Evidence for the exclusive decay

$B_c \rightarrow J/\psi\ \pi^{\pm}$

Saverio D'Auria

For the

CDF collaboration

Contents

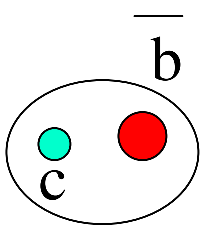
- The B_c meson: what is known, why it is relevant
- The Tevatron and the CDF detector
- The search strategy: *"blind analysis"*
- The results

B_c: the 15^{th} type of meson foreseen by the quark theory:

$$\begin{pmatrix} u \\ d \end{pmatrix}\begin{pmatrix} c \\ s \end{pmatrix}\begin{pmatrix} t \\ b \end{pmatrix}$$

$u\underline{b}$ $\underline{u}c$ $u\underline{s}$ ud $u\underline{u}$	B^+ D^0 K^+ π^+ π^0,ρ
$d\underline{b}$ $\underline{d}c$ $d\underline{s}$ $d\underline{d}$	B0 D^+ K^0 π^0
$s\underline{b}$ $\underline{s}c$ $s\underline{s}$	B_s D_s φ
$c\underline{b}$ $c\underline{c}$	B_c J/Ψ
$b\underline{b}$	*Y*

Ground state of a *c*-$\underline{b}$ quark combination.



B_c meson

1947 Lattes Occhialini Powell: π^+ discovered
1964 Quark model of mesons: u,d,s
1974 J/ψ discovered: *c*-quark
1977 *Y* discovered: *b*-quark
1994 *t*-quark found: too heavy, no bound state
1998 B_c observed at CDF: semileptonic decays only

Why B_c is interesting:

- Together with η_b the B_c is the only other meson ground state to have theoretical prediction more precise than experimental mass measurement. Validation of lattice and potential models.
- Spectroscopy of excited states: verify different models.
- Fragmentation: its production rate can shed light on fragmentation mechanism (only heavy quarks involved).
- B_s physics: some B_s are product of B_c decays: production rate and branching fraction to B_s to assess the B_c contribution to B_s lifetime and mixing: source of dilution (same–side π, instead of K).

For future experiments:

- *B_s mixing: perfect source of tagged B_s.*
- CP asymmetry measurement in $\underline{D}^0 D_s$ decay mode.
- Rare decays.

Meson made of a $\bar{b}$ and c quark

Evidence at CDF in '98

Mass measured with large uncertainty, due to the neutrino that escapes detection: (6400 ±390$_{stat}$ ± 130$_{sys}$) MeV/c^2 →

Also lifetime not precisely measured, for the same reason →

Observed in Semi Leptonic mode only: $B_c \to J/\psi\ l\ \nu\ X$

PDG 2004

Citation: S. Eidelman *et al.* (Particle Data Group), Phys. Lett. B **592**, 1 (2004) (URL: http://pdg.lbl.gov)

$B_c^\pm$

$I(J^P) = 0(0^-)$
I, J, P need confirmation.

Quantum numbers shown are quark-model predictions.

$B_c^\pm$ MASS

VALUE (GeV)	*DOCUMENT ID*		*TECN*	*COMMENT*
6.4 ±0.39±0.13	[1] ABE	98M	CDF	$p\bar{p}$ 1.8 TeV
• • • We do not use the following data for averages, fits, limits, etc. • • •				
6.32±0.06	[2] ACKERSTAFF	98O	OPAL	$e^+e^- \to Z$

[1] ABE 98M observed $20.4^{+6.2}_{-5.5}$ events in the $B_c^+ \to J/\psi(1s)\ell\nu_\ell$ with a significance of > 4.8 standard deviations. The mass value is estimated from $m(J/\psi(1S)\ell)$.

[2] ACKERSTAFF 98O observed 2 candidate events in the $B_c \to J/\psi(1S)\pi^+$ channel with an estimated background of 0.63 ± 0.20 events.

$B_c^\pm$ MEAN LIFE

VALUE (10^{-12} s)	*DOCUMENT ID*		*TECN*	*COMMENT*
$0.46^{+0.18}_{-0.16}\pm0.03$	[3] ABE	98M	CDF	$p\bar{p}$ 1.8 TeV

[3] The lifetime is measured from the $J/\psi(1S)\ell$ decay vertices.

B_c^+ DECAY MODES × B($\bar{b} \to B_c$)

B_c^- modes are charge conjugates of the modes below.

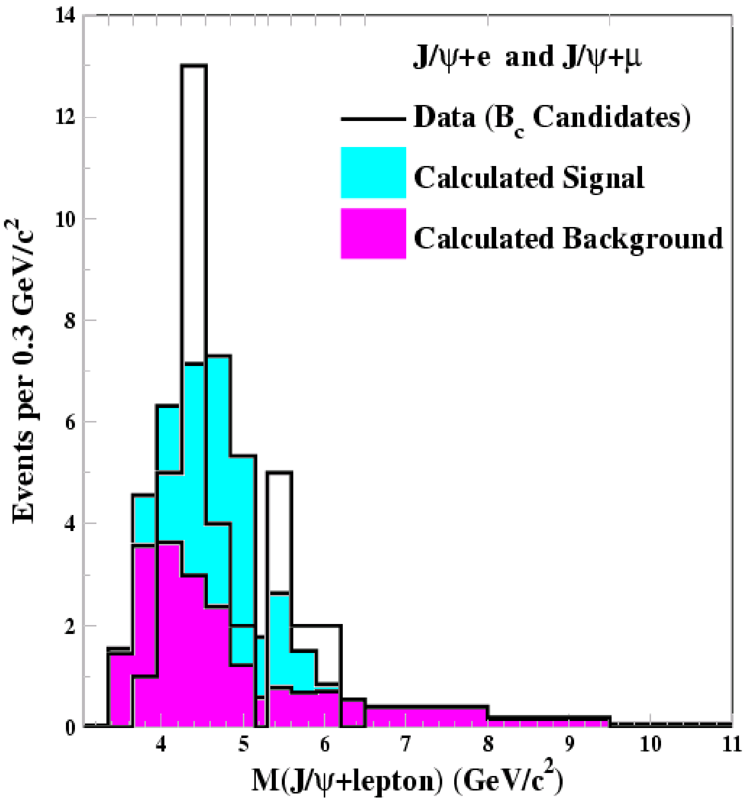
	Mode	Fraction (Γ_i/Γ)	Confidence level
	The following quantities are not pure branching ratios; rather the fraction $\Gamma_i/\Gamma \times$ B($\bar{b} \to B_c$).		
Γ_1	$J/\psi(1S)\ell^+\nu_\ell$ anything	$(5.2^{+2.4}_{-2.1}) \times 10^{-5}$	
Γ_2	$J/\psi(1S)\pi^+$	$< 8.2 \times 10^{-5}$	90%

CDF Run-I

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

10.6 ± 2.3 background events

$110\ pb^{-1}$



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

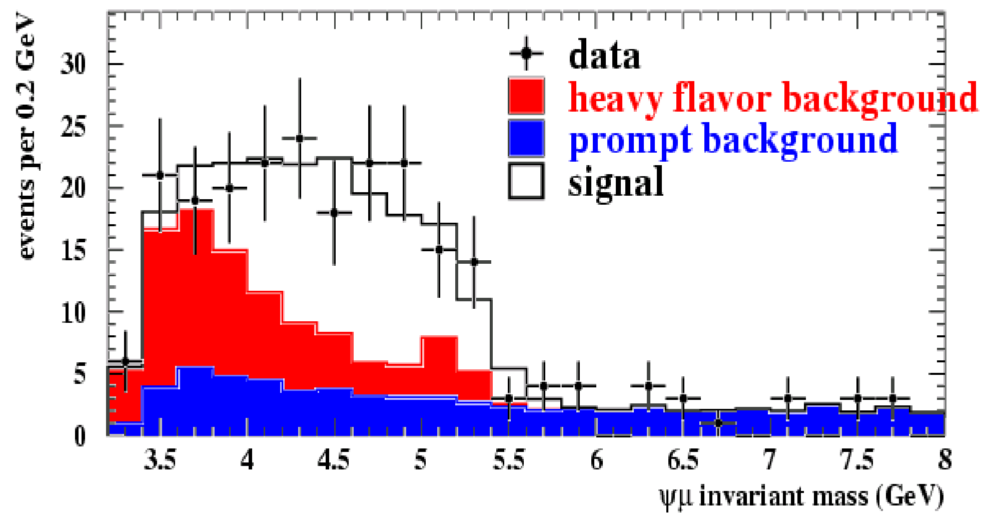
Mass: $(6.4 \pm 0.39 \pm 0.13)$ GeV/c^2

PRL 81 n.12 (1998)

D0 Run-II

$95 \pm 12 \pm 11$ signal events

$210\ pb^{-1}$



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

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

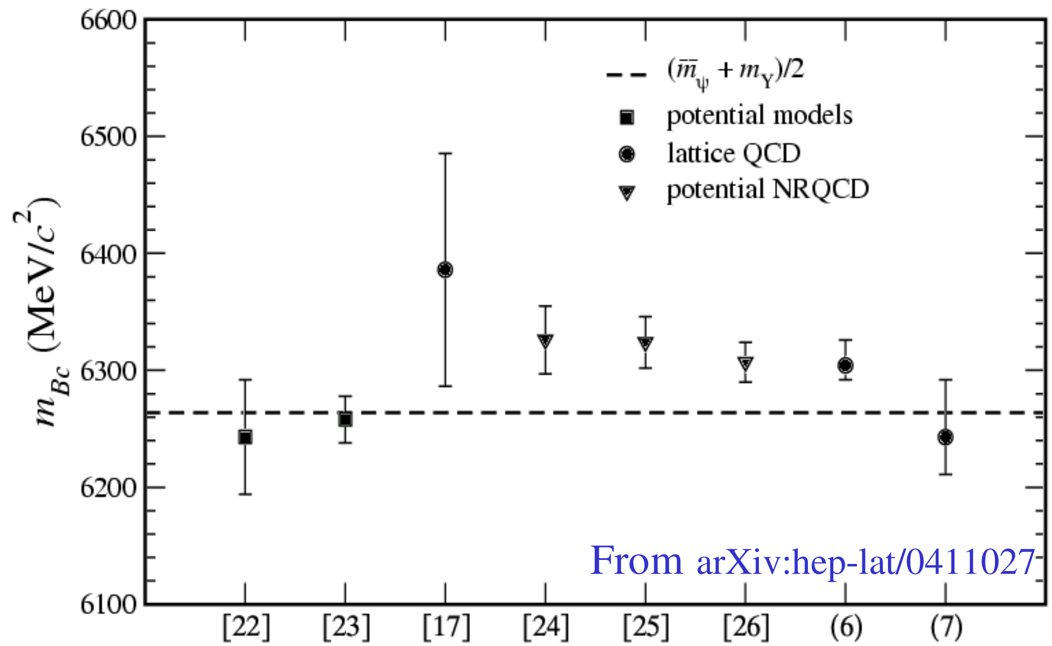
ICHEP 2004

Theory can calculate the B_c mass with a very small uncertainty.

Un-quenched QCD latest calculation of the mass:

M(Bc) = (6304 ±12(stat⊕sys)+18(discr)) MeV/c²

arXiv:hep-lat/0411027



22] I.F. Allison et al. hep-lat/0411027

23] W.K. Kwong & J.L. Rosner Phys Rev D 44, 212 (1991)

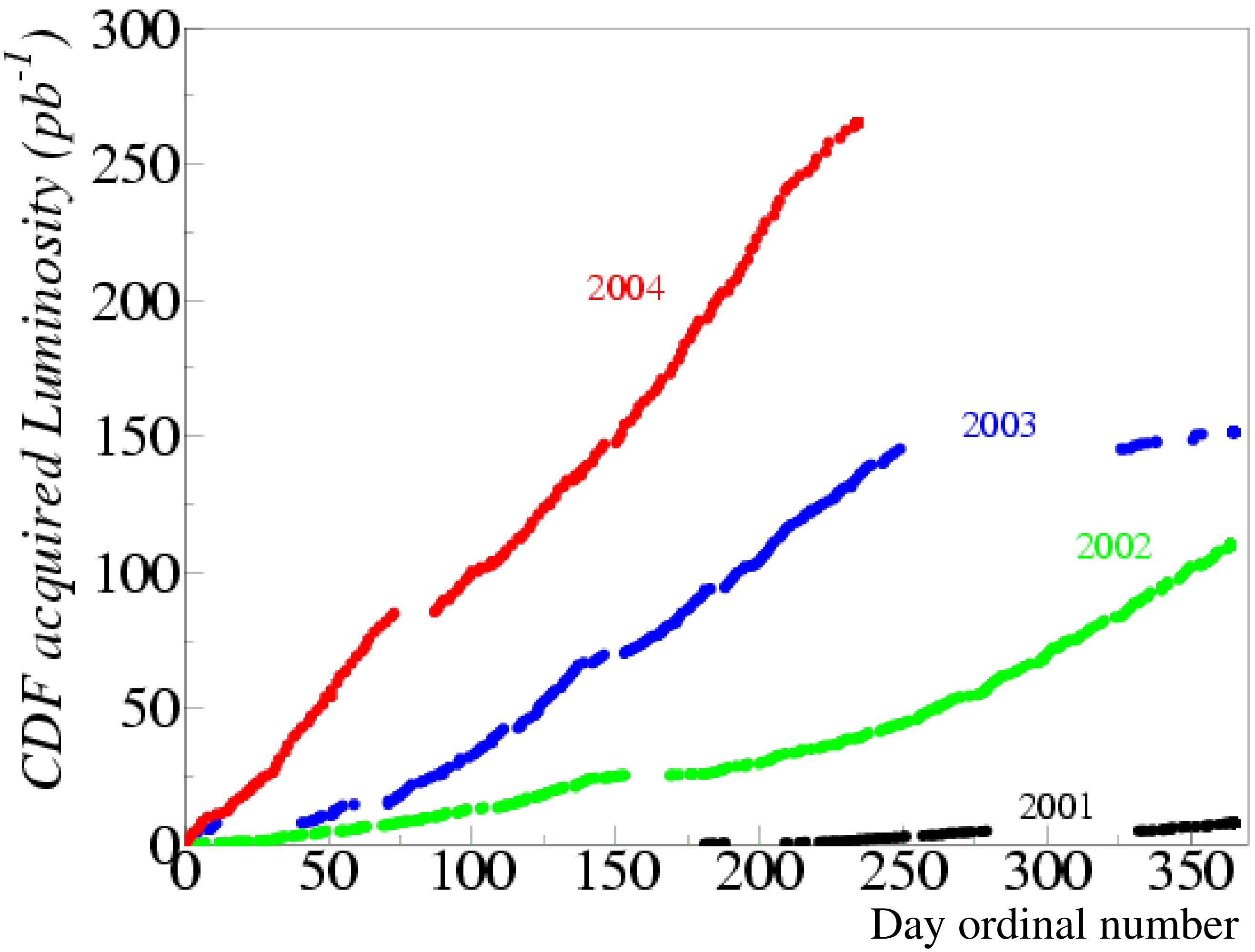
17] H. P. Shannahan et al. Phys. Lett. B 453, 289 (1999)

