Measurement of
$B(t \to Wb)/B(t \to Wq)$ at DØ

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Motivation

- B(t → Wb) ~ 100 % (from V_{tb}) in the Standard Model
- We can write the ratio R = B(t → Wb) / B(t → Wq)

$$R = \frac{|V_{tb}|^2}{|V_{tb}|^2 + |V_{ts}|^2 + |V_{td}|^2} = |V_{tb}|^2$$

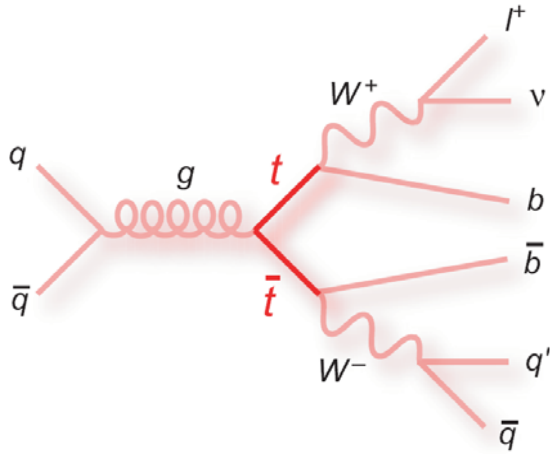
- The CKM matrix element $|V_{tb}|$ is constrained based on the assumptions : 1. The CKM matrix is unitary 2. Quark has the three generation structure
- $|V_{tb}|$ is bounded between 0.9990 and 0.9992
- R measurement analysis provides a cross check of the assumptions and the SM prediction
- A deviated value of R could lead us new physics such as a fourth quark generation

Top Quark and Background

Top-pair production

Lepton + jets
- One W decays hadronically
- One W decays leptonically

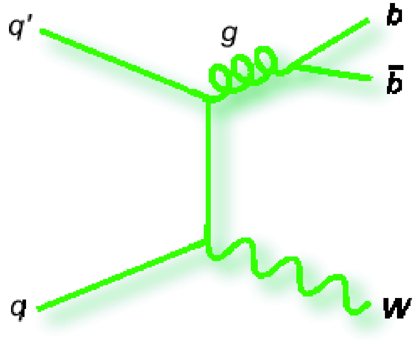
Dilepton
- Both Ws decay leptonically



W+Jets

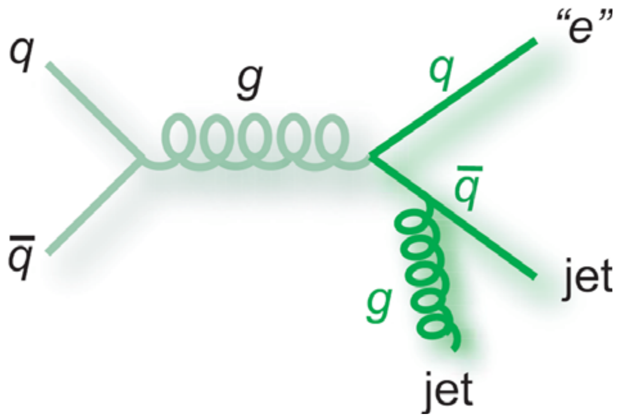
Contain a real lepton from W decay

Wjj (j = g,u,d,s,c,b)



Misidentified multijet events (QCD)

