Top Quark Pair Production at 1.96 GeV using Lepton + Jets events at CDF

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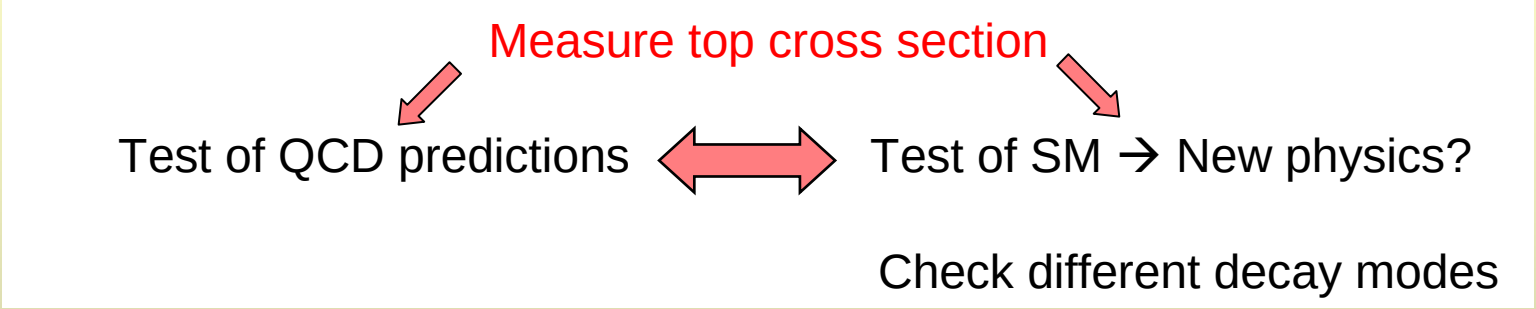
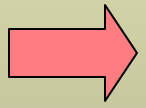
HEP2005 Lisboa, Portugal

Motivation

- Top quark: The young member of the SM family
  - Discovered in 1995 but still almost everything to learn
  1. Is the W+jets event excess pure $t\bar{t}$ production?



2. Want to measure top properties, but first ….
   - Need large top quark datasets
   - Understand the W+Jets sample
     - Learn the backgrounds



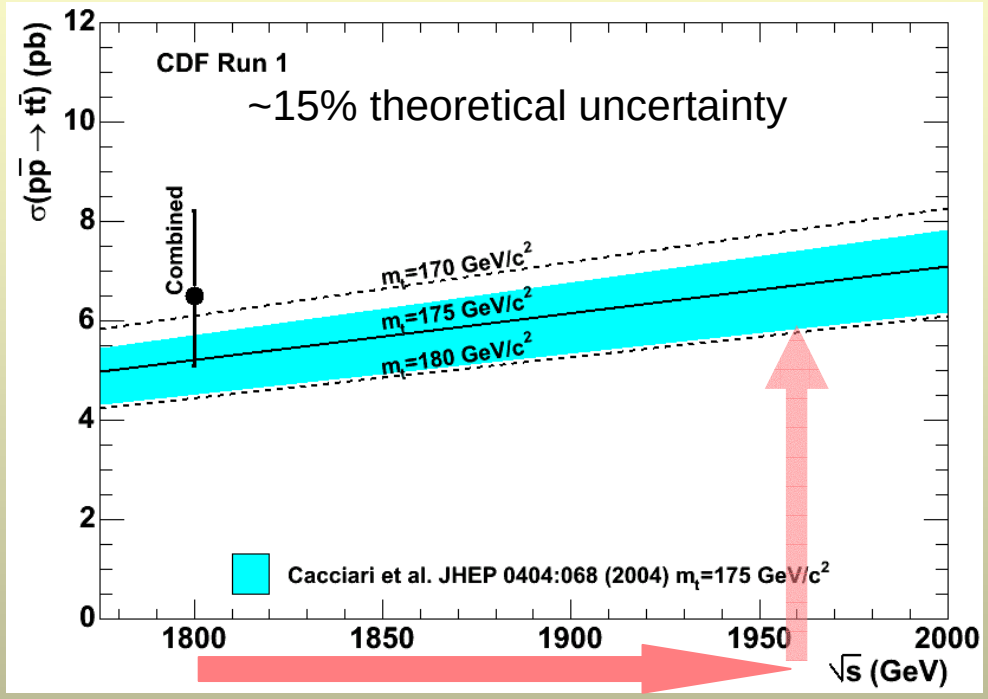
Measure top cross section

The Tevatron

	Luminosity (pb^{-1})
Delivered	> 1000
CDF to tape	~ 900
Today's results update	~ 350
Published	~ 200

Top Quark Pair Production at the Tevatron

Top pairs produced via strong interaction

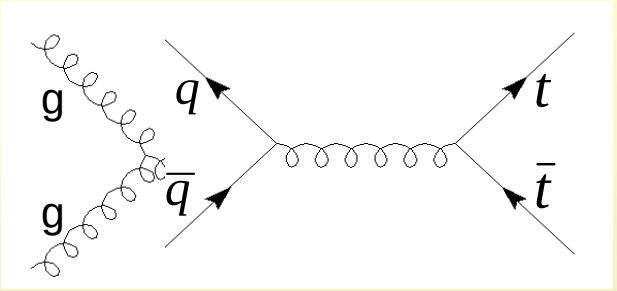


Run 1
($\sqrt{s}$ = 1.8 TeV)

Run 2
($\sqrt{s}$ = 1.96 TeV)

