ABM12 and beyond

S.Alekhin (*IHEP Protvino & DESY-Zeuthen)*

- ABM12 release and benchmarks
- Recent DY data from the LHC and Tevatron
- Update of the strange sea
- Theoretical issues in the jet data analysis

sa, Blümlein, Moch hep-ph/1310.3059

PDF4LHC meeting, CERN, 13 Dec 2013

The ABM fit ingredients

DATA:

- DIS NC inclusive (Q^2>1000 GeV^2)
- DIS charm production (determination of $m_c(m_c)$)
- DIS μμ CC production
- fixed-target DY
- LHC DY distributions
- t-quark production c.s.

QCD:

- NNLO evolution
- NNLO massless DIS and DY coefficient functions (Z- and Z-γ terms)
- NLO+ massive DIS coefficient functions (**FFN scheme**)
  - (NLO + NNLO threshold corrections, running mass)
- NNLO exclusive DY (DYNNLO 1.3 / FEWZ 3.1)
- NNLO inclusive ttbar production (pole / running mass)

Deuteron corrections in DIS:

- Fermi motion
- off-shell effects

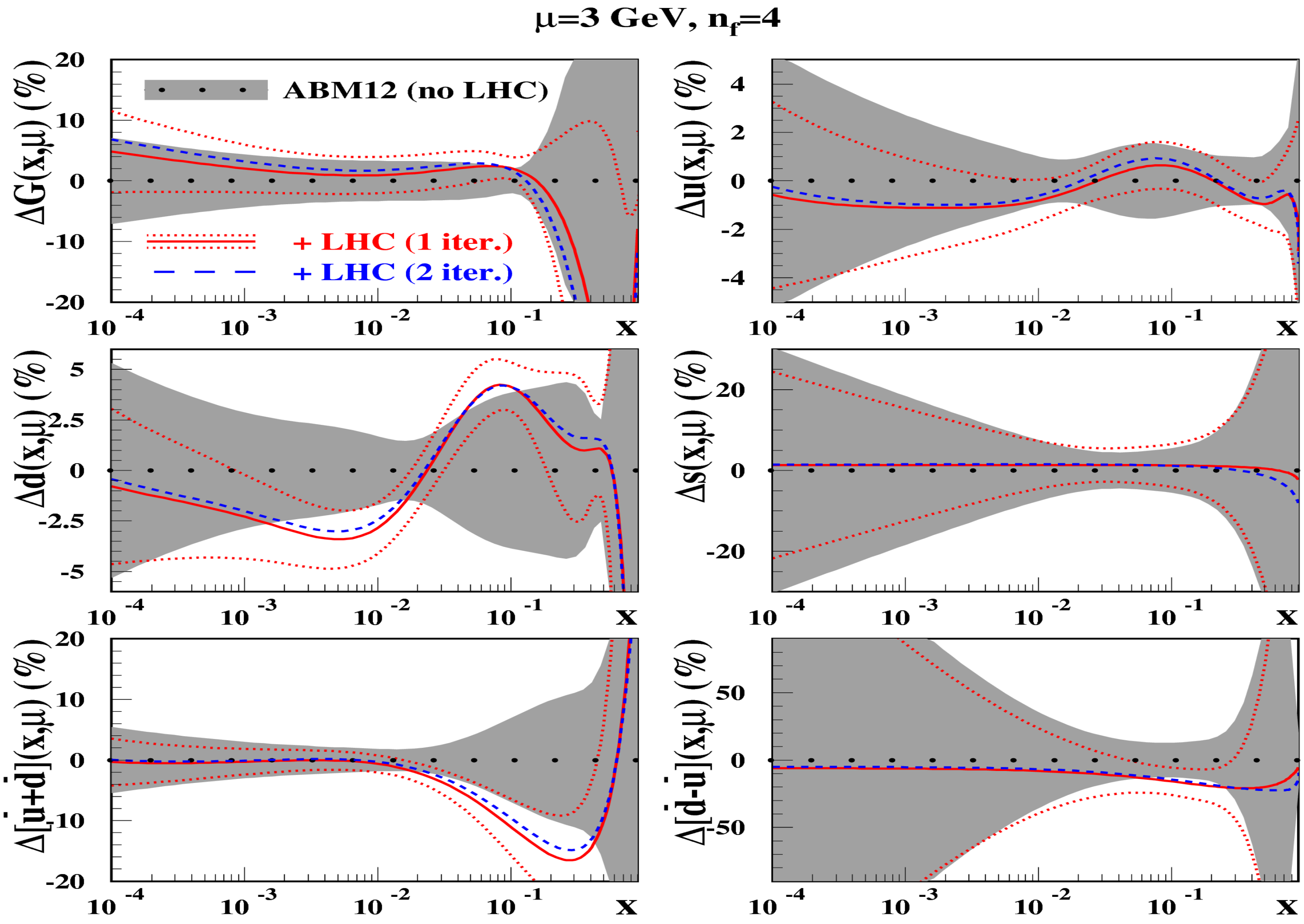
Power corrections in DIS:

- target mass effects
- dynamical twist-4 terms

The jet data are still not included: The NNLO corrections may be as big as 15-20%

Gehrmann-De Ridder, Gehrmann, Glover, Pires JHEP 1302, 026 (2013)

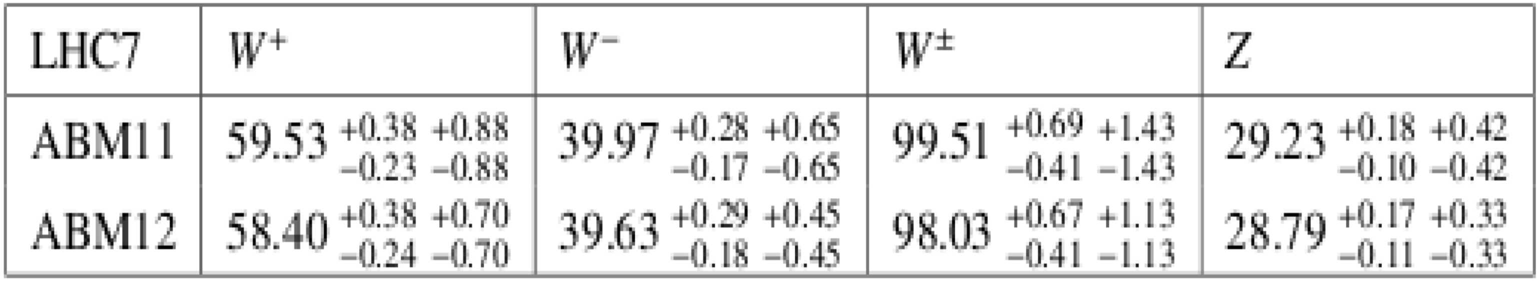
Impact of the LHC DY data on the PDFs



- d-quarks increase at x~0.1; *the errors get smaller*
- non-strange sea decrease at x~0.1
- strange sea stable → the enhancement observed by ATLAS is not reproduced

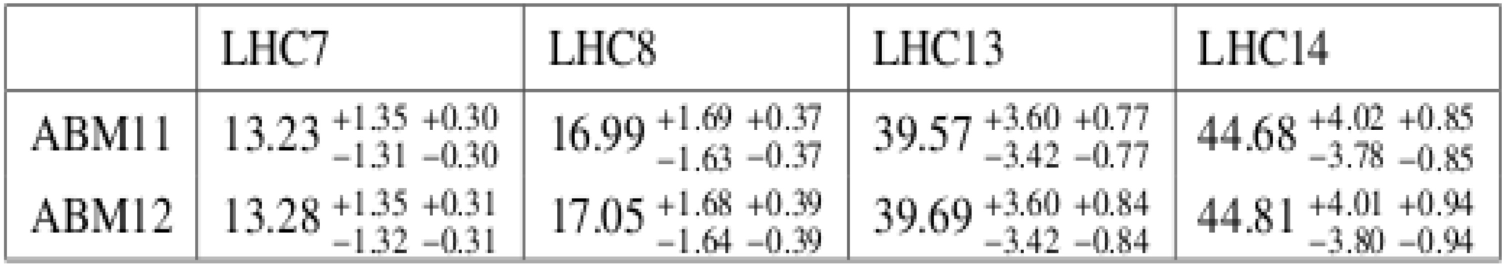
The algorithm used to include the LHC data is quite stable

