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Limit on the $B_s \to K_s^0 \rho^0$ Branching Ratio

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Abstract

From a sample of 1.14 million Z^0 hadronic decays recorded in 1990, 1991 and 1992 by the ALEPH detector, the decay mode $B_s \to K_s^0 \rho^0$ is studied. An upper limit of 7.8 10^{-4} at the 90% confidence level is obtained for the branching ratio.

The $B_s \to K_s^0\rho^0$ decay mode is interesting for measuring the γ angle of the unitarity triangle [1]. While its rate is expected to be small as this decay implies $V_{b\to u}$ transition and is color suppressed, no experimental limit has yet been obtained. This work is the first attempt in this direction.

1 Selection of the $B_s \to K_s^0\rho^0$ decay mode

The analysis has been carried out on 1.14 million events collected by the ALEPH detector at LEP in 1990, 1991 and 1992 and available in the nano-DST form(version 111). The Monte Carlo sample consists of 1008 events of the $B_s \to K_s^0\rho^0$ decay mode especially generated for the present analysis.

1. K_s^0 are reconstructed using tbe YRMIST package.
   The K_s^0 are identified by means of their $\pi^+\pi^-$ decay products. The analysis is performed using the informations of the YRFT bank written by the YRMIST package at the nano-DST creation. To reduce the background the following selection cuts are applied to the K_s^0 candidates:
   - a cut on the invariant mass M is done requiring $|M - M_{K^0}|$ to be less than 40 MeV/c^2;
   - a rough agreement with the mass hypothesis is set by requiring the pull on the the mass $|M - M_{K^0}|/\sigma(M_0)$ to be less than 5;
   - the angle θ^* between the decay particles and the K_s^0 direction in the K^0 center of mass system has to satisfy $|cos(\theta^*)| < 0.95$;
   - the proper time t/τ_{K^0} is calculated with $c\tau_{K^0} = 2.675cm$. It has to be larger than 0.10;
   - if a track pair gave two candidates of the same mass hypothesis but at different vertex position, the candidate with the larger χ^2 is rejected. If two candidates share a track, the candidate with the smallest χ^2 is kept;
   - when there is a kinematic ambiguity of the K_s^0 candidate with $\Lambda, \bar{\Lambda}, \gamma$, the K_s^0 candidate is rejected;
   - the momentum of the K_s^0 has to be greater than 2 GeV/c.
2. $B_s \to K_s^0\rho^0$ selection
   - two charged tracks each with momenta greater than 1 GeV/c are associated to form a ρ.
   - the ρ candidate is required to have a reconstructed mass within 150 MeV of the known value(770 MeV).
   - $P(\rho) > 6GeV/c$
   - the ρ and the K_s^0 are combined to form a B_s

- $X_E(B_s) = E(B_s)/E_{(beam)} > 0.5$
- the angle $\theta^*(K_s^0)$ between the K_s^0 and the B_s in the rest frame of the B_s has to satisfy $|cos\theta^*(K_s^0)| < 0.8$
- the angle $\theta^*(\pi/\rho)$ between one of the pion and the ρ vector meson helicity axis in the rest frame of the ρ vector particle has to verify $|cos\theta^*(\pi/\rho)| > 0.4$
- the probability function $P_{(uds)}$ for the event calculated by QIPBTAG is required to be less than 0.01.This selection has 70% efficiency and 77% purity on $Z \rightarrow b\bar{b}$, it eliminates 98% of $Z \rightarrow \bar{u}u, \bar{d}d, \bar{s}s$ and 82% of $Z \rightarrow \bar{c}c$ events [2].

The $K_s^0\rho^0$ invariant mass spectrum is shown in fig.1.

