The short term strategy and plan for ttbar and single-top at the LHC

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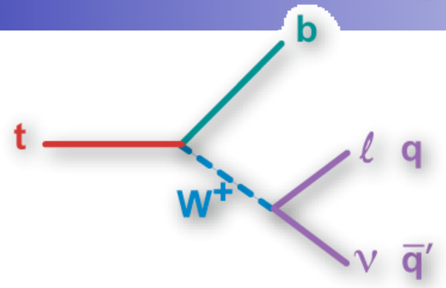
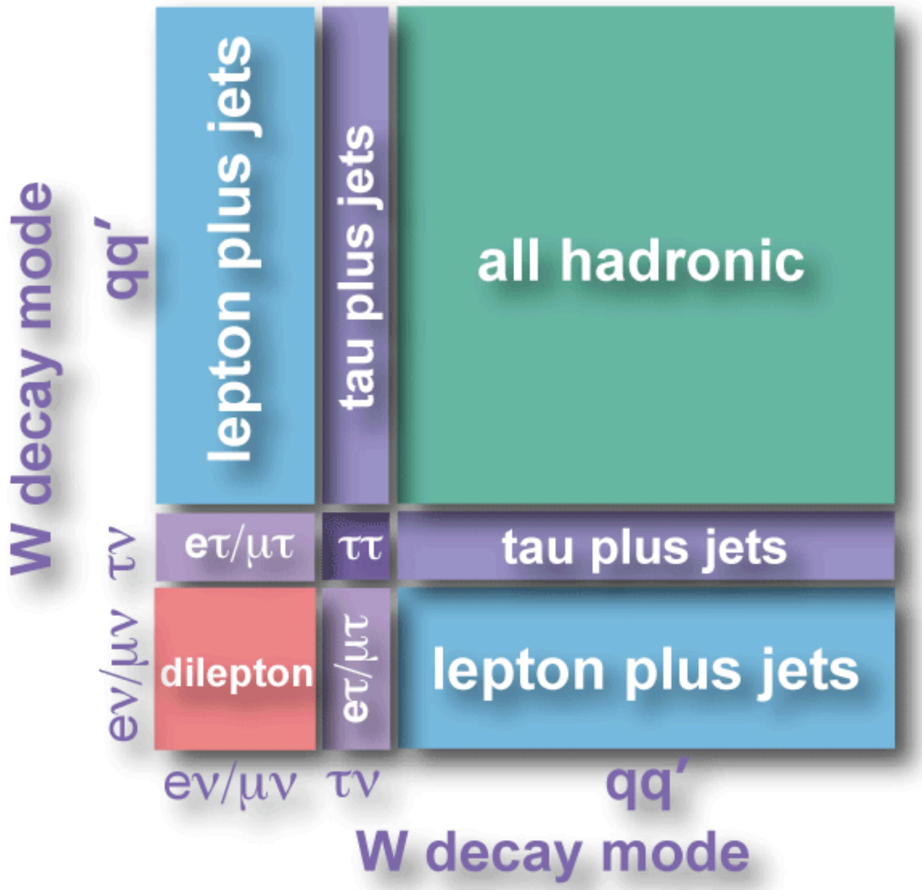
Top decay channels





Top-antitop decay modes

•Di-leptonic channel:

- low statistics (9%)
- clean signature S/B 4.5-6.5

•Semi-leptonic channel (e/μ):

- 45% of total
- S/B≈1 (without b-tag)
- Visible top and/or W invariant mass peaks helps

•Fully hadronic(46%):

- high QCD backgrounds.
- Not easy to trigger on (no leptons, need b-tag trigger?)

  Not for early data

First top measurements

The first top measurement to be done with early data is the ttbar x-section determination

Dilepton channel

- 2 opp. charges leptons
- 2 jets or more

- Backgrounds
  - 2 real leptons
    - Drell-Yan
    - Dibosons
    - Single-top (Wt)
  - fake leptons
    - W+jets, QCD
- Strategy
  - Veto Z window and MET

Lepton+jets channel

- 1 lepton
- 4 jets or more

- Backgrounds
  - combinatorial
  - W+jets
  - single-top
  - fake leptons
- Strategy
  - reconstruct hadronic top
  - cut or fit

Analysis strategy

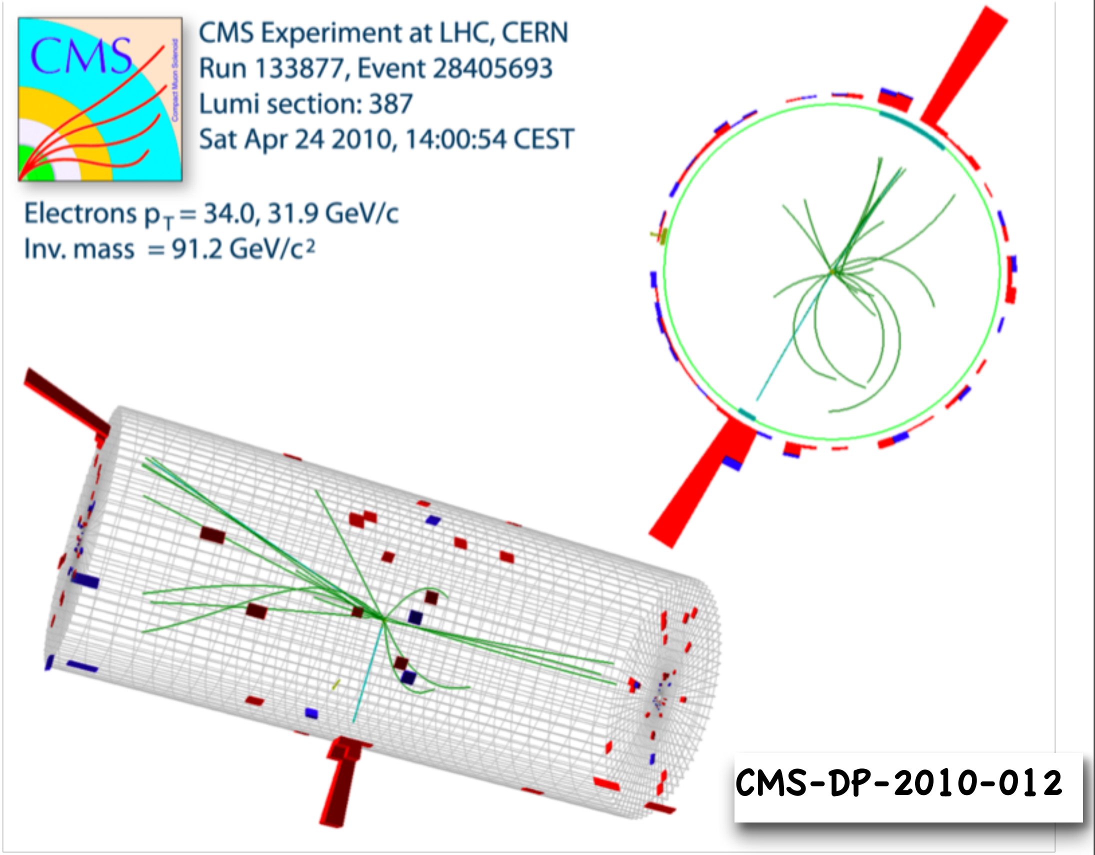
- **Very basic selection:**
  - ➢ Use unprescaled single lepton triggers
  - ➢ Very simple/safe object definition
  - ➢ Consider to use b-tag but with caution
  - ➢ Also MET is not used in some analysis
- **Data-driven background measurements**
  - ➢ Avoid to rely too heavily on simulation:
    - large theoretical uncertainties (QCD-multijet, W+jets about 80-100%)
    - Acceptance uncertainties (lepton fake rate, b-tagging efficiency …)
  - ➢ Use data to measure main backgrounds

All results shown in the next slides are at 10-14 TeV with extrapolations to 7 TeV (where given).

En Route to Top Measurements

Many studies needed before we can look at top physics in real data

- **Lepton reconstruction**
  - ID and fake rates
  - isolation
  - (trigger) efficiencies via Tag&Probe with Z-events
- **Jet and MET reconstruction**
  - Efficiencies
  - Jet energy scale
- **Electroweak physics**
  - Study of W and Z events
- **Testing data driven background estimation methods**
- ...

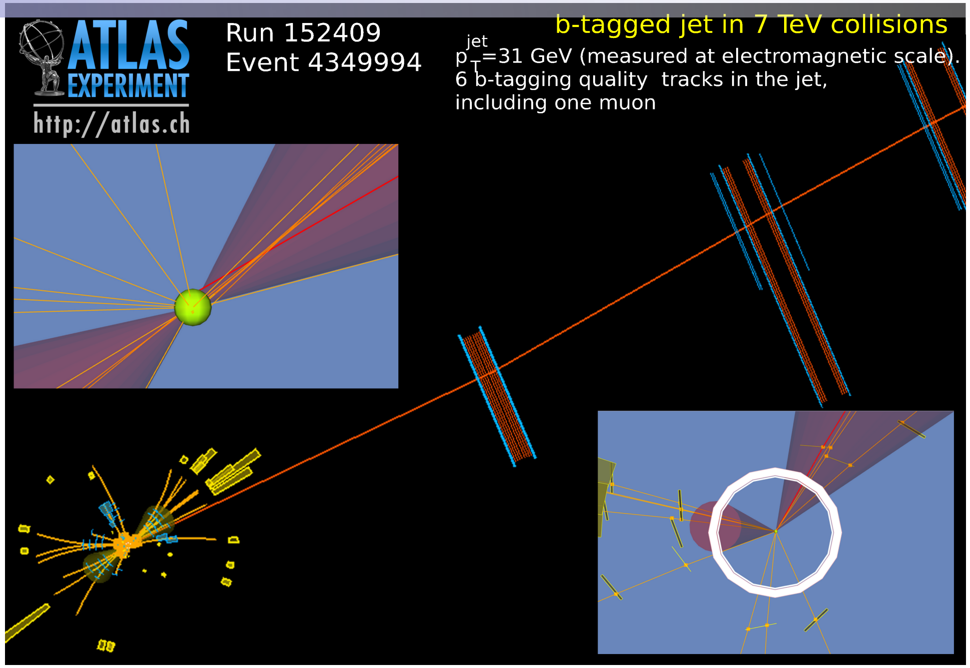


CMS-DP-2010-012

With increasing recorded luminosity slowly pushing understanding into the kinematical region of top physics

Flavour Tagging Today

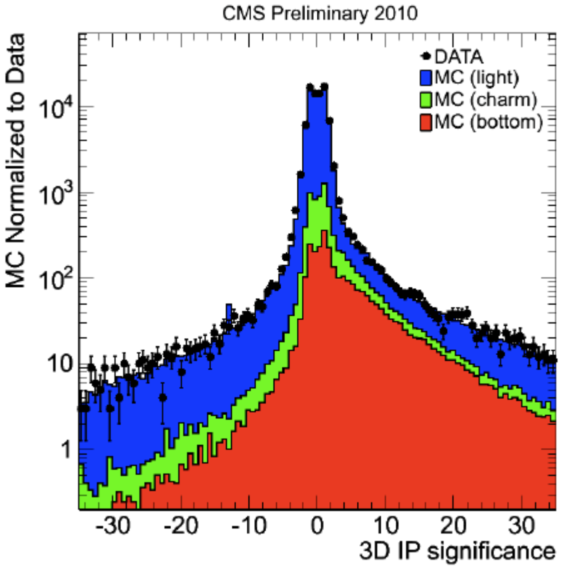
- **Both experiments are studying flavour tagging with the data in hand.**
  - Many tagged jets have been found, sometimes correlated with nearby leptons or second tags in the event
- **The emphasis is on “early taggers”**
  - Not necessarily the ultimate performance, but can be understood quickly.

