李政道传奇：纵横科学跨域起舞

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The Legend of T.D. Lee: Dancing Across Scientific Domains

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物理学家李政道先生于2024年8月4日永远离开了我们。在我们缅怀他一生时，看见他是一位在很多物理学领域创造了历史性成就的顶级科学家、一位桃李满天下的教育家、一位为大国搭建科教框架的战略科学家、一位打通了东西方科学界限的使者、具有一缕跨科学与人文艺术的有趣且美好的灵魂……他如何取得了这么多精彩的成就？如何游弋于科学和人文之间、为不同文化架起桥梁？为什么对培养学生倾注了那么多的心血？

第一章: 细推物理行乐，跨域探索求真

李政道先生对自然界充满好奇心，科研活动涉猎极广，大至宇宙和星球、小至原子核和基本粒子；从经典力学、统计力学、流体学，到凝聚态、核物理、量子场论，这每一个领域都可以让很多优秀的科学家皓首穷经而未必达到高峰，他却自由地从一个领域游弋到另一个领域、多项成就都可达诺奖水平。图一展示了李政道曾涉及的科研领域，以下简略介绍他的几项理论成果。

李政道做研究生时发表了第一篇论文（参考文献1），关于介子与核子和轻粒子的相互作用，他与马歇尔·罗森布鲁斯（Marshall Rosenbluth）及杨振宁合作，发现好几个衰变和捕获过程的耦合常数大致相同，于是认为存在同一种“中间波色子”（他们命名为“W”粒子， W即 Weak–弱），首次把费米（Enrico Fermi）提出的β衰变由某种“弱力”导致的思路、提升到弱力是一种与电磁力、引力类似的普适作用力，这也开启了李政道与弱力的一辈子缘分。李政道当年的博士生庞阳教授说，“李先生经历了人类对弱力的整个认知过程，包括弱力被发现、到宇称守恒破缺、再到有关弱力的各种理论建立和新现象的预测、以及大量实验验证”。弱相互作用力是20世纪下半叶最为神秘、给人类带来最多惊喜的物理学领域之一[SC1]，至今仍然有很多不解之谜。

李政道完成于1949年的博士论文（参考文献2），研究了白矮星的成分构成、平衡态和稳定性。当时人们基于苏·钱德拉塞卡（S. Chandrasekhar）的工作，认为白矮星主要由氢组成，是一种早期恒星，最后能冷却为白矮星的恒星临界质量约是太阳的4倍，而李政道认为白矮星主要由氦组成、是一种晚期恒星，其临界质量是太阳的1.44倍。李政道的博士论文获得了当年芝加哥大学的优秀论文奖，其主要研究结论直到现在仍然被科学界认可。笔者认为，当苏·钱德拉塞卡于1983年因其白矮星工作获得诺奖时，李政道也有资格成为此项成果共同获奖人。

1951年，李政道发表了二维液体和三维液体湍流差异的研究结果（参考文献3），这是流体力学中非常重要的问题，对气象预报等领域尤其有用。该论文得到著名数学家、计算机之父冯·诺伊曼（John Von Neumann）的欣赏，他当时力主把李政道招进普林斯顿高等研究院，期望着年轻的李政道在新兴的计算科学领域施展才华，尽管李政道心仪的研究方向是理论物理。

1952年，李政道与杨振宁合作同时发表了两篇论文（参考文献4、5），用严格数学分析方法研究物态和相变，他们理论推导出了不连续相变（气体-液体一级相变）的过程，被称为“李-杨定理”，至今仍然是统计和凝聚态物理的经典成果。当时在普林斯顿高等研究院就职的爱因斯坦（Albert Einstein）读了这两位年轻科学家的文章之后，特意把他们请去自己的办公室讨论其物理意义。伊利诺伊大学厄巴纳-香槟分校物理学博士、四川大学敖平教授认为：[SC2]这无疑是一项可获诺奖的成果，后来几项不如“李-杨定理”重要的相变理论，如连续相变（二级相变）、拓扑相变、及平均场相变理论等，都先后获得了诺奖。

1954年，李政道的主要精力放在“李模型”（参考文献6）的构建上。庞阳博士认为，“这个模型是场论中少有的可解模型，重整化可通过此模型严格推导出来，对之后的场论和重整化影响很大”。当时物理学界的翘楚人物如奥本海默（Julius Robert Oppenheimer）、泡利（Wolfgang Ernst Pauli）和海森堡（Werner Karl Heisenberg）等都对“李模型”赞誉有加。

1955年，李政道的兴趣转向了θ-τ之谜，当时理论物理的研究热点。θ-τ是两个不同粒子、还是同一粒子？有些基本物理学常识和原理（比如宇称守恒）有问题吗？该年他与J. Orear合作发表了一篇相关文章（参考文献7）做尝试性探讨。1956年4月初，物理学界众多重量级科学家在罗切斯特城就θ-τ之谜举行了专题研讨会，科学家们畅所欲言，提出了各种各样的假说和思路，但并未形成任何共识。

罗切斯特会议之后，李政道立刻与哥伦比亚大学的同事斯坦伯格教授（Jack Steinberger，1988年诺贝尔物理学奖获得者）讨论θ-τ现象及相关的宇称问题，并提出用赝标量思路来做理论梳理和实验设计。由于吴健雄先生在β衰变领域实验经验丰富，李政道很快去找吴健雄讨论β衰变与宇称守恒的问题，吴健雄立刻认识到之前的β衰变实验从未检验过宇称是否守恒，而这个实验非常重要，于是放下其它事很快投入实验中。

1956年杨振宁与李政道一道研究宇称守恒问题，并做出了非常重要的贡献。1956年6月，李杨二位先生完成了他们的历史性论文“弱作用力下宇称是否守恒的问题”（参考文献8），提出实验测量离散对称性“电荷共轭”、“宇称”和“时间反演”的条件，指出已有的弱相互作用实验从未检验这些对称性、并建议了几种检验弱相互作用宇称是否守恒的实验。该文于1956年10月发表后，立刻在物理学圈引起了震撼[Office3]。[SC4]1957年初，他们又发表了“二分量中微子与宇称守恒的理论”一文（参考文献9），对宇称不守恒做出了明确的理论阐述和结论。1957年1月，吴健雄团队完成了通过β衰变实验确认了弱相互作用下宇称不守恒的论文，随即有近百个实验从不同角度确认该结论。

弱力情况下宇称守恒破缺这项成果是石破惊天的。作为普通人，我们看见了两位年轻的华人科学家以史上最快的速度获得物理学诺奖（1956年10月发表论文，1957年10月获奖），后续大量科学家沿着这个方向继续研究、并有十几位科学家先后因相关成就获得诺奖。而物理学家们受到的震撼更为直击人心，因为物理世界的一项准公理被推翻了。1944年物理学诺奖获得者伊西多·拉比（Isidor Isaac Rabi）说：“一个相当完整的理论结构在基础上被粉碎了，我们不确定如何将这些碎片重新拼凑起来。”1945年物理学诺奖获得者泡利说：“我不相信上帝是一个弱左撇子”。但在大量实验结果和李杨二位先生无懈可击的理论分析面前，骄傲的泡利也不得不认可。

美国理论物理学家、科普作家杰里米·伯恩斯坦（Jeremy Bernstein）多次讲述一个故事：1958年春天，他在普林斯顿高等研究院工作，当时李政道和杨振宁也在那里，他们刚获得了诺奖。一个周六上午，他看见李政道从远处走过来就迎上去问李政道是否考虑过超精细分裂对μ子原子的影响。李政道把他带到办公室，快速在黑板上演算，伯恩斯坦说自己完全跟不上李政道的节奏。周一他发现自己的信箱[SC5]里有一篇打印好的论文，署名了三个作者，伯恩斯坦、李政道和杨振宁。他顿时惊呆了，犹如“处女怀孕”，一是震惊于李政道的工作速度，更是因为他仅仅问了李政道一个问题而没有做什么研究工作，就这样成为了这篇论文的第一作者。他说李政道此举非常慷慨，如果他们在文章中仅仅鸣谢他也符合科学界惯例……由于这篇文章，普林斯顿高等研究院决定再聘任伯恩斯坦一年，他也受到很多朋友们的羡慕。其他人也讲述过类似的小故事，显示了李政道的科研伦理操守和大气的为人。

三十岁就站在科学巅峰的李政道，接下来的科研活动继续跨学科随心所欲的选题风格，以“细推物理须行乐”的人生境界，听从自己的好奇心做了很多重大而有趣的科研课题，如1964提出的KLN定理（参考文献10），证明了散射过程的物理观测量中没有红外发散，奠定了用高能喷注方法发现夸克和胶子的理论基础。庞阳等对李政道的主要工作做过比较系统的整理（参见文献11,12,13）。当谈及李政道为什么能够在这么多物理领域行走自如、硕果累累时，李政道当年的博士生任海沧教授认为，“物理学最根本的原理其实只有几条，李先生对物理学精髓的理解非常深入、一通百通，专业之间的边界对他没有约束。”庞阳也持类似观点：“李先生的研究都是从最基本的原理出发推导。这些基本原理对各物理分支都适用，因此在李先生这里没有不同物理领域的边界。”

图一：李政道的科研领域（信息来源：上海交通大学李政道图书馆）。

Physicist T.D. Lee left us forever on August 4, 2024. As we commemorate his life, we see him as a top scientist who made historic achievements in many fields of physics, an educator with students all over the world, a strategic scientist who built scientific and educational frameworks for great nations, an envoy who bridged the boundaries between Eastern and Western science, and a soul with interesting and beautiful cross-disciplinary interests in science, humanities, and arts... How did he achieve so many brilliant accomplishments? How did he navigate between science and humanities, building bridges between different cultures? Why did he devote so much effort to nurturing students?

