Standard Model Physics in ATLAS at the start of the LHC

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on behalf of ATLAS Collaboration

Les Rencontres de Physique de la Vallee d'Aoste

La Thuile

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Outline

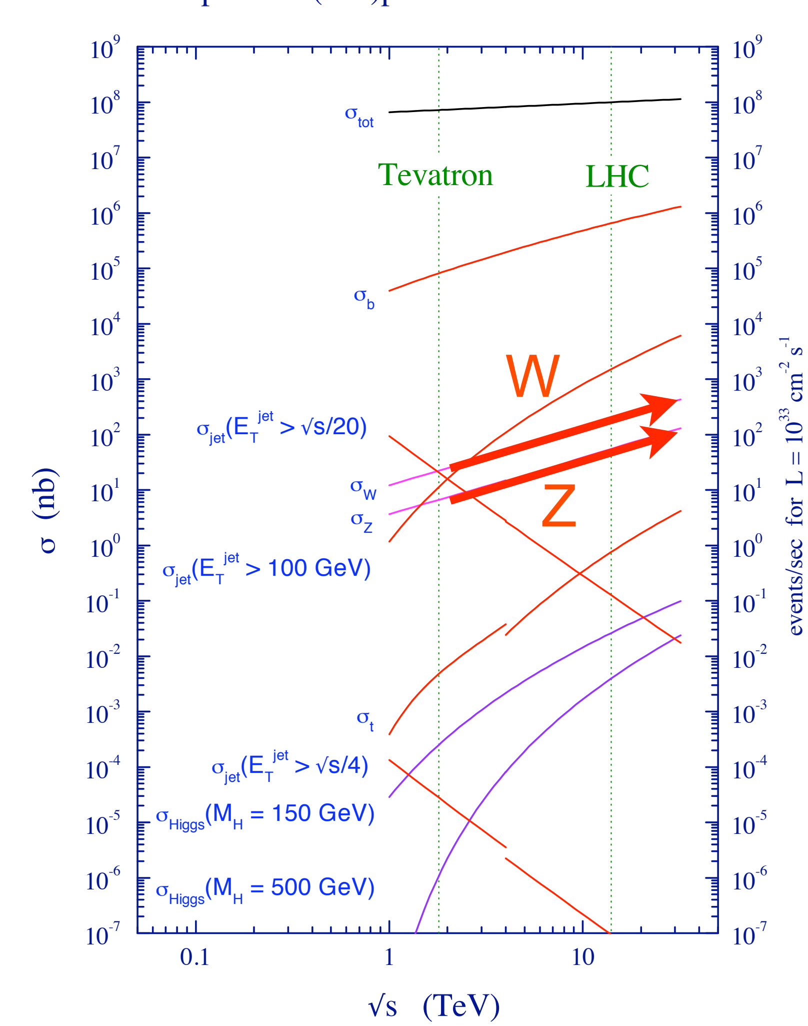
- **Focus on main items for Standard Model physics in early data**

Channels (examples …)	Events to tape for 100 pb^{-1} (ATLAS)	Total statistics from LEP and Tevatron
$W \to \mu \nu$	~ 10^6	~ 10^4 LEP, ~ 10^{6-7} Tevatron
$Z \to \mu \mu$	~ 10^5	~ 10^6 LEP, ~ 10^{5-6} Tevatron
$t\bar{t} \to W b W b \to \mu \nu + X$	~ 10^4	~ 10^{3-4} Tevatron
QCD jets $p_T > 1$ TeV	> 10^3	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

- LHC and ATLAS status
- Minimum Bias and Underlying Event
- J/ψ and Υ resonances
- W and Z (+jets) physics
  - ★ detector calibration/understanding
  - ★ inclusive cross sections
  - ★ constraints on PDF's
- Top physics
  - ★ detector calibration/understanding
  - ★ first top cross section measurement
- QCD physics
  - ★ jet cross section measurement
  - ★ constraints on PDF's
- Summary

LHC early data

- **LHC key parameters**
  - ★ **p-p collisions at 14 TeV** (x7 wrt Tevatron)
  - ★ **design luminosity of 10^{34} cm^{-2}s^{-1}** (x100 wrt Tevatron)
  - ★ bunch crossing of 40 MHz (1GHz pp collisions)
  - ★ Heavy particles production rates $10^{+3...-6}$ Hz (W, Z, t, H, Susy,..) with high sensitivity to New Physics

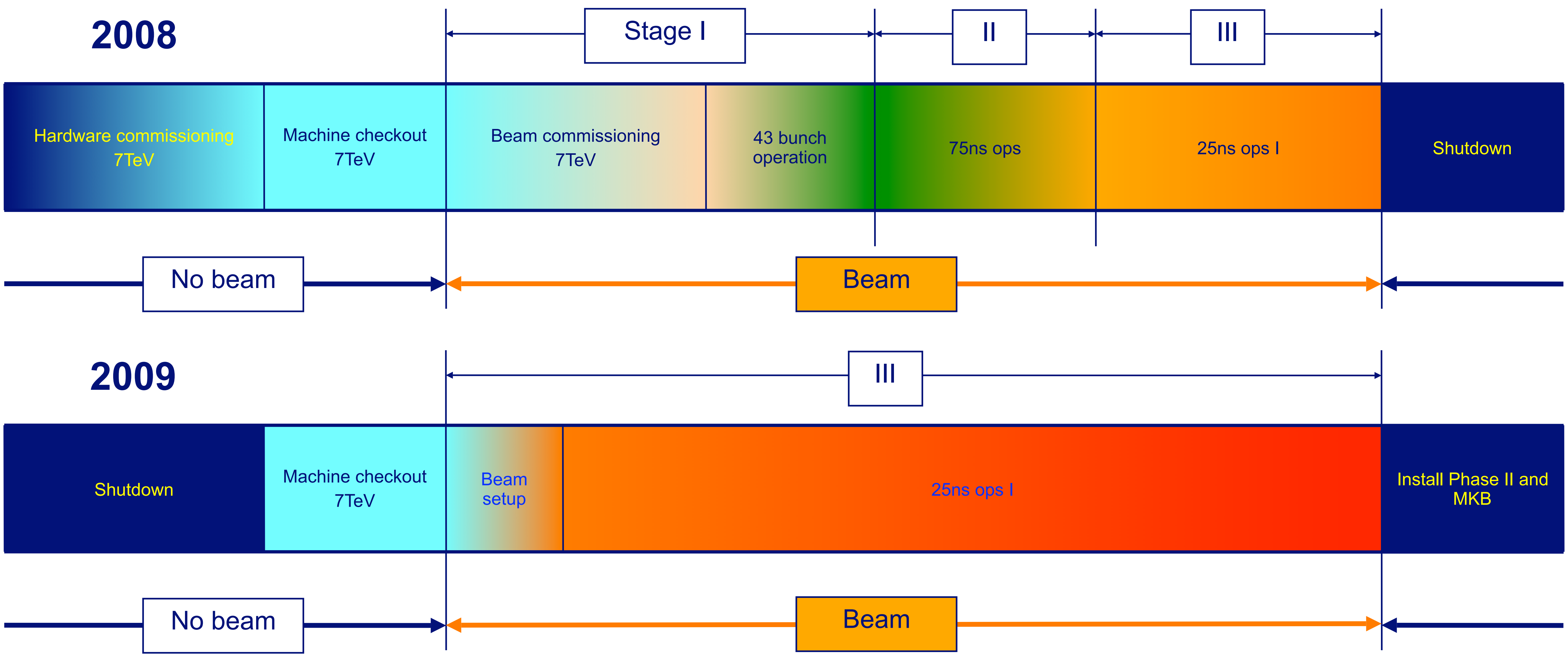


- At regime: ~6x10^6 s of pp physics running per year
  - ★ **~0.6 fb^{-1}/year if L=10^{32} cm^{-2}s^{-1}**
  - ★ **~6 fb^{-1}/year if L=10^{33} cm^{-2}s^{-1}**

- **Start-up trigger menu** for low-luminosity (10^{31} cm^{-2}s^{-1})
  - ★ less stringent requirements with lower thresholds without complex criteria (e.g. isolation on lepton final state)
  - ★ trigger item examples: e10, 2e5, γ20, 2γ15, μ10, 2μ4, j120

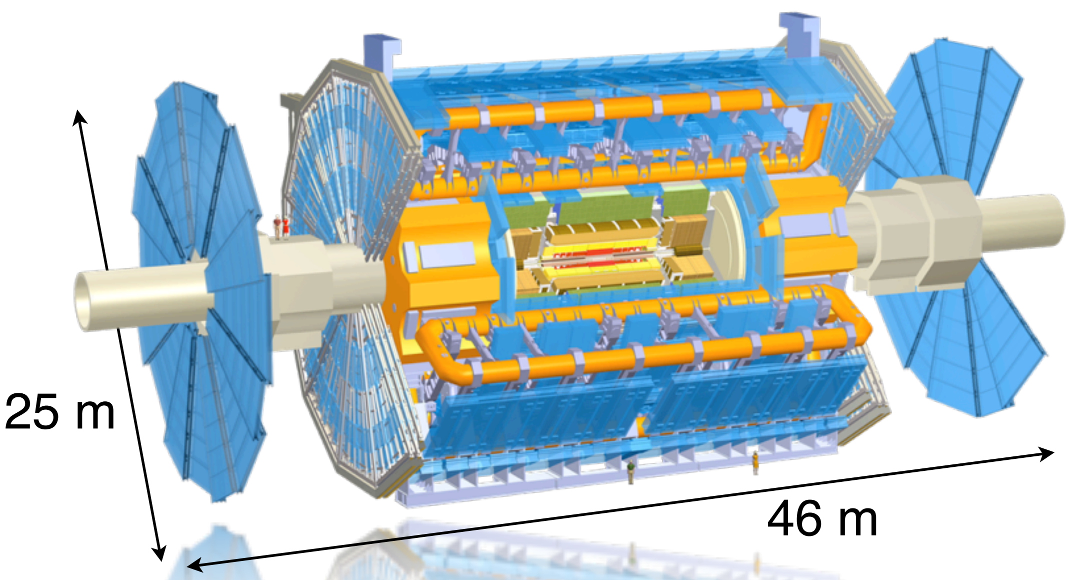
LHC schedule

- Current schedule
  - ★ End of May 2008: machine closed
  - ★ End of June 2008: beam commissioning at 7 TeV
  - ★ **1-2 months for colliding beams at 14 TeV**
    ⇒ aim for 10^{32} $cm^{-2}s^{-1}$ by end 2008 with ~100 pb^{-1} integrated luminosity



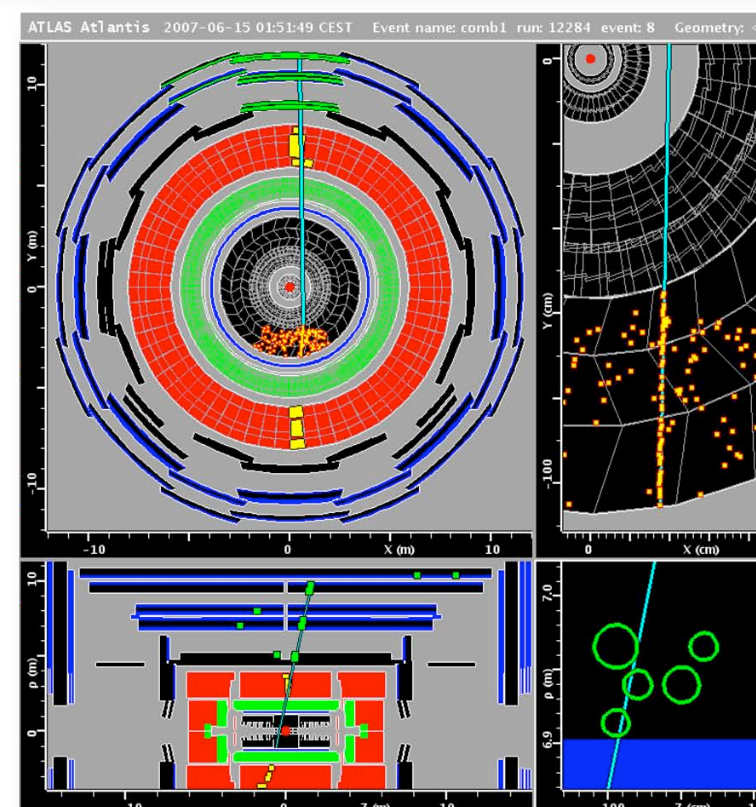
ATLAS

- The wide ATLAS physics programme (SM precision measurements, Higgs, SUSY, BSM, ...) puts **stringent requirements on the detector performance**



Detector component	resolution	η coverage
Tracking	$\sigma_{p_T}/p_T = 0.05\%\ p_T \oplus 1\%$	$\lvert\eta\rvert < 2.5$
EM calorimetry	$\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$	$\lvert\eta\rvert < 3.2$
Hadronic calorimetry (jets)		
barrel and end-cap	$\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$	$\lvert\eta\rvert < 3.2$
forward	$\sigma_E/E = 100\%/\sqrt{E} \oplus 10\%$	$3.1<\lvert\eta\rvert<4.9$
Muon spectrometer	$\sigma_{p_T}/p_T = 10\%/p_T$ @ p_T=1 TeV	$\lvert\eta\rvert < 2.7$

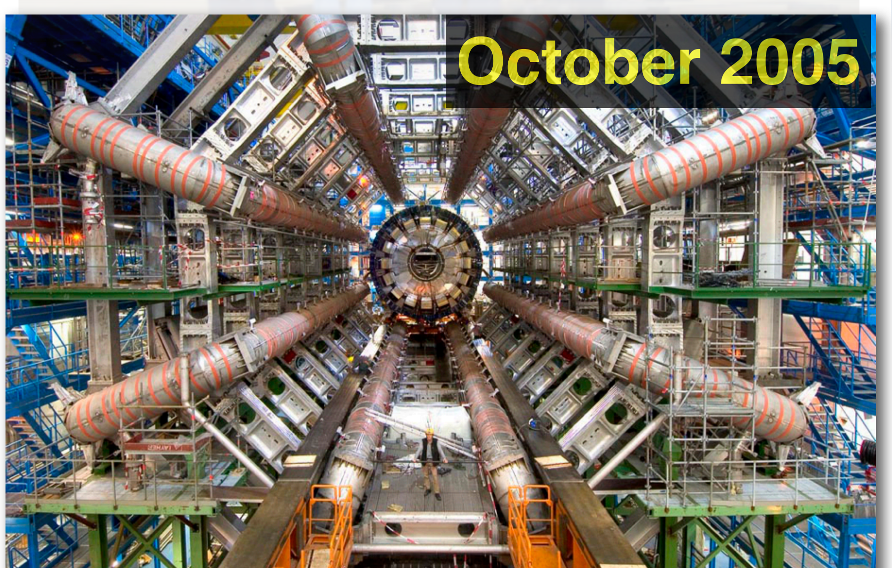
- **Installation** and **commissioning** are in well advanced status
  - ★ **Completion of detector installation and services**, only part of forward muon chambers and shieldings still in surface
  - ★ **Hardware commissioning** of all electronics components, control, safety systems
  - ★ **Full test of the data taking chain** with calibration and cosmic events: operation mode mimics ATLAS runs
  - ★ **Test of all online/offline/computing software**



- Get more details from **http://atlas.web.cern.ch**

ATLAS installation gallery

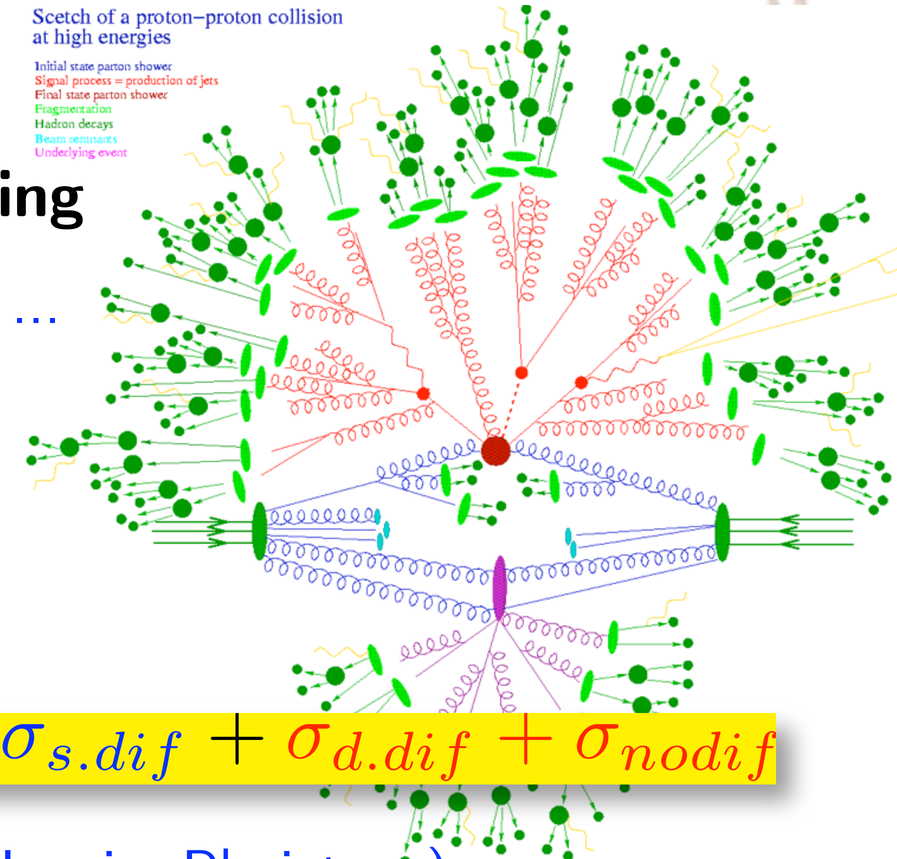
- The ATLAS detector installation is a long process started 5 years ago ....



- .... now we are ready to close detector for the LHC start-up !

Minimum Bias and Underlying Event

- Explore **fundamental aspects on p-p collisions**
- Calibration of major **physics tools** and **detector understanding**
  - ★ pile-up, energy/momentum scales, isolation properties, vertexing, ...
- **Tuning of Monte Carlo models**
  - ★ hard/soft interactions, ISR, FSR, MPI, ...



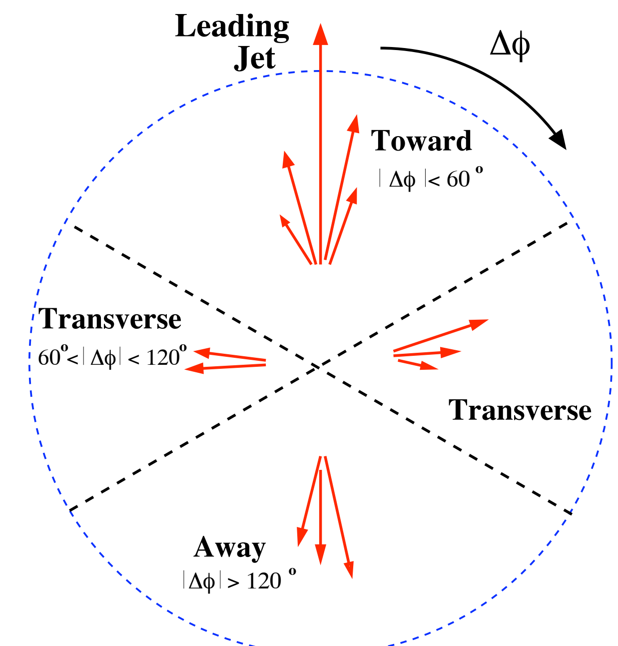
- **Minimum Bias** is defined as the *inelastic non-single diffractive*[1] part σ_{tot}

$$\sigma_{tot} = \sigma_{elas} + \sigma_{s.dif} + \sigma_{d.dif} + \sigma_{nodif}$$

  - ★ Dominated by soft interactions which needs modelling (**Pythia**, Herwig, Phojet, ...)

Process (pp collisions at √s = 14 TeV)	Cross section (mb)	
	Phojet1.12	Pythia6.2
non-diffractive	69.2	55.2
single-diffractive	11.2	14.3
double-diffractive	4.1	9.8
elastic	33.6	22.2

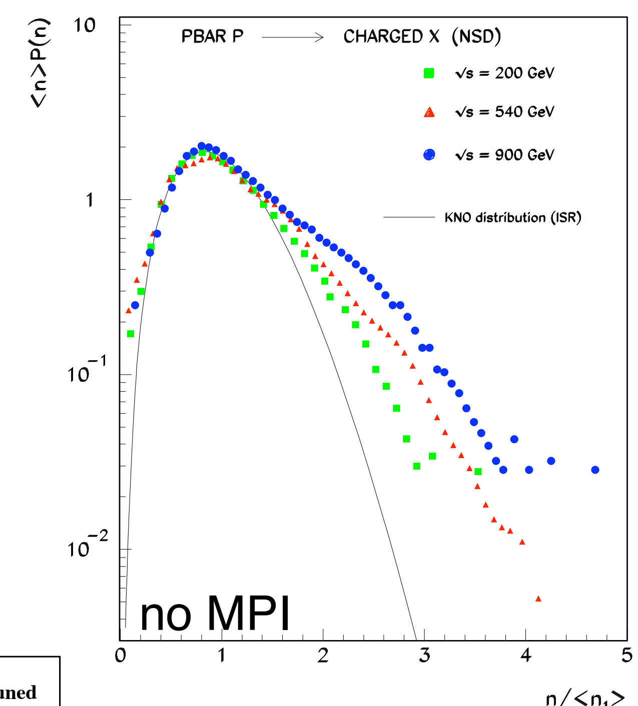
- **Underlying event** is defined as *everything except the outgoing hard scattered jets*
  - ★ Hard part from ISR, FSR + scattering particles
  - ★ Soft part from beam-beam remnants

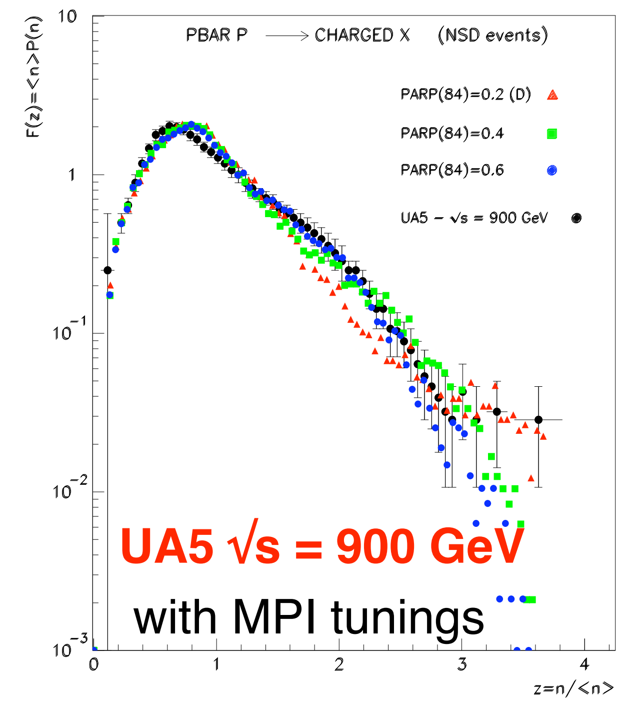


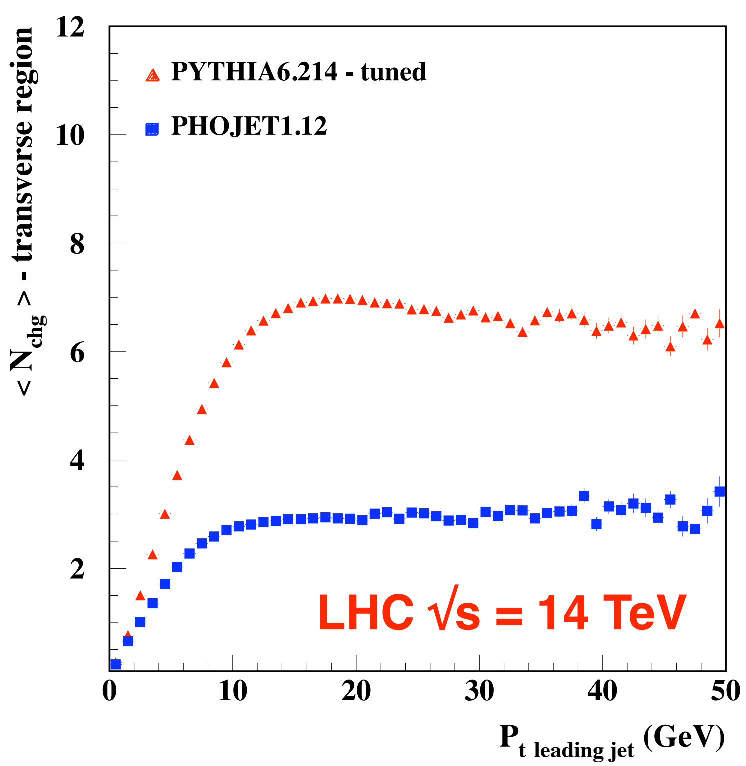
[1] ATLAS min-bias after trigger with ~50% $\sigma_{d.diff}$ and ~50% $\sigma_{s.diff}$ ⇒ further corrections are needed!

