Top Physics Overview (Experiment)


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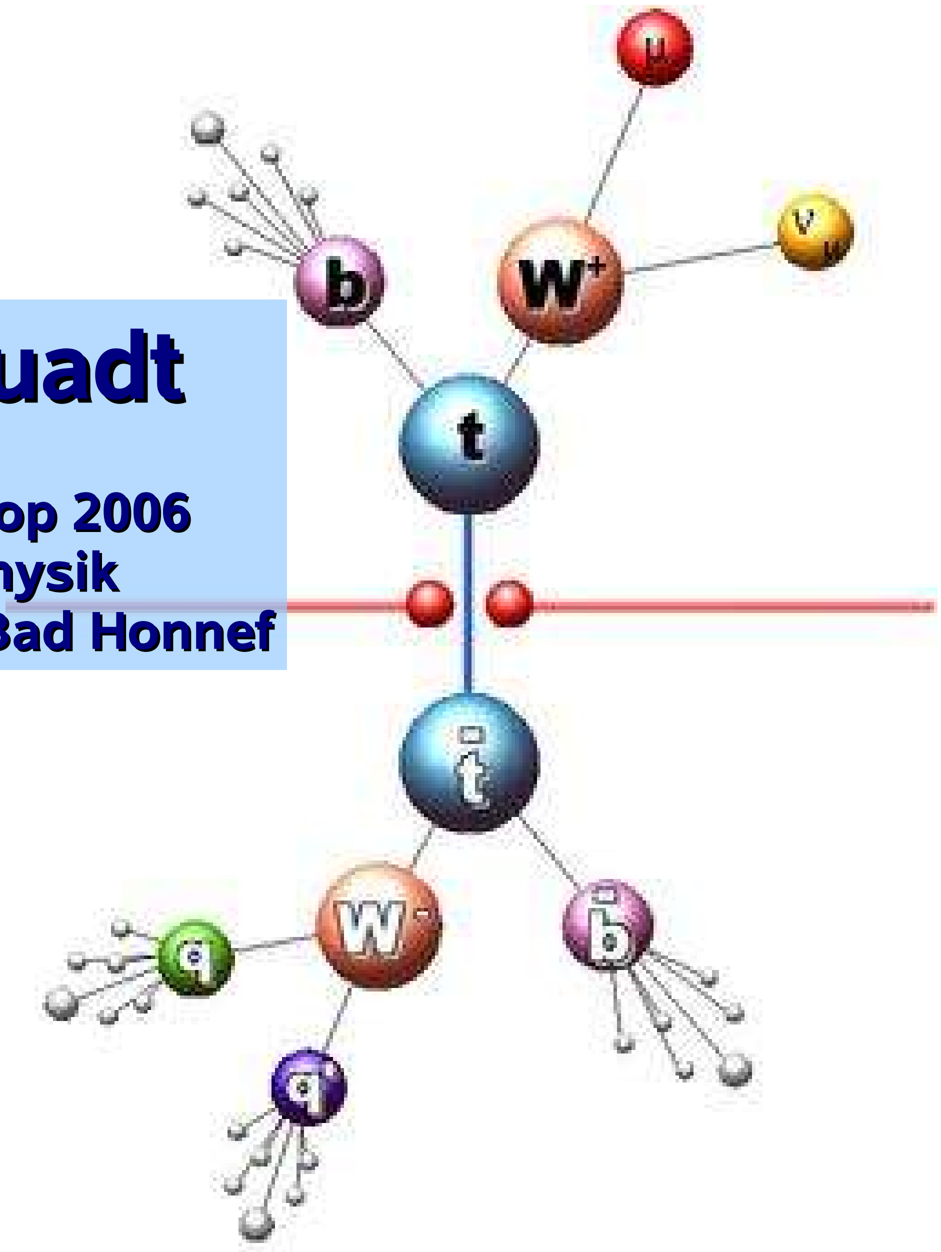
LHC-D Workshop 2006
Topquark Physik
3./4. March 2006, Bad Honnef



Outline

- Introduction

  ... Experiments & Theory ...

- Top Quark Production

  ... in Weak and Strong Interactions ...

- Top Quark Properties

  - Mass & Charge
  - Decay (Lifetime, W-helicity, spin-correlations)

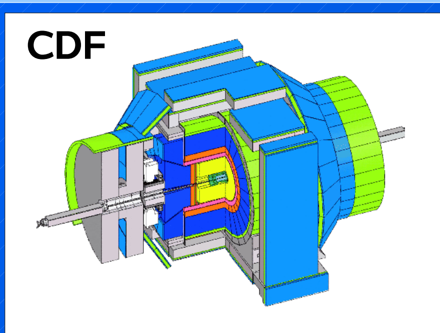
- Conclusion

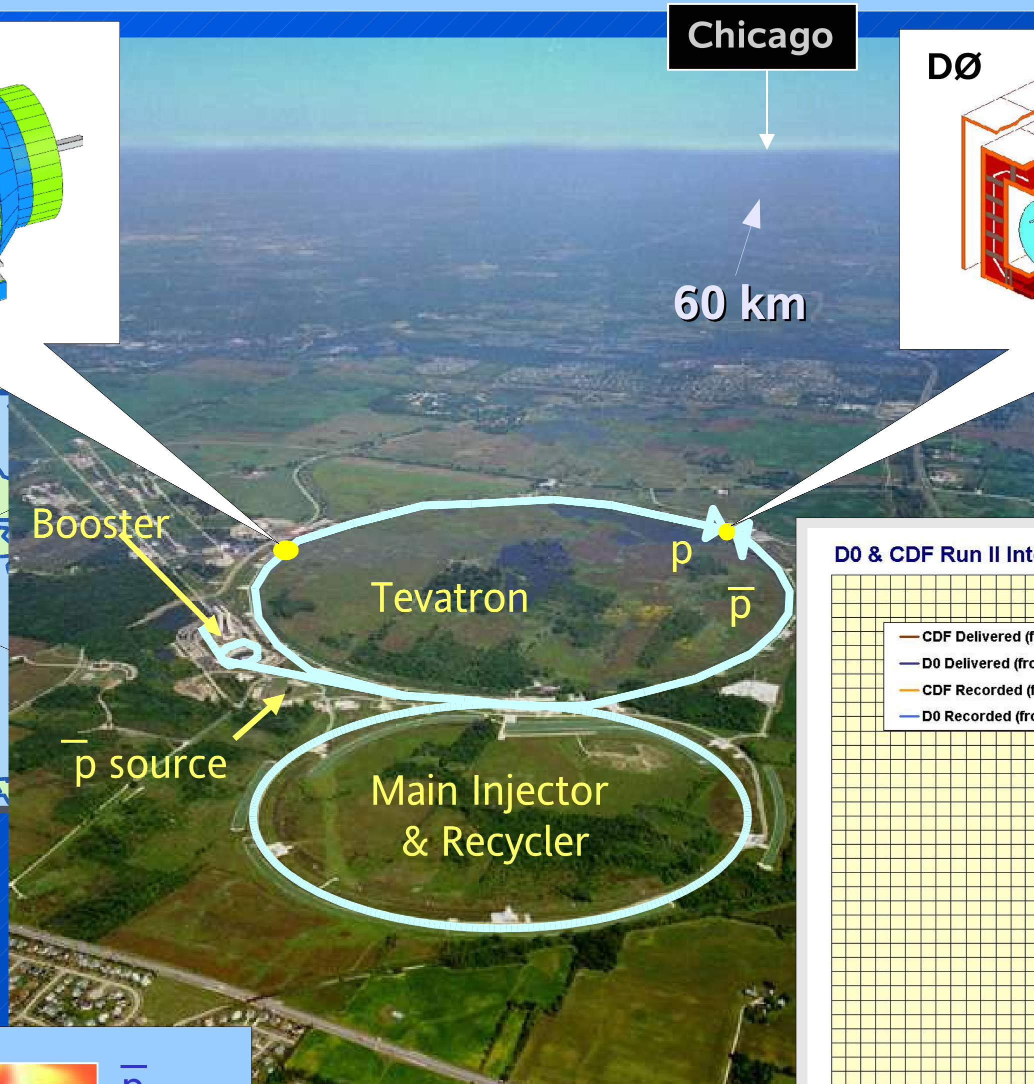
Here :
- overview
- some technical & physics details on selected topics

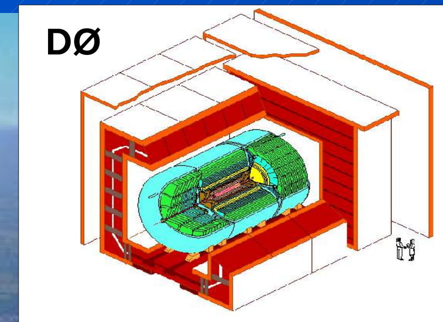
Introduction

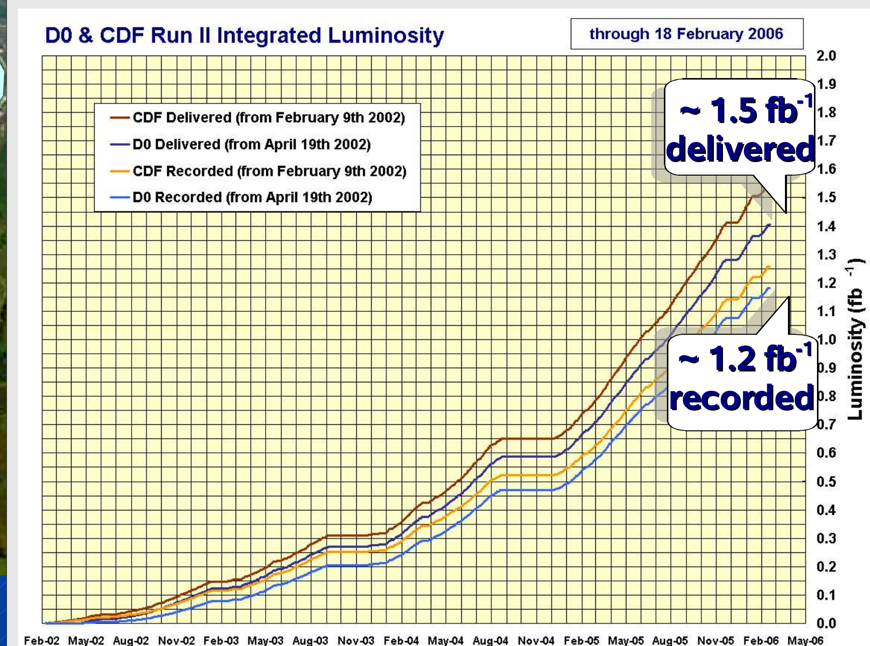
… Experiments …

The TEVATRON at Fermilab









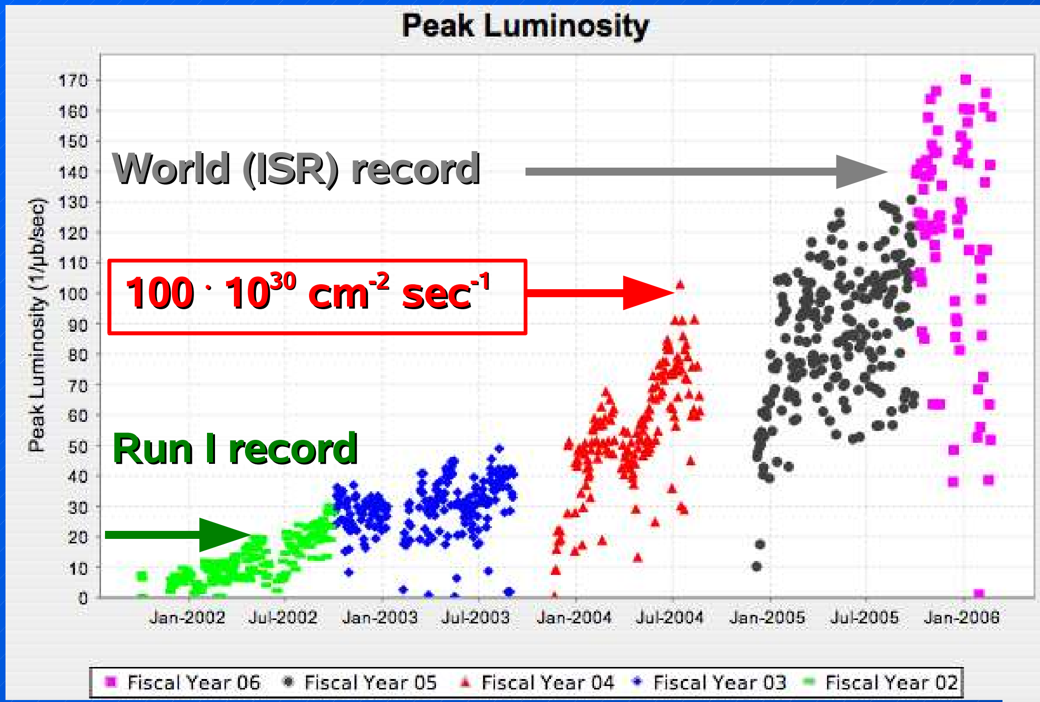
$\sqrt{s}$ =1.8 - 1.96 TeV, Δt = 396 ns

Run I 1987 (92)-95 L_{int} ~ 125 pb^{-1}

Run II 2001-09(?) 4-9 fb^{-1}

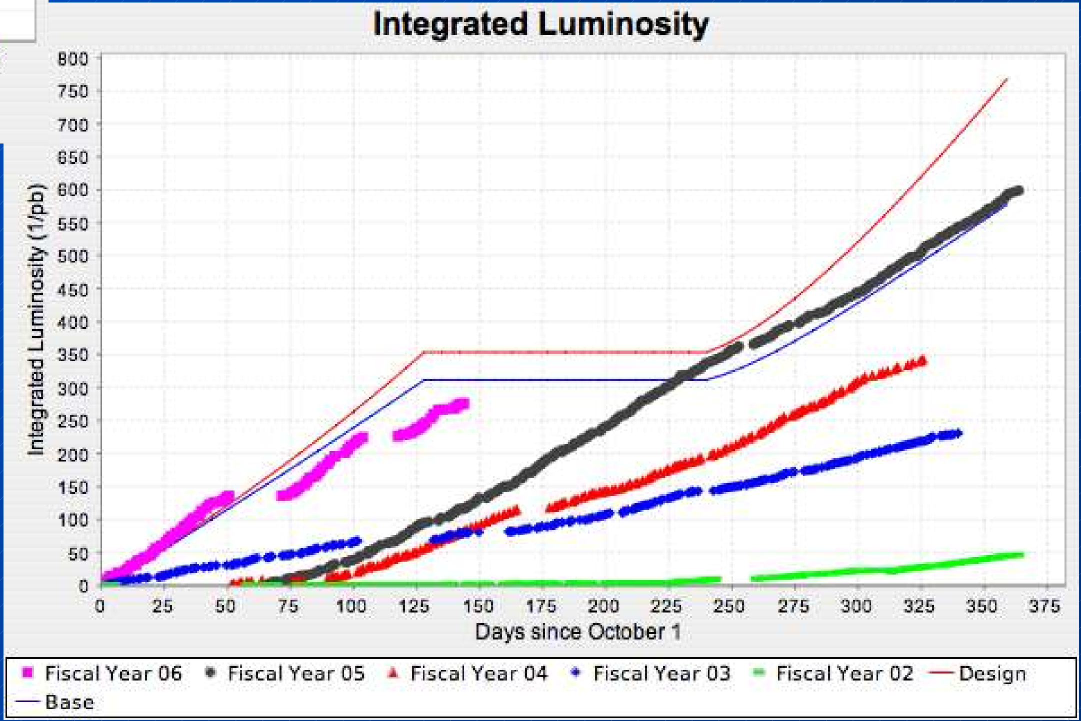
In spring 2002 passed Run-I lumi record
CDF & DØ data taking ε ~90%

The TEVATRON Performance

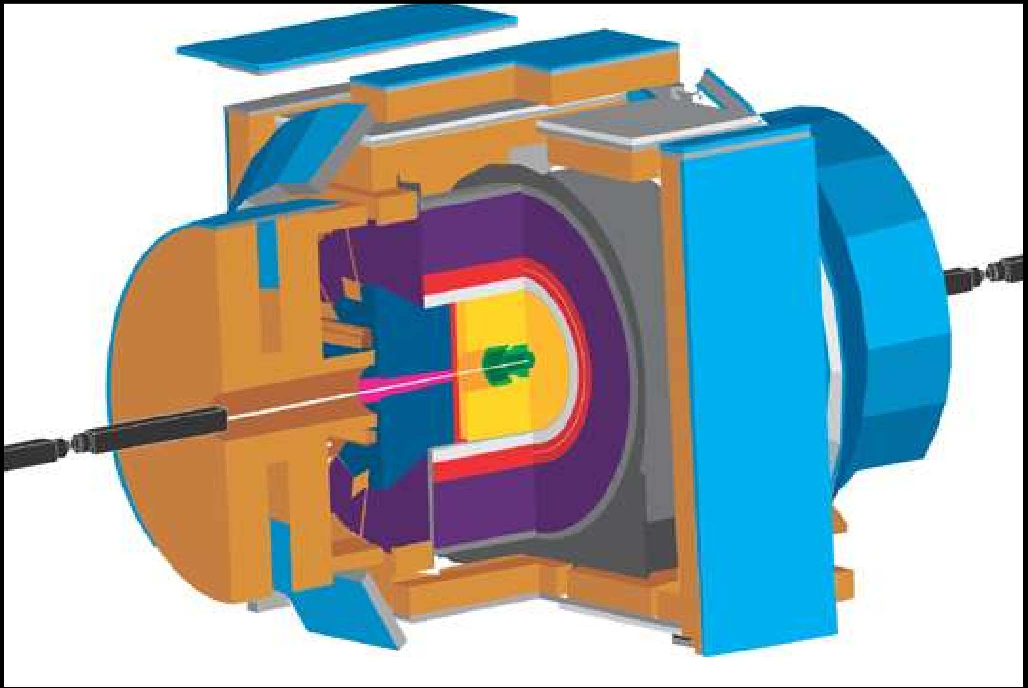


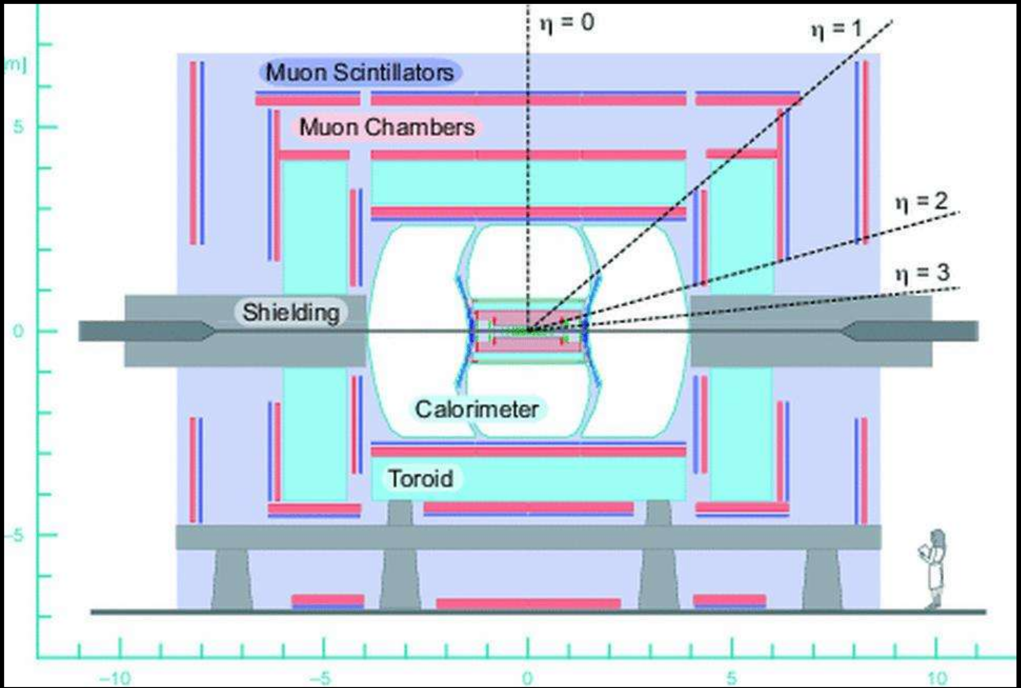
Peak luminosity:

- $1 \cdot 10^{12}$ P, twice the SPPS number !
- in spring 2002 passed Run I record
- in 2004-06 close to or above optimistic design scenario
- recycler and electron cooling in operation



The CDF and DØ Experiment





- new bigger silicon, new drift chamber, TOF
- Upgraded calorimeter and muon system
- Upgraded DAQ/trigger
- Displaced track trigger
- ~750 physicists

- new silicon and fibre tracker
- new ~2 T solenoid
- upgraded muon system
- upgraded (track) trigger/DAQ
- Roman pots
- 19 countries, 83 institutes, 664 physicists

resolutions:

