Experimental Top Physics

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EXCELENCIA SEVERO OCHOA

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Outline

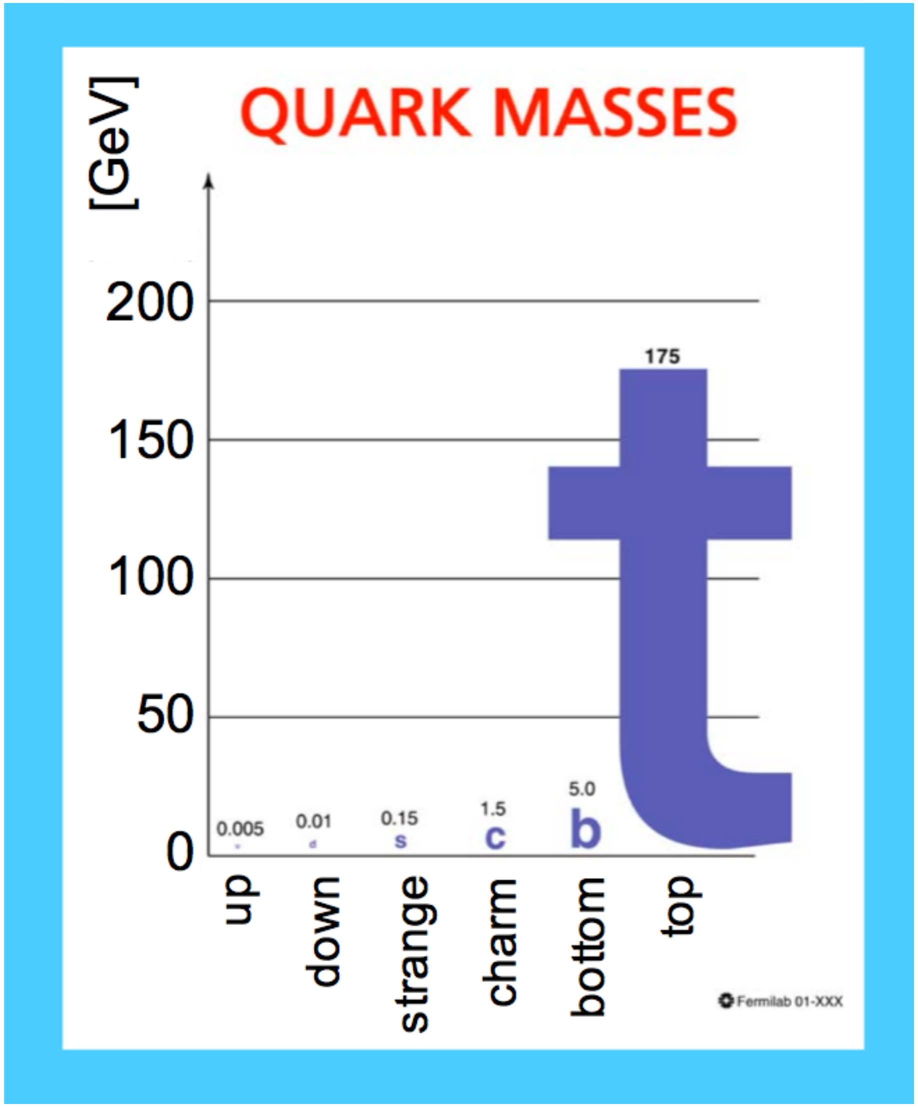
Top Physics in this lecture:

- Production and decay modes

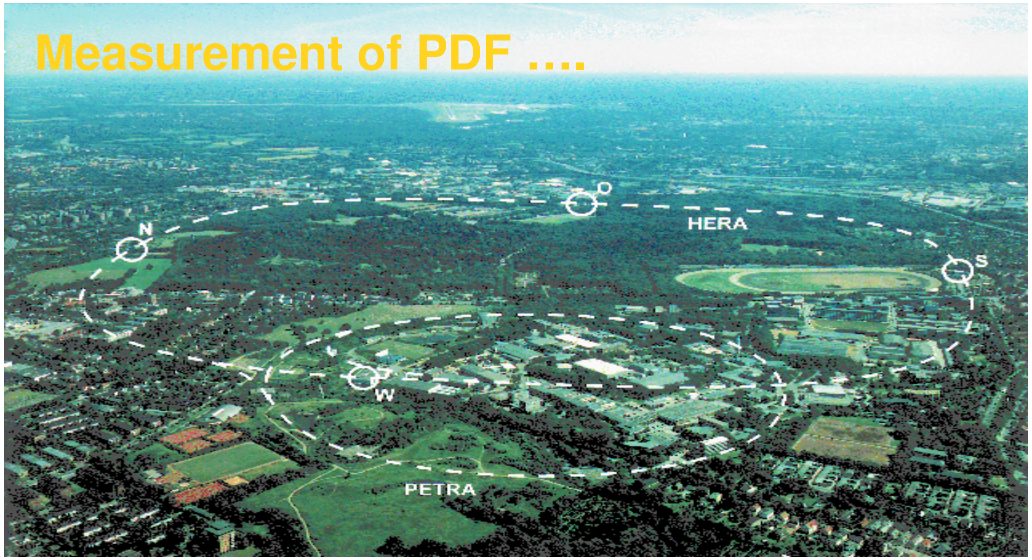
- Cross-section measurement:
  - top pair production
  - single top production

- Top Quark Properties:
  - Top Mass
  - Mass Asymmetry
  - Forward/Backward Asymmetry
  - Charge Asymmetry

- New physics in the top sector:
  - $W' \rightarrow tb$
  - ttbar Resonances (Z', G_{kk}, g_{KK})



Hadron Colliders

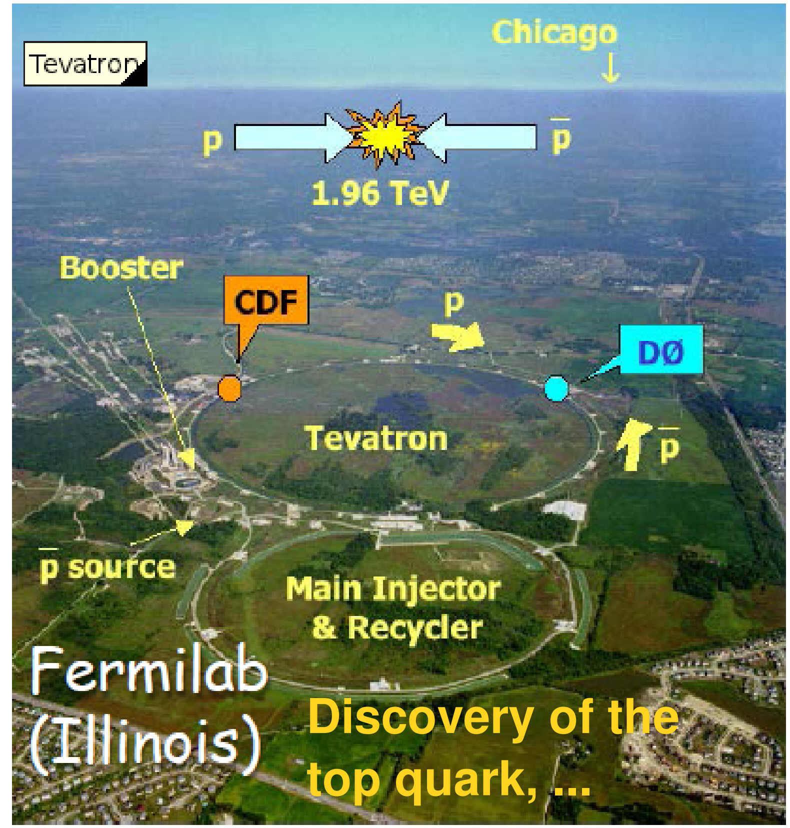


Double Storagering with 6.3km Circumference

- 920 GeV Protons – 27.5 GeV (e^+, e^-)

- HERA experiments:
H1 and ZEUS

1992-2007



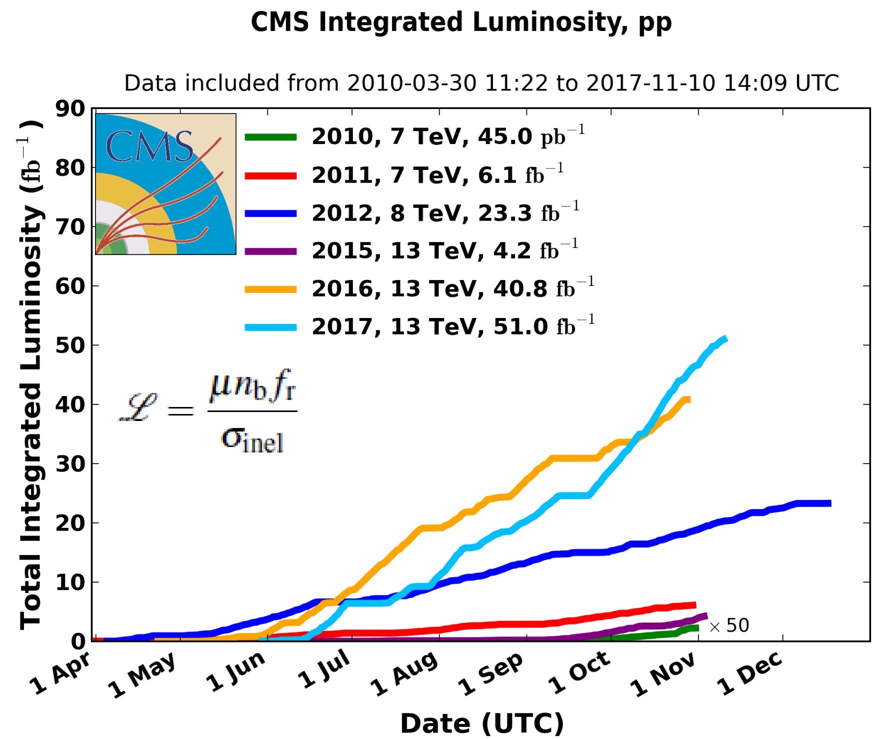
- p-pbar collider
- TeVatron experiments:
CDF, D0

1987-2011

Large Hadron Collider (LHC)

$$\mathscr{L} = \frac{R_{\text{inel}}}{\sigma_{\text{inel}}}$$

$$\mathscr{L} = \frac{\mu n_{\text{b}} f_{\text{r}}}{\sigma_{\text{inel}}}$$



LHC facts:

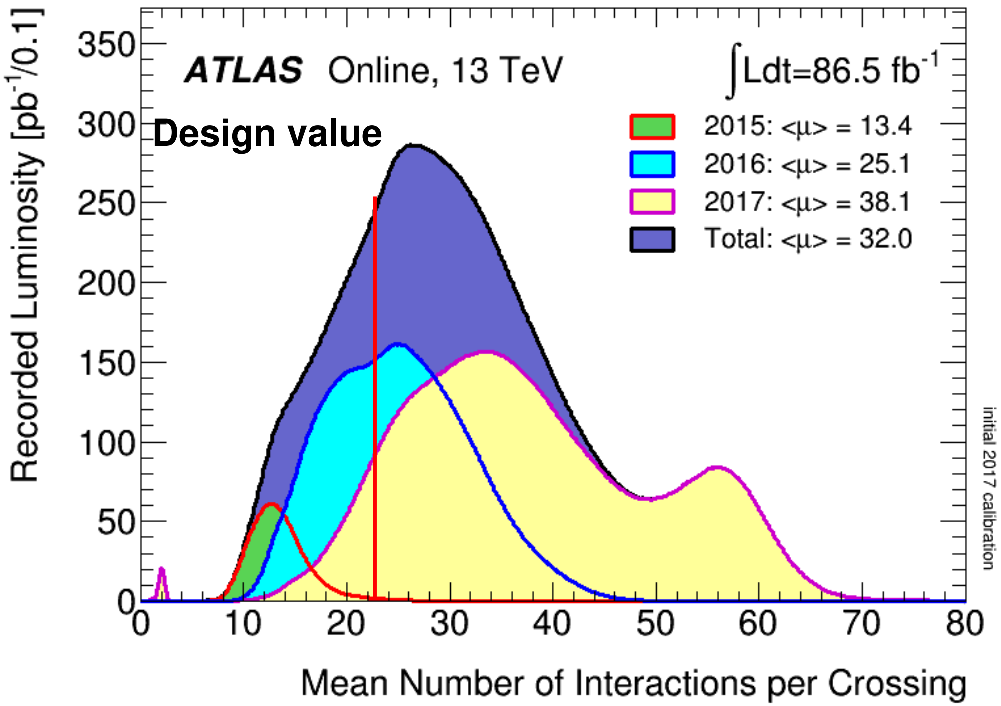
- Circumference: 26.7 km
- Dipole mag. Field: 8.3 T
- Dipole temperature: 1.9 K
- Beam energy: 7 TeV
- Turns frequency: 11 kHz
- Collisions freq.: 600 MHz

Luminosity during data-taking:	2012	2017	Nominal
• E.c.m.:	8 TeV	13 TeV	14 TeV
• Peak Luminosity [$cm^{-2}s^{-1}$]:	7.7×10^{33}	2.1×10^{34}	1×10^{34}
• Bunch spacing:	50 ns	25 ns	25 ns
•Max. average int. per b.c. :	37	78	23
• ATLAS Luminosity uncert.:	1.9% prel.	3.7%	-

- *~29 fb^{-1} of data delivered during Run 1 (2011-2012)*
- *~103 fb^{-1} of data delivered during Run 2 so far (2015-2018)*

LHC Luminosity and interactions per bunch crossing

Luminosity is measured with forward/tracking detectors and calibrated with beam separation scans



Proton bunches are separated 25 ns (7.5m).
About 2500 colliding bunches of protons can circulate in the LHC with an intensity of 10^{11} p/bunch

- Pileup already above design level, thanks to excellent performance of the LHC.
- Peak luminosity (cm^{-2} s^{-1}): 7.7x10^{33} (2012), 2.1x10^{34} (2017).

ATLAS Detector

	ATLAS
Magnetic field	2 T solenoid + toroid: 0.5 T (barrel), 1 T (endcap)
Tracker	Silicon pixels and strips + transition radiation tracker $\sigma/p_T \approx 5 \cdot 10^{-4}\, p_T + 0.01$
EM calorimeter	Liquid argon + Pb absorbers $\sigma/E \approx 10\%/\sqrt{E} + 0.007$
Hadronic calorimeter	Fe + scintillator / Cu+LAr (10λ) $\sigma/E \approx 50\%/\sqrt{E} + 0.03$ GeV
Muon	$\sigma/p_T \approx 2\%$ @ 50GeV to 10% @ 1TeV (Inner Tracker + muon system)
Trigger	L1 + HLT (L2+EF)

ATLAS Collaboration

38 Countries

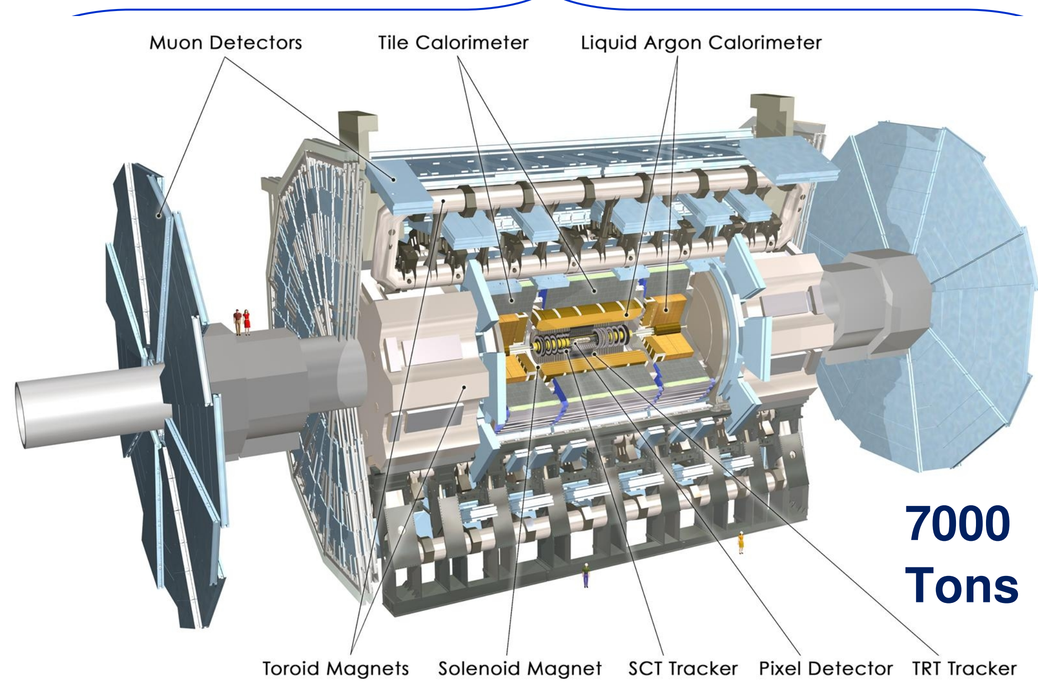
182 Institutions

2900 Scientific Authors total

(~1900 with a PhD)

