THESIS ABSTRACT

学 位 论 文 摘 要 汇 编

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目　　录

高能重粒子碰撞中的次级碰撞过程与末态 k^+/π^+ 比例的升高

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摘　要

高能重离子碰撞是指每核子能量大于10GeV的较重的原子核之间的碰撞，通过高能量重离子碰撞实验，人们可以研究高能原子核碰撞的多重产生机制，可以研究高温高密度的条件下是否存在格点规范理论所预言的从核物质到夸克胶子等离子体的相变.这是高能重离子碰撞研究的两个互相关联的方面.高能原子核碰撞是一个涉及到强相互作用的大尺度行为和禁闭机制的复杂的多体问题，因此，人们无法应用微扰 QCD 理论来处理这方面的具体问题.目前对高能重离子碰撞的理论研究大都是依据已有的一些强子－强子碰撞的唯象模型结合强子－原子核碰撞的实验规律来建立起高能原子核－原子核碰撞的唯象模型，通过把理论模型的计算结果与近年来的 BNL(14.5GeV)和 CERN(200A.GeV)的重离子碰撞的实验数据相比较，人们可以不断加深对高能量重离子碰撞的多重产生机制的理解和认识.只有在对大量的常规原子核碰撞过程的现象有了可靠的描述的基础之上，人们才有可能从实验数据中分离出反常的现象，分析夸克胶子等离子体的形成信号才会有可靠的保证.

对一个确定的瞄准参数的原子核－原子核碰撞事例，通常有多个核子参与相互作用，如何把只是涉及两个粒子的强子－强子作用模型推广到原子核－原子核碰撞过程中去，是一个非常重要的问题.为了得到原子核－原子核碰撞得最后结果，还需要对所有可能的不同瞄准参数的事例进行几何平均.

本论文的工作之一就是讨论了原子核－原子核碰撞的参加者核子模型，并且根据参加者核子模型对 CERN 的 O(200A.GeV)与不同靶核碰撞在中心快度区和靶核碎裂区的横向能量分布进行了计算和研究，结果表明横向能量分布随靶核质量增大而变宽这一现象基本上是由于原子核的几何效应造成的.我们对不同的靶核只用了一套与靶核无关的参数即每个参加者核子贡献的平均横向能量就基本可以预 CERN 的 NA35 组和 NA34 组的实验数据符合得很好.然而，在中心快度区我们得到的每个参加者核子贡献的平均横向

能量比从相应的核子－核子碰撞推出的值要略大一些.在靶核碎裂区,如果我们把每个靶参加者核子贡献的平均横向能量取为对随靶核增大而增加,那么,计算结果就可以与实验数据更好地符号.我们认为这表明在原子核碰撞中存着一些次级碰撞过程,而且次级碰撞的影响主要在靶核碎裂区.

通过对 WA80 实验组的数据进行分析，人们确实可以发现在原子核碰撞过程中存在着次级碰撞过程的迹象．因此,要完整地描述高能原子核碰撞,在理论模型中应该包含次级碰撞过程．根据强子－原子核碰撞的实验结果人们可以发现,发生次级碰撞的次级粒子的能量都较低,较高能量的次级粒子都是在原子核外形成的,没有发生次级碰撞过程．这说明次级粒子在其自身静止系中需要一定的固有形成时间.

本论文的另一研究工作就是通过考虑次级粒子的形成时间，自然地将参加者核子模型发展成为可以包括次级碰撞过程的模型．并且根据此物理图像,计算了高能原子核－原子核碰撞过程中由于 PI 介子与核子的次级碰撞过程而导致的末态的 K^+/π^+ 比例 的增加．BNL 的 E802 组在 SI(14.5A. GeV)与 AU 的中心碰撞中发现 K^+/π^+ 比例约为 20%,远远高于 PP 过程中相应的比值(5%)．而 K^+/π^+ 比例的显著升高被认为是在高能重离子碰撞中形成高重子数密度的夸克－胶子等离子体的可能的形成信号．为了最终能够确认或排除一个夸克－胶子等离子体的信号,人们必须对其他可能的机制造成为的影响进行深入的理论分析.本文的研究结果表明仅仅由于 π 介子与核子的次级碰撞过程而导致的 K^+/π^+ 比例的升高还不足以解释 E802 组的实验结果.

