Properties of Excited B-Mesons B^{**} and B_s^{**}: Masses, Production Rates and Decay Branching Fractions

And

First Measurement of the B^0_s Semileptonic Branching Ratio to an Orbitally Excited D_s^{**} state: $Br(B^0_s \rightarrow D^-_{s1}(2536)\mu^+\nu X)$

Mark Williams on behalf the DØ Collaboration

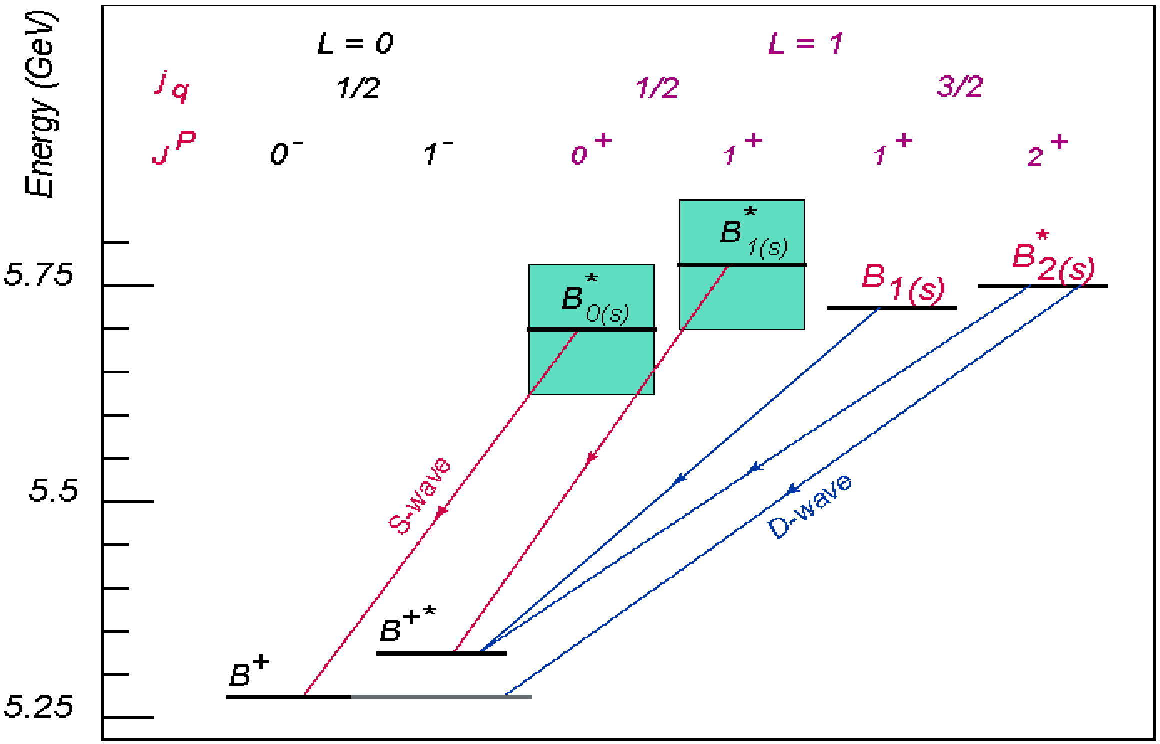
Contents

Part A: The B^{**} System

- **Masses, Widths, Branching Fractions**
- **Production Rates**

b-Meson Spectroscopy – Theory (B^{**} and B_s^{**})

- The (bd) and (bs) quark systems are well modeled by the Heavy-Quark limit, since M(b) >> M(u,d,s).
- Theory predicts four doubly-excited states, in addition to the well-measured ground states B^+, B_s^+ and singly-excited states B^{+*}, B_s^{+*}.

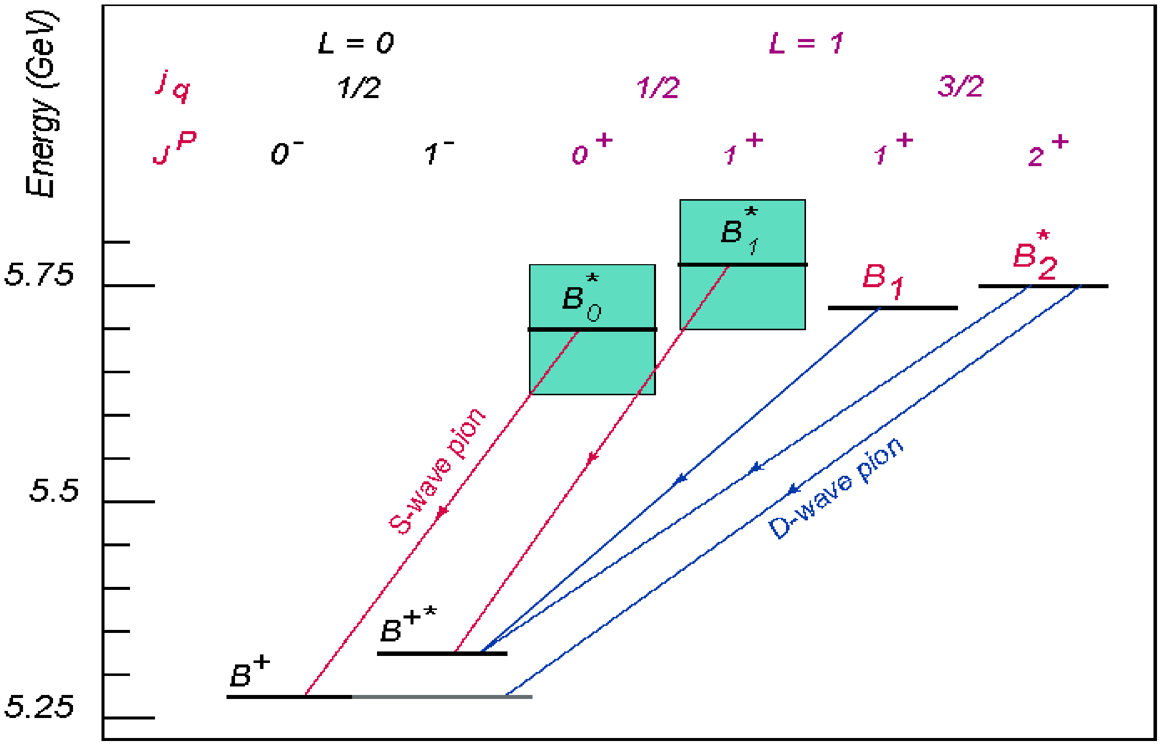


- The two L=1, j_q=½ states are predicted by theory to be very wide (Γ >100 MeV/c²) and so cannot be distinguished from the background (S-wave decay).

- Studies are therefore limited to the observation and measurement of the narrow states $B_{1(s)}$ and $B_2^*{}_{(s)}$, collectively denoted by $B_{J(s)}$.

b-Meson Spectroscopy – Theory (B^{**})

- The two narrow B^{**} states decay by D-wave π release.
- B_1 decays 100% to B^{+*} (Parity/angular momentum conservation).
- B_2^* decays ~50% to B^{+*} and ~50% to B^+ (Theory).
- B^{+*} then decays ~100% to the ground state B^+, emitting a photon γ of energy 45.78 ±0.35 MeV (Well-measured).



Also neutral pion modes ⇒ We need to consider ispspin symmetry.

Charge conjugated states are implied.

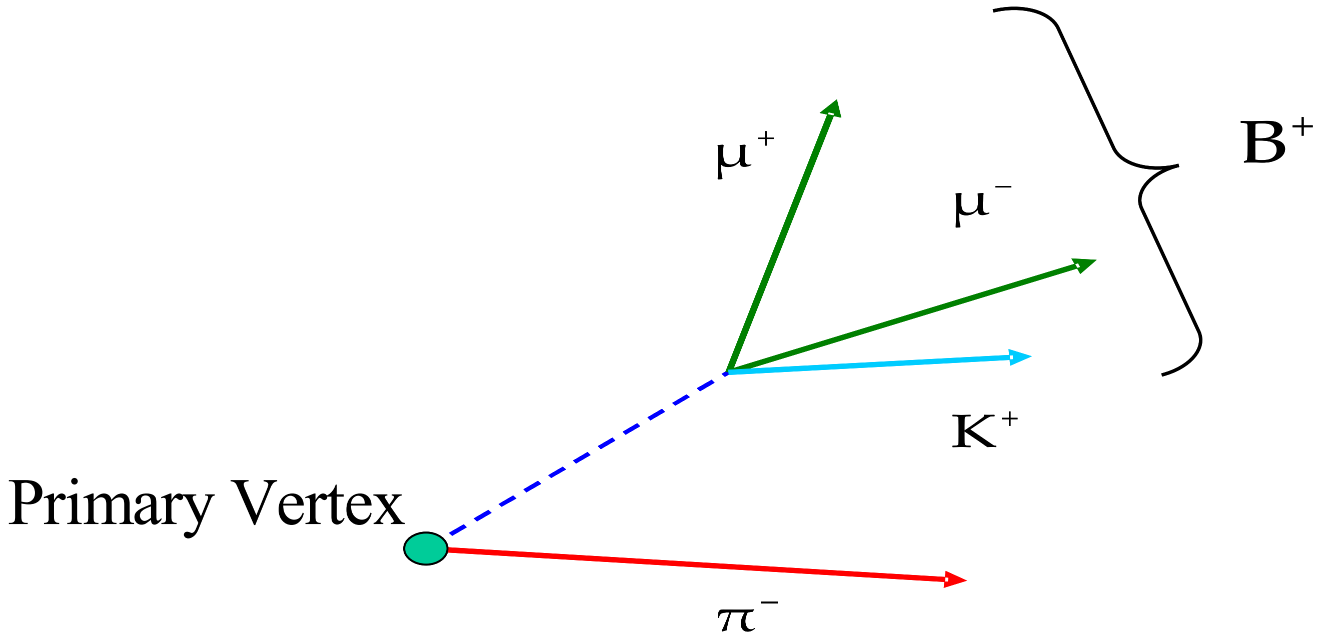
B^{**} Reconstruction and Event Selection

B_J mesons reconstructed through decays:

- $B_J \rightarrow B^{+(*)}\pi^-$
- $B^{*+} \rightarrow B^+\gamma$ (100%) (45.78±0.35 MeV photon undetected)

B^+ reconstructed from final state $K^+\mu^+\mu^-$:

- $B^+ \rightarrow J/\psi\, K^+$
- $J/\psi \rightarrow \mu^+\mu^-$

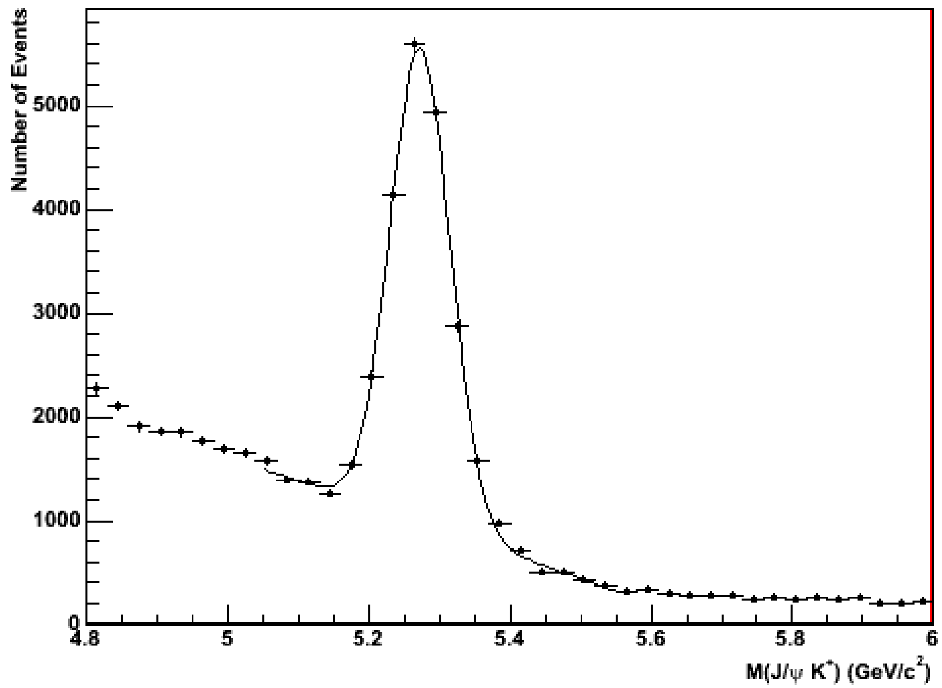


Reconstruction of B^+ Candidates

B^+ mesons are reconstructed in the final state: $B^+ \rightarrow J/\psi K^+$

•Selection: A combined-tag cut on the following variables:

•Impact parameter significance of B^+
•Impact parameter significance of K^+
•Transverse momentum of K^+
•Minimal transverse momentum of the two muons from J/ψ decay.
•Decay length significance of B^+



Fitting with Gaussian (Signal) + second-order polynomial (Background):

- **Reconstructed Mass:** **5273 ± 0.5 MeV/c^2**
- **Mass Resolution:** **42.5 ± 0.5 MeV/c^2**
- **Number of Events:** **16,219 ± 180**

B_J Reconstruction and Selection: B_J events

For each B^+ meson reconstructed, an additional track (π) is required, which must pass the following selection criteria:

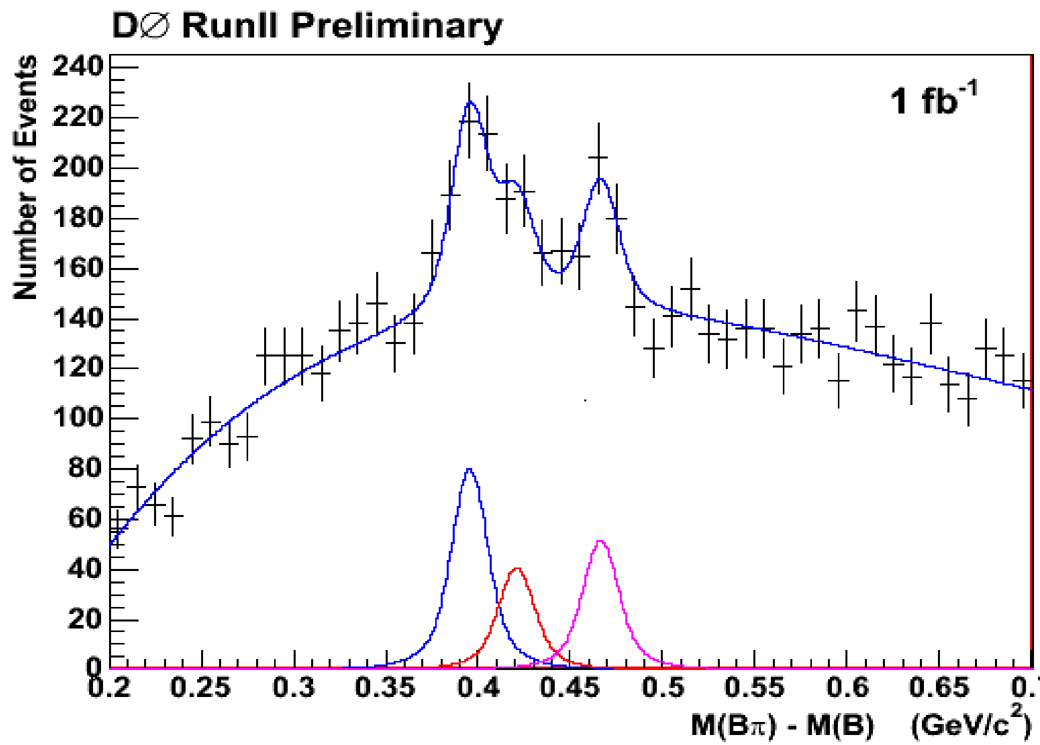
- $\geq$ 2 hits in silicon tracker
- $\geq$ 2 hits in central fiber tracker
- Transverse momentum $\geq$ 0.75 GeV/c
- Correct charge correlation (i.e. $B^+\pi^-$ or $B^-\pi^+$ combinations only)
- 2σ B^+ mass window: $5.19 \leq M(B^+) \leq 5.36$ GeV/c^2
- $S_{PV} \leq \sqrt{6}$ (Impact parameter significance)

For each track in an event satisfying the above selections, the mass difference $\Delta M = M(B^+\pi^-) - M(B^+)$ is computed. The distribution of this variable can then be interpreted in terms of the B^{**} transitions.

B_J Mass Distribution: Fitting

- The signal is fitted by three peaks, each a convolution of a relativistic Breit-Wigner with a double-gaussian mass resolution function.

- Free Signal Parameters:
- $f_2 = Br(B_2^* \rightarrow B^*\pi) / Br(B_2^* \rightarrow B^{(*)}\pi)$
- $f_1 = Br(B_1^* \rightarrow B^*\pi) / Br(B_J \rightarrow B^{(*)}\pi)$
- $N(B^{**})$
- $M(B_1)$
- $\Delta M_{21} = M(B_2^*) - M(B_1)$
- $\Gamma(B^{**}) \equiv \Gamma(B_2^*) = \Gamma(B_1)$

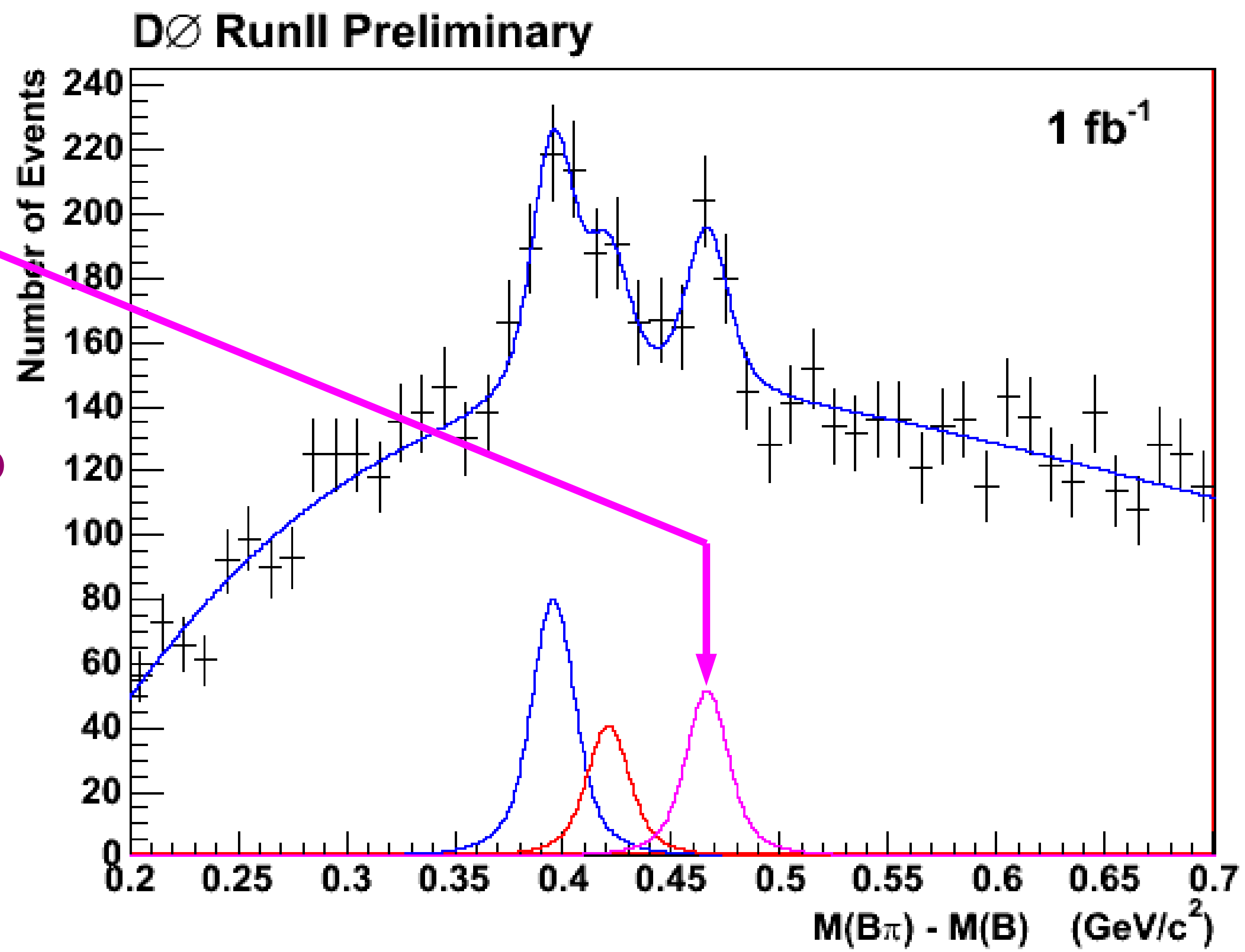


- The background is fitted by a fourth-order polynomial function.

