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Weak Interactions and Neutrinos
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Tevatron Results on Top

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on behalf of the
DØ and CDF Collaborations

Outline

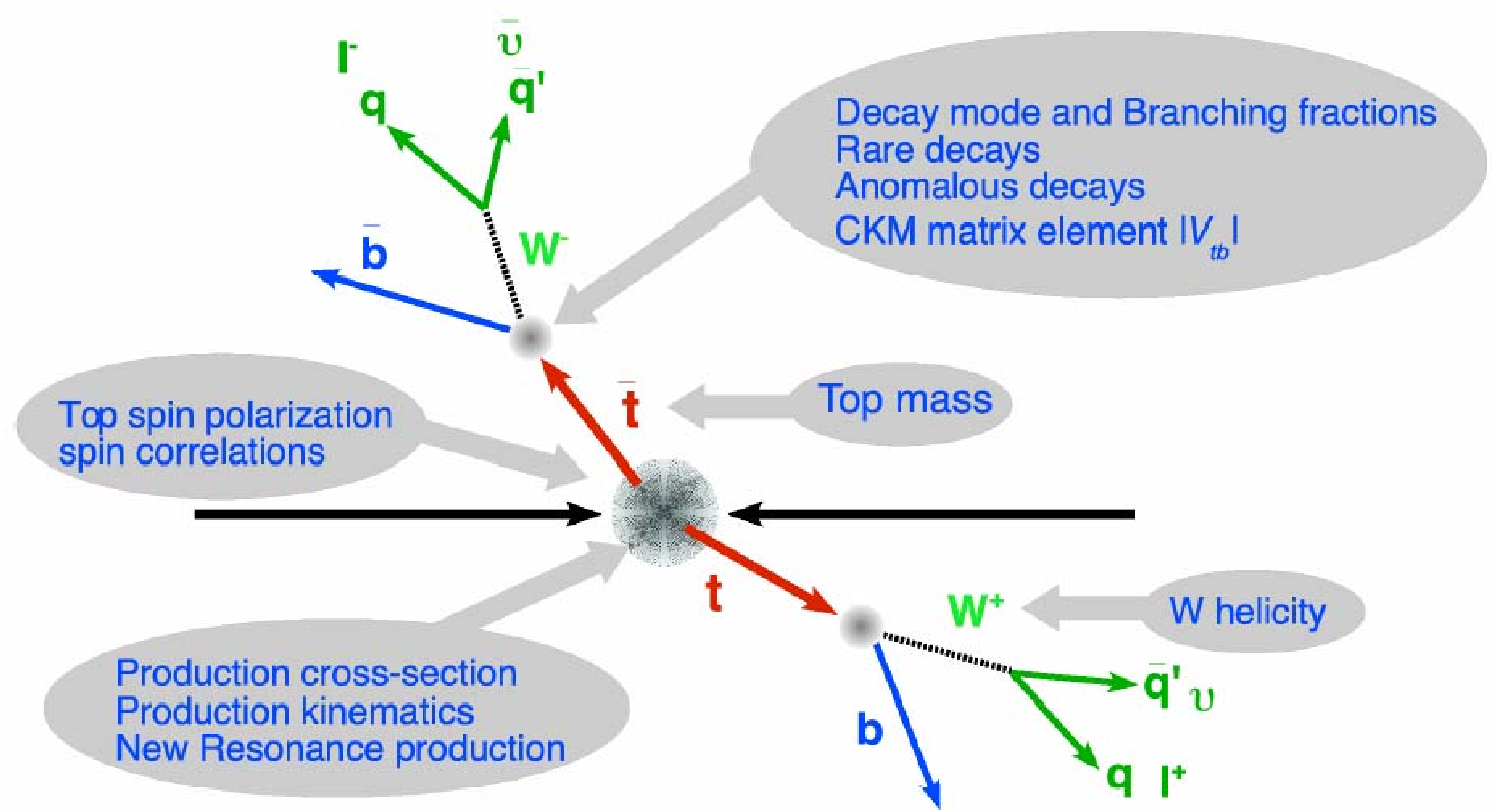
- Introduction & Motivation
- Top Pair Analyses:
  - Final States
  - Top Mass
  - Cross-section
  - Top Properties
- **Evidence** for Electroweak Single Top Production
- Conclusions & Outlook

Introduction & Motivation

Tevatron:

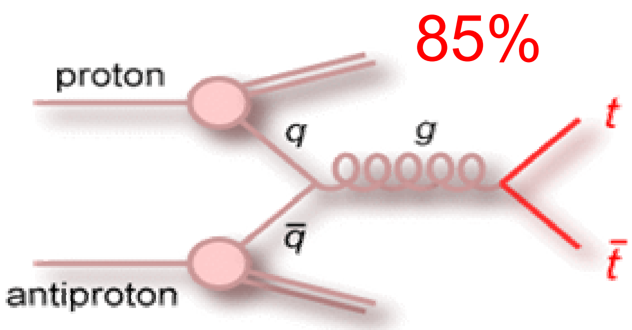
- Only place to make top quarks.
- Top production:
  - Pair production
  - Electroweak single top production
- RunII:
  - 1.8 fb^{-1} delivered in each experiment.
  - Record luminosities acheived ($\sim 250 \times 10^{30} cm^{-1} s^{-2}$)

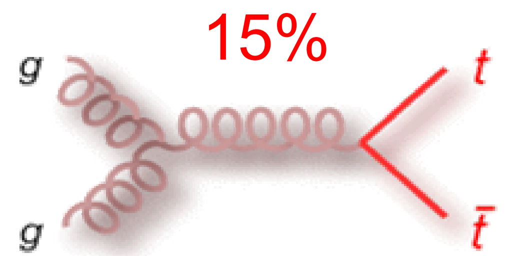
Introduction & Motivation



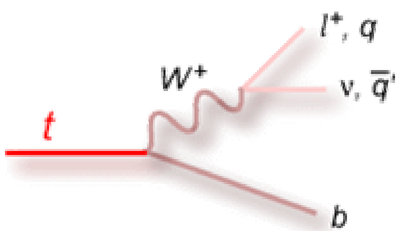
Top Pair Analyses

Final States

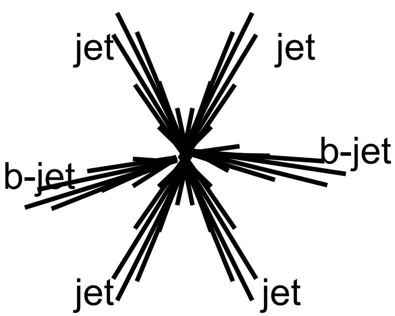




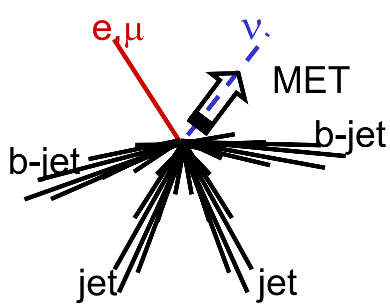
SM Decay:



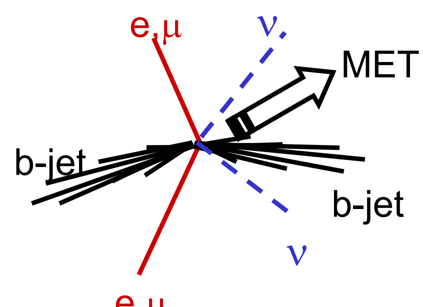
Three different final states:



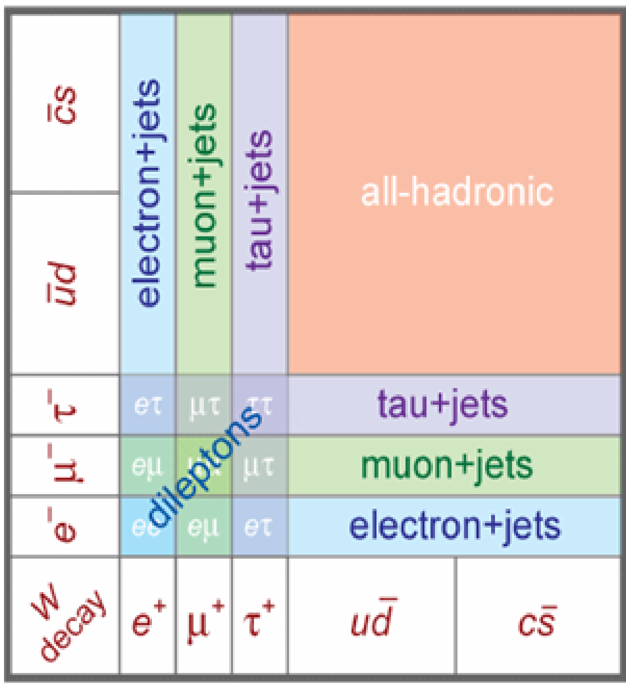
All-hadronic
(BR~46%)
Huge bkgd



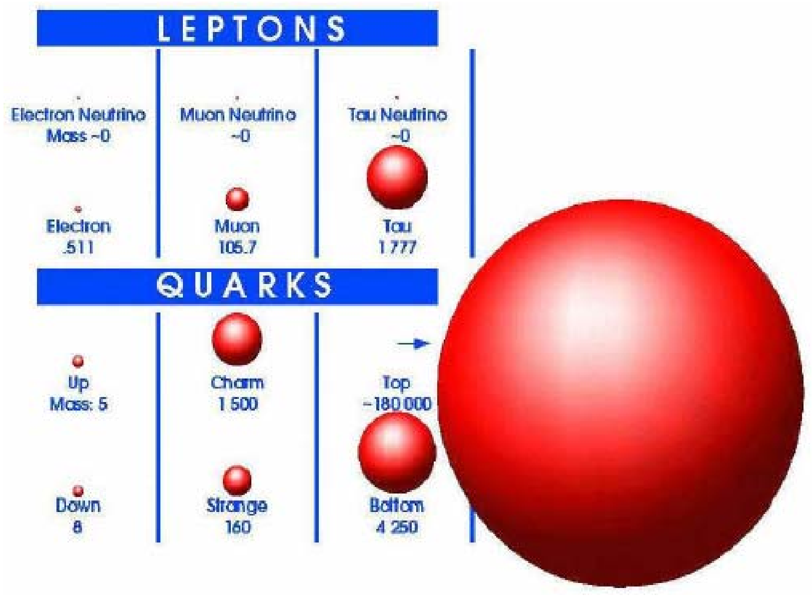
Lepton+jets
(BR~30%)
Moderate bkgd



Dilepton
(BR~5%)
Low bkgd



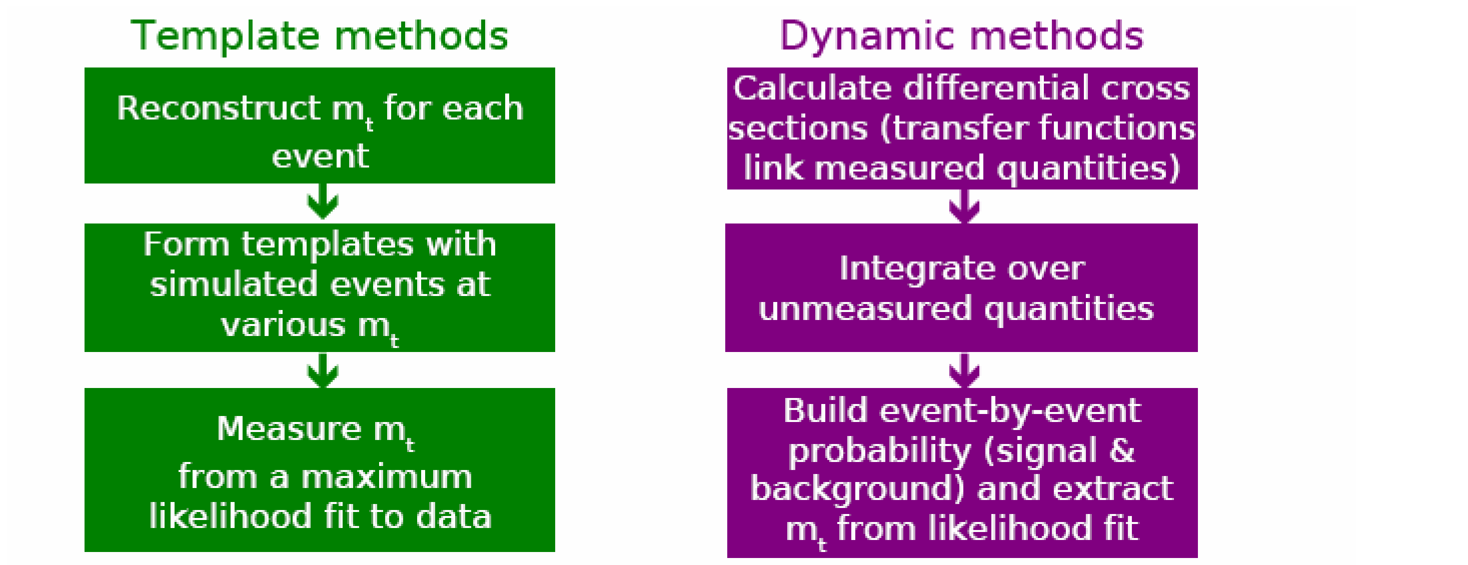
Top Mass



- Motivation:
  - Top is the heaviest known elementary particle.
  - Precision m_t and m_W measurements help constrain Higgs mass.
  - Sensitive probe to Physics beyond the Standard Model.

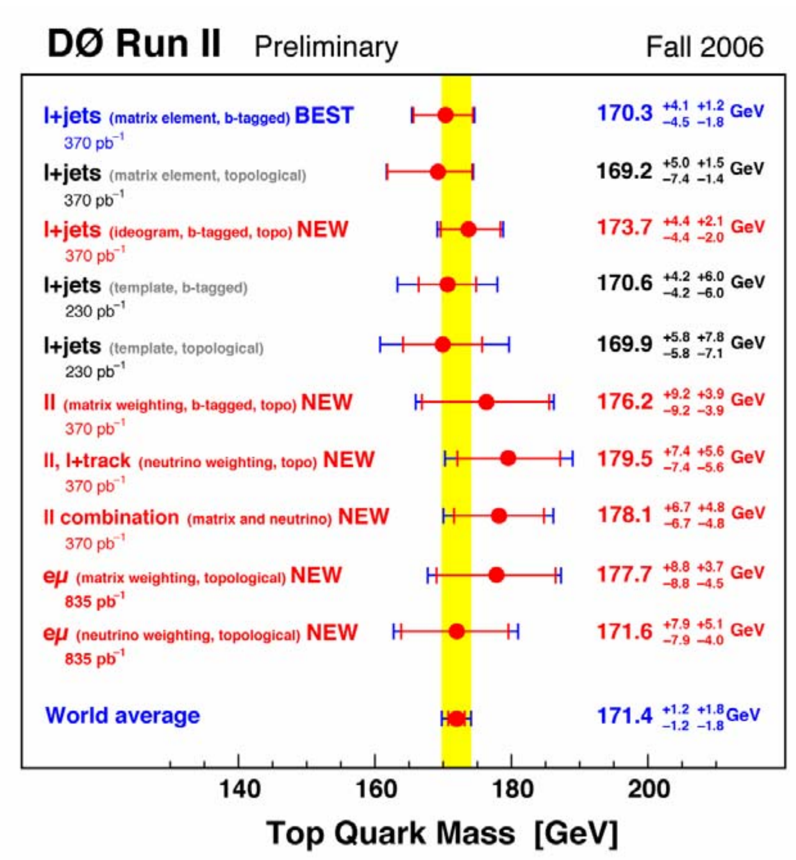
Top Mass

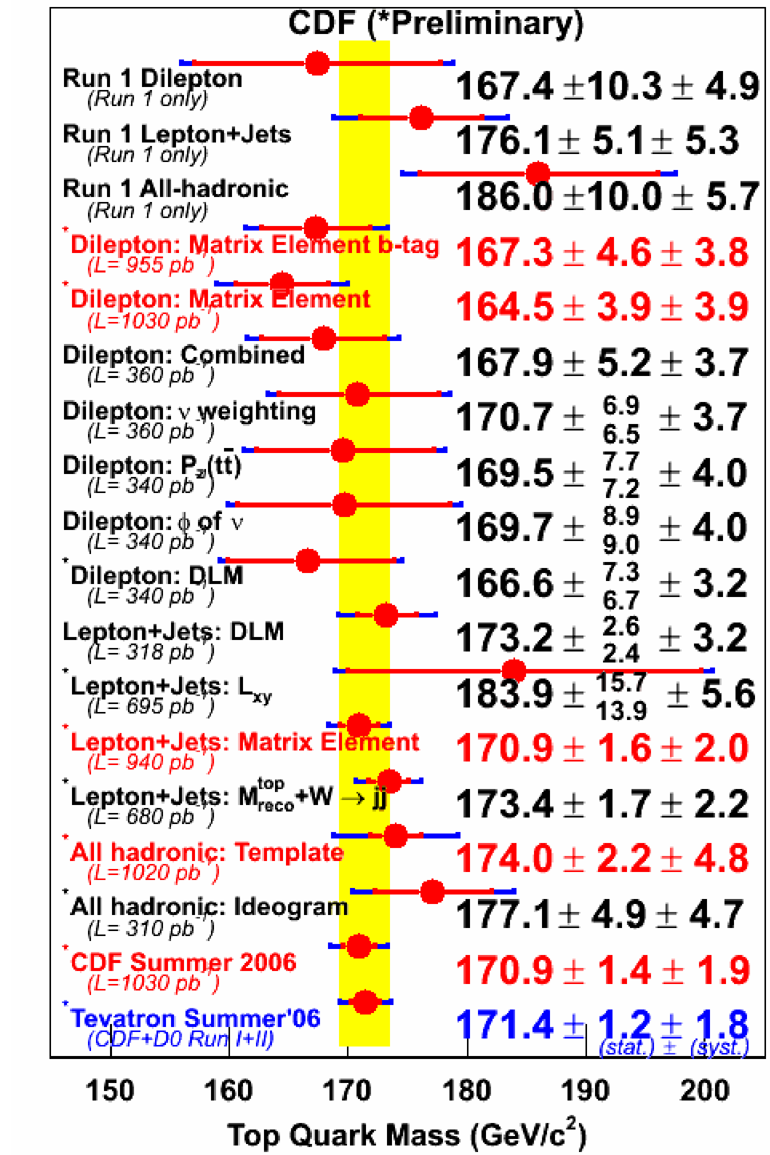
- Mass extraction methods:
  1. Select signal-like events.
  2. Reduce backgrounds (b-tagging, cuts, likelihoods).
  3. Reconstruct the final state (combinatorics, fit).
  4. Use sophisticated technique to extract top mass:



Top Mass

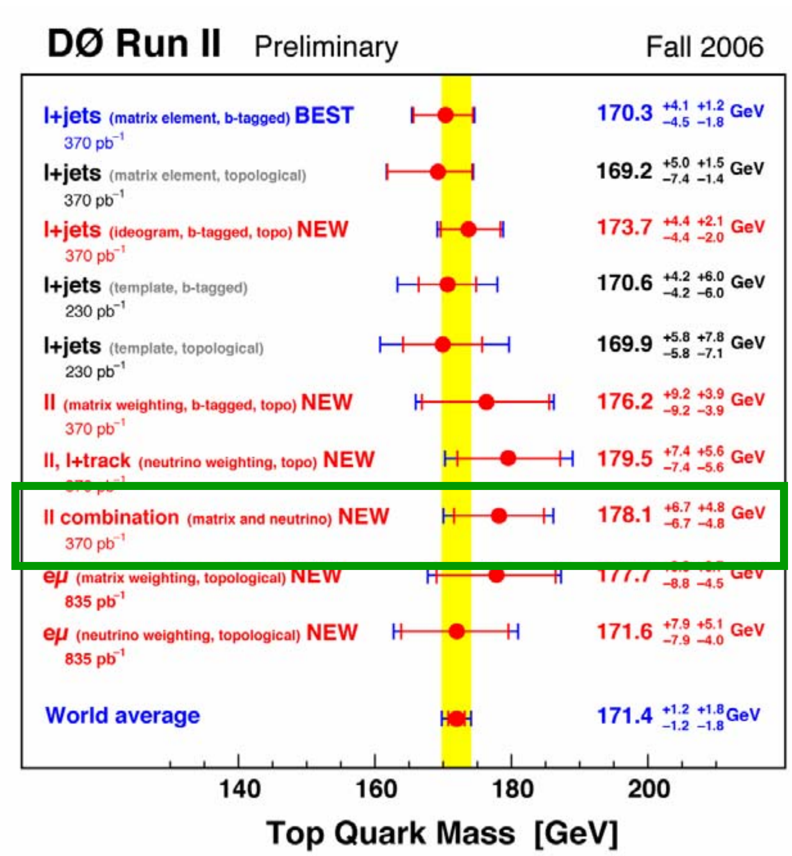
- Many analyses:

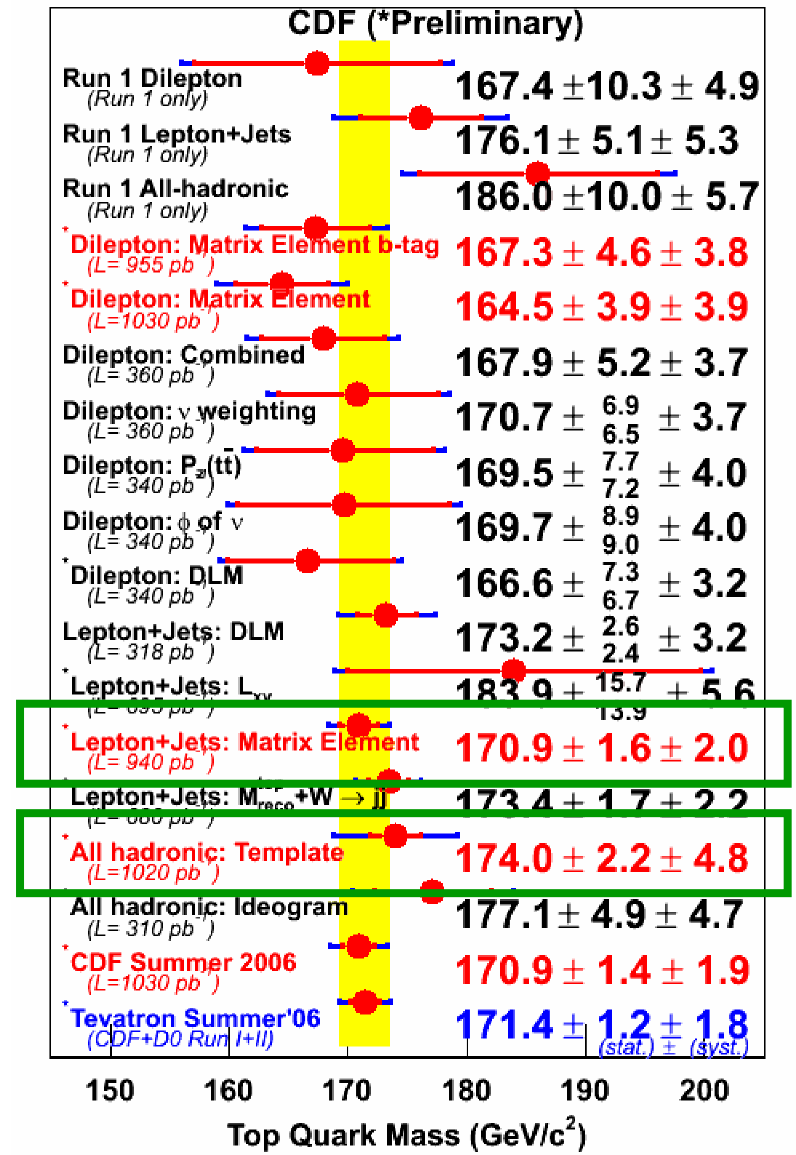




Top Mass

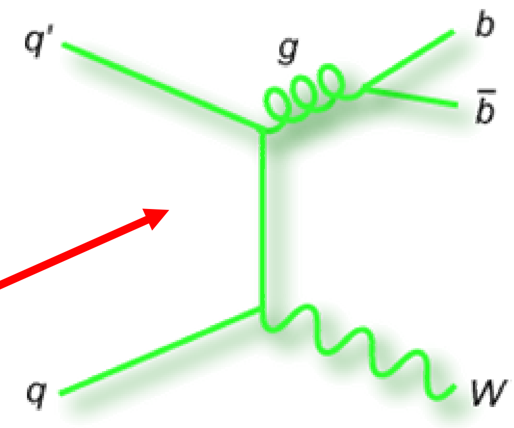
- Many analyses:





Matrix Element

- Most precise measurements in CDF and DØ use ME with in situ W→jj JES calibration.
- Lepton+jets:
  - CDF Event selection:
    - 1 e(μ): $E_T(p_T)$ > 20 GeV
    - 4 Jets: E_T > 15 GeV, $|\eta| < 2.0$
    - MET > 20 GeV
    - ≥1 b-tagged jet
    - QCD veto
  - Main Background: W+jets



- Method:
  - For every event calculate the probability to be signal or background:

$$P_{t\bar{t}}(\vec{x};m_t,JES)=\frac{1}{\sigma}\int dq_1 dq_2 f(q_1) f(q_2)\, d\sigma_{t\bar{t}}(\vec{y};m_t)\, W(\vec{x},\vec{y};JES)$$