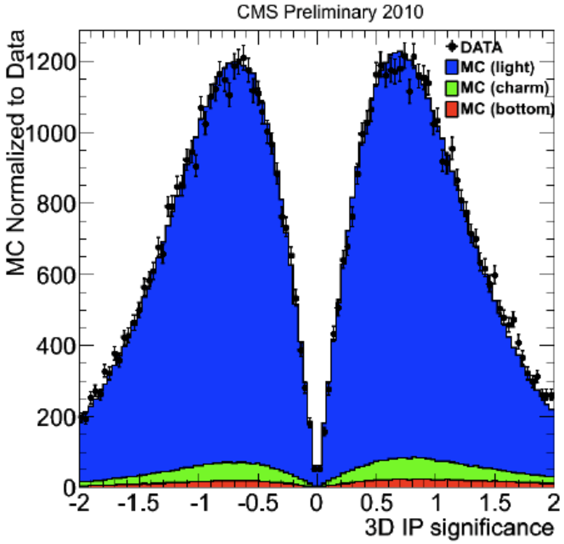


Run 152409
Event 4349994

b-tagged jet in 7 TeV collisions

p_T^{jet}=31 GeV (measured at electromagnetic scale).
6 b-tagging quality tracks in the jet,
including one muon





CMS-DP-2010-015

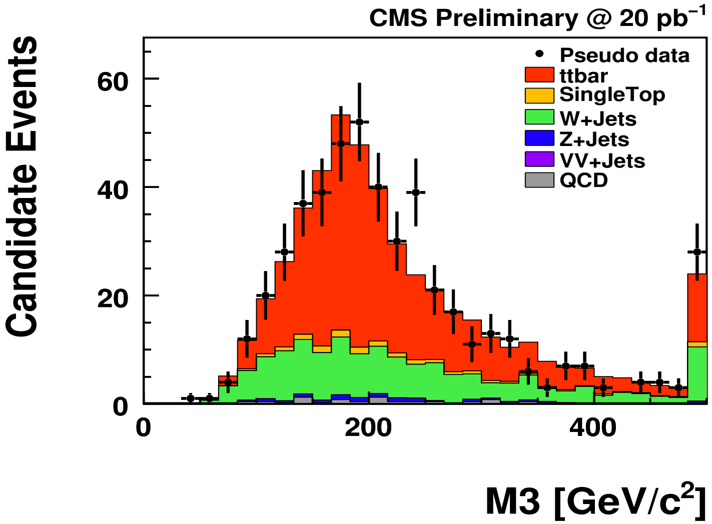
CMS Muons+jets selection @ 10 TeV

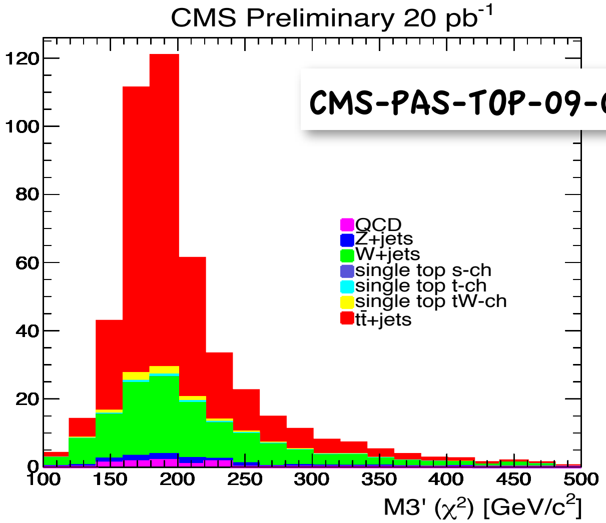
- Event selection at 20 pb^{-1}
  - Exactly one high p_T isolated muon >20 GeV
  - 4 high p_T jets of >30GeV

No MET

- Top Quark Reconstruction
  - M3: Combine 3 jets (highest pt sum) to form hadr. Top
  - M3': χ^2 sorting using W mass and MET

@10 TeV 20pb^{-1}	Signal: muon. ch.	backgrounds	S/N
after selection	320	171	1.9





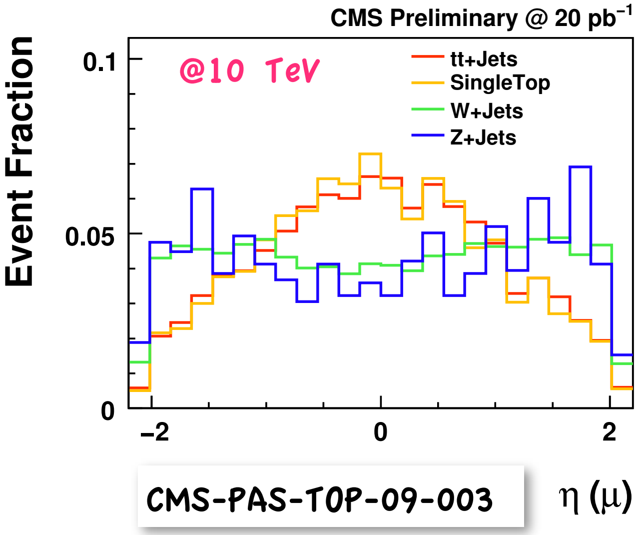
CMS-PAS-TOP-09-003

CMS Muons+jets x-section measurement

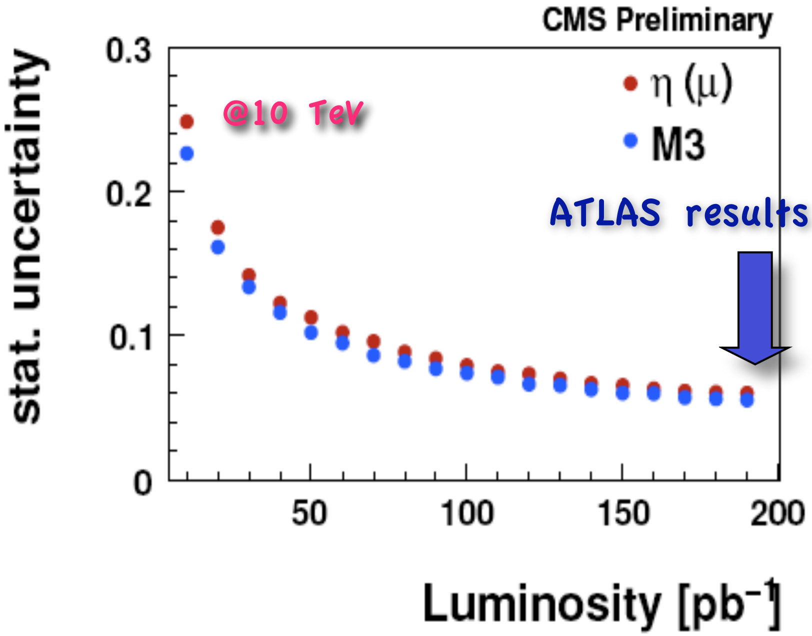
- Template fit for: M3, M3', Muon η
- Input to the fit are only three templates
  - tt+Jets, Single top, W+jets

    (Z+jets has very similar shape

    Expected QCD amount very small)



CMS-PAS-TOP-09-003



ATLAS results

Source	Uncertainty [%]		
	Fit to $\eta(\mu)$	Fit to M3	Fit to M3'
Statistical Uncertainty (20 pb^{-1})	17.7	16.3	11.5
Jet Energy Scale	16.7	15.1	19
$t\bar{t}$ MC Generator	1.9	14.9	14
$t\bar{t}$ ISR/FSR	3.3	7.7	2
W+jets Factorization scale	4.4	4.7	4
W+jets Matching threshold	5.5	2.8	4
Single Top Shape	0.1	0.8	1
PDF Uncertainty	5.0	5.0	5.0
Total Systematic Error	19.2	23.8	25.0
Luminosity Error	10.0	10.0	10.0

CMS data driven background estimate

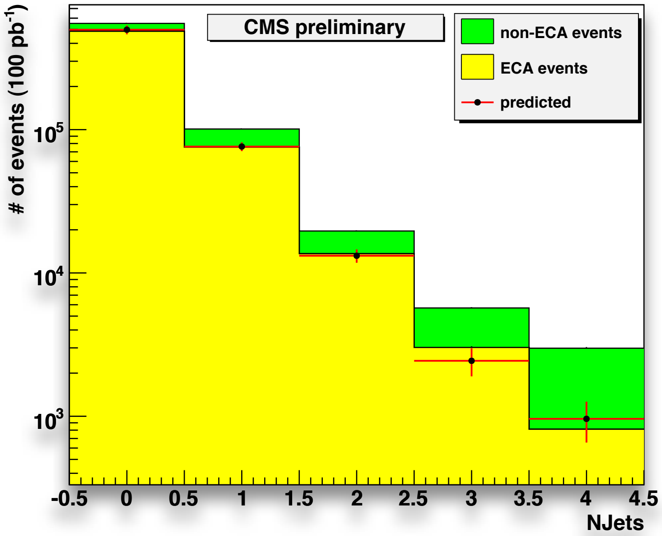
- In pp collisions W+jets events are charge asymmetric
  - Use these (and other) events with charge asymmetry (ECA) to estimate the EWK background
- Total number of ECA events can be obtained by counting the difference between W^+ and W^-

$$(N_+ + N_-)_{data} = R_\pm(W) \times (N_+ - N_-)_{data}$$

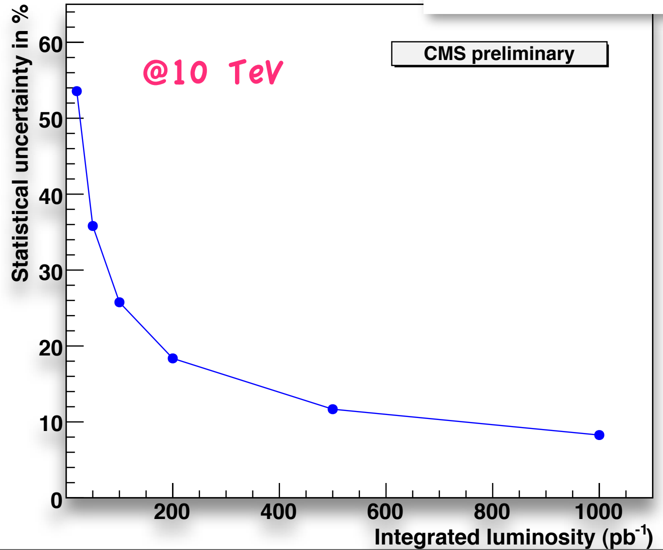
using the prediction from MC

$$R_\pm(W) = \frac{N_{W+} + N_{W-}}{N_{W+} - N_{W-}}$$

Initially statistically limited



CMS-PAS-TOP-09-003

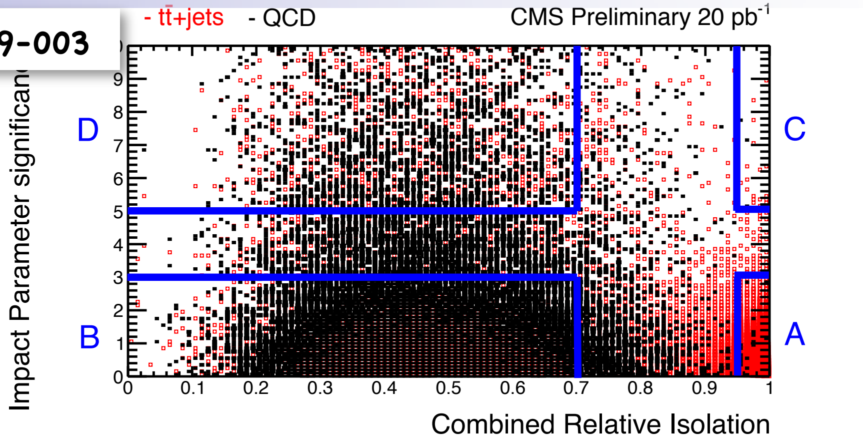


CMS: QCD background estimate

CMS-PAS-TOP-09-003

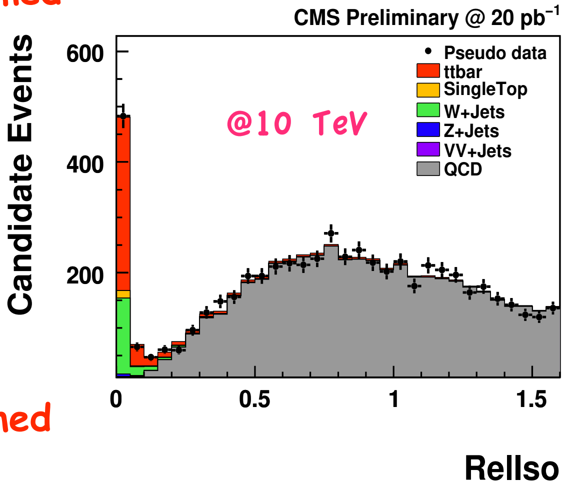
- ABCD method
  - Using two independent discriminating variables
  - Combined relative isolation
  - Muon impact parameter significance