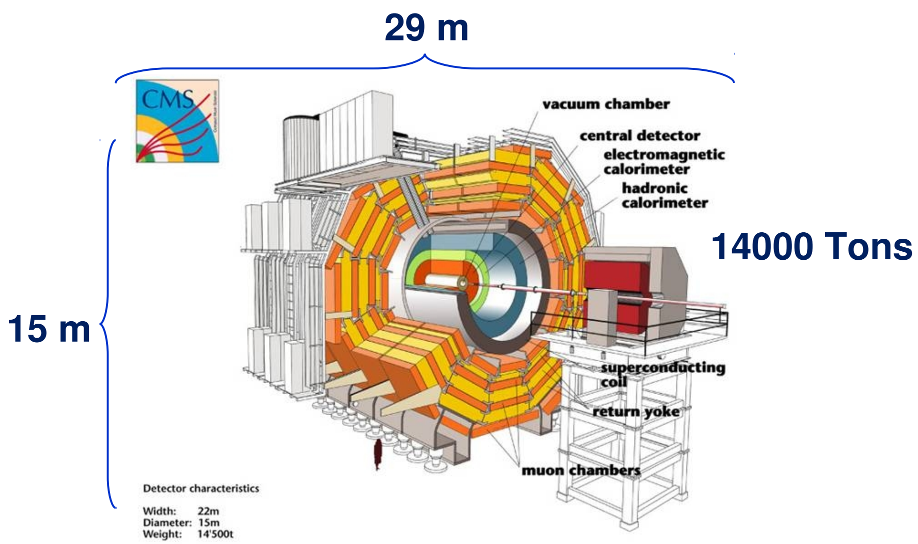
45 m

24 m

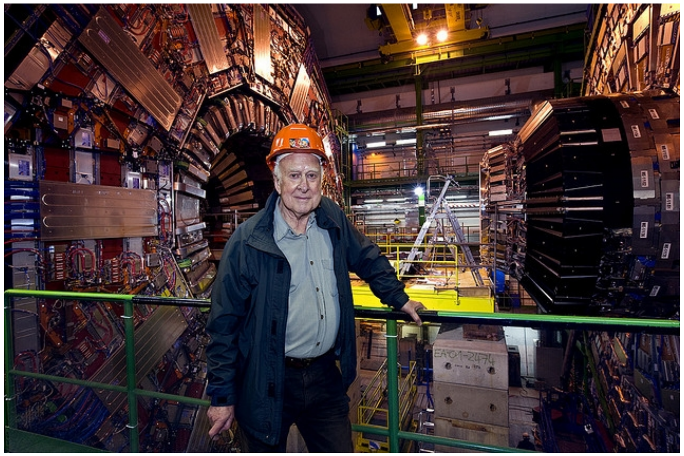


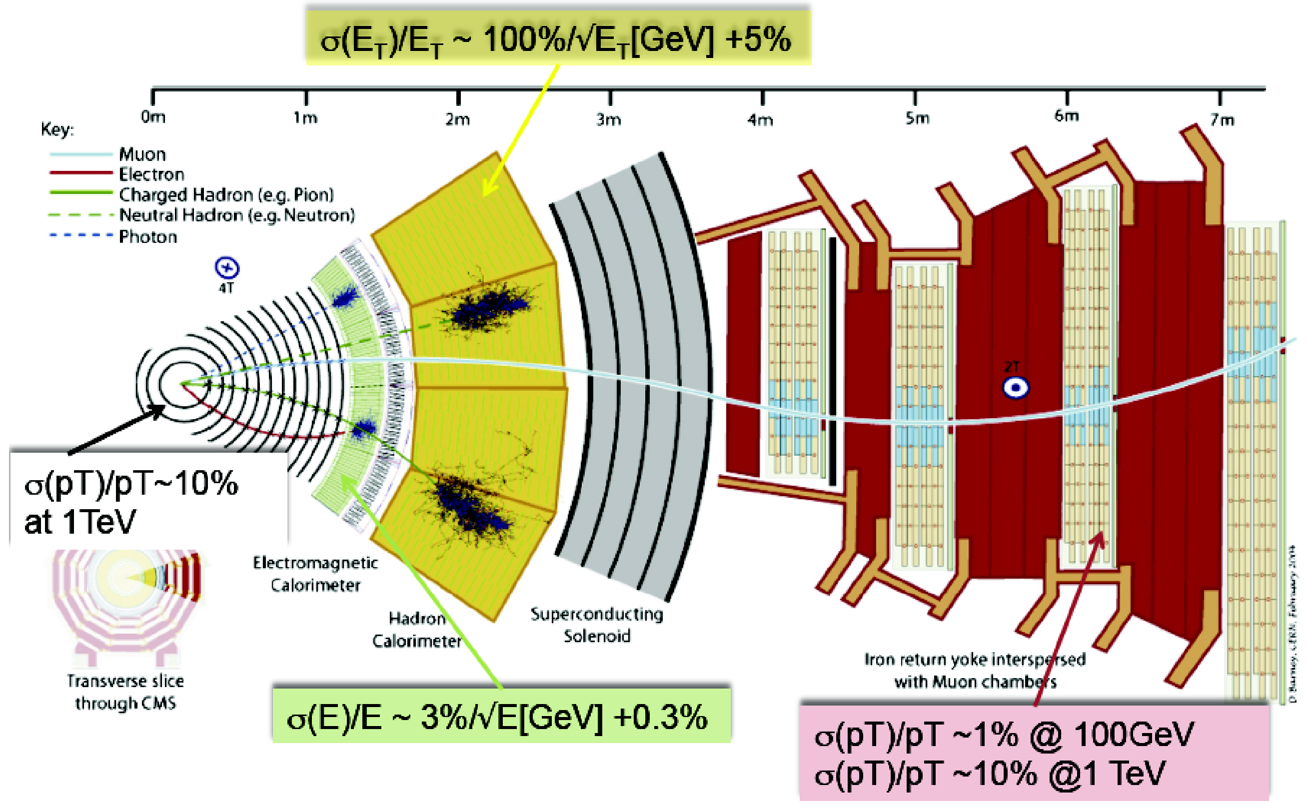
7000 Tons

CMS Detector



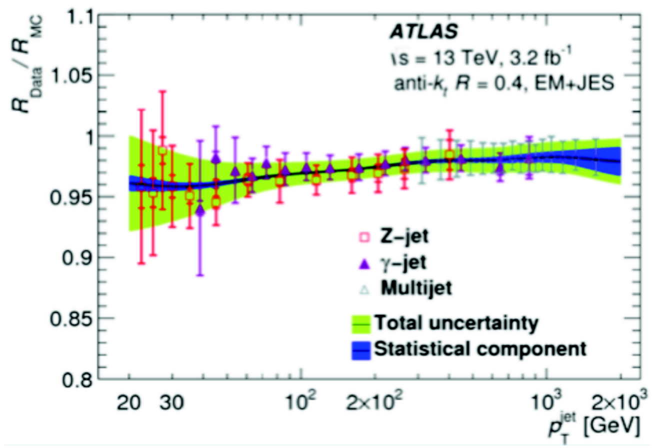
CMS Collaboration
42 Countries
182 Institutions
3300 Scientific Authors total
(~900 students)

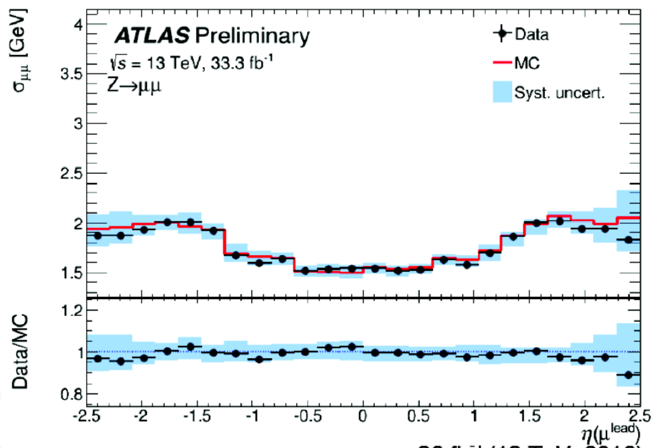


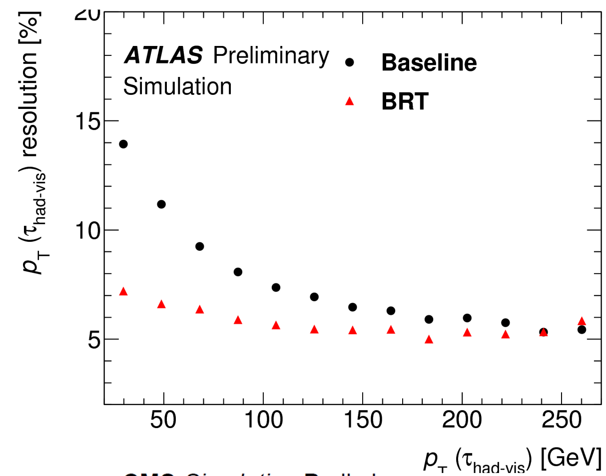


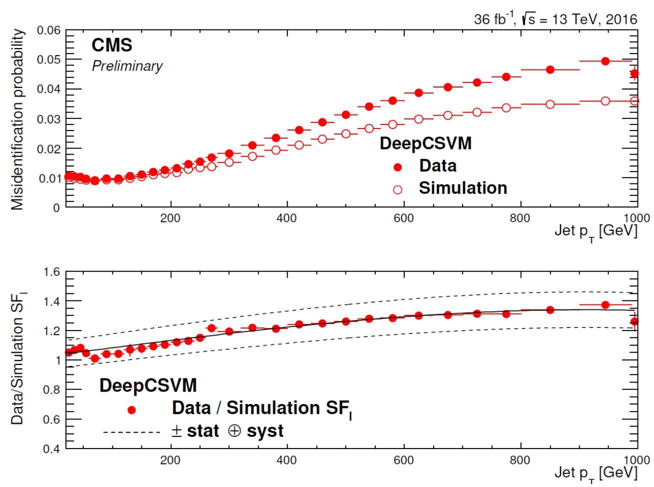
Reconstruction Performance

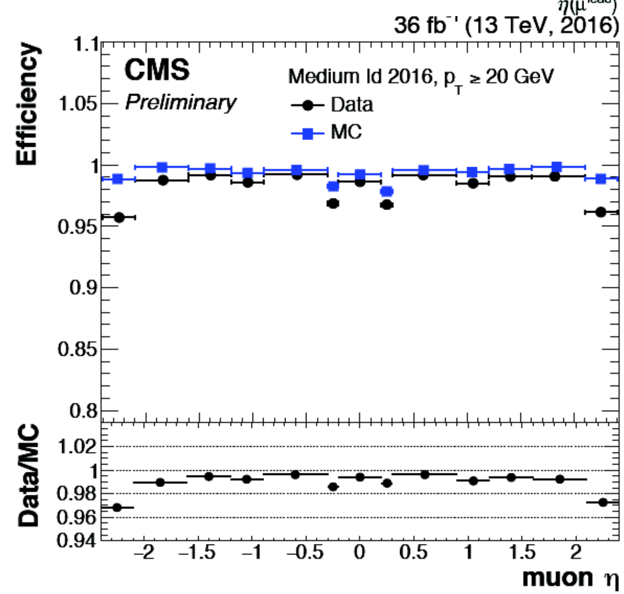
Performance Results links: **ATLAS** **CMS**

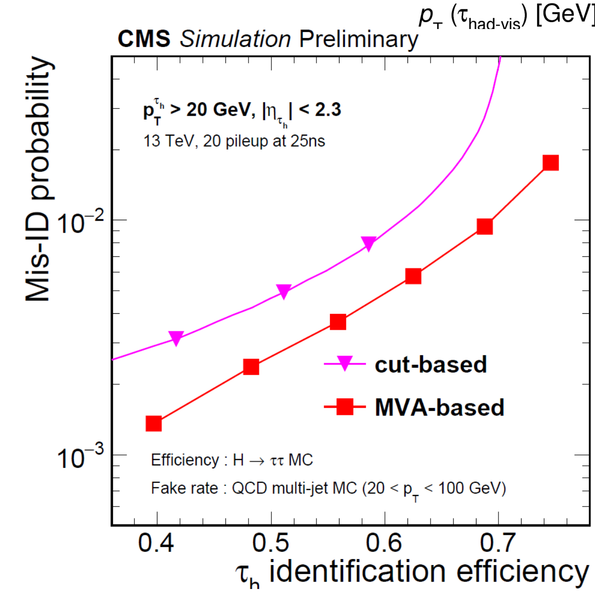






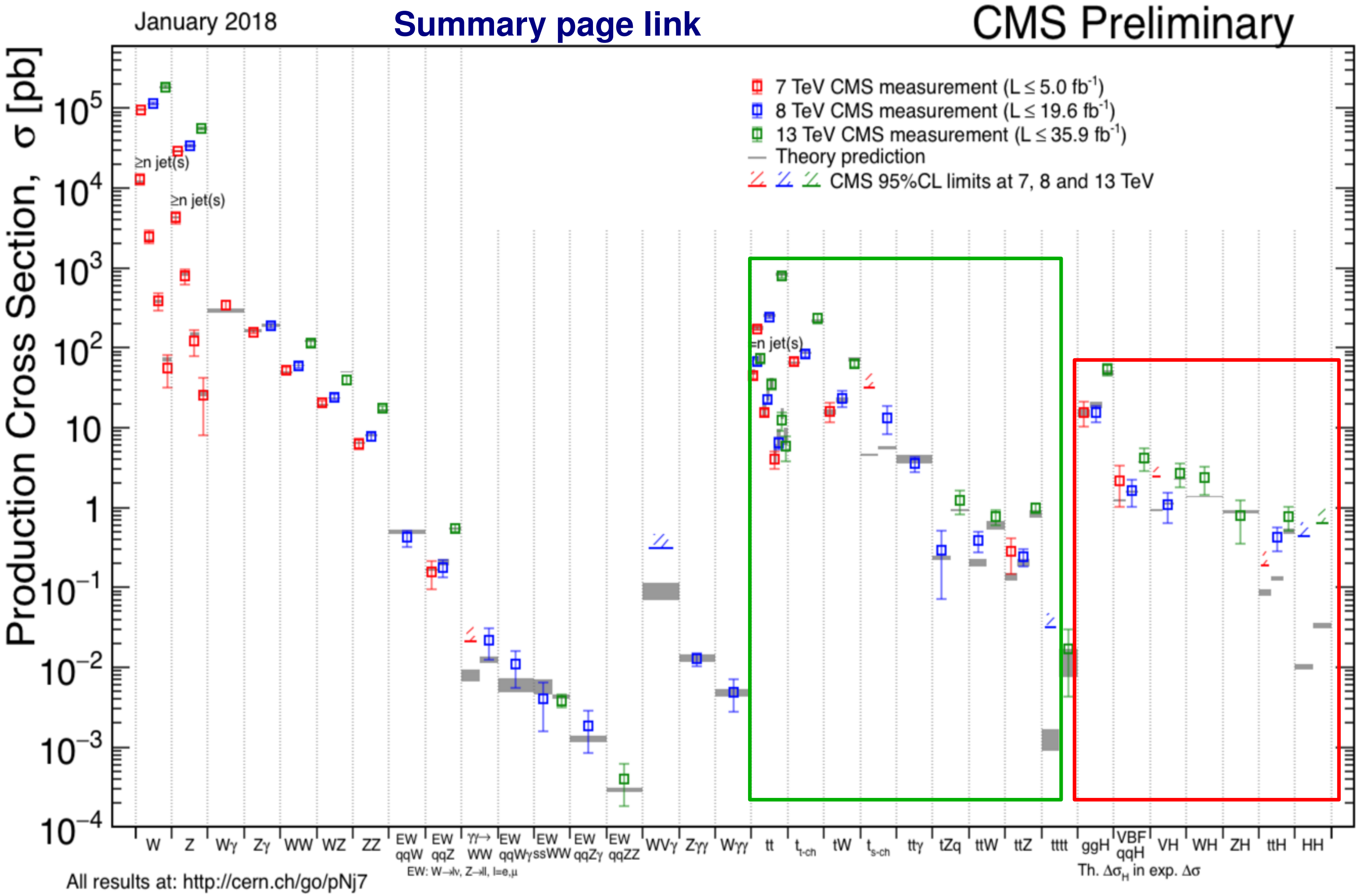






- Despite using different techniques, both experiments achieved a precise knowledge of the Jet Energy scale and its uncertainties.
- Isolation requirements are frequently applied to leptons to reduce the fake rate.
- The experiments succeeded in obtaining a low dependence wrt pileup observables.

Summary of SM results

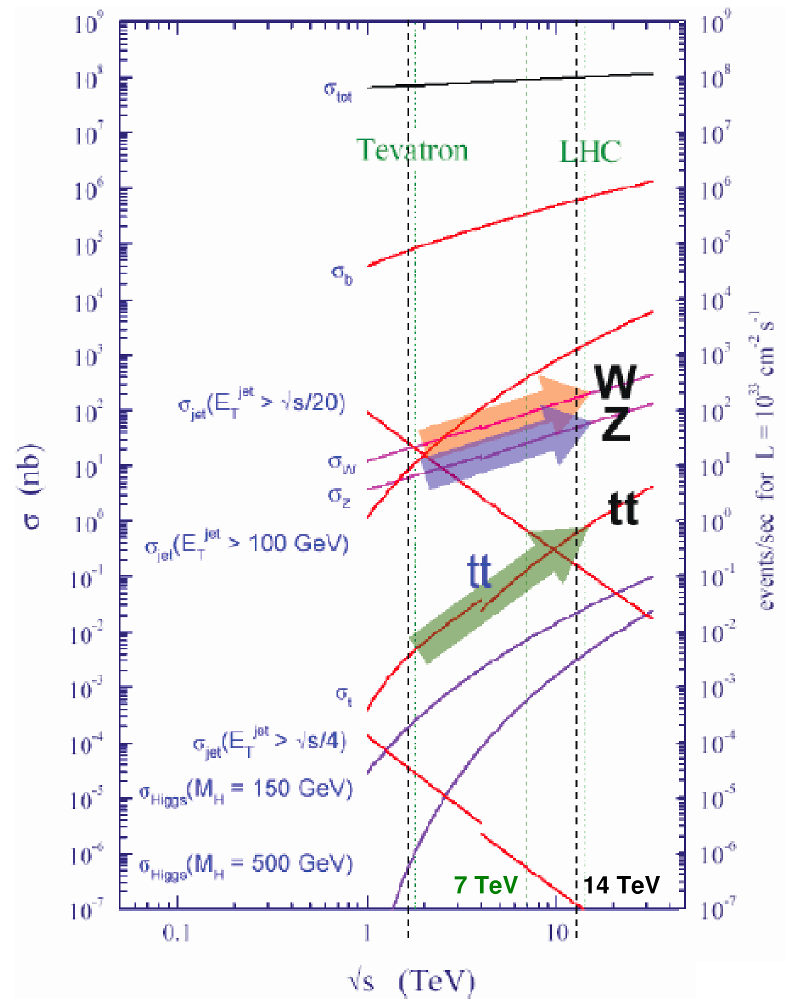


- Good agreement with SM expectations within uncertainties.
- Experimental uncertainties are in some cases at the level of the theor. predictions

Measurements of the Higgs and top cross-sections down to few pb (~tens of fb in some cases if we include also the BR).

Top Quarks @ Colliders

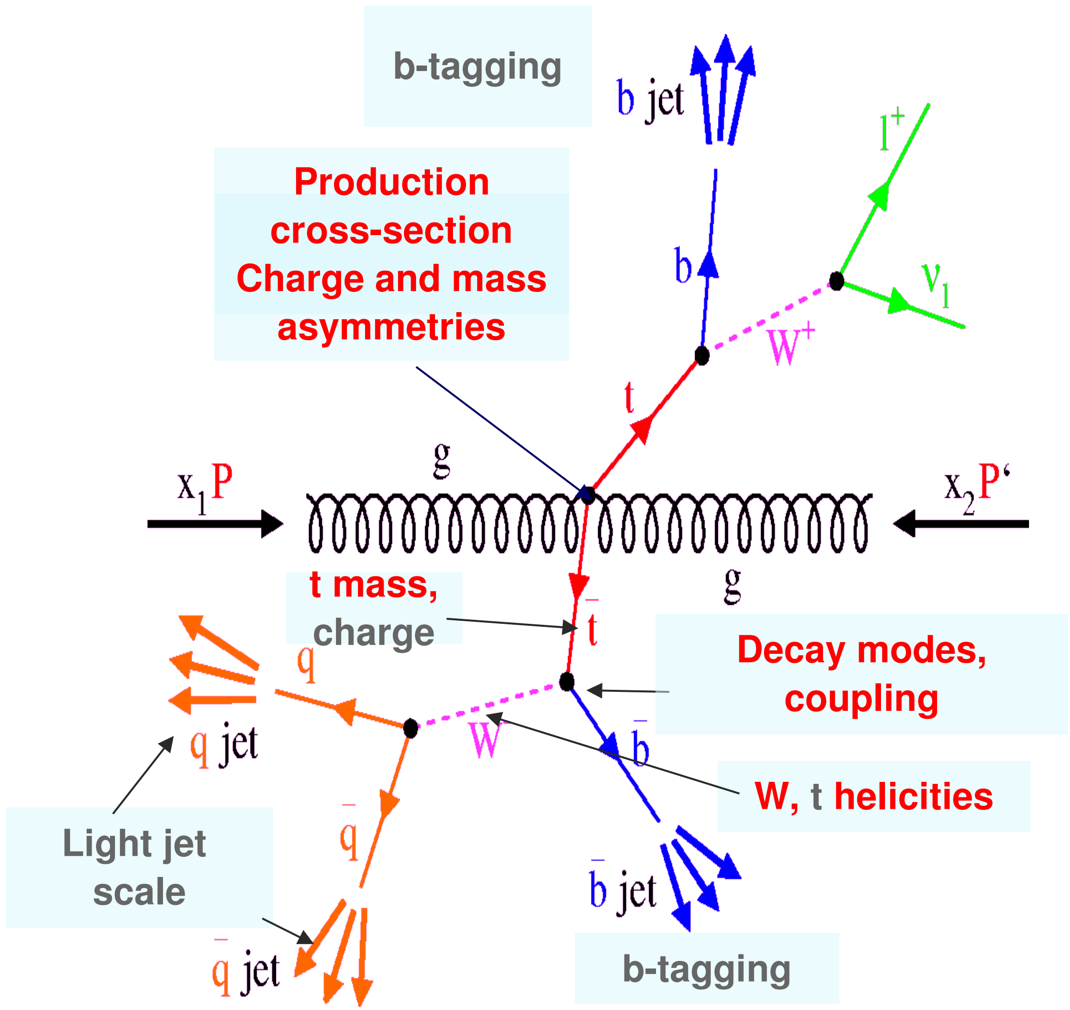
- Completes the 3 family structure of SM
- Electric charge = 2/3 · | e |
- Mass ~173.10 ± 0.60 GeV (PDG)
- Fast decay: $\tau \sim 4 \cdot 10^{-25}$s, Γ = 1.42 GeV
- Dominant decay to t → Wb:
- | Vtb | > 0.999 ; BR(t → Wb) ~100%
- BR(t → Ws) ≤0.18%
- BR(t → Wd) ≤0.02%



Top quark production rates rapidly increase as a function of the centre of mass energy.
It increases by a factor 4 at LHC between 7 TeV and 14 TeV energy in the centre of mass.

