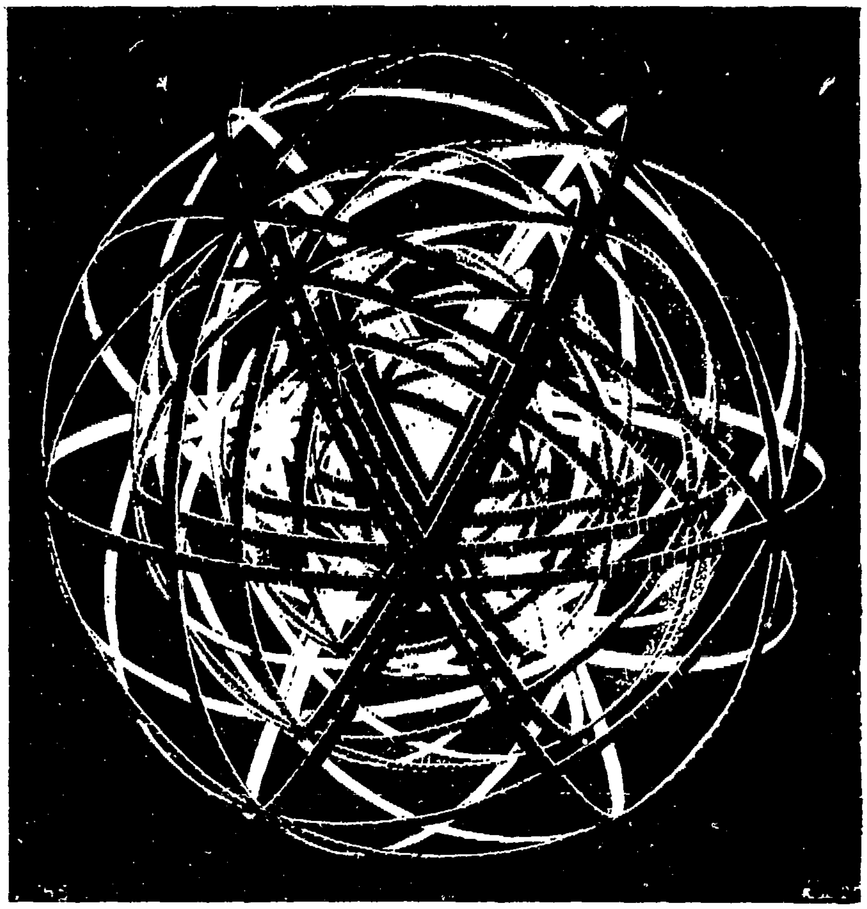
INSTITUT NATIONAL DE PHYSIQUE NUCLEAIRE
ET DE PHYSIQUE DES PARTICULES

LPNHE_Paris

L.P.N.H.E.P. _ 90.04



Determination of α_s from Jet Production Rates and Energy-Energy Correlations on the Z^0 Resonance

R. Pain for DELPHI Collaboration *

October 1990

UNIVERSITES PARIS VI ET PARIS VII

4 PLACE JUSSIEU_TOUR 33_REZ-DE-CHAUSSEE_75252 PARIS CEDEX 05

LABORATOIRE DE PHYSIQUE NUCLEAIRE ET DE HAUTES ENERGIES

LPNHEP-- 90-04

M.C. ESCHER "Anneaux concentriques"

Determination of α_s from Jet Production Rates and Energy-Energy Correlations on the Z^0 Resonance

R. Pain for DELPHI Collaboration *

October 1990

Abstract

This presentation uses data obtained from the DELPHI experiment at LEP. The strong coupling constant α_S is determined in two different analyses of the Z^0 decay into multi-hadronic final states. The first uses the jet production rates and the second the asymmetry of energy-energy correlations. Both methods compare experimental data with second order of perturbative QCD predictions. The results are $\alpha_s(M_Z) = 0.114 \pm 0.003 \pm 0.004 \pm 0.012$ using the jet rates method and $\alpha_s(M_Z) = 0.106 \pm 0.003 \pm 0.003 \pm 0.003$ from the energy-energy correlations method.