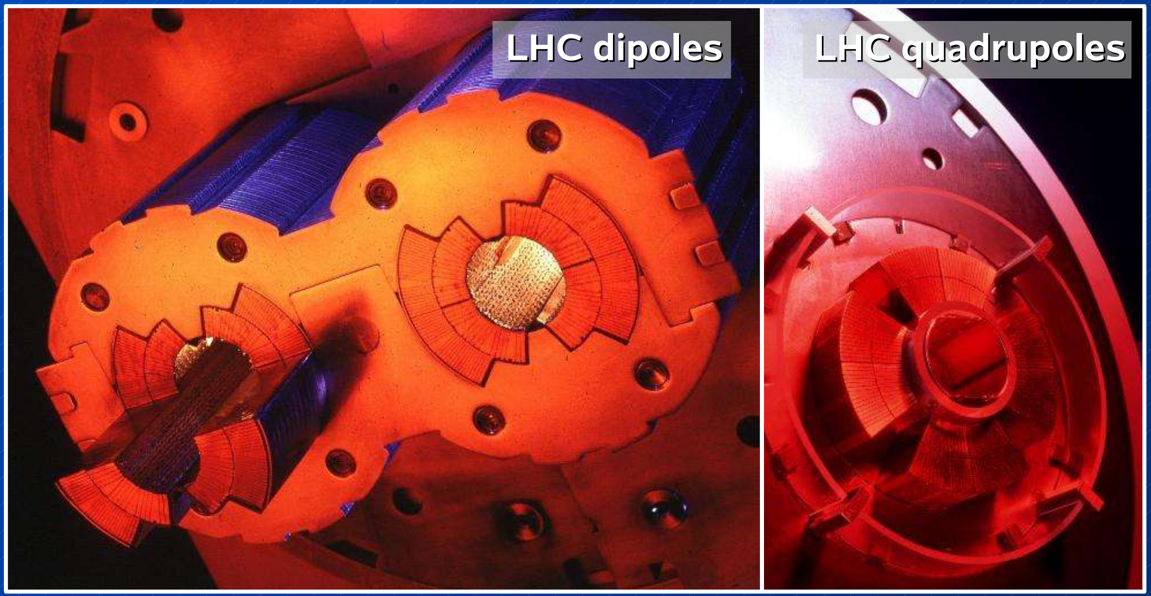
EM: σ_E/E = 13.5 - 15% / sqrt(E)

HAD: σ_E/E = 50 – 80 % / sqrt(E)

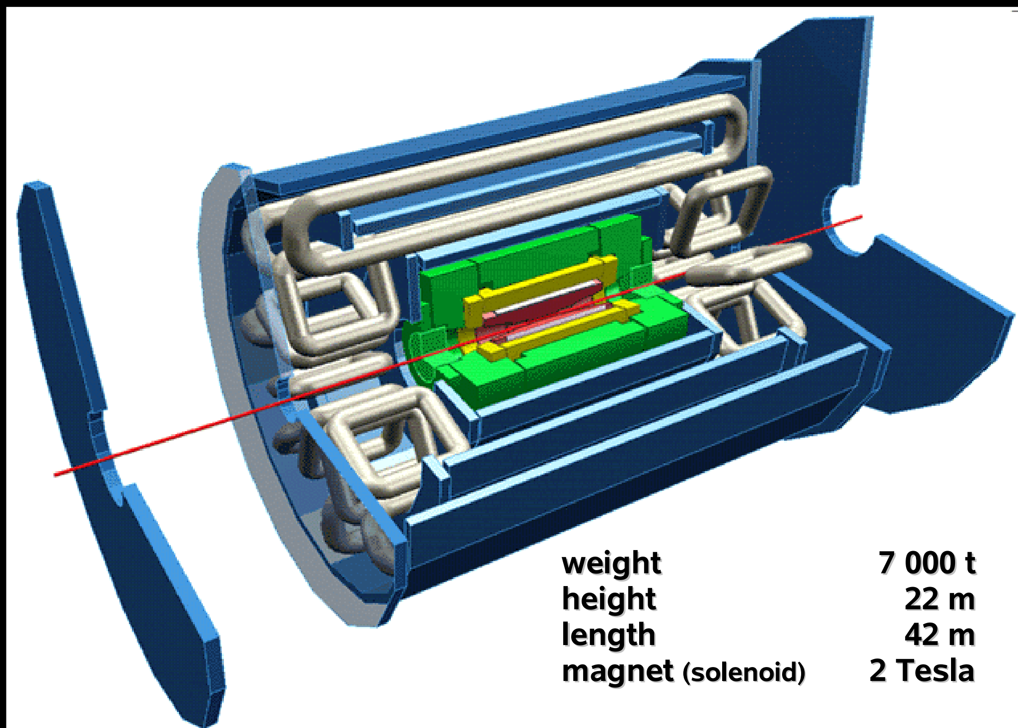
The Large Hadron Collider - LHC

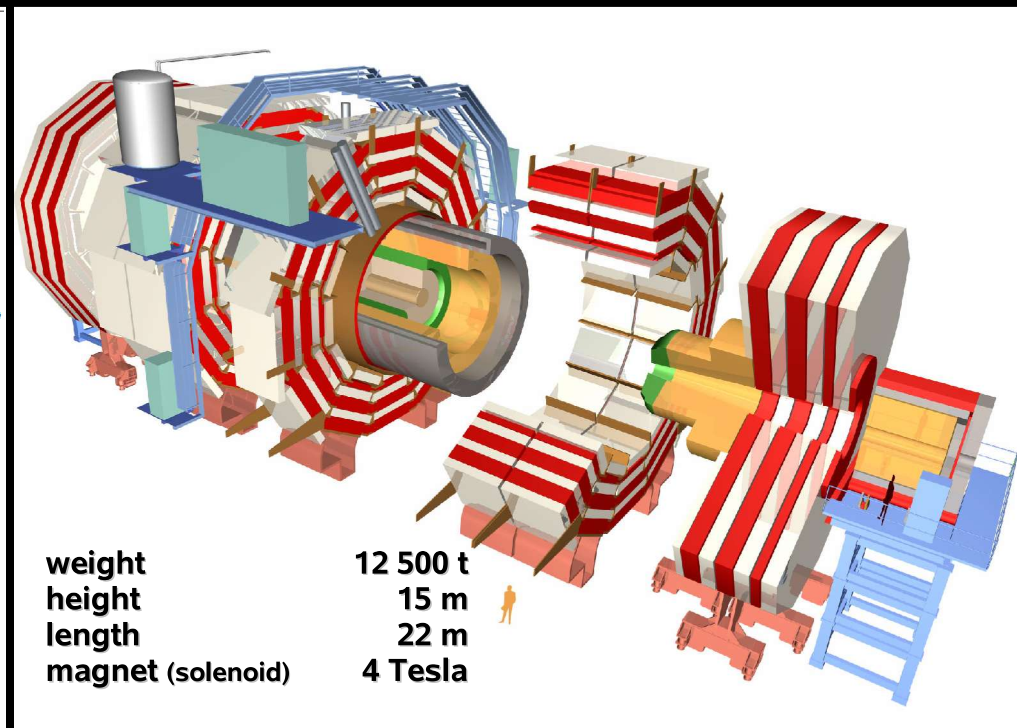
<u>The **L**arge **H**adron **C**ollider:</u>

- proton-proton collider (no $p\bar{p}$)
  ⇨ 2 separate beampipes
- 10 fb^{-1} per year
- high energy: $\sqrt{s}$ = 14 TeV
- 40 Mio. collisions per second
- first collisions in 2007
- 4 experiments:
  ATLAS, CMS, ALICE, LHC-B



The ATLAS and CMS Experiment





- Precise tracking and vertexing
  silicon pixel and strip detectors & transition radiation det.
  2 & 4 T solenoid and toroid magnets (air core or iron core)
- EM & Had Calorimeters and muon systems
- Fast DAQ/trigger
- > 2 000 physicists each

resolutions:

EM: $\sigma_E/E = 0.5 - 10\% / \mathrm{sqrt}(E)$

HAD: $\sigma_E/E = 50 – 70\ \% / \mathrm{sqrt}(E)$

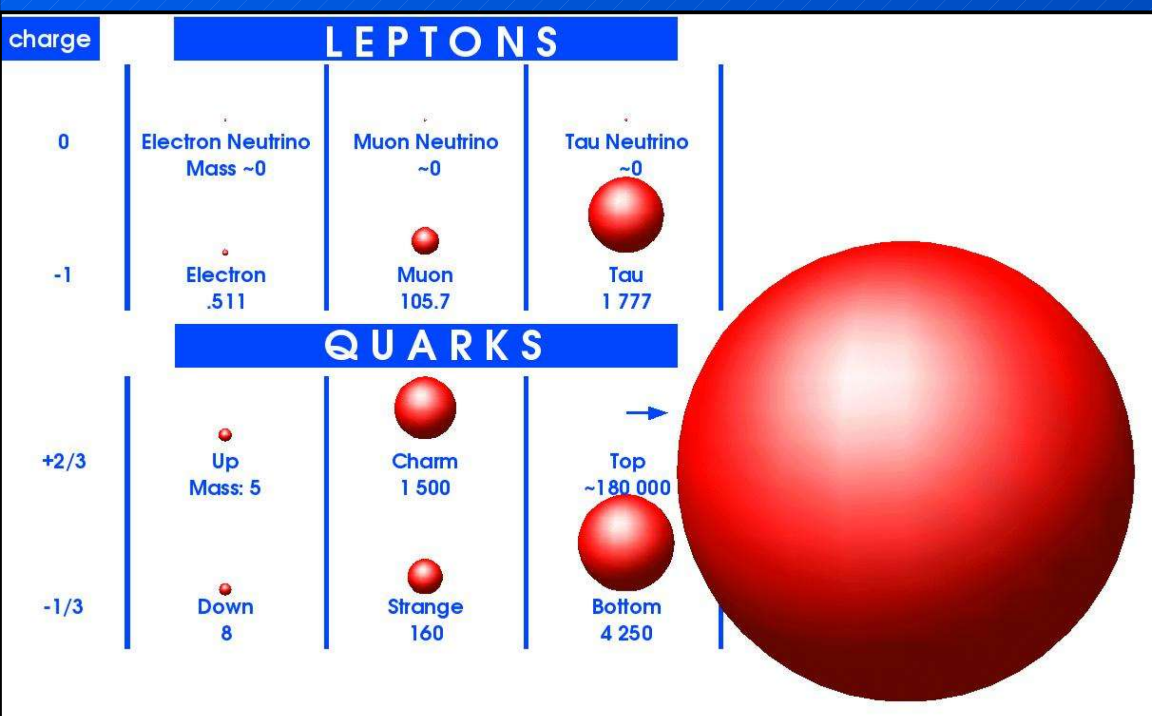
Introduction

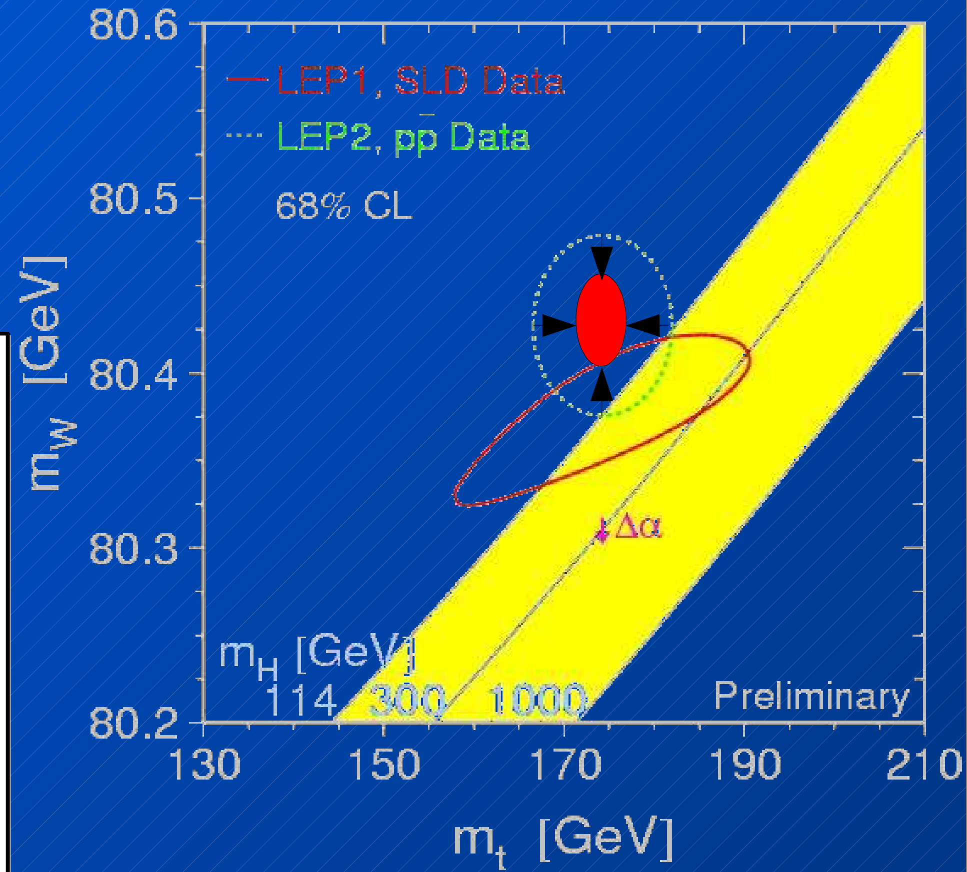
… Theory …

Top Quark in the Standardmodel

Why is the Top Quark so interesting ?

- completes the quark sector
- large mass $m_{top} \sim 180\ \text{GeV} / c^2$
- short lifetime $\tau \sim 5 \cdot 10^{-25}\text{s} \ll \Lambda^{-1}_{QCD}$
- sensitive to physics beyond the Standard Model





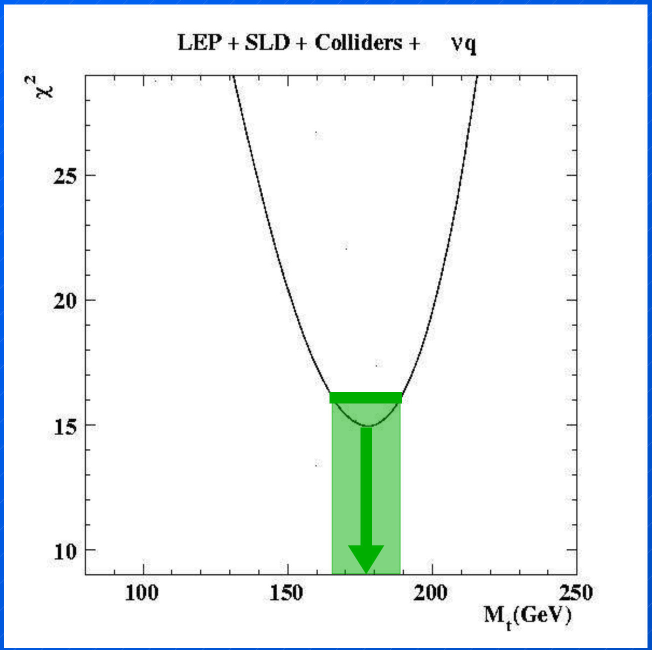
Only `recent' discovery ⇨

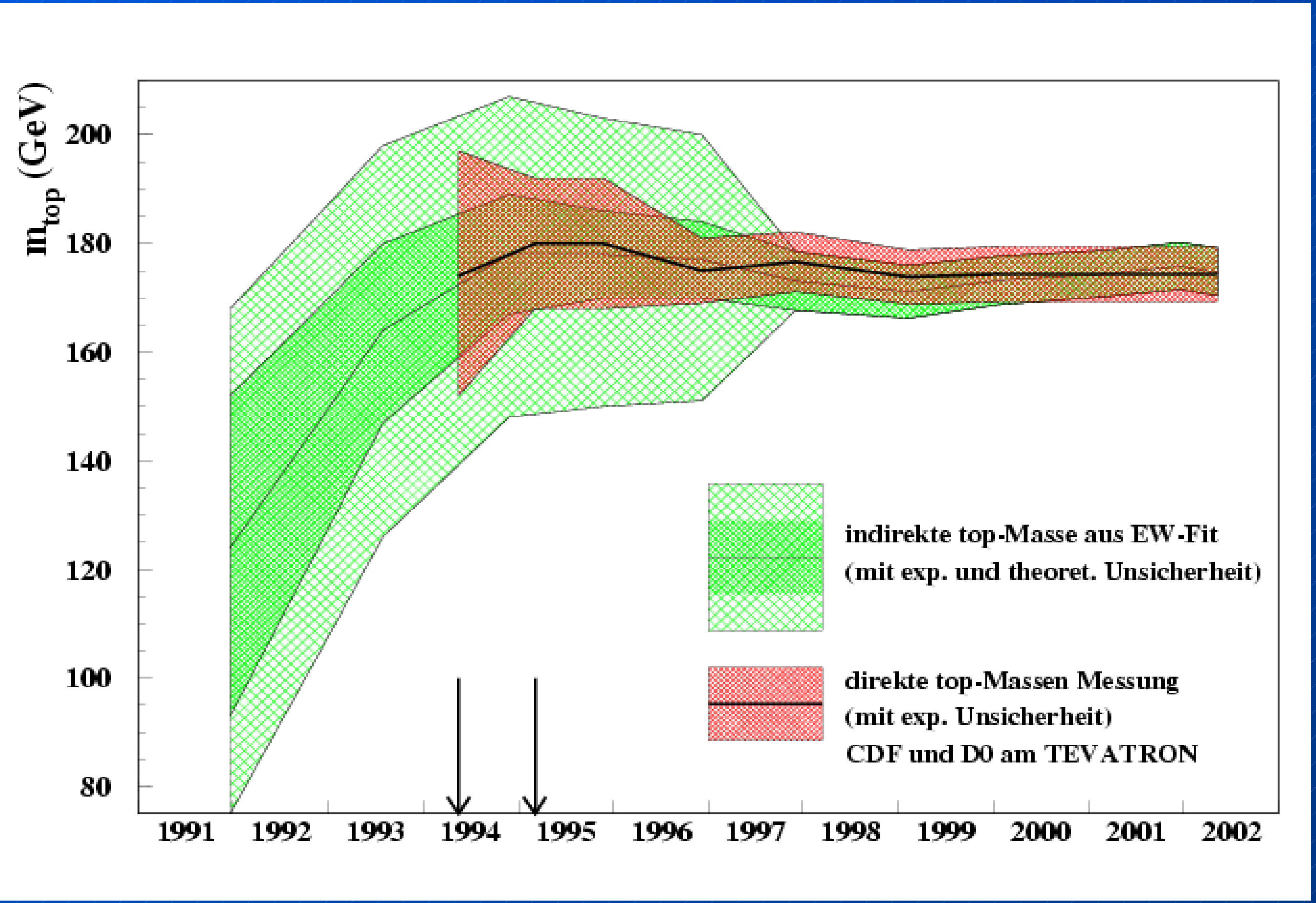
- charge unmeasured
- reasonable mass measurements
- study weak and strong top physics

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

$m_t \sim v/\sqrt{2}$, Yukawa coupling $\lambda_t \sim 1$

Discovery of the Top Quark





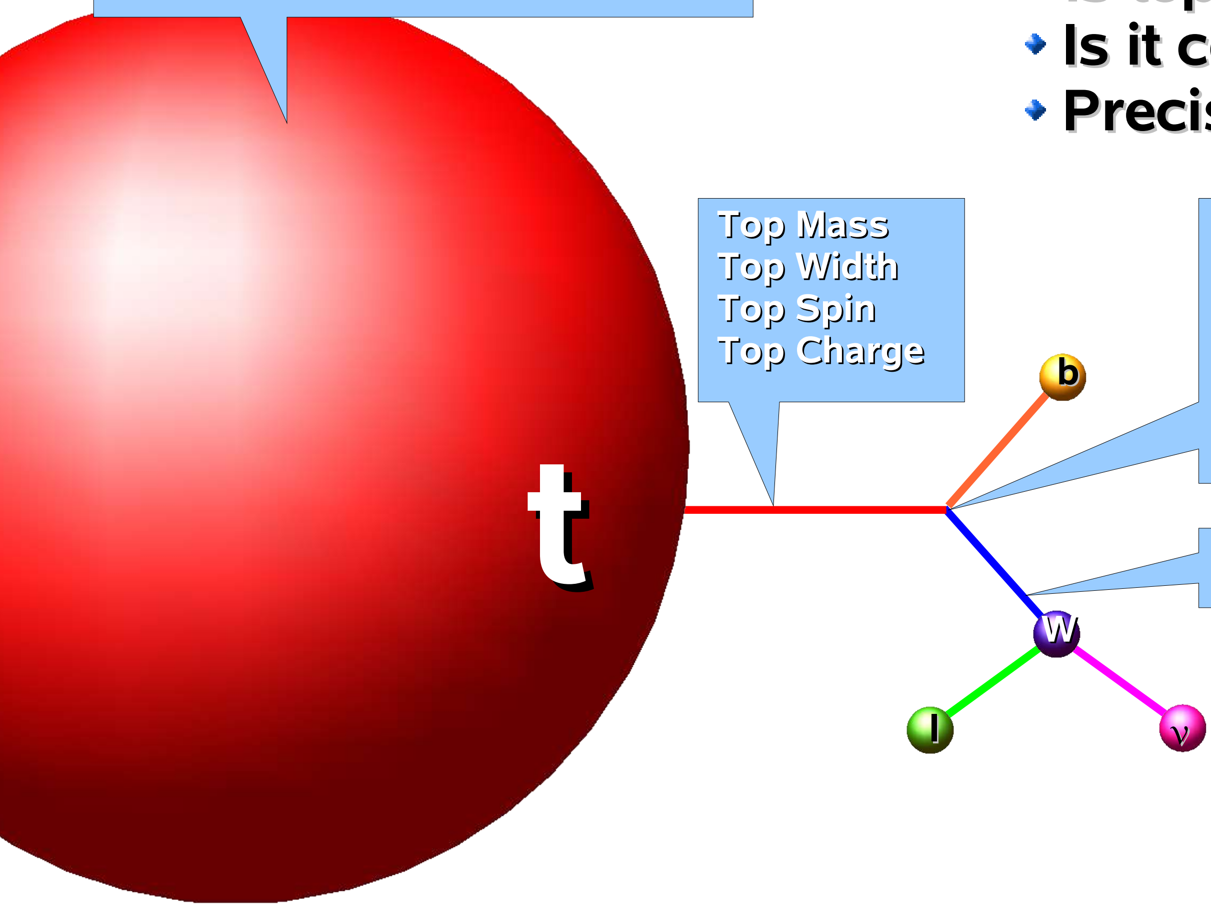
... discovered the top in 1995 by CDF & D0
exactly where it was expected ...

