Prospettive fisica W, Z, QCD a LHC e dopo

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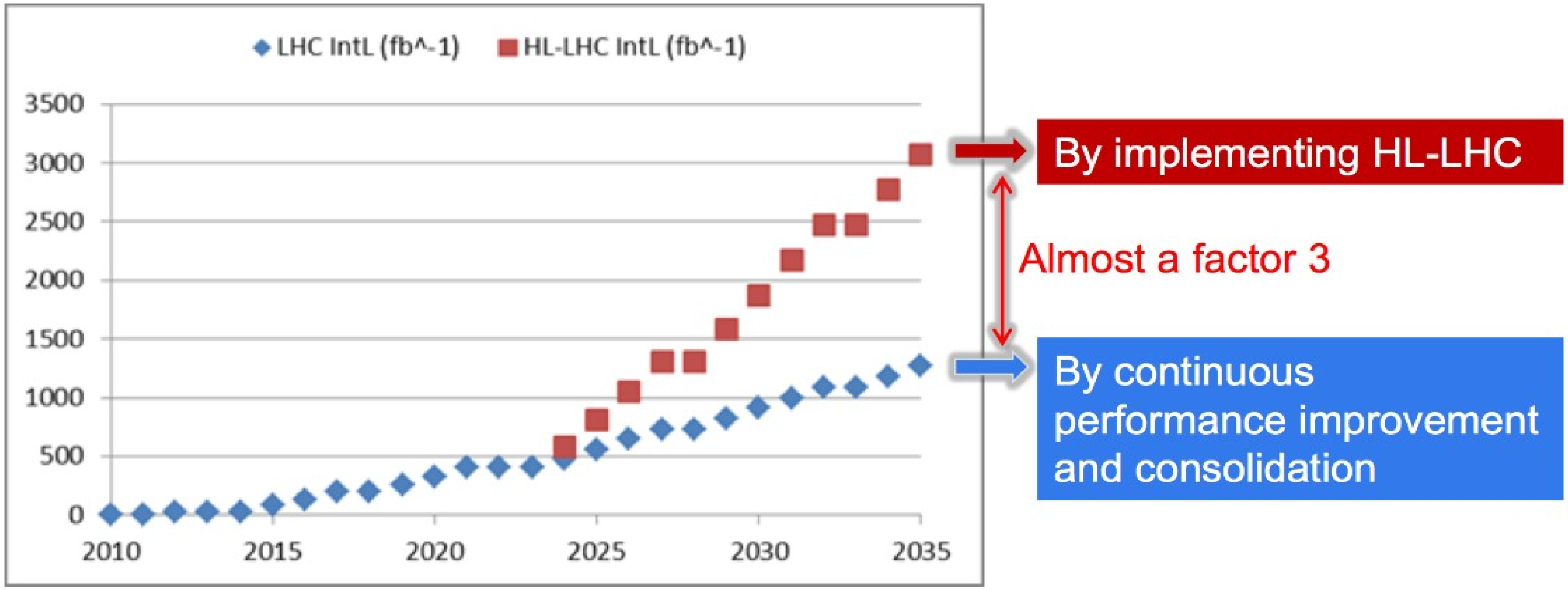
INTRODUCTION/1

- Aims of this talk:

  1- Try to give a comprehensive review of the possible improovement on Electroweak and QCD measurement

  2- Give hints and suggestions *to open a discussion*

Focused on 14 TeV LHC 300 fb^{-1} and HL-LHC 3000 fb^{-1} luminosities with also “numbers” for future collider: ILC, TLEP



INTRODUCTION/2

Standard Model studies in ≥ 2014 as indirect search of new physics

Precision observables are important to characterize new physics...if any

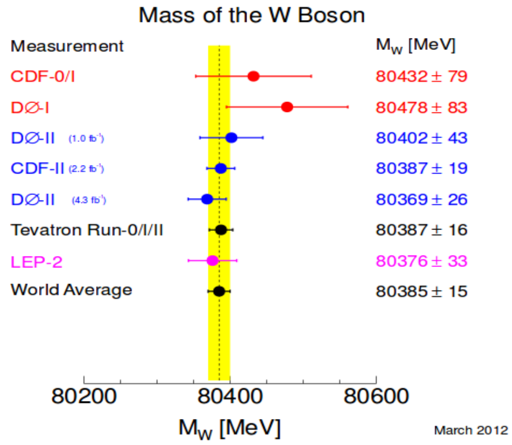
- **Electroweak:**
  - m_W
  - $\sin^2(\theta^l_{eff})$
  - Multi-boson production TGC & QGC

- **QCD:**
  - PDF
  - $\alpha_s(M^2_Z)$
  - QCD high order corrections

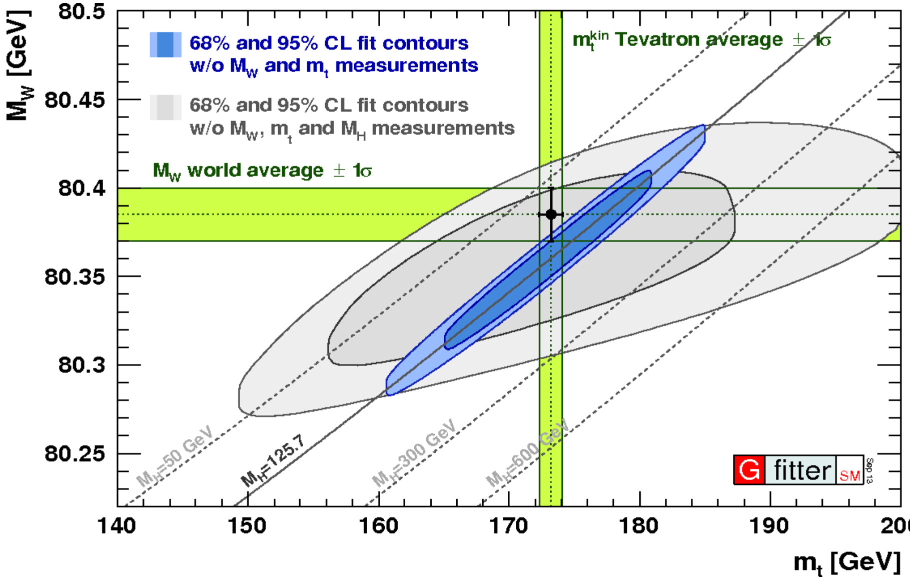
- **Summary and Hints for discussion**

Measuring M_W

A precise measurement of M_W provides a crucial test on the SM predictions



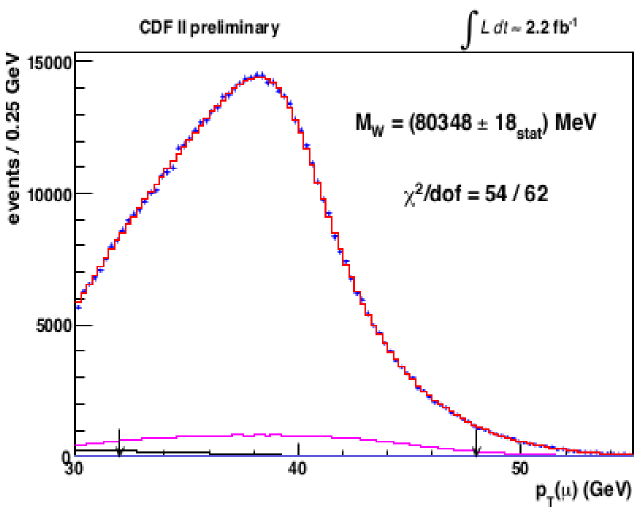
Constrain on M_H via EW fit.

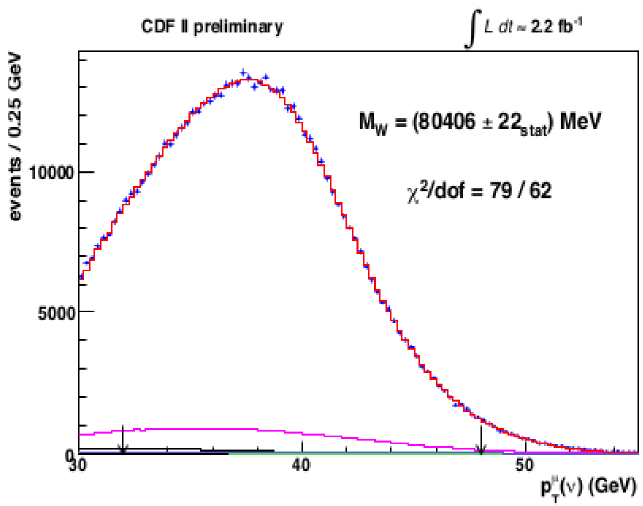


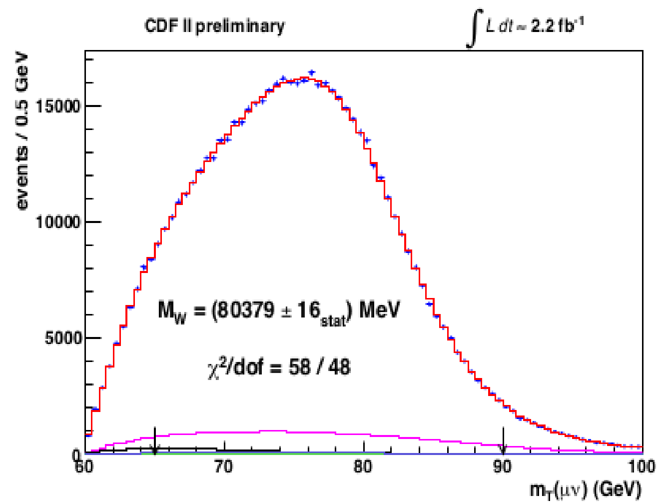
Final ΔM_W Tevatron combined achievement: ~ 9 MeV

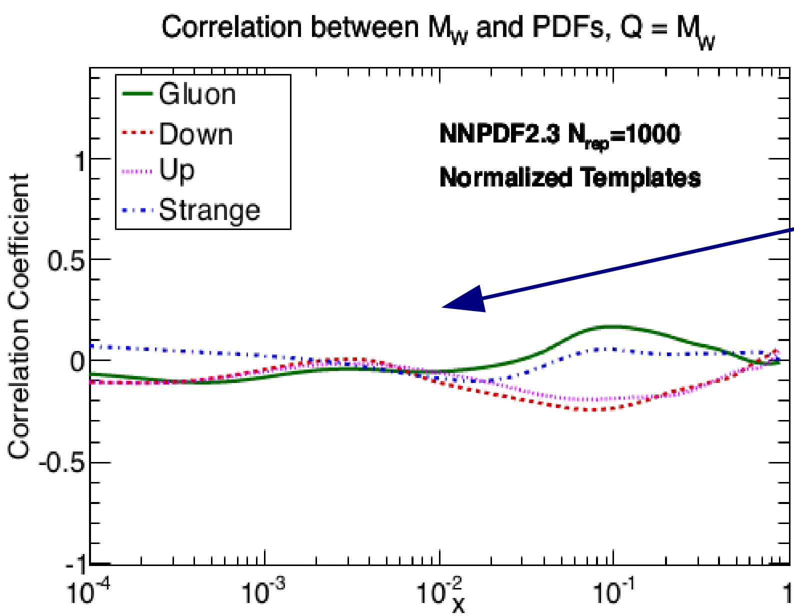
W boson mass M_W measured from the transverse mass distribution of the lepton pair $m_T(l\nu)$ or the transverse momentum of the charged lepton or neutrino

Need to understand QCD higher order Correction and EW corrections.