2 Specific Monte Carlo generation

To get Monte Carlo events for the specific $B_s \rightarrow K_s^0\rho^0$ decay mode, the following operations are done:

1. the parameter PARJ 2 is set to 1.0 (instead of 0.3) in order to suppress the production of u or d quark.
2. the parameter PARJ 1 is set to 0.0 (instead of 0.1) to completely suppress diquark-antidiquak production: no b baryon is produced.
3. $V_{b\rightarrow u}$ transitions are required to occur with 100% branching fraction.With these prescriptions only B_s are obtained.
4. Most frequent decays of the B_s consist of complex final states as often the $\bar{u}u$ quarks couple to a string which fragments in many bodies. We filter the events where this decay consist only of a ρ^0K^0 final state produced by: $\bar{u}u \rightarrow cluster \rightarrow \rho^0$ and $d\bar{s} \rightarrow K^0$.It selects about 3.4 10^{-3} of the generated events.

The ρ and K^0 being generated independently, no angular momentum correlation is taken into account, i.e. the ρ is generated unpolarized. Thus, the distribution $cos\theta^*(\pi/\rho)$ obtained directly from the Monte Carlo is flat in contrast to the $cos^2\theta^*$ distribution expected for the signal. A Monte Carlo filter is performed to get the correct behaviour of this distribution. These events are processed through GALEPH and JULIA and a nano-DST is produced with 1008 events.

From these Monte Carlo events, we evaluate a detection efficiency of $\epsilon = (7.7 \pm 1.1)\%$ and a B_s mass resolution of $\sigma = 44.4\ MeV/c^2$. The detection efficiency results from the following contributions: 0.28 from the reconstruction, 0.76 from the momentum cuts, 0.86 from the X_E cut, 0.83 from the angle cuts, 0.69 from the cut on the ρ mass and 0.74 from theP_{uds} QIPBTAG probability. The B_s mass resolution has been derived from the difference between the MC truth mass and the MC reconstructed mass which is displayed in fig.2.

3 Limit on the $B_s \rightarrow K_s^0\rho^0$ branching ratio

From the mass distribution displayed in fig.1, we obtained the 90% confidence level upper limit in the following way. In the $\pm 90 MeV/c^2$ mass region aroud the B_s mass:5.37 GeV [3], there are 2 events. This mass range has been chosen as corresponding to about $\pm 2\ \sigma$ where σ is the expected B_s mass resolution. In this mass range one expects 4.2 background events as it can be estimated from the number of events seen between 5 and 6 GeV/c^2 We set an upper limit on the branching ratio $B(B_s \rightarrow K_s^0\rho^0)$ from the following calculation:

$$B(B_s \rightarrow K_s\rho^0) < \frac{3.2 \cdot \epsilon_H}{2.0 \cdot N_Z \cdot (\Gamma_{b\bar{b}}/\Gamma_Z) \cdot f_s \cdot Br(K_s \rightarrow \pi_1\pi_2) \cdot \epsilon}$$

where 3.2 is the upper limit on signal at 90% C.L., $f_s = 0.15$, $\Gamma_{b\bar{b}}/\Gamma_Z = 0.22$, $Br(K_s \rightarrow \pi\pi) = 0.686$ and the hadronic Z decay efficiency $\epsilon_H = 0.974$, thus $B(B_s \rightarrow K_s\rho^0) < 7.8\ 10^{-4}$.

This value is three orders of magnitude greater than the expected value, about 10^{-6} [4], however it is the first experimental limit.

