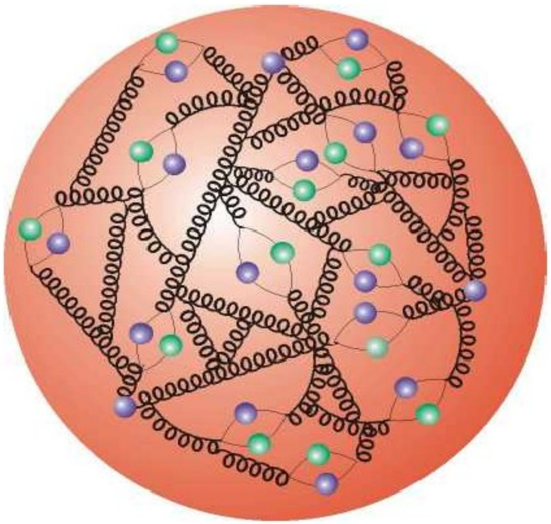
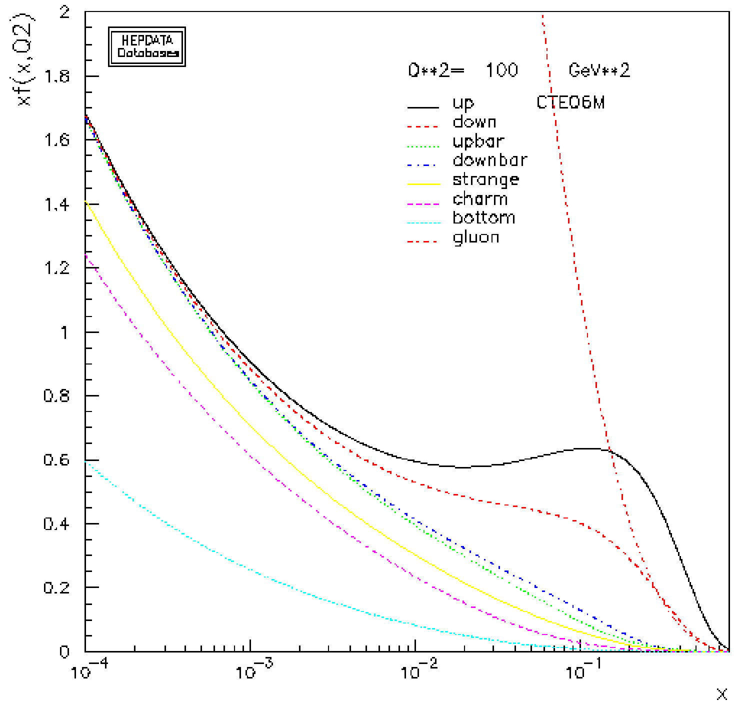
Impact of PDFs uncertainties on LHC precision measurements

Current picture of the proton





Outline

- ✓Cross section estimates using parton luminosity
- ✓PDFs uncertainties
- ✓W and Z cross section as precision benchmarks
- ✓Correlations between cross sections and PDFs
- ✓ttbar cross section as precision benchmark??
- ✓PDFs impact on Higgs physics and BSM physics

Parton luminosity

To have an idea of PDFs impact on different processes it is useful to define a parton luminosity

$$\frac{\Delta L_{ij}}{d\hat{s}\,dy}=\frac{1}{s}\frac{1}{1+\delta_{ij}}[f_i(x_{1,}\mu)f_j(x_2,\mu)+(1\Leftrightarrow 2)]$$

The usual formula of the parton model

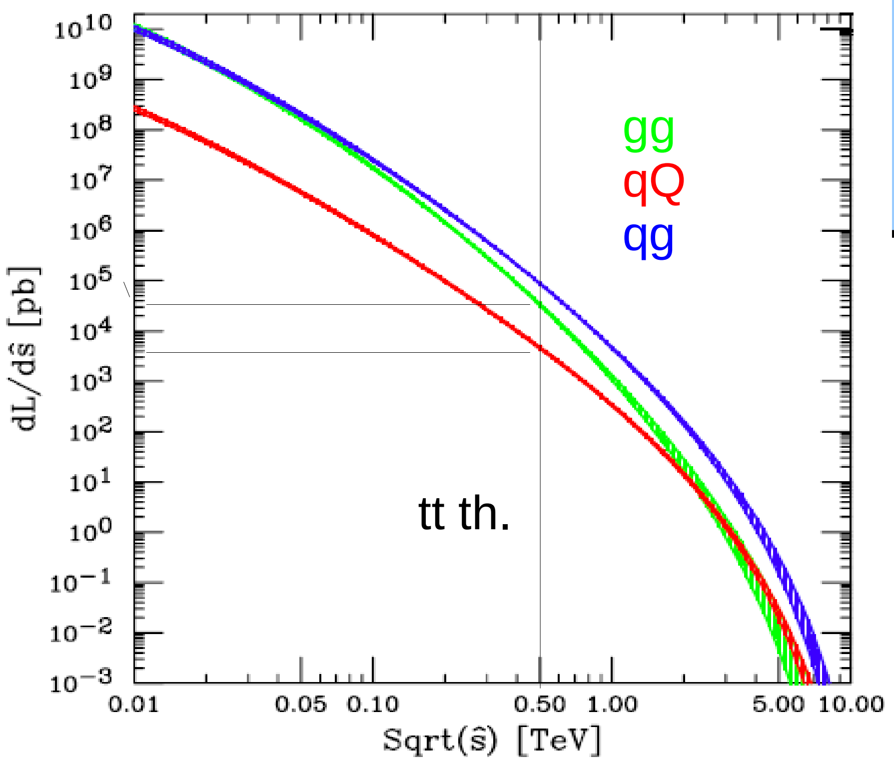
$$\sigma=\sum_{i,j}\int_0^1 dx_1\,dx_2\,f_i(x_{1,}\mu)f_j(x_{2,}\mu)\hat{\sigma}_{ij}$$

can be rewritten as

$$\sigma=\sum_{ij}\int\left(\frac{d\hat{s}}{\hat{s}}\right)\left(\frac{d L_{ij}}{d\hat{s}\,dy}\right)(\hat{s}\,\hat{\sigma}_{ij})$$

This allows to estimate production rates as a product of a differential luminosity times a scaled matrix element for the hard scattering

Cross section estimates



At 500 GeV (threshold of ttbar production) the gg factor is 10 times bigger than qq one. That's why @LHC gluon fusion is the dominant process

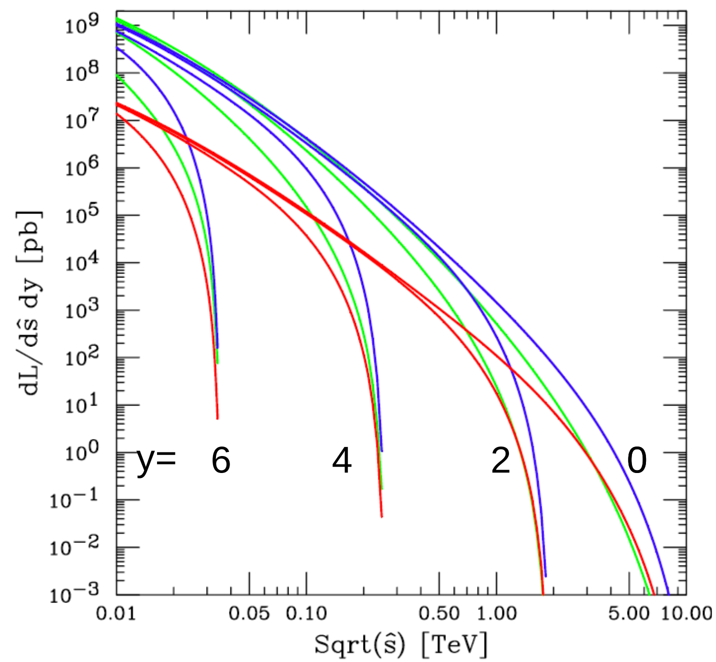
These curves allow to have also a fast estimation of the cross section of a process

$$\sigma = \frac{\Delta \hat{s}}{\hat{s}} \left(\frac{dL_{ij}}{d\hat{s}}\right)(\hat{s}\hat{\sigma}_{ij}) \longrightarrow$$

~1 * 4e^4pb * 0.012
=500pb (LO)