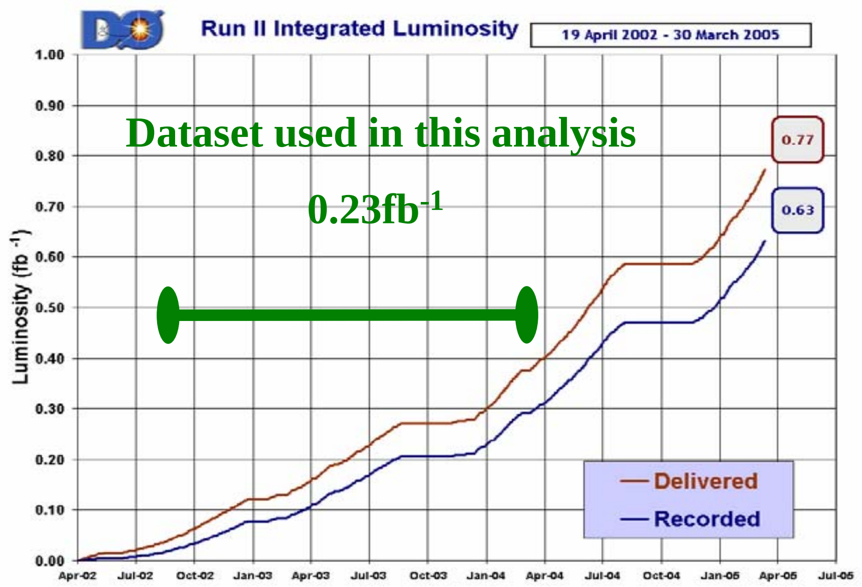
Contain fake isolated electron or muon



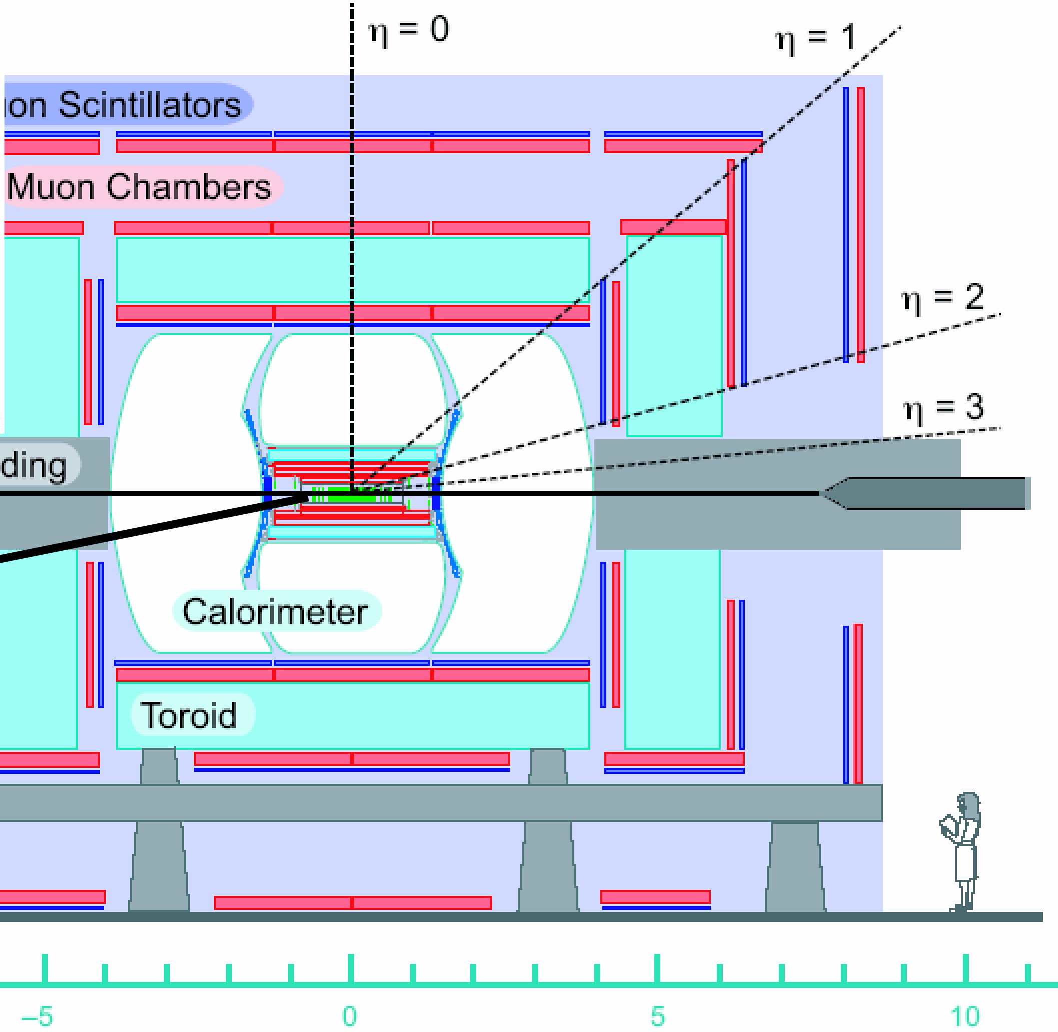
Diboson events

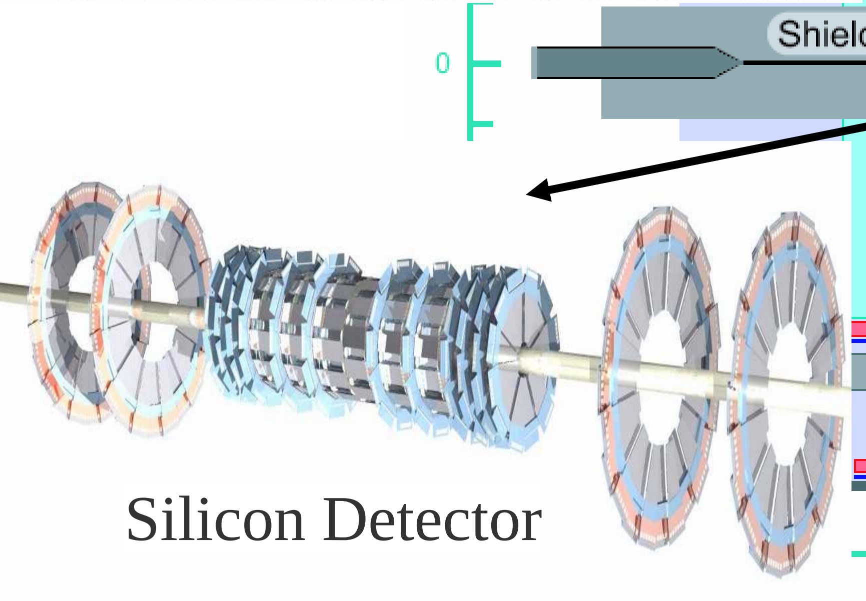
WW, WZ, ZZ

DØ Detector and Dataset



Center of Mass Energy: 1.96TeV



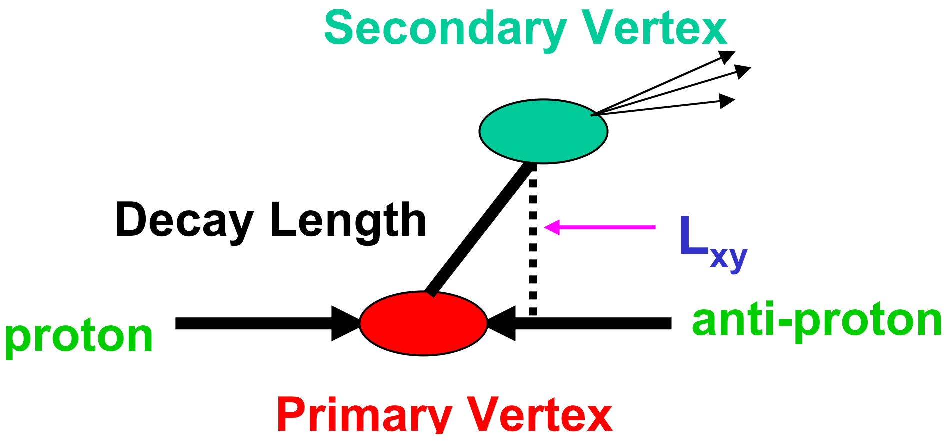


Silicon Detector

Event Selection

- **Requirements**
  - 1 isolated lepton (electron or muon) $p_T > 20$ GeV
  - High missing transverse energy from neutrino $\not{E}_T > 20$ GeV
  - Jets: one or more jets with $|y| < 2.5$ $p_T > 15$GeV
  - No second high p_T lepton
- **b-jet identification (B-tagging)**
  - Secondary vertex tagging algorithm
  - Three separate datasets: exactly one tagged jets, at least two tagged jets or zero tagged jets