24] E.J. Eichten & C Quigg Phys Rev D 49 5845 (1994)

25] N. Brambilla & A. Vairo Phys Rev D 62 094019 (2000)

26] N. Brambilla et al. Phys Lett B 513, 381 (2001)

The CDF detector

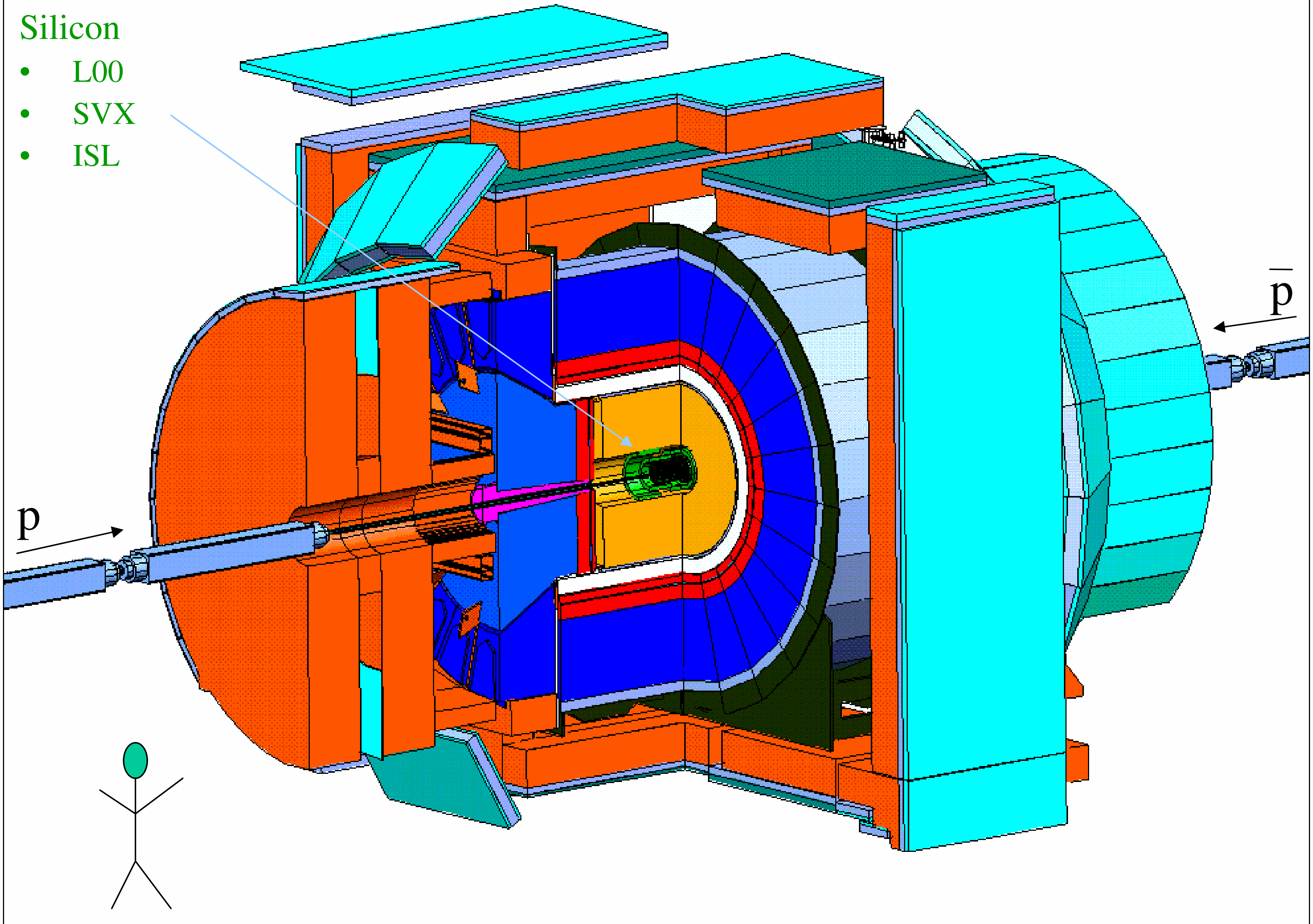


Integrated luminosity on tape to date: 360 pb^{-1}"good runs"
Require Silicon, Central Drift Chamber, muon system in good operating conditions. All available data are used in this analysis

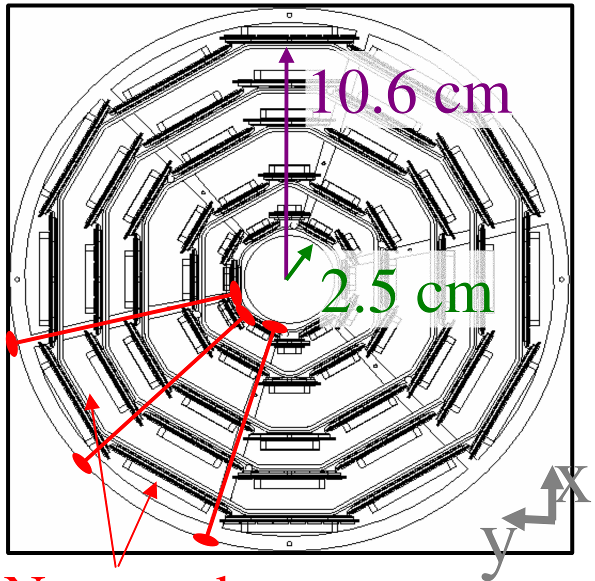
Inner tracker

Silicon

- L00
- SVX
- ISL



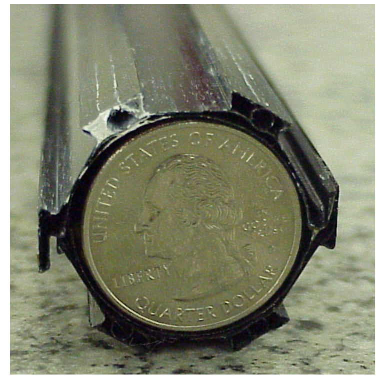
SVX II

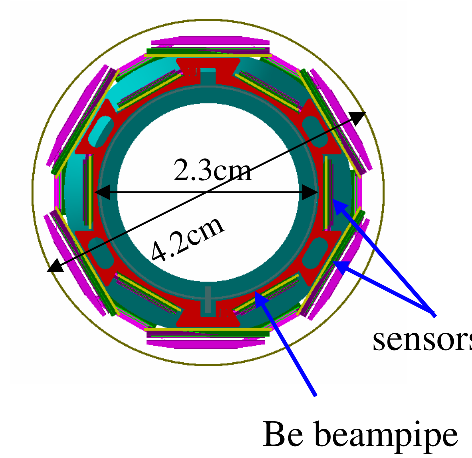


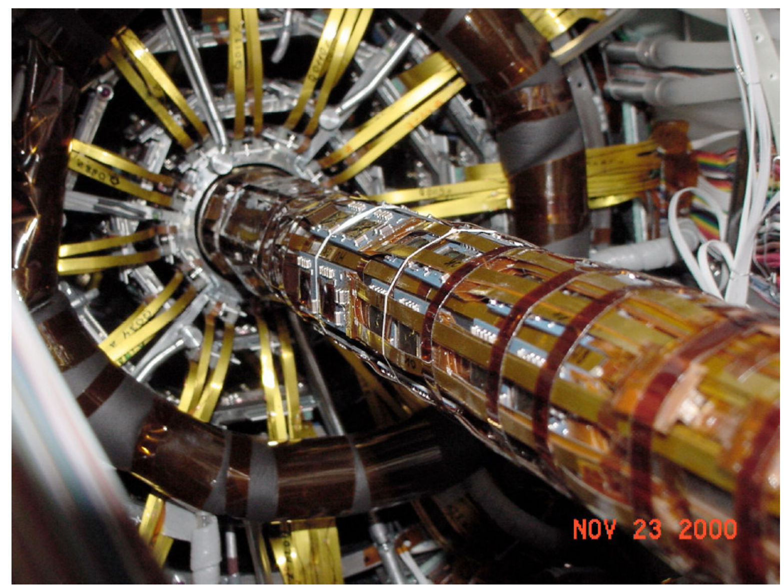
Note wedge symmetry

- ISL:
  - phi-small angle stereo layer(s)
- SVX:
  - •3 phi-z, 2 phi-small angle layers
- L00:
  - •1 single–sided layer <r>= 1.6 cm

Layer-00







Analysis performed in 3D. First CDF analysis to benefit of L00

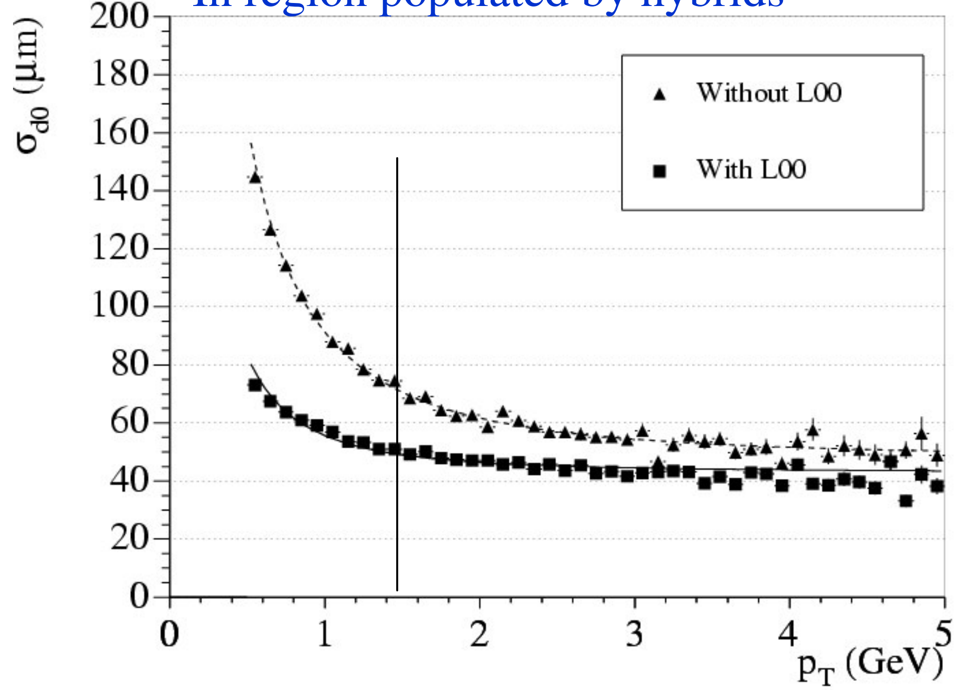
L00 performances.

Measured using impact parameter of prompt tracks

Fit to:

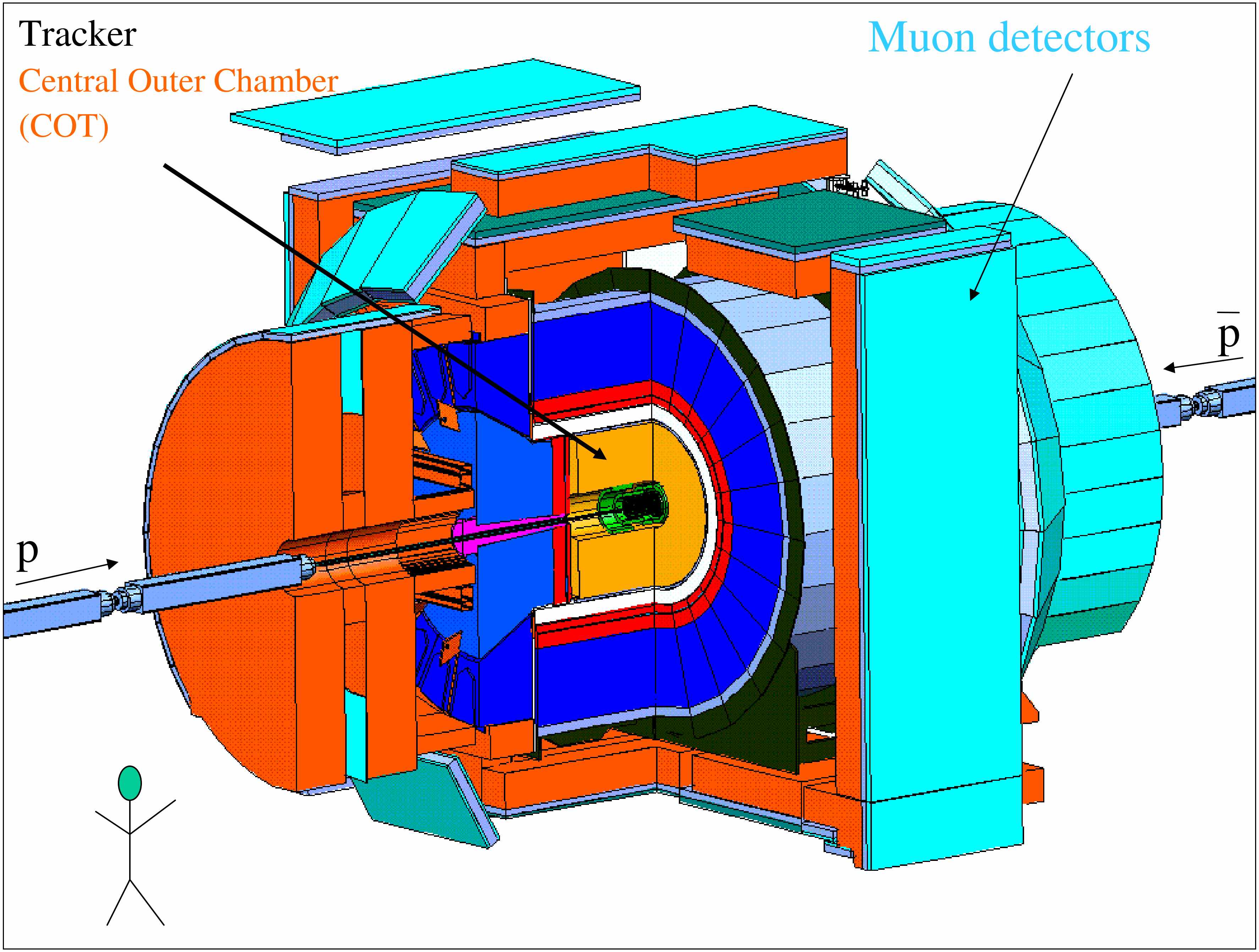
- Asymptotic resolution,
- Multiple scattering

