**Part I current situation and trend analysis at home and abroad**

Including the overall research situation and level at home and abroad related to the project, the latest progress and development prospects. It is limited to 2000 words, and briefly lists the main institutions and typical achievements, representative literature and relevant patents and standards of the five representative domestic and foreign institutions engaged in relevant research, and lists the five representative achievements, patents and standards of the project in relevant aspects.

Resistive plate chamber (RPC) is a traditional parallel plate structure gas detector, which is widely used in high-energy physics experiments because of its simple structure and suitable for large-area construction. It is usually used as a muon trigger detector and hadron calorimeter in the outer layer, as well as in large-area high-altitude cosmic ray observation experiments. The early RPC works in streamer mode, and the signal amplitude is large. It can directly obtain the signal without front-end amplification, but the time resolution and counting rate are poor; At present, the RPC in the running experiment usually works in the avalanche mode, the counting rate ability has been greatly improved, and has nanosecond time-resolved performance. The muon spectrometer in atlas experiment uses 2mm air gap RPC as muon trigger detector in the barrel, with a total area of 3600 square meters, a total number of channels of more than 350000, and a design counting rate of 100 Hz/cm2. It has been running stably in atlas experiment for nearly 15 years and has achieved fruitful physical results.

With the LHC plan to upgrade to the high brightness hl-lhc, it is expected that the final state particle flux will also increase by an order of magnitude, and the existing atlas RPC cannot operate normally at such a high count rate. In order to improve the counting rate ability of RPC, Atlas proposed the method of narrow air gap RPC, which reduced the air gap width of RPC to 1mm, the average avalanche charge from the original 30 PC to several PC, and the thickness of electrode plate from 2mm to 1.4mm, so as to improve the counting rate ability by one order of magnitude, and also improve the service life of the detector. By using high sensitivity and high signal-to-noise ratio front-end electronics based on Gesi process, the reduced gas gain in the narrow air gap is compensated to ensure that the detection efficiency is not affected. In the atlas phase II upgrade phase, this new narrow air gap RPC technology and front-end electronics design will be adopted, and three new RPC detectors will be added in the inner layer of the barrel, with a total area of 1400 square meters, to ensure the muon trigger efficiency in the hl-lhc operation. This new type of narrow air gap RPC is a high count rate and anti-aging detector technology that must be developed in the future high-energy and high brightness collision physics experiments.

The research work on RPC and narrow air gap RPC was previously led by Italy INFN, who was responsible for the construction of all existing atlas RPC detectors [?]. Atlas China team has been involved in the relevant work of muon spectrometer since phase-I, and fully participated in the development and construction of RPC detector and electronics in phase II, including the study of detector performance, the design, manufacture, batch production process and quality control of detector and readout board, and the development and testing of Electronics. It has the ability to independently carry out the design and construction of RPC detector [?].

Narrow air gap technology can comprehensively improve the performance of RPC, such as counting rate, time resolution, and working life, which is an important direction of RPC development in the future; This will be the first large-scale application of 1mm air gap RPC in particle physics experiments.

**Part II research objectives and contents**

1、 Project objectives and assessment indicators

（1） The relationship between the declared items and the direction of the guidelines

Including the matching between the project and the direction of the guide, and the supporting effect on the goal of the direction of the guide. Limited to 1500 words.

In order to meet the challenges of high particle flux, high radiation dose and high data volume brought by high brightness hl-lhc, for Atlas muon spectrometer, three muon trigger detectors must be added in the inner layer of the barrel to ensure the muon trigger efficiency and improve the coverage area. Develop a narrow air gap RPC detector with high counting rate and nuclear electronics, and complete the corresponding manufacturing, installation and commissioning tasks in accordance with the atlas agreement, which conforms to and fully covers the direction and objectives of the atlas muon spectrometer in the guide.

（2） Project objectives, assessment indicators, assessment methods/methods

Limited to 2000 words (excluding forms), and fill in the following table.

The narrow air gap RPC muon trigger detector and readout electronics, according to the atlas phase II upgrade requirements, set the research goal to improve the RPC count rate ability, improve the time resolution performance, ensure the detector has high detection efficiency, and complete the detector production, installation and testing tasks specified in the agreement.