NNLO benchmarks for the LHC



LHC7	W^+	W^-	$W^\pm$	Z
ABM11	$59.53^{+0.38\;+0.88}_{-0.23\;-0.88}$	$39.97^{+0.28\;+0.65}_{-0.17\;-0.65}$	$99.51^{+0.69\;+1.43}_{-0.41\;-1.43}$	$29.23^{+0.18\;+0.42}_{-0.10\;-0.42}$
ABM12	$58.40^{+0.38\;+0.70}_{-0.24\;-0.70}$	$39.63^{+0.29\;+0.45}_{-0.18\;-0.45}$	$98.03^{+0.67\;+1.13}_{-0.41\;-1.13}$	$28.79^{+0.17\;+0.33}_{-0.11\;-0.33}$

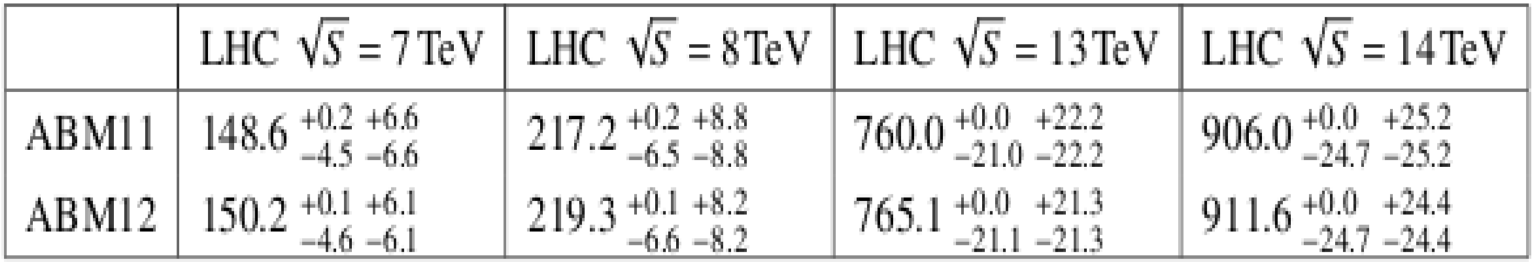
The W,Z cross sections go down by ~1σ



	LHC7	LHC8	LHC13	LHC14
ABM11	$13.23^{+1.35\;+0.30}_{-1.31\;-0.30}$	$16.99^{+1.69\;+0.37}_{-1.63\;-0.37}$	$39.57^{+3.60\;+0.77}_{-3.42\;-0.77}$	$44.68^{+4.02\;+0.85}_{-3.78\;-0.85}$
ABM12	$13.28^{+1.35\;+0.31}_{-1.32\;-0.31}$	$17.05^{+1.68\;+0.39}_{-1.64\;-0.39}$	$39.69^{+3.60\;+0.84}_{-3.42\;-0.84}$	$44.81^{+4.01\;+0.94}_{-3.80\;-0.94}$

The Higgs cross sections are stable

m_H=125 GeV



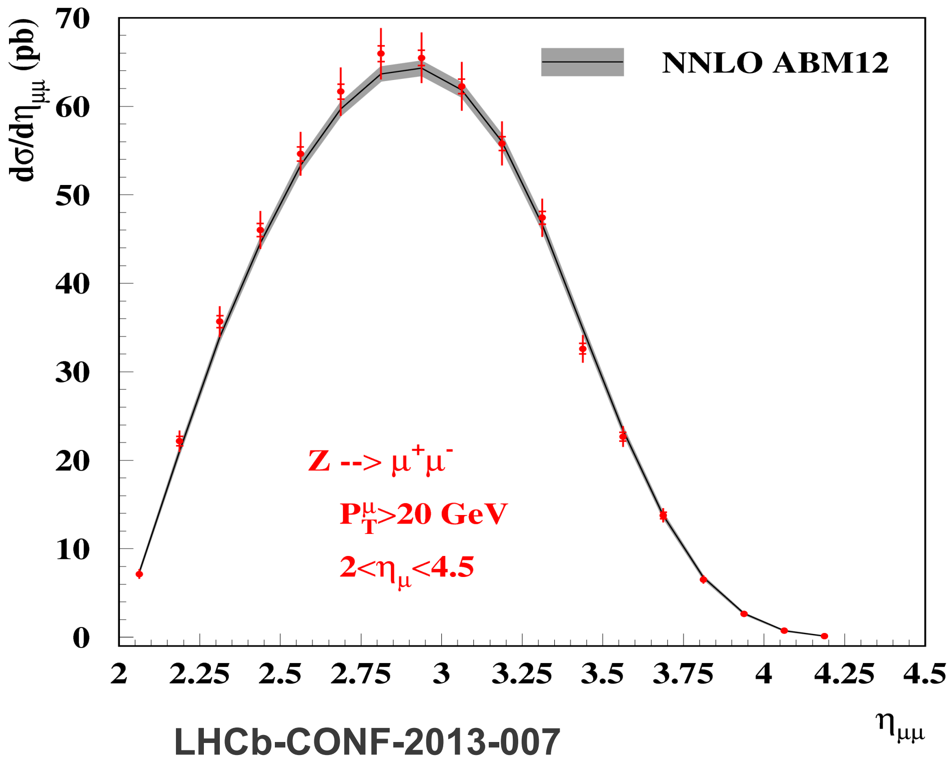
	LHC $\sqrt{S}=7$ TeV	LHC $\sqrt{S}=8$ TeV	LHC $\sqrt{S}=13$ TeV	LHC $\sqrt{S}=14$ TeV
ABM11	$148.6^{+0.2\;+6.6}_{-4.5\;-6.6}$	$217.2^{+0.2\;+8.8}_{-6.5\;-8.8}$	$760.0^{+0.0\;+22.2}_{-21.0\;-22.2}$	$906.0^{+0.0\;+25.2}_{-24.7\;-25.2}$
ABM12	$150.2^{+0.1\;+6.1}_{-4.6\;-6.1}$	$219.3^{+0.1\;+8.2}_{-6.6\;-8.2}$	$765.1^{+0.0\;+21.3}_{-21.1\;-21.3}$	$911.6^{+0.0\;+24.4}_{-24.7\;-24.4}$

The t-quark cross sections go somewhat up

$m_t(m_t)$=162 GeV

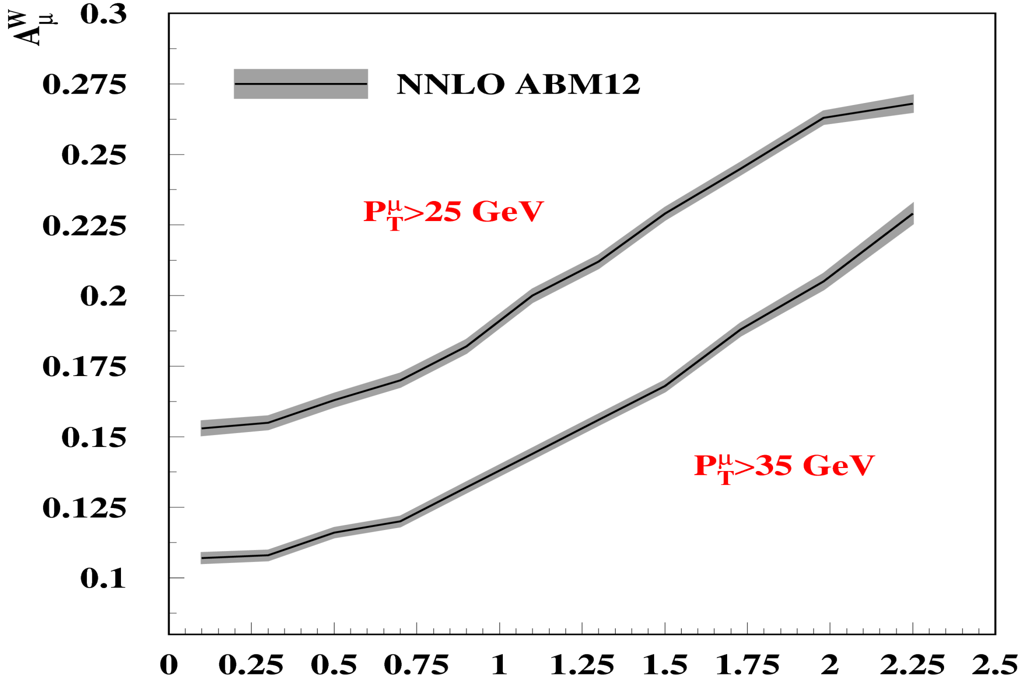
Comparison with unpublished DY LHC data

LHCb (7 TeV, 1 1/fb)



