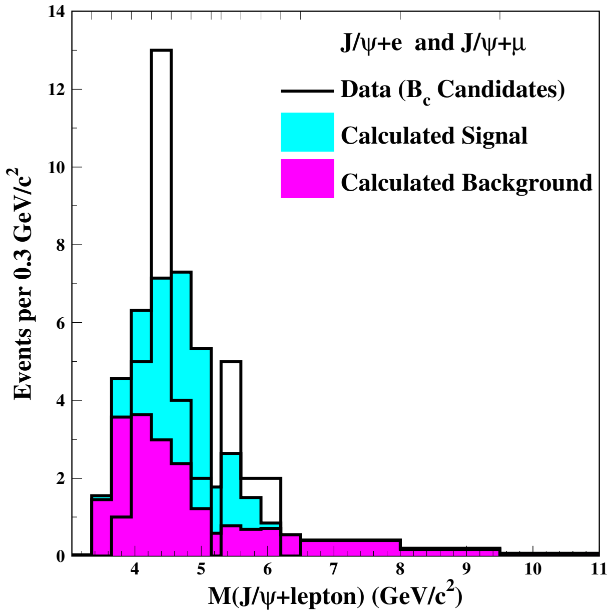
EVIDENCE FOR THE EXCLUSIVE DECAY $B_c \to J/\psi\pi$

Peter Bussey, Saverio D'Auria, Ludovic Nicolas, Vaia Papadimitriou, Mario Spezziga
(Glasgow, FNAL, Texas Tech)
+ CDF COLLABORATION

Why study the B_c?

- Although the state has probably been seen, it has not yet been fully characterised experimentally.
- As an entirely "heavy quark" state, its properties can be predicted theoretically better than lighter states.
- In particular there are precise lattice gauge predictions of its mass.
- Its production rate may be able to shed light on fragmentation mechanisms.

Seen so far by CDF and D0 in J/ψ + lepton + X (3-lepton final state)



CDF Run I:

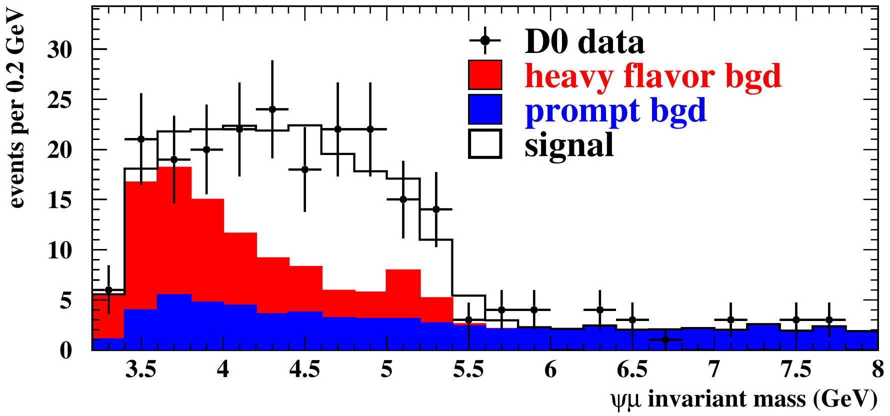
$20.4^{+6.2}_{-5.5}$ signal events.

110 pb^{-1} data.

Lifetime: $0.46^{+0.18}_{-0.16} \pm 0.03$ ps

Mass: $6.4 \pm 0.39 \pm 0.13$ GeV/c^2

(PRL 81, 1998)



D0 Run II:

$95 \pm 12 \pm 11$ signal events.

210 pb^{-1} data.

Lifetime: $0.45^{+0.12}_{-0.10} \pm 0.12$ ps

Mass: $5.95^{+0.14}_{-0.13} \pm 0.34$ GeV/c^2

(ICHEP 2004)

Incompletely reconstructed!

EXCLUSIVE DECAY MODE

We use the CDF $J/\psi \to \mu^+\mu^-$ trigger and study:

- Exclusive decay channel $B_c \to J/\psi\pi^\pm$
- Reference channel $B_u \to J/\psi K^\pm$ to test MC modelling.