Secondary Vertex Tagging Algorithm



Secondary Vertex

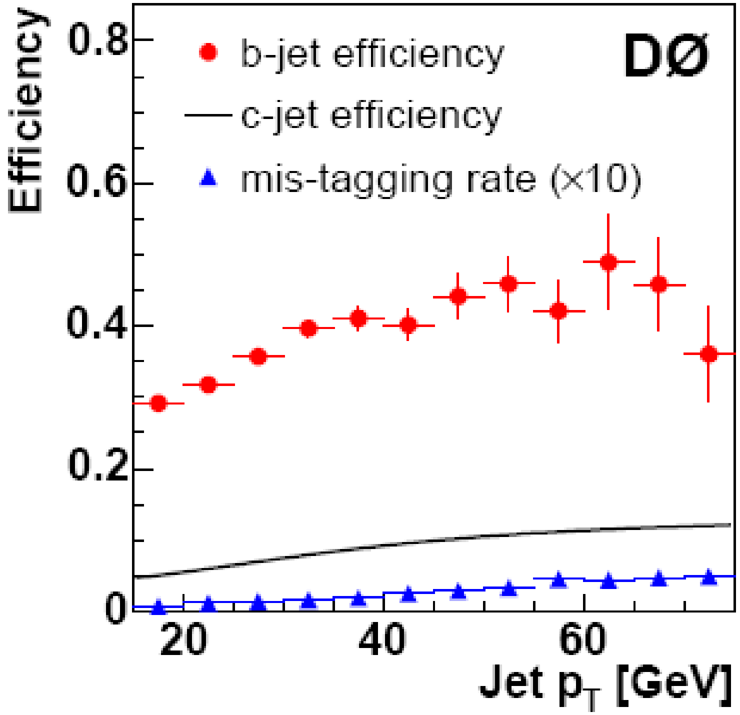
Decay Length

L_{xy}

proton

anti-proton

Primary Vertex



- Find a decay length, L for each vertex
- Define the decay length significance in transverse plane

$$L_{significance} = L_{xy} / \sigma_{Lxy}$$

- If $L_{significance} > 7$, the event passes SVT algorithm
- Tag rate ~ 40%
- Mistag rate ~ 0.2%

Analysis Method

- Decide the ratio R and $t\bar{t}$ cross section σ simultaneously
- Separate final states with (electron, muon) (3, 4jets) (0, 1, 2tags)
- Expected event numbers are fitted to observed data numbers for the 1, 2 tag channels
- Due to small $t\bar{t}$ event numbers in the 0 tag channels topological likelihood discriminant is constructed

$$R = \frac{B(t \to Wb)}{B(t \to Wq)}$$

b-tagged jet number	0		1		2	
Jet mulitplicity	3	4	3	4	3	4
	not used	topological likelihood	fit to the observed event numbers			

For electron (or muon) channel

$t\bar{t}$ Event Tagging Probabilities

- $t\bar{t}$ event tagging probability: fraction of identified $t\bar{t}$ event number and total $t\bar{t}$ event number
- If R is equal to 1 the branching fraction B(t → Wb) is 100%
- If R is less than 1 the decay of the two top quarks in a $t\bar{t}$ event can produce either 0, 1 or 2 b quarks
- The event tagging probabilities are derived separately for the three possibilities

Scenario 1	$t\bar{t} \to W^+ b W^- \bar{b}$	**two b quarks**
Scenario 2	$t\bar{t} \to W^+ b W^- \bar{q}_l$	**one b quark one light quark**
Scenario 3	$t\bar{t} \to W^+ q_l W^- \bar{q}_l$	**two light quarks**

$t\bar{t}$ Event Tagging Probabilities

number of b quarks in the final states	0	1	2
probabilities to obtain each of the three final states	$(1-R)^2$	$2R(1-R)$	R^2

$t\bar{t}$ event tagging probability = **probability to have each final state** X **probability to identify each final state**

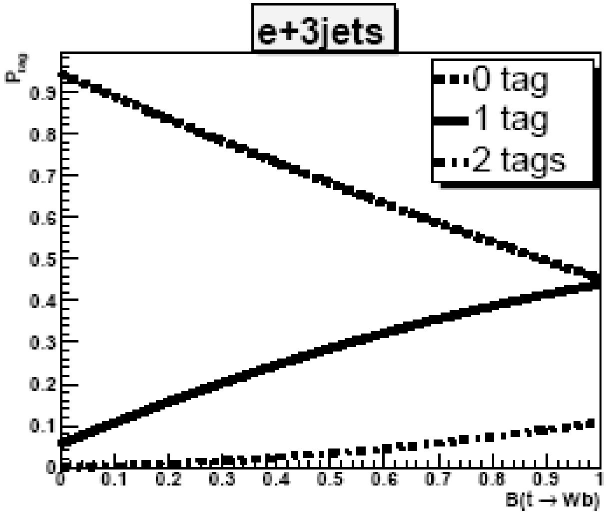
physics issue **detection issue**

$$P^{n\ tag}(t\bar{t}, R) = R^2 P^{n\ tag}(t\bar{t} \to bb) + 2R(1-R)P^{n\ tag}(t\bar{t} \to bq_l) + (1-R)^2 P^{n\ tag}(t\bar{t} \to q_l q_l)$$