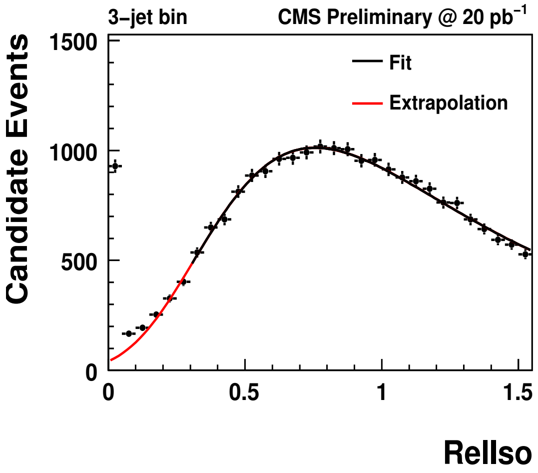
$$N_A = (N_B \cdot N_C)/N_D$$



50% uncertainty conservatively assumed

- Extrapolation of isolation var.
  - Fit muon isolation in side-band region
  - Extrapolate into signal region





50% uncertainty conservatively assumed

ABCD method

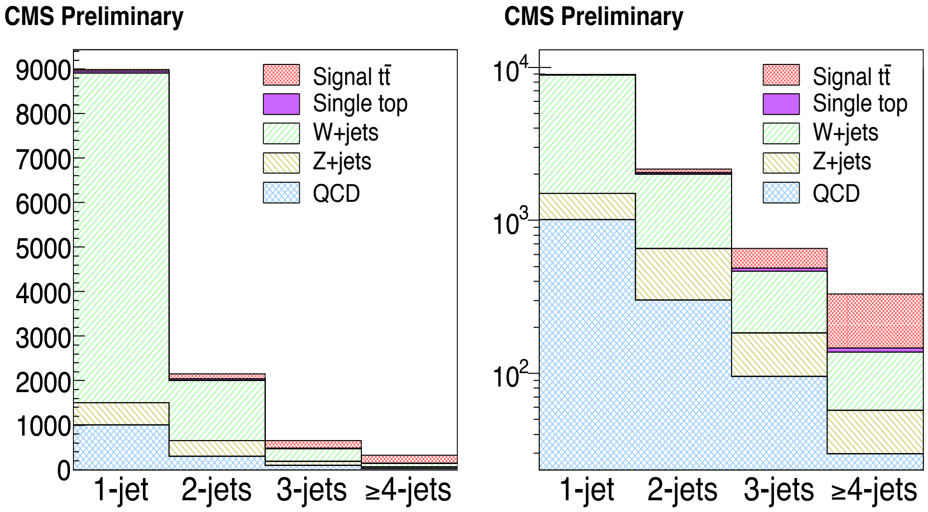
Jets	N(QCD) Predicted	N_B	N_C	N_D	N(QCD) Estimated
2	327	86625	61	16240	325 ± 26
3	53	24216	10	5058	48 ± 9
≥ 4	7	5345	3	1148	12 ± 5

Side-band extrapolation

Jets	N(QCD) Predicted	N(QCD) Estimated
2	327	378 ± 82
3	53	47 ± 24
≥ 4	7	13 ± 7

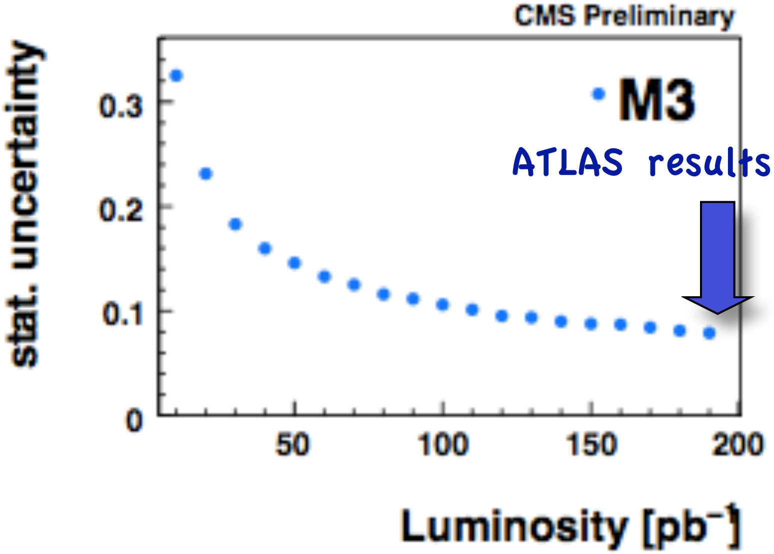
CMS Electron+jets x-section

- Baseline selection at 20 pb^{-1}
  - High p_T isolated electron >30 GeV
  - 4 high p_T jets of >30GeV
- Couple of different options to reject γ conversions and Z's

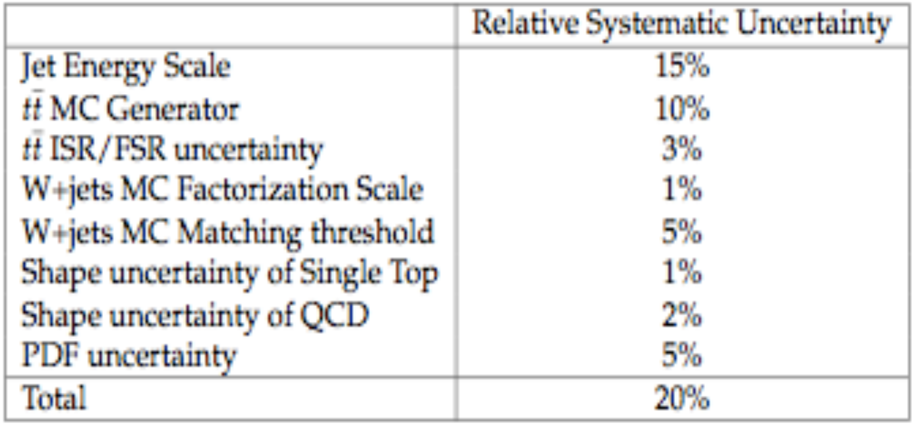


CMS-PAS-TOP-09-004

- Cross section measurement using M3 template method



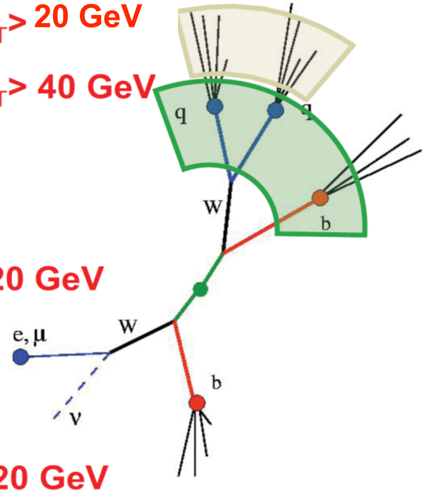
ATLAS results



	Relative Systematic Uncertainty
Jet Energy Scale	15%
$t\bar{t}$ MC Generator	10%
$t\bar{t}$ ISR/FSR uncertainty	3%
W+jets MC Factorization Scale	1%
W+jets MC Matching threshold	5%
Shape uncertainty of Single Top	1%
Shape uncertainty of QCD	2%
PDF uncertainty	5%
Total	20%

ATLAS Lepton+jets selection @ 10 TeV

- **Basic event selection**
  - high p_T isolated lepton
  - 4 high p_T jets, 3 of them >40GeV
- **Additionally**
  - MET>20GeV
  - Combine 3 jets to form hadronic Top (selection that maximizes p_T top)
  - 2 jets satisfy W mass constraint (m_W±10GeV) ε=10%.



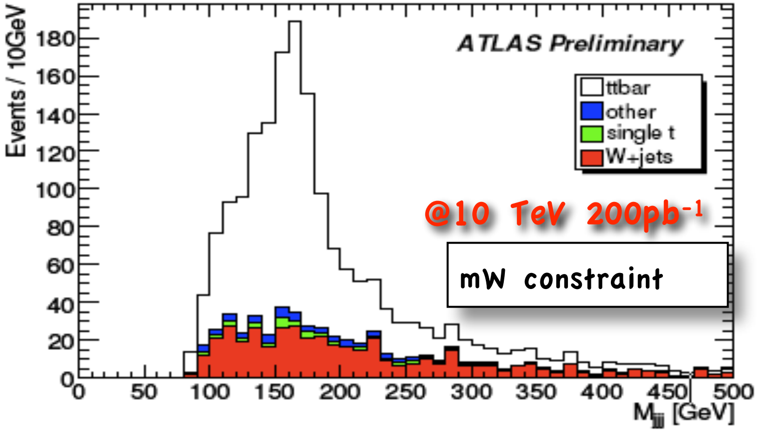
4 jets p_T> 20 GeV

3 jets p_T> 40 GeV

P_T^{lep} > 20 GeV

E_T^{miss} > 20 GeV

No b-tagging



@10 TeV 200pb^{-1}

mW constraint

Requiring at least 1 b-tagged jet improves S/B of a factor of 3-4

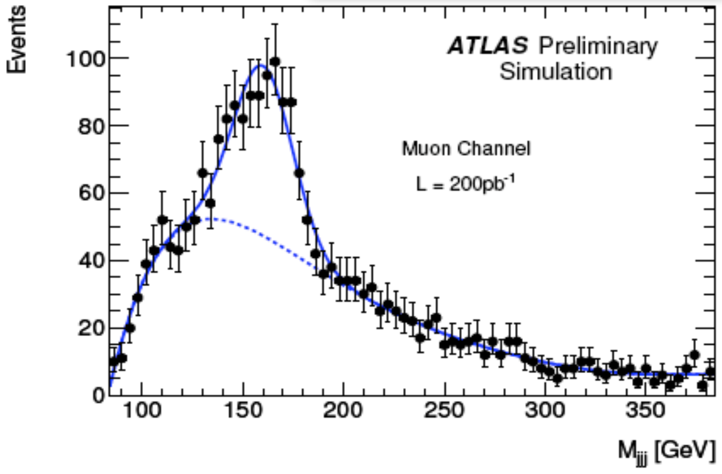
ATL-PHYS-PUB-2009-087

@10 TeV 200pb^{-1}	Signal: electr. ch.	backgrounds	S/N
after selection	1286	598	2.1

ATLAS 2 methods to extract x-sec

- **Cut and count method C&C:**
  - Advantage: simple method
  - Disadvantage: Depends on background subtraction. Evaluate backgrounds from data!

ATL-PHYS-PUB-2009-087



- **The fit or template fit to hadronic top mass:**
  - Advantage: much less sensitive to the Jet Energy scale and background normalisation
  - Disadvantage: relies on shape of distributions

Electron channel

Method	$\Delta\sigma/\sigma$	Dominant syst.
C&C	$3.4(\mathrm{stat})^{+18.2}_{-21.1}(\mathrm{syst})\pm 29.3(\mathrm{lumi})\%$	JES, ISR/FSR, W+jets
Fit	$14(\mathrm{stat})^{+6}_{-15}(\mathrm{syst})\pm 20(\mathrm{lumi})\%$	JES, ISR/FSR
No MET	$3.4(\mathrm{stat})^{+23}_{-25}(\mathrm{syst})\pm 34(\mathrm{lumi})\%$	JES, ISR/FSR, W+jets

ATLAS W+jets data driven estimate

- After event selection (requiring 2 leptons 80<mll<100 GeV for Z's and 1 lepton +MET for W's) use low jet multiplicity region as control region (CR) for Z +jets (W+jets) events
- Extrapolate ratio in the top signal region (SR) : 4 jets or more
- Use ratio W / Z to extrapolate W into signal region

$$(W^{SR}/W^{CR})_{data} = (Z^{SR}/Z^{CR})_{data} \cdot C_{MC} \qquad C_{MC} = \frac{(W^{SR}/W^{CR})_{MC}}{(Z^{SR}/Z^{CR})_{MC}}$$

