Expectations for Top Physics at CMS

IPM09, اصفهان (Isfahan)

Steven Lowette

University of California, Santa Barbara

Outline

- the top quark – a peculiar particle
- from the Tevatron to the LHC
- top physics with first data
- the top quark as a calibration tool
- measuring top quark properties
- the top quark as a probe for new physics

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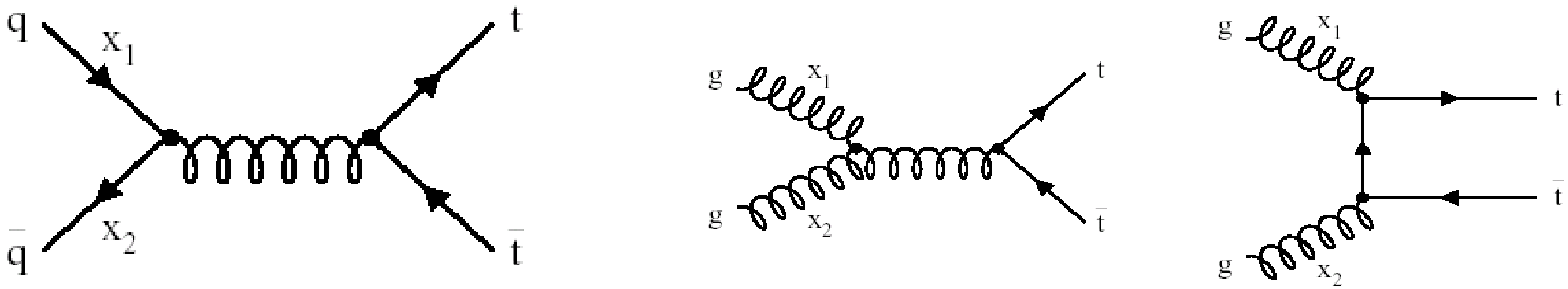
The top quark

- SU(2) partner of the b-quark, heavy brother of the up and charm quark
  - ➔ fermion, electrical charge 2/3
- discovered at the Tevatron in 1995
  - ➔ completes the third generation of fermions in the Standard Model
  - ➔ still the only place where the top quark was studied directly
- heaviest fundamental particle known: m_{top} = 173.1 ± 0.6 ± 1.1 GeV
  - ➔ precision of 0.7% !
- pair production cross section ~ 7 pb
  - ➔ only a few ten-thousands tops have been produced so far
- the top can also be produced alone
  - ➔ single top observation (5σ) came only less than 2 months ago from both DØ (arXiv:0903.0850) and CDF (arXiv:0903.0885)

Top pair production: the Tevatron versus the LHC

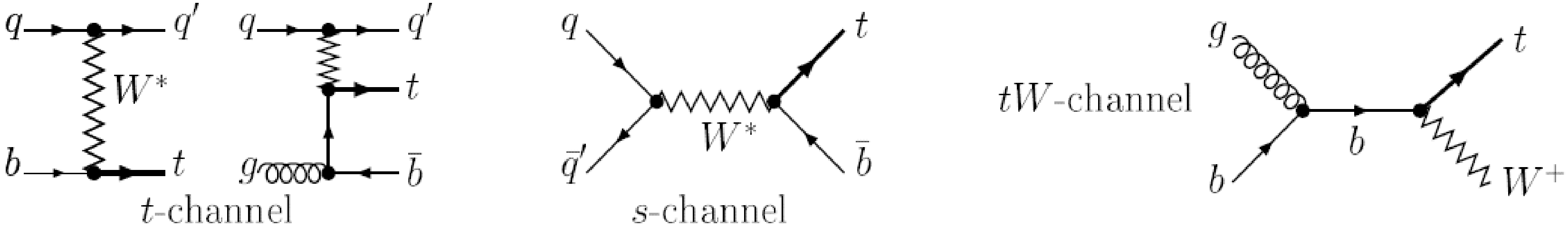
- production through the strong interaction
  - → Tevatron: ~ 7pb ; LHC (14TeV): ~ 830pb
- at the kinematic threshold for top pair production: $s_{hat} = x_1\ x_2\ s = (2m_t)^2$
  - → Tevatron: $x_1x_2 = 0.034$ -> <x> ~ 0.19 -> valence quarks dominant
  - → LHC (14TeV): $x_1x_2 = 0.0006$ -> <x> ~ 0.025 -> gluon sea dominant
- ttbar cross section is largest at the kinematic threshold
  - → Tevatron: dominated by ~ 85% qq->tt
  - → LHC (14TeV): the inverse: dominated by ~ 87% gg->tt



- Tevatron measurement: gg->tt / pp->tt < 0.38 (95% CL) (CDF link)

Single top production

- produced through the weak interaction
- three distinct production modes



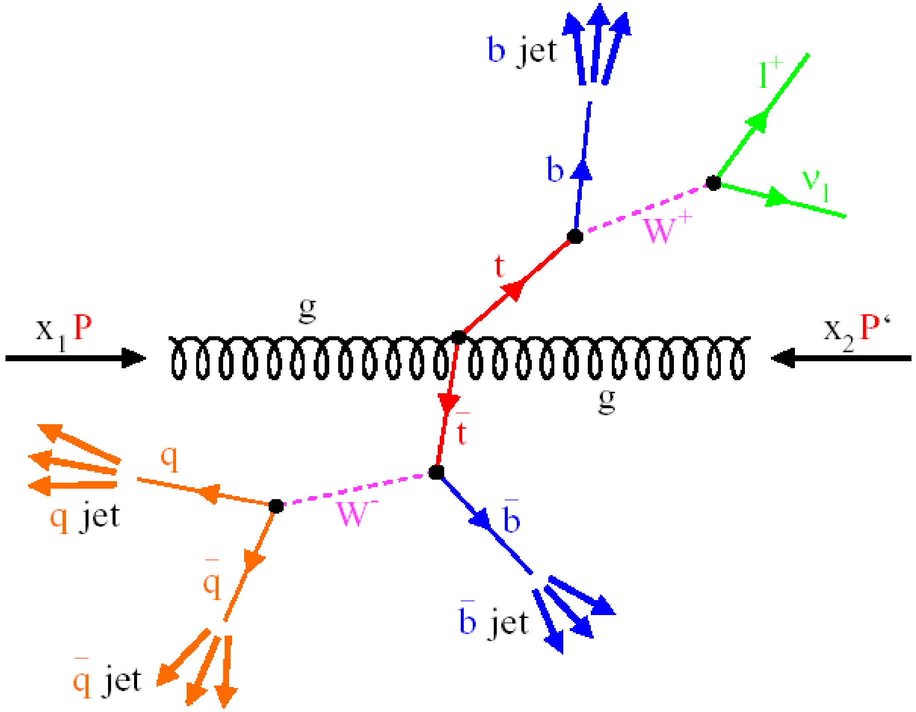
- LHC cross sections (14TeV)

	t-channel	s-channel	tW-channel
top	σ^{NLO} = 153 pb	σ^{NLO} = 6.6 pb	σ^{NLO} = 60 pb
anti-top	σ^{NLO} = 90 pb	σ^{NLO} = 4.1 pb	σ^{NLO} = 60 pb
Tevatron	x 120	x 10	x 400

- processes with gluons in the initial state become dominant at LHC
  - → best possibilities in t-channel: large cross section + forward quark
  - → tW-channel within reach
  - → s-channel very difficult

The top quark decay

- Standard Model prediction
  - lifetime $\tau = 0.4 \times 10^{-24}$ s
  - decay before hadronization
  - BR(t->Wb) ~ 100% ($|V_{tb}| \sim 1$)
- note: this prediction assumes
  - no additional quark families with $m_{b'} + m_W < m_t$
  - unitarity of the CKM matrix



- exploration of rare decays is a handle to new physics
- some limits set at Tevatron, often statistically limited
  - BR(t->Zq) < 3.7% (95% CL) (CDF link)
  - BR(t->H^+b) < 35% (95% CL) (D0 link)
  - BR(t->Wb)/BR(t->Wq) > 0.79 (95% CL)
    $|V_{tb}|$ > 0.89 (95% CL) if 3x3 CKM is unitary (D0 link)

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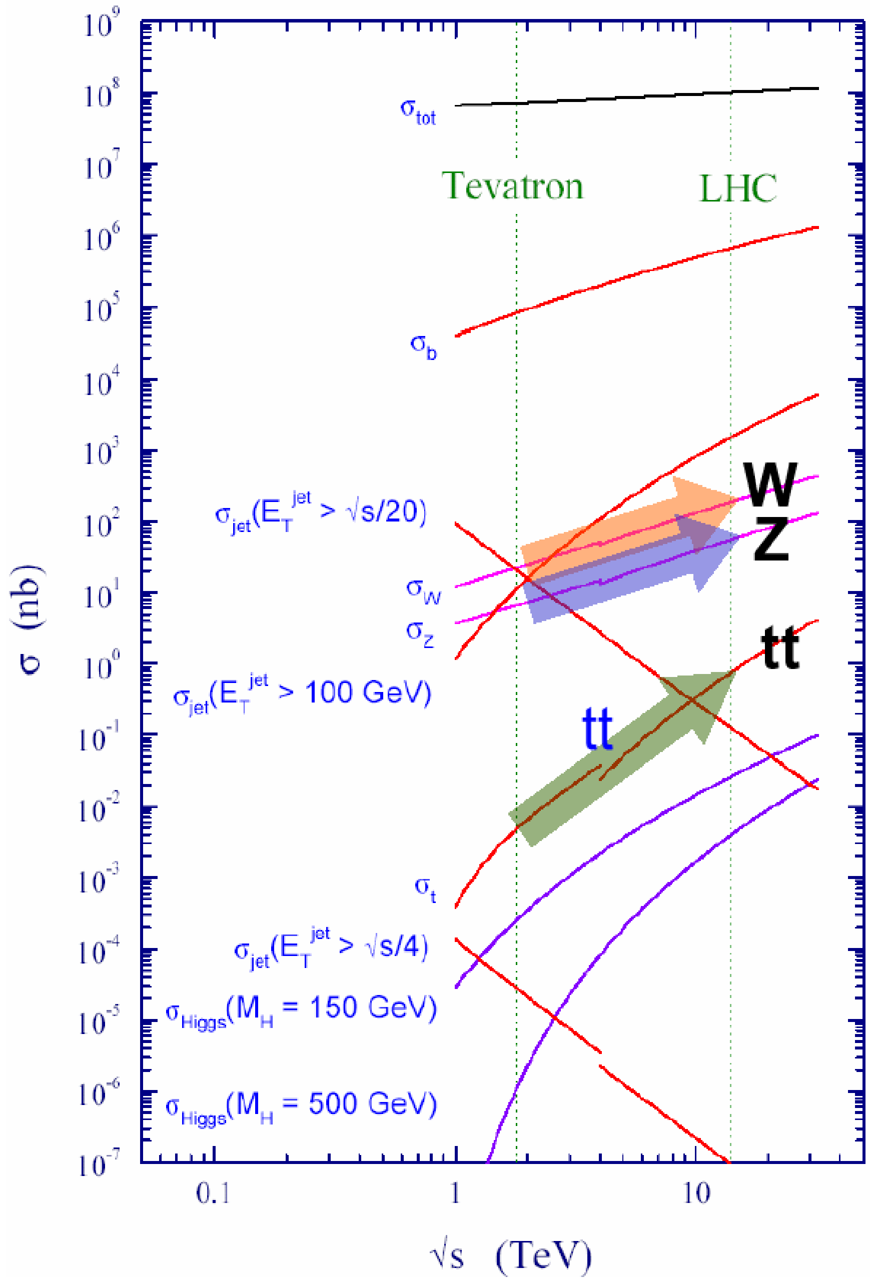
At the LHC, everything is "Large"

- "standard candles" are overwhelming
  - → W's: ~200/s ; Z's: ~50/s
- top quark rate huge: reaching 1/s
  - → Tevatron: thousands
  - → LHC: millions!

