Recent Tevatron Results on Heavy Flavors

Peter H. Garbincius - Fermilab – member of DØ

2 weeks old!

DØ: *Observation of a new $B_s^0 \pi^\pm$ state*

arXiv:1602.07588 – submitted to Phys. Rev. Lett.

very briefly

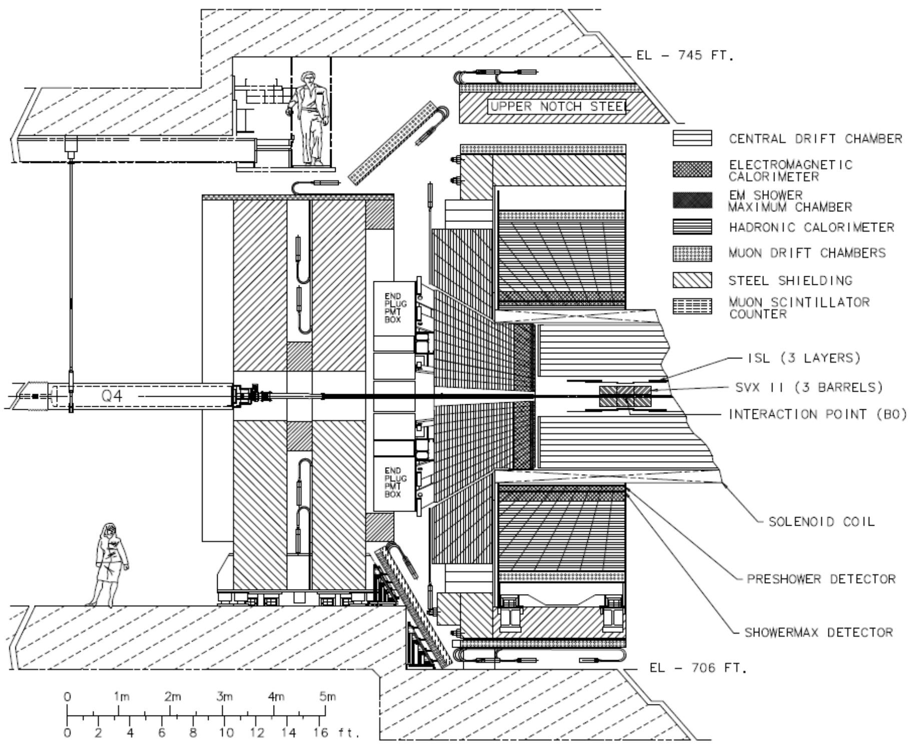
CDF: *Measurements of the $B_c^\pm$ production cross section in $p\bar{p}$ collisions at sqrt(s) = 1.96 TeV*

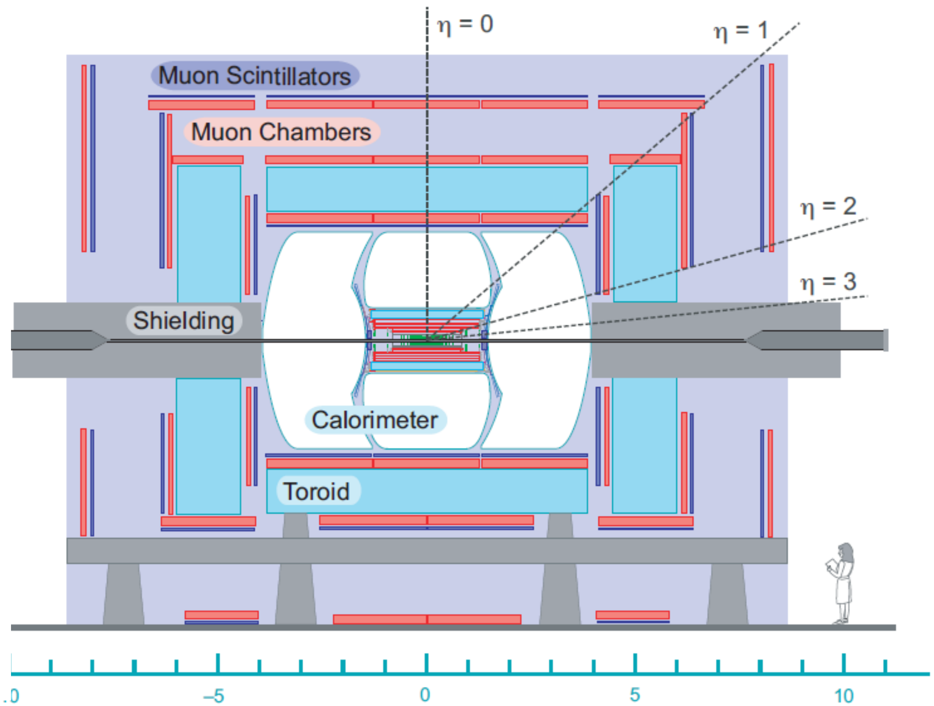
arXiv:1601.03819 – accepted for pub. by Phys. Rev. D

Tevatron $p\bar{p}$ at $\sqrt{s}$ = 1.96 TeV
shutdown at end of September 2011
FINAL analyses based on *FULL* Run II data sets

CDF II: $\int \mathcal{L}\, dt$ = 9.3 fb^{-1}
displaced vertex triggers
PID by *dE/dx* and TOF

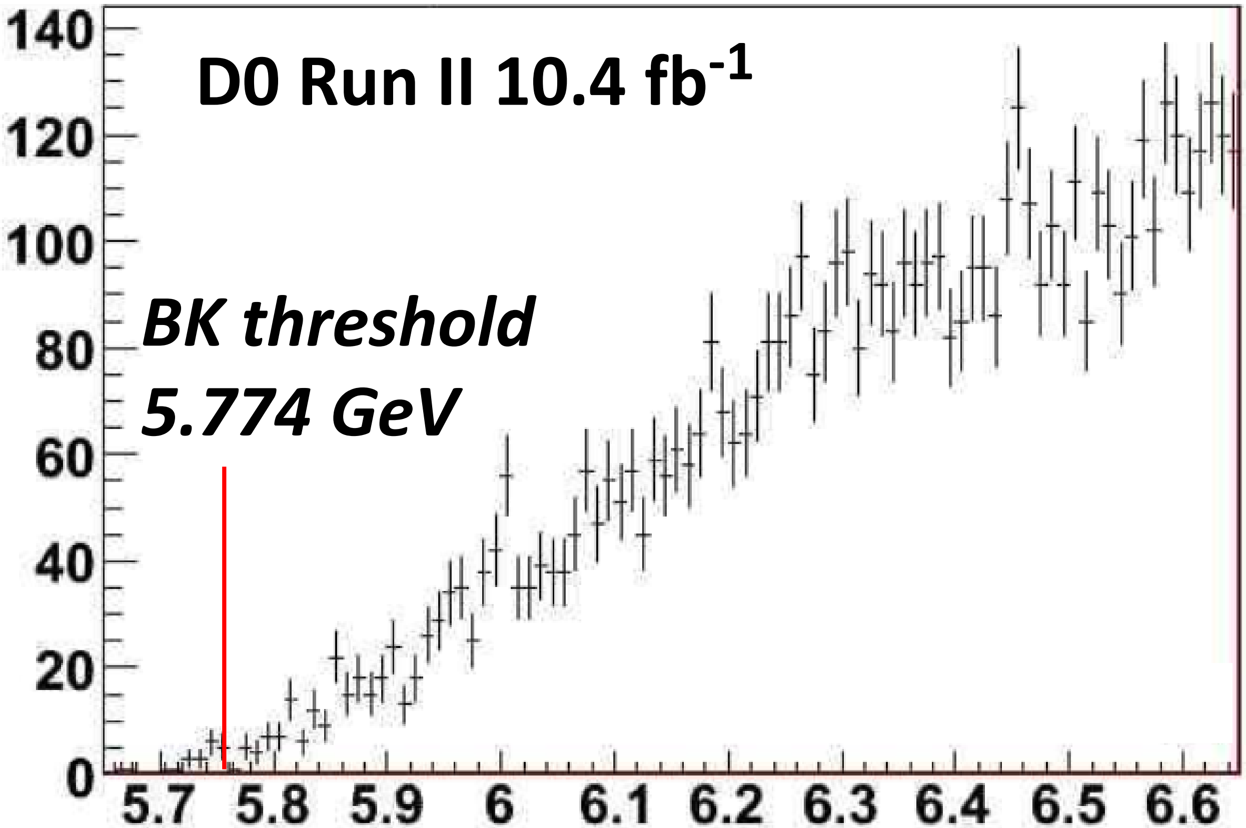
DØ: $\int \mathcal{L}\, dt$ = 10.4 fb^{-1} for *b*-physics
(without calorimetry)
excellent μ-id and coverage





D0: Observation of a new $B_s^0 \pi^\pm$ state

start by searching for strong decays of excited $B_s^{**} \rightarrow B_s^0 \pi^+ \pi^-$



Mass($B_s^0 \pi^+ \pi^-$) - GeV
(threshold 5.645 GeV)

nothing seen

look at $B_s^0 \pi^\pm$

→ exotic = b, s, u, d

quite a few exotic candidates are recently reported tetra-quarks or penta-quarks

so worth looking!

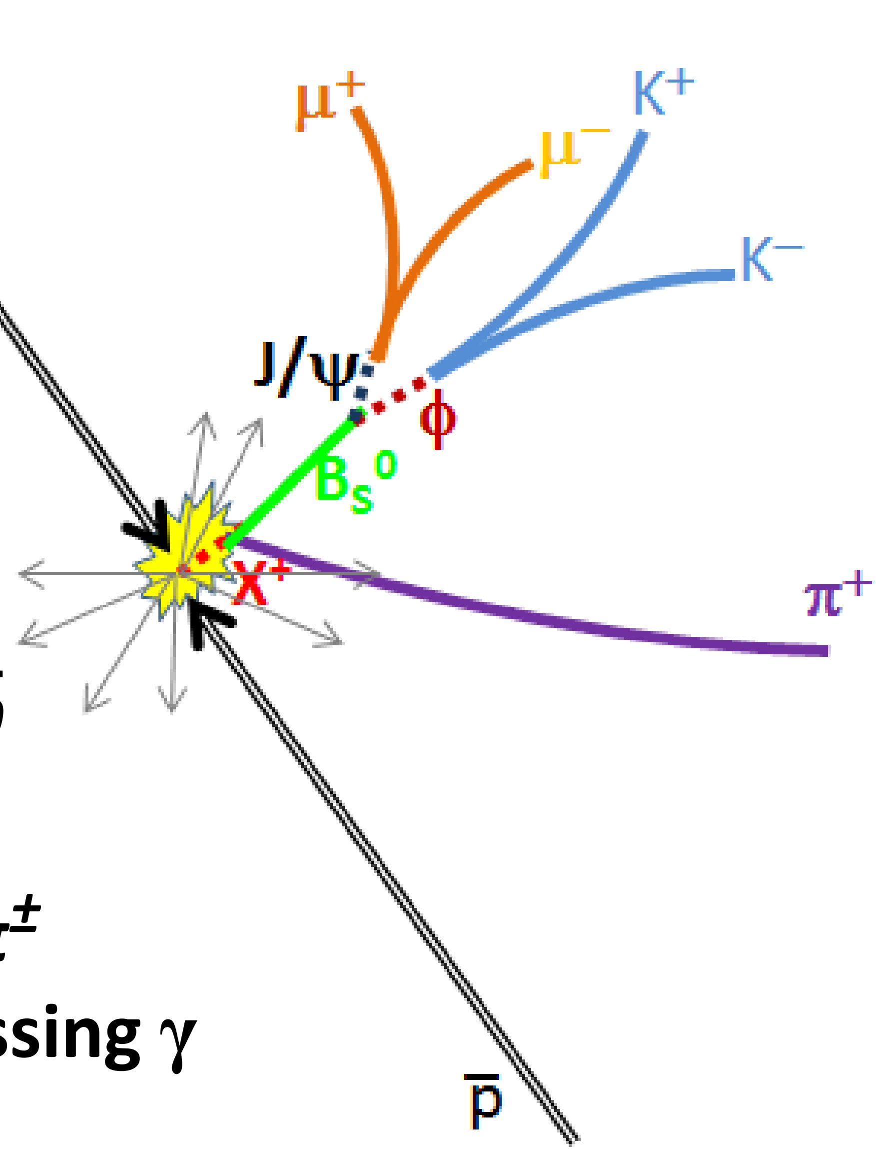
D0: Observation of a new $B_s^0 \pi^\pm$ state

$X \to B_s^0 \pi^\pm$

$B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+ \mu^-$

$\phi \to K^+ K^-$



without b-$\bar{b}$ tagging,

can't tell B_s^0 from $\overline{B_s^0}$

also could have $X \to B_s^{*0} \pi^\pm$

with $B_s^{*0} \to B_s^0$ + missing γ

D0: Observation of a new $B_s^0\pi^{\pm}$ state

Used full Run II data set 2001-2011 of 10.4 fb^{-1}

Require a single muon or dimuon trigger.

