Standard Model Measurements @ LHC Startup

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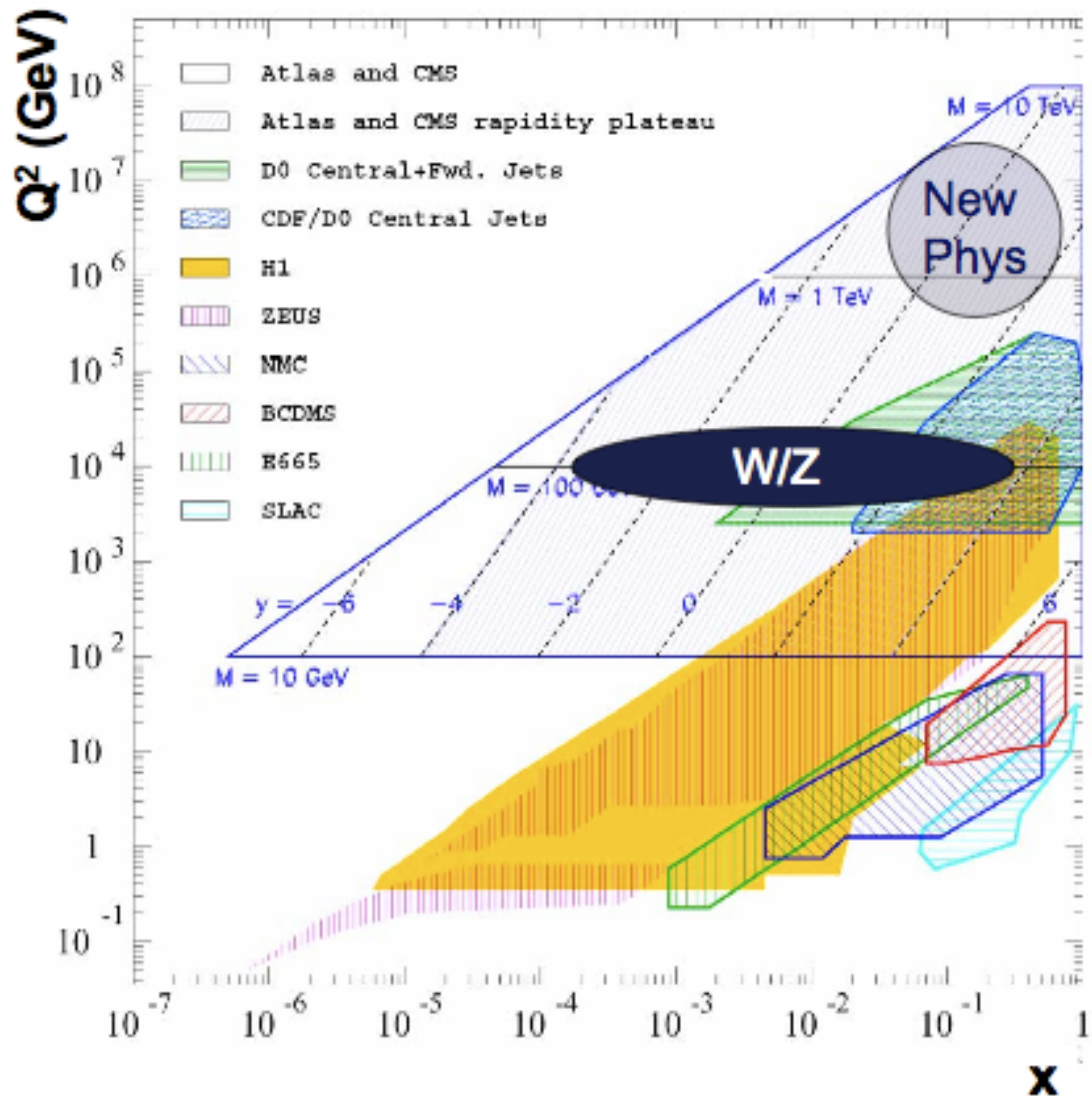
Thanks to all my colleagues on
the CMS/ATLAS experiments for the
material presented in this talk

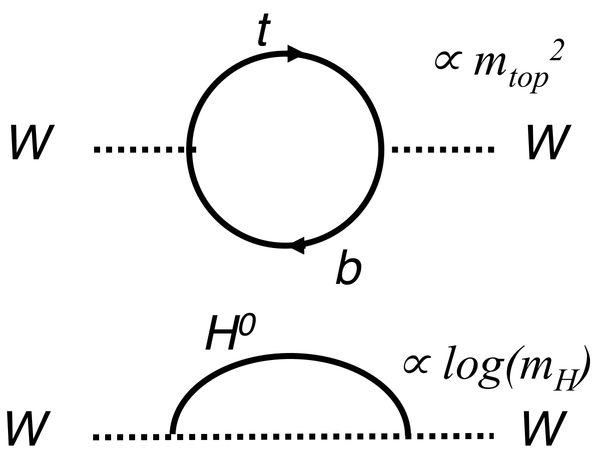
A New Energy Domain

- The kinematic acceptance of the LHC detectors allows to probe a new range of x and Q^2
- Q^2 up to $\sim 10^8$
- x down to $\sim 10^{-6}$

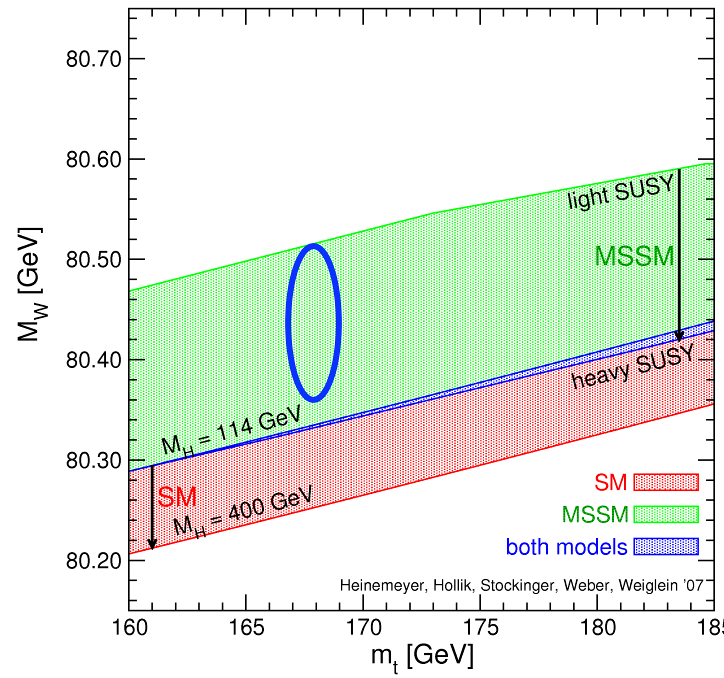


Importance of SM measurements

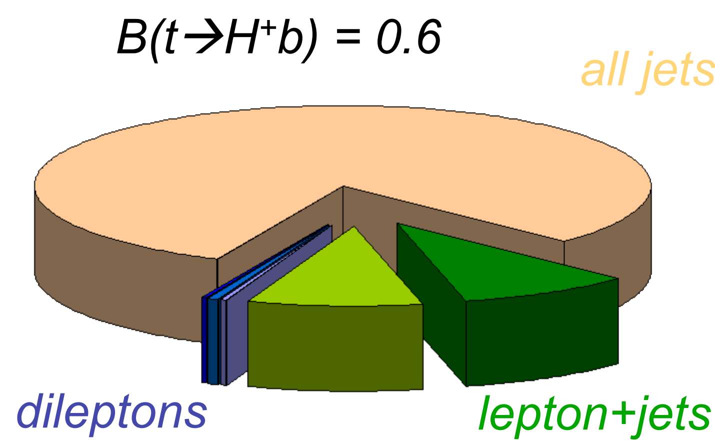
- Test Higgs Sector



  - m_H
    <160 GeV @ 95% C.L.
    <190 GeV incl. LEP-2 limit

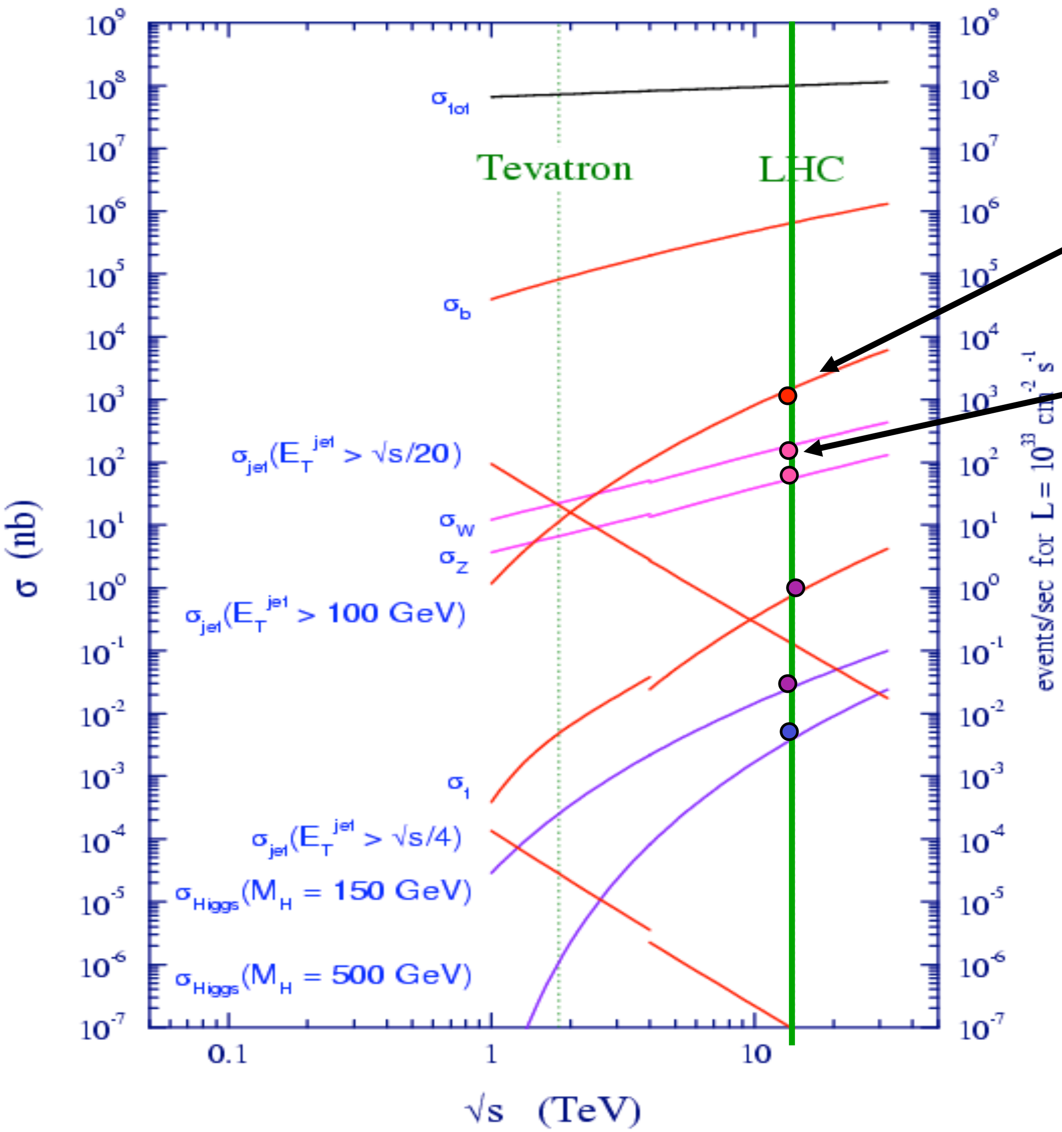


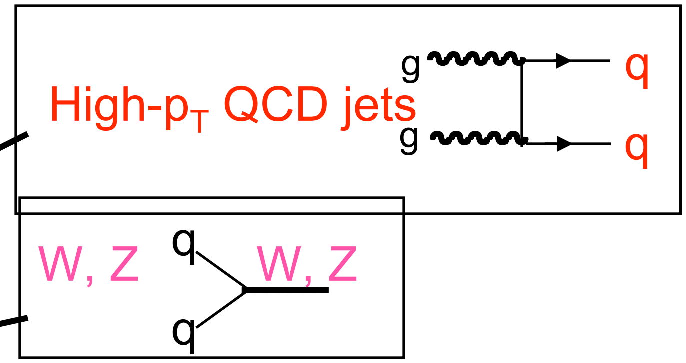
- Top Quark Properties
  - how is its mass generated?
    - topcolor?
  - does it couple to new physics?
    - massive G, heavy Z', H^+, …