Process	Tevatron x-sec.	LHC x-sec. (14 TeV)	Tevatron to LHC
top pairs	7 pb	830 pb	x 120
single top s-channel	0.9 pb	11 pb	x 10
single top t-channel	2.0 pb	250 pb	x 120
single top tW-channel	0.15 pb	66 pb	x 400

- top quark physics at LHC allows precision measurements
- top quark events become standard candle themselves, providing control and calibration samples



From the Tevatron to the LHC

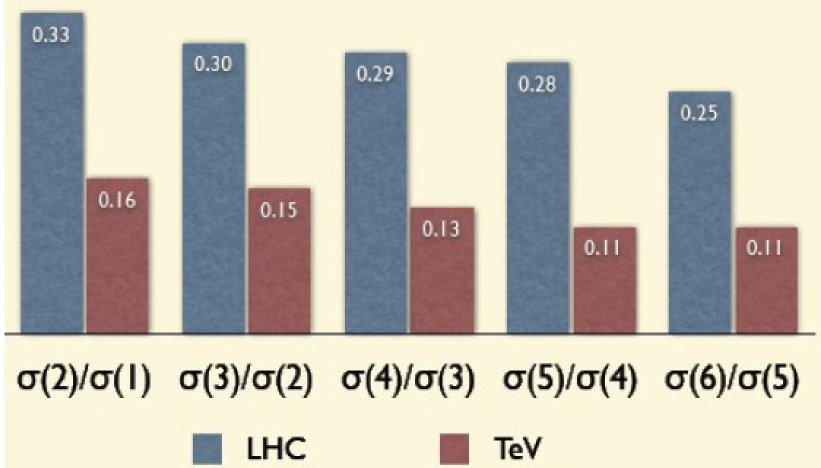
- σ(tt) grows more rapidly than QCD, W and Z cross sections as a function of the center-of-mass energy
- so backgrounds are expected negligible?
  - → no! argument only works inclusively...
- example: W+jets
  - → σ(W) increases with a factor ~10
  - → σ(W+4jets) with a factor ~100
- also LHC will need to control QCD, W+jets,...

M. Mangano

W+Multijet rates

σxB(W→eν)[pb]	N jet=1	N jet=2	N jet=3	N jet=4	N jet=5	N jet=6
LHC	3400	1130	340	100	28	7
Tevatron	230	37	5.7	0.75	0.08	0.009

E_T(jets) > 20 GeV , |η|<2.5 , ΔR>0.7



- Ratios almost constant over a large range of multiplicities
- O(α_s) at Tevatron, but much bigger at LHC

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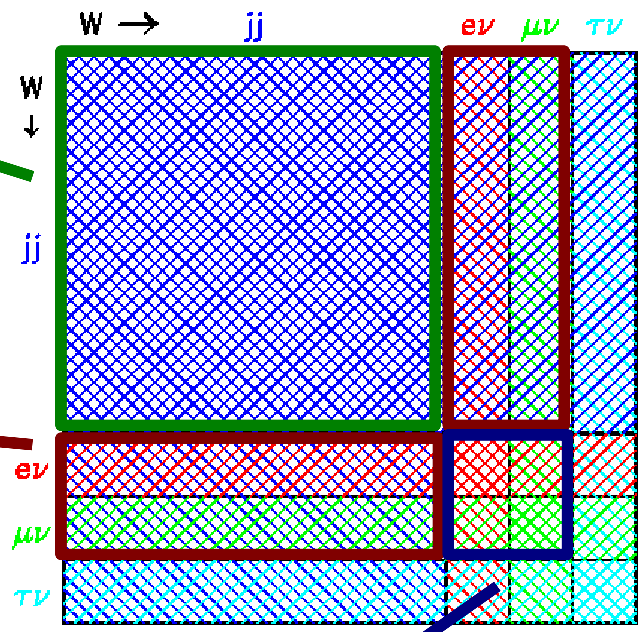
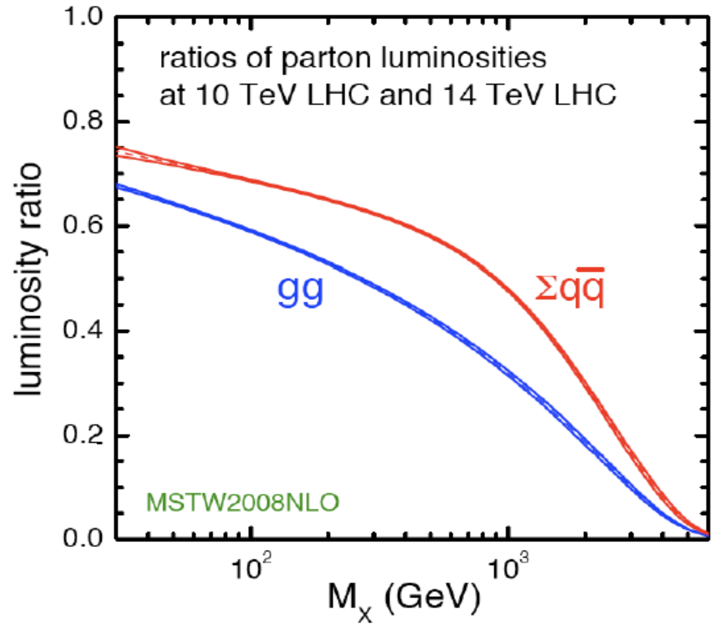
A feeling of a 10 fb^{-1} LHC analysis with top pairs

from CMS Physics TDR Vol. II, 2006

- Fully hadronic decay channel
  - 3.7M ev/10fb^{-1}
  - main background: QCD multijet
  - 6 jets E_T>40GeV, 2 b-tags
    - S/B ~ 1/19 for 2.7% eff.
- Lepton + jets decay channel (e/mu)
  - 2.5M ev/10fb^{-1}
  - main background: W+multijet, ~no QCD
  - lepton p_T>20GeV, 4 jets E_T>30GeV, 2 b-tags
    - S/B ~ 26 for 6.5% eff.
- Dilepton decay channel (e/mu)
  - 0.4M ev/10fb^{-1}
  - main background: Z+jets, WW, no QCD
  - lepton (1|2) p_T>(35|25)GeV, MET>40GeV, 2 jets E_T>25GeV
    - S/B ~ 10 for 20% eff.



LHC Chamonix workshop aftermath



- LHC will run at 10TeV c.o.m. energy
- year-long run in 2009-2010:
  deliver ~200/pb good collisions to experiments
- quark-initiated processes gain importance

- how does the picture change for top physics?

$$\frac{\sigma(t\bar{t})\ \text{at 14 TeV}}{\sigma(t\bar{t})\ \text{at 10 TeV}} = 2.3$$

  → typical acceptances in ttbar found to be the same

- what about the backgrounds? only really relevant for lepton+jets

$$\frac{\sigma(W)\ \text{at 14 TeV}}{\sigma(W)\ \text{at 10 TeV}} = 1.4$$

  but not clear how W+4 jets scales...

  → probably pessimistic; Tevatron rejects more with similar selection

- bottomline: factor 2 loss in cross section for similar background rejection
- all results in the remainder of the talk are for 14TeV collisions

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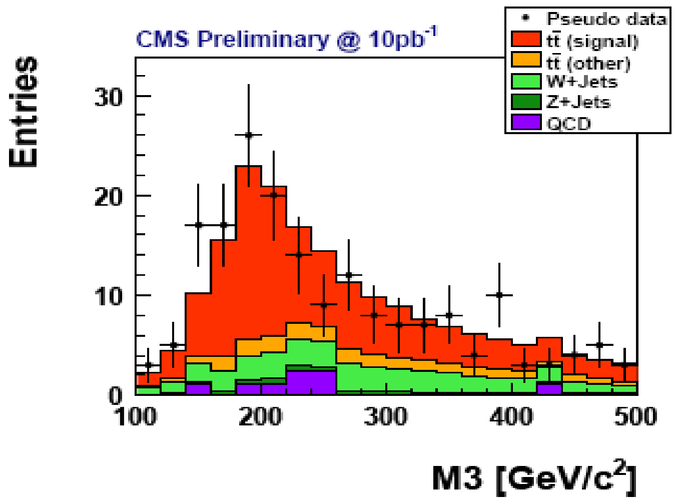
Rediscovery of the top quark

- much more statistics with 10/pb than used for the original top discovery
- but the detector and hence physics objects will not be well understood
  - → need simple, robust methods for event selection
    - e.g. high thresholds to avoid not-well controlled noise
    - MET and b-tagging will probably not be sufficiently understood
- a mass peak from lepton+jets is much easier to establish than a cross section deviation as a function of number of jets
  - → but also here no advanced kinematic methods can be employed to select which jets to combine, because JES will not be well known
  - → no mass measurement, so mass doesn't need to be at the right value
- top rediscovery with 10 pb^{-1} in lepton+jets

CMS PAS TOP-08-005

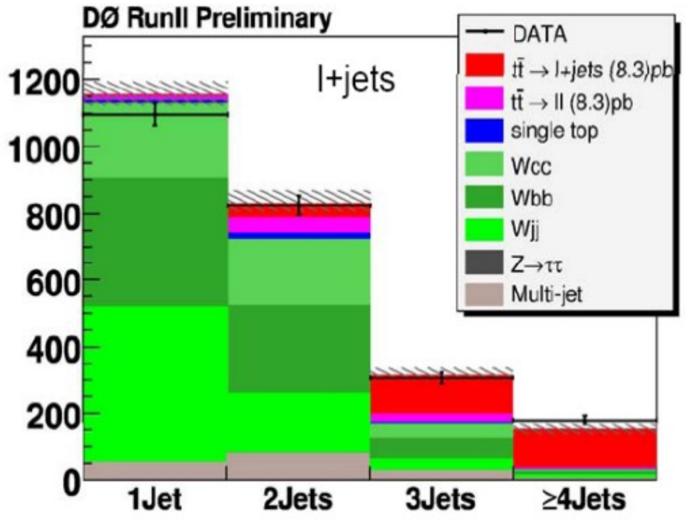
  - → hard isolated muon
  - → 4 hard jets
  - → angular muon-jet separation
  - → top mass from 3 jets with highest ΣE_T
    - yields ~35% correct assignment



