

THESIS ABSTRACT

学位论文摘要汇编

(1990 年)

中国科学院高能物理研究所

INSTITUTE OF HIGH ENERGY PHYSICS
ACADEMIA SINICA

目 录

(Contents)

1. 宁强碳质球粒陨石难熔包体地球化学研究 (方 虹) (1)
Geochemical Investigation of the Refractory
Inclusions in the Ningqiang Carbonaceous Chondrite
2. 宇宙线超高能核作用事例特性及其有关现象的研究 (张春生) (11)
The Investigation of the Characteristics of Superhigh
Energy Cosmic Ray Hadronic Interactions and relative
Phenomena
3. 在巴巴散射过程中寻找低质量 e^+e^- 共振态实验预研 (陈 宇) (16)
Experimental Design and Preparation for A Search
of Resonant Bhabha Scattering in MeV Range
4. 多道分析器智能接口 (丁启华) (19)
Intelligent Interface of MCA
5. 利用BEPC 研究光电诱导解吸 (陈晨亮) (21)
Study of the Photoelectron Induced Gas Desorption in BEPC
6. 20m²地下 μ 子闪烁体探测器的研制 (曹 臻) (23)
The 20m² Underground Scintillator Muon
Detector in Huairow EAS Array
7. 加速器辐射场中子能谱测量方法的研究 (郭应寿) (25)
Research in the Measurement of Neutron Spectrum
in Accelerator Radiation Field
8. 人体必需微量元素硒的测试及其生物效应的研究 (田继兵) (29)
Selenium Determination in Human Body and Its
Biological Function
9. TOF 方法鉴别试验束中次级正电荷粒子 (徐建国) (32)
Using TOF Method to Measure the Secondary
Particles of Test Beam
10. 高塔法测量第五种力效应—实验方法和塔上重力初步测量 (李云德) ... (34)
High-Tower Method for Detecting the Effect

of the Fifth - Force Experimental Method and
Tower Gravitation Measurement

11. 辐照加速器控制软件 (张曾博) (36)
Irradiation Accelerator Control Software
12. 软X射线光刻中硅掩模的研制 (叶朝霞) (39)
The Research and Fabrication of Silicon Mask
in Soft X-Ray Lithography
13. 闪烁晶体抗辐照性能研究 (王亚东) (41)
Radiation Hardness Studies of BaF_2 Crystal
14. 实现BITBUS与VME总线间的数据传送-BTB的研制 (续 翔) ... (43)
The Design of Bus Transfer Board Data Transfer
Between BITBUS and VMEBUS
15. BEPC束流输运线一级控制软件 (张晓龙) (45)
The Level Computer Control Softwares for The
BEPC Beam Transport System
16. 支持DFD和SADT的软件工程工具 (张伟丰) (49)
Automatic Tools Supporting Software Engineering
Methodologies
17. 同步辐射微探针X荧光分析的研究 (赵盛红) (51)
A Research on the Synchrotron Radiation X
Fluorescence Analysis
18. 用 N^+ 离子直接注入钢及反冲注入镀Ti膜钢表面的机
械性能改进 (姜福友) (53)
Steel Surface Modification with N Ion Direct
Implantation and Recoil Implantation with
Pre-deposited Ti Surface Film
19. $\text{Ni}\{001\}\text{C}(2\times 2) - \text{Al}$ 合金表面上CO的分解吸附 (姚 军) (57)
Dissociation of CO on Oxygen Contaminated
 $\text{Ni}\{001\}\text{C}(2\times 2) - \text{Al}$ Surface
20. Bitbus分布式系统在电源控制中的应用研究 (姚宏宾) (59)
The Application of Bitbus in Power Supply Control
21. 200 AGeV $^{32}\text{S} + \text{Em}$ 和60 AGeV $^{16}\text{O} + \text{Em}$ 相互作用中的弹

核与靶核碎裂现象研究 (高怀林)	(61)
The studies of the projectile and target fragmentations in the interactions of ^{32}S at 200 AGeV and ^{16}O at 60A GeV with Emulsion nuclei	
22. 基于STD总线用于高能宇宙线研究的多参数数据获取系统 设计与研制 (王煊玉)	(64)
Study of Multiparameter Data Acquisition System Based on STD BUS Used in High Energy Cosmic Ray	
23. 倍频腔束团相宽监测方法研究 (王 劲)	(68)
A Method for Measuring Bunch Length by Harmonic Cavity	
24. 1.1GeV 电子直线加速器束流损失监测系统 (张昌忠)	(70)
Beam Loss Monitoring System For BEPC 1.1GeV LINAC	
25. 加速器控制软件的开发研究 (邵 凯)	(73)
The Development and Research of the Accelerator Control Software	