Method

- Blind the mass region 5.6 – 7.2 GeV/c^2
- Use MC to model expected behaviour of signal events.
- Use data in blinded region to quantify background (it is mainly bgd).
- Optimize a set of kinematic cuts.

OPTIMISATION OF CUTS

The optimised quantity is: $\Sigma = \dfrac{S}{1.5 + \sqrt{B}}$

S = number of signal events from MC

B = average number of data events from whole blinded region scaled to 2σ in resolution about nominal signal mass (6.4 GeV/c^2).

The cut quantities optimised on were:

– p_T of pion (>1.8 GeV)

– χ^2 of secondary vertex fit (9.0)

– L_{xy}/error of pion (4.4)

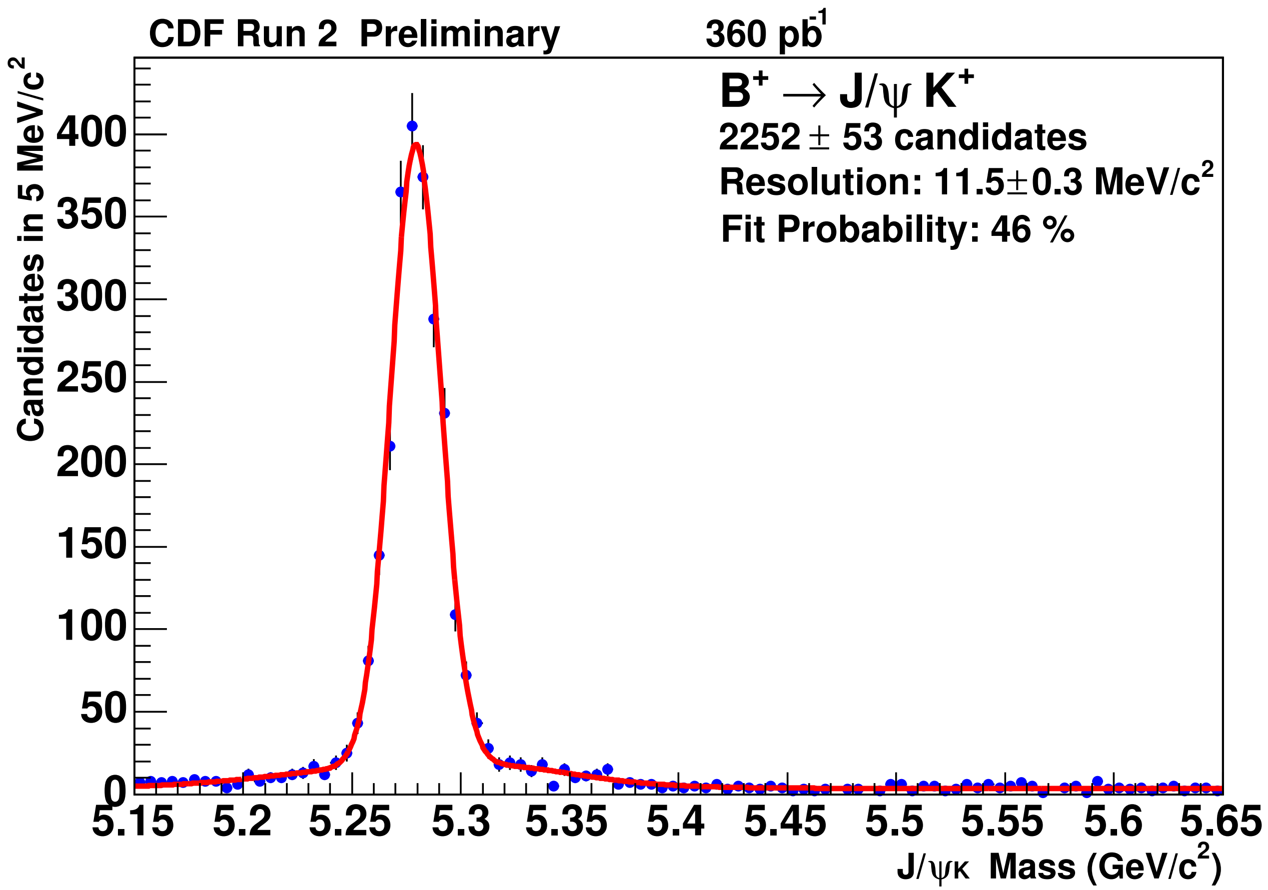
– $c\tau$ upper cut (0.075 cm)