Intermezzo: on measuring cross sections

- cross section measurements seem easy in principal
  - select events with some cuts
  - subtract your expected background contribution
  - count the obtained number of events
  - extract cross section folding in selection and trigger eff.'s and luminosity
- event selection: not just a set of random cuts
  - needs to be simple -> avoid unnecessary uncertainties
  - but needs to efficiently reduce backgrounds and systematics
- estimating backgrounds: the difficult part
  - one should always aim for data-driven techniques
  - defining and understanding control samples can be difficult, extrapolation to signal region must be proved to work, uncertainties must be assessed
- translating back to cross section
  - less difficult as long as you stick to default cuts -> efficiencies and uncertainties will be obtained for you
  - otherwise there's a lot of work in this as well, for instance in the trigger

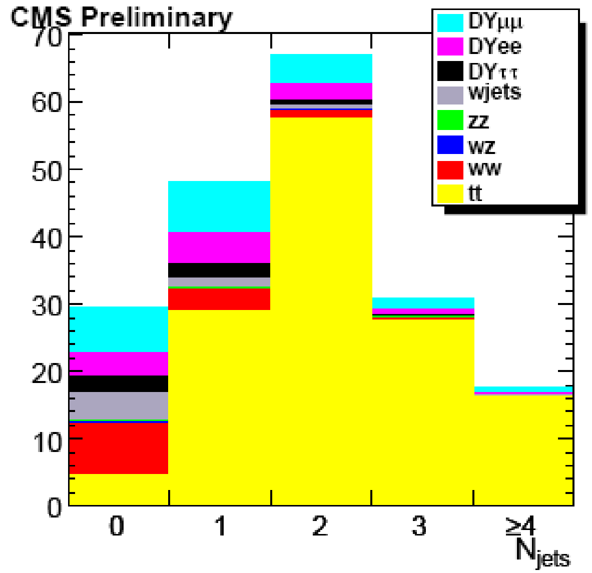
- the result of a cross section analysis can typically be summarized in 1 plot
  - → # events as a function of # jets, comparing MC expectations to data
  - → proving signal, backgrounds and control regions are well understood
  - → a lot of work in 1 number and 1 plot!



Cross section measurements in early data

- example: ttbar dilepton cross section with 10/pb
  - → ee, μμ and eμ channels each an analysis themselves
  - → Z->dilepton is the main background
  - → 0 and 1 jet bins crucial to prove understanding of backgrounds in control region
  - → expected statistical uncertainty O(10%)
  - → comparable systematics anticipated; work ongoing

CMS PAS TOP-08-001

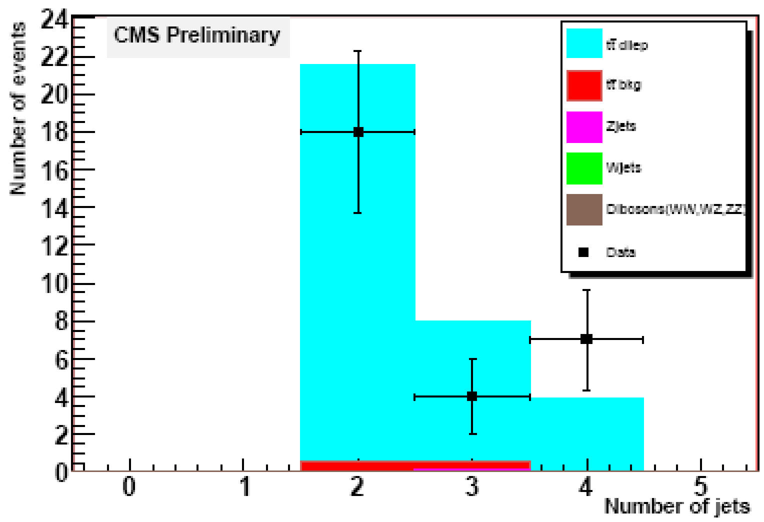


Control of the QCD background

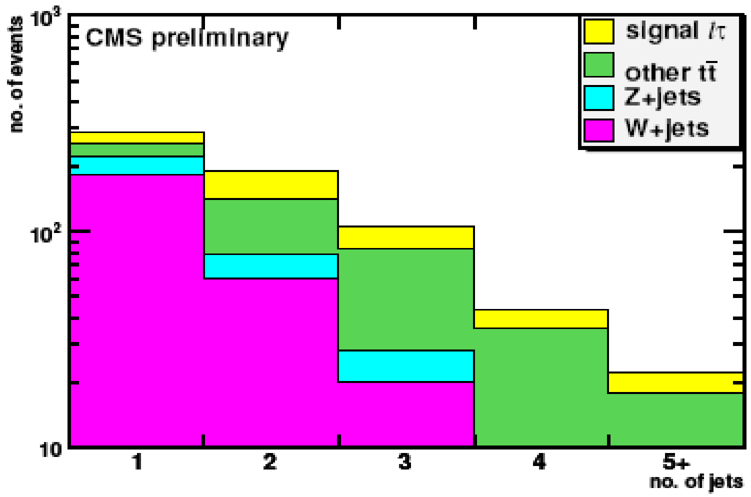
- example of one background study as part of a cross section measurement
- QCD multijet events can look like top events
  - → when a real lepton within a jet looks as if it is isolated
  - → when weird jet or misreconstruction "fake" a lepton (esp. electrons)
- both effects are rare (but QCD cross section is huge!)
  - → impossible to model reliably in simulations
  - → need to estimate from data the amount of QCD passing the selection cuts
- several methods being developed
  - → "ABCD": use low MET and/or bad Iso to predict high MET, low Iso
  - → similar: isolation vs $p_{T,lepton}$ or $d_{0,muon}$
  - → ad-hoc method of extrapolation of the Iso variable in the signal region
  - → all these methods have their drawbacks and limits, but can probably be sufficient for this small QCD contamination, allowing large uncertainties
- area of large activity! [also as part of the CMS V+jets group]

Cross section measurements with 100/pb

- detector will be a bit better understood
  - → alignment and calibrations, MET cleanup, first b-tag efficiency measurements
- and 10x more statistics!
- both allow a much cleaner selection of the signal events of interest



- example 1: CMS PAS TOP-08-002
  - → top -> dilepton, using b-tagging



- example 2: CMS PAS TOP-08-004
  - → top -> tau-jet + electron/muon + large MET
- differentiation of larger jet multiplicities is interesting for MC tuning and searches with multi-jets, like in SUSY

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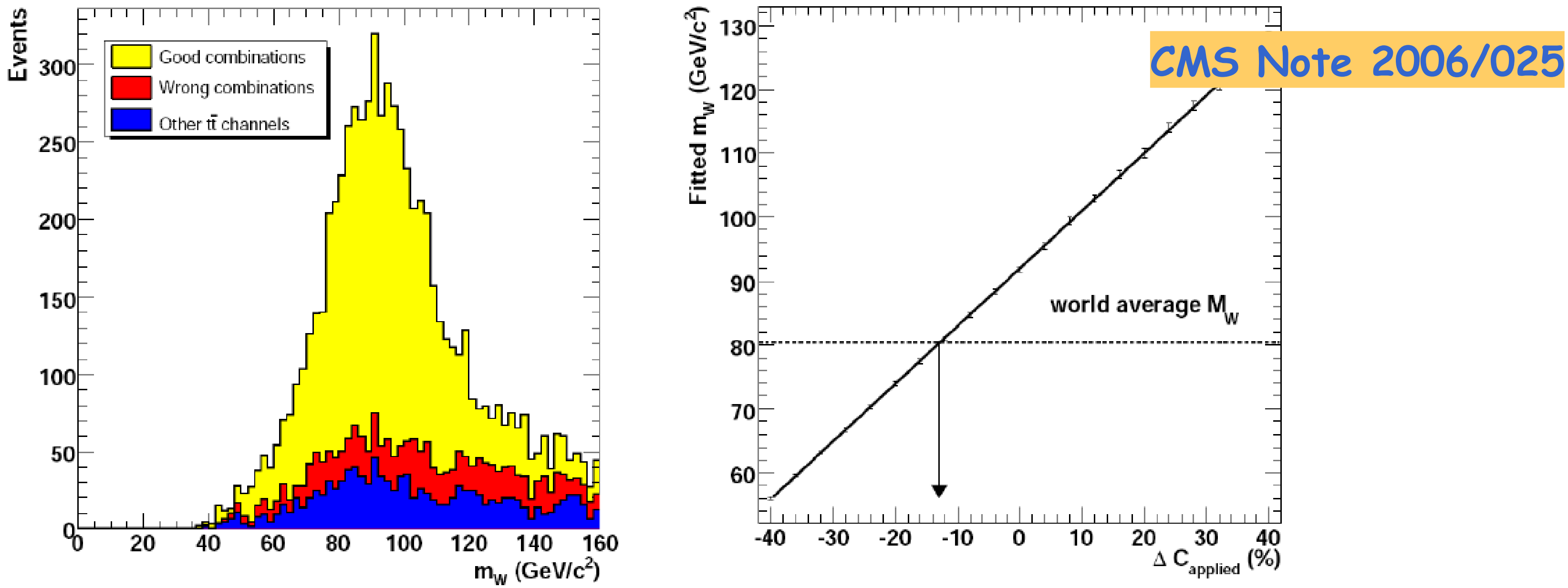
Jet energy scale calibration using the W-mass constraint

- reconstructed hadronic W mass in lepton+jets events is sensitive to jet energy scale of light quark jets
- imposing the W-mass it is possible to determine the JES corrections down to the parton level
- needed correction for true W mass scales linear with initial miscalibration

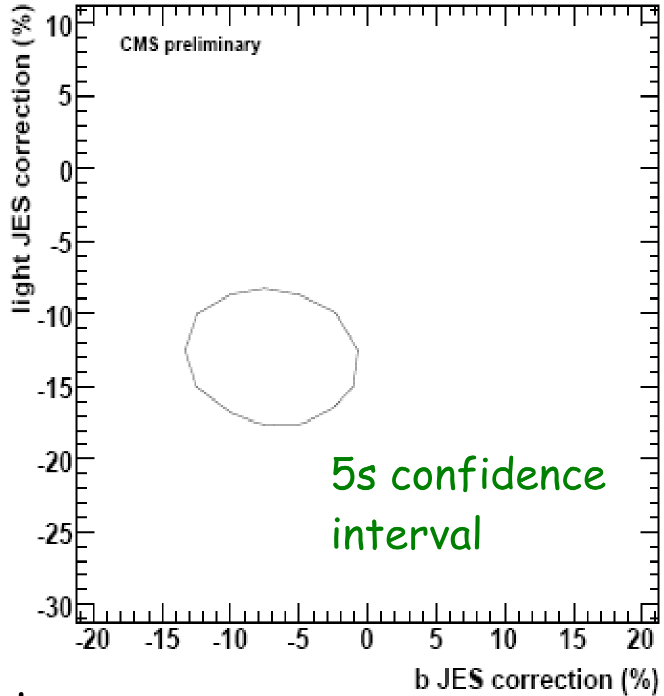


- top quarks will be the most important JES calibration sample at the LHC

Extension to calibration of b-jet energy scale

CMS PAS TOP-08-002

- full kinematic fit imposes W and top mass on 3 well-paired jets
- miscalibrations are applied on all 3 jets to scan for the JES corresponding to the true W and top mass
- closure test on MC ok, no significant bias expected
- systematics
  - pile-up -> can be monitored via primary vertex count
  - effect combinatorial and non-ttbar background negligible
  - effect from jet energy resolution negligible
- expected performance
  - ~1% statistical uncertainty on JES for light and b-jets
- this is inclusive, can be differentiated versus p_T,$|\eta|$
- detailed understanding of pile-up – JES interplay crucial



