Lawrence Berkeley National Laboratory
Recent Work

Title
FURTHER EVIDENCE FOR PIGNOTTI'S TRAJECTORY

Permalink
https://escholarship.org/uc/item/9r387251

Authors
Phillips, Roger J.N.
Rarita, William.

Publication Date
1964-12-01

eScholarship.org Powered by the California Digital Library
University of California

UCRL-11830
c.2

University of California

Ernest O. Lawrence Radiation Laboratory

FURTHER EVIDENCE FOR PIGNOTTI'S R TRAJECTORY

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

Berkeley, California

UCRL-11830
c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

Rept. submitted for publication in Physical Review Journal.

UCRL-11830

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

AEC Contract No. W-7405-eng-48

FURTHER EVIDENCE FOR PIGNOTTI'S R TRAJECTORY

Roger J. N. Phillips and William Rarita

December 1, 1964

UCRL 11830

FURTHER EVIDENCE FOR PIGNOTTI'S R TRAJECTORY*

Roger J. N. Phillips+

Lawrence Radiation Laboratory
University of California
Berkeley, California

and

William Rarita
752 Grizzly Peak Boulevard
Berkeley, California

December 1, 1964

ABSTRACT

The high-energy $K^{\pm}p$ and $K^{\pm}n$ total cross section and the $K^- + p \to \bar{K}^0 + n$ charge-exchange data contain further evidence for the Regge trajectory R proposed by Pignotti. The signature factor is important in fitting these data; thus there is also some support for the Regge-pole hypothesis itself.

I. INTRODUCTION

Pignotti recently suggested the existence of a new octet of even-signature boson Regge trajectories.[1] They are expected to lie near the ρ trajectory and thus to give no 0^+ bound states or resonances; however, they may give 2^+, etc., resonances, and it has been suggested that the A_2 meson may lie on one of these trajectories.[2]

Some evidence for the I = 1 member of this octet, called R, was found by Ahmadzadeh.[3] He showed that the differences between high-energy pp and np total cross sections, together with $n + p \to p + n$ charge-exchange data, are readily explained by using a combination of the ρ and R trajectories, whereas ρ alone fails.[4]

The present note shows there is further evidence for R in the differences of $K^{\pm}p$ and $K^{\pm}n$ total cross sections,[5] and in $K^- + p \to \bar{K}^0 + n$ charge exchange.[6] Here again ρ is inadequate, but the addition of R explains the discrepancies in a natural way.

From a theoretical viewpoint these KN and $\bar{K}N$ processes have many similarities to NN and $\bar{N}N$ scattering; isospin considerations are the same and so are the Regge trajectories that one assumes to dominate forward scattering.[7] Our formalism is therefore related to that of Ahmadzadeh[3]; our arguments, however, are different. The data we consider have three new features: (a) The KN and $\bar{K}N$ data are more precise[8] than the corresponding NN and $\bar{N}N$ data. (b) The charge exchange, $K^- + p \to \bar{K}^0 + n$, is the direct analogue of $\bar{p} + p \to \bar{n} + n$ rather than the $n + p \to p + n$ case already studied in reference 3. The ρ and R contributions therefore combine in a different way, and a different kind of test of the formalism is made.

(c) KN and NN may be similar theoretically, but are quite independent experimentally.

II. FORMALISM

We discuss only the scattering amplitude at zero angle. At this angle are found the most stringent constraints, which provide the clearest evidence for R.[9]

We assume that high energy forward scattering in the range to be discussed is controlled by Regge poles in the crossed channel. Mandelstam has shown that there are probably branch points in the complex angular-momentum plane, which cannot be ignored asymptotically.[10] Nevertheless, there seems to be a good chance that over a wide range--perhaps up to 100 GeV or more--these branch points are not yet important and the Regge poles dominate.[11]

These Regge poles can have isospin I = 0 or 1 and G-parity G = ± 1. Let us denote the contribution to the K^+p elastic amplitude from the Regge poles with common isospin and G-parity by the symbol (I,G). Then the KN and $\bar{K}N$ amplitudes of interest can be written as follows:

$$
\begin{aligned}
A(K^+ + p \to K^+ + p) &= (0,1) + (0,-1) + (1,1) + (1,-1) \\
A(K^+ + n \to K^+ + n) &= (0,1) + (0,-1) - (1,1) - (1,-1) \\
A(K^- + p \to K^- + p) &= (0,1) - (0,-1) + (1,1) - (1,-1) \\
A(K^- + n \to K^- + n) &= (0,1) - (0,-1) - (1,1) + (1,-1) \\
A(K^+ + n \to K^0 + p) &= 2[(1,1) + (1,-1)] \\
A(K^- + p \to \bar{K}^0 + n) &= 2[-(1,1) + (1,-1)] \, .
\end{aligned}
\tag{1}
$$