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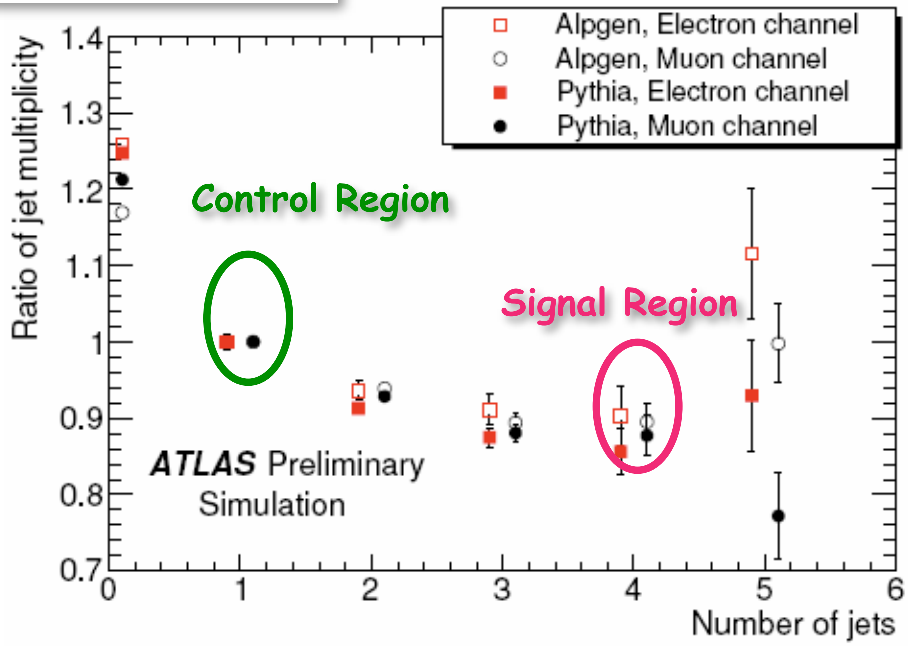


Overall uncertainty

20% @10 TeV with 200 pb^{-1}

(50% @7 TeV with 10 pb^{-1}

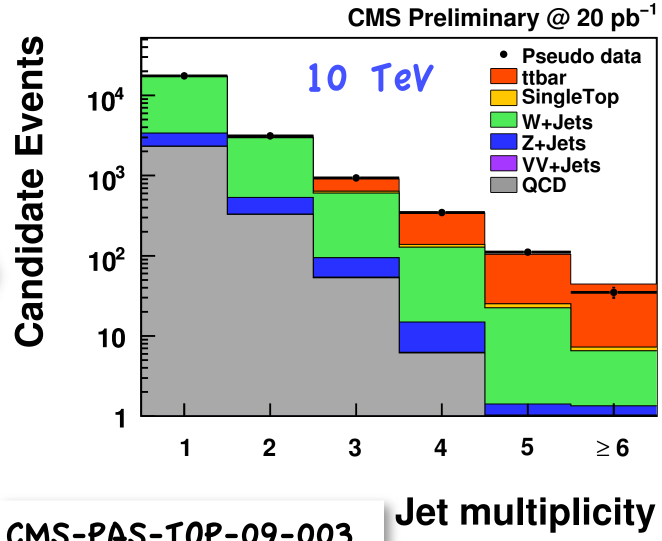
20% @7 TeV with 100 pb^{-1})

Largest contributions from:

- 50% uncertainty on QCD
- C_{MC} (~12% pythia-alpgen)

Top Quark "Rediscovery" at 7 TeV Lepton+Jets

- Few pb^{-1} gets us to an interesting region
  - Plot for 20 pb^{-1} at 10 TeV; looks similar to what expected for ~50 pb^{-1} at 7 TeV
  - At 7 TeV and 10 pb^{-1}, we expect ~60 top events per lepton flavour per experiment over a background of ~40 in the 4 jet, 5 jet and 6+ jet bins.
  - The dijet mass is expected to show a peak near the W: additional confirmation.



CMS-PAS-TOP-09-003

Done without flavour tagging, which can be used to confirm the top content of the W +multijet sample.

Cross-section scaling →

$$\sigma(t\bar{t})_7 \cong 40\%\ \sigma(t\bar{t})_{10} \qquad \sigma(W+jets)_7 \cong 45\%\ \sigma(W+jets)_{10}$$

ATLAS di-lepton analysis

@10 TeV 200 pb^{-1}

- Basic event selection
  - 2 high p_T (>20 GeV) isolated lepton
  - ≥2 jets p_T >20 GeV
  - MET>20 (eμ)/35 (ee/μμ) GeV
  - veto Z mass window

Simple cut-and-count method

Profile likelihood ratio → final sensitivity

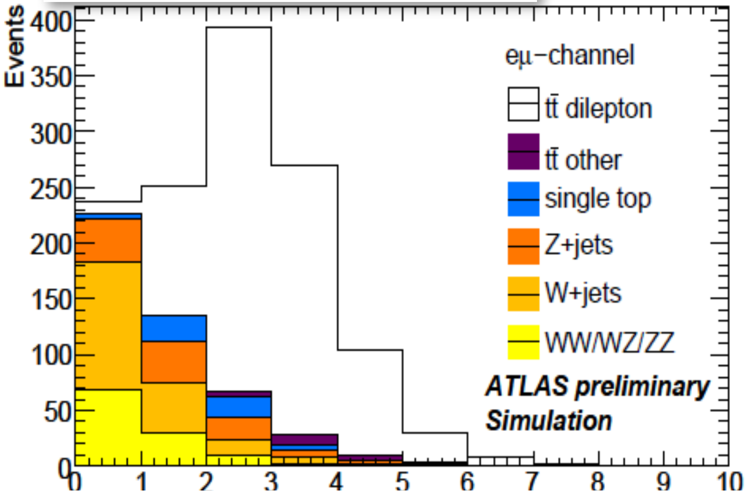
(eμ,ee, μμ combined)

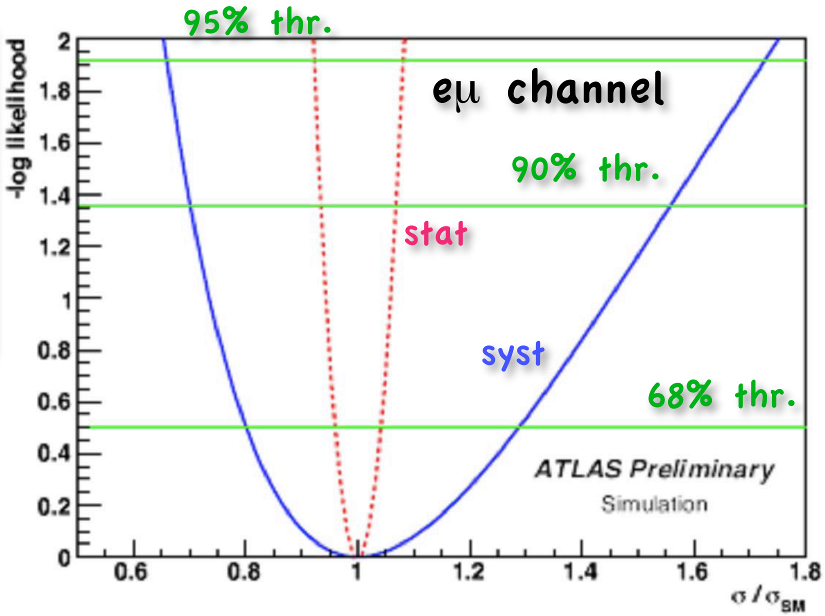
$$\Delta\sigma/\sigma = 3.1(\text{stat})^{+9.6}_{-8.7}(\text{syst})^{+26.2}_{-17.4}(\text{lumi})\%$$

↑

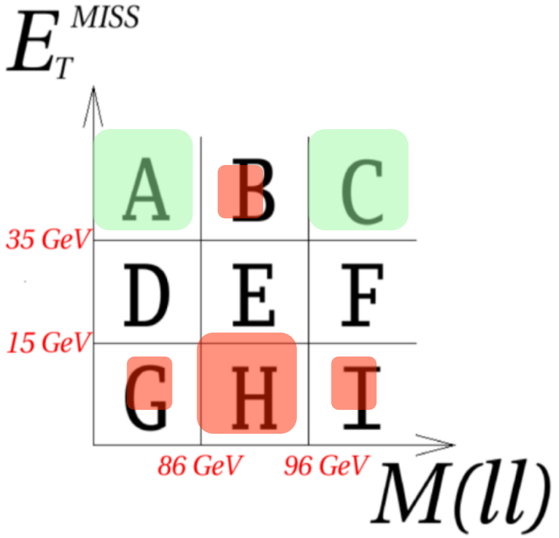
Signal model, fake rate

ATL-PHYS-PUB-2009-086





ATLAS: Drell-Yan Bkg and fake rates



Drell-Yan mainly in G,H,I – ttbar in A,C

Use Z Monte-Carlo and Data (same for C_{Est})

$$A_{Est} = G_{Data}\left(\frac{A_{MC}}{G_{MC}}\right)\left(\frac{B_{Data}}{H_{Data}}\right)\left(\frac{H_{MC}}{B_{MC}}\right)$$

Systematic uncertainty:

- Shift boundaries of the grid
  ~15% for both channels

Fake leptons from W+jets and QCD

- Define a "tight(T)" and a "loose(L)" lepton
- Efficiencies for "real (R)" ε and "fake(F)" f leptons from data from a signal and control region, respectively

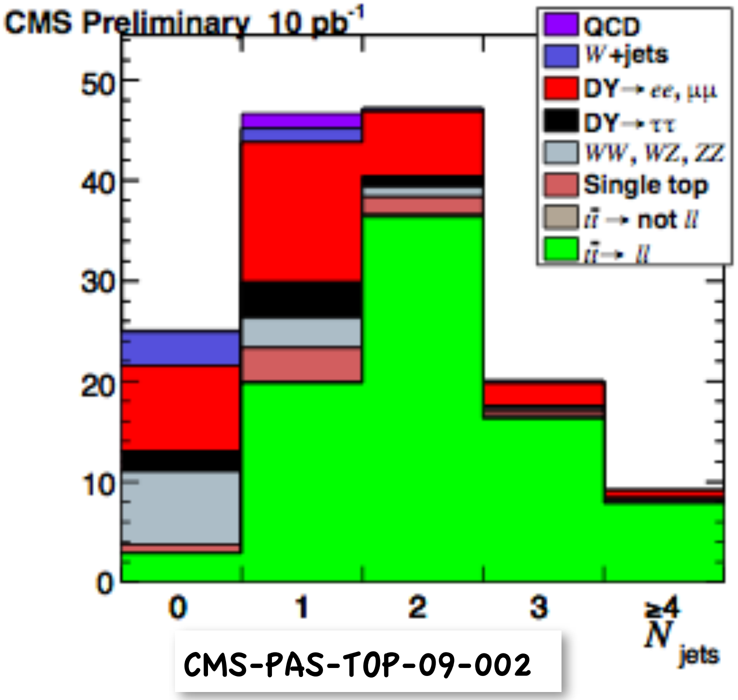
$$N_{\rm Fake} = \left[\frac{f_2(\epsilon_2-1)}{\epsilon_2-f_2} + \frac{f_1(\epsilon_1-1)}{\epsilon_1-f_1}\right] N_{\rm TT} + \frac{f_2\epsilon_2}{\epsilon_2-f_2} N_{\rm TL} + \frac{f_1\epsilon_1}{\epsilon_1-f_1} N_{\rm LT}$$

Rate uncertainty 50-100%

CMS di-lepton analysis

@10 TeV

- Basic event selection for 10 pb^{-1}
  - 2 high p_T (>20 GeV) isolated lepton
  - ≥2 jets p_T >30 GeV
  - MET>20 ($e\mu$) / 30 ($ee/\mu\mu$) GeV
  - veto Z mass window
  - Alternative scenario: using track jets instead of calorimeter jets



CMS-PAS-TOP-09-002

- Event selection for 100 pb^{-1}
  - Taking advantage of b-tagging
  - Tighter MET cut:
  - 30 ($e\mu$) / 50 ($ee/\mu\mu$) GeV

10/pb data estimates:

$\Delta\sigma/\sigma$ = ±15%(stat) ± 10 %(syst) ±10%(lum)

Top “Rediscovery” at 7 TeV – di-lepton

- With ~10 pb^{-1} convincing signal
  - Each experiment will have ~30 events with an expected background of 5 or 6.
- Even with 5 pb^{-1}, signal already plausible:
  - Each experiment will have ~15 events over a background of around 3.
- At 1 pb^{-1}, interesting event displays will start to appear at conferences

Expected 10 pb^{-1} sensitivity (per experiment)

Channel	N(Signal)	N(background)
$e - \mu$	14	2.5
$e - e$	4.3	1.1
$\mu - \mu$	6.6	1.9
Total	25	5.5

ATL-PHYS-PUB-2009-086 + scaling to 10 pb^{-1} @ 7 TeV.