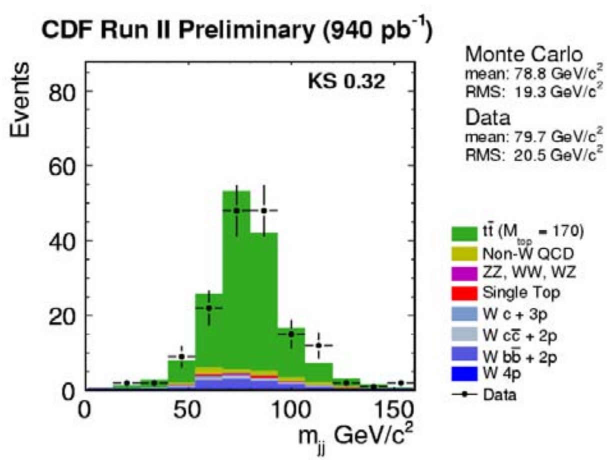
Parton distribution functions | Differential cross section (LO matrix element) | Transfer Function: maps parton level (y) to reconstructed variables (x)

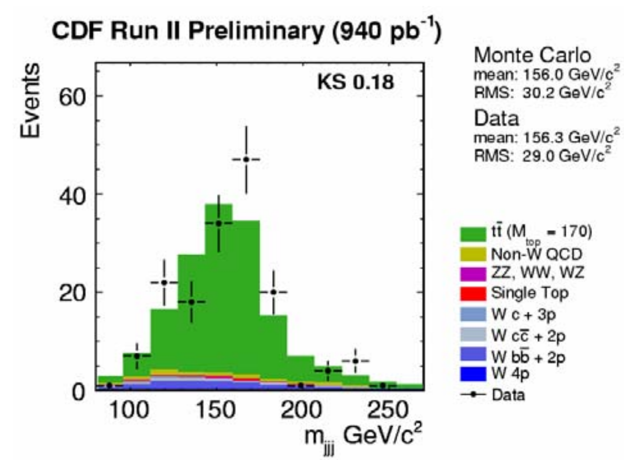
  - Use maximum likelihood to fit simultaneously m_t, JES, and C_s (signal fraction)

$$L(C_s,m_t,JES)\propto\prod_{events}\left(C_s P_{t\bar{t}}(m_t,JES)+(1-C_s)P_{W+jets}(JES)\right)$$

Matrix Element

- Data and Model agree well:



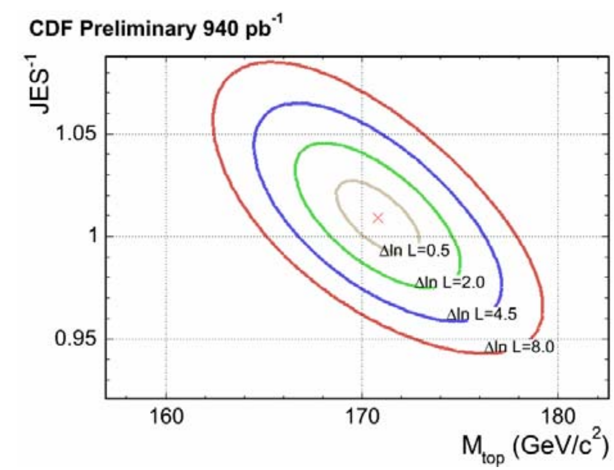


- Result (940 pb^{-1}):

$$m_t = 170.9 \pm 1.6 \pm 2.0\ GeV/c^2$$

Error: **1.5%**

Most precise measurement in the World



Dilepton Neutrino Weighting

- 18 independent kinematic variables (6 particles momenta)
- 14 measured quantites (momenta of ℓ's, b's and E_{xmiss}, E_{ymiss})
- Use 3 constraints m_{W+}, m_{W-} and $m_t = m_{tbar}$
- Drop MET, and use templates of m_t and grid of ν rapidities
- The ν's four-momenta can be calculated and compared to MET:

$$W = \frac{1}{N}\sum_{i=1}^{N} \exp\left(\frac{-(p_{x,i}^{\nu} - MET_x)^2}{2\sigma_{E_x}^2}\right) \exp\left(\frac{-(p_{y,i}^{\nu} - MET_y)^2}{2\sigma_{E_y}^2}\right)$$

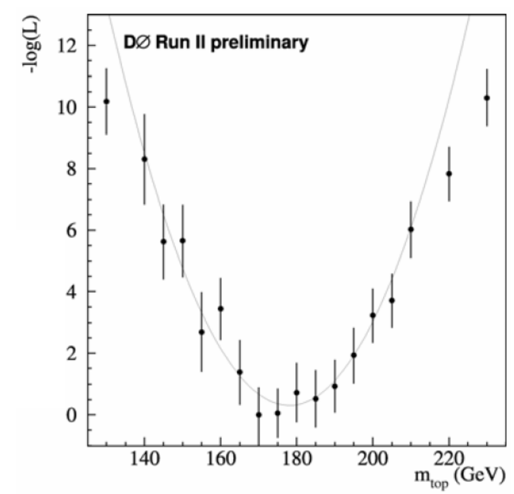
- Minimize $-\ln[L(w, n_{bkgd}, N_{observed}; m_t, n_{signal}, n_{bkgd})]$ at each MC point mass point, then fit to lowest $-\ln L$ point to find top mass

Event selection: 2 leptons p_T > 15 GeV, ⩾2 jets E_T > 20 GeV

ee channel
- $80 < m_{ee} < 100$ GeV
- $E_T^{miss} > 40(35)$ GeV if $m_{ee} < 80 (> 100)$ GeV
- Sphericity > 0.15

$\mu\mu$ channel
- Contour cut on E_t^{miss} and $\Delta\phi(\mu_1, E_T^{miss})$ plane
- Z fitter χ^2 test

$e\mu$ channel
- Electron shape cut
- $E_T^{miss} > 25$ GeV
- $H_T > 140$ GeV

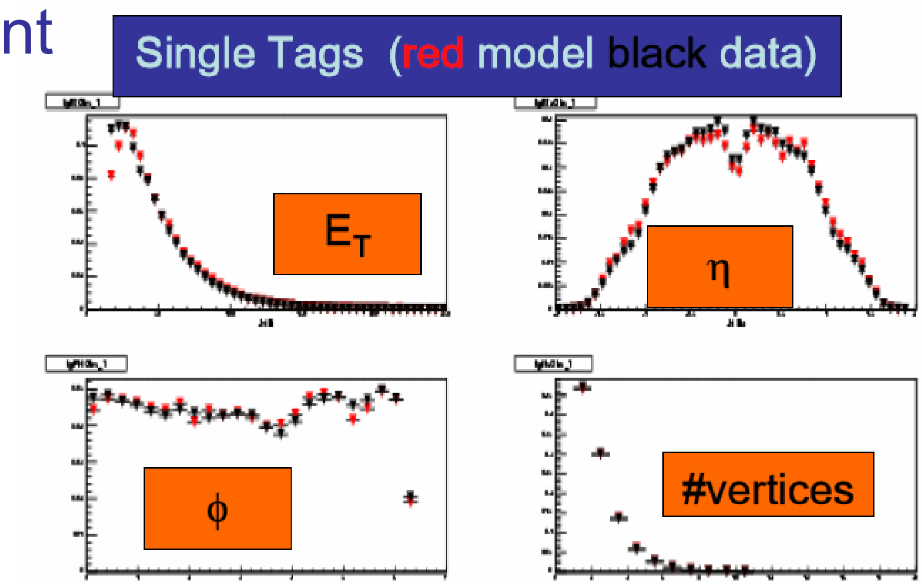


- Result (370 pb^{-1}):

$$m_t = 178.1 \pm 6.7 \pm 4.8\ GeV/c^2$$ **(4.6%)**

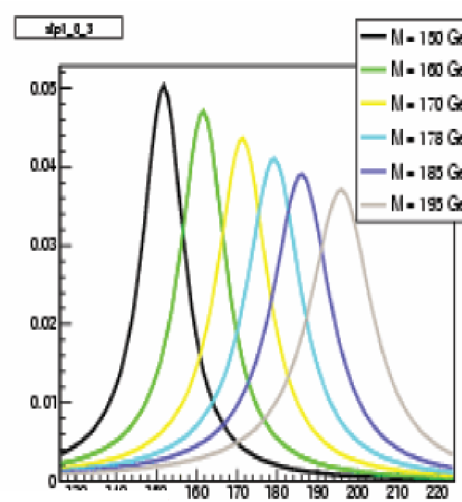
All Hadronic 2D Template

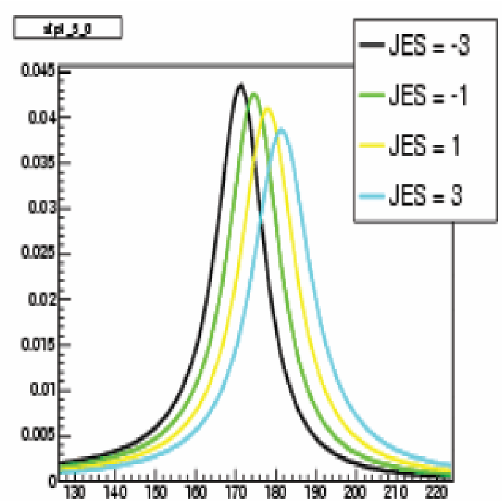
- Huge QCD/Multijet background
- Event Selection:
  - 6 jets: $|\eta|<2$, $E_T>15$ GeV
  - Cuts on jet shapes (aplanarity and centrality)
  - $\Sigma E_T>280$ GeV/c^2
  - Require ≥1 b-tags
  - Impose ttbar-ME Likelihood cut
- Background obtained from data before ME Likelihood requirement

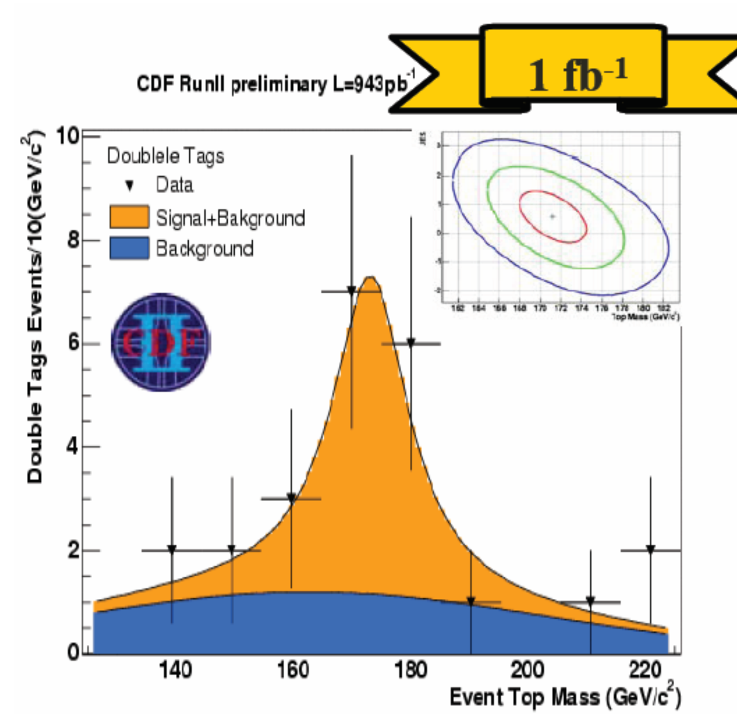


All Hadronic 2D Template

- 2D Template analysis (m_t and JES)
  - Signal templates derived from a matrix element calculation
  - Background templates from data driven background model







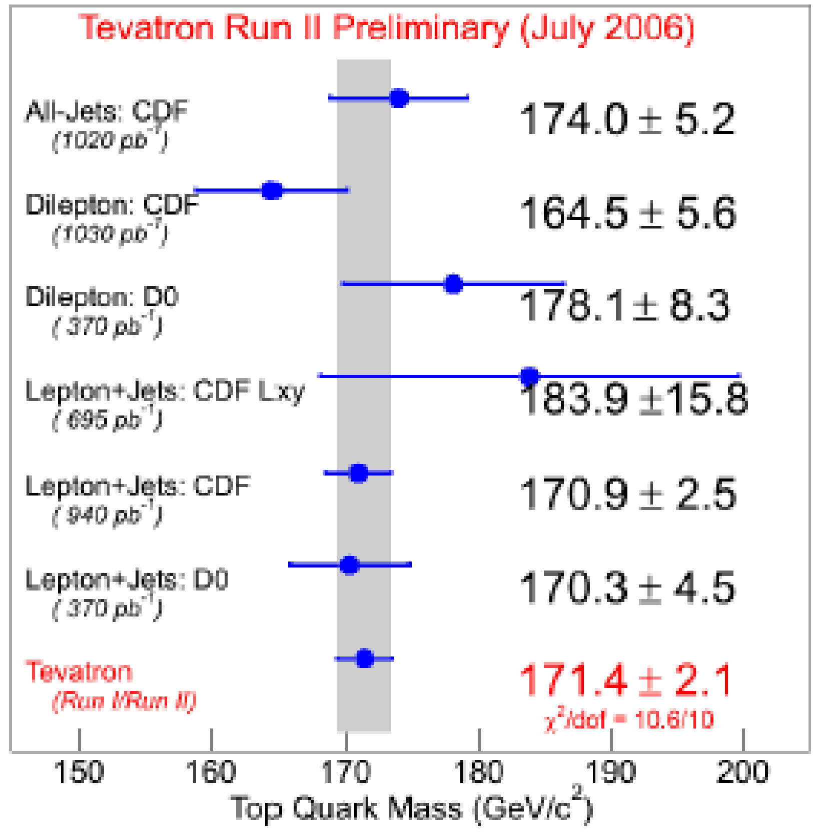
- Result (943 pb^{-1}):

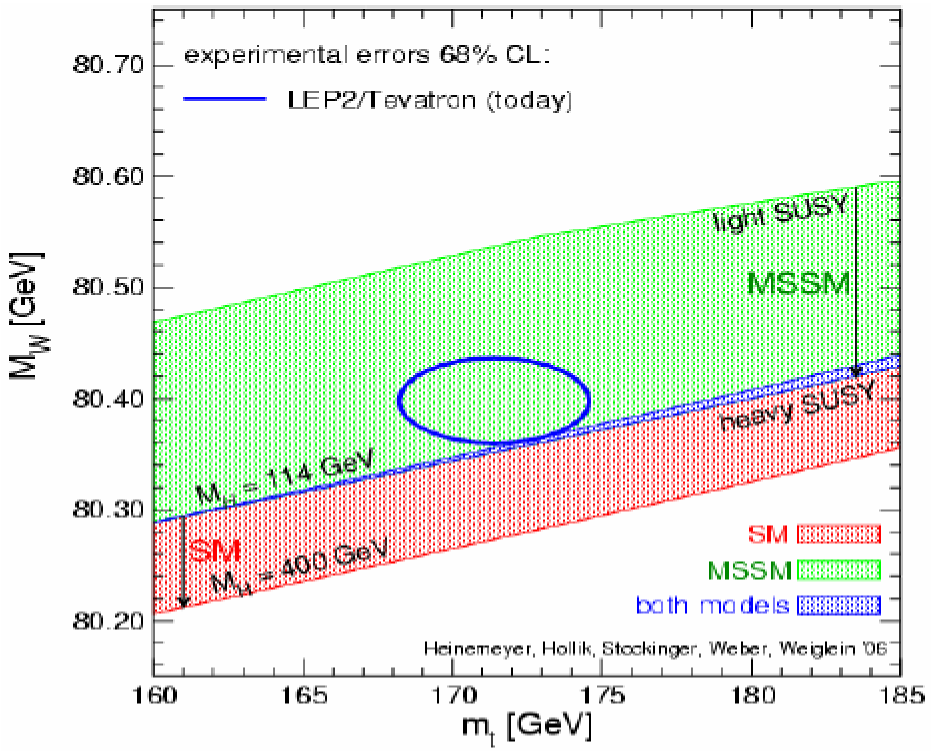
$$m_t = 171.1 \pm 3.7 \pm 1.9\ GeV/c^2$$ **(2.4%)**

Top Mass

- Tevatron combined measurement (July 2006):

$m_t = 171.4 \pm 1.2 \pm 1.7\ GeV/c^2$ **(1.2%)**

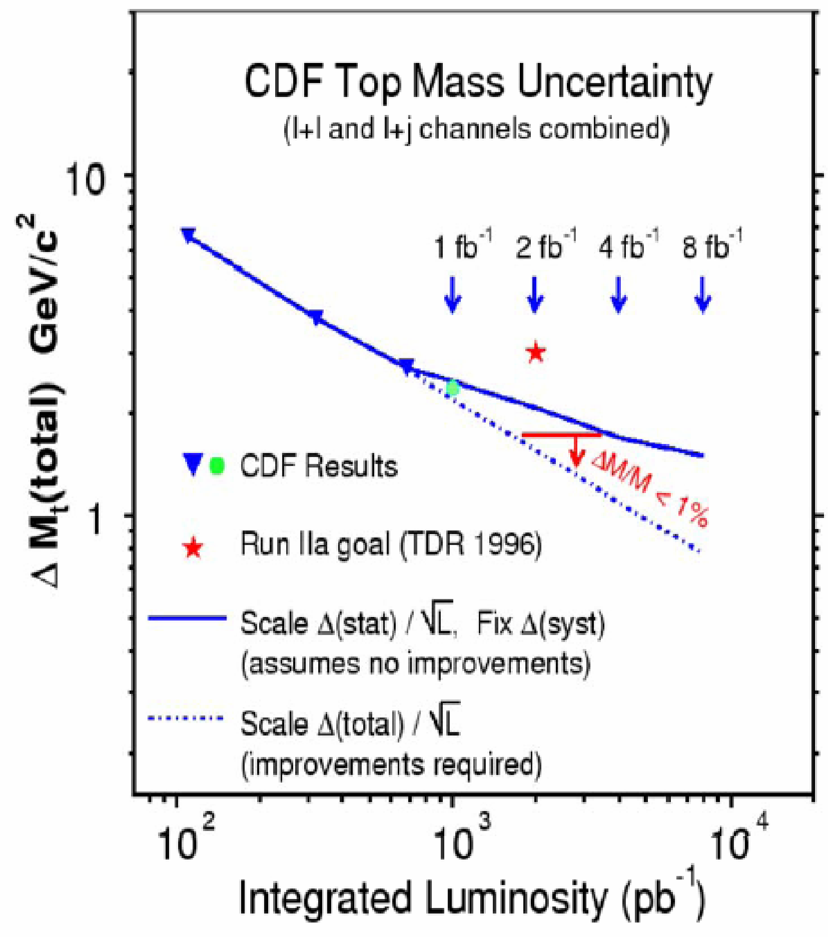




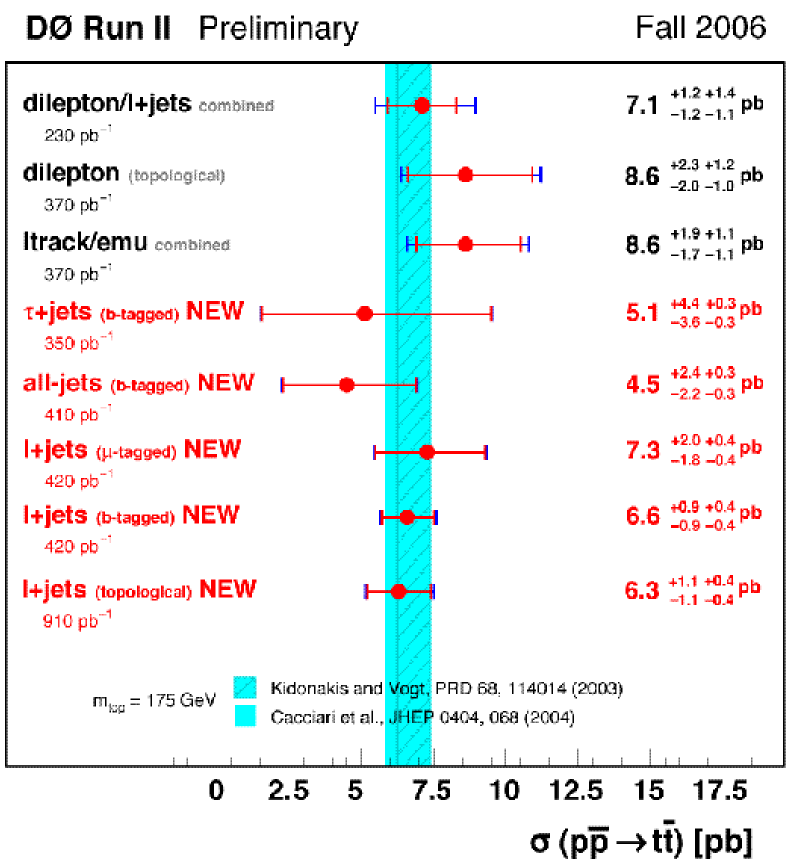
Top Mass

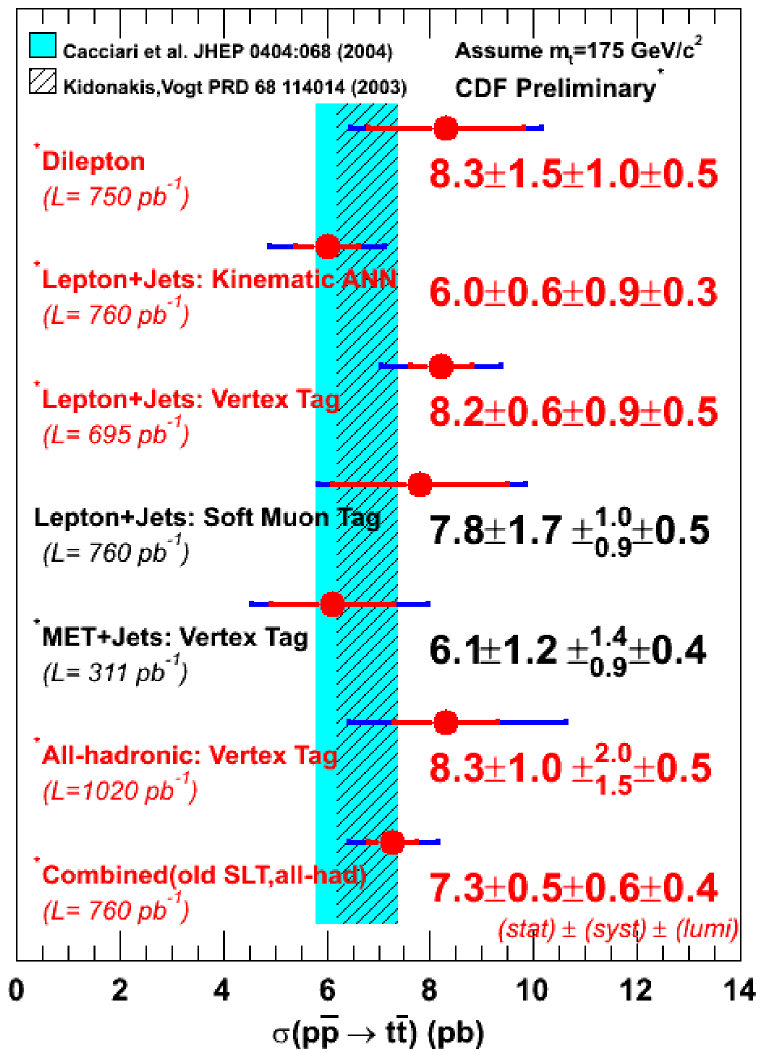
- CDF new results better than prediction 6 months ago:

All-hadronic not included

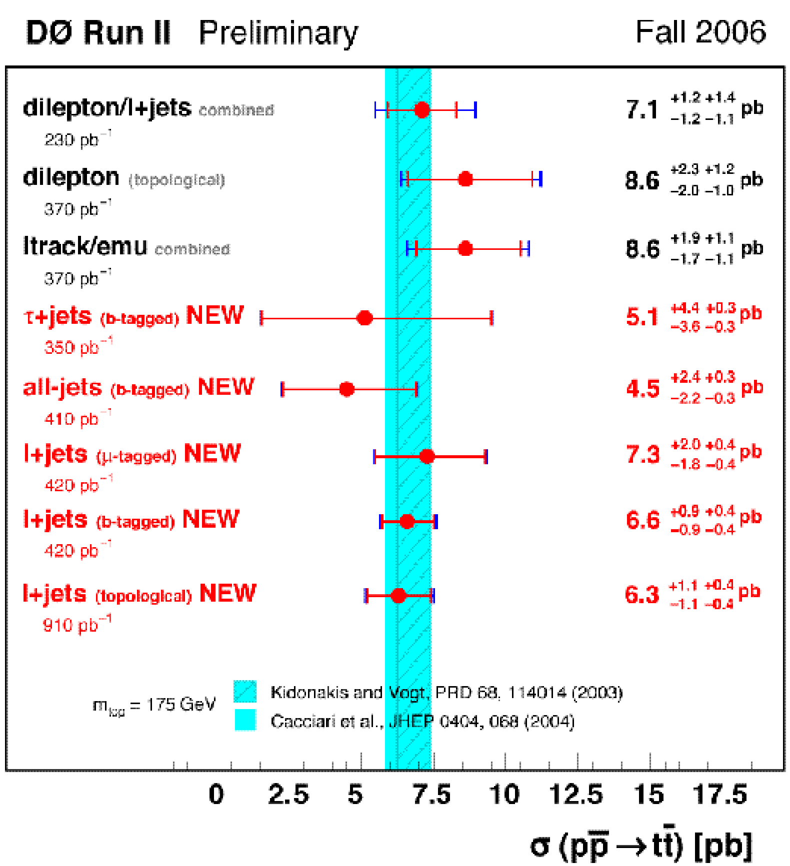


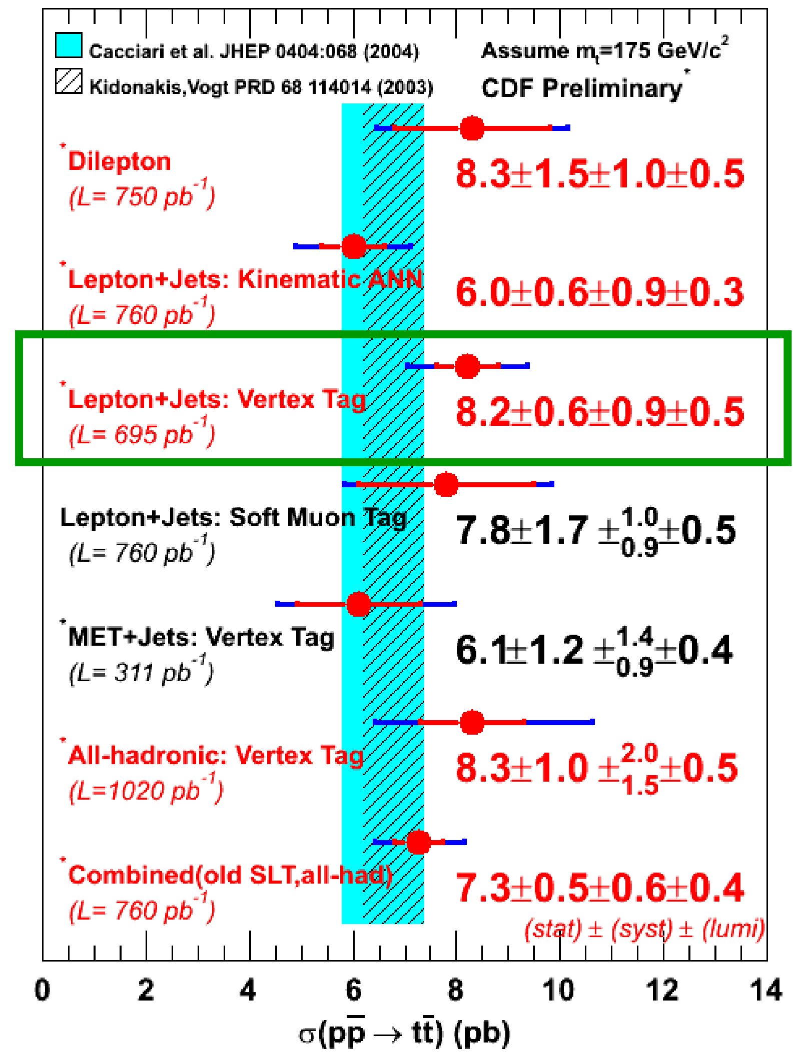
Top Pair Cross Section





Top Pair Cross Section





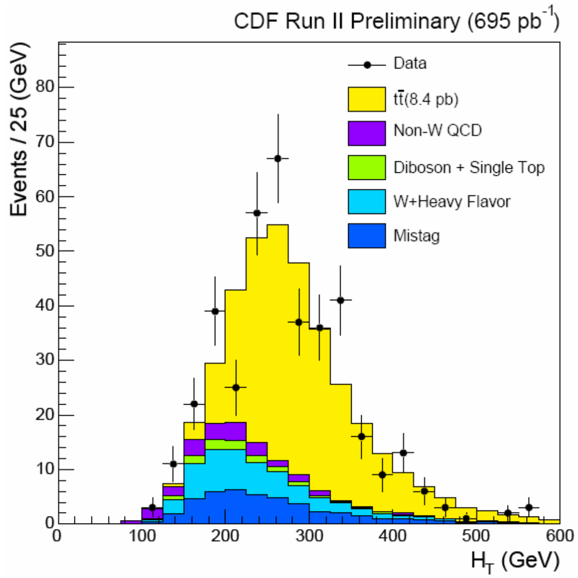
Lepton+jets B-tagging

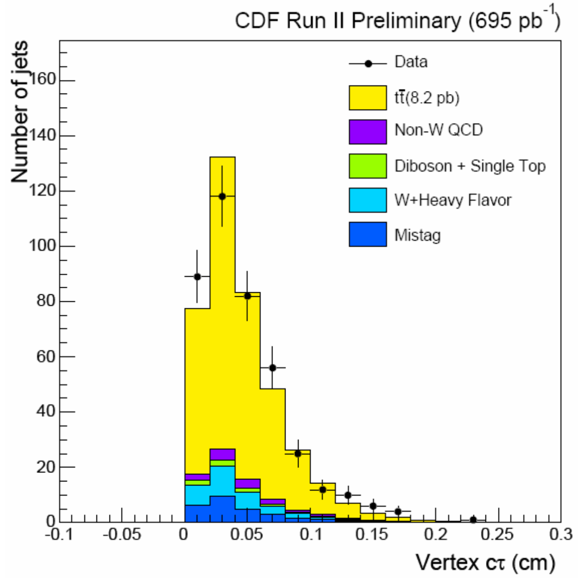
- Counting experiment:

$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bkg}}{\varepsilon_{t\bar{t}} \times \int L dt}$$

- Event selection:
  - lepton p_T>20 GeV
  - MET >20 GeV
  - ≥3 jets: E_T>15 GeV
  - H_T > 200 GeV
  - ≥1 b-tag
- Result: $\sigma_{t\bar{t}} = 8.2 \pm 0.6 \pm 1.0\ pb$

(Error starts being dominated by systematics) **(15%)**



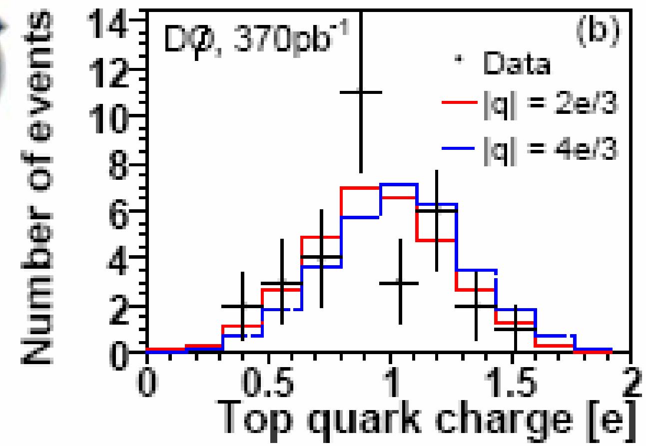


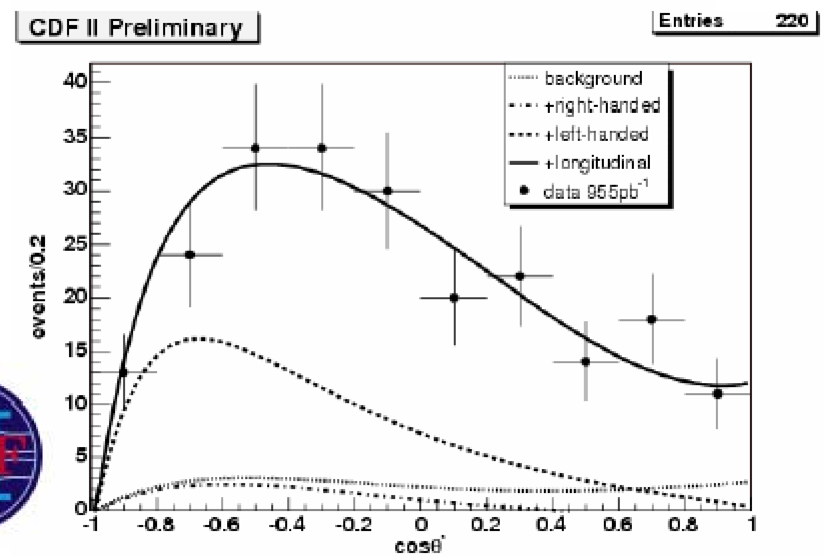
Properties

- Charge:
  - Might be 2/3 or 4/3.
  - There might be exotic couple -1/3/-4/3.
  - DØ (370 pb^{-1}): 4/3 excluded at 92% CL.
- W helicity:
  - SM: $f_-=0.3$, $f_0=0.7$, $f_+\sim0$
  - CDF(955 pb^{-1}): combined f_0 & f_+ mesurement:

$$f_0 = 0.74 \pm 0.25 \pm 0.06$$

$$f_+ = -0.06 \pm 0.10 \pm 0.03$$

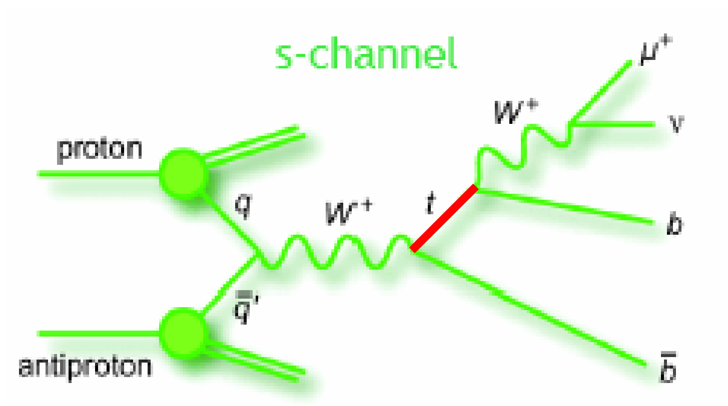




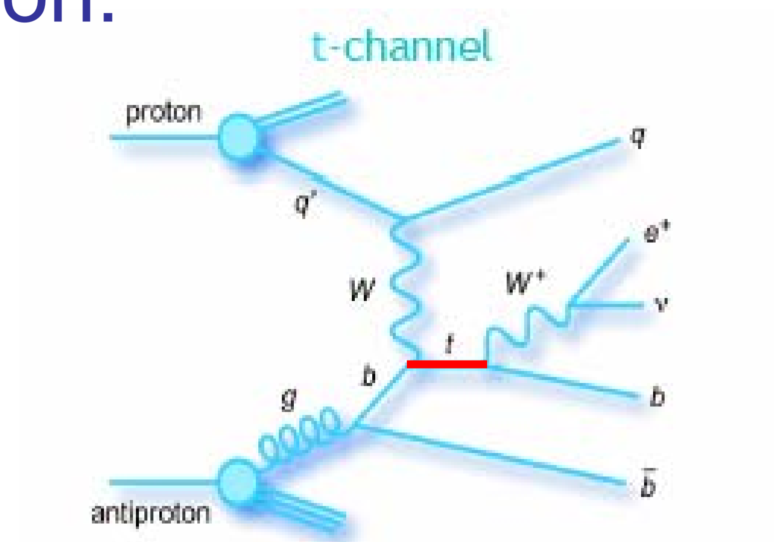
Evidence for Single Top

Single Top

Introduction & Motivation:



$$\sigma_{NLO} = 0.88 \pm 0.14\, pb^*$$



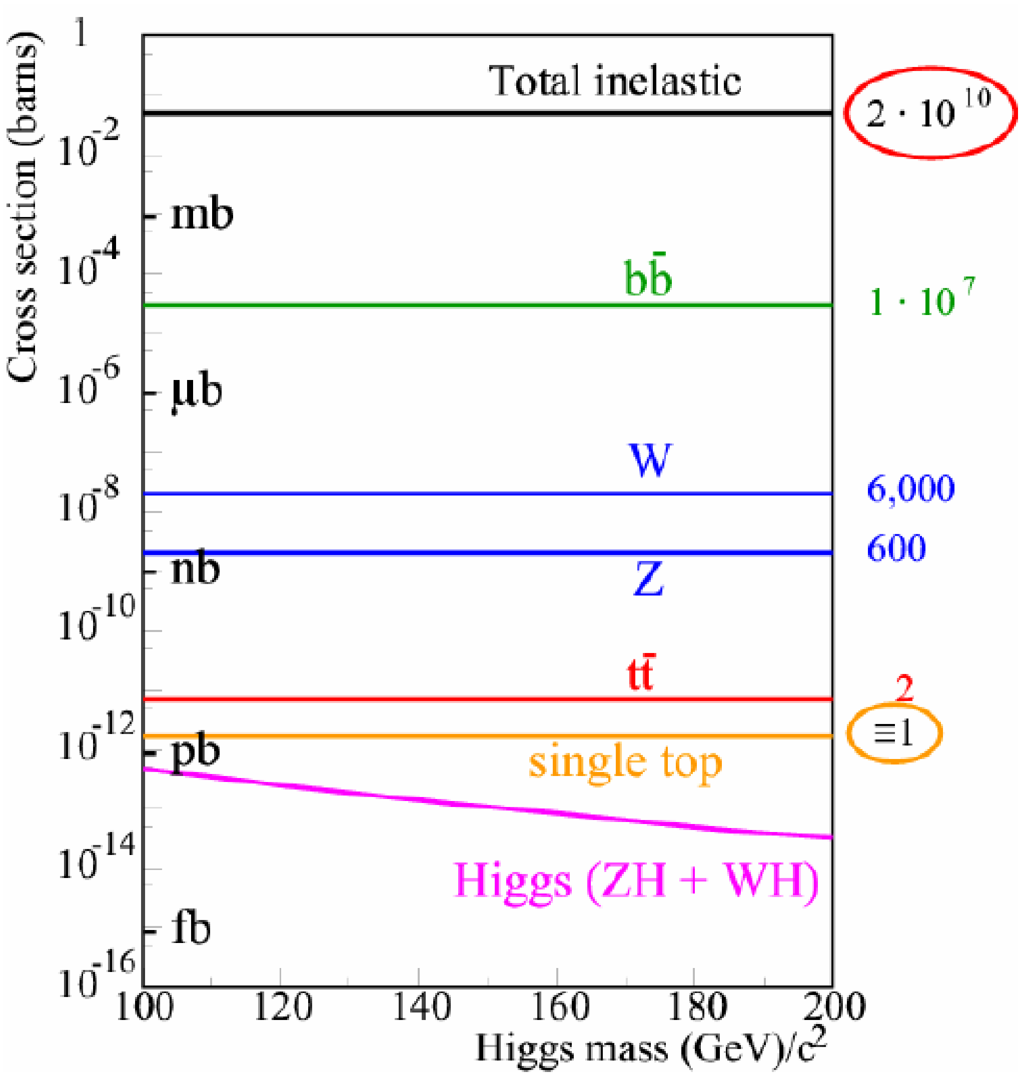
$$\sigma_{NLO} = 1.98 \pm 0.25\, pb^*$$

- Directly measure $|V_{tb}|$ for the first time
- Cross section sensitivity to beyond the SM processes
- Source of polarized top quarks. Spin correlations measurable in decay products.
- Important background to Higgs search
- Test of techniques to extract a small signal out of a large background

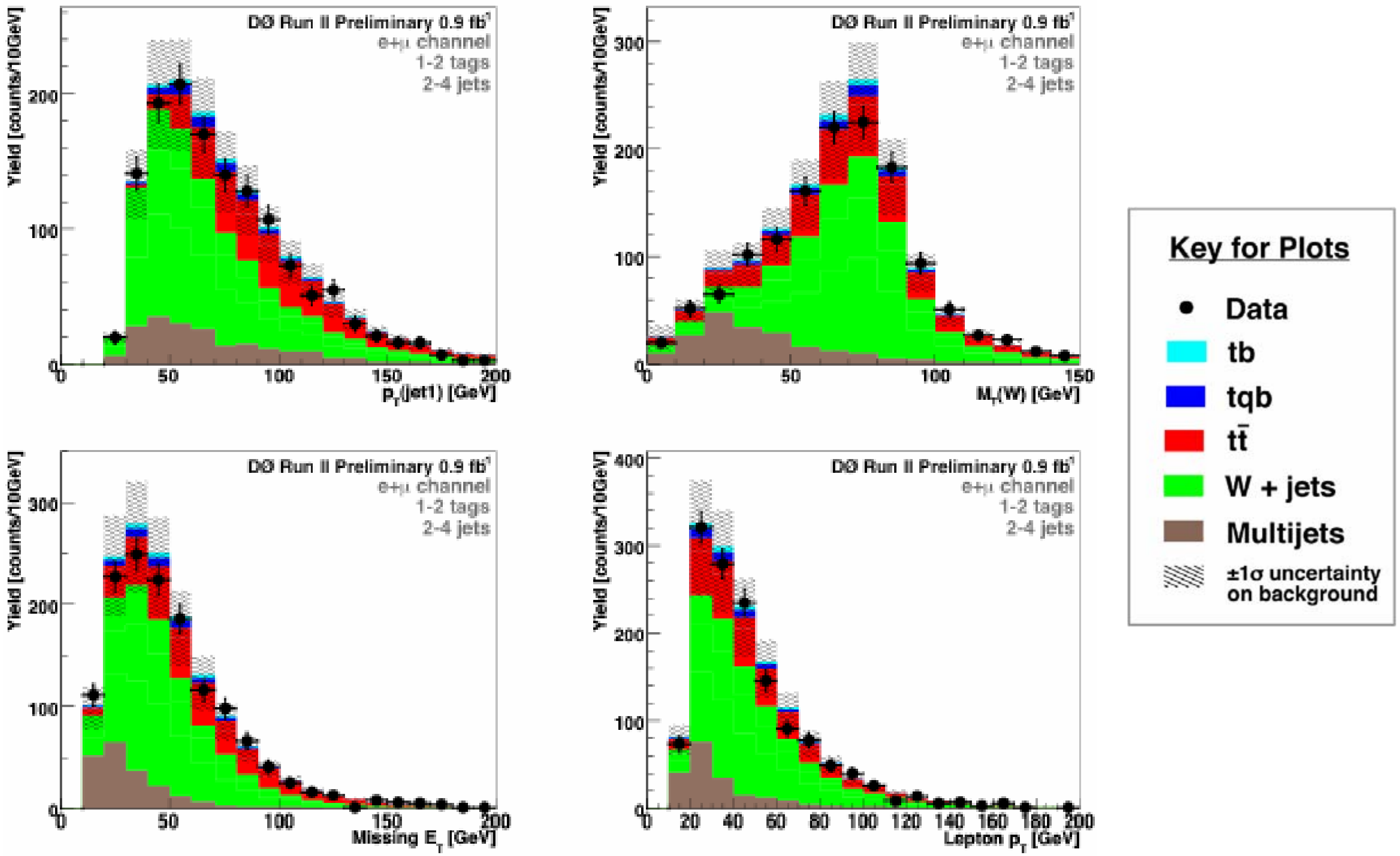
(*) Phys.Rev. D70 (2004) 114012

Single Top

- Backgrounds:
  - W+jets
  - top pairs
  - QCD
- Event selection:
  - Lepton+jets like with NN b-tag.
  - Pushing to loose cuts.
- Difficulty:
  - Lower jet multiplicity.
  - Less energetic events.



Single Top



(background model is verified before b-tagging is applied)

Single Top

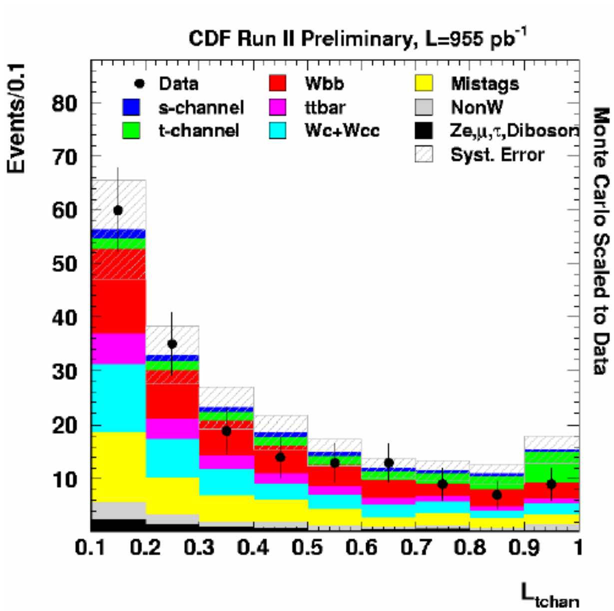
Source	Event Yields in 0.9 fb^{-1} Data Electron+muon, 1tag+2tags combined 2 jets	3 jets	4 jets
tb	16 ± 3	8 ± 2	2 ± 1
tqb	20 ± 4	12 ± 3	4 ± 1
$t\bar{t} \to ll$	39 ± 9	32 ± 7	11 ± 3
$t\bar{t} \to l$+jets	20 ± 5	103 ± 25	143 ± 33
$W+b\bar{b}$	261 ± 55	120 ± 24	35 ± 7
$W+c\bar{c}$	151 ± 31	85 ± 17	23 ± 5
$W+jj$	119 ± 25	43 ± 9	12 ± 2
Multijets	95 ± 19	77 ± 15	29 ± 6
Total background	686 ± 41	460 ± 39	253 ± 38
Data	697	455	246

s-channel	15.4 ± 2.2
t-channel	22.4 ± 3.6
$t\bar{t}$	58.4 ±13.5
Diboson	13.7 ± 1.9
Z + jets	11.9 ± 4.4
Wbb	170.9 ± 50.7
Wcc	63.5 ± 19.9
Wc	68.6 ± 19.0
Non-W	26.2 ± 15.9
Mistags	136.1 ± 19.7
Single top	37.8 ± 5.9
Total background	549.3 ± 95.2
Total prediction	587.1 ± 96.6
Observed	644

Expected single top signal is smaller than background uncertainty!
→ No counting experiment, requires advanced analysis techniques

Single Top

Likelihood:



no evidence of signal

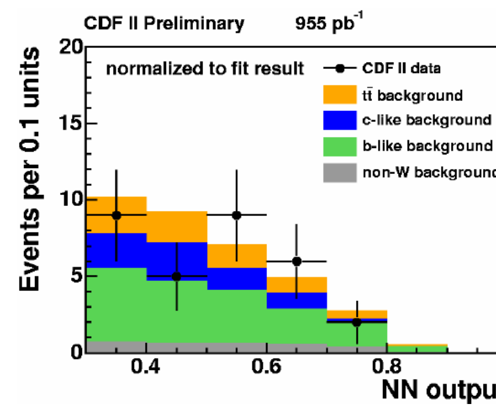
σ < 2.7 pb @ 95% CL

From s and t likelihoods

Neural Network:

no evidence of signal

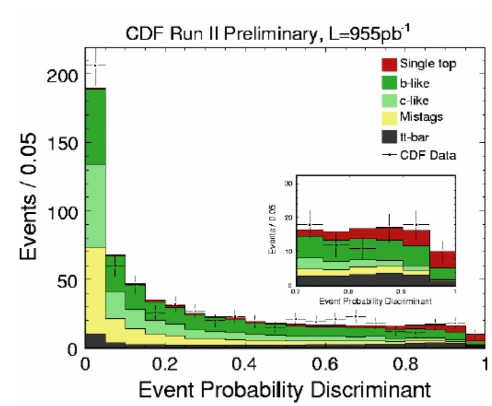
σ < 2.6 pb @ 95% CL



Matrix element:

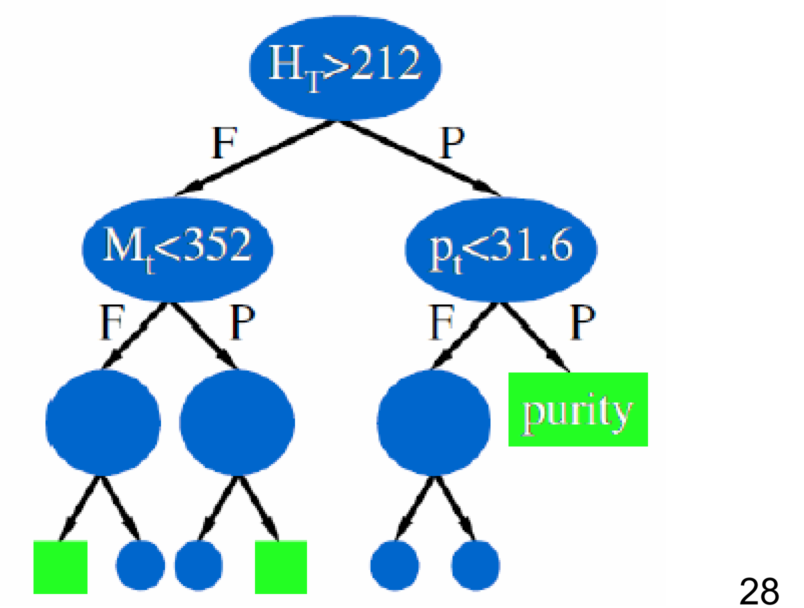
$$\sigma = 2.7^{+1.5}_{-1.3}\ pb$$

p-value = 1.0% (2.3σ)



Single Top

- DØ multivariate methods:
  - Matrix Element. Expected: $\sigma_{s+t} = 3.0^{+1.8}_{-1.5}\ pb$ p-value = 3.7%
  - Bayesian NN:
    - Find posterior probability density for all possible weights in NN
    - Expected: $\sigma_{s+t} = 2.9^{+2.0}_{-1.8}\ pb$ p-value = 9.7%
  - Boosted Decision Trees:
    - Select best cut recursively for failed and passed events
    - Average over retrained trees that focus on mis-identified events
    - Expected: $\sigma_{s+t} = 2.7^{+1.6}_{-1.4}\ pb$ p-value = 1.9%