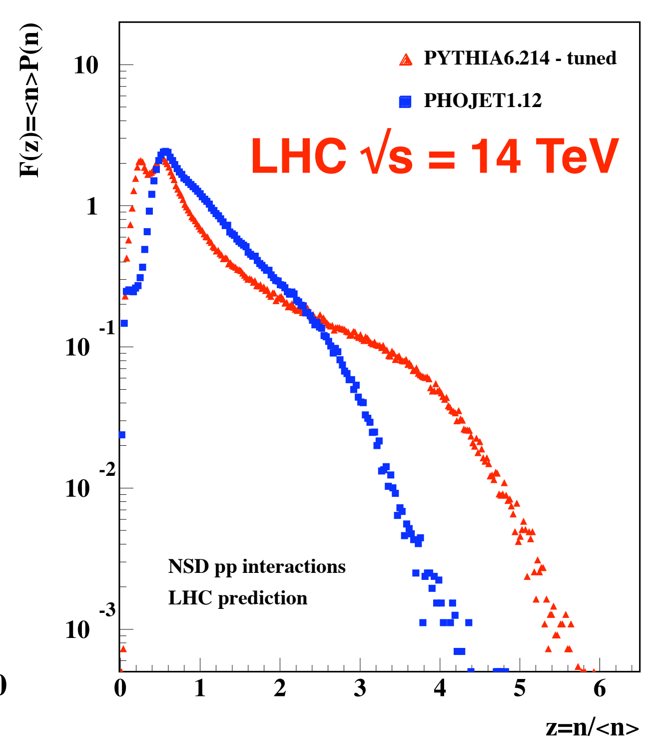
Minimum Bias and Underlying Event

- ISR, FSR, SPECTATORS are not enough to account from the observed multiplicities, p_T spectra, KNO scaling violation (AFS, UA1, CDF...) ⇒ **Multi Parton Interaction needed**
  - ★ MPI observed from double high-p_T scatterings at AFS, CDF and HERA photo-production
  - ★ complex scenario with smooth transition from soft to hard interactions and double gaussian matter distribution gives best agreement with data





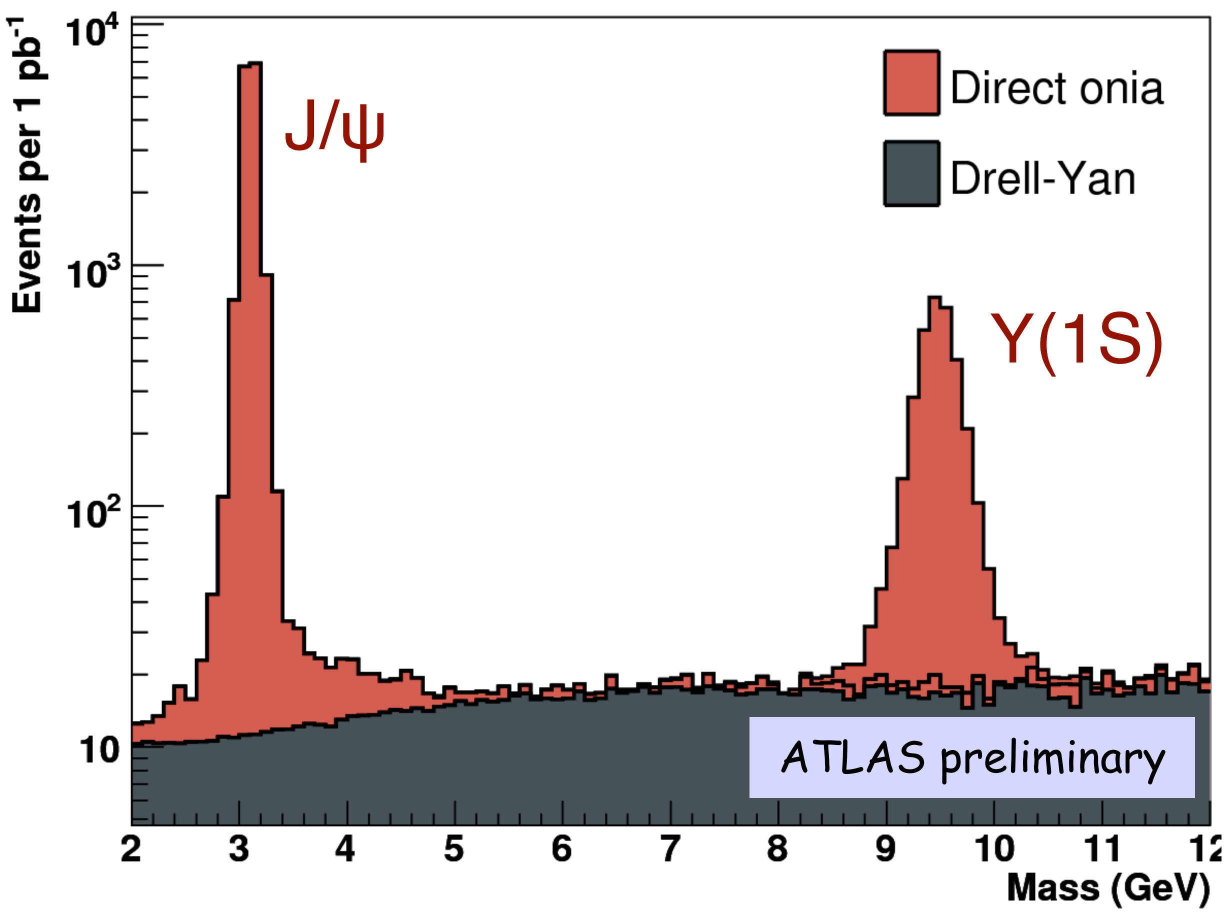




- LHC energy predictions differs of **~30% for MB and a factor ~2 for UE** (Pythia6.214-tuned vs. Phojet1.12)
  - ★ **LHC measurements will be crucial to select best physics model**

J/ψ and ϒ resonances

- J/ψ and ϒ produced with high cross sections ⇒ **very high statistics**
- After all cuts
  - ★ about 4200 (800) J/Ψ (ϒ) → μμ events per day at L = 10^{31} $cm^{-2}s^{-1}$
    (assuming roughly 30% machine times detector data taking efficiency)
  - ★ about 15600 (3100) event for 1 pb^{-1} integrated luminosity

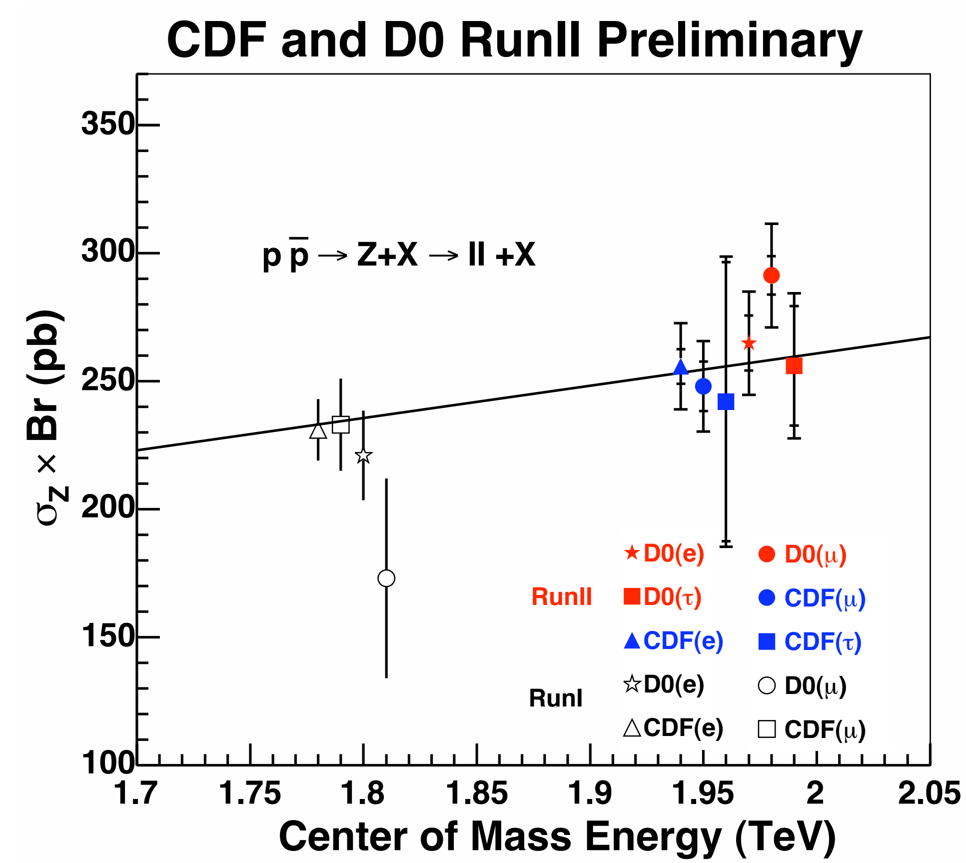


1 pb^{-1} = 3 days at 10^{31} $cm^{-2}s^{-1}$
with 30% efficiency

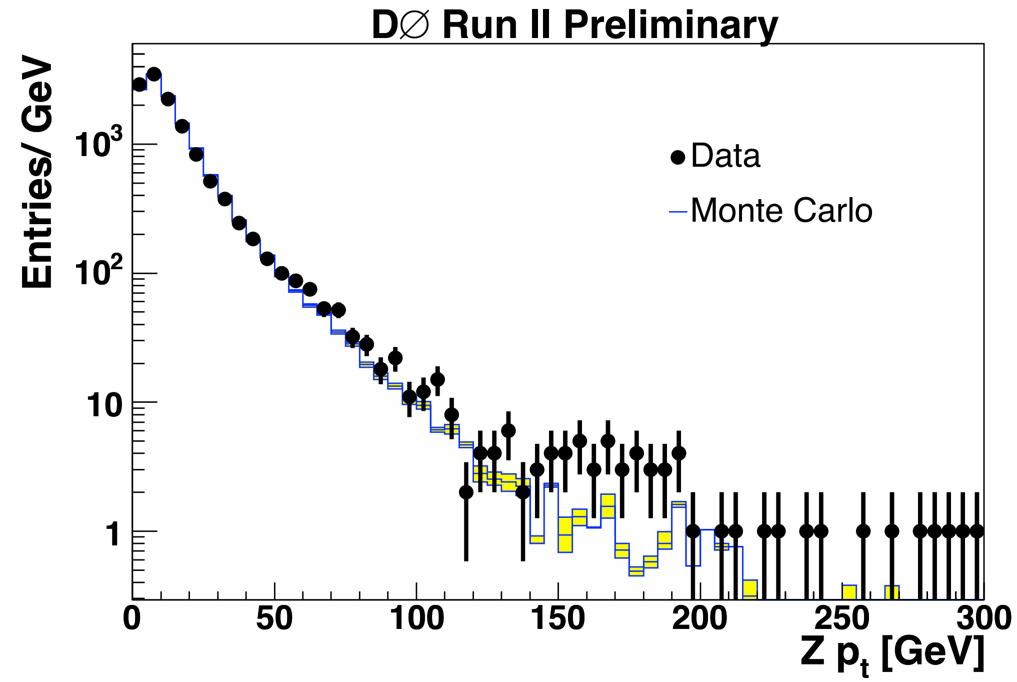
- **Input from data for very first detector calibration/understanding analysis**
  - ★ tracker momentum scale,
    trigger performance,
    detector efficiencies, sanity checks

W,Z physics

- Measurements of Electroweak observables
  - ★ **W,Z cross sections**
  - ★ W mass and width, $\sin^2\theta_{eff}$, A_{FB}
  - ★ W charge asymmetry $A(\eta_l)$ and differential cross sections
  - ★ Di-Boson productions
  - ★ to search for new physics looking at high invariant mass tail, ...

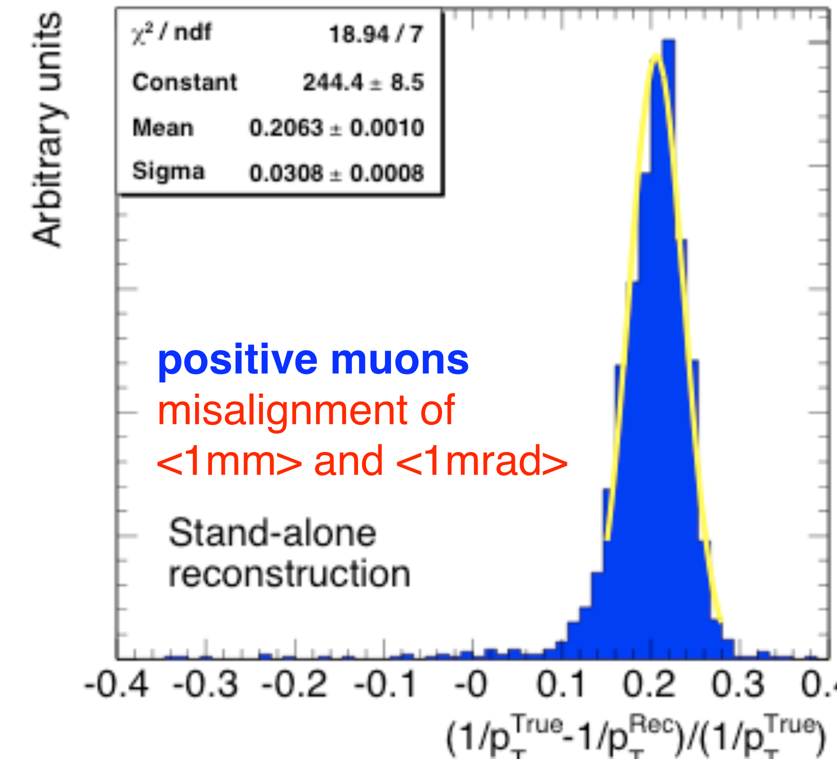


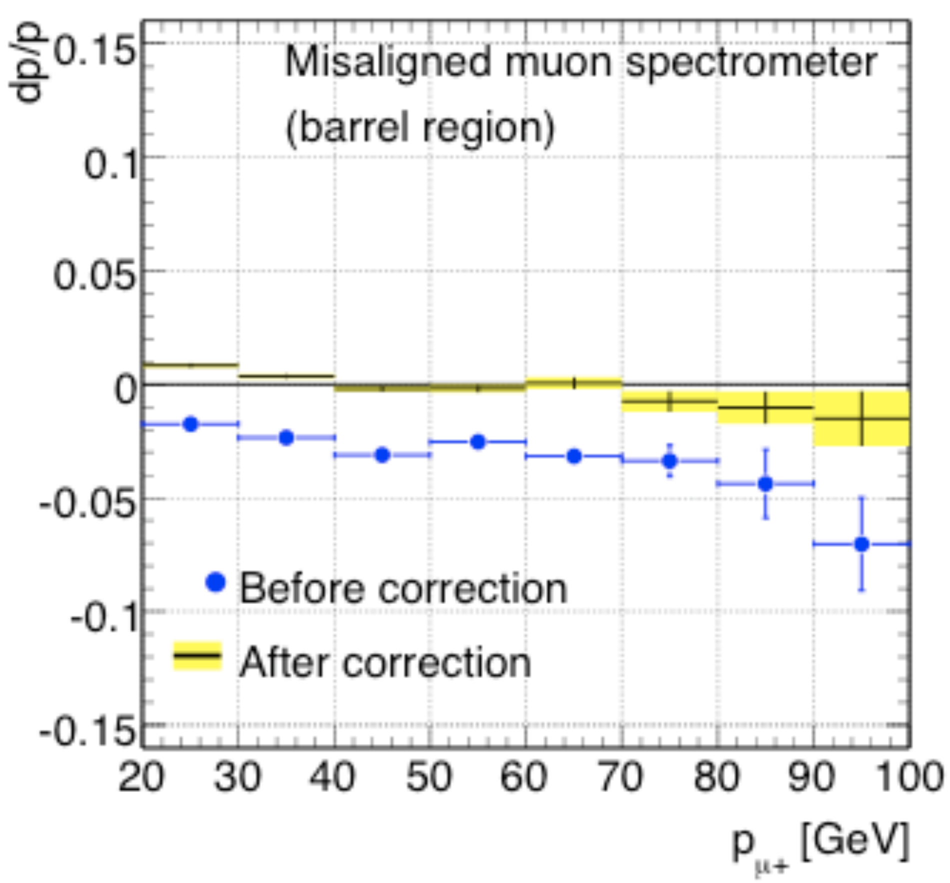
- Single W/Z boson production is a clean processes with large cross section useful also for
  - ★ **"Standard candles" for detector calibration/understanding**
  - ★ **constrain PDFs** looking at σ_{TOT}, W rapidity, ...
  - ★ monitor collider luminosity

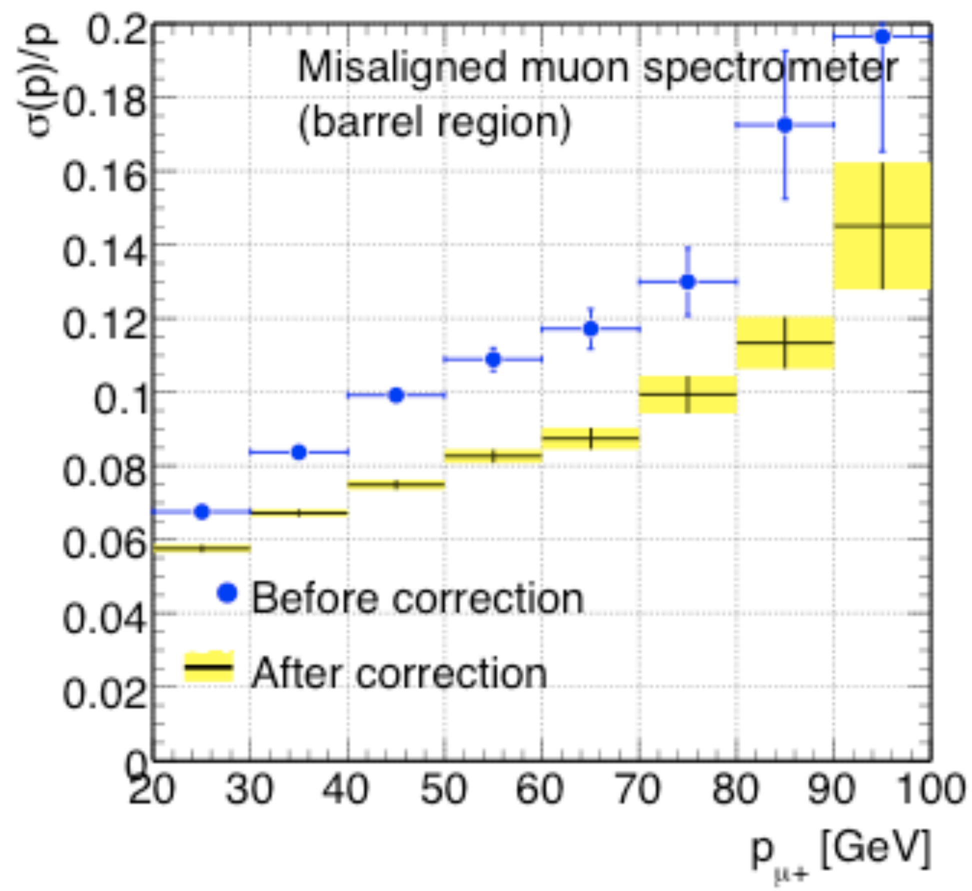


Alignment with $Z \to \mu^+\mu^-$

- Observation: **decrease of momentum resolution** is first order due to **sagitta shifts in spectrometer sectors**
  - ★ Z boson mass constraint
  - ★ Muon from Z boson reconstructed in tower A, have other partner muon in different tower, independently misaligned
  - ★ Results for **1 day at 10^{33} cm^{-2}s^{-1}**
  - ★ More statistics allow for in-sector corrections with further reduction of standard deviation

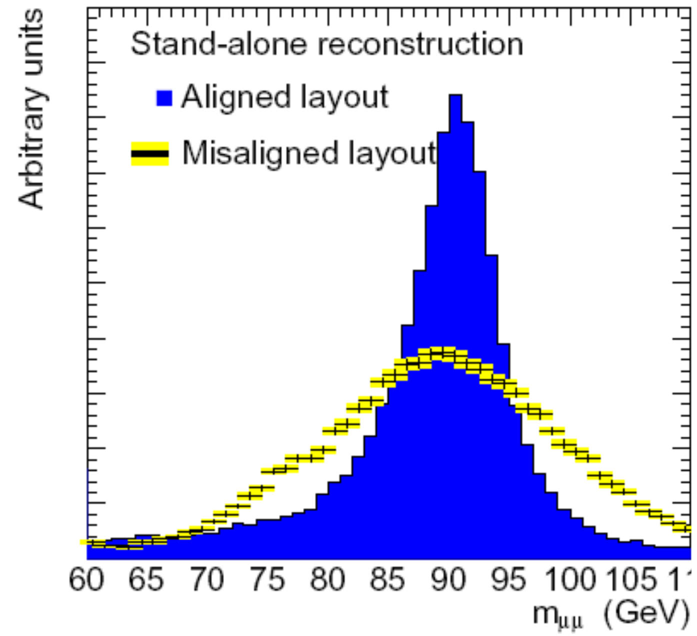


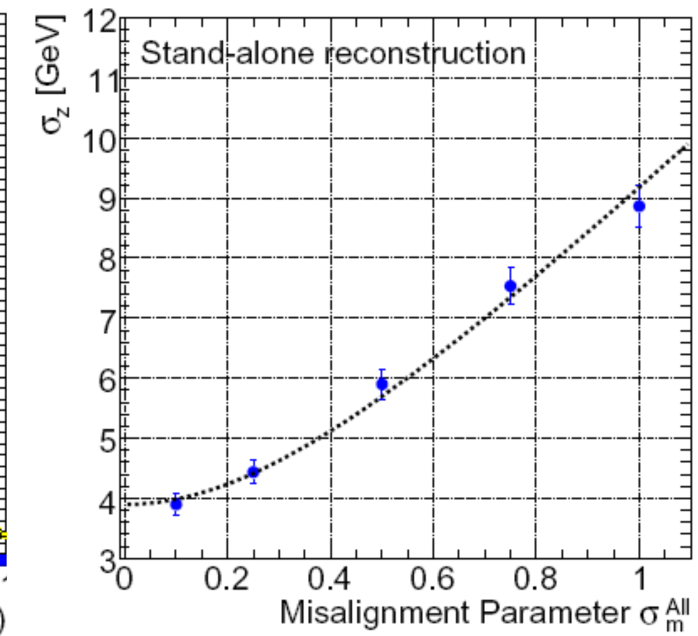




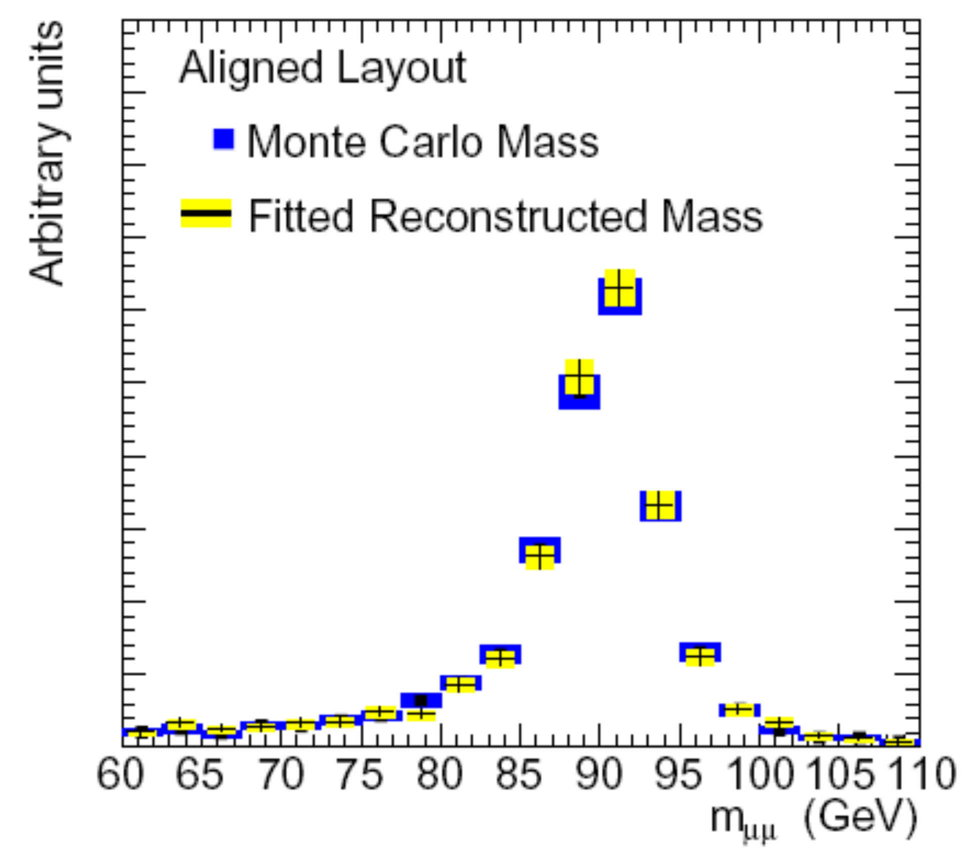
Momentum resolution from $Z \rightarrow \mu^+\mu^-$

- Determination of **momentum resolution** for muons from a Z boson decay
  - ★ Momentum range about 20-80 GeV
  - ★ Use peak position for momentum **scale**
  - ★ Use peak width for momentum **resolution**





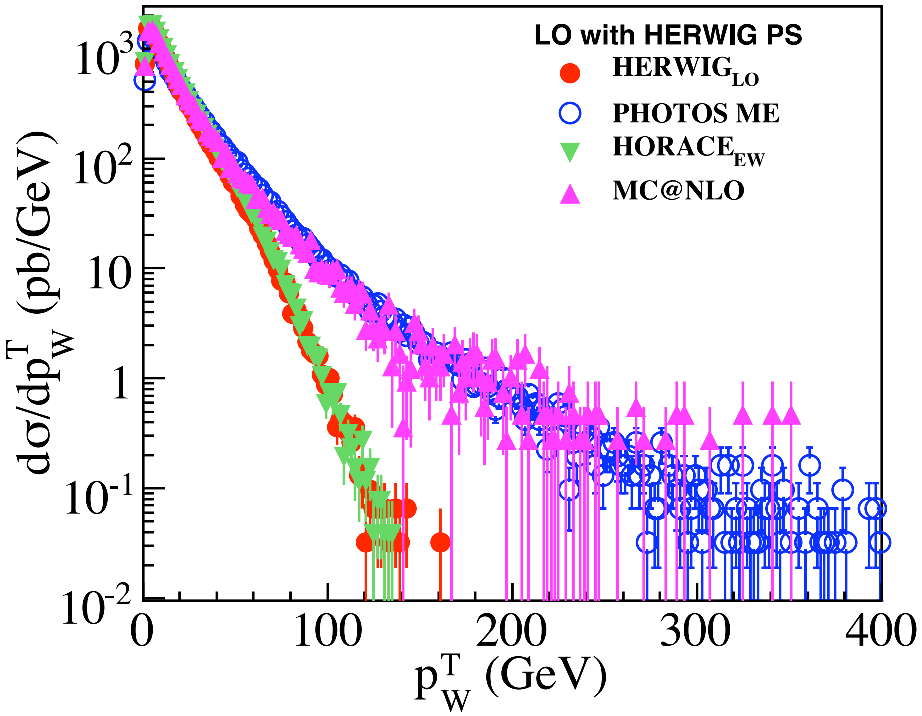
- Monte Carlo Spectra method
  - ★ "Adjust" reconstructed momentum to fit MC Z lineshape
    - **Momentum scale can be estimated to about 1%** using 30.000 events (for a misaligned geometry with a gaussian resolution of ~12%)
- Parametrized shape method
  - ★ As above but resolution is parametrized as a function
    - Generated momenta smeared with resolution parametrization
    - Momentum scale can be determined at 1% level for an aligned muon spectrometer layout