Additionally b-tagging might be used

Cross-section scaling →

$$\sigma(t\bar{t})_7 \cong 40\%\ \sigma(t\bar{t})_{10} \qquad \sigma(W+\text{jets})_7 \cong 45\%\ \sigma(W+\text{jets})_{10}$$

Effects of new physics

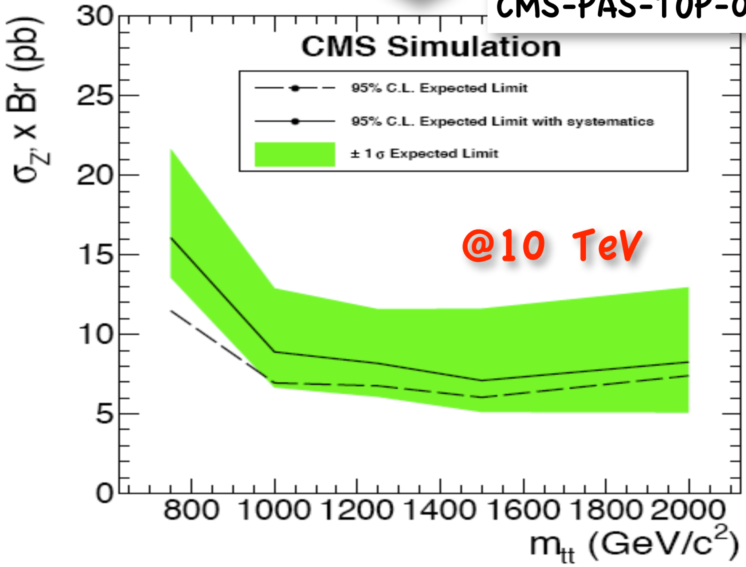
- Physics beyond the Standard Model: Supersymmetry, Large Extra Dimensions, heavy resonances…has often a lot of top activity
- For resonances the cross sections are expected to be small - of the order of few picobarns up to 100pb in the most extreme cases.

Z’xBR(tt) @10 TeV

σ*BR~5-10 pb with L=200 pb^{-1}

limits in $M_{Z'}$ range 1-3 TeV can be improved

CMS-PAS-TOP-09-009

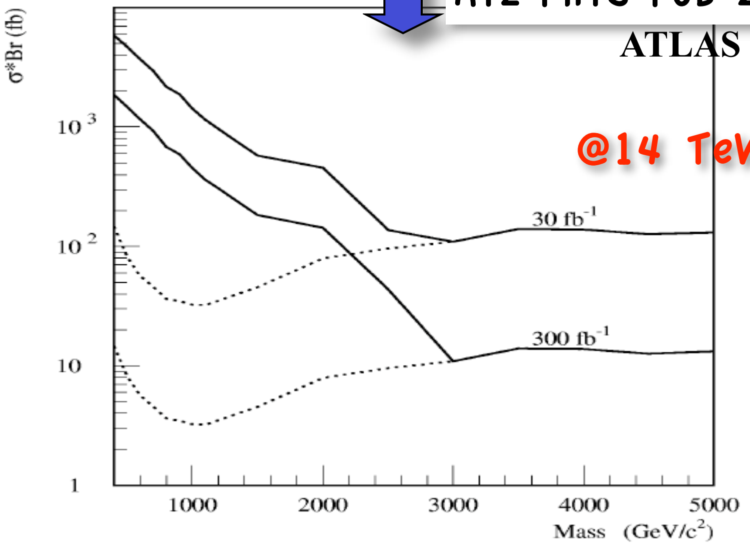


@10 TeV

In fact the 5 σ discovery potential for a narrow ttbar resonance needs quite some integrated luminosity: @14TeV

σ*BR~0.1 pb with L=30 fb $^{-1}$ M_{res}>3 TeV

ATL-PHYS-PUB-2009-086



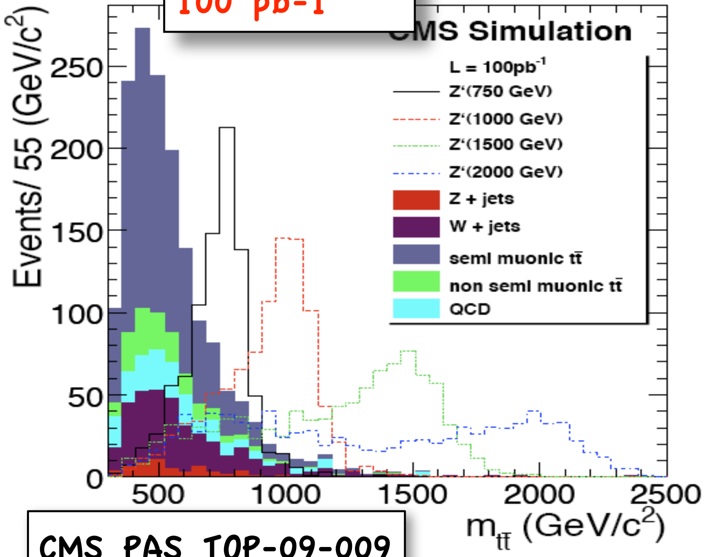
@14 TeV

Effects of new physics on x-section measurement

Effect of Z' on tt-bar x-section measurement Is small: even when assuming Z′ coupled to ttbar:

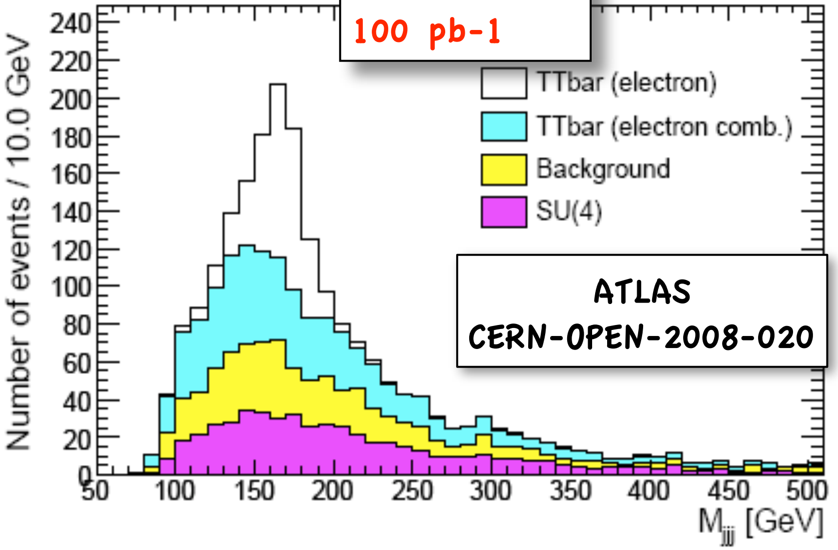
- *even in the case of 100% coupling to ttbar, expected cross-section only a few pb number of events passing cuts≈1% of ttbar*

@10 TeV
100 pb-1



CMS PAS TOP-09-009

@14 TeV
100 pb-1



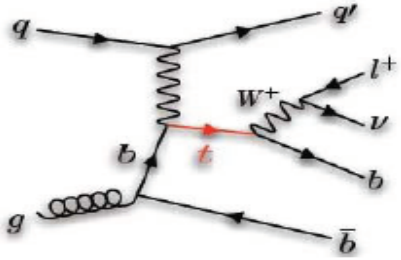
ATLAS
CERN-OPEN-2008-020

- **mSugra scenarios give also negligible contributions apart from SU4 which gives sizeable contributions**

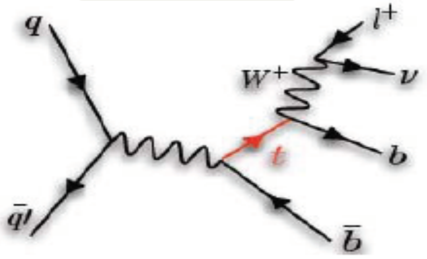
- *indistinguishable from W+jets background*

EW-production: single top

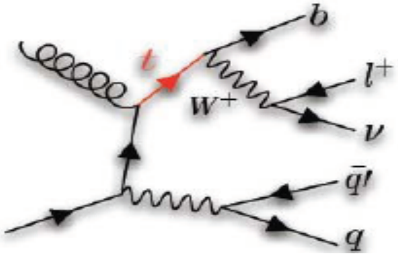
t-channel



s-channel



W+t channel



ttbar not the only way to produce top quarks.

Single top is an interesting alternative:

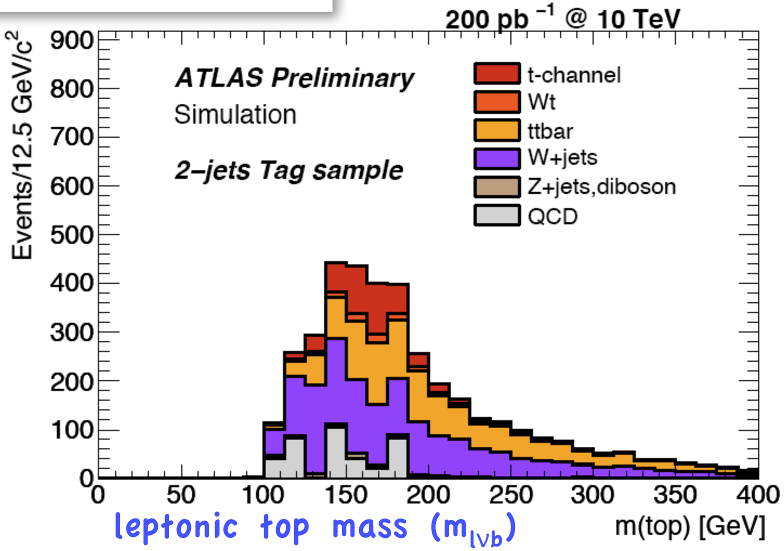
- Tests directly electroweak production mechanism
- Three different production mechanisms probe different kinematics, and are sensitive to different BSM scenarios
- Large cross section: $\sigma_{t\text{-chan}} \sim 1/3\sigma_{tt}$ – the large data samples will eventually allow single top to be studies in more detail than at Tevatron

ATLAS 10 TeV single top t-channel

Preselection:

- 1 isolated lepton P_T>20 GeV, MET>20 GeV,
  2-4 jets P_T>30 GeV, $M_t(W)$>30 GeV → against QCD
- ≥1 b-tag
- only events in 2 jet bin used for x-section

ATL-PHYS-PUB-2010-003



leptonic top mass ($m_{l\nu b}$)

@10 TeV,200 pb^{-1}	Cut based	Likel.
S	118	112
B	185	127
S/B	0.64	0.89

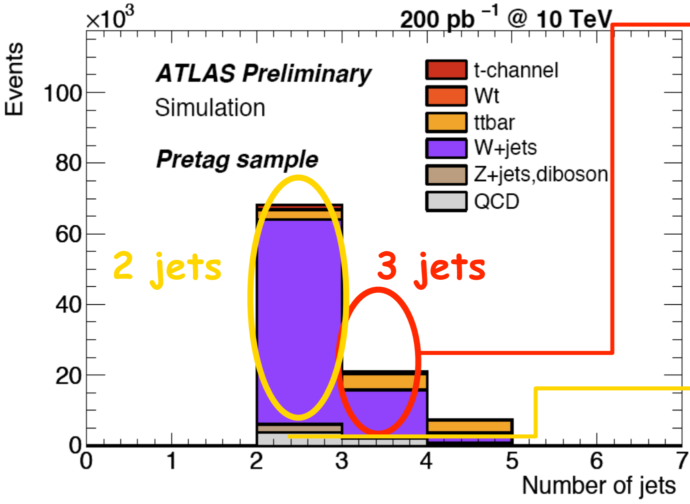
Overall sensitivity is better for likelihood method (2.7 σ)

Method	$\Delta\sigma/\sigma(\%)$	Dominant syst.
Optimised cuts	15(stat)±34.7(syst)±11(lumi)	b-tag(26%), bkg normalisation, ISR/FSR, Generator
Likelihood	14(stat)±32.1(syst)±11(lumi)	b-tag(22%), bkg normalisation, ISR/FSR, Generator

ATLAS t-chan Background estimation

ATL-PHYS-PUB-2010-003

- Low S/B-> measurement dominated by syst uncertainty on background estimate.
- Need data-driven meas. of ttbar and W+jets rates



Normalization of ttbar and W+jet BKg

- 1 lep, 3 jets, MET, no b-tag
- max likelihood fit of NN discriminant output

constrain 2-jets background using the measurement performed in the 3-jets sample (assuming Alpgen correctly predicts the ratio)