- **Use $t\bar{t}$ Monte Carlo to compute the event tagging probabilities**
- **No Monte Carlo samples for**

$$t\bar{t} \to W^+ b W^- \bar{q}_l$$

$$t\bar{t} \to W^+ q_l W^- \bar{q}_l$$



$t\bar{t}$ event identification and R

Scenario 2

$$t\bar{t} \to W^+ b W^- \bar{q}_l$$

Scenario 3

$$t\bar{t} \to W^+ q_l W^- \bar{q}_l$$

$$P^{n\ tag}(t\bar{t}, R) = R^2 P^{n\ tag}(t\bar{t} \to bb) + \boxed{2\,R(1-R)P^{n\ tag}(t\bar{t} \to bq_l)} + \boxed{(1-R)^2 P^{n\ tag}(t\bar{t} \to q_l q_l)}$$

- Use standard $t\bar{t}$ Monte Carlo
- Consider a jet matching $\bar{b}$ from $\bar{t}$ as light jet
- Apply light jet tagging probability to the $\bar{b}$
- Apply b tagging probability to the other b jet from t
- Compute 0, 1 and 2 tag probabilities

- Use standard $t\bar{t}$ Monte Carlo
- Apply light jet tagging probabilities to jets matching the b and $\bar{b}$
- Compute 0, 1 and 2 tag probabilities

standard $t\bar{t}$ Monte Carlo

$$t\bar{t} \to W^+ b W^- \bar{b}$$

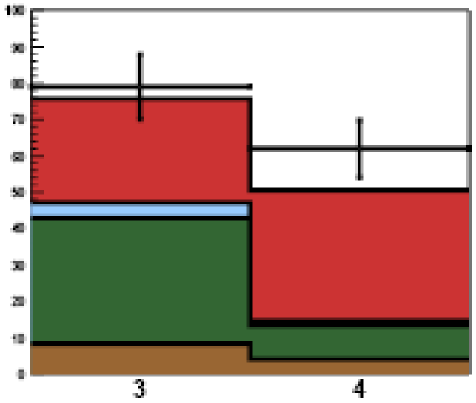
Maximum Likelihood Fit

- R and σ are obtained by a maximum likelihood fit to the observed number of events
- Eight different channels : electron or muon with 3 or ≥ 4 jets and one or two tags

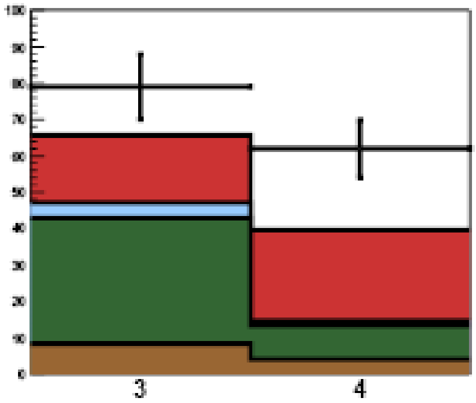
$$\mathcal{L} = \prod_i P(N_i^{obs}, N_i^{predicted}(R,\sigma))$$