Phenomenological Study of High Energy Heavy－ion Collision

Name: Ren Jianglong
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ABSTRACT

Relativistic heavy－ion collisions (RHIC) are the collisions between two heavy nuclei with the energy per nucleon greater than 10 GeV. The aims of studying RHIC are to investigate the multi－paticle production mechanism in the nuclear collision and to explore the existence of the Quark－Gluon－Plasma (QGP) at the high temperature and high density as predicted by the Mont－Carlo calculations of the Lattice Guage Theory. The high energy nucleus－nucleus collision is a very complicated many－body problem involving the long distance behavior of the strong interaction and the confinement mechanism of partons. Now the theoretical studies about the high energy nucleus－nucleus collisions are mostly based on the phenomenological models of the hadron－hadron collision combined with the experimental features of the hadron－nucleus collision. Through the comparisons between the results of theoretical models and the recently available experimental data of BNL(14.5 A. GeV) and CERN(200 A. GeV), people can understand more about the multi－partical production mechanism in the high energy nucleus－nucleus collision. After one has a better description of massive experimental data of conventional nuclear collisions, it is possible to seperate new phenomena and to analyse the signatures of the formation of GGP.

There are usually more than two nucleons involved in the nuclear collision at a fixed impact parameter. It is a important problem to extrapolate the models of the hadron－hadron collision to the nucleus－nucleus collision. To get the final results of the nucleus－nucleus collision , one must make the geometrical average over all possible impact parameters.

One reseach work of this dissertation is to discuss the paticipant nucleon model of the high energy nucleus – nucleus collisions. We have calculated the distributions of the transverse energy in the midrapidity and the target fragmentation region for the projectile O (200A. GeV) colliding with different target nuclei dased on the participant nucleon model. Our calculations show that the distribution of transverse energy becomes wider as the target nuclear mass increases, which is due to the nuclear geometry . We have used a set of parameters – the mean transverse energy contributed by each participant nucleon. The value of the parameters are independent of target nuclei. Our calculations are consistent with the experimental results of the NA34 and NA35 collaborations of CERN very well.

But , in the midrapigity region the mean transverse energy contributed by each participant nucleon is slightly greater than the corresponding value in the nucleon – nucleon collision. While in the target fragmentation region, our calculations can fit to the experimental data much better, if we choose the mean transverse energy contributed by each target nucleon slightly depending on the mass of the target nuclei. These imply the existence of secondary collisions in the nucleus – nucleus collision, especially in the target fragmentation region.

By analysing the data of WA80 collaboration, we find the indication of the existence of secondary collisions in the nuclear collisions. Therefore, it is neccessary to incorporate the secondary collisions in theoretical models to describe the high energy nucleus – nucleus collision. According to the experimental data of high energy hadron – nucleus collisions, the particals which participate the secondary collisions have relatively low energies. The particals with high energy are formed outside the target nuclei, so they do not participate the secondary collision. These imply that secondary particals need a certain proper formation time in their own rest system.

Nother reseach work of this dissertation is to analyse the effect of secondary collisions on the K^+/π^+ ratio in RHIC. By considering the formation time of secondary particals we have developed the participant nuceon model incorperating the secondary collisions naturally and calculated the increase of the K^+/π^+ ratio caused by the secondary collisions of pions with target nucleons. The E802 collaboration

at BNL found that in the central collisions of Si(14.5A. GeV) with Au the K^+/π^+ ratio is about 20% which is far above the corresponding value in p−p collisions (about 5%). The enhancement of the K^+/π^+ ratio is believed to be a possible signature of Quark−Gluon−Plasma in RHIC. To confirm or exclude a signature of QGP, people must analyse the influence of other non−QGP mechanisms carefully. Our calculations show that the secondary collisions of pions with the target nucleons is not enough to explain the data of E802 collaboration.