Chapter 1: Delving into Physics with Joy, Exploring Across Disciplines in Pursuit of Truth

T.D. Lee was filled with curiosity about nature, and his research activities were extremely broad, ranging from the cosmos and stars to atomic nuclei and elementary particles; from classical mechanics, statistical mechanics, fluid dynamics, to condensed matter physics, nuclear physics, and quantum field theory. Each of these fields could occupy many excellent scientists for a lifetime without necessarily reaching the pinnacle, yet he freely moved from one field to another, with multiple achievements worthy of Nobel Prize level. Figure 1 shows the research fields Lee was involved in, and the following briefly introduces some of his theoretical achievements.

Lee published his first paper as a graduate student (Reference 1), on the interaction of mesons with nucleons and light particles. Working with Marshall Rosenbluth and C.N. Yang, they discovered that several decay and capture processes had approximately the same coupling constants, leading them to propose the existence of a "intermediate vector boson" (which they named the "W" particle, W for Weak). This was the first time Enrico Fermi's idea of β decay being caused by a "weak force" was elevated to the concept of weak force as a universal force similar to electromagnetic and gravitational forces, marking the beginning of Lee's lifelong connection with the weak force. Professor Pang Yang, Lee's former doctoral student, said, "Mr. Lee experienced the entire process of human understanding of the weak force, including its discovery, the violation of parity conservation, the establishment of various theories related to the weak force and predictions of new phenomena, as well as numerous experimental verifications." The weak interaction force was one of the most mysterious areas of physics in the latter half of the 20th century, bringing the most surprises to humanity, and still has many unsolved mysteries.

Lee's doctoral thesis completed in 1949 (Reference 2) studied the composition, equilibrium state, and stability of white dwarfs. At that time, based on the work of S. Chandrasekhar, people believed that white dwarfs were mainly composed of hydrogen, were early-stage stars, and the critical mass of stars that could eventually cool into white dwarfs was about 4 times that of the sun. However, Lee argued that white dwarfs were mainly composed of helium, were late-stage stars, and their critical mass was 1.44 times that of the sun. Lee's doctoral thesis won the outstanding thesis award at the University of Chicago that year, and its main research conclusions are still accepted by the scientific community today. The author believes that when S. Chandrasekhar received the Nobel Prize in 1983 for his work on white dwarfs, Lee was also qualified to be a co-recipient of this achievement.

In 1951, Lee published research results on the differences between two-dimensional and three-dimensional fluid turbulence (Reference 3), which is a very important problem in fluid dynamics and particularly useful in fields such as weather forecasting. This paper was appreciated by the famous mathematician and father of computer science, John von Neumann, who strongly advocated for recruiting Lee to the Institute for Advanced Study at Princeton, hoping that the young Lee would display his talents in the emerging field of computational science, although Lee's preferred research direction was theoretical physics.

In 1952, Lee collaborated with Yang Chen-Ning to simultaneously publish two papers (References 4, 5), using rigorous mathematical analysis methods to study phase states and transitions. They theoretically derived the process of discontinuous phase transitions (gas-liquid first-order phase transitions), known as the "Lee-Yang theorem," which remains a classic result in statistical and condensed matter physics to this day. Albert Einstein, who was working at the Institute for Advanced Study at Princeton at the time, read the articles by these two young scientists and specifically invited them to his office to discuss their physical significance. Professor Ao Ping, a physics Ph.D. from the University of Illinois at Urbana-Champaign and now at Sichuan University, believes that this was undoubtedly an achievement worthy of a Nobel Prize. Several phase transition theories that came later and are not as important as the "Lee-Yang theorem," such as continuous phase transitions (second-order phase transitions), topological phase transitions, and mean-field phase transition theory, have all subsequently received Nobel Prizes.

In 1954, Lee's main focus was on constructing the "Lee Model" (Reference 6). Dr. Pang Yang believes, "This model is one of the few solvable models in field theory, where renormalization can be rigorously derived through this model, greatly influencing subsequent field theory and renormalization." Leading figures in the physics community at the time, such as Julius Robert Oppenheimer, Wolfgang Ernst Pauli, and Werner Karl Heisenberg, all highly praised the "Lee Model."

In 1955, Lee's interest turned to the θ-τ puzzle, a hot topic in theoretical physics at the time. Were θ and τ two different particles or the same particle? Was there a problem with some basic physics knowledge and principles (such as parity conservation)? That year, he collaborated with J. Orear to publish a related article (Reference 7) for tentative discussion. In early April 1956, many heavyweight scientists in the physics community held a special seminar on the θ-τ puzzle in Rochester. Scientists spoke freely, proposing various hypotheses and ideas, but no consensus was reached.

After the Rochester conference, Lee immediately discussed the θ-τ phenomenon and related parity issues with his colleague at Columbia University, Professor Jack Steinberger (1988 Nobel Prize winner in Physics), and proposed using the pseudoscalar approach for theoretical analysis and experimental design. Due to C.S. Wu's rich experimental experience in the field of β decay, Lee quickly went to discuss β decay and parity conservation issues with Wu. Wu immediately realized that previous β decay experiments had never tested whether parity was conserved, and this experiment was very important, so she quickly put aside other matters and devoted herself to the experiment.

In 1956, Yang Chen-Ning and Lee worked together on the parity conservation problem and made very important contributions. In June 1956, Lee and Yang completed their historic paper "Question of Parity Conservation in Weak Interactions" (Reference 8), proposing conditions for experimental measurement of discrete symmetries "charge conjugation," "parity," and "time reversal," pointing out that existing weak interaction experiments had never tested these symmetries, and suggesting several experiments to test whether parity is conserved in weak interactions. The paper was published in October 1956 and immediately caused a sensation in the physics community. In early 1957, they published another paper "Parity Nonconservation and a Two-Component Theory of the Neutrino" (Reference 9), providing a clear theoretical explanation and conclusion on parity nonconservation. In January 1957, C.S. Wu's team completed a paper confirming parity nonconservation in weak interactions through β decay experiments, followed by nearly a hundred experiments confirming this conclusion from different angles.

The discovery of parity violation in weak interactions was earth-shattering. As ordinary people, we saw two young Chinese scientists receive the Nobel Prize in Physics at the fastest speed in history (paper published in October 1956, award received in October 1957). Subsequently, many scientists continued to research along this direction, and more than a dozen scientists have since received Nobel Prizes for related achievements. The shock to physicists was even more profound, as a quasi-axiom of the physical world had been overturned. Isidor Isaac Rabi, the 1944 Nobel Prize winner in Physics, said: "A rather complete theoretical structure has been shattered at the base and we are not sure how the pieces will be put together." Wolfgang Pauli, the 1945 Nobel Prize winner in Physics, said: "I do not believe that God is a weak left-hander." However, faced with numerous experimental results and the impeccable theoretical analysis of Lee and Yang, even the proud Pauli had to acknowledge it.

American theoretical physicist and science writer Jeremy Bernstein has repeatedly told a story: In the spring of 1958, he was working at the Institute for Advanced Study in Princeton, where Lee and Yang were also present, having just received the Nobel Prize. One Saturday morning, he saw Lee walking from afar and approached to ask if Lee had considered the effect of hyperfine splitting on muonic atoms. Lee took him to his office and quickly calculated on the blackboard. Bernstein said he could not keep up with Lee's pace at all. On Monday, he found a printed paper in his mailbox with three authors listed: Bernstein, Lee, and Yang. He was stunned, as if experiencing a "virgin pregnancy," shocked both by Lee's working speed and by the fact that he had merely asked Lee one question without doing any research work, yet became the first author of this paper. He said Lee's gesture was very generous, and it would have been in line with scientific conventions if they had merely acknowledged him in the article... Because of this paper, the Institute for Advanced Study at Princeton decided to reappoint Bernstein for another year, and he was envied by many friends. Others have also recounted similar anecdotes, demonstrating Lee's scientific ethics and magnanimous character.

Standing at the pinnacle of science at the age of thirty, Lee continued his interdisciplinary and free-spirited approach to choosing research topics in his subsequent scientific activities. With a life philosophy of "delving into physics with joy," he followed his curiosity to tackle many significant and interesting research topics. For example, in 1964, he proposed the KLN theorem (Reference 10), which proved that there is no infrared divergence in the physical observables of scattering processes, laying the theoretical foundation for discovering quarks and gluons using high-energy jet methods. Pang Yang and others have systematically compiled Lee's major works (see References 11, 12, 13). When discussing why Lee could move so freely and fruitfully across so many fields of physics, Professor Ren Haicang, Lee's former doctoral student, believes, "There are actually only a few fundamental principles in physics. Mr. Lee's understanding of the essence of physics is very deep and all-encompassing, and the boundaries between disciplines pose no constraint to him." Pang Yang holds a similar view: "Mr. Lee's research always starts from deriving from the most basic principles. These basic principles apply to all branches of physics, so there are no boundaries between different fields of physics for Mr. Lee."

Figure 1: T.D. Lee's research fields (Source: T.D. Lee Library, Shanghai Jiao Tong University).