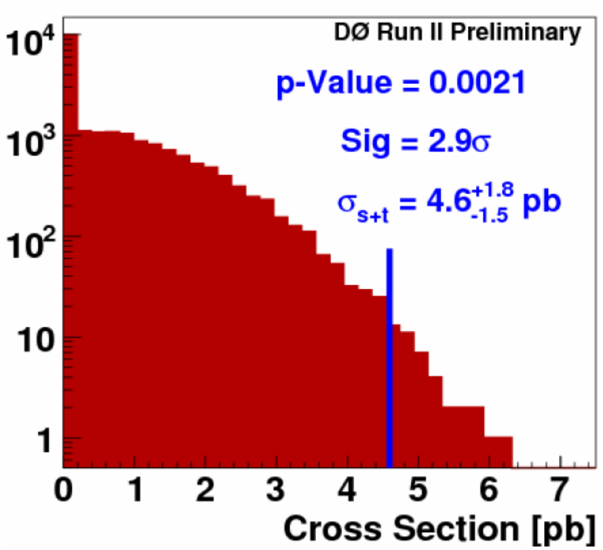


Single Top

Matrix Element

$$\sigma_{s+t} = 4.6^{+1.8}_{-1.5}\, pb$$

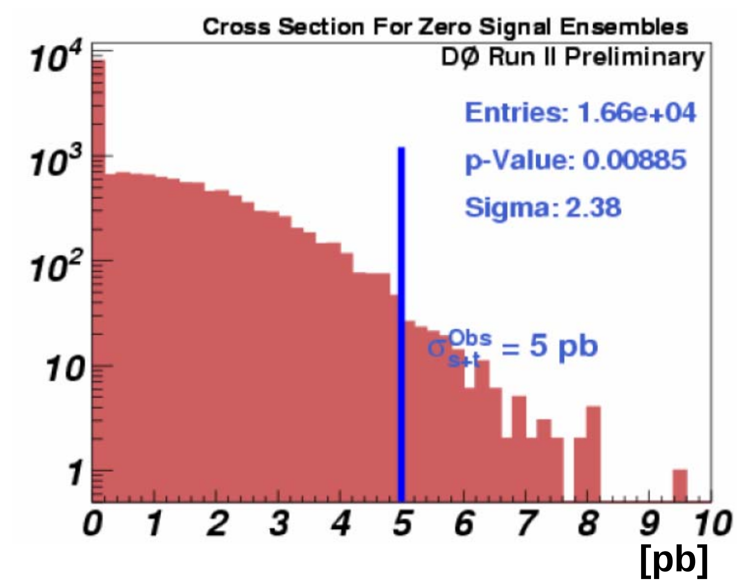
p-value = 0.21% (2.9σ)



Bayesian NN

$$\sigma_{s+t} = 3.0 \pm 1.9\, pb$$

p-value = 0.89% (2.4σ)



Single Top

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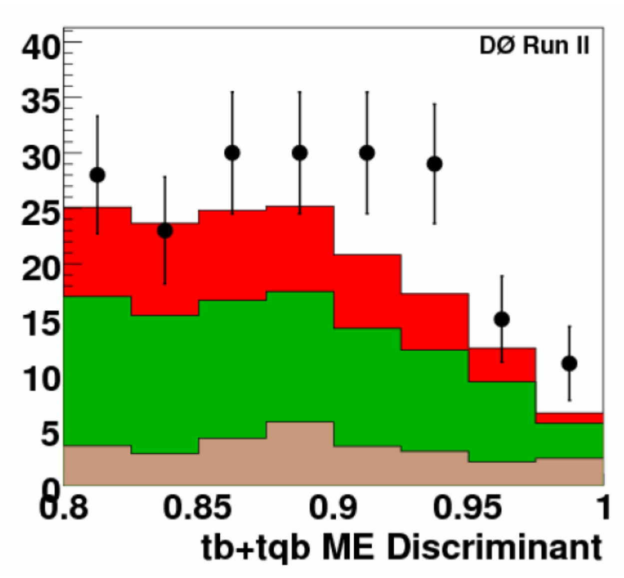

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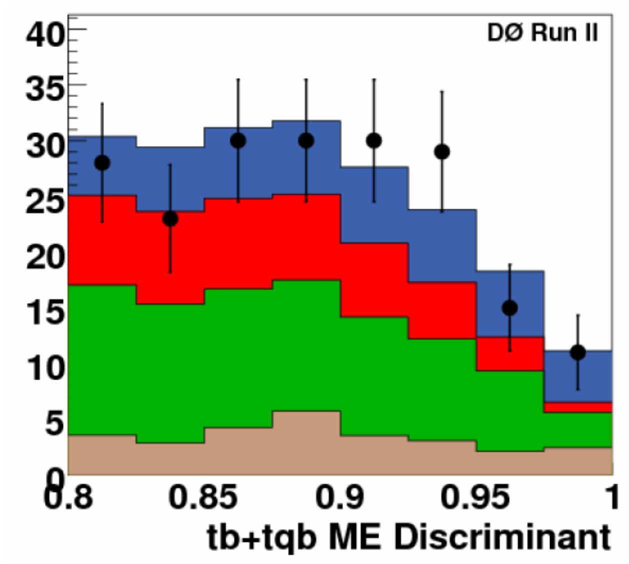
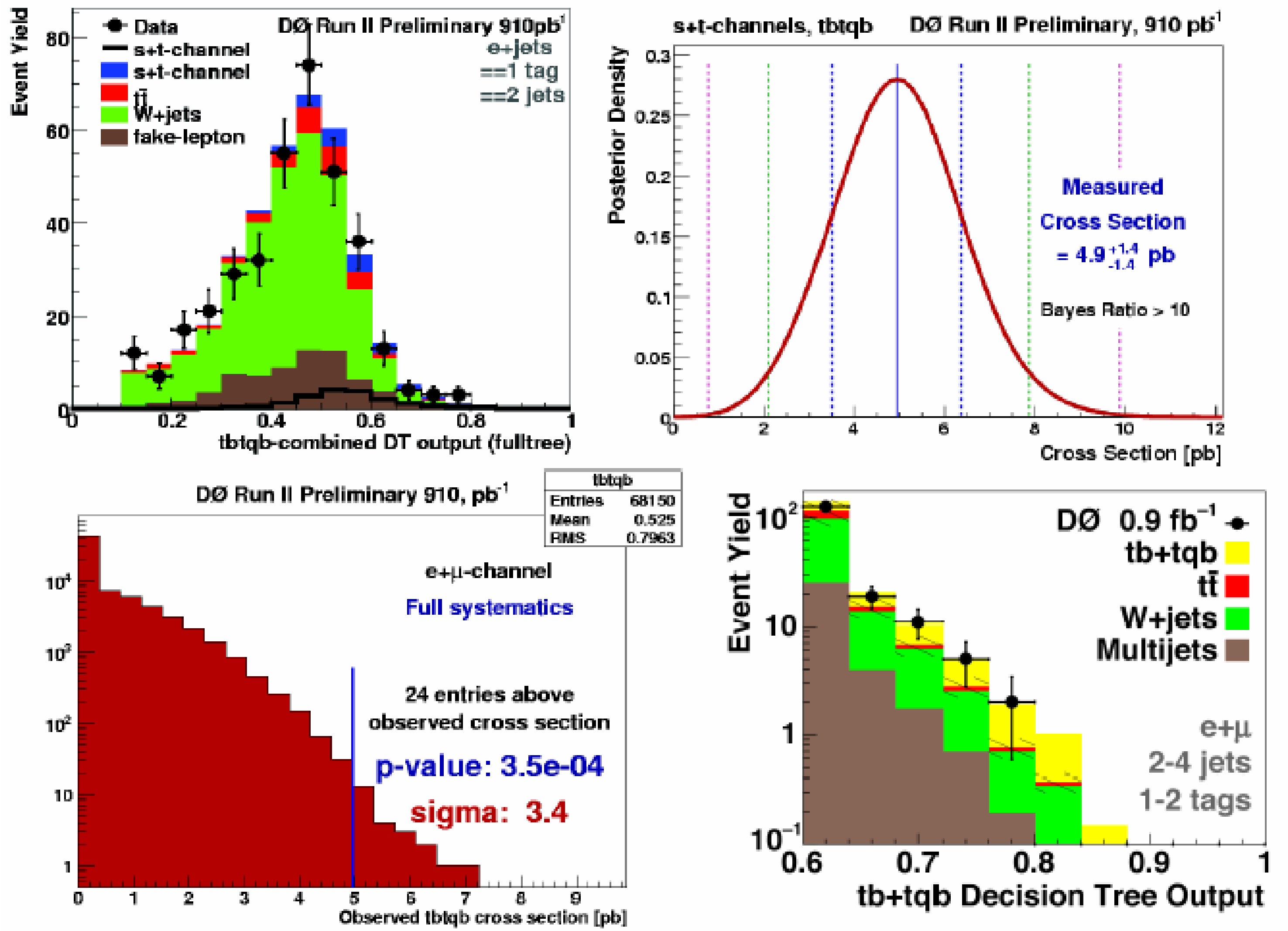


Decision Trees



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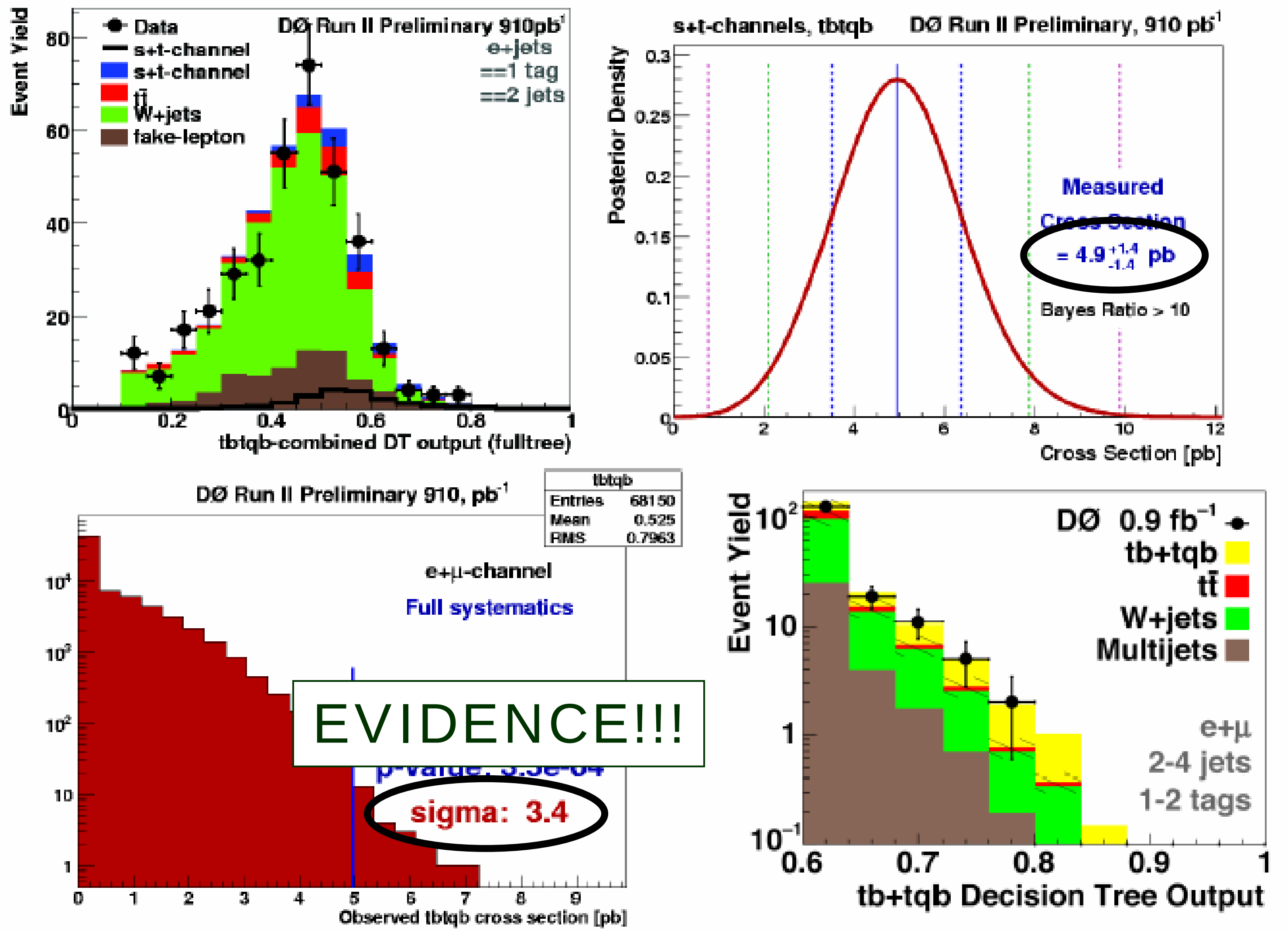


S.M. compatibility: 11% (1.1σ)

Single Top

- Evidence → Direct measurement of $|V_{tb}|$
  - Translate tb+tqb cross section into measurement of the strength of V−A coupling $|V_{tb}f_1^L|$ in Wtb vertex (f_1^L: arbitrary left-handed form factor)
  - Assume $V_{td}^2 + V_{ts}^2 << V_{tb}^2$ and pure V−A and CP-conserving Wtb interaction:

$$\left| V_{tb} f_1^{L} \right| = 1.3 \pm 0.2$$

  - Also assuming $f_1^L = 1$:

$$0.68 < |V_{tb}| < 1 \text{ @ } 95\% \text{ CL}$$

  - No assumption about number of quark families or CKM matrix unitarity

Conclusions & Outlook

- There is a very rich program in Top Physics at the Tevatron that the LHC will take advantage of.
- July 2006 Tevatron combined top mass:

  $$m_t = 171.4 \pm 1.2 \pm 1.7\ GeV/c^2$$ **(1.2%)**

  dominated by the CDF lepton+jets measuerent:

  $$m_t = 170.9 \pm 1.6 \pm 2.0\ GeV/c^2$$ **(1.5%)**

  The precision is better than expected
- CDF combined top pair production cross section:

  $$\sigma_{t\bar{t}} = 7.3 \pm 0.5 \pm 0.7\ pb$$ **(12%)**
- Evidence of electroweak single top production has been found at DØ with the Decision Trees analysis. Measured cross section:

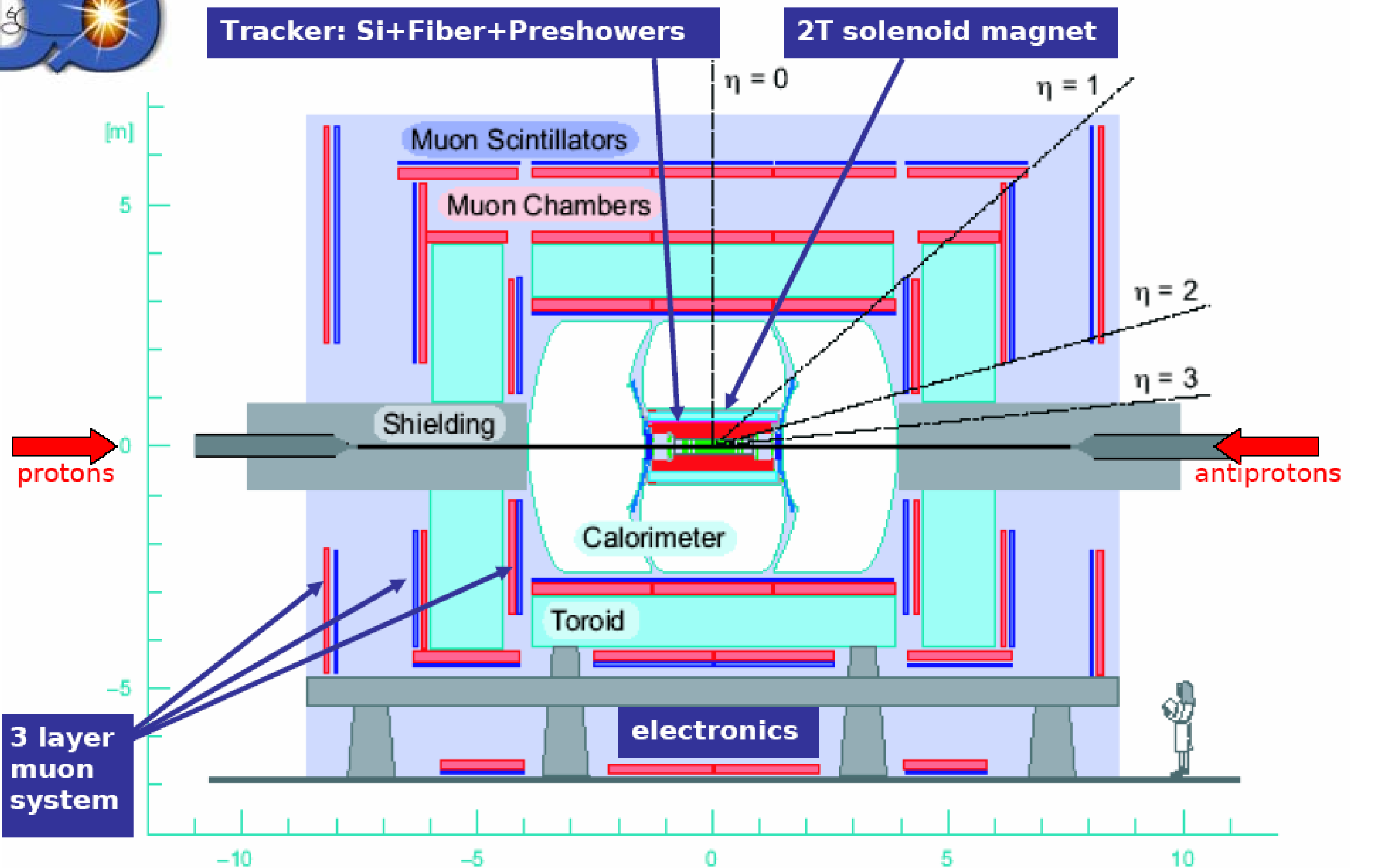
  $$\sigma_{\mathrm{s+t}} = 4.9 \pm 1.4\ pb$$ **(3.4σ)**

  And a first direct measurement of $|V_{tb}|$ has been made:

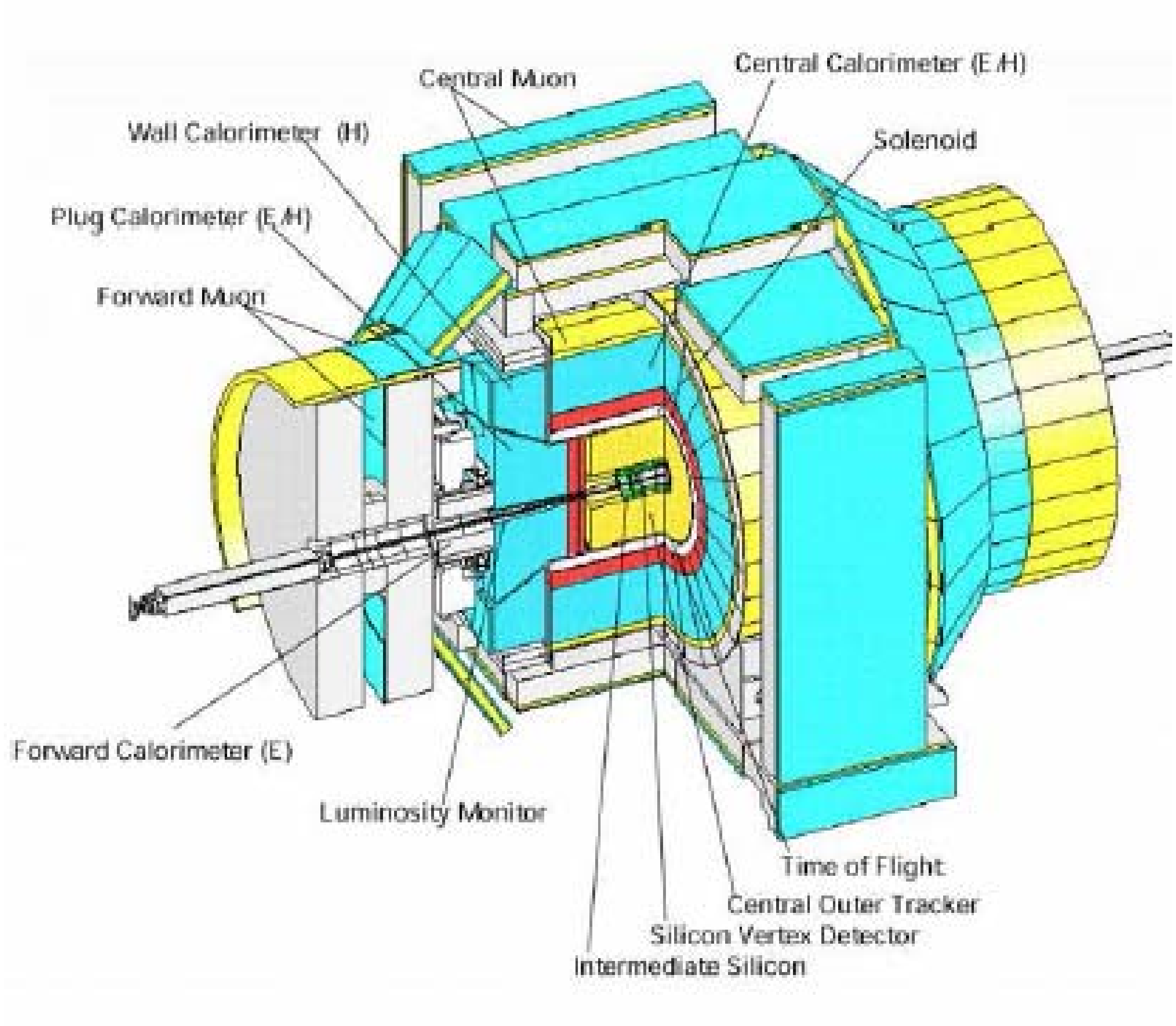
  $0.68 < |V_{tb}| < 1$ @ 95% CL

Backup slides

Introduction and Motivation



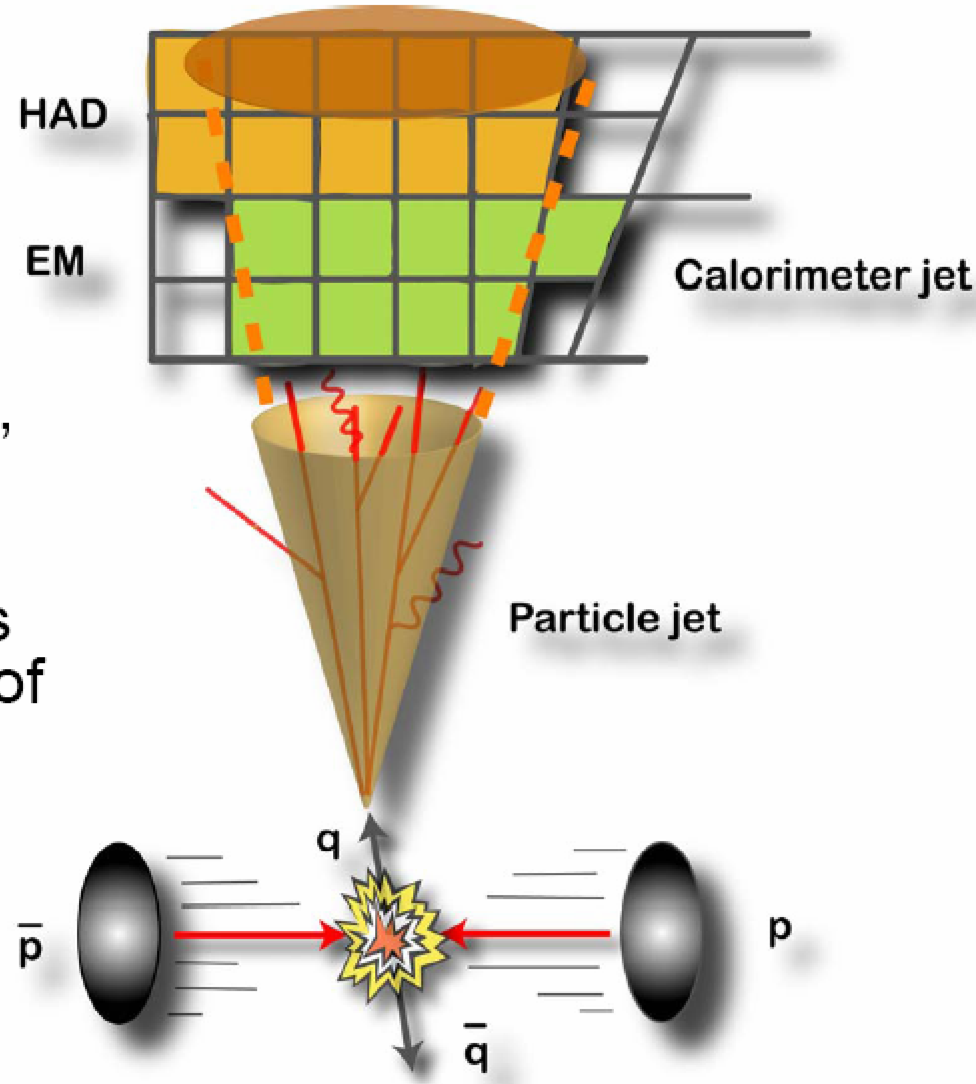
The CDF Detector



JES

Determine the energy of the quarks produced in the hard scattering:

- Correct for hadronization, calorimeter non-linearity and non-compensation, multiple-interactions, underlying event, algorithm effects ….
- Derived from Data and MC
- Jet energy scale uncertainties known to ~3% for M_{top} range of jet energies