B_J Mass Distribution: Interpretation

$B_2^* \rightarrow B^+\pi^-$ Mass Peak

Highest energy transition, directly to the ground state: no missing energy (γ)



B_J Mass Distribution: Interpretation

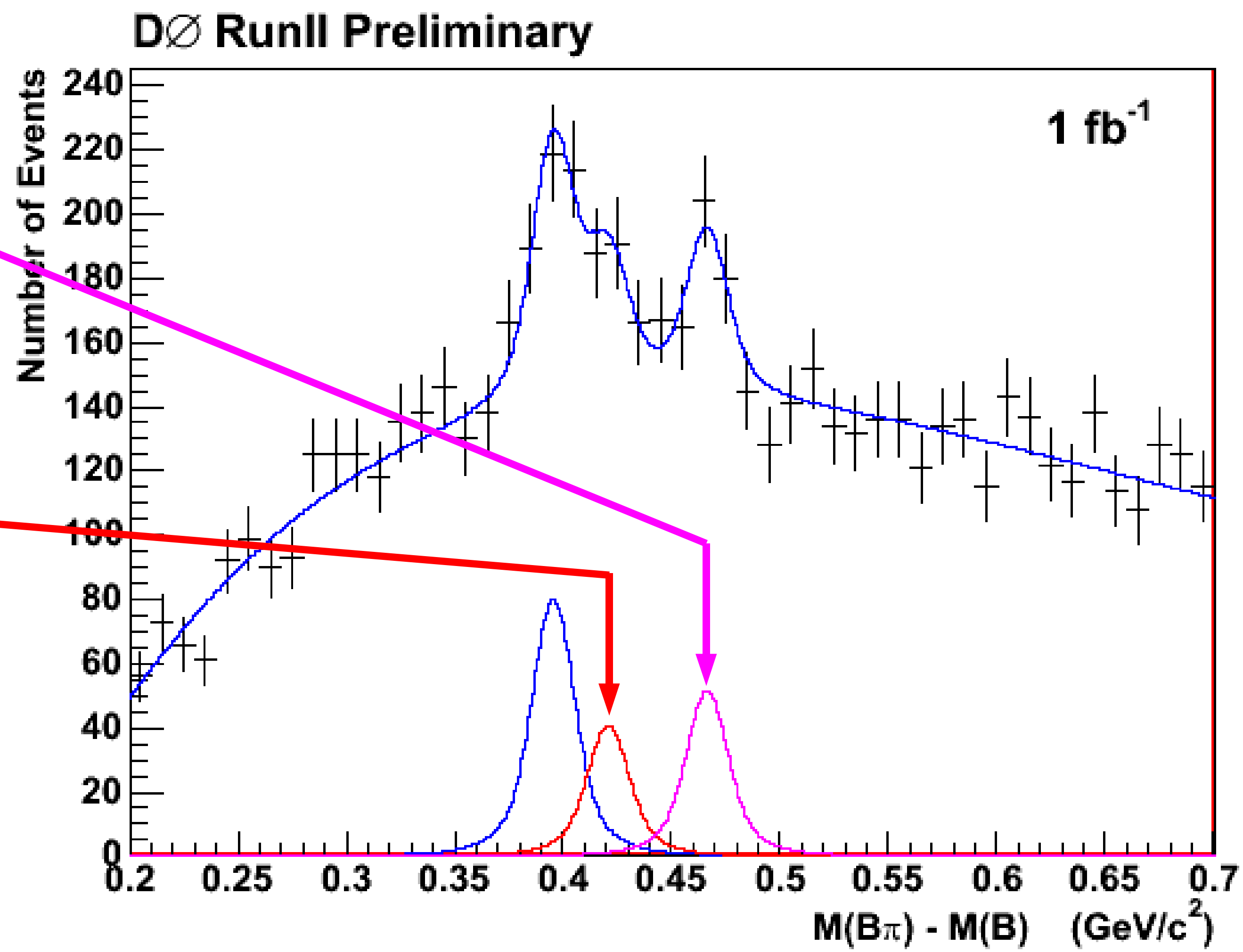
$B_2^* \rightarrow B^+\pi^-$

Mass Peak

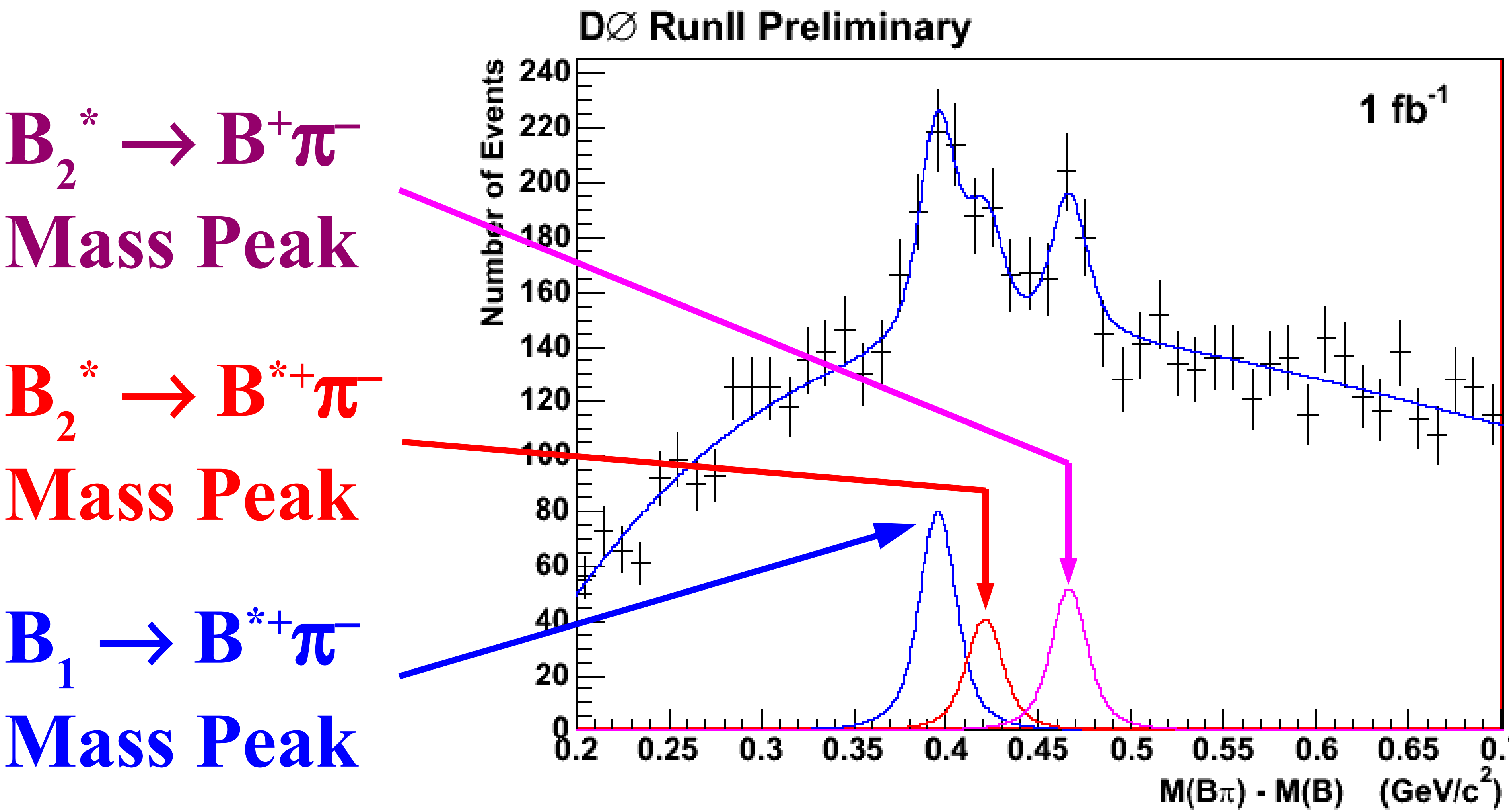
$B_2^* \rightarrow B^{*+}\pi^-$

Mass Peak

Second 'indirect' mass peak separated from direct peak by the photon energy of 45.78 MeV.



B_J Mass Distribution: Interpretation



Single peak for B_1 decays, with 45.78 MeV missing energy. Direct decay forbidden by conservation laws.

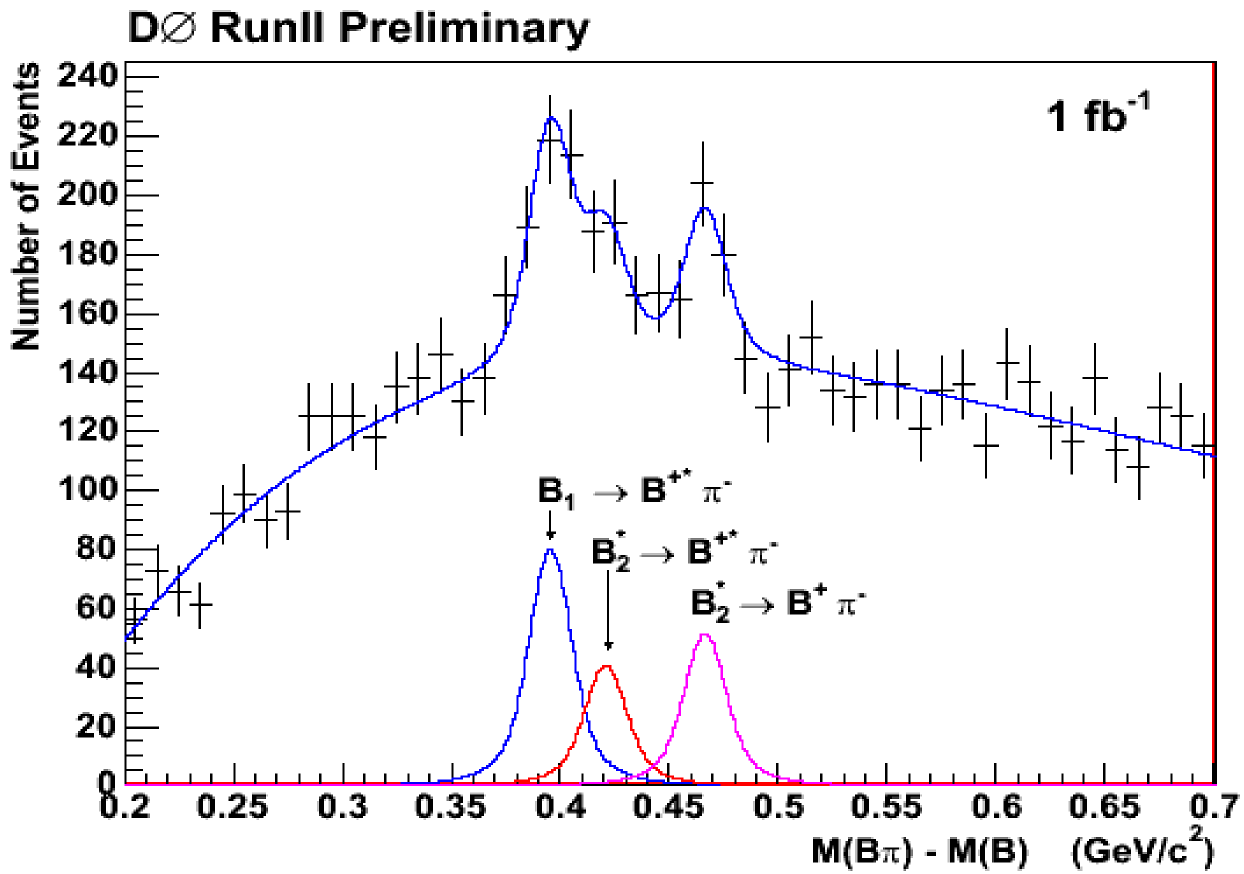
B_J Mass Distribution: Final Fit Results

Fit Parameters:

- $N(B^{**}) = 504 \pm 80$
- $\Delta M_1 = 441.3 \pm 2.5$ MeV/c^2
- $\Delta M_{21} = 25.2 \pm 3.0$ MeV/c^2
- $f1 = 0.464 \pm 0.064$
- $f2 = 0.442 \pm 0.092$
- $\Gamma = 6.55 \pm 5.3$ MeV/c^2

- $\chi^2/NDF = 62.4/79 = 0.90$

Statistical errors only.



