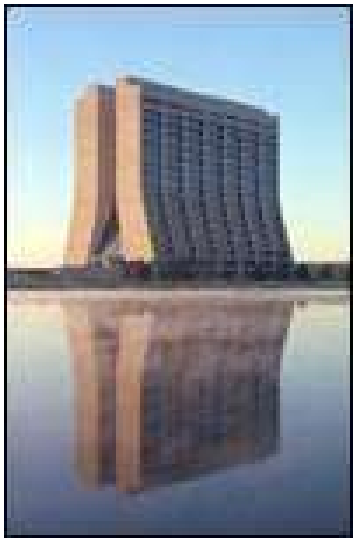
Measurement of the Top Quark Pair Production Cross Section in the Lepton+Jets Channel using a Topological Likelihood

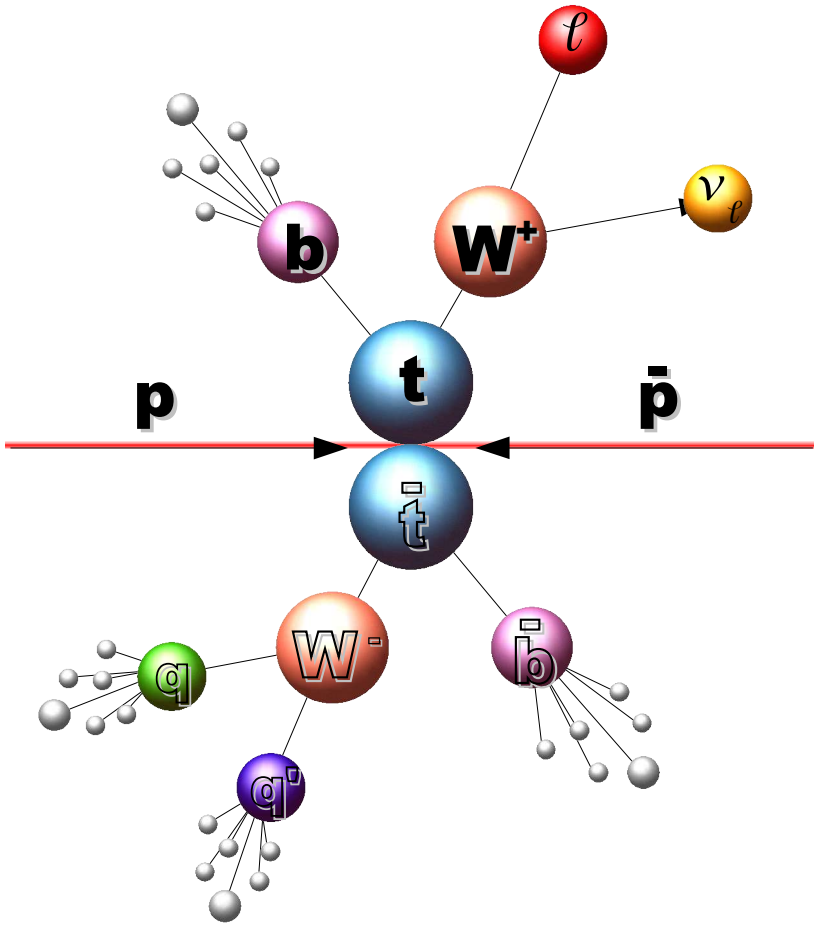
on behalf of the DØ Collaboration



with the DØ Detector in Run II at the Fermilab Tevatron at a center of mass energy of √s = 1.96 TeV

Tobias Golling - DPF - August 28th 2004

Overview



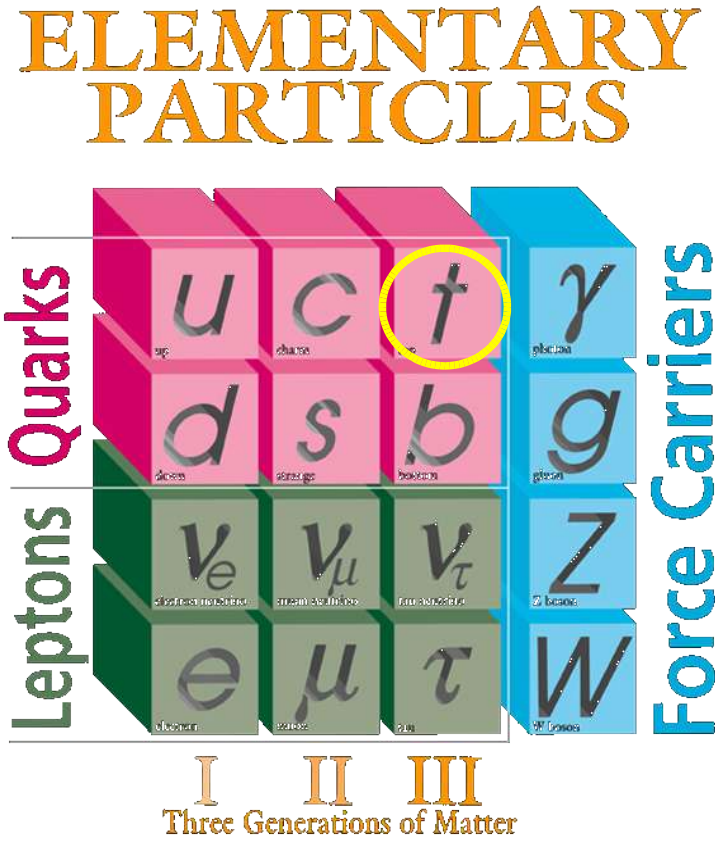
- Physics Motivation
- Top Quark Production and Decay

- Signature
- W+Jets Preselection
- Backgrounds
- Overview over the Analysis Method

