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Production and Properties of Heavy Flavour at CDF

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On behalf of the CDF collaboration

ICHEP 2012, Melbourne

Heavy Flavour Production and Decays

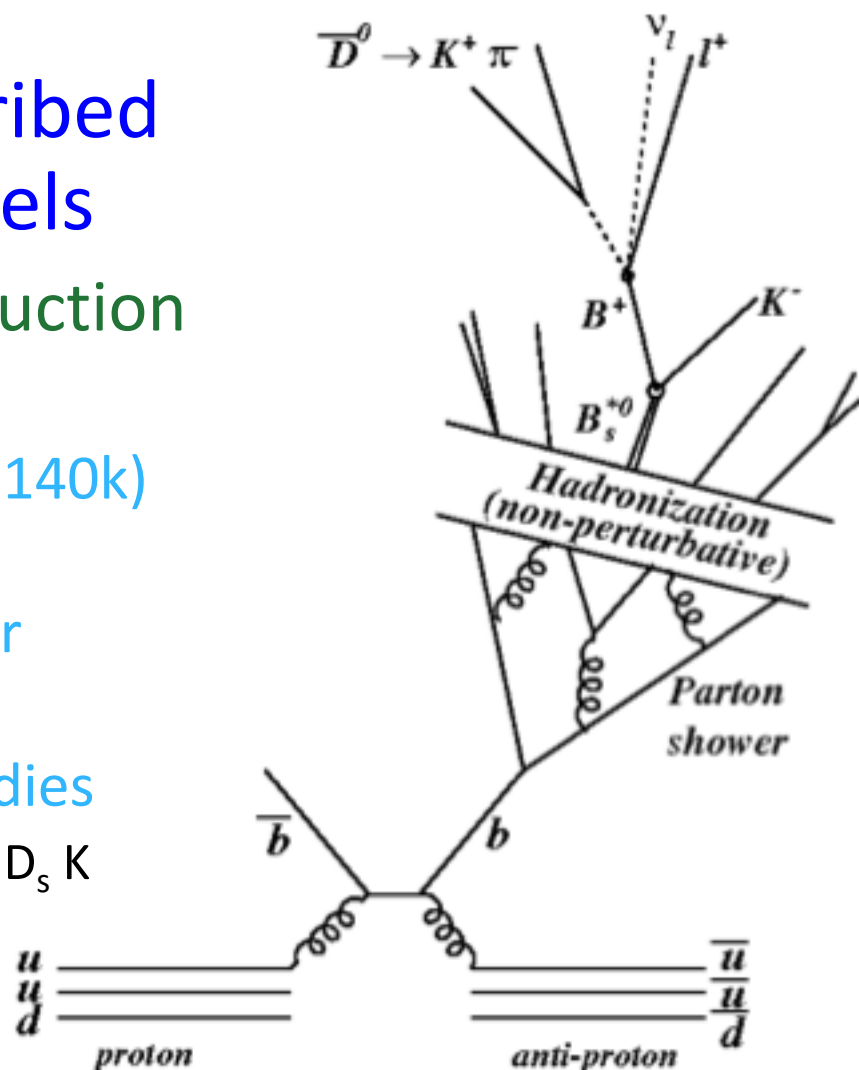
- Fragmentation
 - Kaons in association with D mesons
- Upsilon decay
 - Spin alignment
- B_c Lifetime
 - Fully reconstructed decay

Fragmentation

CDF Public Note 10704

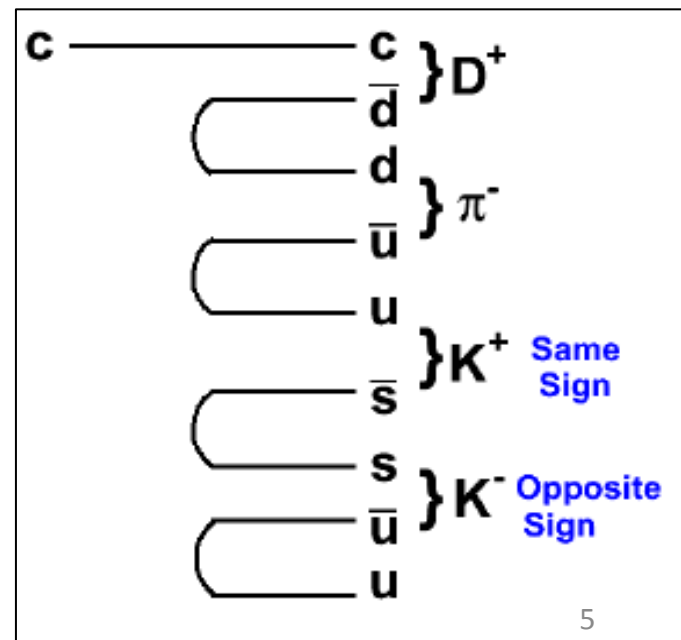
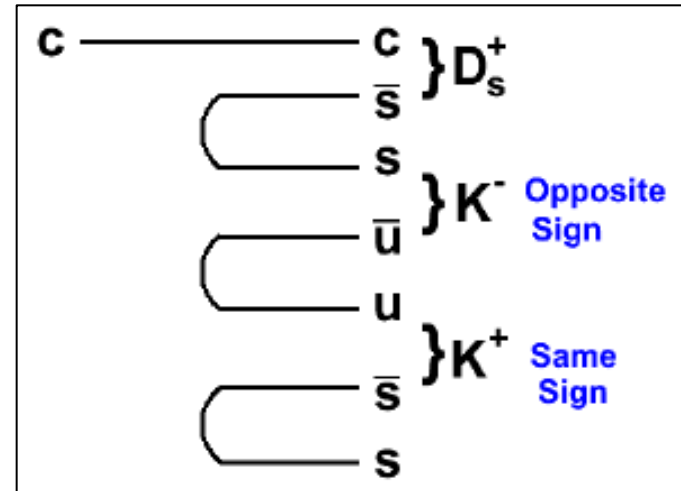
Fragmentation