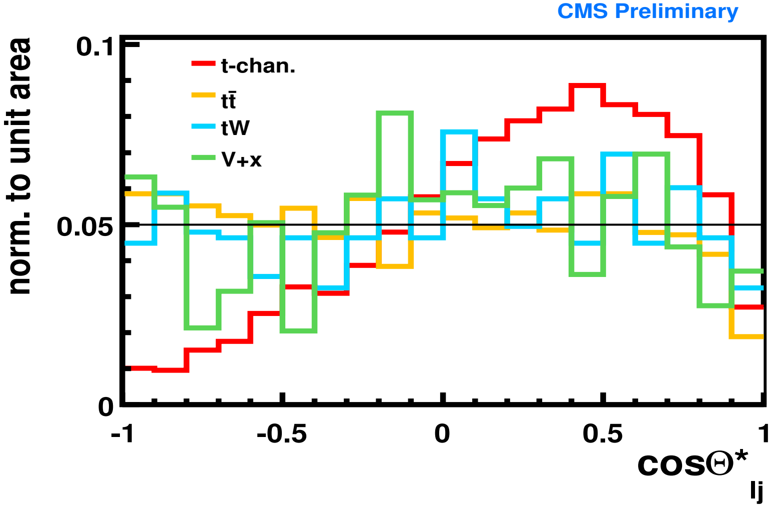
Source		W+jets	$t\bar{t}$
statistical		±2.0%	±3.5%
JES	+5%	+11.5%	-3.8%
	−5%	-13.4%	+3.7%
PDF		–	±4.5%
Single-top fraction		±4%	±0.3%
Total		±14.1%	±6.9%

CMS Single top in t-channel

CMS PAS TOP-09-005

Selection (muon channel)

==1 isolated lepton (μ) p_T>20 GeV, ==2jets p_T>30 GeV, ==1 b-tag, M_TW>50 GeV (reconstruction using MW constraint and MET variation)



Cross section measurement

- Tops are almost 100% left-handed polarized
- Polarization measurable in decay products
- Use polarization templates to measure x-section

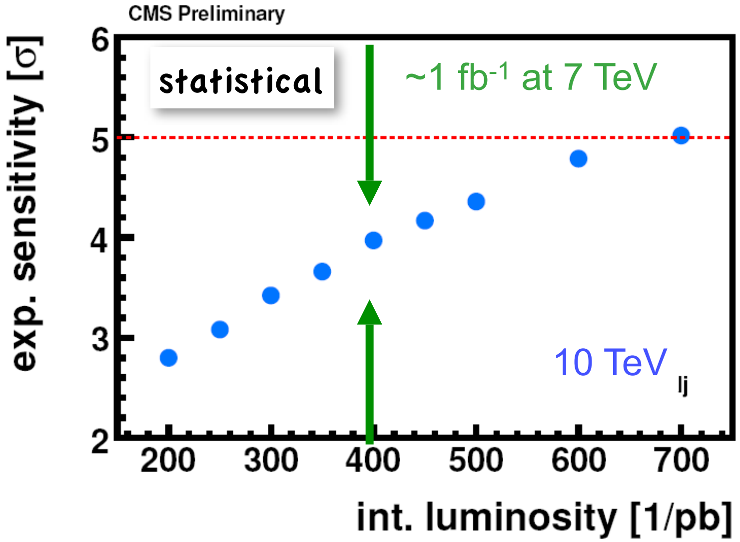
Source of uncertainty	$\Delta\sigma$ [%]	Expected sensitivity
statistical	± 35	2.8σ
b tagging	± 7.3	2.7σ
mistag	± 0.4	2.7σ
JES	± 5.5	2.7σ
MET	± 9.9	2.7σ
PDF	± 5.5	2.7σ
total	± 39	2.7σ

Single top perspectives at 7 TeV

- **Single top production is quite challenging**

The top pair background is enormous!

W+jets is large (large uncertainties)



- **ATLAS t-channel:**

Significance similar to the one at 10TeV with a 2-3 times larger luminosity
Needs a lot of preparation work concentrating on b-jet ID, precise measurement of the backgrounds, validation of multi-variate methods

3σ excess with ~500 pb^{-1}
Observation: ~1 fb^{-1}

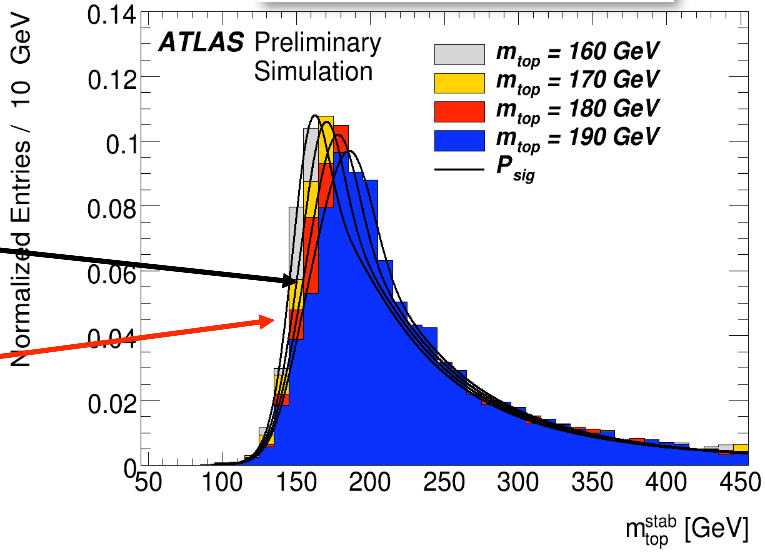
ATLAS top mass prospects via Template Method

Fit m_{top} estimator to the sum of signal and background PDFs

signal PDF from Monte Carlo signal at different generated m_{top}

background PDF from the sum of physics bkg process

ATL-PHYS-PUB-2010-004



1-D

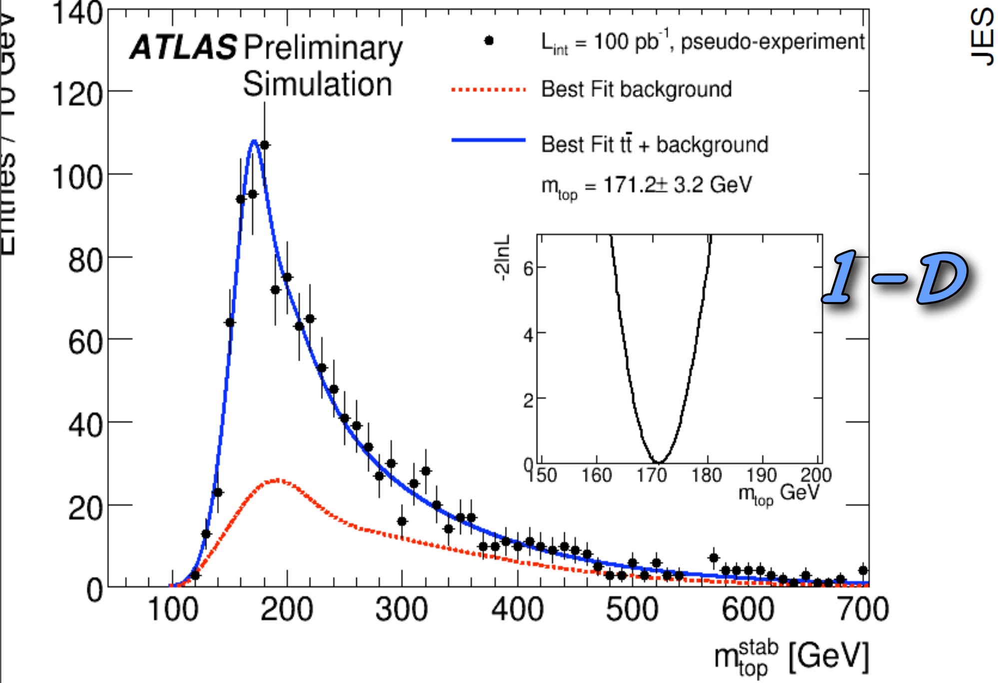
1-d analysis based on minimal event information: exploits m_{top}^{stab} estimator sensitive to m_{top} changes, but stable with respect to JES

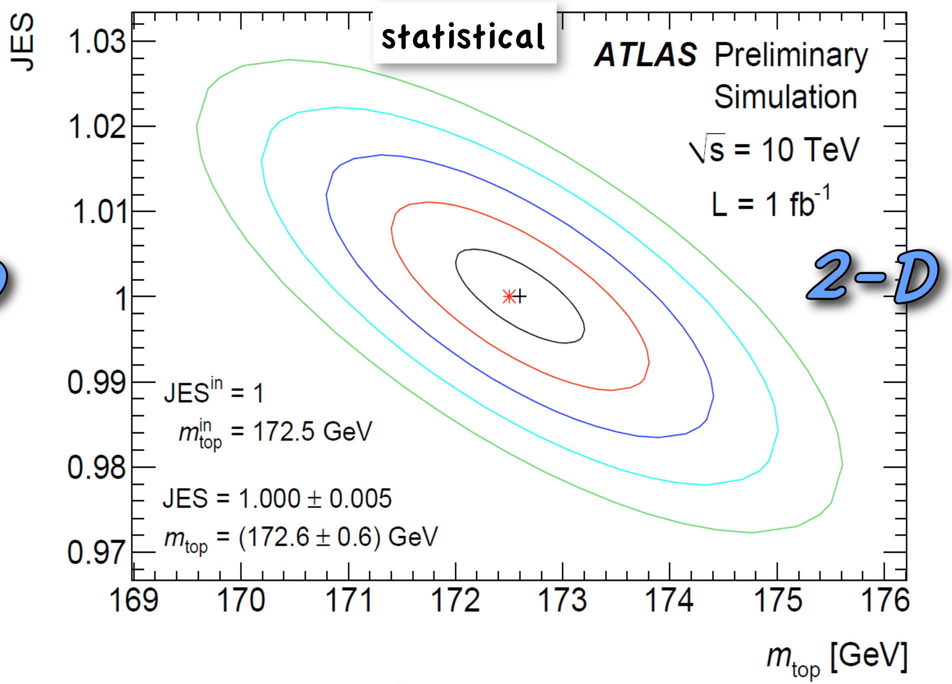
$$m_{top}^{stab} \equiv \frac{m_{top}^{reco}}{m_W^{reco}} \cdot m_W^{PDG}$$

2-D

2-d analysis, requiring detailed understanding of detector performances, uses b-tagging and kinematic fit to simultaneously determines m_{top} and the JES from the data, using both the reconstructed top and W boson masses.

Expectations 100pb^{-1}, 1 fb^{-1} @ $\sqrt{s}$=10 TeV





@10 TeV, 100 pb^{-1} (μ-channel), S/B~ 1.3

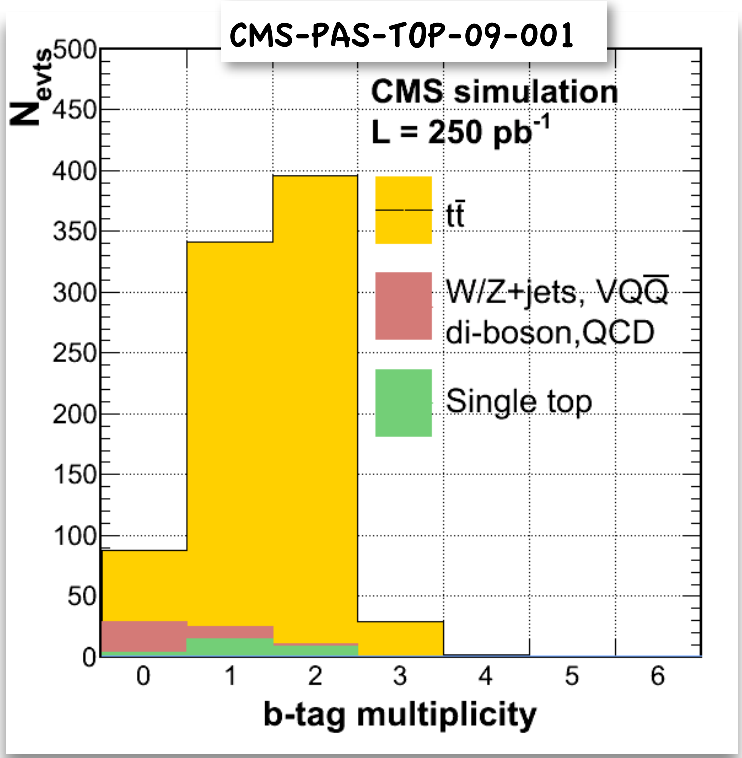
@10 TeV, 1fb^{-1}, S/B~ 8.0
n-σ contour plot for m_{top}-JES (e+μ comb)