- Background for potential discoveries

Cross Sections





- σ_W~ 150 nb

BR(W →e+μ) ~ 20%

10 fb^{-1} ⇔300M leptonic events

Rate(10^{33} cm^{-2} s^{-1}1) ~ 30 Hz

Rate(10^{34} cm^{-2} s^{-1}) ~ 300 Hz

- σ_Z~ 50 nb

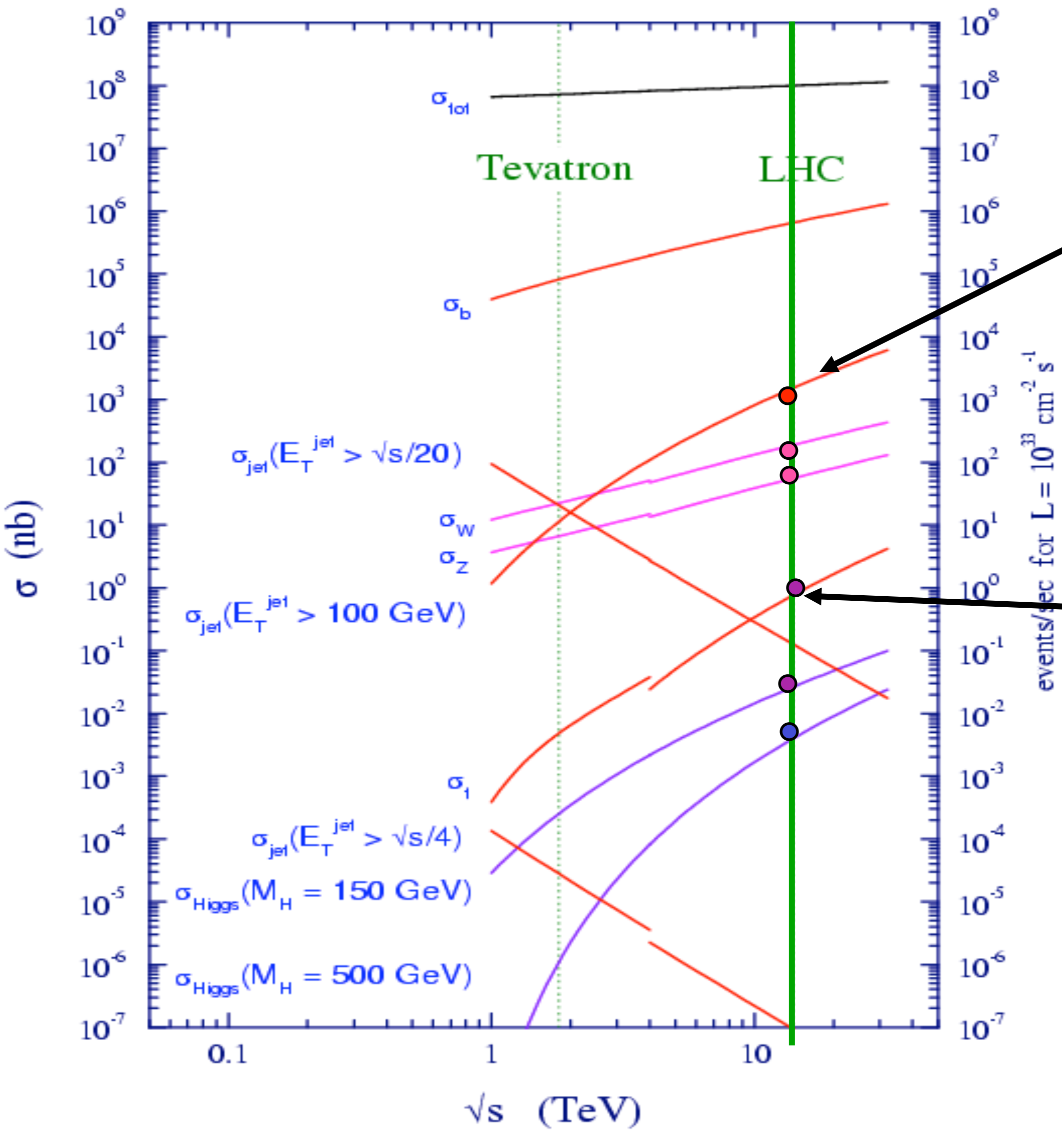
BR(Z → ee+μμ) ~ 6.6%

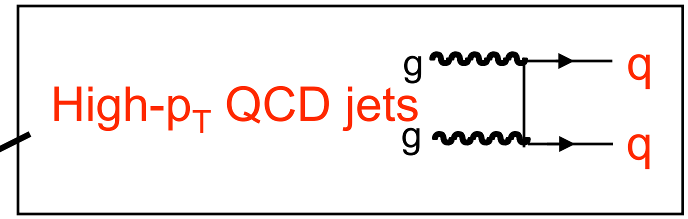
10 fb^{-1} ⇔33M leptonic events

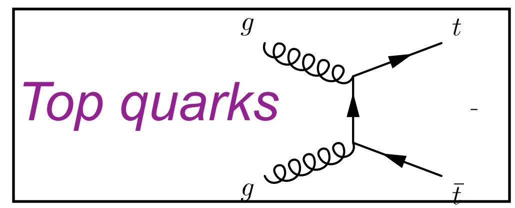
Rate(10^{33} cm^{-2} s^{-1}) ~ 3.5 Hz

Rate(10^{34} cm^{-2} s^{-1}) ~ 35 Hz

Cross Sections







- *σ_{tt}~ 800 pb*

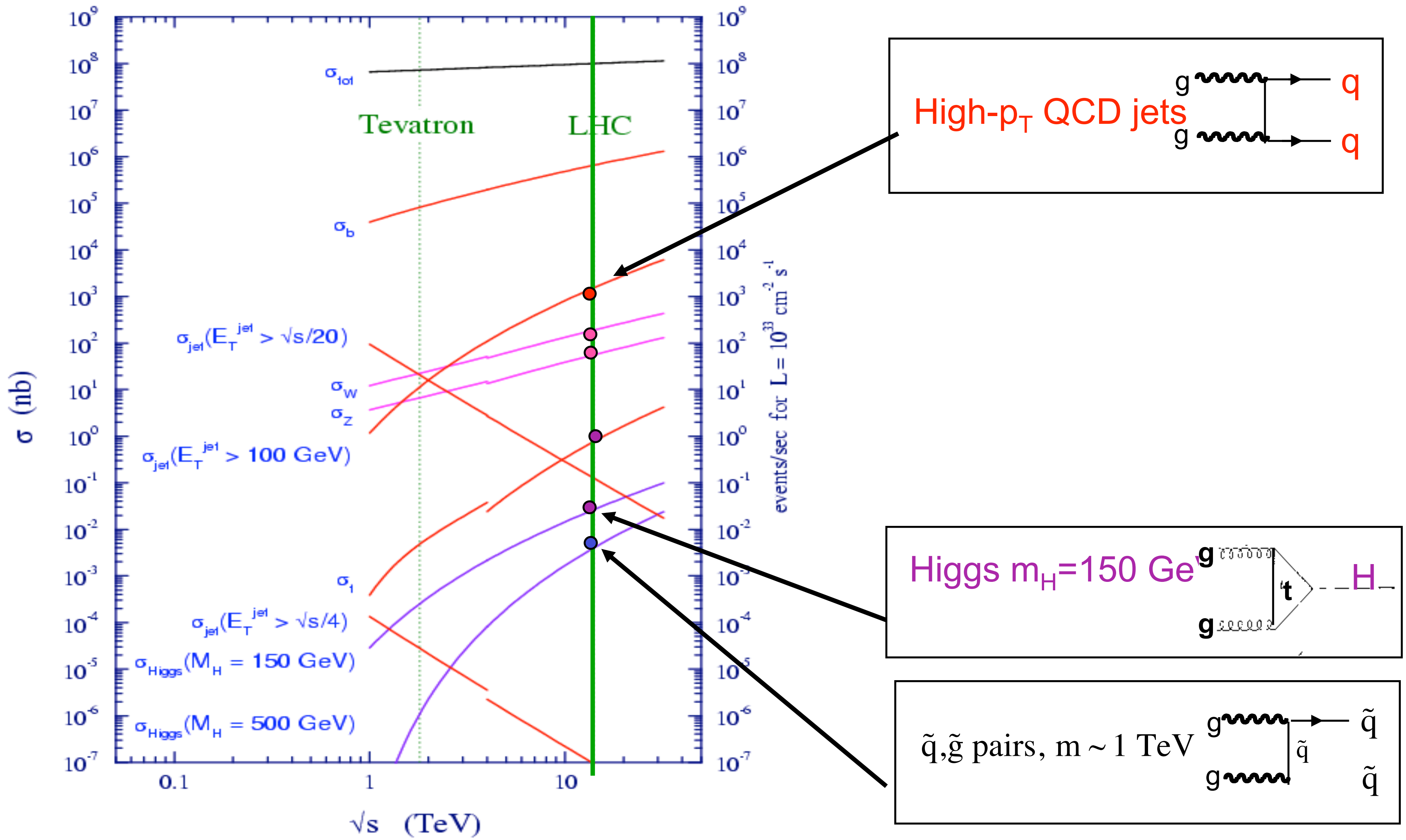
BR(W →e+μ) ~ 30%

10 fb^{-1} ⇔2.4M leptonic events

Rate(10^{33} cm^{-2} s^{-1}1) ~ 0.2 Hz

Rate(10^{34} cm^{-2} s^{-1}) ~ 2 Hz

Cross Sections

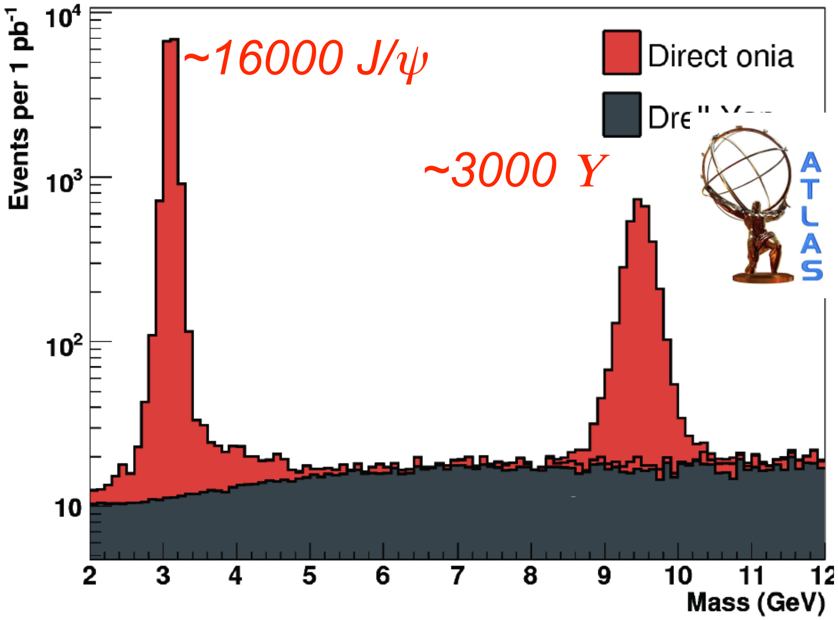


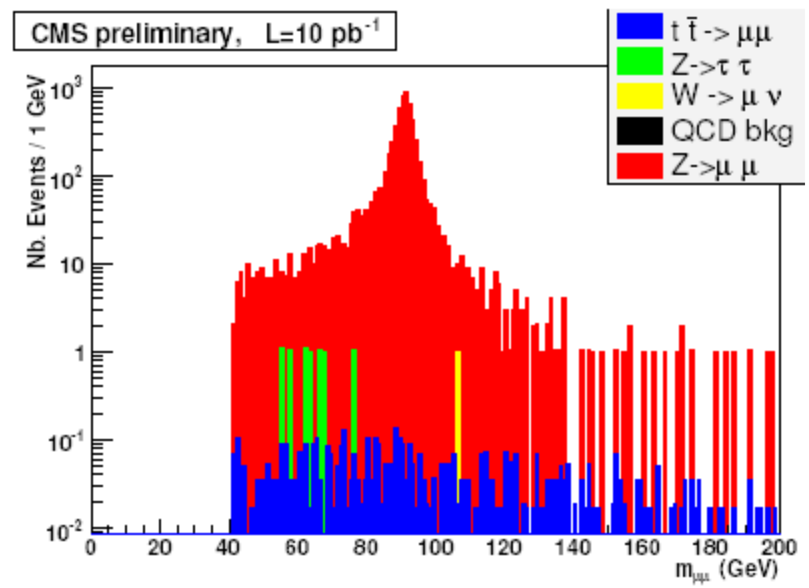
First Measurements: (J/Ψ, Υ, Z)→μμ

- Statistics for 1pb^{-1}(3.85days) @ 10^{31}
- assuming a 30% detector+machine efficiency

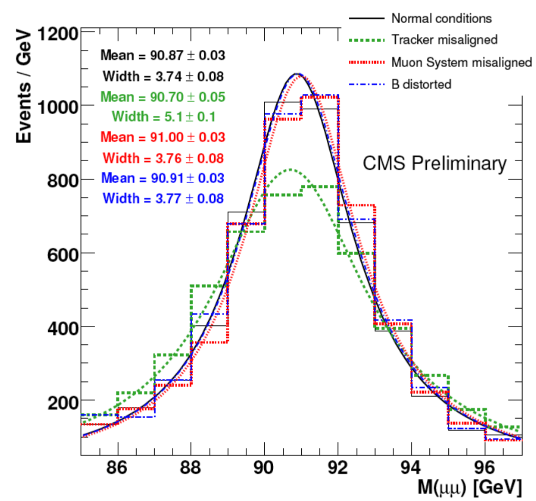
After selection

600 Z→μμ per pb^{-1}



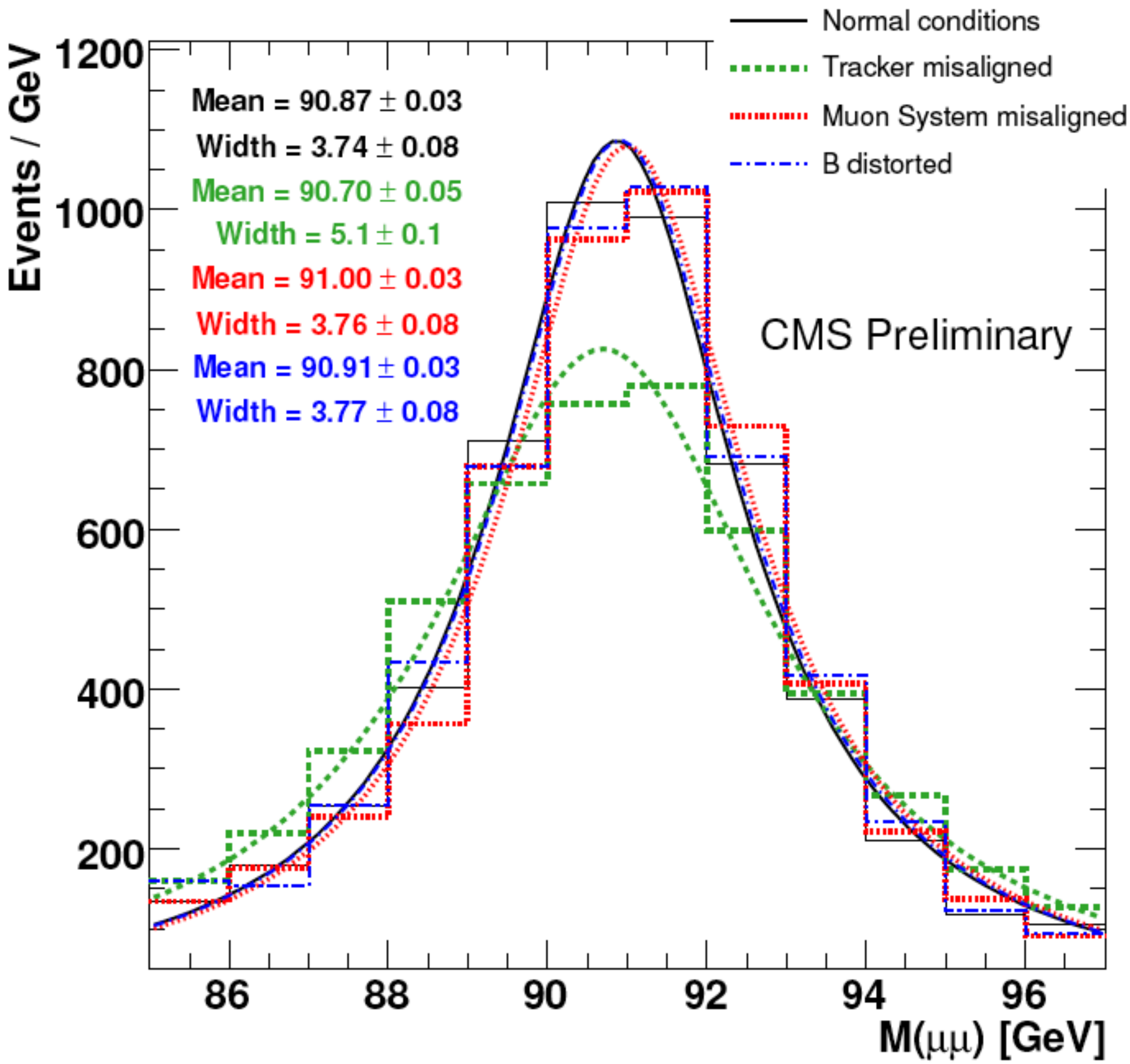


- Use the resonances to perform:
  - sanity checks
  - tracker alignment and momentum scale
  - detector efficiencies, trigger performance,
  - uncertainties on the magnetic field (distorted B field)



Alignment with Z→μμ

- Tracker alignment studies:

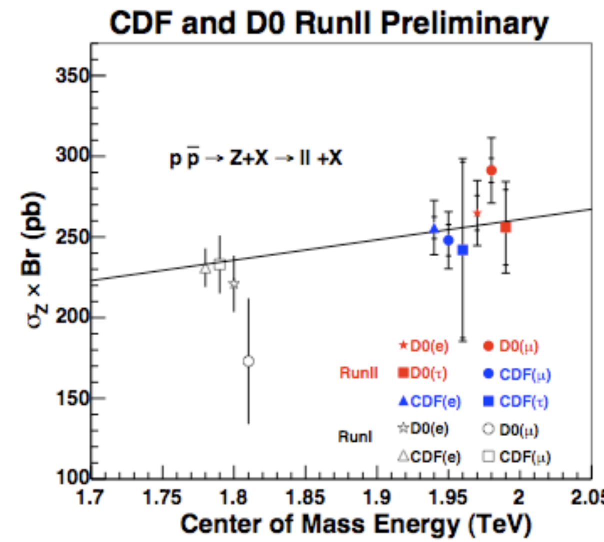


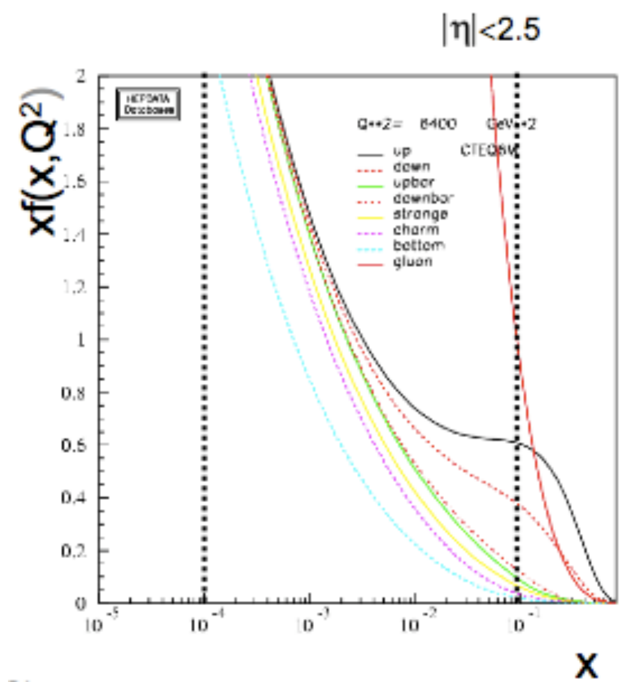
Electroweak Measurements

W and Z production

- W/Z rates at the LHC (LO):
  - $\sigma(W \to \ell\nu) \sim 16.8$nb $\to \sim 10^6$ events in $\int L\,dt = 100\ pb^{-1}$
  - $\sigma(Z \to \ell\ell) \sim 1.65$nb $\to \sim 10^5$ events in $\int L\,dt = 100\ pb^{-1}$
- Various measurements will be performed at a kinematic region different than earlier experiments.

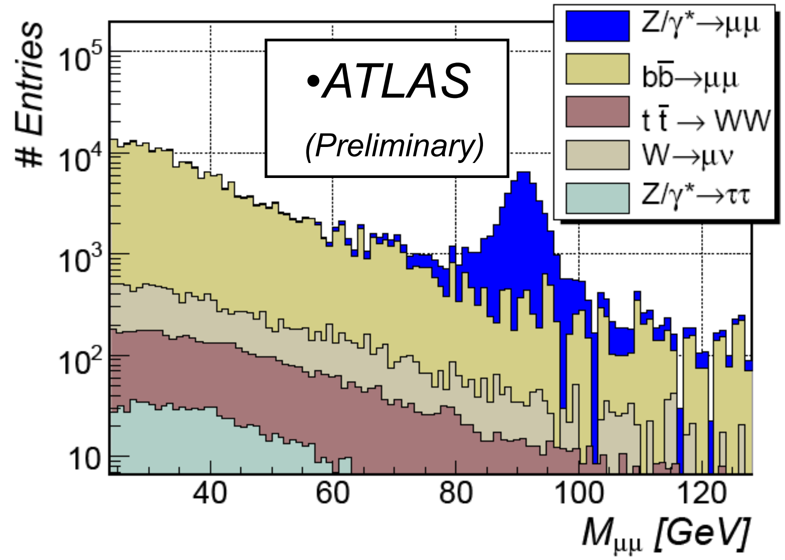
- Measurements of EW observables
  - W,Z cross sections
  - W mass and width, sin2 ϑ_{eff}, A_{FB} from Z events
  - W charge asymmetry A(ηl)
  - Di-Boson productions
  - Measurement of triple gauge couplings
- Single W/Z boson production is a clean processes with large cross section useful also for
  - "Standard candles" for detector calibration /understanding
  - constrain PDFs looking at σ_{TOT}, W rapidity, ...
  - Luminosity measurement



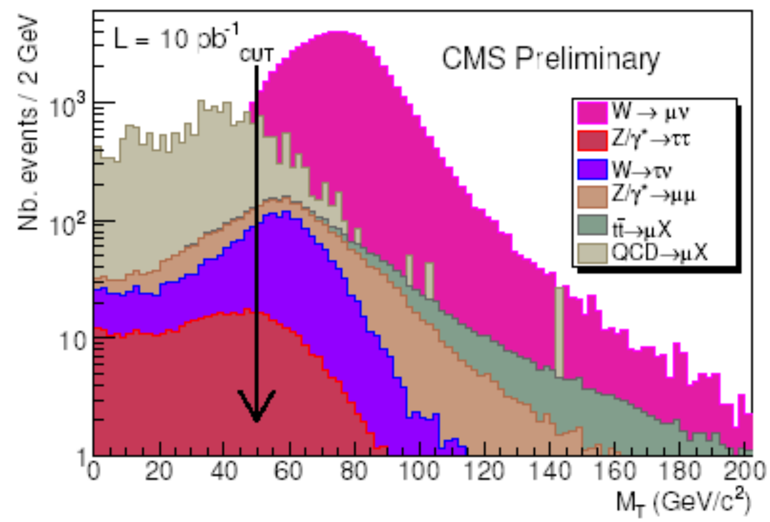


W & Z cross section

- Not statistically limited
- Data driven bkg determination a la Tevatron
- Shape of of W→ μν events from Z→ μμ events



- Experimental systematics(1%) from
  - Efficiency extraction, momentum scale, misalignment, magnetic field, collision point uncertainty, underlying events, (pileup)
- Theoretical uncertainties (2%) arising from
  - PDF choice, initial state radiation, p_T effects (LO to NLO), rel. acceptance determination
- Luminosity measurement limited to 10%
- Expected Precision for $\int \mathcal{L}\,dt = 100\ pb^{-1}$



$$\frac{\Delta\sigma}{\sigma}(pp \to Z/\gamma^* + X \to \mu\mu)$$

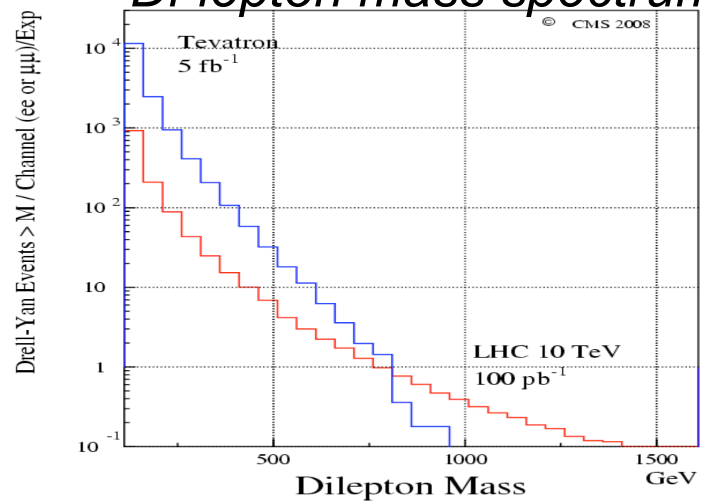
$$= 0.004\ (\text{stat}) \pm 0.008\ (\text{ex.sys}) \pm 0.02(\text{th.sys}) \pm 0.1(\text{lumi})\ \ (\text{ATLAS})$$

$$= 0.004\ (\text{stat}) \pm 0.011\ (\text{ex.sys}) \pm 0.02(\text{th.sys}) \pm 0.1(\text{lumi})\ \ (\text{CMS})$$

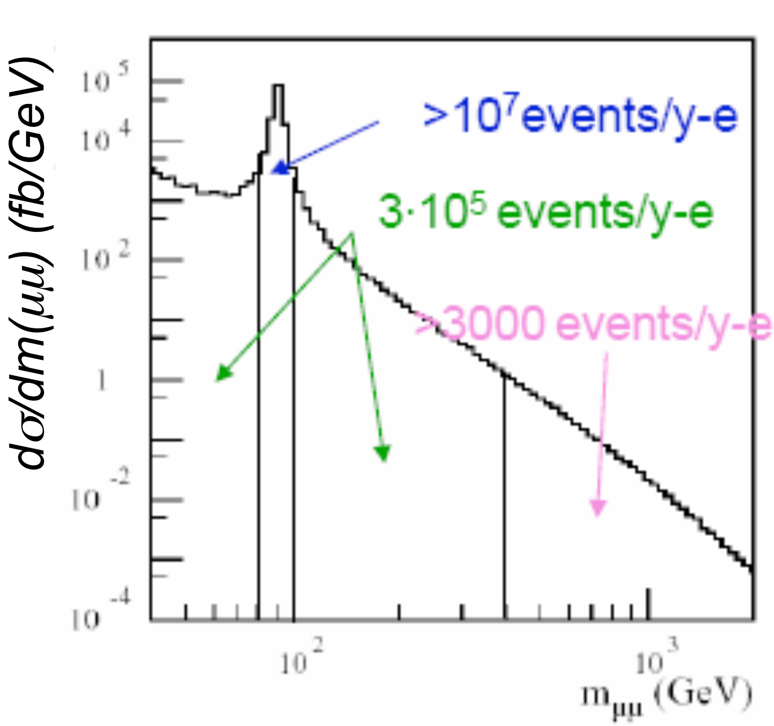
High-Mass Lepton pair Production

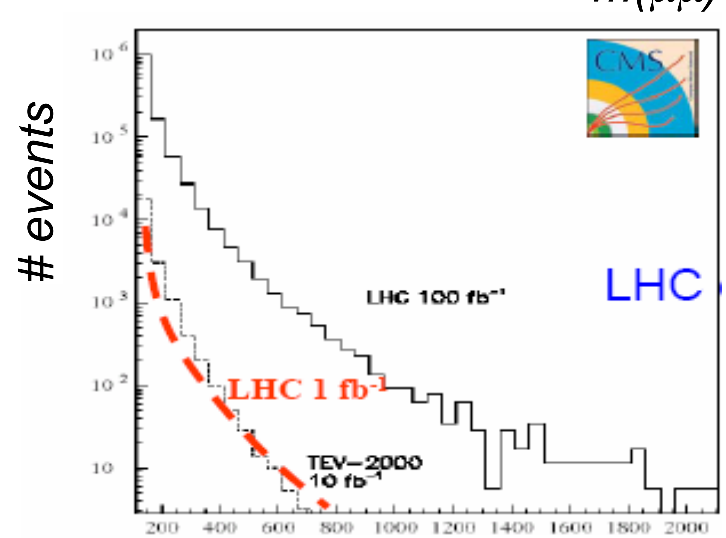
- Important benchmark process
- Deviations from SM cross section indicates new physics
- With 100 pb^{-1} @ 14 TeV, range probed > 800 GeV