- Quark fragmentation described by phenomenological models
 - Study charged particle production around heavy quarks
 - Kaons near D_s (260k) and D^+ (140k) both decaying to $\phi\pi$
 - B_s flavour tagging used similar techniques
 - D used for fragmentation studies
 - No known resonance decay to $D_s K$
 - Charged D 's do not mix
 - Select prompt D 's to minimise contamination from B 's



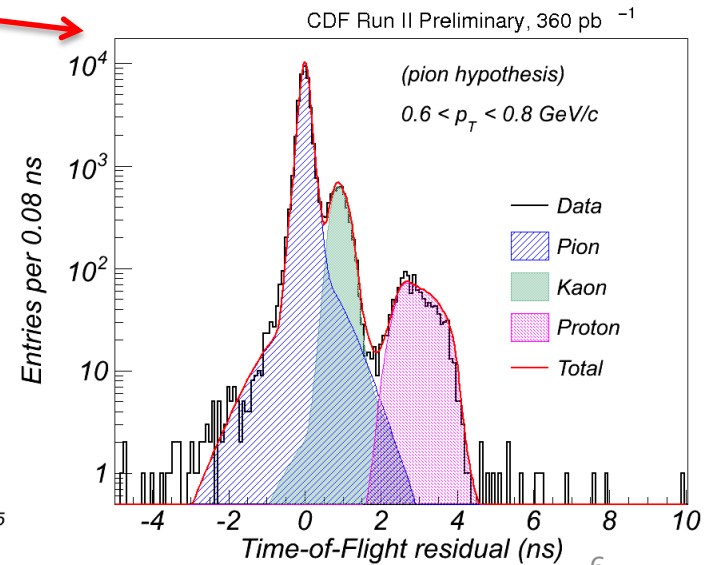
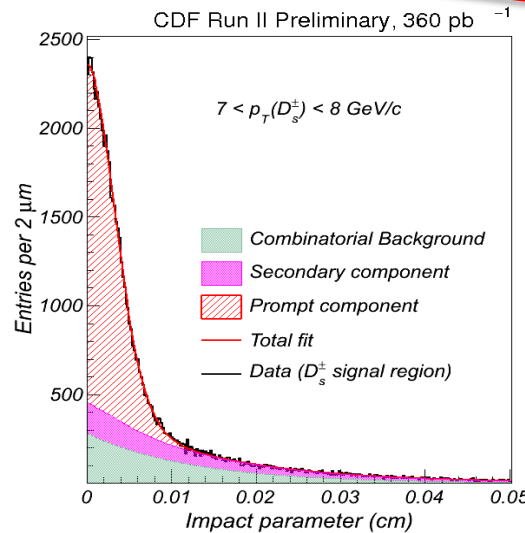
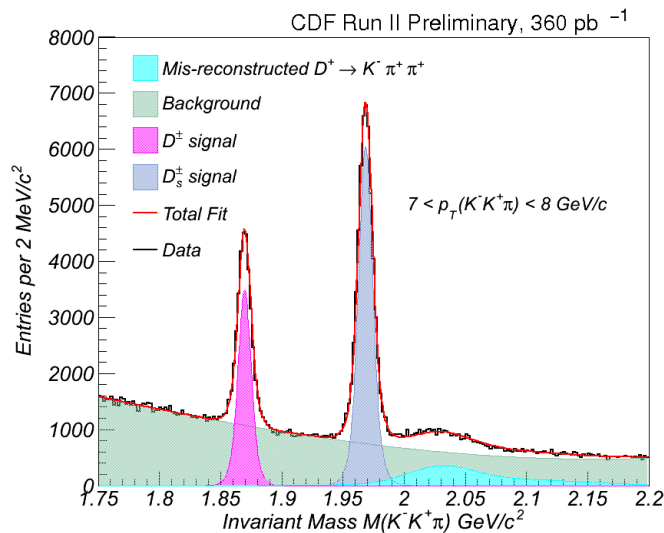
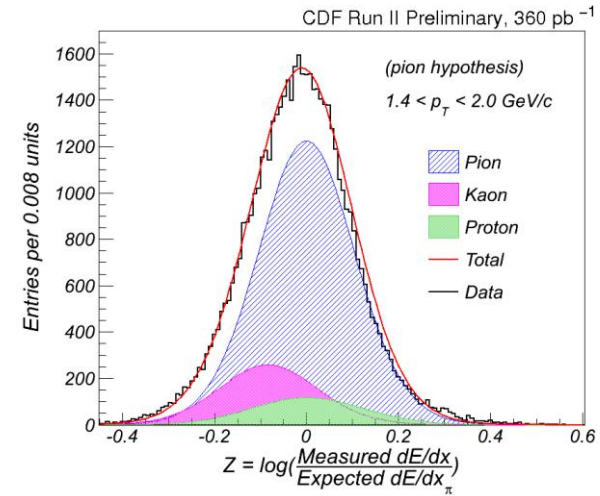
Probing Fragmentation

- Charge correlation between D and K
 - For D_s
 - Opposite sign => early in fragmentation chain
 - Same sign => later in fragmentation chain
 - For D^+
 - Random charge correlation



