Charmless hadronic B decays at

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on behalf of the BABAR Collaboration

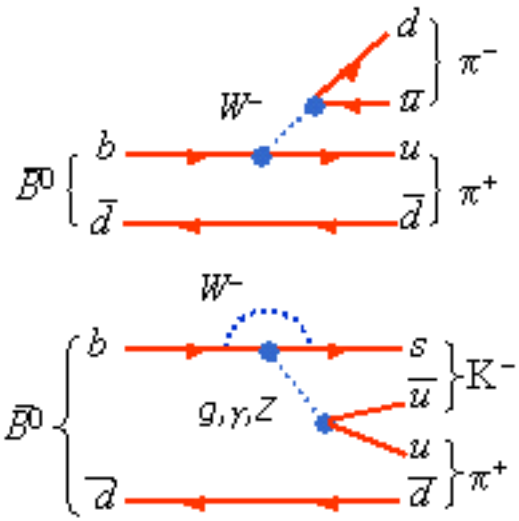
Heavy Flavour, EPS HEP 2001
Budapest, July 13th

Outline:

- Physics Motivation
- PEP-II & BABAR
- Analysis Strategies
- Results

charmless modes:

- **Two Body: $\pi\pi$, Kπ, KK**
- **Quasi Two Body: $a_0\pi$**
- **Three Body: $\rho\pi$**



all charge combinations

motivations:

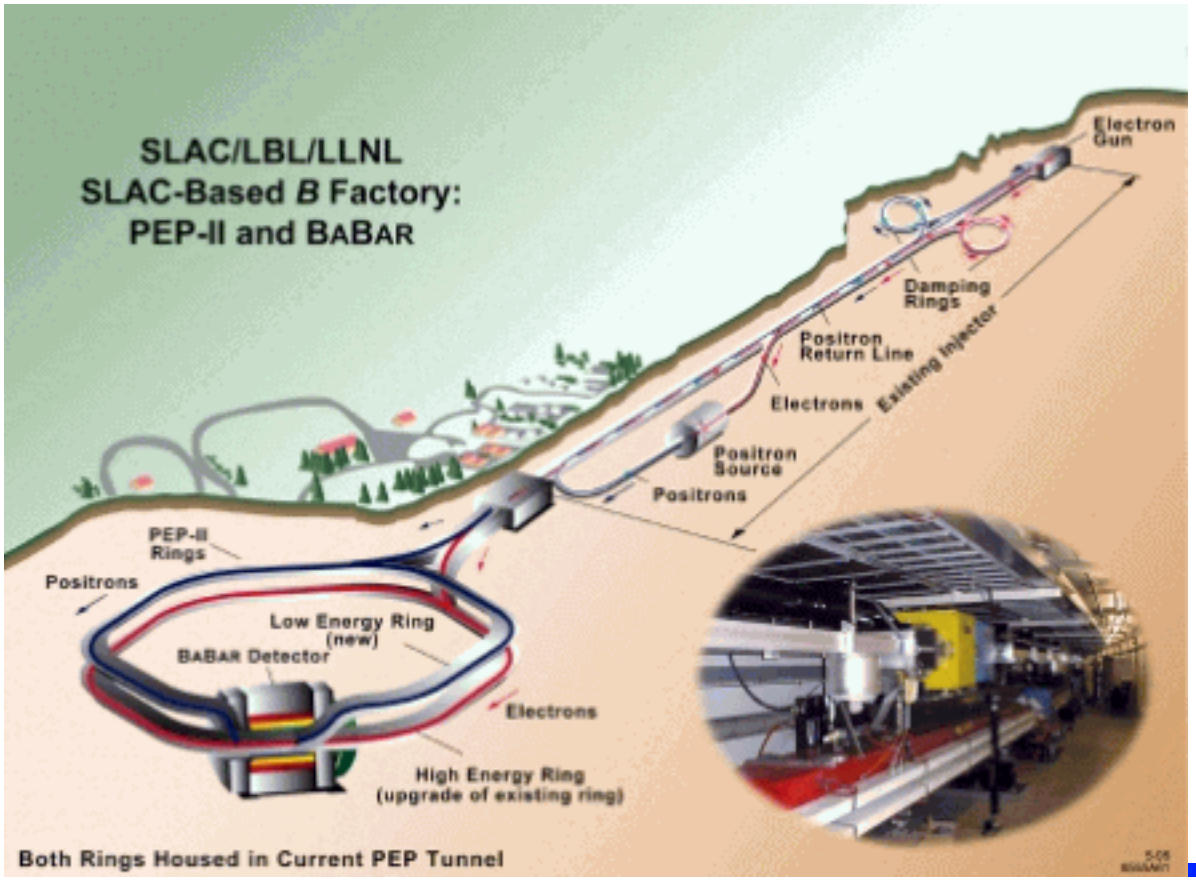
- **BR measurement:** *rare decays with BR<10^{-5}*
- **direct CP violation:** *tree-penguin interference*
- **extraction of α in presence of penguin diagrams**
  - *Dalitz plot amplitude analysis*
  - *isospin-based analysis*

PEP-II and BABAR @ SLAC

- **Asymmetric Collider @ Y(4S) resonance**

$B\bar{B}$ pairs in a coherent L=1 state

	Goal	Achieved
nb^{-1}/sec	3.0	3.28
pb^{-1}/day	135	214
fb^{-1}/week	0.8	1.24
fb^{-1}/month	3.3	4.1

