Università degli Studi di Padova
Department of Physics and Astronomy

ICHEP 2022
XLI International Conference on High Energy Physics
July 6th -13th
Bologna

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on behalf of LHCb Collaboration

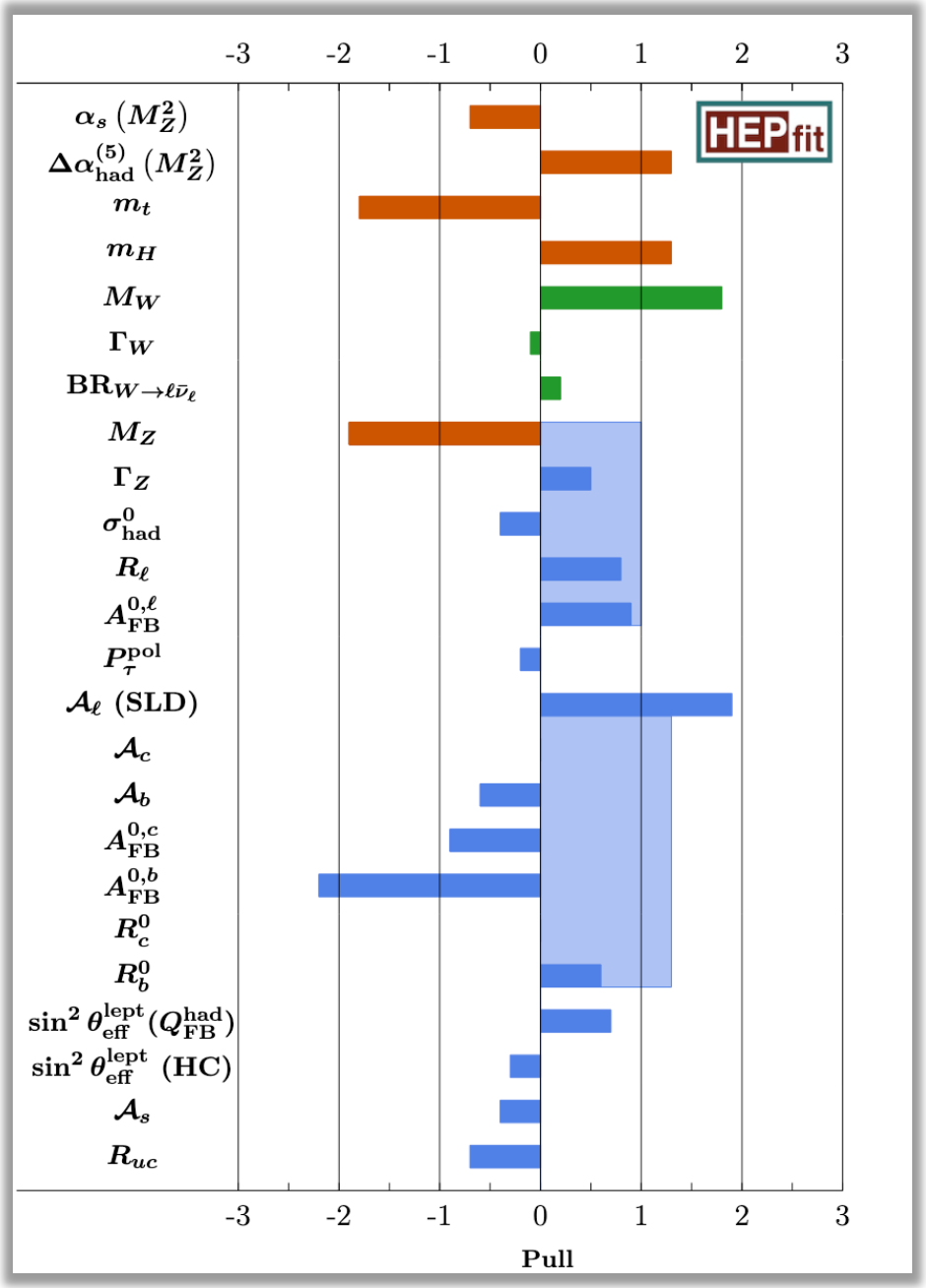
Electroweak Physics in the Forward Region

Electroweak Physics in the 2020s

Global analysis of electroweak data in the Standard Model December 2021
https://arxiv.org/pdf/2112.07274v1.pdf