Method

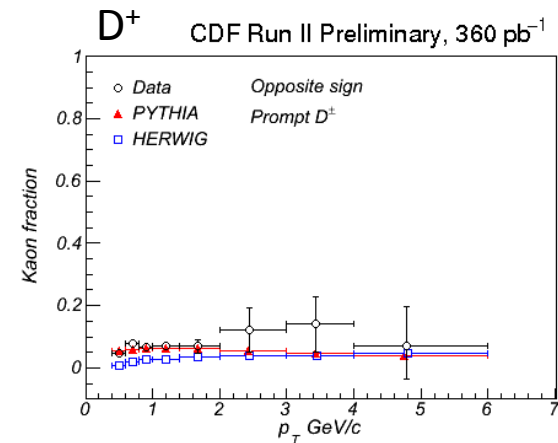
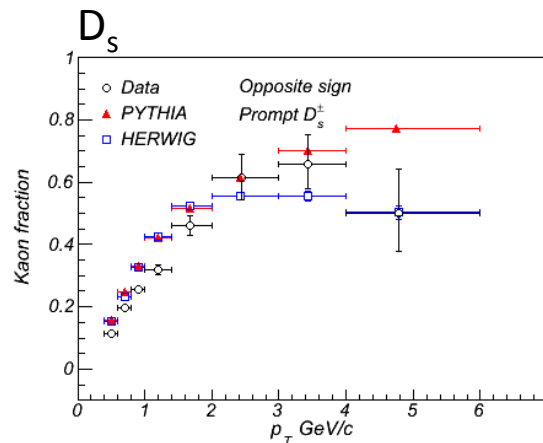
- Take maximum p_t tracks in $\Delta R=0.7$ cone around D candidate
 - Measure kaon fraction with likelihood fit
 - Particle ID: time of flight, dE/dx



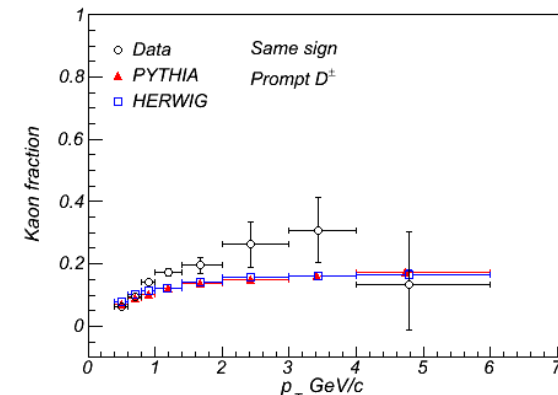
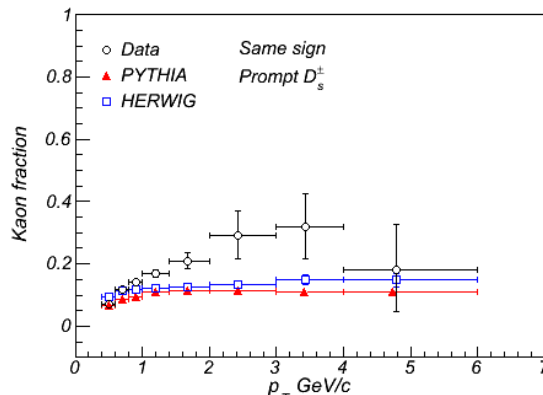
Compare to Pythia/Herwig

- Pt distribution for early fragmentation kaons better agreement than later steps

Opposite sign



Same sign



Upsilon Spin Alignment

Phys. Rev. Lett. 108, 151802 (2012)

Upsilon Spin-alignment

- Discrepancies among experimental results

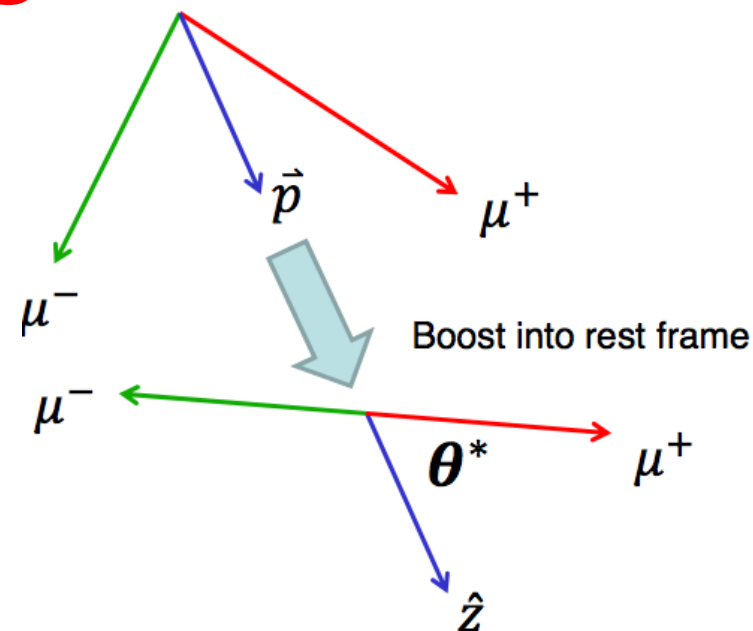
- Distribution described by:

$$\frac{d\Gamma}{d\Omega} \propto 1 + \lambda_\theta \cos^2 \theta + \lambda_\varphi \sin^2 \theta \cos 2\varphi + \lambda_{\theta\varphi} \sin 2\theta \cos \varphi \quad \text{PRL 102,151802 (2009)}$$