Same plots as above but at different rapidity values

→ Ttbar produced only at y<3

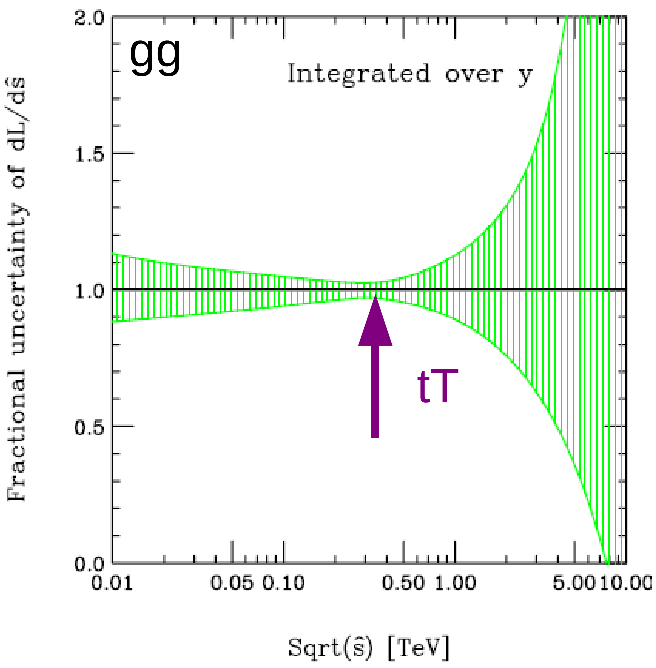


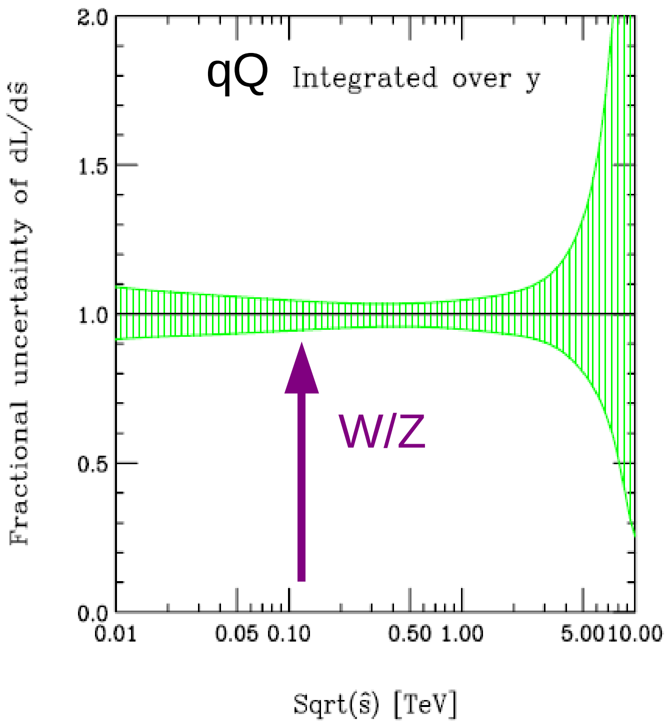
PDFs uncertainties

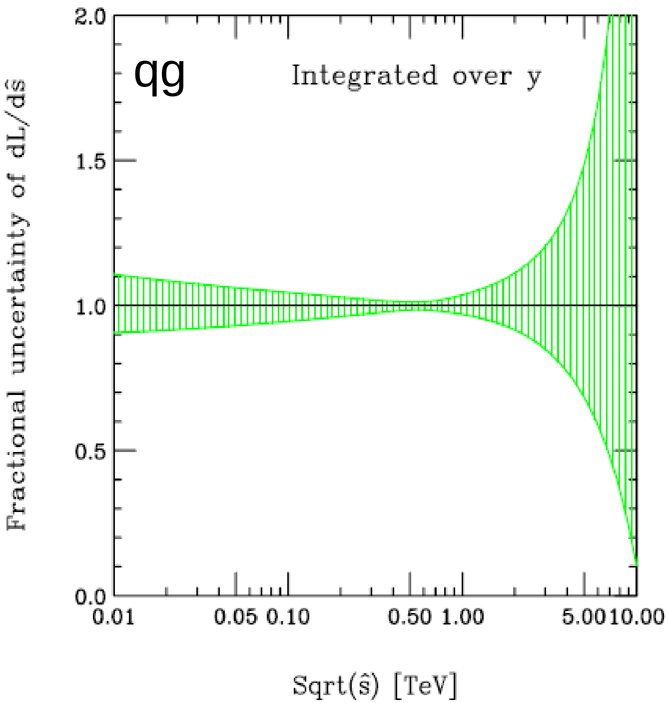
PDFs luminosity uncertainty is constant all over the SM range

High-x physics (e.g. high E_T jet cross section) will strongly depend on gluon PDF uncertainty --> need to lower the incertitude

Use LHC data (e.g. Top data) to constrain gluon PDF







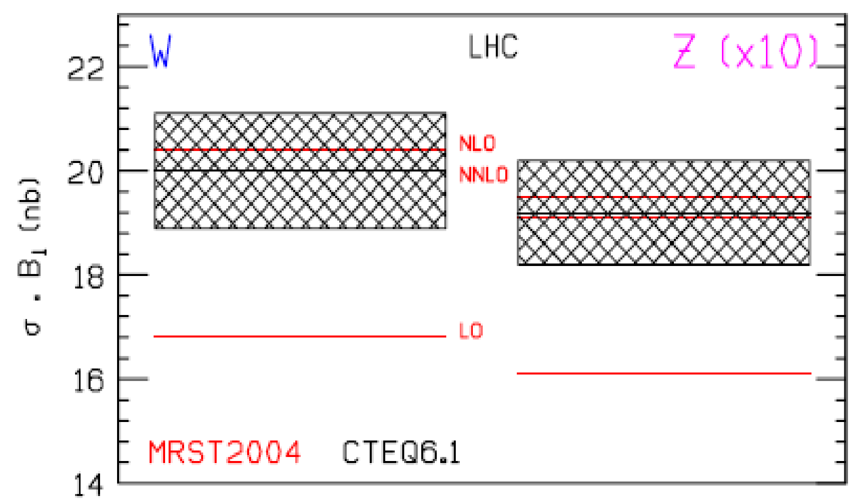
W and Z cross section as precision benchmarks

W and Z cross sections could be used as a useful normalization benchmark
--> they are well known and good accord between CTEQ6 and MRST

- W/Z cross section could be used as a useful luminosity normalization benchmark
  -->event rates for pp->W/Z can be measured with accuracy of ~1%
- These measurements will be used to constraint PDF’s and monitor LHC luminosity
- Luminosity will not be known to a better accuracy than 15 % in the first period

$\sqrt{s}$	Scattering process	σ, $\Delta\sigma$
1.96	$p\bar{p} \to (Z^0 \to l^+l^-)X$	241(8)
	$p\bar{p} \to (W^\pm \to l\nu_l)X$	2560(40)
	$p\bar{p} \to t\bar{t}X$	7.2(5)
14	$pp \to (Z^0 \to l^+l^-)X$	2080(70)
	$pp \to (W^\pm \to l\nu_l)X$	20880(740)
	$pp \to (W^+ \to l^+\nu_l)X$	12070(410)
	$pp \to (W^+ \to l^-\bar{\nu}_l)X$	8810(330)
	$pp \to t\bar{t}X$	830(30)

$\Delta\sigma$ =3%



W and Z cross section as precision benchmarks

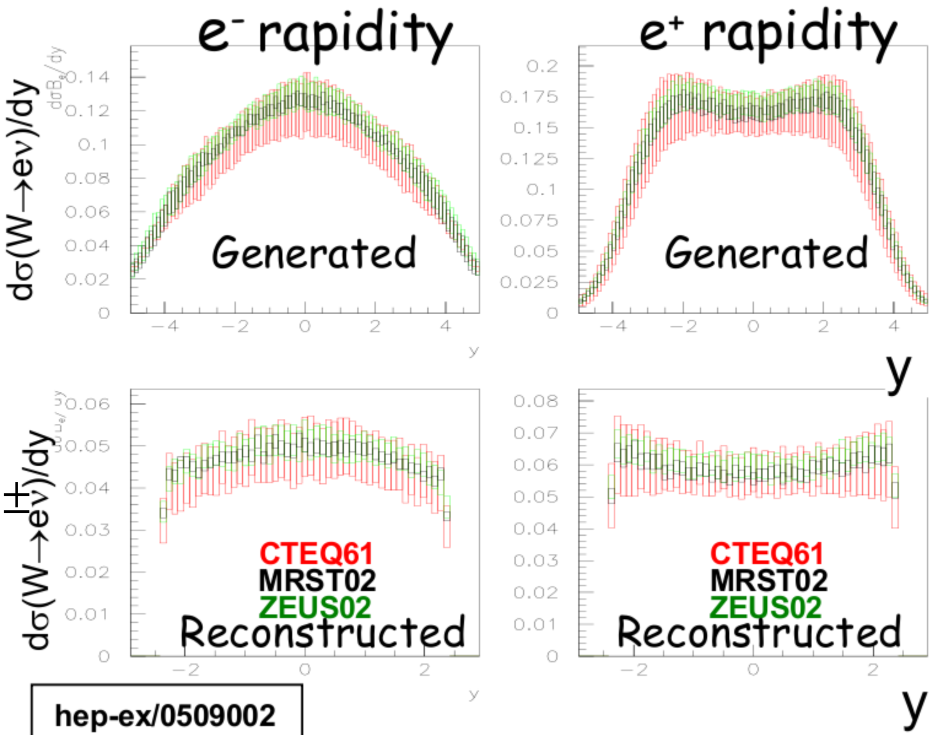
From an experimental point of view...

- $\sigma(Z \to ll + X) = 1160 \pm 1.5$ (stat) $\pm$ 27 (syst) $\pm$ 116 (lumi) pb

p_T effects in LO/NLO	1.83 %
Tracker efficiency	1 %
PDF uncertainty	0.7 %

- $\sigma(W \to l\nu + X) = 14700 \pm 6$ (stat) $\pm$ 485 (syst) $\pm$ 1470 (lumi) pb

p_T effects in LO/NLO	2.29 %
Missing E_T	1.33 %
Trigger efficiency	1 %
Muon efficiency	1 %



Small uncert. --> we can distinguish the PDFs set

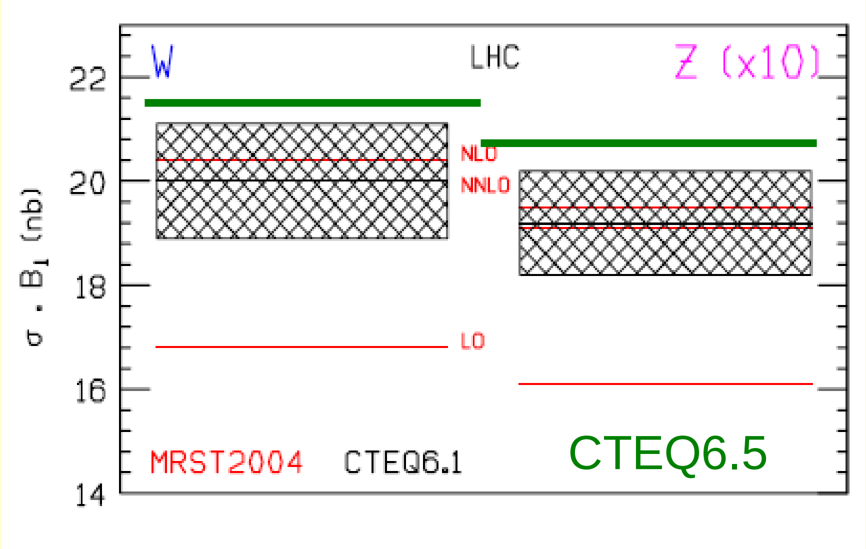
- Theoretical uncertainties dominated by PDFs
- At LHC experimental uncertainty dominated by systematics
- The detector acceptance dominates the systematic theory (PDFs uncertainty for acceptance is ~5-10 times smaller than for xsect itself)

