

**HADRONIC B DECAYS
TO CHARMLESS FINAL STATES
AND TO $J/\psi K^*$**

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for the **BABAR** Collaboration

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BABAR

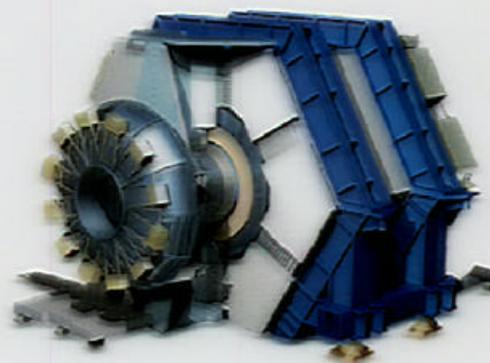
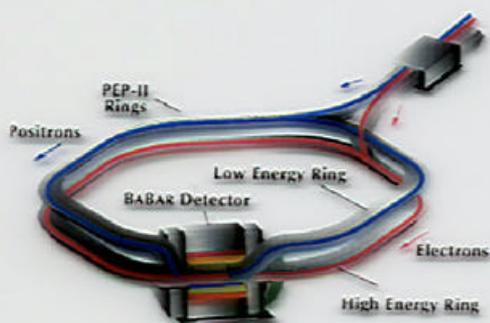
OUTLINE

Charmless Hadronic B Decays

- Where We Stand
- Selection Variables and Strategies
- Measurement of $B \rightarrow h^+h'^-$ Branching Fractions

$B \rightarrow J/\psi K^*$ Decay Amplitudes

- Angular Distribution
- Candidate Selection
- Angular Analysis and Fitting Method
- Systematics and Results

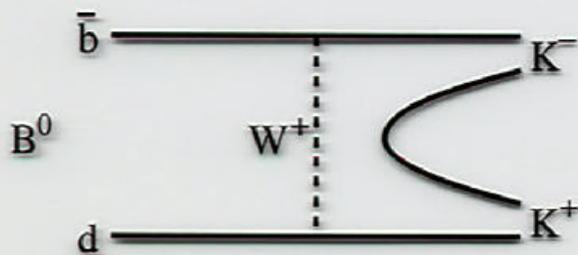


BABAR

CHARMLESS HADRONIC B DECAYS

Motivation:

- Search for direct CP-violation
- Search for mixing induced CP-violation: determ. of α
- Constraint on UT angle γ through $A(b \rightarrow u) \propto V_{ub} \equiv |V_{ub}|e^{-i\gamma}$ trees and $b \rightarrow s$ penguins (λ^2 suppressed). Non-leading Factorization Approximation can predict complex phases.
- Test of QCD dynamics in heavy quark decays to light final states



WHERE WE STAND

Progress on analyses already presented:

2-body: $\pi^\pm \pi^\mp, \pi^\pm K^\mp$ and $K^\pm K^\mp$
 Quasi-2-body: $\omega K_S^0, \eta' K^\pm, \eta' \pi^+ \pi^-, \eta' K_S^0$
 3-body: $\rho^0 K^\pm, \rho^0 \pi^\pm, \rho^\pm \pi^\mp, K^{*0} \pi^\pm,$
 $\pi^+ \pi^- \pi^+, K^+ \pi^- \pi^+$

New modes presently analyzed:

2-body: all modes with neutral $\pi^0 K^0$
 Quasi-2-body: $\omega h, \eta' h, \phi h$, with $h \equiv \pi, K, K^0, \pi^0$
 3-body: all hhh , with $h \equiv \pi^\pm, K^\pm, K^0, \pi^0$
 Four-body $3h^\pm h^0$ ($K^* \rho, \rho \rho, a_1 \pi$)

BABAR Data Sets

Osaka analyses: $\simeq 9 \text{ fb}^{-1}$ on $\Upsilon(4S)$ resonance
 $\simeq 1.5 \text{ fb}^{-1}$ below (off) $B\bar{B}$ production

Full RUN 1999-2000 analyses: $\simeq 21 \text{ fb}^{-1}$ on resonance
 $\simeq 3 \text{ fb}^{-1}$ off resonance

Total number of $(22.7 \pm 0.4) \times 10^6 \Upsilon(4S)$

Common Analysis Strategies

Blind Analysis:

- Signal region in all variables hidden until finalization of cut optimization, evaluation of systematics, probability density functions (PDF) for ML fits, etc.