Top Quark Physics

Tevatron Run I : top quark discovery (1995) **Run II &LHC :** with high precision answer ...

- Why is top so heavy ?
- Is top/third generation special ?
- Is top involved in EWSB ?
- Is it connected to new physics ?
- Precision measurement of couplings

tt Production Cross-Section
tt Production via interm. Resonances
Production Kinematics
Spin Polarization



Top Mass
Top Width
Top Spin
Top Charge

Anomalous Couplings
CP Violation
Rare/non-SM Decays
Branching Ratios
$|V_{tb}|$

$$\frac{-i\,g}{2\sqrt{2}}\,\bar{t}\,\gamma^{\mu}\left(1-\gamma^{5}\right)V_{tb}\,b\,W_{\mu}$$

$g \simeq 0.67$
$V_{tb} \simeq 1$
$m_{top} > m_W\ (phase\ space)$

W helicity

Decay Topology in $t\bar{t}$

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

Top-Antitop Signatures:

`dilepton channel'

5% : 2 jets, 2 charged leptons, 2 ν

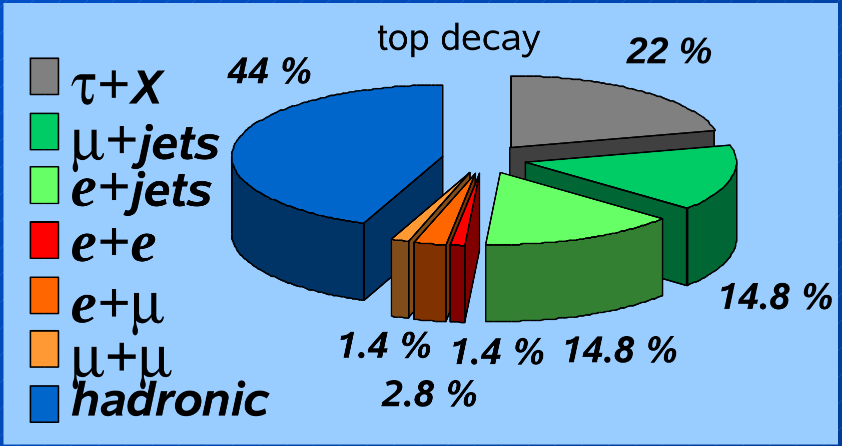
'lepton+jets channel'

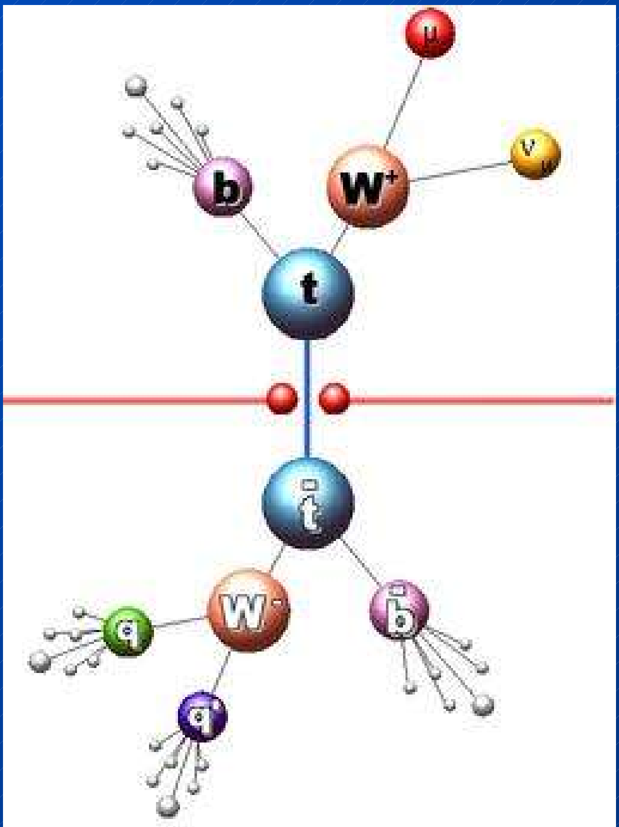
30%: 4 jets, 1 charged lepton, 1 ν

'all-jets channel'

40%: 6 jets

always 2 jets are b-jets

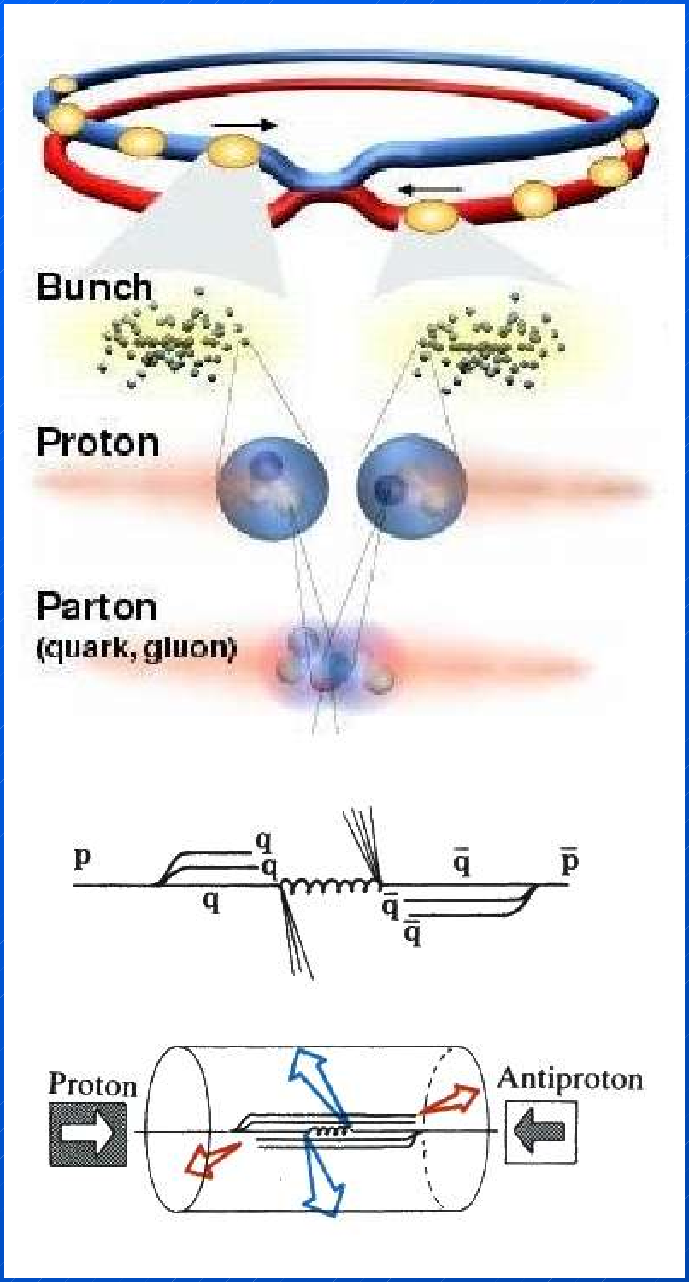




Top Quark Production

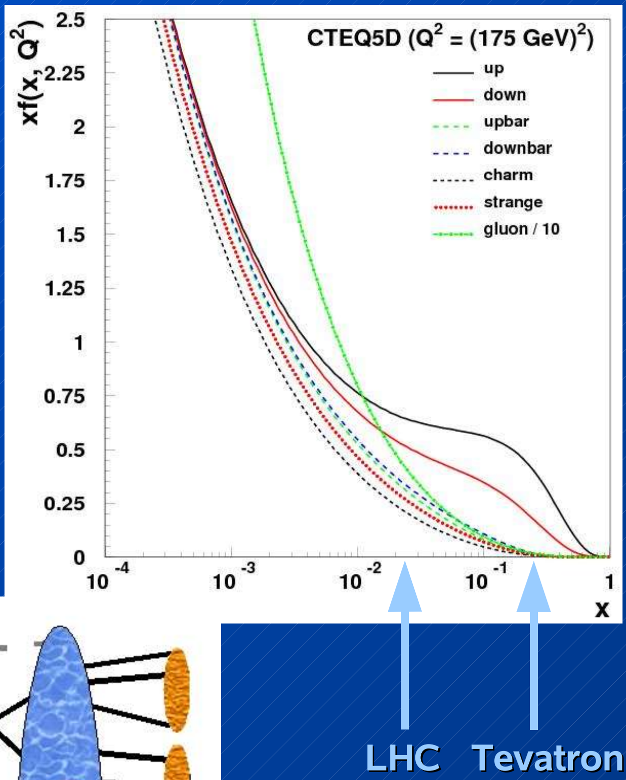
in Strong Interactions

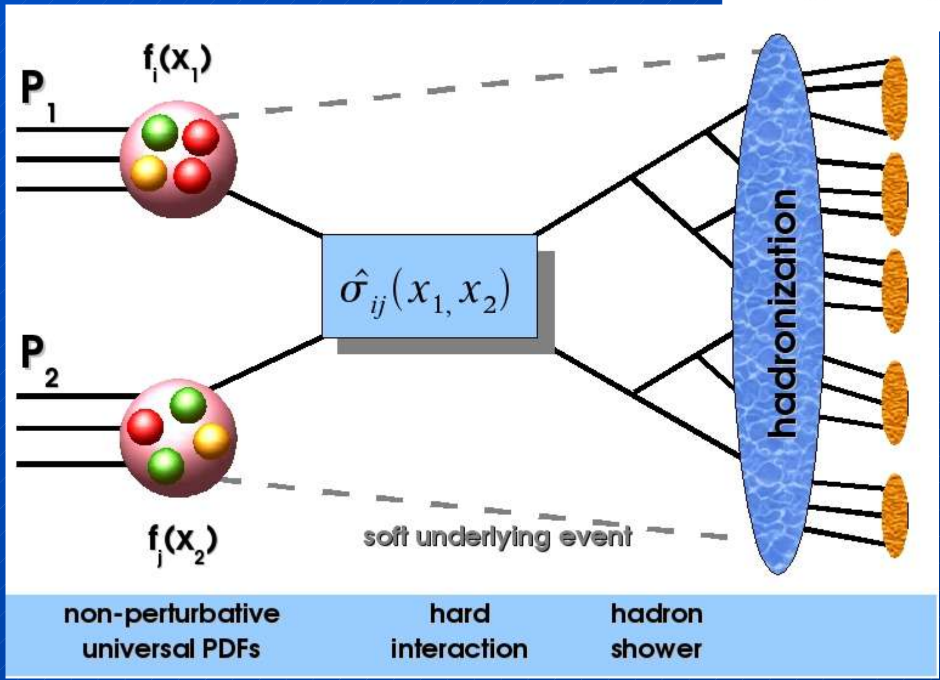
Parton-Parton Interactions



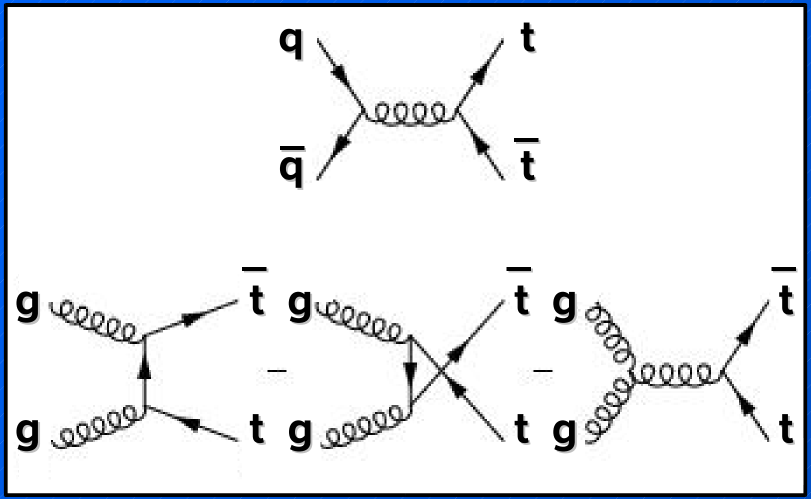
proton has substructure
(structure function $F_2(x,Q^2)$)

- ⇨ **quark momentum distribution**



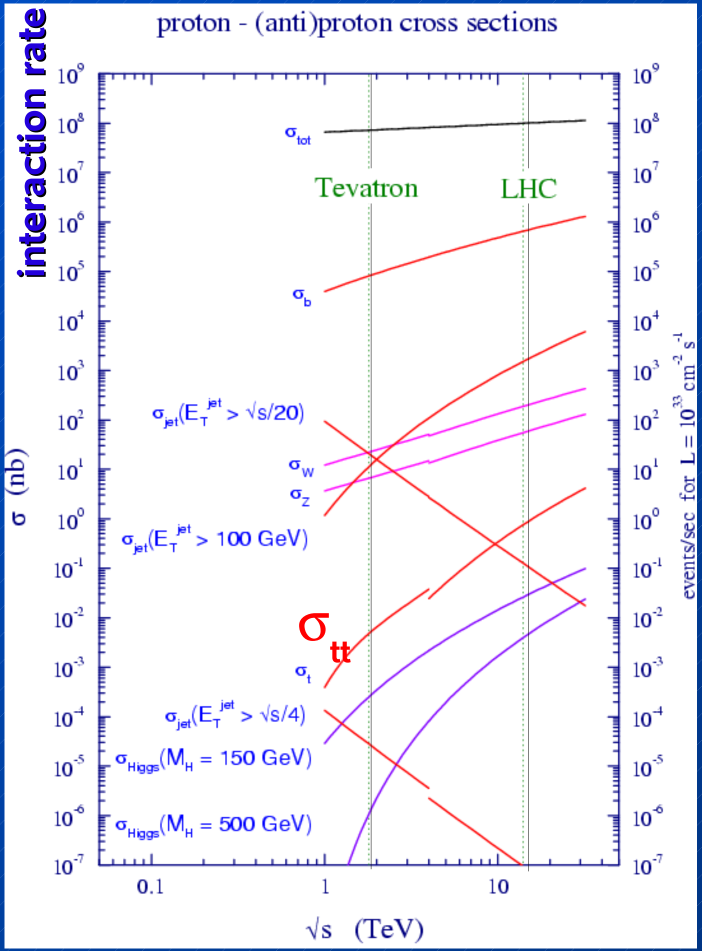


Strong Top Quark Production



	Tevatron	LHC
$q\bar{q}$	~ 85 %	15%
gg	~ 15 %	85%

	Run I	Run II (2 fb^{-1})	LHC (10 fb^{-1})
no ttbar (m_t sample ≥1 b-tag)	20	800	8 * 10^6



- establish top signal
- measure cross section as QCD test
- cross section and topology close to Higgs physics

Ttbar Xsec Measurements at Tevatron

dilepton	Topological selection (lepton pT, MET, Njets)	⇨ counting experiment
	b-tag selection (lepton pT, MET, SVX-tag, Njets)	⇨ counting experiment
	lepton+track (lepton pT, MET, isolated track, Njets)	⇨ counting experiment
	dilepton 2-dim. (MET,Njet) fit for ttbar, WW, $Z\rightarrow\tau\tau$	⇨ 2-dim. fit
l+jets	Topological selection (e/mu+jets, lepton pT, MET, Njets), topological & kinematic variables, 1-dim. fit	⇨ 1-dim. fit
	b-tag selection (e/mu+jets, lepton pT, MET, Njets), b-tag (SVX, IP, jet-prob., soft-mu)	⇨ counting experiment
	kinematic fit (MET or jet ET) in b-tagged events	⇨ 1-dim. fit
	combined fit of 0, 1, 2-tag sample and Br(t->Wb)/B(t->Wq)	⇨ 2-dim. fit
alljets	Kinematic & topological selection, Njet distribution	⇨ 1-dim. fit
	Kinematic & topological selection, ANN-output	⇨ counting experiment

Dilepton, CDF Xsec (I)

$197\ pb^{-1}$

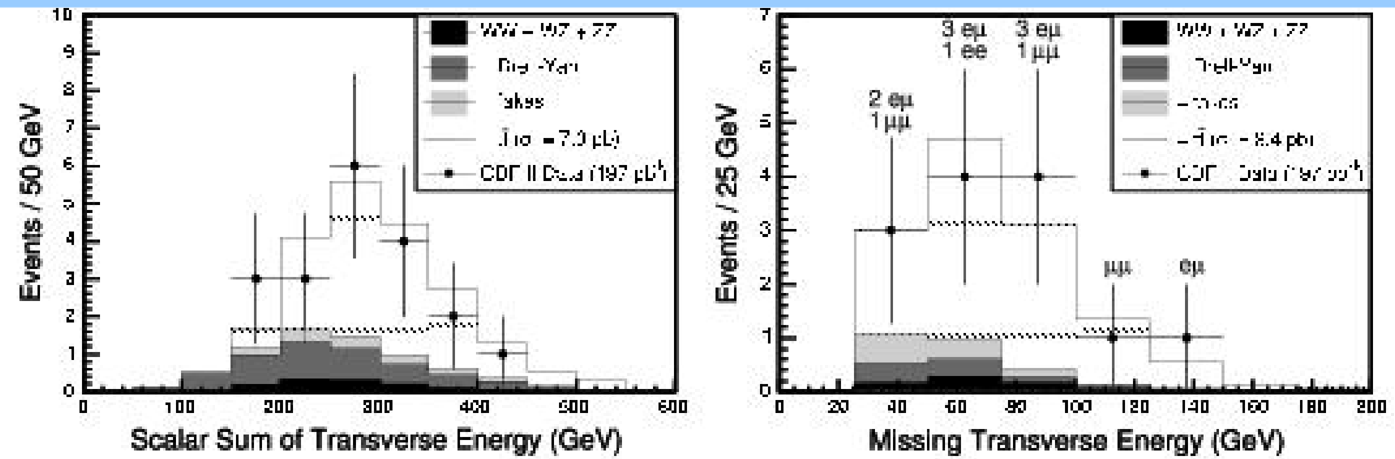


Figure 4.1: Left: H_T distribution for events from the LTRK analysis with ≥ 2 jets. Right: $\not{E}_T$ for events from the DIL analysis with $H_T > 200$ GeV and ≥ 2 jets.

	LTRK			DIL			
	$N_{jet} = 0$	$N_{jet} = 1$	$N_{jet} \geq 2$	$N_{jet} = 0$	$N_{jet} = 1$	$N_{jet} \geq 2$	$H_T >$ 200 GeV
Diboson	21.8 ± 5.2	6.3 ± 1.5	1.2 ± 0.3	11.4 ± 3.3	3.2 ± 0.9	1.1 ± 0.3	0.7 ± 0.2
Drell-Yan	26.5 ± 9.8	16.4 ± 6.0	4.2 ± 1.6	4.4 ± 1.9	2.9 ± 1.1	1.3 ± 0.5	0.9 ± 0.5
Fakes	16.5 ± 2.4	5.0 ± 1.0	1.5 ± 0.5	3.0 ± 1.2	2.4 ± 1.0	1.5 ± 0.6	1.1 ± 0.5
Total Bgd	64.8 ± 11.3	27.7 ± 6.3	6.9 ± 1.7	18.8 ± 4.0	8.5 ± 1.8	3.9 ± 0.9	2.7 ± 0.7
Expected $t\bar{t}$	0.3 ± 0.2	3.4 ± 0.6	11.5 ± 1.5	0.1 ± 0.0	1.3 ± 0.2	8.5 ± 1.2	8.2 ± 1.1
Total	65.1 ± 11.3	31.1 ± 6.3	18.4 ± 2.3	18.9 ± 4.0	9.8 ± 1.9	12.4 ± 1.6	10.9 ± 1.4
Observed	73	26	19	16	9	14	13

Signal-to-background vs. acceptance

Dilepton, CDF Xsec (II)

Signal and background uncertainties	LTRK	DIL
Lepton (track) ID	5% (6%)	5%
Jet energy scale - signal	6%	5%
Jet energy scale - background	10%	18-29%
Initial/final state radiation	7%	2%
Parton distribution functions	6%	6%
Monte Carlo generators	5%	6%
WW, WZ, ZZ diboson estimate	20%	20%
Drell-Yan estimate	30%	51%
Fake estimate	12%	41%

Table 4.2: Summary of systematic uncertainties.