- Here $P(N^{obs}, N^{predicted})$ denotes the Poisson probability

R = 1



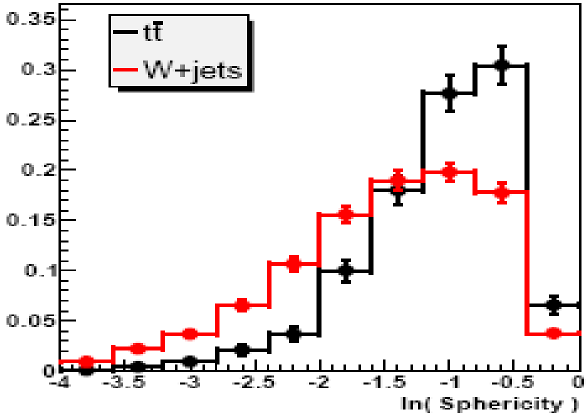
R = 0.5

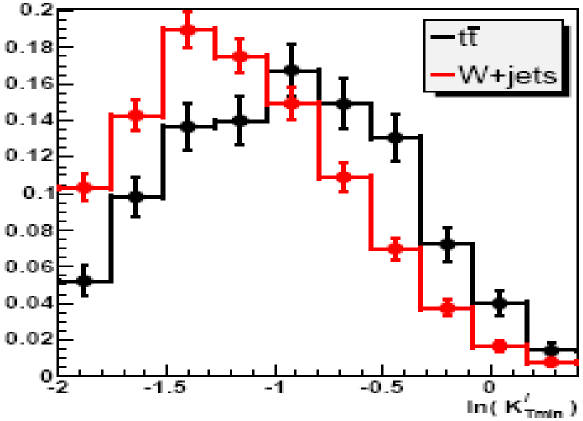


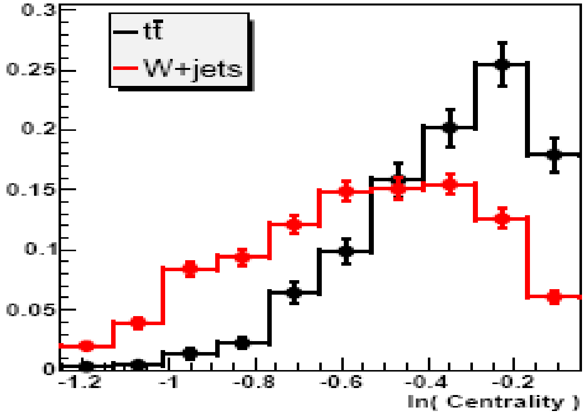
example

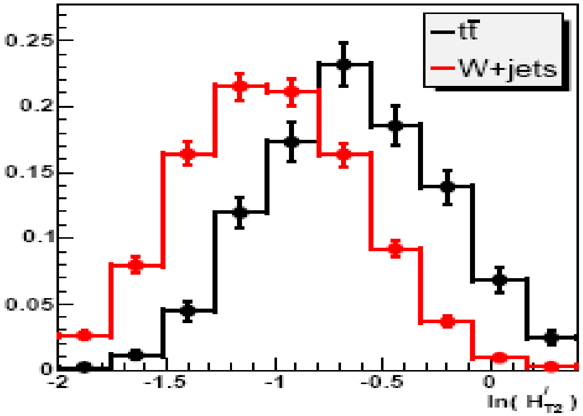
Treatment of 0 Tag Sample

- Total number of observed events in the 0 tag sample is too small to constrain R and σ
- Use topological discriminating variables and build likelihood









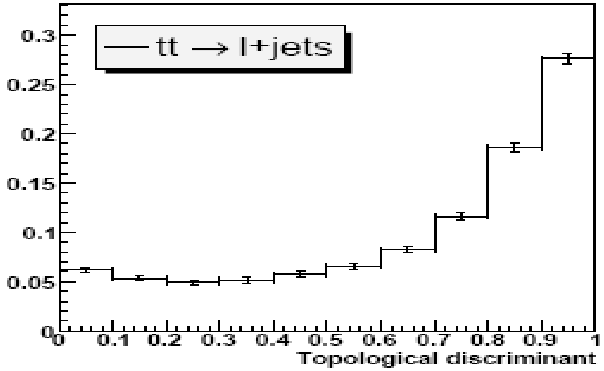
1. Sphericity
2. KTminP
3. Centrality
4. HT2P

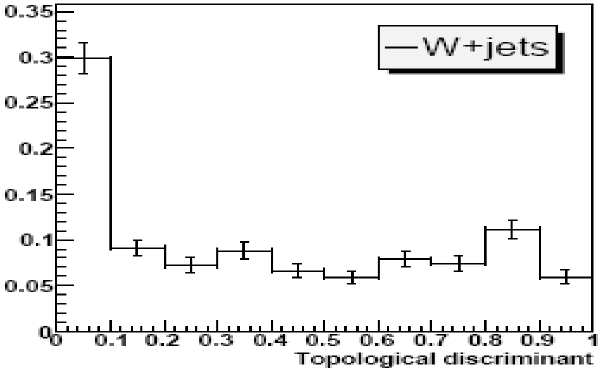
Treatment of 0 Tag Sample

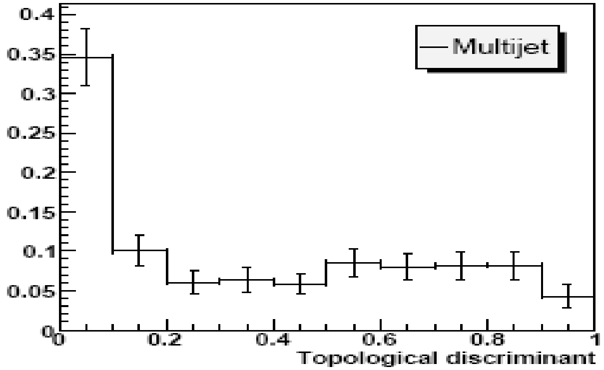
- Apply only in electron or muon with ≥ 4 jets and 0 tag sample