Di-lepton mass spectrum



m(μμ) GeV

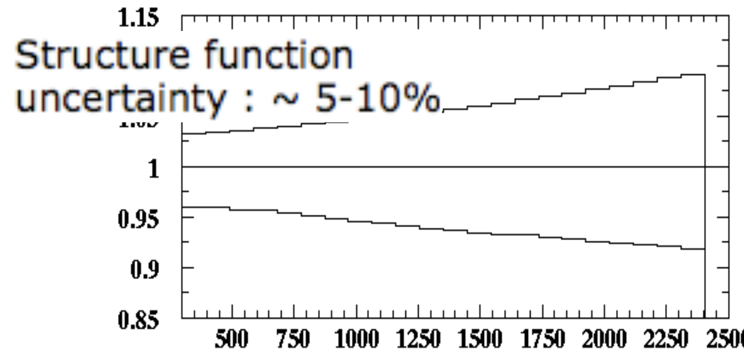


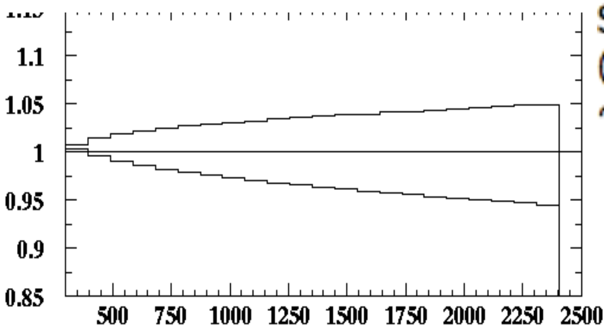


m(ll) GeV

High-Mass Lepton pair Production

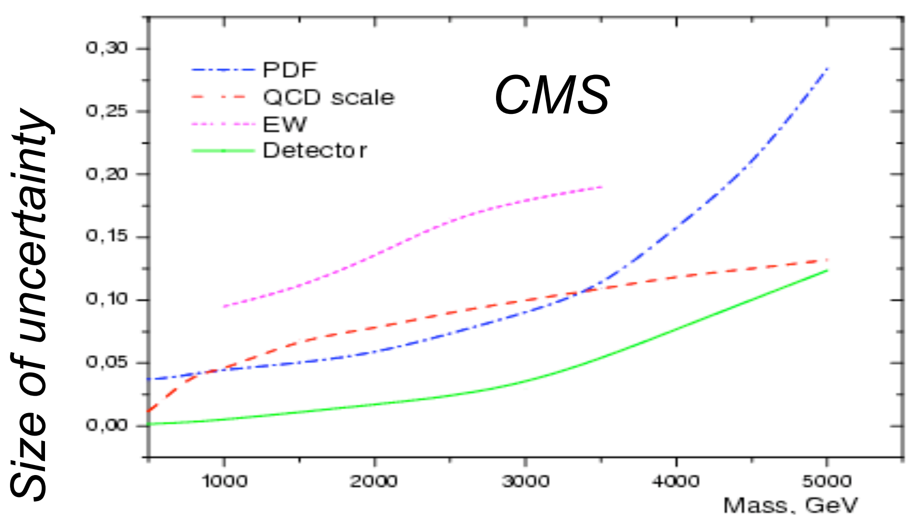
- Parton level MC@NLO variations with QCD scales and PDF errors (CTEQ6)





Scale uncertainty (factor 10 variation) : ~ 5% at high mass

Systematic error



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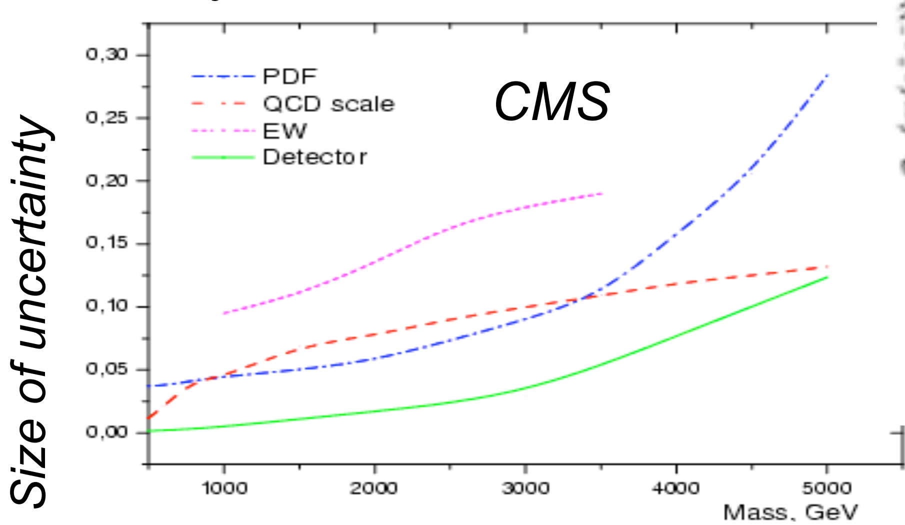
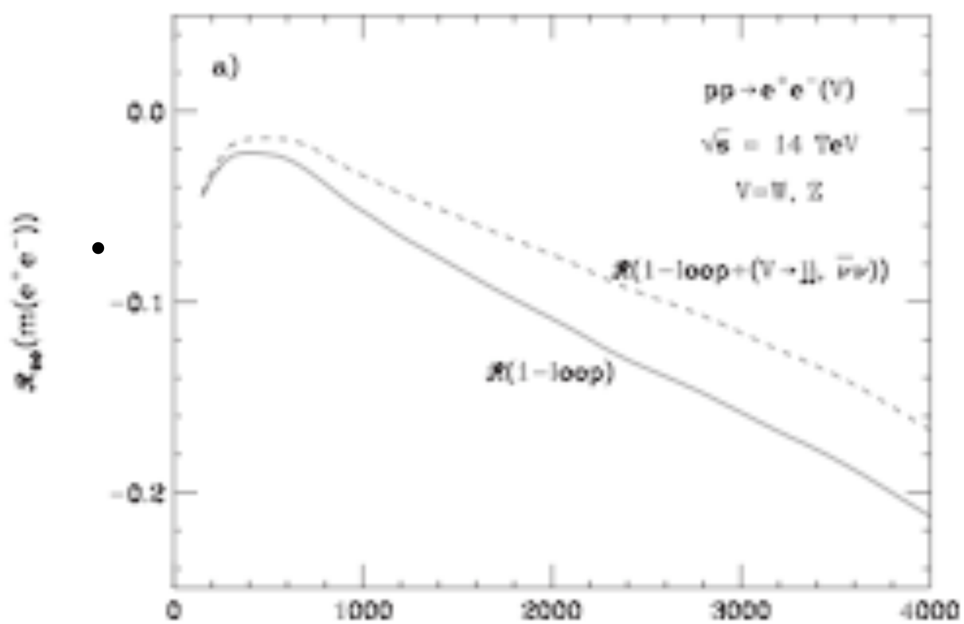
High-Mass Lepton pair Production

- *EW corrections beyond NLO*
    - *(Baur PRD75, 2007)*
- *Effect of including O(α) correction (solid) & Real V=W, Z radiation (dashed).*
- *NLO corrections decrease the LO distribution by*
    -7% @ 1 TeV and -20% @4TeV

Systematic error





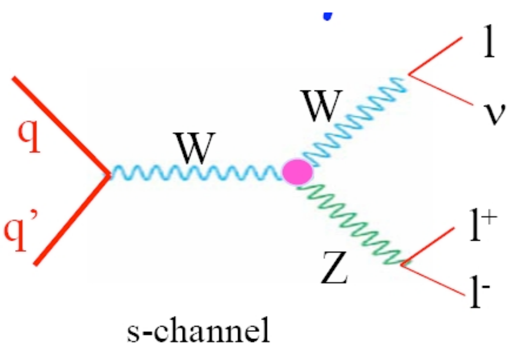
Issues:

- While the total cross-sections don't teach us much about how to constrain the theory; the effects that hinder our high-mass predictions are also playing here.

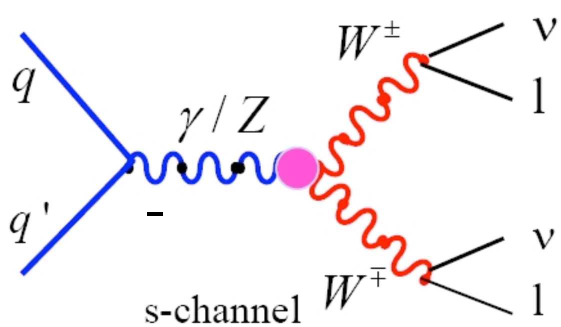
- Specifically, the acceptance uncertainties (not knowing how many events are outside the y, M, p_T(l) windows we select) should be improved.
- Thus important to analyse the shapes: $d\sigma/dy$, $d\sigma/dp_T$, $d\sigma/dM$.
  - Z events are better than W in this respect (fully measured).
  - Since the Z decay is well known, the acceptance uncertainty on differential cross-sections is small.
- Improvement on the theoretical description then comes from:
  - Confronting data and theory within the analysed (y,pT,M) domain
  - Better extrapolation outside the analysed domain

Di-boson production

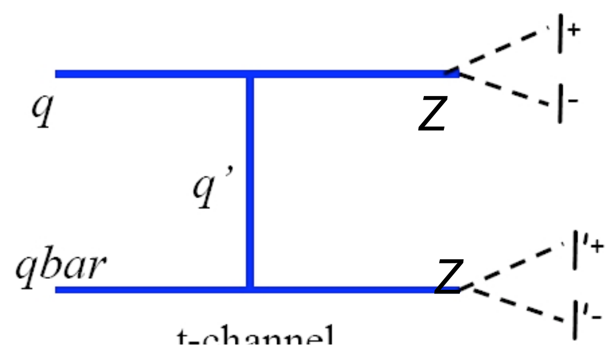
- Probes non abelian SU(2)xU(1) structure of SM
- Trilinear gauge boson couplings measured directly from ZW, WW, ZZ cross section
  - Charged TGC: WWZ, WWγ→ exist in SM
    - study WW and WZ/γ final states
  - Neutral TGC: ZZZ, ZZγ, Zγγ→ do not exist in SM
    - study ZZ/γ final states
- Probing TGC is at the core of testing SM: values are O(0.001)



σ(SM)=58 pb



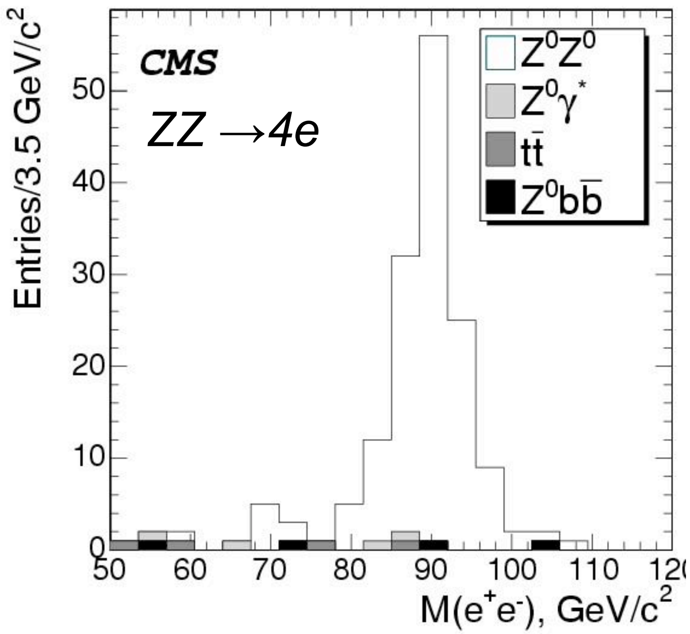
σ(SM)=128 pb

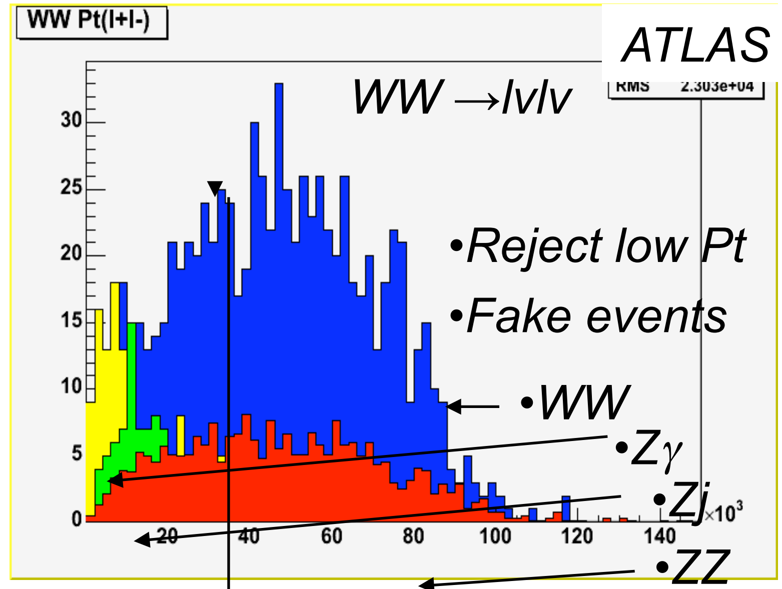


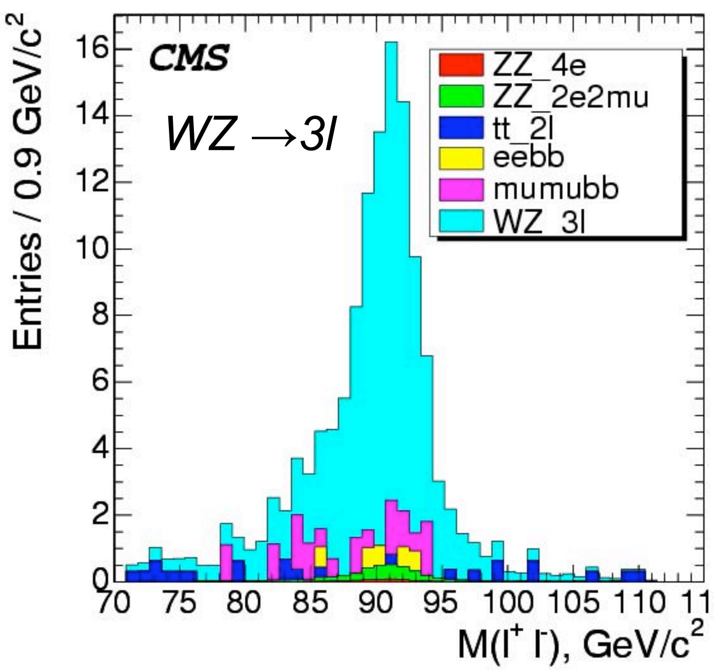
σ(SM)=17 pb

s-channel suppressed by $O(10^{-4})$

ZZ, WZ, WW







Di-boson production for $\int \mathcal{L} dt = 1\ fb^{-1}$.

Channel	# events	bkgs	S/√B
ZW	75.7	ZZ→4ℓ, Z+jet, Zγ, DY	30.1
WW	358.7	DY, Z+jet, tt, ZW, Zγ, ZZ, W +jet	18.9
ZZ	13	Nearly bkg free, Zγ, tt, Zbb	0 bkg events

Signal Significance

- $1 fb^{-1}$:

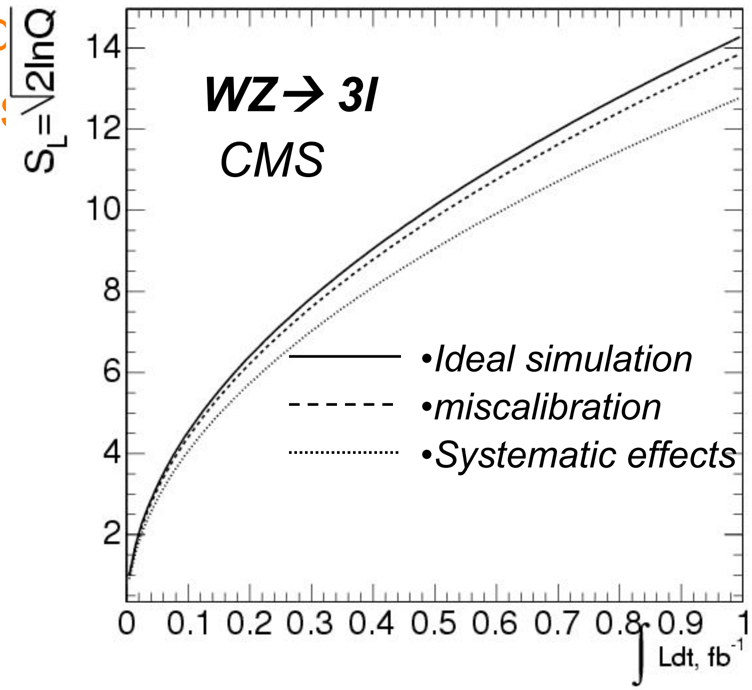
ZZ→ 4e: 7.1 signal and 0.4 background

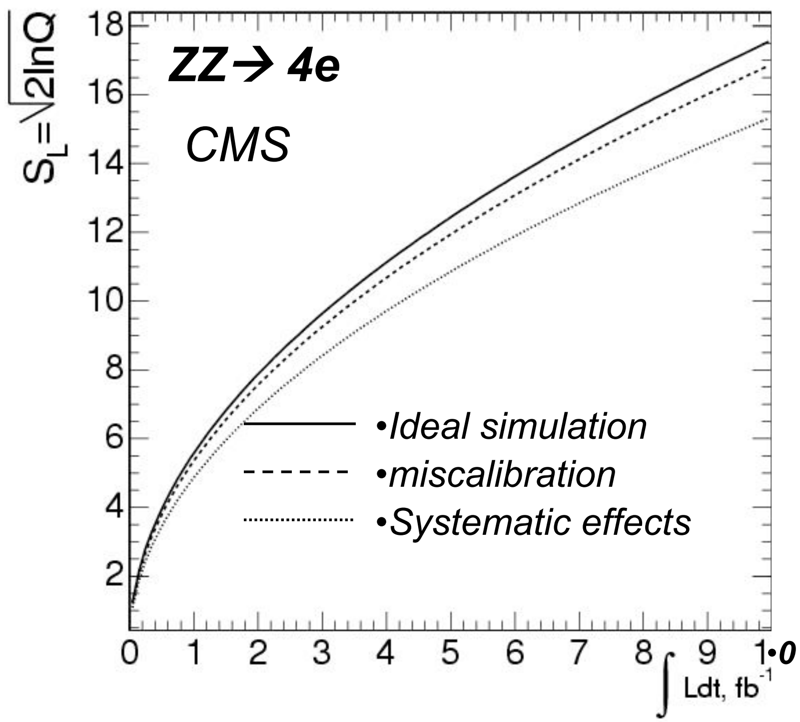
WZ →3l: 97 signal and 2.3 backgrounds

- 5 σ observation with :

ZZ : ~1 fb^{-1}

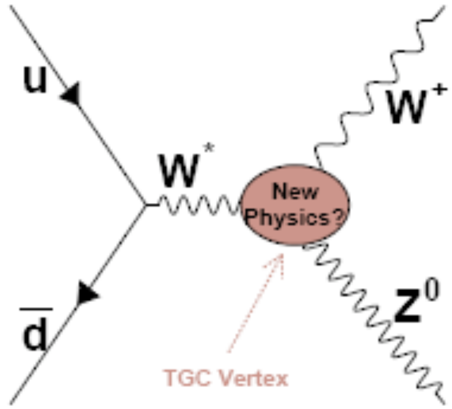
WZ : ~150 pb^{-1}

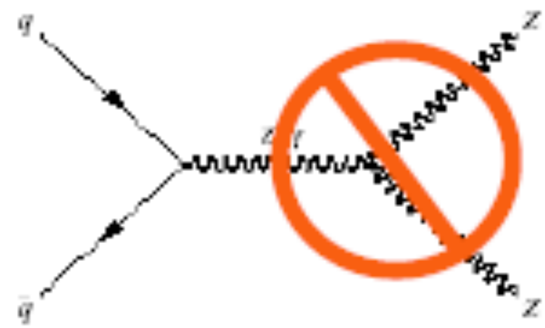




$$S_L = \sqrt{2\ln Q}, \qquad Q = \left(1+\frac{N_S}{N_B}\right)^{N_S+N_B} e^{-N_S}$$

Triple gauge boson couplings





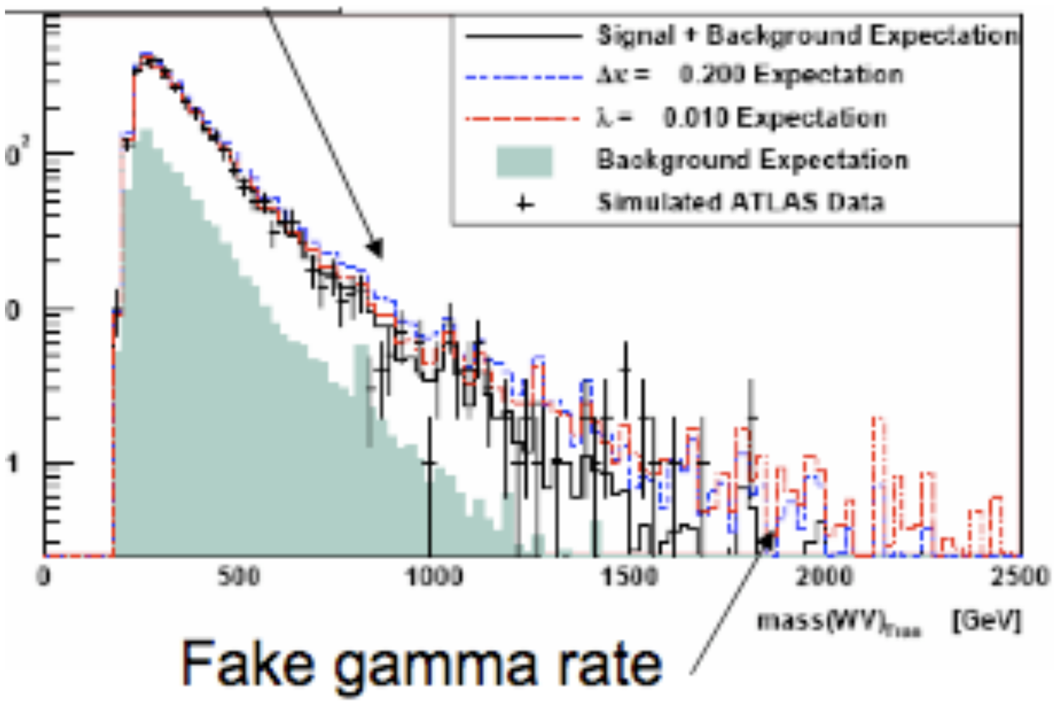
•*No tree level neutral couplings in SM*