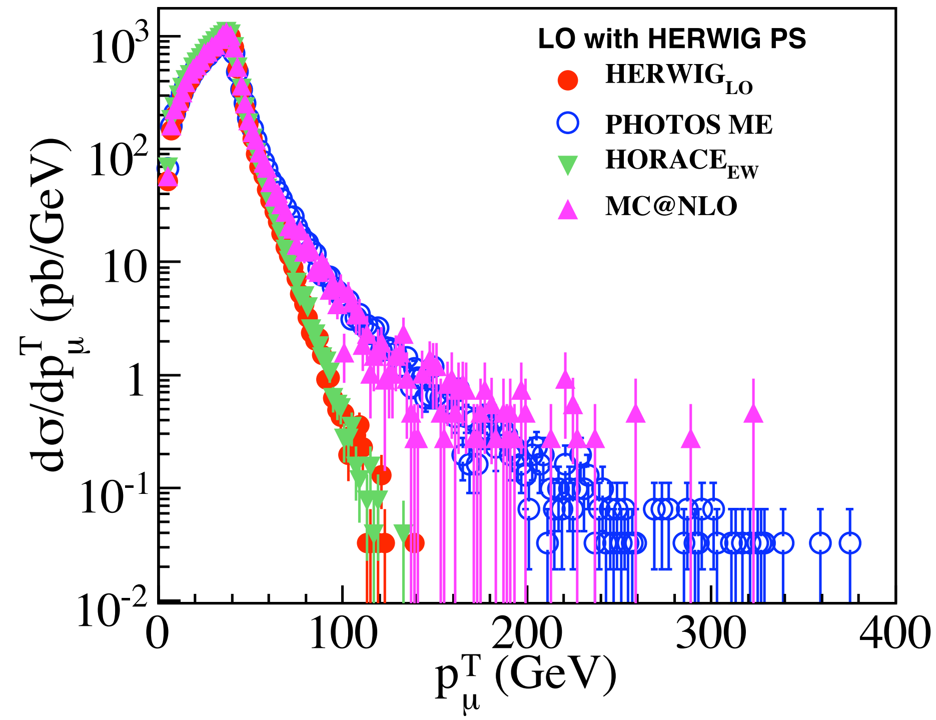


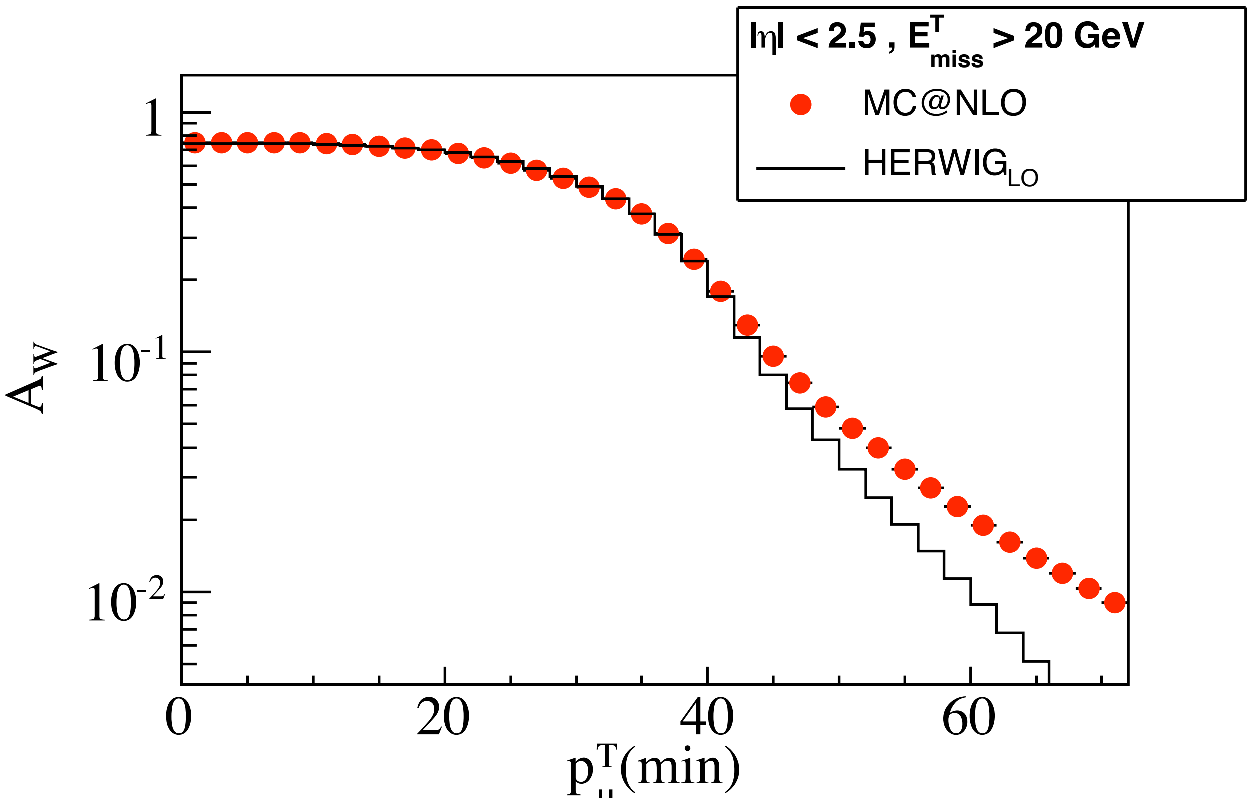
Acceptance studies in $W \to \mu\nu$

- Study the **acceptance corrections** due to geometrical coverage of detector and trigger

  - ★ Theoretical description with **NLO QCD** and **EW** corrections
  - ★ **MC@NLO**, **Photos** and **Horace** generators with **Herwig** parton shower





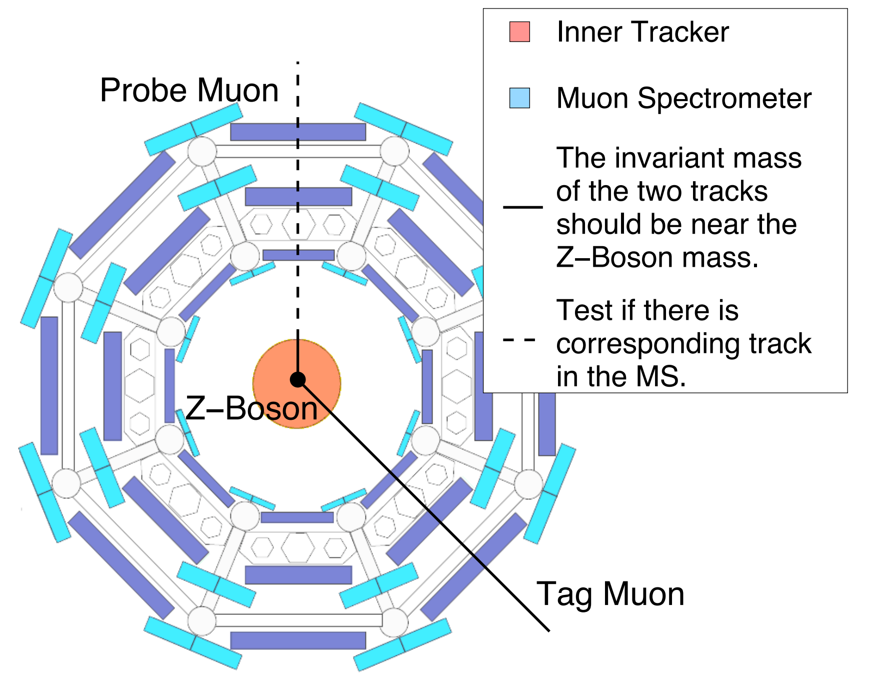


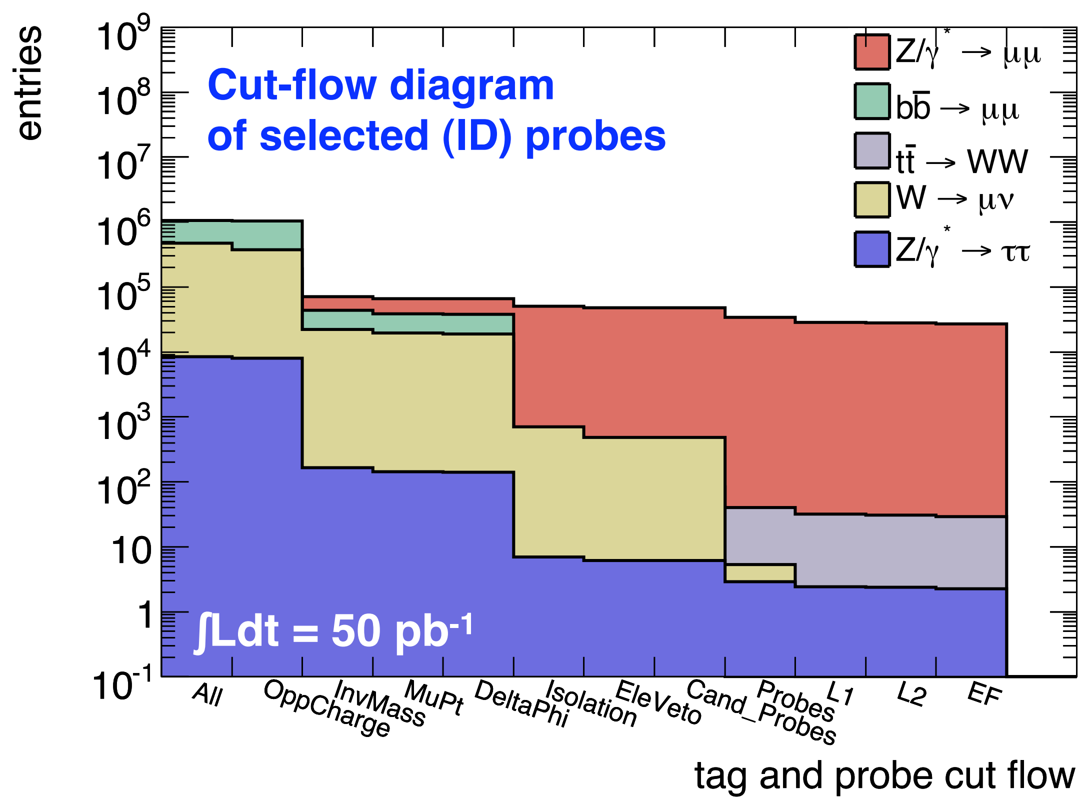
- Transverse momentum and pseudo-rapidity cumulative curves
  - ★ LO and NLO comparisons
  - ★ QCD corrections effect up to 2%
  - ★ lower impact from EW corrections (<1%)

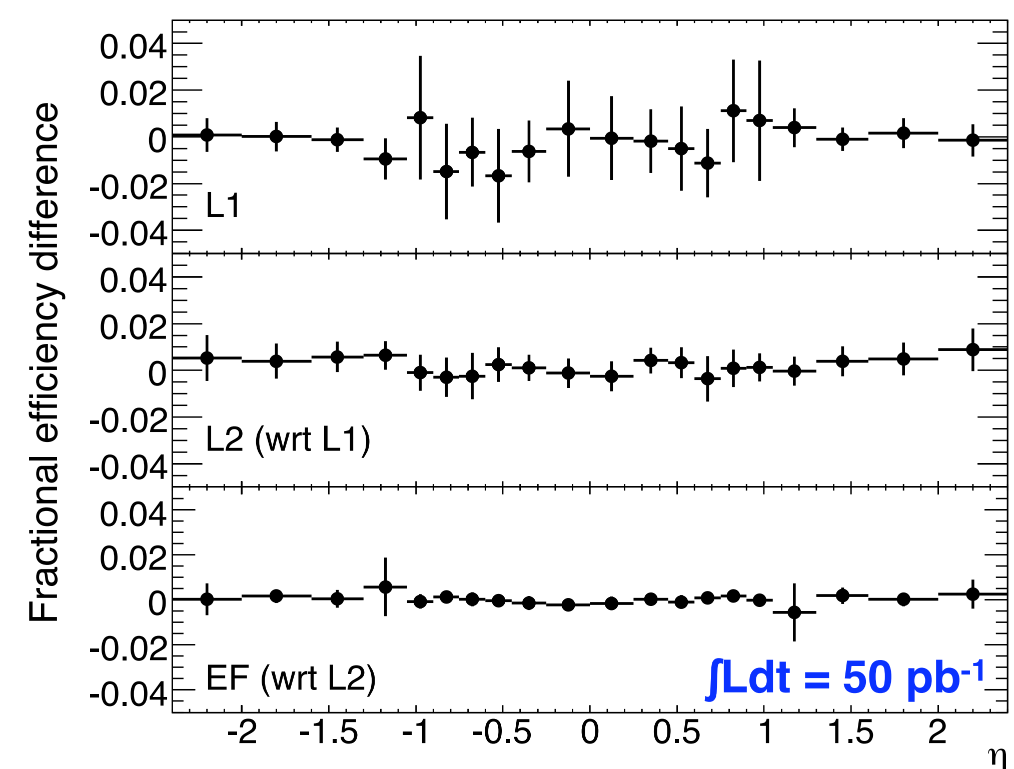
Trigger efficiency from $Z \to \mu^+\mu^-$

- Measurements referred to Inner Detector and Muon Spectrometer offline reconstruction
  $c_1 * c_2 < 0$, $81 < M_{\mu\mu} < 101$ GeV, $p_T > 20$ GeV
- Background rejection with kinematic and tight isolation cuts
  - ★ **ID** $\Rightarrow \Sigma N^{ID} < 4$, $\Sigma p_T^{ID} < 8$GeV,
  - ★ **Calo** $\Rightarrow E_{jet} < 15$GeV, $\Sigma E_T^{EM} < 6$GeV
- **Errors for 50 pb^{-1} ≈ 0.3% (stat) ± 0.5% (syst.) background contribution <0.1%**

Tag and Probe method

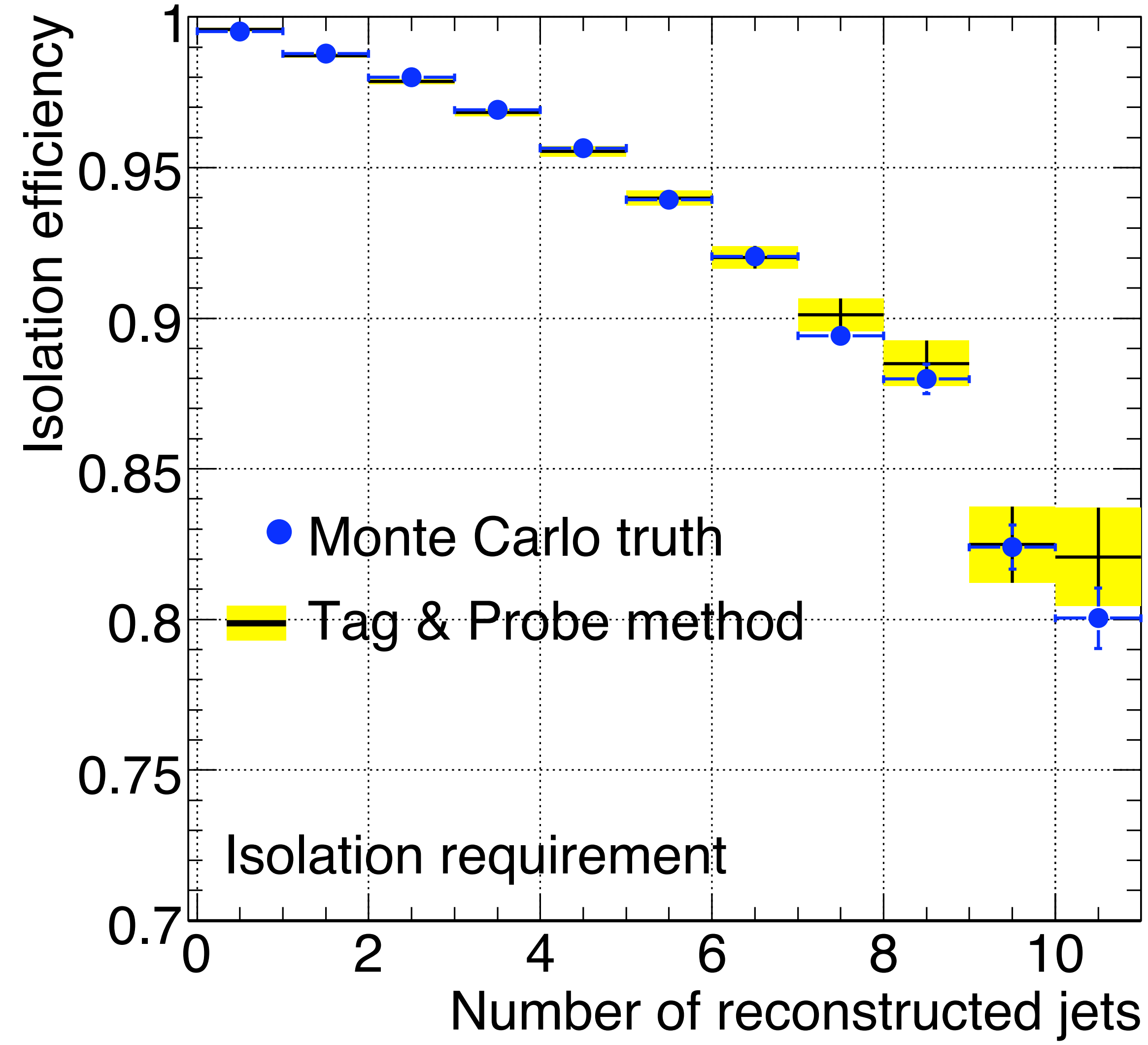






Further Systematic Uncertainties

- **Efficiency of isolation requirement** also determined via Tag and Probe
  - ★ Avoid correlations determining isolation efficiency versus number of reconstructed jets
  - ★ Early Data:
    - $\Delta\varepsilon_{iso}/\varepsilon_{iso}$=0.002(stat)±0.003(sys)
  - ★ High Luminosity Measurement:
    - $\Delta\varepsilon_{iso}/\varepsilon_{iso}$=0.000(stat)±0.001(sys)
- Main systematic from background
- **Efficiency of kinematic cuts** Uncertainty arises from uncertainty on momentum scale measurement
  - ★ $\varepsilon_{kinematic}$=0.906±0.003(sys)
- Uncertainty on **impact-parameter** and **misalignments** should be negligible



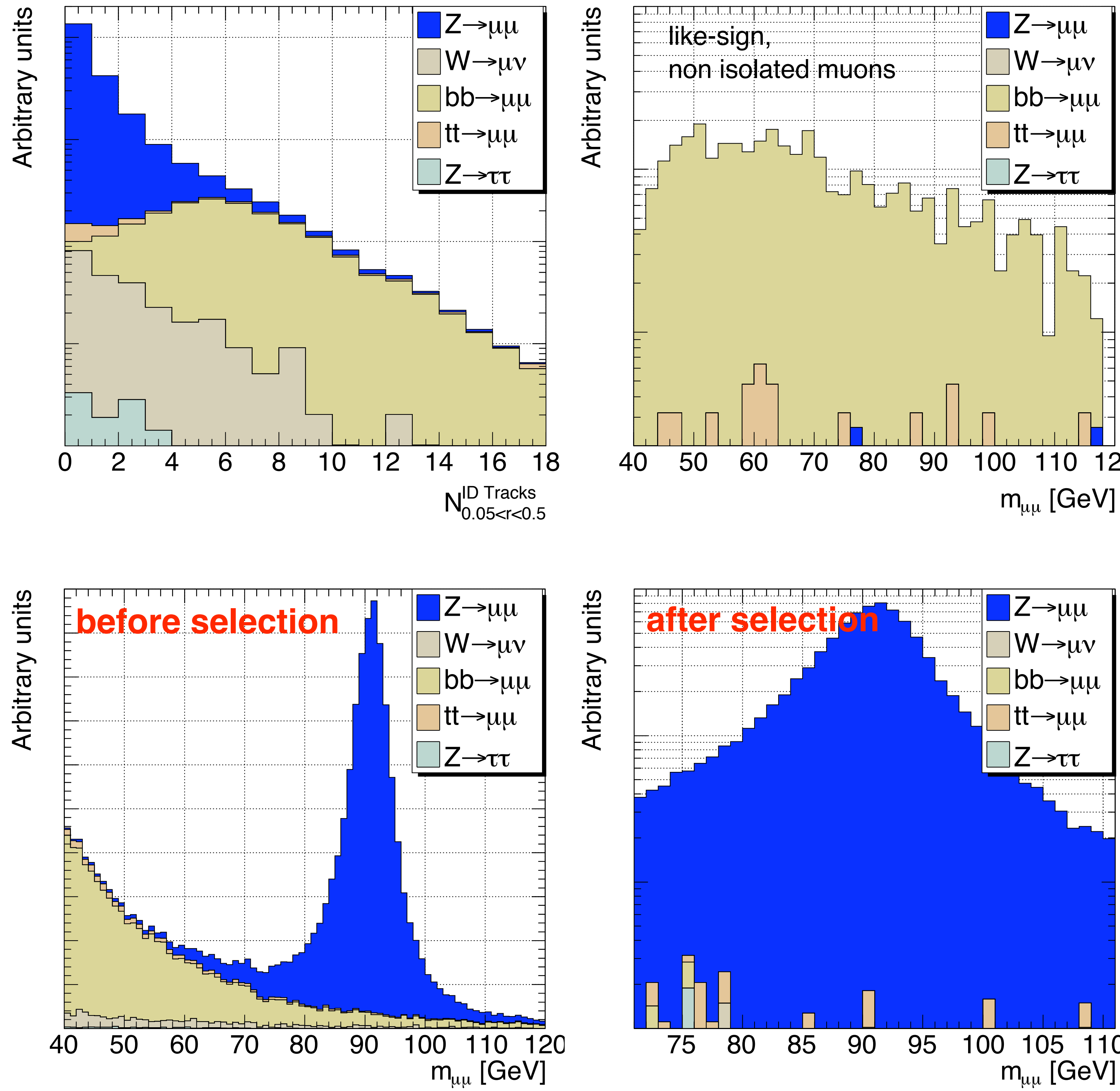
- **Impacts of PDFs** on the acceptance ≈1% uncertainty

Z→μ⁺μ⁻ cross section

- Selection based on Muon Spectrometer tracks in $|\eta| < 2.5$
  - ★ Isolation via Inner Detector only or also with Calorimeter-based cuts
- **QCD background from data**
  - ★ QCD enriched sample (like-sign) and normalization to signal selection from MC
- Background uncertainty expected ≈ 0.2%
- **$100 pb^{-1}$ overall uncertainty (%)**

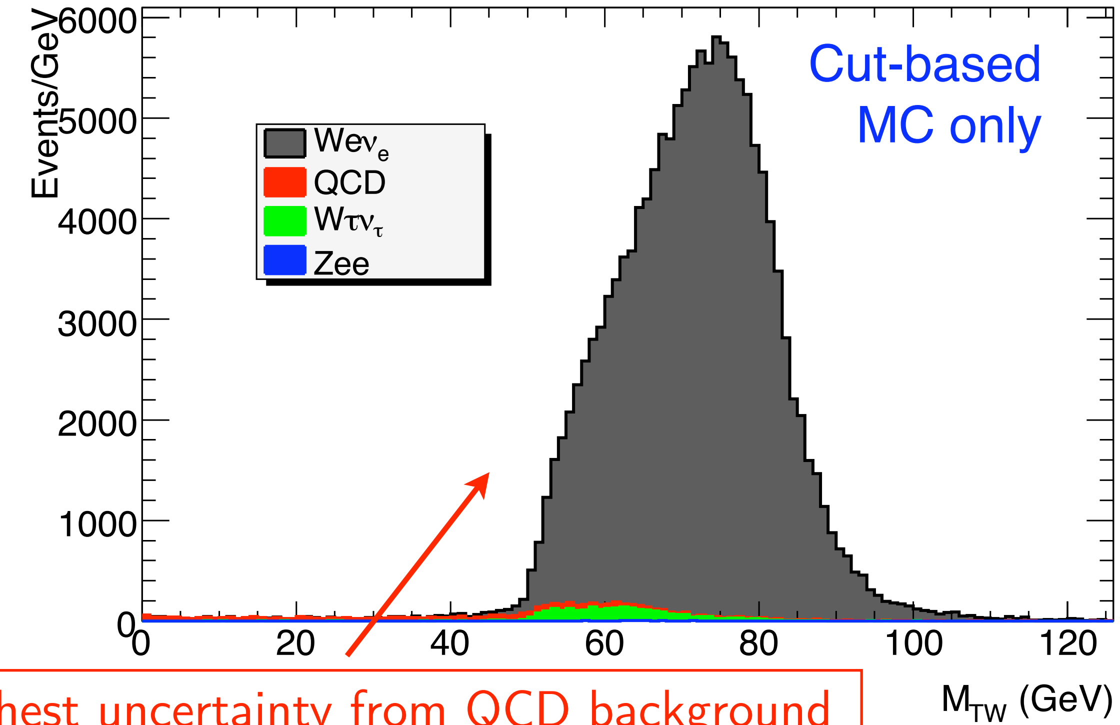
stat	exp syst	th syst[1]	lumi
±0.004	±0.008	±0.02	±0.1

