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Latest Heavy Flavour results from Tevatron

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Representing D0 and CDF collaborations

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Introduction

- Tevatron was closed about four years ago but the experiments (D0 and CDF) are still very active in producing physics results
- Heavy flavour (HF) results from Tevatron are currently dominated by D0, although CDF also obtained several interesting results
- There are some advantages of the Tevatron data sample especially important for the HF studies
  - CP-symmetric initial state ($p\bar{p}$ collision)
  - Regular reversal of magnet polarities (for D0 experiment)
  - Low pile-up
- Many of the new results are related to the measurement of the charge asymmetry of the final states

In this talk

- B^+B^- forward-backward asymmetry (D0)
- $b\bar{b}$ forward-backward asymmetry (CDF)
- $\Lambda_b\bar{\Lambda}_b$ forward-backward asymmetry (D0)
- $\Lambda\bar{\Lambda}$ forward-backward asymmetry (D0)
- Test of CPT symmetry (D0)
- $X(4140)$ production (D0)

B^+B^- FB asymmetry (D0)

- FB asymmetry of b-quark production

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

  - Forward direction for b quark (B^- meson) is the same as the direction of the incoming proton
  - Forward direction for $\bar{b}$ quark (B^+ meson) is the same as the direction of the incoming $\bar{p}$
  - The measurement is performed using a cleanly reconstructed $B^{\pm} \rightarrow J/\psi\, K^{\pm}$ decay
- Studying this asymmetry can help to understand the $t\bar{t}$ forward-backward asymmetry
- Good test of the SM

B^+B^- FB asymmetry (D0)

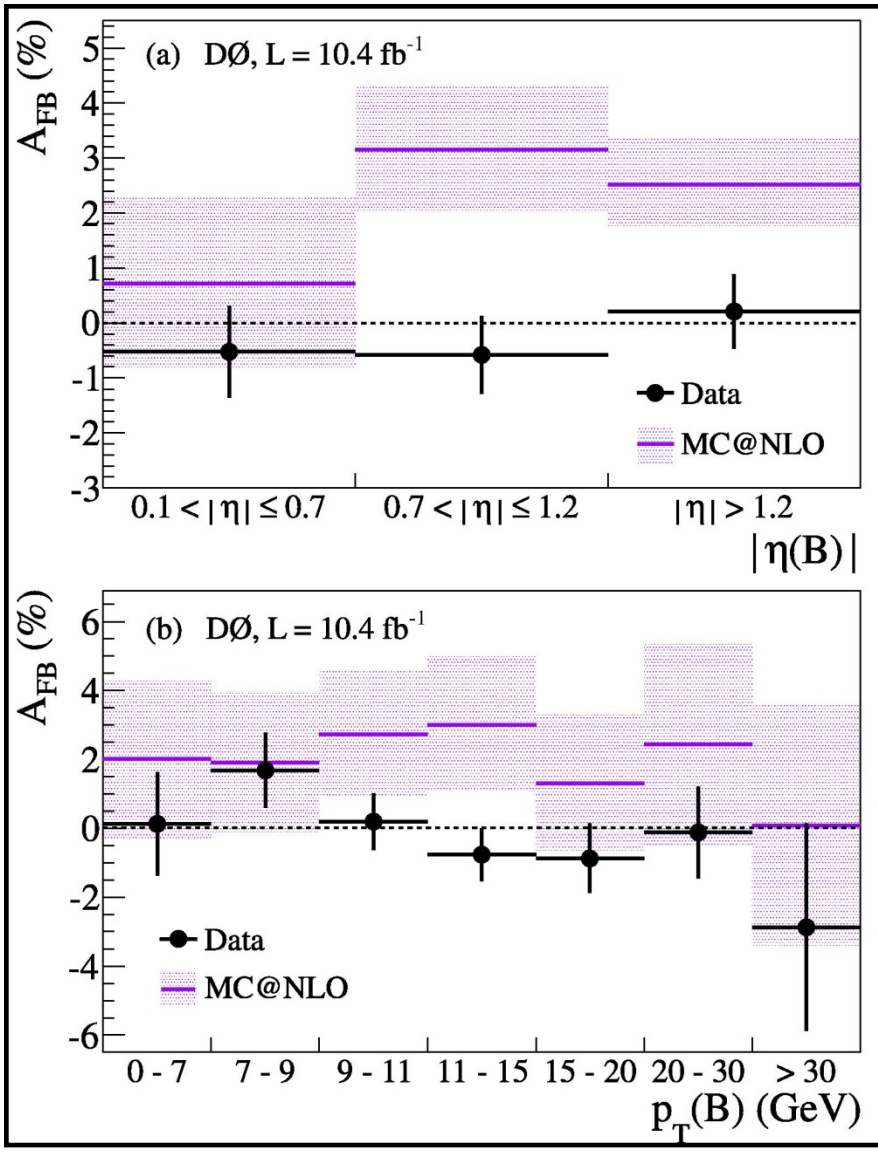
- D0 does not observe any significant FB asymmetry

$$A_{FB}(\text{D0}) = [-0.24 \pm 0.42 \pm 0.19]\%$$

– Result is published in PRL 114, 051803(2015)

