Open Charm Hadron Production and Spectroscopy at LHCb

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(on behalf of the LHCb Collaboration)

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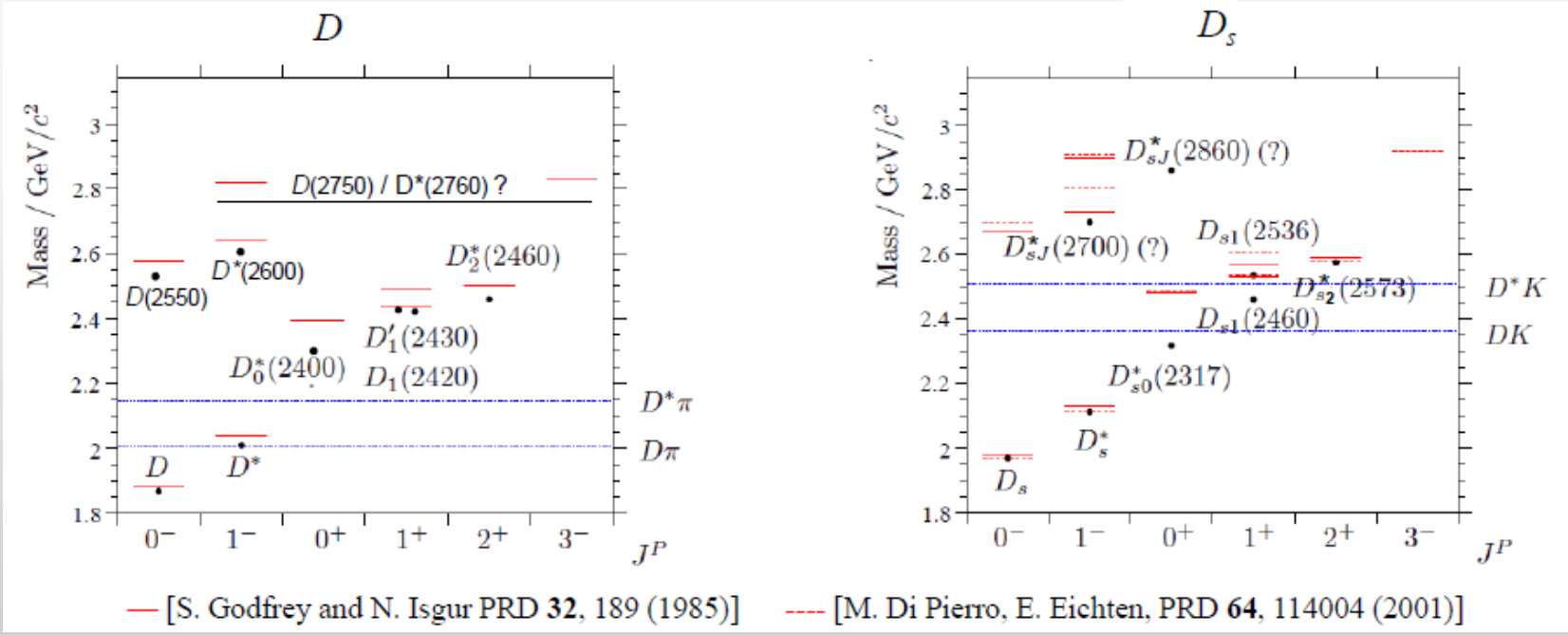
Outline

- Spectroscopy
  - Search for D_J/D_{sJ} states in the $D^{(*)}$ π/K mass distributions
- Production
  - D^0 production asymmetry [LHCb-CONF-2011-023]
  - Charm cross-sections [LHCb-CONF-2010-013]