Top production is a very interesting process to study at LHC, but it is also a serious background for high mass searches and measurements.

Top Quark Physics @ Colliders



- Top production and decays allows to test several parameters of the Standard Model and to probe the existence of New Physics.

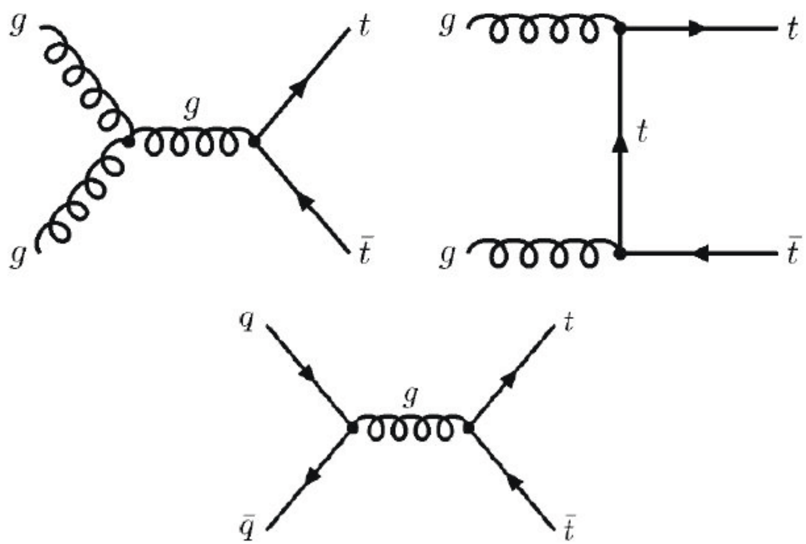
- Top-quark is the heaviest quark by far.

  Production
- Cross-section can be sensitivity to new physics decays.
- Top Mass is a fundamental parameter of the SM with several implications, e.g. EW vacuum stability.

Top Production @ Colliders

$$\sigma(p_1,p_2;Q,\{...\}) = \sum_{a,b}\int dx_1 dx_2 f_{a/h_1}(x_1,Q^2) f_{b/h_2}(x_2,Q^2)\hat{\sigma}_{a,b}(x_1 p_1, x_2 p_2, Q, \{...\};\alpha_s(Q))$$

"*Measured*" xsec — Parton Distribution Functions (PDFs) — "*Theoretical*" xsec



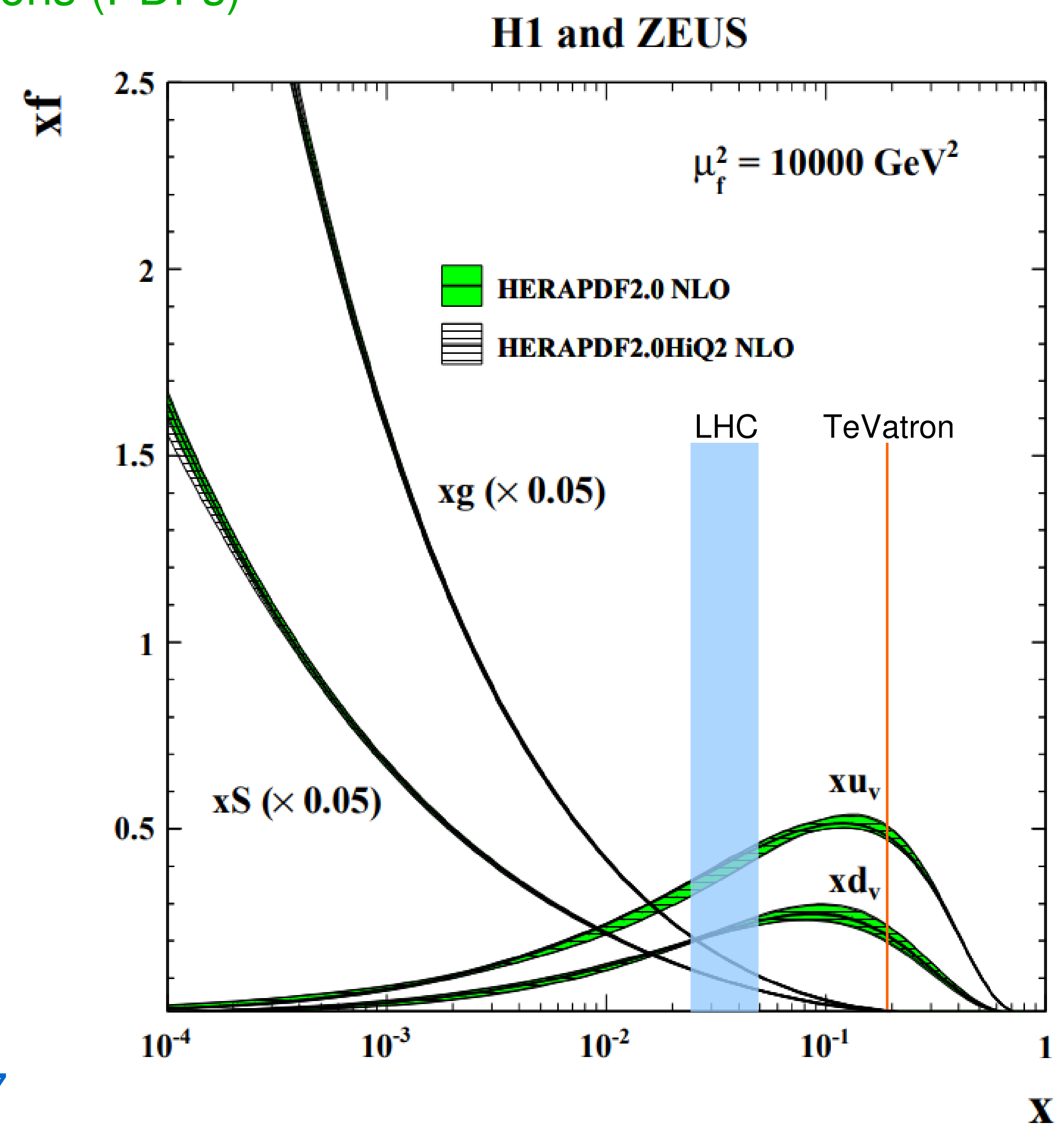
ttbar production at TeVatron and LHC:

$$\hat{s} \geq 4m_t^2 \Rightarrow x_i x_j = \hat{s}/s \geq 4m_t^2/s$$

$$x \approx \frac{2m_t}{\sqrt{s}}$$

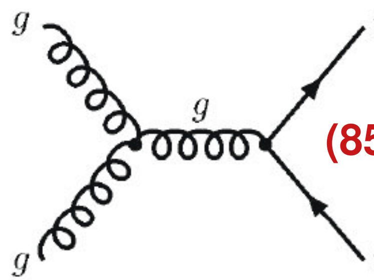
= 0.18-0.19 TeVatron

= 0.025-0.050 LHC14-LHC7

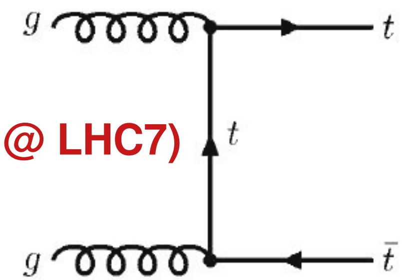


Top Quark Production

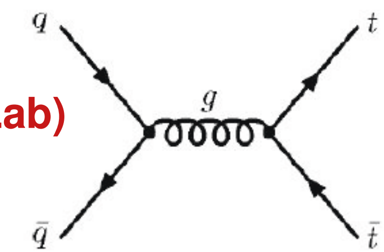
LHC: Gluonic production dominates



(85% @ LHC7)



(90% @ FermiLab)



10 ttbar events per day at TeVatron

$\sigma(t\bar{t}$ 1.96 TeV$)^{\text{approx NNLO}}$= 7.5 ± 0.5 pb

$\sigma(t\bar{t}$ 7 TeV$)^{\text{approx NNLO}} = 165\ ^{+11}_{-16}$ pb

$\sigma(t\bar{t}$ 14TeV$)^{\text{approx NNLO}} = 874\ ^{+14}_{-33}$ pb

⇒ ***1 tt/sec @ L=5•10 ^{33} cm^{-2} s^{-1}** (LHC7)*

Cross section LHC ~ 20 x Tevatron

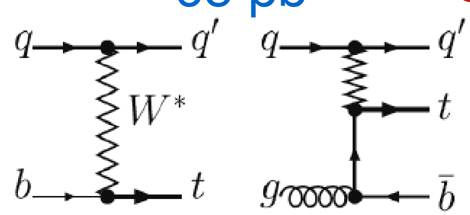
Background LHC ~ 8 x Tevatron

Use of b-tagging is not strictly essential to establish ttbar signal at LHC

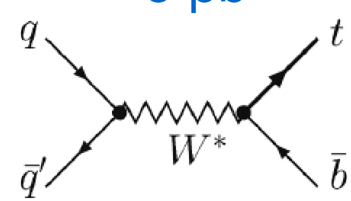
@ NLO + NNLL mtop = 172.5 GeV

	t-chan	Wt chan	s-chan
σ_{7TeV} (pb)	64.6±2.4	15.7±1.1	4.6±0.2
σ_{8TeV} (pb)	87.8±3.4	22.4±1.5	5.6±0.2
σ_{13TeV}	221^{+5}_{-2}±3	72.6±1.1±1.8	11.29±0.18±0.26

~65 pb @ LHC7 ~5 pb

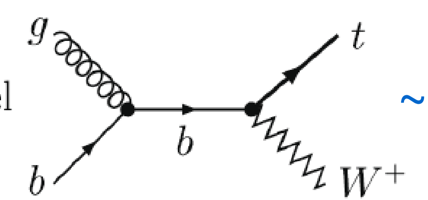


t-channel



s-channel

tW-channel

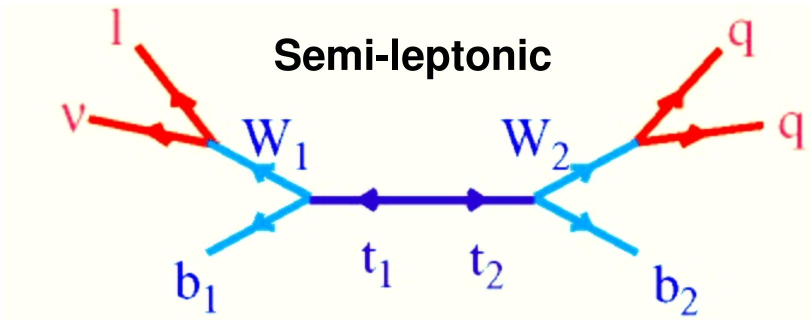


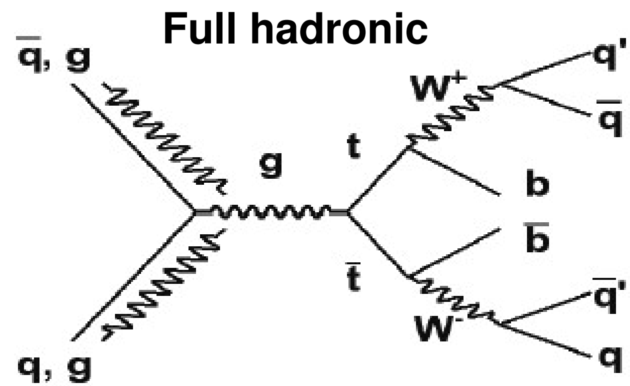
~16 pb

LHC7 = LHC @ sqrt(s)=7TeV

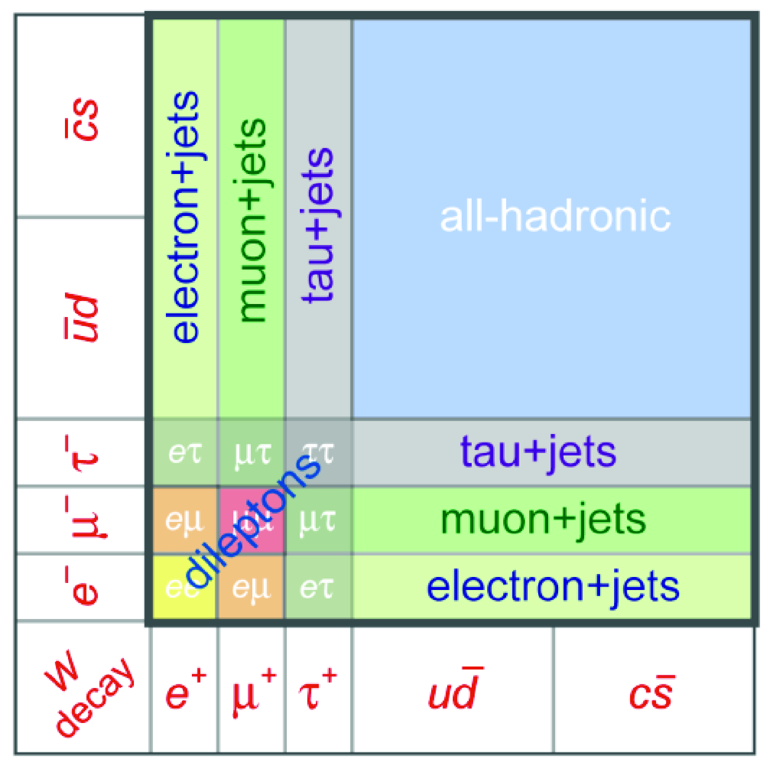
Top Quark decays

ttbar final states for the cross section measurement



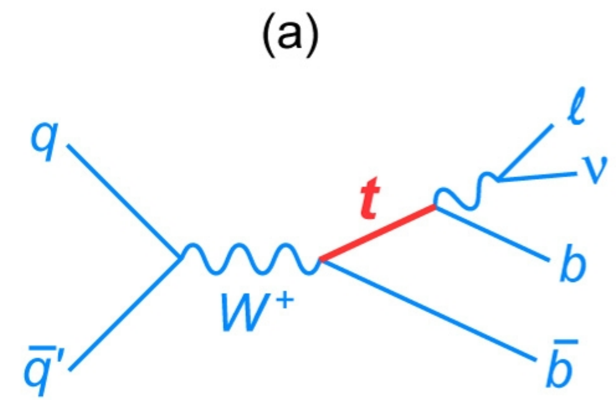


- Full hadronic **45%**: 6 jets
  - High bkgs (mainly QCD)
- Semi-leptonic **30%**: ℓ+ MET+ 4 jets
  - (ℓ=e,μ)
  - Moderate bkgs (mainly W+jets)
- Di-leptonic **11%**: 2ℓ+ MET+ 2 jets
  - (ℓ=e,μ,τ)
  - Low bkgs (mainly Z+jets)



Single Top Quark decays

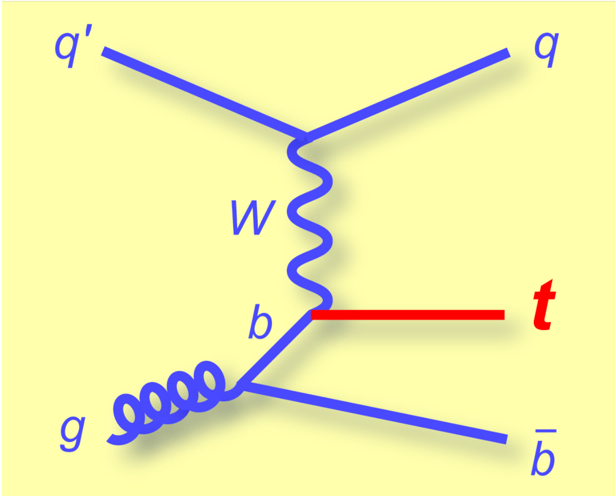
- Single top: 1,2 ℓ+ MET+2,3 jets
  - High bkg, mainly W+Heavy Flavour and ttbar



Fundamental difference with top-anti-top production is the production mode:

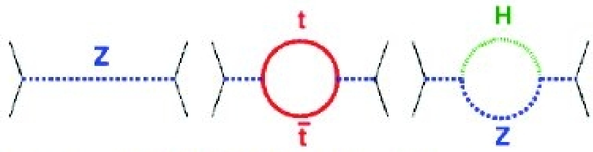
- ttbar produced by QCD processes,

- Single top is produced in EW processes. It allows to study top/antitop ratio, V_{tb} vertex, top polarization.....