Cross section increases: 1.295 ± 0.015

$6.5^{+\,1.7}_{-1.4}$ pb → 8.5 pb



~15% ~85%

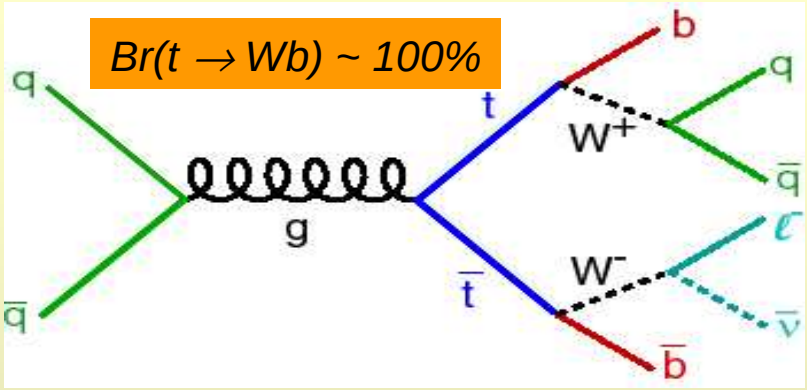
Theoretical uncertainty: ~ ±15%

- PDFs
- Renormalization/factorization scale

M_{top} (GeV/c^2)	$\sigma(p\bar{p} \to t\bar{t})$ (pb)
170	7.8
175	6.7
178	6.1

M. Cacciari et al. JHEP 0404:068 (2004)
N. Kidonakis and R. Vogt, Phys. Rev. D 68 114014 (2003)

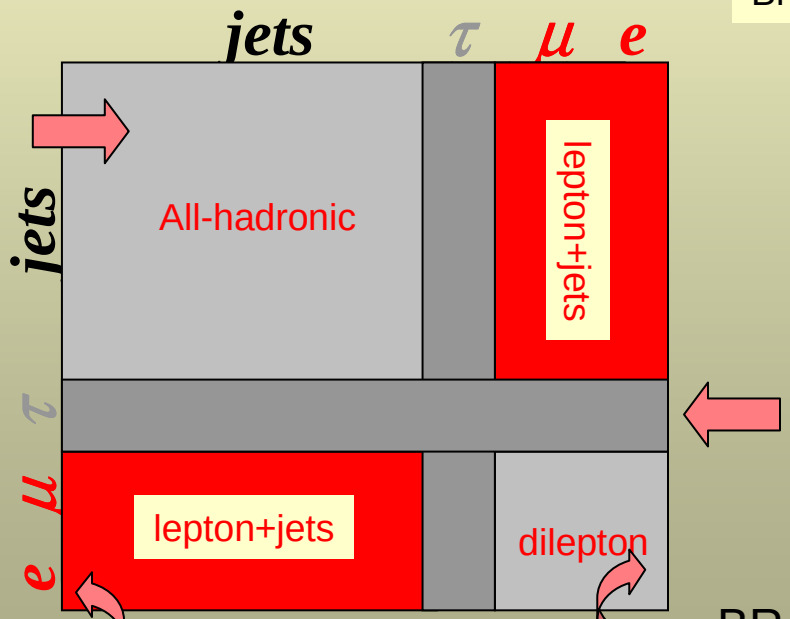
Event Signatures from $t\bar{t}$ Decay



Always:
2 b quarks +
2 W bosons

- Final state given by the W boson decays

Br(W → leptons) = 1/3
Br(W → quarks) = 2/3



- BR = 44%
- S/B ~ 1/5

Assuming:
M_{top} = 178 GeV/c^2

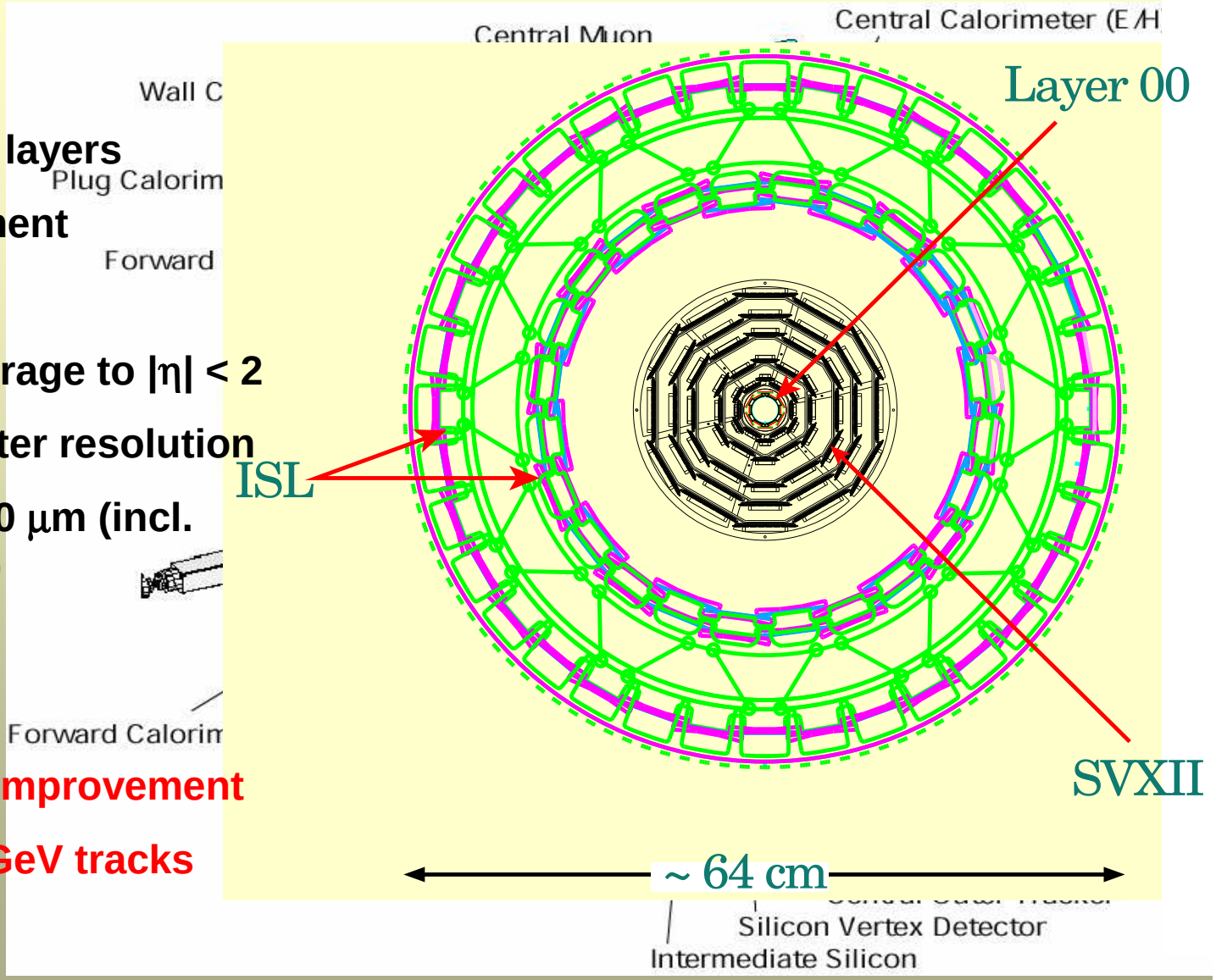
- New today (next talk)
- BR = 21% → 15%