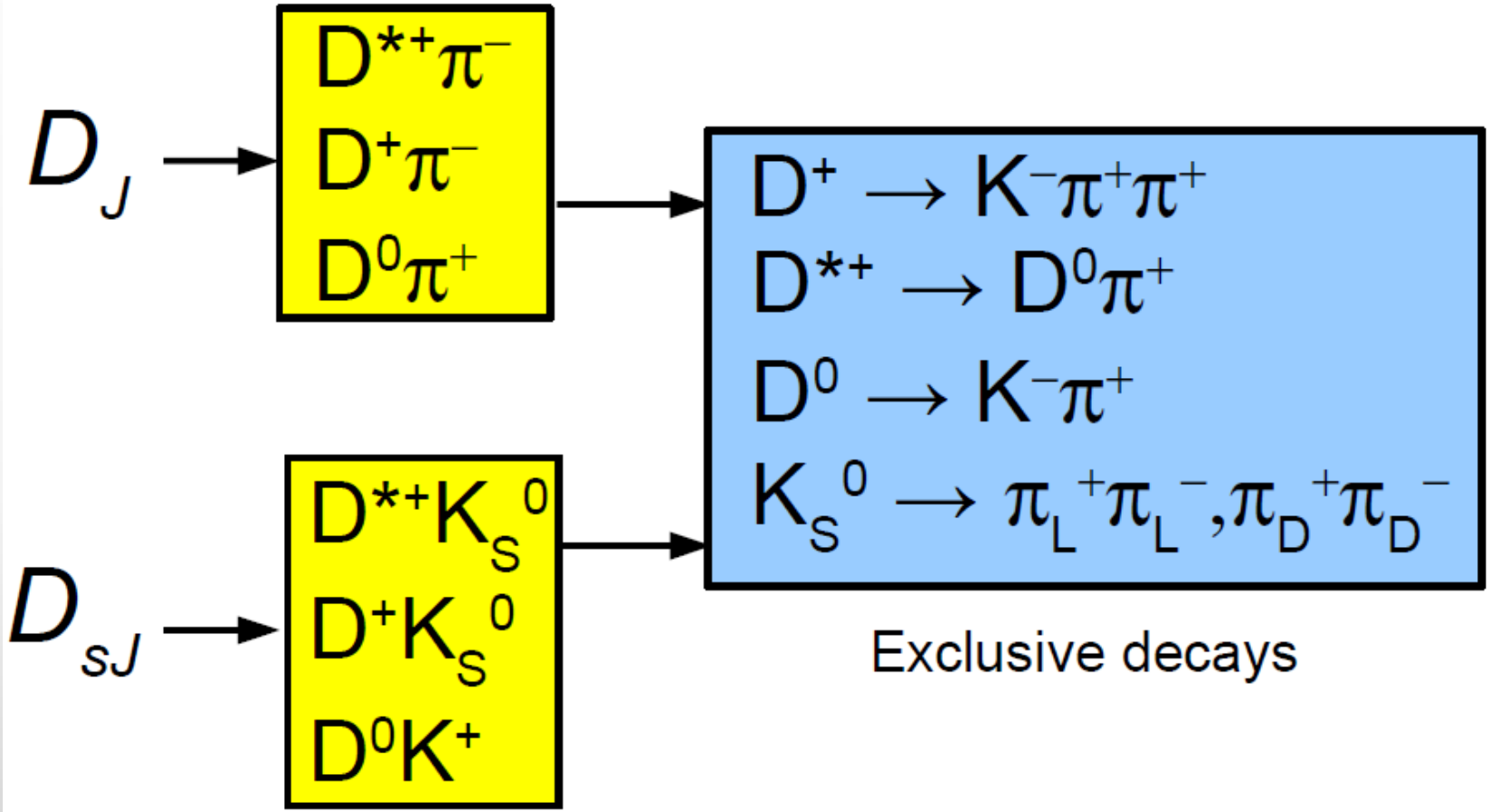
Charm Spectroscopy

PREDICTIONS FOR D AND D_S STATES

- **Predictions of the D and D_s mass eigenstates were performed in 1985 using QCD potential models.**
- **The masses of $D_{(s)1}$ and $D^*_{(s)2}$ states were successfully predicted before their discoveries.**
- **In 2003 observation of two unexpected new states: $D^*_{s0}(2317)$ and $D_{s1}(2460)$.**
- **Recently BaBar and Belle observed new D_J and D_{sJ} states: D(2550), $D^*(2600)$, D(2750), $D^*(2760)$, $D_{s1}^*(2710)$, $D_{sJ}^*(2860)$, $D_{sJ}(3040)$. Many of them need to be confirmed.**

