ТРАГАЊЕ ЗА НОВИМ ТЕШКИМ НАЕЛЕКТРИСАНИМ ГРАДИЈЕНТНИМ БОЗОНИМА НА АТЛАС ДЕТЕКТОРУ

НЕНАД ВРАЊЕШ

Ανίχνευση νέων ηλεκτρικά φορτισμένων βαρέων μποζονίων βαθμίδας στον ανιχνευτή ATLAS

Nenad Vranješ

A SEARCH FOR NEW HEAVY CHARGED GAUGE BOSONS AT ATLAS

Nenad Vranješ

Outline of the Thesis

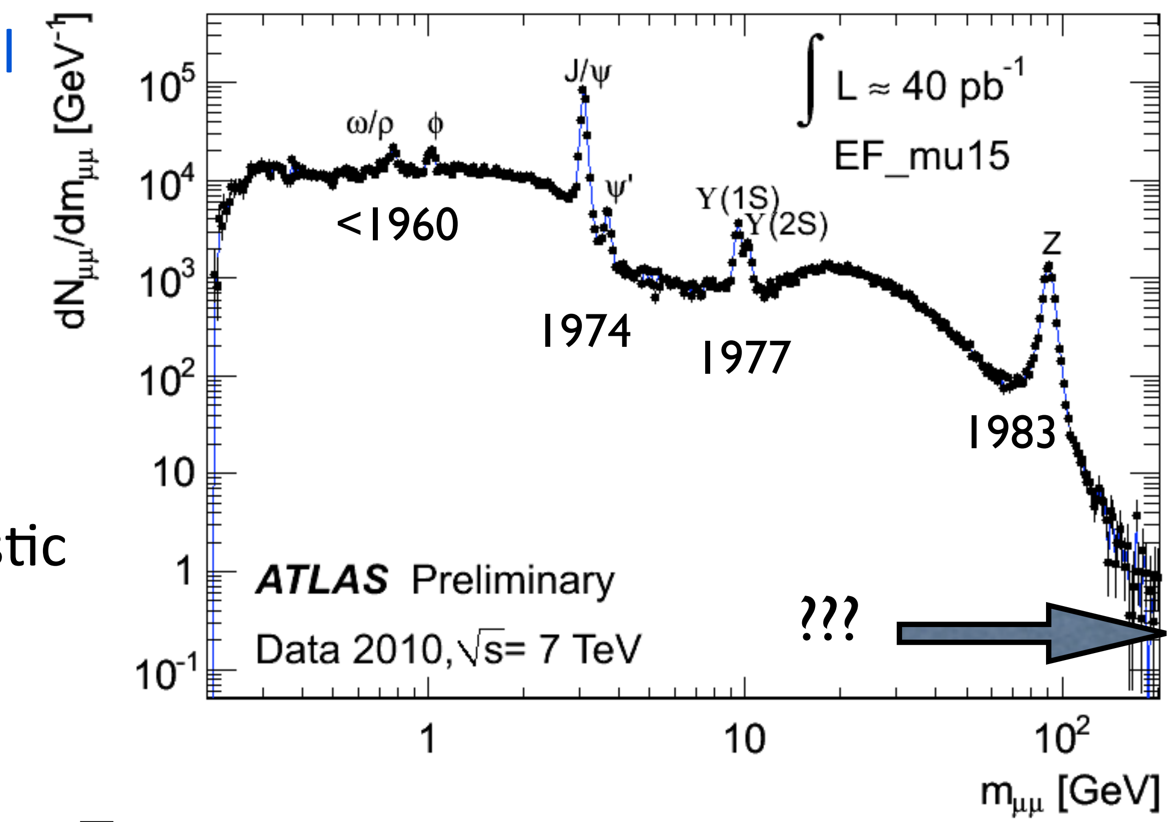
- A search for Physics Beyond Standard Model
- W' heavy copy of the W boson = same couplings to fermions as W
  - Also consider charged partner to chiral bosons (W*), anomalous couplings to leptons
- Leptonic signature: W'/W*-> lepton + neutrino, lepton= e/μ
- First collision data: 36 pb^{-1}
  - (+ beginning of 2011: 205 pb-1)
- Transverse mass distribution used as a discriminant variable
  - m_T > (1/2) m(W'/W*) as a search region for all masses W'/W*
- Main results published in several ATLAS notes and Phys. Lett. B 701 (2011) 50
  - Not the 'latest & greatest' ATLAS result Phys. Lett. B 705 (2011) 28
- I will just outline the main points of the thesis, skip many details

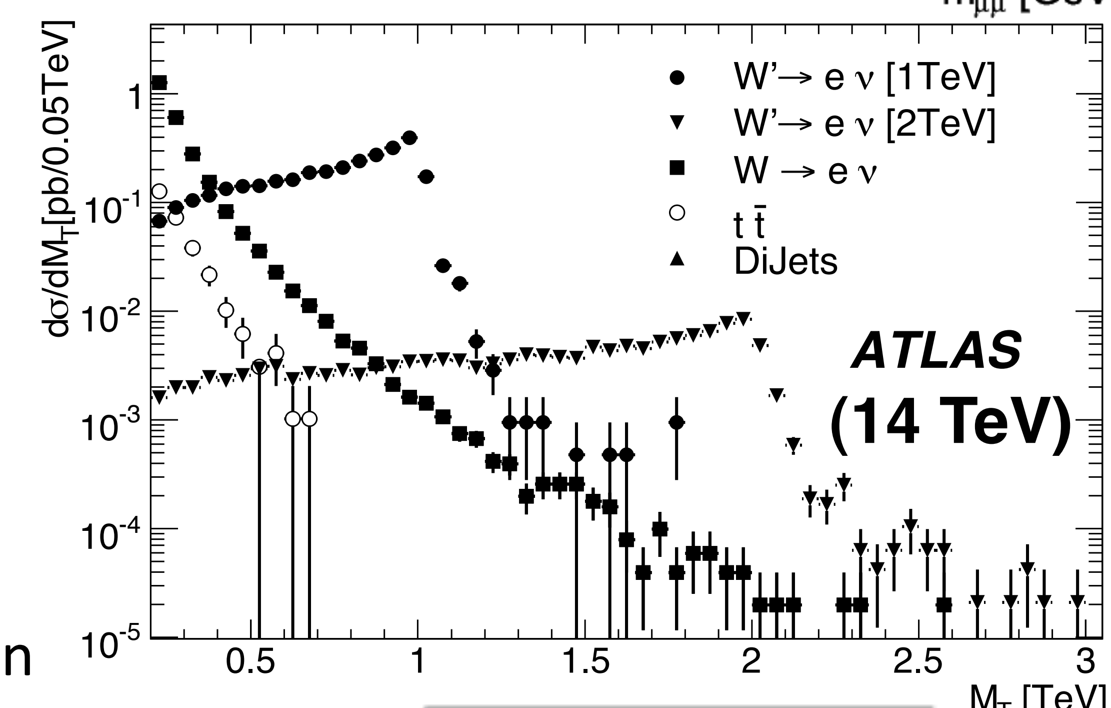
Motivation for BSM Searches

- Standard Model is a great success of 20th century physics! In particular:
  - It unifies electromagnetic and weak force
  - It is a renormalizabile theory which preserves its predictive power beyond tree-level computations and allows for the probing of quantum effects.
  - Excellent agreement with the data of LEP, SLC, Tevatron, HERA and the B factories. Some observables measured with 0.1% precision.
- But, it is widely believed that it is NOT final theory of the elementary particles (the whole Universe?). For example (personal list):
  - Why does the weak force distinguish left and right? Do RH charged-current weak interactions exist in nature?
  - SM cannot describe the recent experimental results on neutrino oscillations. What is the nature of neutrinos (Dirac or Majorana?)
  - SM clearly distinguishes strong and EW interactions and no real unification between them exist; the evolution of the three SM coupling constants does not lead to a common crossing point at a GUT scale.
  - The Higgs mass extremely sensitive to radiative corrections, and fine-tuning of the Higgs mass is required. Why is $M_W << M_{Pl}$?
  - What about the gravity?

How to Search For New Physics?

- New Physics <=> Physics Beyond Standard Model may be detected in any deviation from the expectation of the SM
  - (Narrow) Resonances on the smooth background
  - Excess in the number of events in characteristic distributions: (effective mass for SUSY)
  - Continuos deviations from SM: contact interactions...
  - Spectacular or 'strange' signatures: high multiplicity events, slowly moving particles, far-away (from the IP) vertices...
- Narrow resonances as famous precedents
- Many models/multi-parameter space of new phenomena. Choose one(few) model(s) (or point in NP phase space) as benchmark. Optimize selection and set limits (if no signal appears)...





$$m_T = \sqrt{2 p_T E_T^{miss} (1 - \cos \varphi_{l\nu})},$$

New Heavy Charged Gauge Bosons

- One attractive way to go beyond SM is by enlarging the gauge group $SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$, either by creating new symmetries or by unifying the symmetries already recognized.
  - Example L-R model: $SU(3)_c \otimes SU(2)_L \otimes SU_R \otimes U(1)_{B-L}$, where $SU(2)_R$ symmetry is broken at a higher scale than the $SU(2)_L$
  - After SSB, the model predicts a right-handed W_R gauge boson mixes with the left-handed SM WL boson, leading to a physical state of new heavy gauge boson.
- Other models: GUT's SO(10) or E6, little Higgs models, Extra Dimensions with KK excitations W^n_{KK} , alternative EWSB...
- NEW SYMMETRIES <=> NEW PARTICLES
  There is a class of models that predict existence of new heavy charged gauge boson
- In the thesis- BENCHMARK model: W'
  - Same couplings to fermions as SM W boson (above 180 GeV tb decay opens up)
  - W'->WZ is forbidden
  - Total width scales with mass of W' for mW'>>mW

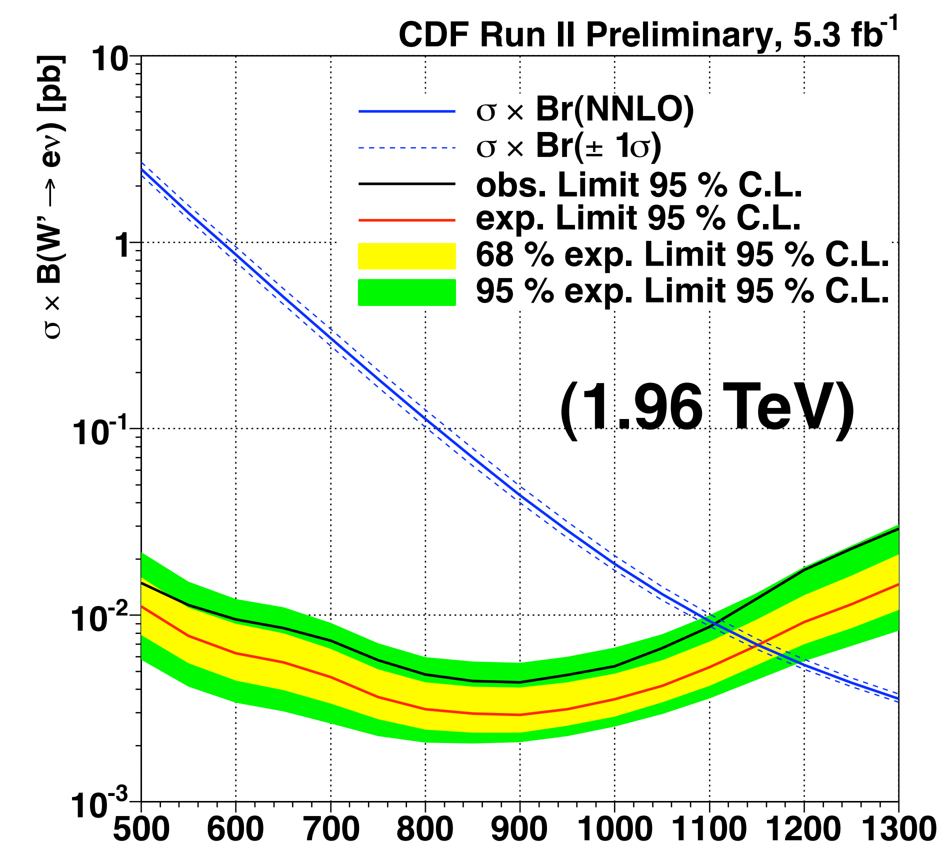
$$\Gamma_{W'} = \frac{4}{3}\Gamma_W \frac{m_{W'}}{m_W}.$$

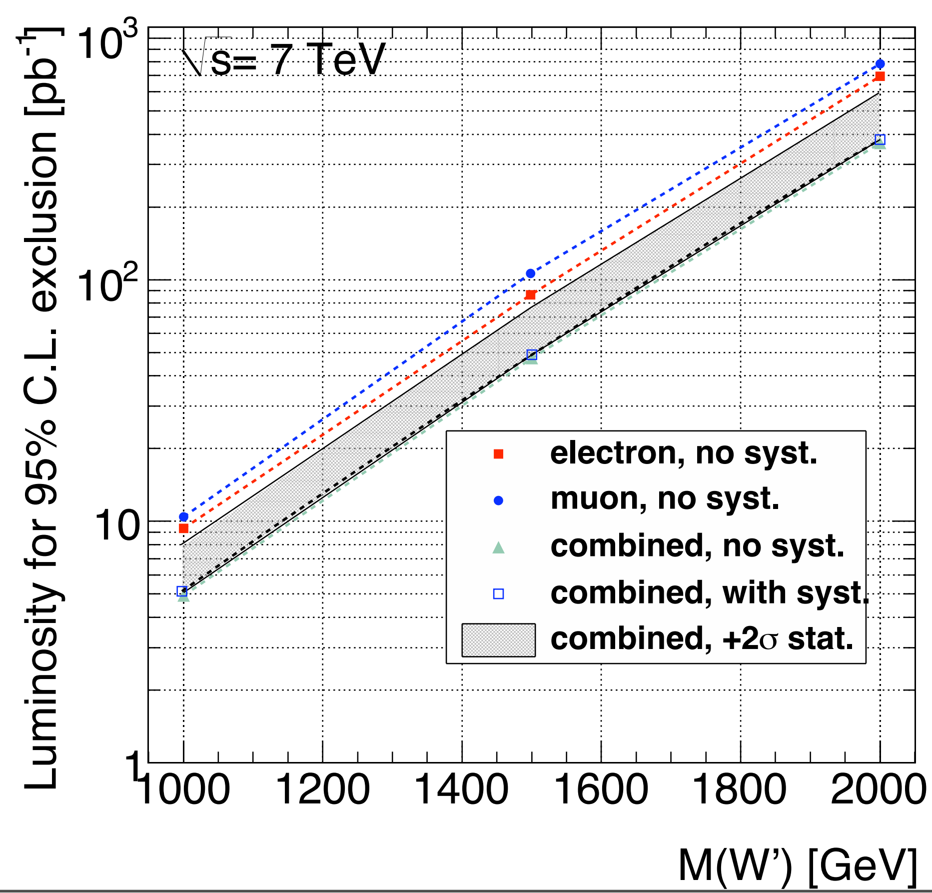
- The heavy charged partner to the chiral boson (W*)
  - Inspired by hierarchy solution, $U(3)_W = SU(3)_W \otimes U(1)_W$ extension of EW gauge group
  - New model, W* magnetic moment type coupling leads to kinematic distributions quite different from those of the SM-like W'

Previous Searches and Pre-Data Taking Prospects

- New charged gauge bosons not observed so far:
  - Most stringent limits from Tevatron, $m_{W'}$>1.1 TeV (95% C.L.)
  - Only electron channel considered, muon resolution too poor at CDF/D0 (for very high-momentum muons)
- ATLAS potential for observing W' has been studied using simulation:
  - Discovery (at least 10 events/channel ~double of 5σ excess) just above the Tevatron limit with ~40pb^{-1} , 1.3 TeV resonance could be observed requiring 5σ
  - Exclusion limit ~1.5 TeV in mass
  - Both channels (electron+muon) improve sensitivity, superb performance of the ATLAS MS

ATL-PHYS-PUB-2010-007
ATL-PHYS-PUB-2009-071



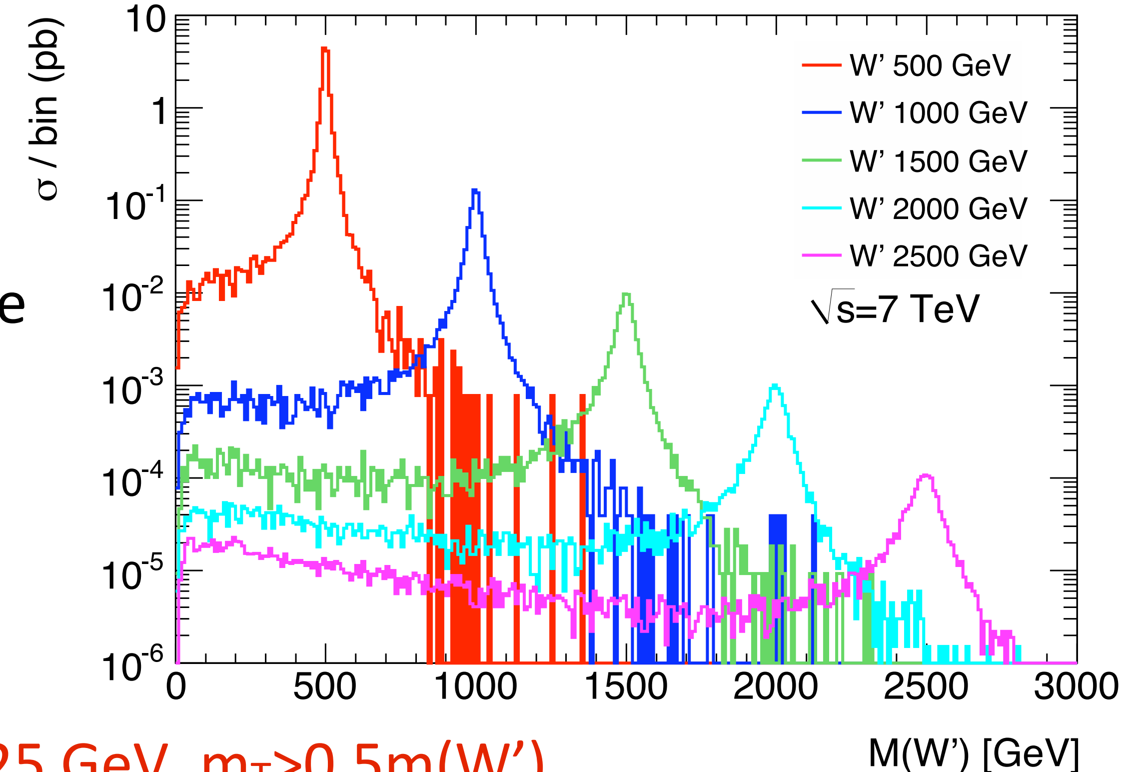


Simulation of W' Production at the LHC

- Simulation of W' signal using PYTHIA (6.4), MRST LO* PDF
  - Same V-A couplings as SM W, no W'/W interference
  - σB(W' → eν) = σB(W' → μν) = σB(W' → τν)
- Cross section falls steeply with W' mass
  leptons more central with higher W' mass
  off-shell boson high for higher masses due to smallness of x

Mass [GeV]	Γ [GeV]	$B(W' \to \mu\nu)$
500	16.684	0.08520
750	25.77	0.08313
1000	34.75	0.08246
1250	43.70	0.08216
1500	52.65	0.08202
1750	61.60	0.08193
2000	70.55	0.08189
2500	88.46	0.08184

- NNLO cross section estimated using FEWZ generator
  - SM W production used, MSTW2008 NNLO PDF, widths and BRs from Pythia
  - NNLO cross section 5-35% lower for m(W') 1.5-2.5 TeV wrt Pythia LO*
  - NNLO cross section underestimated for higher masses, integration collapse away from resonance
- Theoretical uncertainties: scales variation, PDF eigenvectors and different choices of PDF: 7.4-18.5% for m(W') 0.5-2.5 TeV
- Correction factors estimated with respect to Pythia in the fiducial volume: $p_T(l)>25$ GeV, $|\eta(l)|<2.5$, $p_T\nu>25$ GeV, $m_T>0.5m(W')$