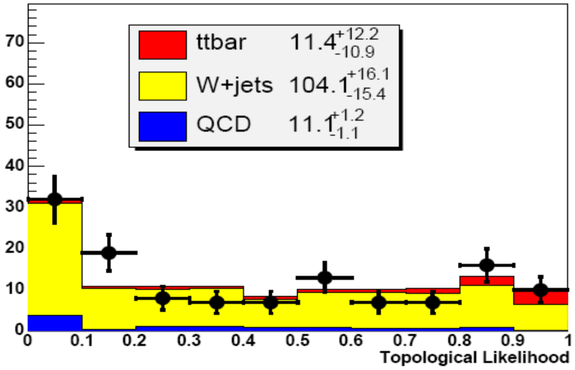
$$\mathcal{L} = \frac{S(x_1, x_2, ...)}{S(x_1, x_2, ...) + B(x_1, x_2, ...)}$$

$$\approx \frac{\prod_i S_i}{\prod_i S_i + \prod_i B_i} = \frac{\prod_i S_i/B_i}{\prod_i S_i/B_i + 1} = \frac{\exp\left(\sum_i (\ln \frac{S_i}{B_i})\right)}{\exp\left(\sum_i (\ln \frac{S_i}{B_i})\right) + 1}$$



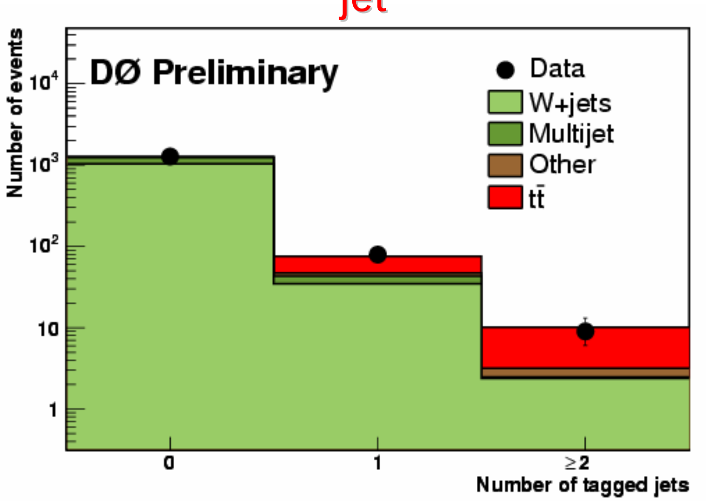




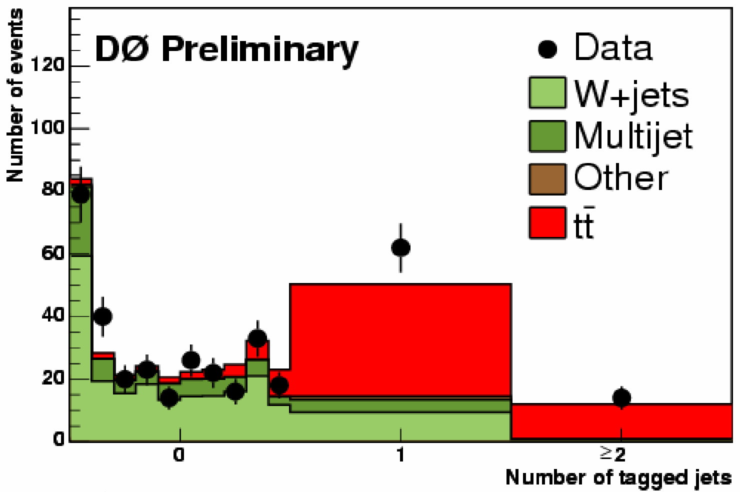


Final Binned Likelihood Fit

$N_{jet}=3$

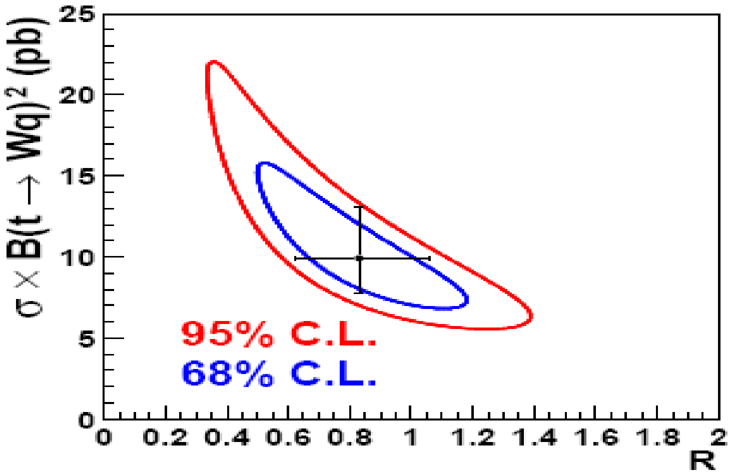