[1] *theoretical syst. related to signal acceptance*

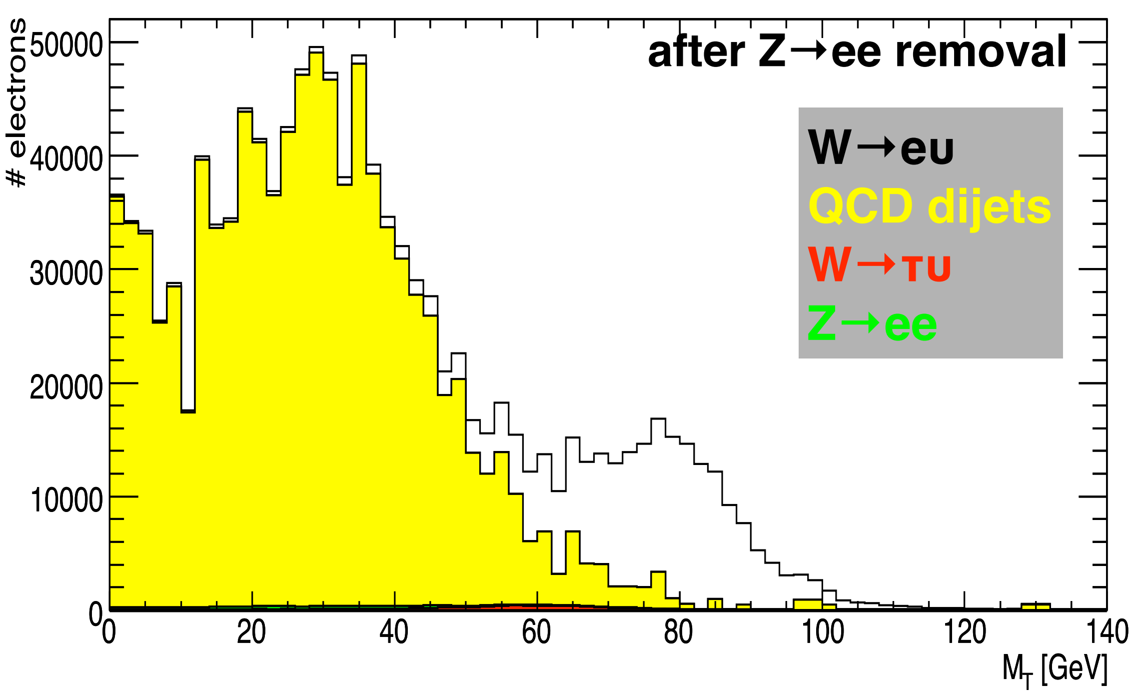


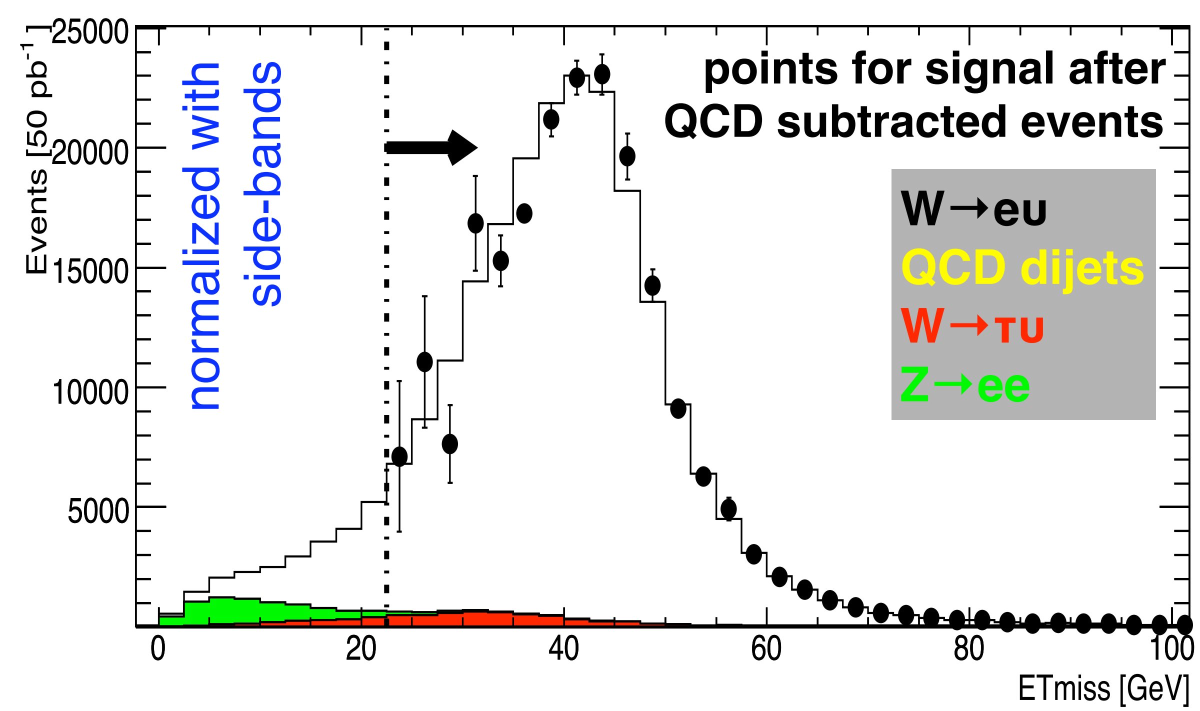
W→eν cross section

- **Cut-based selection:** 20 GeV electron trigger
  - ★ E_T>25 GeV, |η|<1.37 or 1.52<|η|<2.4
  - ★ E_T^{miss}>25 GeV + Jet veto: E_{jet}<30 GeV
- **Data driven selection**
  - ★ QCD background estimation from data
  - ★ Zee removed with $M_{e\text{-}e}$, $M_{e\text{-}\gamma}$, $M_{e\text{-}EMjet}$
  - ★ QCD enriched sample with same kinematical γ-selection ⇒ shape measurement



Highest uncertainty from QCD background

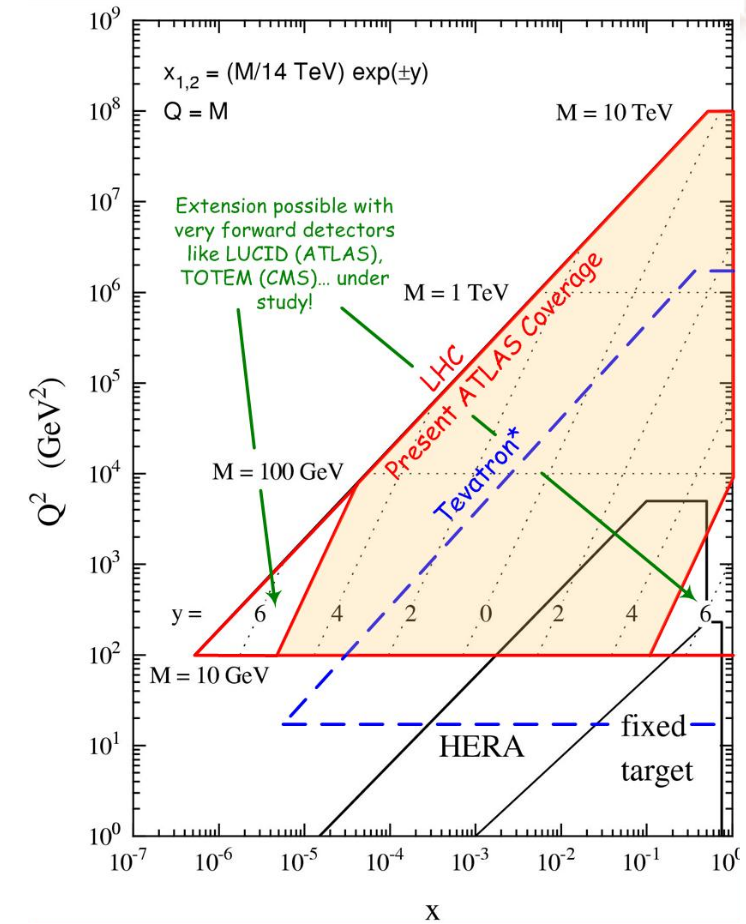


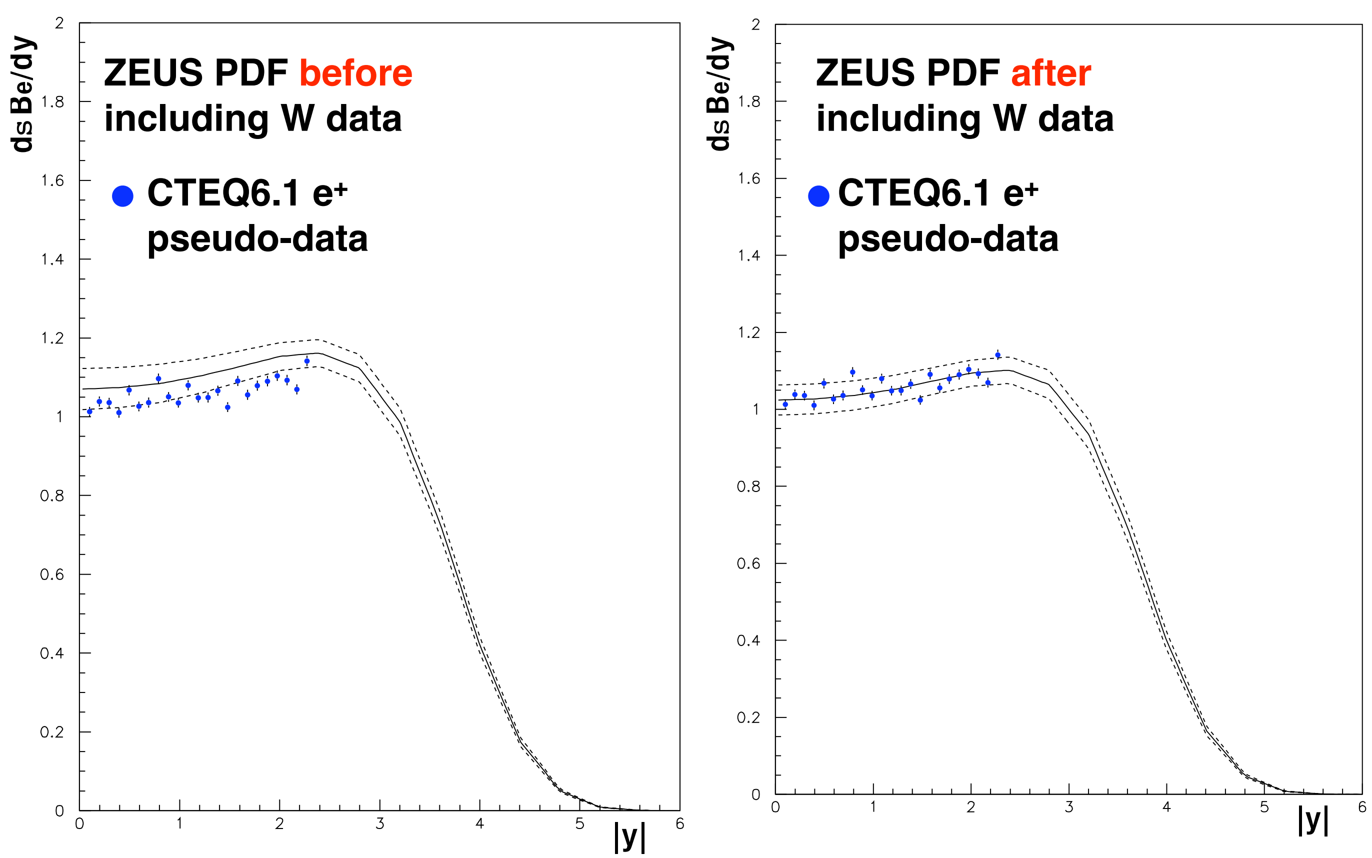


- **Overall uncertainty (%) for 50pb^{-1}: ±0.002(stat) ±0.05(ex syst) ± 0.1(lumi)**

PDF's constraints from W,Z

- At the **EW scale** LHC will explore **low-x partons**
  - ★ $10^{-4}<x<0.1$ over measurable rapidity range ($|y|<2.5$)
  - ★ Scattering between sea quarks: **gluon is the dominant parton**
- **Use of LHC data to improve precision on PDFs**
  include ATLAS W rapidity "pseudo-data" in global PDF fits
  - ★ **Simulate real experimental conditions:** 1M "data" sample with CTEQ6.1 PDF + detector simulation included (+4% exp error) in the global ZEUS PDF fit (with det./gen. level corrections).



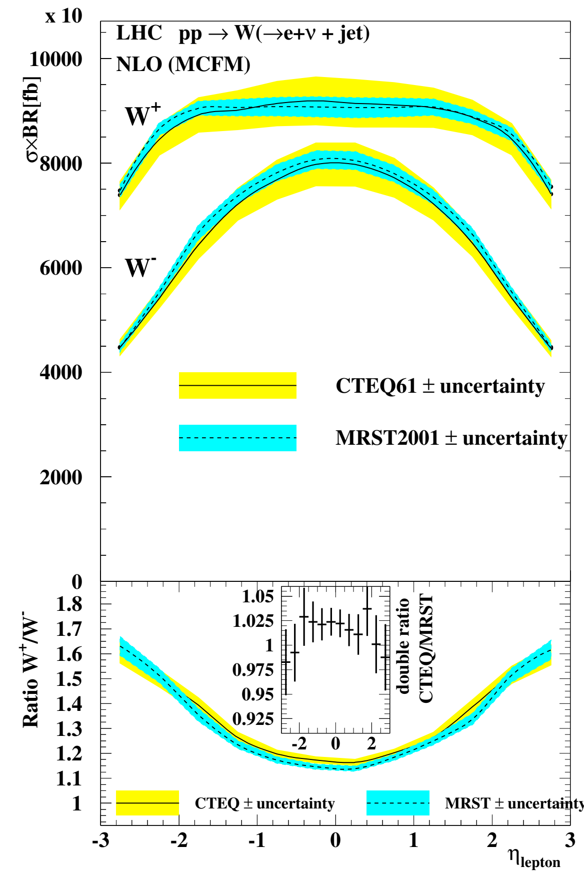


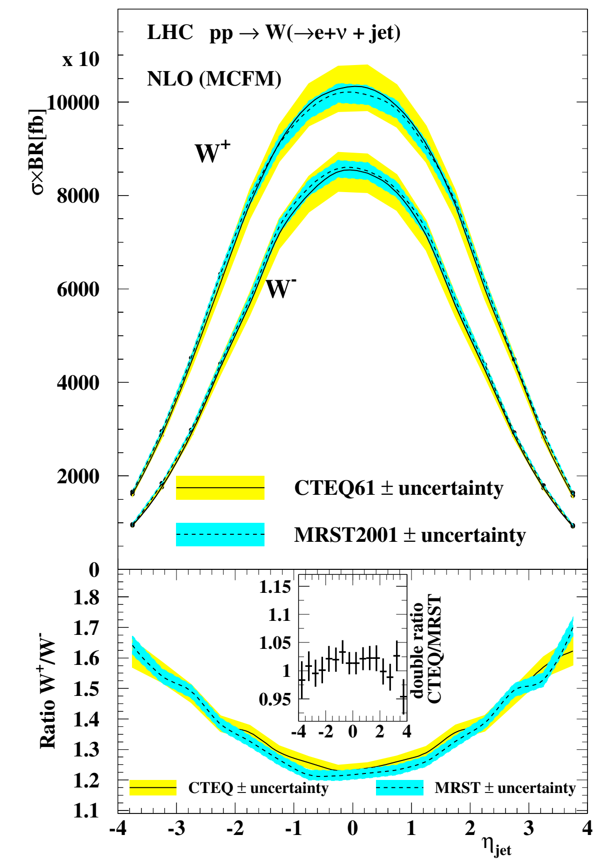
- **low-x gluon** distribution determined by **shape parameter λ**, $xg(x)\sim x^{-\lambda}$
  - ★ BEFORE **λ = -0.199 ± 0.046**
  - ★ AFTER **λ = -0.186 ± 0.027**
- **41% error reduction with 100 pb^{-1} of data**

Normalization free
⇒ luminosity independent

PDF's constraints from W,Z + jets

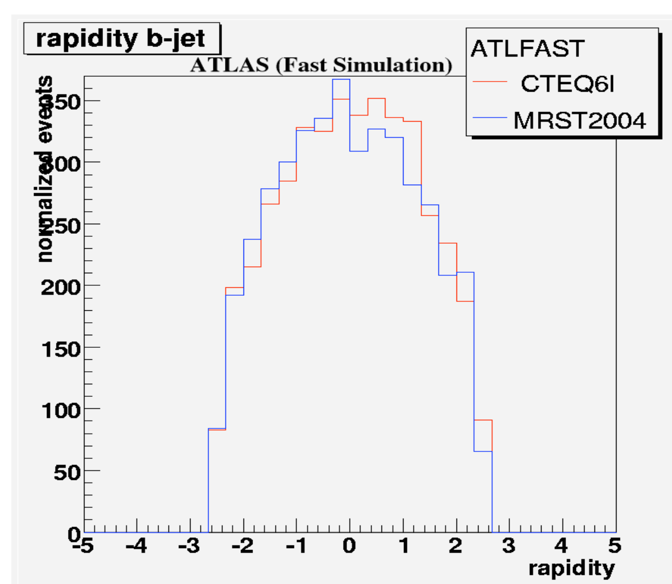
- In the inclusive production of **W/Z + jets** at least one reconstructed jet is required
  - ★ given the presence of an hard jet ($p_T > 25$ GeV) it can be expected that PDFs are different from single boson production
  - ★ Can contribute to better understanding of gluon and heavy quark (s,c,b) distributions (also of course as test for pQCD)

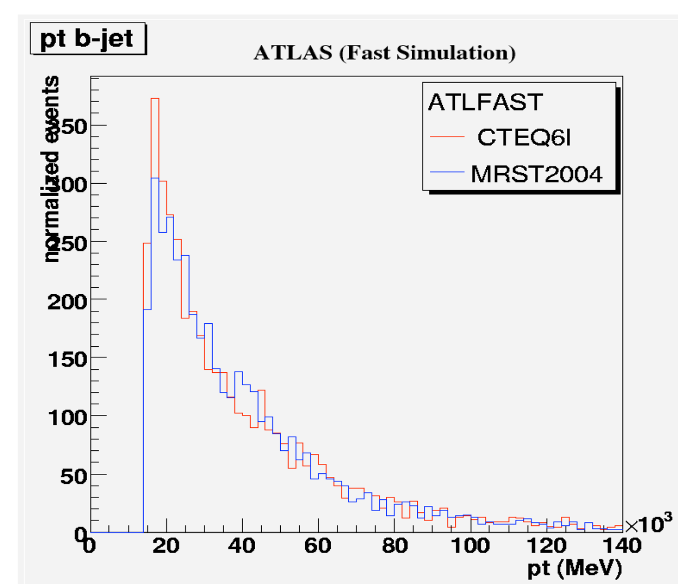




- **Production with b-jet:** main from gb → Zb
  σ(@LHC, p_T>15GeV and $|\eta|$<2.5) = 1040 pb
  - ★ bb → Z contributes up to %5 to σ_{tot}
  - ★ 1% $\delta\sigma_{tot}$ ⇒ 20% precision on b-PDFs

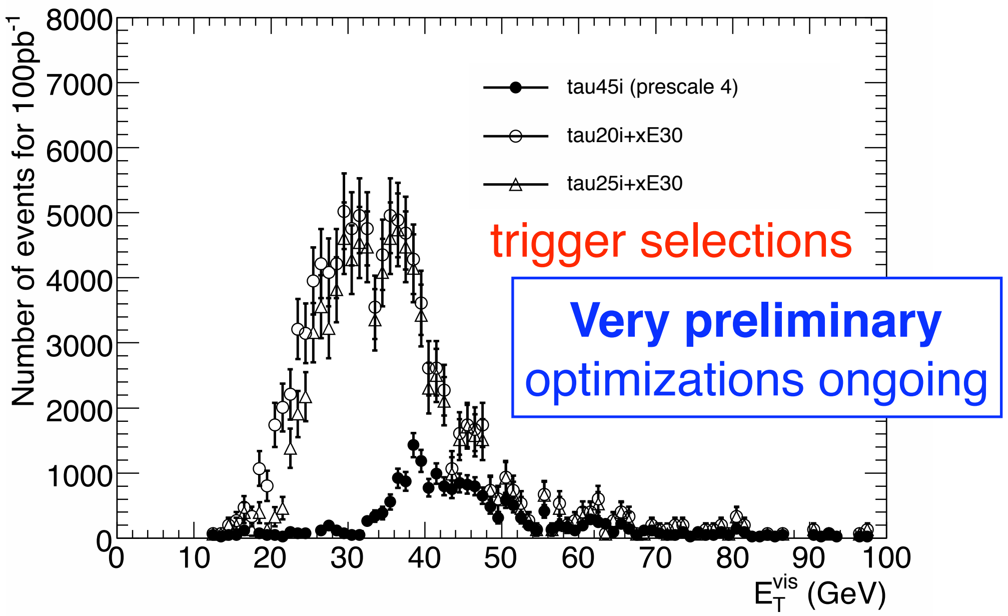
- **Z→μμ + b-jet** preliminary analysis
  - ★ 5% low-p_T regions differences from PDFs
  - ★ if systematics can be kept below, measurement can be sensitive to b-PDF

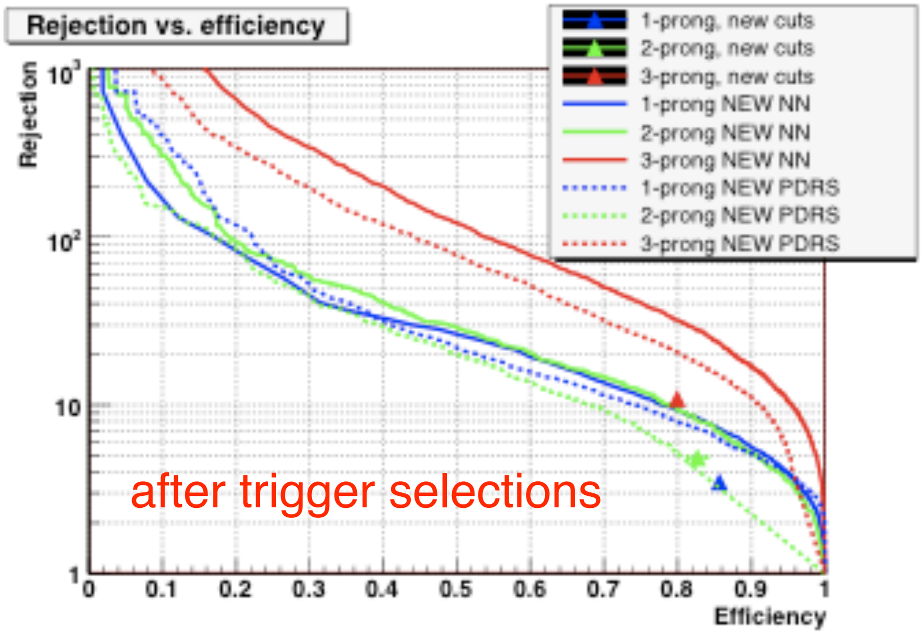




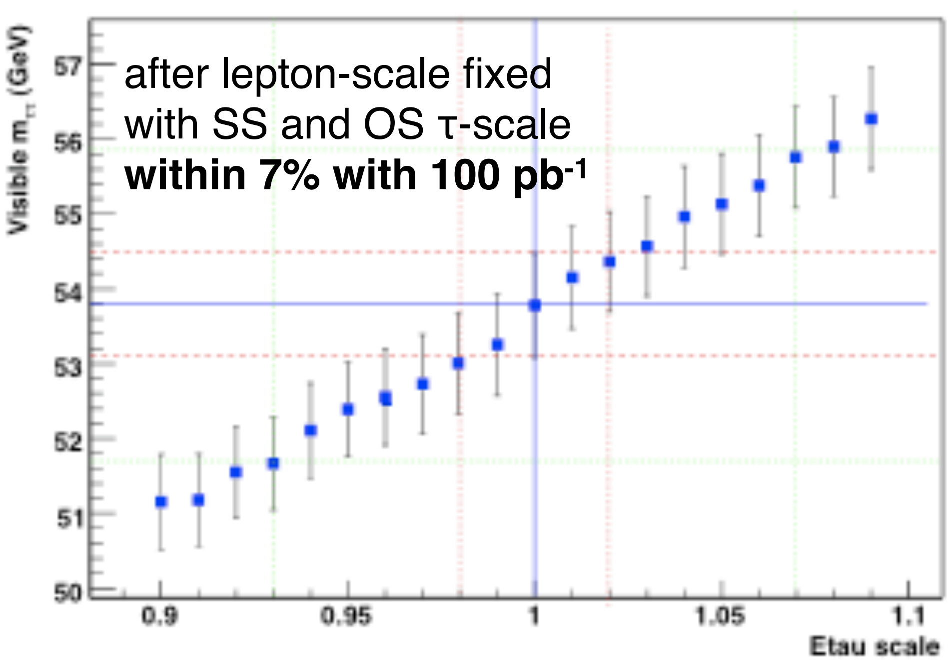
W,Z τ physics

- Measurement of **τ identification efficiency**, **simulation tuning**, **cross section analysis**
  - ★ **W→τν with hadronic τ decays:** τ trigger optimization (Z→ττ unbiased sample) and offline selection tuning (e,μ vetoes, rejection of QCD jets)





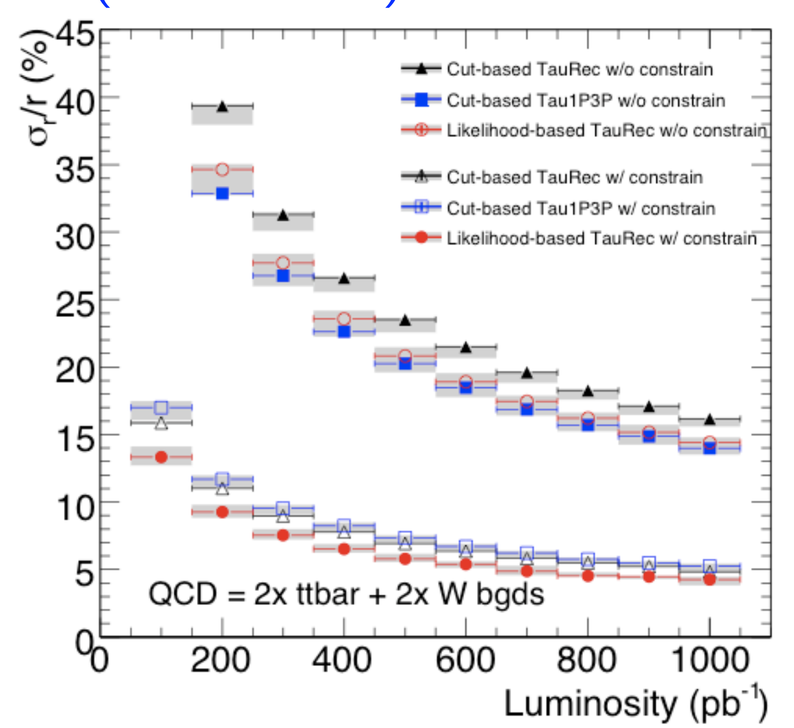
  - ★ **Z→ττ:** lower rate but more robust selection and background control (SS and OS)



QCD background rejection

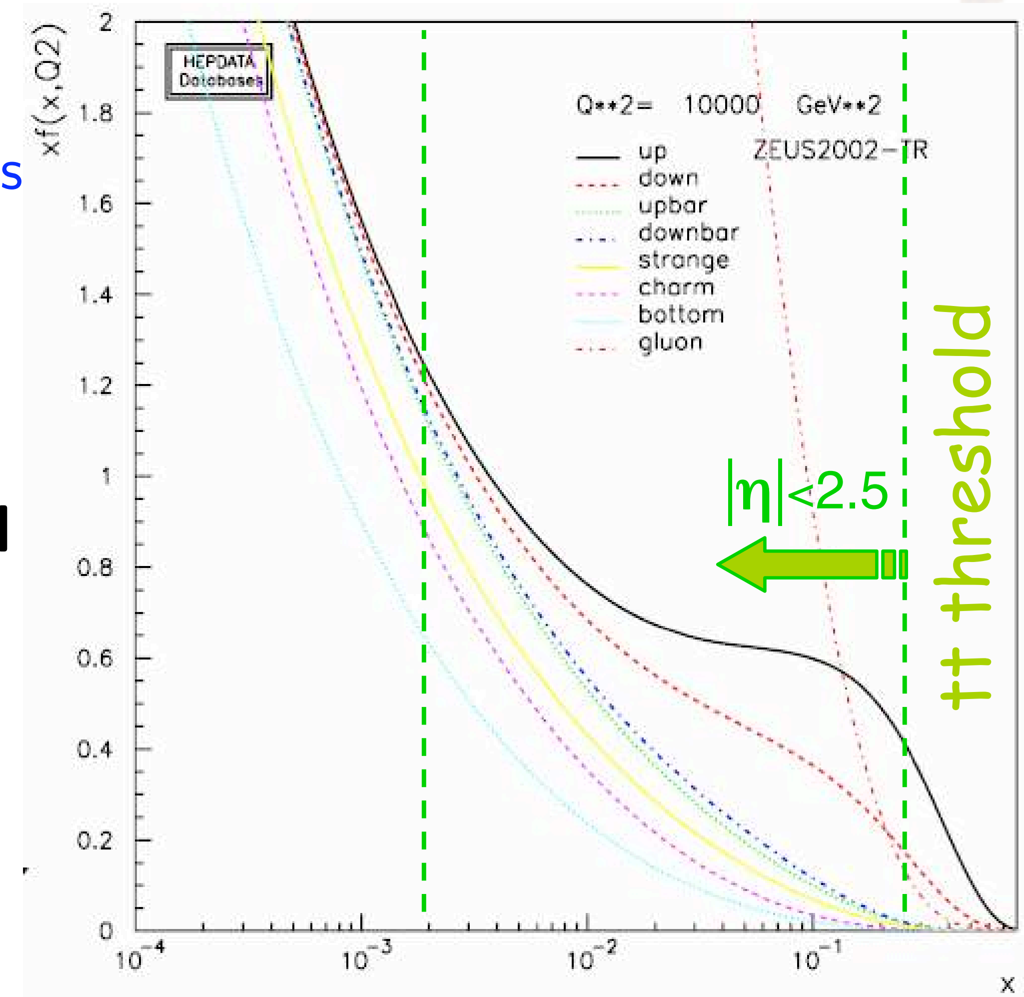
e.g. looking at isolation outside τ-id cone and re-calculating track multiplicity

fraction of τ events for cross section measurement by likelihood fit (red points)