Exp uncertainties (e+m comb)	stat	syst	total
1-D analysis @ 100 pb^{-1}	2 Gev	4 GeV	4.5 GeV
2-D analysis @ 1fb^{-1}	0.6 GeV	2 GeV	2.1 GeV

main syst:
ISR/FSR
b-jet scale

CMS - rare Top Decays

- The limits on the FCNC decays $t \to qZ$ and $t \to q\gamma$ are driven by the top quark pair yield: more tops implies a better limit
- The measurement of $BR(t \to Wb)/BR(t \to Wq)$ (=R) is driven by the knowledge of the b-tagging efficiency.
  - Measure R/ε_b in a data-driven manner:

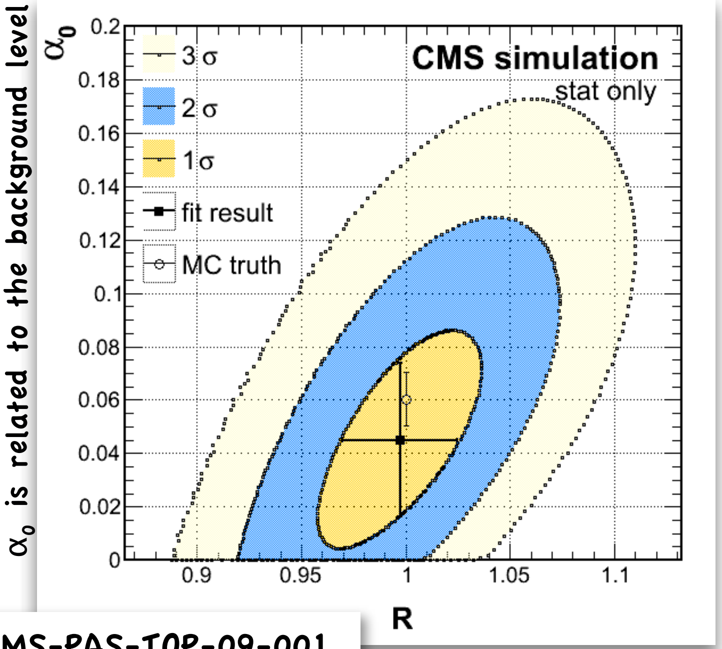

CMS-PAS-TOP-09-001

- Select dilepton (e-μ) events as pure as possible:
  - not to be affected by non top contamination in the sample
- Measure the number of events with 0, 1 and 2 tags.
  - The ratios N_2/N_1 and N_1/N_0 depend differently on R and ε_b (i.e. not only on their product)
- Correct for misassignment of jets

CMS- rare Top Decays

- With 250 pb^{-1} of 10 TeV data, ±9% syst. (mainly b-tag), measurement of R
  - This is the present PDG uncertainty
  - The systematic uncertainties are uncorrelated wrt Tevatron'

@7 TeV this corresponds to ~600 pb^{-1} (mid-2011)



CMS-PAS-TOP-09-001

- Given that LHC is expected to give us many top events: measurements can be performed in different way wrt Tevatron.

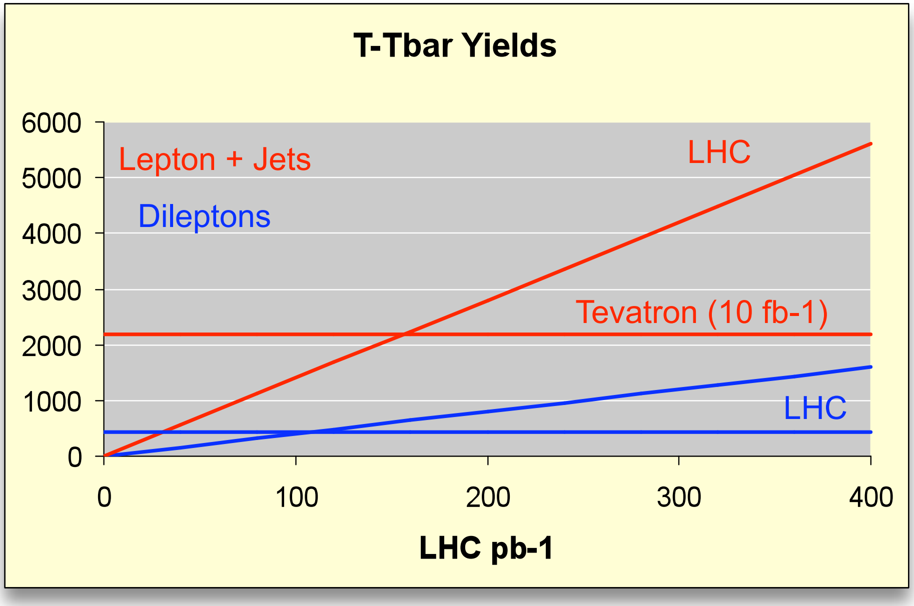
we can restrict to the cleanest e-μ channel

adds robusteness and makes combination easier

Independent systematic uncertainties

7TeV:How will things look like with few hundred pb^{-1}

- Each experiment expects top yields of
  - Dilepton: ~400 per 100 pb^{-1}
  - Lepton (e & μ) + Jets: ~1400 per 100 pb^{-1} (with large variations depending on selection requirements)



- By the end of 2010, the LHC we may have samples comparable to Tevatron's.

- By the end of 2011, the top samples will be substantially larger

- The physics program with a few hundred pb^{-1} will look very familiar
  - Top cross-section (at a new energy)
  - Top mass (at the end of the 2011 we might have a determination competive with Tevatron, also averages over 4 experiments, not 2 will be possible)
  - Single Top
  - Rare decays

Conclusions

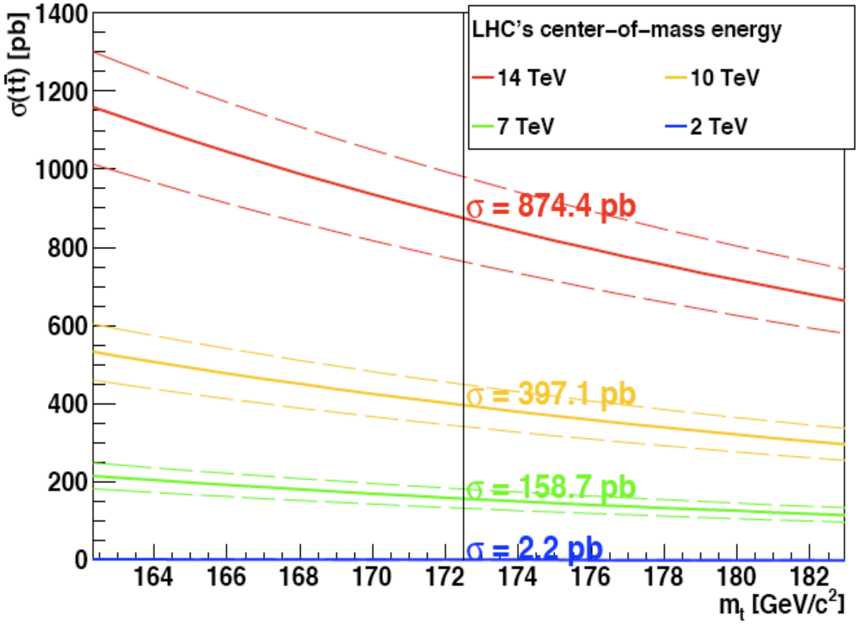
- @LHC the high production rate will allow very rich top quark physics
  - Probing Standard Model
  - Hints of new physics?
- Our roadmap will be
  - strict collaboration with performance and reconstruction groups
  - Concentrate on simple selections, eventually using b-tagging.
  - First estimate backgrounds from data: QCD, W/Z+jets

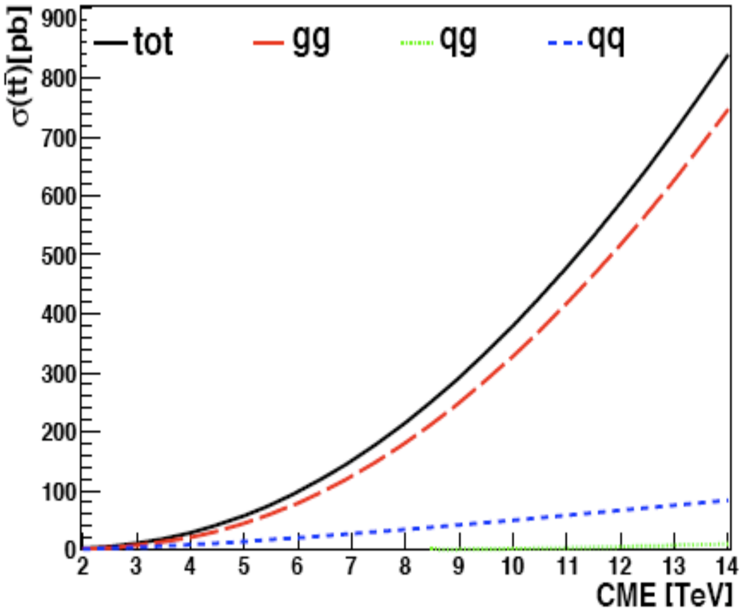
Perspectives for early data

- Exciting results already with few ten of pb^{-1}: top re-discovery
- Use top event to calibrate and understand the detector:
  - trigger and lepton ID
  - b-tag
  - Light jet b-jet energy scale
  - MET..

Back-up

tt-bar x-section dependence from ECM





CME(TeV)	σ_{tot}(pb)	σ_{gg}/σ_{tot}	σ_{qq}/σ_{tot}
14	839.9	89%	10%
10	379.8	86%	13%
7	150.8	55%	18%

NLO+NLL top pair production cross-section arXiv:hep-ph/0804.2800

errors consist of factorisation and rinormalisation scales and on the parton distribution functions

Trigger commissioning

What can we expect with different integrated luminosities:

- few tens pb^{-1}= verify detection of top, get single efficiency number with 5%-10% accuracy

- @50-100 pb^{-1} = we get enough events to see turn on curves.

- An important check is to evaluate the absolute fraction muons versus electrons in semileptonic ttbar events:

  Check that can be done without depending on acceptances etc..

- Verify electron trigger in $Z \rightarrow ee$: the environment and kinematics are different, at present the differences are within few %, but this has to be verified with data.

  The isolation of electrons could play a different role.

- Commissioning of MET and jets trigger:

  By using events triggered by lepton trigger and verify that jet trigger and MET fired at proper thresholds.

Systematic uncertainties: electron channel

@10TeV 200 pb-1	Cut & count Error (%)	Fit method Error (%)
Lepton id	±1	±1
Lepton trigger	±1	±1
20% W+jets	±17.4	±3.3
JES(+5%-5%)	+8.6-9.3	-3.7
PDF	±1.9	±1.9
ISR/FSR	+7.6-8.2	-12.9
Signal MC	±4.4	±4.5
Bkg uncertainty	±0.4	-

Cut & count $\Delta\sigma / \sigma = 3.4(stat)^{+18.2}_{-21.1}(syst) \pm 29.3(lumi)\%$

Fit $\Delta\sigma / \sigma = 14(stat)^{+6}_{-15}(syst) \pm 20(lumi)\%$

Fake lepton rate for dileptons

- Define a “tight(T)” and a “loose(L)” lepton, which contains higher rate of fake leptons.
- Efficiencies for “real(R)” ε and “fake(F)” f leptons from data
  - $\varepsilon_{12} = N_{T|R}/(N_{T|R}+N_{L|R})$: tag and probe in Z window
  - $f_{12} = N_{T|F}/(N_{T|F}+N_{L|F})$ from low MET (<15 GeV) or low Δφ<1 rad(angle between lepton and MET) fake enriched samples
- Extract number of fake events from matrix inversion

$$\boxed{\begin{bmatrix} N_{\rm TT} \\ N_{\rm TL} \\ N_{\rm LT} \end{bmatrix} = \begin{bmatrix} \epsilon_1\epsilon_2 & \epsilon_1 f_2 & f_1\epsilon_2 \\ \epsilon_1(1-\epsilon_2) & \epsilon_1(1-f_2) & f_1(1-\epsilon_2) \\ (1-\epsilon_1)\epsilon_2 & (1-\epsilon_1)f_2 & (1-f_1)\epsilon_2 \end{bmatrix} \begin{bmatrix} N_{\rm RR} \\ N_{\rm RF} \\ N_{\rm FR} \end{bmatrix}}$$

where $N_{RR/RF/FR}$ is the number of events with 2 Real and 1 Real and 1 Fake(F) leptons from Truth. Where ε_1 and ε_2 (f_1 ,f_2) are the eff. for the first and the second lepton to be reconstructed as a tight lepton.

