Measurement of the branching fractions of narrow D** mesons and other semi-leptonic b decays at the DØ experiment

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for the DØ collaboration

Outline:

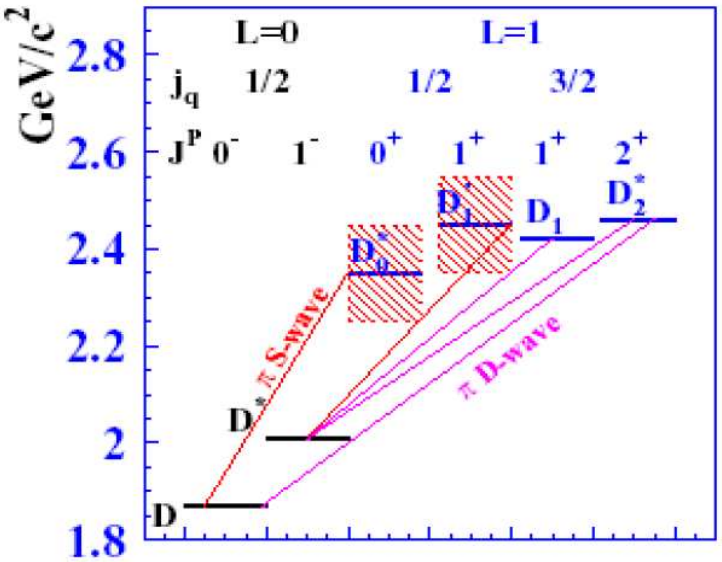
- Context and experimental setup
- First measurement of semi-leptonic B→D** branching fractions for separate states
- Evidence of semi-leptonic $B_s \rightarrow D_s^{**}$
- Observation of semi-leptonic $\Lambda_b \rightarrow \Lambda_c$ decays
- Conclusion

Reference: Submitted to PRL, hep-ex/0507046
See also: www-d0.fnal.gov/Run2Physics/WWW/results.htm

D** properties

- D**: excited, bound state of c and light quark
- $B \rightarrow D^{**} \mu \nu X$
- Everywhere: charge conjugated states are always implied!
- $m_c >> \Lambda_{QCD}$: spin of c decouples from light quark spin and angular momentum of system
- Conservation of parity and orbital angular momentum:
  - D_1 and D_2^* decay to $D^* \pi$

Nomenclature for D**	
D_1 D_2^*	▪Light quark spin and angular momentum in same direction ▪narrow decay width O(10 MeV/c^2)
D_0^* D_1'	▪Light quark spin and angular momentum in opposite direction ▪broad decay width O(100 MeV/c^2)