Analysis Techniques:

- *cut and count*
- Max. Likelihood fits for signal and background yields
- Combination of event shape variables with Fisher and NN

SUMMARY OF BRANCHING FRACTIONS

PRELIMINARY

Data Set: $\approx 0.5 \times$ RUN 1999-2000 (Summer 2000)

Decay Mode	BR ($\times 10^{-6}$)	Method
$\pi^\pm \pi^\mp$	$9.3^{+2.6}_{-2.3} {}^{+1.2}_{-1.4}$	ML fit
$K^\pm \pi^\mp$	$12.5^{+3.0}_{-2.6} {}^{+1.3}_{-1.7}$	ML fit
$K^\pm K^\mp$	< 6.6 (90% CL)	ML fit
$K^{*0} \pi^+$	< 28 (90% CL)	cut & count
$\rho^0 K^+$	< 29 (90% CL)	cut & count
$K^+ \pi^- \pi^+$	< 54 (90% CL)	cut & count
$\rho^0 \pi^+$	< 39 (90% CL)	cut & count
$\pi^+ \pi^- \pi^+$	< 22 (90% CL)	cut & count
$\rho^\pm \pi^\mp$	$49 \pm 13^{+6}_{-5}$	cut & count
ωh^+	< 24 (90% CL)	cut & count
ωK^0	< 14 (90% CL)	cut & count
$\eta' K^+$	$62 \pm 18 \pm 8$	cut & count
$\eta' K^0$	< 112 (90% CL)	cut & count

RUN 1999-2000 ANALYSIS OF $B^0 \Rightarrow h^+ h'^-$ **$\simeq 21 \text{ fb}^{-1}$ ($\simeq 3 \text{ fb}^{-1}$) on (off) resonance data**

- B Candidate Selection
 - Kinematic variables
 - Particle identification
 - Background discrimination
- Control samples from $b \rightarrow c$ decays
- Maximum Likelihood fit
- Systematic studies and cross checks
- Results

SELECTION OF B CANDIDATES

Kinematic Variables

- Energy Difference:

$$\Delta E \equiv E_B^* - E_{\text{beam}}^*$$

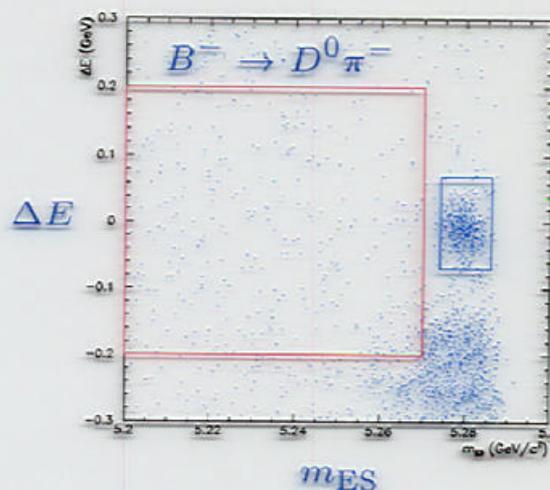
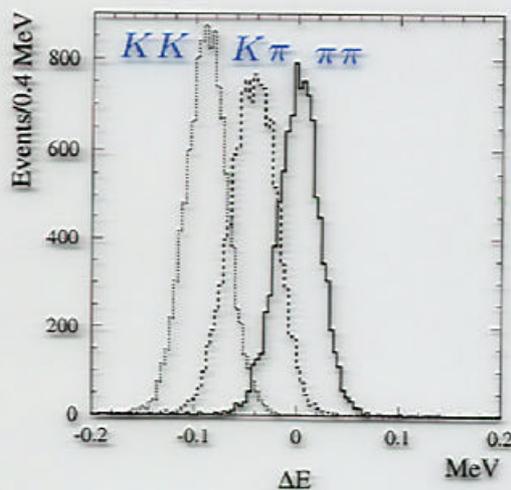
signal width $\simeq (20-30)$ MeV (domin. by track mom. resolution)
 background linearly decreasing