Impact of heavy quarks mass

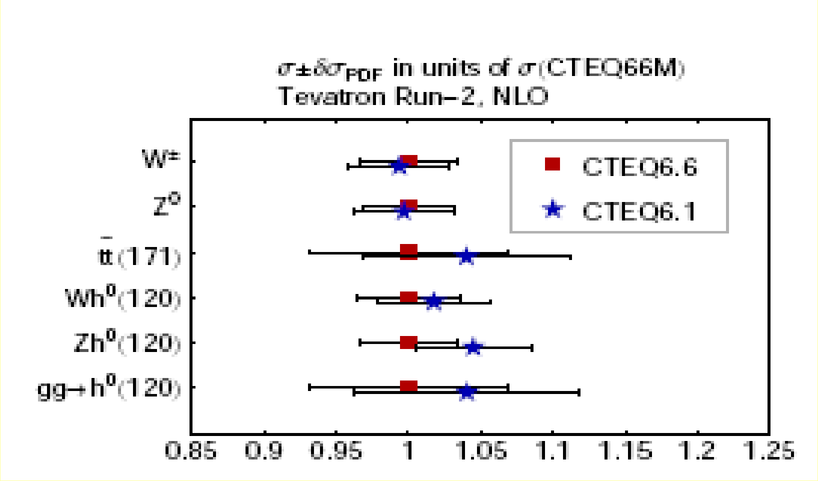
Giving a mass to heavy quarks in PDFs fits has an impact on the results (CTEQ6.5)

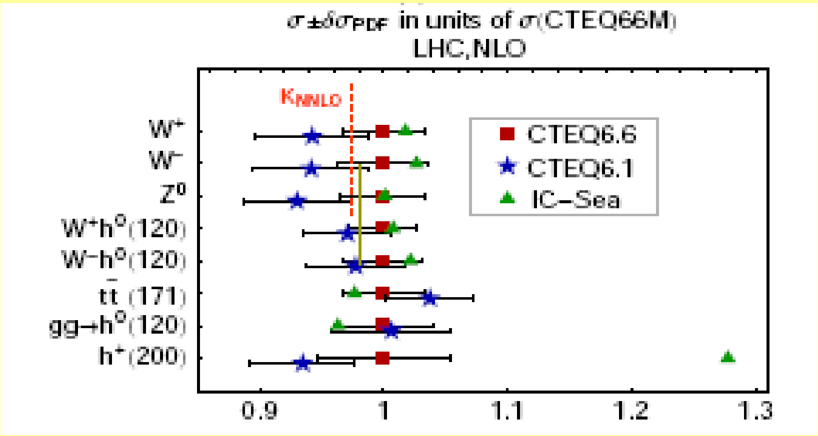
Cross section for W and Z increases by 7-8%

CTEQ and MRST do not agree anymore



Heavy quarks mass impact at Tevatron and at LHC

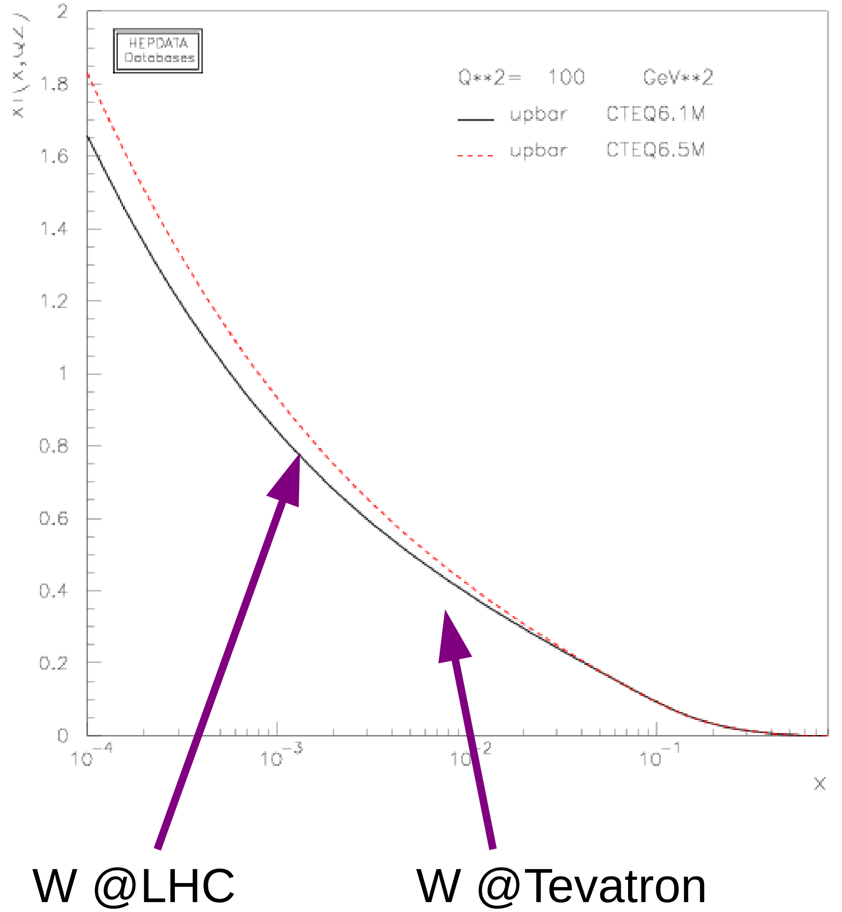




Impact of heavy quarks mass

LHC is a pp collider --> most qbars are sea quarks. W and Z cross sections depend strongly on ubar and dbar PDFs

For x=W production threshold @ LHC the difference of the two PDFs bigger than for X=W threshold @ Tevatron



Correlation between cross section

1)We can parametrize the dependence of a cross section wrt the PDF parameters

2)Mapping the PDF dependence of xsect1 vs PDF dependence of xsect2 we can see an eventual correlation between them.

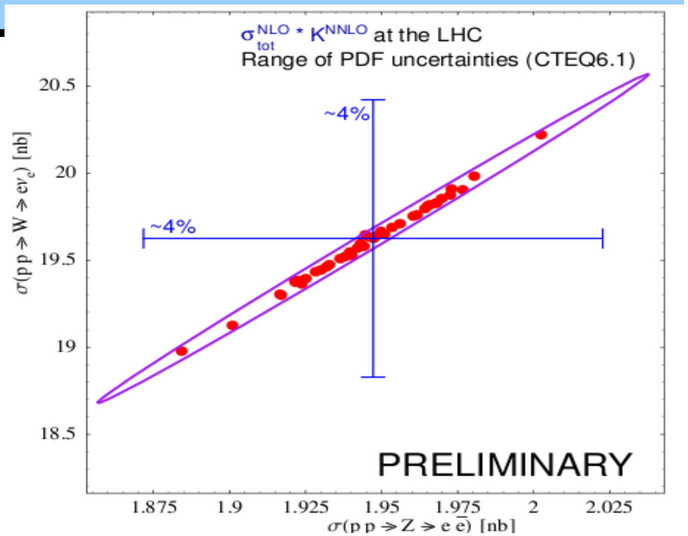
3)LHC collaborations will normalize many xsect to standard candle xsect as σ_W, σ_Z (they will measure σ_1/σ_{SC})

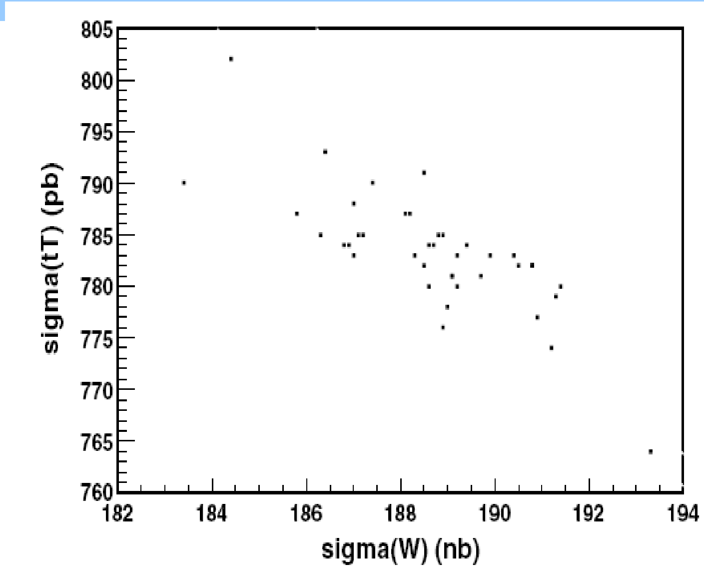
- Dependence on systematics may cancel out
- PDF uncertainties cancel out in correlated xsect, add up in anti-correlated ones

4)It will be good to find a correlated standard candle xsect for any interesting cross section

Correlations between σ_W / σ_Z /σ_t and PDFs

- Strong correlation for W and Z due to PDFs
- Anti-correlation for Z and tT cross sections

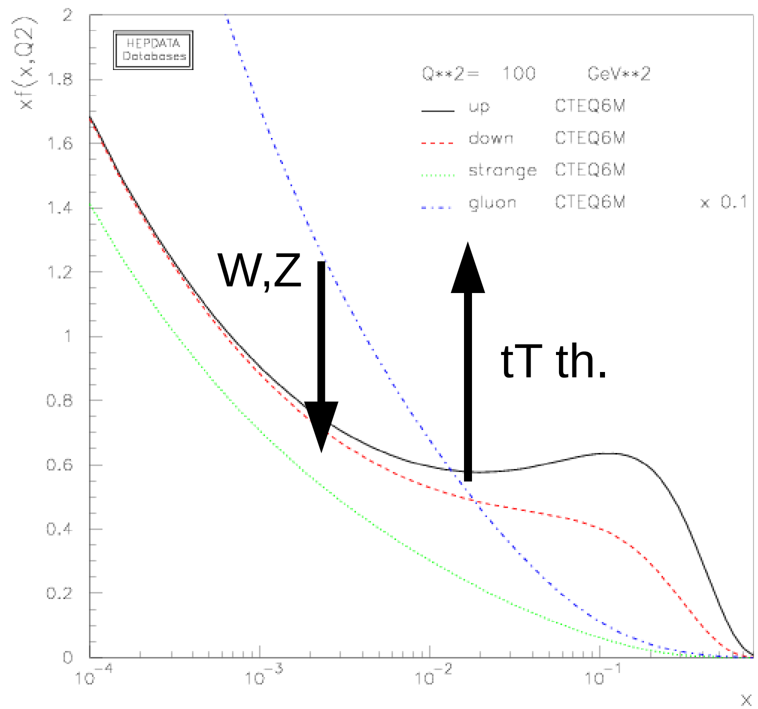




1) If we rise the gluon PDF value at high x, we lower it at low x (global area has to be constant)

2) Less gluon means less sea-quarks (because of DGLAP eqs.)

