$\sin^2\theta_W$ extraction at HL-LHC with LHeC PDFs

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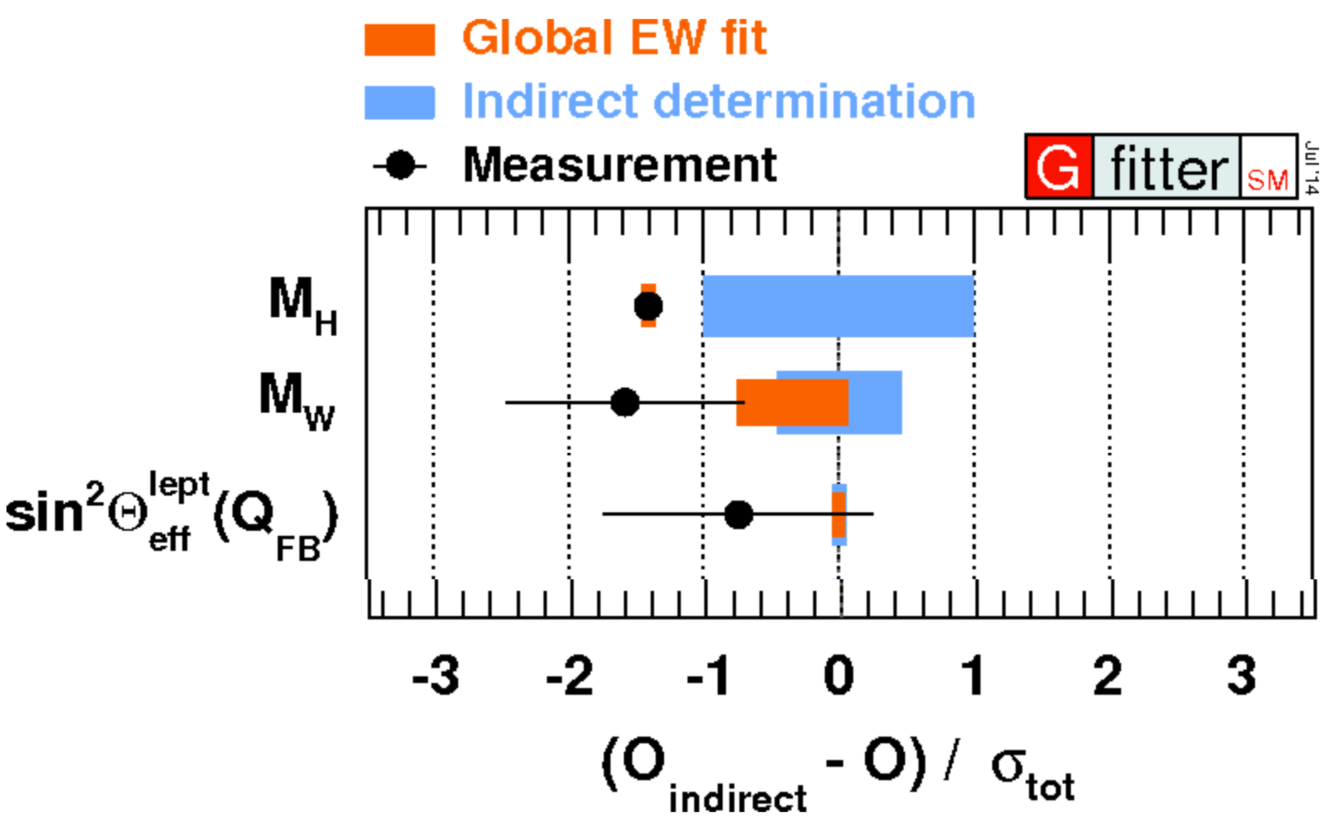
Key parameter of EW



Indirect determination of M_W and $\sin^2\theta^{eff}$ more precise then the experimental measurement:

- This call for a precise direct Measurement
- Stringent test of the self consistency of the SM

The measurement of $\sin^2\theta_W$ tests this relation:

$$\sin^2_{\text{eff}}\theta_W = \left(1 - \frac{m_W^2}{m_Z^2}\right)\kappa$$

$\pm 20\times10^{-5}$ error in $\sin^2\theta^{eff}$ corresponds to $\pm$10MeV error in M_W

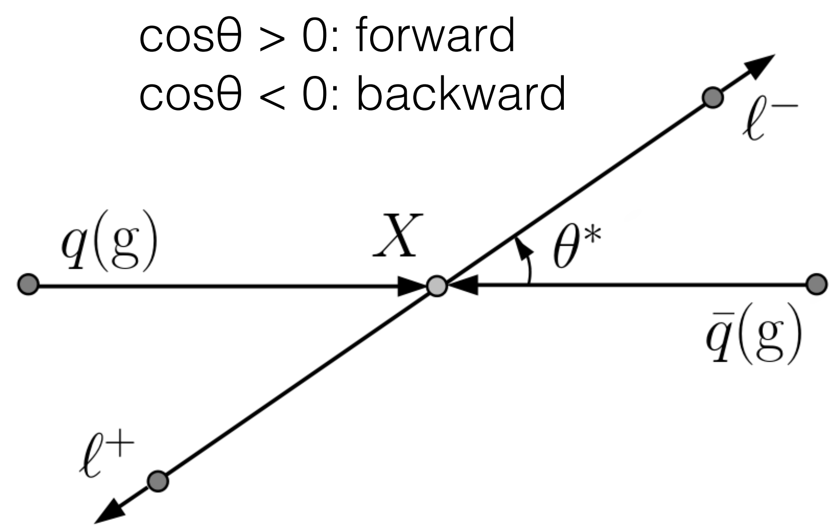
Forward-Backward asymmetry

- The Drell-Yan production cross section as function of the scattering angle θ.

$$\frac{d\sigma}{d\cos\theta} = \frac{4\pi\alpha^2}{3s}\left[\frac{3}{8}(A(1+\cos^2\theta) + B\cos\theta)\right]$$

$$B = -4Q_l g_A^q g_A^l \chi_1 + 8 g_A^q g_V^q g_A^l g_V^l \chi_2 \,,$$

B ~ Z/γ* and V-A interference



$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{3}{8}\frac{B}{A}$$

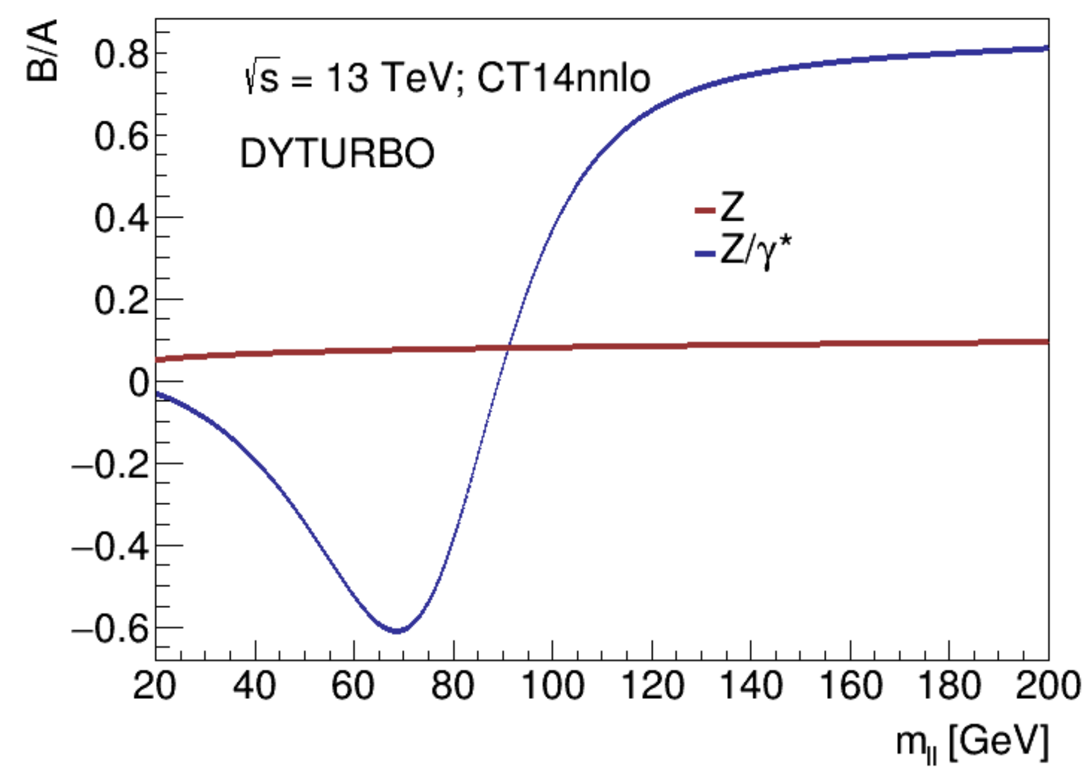
- Linear term in cos(θ) give rise to non-vanishing forward-backward asymmetry

- The V-A interference contribution is proportional to g_V g_A, and depends on the weak mixing angle θ_W

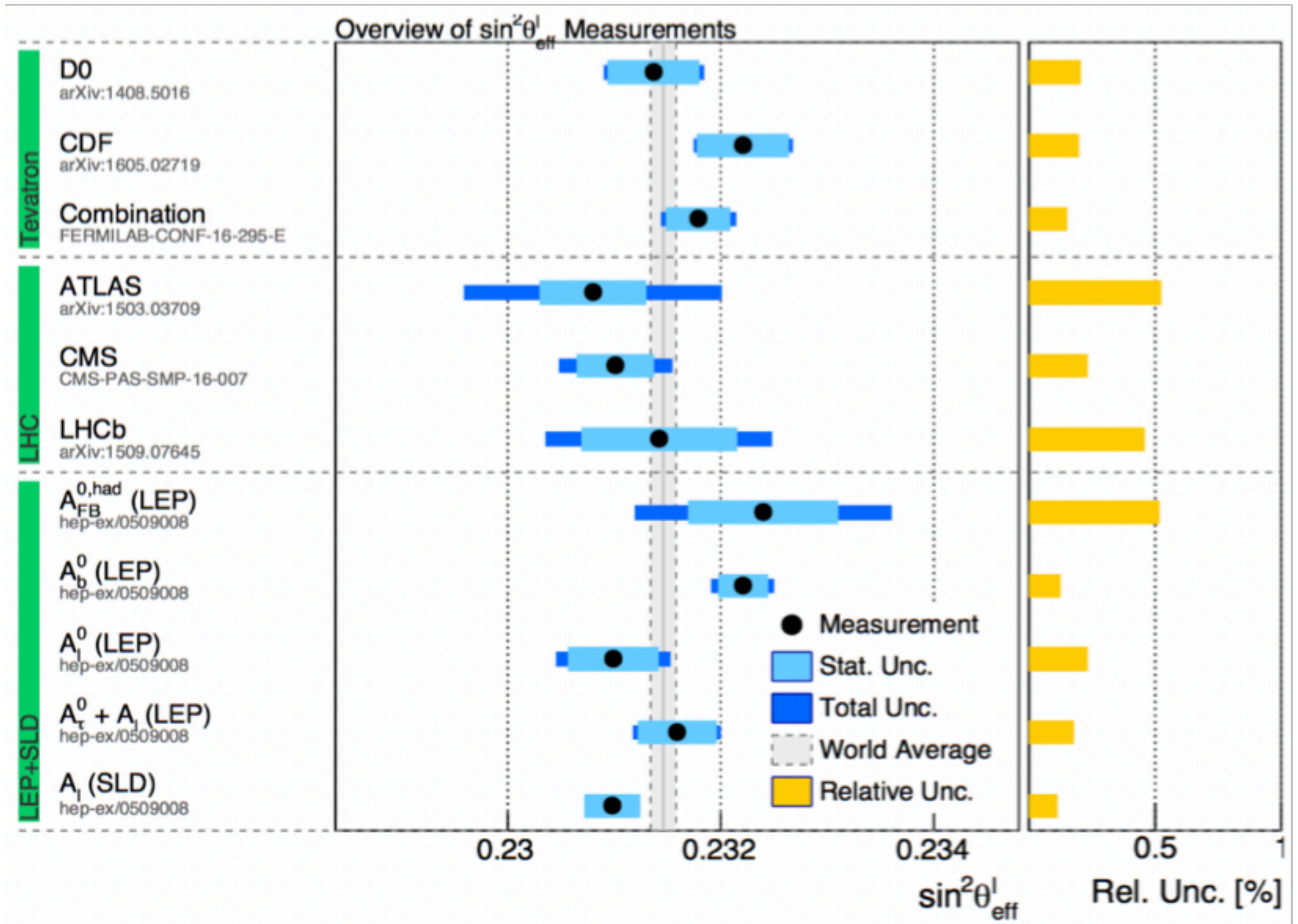
$$g_V^f = T_3^f - 2Q_f \sin^2\theta_W$$

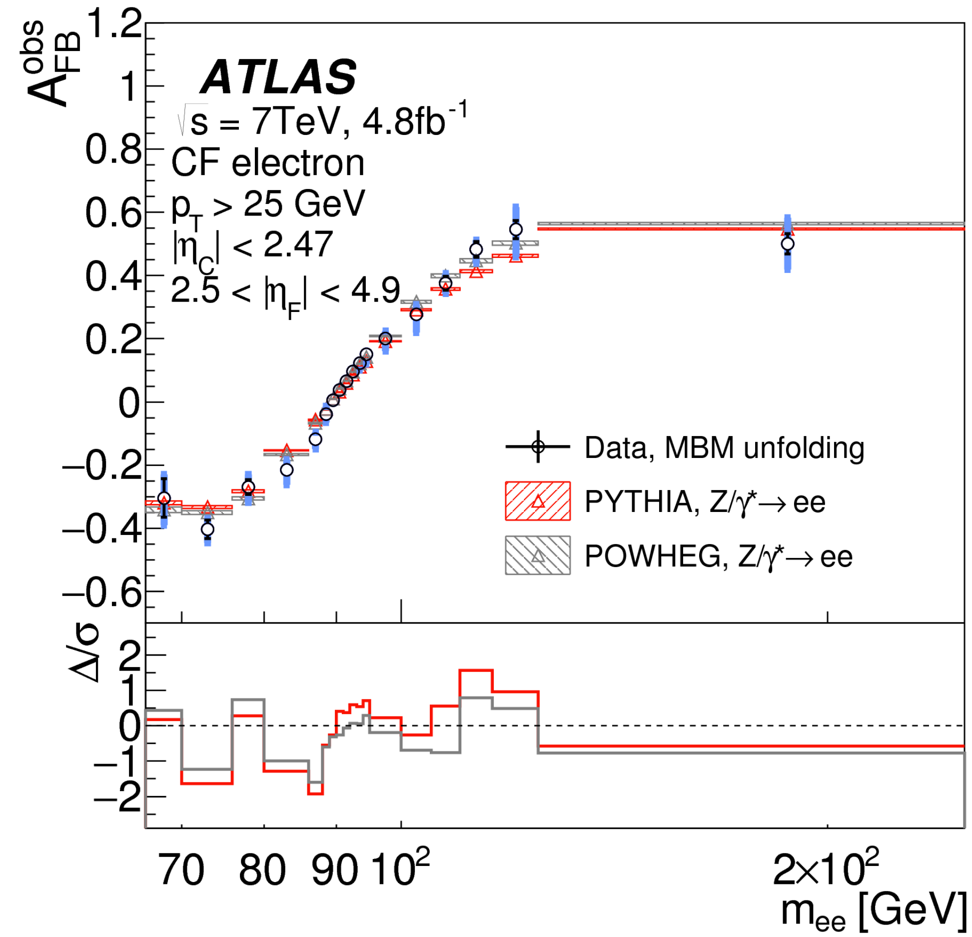
- The Z/γ* interference contribution is proportional to $(s - m_Z^2)$

➡ A_{FB} changes sign at the Z pole



Published sin2θW results





the open question is if @ LHC (HL-LHC) we can reach LEP precision

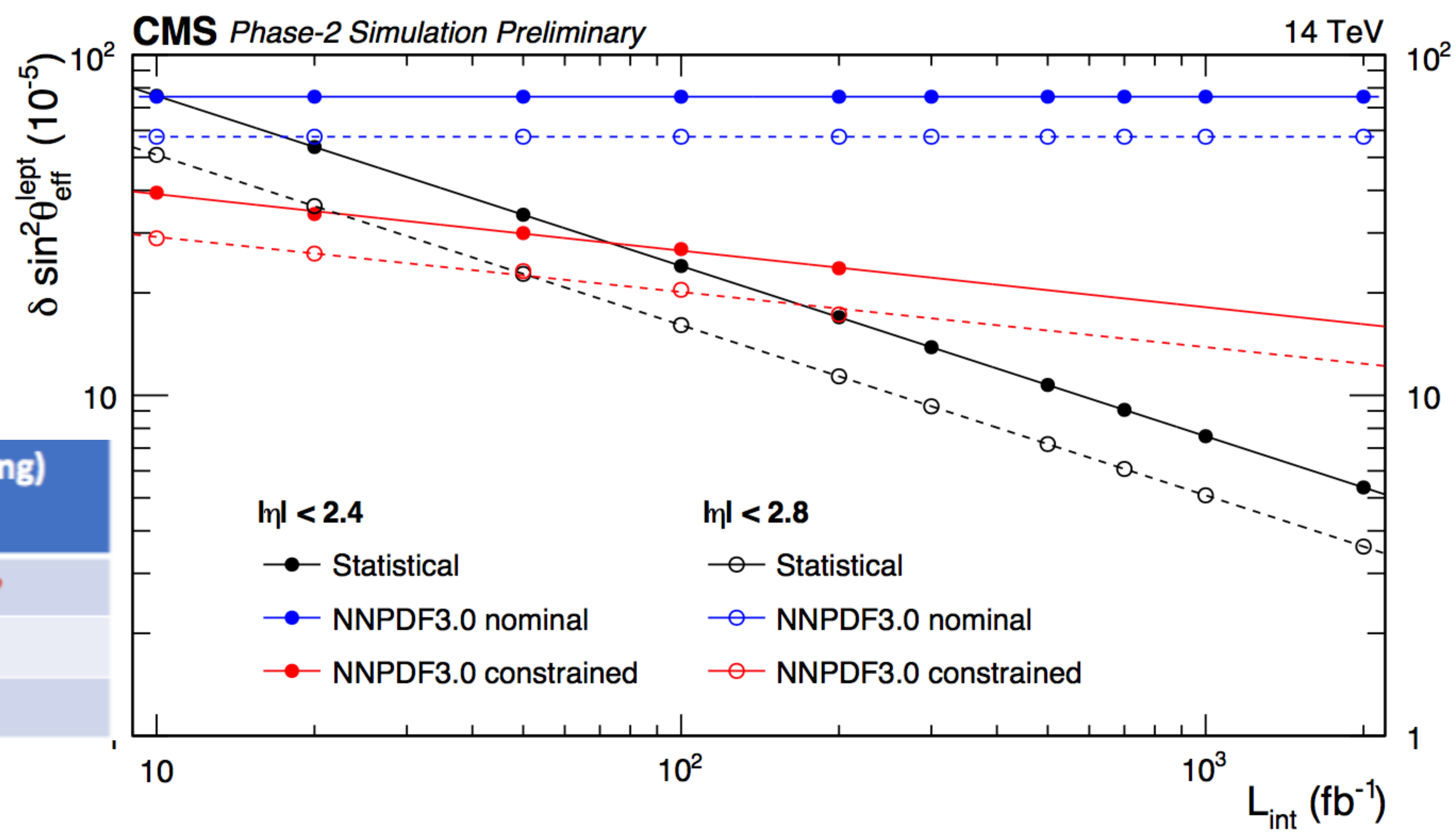
AFB ATLAS 2011 measurement:
Limited by PDF uncertainty

CMS/LHCb projections

https://indico.cern.ch/event/647676/contributions/2721144/attachments/1549078/2432924/jan_kieseler_SM.pdf
https://indico.cern.ch/event/647676/contributions/2759749/attachments/1549711/2434260/HLLHC2017Savin.pdf
https://indico.cern.ch/event/647676/contributions/2759751/attachments/1550102/2434846/CK_HLLHC_forwardEW.pdf

L_{int}	$\delta_{stat}[10^{-5}]$		$\delta^{nominal}_{nnpdf3.0}[10^{-5}]$		$\delta^{constrained}_{nnpdf3.0}[10^{-5}]$	
(fb^{-1})	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$	$\|\eta\| < 2.4$	$\|\eta\| < 2.8$
10	76	51	75	57	39	29
100	24	16	75	57	27	20
500	11	7	75	57	20	16
1000	8	5	75	57	18	14
3000	4	3	75	57	15	12
19	43		49		27	
19 (from [1])	44		54		32	

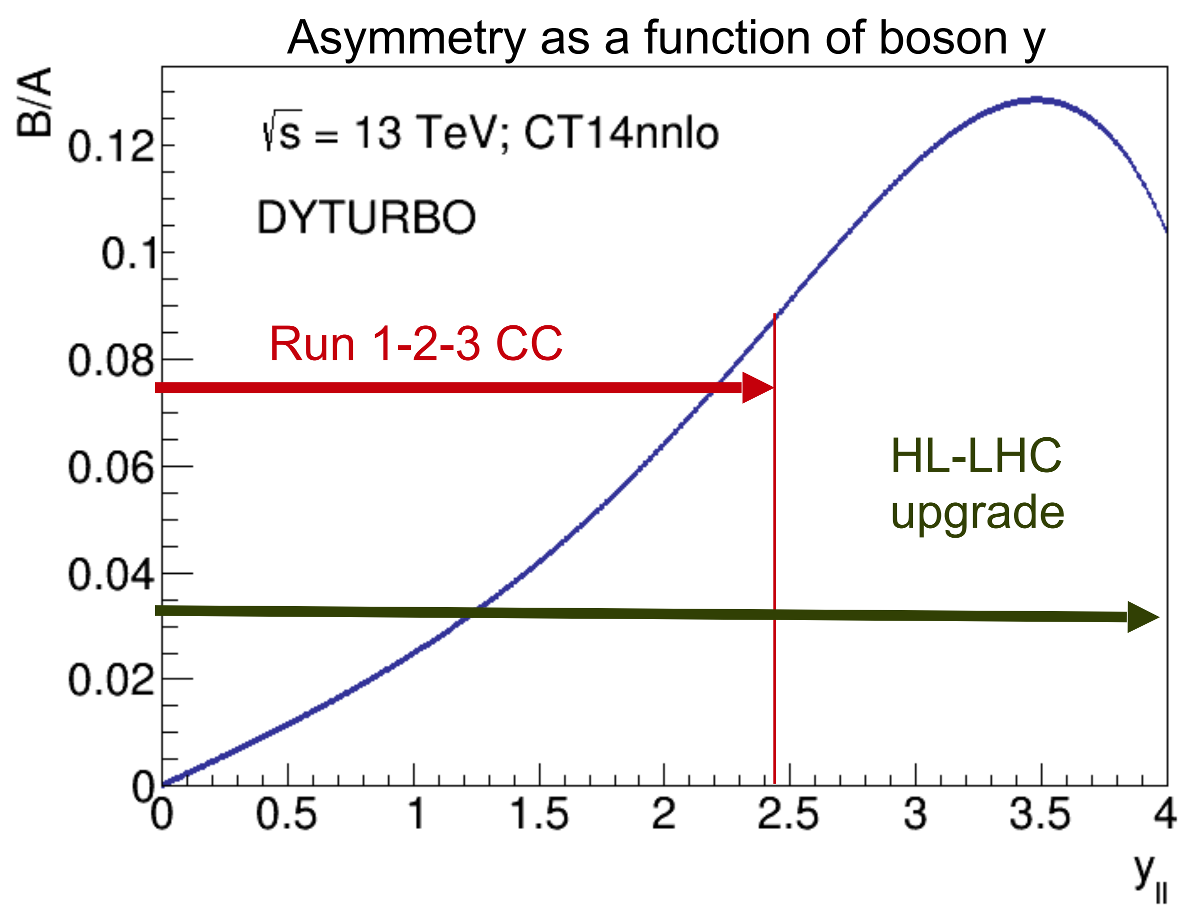
CMS-PAS-FTR-17-001



Period	Statistical Sensitivity (naïve scaling) $\sin^2\theta^{eff}_{lept}$ / 10^{-5}
End of Run 2	50
End of Run 3	20
300/fb	7

Naïve scaling
Naïve scaling

ATLAS coverage



- Similar sensitivity studies are ongoing in ATLAS
- different detector categories with further rapidly coverage
  - CC (|η| < 2.47)
  - CF (|η| < 2.47 & 2.47 < |η| < 4)
  - FF (2.47 < |η| < 4)

Comparable results as CMS and LHCb

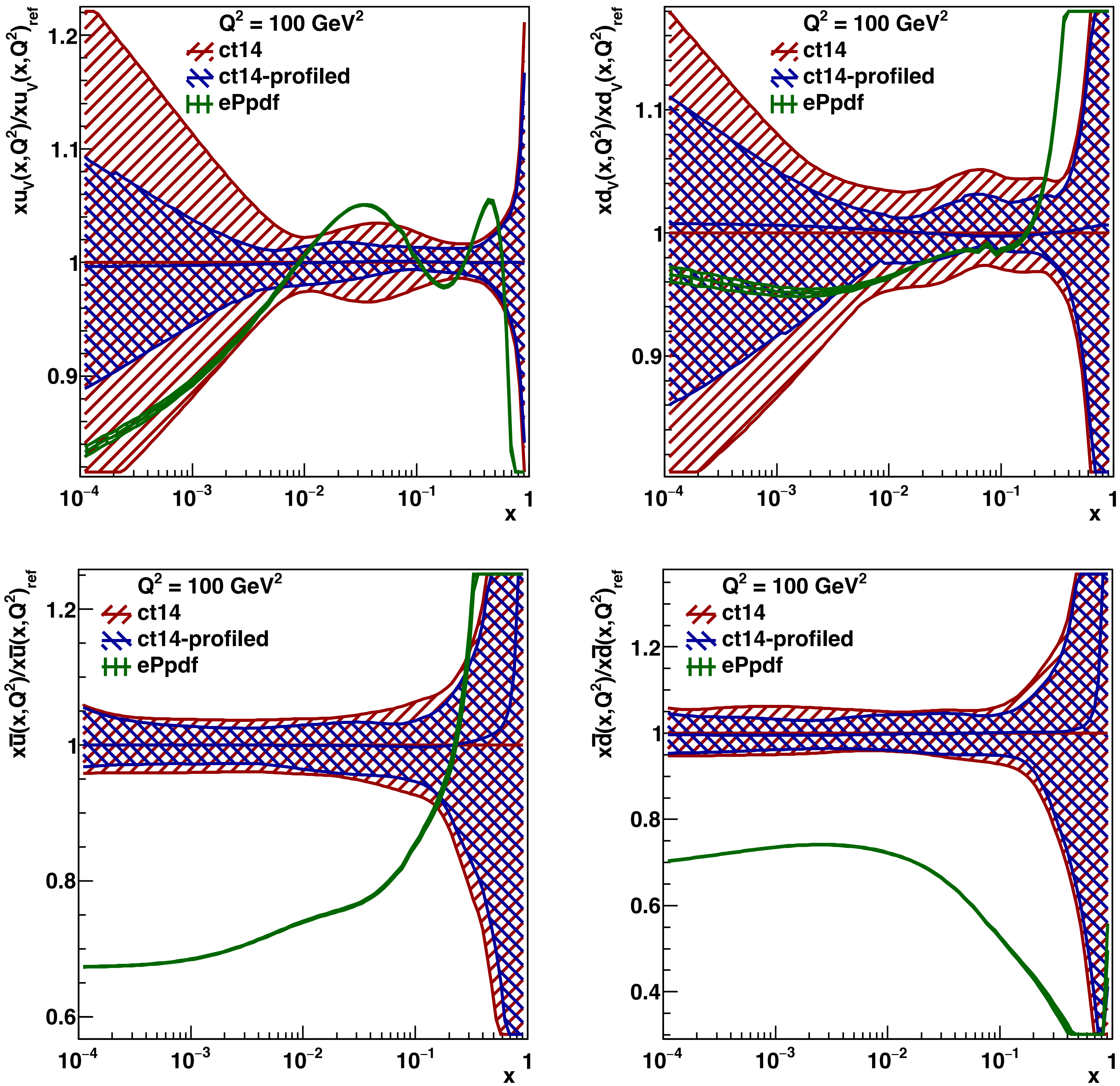
For ATLAS projection the CT14NNLO PDF are considered as baseline uncertainty are considered

In ATLAS we are also considering the LHeC prospect PDF set

Using LHeC PDFs a factor of 10 improvement for PDF error factor of 5 on the final measurement

LHeC PDF set

LHeC project ("TDR")
LHeC PDf Projection



- 0.1 to 0.5% uncertainties on valence and sea quarks
- r_S is fixed
- sea PDFs very suppressed wrt CT14
- No modelling uncertainties
- 12 parameters

Is all this OK for a realistic projection ?

Summary

- Prospects for reaching LEP+SLC accuracy on the measurement of $\sin^2\theta_W$ at HL-LHC
- The availability of LHeC PDF could dramatically change the picture, with a factor of 5 improvement over LEP+SLC accuracy
- In ATLAS we would like to include LHeC PDF in our prospect studies

- Are there any plans to provide an updated LHeC PDF set.

Period	LHCb Yield	Statistical Sensitivity (naïve scaling) $\sin^2 \theta_{lept}^{eff}$ / 10^{-5}
End of Run 2	700k	50
End of Run 3	7M	20
300/fb	40M	7

Naïve scaling Naïve scaling