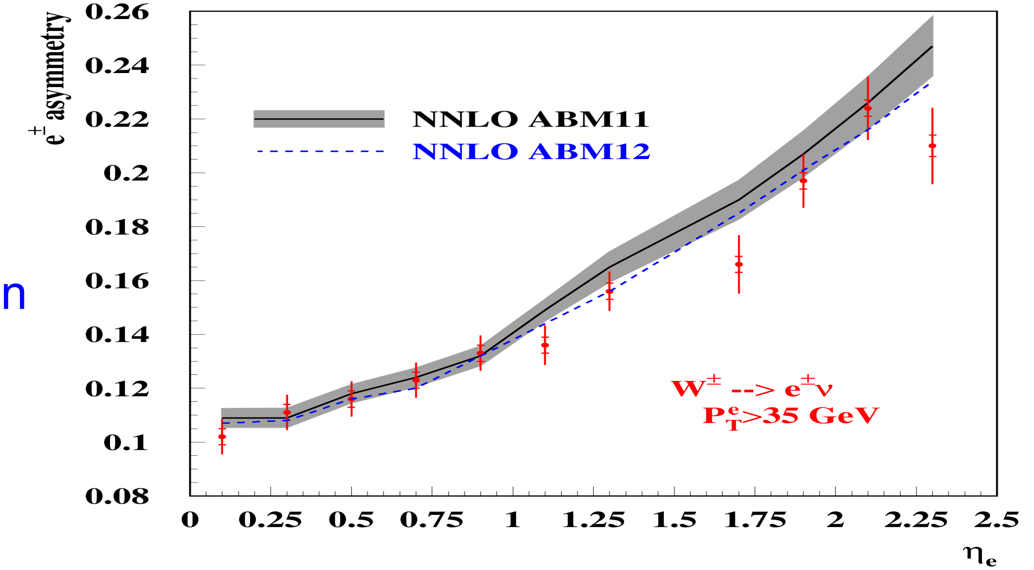
LHCb-CONF-2013-007

CMS (7 TeV, 4.7 1/fb)



- Good agreement with new LHCb data
- Improved accuracy of the charged-lepton asymmetry predictions for CMS; better agreement with the updated CMS data

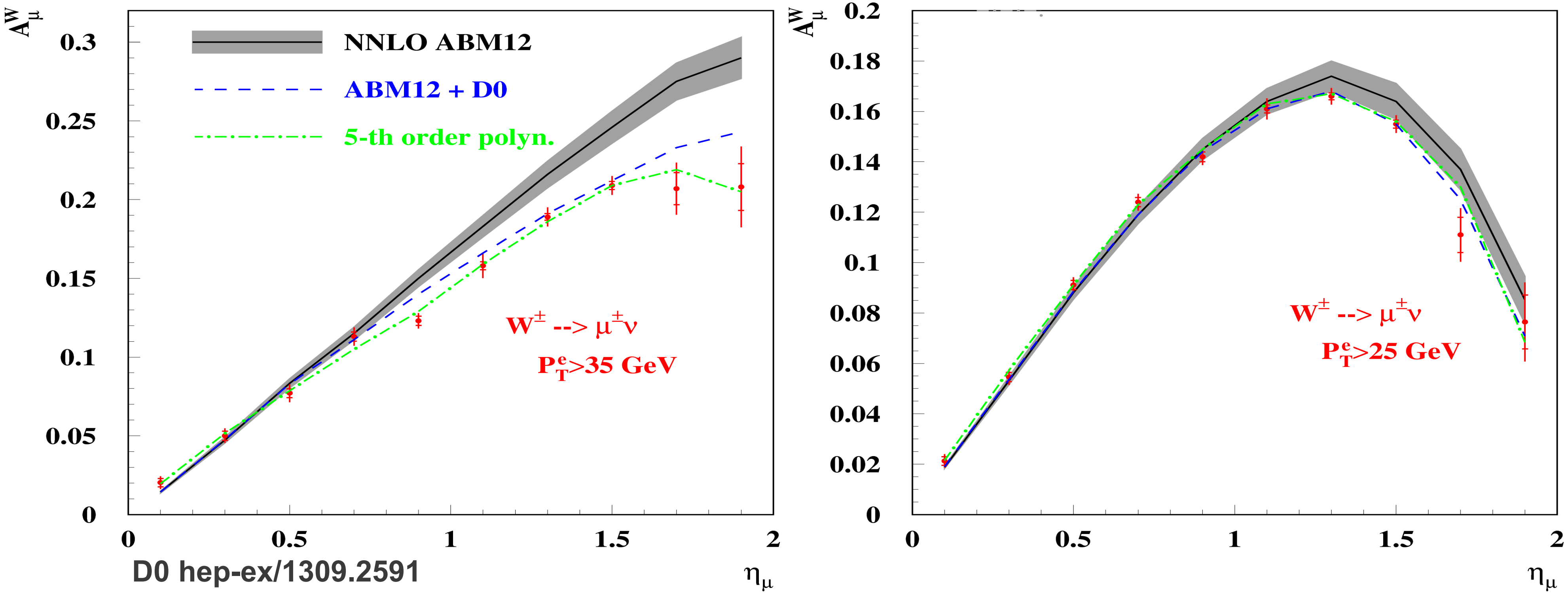
CMS (7 TeV, 840 1/pb)



sa, Blümlein, Moch hep-ph/1310.3059

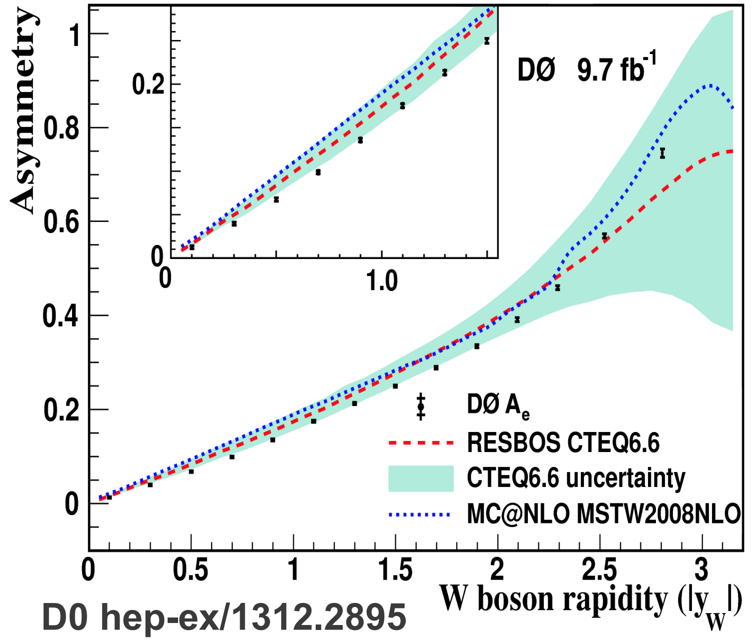
Comparison with recent DY Tevatron data

D0 (1.96 TeV, 7.3 1/fb)



