Results from CDF and D0 on:

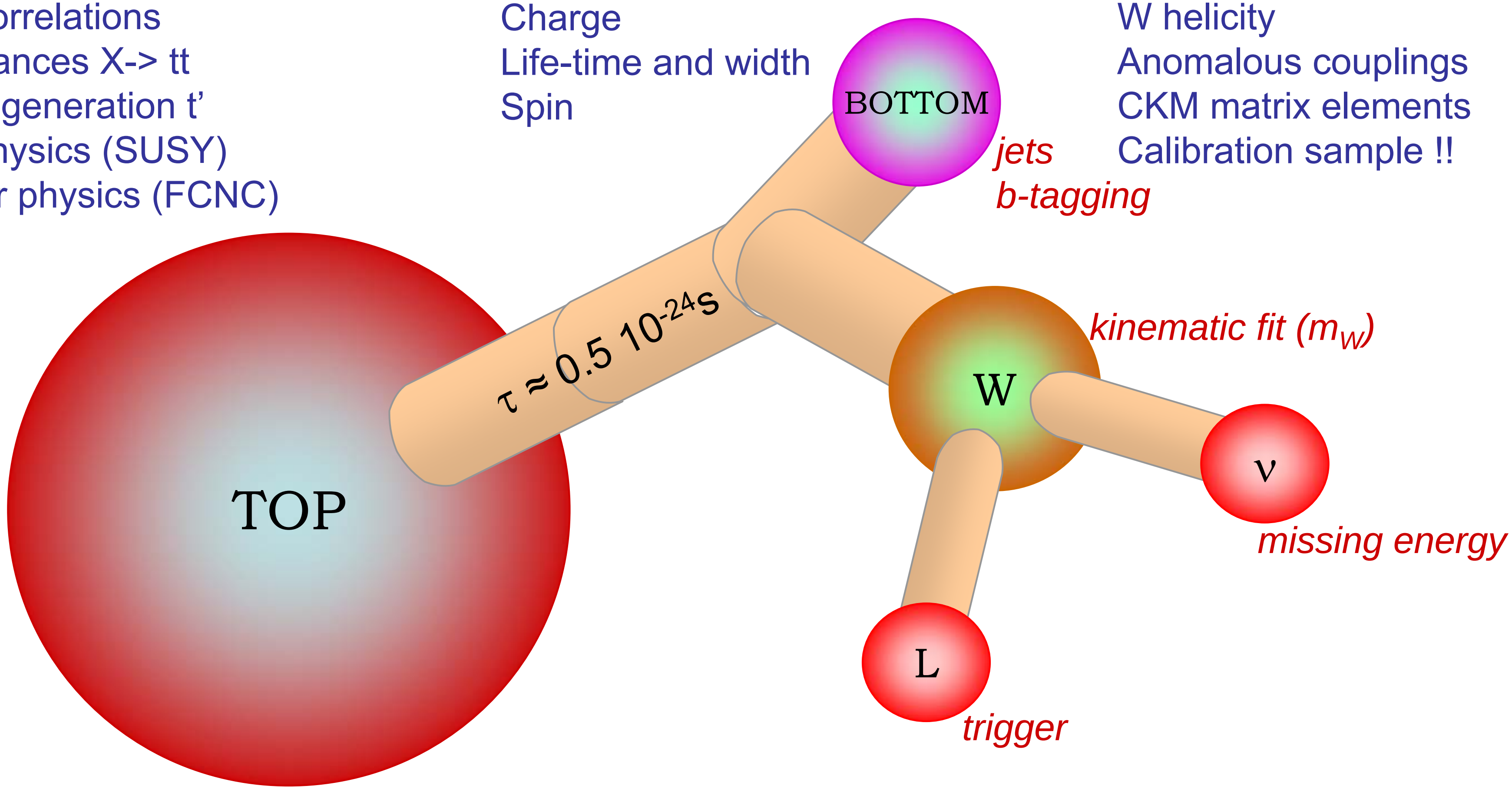
1. **Pair Production of Top Quarks**
   - Cross Section
   - Search for Resonances
   - Forward-Backward Asymmetry
2. **Single Top Production**
   - Search for SM EWK Production
   - Search for Anomalous Processes
3. **Decay Physics**
   - W Helicity
4. **Top Properties**
   - Mass
   - Charge
   - Lifetime
5. **Outlook**

Top Subjects

PRODUCTION
Cross section
Spin-correlations
Resonances X-> tt
Fourth generation t’
New physics (SUSY)
Flavour physics (FCNC)

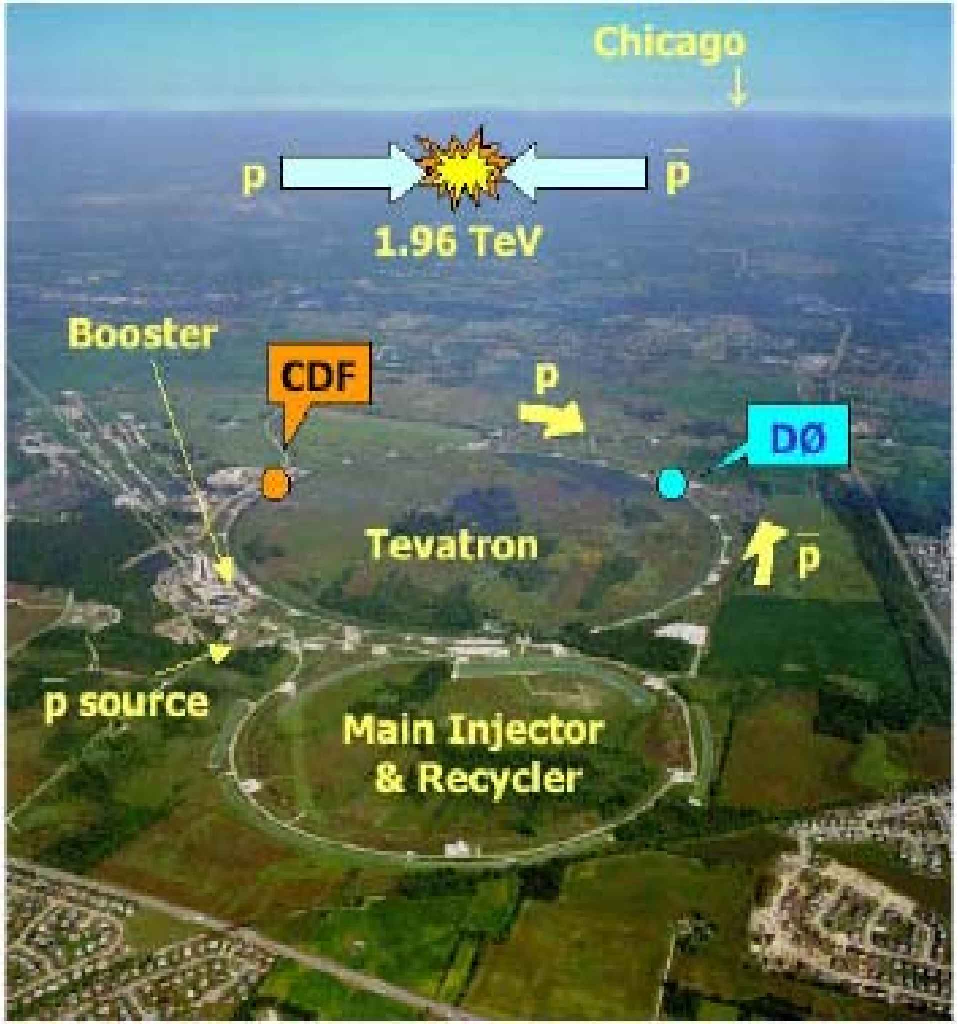
PROPERTIES
Mass
Charge
Life-time and width
Spin

DECAY
Charged Higgs
W helicity
Anomalous couplings
CKM matrix elements
Calibration sample !!



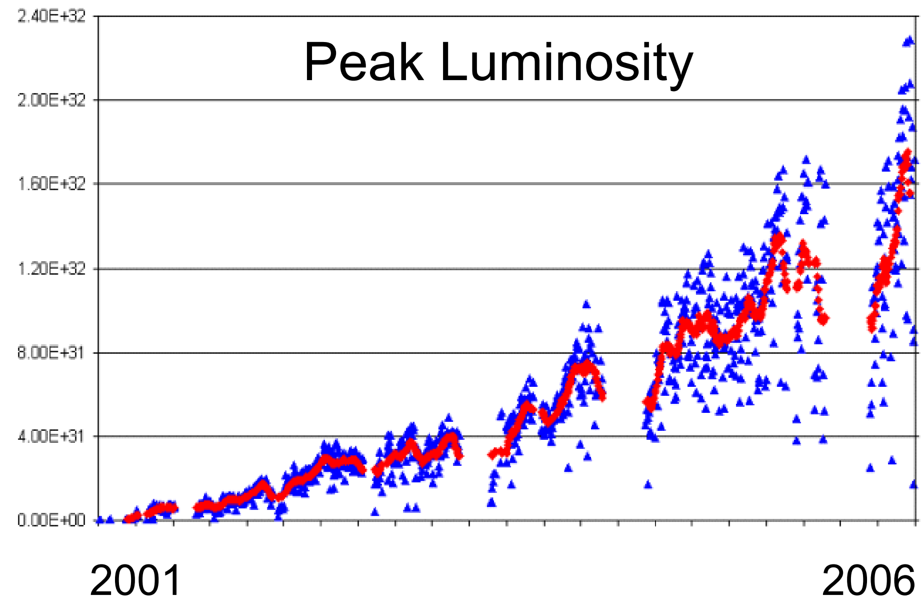
J. D‘Hondt (VUB)

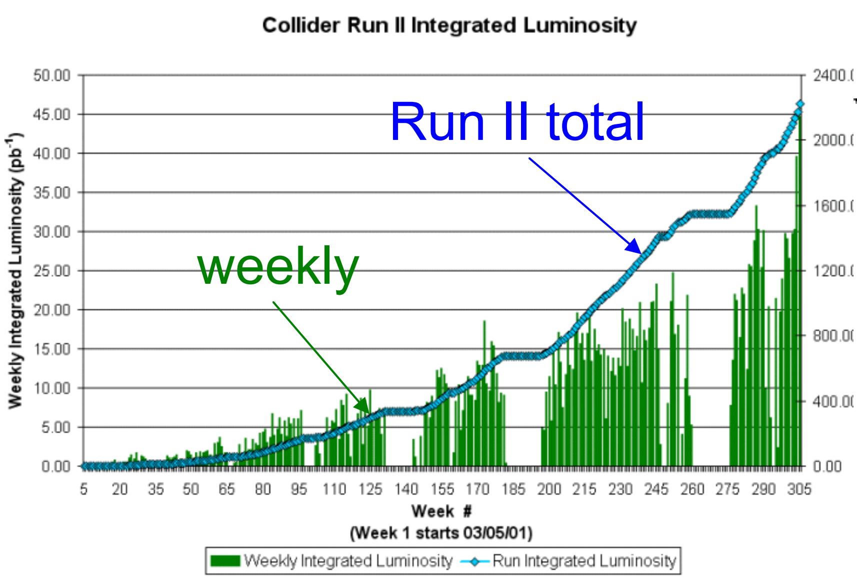
- Currently the world's only top quark "factory"
- Run I (1992-1996)
  $\sqrt{s}$ = 1.8 TeV
  Integrated Luminosity ~110 pb^{-1}
  top discovery!
- Run II (2001-present)
  $\sqrt{s}$ = 1.96 TeV
  30% higher $t\bar{t}$ cross section
  Integrated Luminosity to date 1.7 fb^{-1}
  Aim for 4-8 fb^{-1} by 2009

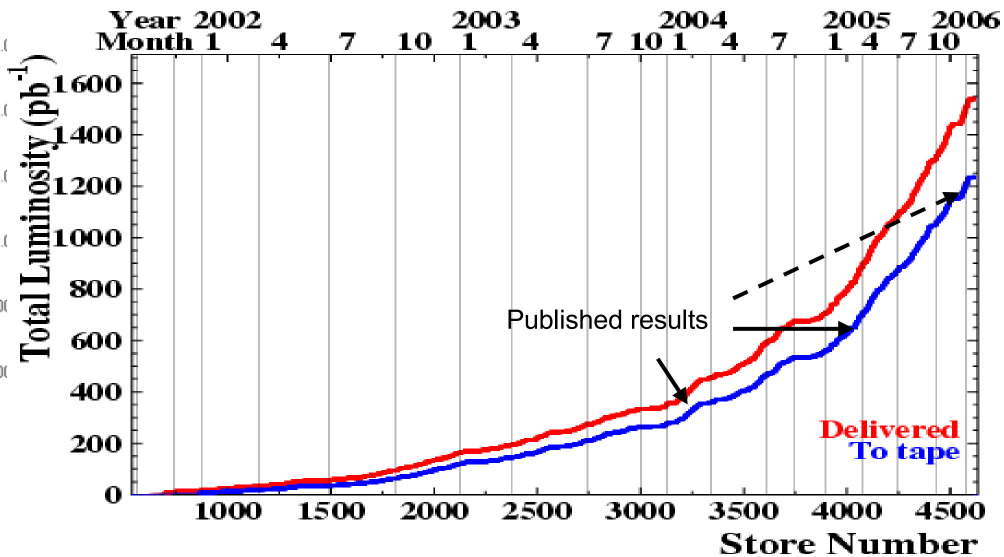


Luminosities:

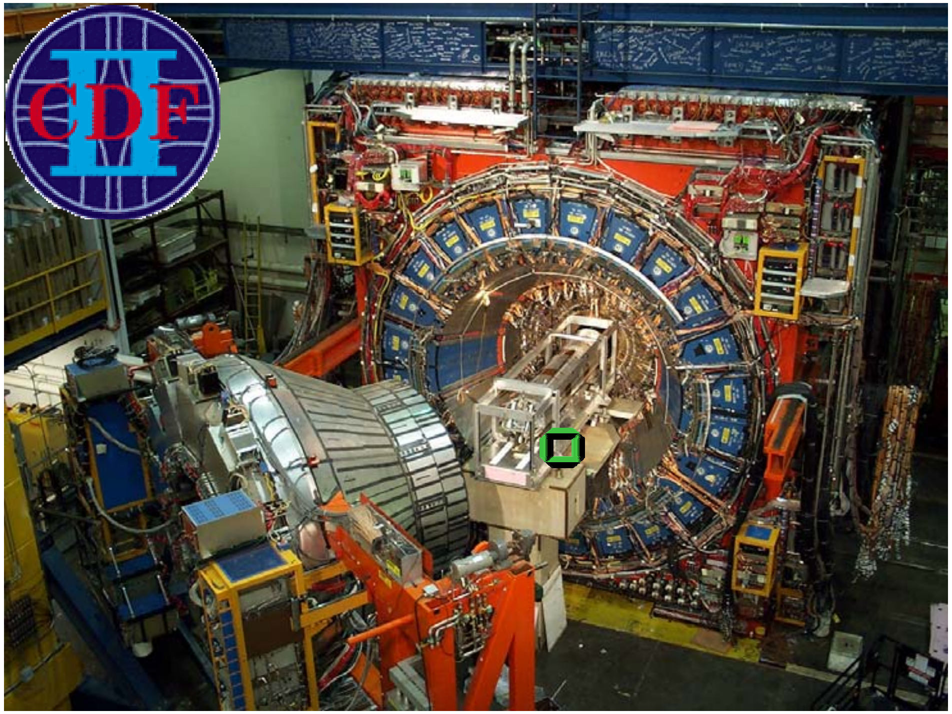
- Record so far (per exp.):
  $2.4 \times 10^{32}\ cm^{-2}s^{-1}$
  $33 pb^{-1}$ per week
- On tape ~1.7 fb^{-1}
- New results with ~320 pb^{-1} to ~750 pb^{-1} (∗7 of Run I)
- Preliminary results with 1 fb^{-1}







CDF and D0 in Run II



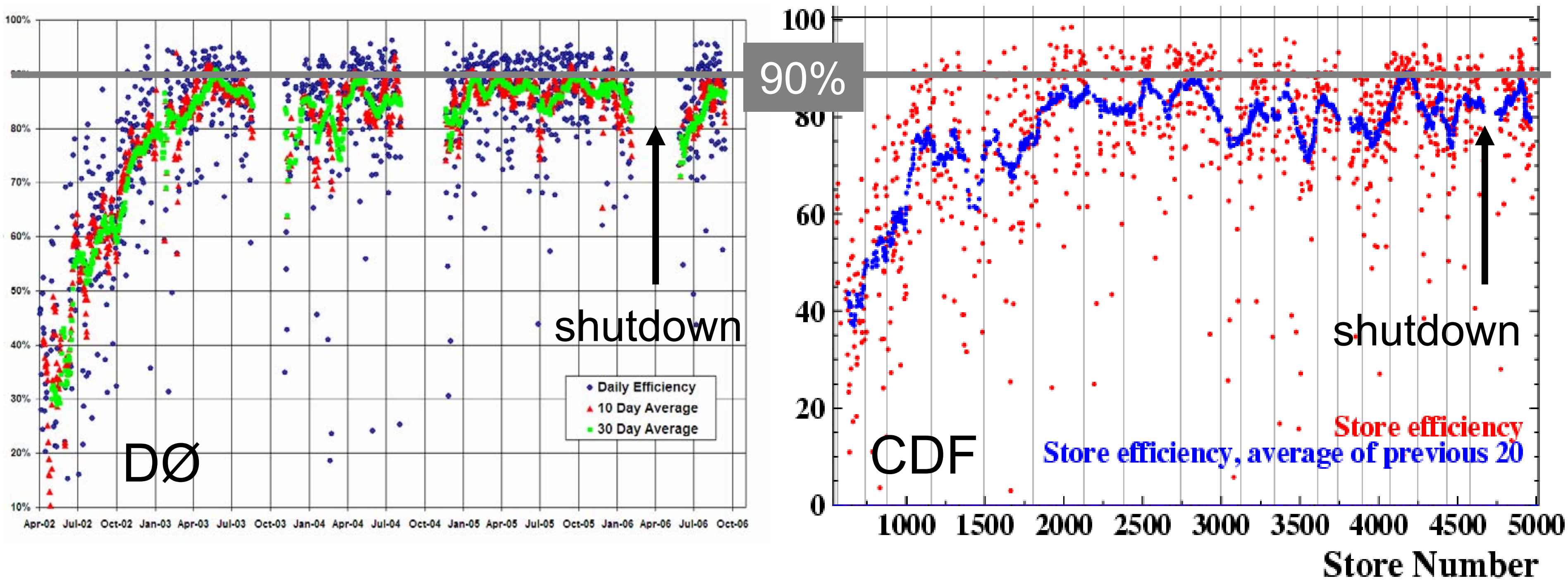
- New silicon tracker, new drift chamber, TOF
- Upgraded calorimeter and muon system
- Upgraded DAQ/trigger
- Displaced track trigger

- New silicon and fibre tracker
- New ~2 T solenoid
- Upgraded muon system
- Upgraded (track) trigger/DAQ
- Roman pots

Resolutions:

EM: σ_E/E = 13.5 – 15% / sqrt(E)
HAD: σ_E/E = 50 – 80 % / sqrt(E)

Data Taking Efficiencies



Challenges with rapidly improving instantaneous luminosity

- Over 100 trigger paths per each experiment - richness of physics
- Trigger rates increase with inst. luminosity.
- Not all of them can be estimated reliably by Monte Carlo.
- Re-optimize triggers with real data

CDF Collaboration

Canada
McGill Univ.
Univ. of Toronto

USA
Argonne National Laboratory,IL
Brandeis Univ.,MS
Univ. of Chicago,IL
Davis UC,CA
Duke Univ.,NC
FNAL,IL
Univ. of Florida,FL
Harvard Univ.,MA
Univ. of Illinois,IL
The Johns Hopkins Univ.,MD
LBNL,CA
MIT,MA
Michigan State Univ.,MI
Univ. of Michigan,MI
Univ. of New Mexico,NM
The Ohio State Univ.,OH
Univ. of Pennsylvania,PA
Univ. of Pittsburgh,PA
Purdue Univ.,IN
Univ. of Rochester,NY
Rockefeller Univ.,NY
Rutgers Univ.,NJ
Texas A&M Univ.,TX
Texas Tech Univ.,TX
Tufts Univ.,MA
UCLA,CA
Univ. of Wisconsin,WI
Yale Univ.,CT