3) Less (anti-) quarks for W production



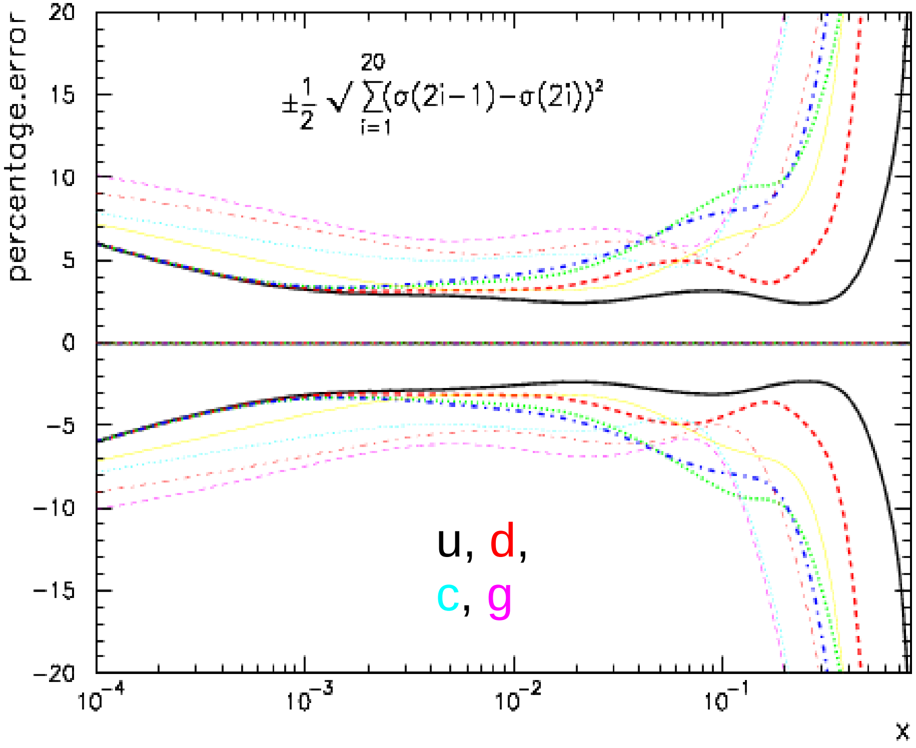
Correlations between σ_W / σ_Z / σ_t and PDFs

@LHC strong contribution of heavy quarks PDFs uncertainty

1) Subprocesses with initial state *s,c* and *b* deliver up to 20% of NLO rate

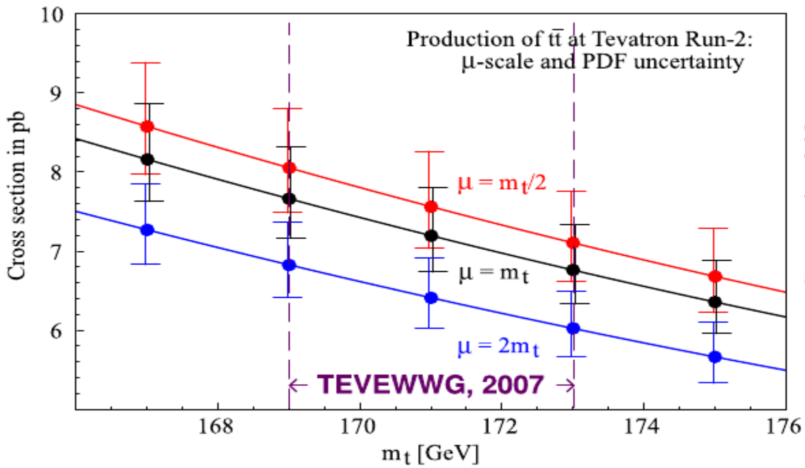
2) These partons are correlated to gluons via DGLAP eq.

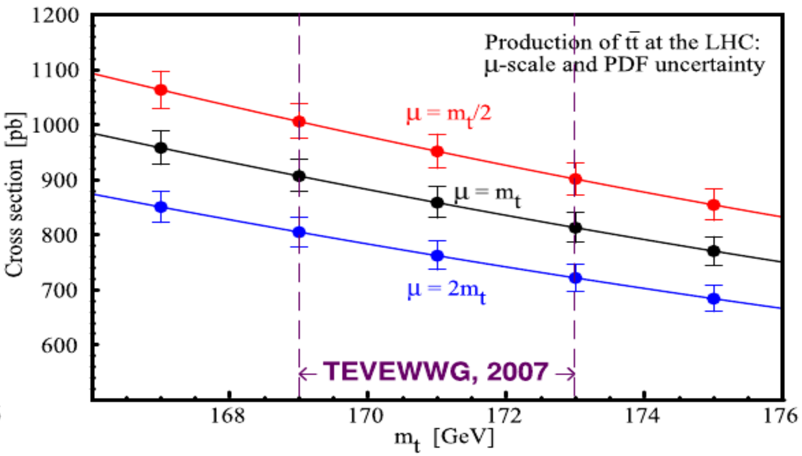
3) σ_W and σ_Z strongly sensitive to uncertainty of gluon PDF rather than to *u* and *d* PDFs (better known)



Quark top production and gluon PDF uncertainty

Calculated NLO top xsect for three values of factorization scale: $\mu=m_t/2$, $\mu=m_t$, $\mu=2m_t$ (error bars are PDF uncertainties)





@LHC the scale dependence is more important than PDF uncertainties on the ttbar xsec

--> higher order correction (NNLO) will have an impact on ttbar prod rate: it should be ready for the end of the year and reduce the associated uncertainty to a few percent

Quark top production and gluon PDF uncertainty

They parametrize the resulting cross section in the vicinity of the world average top mass

$$m_t = 171 \pm 1.1(stat.) \pm 1.5(syst.)$$

by the function

$$\sigma(\mu, m_t) = A(\mu) + B(\mu)(m_t - 171) + C(\mu)(m_t - 171)^2$$

The scale dependence bigger than Δ_{PDF}

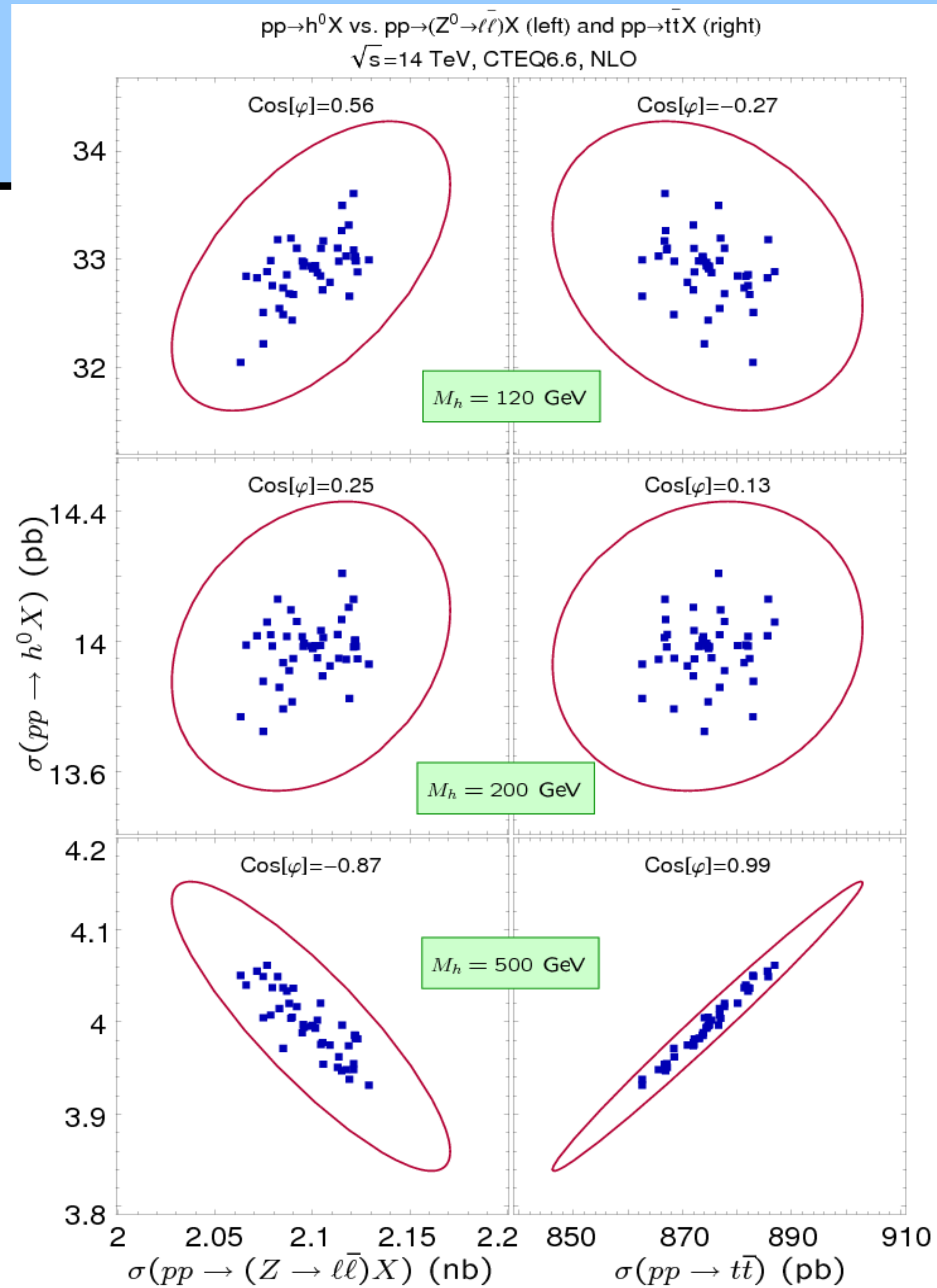
		$p\bar{p} \to TX$ ($\sqrt{s} = 1.96$ TeV)			$pp \to TX$ ($\sqrt{s} = 14$ TeV)		
Final state	Parameter	$\mu = m_t/2$	$\mu = m_t$	$\mu = 2\,m_t$	$\mu = m_t/2$	$\mu = m_t$	$\mu = 2\,m_t$
$T = t\bar{t}$	A [pb]	7.546	7.197	6.412	951.2	857.9	761.6
	B [pb·GeV^{-1}]	-0.237	-0.225	-0.201	-26.12	-23.43	-20.81
	C [pb·GeV^{-2}]	0.0041	0.0039	0.0034	0.44	0.37	0.33
	$\Delta_\mu(m_t = 171)$	$+5\%$	reference	-11%	$+11\%$	reference	-11%
	$\Delta_{PDF}(m_t = 171)$	$^{+8.4}_{-6.4}$ **(7.4)%**			$^{+3.3}_{-3.2}$ (3.3)%		
$T = t$ (t-channel)	A [pb]	1.96	2.01	2.058	248	248.4	249.1
	B [pb·GeV^{-1}]	-0.034	-0.036	-0.037	-1.93	-2.19	-2.24
	$\Delta_\mu(m_t = 171)$	-2.7%	reference	2.6%	-1.6%	reference	2.4%
	$\Delta_{PDF}(m_t = 171)$	**10.3%**			3.2%		