- Beam Energy Substituted Mass:

$$m_{\text{ES}} \equiv \sqrt{E_{\text{beam}}^{*2} - p_B^{*2}} \simeq \sqrt{(s/2 + \vec{p}_0 \vec{p}_B)^2 / E_0^2 - p_B^2}$$

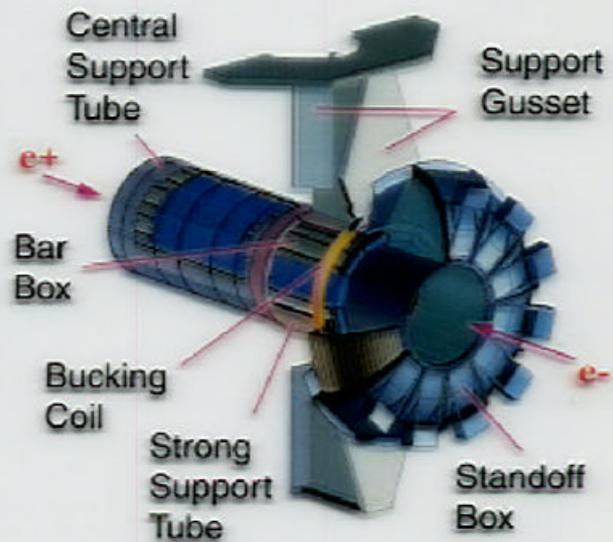
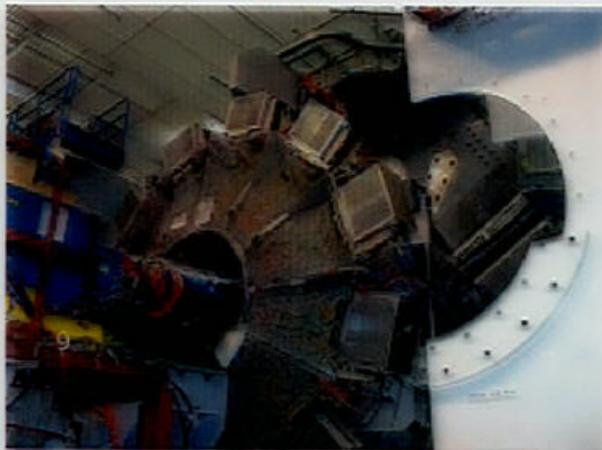
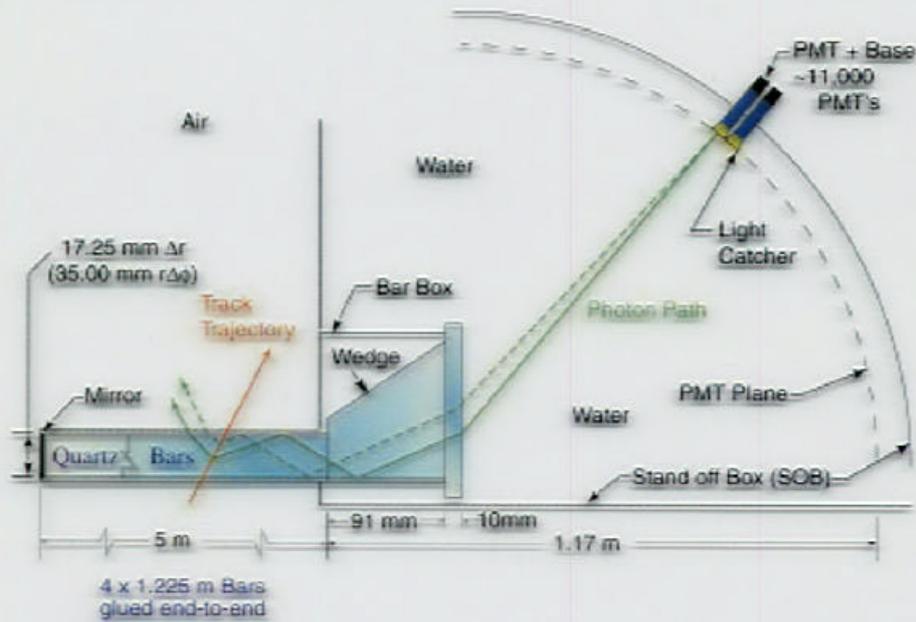
signal width $\simeq (2.5-3)$ MeV/ c^2 (domin. by spread in beam energy)
 background Argus function