China
Academia Sinica,
Taiwan

Korea
KHCL

Russia
JINR, Dubna
ITEP, Moscow

Germany
Univ. Karlsruhe

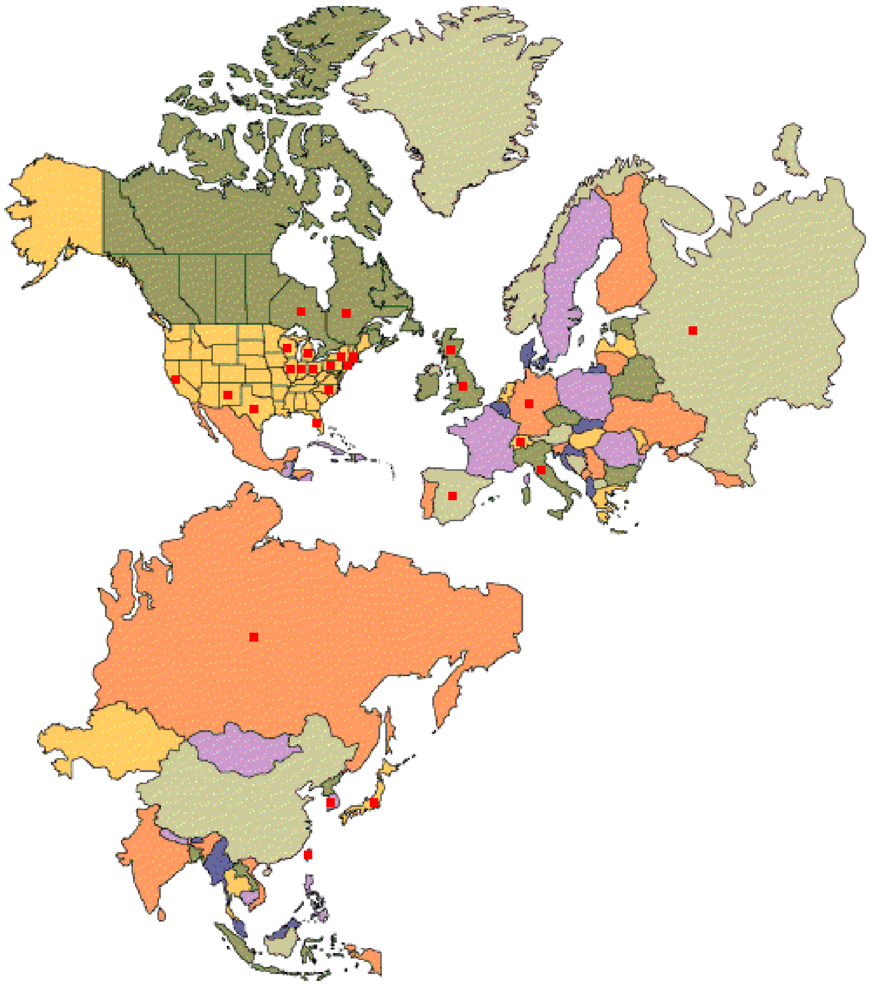
Switzerland
Univ. of Geneva

UK
Glasgow Univ.
Univ. of Liverpool
Univ. of Oxford
Univ. College London

Italy
Univ. of Bologna,INFN
Frascati, INFN
Univ. di Padova,INFN
Pisa, INFN
Univ. di Roma I,INFN
INFN-Trieste
Univ. di Udine

Spain
Univ. of Cantabria

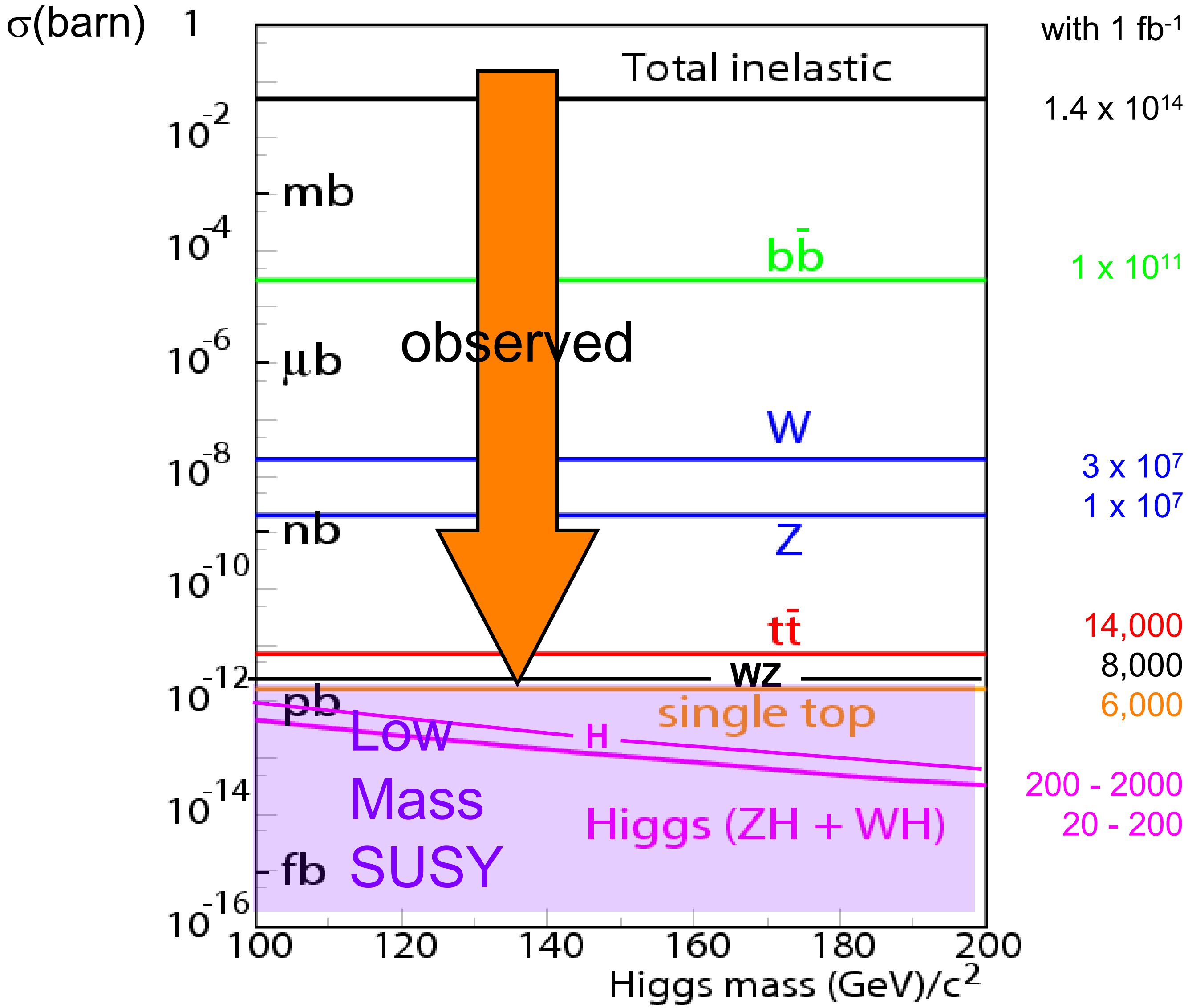
Japan
Hiroshima Univ.
KEK
Osaka City Univ.
Univ. of Tsukuba
Waseda Univ., Tokyo



730 Physicists from 13 nations, 61 Institutions; 23 from Germany

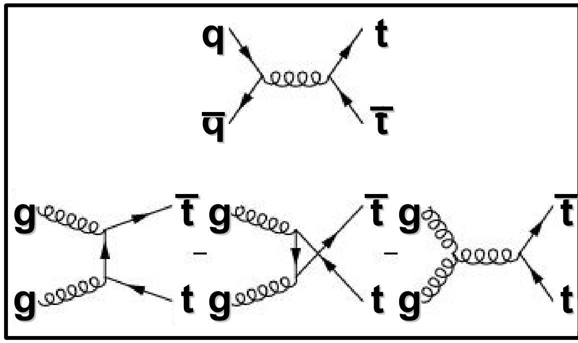
670 Physicists from 20 nations, 91 institutions, ~40 from Germany

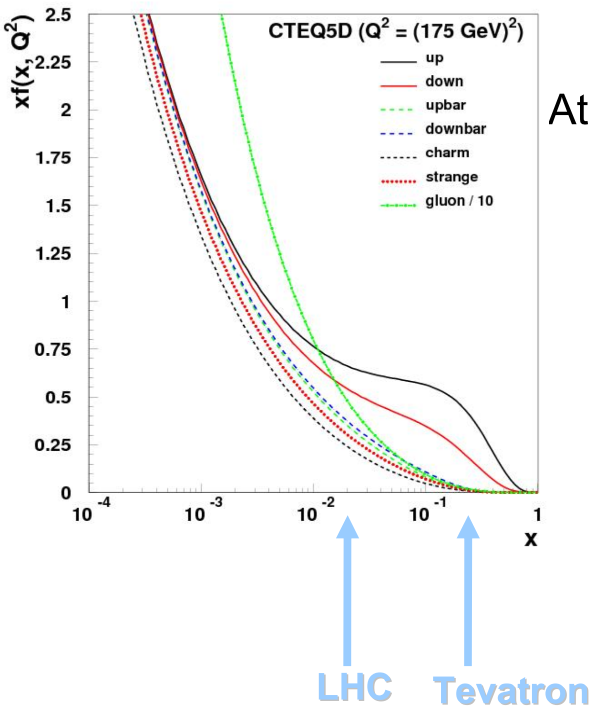
Physics at the Tevatron



1. PAIR PRODUCTION OF TOP QUARKS

	TEV	LHC
$q\bar{q} \to t\bar{t}$	~85%	~15%
$gg \to t\bar{t}$	~15%	~85%

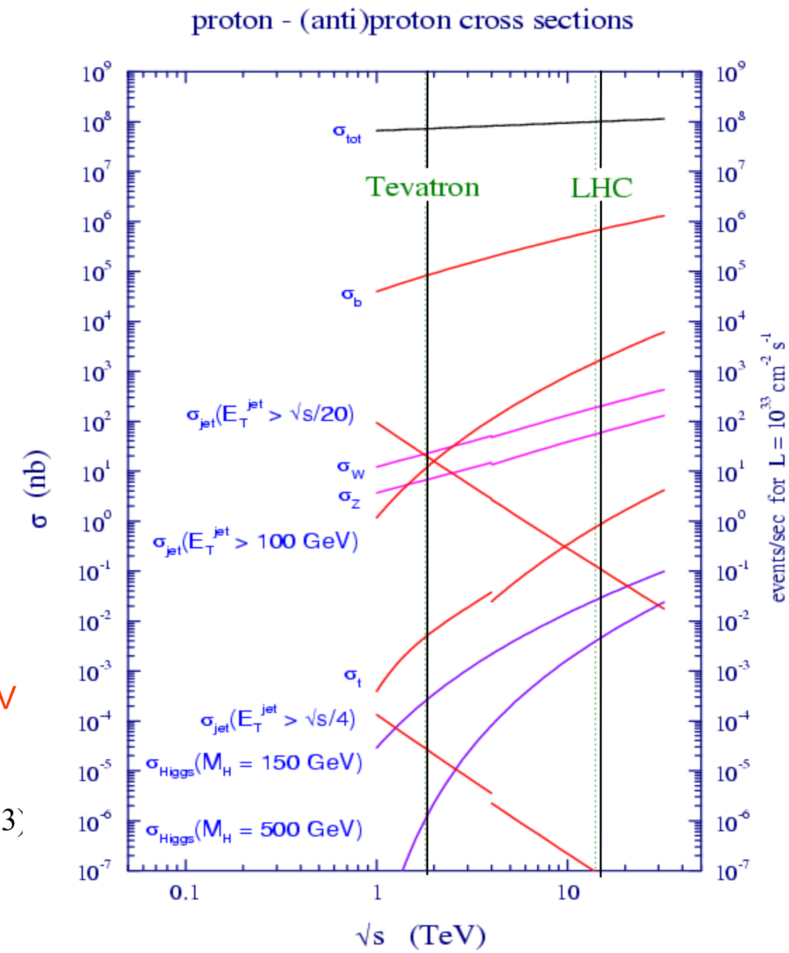




At the Tevatron, within SM:

$\sigma_{tt} = 6.7 \pm^{0.7}_{0.9}$ pb @ m_{top} = 175 GeV

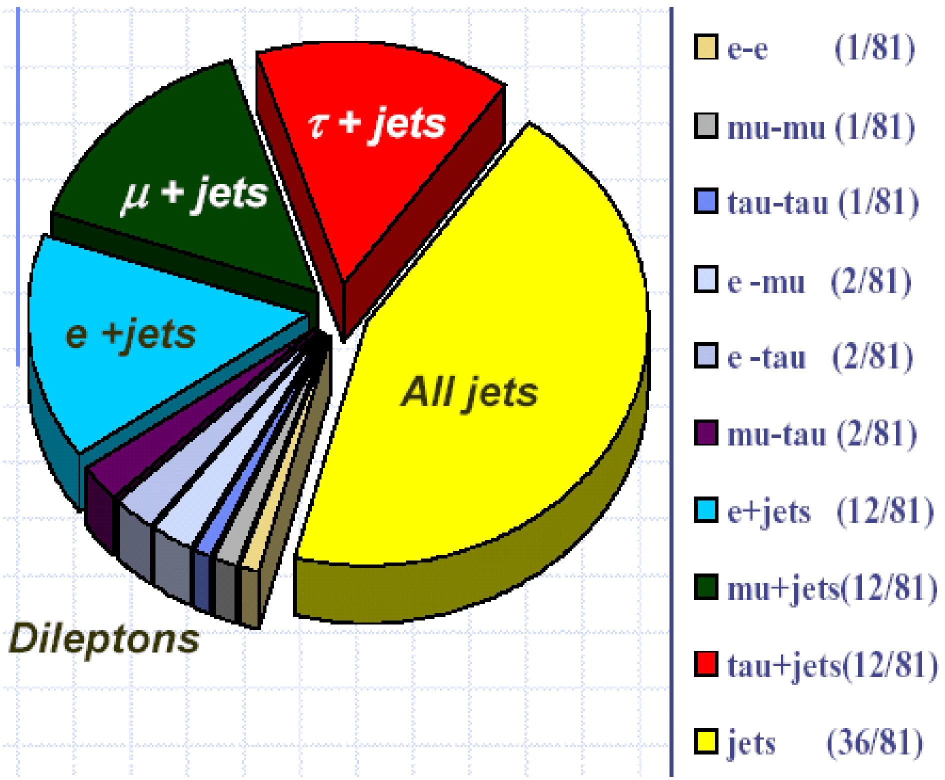
Cacciari et al. JHEP 0404:068(2004)
Kidonakis,Vogt PRD 68 114014(2003)

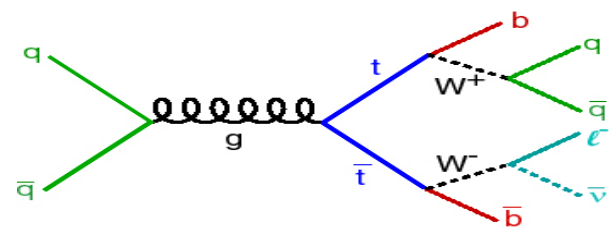


One top pair every 10^{10} inelastic collisions

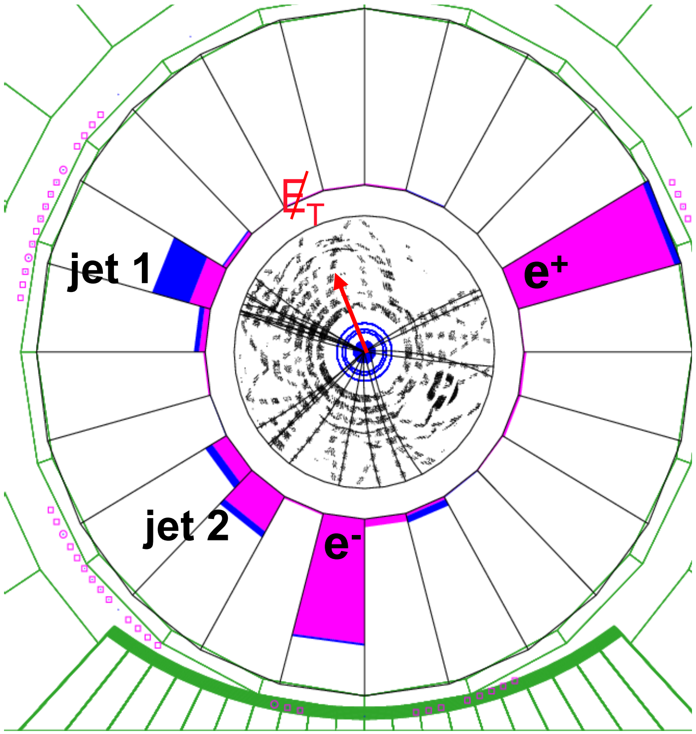
So far (0.93 fb^{-1}):
Produced ~6000 top pairs
Fully reconstructed ~233 top quark pairs

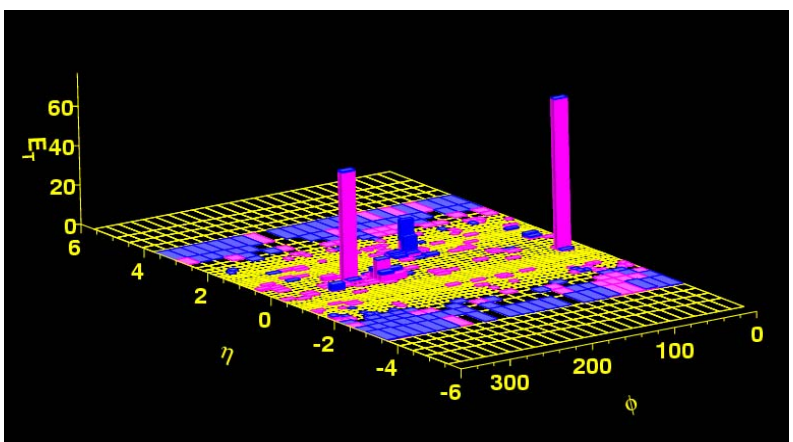
Top Quark Decay Modes





- **$t \rightarrow Wb$**
  Events classified by W decay
  - "Lepton [e,μ] + jets" (30%)
    $tt \rightarrow bl\nu bqq'$
  - "Dilepton [e,μ]" (5%)
    $tt \rightarrow bl\nu bl\nu$
  - "All jets" (44%)
    $tt \rightarrow bqq'bqq'$
  - **"Tau + X" (21%)**





Finding the top:

Signal:

- Triggering on lepton
- High missing transverse energy ($\not{E}_T$)
- High E_T jets, central and spherical
- Two b-jets (displaced vertex)

Background:

- W+jets:
  dominant in leptonic modes
  fakes the second lepton
- Drell-Yan(dileptons): no $\not{E}_T$
- QCD: huge in all jet mode

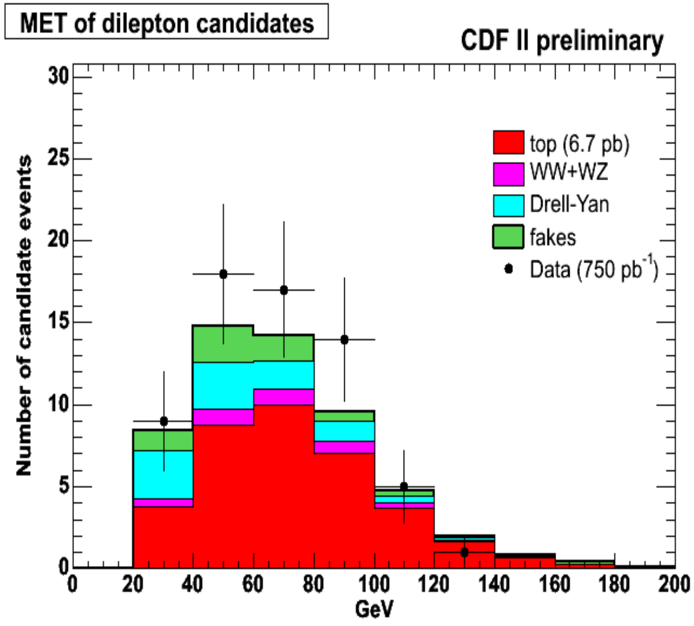
Determination of the cross section

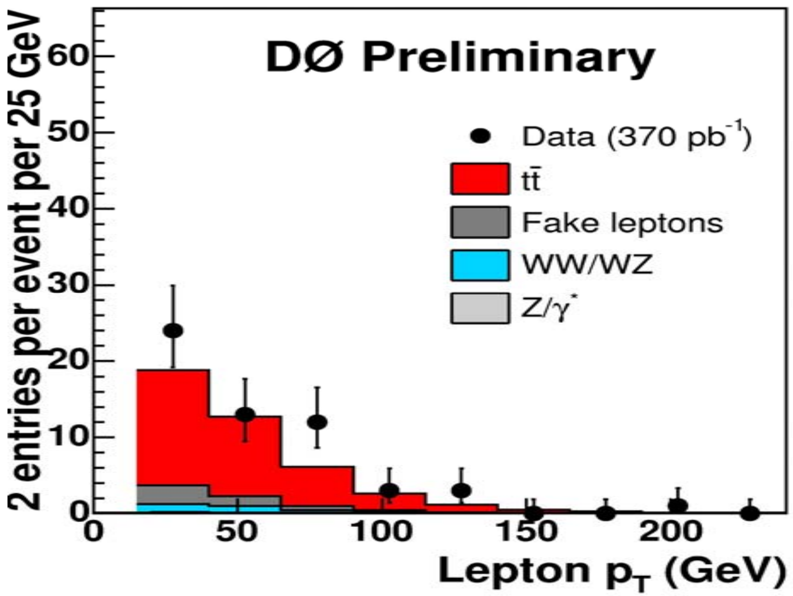
$$\sigma_{t\bar{t}} = \frac{N_{obs} - N_{bgd}}{\varepsilon_{t\bar{t}} \cdot \int L dt}$$