第二章: 纵横理论实验，延续费米神话

伊西多·拉比是著名实验物理学家，其知名成就是发现了核磁共振。拉比称赞费米是世界上最后一位同时身兼理论家和实验家的物理全才。的确，无论是在曼哈顿项目中、在芝加哥大学、哥伦比亚大学乃至整个美国物理学界，费米就是一个理论和实验都无所不通的神话。1953年秋天，担任过哥伦比亚大学物理系系主任的拉比和他的同事们把年仅27岁的李政道招进哥伦比亚大学做教授之时，期待这位费米的学生也是通晓实验的理论物理学家。若干年后，拉比应该欣慰自己的确找到了费米的传人。

事实上，李政道的理论性工作，比如“弱作用力下宇称是否守恒的问题”，其理论阐述包含了很多对物理世界的洞察，文章中提出的验证理论的实验设想更是神来之笔。李政道与实验物理学家交往密切、了解很多人的工作内涵和能力，可以畅通及时地与他们交流。就宇称是否守恒的问题，他在半年多时间内鼓动了三组哥伦比亚大学的同事们从事相关实验，他还推动了芝加哥大学及其他地方的科学家们尽早从事相关实验。这种师承于费米先生的理论与实验密切结合的研究风格，犹如人的指纹独特而稳定，贯穿李政道的整个科研生涯。

1970年前后，李政道和Wick教授（Gian Carlo Wick）发表了一系列论文（参考文献14、15、16），他们创建的“李-Wick模型”，预测了极端条件下物质将产生新相变、出现新物态等现象，而高速重离子对撞是验证该理论的方法。庞阳解释说，“现在基础物理学理论框架都基于对称性，然后引入对称性破缺机制进行修正，对称性破缺对应一定的真空特征，李-Wick理论认为相对论重离子对撞可以改变真空特性，从而通过实验直接验证对称性破缺机制”。之后，越来越多的物理学家投入该领域，逐渐发展成相对论重离子对撞（RHIC）物理学分枝。同时，量子色动力学及相应的高能物理实验兴起，研究基本粒子和强相互作用力的科学家也发现了相对论重离子对撞的科学价值并投入其中。

李政道从1983年开始参与布鲁克海文国家实验室筹建相对论重离子对撞机的工作，并承担越来越多的责任（参考文献 17）。筹建一座大科学装置过程非常复杂，科学理论与实验、工程、预算和筹资及人事等各种问题此起彼伏。美国加州大学洛杉矶分校黄焕中教授从1990年即开始参与RHIC筹建工作，目前仍经常利用RHIC从事科学研究。他说，“李先生最早提出了用相对论重离子对撞来激发真空、产生新物质态，即夸克胶子等离子体。他是建造相对论重离子对撞机最重要的推动者之一。”

在对撞机接近完成的1997年，日本理化学研究所（RIKEN）与美国布鲁克海文国家实验室（BNL）联合成立“RIKEN-BNL研究中心”，以相对论重离子对撞机为核心科研装置，日本、美国双方都力推李政道成为该中心的创始主任。在李政道担任中心主任的几年时间里（1997-2003），相对论重离子对撞机于1999年完成了，并于2000年投入实验。科学家们于2005年用RHIC产生了极热、极高密度夸克胶子等离子体，或称“完美液体”，这被认为是宇宙大爆炸初极短时间内的物态，这个相变过程也被发现和记录下来了。另外，科学家在RHIC实验中也对手征对称性破缺和恢复机制进行了丰富的研究。这些理论和实验对人类理解基础物理学理论、基本粒子和核物理、及宇宙起源等意义重大。庞阳认为，“这些是可获诺奖的成就，李先生对高能和核物理实验的贡献不亚于他对理论物理的贡献”。

由于科研需要强大的计算工具，该中心还与哥伦比亚大学合作建造了一台当时世界最快的超级计算机。李政道积极推动该中心与中国科学界合作，经常以“中国高等科学技术中心”为基地在中国举办重离子对撞物理研讨会，还邀请了中科院近代物理研究所、中国科学技术大学、上海应用物理所、兰州大学、清华大学等单位参与RHIC国际合作实验。从中心主任位置退下后，李政道仍一直担任荣誉主任，长期关心支持其工作。目前，该中心聚集了全球一百多位理论和实验物理学家、并支持很多国际合作项目，相对论重离子对撞机仍然在高效运转，帮助科学家们探索自然界最宏观和最微观的奥秘，在宇宙学、核物理和高能物理等交叉领域源源不断地产出科研成果。

建造加速器也一直是中国科学家们的梦想。但由于加速器涉及的科技和工程比较复杂、所需资金量也较大，并且其科技内涵一直在快速进步中，中国加速器的立项过程经历了几十年，所谓“七（次）下八（次）上”。1972年后，李政道等旅美科学家开始陆续回到中国交流，中国科学界获得了新鲜的科技力量，构建加速器的方案也变得越来越具体和紧迫。

1979年初中美建交之际，也签订了“中美科技合作协议”，其中最初合作项目就落地在高能物理领域，中美高能物理联合委员会随即成立。李政道对这份协议的签订和后续执行都起到了关键作用，并担任中美高能合作总顾问。“中美科技合作协议”一般5年续签一次，每当出现问题之时，李政道就会斡旋其中协助化险为夷。过去几十年，每年中美高能科学家都开一次联合会议，在中国和美国的科学重镇轮流举行。

1980年1月，国际粒子物理学大会在广州从化召开。李政道此时已经决定了支持中国建造加速器，他认为兹事体大，于是亲自游说与会者参与和支持。大部分与会者都签字支持，但也有个别与会科学家发公开信不赞成此事。尽管无论是支持还是反对作为学术意见都无可厚非，但值得一提的是李政道为“支持”这一声承诺不仅压上自己声誉、还奉献了几十年宝贵的生命和大量政治资源，而反对者在发了一封公开信后就轻轻地转身没有然后了。

1981年3月，中国科学家团队前往美国洽谈加速器设计方案，他们与李政道、袁家骝、吴健雄及美国斯坦福直线加速器中心主任潘诺夫斯基等美国科学家经过慎重讨论后，一致认为在中国建造2×22亿电子伏特正负电子对撞机是最好的方案。此方案造价较低、物理窗口内容丰富，还可以在做高能物理研究的同时也做同步辐射应用研究，实现“一机两用”。但这种对撞机建造难度较大，科学家们经过反复修改方案细节，于1984年10月正式破土动工，邓小平和李政道都参加了破土仪式。

建造加速器不仅需要理论和实验物理学家，也需要大量的各种工程技术专家。李政道了解世界高能物理理论、实验以及相关支撑技术的前沿情况，也非常了解中国科学界的状况。于是，借中美科技合作协议之力，他动员了美国好几家国家实验室的相关科技人员无偿支持中国加速器的设计和建设，还创造条件把中国高能科学家作为访问学者送往美国的多所国家实验室定向培养。

1988年10月，北京正负电子对撞机正式投入运行。邓小平和李政道二位先生再次携手、出席建成典礼。接下来，中美科学家合作的重点转到正负电子对撞机的运行、物理实验的设计以及数据的处理和分析等。21世纪之后，中美高能物理联合委员会的工作重点转向了北京正负电子对撞机重大改造工程、以及上海同步辐射光源工程、大亚湾中微子实验和散裂中子源工程等项目合作。

中美双方几十年科技领域的持续合作成果斐然，很多中国科学院和高校的科学家们都曾参与这些大科学项目，涌现出一批一流骨干力量，如目前担任中国物理学会会长的张杰院士，以及先后出任中国科学院高能所所长的叶铭汉、方守贤、郑志鹏、陈和生、王贻芳等院士。李政道为了这些项目一直忙碌着，总是在解决最棘手的问题，中国同行们亲切地称他为“李政委”。在工作质量上，李政道先生要求很高、很严格，有些与他近距离工作的人，不仅记得李政道对他们及时的鼓励与表扬，也清晰记得自己曾受过的批评。

图二：1979年6月10日-13日，中美高能物理联合委员会第一次会议在北京召开，邓小平、方毅接见了中美高能物理联合委员会成员。（图片来源：中国科学院高能物理所网站）

这几十年中美科技合作还带来的多项高技术副产品，例如“互联网进入中国”就是其中一项伟大“副产品”。1986年8月25日，高能所的吴为民通过一条辗转的远程拨号线给欧洲核子中心的斯坦伯格教授发出了一封Email，这是从中国通向世界的第一封Email。但早期拨号上网速度很慢、费用很高，因此只是个别人才能偶尔使用的“奢侈品”。

1988年秋，许榕生博士由李政道推荐回到了高能所工作。许博士经由李政道先生推动的中美联合物理学招生项目（CUSPEA）于1982年春赴美，大部分时间都在斯坦福直线加速器中心（SLAC）学习和工作，熟悉加速器和美国能源部建立的早期网络APARNet。此时正好北京正负电子对撞机建成运作了，许博士迅速投入到高能所实验数据分析和软件编程的工作中。

1988年年末，斯坦福大学高能物理教授瓦特·托基（Walter Toki）提出了中美之间应该连接一条互联网专线，但这事由于后来的政治事态发展而搁浅。在1991年中美高能合作联合会议上，美国科学家们再次提出基于北京正负电子对撞机实验的合作来建设一条中美之间的国际计算机联网专线，以解决实验数据传输与通讯等方面的问题。认识到此事的重要性，李政道特别为此与中国领导人沟通。同时，他也与托基教授等美国科学家一道游说美国政府，排除美国方面的诸多顾虑和障碍。两国政府同意之后，许博士就成为建设这项计算机联网工程的中方技术负责人。