BEPC 正电子源优化

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摘　要

正电子产额，定义为 I_{e+}/I_{e-} 或 I_{e+}/I_{e-}，E—(GeV)，是正电子源的一个重要物理量，它的高低直接关系到正电子加速器的优劣。正电子源的优化就是使给定的条件下，系统及其参数选择最佳，正电子产额最高。自从 1958 年 Stanford 建成世界上第一台正电子加速器后，由于正电子束的多种用途，世界各大实验室都先后建造了自己的正电子加速器。由于系统及其参数的不同，他们都有一套自己的优化方案。本文就是为 BEPC 正电子源选择一套优化方案，直接为工程服务。

使用 Monte－Carlo 技术，程序包 EGS，我们对高能电子在介质中的电磁级联过程进行了模拟，提出了 6mm 厚的 Ta－10W 复合靶方案。对出靶正电子在相空间分布进行了讨论，阐述了靶后匹配磁场的作用和捕获节 RF 相位的选择原则。用全粒子运动方程(LILY 程序)，对正电子在靶后匹配，聚焦和加速系统中的运动进行了跟踪，得到目前状况下 BEPC 正电子产额为 3.9 ‰，并对产额对各参数的依赖关系进行了计算和分析，得到一些非常有用的结果。譬如捕获节加速相位，打靶电子束的截面同正电子产额的关系，如果选择不当，就很难到正电子。如果把目前状况下匹配磁场峰值移到靶平面，过渡线圈激励电流从 700A 提高到 1200A，正电子产额可提高约 35% 。计算还证明，即使系统不做任何改动，仍可通过增加电子枪电流方法来提高正电子束流。我们还计算了系统安装误差对正电子束流输运的影响，提出了磁元件的安装公差：平移公差 $\Delta X < 0.1$mm，旋转公差 $\Delta\alpha < 2$mrad。匹配渐变磁场下降快慢程度，匹配和聚焦磁场的强弱对正电子产额的影响，我们也进行了计算，得到预期的结果。

我们还对弱流正电子束的测量和束流发射度，能散同时测量方法做了简介，用束测实验对部分理论计算结果进行了检验，正电子产额 3.2 ‰，计算同实验吻合较好。正电子束流实验还证明，对 BEPC 注入器，不用正负电子分离装置，也能对正电子束流进行监测，只要仔细调节捕获节 RF 相位，使正电子束能谱特性最佳，这时电子的能谱特性很差，后面的"三合一"透镜组可把大部分电子偏掉。

Optimization of BEPC Positron Source

Name: Pei Guoxi
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ABSTRACT

The quality of a e^+ accelerator is directly symbolized by the positron yield, a very important parameter of positron source defined by I_{e^+}/I_{e^-} or $I_{e^+}/I_{e^-} * E$ —(GeV). Optimization of positron source means to find out the highest efficient yield by choosing the system and its parameters under a given set of conditions. Because of good quality e^+ beam has many applications, several laboratories in the world began to build positron accelerators since Stanford built the first one - Stanford Mark III accelerator in 1958, such as Saclay, Saskatchewen, KEK, FRASCATI and SLAC etc. And they all have themselves optimization work since the systems and parameters are different. My work is directly contributed to BEPC project by choosing an optimization plan for BEPC positron producing system.

We use EGS program to simulate the electron - gamma shower of high energy electrons in a medium, and find 6mm thick Ta - 10W complex target is the best choice for 150 Mev bombarding electrons.

Positron distributions in phase space at the downstream of the target are found, the function of matching field and capture section RF phase's choosing rule are described. e^+ motions are traced by a numerical procedure of particle motion equations in the matching, focussing and accelerating systems, the yield is about 0.0039 at the present status. We have also calculated the yield's dependence upon system parameters, and gotten some useful results, such as the relations between e^+ yields and RF phase of acceleration tubes, cross sections of e^- beam which strikes the target etc. No positrons will be got if you don't choose or adjust them proporly. If the position of peak field of matching device moves to target

and driving current of the bridge coils increase from 700A to 1200A, we can hope to obtain a yield gain of about 35%. Calculations have shown that, we can get more positrons by increasing electron gun current, say 10A, without changing any component of BEPC injector. From the view point of optimizing e^+ source, we have calculated the effect of the tapered solenoid's misalignment on e^+ yield, and gotten the translational installation tolerance is 0.1mm and rotational tolerance 2mrad which is in agreement with SLAC result. The slope and magnitude of tapered matching field's effect on e^+ yield have been calculated, and the results are expected.