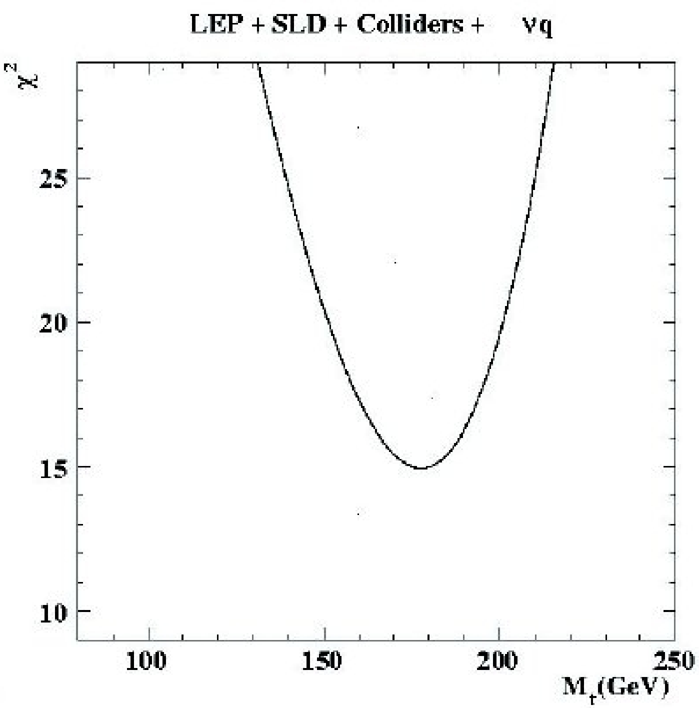
Top Quark Discovery

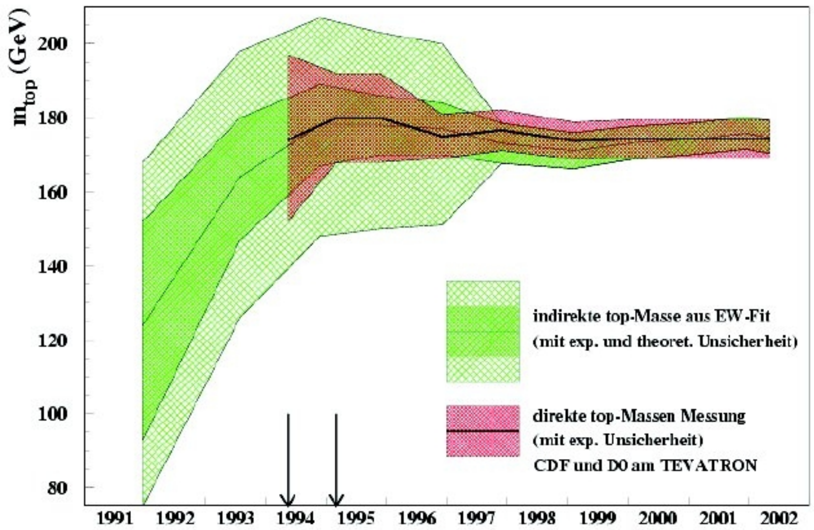
Indirect Top quark mass bounds from EW measurements



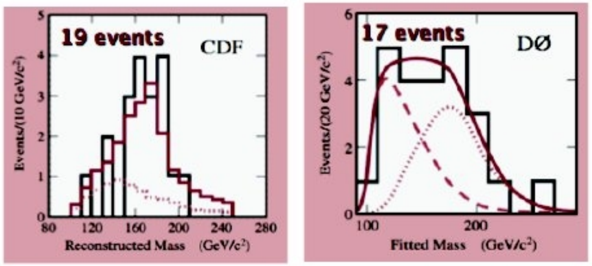
$M_Z^2 = M_Z^{2\ 0.\text{order}} / (1 - \Delta)$

$\Delta \approx \ldots m_t^2 \ldots + \ldots \ln m_h \ldots$





Top quark discovery in 1995 by CDF and D0 at Tevatron (Fermilab)

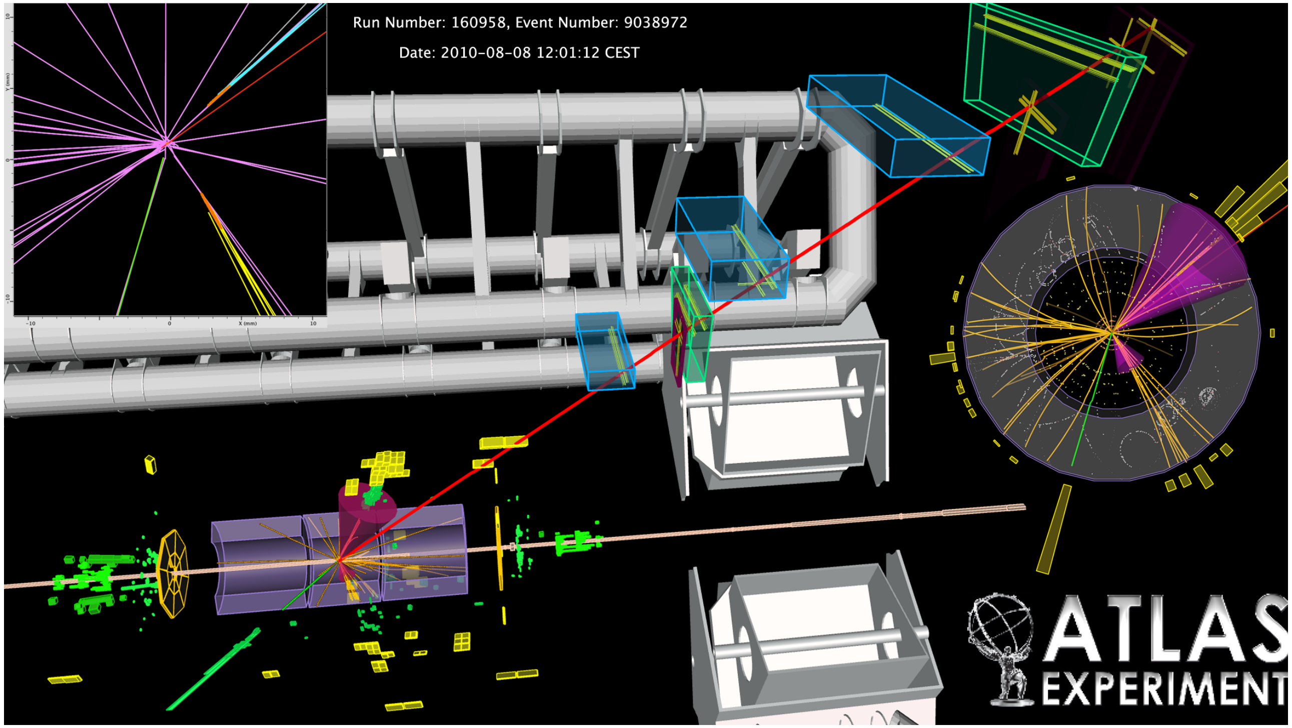


F. Abe *et al.* (CDF collaboration), PRL 74:2626-2631 (1995)
S. Abachi *et al.* (D0 collaboration),PRL 74:2632-2637 (1995)

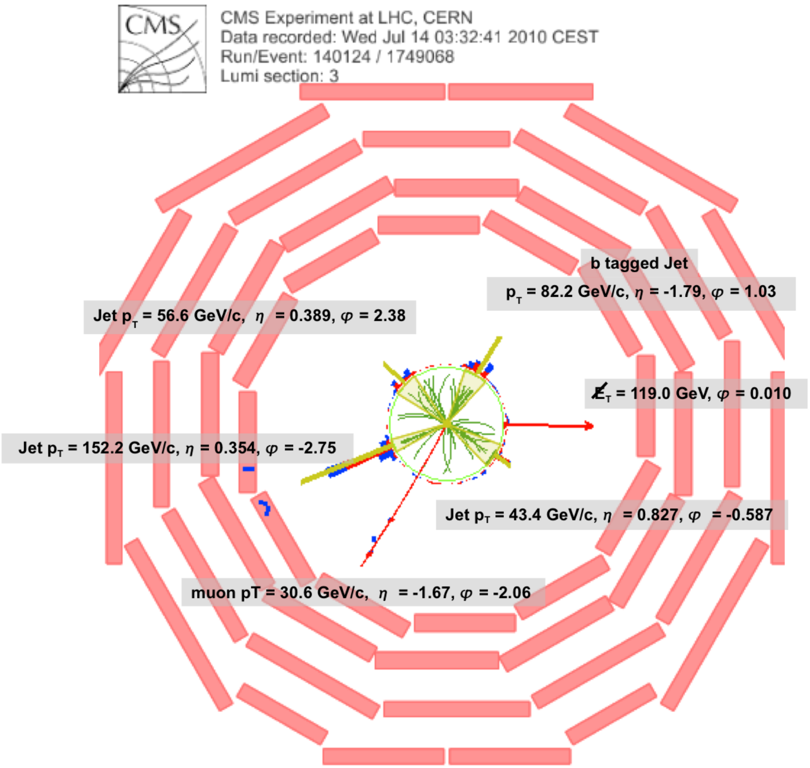
lepton+jets final state
requiring >= 4 jets and 1 lepton.

Real Events

Two ttbar event candidates



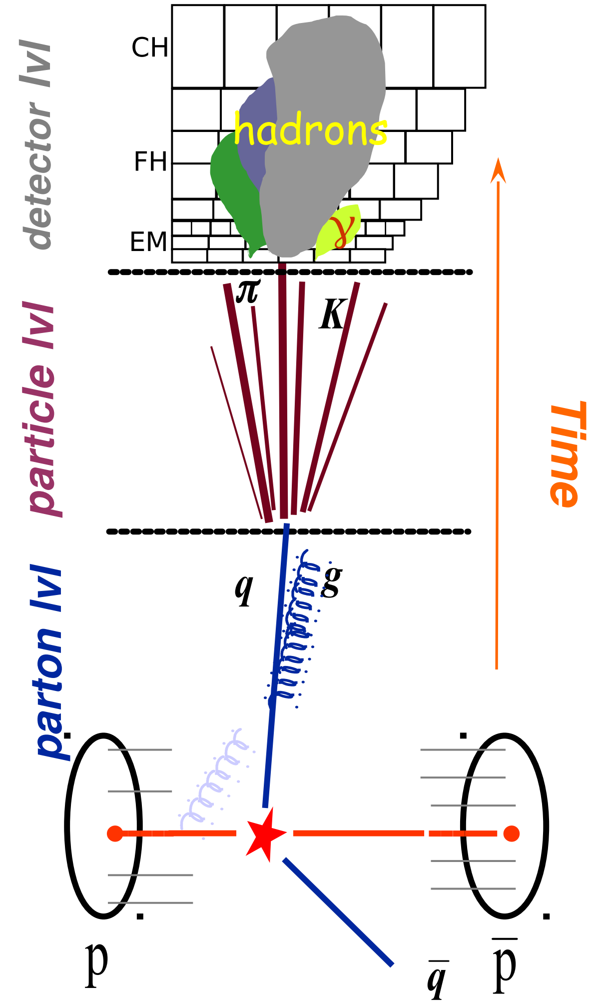
Di-lepton e-μ event



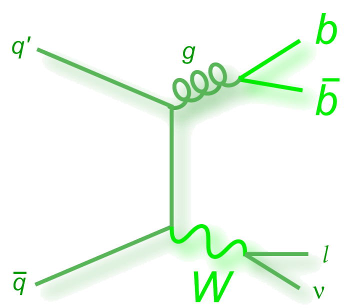
Single lepton mu+jets event

Cross-section measurements

- **Fiducial cross-section**
  - Extract number of observed events by subtracting background estimate
  - Correct total number of events by selection efficiency
  - Less model dependent, smaller extrapolations
- **Total cross-section**
  - Correct fiducial cross-section by the fiducial acceptance and branching fractions
  - Remove channel and selection dependence
  - More intuitive interpretation

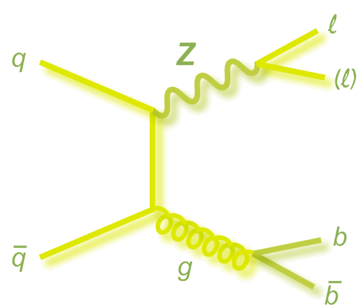


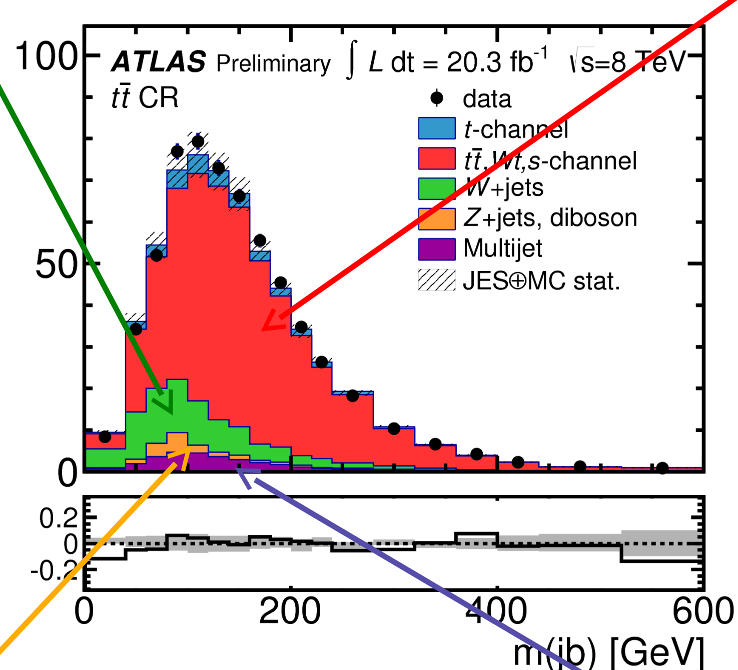
Signal and Backgrounds

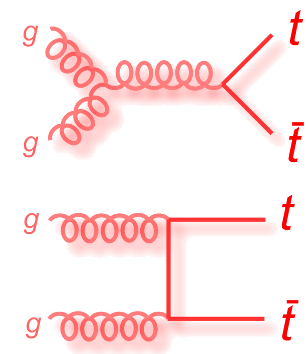


W+jets (W+bb) : One of the largest backgrounds.

Z+jets (Z+bb) : One of the leptons is missed

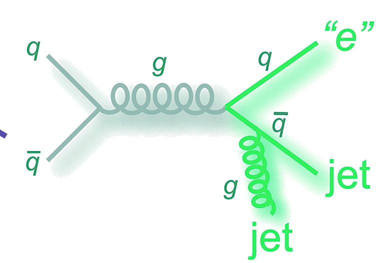






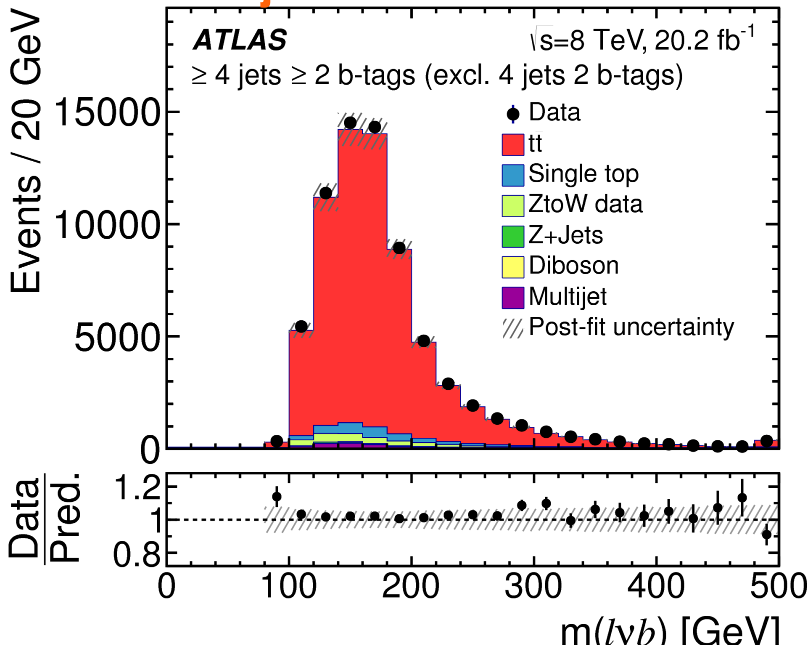
top-pairs : Signal, but also background for single top channels

Multijet : large cross-section process. One of the jets is miss-identified as a lepton.

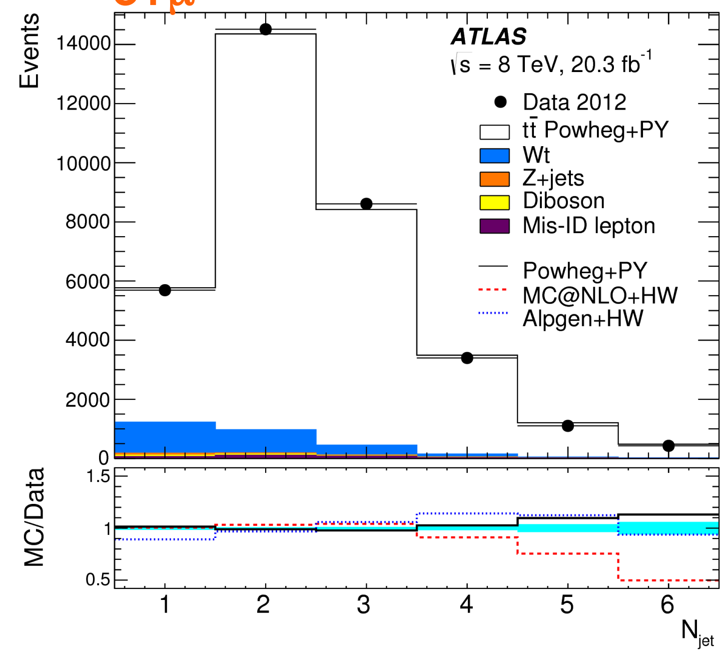


ttbar cross section

ℓ+jets



e+μ



$$\sigma_{\rm inc}(t\bar{t}) = 248.3 \pm 0.7\,({\rm stat.}) \pm 13.4\,({\rm syst.}) \pm 4.7\,({\rm lumi.})\ {\rm pb}$$

$$\sigma_{\rm fid}(t\bar{t}) = 48.8 \pm 0.1\,({\rm stat.}) \pm 2.0\,({\rm syst.}) \pm 0.9\,({\rm lumi.})\ {\rm pb.}$$

$$\sigma_{t\bar{t}} = 182.9 \pm 3.1 \pm 4.2 \pm 3.6 \pm 3.3\ {\rm pb}\ (\sqrt{s} = 7\ {\rm TeV})$$

$$\sigma_{t\bar{t}} = 242.4 \pm 1.7 \pm 5.5 \pm 7.5 \pm 4.2\ {\rm pb}\ (\sqrt{s} = 8\ {\rm TeV})$$

(stat) (syst) (theo) (lumi)

Analysis in the ℓ+jets channel (ℓ=e,μ):

- Binned maximum-$\mathcal{L}$ fit with three regions
  - Based on n. of jets and b-tag jets
  - Separate signal and background (NN)
  - Control W+jets background
  - Fit b-tagging and JES uncertainties
- Dominant uncertainties
  - Top model., JES, lepton ID/trigger, lumi

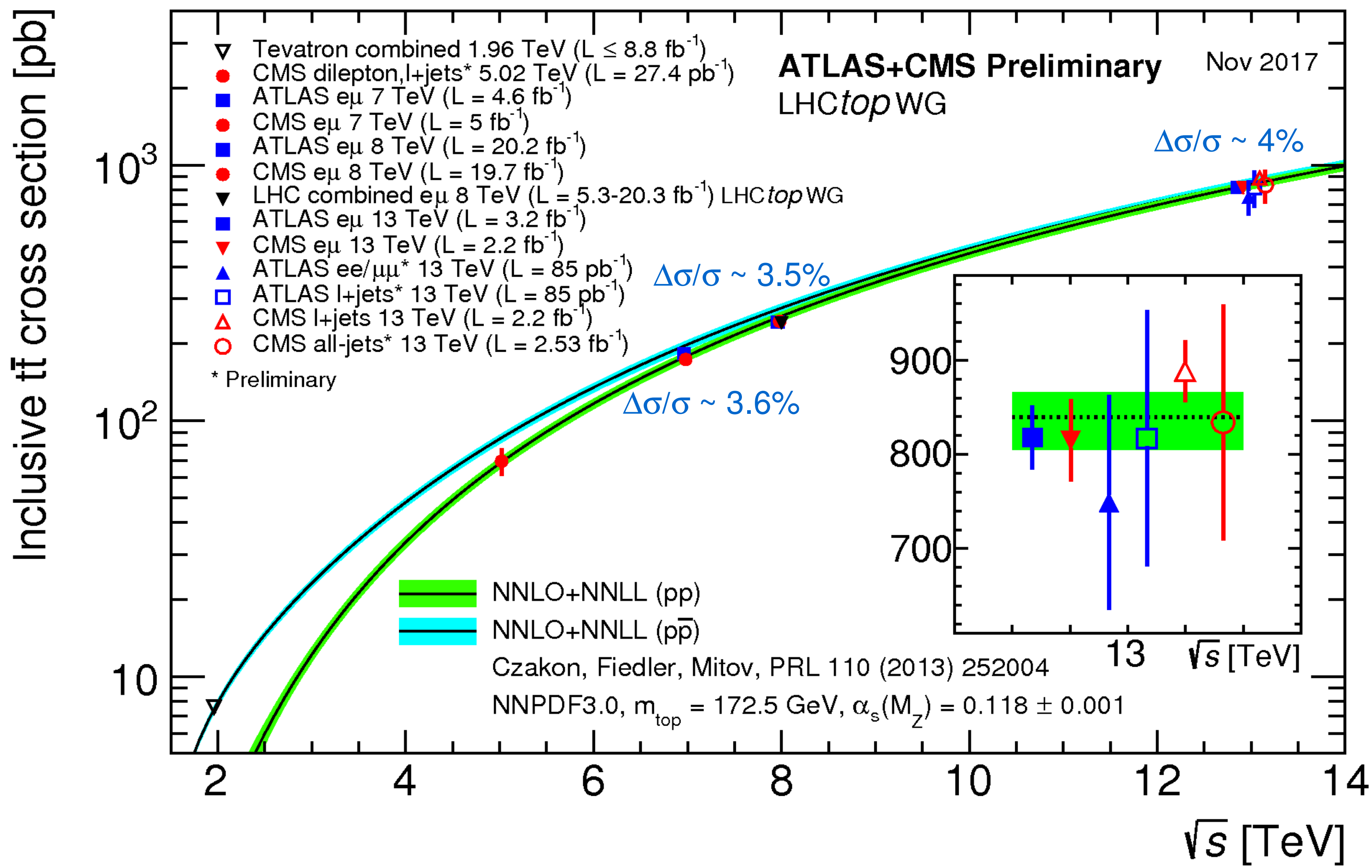
- Very precise measurement
- Using a very clean channel to reduce backgrounds and systematics
- To reduce uncertainties, the b-tagging efficiency is extracted from the Number of 1-tag and 2-tags events:

$$N_1 = L\sigma_{t\bar{t}}\ \epsilon_{e\mu} 2\epsilon_b(1 - C_b\epsilon_b) + N_1^{\rm bkg}$$