- Topological Likelihood

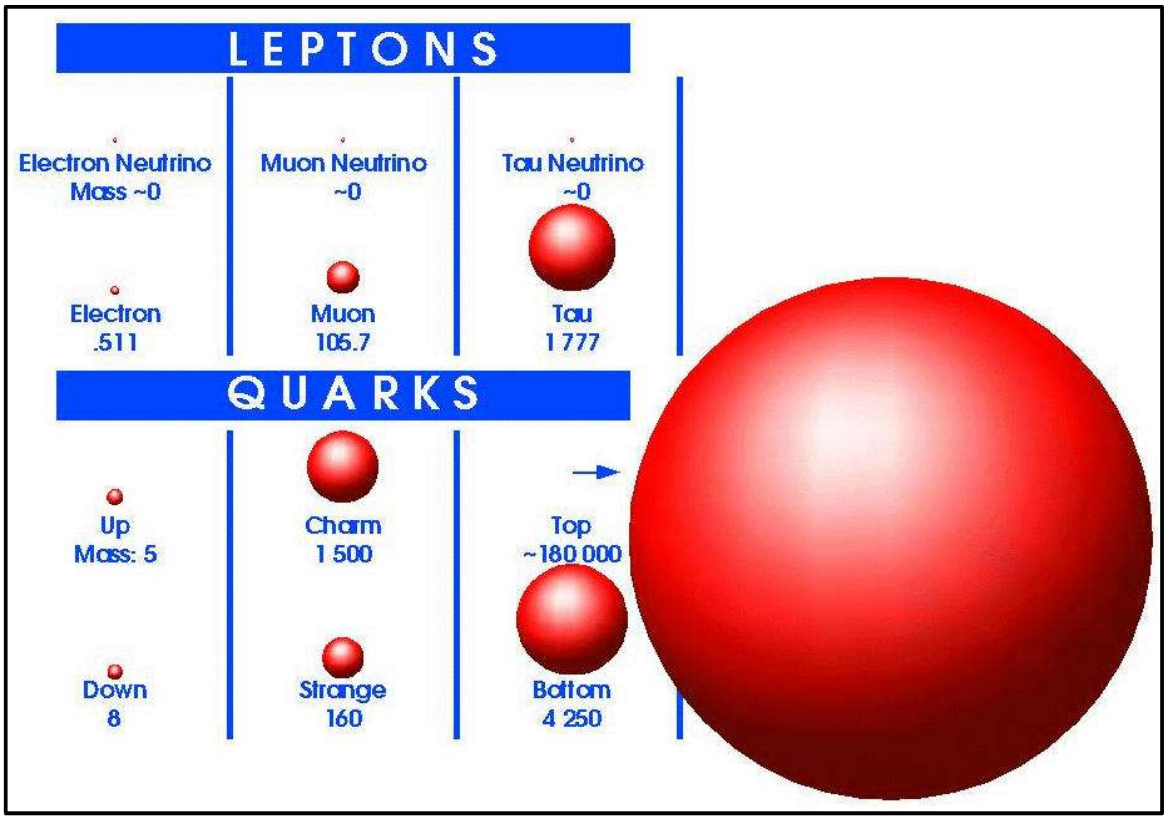
- Result, Summary & Outlook

The Top Quark in the Standard Model



Why is the Top Quark so interesting ?

- **completes the quark sector**
- **large mass** $m_{top} \sim 180\ GeV / c^2$
- **short lifetime** $\tau \sim 5 \cdot 10^{-25}\ s$
- **sensitive to physics beyond the Standard Model**



Discovery of the Top Quark in 1995 by the CDF and DØ Collaborations.

Top-antitop production cross section

- **test of perturbative QCD**
- **sensitive to**
  - **top decays to New Physics particles (e.g. charged Higgs)**
  - **Physics beyond the SM decaying to top-antitop**

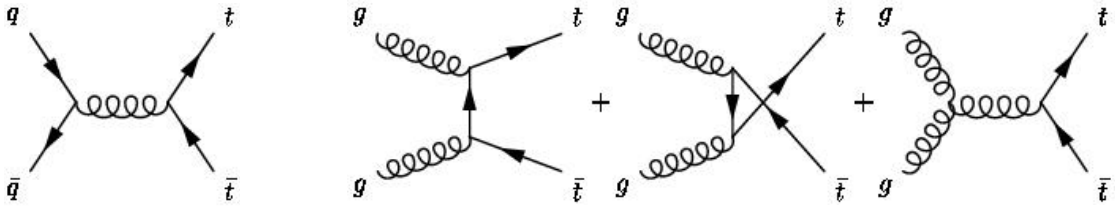
Higgs-Boson coupling to fermions: $\lambda_f \sim m_f$

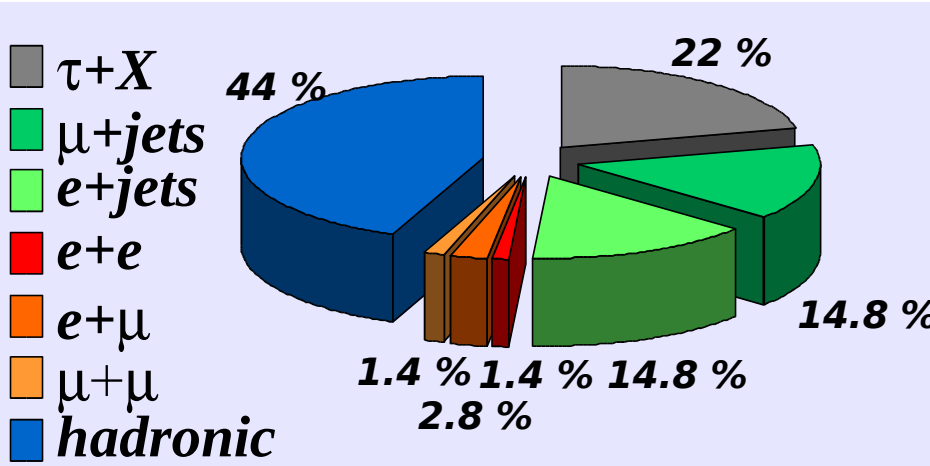
$\lambda_t \sim 1$

Top Quark Production & Decay

Top quarks mainly produced in pairs at Tevatron

qq (85%) **gg** (15%)





Top quarks decay predominantly (~100%) to a W-Boson and a b-quark

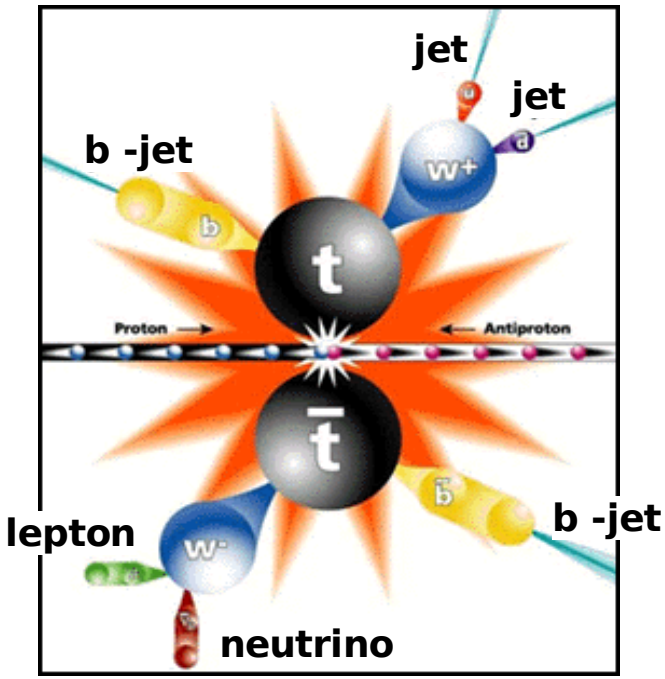
Top-Antitop Signatures determined by the W decay modes:

`dilepton channel'
~5% : 2 jets, 2 charged leptons, 2 neutrinos

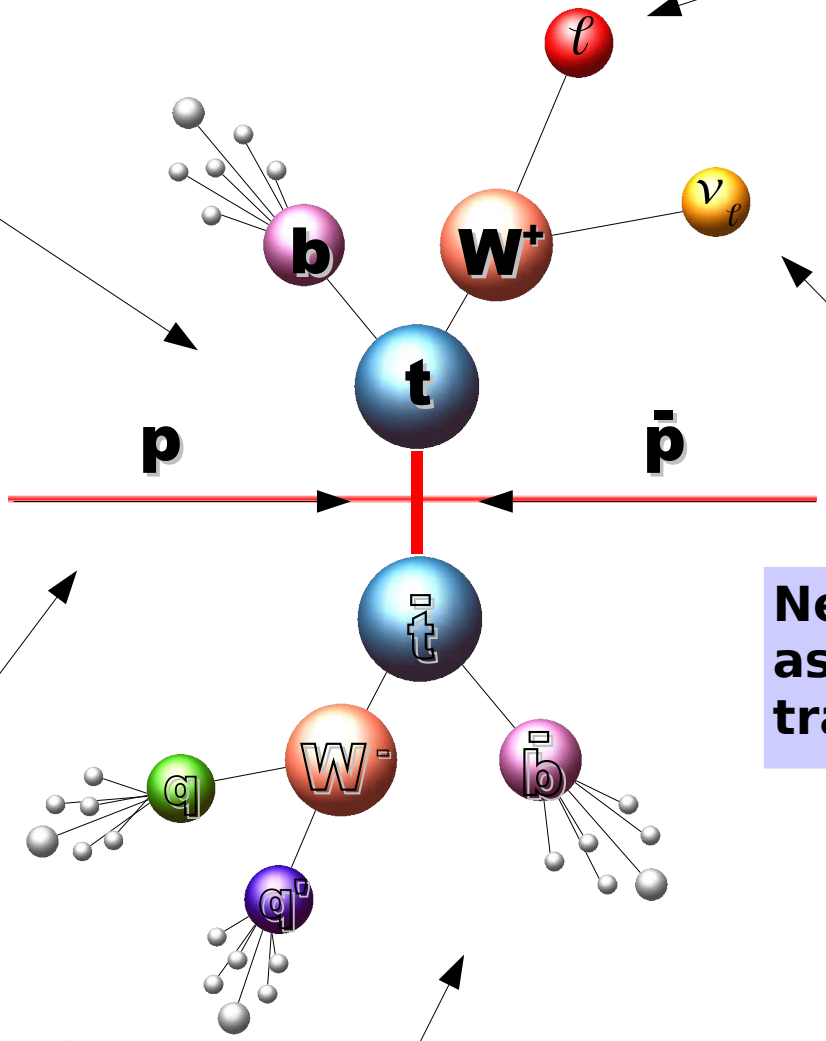
`lepton+jets channel'
~30%: 4 jets, 1 charged lepton, 1 neutrino

`all-jets channel'
~40%: 6 jets

always 2 jets are b-jets



Signature - W+Jets Preselection



Hard scatter primary vertex

Isolated high p_T lepton

Neutrino reconstructed as missing transverse energy

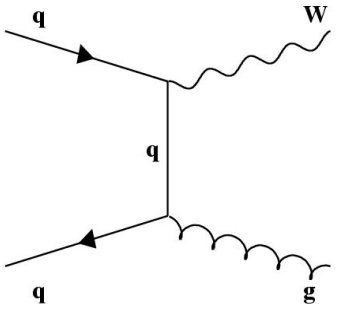
≥ 4 jets with p_T > 15 GeV and $|\eta|$ < 2.5

Backgrounds

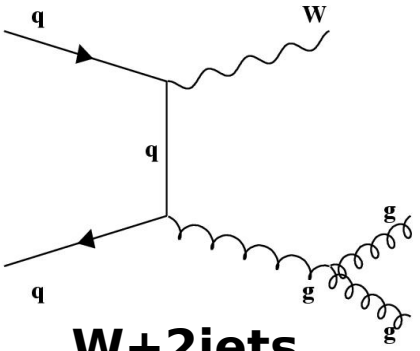
Physics Background:

Electroweak W production

- **W → $\ell+\nu_\ell$**
- **additional ≥ 4 jets from ISR**



W+1jet



W+2jets

...

Instrumental Background (fake lepton, fake MET):

QCD multijet production

Electron Fakes:

Electrons faked by (electromagnetic) jets

MET Fakes:

Misreconstructed calorimeter energy

Muon Fakes:

Muon-fakes are real muons which are fakely isolated (muons from semileptonic b-decays, where the b-jet is not reconstructed)