An approach of both beam emittance and energy spread measurements at the same time and the measurement of weak positron beam current are discussed. Some of the calculated results have been checked by experiments, the positron yield is 0.0032. Both are in reasonable agreement. Positron beam experiment have also proven that, we can monitor and measure e^+ beam without using e^+, e^- seperator device. Only one thing needs to do, carefully adjust capture RF phase, so the positron energy spectrum will be fine while electron's bad, and during transportation, lots of electrons will be lost.

关于自发破缺机制和 Higgs 粒子性质的研究

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摘　要

本文的内容是关于自发破缺机制和希格斯粒子现象学的研究。

第一章　介绍了希格斯机制以及关于有效势的辐射修正产生破缺的 Coleman Weinberg 定理，在此基础上讨论了由真空稳定性要求得到的关于 Higgs 粒子的质量限，并且介绍了多重 Higgs 模型。

第二章　较详细地介绍了能量动量张量的迹反常和低能定理，以及有关的 Higgs 粒子与核子或 π 介子的等效耦合。

第三章　介绍了对于不同质量范围的 Higgs 粒子的一些主要的衰变和产生过程及其唯象性质。

第四章　回顾了有关寻找 Higgs 粒子的实验状况。

以下几章概况地总结了作者在导师指导下进行的有关工作。

第五章　研究了一种具有定域标度规范对称性的与引力耦合的非标准弱电模型，讨论了自发破缺机制在这种理论中的意义并且讨论了在吸收了 Higgs 场的模这一自由度后，有质量标度规范场的质量的宇宙学限制。提出了用自发破缺机制来代替近似的标度不变性的破缺的观点。将这一观点应用到对极早期宇宙的讨论中并指出由引力理论中的瞬子解— Wormhole 解所构成的时空拓扑可以是标度不变性破缺的结果。

第六章　分析了目前关于质量小于两倍 μ 轻子质量的 Higgs 粒子的实验，指出需要更确定的与 Higgs 粒子衰变模式无关的实验检验，研究了在核碰撞中 π 介子的阈下产生实验中寻找轻的电中性的标量或赝标 Higgs 粒子的可能性以及由此可以给出的对 Higgs 粒子与核子耦合强度的上限。

第七章　讨论了双圈图计算中遇到的一些特殊问题的处理方法，包括对费曼振幅的计算，紫外发散，红外发散和共线发散的维数正规化方案等，在大费米子质量的极限下，给出了对 Higgs 粒子湮灭到两光子过程的 QCD 修正的计算。

On Spontaneous Symmetry Breaking and the properties of the Higgs Particle

Name: Zheng Hangqing
Supervisor: Hu Ning
Degree: Doctor

ABSTRACT

Part of this paper is devoted to study a kind of non-standard electroweak model containing locale scale invariance. The cosmological constraints on the mass of the scale gauge boson which becomes massive after symmetry breaking by absorbing the last degree of freedom of the Higgs field is given. It is studied that the instanton(wormhole) configration of space-time topology in quantum gravity may be a consequence of broken approximate scale invarance. The possibility of seaching for light neutral scalar or pseudoscalar Higgs particle from subthreshold neutral pion production experiments in nucleus-nucleus collision is also investigated. Finally, first order QCD correction to the process of the Higgs particle decays into two photons is calculated, the speciality of two loop calcuation is also discussed.