– Previous measurements: λ_θ only

- Not invariant under change in reference system
- Bias could be introduced if acceptance not uniform in φ

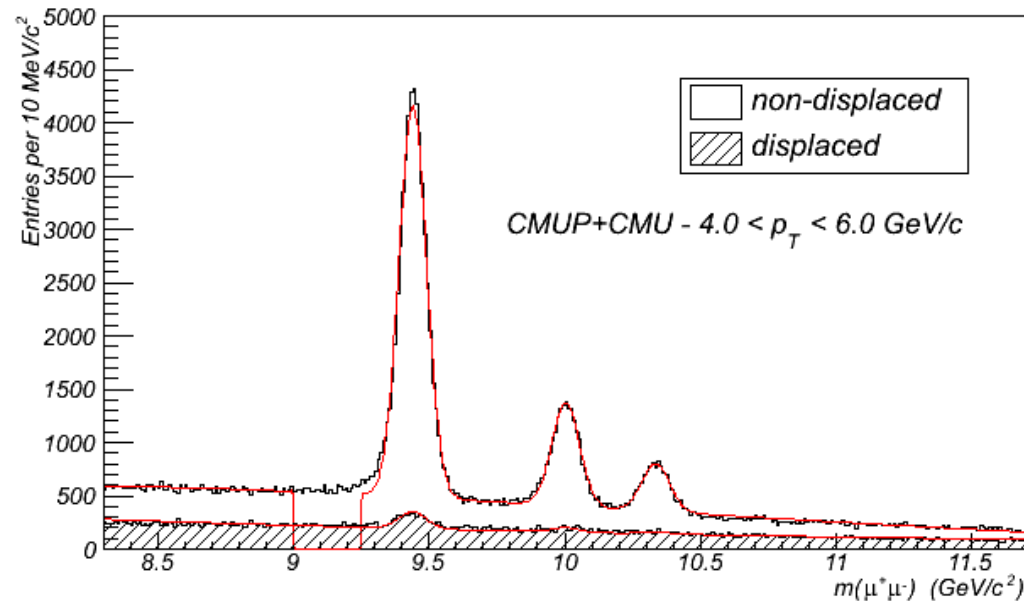
– This measurement: full 3D measurement



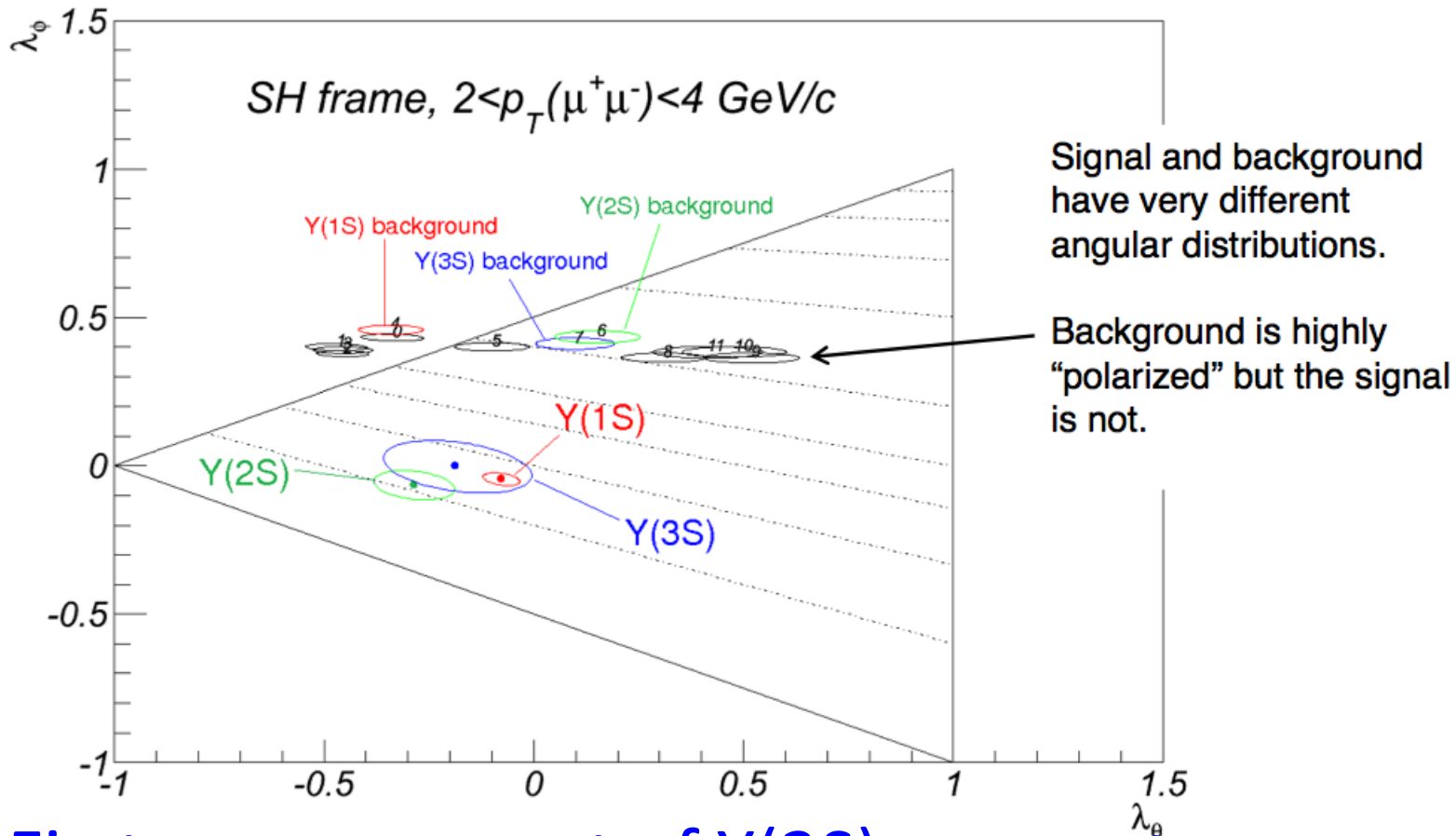
Upsilon

CDF Run II, 6.7 fb^{-1}

- 550k $\Upsilon(1S)$, 150k $\Upsilon(2S)$, 76k $\Upsilon(3S)$ decaying to $\mu\mu$
- Background dominated by bb decays to muons
 - Constrain background by scaling background in displaced (b-enriched) sample by extrapolation from sidebands