- Rate uncertainty 50-100%

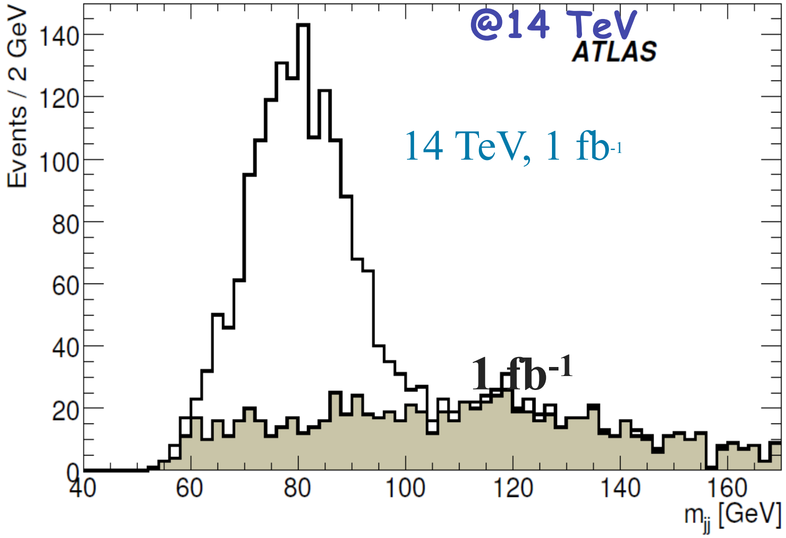
$$N_{\rm Fake} = \left[\frac{f_2(\epsilon_2-1)}{\epsilon_2-f_2} + \frac{f_1(\epsilon_1-1)}{\epsilon_1-f_1}\right] N_{\rm TT} + \frac{f_2\epsilon_2}{\epsilon_2-f_2} N_{\rm TL} + \frac{f_1\epsilon_1}{\epsilon_1-f_1} N_{\rm LT}$$

JES calibration

Select pure sample of W's in semi-leptonic channel.

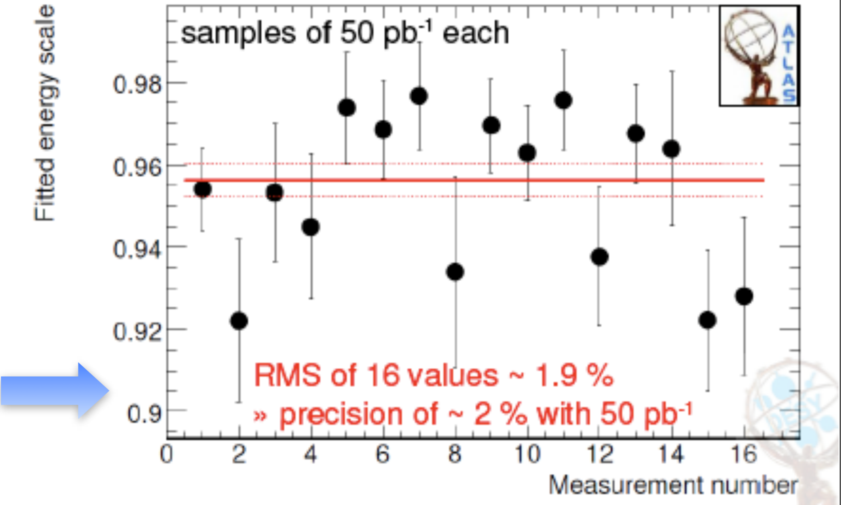
1 isol. lepton pT > 20 GeV, 4 jets p_T > 40 GeV,

E_{Tmiss} > 20 GeV, 2 b-tags, 150 GeV < m_t < 200 GeV



- **Iterative method :**
  - find the ratio $\alpha i = M_W^{PDG}/M_i$ where M_i=peak value of dijets forming W the for the Energy interval i.
  - Reiterate procedure few times, with new calibration (converges after few iterations)

- **Template method: ensemble test with scale variations**
  - Template histograms of mjj=mW with different E scales a and relative E resolutions b (PYTHIA tt events)
  - compared with MC@NLO tt events. Fit each template histogram to mjj in the « data », find best $\chi 2$
  - Systematics~ 1-2% =given by the stability of the result when changing the combinatorial background
  - Stability of the method with lower luminosities < 2%



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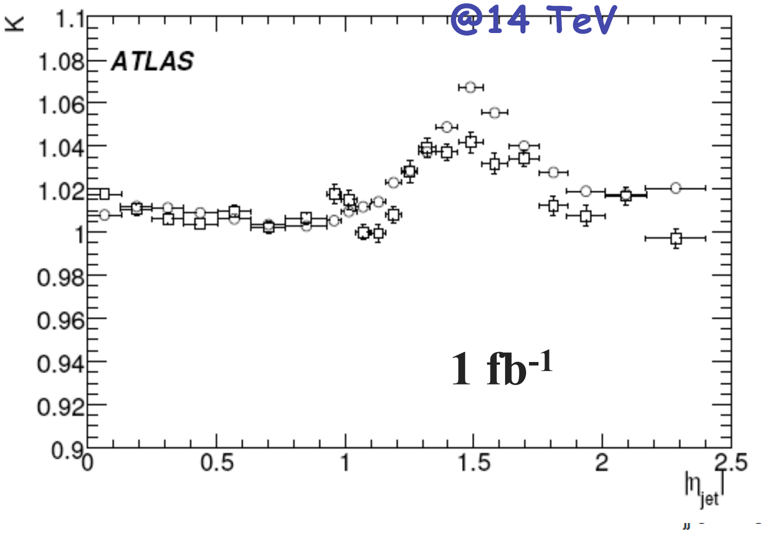

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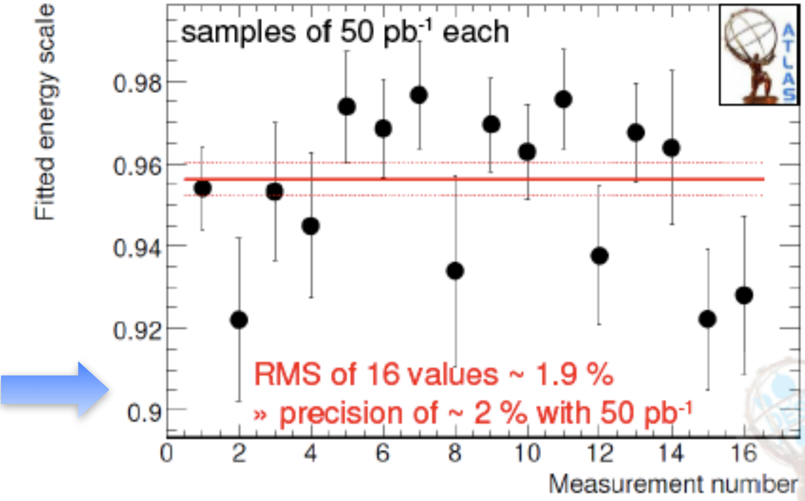


RMS of 16 values ~ 1.9 %
» precision of ~ 2 % with 50 pb^{-1}

Light JES and b-Jet Energy Scale

- Apply light jet energy calibration done using W→jj in tt events to b-JES:

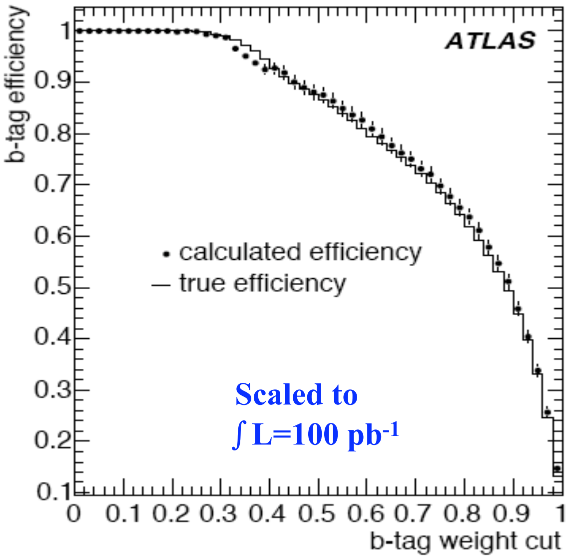
  rely on MC to parametrize JES & b-JES difference

- Use the data to cross-check:
  - P_T balance in Z+jet events (Z→leptons): it allows for b-jet calibration and is the most promising channel to provide the corrections, but for the bJES,

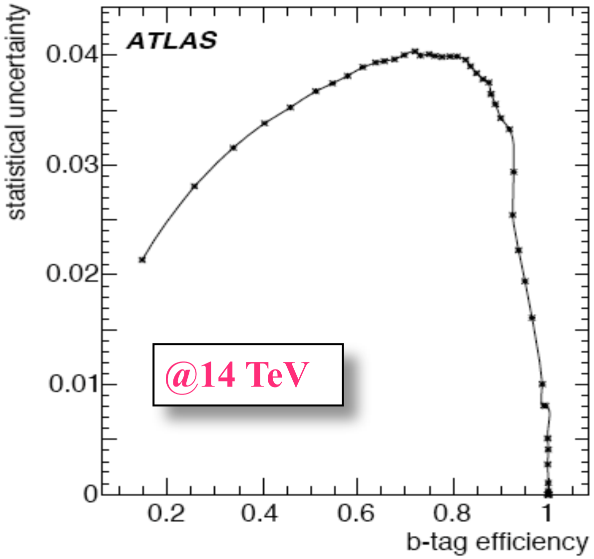
    only small % of the events contain a b-jet: large systematics coming from b-mistag

- A cross check channel would be extremely useful. One can use Zj→bb+j : it would be a powerful tool for the cross check of the b-jet calibration. CDF experience (~2% @0.6fb^{-1}) .
  - Special SVT trigger sample: require a leading high PT non-b jet: 120 GeV. This decreases the LVL1 rate, allows to strongly reduce the contribution from direct bb production.

Data Driven b-tag efficiencies and systematics



Scaled to $\int L = 100\ \mathrm{pb}^{-1}$



@14 TeV

Systematic	Counting		Topological	Likelihood	Kinematic
	lepton+jet	dilepton			
Light jets and τ	0.1	0.7	0.5	5.2	0.6
Charm jets	0.0	0.8	0.7	4.6	2.2
Jet energy scale	0.9	0.5	0.5	2.5	1.1
b-jet labelling	1.4	1.4	-	-	-
MC generators	0.1	2	0.2	5.9	5.5
ISR/FSR	2.7	2	1	2.2	0.5
W+jet background	1.2	0.3	2.8	9.6	0.3
Single top background	0.1	0.1	1.2	-	1.2
Top quark mass	0.3	0.5	-	4.1	-
Total systematic	3.4	3.5	3.4	14.2	6.2
Statistical ($100\ \mathrm{pb}^{-1}$)	2.7	4.2	-	5.0	7.7
Statistical ($200\ \mathrm{pb}^{-1}$)	1.9	3.0	6.4	4.4	5.5

ATLAS di-lepton x-section

The likelihood function can be maximized to determine the maximum likelihood estimate of all the parameters ˆσsig, ˆ L, ˆαj, where α are different sources of systematics.
We then consider the likelihood ratio

$$r(\sigma_{sig}) = \frac{L(\sigma_{sig}, \hat{\mathcal{L}}, \hat{\alpha}_j)}{L(\hat{\sigma}_{sig}, \hat{\mathcal{L}}, \hat{\alpha}_j)}$$

and the profile likelihood ratio

$$\lambda(\sigma_{sig}) = \frac{L(\sigma_{sig}, \hat{\hat{\mathcal{L}}}, \hat{\hat{\alpha}}_j)}{L(\hat{\sigma}_{sig}, \hat{\mathcal{L}}, \hat{\alpha}_j)}$$

where ˆˆL and ˆˆαj represent the conditional maximum likelihood estimates of L and αj holding σsig fixed.
Note, the profile likelihood is always greater than the likelihood ratio, except at the maximum likelihood estimate where they are equal. This means that the curve of −2 log λ is broader than −2 log r, and the difference in the intervals can be attributed to systematics.