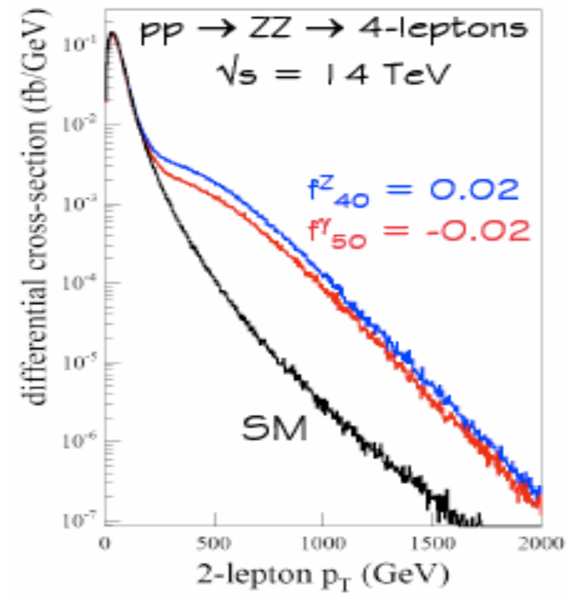
$$\underbrace{\Delta g_Z^1, \Delta\kappa_Z, \Delta\kappa_\gamma}_{\text{grows} \sim \sqrt{\hat{s}}} \quad \underbrace{\lambda_Z, \lambda_\gamma}_{\text{grows} \sim \hat{s}} \quad \underbrace{h_{1,3}, f_{4,5}}_{\text{grows} \sim \hat{s}^{\frac{3}{2}}} \quad \underbrace{h_{2,4}}_{\text{grows} \sim \hat{s}^{\frac{5}{2}}}$$

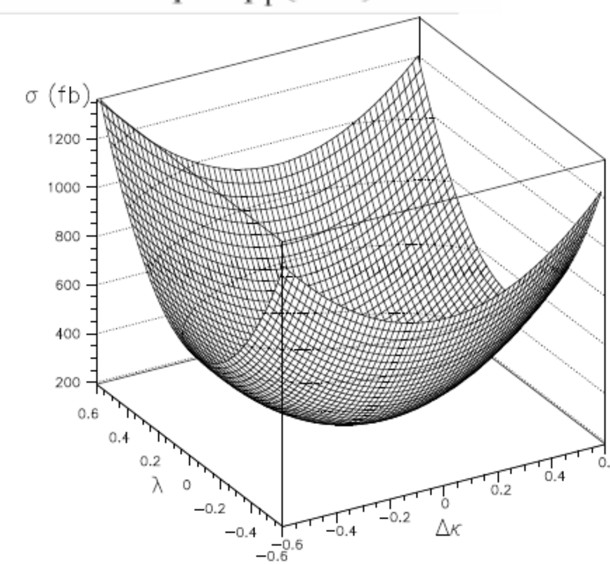
- Variables sensitive to modification to TGC structure from BSM effects
  - Cross section
  - Boson p_T(V=W, Z, γ)
  - Production angle
- Anomalous coupling
  - enhancement of X-section at high Pt (g- and λ−type couplings)
  - changes in η and angular distributions (κ-type coupling

TGC

- λ_Z, $\Delta\kappa_\gamma$, λ_γ : maximum likelihood fit to 1-d P_T (V) distribution







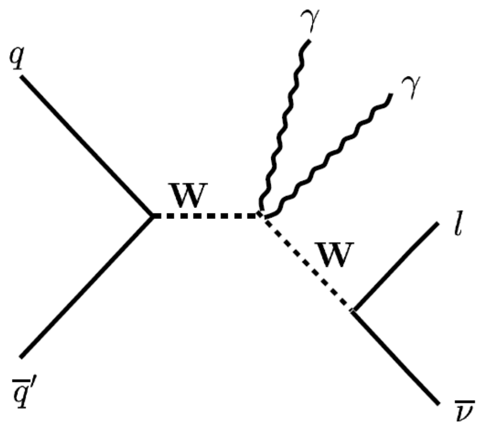
- $\Delta\kappa_z$, Δg_{1z} : fit to 2-d distr. of $P_T(Z)$ vs. $P_T(l_W)$
- TGC limits for 30 fb^{-1}: 95% CL incl. syst.

  λ_Z: (-0.0073, 0.0073) λ_γ : (-0.0035, 0.0035)

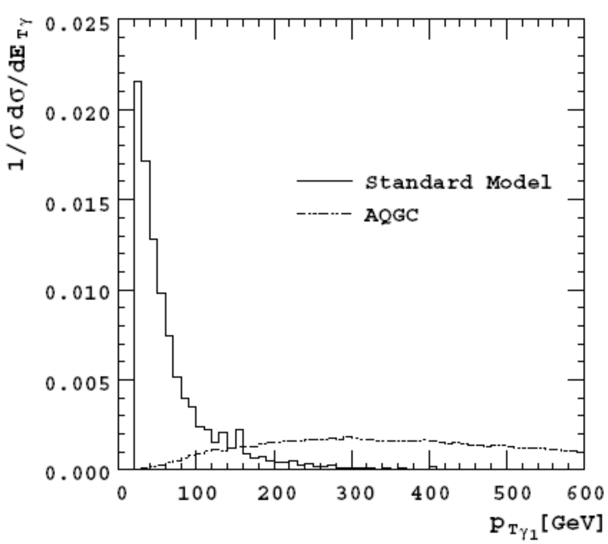
  $\Delta\kappa_Z$: (-0.11, 0.12) $\Delta\kappa_\gamma$: (-0.075, 0.076)

  Δg_{1Z} : (-0.0086, 0.011)

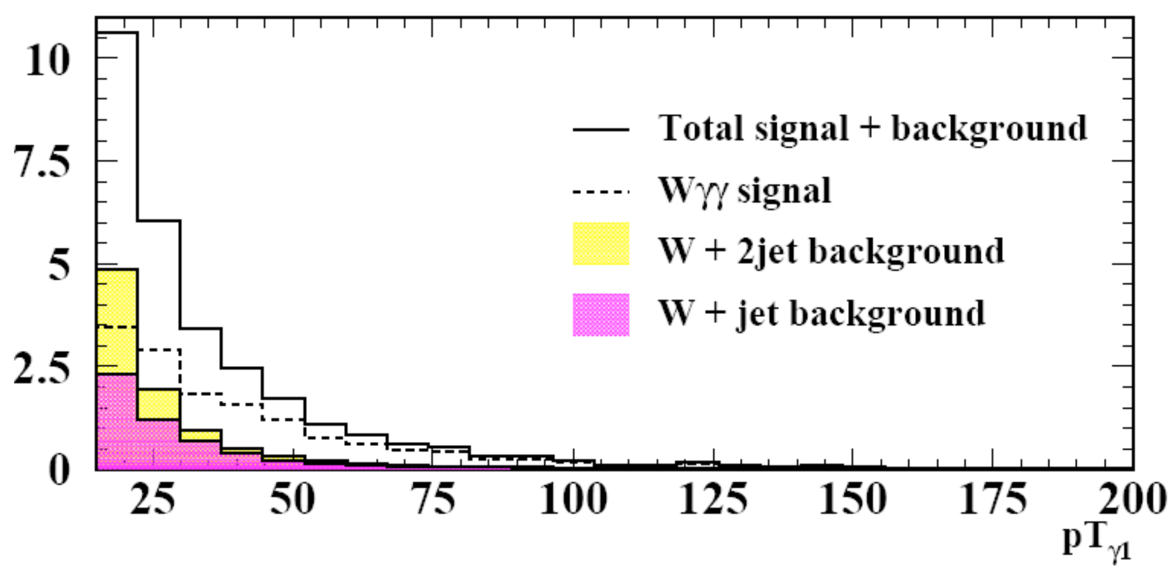
Anomalous Quartic couplings



- *Look for $W\gamma\gamma$, low production threshold at M_w*
- *S/B~1*



- *ATLAS $30fb^{-1}$ $e^-\nu\gamma\gamma$ ~14 events (~x4 for $l^{+/-}\nu\gamma\gamma$)*



Top Quarks

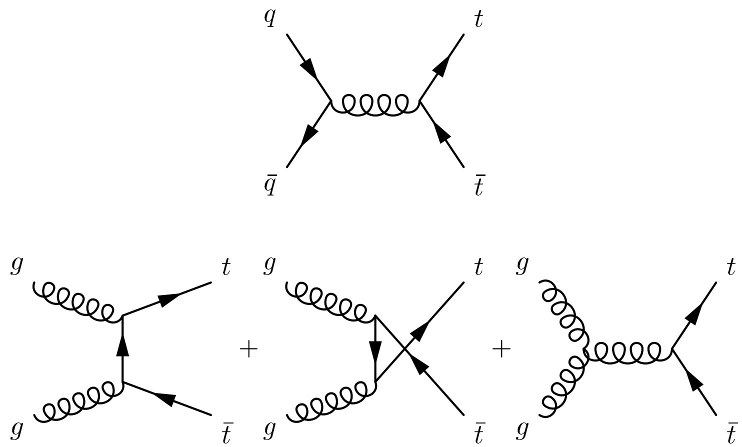
- The “top quark physics” baton will be passed from the Tevatron to the LHC in the next year

Why top quark physics?

- Top quark within Standard Model:
  - It exists! Measure its fundamental parameters (production cross -section, mass, couplings, etc.)
- Top quark beyond the Standard Model:
  - Top may be produced in new particle decays (t-tbar resonances, heavy H …)
  - Top quarks may decay in peculiar ways, e.g. $t \rightarrow H+b$
  - Top production will be a background many new physics processes
- Top is a 'template' for many new physics topologies
  - Complex decay signatures involving leptons, missing energy, multi -jets, b-jets
    - Understand the detectors, develop the tools needed for hunting for exotic things
  - $\Rightarrow$ Understanding top physics is essential in many searches

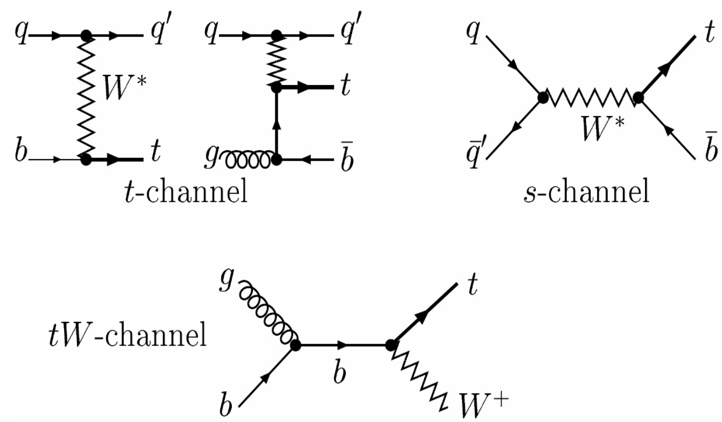
Top physics at LHC

•*strong t-tbar pair production*



•σ_{tt}*(th)=830±100 pb @ 14 TeV*

•*electroweak single top production*



•σ_{t}*(th) ≈ 320 pb @ 14 TeV*

- At 10^{33} $cm^{-2}s^{-1}$ ('nominal' low luminosity), get 1 top pair/second, or 8M/year
  - Initial data samples in 2008: 10-100 pb^{-1} ≡ few 1000 or 10000s of such events not including experimental acceptance and reconstruction efficiencies
    - Note will start LHC in summer 2008 with reduced beam energy (√s≈10TeV) - top pair cross-section reduced by factor ~2

Msmn’ts @ Startup

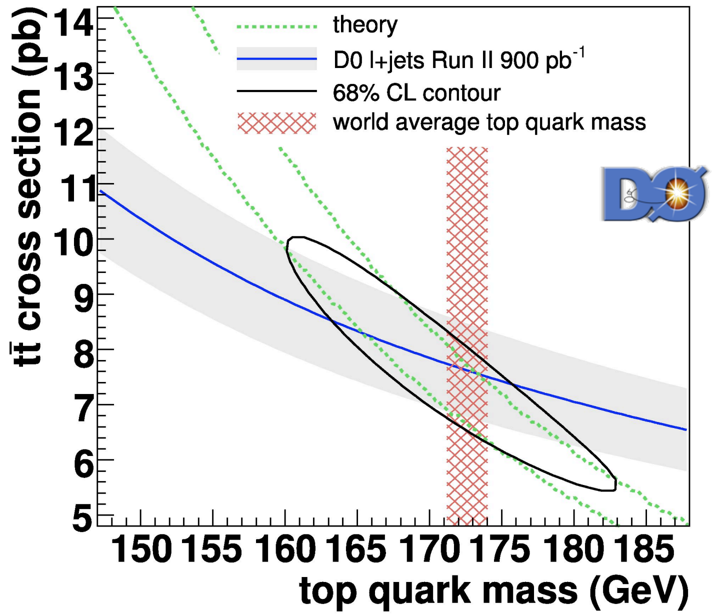
- $10 pb^{-1}$ & $100 pb^{-1}$
- Complicated event:
  - Need to understand all objects in the event: leptons, jets, Missing Energy.
- Use samples for calibration
  - jet energy scale
  - performance of b-jet algorithm.
  - Understanding the shape of Missing Transverse Energy
- Measure production cross section
  - Strong pair production and Electroweak single production.

implications of cross section

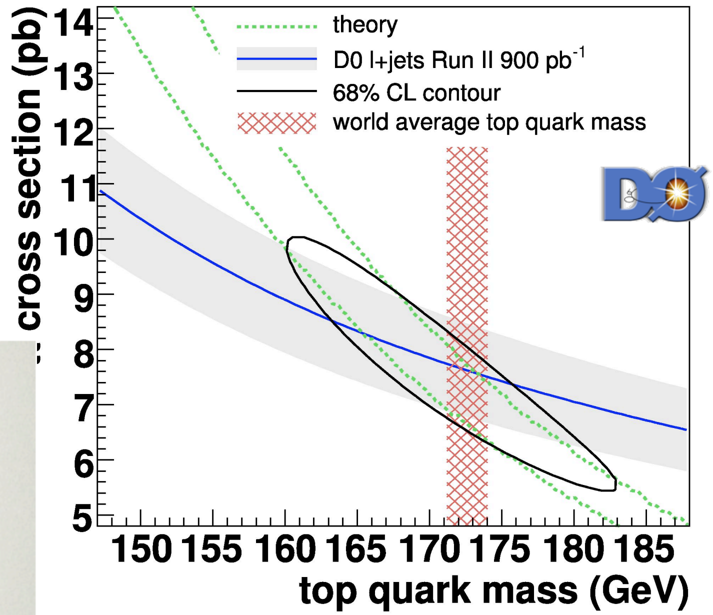
- compare different channels
  - B(t→Wb)>0.79 @ 95% CL
  - B(t→H⁺b)<0.35 @ 95% CL

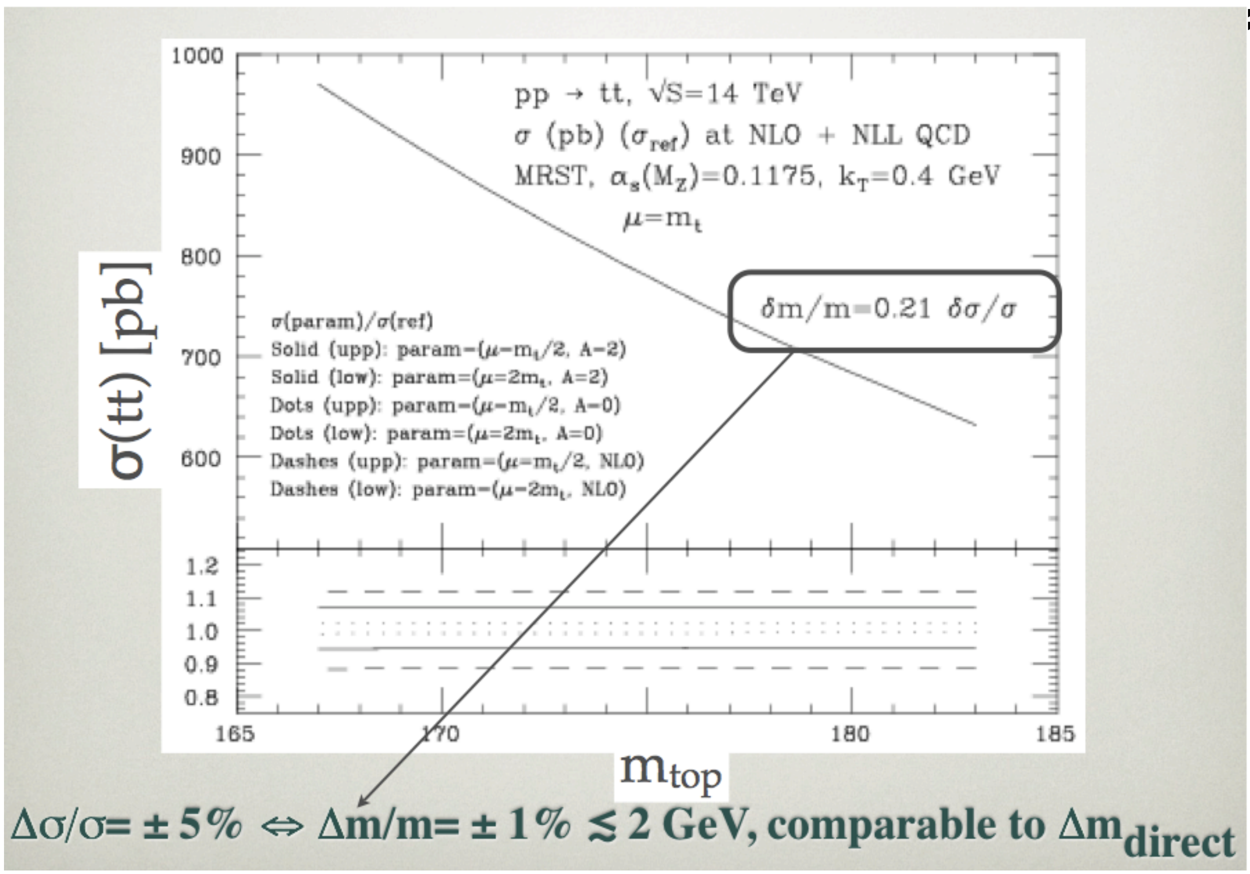
    for $m_{H+} = m_W$ and $H^+ \to cs$
- Test QCD predictions
  - Validate predictions for massive fermion pair production rate (e.g. gluinos, T quarks in little-Higgs models, etc.)
  - Test accuracy of resummation techniques, validating their use in other contexts
  - Provide input in determination of PDF: gg dominant, almost no qg/qqbar, no qq
- compare with theory (D0)
  - $\sigma_{tt} = 7.62 \pm 0.85$ pb

    for $m_{top} = 172.6$ GeV
  - $m_t = 170 \pm 7$ GeV



implications of cross section





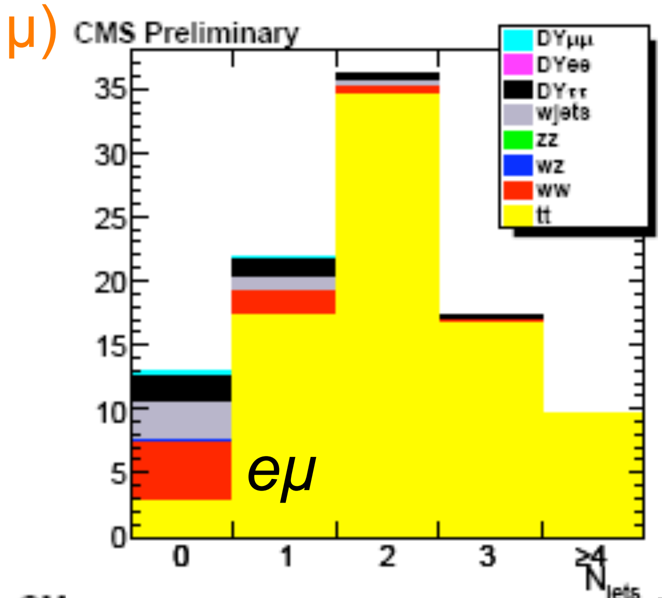
Mangano, Top2008

Dilepton Signal Significance ($10pb^{-1}$)

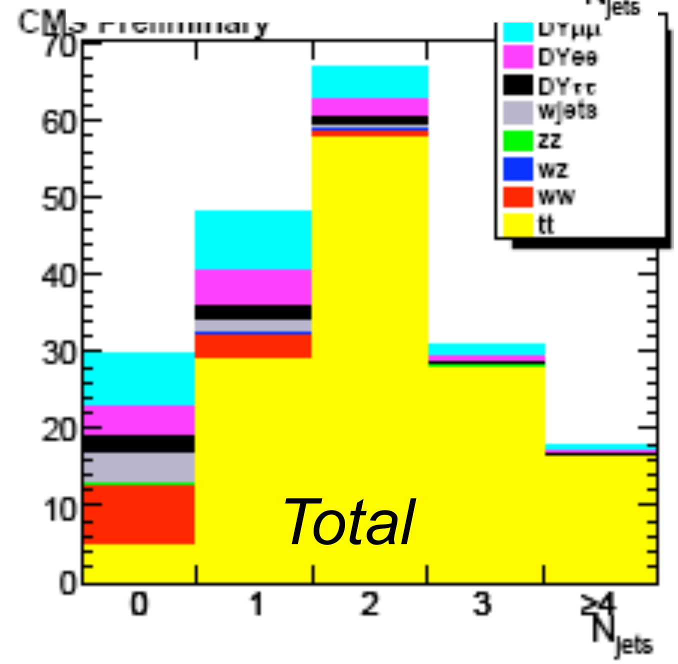
Trigger Requirements: two leptons (ee, eμ or μμ)