Select $B_s^0 \to J/\psi\phi$ candidates:

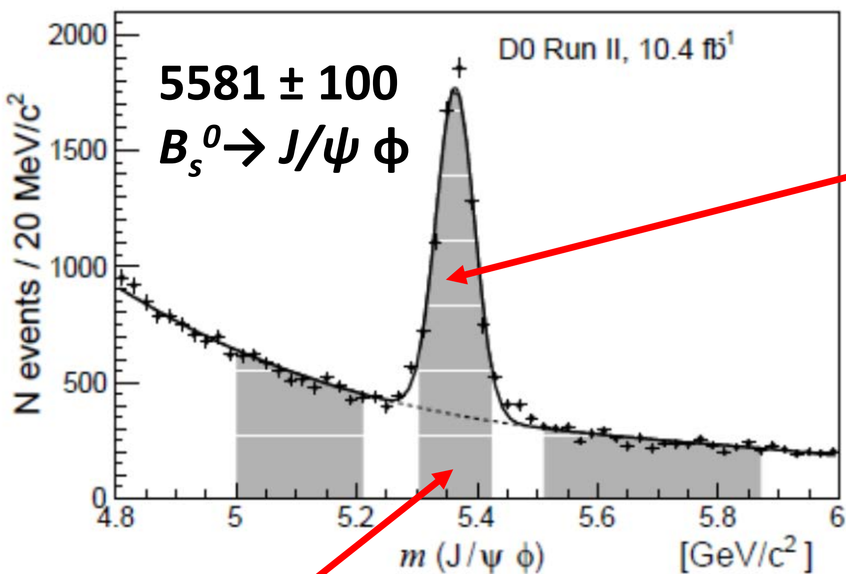
- $2.92 < M(\mu\mu) < 3.25$ GeV
- $p_T(K) > 0.7$ GeV; $1.012 < M(KK) < 1.03$ GeV
- $5.304 < M(J/\psi K^+K^-) < 5.424$ GeV; $L_{xy}/\sigma(L_{xy}) > 3$

Add a track assumed to be a pion, consistent with coming from PV:

- $p_T(\pi) > 0.5$ GeV, $IP_{xy} < 0.02$ cm, $IP_{3D} < 0.12$ cm
- $p_T(B_s\pi) > 10$ GeV
- $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.3$ (the "cone" cut)

  = angle between B_s^0 and $\pi^{\pm}$

D0: Observation of a new $B_s^0\pi^\pm$ state

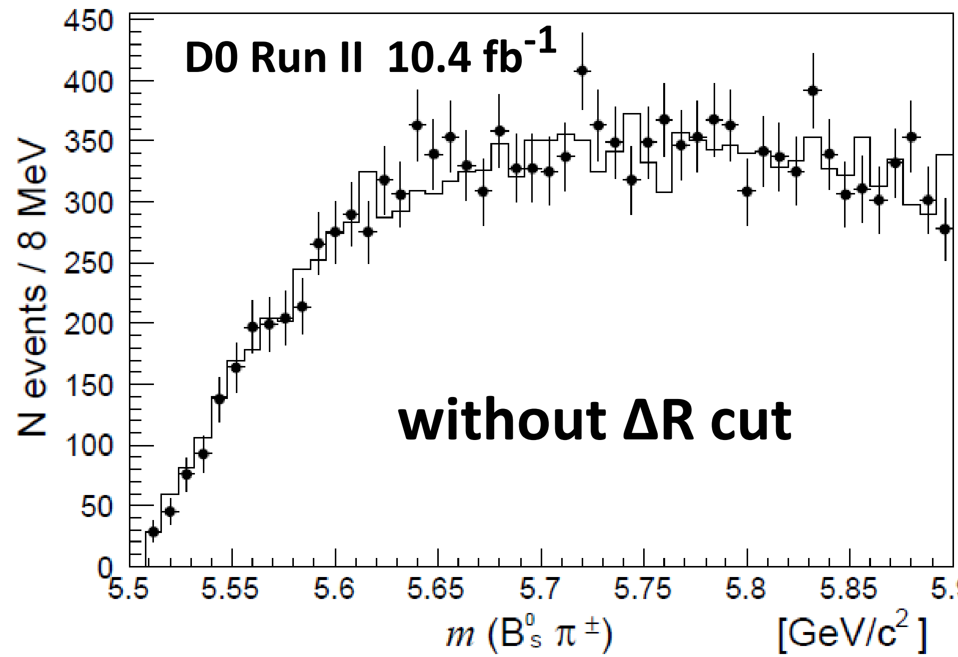


± 2 σ selection band

2 component background model:

"Genuine Background" is the B_s^0 peak:
use Monte Carlo B_s^0 peak + random π
71% of total background (*histogram*) ↓

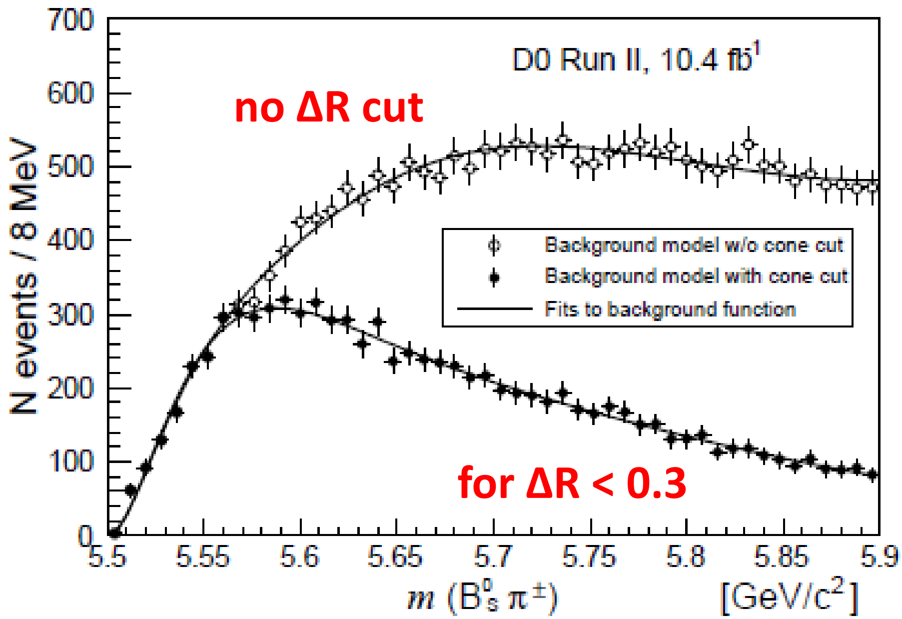
"Combinatorial Background"
under the B_s^0 peak:
use data: sidebands + random π
29% of total background (*points*) →

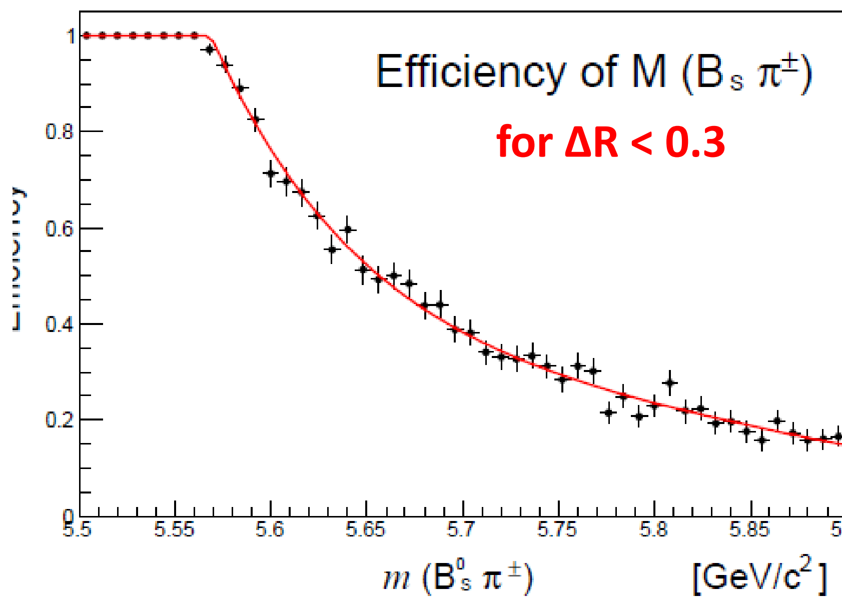


bgr = 29% combinatorial + 71% genuine

D0: Observation of a new $B_s^0 \pi^{\pm}$ state

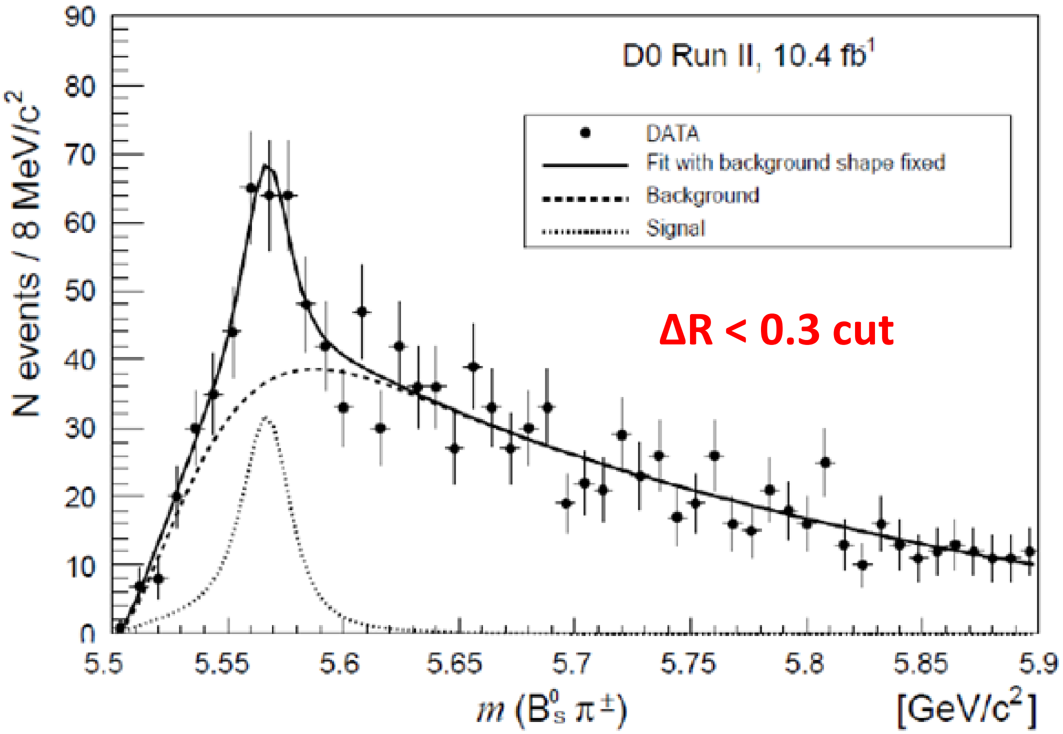
background model





$$F_{bgr}(m_{B\pi}) = \left(C_1 + C_2 \cdot m_0^2 + C_3 \cdot m_0^3 + C_4 \cdot m_0^4\right) \times exp\left(C_5 + C_6 \cdot m_0 + C_7 \cdot m_0^2\right)$$

D0: Observation of a new $B_s^0\pi^\pm$ state



add π to B_s →

S-wave relativistic Breit Wigner

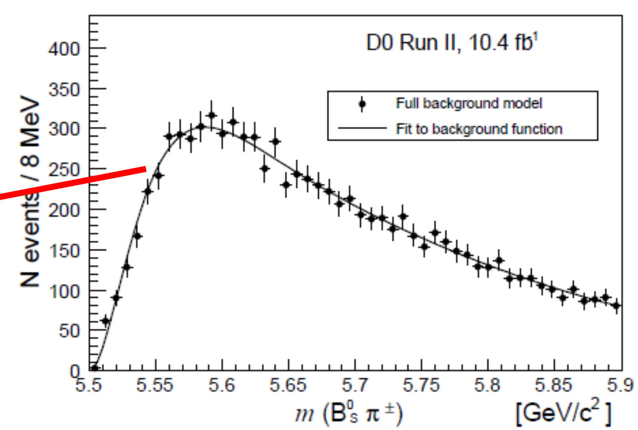
$$BW(m_{B\pi}) \propto \frac{M_X^2\Gamma(m_{B\pi})}{(M_X^2 - m_{B\pi}^2)^2 + M_X^2\Gamma^2(m_{B\pi})}$$

$$\Gamma(m_{B\pi}) = \Gamma_X \cdot (q_1/q_0)$$

convolute *BW* with MC mass resolution σ = 3.9 MeV

and multiply by Eff($M_{B_s\pi}$, ΔR cut) = from prior slide

fixed bgd shape

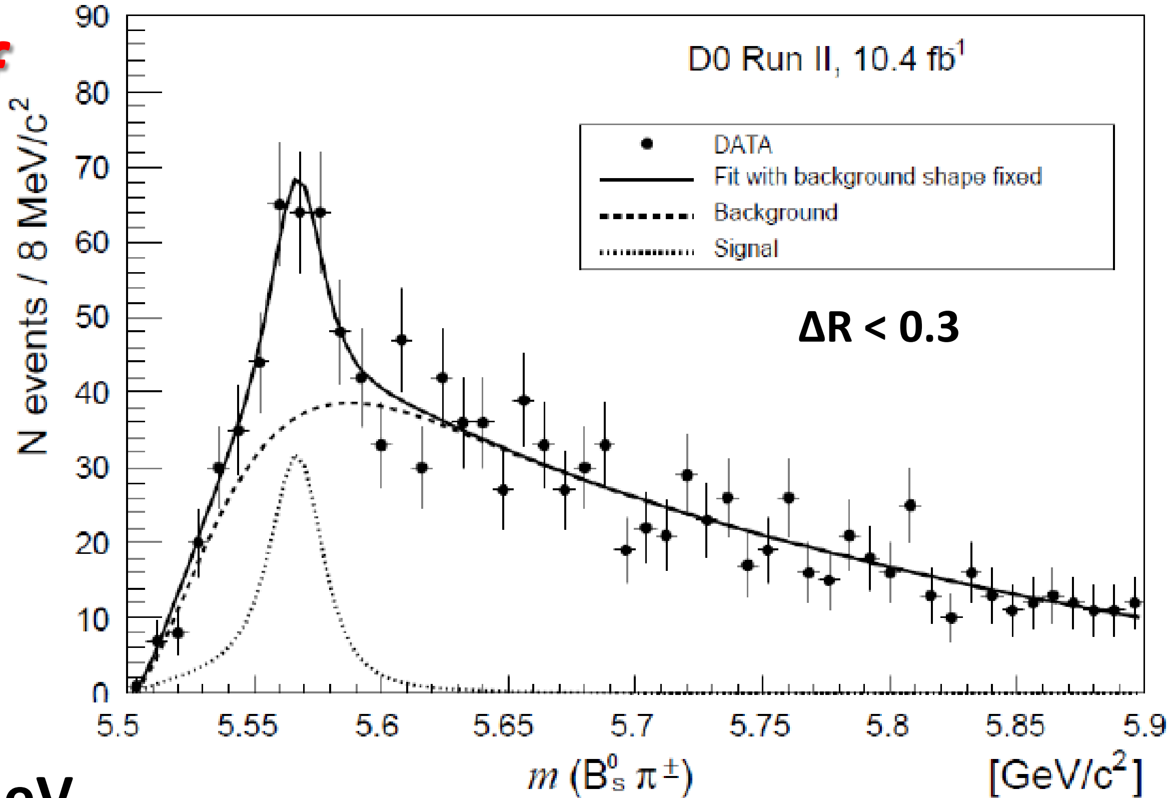


$$F = f_{sig} \times F_{sig}(m_{B\pi}, M_X, \Gamma_X) + f_{bgr} \times F_{bgr}(m_{B\pi})$$

fitting function

vary: f_{sig}, M_X, Γ_X, f_{bgr}

D0: Observation of a new $B_s^0 \pi^\pm$ state



Fit for ΔR < 0.3 cut:

M_X = 5567.8 ± 2.9 (stat) MeV

Γ_X = 21.9 ± 6.4 MeV ↔ *strong decay!*   Mass res is ± 3.9 MeV r.m.s.

