計畫編號：BN04-00
計畫名稱：質量生成：從重夸克到微中子— 攀越粒子物理巔峰 —
計畫主持人：侯維恕
計畫摘要(中)：

本三年期拔尖計畫目標為將台大的粒子物理研究在全世界及亞洲根扎更深，無論深廣度都能更臻一流。計畫期間正好涵蓋大強子對撞機 LHC 的啟用與初取數據，將推進能量前沿。國科會多年支持台大製作 CMS 實驗 Preshower 子系統所有的 SMB 系統母板，已在 2007 年交付，重心轉向物理分析。在國科會經費之上，子計畫一投入本計畫逾三分之一的經費增強人力及運籌能力。我們訂定搜尋四代夸克戰略，目標為可早期出論文，甚至有所發現，並藉此訓練組員。團隊核心成員均在 Belle 身經百戰，使台大物理論文在 Belle 佔到百分之二十！Belle 自 2009 年起將升級。子計畫二參與矽頂點偵測器升級並「画素」偵測器(可用在 ILC)之研發，Belle 物理分析則將趨緩。超級 Belle 於 2012 完成後數據量提高，可精密測量 B、D 及　物理，與 LHC 互補。微中子實驗目前的焦點在測量旋轉角　13，若發現不為零則可能在輕子系統偵測 CP 破壞。子計畫三參與大亞灣反應器微中子實驗之建造。台灣是距深圳及香港最近之高科技與高能實驗基地，有地利之便，而大亞灣實驗可能在本計畫期間發表初步結果。在經費困難的情況下本組一直研發「穿山看活躍星系核」的 NuTel 微中子望遠鏡，終於在 2007 年克服挑戰，製成二米廣角反射鏡，下一步是完成野地測試。子計畫四已匯集國科會、LeCosPA 中心及中研院天文所的一定支持，將在國內從事這個集宇宙線、微中子望遠鏡及「　出現」於一身的新穎實驗之實地運作。天文數學大樓即將在台大建成，NuTel 是我們的粒子天文物理研發方向，且與 LeCosPA 參與的 ANITA 及 IceRay 實驗相關。Belle 實驗的成功有強力國內理論支持，子計畫五加強理論與實驗之互動，發展對其他各實驗子計畫之理論支持。

本計畫在台大推動發展完整的粒子物理實驗計畫架構，從事對撞機(CMS)、重夸克(CMS 及 SuperBelle)及微中子(大亞灣及 NuTel)物理研究，探討電弱與 CP 對稱破壞並粒子天文物理。質量生成機制是整個計畫探究的核心。總主持人匯集理論與實驗實務經驗於一身，在過去十二年藉 Belle 實驗推動「B 物理與 CP 破壞」有豐碩的成果，將藉總計畫整合各子計畫，朝向在台大成立「粒子物理中心」而努力。
計畫摘要(英)：

This 3 year Project aims at sowing and plowing Particle Physics at NTU deeper into the global and East Asian arena, to attain world class in both breadth and depth. On the world scale, the next energy frontier will soon be pushed back by the Large Hadron Collider at CERN, where our Project period covers the commissioning and early data phase. Funded by NSC since 2001, NTU has delivered all the System MotherBoards, our main hardware contribution to the Preshower subdetector, to CMS. Emphasis is shifting to physics analysis. Topping off NSC funding, Sub-Project 1 carries > 1/3 of our Project budget, to elevate our manpower and presence at CERN. We have set the relatively sheltered analysis strategy of b' and t' search. It aims for early limits or discovery, while training members for the next round. The core of our CMS analysis team was battle-hardened from the Belle experiment at KEK, Japan, where we have produced 20% of physics output. Belle itself, however, will enter upgrade phase starting 2009. Our CMS hardware team would switch to Sub-Project 2 to join the construction of the silicon vertex detector upgrade, as well as pixel detector R&D (which could be used for ILC). Belle analysis will continue at a lower level. When completed in 2012, SuperBelle will reach 10 times the data of Belle, to doprecision B, D and . measurements, complementary to the LHC program. After enjoying spectacular progress in past decade, the current focus of neutrino physics is measuring the third mixing angle 13. A nonzero value will open up possibilities for future studies of CP violation in the lepton sector. Sub-Project 3 constructs critical detector elements for the Daya Bay Reactor Experiment, where Taiwan is the closest tech and HEP base to the Shenzhen/Hong Kong site. First preliminary results could appear within project period. At the intersection of neutrino and particle astrophysics, NTU has been developing on a shoestring budget for years the NuTel neutrino telescope for "seeing AGNs from behind a mountain". The wide-field optics challenge was finally overcome in 2007, and a 2m mirror was constructed. The next step is to complete a field test. Sub-Project 4 has gathered support from community (NSC), LeCosPA Center at NTU, and ASIAA, and will work on the domestic operation of a novel cosmic ray, neutrino telescope, . appearance

experiment. With the AstroMath building being completed at NTU, this is our “15% project” into particle astrophysics, overlaping in science with the ANITA and IceRay experiments pursued by LeCosPA. Inspired by the strong theory-experiment link for Belle, Sub-Project 5 aims at improving theory-experiment links for Sub-Projects 1 – 4.