Muon Channel

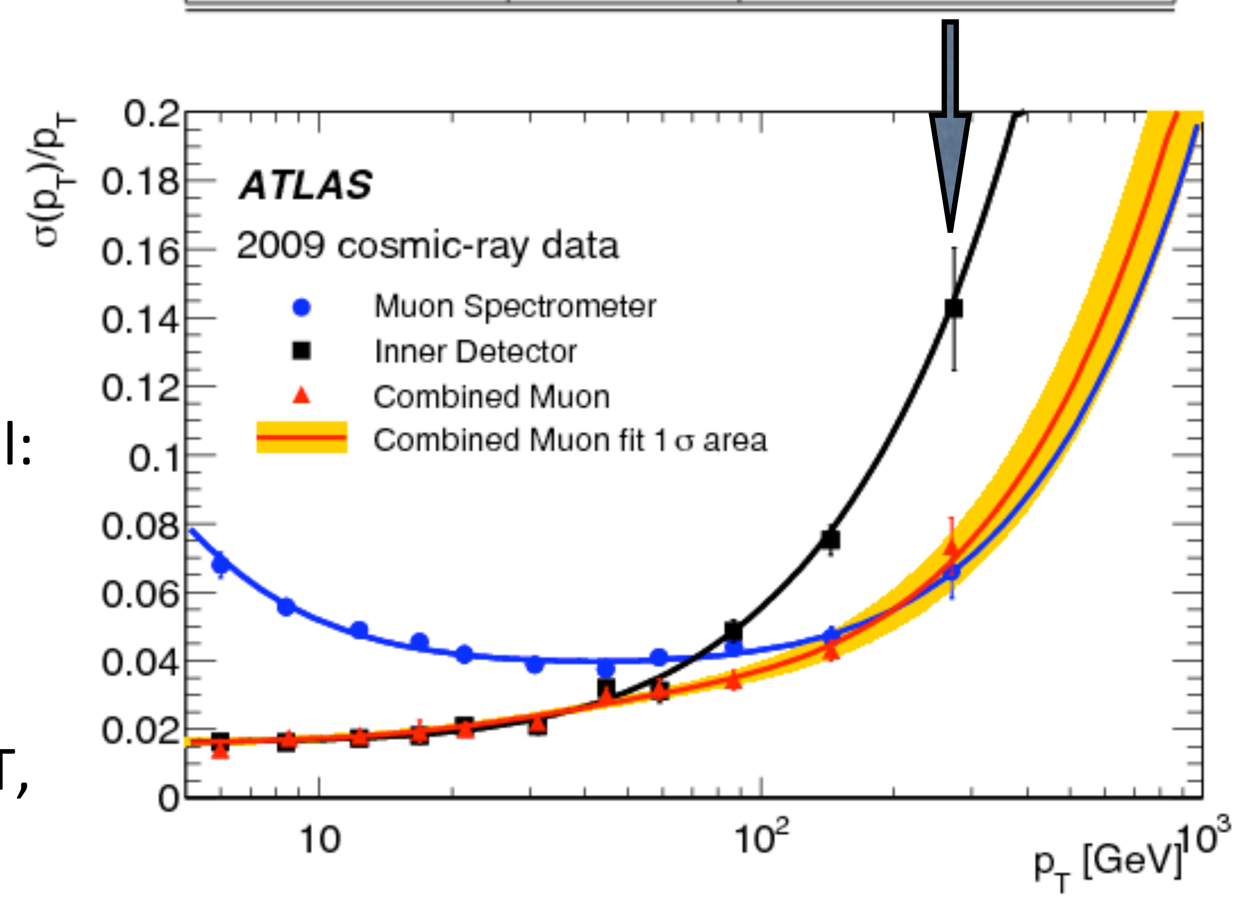
ATLAS Readiness for pp Collisions (focus on MS)

- 2008/2009 ATLAS detector (+ trigger&DAQ, DQ and Computing) commissioned using high statistics samples of cosmic-ray events.
- MS commissioned with 60M cosmic ray events
  - 0.1/TeV resolution requires 30 µm uncertainty (40 µm intrinsic MDT uncertainty)
  - Optical alignment system with muons w/o B-field: 5(25) x worse in Large(Small) chambers than required
  - Cosmics with B-field on give 30 µm for Large Sectors
  - The resolution function for MS is fitted with the sum in quadrature of three terms
- ID alignment statistically limited, no module-to-module alignment and reduced DOF in the barrel: nominal MC resolution not achieved, 50%/TeV
- MS standalone results gives the resolution extrapolated to 1 TeV about 20%.
  MS(ID) dominates the resolution at high (low)-pT, respectively.

$$\frac{\sigma p_T}{p_T} = \frac{p_0}{p_T} \oplus p_1 \oplus p_2 \times p_T$$

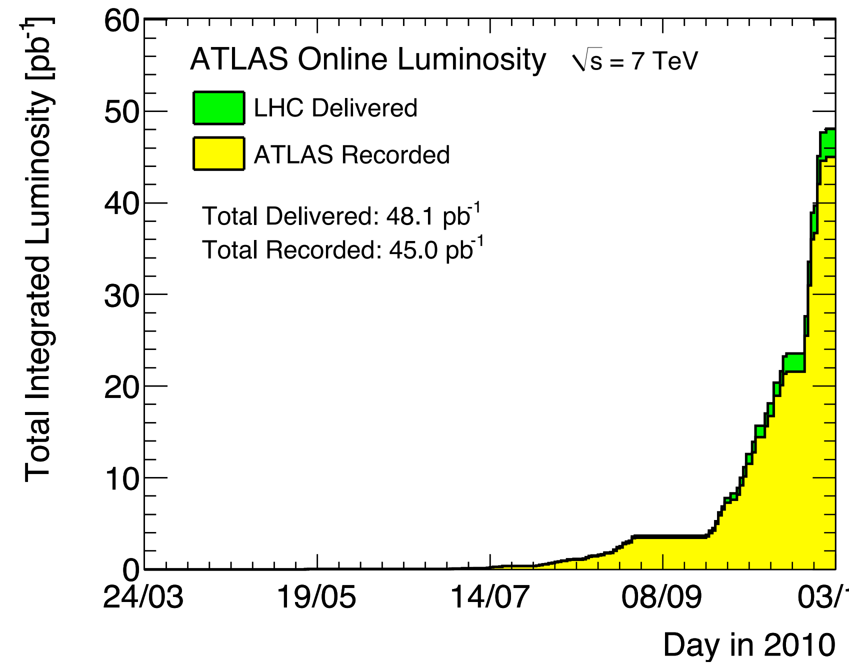
p_0=energy loss corrections (0.29 GeV),
p_1=multiple scattering term
p_2= intrinsic resolution

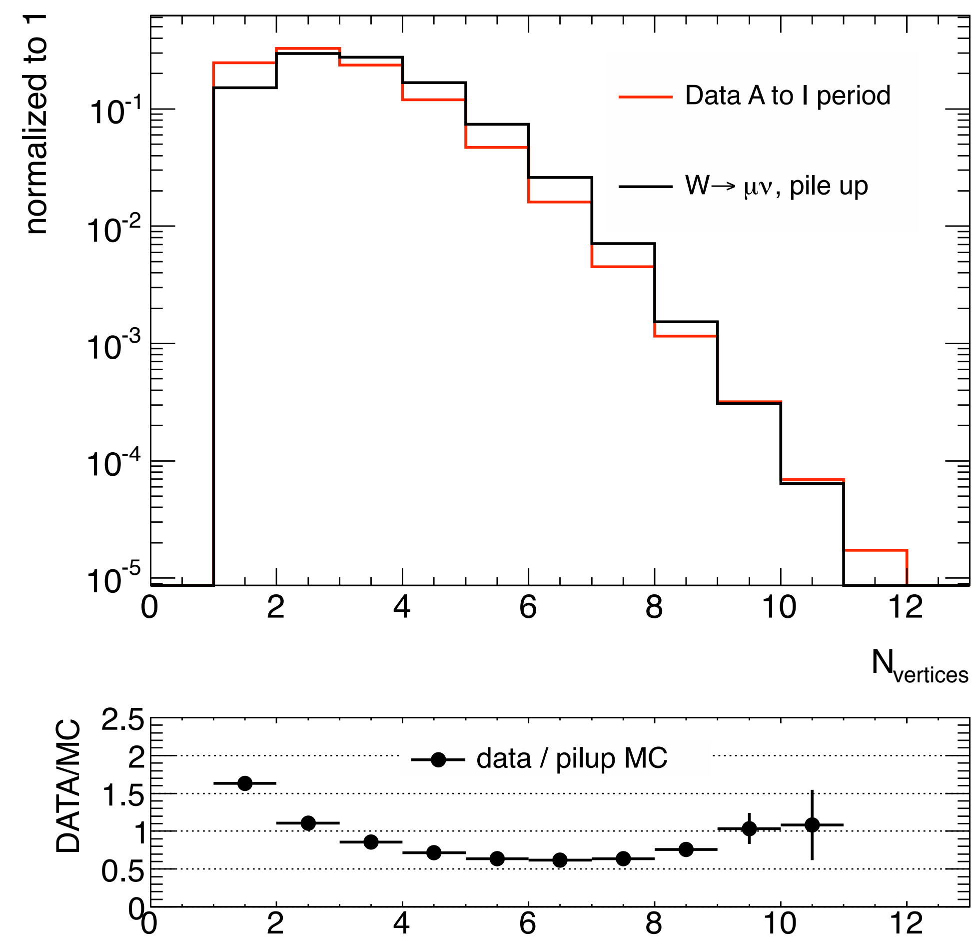
Fitted resolution	p_1	p_2
ID	$1.6 \pm 0.1\%$	$(53 \pm 2) \times 10^{-5} GeV^{-1}$
MS	$3.8 \pm 0.1\%$	$(20 \pm 3) \times 10^{-5} GeV^{-1}$
CB	$1.6 \pm 0.1\%$	$(23 \pm 3) \times 10^{-5} GeV^{-1}$



Detector Conditions, Pileup and Event Preselection

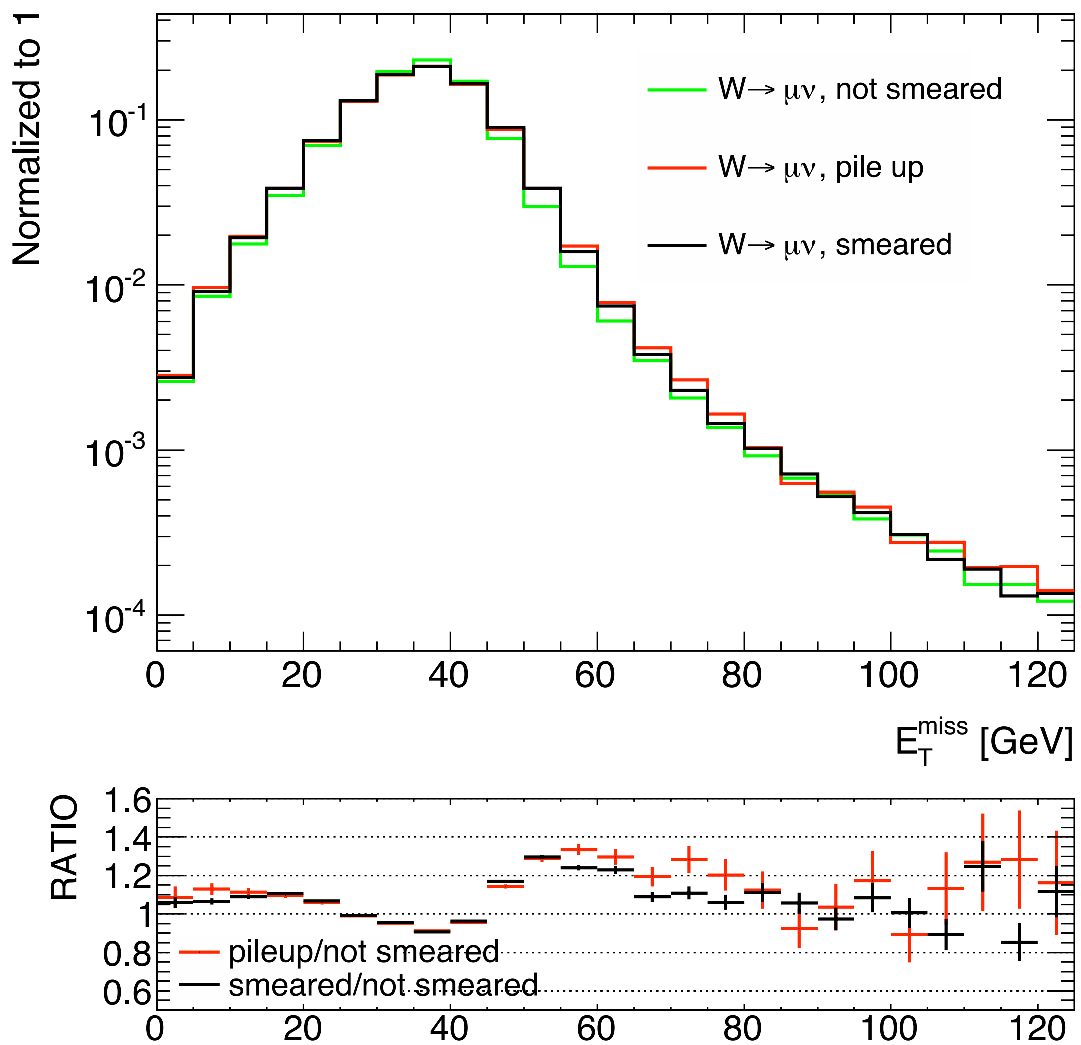
- pp collisions √s= 7 TeV, 2010 data taking, 36 pb^{-1}
  - Data taking efficiency 90-100% depending on the system (All GOOD: ~80%)
  - Luminosity 0.0043×10^{30} - 207×10^{30}, <μ>=0.0384-3.82, no out-of-time pileup
  - Dedicated pileup samples <μ>=2.2, reweighting events in order data match MC.
- Also 2011-dataset with 205 pb^{-1} of data used for the preliminary result, higher pile-up
- Event Preselection
  - Events pass 'Good Run List'
  - Trigger, lowest unprescaled (depending on period)
  - Primary vertex (at least 3 tracks), |z|<15cm
  - Jet Cleaning

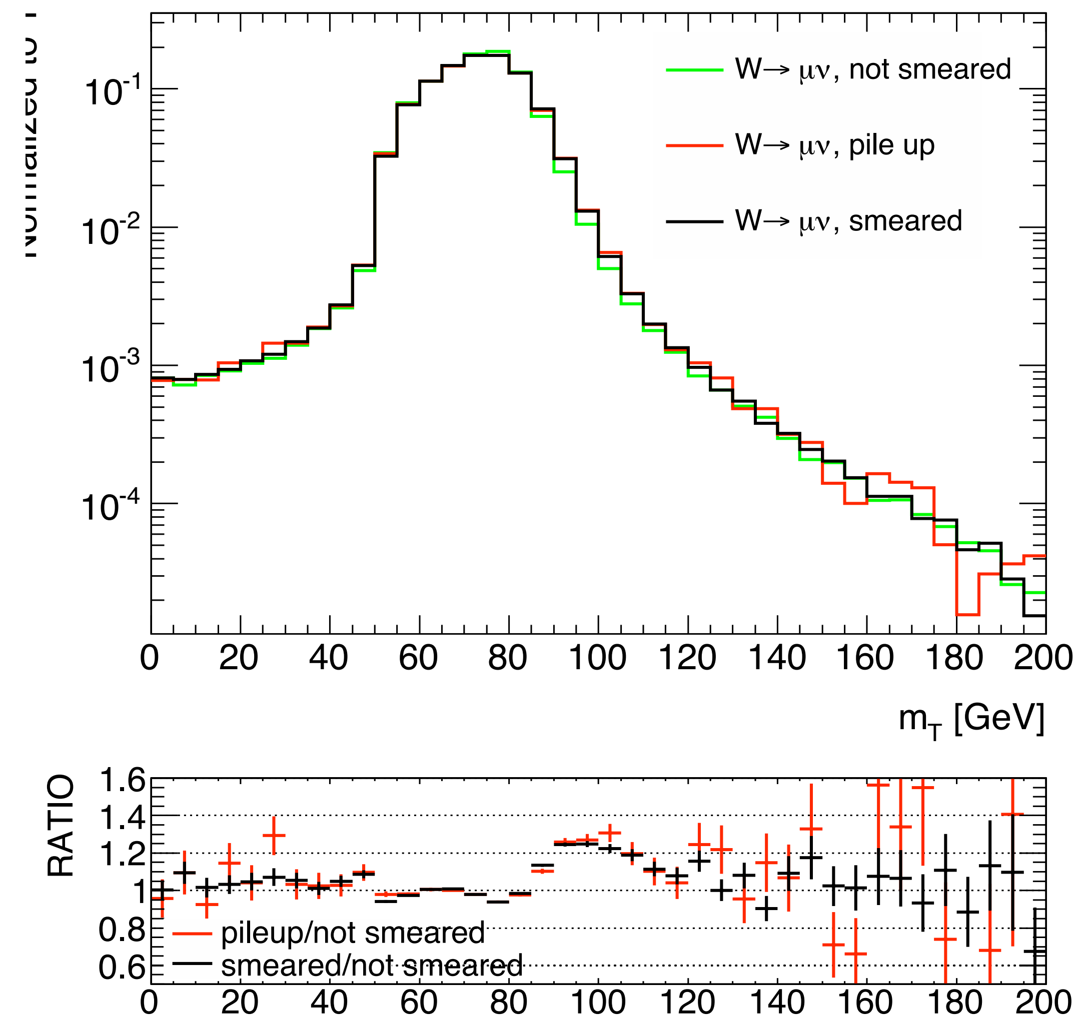




MC corrections

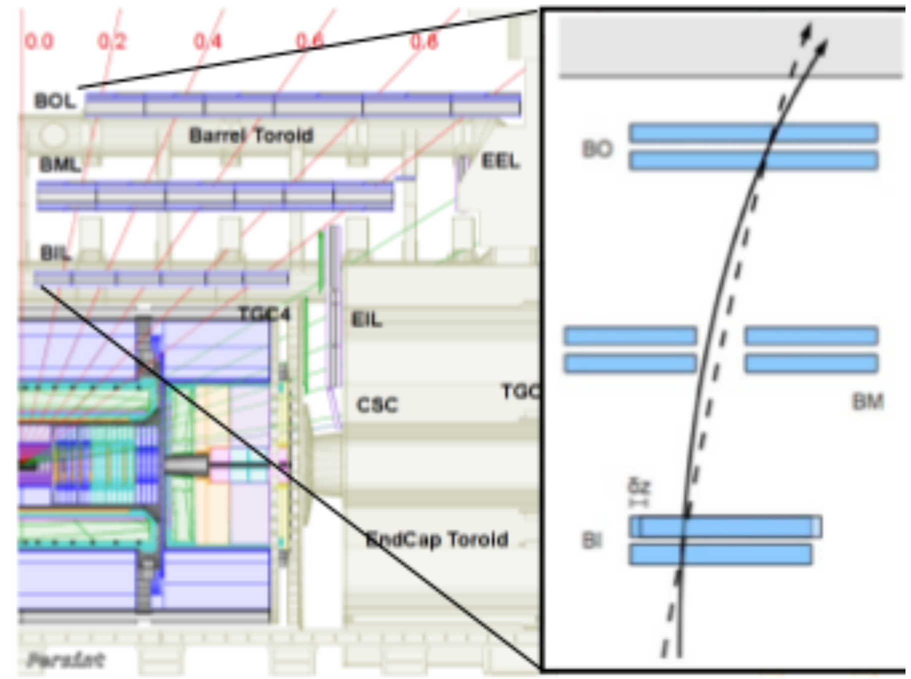
- Muon momentum scaling and smearing $q/p = [(q/p)_{\text{ini}} + S_1 g_1 (q/p)_{\text{ini}} + S_2 g_2 \sin\theta]/S_p + S_o.$
  - S_1=0.023 ± 0.03, S_2=(0.18±0.04)/TeV S_P=1±0.001 S_0=(0.0±0.071)/TeV
- Muon efficiency: no scale factor, assign large uncertainty. Trigger efficiency: 0.967±0.007
- Missing Energy Scaling and smearing calculated from Local Hadronic Topoclusters $E_{\parallel(\perp)} = S_m(E_{\parallel(\perp),ini}) + S_r g,$ S_m=4.0±0.4 GeV S_r=1.0±0.2