N_X = 133 ± 31 events   χ2 = 32.4 for 46 DF

***Local* significance = sqrt(-2 *ln* (L_0/L_{max})) = sqrt(43.56) = 6.6 σ**

***Global* significance using Gross & Vitells LEE => 6.1 σ**

D0: Observation of a new $B_s^0 \pi^\pm$ state

Systematic Uncertainties

TABLE I: Systematic uncertainties for the observed $X(5568)$ state mass, natural width and number of events.

Source	mass, MeV/c^2	width, MeV/c^2	rate, %
Background shape			
MC samples with soft or hard B_s^0	+0.2 ; −0.6	+2.6 ; −0.0	+8.2 ; −0.0
Sideband mass ranges	+0.2 ; −0.1	+0.7 ; −1.7	+1.6 ; −9.3
Sideband mass calculation method	+0.1 ; −0.0	+0.0 ; −0.4	+0.0 ; −1.3
MC to sideband events ratio	+0.1 ; −0.1	+0.5 ; −0.6	+2.8 ; −3.1
Background function used	+0.5 ; −0.5	+0.1 ; −0.0	+0.2 ; −1.1
B_s^0 mass scale, MC and data	+0.1 ; −0.1	+0.7 ; −0.6	+3.4 ; −3.6
Signal shape			
Detector resolution	+0.1 ; −0.1	+1.5 ; −1.5	+2.1 ; −1.7
Non-relativistic BW	+0.0 ; −1.1	+0.3 ; −0.0	+3.1 ; −0.9
P-wave BW	+0.0 ; −0.6	+3.1 ; −0.0	+3.8 ; −0.0
Other			
Binning	+0.6 ; −1.1	+2.3 ; −0.0	+3.5 ; −3.3
Total	+0.9 ; −1.9	+5.0 ; −2.5	+11.4 ; −11.2

applying ± 11.3% systematic uncertainty to Yield of *X*(5568)

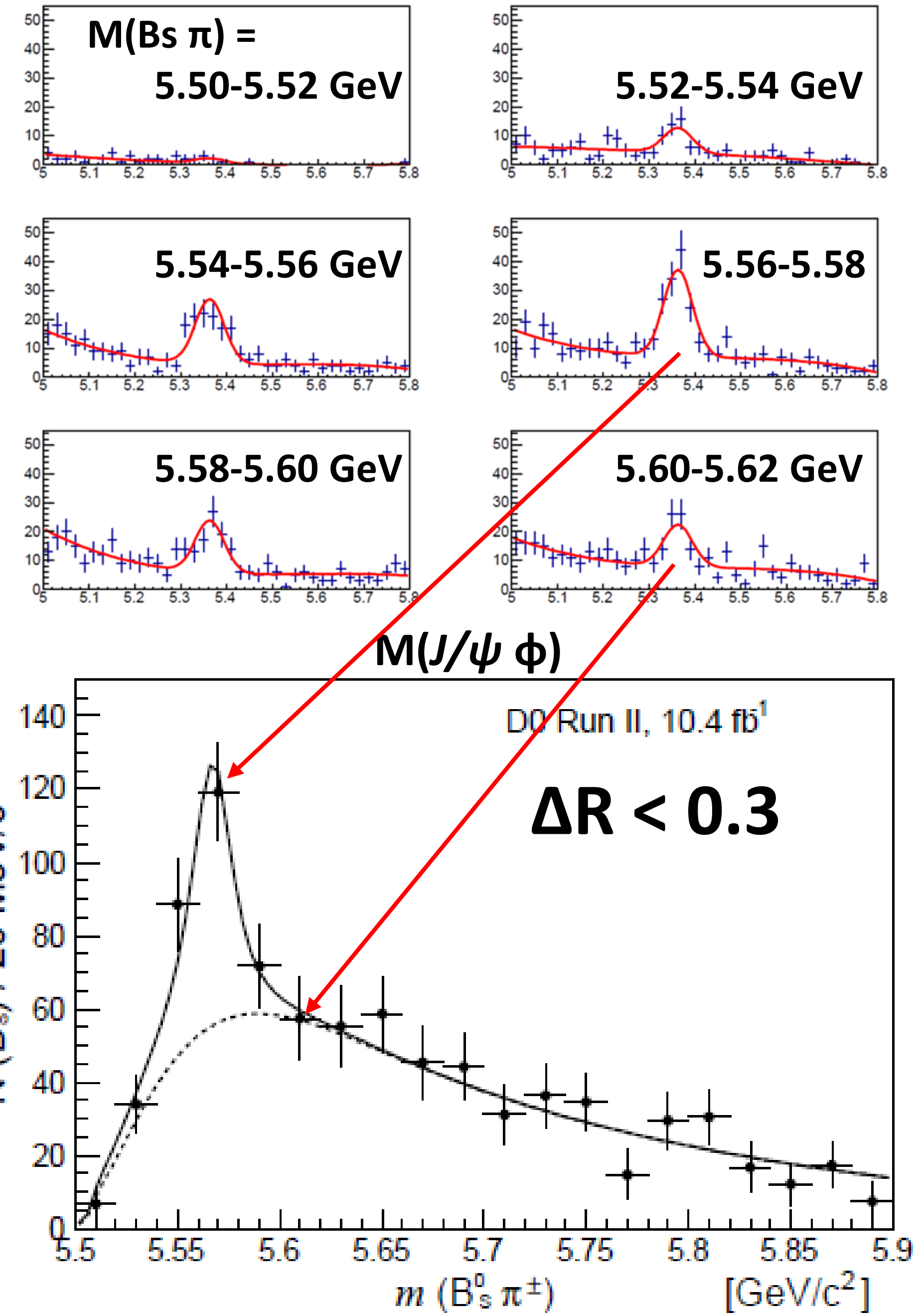
reduces significance to 5.1 σ (incl. LEE & syst.)

D0: Observation of a new $B_s^0 \pi^{\pm}$ state

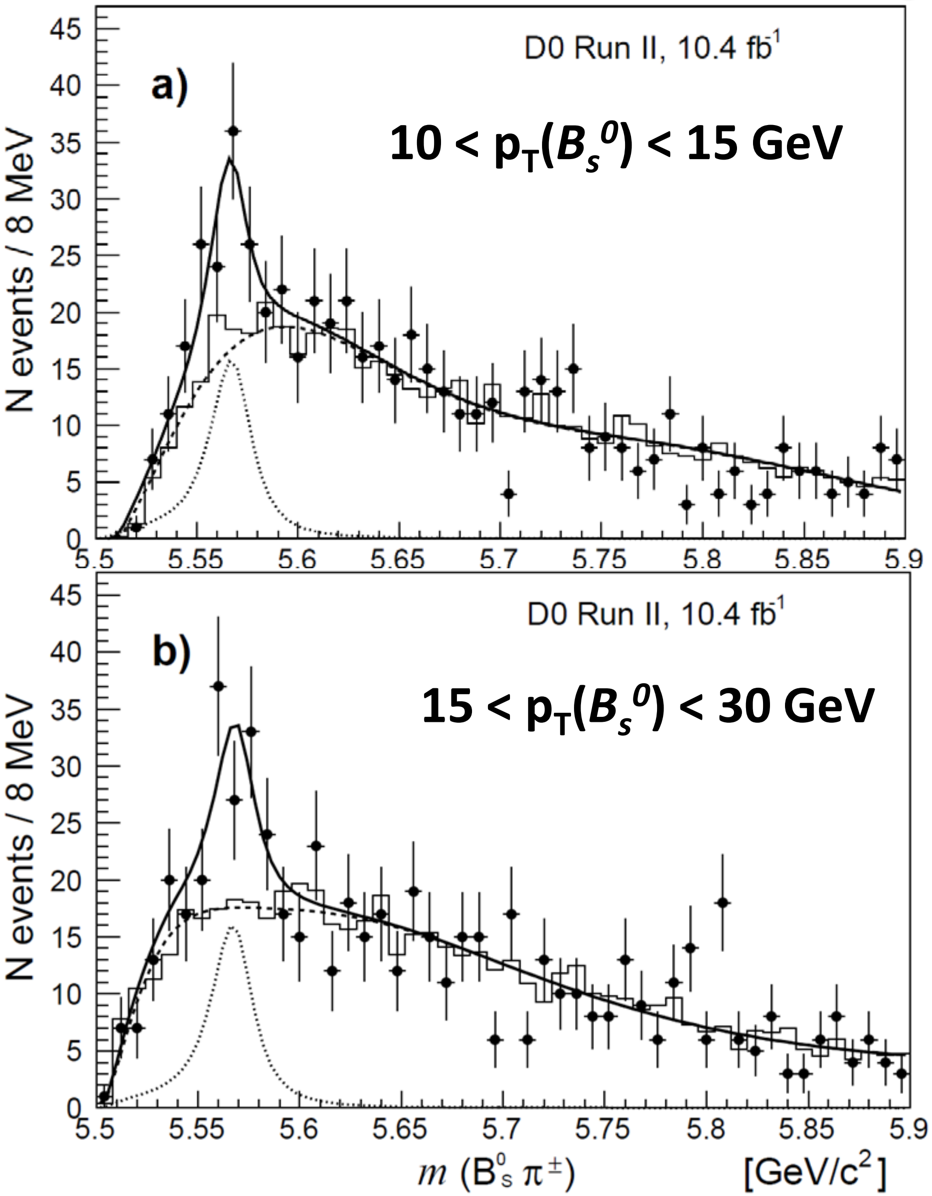
alternate method:
use *all* $J/\psi\ \phi$ with
$4.8 < M(J/\psi\ \phi) < 6$ GeV
and later fit for B_s^0
rather than mass selection cut

This removes the "combinatorial" background component

fix M_X and Γ_X
fit $N_X = 118 \pm 22$ events



D0: Observation of a new $B_s^0 \pi^\pm$ state



a cross-check

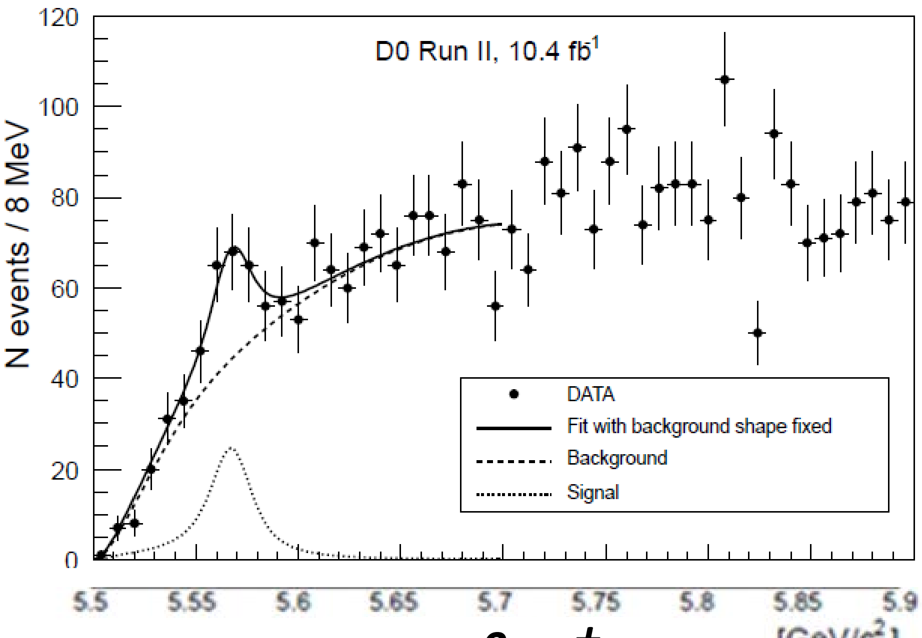
$p_T(B_s^0)$	10-15	15-30	GeV
N_X	58.6 ± 16.7	67.5 ± 21.8	events
M_X	5566.3 ± 3.3	5568.9 ± 4.4	MeV
Γ_X	18.4 ± 7.0	21.7 ± 8.4	MeV

background shape varies, but M_X and Γ_X do not!

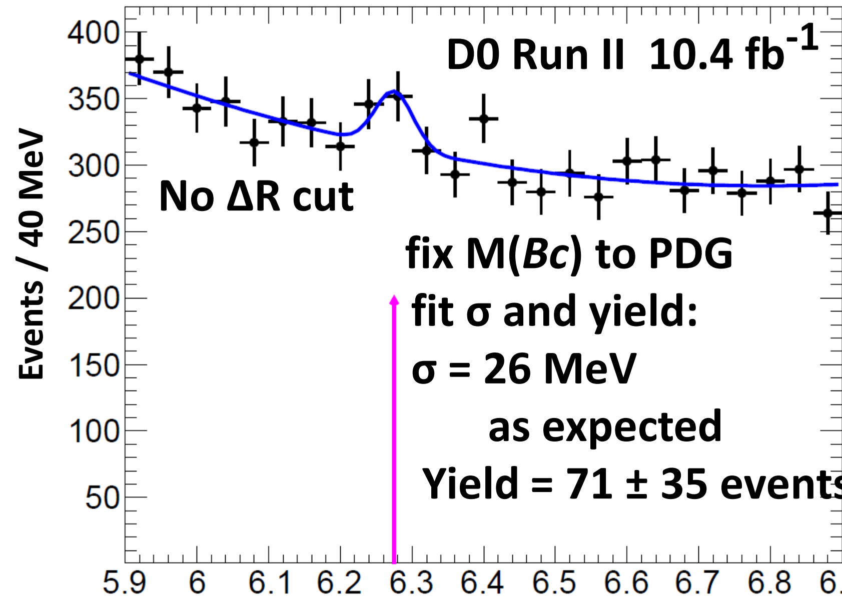
D0: Observation of a new $B_s^0\pi^{\pm}$ state

without ΔR cut

do we see $B_c^{\pm} \rightarrow B_s^0\pi^{\pm}$?