LTRK:
more background
but tighter track pT cut
tighter MET cut in Z-mass window
⇨ less background error from JES

$$LTRK: \sigma_{tt} = 7.0^{+2.7}_{-2.3}(stat.)^{+1.5}_{-1.3}(syst.) \pm 0.4(lumi)\ pb$$

$$DIL: \sigma_{tt} = 8.4^{+3.2}_{-2.7}(stat.)^{+1.5}_{-1.1}(syst.) \pm 0.5(lumi)\ pb$$

Large (physics) background
⇨ theory input dominates uncertainty

Dilepton, CDF Xsec (III)

184 pb^{-1}

Softer cuts
form 2-dim. Templates (Njets, MET)
fit relative fractions of
ttbar, WW, Z→ττ, background to data

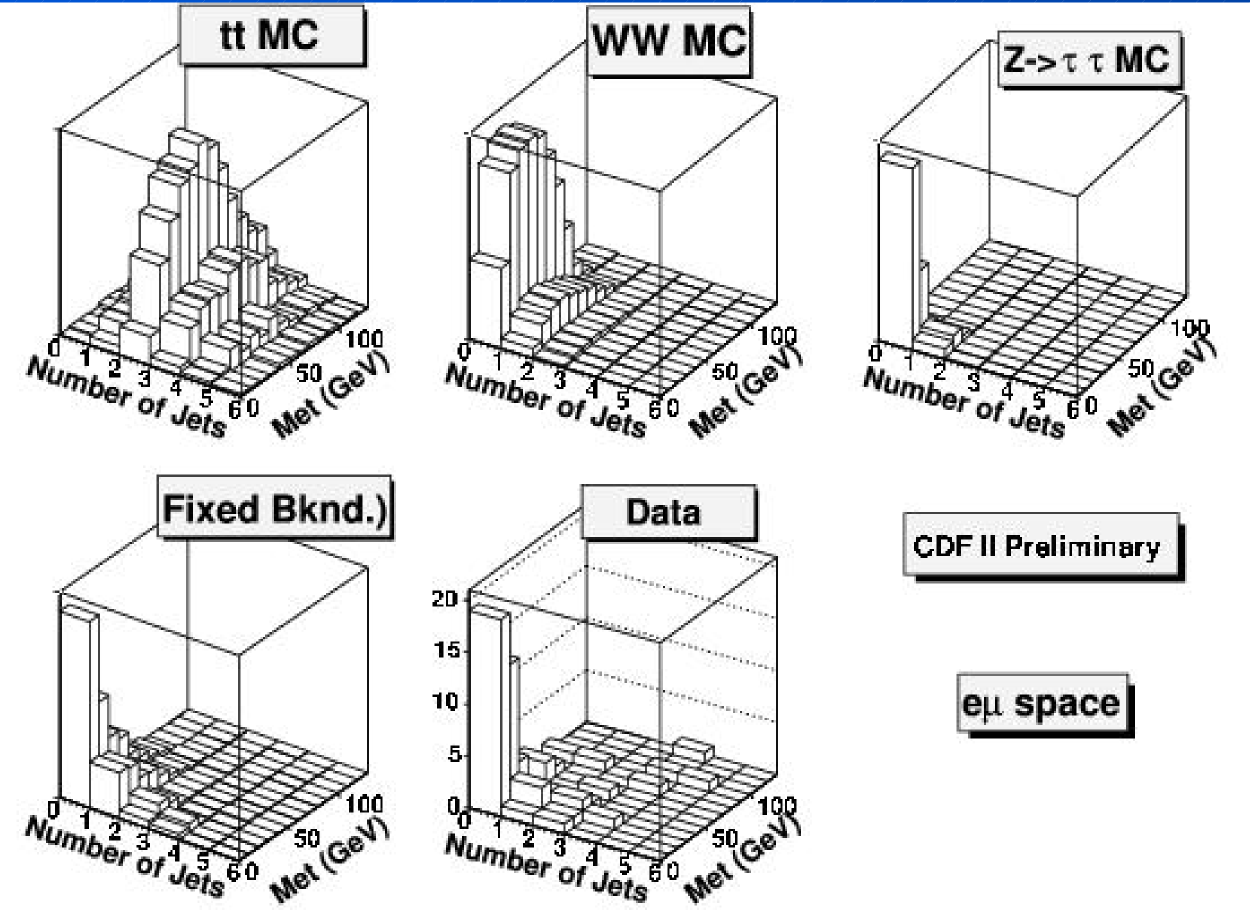


Figure 4.2: The 2-dimensional distributions of the Standard Model "signal" sources, "background" sources (summed together) and from 184 pb^{-1} of data in the $\not{E}_T$-N_{jet} plane for the example of the $e\mu$ channel.

Dilepton, CDF Xsec (III)

	$t\bar{t}$	WW	$Z \to \tau\tau$
Trigger efficiency	1%	1%	1%
lepton ID	2%	2%	2%
Track isolation	4%	4%	4%
$\not{E}_T^{sig}$ (ee and $\mu\mu$ only)	3%	3%	-
Generator syst.	3%	4%	2%
Total	6.2%	2.8%	5.0%
luminosity	6%		

Table 4.4: Summary of systematic uncertainties on the acceptance for each "signal" process.

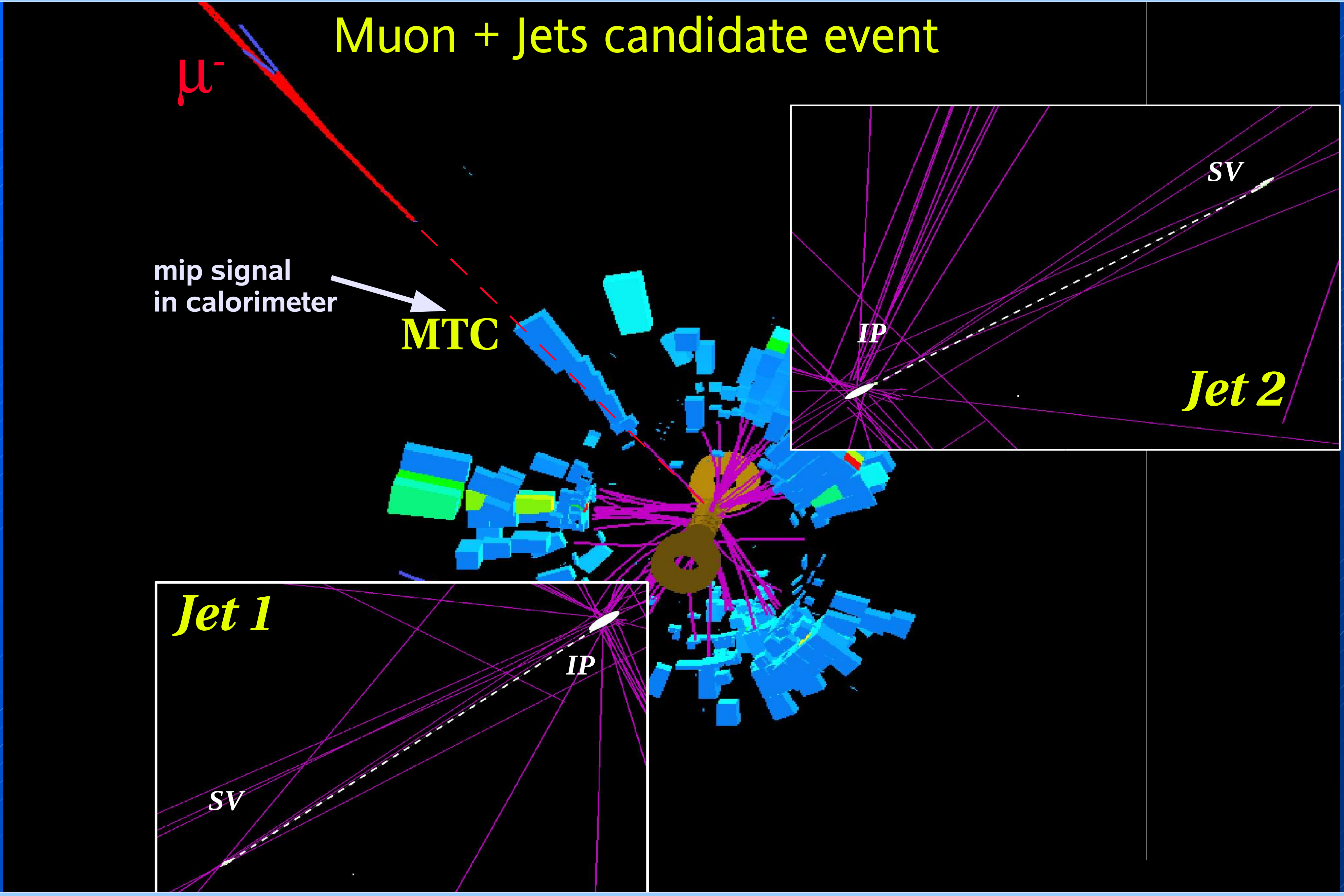
- Acceptance errors dominated by experimental effects

		$t\bar{t}$	WW	$Z \to \tau\tau$
Jet Energy Scale & $\not{E}_T$	$e\mu$	13%	7.5%	3.5%
	$ee + \mu\mu$	12%	13%	-
Jet Multiplicity	$e\mu$	8%	2%	3%
	$ee + \mu\mu$	9%	8%	-
Generator	$e\mu$	5%	2%	4%
	$ee + \mu\mu$	5%	3%	-
PDF's	$e\mu$	1%	1%	1%
	$ee + \mu\mu$	1%	1%	-
Total	$e\mu$	16%	8%	6%
	$ee + \mu\mu$	16%	15%	-

Table 4.5: Summary of systematic uncertainties on the fitted cross sections from the $\not{E}_T$-N_{jet} shapes.

- Shape information dominates systematic uncertainty
- here energy scale on ET and MET dominate

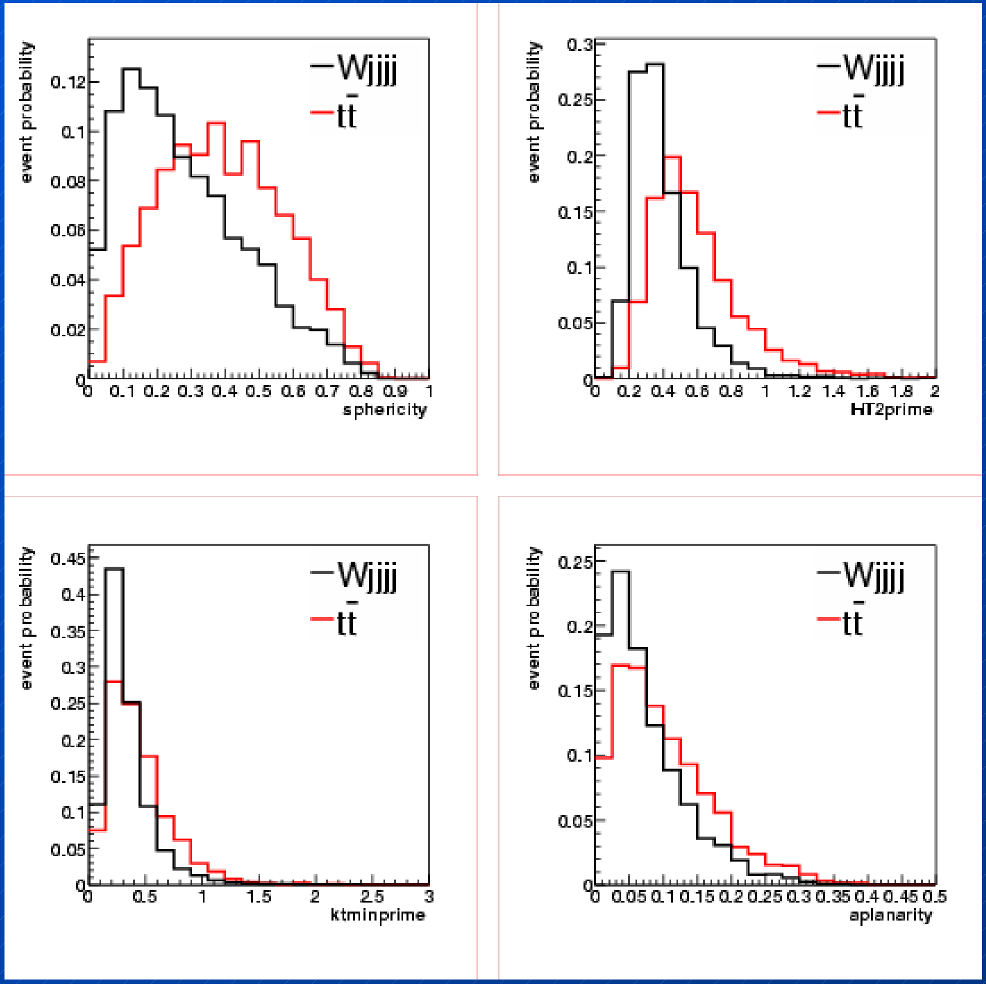
A Typical μ+Jets Candidate Event



L+Jets, DØ Topological Xsec (I)

230 pb^{-1}

choose topological variables:
- with **strong separation** potential
- with **small sensitivity to jet energy scale**



use the following variables:

angular dependent:
- sphericity
- aplanarity
- centrality

energy-dependent quantities:
- HT
- Ktmin

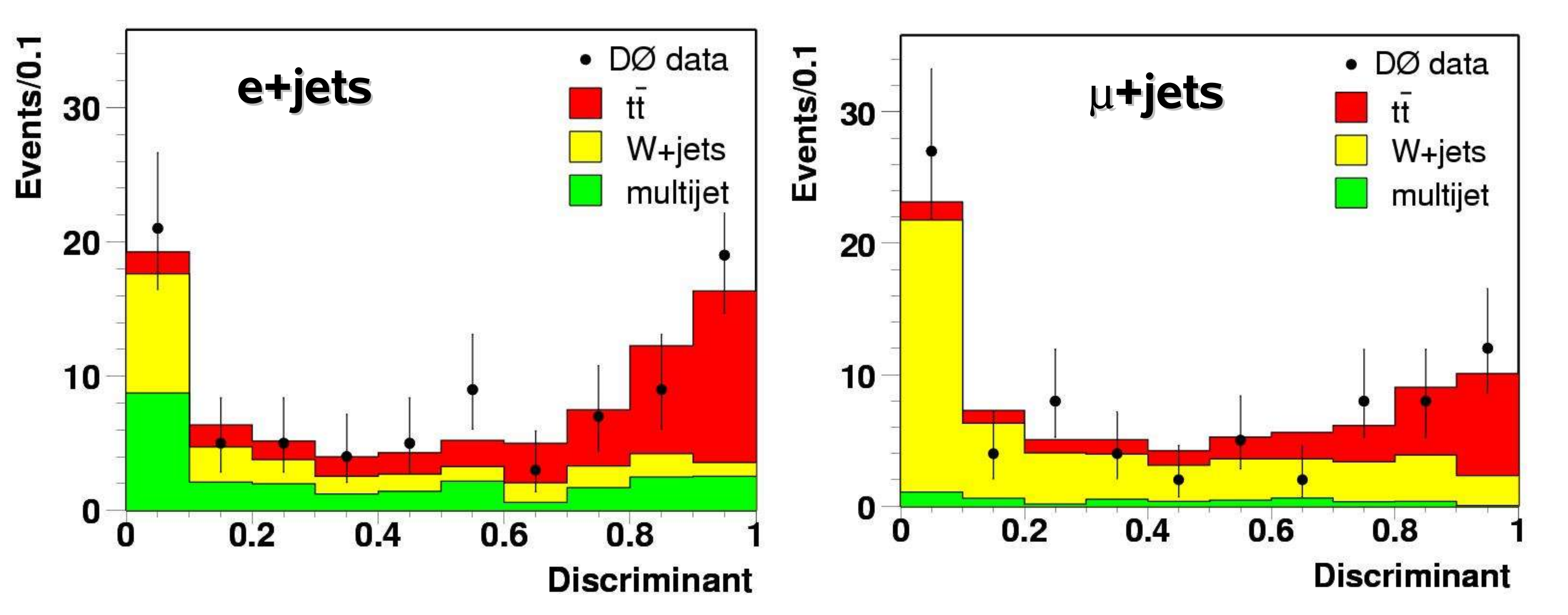
Background sensitive quantities
- Delta phi(l,MET)

topological likelihood:

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

i=1..6,
S = $t\bar{t}$-distribution,
B = Wjjjj-distribution

L+Jets, DØ Topological Xsec (II)



Combined result:

$$\sigma_{tt} = 6.7^{+1.4}_{-1.3}(stat.)^{+1.6}_{-1.1}(syst.) \pm 0.4(lumi)\, pb$$

L+Jets, DØ Topological Xsec (III)

Source	e+jets		μ+jets		l+jets	
Lepton identification	±0.3		±0.2		±0.2	
Jet energy calibration	+1.8	-1.2	+1.0	-0.7	+1.4	-1.0
Jet identification	+0.2	-0.2	+0.2	-0.1	+0.2	-0.1
Trigger	+0.1	-0.1	+0.4	-0.3	+0.3	-0.2
Multijet background	±0.3		±0.03		±0.2	
W background model	±0.2		±0.4		±0.3	
MC statistics	±0.5		±0.3		±0.3	
Other	±0.2		±0.1		±0.2	
Total	+1.9	-1.3	+1.2	-1.0	+1.6	-1.1

D0

Table 4.16: Systematic uncertainties on $\sigma_{t\bar{t}}$ (pb).

CDF

Effect	Acceptance (%)		Shape (%)		Total(%)	
Jet E_T Scale	4.7	(4.7)	12.2	(21.4)	16.9	(26.1)
W+jets Q^2 scale	-	(-)	10.2	(24.6)	10.2	(24.6)
QCD fraction	-	(-)	0.6	(2.4)	0.6	(2.4)
QCD shape	-	(-)	1.1	(4.5)	1.1	(4.5)
Other EWK	-	(-)	2.0	(1.8)	2.0	(1.8)
$t\bar{t}$ PDF	1.5	(1.5)	2.9	(2.2)	4.4	(4.7)
$t\bar{t}$ ISR	2.1	(2.1)	1.9	(1.1)	3.0	(2.9)
$t\bar{t}$ FSR	1.7	(1.7)	1.0	(1.5)	2.7	(3.7)
$t\bar{t}$ generator	1.4	(1.4)	0.3	(1.0)	1.7	(2.4)
Lepton ID/trigger	2.0	(2.0)	-	(-)	2.0	(2.0)
Lepton Isolation	5.0	(5.0)	-	(-)	5.0	(5.0)
Luminosity	-	(-)	-	(-)	5.9	(5.9)
Total					22.3	(37.8)

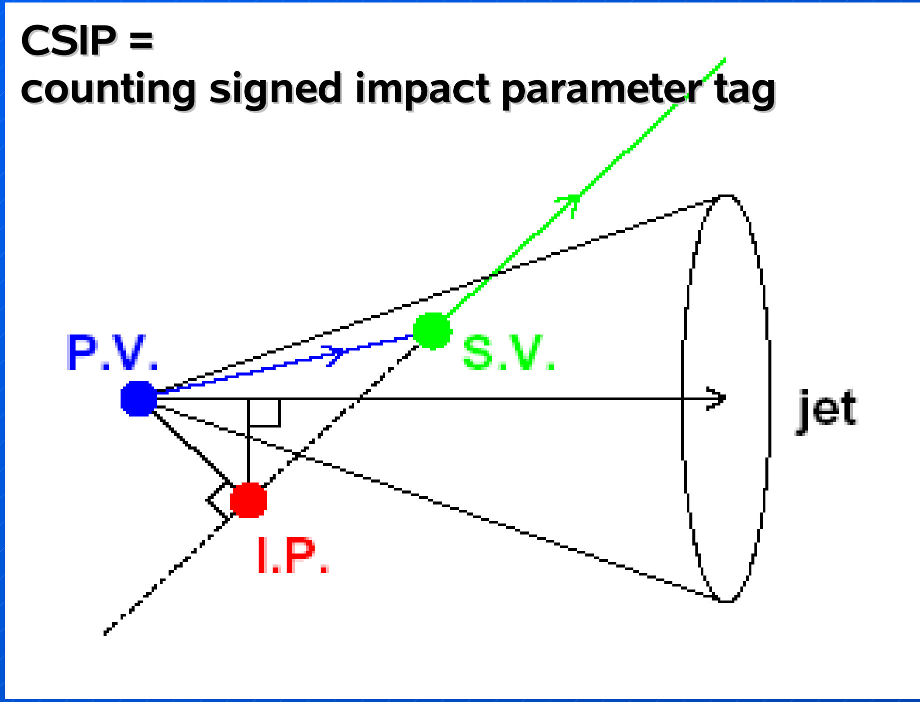
Table 4.8: Systematic uncertainties in % on the cross section, for fits to the ANN output (H_T) distribution in the $W+\geq 3$ jets sample.