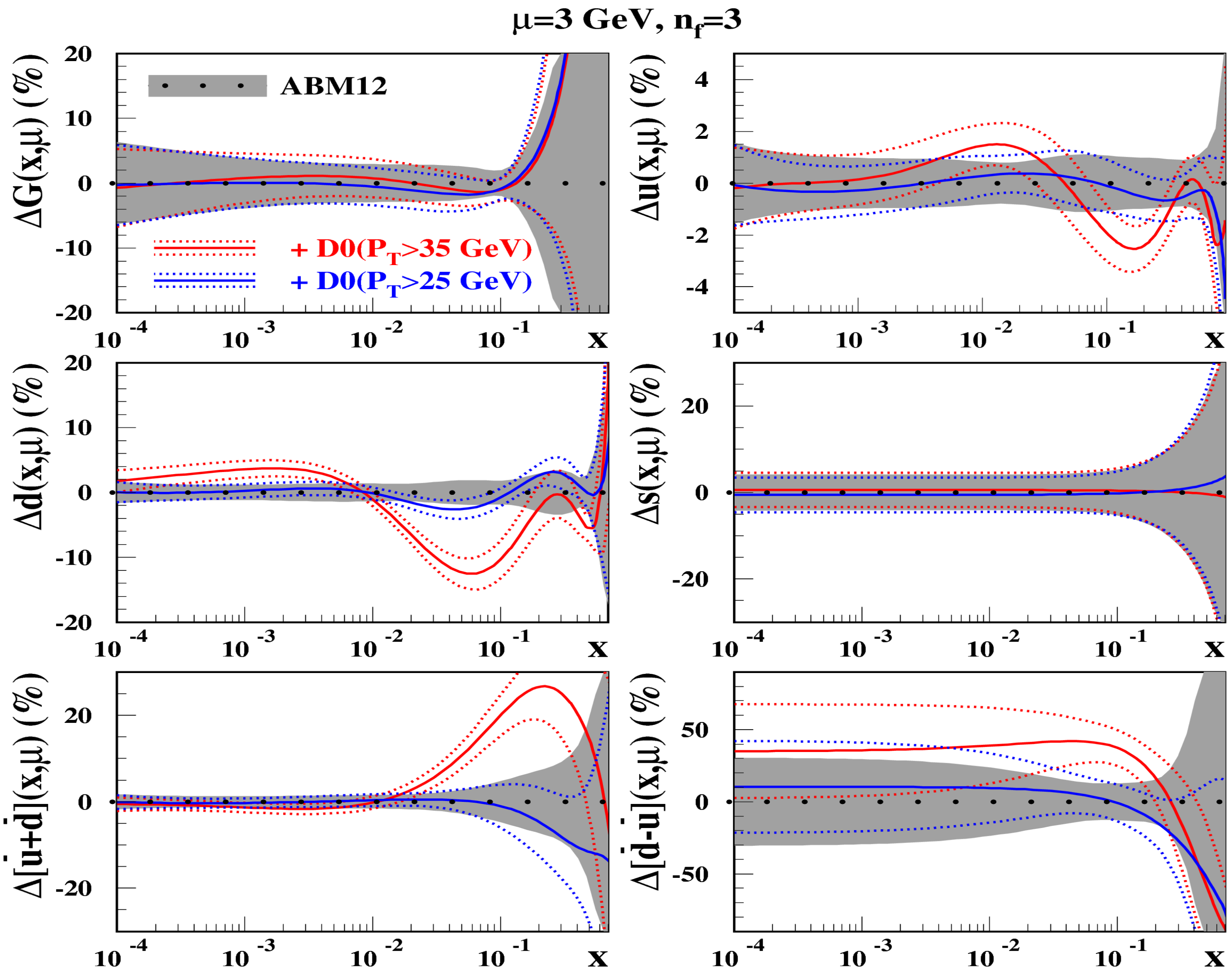
D0 hep-ex/1309.2591

- Poor agreement with the ABM12 predictions at $P_T > 35$ GeV
- Poor description in the fit: $\chi^2 = 40/10$ and $19/10$ for $P_T > 35$ and 25, respectively
- Polynomial fit gives $\chi^2 = 11/10$, however displays a step structure at Y~1
- Smooth shape is observed in case of electron



D0 hep-ex/1312.2895

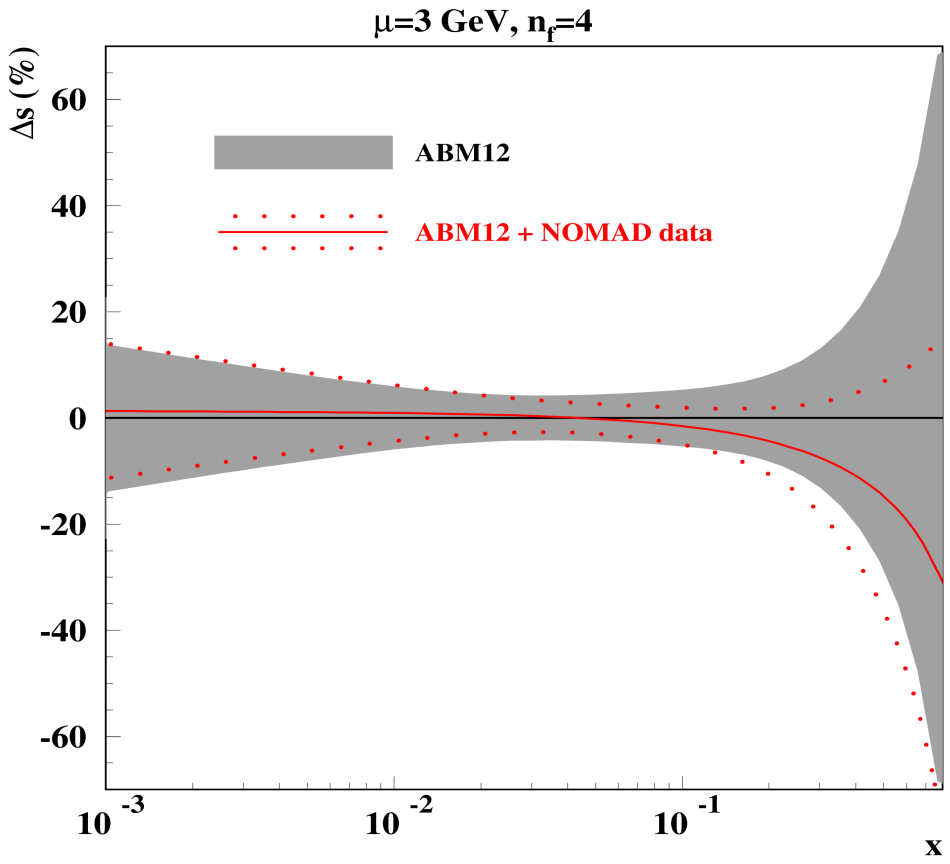
Impact of DY D0 data



The trend is opposite to the case of LHC data

Impact of the data on PDFs is quite sensitive to the the cut on P_T

NOMAD charm data in the ABM fit



The data on ratio 2μ/incl. CC ratio with the 2μ statistics of 15000 events (much bigger than in earlier CCFR and NuTeV samples).

NOMAD NPB 876, 339 (2013)

Systematics, nuclear corrections, etc. cancel in the ratio

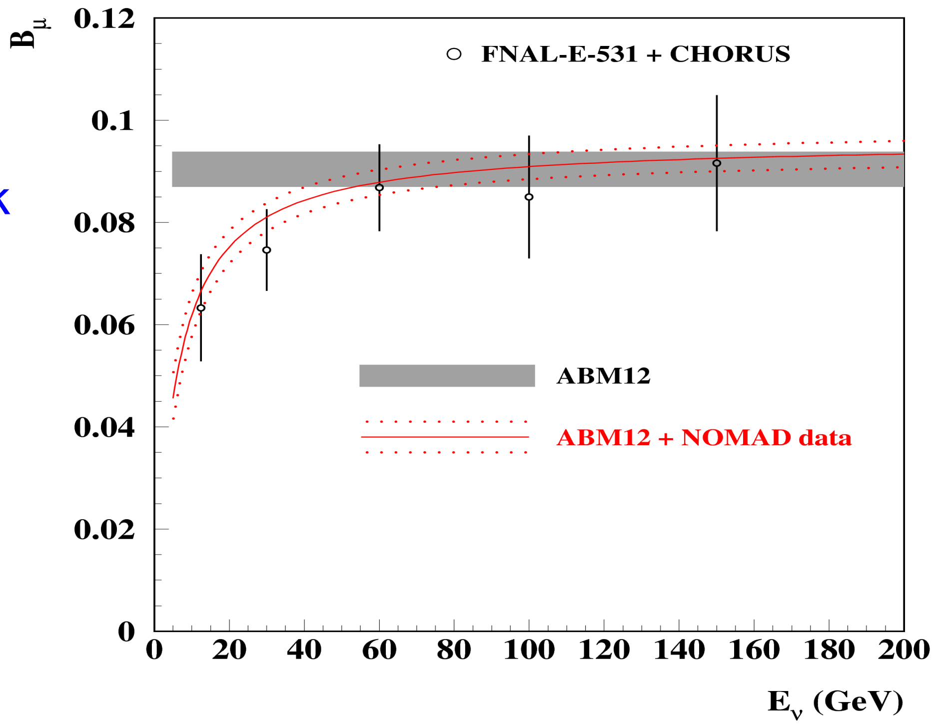
- pull down strange quarks at x>0.1 with a sizable uncertainty reduction
- $m_c(m_c)$=1.23±0.03(exp.) GeV is comparable to the ABM12 value