$N_{jet}\geq 4$

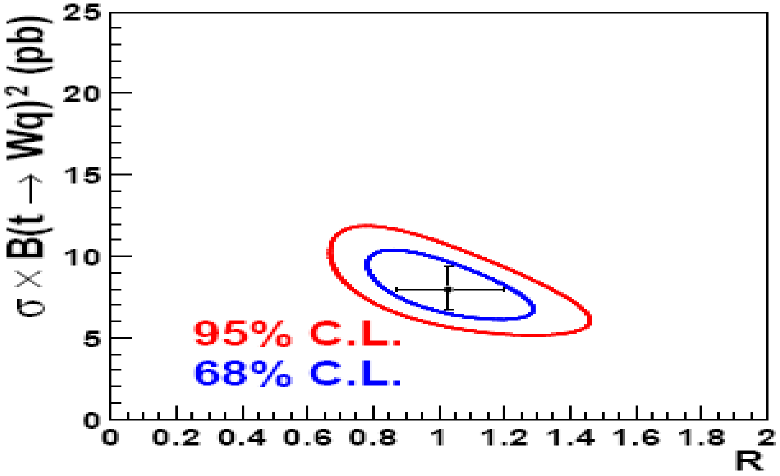


Improvement

Without 0-tag

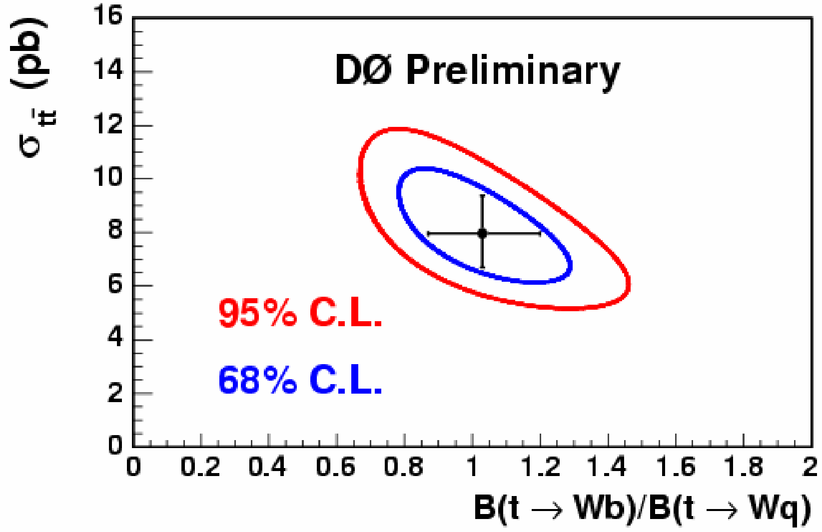


With 0-tag



Conclusions

- **Results**



- $\dfrac{Br(t \to Wb)}{Br(t \to Wq)} = 1.03^{+0.19}_{-0.17}\,(stat + syst)$
- $\sigma_{t\bar{t}} = 7.9^{+1.7}_{-1.5}(stat + syst) \pm 0.5(lumi)\,pb$

First measurement of R in DØ
Good agreement with the standard model expectation
Topological likelihood in the 0 tag samples make significant improvement