$M(B_s^0\pi^{\pm})$



$B_c^{\pm}$

$M(B_s^0\pi^{\pm})$

for no ΔR cut, $5.506 < M(B_s^0\pi^{\pm}) < 5.700$ GeV

***fix*: M_X = 5567.8 MeV as for ΔR < 0.3**

***fix:* Γ_X = 21.9 MeV as for ΔR < 0.3**

***fit:* N_X = 106 ± 25 events $\chi2$ = 18.4 for 23 DF**

D0: Observation of a new $B_s^0 \pi^\pm$ state

cross-checks performed

Use left (right) sideband for the non-B_s^0 background

Use two versions of Pythia for the B_s^0 background

Compare sidebands with "undersignal"

Allow background shape parameters to be free

Extract the signal yield without the cone cut

Use different B_s^0 mass ranges; modify the B_s^0 vertex cuts

Compare π^+ and π^- subsamples

Examine different detector regions (ϕ, η)

Test $B_s^0 K$ and $B_s^0 p$ hypotheses

Study $m(B_d^0 \pi^\pm)$ on the full Run II data sample

Look for decay $B_s^{**} \to B_s^0 \pi^+ \pi^-$

D0: Observation of a new $B_s^0 \pi^{\pm}$ state

How many *X*(5568) particles are produced?

Ratio = $\sigma(X) * \mathcal{B}(X \rightarrow B_s \pi)/\sigma(Bs)$

Since we have same B_s decay mode,

$$\sigma(X) * \mathcal{B}(X \rightarrow B_s \pi)/\sigma(B_s) = \frac{N(X \rightarrow B_s \pi)}{N(B_s)} \quad \frac{1}{\text{eff}(\pi) \sim 34\ \%}$$

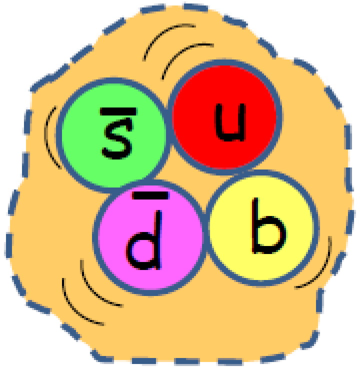
TABLE II: The $X^+(5568)$ number of events, mass, and natural width, the number of reconstructed B_s^0 mesons, the reconstruction efficiency of the soft pion $\epsilon(\pi^{\pm})$, and the production ratio R $(X^+(5568)/B_s^0)$ for two $p_T(B_s^0)$ ranges.

Parameter	$10 < p_T(B_s^0) < 15$ GeV/c	$15 < p_T(B_s^0) < 30$ GeV/c
N $(X^+(5568))$	58.6 ± 16.7	67.5 ± 21.8
M $(X^+(5568))$	5566.3 ± 3.3	5568.9 ± 4.4
$\Gamma\,(X^+(5568))$	18.4 ± 7.0	21.7 ± 8.4
N (B_s^0)	2463 ± 63	1961 ± 56
$\epsilon(\pi^{\pm})$	$(26.1 \pm 3.2)\%$	$(42.1 \pm 6.5)\%$
R $(X^+(5568)\ /\ B_s^0)$	$(9.1 \pm 2.6 \pm 1.6)\%$	$(8.2 \pm 2.7 \pm 1.6)\%$

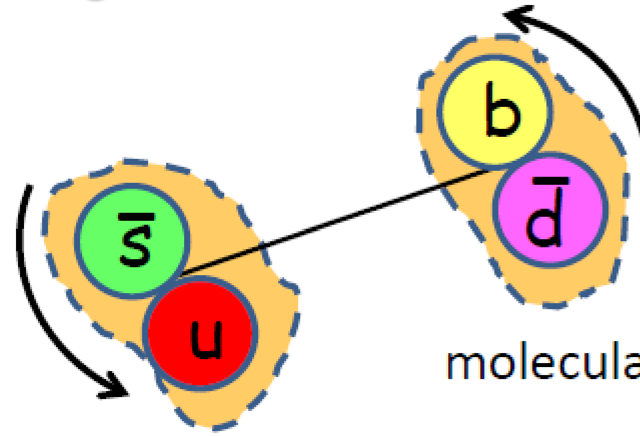
average Ratio($10 < p_T(B_s) < 30$ GeV) =

$$\sigma(X) * \mathcal{B}(X \rightarrow B_s \pi)/\sigma(B_s) = (8.6 \pm 1.9 \pm 1.4)\%$$

D0: Observation of an exotic $B_s^0\pi^\pm$ b, s, u, d state



tetraquark



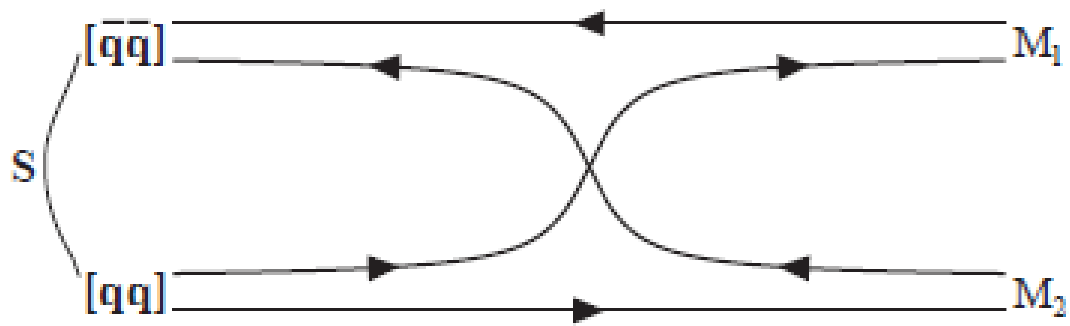
molecular state

BK molecule is disfavored for *X*(5568) since it would have ~ 206 MeV Binding Energy

di-quarks

[b̄ d̄]

[u s]

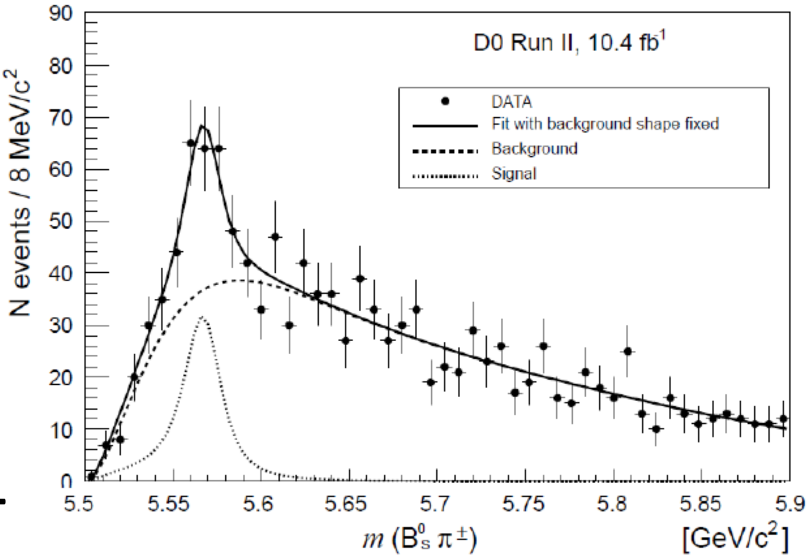


Bs (b̄ s)

π+ (u d̄)

L. Maiani *et al.*, "New Look at Scalar Mesons", Phys. Rev. Lett. 93, 212002 (2004)

D0: Observation of a new $B_s^0 \pi^\pm$ state summary



4 different flavors = ***b, s, u, d***

$X(5568)^\pm \rightarrow B_s^0 \pi^\pm$ with $J^P = 0^+$

$M_X = 5567.8 \pm 2.9$ (stat) $^{+0.9}_{-1.9}$ (syst) MeV

$\Gamma_X = 21.9 \pm 6.4$ MeV

with significance of 5.1 σ incl. LEE & systematics

$\sigma(X) * \mathcal{B}(X \rightarrow B_s^0 \pi)/\sigma(B_s^0) = (8.6 \pm 1.9 \pm 1.4)\%$

$\rightarrow$ 8-9% of all B_s^0 are from $X(5568)^\pm$

or $X(5615)^0 \rightarrow B_s^{*0} \pi^\pm$ with $J^P = 1^+$

CDF: $B_c^{\pm}$ production cross section in pp collisions at sqrt(s) = 1.96 TeV

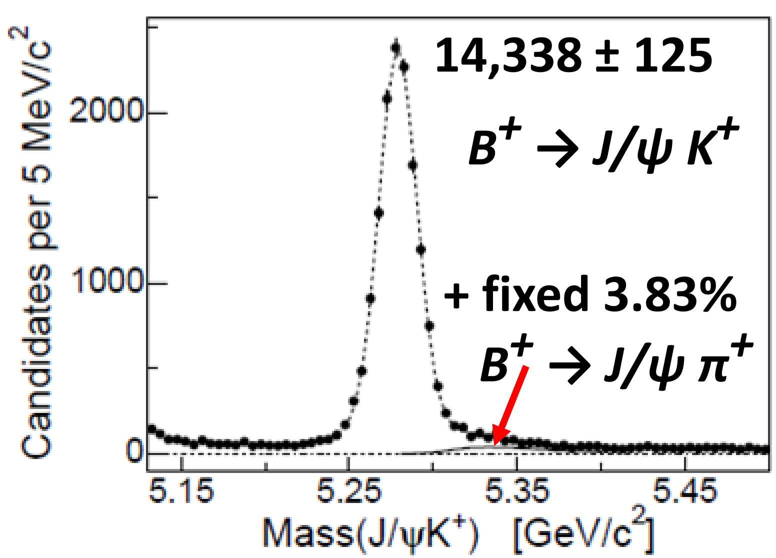
Uniqueness: $B_c^+(\bar{b}\,c)$ is most massive meson with two un-like quarks
it is only accessible at hadron colliders

Measure ratio

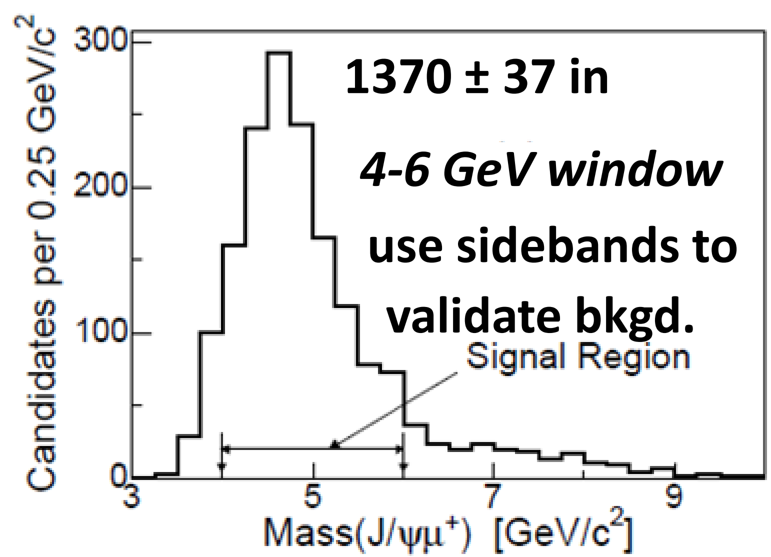
$$\mathcal{R} = \frac{\sigma(B_c^+)\,\mathcal{B}(B_c^+ \to J/\psi\,\mu^+\,\nu)}{\sigma(B^+)\,\mathcal{B}(B^+ \to J/\psi\,K^+)}$$

for same kinematics
and same topology

J/ψ + charged track (assumed K^+)

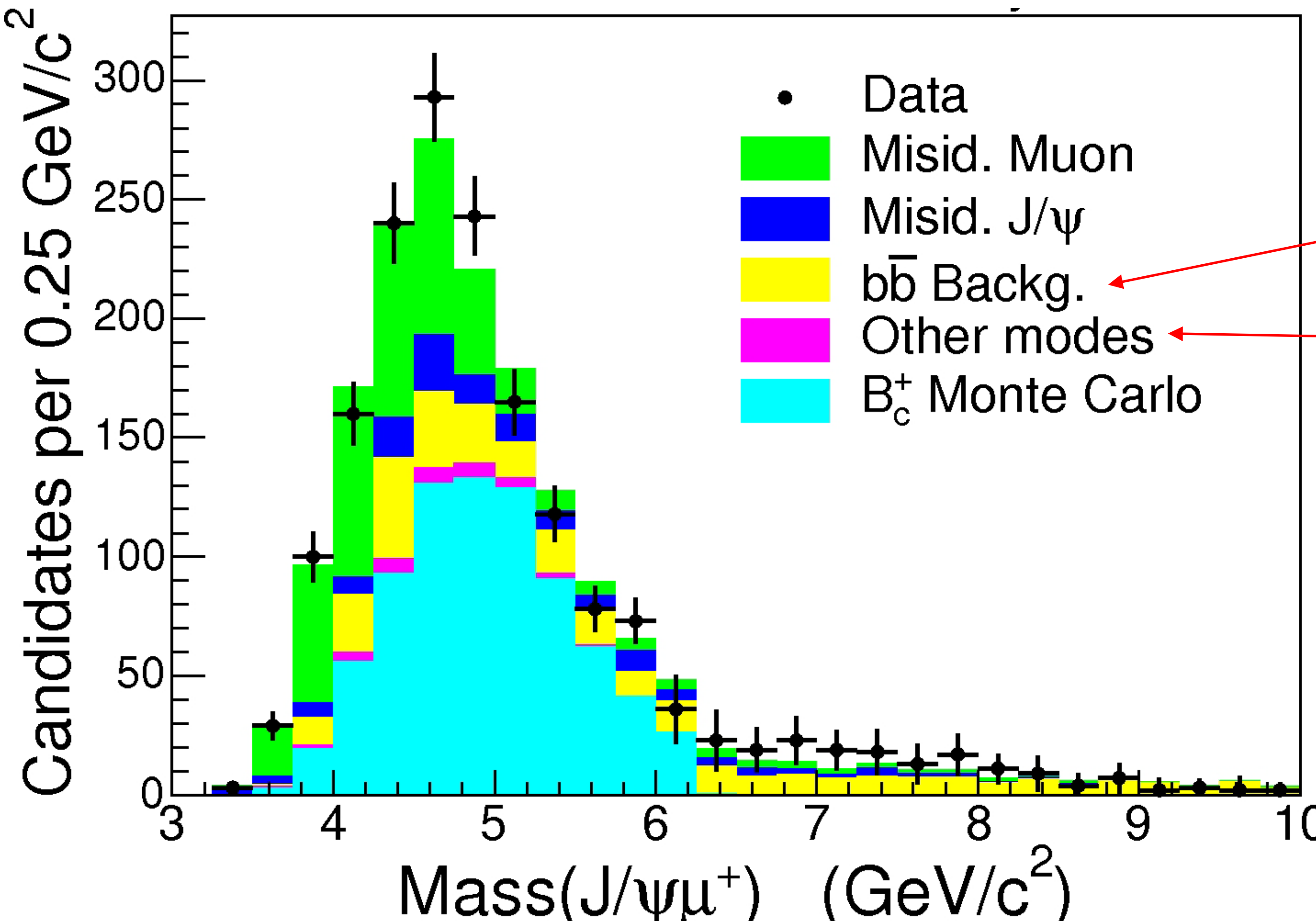


$B_c^+ \to J/\psi\,\mu^+\,\nu$ candidates



understand Bc backgrounds!