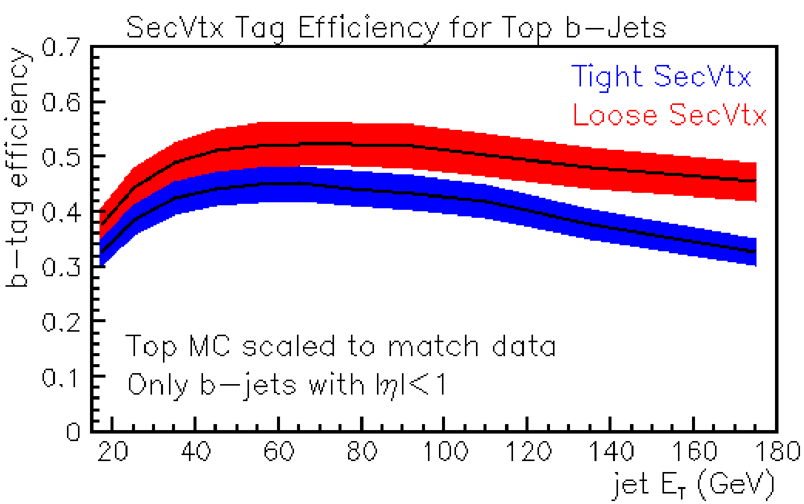


=> Largest uncertainty in M_{top}

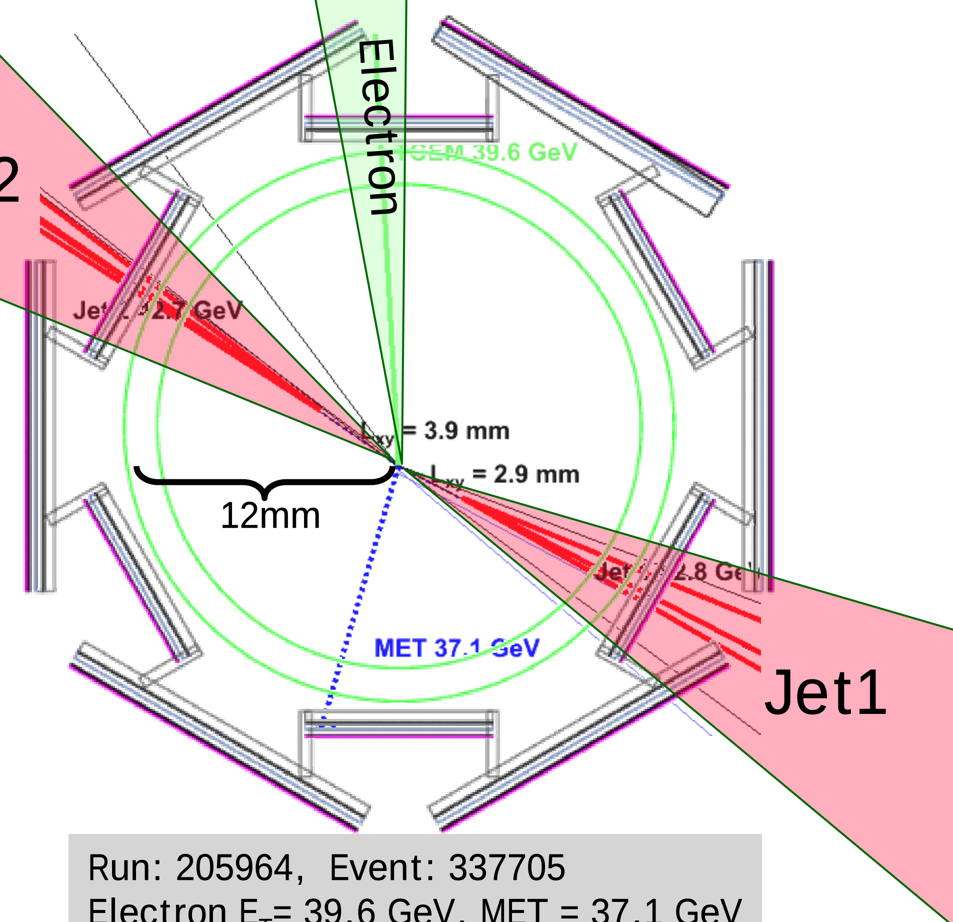
SVT

Secondary Vertex Tagging

- Signature of bottom quark decay is a **displaced secondary vertex**
- Use long lifetime of B hadrons: $c\tau$ ~450 μm + large boost from top decay $\rightarrow$B hadrons travel L_{xy}~ 3mm before decaying with large charged track multiplicity
- Tagging efficiency per jet ~40%



CDF W+2jet Candiate Event:
Close-up View of Layer 00 Silicon Detector



Run: 205964, Event: 337705
Electron E_T= 39.6 GeV, MET = 37.1 GeV
Jet 1: E_T = 62.8 GeV, L_{xy} = 2.9mm
Jet 2: E_T = 42.7 GeV, L_{xy} = 3.9mm

CDF M_{top} lep+jets ME

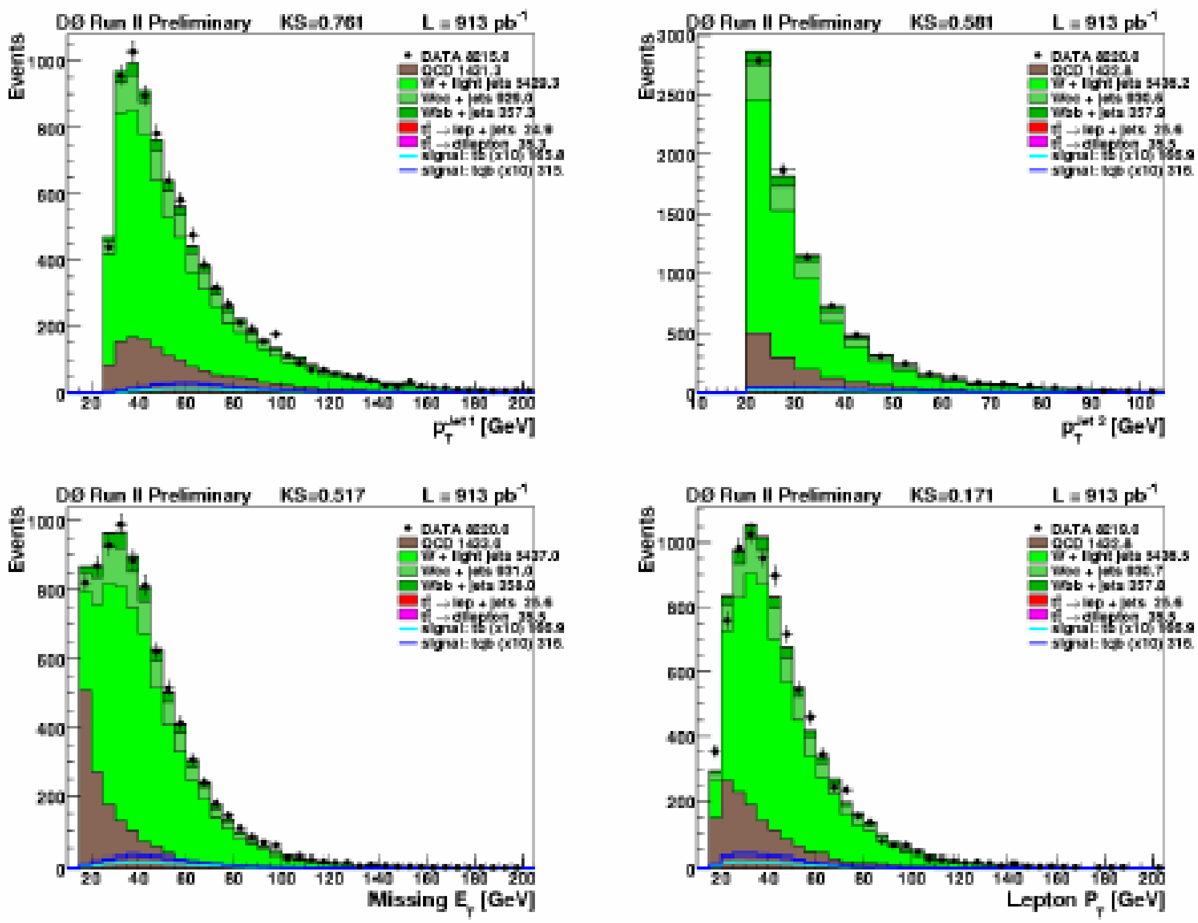
Source of uncertainty	CDF Magnitude (GeV/c^2)
b-JES	0.6
Signal (Initial and final state radiation, parton distribution functions)	1.1
Background (composition and shape)	0.2
Fit (Method, Monte Carlo statistics)	0.4
Monte Carlo (Modeling of ttbar)	0.2
Total	**1.4**

Single Top Event Selection and Method

- Only one tight and no other loose lepton
  - electron: p_T > 15 GeV and $|\eta_{det}| < 1.1$
  - muon: p_T > 18 GeV and $|\eta_{det}| < 2$
- 15 < MET < 200 GeV
- 2-4 jets with p_T > 15 GeV and $|\eta_{det}| < 3.4$
  - Leading jet with p_T > 25 GeV and $|\eta_{det}| < 2.5$
  - 2nd leading jet p_T > 20 GeV
- Other clean up cuts
- At least one b-tagged jet

Event Selection and Method

Before b-tagging:

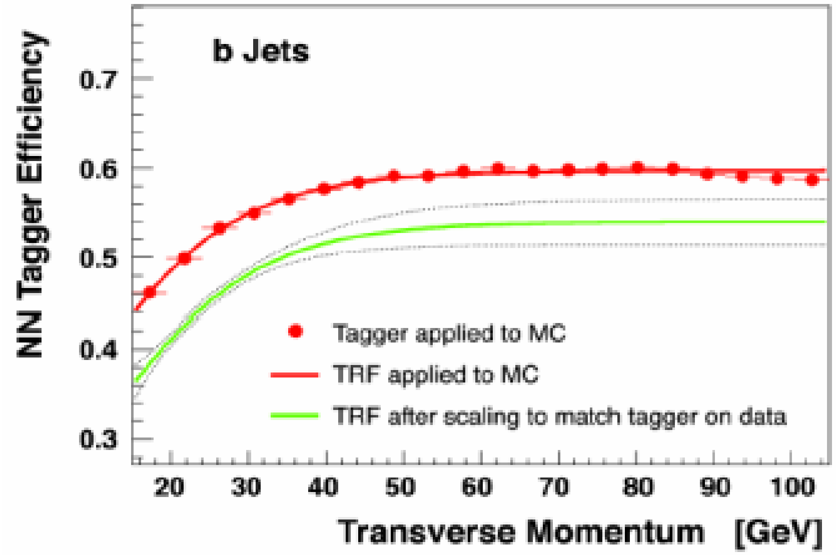


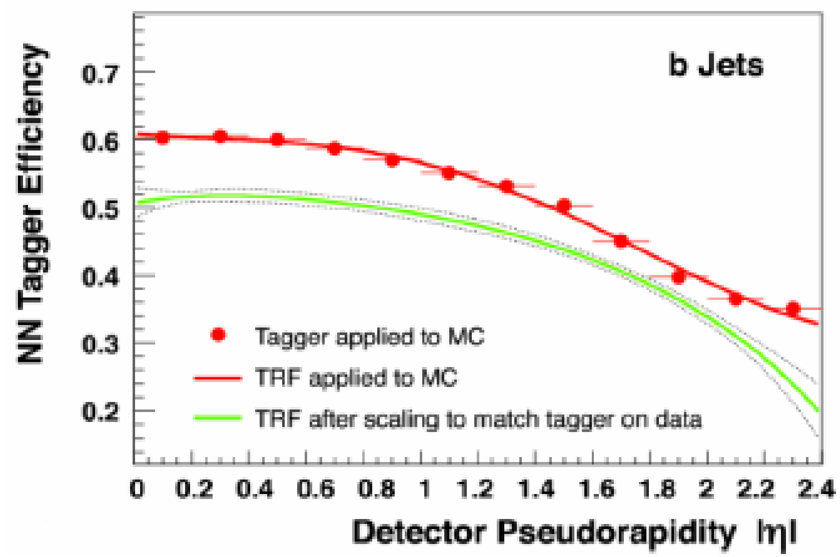
- Normalize W+multijet to data in every jet bin before tagging
- Checked 90 variables: simulation gives good description of data
- Shown: electron channel, 2 jets

Event Selection and Method

Neural network B-jet Tagger:

- NN trained on 7 input variables from SVT, JLIP and CSIP taggers.
- Much improved performance with respect to JLIP:
  - fake rate reduced by 1/3 for same b-efficiency
  - smaller systematic uncertainties
- Tag Rate Functions (TRFs) in η, p_T , z_{PV} applied to MC
- Operating point:
  - b-jet efficiency 50%
  - c-jet efficiency 10%
  - Light jet efficiency 0.5%





Event Selection and Method

Percentage of single top *tb+tqb* selected events and S:B ratio (white squares = no plans to analyze)					
Electron + Muon	**1 jet**	**2 jets**	**3 jets**	**4 jets**	**≥ 5 jets**
0 tags	10% 1 : 3,200	25% 1 : 390	12% 1 : 300	3% 1 : 270	1% 1 : 230
1 tag	6% 1 : 100	21% 1 : 20	11% 1 : 25	3% 1 : 40	1% 1 : 53
2 tags		3% 1 : 11	2% 1 : 15	1% 1 : 38	0% 1 : 43

Event Selection and Method

Systematic uncertainties can be
• either “shaped” (jet energy scale, tag rate functions): shift inputs by ±1, redo analysis
• or “normalization”: uncertainties assigned per background, jet multiplicity, lepton, number of tags

Examples of Relative Systematic Uncertainties

ttbar cross section	18%
luminosity	6%
electron trigger	3%
muon trigger	6%
jet energy scale	wide range
jet fragmentation	5–7%
heavy flavor ratio	30%
tag-rate functions	2–16%

Event Selection and Method

Ensemble tests: to verify machinery...

- **Create thousands of sets of pseudo-data and run analysis on them.**
- **generated ensembles:**
  - 0-signal ensemble (s+t = 0pb) → Significance
  - SM ensemble (s+t = 2.9pb)
  - "Mystery" ensembles to test analyzers (s+t=??pb)
  - Ensembles at measured cross section (s+t=measured)
  - A high luminosity ensemble

Event Selection and Method

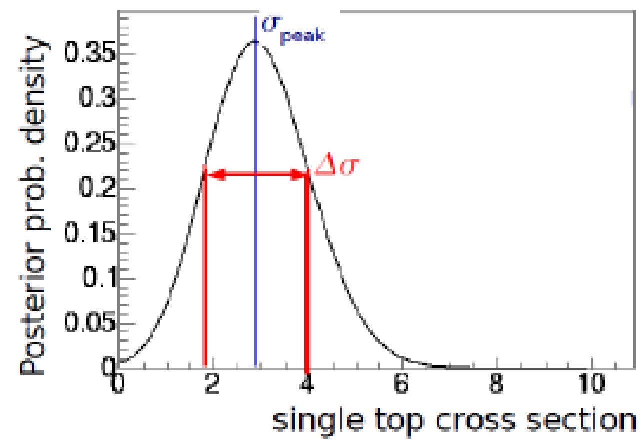
Method to measure the cross section:

Probability to observe data distribution D, expecting y:

$$y = \alpha L \sigma + \sum_{s=1}^{N} b_s = a\sigma + \sum_{s=1}^{N} b_s$$

$$P(D\,|\,y) = P(D\,|\,\sigma, a, \vec{b}) = \prod_{i=1}^{nbins} P(D\,|\,y_i)$$

$$P_{post}(\sigma\,|\,D) \equiv P(\sigma\,|\,D) \propto \iint_{a\,b} P(D\,|\,\sigma, a, \vec{b}) P_{prior}(\sigma) P_{prior}(a, \vec{b})$$

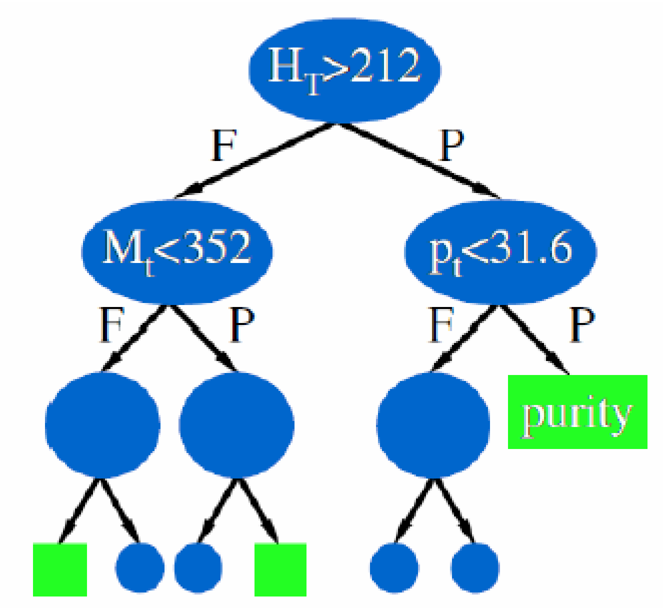


- Bayesian posterior probability density.
- Shape and normalization systematics treated as nuisance parameters.
- Correlations between uncertainties properly accounted for.
- Flat prior in signal cross section.

Multivariate Analyses: Decision Trees

Training

- Start with all events (first node)
- For each variable, find the splitting value with best separation between children (best cut).
- Select best variable and cut and produce Failed and Passed branches
- Repeat recursively on each node
- Stop when improvement stops or when too few events left.

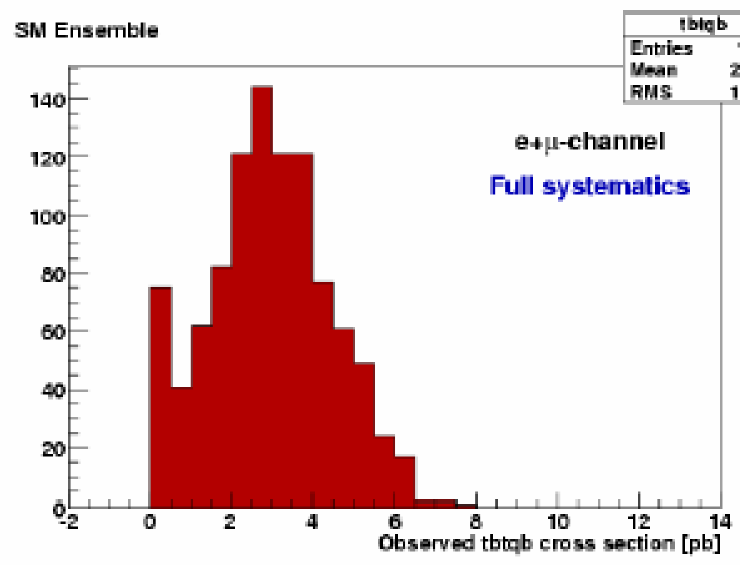


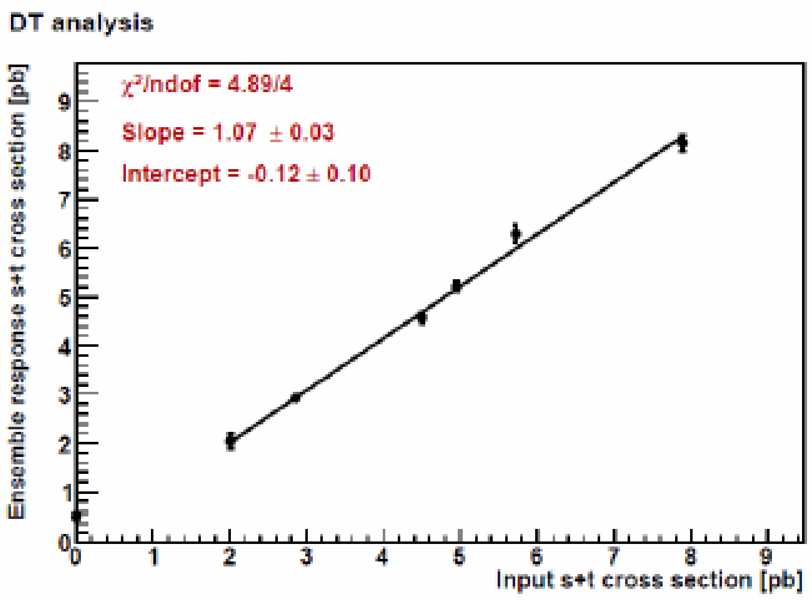
Adaptative Boosting

- Train several trees giving higher weights to misclassified events.
- Result: weighted average over trees results

Multivariate Analyses: Decision Trees

- Application: train 36 separate trees (s/t/s+t, e/μ channel, 2/3/4 jets, 1/2 tags)
- Performance on ensemble tests:





Multivariate Analyses: Matrix Elements

Approach:

- Use the 4-vectors of all reconstructed leptons and jets
- Use matrix elements of main signal and background diagrams to compute an event probability density for signal and background hypotheses.
- Goal: calculate a discriminant:

$$D_S(\vec{x}) = P(S \mid \vec{x}) = \frac{P_{Signal}(\vec{x})}{P_{Signal}(\vec{x}) + P_{Background}(\vec{x})}$$

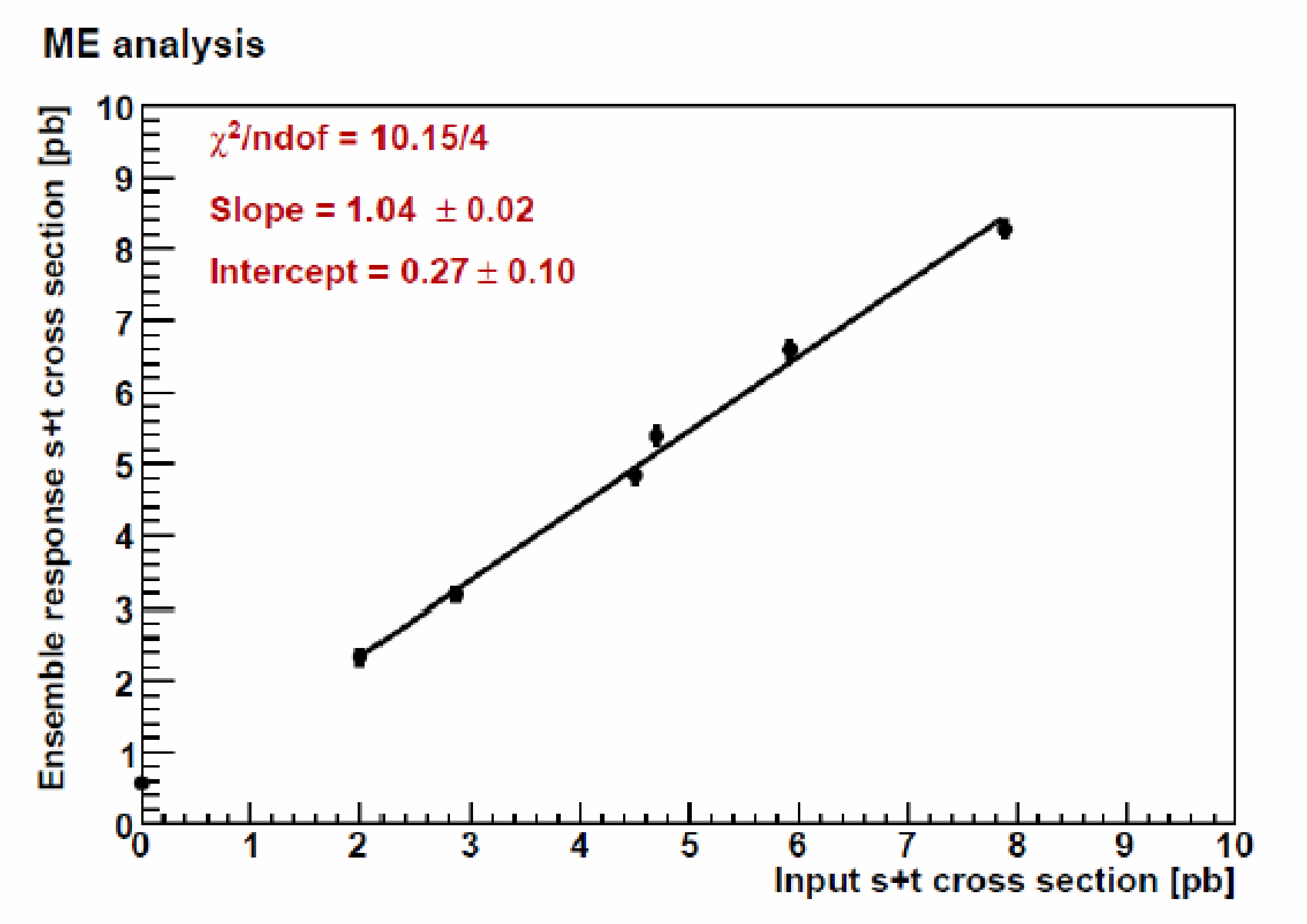
where

$$P(\vec{x}) = \frac{1}{\sigma}\int d\sigma(\vec{y})dq_1dq_2\, f(\vec{x}_1)\, f(\vec{x}_2) W(\vec{y},\vec{x})$$

Parton distribution functions

Transfer function (detector response)