宁强碳质球粒陨石难熔包体地球化学研究

姓 名: 方 虹

导 师: 冯锡璋

学 位: 博 士

摘 要

宁强碳质球粒陨石是中国第一块降落的碳质球粒陨石。本工作采用了光学显微镜, 阴极发光显微镜, 电子探针, 仪器中子活化分析等多种手段, 对这块陨石难熔包体的地球化学特征(包括岩石学, 矿物学及化学成份)进行了研究。目的在于通过对宁强及其它 CV 陨石, 尤其是 ALLENDE 陨石难熔包体特征的比较, 确定球粒陨石类别与难熔包体类别之间的相关关系。基于对形成包体的能量特征的分析, 文章推断上述相关关系的可能成因以及难熔包体的天体化学意义。

本工作共考查了约 70 克宁强陨石样品, 描述了宁强十三个富钙铝包体, 十五个橄榄石集合体及一些熔融球粒, 并不同程度地讨论了这些样品的成因。宁强陨石全岩的特征(岩石学, 岩石化学以及陨石基质的化学成份特征)由于与难熔包体总体特征有关也被给予研究。所得到的主要结果如下:

1. 宁强陨石的岩石学, 岩石化学及基质的化学成份

(1) 宁强陨石的岩石学, 岩石化学特征与 CV 陨石相应特征相似, 尽管宁强陨石具有相对于 ALLENDE 和 CV 陨石的很低的富钙铝包体, 较高的杆榄石集合体的模式丰度和较高的基质/球粒的体积比, 宁强陨石仍是一块典型的氧化形 CV 陨石。宁强陨石的难熔亲岩及亲铁元素 (Ca, Al, Ti, V, La, Nd, Sm, Sc, Ir) 被贫化, (约 $0.86 \times \text{ALLENDE}$, 约 $0.83 \times \text{CV}$), 这一特征与包体较低的丰度特征相当吻合。亲铁元素 Fe, Co, Ni, Au 的丰度与 ALLENDE 和 CV 陨石相应丰度接近, 而 Na 略有富集, Mn, Cu 显示贫化的特征。

(2) 宁强基质的元素重量比值 (Na, K, Mg, Ca, Fe, Al, Ti, Mn, Ni) / Si 处于 CV 球粒陨石相应比值的变化范围之内, 而 Ca/Si, Al/Si 值相对于其它 CV 陨石基质的同样比值较高。与全岩相比, 宁强基质中的轻稀土和元素铁略显富集, 其它元素相差不大。无论是主要还是微量元素在宁强陨石基质中的分布都是不均匀的。

(3) 宁强陨石难熔组份暗色边中富集了铁, 而难熔亲岩元素以及 Au, Co, Ni 相

对于陨石基质的平均成份显示出贫化的特征。

2. 白云母—石英脉

本工作中,我们在宁强陨石的一块薄片中发现了一条白云母石英脉。有关类似的物质在其它陨石中的报道尚未见到。这条脉中的矿物组成有石英,白云母,伊利石(此矿物第一次被发现在陨石中),绿泥石和一些不透明矿物。脉壁由一成份相似于陨石基质的暗色条带构成。我们讨论了这条脉的形成条件和成因。

3. 细粒包体和富尖晶石包体

宁强陨石的细粒包体在形貌及蚀变特征上与 ALLENDE 陨石类似包体相应特征相似。宁强富尖晶石包体 NQ-32 的矿物组成为尖晶石和辉石,其(II)型稀土,亲铁及挥发性元素相对于 CI 球粒陨石的丰度模式分别与 ALLENDE 陨石富尖晶石包体相应丰度模式相似,包体 T-15-I3 的矿物组成与环圈结构与 ALLENDE 陨石包体 0702 的特征相似。