Cross Section in the Dilepton channel

	obs	expected
ee	12	14.3 ± 2.2
μμ	24	16.1 ± 2.4
eμ	28	25.0 ± 1.5

	obs	expected
ee	5	4.5 ± 0.5
μμ	2	3.8 ± 0.5
eμ	21	15.8 ± 2.8

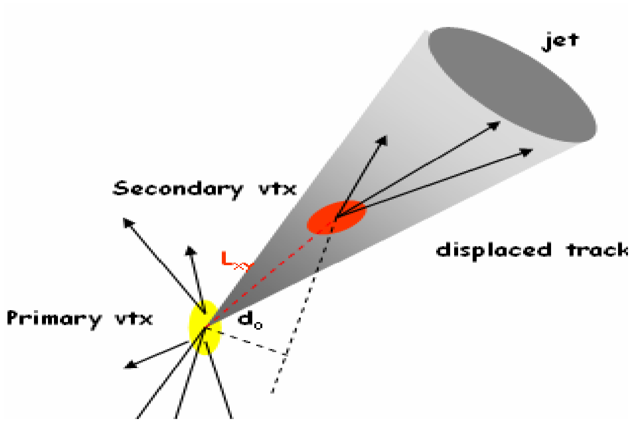




σ (tt) = 8.3 ± 1.5 (stat) ± 1.0 (syst) ± 0.5 (lumi) pb

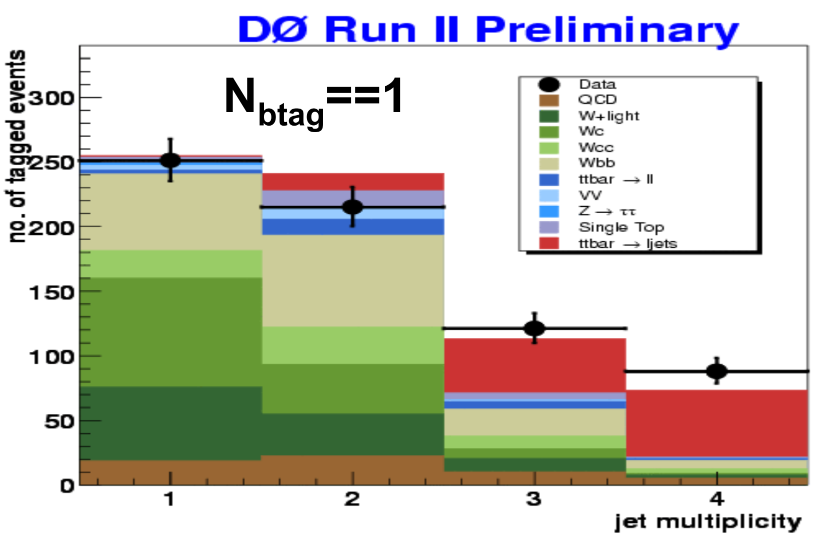
σ (tt) = 8.6 ± 2.3 (stat) ± 1.1 (syst) ± 0.6 (lumi) pb

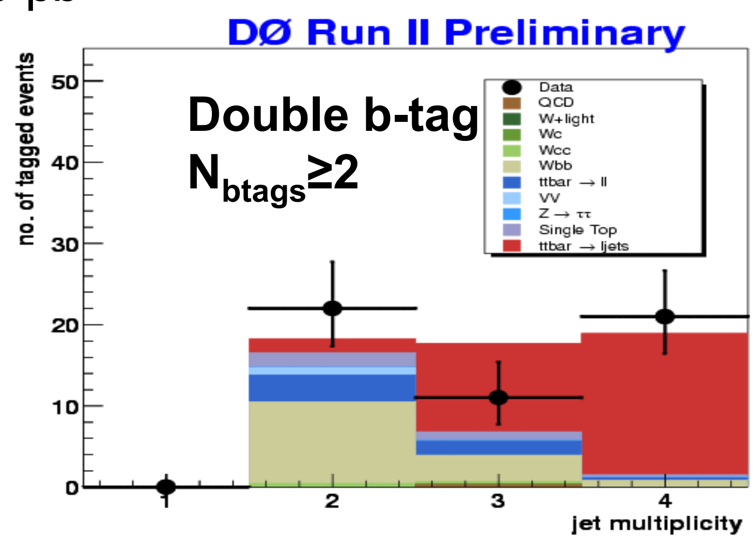
Lepton + Jets with b-Tagging



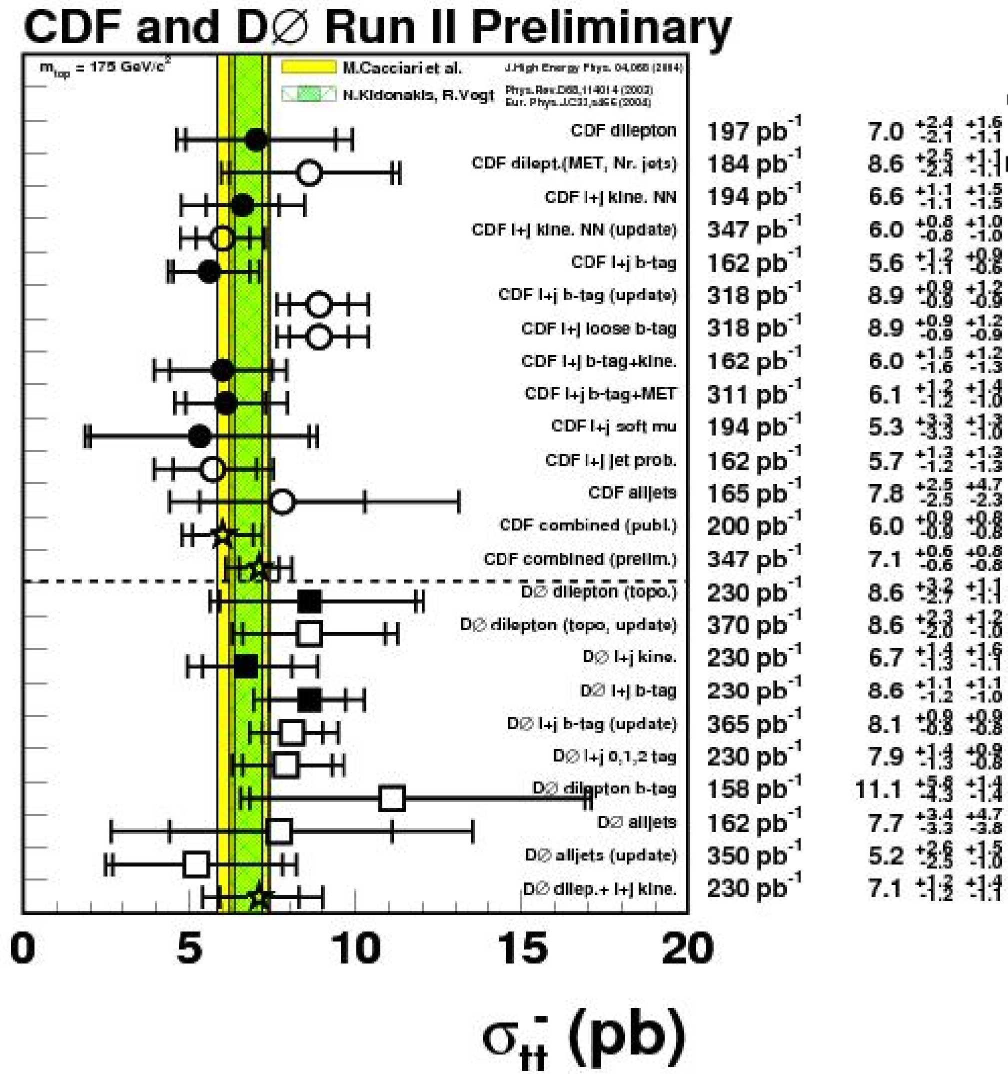
- B-jets are tagged by finding displaced vertex within a jet
- B-quark lifetime cτ ~ 450 μm
- Strong background reduction

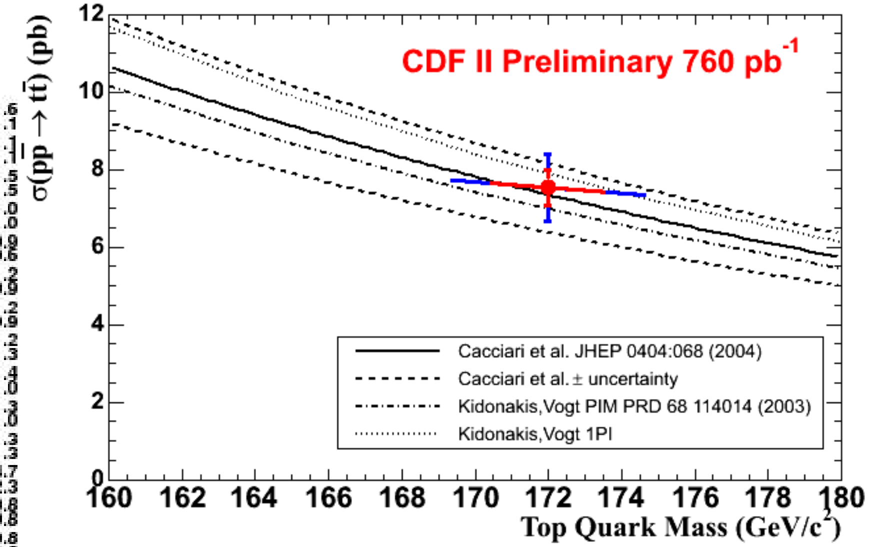
370 pb^{-1}

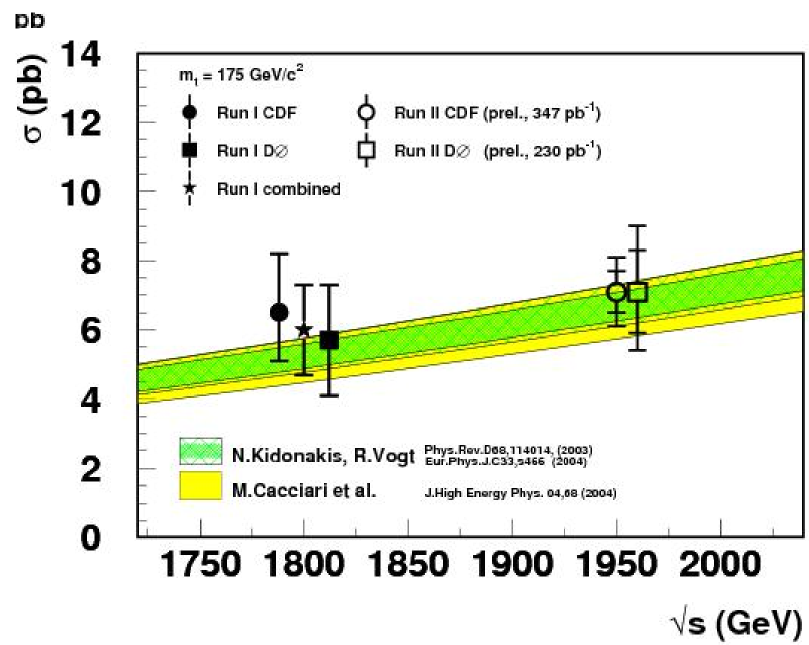




$$\sigma(t\bar{t}) = 8.1 \pm 0.9(\text{stat}) \pm^{0.9}_{0.8}(\text{syst}) \pm 0.5(\text{lumi})\,\text{pb}$$


CDF and DØ Run II Preliminary
m_top = 175 GeV/c²
M.Cacciari et al. J.High Energy Phys. 04,068 (2004)
N.Kidonakis, R.Vogt Phys.Rev.D68,114014 (2003) Eur. Phys.J.C33,s466 (2004)
CDF dilepton 197 pb⁻¹ 7.0 +2.4 -2.1 +1.6 -1.1
CDF dilept.(MET, Nr. jets) 184 pb⁻¹ 8.6 +2.5 -2.4 +1.1 -1.1
CDF l+j kine. NN 194 pb⁻¹ 6.6 +1.1 -1.1 +1.5 -1.5
CDF l+j kine. NN (update) 347 pb⁻¹ 6.0 +0.8 -0.8 +1.0 -1.0
CDF l+j b-tag 162 pb⁻¹ 5.6 +1.2 -1.1 +0.9 -0.6
CDF l+j b-tag (update) 318 pb⁻¹ 8.9 +0.9 -0.9 +1.2 -0.9
CDF l+j loose b-tag 318 pb⁻¹ 8.9 +0.9 -0.9 +1.2 -0.9
CDF l+j b-tag+kine. 162 pb⁻¹ 6.0 +1.5 -1.6 +1.2 -1.3
CDF l+j b-tag+MET 311 pb⁻¹ 6.1 +1.2 -1.2 +1.4 -1.0
CDF l+j soft mu 194 pb⁻¹ 5.3 +3.3 -3.3 +1.3 -1.0
CDF l+j jet prob. 162 pb⁻¹ 5.7 +1.3 -1.2 +1.3 -1.3
CDF alljets 165 pb⁻¹ 7.8 +2.5 -2.5 +4.7 -2.3
CDF combined (publ.) 200 pb⁻¹ 6.0 +0.9 -0.9 +0.8 -0.8
CDF combined (prelim.) 347 pb⁻¹ 7.1 +0.6 -0.6 +0.8 -0.8
DØ dilepton (topo.) 230 pb⁻¹ 8.6 +3.2 -2.7 +1.1 -1.1
DØ dilepton (topo, update) 370 pb⁻¹ 8.6 +2.3 -2.0 +1.2 -1.0
DØ l+j kine. 230 pb⁻¹ 6.7 +1.4 -1.3 +1.6 -1.1
DØ l+j b-tag 230 pb⁻¹ 8.6 +1.1 -1.2 +1.1 -1.0
DØ l+j b-tag (update) 365 pb⁻¹ 8.1 +0.9 -0.9 +0.9 -0.8
DØ l+j 0,1,2 tag 230 pb⁻¹ 7.9 +1.4 -1.3 +0.9 -0.8
DØ dilepton b-tag 158 pb⁻¹ 11.1 +5.8 -4.3 +1.4 -1.4
DØ alljets 162 pb⁻¹ 7.7 +3.4 -3.3 +4.7 -3.8
DØ alljets (update) 350 pb⁻¹ 5.2 +2.6 -2.5 +1.5 -1.0
DØ dilep.+ l+j kine. 230 pb⁻¹ 7.1 +1.2 -1.2 +1.4 -1.1
0
5
10
15
20
σ_tt̄ (pb)


CDF II Preliminary 760 pb⁻¹
σ(pp̄ → tt̄) (pb)
Top Quark Mass (GeV/c²)
Cacciari et al. JHEP 0404:068 (2004)
Cacciari et al. ± uncertainty
Kidonakis,Vogt PIM PRD 68 114014 (2003)
Kidonakis,Vogt 1PI

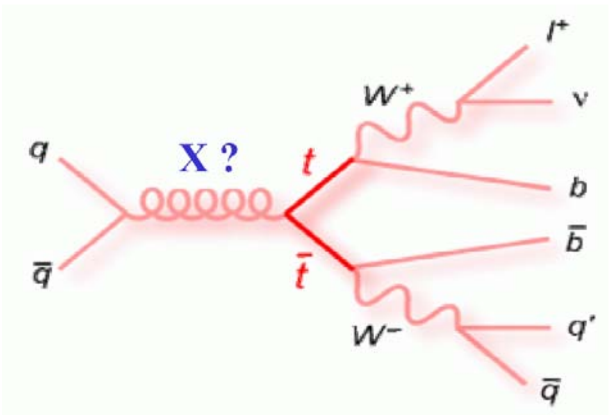

σ (pb)
m_t = 175 GeV/c²
Run I CDF
Run I DØ
Run I combined
Run II CDF (prel., 347 pb⁻¹)
Run II DØ (prel., 230 pb⁻¹)
N.Kidonakis, R.Vogt Phys.Rev.D68,114014, (2003) Eur.Phys.J.C33,s466 (2004)
M.Cacciari et al. J.High Energy Phys. 04,68 (2004)
√s (GeV)

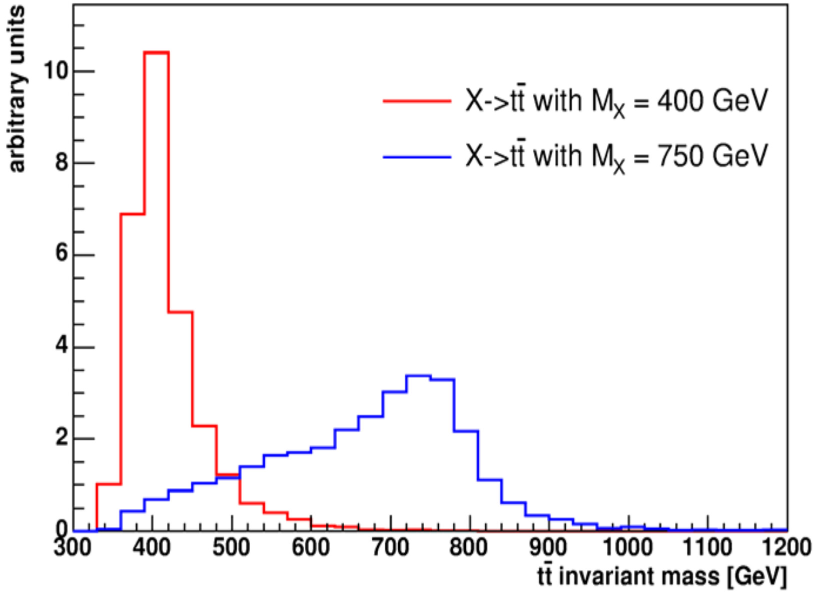
Topcolor-Assisted Technicolor
Hill, Phys Lett. B345, 483 (1995);
Hill and Parke Phys. Rev. D49, 4454 (1994):

- Introducing a new strong interaction
- Predicts new massive bosons "topgluons" and a topcolor Z'

Search for Leptophobic Z':
Assume resonance mass M_X in the range [350-1000] GeV

Assume resonance width $\Gamma_X=0.012\cdot M_X$



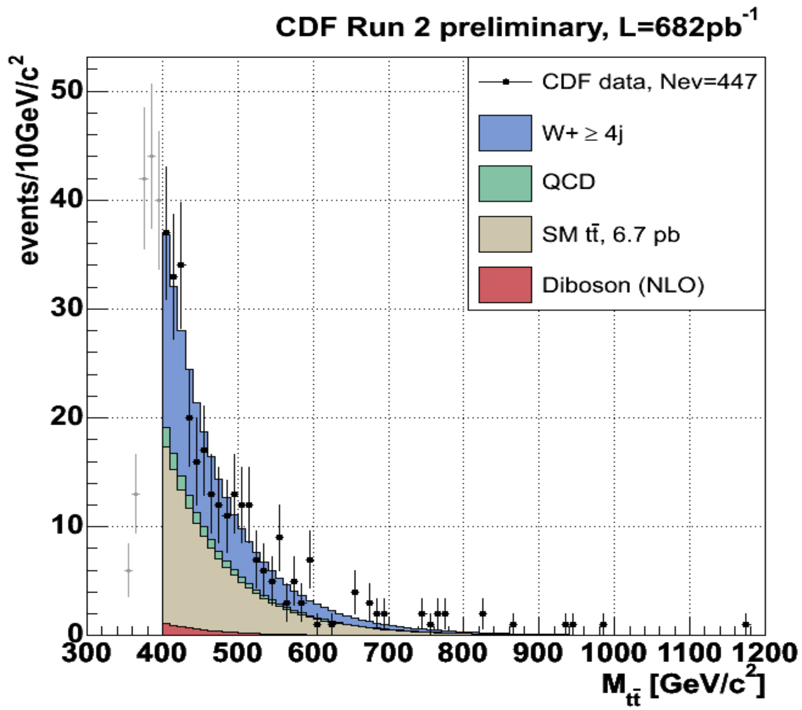


Consequences:

- cross-section higher than SM expectation
- resonances in the $t\bar{t}$ mass distribution

CDF:

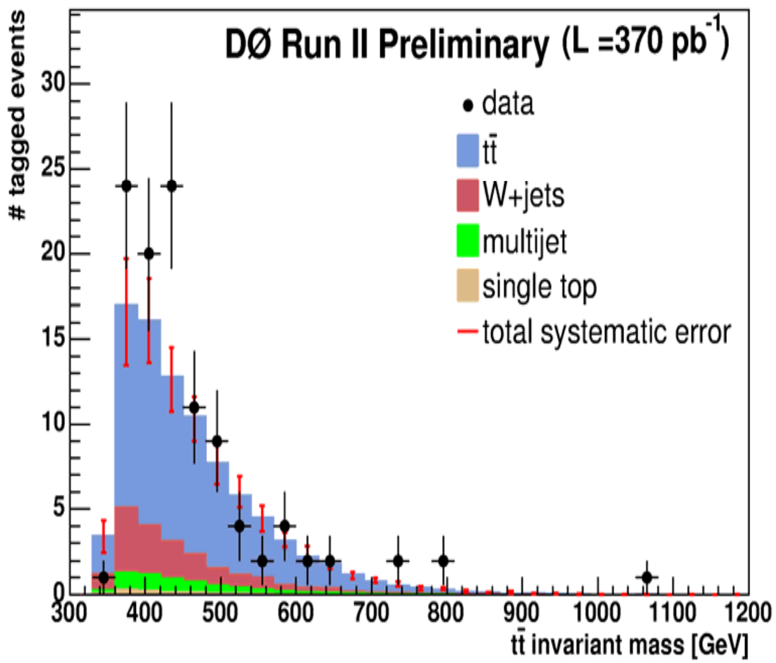
lepton+jets selection, no b-tagging requirements



M_X>725 GeV @95% C.L.