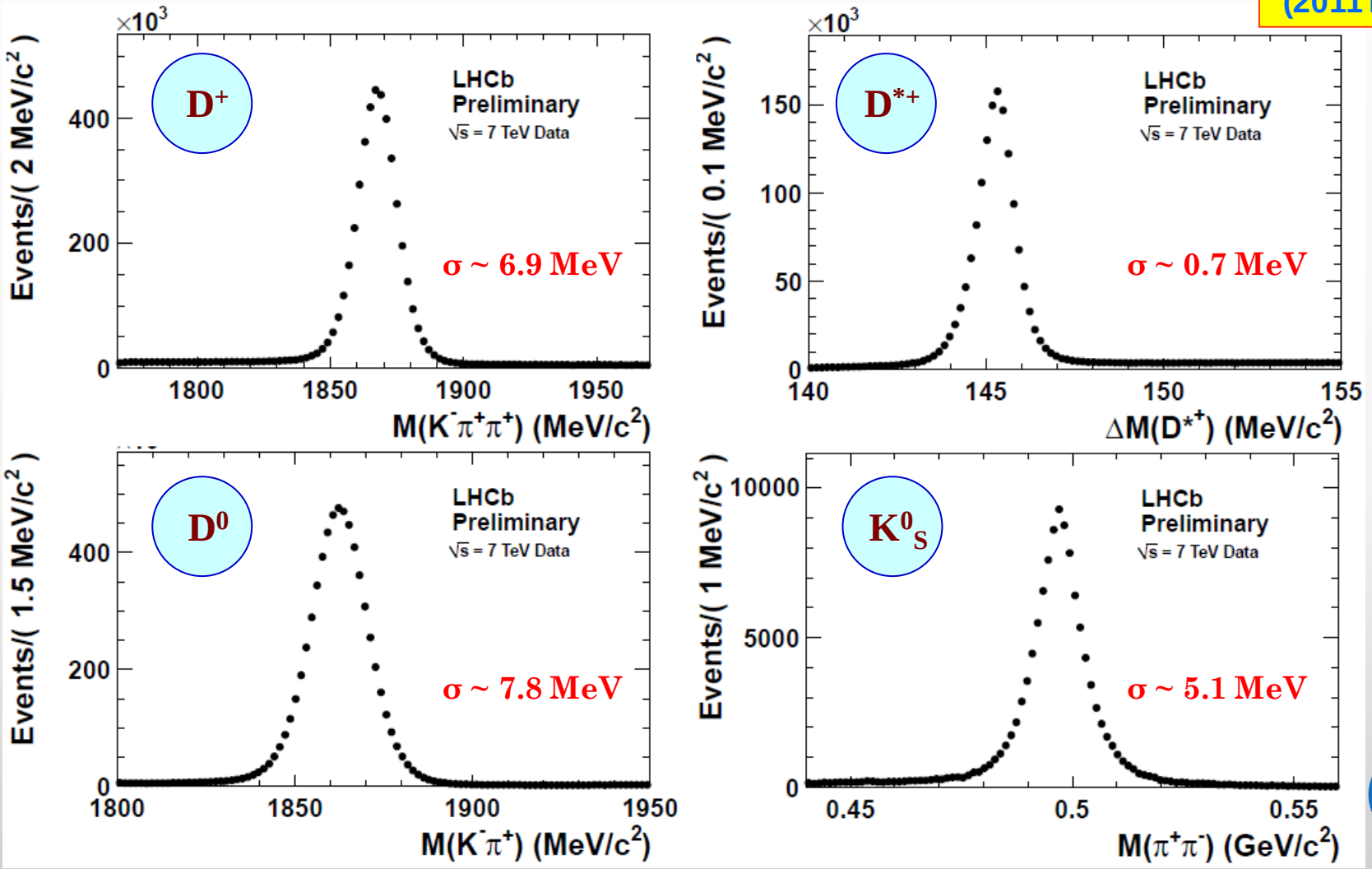


Decay Modes


D_J
$D^{*+}\pi^-$
$D^+\pi^-$
$D^0\pi^+$
D_{sJ}
$D^{*+}K_S^0$
$D^+K_S^0$
D^0K^+
$D^+ \to K^-\pi^+\pi^+$
$D^{*+} \to D^0\pi^+$
$D^0 \to K^-\pi^+$
$K_S^0 \to \pi_L^+\pi_L^-, \pi_D^+\pi_D^-$
Exclusive decays
Inclusive production

$D^0/D^{(*)+}$ and K^0_S Samples

$\mathcal{L} \sim 320\ pb^{-1}$ (2011 Data)