4. 橄榄石集合体与熔融球粒

我们发现宁强陨石中的橄榄石集合体是一类岩石学和化学成份特征变化较明显的物质。我们将橄榄石集合体分为了 A, B, C 三类。A 类的组成物质粒度细小, B 类的颜色极为洁白,组成物质粒度相对较粗; C 类为灰白或黄白色。三类集合体的稀土模式均为平坦型,一般具有负的 Ce 异常。Eu 和 Yb 的异常不明显。亲铁和中等挥发性元素相对于 CI 的富集系数多小于一。从 A 到 B 再到 C 类,难熔元素丰度成逐渐减少的变化趋势。B 类集合体 NQ-5 中极为贫化 Fe, Co, 而它的粗粒相比其细粒富含难熔元素,贫化非难熔元素。三类集合体难熔元素相对于 CI 球粒陨石富集系数的平均值为 8.4, 大于 ALLENDE 陨石的相应数值(4.3)。这表明宁强橄榄石集合体比 ALLENDE 橄榄石集合体富含难熔组份。ALLENDE 橄榄石集合体成份与宁强陨石的 C 类橄榄石集合体成份相似。

熔融球粒中难熔元素(Al, Sc, Ti, La, Sm, Ho, Tm, Yb, Lu, Ta, V, Ir)相对于 CI 富集系数的平均值为 6.39。熔融球粒的化学成份与 C 类橄榄石集合体的成份相对较为接近。熔融球粒的 Ir/Sm 比小于 C 类橄榄石集合体的相应数值。熔融球粒中 Cr-Sm 成负相关。单个球粒中 Fe, Au 在其边部比内部更为富集。

5. 富黄长石包体

不同的富黄长石包体在它们的形状,大小和结构等方面特征上往往显示出差异。例如:它们的形状可以为不规则的,团块形的,准球形和球形的。多数包体小于 3-4 个毫米,本工作找到的最大者小于一个厘米。有些包体是细粒结构,有些包体为粗粒结构,两种结构混杂的包体也存在。许多包体有辉石质边缘。宁强包体中黄长石的成

份接近于钙铝黄长石。它们的 AK 值多数在 5-15mol% 的范围内。难熔元素 Ir, La, Ce, Sm, Eu, Tb, Ho, Yb, Lu, Sc, Ti 相对于 Cl 的富集系数的平均值为 28.39, 大于 ALLENDE 陨石相应数值(17.50)。非难熔元素 Na, Cr, Mn, Fe, Co, Ni, Au 的丰度与 ALLENDE 陨石同类包体相应丰度相似。这些元素的富集系数大多数小于一。元素 Sc 显示出在辉石中富集, 在黄长石, 尖晶石中贫化的明显的选择性。相对于其它难熔元素, 元素 Ir 和 V 在某些包体中的富集系数较小, 显示出不同程度的分馏。除了包体 NQ-18 以外, 大多数包体具有平坦的稀土模式, Eu 异常不明显。NQ-18 的稀土模式中, 轻稀土富集, 重稀土贫化, Ce, Eu, 显示出负异常。在包体 PM010 和 S4-8 中, 发现了一种极为富 Al 的辉石, 我们认为这很可能是单斜辉石的新变种。

总的来讲, 宁强与 ALLENDE 陨石包体的比较表明, 它们的包体特征有许多相似之处, 主要的相似表现在包体类别的相似, 即两块陨石都以富黄长石, 富尖晶石和富橄榄石的集合体为主, 而未找到存在于 CM 陨石中的富含黑铝钙石的超难熔包体。尽管宁强陨石各富黄长石包体在形状, 大小和结构等岩石学特征上显示出差别, 但这些包体大多数可以在 ALLENDE 陨石中找到特征相似的包体。富橄榄石集合体和富黄长石包体的稀土模式大多数为平坦型, 富尖晶石包体 NQ-32 有 II 型的稀土模式, 这些特征进一步证实了同类球粒陨石的难熔包体特征, 尤其是它们的类别是相似的。

对宁强与 ALLENDE 陨石难熔包体的差别也进行了研究。宁强陨石包体的丰度明显少于 ALLENDE 的。宁强陨石包体的大小常常更小些。大多数宁强陨石富 Ca, Al 包体相似于 ALLENDE 陨石的 A 类包体, 而与 ALLENDE 陨石 B 类包体相似的包体在宁强陨石中少见。宁强包体中黄长石的成份似乎比 ALLENDE 陨石黄长石成份更为富铝, 黄长石的成份范围也更窄。宁强橄榄石集合体和富黄长石包体难熔元素的富集系数大于 ALLENDE 陨石的相应数值, 我们推断宁强陨石包体的成份总体上比 ALLENDE 陨石包体成份更加难熔。