The semi-leptonic branching ratio B_μ is a bottleneck

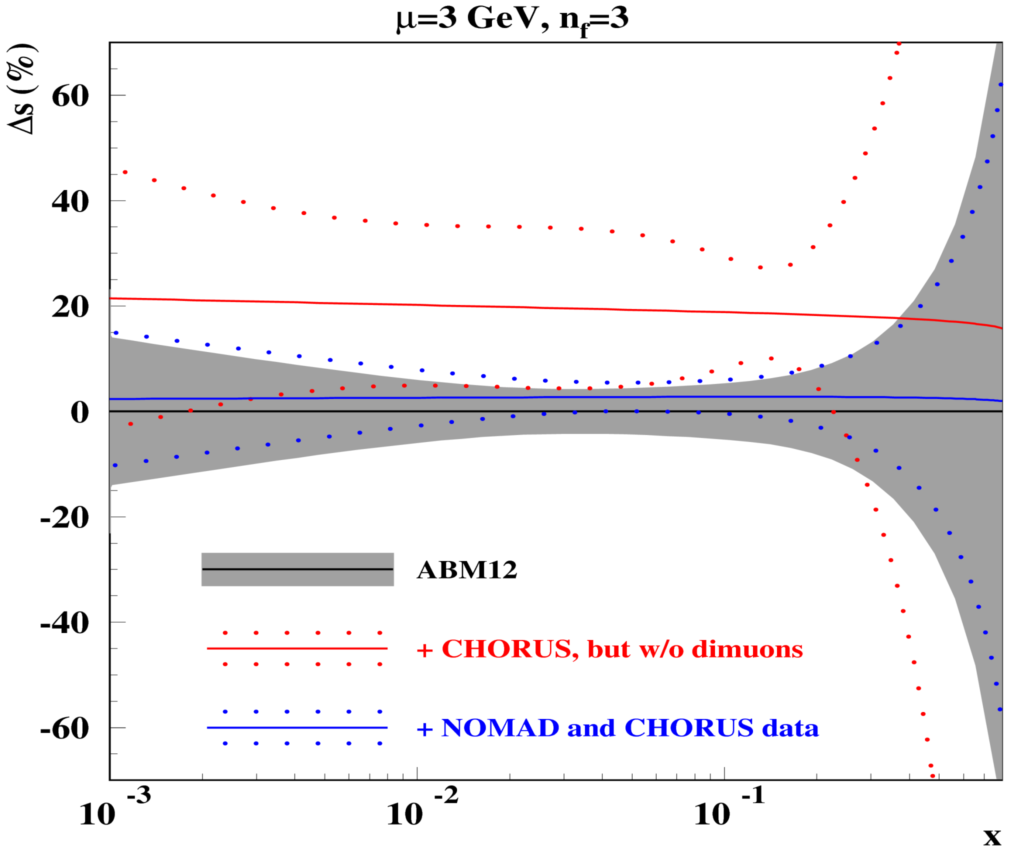
- weighted average of the charmed-hadron rates

$$B_\mu(E_\nu)=\sum_h r^h(E_\nu)B_\mu^h = a/(1+b/E_\nu)$$

- fitted simultaneously with the PDFs, etc. using the constraint from the emulsion data



CHORUS charm data in the ABM fit

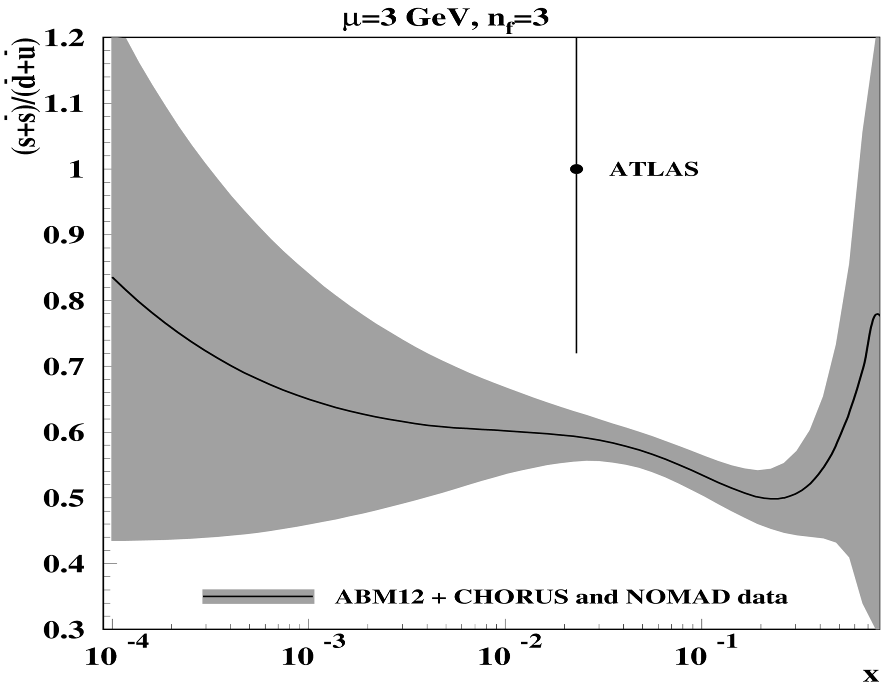


in collaboration with R.Petti

Emulsion data on charm/CC ratio with the charmed hadron vertex measured

CHORUS NJP 13, 093002 (2011)

- full phase space measurements
- no sensitivity to B_μ
- low statistics (2013 events)



CHORUS data pull strangeness up, however the statistical significance of the effect is poor

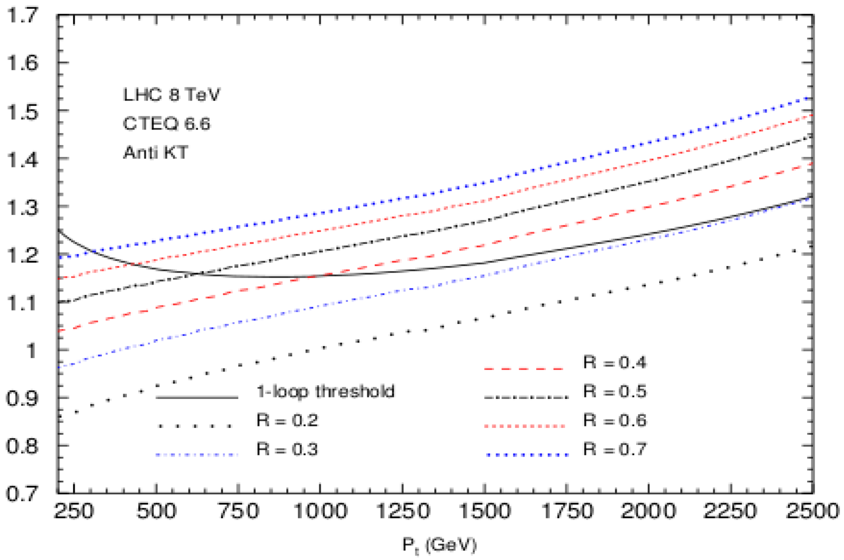
In the combined CHORUS-NOMAD-NuTeV the strange sea uncertainty is improved

The strange suppression factor goes lower than the ATLAS result

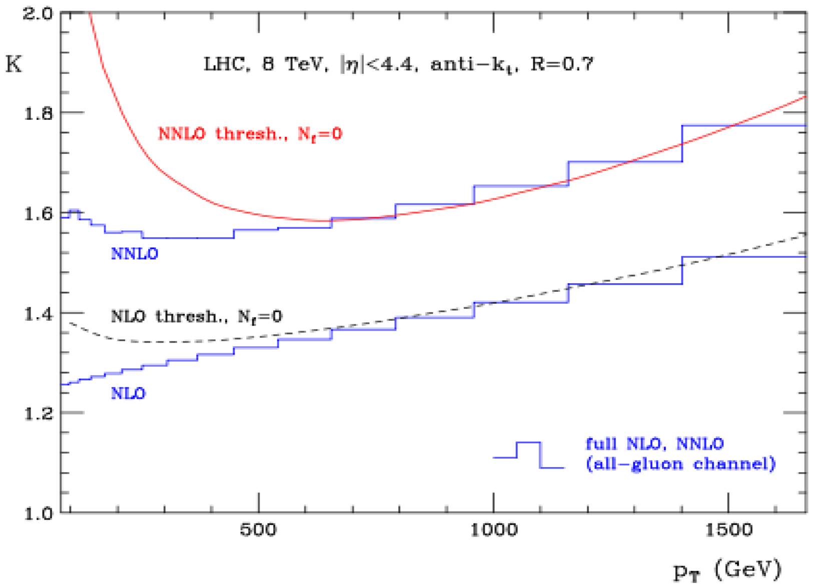
Status of QCD theory for jet cross sections

- One-jet inclusive jets hadro-production $P + P(\bar{P}) \to J(R) + X(s_4)$
  - NLO known since long
  - large threshold corrections of type $\alpha_s^l \, [\ln^{2l-1}(s_4/p_T^2)/s_4]_+$ from soft/collinear gluon radiation Kidonakis, Owens, hep-ph/0007268
  - $\ln R$ dependence on jet's cone size R in small cone approximation de Florian, Vogelsang, arXiv:0704.1677
- Threshold terms (Kidonakis, Owens '01) used as approximation to unknown NNLO corrections
  - applied in PDF analyses MSTW, arxiv:0901.0002
  - applied in experimantal analyses of jet data D0 Collaboration, arXiv:0911.2710, arXiv:1207.4957
- Check of validity of those approximations very important