B-Tagging Efficiency Measurement

CMS Note 2006/013

- b-jet-rich samples are selected in ttbar e+mu, mu+jets and e+jets events
  - → challenges in selecting a pure b-jet sample come from both process backgrounds and combinatorial background
- extraction of b-tagging efficiencies from b-jet samples
  - → apply any b-tag algorithm on a selected data sample -> fraction x_{tag} tagged
  - → estimate sample's b-tag purity x_b and mistag probability ε_0 from MC

$$\epsilon_b = \frac{1}{x_b}\left[x_{tag} - \epsilon_o (1 - x_b)\right]$$

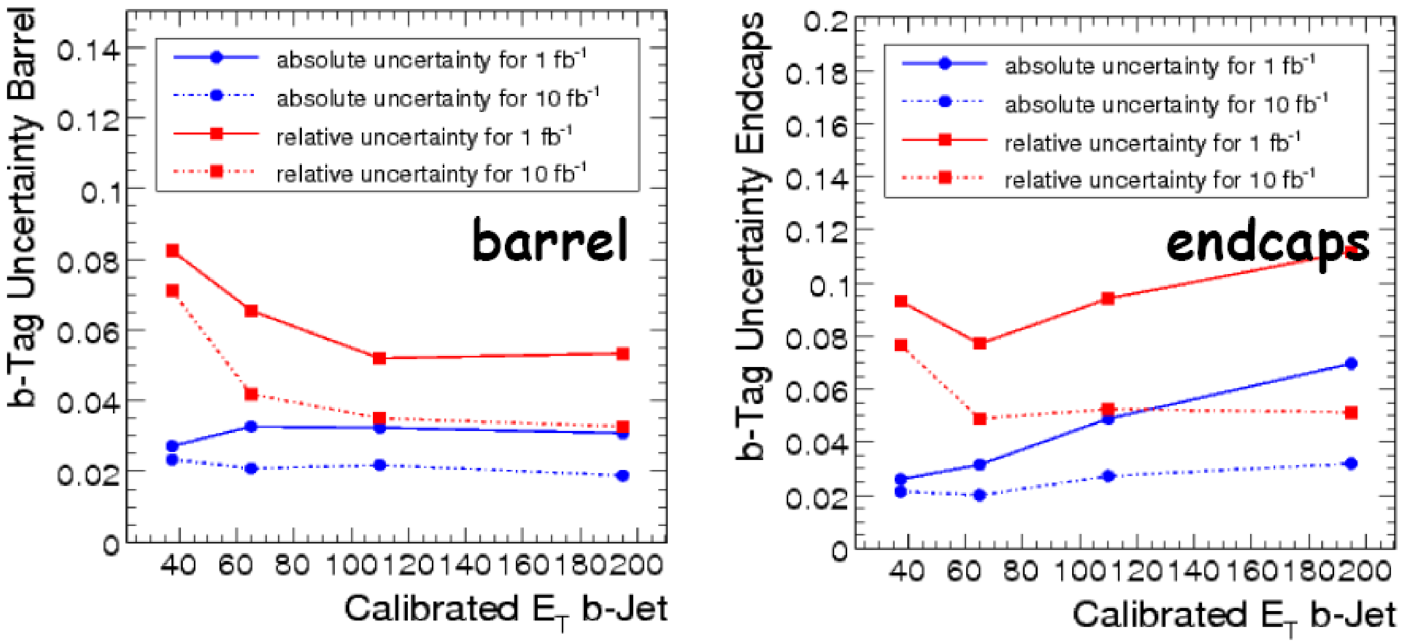
from data, contributes statistical uncertainty (x_{tag})

from MC shown not to contribute additional systematics (ϵ_o)

from MC, systematics determined as function of likelihood ratio cut (x_b)

- systematics
  - → by far dominated by uncertainties on initial state gluon radiation
  - → we will need LHC data or better Monte-Carlo to improve
  - → no systematics from misalignment -> this is in fact measured
  - → systematics decrease as the purity of selected samples is increased!

- differentiation versus p_T and η possible with $1fb^{-1}$ of data
- three samples are exclusive and similar -> can be combined



- top events will provide the most important b-tagging efficiency calibration samples at the LHC
- new methods are in the works, especially to measure c-jet and possibly light jet efficiencies simultaneously

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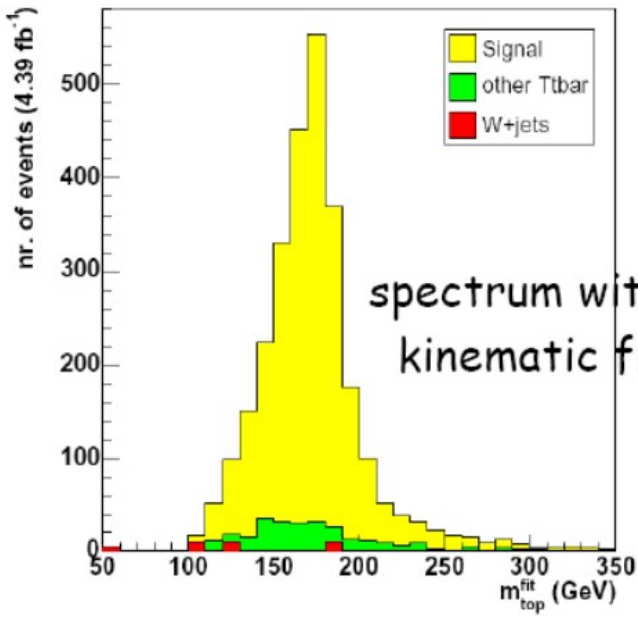
Top mass strategies in the golden channel

CMS Note 2006/066

- lepton + jets event selection: efficiency ~6%
  - 1 isolated lepton and 4 jets, of which 2 b-tagged
  - extra cuts on kinematic fit, jet combination likelihood and signal/background separation likelihood
- mass reconstruction performed for the hadronically decaying top
  - leptonic side used for determination of the best jet association
- estimators studied:
  - Gaussian fit on the reconstructed top mass peak
  - parameterized ideogram
    - an event-by-event pdf as a function of the top mass, with top mass uncertainty calculated from fit and assumed Gaussian
  - full scan ideogram
    - the event-by-event top mass resolution function is now built by scanning with an additional top mass constraint in the kinematic fit
  - details in the backup



spectrum with kinematic fit

Systematics for the top mass in the golden channel

- most of the following table consists of ambitious detector systematics

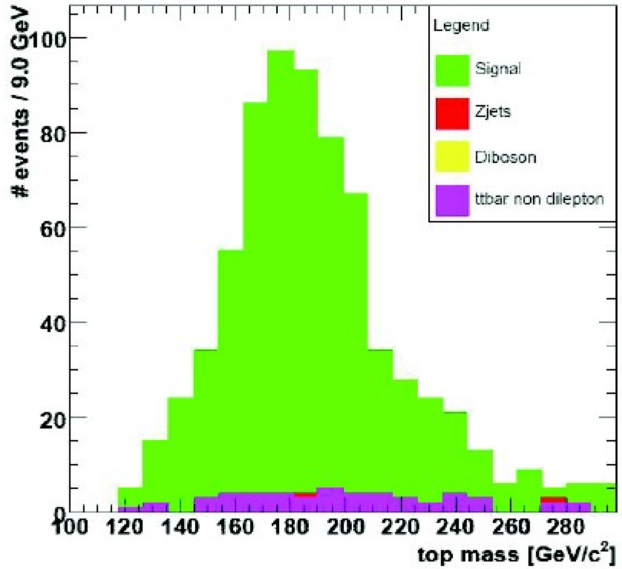
	Standard Selection		
	Gaussian Fit Δm_t (GeV/c²)	Gaussian Ideogram Δm_t (GeV/c²)	Full Scan Ideogram Δm_t (GeV/c²)
Pile-Up *(5% On-Off)*	0.32	0.23	0.21
Underlying Event	0.50	0.35	0.25
Jet Energy Scale *(1.5%)*	2.90	1.05	0.96
Radiation (pQCD)	0.80	0.27	0.22
Fragmentation	0.40	0.40	0.30
b-tagging *(2%)*	0.80	0.20	0.18
Background	0.30	0.25	0.25
Parton Density Functions	0.12	0.10	0.08
Total Systematical uncertainty	3.21	1.27	1.13
Statistical Uncertainty (10fb^{-1})	0.32	0.36	0.21
Total Uncertainty	3.23	1.32	1.15

- main uncertainty from the b-jet energy scale
- to reach 1 GeV uncertainty we need a very good detector understanding
  - → the more recent CMS studies indicate that this should indeed be possible

Top mass from the di-lepton decay channel

CMS Note 2006/077

- event selection similar to cross section
- kinematics underconstrained, but indirect mass reconstruction possible
- most important systematic from jet energy scale (also neutrino modeling)
  - → expected 4.2/2.9/1.0 GeV for 1/10/>10 fb^{-1}
- systematics dominated already for 1 fb^{-1}



Top mass from the fully hadronic decay

- all kinematics measured
- needs to trigger on b-jets
- jet pairing: 6 possible combinations after b-tag
- need to deal with multi-jet background
- systematics the main problem, again...
- needs very good detector understanding and advanced analysis techniques

	Δm_t[GeV/c^2]
Pile Up	0.4
Underlying Event	0.6
PDF	1.4
IS/FS Radiation	2.3
Fragmentation	0.9
Jet Energy Scale	2.3
b-Tagging	0.3
Background	2.0
Statistical (1fb^{-1})	0.6

IS/FS Radiation: due to pairing ambiguities

Jet Energy Scale: mainly from b-jet scale

Top mass from b->J/Ψ->μμ decays

CMS Note 2006/058

- top mass is correlated to $m_{J/\Psi\ell}$, for J/Ψ and lepton from same top
- "only" involving leptons
  - → very good mass resolution
  - → orthogonal systematics, mostly theoretical: fragmentation, Λ_{QCD},...
- but low statistics this time! BR(tt->J/ΨℓX) ~ 5.5 10^{-4} -> 4500 per $10fb^{-1}$
  - → and don't forget trigger, reconstruction and pairing efficiencies
- this mass determination only becomes useful at high luminosity

Top mass from b decay length

hep-ex/0501043

- top mass is correlated to decay length of the B-meson decay in the b-jet
- currently gaining importance at the Tevatron
- "only" involving tracks
  - → orthogonal systematics, mostly theoretical: fragmentation, Λ_{QCD},...
- not explored yet for CMS! statistics no problem, best at low luminosity

CMS PAS in preparation

Constraining V_{tb} through the R = t->Wb / t->Wq ratio

- test of the standard model (unitarity of the CKM matrix)
  - → sensitive to anomalous decays or a 4th fermion generation
- complement of the b-tagging efficiency measurement in ttbar events
- analysis strategy
  - → standard event selection for ttbar lepton + 4 jets
  - → choose a working point for b-tagging
  - → determine the distribution of the number-of-b-tags (0 up to 4)
  - → fit this distribution to the expectation, with R and mistag rate as free parameters and b-tag efficiency from an independent measurement
- background subtraction can be made data-driven
- main systematics expected from the b-tagging efficiency and the jet energy scale and resolution
- analysis under review, public results expected soon