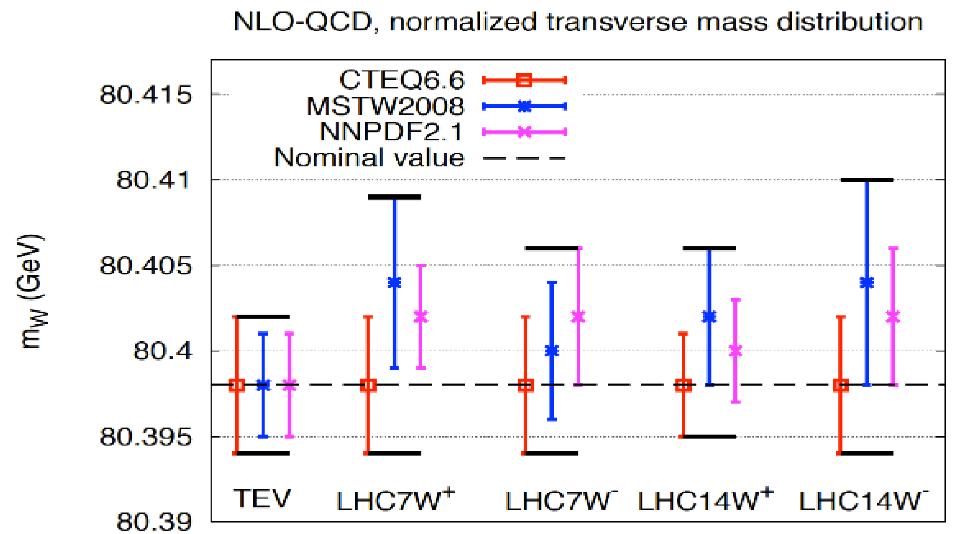






PDF uncertainty @LHC of order 10 MeV (2xTevatron)

To reduce PDF uncertainty in the M_W measurement from $m_T W$,new data constraining all quark flavors and gluons in the broadest possible x range are needed

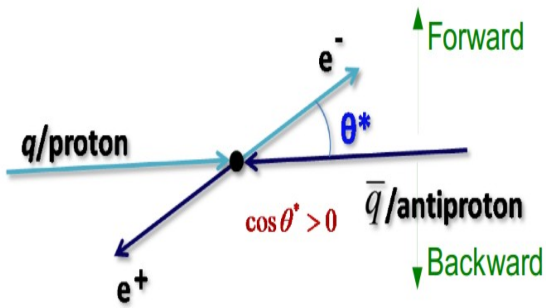


ΔM_W [MeV]	LHC		
$\sqrt{s}$ [TeV]	8	14	14
$\mathcal{L}[\text{fb}^{-1}]$	20	300	3000
PDF	10	5	3
QED rad.	4	3	2
$p_T(W)$ model	2	1	1
other systematics	10	5	3
W statistics	1	0.2	0
Total	15	8	5

Unc. can be reduced to 5(3) MeV (NNPDF2.3) if descrepancies between sets is removed (Rojo, Vicini, 2013)

Reasonable ambition for LHC is a target of **5 MeV** in ΔM_W as total precision

Measuring $\sin^2(\theta^l_{eff})$



Define Forward-Backward asymmetry:

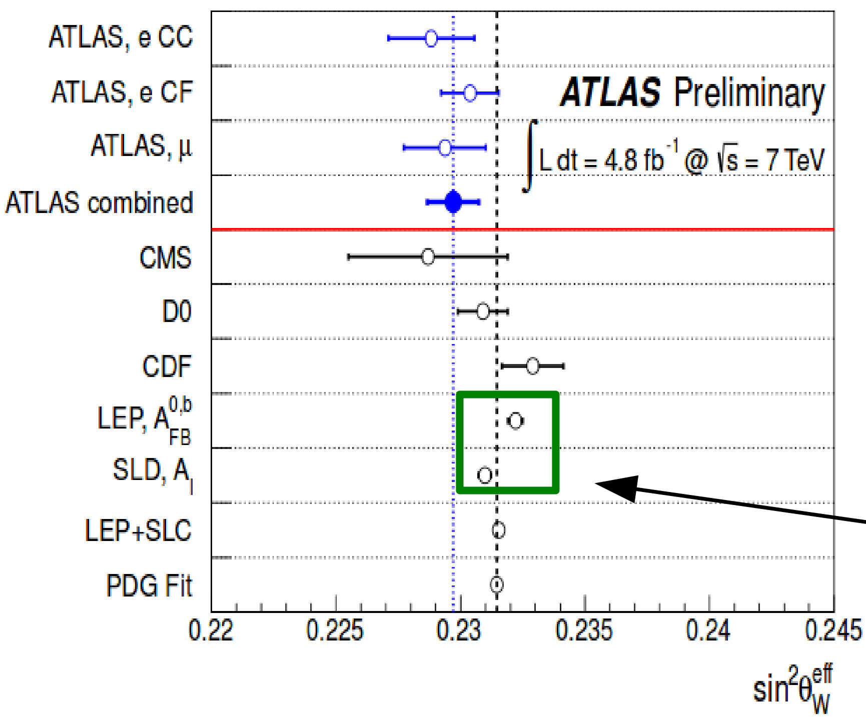
$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

In hadron collider the forward-backward asymmetry (A_{FB}) is measured and used to determine the $\sin^2(\theta^l_{eff})$

Measuring $\sin^2(\theta^l_{eff})$ at *pp* collider (LHC) is difficult due to reduction/dilution of A_{FB}

ATLAS partially solves the problem using forward lepton (reduction of unc.)

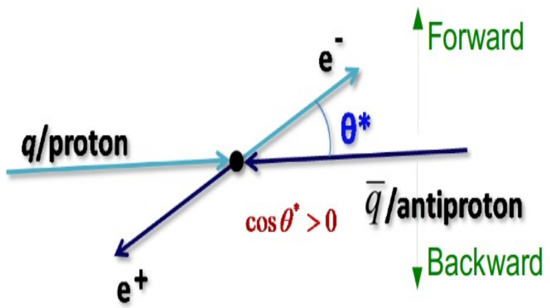
$$\text{CF electron} : \sin^2\theta^l_{\text{eff}} = 0.2304 \pm 0.0006(\text{stat.}) \pm 0.0010(\text{syst.})$$



Precision achieved is comparable to Tevatron but not enough!

Tension between the two most precise measurements (LEP and SLD) to be solved

Measuring $\sin^2(\theta^l_{eff})$



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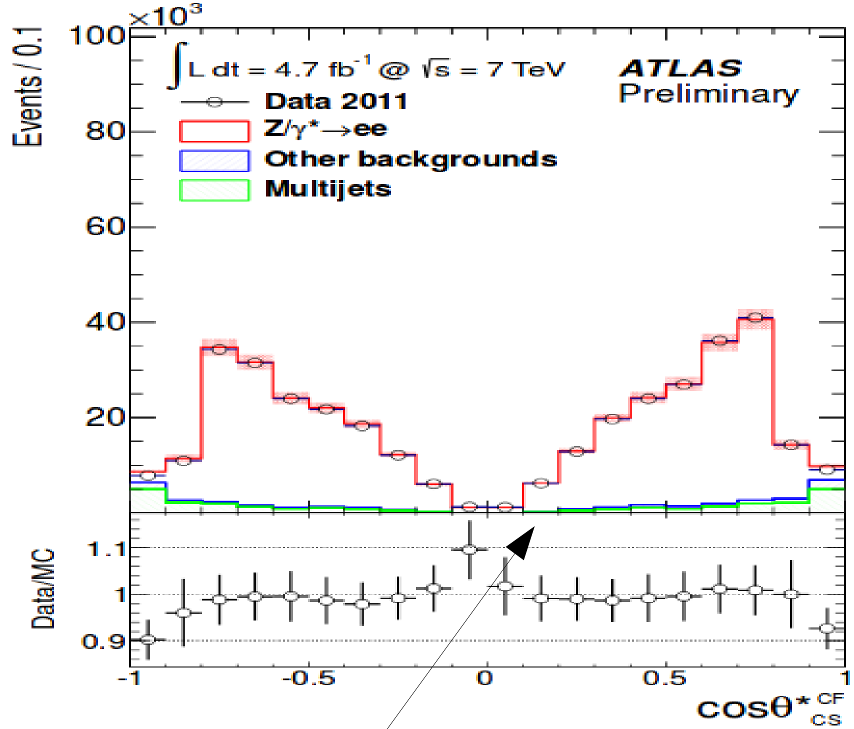

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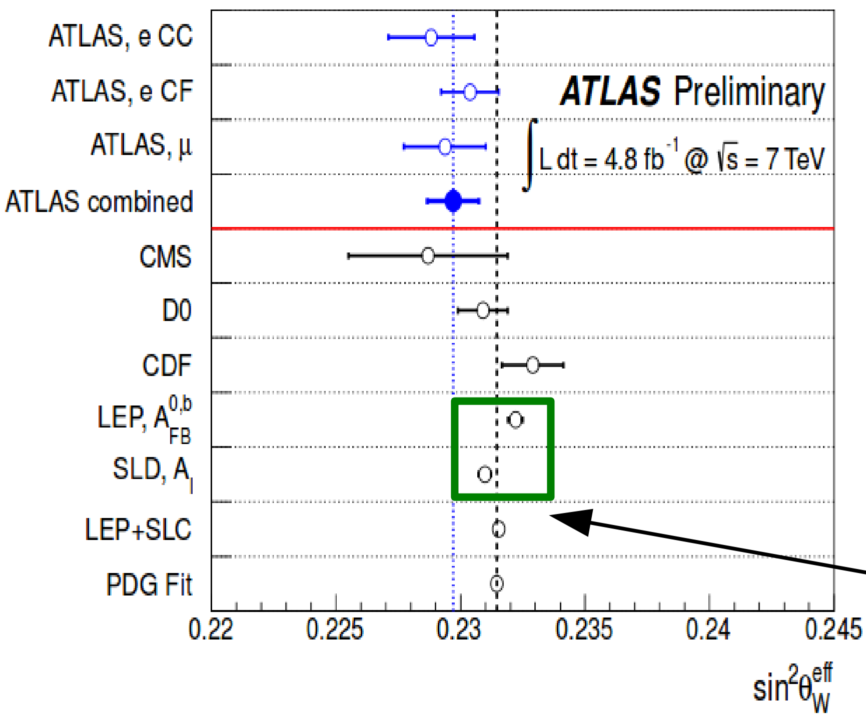

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Recent improvements introduced in CDF analysis.