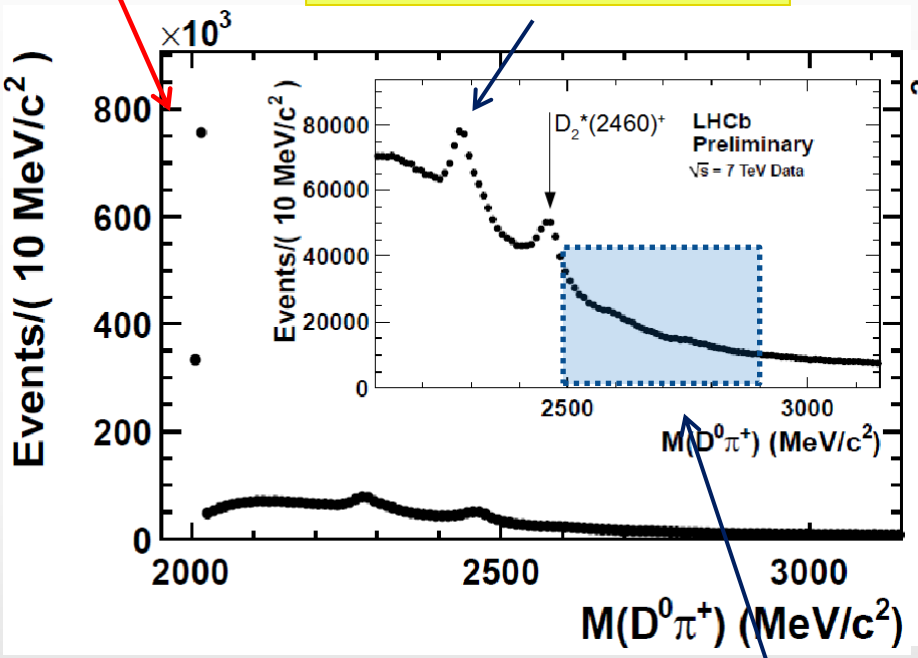
$D^{0/+}\,\pi^{+/-}$ Mass Spectra

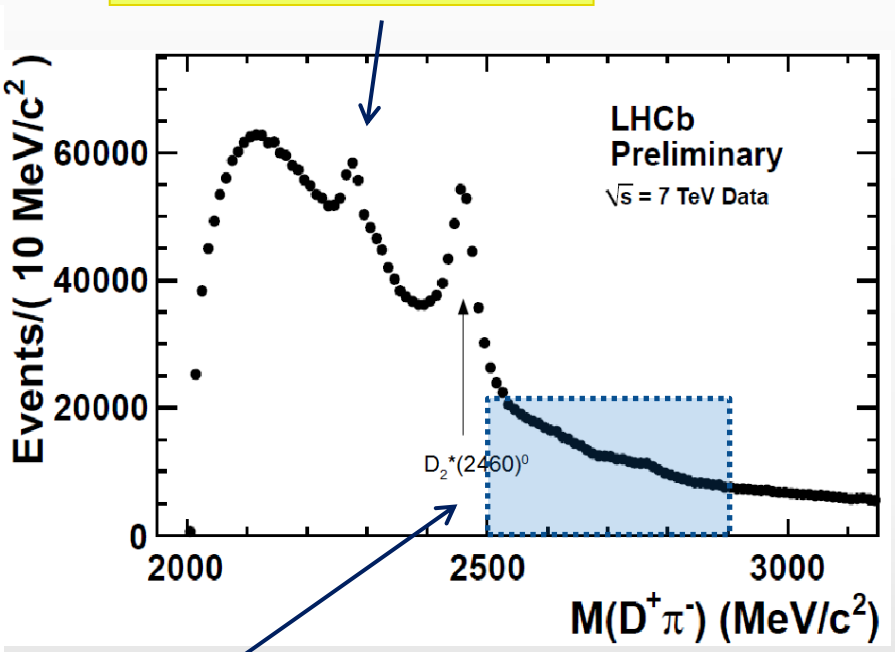
$\mathcal{L}$ ~320 pb^{-1} (2011 Data)

$D^{*+} \rightarrow D^0\pi^+$

$D_1(2420)^+ / D_2^*(2460)^+$ feed-down
└▶ $D^{*0}\,\pi^+$
└▶ $D^0\,\pi^0$(~62%)

$D_1(2420)^0 / D_2^*(2460)^0$ feed-down
└▶ $D^{*+}\,\pi^-$
└▶ $D^+\,\pi^0$(~31%)





Regions of interest

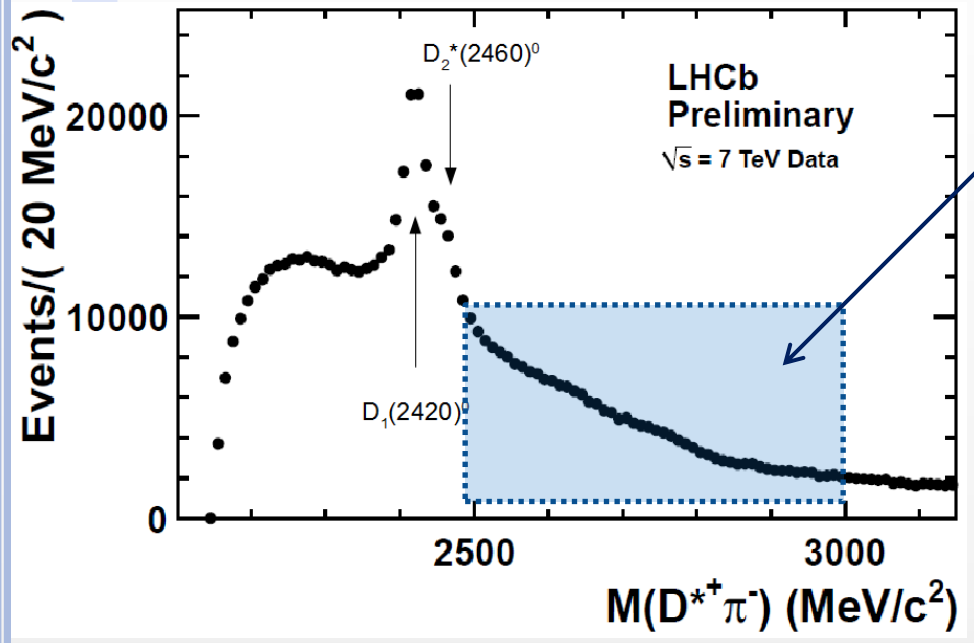
BaBar found two new D_J states (+ isospin partners)

[Phys.Rev.D 82, 111101(2010)]

Resonance	Mass (MeV/c²)	Width (MeV)
$D^*(2600)^0$	$2608.7 \pm 2.4 \pm 2.5$	$96 \pm 6 \pm 3$
$D^*(2760)^0$	$2763.3 \pm 2.3 \pm 2.3$	$60.9 \pm 5.1 \pm 3.6$

$D^{*+}\pi^-$ Mass Spectrum

$\mathcal{L}$ ~320 pb^{-1} (2011 Data)



Region of interest

Spin-parity explored by studying:

The distribution of the helicity angle θ_h

For natural spin-parity: $\frac{dN}{d\cos\theta_h} \cong 1-\cos^2\theta_h$

θ_h ≡ angle formed by the π from D^* decay with respect to the pion in the D^* rest frame