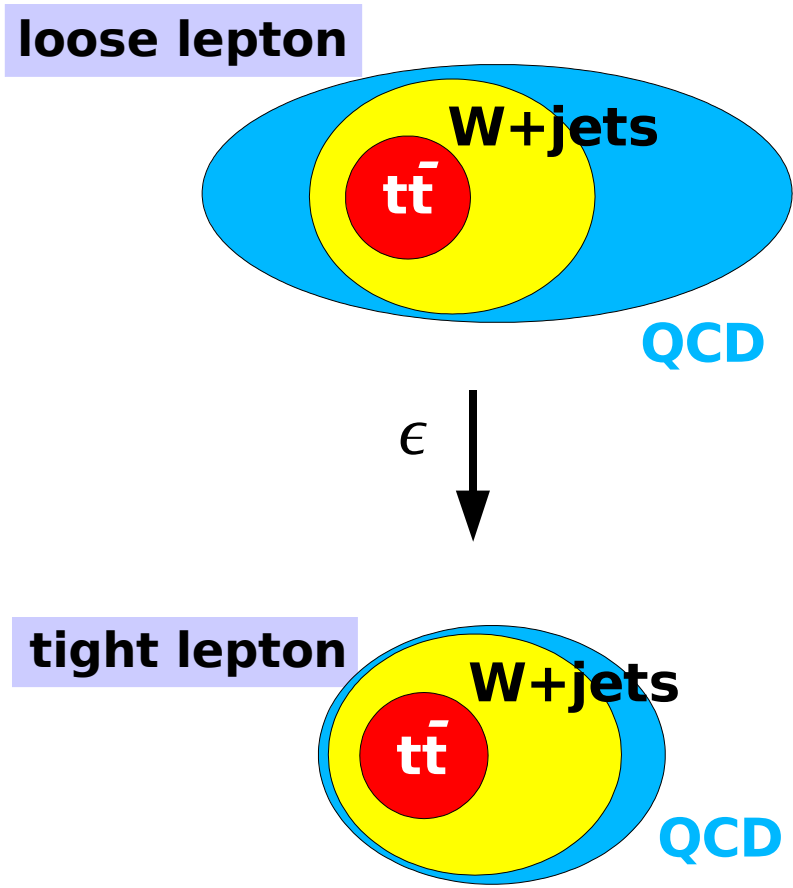
Determination of QCD Background

- Determine instrumental QCD multijet background purely from data

$$N_{loose} = N_{QCD} + N_{W+ttbar}$$

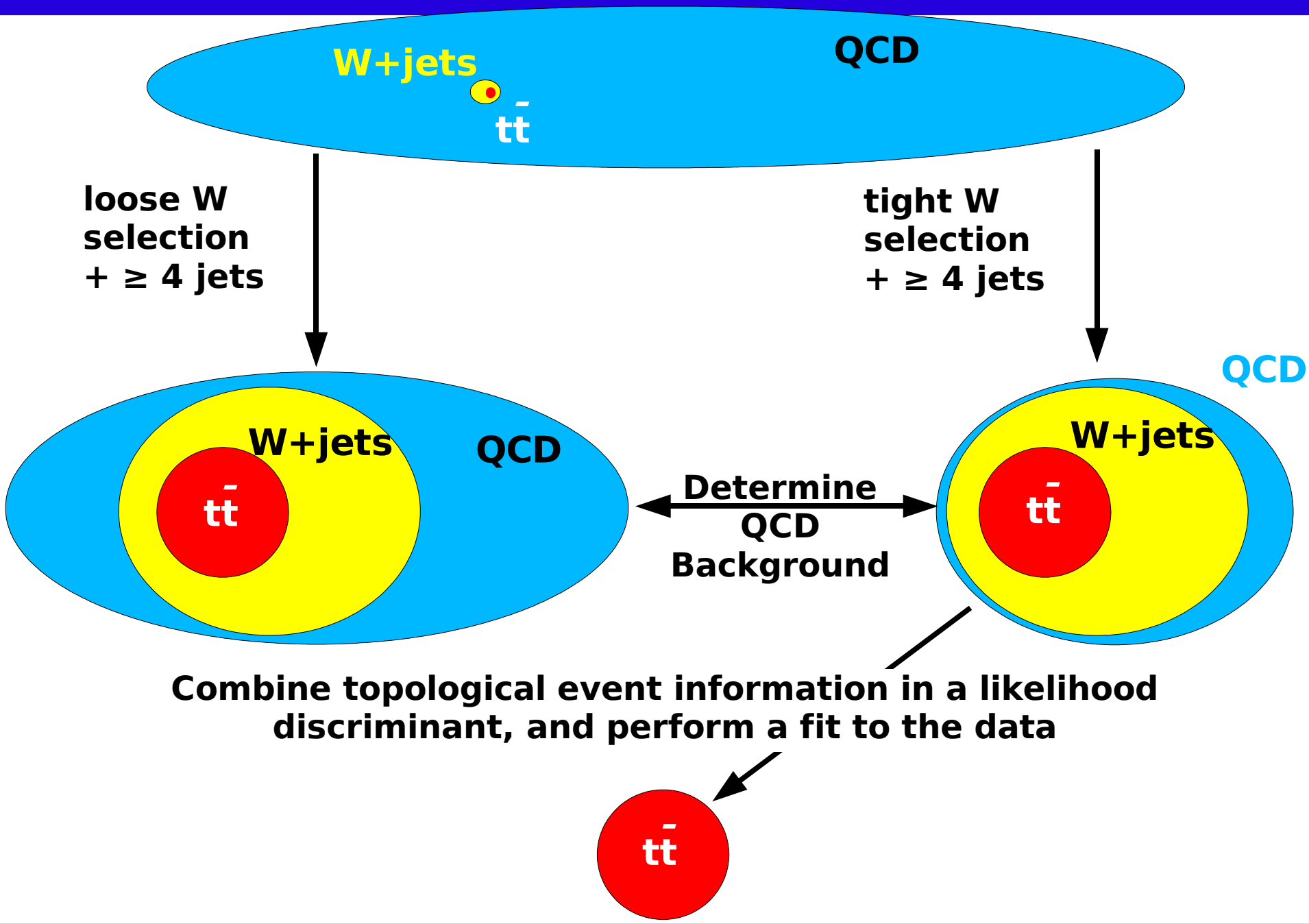
$$\epsilon \downarrow \quad \epsilon_{QCD} = 8\% \downarrow \quad \epsilon_{W+ttbar} = 82\% \downarrow$$

$$N_{tight} = \epsilon_{QCD} * N_{QCD} + \epsilon_{W+ttbar} * N_{W+ttbar}$$



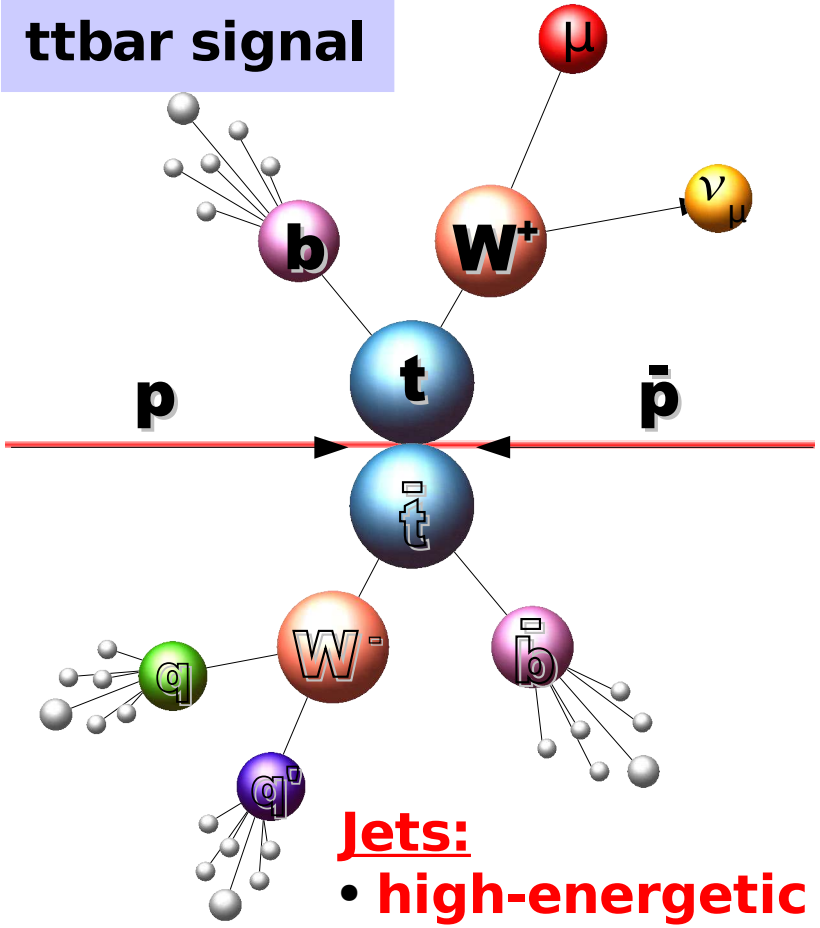
- Solve linear system of equations for N_{QCD} and $N_{W+ttbar}$