Top production

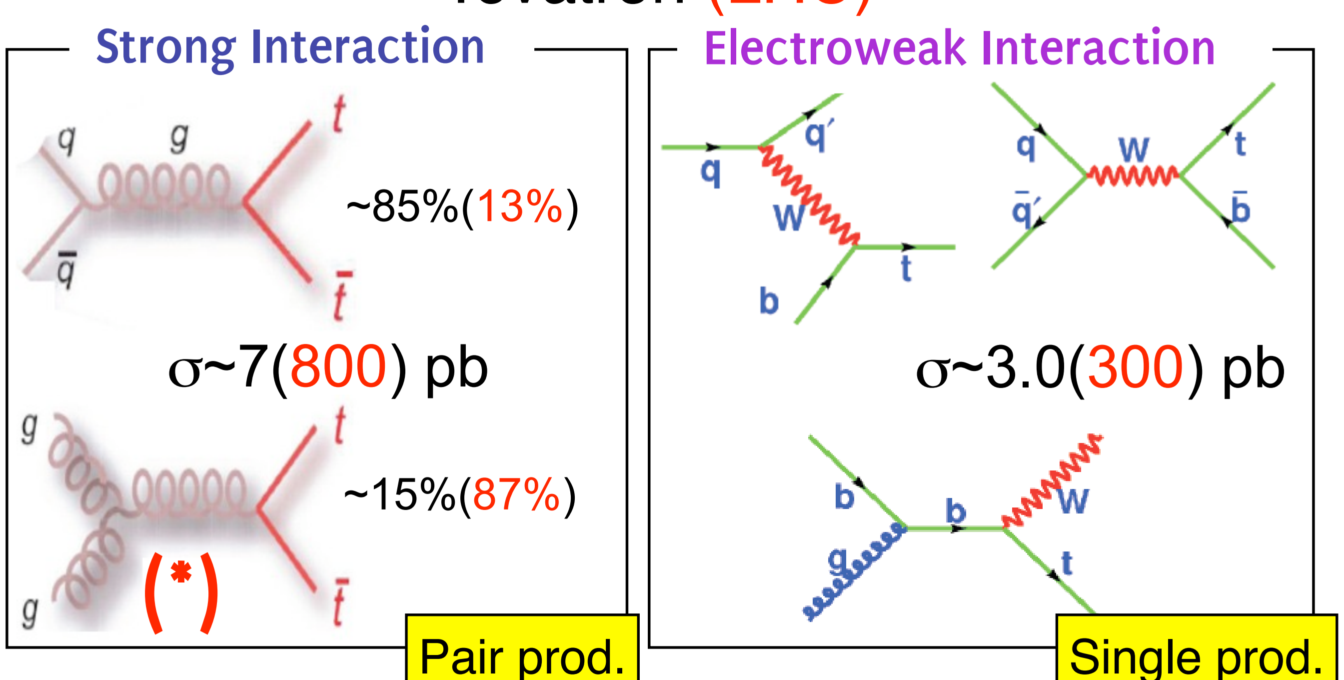
- **Top production at LHC**
  - ★ a real **top "factory"**: expected about $8{\cdot}10^6$ top pair events per experiment in a 10^{33} year (2 events/s !)
  - ★ a factor 10 increase in subsequent years



- Parton kinematics region **(low-x) is gluon dominated**

$$x_1 x_2 = \frac{\hat{s}}{S} \geq \frac{4m_t^2}{S} \simeq 6 \cdot 10^{-4}$$

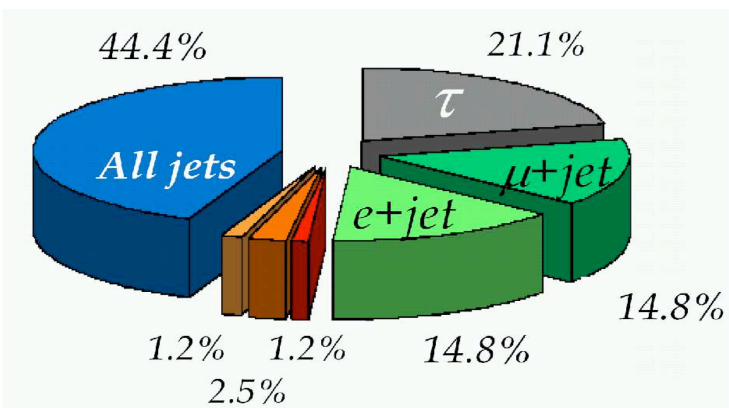
Tevatron (LHC)



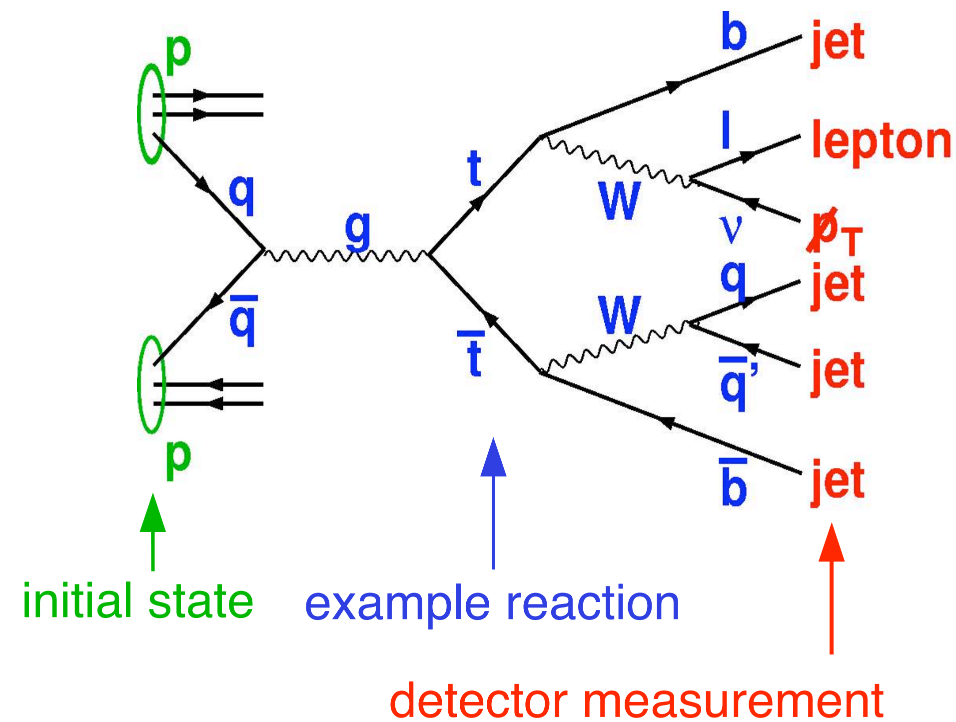
- Low statistics errors already in early phases, **systematics are dominant**
  - ★ collider luminosity
  - ★ PDF's uncertainty (gluon distribution)
  - ★ detector systematic effects

Top pairs decay

- **Event topologies**
  - Top decays predominantly in W+b quark
  - Experimental signatures are determined by **W decay**



5% di-leptons
30% lepton+jets
44% all hadronic
21% with τ decay



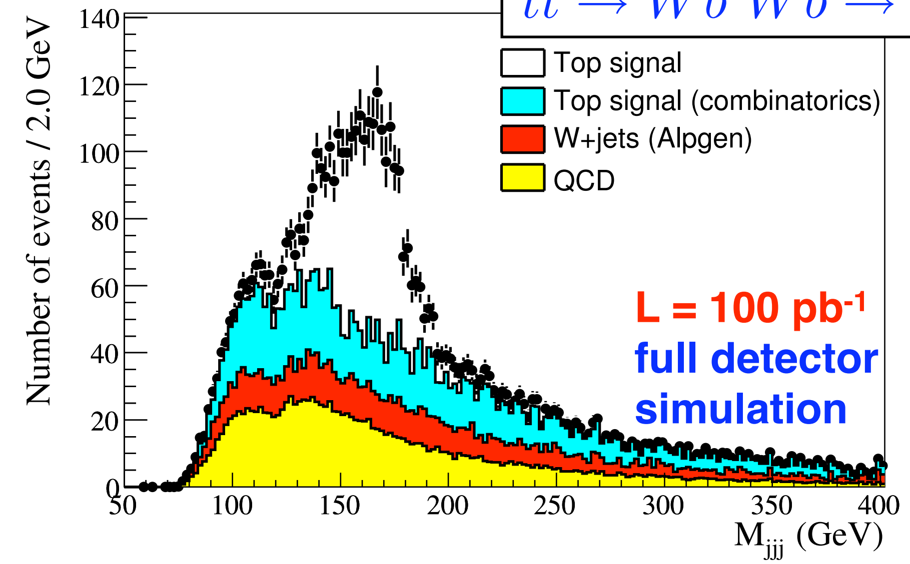
- **Lepton-jets** decay is the "gold-plated" channel
  - 1 energetic, isolated lepton
  - 4 energetic jets (of which 2 b-jets)
  - missing transverse energy
- **Detector calibration**
  - **over-constrained kinematics** allow for b-tagging, missing energy and light-jets studies
- **Estimation of σ_{top} and MC tunings**

Typical event selection
Isolated lepton $p_T > 20$ GeV
$E_T^{miss} > 20$ GeV
4 or 3(+1) Jets with $E_T > 40(20)$ GeV, $|\eta| < 2.5$
$>$ 1 b-jet ($\varepsilon_b \approx 50\%$, $\varepsilon_{uds} \approx 10^{-3}$, $\varepsilon_c \approx 10^{-2}$)
BKG < 2% (W/Z + jets, WW, ZZ, WZ)
signal efficiency ≈ few %

Detector calibration with top

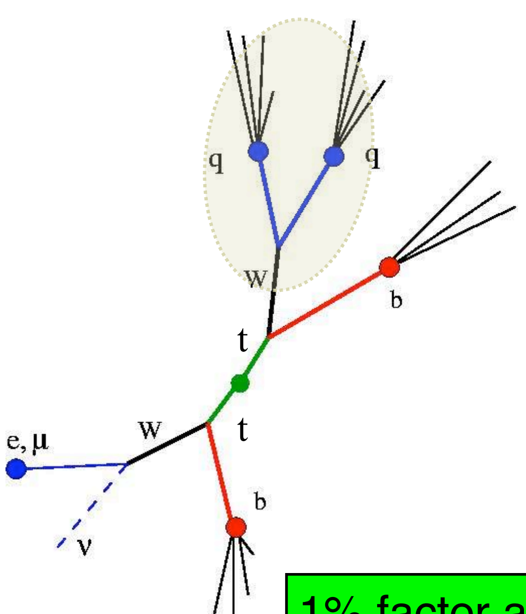
- **Missing transverse energy** studies
  - top mass peak still visible on 3-jets mass distribution without E_T^{miss} selection (x10 QCD background)
  - E_T^{miss} resolution analysis using W mass constraint and lepton measurement

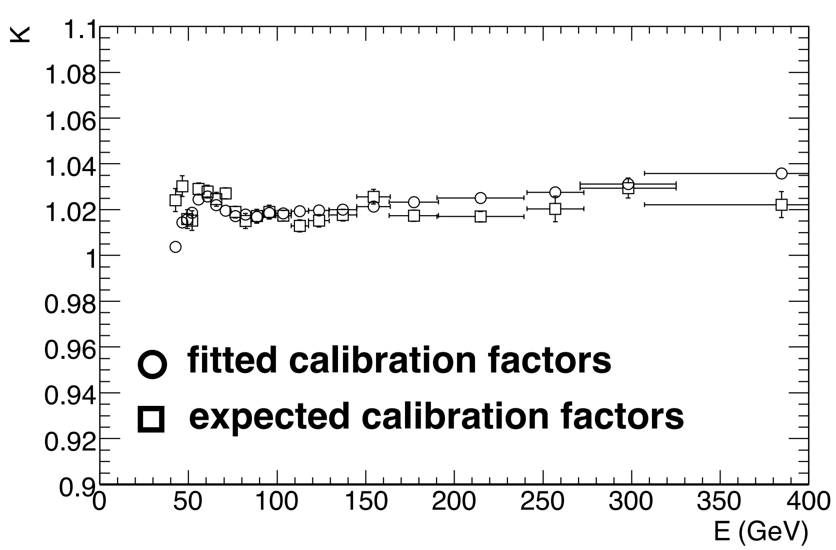
$t\bar{t} \rightarrow Wb\, Wb \rightarrow bl\nu\, bq\bar{q}$



- **Light-jet energy scale calibration**
  - selection of a clean Wjj sample using b-tagging (purity 80%)

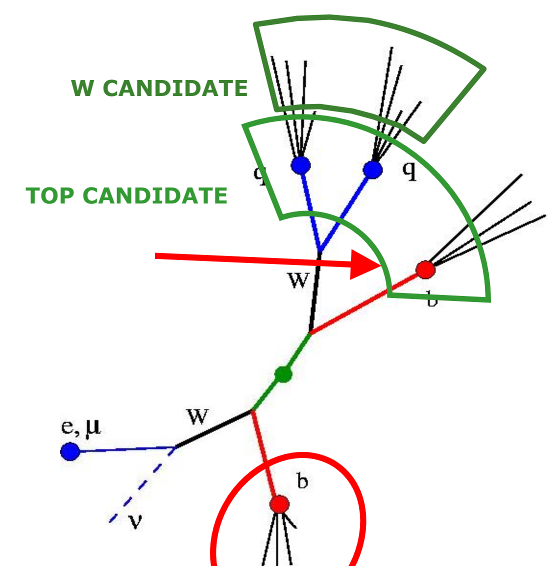
$$M_W^{PDG} = \sqrt{2K_1E_1K_2E_2(1-cos\theta_{jj})} = \sqrt{K_1K_2}M_{jj}$$

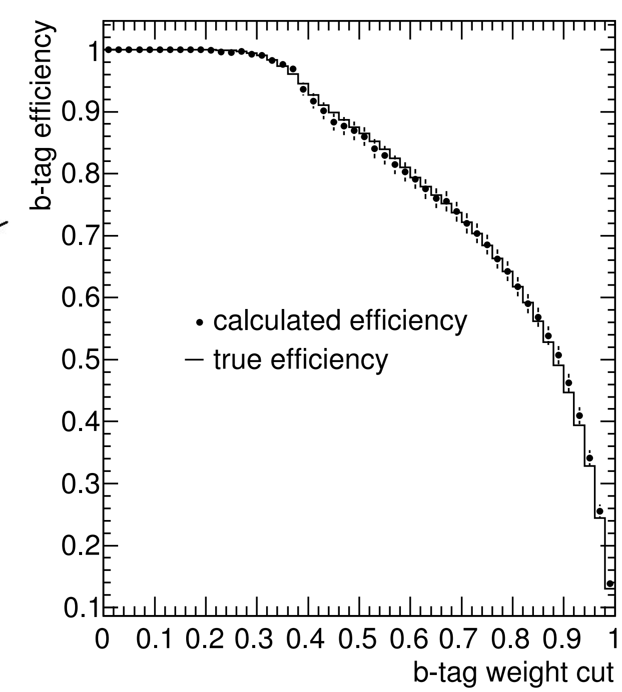




1% factor accuracy achievable with $1fb^{-1}$

- **b-tagging calibration**
  - Use of mass constraints, only one jet is tagged as b-jet (on W leptonic decay side)
  - enriched b-jet samples to study performance

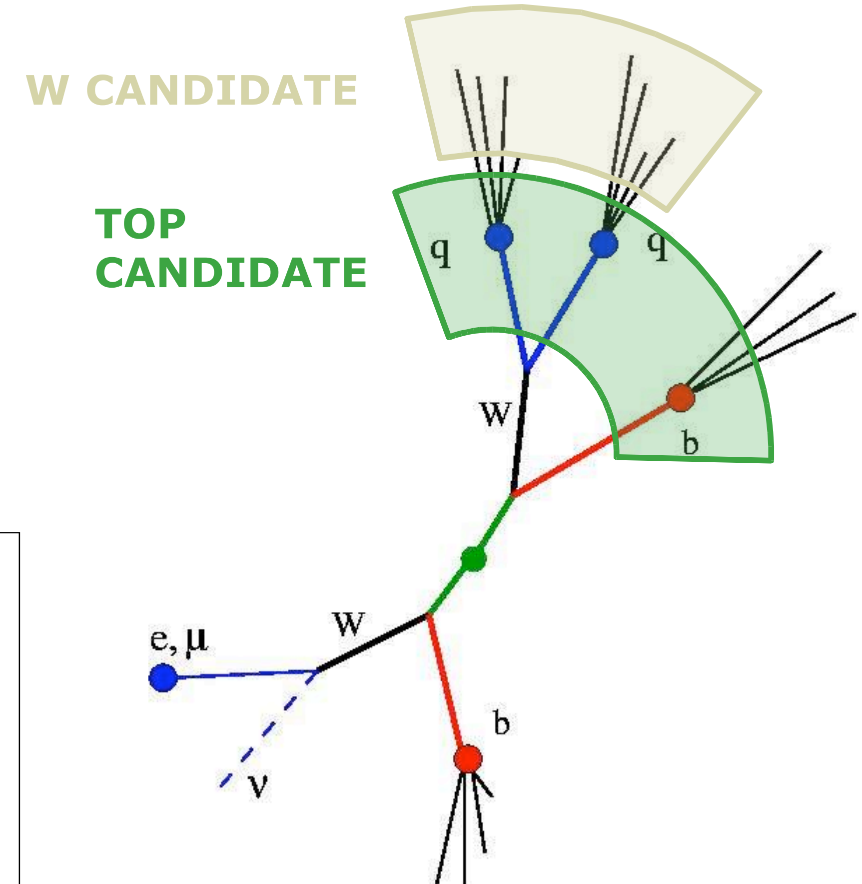


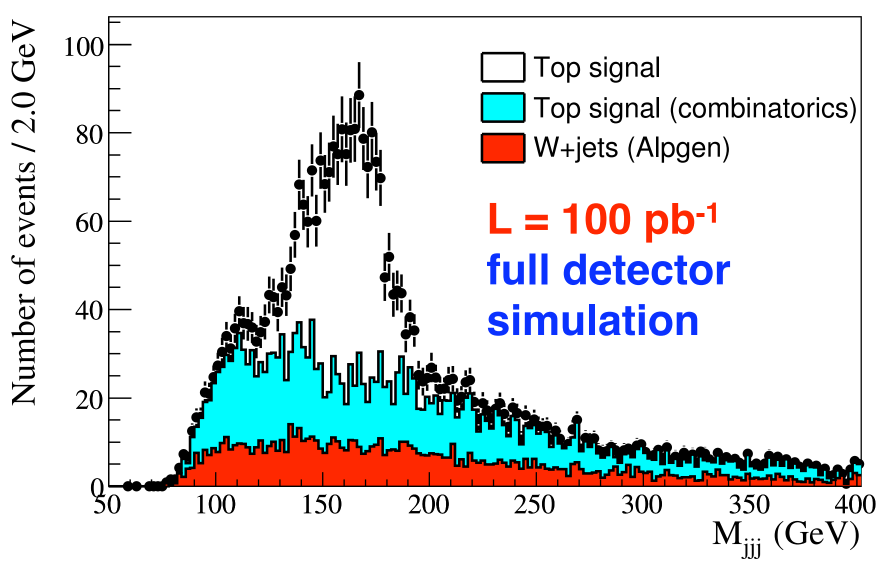


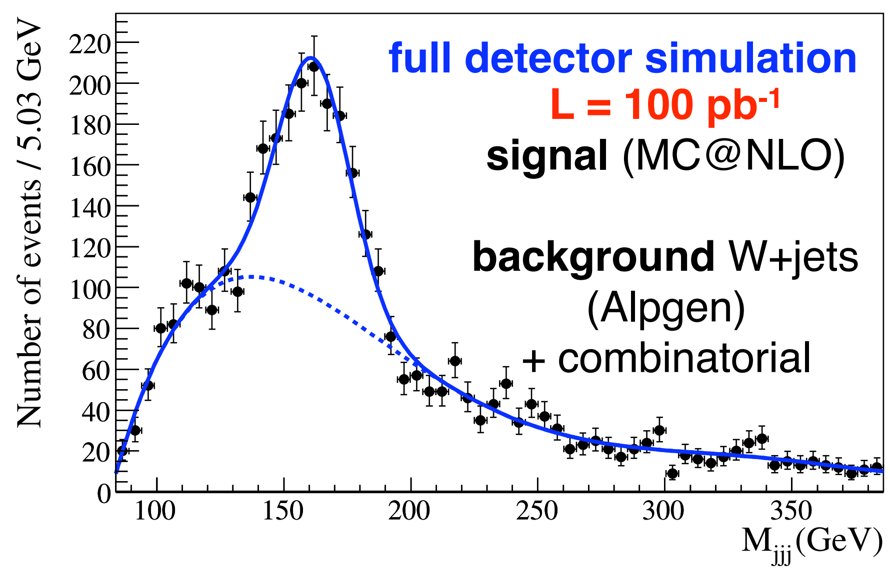
main syst. from ISR, FSR

Semi-leptonic top cross section

- $t\bar{t} \rightarrow Wb\,Wb \rightarrow bl\nu\; bq\bar{q}$ **inclusive cross section**
  - ★ **selection without b-tagging for early data**
  - ★ **hadronic top** candidate as 3-jets combination with highest p_T (correct pairing of about 25%)
  - ★ **W boson** constraint: 1 of 3 di-jets mass within 10 GeV in reconstructed M_W

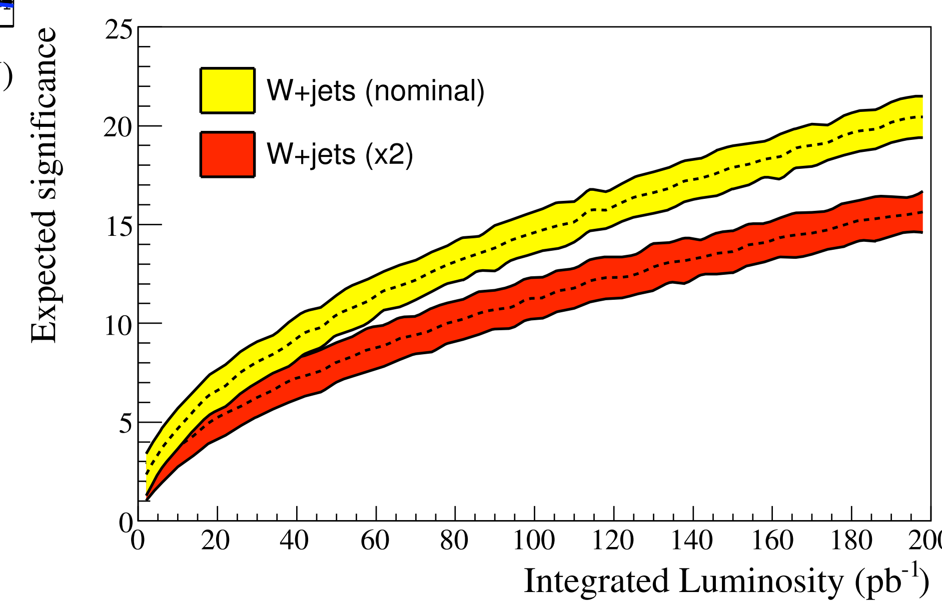






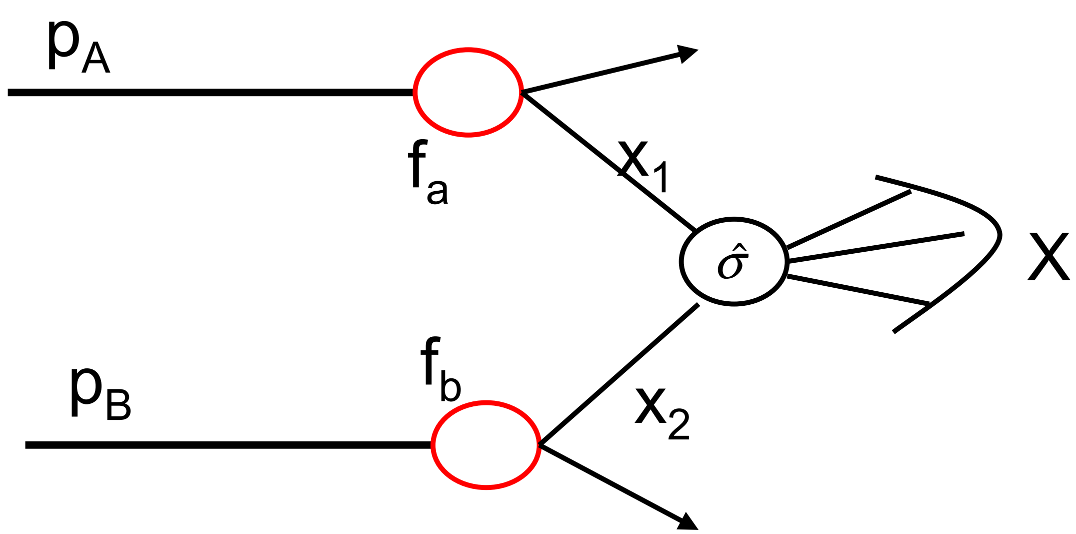
- **Top mass peak clearly visible in 100 pb^{-1} (few days!)**
  - ★ good statistical significance
  - ★ systematics from light-jet and b-jet scales:
    2% uncertainty on light-jet scale
    5% uncertainty on b-jet scale