Two more states observed by BaBar

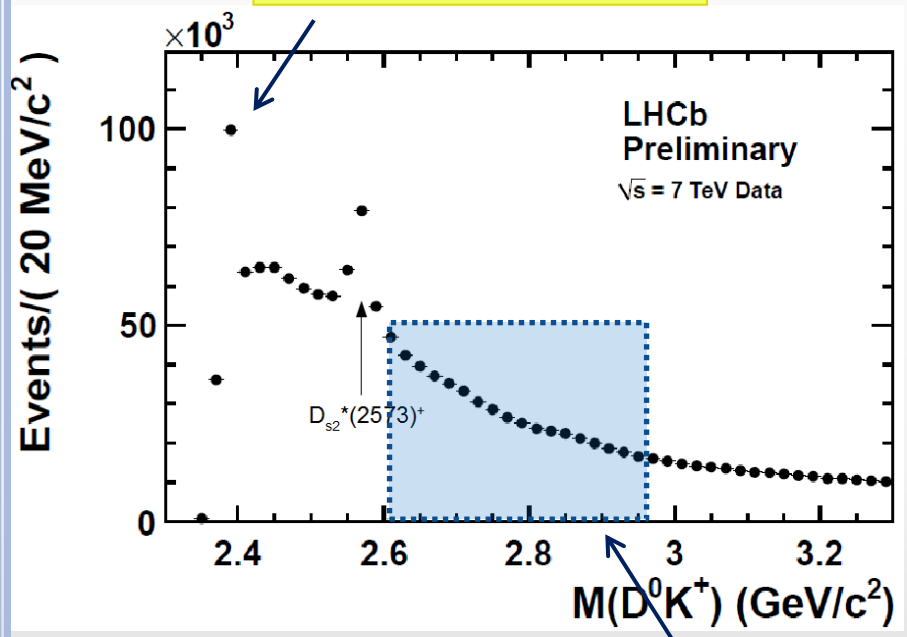
Resonance	Mass (MeV/c^2)	Width (MeV)
$D(2550)^0$	2539.4 ± 4.5 ± 6.8	130 ± 12 ± 13
$D^*(2600)^0$	2608.7 ± 2.4 ± 2.5	96 ± 6 ± 3
$D(2750)^0$	2752.4 ± 1.7 ± 2.7	71 ± 6 ± 11

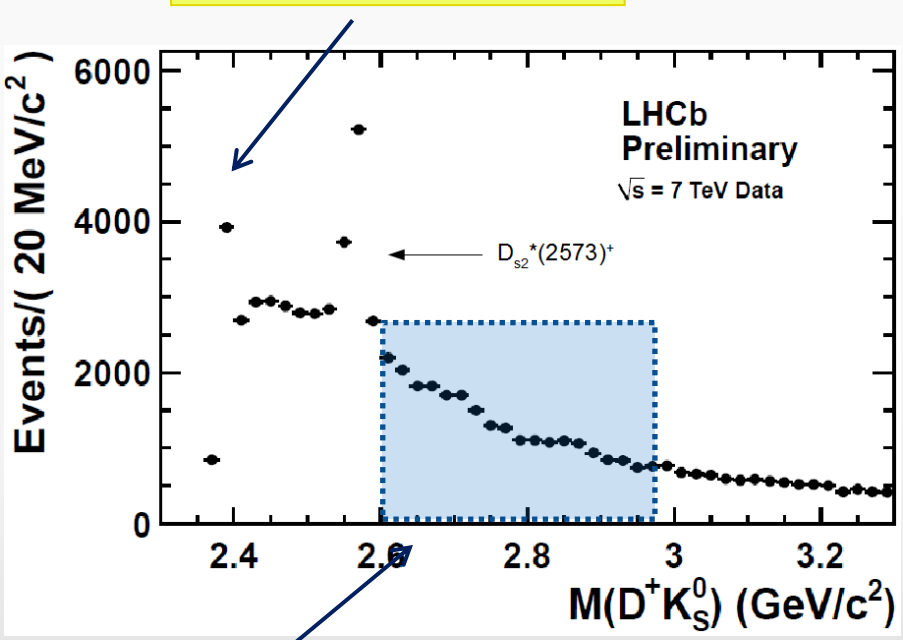
D^0K^+ and $D^+K^0_S$ Mass Spectra

$\mathcal{L}$ ~320 pb^{-1} (2011 Data)

$D_{s1}(2536)$ feed-down
└▶ $D^{*0}K^+$
└▶ $D^0\pi^0$ (~62%)
└▶ $D^0\gamma$ (~38%)

$D_{s1}(2536)$ feed-down
└▶ $D^{*+}K^0_S$
└▶ $D^+\pi^0$ (~31%)
└▶ $D^+\gamma$ (~2%)





