JUNO
Jiangmen Underground Neutrino Observatory

实验计划
Experiment Plan

■ 本实验计划在 2017 年完成实验站基建工程，2019 年完成探测器的安装，2020 年调试、取数。

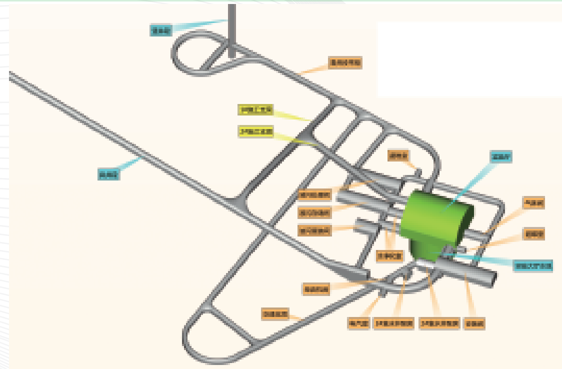
■ Construction work on the experiment station is planned to be completed in 2017, the detector will be completely installed in 2019, and commissioning and data-taking will begin in 2020.

- 2013年：Completion of conceptual and construction design of the detector and invitation for bids　完成探测器概念设计及基建设计与招标
- 2014年：开始基建施工，完成PMT样管与探测器小模型　Start of construction; completion of PMT sample tube and prototype of detector
- 2015年：Production line of PMTs　开始PMT生产线制造
- 2016年：开始PMT生产，完成探测器设计与主要设备招标　Start of PMT production, completion of design and equipment bidding
- 2017年：Completion of construction and start of installation　完成基建，开始探测器安装
- 2018年：继续探测器安装及液闪生产　Detector installation and liquid scintillation production
- 2019年：Installation　完成探测器安装
- 调试取数　Commissioning and data-taking

实验站配套基建工程
Civil Construction of the Experiment Station

■ 为了减少宇宙射线对于实验的干扰，实验厅建在地下 729 米深处，因此，实验站建设包含地下、地上两部分内容：地下建筑主要为斜井(1341 米)、竖井(616 米)、实验厅(跨度 50 米、高 70 米)及附属洞室。地上建筑主要包括: 装配大厅、绞车房、地上动力中心、空调机房、氮气及纯净水房、办公楼等。

■ 本工程采用总承包建设模式，由黄河勘测规划设计有限公司、中国水利水电第六工程局有限公司与河南锦源建设有限公司组成的总承包联合体负责工程建设，计划在 3 年内(2015–2017)建成。



■ 江门中微子实验站配套基建工程地下洞室三维布置图
3D layout of JUNO underground construction

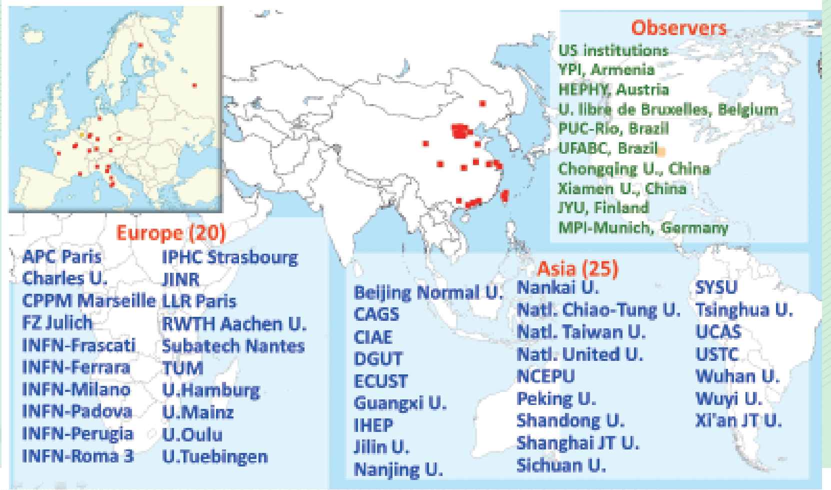
■ The experimental hall will be built 729 meters underground to reduce cosmic rays. The construction of the experiment station consists of two parts: above-ground and underground. The underground structure includes an inclined shaft (1341 meters), a vertical shaft (616 meters), an experiment hall (50 meters in span and 70 meters in height) and auxiliary chambers. The ground structures mainly include an assembly hall, a hoist room, a ground power center, air conditioner rooms, nitrogen and purified water rooms, office buildings and so on.