 - Obtain geometric acceptance from MC



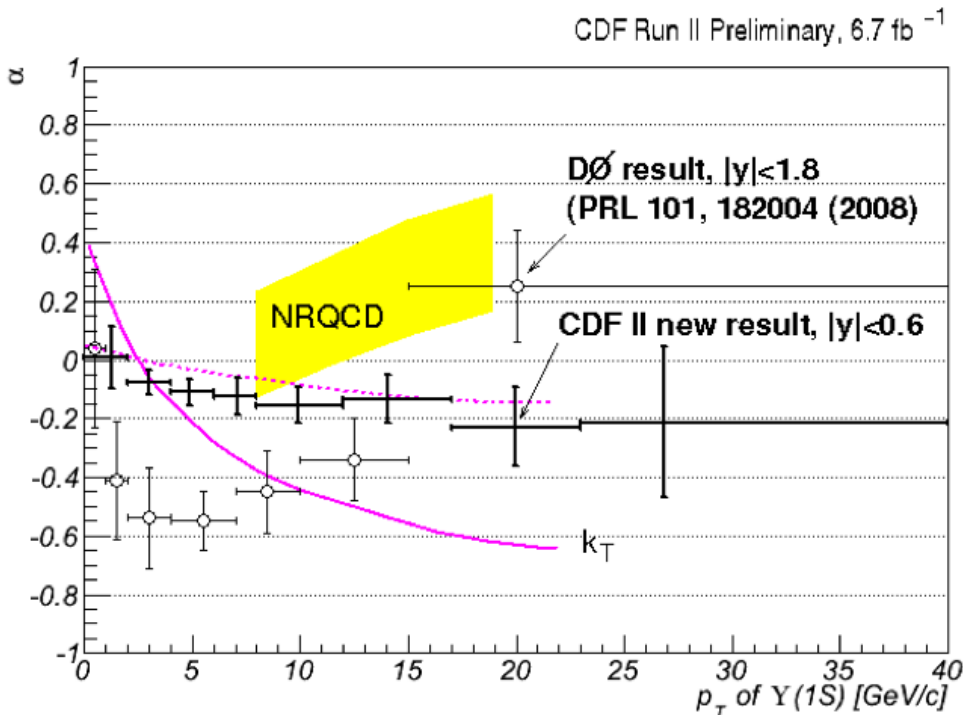
Results



- First measurement of Y(3S) parameters
- None of the 3 states shows evidence of polarisation
 - Frame invariance crosschecks performed

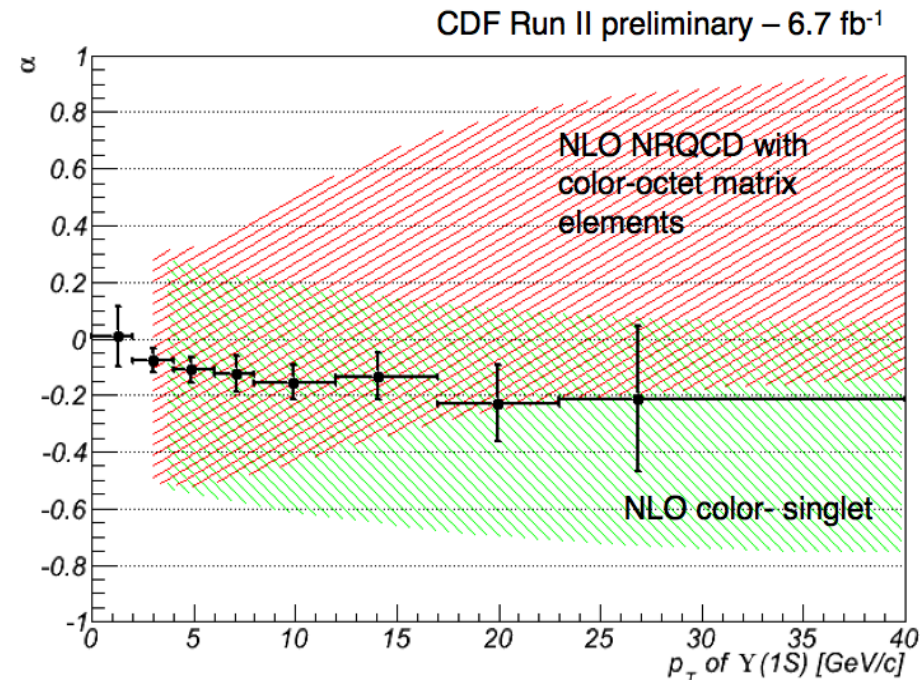
Compare with Theory

- Y(1S) parameter: $\alpha = \lambda_\theta$



NRQCD – Braaten & Lee, Phys. Rev. D63, 071501(R) (2001)
 k_T – Baranov & Zotov, JETP Lett. 86, 435 (2007)