– χ^2 of pion at 2ndary vtx (2.6)

– Impact parameter of candidate (0.0065 cm)

– Pointing angle of candidate (0.4 rad)

REFERENCE PLOT



Reference B_u plot after all cuts (except upper $c\tau$).

UNBLINDING METHOD

Run many toy MCs in which only background is simulated.

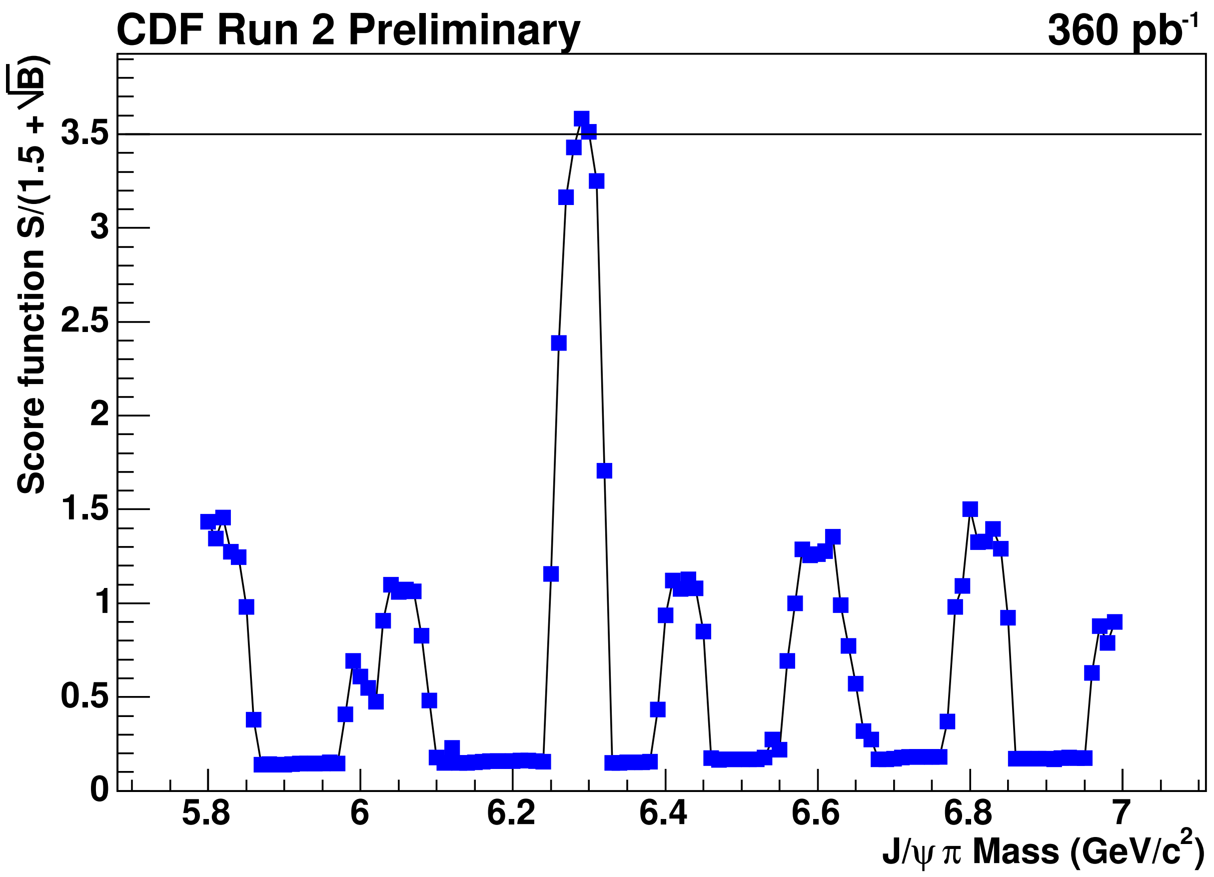
Take the statistics from the experimental data in the blinded region.