Topological Analysis Overview



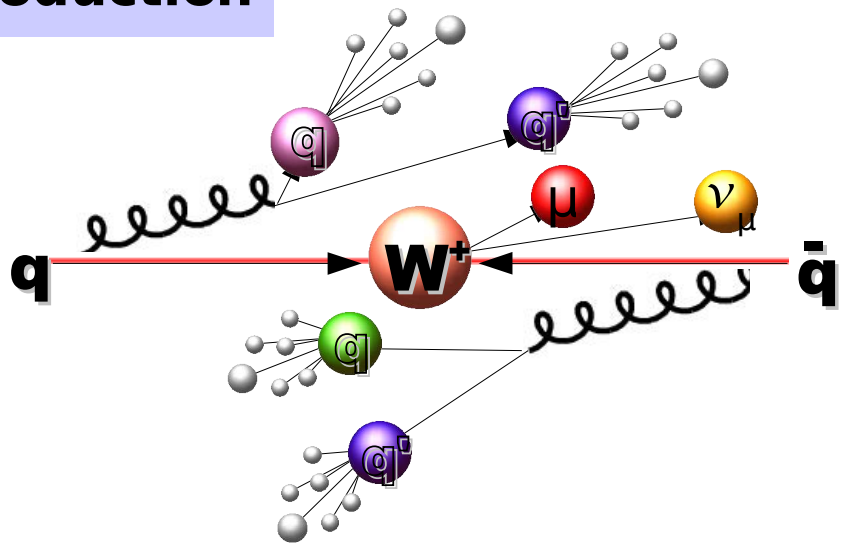
Event Topology

ttbar signal



Jets:
- **high-energetic**
- **isotropic**

Electroweak W production



Jets dominated by QCD-Bremsstrahlung:
- **low-energetic**
- **in the forward region**

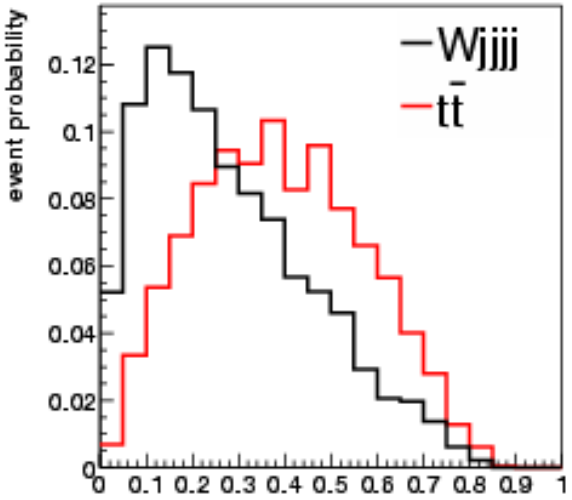
→ **Define variables which describe the event topology**

Criteria: **- Good separation power**
- Low sensitivity to the jet energy scale (dominant systematic uncertainty)

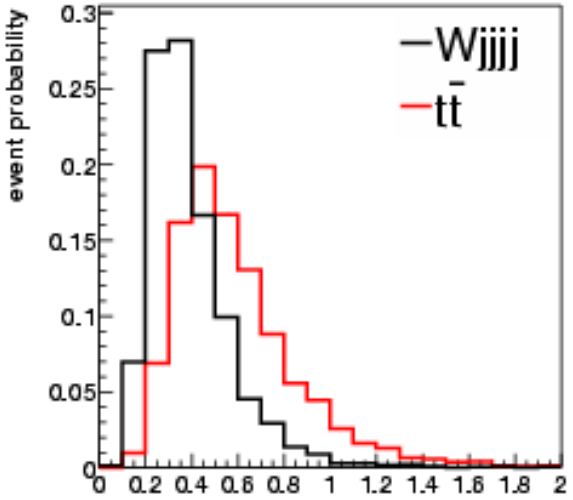
Topological Variables

Variables describing the angular distributions of the physics objects in the final state:

- ***Sphericity***
- ***Aplanarity***



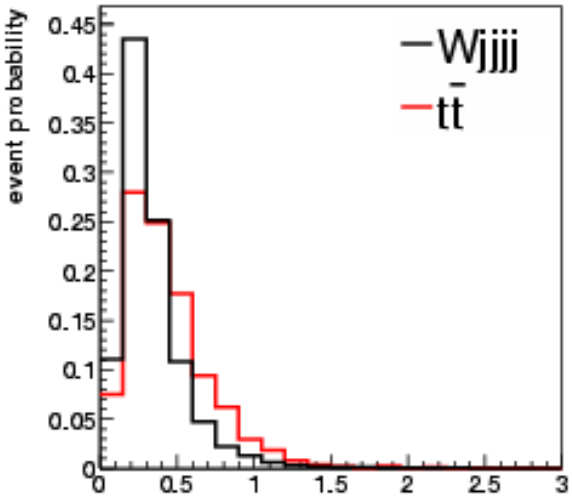
Sphericity



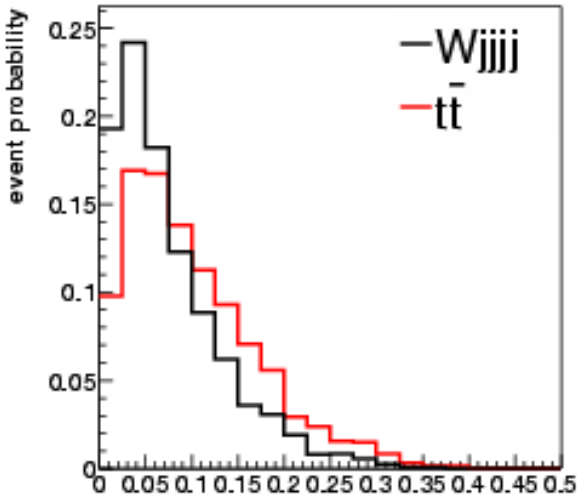
H_T2'

Ratios of energy dependent variables:

- ***H_T2'*** **(describes centrality)**
- ***K_{Tmin}'*** **($=\Delta R_{min}(jet,jet)\cdot E_T^{min}/E_T^{W}$)**



K_{Tmin}'



Aplanarity

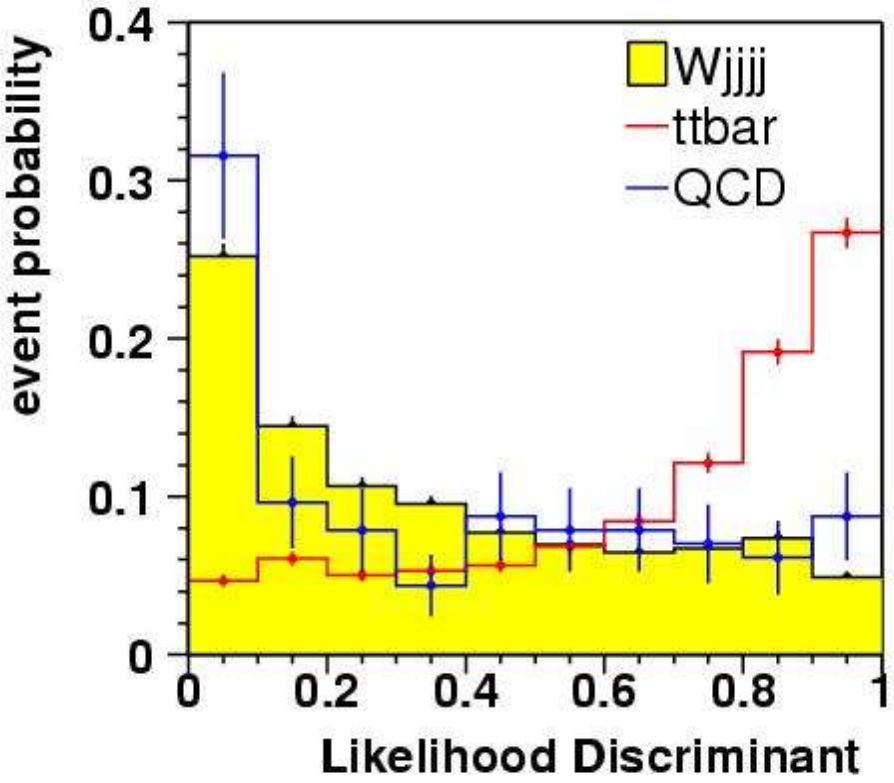
Likelihood Discriminant (LD)