Recent calculations:
 Significant feed-down from χ_b states:

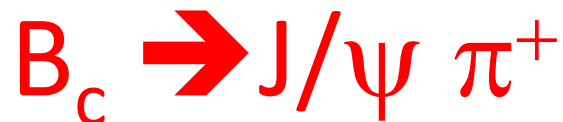


Nucl. Phys. B 214, 3 (2011) summary:

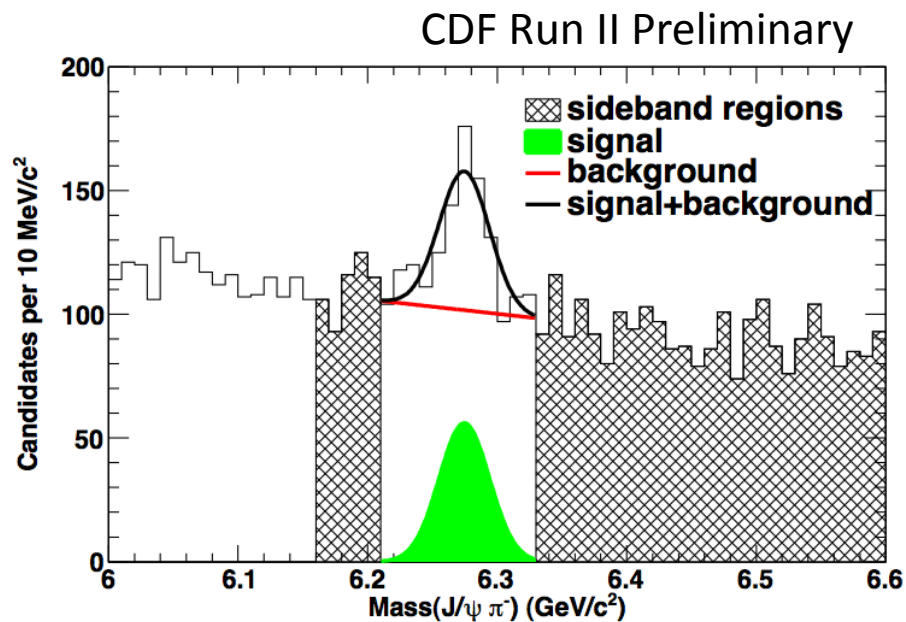
- NLO NRQCD – Gong, Wang & Zhang, Phys. Rev. D83, 114021 (2011)
- Color-singlet NLO and NNLO* - Artoisenet, *et al.* Phys. Rev. Lett. 101, 152001 (2008)

B_c Lifetime

CDF Public Note 10533

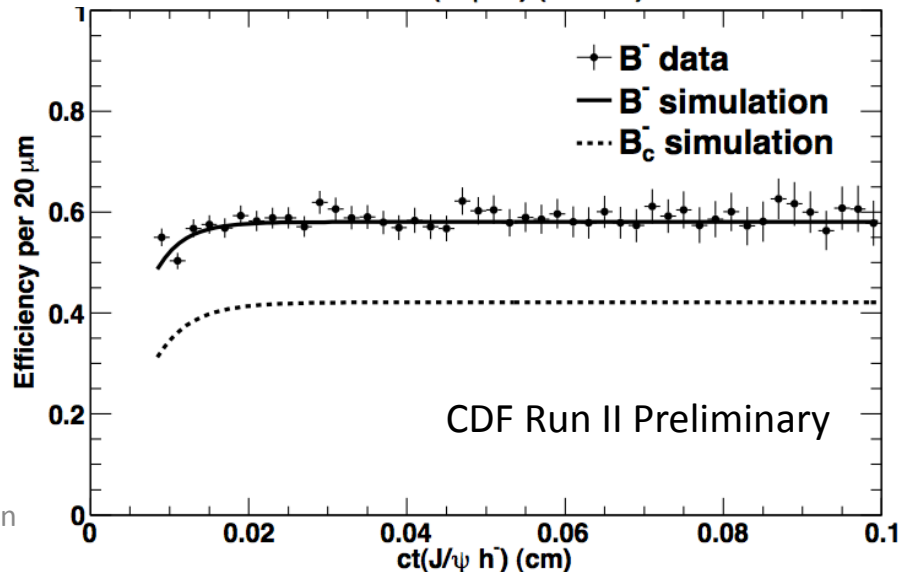
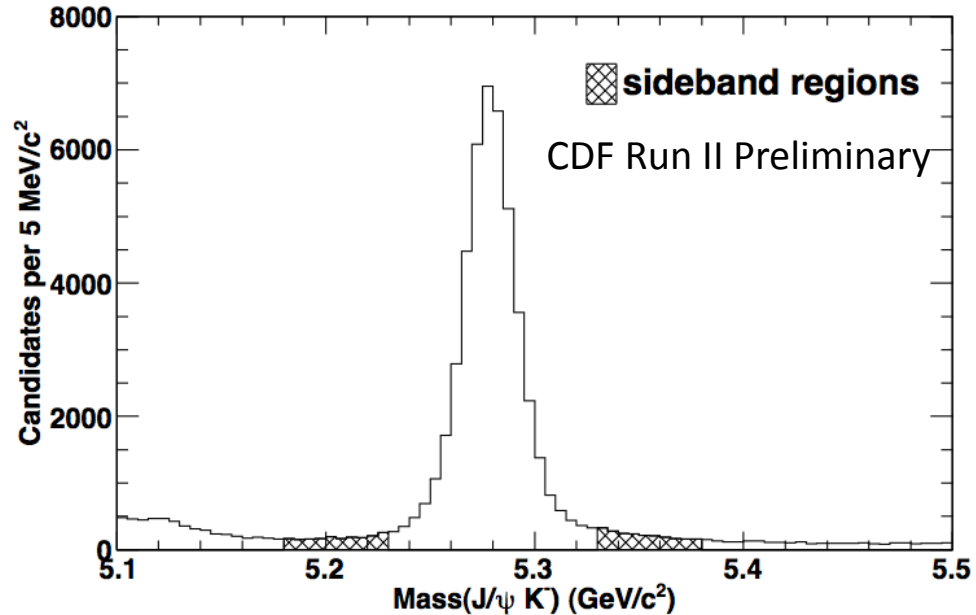