Analysis requirements

- Lepton pT > 20 GeV.; opposite sign leptons which are isolated both in calorimeter and tracker.
- Missing Energy E_t^{miss}:
  - (eμ > 20 GeV ee & μμ >30 GeV)
- Z removal



- Require jets with pT > 30 GeV
- Jet multiplicity spectra
  - Signal region: $N_j \geq 2$
  - Background region N_j=0,1
    - Major backgrounds: Drell Yan + Jets
- Signal Significance S:B ~ 25:1
- Statistical uncertainty ~ 9%



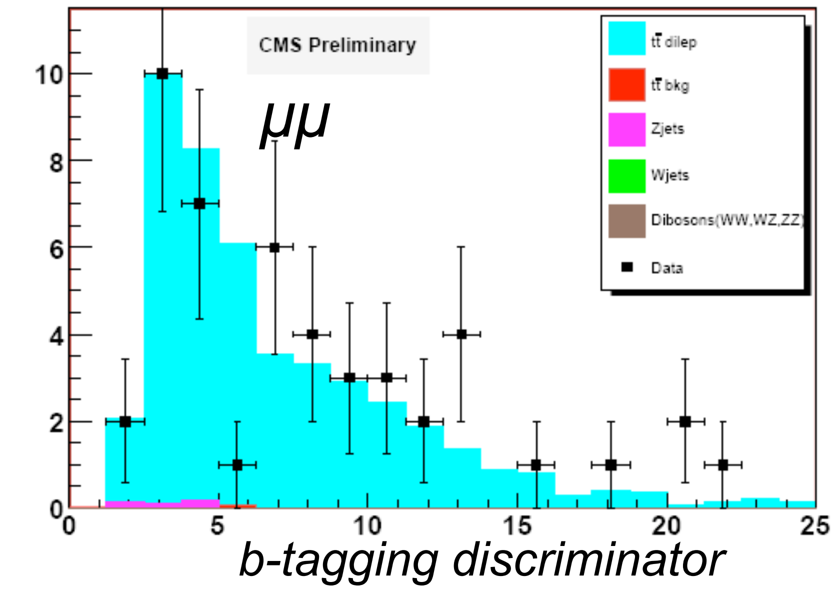
Dilepton Signal ($100pb^{-1}$)

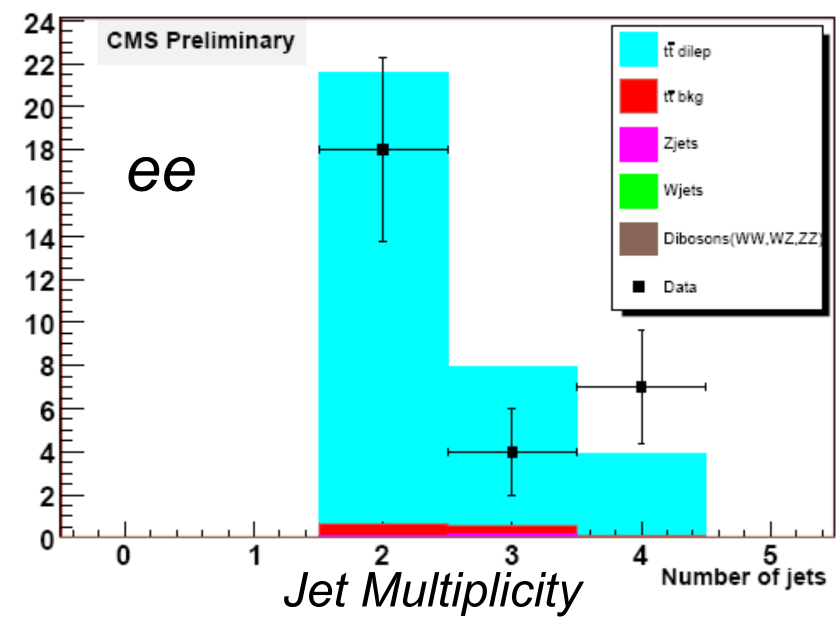
- Require b-jets tagged using the simplest b-taggers.
  - b-tag ε = 65%, light quark mistag rate = 13%
- Pseudo data sample generated
  - Detector simulation includes calibration and alignment conditions as expected during the initial data dating with fist $100pb^{-1}$
- Measure tt production cross section
- Compute efficiencies from a combination of data and MC.

$\varepsilon_{t\bar{t}}^{HLT}$: HLT efficiency from data

$\varepsilon_{t\bar{t}}^{MC}$: event selection efficiency (MC)

$\varepsilon_{t\bar{t}}^{reco/sel}$: MC vs data correction factor





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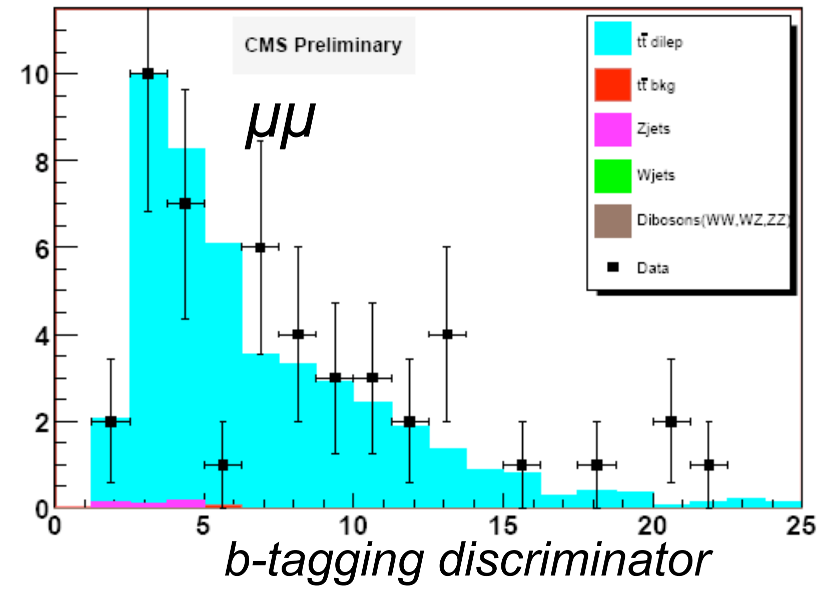
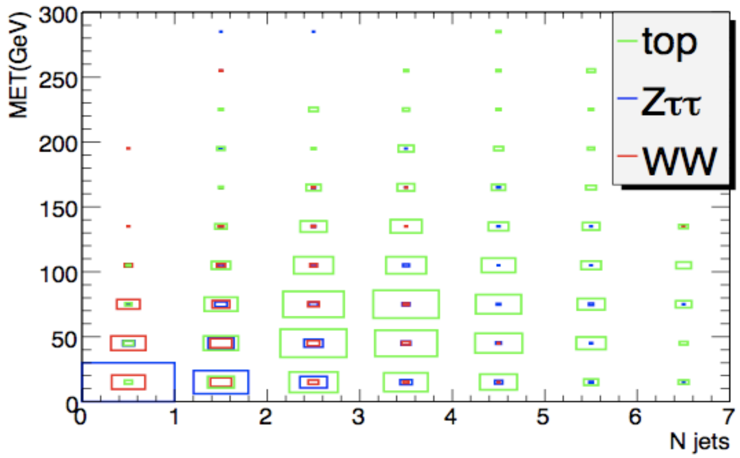


	ε_{tt}	$(\Delta\sigma/\sigma)_{stat}$
ee	2.3%	15%
μμ	3.5%	18%
eμ	3.2%	11%

All channels $(\Delta\sigma/\sigma)_{stat}$ = 8%

Dilepton Cross Section ($100 pb^{-1}$)

- Template Method:
  - Build 2-D distributions from (E_T^{miss}, N_{jets}) for signal & bkg
  - Maximize likelihood to extract parameters
  - Additional systematics from template shapes



dataset	$e\mu$	ee	$\mu\mu$	all channels
$t\bar{t}$ (signal)	555	202	253	987
ε [%]	6.22	2.26	2.83	11.05
Total bkg.	86	36	73	228
S/B	6.3	5.6	3.4	4.3

ncertainty:

Expt	Int.L	Method	Stat(%)	Syst(%)	Lumi (%)
ATLAS	100 pb^{-1}	count	3.6	3.6	5
ATLAS	100 pb^{-1}	template	3.8	4.2	5
ATLAS	100 pb^{-1}	likelihood	5.2	6.7	5
CMS	10 fb^{-1}	count	0.9	11	3

eτ, μτ Events (100 pb^{-1})

- Event Selection:
  - At least one e/m with pT>30 geV
  - One t candidate (opposite charge)
    - pTleadTrk > 20GeV/c, |η| < 2.4
  - ETmiss > 60 GeV
  - Objects separated by ΔR > 0.3
  - tagging b-jets could possibly double S/B

	one-prong	three-prong
S/B	0.397	0.139
ε(eτ)	2.1%	0.42%
ε(μτ)	2.7%	0.43%

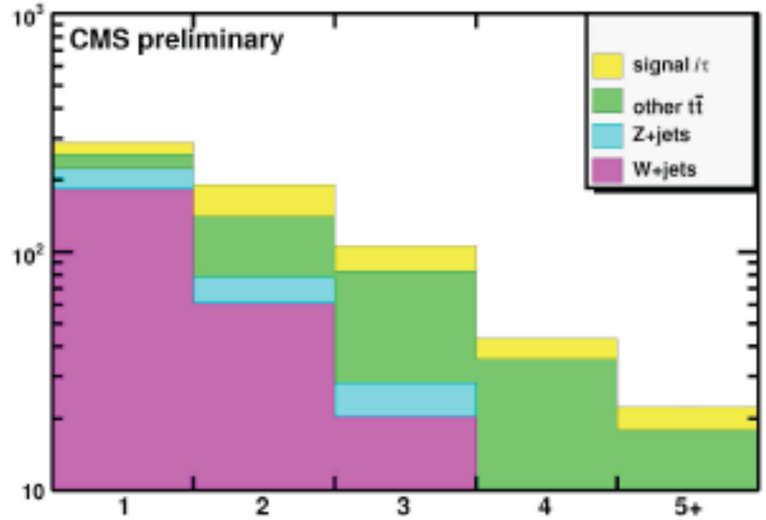
- Large mis-identified jets → τ background
  - QCD W+jets and Semileptonic ttbar
    - Use di-jet samples (γ+jets and multi-jet) to determine the fake jet → τ fake prob as a function of p_T.
    - Apply the mis-id rate to the jets passing selection to obtain the background spectrum.

eτ, μτ Cross section (100 pb^{-1})

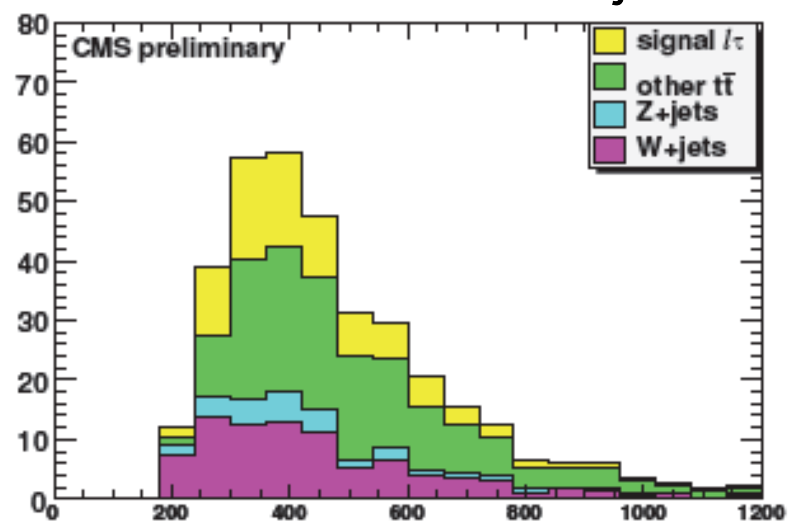
- Cross section:
- Initially measure the ratio

$$R = \frac{\sigma[t\bar{t} \rightarrow (l\nu)(\tau\nu_\tau)b\bar{b}]}{\sigma[t\bar{t} \rightarrow (l\nu)(l\nu)b\bar{b}]}$$

- Sensitive to non-SM physics in top decays
  - Important background for SUSY/H searches
- Some Systematic uncertainties cancel out in the ratio.



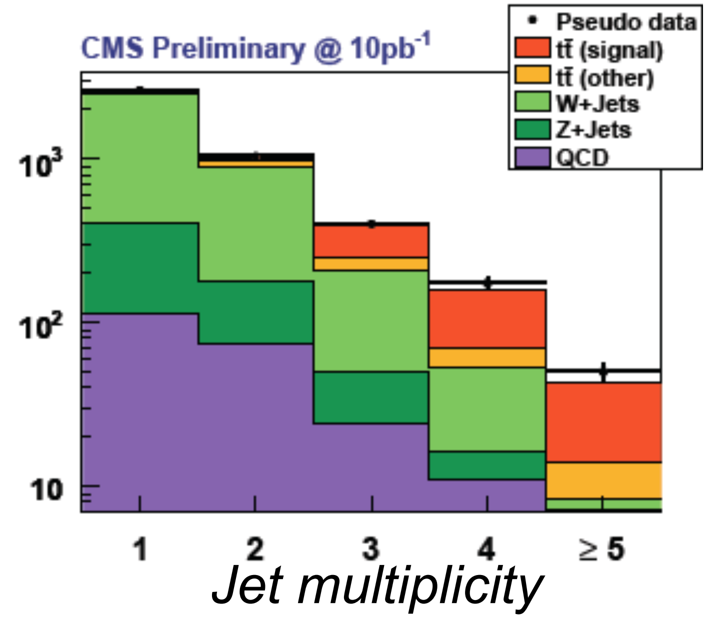
No jets

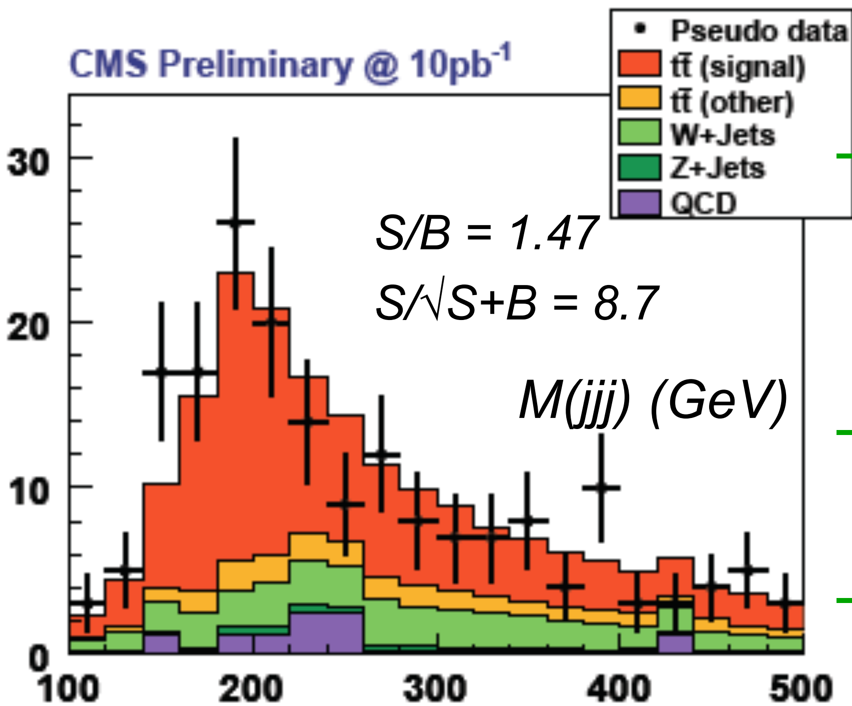


HT(GeV)

Single Lepton + Jets (10 pb^{-1})

- Trigger on non-isolated single μ
- Event Selection:
  - pT(μ) > 30 GeV; |η(μ)| < 2.1
  - Track and calorimeter isolation
    - Can establish signal for 100 pb^{-1},even with pessimistic background

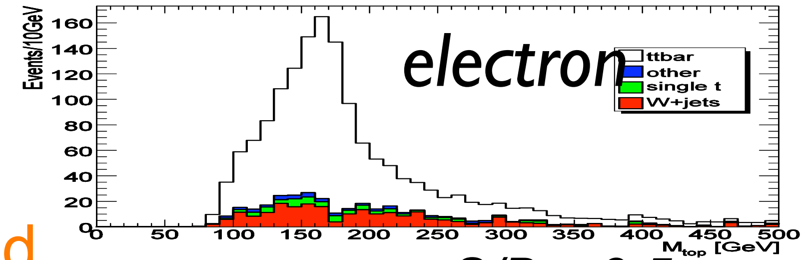




- Jet cuts
  - N jets ≥ 4 with pT jet >40 GeV
  - N jets (pT jet>65) ≥1
- Select the three jets that combine to maximize $(\sum_{i=1}^{3} \vec{p}_{J,i})_T$
- 30% efficiency

Single Lepton + Jets (100 pb^{-1})

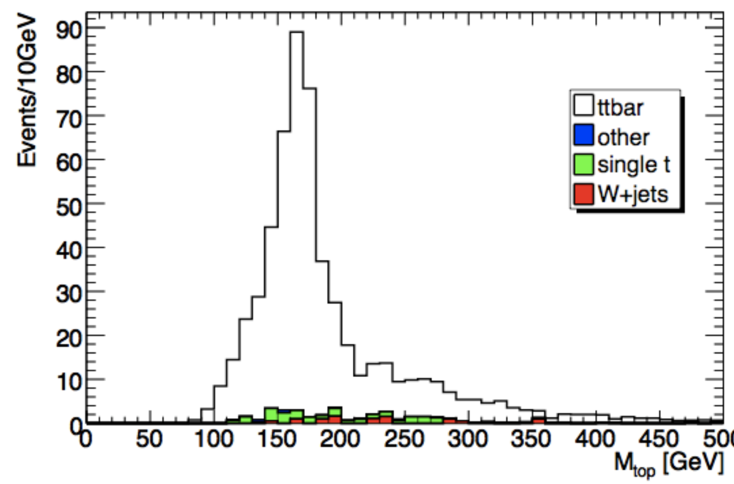
- Event Selection:
  - High p_T lepton. Jets, E_T^{miss}
  - Eff: ε~18% (e); : ε~ 24% (mu)
- Expect peak in top mass constructed using the 3-jet combination with highest P_T
- Further improvements:
  - MW constraint (S/B = 3.5)
  - Centrality (S/B = 5)
- Peak clearly visible with 100/pb
- $\Delta\sigma/\sigma$(stat) = 3.5%
- $\Delta\sigma/\sigma$(sys) ~ 15%



S/B = 3.5

S/√S+B = 31

- Requiring one or 2 b-tags
  - Purity improved by a factor of 4, but signal efficiency reduced by a factor of 2.