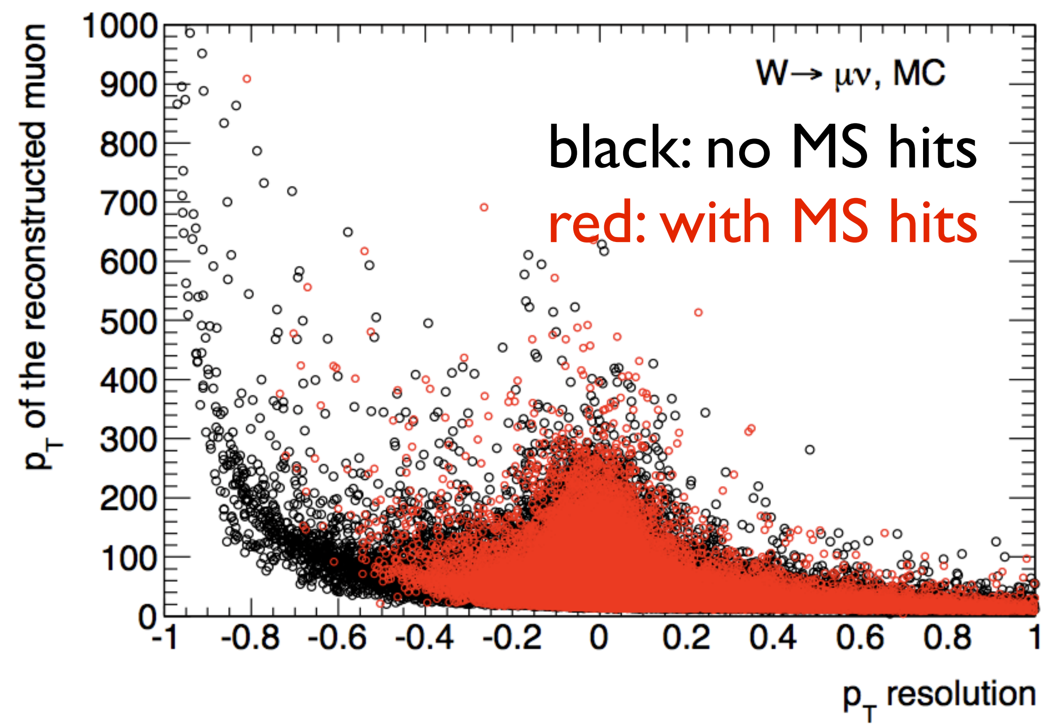


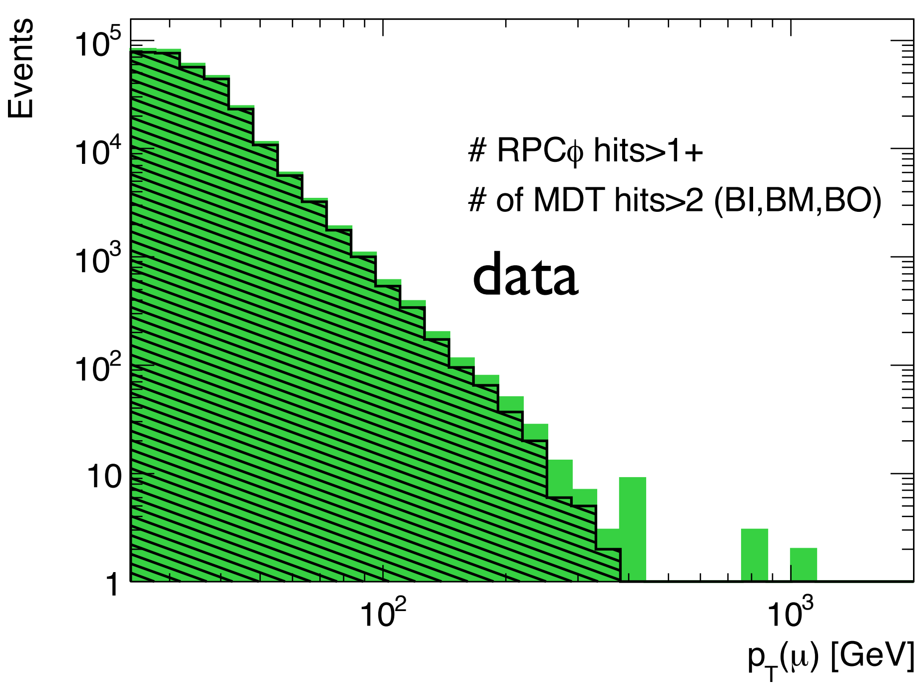


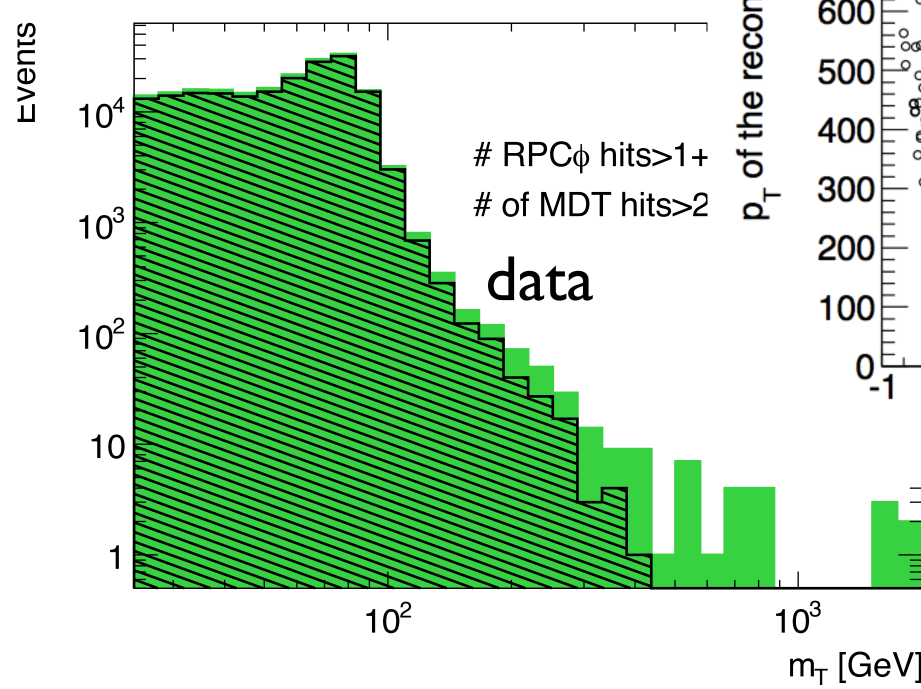
Muon Selection

- p_T>25 GeV, |η|<1.05
- Combined muons, muon momentum from MS (extrapolated to PV)
- ID hits (in order to suppress muons from decay in flight and fakes from punch-troughs into the MS)
- $|d_0|$<1mm, $|z_0|$<5mm
- at least one ϕ hit in each of at least 2 of 3 RPC layers
- muons are rejected if they have hits in BIS7 and BIS8
- at least 3 hits in each of 3 stations in MS
- trigger matching







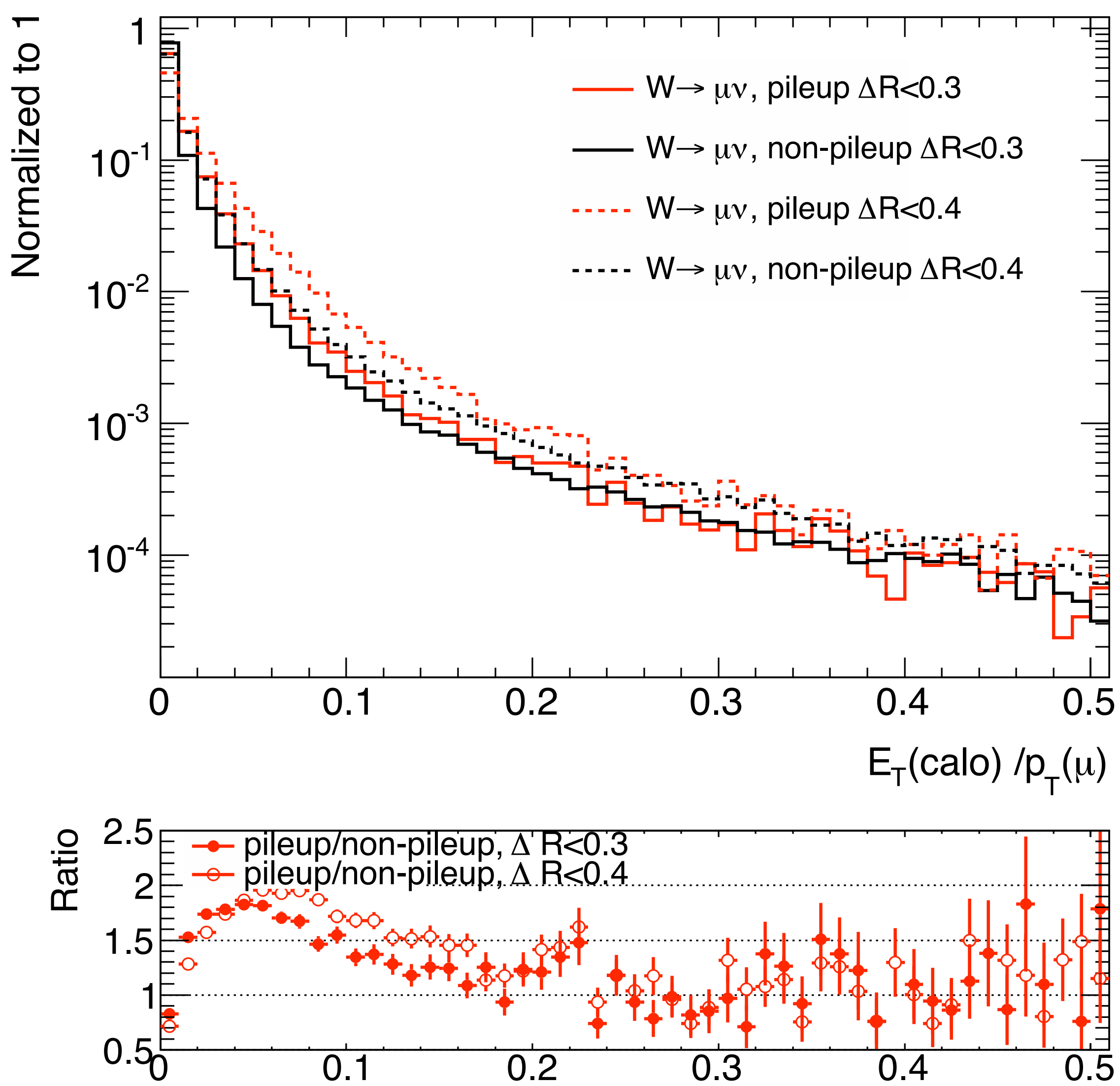


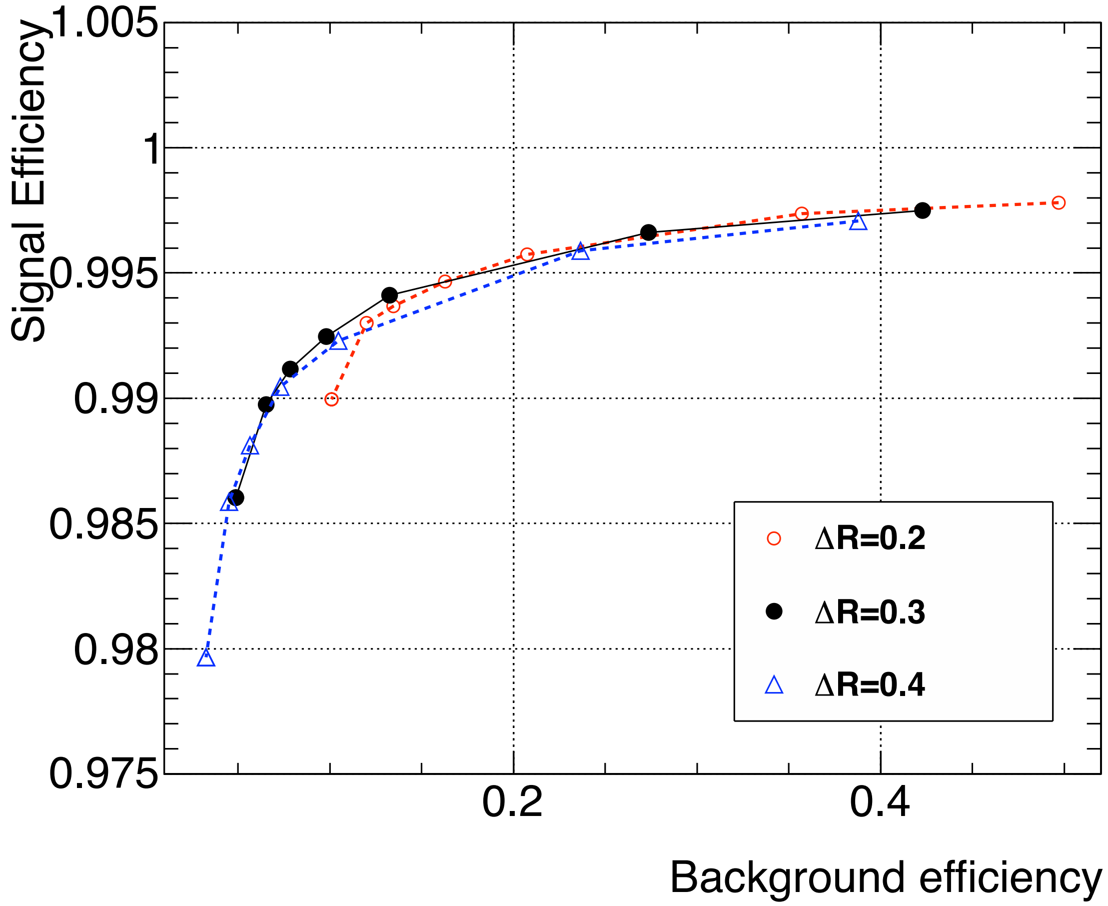
Isolation optimization

- Muons from W' isolated from other tracks and from jets, in contrast to QCD (heavy flavor), tt

$$\sum p_T(trk)/p_T(\mu), \quad \sum E_T/p_T(\mu)$$

- Calorimeter isolation: pileup systematic uncertainty with respect to track isolation



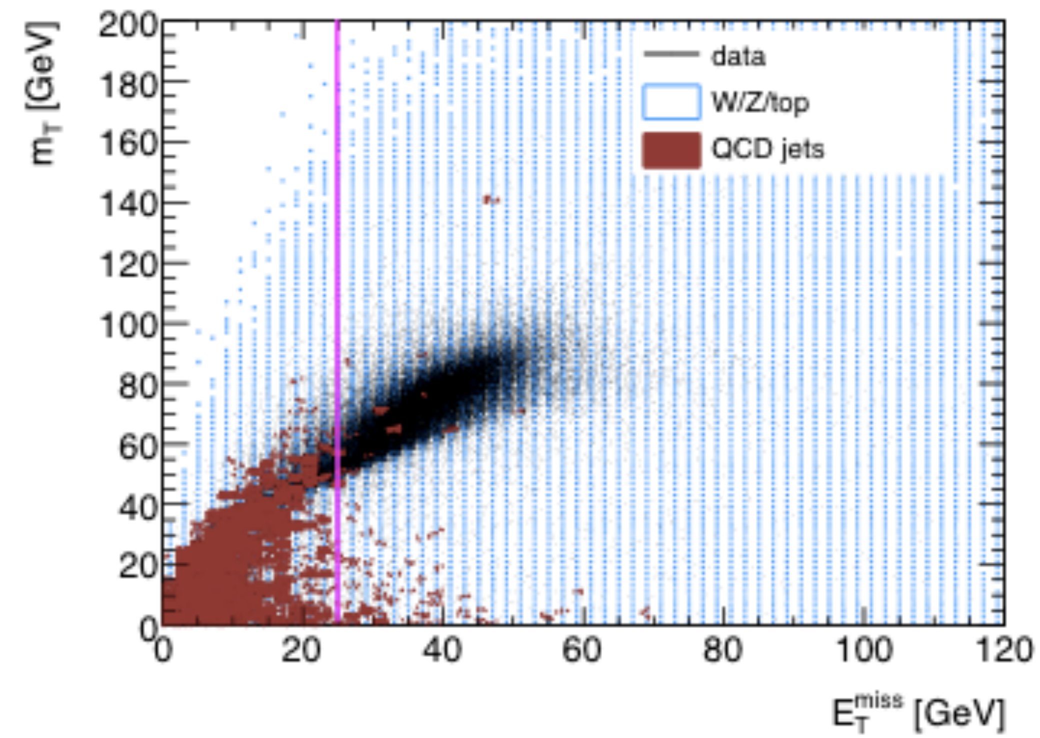


Relative track isolation: <5% dR<0.3

Loss in signal efficiency ~1% (not mass dependent)

Additional Selection Requirements

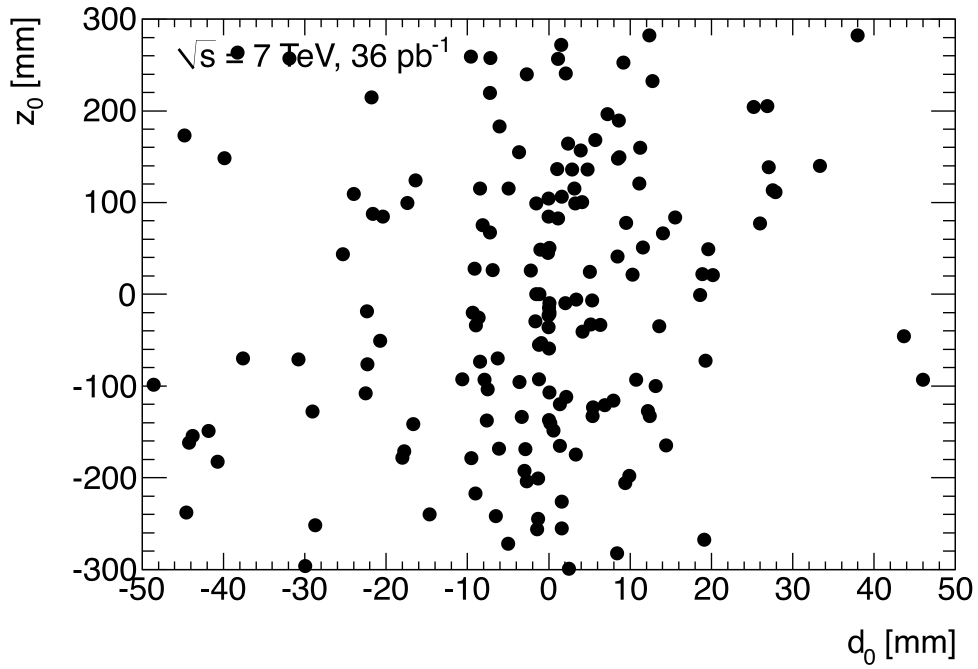
- Missing Energy > 25 GeV ✔
  - Further suppress QCD, clean W peak
- Veto second muon ✘
  - Suppress Drell-Yan (50% reduction)
- MET/p_T cut ✘
  - Tevatron cut: further suppress QCD and W+jets
- Lepton fraction ✘
  - 'CSC' cut: suppress QCD and tt
- Keep search as general as possible (in-spite of high signal efficiency, typical 98-100%)
- Background estimated using MC, no normalization on W peak

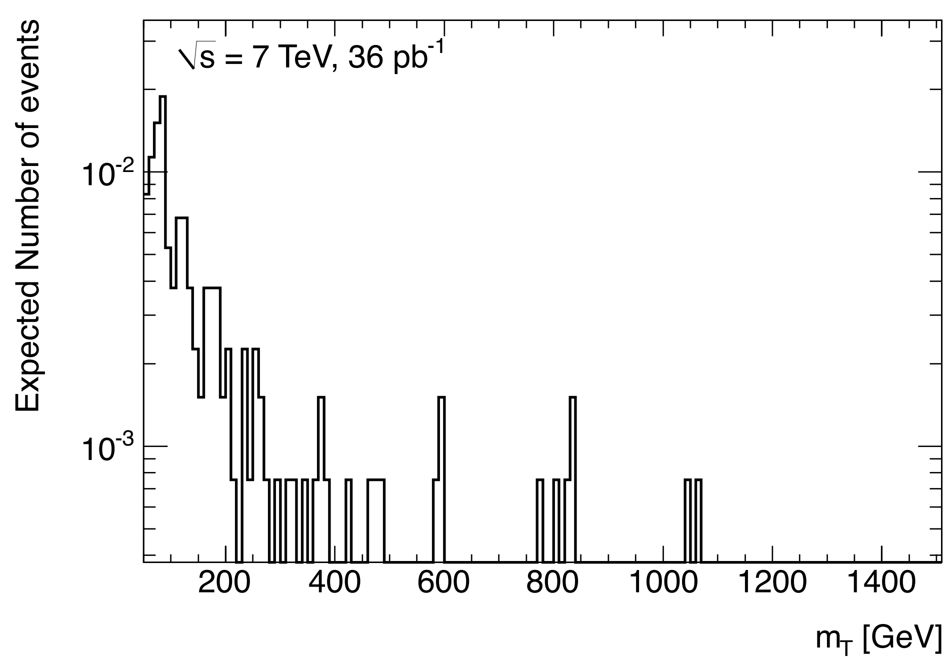


Estimation of Cosmic-Ray Background

- Cosmic rays background is suppressed by requiring the muons have small values of impact parameters: $|d_0| < 1$ mm and $|z_0| < 5$ mm

- The reconstruction efficiency is flat (or at least slowly-varying) in the region immediately surrounding the selection, windows in the surrounding region are used to estimate the number cosmic events in the selection region:



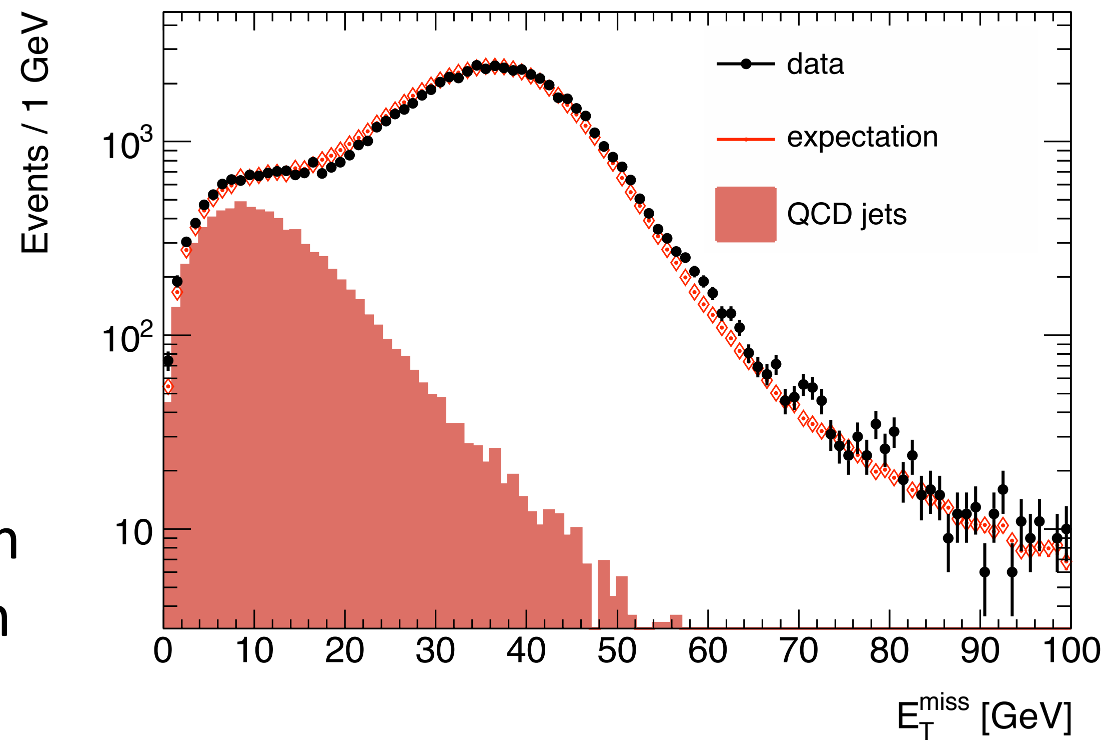


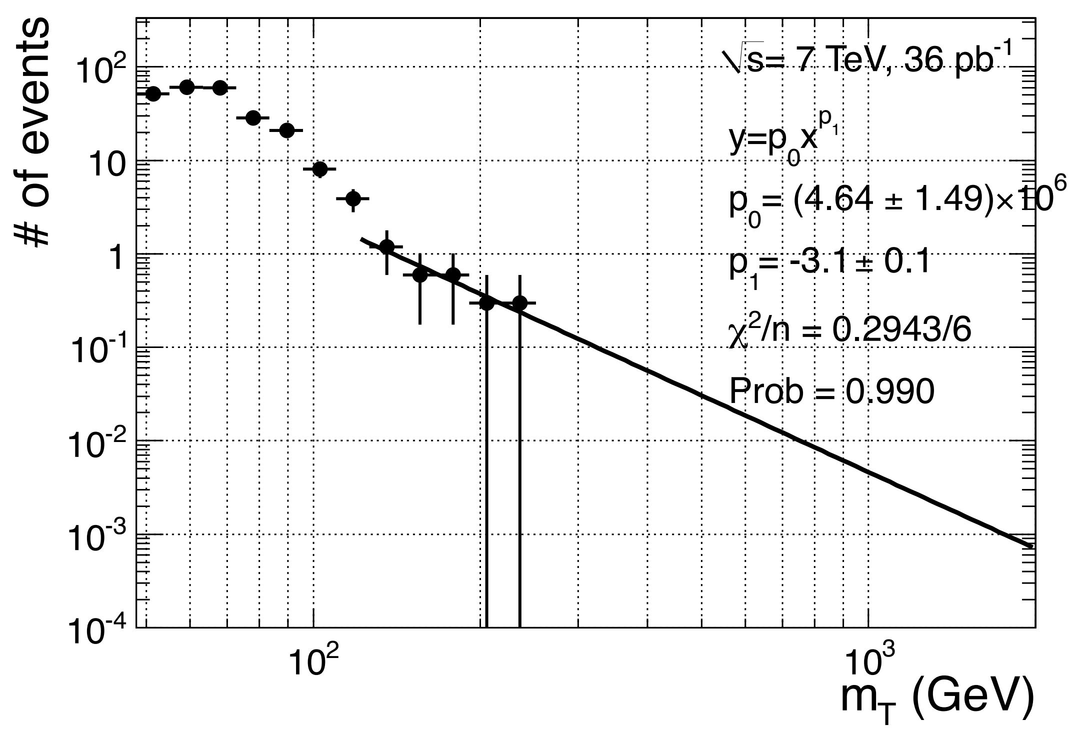
$m_{T\min}$ [GeV]	Expected Events
250	0.022 ± 0.007
750	0.013 ± 0.005
500	0.008 ± 0.004
625	0.006 ± 0.003
750	0.006 ± 0.003
875	0.002 ± 0.002

Negligible with respect to irreducible background

Estimation of QCD Background

- Theoretical cross section for QCD production has large uncertainty, not yet been measured in data with sufficient precision.
- Method: $0.2 < \sum p_T / p_T < 0.4.$
  - Obtain 'QCD rich' sample by inverting isolation
  - The events in QCD-reach sample are assumed to have kinematic distributions similar to the QCD contribution in the signal sample. MET distribution is used as a template which is then combined with other backgrounds into one distribution
  - A two-parameter binned maximum likelihood method is used to compare the data distribution in the signal sample to the reference distribution
  - QCD estimated 1.3% +0.3% -0.1% of the total background
- Extrapolation to high transverse momentum region
  - Power-low fit, conservative estimate with m_T>120 GeV
  - QCD 1% of the background, 100% uncertainty

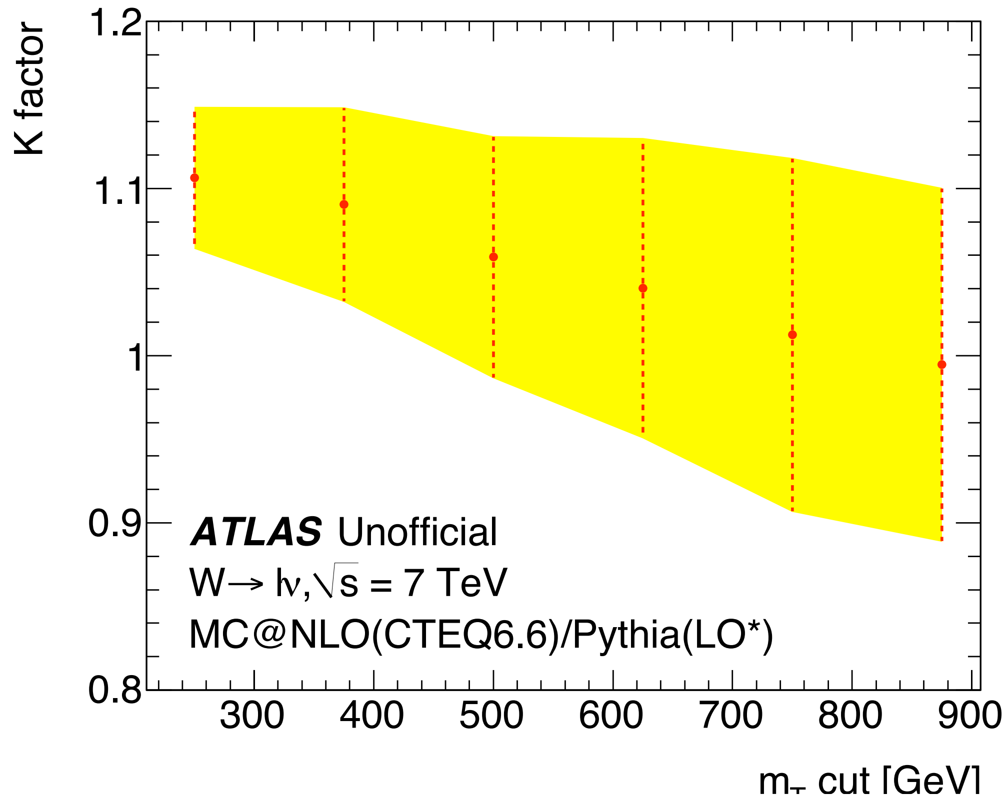




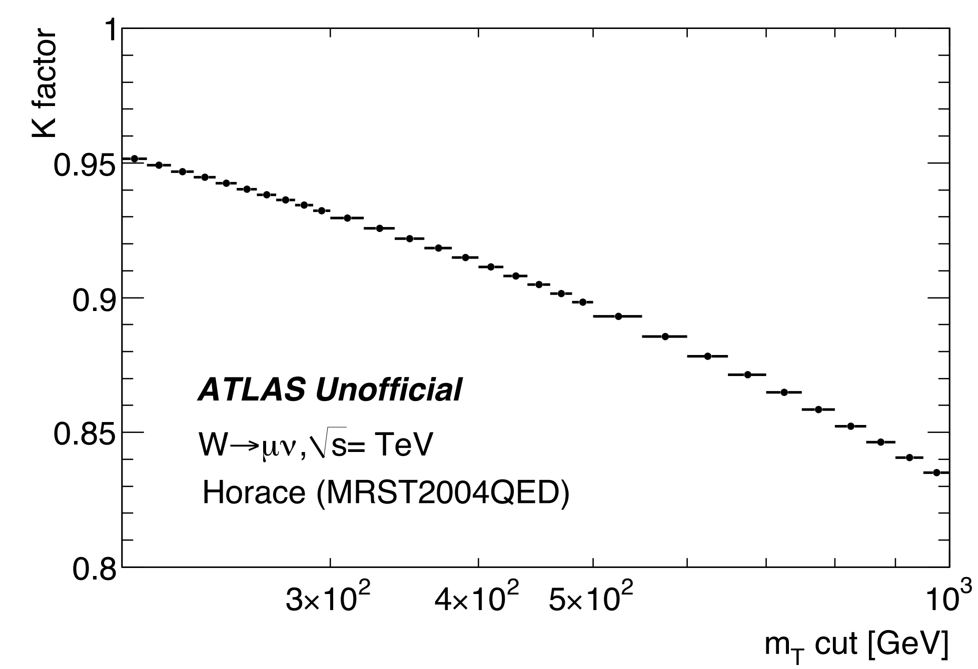
Theory Corrections and Systematic Uncertainties

- High mass W/Z background corrections provided
- Corrections/uncertainties as a function of m_T cut rather than mass bin. Assume the same correction for NNLO and NLO with respect to Pythia
  - QCD corrections: MC@NLO
  - Electroweak (photon from photons,FSR, EW loops/Pure Weak): Horace
- Systematic uncertainties: PDF and scale variations, 10%

$$C^{W\to\ell\nu}_{\sigma,QCD} = K(m_{T\min})/K(m_W),$$

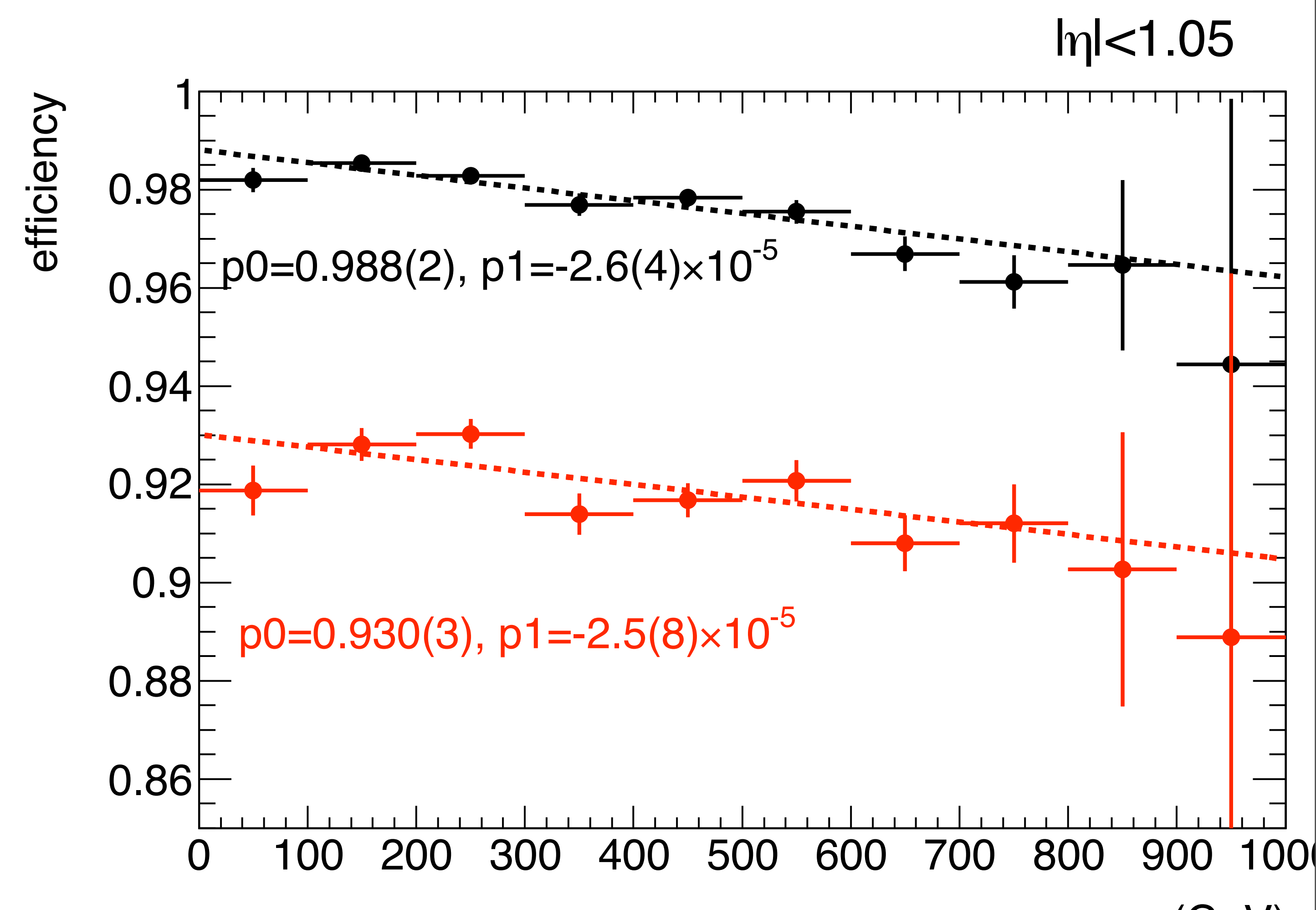


$m_{T\min}$ [GeV]	$C^{W\to\ell\nu}_{\sigma,QCD}$	$C^{W\to\ell\nu}_{\sigma,EW}$	$C^{W\to\ell\nu}_{\sigma,th}$
250	$1.038\pm3.8\%$	$0.954\pm3.0\%$	$0.990\pm4.8\%$
375	$1.023\pm5.3\%$	$0.937\pm3.0\%$	$0.958\pm6.1\%$
500	$0.993\pm6.8\%$	$0.918\pm3.0\%$	$0.912\pm7.4\%$
625	$0.976\pm8.6\%$	$0.901\pm3.0\%$	$0.879\pm9.1\%$
750	$0.950\pm10.4\%$	$0.889\pm3.0\%$	$0.844\pm10.8\%$
875	$0.933\pm10.6\%$	$0.875\pm3.0\%$	$0.816\pm11.0\%$



Detector Systematic Uncertainties

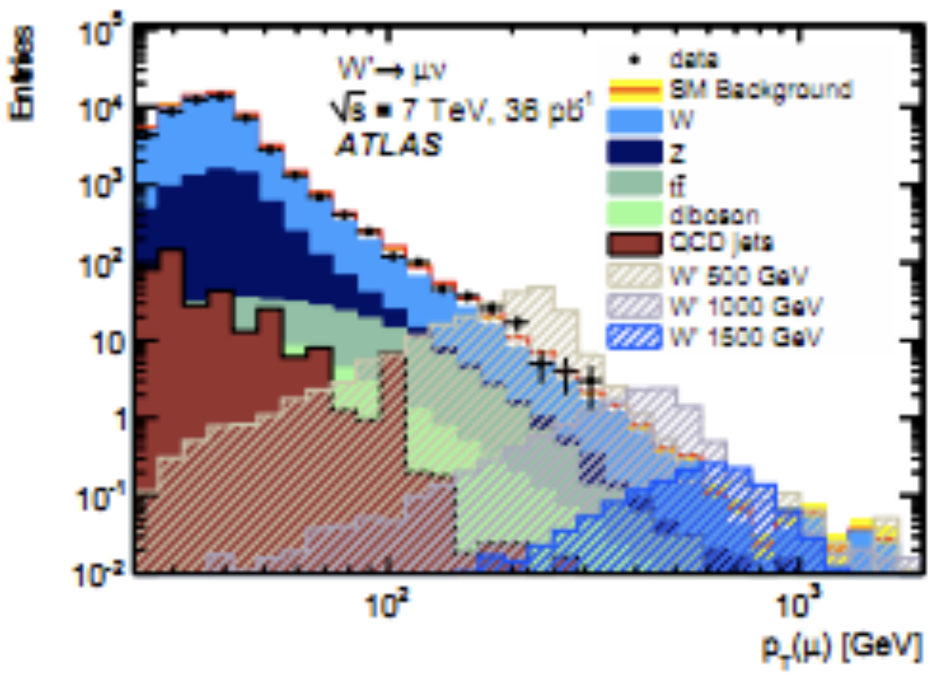
- Luminosity uncertainty ±11 %
- Trigger efficiency: 7%
- Muon reconstruction efficiency -2.6/TeV
  1-2% (1-1.6% for background)
- Muon resolution and scale: up to 0.5%
  (0.4-3.2% for background)
- Curvature offset: <1%
  (<3% background)
- MET scale/resolution: negligible
- Vertex finding < 1%

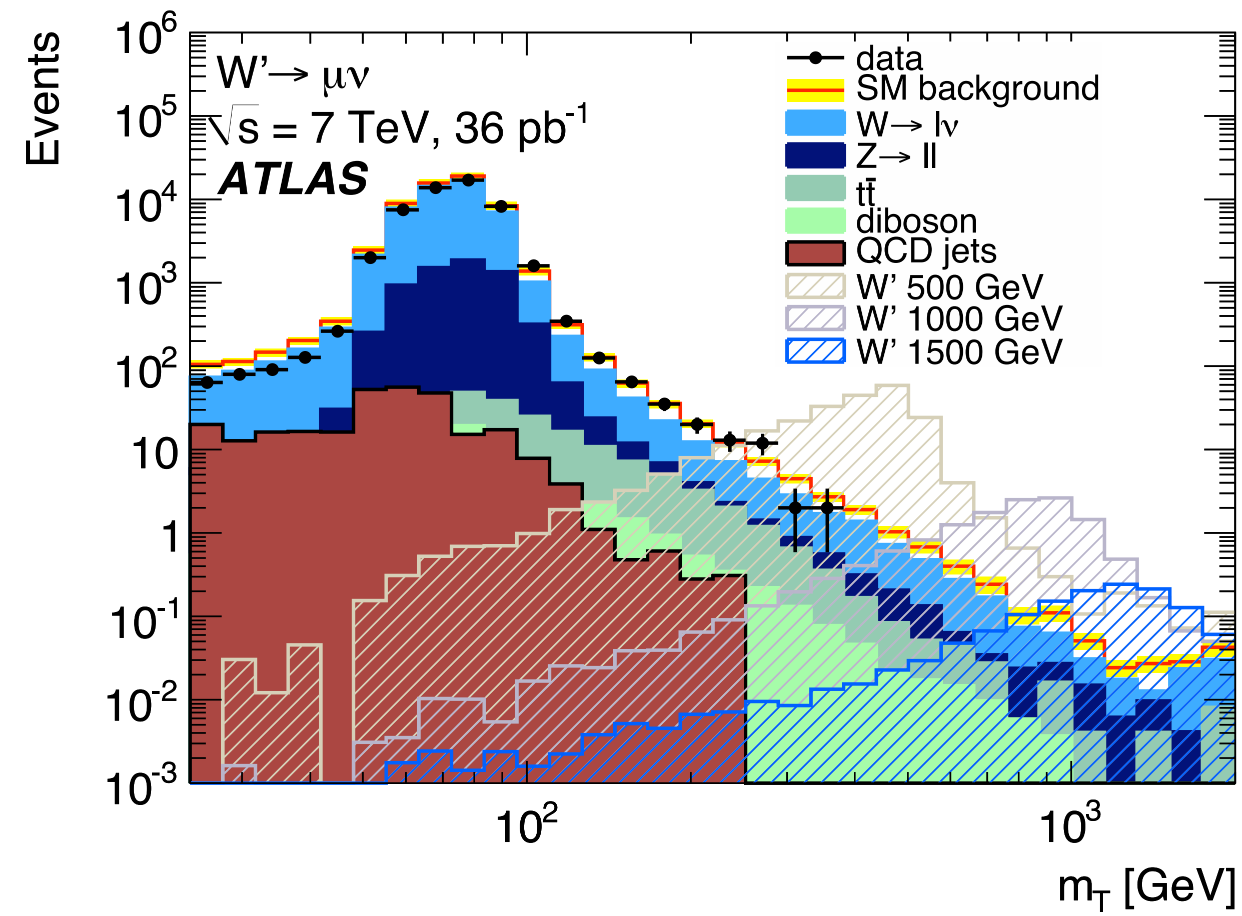


Final Results: Muon Channel

- Good agreement between data and predictions: No excess found!
- Systematic uncertainties dominated by efficiency extrapolation (signal) and limited MC statistics and theory (background)
- Negative fluctuation of data for mT>750 GeV, 0.4% Poisson probability
- No evidence of catastrophic efficiency loss for high p_T muons

m [GeV]	signal	ε_{sig}	N_{sig}	N_{bg}	N_{obs}
500	W'	0.339 ± 0.008	212 ± 17	20.01 ± 1.1	16
	W^*	0.228 ± 0.004	104 ± 8		
750	W'	0.362 ± 0.009	42.1 ± 2.7	5.48 ± 0.45	0
	W^*	0.230 ± 0.005	19.6 ± 1.5		
1000	W'	0.381 ± 0.010	11.6 ± 0.9	2.11 ± 0.26	0
	W^*	0.242 ± 0.005	5.4 ± 0.5		
1250	W'	0.386 ± 0.011	3.66 ± 0.33	1.03 ± 0.17	0
	W^*	0.237 ± 0.005	1.63 ± 0.20		
1500	W'	0.383 ± 0.012	1.24 ± 0.14	0.63 ± 0.13	0
	W^*	0.235 ± 0.006	0.54 ± 0.08		
1750	W'	0.360 ± 0.012	0.43 ± 0.06	0.49 ± 0.10	0
	W^*	0.239 ± 0.006	0.20 ± 0.04		