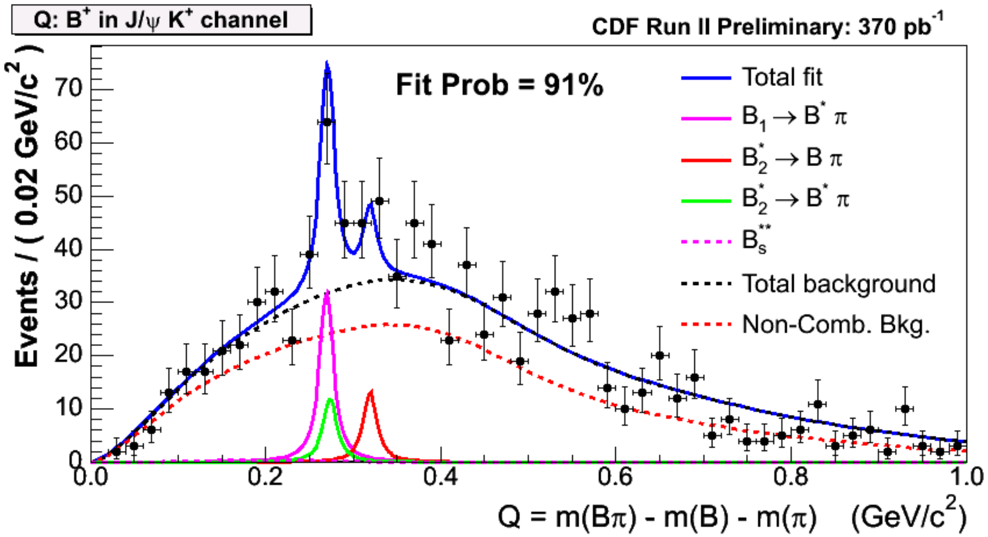
- No B^{**} contribution: $\chi^2 = 142$ (increase of 79 ⇒ ~7σ statistical significance).
- Single B^{**} peak: $\chi^2 = 82$ (increase of 20).

B_J Mass Distribution: Final Results

- Detection efficiencies are energy dependent (P_t selection). Correcting for this effect leads to an upward shift in the fractions f_1 and f_2.
- In addition, masses are corrected to account for the DØ momentum scale uncertainty. (Scaled in proportion to $M(B^+)_{PDG}$ - $M(B^+)_{D0}$, with 100% systematic error assigned to this correction).
- With these shifts included, and systematic errors taken into account:
  - $M(B_1)$ = **5720.8 ± 2.5 (stat) ± 5.3 (syst)** MeV/c^2
  - $M(B_2^*)$ - $M(B_1)$ = **25.2 ± 3.0 (stat) ± 1.1 (syst)** MeV/c^2
  - $\Gamma(B_1) = \Gamma(B_2)$ = **6.6 ± 5.3 (stat) ± 4.2 (syst)** MeV/c^2
- The Branching ratio of B_2^* to the excited state B^* was measured as:
  - $Br(B_2^* \rightarrow B^*\pi) / Br(B_2^* \rightarrow B^{(*)}\pi)$ = **0.513 ± 0.092 (stat) ± 0.115 (syst)**
- The fraction of the B_J sample in the state B_1 was measured as:
  - $Br(B_1^* \rightarrow B^*\pi) / Br(B_J \rightarrow B^{(*)}\pi)$ = **0.545 ± 0.064 (stat) ± 0.071 (syst)**

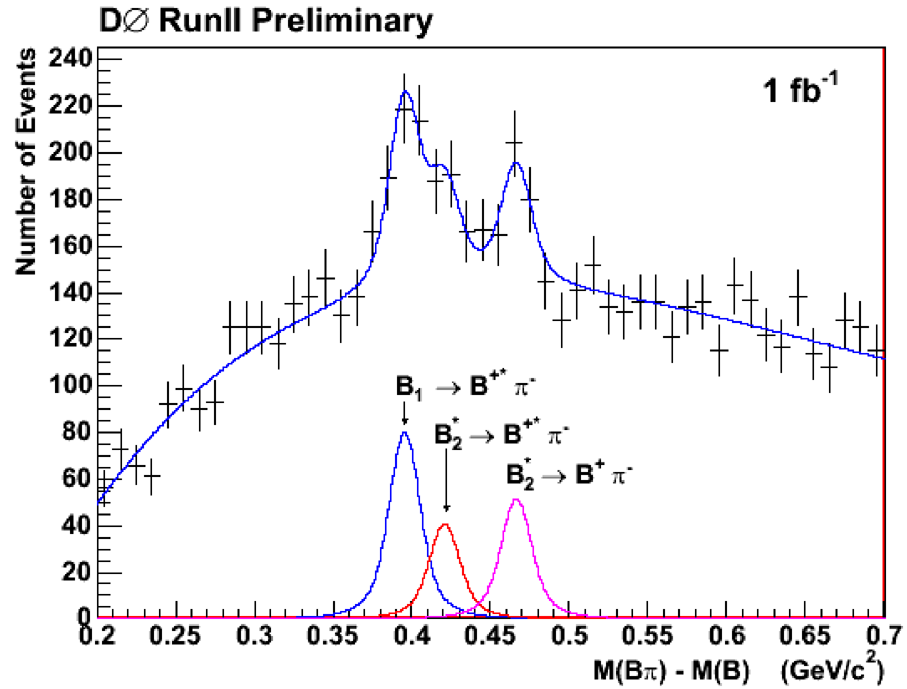
B_J Analysis: Comparison with CDF

CDF (370 pb^{-1})



- CDF make no measurement of branching fractions or production rate.

DØ (1 fb^{-1})



	CDF	DØ
$M(B_1)$ (MeV/c²)	$5734 \pm 3 \pm 2$	$5720.8 \pm 2.5 \pm 5.3$
$M(B_2^*) - M(B_1)$ (MeV/c²)	$4 \pm 5 \pm 1$	$25.2 \pm 3 \pm 1.1$
Γ (MeV/c²)	16 ± 6 (fixed)	$6.6 \pm 5.3 \pm 4.2$

B^{**} Relative Production Rate (1)

From the number of B_J and B^+ events, it is possible to calculate a production rate of the B_J meson relative to the B^+. Efficiencies of detecting each of the three decays were calculated from Monte Carlo simulation:

- $\eta(B_1 \to B^{+*}\pi^-)/\eta(B^+) = 28.2 \pm 0.8$ %
- $\eta(B_2 \to B^{+*}\pi^-)/\eta(B^+) = 30.5 \pm 0.8$ %
- $\eta(B_2 \to B^+\pi^-)/\eta(B^+) = 35.5 \pm 0.8$ %

The MC was reweighted to make the B^+ transverse momentum match that in data, and thus avoid bias from the Pt cuts.

The numbers $N(B^{**})$, $N(B^+)$, f_1 and f_2 are then used to calculate production rates:

- $R(b \to B_1 \to B^{*+}\pi^-) / R(b \to B+) = 6.3 \pm 1.3$ %
- $R(b \to B_2^* \to B^{*+}\pi^-) / R(b \to B+) = 2.5 \pm 0.7$ %
- $R(b \to B_2^* \to B^+\pi^-) / R(b \to B+) = 2.2 \pm 0.6$ %

- Combined Rate: $R(b \to B_J \to B^{(*)+}\pi^-) / R(b \to B+) = 11.0 \pm 1.6$ %

B^{**} Relative Production Rate (2)

Including $B^{**} \rightarrow B^0\pi^0$ decays, a factor 3/2 is included (Isospin symmetry)

There are also systematic errors:

Source	**Systematic Error**
N(B**) Uncertainty	2.3%
N(B+) Uncertainty	0.1%
Reweighting Error	0.7%
Uncertainty in Resolution in MC	1.5%
Pion Reconstruction Efficiency Uncertainty	0.4%
Total	2.8%

The final value for the relative production rates of B_J versus B^+ is then:

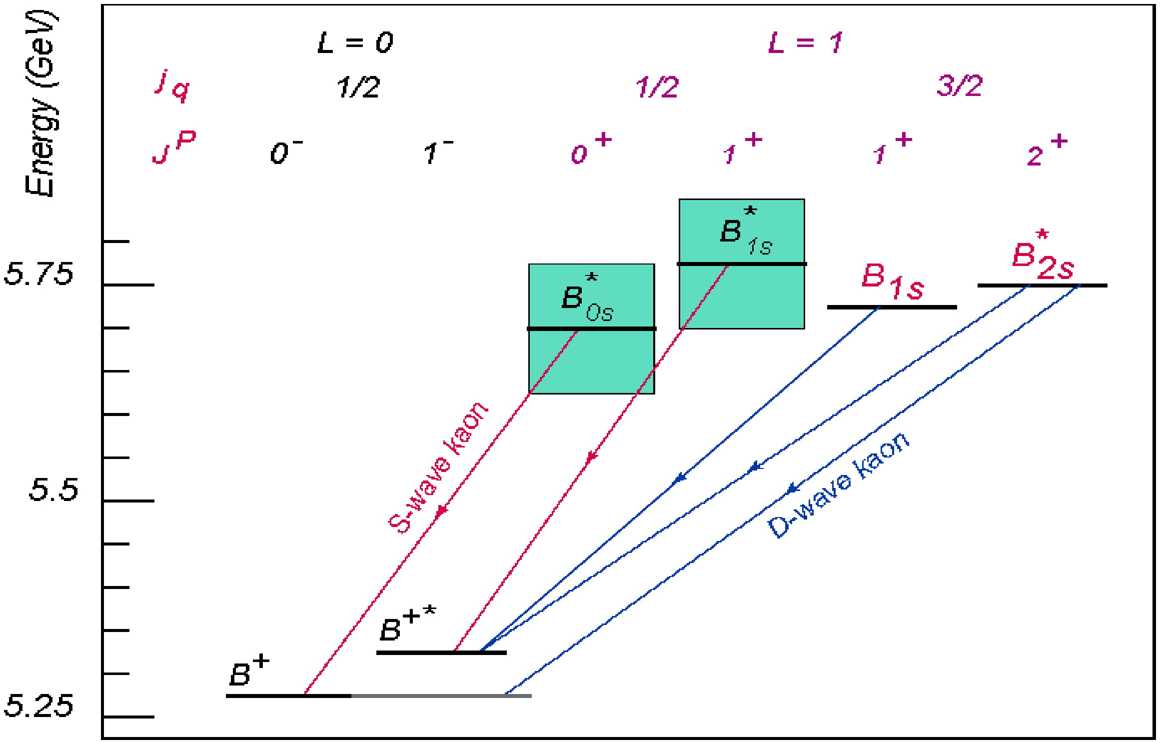
- **$R(b \rightarrow B_J \rightarrow B^{(*)}\pi) / R(b \rightarrow B+) = 16.5 \pm 2.4\ (stat) \pm 2.8\ (syst)\%$**

Part B: The B_s^{**} System

- **Masses, Widths, Branching Fractions**

B_s^{**} Reconstruction and Selection

- Same four-level structure as B^{**} system.
- Pion decay prohibited, so B_s^{**} de-excite to $B^{+(*)}$ through kaon decay.
- Two L=0, j_q=½ states decay through S-wave so cannot be observed currently.



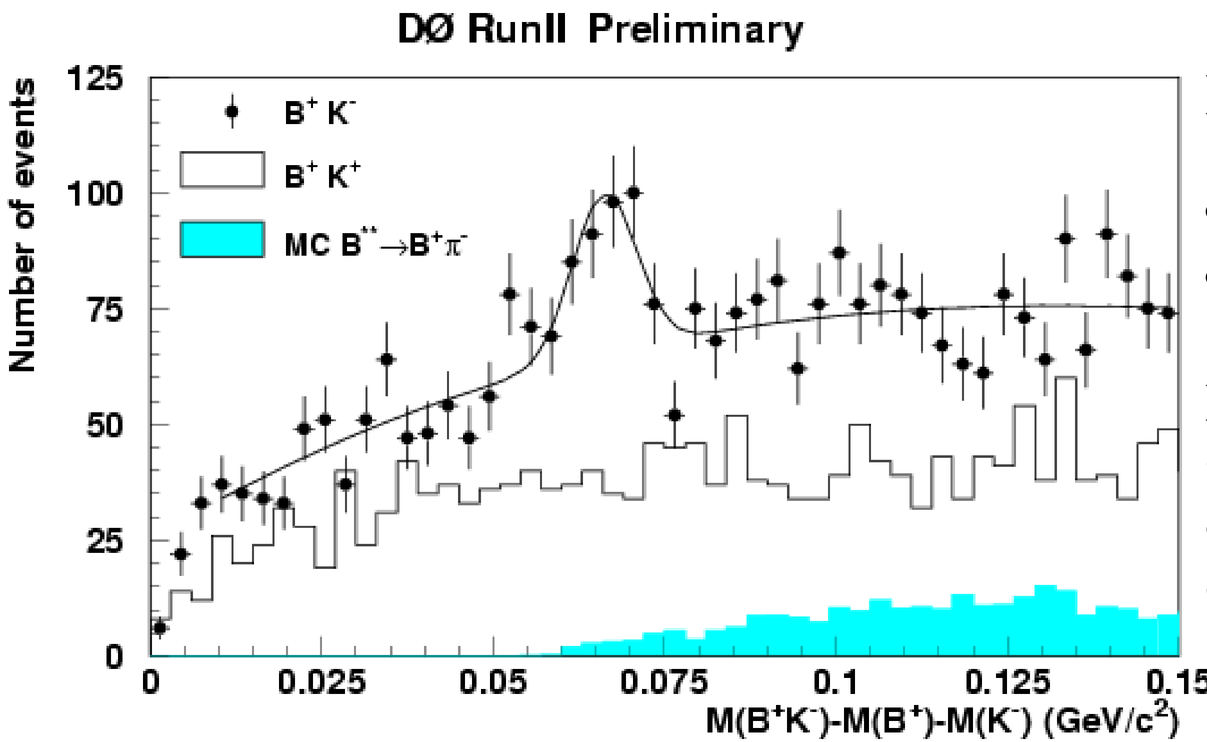
Selection: Same as B^{**} except...

- Additional track is assigned the mass of a kaon, not a pion.
- Transverse momentum ≥ 0.60 GeV/c (0.75 GeV/c for the B_J analysis)

Mass Difference $\Delta M = M(B^+K^-) - M(B^+) - M(K^-)$ is then plotted to look for B_s^{**} transitions.

B_s^{**} Mass Distribution: Final Fit

Single peak observed. Fit is Gaussian (Signal) + polynomial (Background)



Fit Parameters:

- $\Delta M = 66.4 \pm 1.3 \pm 1.0$ MeV/c^2
- $\sigma = 4.7 \pm 1.5$ MeV/c^2

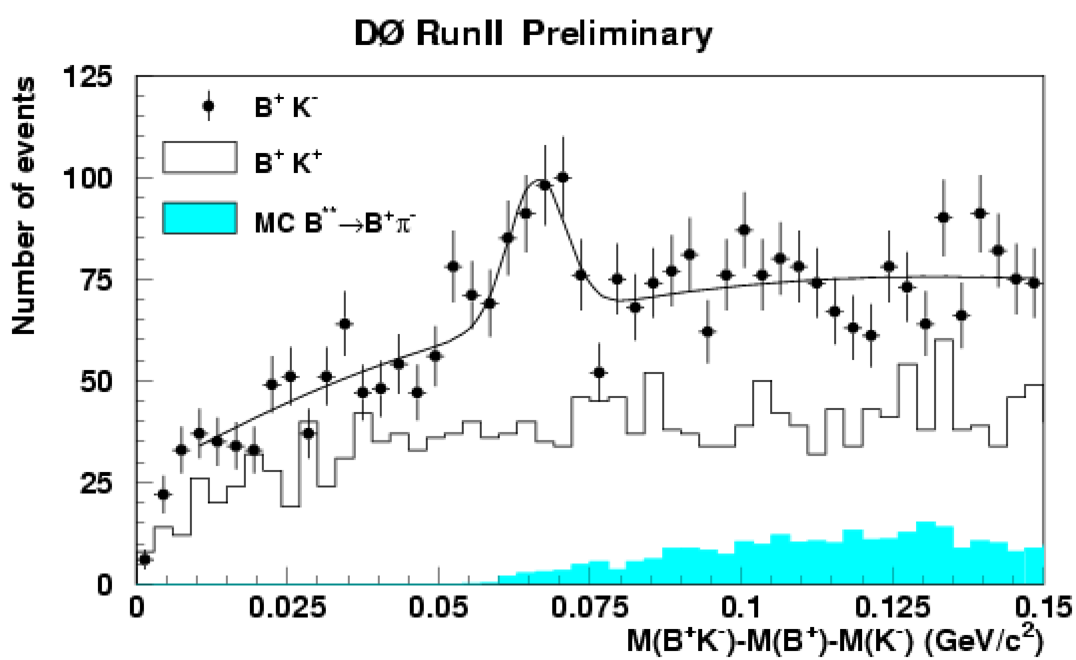
Here σ is the width of the Gaussian. The physical width of the state has not been extracted.

Without the B_{sJ} signal contribution: χ^2 increases by ~36 (>5σ statistical significance).

B_{sJ} Mass Distribution: Interpretation

Only one peak is observed in the B_s^{**} mass distribution. For the B^{**} system there were three peaks corresponding to:

- $B_1 \rightarrow B^{+*}\pi^-$ $M(B\pi) - M(B) = 395.5\ \mathrm{MeV}/c^2$
- $B_2^* \rightarrow B^{+*}\pi^-$ $420.8\ \mathrm{MeV}/c^2$
- $B_2^* \rightarrow B^+\pi^-$ $466.6\ \mathrm{MeV}/c^2$



The observed peak in the B^+K^- mass distribution is interpreted as the decay:

- $B_{s2}^* \rightarrow B^+K^-$
  $M(BK) - M(B) = 66.4\ \mathrm{MeV}/c^2$

Why don't we observe the other two decays?

Why don't we see $B_{s2}^{*} \rightarrow B^{+*}K^{-}$ decay?

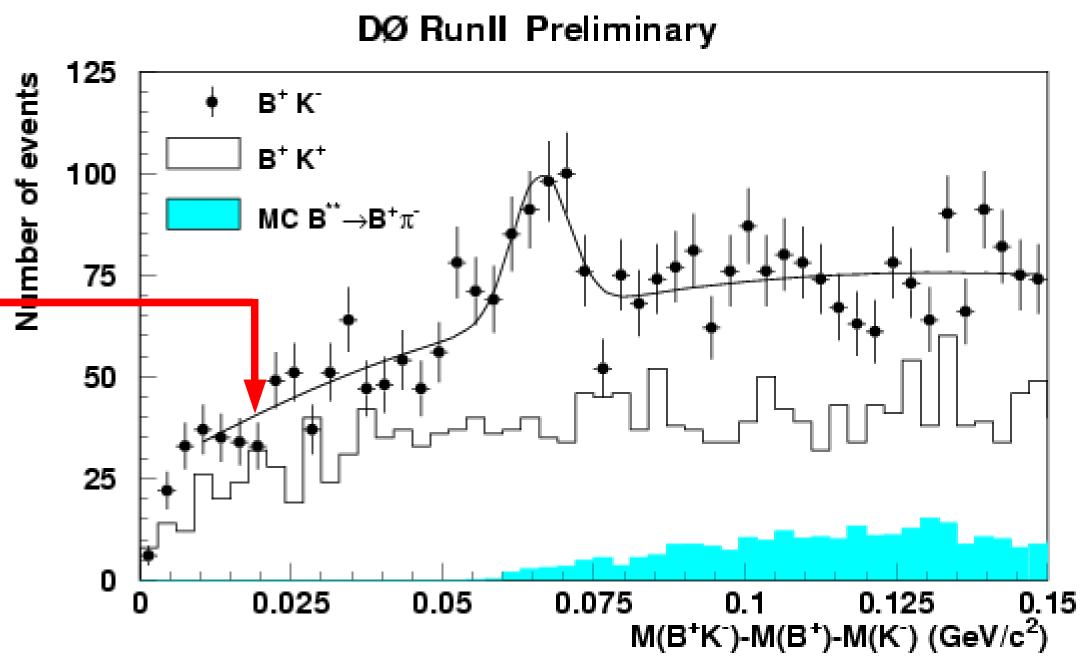
- We observe the decay to the ground state $B_{s2}^{*} \rightarrow B^{+}K^{-}$. According to theory, B_{s2}^{*} is also allowed to decay to B^{+*} with equal probability.