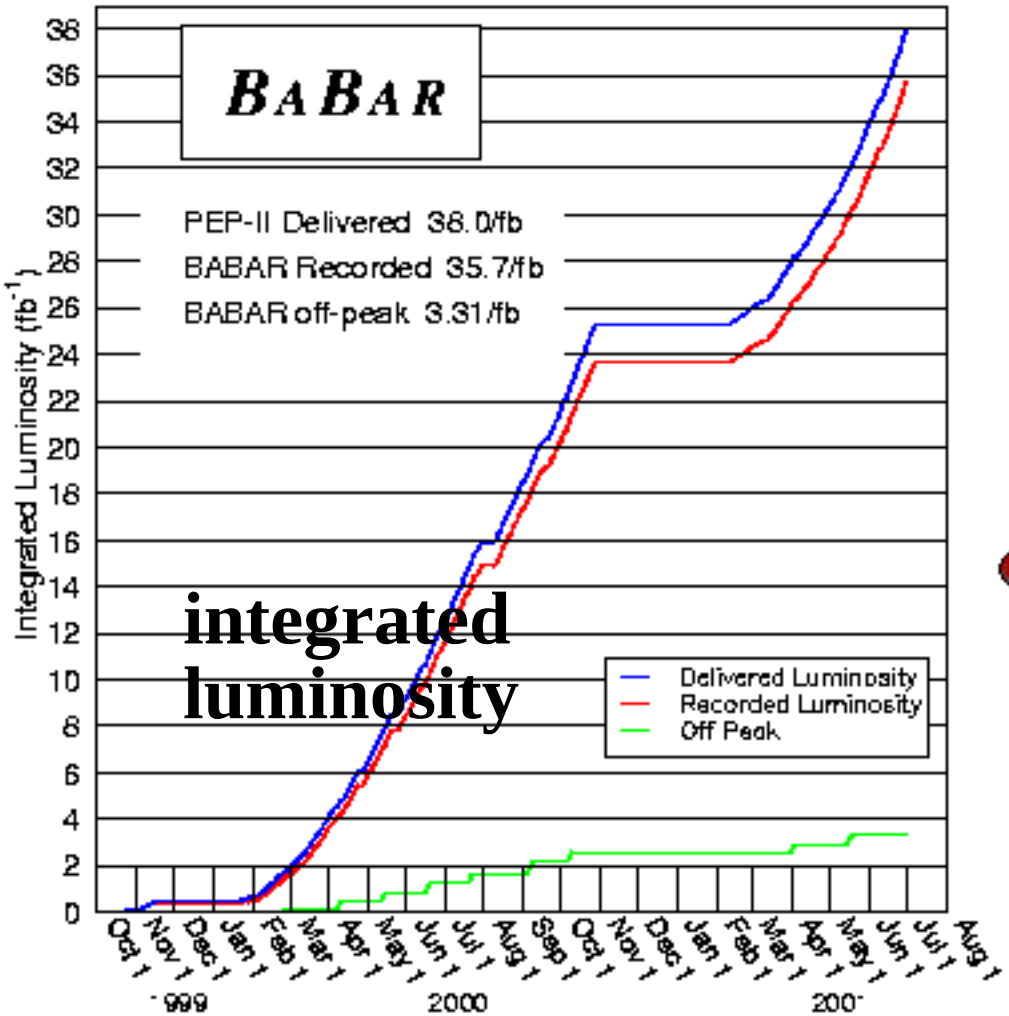


$E(e^-) = 9.0$ GeV

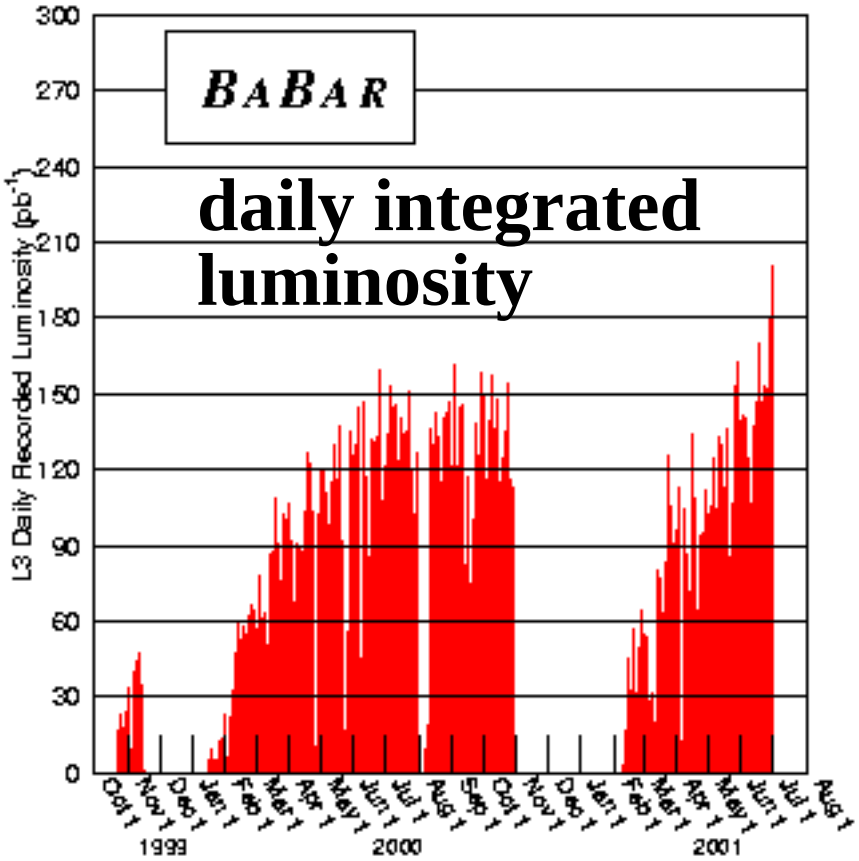
$E(e^+) = 3.1$ GeV

$\beta\gamma = 0.56$

PEP-II and BABAR Luminosities



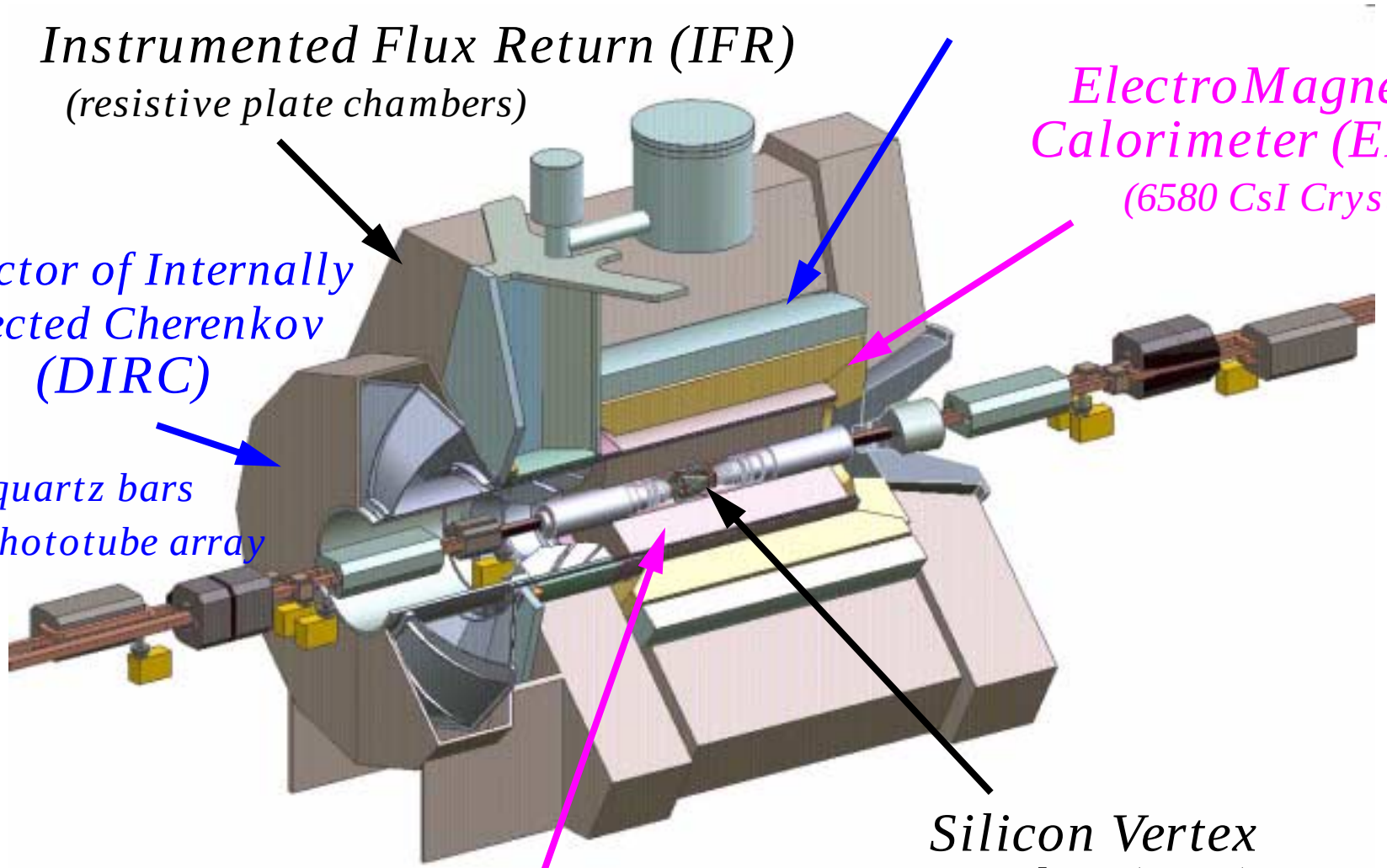
integrated luminosity



daily integrated luminosity

- **1999-2000 DataSet**
  - *20.7 fb^{-1} on-peak*
    (22.7 10^6 $B\bar{B}$ pairs)
  - *2.6 fb^{-1} off-peak*

BABAR Detector

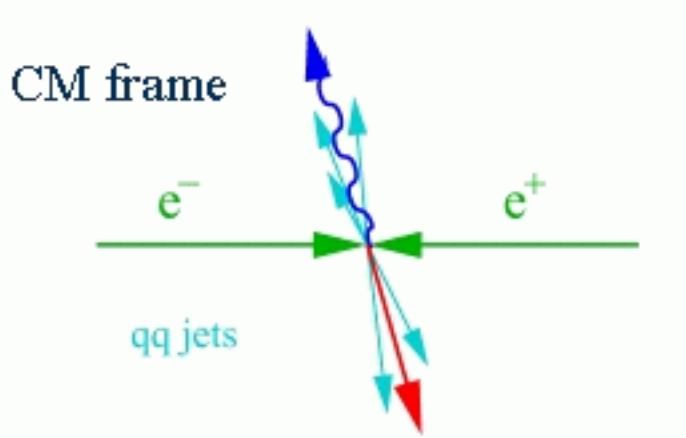


Analysis Strategy

- **background contamination:**