- BR = 30%
- S/B ~ 1/5 – 5

- BR = 5%
- S/B ~1.6 – 3.0

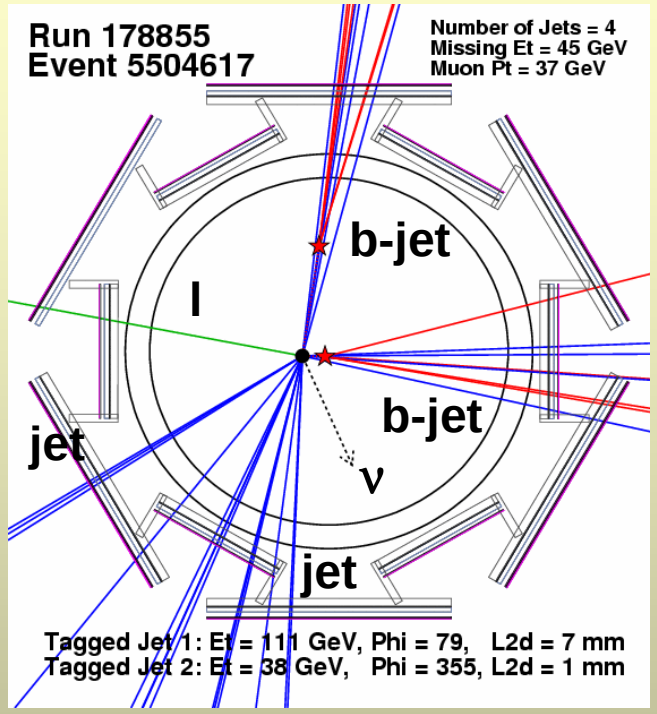
The CDF Run II Detector

- **SVX II**
  - **5 double sided layers**
  - **r-ϕ-z measurement**
- **ISL**
  - **Increases coverage to |η| < 2**
  - **Impact parameter resolution**
    - **SVX/ISL: 40 μm (incl. beam width)**
- **L00**
  - **On beampipe**
  - **I.P. resolution improvement**
    - **20% for 1 GeV tracks**



Lepton+Jets Event Selection

318 pb^{-1}



W + Jets Sample

- High P_T electron or muon
  - E_T or P_T > 20 GeV
  - Lepton isolated from jets
- Large missing energy from neutrino
  - MET>20 GeV
- ≥ 3 high E_T>15 GeV jets
- M_T(W) > 20 GeV

Top is Massive!

Large total event transverse energy:
jets E_T + lepton p_T, E_T + MET

Four jets in the final state

Two from b-quarks

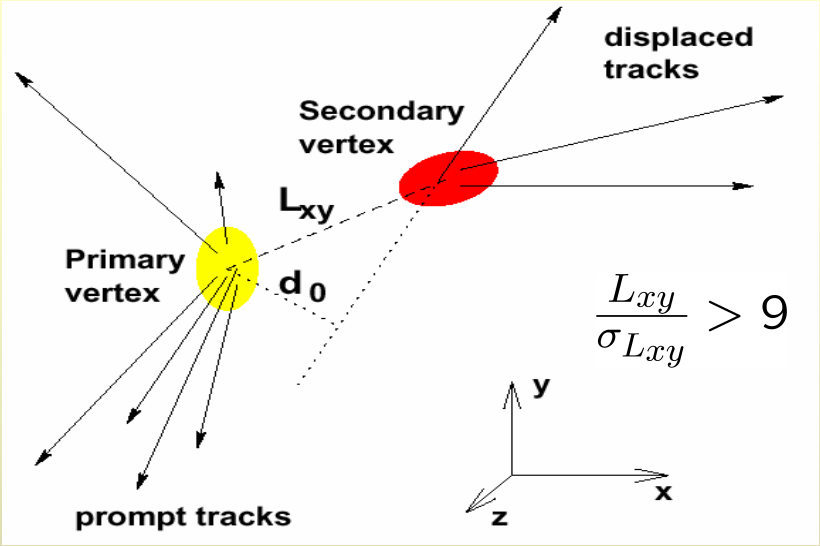
Possible additional jets from gluon radiation (ISR, FSR)

