THESIS ABSTRACT

学位论文摘要汇编

(1992 年)

中国科学院高能物理研究所

INSTITUTE OF HIGH ENERGY PHYSICS
ACADEMIA SINICA

THESIS ABSTRACT

学 位 论 文 摘 要 汇 编

高能物理研究所学位委员会
一九九三年五月

目　　录

用高山乳胶室研究超高能核作用

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摘　要

用大面积高山乳胶室观测宇宙线超高能核作用，是探索 $10^{14}-10^{17}$V 能域核作用规律和寻找新现象的重要手段之一。本工作在参与中日合作西藏甘巴拉山乳胶室实验各年度 X 光片的包装、处理和乳胶室拆室、建室及维护工作的同时，对大族事例（$\Sigma E_r \geq 200$TeV）及小族事例（$20\text{TeV} \leq \Sigma E_r \leq 200\text{TeV}$）进行了扫描与测量，获得大族事例 10 个，小族事例 68 个，其中 K7492 事例的能量高达 $\Sigma E_r = 3079.2$TeV。

为分析所获得的实验数据，我们在模拟计算中引入 UA7 实验的最新结果，对 ISR 和 SPS 非弹过程膺快度分布的实验数据进行最佳参数拟合直至其最高能量 $\sqrt{S} = 900$GeV，假定次级粒子多重数分布近似遵循 KNO－Scaling，横动量近似遵循指数分布，构造了一个适合于分析乳胶室实验结果的强子—强子核相互作用的参数化模型。在重核为主的混合初级宇宙线成分假定下，将参数化模型外推到超高能区，应用于超高能宇宙线粒子在大气中行为的 Monte－Carlo 计算（标记为 MPI 模型，并与本工作所获得的实验数据综合他人测量结果）作了广泛的比较与讨论，以研究超高能核作用的规律。利用 MPI 模型，本工作同时细致地讨论了碎裂区次级粒子平均横动量下降对乳胶室实验模拟计算结果的影响。

对 K7492 事例的分析表明，传统的族事例集团化方法和多心结构事例选择标准的应用存在着一定的局限性。我们对传统的集团化方法进行了改进，采用扫描集团化方法对族事例进行集团化处理，重新定义了多心结构事例的选择标准。通过多心结构事例实验数据（综合他人测量结果）与模拟计算结果的比较，研究超高能区核相互作用的规律。本工作同时提出了用主集团的能量份额来辨认由初级质子所产生的大族事例（$\Sigma E_r \geq 500$TeV），该方法的应用对于初级宇宙线成分的研究是很有意义的。

对 $\Sigma E_r = 20-200$TeV 能区小族事例中的小 <R> 事例进行了分析。通过实验数据（综合他人测量结果）与模拟计算结果的比较，发现小 <R> 事例出现的频率高

出模拟计算值一倍左右，且不含强子。本工作不认为该现象联系于新的物理，尝试用初级宇宙线 γ 来解释高出模拟计算所预言的小 <R> 事例，并利用族事例的平均横向扩展 <R> 作为挑选由初级 γ 所产生的族事例的标准，对大于 10^{14}eV 能区初级宇宙线中初级 γ 的含量及能谱形式作出了估计。

利用高山乳胶室观测超高能大天顶角宇宙线 μ 子(国家青年科研基金资助课题)，本工作同时对与超高能核作用特征及初级宇宙线化学成分紧密相关的大天顶角超高能宇宙线 μ 子进行了扫描和测量，在天顶角 $M(=\mathrm{tg}\theta)\geqslant 2.5$ 的范围内共获得 23 个 μ 子事例，测量事例 126 个(综合他人扫描结果)，尝试用马鞍型曲线来确定 μ 子簇射的能量，并对 μ 子在乳胶室内的行为进行模拟计算，对所获得的 μ 子事例(综合他人扫描结果)进行了分析，在 $E_\mu\geqslant 2$TeV 的范围内给出了海拔 5500 米处 μ 子的流强、簇射能谱与簇射天顶角分布，为进一步研究超高能核作用规律和初级宇宙线成分打下基础。

Studying the Nuclear Interaction in Superhigh Energy Region with Mt. Emulsion Chamber