非微扰 QCD 中手征对称性自发破缺及强子结构的研究

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学　位: 博　士

摘　要

本文的第一部分回顾了目前关于非微扰 QCD 中手征对称性自发破缺及强子波函数的研究. 其中包括 Nambu－Jona－Lasinio 理论, 三种流行的处理手征对称性自发破缺的有效势理论, 还介绍了关于夸克有效质量的计算, 短程力及线性禁闭势分别对手征对称性自发破缺的影响等方面的研究现状. 本文还简单介绍了 QCD 求和规则及背景场方法处理非微扰效应的基本思想及其它们通过真空凝聚定强子波函数的方法, 介绍了检验强子波函数的一些物理过程以及目前存在的一些关于强子波函数的唯象模型. 本文的第二部分是作者的研究成果. 在关于手征对称性自发破缺的研究中, 作者提出了一种用关于夸克凝聚的自洽方程确定重整化群不变的夸克凝聚数值的方法, 计算了发生动力学自发破缺强耦合常数的阈值. 在单圈、双圈近似下分别计算了夸克凝聚的数值, 得到了合理的结果. 同时给出了一种发生动力学自发破缺的图象. 作者还给出了存在与胶子凝聚有关的非微扰核时的 Schwinger－Dyson 方程的形式, 并用这一方程计算了夸克凝聚及发生动力学自发破缺的耦合常数的阈值, 得到了与用自洽方程讨论时相符的结果, 还讨论了非微扰核对手征对称性自发破缺的影响. 另外, 作者还利用 SD 方程与 Slavnov－Taylor 等式讨论了中程力可能对动力学自发破缺产生的效应. 在 Brodsky－Huang－Lepage 提出的介子波函数基础上, 我们给出了膺标介子和矢量介子波函数的一般形式, 并讨论了它们的性质, 还把这种波函数应用到重味介子 D、B 的半轻子及非轻子衰变过程中, 修正了目前国际上流行的 Bauer－Stech－Wirbel(BSW)的波函数模型, 给出了与实验自洽的理论结果并预言了尚未存在实验过程的分支比, 还给出了 K－M 矩阵 V　的上限, 这一上限比BSW 模型的值要小. 另外, 作者还将强子有结构的观点用于 W, Z 粒子, 讨论了复合模型对 Z 粒子强子衰变宽度的影响. 这种影响使 Z 的强子衰变宽度比标准模型的预言值要小. 这种差别可望在 LEP 上高精度的 Z 粒子性质测量中得到验证.

On Chiral Symmetry Breaking and Hadromic Structure in Nonperturbative QCD

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Degree: Doctor

ABSTRACT

This thesis is divided into two parts. In the first part we review the study on chiral symmetry breaking and hadronic wavefunction in QCD. After a brief review of the famous Nambu－Jona－Lasinio model, we discuss some fundamental aspects of alternative forms of the effective potential for composite operators and we look at the nature of their stationary points. We also include the calculations of quark dynamical mass. In addition, the status of the study on the range of forces responsible for chiral symmetry breaking is given. The contributions to chiral symmetry breaking both from short－distance range force and from linear confinement force are reviewed respectively. We also discuss the basic ideas of QCD sum rule and background field theory, their methods of determining hadronic wavefunctions by considering quark condensate and gluon condensate. Some physical processes which are effective to test hadronic wavefunctions are also discussed. Furthermore, we give the forms of some existing models of hadronic wavefunctions. The second part of the thesis is devoted to some research achievements of the author. We use the consistent equation for quark condensate in the chiral limit to determine the remormalization group invariant quark condensate. A critical point at which the strong coupling constant is big enough for chiral symmetry breaking to take place is found. They are analysed at one－ and two－loop levels respectively. An intuitive picture of the condensation above the critical coupling constant is discussed. We also improve the SD equation by adding the nonperturbative kernel associated with gluon condensate. The solution for the quark condensate from the SD equation is in agreement with that

obtained from the consistent equation for quark condensate. It is also found that the intermediate range kernel makes the critical coupling constant above which chiral symmetry breaks smaller and increases the value of quark condensate. Based on the meson wavefunctions proposed by Brodsky – Huang – Lepage, we determine the wavefunctions for pseudoscalar and vector mesons and discuss their properties. We also modify the BSW model by applying these wavefunctions to exclusive decays of D and B mesons and obtain the results consistent with experiments. Predictions for unmeasured processes are also given. Comparisons between our results and those of BSW are given. An upper limit of $V_{}$ which is smaller than that of BSW model is found. In addition, we apply the ideas that hadrons have structure to W and Z bosons and find that the composite model corrections to Z hadronic decays make the width smaller than that of the standard model. This may be tested on LEP by the high statistic measurements of Z properties in the future.