$$LD = \frac{\prod_i S_i}{\prod_i S_i + \prod_i B_i}$$

S_i = ttbar signal

B_i = W+jets background

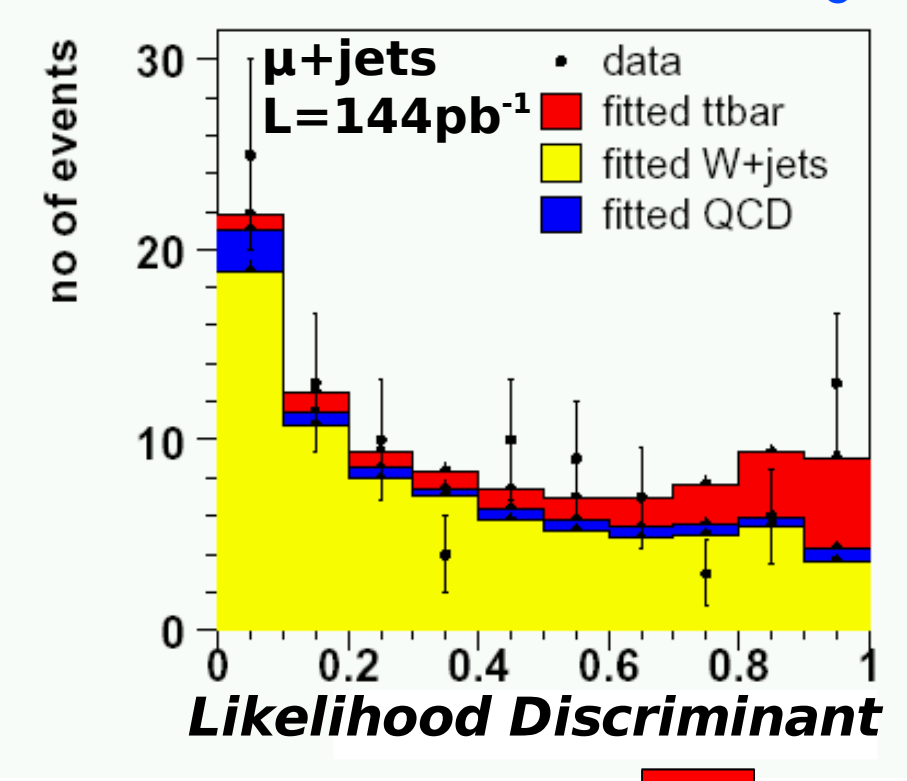
i runs over the 4 topological variables

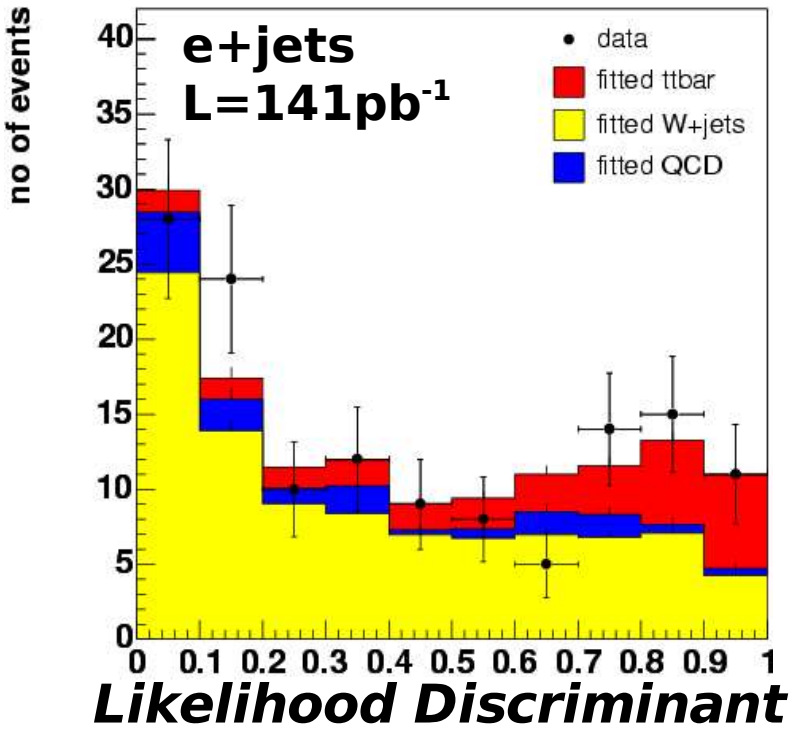


- **Describe data by a linear combination of ttbar, W+4jet and multijet (QCD)**
- **Constrain QCD by using the loose and tight system of equations**
- **Fit the relative fractions**

Likelihood Fits for μ+Jets & e+Jets

Fit linear combination of QCD (inverted tight selection in data), W+4jet and ttbar to data