DØ:

lepton+jets selection, at least one b-tagged jet (secondary vertex tag)

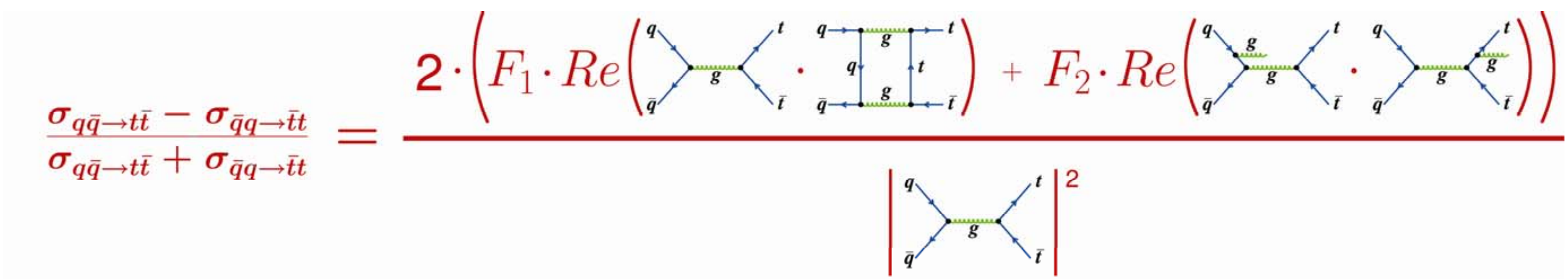


M_X>680 GeV @95% C.L.

Top pair production well described by QCD

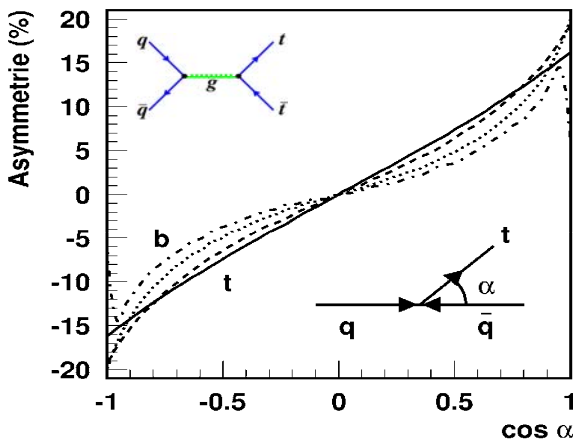
- NLO QCD: expect an assymmetry:
  - Interference of Gluonradiation in the initial and final state
  - Interference of box diagrams with leading order graphs

- Total asymmetry: 6-8%

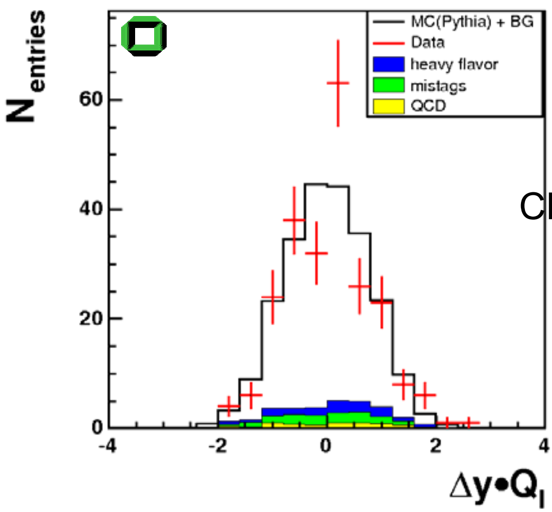


J. Kühn et al.

Effect can be measured only at the Tevatron!



Data, BG, MC comparison: $N_{jets} \geq 4$



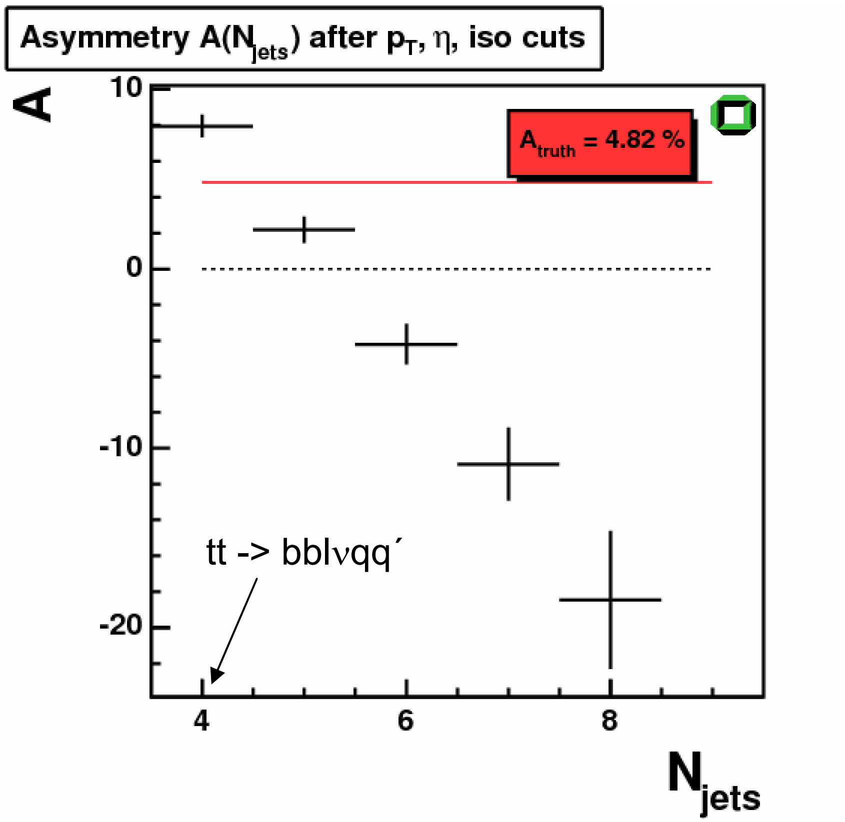
CDF 955 pb^{-1} prel.

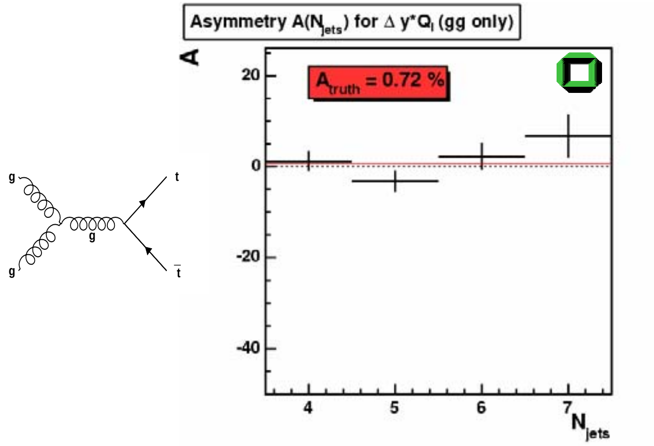
- Conservation of C-Parity
  $\Rightarrow N_{\bar{t}}(\cos\alpha) = N_t(-\cos\alpha)$

- Determination of $\cos\alpha$ difficult
  $\Rightarrow$ Use difference of rapidity of Top-Quarks Δy

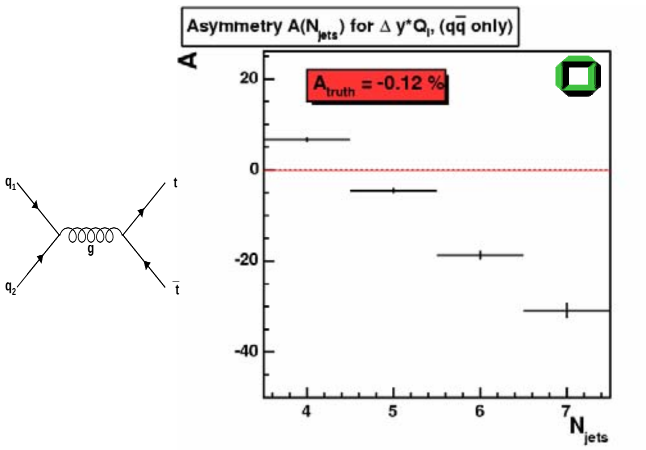
So far we don‘t see a significant effect

Dependence of Asymmetry on N_{jets} in M/C



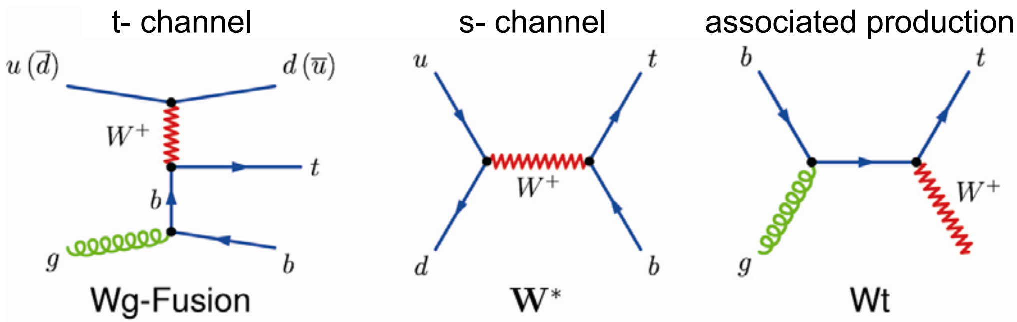


Pythia



MC@NLO simulation of $t\bar{t}$
in the lepton-jet channel

2. SINGLE TOP PRODUCTION



Theoretical cross sections at /s = 1.98 TeV

1.98 ± 0.08 pb — 0.88 ± 0.05 pb — 0.1 ± 0.02 pb

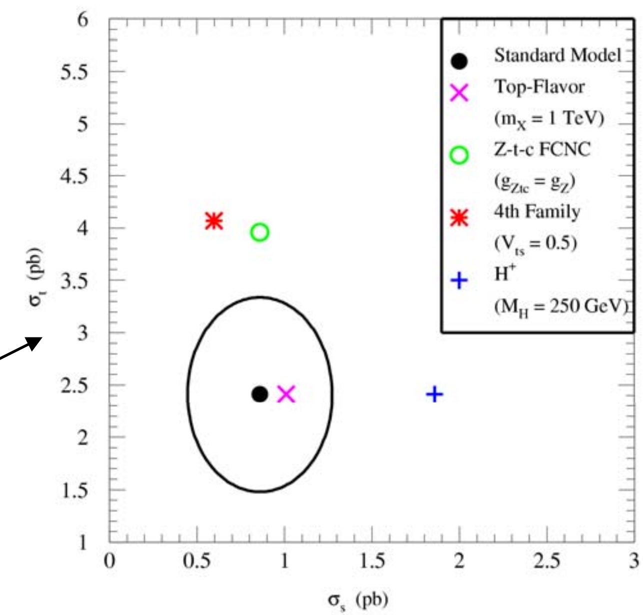
B.W. Harris *et. al.* Phys. Rev. D 66, 054024 (2002)

Observation of single top allows direct access to V_{tb}

- cross section x BR $\propto V_{tb}^2$
- study top-polarization and EWK top interaction

Test of non-SM phenomena

- 4^{th} generation
- FCNC couplings like $t \rightarrow Z/\gamma$ c
- heavy W' boson
- anomalous Wtb couplings

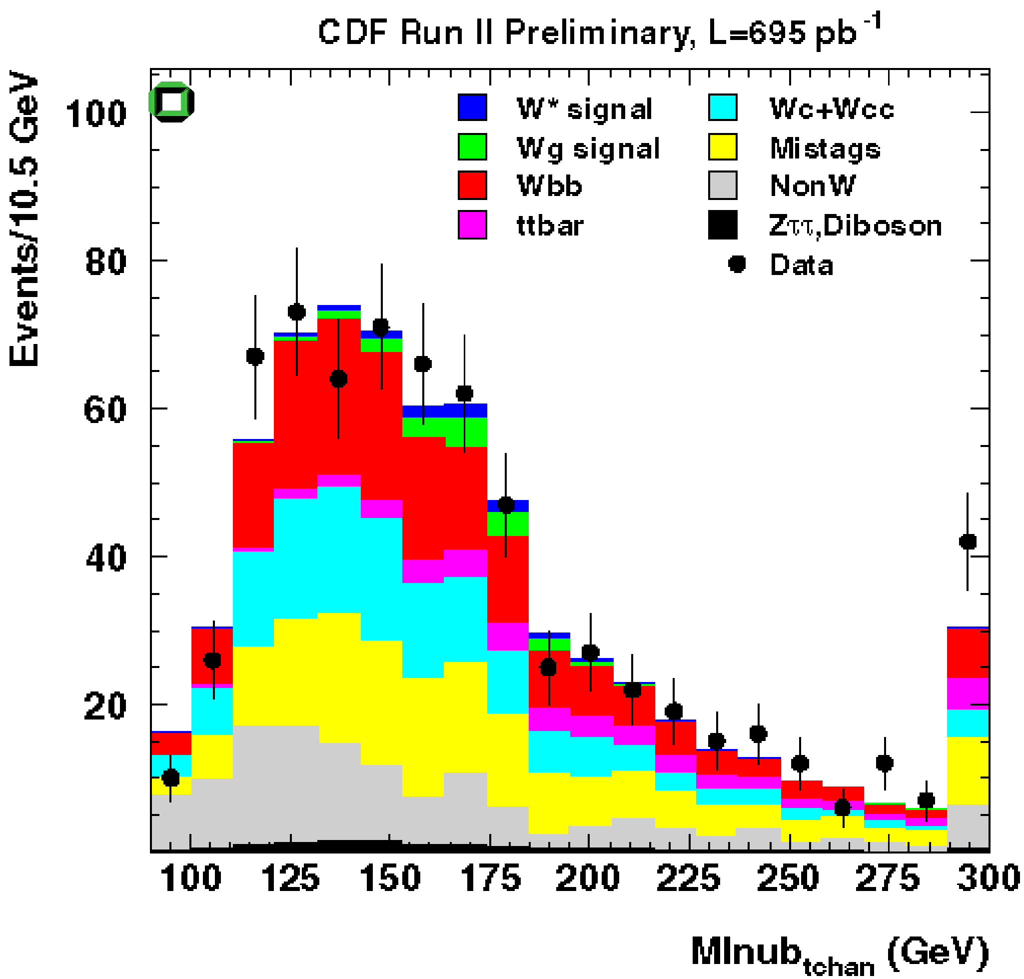


Y. Tait, PRD63, 014018(2001)

Potentially useful for Higgs searches

- single top has same final state as Higgs+W (associated) production

Challenge: Background



- Main background:
  - W+Jet events
  - Bottom-Antibottom events
  - Top-Antitop events
  - Diboson production
- After standard selection: signal to background ratio
  S/B = 1/20
- Observed number of events:
  689

Improved b-Jet-Identification

50% of all background from W+charm or W+light parton with mistags

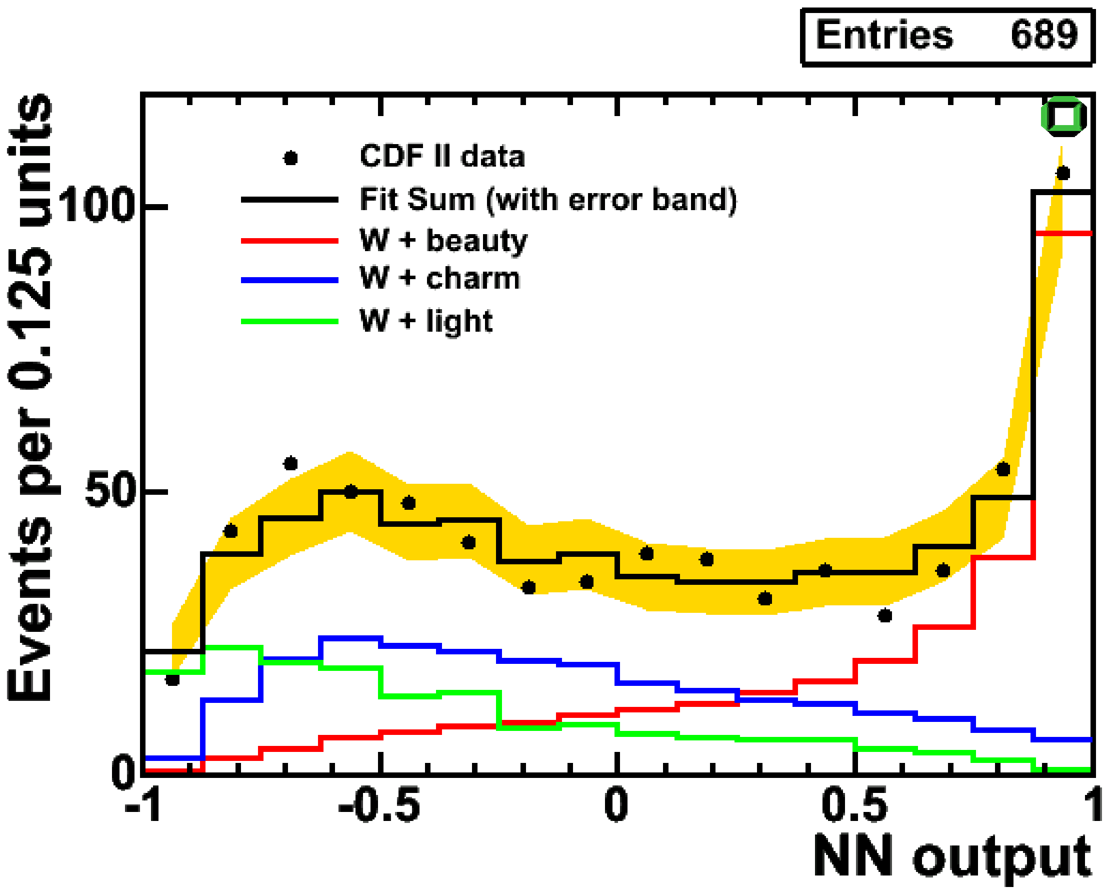
Improvement:
Combination of 25 Jet or track variables to a discriminant e.g. mass of particles from vertex, decay length, track multiplicity

This allows for an in situ measurement of heavy flavor composition of background

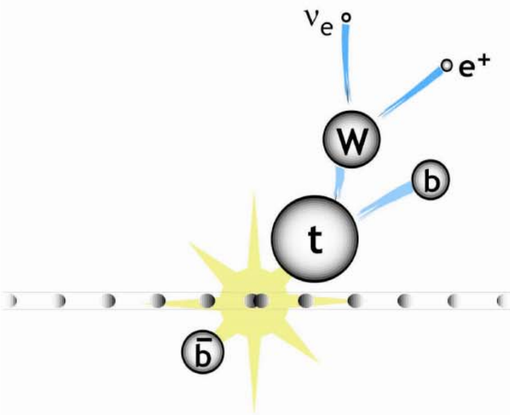
First NN b Tagger at a hadron collider

NN algorithm developed by M. Feindt

Fit of W + 2Jet events with secondary vertex

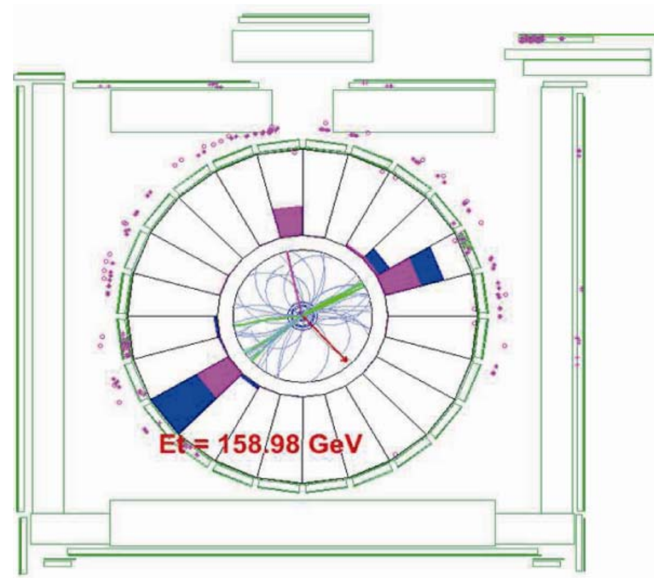


2.1 Search for SM Single Top Production



Selektionsschnitte

- isoliertes, zentrales e od. μ
  $P_T > 20$ GeV/c
- $\not{E}_T > 20$ GeV
- Veto: Z^0, Zwei-Lepton-Ereignisse
- 2 Jets:
  $E_T > 15$ GeV und $|\eta| < 2.8$
- ≥ 1 identifizierter b-Jet
- $140\ \mathrm{GeV}/c^2 \leq M_{\ell\nu b} \leq 210\ \mathrm{GeV}/c^2$