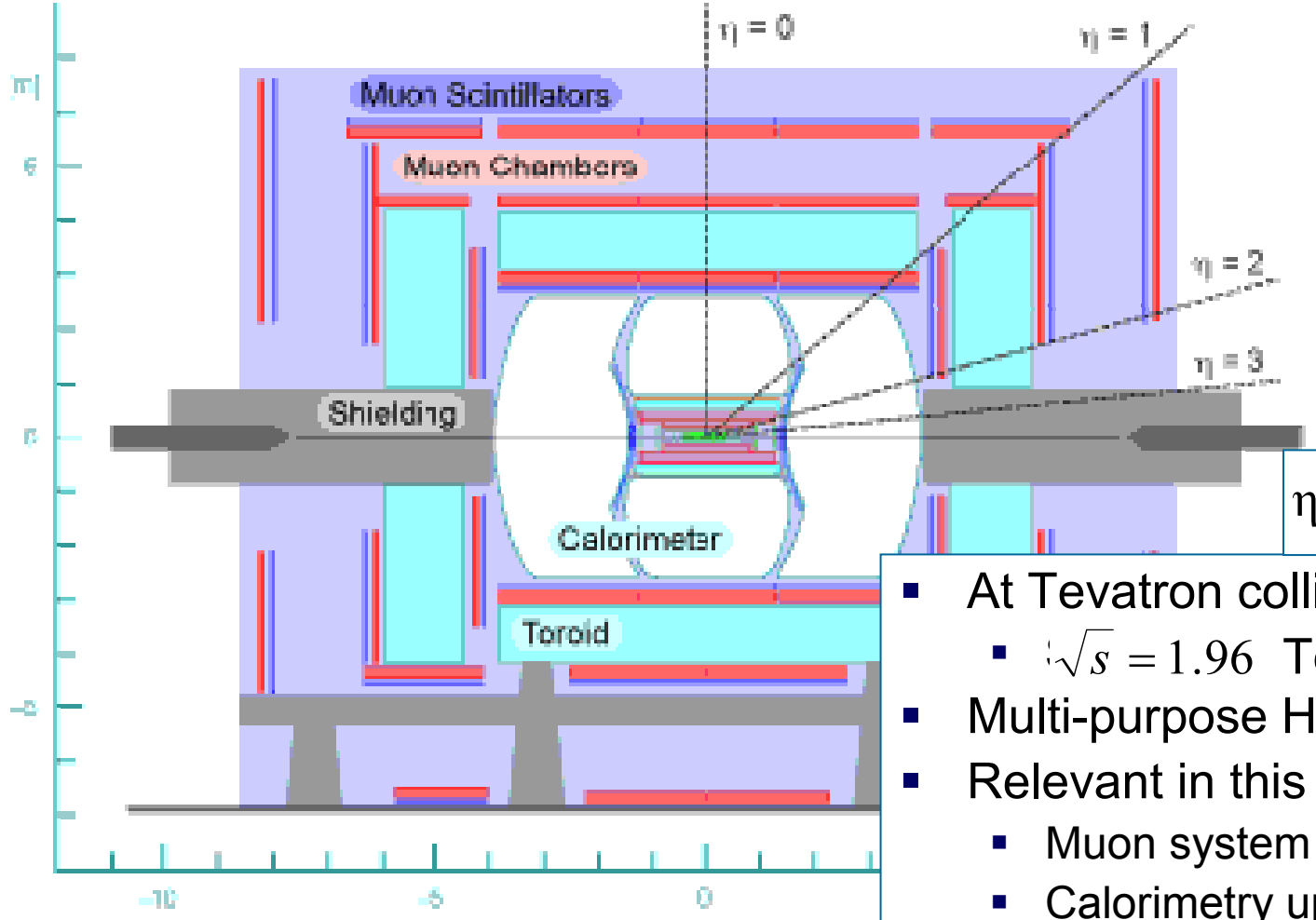
Motivation: Heavy Quark Effective Theory

- HQET: Infinite quark mass corresponds to static colour field
  - Light quark does not "feel" substitution b→c
  - There are $1/m_c$ corrections needed for quantitative predictions
- Sensitive to $1/m_c$ corrections:

$$R = \frac{Br(B \to D^*_2 \ell\bar{\nu})}{Br(B \to D_1 \ell\bar{\nu})} = 1.6 \text{ (if } m_c \to \infty)$$

- R important input to mixing and lifetime studies
- R is relatively model-independent
  - But can be as low as 0.4 in some models
- R_π measured by Belle (hadronic B decays) [Belle,Phys.Rev.D 69,112002 (2004)]

The DØ detector



$$\eta = -\ln\left(\tan\left[\theta/2\right]\right)$$

- At Tevatron collider
  - $\sqrt{s} = 1.96$ TeV
- Multi-purpose HEP detector
- Relevant in this presentation:
  - Muon system up to |η|<2
  - Calorimetry up to |η|<3
  - Tracking up to |η|<2.0

Detector: Details

Silicon Tracker

- R<10 cm
- Silicon microstrips
  - Pitch 50-80 μm
  - Barrels and disks

Fibre Tracker

- R<52 cm
- Scintillating fibers
  - Barrel only

Central magnet

- 2T solenoid

Calorimeter

- Liquid argon + Uranium

Muon system

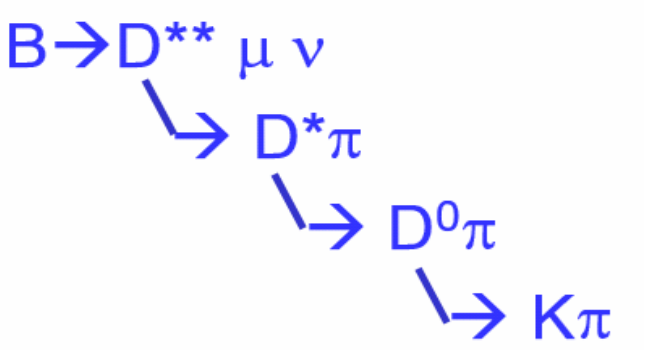
- Drift tubes
  - Three layers
- Scintillating counters
  - Between drift tube layers
- 1,8T toroid