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ABSTRACT

Observing the superhigh energy nuclear interactions of cosmic rays with the large area Mt. emulsion chamber is an important way to understand the law of nuclear interaction and to search for new phenomena in the energy region $10^{14}-10^{17}$eV. Author was involved in all kinds of technical works in preparation for the emulsion chamber experiment on Mt. Kanbala in Tibet (China-Japan Collaboration), such as packing and disposing of X-ray films, building, disassembling and maintaining the emulsion chambers etc., meanwhile author has also participated in scanning and measuring the events. In the result, 10 big family events ($\Sigma E_\gamma \geq 200$TeV) and 68 small family events ($20\text{TeV} \leq \Sigma E_\gamma \leq 200\text{TeV}$) were obtained, among them the largest event K7492 has the energy as high as $\Sigma E_\gamma \sim 3079.2$TeV.

In order to analyse the experimental data obtained, we put the recent results of UA7 experiment into simulation calculation, assuming that the multiplicity distribution of secondary particles in nuclear interactions approximately follows the KNO Scaling, and transverse momentum approximately follows $f(Pt) = P_t e^{-\beta p_t}$ (where β is a constant), by best fitting the pseudorapidity data from ISR and SPS in inelastic processes, a hadron-hadron nuclear interaction parametrization model has been constructed that is suitable to analyse the experimental results of Mt. emulsion chambers. Under the assumption that heavy nuclei are dominant in the mixed primary cosmic rays, the hadron-hadron nuclear interaction parametrization model was extrapolated to superhigh energy region to describe the behavior of

superhigh energy cosmic ray particles in the atmosphere (denoted as MPI model), the simulated results were compared with the experimental data obtained by this work (meanwhile synthesizing the experimental data from other peoples) in details. At the same time, the influences on simulated results from the falling of mean transverse momentum of secondary particles in fragmentation region were also discussed in details.

Analyses of K7492 event showed, the application of traditional clustering method and criterion of multi-core events has been limited in a certain extent. We improved the traditional clustering method, clustered the family events in the scanning way, redefined the criterion of multi-core event. Through analysing the experimental data of multi-core events (synthesizing the experimental data from other peoples), and comparing the experimental results with simulation calculation, the nuclear interactions in the superhigh energy region were studied. Simultaneously, the method of using the energy fraction of main clusters to distinguish the big family events ($\Sigma E_\gamma \geqslant 500$TeV) that is produced by primary proton was proposed by this work, it is significant in the understanding of primary cosmic ray composition.

The small family events in the energy region ($20\text{TeV} \leqslant \Sigma E_\gamma \leqslant 200\text{TeV}$) were analysed, through the comparison of experimental data (synthesizing the experimental data from other peoples) with simulation calculation, we discovered that the fraction of events with small $<R>$ (mean transverse spread of family event) is abuot a factor of two higher than the Monte Carlo expectation, and no hadron in it. We tried to use the primary cosmic ray p to interpret the excess of samll $<R>$ events. At the same time, using the $<R>$ of family event as the criterion to select events which are produced by primary γ, the energy spectrum of primary p , and the fraction of primary p in primary cosmic rays were estimated.

Observing the large zenith angle cosmic ray muons in the superhigh energy region with Mt. emulsion chamber (supported by the National Youth Scientific Research Foundation). Large zenith angle cosmic ray muons in the superhigh energy region which have close relation with nuclear interaction characteristics and primary cosmic ray composition, were scanned and meas-

ured. In total 23 muon events were obtained in $M(=tg\theta \geqslant]2.5$ region, 126 muon events (synthesizing the scanning results of other peoples) were measured. The muon shower energy was determined by saddle-shape curves, and the behavior of muons inside emulsion chambers was simulated, muon events got by this work (meanwhile synthesizing the scanning results of other peoples) were analysed. The intensity of muons, the shower energy spectrum and the zenith angle distribution of muon showers on the altitude of 5500m above sea level in the energy region $E_\mu \geqslant 2$TeV were shown, which laid a foundation for further study of nuclear interaction and primary cosmic ray composition in the superhigh energy region.