In region populated by hybrids

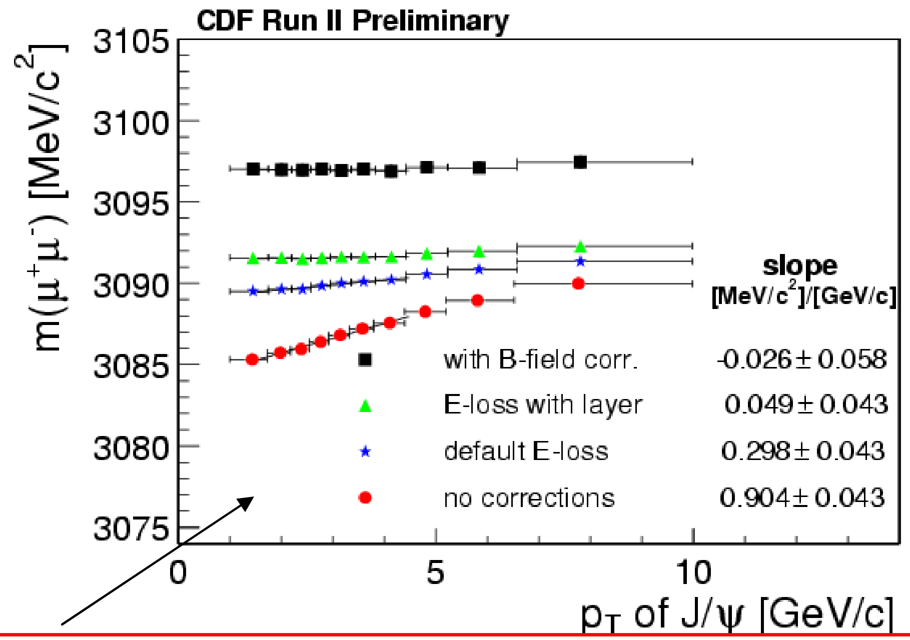


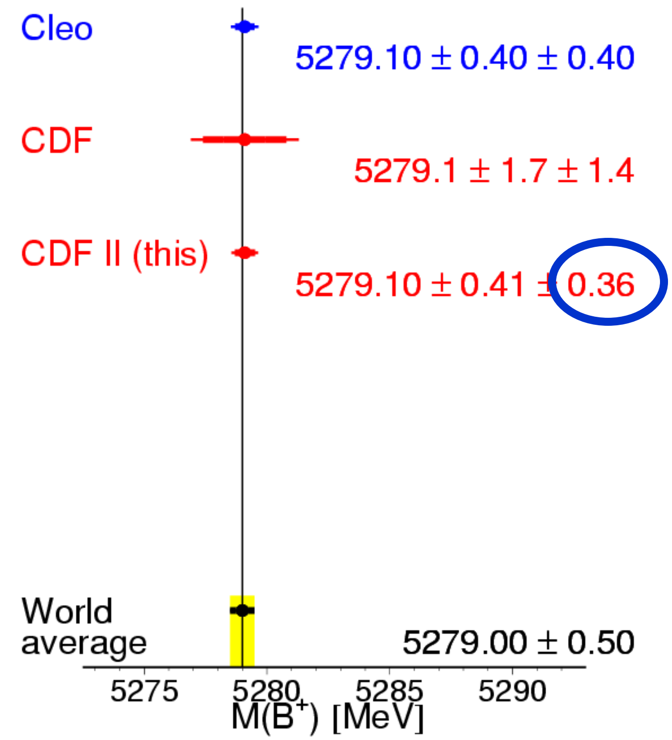
Asymptotic resolution:
beam size accounted for
Resolution improves from 35.6 to 25.1 μm
Larger improvement at low momentum

Improves matching of pions to J/ψ vertex


Tracker
Central Outer Chamber
(COT)
Muon detectors
p
p̄

CDF performances in *b*-meson mass measurement:



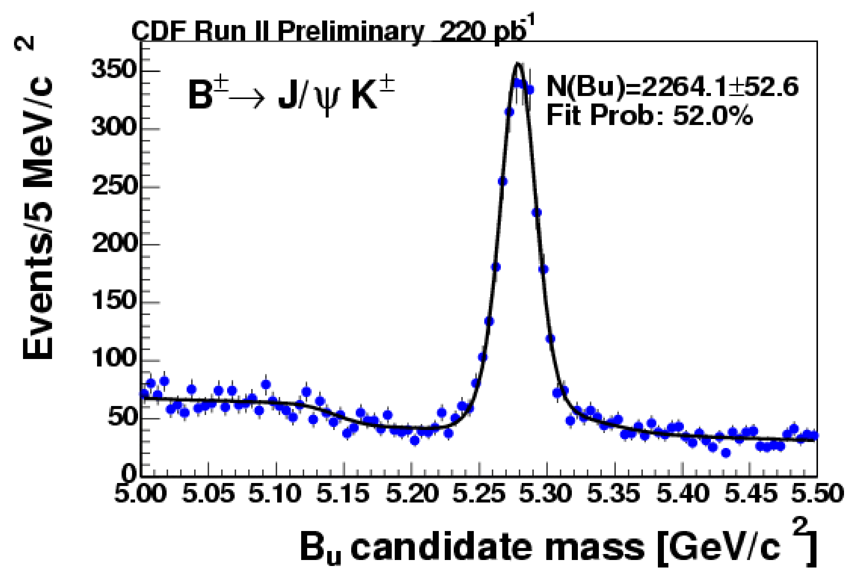


Mass scale calibrated precisely on J/ψ mass

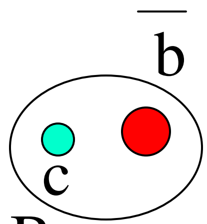
Systematic uncertainty at sub-MeV/c^2 level

Best single-experiment measurement of the mass of b-hadrons.

Excellent place to detect a Fully-reconstructed decay of B_c *and to measure its mass*.



The search strategy



B_c meson

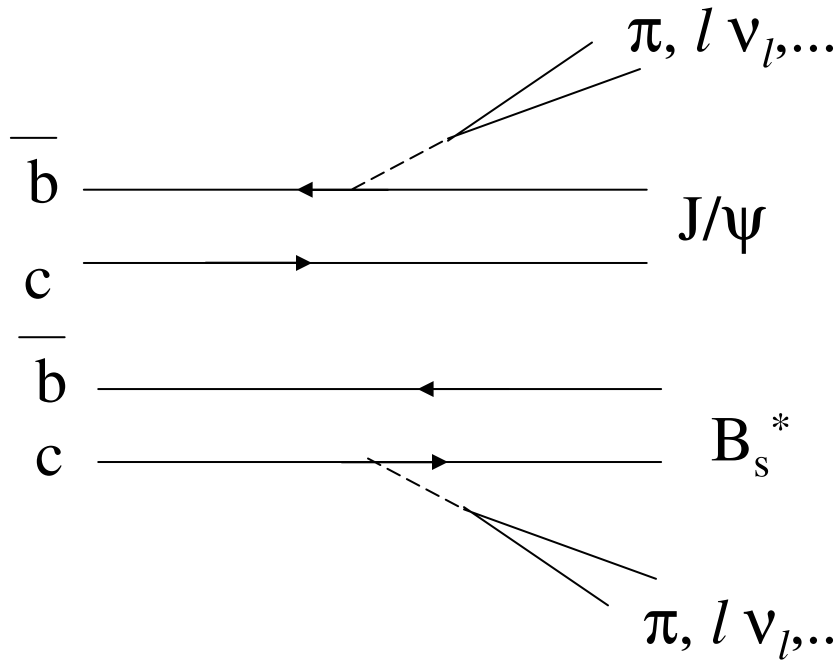
The only meson in which both quarks can decay weakly: *b*-decays and *c*-decays.

Choose a decay mode that

- Has only charged tracks in final state
- Has a reasonable branching fraction to the final state

Kiselev hep-ph/0308214

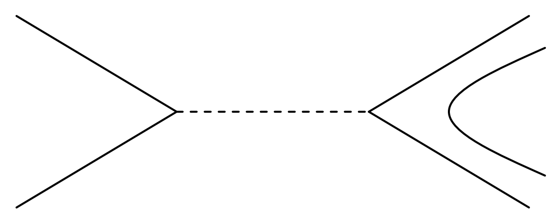
Decay	BR (%)	Final state	BR to Final state
$J/\psi\ \pi$	0.13	$(\mu\ \mu)\ \pi$	$7.8 \cdot 10^{-5}$
$\eta_c\ \pi$	0.20	$(\pi\pi\ KK)\ \pi$	$1 \cdot 10^{-4}$
$J/\psi\ a_1$	0.13*	$(\mu\ \mu)\ (\pi\ \pi\ \pi)$	$3.4 \cdot 10^{-5}$
$D^0\ D^+$	$1.4 \cdot 10^{-2}$	$(K\ \pi)\ K\ \pi\ \pi$	$5 \cdot 10^{-7}$
$J/\psi\ D_s$	0.17	$(\mu\ \mu)\ KK\ \pi$	$1.8 \cdot 10^{-5}$
$B_s\ \pi$	16.4	$(KK)\pi\pi\pi$	$5 \cdot 10^{-6}$



We have chosen the decay mode:

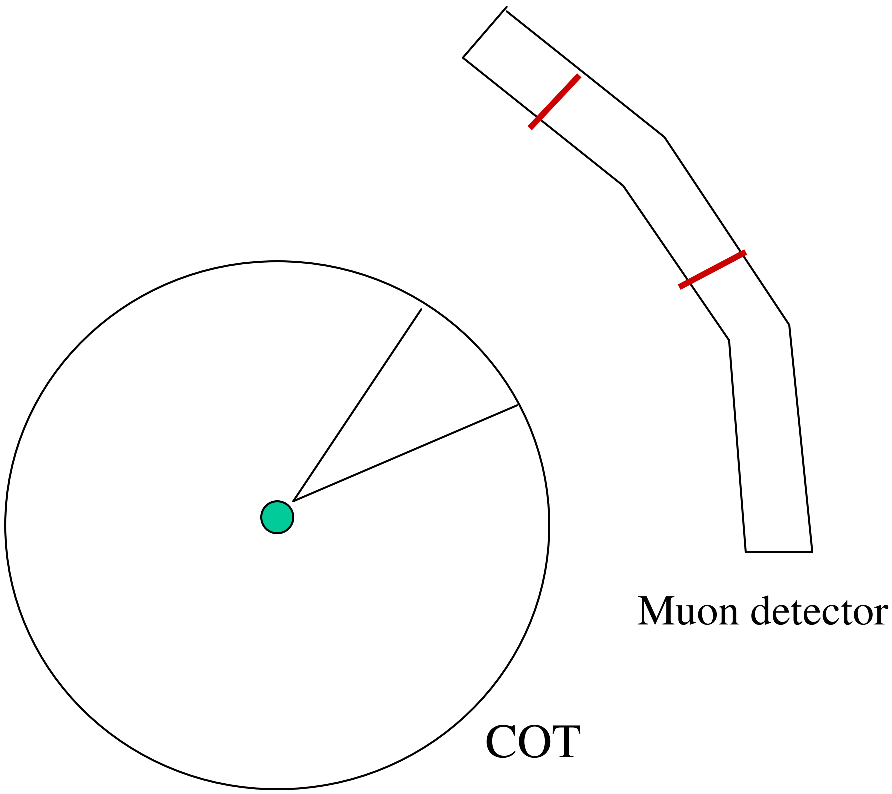
$B_c \rightarrow J/\psi\ \pi^{\pm}$

Advantages: we have a good trigger for this mode, simple two-body decay, only 3 tracks large final branching ratio.



The Trigger

This channel can be studied using the J/ψ di-muon trigger path



2 muon “stubs”

matched to Drift Chamber trigger tracks:

With opposite charge

Within J/ψ mass window

No lifetime information used in this trigger path. Unbiased for lifetime measurement, can go as low as possible in lifetime cuts.

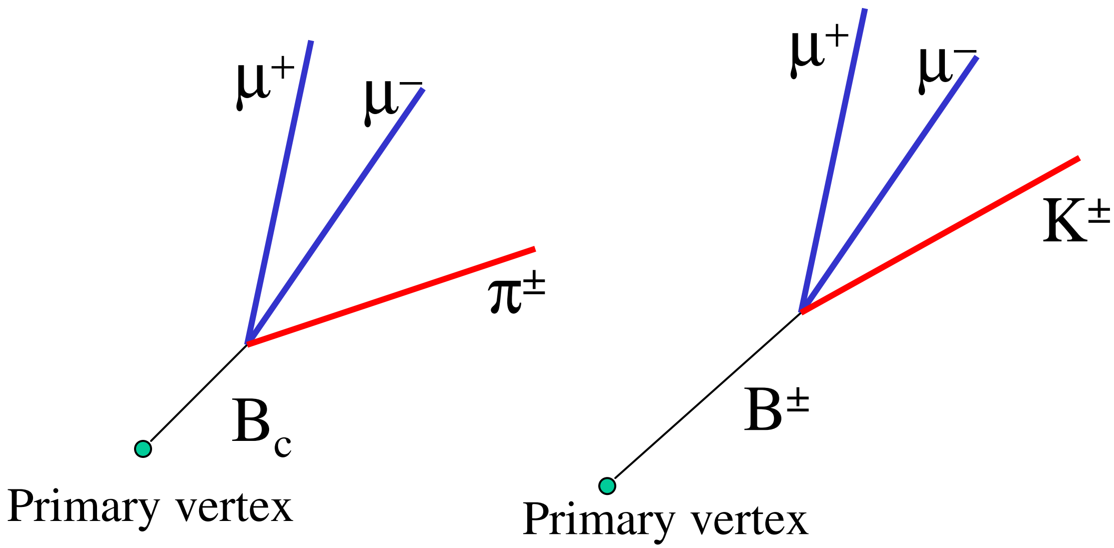
p_T cuts for trigger muons: $p_T > 1.5$ GeV/c

Trigger on low momentum J/ψ possible

Extended muon coverage (CMX) also used

The decay mode $B_c \rightarrow J/\psi\ \pi^{\pm}$

Same topology as a very well known decay mode of $B^{+} \rightarrow J/\psi\ K^{+}$



Analysis method:

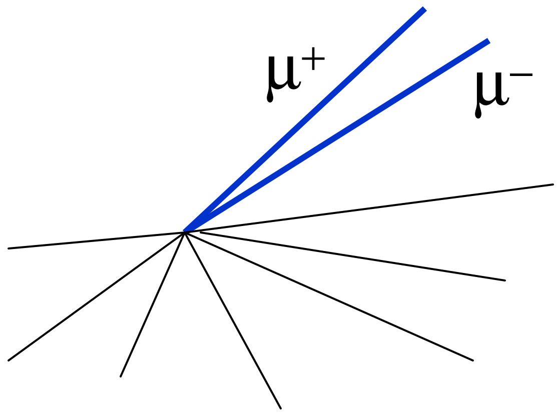
- Reconstruct $\mu^{+}\mu^{-}$ vertex
- Constrain $\mu^{+}\mu^{-}$ to J/ψ mass
- Attach a third track with p_T threshold
- Require
  - good vertex χ^2,
  - decay length,
  - pointing to primary vertex

Experimental difficulties:

- B_c lifetime is shorter than light *b*-mesons (charm decay dominates) → secondary vertex closer to the primary vertex. Need best spatial resolution (first use of "L00" hits and track-fitted primary vertex position).
- Expected signal > 10 times smaller than the signal in the semileptonic decay.