- H_T > 200 GeV
- ≥ 1 b-tag

or

- ≥ 2 b-tags

Secondary Vertex B-Tagging Algorithm

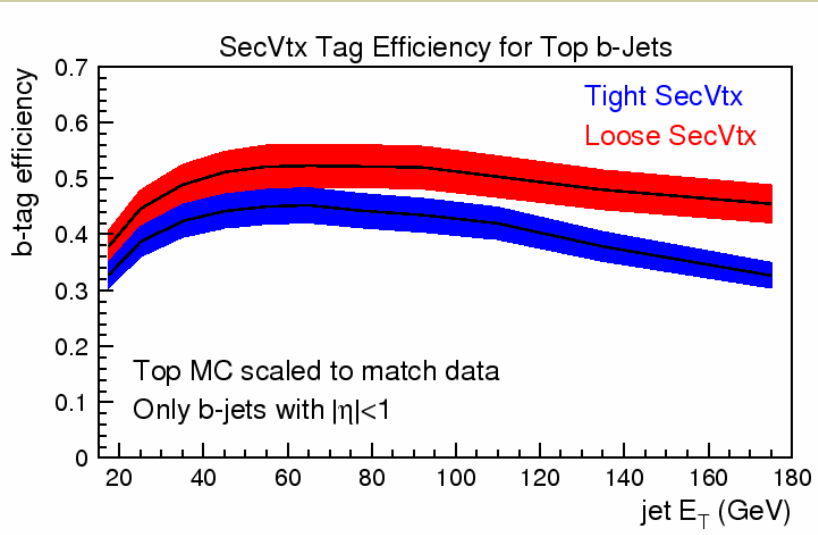


New offline/ Updated tagger

- Tracking improvements
  - Silicon L00
  - More forward tracks |η|>1
- Algorithm optimization
  - Loosen track selection
  - Tighten vertex quality requirements

~ 20% b-jet efficiency increase
~ 30% mistag increase/jet

Tight/Loose Secondary Vertex Tagger



Quark	Tight SecVtx	Loose SecVtx
Data Efficiency (%)		
b	40.3 ± 2.7	48.5 ± 3.5
c	8.7 ± 1.2	12.8 ± 1.8
Mistags/jet (%)		
light	0.5	1.2

20% b-jet efficiency increase

Top Cross Section: Tight / Loose Tagger

- Acceptance and efficiency from Pythia MC

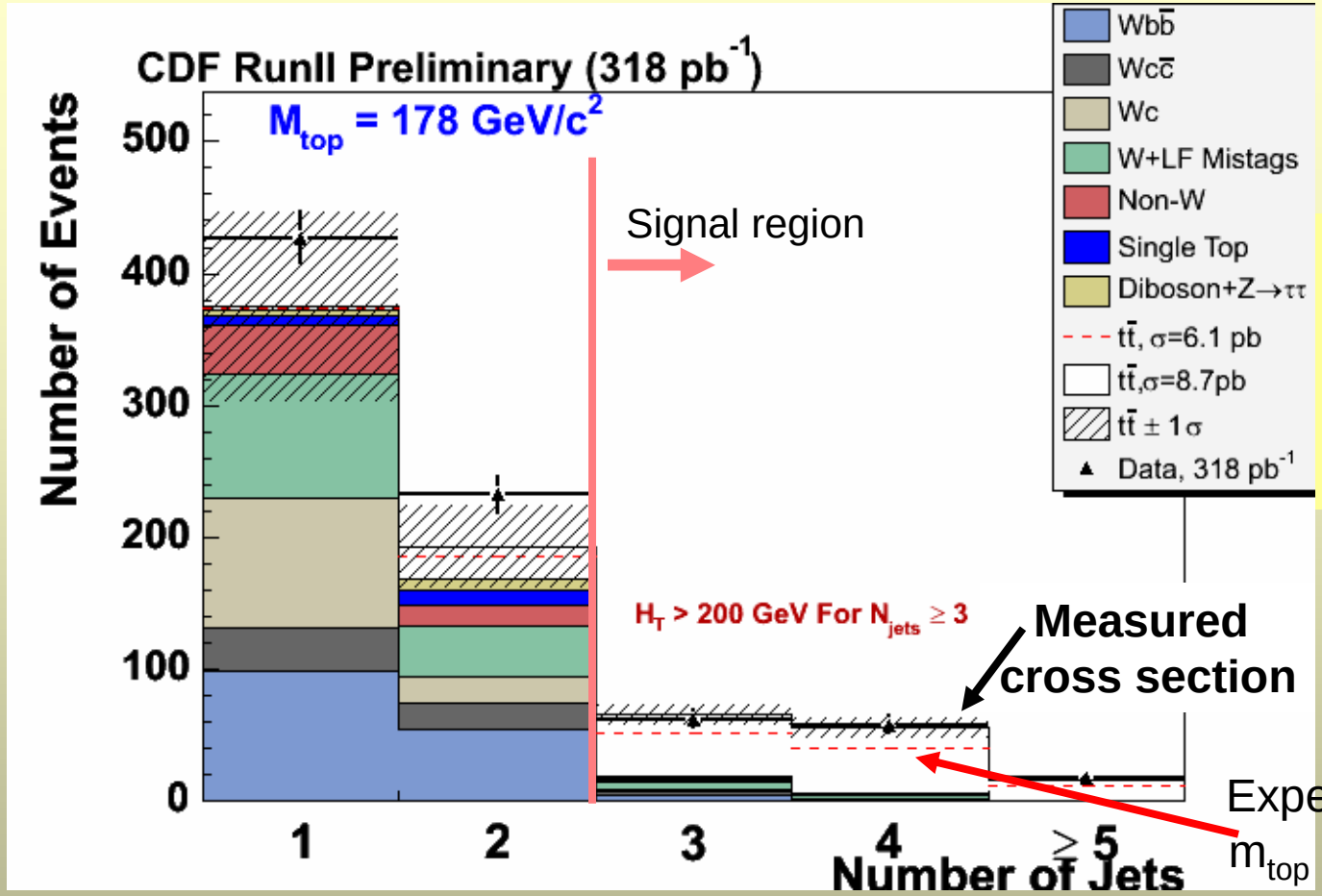
$$\sigma(t\bar{t}) = \frac{N_{obs} - N_{bkg}}{A\epsilon_b \int Ldt}$$