- B_c was discovered at CDF
 - Short lifetime: b or c can decay or annihilate
 - Previous lifetime measurements only on partially reconstructed decays
- Fully reconstructed decay
- Background parameters from sidebands



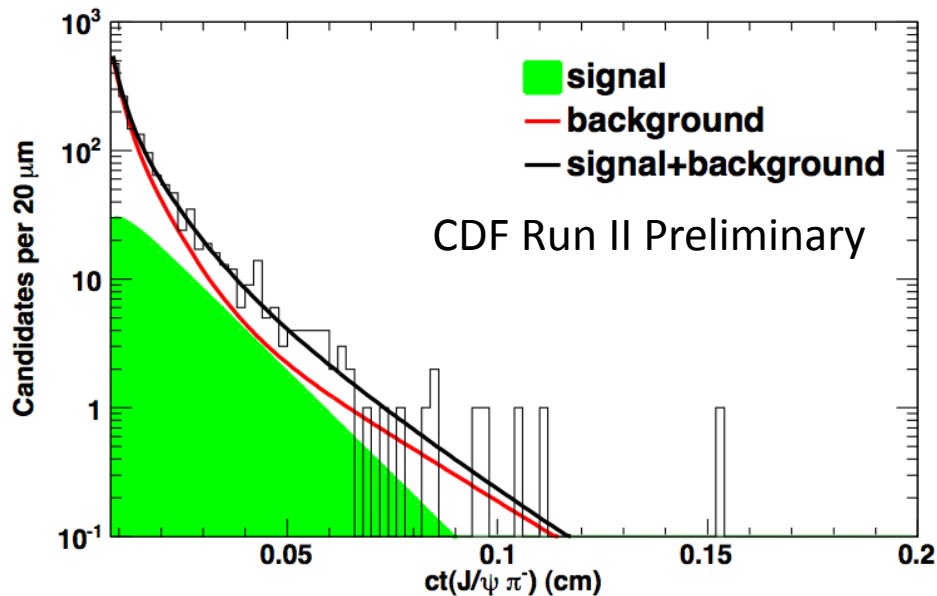
Method

- $B^+ \rightarrow J/\psi K^+$ used as a control sample
- Validate
 - ct Efficiency
 - biased by cut requiring small pointing angle between decay vector and B momentum vector
 - Background model
 - Fitter



Results

- **Fit:**
$$L = \prod_i [f_s \cdot M_s(m_i, \sigma_{m_i}) \cdot T_s(c\tau_i) + (1 - f_s) \cdot M_b(m_i) \cdot T_b(c\tau_i)]$$



– Signal

- Mass: Gaussian
- Decay time: exponential convoluted with resolution

– Background

- Mass: linear
- Decay time: 3 exponential

$$\tau(B_c^-) = (0.452 \pm 0.048 \pm 0.027) \text{ ps}$$

$$c\tau(B_c^-) = (136 \pm 14 \pm 8) \mu\text{m}$$

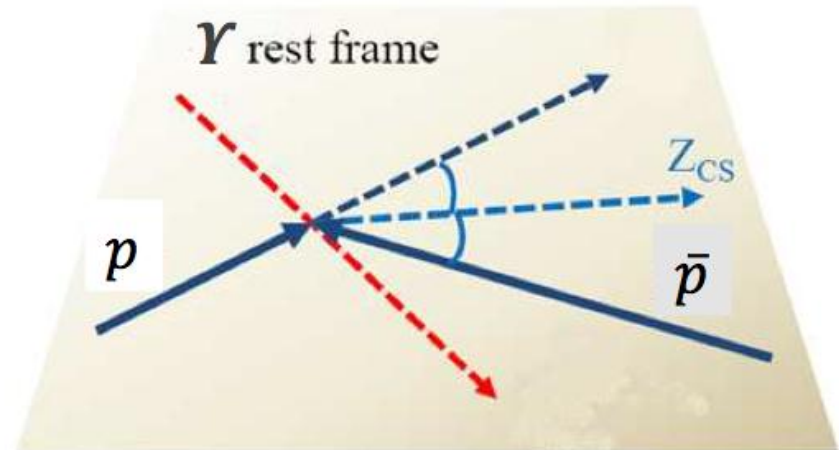
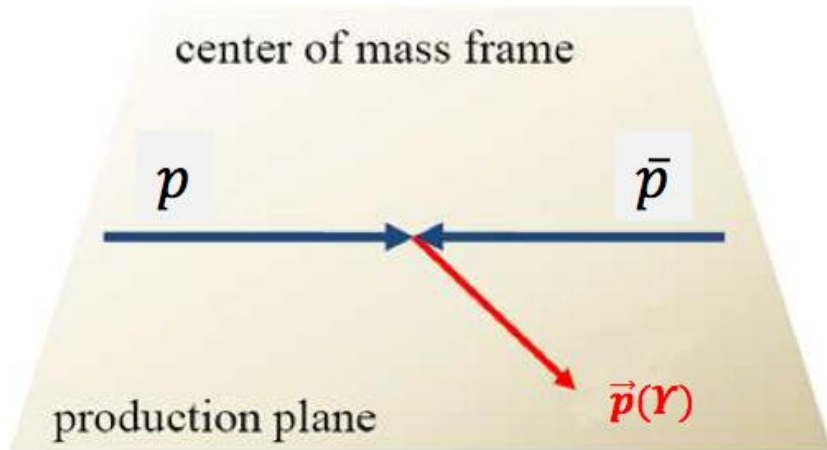
Crosscheck: $c\tau(B_c^-) = (135 \pm 16 \pm 10) \mu\text{m}$