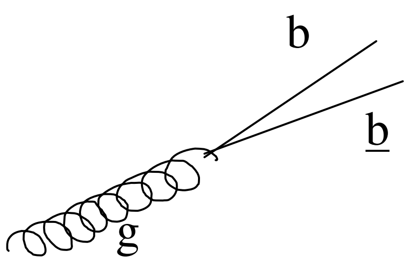
Background

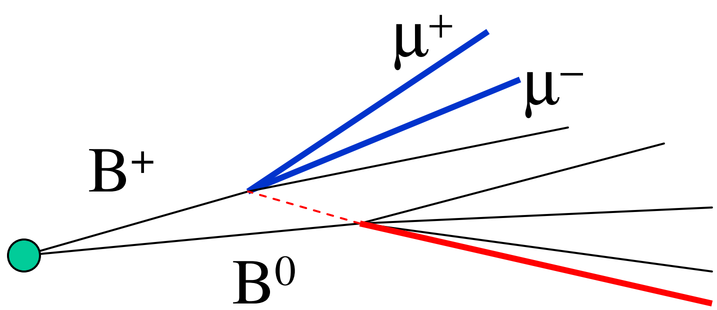
- Large "**prompt**" background from prompt J/ψ plus track from primary vertex



Require candidates with decay length >0
Cut on p_T of the "third track"

- Possible background from collinear *b* *b̲* production (*gluon splitting*).





Require good 3D vertex

Expected sensitivity calculated with respect to $B^+ \to J/\psi\, K^+$,
It is the same channel used as a reference in the Run-I observation .

Ratio of efficiencies — Number of events in $B^+ \to J/\psi\, K^\pm$

$$S = \frac{\varepsilon_c}{\varepsilon_u} N_u \frac{\sigma_c\, BR(B_c \to J/\psi\, \pi)}{\sigma_u\, BR(B_u \to J/\psi\, K)}$$

$\varepsilon_c/\varepsilon_u$: From Monte Carlo simulation

N_u: From data

Fraction: Call it "R"

define
$$R_2 = \frac{\mathcal{BR}(B_c \to J/\psi \pi^\pm)}{\mathcal{BR}(B_c \to J/\psi l \nu)}$$

$$R = R_2 \times \frac{\sigma(B_c) \times \mathcal{BR}(B_c \to J/\psi l \nu)}{\sigma(B_u) \times \mathcal{BR}(B_u \to J/\psi K^\pm)}$$

To evaluate the expected signal we use previous measurement and one ratio of *BR*.

We know
$$\frac{\sigma(B_c) \times \mathcal{BR}(B_c \to J/\psi l \nu)}{\sigma(B_u) \times \mathcal{BR}(B_u \to J/\psi K^\pm)} = 0.132 \pm 0.06$$
From CDF Run-1

All theoretical uncertainties are in the value of R_2

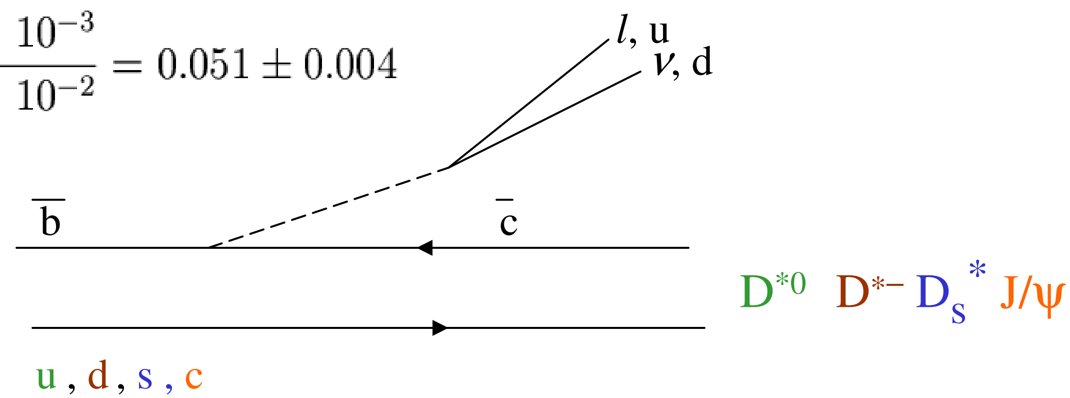
R_2 is decay ratio of pionic to semileptonic mode. We can get it

- From theoretical predictions
- From experimental values in light *b*-mesons using simple quark spectator model

$$\frac{\mathcal{BR}(B_u \to \bar{D}^{*0}\pi^+)}{\mathcal{BR}(B_u \to \bar{D}^{*0}l\nu)} = \frac{(4.6 \pm 0.4) \times 10^{-3}}{(6.5 \pm 0.5) \times 10^{-2}} = 0.071 \pm 0.008$$

From PDG 2004

$$\frac{\mathcal{BR}(B_d \to D^{*-}\pi^+)}{\mathcal{BR}(B_d \to D^{*-}l^+\nu)} = \frac{(2.76 \pm 0.21) \times 10^{-3}}{(5.44 \pm 0.23) \times 10^{-2}} = 0.051 \pm 0.004$$



Ref.	R_2
B_u	0.071 ± 0.008
B_d	0.051 ± 0.004
Kiselev	0.068
Erbert et al.	0.069
Berezhnoy et al.	0.080
El-Hadi et al.	0.074
C.H. Chang et al.	0.10
Colangelo et al.	0.13
A. Yu Anisimov et al.	0.06
hep-ph/0201071	0.06–0.32

← Theoretical predictions vary by a factor of 2

We assumed $R_2 = 0.06$

The analysis method

The blind analysis
The analysis cuts
The use of Monte Carlo
The statistical method

We performed a “blind analysis”:

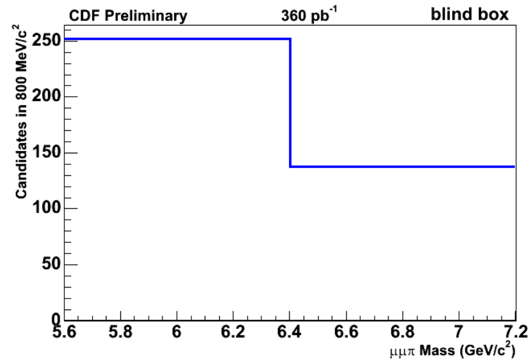
Reason: we don’t want to influence the choice of cuts based on visual inspection of the result (or, worst, on fit).

Blinding procedure:

Within search window substitute the mass value with one of two values

$M_{\mu\mu\pi} = 6.0$, if $5.6 < M_{\mu\mu\pi} < 6.4$

$M_{\mu\mu\pi} = 6.8$, if $6.4 < M_{\mu\mu\pi} < 7.2$



Search window = PDG mass value ± 2 σ → from 5.6 to 7.2 GeV/c^2

Optimization of cuts based on Monte Carlo simulation of signal

Assume all candidates in this mass window are background:

Fraction of expected signal contribution assumed small.

$$\text{Maximize} \quad \Sigma = \frac{S}{1.5 + \sqrt{B}}$$

S = number of signal events from MC

B = average number of background events (data) from whole region in a window $\pm 2\text{-}\sigma_M$ wide (60.4 MeV/c^2).

Balanced score-function for limit and “discovery” (hep-physics/0308063) avoid fine-tuning

Use of Monte Carlo:

- For relative efficiency with respect to B^+ only for sensitivity studies
- For cut optimization.

Generator: Single b-meson generator using meson p_T-y spectrum from Chang et al.

Full detector simulation, run-dependant conditions for beam position and silicon coverage, full L1 and L2 trigger simulation

Optimize cuts using measured values for mass ($M = 6.4$ GeV/c^2) and lifetime ($c\tau = 0.46$ ps), check cut robustness with other values, within range.

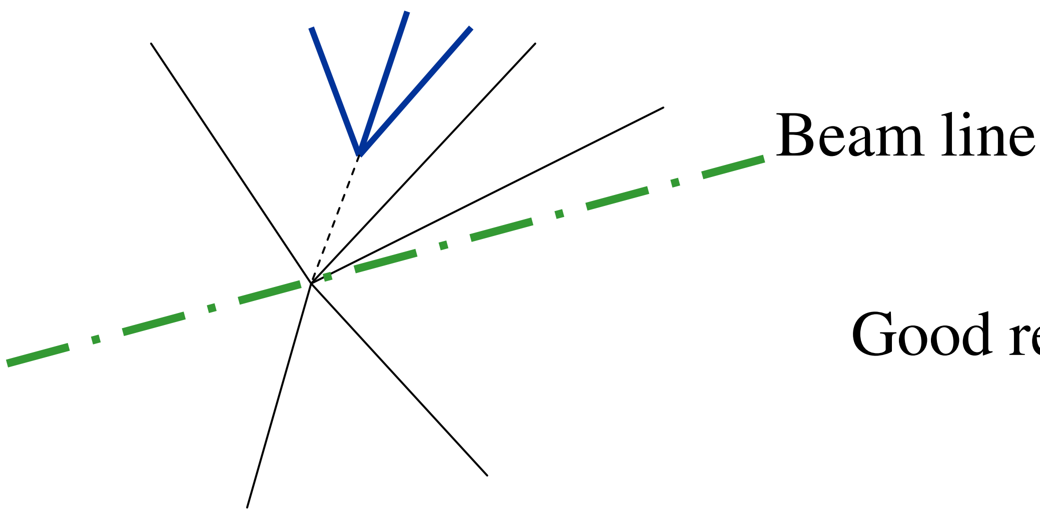
Pythia MC used when underlying event is needed (track-fitted primary vertex)

Rely on reference sample $B^+ \rightarrow J/\psi\ K^+$ for other quantities.

Performed checks on reference sample for MC quantities.

Event reconstruction

Used the track-fitted primary vertex position:



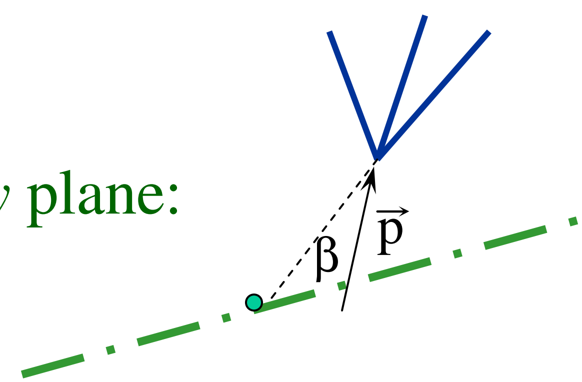
Good resolution in z as well as in x-y

Exclude candidate tracks

Algorithm to exclude tracks with large impact parameter.

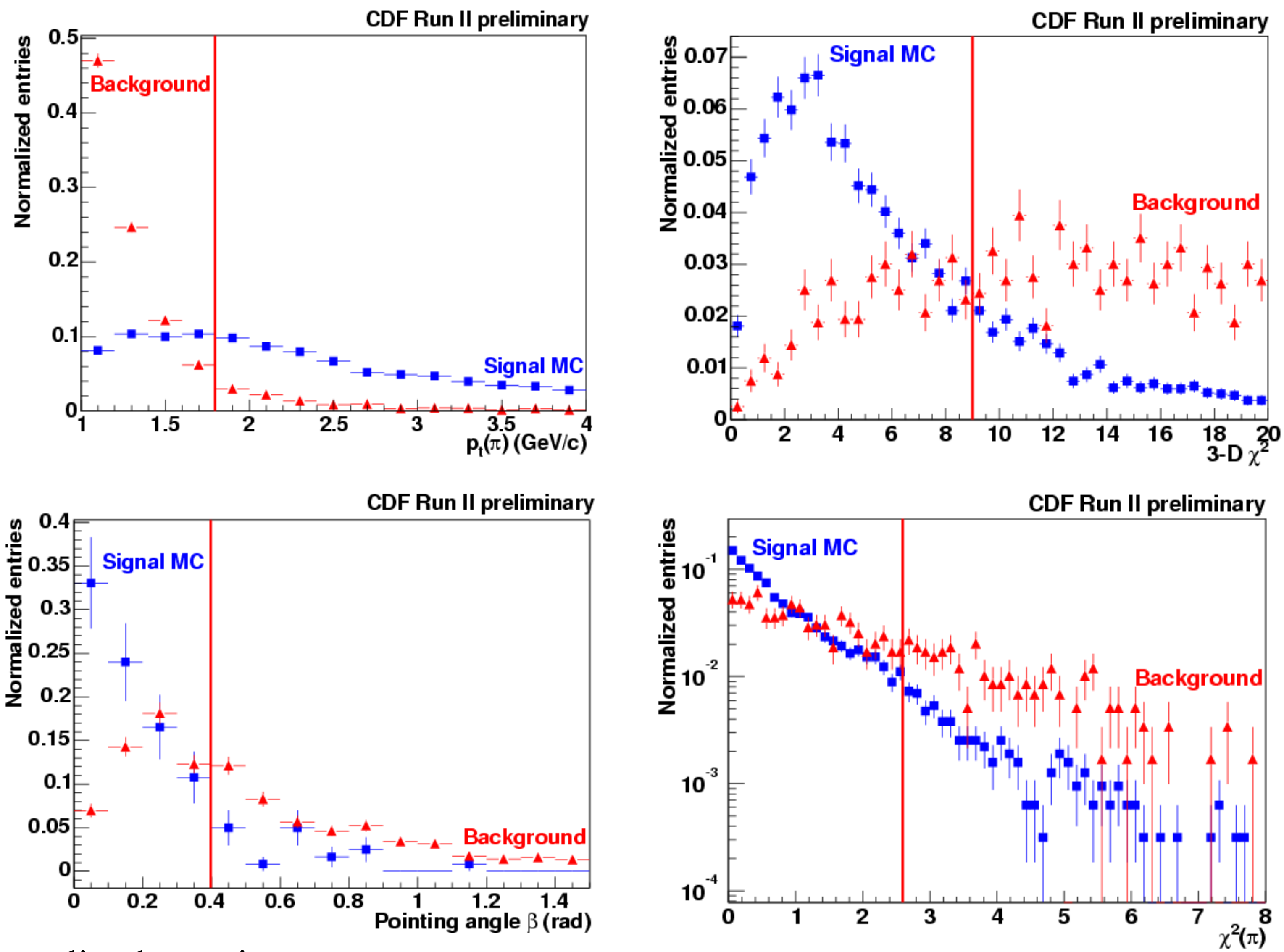
Motivation for each cut

- p_T of the third track (π):
  - To cut off the low-momentum tracks from underlying event
- 3D vertex $\chi^2 = \chi^2(\pi) + \chi^2(\mu 1) + \chi^2(\mu 2)$
  - To ensure good 3-track vertex:
- Significance of the projected decay length: L_{xy} /↓(L_{xy})
  - To select non-prompt candidates
- Contribution to the 3D Vertex due to the third track $\chi^2(\pi)$:
  - To ensure that the third track is correctly assigned to the J/ψ vertex
- Pointing angle β (in 3D):
  - To select fully reconstructed decays
- Impact parameter of reconstructed meson in *x*-*y* plane:
  - As before, very powerful for short decay.
- Upper ct cut:
  - to cut background from long-lived *b*-hadrons



Cuts optimized using "N-1" iterative process

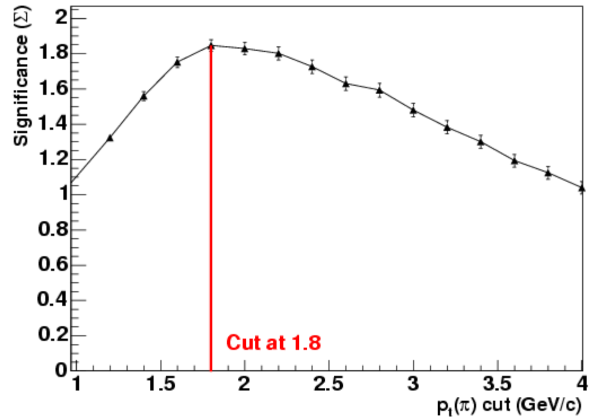
“N-1” distributions of quantities on which we cut.