1 Introduction

High energy e^+e^- annihilations provide a direct and detailed test on perturbative QCD. This paper presents the results obtained by Delphi experiment at LEP concerning the strong coupling constant α_s and the parameter $\Lambda_{\overline{MS}}$. The values of α_s and Λ are determined by comparison of perturbative QCD with experimental data analysed by two methods : jet production rates and the asymmetry of energy-energy correlations.

α_s as a fonction of Λ is taken to second order [1]

$$\alpha_S(\mu) = \frac{12\pi}{(33-2N_f)\ln\frac{\mu^2}{\Lambda^2}}\left[1 - 6\frac{(153-19N_f)\ln\ln\frac{\mu^2}{\Lambda^2}}{(33-2N_f)^2\ln\frac{\mu^2}{\Lambda^2}}\right]$$

where μ is the renormalisation scale and N_f the number of flavours involved at that scale. From the theoretical point of view, μ is a free parameter. One often uses the parameter f defined as $\mu^2 = fs$ where $\sqrt{s}$ is the center of mass energy.

The string fragmentation model is used in both methods and the jet rates analysis uses the KL' recombination scheme [2].

The dependence on fragmentation models, recombination scheme and energy scale have been studied in detail.

*Talk presented at the QCD 90 conference 07-13 July 1990, Montpellier, France

2 Detector and data selection

The DELPHI detector has been described in detail elsewhere[3]. For this analysis only charged particles were considered, where the energy is calculated using the momentum as given by the Inner Detector, the time projection chamber and the Outer Detector and assuming a pion mass.

The tracks are required to have:

- Impact parameter at the nominal primary vertex $< 5cm$ in R and $< 10cm$ in z
- $25^0 <$ polar angle $< 155^0$
- Momentum > 0.1 GeV/c.
- Track length > 50 cm.

Events were kept if :

- Charge energy in each hemisphere > 3 GeV.
- Total charged energy > 15 GeV.
- At least 5 tracks with momentum > 0.2 GeV/c.
- $40^0 <$ polar angle of the spericity axis $< 140^0$.
- Missing momentum < 30 GeV/c.

The data were taken during the first month of LEP oeration in 1989 at $91GeV$ center of mass energy. Two data samples were used : 1727 events with the magnetic field at approximately half of its nominal value (0.7 T) and 4990 events with the full field (1.2 T). According to Monte Carlo estimates, the background due to beam gas interactons and $\gamma\gamma$ events contributes less than 0.1% and the contamination from $\tau^+\tau^-$ events is 0.2%.

The data were corrected for detector acceptance and resolution and initial state radiation by Monte Carlo using the JETSET parton shower model [4].

3 Jet Production rates

The value of the relative production rates depends on the value of α_s. These observables are almost independent of fragmentation but need a recombination scheme in order to access the parton level from the hadronic final states.

α_s was determined by fitting the theoretical predictions of the relative jet rates to experimental data [5]. They are defined by

$$R_i(y) = \sigma_i(y)/\sigma_{tot}$$

where σ_i is the cross section for a final state containing i partons and y the theoretical cut-off parameter used to remove soft or collinear partons.

The KL' recombination scheme was used to obtain jets from multihadronic events. The jets are reconstructed as follows : any pair of particles with $y_{ij} = 2E_iE_j(1-cos\theta_{ij})/(\Sigma E_i)^2$ smaller than a cutoff y_{cut} was replaced by a pseudo-particle with momentum $p^\mu = p_i^\mu + p_j^\mu$. The algorithm was iterated until all $y_{ij} > y_{cut}$. The rates were then corrected for detector acceptance, resolution and initial state radiation. A correction was applied for small remaining fragmentation effects :

$$R_{i-jet}(y_{cut}) = \Sigma M_{ij}(y_{cut} = y)R_{j-parton}(y)$$

where M_{ij} is calculaded by Monte Carlo with KL' matrix elements and string fragmentation.
The data in different bins of the R_i distributions are highly correlated. In order to simplify the statistical treatment, differential multiplicities defined by the D_i functions were used :

$$D_2(y_{cut}) = dR_2(y_{cut})/dy_{cut}$$

$$D_3(y_{cut}) = dR_3(y_{cut})/dy_{cut} + D_2(y_{cut})$$

Two different fits were performed. The first is the fit of Λ to the D_2 function over the range $0.05 < y_{cut} < 0.25$, where the 4-jet rate is negligible and hadronization correction are small, and to $R_2(y_{cut} = 0.05)$ (see figure 1). It leads to:

$$\alpha_s(M_Z) = 0.114 \pm 0.003(stat) \pm 0.004(syst) \pm 0.012(th)$$

where the theoretical error is given by the influence of recombination scheme and renormalisation scale.