Theoretical issues in the jet data analysis



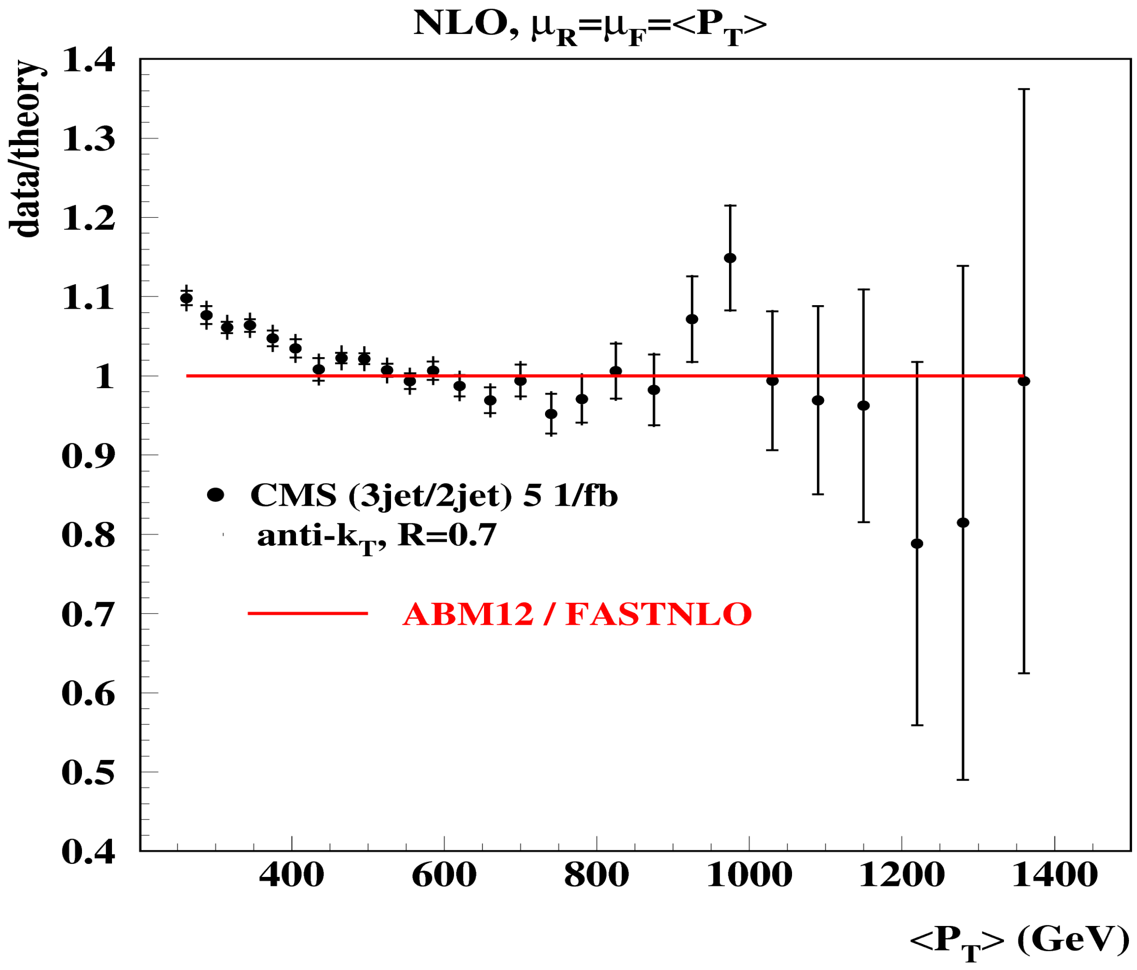
- threshold logarithms alone (w/o $\ln R$) at 1-loop fail to describe exact results Kumar, Moch, arXiv:1309.5311



- cone size dependence $\ln R$ numerically important de Florian, Hinderer, Mukherjee, Ringer, Vogelsang, arXiv:1310.7192
- nice match with exact NNLO (purely gluonic) computation Currie, Gehrmann-De Ridder, Glover, Pires, arXiv:1310.3993

Revision of the NNLO PDF analyses based on jet data, particularly using the threshold resummation → impact on the PDF4LHC recommendation

CMS jets in ABM fit



CMS hep-ex/1304.7498

P_T(GeV) >	500	400	300	NLO ABM12
$\alpha_s(M_Z)$	0.1181(10)	0.1200(9)	0.1220(9)	0.1179(11)

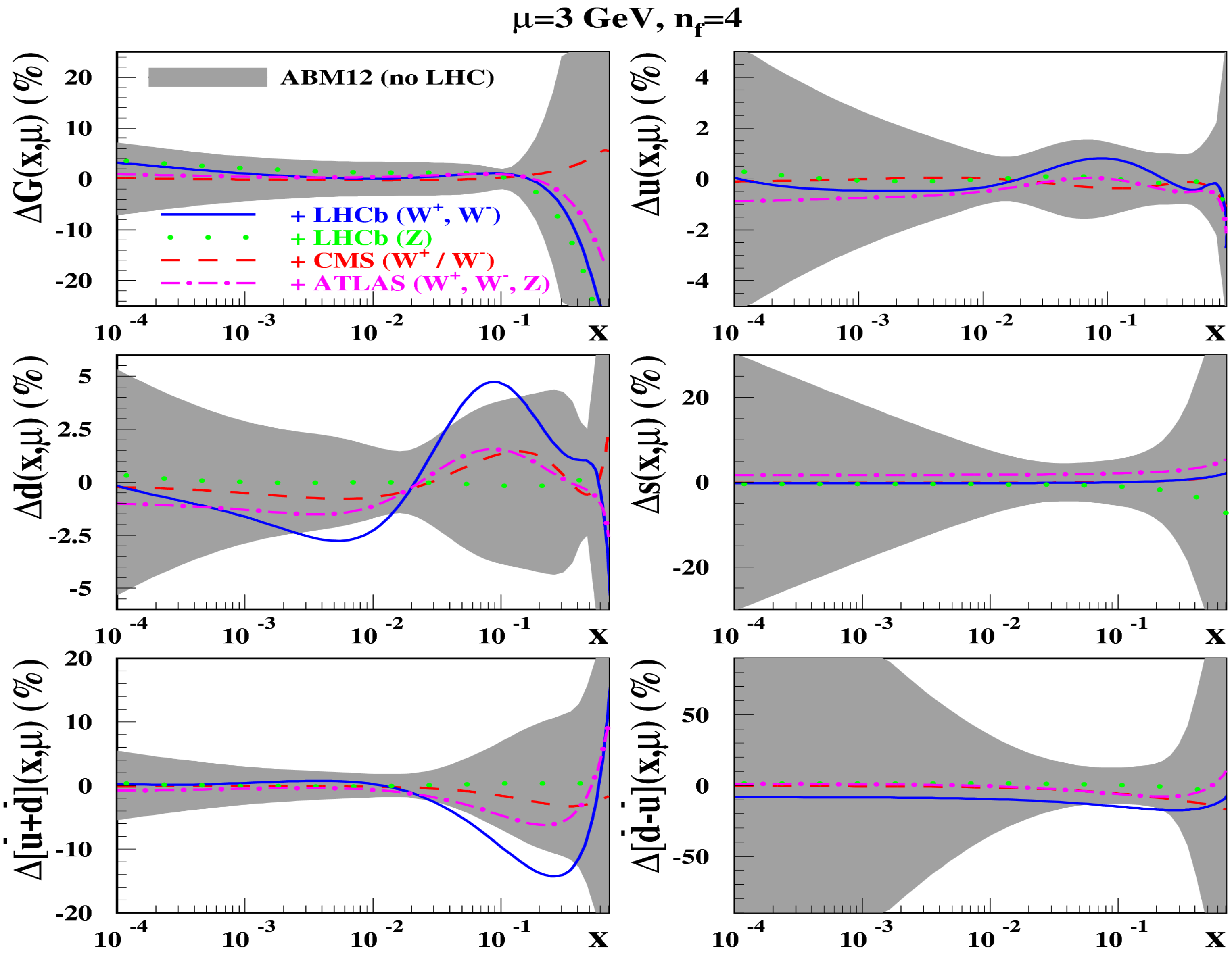
The discrepancies are localized at small PT: NNLO corrections? scale choice?