Regions of interest

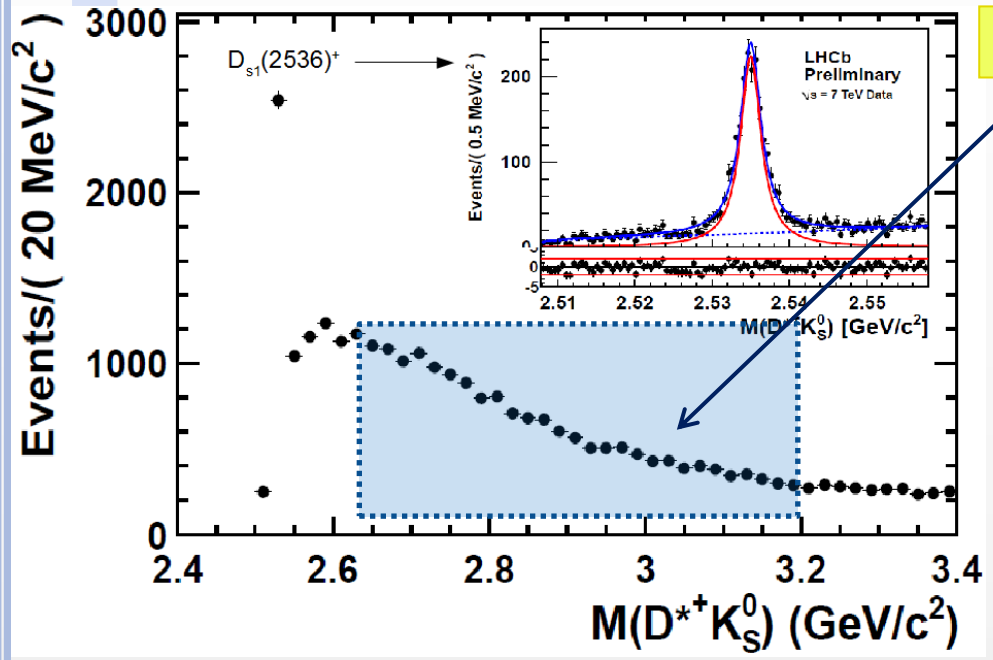
BaBar found two new D_{sJ} states

[Phys.Rev.D 80, 092003(2009)]

Resonance	Mass (MeV/c^2)	Width (MeV)
$D_{s1}^*(2700)$	$2710 \pm 2^{+12}_{-7}$	$149 \pm 7^{+39}_{-52}$
$D_{sJ}^*(2860)$	$2862 \pm 2^{+5}_{-2}$	$48 \pm 3 \pm 6$

$D^{*+}K^0_S$ Mass Spectrum

$\mathcal{L}$ ~320 pb^{-1} (2011 Data)



Region of interest

Spin-parity explored by studying:

- **The distribution of the helicity angle θ_h**

  For natural spin-parity: $\frac{dN}{d\cos\theta_h} \cong 1-\cos^2\theta_h$

- **Ratios of the D*K over the DK branching fractions [P. Colangelo et al., Phys.Rev.D77, 014012 (2008)]**

θ_h ≡ angle formed by the π from D^* decay with respect to the kaon in the D^* rest frame

One more state observed by BaBar

Resonance	Mass (MeV/c^2)	Width (MeV)
$D_{s1}^*(2700)$	$2710 \pm 2\ ^{+12}_{-7}$	$149 \pm 7\ ^{+39}_{-52}$
$D_{sJ}^*(2860)$	$2862 \pm 2\ ^{+5}_{-2}$	$48 \pm 3 \pm 6$
$D_{sJ}(3040)$	$3044 \pm 8\ ^{+30}_{-5}$	$239 \pm 35\ ^{+46}_{-42}$

Charm Production

$A_P(D^0)$ Production Asymmetry

Knowledge of such an asymmetry important for CPV measurement and for QCD models

L~37 pb^{-1} (2010 Data)

$$A_{\rm RAW}(f) \equiv \frac{N(D^0 \to f) - N(\bar{D}^0 \to \bar{f})}{N(D^0 \to f) + N(\bar{D}^0 \to \bar{f})}$$

$$A_{\rm RAW}(f)^* \equiv \frac{N(D^{*+} \to D^0(f)\pi^+) - N(D^{*-} \to \bar{D}^0(\bar{f})\pi^-)}{N(D^{*+} \to D^0(f)\pi^+) + N(D^{*-} \to \bar{D}^0(\bar{f})\pi^-)}$$

D^0 production asymmetries results from the solution of the system

$$\begin{aligned}
A_{CP}^{RAW}(K\pi) &= A_{CP}(K\pi) + A_D(K\pi) + A_P(D^0) \\
A_{CP}^{RAW}(K\pi)^* &= A_{CP}(K\pi) + A_D(K\pi) + A_D(\pi_s) + A_P(D^*) \\
A_{CP}^{RAW}(KK)^* &= A_{CP}(KK) + A_D(\pi_s) + A_P(D^*) \\
A_{CP}^{RAW}(\pi\pi)^* &= A_{CP}(\pi\pi) + A_D(\pi_s) + A_P(D^*)
\end{aligned}$$

4 observables

3 ext. inputs
Physics CP asymmetries.

3 unknowns:
Detection asymmetry of D^0.
Detection asymmetry of soft pion and D^* production asymmetries
D^0 production asymmetries.