许榕生小组历时18个月的工作后, 从北京高能所到美国斯坦福直线加速器中心计算机的64K bps TCP/IP专线最终于1993年3月2日全程联通。在这个过程中，李政道先生总是在关键时刻与中国政府高层领导进行沟通，帮助扫除观念和官僚障碍，由上至下地推动电信部门的支持，当时参与此工程的邮电部门员工很诧异经常接到高层“加快速度”的指示。

1994年3月，中国正式签约加入国际互联网，大量国际通道纷纷开通。同年，高能所率先建立了中国第一个WWW网站。接下来的两年，许榕生等科学家像互联网“传教士”一样在中国各地巡回报告、科普互联网技术和应用。如果形容李政道先生是中国互联网发展史上的一个关键节点和一台连接中国和美国的“路由器”，那么许榕生就是李政道构建并发送回祖国的一个能够自复制的“软件包”，快速克隆助力互联网大潮兴起。

Chapter 2: Mastering Theory and Experiment, Continuing Fermi's Legacy

Isidor Isaac Rabi was a renowned experimental physicist, famous for discovering nuclear magnetic resonance. Rabi praised Fermi as the world's last all-around physics genius who excelled in both theory and experiment. Indeed, whether in the Manhattan Project, at the University of Chicago, Columbia University, or throughout the American physics community, Fermi was a legendary figure versed in both theory and experiment. In the fall of 1953, when Rabi, who had served as the chairman of Columbia University's physics department, and his colleagues recruited the 27-year-old T.D. Lee to Columbia as a professor, they expected this student of Fermi to be a theoretical physicist well-versed in experiments. Years later, Rabi would have been gratified to know that he had indeed found Fermi's successor.

In fact, Lee's theoretical work, such as "The Question of Parity Conservation in Weak Interactions," contained many insights into the physical world, and the experimental proposals in the paper to verify the theory were strokes of genius. Lee had close relationships with experimental physicists and understood many people's work content and capabilities, allowing him to communicate with them freely and promptly. On the question of parity conservation, he motivated three groups of colleagues at Columbia University to conduct related experiments within six months, and he also encouraged scientists at the University of Chicago and elsewhere to carry out relevant experiments as early as possible. This research style, closely combining theory and experiment inherited from Fermi, was as unique and stable as a person's fingerprint, permeating Lee's entire scientific career.

Around 1970, Lee and Professor Gian Carlo Wick published a series of papers (References 14, 15, 16). Their "Lee-Wick model" predicted phenomena such as new phase transitions and new states of matter under extreme conditions, with relativistic heavy-ion collisions as the method to verify this theory. Pang Yang explained, "Now, the theoretical framework of fundamental physics is based on symmetry, and then symmetry-breaking mechanisms are introduced for corrections. Symmetry breaking corresponds to certain vacuum characteristics. The Lee-Wick theory believes that relativistic heavy-ion collisions can change vacuum properties, thus directly verifying the symmetry-breaking mechanism through experiments." Subsequently, more and more physicists entered this field, gradually developing into the branch of Relativistic Heavy Ion Collision (RHIC) physics. Meanwhile, with the rise of quantum chromodynamics and corresponding high-energy physics experiments, scientists studying elementary particles and strong interactions also discovered the scientific value of relativistic heavy-ion collisions and became involved.

Lee began participating in the work of building the Relativistic Heavy Ion Collider at Brookhaven National Laboratory in 1983, taking on increasingly more responsibilities (Reference 17). The process of building a large scientific facility is very complex, with various issues arising in scientific theory and experiments, engineering, budgeting, funding, and personnel. Professor Huang Huanzhong from the University of California, Los Angeles, has been involved in the RHIC construction work since 1990 and still frequently uses RHIC for scientific research. He said, "Mr. Lee was the first to propose using relativistic heavy-ion collisions to excite the vacuum and produce new states of matter, namely quark-gluon plasma. He was one of the most important promoters of building the Relativistic Heavy Ion Collider."

In 1997, as the collider was nearing completion, the RIKEN Institute of Japan and the Brookhaven National Laboratory (BNL) of the United States jointly established the "RIKEN-BNL Research Center," with the Relativistic Heavy Ion Collider as the core research facility. Both Japan and the United States strongly supported Lee becoming the founding director of the center. During Lee's tenure as the center's director (1997-2003), the Relativistic Heavy Ion Collider was completed in 1999 and began experiments in 2000. In 2005, scientists used RHIC to produce extremely hot, high-density quark-gluon plasma, also known as "perfect liquid," which is believed to be the state of matter in the extremely short time after the Big Bang. This phase transition process was also discovered and recorded. Additionally, scientists conducted extensive research on chiral symmetry breaking and restoration mechanisms in RHIC experiments. These theories and experiments are of great significance for human understanding of fundamental physics theories, elementary particles and nuclear physics, and the origin of the universe. Pang Yang believes, "These are achievements worthy of a Nobel Prize. Mr. Lee's contributions to high-energy and nuclear physics experiments are no less than his contributions to theoretical physics."

Due to the need for powerful computational tools in scientific research, the center also cooperated with Columbia University to build what was then the world's fastest supercomputer. Lee actively promoted cooperation between the center and the Chinese scientific community, often organizing heavy-ion collision physics seminars in China based at the "China Center of Advanced Science and Technology." He also invited institutions such as the Institute of Modern Physics of the Chinese Academy of Sciences, the University of Science and Technology of China, the Shanghai Institute of Applied Physics, Lanzhou University, and Tsinghua University to participate in RHIC international collaborative experiments. After stepping down from the position of center director, Lee continued to serve as honorary director, showing long-term concern and support for its work. Currently, the center brings together more than 100 theoretical and experimental physicists from around the world and supports many international cooperation projects. The Relativistic Heavy Ion Collider continues to operate efficiently, helping scientists explore the most macroscopic and microscopic mysteries of nature, continuously producing research results in the interdisciplinary fields of cosmology, nuclear physics, and high-energy physics.

Building accelerators has always been a dream of Chinese scientists. However, due to the complexity of the technology and engineering involved in accelerators, the large amount of funding required, and the rapid progress in their scientific and technological content, the process of establishing accelerator projects in China took decades, known as "seven downs and eight ups." After 1972, overseas Chinese scientists like Lee began returning to China for exchanges, bringing fresh scientific and technological power to the Chinese scientific community. The plans for building accelerators also became increasingly concrete and urgent.

In early 1979, when China and the United States established diplomatic relations, they also signed the "China-US Agreement on Cooperation in Science and Technology," with the initial cooperation project landing in the field of high-energy physics. The China-US Joint Committee on High Energy Physics was promptly established. Lee played a crucial role in the signing and subsequent implementation of this agreement and served as the general consultant for China-US high-energy cooperation. The "China-US Agreement on Cooperation in Science and Technology" is generally renewed every five years, and whenever problems arose, Lee would intervene to help resolve them. Over the past decades, Chinese and American high-energy scientists have held a joint meeting every year, rotating between scientific centers in China and the United States.

In January 1980, the International Particle Physics Conference was held in Conghua, Guangzhou. By this time, Lee had decided to support China in building an accelerator. Considering the importance of the matter, he personally lobbied the participants to participate and support. Most participants signed in support, but a few attending scientists issued open letters opposing the project. Although both support and opposition are acceptable as academic opinions, it is worth mentioning that Lee not only staked his reputation on his promise of "support" but also dedicated decades of his precious life and numerous political resources, while the opponents simply turned away after issuing an open letter.

In March 1981, a team of Chinese scientists went to the United States to discuss accelerator design plans. After careful discussions with Lee, Yuan Jialiu, C.S. Wu, and American scientists such as Wolfgang K.H. Panofsky, the director of the Stanford Linear Accelerator Center, they unanimously agreed that building a 2×22 GeV electron-positron collider in China was the best option. This plan was relatively low-cost, rich in physics research opportunities, and could achieve "dual use" by conducting high-energy physics research while also doing synchrotron radiation application research. However, this type of collider was more challenging to build. After scientists repeatedly modified the plan details, construction officially began in October 1984, with both Deng Xiaoping and Lee participating in the groundbreaking ceremony.

Building an accelerator requires not only theoretical and experimental physicists but also a large number of various engineering and technical experts. Lee understood the frontiers of world high-energy physics theory, experiments, and related supporting technologies, and was also very familiar with the situation in the Chinese scientific community. Thus, leveraging the China-US Science and Technology Cooperation Agreement, he mobilized relevant scientific and technical personnel from several US national laboratories to provide free support for the design and construction of China's accelerator. He also created conditions to send Chinese high-energy scientists as visiting scholars to multiple US national laboratories for targeted training.

In October 1988, the Beijing Electron-Positron Collider was officially put into operation. Deng Xiaoping and Lee once again joined hands to attend the completion ceremony. Subsequently, the focus of cooperation between Chinese and American scientists shifted to the operation of the electron-positron collider, the design of physics experiments, and data processing and analysis. After the 21st century, the work focus of the China-US Joint Committee on High Energy Physics shifted to major renovation projects of the Beijing Electron-Positron Collider, as well as cooperation on projects such as the Shanghai Synchrotron Radiation Facility, the Daya Bay Neutrino Experiment, and the China Spallation Neutron Source.