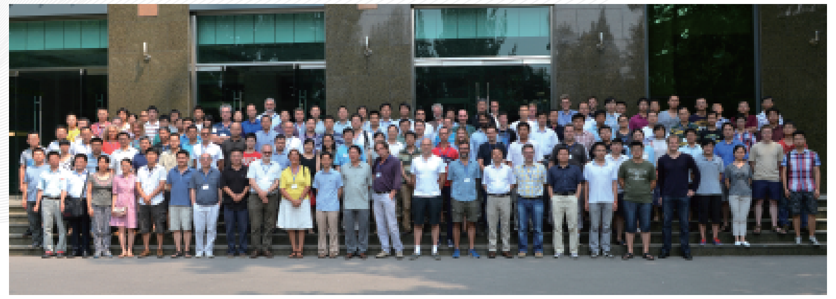
■ A consortium consisting of three companies, Yellow River Engineering Consulting Co., Ltd (YREC), Sinohydro Engineering Bureau 6 Co., Ltd and Henan Jinyuan Construction Co., Ltd, has been contracted for the construction. The construction project is expected to be completed in 3 years (2015-2017).

国际合作
International Cooperation

■ 江门中微子实验是一个以我国为主、多国参与的大型基础科学研究项目。合作单位在原来大亚湾中微子实验合作组的基础上进一步扩大，目前共有 8 个国家和地区的 45 个单位参加，共 300 余人。2014 年 7 月 28 日，江门中微子实验国际合作组在北京正式成立。

■ The Jiangmen Underground Neutrino Observatory (JUNO) is a large-scale fundamental scientific research project led by China with the participation of various countries. JUNO consists of more than 300 scientists from 45 institutions in 8 countries and regions. The International Collaboration of JUNO was officially founded in Beijing on 28th July, 2014.





中国科学院高能物理研究所
Institute of High Energy Physics,Chinese Academy of Sciences
地址：北京市石景山区玉泉路19号乙
邮编：100049
电话：010–88235008
传真：010–88233105
网址：www.ihep.cas.cn

江门中微子实验
Jiangmen Underground Neutrino Observatory

江门中微子实验站配套基建工程地面建筑三维布置图
3D layout of JUNO ground construction

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Institute of High Energy Physics,Chinese Academy of Sciences

JUNO

Jiangmen Underground Neutrino Observatory

什么是中微子

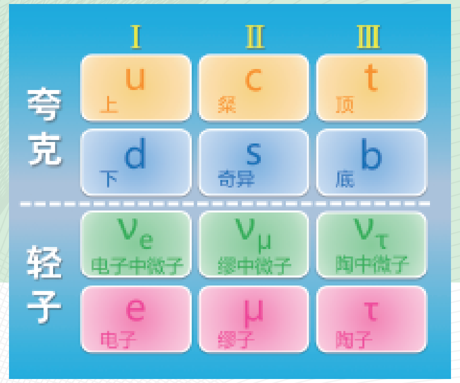
What is the Neutrino?

- 粒子物理的研究结果表明，构成物质世界最基本的粒子有12种，包括6种夸克（上、下、奇异、粲、顶、底），3种带电轻子（电子、缪子和陶子）和3种中微子（电子中微子、缪中微子和陶中微子）。

- 中微子常用符号 ν 表示，它不带电，质量非常轻（小于电子的百万分之一），以接近光速运动。中微子只参与非常微弱的弱相互作用，具有极强的穿透力。穿越地球直径那么厚的物质，在100亿个中微子中只有一个会与物质发生反应，因此中微子的检测非常困难。所以，在所有基本粒子中，人们对中微子了解最少。实际上，大多数粒子物理和核物理过程都伴随着中微子的产生，例如核反应堆发电（核裂变）、太阳发光（核聚变）、天然放射性（贝塔衰变）、超新星爆发、宇宙射线等等。宇宙中充斥着大量的中微子，大部分为宇宙大爆炸的残留，大约为每立方厘米300个。