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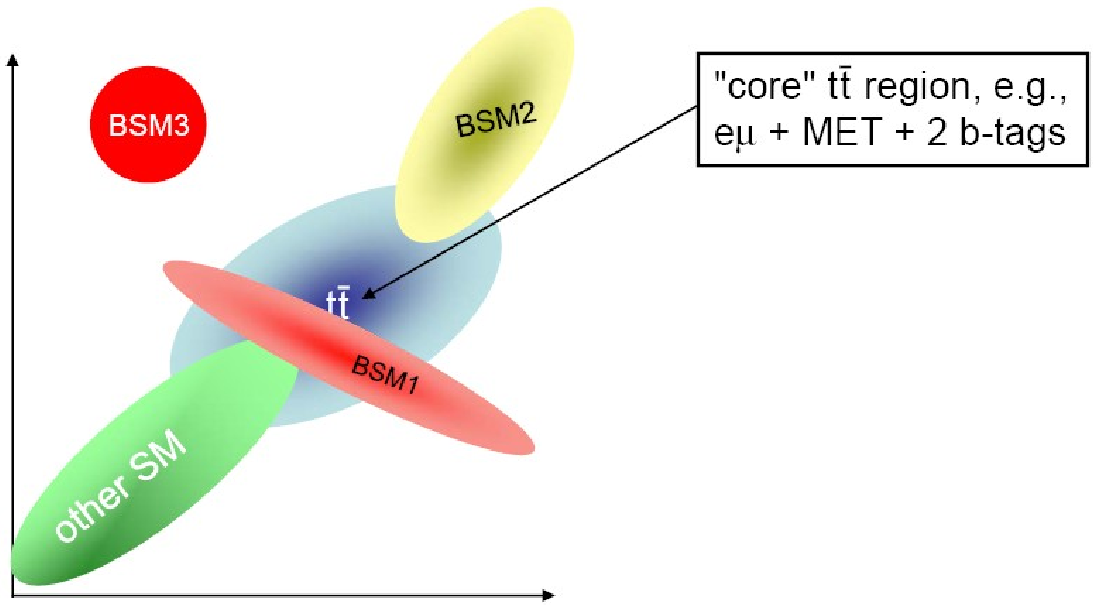
Top physics as integral part of a CMS discovery program

- top events live in some multi-dimensional space of event requirements
- SM backgrounds populate a separate, but not completely disjoint region
- in a simplified picture, new physics can
  - → strongly overlap with the core ttbar region (BSM1)
  - → be only affected by the tail of ttbar (BSM2)
  - → be almost totally distinct (BSM3)



- first task: prove to ourselves that we understand the control regions
- then ask: is the ttbar sample consistent with the ttbar hypothesis
  - → opens up a broad search for ttbar physics early on

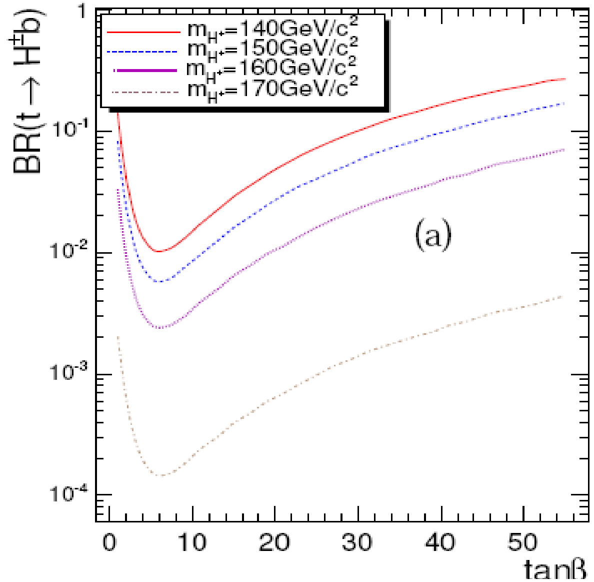
New physics in top-related differential distributions

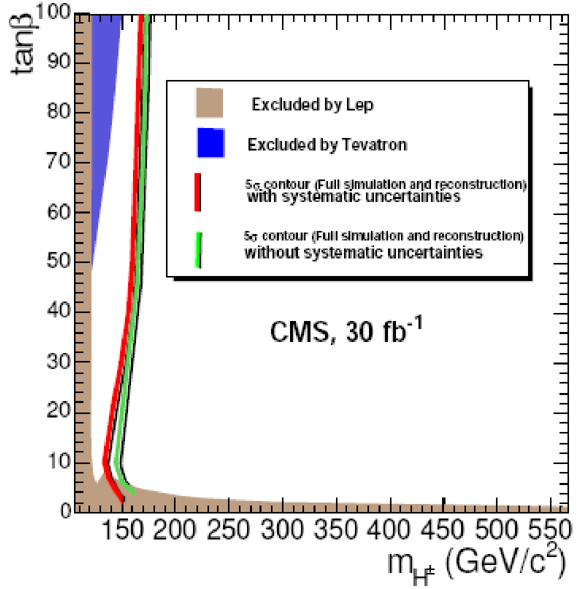
- examples of such distributions include m_{tt}, $p_{T,top}$, H_T
- the Tevatron provides constraints up to relatively low scales
- at the LHC we can go to scales of several TeV
  - → e.g. high-mass resonances in the m_{tt} spectrum, from MSSM, RS,...
  - → these are not necessarily long-term studies
- at such scales we will need to deal differently with top quarks
  - → the high boost will collimate the decay products of top quarks into so-called "top jets" -> can be reconstructed summing all energy in large cones
  - → leptons lose their isolation -> needs different trigger approaches
- first studies are proceeding
  - → last year a working group was started on highly-boosted top quarks in CMS
  - → currently the use of a dedicated boosted-top jet-algorithm is under review

Charged Higgs observability in top decays

CMS Note 2006/056

- charged Higgs $H^{\pm}$ bosons arise in models with 2 Higgs doublets, like MSSM
  - → fully described at tree level by 2 parameters: tanβ and $m_{H\pm}$
- channel of interest:
  - $t\bar{t} \to WbH^{\pm}b$, $W \to \ell\nu$
  - with $H^{\pm} \to \tau\nu$ (BR ~ 98%) and $\tau \to$ hadrons
- selection: 1 muon/electron, 1 tau jet, at least 3 jets, exactly 1 b-tag, hard MET cut
- systematics from b & tau tagging, ttbar knowledge,...
  - → no data-driven methods yet though
  - → analysis currently systematics dominated
- the LHC will allow exploration up to the top mass for high tanβ
  - → smooth transition to $m_{H+} > m_t$



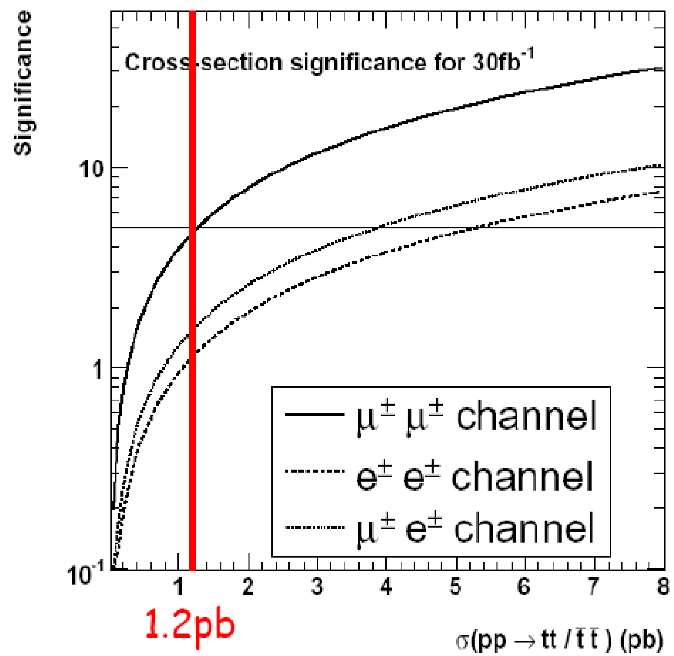


Search for an excess of same-charge top pairs

CMS Note 2006/065

- corresponds to a search for a same-charge signal with ttbar kinematics
- fully leptonic final states considered: mu+mu, e+mu and e+e
  - simple selections: two leptons and two b-jets
- wrongly charged leptons can be fakes or charge mis-id'd leptons
  - mu+mu is the most powerful channel
- analysis looks for a deviation of the $R = N_{++,--} / N_{+-}$ ratio
  - $1 fb^{-1}$: $R_{\mu\mu} = 0.0027 \pm 0.0007$ (stat)
  - most systematics cancel in ratio
  - systematics from tau's and Z+jets uncertainties negligible, and none expected from knowledge of charge mis-id
- same-sign signal reach depends directly on integrated luminosity
- much better results can be obtained working in specific models

significance vs. SS tt x-sec.



New physics in rare top decays

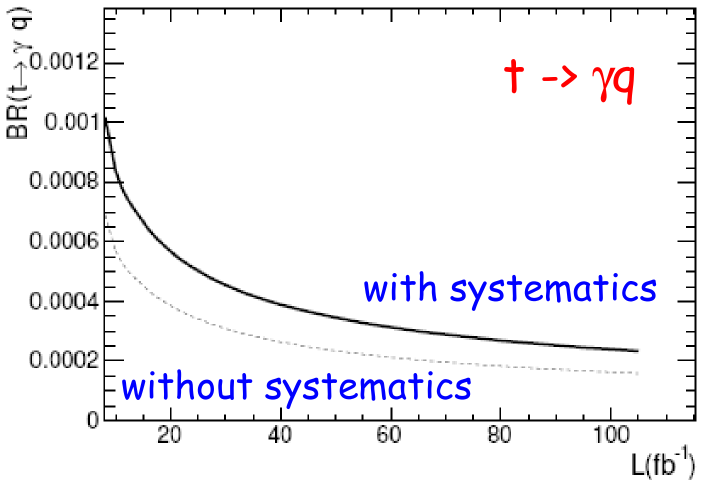
CMS Note 2006/093

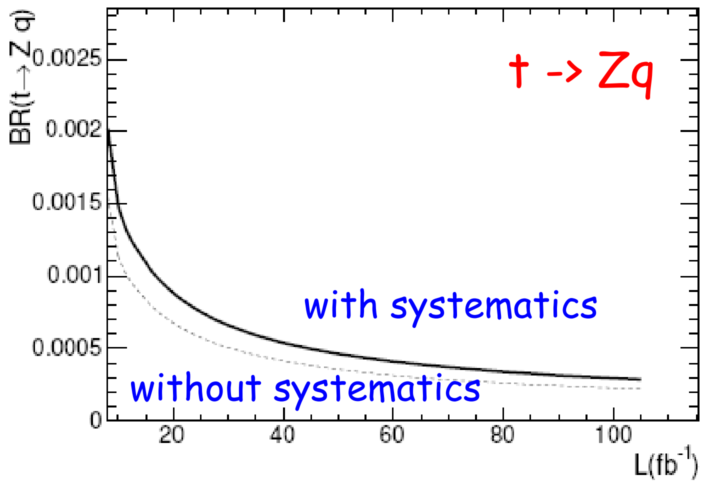
- beyond the SM, rare top decays through loops can become sizable