	Top Tagging Efficiency/Evt (%)		
	Tight	Loose	Gain
≥ 1-tag	60 ± 3	69 ± 4	15%
≥ 2-tag	16 ± 4	23 ± 4	44%

  - Efficiency corrected with data/MC SF

- Backgrounds:
  - Wbb,Wcc,Wc
    - ALPGEN+HERWIG MC
    - Normalized to pretag W+jets data
  - W+light (mistags)
    - Mistag matrix from jet sample
    - Applied to pretag W+jets data
  - Non-W
    - From data
  - Electroweak (single top, WW, WZ, Z-> $\tau\,\tau$)
    - From Pythia MC
    - Small contribution

Top Cross Section (Tight Tagger)



Systematics

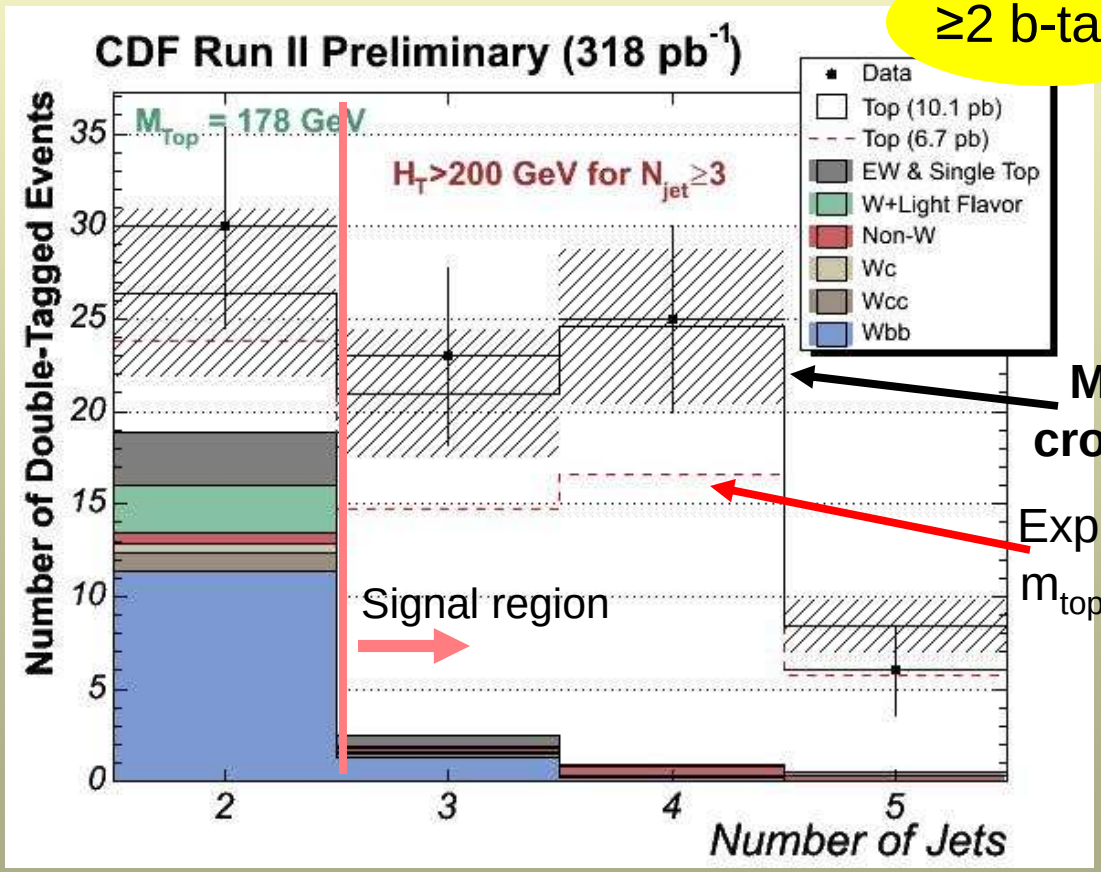
B-Tagging: 5.2%
Lepton Isolation: 5%
W+Heavy Flavor: 4.4%
Luminosity: 5.9%
Total: 11%

Sample	Events	*tt* fraction	σ(*tt*)
≥ 1 b-tag	138	81%	$8.7^{+0.9}_{-0.9}\ ^{+1.2}_{-0.9}$ pb
≥ 2 b-tags	33	91%	$8.7^{+1.8}_{-1.6}\ ^{+1.9}_{-1.3}$ pb

Top Cross Section (Loose Tagger)

Sample	Events	*tt* fraction	$\sigma(tt)$
≥ 1 b-tag	174	73%	$8.7^{+0.9}_{-0.9}{}^{+1.2}_{-0.9}$ pb
≥ 2 b-tags	54	92%	$10.1^{+1.6}_{-1.4}{}^{+2.1}_{-1.4}$ pb

≥2 b-tags



Systematics

B-Tagging: 13.4%
Lepton Isolation: 5%
W+Heavy Flavor: 3.0%
Luminosity: 5.9%
Total: 17%