Note: ΔE is shifted by ≈ 45 MeV for wrong hadron hypothesis (mass), while m_{ES} (as defined above) is independent of the boost



PID IN BABAR : THE DIRC (I)

Detection of Internally Reflected Cherenkov Light

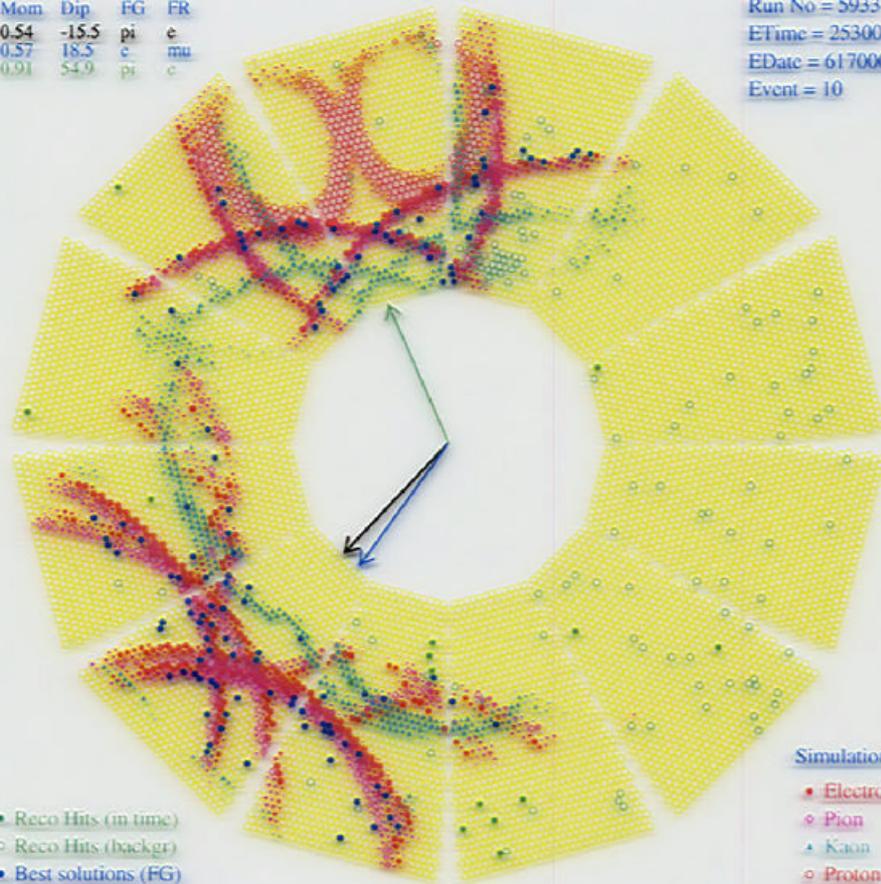


PID IN BABAR : THE DIRC (II)

Excellent π/K separation at high momenta ($1.7 \sim 4.3$ GeV) is critical for analysis of charmless two-body modes