The evaluation indexes include: the counting rate ability reaches more than 1 kHz/cm2, the detection efficiency is higher than 95%, and the time resolution is better than 1 ns. The above performance indicators have been carefully evaluated by cosmic ray test, radioactive source test, or beam test arranged by Atlas muon detector upgrade cooperation group.

**Project objectives, expected results and assessment indicators**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Project objectives**  | **Name of expected results**  | **Expected results** **type**  | **Corresponding** **topic**  | **Assessment indicators**  | **Assessment methods and evaluation means**  |
| **index** **name**  | **Existing index value/status at project initiation**  | **Mid term indicator value/status**  | **Indicator value/status at completion**  |
|  | 1: Narrow air gap RPC detector  | □ new theory □ new principle □ new product □ new technology □ new method □ key components □ database □ software □ application solutions ■ experimental devices/systems □ clinical guidelines/specifications □ engineering processes □ standards □ papers □ invention patents □ others  | Upgrade of MUSON detector in atlas experiment  | Count rate  | 100 hz/cm2  |  | >1 khz/cm2  | Experimental test  |
| detection efficiency  | 90% |  | 95% | Experimental test  |
| Time resolution  | >1 ns  |  | <1 NS  | Experimental test  |
| 2: | Ibid  |  | Indicator 2.1  |  |  |  |  |
|  |  |  |  |  |
| And  | Ibid  |  | index  |  |  |  |  |
|  |  |  |  |  |
| **Assessment index of scientific and technological Report**  | **Serial number**  | **Report type**  | **number**  | **Submission time**  | **Disclosure category and time limit**  |
|  |  |  |  |  |
| Completion of other objectives and assessment indicators  |

（3） Presentation and description of expected results of the project

Limited to 1000 words.

RPC topic:

Complete the design of BIS-1 and bis2-6 narrow air gap RPC that meet the requirements of atlas phase II upgrade index, complete the production and testing of bis RPC readout board and detector, establish the corresponding production process and quality control method, and participate in the engineering installation and commissioning of detector.

2、 Project research content, research method and technical route

（1） Main research contents of the project

The key scientific and technical problems to be solved and the main research contents to be carried out for these problems are limited to 3000 words.

In order to cope with the high particle flux background and accumulation effect brought by the high brightness hl-lhc, and to solve the problem of insufficient counting rate ability of the existing RPC trigger detectors and the aging problem of long-term operation, Atlas muon spectrometer needs to add three layers of RPC detectors in the inner layer of the barrel to maintain the overall muon trigger efficiency of the system and improve the effective coverage of the whole spectrometer. The new three-layer RPC detector will adopt a new generation of narrow air gap structure, with an air gap width of 1 mm (the existing atlas RPC air gap width is 2 mm). By reducing the avalanche development length in the air gap, the avalanche charge will be reduced, so as to improve its counting rate ability and working life, and also improve its time-resolved performance; The thickness of the electric board material used as the electrode plate was also reduced from 2 mm to 1.4 mm. By reducing the voltage drop on the electrode plate material, the counting rate ability was further improved. Due to the reduction of gas gain caused by the narrow air gap structure, the front-end electronics design with high sensitivity and high signal-to-noise ratio based on Gesi process is used to compensate, and the detection efficiency is not affected. According to the geometric characteristics of the detector, the dual terminal readout signal is used and the time difference of the signal is used for positioning, so as to reduce the number of electronic channels and improve the position resolution. The above technical route has passed the technical research in the early stage, and has been verified by principle, prototype detector performance test and engineering prototype test. With the strong support of the Ministry of science and technology and the NSFC, the Chinese team has been deeply involved in the development of detectors and electronics, and has completed the construction of four engineering prototypes, verifying the ability of the Chinese team in the performance research and engineering construction of detectors.