高能物理数据处理中的形状分析方法

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摘　要

本文研究高能物理数据分析中的形状分析方法．形状分析方法是建立和分析形状的明确描述的数学方法．高能物理数据分析中有两个典型的问题可以应用形状分析方法．它们是发射度形状分析和谱仪径迹重建．

实测发射度形状中包含了杂质离子的发射度形状，我们就是要利用形状分析方法消除杂质离子的发射度形状．针对发射度形状分析问题，我们所做的努力如下：

1．利用链码串描述发射度形状的边界．

2．从边界点中抽取对理解形状起关键作用的点，从而获得形状的多边形描述．

3．把描述形状的多边形分割成一组基本凸多边形．为了克服干扰信号对分割的影响，我们引入凸度的概念．在证明了凸度的几个数学性质后，我们确信凸度可以作为一种控制分割过程的准则．凸度的实际应用也说明了这点．

4．利用语法分析方法和关系结构分析法分析形状的结构，并比较了两者的不同．研究了简化关系结构计算的问题．

5．通过对模拟和实际数据的处理，证明形状分析方法对消除杂质离子的发射度形状有明显效果，85%以上的杂质离子发射度形状能被消除．形状分析法使束流诊断达到了智能化的水平．

谱仪数据分析要求径迹重建速度要尽可能地快，我们就是利用形状分析方法加快径迹重建速度．针对谱仪径迹重建问题，我们所做的努力如下：

1．通过对螺旋线最小二乘拟合原理的讨论，我们确信加快径迹重建的关键是 xy 平面的径迹重建，而 xy 平面的径迹重建的关键是将触发的漂移室单元分组，使每组中的单元都对应同一条径迹．完成单元分组计算量最小的方法是预先把可能的单元组合都求出，形成径迹字典．

2．我们提出了一种构造径迹字典方法，这种方法不对漂移室单元空间分布对称性附加任何前提条件．

3. 针对径迹字典寻找短径迹的弱点，我们提出了一种径迹生长规则方法. 利用这种径迹生长规则，寻找径迹就是一个在确定的树状径迹生长规则控制下触发单元从漂移室内单元层生长到外单元层的过程.

4. 为了确定径迹生长规则和克服漂移单元空间不均匀的问题，我们提出了一种新的描述单元间连接关系的连接码. 利用这种连接码获得了北京谱仪主漂移室的径迹生长规则.

5. 提出了径迹的连接码表达式描述方法，并讨论了获得这种表达式的方法. 这种表达式的语法结构体现了径迹的分支结构.

6. 我们为北京谱仪主漂移室实现了基于径迹字典的径迹重建法和基于径迹生长规则的径迹重建法. 对大量径迹重建的结果表明我们提出的径迹生长规则法比现行的计算法能提高速度约60%.

本文所研究的形状分析方法在数据处理中有广泛应用. 例如，在复杂波形分析中，可以先用形状分析法分析复杂波形的结构，然后再作相应的处理，在测量数据的聚类问题中，可以先把问题转化为一个涉及形状结构分类的问题，然后利用形状分析方法加以解决. 从长远看，本文所研究的形状分析方法是进一步实现数据处理智能化的基础.

Applying Shape Analysis Methodes to the Data Analysis Problems in the High Energy Physics Data Processing

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ABSTRACT

This dissertation concentrates on applying shape analysis methods to the data analysis problems in the high energy phyiscs data processing. The shape analysis methods concern the construction and analysis of explicit and meaningful representation of shape. In the field of the high energy phyiscs data processing, there are two typical problems which involve the shape analysis problems. They are the emittance shape analysis and track reconstruction.

The practical measurement of particle beam emittance may contain several overlapping ellipses due to kinds of differnt ions. Among these ions, only one kind of ion is needed, and the rest kinds of the ions can be regarded as impurity ions. We use shape analysis methods to identify the emittance ellipses caused by impurity ions and remove them. Such a procesing will result in a resonable estimate of beam emittance. The highlights of the research are as follows:

1. to represent the contour of the measurement emittance shape in chain codes.
2. to extract the key points from the contour which are considered to be of significance in the understanding of the shape.
3. to decompose the shape into a set of basic convex polygons which are crucial to the representation of the structure of the shape. A new concept—convexity, is introduced to facilitate the decomposition process.