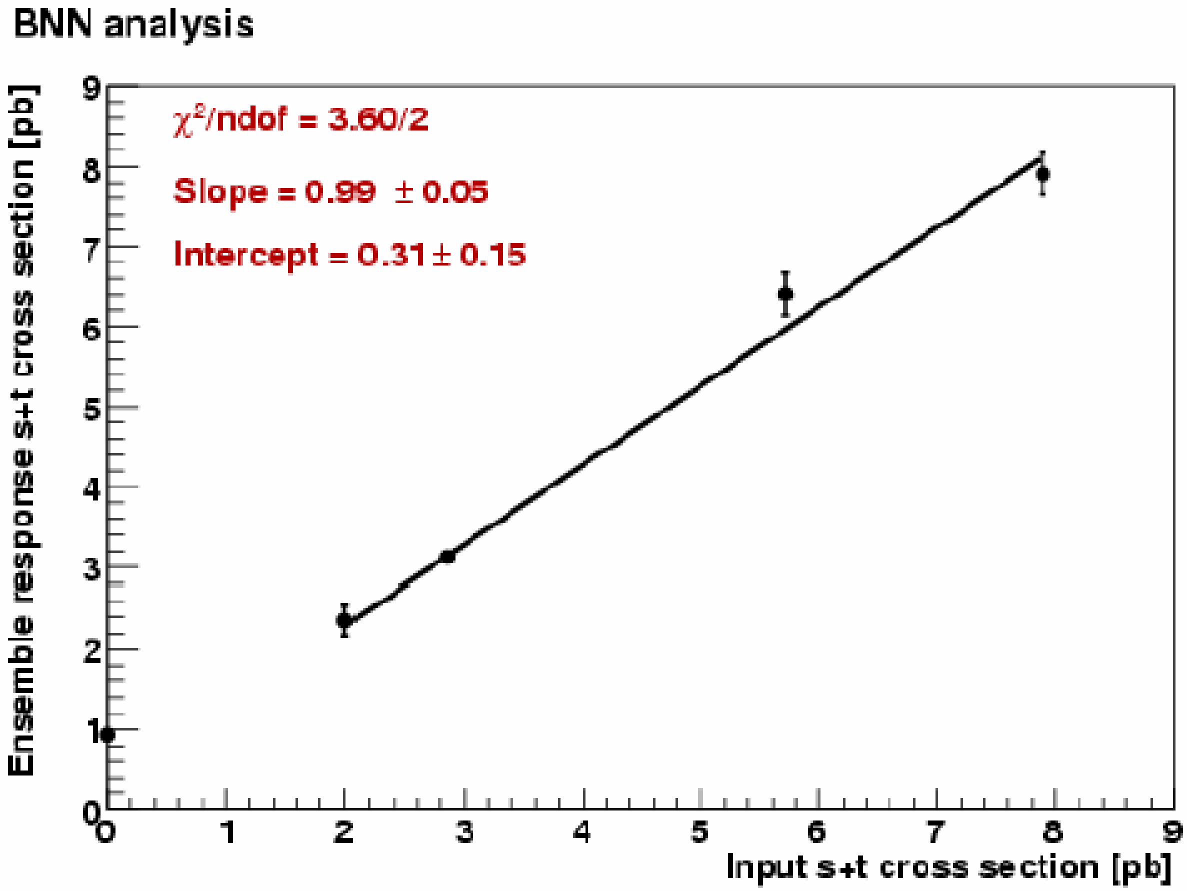
Multivariate Analyses: Matrix Elements



Multivariate Analyses: Bayesian Neural Networks

- A different sort of neural network:
  - Instead of choosing one set of weights, find posterior probability density over all possible weights
  - Averaging over many networks weighted by the probability of each network given the training data
  - Less prone to overtraining
  - For details see: http://www.cs.toronto.edu/radford/fbm.software.html
- Use 24 variables (subset of DT variables)

Multivariate Analyses: Bayesian Neural Networks

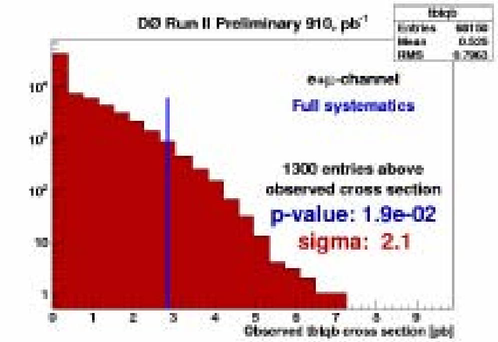


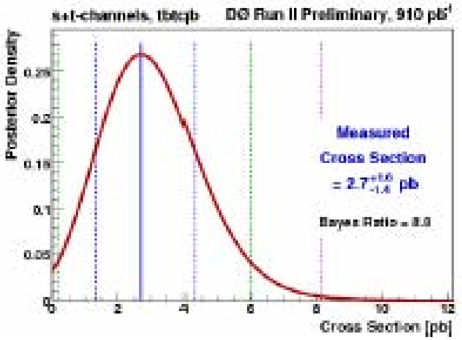
Cross Sections & Significance

EXPECTED

Decision Trees

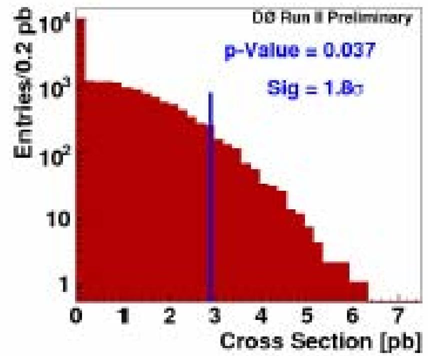
p-value **1.9%**

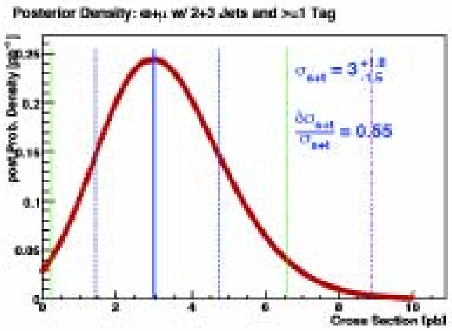




Matrix Elements

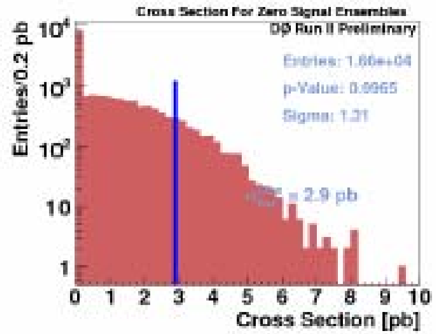
p-value **3.7%**

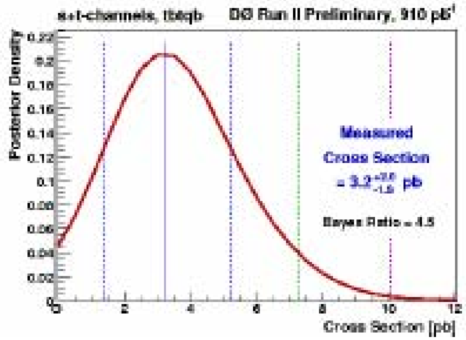




Bayesian NN

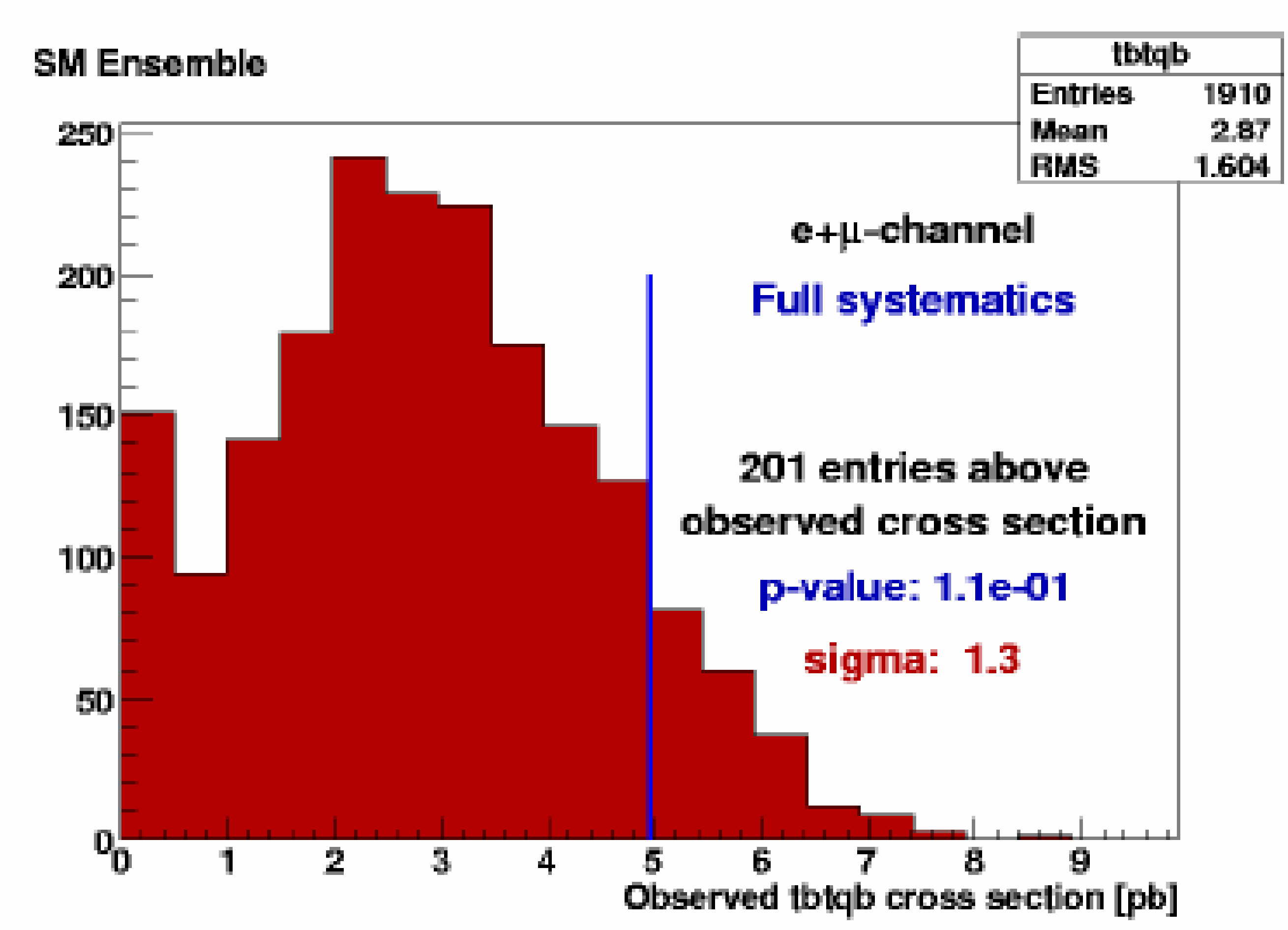
p-value **9.7%**





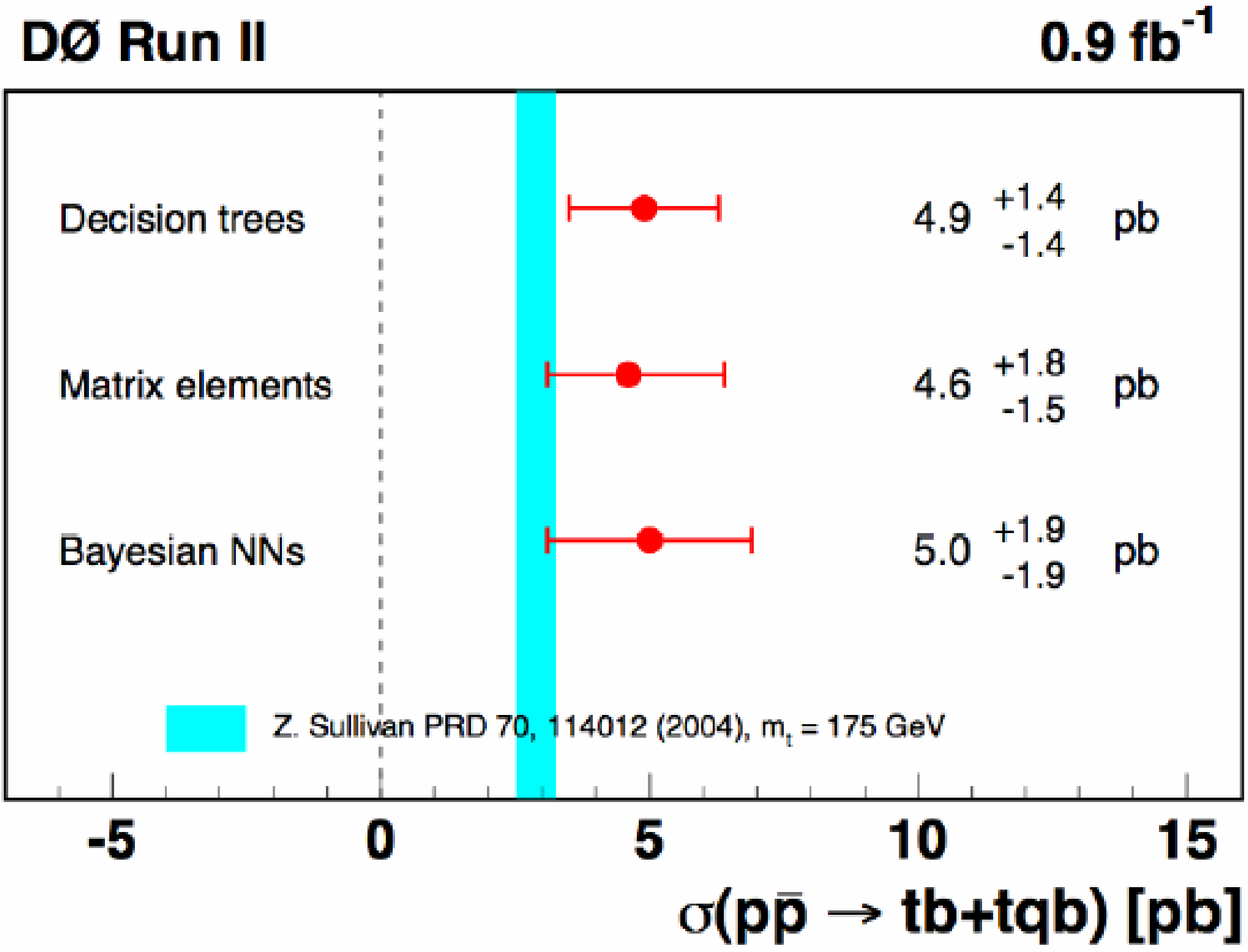
Cross Sections & Significance

Decision Trees: Consistency with the S.M.



Cross Sections & Significance

All Methods Summary:

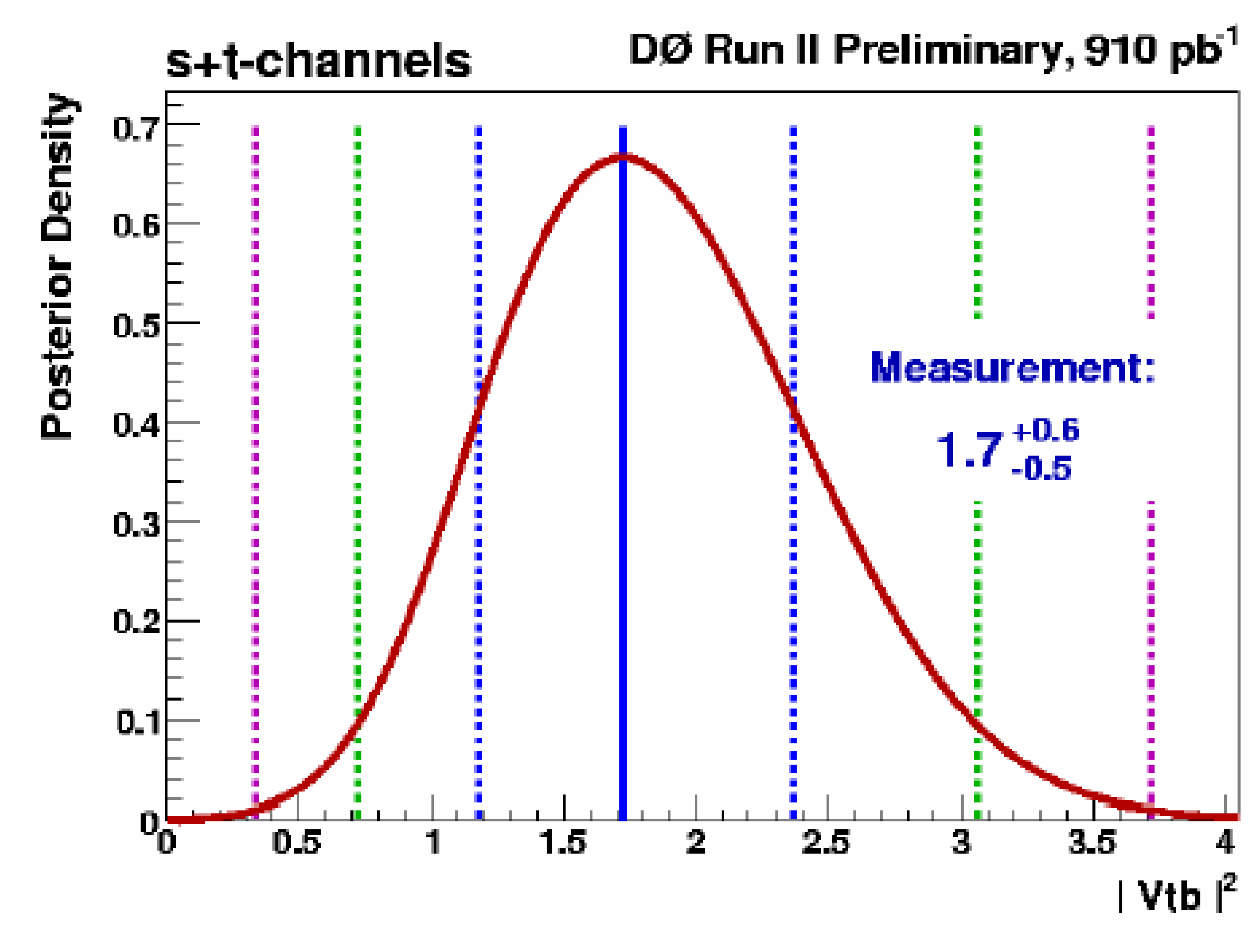


First Direct Measurement of $|V_{tb}|$

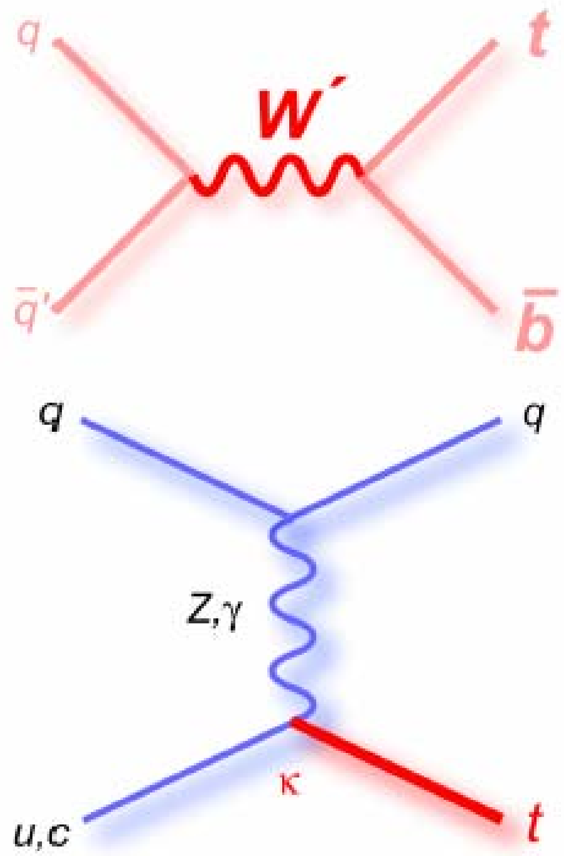
- Given that we now have a measurement of the single top cross section, we can make the first direct meassurement of $|V_{tb}|$.
- Use the same infrastructure as cross section measurement but make a posterior in $|V_{tb}|^2$.
- Caveat: assume SM top quark decays.
- Additional theoretical errors are needed (see hep-ph/0408049)

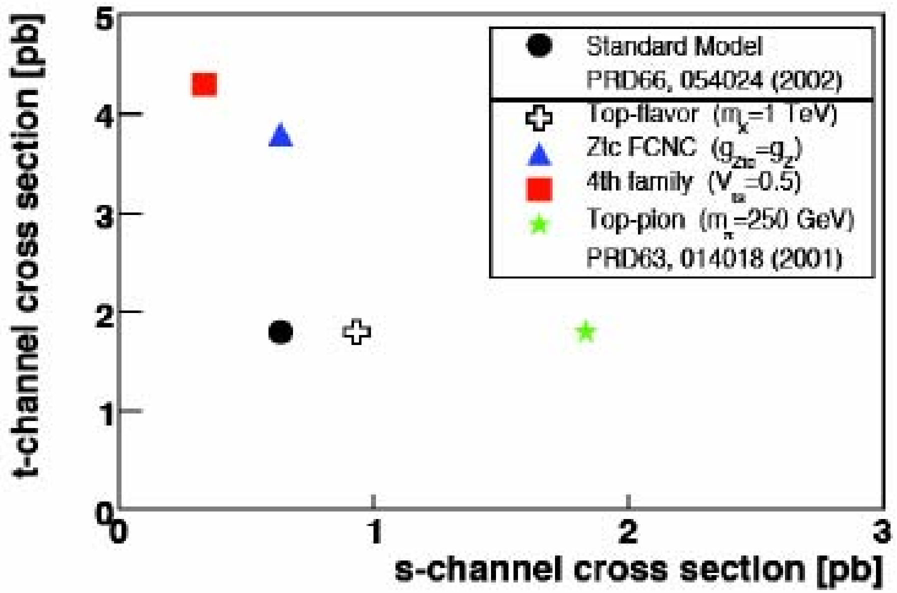
	s	t
top mass	13%	8.5%
scale	5.4%	4.0%
PDF	4.3%	10.0%
α_s	1.4%	0.01%

First Direct Measurement of $|V_{tb}|$

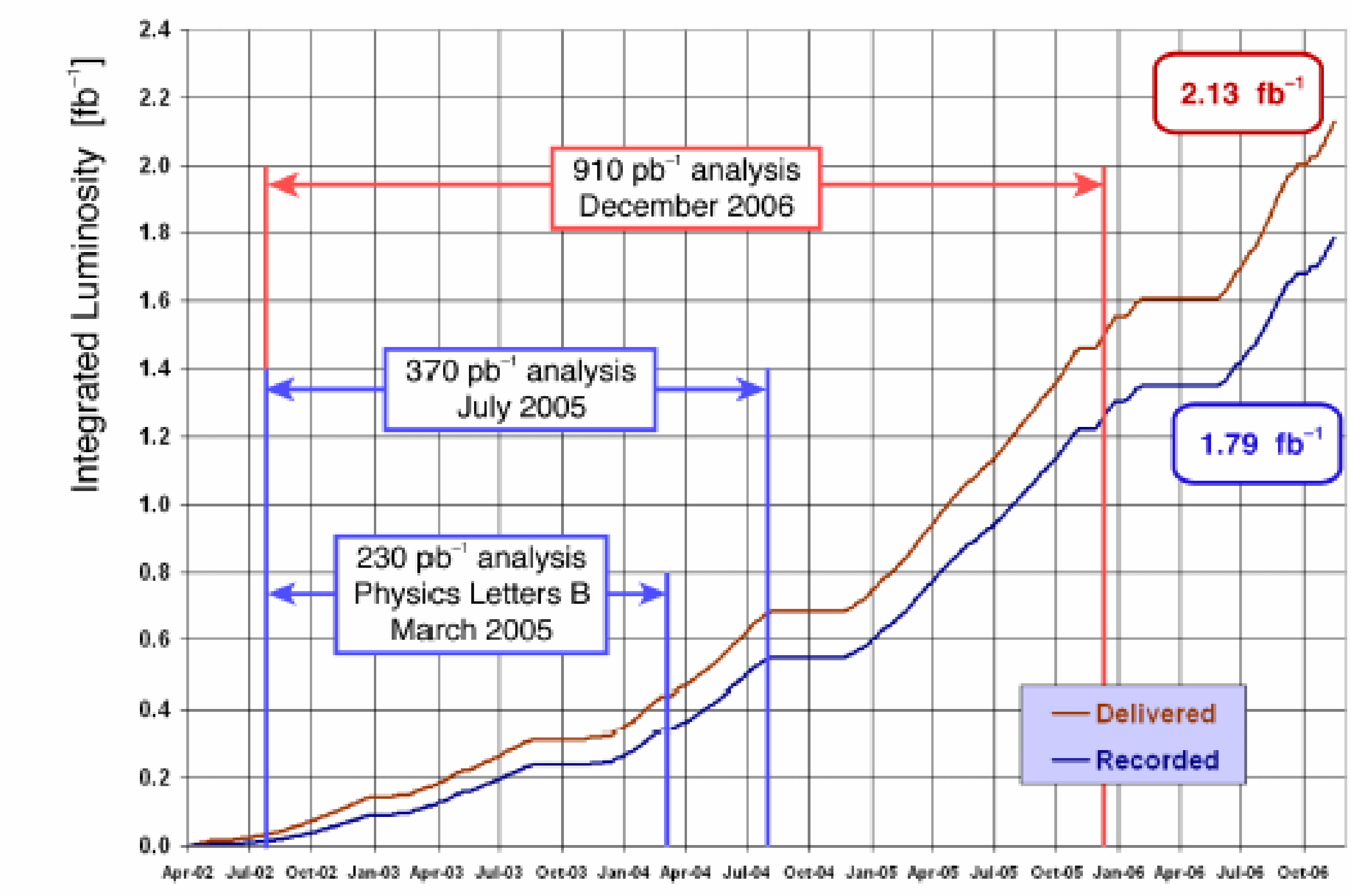


Motivation: New Physics





DØ Integrated Luminosity



Electron ID

We require electrons to be within the central calorimeter: $|\eta^{det}| < 1.1$.