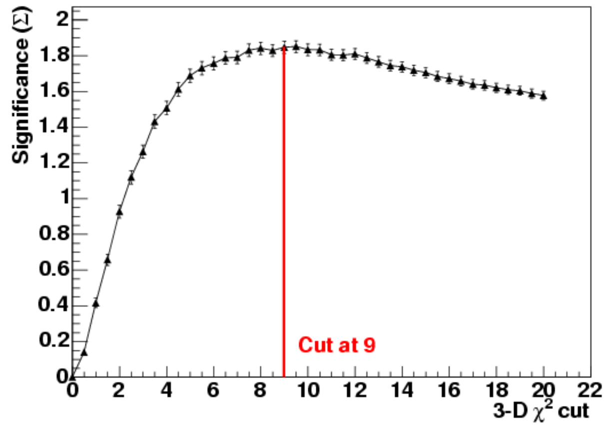


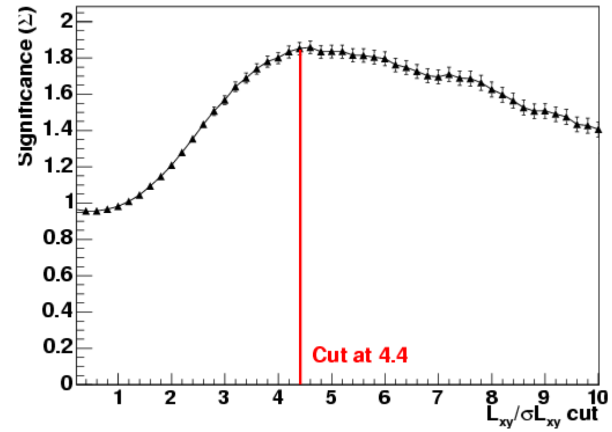
Normalized to unit area

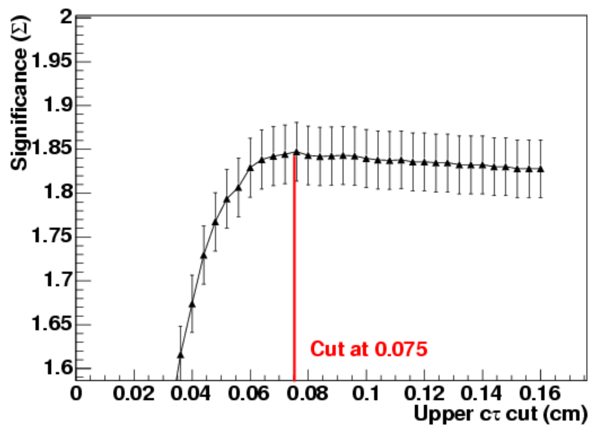
Shape of signal and background quite different

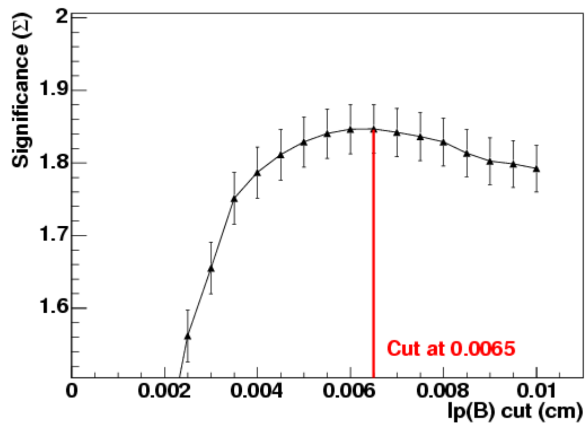
“N-1” cut optimization graphs

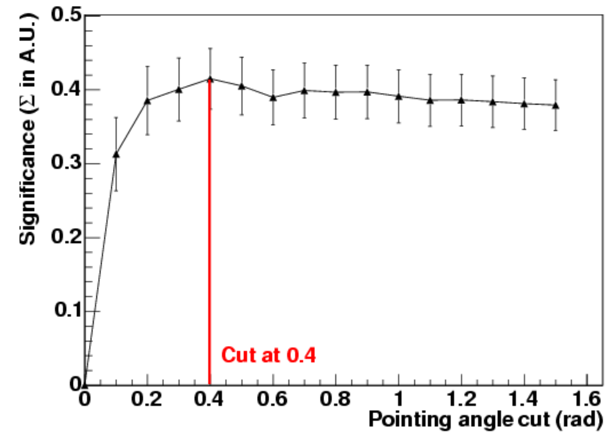


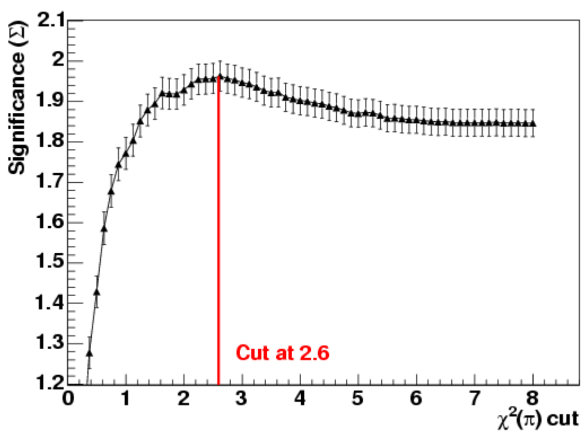












$$\Sigma = \frac{S}{1.5+\sqrt{B}} \quad \text{vs. cut value}$$

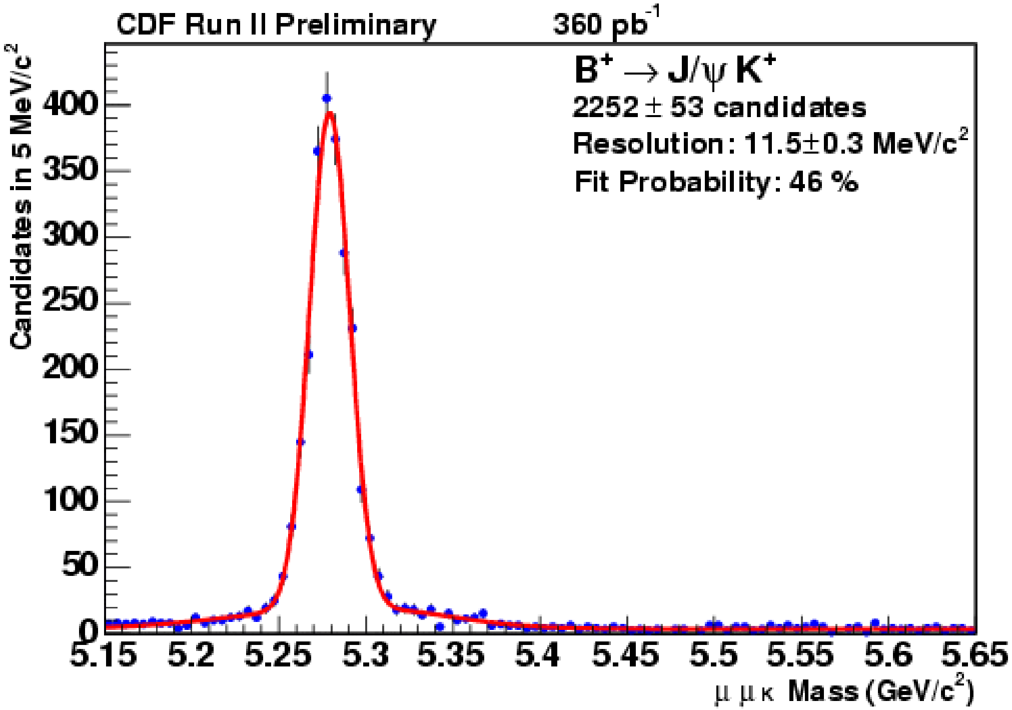
Summary of analysis cuts

Summary of cut values used:

1. p_T (π) > 1.8 GeV/c
2. $L_{xy}/\sigma(L_{xy})$ > 4.4
3. χ^2(3D) < 9.0
4. $d_0(B_c)$ < 65 μm
5. pointing angle < 0.4 radians
6. $\chi^2_{vtx}(\pi)$ < 2.6
7. ct < 750 μm

Cut	MC Efficiency	N-1 data entries	Background rejection
$L_{xy}/\sigma(L_{xy})$	42.0%	11930	96.7%
p_T (π)	62.3%	3043	87.1%
χ^2(3D)	80.5%	762	48.4%
Pointing angle	85.4%	768	48.8%
$\chi^2_{vtx}(\pi)$	92.7%	565	30.4%
$d_0(B_c)$	97.5%	448	12.3%
ct <	98.7%	410	4.1%

Reference channel



$B^+ \to J/\psi K^+$

Used for

- checking data/MC
- estimating expected significance

Using same cuts (but no upper cτ cut) : 2252 signal events in B^+

(efficiency = 60% with respect to cuts used in B^+ mass measurement that has 10× more background)

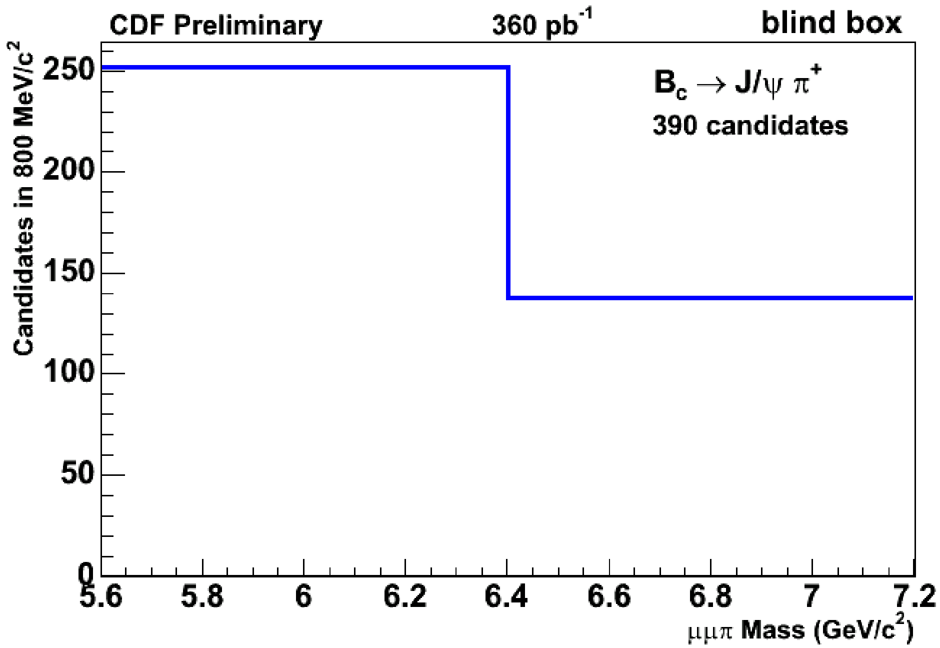
Using these cuts the relative efficiency from Monte Carlo is

$$\frac{\varepsilon_c}{\varepsilon_u} = 58.6 \pm 1.8\%$$

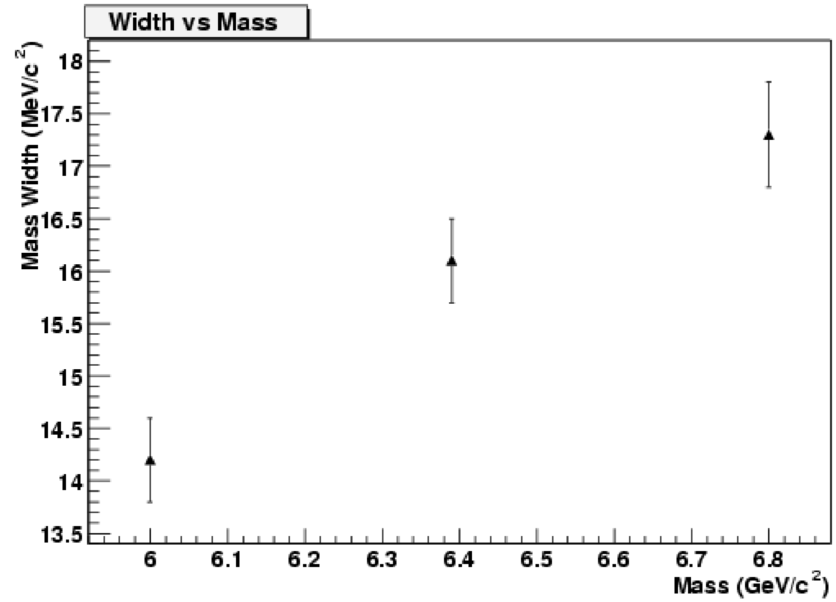
$$S = \frac{\varepsilon_c}{\varepsilon_u} N_u R$$

Based on "standard" values of MC (i.e. spectrum) and lowest theoretical value for R = 0.008 we have estimated an expected signal S ranging from 4 to 30 events, as the lifetime varies within the 1-σ uncertainty

Background expected



Resolution as a function of invariant mass

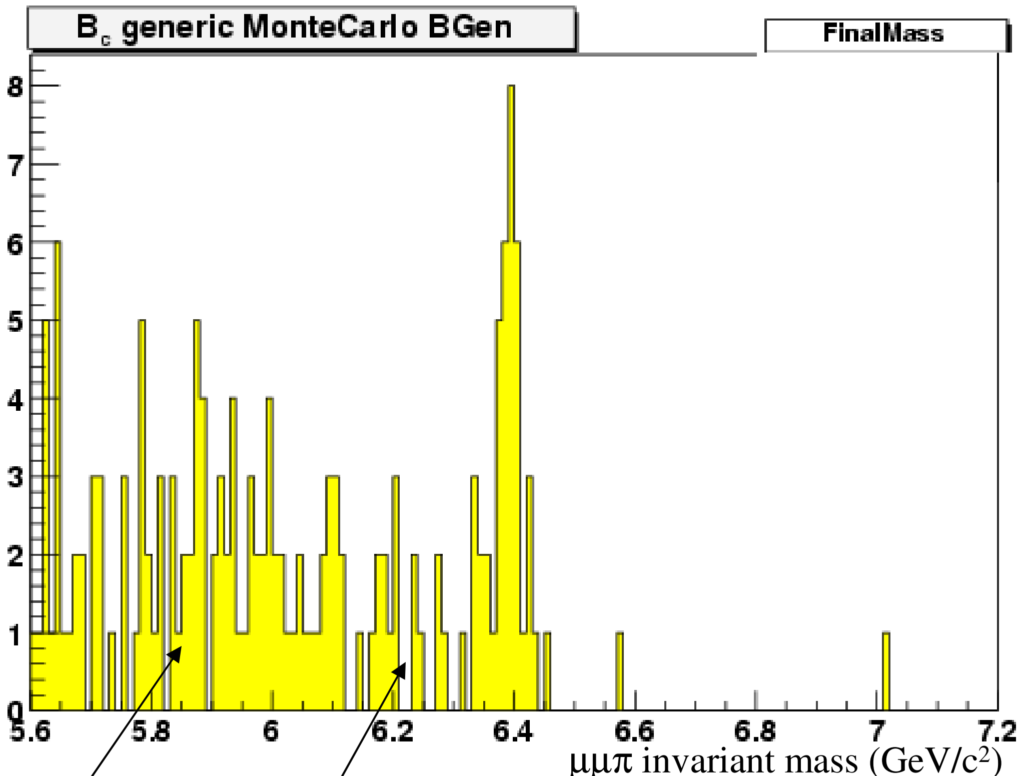


Background: 390 events survive the cuts.
The expected resolution varies from 13 to 19 GeV/c^2 over the mass range

The average background ranges from 9 to 20 events in a $\pm 2\ \sigma_M$ region around the mass peak. σ_M = detector resolution from MC (checked on J/ψ K).