$\Rightarrow$ **3.6 % on σ_{top}**

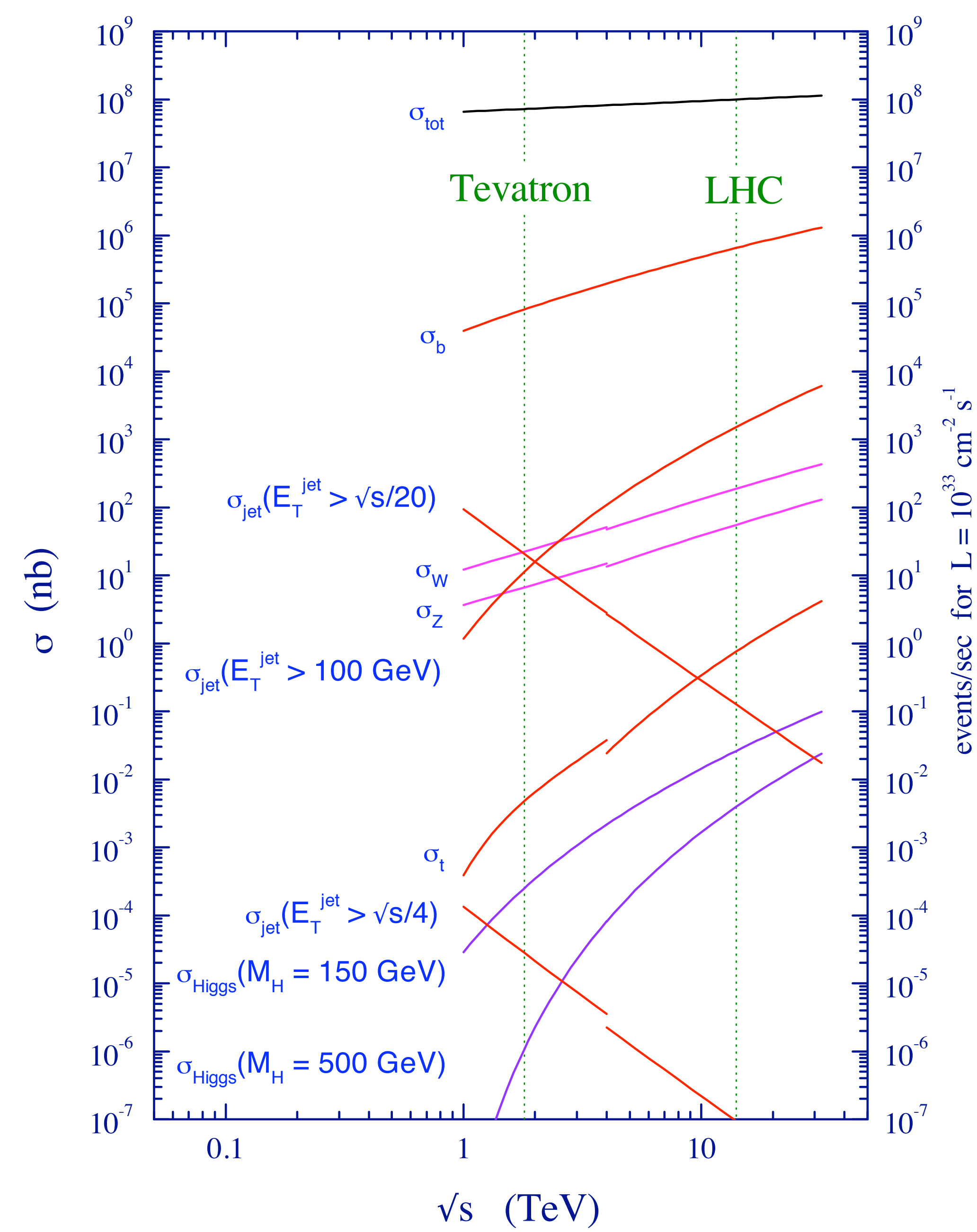


QCD physics

- **QCD is involved in every process at LHC**



$$\sum_{a,b} \int dx_1 dx_2 f_a(x_1, Q^2) f_b(x_2, Q^2) \hat{\sigma}_{ab}(x_1, x_2, \alpha_s(Q^2))$$

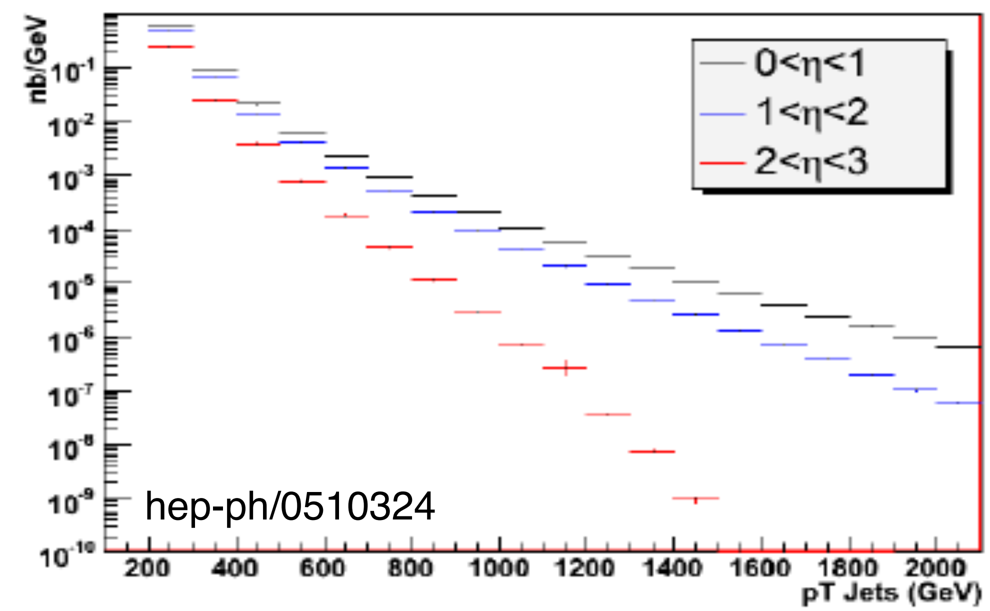


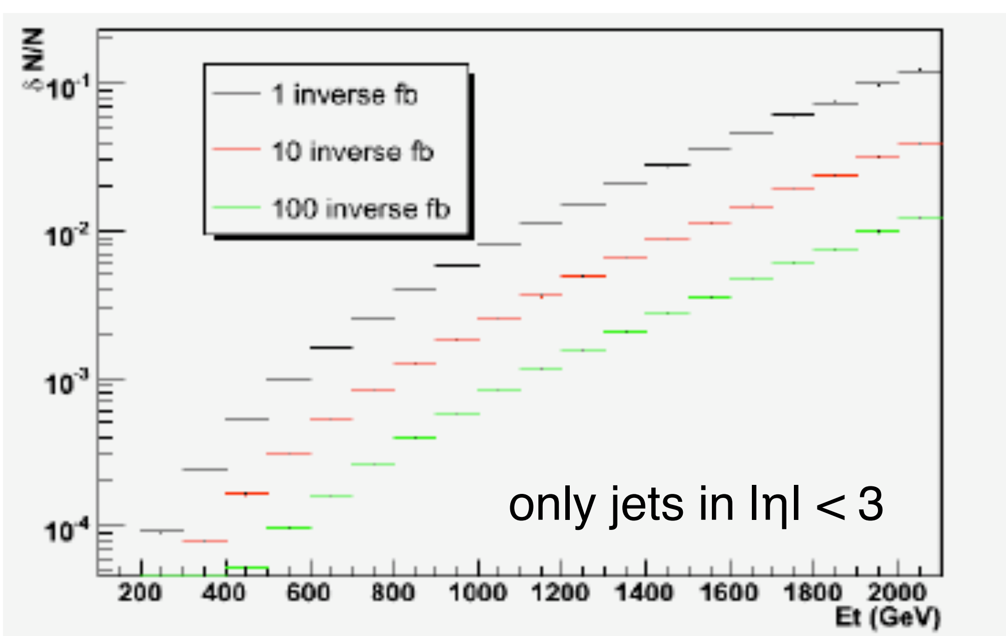
- Main goals of QCD measurements are:
  - ★ precision tests of Standard Model
  - ★ input to understand beyond SM signal cross sections
  - ★ input to understand background processes for searches

Jet cross sections

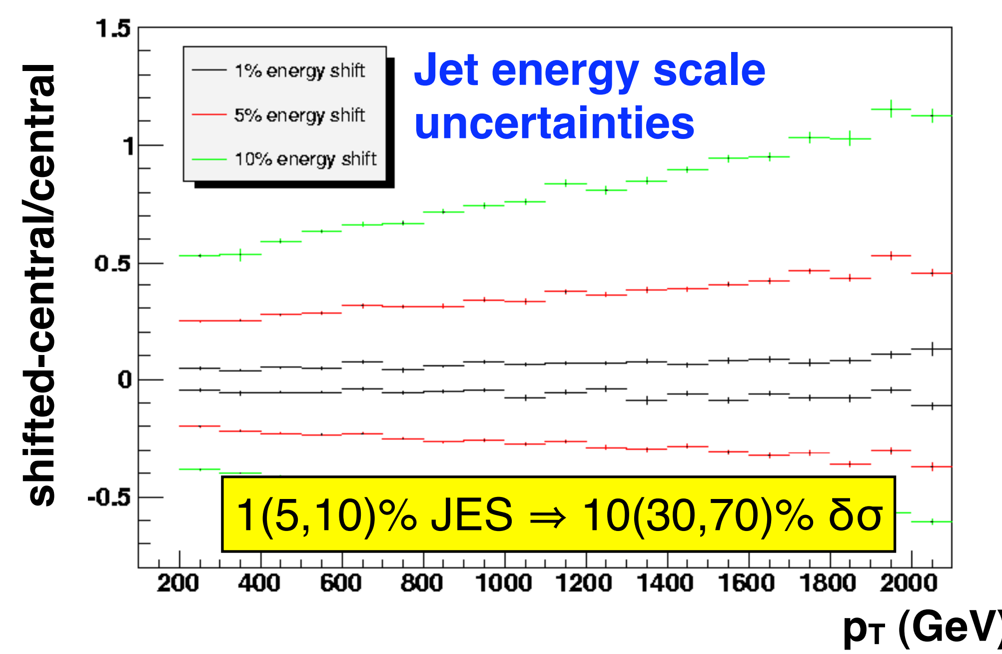
- **Inclusive jet cross sections** one of the early (low integrated luminosity) measurement at ATLAS
  - ★ Determination of α_s possible and test of pQCD over more than 8 orders of magnitude
  - ★ Sensitive to new phenomena (quark compositeness)
- **Statistical errors**
  - ★ (Naïve) $\sqrt{N}/N$ vs. E_T for different $\int Ldt$
  - ★ For a jet P_T of ~1 TeV 1% error expected for 1 fb^{-1}. In the large η region ($3.2 < |\eta| < 5$) error up to 10%

Computed using NLO jet cross section
CTEQ6.1, μF=μR=PT/2, KT algorithm (D=1)





- **Experimental uncertainties**
  - ★ Luminosity determination, Jet Energy scale
  - ★ Jet resolution, UE subtraction, trigger eff, etc

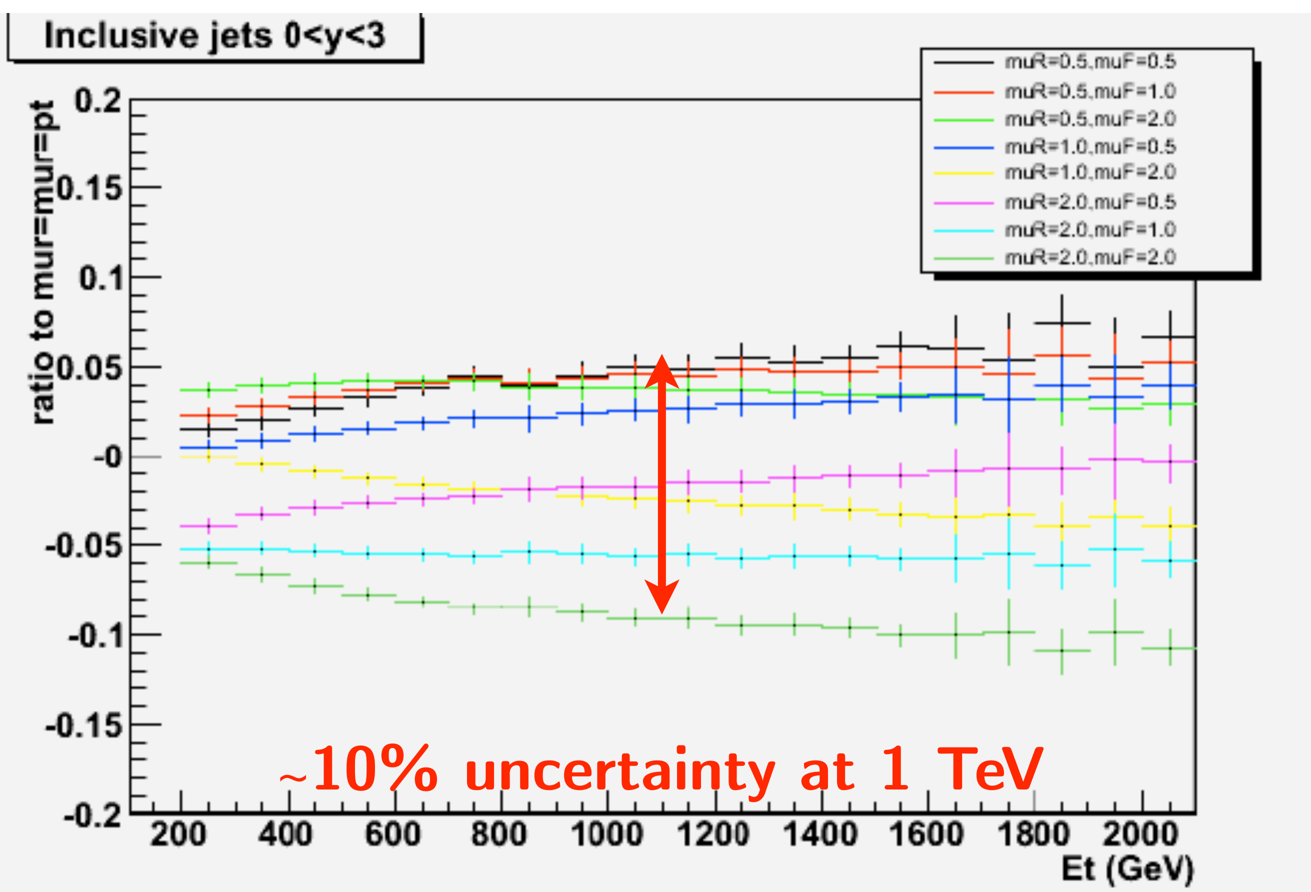


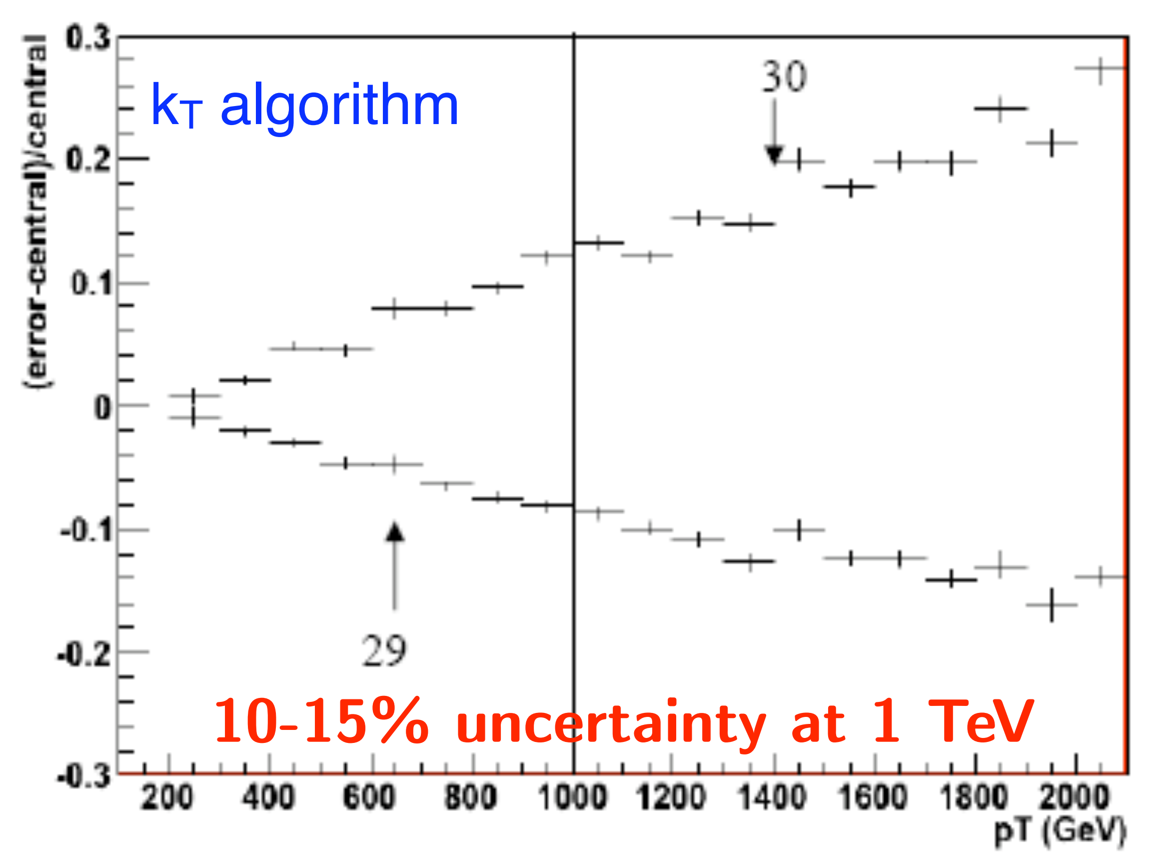
Jet cross sections

- **Theoretical errors** $\sum_{a,b} \int dx_1 dx_2 f_a(x_1, Q^2) f_b(x_2, Q^2) \hat{\sigma}_{ab}(x_1, x_2, \alpha_s(Q^2))$

  - ★ **Renormalization (μ_R) and factorization (μ_F) scales uncertainties**
    (from perturbative calculation at fixed orders)
  - ★ μ_R and μ_F have been varied independently between $0.5P_T^{max}$ and $2P_T^{max}$
    (P_T^{max} is the transverse momentum of the leading jet)

  - ★ **PDFs uncertainties**
  - ★ Evaluated using CTEQ6, 6.1 error sets.
  - ★ 29 and 30 error sets dominate the uncertainty of the inclusive cross section in the TeV region. Related to the high x gluon (relatively large uncertainty from DIS)





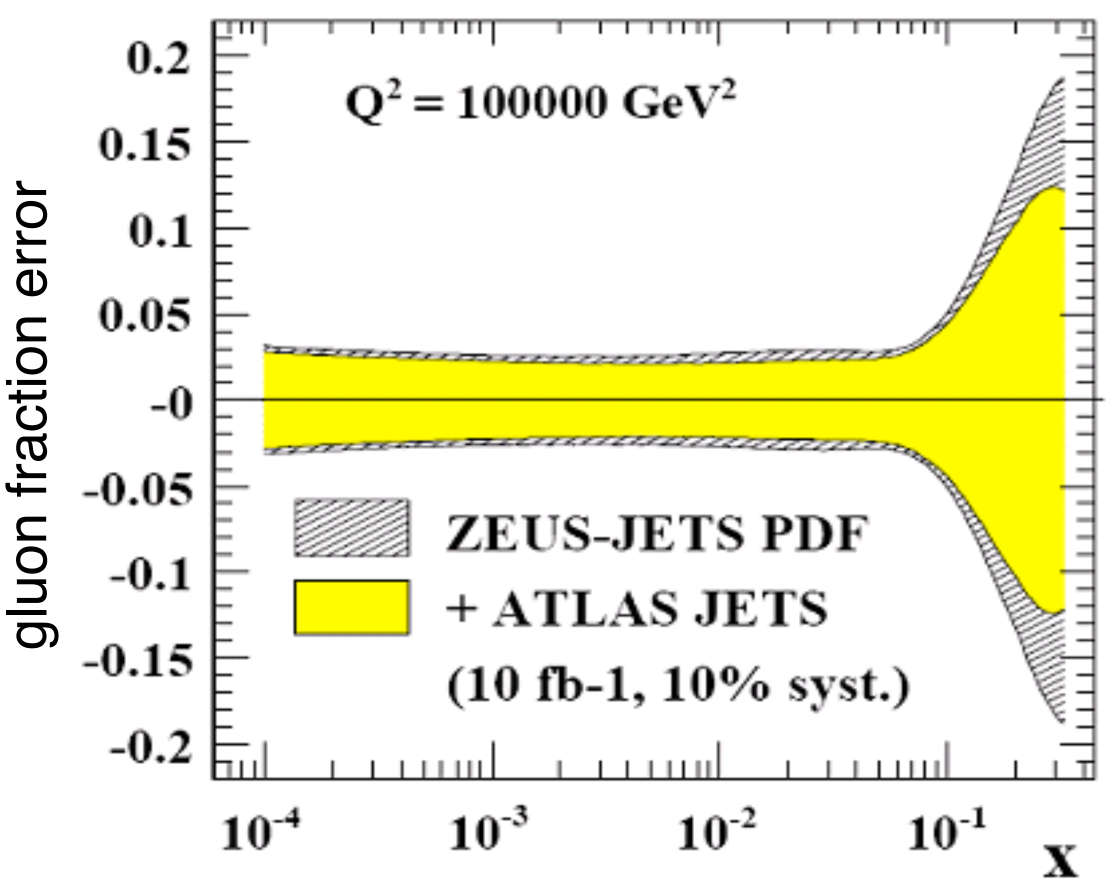
PDF's constraints from Jets

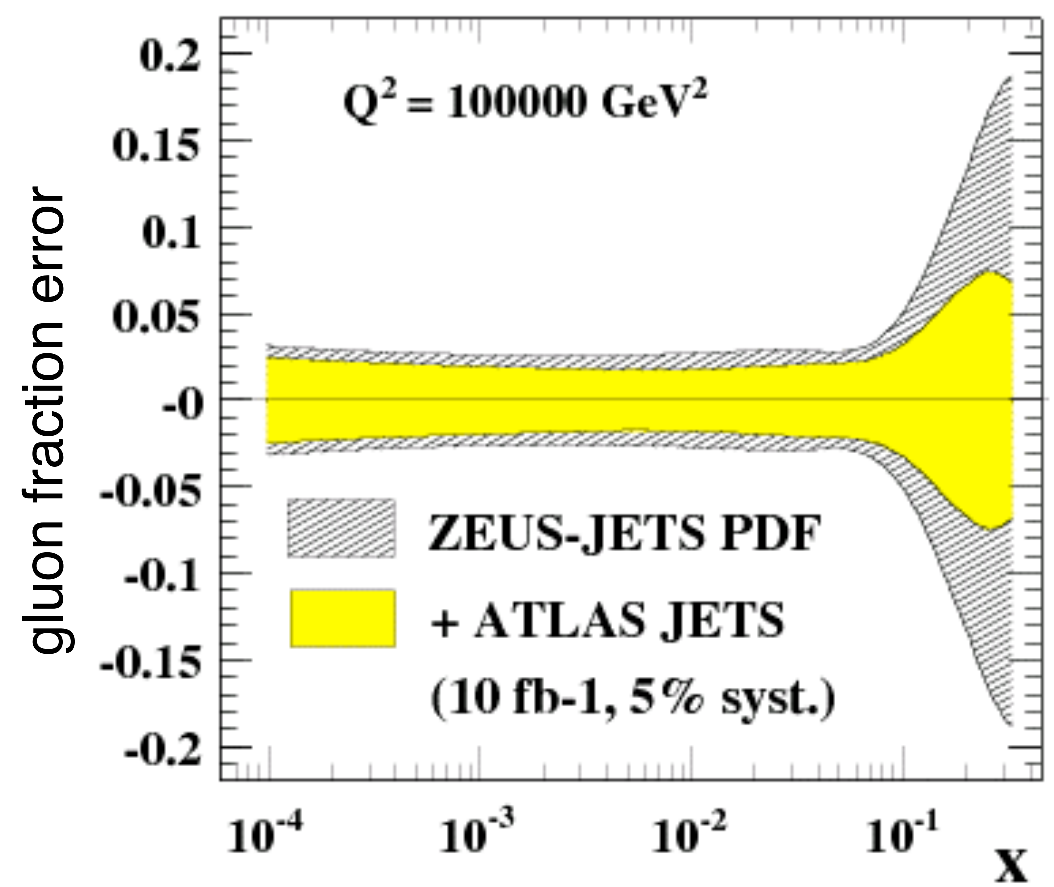
- ATLAS pseudo-data for 0<η<1, 1<η<2, 2<η<3 up to p_T = 3 TeV was used in a global (ZEUS) fit to assess the **impact of ATLAS data on constraining PDFs**

★ Preliminary results suggest that ATLAS data can constrain the high x gluon

★ Increasing statistics from 1fb^{-1} to 10 fb^{-1} (= 1 year of low luminosity data taking) leads to small improvements

★ Decreasing systematic errors leads to a significant improvement





Summary

LHC physics at $\sqrt{s} = 14$ TeV should finally start this year !