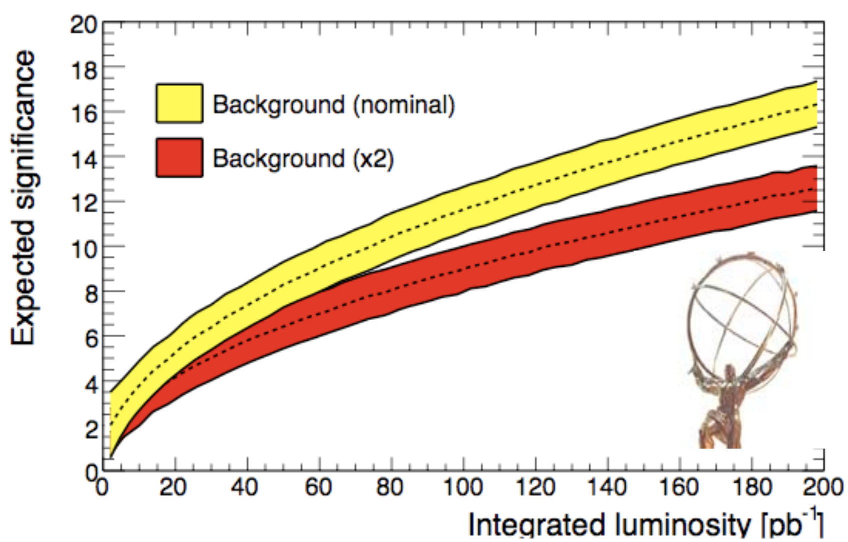


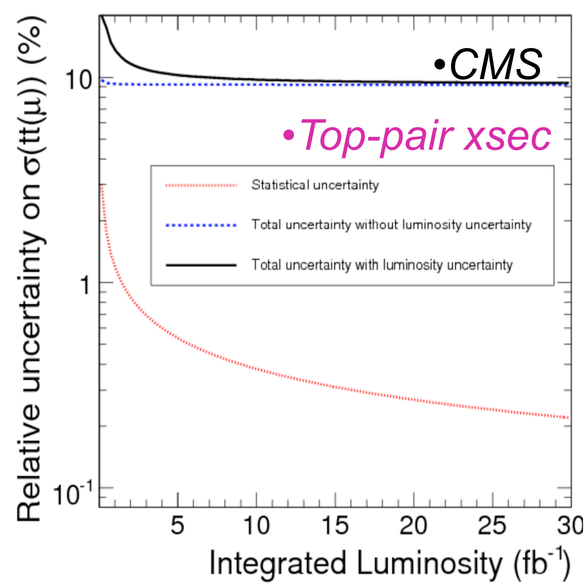
b-tag+M_W *constraint*

Single Lepton + Jets

- Cross Section Extraction:
  - Likelihood Fit to mass spectra (Gaussian sig. +Chebychev pol bkg)
    - Sensitive to the shape of spectrum.
    - For O(fb^{-1}), b-tagging, PDFs & luminosity become important

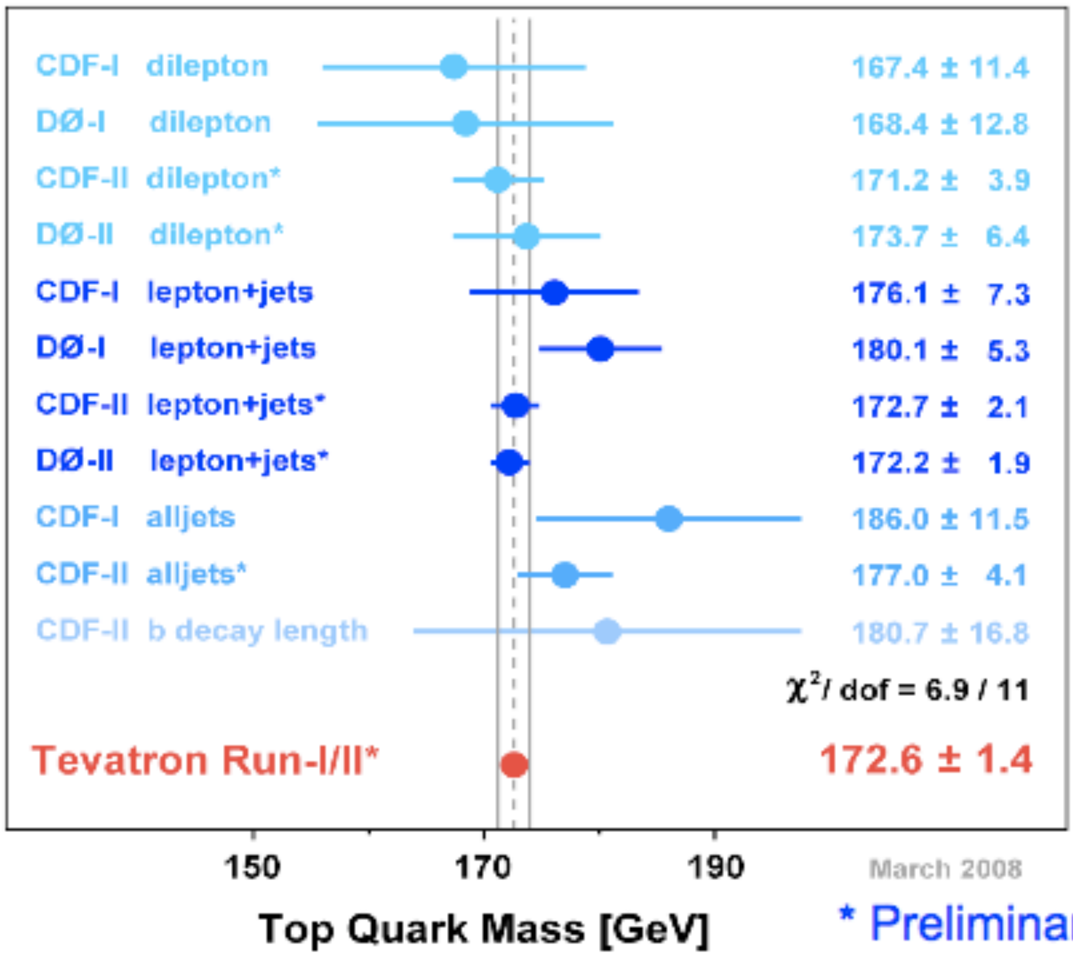
Expt	Int.L	Method	Stat (%)	Syst (%)	Lumi (%)
ATLAS	100 pb^{-1}	count ($W\rightarrow e$)	2.5	14	5
ATLAS	100 pb^{-1}	likelihood	7.4	15	5
CMS	1 fb^{-1}	count	1.2	9.2	10
CMS	10 fb^{-1}	count	0.4	9.2	3





Top Quark Mass

- Current Status:

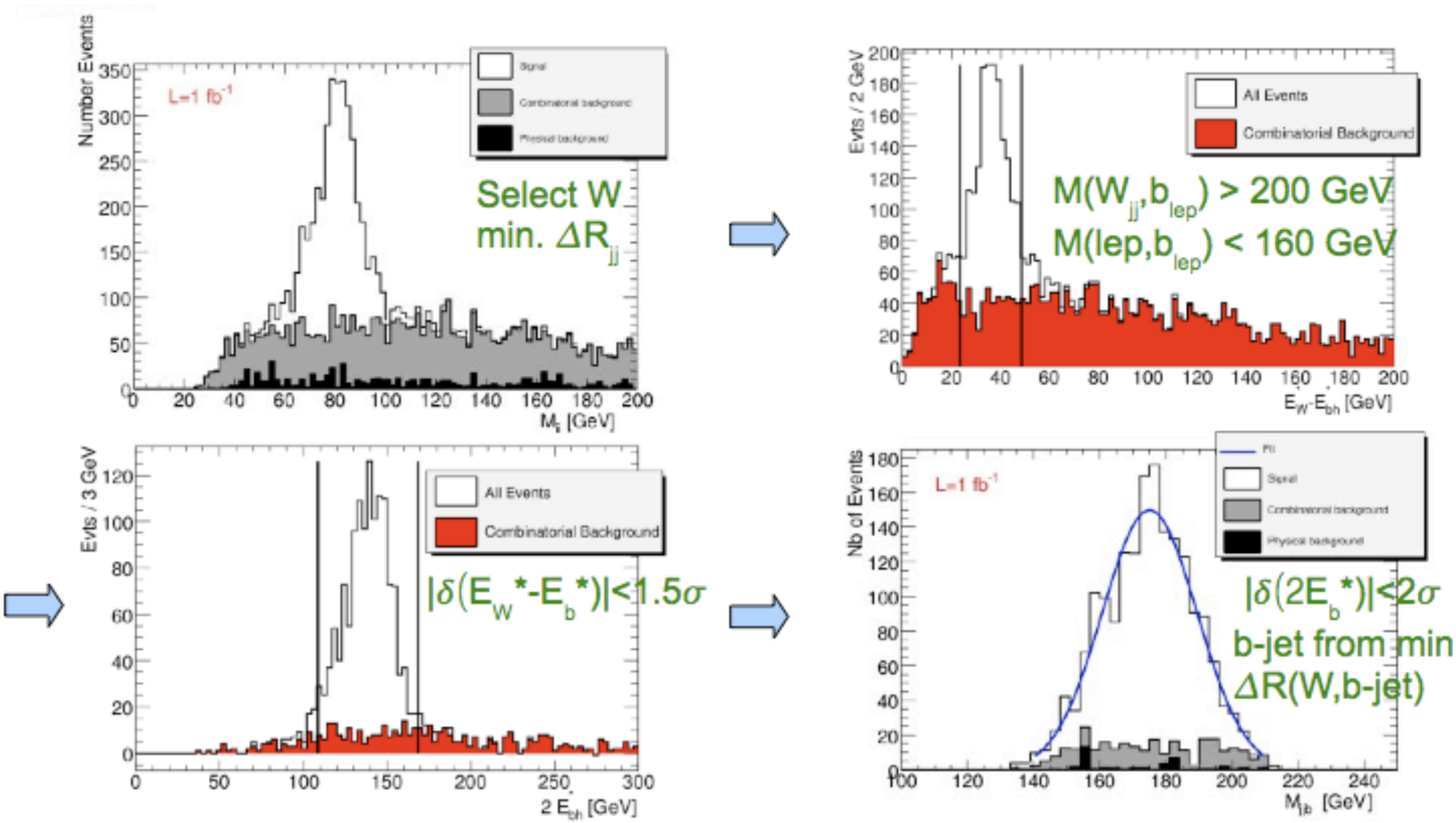


$\delta M_{top}/M_{top} < 1\%$

* Preliminary

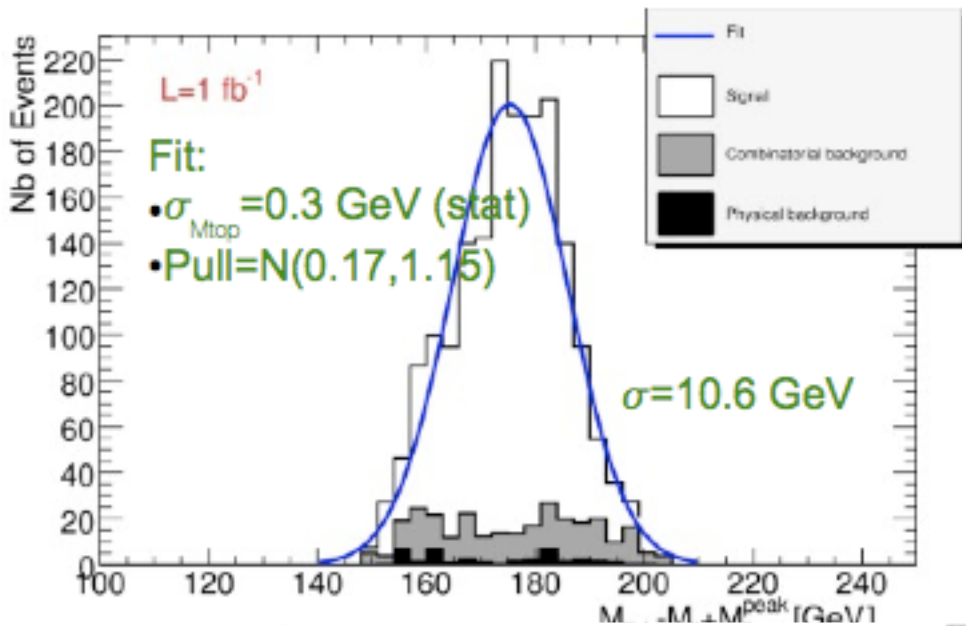
Mass: Semileptonic Events

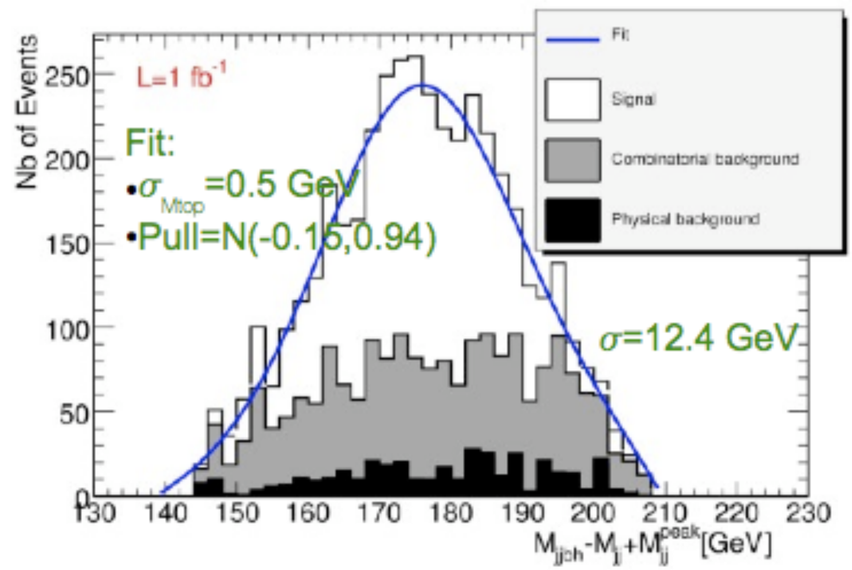
- Fit reconstructed hadronic top quark to Gaussian + polynomial.



Mass: Semileptonic Events

- Overall uncertainty: δM top ~ 1 GeV for 1 fb^{-1} (assuming 1% δJES)
- During startup assuming 5% δJES: δM ~ 3.5 GeV





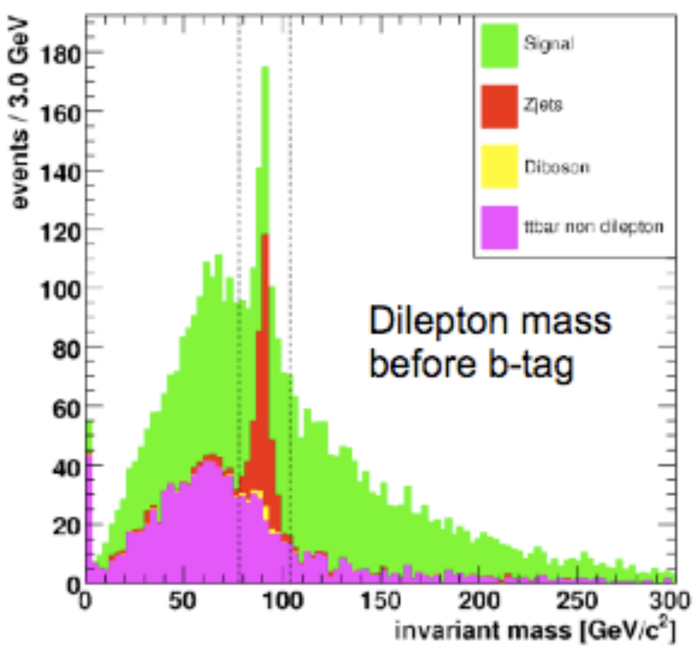
Systematic uncertainty	χ^2 minimization method	geometric method
Light jet energy scale	0.2 GeV/%	0.2 GeV/%
b jet energy scale	0.7 GeV/%	0.7 GeV/%
ISR/FSR	$\simeq$ 0.3 GeV	$\simeq$ 0.4 GeV
b quark fragmentation	$\leq$ 0.1 GeV	$\leq$ 0.1 GeV
Background	negligible	negligible

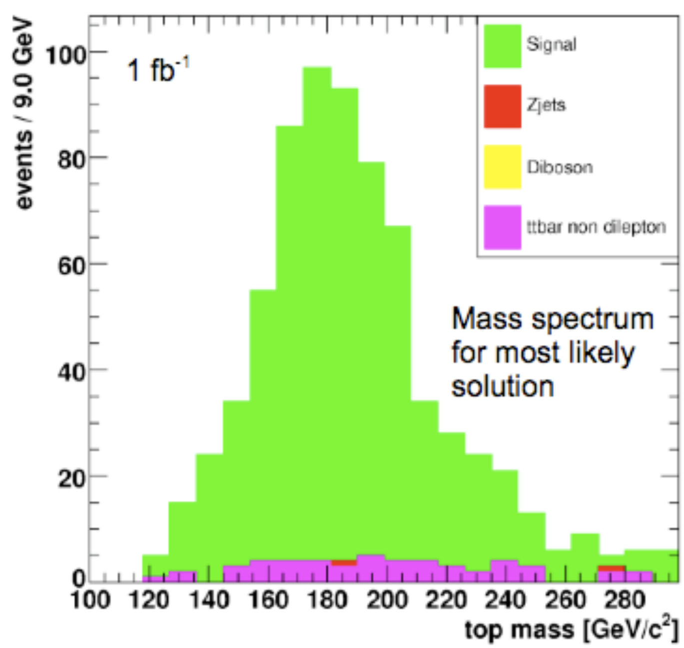
Systematic uncertainty	1 *b*-tagged jet	No *b*-tagging
Light jet energy scale [GeV/%]	0.3	0.4
b jet energy scale [GeV/%]	0.7	0.7
background [GeV]	< 1	1

Mass Dilepton Events

- The event is under constrained so assume top quark mass and longitudinal direction of the neutrinos.
  - Solve system analytically (using methods developed at the Tevatron)
  - Step in top mass 100-300 GeV and weight event solutions according to the E_T^{miss} measurement and expected neutrino distributions.
  - Pick most likely top mass
- **Overall uncertainty:**

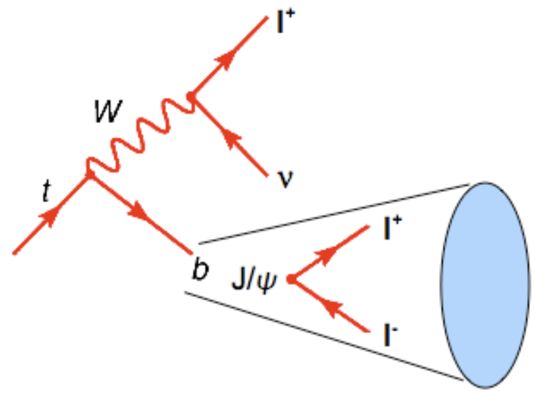
M_{top} ~ 4.5 GeV for 1 fb^{-1} M_{top} ~ 1.2 GeV for 10 fb^{-1}

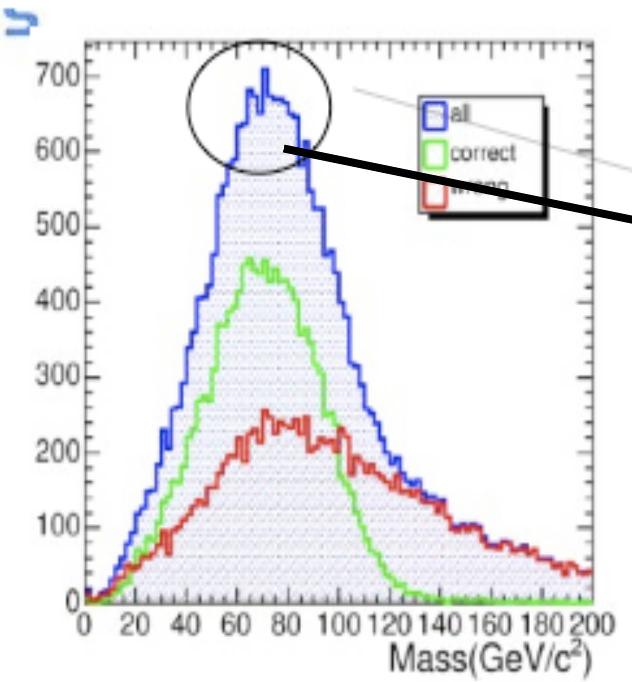


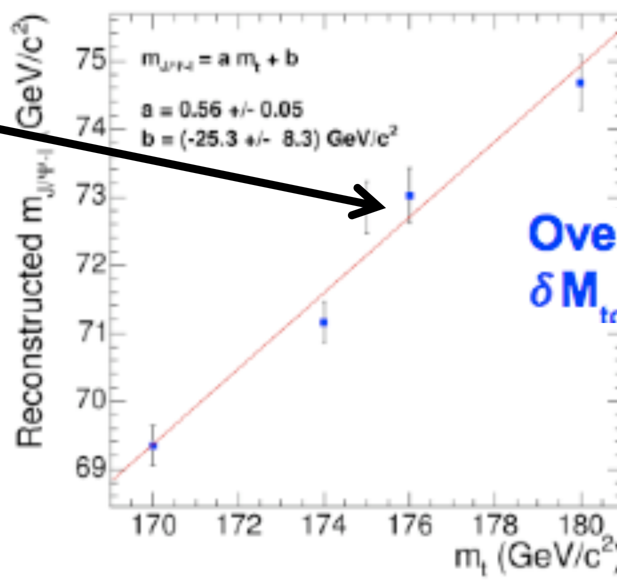


Mass: Dilepton Events $t\bar{t} \to (J/\psi) l\nu + X$

- Very small branching ratio : ~5.5*10^{-4}
- same flavor opposite charged non-isolated low momentum leptons
  - J/ψ mass constraint; 2 b-tagged jets
  - Combine J/ψ with leading lepton
  - Fit peak using polynomial
- Mass indirect: linear lookup from MC







Overall uncertainty:
δM_{top} ~ 2 GeV after 20 fb^{-1}

Single Lepton: di-top mass spectrum

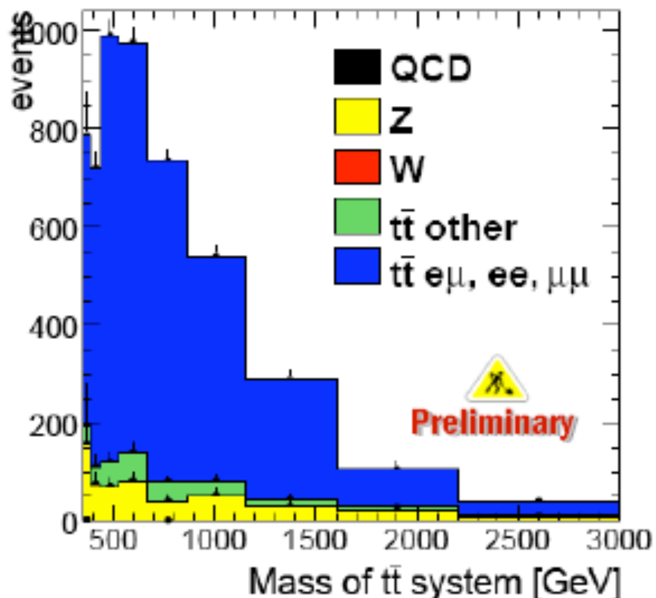
- Use Default selection.
- Kinematic fit imposes M_W and
- M_{top} + min X^2 used to choose jet
- assignment → improves reco