$A_{CP}(K\pi)$ assumed negligible

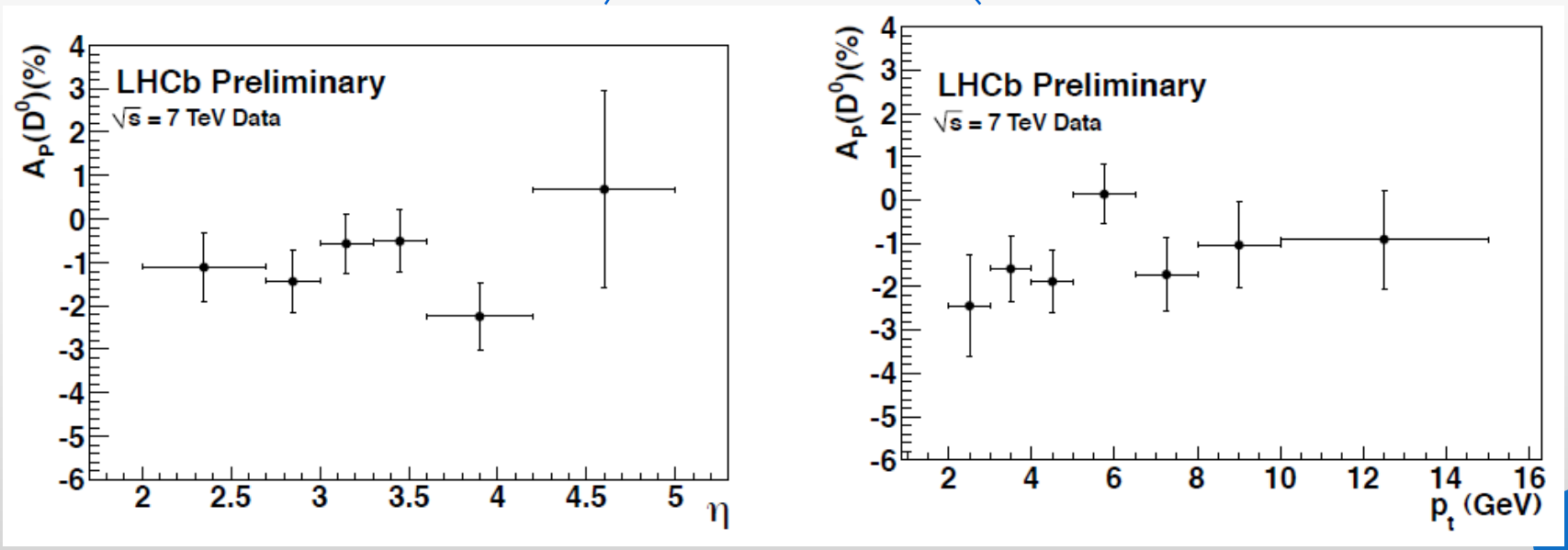
$A_P(D^0)$ Production Asymmetry

LHCb Preliminary

$A_P(D^0) = (-1.08 \pm 0.32 \pm 0.12)\ \%$

First measurement of $A_P(D^0)$

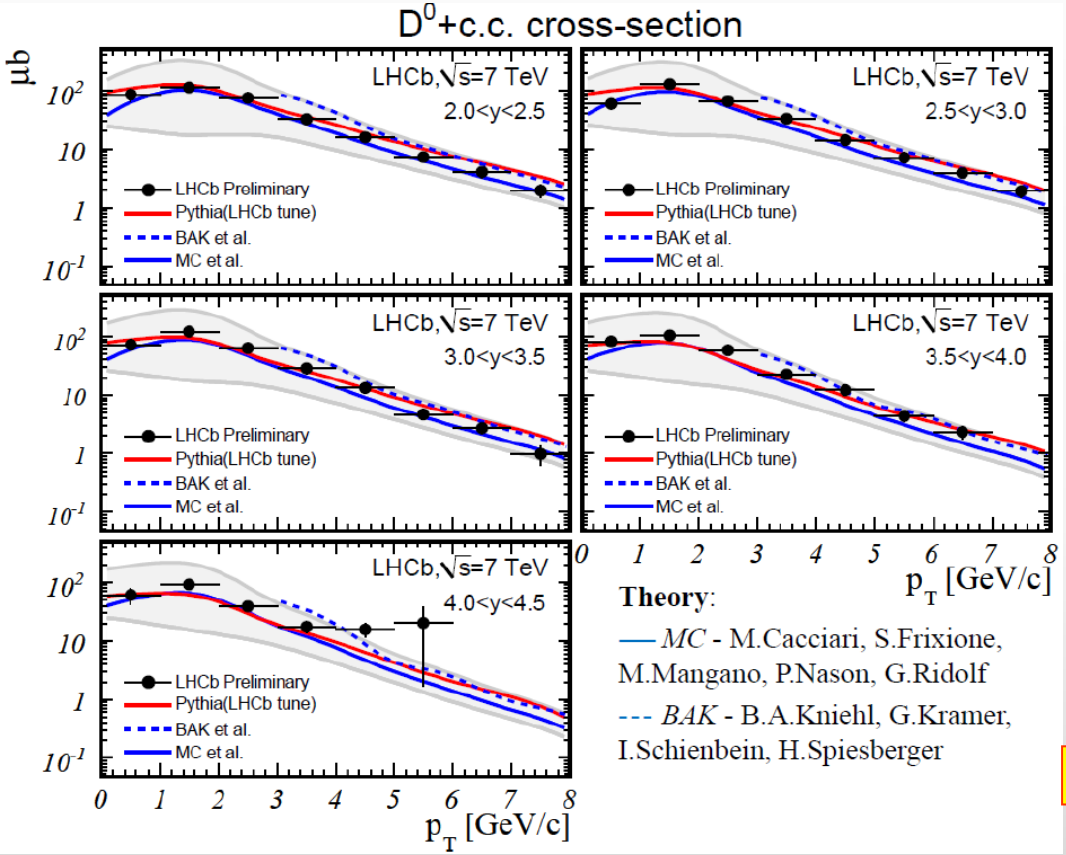
Weighted average

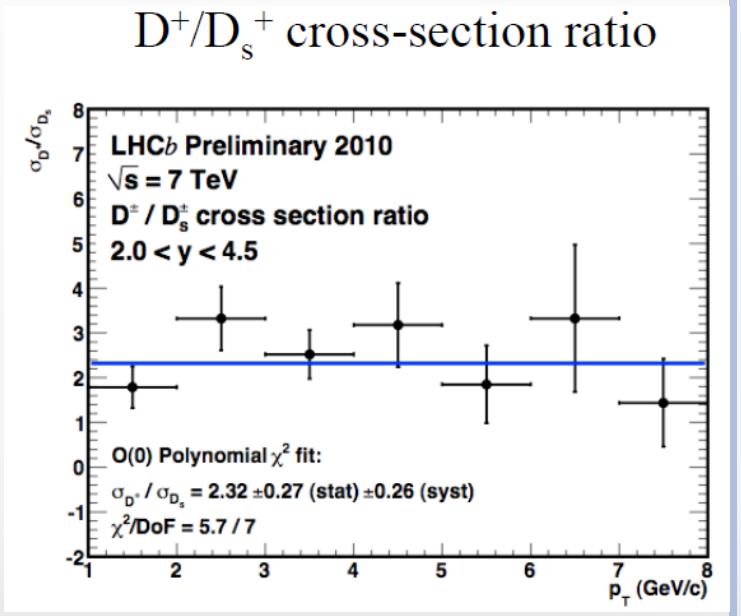


Using 37 pb^{-1}, there is no evidence of dependence of production asymmetry on the pseudo-rapidity and the transverse momentum

Open Charm Production Cross-Section

Production cross-section measurements for D^0, D^+, D^{*+}, D_s^+





LHCb preliminary

$\sigma(pp \to D^+X)/\sigma(pp \to D_s^+X) = 2.32 \pm 0.27 \pm 0.26$