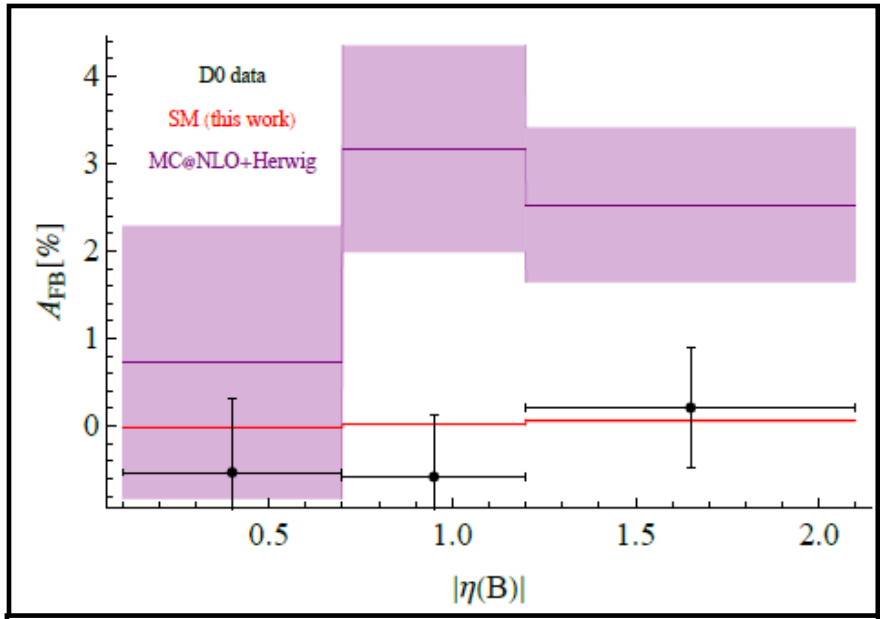
- D0 result differs by 3.5 σ from the SM prediction (MC@NLO)

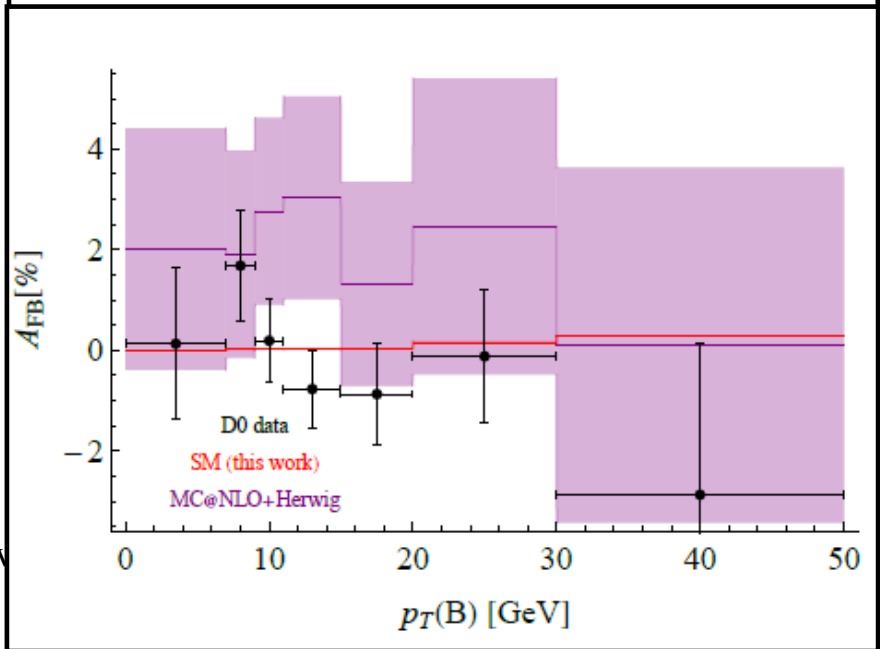
$$A_{FB}(\text{SM}) = [+2.31 \pm 0.34 \pm 0.44]\%$$