- Current measurements of EW observables are consistent with the SM predictions.
- CDF W boson mass measurement needs dedicated discussion, see EWK session at 5:00pm
- Precision measurements of EKW observables allow to search for New Physics effects

Dedicated session today's afternoon



SM inputs

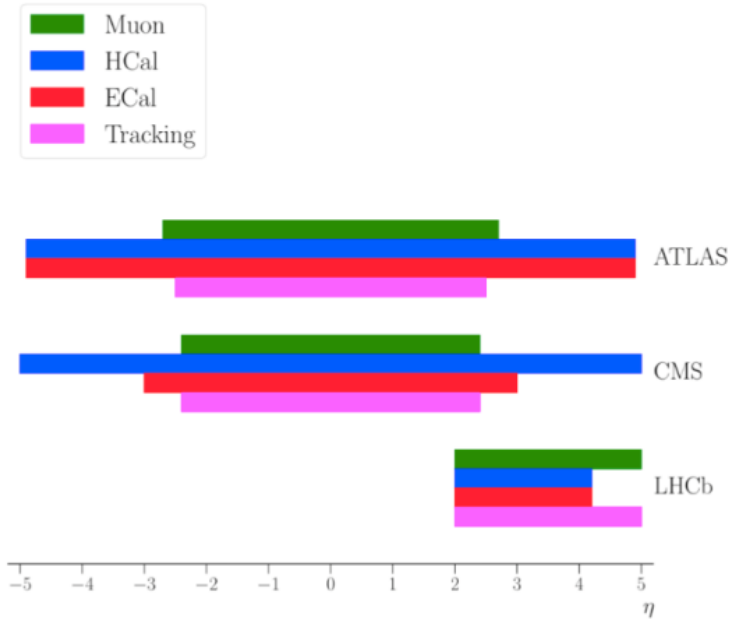
CC observables

NC observables

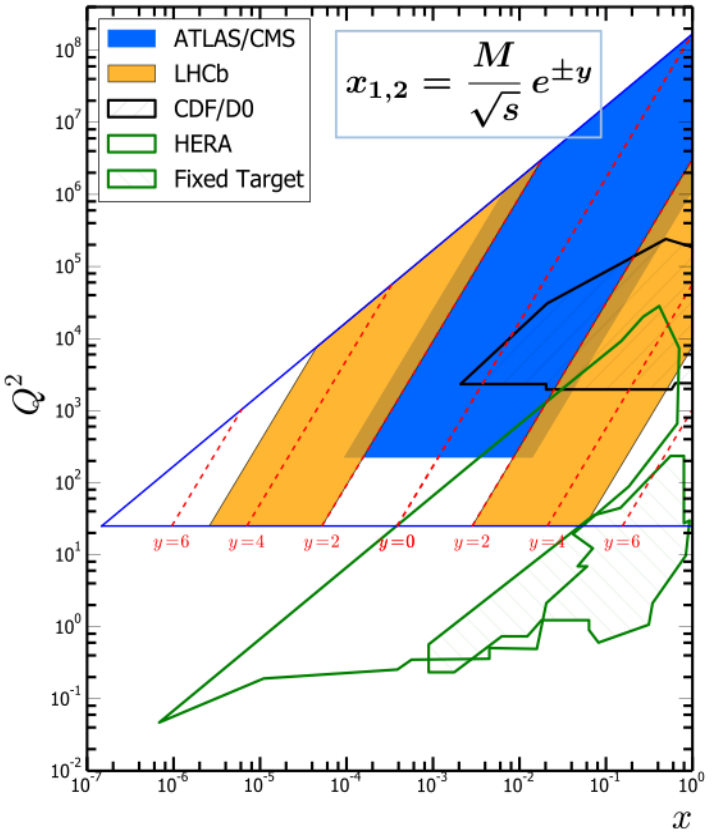
Electroweak Physics at LHCb

LCHb detector covers the forward region

Complementary to ATLAS and CMS



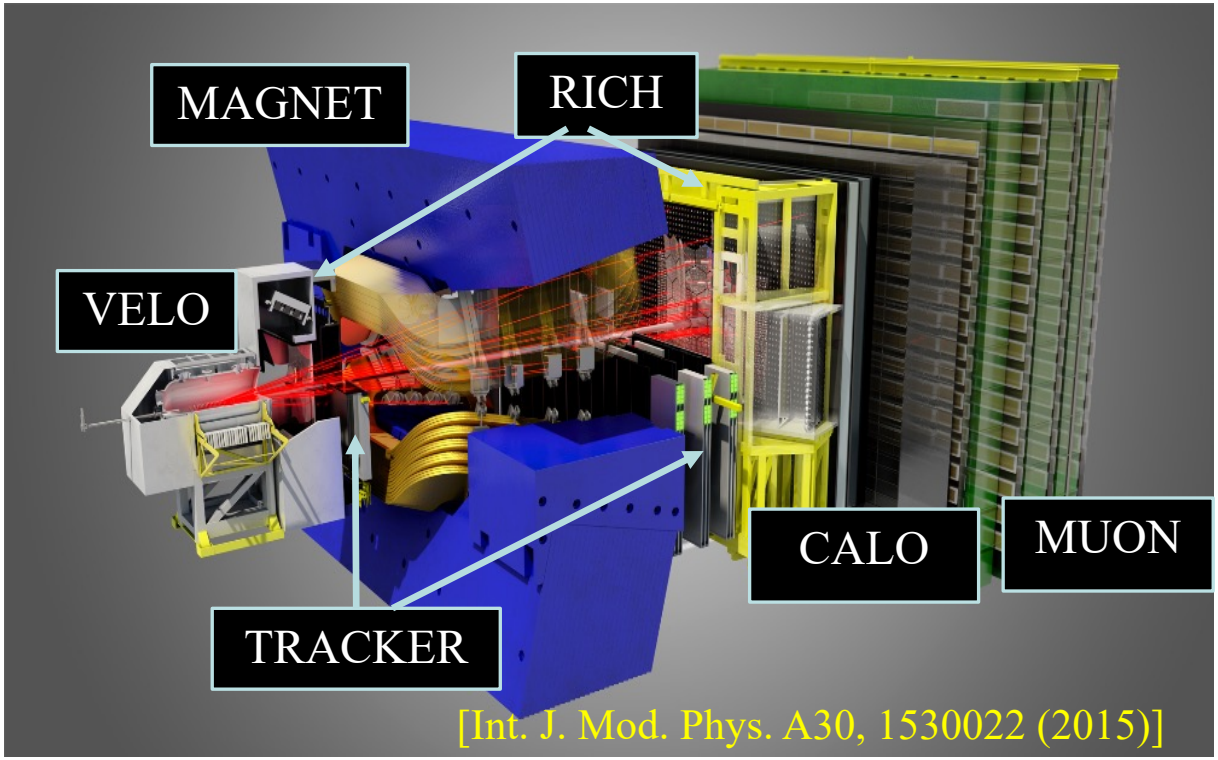
LHC 13 TeV kinematics



LHCb characteristics allow to perform unique observable measurements! At this conference:

- Dark Matter searches (Daniel Johnson)
- Jet fragmentation and QCD measurements (Naomi Cooke)
- Probing Parton Distribution Functions (Menglin Xu)
- W mass measurement (Miguel Ramos Pernas)

General Purpose Detector in the Forward Region



Excellent tracking:

- momentum resolution $\frac{\delta p}{p} \sim 0.5 - 1\%$ for tracks $(5 - 100\ \mathrm{GeV}/c)$
- efficiency > 96%
- IP resolution ~20μm for high p_T tracks

Well suited also for electroweak measurements:

- full rapidity coverage $2 \leq \eta \leq 4.5$ (ATLAS/CMS $|\eta| \leq 2.5$);
- low momentum triggers;
- low pile-up environment.

Disadvantages:

- low acceptance for high mass objects, low luminosity respect to ATLAS/CMS;
- no missing energy measurement.