  - **large contamination from continuum (light quark production)**

    $\sigma(q\bar{q})/\sigma(B\bar{B})*Br \sim 10^5 - 10^6$
  - **background suppression through topological variables**

    bkg: *jet-like events* **signal:** *spherical events*



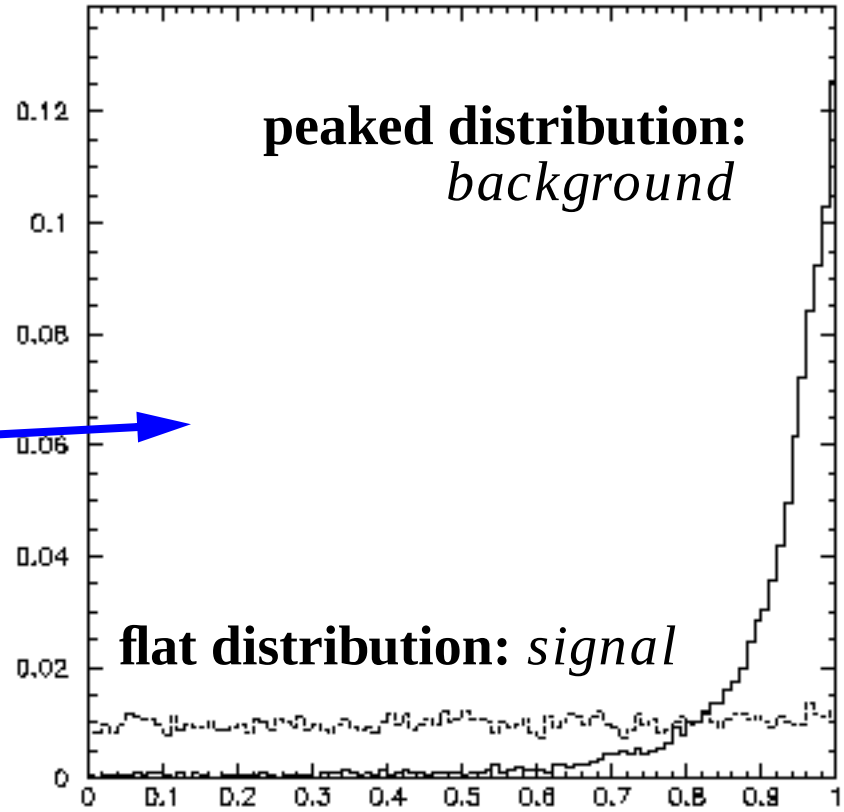
- **selection of the B candidates on kinematics**

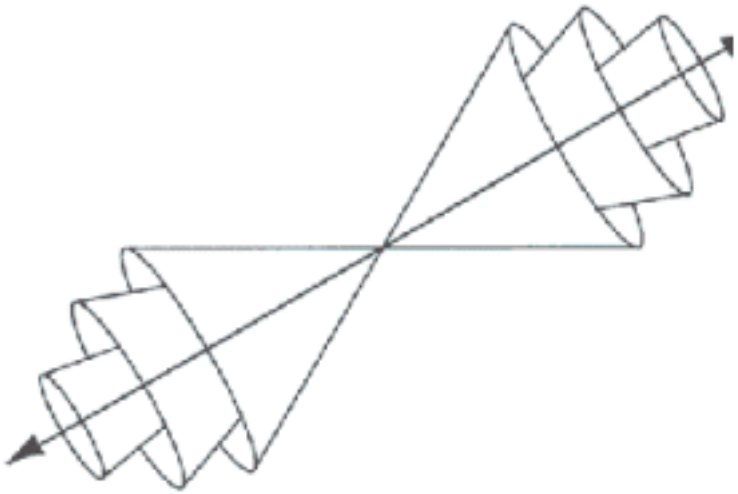
  rejection factor *against continuum background* **~ 10^3**
- **particle identification**