Decay	SM	two-Higgs	SUSY with $R\!\!\!/$	Exotic Quarks	Exper. Limits(95% CL)
$t \to gq$	5×10^{-11}	$\sim 10^{-5}$	$\sim 10^{-3}$	$\sim 5 \times 10^{-4}$	< 0.29 (CDF+TH)
$t \to \gamma q$	5×10^{-13}	$\sim 10^{-7}$	$\sim 10^{-5}$	$\sim 10^{-5}$	< 0.0059 (HERA)
$t \to Zq$	$\sim 10^{-13}$	$\sim 10^{-6}$	$\sim 10^{-4}$	$\sim 10^{-2}$	< 0.14 (LEP-2)

<0.037 (CDF)

- selections devised to isolate ttbar events with one top in a rare decay
  - → need to select as little ttbar, single top,... as possible
- expected sensitivity:





- statistically limited in the beginning, but great potential in the long run

Conclusions

- top quarks provide a very rich physics program at the LHC
  - SM measurements in the top sector
  - calibrations
  - beyond the SM searches
- early day top physics will be exciting
  - many analyses become accessible in the first LHC year, some immediately
  - ideal playground to acquire understanding of the complete CMS detector
- top quark physics should be seen as an essential part of an global CMS discovery program
  - top physics is omnipresent in CMS, as a signal, as a background or as a playground for tools and calibrations

Backup

Backup

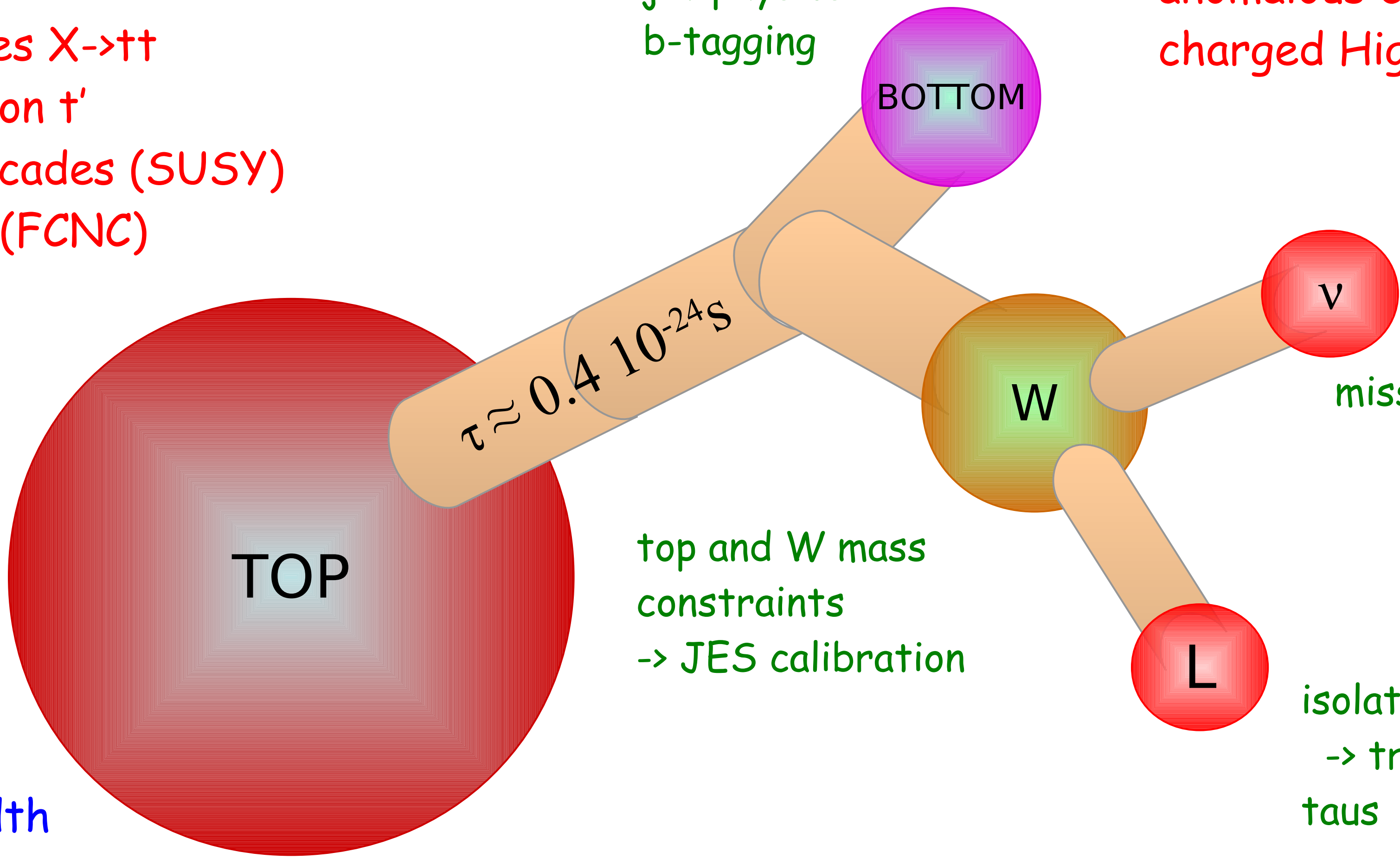
PRODUCTION

cross section - kinematics
pair production - single top
spin-correlations
heavy resonances X->tt
fourth generation t'
new physics cascades (SUSY)
flavour physics (FCNC)

DECAY

W helicity
CKM matrix elements
anomalous couplings
charged Higgs

jet physics
b-tagging



missing energy

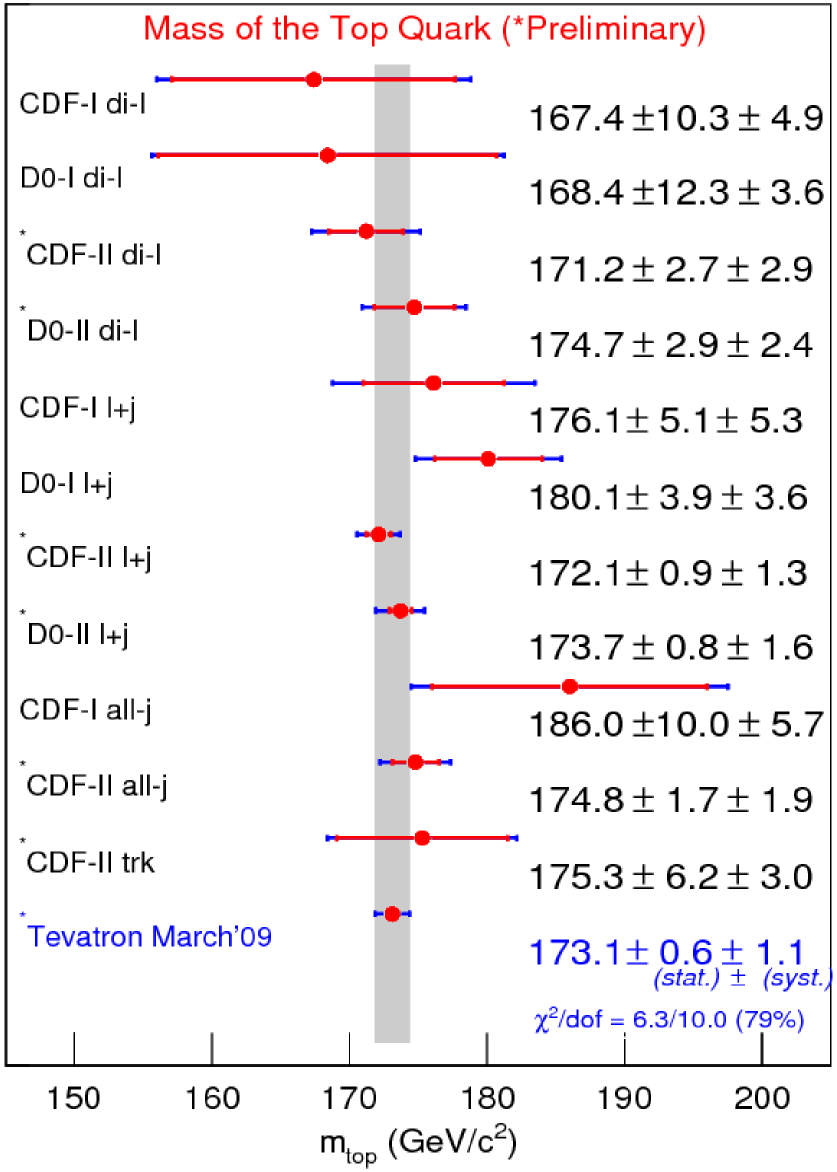
top and W mass
constraints
-> JES calibration