- 1998年超级神冈实验证明了中微子存在振荡现象，即由一种中微子转变为另一种中微子，也称之为不同类型的中微子的混合。中微子的混合参数描述了中微子之间相互转变的规律。中微子振荡间接证明了中微子具有微小的质量，对粒子物理、天体物理与宇宙学具有重大影响。另外两个证实中微子振荡的实验SNO与KamLAND也分别被评为当年的世界十大科技新闻。大亚湾实验已在这一世界前沿热点领域取得重大成果，发现了中微子第三种振荡模式，打开了理解反物质消失之谜的大门，被《Science》评选为2012年度十大科学突破之一。

- 中微子有大量谜团尚未解开。包括它的质量大小和起源、磁矩和CP破坏的大小等等。同时，对它的研究远远超出了粒子物理的范畴，是粒子物理、天体物理、宇宙学、地球科学的交叉与热点学科。



- 构成物质世界的12种基本粒子，其中3种为中微子

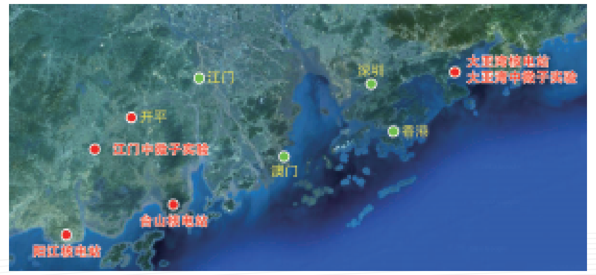
- Twelve types of elementary particles, of which three are neutrinos, constitute the building blocks of the matter world.

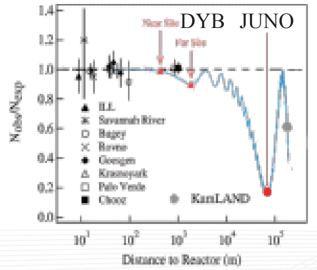
- Based on particle physics experiments, it has been found that matter consists of twelve elementary particles, including six types of quark (u, d, c, s, t, b), three types of charged lepton (electron, muon, tau), and three types of neutrino (electron neutrino, muon neutrino and tau neutrino).

- The neutrino is denoted by the Greek letter ν (nu). It has no electrical charge and very little mass (less than one millionth of the mass of an electron), and moves at a speed nearly equal to that of light. Since neutrinos have very little interaction with matter, a typical neutrino passes through normal matter unimpeded. When penetrating the earth, given the thickness of the earth's diameter, only one out of every ten billion neutrinos interacts with matter, which makes the detection of neutrinos very difficult. Among all the elementary particles, the neutrino is the least known. However, neutrinos are generated in many particle physics and nuclear physics processes, such as in nuclear power generation (nuclear fission), the glowing of the sun (nuclear fusion), natural radioactivity (beta decay), supernova explosions and cosmic rays, etc. The universe has large quantities of neutrinos, most of which are left over from the Big Bang, with about 300 in every cubic centimetre.

- In 1998, the Super-Kamiokande experiment discovered the oscillation of neutrinos, namely the conversion of one type of neutrino into another type, which is also called the mixing of neutrinos. The mixing parameter describes the rule of transformation. The oscillation of the neutrinos implies that neutrino has a tiny mass. This result had a huge impact on particle physics, astrophysics and cosmology. Many other experiments, e.g. SNO and KamLAND, confirmed the phenomenon of neutrino oscillation. The Daya Bay Experiment has significant contributions in this field with the discovery of the third type of neutrino oscillation mode. It was selected as one of the top ten scientific breakthroughs of the year 2012 by *Science* magazine, as it opens a door to understand why matter dominates over antimatter in the universe.

- Numerous mysteries of neutrinos are still unsolved, including the origin and the size of their masses, the mass hierarchy, and the CP violation. Meanwhile, studies of neutrinos go far beyond the field of particle physics: astrophysics, cosmology, and earth science are also involved.