Run: 153389 · Event: 361345
- CEM Electron E_T=50.9 GeV, η=0.24
- MET=25.7 GeV, Phi=5.6
- Jet1 E_T=173.8 GeV, η=0.45
- Jet2 E_T=149.8 GeV, η=-0.13

S. TOP CANDIDATE

Simulation: MadEvent

Systematics and Event Selection Efficiencies

CDF II 695 pb^{-1} Preliminary

Source	t-channel	s-channel
JES	1.8%	1.2%
ISR	1%	2%
FSR	5%	1%
PDF	2.5%	2.2%
MC	2%	1%
ϵ_{evt}	10.3%	8%

Event selection efficiency(*)

s-channel 1.87 ± 0.15%

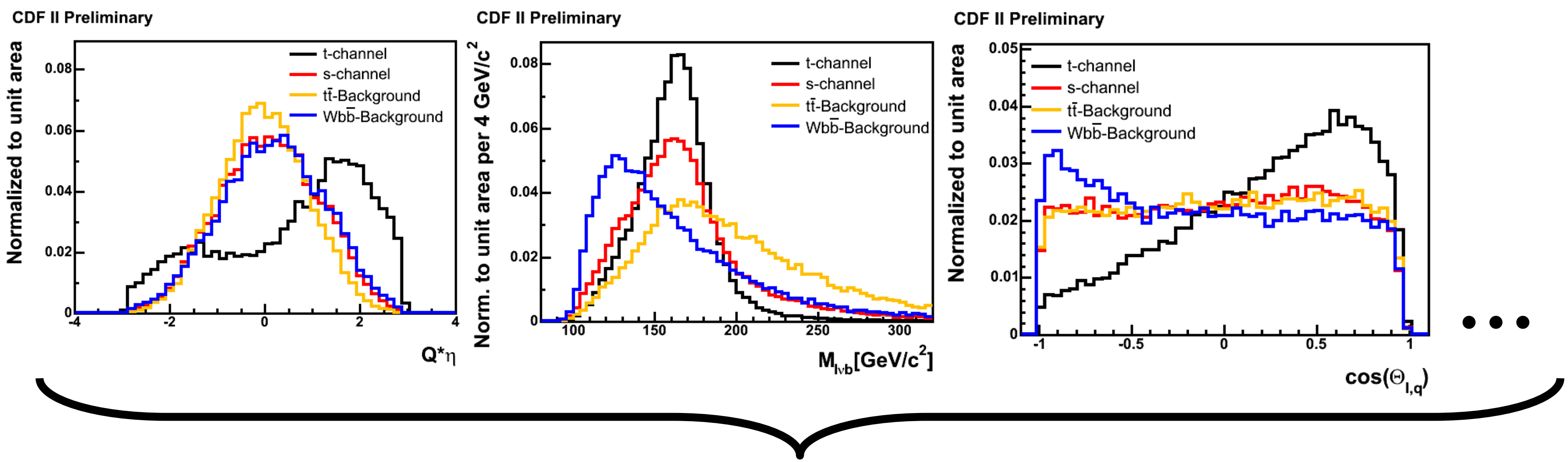
t-channel 1.21 ± 0.17%

(∗) Including W→leptons BR

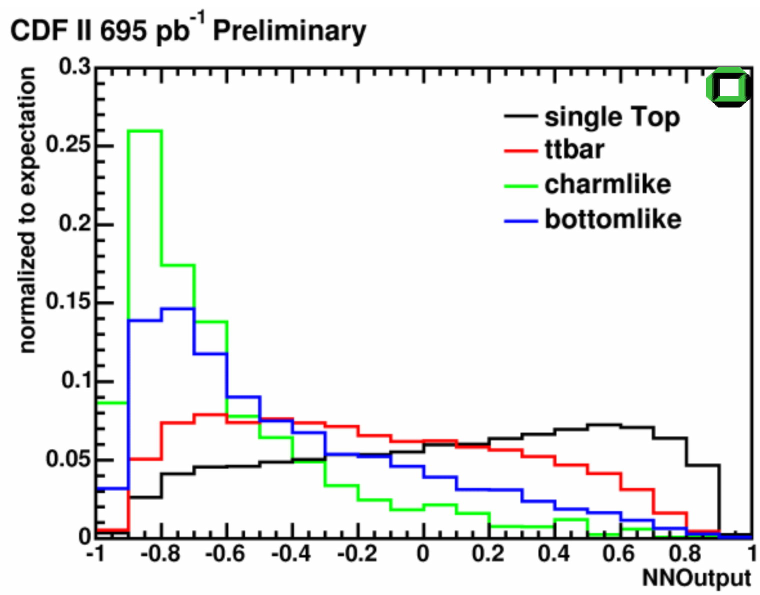
CDF II 695.5 pb^{-1} Preliminary

	W + 2 jets
Pretag W	13934 ± 550
Non-W	119.5 ± 40.4
Mistags	164.3 ± 29.6
$Wb\bar{b}$	170.7 ± 49.2
$Wc\bar{c}$	64.5 ± 17.3
Wc	69.4 ± 15.3
$t\bar{t}$	40.3 ± 3.5
WW	3.8 ± 0.4
WZ	6.1 ± 0.6
ZZ	0.2 ± 0.0
$Z- > \mu\mu$	4.4 ± 0.5
$Z- > \tau\tau$	2.6 ± 0.3
Total Background	645.9 ± 96.1
Single Top	28.2 ± 2.6
Total Prediction	674.1 ± 96.1
Observation	689

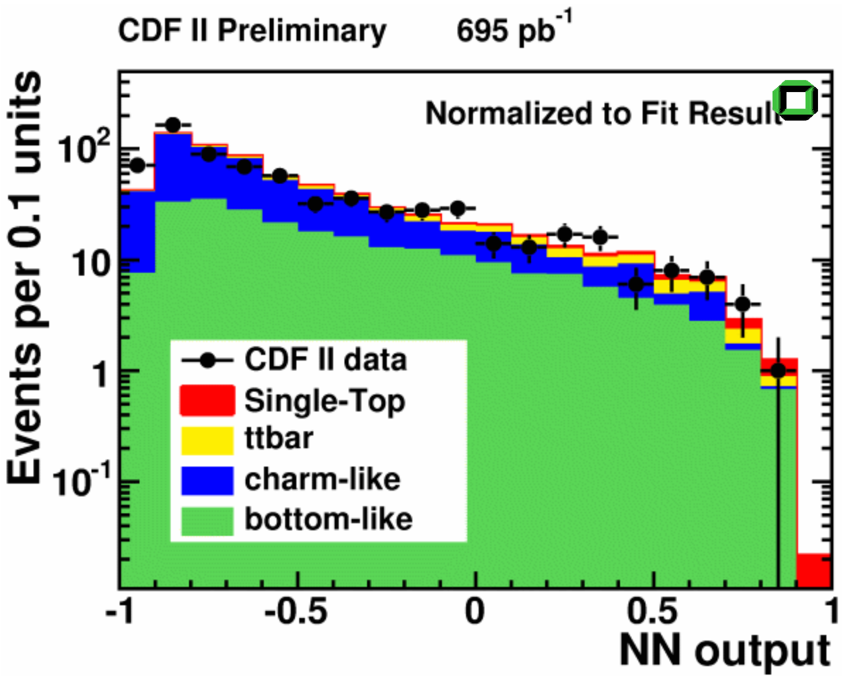
Neural Net for Single Top Search

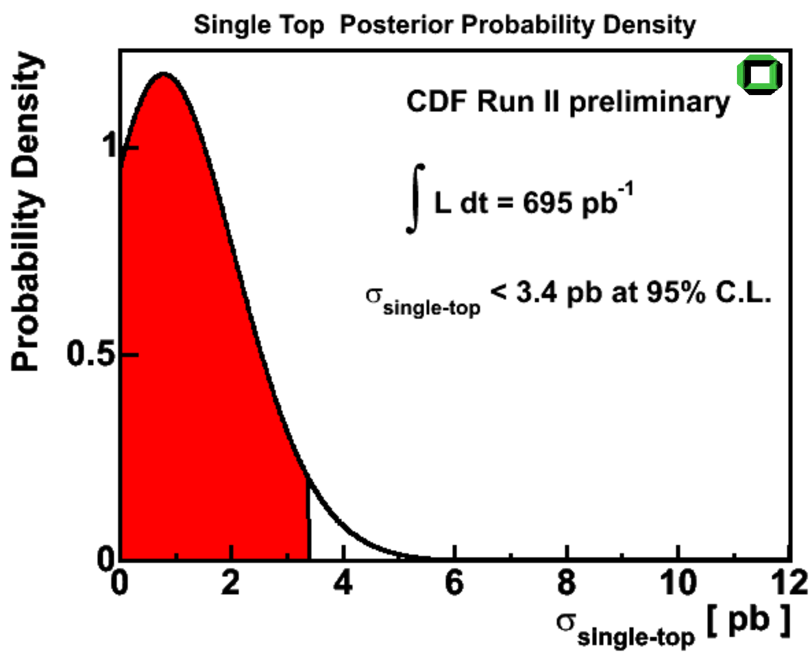


14 Variables, e.g. Q · η, reconstructed top mass, top quark polarisation, Jet E_T and η, NN b Tagger-Output, W boson η



Fit of signal and background templates to CDF II data





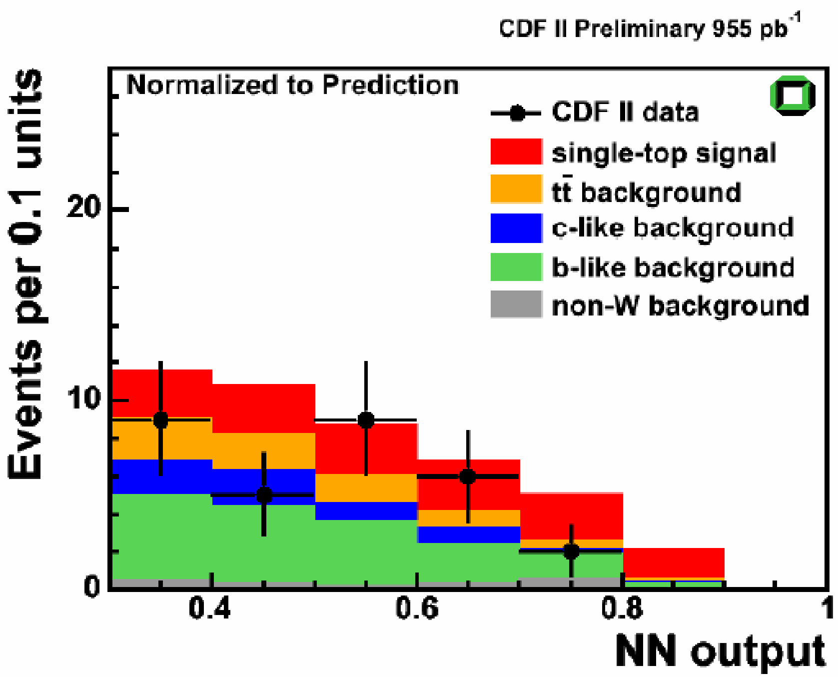
$\sigma_{Fit} = 0.8\ ^{+1.3}_{-0.8}\ (stat.)\ ^{+0.2}_{-0.3}\ (syst.)$ pb

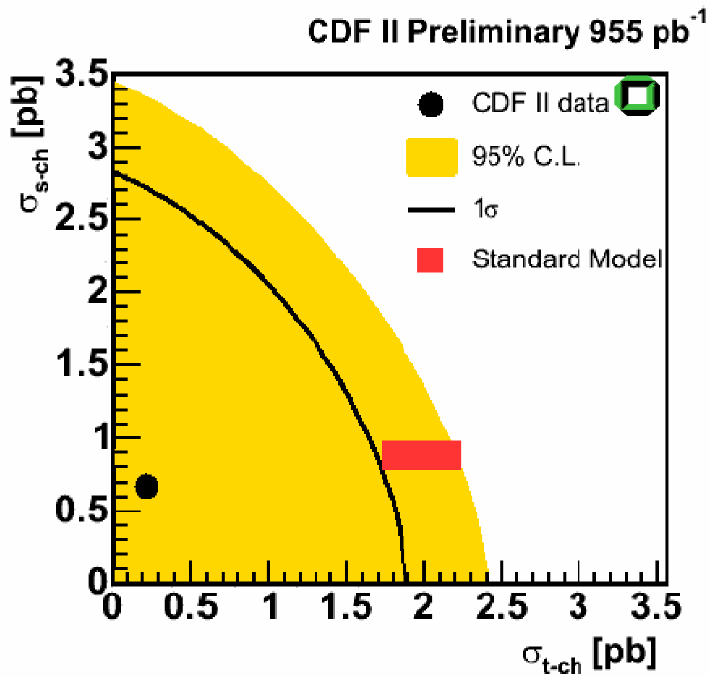
$\sigma_{SM} = 2.9 \pm 0.4$ pb

Indication of a deficit ?

Calculation of 95% upper limits with Bayesian statistics

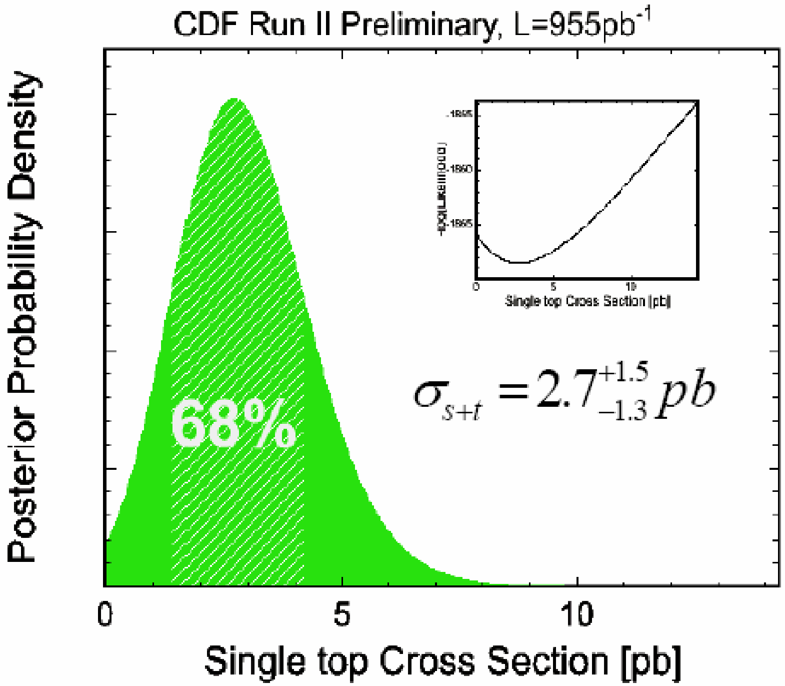
Separation of t- und s-channel with 2D-Likelihood



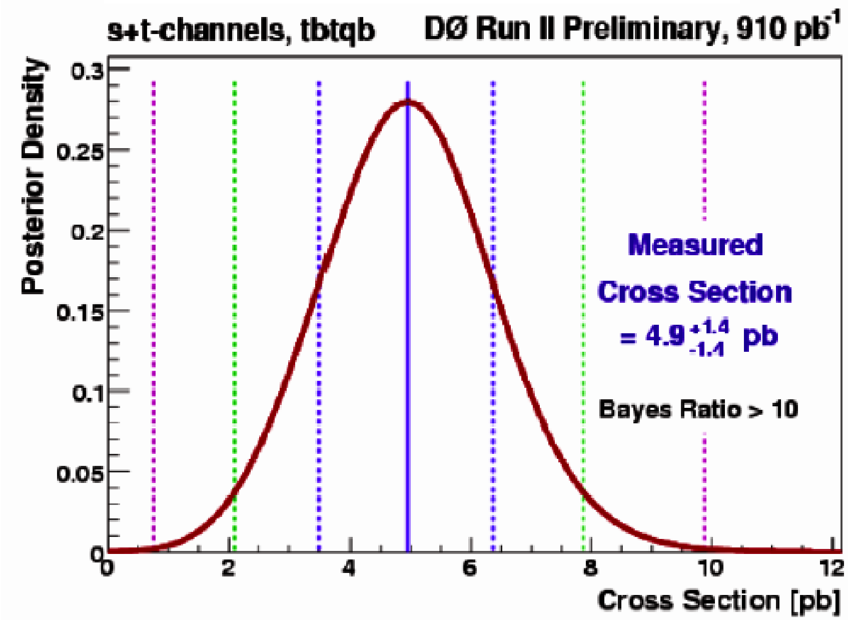


σ (Single-Top) < 2.6 pb

σ_{SM} (Single-Top) = 2.9 ± 0.4 pb



p-value = 1% → 2.6 sigma

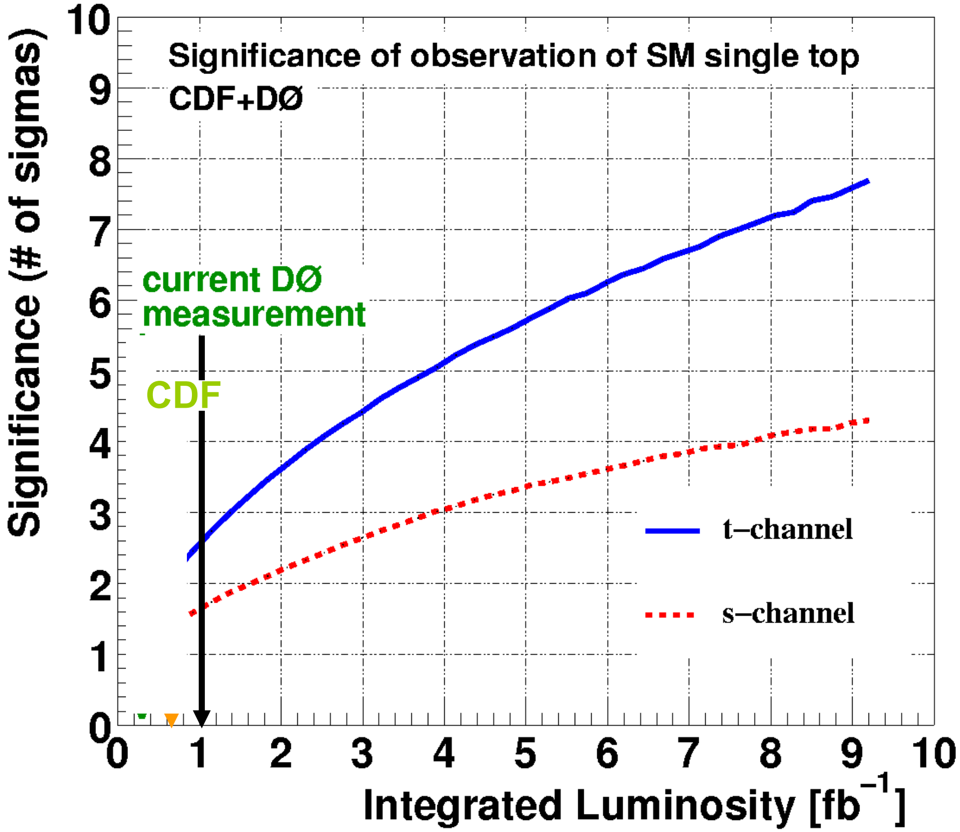


p-value = 0.035% → 3.4 sigma

$(V_{tb})^2 = 1.7 \pm 0.6$

At present results are inconsistent and all unlikely!