The continuous cooperation between China and the United States in the scientific and technological fields over the past decades has yielded remarkable results. Many scientists from the Chinese Academy of Sciences and universities have participated in these major scientific projects, producing a group of first-class core talents, such as Academician Zhang Jie, who currently serves as the president of the Chinese Physical Society, and academicians Ye Minghan, Fang Shouxian, Zheng Zhipeng, Chen Hesheng, and Wang Yifang, who have successively served as directors of the Institute of High Energy Physics, Chinese Academy of Sciences. Lee has been busy with these projects, always solving the most difficult problems. His Chinese colleagues affectionately call him "Commissioner Li." In terms of work quality, Mr. Lee had very high and strict requirements. Some people who worked closely with him not only remember Lee's timely encouragement and praise but also clearly recall the criticisms they received.

Figure 2: From June 10-13, 1979, the first meeting of the China-US Joint Committee on High Energy Physics was held in Beijing. Deng Xiaoping and Fang Yi received the members of the China-US Joint Committee on High Energy Physics. (Image source: Website of the Institute of High Energy Physics, Chinese Academy of Sciences)

The decades of China-US scientific and technological cooperation have also brought many high-tech byproducts, such as "the Internet entering China," which is one of the great "byproducts." On August 25, 1986, Wu Weimin from the Institute of High Energy Physics sent an email to Professor Steinberg at CERN through a roundabout long-distance dial-up line, which was the first email from China to the world. However, in the early days, dial-up internet speeds were very slow and expensive, making it a "luxury" that only a few people could occasionally use.

In the autumn of 1988, Dr. Xu Rongsheng returned to work at the Institute of High Energy Physics on Lee's recommendation. Dr. Xu went to the United States in the spring of 1982 through the China-US Physics Examination and Application (CUSPEA) program promoted by Lee, spending most of his time studying and working at the Stanford Linear Accelerator Center (SLAC), familiarizing himself with accelerators and the early network APARNet established by the US Department of Energy. At this time, the Beijing Electron-Positron Collider had just been completed and put into operation, and Dr. Xu quickly engaged in the work of experimental data analysis and software programming at the Institute of High Energy Physics.

At the end of 1988, Walter Toki, a professor of high-energy physics at Stanford University, proposed that there should be an internet dedicated line between China and the United States, but this was shelved due to subsequent political developments. At the 1991 China-US High Energy Cooperation Joint Conference, American scientists again proposed building an international computer network dedicated line between China and the United States based on cooperation in the Beijing Electron-Positron Collider experiment to solve problems in experimental data transmission and communication. Recognizing the importance of this matter, Lee specially communicated with Chinese leaders about it. At the same time, he also lobbied the US government along with Professor Toki and other American scientists to eliminate various concerns and obstacles on the US side. After both governments agreed, Dr. Xu became the Chinese technical leader for building this computer networking project.

After 18 months of work by Xu Rongsheng's team, the 64K bps TCP/IP dedicated line from the Institute of High Energy Physics in Beijing to the Stanford Linear Accelerator Center computer in the United States was finally fully connected on March 2, 1993. Throughout this process, Lee always communicated with high-level Chinese government leaders at critical moments, helping to remove conceptual and bureaucratic obstacles and promoting support from the telecommunications sector from top to bottom. The postal and telecommunications department employees involved in this project were surprised to frequently receive instructions from high-level officials to "speed up."

In March 1994, China officially signed an agreement to join the international Internet, and numerous international channels were opened. In the same year, the Institute of High Energy Physics took the lead in establishing China's first WWW website. Over the next two years, scientists like Xu Rongsheng traveled around China like Internet "missionaries," giving reports and popularizing Internet technology and applications. If we describe Lee as a key node in the history of China's Internet development and a "router" connecting China and the United States, then Xu Rongsheng was a self-replicating "software package" constructed and sent back to the motherland by Lee, rapidly cloning and contributing to the rise of the Internet wave.

第三章: 科学使徒奔忙，架起科文桥梁

英国文学家斯诺（C.P. Snow）于1959年在哥伦比亚大学做了一个精彩的演讲。他认为，人文和科学之间有文化鸿沟，宇称守恒破缺的发现是人文和科学交叉的结果，并为它们之间架起了桥梁，展现出特别的美和原创性。

的确，人类的审美偏好背后有一种神秘的力量，深刻地影响着科学家洞察自然的视角及构建哲学思路和科学理论的选择。对常识和审美观的颠覆往往是反人性的，科学家也不例外，他们对美的迷恋甚至有着格外沉重的仪式感。古希腊时代毕达哥拉斯学派门生希帕索斯发现了“丑陋的”无理数，破坏了有理数世界之美，引发了一场毕达哥拉斯学派数学危机，因而被其他同门弟子投进了大海。

对称性是一种人类非常基本的审美原则，也是物理学家们构建理论不言而喻的准公理。已知的四大作用力中的三种，即引力、电磁力、强力都遵循对称原则，而到了弱力，有些对称性（如宇称）却破缺了，这不仅是惊世骇俗之科学新发现，也突破了普通人的审美常识。其实，如果所有的力都尊从对称原则，那么自然是美而单调的，对称性在弱力下出现破缺让世界呈现出更多迷人的可能性，带来大量崭新的物理学，例如粒子衰变的神秘举止、中微子的种类和属性、暗物质之谜等等。

突破边界、为不同文化“架桥梁”等行为不仅出现在李政道的科学活动中，也是他很多社会活动的特点。

1986年，李政道和周光召一起发起成立了“中国高等科学技术中心”（CCAST），二位分别担任正副主任。这是一个具有独立法人地位的民间科研机构，其核心任务是在中国创造一个具有世界水平和国际氛围、宽松而不受行政约束的研究环境，资助国内和海归科学家从事前沿科学研究，促进国内外科学交流。这个中心由中国政府和意大利政府出资的民间机构“世界实验室”共同资助。这种机构形态和运营模式在当时的中国是突破性的。

曾担任CCAST秘书长二十余年的柳怀祖先生回忆说（参考文献18），举行各种学术交流研讨会是中心的经常活动，活动邀请国外一线科学家来参加、并向全国科学家开放，让国内学者及时了解国内外学术进展。中心还根据国内特别需要举办活动，例如1998年中心与美国加速器学校合作，从美国、欧洲聘请了30位国际上著名的加速器物理和技术专家，在北京开办了“中国加速器物理学校”，对一百多名来自全国相关高校的学员进行了一个多月的强化培训，这些人后来都成为中国各科学大装置的技术骨干。在李政道活跃领导CCAST的二十余年，该中心在提升中国科研国际化方面硕果累累，培养了大批具有国际视野的中国科学家，在国际科学期刊发表了约四千篇论文，让中国科学家的成果传播全球。

1993年5月，李政道先生受梵蒂冈教皇保罗二世的邀请，作为全球科学家的代表接受教廷就四百年前他们迫害伽利略的事件道歉，以了却一桩科学和宗教之间数百年的积怨。此事在国际上影响很大，欧美及很多基督教国家主流媒体都广泛报道。选择和被选择参与这种穿越科学和宗教、穿越时空的活动，凸显了李政道科学使徒的国际声望、个人情操与品味。

李政道与意大利的渊源与他的导师费米是意大利人有关，更重要的是李政道在自己的科研生涯中结识了很多意大利科学家，如核物理学家Antonino Zichichi教授，他曾担任欧洲物理学会主席，并创立了“世界实验室”。为了感谢意大利政府和人民的慷慨和情谊，李政道于2009年特意设计了一座伽利略铜像，采用了伽利略手持自制的望远镜所观察到的木星卫星图景，该铜像以“中国高等科学技术中心”的名义捐赠给了罗马圣玛丽亚天使与殉道者大教堂。今天，这座庄严而特别的伽利略铜像仍矗立于该教堂，述说中意科学合作的故事，聆听后世佳话。

李政道先生对绘画情有独钟，他说：科学和艺术是一枚硬币的两面。李政道的画中世界十分缤纷美丽，犹如他的科学世界。他早期的画大都为夫人而作，特别是在夫人没有随行的出差途中，他把随身携带的画本画笔拿出来，记录看见的美景，回家与夫人共赏。李政道的很多画作都题写了情深侃侃的话语，凸显一位深爱妻子的丈夫数十年如一日的情意。李政道也会给家里其他亲人作画，儿孙们的生日都可能收到一份特别的画作，让他们享受独特的快乐。

李政道的画作也让很多学生、亲朋好友、同事欣喜。徐依协是第一位CUSPEA女生，于1980年赴美进入哥伦比亚大学。在美国硅谷的CUSPEA学者们为李政道先生举办的追思会上，她声音哽咽地回忆道：“从某年圣诞节开始，我惊喜地收到李先生自己创作的圣诞春节贺年卡。卡片正面是鲜艳夺目的花卉、水果，里边加页附一张生肖动物卡通画……那些年我多次搬家，甚至跨洋于硅谷和上海，李先生的贺卡一直追随着我的新地址，成为我每年十二月翘首盼望的那份最珍贵的圣诞惊喜。”包括笔者在内的很多收到过李先生特绘新年贺卡的人都曾有过与徐依协类似感受，这是一颗心温暖另一颗心的瞬间。

李政道还把他对绘画的喜爱带进了科学活动中。他不是专业画家，知道自己的绘画技巧水准有局限，于是他虚心地结识艺术家，请画家们画出他想象的物理世界。有时他口述物理场景、请画家们作画，有时他自己作一草图，请画家再次创作。就这样，他前后与吴作人、李可染、黄胄、华君武、常沙娜、吴冠中等合作，创作出了很多物理题材画作，比如“相对论重离子碰撞”（李可染）、“对称乎”[SC6]（吴冠中）等。这些画作往往被用作物理期刊和会议论文集封面、或会议海报主题画，成为与会者的收藏品。有些画作被再创作为雕塑、立于一些科研机构伴随年轻一代的科学家们。

李政道是一位善假于物、乐于把点连成线的社会活动家，他不仅因为年少成名而广受尊重，也洞悉人性、品味高尚，愿意用自己能够涉及的资源为世界各地（特别是中国）的科学活动提供方便，也为科学与人文艺术、科学与宗教之间架起桥梁。

Chapter 3: The Apostle of Science Bustles, Building Bridges Between Science and Culture

British literary figure C.P. Snow gave a brilliant speech at Columbia University in 1959. He believed that there was a cultural gap between the humanities and sciences, and that the discovery of parity non-conservation was a result of the intersection of humanities and sciences, bridging the gap between them and revealing special beauty and originality.