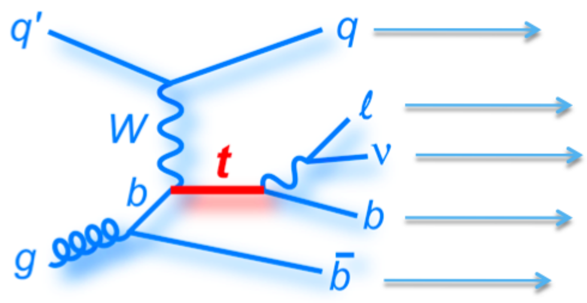
$$N_2 = L\sigma_{t\bar{t}}\ \epsilon_{e\mu} C_b {\epsilon_b}^2 + N_2^{\rm bkg}$$

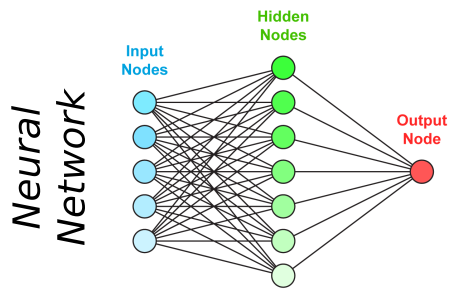
ttbar cross section - Summary

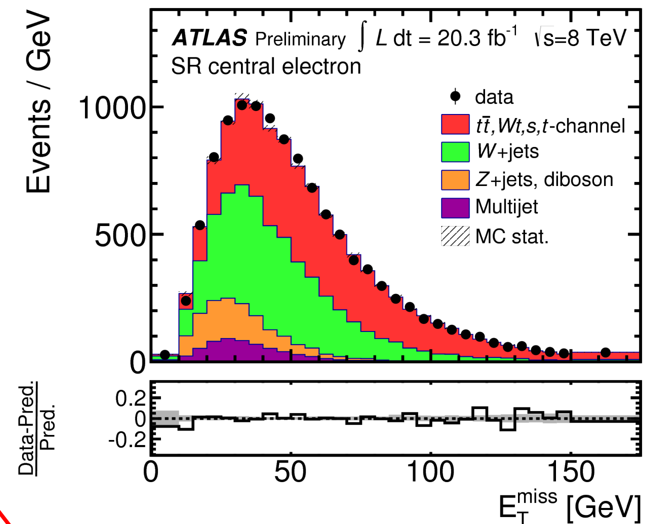
Measurements of the ttbar cross section in different final states and center of mass energies:

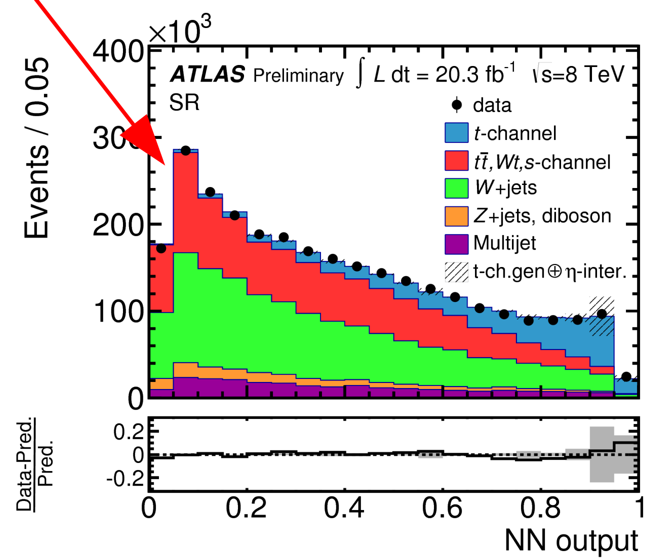


Single Top cross section - Tchan









Signal:
After event selection the signal over background ratio is 15%

Backgrounds:
Large contributions coming from top pairs and W+jets

Multivariate analysis :
t-channel discrimination by combining 14 kinematic variables in a neural network.

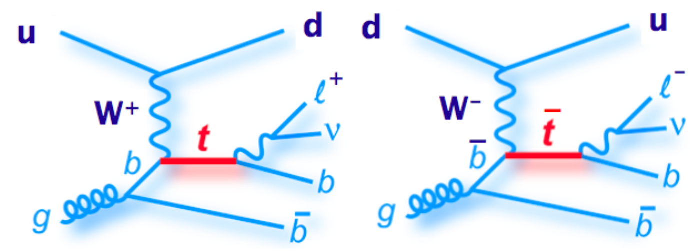
$$\sigma_{\rm fid} = 3.37 \pm 0.05\,({\rm stat}) \pm 0.47\,({\rm syst.}) \pm 0.09\,({\rm lumi.})\ {\rm pb}$$

Top-antiTop Ratio

Motivation :

- Ratio R_t is sensitive to the ratio of u-quark to d-quark **PDFs** in the range 0.02 < x < 0.5

$$R_t = \frac{\sigma_t(t)}{\sigma_t(\bar{t})}$$



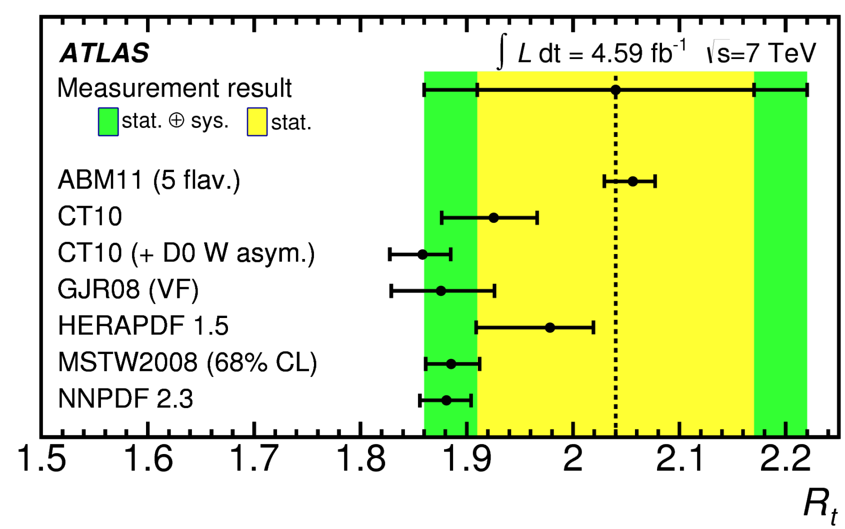
- Smaller uncertainties than the total cross section because of **partial cancellations**

Backgrounds :

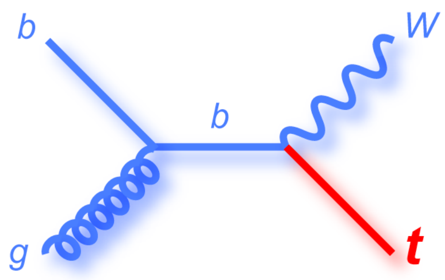
- Data driven estimates for multijet and W+jets.

Neural Network training done individually for 4 channels and all discriminants are fitted simultaneously.

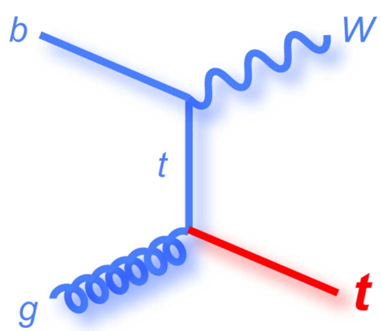
$$R_t = 2.04 \pm 0.13(\text{stat.}) \pm 0.12(\text{syst.})$$

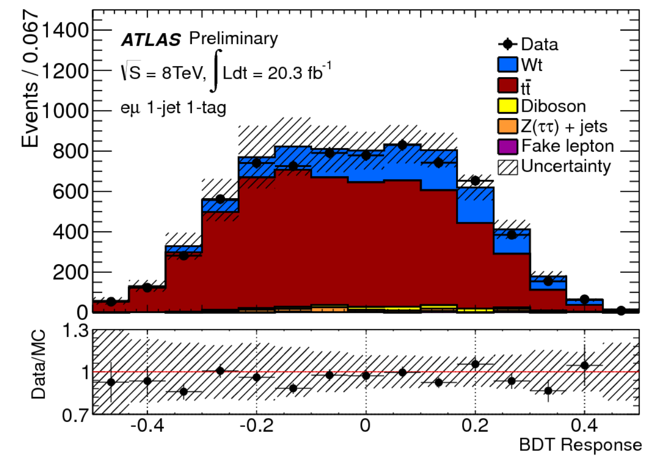


Single Top cross section - Wt

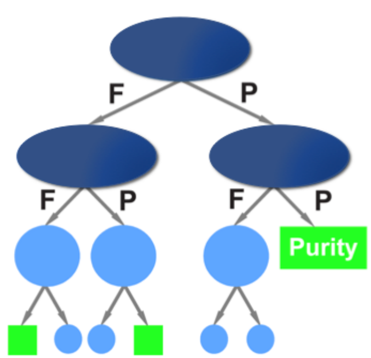


- exactly 2 opposite charge and isolated leptons
- missing energy (E_T^{miss}), 2 neutrinos
- 1 b-jet from top decay

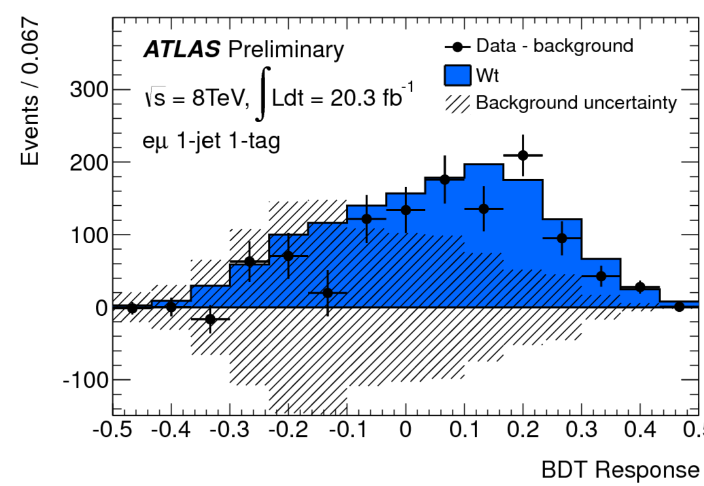




Boosted Decision Tree



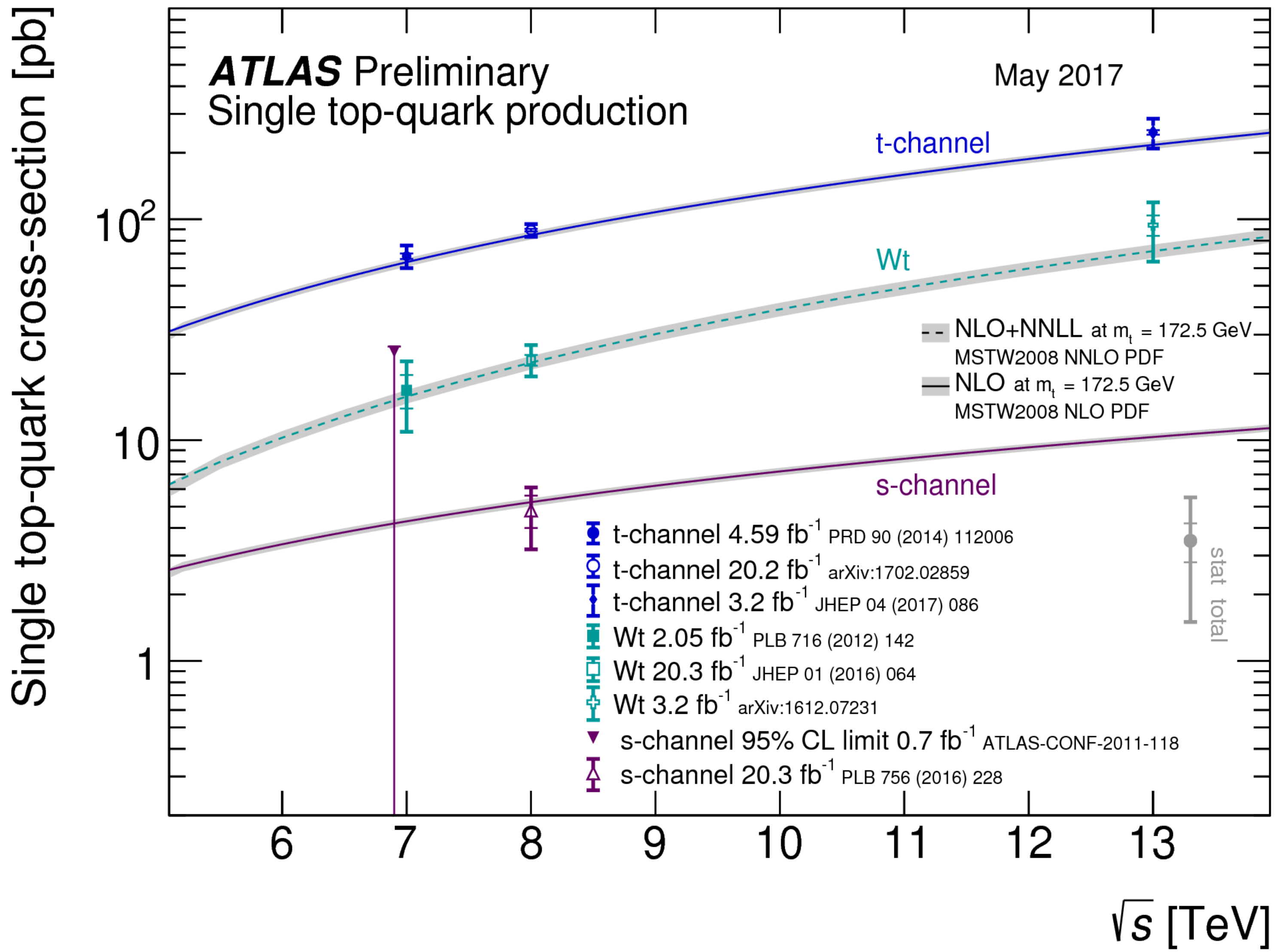
BDTs optimized for selection of 1 and 2 jets to take into account difference in topology.



$$\sigma_{\rm wt} = 27.2 \pm 2.8\,({\rm stat.}) \pm 5.4\,({\rm syst.})\ {\rm pb}$$

Significance = 4.2σ

Single Top cross section Summary



Summary of single-top Results for 7, 8 and 13 TeV for ATLAS @ LHC.
Clear measurement of single-t and Wt processes.
For the s-chan the measurment has a large relative uncertainty.

Top Mass Measurement

Detector gives you 4-vectors:

Does not always give you 4-vectors (neutrinos!)
Detector/Object resolutions (e.g. Jet Energy Scale)
Background contamination
Incorrect reconstruction (e.g. bad jet assignment)
Top mass width
Etc.

Two common methods to address this:

Matrix Element → Uses all the information; Computationally *very* expensive

Template Method → Flexible, subsets the information used; "Fairly easy" to implement

What do we measure?

Top Mass Reconstruction

Example of Top Mass Reconstruction in lepton+jets

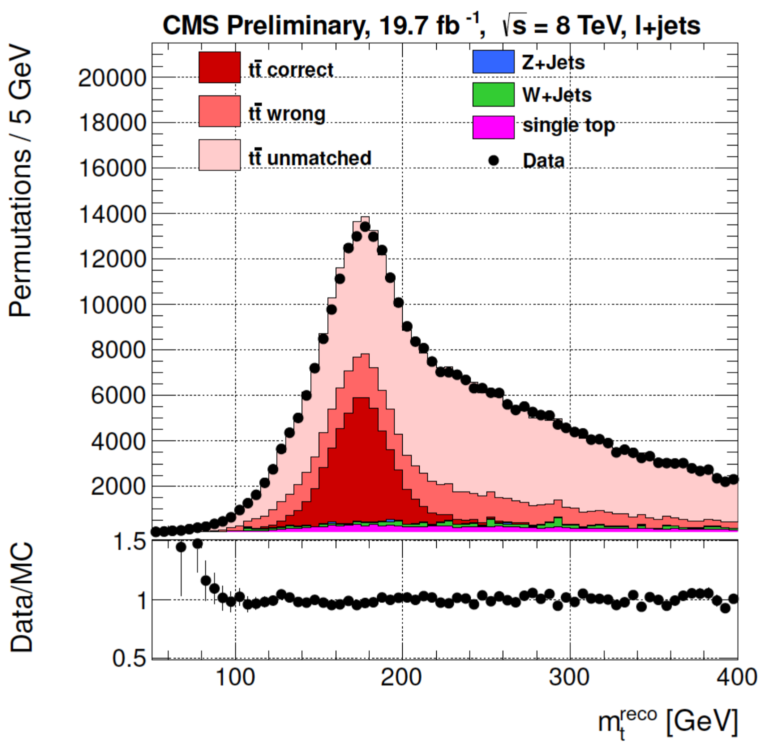
Assign 4 leading jets to partons from decay (obey b-tag)

– Kinematic fit with constraints:

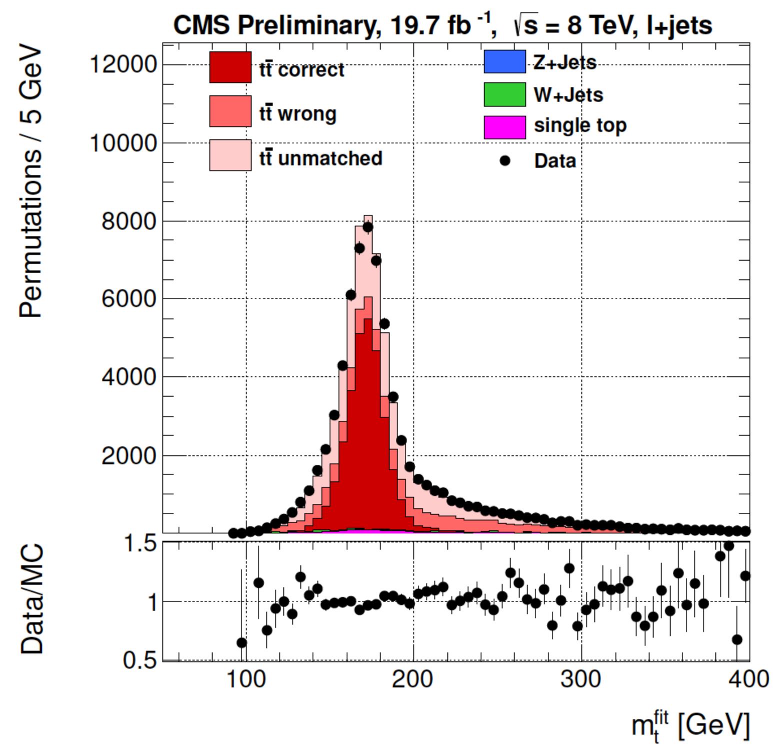
M_W = 80.4 GeV, mt=mtbar

– Weight each permutation by $P_{gof} = \exp-(1/2\chi^2)$, select $P_{gof} > 0.2$

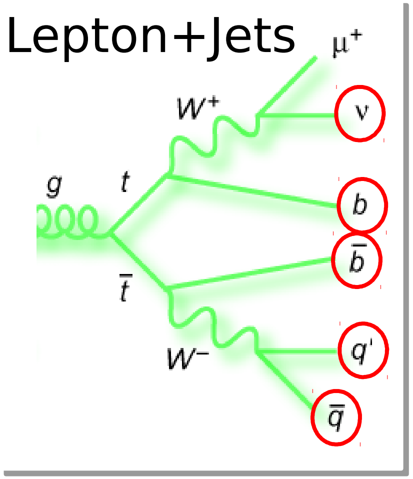
• 28750 events in 19.7 fb^{-1} 2012 data (94% ttbar, 44% correct perm.)