Top Cross Section Using Kinematics in a Neural Net

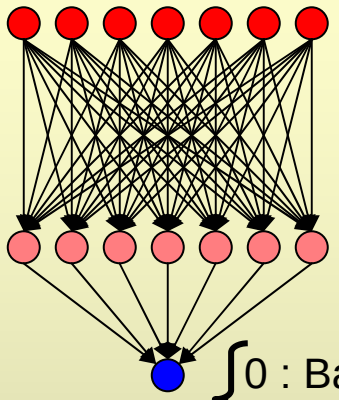
- Method uses pretag sample
  - Independent of b-tagging
  - Top kinematics and event shape information combined in a NN
- Updated result
  - 194 pb^{-1} → 347 pb^{-1}
- Lepton + Jets Selection
  - No H_T or M_T cuts
  - Additional QCD CUT:
    - $\Delta\phi$ cut: $0.5 < \Delta\phi$(MET-leading jet) < 2.5 for MET < 30 GeV

≥ 3-Jet Sample:
a priori most sensitive
≥ 4-Jet Sample:
better S:B → cross check

The Neural Network

- Seven input variables
  - H_T
  - Aplanarity
  - Maximum jet η
  - ΣE_T (Jets 3, 4, and 5)
  - $\Sigma p_Z / \Sigma E_T$
  - Minimum dijet invariant mass
  - Minimum dijet separation (ΔR)

Feed Forward Network



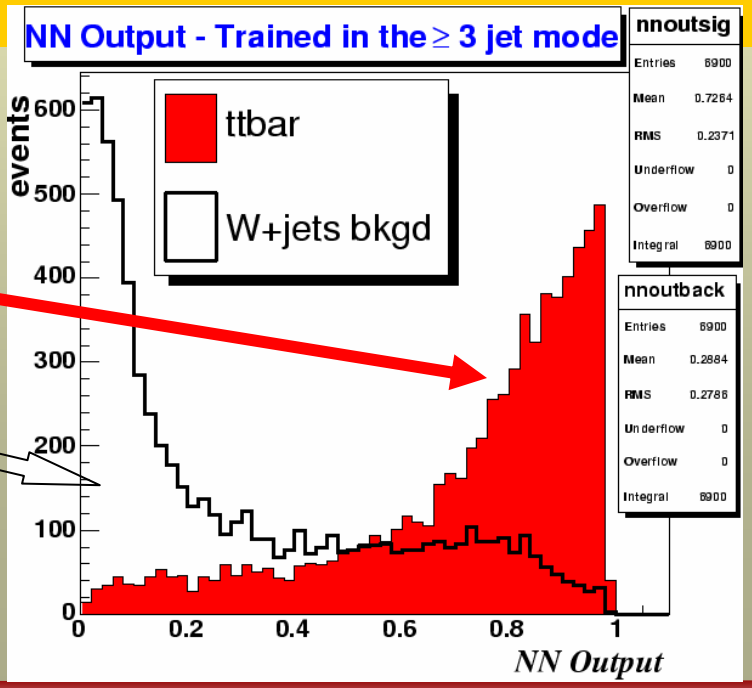
7 Input Nodes

1 Hidden Layer

0 : Background
1 : Top Signal

NN Training

- Signal:
  - PYTHIA *tt* MC
- Background:
  - ALPGEN+HERWIG
    W + 3*p* and *W* + 4*p* MC
- Other backgrounds are ignored in the training