- First data will be extremely important to **calibrate/understand** ATLAS detector
  - ★ Use of **"standard candles"** like J/Ψ and ϒ resonances, W/Z production, semi-leptonic top pairs decay, etc.
- "Re-discover" **Standard Model** physics measuring at **$\sqrt{s} = 14$ TeV**
  - ★ **Minimum-bias and UE, W, Z, tt, QCD, ...**
  - ★ **Tuning** and validation of **Monte Carlo** generators
  - ★ **Measure** main **backgrounds** for **New Physics** (W/Z+jets, tt+jets, multi-jets) preparing the road to discoveries
- Theoretical predictions very often are limited by the **PDF uncertainties**
  - ★ **HERA** largely improved our knowledge of PDFs
  - ★ At LHC gluon/sea interaction are dominant at **low-x: explore new kinematical regions**
  - ★ Current uncertainties (<5% on $\sigma_{W,Z}$ - different sets agree within 8%, 1% on asymmetries) can be substantially **reduced using very first LHC data**

Back-up slides

Inclusive cross section

- Used in the past as a test for perturbative QCD
- With large Tevatron and LHC datasets main uncertainties are non-statistical:
  - ★ in particular from luminosity (5-7%) and systematics (2-3%) (D0 Note 4750, $\sigma_{W \to \mu\nu}$)
- Cross sections ratio as indirect measurement for W width (not affected by above systs.)

$$R_{W/Z} = \frac{\sigma(W)}{\sigma(Z)} \times \frac{\Gamma(W \to l\nu)}{\Gamma(W)} \times \frac{1}{Br(Z \to ll)}$$

- Taking theoretical prediction as input, possible use for:
  - ★ hadronic luminosity monitor
  - ★ PDF's constraint analysis

$$\int \mathcal{L} dt = \frac{1}{Br \cdot \int \mathcal{F}_a \mathcal{F}_b \times \hat{\sigma}^{ab}} \frac{N_{obs}}{A\epsilon}$$

- Main analysis issues:
  - ★ Acceptance studies with best NLO QCD and EW theoretical predictions
  - ★ Trigger and offline efficiencies measurement from data to not rely on MC simulations
  - ★ Event selections and background evaluation
  - ★ Detailed systematics studies

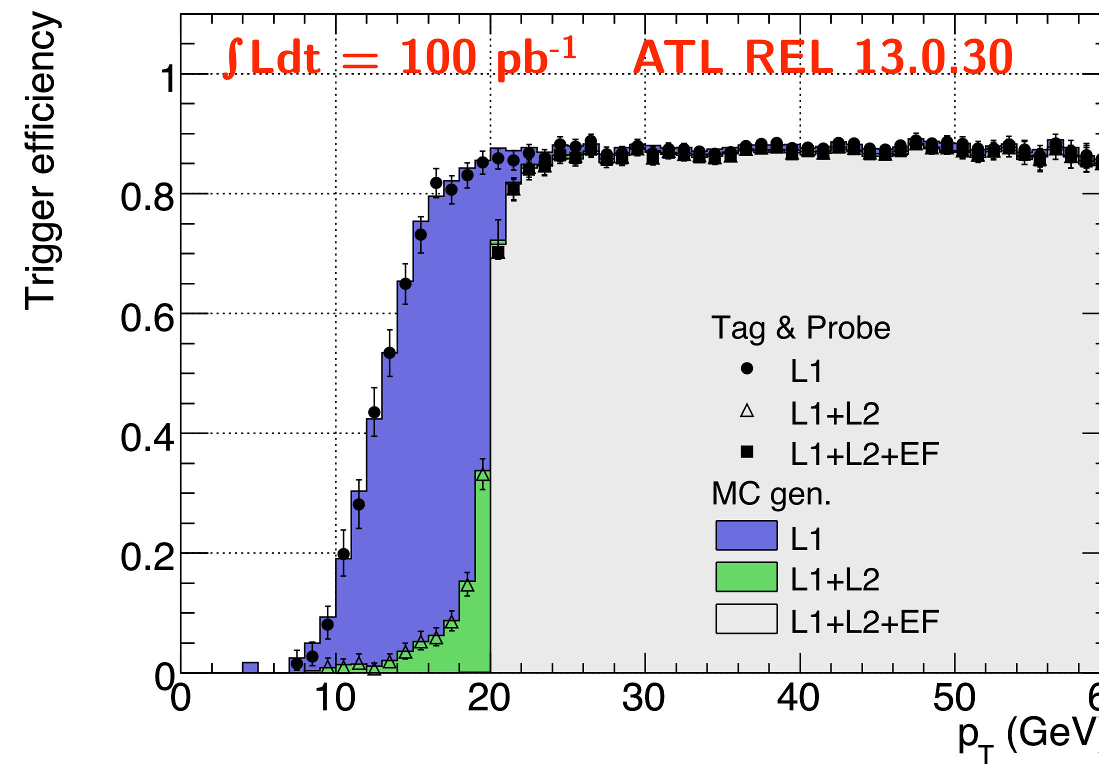
10^{31} cm^{-2}s^{-1} trigger menu

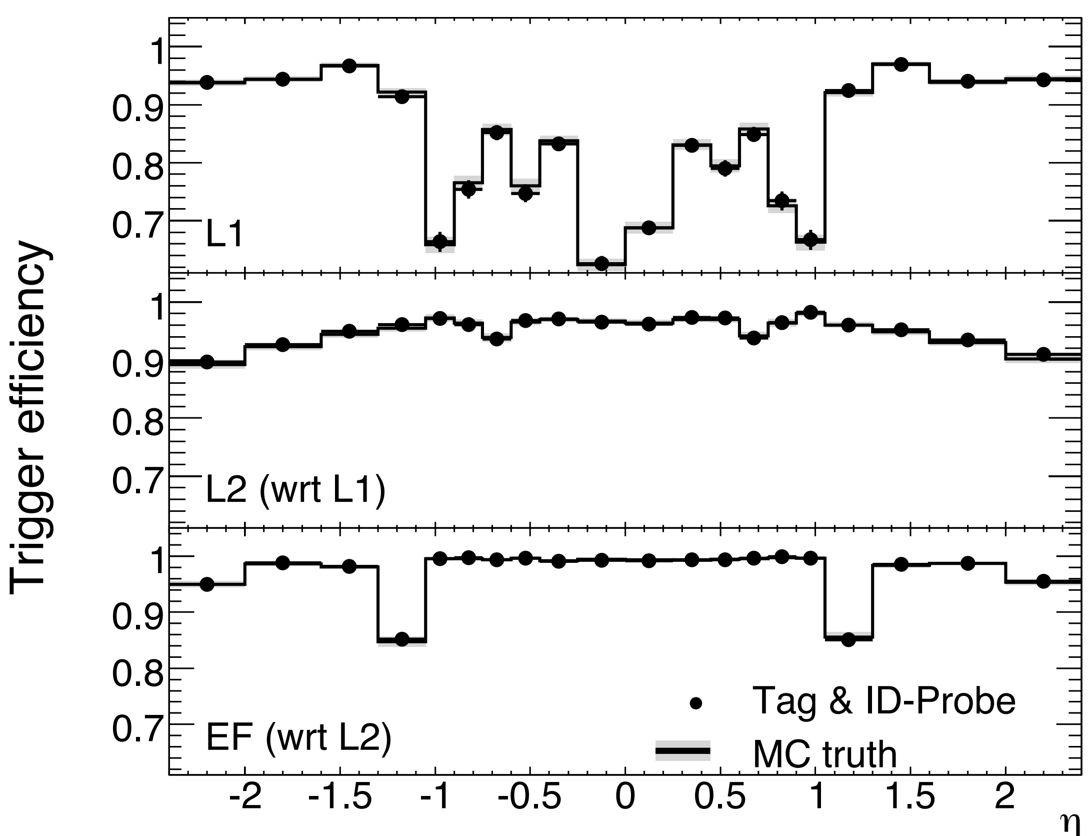
Signature	L1 rate (Hz)	HLT rate (Hz)	Comments
Minimum bias	Up to 10000	10	Pre-scaled trigger item
e10	5000	21	$b, c \rightarrow e, W, Z$, Drell-Yan, $t\bar{t}$
2e5	6500	6	Drell-Yan, $J/\psi, \Upsilon, Z$
γ20	370	6	Direct photons, γ-jet balance
2γ15	100	< 1	Photon pairs
μ10	360	19	$W, Z, t\bar{t}$
2μ4	70	3	B-physics, Drell-Yan, $J/\psi, \Upsilon, Z$
μ4 + J/$\psi(\mu\mu)$	1800	< 1	B-physics
j120	9	9	QCD and other high-p_T jet final states
4j23	8	5	Multi-jet final states
τ20i + xE30	5000 (see text)	10	$W, t\bar{t}$
τ20i + e10	130	1	$Z \rightarrow \tau\tau$
τ20i + μ6	20	3	$Z \rightarrow \tau\tau$

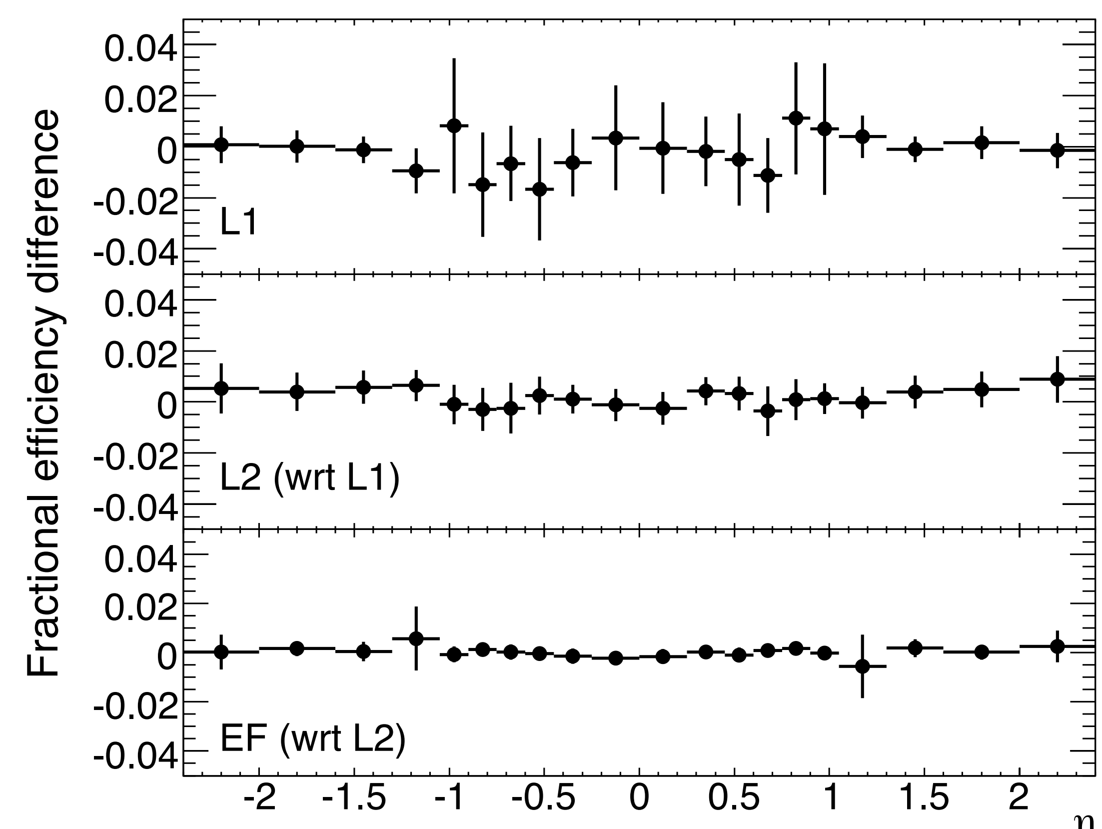
Table 64. Subset of items from an illustrative trigger menu at 10^{31} cm^{-2} s^{-1}.

Trigger efficiency from $Z \rightarrow \mu^+\mu^-$

- Measurement of turn-on trigger curves and η, φ dependences
  - ★ Use standalone and combined reconstructions to cope with early data requirements
    - e.g. ID-MS alignment
  - ★ goal is to provide a detailed map of $\varepsilon(p_T,\eta,\varphi)$ for physics analysis

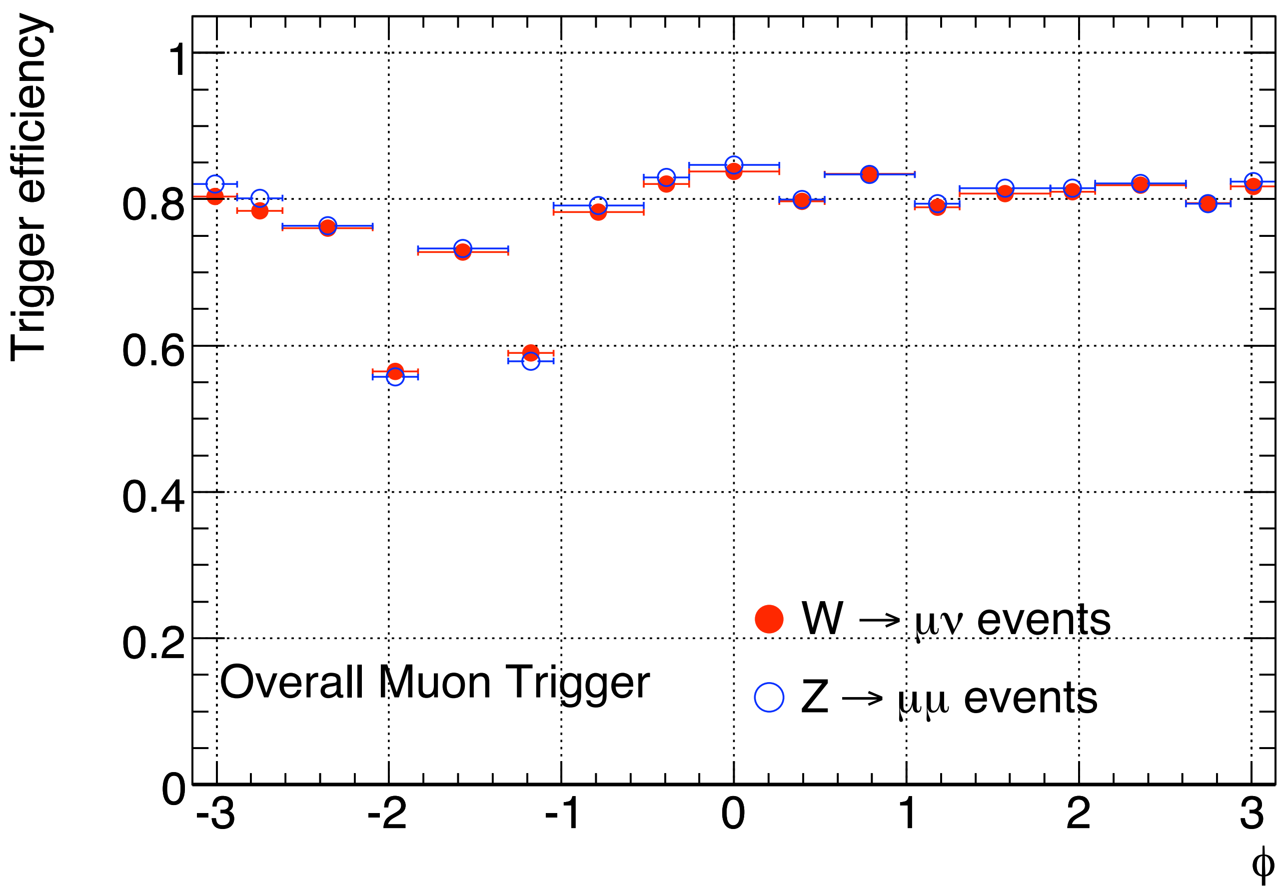


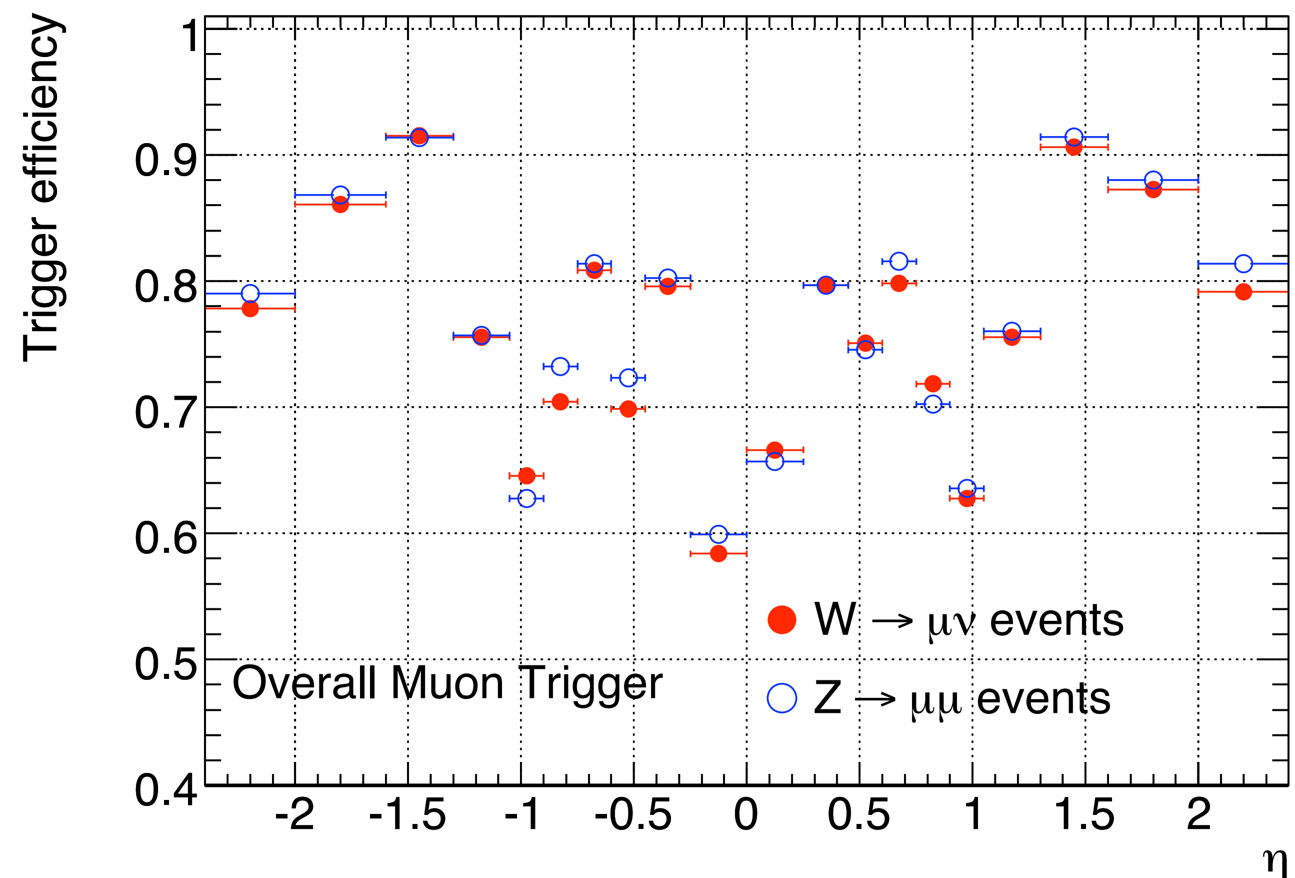




W vs Z muon trigger efficiency

- Comparisons of muon trigger efficiency from W and Z events from MC truth (wrt to all events with at least 1 muon in trigger coverage, no off. cuts)





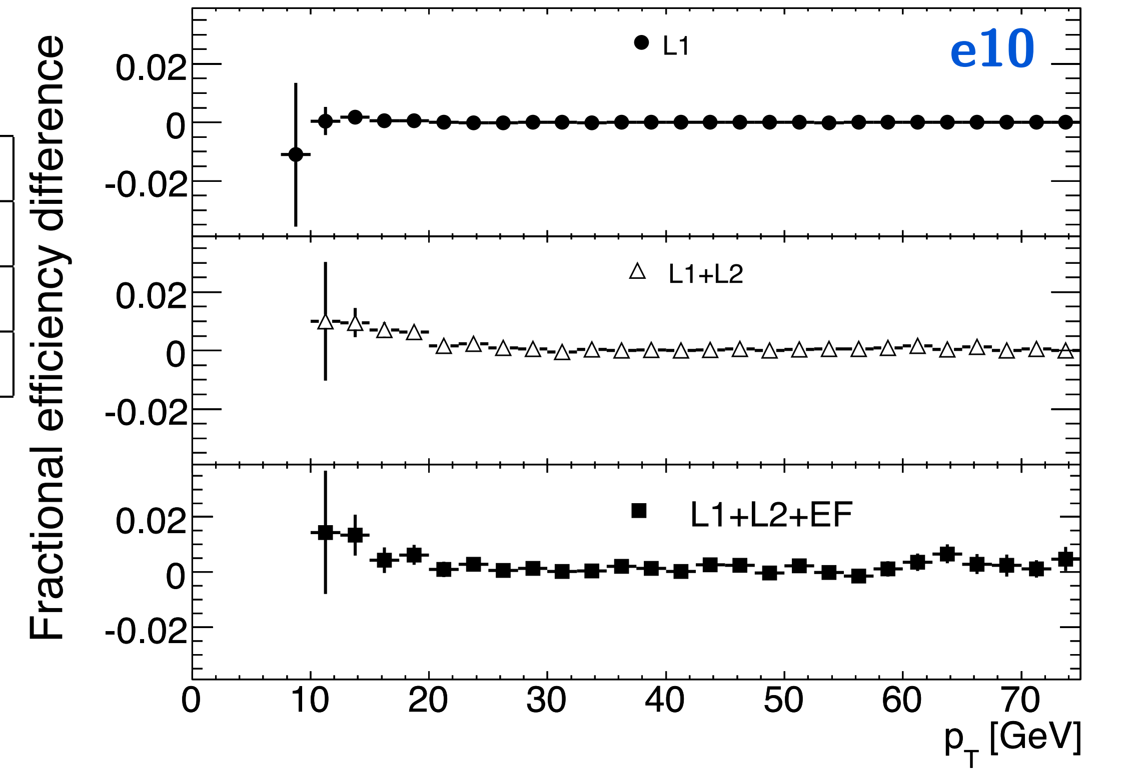
High luminosity ($\int \mathcal{L}dt = 1000\ pb{-}1$)			
Detector region	**Barrel** ($\|\eta < 1.05\|$)	**Endcap** ($1.05 < \|\eta\| < 2.4$)	**Overall** ($0 < \|\eta\| < 2.4$)
$\|\epsilon_{mu20i}^{W\rightarrow\mu\nu} - \epsilon_{mu20i}^{Z\rightarrow\mu\mu}\|$	0.005 ± 0.001	0.004 ± 0.001	0.008 ± 0.001

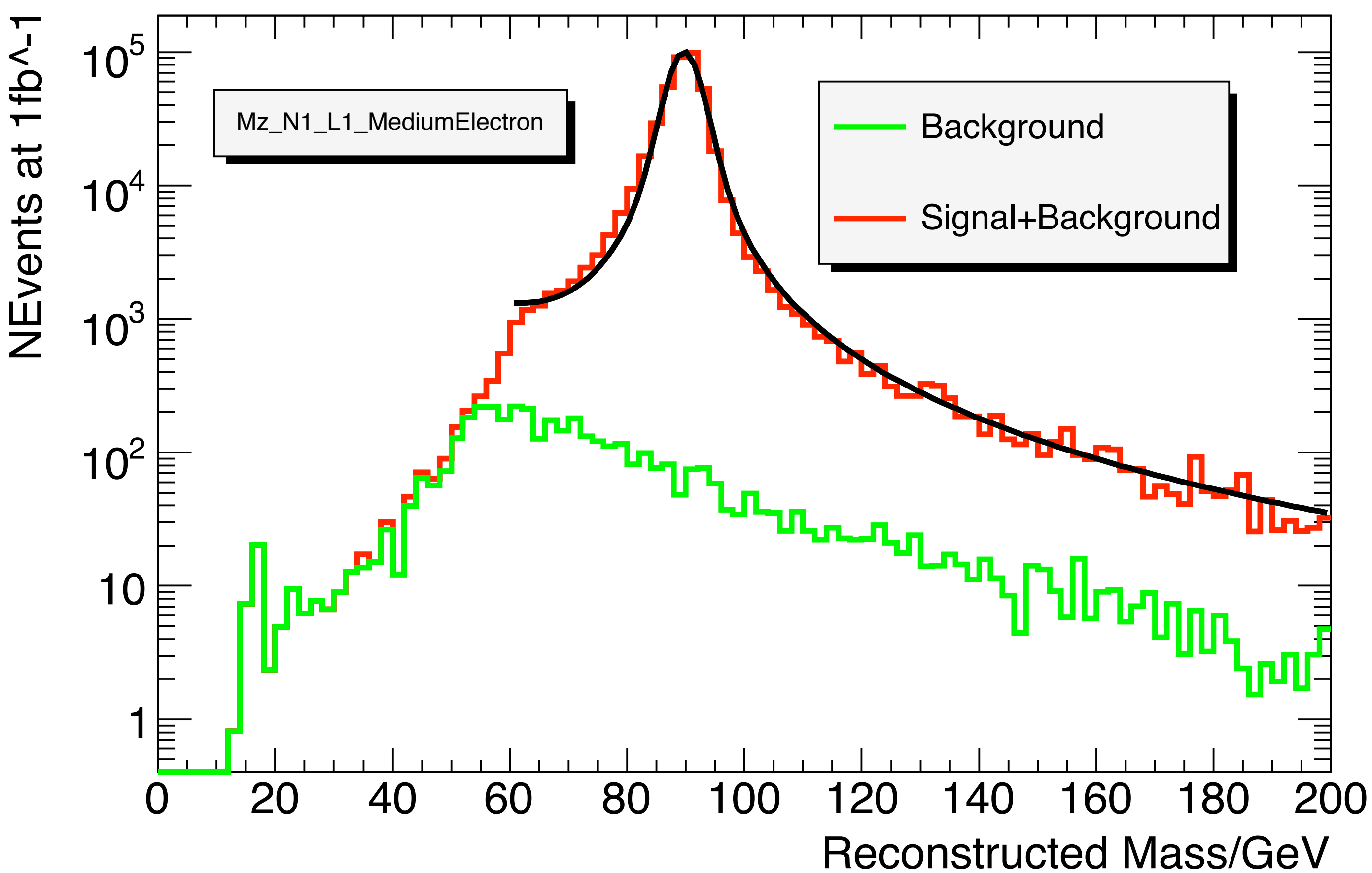
Trigger efficiency from $Z \rightarrow e^+e^-$

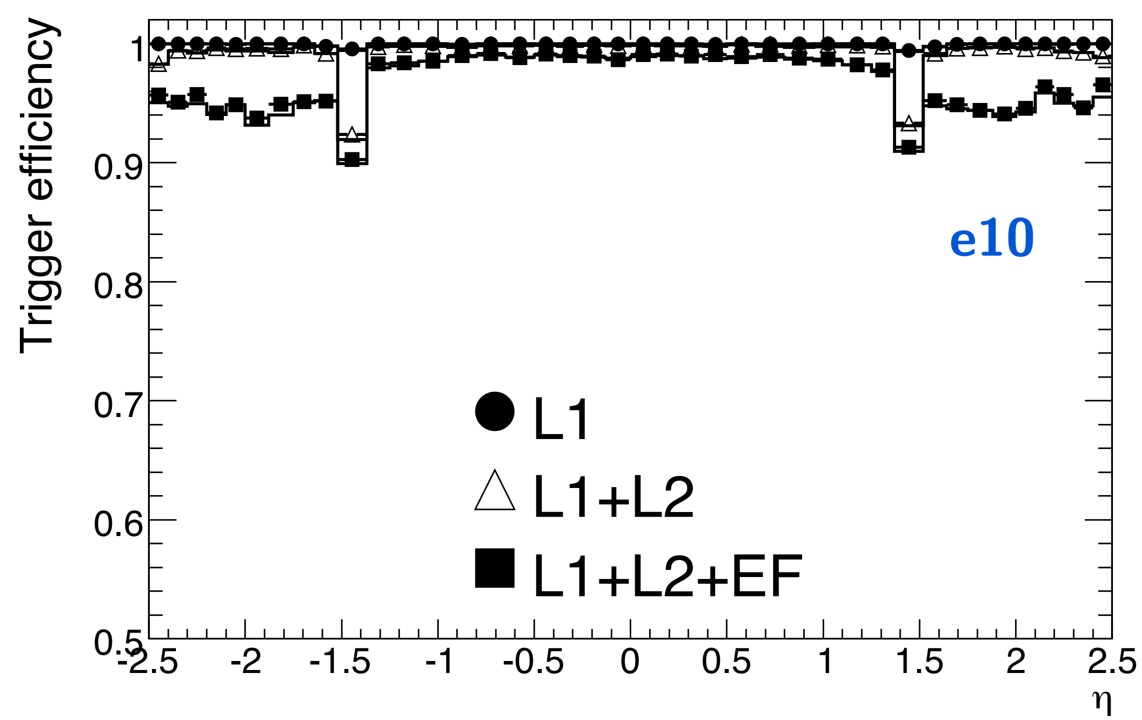
- Trigger items e10, e22

Cut on	Requirement
Invariant Mass Requirement	$70 < M_{ee}^{rec} < 100\ GeV$
Transverse Momentum	$p_T > 25\ GeV$ or $15\ GeV$
Pseudorapidity	$0 < \lvert\eta\rvert < 1.37$ or $1.52 < \lvert\eta\rvert < 2.4$