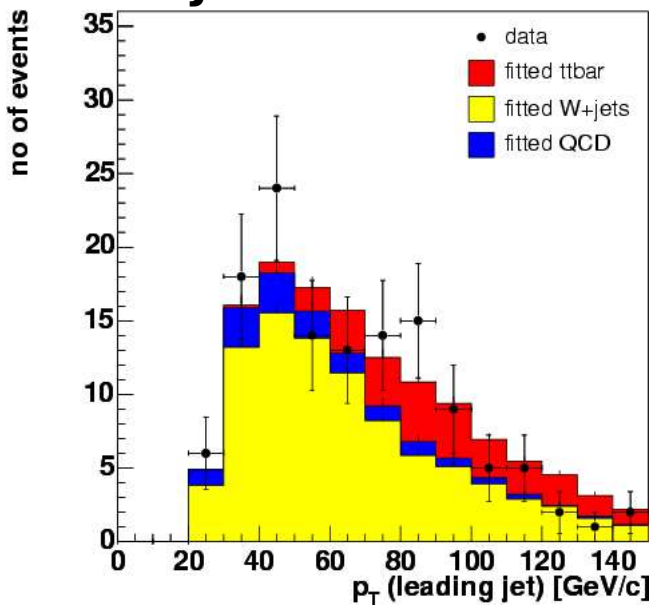


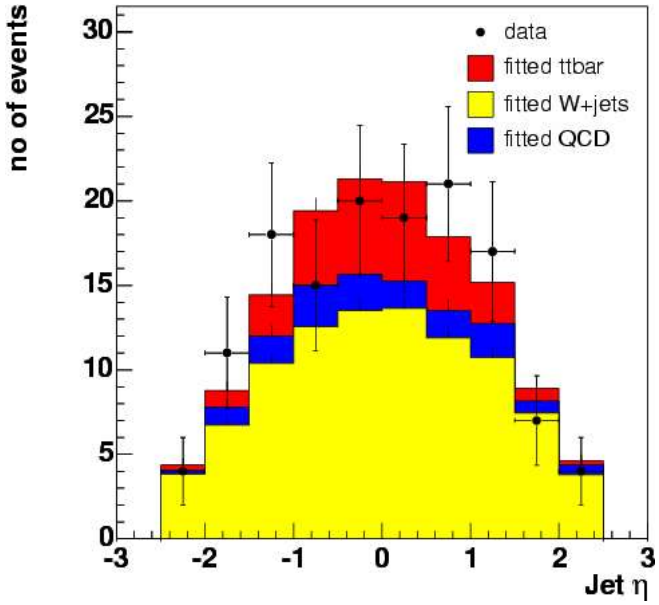


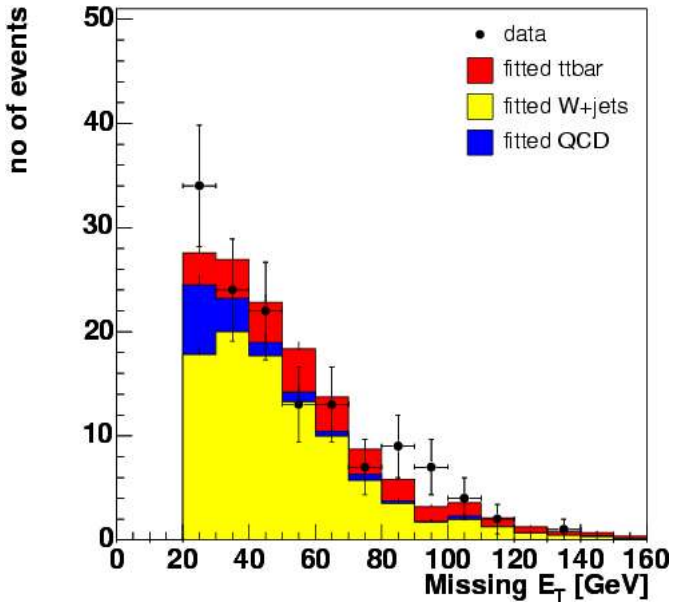
	muons	*electrons*
Nev	*100*	*136*
fitted N^{W}	*74.7 + 12.7 – 12.0*	*94.6 + 15.8 - 15.0*
fitted N^{QCD}	*7.1 + 0.9 – 0.9*	*14.1 + 1.2 - 1.2*
fitted N^{tt}	*17.8 + 9.9 – 8.7*	*27.5 + 12.7 - 11.7*