Because the narrow air gap RPC works under such extreme detector structure and working conditions, to complete the construction of new detectors with a total amount of more than 1400 square meters and ensure that all detector units have excellent, uniform and consistent performance, it is necessary to finally optimize the design of detectors on the basis of preliminary work, And further improve the production process and establish a unified batch production process and quality control method, and finally successfully complete the project construction, on-site installation and commissioning. Through the research of this project, we can fully grasp the key technology of the construction of large area narrow air gap gas detector.

（2） Research methods to be adopted for the project

1. For the problems to be solved in the project research, the proposed methods, principles, mechanisms, algorithms, models, etc

Limited to 2000 words.

RPC topic:

According to the key problems of narrow air gap RPC muon trigger detector that need to be solved at this stage, the project plans to carry out targeted research in the following aspects.

1) Study of air gap fabrication process and uniformity control. The narrow air gap RPC has a large area (more than 1.7 meters in length and 1.1 meters in width) and a small air gap width (1 mm). The accuracy of the air gap should be controlled within ± 10 microns. In addition to the special research on the processing method and process of the gasket and frame that determine the air gap thickness, it is also necessary to establish a special automatic gasket arrangement, dispensing and coating equipment, and optimize the manufacturing process and various parameters to ensure the overall manufacturing accuracy and uniformity of the detector.

2) Flatness control of readout board fabrication. The RPC readout board will be made of honeycomb structure with light weight and high strength. The flatness of the honeycomb board will determine the flatness of the final detector. Therefore, the readout board is required to have a flatness better than 100 μ M. Therefore, it is necessary to establish and optimize the corresponding batch production process and quality control methods.

3) Research on mass production and quality control methods of front-end electronics. Front end electronics is the core device for the normal operation of narrow air gap RPC. The quality control in batch production is particularly important. Therefore, it is necessary to establish a special quality control method and batch test method.

4) Detector performance test. All completed single-layer detectors need to pass cosmic ray test to check their performance. RPC detector has large area, many channels and short time for batch production, so it is necessary to design and build a large-scale multi-layer detector test platform and data acquisition system.

5) Installation and commissioning. With the progress of engineering construction, the detectors manufactured and tested will be delivered to CERN experimental site in batches. After performance testing, they will be gradually installed on atlas experimental device according to the engineering installation arrangement, and will be tested and debugged on site.

2. Feasibility and advancement analysis of project research method (technical route)

Limited to 2000 words.

RPC topic:

As a traditional gas detector, large area RPC has experienced a long period of development, accumulated a lot of experience in detector production, testing and quality control, and has been successfully applied in many large-scale experiments. According to the characteristics of narrow air gap, the Chinese group has carried out fruitful research work in the design and manufacture of detectors, electronics development and testing, research on double ended readout performance, fabrication of large-area honeycomb readout boards and quality control.

On the basis of these preliminary studies and in combination with the accumulated experience in international cooperation, the key links in RPC design, construction and quality control are further refined and adjusted, and standardized processes and methods are established to ensure high-quality completion of engineering construction tasks.

(the Italian INFN team and relevant units in the atlas muon detector upgrade cooperation group are internationally leading research and development teams in the field of RPC detectors, and have given strong support to the China group through international cooperation in the project.)

3、 Project decomposition scheme

（1） Subject breakdown

Around the project objectives, the project objectives can be decomposed according to needs, and the specific role of each topic in the project and the logical relationship between them are briefly described. It is recommended to use charts to describe. Limited to 2000 words.

（2） Contents of each subject

Describe the research objectives, main research contents, major scientific problems or key technologies to be solved, assessment indicators and evaluation means/methods of each subject item by item. Each topic is limited to 3000 words.

1. Topic 1: Atlas muon detector upgrade

Research objectives: according to the upgrade requirements of atlas phase II, develop high count rate narrow air gap RPC detector and nuclear electronics, comprehensively improve the count rate ability of RPC, improve the time resolution performance, ensure the detector has high detection efficiency, and complete the corresponding manufacturing, installation and commissioning tasks in accordance with Atlas protocol.