The second fit includes the values of y_{cut} down to 0.02 where the 4-jet rate and fragmentation effects become important. Simultaneous fit of Λ and $f = \mu^2/s$ to the D_2 (over the range $0.02 < y_{cut} < 0.25$) and D_3 (over the range $0.02 < y_{cut} < 0.08$) results in values of Λ of about 90 MeV and in small values of f around 0.001 (see figure 2).

In this last case, the results are sensitive to the value of the renormalisation scale μ. This might be an effect of the unknown higher order contribution in the 4-jet rate where only the leading order ($O(\alpha_S^2)$) has been calculated so far.

4 Energy-energy correlation

The distribution of energy-energy correlations (EEC) was first introduced by Basham, Brown, Ellis and Love [6]. This infrared-safe variable is weakly dependent on fragmentation effects and on the choice of the renormalisation scale μ. EEC does not use any recombination scheme.

Experimentally, EEC(χ) is the histogram of the angle χ between any two particles in the event weighted by the product of the two normalized energies of the pair :

$$\frac{dEEC(\chi)}{d\chi} = \frac{2}{N\Delta\chi} \sum_{event}^{N} \sum_{i>j} \frac{E_i E_j}{(\sum_i E_i)^2}$$

where N is the number of events, $\Delta\chi$ is the bin size, χ is the angle between particles i and j and E_i is the energy of particle i.

The asymmetry of EEC defined by

$$AEEC(\chi) = EEC(180^o - \chi) - EEC(\chi)$$

has smaller $O(\alpha_s^2)$ corrections and is less sensitive to fragmentaton effects because they contribute symmetrically to EEC at first order. AEEC was calculated after corrections for detector acceptance, resolution and initial state radiation.

Figure 3 shows the EEC and AEEC distributions compared with parton shower and matrix element models. The disagreement with the parton shower model could be explained by an overestimate of the default value of the parameter Λ in JETSET.

In this analysis [7] the generator used for the evaluationof α_s and Λ was JETSET 7.2 matrix element with ERT [8] calculation and the default value for $f = \mu^2/s = 0.002$. The string model was used for the fragmentation of partons with the parameters tuned at $\sqrt{s} = 91GeV$ [9]. The renormalisation scale μ, as well as the fragmentation parameters, are optimized in order to describe reasonably well all the aspects of multihadron production.

The integral of AEEC over the range $28.8^o < \chi < 90^o$ was first compared to the prediction of the Monte Carlo by producing the curve of the integral as a function of Λ (see figure 4)

$$\Lambda = 108 \pm 30(stat)^{+25}_{-20}(syst)MeV$$

$$\alpha_s(M_z) = 0.106 \pm 0.004(stat) \pm 0.003(syst)$$

The fit of the Monte Carlo distribution to the experimental curve of AEEC(χ) for the range $28.8^o < \chi < 90^o$ gives the following results :

$$\Lambda = 104^{+25}_{-20}(stat)^{+25}_{-20}(syst)^{+30}_{-00}(th)MeV$$

$$\alpha_s(M_z) = 0.106 \pm 0.003(stat) \pm 0.003(syst)^{+0.003}_{-0.000}(th)$$

As contents of the bins are highly correlated, the statistical error was derived from the variance of the α_s values determined from nine independent subsamples of the data. The systematic error was determined from the variations of several fragmentation parameters. Their maximum allowable variation was estimated from a fit to the rapidity and aplanarity distributions. The scale dependence gave a systematic contribution of 30 MeV on Λ and is given as the theoretical error.

5 Conclusion

The DELPHI collaboration has performed independent determinations of $\alpha_s(M_z)$. All uncertainties due to the fragmentation model, the recombination scheme and the renormalisation scale were taken into account. We obtain

$$\alpha_s(M_z) = 0.114 \pm 0.003(stat) \pm 0.004(syst) \pm 0.012(th)$$

$$\alpha_s(M_z) = 0.106 \pm 0.003(stat) \pm 0.003(syst)^{+0.003}_{-0.000}(th)$$

from the jet rates and the AEEC respectively.