一些关于陨石类别与包体类别相关关系的可能成因以及包体的天体化学意义的看法被提出如下:

1) 陨石难熔包体形成于孤立的, 小规模的热事件中; 形成于冷的太阳星云中; 形成在小行星带中。

2) 在邻近小行星带的位置, 可能曾有某一高能事件发生, 陨石包体就是这一事件对太阳星云物质间接影响的结果, 各类陨石包体类别的不同可能与这一事件对星云物质的影响程度不同有关, 而这一影响程度与不同的陨石到这一事件发生位置的距

离不同有关。

3) 单个包体只能反应发生在十分有限的星云空间的热过程, 对于宏观星云的物理化学状态的指示意义有限, 然而, 如果将陨石包体研究与天文学观测相结合, 包体虽然体积微小, 却能为我们揭示太阳系更大范围空间的历史, 这也就是说, 这些难熔包体将具有更大的天体化学意义。

Geochemical Investigation of the Refractory Inclusions in the Ningqiang Carbonaceous Chondrite

Name: Fang Hong

Supervisor: Feng Xizhang

Degree: Doctor

ABSTRACT

The Ningqiang carbonaceous chondrite is the first falling carbonaceous chondrite in China. The geochemical characteristics of the refractory inclusions in the meteorite including petrology, mineralogy and chemical compositions were studied by many kinds of scientific methods such as optical microscope, electron microprobe, and instrumental-activation analysis and so on. The purpose of the work is to confirm the correlation between the types of chondrites and the types of refractory inclusions through comparing the inclusion characteristics of Ningqiang with other CV chondrites, especially the Allende meteorite. On the basis of the analysis for the features of the energy required in forming the inclusions, the paper inferred the possible genesis of about the correlation and the cosmochemistry significance of the refractory inclusions.

About 70 grams of Ningqiang material were used for investigation. we described Ningqiang's 13 Ca, Al-rich inclusions, 15 olivine aggregates, and some melting chondrules, discussed in different degree of detail the origin of these samples. Because of having some relationship with the bulk feature of inclusions, the rock features of this meteorite in petrology, petrologic chemistry, and meteorite matrix chemical compositions were also studied. The main results are as follows.

1. Petrology, Petrologic Chemistry, and Matrix Chemical Compositions of the Ningqiang Chondrite

(1) The characteristics in petrology, petrologic chemistry of the Ningqiang chondrite are similar to those of CV chondrites's. In spite of its low model abundances of the Ningqiang refractory inclusions, high model abundances of olivine aggregates, and high matrix/chondrule volumetric ratio relative to Allende and CV chondrite, the Ningqiang meteorite is a typical oxidizing CV chondrite. Refractory lithophile and refractory siderophile elements (Ca, Al, Ti, V, La, Nd, Sm, Sc, Ir) are depleted in Ningqiang ($-0.86 \times$ Allende, $-0.83 \times$ CV), it most likely associated with the low abundances of refractory inclusions. The abundances of siderophile element Fe, Co, Ni, Au are close to those in Allende and CV chondrite, Na is slightly enriched and Mn, Cu show depletion.

(2) The elemental weight ratios (Na, K, Mg, Ca, Fe, Al, Ti, Mn, Ni) / Si of Ningqiang matrix are within the range of the corresponding ratios of CV chondrite matrix, Ca/Si and Al/Si ratios are high relative to those in the other CV chondrite matrix. Comparing with the whole-rock bulk composition, the Ningqiang matrix is slightly enriched in light REE and Fe, other elements do not show obvious differences. The chemical compositions of either major elements or trace elements exhibit heterogeneous distribution in the Ningqiang matrix.

(3) In the chemical compositions of the black rim of the refractory compound in Ningqiang, element Fe is enriched and refractory lithophile elements and Au, Co, Ni are depleted to the mean composition in the Ningqiang matrix.

2. A Muscovite-Quartz Vein A Muscovite-Quartz Vein was found in a Ningqiang thin section in this work. No report about the analogous object in meteorite has been seen. The mineral constituents of the vein are quartz, muscovite, illite (which was discovered firstly in meteorites), chlorite and some opeque minerals. The wall of the vine was composed of a black belt whose chemical compositions is similar to that of the matrix of the meteorite. We also have discussed the forming condition and origin of the vine.