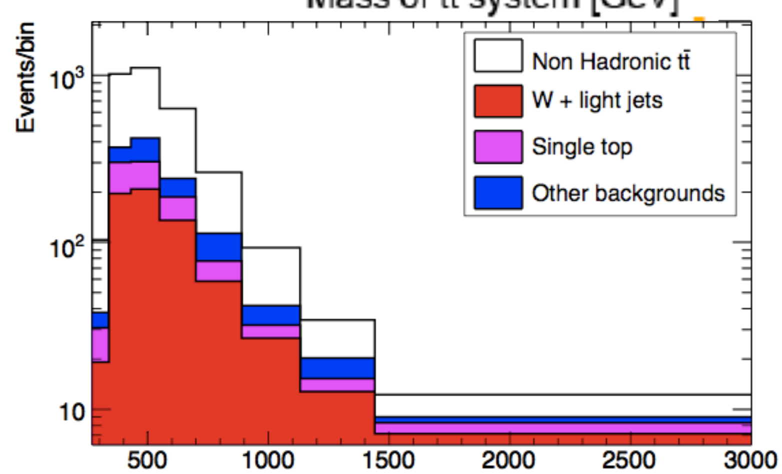
Resolution: critical.
$RMS(M_{tt}^{true} - M_{tt}^{reco})/M_{tt}^{true}$ ~5% to 9% in 200 to 850 GeV range

Variable bin size (2•8% M_{tt}) to reduce bin-to-bin migrations

Expected stat uncertainty on M_{tt} bins: from ~3% to ~25% (8% on av)

Consistency check of SM and openly sensitive to new physics



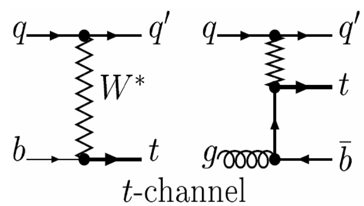


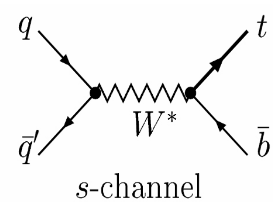
Single top production at LHC

- Electroweak top quark production - contrast to pair production
  - Sensitive to new particles (e.g. H^+, W') and flavor changing neutral currents
    - background to many new physics searches (lepton, missing energy)
- Overall cross section is large (c.f Tevatron), can distinguish contributions:

•*t-channel:*

•σ_t=247±12 pb



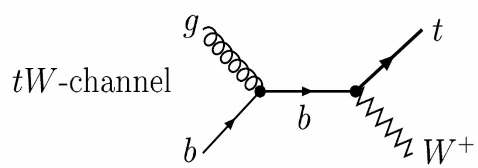


•*s-channel:*

•σ_t=11±1 pb

•*Wt-channel:*

•σ_t=66±2 pb



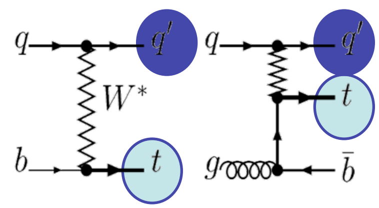
•(*c.f. top-pair*

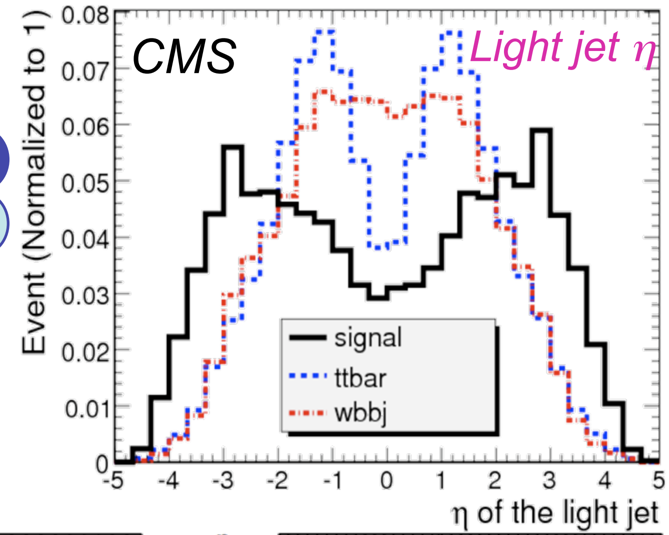
•σ_{tt}=830±50 pb)

  - Large backgrounds from top pair production, also W+multijet and QCD jet events
- At LHC - attempt to measure all production modes (s-chan & Wt challenging)
  - Can then extract $|V_{tb}|$ and study polarization, charge asymmetries, searches …
  - Basic event signatures: high E_T lepton, missing E_T, restricted number of jets
    - Fighting large backgrounds which will have to be understood from data

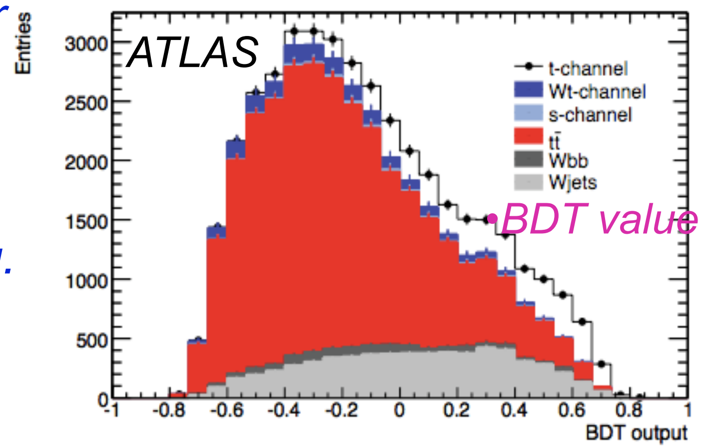
Single top production: t-channel

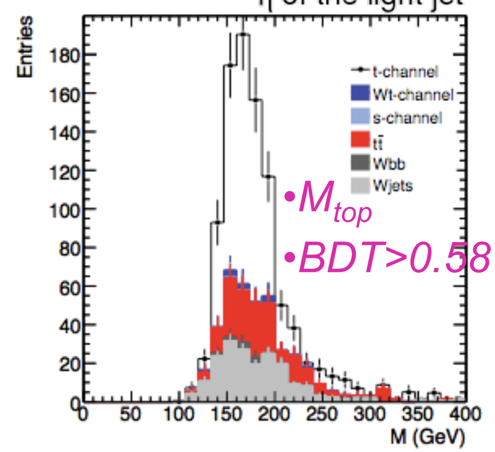
- Require lepton, missing E_T and one b-jet from the top quark decay
- Jet from light quark is **forward,** can require this jet and/or veto additional central jets
  - Second b-jet is usually soft - below E_T cut





- *O(1k) events per fb^{-1}, similar size tt background ⇒ large systematics (jet E scale, ε_b)*
- *Can be reduced by multivariate techniques - e.g. Boosted Decision Tree with event shape variables*
- *Measurement to ~10% precision possible with 10 fb^{-1}*
  - *Then get $|V_{tb|}$ to ~5%*

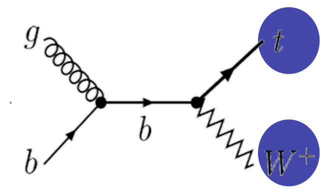


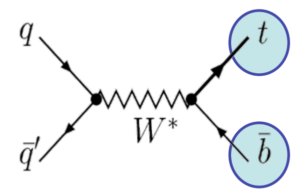


Expt	Int.L	Method	Stat(%)	Syst(%)	Lumi (%)
CMS	10 fb^{-1}	count	2.7	8	5

Single top prod.: W-t & s-channel

- Much smaller signal cross-sections, very large background
    - Especially from top-pair events where some particles are missed
  - W-t: channel: Single b-jet; look for two light jets consistent with W decay (l-j channel), or second lepton from leptonic W decay
    - Use control region with similar kinematics but rich in top-pairs (e.g. require extra b-jet) to estimate background, cancel syst)
  - S-channel: Two b-jets, lepton + missing ET, no other high ET jets





- *Multivariate techniques can be used to enhance signal significance*
- *Some representative analysis results - note small S/B and large syst.*
    - *Mainly from background - b-tagging, jet energy scale, PDFs,*

Expt	Channel	Int.L	Nsignal	S/B	Stat(%)	Syst(%)	Lumi (%)
CMS	W-t (l-j)	10 fb^{-1}	1700	0.18	7.5	17	8
CMS	W-t (l-l)	10 fb^{-1}	570	0.37	8.8	24	5
CMS	s-chan	10 fb^{-1}	270	0.13	18	31	5

- *Need O(10) fb-1 of data and careful background studies to establish 5σ signals*

The Roadmap

O(10pb-1)	W/Z	Calibration /Alignment Lepton ID Missing Et Isolation	2008
O(100pb-1)	W/Z + jets Top physics	PDfs B tagging , missing Et "Multi Variables" analysis	
O(1fb-1)	Precision Top Physics TGC	In Situ Final Jets Calibration Full detector understanding	2009
	Solid Grounds for New Physics Should be Established		
O(100fb-1) and more	$\sin^2(\vartheta)$ M_W		

Conclusions

- ATLAS and CMS are eagerly awaiting the first data …
  - Detectors/software/analysis strategies are ‘almost’ ready …
- Useful measurements can already be performed with ~ 100 pb^{-1}
  - … that we might hope to get in 2008 or soon after

- W and Z events provide important early measurements at LHC.
    - Help to understand detectors and physics performance .
    - Precision measurements with data of 1 fb^{-1} get limited by thoeretical uncertainties,
    - Reduce theoretical errors, mainly by constraining PDFs.

- Top Quark Physics will benefit from the large samples:
  - Early pair production cross-section measurement
    - 10-20% with O(100 pb^{-1}), then work on systematics
    - E.g. detailed understanding of b-tagging algorithm performance
  - Searches for non-SM physics in top production/decay can start immediately…
    - Consistency of cross-section in different channels; top-pair vs single t

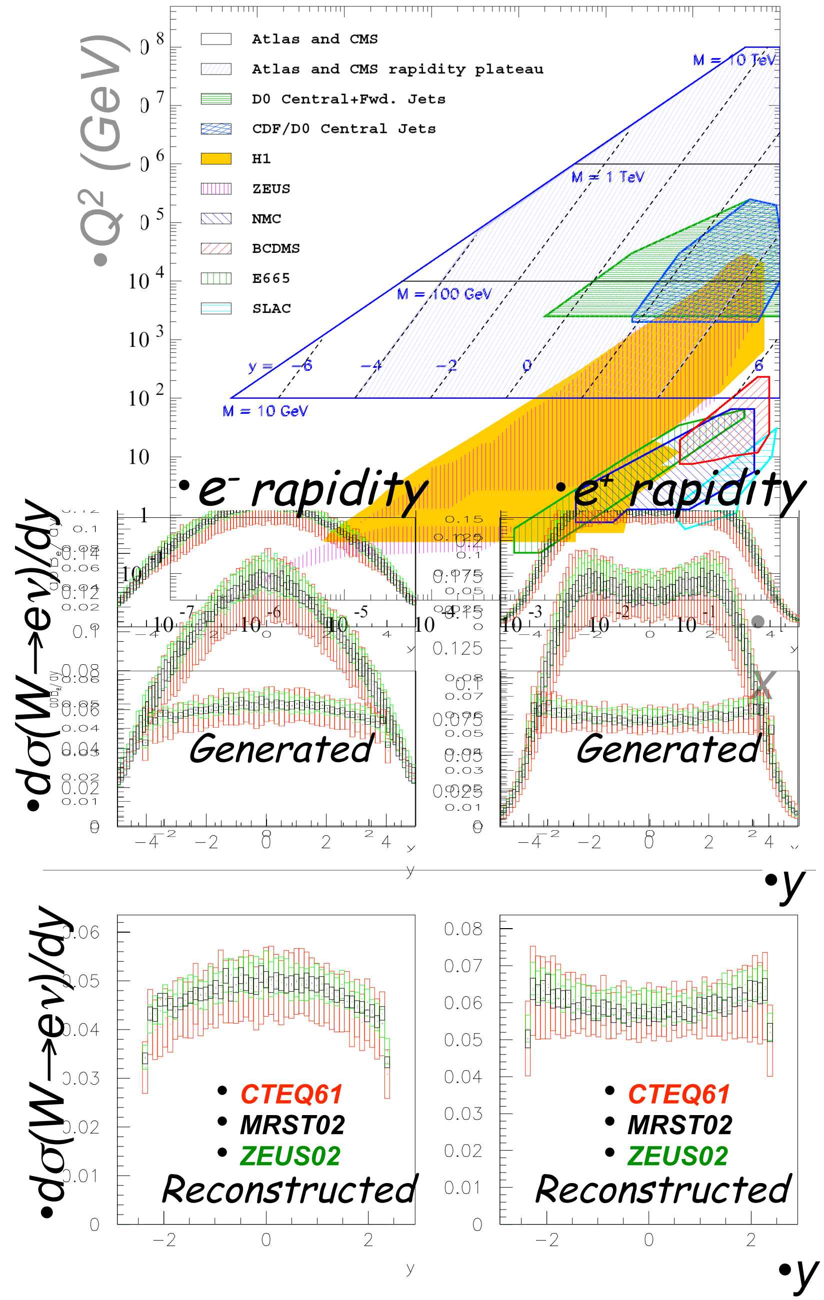
Backup Slides

PDF constraints from W→ℓν

- Main (LO) contribution

$$u\bar{d} \rightarrow W^+ \quad d\bar{u} \rightarrow W^-$$

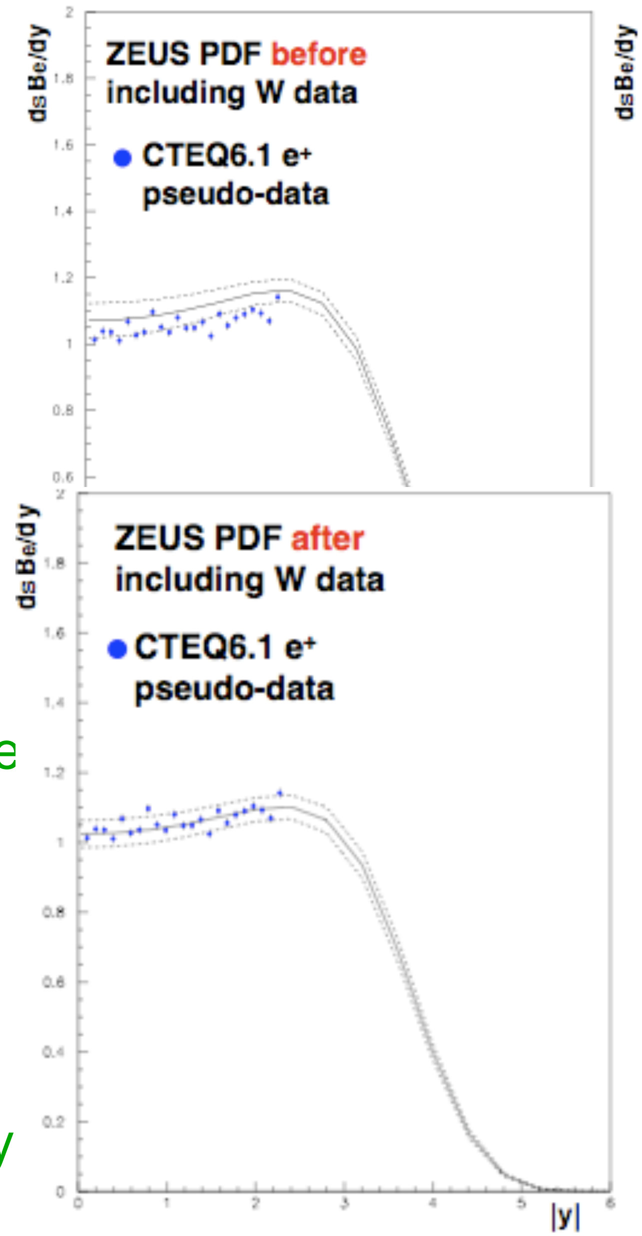
- At the EW scale LHC will explore low-x partons.
  - $10^{-4}<x_{1,2}<0.1$ over measurable rapidity range |y|<2.5.
  - low-x uncertainties on present PDF are large (4-8%)
- Measurements of $e^{\pm}$ angular distributions can provide discrimination between different PDF.
  - experimental precision is sufficiently small (<5%)



PDF constraints from $W \rightarrow \ell\nu$

Example:

- Simulate 10^6 W→enu events (an equivalent of $150pb^{-1}$ of data)
- Generated with CTEQ6.1 PDF and detector simulation
- Introduce 4% systematic errors from detector simulation (statistical error negligible)



- Include pseudo-data in the global ZEUS PDF fit ⇒ error on low-x gluon shape reduced by 41%
  - systematics (e.g. e± acceptance vs η) are already controlled to a few percents with Z→ee
- low-x gluon distribution determined by shape parameter λ, $xg(x) \sim x^{-\lambda}$:

  BEFORE $\lambda = -0.199 \pm 0.046$
  AFTER $\lambda = -0.186 \pm 0.027$

  - Normalisation free → independent of luminosity

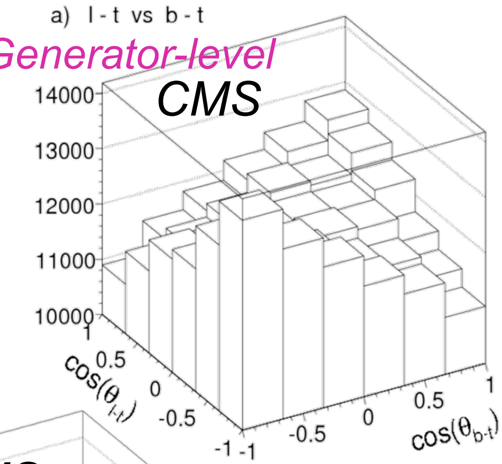
Top-pair spin correlations

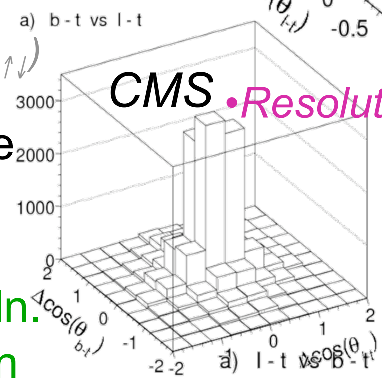
- Top decays before hadronisation or depolarisation
  - Decay products give info on top quark spin
  - Look for correlations between top/anti-top (↑↑ vs ↑↓)
    - Different for qq and gg production, in SM A≈0.32
- Measure decay angle distribution in semileptonic events

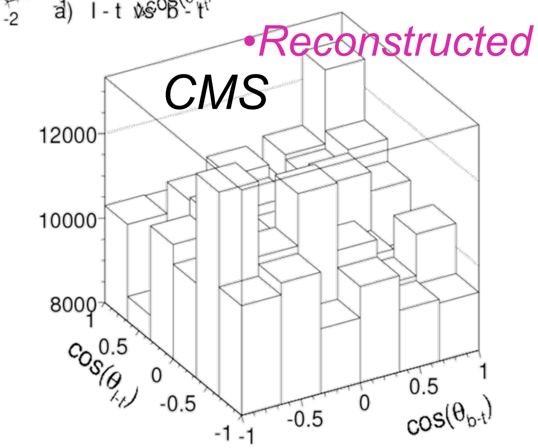
$$\frac{1}{N}\frac{d^2N}{d\cos\theta_l\, d\cos\theta_q} = \frac{1}{4}(1 - \mathcal{A}\kappa_l\kappa_q \cos\theta_l \cos\theta_q)$$

•; $A=(N_{\uparrow\uparrow} - N_{\uparrow\downarrow})/(N_{\uparrow\uparrow}+N_{\uparrow\downarrow})$

    - $\theta_l(\theta_q)$ angle between lepton (quark) in top quark frame and top momentum in top pair rest frame
    - Can use b-quark or lower energy light quark
  - Fully reconstruct events - distribution distorted by resln.
  - ATLAS/CMS expect 5σ observation of spin correlation with O(10 fb^{-1}) data, in both semileptonic and dileptonic decays
    - Systematics dominate (jet energies, b-tagging, PDFs)
- Various related observables - e.g. W polarisation
  - Also look for anomalies in t→Wb vertex structure
    - Can give hints for new physics in top decay