The Higgs boson

Correlation between Higgs cross section and
-Z (left)
-tT (right)
@ different masses

The main Higgs production channel is the gluon fusion

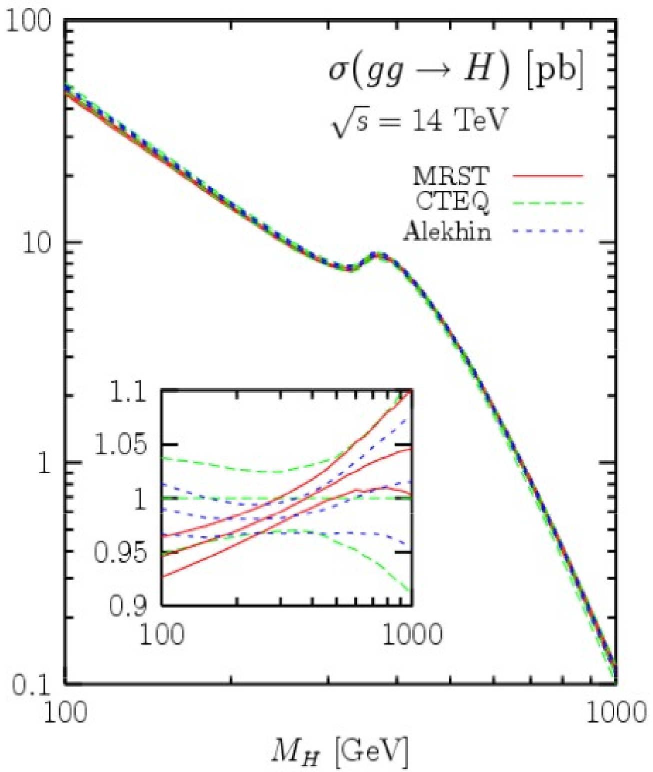
-->very strong (anti) correlation if its mass is close to ttbar threshold



The Higgs boson

PDFs uncertainties will not mask the Higgs boson

--> PDFs uncertainties for the Higgs production within 5% all over the production range



ttbar production as a standard candle

Precise measurements of ttbar rates could provide constraints on gluon and heavy quark PDFs

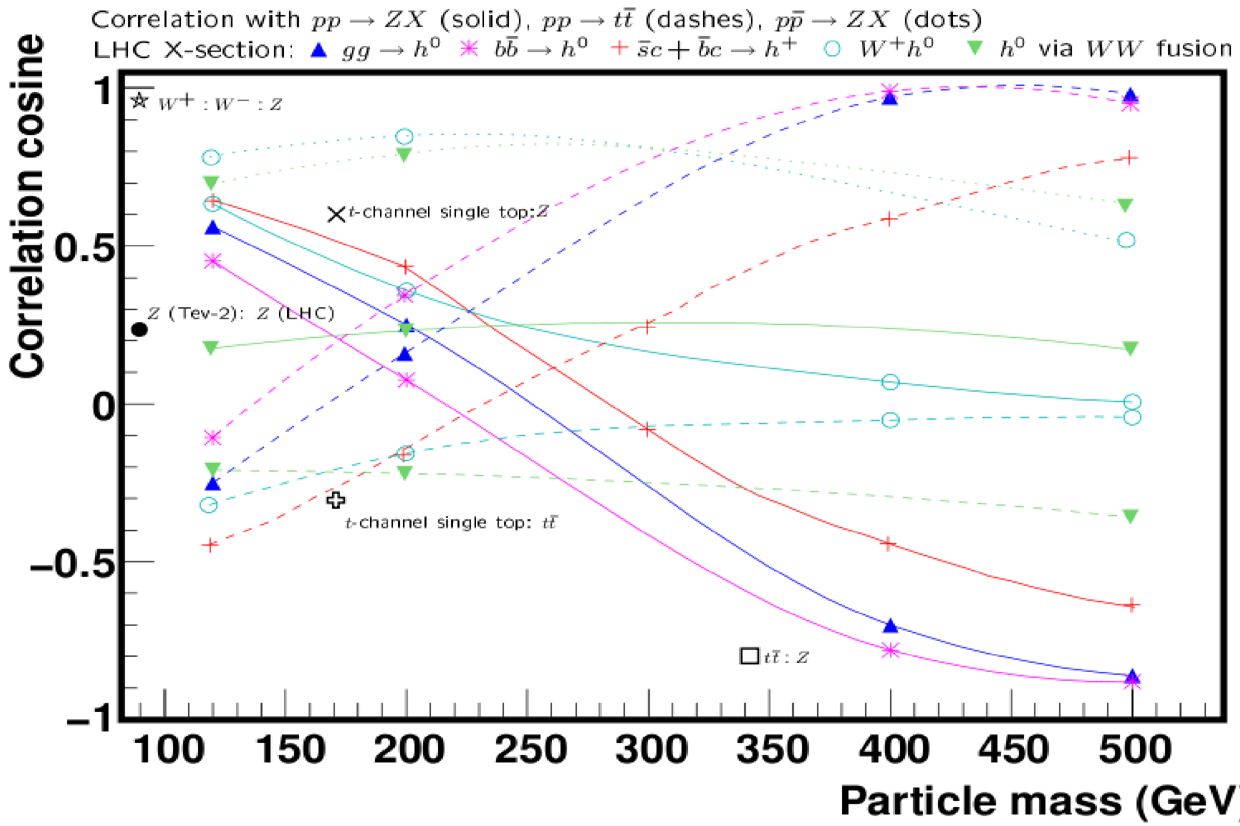
At the LHC the ttbar prod rate is anti correlated with Z and W

Possibility of use (not immediately) the σ_{tt} as a standard candle: if a cross section is anti-correlated with W xsec, it could be normalized to σ_{tt} to reduce PDFs errors

Correlation between different Higgs production rates and

- ttbar (dashes)
- LHC Z (solid)
- Tev. Z (dots)

gg->h^0
bbar->h^0
csbar+scbar->h^0
W fusion ->h^0



Impact of PDF uncertainties on discovery physics

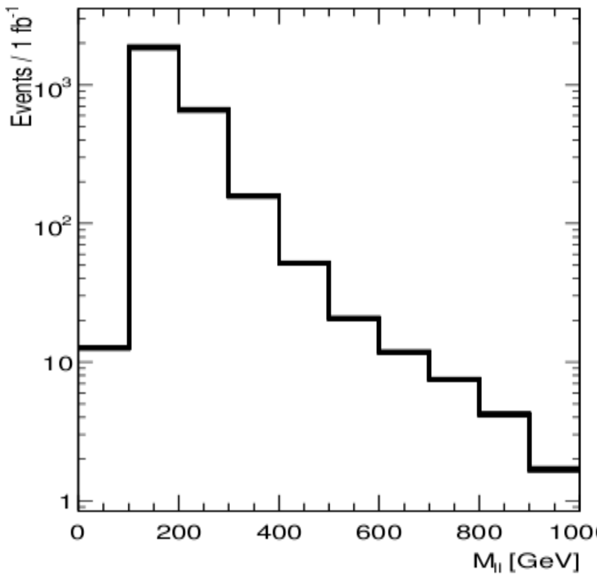
Some classes of discovery physics not much compromised by PDFs uncertainty

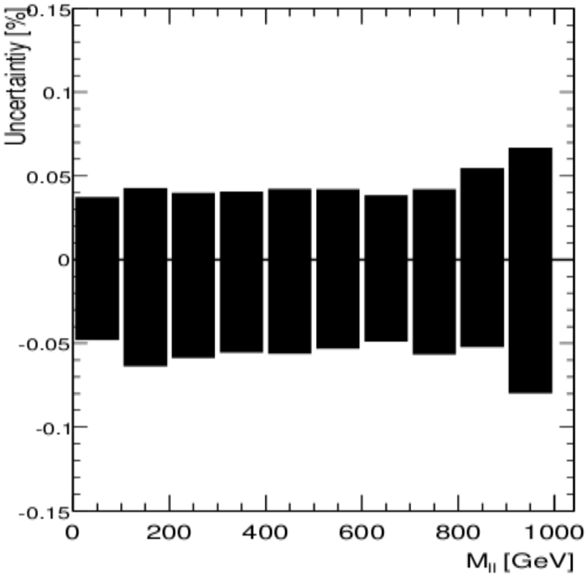
1) SM Higgs

2)PDF uncertainties on high mass di-lepton production. They do not mask Z' production