Indeed, there is a mysterious force behind human aesthetic preferences that profoundly influences scientists' perspectives on nature and their choices in constructing philosophical ideas and scientific theories. Subverting common sense and aesthetic views is often against human nature, and scientists are no exception. Their fascination with beauty even carries an especially heavy sense of ritual. In ancient Greece, Hippasus, a disciple of the Pythagorean school, discovered the "ugly" irrational numbers, destroying the beauty of the rational number world and triggering a mathematical crisis in the Pythagorean school, resulting in him being thrown into the sea by his fellow disciples.

Symmetry is a very basic aesthetic principle for humans and an implicit axiom for physicists in constructing theories. Three of the four known fundamental forces - gravity, electromagnetism, and strong force - all follow the principle of symmetry. However, in the weak force, some symmetries (such as parity) are broken. This is not only a shocking new scientific discovery but also breaks through ordinary people's aesthetic common sense. In fact, if all forces adhered to the principle of symmetry, nature would be beautiful but monotonous. The symmetry breaking in the weak force presents more fascinating possibilities in the world, bringing about a large amount of new physics, such as the mysterious behavior of particle decay, the types and properties of neutrinos, the mystery of dark matter, and so on.

Breaking boundaries and "building bridges" between different cultures are not only present in Lee's scientific activities but are also characteristics of many of his social activities.

In 1986, Lee and Zhou Guangzhao jointly initiated the establishment of the "China Center of Advanced Science and Technology" (CCAST), with the two serving as director and deputy director respectively. This is an independent civilian scientific research institution, with the core mission of creating a world-class and international research environment in China that is relaxed and free from administrative constraints, funding domestic and returned scientists to engage in cutting-edge scientific research, and promoting domestic and international scientific exchanges. This center was co-funded by the "World Laboratory," a civilian organization funded by the Chinese and Italian governments. This institutional form and operational model were groundbreaking in China at the time.

Mr. Liu Huaizu, who served as the secretary-general of CCAST for over 20 years, recalled (Reference 18) that holding various academic exchange seminars was a regular activity of the center. These activities invited leading foreign scientists to participate and were open to scientists nationwide, allowing domestic scholars to stay up-to-date with academic progress at home and abroad. The center also organized activities based on special domestic needs. For example, in 1998, the center cooperated with the US Accelerator School to invite 30 internationally renowned accelerator physics and technology experts from the US and Europe to establish the "China Accelerator Physics School" in Beijing. They provided intensive training for over 100 students from relevant universities across the country for more than a month. These individuals later became the technical backbone of various major scientific facilities in China. During the more than 20 years of Lee's active leadership of CCAST, the center achieved fruitful results in enhancing the internationalization of Chinese scientific research, cultivating a large number of Chinese scientists with international perspectives, publishing about 4,000 papers in international scientific journals, and spreading the achievements of Chinese scientists globally.

In May 1993, Lee was invited by Pope John Paul II of the Vatican to accept an apology on behalf of global scientists for the persecution of Galileo four hundred years ago, resolving centuries of grievances between science and religion. This event had a significant international impact and was widely reported by mainstream media in Europe, America, and many Christian countries. The choice and being chosen to participate in such an activity that transcends science and religion, as well as time and space, highlighted Lee's international reputation as a scientific apostle, as well as his personal character and taste.

Lee's connection with Italy is related to his mentor Fermi being Italian, but more importantly, Lee met many Italian scientists during his scientific career, such as nuclear physicist Professor Antonino Zichichi, who served as the president of the European Physical Society and founded the "World Laboratory." To express gratitude for the generosity and friendship of the Italian government and people, Lee specially designed a bronze statue of Galileo in 2009, using the scene of Jupiter's satellites observed by Galileo with his self-made telescope. The statue was donated to the Basilica of Santa Maria degli Angeli e dei Martiri in Rome in the name of the "China Center of Advanced Science and Technology." Today, this solemn and special Galileo statue still stands in the church, telling the story of scientific cooperation between China and Italy, and listening to the beautiful tales of posterity.

Lee had a particular fondness for painting. He said: Science and art are two sides of the same coin. The world in Lee's paintings is very colorful and beautiful, just like his scientific world. His early paintings were mostly made for his wife, especially during business trips when she couldn't accompany him. He would take out his sketchbook and brushes that he carried with him to record the beautiful scenery he saw, and share it with his wife when he returned home. Many of Lee's paintings were inscribed with deeply affectionate words, highlighting the decades-long love of a husband deeply in love with his wife. Lee would also paint for other family members, and his children and grandchildren might receive a special painting on their birthdays, allowing them to enjoy unique happiness.

Lee's paintings also delighted many students, friends, and colleagues. Xu Yixie was the first female CUSPEA student who went to Columbia University in 1980. At the memorial service held for Lee by CUSPEA scholars in Silicon Valley, she recalled with a choked voice: "Starting from one Christmas, I was surprised to receive Christmas and Spring Festival greeting cards created by Mr. Lee himself. The front of the card featured vibrant flowers and fruits, with an additional page inside containing a cartoon of the zodiac animal... Over those years, I moved many times, even across the ocean between Silicon Valley and Shanghai, but Mr. Lee's greeting cards always followed my new address, becoming the most precious Christmas surprise I eagerly anticipated every December." Many people, including the author, who received specially drawn New Year's cards from Lee, had similar feelings to Xu Yixie. This is a moment when one heart warms another.

Lee also brought his love for painting into his scientific activities. He was not a professional painter and knew the limitations of his painting skills, so he humbly befriended artists and asked them to paint the physical world he imagined. Sometimes he would describe physical scenes orally and ask artists to paint them, and sometimes he would make a sketch himself and ask artists to recreate it. In this way, he collaborated with Wu Zuoren, Li Keran, Huang Zhou, Hua Junwu, Chang Shana, Wu Guanzhong, and others, creating many paintings with physics themes, such as "Relativistic Heavy Ion Collision" (Li Keran) and "Symmetry?" (Wu Guanzhong). These paintings were often used as covers for physics journals and conference proceedings, or as theme paintings for conference posters, becoming collectors' items for participants. Some paintings were recreated as sculptures, standing in some research institutions to accompany the younger generation of scientists.

Lee was a social activist who was good at utilizing resources and enjoyed connecting dots. He was not only widely respected for his early fame but also had insights into human nature and refined taste. He was willing to use the resources he could access to facilitate scientific activities around the world (especially in China) and to build bridges between science and the humanities and arts, as well as between science and religion.

第四章: 教育大师报恩，薪火相传利人

李政道经常深情地向学生们说起他的三位老师如何改变了他的人生——束星北是他的物理学启蒙老师，吴大猷提升了他对物理的理解并是推荐他赴美留学的恩师，费米则把他带进了世界物理学前沿……因此他总是希望能够在教育下一代方面做得更多、更好，这既是为了报答他的老师们的恩情，也希望把知识和善意传播开去。李政道的“报恩”如大海般汹涌澎湃，前无古人，后人难追。

1972年回国访问，李政道看见了中国与世界在科学领域的距离，遇到了大量如饥似渴希望了解世界科技前沿的学者和学子们，之后他每次回国都在想着如何为他们做点什么。他访问祖国时经常强调要加强科学基础理论的教育和研究，不能仅只注重技术和产品。他说科学、技术和产品的关系犹如水、鱼、鱼市场，三者既有逻辑递升关联、也缺一不可。他认为应该对学生们尽早进行科技教育，并向国家领导人建议从少年开始培养科技人才，这是中国科技大学于1977年开设“少年班”的支点。几十年来，少年班不仅培养出了很多杰出的科学家，更重要的是养成了几代人热爱追求科学的氛围。

1979年4月，李政道教授亲自来到中科院授课，在两个多月中，开设了“统计力学”与“场论简引和粒子物理”两门课程。当时曾参与听课的中科院研究生徐依协说，“听课者总共1000多人，将北京科学院大礼堂挤得满满的。李先生每天连续上三个多小时的课。即便是星期六、星期天和五一假期都没有休息。课后，围满他的学生不断提问，他耐心解释。每天中午，他还要轮流请听课的学生们共进午餐。”