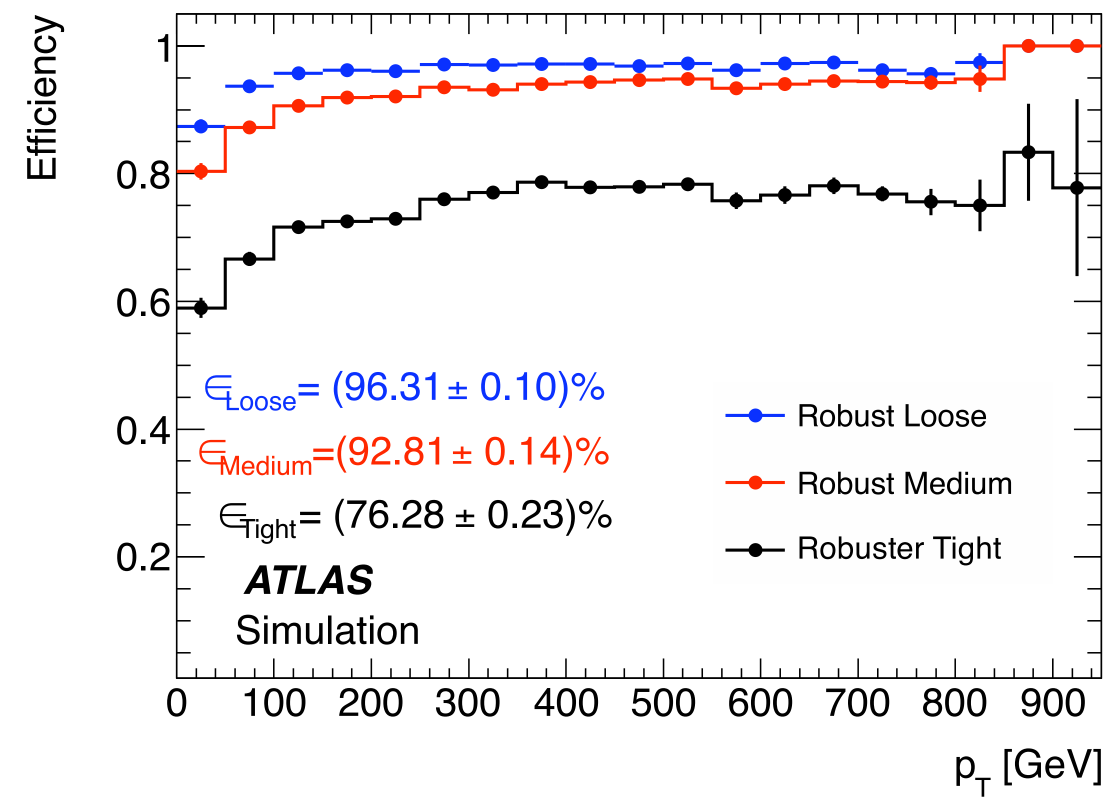


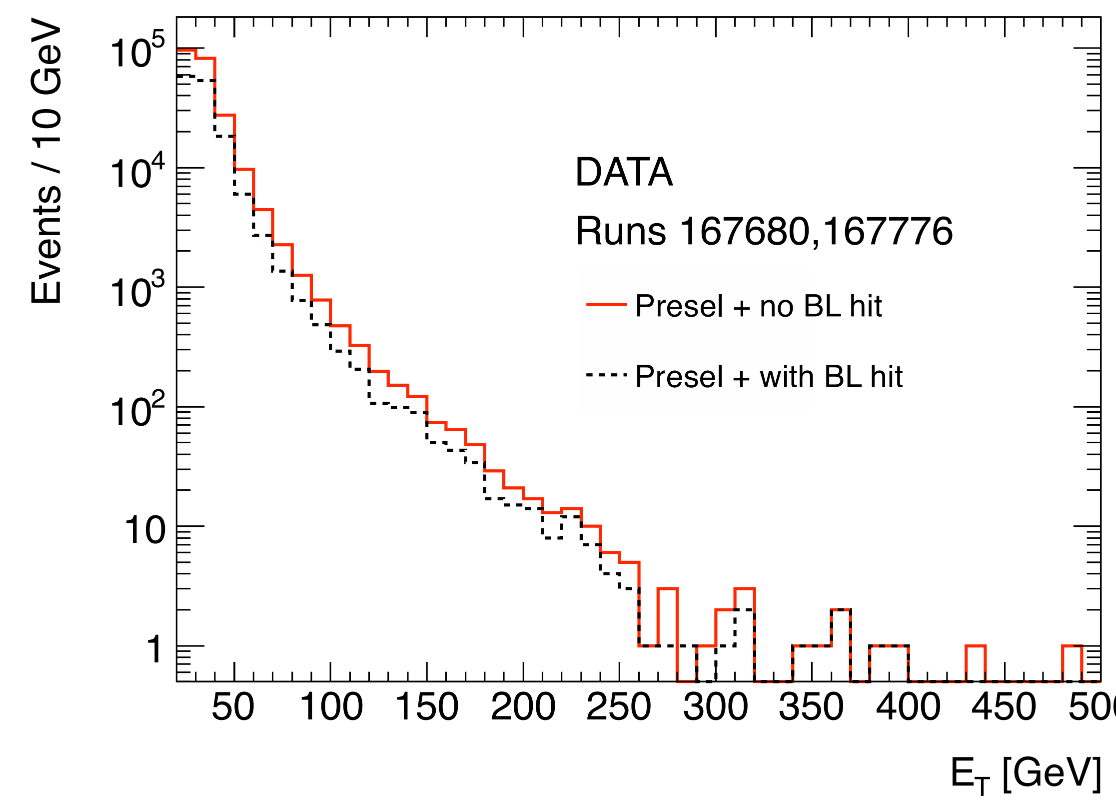


Electron Channel

Electron Selection

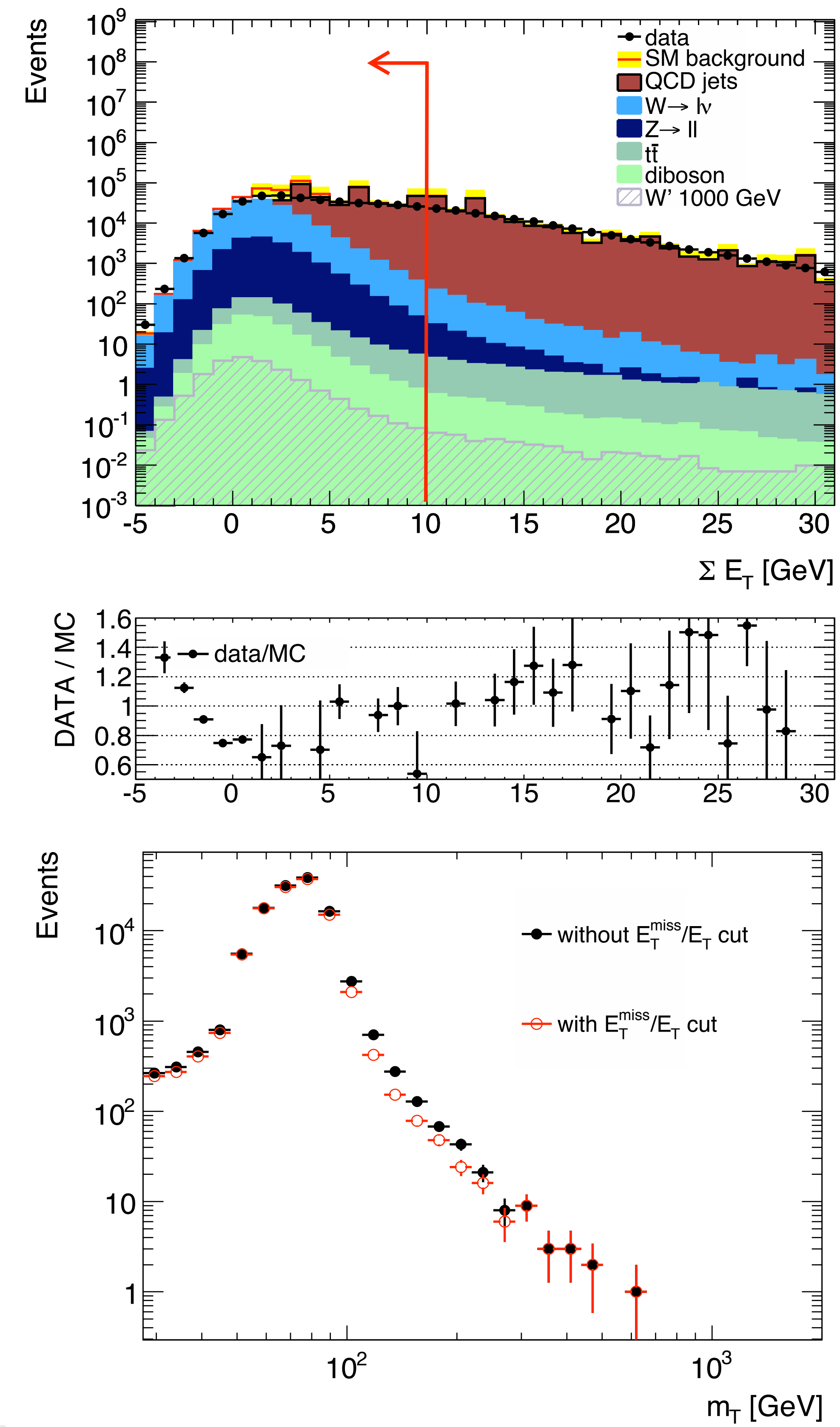
- Same preselection as in muon channel (electron trigger)
- Egamma candidate, 'Medium' identification
    - Medium vs Loose: similar efficiency with higher rejection
    - Medium vs Tight: difficult to model E/P, no pion/electron separation for E>200 GeV
- Track B-layer hit found if expected
    - Remove γ conversions, 2-1.5% signal loss
- $|\eta|<2.4$, $|\eta|>1.52$ or $|\eta|<1.37$, $E_T>25$ GeV
- Outside bad regions ('OTX' and wrong BCID in 28 trigger towers)
- $|d_0|<1mm$, $|z_0|<5mm$
- Trigger match





Event Selection in the Electron Channel

- MET > 25 GeV
- Calorimeter isolation: ΣE_T<10 GeV in 0.4 cone
  - More powerful for QCD suppression in high m_T
  - Calorimeter leakage based on MC estimate, large systematic uncertainty
  - Small effect of pileup for conservative choice of cut
  - Signal efficiency 97-96% (decreasing with mass)
- MET/E_T >0.6
  - Even after isolation QCD contamination high
  - Missing Energy should be balanced with electron energy
  - Asymmetric cut chosen in order to maximize signal efficiency



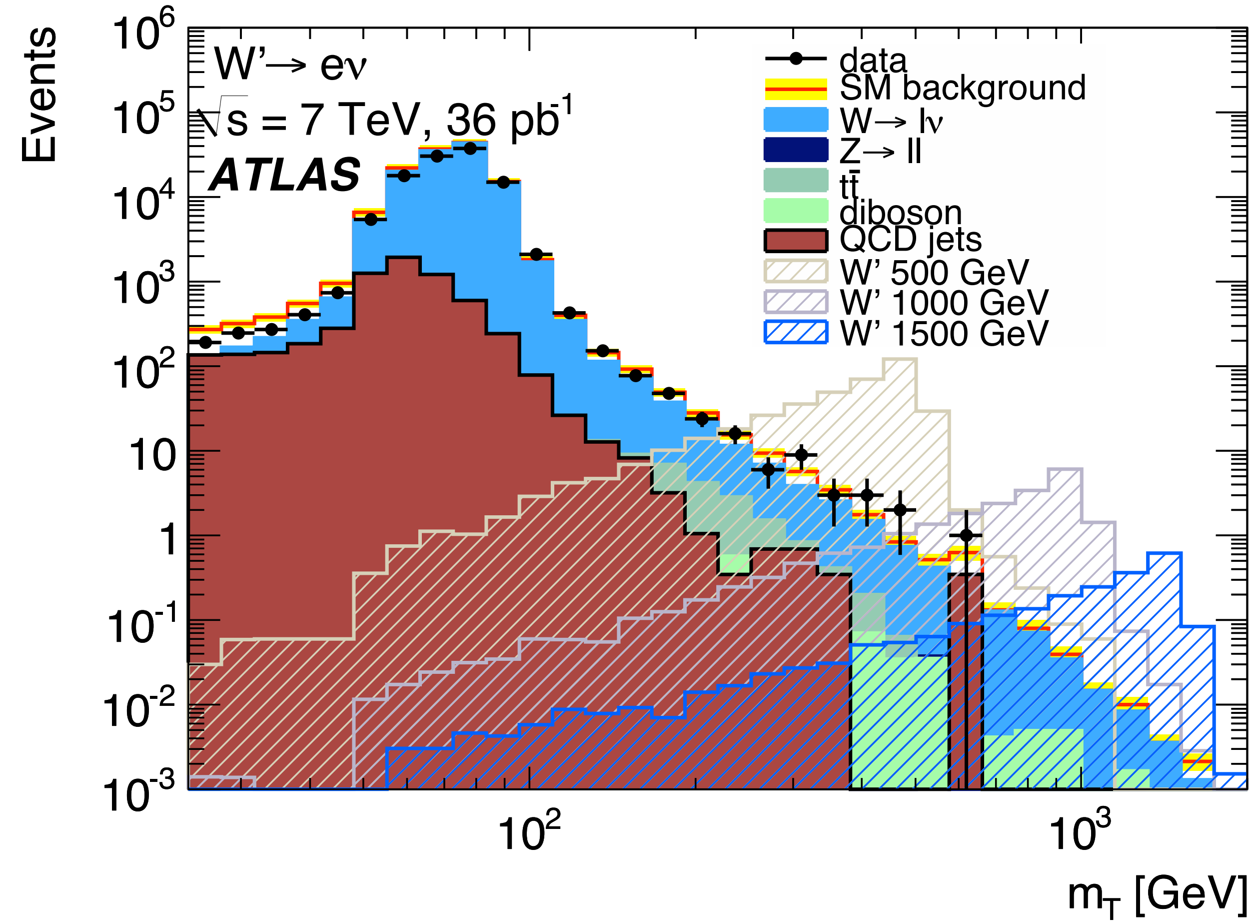
Background,Corrections and Uncertainties

- QCD background estimated from data, 4 different techniques, extrapolation to high m_T
- Trigger, reconstruction and identification efficiency with no scale factor, uncertainty 3.6%
- Mass-dependent correction factors introduced for the signal selection efficiency and the Monte Carlo background level: 3.5% uncertainty due to data/MC lateral shower shapes discrepancy
- Isolation uncertainty dependent on jet multiplicity: 1.5%
- MET/E_T modeling, higher order corrections: 0.2%
- Signal uncertainty dominated by reco/id 3.6%, isolation leakage 0.3-3% and jet activity and isolation 1.5%
- Background dominated by reco/id, isolation leakage and energy scale 7%
  - Theory and PDF: 5-11% for W/Z

Final Results: Electron Channel

- Good agreement between data and predictions: No excess found!
- No large fluctuations compared to the predicted background
- Systematic uncertainties dominated by efficiency, isolation leakage and energy scale
- Same theoretical corrections and uncertainties as in the muon channel
- Greater acceptance with respect to the muon channel: trigger and whole coverage in eta.

m [GeV]	signal	ε_{sig}	N_{sig}	N_{bg}	N_{obs}
500	W'	0.556 ± 0.024	349 ± 30	23.08 ± 2.2	24
	W^*	0.455 ± 0.019	208 ± 18		
750	W'	0.565 ± 0.025	65.8 ± 4.8	4.36 ± 0.40	6
	W^*	0.466 ± 0.020	39.6 ± 3.5		
1000	W'	0.562 ± 0.025	17.1 ± 1.4	1.20 ± 0.12	1
	W^*	0.473 ± 0.021	10.5 ± 1.0		
1250	W'	0.552 ± 0.026	5.23 ± 0.51	0.431 ± 0.062	0
	W^*	0.469 ± 0.021	3.22 ± 0.42		
1500	W'	0.530 ± 0.028	1.71 ± 0.21	0.177 ± 0.025	0
	W^*	0.457 ± 0.023	1.06 ± 0.17		
1750	W'	0.503 ± 0.027	0.59 ± 0.09	0.075 ± 0.011	0
	W^*	0.454 ± 0.027	0.37 ± 0.07		