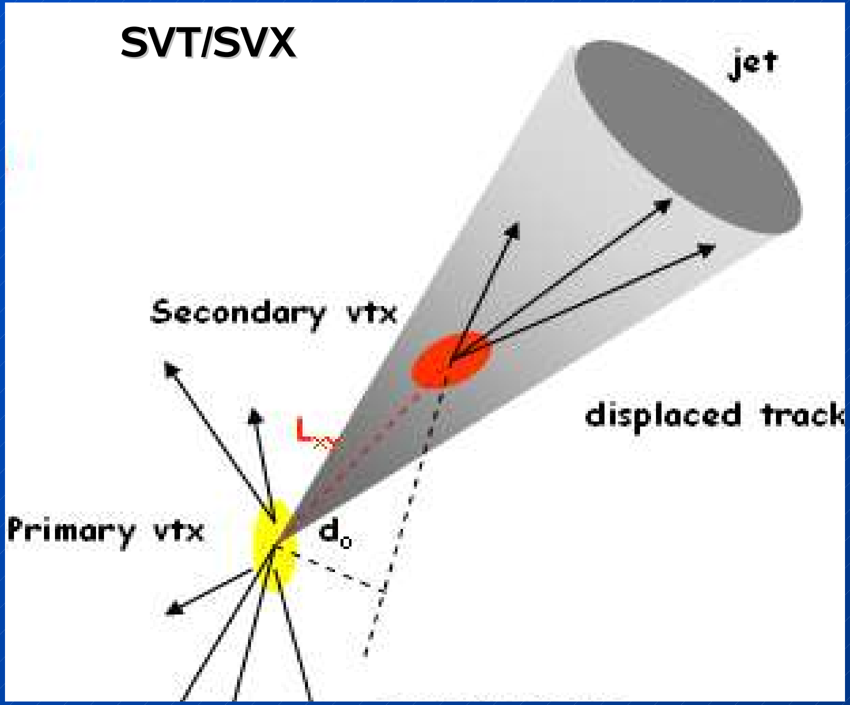
Jet energy scale and W+jets background modeling dominate uncertainties, in particular in template shapes

- ⇨ **only LO W+jets MC (flavour composition ?)**

b-tagging at CDF & DØ

- b-hadron lifetime cτ ~ 450 μm
- b-hadrons travel L_{xy} ~ 3 mm before decay





- count the number of track with large positive DCA significance σ
- jet is tagged if
  $N_{tr}(\sigma>2)>3$ or
  $N_{tr}(\sigma>3)>2$

- explicitely reconstruct 3D vertices out of track jets
- cut on decay length significance
- tagging eff. ~50%

⇨ can also tag muon in jet from soft-lepton decay
also jet probability … taggers

Lepton+Jets, b-tag Xsec (D0, I)

Flavour fractions in W+Jets from ALPGEN/HERWIG
tag-rate functions (mistags) from data
tagging efficiency from data (+MC correction)
Njet=1,2 ⇨ control bins
Njet=3,4 ⇨ signal
Combination of Njets=3,4; e/mu channel, 1-tag, ≥2 tags

counting experiment

365 pb^{-1}

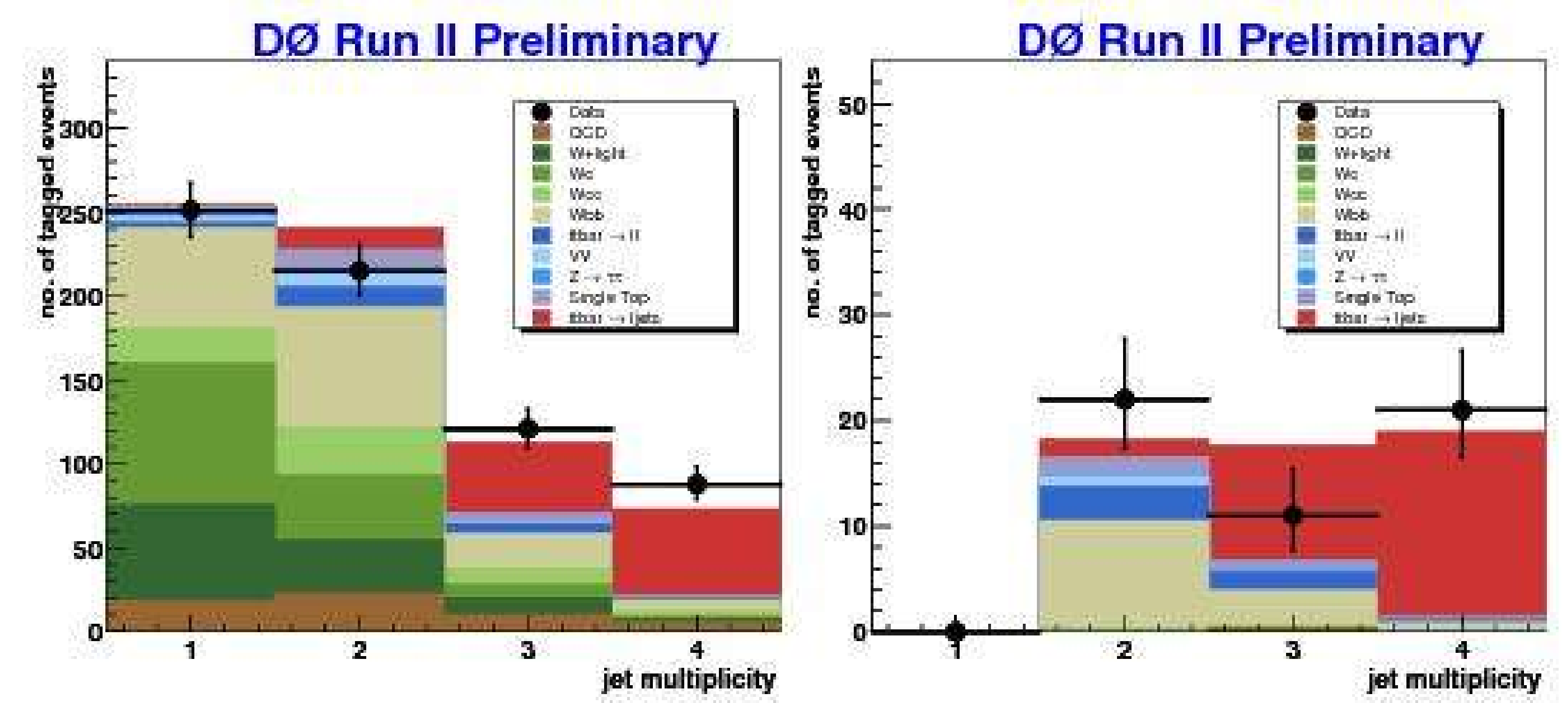


Figure 4.16: Expected and observed number of single-tag (left) and double-tag events (right).

Lepton+Jets, b-tag Xsec (D0, II)

Source	Offset (pb)	σ^{+}(pb)	σ^{-} (pb)
Muon preselection	+0.02	+0.18	-0.15
Electron preselection	-0.02	+0.18	-0.15
Muon triggers	+0.07	+0.34	-0.28
Jet energy calibration	-0.07	+0.24	-0.21
Jet reco and jet ID	-0.09	+0.23	-0.18
SML b-tag efficiency in MC	+0.03	+0.15	-0.14
SML b-tag efficiency in data	+0.18	+0.40	-0.35
Heavy quark mass on W fractions	-0.00	+0.18	-0.19
W fractions matching + higher order effects	+0.01	+0.44	-0.44
Event statistics for matrix method	-0.02	+0.15	-0.15
Total		+0.9	-0.8

Table 4.18: Systematic uncertainties on $\sigma_{t\bar{t}}$ (pb).

W+jets modelling and flavour fractions dominanting systematic uncertainty

Lepton+Jets, b-tag Xsec (CDF, I)

- Standard l+jets selection+b-tag in W+≥ 3 jets
- fit jet ET spectrum

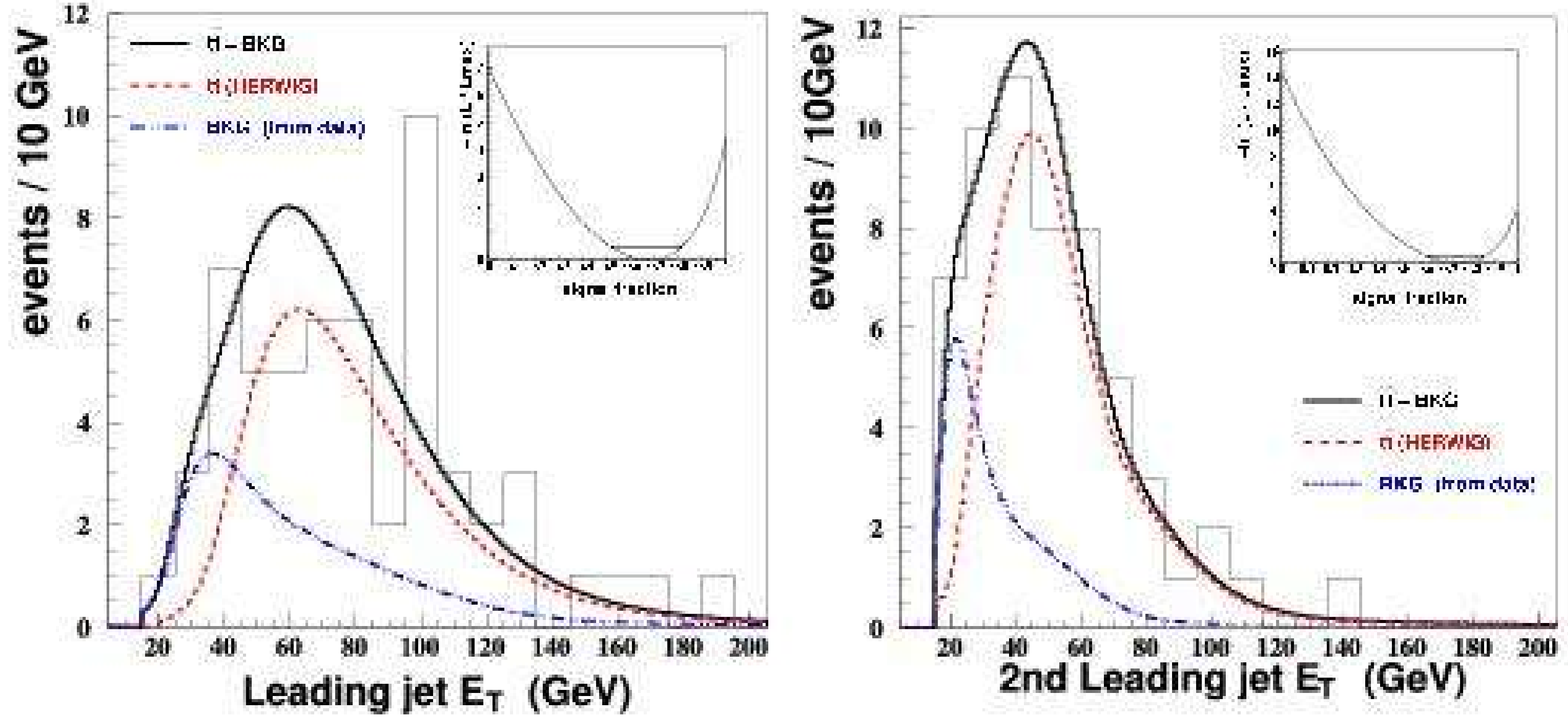


Figure 4.5: The fifty seven candidate events (histogram) with the best fit curve (solid). The best fit composition, $t\bar{t}$ (dashed) and background (dot-dashed), is also shown. The inset shows the $-\ln(\mathcal{L}/\mathcal{L}_{max})$ as a function of the signal fraction. Left: Leading jet E_T spectrum; Right: Second leading jet E_T spectrum.

Lepton+Jets, b-tag Xsec (CDF, II)

- Standard l+jets selection+b-tag in W+≥ 3 jets
- fit jet ET spectrum

Source	Shape (%)	Acceptance (%)	Total (%)
Jet energy Scale	±10.8	±4.5	±15.3
absolute b-tag efficiency	-	±7.4	±7.4
background statistics	$^{+2.6}_{-6.9}$	-	$^{+2.6}_{-6.9}$
luminosity	-	±5.9	±5.9
lepton ID	-	±5.0	±5.0
b-tag effic. (E_T dependence)	±1.9	±2.5	±4.4
PDF	±3.4	±0.8	±4.2
gluon rad., non-W shape, other acceptance syst., non-W rate, $t\bar{t}$ shape, single top product.	...	...	...
total	$^{+12.4}_{-13.9}$	±12.3	$^{+20.6}_{-21.5}$

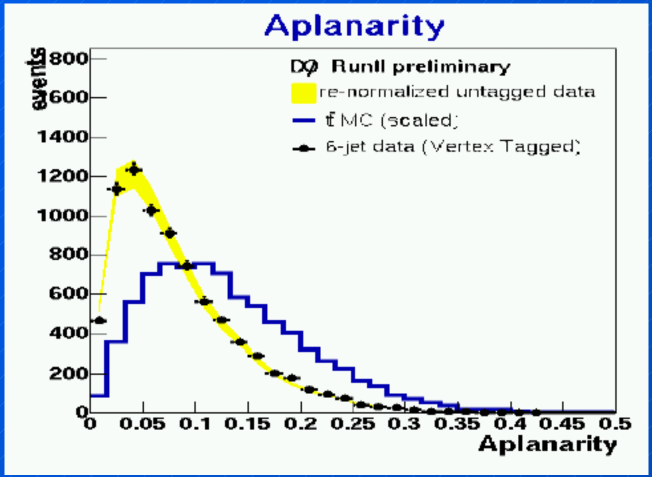
Table 4.9: Systematic uncertainties for the $t\bar{t}$ cross section from shape and acceptance affects in the l+jets b-tag + kinematics analysis.

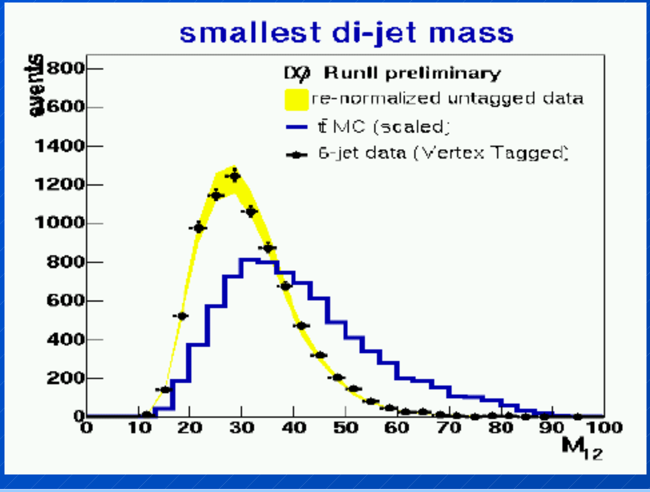
- Shape uncertainty dominated by JES

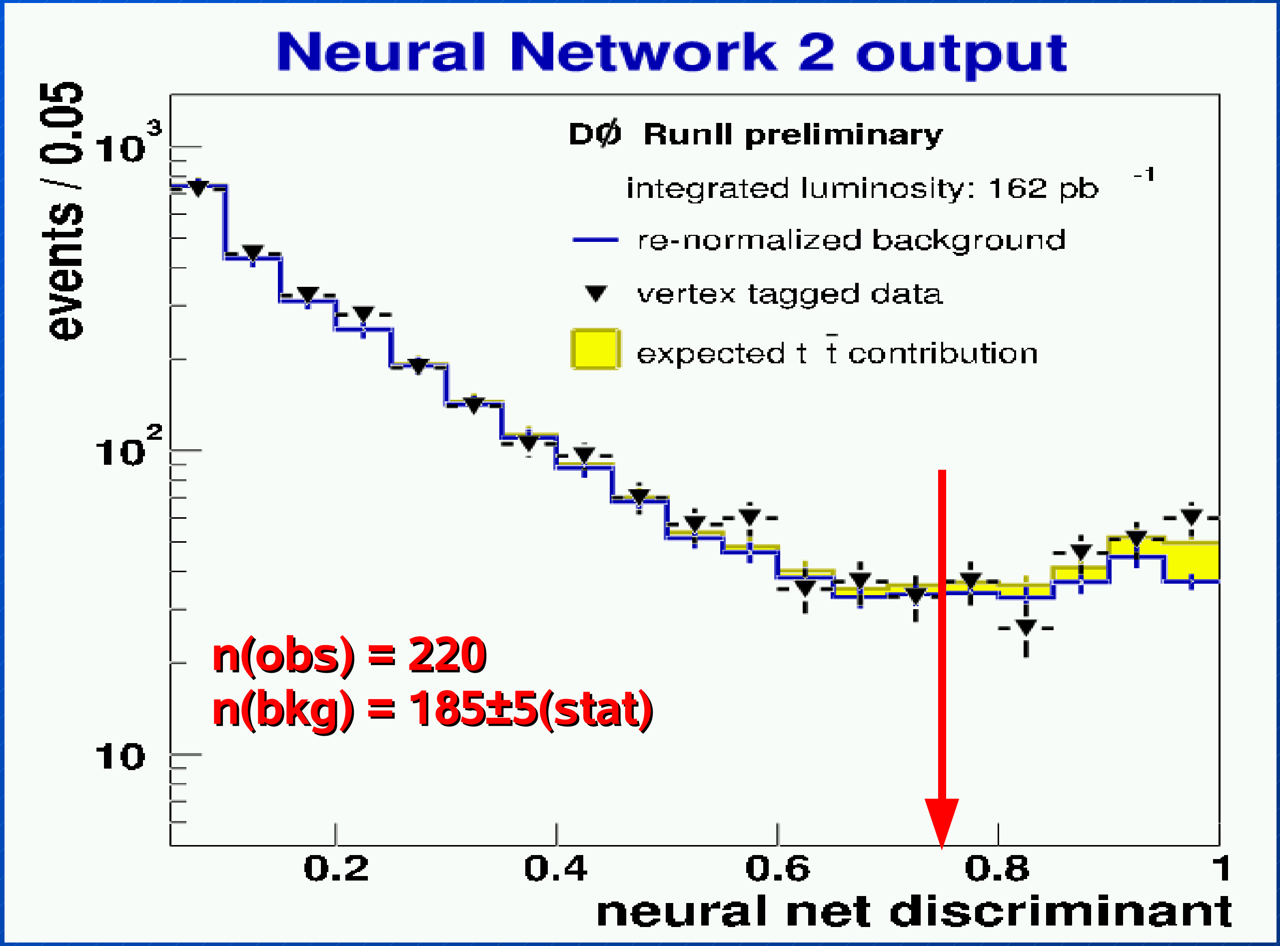
Alljets Xsec Analyses

Use b-tagging (SVX) + tight kinematic cuts

- ≥ 6 jets
- exactly 1 b-tagged jet
- kinematic neural network
  ⇨ second neural network including reconst. masses