Comparison with SM

- Improved calculations (C. W.Murphy, arXiv: 1504.02493) restore the agreement with the SM





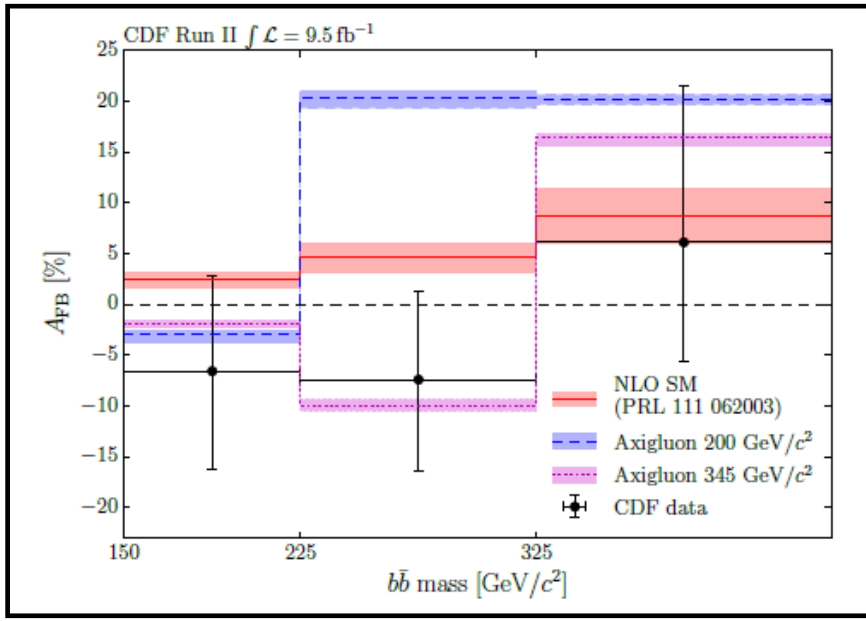
$b\bar{b}$ F-B asymmetry (CDF)

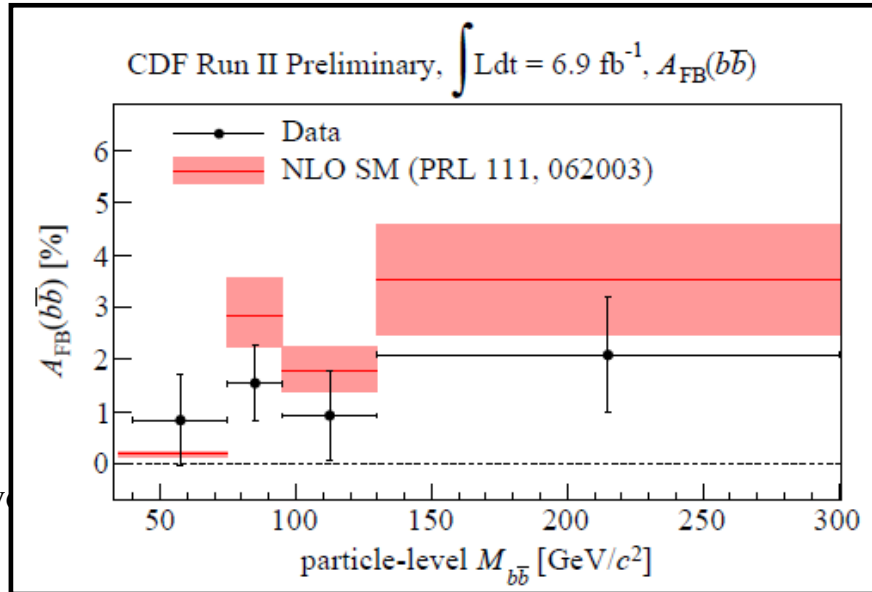
- CDF measures jet charge (high mass analysis) or muon charge (low mass analysis) of two b jets and determine the F-B asymmetry defined as:

$$A_{FB} = \frac{n(\Delta y > 0) - n(\Delta y < 0)}{n(\Delta y > 0) + n(\Delta y < 0)}$$

$$\Delta y = y(b) - y(\bar{b})$$

- Obtained result are consistent with the SM prediction
  - Phys. Rev. D 92, 032006 (2015)
  - CDF note 11156





$\Lambda_b\overline{\Lambda}_b$ F-B asymmetry (D0)