Projections

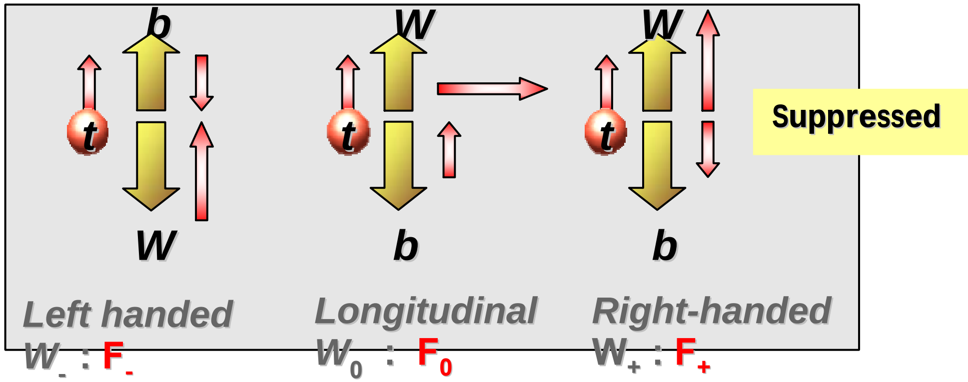


- Assume no further improvement in analysis technique, methods, and resolution:

  it will take 2-3 fb^{-1} of data for each experiment to establish single top production

- To separate s- channel from t-channel: 3-4 fb^{-1} will be needed

Three possible helicities:



$$F_0 = \frac{m_t^2}{2M_W^2 + m_t^2}$$

Distribution of Angle θ* between charged lepton in W system and W-Boson in Top-Quark system:

$$\frac{dN_{h_W=-1}}{d(\cos\theta^*)} \sim \frac{3}{8}(1-\cos\theta^*)^2$$

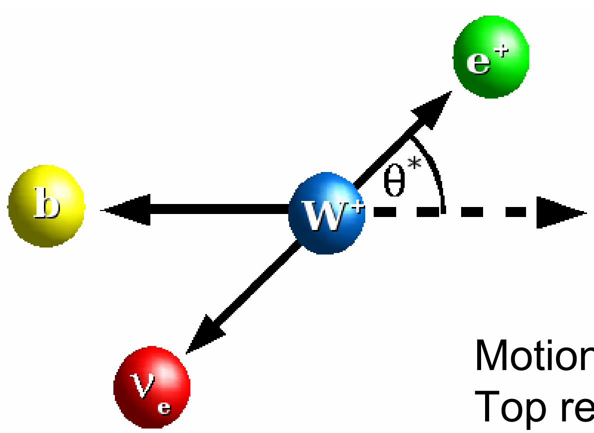
$$\frac{dN_{h_W=0}}{d(\cos\theta^*)} \sim \frac{3}{4}(1-\cos^2\theta^*)$$

$$\frac{dN_{h_W=+1}}{d(\cos\theta^*)} \sim \frac{3}{8}(1+\cos\theta^*)^2$$

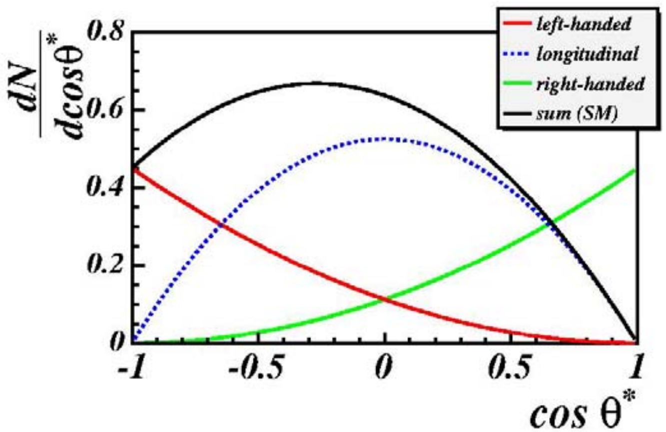
SM:
$F_- = 0.30$

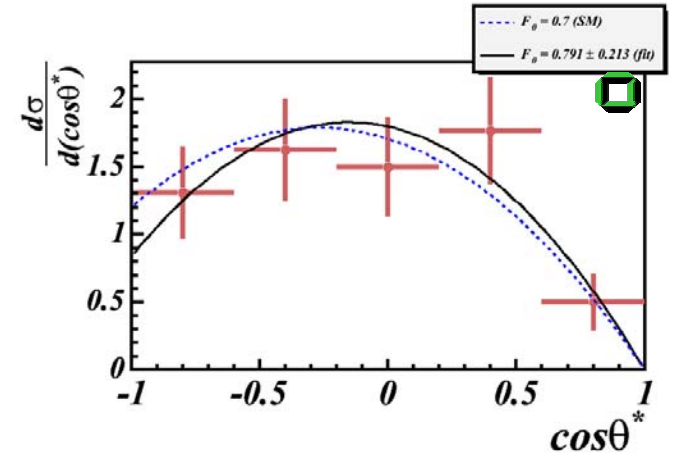
$F_0 = 0.70$

$F_+ = 0.0004$

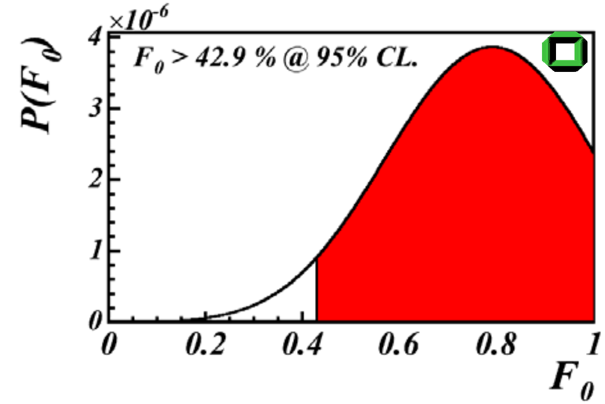


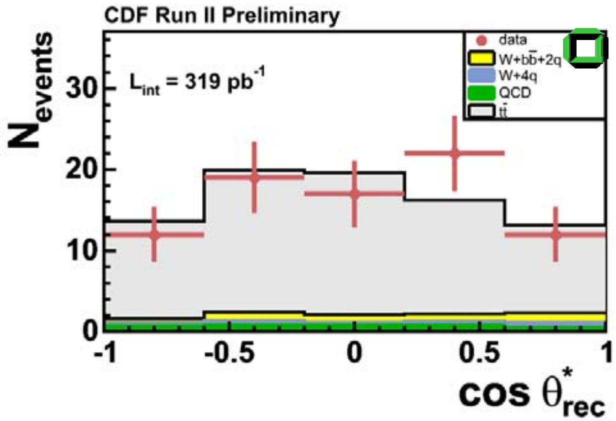
Motion of W in Top rest system





Raw data: 85 $t\bar{t}$ lepton + jets candidates in 319 pb^{-1}





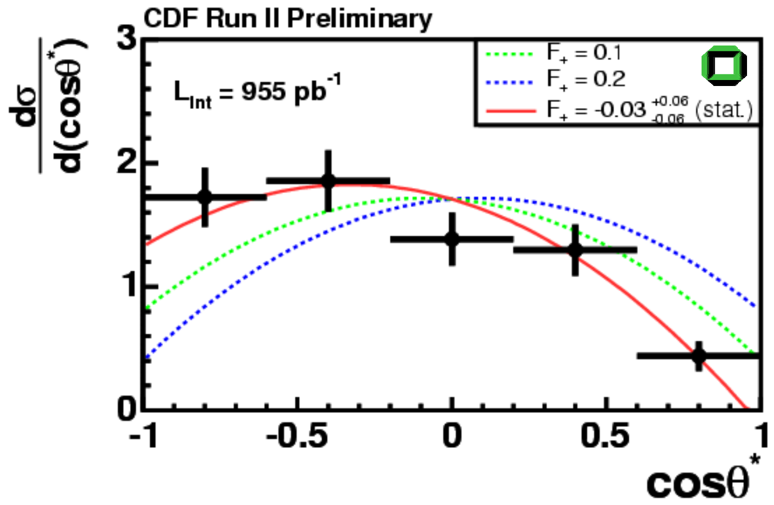
F_0 = 85+15-22 +- 6 (stat) %
F_0 > 43% @ 95% C.L.
F_+ = 5+11-5 +- 3 (stat) %
F_+ < 26% @ 95% C.L.

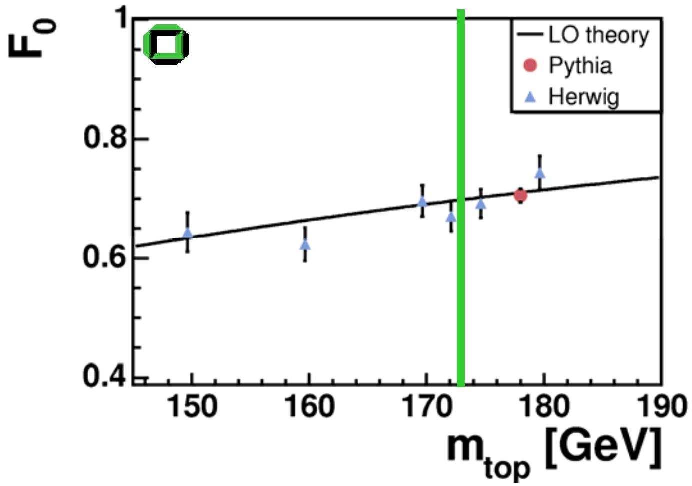
Next steps: publish analysis with 1 fb^{-1}:

Expected precision ca. 15%

(At LHC 1%)

Worth looking at: mass dependence of F_0





$F_0 = 0.59 \pm 0.12$

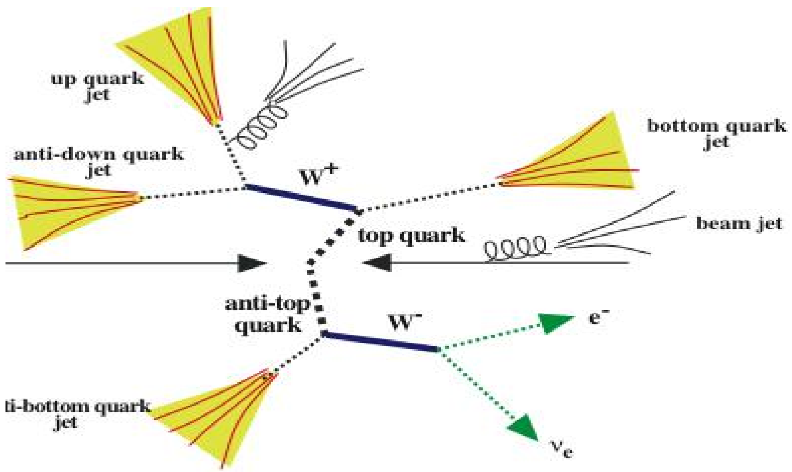
4. TOP QUARK PROPERTIES

4.1 Mass of the Top Quark

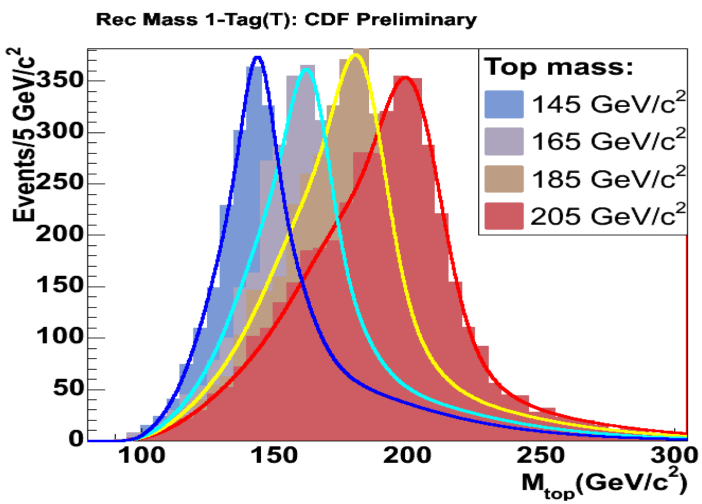
dilepton	Neutrino weighting ($\eta \rightarrow \varphi$)	⇨ 1-dim. fit
	Phi-weighting ($\varphi \rightarrow \eta$)	⇨ 1-dim. fit
	P_z(tt) method	⇨ 1-dim. fit
	ME weighting	⇨ 1-dim. fit
	ME method	⇨ 1-dim. fit
l+jets	○ Template method in m_{top} after kinematic fit, topological or b-tag, with internal or external JES constraint	⇨ 1- or 2-dim. fit
	Matrix Element/Dynamical Likelihood Method, topological or b-tag, with internal or external JES constraint, complex analysis	⇨ 1- or 2-dim. fit
	Ideogram method (W-mass @ LEP), compare signal and background mass spectrum, chi^2 weighting (kine fit), with internal/external JES constraint	⇨ 1- or 2-dim. fit
	○ Decay Length Method, compare transv. Decay length spectrum with expecation from $c\tau(B) \cdot \beta(m_{top})\gamma(m_{top})$	⇨ 1-dim. fit
alljets	Kinematic fit, only from Run-I	⇨ 1-dim. fit

A. Quadt, Bonn

CDF Lepton+jets Analysis

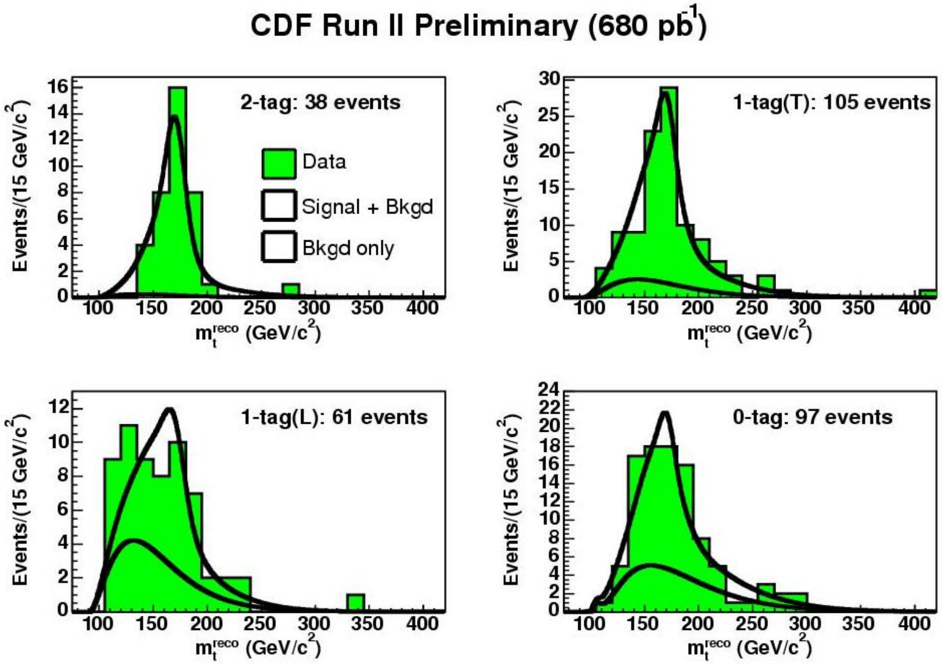


- Constrain $m(jj) = m_W$, $m(\ell\upsilon) = m_W$ and $m(\ell\upsilon b) = m(jjb)$
  - 24 possibilities for 0 b-tags
  - 12 possibilities for 1 b-tag
  - 4 possibilities for 2 b-tags
- Select configuration with best χ^2 fit -> obtain M_{reco}



- 2005 New: Jet Energy Calibration in situ
- Simultaneous fit to invariant mass of W->jj
- Global factor used to correct energies of jet
- Reduces systematic uncertainty

Fit four data samples (0-tag, 1-tag(Loose), t-tag(Tight), 2-tag with SecVtx tagger) in m_{top} and ΔJES, i.e. 2-dim fit :



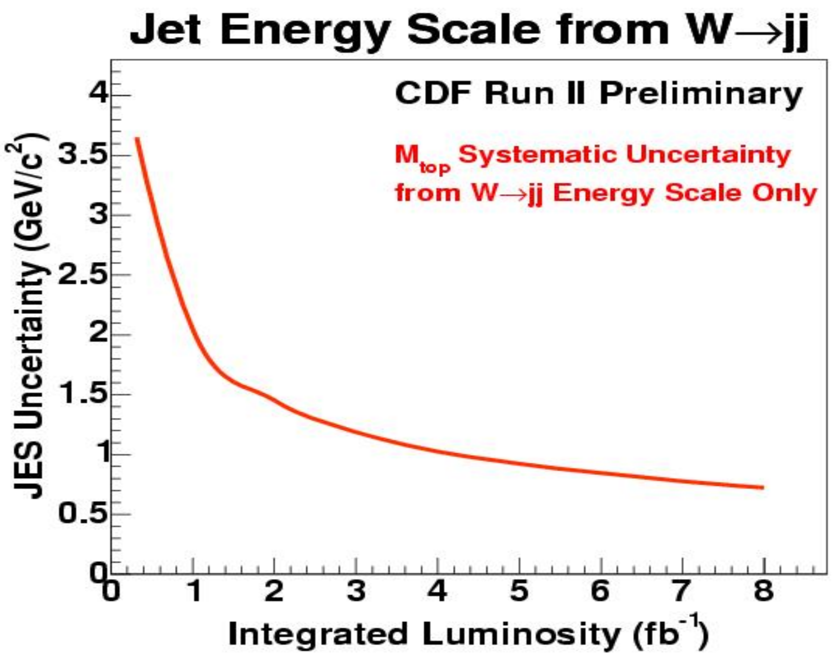
Systematics

Source	Magnitude (GeV/c²)
Residual JES	0.42
b-JES	0.60
Generator	0.19
ISR	0.72
FSR	0.76
b-tag *ET* dependence	0.31
Background composition	0.21
PDF	0.12
Monte Carlo statistics	0.04
Lepton p_T scale factor	0.22
Multiple interactions	0.05
Total	1.36

$$M_{top} = 170.9 \pm 1.6(\text{stat.}) \pm 1.4(\text{JES}) \pm 1.4(\text{syst.})\ \text{GeV}/c^2$$

Future Projection

Systematic Source	Uncertainty (GeV/c^2)
Radiation	0.7
Model	0.7
b-jet	0.6
Method	0.6
PDF	0.3
Total	1.3
Jet Energy	2.5



- Expect significant reduction in JES uncertainty with more data
- Turning JES systematic into a statistical uncertainty

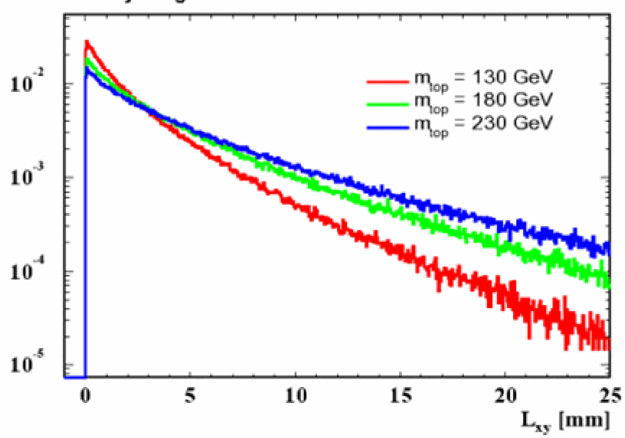
Decay Length Technique

method by C. Hill *et al.* at PRD 71, 054029

- Top quarks at Tevatron produced nearly at rest
  ⇨boost of the b-quark a function of m_{top}

$$\gamma_b = \frac{m_t^2 + m_b^2 - m_W^2}{2 m_t m_b} \approx 0.4 \frac{m_t}{m_b}$$

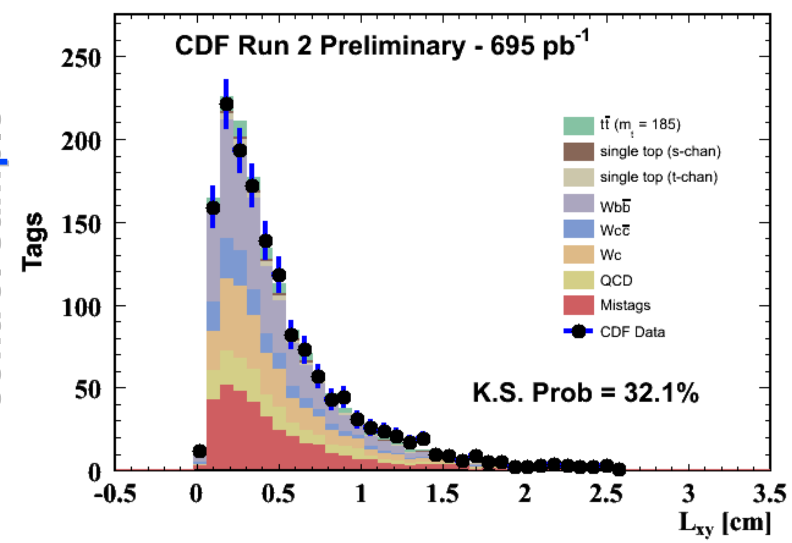
- Measure transverse decay length of B-hadrons from top decay ⇨infer on top quark mass



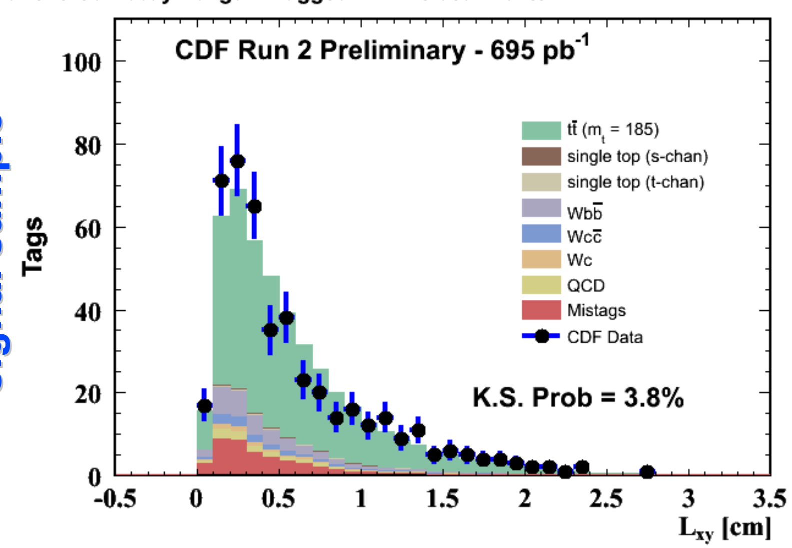
- Select l + ≥ 3 jets events with ≥ 1 SecVtx tag in 695 pb^{-1} ⇨ 456 pos. SecVtx tags in 375 events

$$m_{top} = 183.9^{+15.7}_{-13.9}(stat.) \pm 5.6(syst.)\, GeV/c^2$$
$$\Delta m_{top}(JES) = 0.3\, GeV/c^2$$