isolated lepton
-> trigger
taus

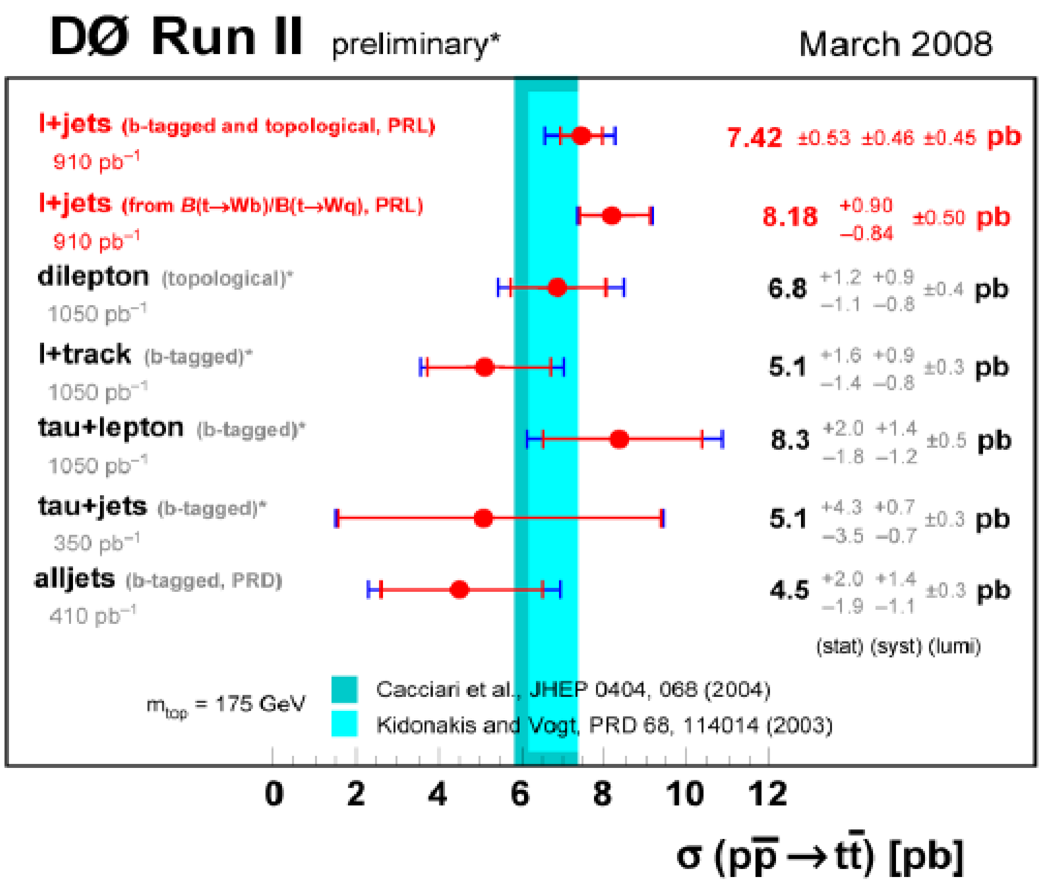
PROPERTIES

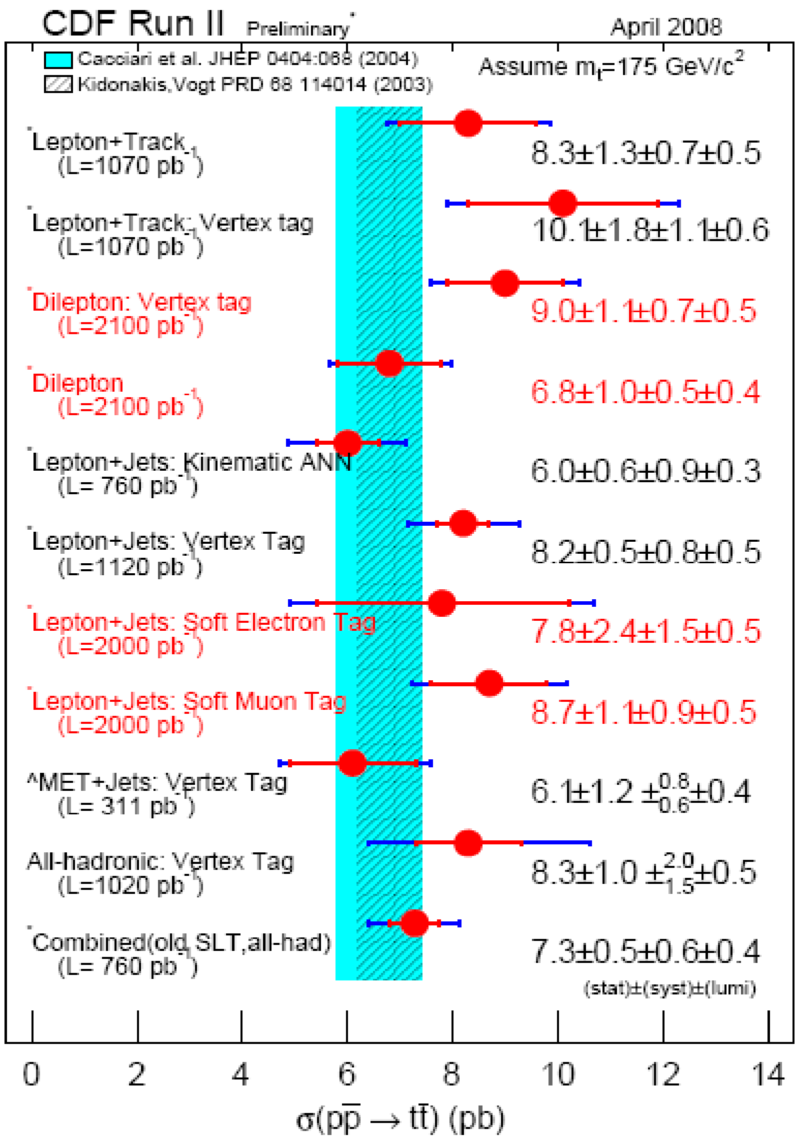
mass
charge
lifetime and width
spin

Backup



Mass of the Top Quark (*Preliminary)
CDF-I di-l
167.4 ±10.3 ± 4.9
D0-I di-l
168.4 ±12.3 ± 3.6
*CDF-II di-l
171.2 ± 2.7 ± 2.9
*D0-II di-l
174.7 ± 2.9 ± 2.4
CDF-I l+j
176.1 ± 5.1 ± 5.3
D0-I l+j
180.1 ± 3.9 ± 3.6
*CDF-II l+j
172.1 ± 0.9 ± 1.3
*D0-II l+j
173.7 ± 0.8 ± 1.6
CDF-I all-j
186.0 ±10.0 ± 5.7
*CDF-II all-j
174.8 ± 1.7 ± 1.9
*CDF-II trk
175.3 ± 6.2 ± 3.0
*Tevatron March'09
173.1 ± 0.6 ± 1.1
(stat.) ± (syst.)
χ²/dof = 6.3/10.0 (79%)
150
160
170
180
190
200
m_top (GeV/c²)

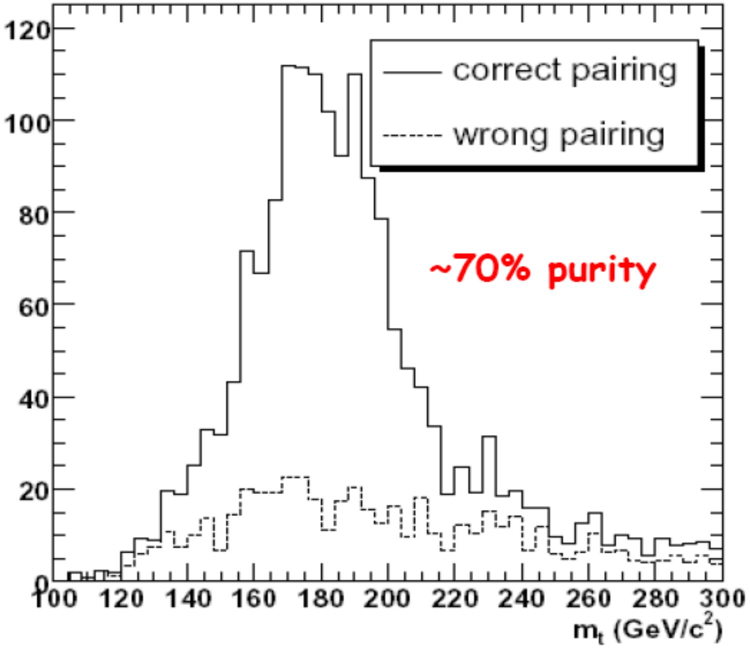

DØ Run II preliminary*
March 2008
l+jets (b-tagged and topological, PRL) 910 pb⁻¹ 7.42 ±0.53 ±0.46 ±0.45 pb
l+jets (from B(t→Wb)/B(t→Wq), PRL) 910 pb⁻¹ 8.18 +0.90 −0.84 ±0.50 pb
dilepton (topological)* 1050 pb⁻¹ 6.8 +1.2 −1.1 +0.9 −0.8 ±0.4 pb
l+track (b-tagged)* 1050 pb⁻¹ 5.1 +1.6 −1.4 +0.9 −0.8 ±0.3 pb
tau+lepton (b-tagged)* 1050 pb⁻¹ 8.3 +2.0 −1.8 +1.4 −1.2 ±0.5 pb
tau+jets (b-tagged)* 350 pb⁻¹ 5.1 +4.3 −3.5 +0.7 −0.7 ±0.3 pb
alljets (b-tagged, PRD) 410 pb⁻¹ 4.5 +2.0 −1.9 +1.4 −1.1 ±0.3 pb
(stat) (syst) (lumi)
m_top = 175 GeV
Cacciari et al., JHEP 0404, 068 (2004)
Kidonakis and Vogt, PRD 68, 114014 (2003)
0 2 4 6 8 10 12
σ (pp̄→tt̄) [pb]

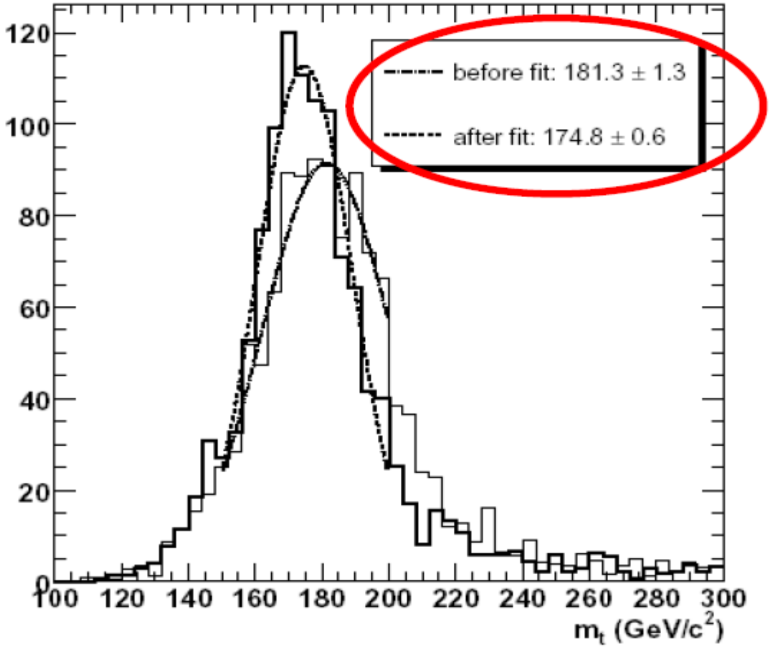

CDF Run II Preliminary
April 2008
Cacciari et al. JHEP 0404:068 (2004)
Kidonakis,Vogt PRD 68 114014 (2003)
Assume m_t=175 GeV/c²
Lepton+Track (L=1070 pb⁻¹) 8.3±1.3±0.7±0.5
Lepton+Track; Vertex tag (L=1070 pb⁻¹) 10.1±1.8±1.1±0.6
Dilepton: Vertex tag (L=2100 pb⁻¹) 9.0±1.1±0.7±0.5
Dilepton (L=2100 pb⁻¹) 6.8±1.0±0.5±0.4
Lepton+Jets: Kinematic ANN (L= 760 pb⁻¹) 6.0±0.6±0.9±0.3
Lepton+Jets: Vertex Tag (L=1120 pb⁻¹) 8.2±0.5±0.8±0.5
Lepton+Jets: Soft Electron Tag (L=2000 pb⁻¹) 7.8±2.4±1.5±0.5
Lepton+Jets: Soft Muon Tag (L=2000 pb⁻¹) 8.7±1.1±0.9±0.5
MET+Jets: Vertex Tag (L= 311 pb⁻¹) 6.1±1.2 +0.8 −0.6 ±0.4
All-hadronic: Vertex Tag (L=1020 pb⁻¹) 8.3±1.0 +2.0 −1.5 ±0.5
Combined(old SLT,all-had) (L= 760 pb⁻¹) 7.3±0.5±0.6±0.4
(stat)±(syst)±(lumi)
0 2 4 6 8 10 12 14
σ(pp̄ → tt̄) (pb)

A few words on kinematic fitting

CMS Note 2006/023

- using kinematic fit techniques, constraints (like mass, momentum balance,...) can be enforced on the reconstructed event topology
- here a linearized least-square method with Lagrange multipliers was used
  - ➔ part of the CMSSW PhysicsTools packages
- example: top mass when W mass enforced in the t->Wb->qq'b decay