Left: di-lepton mass spectrum

Right: uncertainty on this spectrum from CTEQ6





Short summary of PDF4LHC workshop

For all details see http://indico.cern.ch/conferenceDisplay.py?confId=27439

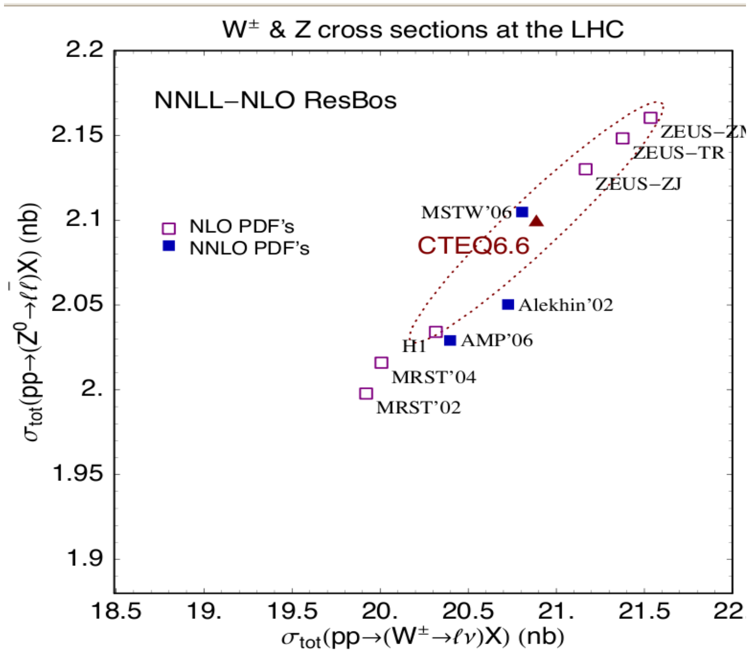
PDF uncertainties come from different sources

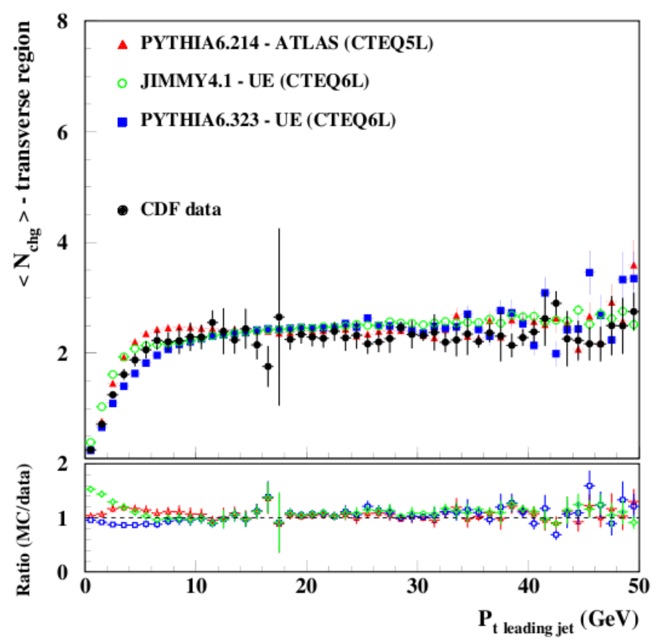
1)PDF fits, parametrization, evolution

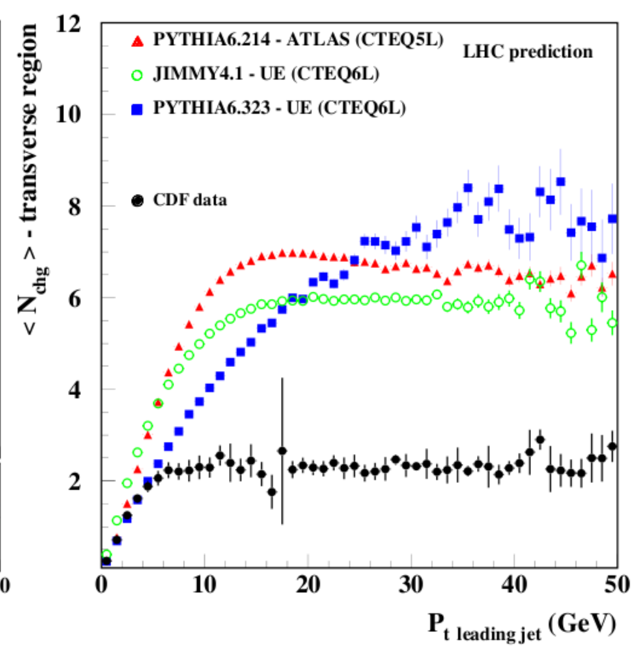
- Quark mass in the fits (talks by J.Huston and P. Nadolsky)
- The set of PDF we choose (CTEQ, MSRT/MSRW, Alekin, NNPDF) – see talk by A M Cooper-Sarkar

2)Small x resummation, evolution of gluon PDF

3)Multiple interactions (underlying event)



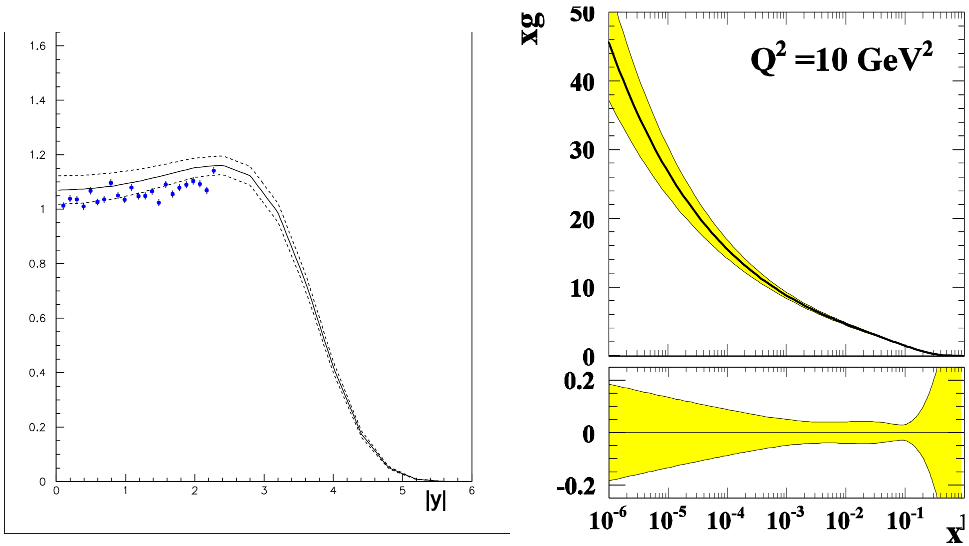




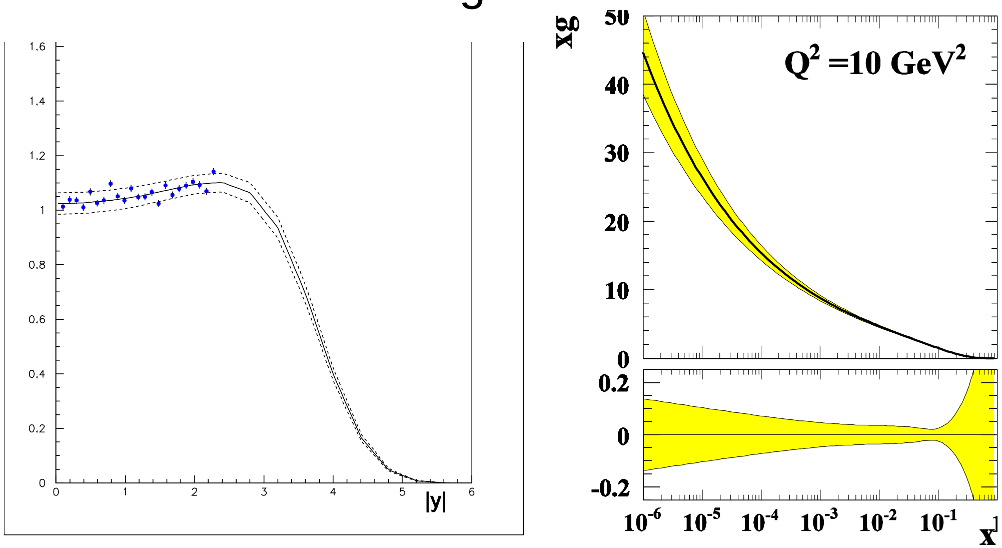
Short summary of PDF4LHC workshop

How to improve PDF using the first LHC data

Before including W data



After including W data



e+ rapidity spectrum and gluon PDF
BEFORE these data are included in PDF fit

e+ rapidity spectrum and gluon PDF
AFTER these data are included in PDF fit

Short summary of PDF4LHC workshop

Other useful channels to constrain PDF

- ✓Direct photon production for the high-x gluon
- ✓Z+ b-jet for Measurement of the b-quark PDF

W+jets: PDF vs JES Uncertainty

PDF vs Jet Scale Uncertainty (Δ JS) with **10%** (5%) jet energy miscal.

(Note: results with tight EF cuts samples)

2.9% < **Δ PDF** < 7.3%
5.8% < **Δ JS** (10%)< 23.6%
3.6% < **Δ JS** (5 %) < 11.9%

↓

PDF Uncert < Expt. Syst. Uncert

Next: When is JES < PDF Unc?
Try with 1,2,3% jet energy miscal.