The isospin dependence of forward scattering is thus due to Regge poles with I = 1. The obvious candidate is ρ, which has G = +1; we shall also consider R, which has G = -1. We write their contributions to the K^+p amplitude in the following form:

$$A_\rho(0) = B_\rho \left(\frac{s - m_K^2 - m_N^2}{s_0} \right)^{\alpha_\rho} \left| 1 - \exp(-i\pi\alpha_\rho) \right| / \sin \pi\alpha_\rho$$

$$A_R(0) = B_R \left(\frac{s - m_K^2 - m_N^2}{s_0} \right)^{\alpha_R} \left| 1 + \exp(-i\pi\alpha_R) \right| / \sin \pi\alpha_R \quad , \tag{2}$$

α_ρ and α_R are the ρ and R trajectories, at squared momentum transfer t = 0; s is the invariant total energy squared; s_0 is a scaling constant, which may be chosen arbitrarily; m_K and m_N are the kaon and nucleon rest masses. The coefficients B_ρ and B_R are related to the residues and are assumed real; the phase of each contribution thus comes entirely from the "signature factor" $[1 \pm \exp(-i\pi\alpha)]$.

In terms of the four real parameters α_ρ, α_R, B_ρ, and B_R, the forward K^-p charge-exchange cross section is

$$\frac{d\sigma}{dt}(K^- + p \to \bar{K}^0 + n)_{t=0} = \frac{m_N^2}{4\pi k^2 s} \left| A_R(0) - A_\rho(0) \right|^2 \quad , \tag{3}$$

where k is the c.m. momentum of K and N. Using the optical theorem, we also find the total-cross-section differences:

$$\sigma_T(K^-p) - \sigma_T(K^-n) = \frac{2m_N}{k\sqrt{s}} \, \mathrm{Im} \, [A_R(0) - A_\rho(0)] \tag{4}$$

$$\sigma_T(K^+p) - \sigma_T(K^+n) = \frac{2m_N}{k\sqrt{s}} \, \mathrm{Im} \, [A_R(0) + A_\rho(0)] \quad . \tag{5}$$

III. DISCUSSION

If ρ alone accounts for these isospin dependent effects, two predictions can be made at any energy (apart from predictions relating to energy dependence):

(i) $\sigma_T(K^-p) - \sigma_T(K^-n) = \sigma_T(K^+n) - \sigma_T(K^+p)$

(ii) $\frac{d\sigma}{dt}(K^- + p \to \bar{K}^0 + n)_{t=0} = \frac{1}{16\pi}[\sigma_T(K^-p) - \sigma_T(K^-n)]^2\left(1 + \tan^2\frac{\pi\alpha_\rho}{2}\right)$.

With $\alpha_\rho \approx 0.5$, the value established by other experiments (e.g., Refs. 3 and 9), prediction (ii) says that the forward charge-exchange cross section is roughly twice the "optical" lower limit. Both these predictions conflict with data.

Figure 1 shows the Brookhaven data[5] for the cross-section differences; the solid curve is a least-squares fit to these 15 points with ρ alone, taking $\alpha_\rho = 0.5$ and optimizing B_ρ. Chi-square for this curve is 70; half of this comes from one point at 8 GeV/c, but even without this point the fit to the data is bad. Allowing α_ρ to vary has little effect; chi-square drops to 69. So prediction (i) fails .

Figure 2 shows the CERN/Zurich $K^- + p \to \bar{K}^0 + n$ data at 9.5 GeV/c,[6] which indicate a forward cross section near 200 $\mu b/(GeV/c)^2$. At this incident momentum, the Brookhaven data[5] indicate $\sigma_T(K^-p) - \sigma_T(K^-n) = 2.0 \pm 0.4$ mb, implying an optical lower limit of 210 ± 80 $\mu b/(GeV/c)^2$. Prediction (ii) states that the forward cross section should be <u>twice</u> the optical limit; it is therefore unsatisfactory. The experimental uncertainity is rather large, admittedly, and this particular point is not conclusive by

itself. However, it supports our previous conclusion that ρ alone is inadequate.