- This decay would lead to a second peak observed at $\Delta M \approx 66.4 - 45.78 \approx 20$ MeV/c^2.

- Interpretation A: This small mass difference leads to kinematic suppression (Plus P_t selection) - resulting in the decay rate for $B_{s2}^{*} \rightarrow B^{+*}K^{-}$ being too small to observe.

- Interpretation B: The background variations hide the $B_{s2}^{*} \rightarrow B^{*+}K^{-}$ signal – need more background studies.

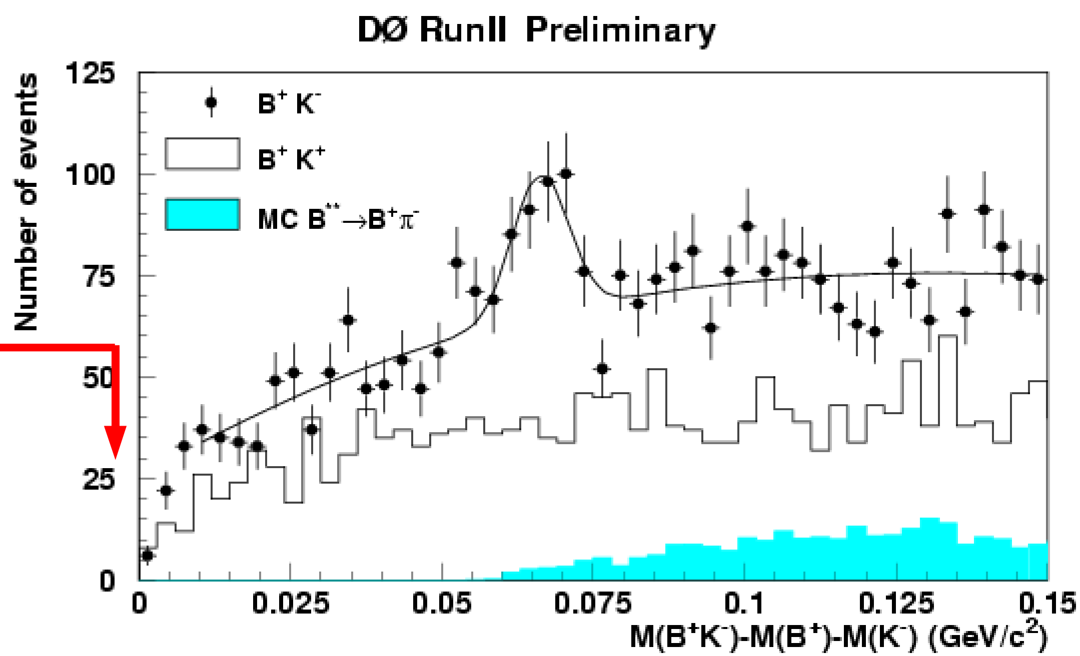
Expected position of $B_{s2}^{*} \rightarrow B^{+*}K^{-}$ mass peak.



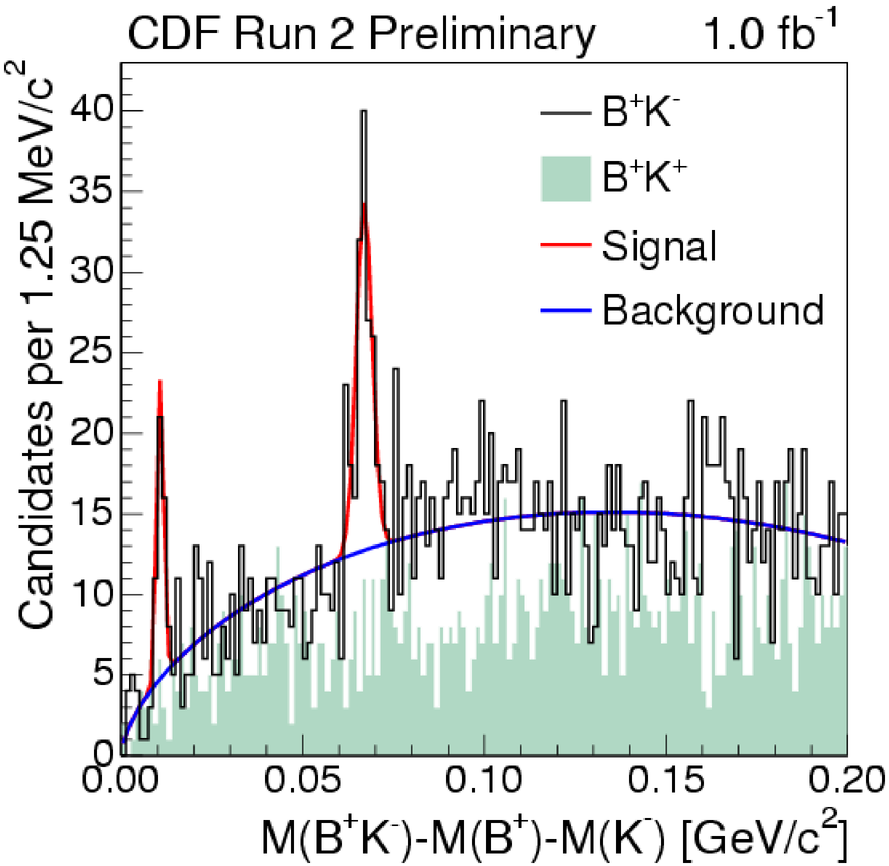
Why don't we see the B_{s1} state?

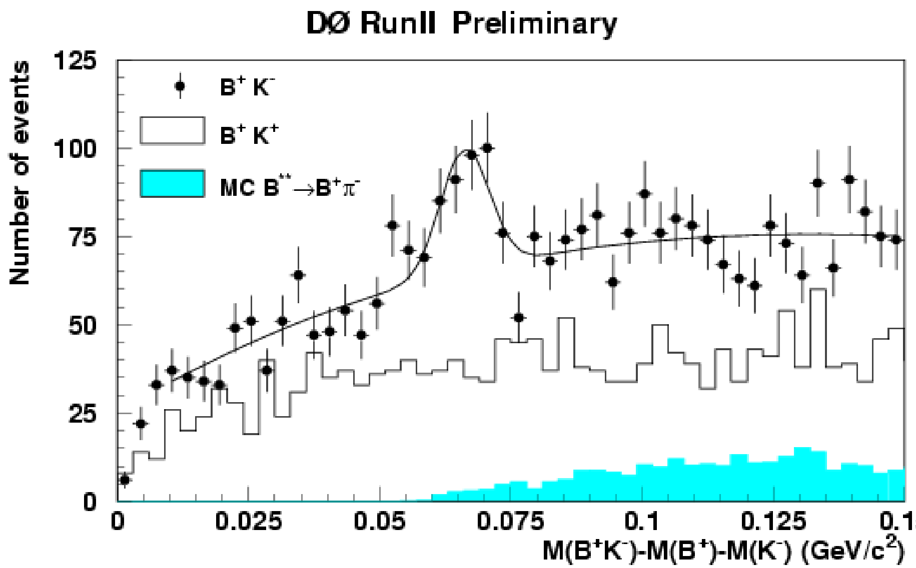
- In the B_d^{**} system: $M(B_2^*) - M(B_1) = 25.2$ MeV/c^2.
- Assuming the same mass splitting in the B_s^{**} system: $M(B_{s1}) \approx 5813$ MeV/c^2.
- In this case, the decay is kinematically forbidden since $M(B_{s1}) < M(B^{*+}) + M(K^+) \approx$ 5819 MeV/c^2. This can explain the absence of the B_{s1} meson in the ΔM distribution.

$B_{s1} \rightarrow B^{+*}K^-$ mass peak expected position.
i.e. forbidden by energy conservation.



B_s^{**} - Do CDF and DØ agree this time?





(MeV/c^2)	CDF	DØ
M(B_{s1})	$5829.4 \pm 0.2 \pm 0.6$	Not Observed
M(B_{s2}^*)	$5839.6 \pm 0.4 \pm 0.5$	$5839.1 \pm 1.4 \pm 1.5$
M(B^*_{s2}) - M(B_{s1})	$10.20 \pm 0.44 \pm 0.35$	N/A

Part C:

First Measurement of the B^0_s Semileptonic Branching Ratio to an Orbitally Excited D_s^{**} state: $Br(B^0_s \rightarrow D^-_{s1}(2536)\mu^+\nu X)$