- 反应堆中微子振荡与反应堆距离的关系

Relationship between neutrino oscillation and distance to the reactor

从大亚湾中微子实验到江门中微子实验 From Daya Bay to Jiangmen

- 在大亚湾中微子实验成功发现中微子的第三种振荡模式后，中微子研究的下一个目标是测量中微子质量顺序。物理灵敏度分析表明，允许的实验站范围在距反应堆 50 至 55 公里，宽为 200 米的区域内。通过详细的地质勘测，选址于广东省江门市开平市，距广东阳江和台山反应堆群约 53 公里。

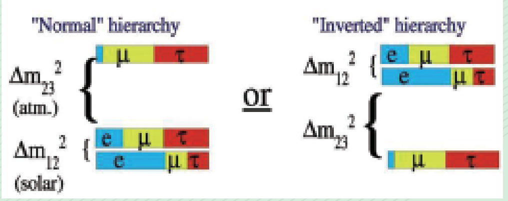
- 2013 年初，中国科学院以战略性先导科技专项（A 类）形式予以立项，正式拉开了建设江门中微子实验的序幕。

- After successfully discovering the third type of neutrino oscillation by the Daya Bay Neutrino Experiment, the next focus is the measurement of the neutrino mass hierarchy. The sensitivity analysis shows that the ideal location of the experiment station is in an area 50 to 55 kilometers in distance from the reactor. Through detailed geological inspection, the experiment site was chosen in Kaiping, Jiangmen City, Guangdong Province, about 53 kilometers from the nuclear reactors at Yangjiang and Taishan Nuclear Power Plants.

- At the beginning of 2013, the CAS approved the project as a Strategic Priority Research Program (A), which officially started the Jiangmen Underground Neutrino Observatory, JUNO.

物理目标 Physics objectives

- 江门中微子实验的首要物理目标是利用反应堆中微子振荡确定中微子质量顺序。同时，可以精确测量中微子 6 个振荡参数中的 3 个，并达到好于 1% 的国际最好水平，并进行超新星中微子、地球中微子、太阳中微子、大气中微子、惰性中微子等多项国际领先的交叉前沿研究。



正质量顺序　　反质量顺序

- The primary goal of the Jiangmen Neutrino Experiment is to utilize the oscillation of reactor neutrinos to detect the mass hierarchy of neutrinos, as well as to accurately measure 3 of the 6 neutrino oscillation parameters to better than 1% precision, and to perform world-leading studies on supernova neutrinos, geo-neutrinos, solar neutrinos, atmospheric neutrinos, sterile neutrinos and so on.

实验意义 Significance

- 中微子的质量顺序在宇宙演化、太阳及超新星中微子的产生与传播、各种长基线中微子振荡等方面有重要影响。精确测量中微子振荡参数，使检验中微子混合矩阵的幺正性、发现新物理成为可能，对中微子物理的未来发展具有重要意义 。中微子是研究天体和地球内部的探针，将在检验超新星爆发机制、验证地球物理模型、研究太阳物理等方面发挥关键作用。

- The Neutrino Mass Hierarchy has a crucial role in the evolution of the universe, the generation and propagation of solar and supernova neutrinos, the oscillation of long baseline neutrinos and other aspects of theoretical and experimental particle physics. Precise measurements of the neutrino mixing parameters will make it possible to inspect the unitarity of the neutrino mixing matrix, may lead to new physics, and will be of great significance to the future study of neutrino physics.Neutrinos are a probe for the study of celestial bodies and the earth's interior, and as such will exert a pivotal role in the inspection of the mechanism of supernova explosions, verification of geophysical models and solar physics.

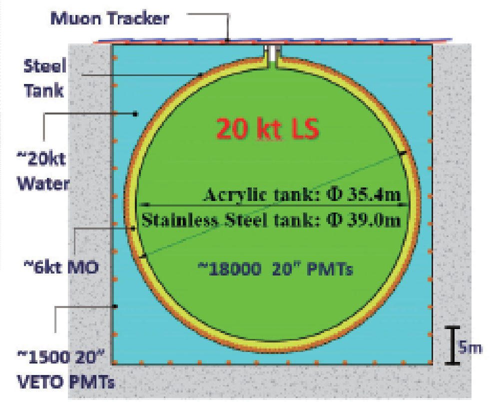
阳江、台山核电站 Yangjiang and Taishan nuclear power plants

- 阳江核电站共规划 6 个反应堆，5 个在建，总热功率为 17.4GW。台山核电站共划 4 个反应堆，2 个在建，总热功率 18.4GW。至 2020 年，阳江与台山核电站有效的反应堆群功率将为世界第一。反应堆的功率越大，释放的中微子数目越多，实验精度就越高。因此，江门中微子实验站是世界上目前发现的最适合利用核反应堆测量中微子质量顺序的地方。