Main research contents:

In order to cope with the high particle flux background and accumulation effect brought by the high brightness hl-lhc, and to solve the problem of insufficient counting rate ability of the existing RPC trigger detectors and the aging problem of long-term operation, Atlas muon spectrometer needs to add three layers of RPC detectors in the inner layer of the barrel to maintain the overall muon trigger efficiency of the system and improve the effective coverage of the whole spectrometer. The new three-layer RPC detector will adopt a new generation of narrow air gap structure, with an air gap width of 1 mm (the existing atlas RPC air gap width is 2 mm). By reducing the avalanche development length in the air gap, the avalanche charge will be reduced, so as to improve its counting rate ability and working life, and also improve its time-resolved performance; The thickness of the electric board material used as the electrode plate was also reduced from 2 mm to 1.4 mm. By reducing the voltage drop on the electrode plate material, the counting rate ability was further improved. Due to the reduction of gas gain caused by the narrow air gap structure, the front-end electronics design with high sensitivity and high signal-to-noise ratio based on Gesi process is used to compensate, and the detection efficiency is not affected. According to the geometric characteristics of the detector, the dual terminal readout signal is used and the time difference of the signal is used for positioning, so as to reduce the number of electronic channels and improve the position resolution. The above technical route has passed the technical research in the early stage, and has been verified by principle, prototype detector performance test and engineering prototype test. With the strong support of the Ministry of science and technology and the NSFC, the Chinese team has been deeply involved in the development of detectors and electronics, and has completed the construction of four engineering prototypes, verifying the ability of the Chinese team in the performance research and engineering construction of detectors.

Because the narrow air gap RPC works under such extreme detector structure and working conditions, to complete the construction of new detectors with a total amount of more than 1400 square meters and ensure that all detector units have excellent, uniform and consistent performance, it is necessary to finally optimize the design of detectors on the basis of preliminary work, And further improve the production process and establish a unified batch production process and quality control method, and finally successfully complete the project construction, on-site installation and commissioning. Through the research of this project, we can fully grasp the key technology of the construction of large area narrow air gap gas detector.

According to the key problems of narrow air gap RPC muon trigger detector that need to be solved at this stage, the project plans to carry out targeted research in the following aspects.

1) Air gap fabrication process research and uniformity control. The narrow air gap RPC has a large area (more than 1.7 meters in length and 1.1 meters in width) and a small air gap width (1 mm). The accuracy of the air gap should be controlled within ± 10 microns. In addition to the special research on the processing method and process of the gasket and frame that determine the air gap thickness, it is also necessary to establish a special automatic gasket arrangement, dispensing and coating equipment, and optimize the manufacturing process and various parameters to ensure the overall manufacturing accuracy and uniformity of the detector.

2) Flatness control of readout board fabrication. The RPC readout board will be made of honeycomb structure with light weight and high strength. The flatness of the honeycomb board will determine the flatness of the final detector. Therefore, the readout board is required to have a flatness better than 100 μ M. Therefore, it is necessary to establish and optimize the corresponding batch production process and quality control methods.

3) Research on mass production and quality control of front-end electronics. Front end electronics is the core device for the normal operation of narrow air gap RPC. The quality control in batch production is particularly important. Therefore, it is necessary to establish a special quality control method and batch test method.

4) Detector performance test. All completed single-layer detectors need to pass cosmic ray test to verify their performance. RPC detector has large area, many channels, and the time for batch production is tight. It is necessary to design and build a large-scale multi-layer detector test platform and data acquisition system.

5) Installation and commissioning. With the progress of engineering construction, the detectors manufactured and tested will be delivered to CERN experimental site in batches. After performance testing, they will be gradually installed on atlas experimental device according to the engineering installation arrangement, and will be tested and debugged on site.

Major scientific problems or key technical problems to be solved:

Through the narrow air gap technology route, the main performance of RPC, such as counting rate capability, time resolution, and working life, can be comprehensively improved, which is the dominant direction of RPC development in the future; The construction of atlas Bi RPC will be the first large-scale application of 1mm air gap RPC detector in particle physics experiments.

Assessment index and evaluation means/METHODS: the counting rate ability is above 1 kHz/cm2, the detection efficiency is higher than 95%, and the time resolution is better than 1 ns. The above performance indicators have been carefully evaluated by cosmic ray test, radioactive source test, or beam test arranged by Atlas muon detector upgrade cooperation group.