B_s Decay through a D_s^{**} State: Theory

$B_s \rightarrow D^+_{s1}(2536)\mu^-\nu$

$D^+_{s1} \rightarrow D^{+*}K_s(\pi^+\pi^-)$

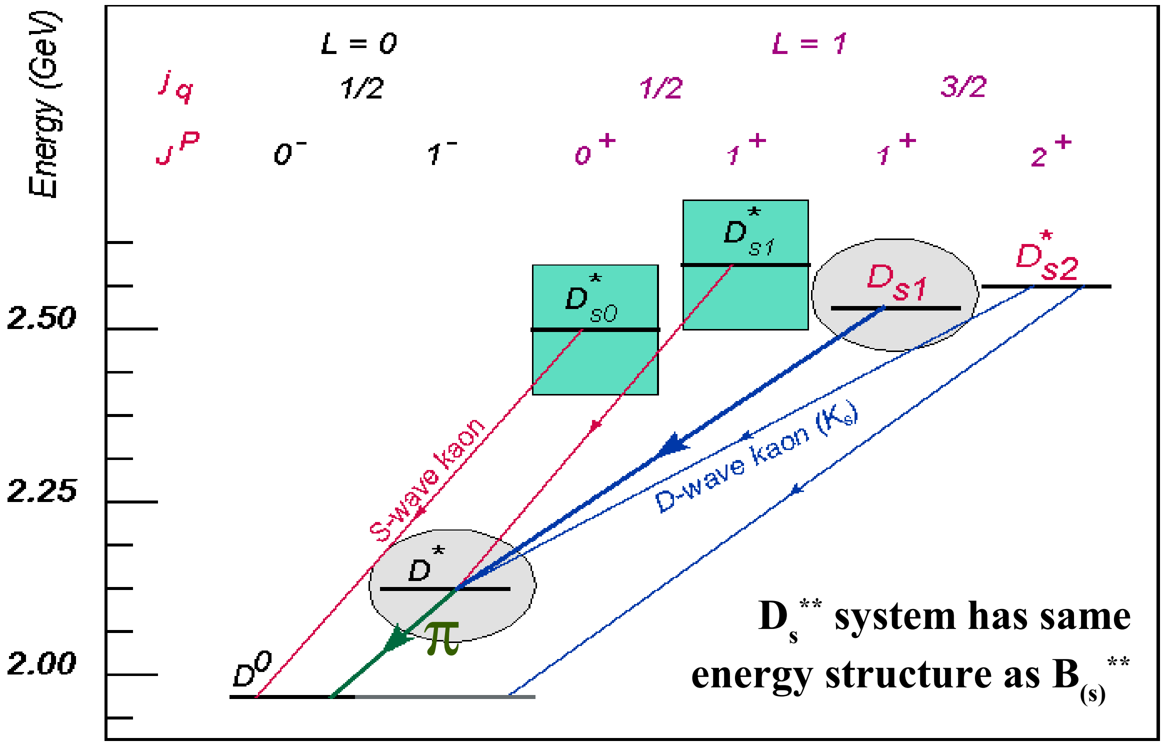
$D^{+*} \rightarrow D^0\pi^+$

$D^0 \rightarrow K\pi$

Important for testing HQET since the semileptonic decay to the heavy excited state is in phase space close to zero recoil, where most of the correction occurs.

Significant fraction of B_s^0 semileptonic decays, making it important for:

- **Comparing inclusive/exclusive decay rates.**
- **Extracting CKM matrix elements.**
- **Using semileptonic decays in B_s^0 mixing.**



D_s^{**} system has same energy structure as $B_{(s)}^{**}$

$B_s \rightarrow D_{s1}(2536)$: Branching Ratio Calculation

We determine our branching ratio...

...by normalising to the known value of $(2.75 \pm 0.19)\%$

$$Br(B_s^0 \rightarrow D_{s1}(2536)\mu\nu X) * Br(D_{s1}(2536) \rightarrow D^{*-}K_s^0) * f(b \rightarrow B_s^0) = Br(b \rightarrow D^{*-}l^+\nu X) * N(D_{s1}) / N(D^*\mu) * 1 / (R^{gen}_{D^*})(\varepsilon_{K_s^0})$$

Fraction of times the b quark will hadronise to $B_s = 0.107 \pm 0.011$

After re-weighting D_s^{**} Monte Carlo to match data, the ratio of (D^* with K_s^0) versus total D^* events is calculated.
This gives the efficiency $\varepsilon_{K_s^0}$ of reconstructing a D_{s1} once a $D^*\mu$ candidate is found:
$\varepsilon_{K_s^0} = 11.1 \pm 0.3\%$.

$B_s \to D_{s1}(2536)$: Branching Ratio Calculation

We determine our branching ratio...

...by normalising to the known value of $(2.75 \pm 0.19)\%$

$$Br(B_s^0 \to D_{s1}(2536)\mu\nu X) * Br(D_{s1}(2536) \to D^{*-}K_s^0) * f(b \to B_s^0) = Br(b \to D^{*-}l^+\nu X) * N(D_{s1}) / N(D^*\mu) * 1 / (R^{gen}_{D^*})(\varepsilon_{K_s^0})$$

Monte Carlo was used to look at all major decays to D^* ($B_d^0 \to D^*\mu\nu$, $B_d^0 \to D^{**0}\mu\nu$, $B^+ \to D^{**+}\mu\nu$, $B_s^0 \to D^*\mu\nu$). In each case the P_t spectra were re-weighted to match D_s^{**} P_t. Efficiencies for all decay channels were combined and determined to be:

- $\varepsilon(b \to D^*\mu X) = (6.08 \pm 0.5)\%$

Using same cuts for reconstructed $D^*\mu$ in signal MC, efficiency was found to be:

- $\varepsilon(B_s^0 \to D_{s1}(2536)\mu \to D^*\mu) = (3.64 \pm 0.02)\%$

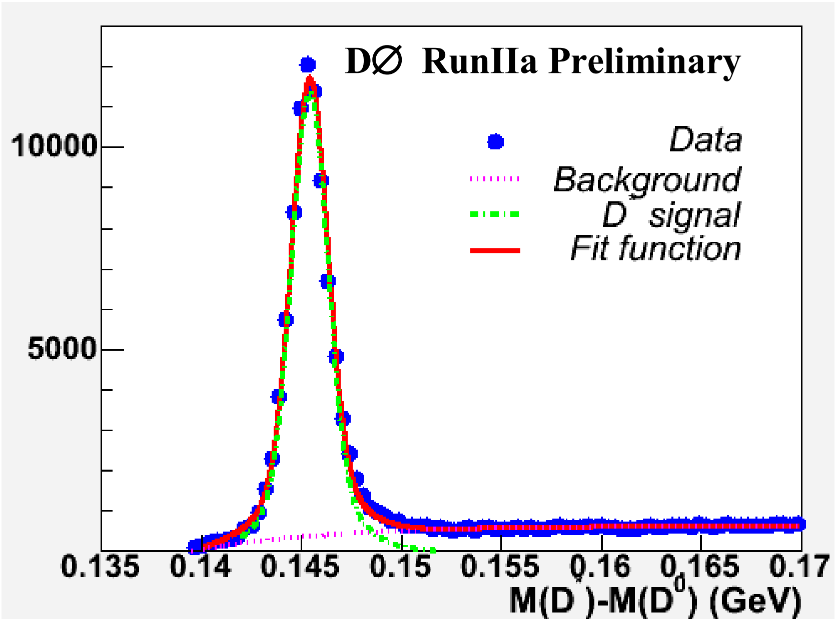
The ratio of efficiencies is then:

- $R^{gen}_{D^*} = 0.600 \pm 0.049$

$B_s \rightarrow D_{s1}(2536)$: Event Selection and Fitting

D^* Selection:

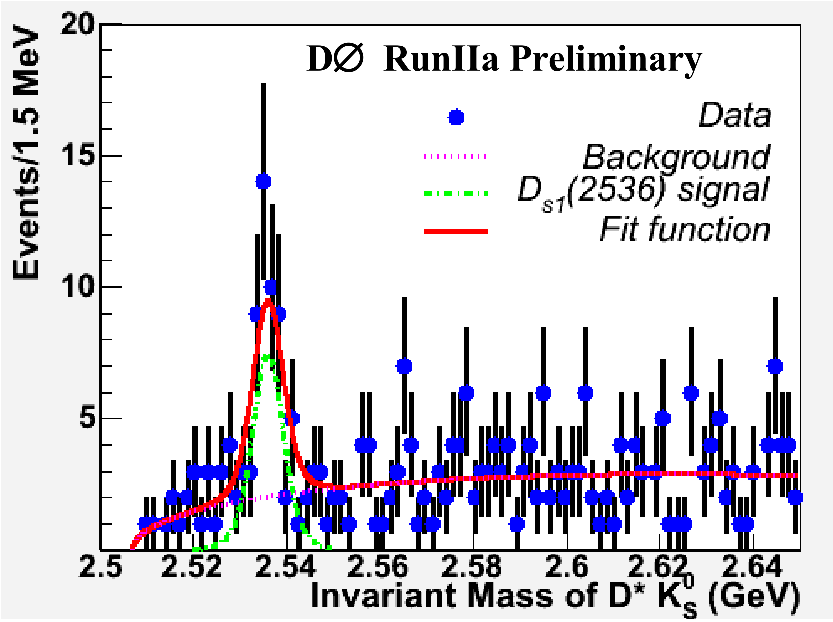
- Require D^0 and μ in event.
- Additional π with $P_t > 0.18$ GeV/c.
- $1.75 < M(D^0) < 1.95$ GeV/c^2.
- Track quality constraints (# Hits).
- Signal Fit: Double Gaussian.
- BG Fit: Exp + Poly with threshold cut-off.



$N(D^*) = 82130 \pm 463$
$N(D_s^{**}) = 43.8 \pm 8.3$

D_s^{**} Selection:

- Require D^* and K_s.
- $1.80 < M(D^0) < 1.95$ GeV/c^2.
- $0.142 < M(D^*)-M(D^0) < 0.149$ GeV/c^2.
- $P_t(K_s) > 1.0$ GeV/c.
- Decay length $(K_s) > 0.5$ cm.
- μ-D^{**} vertex has mass $< M(B_s)$.
- Signal Fit: Double Gaussian.
- BG Fit: Exp + Sqrt with threshold cut-off.



$B_s \rightarrow D_{s1}(2536)$: Results and Interpretation

Putting all the numbers together:

$$Br(B_s^0 \rightarrow D_{s1}(2536)\mu\nu X)Br(D_{s1}(2536) \rightarrow D^{*-}K_s^0)f(b \rightarrow B_s^0) =$$

$$(2.29 \pm 0.43\ (stat) \pm 0.36\ (syst))\ x\ 10^{-4}$$

How does this compare with theory?

Using $f(b \rightarrow B_s^0) = 0.107 \pm 0.011$

And ***assuming*** $Br(D_{s1}(2536) \rightarrow D^{*-}K_s^0) = 0.25$ **We obtain:**

Source	$Br(B_s^0 \rightarrow D_{s1}(2536)\mu\nu)$
This Result	(0.86±0.16(stat.)±0.13(syst)±0.09(prod. frac.))%
ISGW2	0.53%
RQM	0.39%
HQET & QCD sum rules	0.195%

Summary: Meson Spectroscopy at DØ

- Excited B spectroscopy was pioneered at LEP in the 90s. Now for the first time, hadron-colliding experiments have begun to probe these systems, making new measurements and improving on old ones.
- CDF and DØ show some agreement in their analyses, but also many conflicting observations. Clearly more data is required in order to understand the origins of these differences and converge on the true physical values.

- Now we're also starting to probe the excited D-states through B_s decays. This looks to be a fruitful source of B_s mesons for future measurements, as well as providing comparison with the $B_{(s)}^{**}$ systems.

Extra Slides:

- B^{**} Fitting Details.
- B^{**} Systematic Errors.
- B^{**} Mass Resolution Measurement.
- $B_s^0 \rightarrow D_s^{**}(2536)\mu\nu$ Systematic Errors.