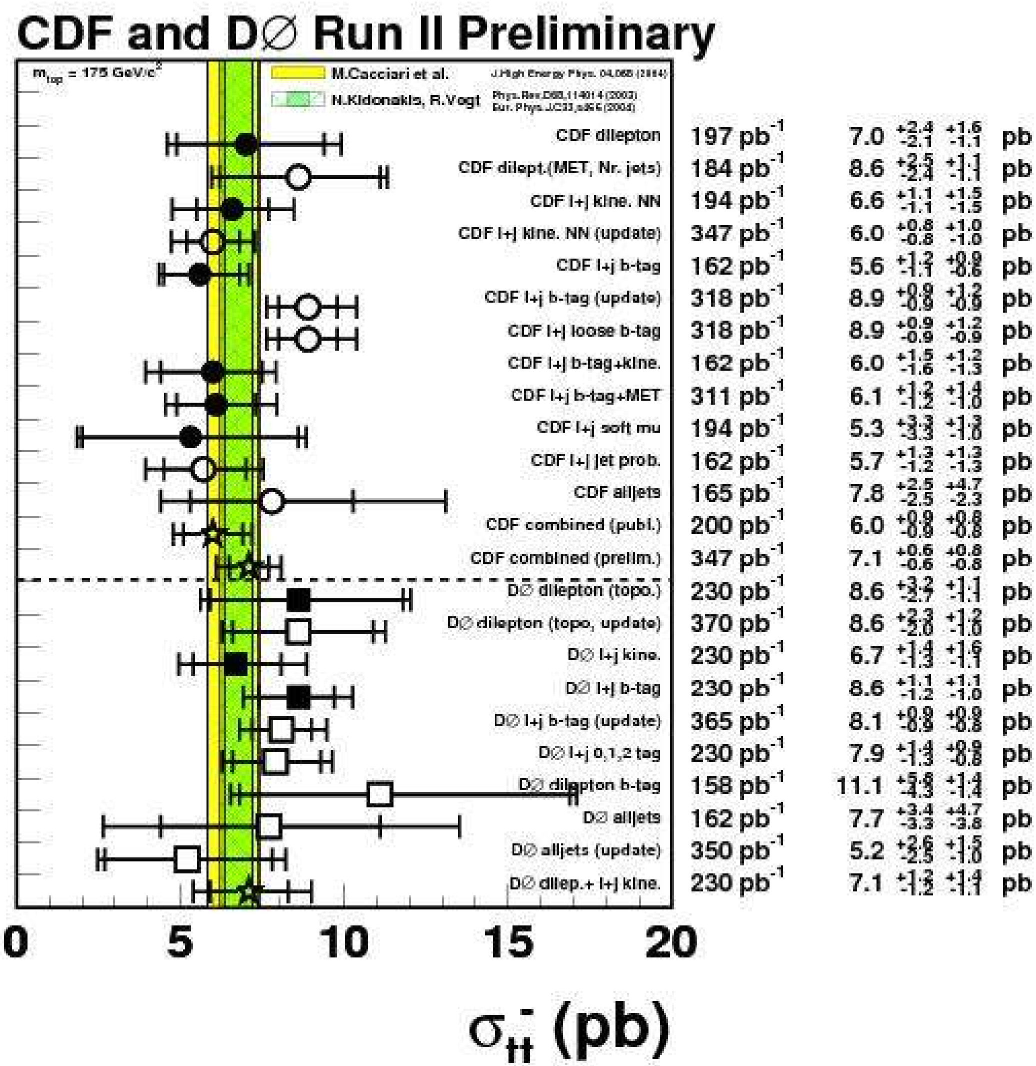


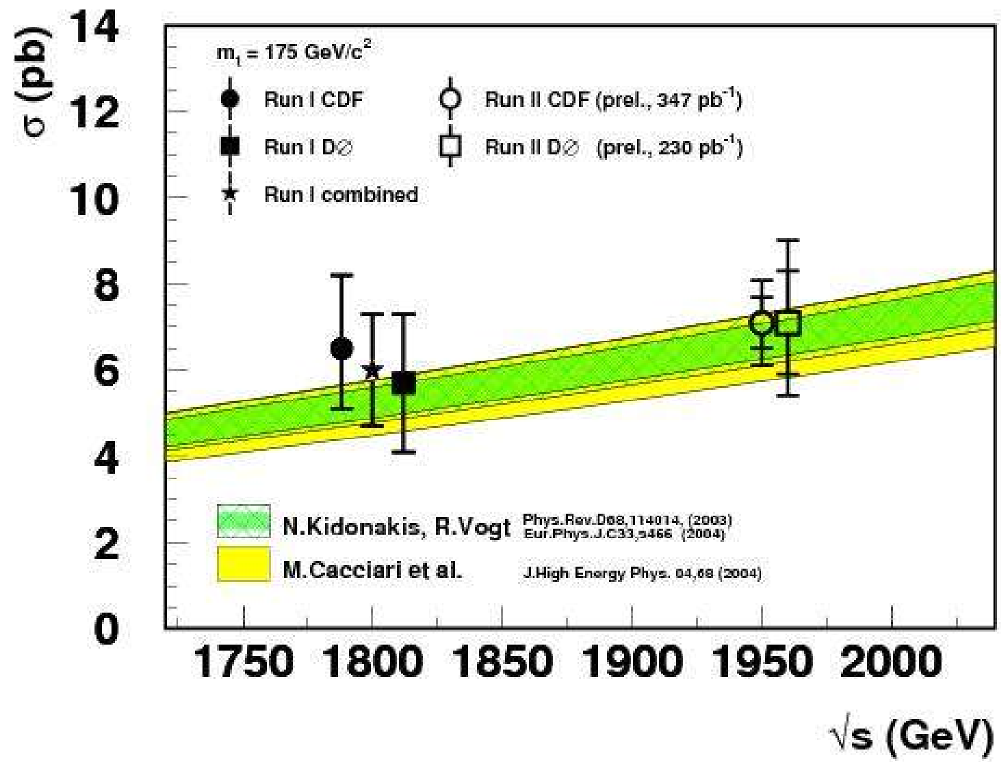


Counting experiment (162 pb^{-1}):

$$\sigma_{tt} = 7.7^{+3.4}_{-3.3}(stat.)^{+4.7}_{-3.8}(syst.) \pm 0.5(lumi)\ pb$$

Run II Top Cross Section - Summary





errors between different channels are correlated

- Measurements demonstrate success of various top detection techniques
- Results within errors consistent with NNLO SM prediction for 1.96 TeV of ~7 pb^{-1}
- Combination being worked on (TevEWWG)
- Latest results (760 pb^{-1}) achieve ~15% precision

Simulation of W/Z+jets

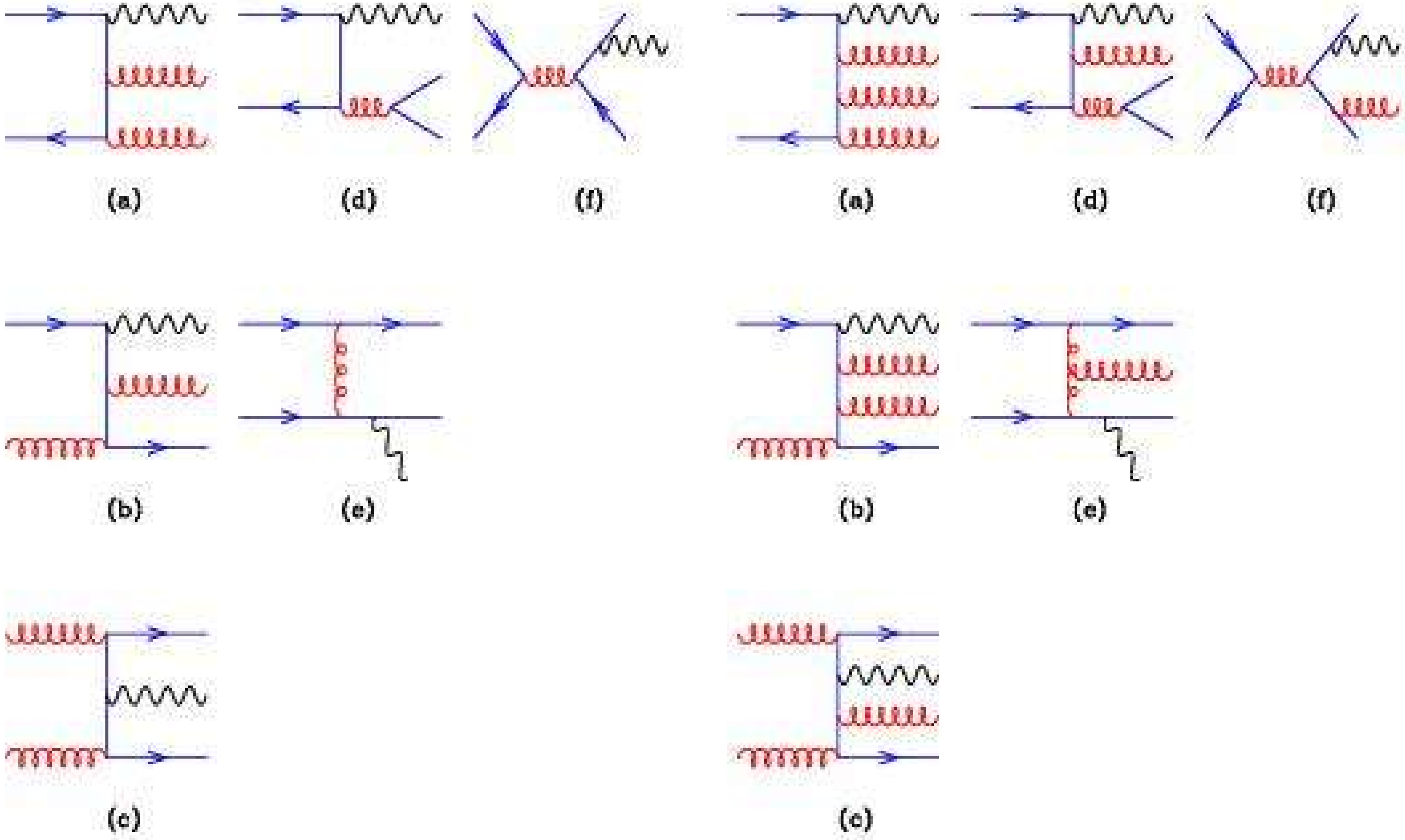


Figure 2.17: Example diagrams for the process parton + parton → W/Z+2 partons (left) and parton + parton → W/Z+3 partons (right). The vector boson is denoted by a wavy line.

Flavour fractions from LO-Monte Carlo (ALPGEN) are direct input the Xsec analyses
How well described ?

b-fraction in W+2 Jet Events

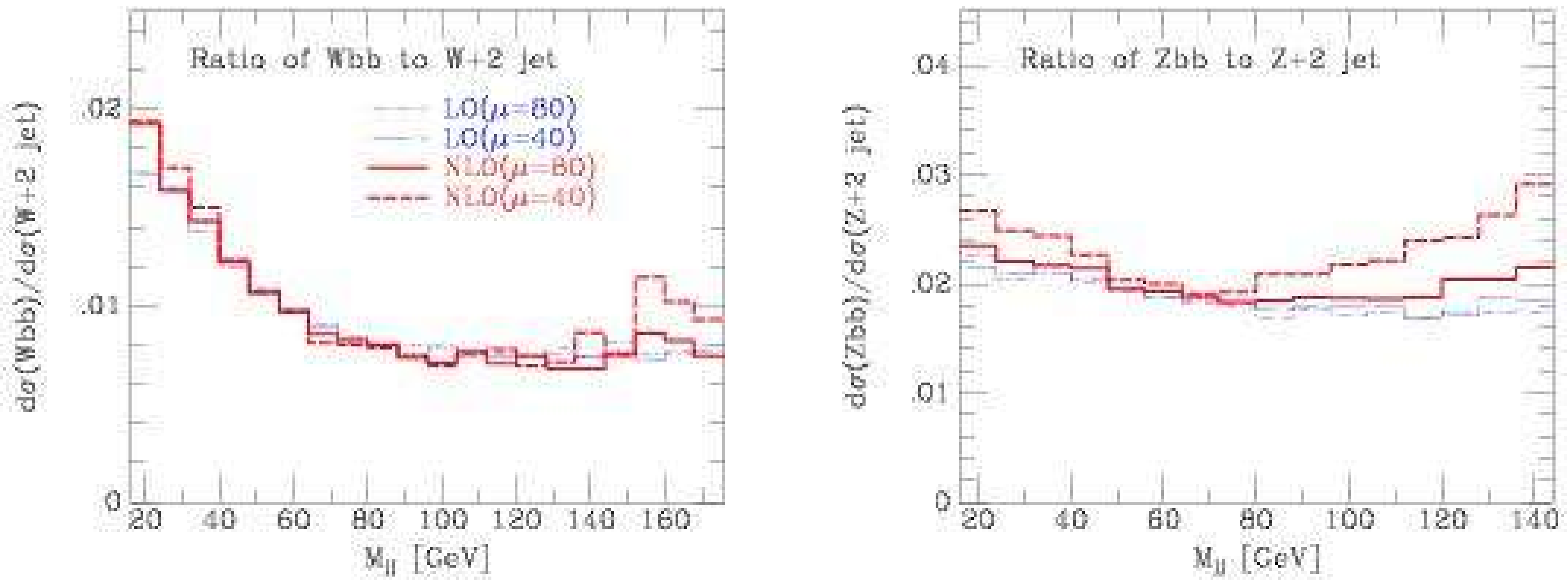


Figure 2.18: Ratio of $W/Z+2$ b-jets to $W/Z+2$ jet events in LO and NLO at two different factorisation scales. From Reference [182].

Flavour fractions and shapes agree in LO and NLO reasonably well for W+2 Jets
first studies for W+4 jets indicate less agreement ⇨ need more studies here
first experimental data indicate factor ~1.5±0.4 higher b-fraction ⇨ need more data

Jet-Parton Matching

- W+4 Jets can originate from W+4 partons and W+3 partons + parton-shower jets
- need to generate lower parton multiplicities as well
- generation of W+4 jets events via W+1,2,3 parton process **VERY** inefficienct !
- Want to generate W+n parton events for n=1,2,3 and 4 separately and combine files afterwards

How to avoid double counting ? ➪ Jet-Parton matching (MLM, CKKW ...)

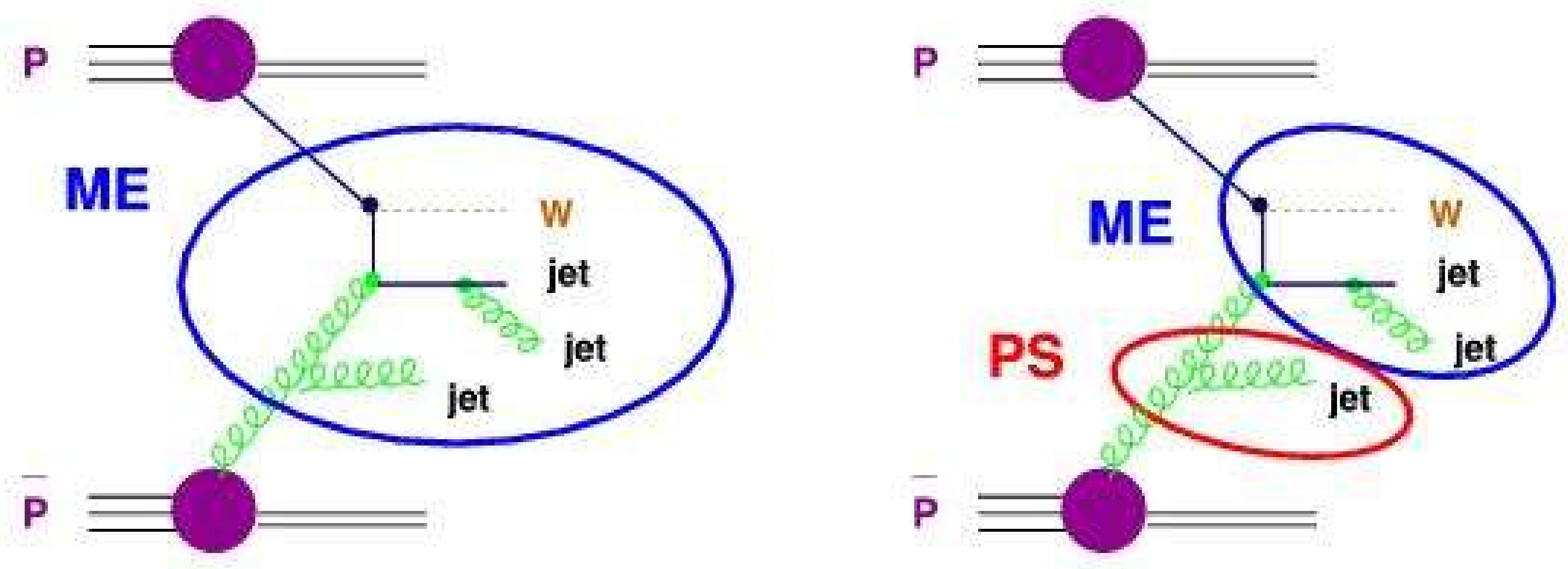
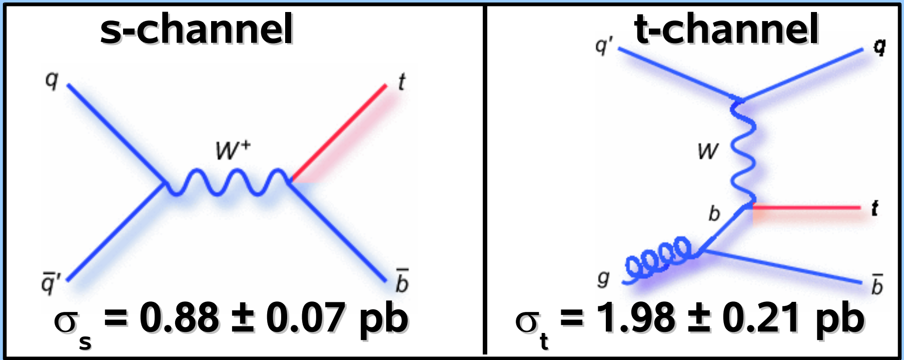


Figure 2.19: Left: $W + 3$ parton process calculated by the matrix element (ME) and no additional jets from the parton shower (PS). Right: $W + 2$ parton process calculated by the matrix element and one additional jet generated by the parton shower. Both processes lead to the same final state.

Top Quark Production in Weak Interactions

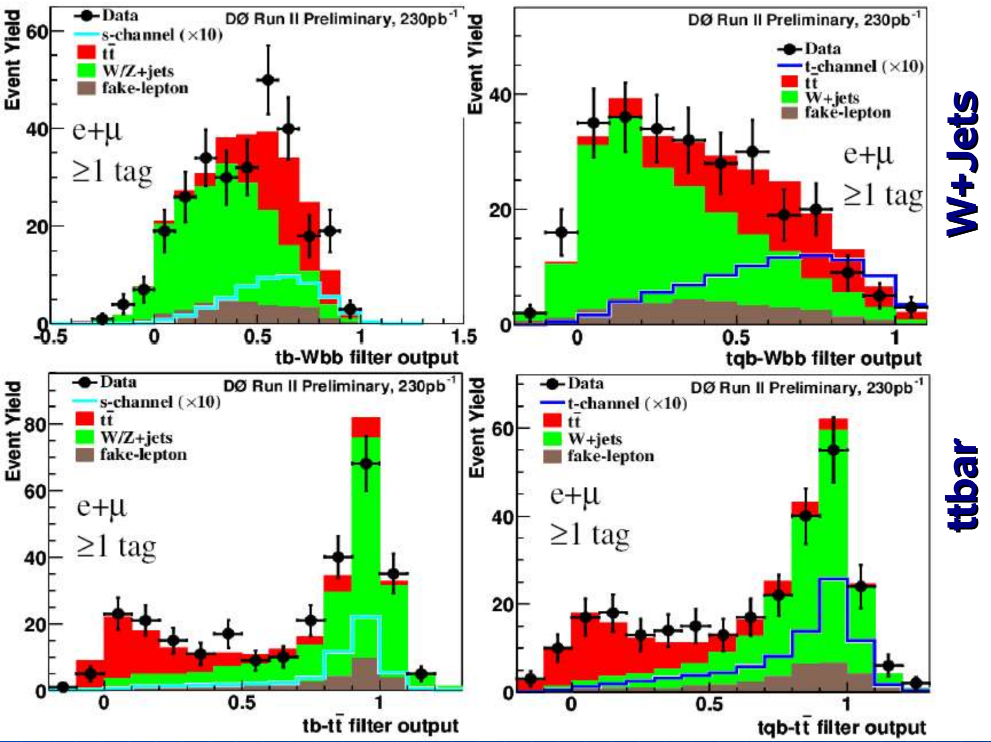
Elektroweak Top Production

- Comparable rate to strong production !!!
- directly sensitive to $|V_{tb}|$
- Search for new physics (W', ...)
- Similar topology to tt in l+jets,
  BUT fewer jets & more forward background
  (W+jets, tt, dibosons, ...)

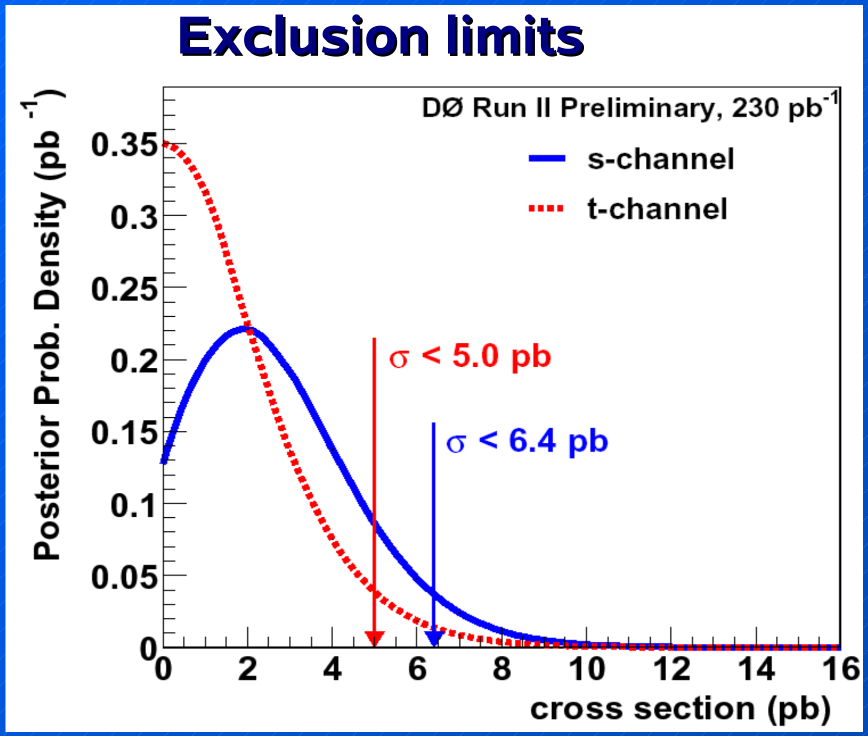


Event Shape Analysis (here NN)

s-channel t-channel



Electroweak Top Production



... improved further ...