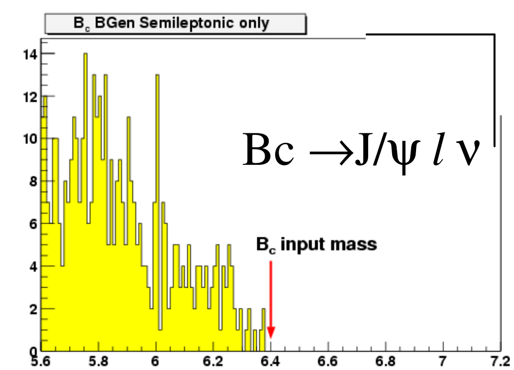
What do we expect from Monte Carlo

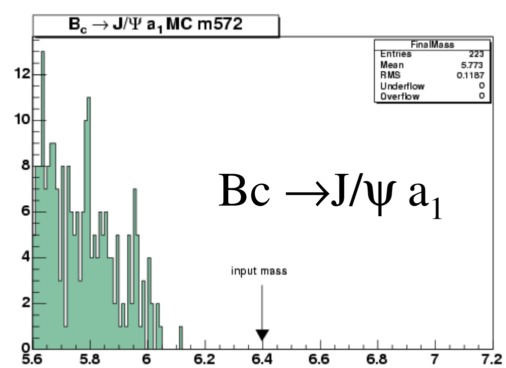
- Signal only,
- mass as in PDG.
- all decays included to MC,
- Full detector and trigger simulation,
- reconstruction and analysis cuts applied



Semi-leptonic decays

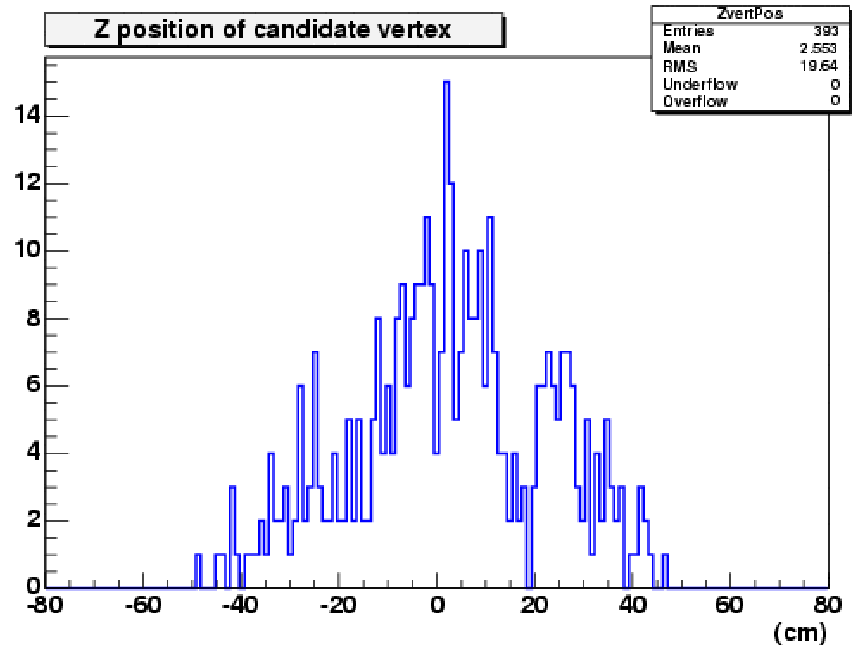
Partially reconstructed decays

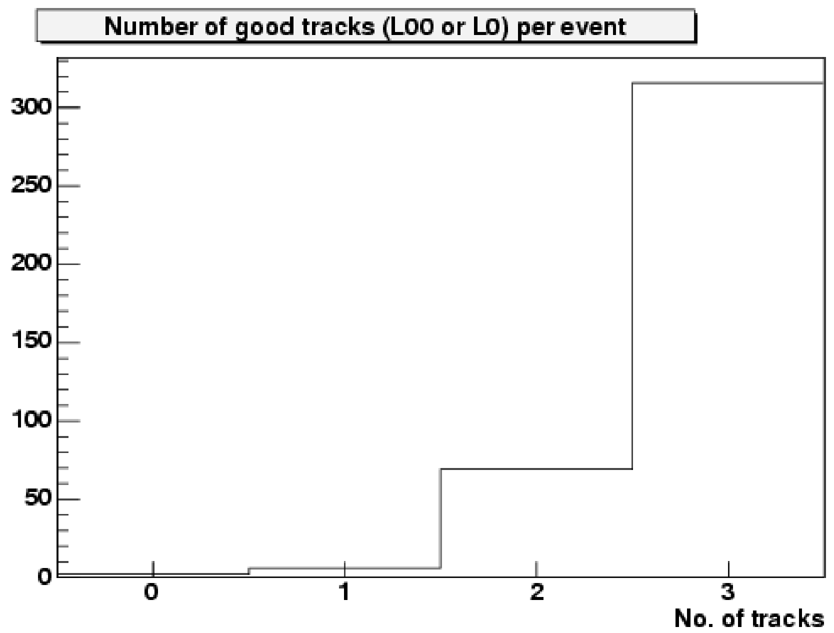


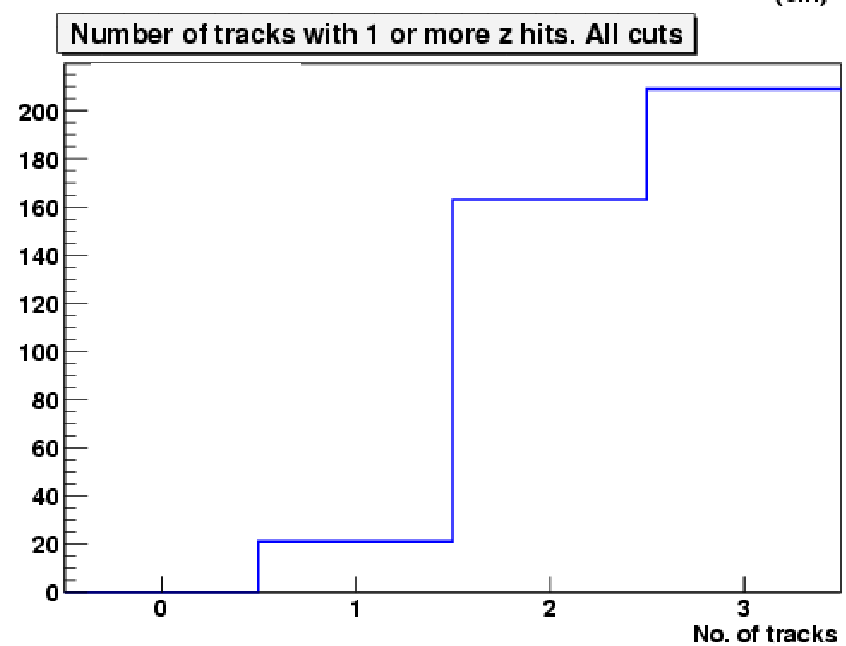


Checks on events passing the cuts

- *z*-distribution looks ok (no excess from "bulkhead regions)
- Silicon hit use ok







The statistical method

We don't know a priori where the mass peak is, if any.
In this case standard methods of establishing signal significance (e.g. Poisson probability) fail (Rolke-Lopez, PHYSTAT 2003) At the limit of infinite search window the probability of occurring in a fluctuation is 1.

We have to set up a way to test
the hypothesis : "there is a significant peak in one place" against the
null hypothesis: "there is no peak in any place in the search window"
What is fixed in our test: the width of the signal (detector resolution)

Some definitions:
"False positive" : mistaking a random fluctuation for a mass peak
"False negative": concluding that there is no significant peak, when instead there is signal. (not a mistake, a missed opportunity)
Philosophical note:
The real truth is unknown and can be inferred only in the limit of infinite statistics. Practically: more statistics and/or independent tests.

The statistical method

Toy MC:

1) Decide in advance on a procedure to search for a peak, i.e define an algorithm and a "significance" or "score function".

2) Decide in advance on a level of acceptable probability for false positive (probability that background fluctuates into a signal): we choose $P_{fp} = 0.1\%$ this is better than single-sided Gaussian tail > 3 σ

3) Deploy the peak-finder method on a "toy Monte Carlo" distribution, containing only background and no signal, to set-up the statistical test: establish the value of the "score function" corresponding to $P_{fp} = 0.1\%$. This completely defines the test.

4) Find the power of the statistical test, i.e. minimum number of real events needed to have only 5% of false negative, using "toy MC". Useful for establishing limit.

5) Apply the same test to the data and find out if it is above or below the threshold determined in step (3).

Toy-MC function:

linear background plus broad Gaussian to simulate partially reconstructed decays

Peak finder:

binned likelihood fit

Fit function:

linear for background, plus gaussian for signal.

Constraints:

peak position and width are fixed,

number of signal events S is constrained to be $S \geq 0$

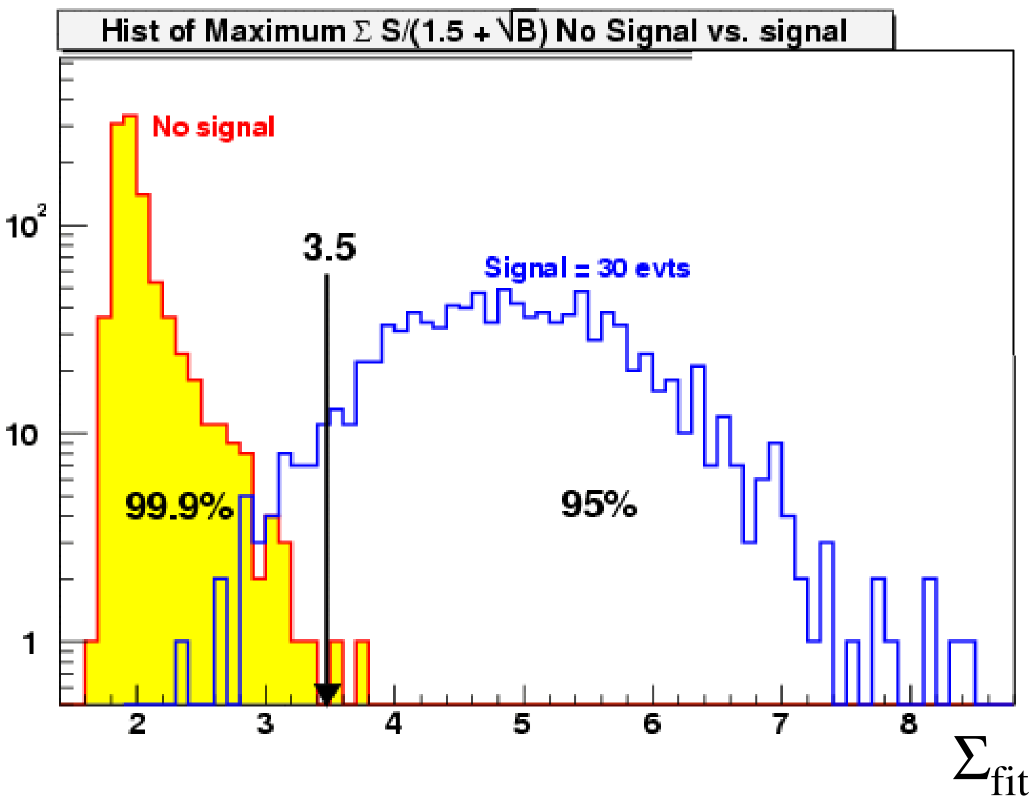
Step: 10 MeV

Range: -100 + 200 MeV from the sliding peak position. Asymmetric to minimize bias from partially reconstructed decays

Score function:

Maximum value of $\Sigma = \dfrac{S}{1.5 + \sqrt{B}}$

Results of toy-MC experiments



Yellow: distribution of the score function for Toy MC experiments with no signal. Threshold set to 3.5

Blue: distribution of the score function for toy MC experiments with $S_{true} = 30$, corresponding to a false negative probability of 5%. Signals smaller than 30 counts can still be detected, with smaller probability.

Decision tree:

If the score function is in any contiguous region in mass above 3.5 (that means probability of fluctuation < 0.1%) we interpret this as evidence for this decay and we measure the mass.

If the score function is everywhere below 3.5 we set a limit on $\sigma \times BR$ as a function of lifetime.

If the score function is above 3.5 in more than one location we declare “crisis” and wait for more data to resolve the issue.