The mathematical properties of the convexity are proved.

4. to analyze the structure of the emittance shape in both syntactic approach and relational approaches.

5. to use the developed methods to process the simulation data and practical measurement data. The processing results show that a great part of the emittance shape(more than 85%) due to impurity ions can be removed. The processing is not sensitive to the noise.

Tracks are the trajectorys of charged particles travelling through a main drift chamber. A track is associated with a set of drift cells of the drift chamber which are triggered by the track. The track reconstruction involves the identifying the sets of drift cells which constribute to specific tracks respectively. Since the tracks are circular arcs passing through the origin of the coordiantes system, the patterns of the drift cells which may form tracks are restricted We employ the shape analysis methods to make use of the restriction on the patterns of the drift cells to speed up the track reconstruction process. The highlights of the research are as follows:

1. to analyze the advantages and disadvantages of current available methods: arc calculation method and the track dictionary method.

2. to propose a new way to generate track dictionary which contains all the possible patterns of drift cells.

3. to propose the track - growth model to accomplish the track reconstruction task. In this model, the track reconstruction is regarded as a track growing process from inner layer of main drift chamber to its outer layer. This growing process is controlled by a set of growth rules which guarantee that outcome of the growth process is a circular track.

4. to propose a scheme to represent linkage relations between drift cells. Based on the scheme, track growth rules can be organized in a tree data structure.

5. to propose a new way to represent the structure of tracks.

6. to compare the track growth method to the currently used methods. The comparison shows that the track growth method is about 60% faster than the arc caculation method and about 10% faster than the track dic-

tionary method.

The shape analysis methods develped in this dissertation have a wide range of applications in the data analysis problems, such as waveform analysis and data clustering. This research can be the basis for the further development of intelligent data analysis.

10^{15}eV– 10^{17}eV 广延空气簇射研究和宇宙线源寻找

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摘　要

超高能γ点源寻找在宇宙线起源研究中具有重要意义。广延空气簇射(简称 EAS)阵列技术则是探测超高能宇宙线的重要手段之一。利用北京怀柔 EAS 阵列，本文对 10^{15}eV– 10^{17}eV 能区的 EAS 现象进行了研究并给出了初步的物理结果。作为本论文的主要工作，作者利用 Monte Carlo 模拟并结合实验数据，对中—日合作羊八井阵列的特性进行了全面系统地分析，对超高能γ点源稳定发射和短期爆发现象进行了研究，同时，对太阳耀斑与甚高能宇宙线的可能关联从实验上进行了探讨，发现了重要的实验现象。具体工作如下：

1. 作者完成了怀柔 EAS 阵列离线分析程序系统的编制。通过 Monte Carlo 模拟计算并结合实验数据分析结果，给出了该阵列对 EAS 阵列基本参数的测定精度。在 10^{15}eV－10^{17}eV 能区，一个非常重要的物理现象是初级宇宙线能谱在 10eV 附近发生拐折，即出现 'Knee'。本工作利用怀柔 EAS 阵列在 1987 年－1989 年间记录的实验数据，对这现象进行了研究，给出了 EAS 带电总粒子数垂直积分谱(size 谱)，在 size 谱上没有发现明显 'knee' 的迹象，但在 size＝10^5 处的绝对积分流强与其它海平面阵列给出的结果是一致的。利用怀柔 EAS 阵列最新结果和本工作在羊八井 EAS 阵列获得的 size 谱，我们对这一课题进行了进一步的讨论。

本工作在不同 size 区间的 EAS 吸收长度，以利用这结果与各种模型计算的模拟结果相比较，获取 10^{15}eV－10^{17}eV 能区，高能核作用的主要特征和初级宇宙线成份的信息。

2. 本工作完成了羊八井 EAS 阵列分析程序系统和 Monte Carlo 模拟程序系统的建立。利用 Monte Carlo 模拟并结合实验数据对该阵列的特性进行了系统的分析研究，确定了事例的选择标准，给出了阵列的角度响应和能量响应函数。基于好的角度分辨可以显著增加信噪比，因此，着重对影响阵列角分辨的因素进行了讨论。由于从实验中观察到了月亮遮挡效应，进一步确认了阵列的角度分辨。