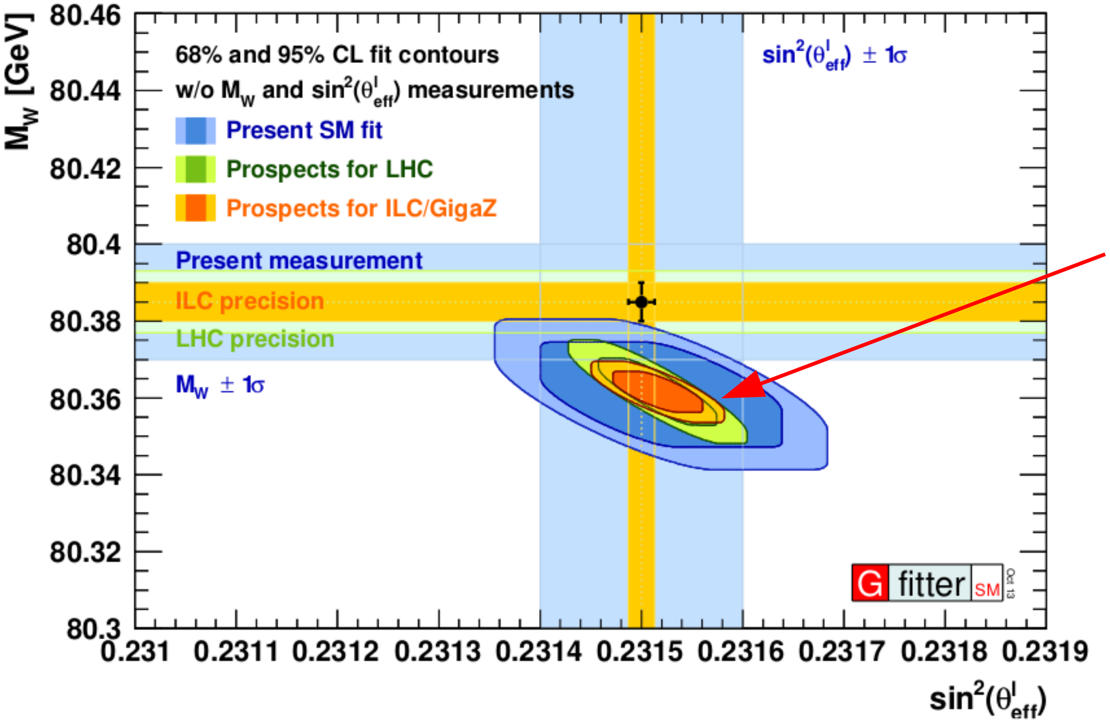
- Event weighting technique, cancellation of acceptance errors and also reduces the statistical errors by 20% (40% <u>pp collider</u>). *arXiv:0911.2850*
- Momentum scale corrections, remove the bias in determination of muon momenta. *arXiv:1208.3710*

In hadron collider measurment theory uncertainty improovement on PDF and QCD correction of factor 7 and 2 are needed

Projection on LHC precision with expected improvements on PDFs and forward lepton tagging analysis show uncertaity comparable to LEP and SLD limits

$\Delta \sin^2\theta^l_{eff}$ $[10^{-5}]$	ATLAS	CMS	LHC/per experiment		
$\sqrt{s}$ [TeV]	7	7	8	14	14
$\mathcal{L}[\text{fb}^{-1}]$	4.8	1.1	20	300	3000
PDF	70	130	35	25	10
higher order corr.	20	110	20	15	10
other systematics	70	181	60 (35)	20	15
statistical	40	200	20	5	2
Total	108	319	75 (57)	36	21

Prediction on the uncerteinties of $\sin^2(\theta^l_{eff})$ for LHC/HL-LHC



EWPOs fit results can test in deep SM consistency

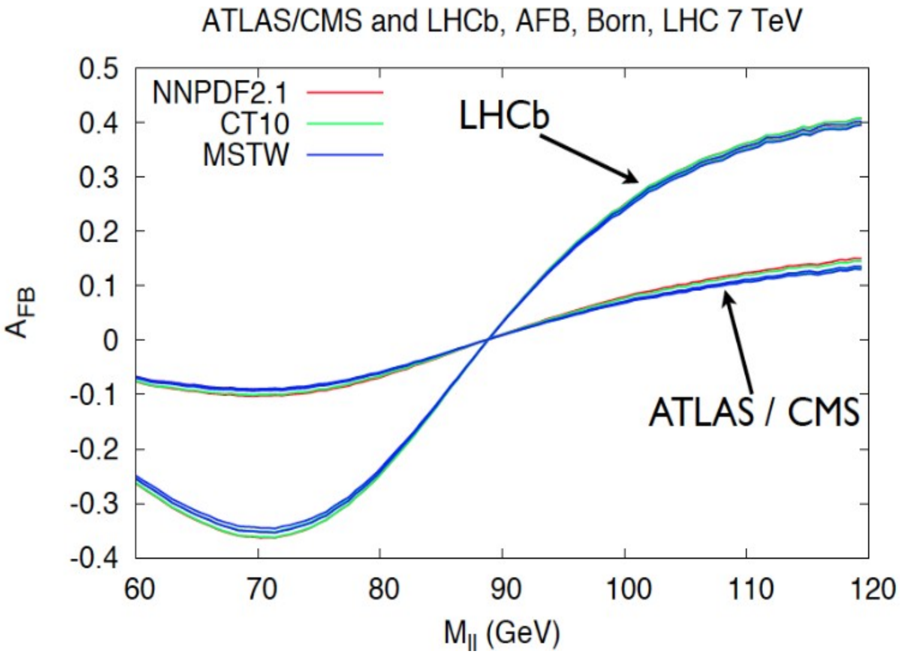
LHC/ILC fit results are obtaind assuming SM prediction:

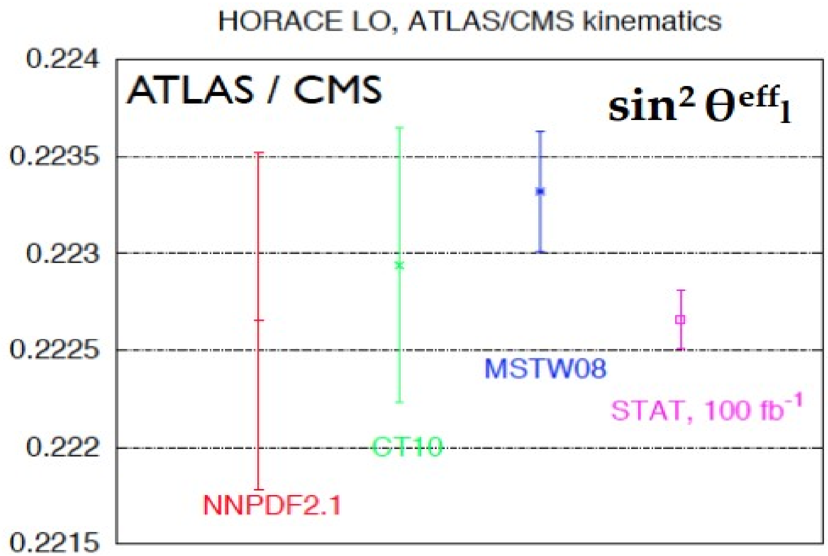
δ_{theo} **M_W** = 4 MeV → 1 MeV

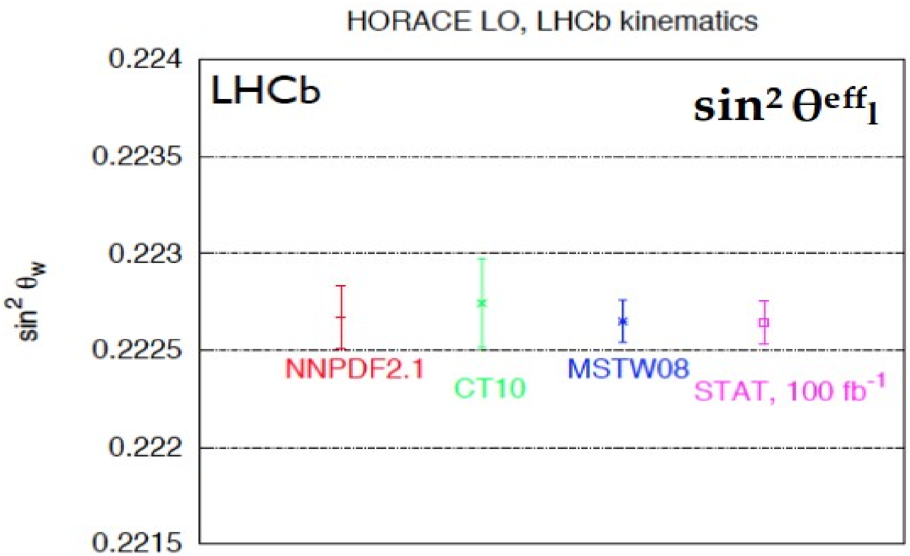
δ_{theo} **$\sin^2(\theta^l_{eff})$** = 4.7×10^{-5} → 10^{-5}

What about LHCb ?

- Most sensitive to AFB asimmetry
- Less sensitive to PDF





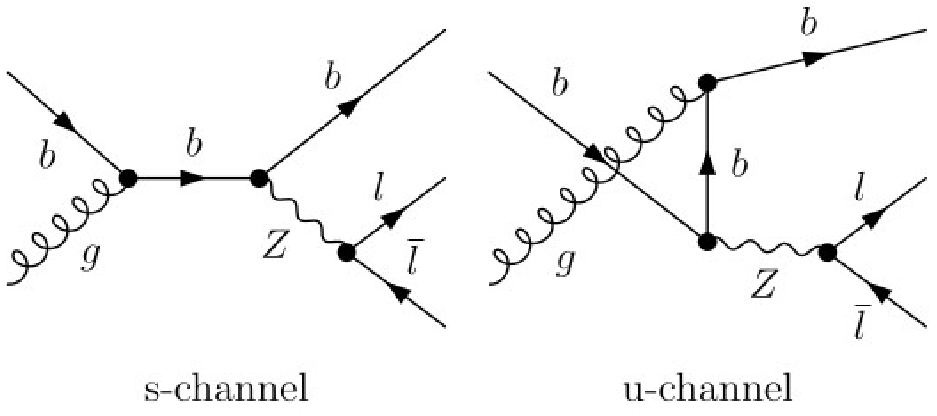


Measuring A^{b0}_{FB} via $A^{b,LHC}_{FB}$

- Highest discrepancy in SM Global Fits
  - δLEP1 = 16×10^{-4} vs δtheo ~ 4×10^{-4}
  - pull value 2.5 σ = 40 ‰
- No experiment measured it after LEP ! Define:

$$A^{b,\mathrm{LHC}}_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

  - experimentally: adapt A_{FB} to LHC, where F/B defined event by event in Z rest frame by the lepton angle wrt bjet axis
  - dilution due to bjet charge measurement
- Simplified feasibility studies set an upper bound on both statistical and systematic uncertainties
- Open field of research both from experimental and theoretical points of view (only LO prediction @ LHC): reduced uncertainties from PDFs and scale variations



$\delta A^{b,LHC}_{FB}$ [‰]	LHC	combined
$\sqrt{s}$ [TeV]	14	14
$\mathcal{L}$ [fb^{-1}]	400	3000
PDF	5	2
other systematics	20	15
statistical	≤ 95	≤ 40
Total	≤ 97	≤ 43

http://dx.doi.org/10.1016/j.physletb.2014.01.010

SUMMARY TABLE FOR M_W and $\sin^2(\theta^l_{eff})$

Current measured values:

$M_W = 80.385 \pm 0.015$ GeV

$\sin^2(\theta^l_{eff}) = (23153 \pm 16) \times 10^{-5}$

SM predictions:

$M_W = 80.360 \pm 0.008$ GeV

$\sin^2(\theta^l_{eff}) = (23127 \pm 7.3) \times 10^{-5}$

	LHC	LHC	ILC/GigaZ	ILC	ILC	ILC	TLEP	SM prediction
$\sqrt{s}$ [TeV]	14	14	0.091	0.161	0.161	0.250	0.161	-
$\mathcal{L}$[fb^{-1}]	300	3000		100	480	500	3000×4	-
ΔM_W [MeV]	8	5	-	4.1-4.5	2.3-2.9	2.8	< 1.2	4.2(3.0)
$\Delta \sin^2 \theta^\ell_{\rm eff}$ [10^{-5}]	36	21	1.3	-	-	-	0.3	3.0(2.6)

- LHC/HL-LHC precision measurements of M_W and $\sin^2(\theta^l_{eff})$ limited by uncertainty on PDFs and theoretical QCD predictions.
- Great improovement will come from Lepton collider: ILC, TLEP.

