tic confinement and propagation with an exponential distribution of particle pathlengths, mean pathlength = 5 g/cm$^2$ of hydrogen, and including the recent spallation cross sections of Lindstrom *et al.*,[6] yields a ratio of nitrogen to carbon in the sources of $0.07\pm 0.02$ [7] which is lower than previous estimates.[8,9] The need for reducing the amount of source nitrogen based on new cross-section measurements has been pointed out by Shapiro, Silberberg, and Tsao.[10]

This result represents the first conclusive high-energy ($\geqslant 1$ GeV/amu) measurement of isotopic composition. Together with further results for other elements at these high energies it is expected to contribute significantly to the problems of confinement, propagation, and the nature of the cosmic-ray sources.

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## COMMENTS

# Comment on High-Energy Behavior of Non-Abelian Gauge Theories

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The high-energy behavior of the sixth-order fermion-fermion scattering amplitude in the Yang-Mills theory is recalculated, and found to be qualitatively different from that given previously.

A year ago, Nieh and Yao[1] studied the high-energy behavior of the fermion-fermion scattering amplitude in the Yang-Mills theory[2] and stated that, for large center-of-mass energy $\sqrt{s}$ and fixed $t = -\vec{\Delta}^2$, this amplitude behaves as $s\ln^3 s$ in sixth order and as $s\ln^5 s$ in eighth order. We have carried out in detail the required computation in this case for the sixth order and found their result qualitatively incorrect; instead, for $s\to\infty$ with fixed $t\leqslant 0$, the spin-nonflip amplitude is determined to be given approximately by

$$\mathfrak{M}^{(6)} \sim -2^{-4}g^6 m^{-2} s[(\ln^2 s - \pi i \ln s)\vec{\tau}^{(1)}\cdot\vec{\tau}^{(2)} f_1(t) + 3\pi i \ln s f_2(t)], \tag{1}$$

where

$$f_1(t)=(\lambda^2+\vec{\Delta}^2)\left\{\int\frac{d^2k_\perp}{(2\pi)^3}\left[\left(\vec{k}_\perp-\frac{\vec{\Delta}}{2}\right)^2+\lambda^2\right]^{-1}\left[\left(\vec{k}_\perp+\frac{\vec{\Delta}}{2}\right)^2+\lambda^2\right]^{-1}\right\}^2, \tag{2}$$

$$f_2(t)=(\tfrac{5}{4}\lambda^2+\vec{\Delta}^2)\left\{\int\frac{d^2k_\perp}{(2\pi)^3}\left[\left(\vec{k}_\perp-\frac{\vec{\Delta}}{2}\right)^2+\lambda^2\right]^{-1}\left[\left(\vec{k}_\perp+\frac{\vec{\Delta}}{2}\right)^2+\lambda^2\right]^{-1}\right\}^2$$
$$-\int\frac{d^2k_{1\perp}}{(2\pi)^3}\frac{d^2k_{2\perp}}{(2\pi)^3}(\vec{k}_{1\perp}{}^2+\lambda^2)^{-1}(\vec{k}_{2\perp}{}^2+\lambda^2)^{-1}[(\vec{k}_{1\perp}+\vec{k}_{2\perp}+\vec{\Delta})^2+\lambda^2]^{-1}, \tag{3}$$

$\lambda$ is the mass of the Yang-Mills boson, $m$ is the mass of the fermion, $g$ is the coupling constant, and $\vec{\tau}^{(i)}$ are the Pauli matrices for isotopic spin of fermion $i$, $i=1,2$. Details of this computation will soon be submitted for publication.

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# Color Gluons and the Decay of the $\psi(3700)$ into $\psi(3100)$*

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The decay of $\psi(3700)$ into $\psi(3100)$ plus hadrons constitutes a violation of Zweig's rule. On the assumption that the de-excitation proceeds through the emission of Yang-Mills gluons in a color-singlet state, I predict a width of $190\pm40$ keV for this process. All parameters entering the calculation are taken from previous fits to the decay widths of the $\psi(3100)$.

The discovery of the narrow mesonic resonances at 3.095 [1] and 3.685 [2] GeV [which we call the $\psi(3100)$ and $\psi(3700)$, or $\psi$ and $\psi'$, respectively] has stimulated some intriguing applications of the twin notions of asymptotic freedom[3] and quark confinement. On the assumption[4,5] that the $\psi(3100)$ is a lightly bound $^3S_1$ state of a heavy charmed quark[6] ($c$) and its antiquark ($\bar{c}$), its narrow width into hadrons (~ 70 keV) has been ascribed[4] to the necessity for de-excitation via annihilation into three vector gluons, each one a member of an SU(3) (color) octet, whose coupling to the charmed quarks in the $\psi(3100)$ is weak. In this model, the branching ratio $\Gamma(\psi\to e^+e^-)/\Gamma(\psi\to \text{hadrons})$ provides an estimate of ~ 0.20 for $\bar{g}^2/4\pi\equiv\alpha_s$, the effective coupling strength of the color gluons to charmed quarks in charmonium.

It is clearly of interest to provide independent corroboration for the role played by the color gauge theory in explaining the narrow width of the $\psi$. In practical terms, can one find other processes in this energy range whose rate depends on $\alpha_s$ in a calculable manner? In this note, I propose that the de-excitation $\psi(3700)\to\psi(3100)+\text{hadrons}$ is such a process, and the rate predicted on the basis of $\alpha_s\simeq 0.20$ lies within the present experimental limits.

At the time of the present writing, the parameters of the $\psi(3700)$ relevant to this discussion are given as $200\text{ keV}<\Gamma_{\text{tot}}<800\text{ keV}$ [7] and $0.48\pm0.06\leq\Gamma(\psi(3700)\to\psi(3100)+\text{hadrons})/\Gamma(\psi(3700)\to\text{all})\leq 0.57\pm0.08$.[8] The lower limit corresponds to saturation by the $2\pi$ channel, and is obtained by assuming that all $\pi$-$\pi$ pairs are produced in an $I=0$ state.

It is perhaps instructive to show first why con-