

***Observation of the $Y(4140)$
in the $J/\Psi\phi$ from $B^+ \rightarrow J/\psi\phi K^+$ Decay at CDF***

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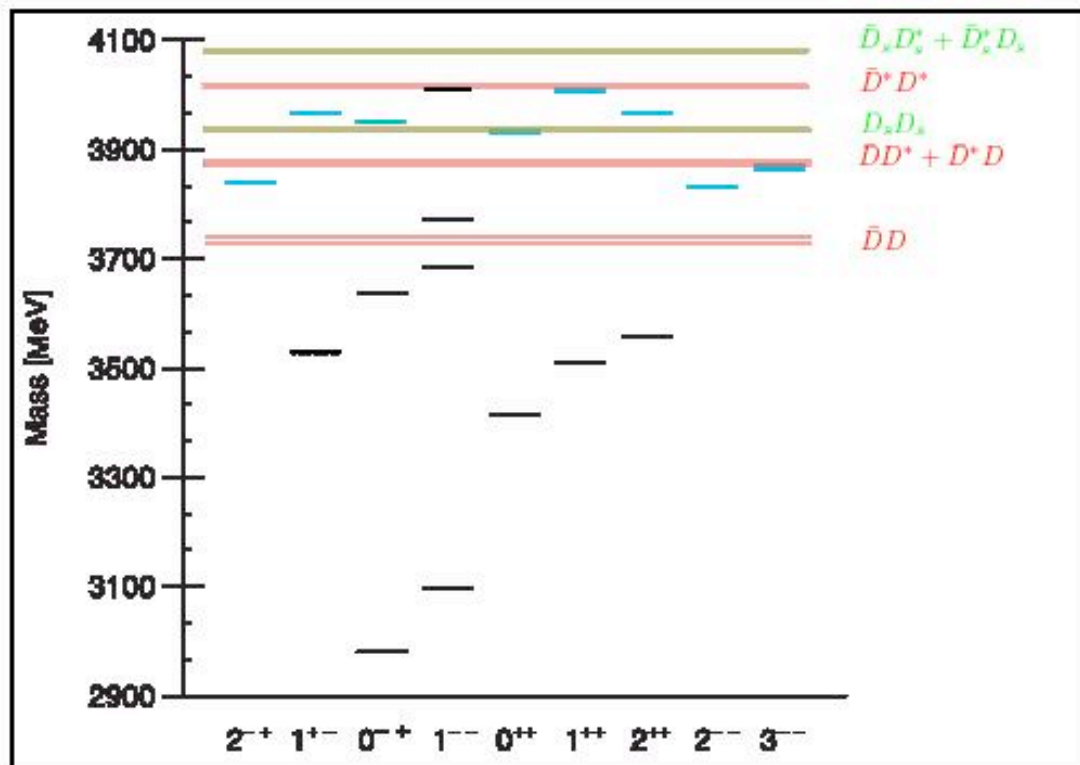
***University of Iowa
(for CDF Collaboration)***



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Motivation--What is $Y(4140)$?

Charmonium Spectrum *Reported by CDF through B decay. PRL 102, 242002 (2009)*



$Y(4140)$

- **Above** charm pair threshold
- But “narrow” strong decay
- Expect **tiny** BF to $J/\psi\phi$ if (cc)
- Close $J/\psi\phi$ threshold like $Y(3940)$, $C=+$

NOT likely to be a conventional charmonium

E. Eichten

Fermilab - Wine and Cheese - Oct. 13, 2006

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Some possible theoretical proposals:

Tetraquark: See arXiv of 0903:3107, 0903:2529, 0906:2485,...

Charmonium hybrid: See arXiv of 0903:3107,...

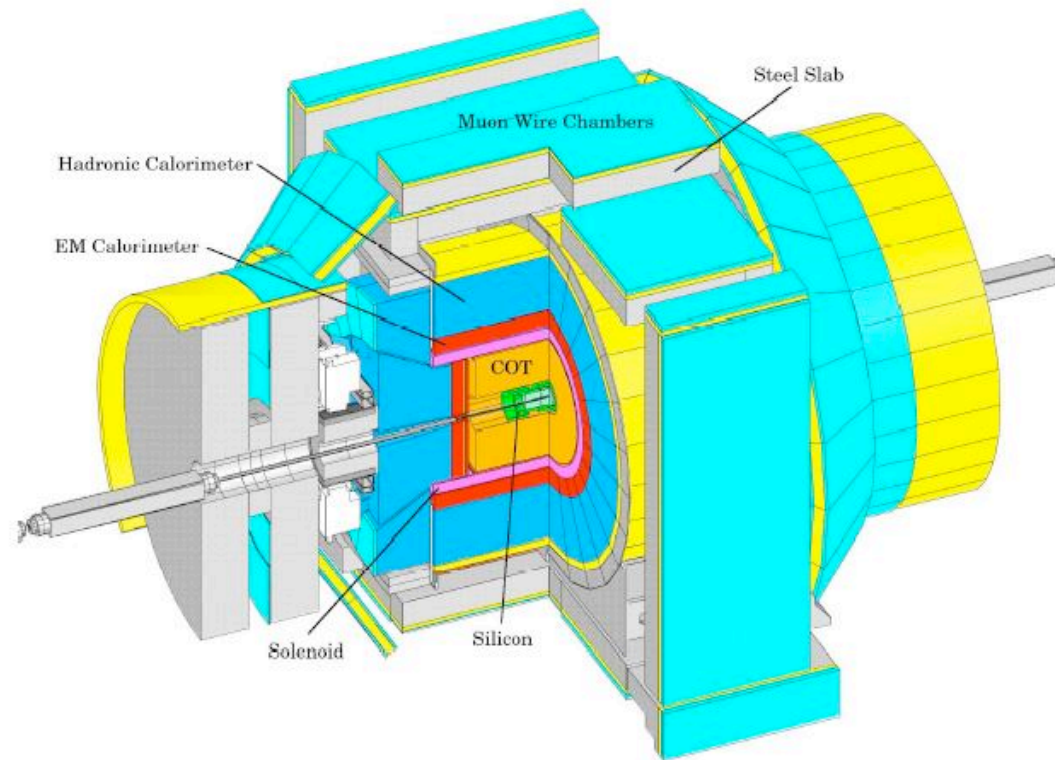
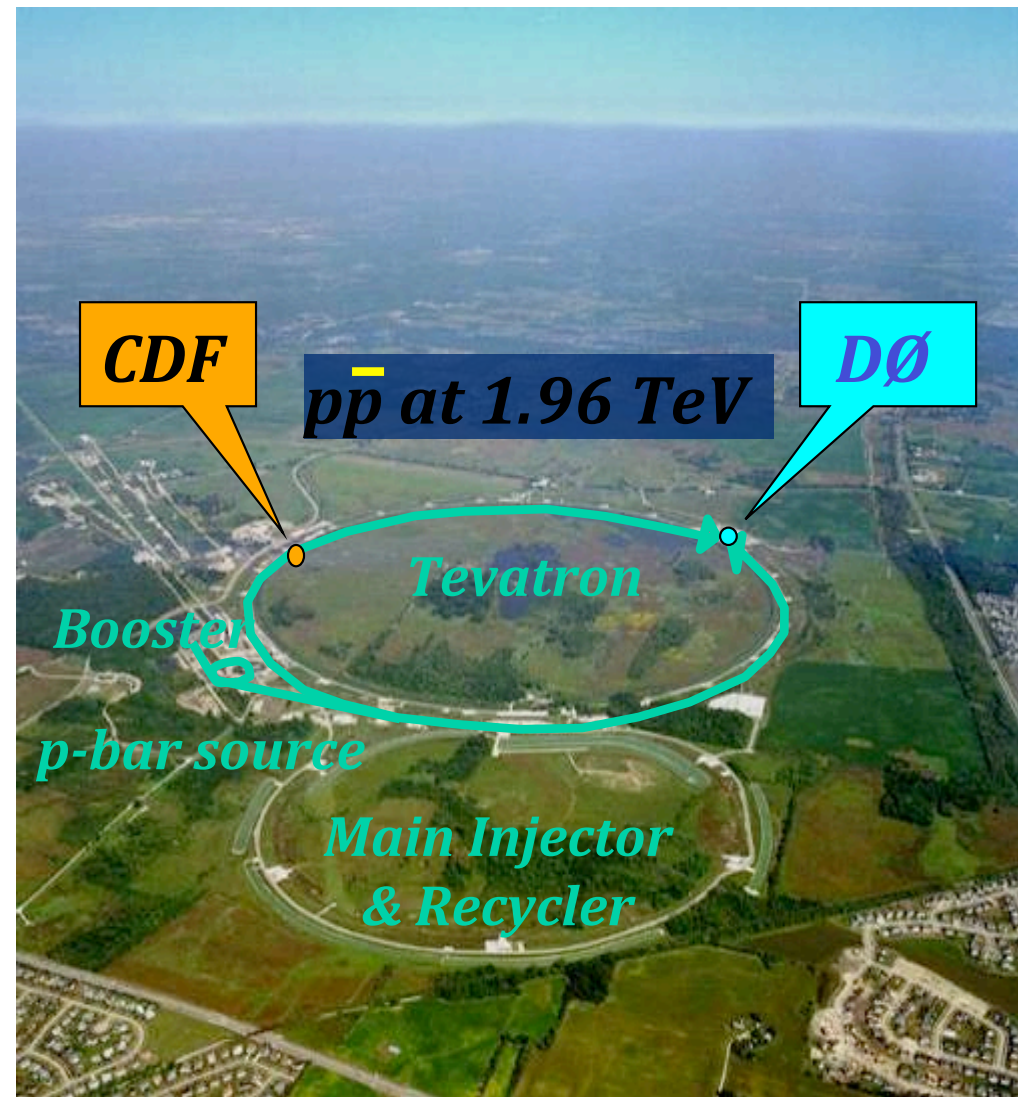
Molecule: See arXiv of 0903:3107, 0903.5424, 0906.0090, 0903.2529,...

Rescattering via $D_s D^$ s : See arXiv:0906:2278, 0905.1595, PR D76, 114002*

Tevatron and CDF

Tevatron

CDF detector



- *Muon: μ ID*
- *ToF: TOF*
- *COT: track p , dE/dx*
- *Silicon: track p , vertex*

Y(4140) Evidence Recap—analysis strategy

PRL 102, 242002 (2009)

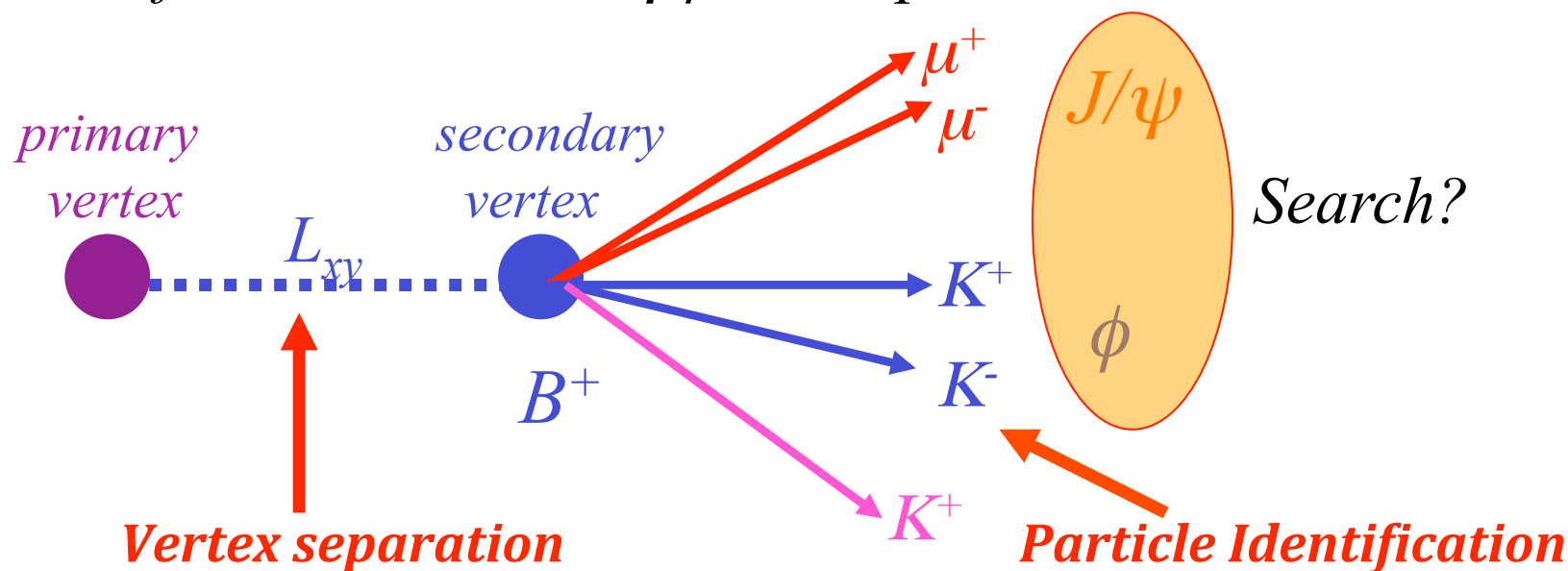
- I) Reconstruct B^+ as:*

$$B^+ \rightarrow J/\psi \phi K^+$$

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

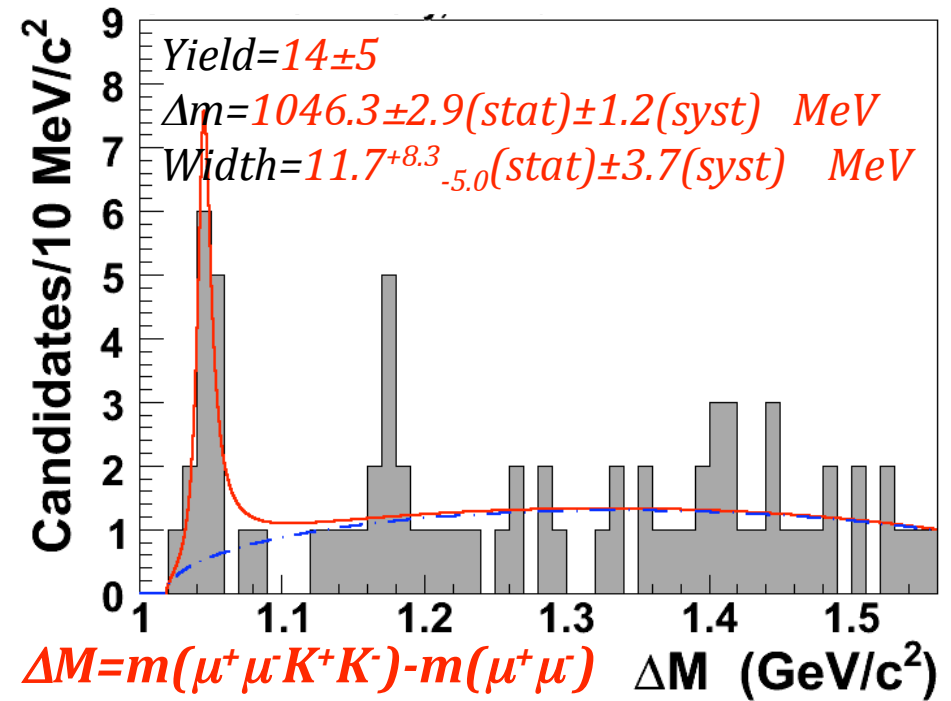
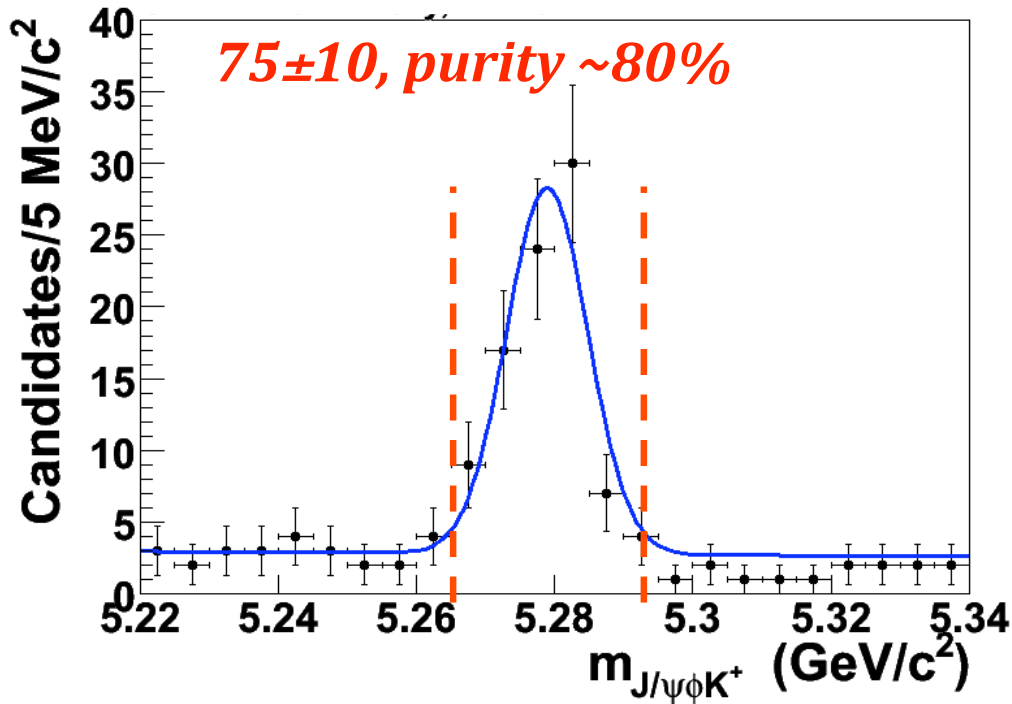
$$\phi \rightarrow K^+ K^-$$

- II) Search for structure in $J/\psi \phi$ mass spectrum inside B^+ mass window*



Y(4140) Evidence Recap—result w/ 2.7fb⁻¹

PRL 102, 242002 (2009)



Significance: at least 3.8 σ for most conservative background

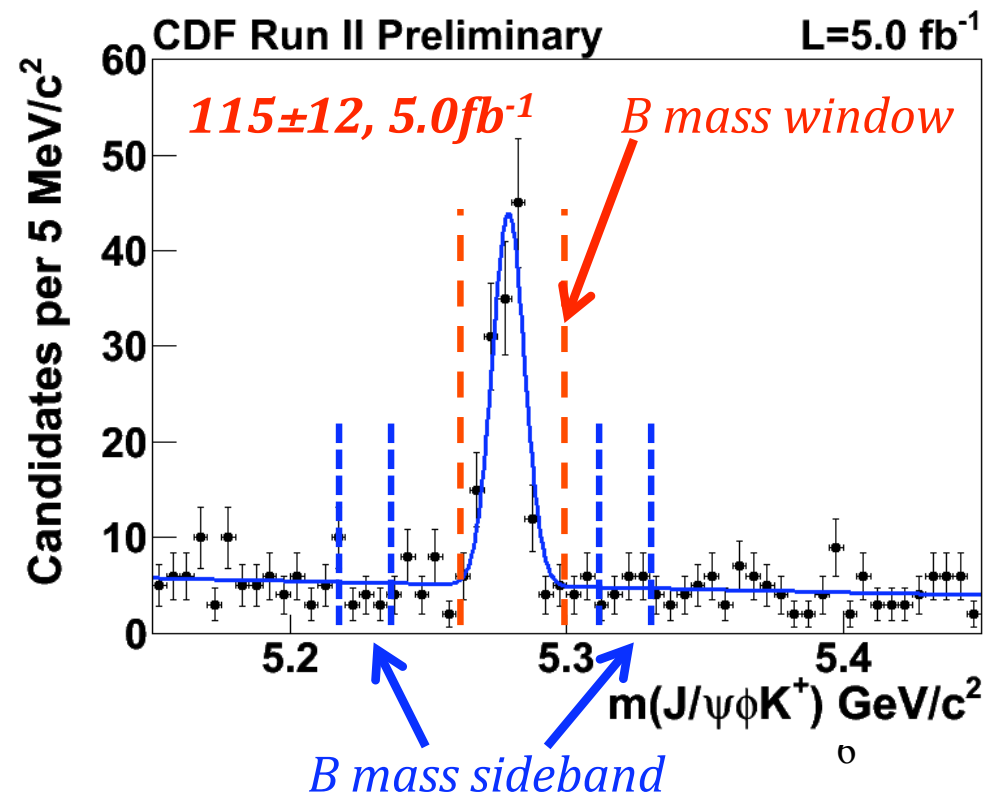
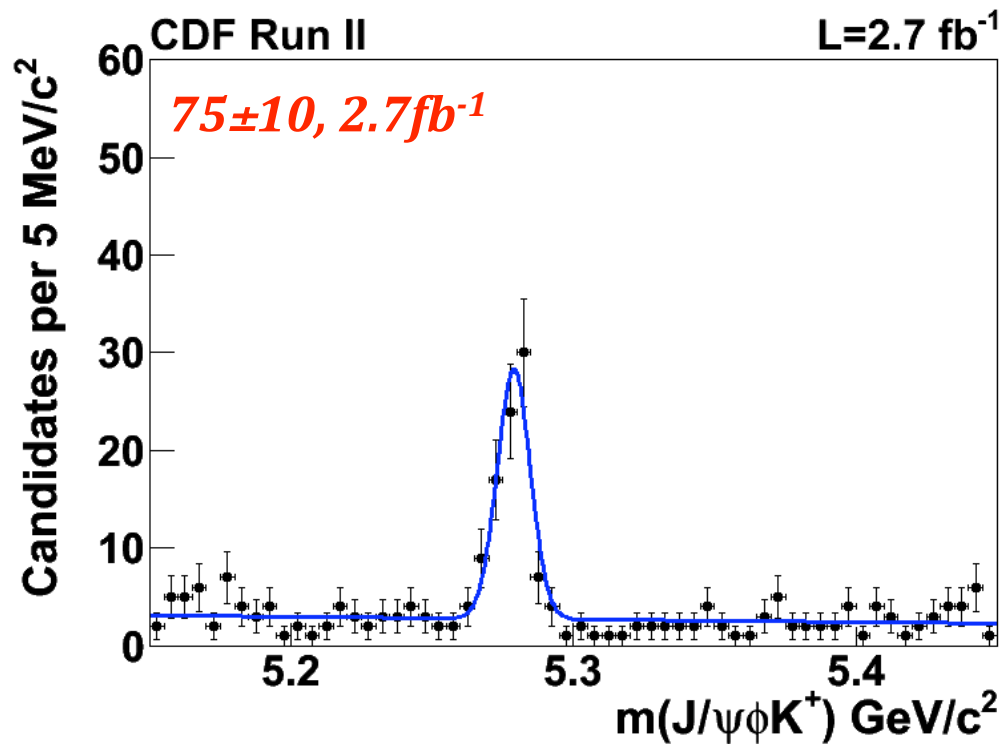
Possible EXOTIC interpretations from theorists: molecule, threshold effect,...

No firm conclusion from Belle due to low efficiency (low pT track around threshold)

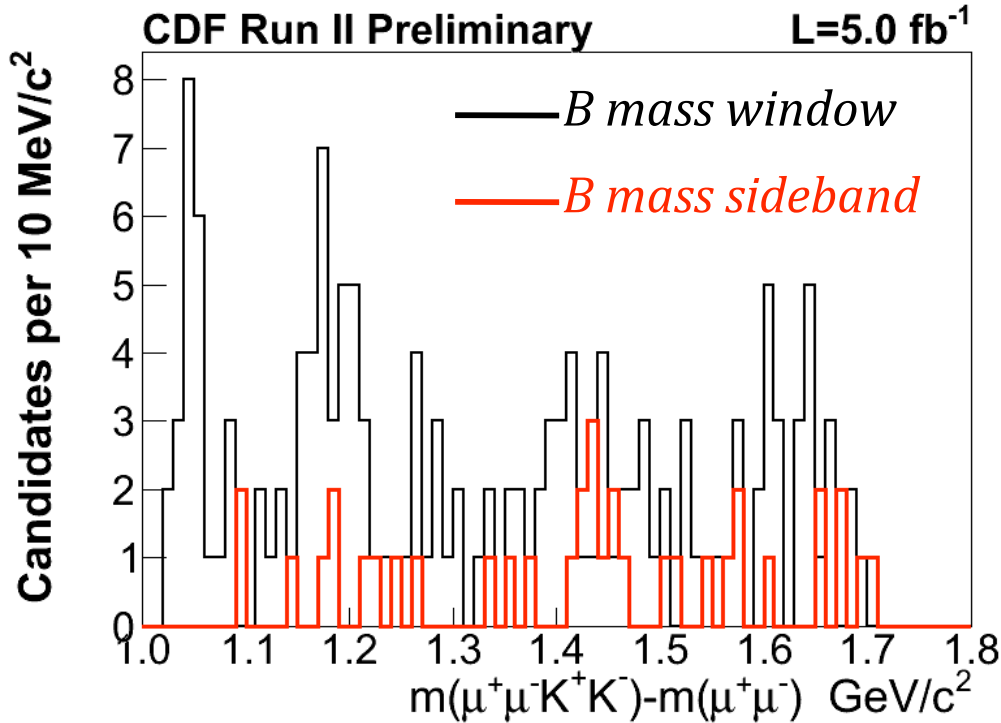
It is important to investigate with CDF new data

CDF update—Dataset and Strategy

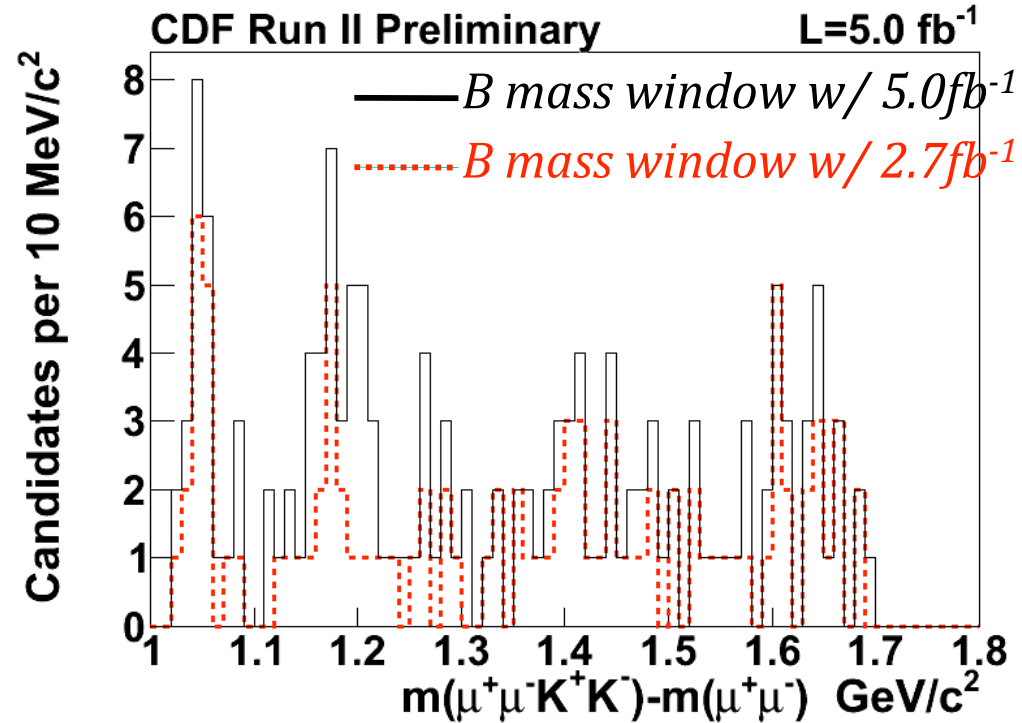
- Up to 5.0 fb^{-1} . Note: CDF dimuon trigger is dynamically pre-scaled
- Combined with a slightly different trigger to increase statistics
- Use the same requirements as in the published paper
- B^+ yield increased by 53%



CDF update— $J/\Psi\phi$ (Δm) distributions

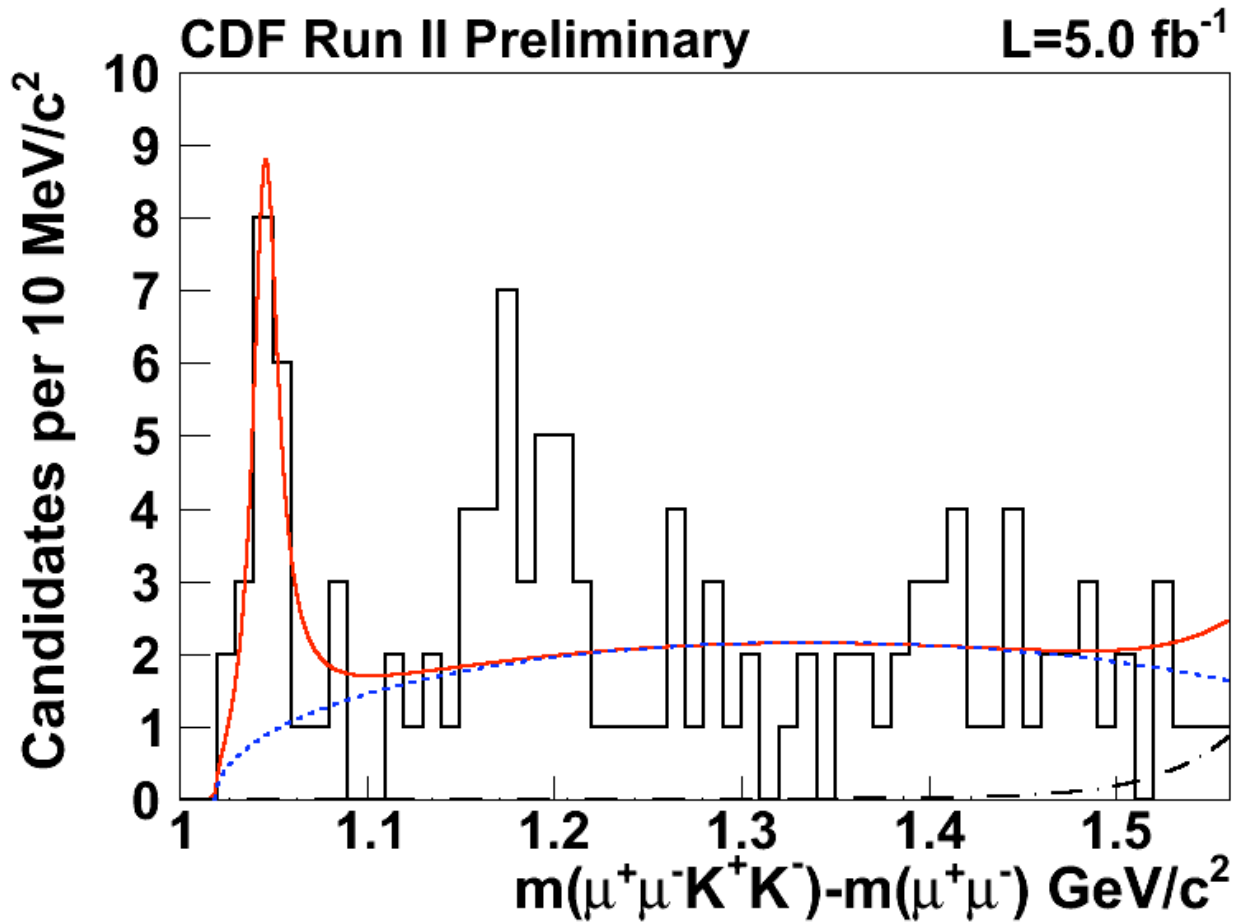


*The excess is seen in B mass window
No evidence from B sideband*



The excess is enhanced w/ more data

CDF update—Fit to the Δm distribution



Signal PDF: *S*-wave BW convoluted with resolution (1.7 MeV)

Background PDF: 3-body phase space (blue dot)

Fixed component for *B*_s component (black dot dash)

$\Delta m, \Gamma$ consistent with previous result, yield is increased

Result w/ 5.0 fb⁻¹:

$$\text{Yield} = 19 \pm 6$$

$$\Delta m = 1046.7^{+2.9}_{-3.0} \text{ MeV}/c^2$$

$$\Gamma = 15.3^{+10.4}_{-6.1} \text{ (stat) MeV}/c^2$$

$$\sqrt{(-2\log(L_{\max})/L_0)} = 5.91$$

Result w/ 2.7 fb⁻¹:

$$\text{Yield} = 14 \pm 5$$

$$\Delta m = 1046.3 \pm 2.9 \text{ (stat) MeV}/c^2$$

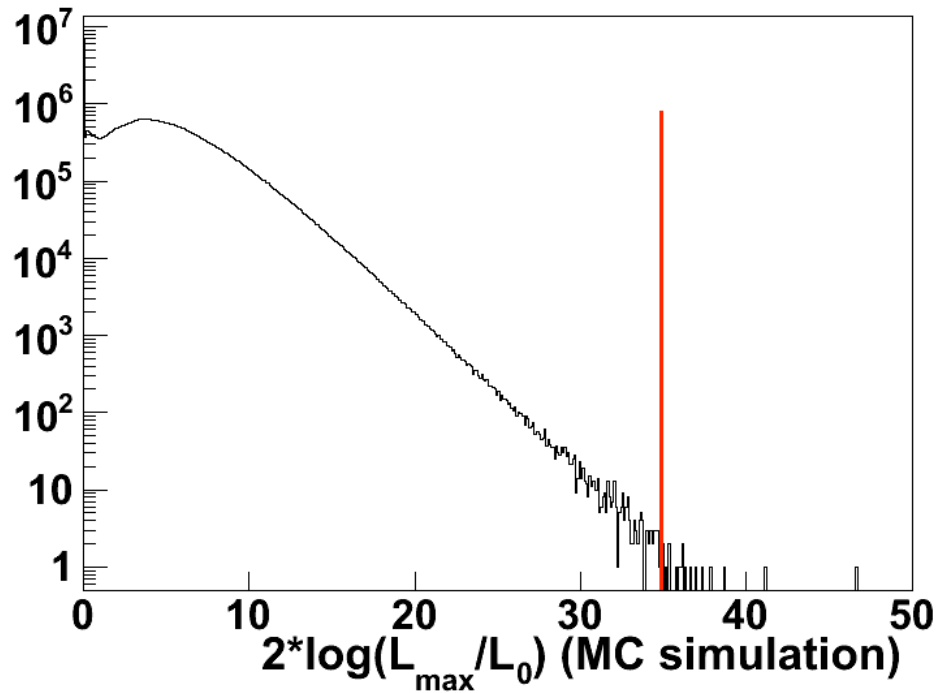
$$\Gamma = 11.7^{+8.3}_{-5.0} \text{ (stat) MeV}$$

CDF update—Significance from Simulation

-using three-body decay phase space only to generate the Δm spectrum

find the most significant fluctuation in Δm [1.02, 1.56] GeV with width in [1.7, 120] MeV

-count the number of trials with $-2\log(L_{\max}/L_0)$ ($-2\Delta\ln$) \geq $-2\Delta\ln$ value in data (34.9)



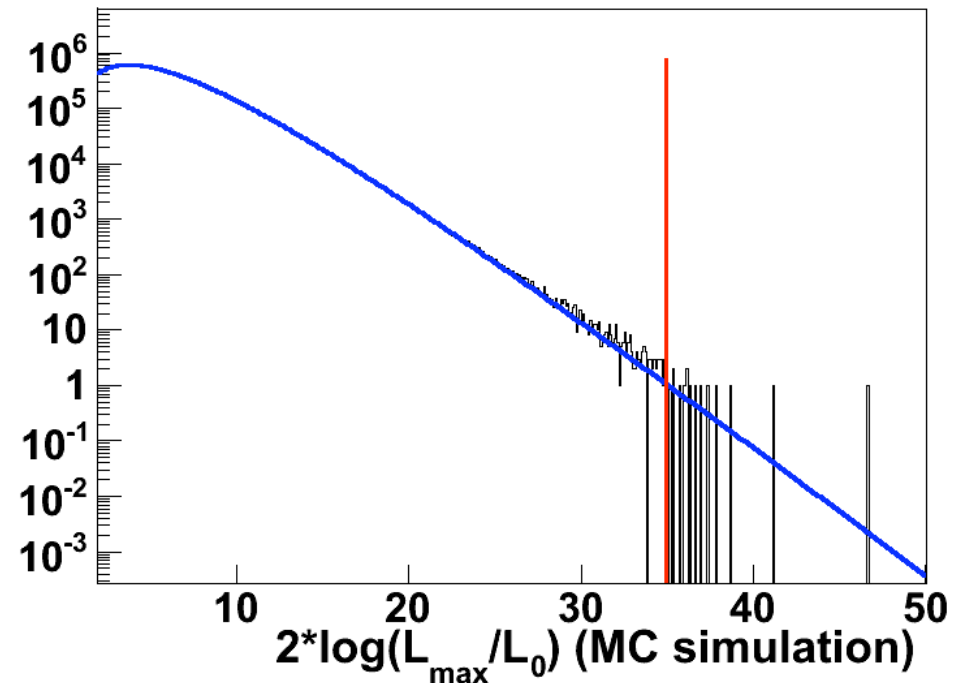
P -value = $2.26e-7$, corresponding to 5.04σ

The $Y(4140)$ significance > 5 sigma assuming the $Y(4140)$ only

Consistent with integrated χ^2 PDF

Fit the tail--[2,50] to χ^2 PDF:

$$f(z; n) = \frac{z^{n/2-1} e^{-z/2}}{2^{n/2} \Gamma(n/2)} ; \quad z \geq 0$$



P -value from integrated χ^2 PDF:

Consistent with integrated χ^2 PDF \longrightarrow $1.8e-7$, 5.09σ

Updated result of $Y(4140)$ parameters

Using J/Ψ mass from PDG, including systematic, the $Y(4140)$ parameters are:

$$\text{Mass: } 4143.4^{+2.9}_{-3.0}(\text{stat}) \pm 0.6(\text{syst}) \text{ MeV}/c^2$$

$$\text{Width: } 15.3^{+10.4}_{-6.1}(\text{stat}) \pm 2.5(\text{syst}) \text{ MeV}/c^2$$

$$\text{Yield: } 19^{+6}_{-5}(\text{stat}) \pm 3(\text{syst})$$

Relative BF (assume S -wave BW for $Y(4140)$ and phase space for B decays):

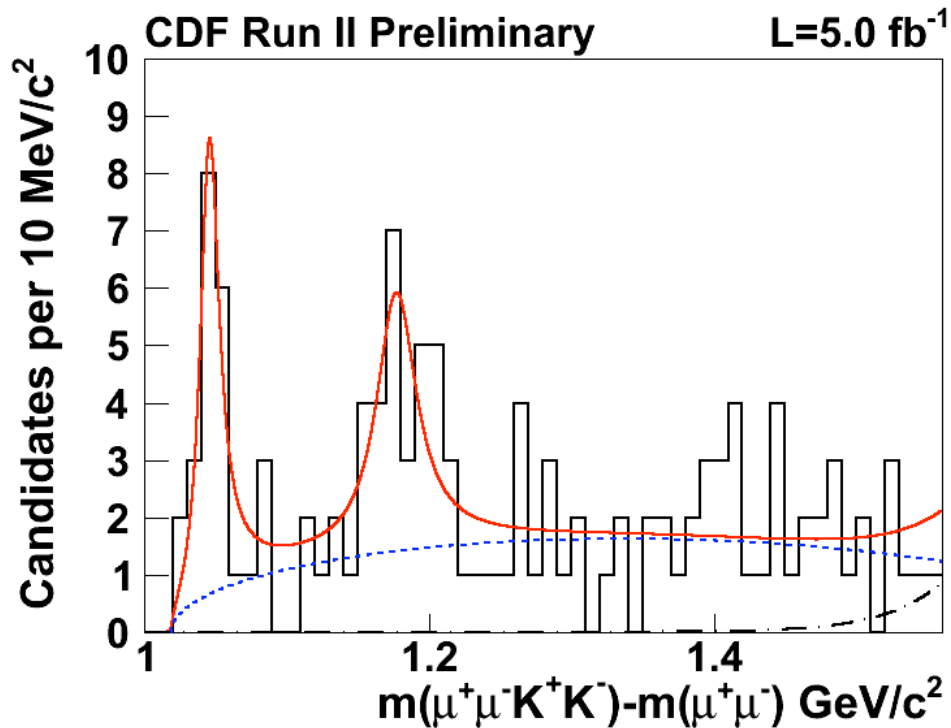
$$\frac{\mathcal{B}(B^+ \rightarrow Y(4140)K^+, Y(4140) \rightarrow J/\psi\phi)}{\mathcal{B}(B^+ \rightarrow J/\psi\phi K^+)} = 0.149 \pm 0.039(\text{stat}) \pm 0.034(\text{syst})$$

Significance: $> 5\sigma$

C parity: positive

Width (15 MeV) is relative narrow but much wider than resolution (1.7 MeV) indicating a strong decay

Suggestive evidence of a second peak



Fix the parameters for $Y(4140)$

*For the excess around 1.18 GeV:
Signal PDF: S -wave BW convoluted
with resolution (3.0 MeV)*

*Background PDF: 3-body phase space
(blue dot)*

*Fixed component for B_s component
(black dot dash)*

$$\sqrt{-2\Delta\ln}: 4.1$$

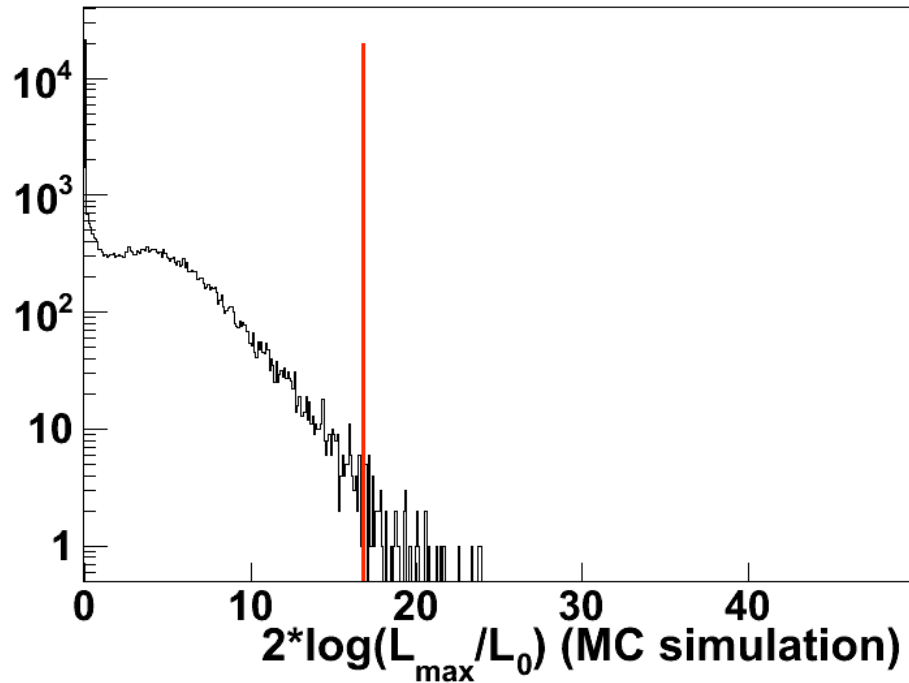
$$\Delta m: 1177.7^{+8.4}_{-6.7} \text{ MeV}$$

$$\text{Width}: 32.3^{+21.9}_{-15.3} \text{ MeV}$$

$$\text{Yield}: 22 \pm 8$$

Interesting, but not yet significant enough to be called a 'discovery'.

Second peak significance from simulation



Significance is determined by the same kind of Toy MC as for the first peak

P-value=1.1e-3, corresponding to 3.1 σ

Adding J/ Ψ mass from PDG, including systematic, the parameters are:

Mass: $4274.4^{+8.4}_{-6.7}(\text{stat}) \pm 1.9(\text{syst}) \text{ MeV}/c^2$

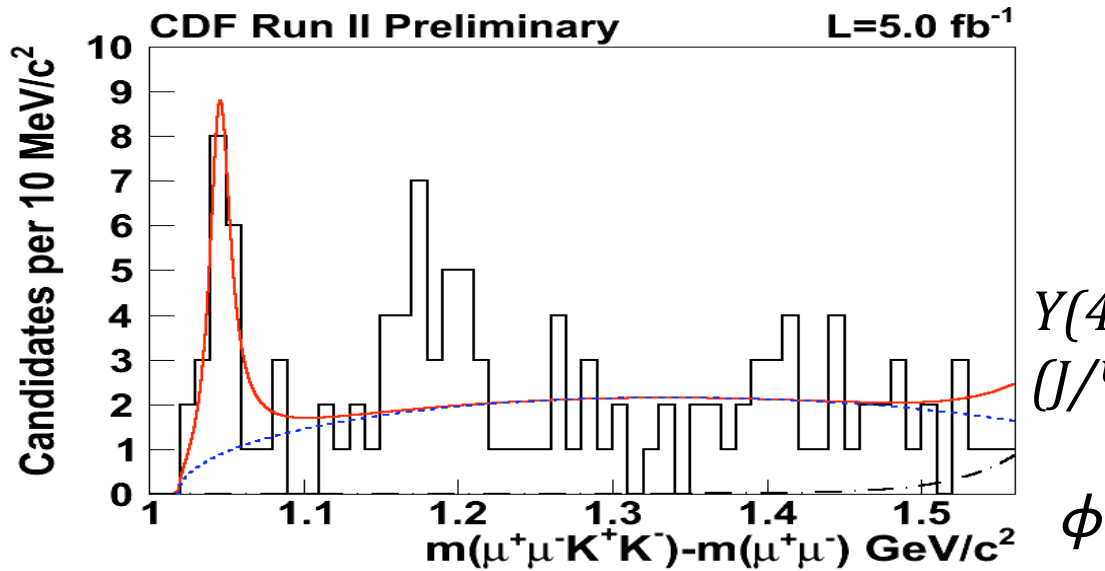
Width: $32.3^{+21.9}_{-15.3}(\text{stat}) \pm 7.6(\text{syst}) \text{ MeV}/c^2$

Yield: $22 \pm 8(\text{stat}) \pm 5(\text{syst})$

Significance: 3.1 σ

C parity: positive

Similarity between $Y(4140)$ and $Y(3940)$



$Y(4140)$
($J/\Psi\phi$)

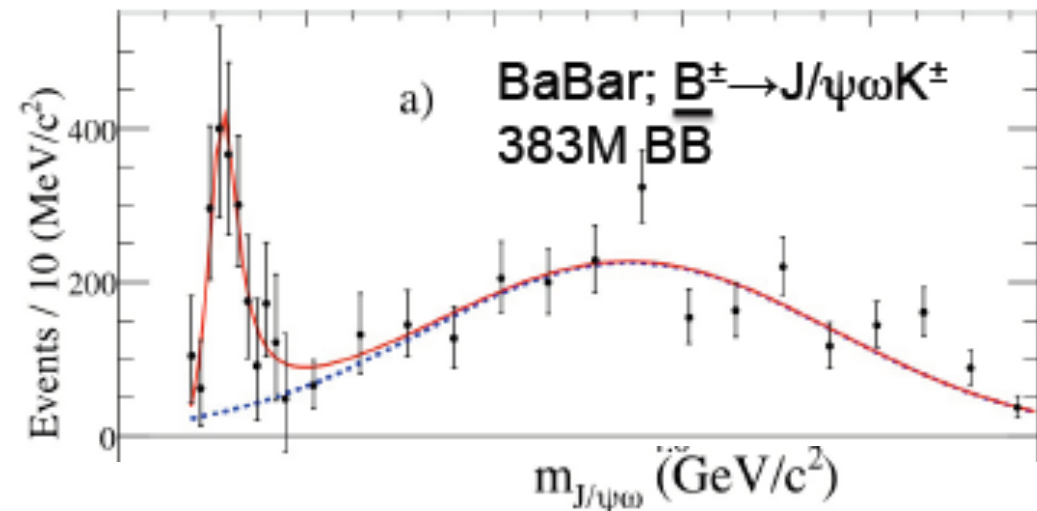
Mass-threshold
(MeV)

$$27^{+2.9}_{-3.0} \pm 0.6$$

width
(MeV)

$$15.3^{+10.4}_{-6.1} \pm 2.5$$

$$4.26 \pm 0.4$$



$Y(3940)$
($J/\Psi\omega$)

$$35^{+3.8}_{-3.4} \pm 2.0$$

$$34^{+12}_{-8} \pm 5$$

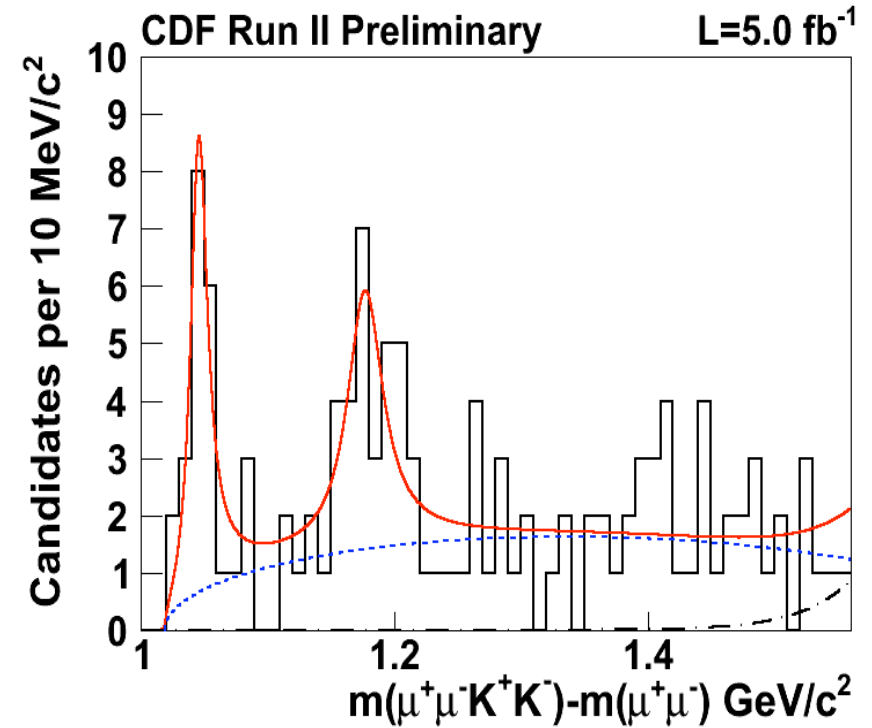
$$8.49 \pm 0.08$$

Almost the same position, both “narrow” but strong decay
Is width connected to decay daughter width?

Summary

- Observed $Y(4140)$ at CDF using more data significance $>5\sigma$
- “narrow” width but a strong decay
Not likely to be a conventional charmonium
- An excess around 4.28 GeV (3.1σ)

Stay tuned!





FY11 Luminosity Projections [delivered]



*12 fb⁻¹ delivered doubles the dataset up to now
and results in analyses with about 10 fb⁻¹*

~12 fb⁻¹