  K/π separation in the momentum region 1.5 < p < 4.5 GeV
- **two analysis methods to extract signal yields:**
  - **cut&count**
  - **maximum likelihood fit**

Background Suppression:

- **Fox-Wolfram moments**
- **cosine of the angle between**
  sphericity axis of B
  and
  the rest of the event
- **cosine of the** *B decay axis*
  with respect to the beam axis





- **momentum flow around the B thrust axis**

Background Suppression (II)

- **A linear *Fisher discriminant* is built from the momentum flow around the B thrust axis**
  - **new variables:**

    momentum-weighted sum

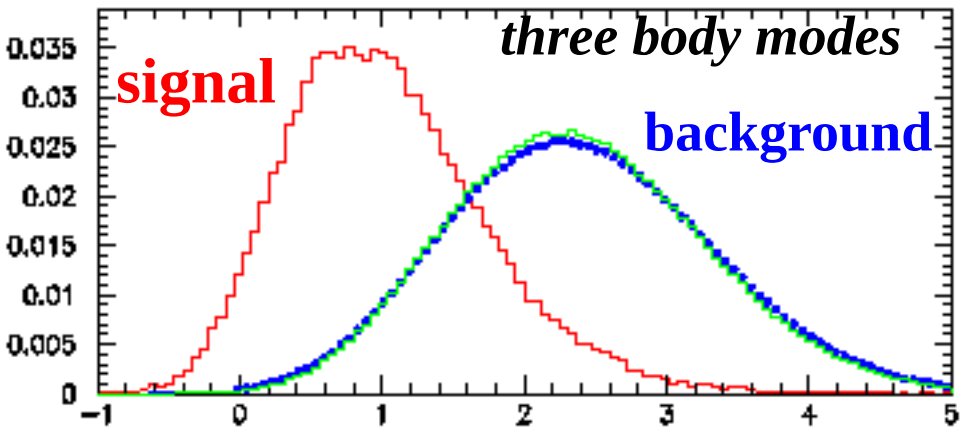
    of the *roe* track $\cos\theta_i$ to the j^{th} power

$$\mathcal{F} = \sum_i \alpha_i \cdot x_i$$

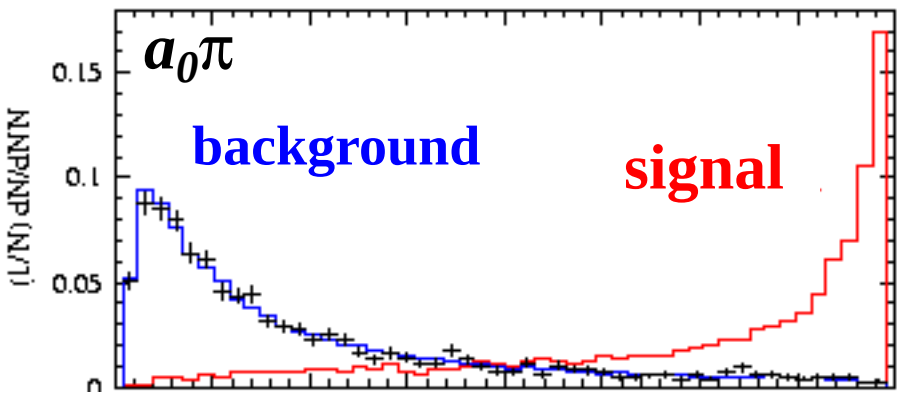
$$L_j^c = \sum_i^{roe} p_i \times |\cos\theta_i|^j$$

➡ **to be included in a *Neural Network***

Fisher discriminant



Neural Network output



Selection of the B candidates: kinematic variables

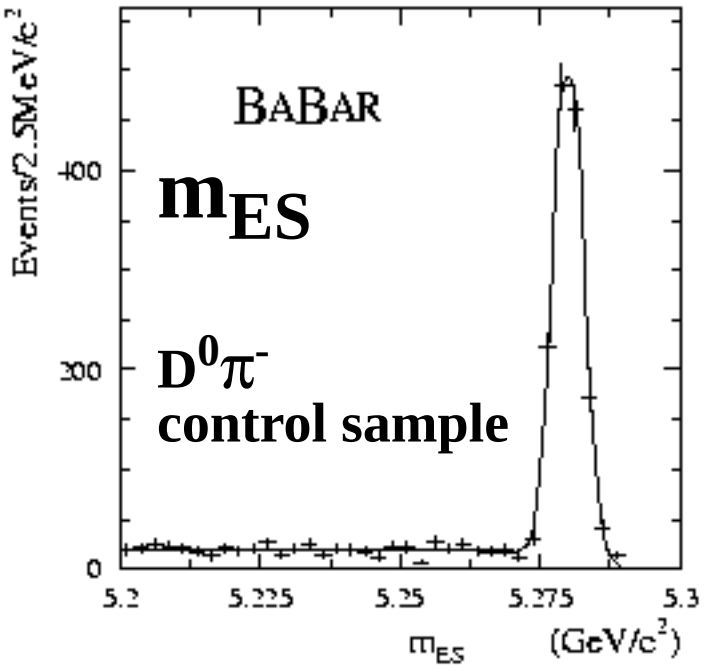
- **ΔE: energy difference between** *B candidate and beam energy*

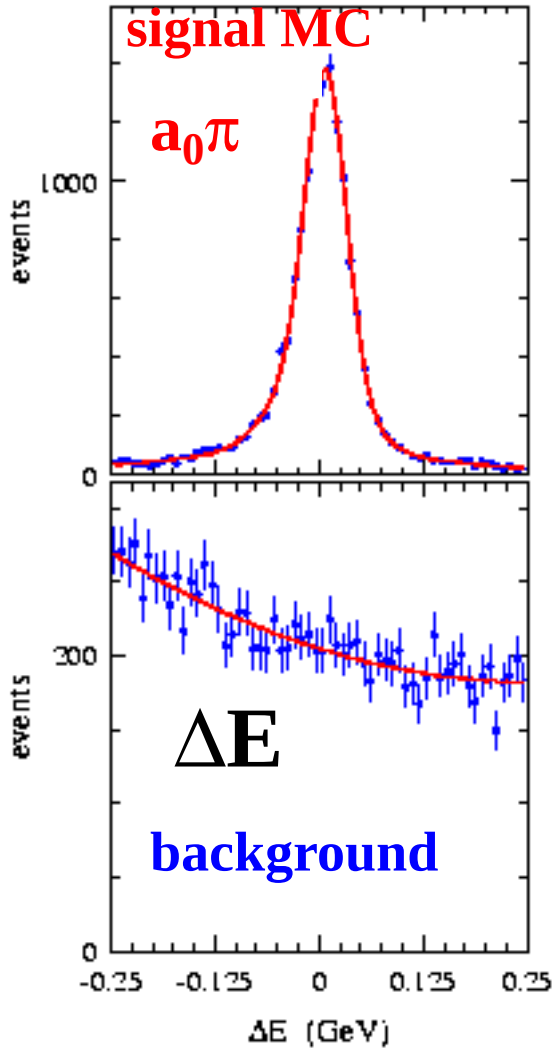
$$\Delta E = E_B^* - \frac{\sqrt{s}}{2}$$