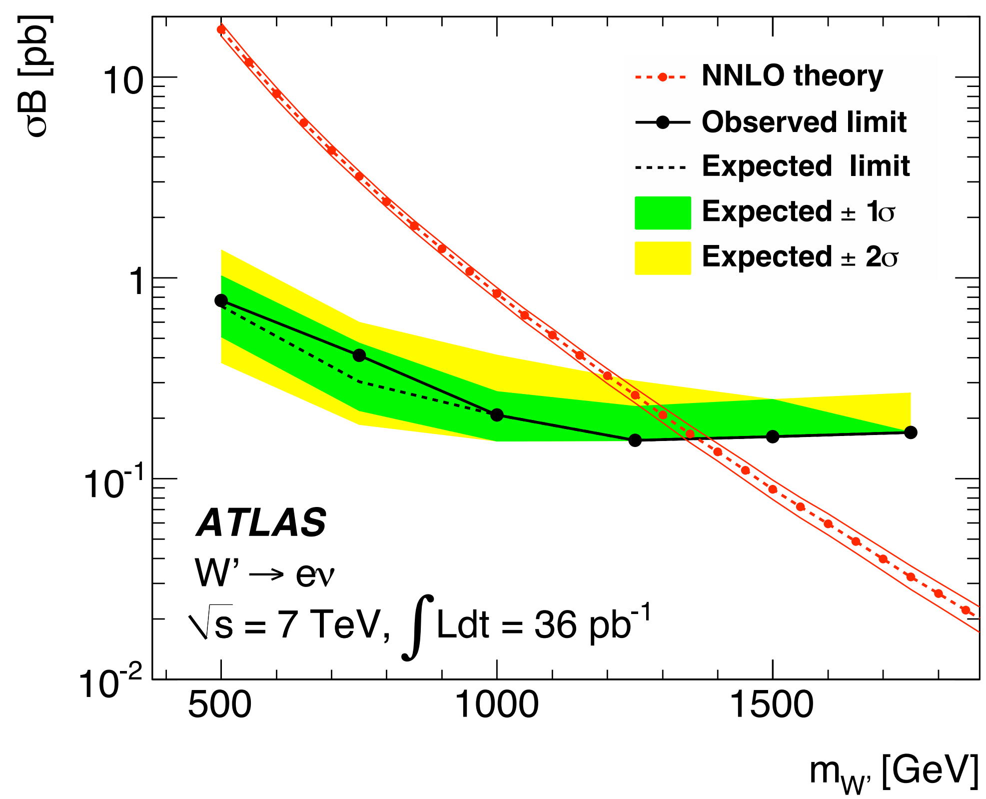


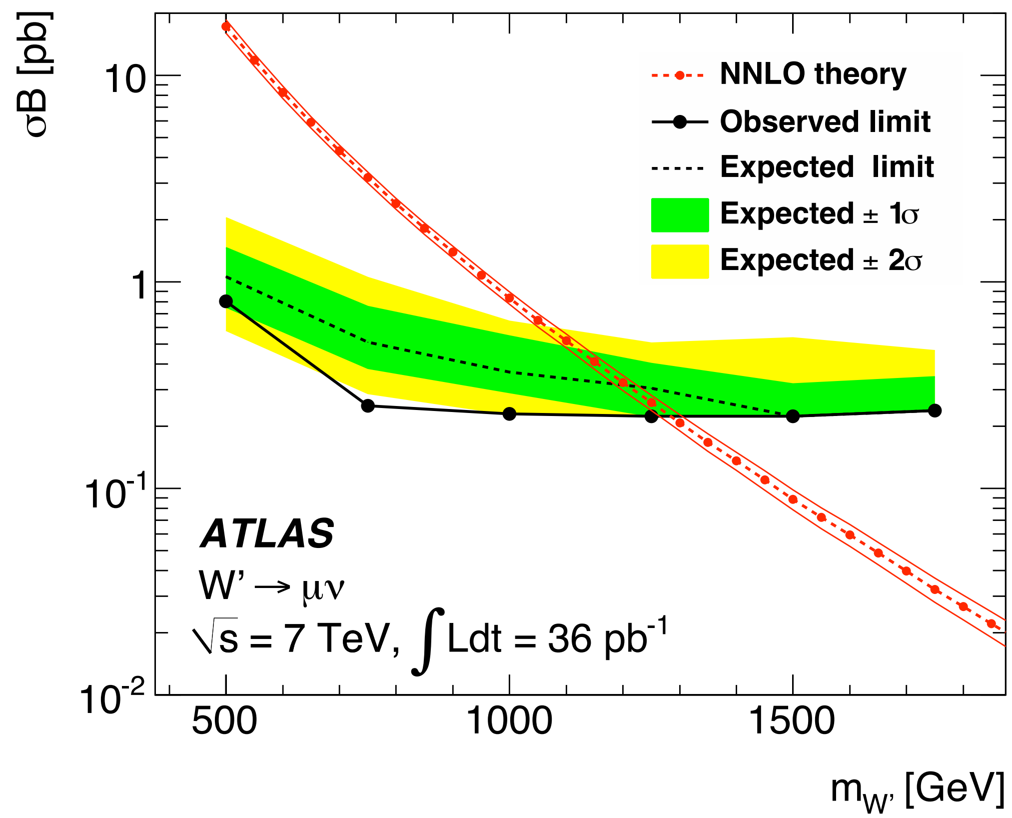
Limits and Further

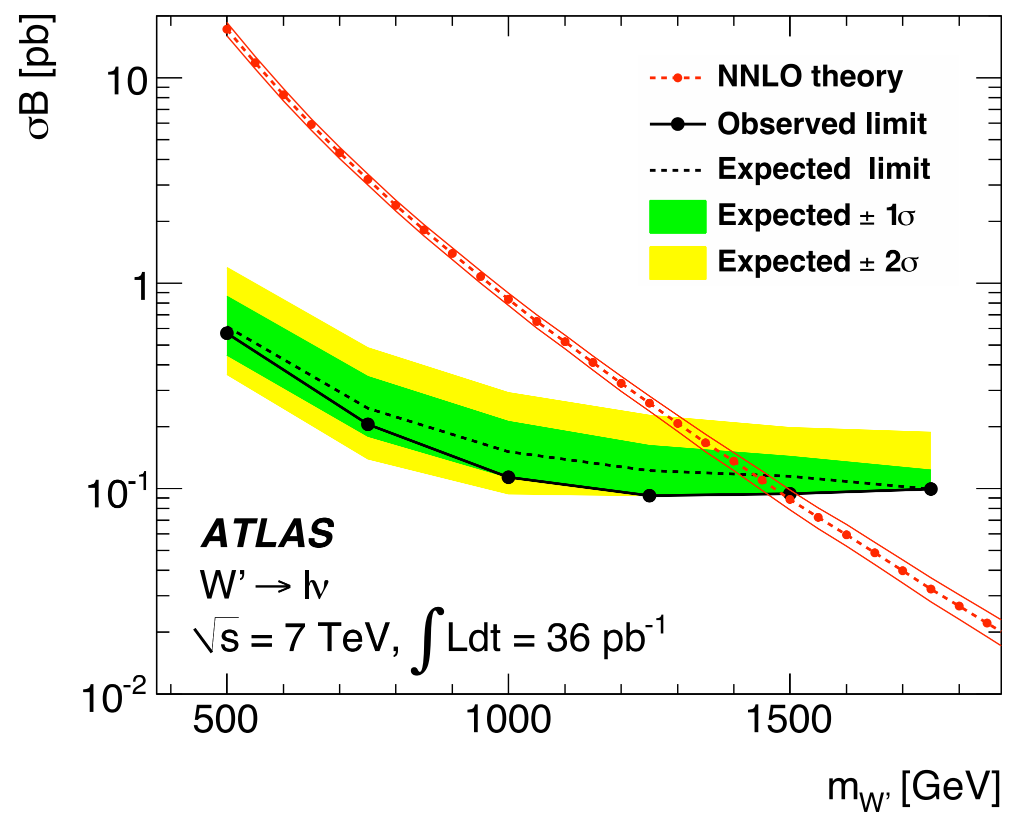
Limit Formalism

- No excess found, set upper limit on σB for W'/W*
- $N_{exp}=N_{signal} + N_{bg}$, $N_{sig}= L\, \varepsilon\, (\sigma B)$
- Likelihood $(\sigma B, \theta_1 \ldots \theta_N)$ = Poisson $(L\, \varepsilon\, (\sigma B) + N_{bg}, N_{obs}) \times \prod_i \text{Gauss}(\theta_i)$
- Take L, ε and N_{bg} as nuisance parameters
  - LLR = -2ln (Likelihood (data | s+b)) / (Likelihood (data | b))
- $CL_{s+b}= P_{s+b}(LLR \geq LLR_{obs})$ $CL_b= P_b(LLR \geq LLR_{obs})$
  $CL_s = CL_{s+b} / CL_b$
- 95% upper CL for σB: CLs= 0.05
- Test statistic for the combined electron and muon channel sum the individual LLR's.
- Uncertainties on ε and N_{bg} uncorrelated nuisance parameters (small effect on the limits)
- Luminosity uncertainty treated as correlated uncertainty for signal and background

Limits with 2010 Data





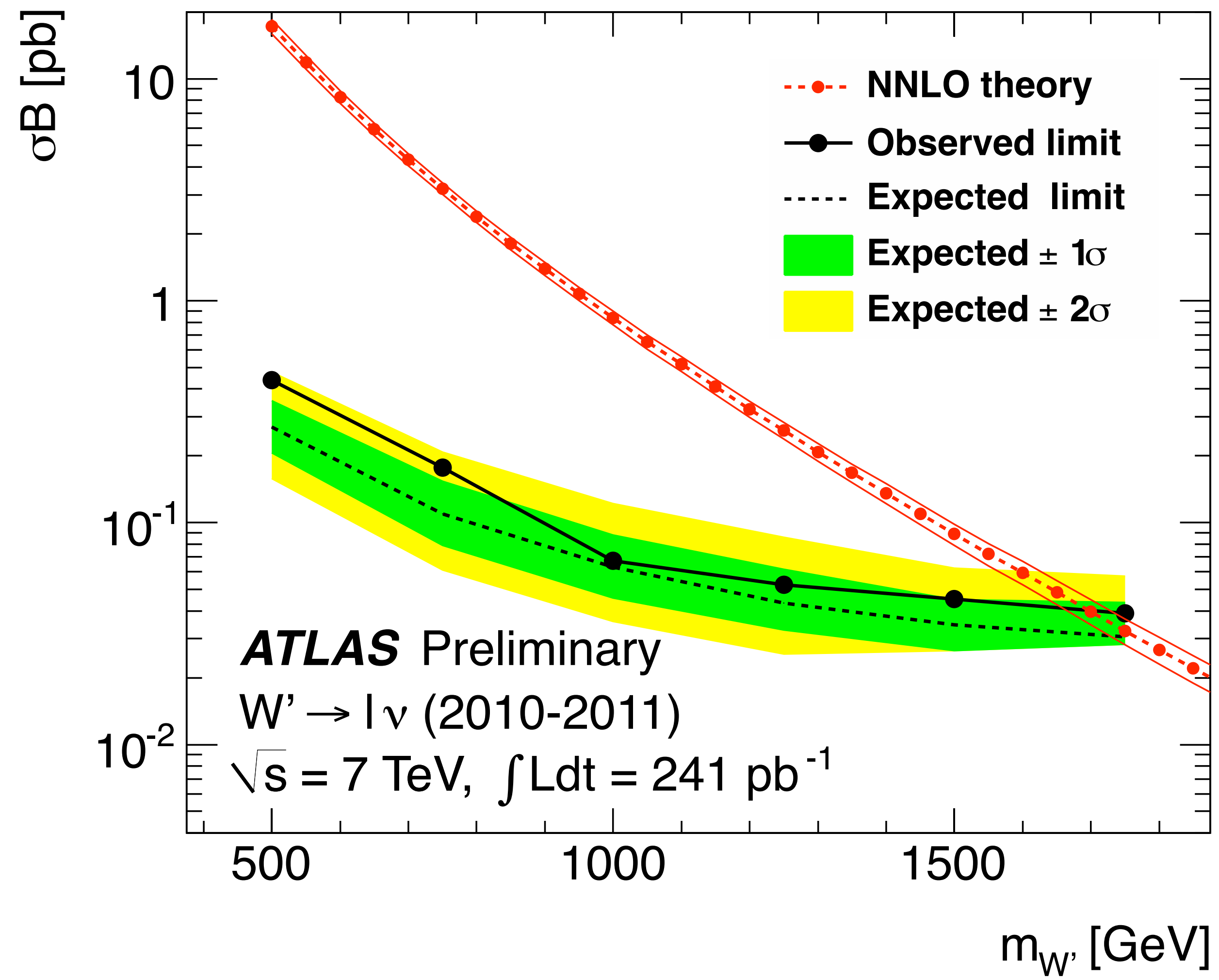


electron/muon/combined limit
1360, 1290, 1490 GeV
(1340,1279, 1470 conservative)
5-10 GeV improvement without uncertainties

W* limit:
1260,1120,1350

Limits with 2010+205 pb^{-1} of 2011 Data

- Preliminary result of 2011
- Only muon channel investigated
  - Combined with 2010 result via combination of LLRs
- Improvement in the analysis:
  - combined measurement of the muon p_T (due to significant improvement in ID alignment); p_T Resolution 0.2/ TeV
  - $|\eta|<2$
  - Larger uncertainty due to increased pileup
- Good agreement data/MC: no excess found
- Mass limit increased to 1.7 TeV (W' only)

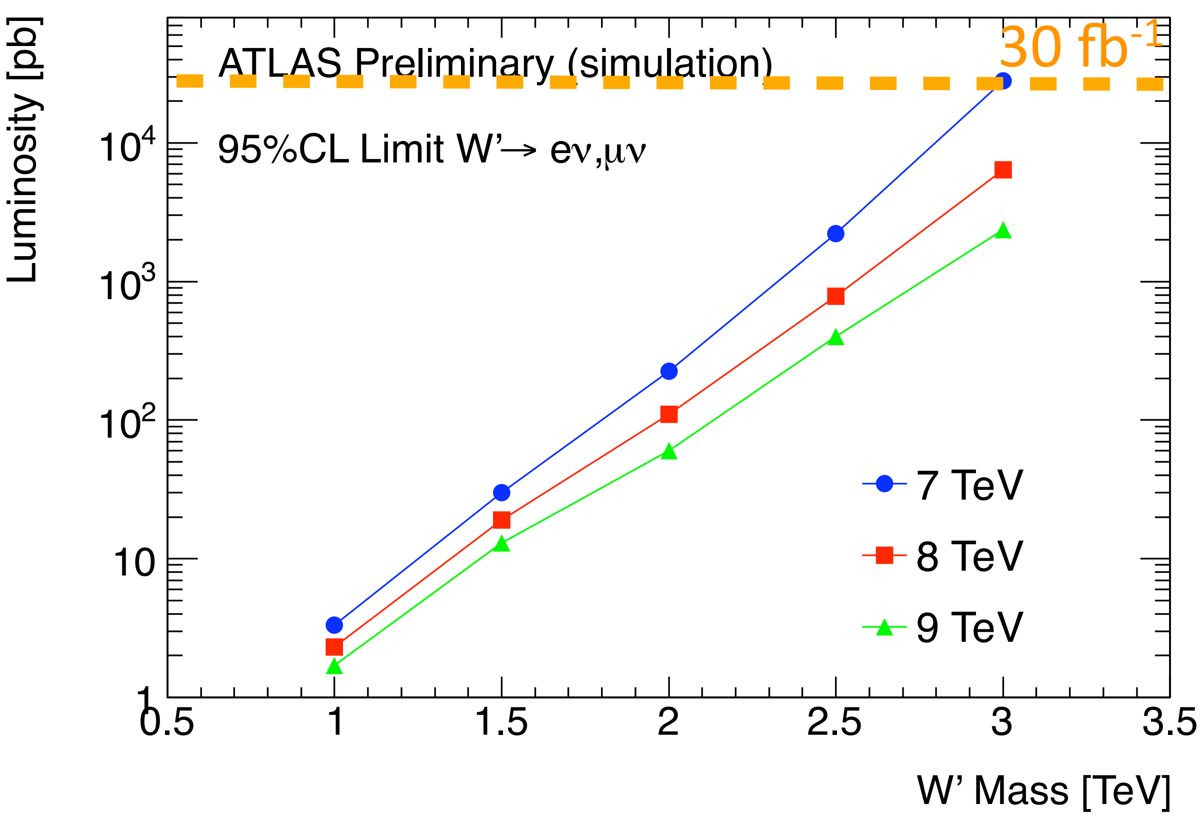


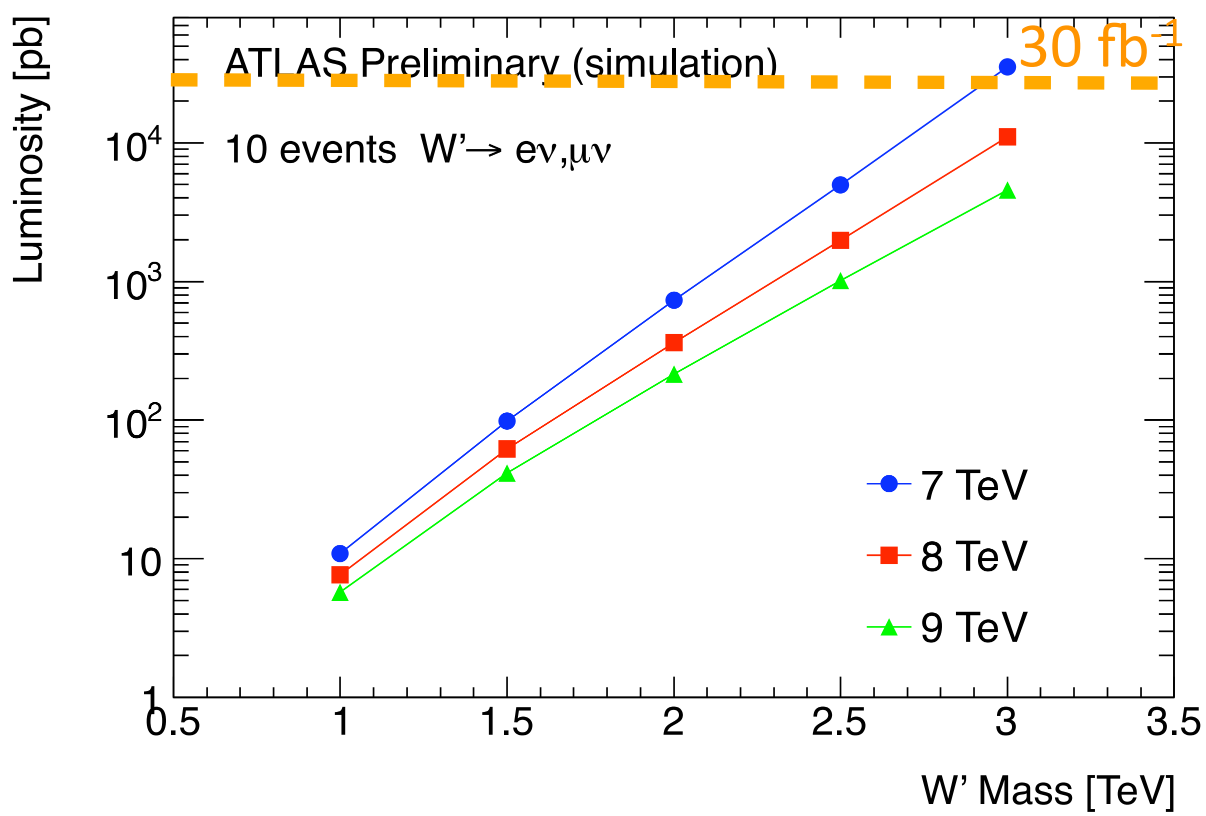
Prospects

- ATLAS sensitivity potential to search for W' studied as a function of energy and integrated luminosity

- Global 'reweighting' applied $$N(\sqrt{s}) = N(7\text{ TeV}) \times \frac{\sigma(\sqrt{s})}{\sigma(7\text{ TeV})} \times \frac{\varepsilon(\sqrt{s})}{\varepsilon(7\text{ TeV})}$$

- Simple estimated,best guess of systematic uncertainties, assumed the whole detector coverage





- Small increase in sensitivity

- With 30 fb^{-1} at 7 TeV it is possible to probe mass scale of ~3 TeV

Summary

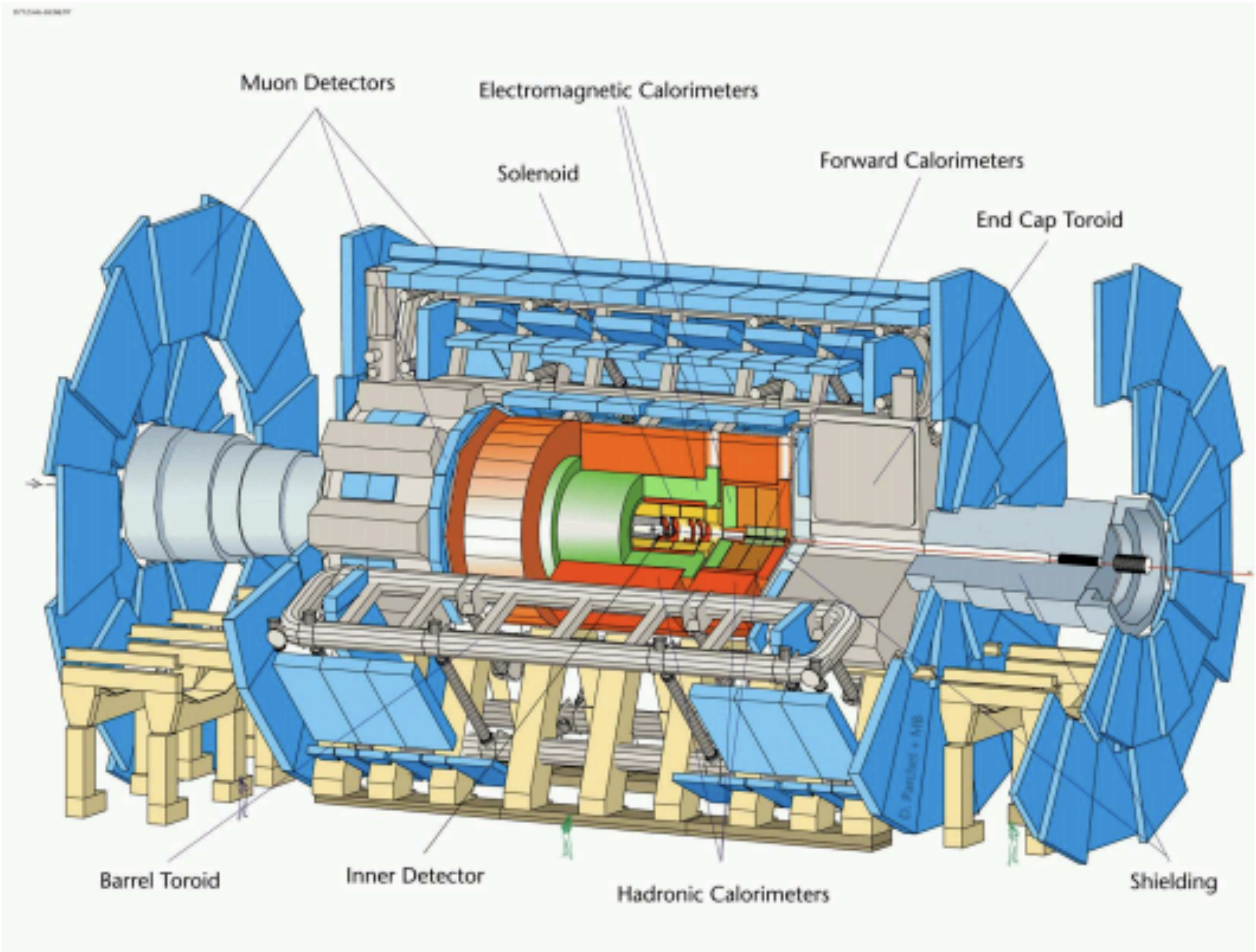
- A search for high-mass states, such as heavy charged gauge bosons (W' and W*) decaying to a lepton (a muon or an electron) and a neutrino is presented.
- The search is performed with 36 pb^{-1} of data, collected during 2010. A preliminary ATLAS result with 205 pb^{-1} of 2011 data also presented.
- Higher order correction for W' production has been evaluated using FEWZ, theoretical uncertainties estimated from PDF and scale variation.
- Muon selection studied in order to select muon+MET candidates, and to improve muon resolution. Also, isolation based on ID established. Possible additional requirements studied.
- For the selection of high mass electron+neutrino candidates, electron identification criteria are established.
- Background estimated from MC and NNLO cross section. QCD and cosmic-ray background from data (4% total).
- Systematic uncertainties estimated for the signal and background. No evidence of new resonance found, limits on σB set using CLs method: $m_{W'}>1.49$ TeV ($m_{W*}>1.35$ TeV).
- Prospects for W' search studied: with 30 fb^{-1} @ 7 TeV sensitivity to 3 TeV W'.