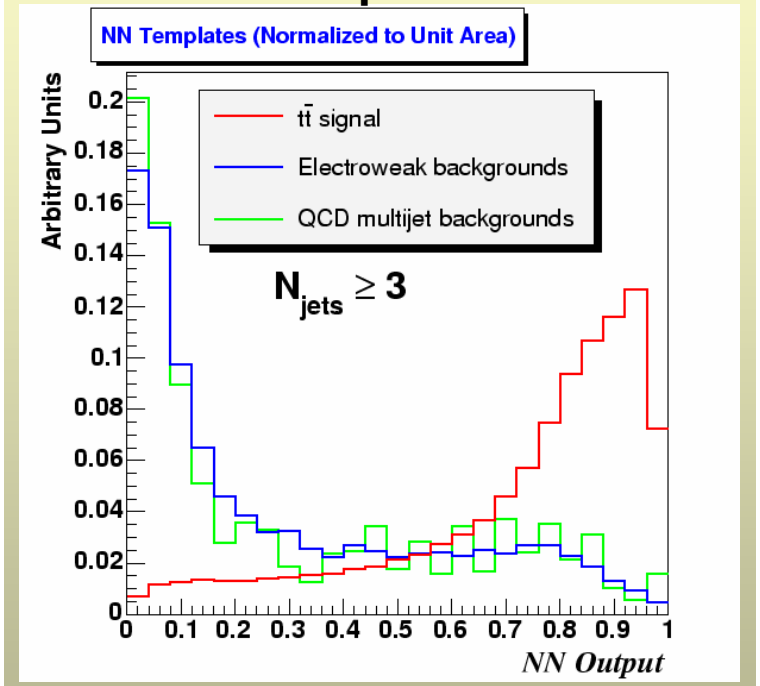


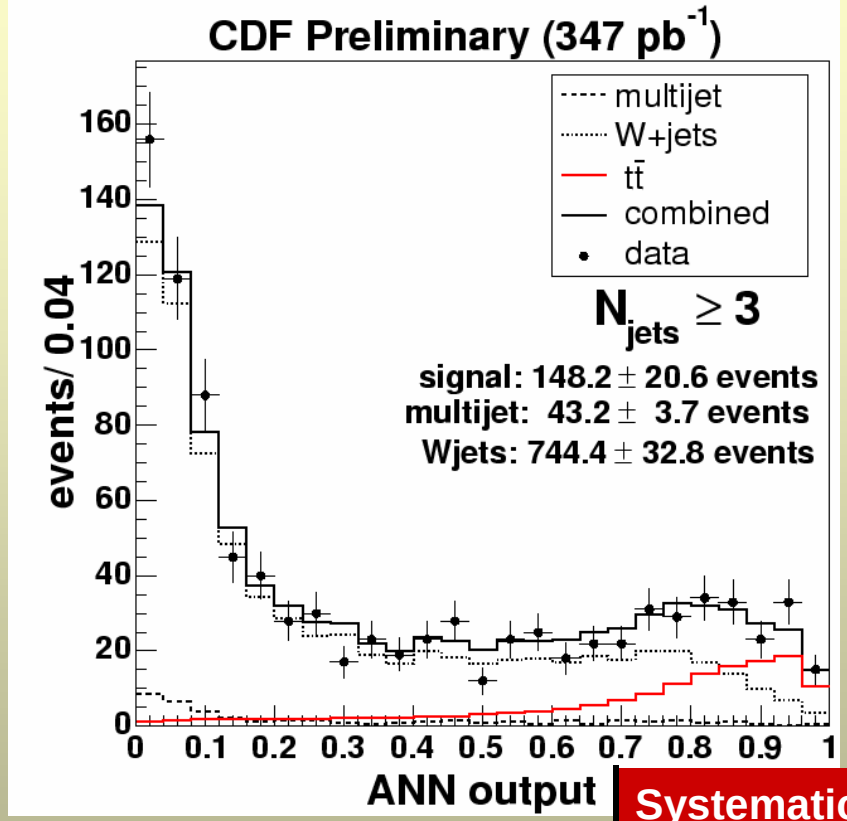
NN Analysis Results

Fit NN output from data to NN templates

tt and W-background float
multijet fixed to 4.6%

Templates



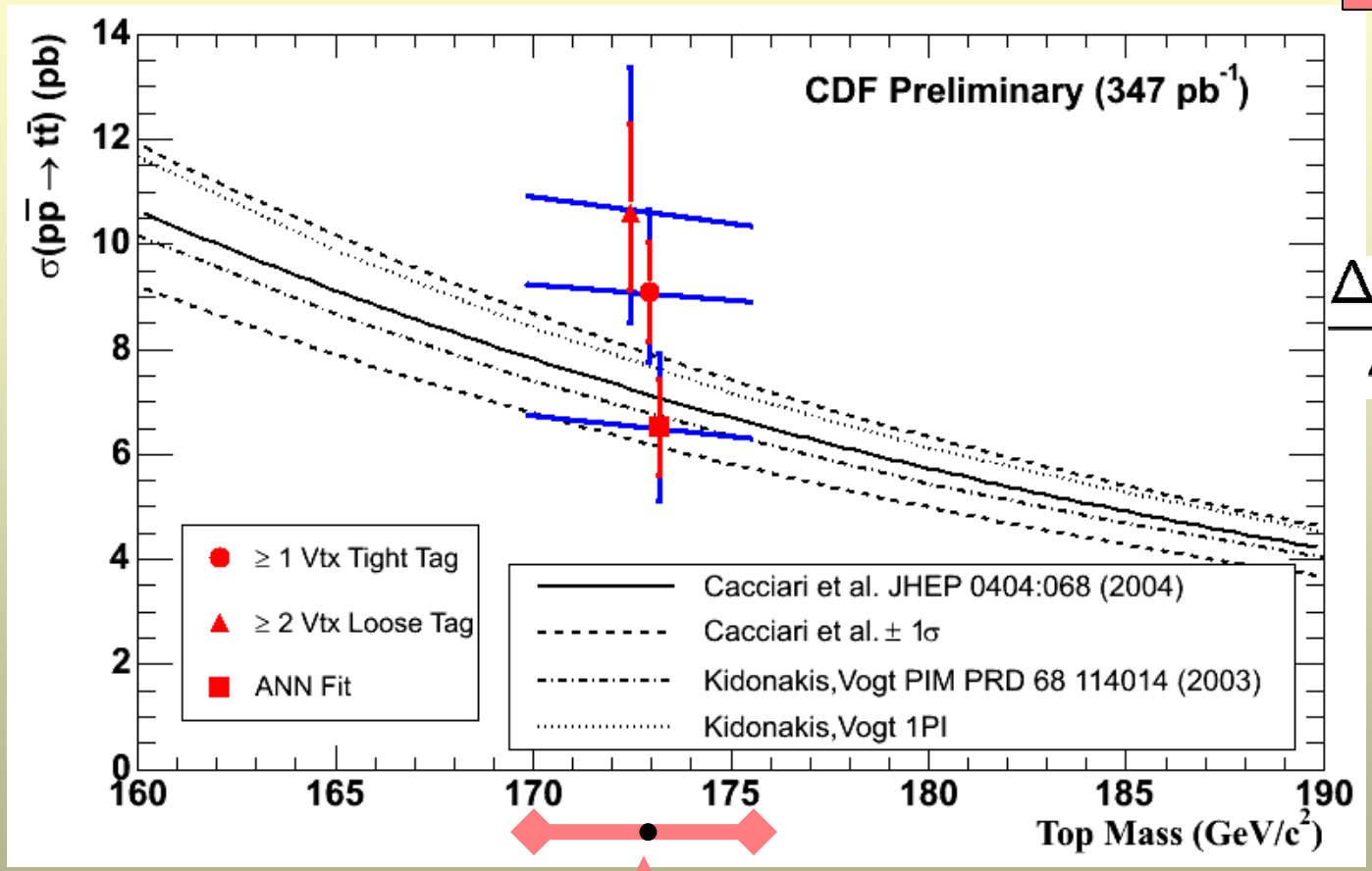


Sample	Events	Fitted *tt*	σ(*tt*)
W + ≥ 3 jets	936	148.2 ± 20.6	6.0 ± 0.8 ± 1.0 pb
W + ≥ 4 jets	210	80.9 ± 15.0	6.1 ± 1.1 ± 1.4 pb