- **m_{ES}: energy-substituted mass**

$$m_{ES} = \sqrt{E_{\rm beam}^{*2} - p_B^{*2}}$$

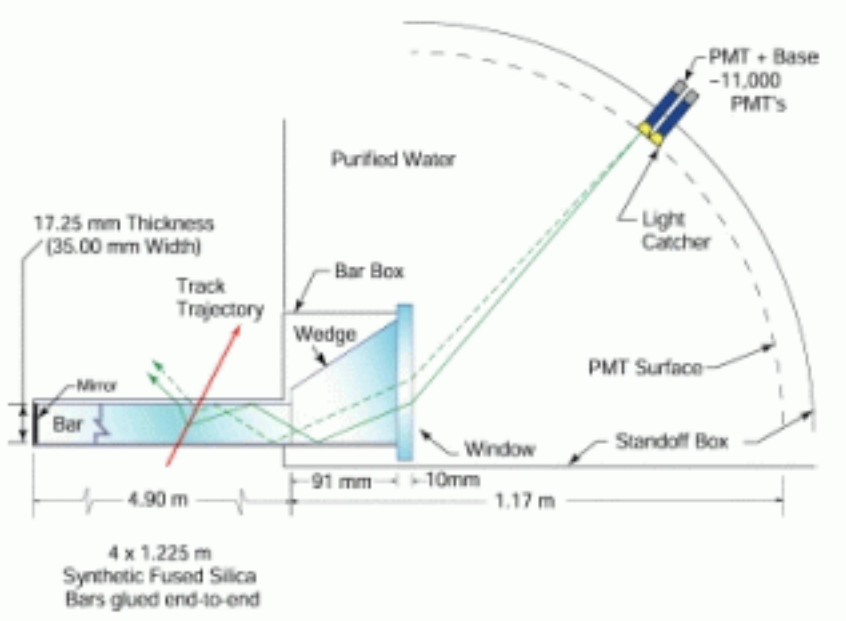
the beam energy is known with better precision than the B candidate energy

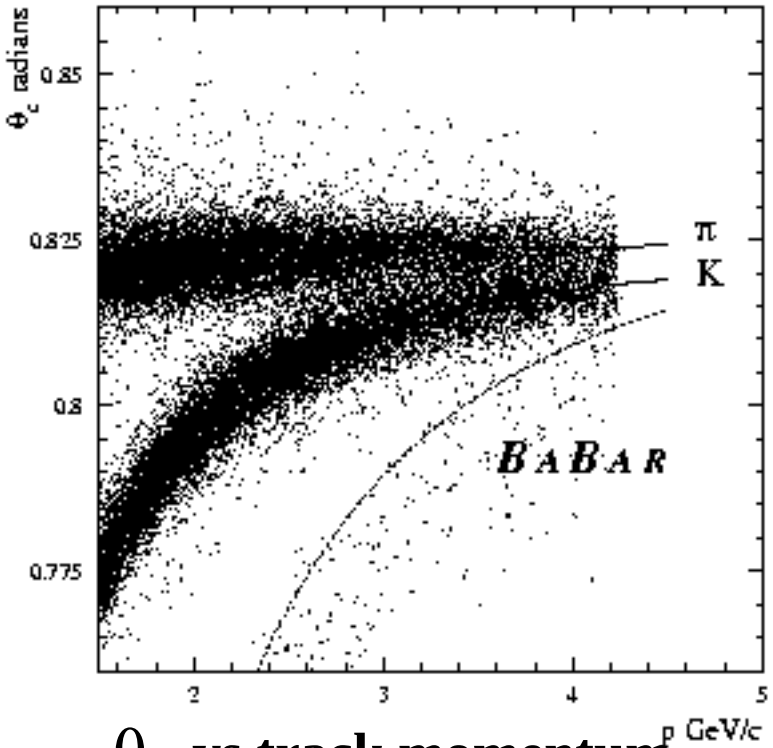




Particle Identification: DIRC:

- Cherenkov angle θ_C: $\cos(\theta_C)=1/(\beta n)$
- kaon threshold ~ 500 MeV/c

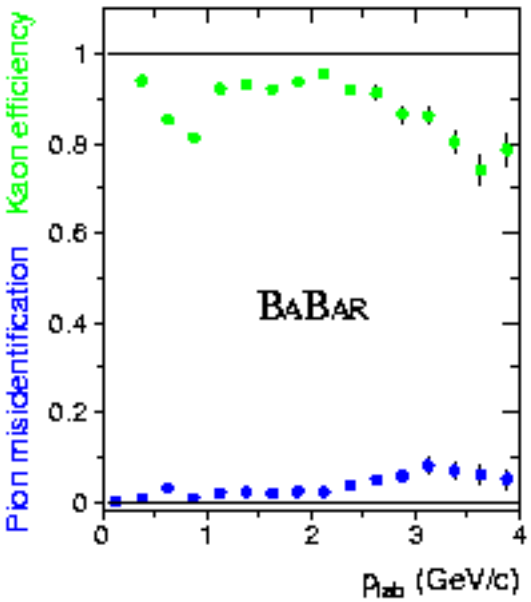




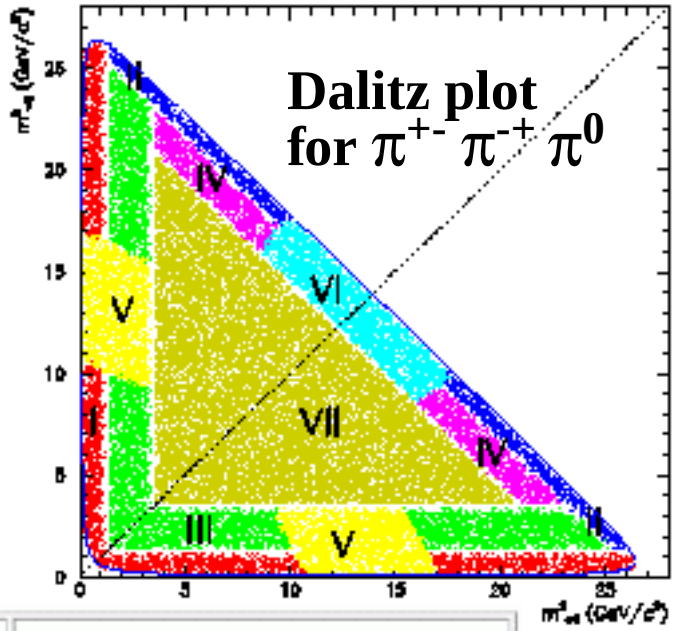
θ_C vs track momentum

- K-π separation
  - 8σ @ 2GeV/c
  - 2.5σ @ 4GeV/c
- DE/dx from
  - SVT and DCH
  - up to 0.7 GeV/c
- Kaon Selection
  - efficiency ~ 90%
  - π mis-id < 10%

Kaon selector



Results: three body modes



- from cut&count analysis

Number of events for each Dalitz plot zone:

zone	[putative dominant resonance]	ε (%)	yields
I	$\rho^{\pm}(770)\pi^{\mp}$	13.5±1.6	89±16±6
II	$\rho^{0}(770)\pi^{0}$	7.4±0.9	6.1±5.8±2.8
III	$\rho^{\pm}(1450)\pi^{\mp}$	15.0±2.1	17.4±9.7±6.9
IV	$\rho^{0}(1450)\pi^{0}$	8.7±1.8	-4.7±3.6±2.2
V	(charged scalar) $\pi^{\pm}$	15.0±2.3	8.6±7.3±2.3
VI	$f^{0}(400-1200)\pi^{0}$	6.7±1.4	-0.3±3.2±3.2
VII	$\pi^{+}\pi^{-}\pi^{0}(NR)$	7.5±1.0	-4.2±7.3±3.8

Results: three body modes (II)

5.0σ stat. sig.

$$\mathcal{BR}(B^0 \to \rho^{\pm}(770)\pi^{\mp}) = 28.9 \pm 5.4 \pm 4.3 \cdot 10^{-6}$$

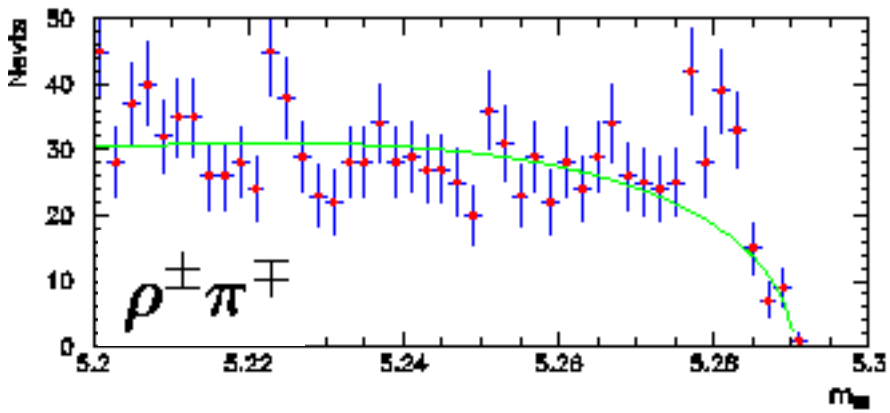
$$\mathcal{BR}(B^0 \to \rho^{0}(770)\pi^{0}) < 10.6 \cdot 10^{-6}$$