这次授课后，李政道认识到短短两个月不可能让学生们系统把握物理学知识，更不可能让他们了解物理学前沿动态及科研方法。于是，他首先从学员中选择5位优秀学生到哥伦比亚大学做研究生，然后组织了一次小型考试，选拔了11人去了5所美国学校，徐依协和任海沧有幸通过考试，于1980年成为哥伦比亚大学研究生。这是之后即将开启的“中美联合招收物理类研究生项目”（CUSPEA）的试点（Pre-CUSPEA）。

1980年1月初，我是中山大学二年级的学生，听说了来自世界各地的华人物理学家在广州从化开学术会议，其中还有大名鼎鼎的李政道、杨振宁二位先生。同学们非常兴奋，商量着如何把这二位科学大师邀请到学校来做报告。之后数百同学签署了邀请信，委托参加会议的中山大学理论物理学家李华钟教授把信转交给了李、杨二位先生，他们当即就答应了。

李政道来中山大学讲座的时候，讲台上的灯光格外明亮，显然是为了方便记者们摄影照相特别安装了不少大灯。李政道上台后严厉地说：“灯光太亮了，都关了！我不是来表演的，是来给学生讲学的！”整个现场顿时鸦雀无声，坐在台下的我，听见了自己怦怦的心跳声。领导随即悄悄安排关了这些大灯。

当命运敲门的时候，人未必能听见，但其雷霆万钧将波及一个人的终生。笔者后来查资料才知道，1980年1月对很多中国学子是一个命运转折点。此时，李政道先生在广州从化的温泉宾馆给方毅副总理写了一封信，他基于1979年所招收的中国留美研究生的成功经验，建议把“中美联合招收物理类研究生项目（CUSPEA）”正规化，扩大到中国和美国的几十所高校。CUSPEA项目就这样正式开始了。

1981年9月，笔者作为大四学生参加了CUSPEA考试并有幸被录取，于1982年去美国匹兹堡市卡耐基梅隆大学（Carnegie-Mellon University）攻读物理学博士学位。作为生长在湘西的孩子，如果不是李政道及很多中美前辈老师们无私引导，很难有机会走近科学前沿。

上海交通大学的李政道图书馆收藏了大量李政道与中国领导人、中美学界、及很多CUSPEA学生的往来信件，记录了前辈们如何携手培育未来科技力量的思路和努力。在CUSPEA项目执行的十年间，李政道每年为此要花1/3的时间，打了无数的电话，写了数千封信。据纽约哥伦比亚大学的CUSPEA同学说，李政道家附近的邮筒经常信满为患，于是李政道和夫人秦惠䇹女士不得不推着小推车去更远的邮筒投递信件。

一个令人不解的插曲发生在该项目刚开始的1980年，当时有几位美国颇有名的华裔教授闻风给中国领导人写信，指责CUSPEA项目由美国大学出题来考中国学生是“丧权辱国”。因为此信，国内部分原来支持CUSPEA项目的人开始采取拖延不行动的态度。柳怀祖先生说，李政道知道此事后很着急，赶忙从美国飞到中国，要求见邓小平先生，最后小平先生拍板让CUSPEA项目按照李政道设计的方案继续进行。

从1979年到1988年十年间，CUSPEA项目共送了915位中国物理类学生赴北美攻读研究生，学费生活费全部由所就读的北美各大学提供奖学金，估计共超过一亿美元。在CUSPEA 40周年的纪念会上，张永德教授（曾担任中国科技大学CUSPEA项目教练）说，“美国大学招生很自主、多元化，要启动CUSPEA这样的项目，统一出卷子、设立类似“高考”的选拔机制，其实施难度可想而知，就算是美国教育部部长亲自出来干，也未必干成！李先生虽然是诺奖获得者，但也只是一位教授，居然把CUSPEA这一项目从无到有地建立起来了，他的沟通与协调能力很令人佩服。”

在CUSPEA项目初步成功后，其他领域的在美学者，如陈省身、吴瑞等教授，也参考CUSPEA的方式组织其专业的中国学生赴美留学。目前，CUSPEA学者中有15位科学家成为中国和欧美主要国家院士，约300多人次在各国际科学技术组织担任职位或成为Fellow，100余人次获得各类科技大奖，有400多位成功的高科技发明家和企业家。中国科学院前院长白春礼院士说，CUSPEA项目是改革开放早期中国与欧美高校人才交流的“破冰之举”，是新中国对外科技和人才交流史上的一座丰碑。李政道自己的评价则是：“CUSPEA比我做宇称不守恒还有意义 。”

在李政道的倡导下，中国于1985年建立了博士后制度，至今已有数十万青年学者前后参与博士后培养。在他的另一建议下，中国还于1986年成立国家自然科学基金委员会，这是目前中国最大、最重要的科研资助机构。这些科教制度建设对中国的人才培养、科研水平和成就的提升，意义都十分重大、长远。

1998年，在李夫人秦惠䇹女士去世后两年之际，李政道及亲友正式设立了“䇹政基金”，其宗旨是鼓励北京大学、复旦大学、苏州大学、台湾清华大学、兰州大学、及上海交通大学的大学生参与科学研究，入选学生被称为“䇹政学者”。过去二十多年，该项目培养了约六千“䇹政学者”。柳怀祖先生说，这个基金会是李夫人生前嘱托设立的，李夫人还特别嘱咐一半的奖励名额留给女生。李政道在哥伦比亚大学的长期工作助理艾琳•赫尼根（Irene Heneghan）女士，协助李政道做了大量工作，[SC7]被李政道称为“中国之友”，她把自己毕生储蓄都捐赠给了该基金，最后长眠于中国。

李政道生前最后一次访问他深情挂念的祖国是在2010年，此时他已经84岁，意识到年迈体渐弱，自己难以再像年轻时一样为祖国和青年学子们奔忙。李政道与时任上海交通大学校长张杰数度“秉烛深谈“，决定把手稿、家族财产和珍藏都捐赠给上海交通大学，以最后的力气协助建立“李政道图书馆”（2014年正式成立）和“李政道研究所”（2016年正式成立），以鼓励年轻一代沿着他的科研轨迹继续前行。

虽然中国传统的报恩情结可能是李政道推动这些项目的起点，他也吸取了很多西方文化中的利他主义精神。2019年是CUSPEA 40周年，李政道给CUSPEA学者们题词：“薪火相传”。笔者曾问李先生的长子李中清教授，李先生期待CUSPEA学者们如何“薪火相传”？我听到的回答是，李先生并不希望CUSPEA学者们对他个人报恩，而是以利他主义精神，把善意善举发扬光大，跨越时间纵向传承。犹如李中清在李先生的追思会上所说，所有受惠于李先生的人都是李先生的一部分，而李政道也永远是他们的一部分。

李政道近百年的人生是跨域起舞的传奇，他突破了很多鸿沟与界限、做了很多很多事情。他像巨人一样从一个科学高峰奔向另一个高峰，跨领域如履平地；他在理论和实验之间娴熟地切换，孜孜不倦探索自然奥秘；他在不同的文化和国度之间优雅地穿梭，搭起一座座桥梁；他还为培养下一代呕心沥血，穿越时空把千万学子带进科学前沿……显然，李政道不是神，只是一位大学教授，在美国经常协助他的只有夫人、秘书和几位研究生，很多事都得亲力亲为。每当想起李政道经常伏案连夜写信、与夫人一起推着装满信件的小车在纽约街头投递信件这些细节和画面，学生们就倍感温暖、不忍动容。他最重要的品质和能力就是善良啊。

现在，辛苦操劳了一辈子的李先生可以安息了，与挚爱的夫人一起长眠于苏州故乡，与费米、奥本海默等师友们再聚，在科学的历史星空中俯瞰着人类前赴后继永远探索自然奥秘。

科学不朽，李政道先生千古！

图三：2016年李政道先生90华诞，笔者组织CUSPEA学者做了一个为他祝寿的视频和画册。李先生收到后很高兴，手持画册欣然留影（王垂林摄影）。

Chapter 4: The Education Master Gives Back, Passing on the Torch to Benefit Others

Lee often spoke affectionately to his students about how his three teachers changed his life — Shu Xingbei was his physics enlightenment teacher, Wu Dayou enhanced his understanding of physics and recommended him to study in the United States, while Fermi brought him to the forefront of world physics... Therefore, he always hoped to do more and better in educating the next generation, both to repay the kindness of his teachers and to spread knowledge and goodwill. Lee's "repayment of kindness" was like a surging sea, unprecedented and difficult for future generations to match.

During his visit to China in 1972, Lee saw the gap between China and the world in the field of science, and met many scholars and students who were eager to learn about the world's scientific and technological frontiers. After that, every time he returned to China, he thought about how to do something for them. When visiting his motherland, he often emphasized the need to strengthen the education and research of basic scientific theories, not just focus on technology and products. He said the relationship between science, technology, and products is like water, fish, and the fish market — they have a logical ascending relationship and are indispensable to each other. He believed that students should receive science and technology education as early as possible, and suggested to national leaders to start cultivating scientific and technological talents from a young age, which was the fulcrum for the University of Science and Technology of China to establish the "Youth Class" in 1977. Over the decades, the Youth Class has not only cultivated many outstanding scientists but, more importantly, fostered an atmosphere of love for science among several generations.