Look for a peak by taking a sliding window in mass from $M - 100$ to $M + 200$ MeV/c^2 about each mass value M to be tested for a peak.

Scan M in 10 MeV/c^2 steps across blinded mass region.

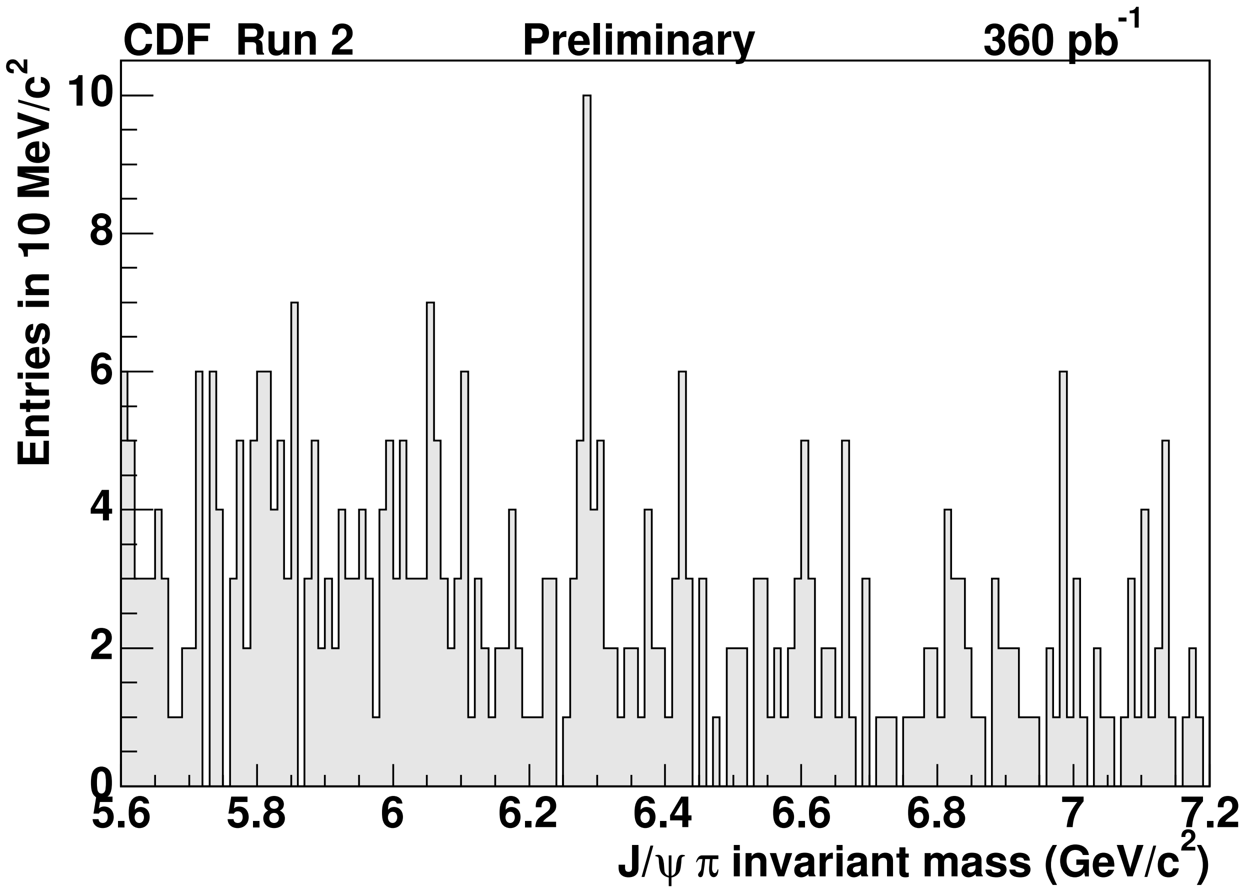
Establish value of Σ that is exceeded by chance (over whole region) one time in 1000.