These results agree well with each other although the two methods involve completely different contributions from fragmentation. This gives confidence in our understanding of events originating from pertubative QCD. The results also agree with the determinations of α_s by other collaborations [10,11,12].

References

[1] Particle Data Group, Phys. Lett. B204 (1988) 1

[2] G. Kramer, B. Lampe, Fortschr. Phys., 37 (1989) 161

[3] The DELPHI Detector, CERN PP2/90-128, submitted to Nucl. Inst. and meth.

[4] T. Sjostrand, Comp. Phys. Comm. 27 (1982) 243, ibid. 28 (1983) 229, T. Sjostrand and M. Bengstsson, Comp. Phys. Comm. 43 (1987) 367

[5] DELPHI Colab., CERN PPE/90-89, submitted to Phys. Lett. B

[6] C.L. Basham, L.S. Brown, S.D. Ellis, S.T. Love, Phys. Rev. D17 (1978) 2298, Phys. Rev. Lett. 41 (1978) 1585, Phys. Rev. D19 (1979) 2018

[7] DELPHI Collab., CERN PPE/90-122, submitted to Phys. Lett B

[8] R.K. Ellis, D.A. Ross, E.A. Terrano, Phys. Rev. Lett. 45 (1980) 1225

[9] W. de Boer, H. Furstenau, J. H. Hohne, preprint Univ. Karlsruhe, IEKP-KA/90 1, submitted to Z. Phys. C

[10] MARKII Collab., Phys. Rev. Lett. 64 (1990) 987

[11] OPAL Collab., Phys. Rev. Lett. 235B (1990) 389

[12] L3 Collab., CERN L3-011.