(Consistent with PDG value: 3.1 ± 0.7)

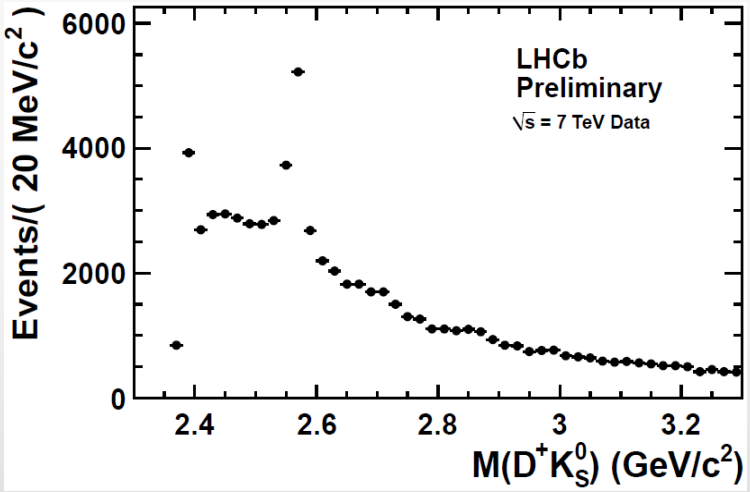
(See back-up slides for more plots)

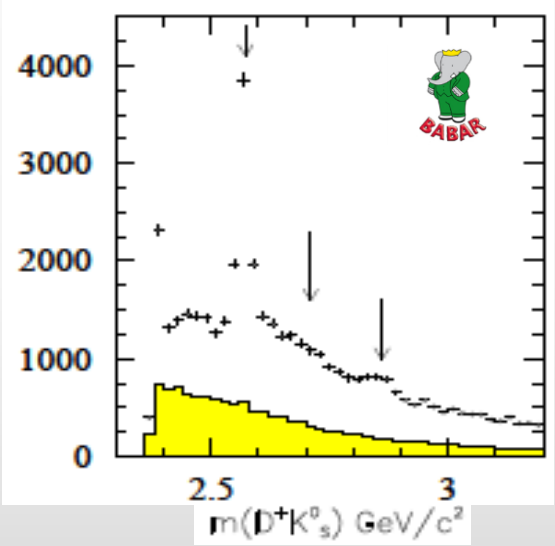
In all modes agreement with theoretical predictions

Conclusion

- **Spectroscopy**
  - **Thank to the excellent performances of LHC and LHCb detector, D_J and D_{sJ} spectroscopy feasible with the same sensitivity of the B-factories**

(e.g.)





- **Production**
  - **D^0 production asymmetry**
  - **Charm cross-sections** **(Update with 2010 data is ongoing)**

Back Up Slides

Open Charm Production cross-section