Summary

- ABM12 PDFs tuned to the available DY LHC data are released:
  - some increase(decrease) of the d(nonstr. sea)-quarks at x~0.1 / μ=3 GeV; marginal change in the strange quarks
  - standard candle cross sections are stable, within the PDF uncertainties; improved accuracy of the LHC predictions, in particular for the charge-lepton asymmetry
  - PDF grids in LHAPDF5 (conversion to LHAPDF6 in progress)
- The value of $\alpha_s(M_Z) = 0.1132(11)$, in agreement with ABM11 and recent JR and CT results
- Good agreement with unpublished DY LHCb and CMS data and poor agreement with the recent D0 data
- Improved accuracy of strange sea using NOMAD and CHORUS data
- CMS data on 3jet/2jet ratio are in agreement with the ABM12 NLO predictions at large P_T; at small P_T data go above by 10%; NNLO corrections are necessary for clarification

Extras

Impact of the separate LHC data sets



The biggest effect come from the LHCb data, i.e. from the large rapidity region

NNLO DY corrections in the fit

The (N)NLO calculations are quite time-consuming → fast tools are employed (FASTNLO, Applegrid,.....)

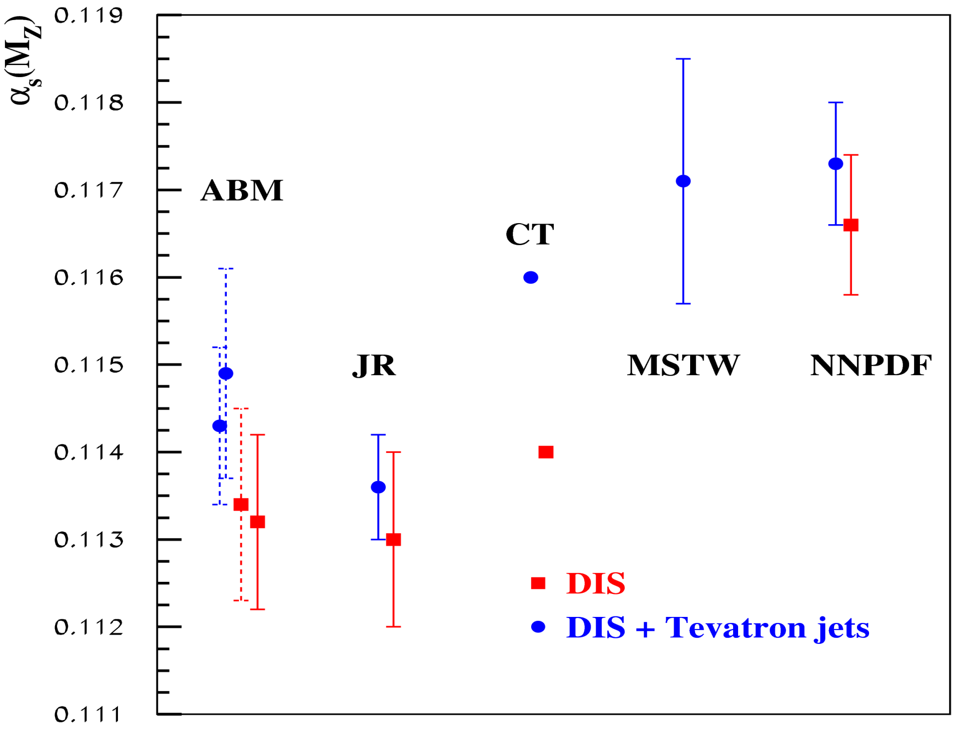
- the corrections for certain basis of PDFs are stored in the grid
- the fitted PDFs are expanded over the basis
- the NNLO c.s. in the PDF fit is calculated as a combination of expansion coefficients with the pre-prepared grids

The general PDF basis is not necessary since the PDFs are already constrained by the data, which do not require involved computations → *use as a PDF basis the eigenvalue PDF sets obtained in the earlier version of the fit*

$\mathbf{P_0} \pm \Delta\mathbf{P}_0$ – vector of PDF parameters with errors obtained in the earlier fit
E – error matrix
P – current value of the PDF parameters in the fit

- store the DY NNLO c.s. for all PDF sets defined by the eigenvectors of **E**
- the variation of the fitted PDF parameters ($\mathbf{P} - \mathbf{P}_0$) is transformed into this eigenvector basis
- the NNLO c.s. in the PDF fit is calculated as a combination of transformed ($\mathbf{P} - \mathbf{P}_0$) with the stored eigenvector values

Value of α_s in/from the PDF fits



- The Tevatron jet data push α_s up by ~0.001

- The MSTW and NNPDF values are bigger than the ABM one in particular due to impact of hight-twist terms and/or error correlations

sa, Blümlein, Moch PRD 86, 054009 (2012)

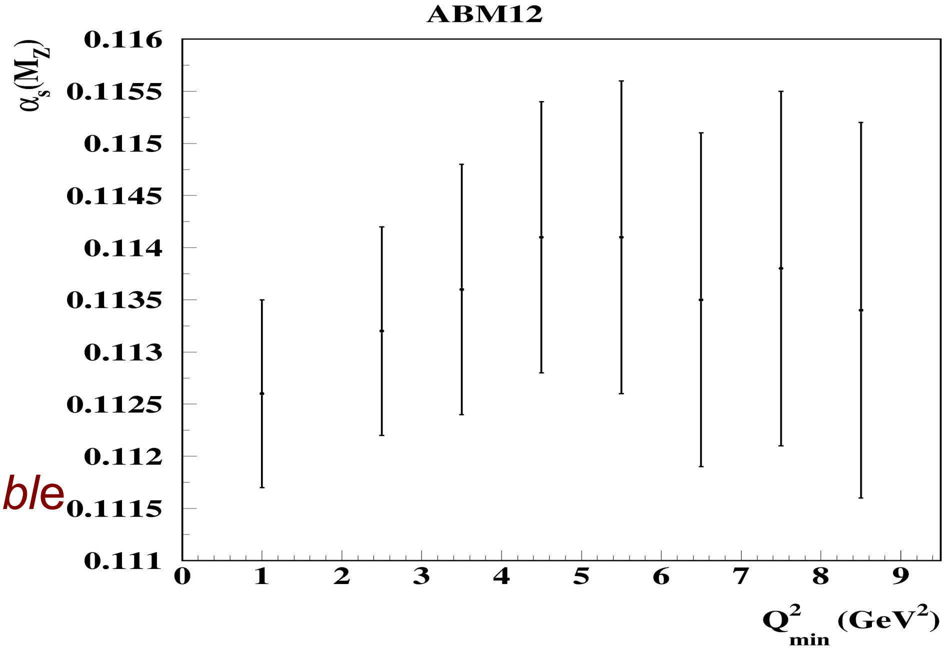
- Recent CT 10 value is more close to ABM (no SLAC data used, stronger cut on Q^2, the error correlations are taken into account)

N.B. The MSTW update gives 0.1155 – 0.1171 depending on the jet data treatment

Thorne QCD@LHC2013

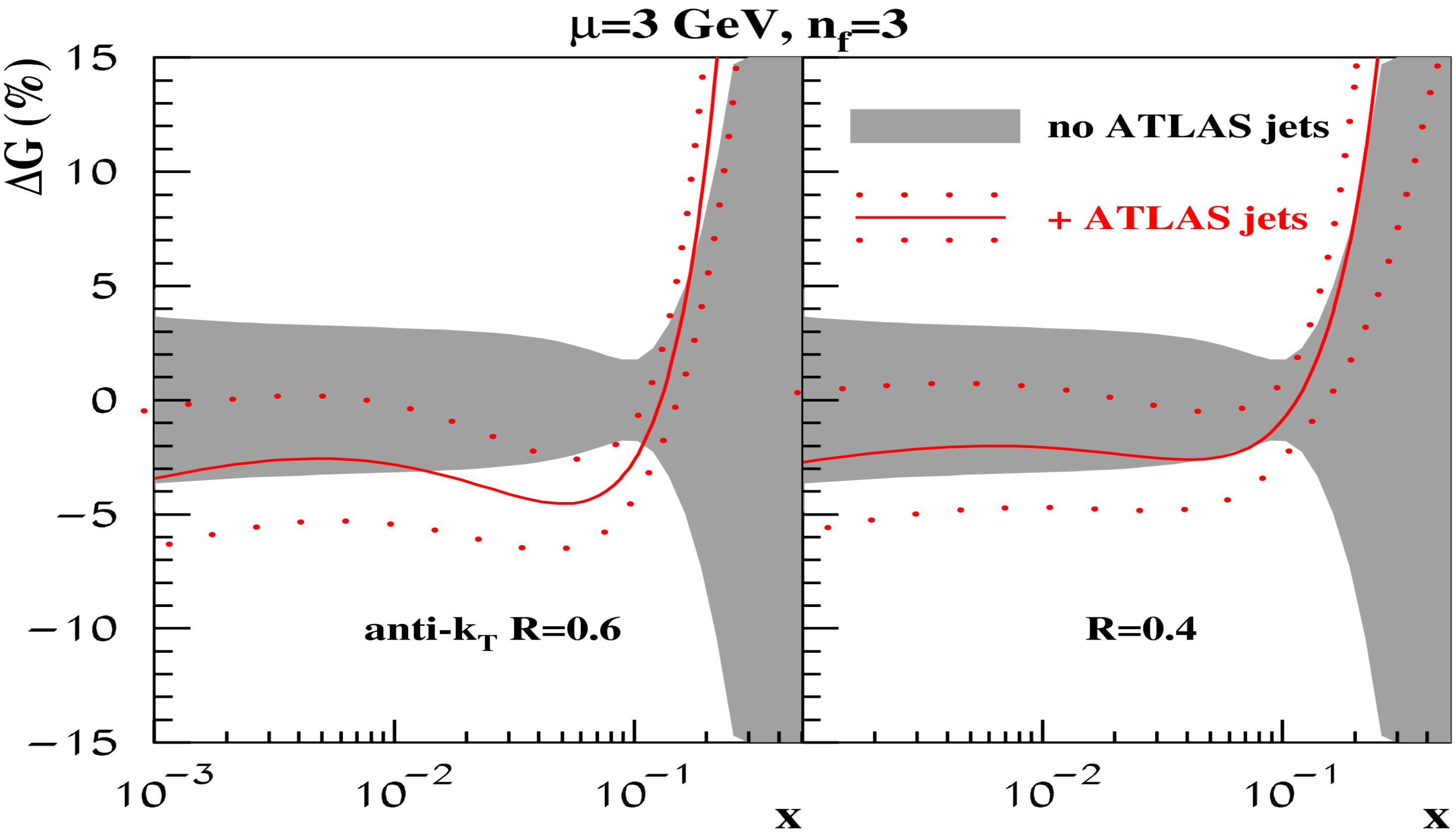
Consistent treatment of HT terms in the ABM fit:

- no sensitivity to the low-Q cut
- $\alpha_s(M_z)$ = 0.1132(11) w/o SLAC and NMC data sensitive to the HT terms → *the cross-check with MSTW, CTEQ and NNPDF is highly desirable*



ATLAS jet data in the ABM fit

ATLAS PRD 85, 0142022 (2012)



$\delta\alpha_s(M_z) = +0.0010$ $\delta\alpha_s(M_z) = +0.0006$

- Pure NLO fit, no NNLO threshold corrections are applied since they are out of control at LHC

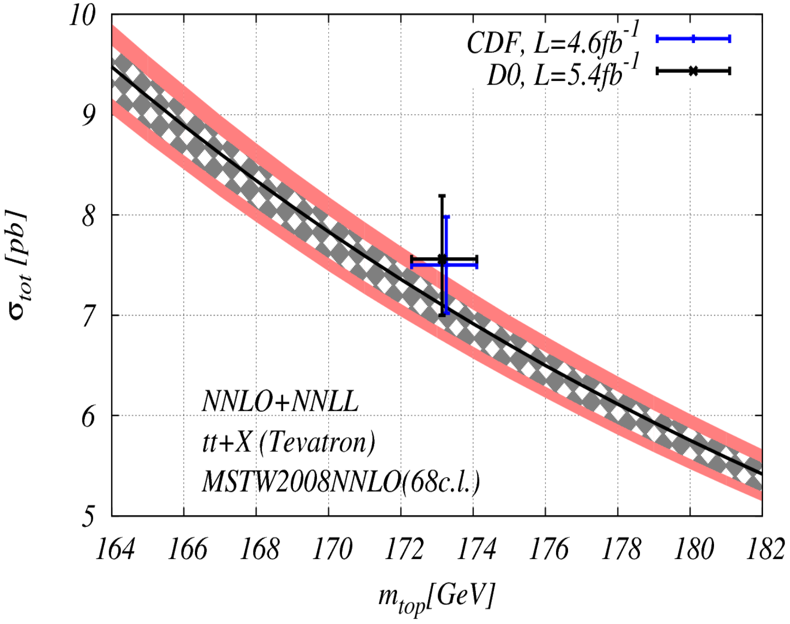
Kumar, Moch hep-ph/1309.5311

- Impact depends on the cone size → underlying events or the NNLO corrections?
- The NNLO corrections may be as big as 15-20% → jet data are irrelevant for the NNLO fit

Gehrmann-De Ridder, Gehrmann, Glover, Pires JHEP 1302, 026 (2013)

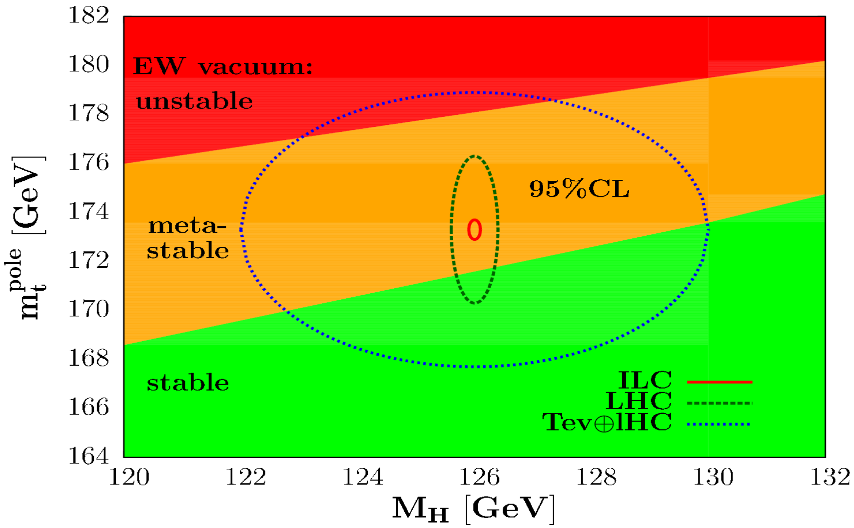
t-quark mass

- m_t(MC)=173.3±1 GeV (Tevatron/LHC)
- m_t(pole)≈ m_t(MC) - 1 GeV
- $m_t(m_t)$≈ m_t(pole) - 9 GeV



Bärnreuther, Czakon, Mitov hep-ph/1204.5201

From the Tevatron c.s. m_t(pole)~171 GeV



Vacuum stability condition requires m_t(pole)~171 GeV

sa, Djouadi, Moch PLB 716, 214 (2012)

CDF&D0	ABM11	JR09	MSTW08	NN21
$m_t^{\overline{\rm MS}}(m_t)$	$162.0\,^{+2.3\,+0.7}_{-2.3\,-0.6}$	$163.5\,^{+2.2\,+0.6}_{-2.2\,-0.2}$	$163.2\,^{+2.2\,+0.7}_{-2.2\,-0.8}$	$164.4\,^{+2.2\,+0.8}_{-2.2\,-0.2}$
$m_t^{\rm pole}$	$171.7\,^{+2.4\,+0.7}_{-2.4\,-0.6}$	$173.3\,^{+2.3\,+0.7}_{-2.3\,-0.2}$	$173.4\,^{+2.3\,+0.8}_{-2.3\,-0.8}$	$174.9\,^{+2.3\,+0.8}_{-2.3\,-0.3}$
$(m_t^{\rm pole})$	$(169.9\,^{+2.4\,+1.2}_{-2.4\,-1.6})$	$(171.4\,^{+2.3\,+1.2}_{-2.3\,-1.1})$	$(171.3\,^{+2.3\,+1.4}_{-2.3\,-1.8})$	$(172.7\,^{+2.3\,+1.4}_{-2.3\,-1.2})$

ATLAS&CMS	ABM11	JR09	MSTW08	NN21
$m_t^{\overline{\rm MS}}(m_t)$	$159.0\,^{+2.1\,+0.7}_{-2.0\,-1.4}$	$165.3\,^{+2.3\,+0.6}_{-2.2\,-1.2}$	$166.0\,^{+2.3\,+0.7}_{-2.2\,-1.5}$	$166.7\,^{+2.3\,+0.8}_{-2.2\,-1.3}$
$m_t^{\rm pole}$	$168.6\,^{+2.3\,+0.7}_{-2.2\,-1.5}$	$175.1\,^{+2.4\,+0.6}_{-2.3\,-1.3}$	$176.4\,^{+2.4\,+0.8}_{-2.3\,-1.6}$	$177.4\,^{+2.4\,+0.8}_{-2.3\,-1.4}$
$(m_t^{\rm pole})$	$(166.1\,^{+2.2\,+1.7}_{-2.1\,-2.3})$	$(172.6\,^{+2.4\,+1.6}_{-2.3\,-2.1})$	$(173.5\,^{+2.4\,+1.8}_{-2.3\,-2.5})$	$(174.5\,^{+2.4\,+2.0}_{-2.3\,-2.3})$

Stronger correlation between m_t, PDFs and α_s at LHC