Division of tasks of participating units

University of science and technology of China: comprehensively presided over the research and construction of RPC and electronics, and was responsible for the research on the manufacturing process and quality control of RPC air gap, the production and flatness control of readout honeycomb panel, the research on the production and testing methods of front-end electronics, the batch test of detectors, and the installation and commissioning of atlas on site.

Shanghai Jiaotong University: fully participated in the production and testing of RPC detector, focusing on the production and partial completion of readout honeycomb panel and flatness test, the production and testing of single-layer detector, and site installation and commissioning.

2. Topic 2:xxxxx (the outline is the same as above)

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(for multiple topics, please refer to the above outline to add corresponding contents)

4、 Main innovations

The main innovation points of the project are briefly described around the basic frontier, common key technologies or application demonstration. The description of each innovation point is limited to 500 words.

1. Innovation point 1:xxxxx

The narrow air gap technology route of muon detector project can comprehensively improve the counting rate, time resolution, working life and other performance of RPC, which is the dominant direction of RPC development in the future; This will be the first large-scale application of 1mm air gap RPC detector in particle physics experiments.

2. Innovation point 2:xxxxx

**Part III research basis of application units and participating units**

1、 Existing work foundation, research achievements, research team, etc. of the applicant

（1） Preliminary task undertaking, comprehensive performance evaluation (acceptance) and relevant research results of the project and subject leading unit in this research direction

Limited to 1000 words.

RPC topic:

During the atlas phase II upgrade, the University of science and technology of China presided over and successfully concluded the national key R&D program Large Hadron Collider (LHC) experimental detector upgrade project, and presided over the atlas experimental brother-in-law detector upgrade project. Through the implementation of the project, I have fully participated in the development of RPC and electronics for Atlas phase II upgrade, and focused on the design, fabrication and testing of honeycomb readout board; Simulation study, performance test and design optimization of the two terminal readout method; The research on batch production process and quality control method has made important contributions to the smooth development of the upgrading work and laid the foundation for the engineering construction.

（2） Scientific research level and main achievements of project and subject leaders

Limited to 2000 words.

Sunyongjie, principal of RPC project:

He graduated from the University of science and technology of China with a doctorate degree and is now an associate professor. He has been engaged in the research and development of new gas detectors for high-energy physics experiments for a long time, and has repeatedly undertaken and successfully completed the research and engineering construction of detector subsystems in large-scale high-energy experiments, including the engineering production and quality control of rhic-star TOF detector MRPC, the research, design and engineering construction of star MTD system lmrpc, the research and engineering construction of BES-III end cap TOF upgraded MRPC detector, Large engineering tasks such as the development of fair-cbm TOF MRPC detector.

（3） Supporting status of relevant scientific research conditions of leading units of projects and projects

Including national (key) laboratories, National Engineering (Technology) centers, national major scientific research infrastructure (including large-scale instruments and equipment), etc., limited to 1000 words.

RPC Project Leader: University of science and technology of China

Relying on the "State Key Laboratory of nuclear detection and Nuclear Electronics", it plays a key role in the R&D and construction of detectors and related electronics in the major scientific projects of particle physics at home and abroad: such as the successful completion of Beijing Spectrometer (BESIII) trigger and readout electronics, end cover time-of-flight detector, RPC detector electronics; Daya Bay neutrino detector RPC electronics; Wukong dark matter detector electronics and calorimeter; Fallacy detectors (MDT, RPC, TGC) and trigger electronics of atlas and CMS; The developed high time-resolution MRPC was successfully applied to star, BESIII and CBM experiments as fallacies and time-of-flight detectors, respectively. Switched capacitor array ASIC design has been carried out, and high-speed waveform digital ASIC technology has been explored based on Jiangmen underground neutrino experiment (Juno); The first domestic product with an effective area of 100cm has been successfully manufactured × 50cm GEM detector. The team's laboratory has infrastructure such as gas detector cosmic ray test system, high-precision detector integrated test platform, advanced nuclear electronics test and assembly platform, which has laid a solid foundation for the smooth implementation of the project.