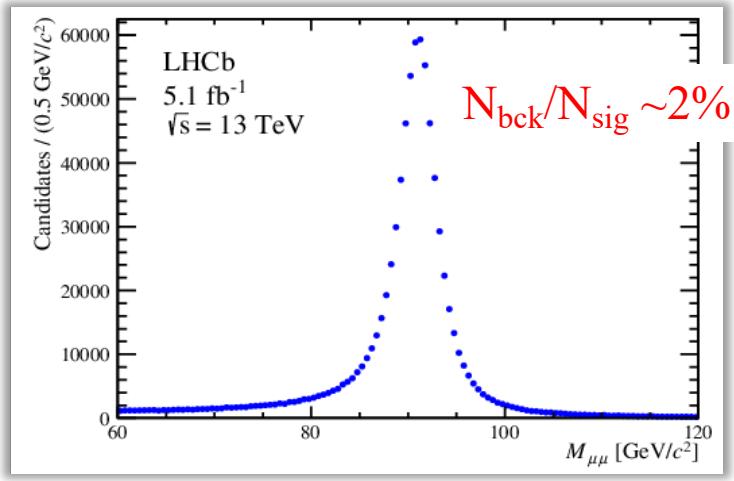
Z^0- boson Cross Section

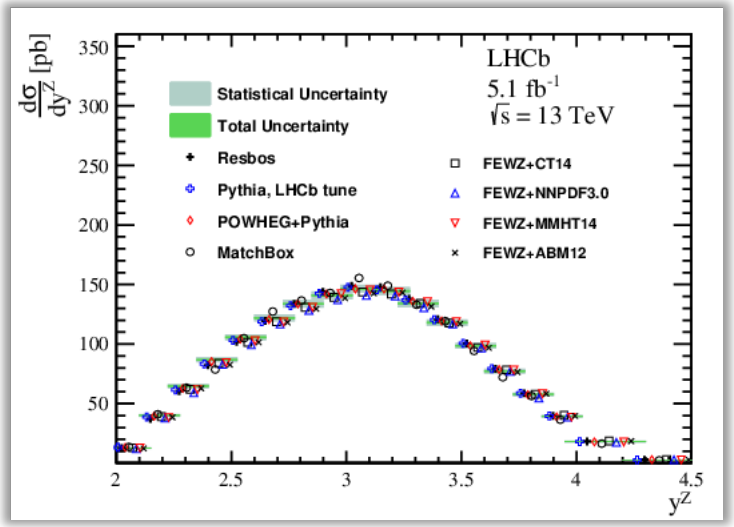
arXiv:2112.07458

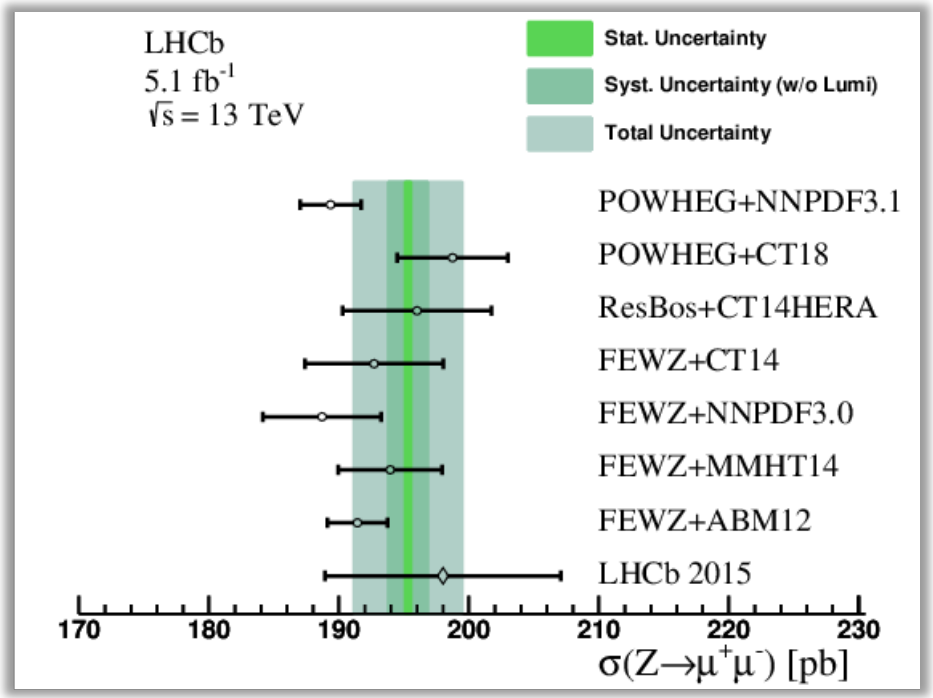
See *Probing Parton Distribution Functions (Menglin Xu)*

- Test NNLO QCD and used for constraining *u*- and *d*-quark parton distribution function.