95% CL limits	DØ	CDF
σ(s-channel)	< 5.0 pb	< 13.6 pb
σ(t-channel)	< 4.4 pb	< 10.1 pb
σ(s+t channels)		< 17.8 pb

... observation with ~1-2 fb^{-1} ...

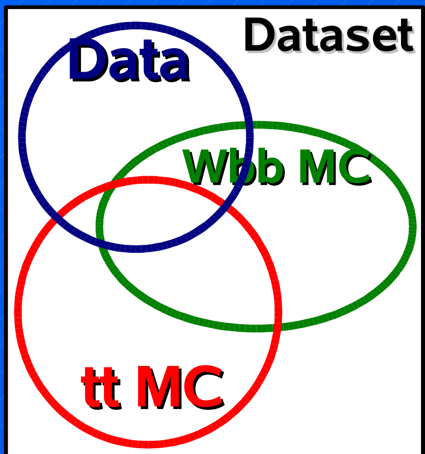
Top Quark Properties

… Mass …

Top Quark Mass Measurements at Tevatron

dilepton	Neutrino weighting (nu->phi)	⇨ 1-dim. fit
	Phi-weighting (phi->nu)	⇨ 1-dim. fit
	Pz(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
alljets	Only from Run-I, little sensitivity	

CDF-II Template Analysis in L+Jets

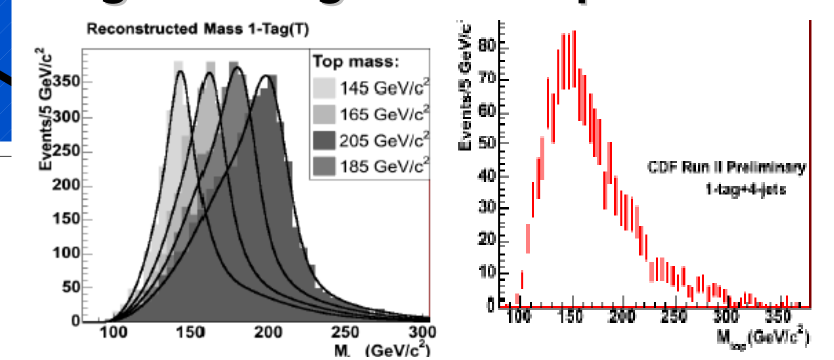


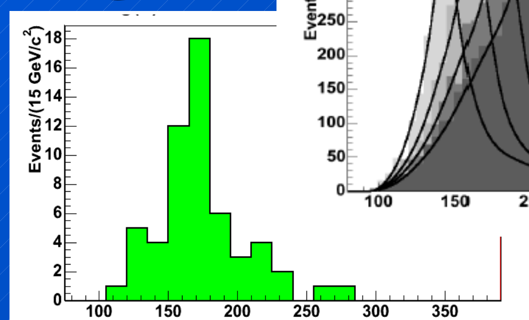
Mass fitter

χ^2 mass fitter:

- Finds top mass that fits event best
- One number per event
- Additional selection cut on resulting χ^2

Signal/background templates

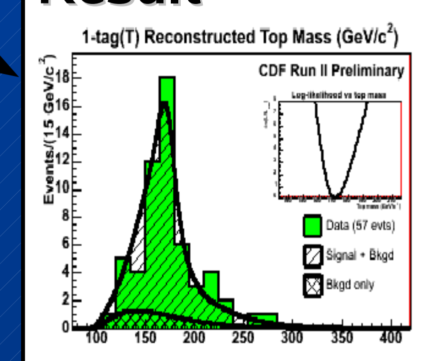




Data

Likelihood fit

Result

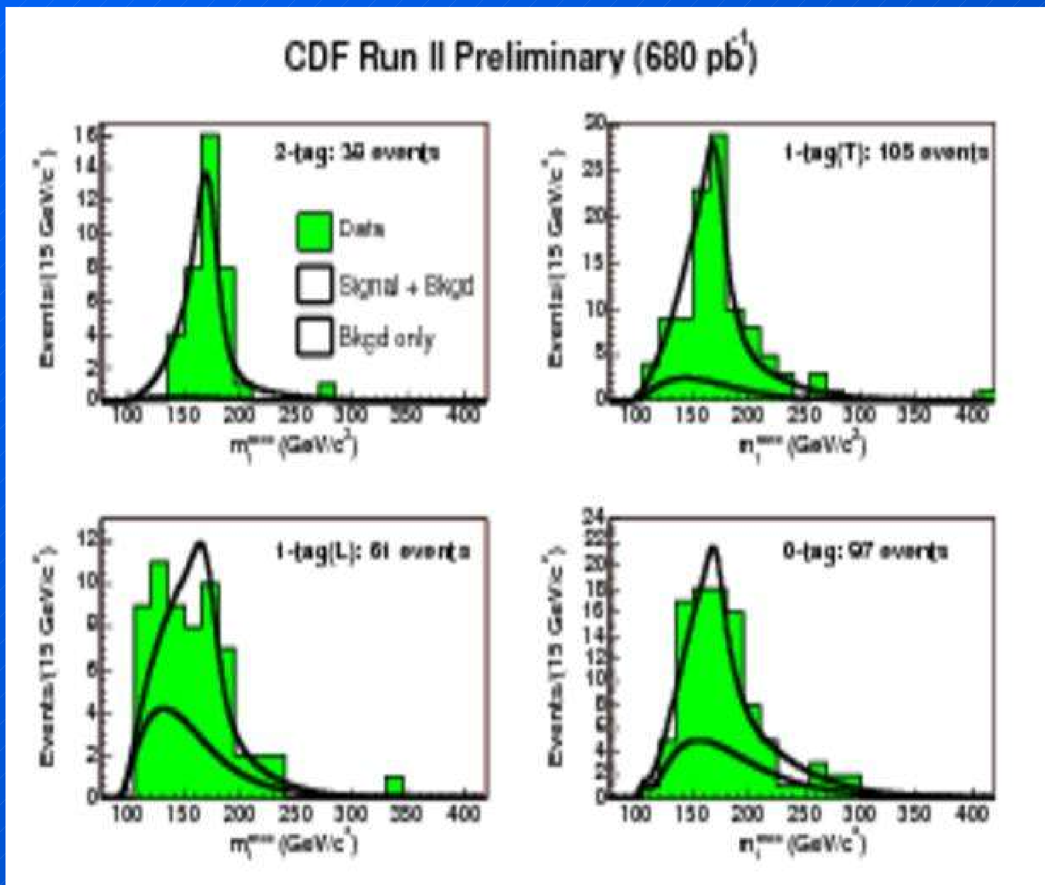


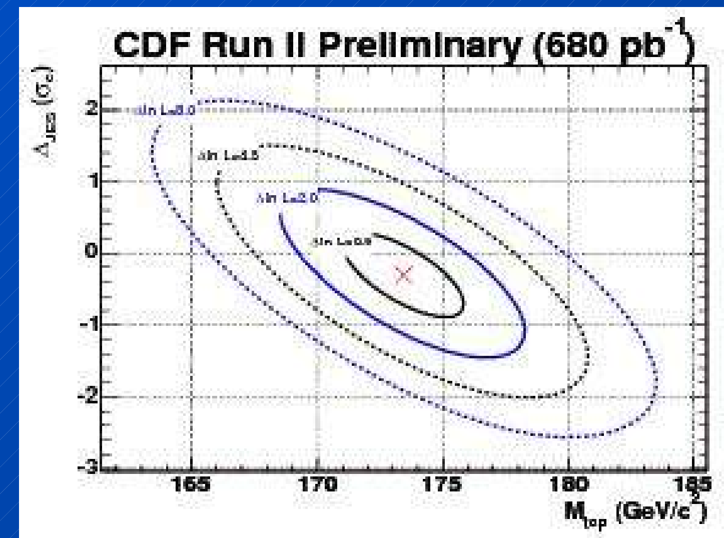
Likelihood fit:

Best signal + bkgd templates to fit data with constraint on background normalization

CDF-II Template Analysis in L+Jets

Fit four data samples (0-tag, 1-tag(L), t-tag(T), 2-tag) in m_{top} and ΔJES, i.e. 2-dim fit :





Systematic Source	ΔM_{top}
b-jet energy scale	0.6
Residual JES	0.7
Background JES	0.4
ISR	0.5
FSR	0.2
Parton Distribution Functions	0.3
Generators	0.2
Background Shape	0.5
b-tagging	0.1
Monte Carlo statistics	0.3
TOTAL	1.3

$$m_{top} = 173.4 \pm 1.7\,(stat) \pm 1.8\,(JES) \pm 1.3\,(syst.)\,GeV/c^2$$

Matrix Element Method

- Obtain probabilities by folding differential X-section with object resolutions:

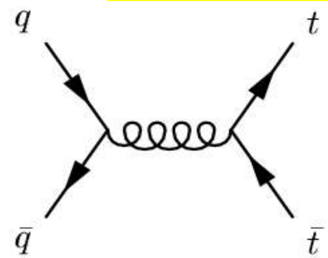
$$P_m(\alpha, x) = Acc(x) \times \frac{1}{\sigma} \int d^n\sigma(y;\alpha)\, dq_1\, dq_2\, f(q_1)\, f(q_2)\, W(x,y)$$

Acceptance (selection, trigger,...)

LO-Matrix element x phase space

PDF's

Transfer Functions (Probability to measure x when y was produced)



Signal (No ISR or FSR)

Background (VECBOS-ME)
W+ 4 Jets
(also found adequate for QCD bkg.)

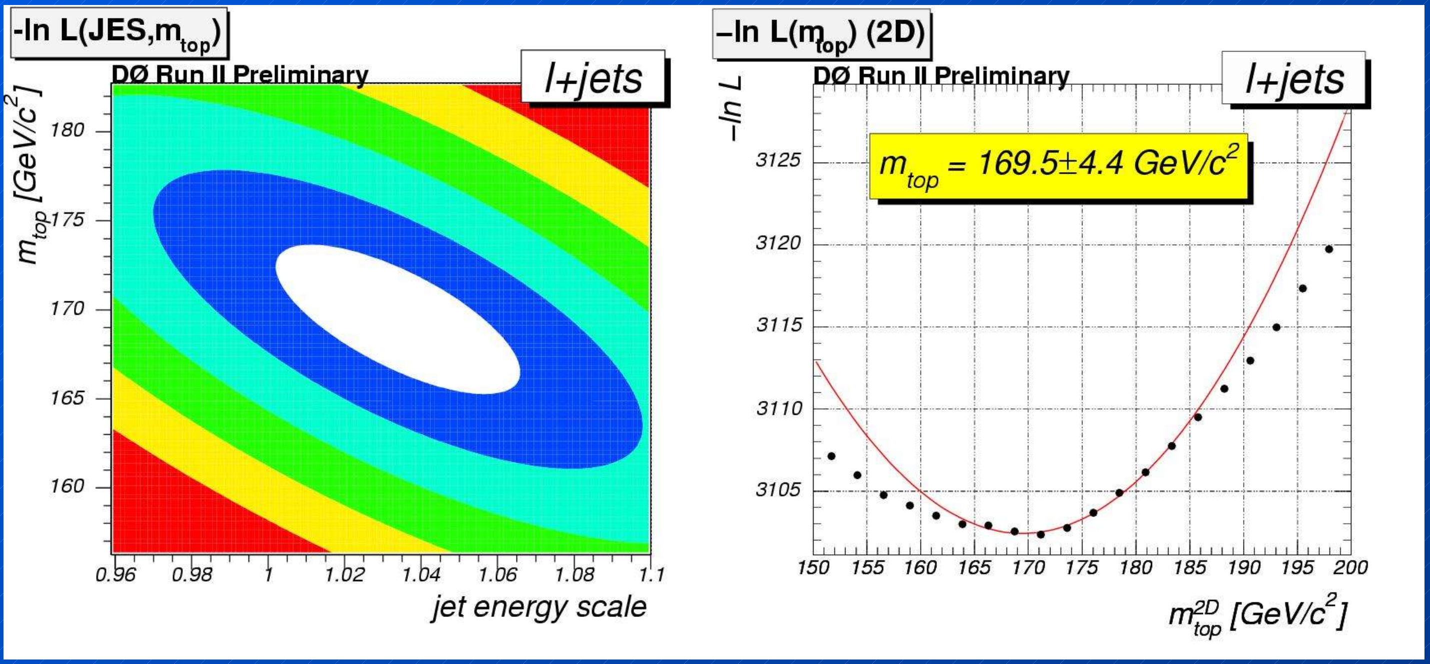
→ need to constrain to exactly 4 Jets

- take permutations (jet-parton-assignment) and reconstruction ambiguities into account by summing over different possibilities

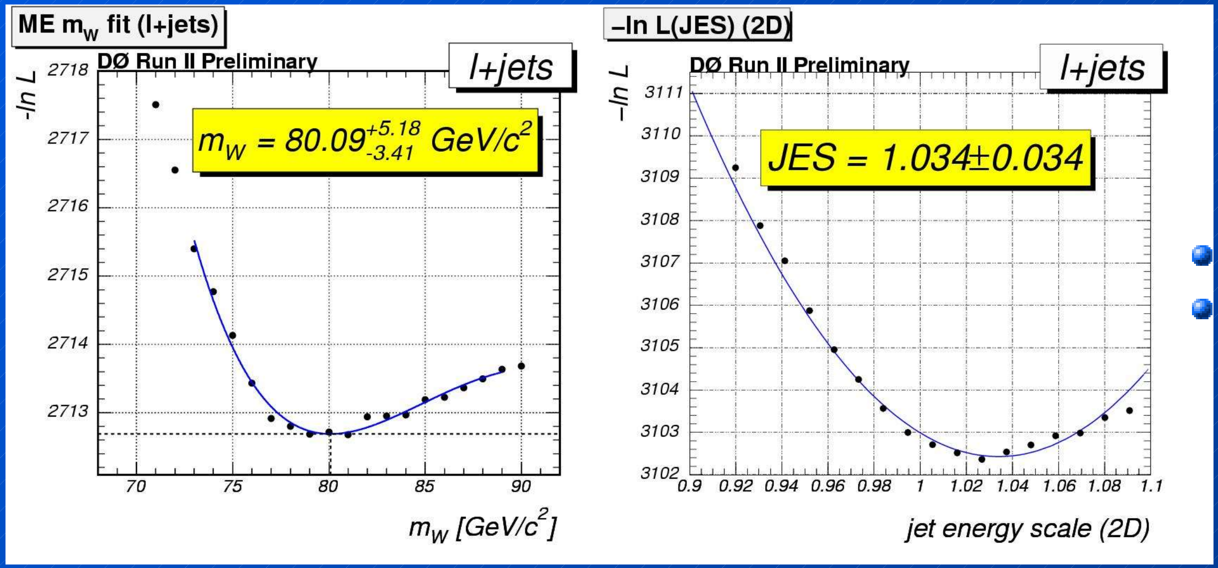
- Transfer functions are set to δ-functions for well-measured quantities (jet-angles, electron momentum)

- for jet-energies: $W_{jets}(E_{part}, E_{jet})$ relating parton- and jet-energies, obtained as parametrization for b- and non-b-Jets from MC

Top Mass in L+Jets



2-dimensional fits to reduce jet energy scale uncertainty
⇨ *in situ* calibration



- does not constrain b-JES
- most of the improvement in 2005 from studies of external JES !!!

CDF-II – DLM in L+Jets (I)

Dynamical Likelihood Method (DLM)

... similar to DØ `matrix element method' ...

Eats up some of the discrimination power of the method

require exactly 4 jets; $\geq$1 b-tag (SVX)

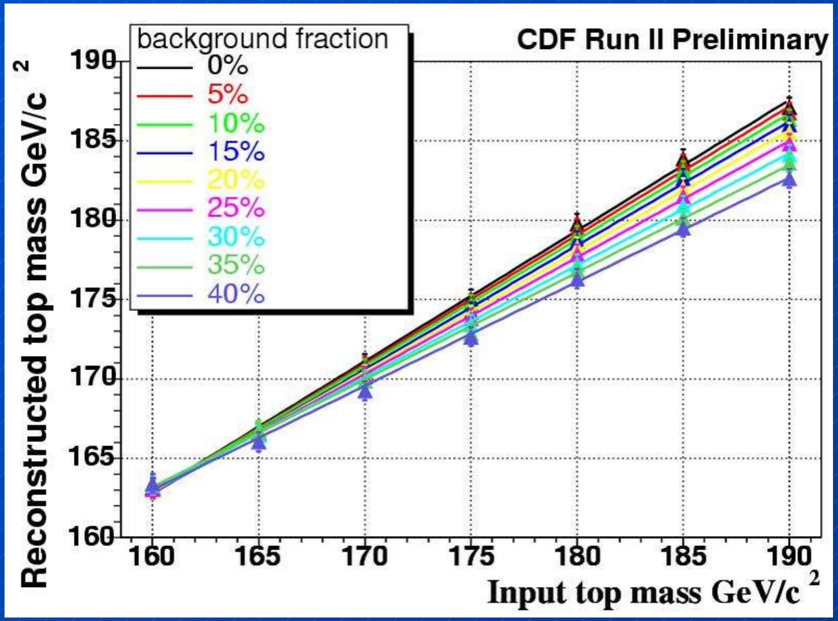
⇨ only 12 or 4 jet-parton combinations/event for 1 or 2 b-tags

select 22 (12 e, 10 μ) candidate events in 162 pb^{-1} ;
expect 20.9 ttbar and 4.2 ± 0.7 bgd

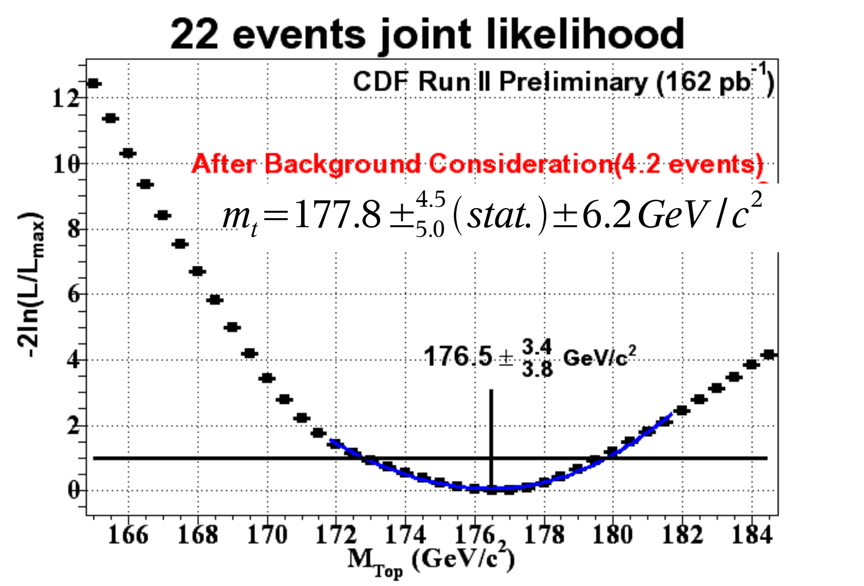
Source	Expected Number of events in W+4jets
Mistag	1.2 ± 0.37
$Wb\bar{b}$	0.7 ± 0.29
$Wc\bar{c}$	0.3 ± 0.12
Wc	0.2 ± 0.12
WW/WZ/ZZ	0.08 ± 0.05
single top	0.17 ± 0.03
QCD(non W)	1.6 ± 0.38
Background Total	4.2 ± 0.71
$t\bar{t}$ expected($\sigma_{t\bar{t}}$=6.7pb)	20.9
Observed events	22

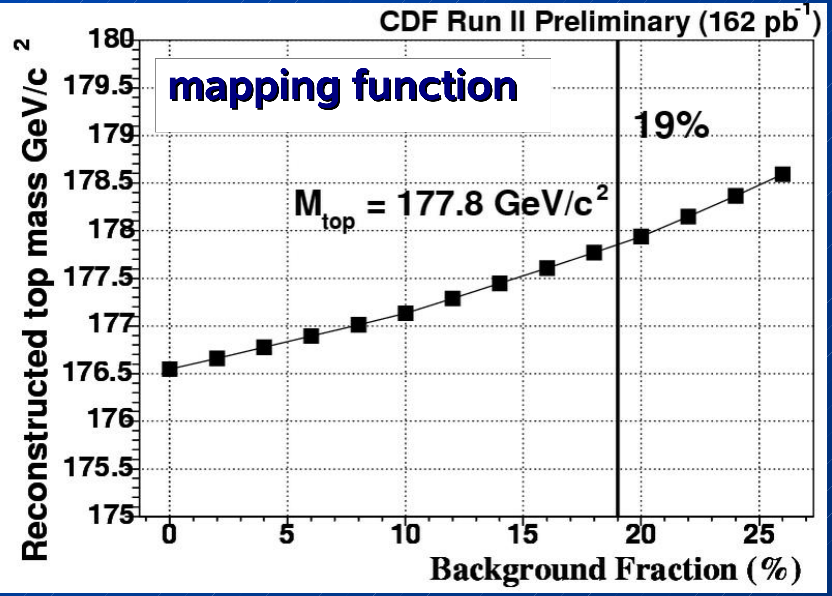
CDF-II – DLM in L+Jets (II)