The addition of R, however, simultaneously removes both contradictions. If we take $B_R \approx B_\rho$ and $\alpha_R \approx \alpha_\rho$, the ρ and R contributions to Eq. (4) tend to reinforce, while those to Eq. (5) tend to cancel, in agreement with experiment. These relations involve the imaginary part of the amplitude only. At the same time, because ρ and R have opposite signature factors, the real parts in Eq. (3) tend to cancel, while the imaginary parts add. Thus the forward charge-exchange cross section should be close to the optical limit. In fact the ρ and R contributions do not have exactly the same energy dependence, but the argument above remains qualitatively true. For a quantitative argument, we make a fit to the data.

The dashed lines in Fig. 1 show the least-squares fits with ρ and R together, fixing $\alpha_\rho = 0.5$ and $\alpha_R = 0.3$ (the latter value suggested by Ahmadzadeh). Chi-square is now only 18, a reasonable value. Allowing α_ρ and α_R to vary has little effect. The forward charge-exchange cross section corresponding to this fit, at 9.5 GeV/c, is 245 $\mu b/(GeV/c)^2$, with an uncertainty of some 10 to 20%. Note that this value is based on the total-cross-section differences alone. It is in reasonable agreement with the data (Fig. 2).

Our arguments rely on the high precision of the data, of course. If there were a systematic increase of both $\sigma_T(K^+n)$ and $\sigma_T(K^-n)$ by about 0.7 mb, the difficulties with predictions (i) and (ii) would vanish: but we know of no reason for such a correction. It would require a 50% increase in the Glauber "shadow" term to produce this effect. In applying the Glauber

formula, the real parts of the forward-scattering amplitudes are ignored in Ref. 5. For πN scattering they are known to be negligible; if for KN and $\bar{K}N$ scattering they are not negligible, the effect will be to reduce rather than increase the shadow term.

It is interesting to compare the roles of ρ and R in $K^- + p \to \bar{K}^0 + n$ and in the other charge-exchange process $K^+ + n \to K^0 + p$. In the former case the real parts tend to cancel, but in the latter their relative sign is reversed, and it is the imaginary parts that tend to cancel. So the $\rho + R$ model predicts that the forward $K^+ + n \to K^0 + p$ cross section greatly exceeds the optical limit at the energies we have been considering.

The cases of NN and $\bar{N}N$ charge exchange are analogous, as we have already remarked. In a $\rho + R$ model, only the spin-independent amplitude enters at $t = 0$. The process $p + n \to n + p$ studied by Ahmadzadeh[3] is analogous to $K^+ + n \to K^0 + p$; the imaginary parts tend to cancel and the real parts dominate. For $p + p \to \bar{n} + n$, the real parts tend to cancel, and the imaginary parts dominate.

Note that in the Regge-pole formalism, with its complex signature factors, an amplitude can change from being mostly real to mostly imaginary when one of the contributions changes sign. This kind of effect is certainly suggested by the K^-p and np charge-exchange data.[12] Other well-known mechanisms to not give such an effect in any simple way: elementary-particle exchange gives an essentially real amplitude, even with initial- and final-state absorption; direct absorption gives an essentially imaginary amplitude.

The importance of the signature factors in fitting the isospin dependence of KN and $\bar{K}N$ data, and in reconciling the apparent differences

between K^-p and np charge exchange, give some empirical support to the Regge-pole hypothesis.

ACKNOWLEDGMENT

We wish to thank Dr. David Judd for the hospitality of the Theoretical Physics Group at the Lawrence Radiation Laboratory, where this work was done.

FOOTNOTES AND REFERENCES

* This work was done under the auspices of the U.S. Atomic Energy Commission.

† Permanent address: A.E.R.E., Harwell, Berks., England.

1. A. Pignotti, Phys. Rev. 134, B630 (1964).

2. S. U. Chung, O. I. Dahl, L. M. Hardy, R. I. Hess, G. R. Kalbfleisch, J. Kirz, D. H. Miller, and G. A. Smith, Phys. Rev. Letters 12, 621 (1964).

3. A. Ahmadzadeh, Phys. Rev. 134, B633 (1964).

4. R. J. N. Phillips, Phys. Rev. Letters 11, 442 (1964).

5. W. Galbraith, E. W. Jenkins, T. F. Kycia, B. A. Leontic, R. H. Phillips, A. L. Read, and R. Rubinstein, report presented to the High Energy Physics Conference at Dubna (1964).

6. P. Astbury, G. Finocchiaro, A. Michelini, C. Verkerk, D. Websdale, C. West, W. Beusch, B. Gobbi, M. Pepin, M. Ponchon, and E. Polgar, report presented to the High Energy Physics Conference at Dubna (1964).

7. Not all the trajectories are common, of course; for example, those associated with 0^- or 1^+ mesons do not affect KN scattering.