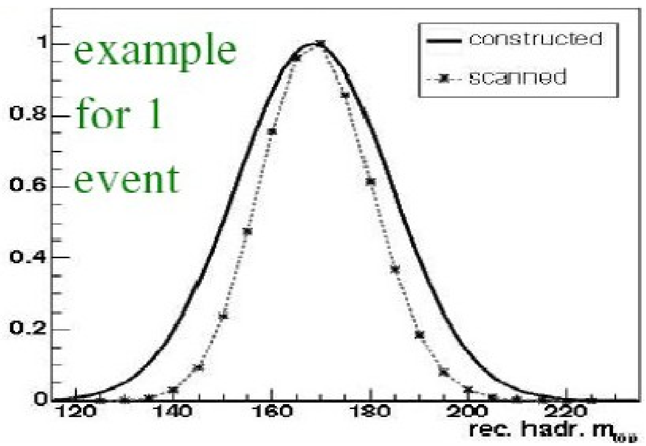




- to obtain the same precision without the fit, 5 times more data is needed

More details on ideograms

- For each event an ideogram $I(\{p_i\}|m_{top})$ can be defined as a probability function to measure the observed parameters $\{p_i\}$ given a certain mass m_{top}
- method 1: this ideogram can be assumed Gaussian, with σ_{m_fit} calculated from the fitted jet covariance matrices:
  → $I(\{p_i\}|m_{top}) \sim \exp[-0.5\,(m_{fit}-m_{top})^2/\sigma_{m\_fit}{}^2]$
- method 2: the ideogram can be scanned imposing different m_{top} hypotheses as an extra constraint in the fit:
  → $I(\{p_i\}|m_{top}) \sim \{P_{m\_top}(\chi_{fit}{}^2)\}$ with m_{top} = 125, 135, ... , 225 GeV



inclusion of b-jet kinematics in the kinematic fit results in a better ideogram resolution

Backup

- to go from the experimental space m_{top} to the theoretical space M_{top}, the ideogram of an event is convoluted with a theoretically expected template function $T(m_{top}|M_{top})$:

  $$\rightarrow L_i(M_{top}) = \int I(\{p_i\}|m_{top}) \,.\, T(m_{top}|M_{top})\, dm_{top}$$

- where

  $$\rightarrow T(m_{top}|M_{top}) = P^{signal} \,.\, [\, P^{comb} \,.\, BW(m_{top}|M_{top}) + (1-P^{comb}) \,.\, B^{comb}(m_{top}) \,] + (1-P^{signal}) \,.\, B^{channel}(m_{top})$$

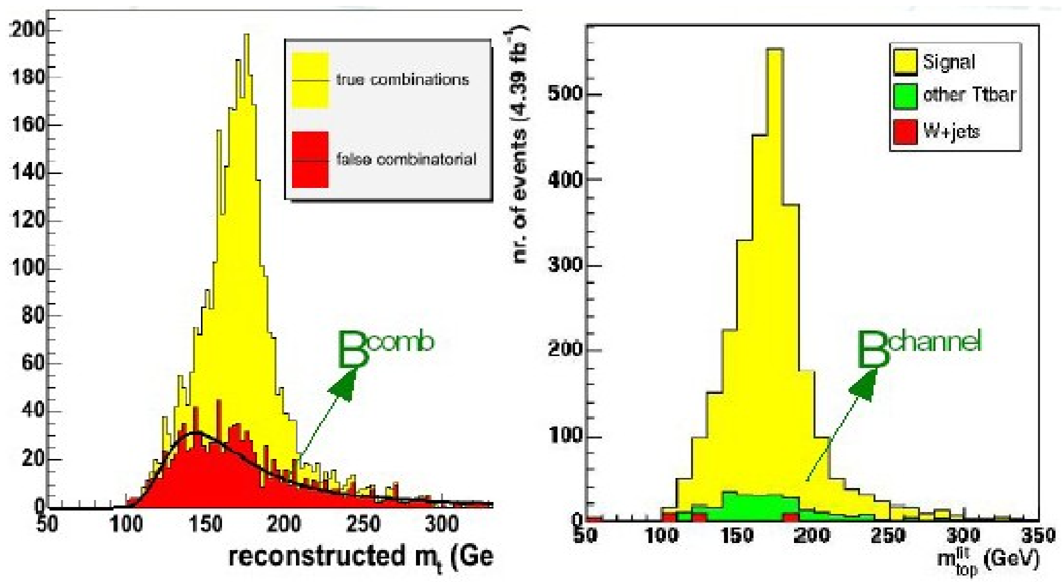
- finally all the event-by-event likelihoods are combined

  $$\rightarrow L_{tot}(M_{top}) = \Pi_i\, L_i(M_{top})$$

- and the minimum of

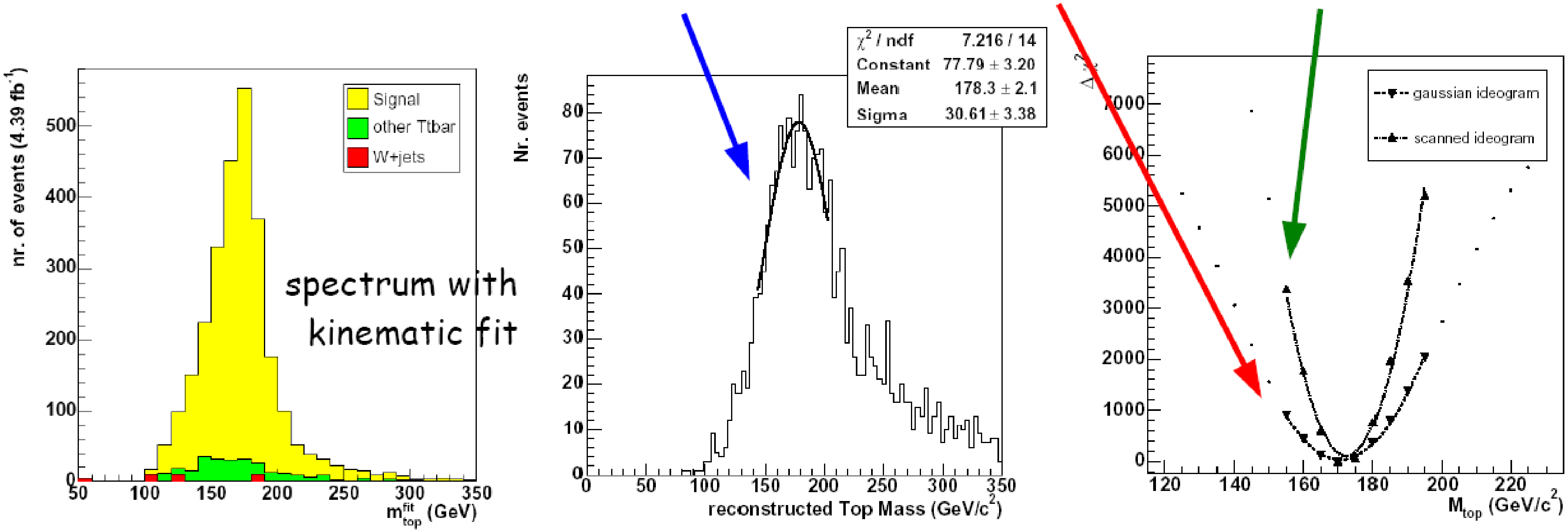
  $$\chi^2 = -2 \ln L_{tot}$$

  gives the best estimate for the top mass



Top mass results in the golden channel

- comparison estimators: Gaussian fit, Gaussian ideogram, scanned ideogram

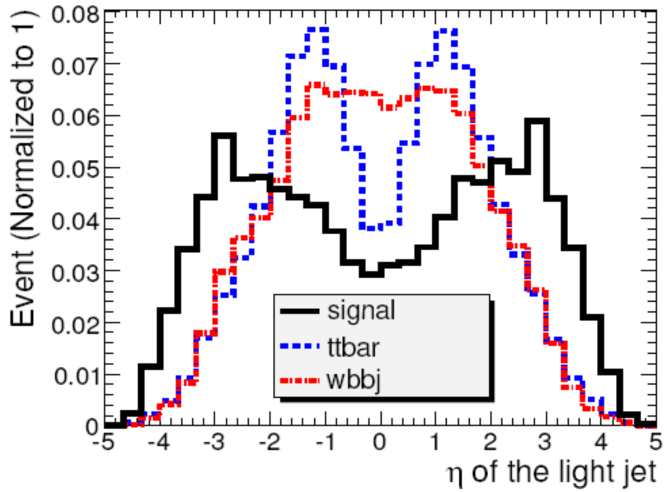


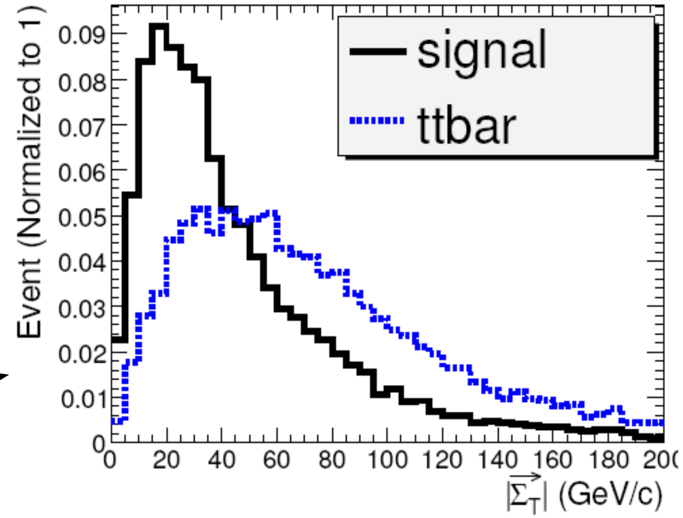
	Gaussian Fit	Gaussian Ideogram	Full Scan Ideogram
Bias (GeV/c^2)	-0.84±0.59	-4.35±0.54	-2.58±0.31
Pull	0.82	1.01	1.01
Expected uncertainty for 1fb^{-1} (GeV/c^2)	1.01	1.14	0.66
Expected uncertainty for 10fb^{-1} (GeV/c^2)	0.32	0.36	0.21

Single top t-channel cross section measurement

CMS Note 2006/084

- best results at the LHC are expected in the process where a W is exchanged in the t-channel
  - ➔ distinct signature of a forward light jet
  - ➔ presence of a lepton, MET and b-jet from single top decay
  - ➔ no ambiguity in reconstructing the top
  - ➔ backgrounds from ttbar, W+jets and QCD multi-jet
- selection involves
  - ➔ standard lepton, MET and b-jet cuts
  - ➔ suppression of backgrounds with a forward jet requirement
  - ➔ wide W transverse mass and top mass window cut
  - ➔ suppression of the ttbar background in particular with a total transverse momentum requirement





Backup

- expected number of events after 10fb^{-1}
  - signal ttbar Wbbj Wjj
  - 2389 1188 195 402
- QCD estimated <8% of total background
- uncertainties for 10fb^{-1}
  - statistical uncertainty: 3%
  - estimation main systematics (theory, b-tagging, JES): 8%
  - luminosity: 5%
- no background estimations from data yet, starts from theory calculations

Other single top channels

CMS Note 2006/086

- tW channel: accessible at 10fb^{-1}
  - both dilepton and semi-leptonic decays possible; di-lepton cleanest
  - ttbar is the major background by far, several times larger than the signal
- s channel: very challenging
  - very large backgrounds from ttbar and single top itself