Multipl	Δ+ PDF (%)	Δ- PDF (%)	Δ+ JS (%)	Δ- JS (%)
W+ ≥1 jets	3.2	2.9	10.7 (5.2)	10.7 (5.2)
W+ ≥2 jets	3.2	2.9	10.2 (5.1)	10.7 (5.2)
W+ ≥3 jets	3.3	2.9	5.8 (3.6)	9.0 (4.0)
W+ ≥4 jets	5.0	3.9	14.7 (7.8)	15.6 (7.0)
W+ ≥5 jets	5.9	4.8	20.8 (9.5)	20.5 (10.7)
W+ ≥6 jets	7.3	5.9	22.2 (10.4)	23.6 (11.9)

Conclusions

- Parton luminosity allows us to quickly estimate cross section and the dominant production process for a given channel
- W and Z cross section will be precision benchmarks for many other cross sections
- Strong influence of heavy quarks PDFs on their calculation. Importance of correlation between cross sections: measuring a ratio between cross sections, if they are correlated, PDFs uncertainties cancel out, add up if anti correlated
- A good measure of the ttbar cross section will allow us to use it as a precision benchmark anti correlated with W cross section.
- Higgs cross section not too affected by PDFs uncertainties
- For jet cross section at large ET, the JES will have a greater impact than PDFs during the first years

Informations stolen from...

Hard interactions of quarks and gluons: a primer for LHC physics (J. M. Campbell et al.)
http://stacks.iop.org/0034-4885/70/89

Implications of CTEQ global analysis for collider observables (Nadolsky et al.)
http://front.math.ucdavis.edu/0802/0007

Top cross section prediction and uncertainties (J. Huston)
http://indico.cern.ch/conferenceDisplay.py?confId=25485

Durham web-site allowing to draw PDFs and their incertainties
http://durpdg.dur.ac.uk/hepdata/pdf3.html

Impact of and constraint on PDFs at LHC (A. M. Cooper-Sarkar)
arXiv:0707.1593v1

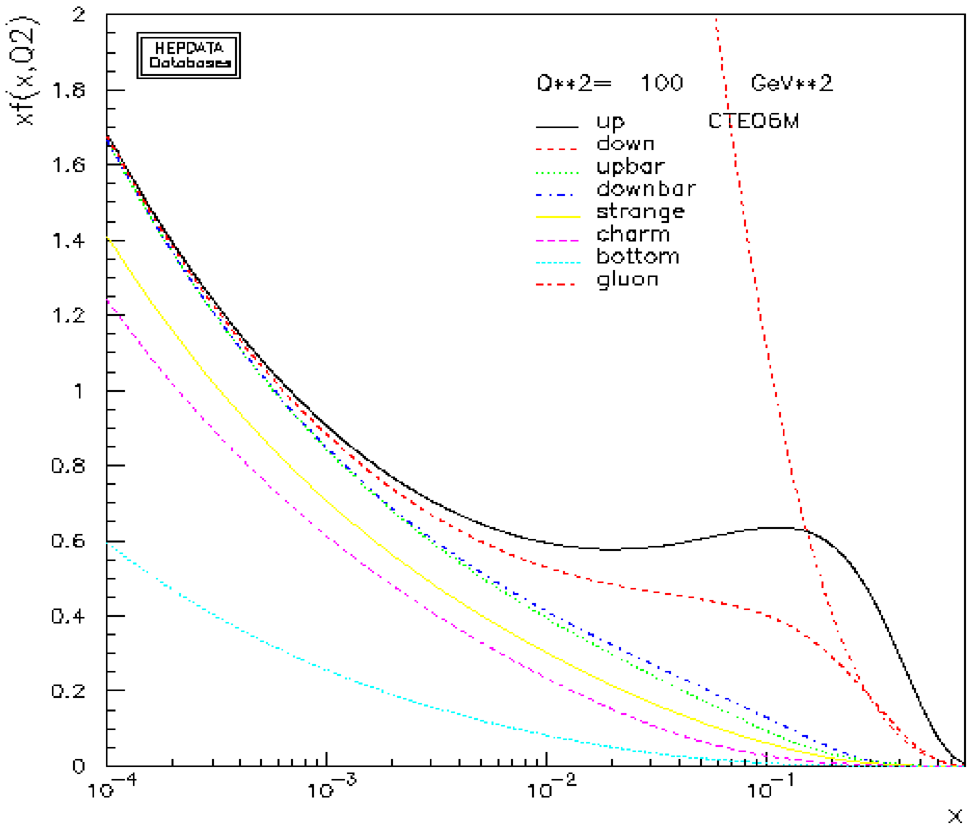
Plan de l'exposé

- Introduction sur les PDFs
- Incertitudes des PDF au LHC

Apres avoir introduit le concept de luminosité partonique qui permet de ... (voir pag 4 et 5 talk J. H.)
Ajouter un dessin avec la structur de proton, quark valence et mer....

- Precision benchmarks (W, Z cross sections, ttbar)
- Their correlation (origin of correlation)
- When we add the mass to the quark

Impact of PDFs incertainties on LHC precision measurements



Short introduction on PDFs????

Impact of PDF uncertainties on discovery physics

BSM physics compromised by PDFs uncertainty is anything which would appear in the high-ET jet cross section

The main contribution to the uncertainty on high-Et xsec come from high-x gluons

The lack of knowledge of the gluon PDF at high x strongly limits the potential discovery of extradimension at LHC (see Juan's talk)

Add plots

Quark top production and gluon PDF uncertainty

La dependence de st des PDFs peut etre mieux comprise en regardant les correlations entre   st et les PDFs.

Ttbar and single top (t-channel)are mostly correlated with g, c and b PDFs. The PDFs uncertainties are of 3% in both case

s-channel of single top not strongly correlated with W,Z x-sec despite similarities with W production.
This because the x~mt/sqrtS~0.01 --> at such high x c and b contributions are smaller than at x=0.005
=> less contribution of gluon-driven PDF incertainty to the xsec

How define correlations between cross sections and PDFs

Consider a x-sec X(*a*), *a* parameters of PDF
The xsec dipendence on one parameter is: → $\cos\phi = \frac{\vec{\nabla} \cdot \vec{\nabla} Y}{\Delta X \Delta Y} = \frac{1}{4 \Delta X \Delta Y} \sum (X_i^{(+)} - X_i^{(-)})(Y_i^{(+)} - Y_i^{(-)})$

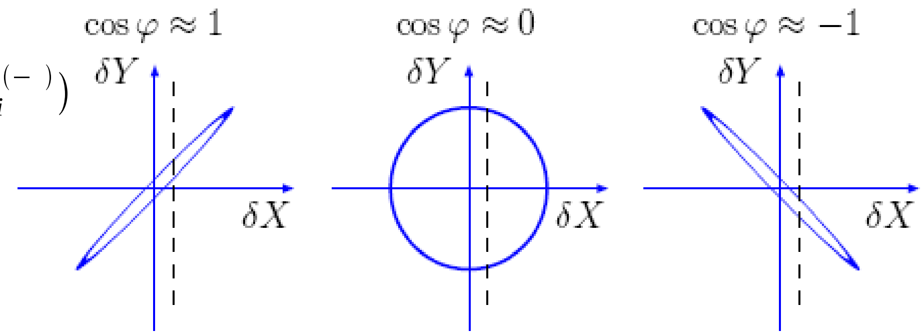
The uncertainty of X due to its dependence on PDFs is → $\Delta X = |\vec{\nabla} X| = \frac{1}{2} \sqrt{\sum_{i=1}^{N} (X_i^{(+)} - X_i^{(-)})^2}$

We take another xsec Y(*a*)

We consider the projection of the tolerance hypersphere onto a cercle in the plane $\vec{\nabla} X, \vec{\nabla} Y$ → This cercle maps on an ellipse

$$\cos\phi = \frac{\vec{\nabla} \cdot \vec{\nabla} Y}{\Delta X \Delta Y} = \frac{1}{4 \Delta X \Delta Y} \sum (X_i^{(+)} - X_i^{(-)})(Y_i^{(+)} - Y_i^{(-)})$$

$$\left(\frac{\delta X}{\Delta X}\right)^2 + \left(\frac{\delta Y}{\Delta Y}\right)^2 - 2\left(\frac{\delta X}{\Delta X}\right)\left(\frac{\delta Y}{\Delta Y}\right)\cos\phi = \sin^2\phi$$



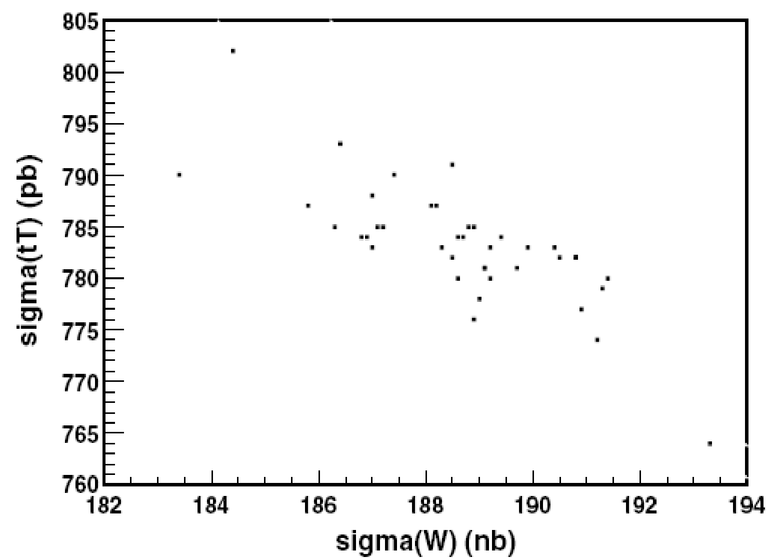
Correlations between σ_W / σ_Z / σ_t and PDFs

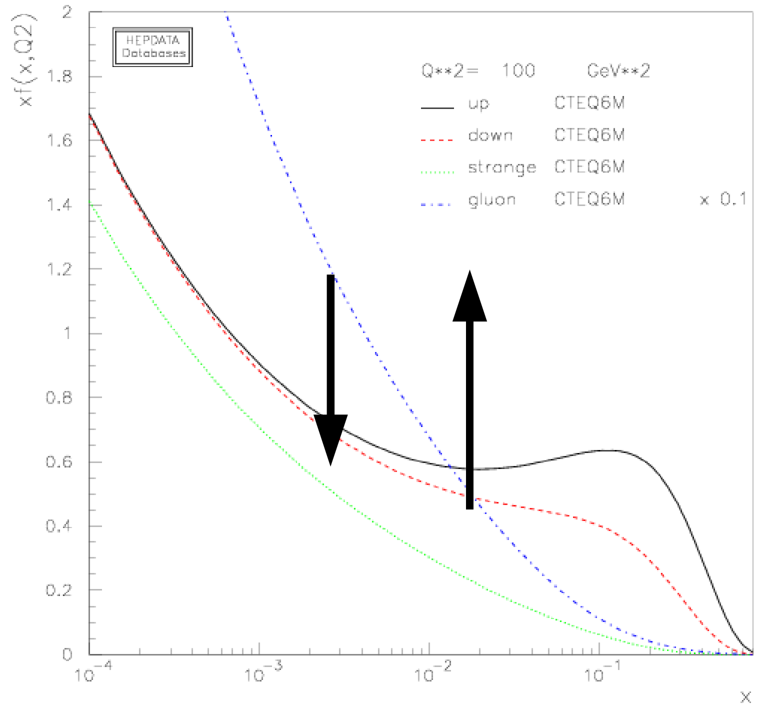
Anticorrelation between ttbar and W cross section

1) If we rise the gluon PDF value at high x, we lower it at low x (global area has to be constant)

2) Less gluon means less sea-quarks (because of DGLAP eqs.)