Mom	Dip	FG	FR
0.54	-15.5	pi	e
0.57	18.5	e	mu
0.91	54.9	pi	e

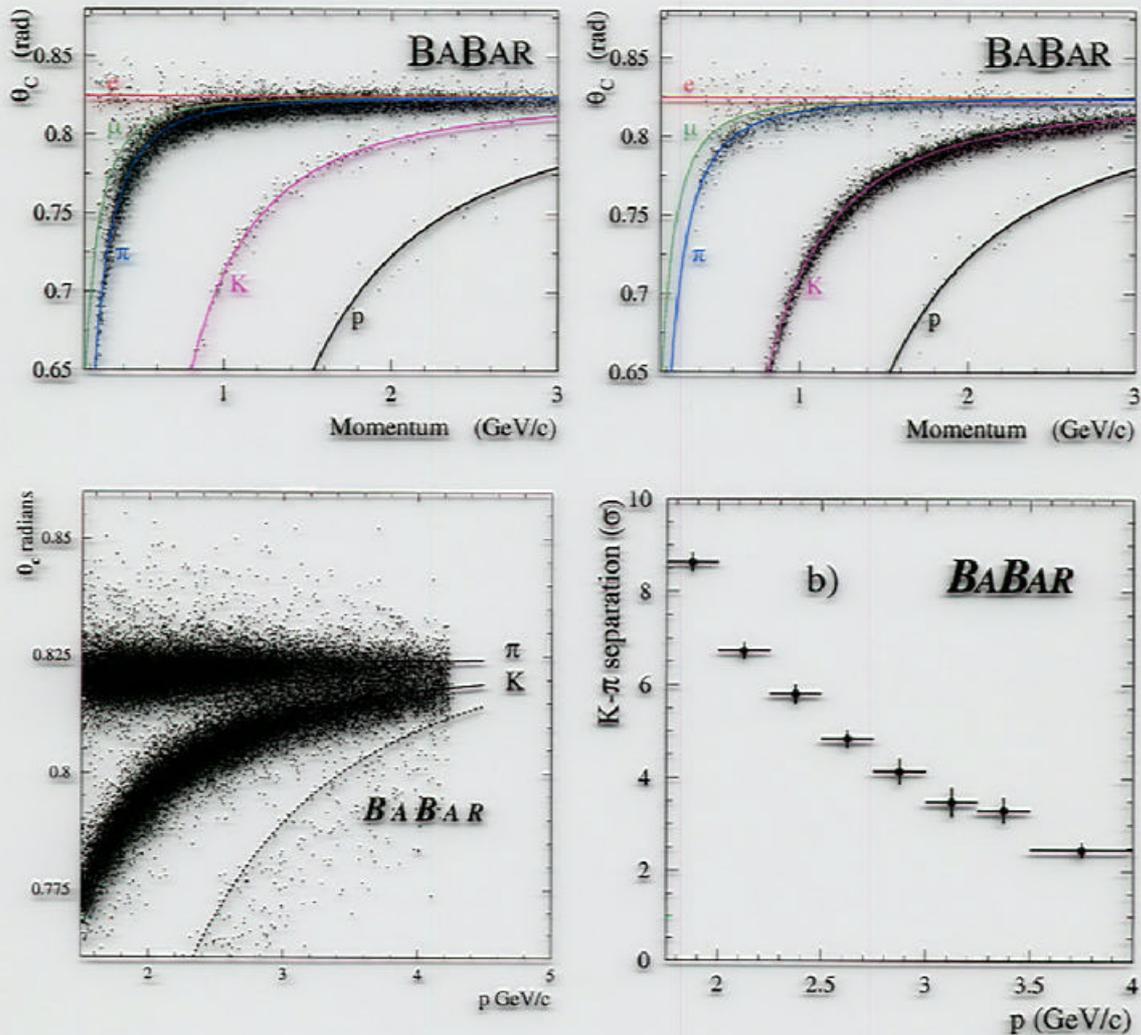
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Tracks satisfying $\beta \cdot n > 1$ ($n_{\text{quartz}} \equiv 1.47$) produce Cherenkov light in quartz bars. The photons are guided through the bars into the light expansion zone where they are detected by $\sim 10\,800$ PMTs.