Summary

- Fresh knowledge of fragmentation from our early dataset
 - Later stages of fragmentation chain not well reproduced by MC
- Upsilon polarisation measurement
 - No significant polarisations
- B_c lifetime measurement
 - First fully reconstructed decay measurement
 - Different systematics from previous measurements but in good agreement

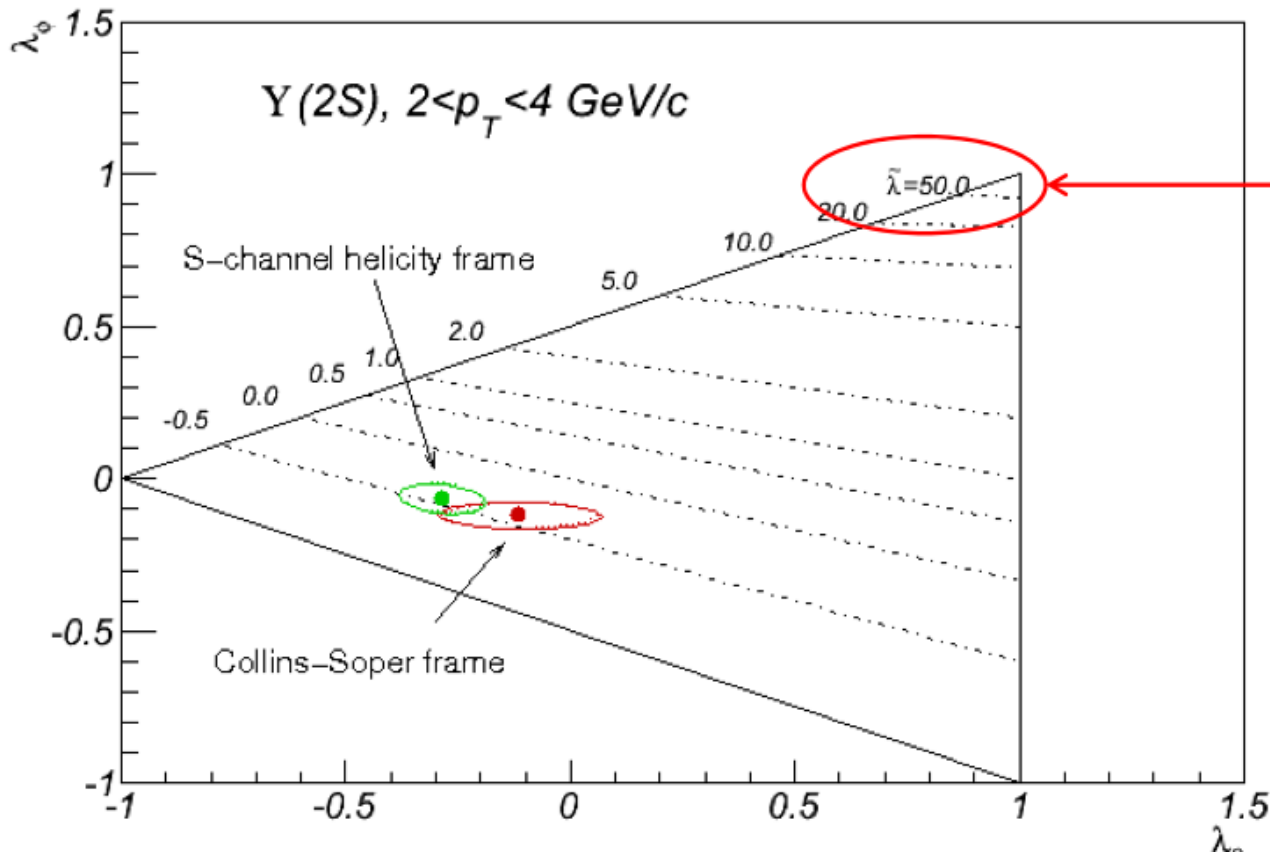
Reference Frames

- S-channel Helicity (SH) – Υ momentum vector defines the z-axis, the x-axis is in the production plane
- Collins-Soper (CS) – z-axis bisects beam momentum vectors in Υ rest frame, x-axis in the production plane:



Crosscheck

CDF Run II Preliminary, 6.7 fb^{-1}



It can be shown that the expression

$$\tilde{\lambda} = \frac{\lambda_\theta + 3\lambda_\phi}{1 - \lambda_\phi}$$

is the same in all reference frames.

We observe that indeed it is.

Crosscheck

- Frame invariant quantity:

$$\tilde{\lambda} = \frac{\lambda_\theta + 3\lambda_\varphi}{1 - \lambda_\varphi}$$

CDF Run II, 6.7 fb^{-1}