Correction for background fraction and m_{top} dependence of transfer fct.
⇨ mapping function



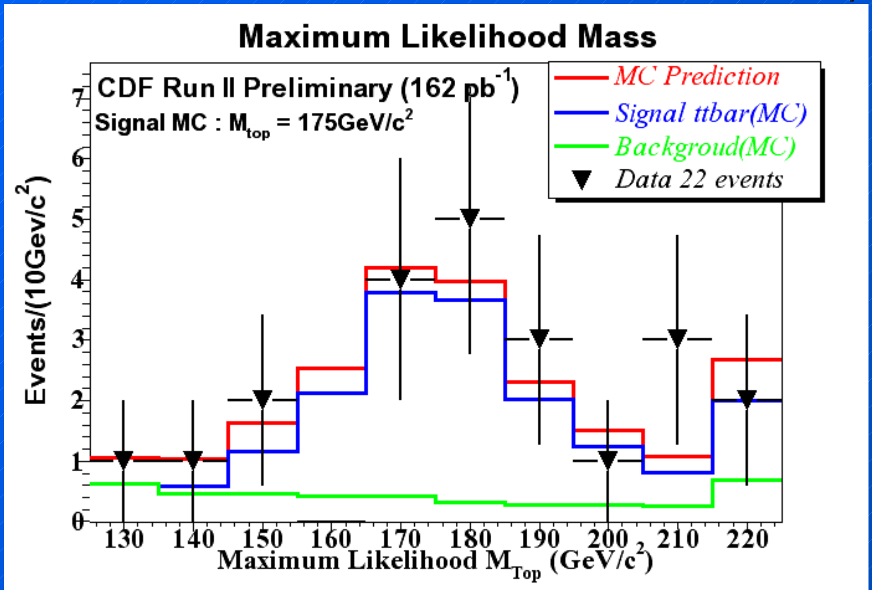
central stat. result





CDF-II – DLM in L+Jets (III)

sanity check: maximum likelihood m_{top}



expected stat. Error: +5.4, -5.0 GeV
observed stat. Error: +4.5, -5.0 GeV

including out-of-cone uncertainty

Source	ΔM_{top} GeV/c^2
Jet Energy Corrections	5.3
ISR	0.5
FSR	0.5
PDFs	2.0
Generator	0.6
Spin correlation	0.4
NLO effect	0.4
Transfer Function	2.0
Background fraction(±5%)	0.5
Background modeling	0.5
Monte Carlo modeling	0.6
Total	6.2

$$m_{top} = 177.8^{+4.5}_{-5.0} \pm 6.2\,GeV/c^2$$

DØ-II Ideogram Analysis in L+Jets (I)

select 101/90 candidates in e/μ +jets in ~160 pb^{-1}
perform kinematic fit to each of the 2(neutrino) * 12 (jets) combinations
⇨ jet assignment probability

$$\omega_i = \exp\left(-\frac{1}{2}\chi_i^2\right)$$

calculate analytical likelihood for each event:

Signal probability

$$P_{evt} = \frac{(S/B)_{samp} \cdot (S/B)_D}{(S/B)_{samp} \cdot (S/B)_D + 1}$$

Gaussian resolution

Relativistic Breit-Wigner

$$L_{evt}(m_t, P_{samp}) = P_{evt} \cdot \left[\int_{100}^{300} \sum_{i=1}^{24} \omega_i \cdot G(m_i, m', \sigma_i) \cdot BW(m', m_t)\, dm'\right]$$

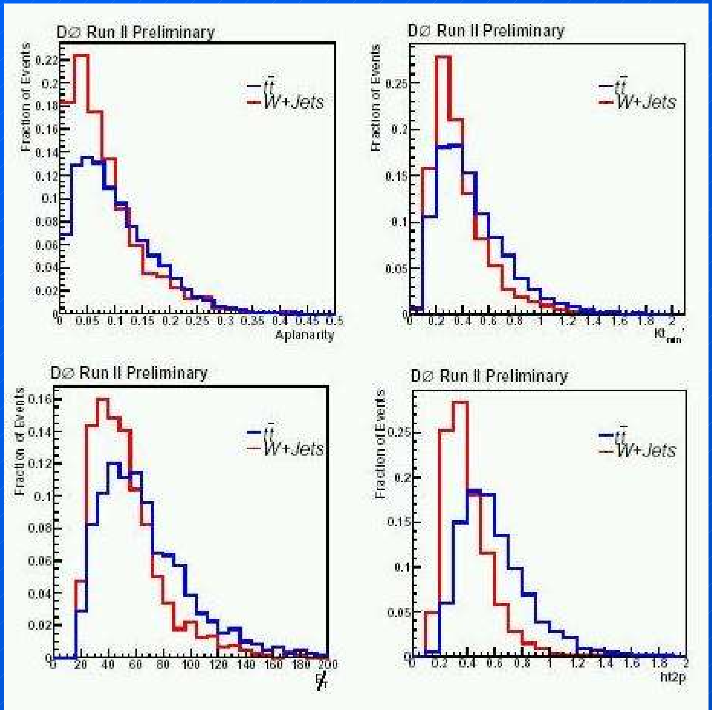
$$+ (1 - P_{evt}) \cdot \sum_{i=1}^{24} \omega_i \cdot BG(m_i)$$

Weighted sum of background shapes

$(S/B)_{samp} =$ ttbar fraction in sample

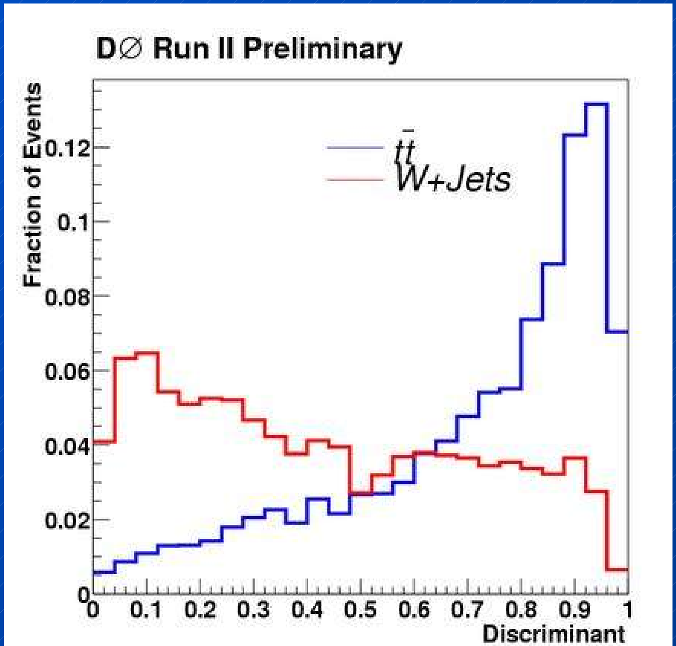
$(S/B)_D =$ Event purity from low bias Discriminant

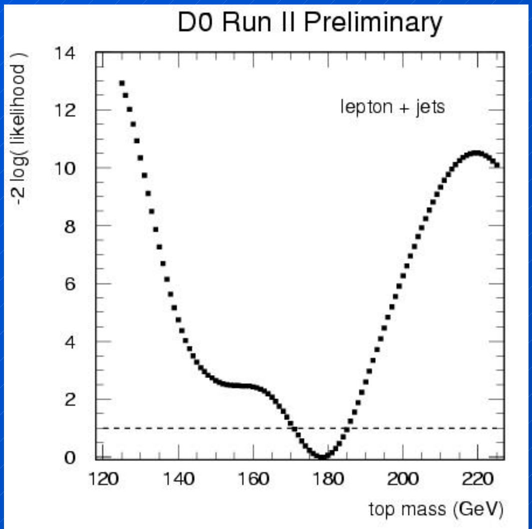
DØ-II Ideogram Analysis in L+Jets (II)



4 topological variables

low-bias discriminant D





Source	Uncertainty
Jet Energy Scale	−5.0 +4.6 GeV
Jet Energy Resolution	±1.0 GeV
Trigger Uncertainty	±0.5 GeV
Underlying Event and Multiple Interactions	+1.8 GeV
Limited MC Statistics	±0.3 GeV
Noise/MI	±2.6 GeV
Background Level	±0.8 GeV
Background Shape	±1.4 GeV
$t\bar{t}$ modeling	±3.8 GeV
total	−7.1 +7.0 GeV

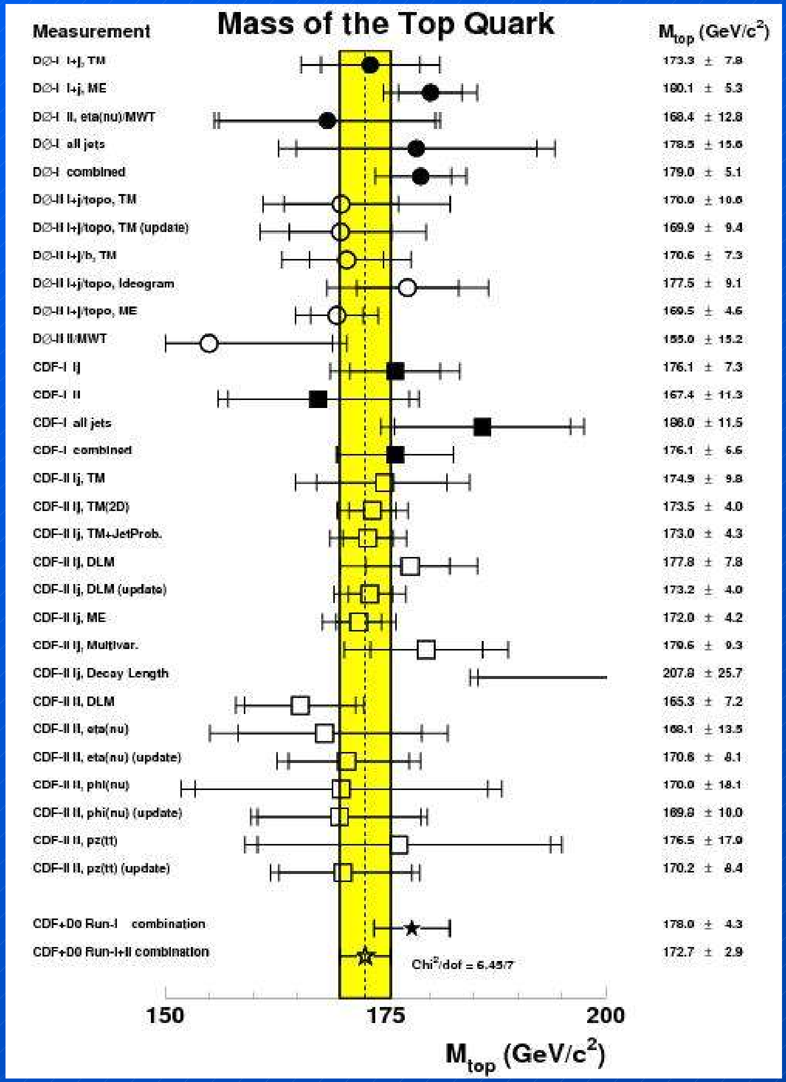
$$m_{top} = 177.5 \pm 5.8 \pm 7.1\, GeV/c^2$$

Top Mass Issues

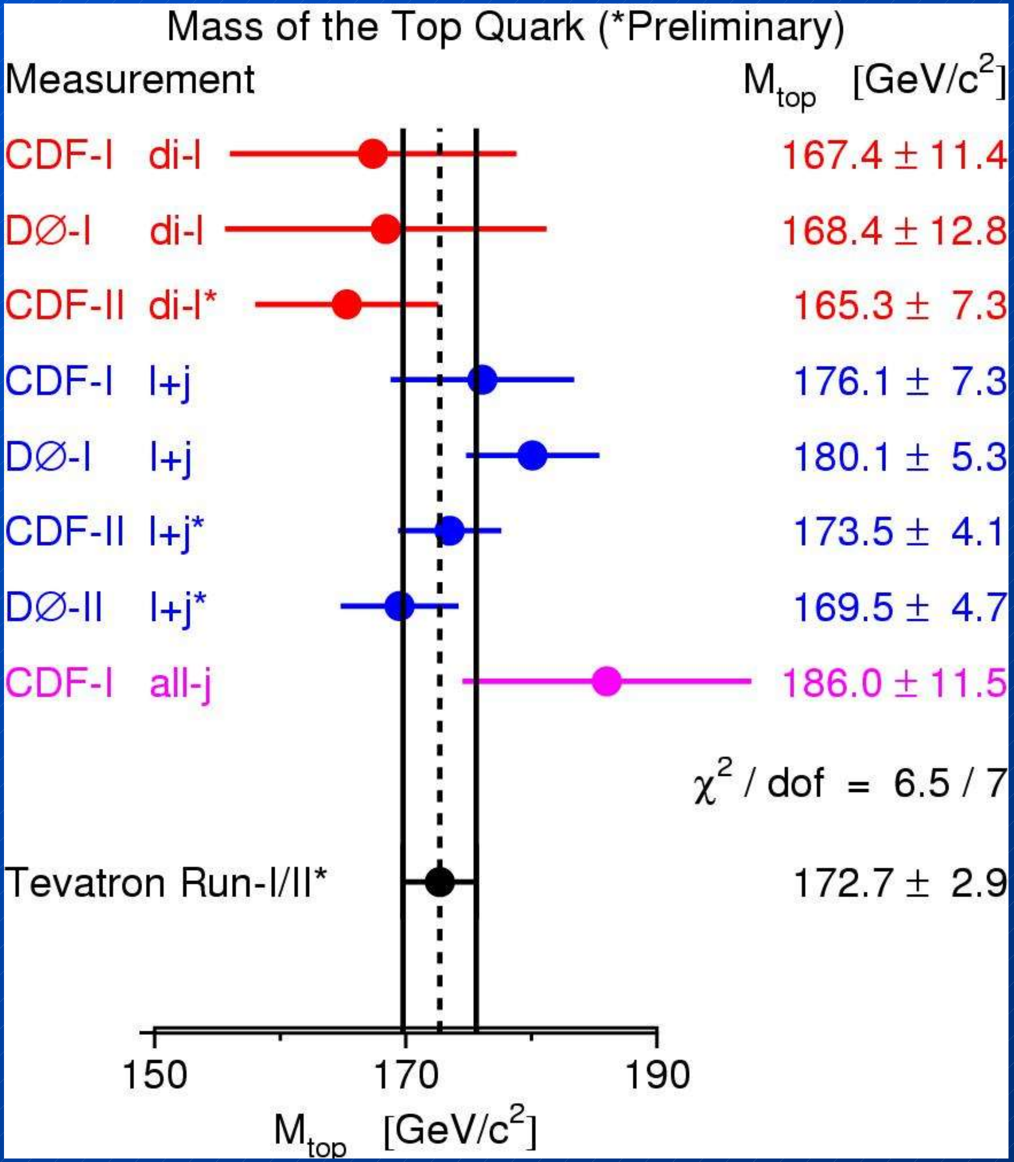
- MC modelling of W+jets background
- flavour composition in W+jets background
- JES (internal vs. external)
- b-JES vs. light quark JES
- MC events (ttbar and W+jets) in NLO
- LO vs. NLO matrix elements in ME/DLM method
- NLO PDFs with uncertainties
- Mtop combination in TEVEWWG needs **full information about correlation of all uncertainties** (channels, experiments, Run-I vs. Run-II ⇨ **should be planned in advance at LHC !!!**)

Top Mass Summary

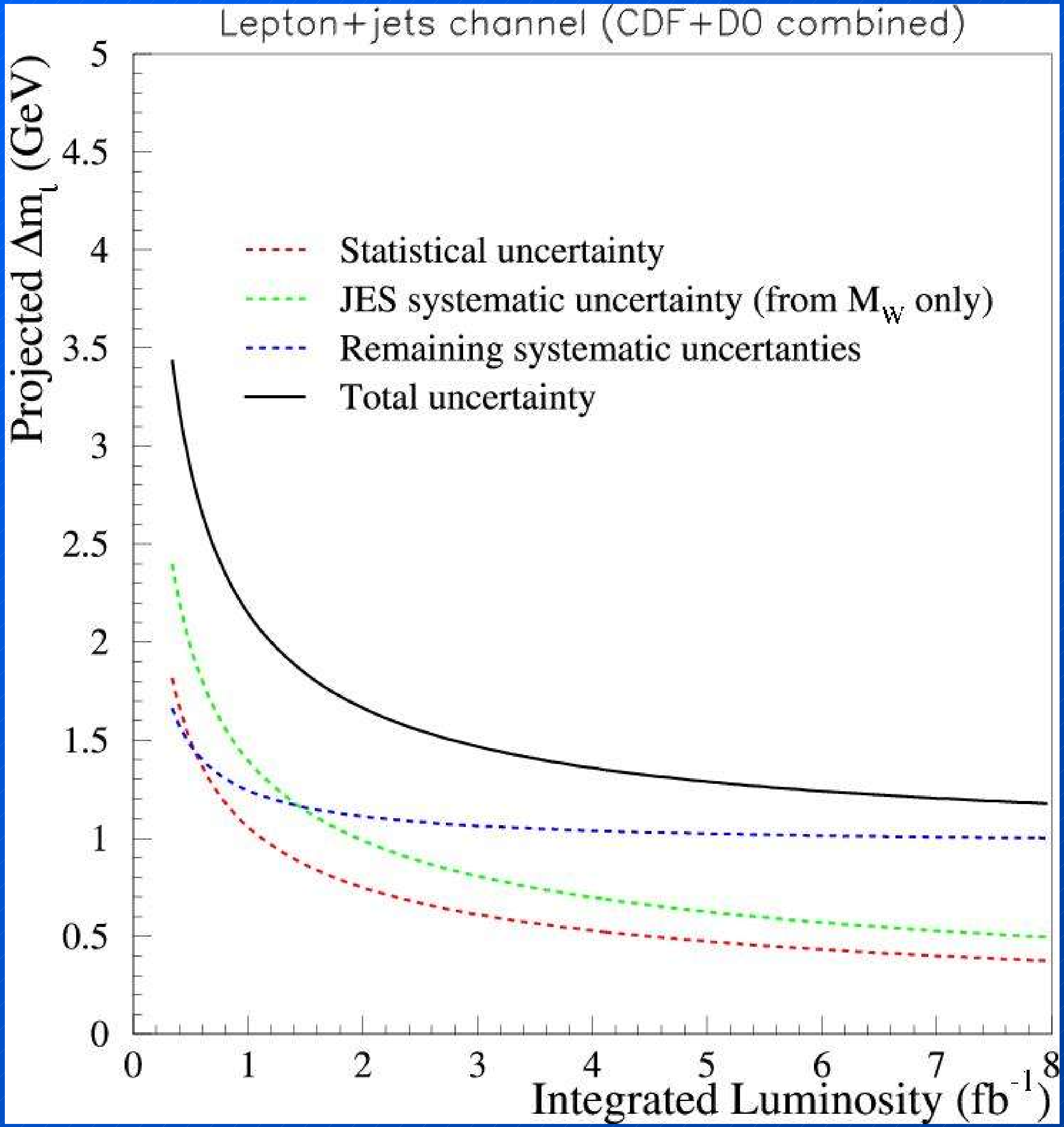
systematics limited:
- **jet energy scale**
- **ttbar modeling**
- **W+jets modeling**



TevEWWG (EPS2005):



Top Mass Outlook



- Tevatron could reach Δm_{top}=1 GeV/c^2 in combination of all channels and both experiments if ...
- ultimate precision in top mass from LHC and Tevatron expected to be comparable

Further
Top Quark Properties

Available Results & Ongoing Studies

Table of Top Property Results:

Measurement	Best Results	Dataset
Mass	173.4 +/- 2.8 GeV/c^2	680pb^{-1}
Cross Section	7.3 +/- 1.1 pb	760pb^{-1}
W Helicity	F_0 = 0.74+0.22-0.34	162pb^{-1}
W Helicity	F_+ < 0.18 @ 95%CL	109pb^{-1}
Top Charge	rule out +4/3 model @ 94%CL	365pb^{-1}
Resonance Searches	M_{x0} < 725 GeV/c^2	682pb^{-1}
Top Lifetime	$c\tau < 53\ \mu m$ @ 95%CL	318pb^{-1}
4th Generation t' Quark	196 < M(t') < 207 GeV/c^2 @ 95%CL	347pb^{-1}
Charged Higgs Searches	Limits on BR(t->H+b)	194pb^{-1}
Anomalous Kinematics	no high p_T excess	194pb^{-1}
BR(t->Wb) / BR (t->Wq)	> 0.61 @ 95%CL	162pb^{-1}
Single Top	s-channel: σ (tb) < 5.0 pb	370pb^{-1}
Single Top	t-channel: σ (tqb) < 4.4 pb	370pb^{-1}
Spin Correlation	κ > -0.25	125pb^{-1}
...	...	...

Summary

- Tevatron and Experiments performing well
- Top physics sensitivity as expected or better (mass)
- Search statistics limits, measurements already now

  systematics limited:

  LO vs. NLO

  W+Jets modelling (Q^2 scales, flavour fractions ...)

  jet-parton matching

  jet energy scale (light quarks, b-quarks, ...)

  correlated vs. uncorrelated uncertainties for combination