CDF: $B_c^{\pm}$ production cross section in $p\bar{p}$ collisions



$b \to J/\psi\, X$
$\bar{b} \to 3^{rd}\, \mu\, X$

$B_c \to 3\, \mu\, X$

\# $B_c^+ \to J/\psi\, \mu^+ \nu$ = 739.5 ± 45.3 events (630.5 bkgd events)

combined stat. & syst. uncertainties

CDF: $B_c^{\pm}$ production cross section in $p\bar{p}$ collisions at sqrt(s) = 1.96 TeV

$$\mathcal{R} = \frac{N_{Bc}/\mathrm{eff}_{Bc}}{N_{B^+}/\mathrm{eff}_{B^+}} \frac{1}{\mathrm{eff}_{3rd\mu}} = 0.211 \pm 0.012\ (\mathrm{stat})\ {+0.021/-0.020}\ (\mathrm{syst})$$

for $p_T(B_c^+) > 6$ GeV/c and $|y| < 0.6$

$N(B_c^+) = 739.5 \pm 45.3$ events

$N(B^+) = 14{,}338 \pm 125$ events

$\mathrm{eff}(B_c^+ \rightarrow J/\psi\ \mu^+\ \nu) = (0.175 \pm 0.001)$ % incl. trigger for 3rd μ

$\mathrm{eff}(B^+ \rightarrow J/\psi\ K^+) = (0.688 \pm 0.002)$ % incl. trigger for K

$\mathrm{eff}(\text{for 3rd } \mu) = 0.962 \pm 0.007\ (\mathrm{stat}) \pm 0.021\ (\mathrm{syst})$

CDF: $B_c^{\pm}$ production cross section in $p\bar{p}$ collisions at sqrt(s) = 1.96 TeV

continuing the calculation:

PDG → $\mathcal{B}(B^+ \to J/\psi\, K^+) = (1.027 \pm 0.031) \times 10^{-3}$

CDF → $\sigma(B^+, p_T > 6, |y| < 1) = (2.78 \pm 0.24)\ \mu b$

assuming $\mathcal{R}(|y| < 1) = \mathcal{R}(|y| < 0.6)$

$\sigma(B_c^+, p_T > 6, |y| < 1)\, \mathcal{B}(B_c^+ \to J/\psi\, \mu^+ \nu) =$

$0.602 \pm 0.034\ \text{(syst)}\ {+0.060/-0.063}\ \text{(syst)} \pm 0.055\ \text{(other)}\ nb$

combining $\sigma(B_c^+)\, \mathcal{B}(B_c^+ \to J/\psi\, \mu^+ \nu) = 0.60 \pm 0.09\ nb$

use theory range $\mathcal{B}(B_c^+ \to J/\psi\, \mu^+ \nu) =$ 1.15-2.37%

→ $\sigma(B_c^+, p_T > 6, |y| < 1) \sim 25 \pm 4$ to $52 \pm 8\ nb$

D0: Observation of a new $B_s^0\pi^\pm$ state

Invitation to:

CDF, LHCb, CMS, ATLAS

Go find those tetraquarks!

Thank you!

Peter

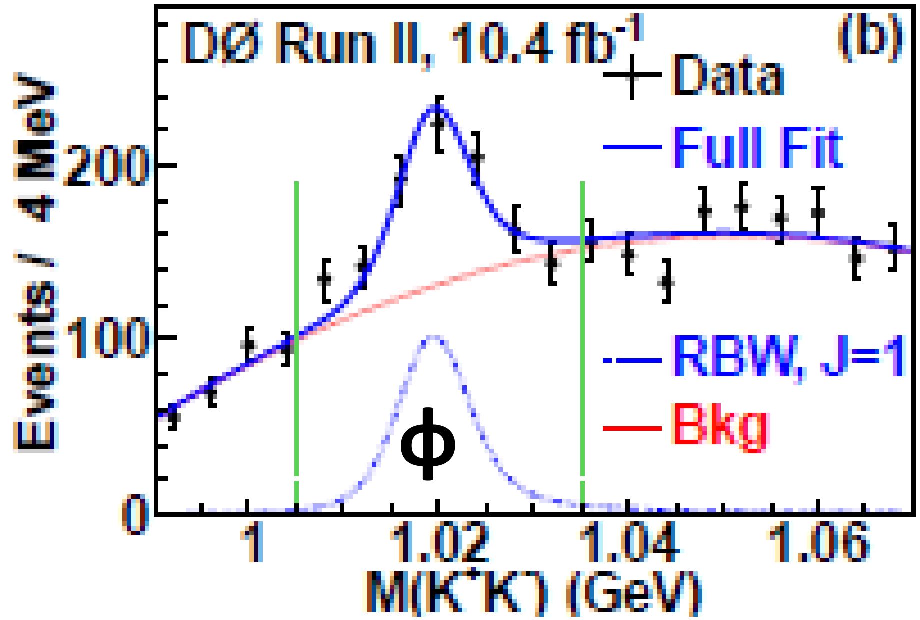
D0: Observation of a new $B_s^0 \pi^{\pm}$ state

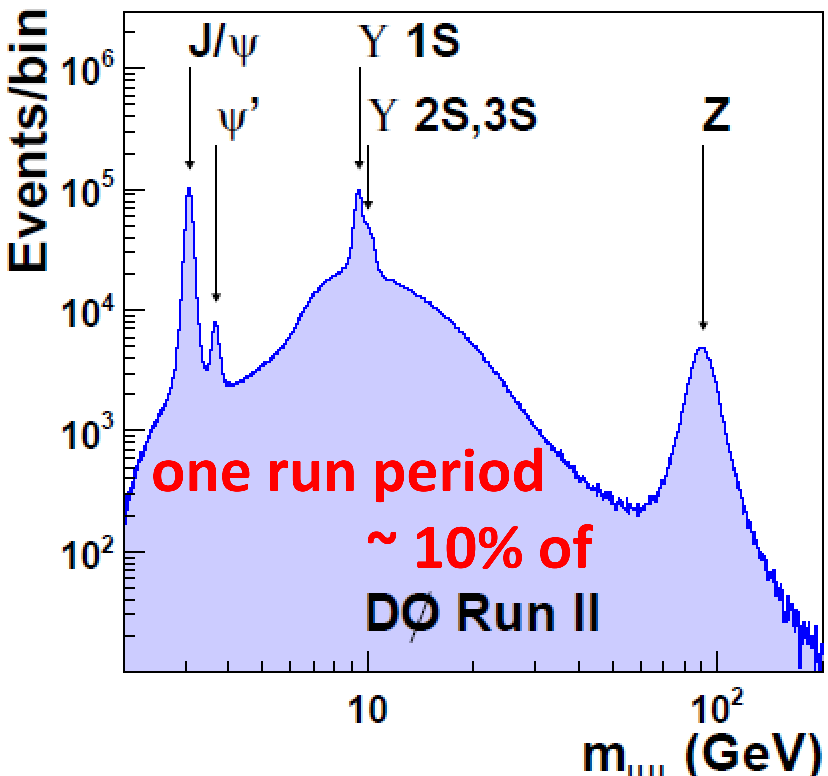
Back-up Materials

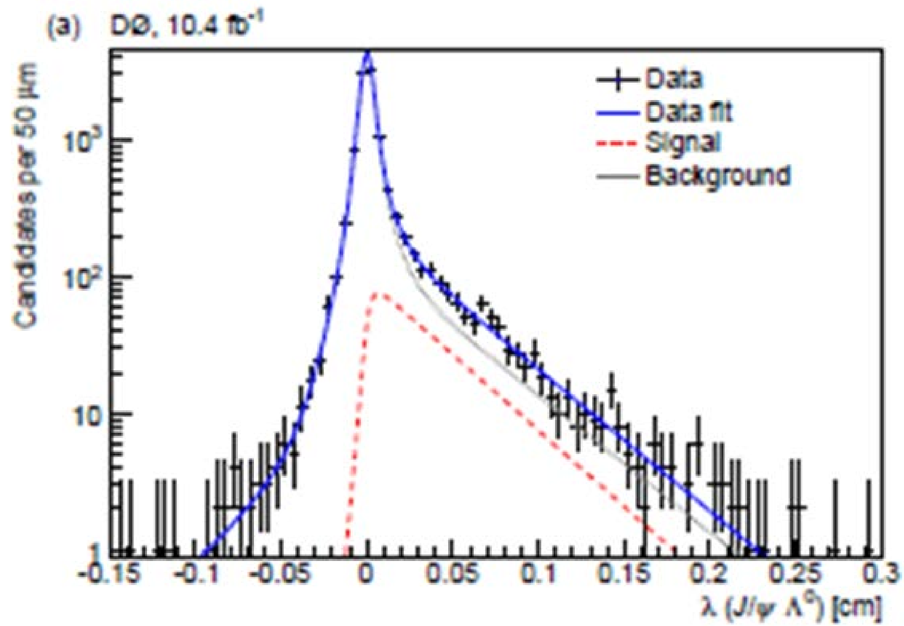
E. Gross & O. Vitells*, "Trial factors of look elsewhere effect in high energy physics",*
Eur. Phys. J. C 70, 525 (2010).

D0: Observation of a new $B_s^0\pi^\pm$ state

from other D0 analyses



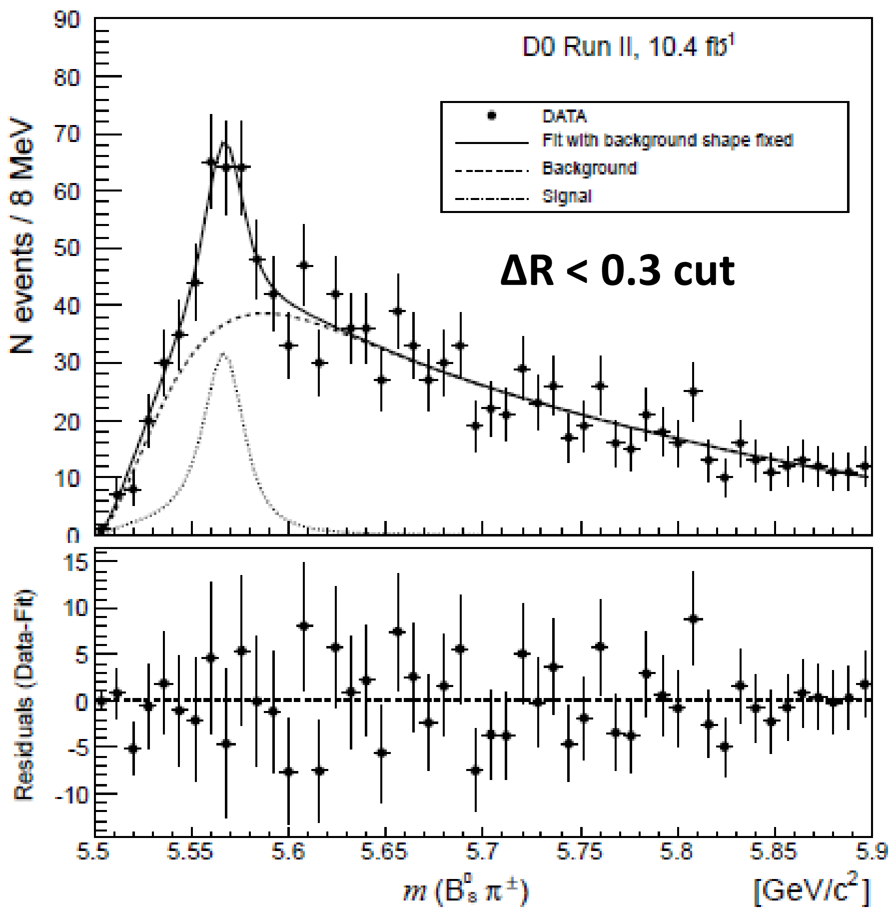




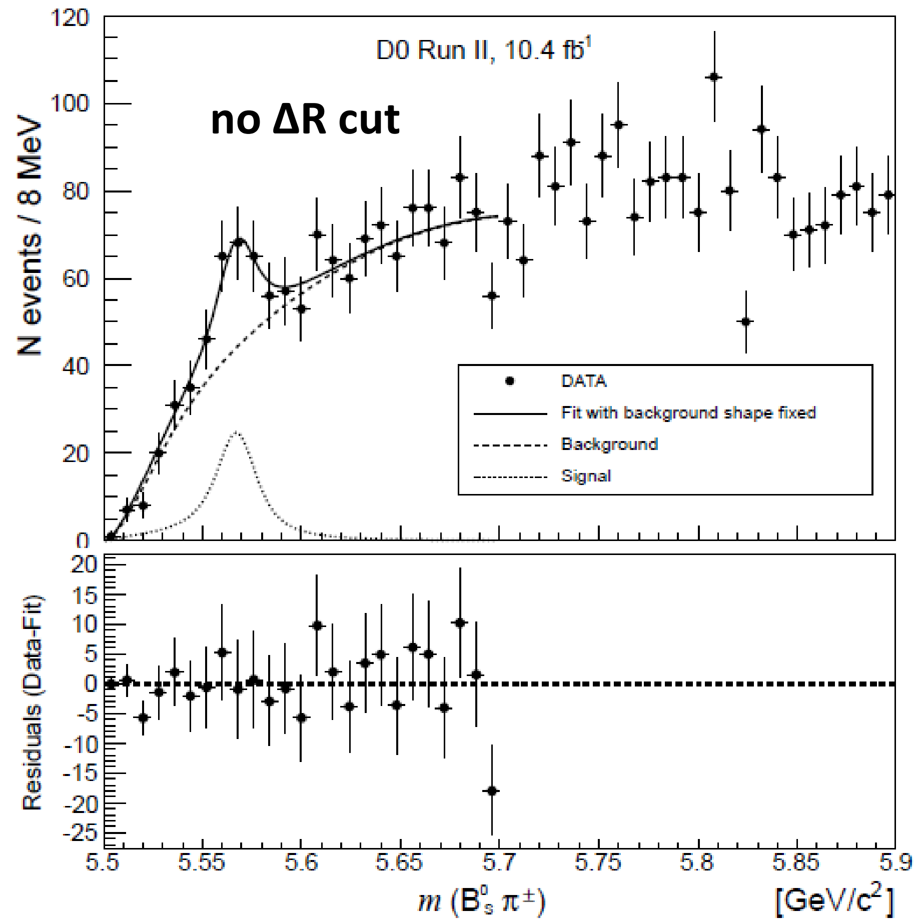
Λ_b lifetime

D0: Observation of a new $B_s^0 \pi^{\pm}$ state

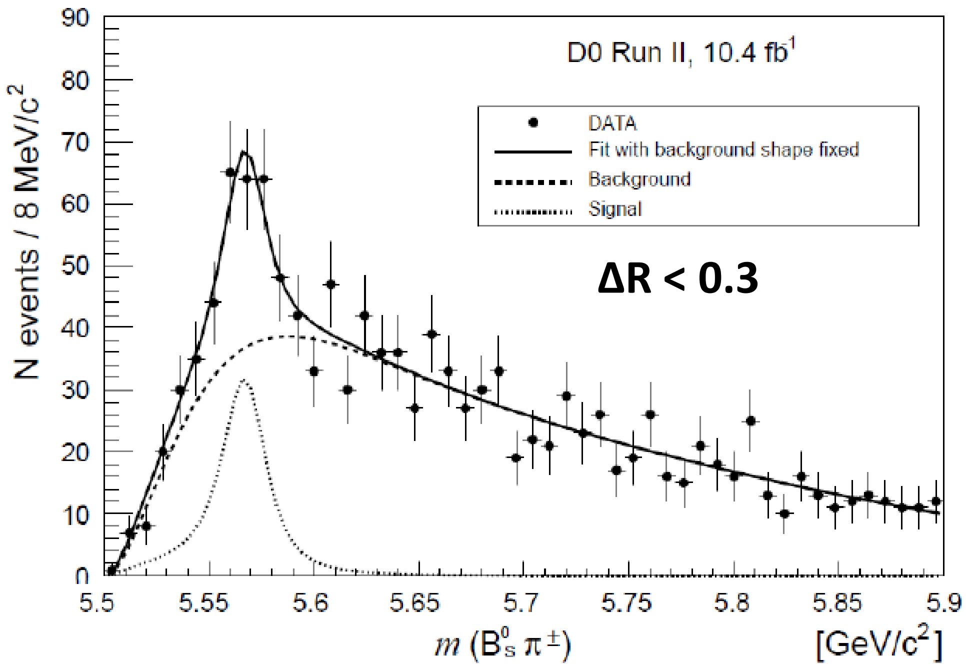
χ^2 = 32.4 for 46 DF



χ^2 = 18.4 for 23 DF



D0: Observation of a new $B_s^0 \pi^\pm$ state



If this state is a direct decay $X \rightarrow B_s^0 + \pi^\pm$

then $J^P = 0^+$ counterpart of $a_0(980)$ replace $s\bar{s}$ by $b\bar{s}$

If this really were $X \rightarrow B_s^{0*} \pi^\pm$ with $B_s^{0*} \rightarrow B_s^0$ with missing 48.7 MeV γ

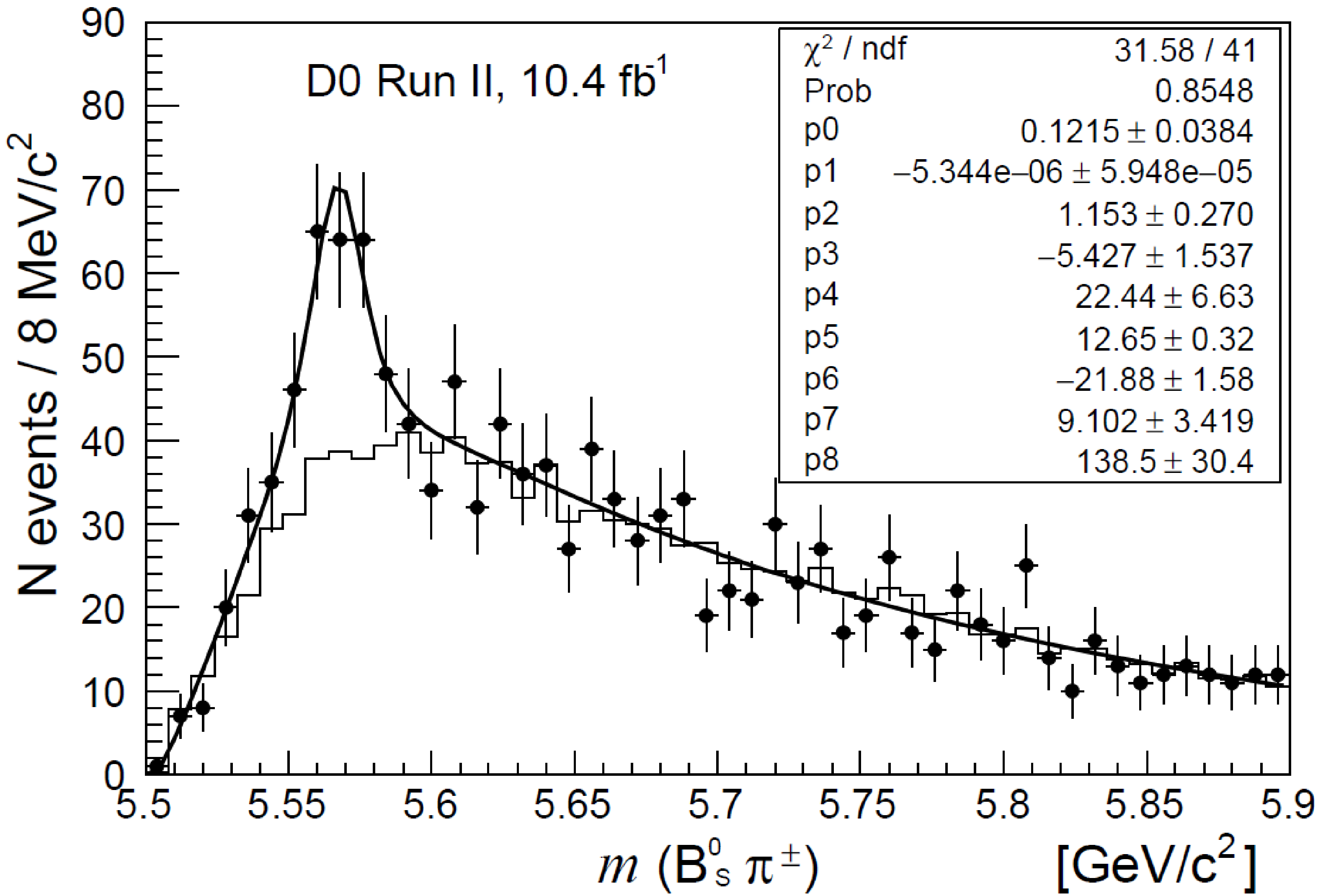
then M_X = 5567.8 + 48.7 (± 2.2) MeV → 5616.5 MeV

and $J^P = 1^+$ counterpart of $Z_b^+ \rightarrow \Upsilon(nS)\, \pi^+$ replace $b\bar{b}$ by $b\bar{s}$

smearing due to missing γ gives a ± 0.85 MeV r.m.s. contribution to M_X

D0: Observation of a new $B_s^0\pi^\pm$ state

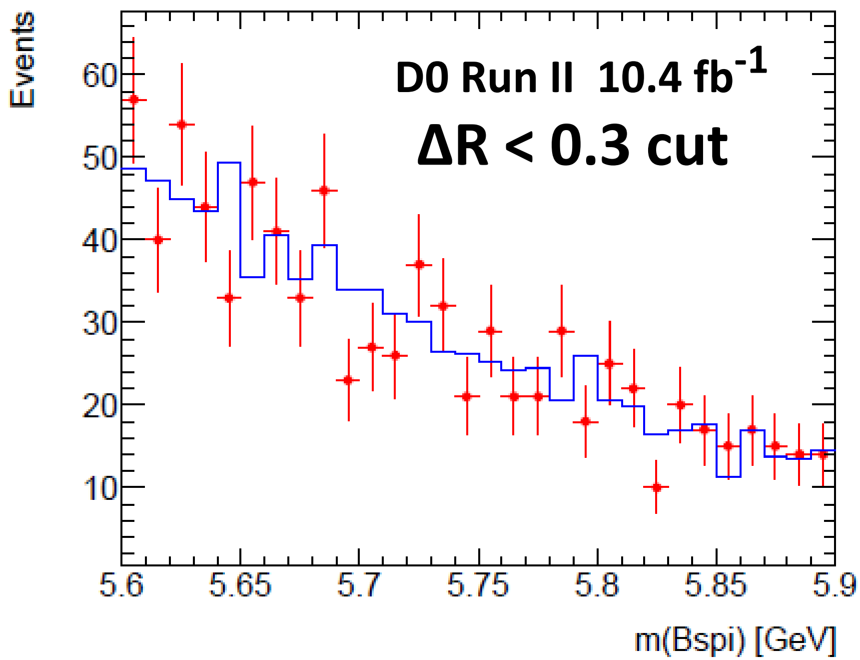
fix M_X and Γ_X, allow N_X and bkgd shape to float



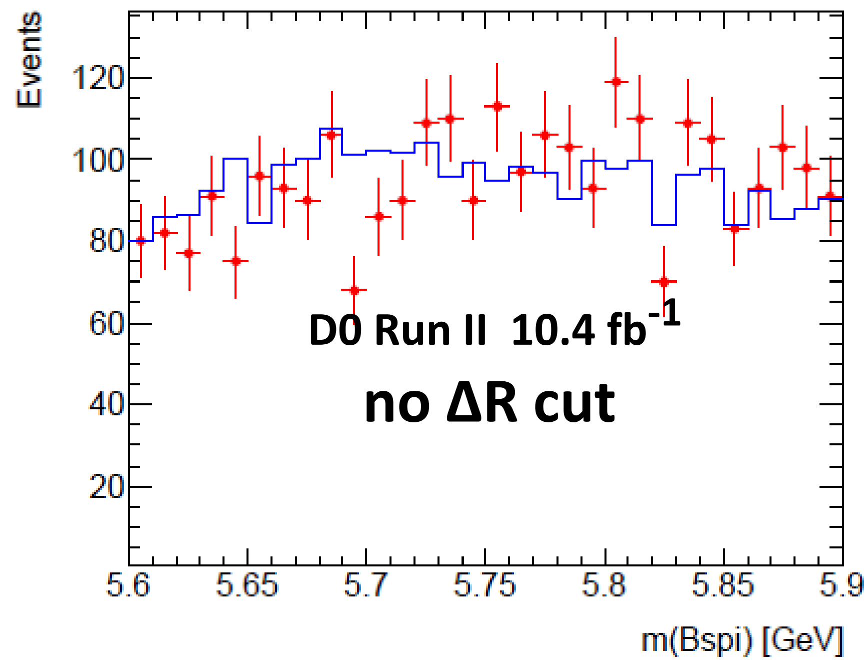
D0: Observation of a new $B_s^0 \pi^\pm$ state

Kolmogorov-Smirnov Probability of Compatibility of Shapes of MC = "real" bkgd model (histo) vs. background data (points) for m(B_s π) above the peak

KS Prob. = 0.999

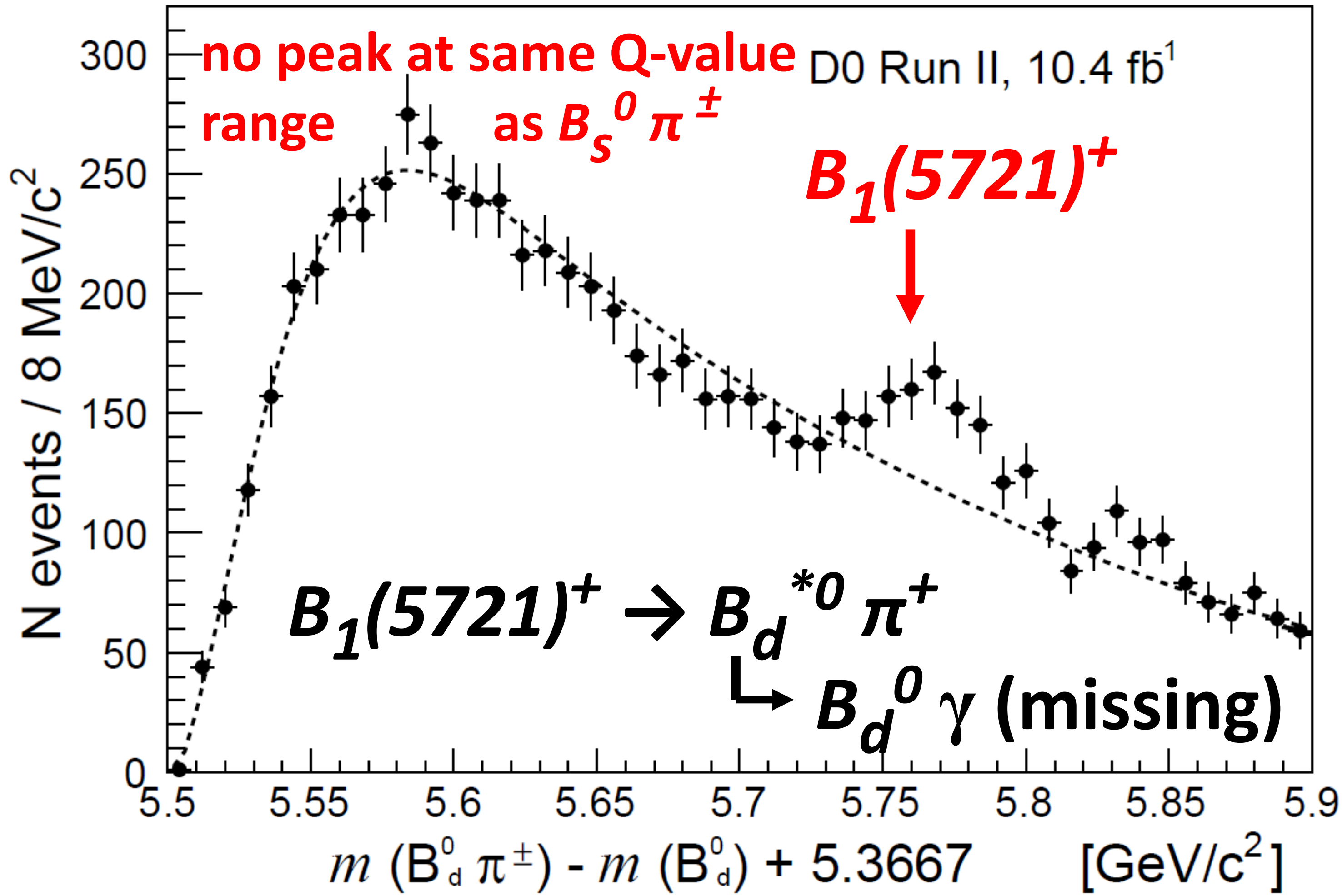


KS Prob. = 0.0034

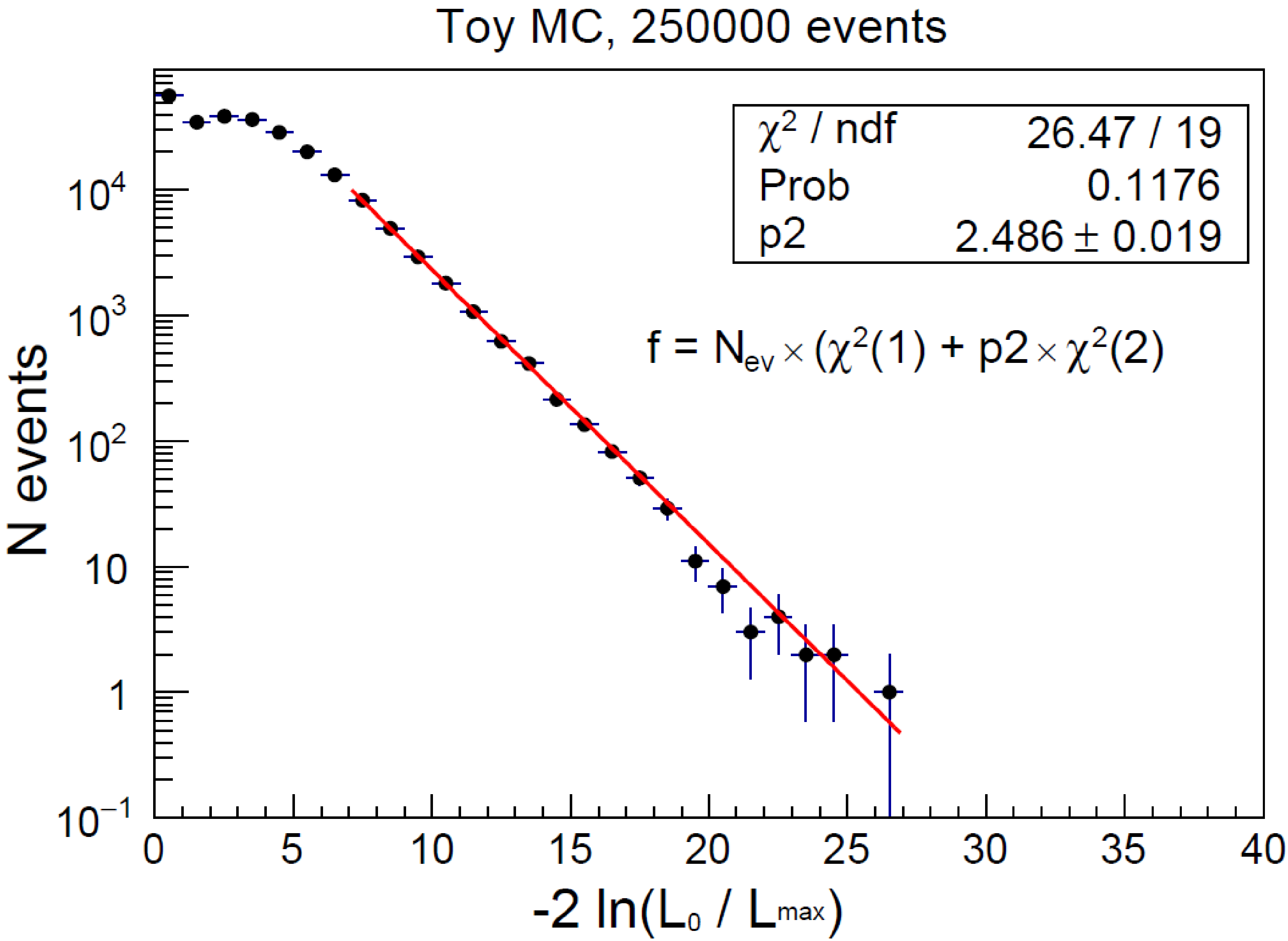


D0: Observation of a new $B_s^0 \pi^\pm$ state

$B_d^0 \pi^\pm$ where $B_d^0 \to J/\psi\, K^{*0}$ and $K^{*0} \to K^+ \pi^-$



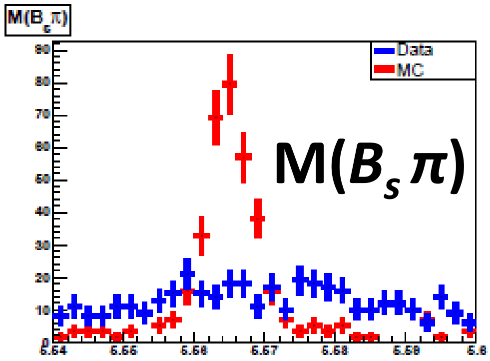
D0: Observation of a new $B_s^0 \pi^{\pm}$ state

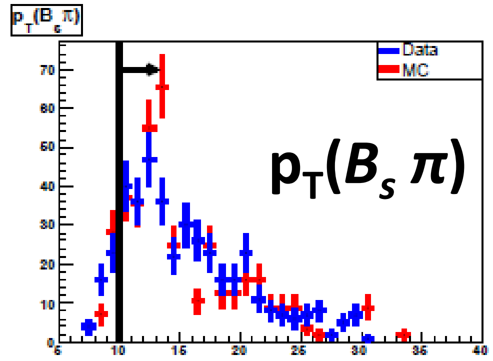


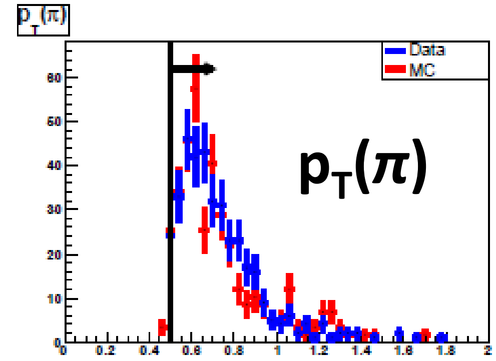
D0: Observation of a new $B_s^0\pi^\pm$ state

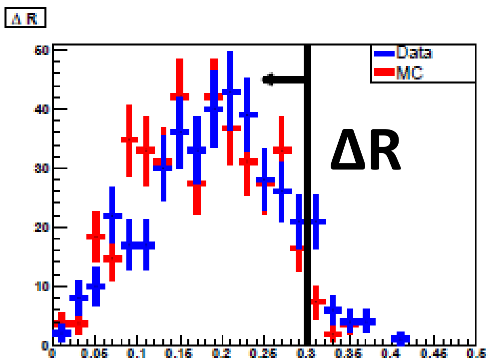
Red = MC

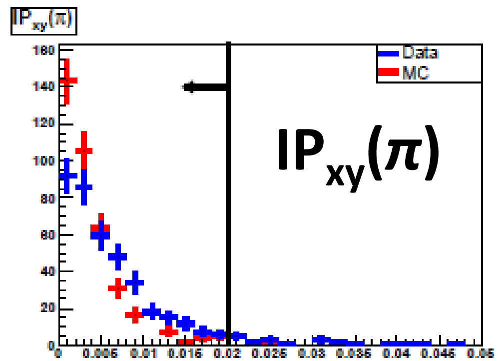
Blue = Data

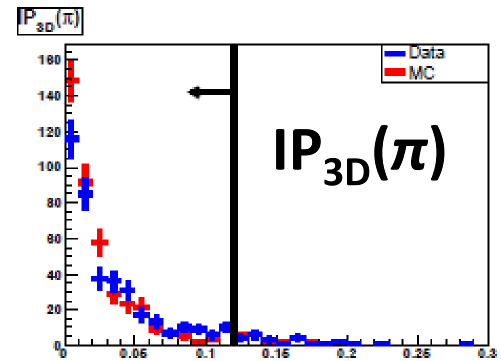


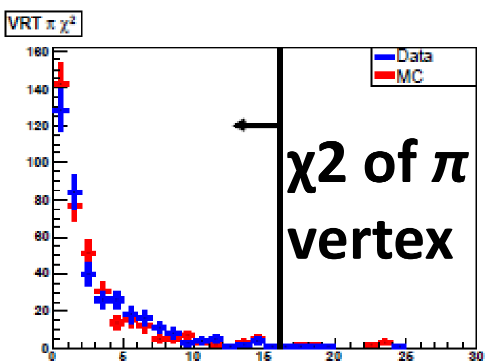


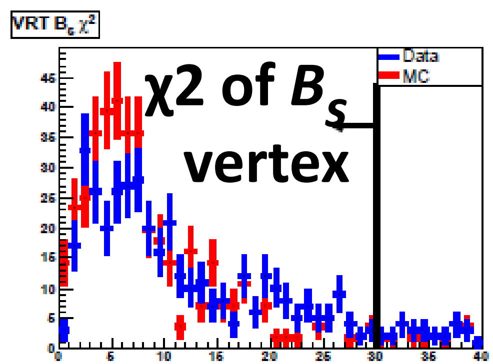






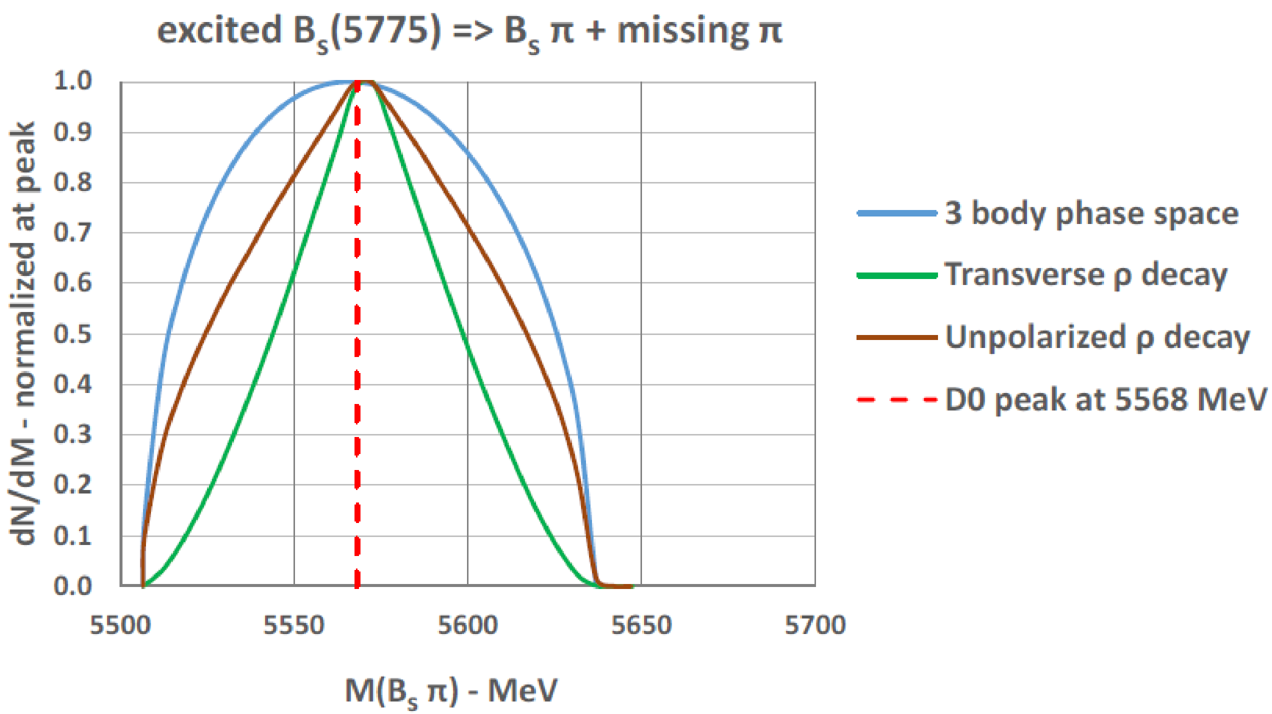


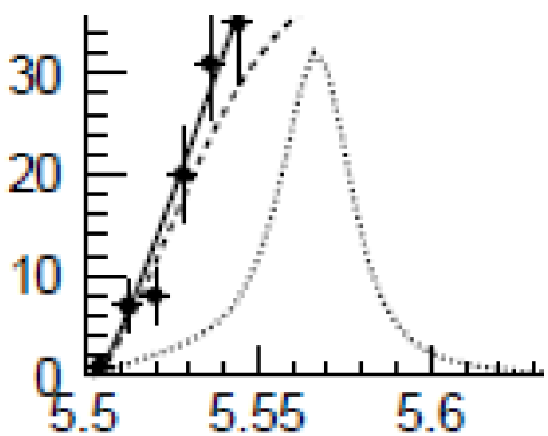




need L_{xy}/σ_{Lxy}

D0: Observation of a new $B_s^0 \pi^\pm$ state

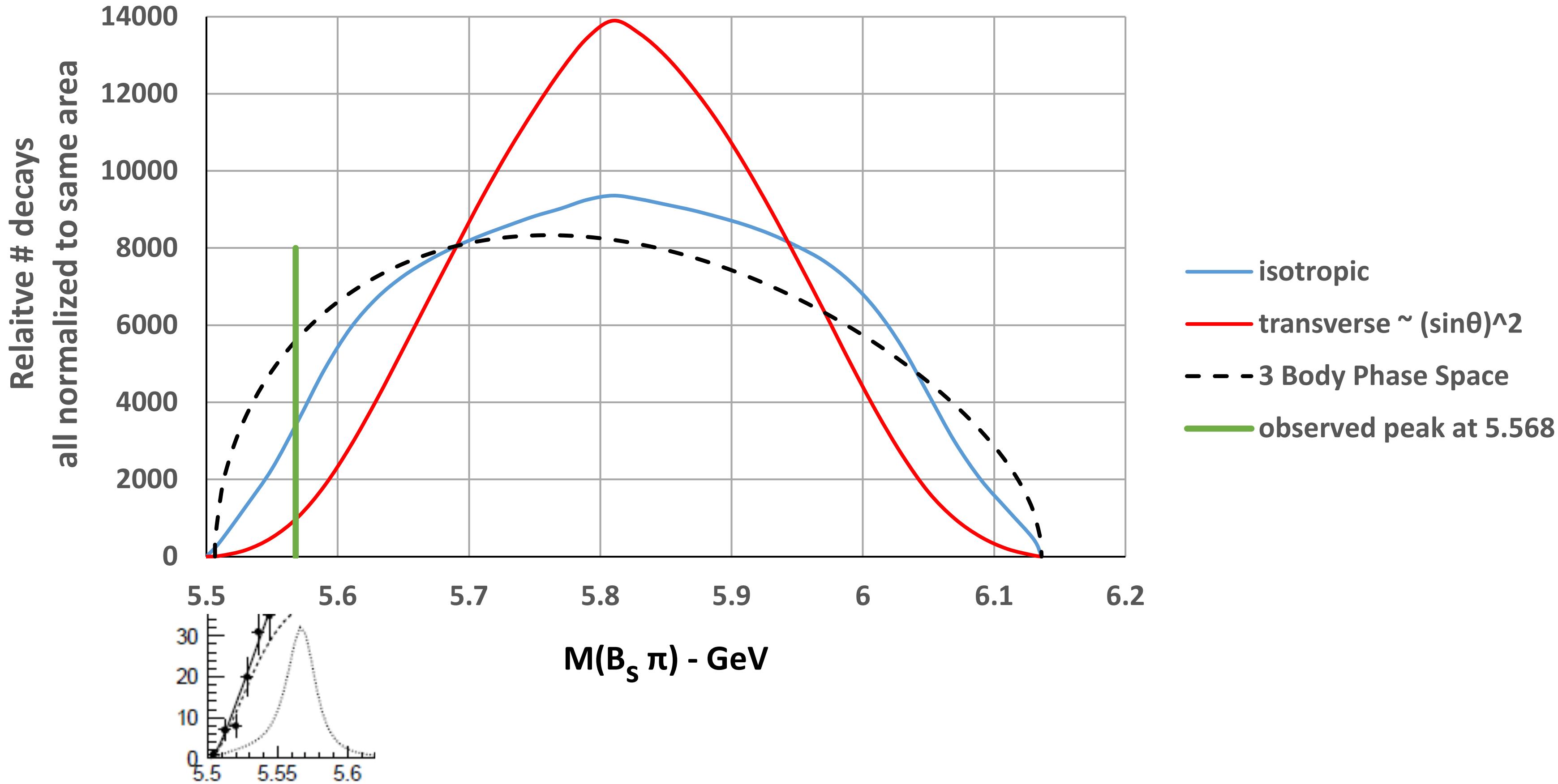




D0: Observation of a new $B_s^0 \pi^{\pm}$ state

$B_c^+ \rightarrow B_s^0 \pi^+$ unobserved π^0

via ρ^+ or 3 Body Phase Space



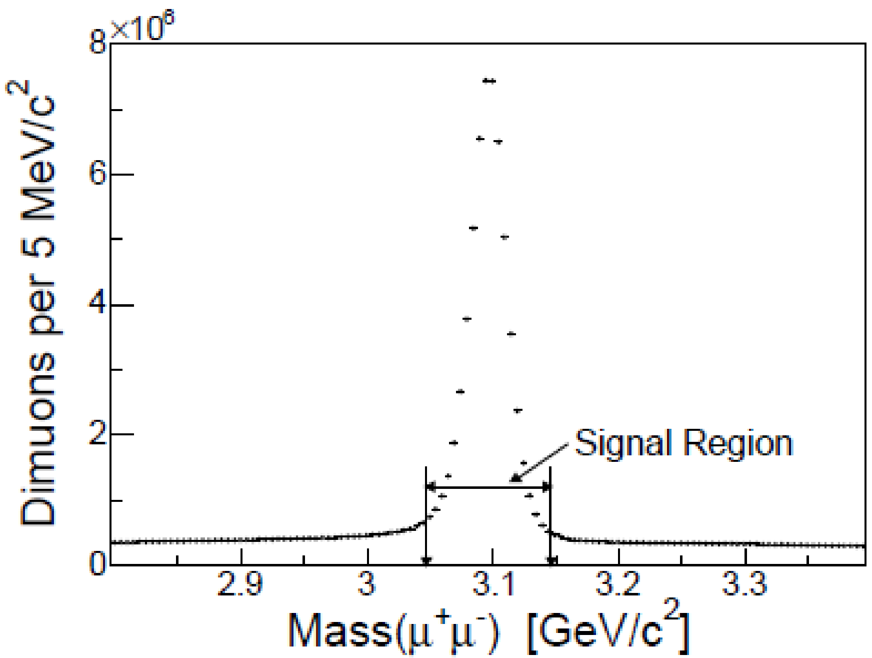
CDF: $B_c^{\pm}$ production cross section in $p\bar{p}$ collisions at sqrt(s) = 1.96 TeV

Backup slides

CDF: $B_c^{\pm}$ production cross section in $p\bar{p}$ collisions at sqrt(s) = 1.96 TeV

Uniqueness: $B_c^+(\bar{b}\,c)$ is most massive meson with two un-like quarks
it is only accessible at hadron colliders

Measure ratio $\mathcal{R} = \dfrac{\sigma(B_c^+)\,\mathcal{B}(B_c^+ \rightarrow J/\psi\,\mu^+\,\nu)}{\sigma(B^+)\,\mathcal{B}(B^+ \rightarrow J/\psi\,K^+)}$ for same kinematics and same topology



common $J/\psi \rightarrow \mu^+\,\mu^-$ either

both μ with $|\eta| < 0.6$ and $p_T > 1.5$ GeV/c

or one μ: $|\eta| < 0.6$ and $p_T > 1.5$ GeV/c

& other μ: $0.6 \leq |\eta| < 1$ & $p_T > 2$ GeV/c

6×10^7 J/ψ events in signal region

3-track events: p_T(third track) > 3 GeV/c

common vertex with J/ψ — $\chi^2 > 0.001$

cut prompt J/ψ: transverse decay length — $L_{xy}/\sigma_{xy} > 3$

uncertainty in decay length — $\sigma_{xy} < 200\ \mu m$

track quality cuts: $\geq$ 3 hits/track in r-ϕ silicon detector

minimum of 10 stereo + min of 10 axial hits/track in central drift chamber (out of 48 + 48 layers)

$\geq$ 43 hits/track for *dE/dx* out of 96 layers in central drift chamber

3rd μ^+ for B_c^+: track in central muon detector for $|\eta| < 0.6$, which penetrate a minimum of

extra 60 cm steel ~ 3.3 interaction lengths

no other track with $p_T > 1.45$ GeV/c

which extrapolates within 40 cm of μ

finally require $p_T(J/\psi$ + track) > 6 GeV/c

B_c Backgrounds:

too much detail for a short talk, see the paper

$B_c^+ \rightarrow J/\psi\ \mu^+ \nu$ Background Summary - # events

$J/\psi\ \mu$ mass range	3-4 GeV	4-6 GeV	> 6 GeV
total # *Bc* candidates	132	1370	208
mis-id J/ψ	11.5	96.5	25.0
mis-id μ	86.7	344.4	32.1
b-bbar background	12.4	178.6	110.4
sub-total mis-id	110.6	619.5	167.5
double mis-id *	-5.1	-19.0	-5.2
total mis-id	105.5	600.5	162.3
other decay modes	2.6	30.0	0
total background	108.1	630.5	162.3
total observed signal	23.9	739.5	45.7
± uncertainty	± 12.5	± 45.3	± 18.7
force MC normalization		739.5	
check sideband model	22.8		27.6
	± 0.6		± 0.6

* subtract double mis-id to avoid double-counting

TABLE IX. Total background for $B_c^+ \to J/\psi\,\mu^+ X$ decays in three invariant-mass ranges. The doubly-misidentified contribution is subtracted from the total to avoid double counting. Entries with no statistical uncertainties listed represent determinations for which the statistical uncertainty is negligible compared with the systematic uncertainty. Enries with no systematic uncertainties are estimated to have negligible systematic uncertainties compared with the statistical errors.

$B_c^+ \to J/\psi\,\mu^+ X$ background	3–4 GeV/c^2	4–6 GeV/c^2	>6 GeV/c^2
Misidentified J/ψ	11.5 ± 2.4(stat)	96.5 ± 6.9(stat)	25.0 ± 3.5(stat)
Misidentified muon	$86.7^{+2.4}_{-4.2}$(syst)	$344.4^{+9.6}_{-16.5}$(syst)	$32.1^{+0.9}_{-1.5}$(syst)
Doubly misidentified	$5.1^{+0.1}_{-0.2}$(syst)	$19.0^{+0.5}_{-0.9}$(syst)	$5.2^{+0.1}_{-0.3}$(syst)
$b\bar{b}$ background	12.4 ± 2.4(stat) ± 0.4(syst)	178.6 ± 12.4(stat) ± 5.8(syst)	110.4 ± 10.7(stat) ± 3.6(syst)
Total misid.+$b\bar{b}$ bg.	105.5 ± 3.4(stat) $^{+2.4}_{-4.2}$(syst)	600.5 ± 14.2(stat) $^{+11.2}_{-17.5}$(syst)	162.3 ± 11.3(stat) $^{+3.7}_{-3.9}$(syst)

TABLE X. $B_c^+ \to J/\psi\,\mu^+ X$ candidates and background subtractions from Table IX.

	3–4 GeV/c^2	4–6 GeV/c^2	>6 GeV/c^2
$N(B_c^+ \to J/\psi\,\mu^+ X)$, reconstr.	132 ± 11.5	1370 ± 37.0	208 ± 14.4
Sum of misid.+$b\bar{b}$ bg.	$105.5^{+4.2}_{-5.4}$	$600.5^{+18.1}_{-22.5}$	$162.3^{+11.9}_{-12.0}$
$N_{\rm obs}$	$26.5^{+12.2}_{-12.7}$	$769.5^{+41.2}_{-43.3}$	45.7 ± 18.7

B_c Backgrounds:

Too much detail for a short talk, see the paper

A. mis-id J/ψ + meson:

B. mis-identified muon background:

1. p, π, K mis-id as μ
2. correction to π, K mis-id
3. hadron fraction in J/ψ-track sample
4. results & systematic uncertainties

C. b-bbar background:

1. unvertexed J/ψ μ pairs
2. simulated unvertexed J/ψ μ pairs
3. fitting unvertexed J/ψ $\Delta\phi$ distrib.
4. results for the b-bbar background

D. Total background:

$B_c^+ \rightarrow J/\phi\ \mu^+\ \nu$ Background Summary - # events

$J/\psi\ \mu$ mass range	3-4 GeV	4-6 GeV	> 6 GeV
total # Bc candidates	132	1370	208
mis-id J/ψ	11.5	96.5	32.1
mis-id μ	86.7	344.4	25.0
b-bbar background	12.4	178.6	110.4
sub-total mis-id	110.6	619.5	167.5
double mis-id *	-5.1	-19.0	-5.2
total mis-id	105.5	600.5	162.3
other decay modes	2.6	30.0	0
total background	108.1	630.5	162.3
total oserved signal	23.9	739.5	45.7
MC normalization	22.8	739.5	27.6

* subtract double mis-id to avoid double-counting

CDF PID

dE/dx ~ mean pulse width in Central Drift Chamber
is proportional to *Q (charge* ~ ∫ *dE/dx* dx)
44 cm ≤ Radius ≤ 132 cm

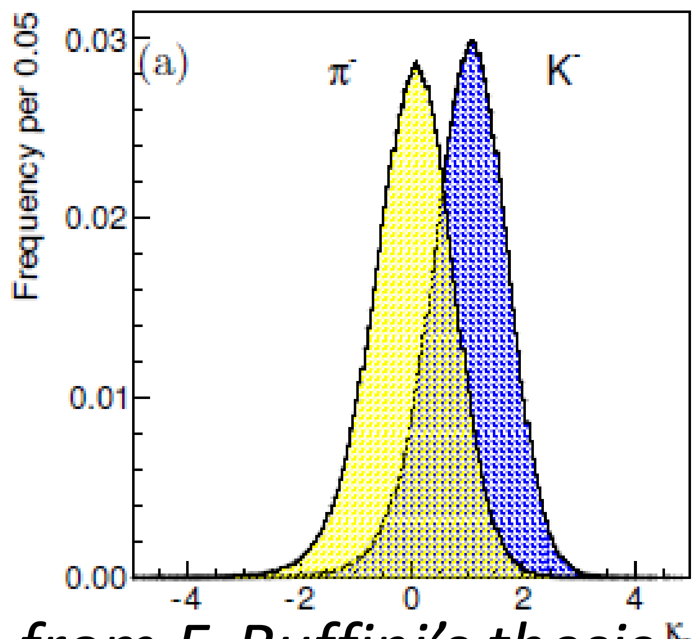
Calibrated with $D^{*+} \rightarrow D^0 \pi^+$ *with* $D^0 \rightarrow K^- \pi^+$
and unambiguous $\Lambda \rightarrow p\, \pi^+$

1.4 σ separation for π K
for $2 < p_T < 10$ *GeV/c*

dE/dx(p) ~ dE/dx(K)

$$\kappa = \frac{dE/dx - dE/dx(\pi)}{dE/dx(K) - dE/dx(\pi)}$$

<kaonness> = 1 for K, 0 for π



from F. Ruffini's thesis