- Systematics of the method < 0.5 %
- Background systematics ≈ 0.5 %

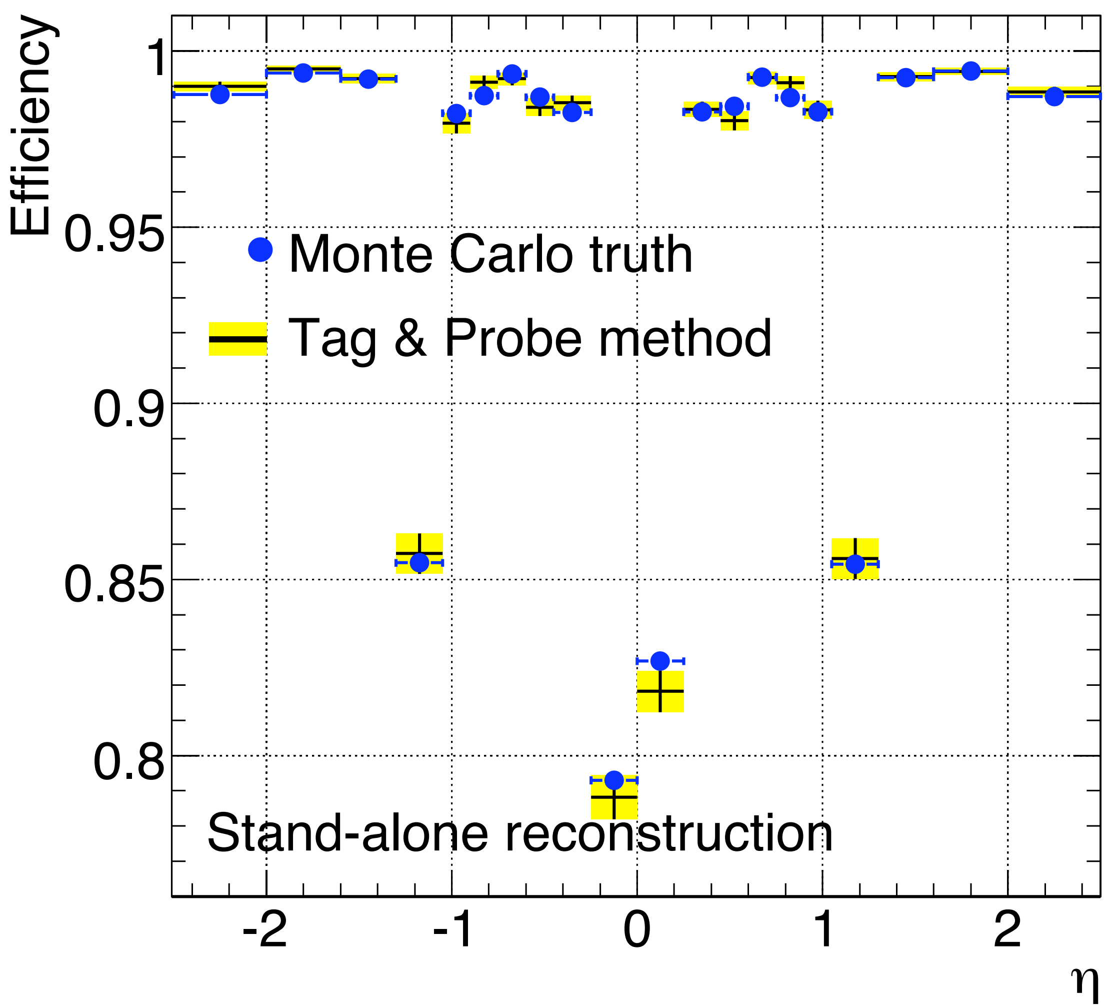


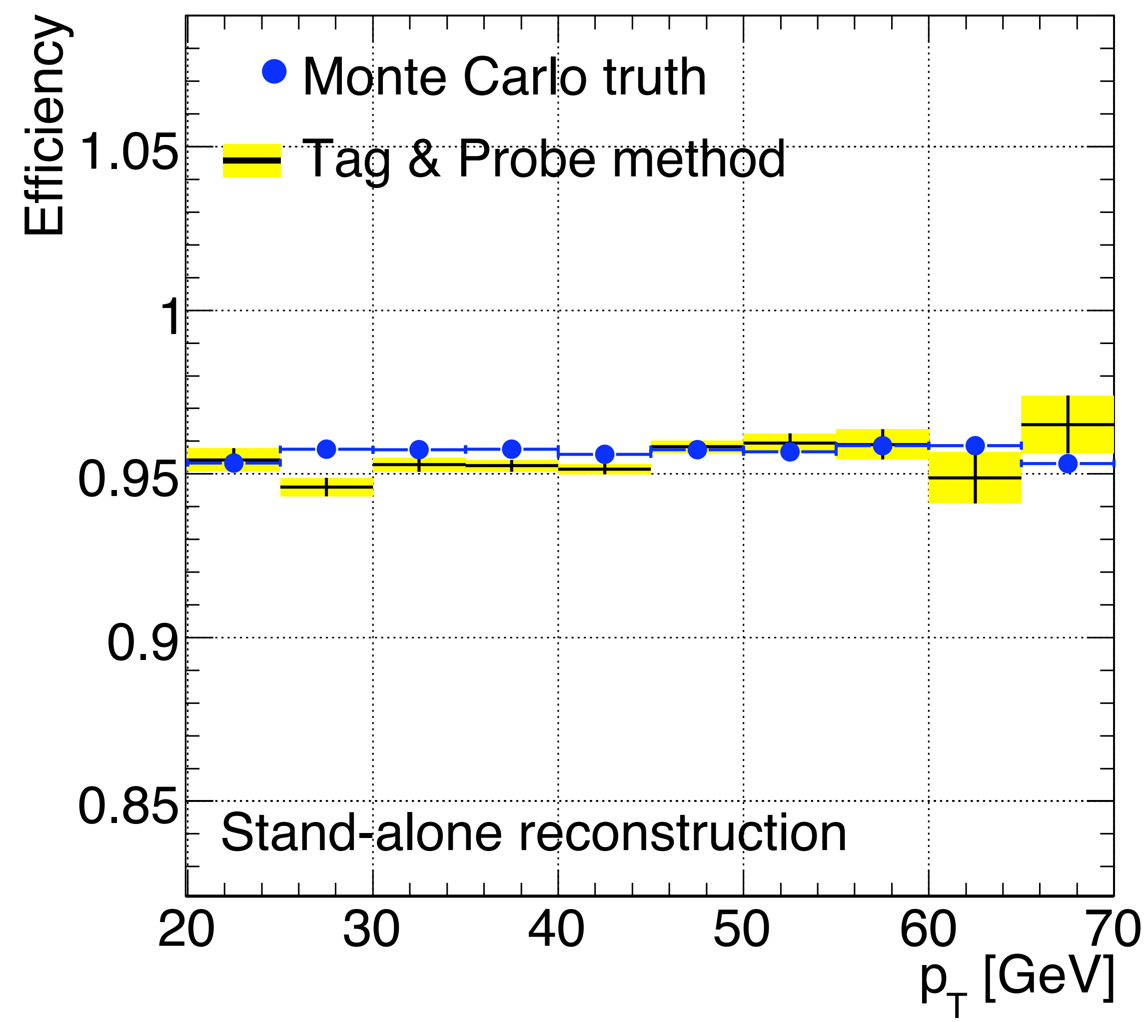




Offline efficiencies from $Z \to \mu^+\mu^-$

- Offline efficiency measured from data with Tag and Probe:
  - ★ same approach as for trigger measurements
  - ★ systematics at 0.2%

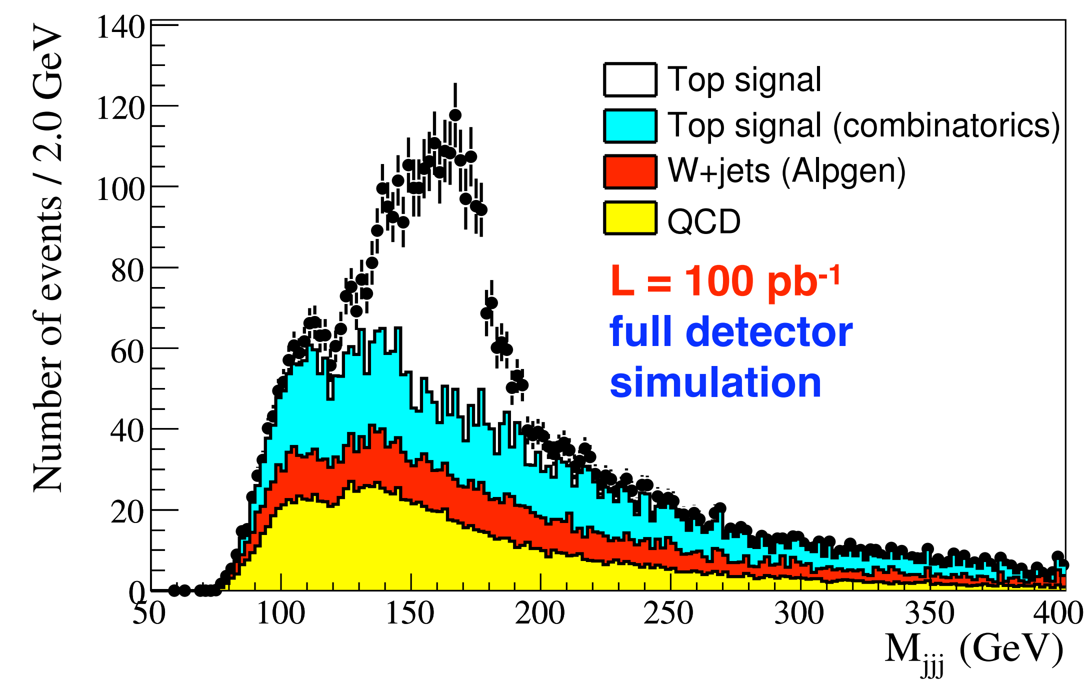




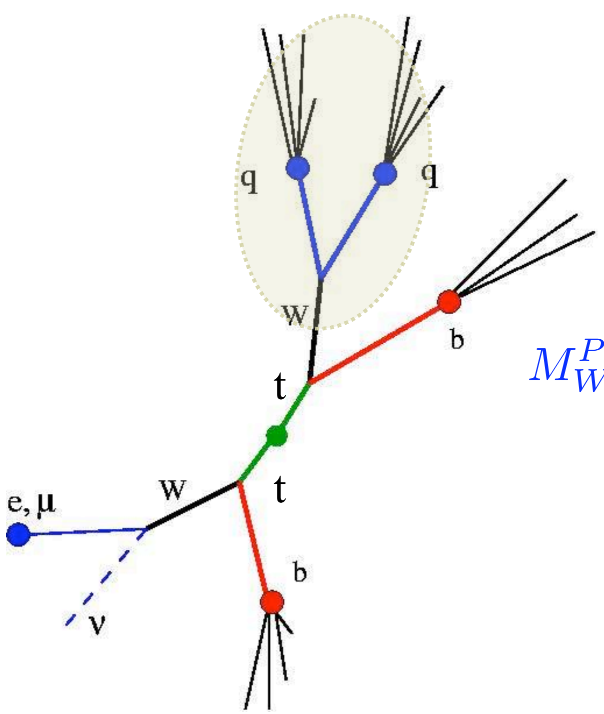
Detector calibration with top

- Missing transverse energy studies
  - ★ difficult to estimate on start-up
  - ★ top mass peak still visible on 3-jets mass distribution without E_T^{miss} selection (x10 QCD background)
  - ★ E_T^{miss} resolution analysis using W mass constraint and lepton measurement

$t\bar{t} \rightarrow Wb\,Wb \rightarrow bl\nu\; bq\bar{q}$



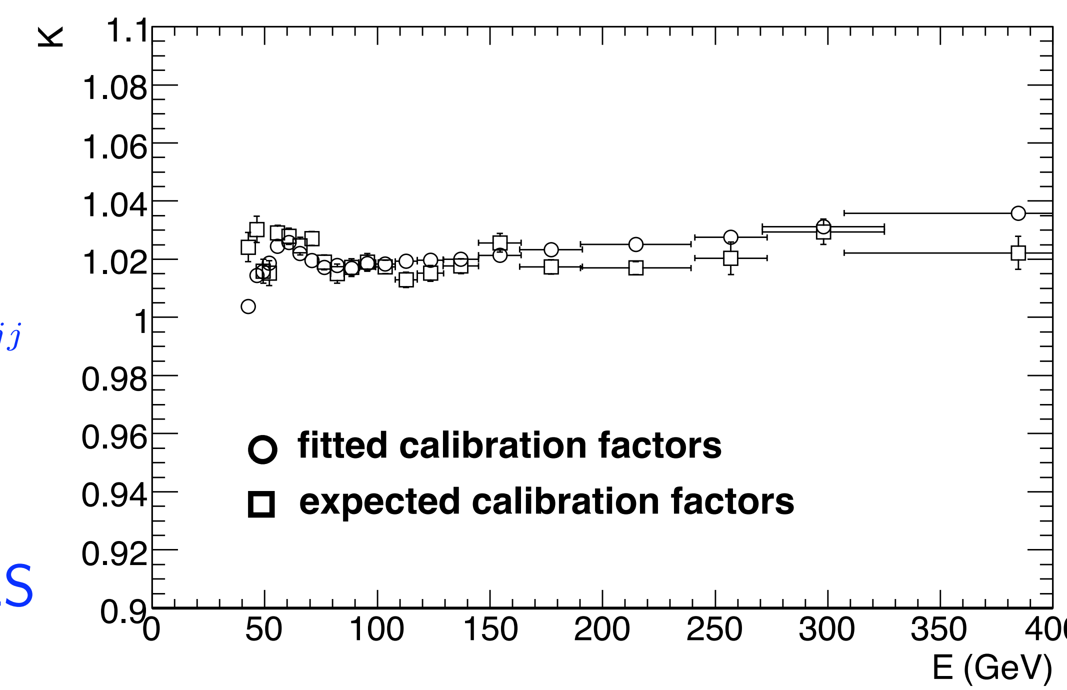
- Light-jet energy scale calibration



- ★ selection of a clean Wjj sample using b-tagging (purity 80%)
- ★ Iterative rescaling method

$$M_W^{PDG} = \sqrt{2K_1E_1K_2E_2(1-cos\theta_{jj})} = \sqrt{K_1K_2}M_{jj}$$

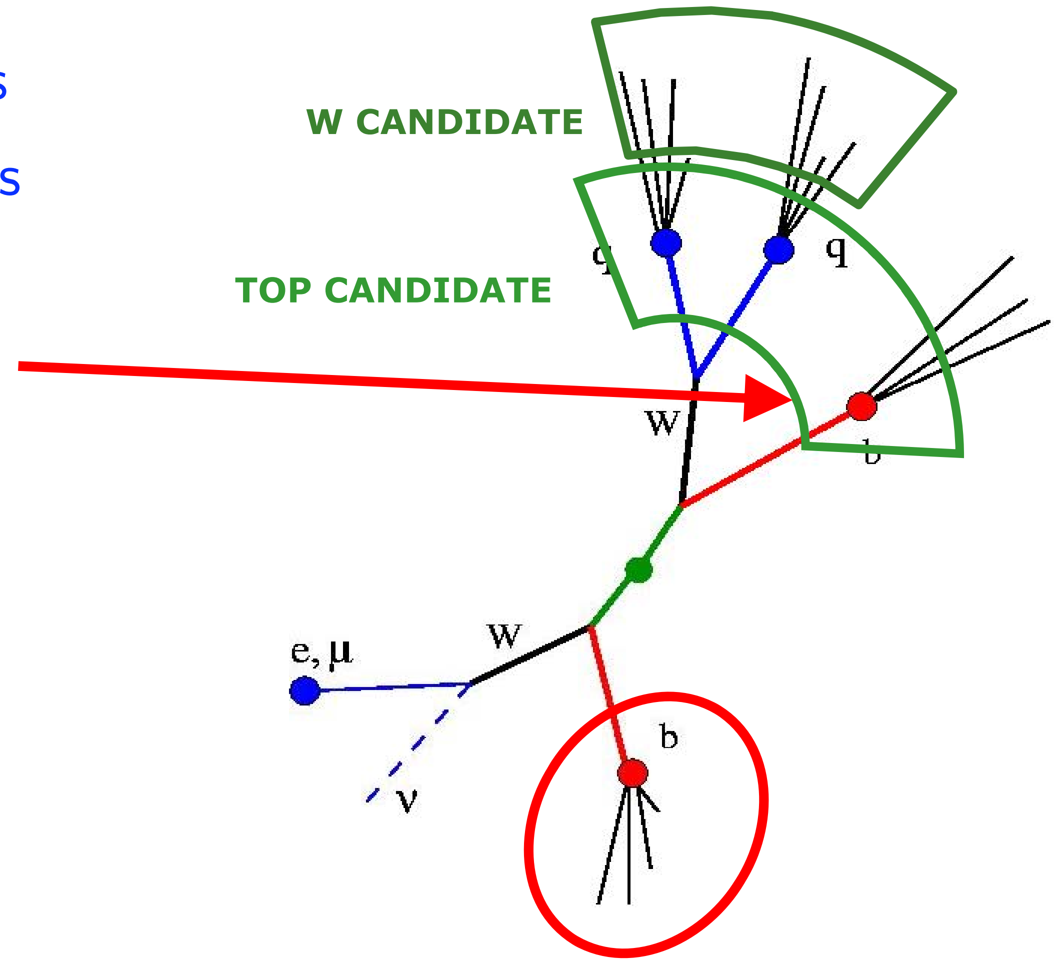
  - 1% K accuracy achievable with 1fb^{-1}
  - also suitable for differential K factors
- ★ also template method for overall JES with 2% precision with 50 pb^{-1}

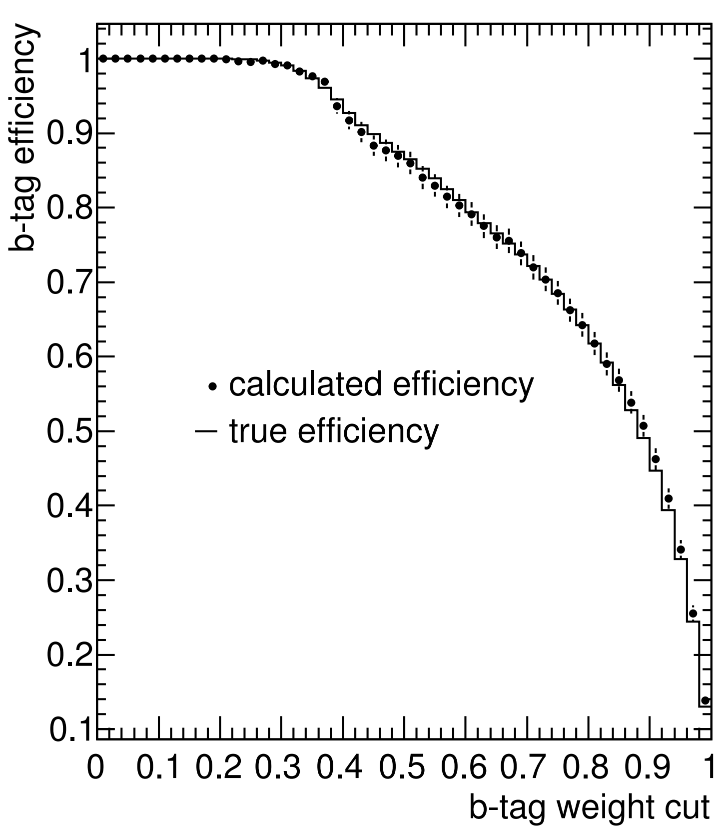


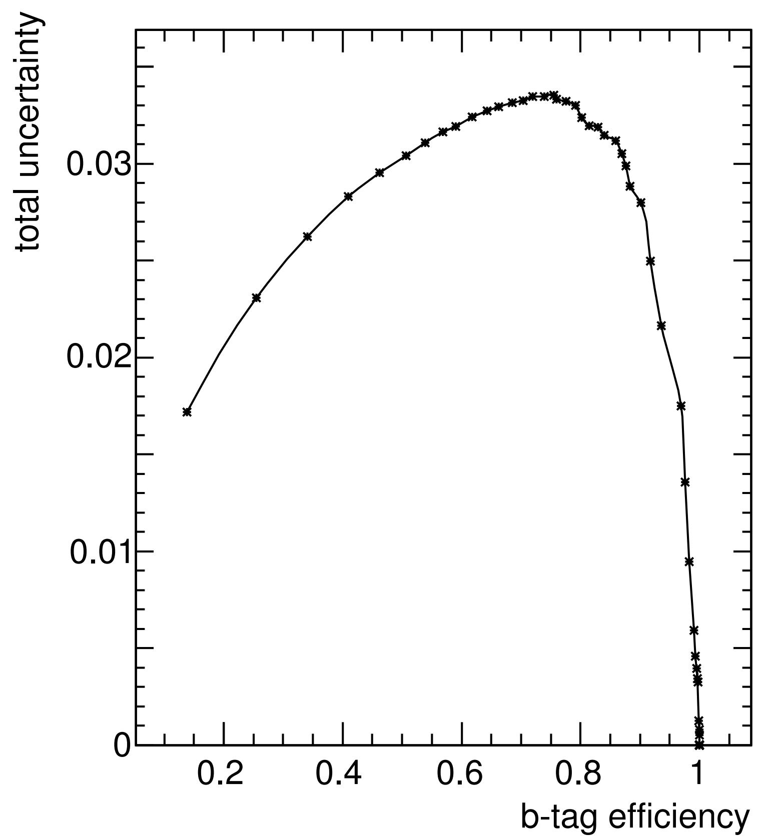
Detector calibration with top

- b-tagging calibration
  - ★ using lepton+jets (and fully leptonic) top pairs decays
  - ★ Optimize the jet pairing efficiency via mass constraints in kinematic fits and likelihoods.
  - ★ Only one jet is tagged as b-jet (on W side)

$t\bar{t} \rightarrow Wb\,Wb \rightarrow bl\nu\;bq\bar{q}$



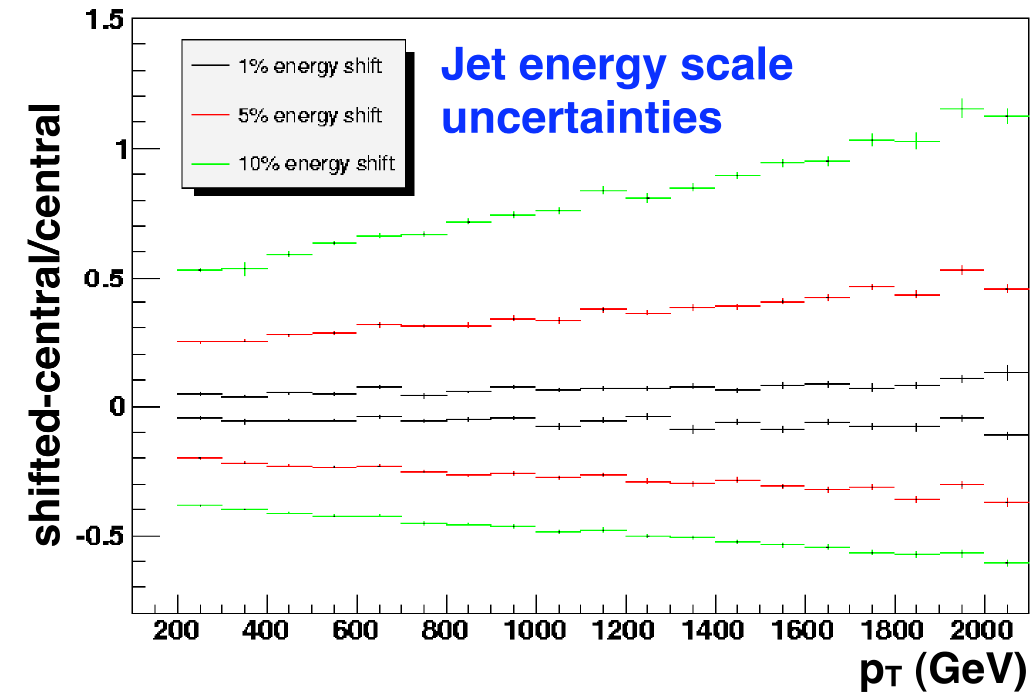


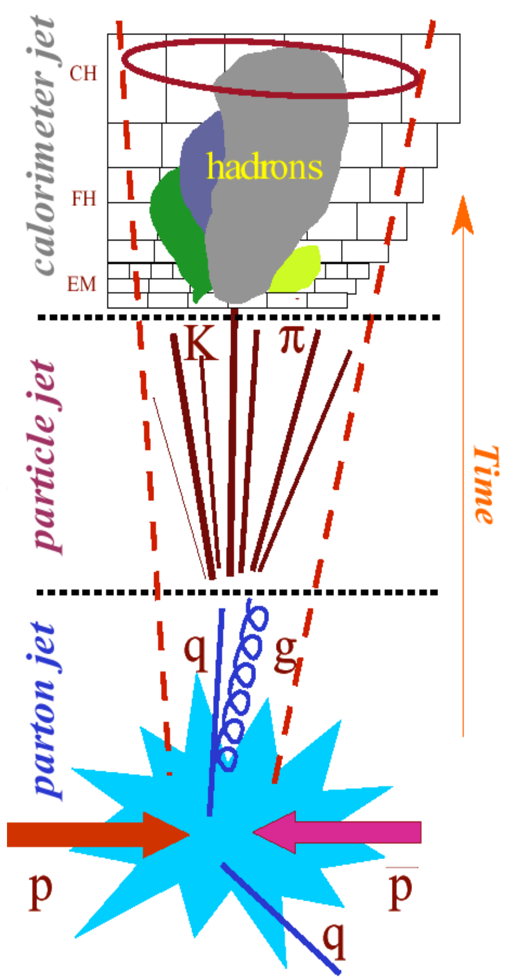


- Isolated jet samples with a highly enriched b-jet content, on which the **b-jet identification algorithms can be calibrated**
  - ★ main systematics from **ISR/FSR**

Jet cross sections

- **Experimental uncertainties**
  - ★ Luminosity determination
  - ★ Jet Energy scale (see plot)
    - 1(5,10)% JES ⇒ 10(30,70)% $\delta\sigma$
  - ★ Jet resolution, UE subtraction, trigger efficiency, etc.
- **Detector effects:** how do we reconstruct and calibrate jets?





- ★ Use seeded-cone and K_T algorithms
- ★ From the calorimeter jet to the particle jet (jet obtained running the reconstruction algorithm on the final state MC particles) use the Monte Carlo tuned on the test beam data
  - **apply cell corrections** (longitudinal energy leakage, signal inefficiencies, noise, signal definition, energy losses, e/h response, reconstruction efficiencies)
- ★ From particle jet to parton jet (if needed):
  - underlying event (tuning with tracks) and hadronization corrections