- Yangjiang nuclear power plant consists of 6 reactors, of which 1 is under commercial operation and 5 are under construction, with total thermal power of 17.4 GW. Taishan nuclear power plant includes 4 reactors, of which 2 are under construction, with total thermal power of 18.4 GW. Up to 2020, the effective power of these reactors should rank first in the world. The more powerful the reactors get, the larger the number of neutrinos which will be released, and therefore the higher the accuracy of the experiment will get. Under such circumstances, the Jiangmen Underground Neutrino Observatory is by far the most favorable location worldwide to utilize nuclear reactors to detect the mass hierarchy ordering of neutrinos.

实验方案

Experiment layout



- 江门中微子实验将建造一个有效质量为 2 万吨的低本底、高透明度的球形液体闪烁体探测器，称为中心探测器。中心探测器浸泡在圆柱形的水池中（灌装有约 2 万吨高纯水），水池兼做水契仑柯夫测器和屏蔽体。

- 水池顶部为约 5600 平方米的宇宙线径迹探测器。

- According to the experiment plan, a 20,000 ton spherical, low-background, high-transparency liquid scintillator detector is to be built, named the central detector. The central detector is to be placed in a cylindrical water pool (filled with 20,000 tons of ultra-pure water), which also serves as Cerenkov detector and shield.

- A cosmic muon tracker is to be installed on the top of the water pool, with an area of 5,600 square meters.

中心探测器

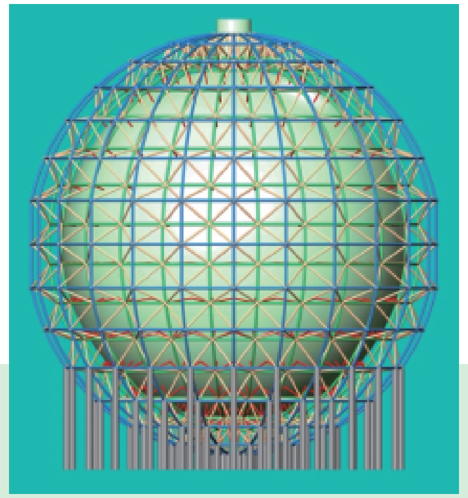
The central detector

- 中心探测器内部灌装有 2 万吨液体闪烁体，由 18000 只 20 英寸高量子效率光电倍增管探测中微子产生的闪烁光。

- 较目前国际最好水平，本探测器的液体闪烁体体积增大了 20 倍，光电子产额增大了 2.5 倍，能量分辨率达到前所未有的 3%。

- The interior of the central detector is to be filled with 20,000 tons of liquid scintillator, and 18,000 20-inch high quantum efficiency photomultipliers will then be placed to detect the flashes generated by neutrinos.

- The volume of liquid scintillator in this detector is 20 times larger than the previous world' s largest, with the photoelectric yield multiplied by 250% and the energy resolution reaching an unprecedented 3%.



水契仑柯夫探测器与顶部径迹探测器

Cerenkov detector and Top Muon Tracker

- 水契仑柯夫探测器有两个作用，一是用作宇宙线探测器，宇宙线穿过水池时，会激发契仑柯夫光，通过水池四周放置的光电倍增管探测契仑柯夫光，可以探测到宇宙射线，从而将它对中微子探测的影响去除；二是作为屏蔽层，屏蔽掉高能宇宙线在附近岩石中产生的大量次级粒子以及岩石本身的天然放射性。水池上方覆盖着顶部径迹探测器，以确定宇宙线的径迹。

- The Cerenkov detector has two main functions. On the one hand, it can detect cosmic rays. Because cosmic rays can excite Cerenkov light when passing through the water pool, the photomultipliers, around the pool, can be used to detect the Cerenkov light and to eliminate the cosmogenic backgrounds. On the other hand, it can be used as a shielding layer to protect the central detector from a large number of natural radioactivity of the rocks and secondary particles from the surrounding rocks produced by high-energy cosmic rays. The Top Muon Tracker is placed above the top of the water pool in order to determine the tracks of cosmic rays.