PID IN BABAR : THE DIRC (II)

⇒ Reconstruction of Cherenkov angle using unbinned maximum likelihood fit



Measure π/K separation with kinematically identified tracks from $D^{*+} \rightarrow D^0 \pi^+ \rightarrow (K^- \pi^+) \pi^+$

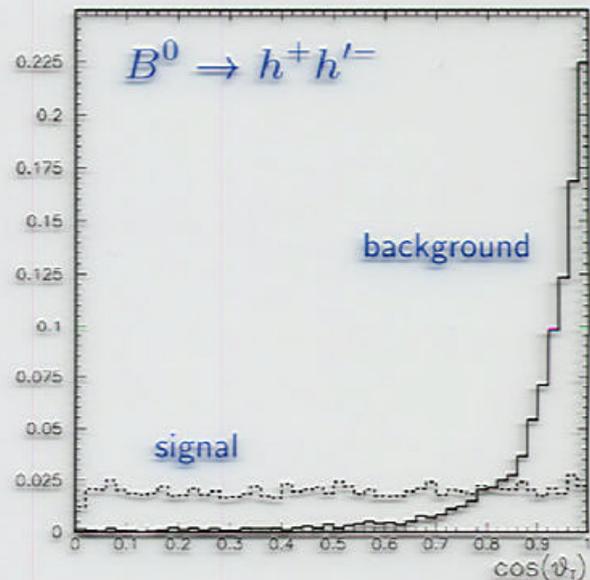
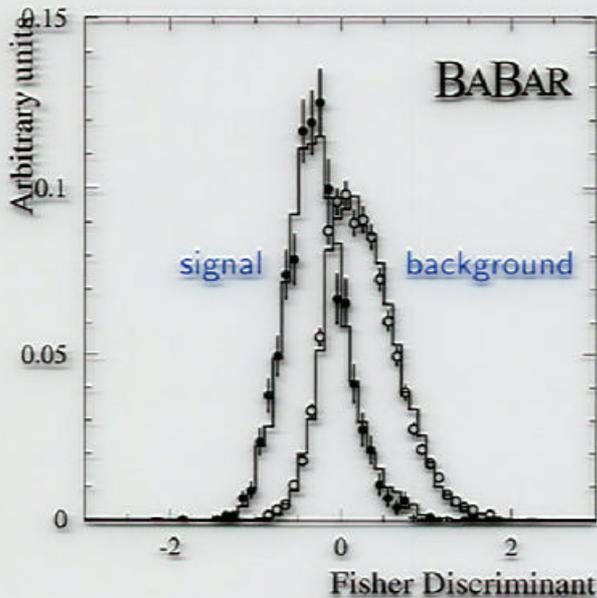
BACKGROUND SUPPRESSION

Continuum $q\bar{q}$ ($q \equiv u, d, s, c$) production is main background source due to closer, "jet"-like event shape

$$\frac{\sigma_{q\bar{q}}(\Upsilon(4S))}{\sigma_{B\bar{B}}(\Upsilon(4S))} \approx 3$$

Variables used for Selection:

- Pre-selection (efficiency: $\approx 67 - 70\%$):
 - Angle between sphericity axis of B cand. and rest of event: $\theta_S < 0.9$
 - Fox-Wolfram moment $R_2 < 0.95$
 - Sphericity > 0.01
 - $N(\text{photons})$ in DIRC > 5
- Fisher discriminant of mom. weighted cones around B (CLEO)