- Data: 2016-2018 ⟶ 5.1 ± 0.1 fb^{-1}





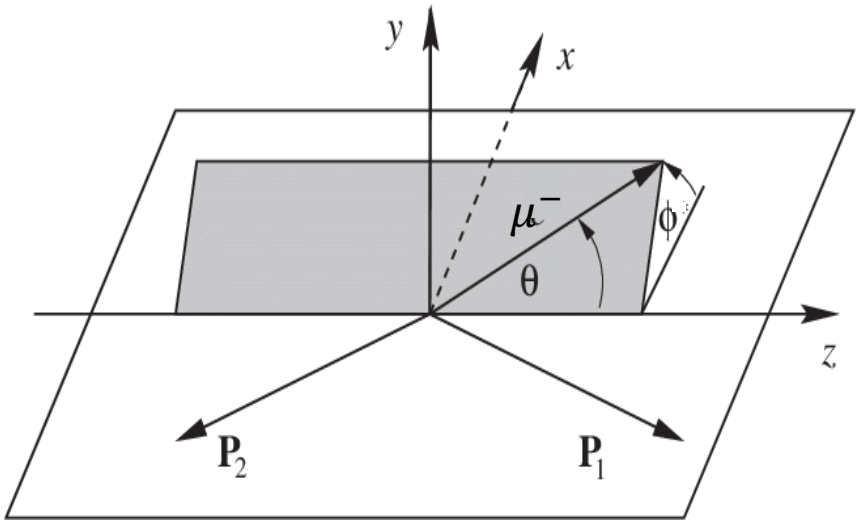


$$\sigma(Z \to \mu^+\mu^-) = 195.3 \pm 0.2(stat.) \pm 1.5(sys.) \pm 3.9(lumi.)\text{pb}$$

Most precise measurement in the forward region @√s=13 TeV

$Z^0 \to \mu^+\mu^-$ Angular Coefficients Measurements

Di-muon pairs near the Z^0-boson mass can
- ☆ Provide information on EWK parameters.
- ☆ Probe proton structure and test underlying strong-interaction dynamics as expected by QCD.



In the Collins-Soper frame

$$\frac{d\sigma}{d\cos\theta\, d\phi} \propto (1+\cos^2\theta) + \frac{1}{2}A_0(1-3\cos^2\theta) + A_1 \sin 2\theta \cos\phi + \frac{1}{2}A_2 \sin^2\theta \cos 2\phi + A_3 \sin\theta \cos\phi + A_4 \cos\theta + A_5 \sin^2\theta \sin 2\phi + A_6 \sin 2\theta \sin\phi + A_7 \sin\theta \sin\phi$$