Loose isolated electron

At least 90% of the energy of the cluster must be contained in the electromagnetic section of the calorimeter. The χ^2 from the 7×7 H-matrix must be less than 50. The energy deposition in the calorimeter must be matched with a charged particle track from the tracking detectors with $p_t > 5$ GeV. Isolation: $(E_{\mathrm{total}}(R < 0.4) - E_{\mathrm{EM}}(R < 0.2))/E_{\mathrm{EM}}(R < 0.2) < 0.15$.

Tight isolated electron

A tight isolated electron must pass the loose isolation requirements above, and have a value of the seven-variable EM-likelihood $\mathcal{L} > 0.85$.

Muon ID

Loose muons must be of *medium* $|\mathrm{nseg}| = 3$ quality and pass the loose cosmic ray rejection timing requirements: $|\Delta t(\text{A layer scint}, t_0)| < 10$ ns and $|\Delta t(\text{BC layer scints}, t_0)| < 10$ ns. The track reconstructed in the muon system must match a track reconstructed in the central tracker with $\chi^2/\text{ndof} < 4$. The central track is required to have distance of closest approach (dca) to the primary vertex of $|\mathrm{dca}(x, y)| < 0.2$. Note that the previous analysis imposed a dca significance cut of 3 standard deviations that has been removed now. Loose muons must be isolated from jets by $\Delta R > 0.5$.

Tight isolated muon

Tight isolated muons are loose muons with the additional isolation criteria: (a) the momenta of all tracks in a cone of radius $R < 0.5$ around the muon direction, except the track matched to the muon, add up to less than 20% of the muon p_T; and (b) the energy deposited in an annular cone of radius $0.1 < R < 0.4$ around the muon direction is less that 20% of the muon p_T

HF Fraction

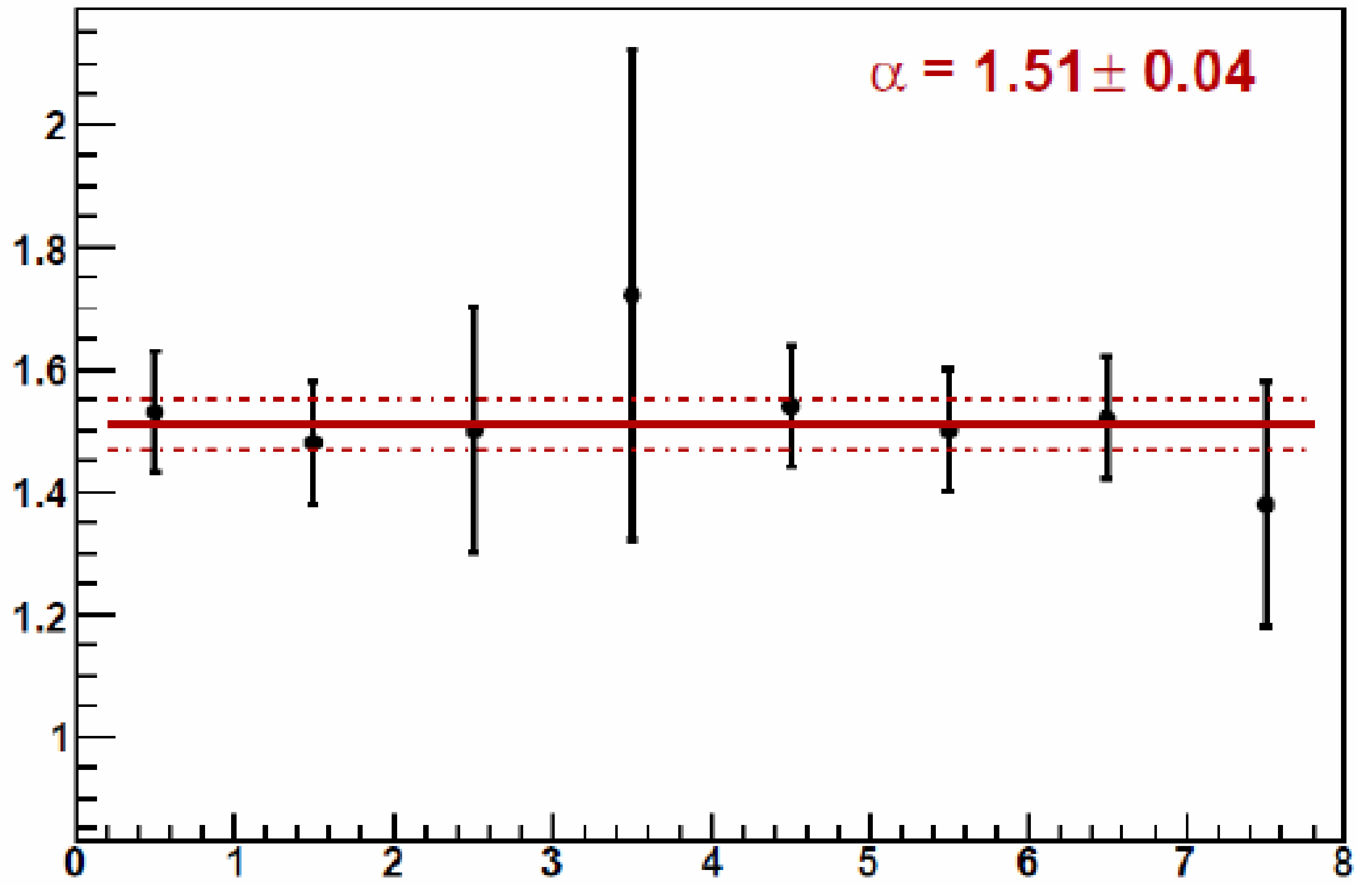
$$\alpha(Wb\bar{b} + Wc\bar{c}) + Wjj + t\bar{t} + \text{QCD} = \text{Data}$$

Scale Factor α to Match Heavy Flavor Fraction to Data

	1 jet	2 jets	3 jets	4 jets
Electron Channel				
0 tags	1.53 ± 0.10	1.48 ± 0.10	1.50 ± 0.20	1.72 ± 0.40
1 tag	1.29 ± 0.10	1.58 ± 0.10	1.40 ± 0.20	0.69 ± 0.60
2 tags	—	1.71 ± 0.40	2.92 ± 1.20	-2.91 ± 3.50
Muon Channel				
0 tags	1.54 ± 0.10	1.50 ± 0.10	1.52 ± 0.10	1.38 ± 0.20
1 tag	1.11 ± 0.10	1.52 ± 0.10	1.32 ± 0.20	1.86 ± 0.50
2 tags	—	1.40 ± 0.40	2.46 ± 0.90	3.78 ± 2.80

HF Fraction

Heavy flavour scale factor α measured in the zero tag bins

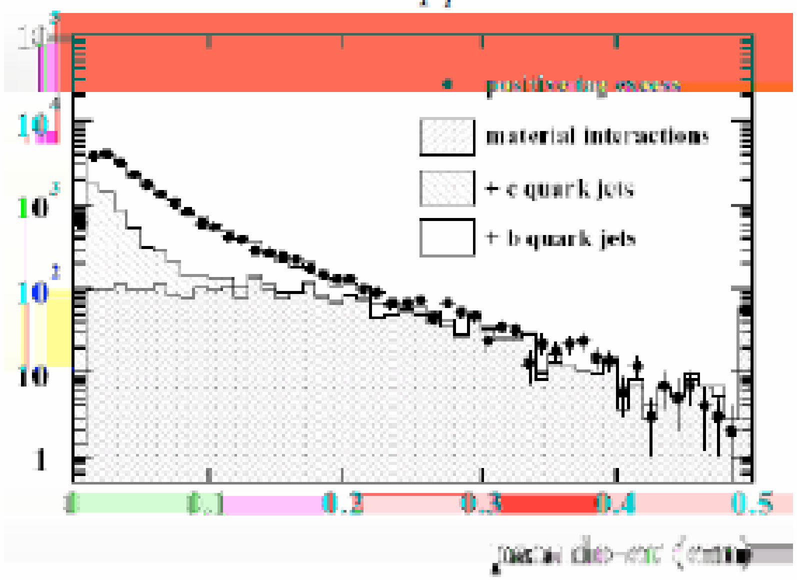


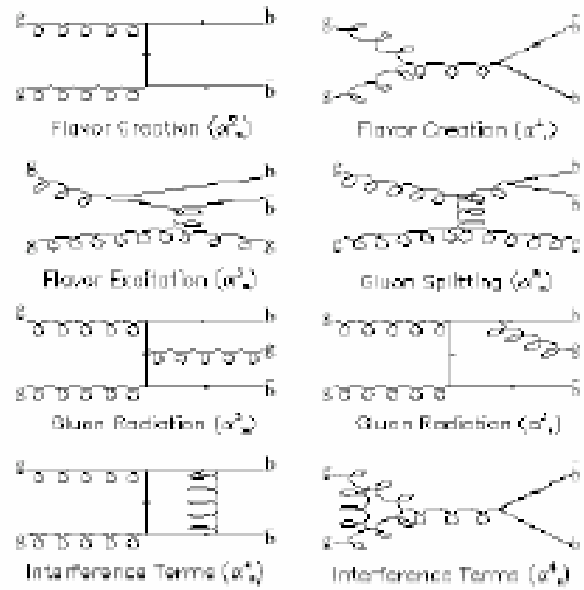
HF Fraction - CDF

1) Estimate generic jet heavy flavor fraction in ALPGEN Monte Carlo
2) Fit for bottom and charm fraction in generic jet data

Difference between the two outcomes suggests K=1.5±0.4
Result supported by study using MCFM: J. M. Campbell, J. Houston, Method 2 at NLO, hep-ph/0405276

$$pseudo-c\tau = L_{2D} \cdot \frac{M^{vtx}}{p_T^{vtx}}$$

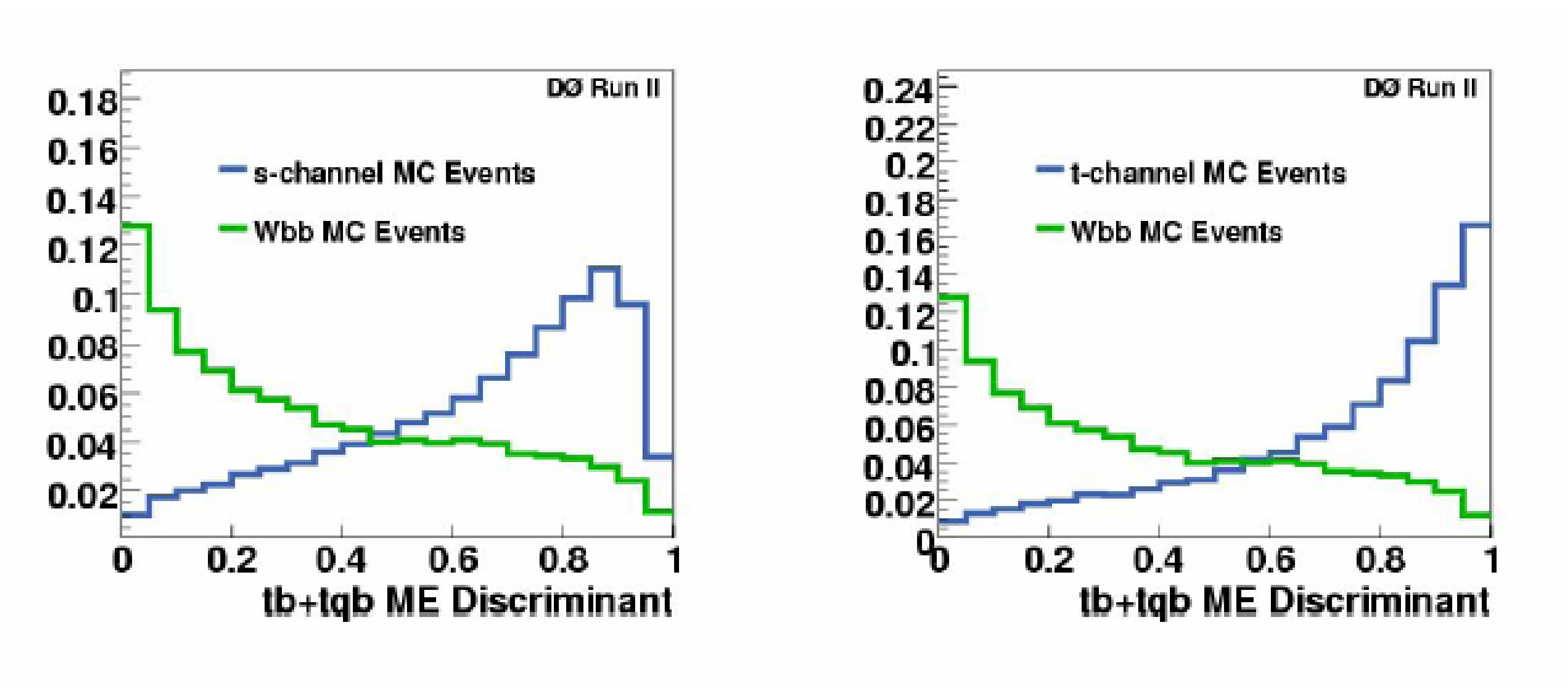




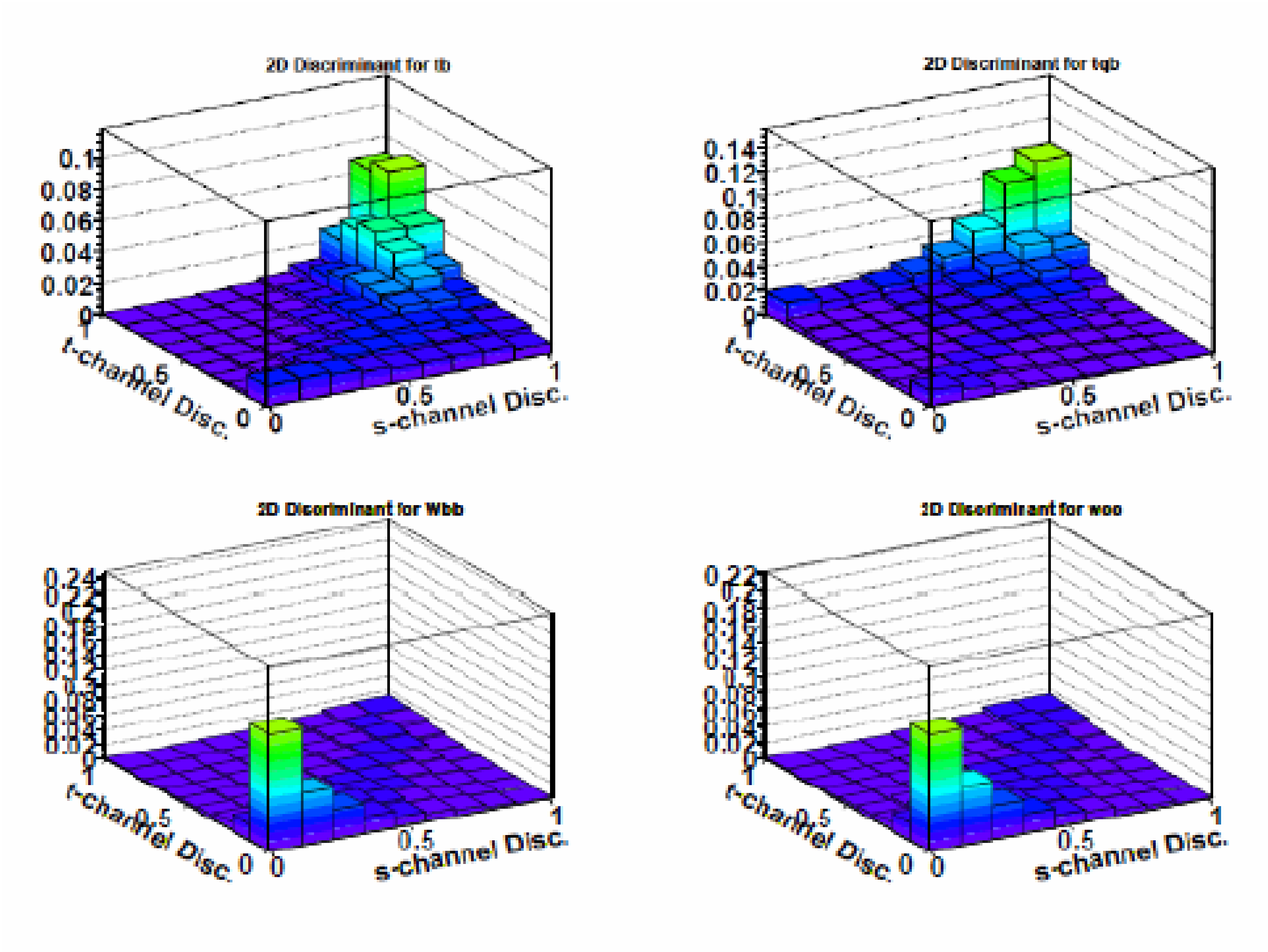
Systematic Uncertainties

Relative Systematic Uncertainties			
$t\bar{t}$ cross section	18%	Primary vertex	3%
Luminosity	6%	Electron reco * ID	2%
Electron trigger	3%	Electron trackmatch & likelihood	5%
Muon trigger	6%	Muon reco * ID	7%
Jet energy scale	wide range	Muon trackmatch & isolation	2%
Jet efficiency	2%	$\varepsilon_{\mathrm{real}-e}$	2%
Jet fragmentation	5–7%	$\varepsilon_{\mathrm{real}-\mu}$	2%
Heavy flavor fraction	30%	$\varepsilon_{\mathrm{fake}-e}$	3–40%
Tag-rate functions	2–16%	$\varepsilon_{\mathrm{fake}-\mu}$	2–15%

Matrix Element Method



Matrix Element Method



Decision Trees Variables

Object Kinematics

p_T(jet1)
p_T(jet2)
p_T(jet3)
p_T(jet4)
p_T(best1)
p_T(notbest1)
p_T(notbest2)
p_T(tag1)
p_T(untag1)
p_T(untag2)

Angular Correlations

ΔR(jet1,jet2)
$\cos(\text{best1,lepton})_{\text{besttop}}$
$\cos(\text{best1,notbest1})_{\text{besttop}}$
$\cos(\text{tag1,alljets})_{\text{alljets}}$
$\cos(\text{tag1,lepton})_{\text{btaggedtop}}$
$\cos(\text{jet1,alljets})_{\text{alljets}}$
$\cos(\text{jet1,lepton})_{\text{btaggedtop}}$
$\cos(\text{jet2,alljets})_{\text{alljets}}$
$\cos(\text{jet2,lepton})_{\text{btaggedtop}}$
$\cos(\text{lepton}, Q(\text{lepton}) \times z)_{\text{besttop}}$
$\cos(\text{lepton,besttopframe})_{\text{besttopCMframe}}$
$\cos(\text{lepton,btaggedtopframe})_{\text{btaggedtopCMframe}}$
$\cos(\text{notbest,alljets})_{\text{alljets}}$
$\cos(\text{notbest,lepton})_{\text{besttop}}$
$\cos(\text{untag1,alljets})_{\text{alljets}}$
$\cos(\text{untag1,lepton})_{\text{btaggedtop}}$

Event Kinematics

Aplanarity(alljets,W)
M(W,best1) ("best" top mass)
M(W,tag1) ("b-tagged" top mass)
H_T(alljets)
H_T(alljets−best1)
H_T(alljets−tag1)
H_T(alljets,W)
H_T(jet1,jet2)
H_T(jet1,jet2,W)
M(alljets)
M(alljets−best1)
M(alljets−tag1)
M(jet1,jet2)
M(jet1,jet2,W)
M_T(jet1,jet2)
M_T(W)
Missing E_T
p_T(alljets−best1)
p_T(alljets−tag1)
p_T(jet1,jet2)
$Q(\text{lepton}) \times \eta(\text{untag1})$
$\sqrt{\hat{s}}$
Sphericity(alljets,W)

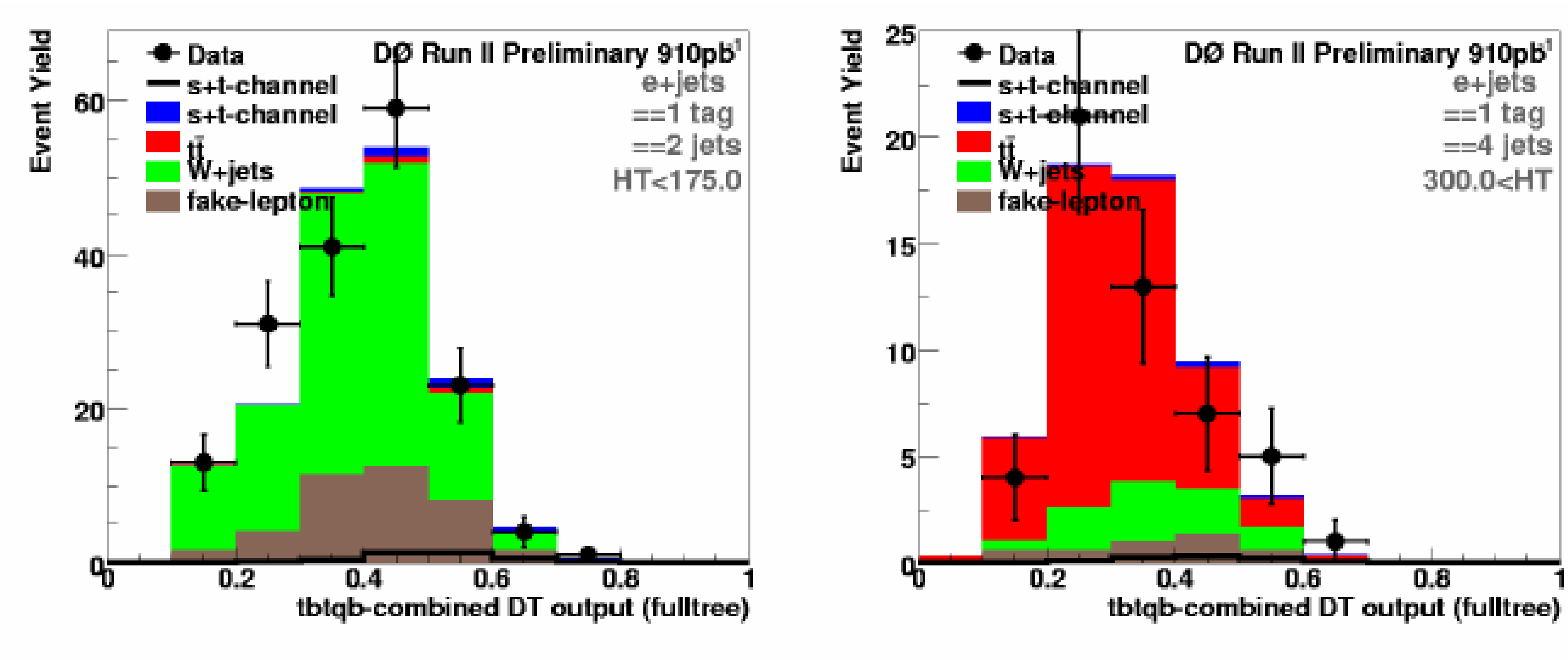
- Adding variables does not degrade performance
- Tested shorter lists, lose some sensitivity
- Same list used for all channels

Ensemble Testing Details

- Use a pool of weighted signal + background events (about 850k in each of electron and muon)
- Fluctuate relative and total yields in proportion to systematic errors
- Randomly sample from a Poisson distribution about the total yield
- Generate a set of pseudo-data (a member of the ensemble)
- Pass the pseudo-data through the full analysis chain (including systematic uncertainties)

Cross-checks: DT

- “W+jets”: =2jets, H_T (lepton,MET,alljets) < 175 GeV
- “ttbar”: =4jets, H_T (lepton,MET,alljets) > 300 GeV
- Shown: tb+tqb DT output for e+jets

