Study of Inclusive Charmonium Production in e^+e^- annihilation and B decays at *BABAR*

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Overview

- Inclusive $B \to XK$ two-body decays are studied

- Update of 2005 study (Phys. Rev. Lett. **96**, 052002 (2006)) to now use 424 fb^{-1} of the BABAR dataset (previous study – 210 fb^{-1})

- Increased luminosity and precision reduces uncertainties and allows for new measurements to be taken.

Motivation

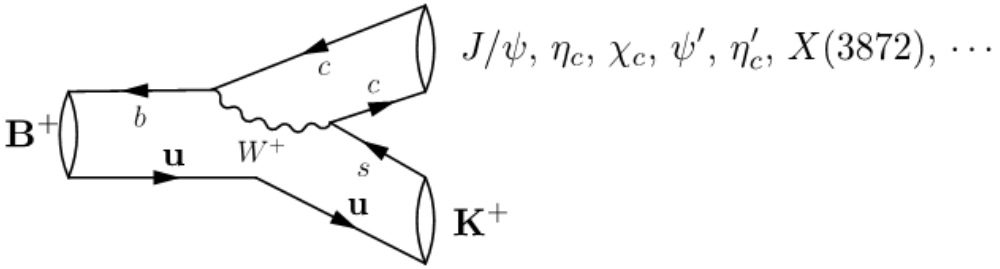
- Provide a clear picture of charmonium spectroscopy

- Determine absolute branching fractions for all known two-body decays of form $B^{\pm} \to X_{c\bar{c}} K^{\pm}$

- Measure a BF (or upper limit) of $B^{\pm} \to K^{\pm} X(3872)$

$B \to X + K^{\pm}$

- In these decays, X is mostly a $c\bar{c}$ state with large phase space.
  - Many different charmonium states are allowed



- We search along a full range of mass to fully characterize these decays and search for exotic charmonium states.
  - Make new measurements on D states as well

- An original method to study inclusive two-body decays is introduced.

$B \rightarrow X_{c\bar{c}} + K$

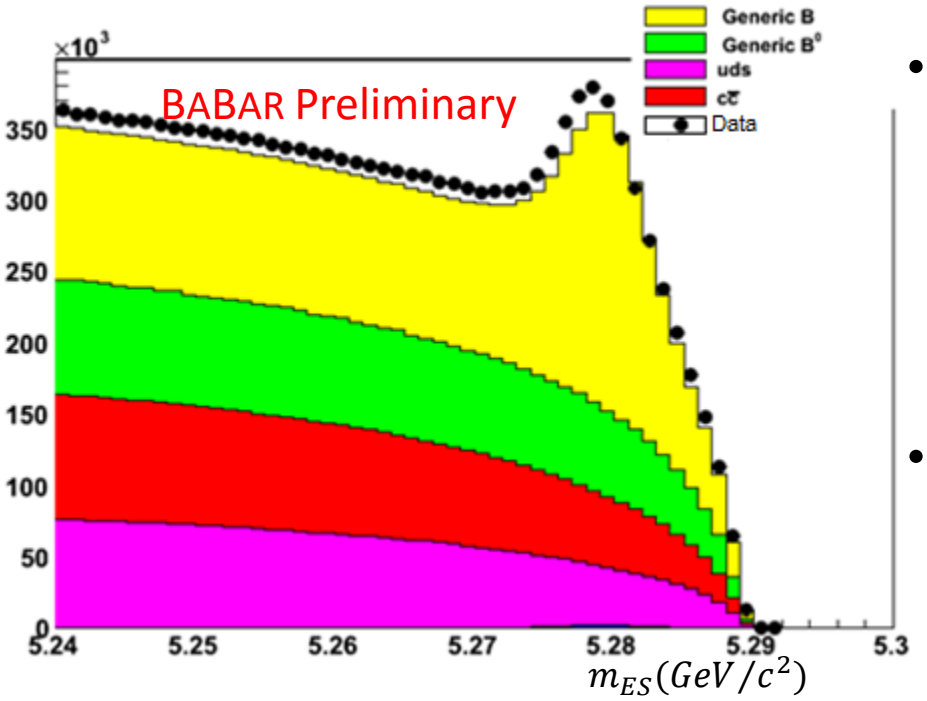
Traditional Method

- Exclusively reconstruct each charmonium ($X_{c\bar{c}}$) state
- Use that measurement to deduce a measurement of $B \rightarrow X_{c\bar{c}}\, K$

This Study

- Use K momentum in B center of mass frame.
- From the spectrum of kaon momentum, one can directly deduce BF of $B \rightarrow X_{c\bar{c}}\, K$
- Details of $X_{c\bar{c}}$ decay not required for measurement

B and K selection



- Fully reconstruct B's
  - Look for the presence of either a $D^{(*)}$, J/ψ, or $D_s^{\pm}$ + multihadrons
  - $1\,670\,000 \pm 4230\ B^{\pm}(stat) \pm 80000\ (syst)$ events obtained (BABAR preliminary)
- Increase S/N - reject secondary kaons
  - Secondary kaons have an isotropic distribution

Analysis method - detailed

- Reconstruction of one B in the event gives the momentum of the other.
  - If non-reconstructed B is a two-body decay, one can calculate the mass of X:

    $$m_x = \sqrt{m_B^2 + m_K^2 - 2E_K m_B}$$
- Fit excess kaons amongst the momentum spectrum at target X's mass to get number of $B \to K^{\pm} + X$ events (N_x)

Analysis method - detailed

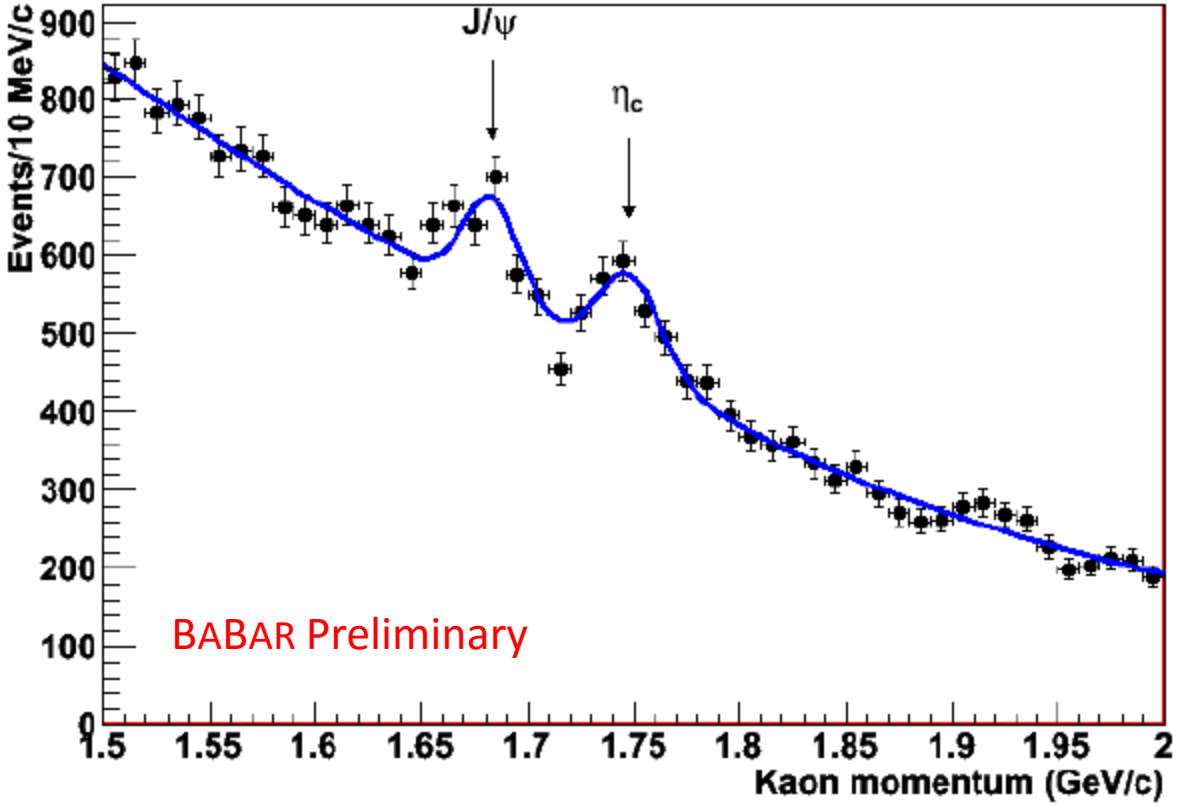
- Two ways to calculate BF of $B \to K^{\pm} + X$:
  - Directly from N_x:

$$BF(B \to K^{\pm} + X) = \frac{N_X}{\epsilon_X \cdot N_B}$$

  - Normalization of J/ψ:

$$BF(B \to K^{\pm} + X) = \frac{N_X}{N_{J/\psi}} \cdot \frac{\epsilon_{J/\psi}}{\epsilon_X} \cdot BF(B \to K^{\pm} + J/\psi)$$

Low mass charmonium



$BF(B^{\pm} \to K^{\pm}\ J/\psi) = (9.6 \pm 1.2(stat) \pm 0.8(sys)) \times 10^{-4}$

$BF(B^{\pm} \to K^{\pm}\ \eta_c) = (13.3 \pm 1.8(stat) \pm 0.3(ref)) \times 10^{-4}$

(both BABAR Preliminary)

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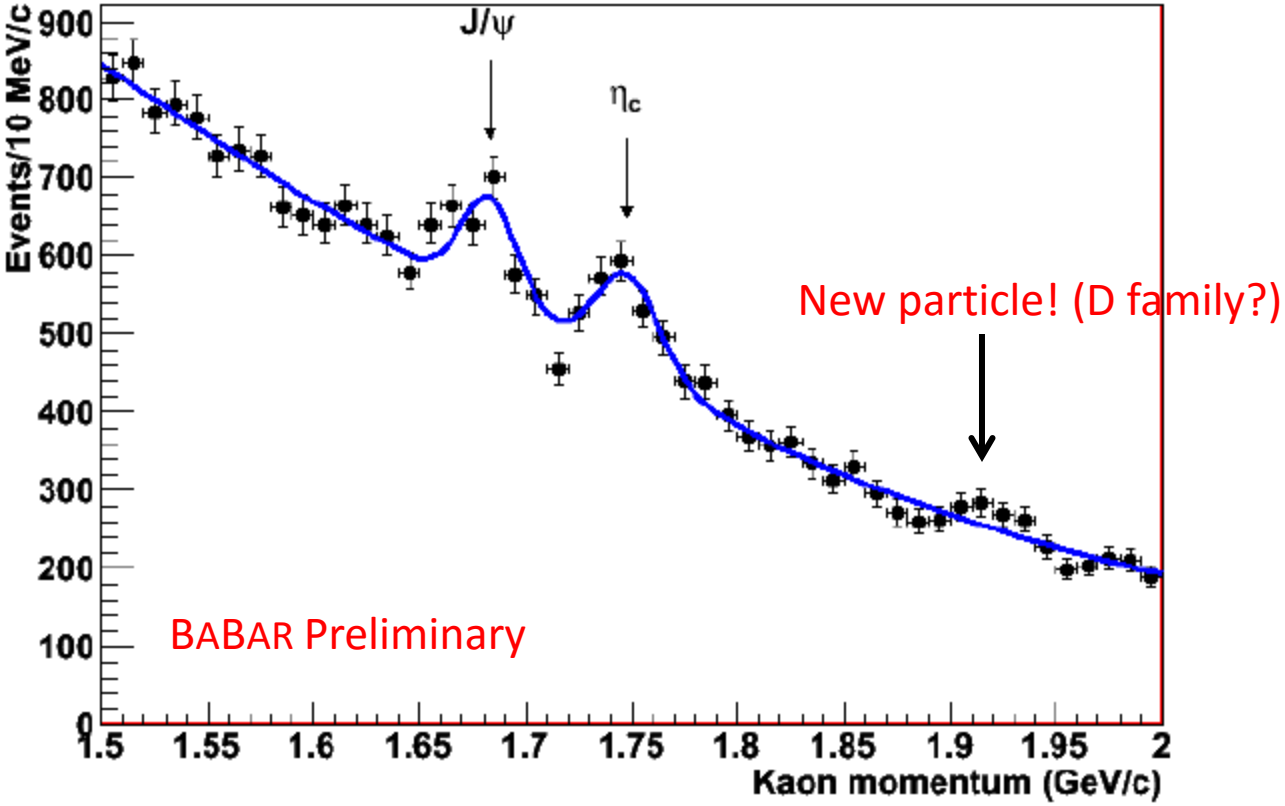

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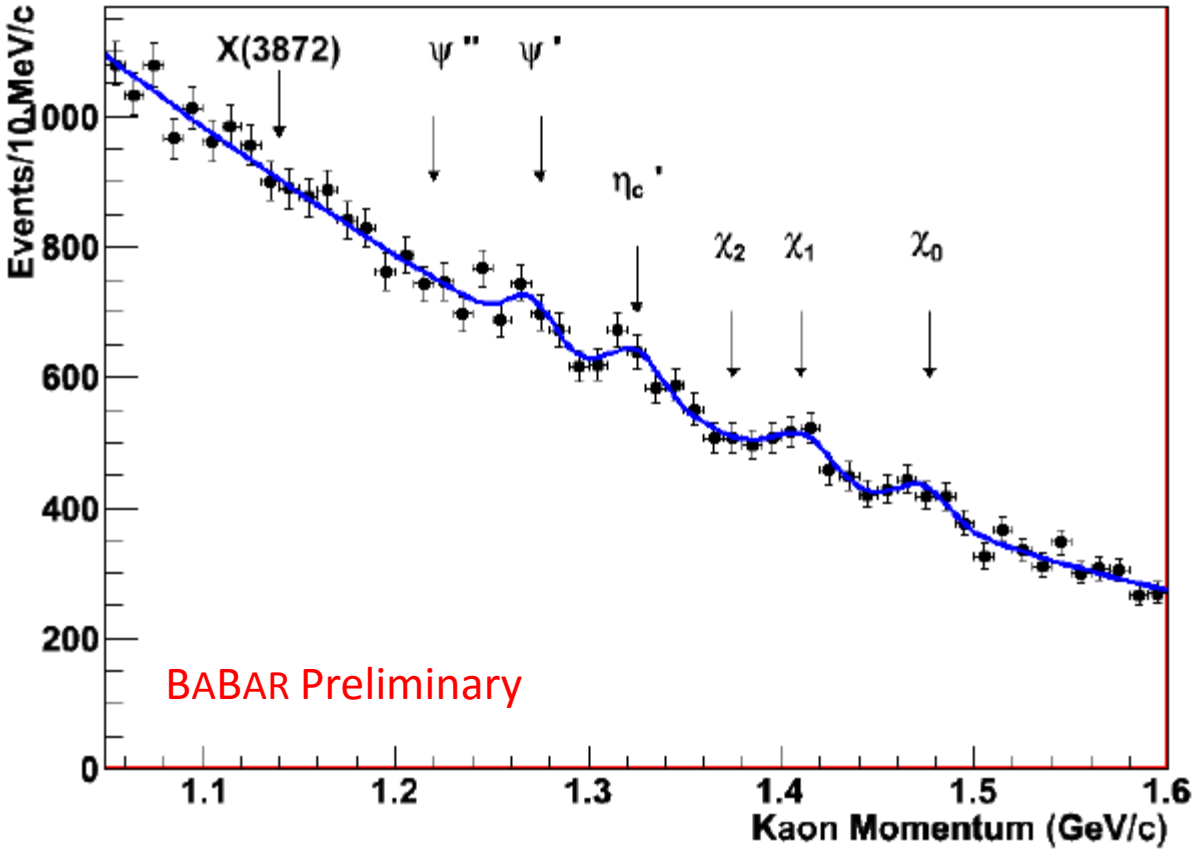
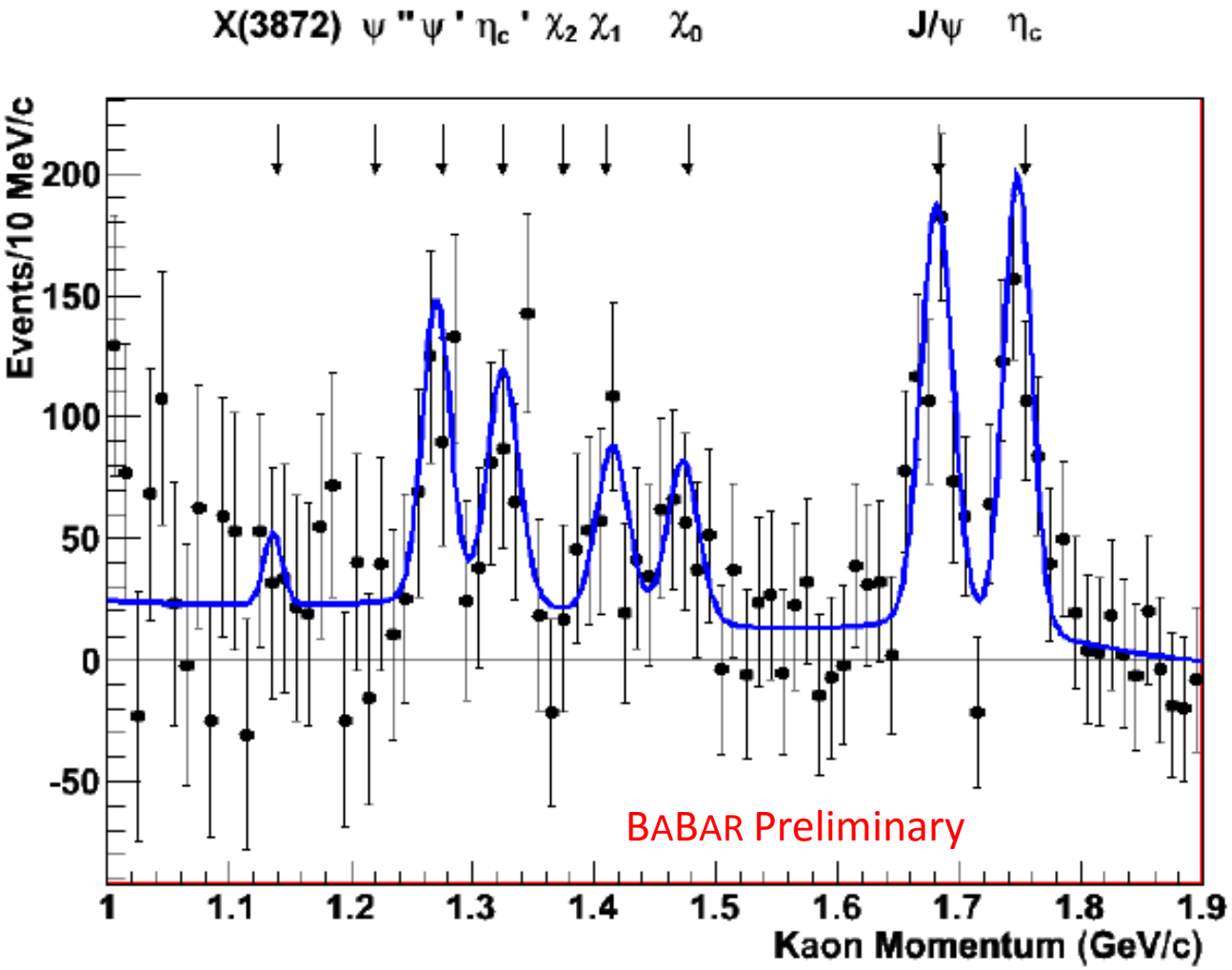
Search for high mass charmonium



Tangible fits for $\chi_0, \chi_1, \eta_c', \text{and } \psi'$

Search for high mass charmonium



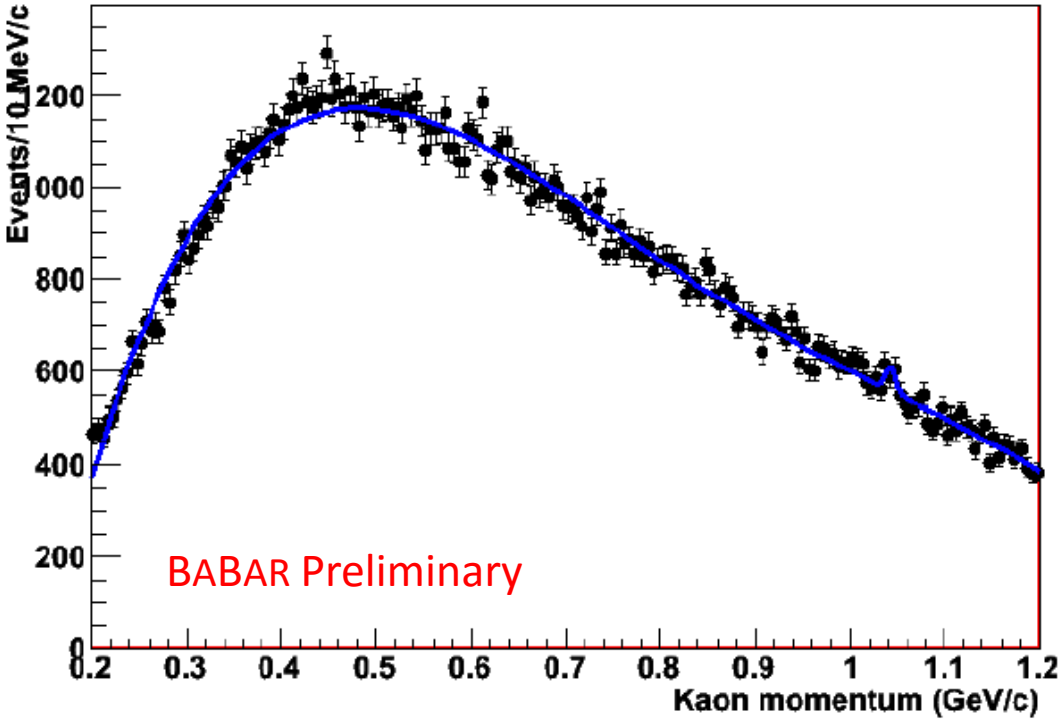
Search for high mass charmonium

- Confirmed coupling of excited states $\psi' - \eta_c(2S)$ related to $J/\psi - \eta_c$ doublet
- No signal observed for χ_2
  - This violates the democratic decay rate for charmonium in two body decays
- Upper limit on X(3872) is set

Particle	Yield	Peak Position	Width	BF(10^{-4})
J/ψ	516±67			9.6±1.2(sta)±0.8(sys)
η_c	655±77	2982±5	<43	13.3±1.8(stat)±0.4(sys)±0.3(ref)
χ_{c0}	218±76			4.4±0.9
χ_{c1}	192±35			7.0±1.3(stat)±1.0(sys)
χ_{c2}	0±32			<1.2
η_c (2S)	283±94	3632±0.007	<33	6.0±2.1(stat)±0.4(sys)
ψ'	293±90			6.2±2(stat)±0.6(sys)
$\psi(3770)$	0±49			<2.0
X(3872)	75±81			1.4±1.5 or < 4.4

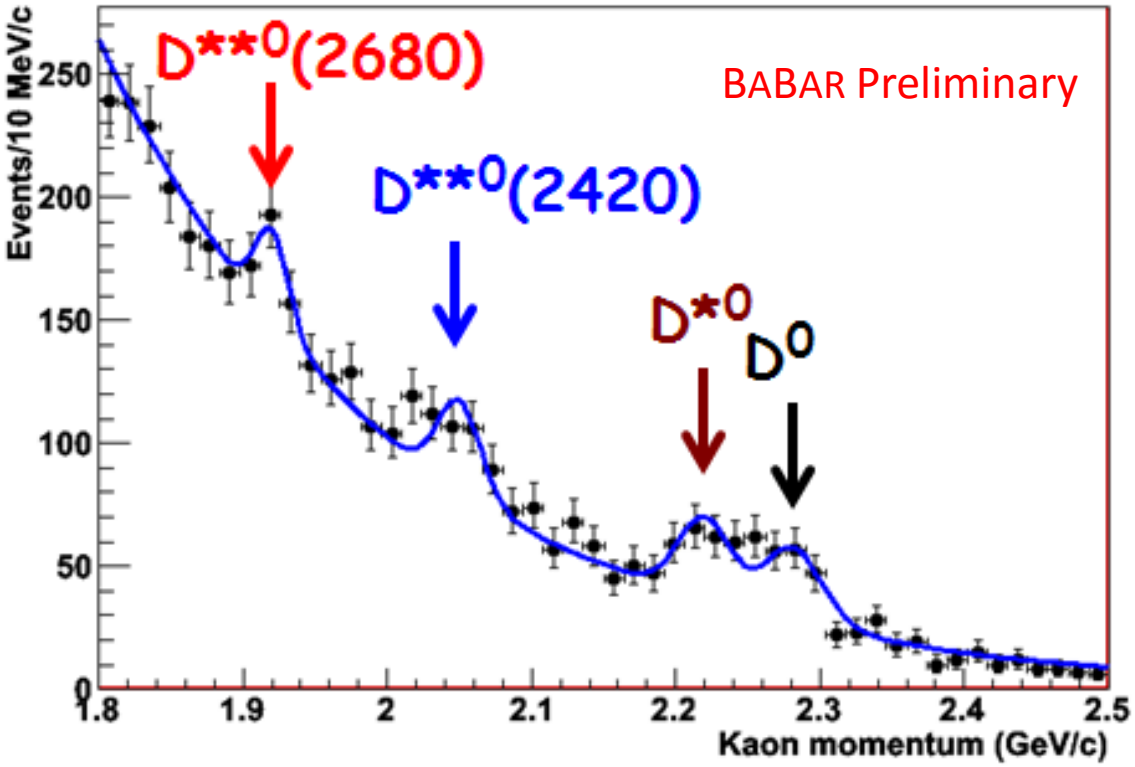
Very high mass resonances

- High background due to low kaon momentum.
  - Only sensitive to narrow resonances ('best' candidate found at 1.0425 GeV/c)
- No signal found from Y(4260) and its excited states – large width.



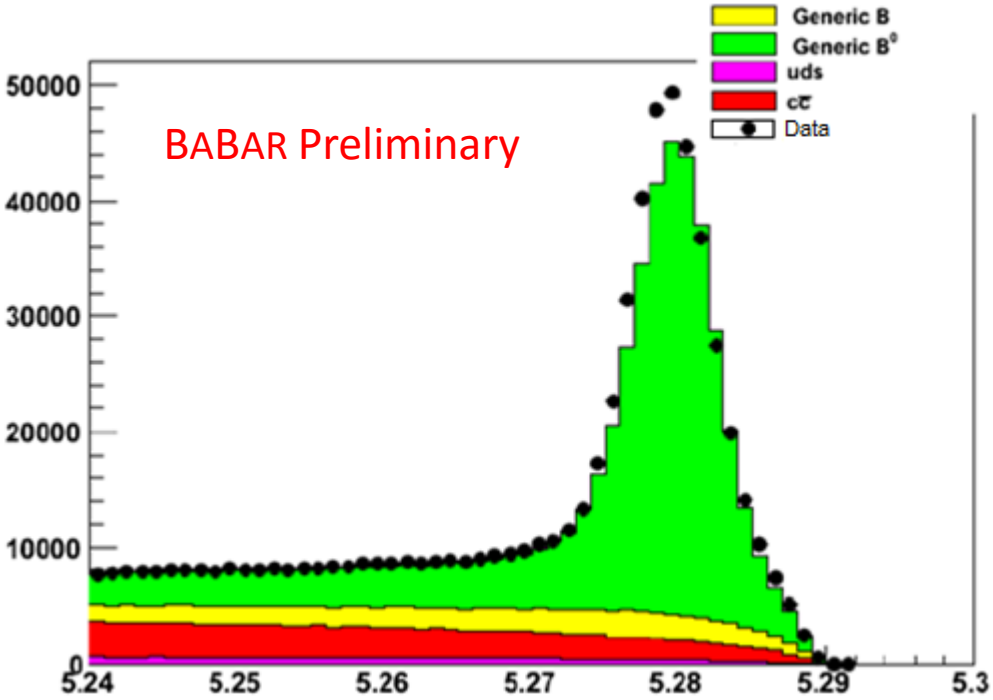
Excited D resonances

Particle	Yield	Peak Position	BF(10^{-4})	PDG 2014
D^0	126±20		3.5±0.5(sta)±0.3(sys)	3.7±0.17
D^{*0}	126±21		3.5±0.5(stat)±0.3(sys)	4.2±0.34
$D_1(2420)^0$	97±25		2.1±0.5(stat))±0.3(sys)	-
$D^{**0}(2680)$	95±29	2.68±0.003	2.1±0.6(stat)±0.3(sys)	-
$D^{\pm}$	44±10		3.3±0.8(sta)±0.3(sys)	2.0±0.21
$D^{*\pm}$	40±10		3.0±0.8(stat)±0.3(sys)	2.1±0.16
$D^*(2420)^{\pm}$	52±13		3.9±1.0(stat))±0.3(sys)	-

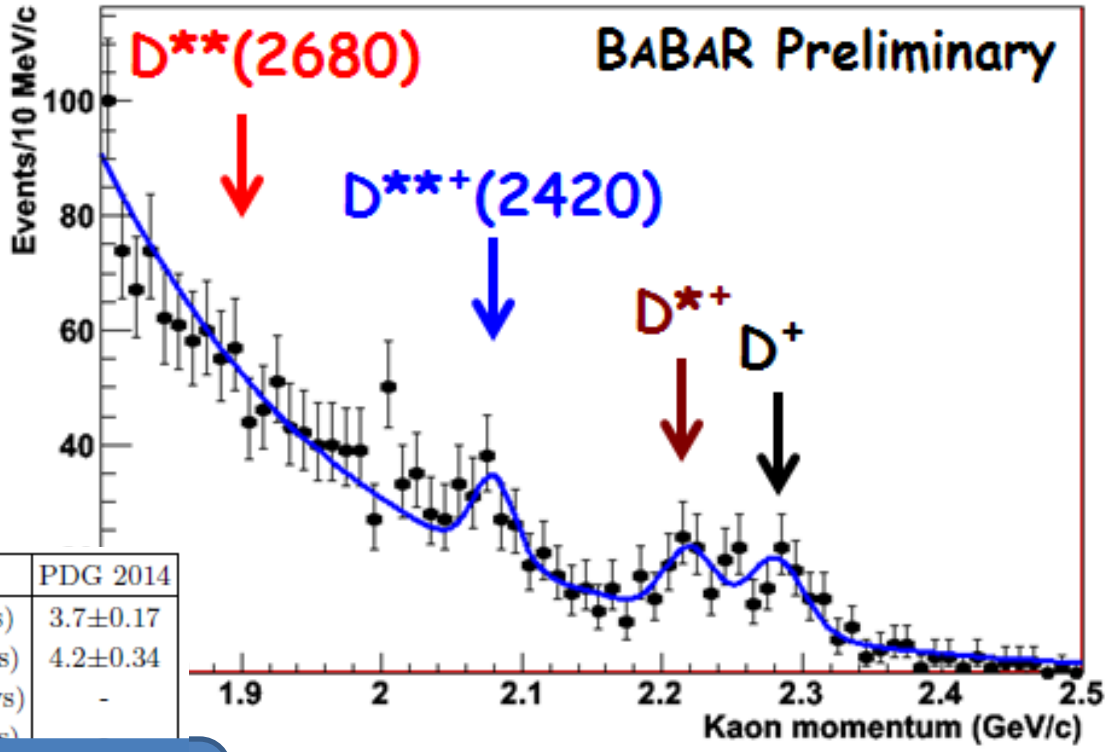


Charged Charmonium

- Analysis is redone with reconstructed B^0
  - $372\,597 \pm 775$ B^0 sample (BABAR Preliminary)
- Measurements in D region agree with PDG



Charged Charmonium – D resonances



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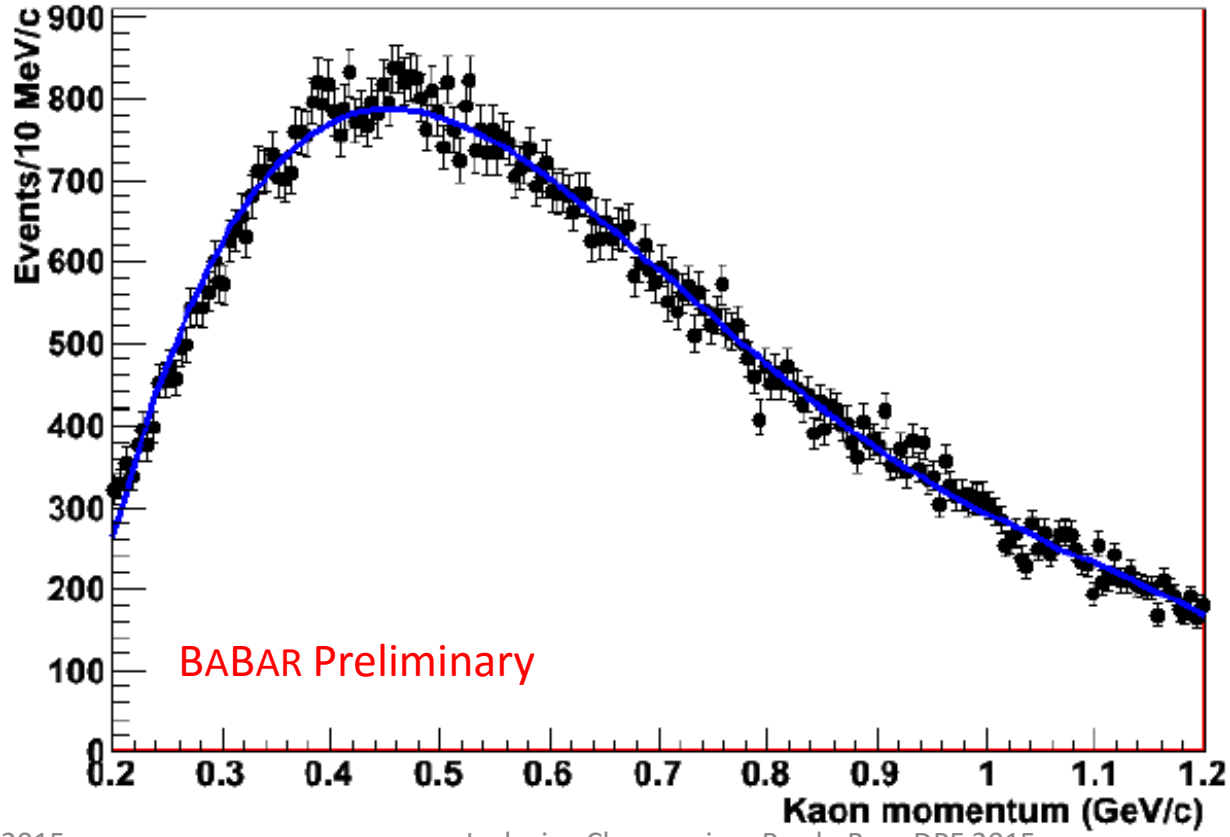
D resonances found in region $1.8\ GeV/c < p_K < 2.5\ GeV/c$

Charged Charmonium

- No evidence found for charmonium-like states Z(3900), Z(4050), and Z(4430)
  - Upper limits have been set



Summary & Conclusions

- An update to previous measurements using full BABAR statistics has been completed.

- We have increased the precision of $B^{\pm} \to \eta_c K^{\pm}$
- We have observed the doublet $\psi' - \eta_c(2S)$
- $BF(B^{\pm} \to \chi_{c0} K^{\pm})$ is now measured

Summary & Conclusions

- No measurement of X(3872), but upper limit is refined
- Evidence of new particle (D family?) at $p_K = 1.92\ GeV/c$ corresponding to mass $2.68\ GeV/c^2$
- Width of charged charmonium-like particles is too large to make a measurement
  - Upper limits Z(3900), Z(4050), Z(4430) respectively (90% CL): $3 \times 10^{-4}, 3 \times 10^{-4}, 5 \times 10^{-4}$ (BABAR Preliminary)

Results

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BABAR Preliminary

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