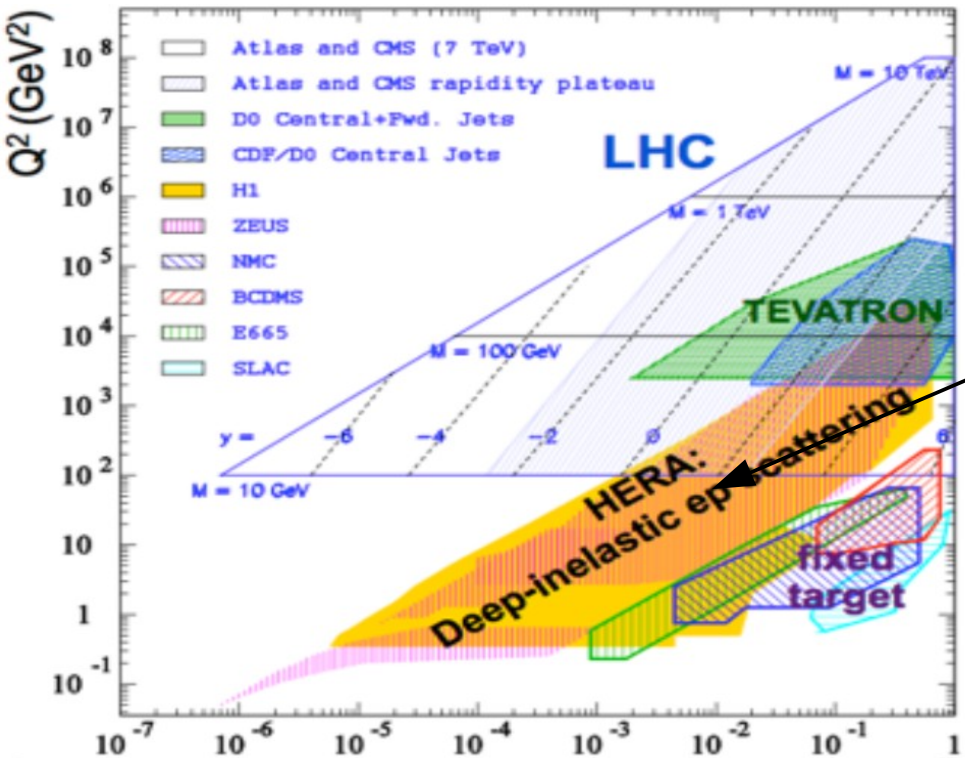
QCD: Parton Distribution Functions

Hadron collider cross section computed in perturbative QCD at NLO

$$\sigma = \sum_{a,b} \int_0^1 dx_1 f_{a/A}(x_1,\mu_F^2) \int_0^1 dx_2 f_{b/B}(x_2,\mu_F^2) \left\{ \int d\hat{\sigma}_{ab}^{LO}(\alpha_s)\, \Theta_{obs}^{(m)} + \alpha_s(\mu_R^2) \left[\int \left(d\hat{\sigma}_{ab}^{V}(\alpha_s,\mu_R^2) + d\hat{\sigma}_{ab}^{C}(\alpha_s,\mu_F^2) \right) \Theta_{obs}^{(m)} + \int d\hat{\sigma}_{ab}^{R}(\alpha_s)\, \Theta_{obs}^{(m+1)} \right] \right\} + \dots$$

$\sigma = \sigma_0 + \alpha_s\, \sigma_{\alpha s} + \dots.$

PDF of the proton are key ingredient to make theoretical predictions at hadron colliders



PDF uncertainty is limiting factor for W/Z physics and also for xsec H prediction at higher energies

PDFs determined in DIS experiments can be used for precise predictions of the production cross sections atppcolliders

BUT

Knowledge of the PDFs must be improved using results from LHC measurements

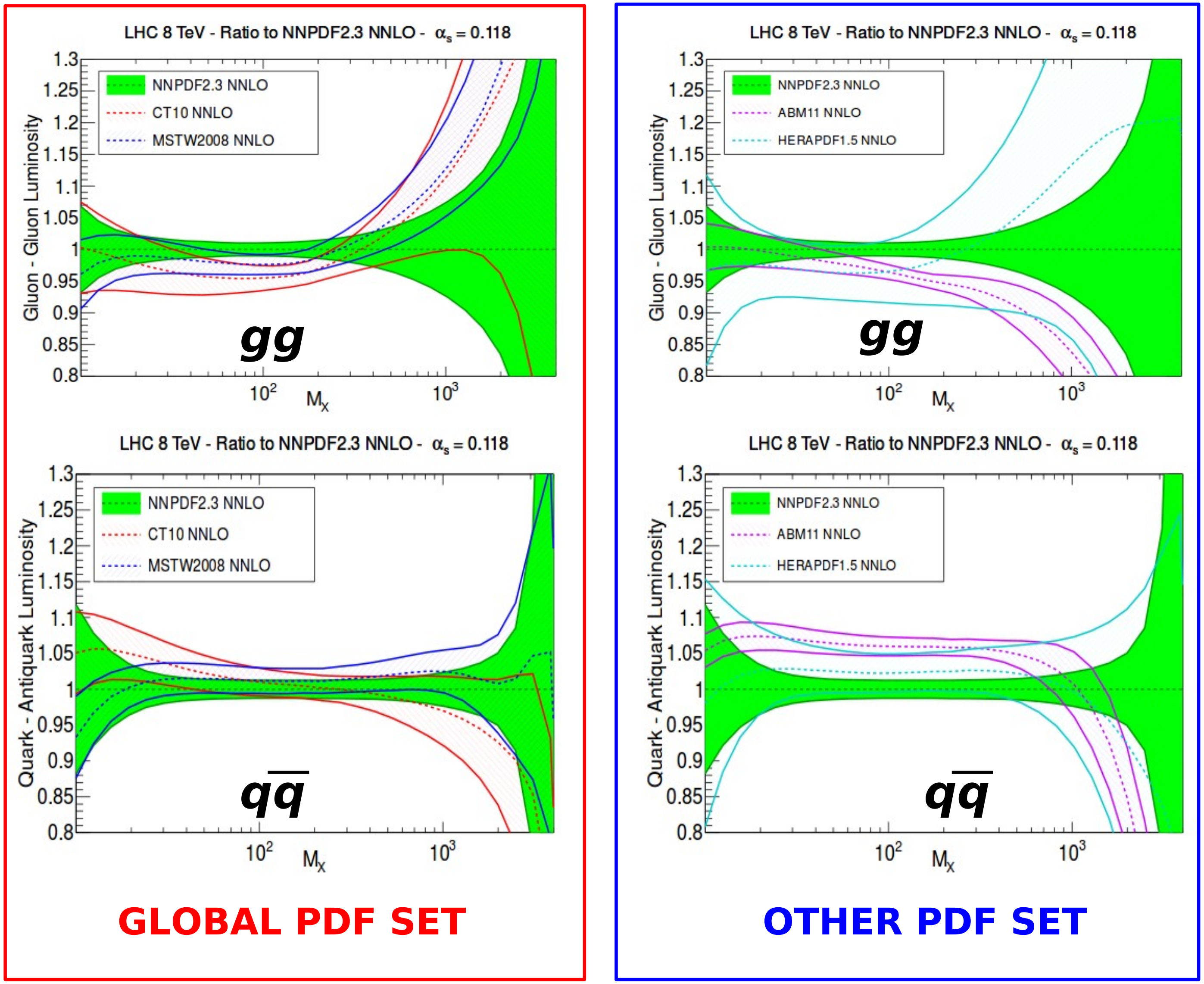
PDFs: Status of the Art

Latest comparisons between recent NNLO PDFs at the level of parton luminosities and cross section

JHEP 1304, 125 (2013)

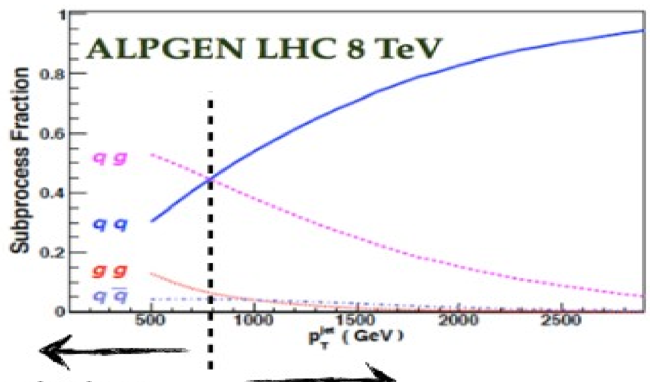
For ***gg*** luminosity not so good agreement in the region of the EW scale between GLOBAL PDF SET

- For ***$q\bar{q}$*** luminosity quite good agreement in the region of the EW scale between GLOBAL PDF SET
- Uncertainty blow up for large-mass final states