A value of 3.5 emerged.



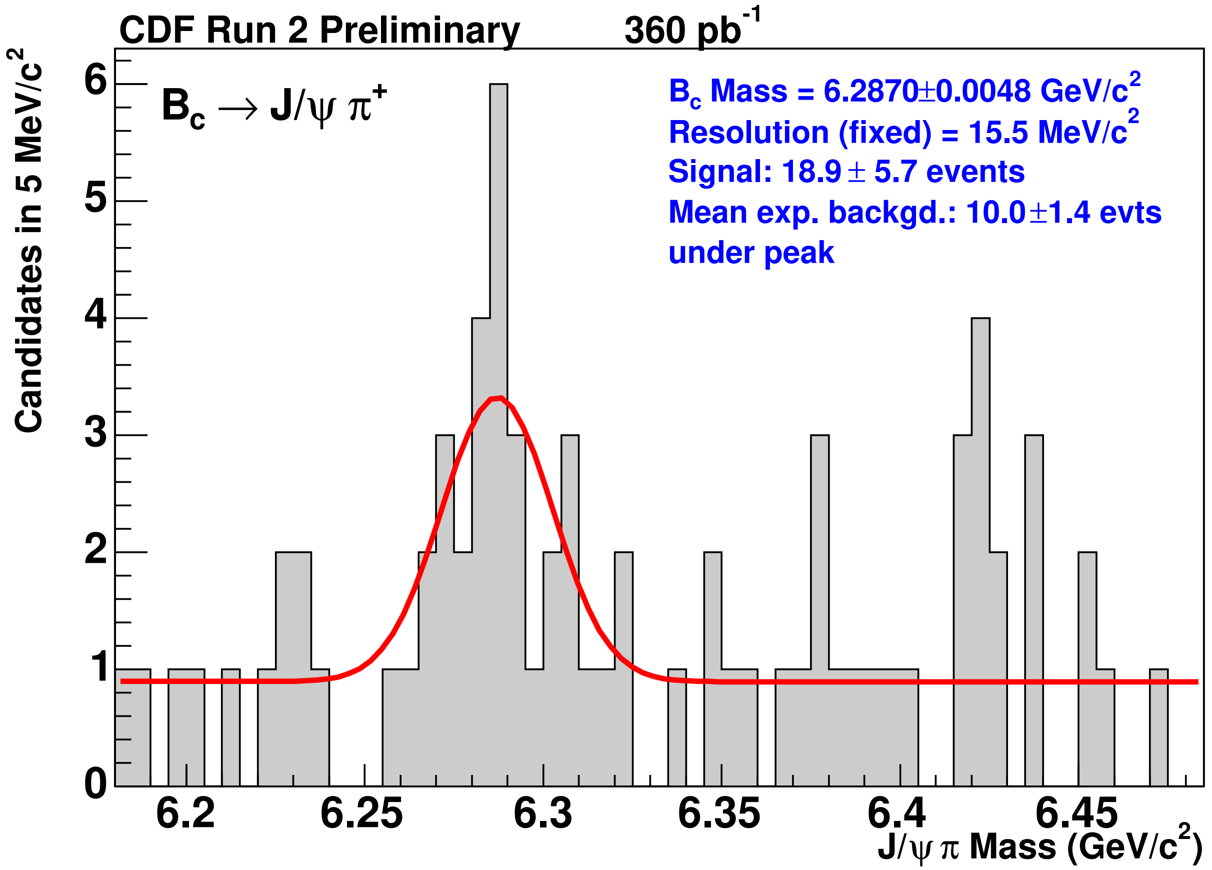
One significant peak seen with Σ above designated minimum.

Several smaller peaks as random fluctuations.



There is a visible peak.