In April 1979, Professor Lee personally came to the Chinese Academy of Sciences to teach. Over more than two months, he offered two courses: "Statistical Mechanics" and "Introduction to Field Theory and Particle Physics." Xu Yixie, a graduate student of the Chinese Academy of Sciences who attended the lectures, said, "There were over 1,000 listeners in total, filling the Beijing Science Academy Grand Hall to capacity. Mr. Lee taught for more than three hours continuously every day, even on Saturdays, Sundays, and during the May Day holiday. After class, students surrounded him with endless questions, which he patiently explained. Every noon, he would also take turns inviting the attending students to lunch."

After this teaching experience, Lee realized that it was impossible for students to systematically grasp physics knowledge in just two months, let alone understand the frontiers of physics and research methods. So, he first selected 5 outstanding students from the participants to become graduate students at Columbia University, then organized a small exam and selected 11 people to go to 5 American schools. Xu Yixie and Ren Haicang were fortunate to pass the exam and became graduate students at Columbia University in 1980. This was the pilot (Pre-CUSPEA) of the "China-US Physics Examination and Application" (CUSPEA) program that was about to be launched.

In early January 1980, I was a sophomore at Sun Yat-sen University when I heard that Chinese physicists from around the world were holding an academic conference in Conghua, Guangzhou, including the renowned Mr. Lee Tsung-Dao and Mr. Yang Chen-Ning. The students were very excited and discussed how to invite these two scientific masters to give reports at the school. Later, hundreds of students signed an invitation letter, entrusting Professor Li Huazhong, a theoretical physicist from Sun Yat-sen University who was attending the conference, to pass the letter to Mr. Lee and Mr. Yang, who immediately agreed.

When Lee came to give a lecture at Sun Yat-sen University, the lights on the stage were exceptionally bright, obviously because many spotlights had been installed specially for journalists to take photographs. After Lee went on stage, he sternly said, "The lights are too bright, turn them all off! I'm not here to perform, I'm here to lecture to students!" The entire venue suddenly fell silent, and I, sitting in the audience, could hear my own heart pounding. The leaders immediately arranged to quietly turn off these spotlights.

When destiny knocks, one might not hear it, but its thunderous impact will affect a person's entire life. The author later learned from research that January 1980 was a turning point in the destiny of many Chinese students. At this time, Mr. Lee wrote a letter to Vice Premier Fang Yi at the hot spring hotel in Conghua, Guangzhou. Based on the successful experience of recruiting Chinese graduate students to study in the United States in 1979, he suggested formalizing the "China-US Physics Examination and Application (CUSPEA)" program and expanding it to dozens of universities in China and the United States. This is how the CUSPEA program officially began.

In September 1981, the author, as a senior student, took the CUSPEA exam and was fortunate to be admitted. In 1982, I went to Carnegie Mellon University in Pittsburgh, USA, to pursue a Ph.D. in Physics. As a child who grew up in Xiangxi, without the selfless guidance of Lee and many Chinese and American senior teachers, it would have been difficult to have the opportunity to approach the frontiers of science.

The T.D. Lee Library at Shanghai Jiao Tong University has collected a large number of correspondence between Lee and Chinese leaders, Chinese and American academic circles, and many CUSPEA students, recording the ideas and efforts of the predecessors in jointly cultivating future scientific and technological forces. During the ten years of the CUSPEA program's implementation, Lee spent 1/3 of his time each year on this, making countless phone calls and writing thousands of letters. According to CUSPEA classmates at Columbia University in New York, the mailboxes near Lee's home were often overflowing with letters, so Lee and his wife, Mrs. Qin Huiqin, had to push a small cart to deliver letters to more distant mailboxes.

A puzzling episode occurred at the beginning of the project in 1980 when several well-known Chinese-American professors in the United States wrote to Chinese leaders, accusing the CUSPEA program of "losing sovereignty and humiliating the country" by having American universities set exam questions for Chinese students. Because of this letter, some people in China who originally supported the CUSPEA program began to take a delaying attitude. Mr. Liu Huaizu said that when Lee learned of this, he was very anxious and hurried from the United States to China, asking to see Mr. Deng Xiaoping. In the end, Mr. Deng decided to let the CUSPEA program continue according to Lee's designed plan.

From 1979 to 1988, the CUSPEA program sent a total of 915 Chinese physics students to pursue graduate studies in North America, with tuition and living expenses fully covered by scholarships provided by various North American universities, estimated to total over $100 million. At the 40th anniversary commemoration of CUSPEA, Professor Zhang Yongde (who served as the CUSPEA program coach at the University of Science and Technology of China) said, "American university admissions are very autonomous and diverse. To start a project like CUSPEA, unifying the exam papers and establishing a selection mechanism similar to the 'college entrance examination,' the difficulty of implementation can be imagined. Even if the U.S. Secretary of Education personally came out to do it, it might not be accomplished! Although Mr. Lee is a Nobel Prize winner, he is only a professor, yet he managed to establish the CUSPEA project from scratch. His communication and coordination skills are very admirable."

After the initial success of the CUSPEA program, scholars in other fields in the United States, such as Professors Chen Shiing-shen and Wu Rui, also organized Chinese students in their specialties to study in the United States, referencing the CUSPEA model. Currently, among CUSPEA scholars, 15 scientists have become academicians in China and major European and American countries, about 300 have held positions or become Fellows in various international scientific and technological organizations, over 100 have received various scientific and technological awards, and there are more than 400 successful high-tech inventors and entrepreneurs. Academician Bai Chunli, former president of the Chinese Academy of Sciences, said that the CUSPEA program was an "ice-breaking initiative" for talent exchange between China and European and American universities in the early days of reform and opening up, and is a monument in the history of China's foreign scientific and technological and talent exchanges. Lee's own assessment was: "CUSPEA is more meaningful than my work on parity non-conservation."

Under Lee's advocacy, China established the postdoctoral system in 1985, and hundreds of thousands of young scholars have participated in postdoctoral training to date. At his another suggestion, China also established the National Natural Science Foundation of China in 1986, which is currently the largest and most important scientific research funding agency in China. The construction of these scientific and educational systems has had a very significant and far-reaching impact on China's talent cultivation and the improvement of scientific research levels and achievements.

In 1998, two years after Lee's wife Mrs. Qin Huiqin passed away, Lee and his family and friends formally established the "Qinzheng Fund," with the purpose of encouraging university students from Peking University, Fudan University, Soochow University, National Tsing Hua University (Taiwan), Lanzhou University, and Shanghai Jiao Tong University to participate in scientific research. Selected students are called "Qinzheng Scholars." Over the past 20+ years, the program has cultivated about 6,000 "Qinzheng Scholars." Mr. Liu Huaizu said that this foundation was established at the behest of Mrs. Lee before her death, and Mrs. Lee specially instructed that half of the award places be reserved for female students. Ms. Irene Heneghan, Lee's long-term work assistant at Columbia University, assisted Lee in doing a lot of work and was called a "Friend of China" by Lee. She donated all her life savings to this fund and was finally laid to rest in China.

Lee's last visit to his beloved motherland was in 2010 when he was already 84 years old. He realized that he was getting old and weak, and it was difficult for him to work tirelessly for his motherland and young students as he did when he was young. Lee had several "candlelit deep conversations" with Zhang Jie, then president of Shanghai Jiao Tong University, and decided to donate his manuscripts, family property, and collections to Shanghai Jiao Tong University. With his last efforts, he helped establish the "T.D. Lee Library" (officially established in 2014) and the "T.D. Lee Institute" (officially established in 2016) to encourage the younger generation to continue along his research trajectory.

Although the traditional Chinese concept of repaying kindness may have been the starting point for Lee to promote these projects, he also absorbed much of the altruistic spirit from Western culture. 2019 marked the 40th anniversary of CUSPEA, and Lee inscribed for CUSPEA scholars: "Passing on the torch." The author once asked Professor Li Zhongqing, Lee's eldest son, how Mr. Lee expected CUSPEA scholars to "pass on the torch." The answer I heard was that Mr. Lee did not want CUSPEA scholars to repay him personally, but to carry forward good deeds with an altruistic spirit, passing them on vertically across time. As Li Zhongqing said at Mr. Lee's memorial service, all those who benefited from Mr. Lee are a part of Mr. Lee, and Lee will forever be a part of them.

Lee's nearly century-long life was a legend of cross-domain dancing. He broke through many gaps and boundaries and did many, many things. Like a giant, he rushed from one scientific peak to another, crossing disciplines as if walking on flat ground; he skillfully switched between theory and experiment, tirelessly exploring the mysteries of nature; he elegantly shuttled between different cultures and countries, building bridges; he also poured his heart and soul into cultivating the next generation, transcending time and space to bring millions of students to the frontiers of science... Obviously, Lee was not a god, just a university professor. In the United States, he was often only assisted by his wife, secretary, and a few graduate students, and had to do many things personally. Whenever students think of the details and images of Lee often writing letters late into the night and pushing a small cart full of letters with his wife to mail them on the streets of New York, they feel warm and moved. His most important quality and ability was kindness.

Now, Mr. Lee, who has worked hard all his life, can rest in peace, lying with his beloved wife in their hometown of Suzhou, reuniting with his teachers and friends like Fermi and Oppenheimer, overlooking humanity's eternal exploration of the mysteries of nature from the historical starry sky of science.

Science is immortal, and Mr. T.D. Lee will be remembered forever!

Figure 3: For Mr. Lee's 90th birthday in 2016, the author organized CUSPEA scholars to make a birthday video and album for him. Mr. Lee was very happy when he received it and gladly posed for a photo holding the album (photographed by Wang Chuilin).

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