3. Fine-grained Inclusions and Spinel-rich Inclusions The

fine-grained inclusions of Ningqiang are similar to the same type Allende inclusions in appearance and alteration features. The mineral constituents in Ningqiang spinel-rich inclusion NQ-32 are spinel and pyroxene. Relative to CI chondrite its elemental abundance models of REE (II type), siderophile as well as moderately volatile elements resemble respectively the abundance models of the spinel-rich inclusions in Allende. The mineral constituents and ring structure of inclusion T-15-I3 are similar to those of inclusion 0702 of Allende respectively.

4. Olivine Aggregates and Melting Chondrules We found that olivine aggregates in Ningqiang are a kind of the object whose characteristics in petrology and chemical compositions varies significantly. By their petrologic and chemical features, we classified them as three types: A, B, C. The material in type A is of fine grain; the color of type B is very white, and its grain size is relatively coarse; the color of type C is white-grey or white-yellow. The models of REE in the three aggregate types are all flat, element Ce generally shows negative anomaly, and Eu, Yb do not show obvious anomalies. The enrichment factors relative to CI chondrite of siderophile and moderately volatile elements in the three aggregate types are mostly less than 1. The refractory element abundances from the type A to B and to C appear a gradually reducing trend. Element Fe and Co in a type B aggregate NQ-5 are very depleted, and its coarse-grained phase contain more refractory elements and less nonrefractory elements than those of the fine-grained phase respectively. The mean of the enrichment factors relative to CI chondrite of the each refractory elements in the three type olivine aggregates is 8.4, which is larger than the corresponding value in Allende (4.3). It indicates that the refractory elements in the Ningqiang olivine aggregates are more abundant than those in the Allende olivine aggregates. The chemical compositions of the Allende olivine aggregates are similar to the those of the Ningqiang type C aggregates.

The mean of the enrichment factors of the refractory elements (Al, Sc, Ti, La, Sm, Ho, Tm, Yb, Lu, Ta, V, Ir) of the Ningqiang melting chondrules is 6.39. The chemical compositions of the melting chondrules are relatively

close to the compositions of the type C olivine aggregates. Ir/Sm ratios in the melting chondrules are less than those in the samples of type C olivine aggregates. There is a negative correlation between elements Cr and Sm in the melting chondrules. In each chondrule the contents of element Fe and Au in edge part are more than those in inner part of the chondrule respectively.

5. Melilite-rich Inclusions The different melilite-rich inclusions in Ningqiang displayed the differences in the petrologic features such as its shape, size and texture and so on. For example: their shape can be irregular, lump, subg, and globe. The size of the inclusions are often less than 3-4 millimeters, the greatest one found in this work is less than 1 centimeter. Some inclusions are of fine-grained texture and some coarse-grained texture, the inclusions with mixed texture of fine-grained and coarse-grained materials are also exist. Many inclusions have pyroxenic edge. The composition of melilite in the Ningqiang inclusions is near gehlenite, their AK values are mostly in the range of 5 to 15 mol%. The mean of the enrichment factors of the refractory elements (Ir, La, Ce, Sm, Eu, Tb, Ho, Yb, Lu, Sc, Ti) of the inclusions is 28.39, which is larger than the corresponding value in Allende (17.5). The abundances of nonrefractory element Na, Cr, Mn, Fe, Co, Ni, Au are similar to those abundances in the same kind inclusions in Allende, The enrichment factors of these elements are mostly less than 1. Element Sc shows a obvious selectivity that it is enriched in pyroxene, and depleted in melilite and spinel. Element Ir and V in some inclusions have small enrichment factors relative to other refractory elements, which showing fractionations of in different degree from other refractory elements. Except for inclusion NQ-18, most inclusion have flat REE model, the Eu anomaly is not significant. In the REE model of NQ-18, light REE are enriched and heavy REE are depleted, and Ce and Eu show negative anomaly. A kind of extremely Al-rich pyroxene in inclusions PM010 and S4-8 was found. We think that there likely is a new variety of clinopyroxene.