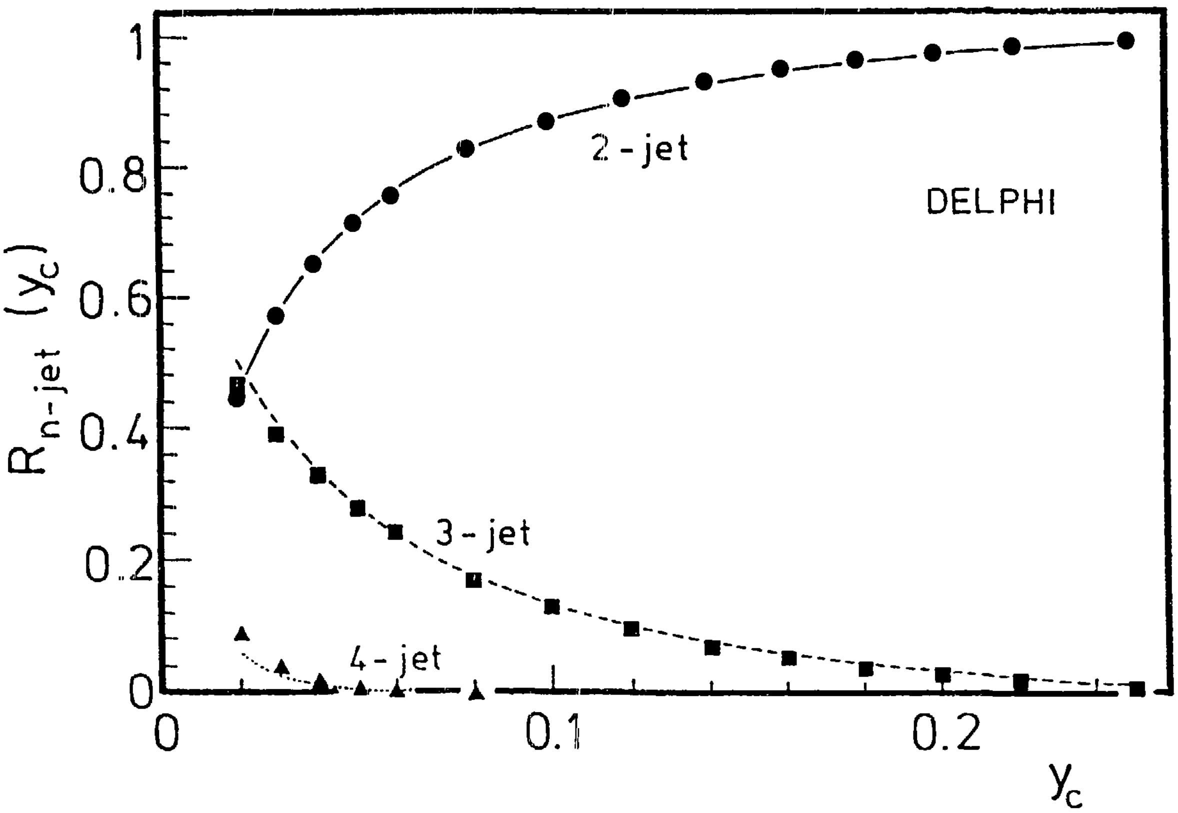


Figure 1

xperimental jet rates ; the curves show the result of the fit to D_2 for .05<y_{cut}<0.25 and to $R_2(y_{cut}=0.05)$.

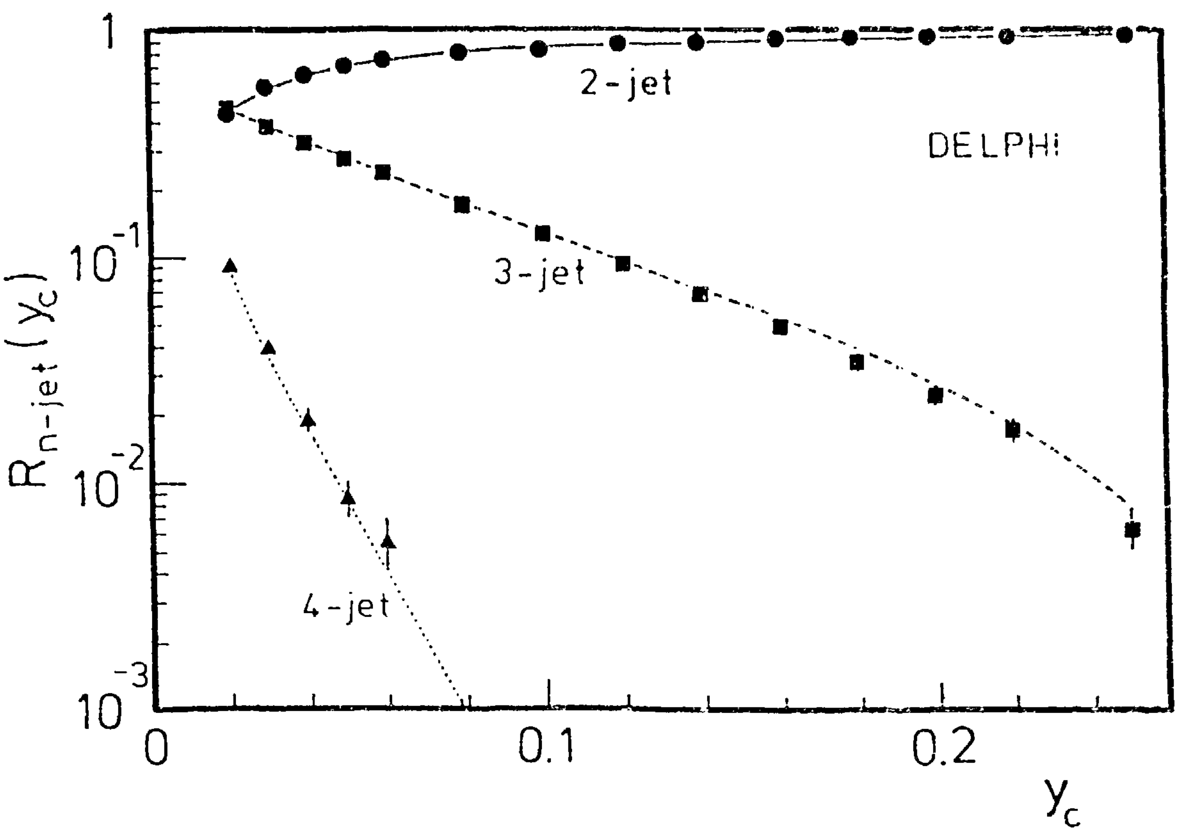


Figure 2

Experimental jet rates ; the curves show the result of the fit to D_2 for $0.02<y_{cut}<0.25$ (and to $R_2(y_{cut}=0.02)$) and D_3 for $0.02<y_{cut}<0.08$ (and to $R_3(y_{cut}=0.25)$.