Thus, we are developing a complete agenda of collider (CMS), heavy flavor (CMS and SuperBelle) and neutrino physics (Daya Bay and NuTel), linking to electroweak and CP symmetry breaking and particle astrophysics. The fundamental question of mass generation is at the core of it all. With the unique synergies of theory and experiment, and the demonstrated performance of the Belle “B physics and CP violation” program in the past dozen years, the CI will synthesize all Sub-Projects into a coherent program, towards the eventual establishment of a “Center for Particle Physics” at NTU in the not too distant future.

計畫編號：BN04-01
計畫名稱：CMS 物理分析
計畫主持人：侯維恕
計畫摘要(中)：

本三年計畫期間正是 LHC 初登場取數據，一定會有所發現，但要是台大自己的就需要戰略。去擠如希格斯子或超對稱等熱門題材是討不了便宜的。我們自 Belle 的成果獲得靈感，訂定搜尋四代夸克的戰略，將較不受威脅，而截面大、衰變特性多樣，僅需一個 $\tilde{fb}^{-1}$的數據便可發表數篇下限甚至發現的論文。組員將藉此熟悉所有的物理分析工具，擴展到更受矚目的方向，就像我們在 Belle 一樣。若發現重於 600 GeV 的夸克，它自身極強的湯川偶合便可能引發電弱對稱破壞，將我們帶進質量產生的核心議題。

本子計畫提供國科會計畫的配合款。自 2001 年起我們獲國科會支持，製作 Preshower 子偵測器所有的 SMB 系統母板，已在 2007 年交付，我們也開始派人在 CERN 常駐。但由台大與中大對分的國科會經費有限，且有些難以突破的限制，如派駐費太低，在 CERN 缺乏足夠的群組運行費等。我們已聘入兩位資深人員全時間派駐 CERN，其中一位是在 CERN 已有 10 年以上博士級研究經驗的外籍副研究員，必須用國際標準聘任，在國科會架構下是聘不到的。要在歐洲與歐美競爭，我們不但要考慮匯率與生活水準差距調整派駐費，

我方人員也須立足點平等。歐盟十分鼓勵其人員往來參與各種工作會。我方組員若無法參與這一類工作會議，將很快被邊緣化。因此本計畫主要編列研究人員薪資、CERN 群組運行費，及(共同)主持人的些許差旅費。這些經費加注在國科會之上，符合「五年五百億」的本意 — 將台大提升至世界一流。

計畫摘要(英)：

The 2008.8~2011.7 period covers the commissioning and early data period of LHC, and discovery is virtually guaranteed. To have NTUCMS discoveries, however, a strategy is needed. “Hot” topics such as Higgs and SUSY are too crowded. Motivated by the S and AK BSM hints (our own work) at the B factories, realizing complete coverage is possible for the first time at LHC, we formed the strategy of 4th generation b’ and t’ quark search. The subject is relatively sheltered from competition, but large cross sections and multiple signatures allow early limit or discovery papers with just 1 fb~1 data. Trained with all the tools of the trade, group members can then fan out — as achieved in Belle — to more lucrative endeavors. If we find very heavy quarks above 600 GeV, the strong Yukawa coupling could itself trigger EWSB, and bring us into the core issue of mass generation.

This Subproposal provides matching funds for the existing NSC proposal, where NTUHEP has received an average of over NT$10M per year since 2001. All the System MotherBoards (SMB), our main hardware contribution to the Preshower subdetector, have been delivered to CERN in 2007, where we now station several members. But the NSC funding is shared between NTU and NCU and is limited. Further, it is constrained by rather old practices, e.g. unrealistic stationing support and insufficient group operation budgets at CERN. We have recently acquired two experienced members in the current 2-year Excellence Project, gave them position titles and stationed them fulltime to CERN, to complement the postdoc and doctoral students funded by NSC. One of them is non-Taiwanese and has 10 years Ph.D. experience at CERN, his salary and benefits must be by international standards, and is not possible under NSC. The overall issue is how to compete with Europeans and Americans. Besides adjusting NSC stationing costs to take into account exchange rate

and living standard differences, our personnel must attain parity with the well-to-do research environ the Europeans enjoy. EU has many programs to encourage exchange and workshops within EU. Our CERN operation budget must cover our group members for such professional activities, otherwise they would be marginalized. So the budget for this Subproposal is mainly for salaries, CERN operation, and some travel for the (Co-)PI(s). This "topping off" nature of existing NSC budget is true to the spirit of the "Excellent Research Projects" — bringing NTU to world class.