8. For example, total cross sections are more accurately known for $\bar{K}N$ than for $\bar{N}N$ scattering. See Ref. 5.

9. We have also made Regge-pole fits to the data at other angles, in the range $0 \leq |t| < 1$ $(GeV/c)^2$, for the πN, KN, $\bar{K}N$, NN, and $\bar{N}N$ systems.

10. S. Mandelstam, Nuovo Cimento XXX, 1127 and 1148 (1963).

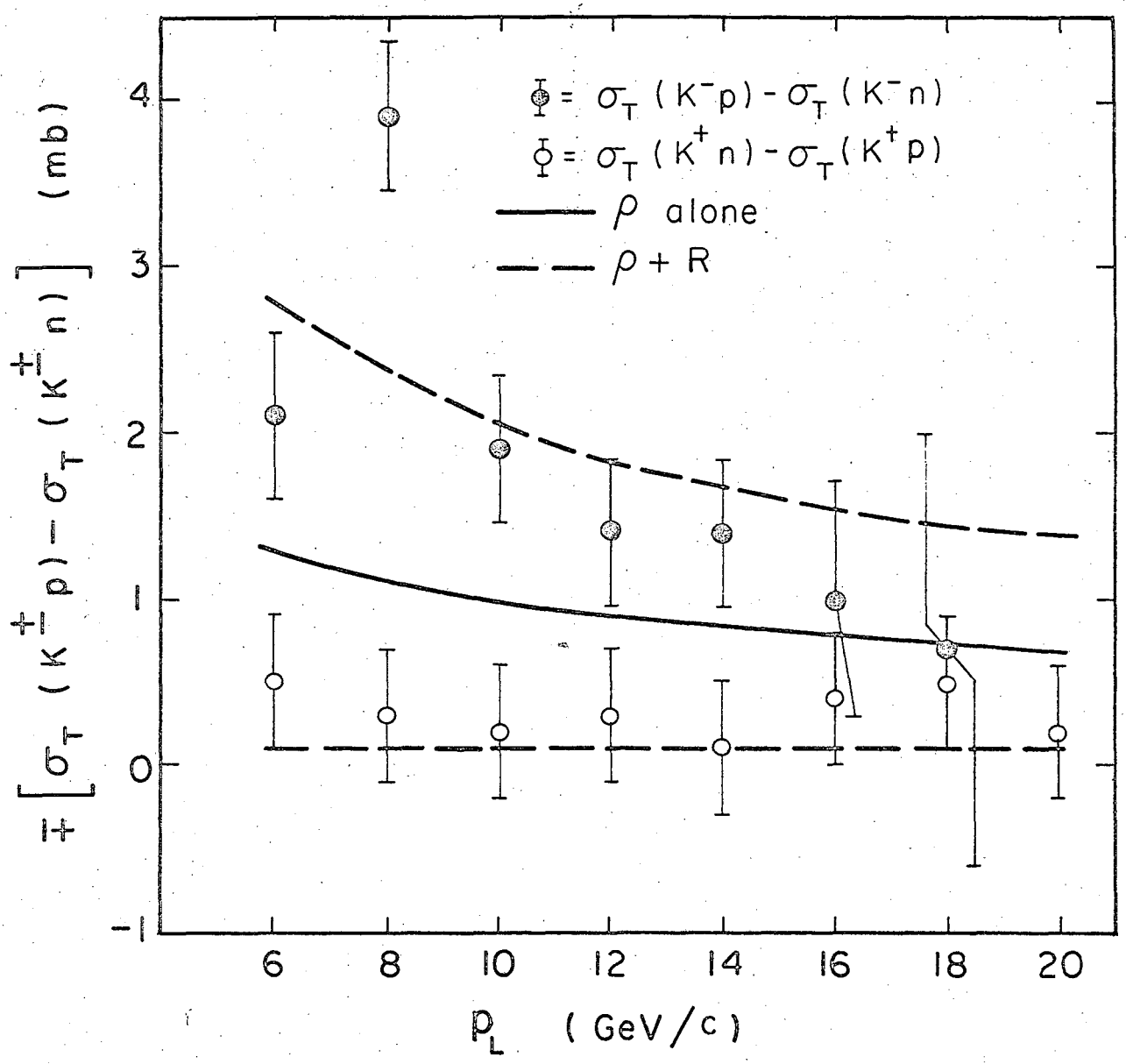
11. G. F. Chew and V. L. Teplitz, Phys. Rev. 136, B1154 (1964).

12. It will be interesting to see whether reactions $K^+ + n \to K^0 + p$ and $\bar{p} + p \to \bar{n} + n$ confirm this effect.