4 Acknowledgements

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References

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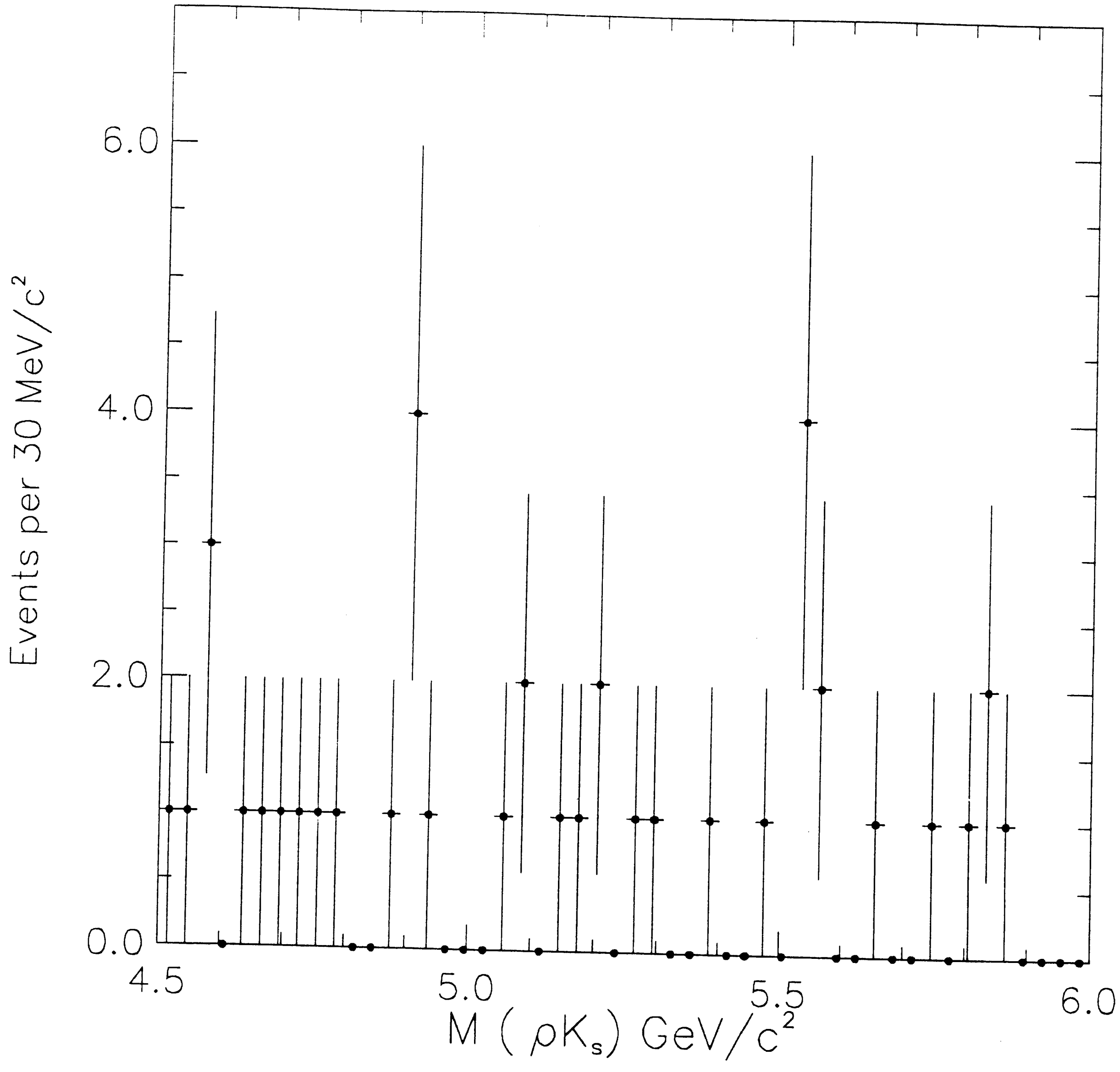
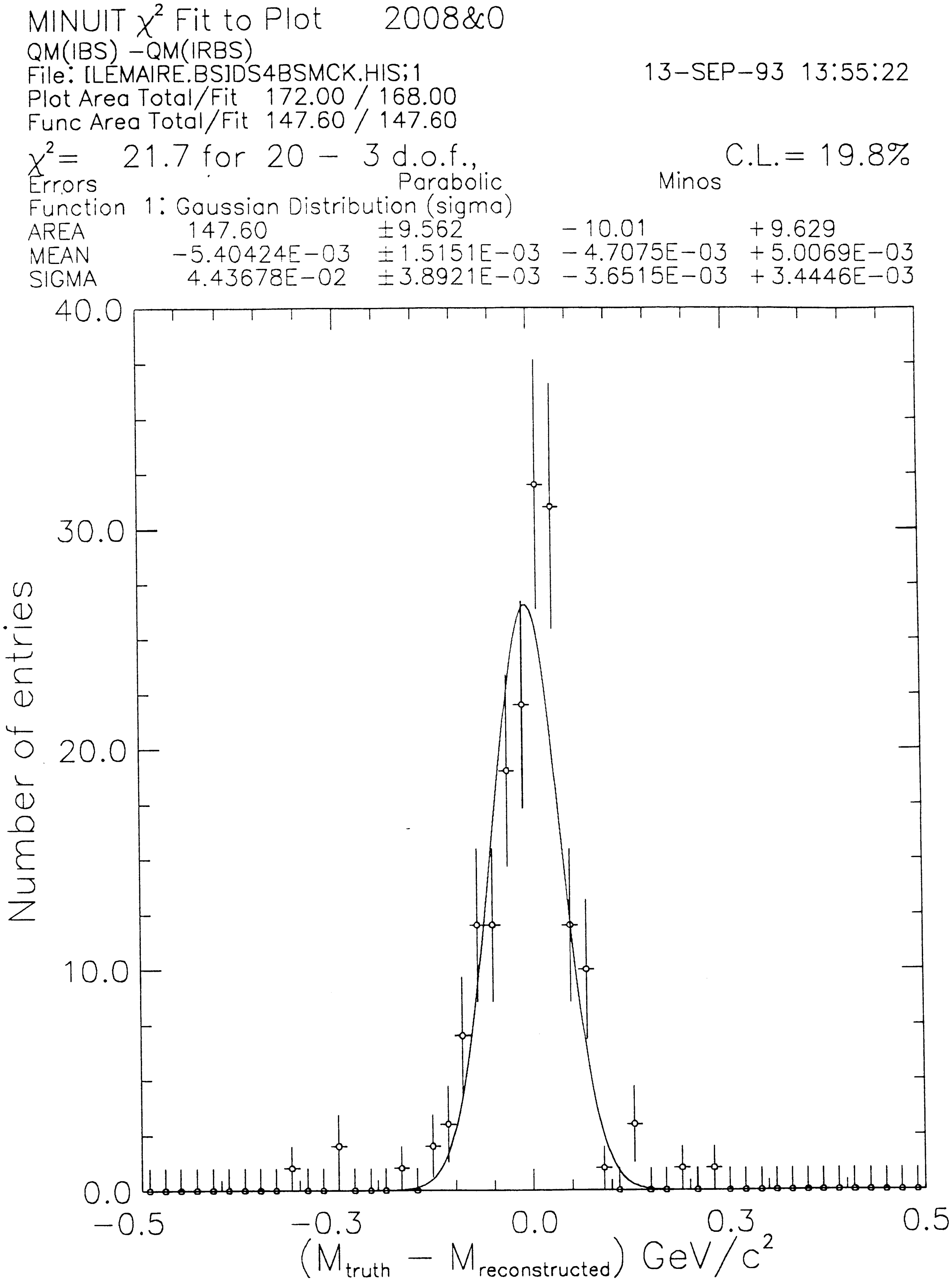


Figure 1: The $K^0_s\rho$ invariant mass plot in $30MeV/c^2$ bins.



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QM(IBS) -QM(IRBS)
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Plot Area Total/Fit  172.00 / 168.00
Func Area Total/Fit  147.60 / 147.60
χ²=    21.7 for  20 -  3 d.o.f.,                         C.L.= 19.8%
Errors                             Parabolic               Minos
Function  1: Gaussian Distribution (sigma)
AREA          147.60        ±9.562        - 10.01          + 9.629
MEAN       -5.40424E-03   ±1.5151E-03   - 4.7075E-03   + 5.0069E-03
SIGMA       4.43678E-02   ±3.8921E-03   - 3.6515E-03   + 3.4446E-03
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Figure 2: Difference between the MC truth and the MC reconstructed masses