3. 探测超高能γ射线为研究宇宙线起源提供了新的探讨，本工作重点研究了北半球三颗最著名的超高能γ点源侯选天体 Cyg X－3,Her X－1, 和 Crab，在对上述点源稳定发射的观测中，没有发现超出，在95%的置信水平下，给出了10TeV时的积分流强上限，它们依次分别为 $1.0\times10^{-12}cm^{-2}s^{-1}$,$0.57\times10^{-12}cm^{-2}s^{-1}$ 和 $1.1\times10^{-12}cm^{-2}s^{-1}$，我们将此结果与其它实验的结果进行比较并对目前超高能γ点源研究的现状提出了看法。

超高能γ点源还可能以瞬态爆发的形式辐射超高能γ射线。本文对 Crab Pulsar 的短期爆发现象进行了实验寻找。我们发现该天体在91年1月18日(UT)有一次持续的约1小时的爆发，在爆发前半小时，向源事例数超出背景约 3.7σ，全天向源事例数超出背景 2.4σ，爆发流强在 10TeV 时估计为 $1.4\times10^{-10}cm^{-2}s^{-1}$，流量为 $1.08\times10^{35}erg/s$。这一发现对研究 Crab 的超高能γ射线发射具有重要意义，同时也证明羊八井阵列非常适于超高能γ源短期爆发现象的研究。

4. 太阳是在宇宙线起源研究中最早被关注的对象，伴随太阳耀斑爆发，会有高能粒子被抛射出来。太阳耀斑爆发和甚高能宇宙线是否会有关联？本工作利用羊八井 EAS 阵列对此问题进行了探讨。在1991年3月太阳耀斑连续爆发期间，我们发现在3月24日前后，阵列触发率出现了明显上升的趋势。且对事例按其 ΣN_i 大小分组之后，在三个不同的 ΣN_i 区间，24日(UT)的触发率出现了高显著性的增长。对应 A(15.8－25.1)，B(25.1－39.8)，C(39.8－63.1)，D(63.1－100)四个区间，增长的显著性分别为 20.1σ，13.4σ，5.9σ，3.4σ。增长的幅度分别为 41.1%，36.8%，21.2%，17.9%，这一增长的对应的能区在 10Tev 至 50Tev 之间。对高能期间的变化及仪器的工作状态，我们进行了仔细的检验，未发现异常的现象。这一事例的证实将引起宇宙线起源中长期形成的某些现象的改变，同时在理论上，也会对太阳物理及太阳耀斑爆发期间粒子的加速机制提出了新的课题。

Searches for $10^{13}-10^{17}$eV EAS and cosmic-ray Sources

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ABSTRACT

Searches for Ultra-high energy (UHE) gamma-ray sources are of great significance to the study of the origin of cosmic rays. And Extensive Air Shower (EAS) array is one of the important means to detect UHE cosmic rays. Working on the EAS array at Huairou, Beijing, we have studied the EAS phenomena within the energy region 10^{15}eV - 10^{17}eV and come to some preliminary physical results. But the dissertation is mainly devoted to a comprehensive and systematic Monte Carlo simulation analysis of the characteristics of the Sino-Japan joint EAS array at Yangbajing, Tibet of China and a comparison between the simulation results and the experimental data. Analysis is also made of the steady and the sporadic emission of UHE gamma-ray point sources. Moreover, we have sought the possible correlation between solar flares and TeV cosmic rays and found an important experimental phenomenon. The datails are summarized as follows:

1. We have completed the compilation of the off-line analysis program for Huairou EAS array. Combined the Monte Carlo simulation with the experimental data, the accuracy of the EAS array and EAS parameters is obtained.

Within the energy region 10^{15}eV - 10^{17}eV, an important feature on the primary cosmic rays spectrum is that it becomes steeper near $10^{15.5}$eV, namely, the appearance of the so-called "knee". The study of this phenomenon by using the experimental data recorded by Huairou EAS array from 1987 to 1989 results in the shower size spectrum for 'vertical-showers'. The ob-