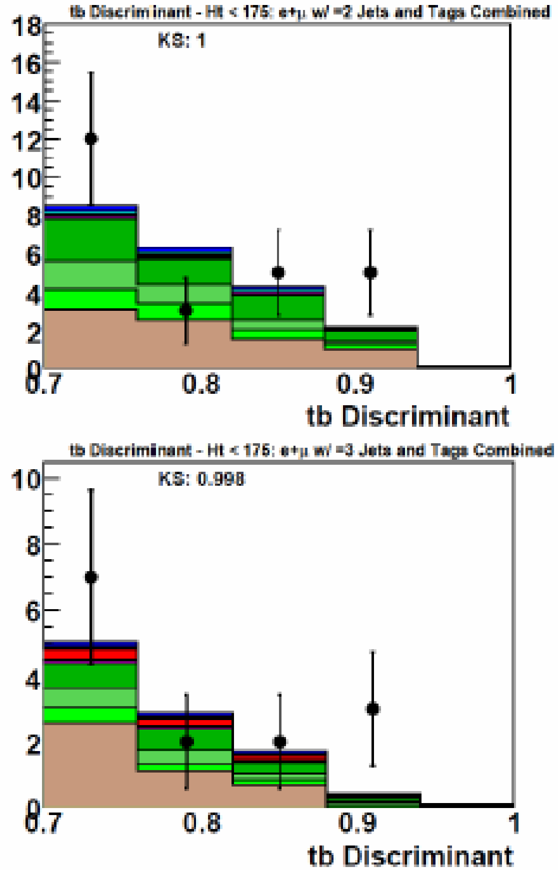


- Good agreement of model with data

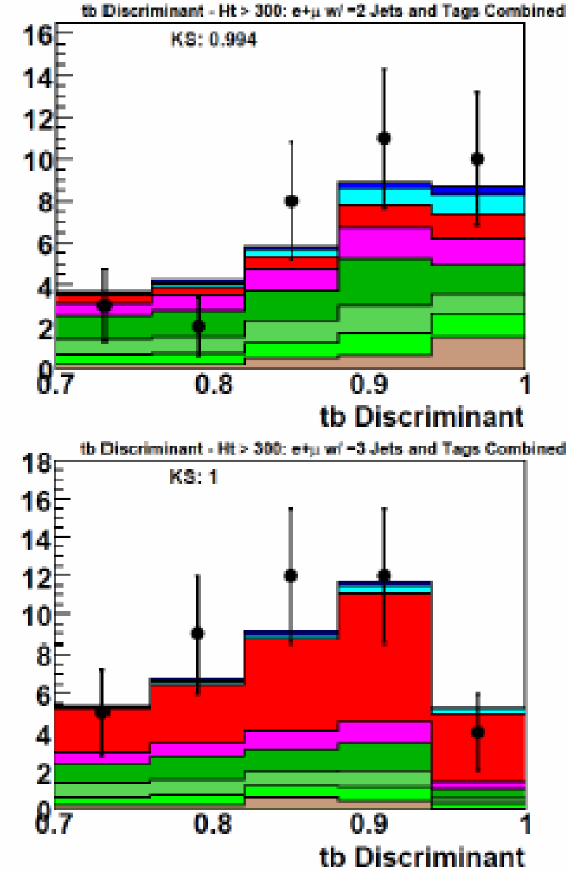
Cross-checks: ME

Look at H_T "sidebands" in 2 and 3 jets

"Soft W-jets"

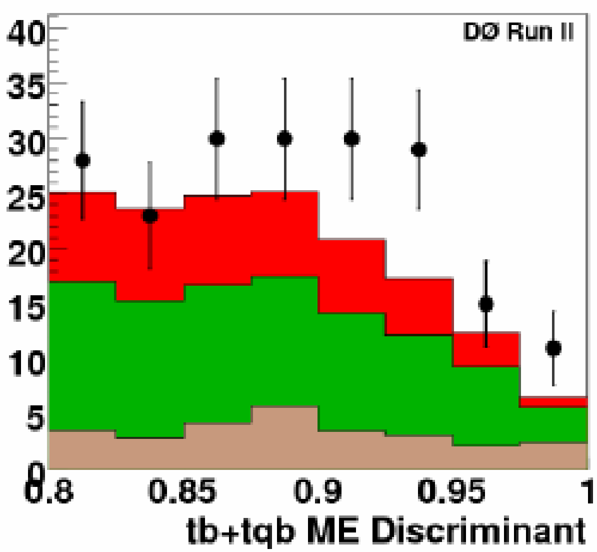


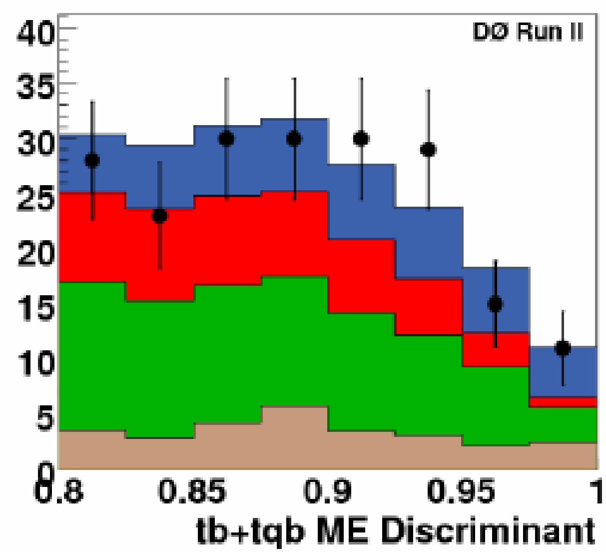
"Hard W-jets"



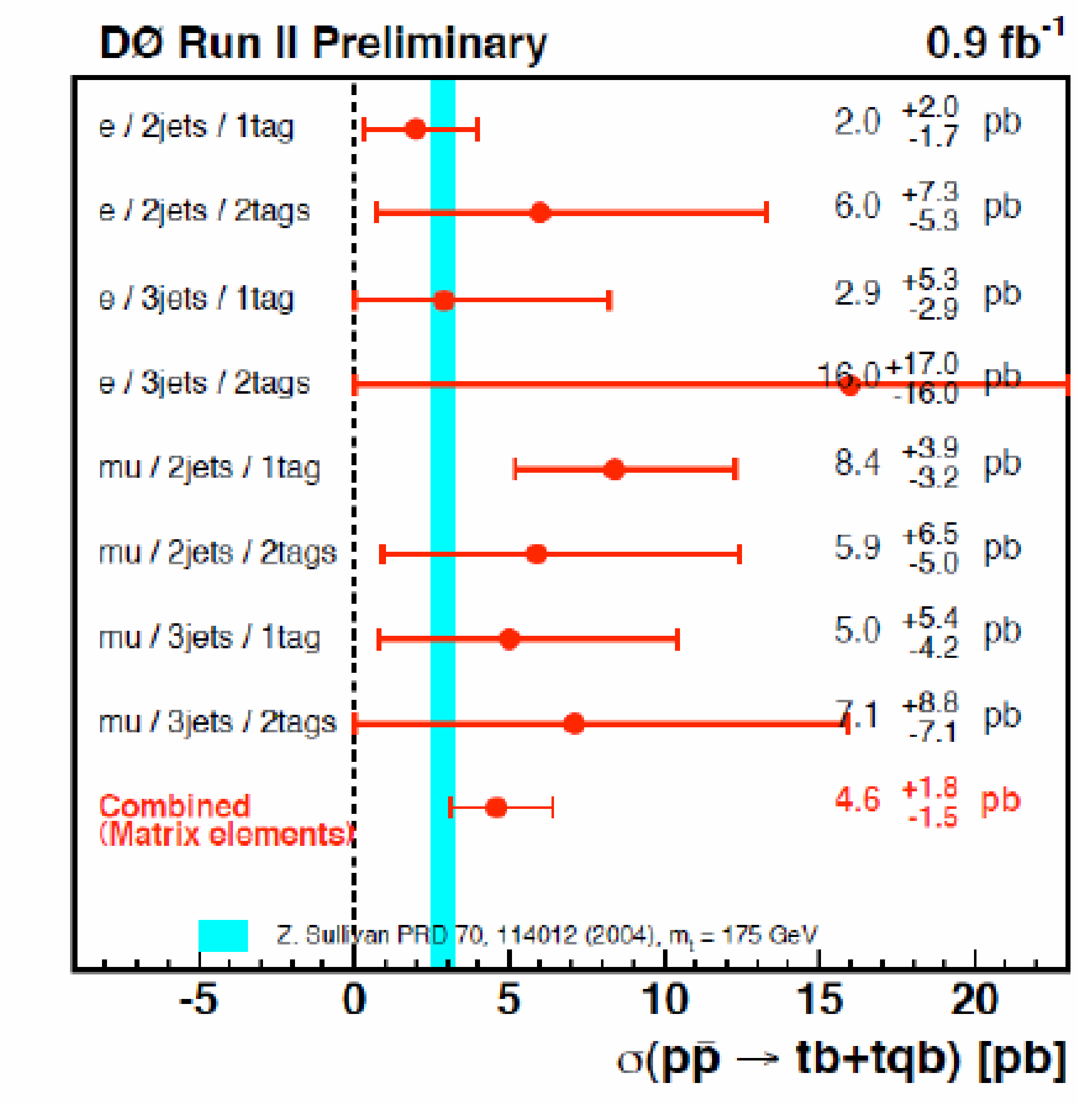
Excess in ME

Discriminant output with and without signal component (all channels combined in 1D to "visualize" excess)



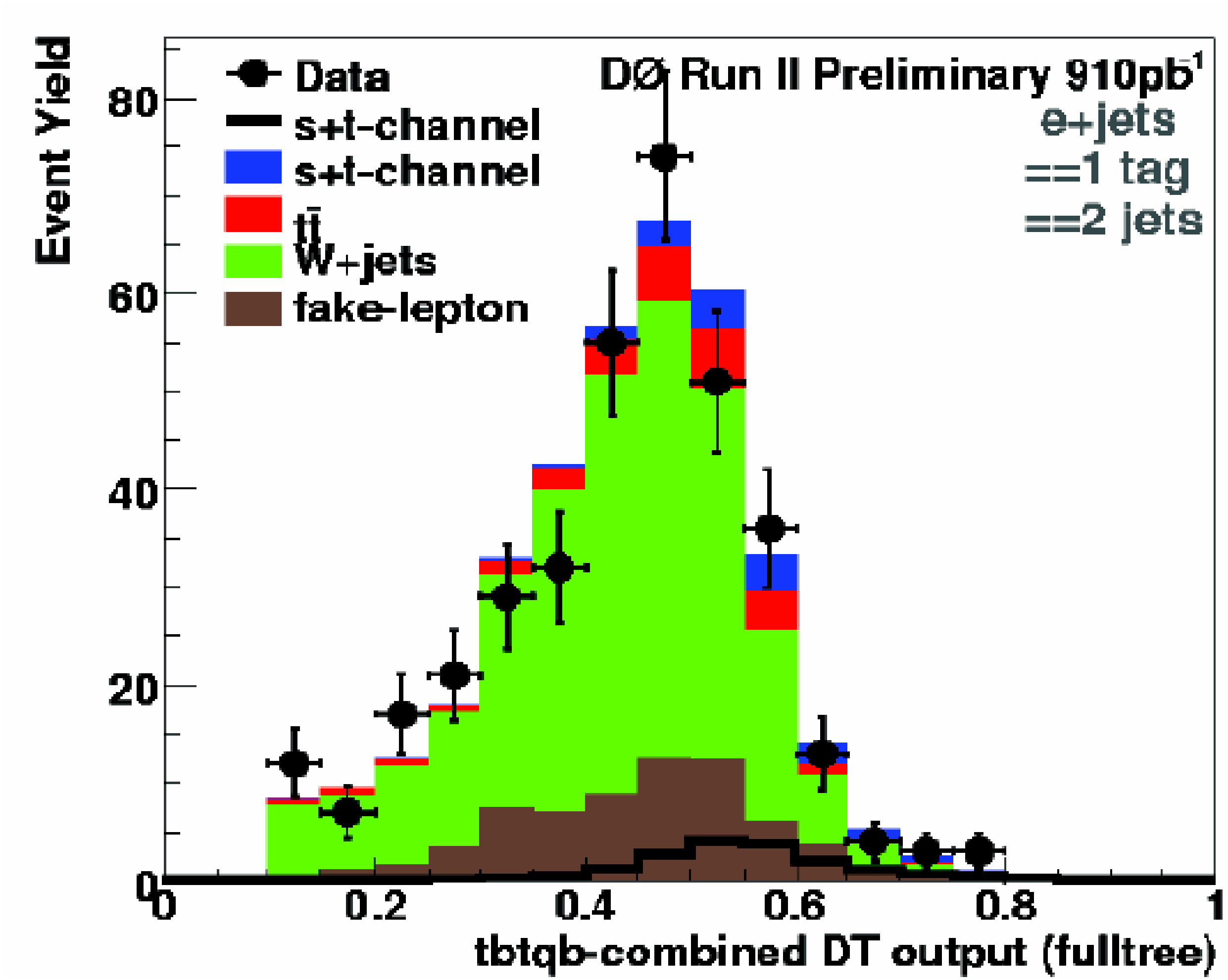


ME: Results Summary

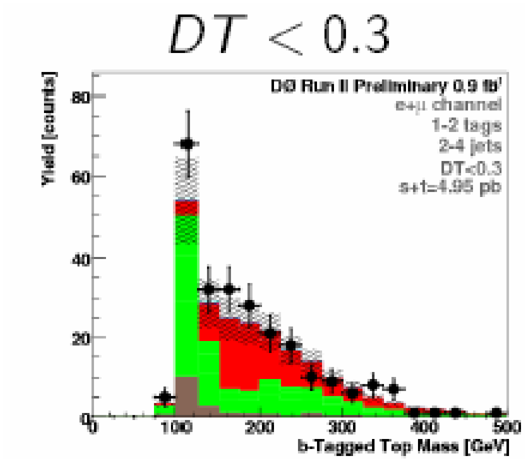


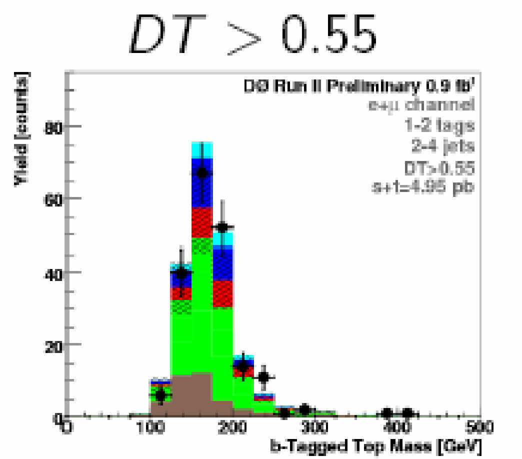
Decision Trees on Data

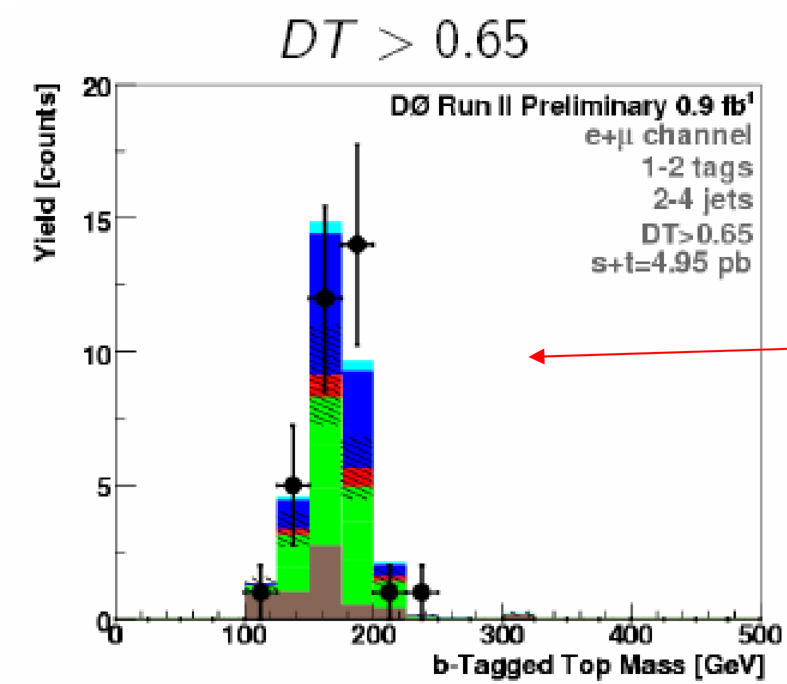
s+t, electron channel, 2 jet, 1 tag:



DT Output: M(W,b)

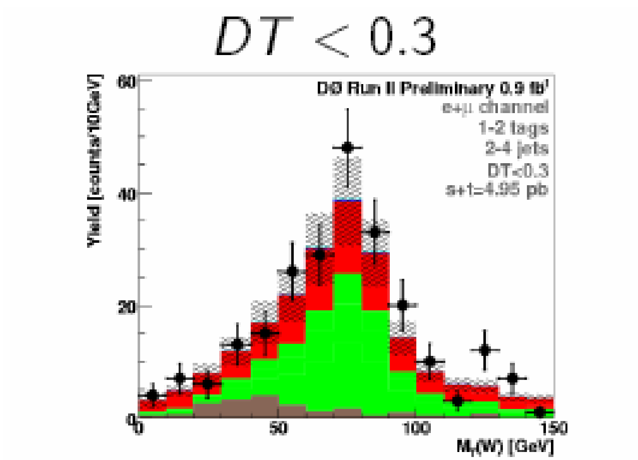


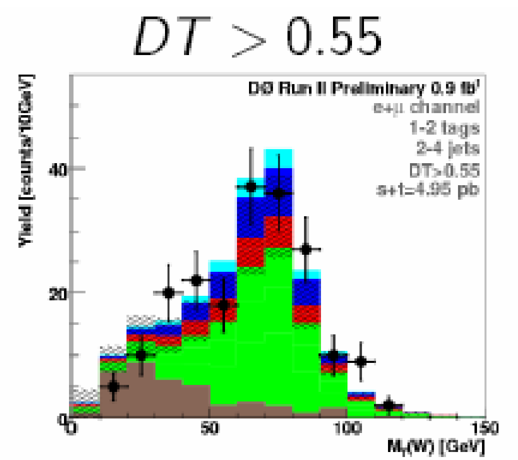


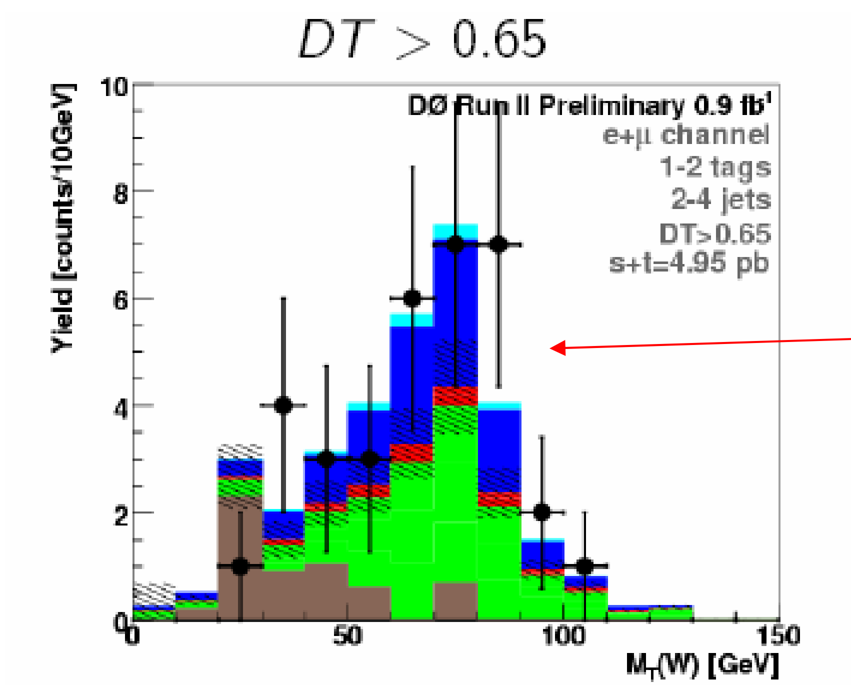


Excess in high DT output region

DT Output: $M_T(W)$

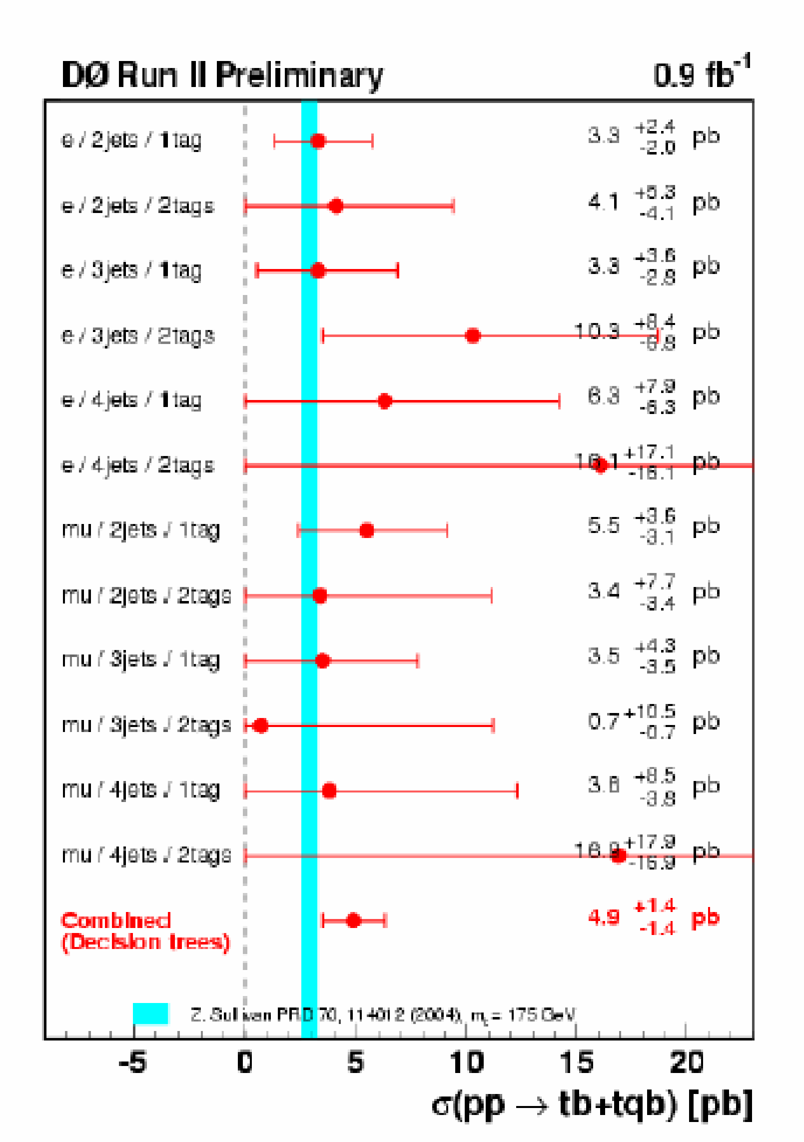






Excess in high DT output region

DT: Results Summary



Correlations Between Methods

Choose the 50 highest events in each discriminant and look for overlap

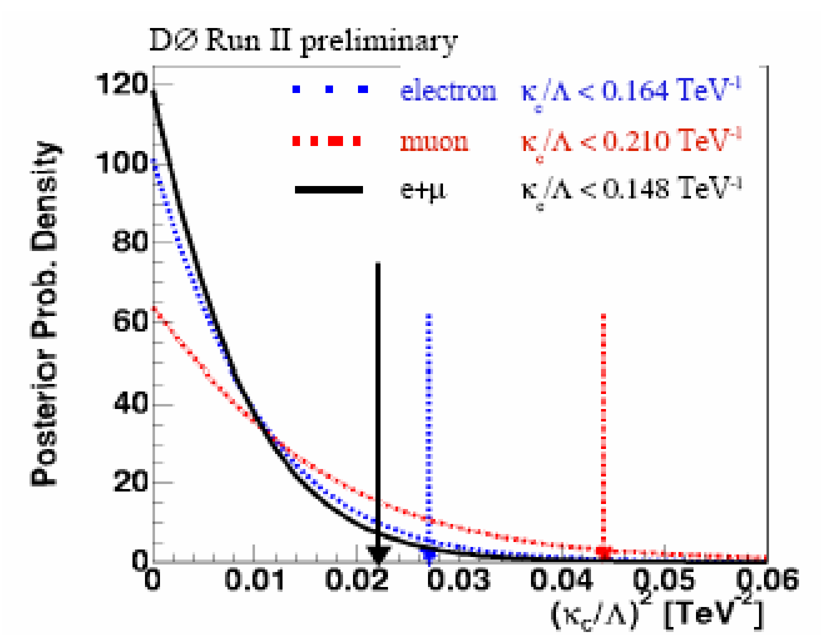
Technique	Electron	Muon
DT vs ME	52%	58%
DT vs BNN	56%	48%
ME vs BNN	46%	52%

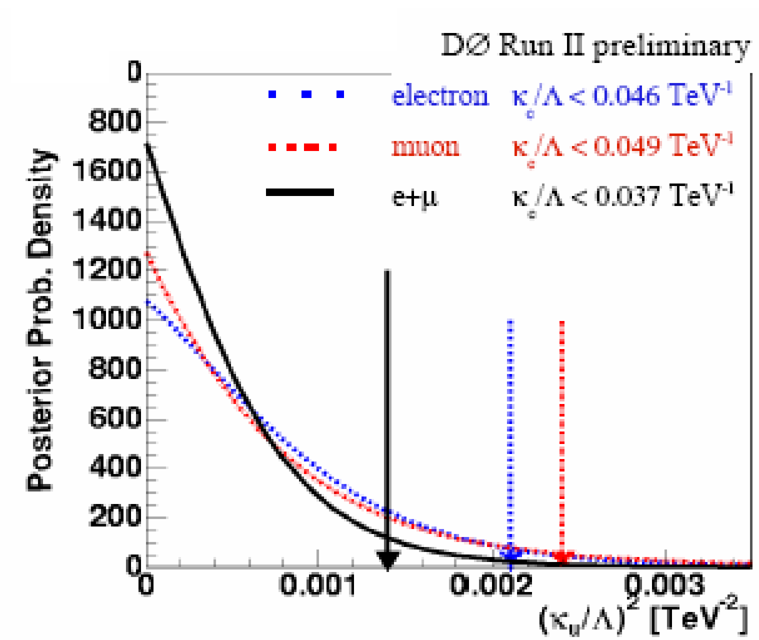
Also measured the cross section in 400 members of the SM ensemble with all three techniques and calculated the linear correlation between each pair:

	DT	ME	BNN
DT	100%	39%	57%
ME		100%	29%
BNN			100%

Single Top

- DØ: Search for FCNC (230 pb^{-1})





Single Top

- DØ: Search for W' (230 pb^{-1})

s-channel: