

# A Search for the $\Theta^{*++}$ in $B^{\pm} \rightarrow p \bar{p} K^{\pm}$

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SLAC

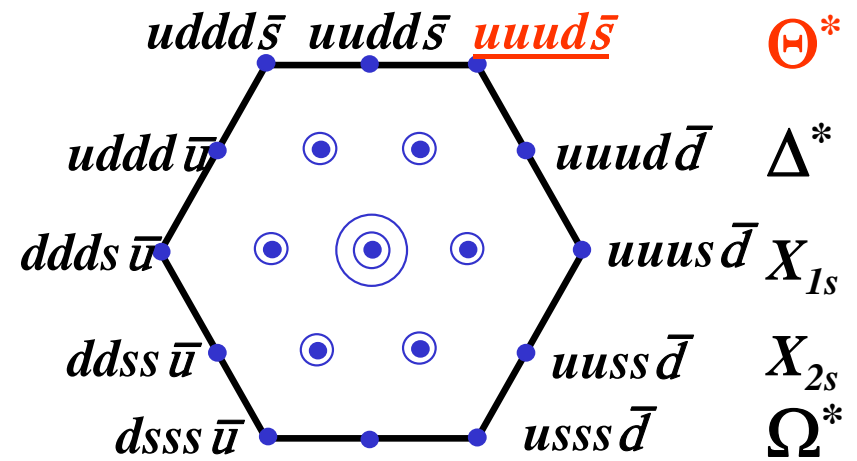
Representing the BaBar Collaboration

DPF Meeting, Riverside, CA

26-31 August 2004



# $\Theta^{*++}$ Pentaquark: Current Status



## Theoretical Predictions

$m(\Theta^{*++})$ , GeV/c<sup>2</sup>

$\Gamma(\Theta^{*++})$ , MeV

B.Wu & B.Q.Ma, Phys.Rev.D, **69** 077501(2004)

1.6

<43

D. Borisjuk *et al*, hep-ph/0307370

1.595

80

H. Walliser *et al.*, J.Exp.Theor.Phys., **97** 433(2004)

1.64-1.69

J. Ellis *et al.*, JHEP 0405:002

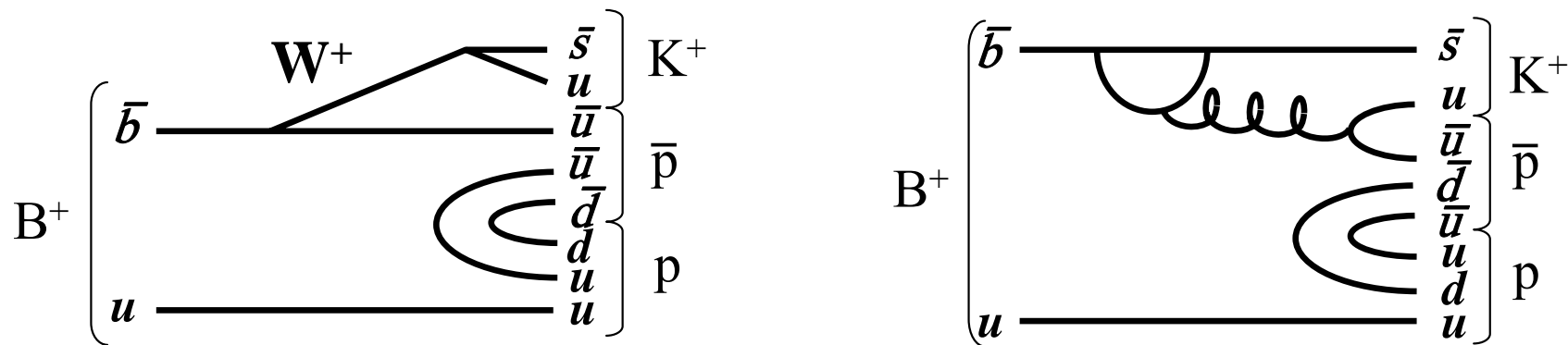
37-66

- $\Theta^{*++} \rightarrow K^+ p$  mode thought to be dominant
- Searches for new particles in  $K^+ p$  scattering: no sign of  $\Theta^{*++}$ , constrains  $\Gamma(\Theta^{*++}) < 15 \text{ MeV}$
- Not seen by experiments that claim  $\Theta^+$  (CLAS, HERMES, SAPHIR, ZEUS)
- No previous searches in B decays (idea: Phys.Lett.B, **587** 62(2004))

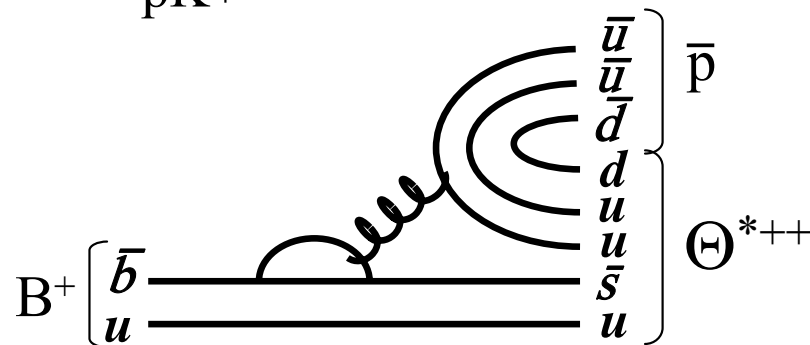


# Talk layout

- Measurement of the charmless  $\mathcal{B}(B^\pm \rightarrow p\bar{p}K^\pm) \sim 10^{-6}$

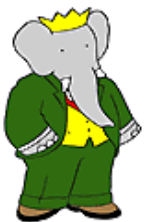


- Search for  $\Theta^{*++}$  in  $m_{pK^+}$

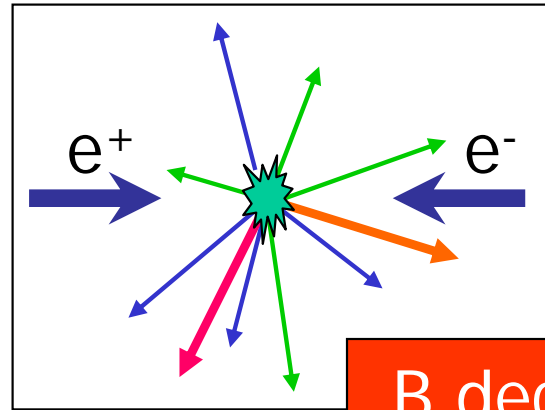


# Analysis Overview

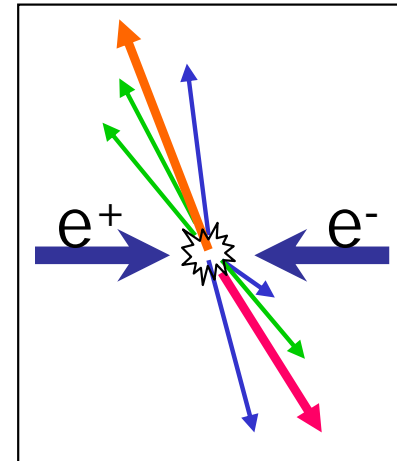
- Data Samples
  - 81 fb<sup>-1</sup> on the  $\Upsilon(4S)$  resonance (89M B<sup>±</sup> mesons)
  - 9 fb<sup>-1</sup> 40MeV below the  $\Upsilon(4S)$  resonance
- Use tracking, particle ID and pair-production kinematics to isolate B<sup>±</sup> → p $\bar{p}$ K<sup>±</sup> signal
- Major Backgrounds:
  - Baryons from the continuum (suppress topologically)
  - Allowed B decays: B<sup>±</sup> → XK<sup>±</sup>, X → p $\bar{p}$   
(X =  $\eta_c, J/\psi, \chi_c, \psi(2S)$ )



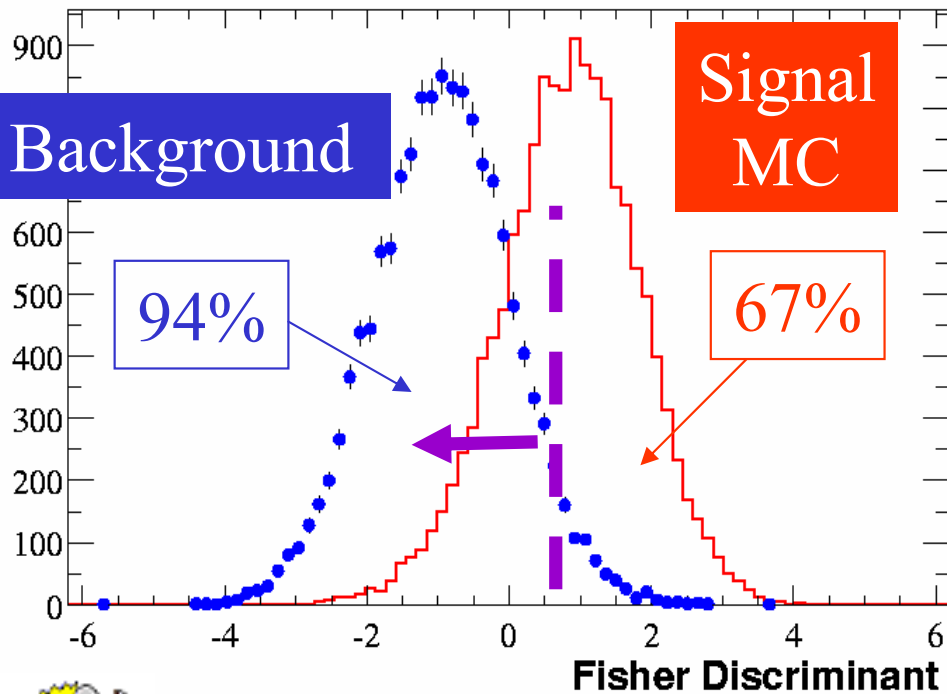
# Continuum Background Suppression



B decay



Continuum  $q\bar{q}$



$$L_2 = \sum_i |p_i^*| (3 \cos^2 \theta_{Thr_{B,i}} - 1) / 2,$$

$$L_0 = \sum_i |p_i^*|,$$

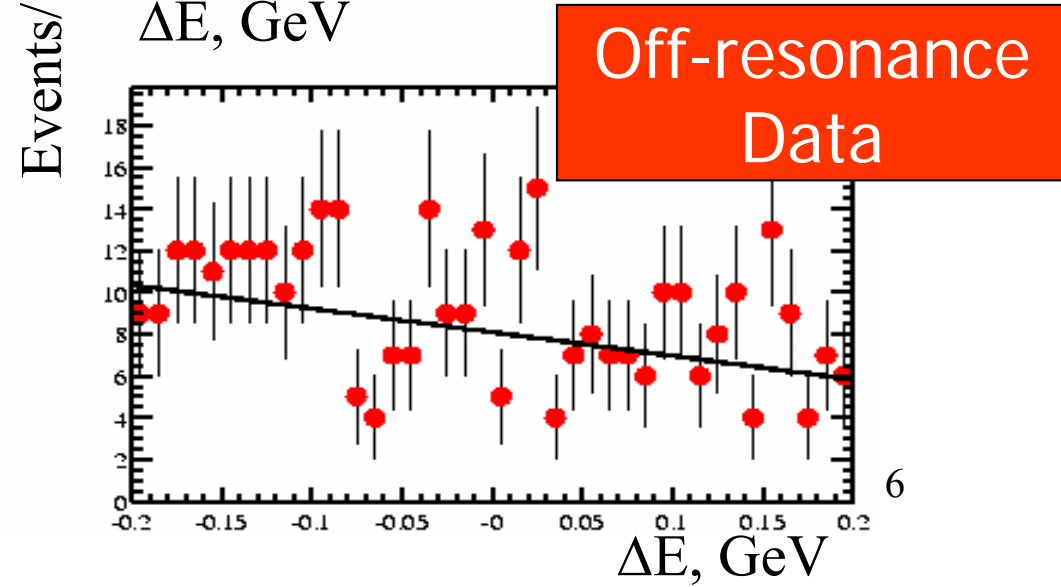
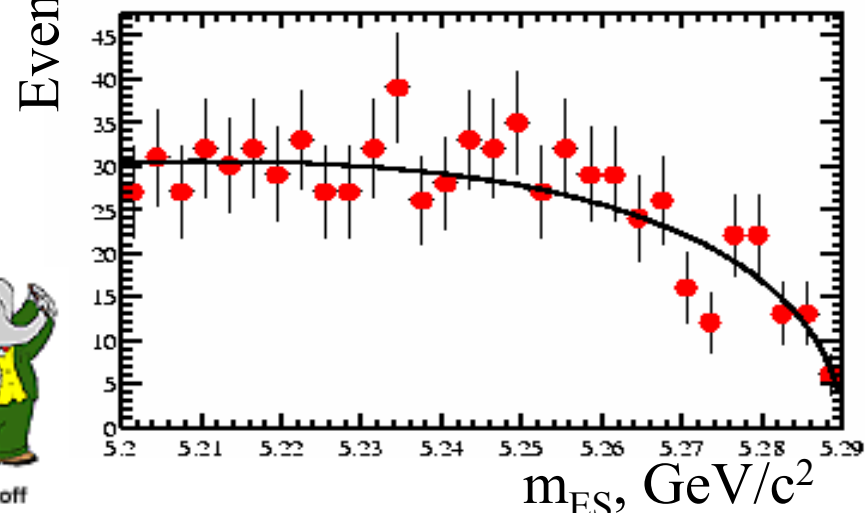
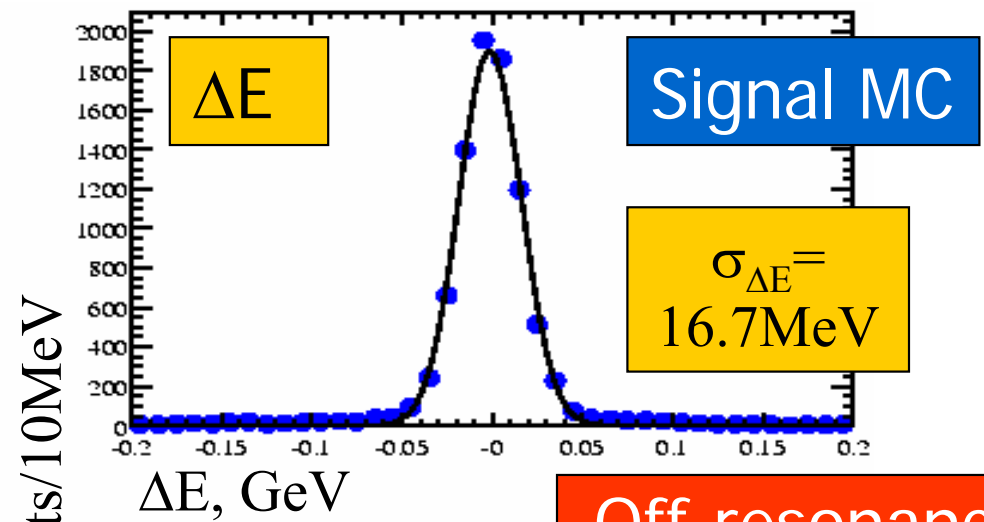
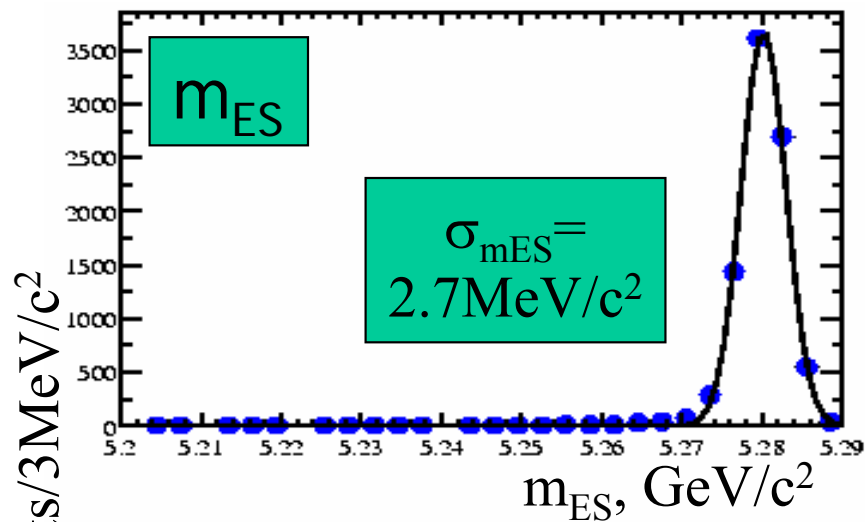
( $i$  = photons and tracks which are not part of the  $B_{p\bar{p}K}$ ) and angles between the  $B_{p\bar{p}K}$  thrust (momentum) and z axis combined into Fisher Discriminant



# B reconstruction

$$m_{ES} = \sqrt{\left(\frac{E_{CM}^2}{2} + p_i \cdot p_B\right)^2 / E_i^2 - p_B^2}$$

$$\Delta E = E_B^* - \frac{E_{CM}}{2}$$

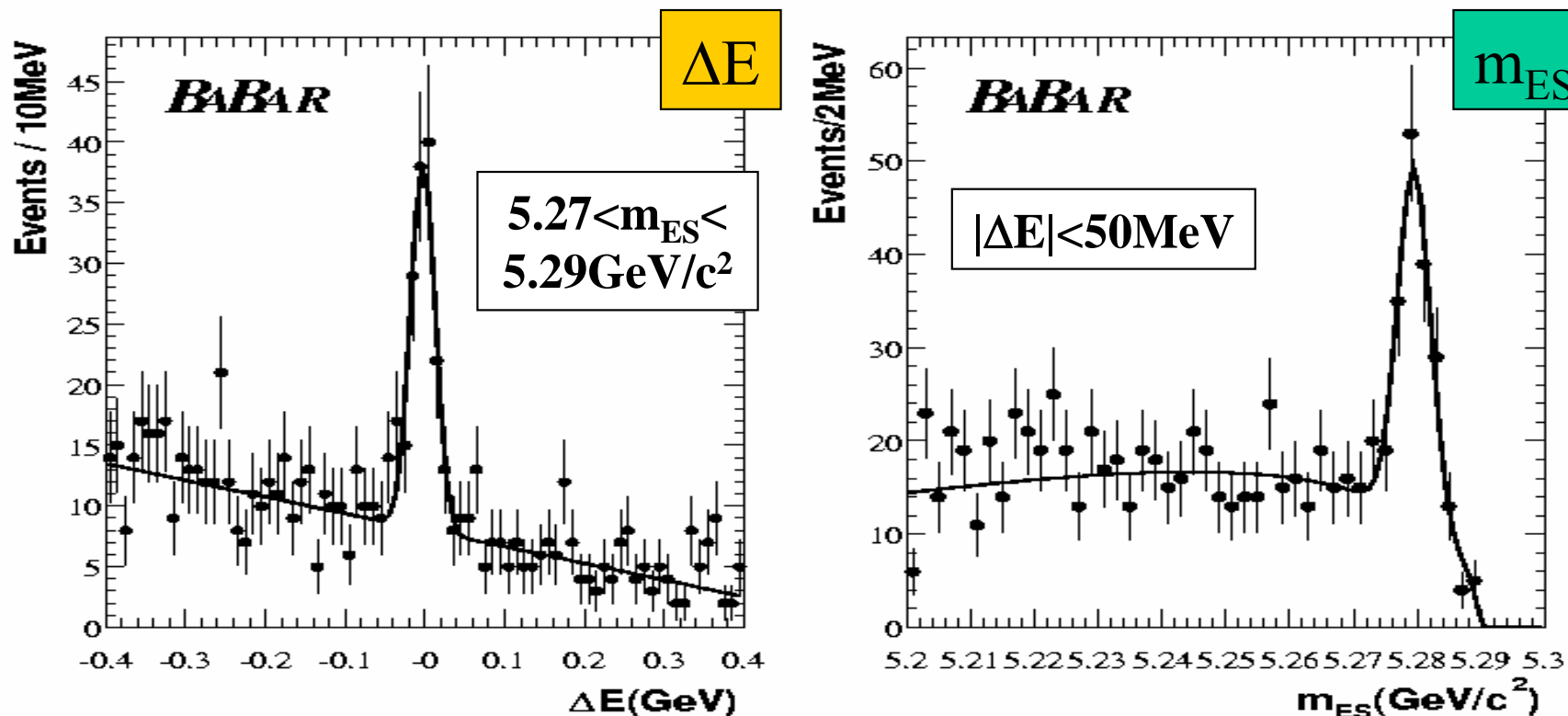


# Expected B decays background

Mode	$BF \times 10^{-6}$	Events in $81 \text{ fb}^{-1}$
Charmonium (undistinguishable from signal)		
$B^\pm \rightarrow \eta_c K^\pm \rightarrow p \bar{p} K^\pm$	$1.08 \pm 0.48$	$22.4 \pm 9.9$
$B^\pm \rightarrow J/\psi K^\pm \rightarrow p \bar{p} K^\pm$	$2.12 \pm 0.13$	$43.9 \pm 2.7$
$B^\pm \rightarrow \chi_{c0} K^\pm \rightarrow p \bar{p} K^\pm$	$0.13 \pm 0.06$	$2.5 \pm 1.1$
$B^\pm \rightarrow \chi_{c1} K^\pm \rightarrow p \bar{p} K^\pm$	$0.05 \pm 0.01$	$0.9 \pm 0.2$
$B^\pm \rightarrow \psi(2S) K^\pm \rightarrow p \bar{p} K^\pm$	$0.14 \pm 0.02$	$2.7 \pm 0.4$
$\pi$ as K mis-identification		
$B^\pm \rightarrow p \bar{p} \pi^\pm$	$3.1 \pm 0.8$	$0.3 \pm 0.1$



# Signal Event Yield

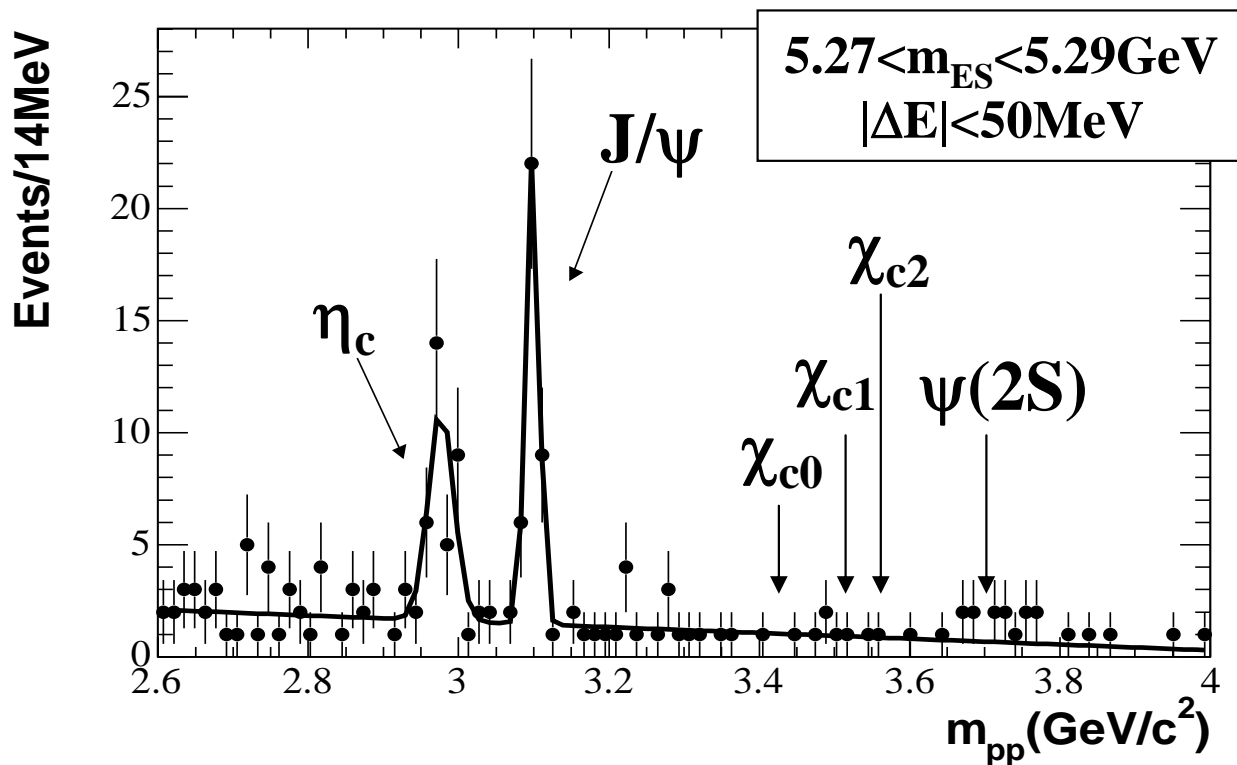


1D fits to data excluding charmonium regions  
( $2.85 < m_{p\bar{p}} < 3.128 \text{ GeV}/c^2$  and  $3.315 < m_{p\bar{p}} < 3.735 \text{ GeV}/c^2$ ):

- $\Delta E$  fit:  $114.2 \pm 13.9$  events
- $m_{ES}$  fit:  $120.3 \pm 13.0$  events



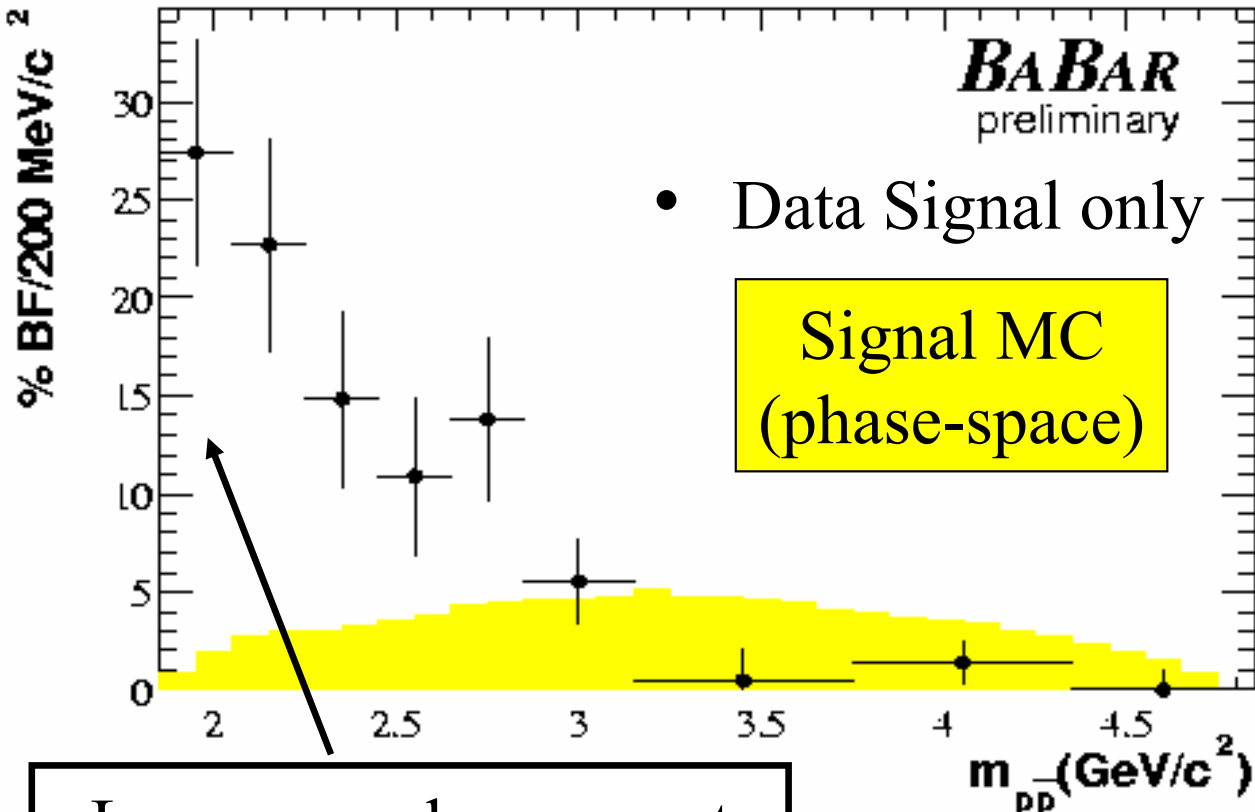
# Charmonium in the data



- Use background under  $\eta_c, J/\psi$  peaks to calculate signal contribution
- Subtract  $\chi_c$  and  $\psi(2S)$  contributions using PDG values for BFs

Mode	Data $\times 10^{-6}$	PDG $\times 10^{-6}$
$J/\psi(p\bar{p})K$	$1.6 \pm 0.4$	$2.1 \pm 0.1$
$\eta_c(p\bar{p})K$	$1.4 \pm 0.4$	$1.1 \pm 0.5$

# Branching fraction measurement\*

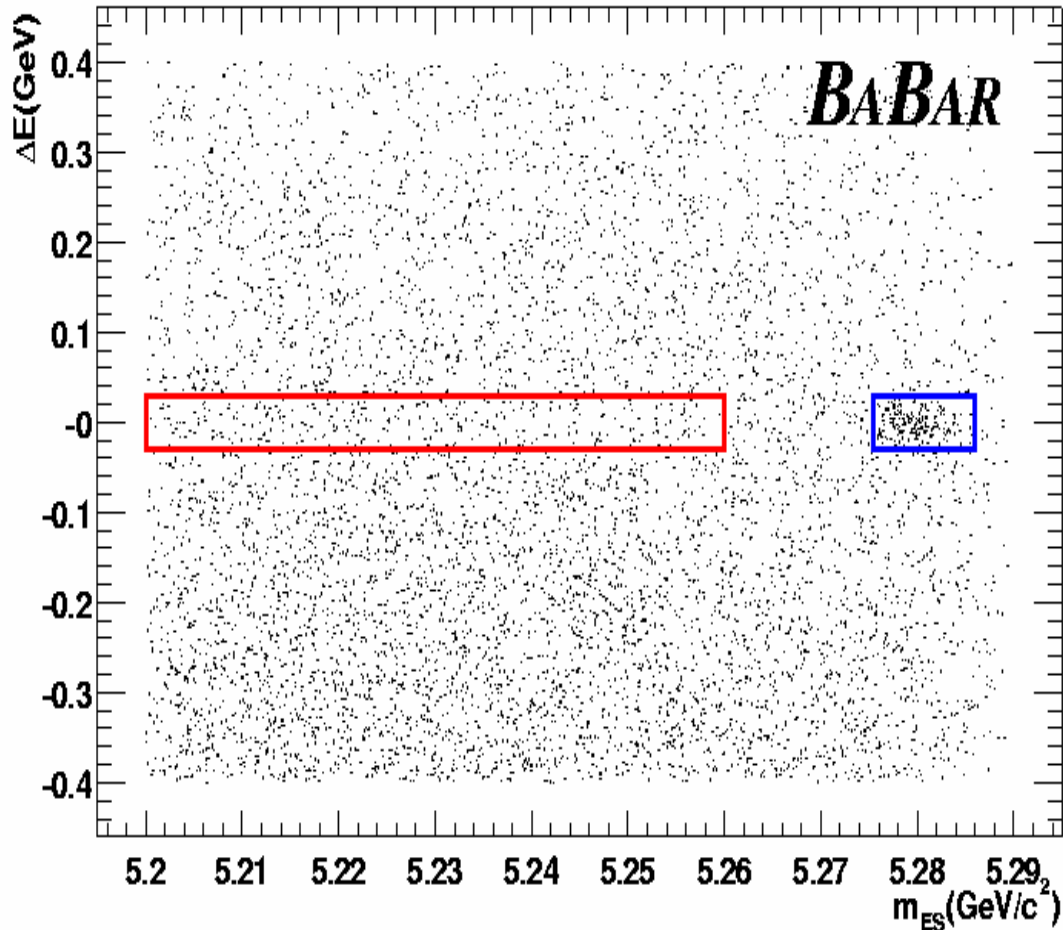


Fractional Systematics	
<b>B counting</b>	1.1%
<b>Tracking</b>	2.4%
<b>PID</b>	6.0%
<b>Fisher Cut</b>	2.0%
<b>MC stat</b>	2.7%
<b>B Bkg</b>	4.2%
<b>Total</b>	<b>8.5%</b>

\* corrected for  $m_{p\bar{p}}$  efficiency

$\mathcal{B}(B^\pm \rightarrow p\bar{p}K^\pm) \times 10^{-6}$	Value	Stat Err	Sys Err
Charmless total (BaBar)	6.7	0.9	0.6
$m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$ (BaBar)	5.4	0.7	0.4
$m_{p\bar{p}} < 2.85 \text{ GeV}/c^2$ (Belle)	4.6	+0.38/-0.34	0.5

# Event Distribution



Sideband:

$$5.20 < m_{ES} < 5.26 \text{ GeV}/c^2$$

$$|\Delta E| < 29 \text{ MeV}$$

368 events

Signal region:

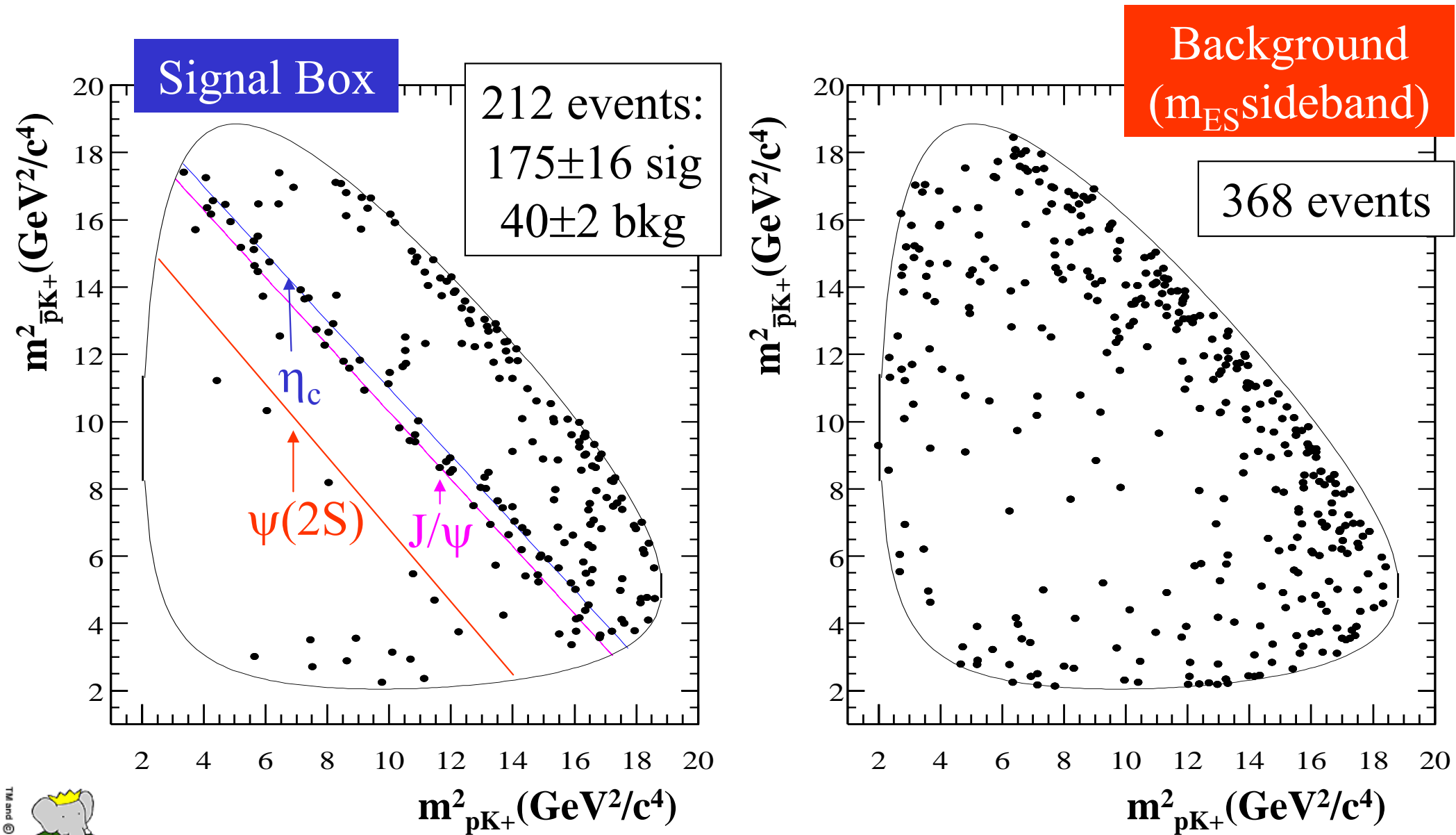
$$5.276 < m_{ES} < 5.286 \text{ GeV}/c^2$$

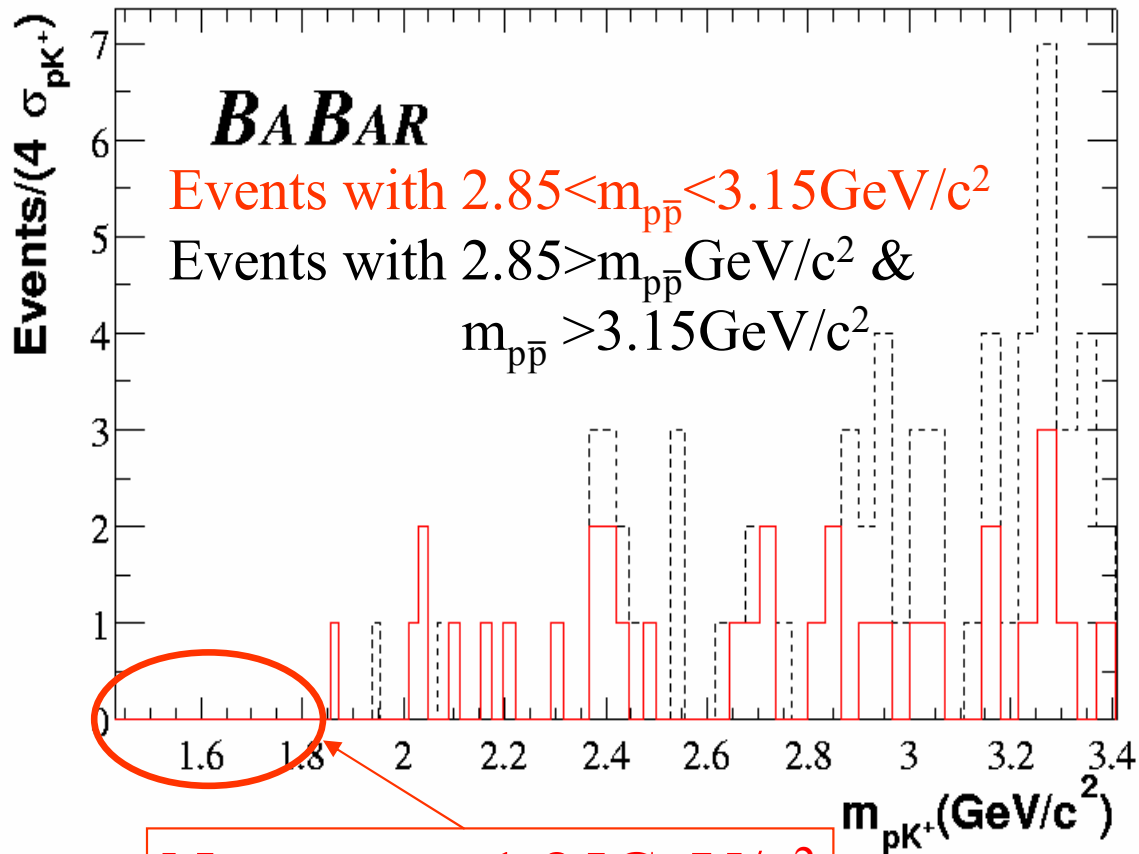
$$|\Delta E| < 29 \text{ MeV}$$

212 events ( $175 \pm 16$  signal-like, incl.  $49 \pm 8$  from charmonium, &  $40 \pm 2$  combinatoric background)



# Dalitz Plot





No events  $< 1.85 \text{ GeV}/c^2$   
 $\epsilon_{\text{av}} = 17.0 \pm 0.2\%$

Use Toy MC to calculate UL  
 with errors on the efficiency & backg  
 (Comp.Phys.Comm. 149, 97(2002)):  
 $\mathcal{B}(B^+ \rightarrow \Theta^{*++} \bar{p}) \times \mathcal{B}(\Theta^{*++} \rightarrow pK^+) < 1.5 \times 10^{-7}$   
 @ 90% CL for  $m(\Theta^{*++}) = 1.43 - 1.85 \text{ GeV}/c^2$

# $\Theta^{*++}$ Search (hep-ex/0408037)

Backgrounds:

- Combinatoric (from sideband)
- $B^\pm \rightarrow \eta_c(J/\psi)K^\pm \rightarrow \bar{p}pK^+$  MC

## Contributions to Systematics

B counting	1.1%
Tracking	2.4%
PID	6.0%
Fisher Cut	2.0%
Signal Box	2.5%
MC stat	1.1%
Background	1.1%

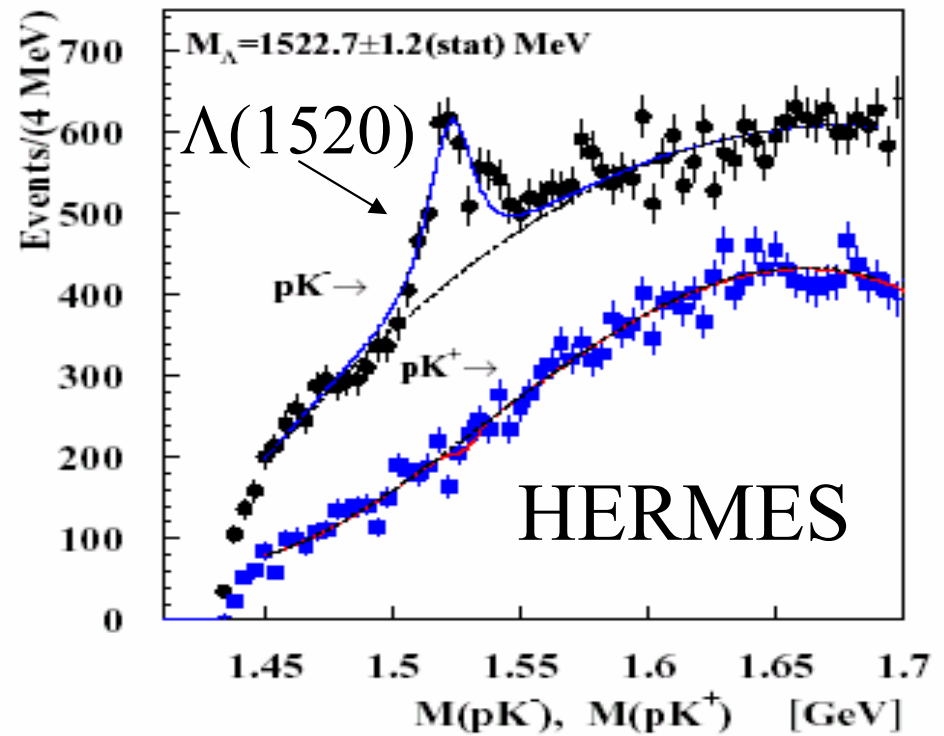
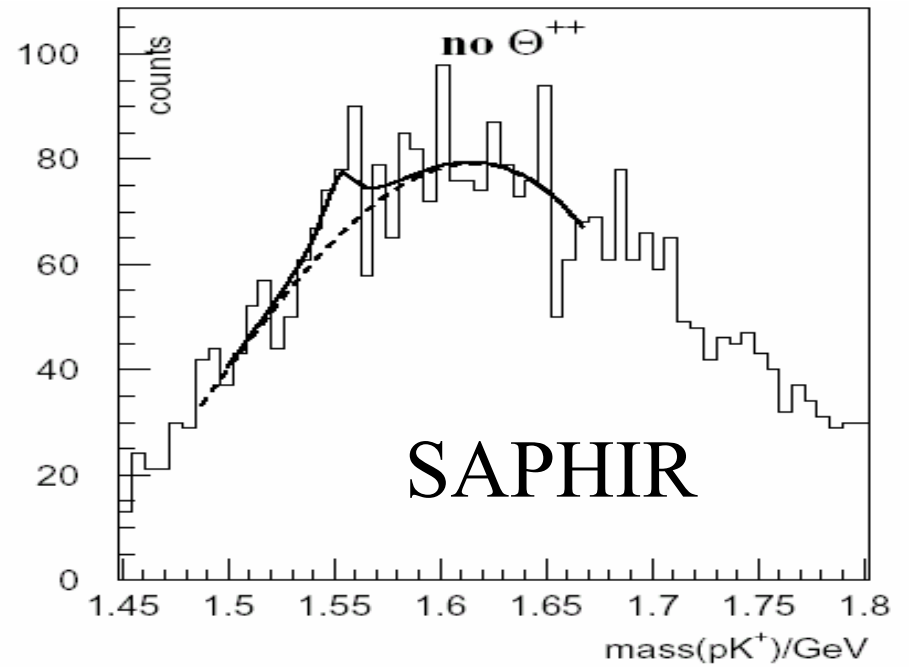
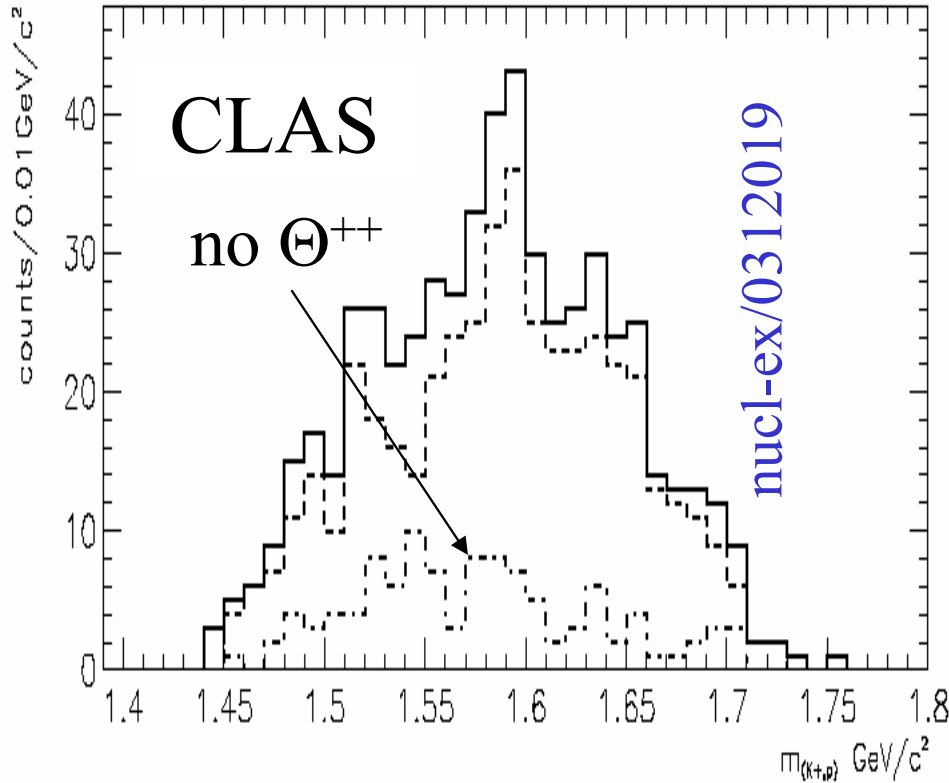
# Summary

- Measured charmless  $\mathcal{B}(B^+ \rightarrow p\bar{p}K^+) = (6.7 \pm 0.9 \pm 0.6) \times 10^{-6}$
- UL on  $\mathcal{B}(B^+ \rightarrow \Theta^{*++}p) \times \mathcal{B}(\Theta^{*++} \rightarrow pK^+) @ 90\% \text{ CL}$   
 $1.5 \times 10^{-7}$  for  $1.43 < m(\Theta^{*++}) < 1.85 \text{ GeV}/c^2$
- Observed low  $m_{p\bar{p}}$  enhancement
- Results consistent with Belle
- Only used  $81 \text{ fb}^{-1}$  so far, BaBar has accumulated  $244 \text{ fb}^{-1}$  up to this summer
- Possible to search for  $\Theta^+$  in B meson decay:  
$$B^0 \rightarrow \bar{p}\Theta^+ \rightarrow \bar{p}pK_s^0$$
- Stay tuned!



# Backup Slides

# Experimental Searches



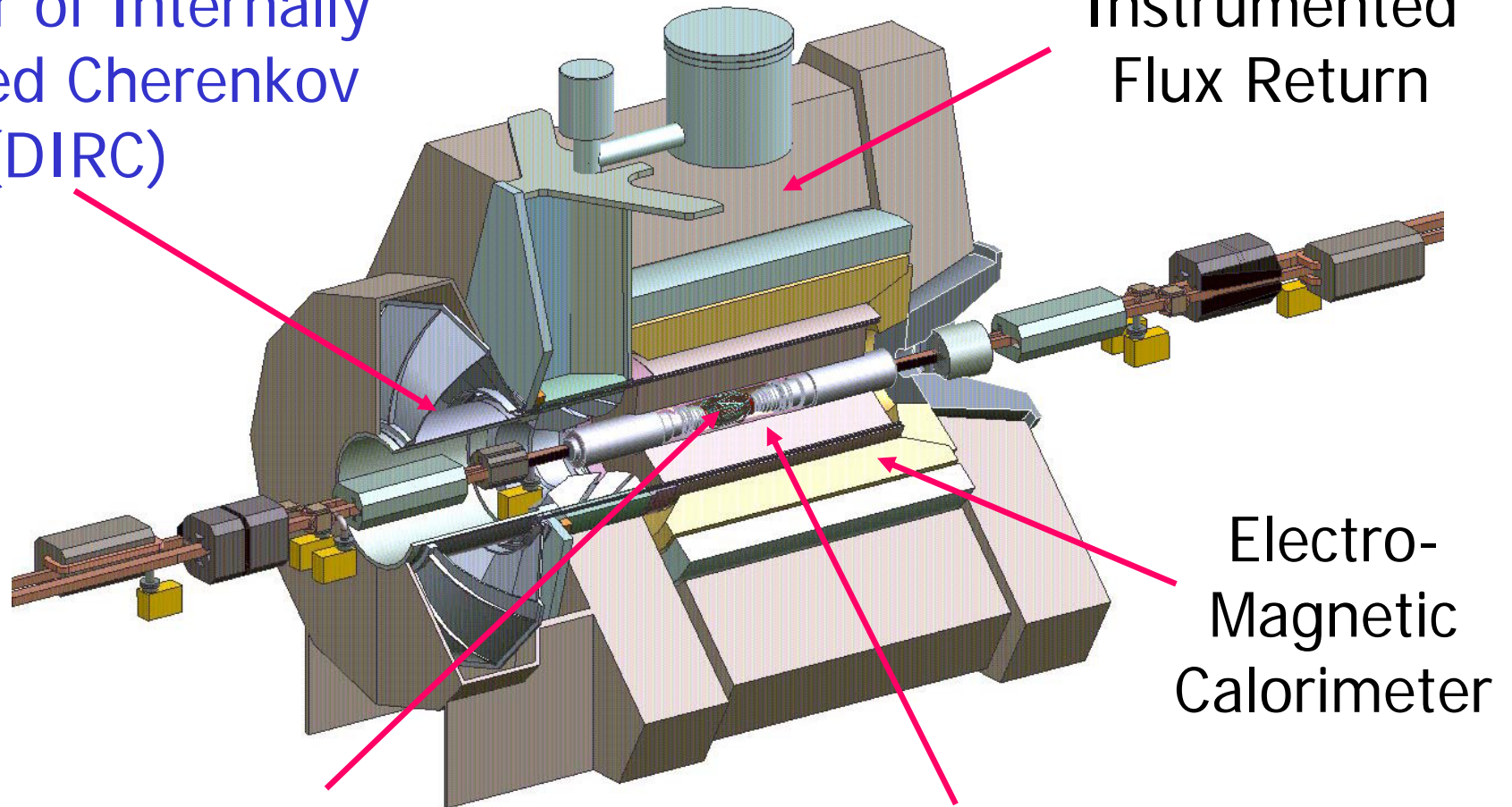
No structure is seen in  $m_{pK^+}$ .



# The BaBar Detector

Detector of Internally Reflected Cherenkov (DIRC)

Instrumented Flux Return



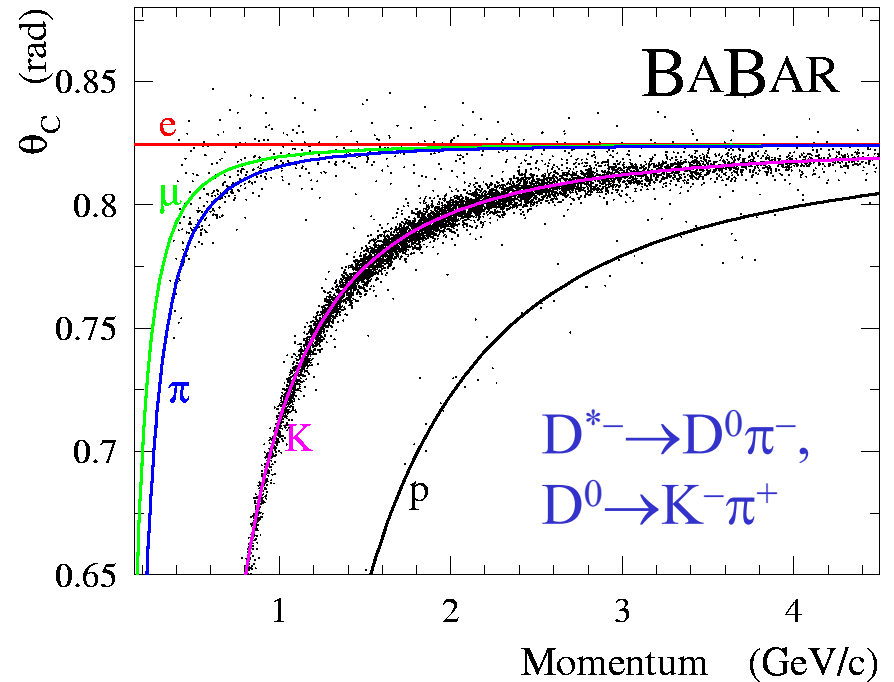
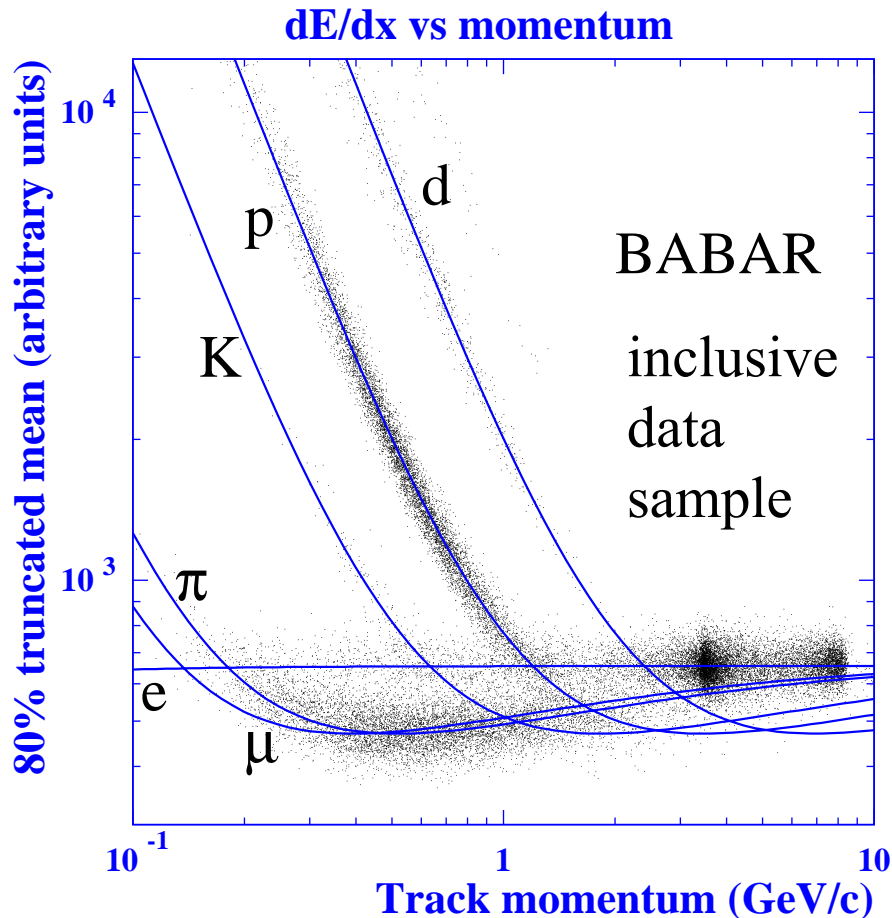
Silicon Vertex Tracker (SVT)

Drift Chamber (DCH)

Electro-Magnetic Calorimeter



# Particle Identification

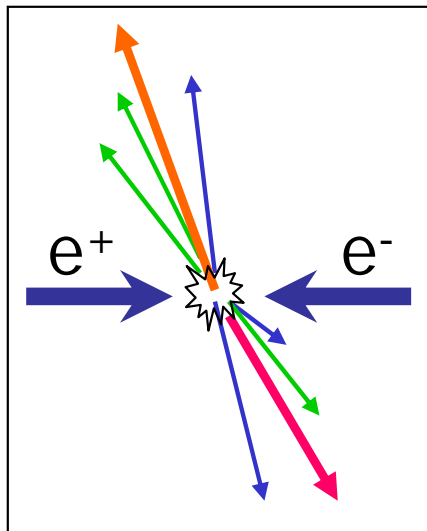


- To distinguish p/K from e,  $\mu$ ,  $\pi$ :
- $p < 0.7$  GeV SVT+DCH
  - $p > 0.7$  GeV DIRC

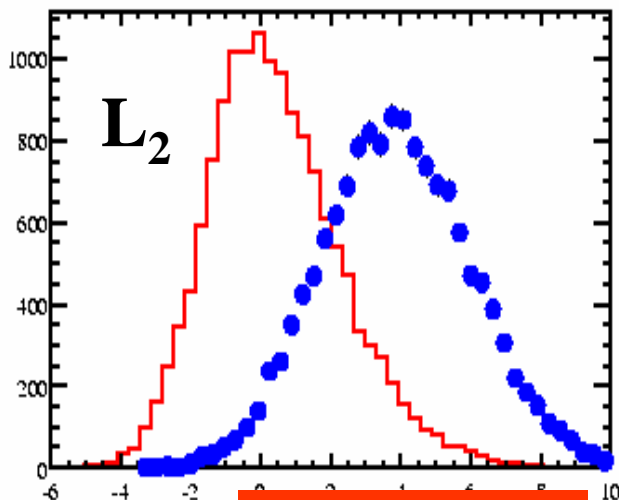
# Event Shape Variables

$$L_2 = \sum_i |p_i^*| (3 \cos^2 \theta_{Thr_{B,i}} - 1) / 2$$

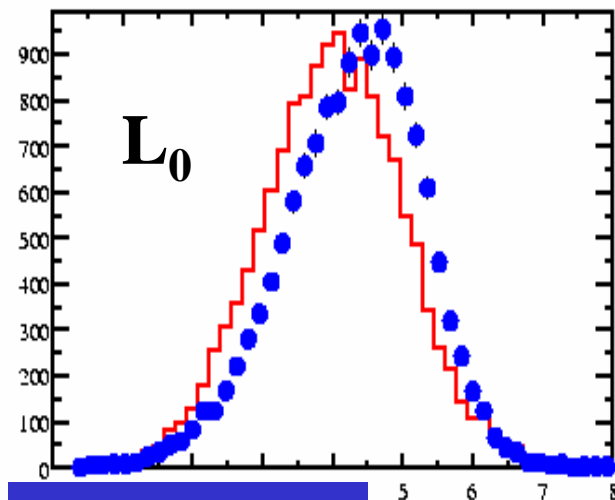
$$L_0 = \sum_i |p_i^*|$$



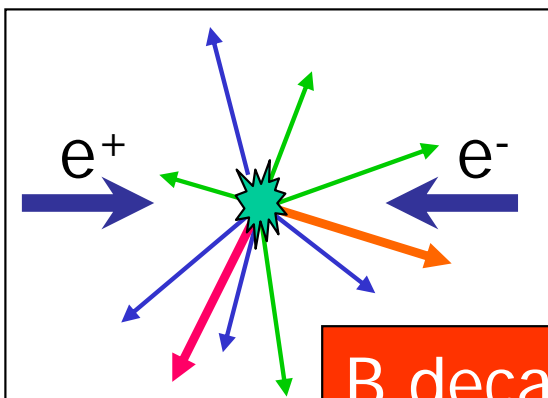
Continuum  $q\bar{q}$



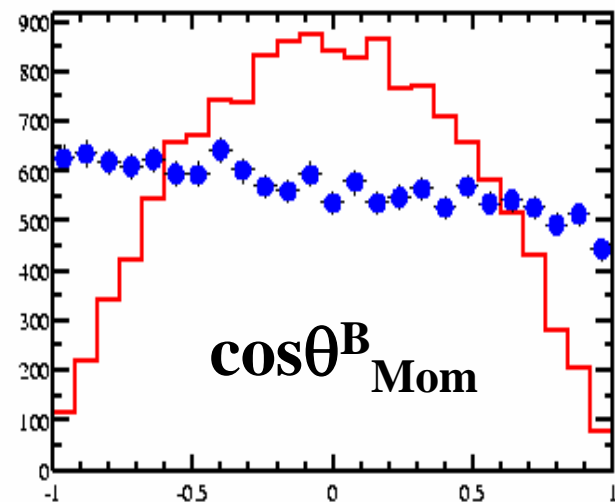
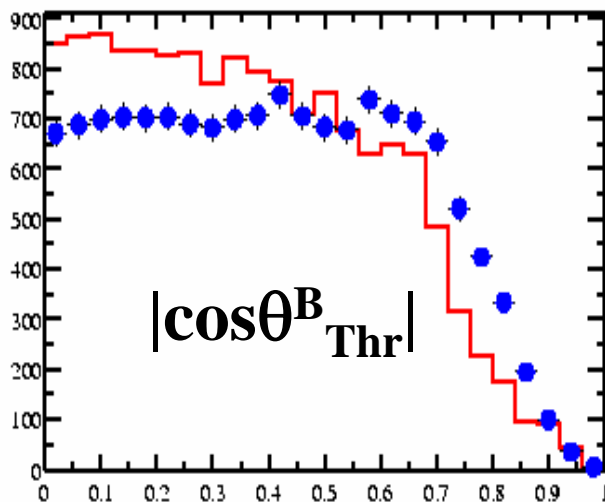
Signal MC



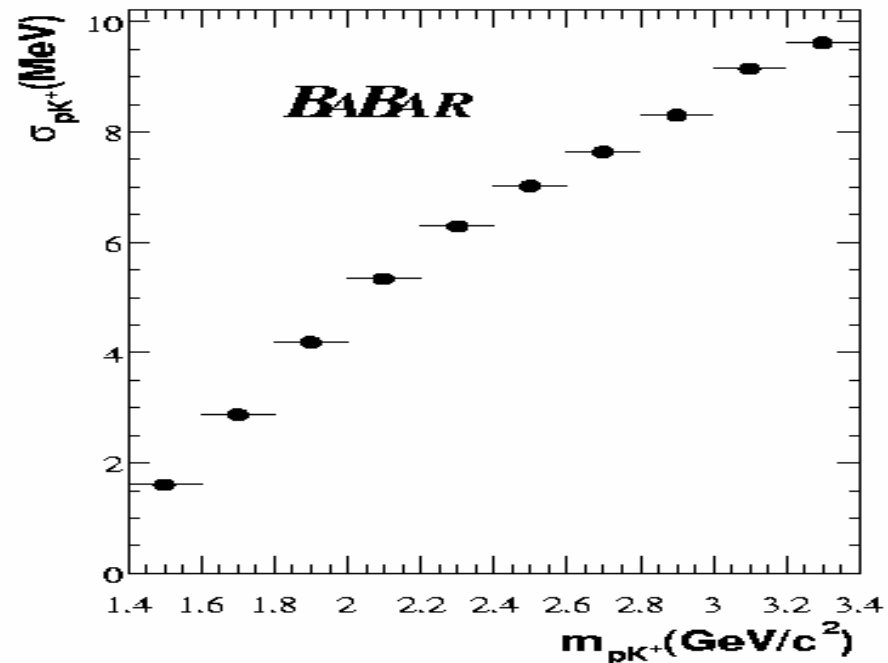
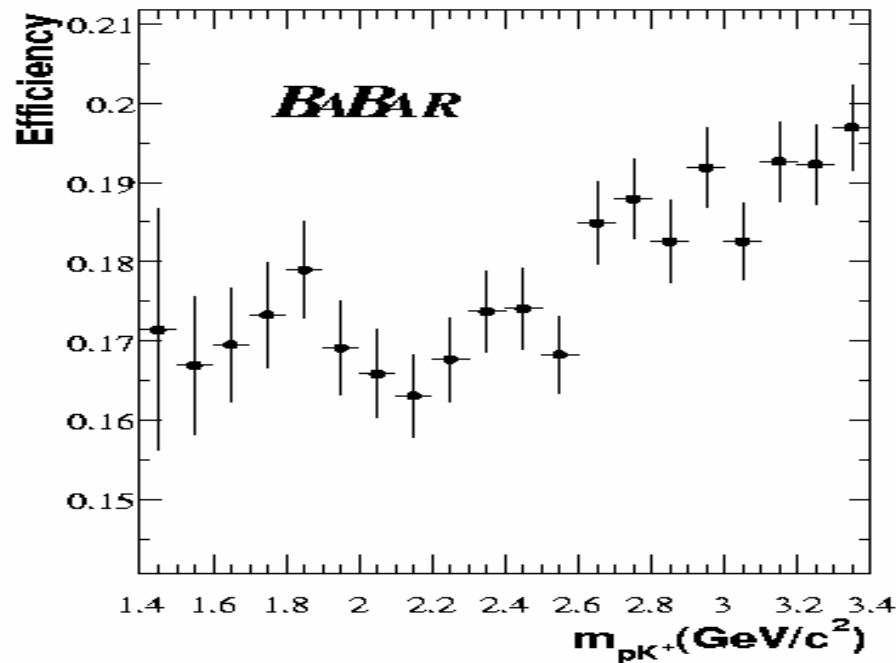
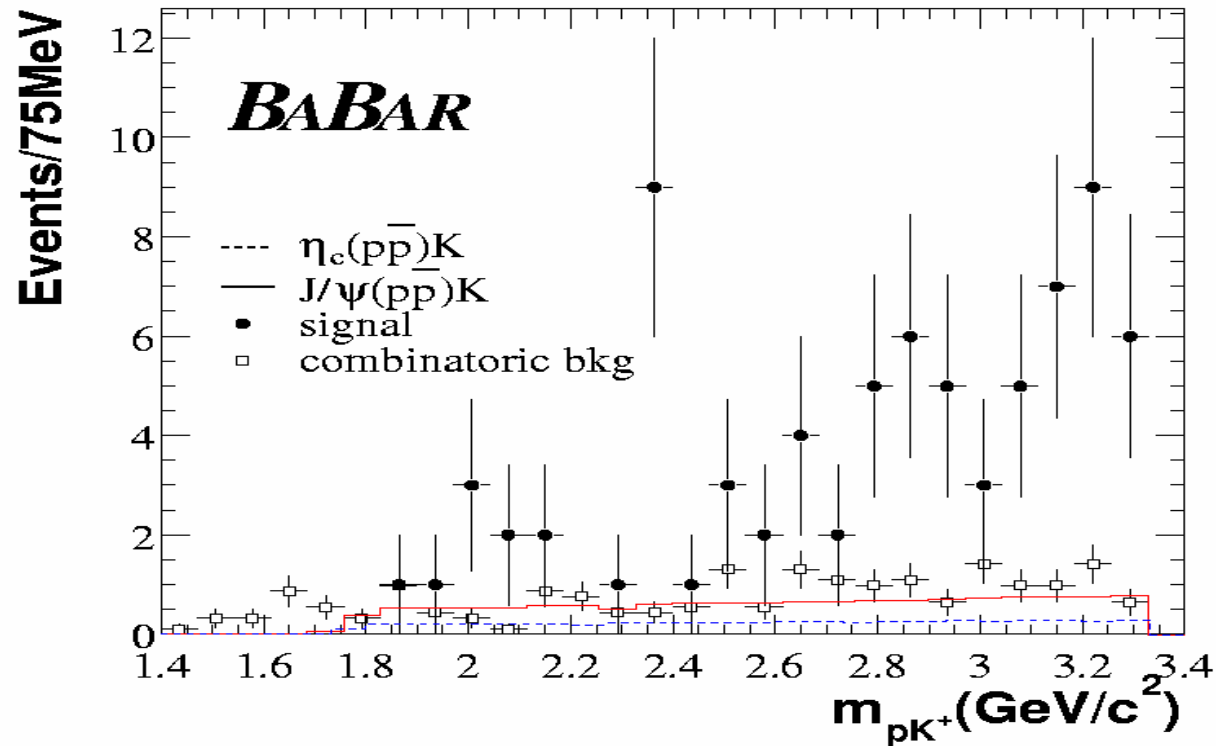
Continuum



B decay

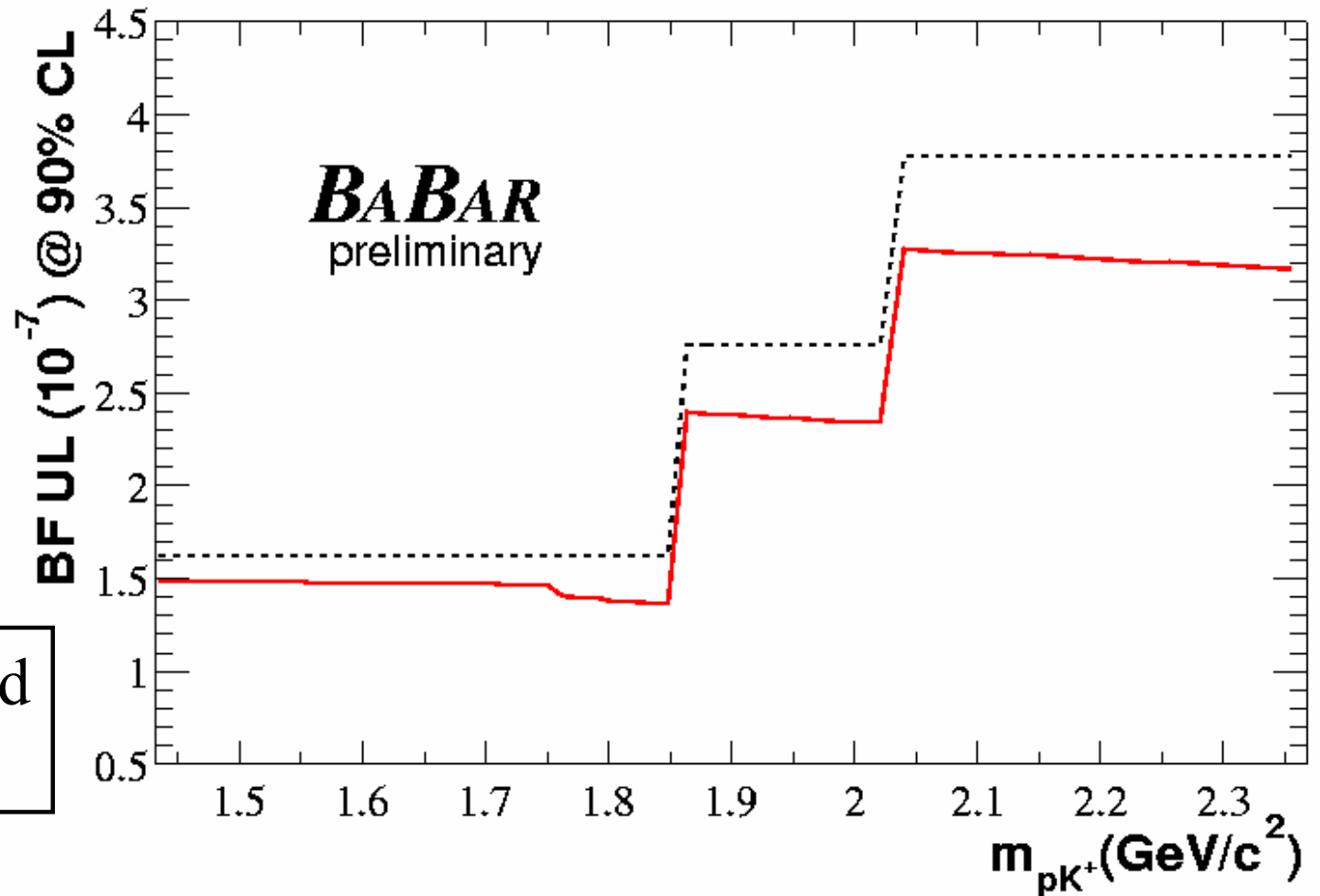


# $\Theta^{*++}$ Search



# $\Theta^{*++}$ Search

without background  
with background



$m(\Theta^{*++}),$ $\text{GeV}/c^2$	Max # Events in any $m_{pK^+}$ bin	UL ( $10^{-7}$ ) @ 90% CL on $\mathcal{B}(B^+ \rightarrow \Theta^{*++} \bar{p}) \times \mathcal{B}(\Theta^{*++} \rightarrow pK^+)$	
1.43-1.85	0	1.63	1.49
1.85-2.00	1	2.76	2.40
2.00-2.36	2	3.78	3.28