Why did we choose probability for a false positive < 0.1% :

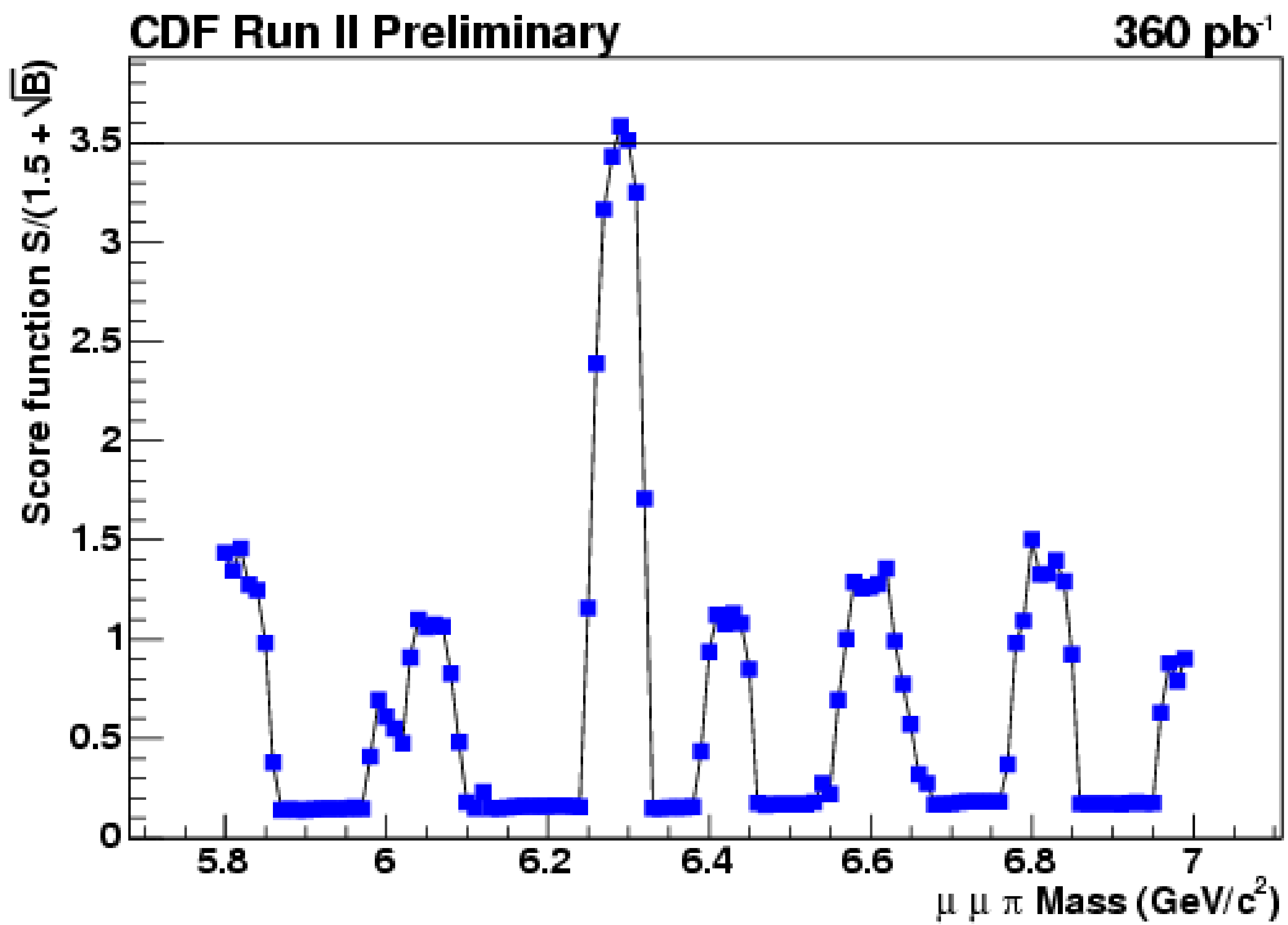
The expected number of signal events ranges from 4 to 60 events, and is a function of lifetime, p_T spectrum, branching ratio.
With present data sample we have 10 times more J/ψ K than Run I
Although not the whole range of values could be excluded, it is a good time to open the box and allow for “evidence”.
To achieve a probability of “false positive” corresponding to the probability of a 5σ Gaussian tail, with the same test would require about > 1 fb^{-1}.

We decided to open the box with these criteria.

The results

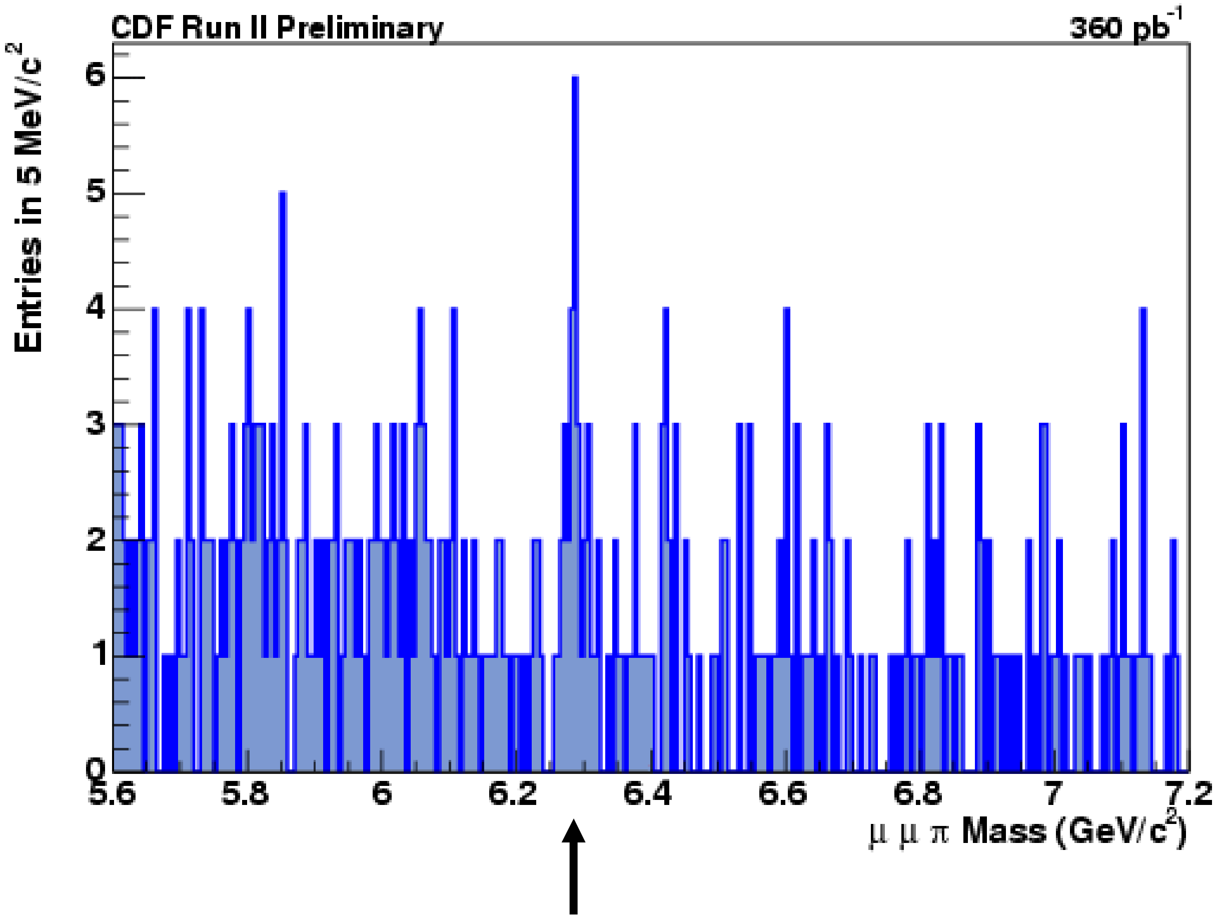
One significant peak

Maximum score is at 3.6 (threshold was at 3.5) ⇒
less than 0.1% probability that it is a statistical fluctuation.



..Let's measure the mass

Here is the mass plot.

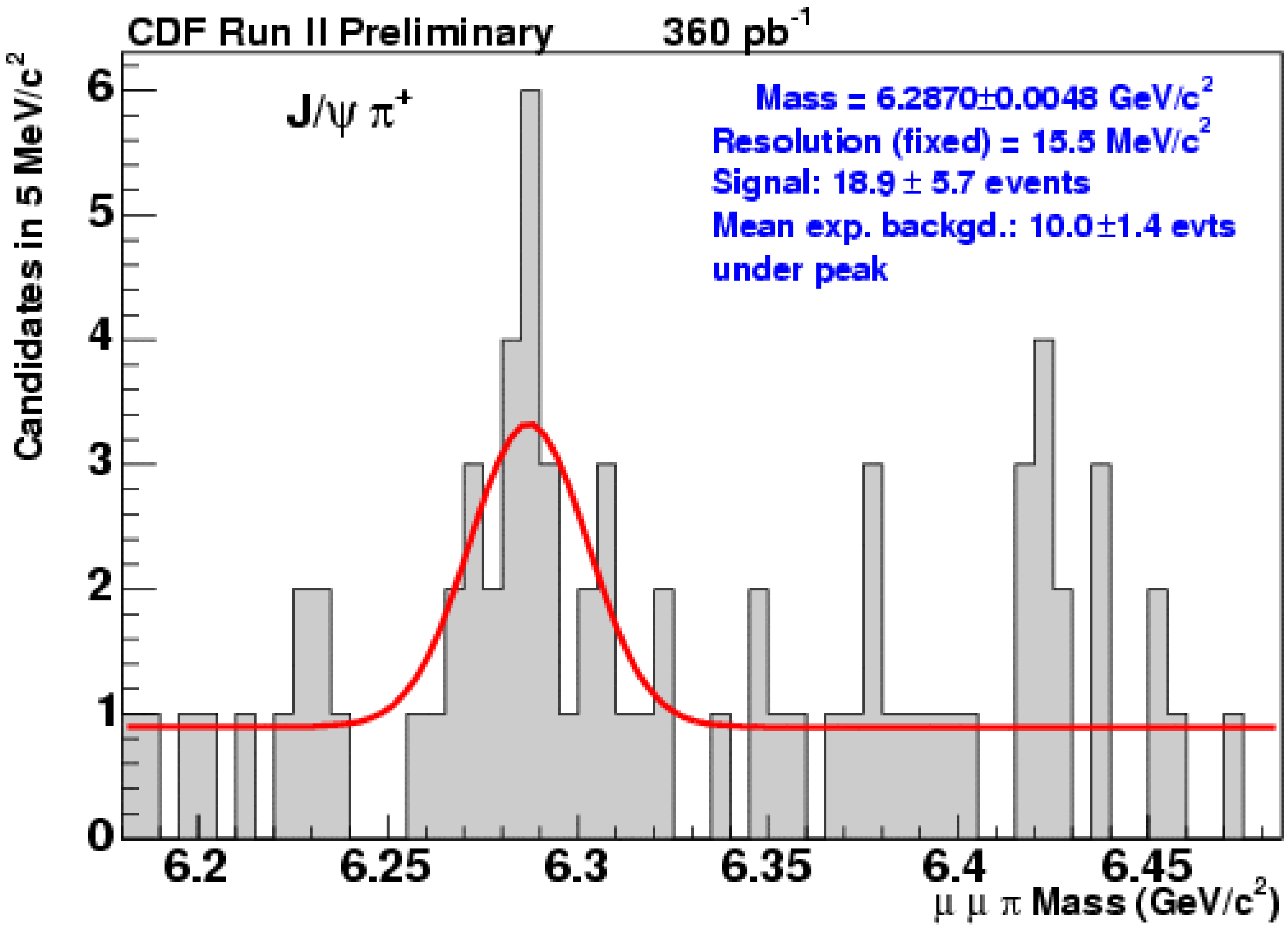


Peak seems to be in the position indicated by likelihood scan.
Qualitative agreement with expected shape from Monte Carlo.

Probability of a fluctuation < 0.1%

Measure mass of highest significance peak, width is constrained.

$$\text{Mass} = (6287.0 \pm 4.8_{stat.})\ \text{MeV}/c^2$$



Systematic Uncertainties:
The mass resolution has been calibrated using the J/ψ mass.
We benefit from other analyses that have pinned down the systematic uncertainties to ≈300 keV for high statistics decay modes.

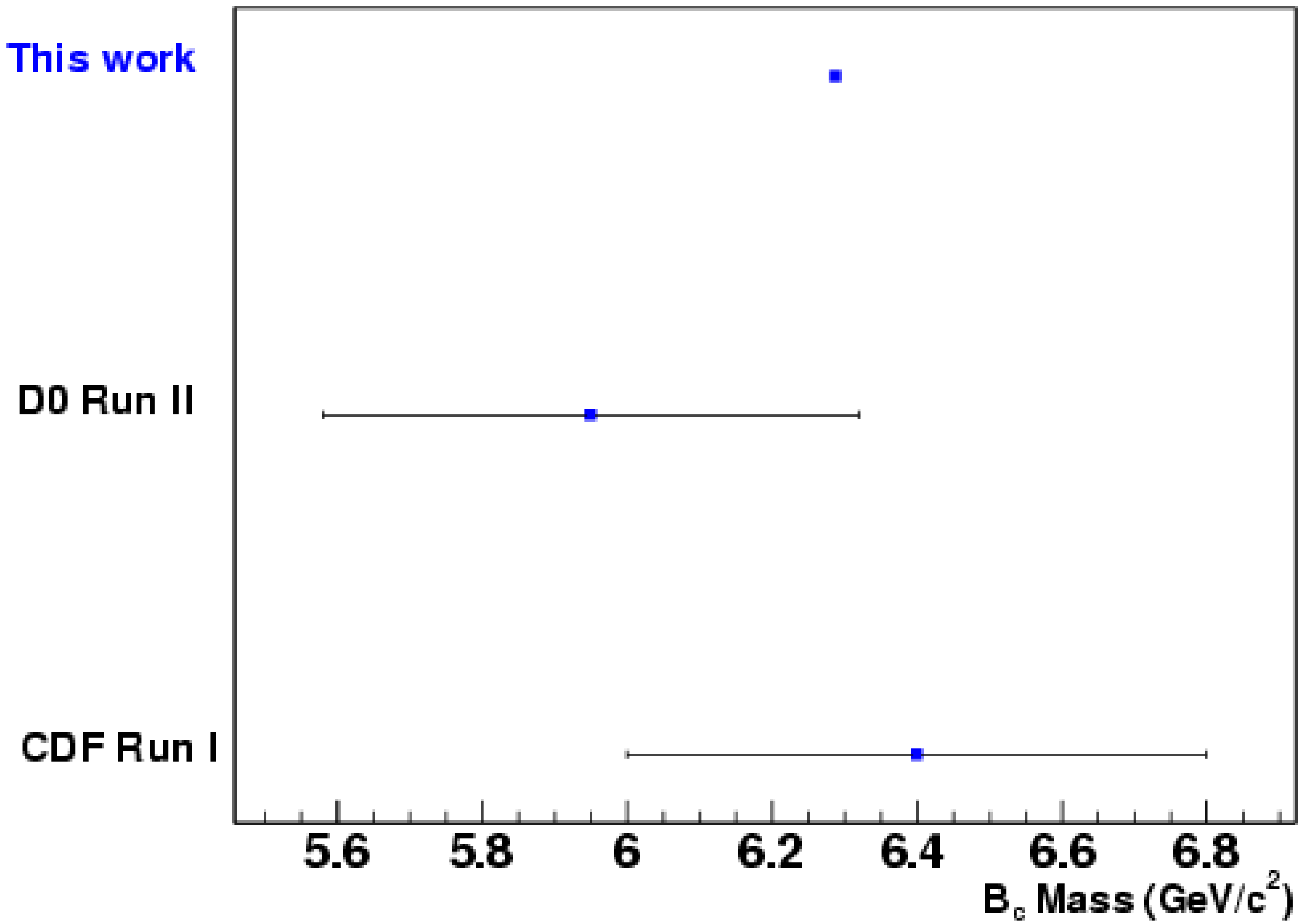
Systematic	Value (MeV/c^2)	
Background shape:	0.8	from fits, changing background shape.
Momentum scale:	0.6	Calculation based on other analysis
π/K dE/dx:	0.2	To extrapolate from other analysis
Tracking:	0.2	from other analysis
Δp_T:	0.5	Additional, to account for different spectrum
Total:	1.1	

Main source of systematic uncertainty is statistics limited.