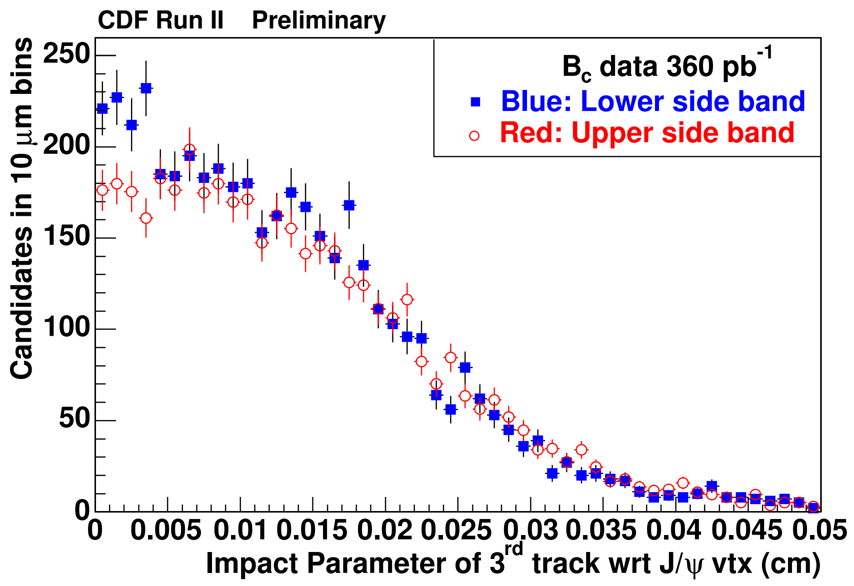
FIT TO RESULT

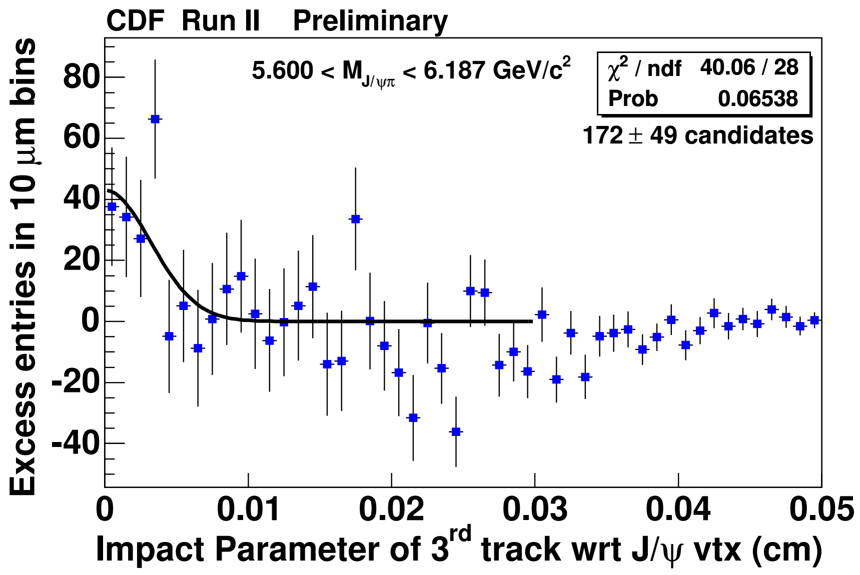


Unbinned likelihood fit: Mass = 6287.0 ± 4.8 MeV/c^2.

Systematics: Background shape (0.8); Mom. scale (0.6); Tracking (0.2); p_T mass dependence (0.5); Total ± 1.1 MeV/c^c