→ LO term

$\neq 0$ at NLO
$A_0 = A_2$ Lam-Tung relation
$A_2 \to$ Boer-Mulders functions

→ LO term, *P violation*

→ $\neq 0$ at NNLO

Fixed to zero in this analysis

A_i Results in the Z^0-boson region

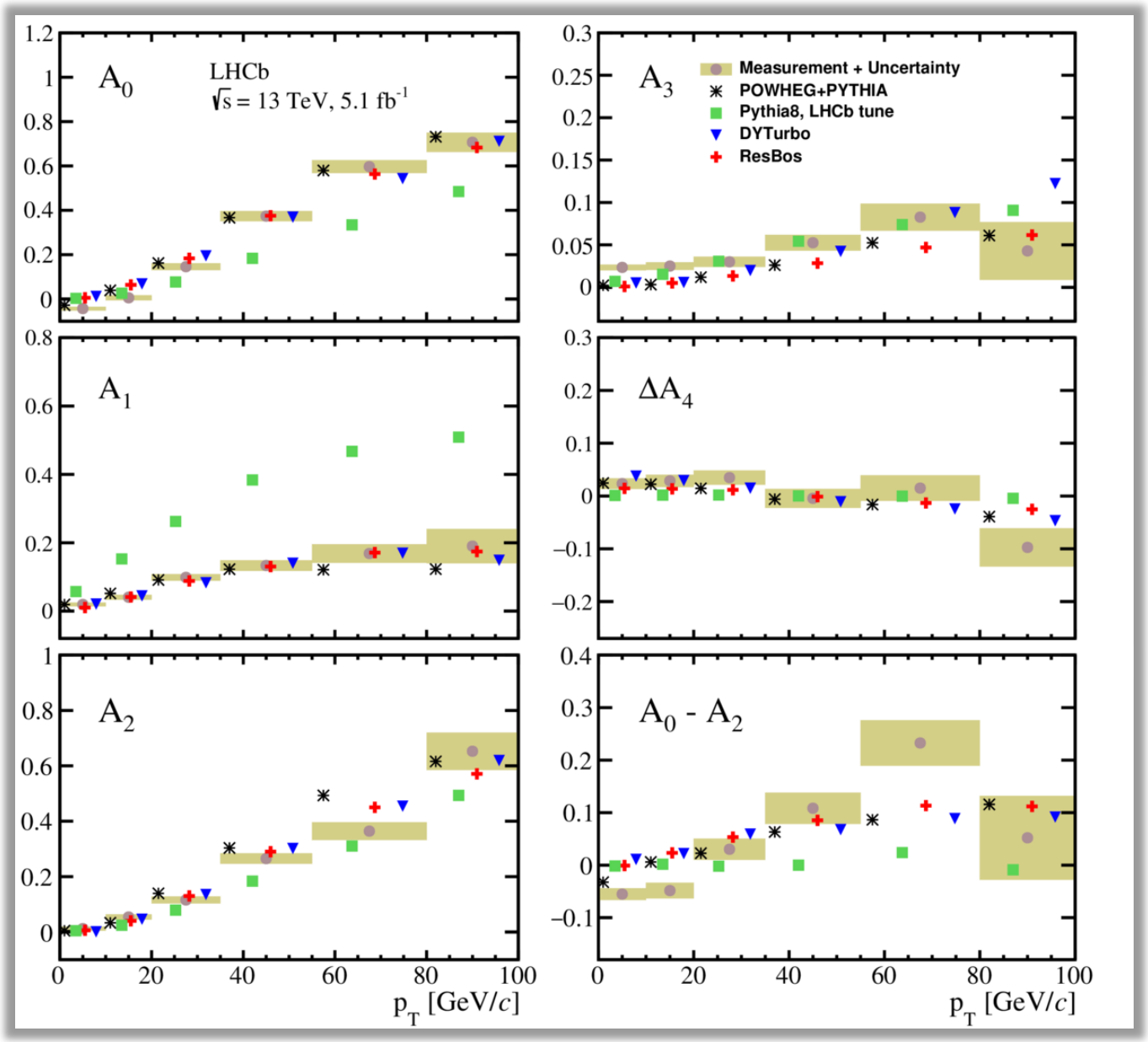
arXiv:2203.01602

First results of pp collisions at $\sqrt{s} = 13$ TeV:

- Data: 2016-2018 → 5.1fb^{-1}
- $y_Z > 2$
- $75 < M_{\mu\mu} < 105$ GeV/c^2

Total uncertainty dominated by the statistical component

- A_1 not in agreement with Pythia8.
- Lam-Tung relation, $A_0 = A_2$, violated consistently with CMS and ATLAS results.