хвала* - *ευχαριστώ

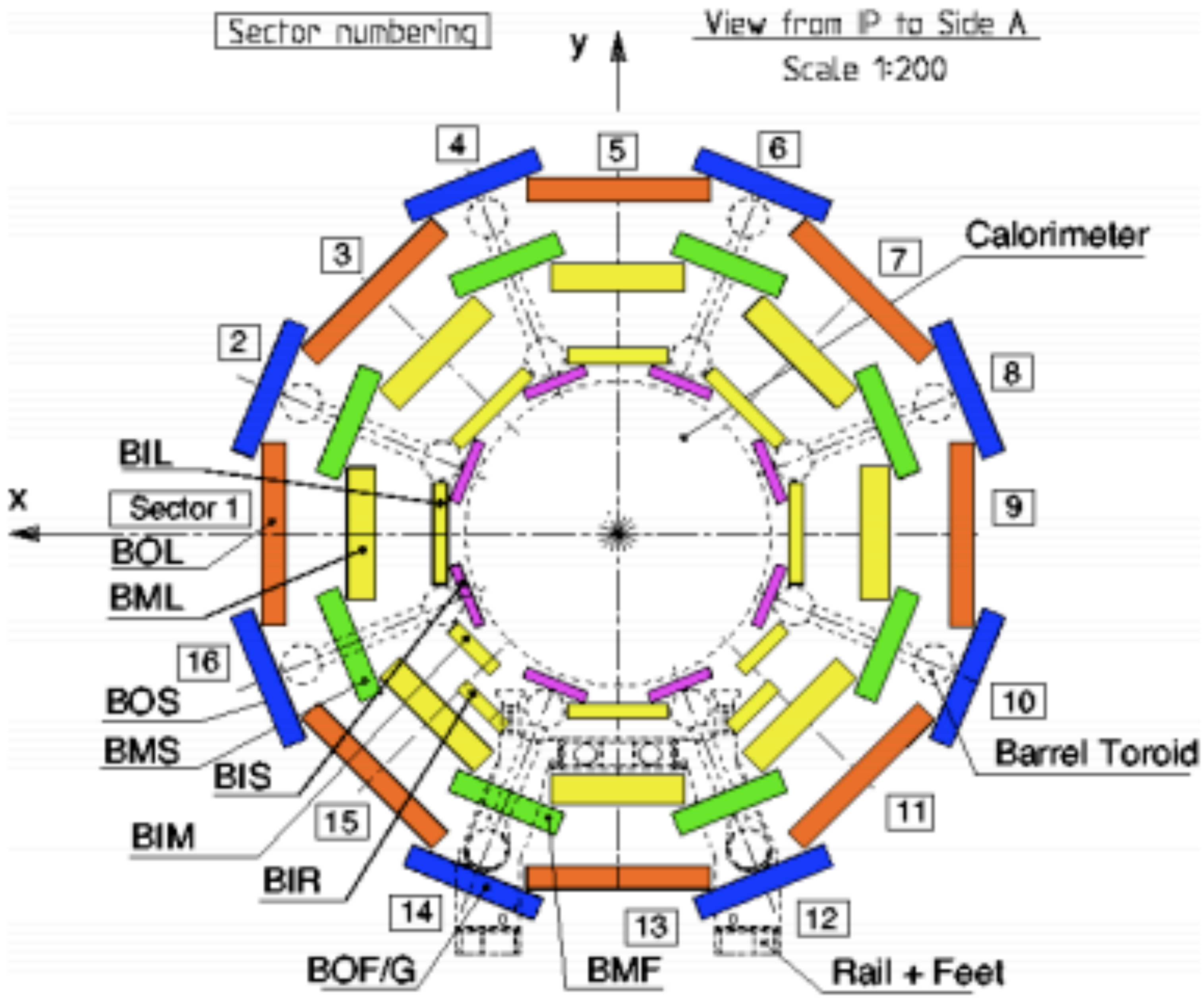
thank you!

Backup

ATLAS Detector

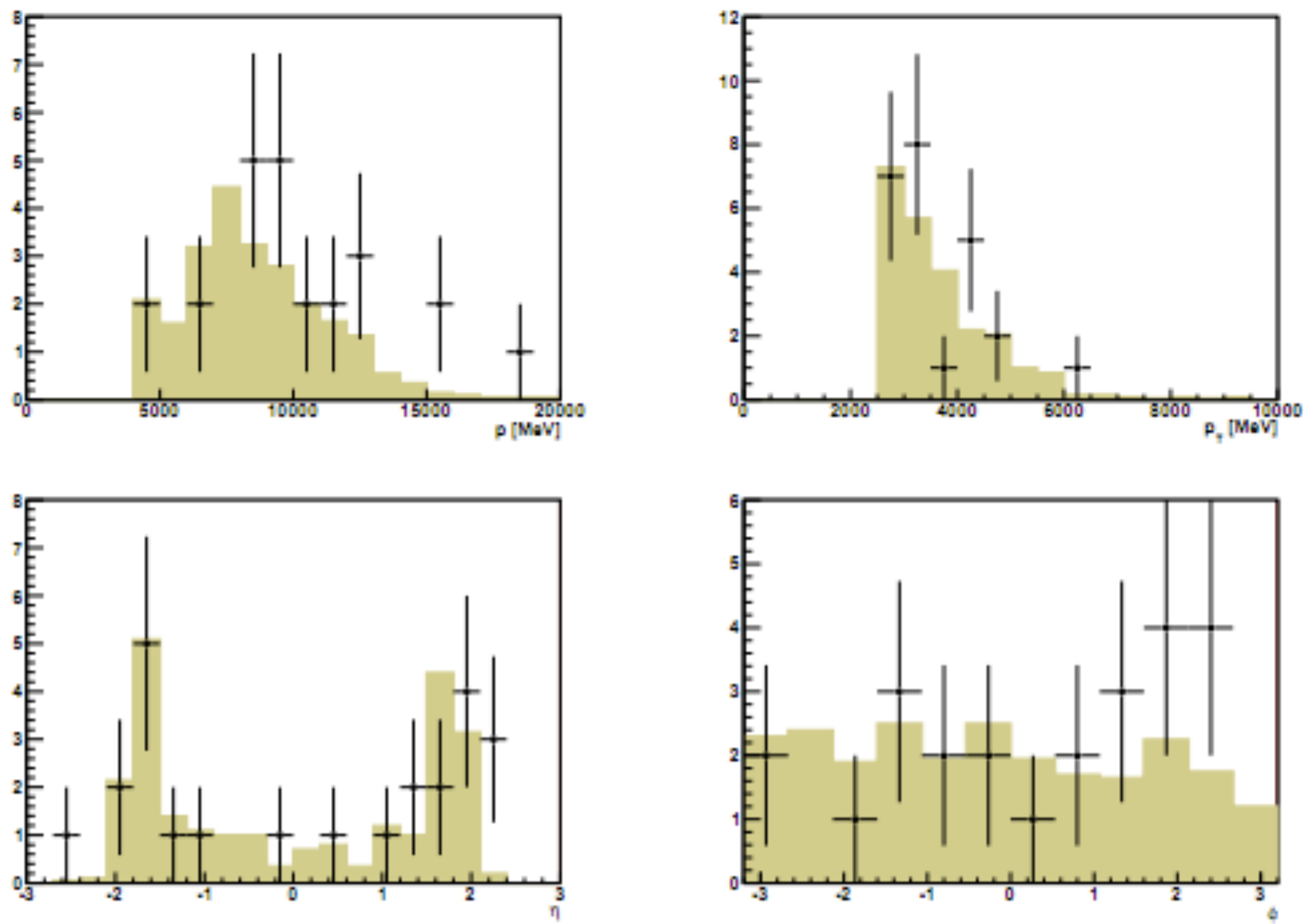


Muon Spectrometer



Performance With the First Collision Data

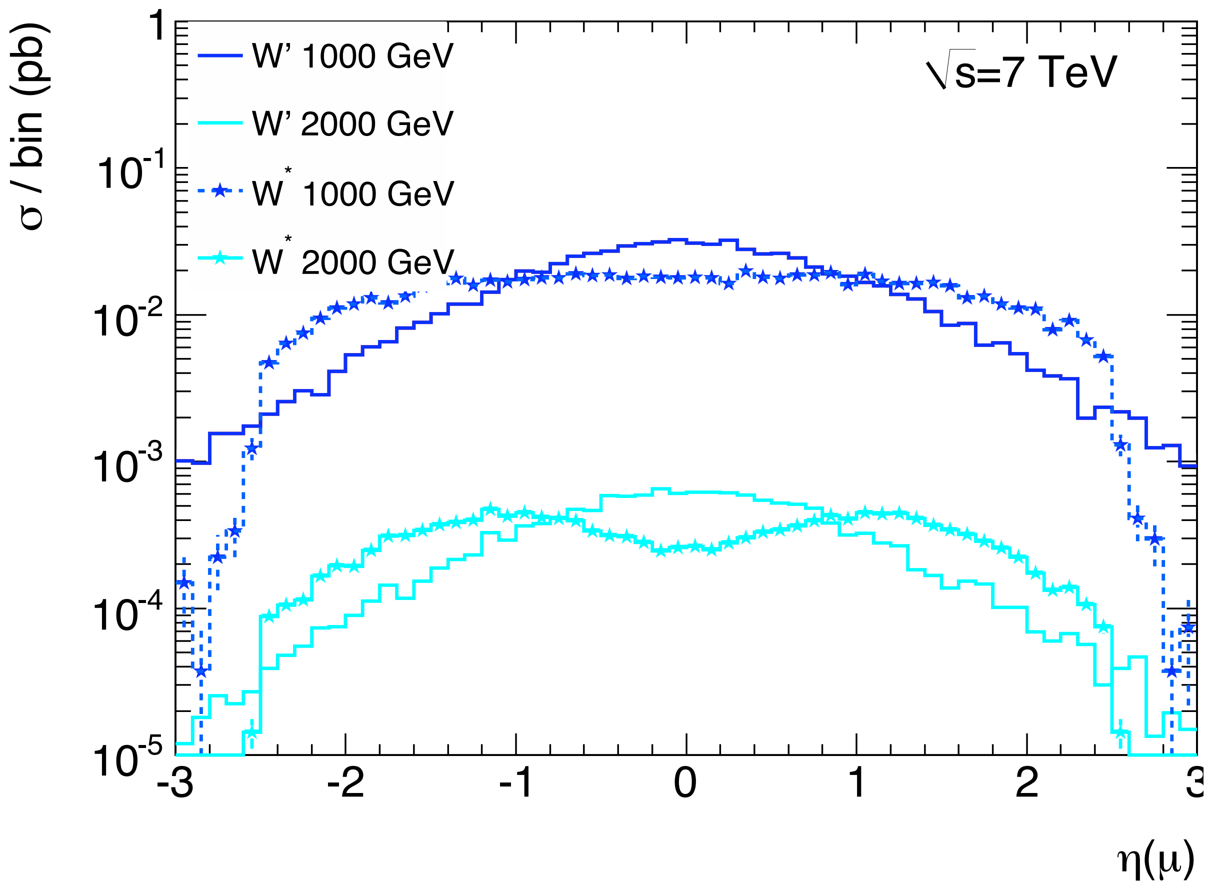
- Staco Combined: $\chi^2_{match} < 50$;
- MuTag: ID track - segment matching $< 3\sigma$;
- Muid Combined and standalone: at least 2 hits in RPCϕ layer;
- MuGirl: at least 6 SCT hits, and at least 2 segments in MS associated with the muon.

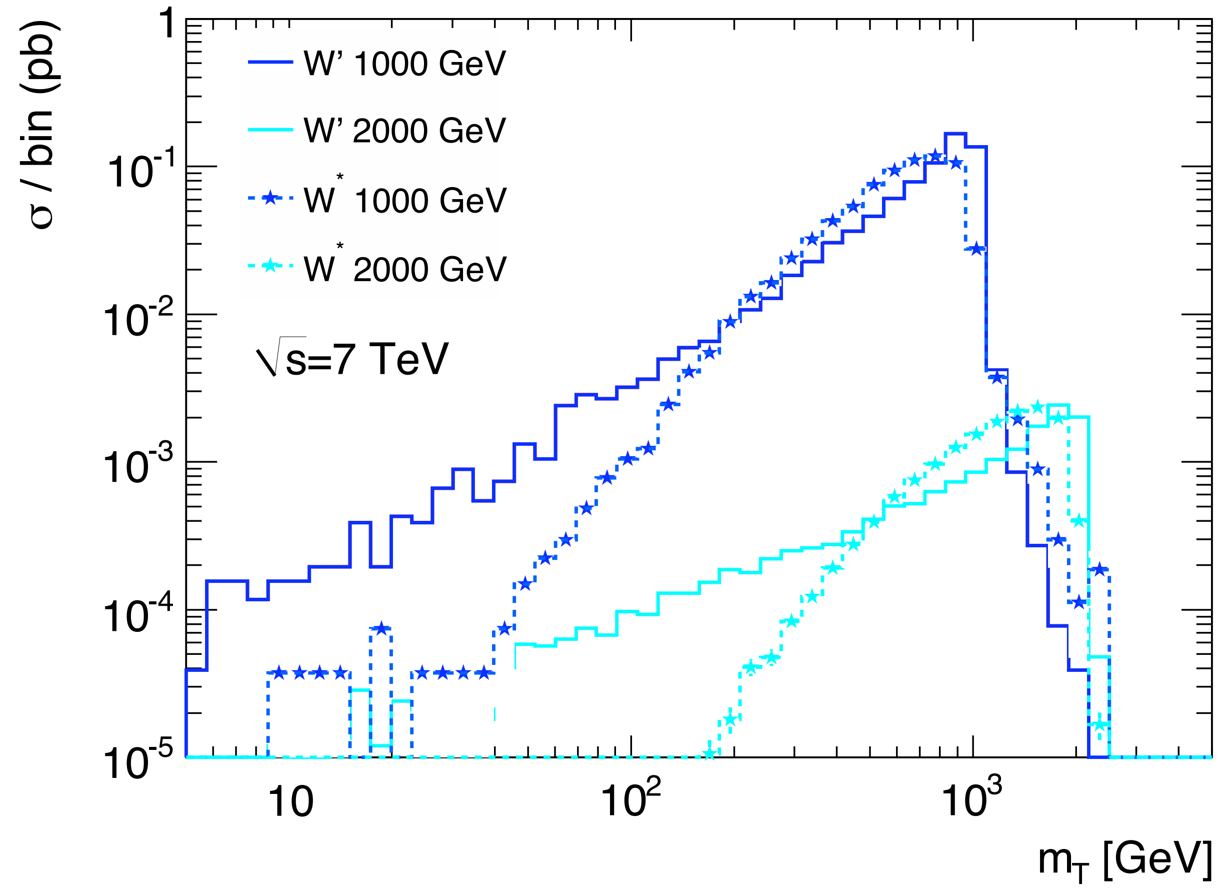


W* cross section

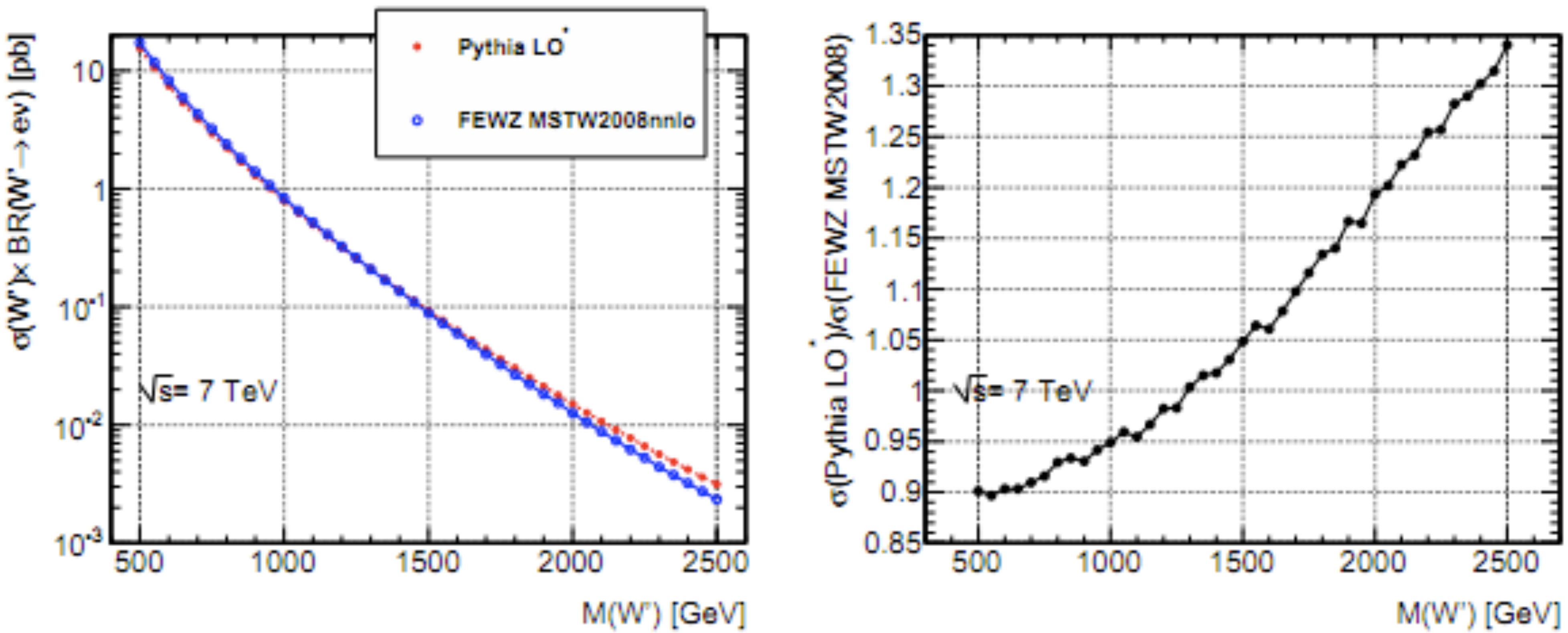
M[GeV]	Γ [GeV]	$B(W^* \to l\nu)$	σB [pb]
500	16.929	0.08305	12.590
750	25.389	0.08327	2.339
1000	33.836	0.08331	0.6098
1250	42.290	0.08333	0.1884
1500	50.745	0.08333	0.0636
1750	59.202	0.08333	0.0226

CompHEP for ME + PYTHIA for PS
CTEQ 6L1
forward leptons, Jacobean peak distorted





NNLO W’ cross sections (with FEWZ)



W' mass [GeV]	500	750	1000	1250	1500	1750	2000	2500
$W' \to e\nu$ with no kinematic cuts								
σB_{LO} [pb]	15.55	2.931	0.779	0.256	0.0926	0.0362	0.0150	0.00314
σB_{NNLO} [pb]	17.25	3.200	0.837	0.261	0.0887	0.0325	0.0126	0.00234
$K_{\text{NNLO}} = \frac{\sigma B_{NNLO}}{\sigma B_{LO}}$	1.11	1.09	1.07	1.02	0.96	0.90	0.84	0.76
$W' \to e\nu$ with $p_T^e > 25$ GeV, $\lvert\eta^e\rvert < 2.5$, $p_T^\nu > 25$ GeV, $m_\text{T} > \frac{1}{2}m_{W'}$								
σB_{LO} [pb]	11.72	2.202	0.581	0.186	0.0646	0.0237	0.0091	0.00133
σB_{NNLO} [pb]	13.34	2.466	0.635	0.194	0.0646	0.0219	0.0076	0.00092
$K_{\square\text{d}} = \frac{\sigma B_{NNLO}}{\sigma B_{LO}}$	1.14	1.12	1.09	1.04	1.00	0.93	0.84	0.69
W' event selection ef□ciency correction factor.								
$K_{\square\text{d}}/K_{\text{NNLO}}$	1.025	1.026	1.019	1.024	1.042	1.031	0.994	0.923