Systematics	Total
Jet Et Scale	8.3%
W+jets Q^2 Scale	10.2%
ttbar PDF	4.4%
Total	16.4%

Cross Section Dependence on Top Mass

Acceptance and efficiency depend on top mass



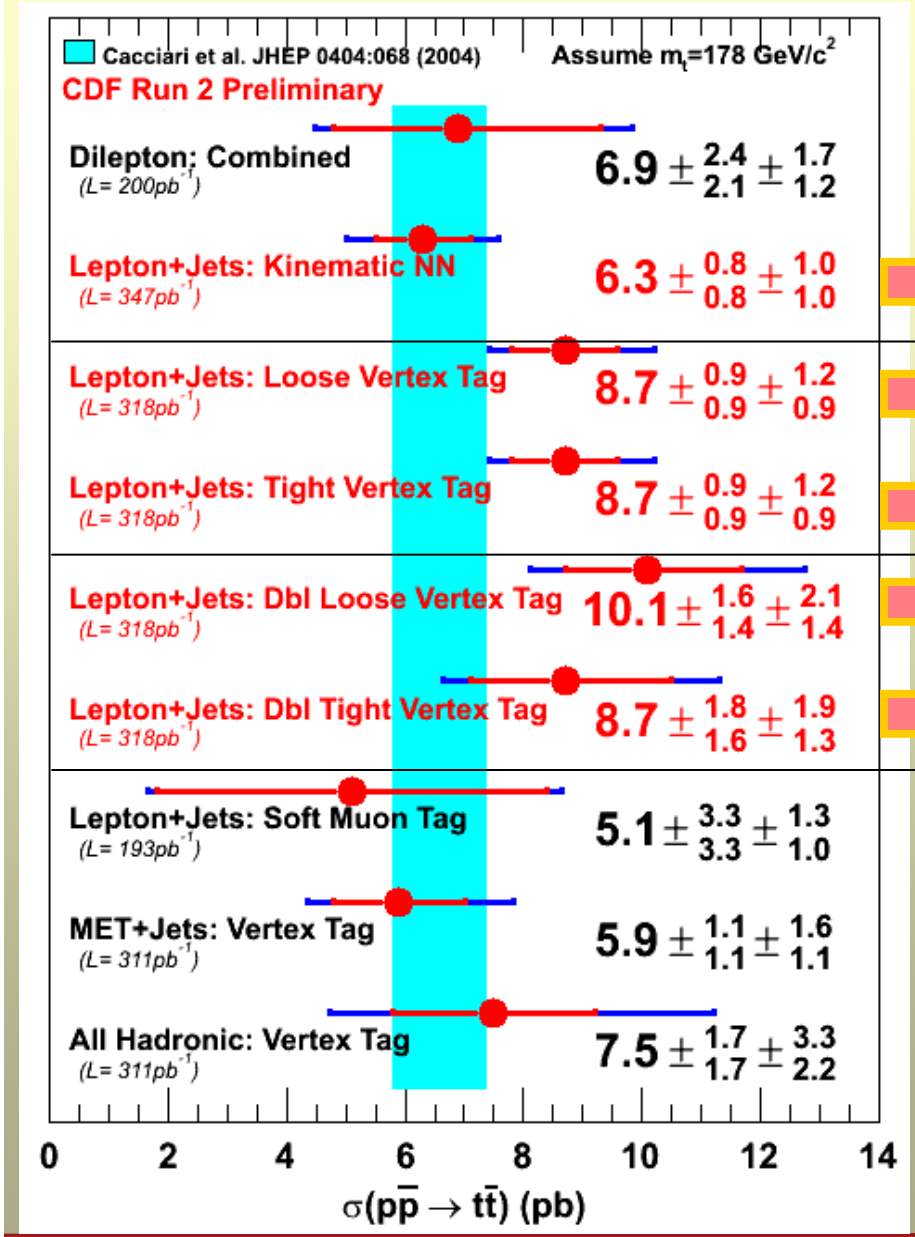
Default:
m_{top} = 178 GeV

$$\frac{\Delta\sigma(m_{top})}{\Delta m_{top}} \sim 0.05 \frac{\text{pb}}{\text{GeV}}$$

Summer 2005 World Average Top Mass
172.7 ± 2.9 GeV/c^2
(hep-ex/0507091)

Theoretical prediction:
$\sigma(p\bar{p} \rightarrow t\bar{t}) = 7.2$ pb $\pm 15\%$

Summary



New: ~350 pb^{-1}

Old: ~200 pb^{-1}

Events	Relative Uncertainty	Relative Uncertainty
936	21%	28%
174	16%	--
138	16%	28%
54	23%	--
33	27%	47%

Overlap: single/double tag { 31% loose, 24% tight

Overlap: loose/tight tagger { 79% single, 61% double

Conclusions

Experimental uncertainty has reached
the theory uncertainty level

Starting Probe of { **QCD** / **New Physics**

1 fb^{-1} winter 2006

Measurement limited by systematic uncertainties

Multiple tagging:

- ≥ 120 double tagged top events in 1 fb^{-1}
- Full reconstruction of events
  - More precise measurement of top mass
  - Study of top properties