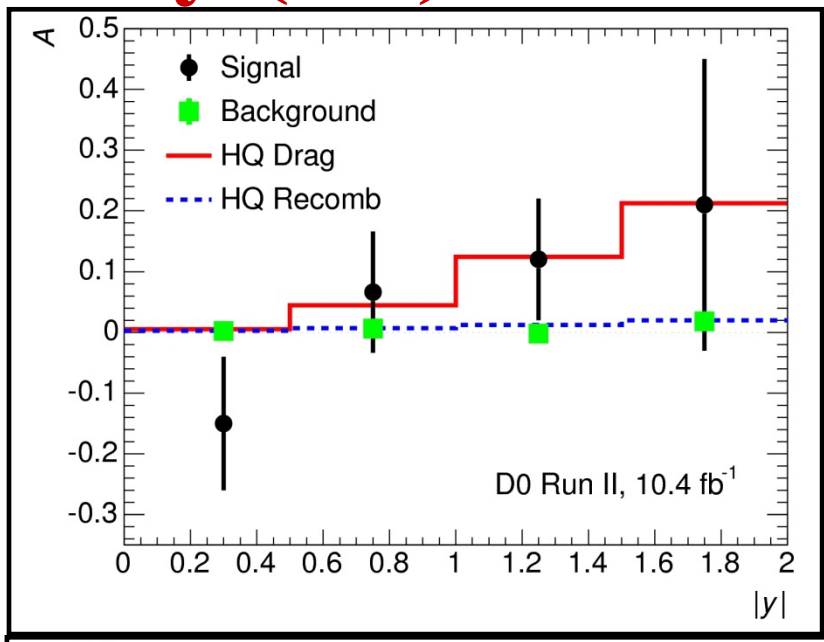
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$

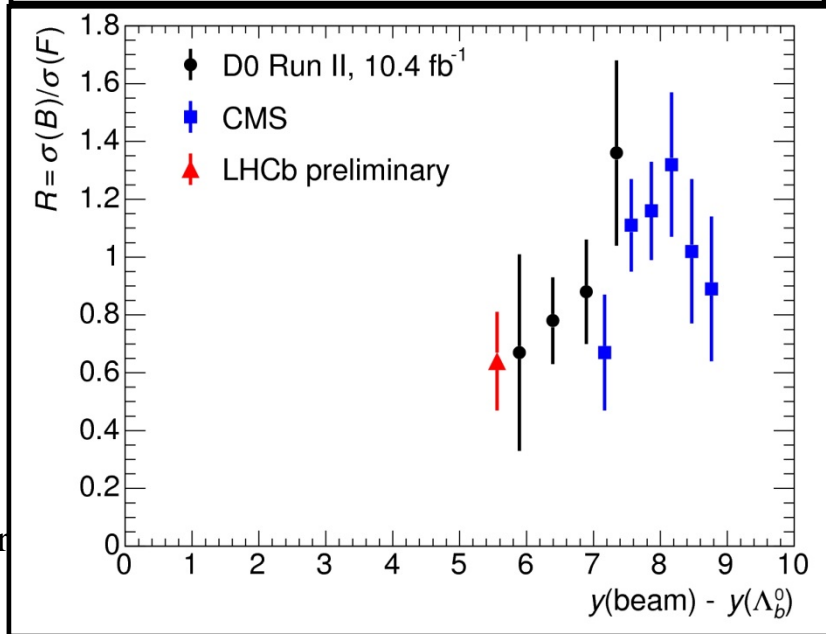
- Forward direction of Λ_b – proton beam
- Forward direction of $\overline{\Lambda}_b$ – anti-proton beam

- Result (Phys.Rev. D91, 072008 (2015))