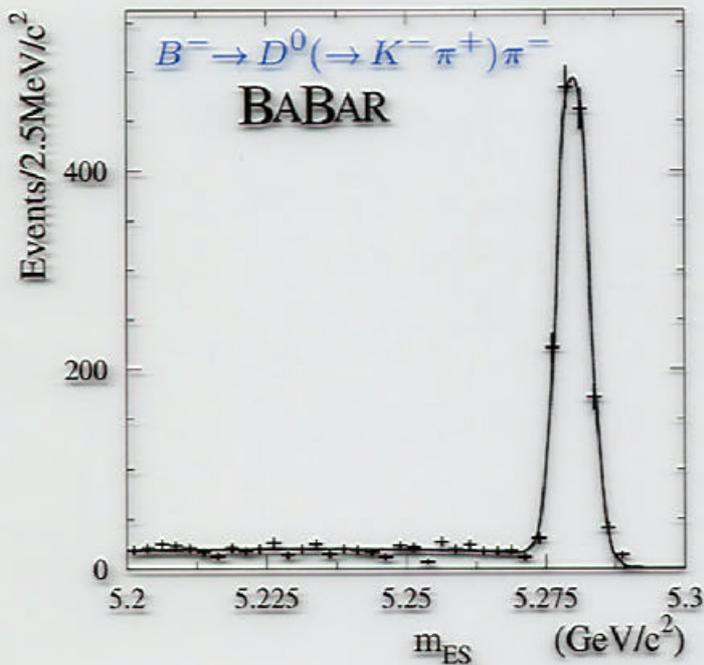


CONTROL AND CALIBRATION SAMPLES

The analysis uses PDFs as fit inputs. These need to be cross-checked with independent samples obtained from:

- ΔE sidebands (on-res. data): $\Delta E < -0.2 \text{ GeV}$ or $\Delta E > 0.14 \text{ GeV}$
⇒ Study background shapes
- Off-resonance data (below $\Upsilon(4S)$)
⇒ Study continuum-only background
- $B^- \rightarrow D^0 \pi^-$ decays, with $D^0 \rightarrow K^- \pi^+$
⇒ Measure mean and width of m_{ES} . Study ΔE resolution (through MC comparison)
- $B \rightarrow D^* X$ decays, with $D^{*+} \rightarrow D^0 \pi^+ \rightarrow (K^- \pi^+) \pi^+$
⇒ Measure PID performance
- Monte Carlo Simulation
⇒ Study selection efficiencies, signal & background distributions

CALIBRATION OF: m_{ES}



← Signal Shape

mean: $5.280 \text{ GeV}/c^2$

width: $2.6 \text{ MeV}/c^2$

Calibration using

$B^- \rightarrow D^0 (\rightarrow K^- \pi^+) \pi^-$ decays

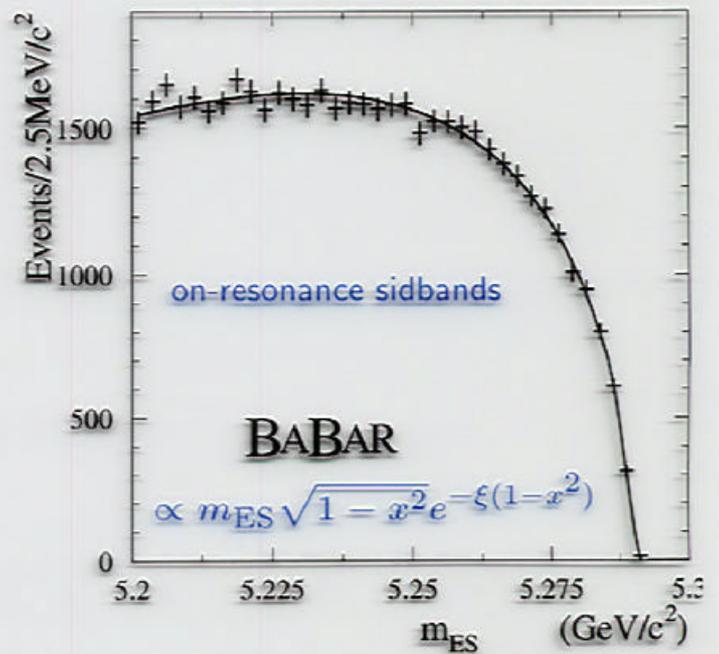
Background Shape \Rightarrow

$\xi = 22.0 \pm 0.5$

Non- $q\bar{q}$ background negligible

Calibration using

sidebands & off-resonance data



CALIBRATION OF: ΔE

ΔE resolution overestimated by MC: rescale the MC ($\sigma_{\Delta E}(\text{MC}) = 21 \text{ MeV}$) to reproduce data ($\sigma_{\Delta E}(\text{Data}) = 26 \text{ MeV}$). Gauge rescaling by means of $B^- \rightarrow D^0 \pi^-$ decays.

ΔE for entire region of sidebands and signal. Solid curve is polynomial fit to sidebands only \Rightarrow