LOWER SIDEBAND CHECK





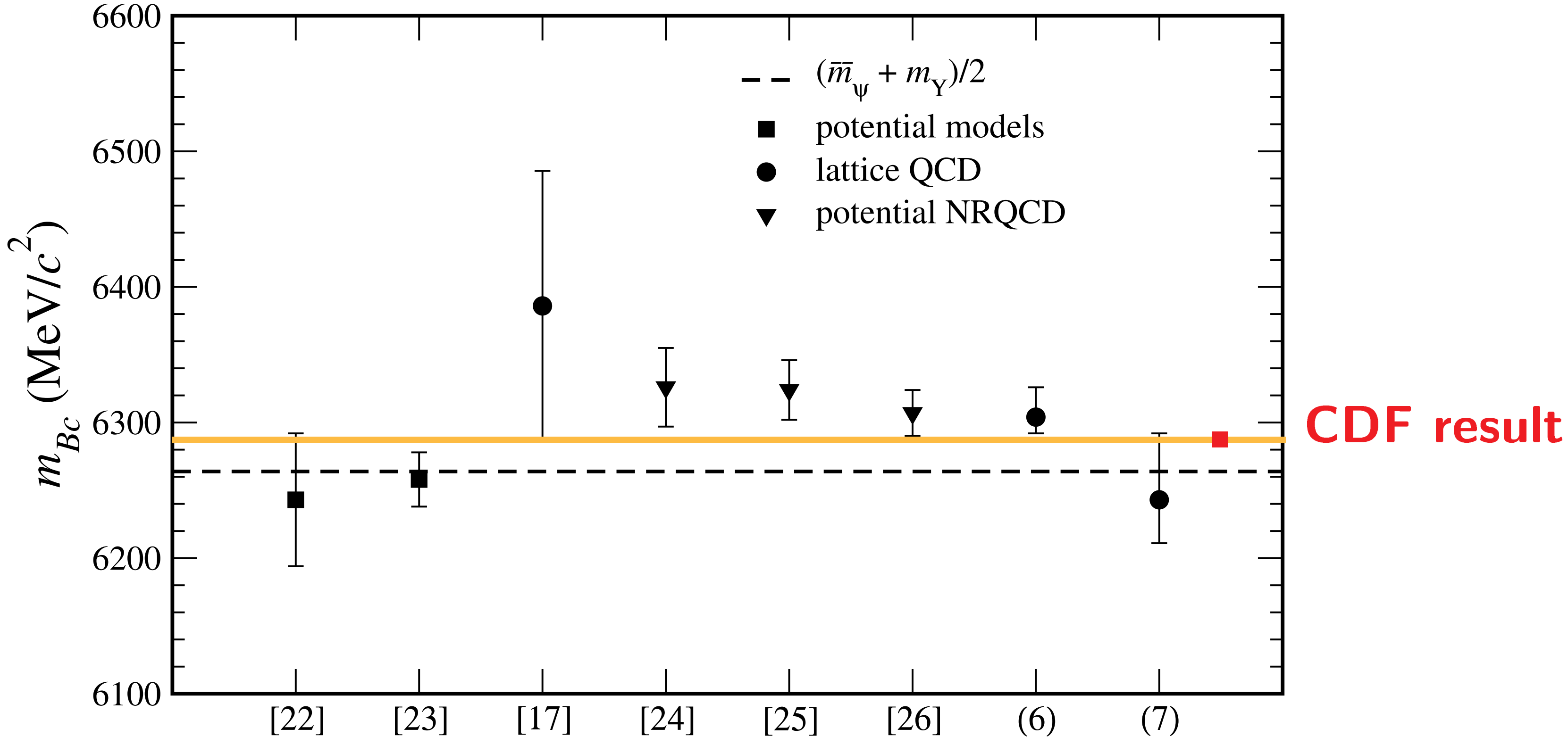
If signal is genuine, Lower Sideband will contain some partially reconstructed decays, while upper just contains random $J/\psi\pi$ associations.

$\rightarrow$ expect signature of events with small π impact parameter wrt J/ψ vertex - in LSB only.

This is seen. Excess $= 172 \pm 49 \pm 11$ low impact parameter events.

Confirms interpretation of the B_c peak.

Comparison with theory: latest Lattice QCD (I F Allison et al, hep-lat/0411027) gives for B_c mass: $6304 \pm 12 \pm 18$ MeV/c^2



CONCLUSIONS

- We have seen evidence for exclusive decay $B_c \to J/\psi\pi$ at CDF.
- For first time, allows an accurate determination of the B_c mass
- Obtain $6287.0 \pm 4.8 \pm 1.1$ MeV/c^2
- Allows comparison with theory models, especially Lattice Gauge calculations.
- Agreement is very good!
- With more statistics can measure decay lifetime more accurately.