Trigger

- Three-level trigger. Reduction from 1.7MHz to 50 Hz

D** branching fraction: method

- Focus on decay



- Identify D** resonance in $D^{*-}\pi^{+}$ invariant mass spectrum
- Normalize fractions to

$$B \to D^{*-}\ \mu^{+}\nu_{\mu}X$$

- Use DØ dataset up to 2004 ≈ 460 pb^{-1}
- B jet constructed with DURHAM algorithm
- Select events with a muon in a jet:

$$p_T^{\mu} > 2\ \text{GeV}/c,\ \left|\eta^{\mu}\right| < 2$$

- K and π identified as tracks in jet, charge correlation with μ and:

$$p_T^{K,\pi} > 0.7\ \text{GeV}/c,\ \left|\eta^{K,\pi}\right| < 2$$

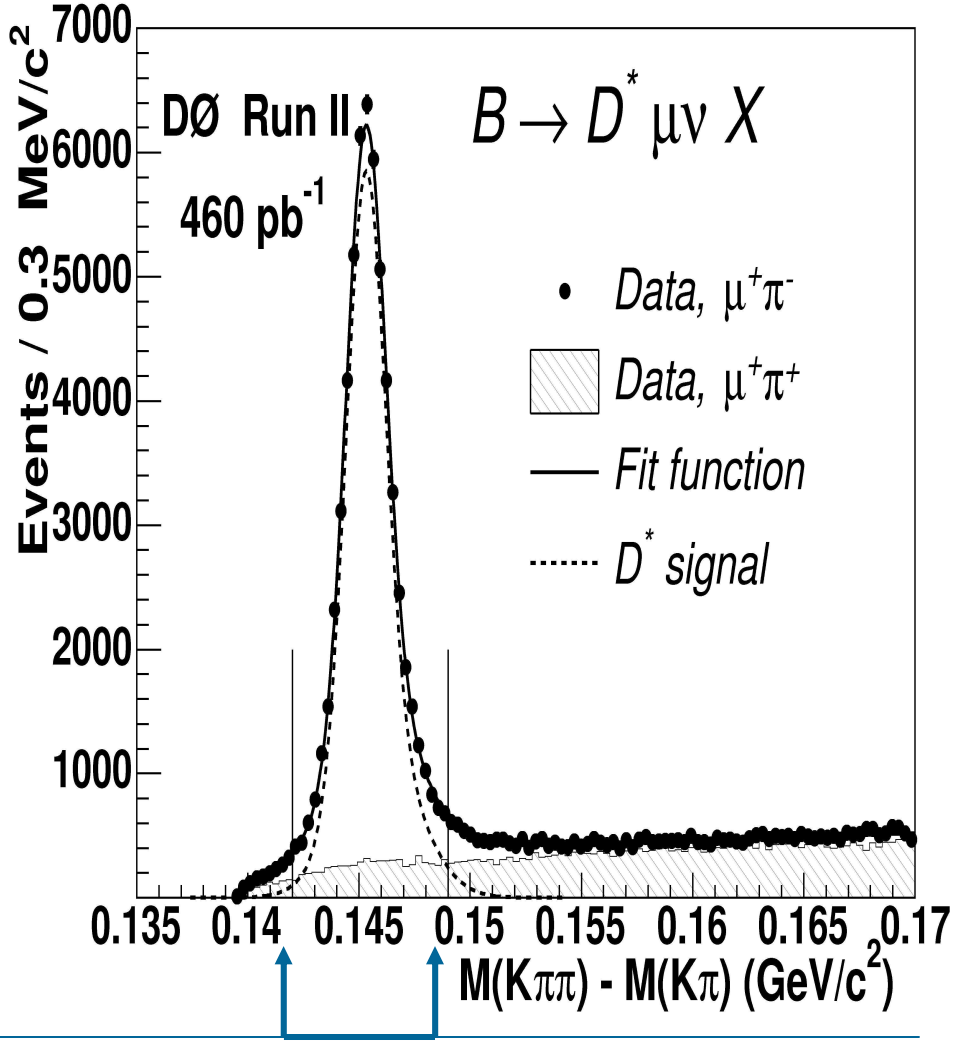
- Use K and π to reconstruct D^0 candidates