A_4 – weak mixing angle

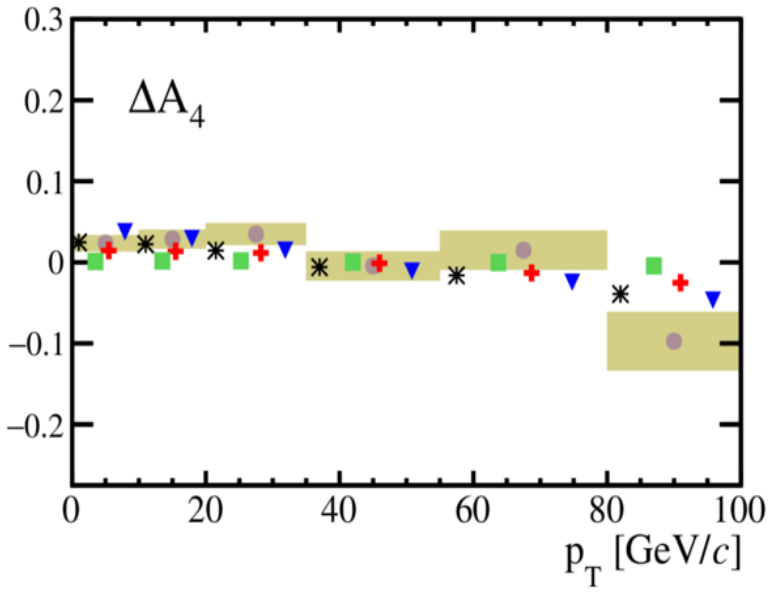
$A_4 \cos\theta$ parity violation term

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

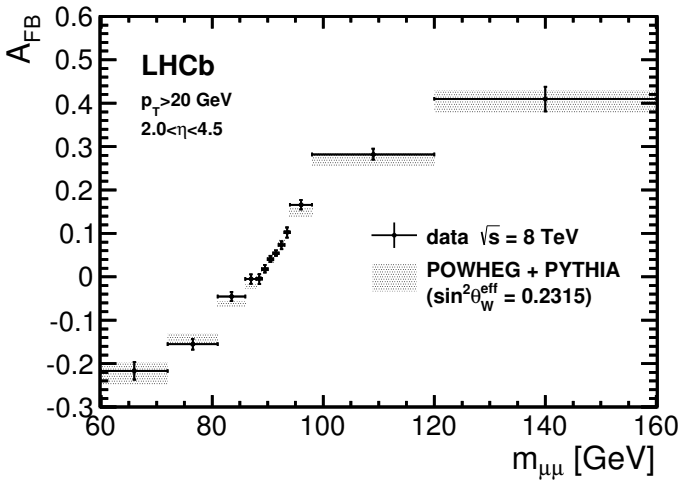
$\sigma_{F(B)}$: integrated cross section for $\cos\theta > 0$ ($\cos\theta < 0$) related to weak mixing angle, $\sin\theta_W$

