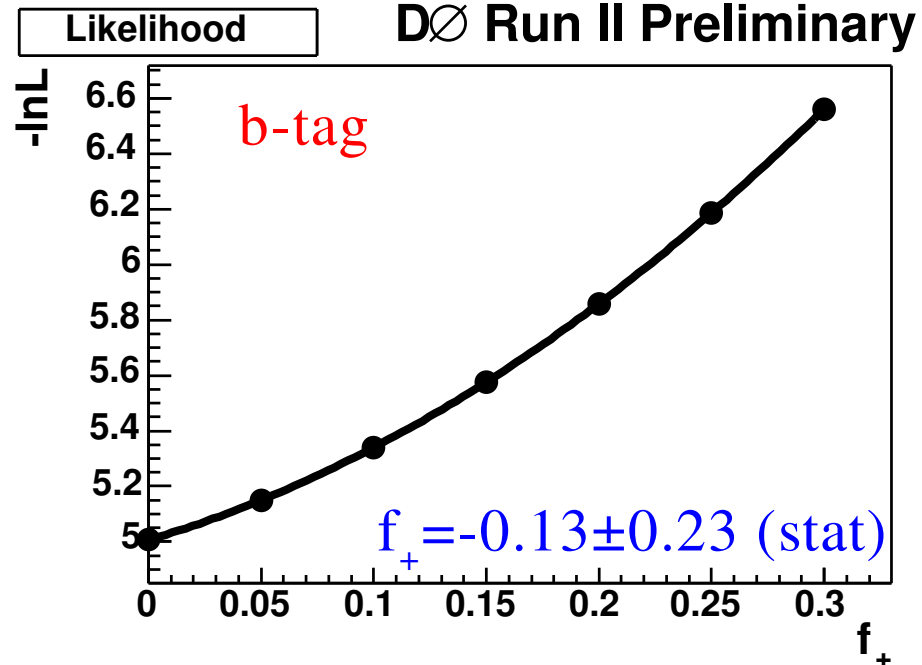
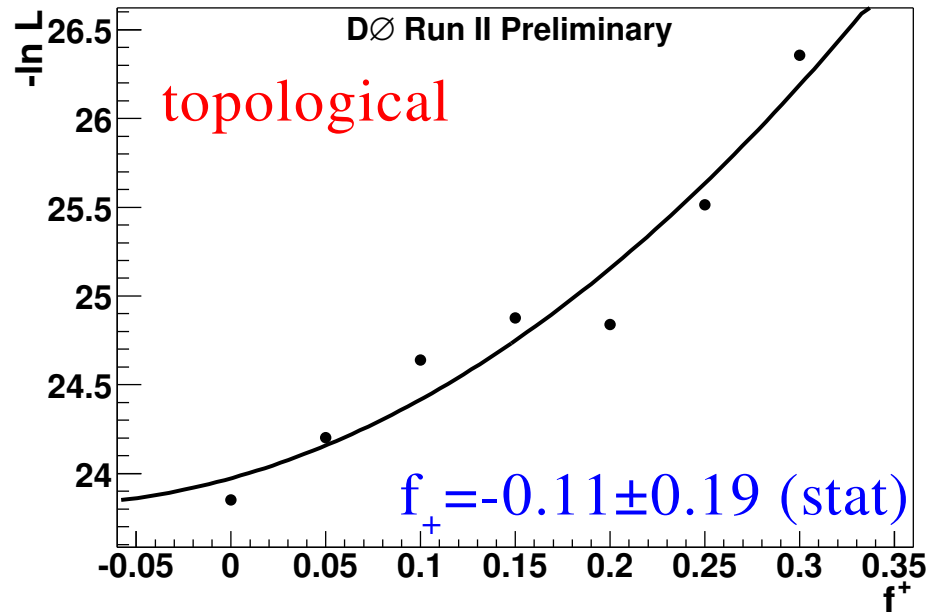
$\cos(\theta)$ distribution in data



➤ Extraction of f_+

- binned Poisson maximum likelihood fit using the decay angle templates ($t\bar{t}$, W+jets and Multijet)

Result



- Central values outside physically allowed region
- Use Bayesian technique to calculate upper limit (90% C.L.)
 - Flat prior:
$$\pi(f_+) = \begin{cases} 1 & 0 \leq f_+ \leq 0.3 \\ 0 & f_+ < 0 \text{ or } f_+ > 0.3 \end{cases}$$
- Result (identical for both analyses)

$f_+ < 0.24$ (90% C.L.) including systematics

Systematics



- Systematic effects studied using ensemble tests
- Main systematics:
 - Top mass
 - Jet Energy Scale
 - Background description
- Included in limit calculation by convoluting the likelihood with a Gaussian function
 - Width of the Gaussian given by total systematic uncertainty
 - topological: 0.15
 - b-tag: 0.11
 - Factor of 1.5-2 smaller than statistical errors !

Summary & Outlook



- **First DØ measurement of f_+** using 158-168 pb⁻¹
- Sensitive variable: **decay angle in W restframe**
- Analyses using **topological** as well as **b-tag** information yield the same preliminary result:

$$f_+ < 0.24 \text{ (90\% C.L.)}$$

- In agreement with the SM prediction
- **Outlook:**
 - Combination of both analyses
 - More data: $\sim 0.5 \text{ fb}^{-1}$ by end of 2004

Backup Slides

Signal Templates



- Topological analysis
 - 7 signal templates: $f_+ = 0.0 \dots 0.3$ in steps of 0.05
 - statistical fluctuations between templates
- b-tagged analysis
 - Combine these 7 templates into 2: V-A and V+A
 - linear interpolation to create mixed templates
 - no statistical fluctuations between templates
 - Possible because:
 - Interference Term between V-A and V+A is negligible (Koerner, Mangano)