$$A_{\mathrm{FB}}(\Lambda_b) = 0.04 \pm 0.07 \pm 0.02$$

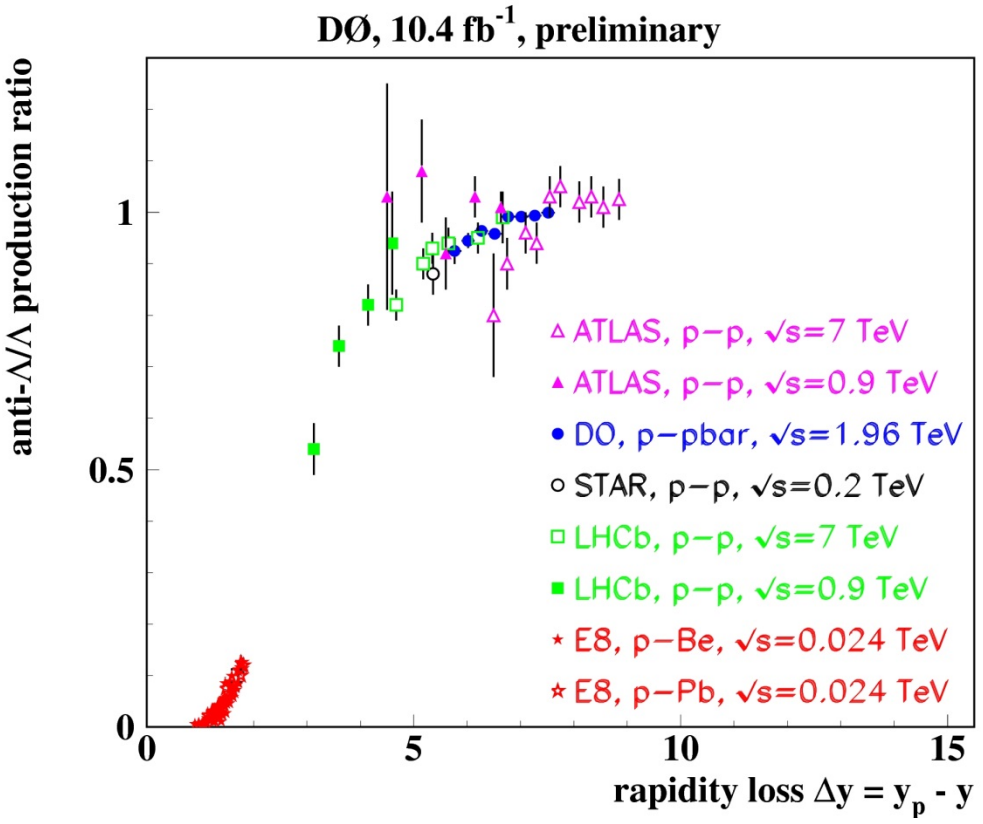
- Consistent with zero
- Consistent with theoretical models (J. Rosner, Phys. Rev. D 90, 014023 (2014))
- Consistent with the measurements at LHC





$\Lambda\bar{\Lambda}$ F-B asymmetry (D0)

- Preliminary result obtained
  - D0 note 6464-CONF
  - Results are consistent with the measurements at different energies and



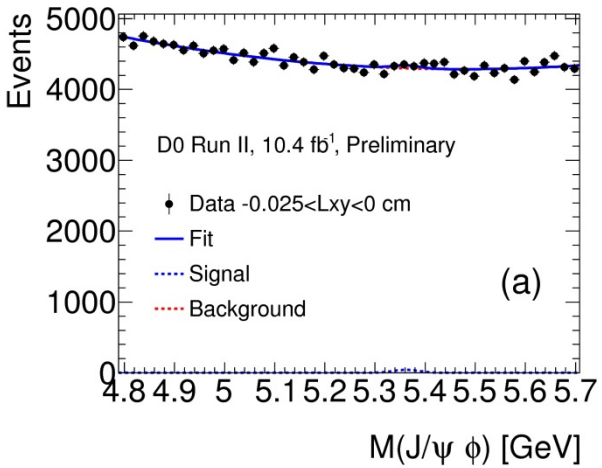
$X(4140)$

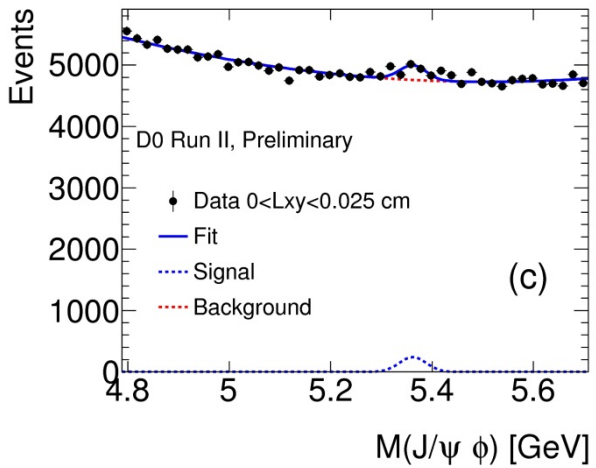
- $X(4140)$ is an unidentified object decaying to $X(4140) \rightarrow J/\psi\ \varphi$
- First observed by CDF in $B^+ \rightarrow J/\psi\ \varphi\ K^+$ decay
- LHCb did not confirm it (Phys Rev. D 85, 091103 (2012)
- Later confirmed by CMS (Phys.Lett. B 734, 261 (2014) and D0 (Phys. Rev. D 89, 012004 (2014)
- Observed only in B^+ decay so far
- New analysis of D0 studies the inclusive production of this object
- Measure its production as a function of its decay length
  - To disentangle the prompt and secondary (from B-hadron decays) components in the $X(4140)$ production
  - Normalize to the production of $B_s \rightarrow J/\psi\ \varphi$