$P_{gof} > 0.2$



Top Mass – Jet Energy Scale



Common curse for all methods

Experiments normally measure in independent control sample.
Resolution not good enough for a state-of-the-art top mass measurement.

In situ Jet Energy Scale measurement

$W \to qq'$

Two poorly measured objects

One very well measured object

Many techniques will constrain it as part of the global fitting process.

Global fit over the full sample
Scale all jets by a constant factor to achieve constraint

Flavor Jet Energy Scale

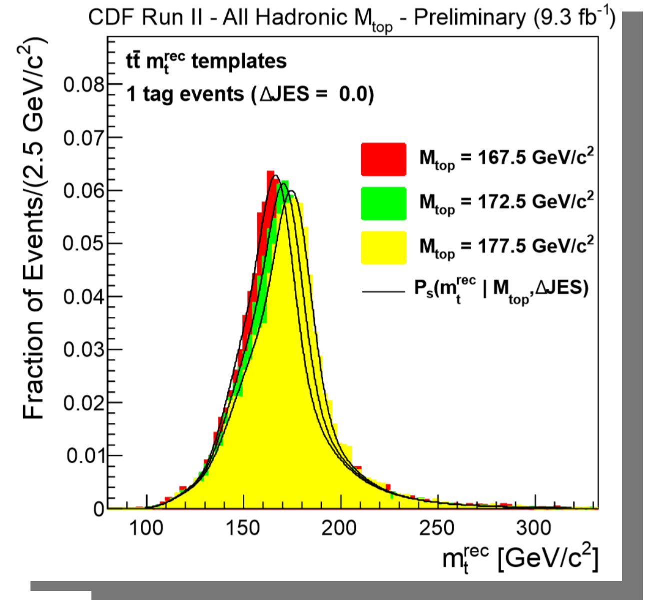
Top Mass – Template Method

Using a distribution sensitive to m_t:

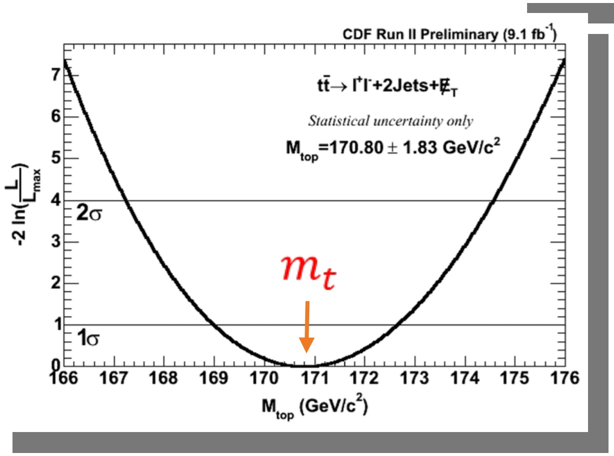
Simulated sample at $m_t = 167.5$ GeV

Simulated sample at $m_t = 172.5$ GeV

Simulated sample at $m_t = 177.5$ GeV



Use a likelihood to estimate template compatibility

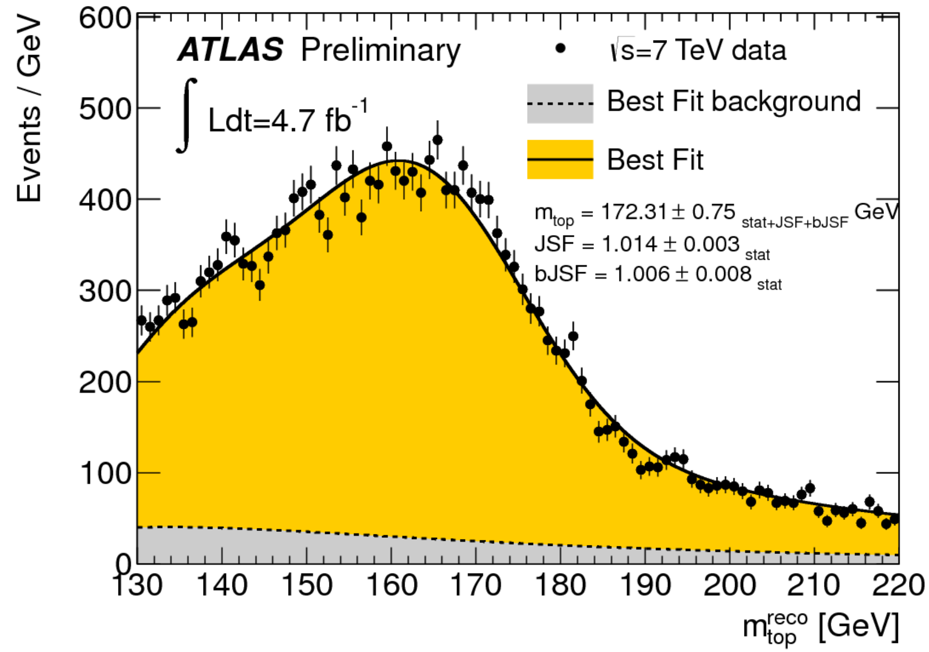


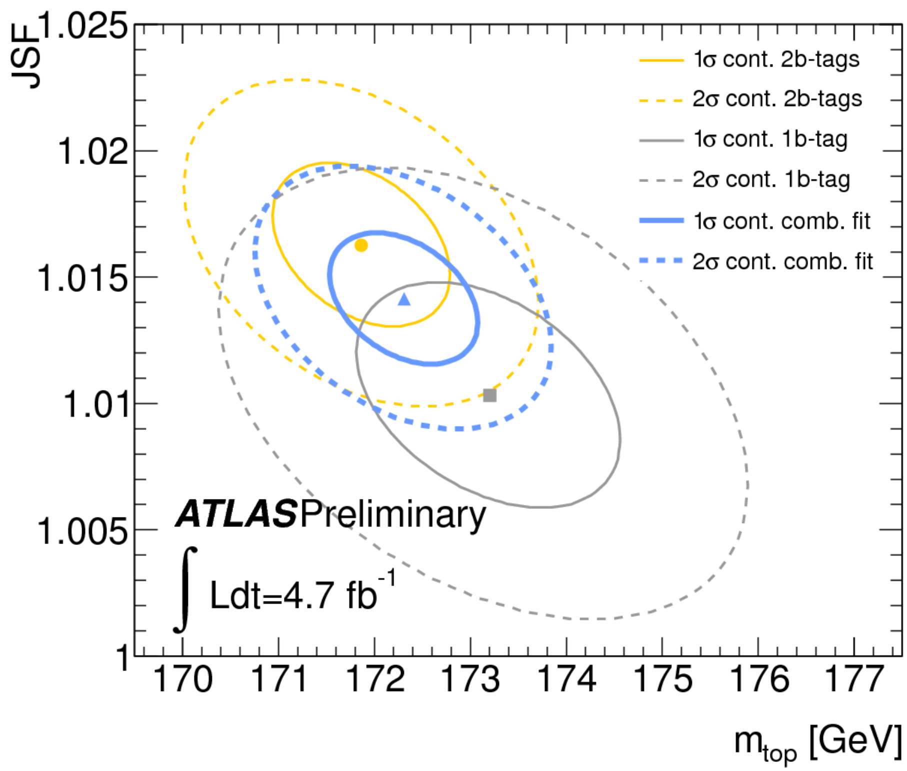
Can be done in two-three Dimension:

- Jet energy scale
- b-Jet energy scale
- Top mass

Top Mass Measurement

- Top Mass measurement using a 3D template fit.
  - ATLAS-CONF2013-046
  - Fitted Distributions:
    - M_{top}^{reco}, M_{W}^{reco} and R_{lb}^{reco}
  - Reduces systematics by 40%
  - Main improvement on the relative scale of Bjet-Light Jets





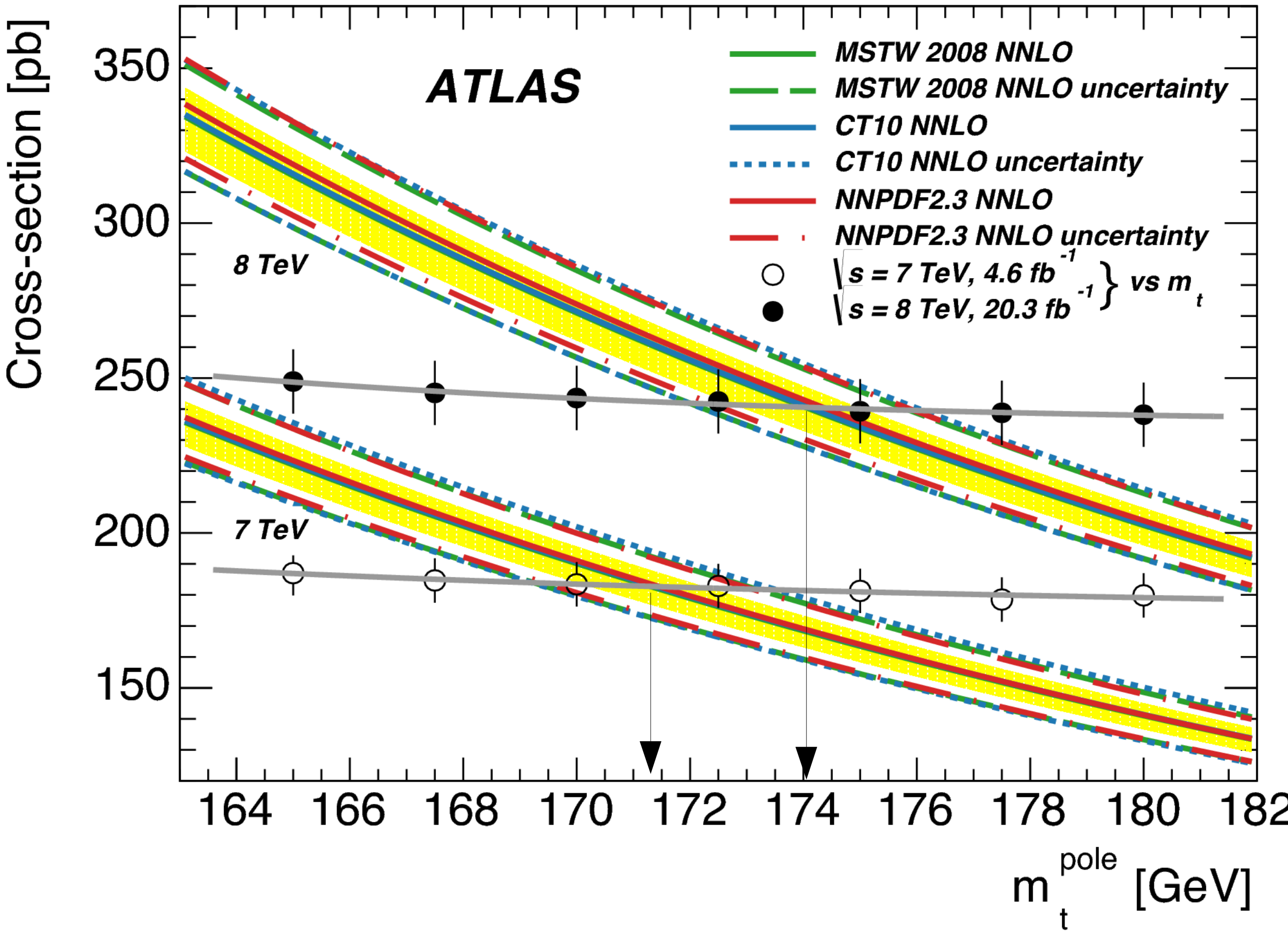
$$R_{lb}^{reco,2b} = \frac{p_T^{b_{had}} + p_T^{b_{lep}}}{p_T^{W_{jet_1}} + p_T^{W_{jet_2}}},$$

$$R_{lb}^{reco,1b} = \frac{p_T^{b_{tag}}}{(p_T^{W_{jet_1}} + p_T^{W_{jet_2}})/2}$$

M_{top}=172.31±0.75(stat+JSF+bJSF) ±1.35 (Syst) GeV

Mass Measurement from xsec

Comparing NNLO+NNLL QCD top pair cross section to data determine top mass in a well defined renormalisation scheme (here: pole mass) and theory uncertainties



M_{top} dependence of measured cross section -0.28%/GeV NNLO+NNLL cross-section

Prediction for various PDFs (band scale uncertainty)

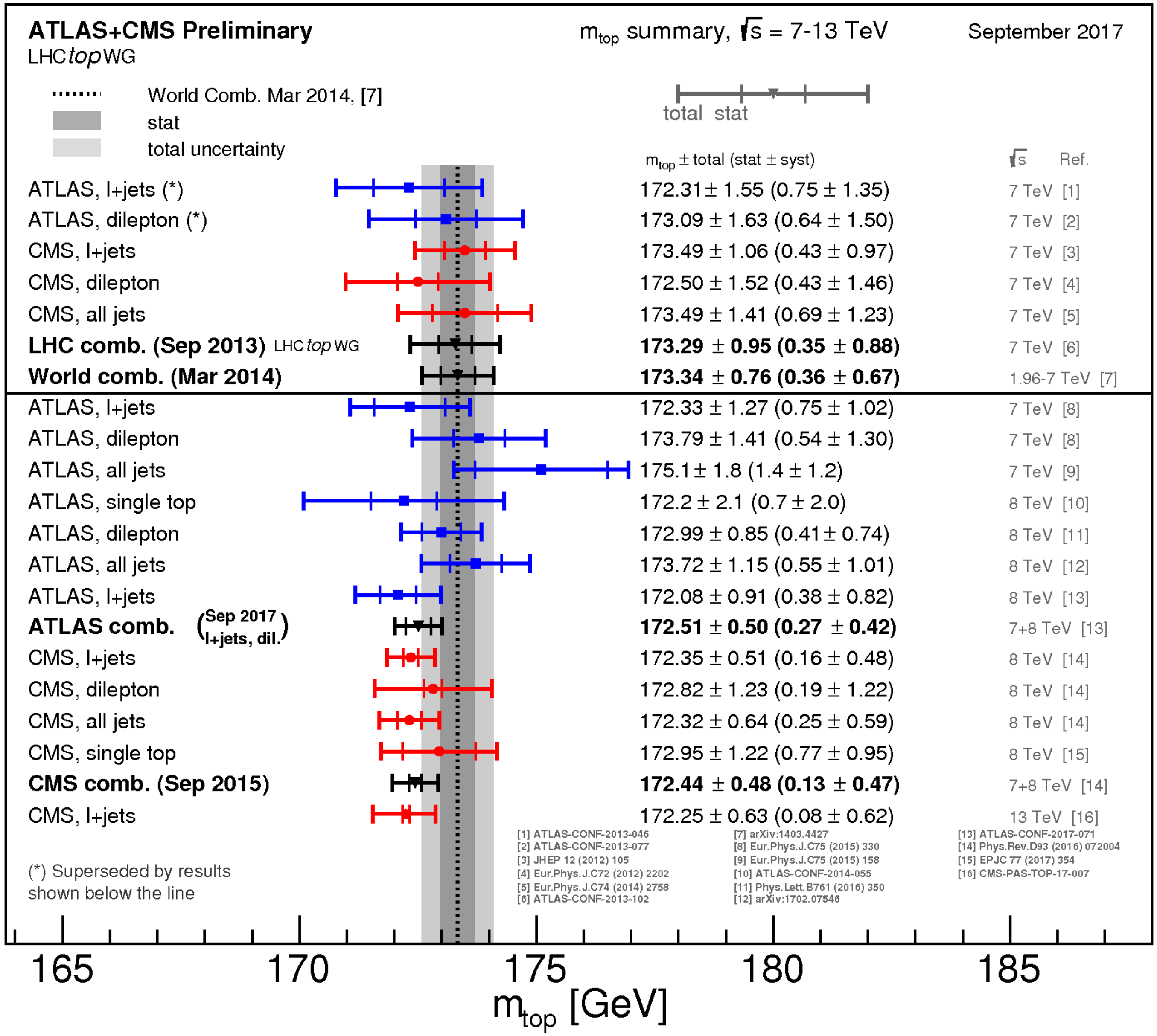
Combined result:

$$m_t^{\rm pole} = 172.9^{+2.5}_{-2.6}\ \mathrm{GeV}$$

Largest exp. syst. (luminosity) uncorrelated for 7 and 8 TeV

Results consistent within 1.7 sigma

Top Mass Summary



Top Mass Reached 0.3% uncertainty!

Mass Asymmmetry

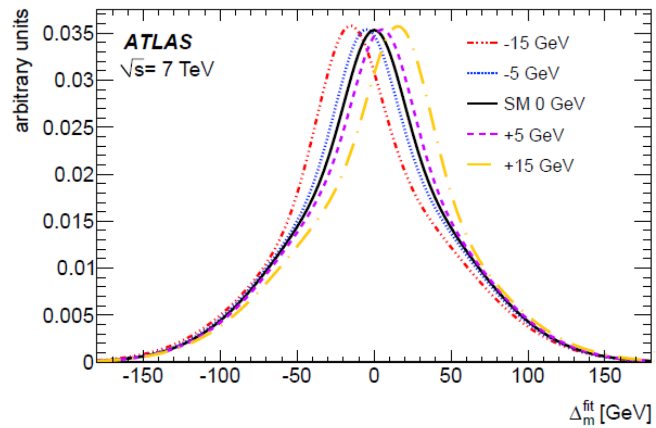


Fig. 1: Parameterization of $\Delta_m^{\rm fit}$ for simulated $t\bar{t}$ samples with different values of Δm.