Generally speaking, the comparison of the inclusions from Ningqiang with those from Allende meteorite indicates that there are many similarities

in the inclusion features, including mainly that the inclusion types of the two meteorites are similar — — — they are mainly melilite — rich and spinel — rich inclusions and olivine — rich aggregates; A kind of super — refractory inclusion which contains abundant hibonite and spinel, and exists in CM meteorite, was not be found. Although the petrologic features of different melilite — rich inclusions in Ningqiang display the differences in the shape, size and texture and so on, most of their equivalent objects can be found in Allende, the REE model of the olivine — rich aggregates and melilite — rich inclusions are mostly flat type, the spinel — rich inclusion NQ — 32 has II type REE model. These characteristics confirmed further that some features of inclusion, especially their types, in a same subgroup of chondrite are similar.

The differences of the inclusions in Ningqiang and Allende meteorites were also studied. The abundance of inclusions in Ningqiang is significantly less than Allende's, and the size of the inclusions of Ningqiang often smaller. The most of Ca —, Al — rich inclusions in Ningqiang are similar to the type A inclusions in Allende meteorite, the inclusions like the type B of Allende is rare in Ningqiang. The Al content of melilite in the Ningqiang inclusions seem more than that of melilite in Allende inclusions, and the composition range of melilites of Ningqiang is narrower than that in Allende melilites. The enrichment factors of refractory elements of Ningqiang olivine aggregates and melilite — rich inclusions have larger values than the corresponding values in Allende meteorite. From these results, we concluded that bulk composition feature of the inclusions in Ningqiang is slightly more refractory than that of Allende inclusions.

Some views about the possible genesis of the correlation between the subgroups of meteorite and the types of meteorite inclusions as well as a the cosmochemistry significance of these inclusions were presented as follows:

(1) The meteorite refractory inclusions were formed in isolated, small scale heat events; formed in a cold solar nebula; formed in the asteroid belt.

(2) In the neighborhood of the asteroid belt, a certain high energy event may have taken place. The refractory inclusions in meteorites were the results of an indirect effect of that event on the material of the solar nebula

from which the inclusions were formed. The different types of inclusions in various subgroups of meteorite may be related to the different extent of the affection from the event, and the affection extent was controlled by the distances between different meteorite to that event.

(3) Individual inclusion can only reflect some nebula heat processes which took place in a very limited nebula space. The their guiding significance to the physical-chemical state of the macrocosmic nebula is limited. However, in spite of the small size of these inclusions the study of meteorite inclusions combining with astro-observation, these inclusions should tell us the story of a greater range solar system space, that is to say these refractory inclusions will have greater cosmochemistry guiding significance.

宇宙线超高能核作用事例特性及其有关现象的研究

姓 名: 张春生

导 师: 霍安祥

学 位: 博 士

摘 要

宇宙线研究是了解超高能区粒子核作用机制和天体物理信息的重要途径。高山乳胶室作为宇宙线实验的主要探测手段之一,用以记录观测原初宇宙线粒子在大气中核级联电磁级联轴心区的高能粒子(称为族事例)。通过对族事例的分析来研究 $10^{14} \sim 10^{16}$ eV 能区中粒子核作用机制和原初宇宙线粒子化学成分是高山乳胶室实验的两个主要课题。高能量的族事例常常在乳胶室中放置的 X 光片上形成一个范围数 cm^2 大小的黑斑,称为 HALO 事例。本文全面系统地分析了甘巴拉山和富士山乳胶室实验组近年来观测到的高能核作用事例特性(主要是 HALO 事例,包括作者所测的数据),详细讨论了各种实验下 HALO 事例的能量标定归一化问题及其相关的三维电磁级联簇射过程,通过把实验数据与蒙特卡罗模拟计算结果作比较,研究了 $10^{15} \sim 10^{16}$ eV 能区粒子核相互作用模型和原初宇宙线粒子的化学成分以及流强。具体工作如下:

1. 本文详细讨论了高能宇宙线粒子在大气中的传播过程和 halo 事例在乳胶室中的形成过程,指出 HALO 黑斑主要是由高能族事例中的粒子在乳胶室中电磁级联簇射相互迭加的结果。对这一现象主要特性的理解不需要象日本巴西乳胶室合作组认为的那样,是由某种未知的新现象产生的。由普通的核作用模型模拟得到的 HALO 事例,其各种重要特性和分布,均与实验观测的事例十分相似,并且普通核作用机制可以产生相当数量的 HALO 事例数目。
2. halo 事例的标定归一化工作是正确分析 halo 事例的基础。本文充分考虑了影响 HALO 事例的标定归一化问题的各种因素,在此基础上给出了一套 HALO 事例裸数据归一化方法,应用这套方法我们得到了较合理的甘巴拉山高度 HALO 事例的流强,它比原来的结果约高 25%。我们也分析了甘巴拉山组和富士山组以往所用的常数标定法的不合理性,指出它低估铁乳胶室 HALO 事例的大小,低估率约为 35%。
3. 本文系统地分析了 HALO 事例的纵向发展、横向分布和其它特性,把实验结果与