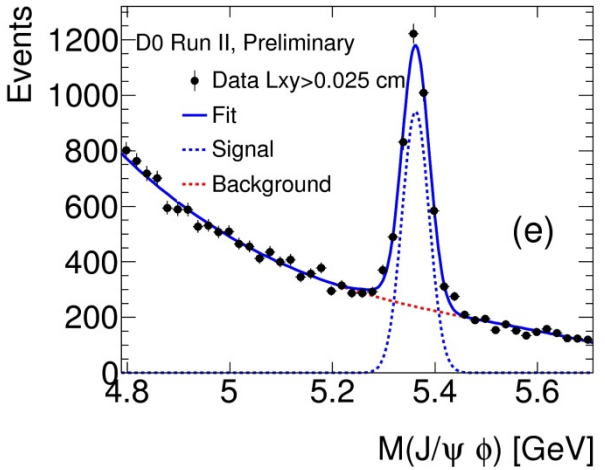
X(4140) production

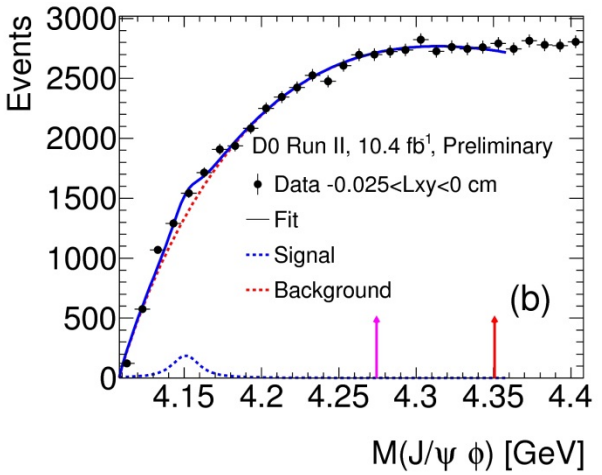
- *X*(4140) is clearly seen even at small proper decay length where the B-hadron contribution is small

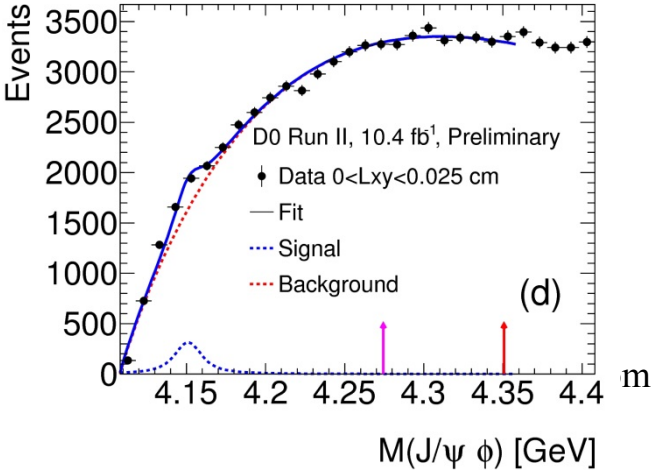
-0.025<L_{xy}<0 cm | **0<L_{xy}<0.025 cm** | **L_{xy}> 0.025 cm**

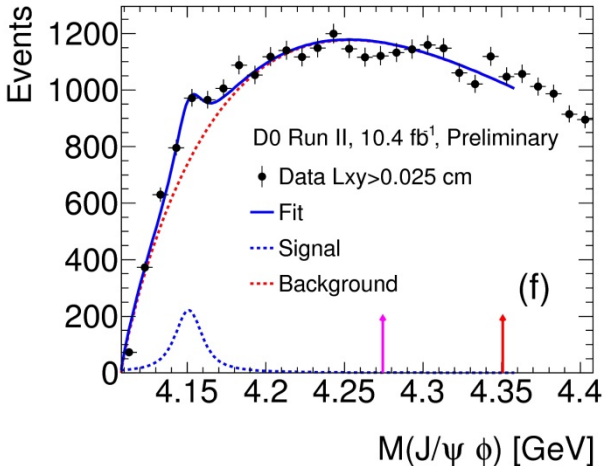












Results

- arXiv: 1508.07846, submitted to PRL
- New measurement of mass and width of $X(4140)$
- Fraction of $X(4140)$ originating from B hadrons is