Comparisons and conclusions

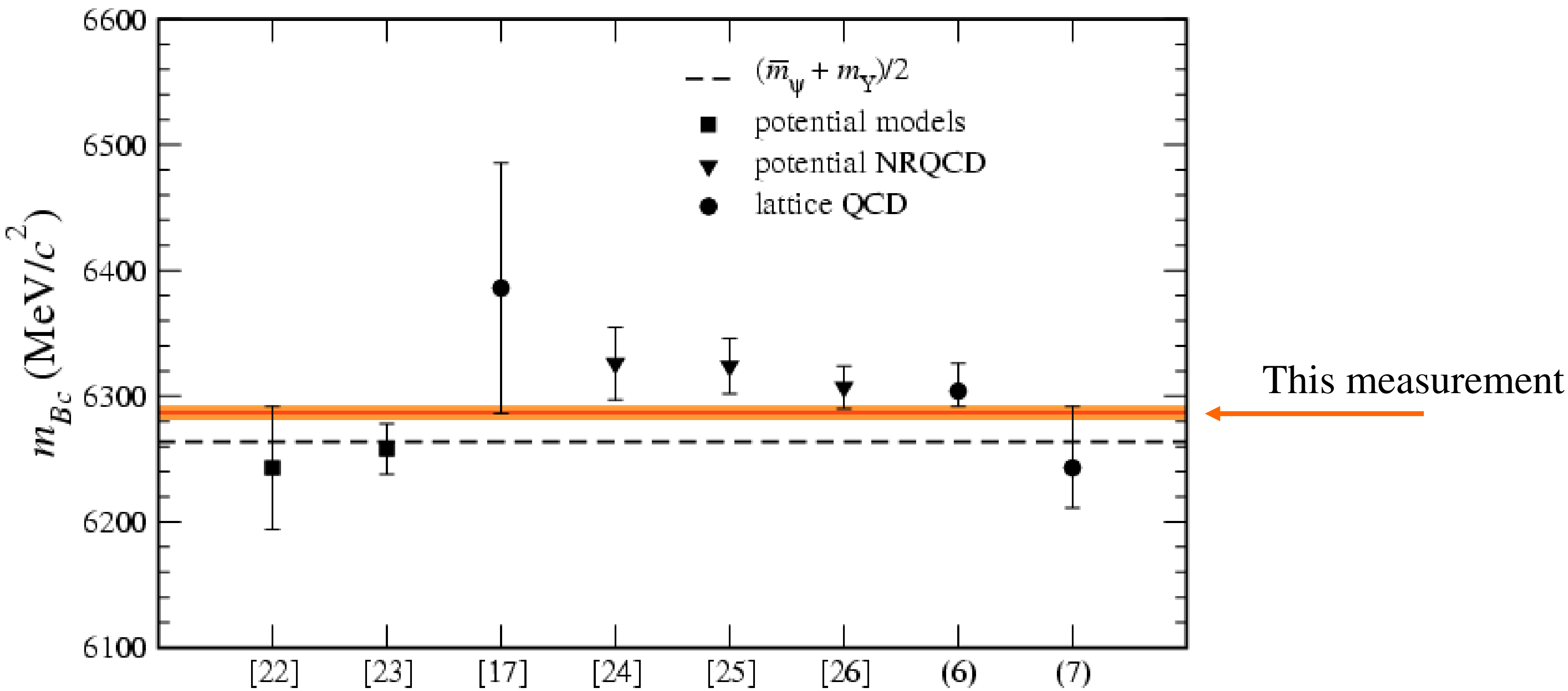
How does this measurement compare with

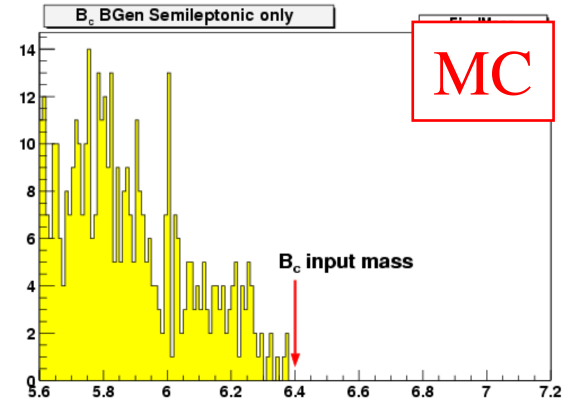
- previous determinations of B_c mass (semileptonic decay)
  - Factor ≈100 more precise, due to the fully reconstructed decay.



How does this measurement compare with

- theoretical calculations
  - General good agreement





Next steps:

measure properties of the B_c

- measurement of B_c lifetime:
  - semileptonic channels
  - fully reconstructed channel(s)
- measurement of production times branching fraction
- measure p_T spectrum
- add more statistics, when we shall have more data
- branching fraction of other decay channels: $J/\psi\ a_1$, $B_s\ \pi$,…
- excited states
- measure spin

Far future:

- rare decays
- ….. Whole new set of measurements possible

Conclusions

- We defined a blind procedure to search for, or set limits on, the decay mode $B_c \rightarrow J/\psi\, \pi$. The criteria was to unblind the analysis when a background fluctuation with probability < 0.1% was achievable.

- Opening the box we found evidence for fully reconstructed B_c decays, with 19 signal events over a background of 10 events.

- Interpreting these events as $B_c \rightarrow J/\psi\, \pi^{\pm}$ we measure a B_c mass of:

$$M(B_c) = (6287.0 \pm 4.8 \pm 1.1)\ \mathrm{MeV}/c^2$$

- This mass number is in good agreement with the theoretical predictions
 note: predictions not used to determine region to search for signal.

- We shall study further the properties of the B_c also with other channels and more statistics.

We are grateful to
our colleagues of the FNAL accelerator division,
who provided luminosity,
to the Fermilab technical staff and to
the funding agencies for support.


Aurora Borealis at 42° N
Fermilab, 9th November, 2004, 3 a.m.

Backup slides

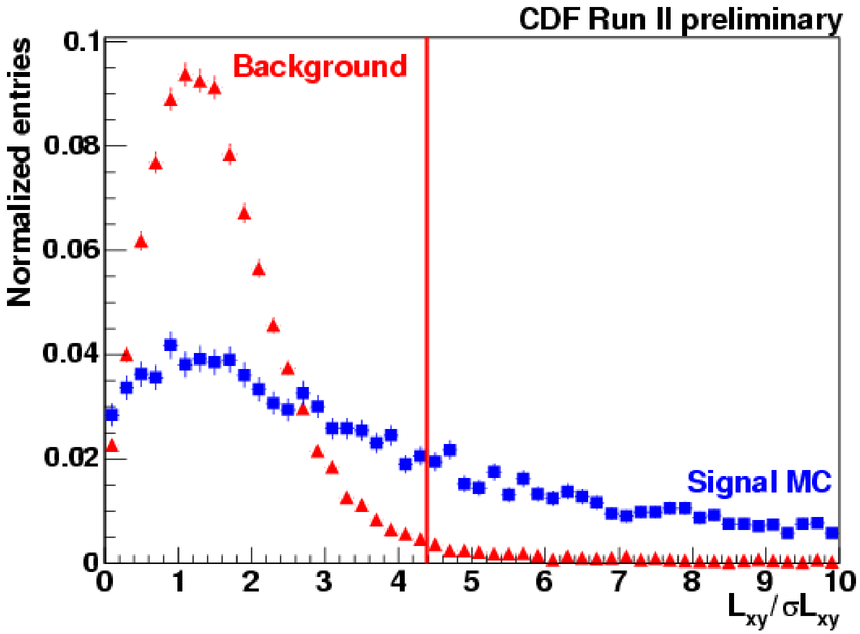
Q:

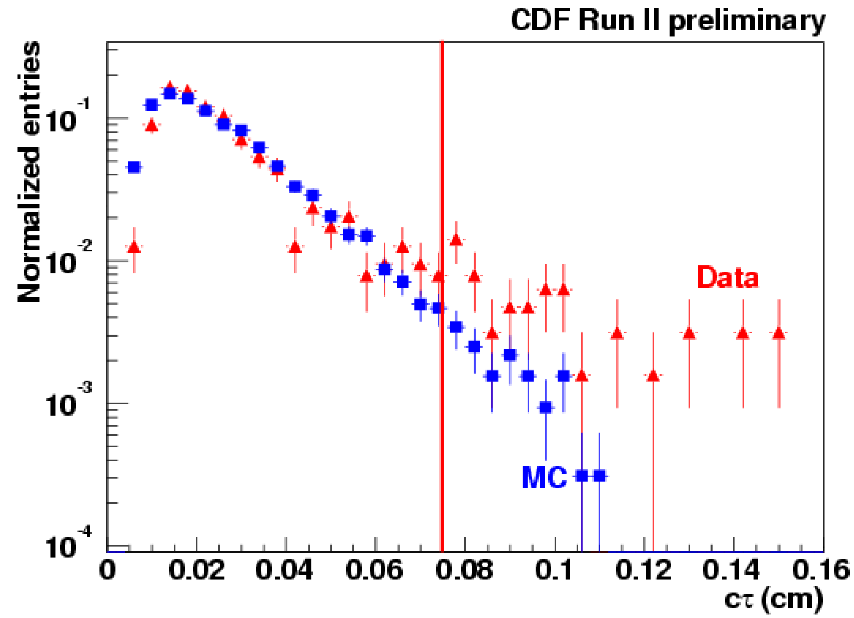
If the search region were the one indicated by theorists, what would the significance of the signal be?

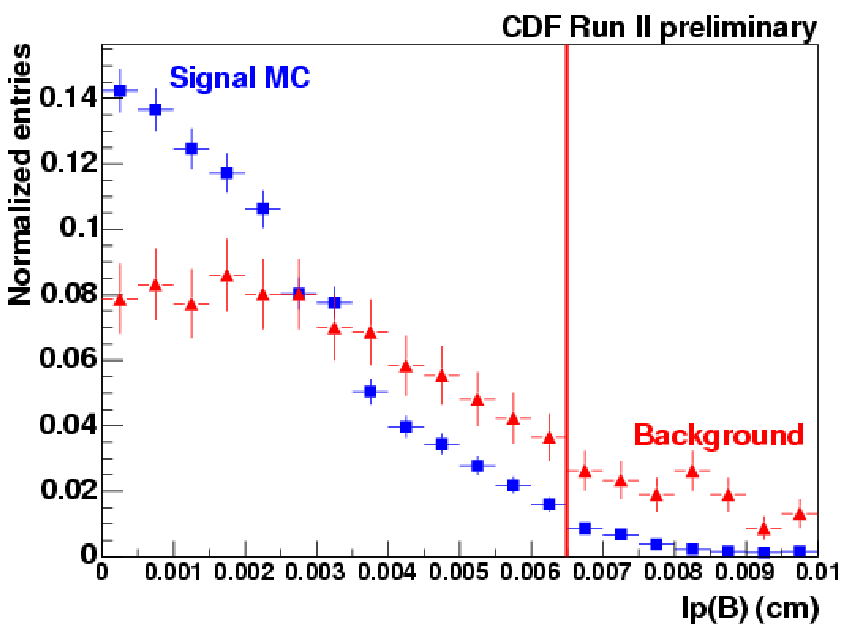
A: The probability that the 29 events are a random fluctuation of an average background of 10 is

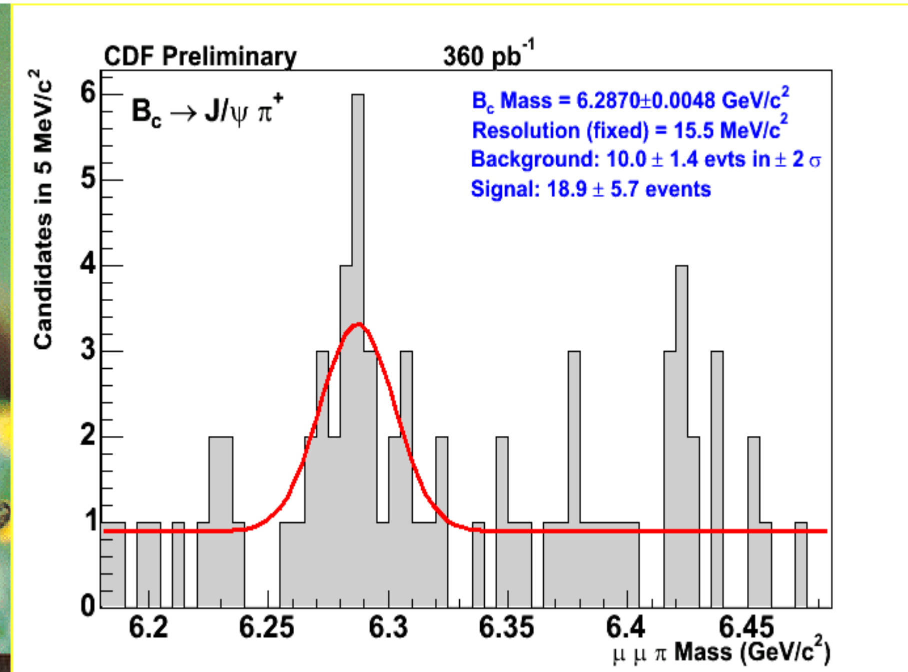
$$P_{S+B} = 1 - \sum_{S+B=0}^{28} \frac{B^{S+B}}{(S+B)!} e^{-B} = 4.7 \cdot 10^{-7}$$

Disclaimer: this statistical test is not what we have done


CDF Run II preliminary
Background
Signal MC
Normalized entries
$L_{xy}/\sigma L_{xy}$


CDF Run II preliminary
Data
MC
Normalized entries
cτ (cm)


CDF Run II preliminary
Signal MC
Background
Normalized entries
Ip(B) (cm)



CDF Preliminary
360 pb^{-1}
$B_c \rightarrow J/\psi\ \pi^+$
B_c Mass = 6.2870±0.0048 GeV/c^2
Resolution (fixed) = 15.5 MeV/c^2
Background: 10.0 ± 1.4 evts in ± 2 σ
Signal: 18.9 ± 5.7 events
Candidates in 5 MeV/c^2
0
1
2
3
4
5
6
6.2
6.25
6.3
6.35
6.4
6.45
μ μ π Mass (GeV/c^2)