几种模型的计算作了比较。

研究发现,90% 以上的 HALO 事例和 70% 以上的 gamma 族事例是由能量为 $10^{15} \sim 10^{17} \text{eV}$ 的原初宇宙线质子产生的,族事例的流强、横向分布和内部结构分布特性对这个能区的原初质子流强和粒子核作用机制很敏感,是研究这两个课题的重要物理量。

两个组的实验数据表明,HALO 事例和 gamma 族事例的多种分布特性都与碎裂区近似的费曼 Scaling 核作用模型的计算结果一致或很接近,Scaling 严重破坏的核作用机制明显地偏离实验数据。

关于宇宙线的原初成分,实验数据支持在 10^{14}eV 以上能区,重核成分逐渐增多,质子成分逐渐减少的混合原初成分假设。原质子的能谱在 $1.5 \times 10^{14} \text{eV}$ 左右开始拐折,谱型变陡,到 10^{16}eV 附近,质子约占总粒子强度的 10% 左右,这比低能端 ($< 10^{13} \text{eV}$) 直接实验测量值的外推结果约低 2.5 倍。

4. 电磁级联簇射现象在宇宙线物理的研究甚至高能物理的研究中起着重要的作用。本工作中我们系统地研究了 $1 \text{GeV} \sim 100 \text{TeV}$ 能区铅、铁和空气物质中的三维电磁级联过程的平均特性,结果如下:

(1) 对簇射的纵向发展,B 近似下的解析计算高估重物质中的次级总电子数,如在铅中,高估率约为 44%,铁中约为 30%。在空气这类轻物质中,B 近似较好成立。

(2) 簇射电子数密度的横向分布比解析计算给出的 N-K 函数或 N-K-G 函数要窄得多,比如在簇射极大值附近,用 $1/2$ Moliere 单位(均方横向扩展单位)的 N-K-G 函数可以近似地拟合电子数密度的横向分布。

(3) 簇射电子穿过 X 光片时,在 X 光片内留下的电离能损的横向分布对乳胶室的实验是非常重要的。这个分布比电子数密度的分布要宽,并且在簇射极大深度附近,很接近 N-K 函数或 N-K-G 函数,这就是长期以来人们用 N-K 函数或 N-K-G 函数,来讨论由 X 光片上的电子能损得到的乳胶室实验数据,也能给出似乎合理结果的原因所在,它是一个“错误”上的巧合。

(4) 为了实际应用的方便,我们给出了一些公式来近似地描写级联簇射发展的特性。

The Investigation of the Characteristics of Superhigh Energy Cosmic Ray Hadronic Interactions and relative Phenomena

Name: Zhang Chunsheng

Supervisor: Huo Anxiang

Degree: Doctor

ABSTRACT

Cosmic ray research is an important way for investigating superhigh energy hadronic interactions and astrophysics. As one of the main experimental detectors, the muon mountain emulsion chamber is used to record a bundle of high energy particles (called a family) in the core region of the EAS, which is originated by primary cosmic rays. Two main subjects of the muon mountain emulsion chamber experiment is investigating the hadronic interactions and primary composition of cosmic rays in the energy region of $10^{14} \sim 10^{17}$ eV from the analysis of family events. Very high energy families are often associated with a halo, a dark spot (extended area with diameter of mm to several cm) recorded on the X-ray film due to a large number of electromagnetic cascade showers developed in the absorber (usually iron or lead). In this thesis, we have analysed the characteristic features of high energy families (mainly halo) obtained by Mts. Kanbala and Fuji collaborations, and discussed the three dimensional development of cascade showers and the normalization problem of the halo spot measured under various experimental conditions. By the comparison of our experimental data with the Monte-Carlo simulation, we have also studied the hadronic interactions and primary proton intensity in the energy region of $10^{15} \sim 10^{16}$ eV. In the following are summarized the detailed works:

1. We discussed the propagation of super high energy cosmic rays in the atmosphere and the formation of a halo in the emulsion chamber. The result