$$\mathcal{BR}(B^0 \to \pi^{+}\pi^{-}\pi^{0}(NR)) < 7.3 \cdot 10^{-6}$$

$$\mathcal{A}_{\rho\pi} = -0.04 \pm 0.18 \pm 0.02$$

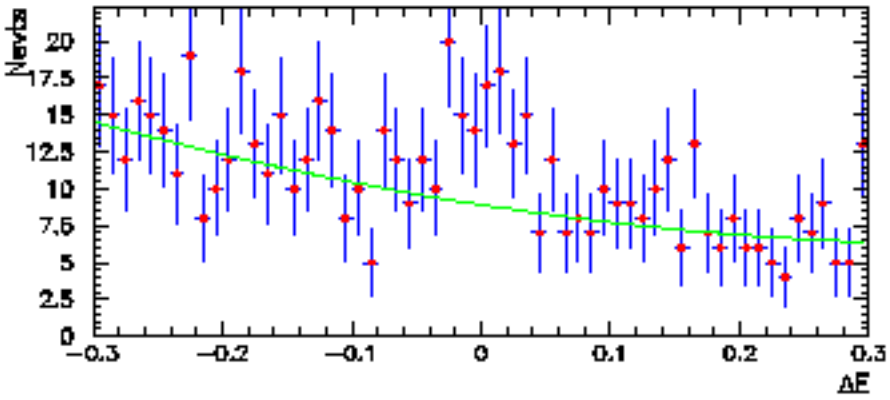
- **m_{ES} distribution** ➡

  bkg: ARGUS shape



- **ΔE distribution** ➡

  bkg: 2^{nd} order polynomial



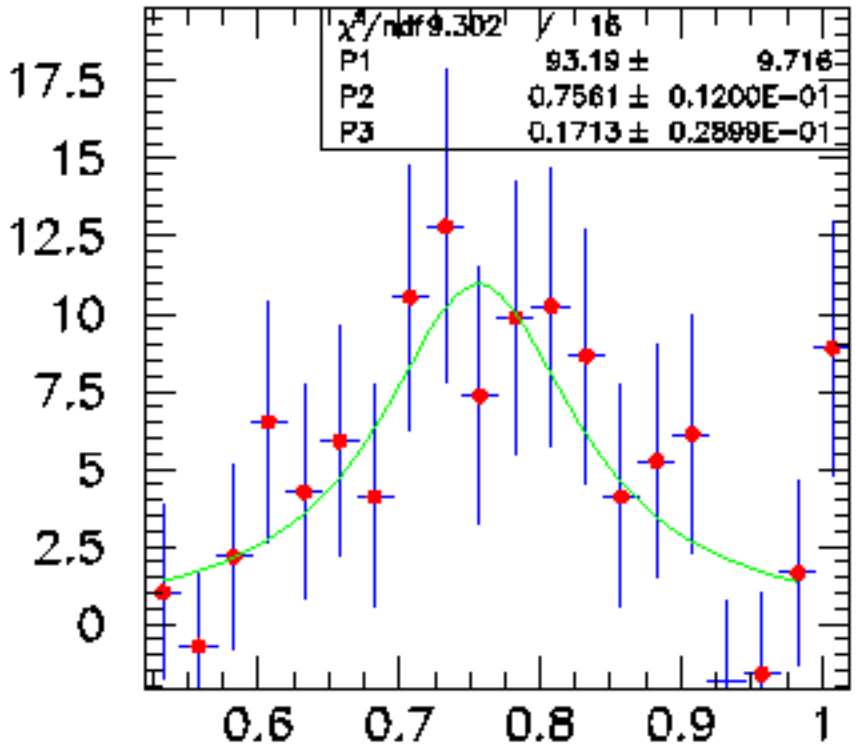
Submitted paper:
hep-ex/0105044

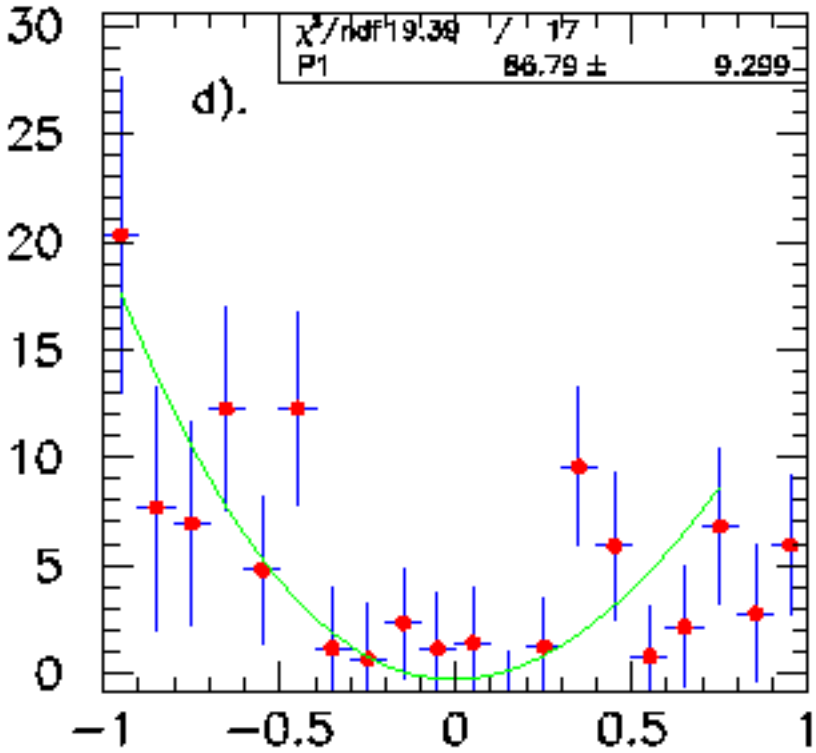
Results: three body modes (III)

$\rho^{\pm}\pi^{\mp}$ mode

ρ mass distribution

non-relativistic Breit-Wigner





ρ helicity

$cos^2(\theta_H)$

Results: quasi-two body modes

$$B^0 \to a_0^{\pm}(980)\pi^{\mp}$$
$$(a_0 \to \eta\pi,\ \eta \to \gamma\gamma)$$

maximum likelihood method analysis

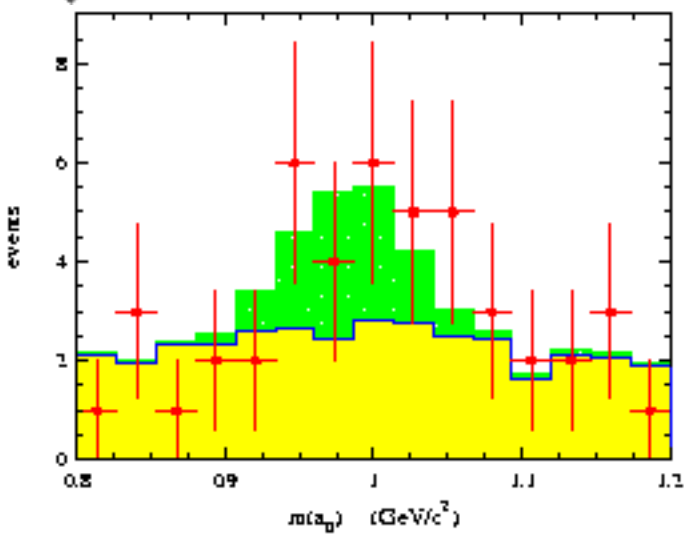
including also the η mass distribution

- **efficiency:** $30.3 \pm 2.0\%$
- Event yield $18.1\ ^{+8.7}_{-7.4}$

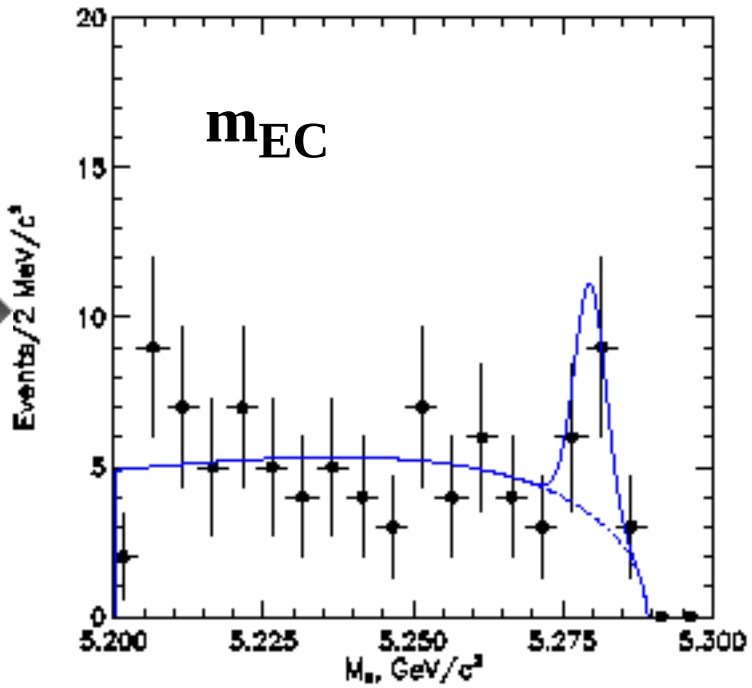
3.1σ stat. significance

- $\mathcal{BR}(B^0 \to a_0\pi) \times \mathcal{BR}(a_0 \to \eta\pi) = 6.7\ ^{+3.2}_{-2.7} \pm 1.2 \cdot 10^{-6}$
- $\mathcal{BR} < 12 \cdot 10^{-6}$ @ 90% CL

a_0 mass distribution



from cut&count analysis 13.5%



Results:

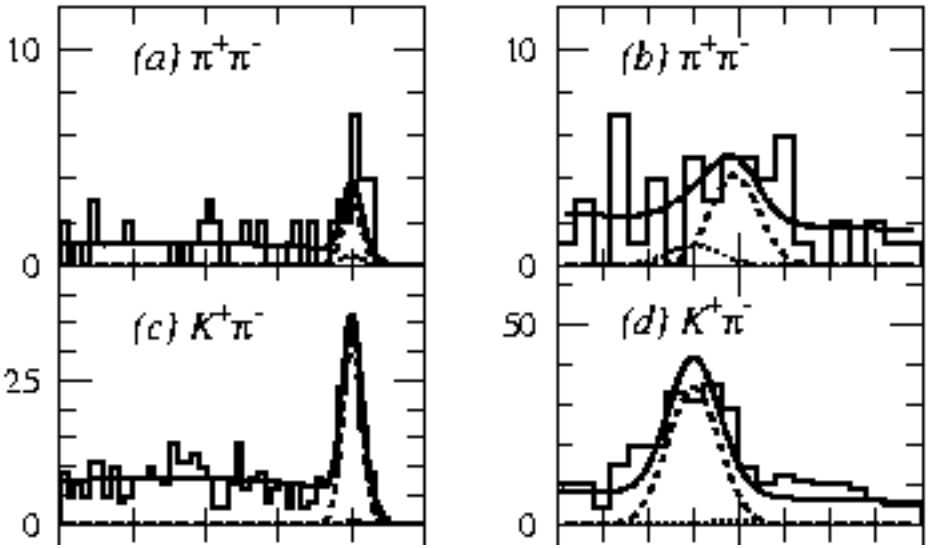
two body modes

ML fit

Mode	ε (%)	N_S	S (σ)	$\mathcal{B}(10^{-6})$
$\pi^+\pi^-$	45	$41 \pm 10 \pm 7$	4.7	$4.1 \pm 1.0 \pm 0.7$
$K^+\pi^-$	45	$169 \pm 17 \pm 13$	15.8	$16.7 \pm 1.6 \pm 1.3$
K^+K^-	43	$8.2^{+7.8}_{-6.4} \pm 3.5$	1.3	< 2.5 (90% C.L.)
$\pi^+\pi^0$	32	$37 \pm 14 \pm 6$	3.4	< 9.6 (90% C.L.)
$K^+\pi^0$	31	$75 \pm 14 \pm 7$	8.0	$10.8^{+2.1}_{-1.9} \pm 1.0$
$K^0\pi^+$	14	$59^{+11}_{-10} \pm 6$	9.8	$18.2^{+3.3}_{-3.0} \pm 2.0$
$\bar{K}^0K^+$	14	$-4.1^{+4.5}_{-3.8} \pm 2.3$	–	< 2.4 (90% C.L.)
$K^0\pi^0$	10	$17.9^{+6.8}_{-5.8} \pm 1.9$	4.5	$8.2^{+3.1}_{-2.7} \pm 1.2$

m_{ES} distributions

$\pi\pi$ and Kπ candidates



ΔE distributions

$\pi\pi$ and Kπ candidates

Submitted paper:

hep-ex/0105061

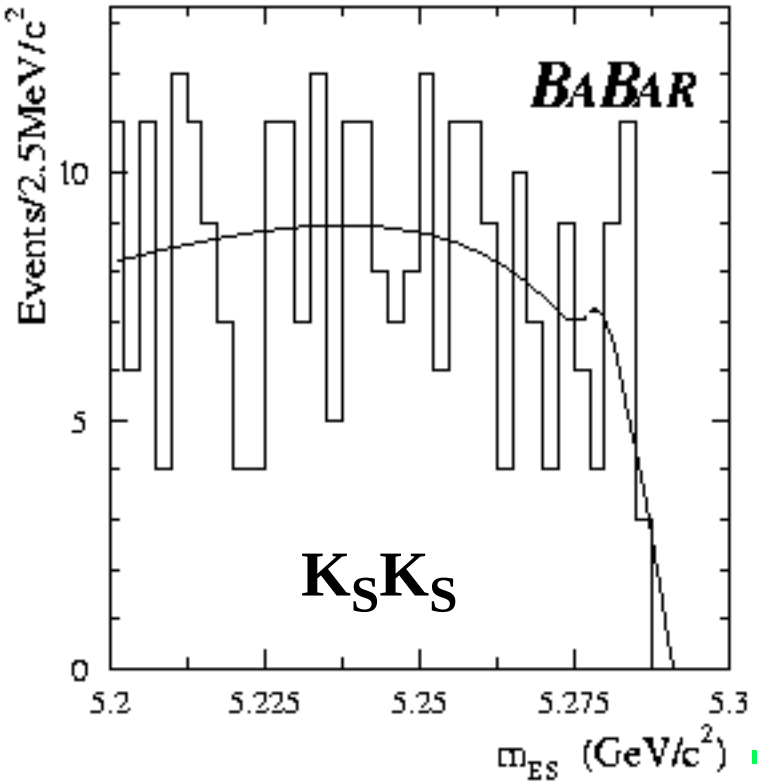
Results: two body modes (II)

maximum likelihood fit

1.5σ *stat. significance*

➡ $K^0\bar{K}^0$ **mode**

- **efficiency on K_SK_S: 36.6 +/- 4.6 %**
- $K_SK_S \text{ yield} = 3.4^{+3.4}_{-2.4}(stat) \pm 3.5(syst)$



$$\mathcal{BR} = 3.5^{+3.5}_{-2.5}(stat) \pm 3.6(syst) \cdot 10^{-6}$$

$$\mathcal{BR} < 10.6 \cdot 10^{-6} \text{ @ 90\% CL}$$

⬅ **m_{ES} distribution**
from the likelihood fit

Summary and outlook

- with 20fb^{-1} in 1999-2000 dataset

$$\mathcal{BR}(B^0 \to \rho^{\pm}(770)\pi^{\mp}) = 28.9 \pm 5.4 \pm 4.3 \cdot 10^{-6}$$

$$\mathcal{A}_{\rho\pi} = -0.04 \pm 0.18 \pm 0.02$$

$$\mathcal{BR}(B^0 \to a_0\pi) \times \mathcal{BR}(a_0 \to \eta\pi) < 12 \cdot 10^{-6} \text{ @ } 90\% \text{ CL}$$

$$\mathcal{BR}(B^0 \to K^0\bar{K}^0) < 10.6 \cdot 10^{-6} \text{ @ } 90\% \text{ CL}$$

- already 11fb^{-1} accumulated during 2001
- 100fb^{-1} foreseen by June 2002
- direct CP violation under study (see Sven's talk)
- with 500fb^{-1} the time-dependent Dalitz plot analysis will lead to sin2α measurement....