$$f_b = 0.39 \pm 0.07 \pm 0.10$$

- Significance of prompt production is 4.7σ

TABLE III: Summary of $X(4140)$ measurements

Experiment	Process	Mass (MeV)	Width (MeV)
CDF [2]	$B^+ \to J/\psi\phi K^+$	$4143.0 \pm 2.9 \pm 1.2$	$11.7^{+8.3}_{-5.0} \pm 3.7$
CMS [4]	$B^+ \to J/\psi\phi K^+$	$4148.0 \pm 2.4 \pm 6.3$	$28^{+15}_{-11} \pm 19$
D0 [5]	$B^+ \to J/\psi\phi K^+$	$4159.0 \pm 4.3 \pm 6.6$	$19.9 \pm 12.6^{+3.0}_{-8.0}$
D0 (this work)	$\bar{p}p \to J/\psi\phi + \text{anything}$	$4152.5 \pm 1.7^{+4.7}_{-3.6}$	$16.3 \pm 5.6 \pm 10.3$

Test of CPT invariance

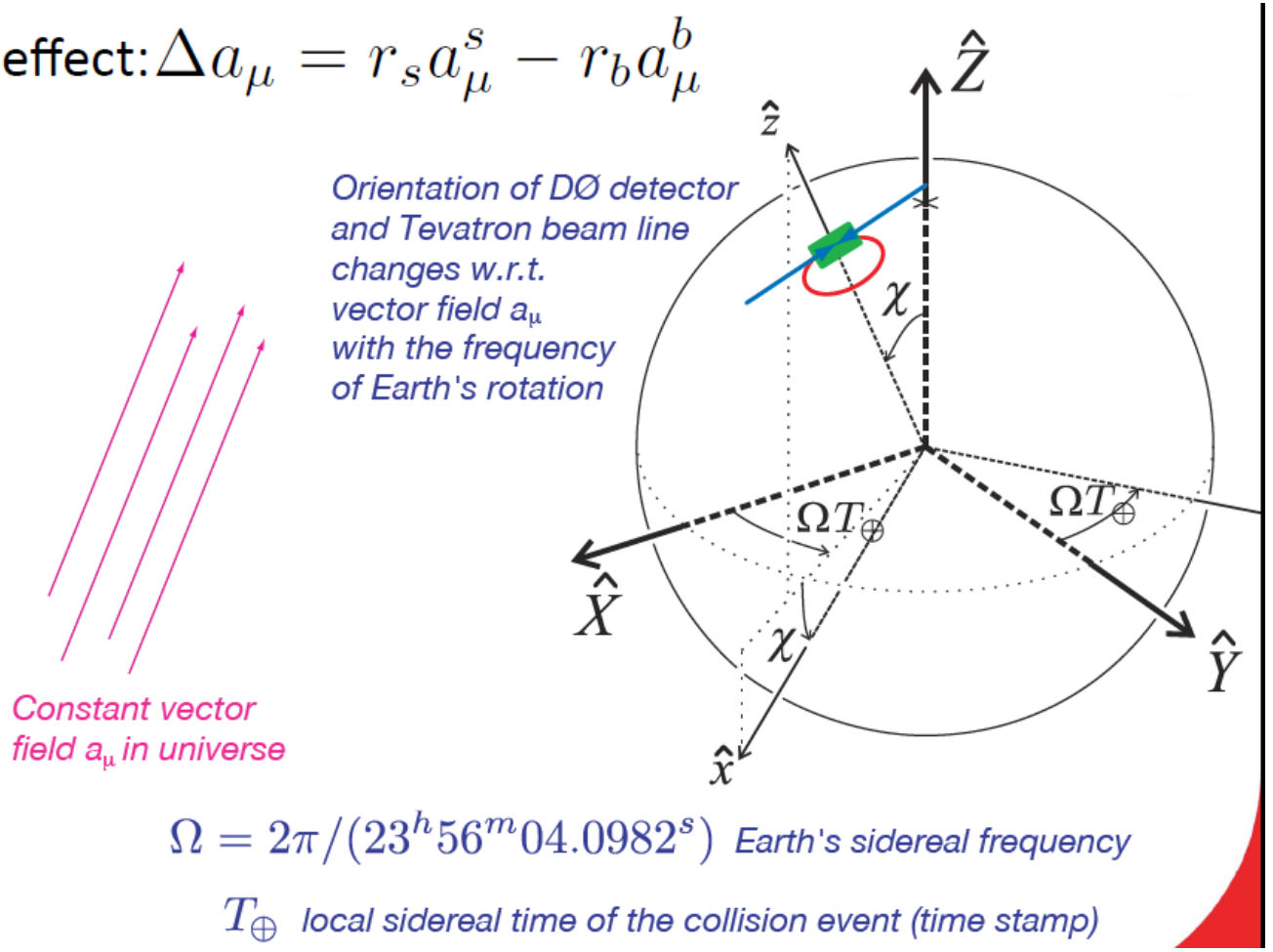
- The oscillation of the B_s system may depend on the CPT-violating parameter ξ_s:

$$|B_{sL}\rangle \propto p\sqrt{1-\xi_s}|B_s^0\rangle + q\sqrt{1+\xi_s}|\bar{B}_s^0\rangle,$$
$$|B_{sH}\rangle \propto p\sqrt{1+\xi_s}|B_s^0\rangle - q\sqrt{1-\xi_s}|\bar{B}_s^0\rangle.$$

  - Its non-zero value means CPT violation
- CPT violation means the violation of the Lorentz invariance
- Thus, one consequence of the CPT violation would be the dependence of the charge asymmetry of the semileptonic B_s decay on the sidereal time (meaning violation of the Lorentz invariance)
  - Sidereal time – time scale that is based on the Earth's rate of rotation measured relative to the fixed stars rather than the Sun

Test of CPT invariance

- Size of effect: $\Delta a_\mu = r_s a_\mu^s - r_b a_\mu^b$



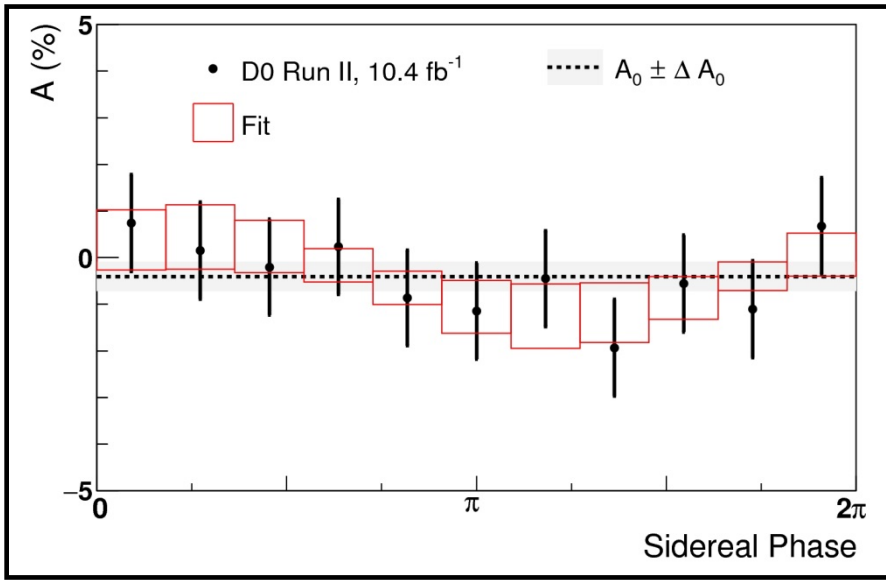
- Taken from: I. Bertram, talk at EPS-2015

Test of CPT invariance

- B_s semileptonic charge asymmetry is measured as a function of the sidereal phase using the $B_s \to D_s \mu \nu$ decay
- The result is expressed in the form of the constraint on the Lorentz-violating four-vector field Δa_β

$$\Delta a_\perp < 1.2 \times 10^{-12} \text{ GeV}$$
$$\left(-0.8 < \Delta a_T - 0.396\, \Delta a_Z < 3.9\right) \times 10^{-13} \text{ GeV}$$

  - Submitted to PRL; arXiv: 1506.04123
  - Δa_T is the time component of Δa_β
- No CPT violation observed
- The first such limit for the B_s system
  - Need the value $\Delta a_T - 0.396 \Delta a_Z \approx 3.7 \times 10^{-12}$ GeV to explain the dimuon asymmetry of D0 experiment (V. Kostelecky and R. van Kooten, Phys. Rev. D82, 101702 (2010)



Conclusions

- Tevatron experiments still produce the new results in heavy flavour physics which are complementary to the LHC measurements
- Several tests of FB production asymmetry are performed
- New observation of $X(4140)$
- The first limit on CPT violation in B_s system