Reconstruction of D* candidates

- Method: start from μD^0 candidates and start adding π tracks

$$D^* \mu \bar{\nu}^{\mu} X \rightarrow D^0 \pi \mu \bar{\nu}^{\mu} X$$

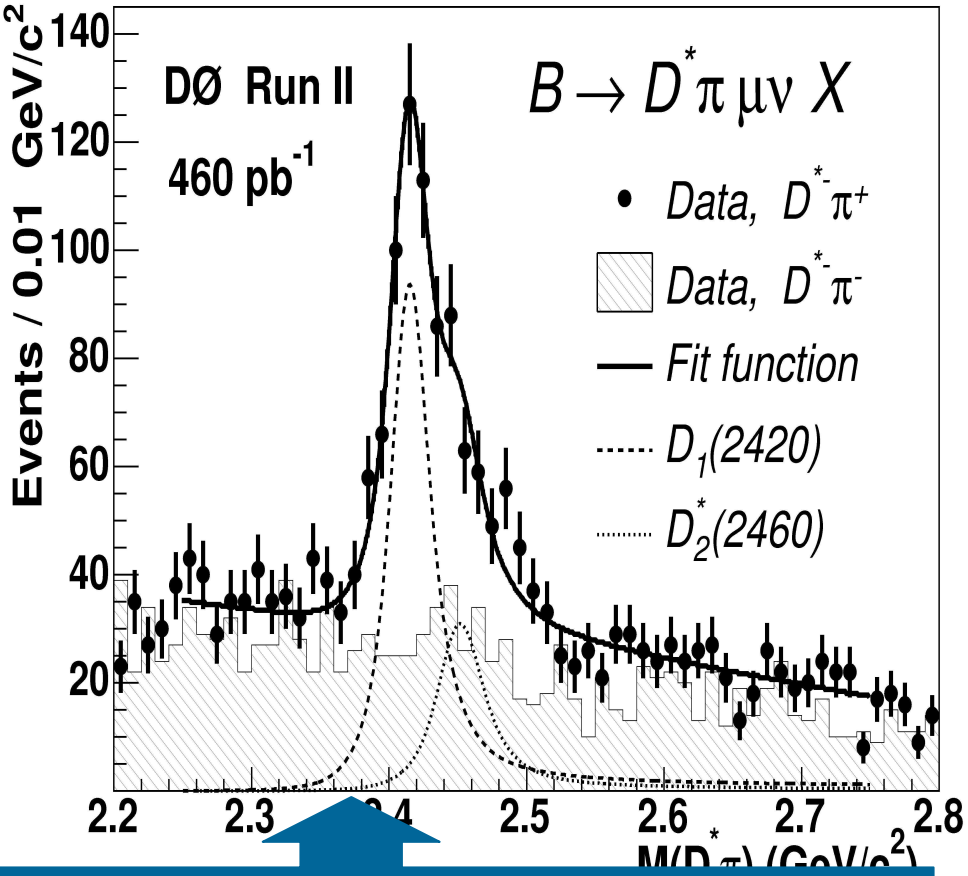
- Reduce B→DD, $g \rightarrow c\bar{c}$ background
  - cut on D^0 : p_T>5 GeV/c
- Keep D* candidates
  - Cut on mass difference
  - Reduce background by quality requirements on D*μ system
- Left: 31k candidates



Reconstruction of D** candidates

$$D^{**}\mu\bar{\nu}^{\mu}X \rightarrow D^{*}\pi\mu\bar{\nu}^{\mu}X \rightarrow D^{0}\pi\pi\mu\bar{\nu}^{\mu}X$$

- Method: add additional π tracks
- Peak interpreted as merged resonances:
  - D_1 (2420)
  - D^*_2(2460)
- Fit:
  - Two Breit-Wigner functions (signal)
  - Second-order polynomial (background)
  - Incl. resolutions and MC/data difference



Wrong sign background same level as right sign. DØ does not observe a wide resonance

B→D**μνX result

D^*_2 candidates	176 ± 37 (stat)
D_1 candidates	467 ± 39 (stat)

Use known
$B \to D^{*-} \mu^+ \nu_\mu X$
for normalization

- Systematic uncertainties include:

  BR(b→D*-), mass resolution, width of D** states, fit errors, D^0 selection, possible wide resonances, MC/data modelling, possible interference

$$Br(B \to \overline{D}^{*0}_2 \mu^+ \bar{\nu} X) \cdot Br(\overline{D}^{*0}_2 \to D^{*+} \pi) = (0.035 \pm 0.007\,(stat) \pm 0.008\,(syst))\%$$

$$Br(B \to \overline{D}^{0}_1 \mu^+ \bar{\nu} X) \cdot Br(\overline{D}^{0}_1 \to D^{*-} \pi) = (0.087 \pm 0.007\,(stat) \pm 0.014\,(syst))\%$$

$$\frac{Br(B \to \overline{D}^{*0}_2 \mu^+ \bar{\nu} X) \cdot Br(\overline{D}^{*0}_2 \to D^{*-} \pi)}{Br(B \to \overline{D}^{0}_1 \mu^+ \bar{\nu} X) \cdot Br(\overline{D}^{0}_1 \to D^{*-} \pi)} = 0.39 \pm 0.09(stat) \pm 0.12(syst)$$

- Use result to extract R:

$$R = 1.31 \pm 0.29\ (stat\ ) \pm 0.47\ (syst\ )$$

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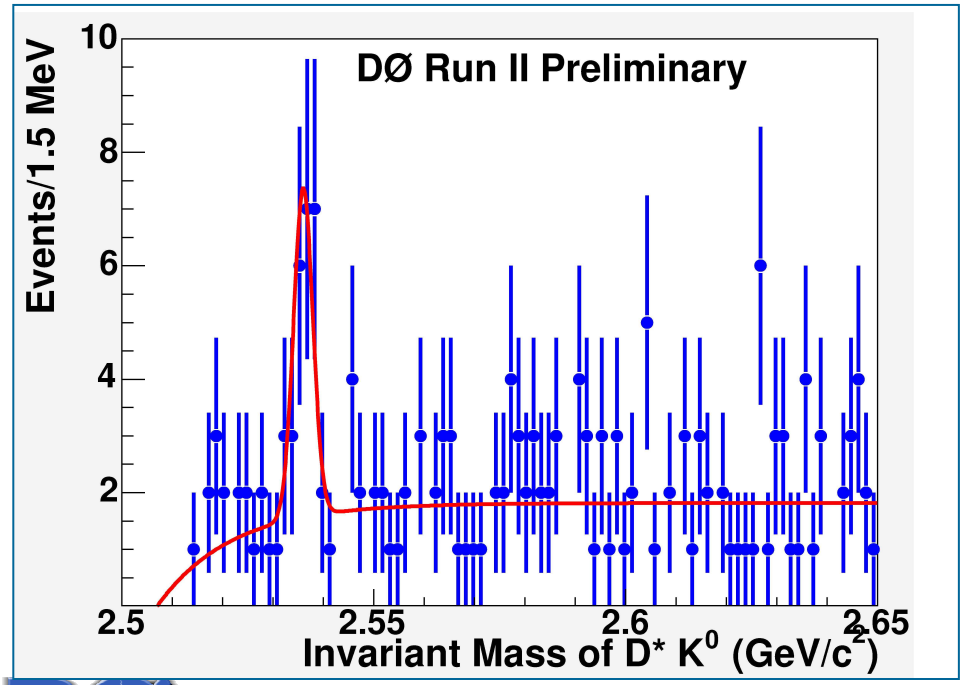
Evidence of $B_s \rightarrow D_s^{**}\mu\nu$

- $D_{s1}^{+} \rightarrow D^{*+} K_S^0$
- Like previous analysis, but examination of D*K invariant mass



- 18 ± 5.5 candidates observed (>3σ, two methods)
- Currently: systematic uncertainties under study
- Preparing to measure production and properties
- New results coming soon!

Goal: lifetime measurement in $\Lambda^0_b \rightarrow \Lambda^0_c \mu\nu$

- Λ^0_b = udb baryon
- $\Lambda^0_b \rightarrow J/\psi\, \Lambda^0$ lifetime already measured by DØ:
  - $\tau(\Lambda_b^0) = 1.22^{+0.22}_{-0.18}(stat) \pm 0.04(syst)$ ps
- Now: use events with muon in jet:
- Method: find decays $\Lambda^{\pm}_c$:

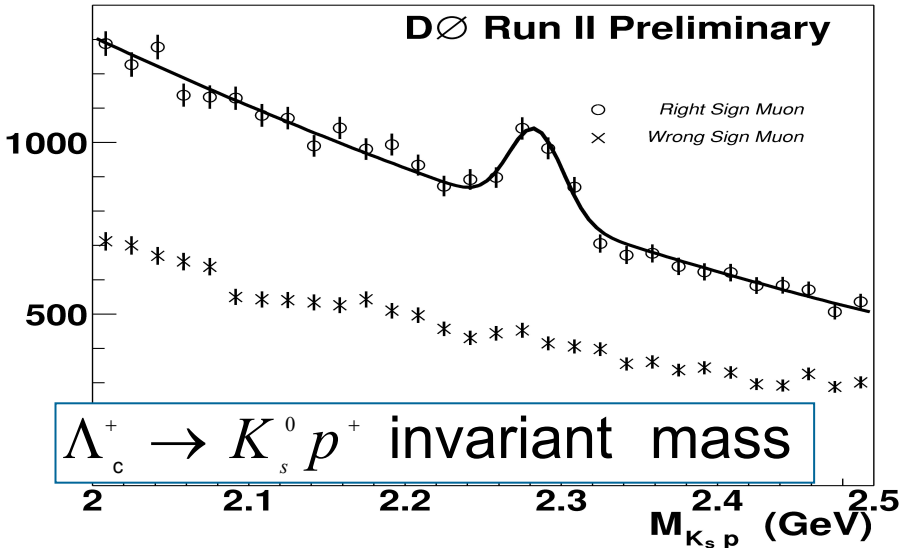
$$\Lambda_c^+ \rightarrow K_s^0 p^+$$

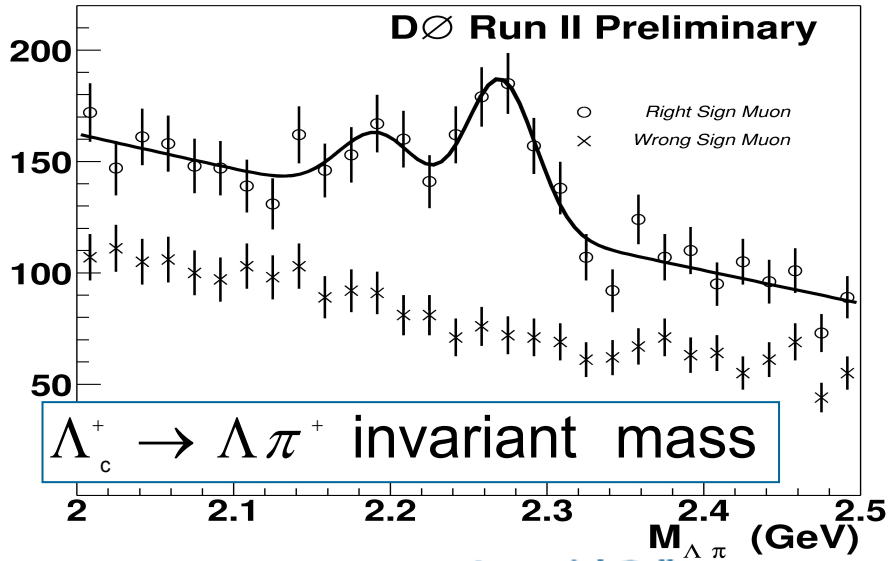
$$\Lambda_c^+ \rightarrow \Lambda \pi^+$$

- Some evidence of

$$\Lambda_c^+ \rightarrow \Sigma^0 \pi^+$$

- Plan to use sample for lifetime measurement





Conclusion

- First time the narrow D** meson branching fractions in semi-leptonic B meson decays have been separately measured:

$$Br(B \to \overline{D}^{*0}_{2}\,\mu^{+}\bar{\nu}X)\cdot Br(\overline{D}^{*0}_{2} \to D^{*+}\,\pi) = (0.035 \pm 0.007\,(stat) \pm 0.008(syst))\%$$

$$Br(B \to \overline{D}^{0}_{1}\mu^{+}\bar{\nu}X)\cdot Br(\overline{D}^{0}_{1} \to D^{*-}\,\pi) = (0.087 \pm 0.007(stat) \pm 0.014(syst))\%$$

$$\frac{Br(B \to \overline{D}^{*0}_{2}\,\mu^{+}\bar{\nu}X)\cdot Br(\overline{D}^{*0}_{2} \to D^{*-}\,\pi)}{Br(B \to \overline{D}^{0}_{1}\mu^{+}\bar{\nu}X)\cdot Br(\overline{D}^{0}_{1} \to D^{*-}\,\pi)} = 0.39 \pm 0.09(stat) \pm 0.12(syst)$$

- This yields:

$$R = 1.31 \pm 0.29(stat) \pm 0.47(syst)$$

- Evidence of D_s^{**}, measurement of properties in progress
- Reconstruction of Λ^0_b possible in semi-leptonic decay, moving towards lifetime measurement