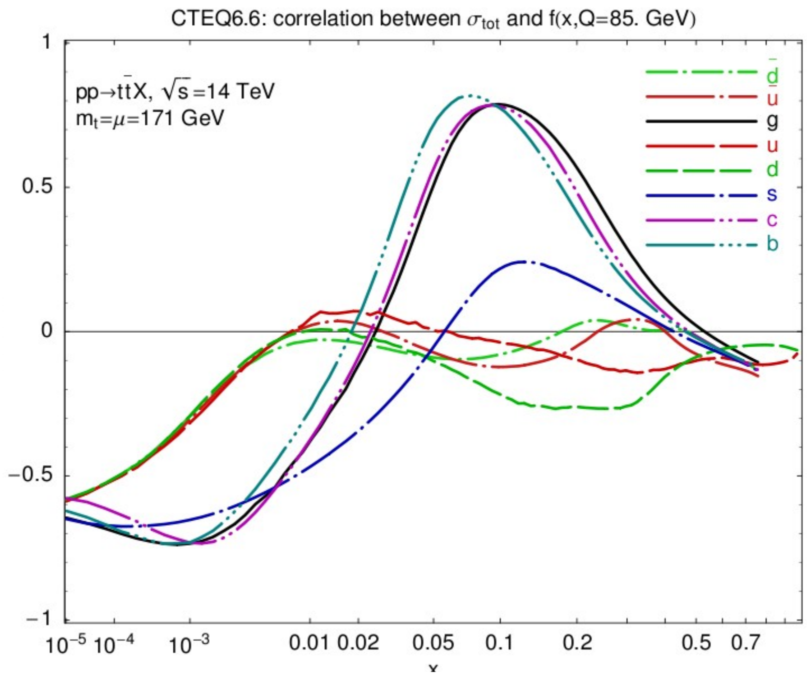
3) Less (anti-) quarks for W production

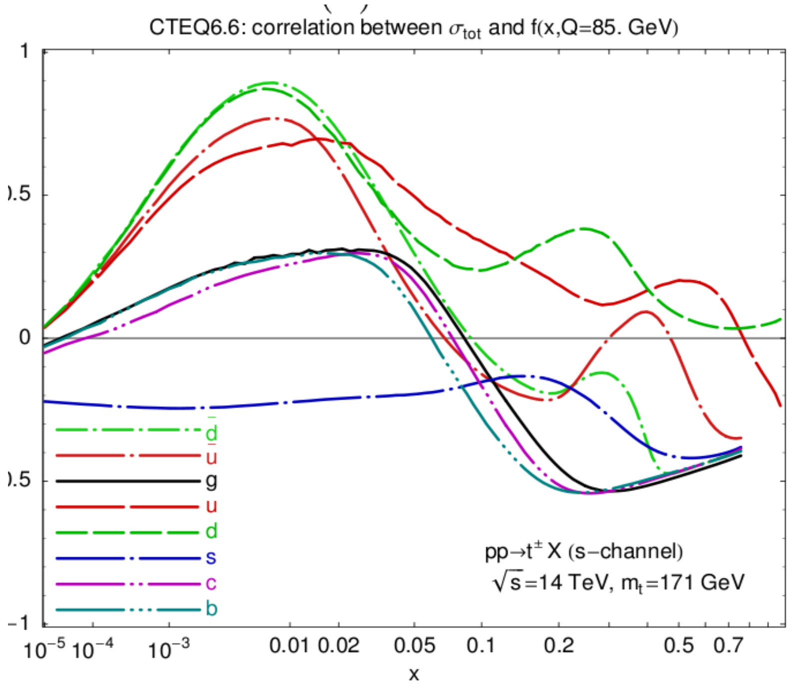




Vedi nota qui sotto

Quark top production and gluon PDF uncertainty





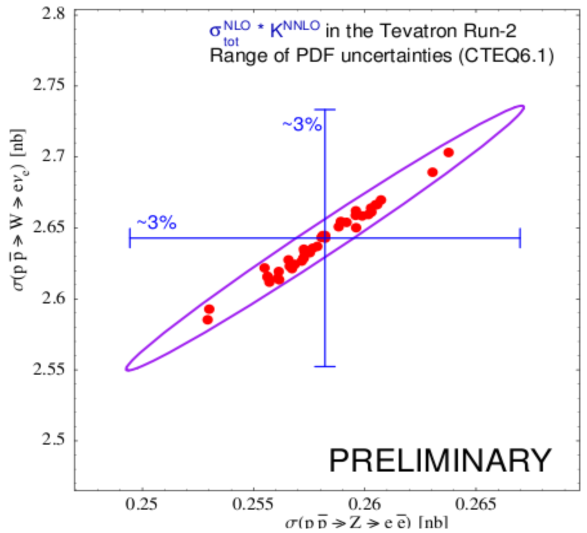
Ttbar and single top (t-channel) are mostly correlated with *g, c* and *b* PDFs. The PDFs uncertainties are of 3% in both case

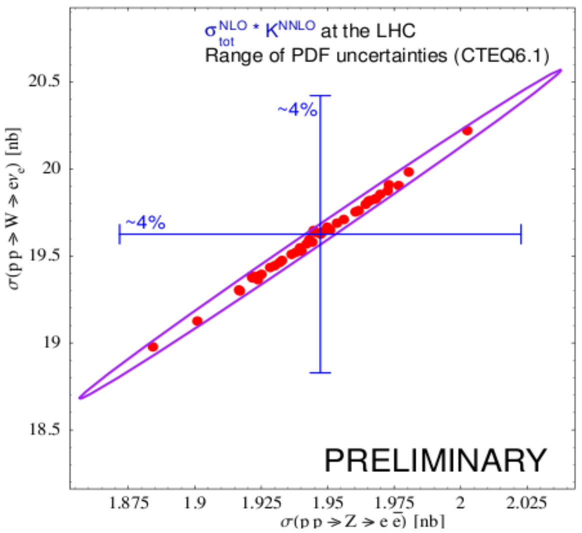
s-channel of single top not strongly correlated with W,Z x-sect despite similarities with W production.
This because the x~mt/sqrtS~0.01 --> at such high x *c* and *b* contributions are smaller than at x=0.005
=> less contribution of gluon-driven PDF incertainty to the xsec

Correlations between σ_W / σ_Z /σ_t and PDFs

Strong correlation due to PDFs

@LHC strong contribution of heavy quarks PDFs incertainty

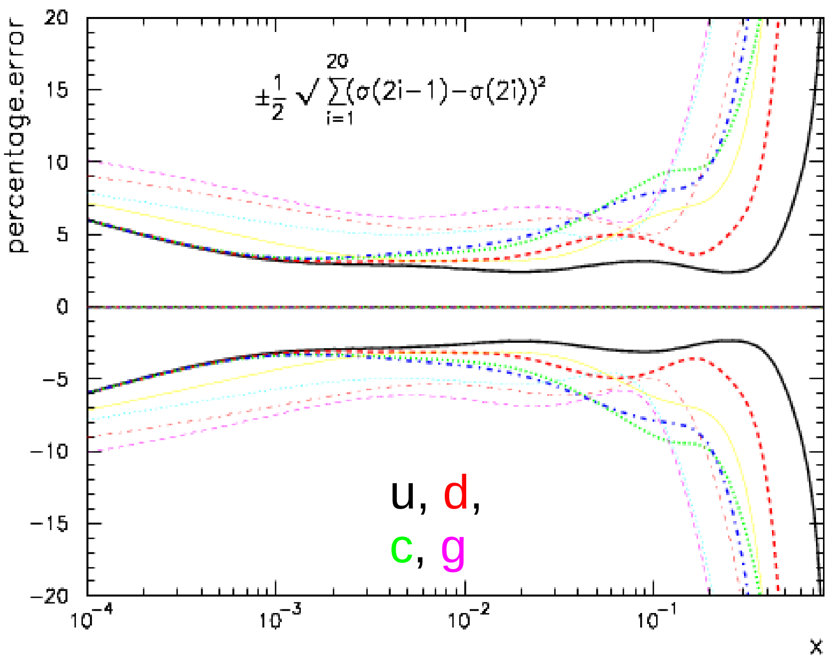




1) Subprocesses with initial state s,c and b deliver up to 20% of NLO rate

2) These partons are correlated to gluons via DGLAP eq.

3) SW and sW strongly sensitive to uncertainty of gluon PDF rather than to u and d PDFs (better known)



Questions

- Pdf uncertainty for the acceptance is 5-10 times smaller than the uncertainty for the cross section itself
- Emchanism of higgs production --> (anti) correlation with W,Z
- The qg luminosity is the higher... which processes correspond to it