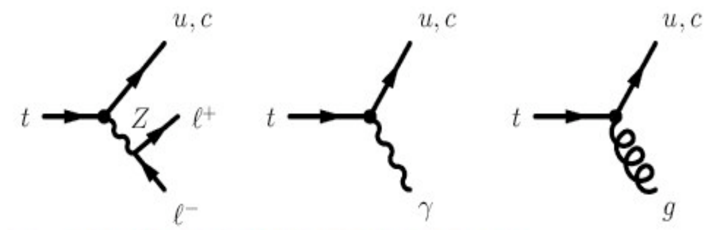






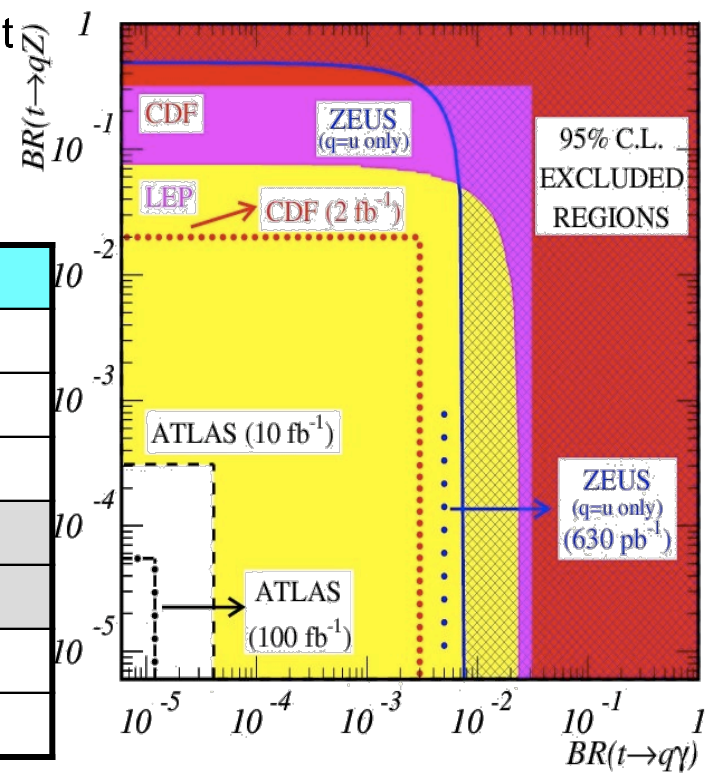
Rare top decays - flavour changing neutral currents

- FCNC decays $t \rightarrow \{Z, \gamma, g\}q$, suppressed in SM ($10^{-10}$)
  - Allowed at tree-level in SUSY, multi-H, exotic quarks
    - Could conceivably get BR 10^{-3} - 10^{-6} …
  - Typical search strategies in top-pair production
    - Assume one quark decays $t \rightarrow Wb$ with leptonic W
    - Look for leptonic Z decay, photon, high E_T gluon jet
  - Backgrounds typically dominated by mis-ID top-pair
    - Remove some contributions using likelihood selection with event shape and top mass reconstruction (ATLAS)



Decay	Expt	Method	BR (5σ sens @ $100 fb^{-1}$)
$t \rightarrow Zq$	ATLAS	Cut ($Z \rightarrow qq$)	5×10^{-4}
	ATLAS	Likelihood ($Z \rightarrow ll$)	1.4×10^{-4}
	CMS	Cut ($Z \rightarrow ll$)	3×10^{-4}
$t \rightarrow \gamma q$	ATLAS	Likelihood	3×10^{-5}
	CMS	Cut	2.5×10^{-4}
$t \rightarrow gq$	ATLAS	Likelihood (3-jet)	1.4×10^{-3}
	ATLAS	Likelihood (>3 jet)	2.2×10^{-3}

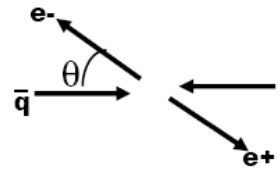
•*Example 95% CL limits:*

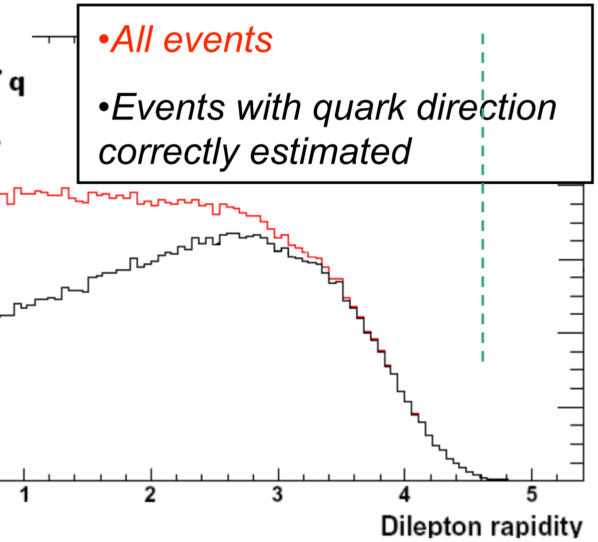


Forward & Backward Asymmetry at the Z

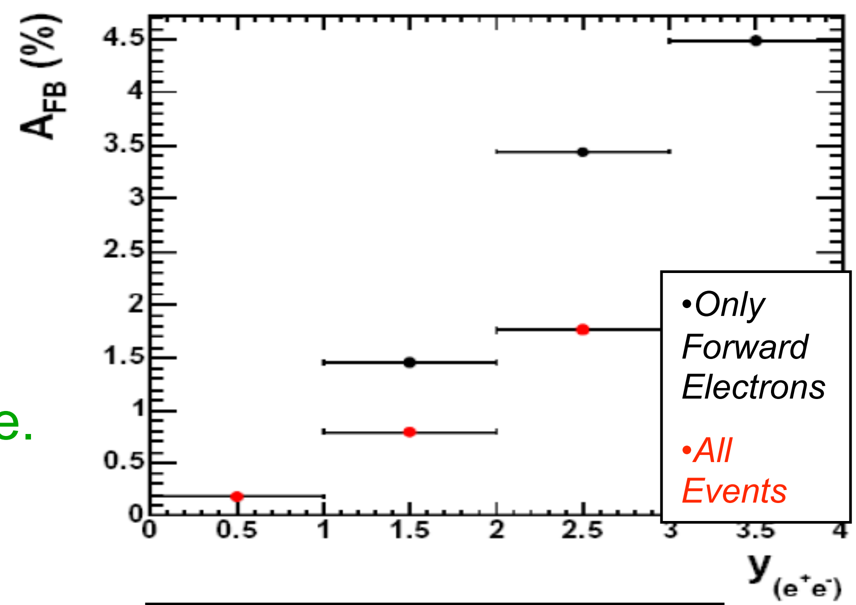
- ϴ-dependence of cross-section

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta} = \frac{3}{8}N_c[1 + \frac{4}{3}A_{FB}\cos\theta + \cos^2\theta]$$





- Assumption for pp-collisions: the quark direction is the same as the boost of the Z
  - Correct for large di-lepton rapidities
  - Only EM calorimenters provide the required large η-coverage

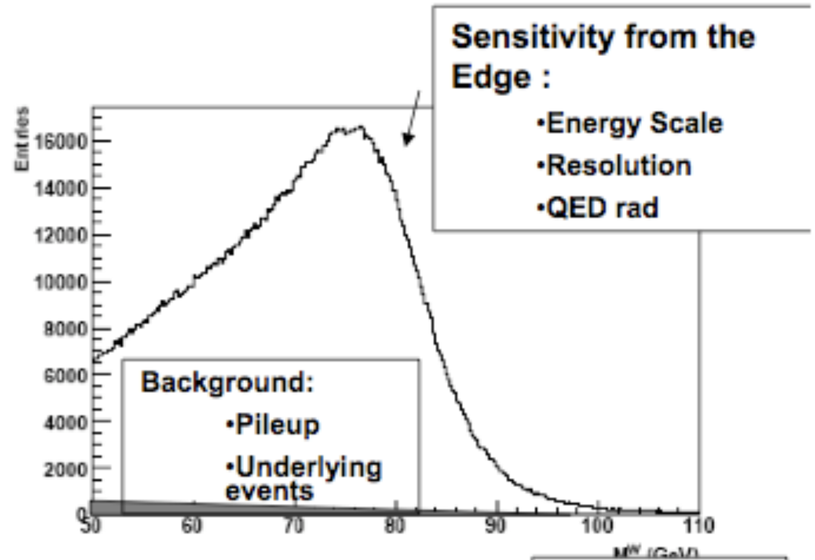


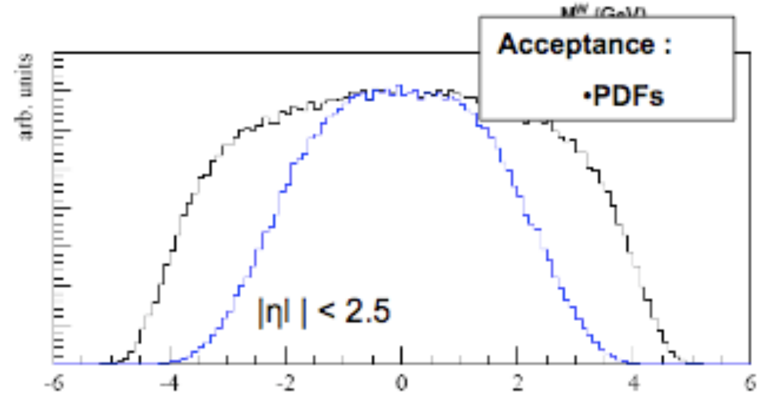
- Determination of A_{FB} is a 'simple' counting problem
  - A statistical precision of the Weinberg angle of 10^{-4} at $\int Ldt=100fb^{-1}$ reachable.
  - Dominating systematic: PDF Uncertainties → Use A_{FB} to constrain

•$A_{FB} = b\ \{ a - \sin^2\theta_{eff}^{lept}(M_Z^2) \}$

THE precision measurement: M_W

- Aim: M_W <15 MeV
- Observables sensitive to M_W
  - Lepton Transverse Momentum
  - **Transverse Mass |η| < 2.5**
- For the production of W and Z : same QCD effects for both!
  - Large uncertainties for prediction of transverse momenta of W,Z (due to soft gluon radiation)
- Use Z to predict W pT spectrum
  - Precision MC needed to correct for
    - Different phase-space ($M_W \neq M_Z$)
    - Different EWK couplings
  - Systematics controlled using the (huge) Z sample

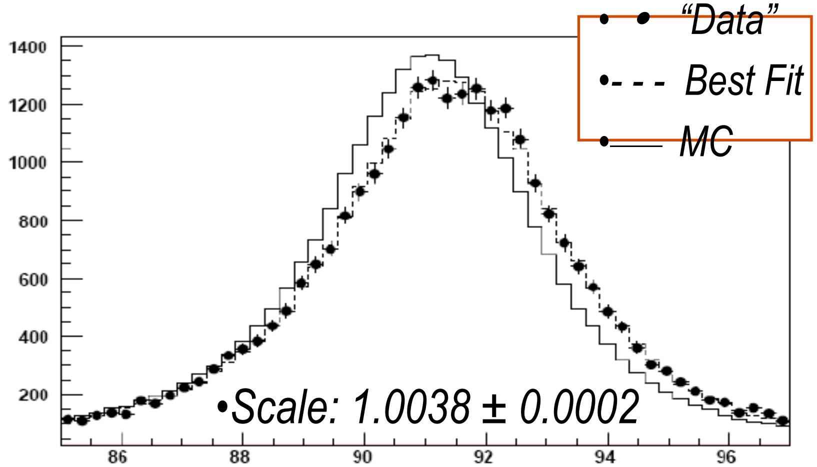


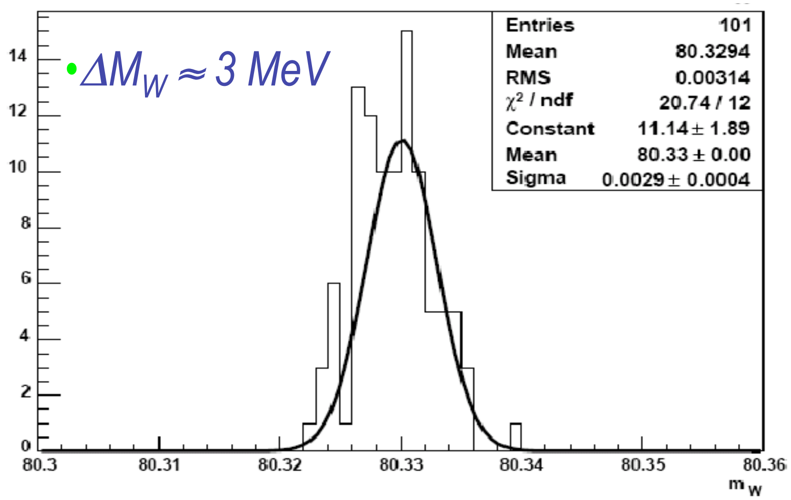


M_W: Systematics

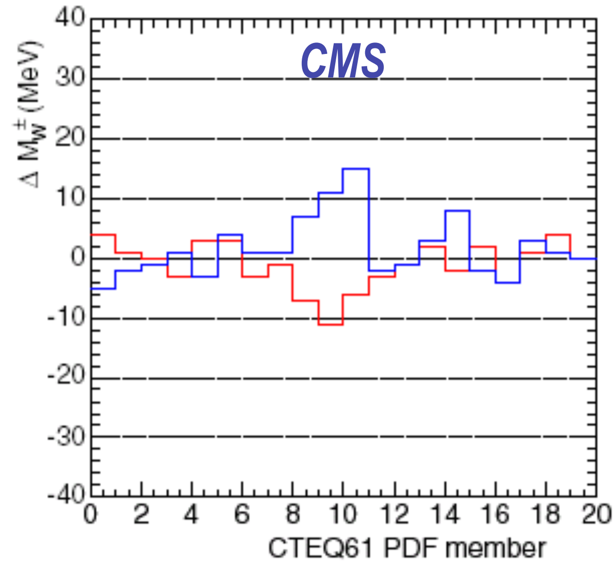
- $\Delta M_W \approx 15$ MeV possible (10 fb^{-1})

Constrain Lepton scale from Z.

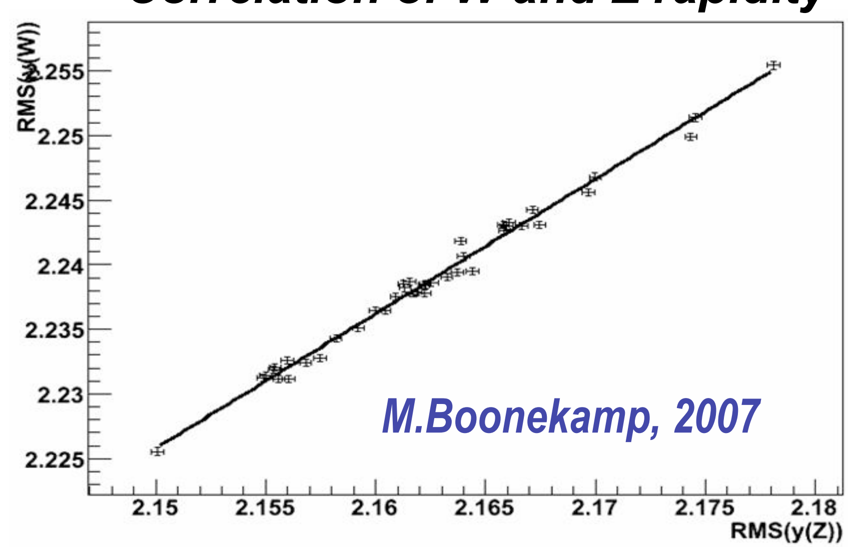




Constrain PDFs

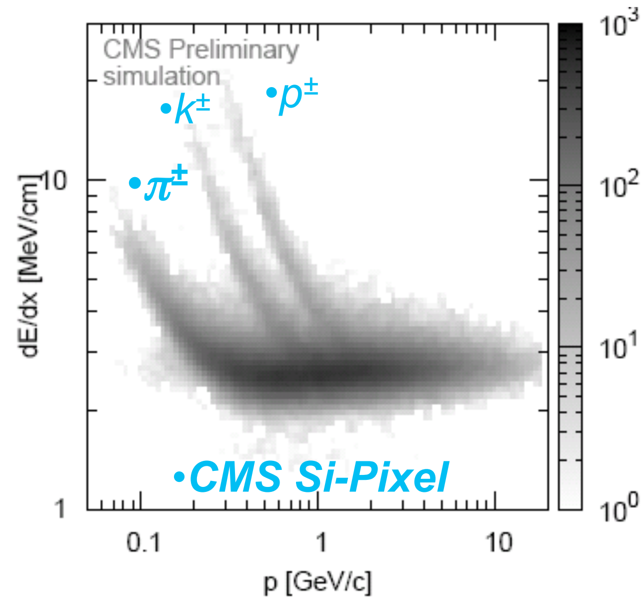


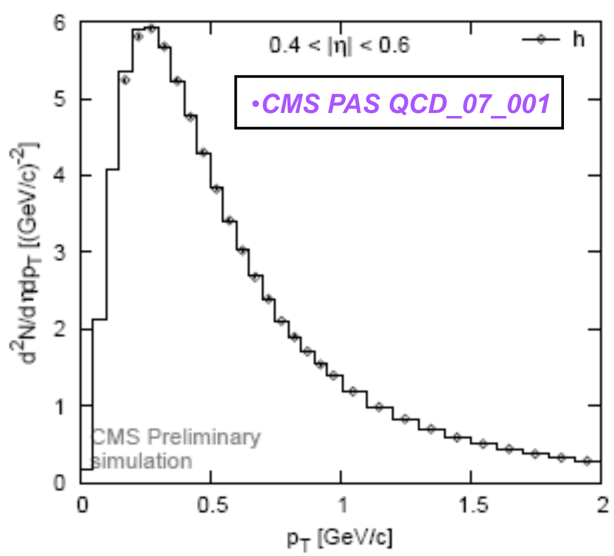
Correlation of W and Z rapidity

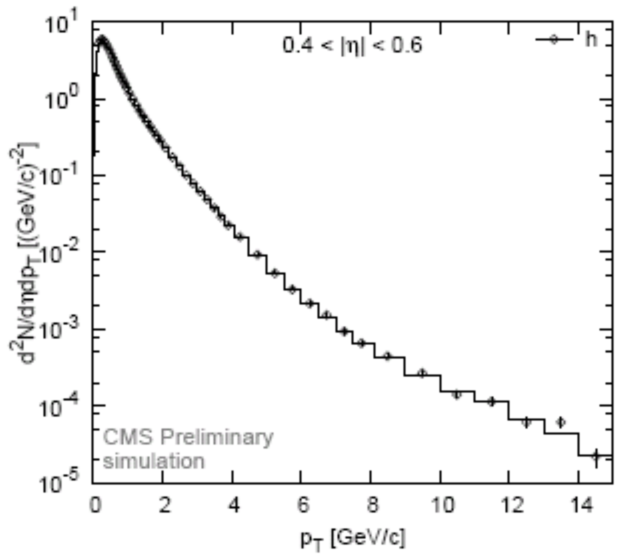


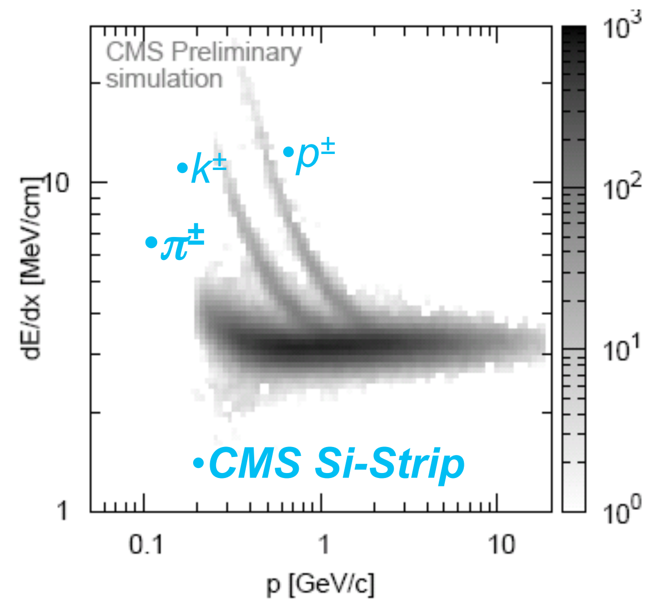
Minimum Bias

- One of the first measurement: charged hadron spectrum in minimum bias events
  - Never measured with $\sqrt{s} > 2$TeV
  - Tool to understand detector response
- Spectrum obtained considering one month of data with an allocated MinBias trigger bandwidth of 1Hz.



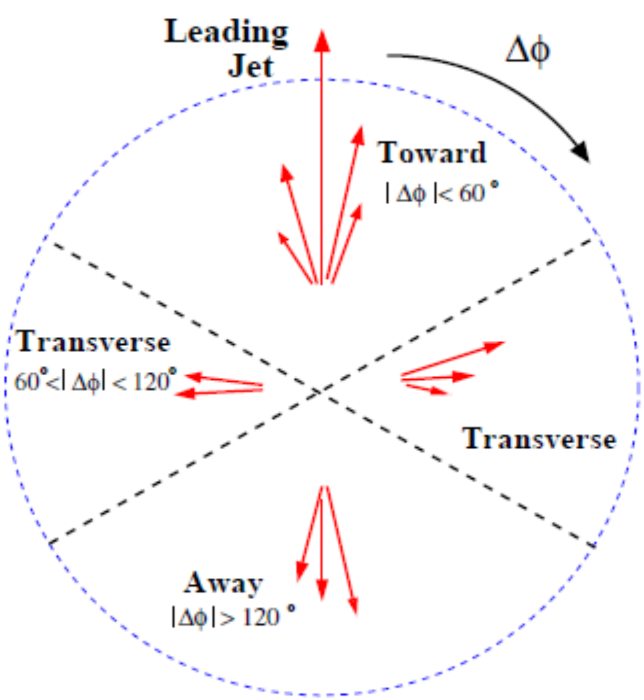






Measurement of Underlying Event

- Underlying event: everything but the leading hard scattering of the collision
  - Important for jet & lepton isolation, energy flow, jet tagging, etc
- Current UE models tuned at Tevatron give different extrapolations for the LHC
- Underlying event uncertain at LHC, depends on
  - multiple interactions, PDFs, gluon radiation
- Look at tracks in transverse region w.r.t. jet activity



•Nº charged particles in transverse region:

•p_T>0.5 GeV and |η|<2