PDF constrain: jet production

Multijet production is the dominant high transverse momentum process at LHC



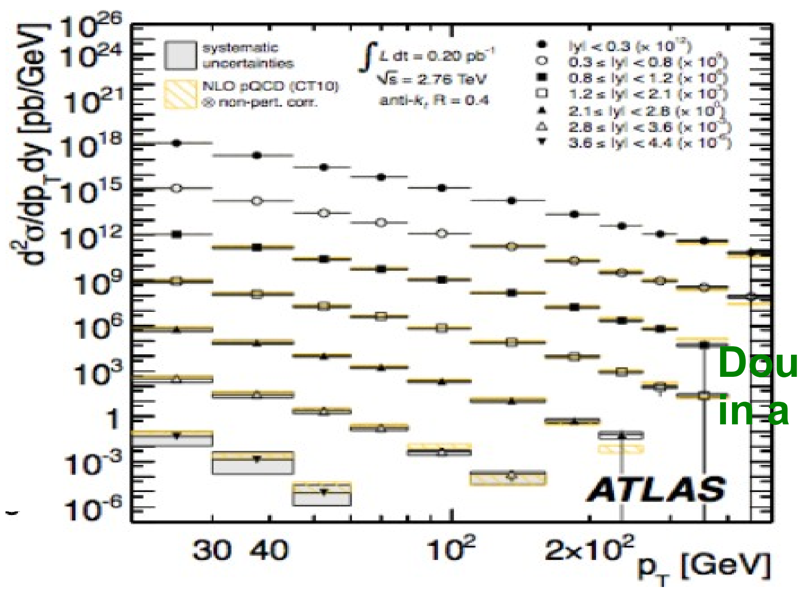
quark-gluon scattering

quark-quark scattering

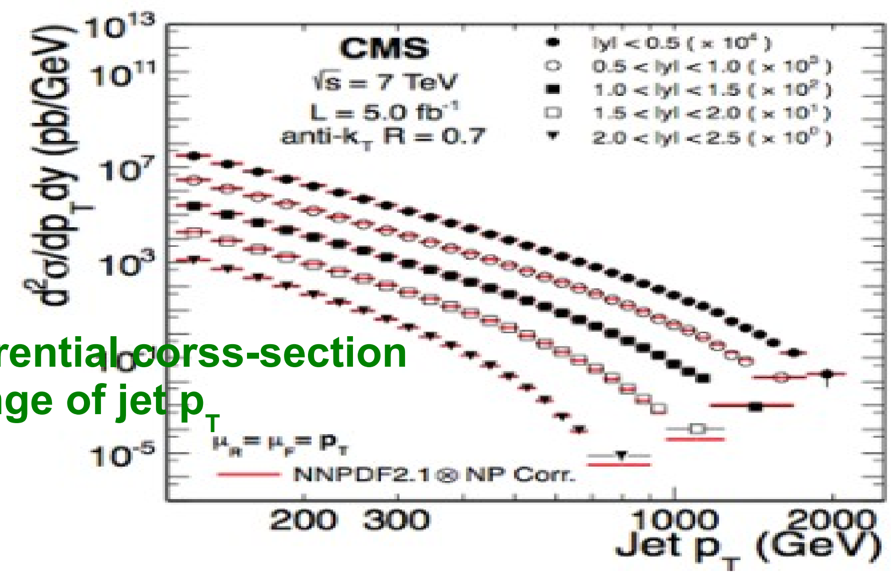
- **for pT < 800 GeV**, quark-gluon scattering is dominant
  jet production sensitive to the gluon
- **for pT > 800 GeV**, quark-quark scattering is dominant
  jet production sensitive to the quark

Data are found to be generally well described by theoretical predictions, corrected for non-perturbative effects

EPJC (2013) 73 2509



Phys. Lett. B 718 (2013) 752

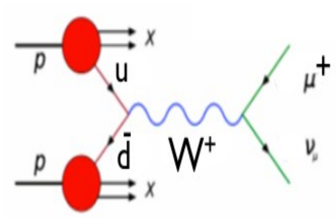


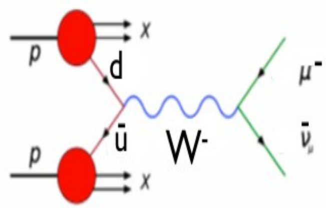
Double differential corss-section in a wide range of jet p_T

PDF constrain: Asimmetry in W decay

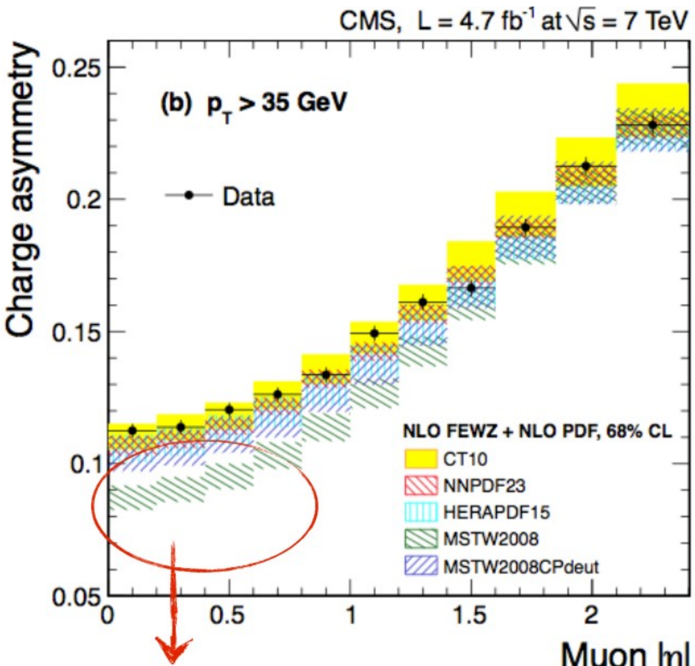
$pp \rightarrow W+X$

$$A(\eta) = \frac{d\sigma/d\eta(W^+) - d\sigma/d\eta(W^-)}{d\sigma/d\eta(W^+) + d\sigma/d\eta(W^-)}$$





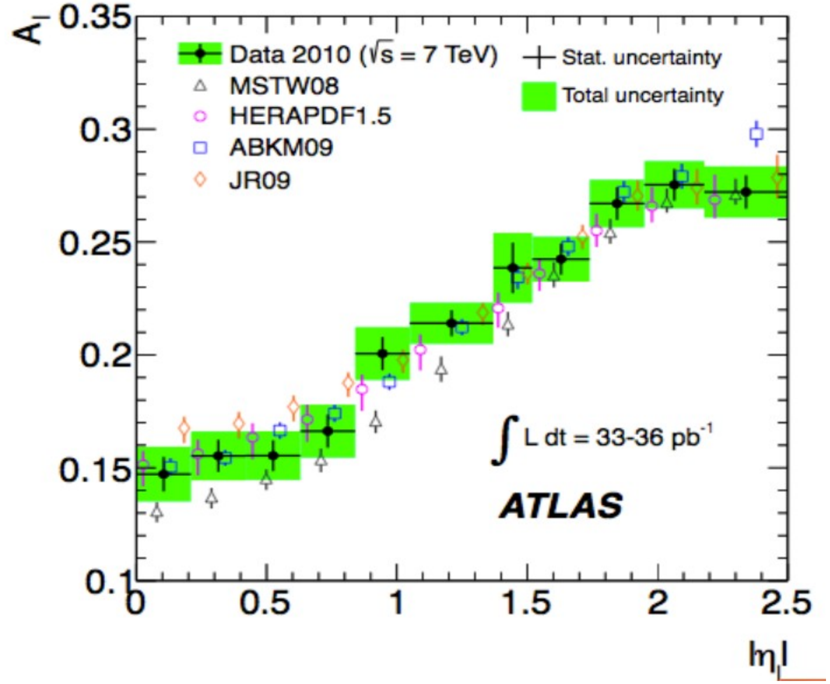
- In pp collision W^+ is produced in eccess respect W^-
- A(W) sensitive to valence quark distribution via ptoduction: $u\bar{d}(\bar{u}d) \rightarrow W^{+(-)}$
- LHC can contribute to understand PDF in the $10^{-3} < x < 10^{-1}$ range



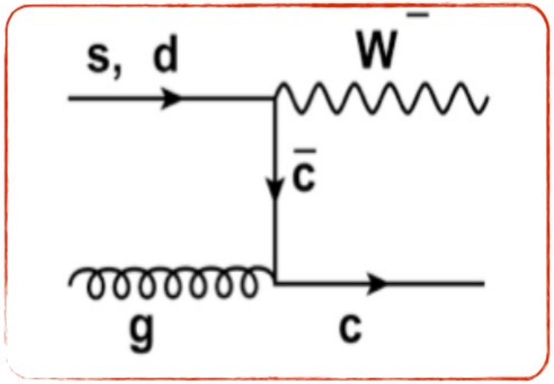
Disagreement between prediction with MSTW2008 and data

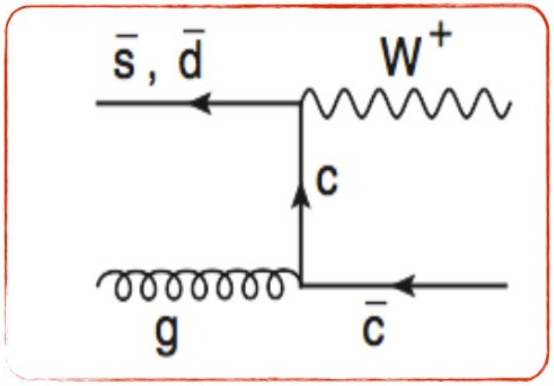
CMS:
Comparison with NLO prediction using FEWZ 3.1 with PDF sets

ATLAS: Comparison of the measured asymmetry with the NNLO predictions using different PDF sets



PDF constrain: W + c production

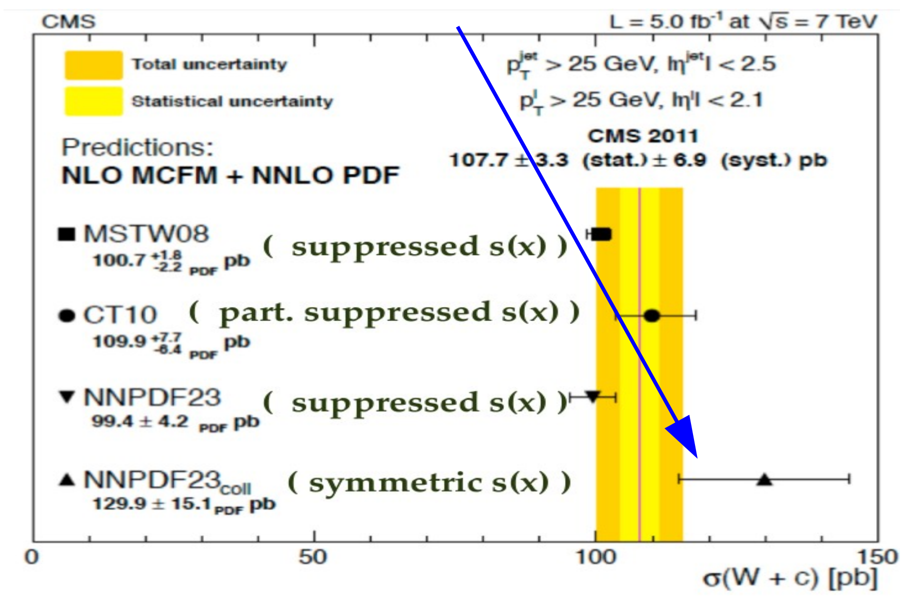




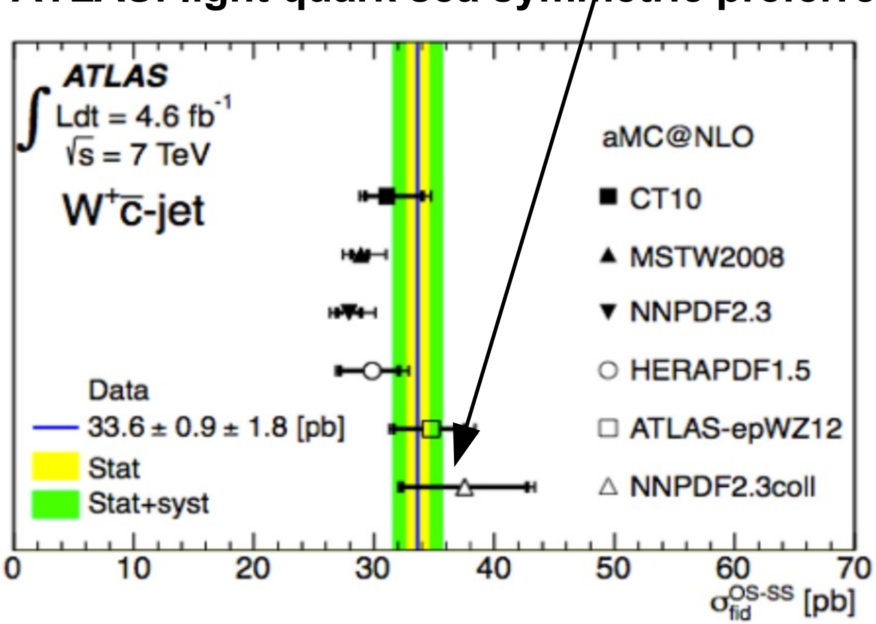
- In pre-LHC PDF fits, strangeness *s(x,Q)* mostly constrained from DIS neutrino data
- W production in association with charm quarks provide a clean probe of the strange PDF at the LHC