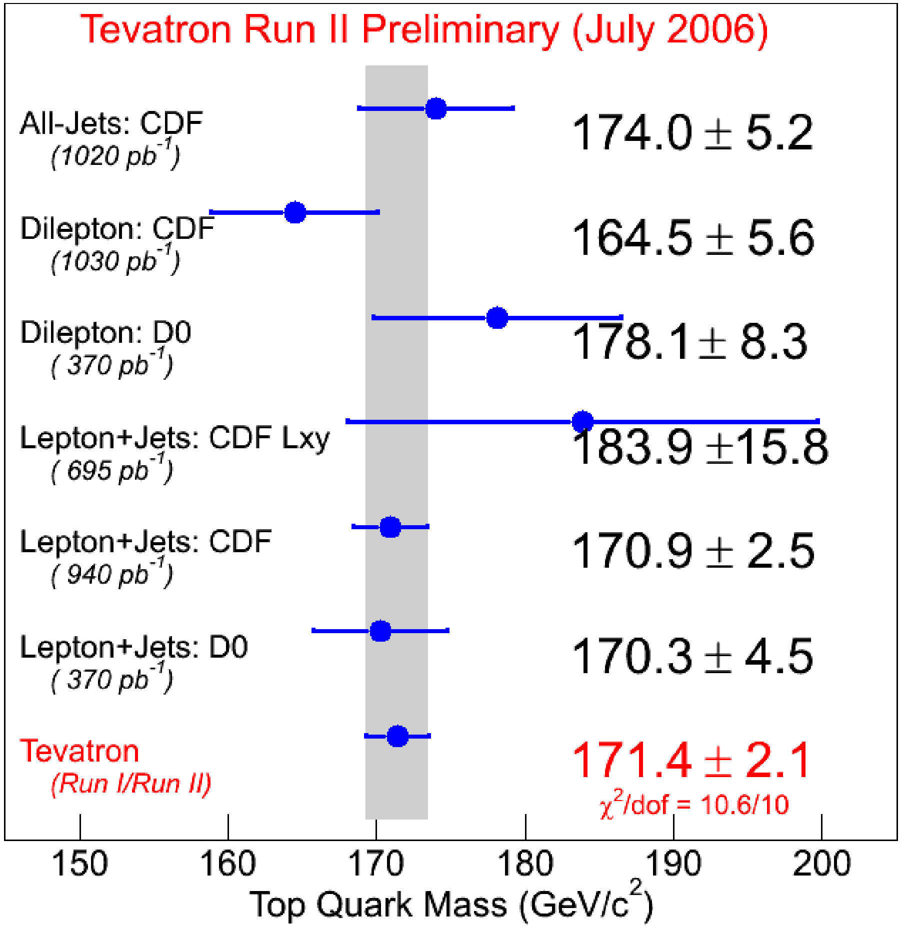
control sample



signal sample



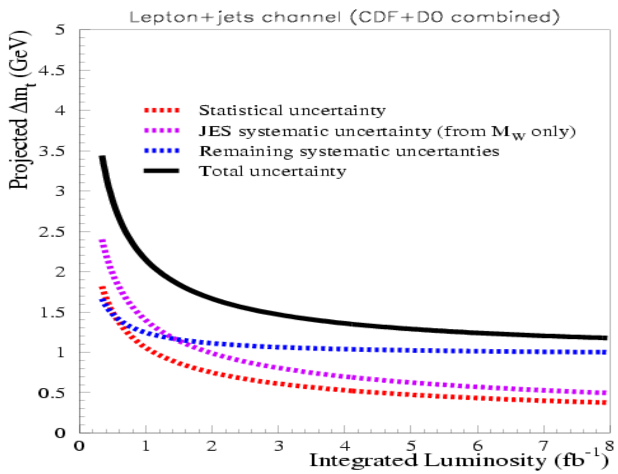
M_{top}: Combination of Tevatron Results



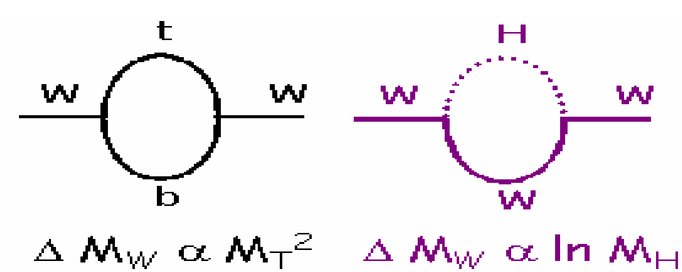
<u>World Average:</u>

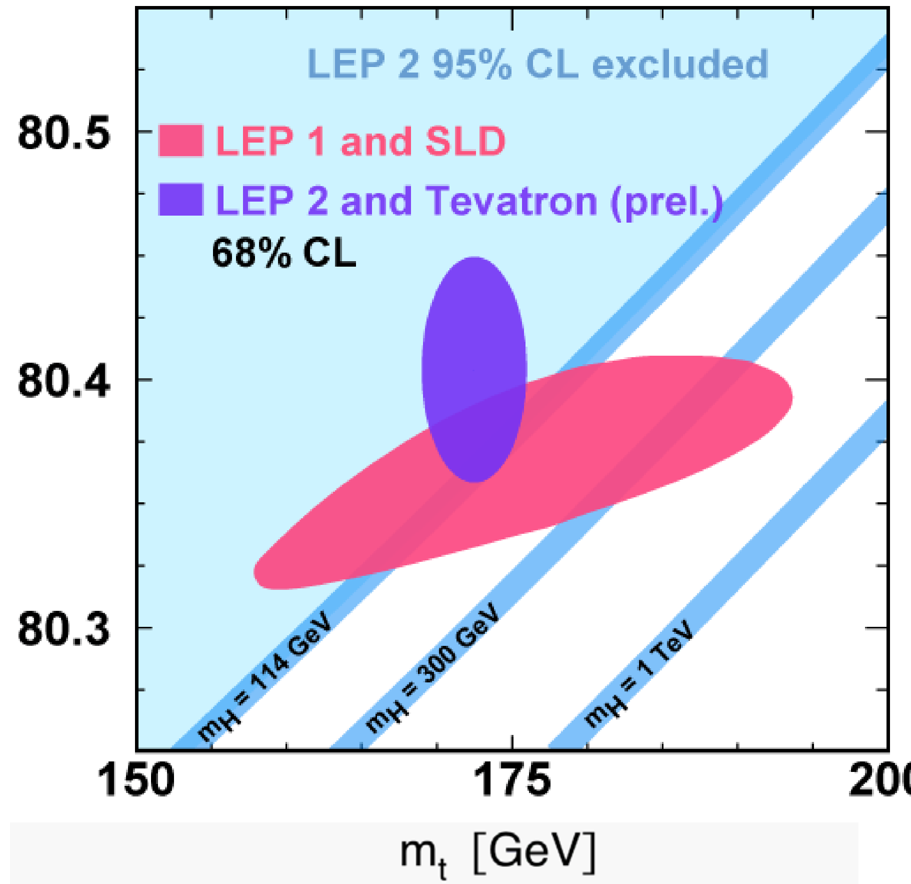
m_t=171.4 ± 1.2 ± 1.4(JES) ± 1.0(syst) GeV/c^2

- Systematics limited!
- Precision Measurement: Δm_t~1.2%
- In the 4-8fb^{-1} future, we expect ...
  - ... ~1.5 GeV <u>total</u> error
  - ... dilepton to become systematics limited
  - ... all-hadronic measurements to contribute significantly



- Radiative corrections relate top quark mass, W boson mass
- Within SM, they allow to place a constraint to the mass of the Higgs



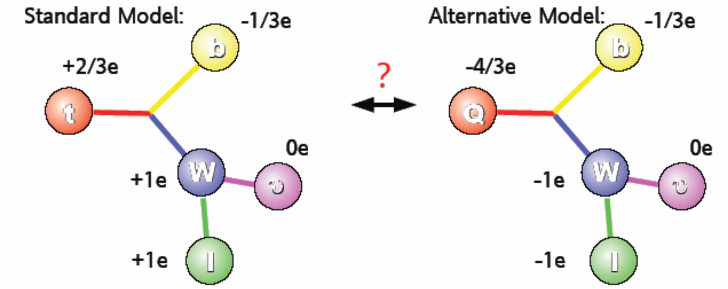


4.2 Charge of the Top Quark

Did we find the Standard Model Top ?

W.-F. Chang et al.,Phys. Rev. D 59, 091503 (1999), (hep-ph/9810531):
exotic doublet of quarks (Q1, Q4)$_R$ with charges (-1/3,-4/3) and M ~ 175 GeV

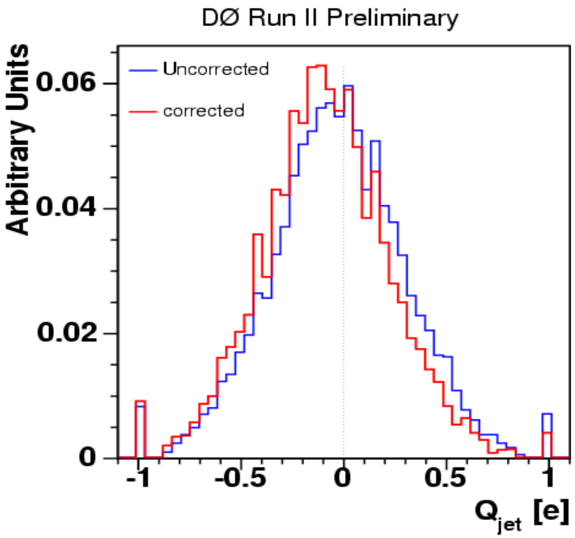
q = -4/3 is consistent with EW data (E. Ma et al. , hep-ph/9909537)



Search by D0:

Lepton+jets, double b-tag events
Determine:

- charge of W (lepton)
- pairing between W and b (χ^2 fit)
- flavor of b-jet



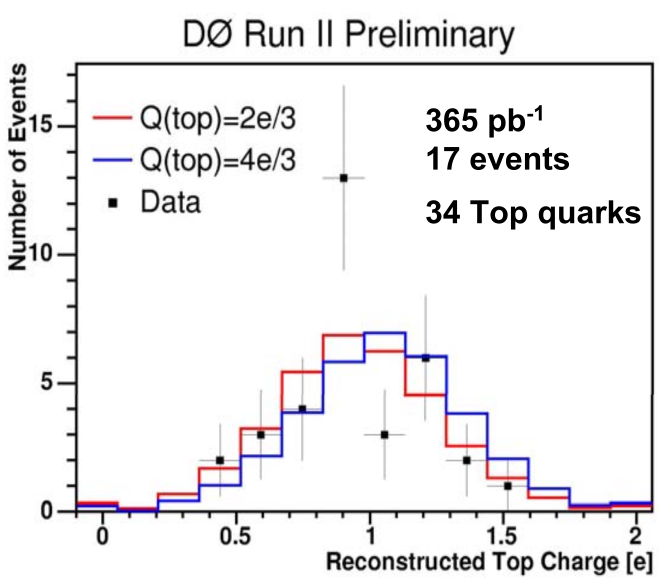
Calibration with a b-jet sample

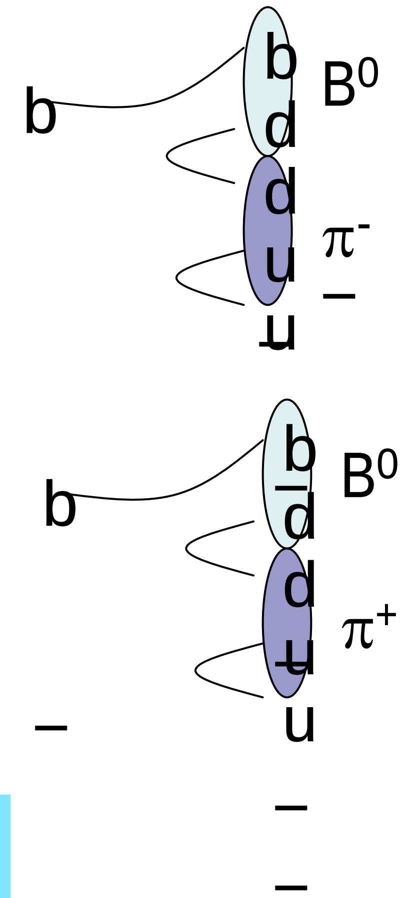
- 17 candidate events with two tagged b-jets, lepton, missing E_T, ≥ 4 jets.
- two entries per event for top and anti-top.
- discriminate b and bbar with jet charge algorithm,

$$q_{jet} = \frac{\Sigma_i q_i \, p_{Ti}^{0.6}}{\Sigma_i \, p_{Ti}^{0.6}}$$

, pT > 0.5 GeV & $\Delta R < 0.5$.

- calibrate Monte Carlo with data using two jet heavy flavor sample with opposite jet tagged with μ charge.





$Q_{top,1} = | \; q_l + q_{,b(l)} \; |$
$Q_{top,2} = | - q_l + q_{,b(j)} \; |$

Excluded Q=4/3 with 94%CL

4.3 Top Lifetime

- Within the SM: τ_{top} ~5 10^{-25} s ($c\tau$ = 3 10^{-10} μm)
- Use d_0-lepton impact parameter with respect to beamline
- Determine detector resolution from $Z^0/\gamma \to e^+e^-/\mu^+\mu^-$

$$\tau_{top} \propto \left(\frac{M_W}{M_{top}}\right)^3$$

$$\tau_{top} \approx 4.7 \cdot 10^{-25}\ \mathrm{s}$$

Data:

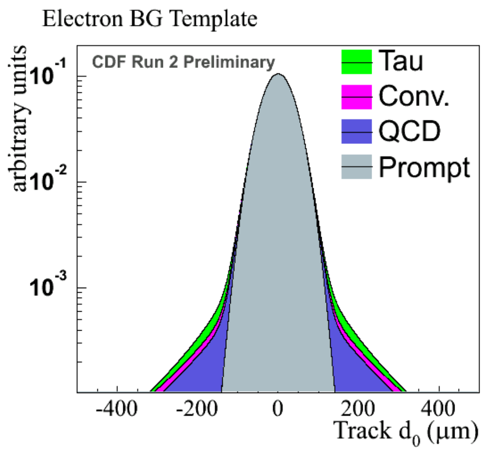
lepton + ≥ 3 jets with ≥1 b-tag in 318 pb-1

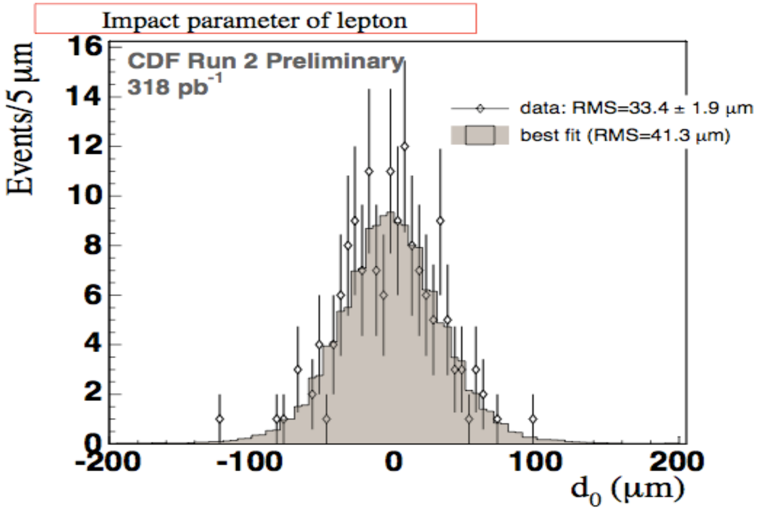
⇨97 e+jets candidates

⇨60 μ+jets candidates

measure impact parameter d_0 for lepton tracks

use max. likelihood fit with templates of variing lifetime (incl. track resolution)





$c\tau < 52.5$ μm, $\tau_{top} < 1.75\times10^{-13}$s with 95% CL

The LHC will be the Top factory !

in 10 fb^{-1}:

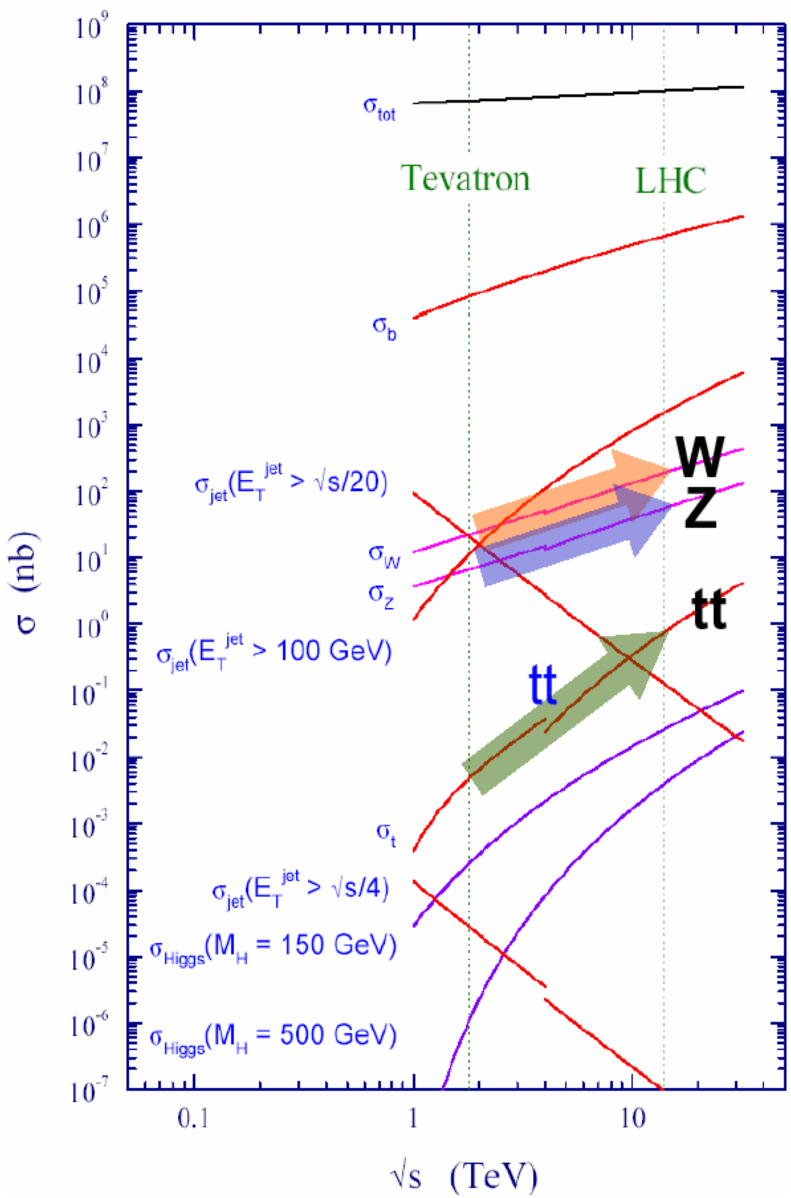
$8 \cdot 10^6$ top-pairs (1 Hz)

$2 \cdot 10^6$ single top events

Precision measurements:
- Mass, Couplings,
- Spin correlations

Means of calibration:
- Lepton ID, b- Jet Identification,
- Jet-Energy scale

Main Background for many searches



5.1 Single Top Quark Production at the LHC

Tevatron:

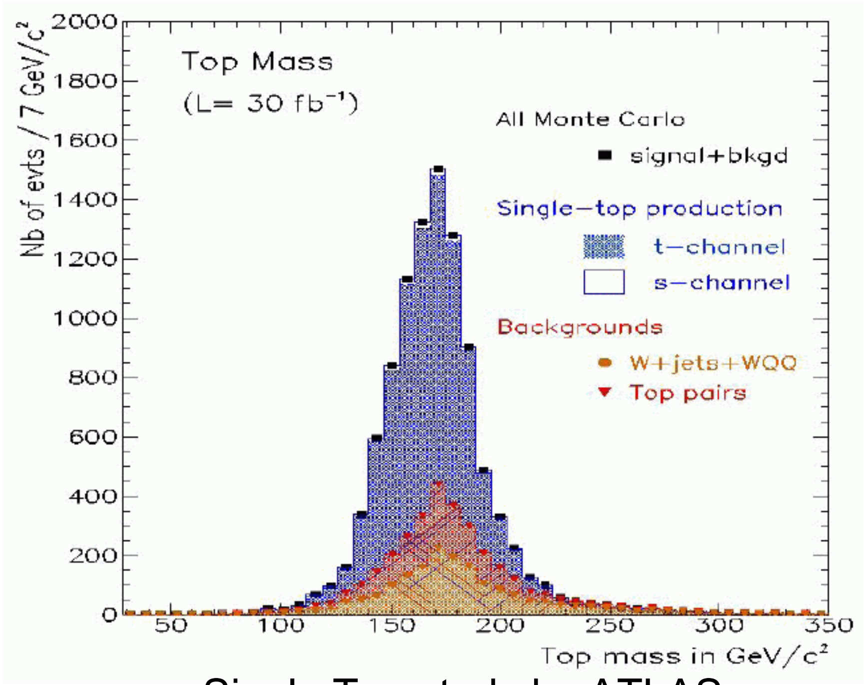
- First observation
- Precision of $|V_{tb}|$ O(10%)