Kinematic Distributions

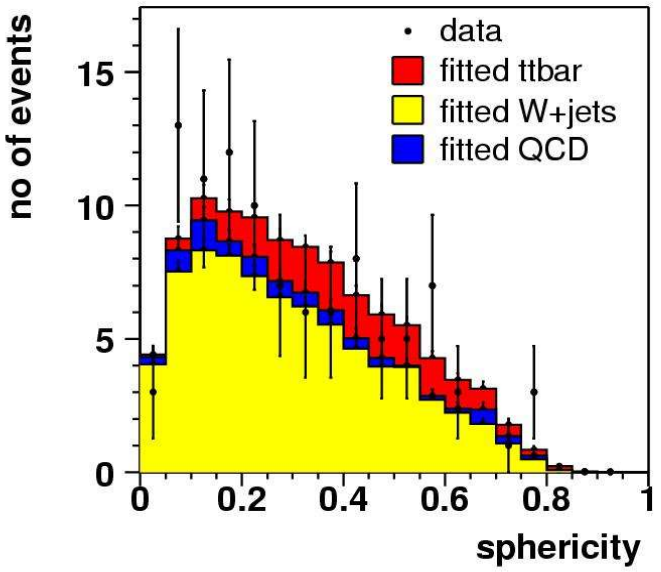
e+jets

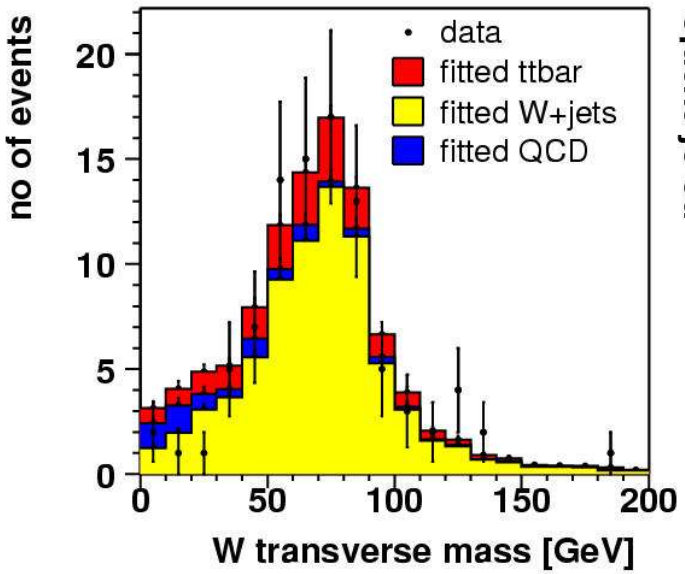


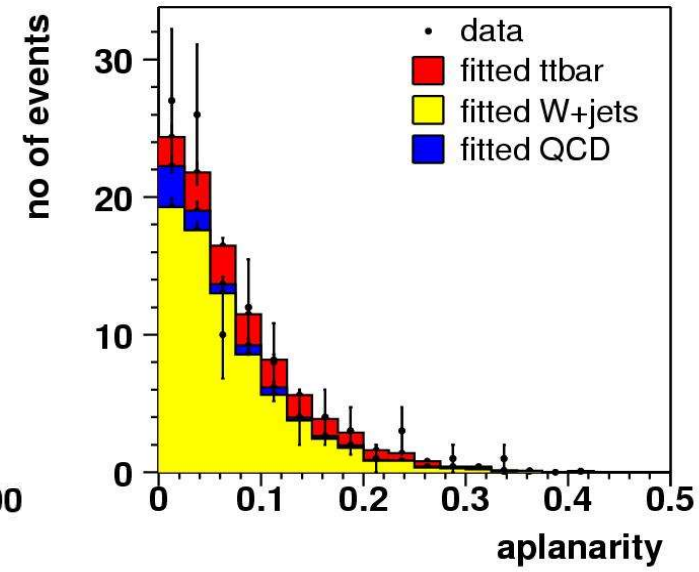




μ+jets





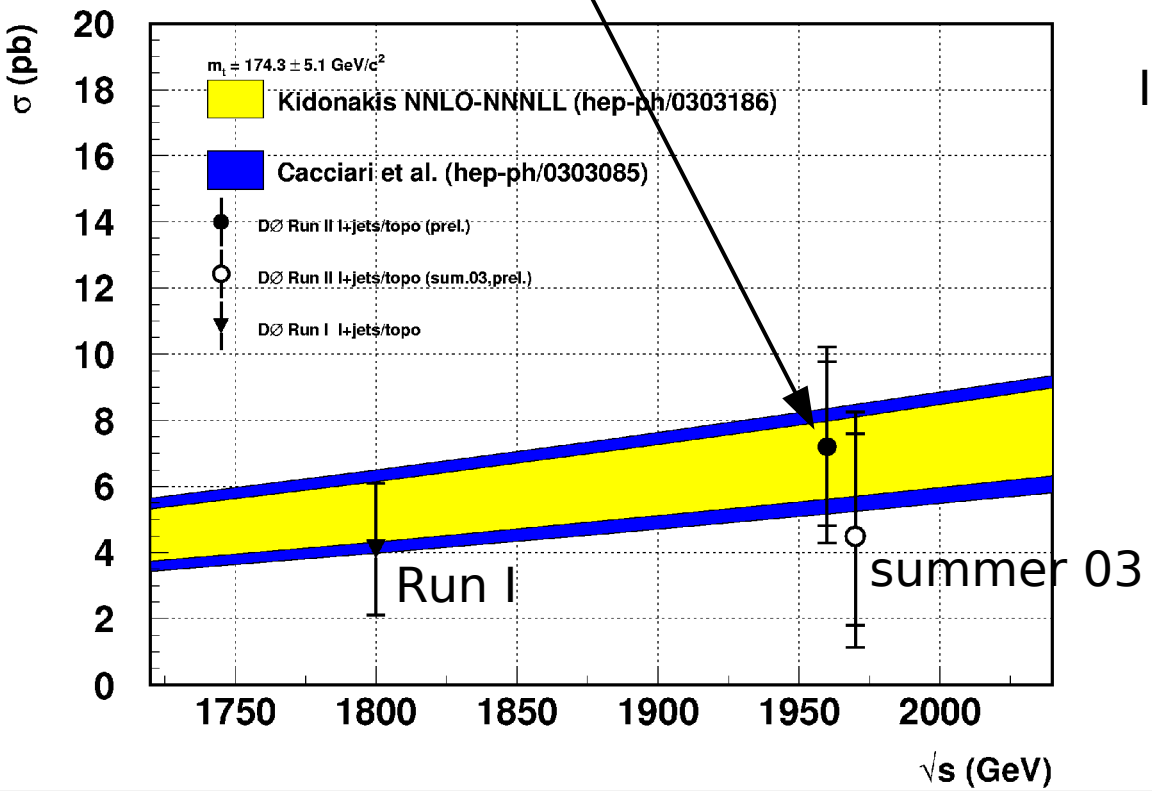


Result
Comparison with Run I & Summer 03

$$\sigma^{e+jets}_{p\bar{p}\to t\bar{t}+X} = 8.8^{+4.1}_{-3.7}(stat)^{+1.6}_{-2.1}(syst)\pm 0.6(lumi)\,pb$$

$$\sigma^{\mu+jets}_{p\bar{p}\to t\bar{t}+X} = 6.0^{+3.4}_{-3.0}(stat)^{+1.6}_{-1.6}(syst)\pm 0.4(lumi)\,pb$$

$$\sigma^{l+jets}_{p\bar{p}\to t\bar{t}+X} = 7.2^{+2.6}_{-2.4}(stat)^{+1.6}_{-1.7}(syst)\pm 0.5(lumi)\,pb$$

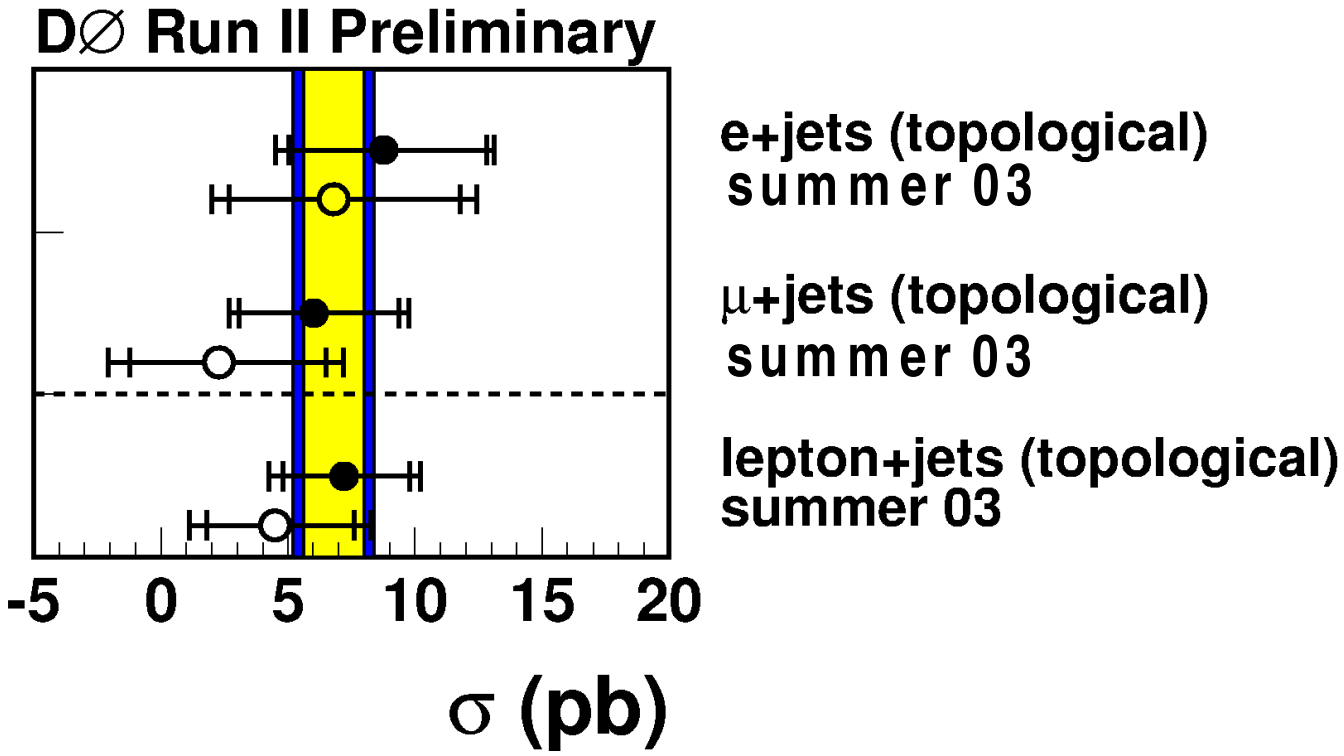


Integrated Luminosity = 143 pb^{-1}

Dominant uncertainties:

- **Jet energy scale**
- **Jet reconstruction efficiency**

Summary & Outlook



Summer 03 → NOW:
Large improvement in statistical and systematic uncertainties

Outlook:
- **Publication this fall**
- **L = 230 pb^{-1}**
- **Improved systematics**