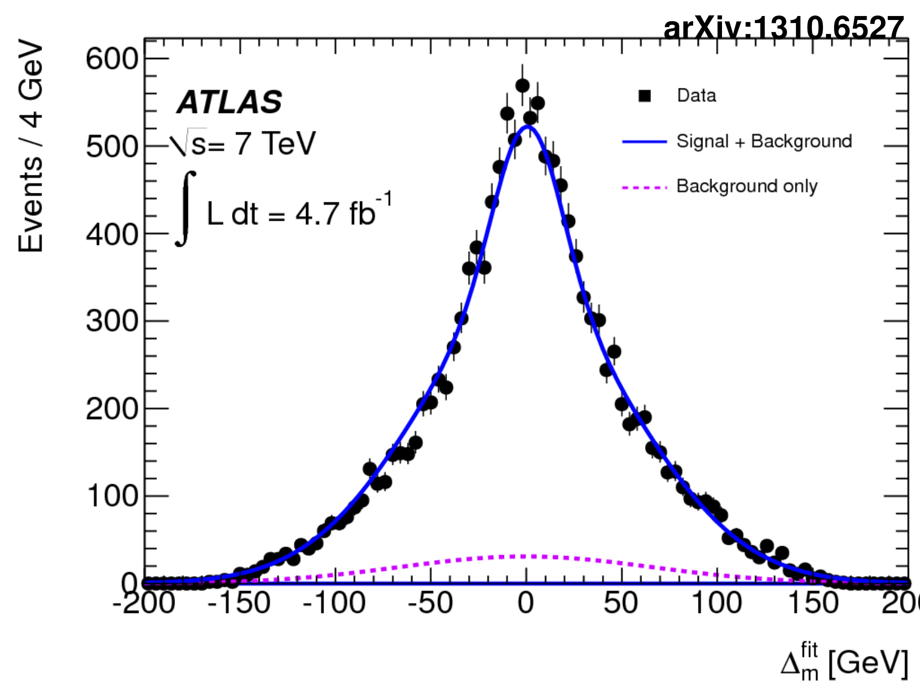
Systematic Uncertainty	$\Delta(\Delta m)$ [GeV]
$b/\bar{b}$ decay uncertainties	0.35
Kaons inside b-jets	0.08
Residual b vs $\bar{b}$ differences	0.08
b-tagging	0.08
Mis-tagging as a b-quark jet	0.05
Jet energy scale	0.04
b-jet energy scale	0.05
Jet energy resolution	0.03
Parton shower	0.08
MC generator	0.08
ISR/FSR	0.07
Calibration method	0.05
Non-$t\bar{t}$ normalization	0.04
Non-$t\bar{t}$ shape	0.04
Parton distribution function	0.02
Lepton energy scale asymmetry	<0.01
Electron reconstruction & identification	0.02
Muon reconstruction & identification	0.04
Top mass input	0.04
Total	0.41

Measurement of the top-anti-top mass difference
In lepton+jets events.
Kinematic fit used to reconstruct top mass.
Unbinned maximum likelihood used to measure Δm.

$$\Delta m \equiv m_t - m_{\bar{t}} =$$

0.67±0.61(stat)±0.41(syst) GeV
consistent with CPT invariance.

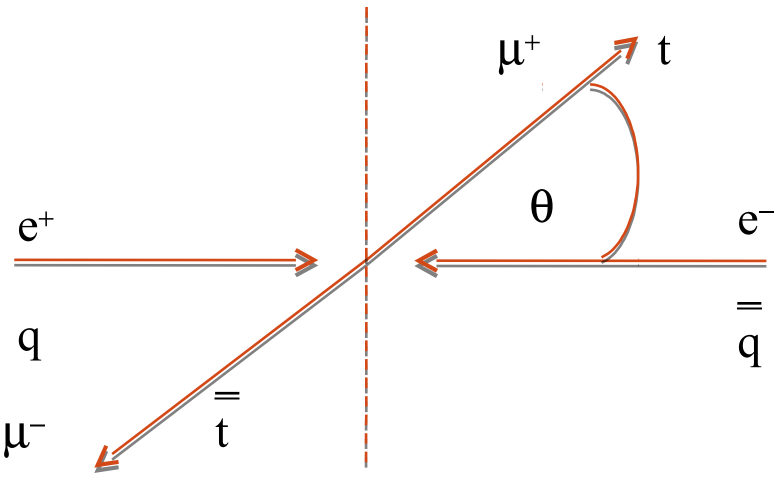
Main systematics are from b/b-bar fragmentation model and b-tagging effect



Forward-Backward Asymmetry

- Asymmetry defined for ee $\rightarrow \mu\mu$

$$A = \frac{N(\cos\theta > 0) - N(\cos\theta < 0)}{N(\cos\theta > 0) + N(\cos\theta < 0)}$$



- In proton-antiproton collisions $\theta \rightarrow y$

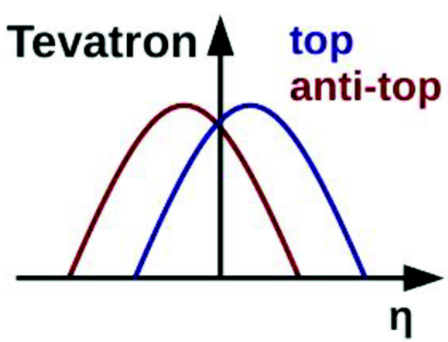
- Δy is invariant to boosts along *z*-axis

$$\Delta y = y_t - y_{\bar{t}} = q_l (y_{leptonic} - y_{hadronic})$$

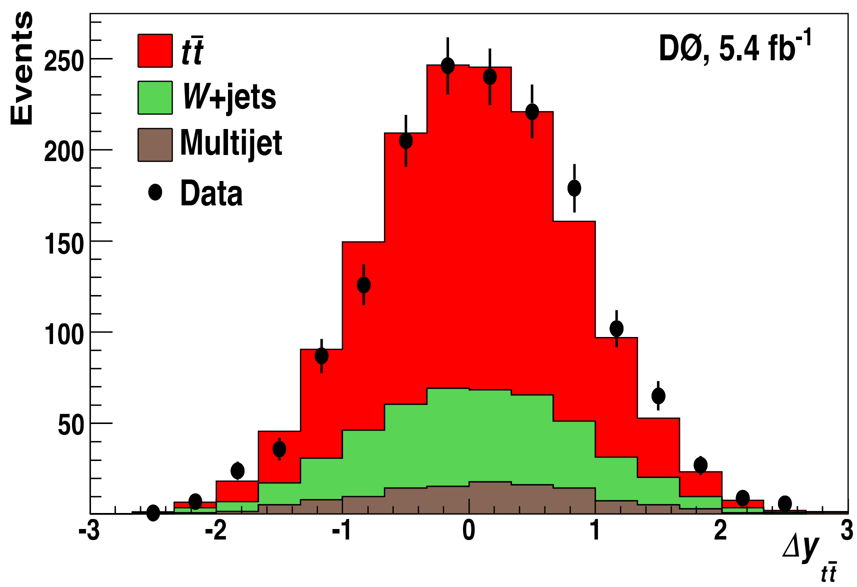
- Asymmetry based on Δy is the same in lab and tt rest frame

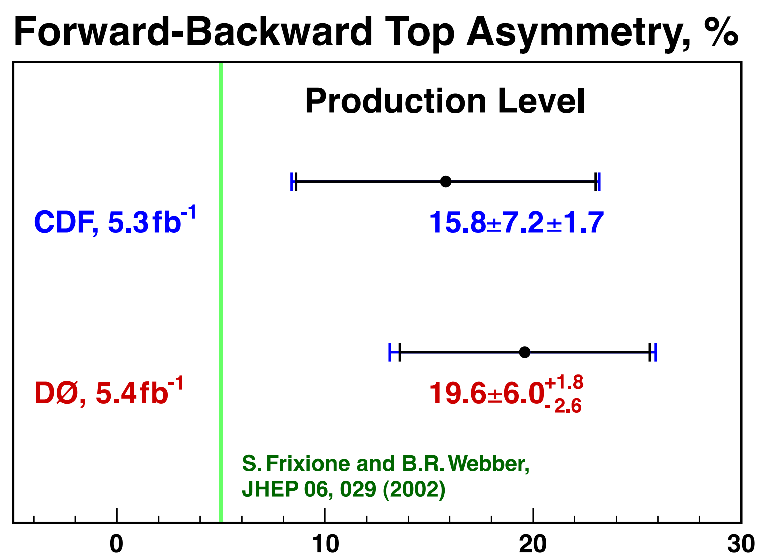
$$A = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

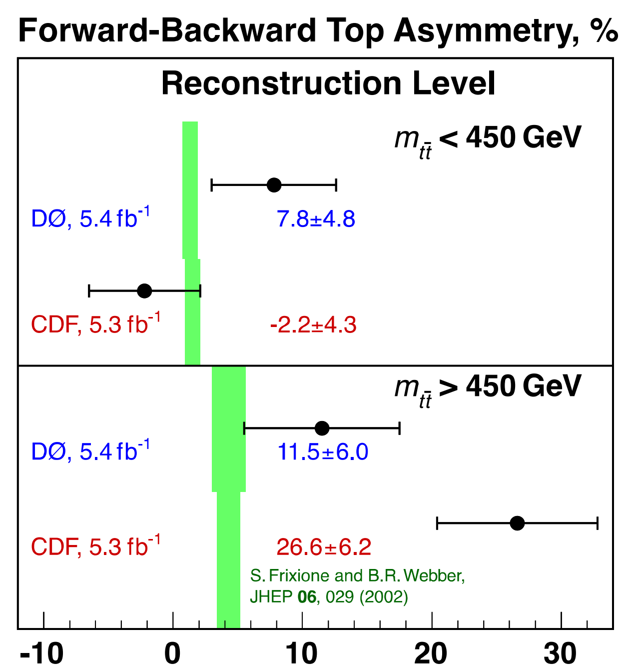
- Asymmetry based on rapidity of lepton from top decay
  - Lepton angles are measured with a good precision



Forward-Backward Asymmetry (2)







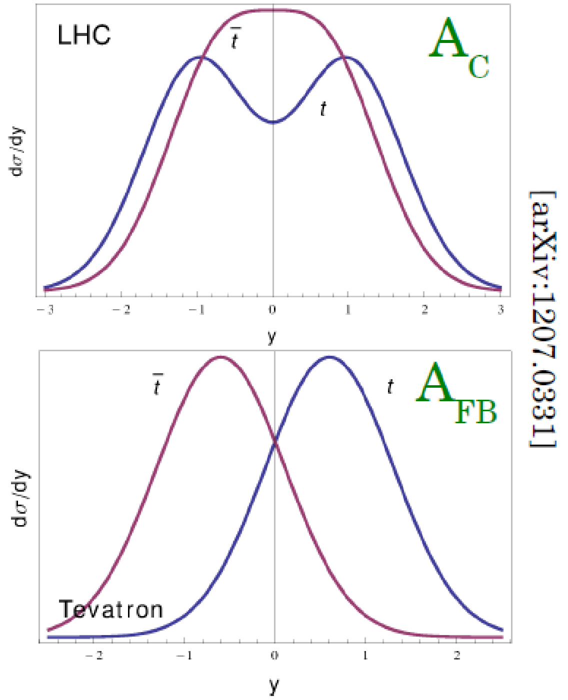
Only qqbar initial state is relevant for this measurement.
The gluon fusion and gq scattering are instead diluting the result

$$A = (9.2 \pm 3.6^{+0.8}_{-0.9})\%$$

$$A(MC@NLO) = (2.4 \pm 0.3^{+0.7}_{-0.5})\%$$

Top Charge Asymmetry

- Small charge asymmetry is expected at the NLO from interference in the production diagrams (~1% @LHC).
- TeVatron experiments reported ~2σ discrepancy wrt NLO QCD.
- LHC: qqbar fraction is much smaller (~15%) than @ TeVatron and it is measured in a different way, due to the overall symmetry of the distribution (pp vs ppbar)
- Results obtained in the l+jets final state, after full reconstruction of the event.



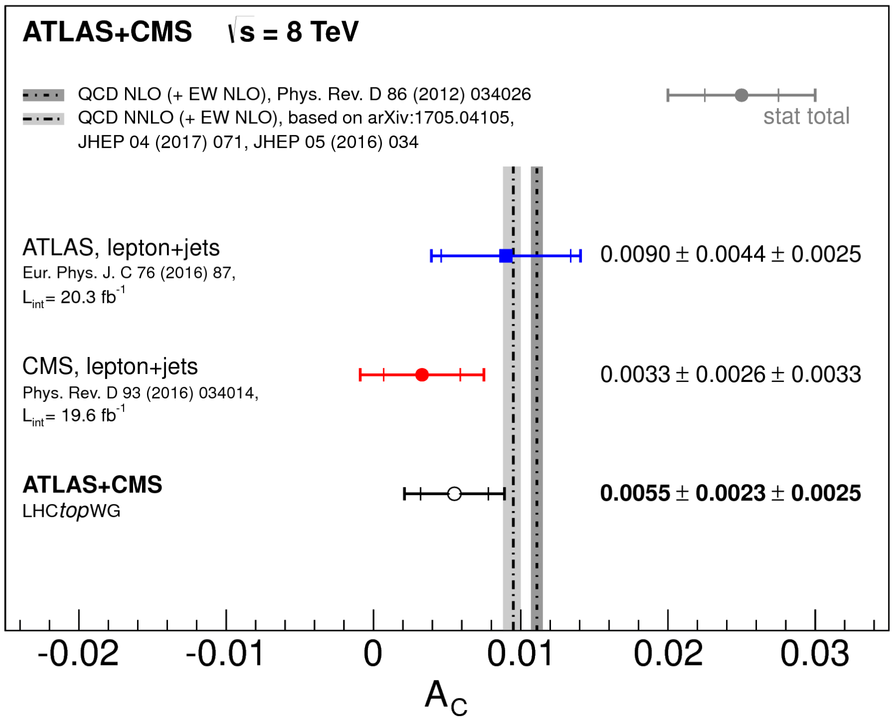
η=pseudo-rapidity **Y=rapidity**

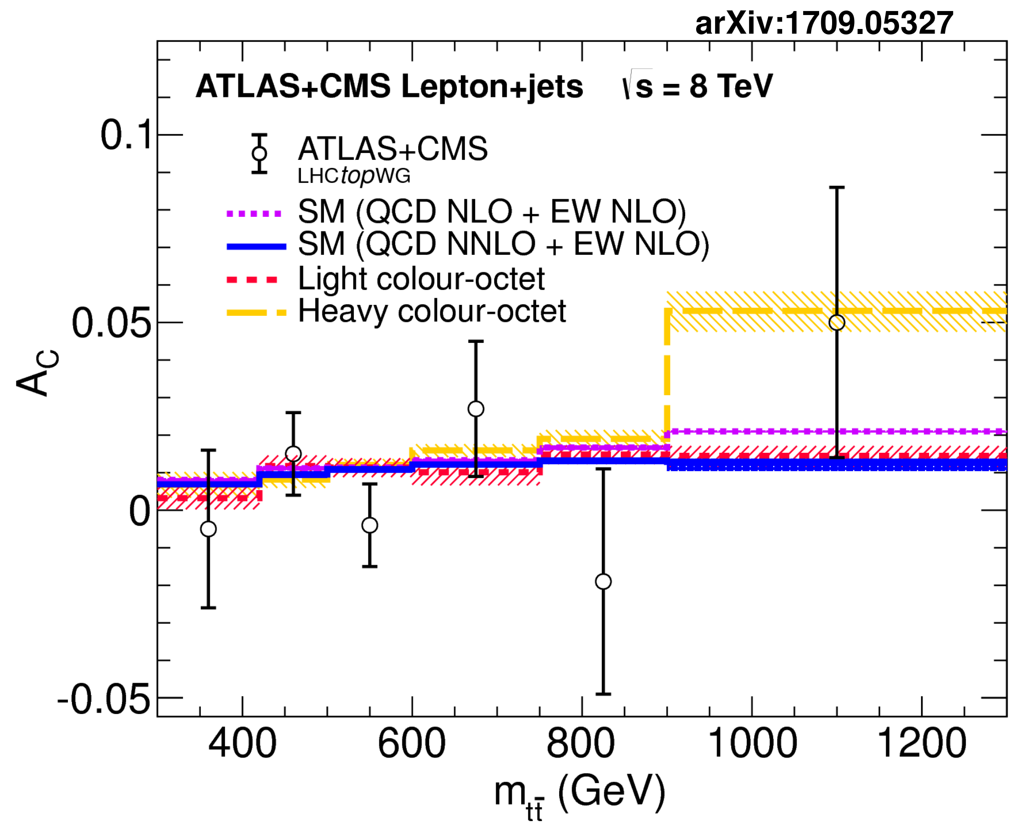
$$\Delta|\eta| = |\eta|_t - |\eta|_{\bar{t}}$$

and cross check with $\Delta(Y^2)$

$$\Delta|Y| = |Y|_t - |Y|_{\bar{t}}$$

Top Charge Asymmetry (2)





Measurement of the ttbar charge asymmetry in lepton+jets events. Motivated by A_{FB} anomaly at TeVatron

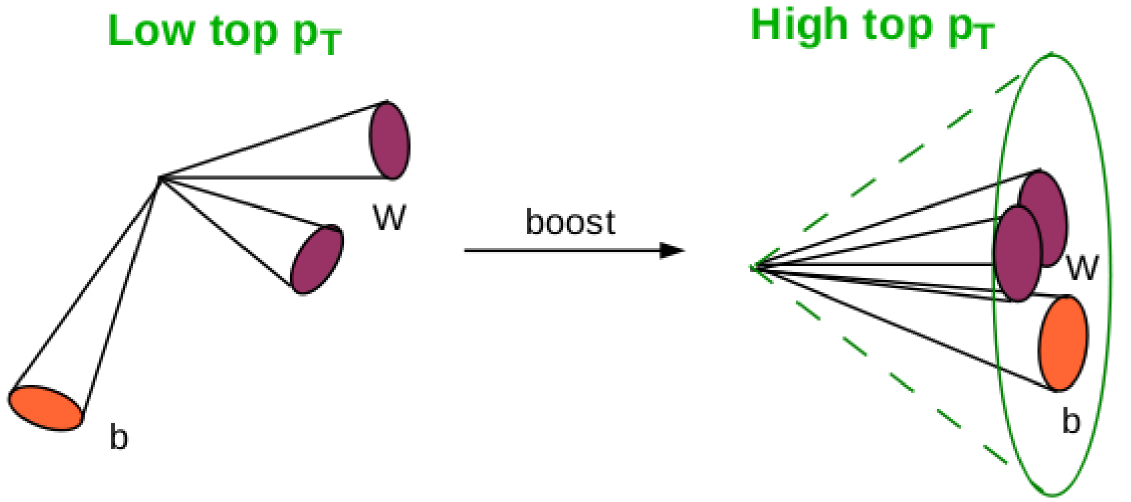
Inclusive and differential measurements are performed.