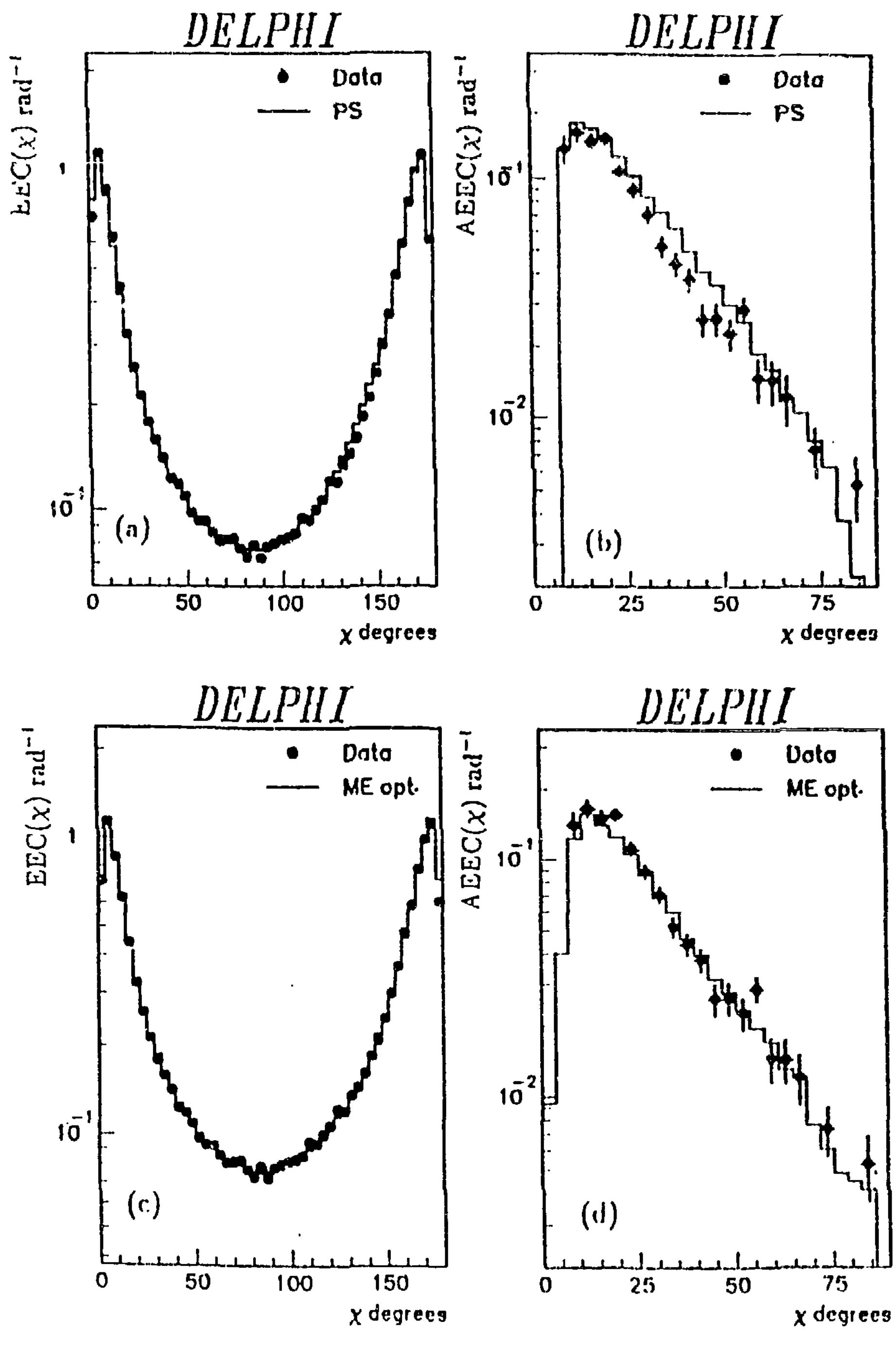


Figure 3
and b) Corrected EEC and AEEC compared with Parton shower.
and d) Corrected EEC and AEEC compared with Matrix element.