$$A_{FB} = \frac{3}{8} A_4$$

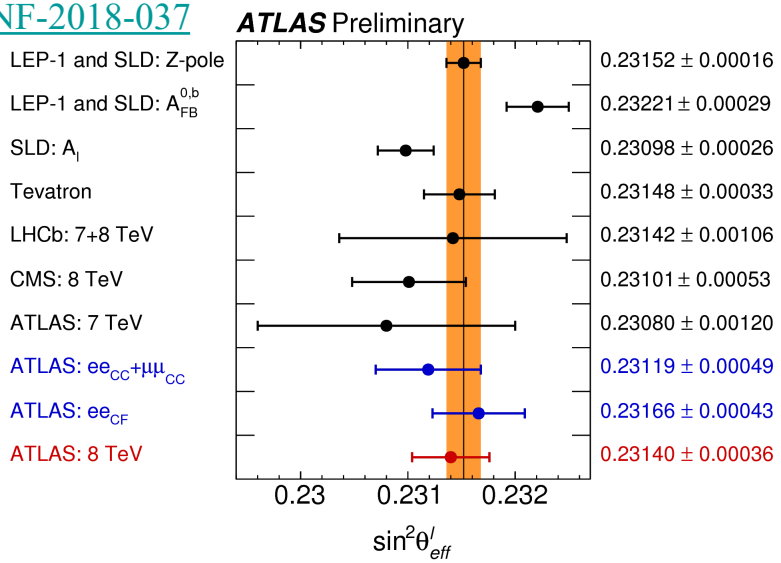
arXiv:2203.01602



JHEP 11 (2015) 190



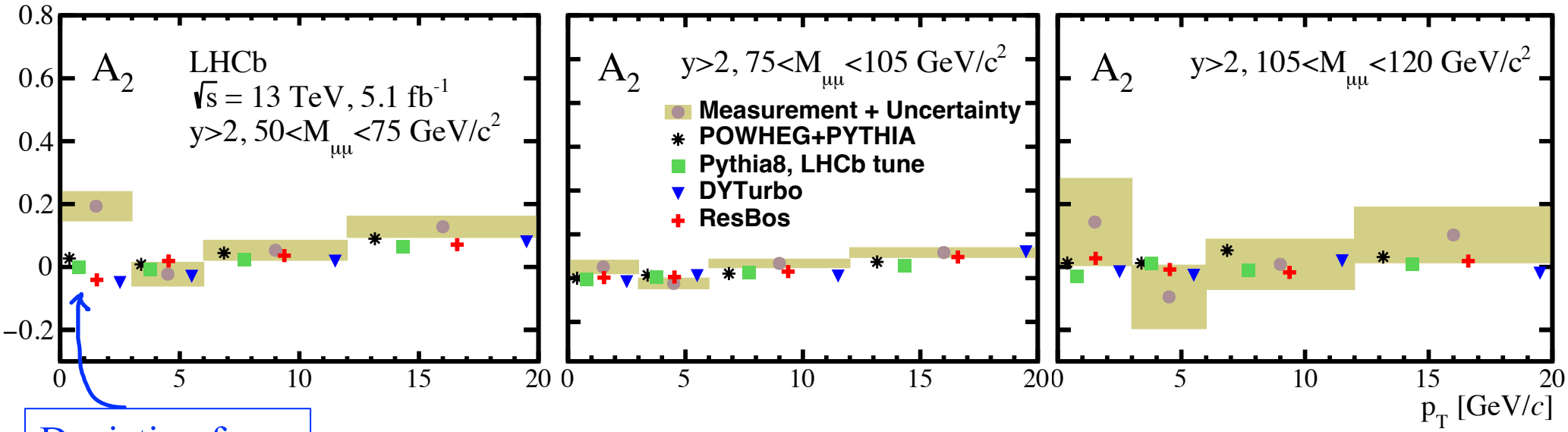
ATLAS-CONF-2018-037



Possibility to reach the SLD+LEP precision with HL-LHC [CERN-LHCC-2018-027]

A_2, Boer-Mulders function

- A_2 is sensitive to transverse momentum dependent (TMD) nucleon parton distribution functions, not experimentally tested yet.
- Boer-Mulders function is T-odd TMD function involves non-perturbative correlation between quark transverse momentum and transverse spin in an unpolarized nucleon.
- None of the predictions include non-perturbative spin-momentum correlations.



Deviation from predictions

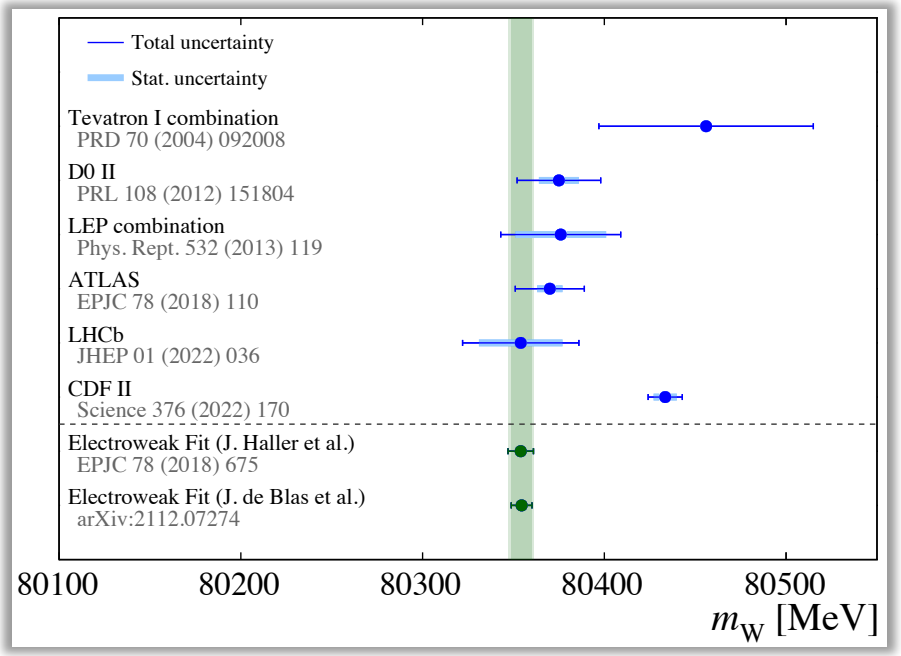
arXiv:2203.01602

Summary and Conclusions

The LHC high statistics data sample is giving the possibility to test electroweak physics sector with a precision that could compete with LEP and SLD. LHCb with its coverage and detector performance is one of the most important players.

The Run III data will allow LHCb to perform high precision measurement of fundamental parameters as $\sin\theta_W$ and m_W

LHCb-figure-2022-003



surprises may appear…