Measured by ATLAS (arxiv:1402.6263) and CMS (arxiv:13101138) with somewhat opposite (?) conclusions

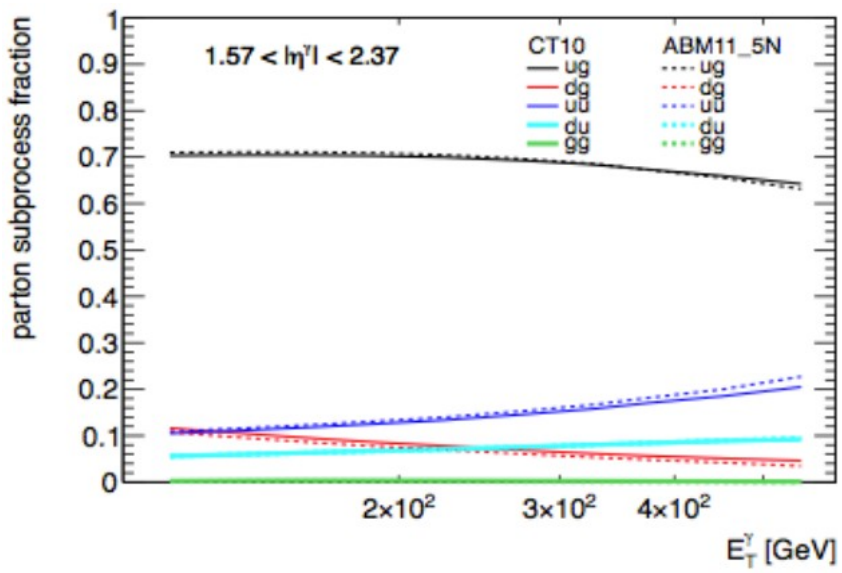
CMS: *s* suppression in agreement with DIS data



ATLAS: light quark sea symmetric preferred



PDF constrain: Isolated photon production



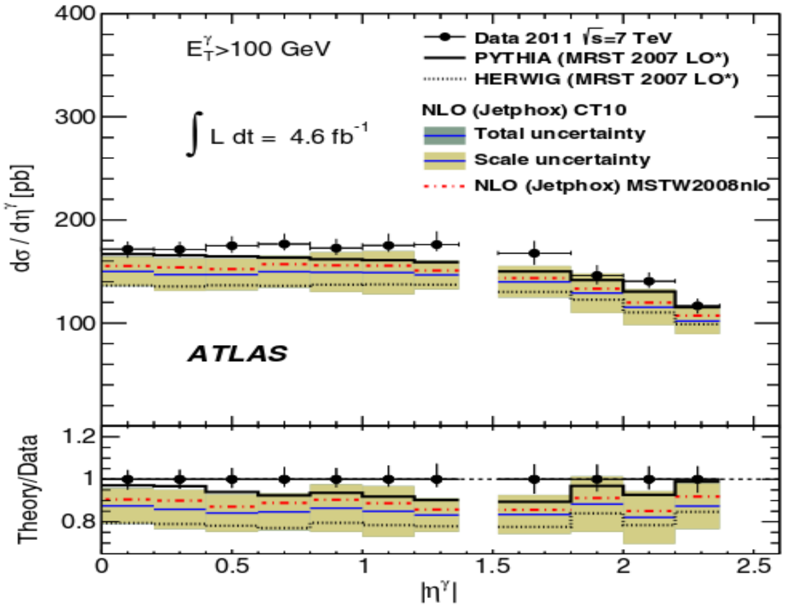
Dominant prompt photons production at LHC

$qg \to q\,\gamma$

Inclusive photon production cross section can provide significant constraints on the gluon distribution

Phys. Rev. D89,052004 (2014)

ATLAS measurement of the cross section for the production of isolated prompt photons as a function of photons pseudorapidity and transverse energy



Data agree with NLO prediction based on CT10 and MSTW2008

PDF: What next?

A sort of whishlist for LHC/HL-LHC:

Traditional measurements:

- *Inclusive jets*: data extending exp to higher pt with smaller systematics

- *Inclusive W and Z production and asymmetries:* quark-antiquark separation (reducing uncertainties)

New LHC measurements:

- *Isolated photons and photon+jets*: medium x gluon (QCD Compton Scattering)

- *W production with charm*: quantify impact in strangeness

Quantitative improovment on PDF from LHC future data difficult to predict: exp. systematics, impact of pile-up at high luminosity… ?

Measuring $\alpha_s(M^2_Z)$

α_s is a fundmental parameters of QCD.

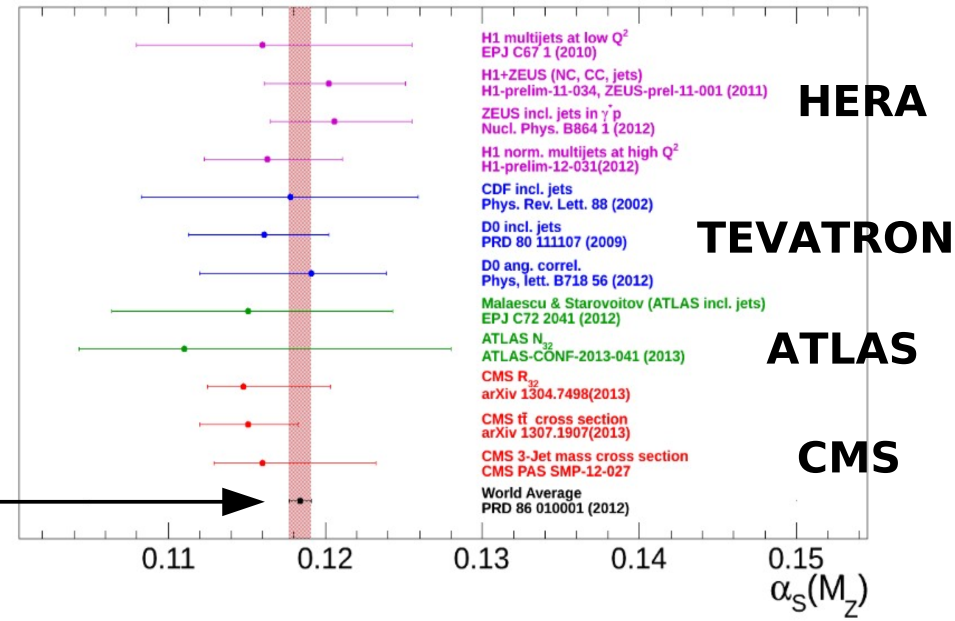
$$\sigma = \sigma_0 + \alpha_s\, \sigma_{\alpha s} + \ldots.$$

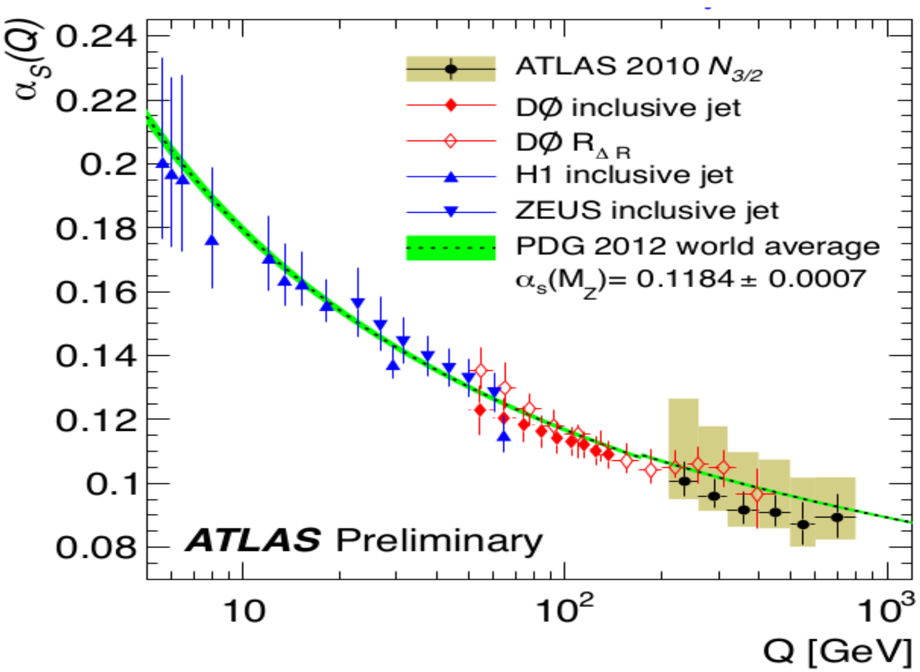
α_s is not observable and predicted

⇩

Value is extracted from experimental measuremesnts at colliders and from lattice QCD calculations:

$$\alpha_s(M_Z^2) = 0.1184 \pm 0.0007$$



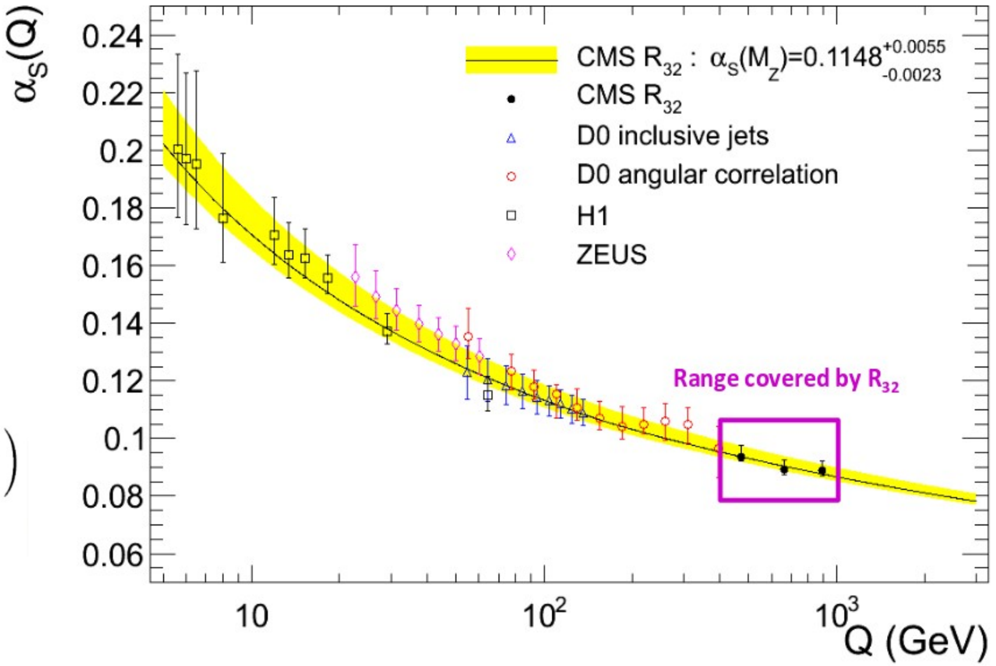


ATLAS-CONF-2013-041

Ratios of inclusive three- to two-jet cross-sections as a function of the pTof each jet in an event ($N_{3/2}$)

$$N_{3/2}(p_T^{(\text{all jets})}) = \frac{\sum_i^{N_{\text{jet}}} \left(d\sigma_{N_{\text{jet}} \geq 3} / dp_{T,i} \right)}{\sum_i^{N_{\text{jet}}} \left(d\sigma_{N_{\text{jet}} \geq 2} / dp_{T,i} \right)}$$

Eur.Phys.J. C73 (2013) 2604



CMS: Ratio between 3-jet and 2-jet production as a function of the average p_T

$$R_{32}\left(\langle p_{T1,2}\rangle\right) \equiv \frac{d\sigma^{n_j\geq 3}/d\langle p_{T1,2}\rangle}{d\sigma^{n_j\geq 2}/d\langle p_{T1,2}\rangle} \propto \alpha_s(Q)$$

From SNOWMASS report:

At hadron collider (LHC/HL-LHC) it will be **challenging to achieve < 1%** relative uncertainty on α_s.

Among hadron collider measurements best precision using tt cross section based on a full NNLO QCD calculation.

CMS Collaboration (2013), 1307.1907

BUT

The improved precision from hadron collider data at relatively high-Q^2 is still important for the robustness of αs determinations, and testing the running of αs and asymptotic freedom, as the current world average of α_s is driven by low-Q^2 measurements.

< 1% and also 0.1% possible at lepton collider (ILC/TLEP) using diffferent methods

See Table in backup for details

QCD: Higher-order corrections

-State of the art: multi-body NLO predictions merged and matched with PS

-NNLO calculations are essential to reduce theoretical uncertainties
- also in PDF analysis

-Up to last year, only small number of processes relevant for PDFs available at NNLO

-Recent important progress was made on some key processes
NNLO inclusive jet production in the gluon-gluon channel has been completed (arxiv:1310.3993), jet data essential in PDF fits for gluons and large-x quarks

-In order to match the desired precision:

- At high energies EW and QCD corrections comparable, NLO EW needed: how to combine?

- high p_T regions make predictions sensitive to EW already at 14 TeV

EW: Multi-bosons production TGC & QGC

Gauge boson couplings: basic characteristics of a non-abelian theory
• In SM triple and quartic GC
• Deviation from SM, i.e. anomalous couplings: new physics evidence

3-gauge couplings: SM $W^+W^-\gamma$ W^+W^-Z
anomalous $Z\gamma\gamma$, $ZZ\gamma$, ZZZ

4-gauge couplings: SM $W^+W^-\gamma\gamma$, $W^+W^-\gamma Z$, W^+W^-ZZ, $W^+W^-W^+W^-$
anomalous $ZZ\gamma\gamma$

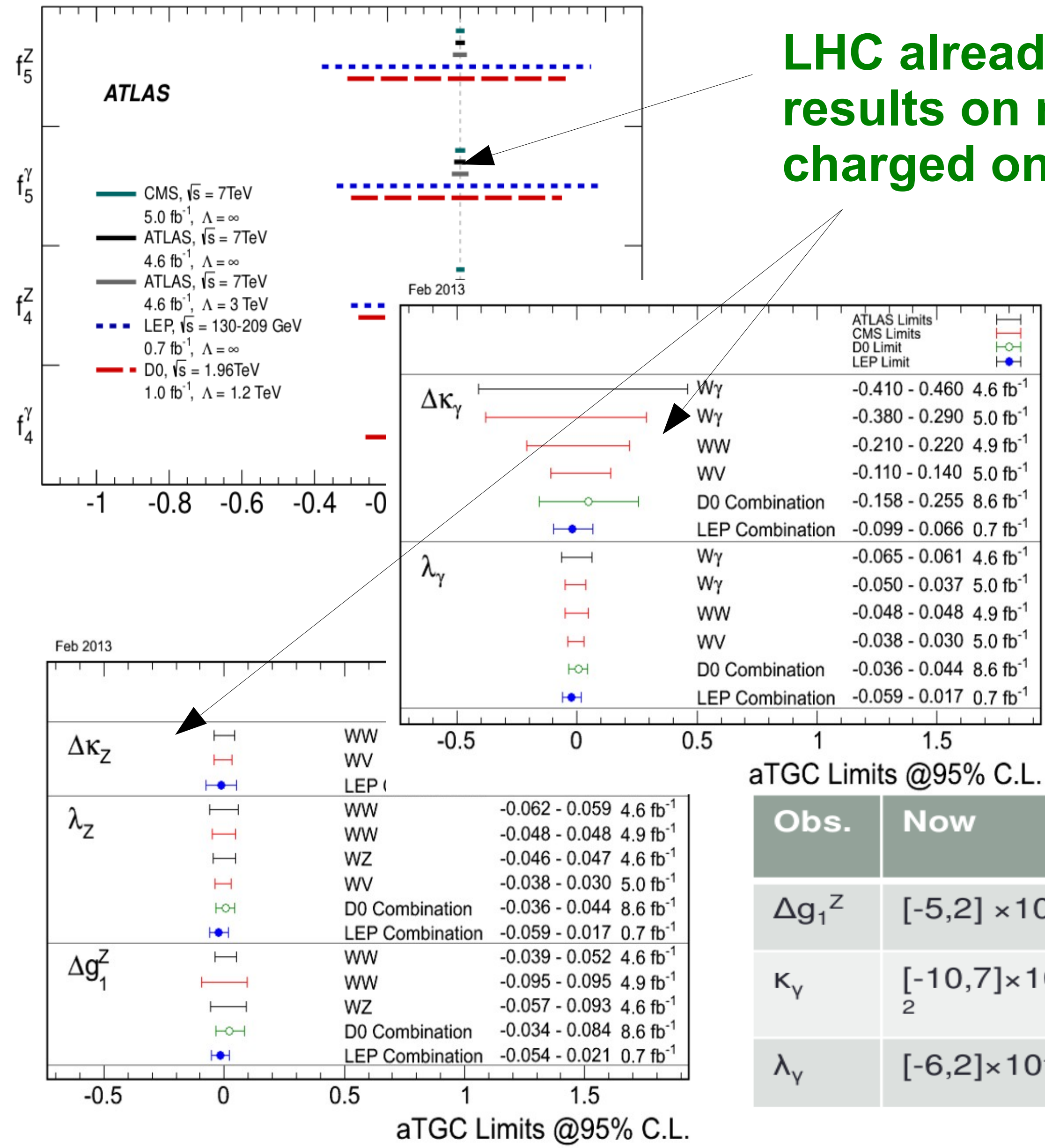
Analysis of multi-bosons production provides a stringent test of the SM

If the new physics scale is well above the energies reached new interactions can be included in the Lagrangian as higher-dimensional operators which are suppressed by the new physics scale Λ → ***EFFECTIVE FIELD THEORY APPROACH***

$$\mathcal{L}_{EFT} = \mathcal{L}_{SM} + \sum_{i=WWW,W,B,\Phi W,\Phi B} \frac{c_i}{\Lambda^2}\mathcal{O}_i + \sum_{j=0,1} \frac{f_{S,j}}{\Lambda^4}\mathcal{O}_{S,j} + \sum_{j=0,\dots,9} \frac{f_{T,j}}{\Lambda^4}\mathcal{O}_{T,j} + \sum_{j=0,\dots,7} \frac{f_{M,j}}{\Lambda^4}\mathcal{O}_{M,j}$$

• If Λ >> experimentally accessible scale, i.e. O(1-2 TeV), the SM is a low (compared to Λ) effective theory
• Both TGC and QGC in **dimension 6** operators, **dimension 8** add genuine QGC

TGC current status



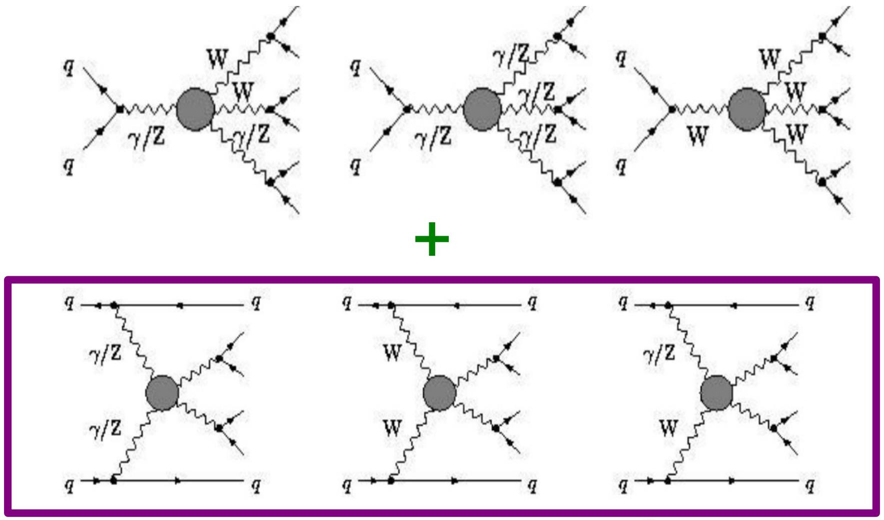
LHC already improoved LEP & Tevatron results on neutral aTGC competitive on charged one

- λ-type κ-type couplings will benefit from large statistics since sensitivity is in the highest part of diboson system energy,pT differential distribution
- ILC will be anyway more precise due due to a cleaner environement

HL-LHC competitive with ILC800

Obs.	Now	LHC 0.3/ab	HL-LHC 3/ab	ILC800
Δg_1^Z	[-5,2] ×10⁻²	3×10⁻³	2×10⁻³	1.8×10⁻⁴
κ_γ	[-10,7]×10⁻²	3×10⁻²	1×10⁻²	1.9×10⁻⁴
λ_γ	[-6,2]×10⁻²	9×10⁻⁴	4×10⁻⁴	2.6×10⁻⁴

Limits on QGC



- Quartic Gauge Couplings arise in both *triboson* production or *diboson* produciton + jets (via ***VBS***)

At LHC bounds on anomalous quartic gauge couplings from two-photon production of a W^+W^- pair at the reported by CMS

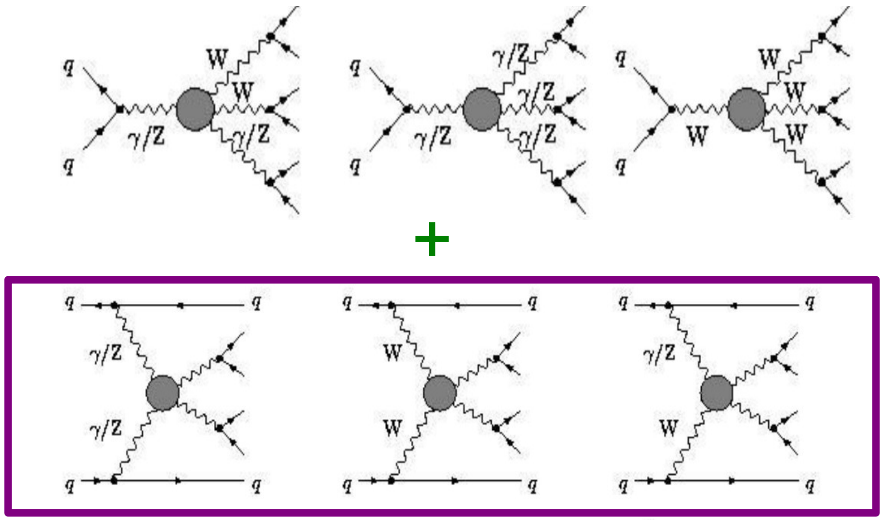
JHEP 1307, 116 (2013)

ATLAS sensitivity studies using the fully-leptonic decay modes of $W^\pm W^\pm$, WZ and ZZ channels in the VBS mode as well as triboson in the Zγγ channel

Increase of Luminosity crucial for gain in sensitivity

Parameter	dimension	channel	Λ_{UV} [TeV]	300 fb^{-1}		3000 fb^{-1}	
				5σ	95% CL	5σ	95% CL
$c_{\Phi W}/\Lambda^2$	6	ZZ	1.9	34 TeV^{-2}	20 TeV^{-2}	16 TeV^{-2}	9.3 TeV^{-2}
$f_{S,0}/\Lambda^4$	8	$W^\pm W^\pm$	2.0	10 TeV^{-4}	6.8 TeV^{-4}	4.5 TeV^{-4}	0.8 TeV^{-4}
$f_{T,1}/\Lambda^4$	8	WZ	3.7	1.3 TeV^{-4}	0.7 TeV^{-4}	0.6 TeV^{-4}	0.3 TeV^{-4}
$f_{T,8}/\Lambda^4$	8	$Z\gamma\gamma$	12	0.9 TeV^{-4}	0.5 TeV^{-4}	0.4 TeV^{-4}	0.2 TeV^{-4}
$f_{T,9}/\Lambda^4$	8	$Z\gamma\gamma$	13	2.0 TeV^{-4}	0.9 TeV^{-4}	0.7 TeV^{-4}	0.3 TeV^{-4}

Limits on QGC



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QGC in pp HE via VBS

Parameter	Luminosity [fb^{-1}]	14 TeV		33 TeV	
		5σ	95% CL	5σ	95% CL
$c_{\Phi W}/\Lambda^2$ [TeV^{-2}]	3000	16.2 (16.2)	9.7 (9.7)	13.2 (13.2)	8.2 (8.2)
	300	31.3 (31.5)	18.2 (18.3)	23.8 (23.8)	14.7 (14.7)
$f_{T,8}/\Lambda^4$ [TeV^{-4}]	3000	2.9 (4.7)	1.7 (2.4)	1.6 (1.7)	1.0 (1.3)
	300	5.5 (8.4)	3.2 (5.3)	2.8 (2.3)	1.8 (1.8)
$f_{T,9}/\Lambda^4$ [TeV^{-4}]	3000	5.7 (6.3)	3.9 (4.6)	3.8 (6.6)	2.5 (3.5)
	300	8.7 (9.0)	6.2 (6.7)	6.3 (10.1)	4.2 (8.2)

Sensitivity increase from 14 to 33 TeV
~ 1.2 - 2 for dim-6 (WZ,ZZ)
~ 12 for dim-8 (Zγγ)
Tribosons look very sensitive to √s

LHC better by 1-2 orders of magnitude compared to lepton colliders

QGC via photon-photon scattering

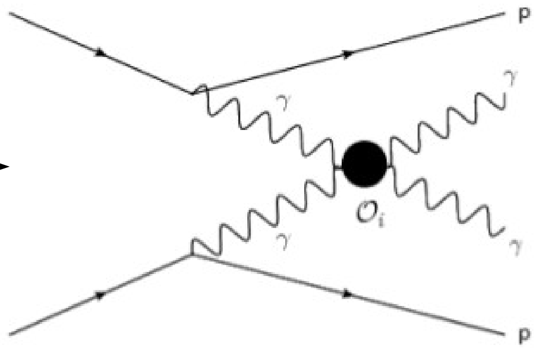
The ATLAS Forward Physics Project (AFP) and the Precision Proton Spectrometer (PPS, CMS/TOTEM)

Forward region exp. ~ 200 m from I.P.

Final state can be γγ, WW , ZZ → ideal to study anomalous quartic gauge couplings (aQGC)

γγγγ anomalous couplings

No constraints from collider experiments



Requirement of two intact protons + kinematics constraints → strong background reduction

$$L_{4\gamma} = \zeta_1^{\gamma} F_{\mu\nu}F^{\mu\nu}F_{\rho\sigma}F^{\rho\sigma} + \zeta_2^{\gamma} F_{\mu\nu}F^{\nu\rho}F_{\rho\sigma}F^{\sigma\mu} \text{ (dimension 8)}$$

Luminosity	300 fb^{-1}	300 fb^{-1}	300 fb^{-1}	3000 fb^{-1}
pile-up (μ)	50	50	50	200
coupling (GeV^{-4})	≥ 1 conv. γ 5 σ	≥ 1 conv. γ 95% CL	all γ 95% CL	all γ 95% CL
ζ_1 f.f. ζ_1 no f.f.	$1 \cdot 10^{-13}$ $3.5 \cdot 10^{-14}$	$9 \cdot 10^{-14}$ $2.5 \cdot 10^{-14}$	$5 \cdot 10^{-14}$ $1.5 \cdot 10^{-14}$	$2.5 \cdot 10^{-14}$ $7 \cdot 10^{-15}$
ζ_2 f.f. ζ_2 no f.f.	$2.5 \cdot 10^{-13}$ $7.5 \cdot 10^{-14}$	$1.5 \cdot 10^{-13}$ $5.5 \cdot 10^{-14}$	$1 \cdot 10^{-13}$ $3 \cdot 10^{-14}$	$4.5 \cdot 10^{-14}$ $1.5 \cdot 10^{-14}$

arXiv:1312.5153 (2013)

Summary & hints for discussion

- The utility of the W/Z precision measurements depends on the scenario
  - If new physics directly discovered, they are a tool to characterize it
  - Otherwise they are a tool to probe regions kinematically inaccessible
  - m_W and $\sin^2(\theta_{eff})$ have different sensitivities to oblique corrections
- Boson couplings are sensitive to physics at high scales
  - The higher the precision the higher the scale probed, in a sense precision always wins (in a wide range)
- Hadronic machines require lots of QCD work to give the best results, both theoretical and experimental
  - PDFs first of all

BACKUP SLIDES

SUMMARY TABLE ON $\alpha_s(M_Z^2)$

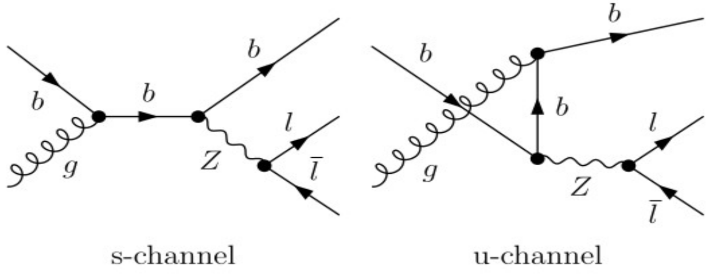
Method	Current relative precision	Future relative precision
e^+e^- evt shapes	expt $\sim 1\%$ (LEP) thry ~ 1–3% (NNLO+up to N^{3}LL, n.p. signif.) [27]	$< 1\%$ possible (ILC/TLEP) $\sim 1\%$ (control n.p. via Q^2-dep.)
e^+e^- jet rates	expt $\sim 2\%$ (LEP) thry $\sim 1\%$ (NNLO, n.p. moderate) [28]	$< 1\%$ possible (ILC/TLEP) $\sim 0.5\%$ (NLL missing)
precision EW	expt $\sim 3\%$ (R_Z, LEP) thry $\sim 0.5\%$ (N^{3}LO, n.p. small) [9, 29]	0.1% (TLEP [10]), 0.5% (ILC [11]) $\sim 0.3\%$ (N^{4}LO feasible, ~ 10 yrs)
τ decays	expt $\sim 0.5\%$ (LEP, B-factories) thry $\sim 2\%$ (N^{3}LO, n.p. small) [8]	$< 0.2\%$ possible (ILC/TLEP) $\sim 1\%$ (N^{4}LO feasible, ~ 10 yrs)
ep colliders	~ 1–2% (pdf fit dependent) [30, 31], (mostly theory, NNLO) [32, 33]	0.1% (LHeC + HERA [23]) $\sim 0.5\%$ (at least N^{3}LO required)
hadron colliders	$\sim 4\%$ (Tev. jets), $\sim 3\%$ (LHC $t\bar{t}$) (NLO jets, NNLO $t\bar{t}$, gluon uncert.) [17, 21, 34]	$< 1\%$ challenging (NNLO jets imminent [22])
lattice	$\sim 0.5\%$ (Wilson loops, correlators, ...) (limited by accuracy of pert. th.) [35–37]	$\sim 0.3\%$ (~ 5 yrs [38])

$A^{b,LHC}_{FB}$, motivations and definition

http://dx.doi.org/10.1016/j.physletb.2014.01.010

- Highest discrepancy in SM Global Fits is in the bottom sector:
  - pull value = $(O_{fit} - O_{meas})/\sigma_{meas}$, pull($A^{b,0}_{FB}$) = 2.5
- Can LHC/hadronic colliders play a role?
  - bottom-*Z* associated production, *Z* rest frame, b-jet reference axis

$$A^{b,\mathrm{LHC}}_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$



  - Definition makes it propoprtional (@ LO) to the LEP observable! Suggests connection also between experimental strategies ...

Measuring $A^{b,\,LHC}_{FB}$

http://dx.doi.org/10.1016/j.physletb.2014.01.010

- Key ingredient is to adapt LEP exp. observables to new process/collider:

$$\langle Q_{FB} \rangle \equiv \left\langle (-1)^{FB} Q_{\rm jet} \right\rangle$$

- Then everything follows, e.g. non pure sample:

$$\langle Q_{FB} \rangle = \sum_f \delta^f A^{f,\rm LHC}_{FB} \; r_f$$

$\delta A^{b,LHC}_{FB}$ [‰]	LHC	combined
$\sqrt{s}$ [TeV]	14	14
$\mathcal{L}$ [fb^{-1}]	400	3000
PDF	5	2
other systematics	20	15
statistical	≤ 95	≤ 40
Total	≤ 97	≤ 43

  - r_f flavour fractions, δ_f mean charges
  - dilution due to δ_f (jet charge measurement)

- Simplified feasibility studies set an upper bound on both statistical and systematic uncertainties
- Open field of research both from experimental and theoretical points of view (only LO prediction @ LHC)