B_J Mass Distribution: Fitting Function

Distribution of ΔM fitted by:

$$F(\Delta M) = F_{sig}(\Delta M) + F_{back}(\Delta M)$$

$$\begin{aligned} F_{sig}(\Delta M) = N\{ & f_1.G(\Delta M, E_1, \Gamma_1) && B_1 \to B^{+*} \\ & + (1-f_1).f_2.G(\Delta M, E_2, \Gamma_2) && B_2^* \to B^{+*} \\ & + (1-f_1).(1-f_2).G(\Delta M, E_3, \Gamma_2)\} && B_2^* \to B^{+} \end{aligned}$$

- The function $G(\Delta M, E, \Gamma)$ is the convolution of a relativistic Breit-Wigner function with the experimental resolution in ΔM. Monte Carlo studies show this resolution to be well parameterized by a double-Gaussian function.
- Γ is the mass width of the state, and 'E' is the energy of the transition.
- The parameters f_1 and f_2 are fractions: f_1 is the proportion of the B_J sample in the state B_1; f_2 is the branching decay ratio of $B_2^* \to B^*$.
- N is the total number of events in the signal.
- Background is parameterized by a 4th order polynomial.

B_J Mass Distribution: Fitting Procedure

Constraints:

- $\Gamma_1 = \Gamma_2 \equiv \Gamma$ *(Predicted to be very close by all theoretical models)*
- $M(B^*) - M(B^+) = 45.78$ MeV/c^2 *(Well-measured experimentally)*
- Mass Resolution parameters fixed from MC studies:
  - σ(wide) = 22.5 ± 5 MeV/c^2
  - σ(narrow) = 8.0 ± 0.3 MeV/c^2

Free Parameters:

- $\Delta M_1 = M(B_1) - M(B^+)$
- $\Delta M_{21} = M(B_2^*) - M(B_1)$
- Γ
- f_1 (Polarisation of initial B_J sample)
- f_2 (Decay Branching Fraction $B_2^* \rightarrow B^*$)
- N (Total number of B_J events in signal)
- Background polynomial coefficients (p0 → p4)

With these free parameters, a χ^2 fit was performed over the ΔM distribution.

B_J Mass Distribution: Systematic Errors

The effect of various sources of systematic error were measured:

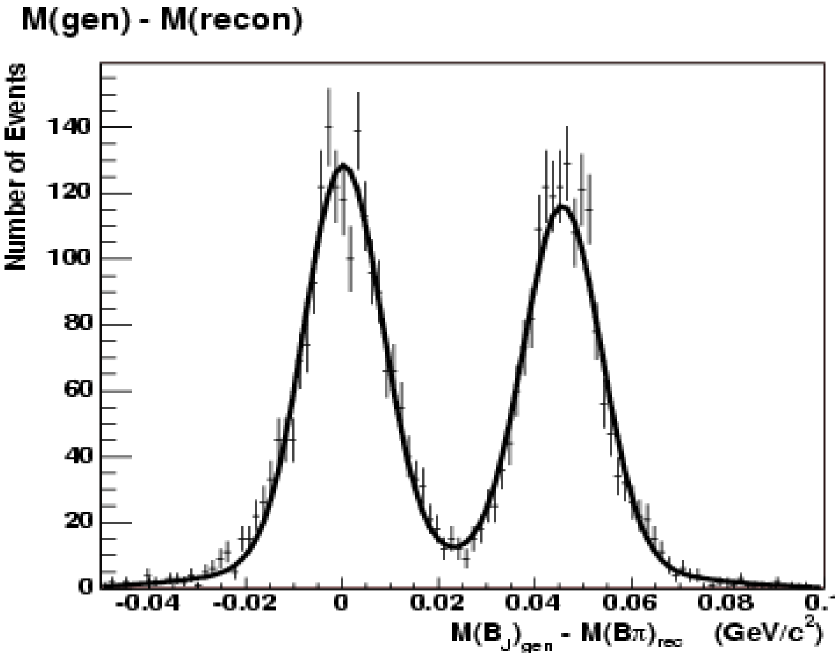
Source	dM(B_1) (MeV/c^2)	dM21 (MeV/c^2)	dΓ($M\varepsilon\varsigma/\chi^2$)	df1	df2	dN
BG Parameterization	0.8	0.3	**3.4**	0.012	0.01	**64**
Fitting Range	0.2	0.2	1.0	0.008	0.01	22
Rebinning	**5.2**	**0.9**	0	**0.069**	**0.114**	18
No Constraint $\Gamma_1 = \Gamma_2$	0.2	0.1	2.1	0	0	2
B* Mass Uncertainty	0.3	0.2	0.04	0.002	0.002	0
Mass Resolution Uncertainty	0.2	0.3	0.75	0.007	0.007	10
Momentum Scale Uncertainty	0.5	0.003	0	0	0	0
Total	**5.30**	**1.04**	**4.2**	**0.071**	**0.115**	**71**

B^{**} Mass Resolution Measurement

To measure the experimental resolution of the variable $\Delta M = M(B_J) - M(B^+)$, Monte Carlo data was used to plot the distribution of $\Delta M_{gen} - \Delta M_{reco}$.

Double-Gaussian Peak Fit:

- **Width(wide) = 22.5 ± 5 MeV/c^2**
- **Width(narrow) = 8.0 ± 0.3 MeV/c^2**
- **N(narrow)/N(wide) = 5.89 ± 1.8**
- **χ^2/ndf = 89/83 = 1.07**

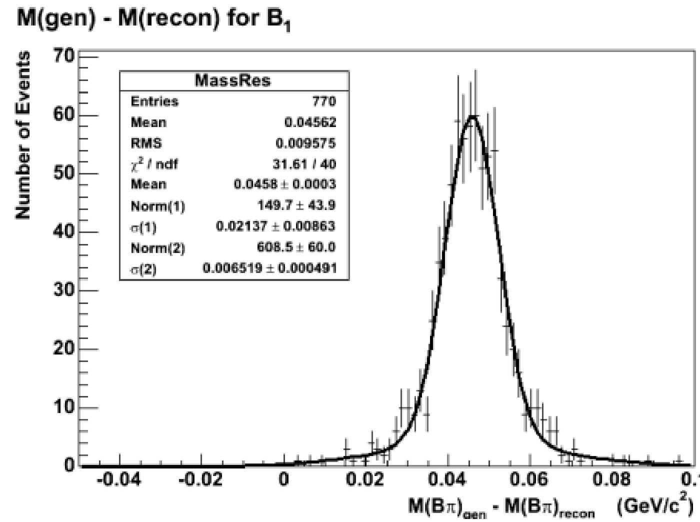


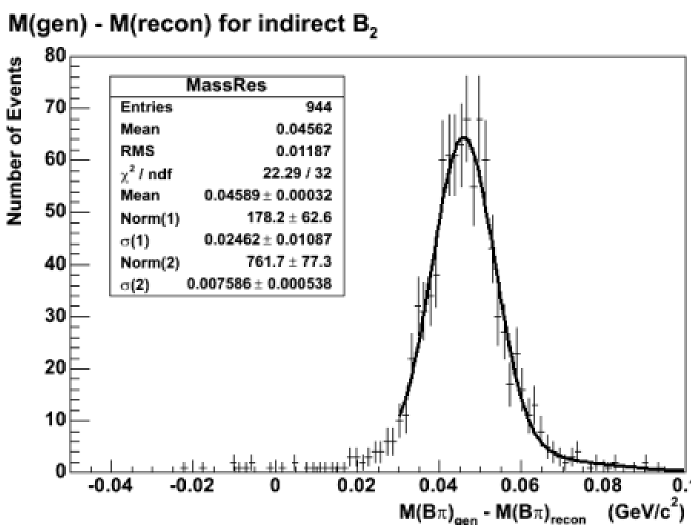
•Two-peak distribution arises because of the missing energy from the unreconstructed photon in all decays via B*. Position of displaced peak is consistent with photon energy of 45.8 MeV
•Single Gaussian Fit returns **χ^2/ndf = 156.7/95 = 1.65**

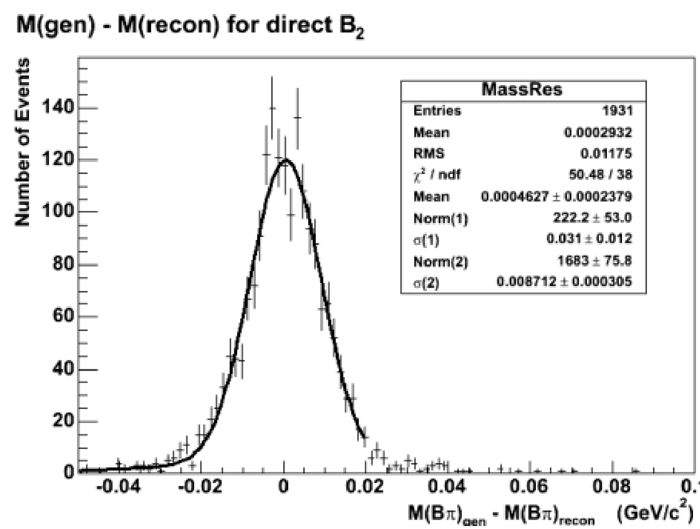
B^{**} Mass Resolution Measurements (2)

Mass Resolution plots.

- Right: $B_1 \to B^{+*}\pi^-$
- Below Right: $B_2 \to B^+\pi^-$
- Below: $B_2 \to B^{+*}\pi^-$







$B_s \to D_{s1}(2536)$: Systematic Errors (1)

The effect of various sources of systematic error were measured:

Source		Systematic error
Normalizing Br	$Br(b \to D^{*}\mu X)$	6.9%
$N(D^{*}\mu)$	Signal Modeling	0.5%
	Background Modeling	1.3%
	ccbar Contribution	2.7%
$N(D_{s1}(2536))$	Signal Modeling	3.0%
	Background Modeling	4.6%
ε_{Ks}	MC Statistics	2.8%
	Semileptonic decay model	1.2%
	Weighting Procedure	2.4%
	Detector Modeling	4.0%
$R^{gen}_{D^*}$	MC stats, PDG Br, and f uncertainties	8.2%
	Weighting Procedure	7.4%
	Semileptonic Decay Model	0.9%

$B_s \to D_{s1}(2536)$: Systematic Errors (2)

- With decay length significance cut, **ccbar contamination** estimate at $3.9 \pm 2.5\%$ - Consistent with zero, but large error (used full error as systematic).
- **Varying signal model:**
  - $N(D^*)$ - fit with both double and triple Gaussian
  - $N(D_s^{**})$ - fit with both single and double Gaussian
- **Varying Background model:**
  - $N(D^*)$ - fit with exponential alone and exponential plus square root function.
  - $N(D_s^{**})$ - fit with exponential plus polynomial.