FIGURE CAPTIONS

Fig. 1. Total cross section differences of Ref. 5. The solid curve is the fit to both sets of data together, assuming ρ alone. The dashed curves are the fits in the two sets of data separately, assuming ρ plus R.

Fig. 2. The CERN/Zurich $K^+ + p \to K^0 + n$ differential cross section at 9.5 GeV/c.



MUB-4721

Fig. 1.

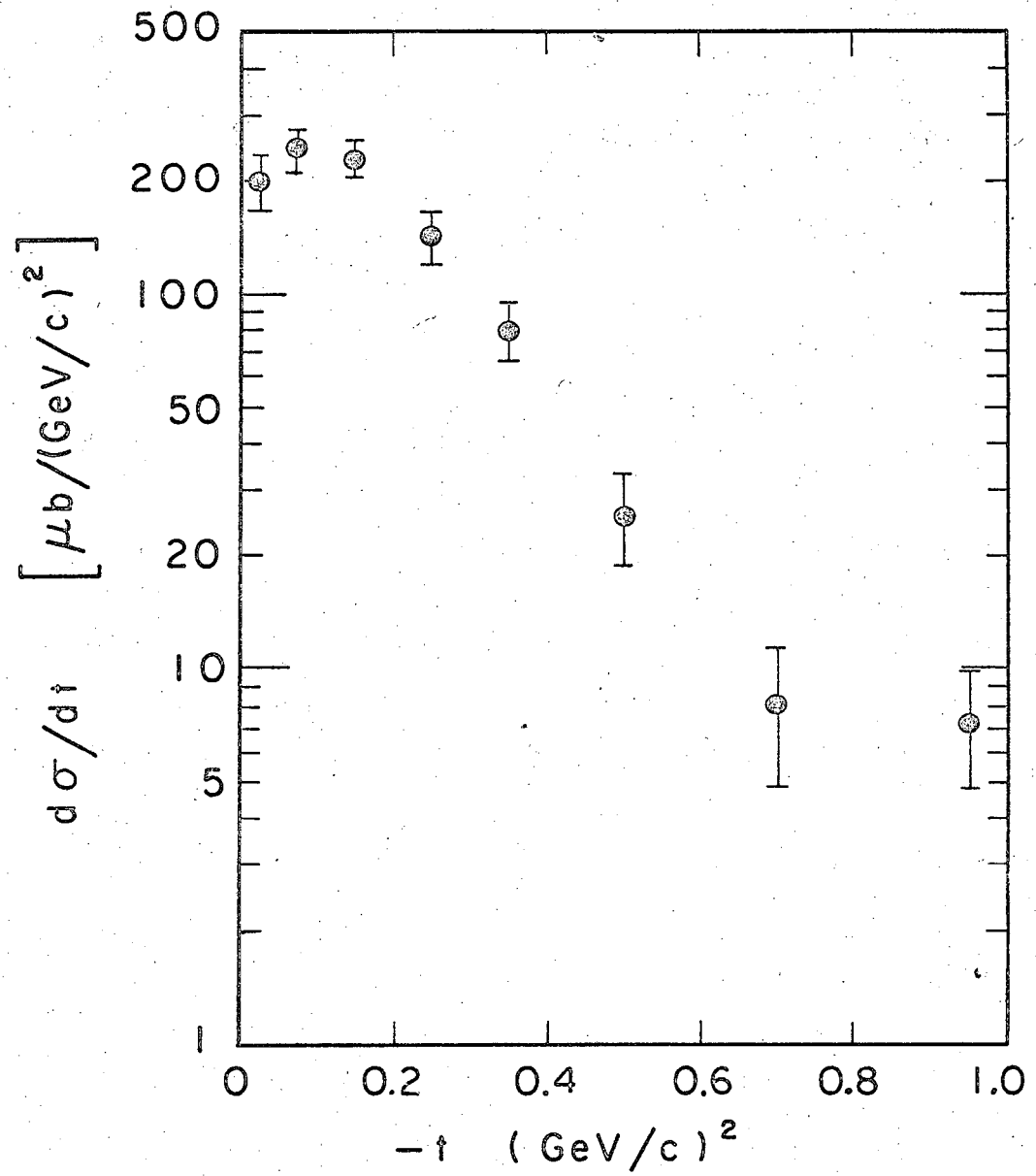

500
200
100
50
20
10
5
1
0
0.2
0.4
0.6
0.8
1.0
dσ/dt [μb/(GeV/c)²]
−t (GeV/c)²
MUB-4720

Fig. 2.

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.