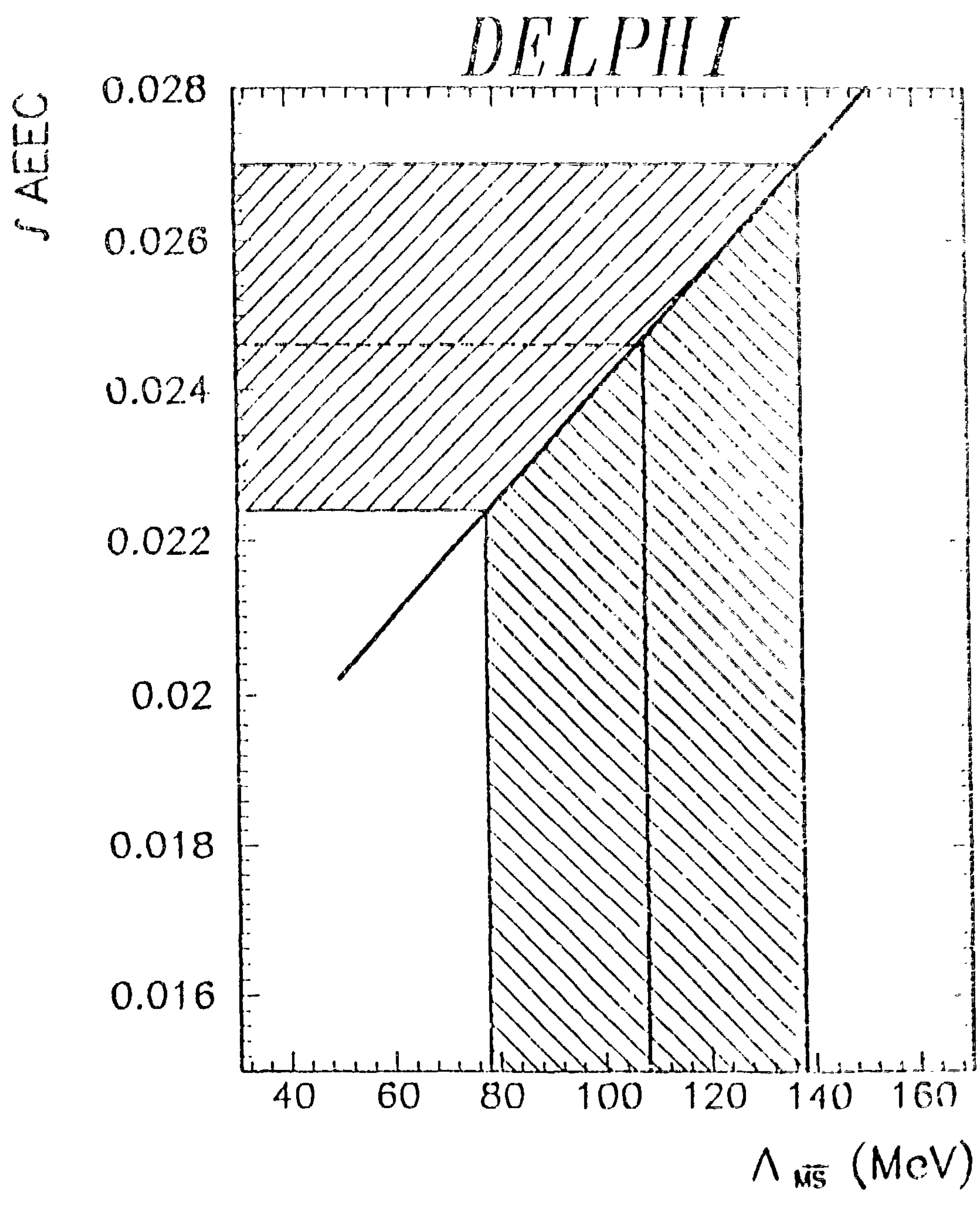


Figure 4
Integral of AEEC between 28.8° and 90° as a function of Λ as calculated from the exact QCD matrix element model with a scale of μ^2=0.002 s. The dashed horizontal line corresponds to the data. The shaded areas indicate the errors.