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

A_c =0.006±0.010 (dominated by stat. uncert.)
consistent with A_C^{SM}= 0.0123±0.0005

Boosted Topologies

- LHC 8-14 TeV
  - BSM theories predict resonances with mass ~ TeV
  - Many of these are expected to decay to dibosons, tt, …
  - Due to high mass, these W,Z,t,H will be at very high p_T (>> m)
    - and their decay products will be strongly boosted



  - **Traditional reconstruction techniques relying on one-to-one jet-to-parton assignment is not always inadequate**

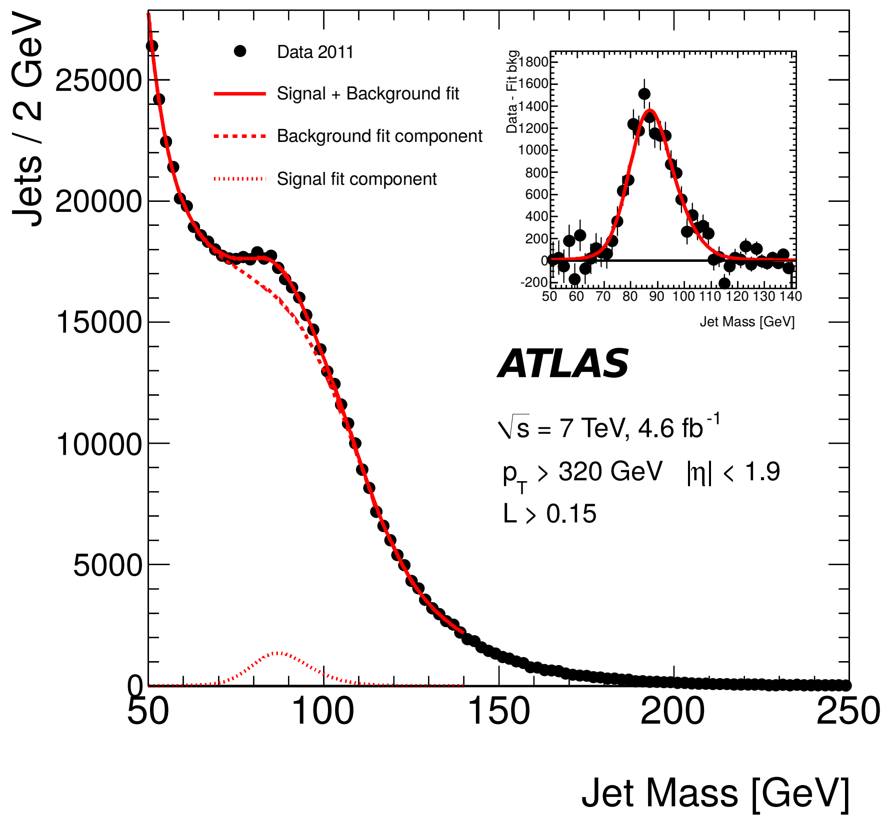
Jet Mass

Single jet mass $m_{jet} = \sqrt{E_{jet}^2 - p_{jet}^2}$

Deduced from four-momentum sum of all jet constituents

Can be reconstructed for any meaningful jet algorithm

Boosted single W

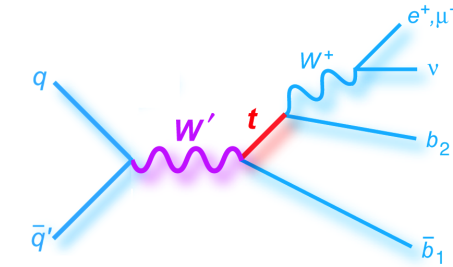


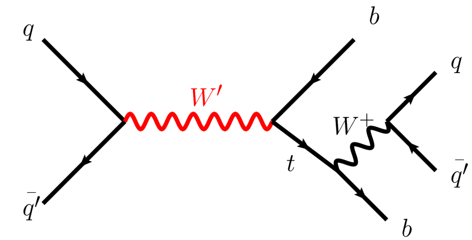
arXiv: 1407.0800v1

Validation of the method on SM processes, especially boosted top-anti-top

Beyond SM searches in the Top Sector

W' is an hypothetical heavier partner of the W.
Predicted for many BSM theories (extra-dimensions, Little Higgs,…)
Search for the decay W’→ tb allows to set limits to leptophobic models





Semi-leptonic decay → clean signature

Similar selection and backgrounds as the s-channel cross-section analysis.

hadronic decay → boosted top reco

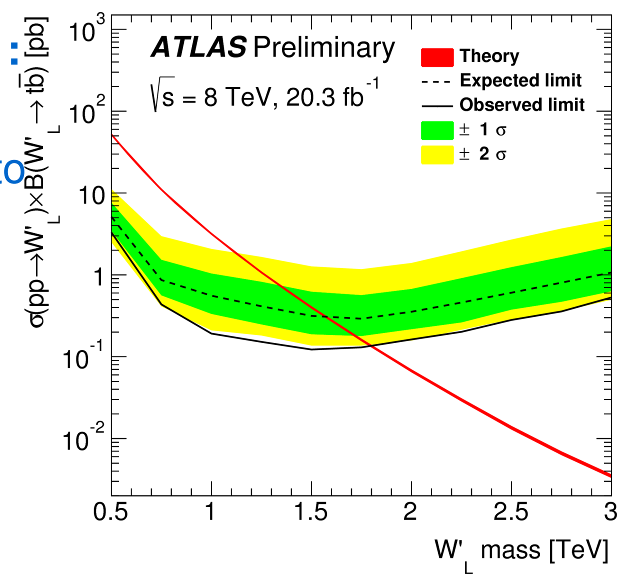
Large backgrond from multi-jet process

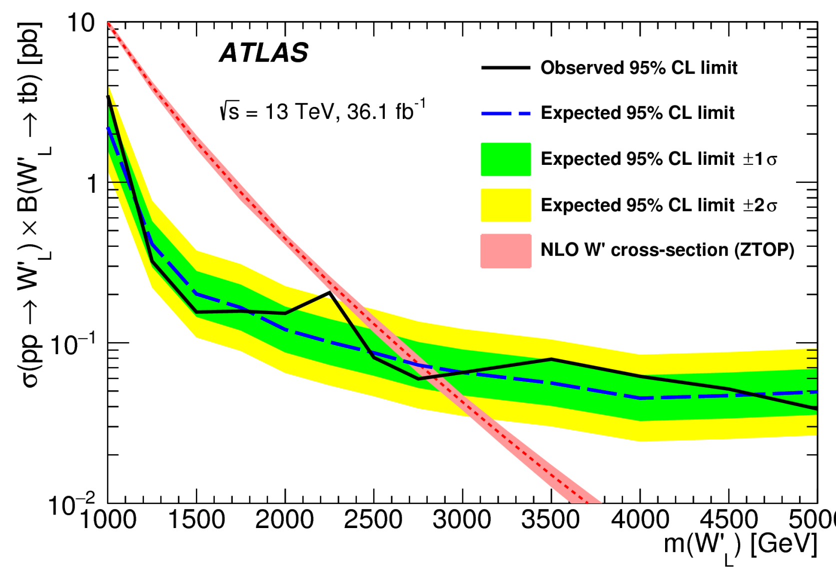
Multivariate analysis :

BDTs optimized for selecting 2 and 3 jets to account for topology.

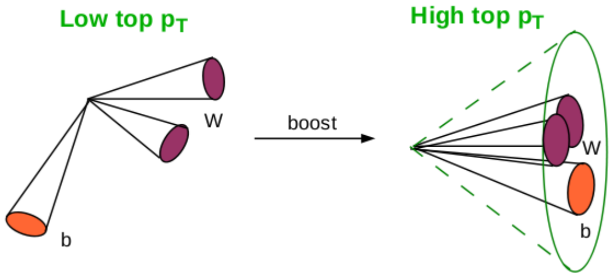
Fit to the BDT output

→ Limit @ 95 CL





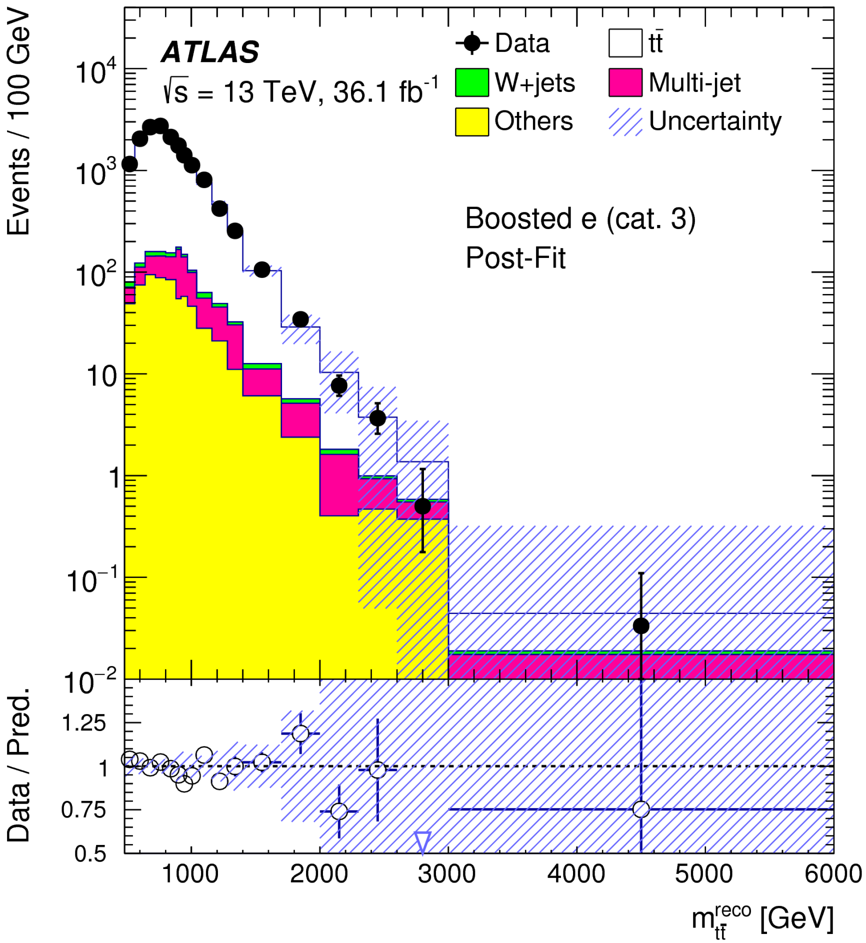
ttbar Resonances

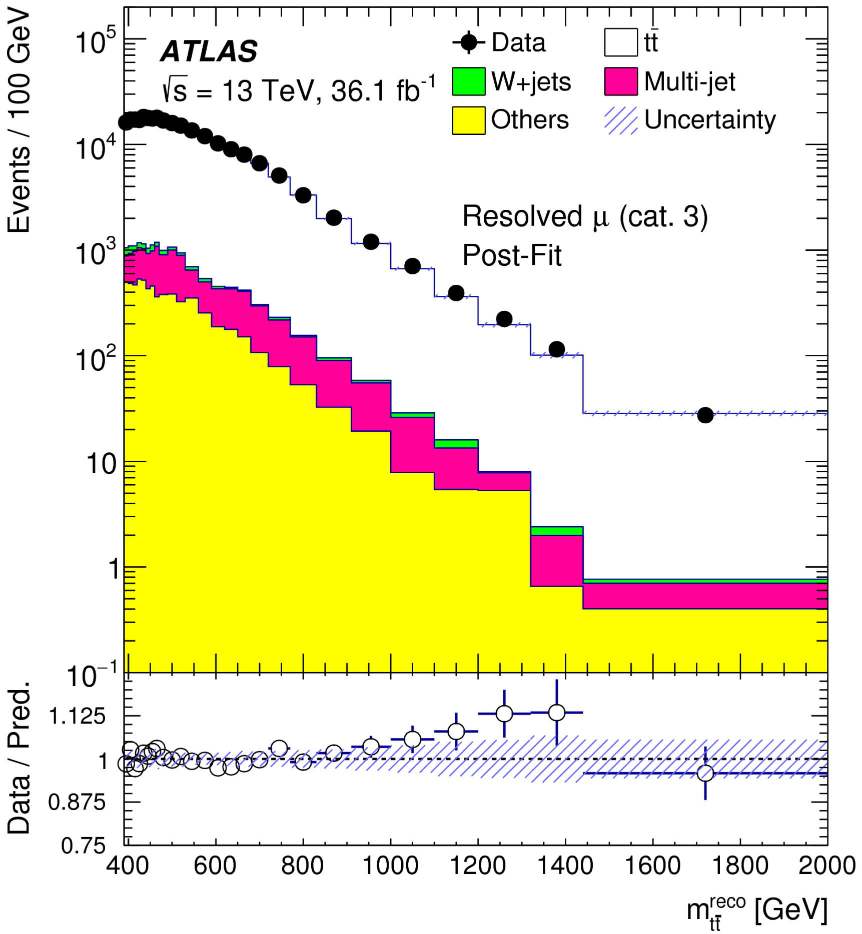


- Benchmark models
  - Topcolor [narrow width] (leptophobic Z' → tt)
  - Kaluza-Klein gluon and Graviton in RS models [broad width] (g_{KK}, G_{kk} → tt)
- Choose semi-leptonic decay channel (tt → WbWb → lnbbqq)
  - Larger BR than fully leptonic
  - Less background than fully hadronic
- Jets are classified as either small radius (R = 0.4) or large (R = 1)
  - p_T(small-R jets) > 25 GeV
  - p_T(large-R jets) > 300 GeV
- M(tt) spectrum is tested for any excess beyond SM
- tt events are reconstructed in two modes
  - Resolved: Hadronic top identified as 2 or 3 small-R jets
  - Boosted: Hadronic top identified as 1 large-R jet

ttbar Resonances (2)

Combining both reconstruction modes, no excess is seen in the M(tt) spectrum



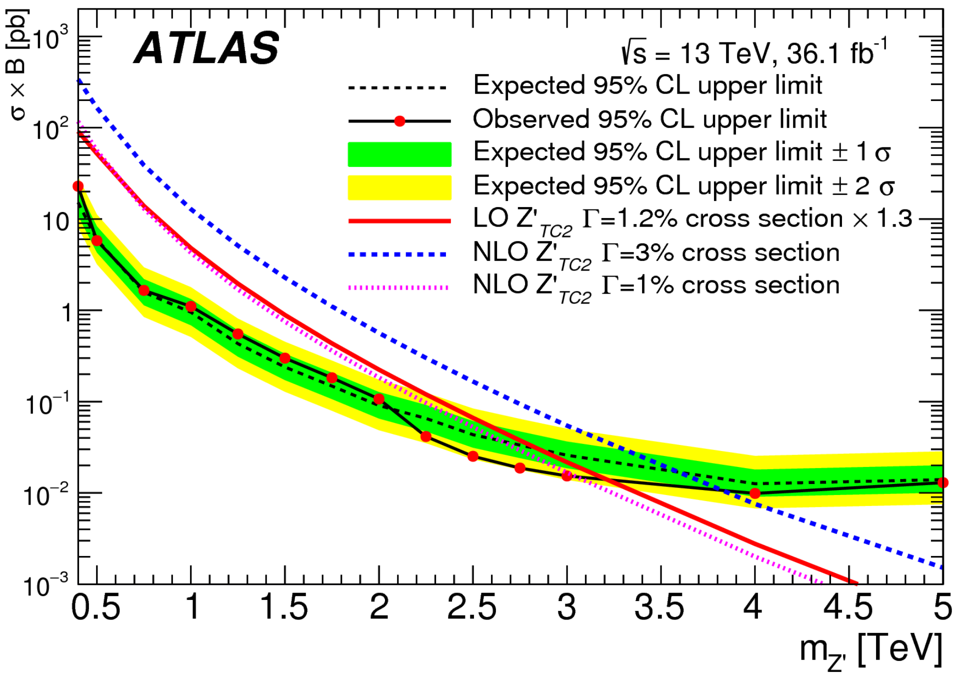


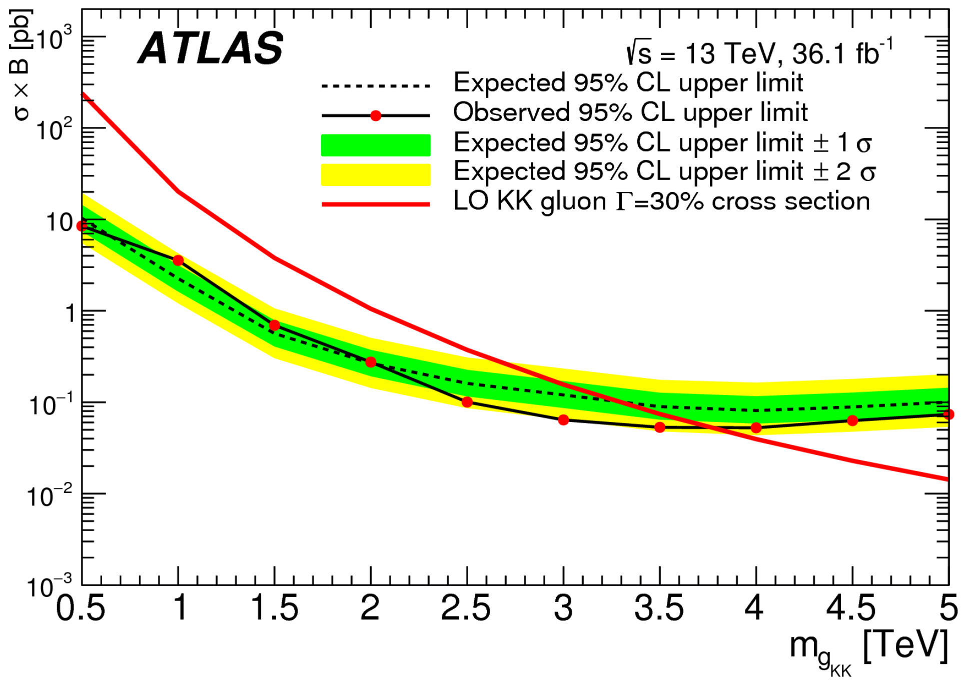
ttbar Resonances (2)

Resulting limits on cross section can be translated to limits on M(Z′) and M(g_{KK})

A narrow lepto-phobic topcolor Z′ is excluded at the 95% CL for 0.5 < M(Z′) < 3 TeV

A broad Kaluza-Klein gluon is excluded at the 95% CL for 0.5 < M(g_{KK}) < 3.7 TeV





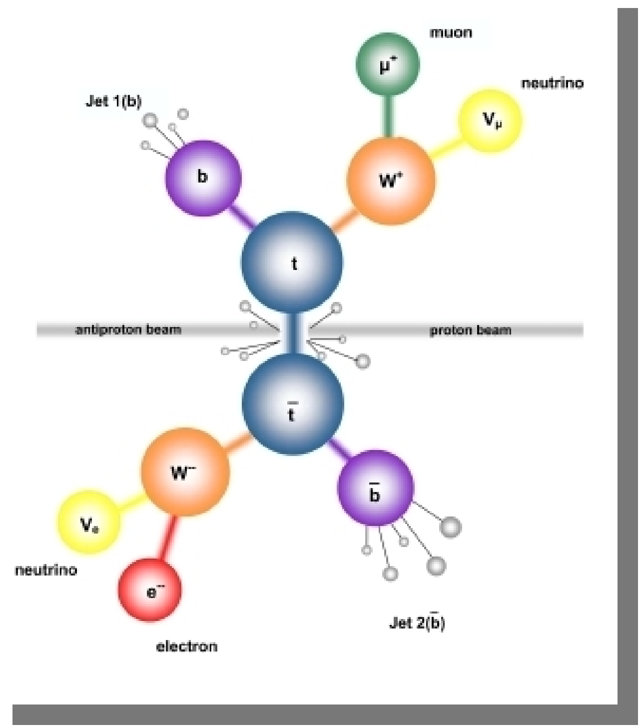
Bonus Slides

Top Mass – Matrix Element

A reverse Monte Carlo approach

MC Generates 100K events → Distributions of kinematic variables for all objects

"Map of kinematic phase space" → Distributions of kinematic variables for all objects



Turn that around:

Given a single event in data, how dense is the part of kinematic phase space is it in? → ***P***

Repeat for all major backgrounds and signal:

Calculate signal and background probability density for all parton-jet assignments as function of M_{top} and JSF

Top Mass – Matrix Element Steps

ALPGEN + Pythia → Detector Simulation → Reconstruction → 4 vectors of reconstructed objects

$$P(m_{top}) = \frac{1}{\sigma_{obs}^{t\bar{t}}(m_{top})} \sum_{i=1}^{24} w_i$$

Normalization

Sum over all possible jet assignments

- Which jet is the first tops?
- Which jets belong to the W?

A weight reflecting the probability of those jet assignments

- tagging probabilities

$$P(m_{top}) = \frac{1}{\sigma_{obs}^{t\bar{t}}(m_{top})} \sum_{i=1}^{24} w_i \int d\rho\, dm_1^2\, dM_1^2\, dm_2^2\, dM_2^2\, d\rho_\ell\, dq_1^x\, dq_1^y\, dq_2^x\, dq_2^y$$

10 dimensional integral over phase space

- Mass of the tops, W's
- Directions of the b-quarks
- Lepton and neutrino direction

Matrix Element Result

In used at DZERO since Run I

- Use different top mass in the Matrix Elements
- Vary the Jet Energy Scale in the transfer functions

174.98±0.58(stat)±0.63(syst) GeV