Event Preselection in the Muon Channel

- Muon trigger, depending on the period

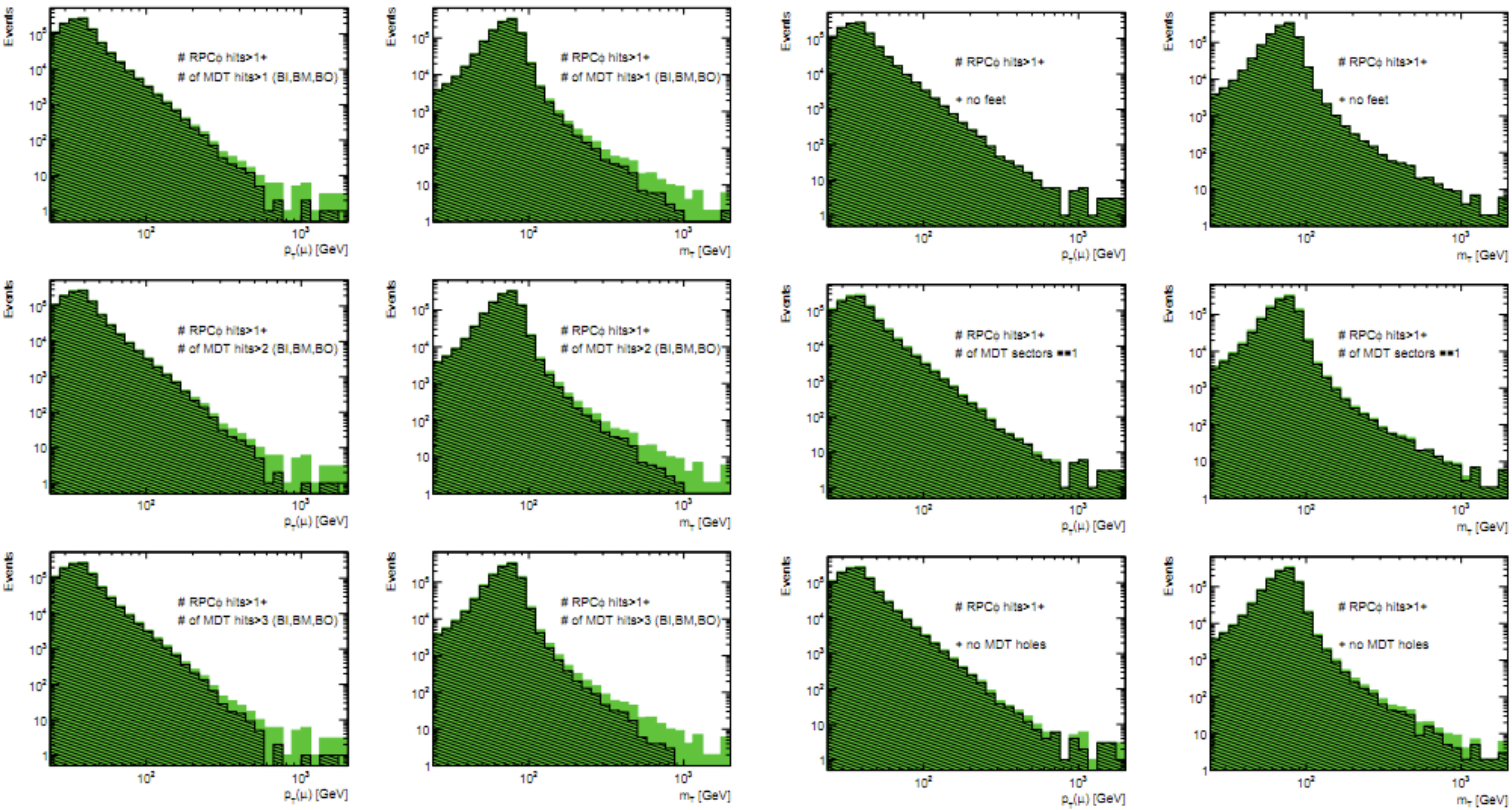
Run periods	Run numbers	Trigger	$\mathscr{L}_{int}$ [pb^{-1}]
A1-E3	152844-160879	L1_MU0	0.76
E4-G5	160899-165956	EF_mu20_MSonly	5.76
G5-I2	166094-167844	EF_mu20, EF_mu30_MSonly, EF_mu40_MSonly	29.83
A1-I2	152844-167844		36.35

- Jet Cleaning
  - electromagnetic fraction is >0.95 and absolute value of jet quality >0.8;
  - energy fraction in the HEC >0.8 and minimum number of cells containing at least 90% of the jet energy <=5;
  - energy fraction in the HEC >0.5 and absolute value of jet quality >0.5;
  - absolute value of jet time computed as the energy squared cells mean time>25 ns;
  - electromagnetic fraction <0.05;
  - maximum energy fraction in one calorimeter layer >0.99 and $|\eta(jet)| < 2$.

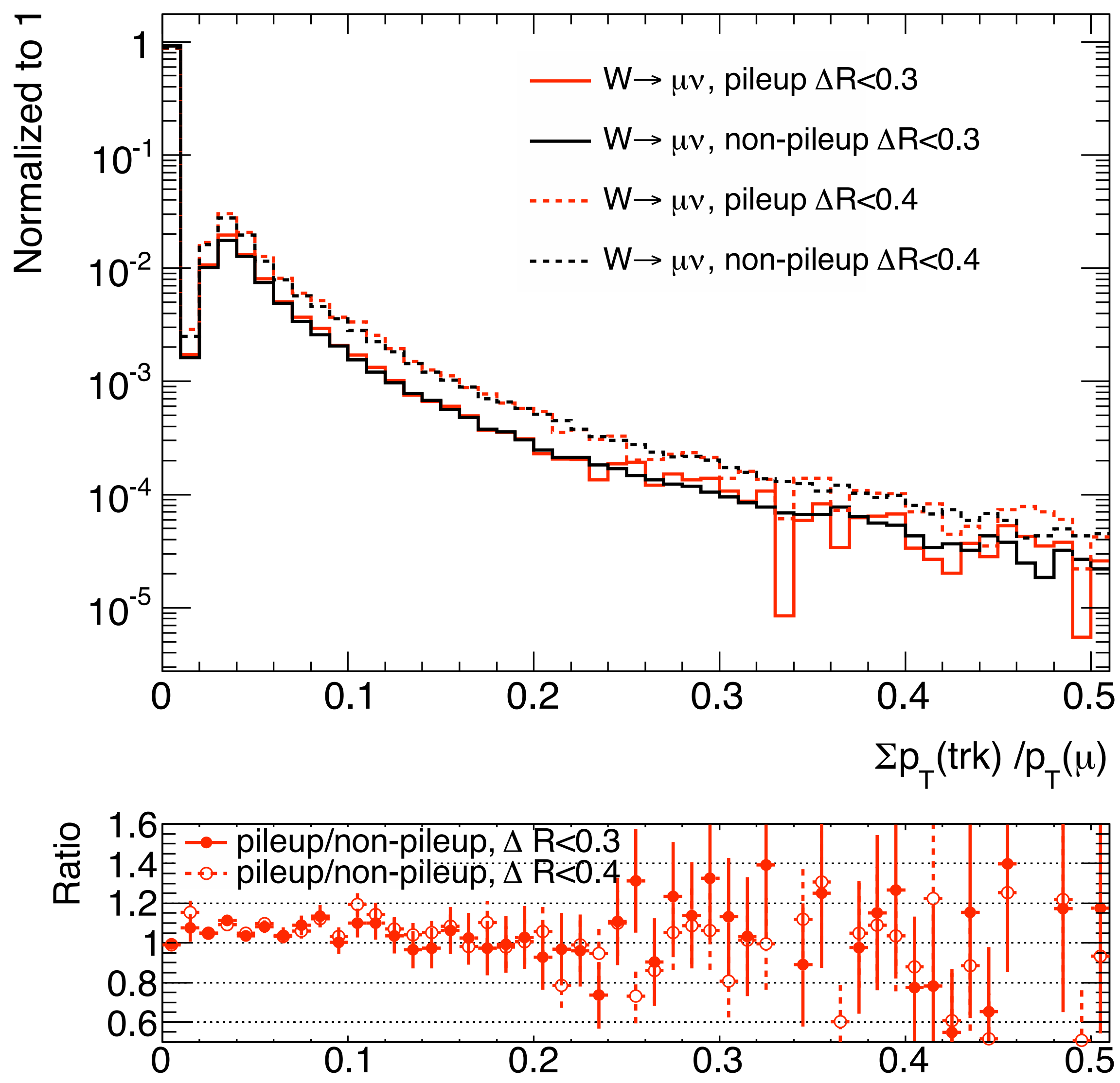
Muon Selection

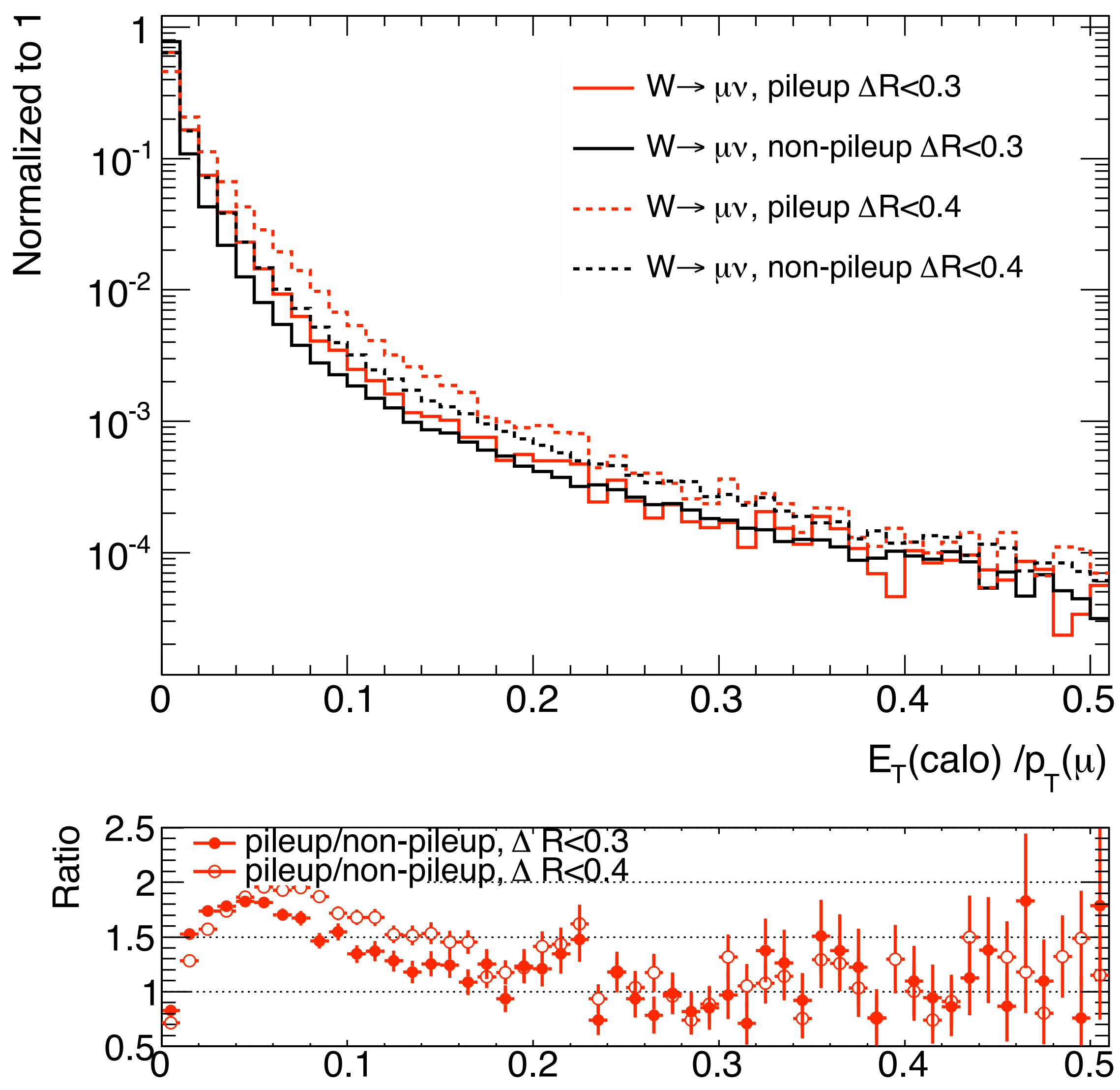
- $|\eta| < 1.05$;
- $p_T > 25$ GeV;
- $N_{hit}^{pixel} > 0$;
- $N_{hit}^{SCT} > 3$;
- $N_{hit}^{pixel} + N_{hit}^{SCT} > 5$;
- $N_{layer}^{RPC\varphi} > 1$ (at least one phi hit in each of at least two of the three RPC layers);
- $N_{hit}^{MDT} > 2$ in each of the three barrel stations;
- muons are rejected if they pick up hits from BIS7 and BIS8 chambers;
- $|d_0| <1$ mm and $|z_0| < 5$ mm, and

Hits in MS: W->munu MC

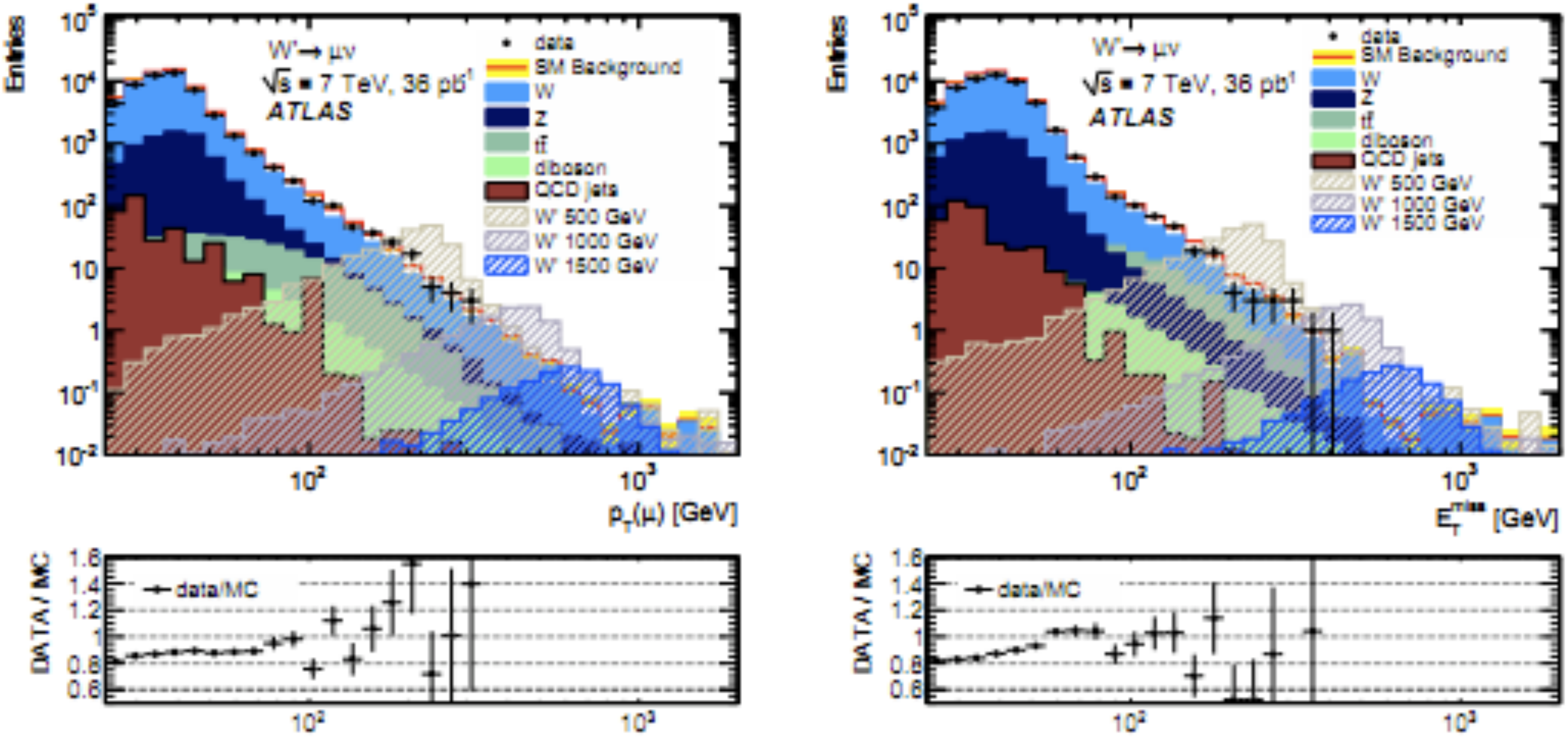


Isolation and pileup

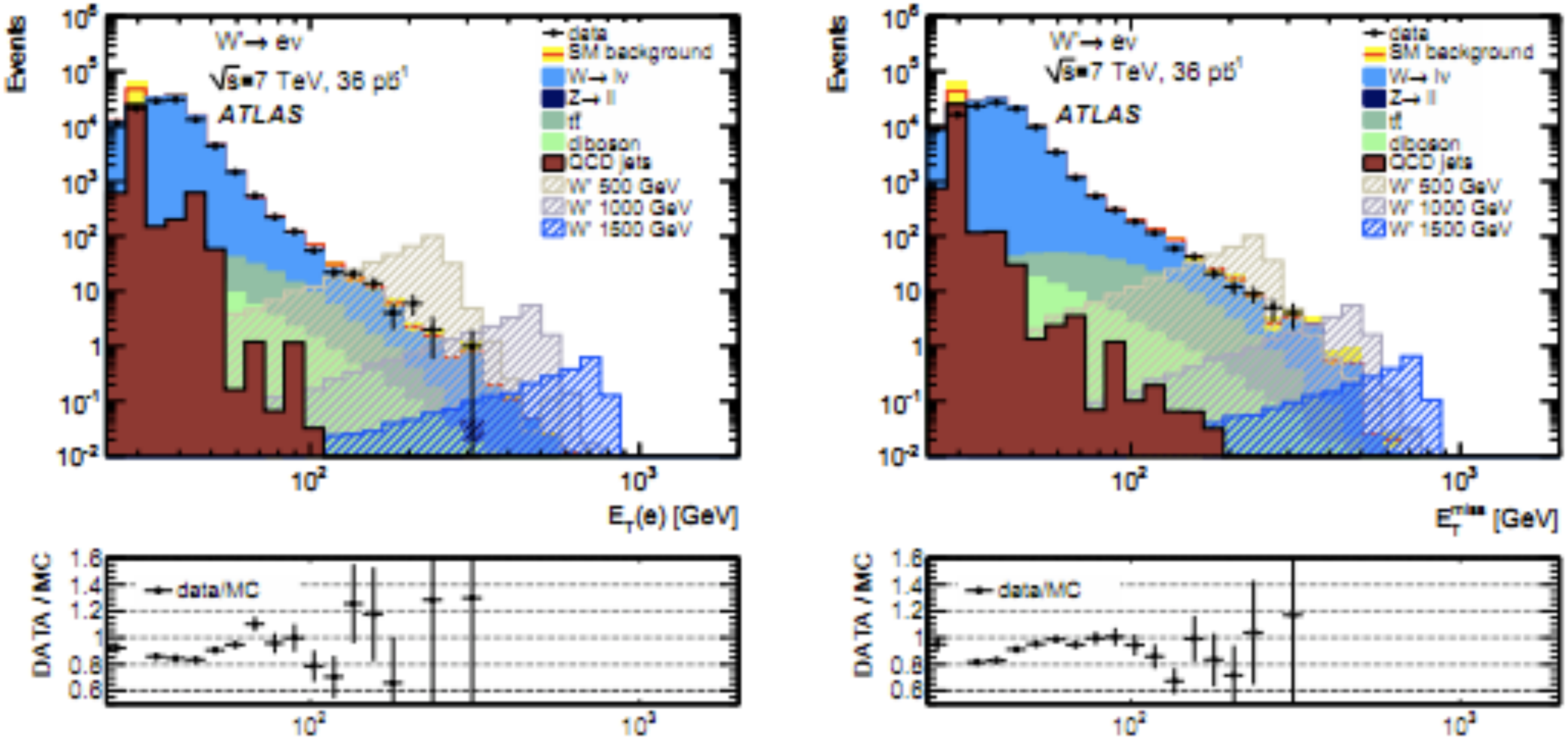




Muon p_T and MET distributions



Electron E_T and MET distributions



ATLAS result with 1 fb^{-1} (latest and greatest)