	1.96 TeV	14 TeV
Single top (s-channel)	0.88±0.12 pb	10±1 pb
Single top (t-channel)	1.98±0.22 pb	245±17 pb
Single top (Wt channel)	0.15±0.04 pb	60±10 pb
Wjj (*)	~1200 pb	~7500 pb
bb+other jets (*)	~2.4x10^5 pb	~5x10^5 pb

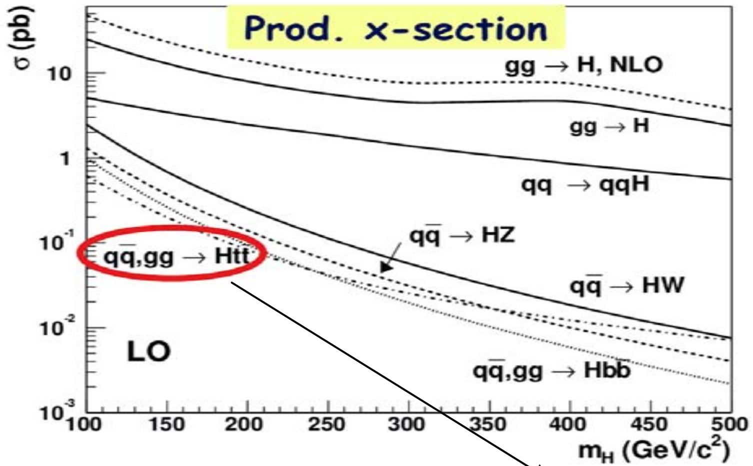
(*) with kinematic cuts in order to better mimic signal
Belyaev, Boos, and Dudko [hep-ph/9806332]

LHC:

- Cross Section x 100
- W+Jets background smaller
- Larger acceptance for leptons, jets in detectors
- Already with 1 fb^{-1} precision of $|V_{tb}|$ O(2%); limited by systematics
- Discovery Channel for $H^{\pm}$



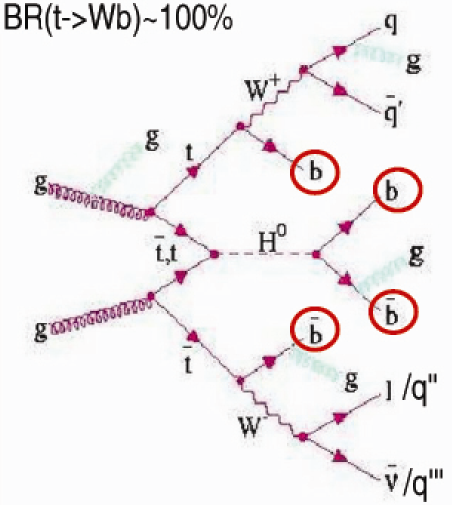
Single Top study by ATLAS



σ = 0.664 pb (NLO, m_H =120 GeV)

40×10^3 with $60 fb^{-1}$ integrated luminosity

BR(t->Wb)~100%



Very challenging topology:

- **4 b jets** from top and Higgs decays
- Depending on W decays:

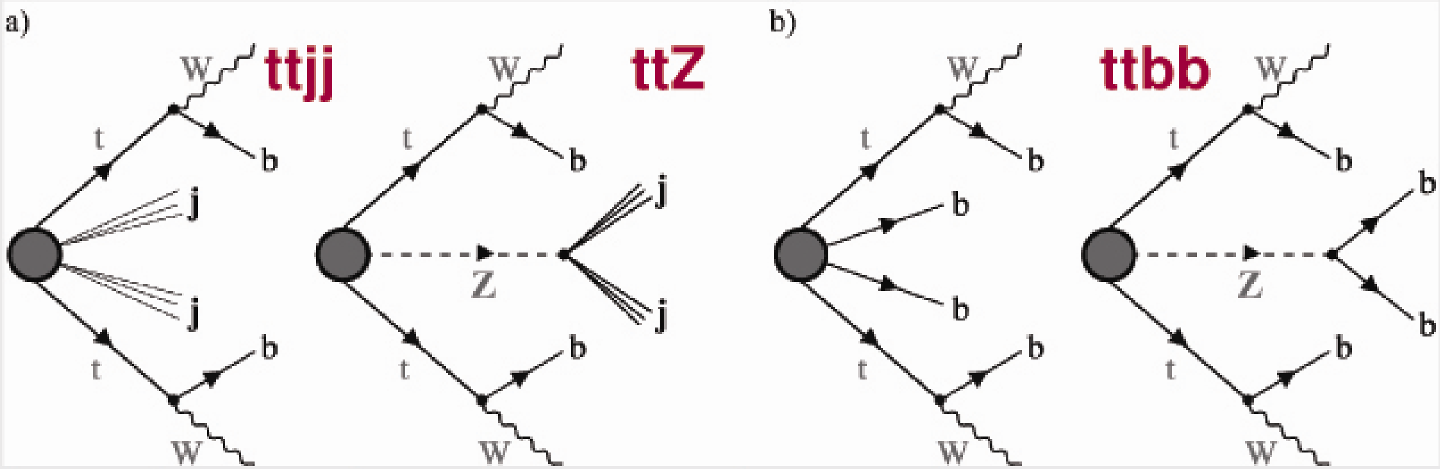
→ **Semi-leptonic channels (~28%):**
  2 light jets +Isolated lepton (e/μ) + Missing Energy

→ **Di-lepton channel (~6% including $\tau \to e/\mu\nu\nu$):**
  2 isolated leptons (e/μ) + Missing Energy

→ **Fully-Hadronic channel (~49%):**
  4 light jets + 4 b jets (very difficult!!)

- additional jets from gluon radiations

ttH, H->bb: Backgrounds



σ	507 pb	0.65 pb	3.28 pb	(leading order)
Exp. Ev. @60fb-1				
	30×10^6	40×10^3	20×10^3	
Simu. Ev.	1.4×10^6	123×10^3	450×10^3	

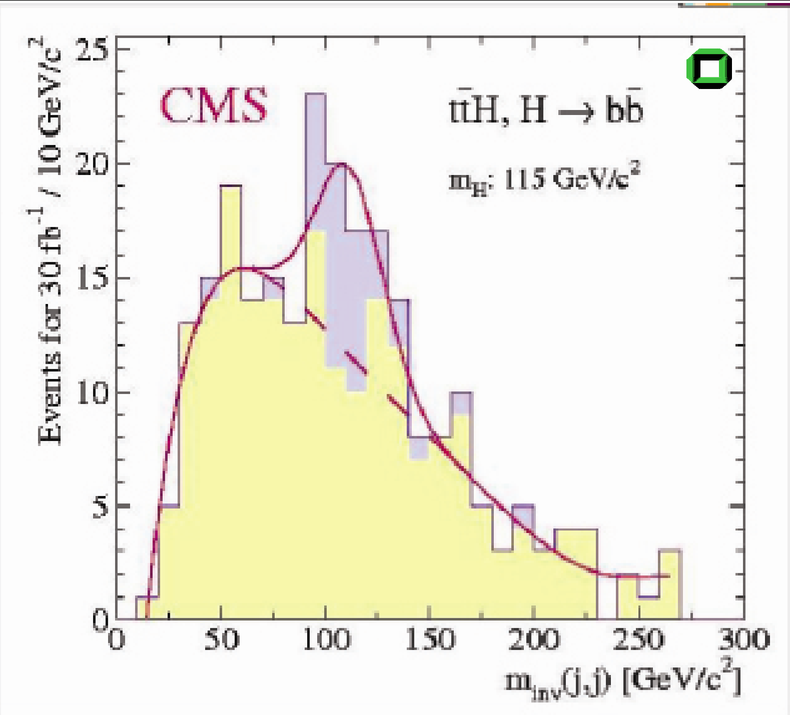
- **ttbb** irreducible background => almost same topology as the signal
- **ttjj** turned out to be the most dangerous background:
  - cross-section $O(10^4)$ higher than signal cross-section and c-mistagging rate.

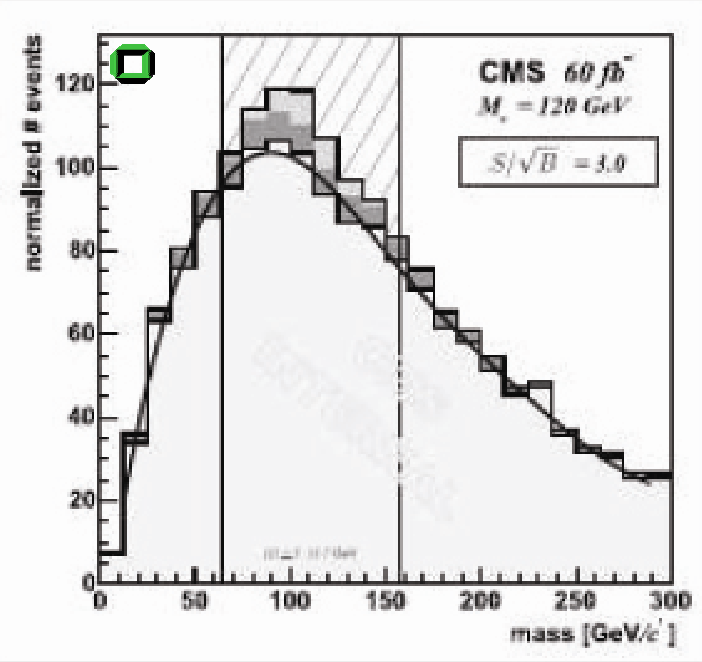
CMS Note 2001/054

Fast Simulation and very optimistic b-tag

S/sqrt(B)~3 @ 30 fb-1 and

mH = 115 GeV in the mass window





CMS Internal Note 2004/048

Fully Simulation and optimistic Btag in ttjj events

S/sqrt(B)~3 @ 60fb-1

and mH=120 GeV in the mass window

Next steps: Background simulations (Comphep/Pythia ->ALPGEN)

Jet-, Lepton-, MET- Reconstruction

Only method to determine Y_t !

CONCLUSIONS

So far, CDF, D0 have "seen" O(200) fully reconstructed $t\bar{t}$ pairs

- Strong production measured to O(10%) – now looking for higher order QCD effects
- Electroweak production not yet established: need more data!
- Decay SM; V-A O(20%)
- Properties SM – will reach limit in mass accuracy at < 1%
- The Top Quark opens the door to Physics at new scales; however: no evidence for non-standard effects so far
- LHC will be giant step forward; ultimate precision at ILC

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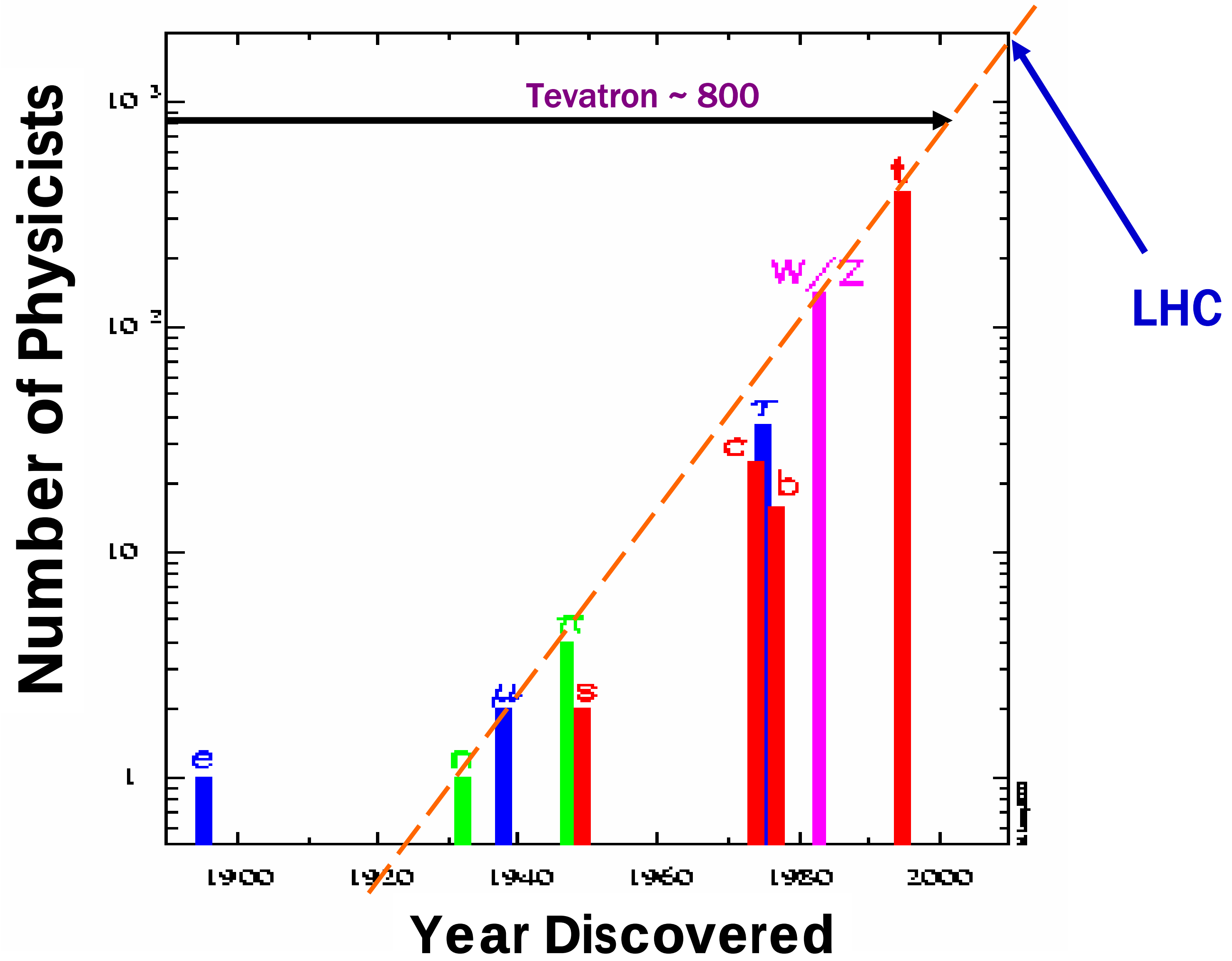
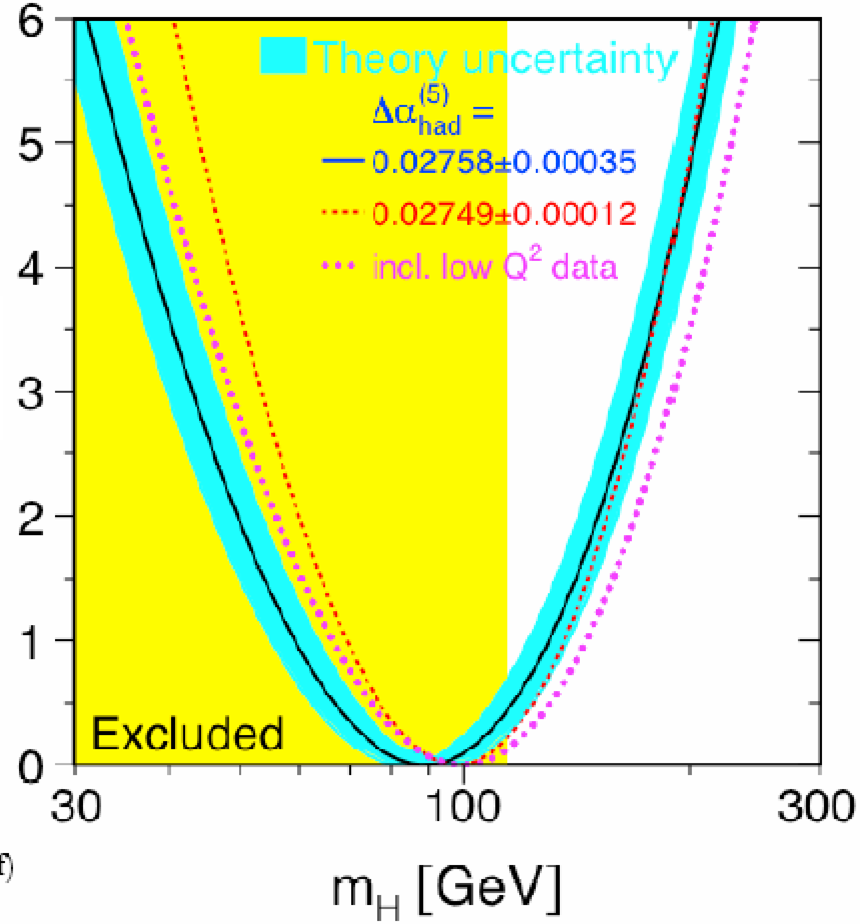
CDF / Wolfgang Wagner and the Karlsruhe Top group

Support by State of Baden-Württemberg, FZK, DFG, EU and BMBF

Number of Physicists for Particle Discovery

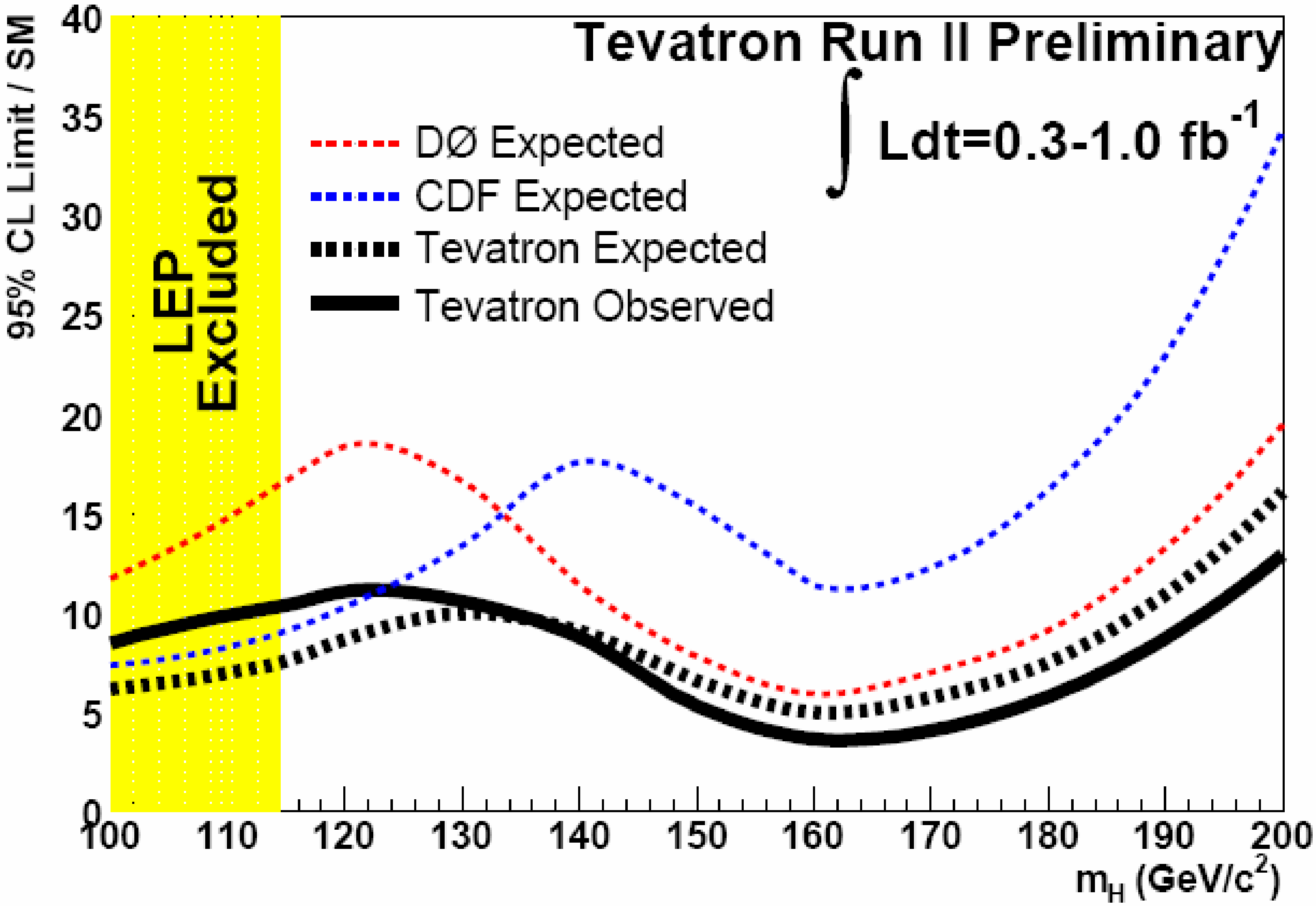


Higgs Impact



M_{higgs} = 89 ± 36 GeV/c²

M_{higgs} < 175 GeV/c² (95% conf)
(207 including LEP2)


Tevatron Run II Preliminary
∫Ldt=0.3-1.0 fb-1
DØ Expected
CDF Expected
Tevatron Expected
Tevatron Observed
LEP Excluded
95% CL Limit / SM
0
5
10
15
20
25
30
35
40
100
110
120
130
140
150
160
170
180
190
200
mH (GeV/c2)