計畫編號：BN04-02
計畫名稱：從 Belle 到超級 Belle 實驗
計畫主持人：張寶棣
計畫摘要(中)：

台大高能物理團隊自參加 Belle 實驗以來，成果十分豐碩。尤其是在許多物理分析上，已有將近 50 篇 Belle 論文是由我們主導發表，佔所有 Belle 論文數的五分之一。其中最重要的是我們發現 b 至 s 夸克時間相關電荷宇稱不守恆測量與理論預期差異，但實驗誤差仍大，需要 10 倍以上的數據才能確認。這項混合 CP 破壞的測量是目前在重味物理上有希望看到新物理的研究之一。本組另一項重大發現是在 B 至 K 衰變中確立了中性 B 介子直接電荷宇稱的不對稱性，而帶電 B 介子卻有不同的不對稱性。這種不同的性質也有可能是新物理所導致的。因此日本 KEK 的同事已經提出超級 B 介子計畫，預計在 2009 年夏天以後，利用原本 Belle 運轉的經費，以三年的時間建造超級 B 介子工廠，與 LHCb 實驗成為研究重味物理的兩大重鎮。

隨著大強子對撞機即將運轉，我們必須把主要的博士級人力遷移至 CMS 實驗，但是同時也在 B 物理上能保持絕佳的生產力。詳細的計畫內容，例如人力的調配，分析團隊的策略以及學生的訓練方式，都包含在這份研究計畫中。因著 Super Belle 可望於 2009 年夏天開始建造，而 BaBar 將於 2008 年秋天關閉。2009 年夏天 B 介子工廠的重要結果將會在會議上發表。雖然我們大部分有經驗的博士後都已經轉往 CMS 實驗，但隨著兩位已有 Belle 分析經驗的碩士生加入成為博士生，以及資深的博士生江政錦和幾位正在訓練的碩士生，我們也希望能在 2009 年夏季會議中報告我們的結果。同時我們也希望與 KEK 硬體專家探討參與 Super Belle 偵測器的建造，將我們在 CMS

的硬體人力轉往 Super Belle 的計畫，並持續我們在 pixel 偵測器研發的工作，為二期 Super Belle 偵測器的升級和未來大型線性加速器實驗作準備。

計畫摘要(英)：

The foundation of High Energy Physics at NTU was through joining the Belle experiment in Japan thirteen years ago. With the discovery of direct and indirect CP violation and many measurements on B meson properties, CKM angles, and charm physics, Belle and BaBar are the two most successful HEP experiments in the past 10 years. Most tantalizing are two possible indications for New Physics: the S and AK problems. The primary goal of B factories has now shifted to precisely measure the Standard Model parameters and search for new physics, which require much more data and, consequently, calls for upgrade to SuperBelle.

NTUHEP's contribution to Belle is wholesome. Hardware-wise, we not only successfully built the extreme forward calorimeter, but also delivered FLEX and trigger timing modules on time for the silicon vertex detector. Our contribution to physics analysis is even more remarkable, consistently publishing more than 20% of Belle papers, including the results on the S and AK problems.

We propose to participate in the three-year construction of SuperBelle. KEK proposes to use existing operation budget to upgrade accelerator and detector to SuperKEKB and SuperBelle, which will boost the luminosity by a factor of 10, with a potential future upgrade to 8 x 1035 cm˜ s˜ı. SuperBelle is complementary to LHCb and ATLAS/CMS, and will provide good opportunities to search for new physics beyond the Standard Model, and rich topics for flavor physics. The new state-of-the-art detector and the clean e˙-e˜ environment will enable quick physics analysis and many papers, and SuperBelle is a guaranteed success.

With the start of LHC in 2008, timing for SuperBelle construction is perfect for us. As involvement in CMS Preshower detector construction winds down, the hardware manpower will switch to SuperBelle construction. At the same time, our experienced analysis manpower built

up under Belle is already being dedicated to the challenging CMS analysis (Subproposal 4) at LHC.

We will collaborate with KEK to build a silicon vertex detector, which we have prior experience. We will be further involved, with KEK and Hawaii, in pixel detector R&D, which is targeted for Phase II of SuperBelle. It is also a key subdetector for the International Linear Collider, the huge world-wide HEP project after the LHC.

計畫編號：BN04-03
計畫名稱：大亞灣微中子振盪實驗
計畫主持人：熊怡
計畫摘要(中)：

在二十世紀結束前所觀測發現的兩類微中子的大混合，亦既太陽微中子振盪與大氣微中子振盪兩大發現，足以顯示粒子物理學中的標準模型理論已不再完美。尚未量度到的第三種混合角雖不大 $\sin^2 2\theta_{13} < 0.15$，卻是足以打開輕子 CP 破壞現象的一支金鑰。為了測量此一混合角的大小，台灣與中、美、俄、港數所名校大學與研究院共同合作開發一大型反微中子探測器實驗，位於大亞灣核電廠旁約一千八百公尺遠的山脈山洞內。利用高山的屏障減少宇宙射線的背景雜訊，大亞灣核電廠所產生的超大量反微中子，以及兩個近距離的同型探測器共同減低實驗系統誤差以得到精確的量度。因此大亞灣微中子振盪實驗是在粒子物理上的前沿物理研究。

此一三年的子計畫預計與香港大學、香港中文大學、加州柏克萊大學的勞倫斯實驗室合作在香港仔隧道地下實驗室，共同建造一大亞灣實驗的原型液態閃爍探測器以研究宇宙射線的背景雜訊，並進一步參與下一階段建造大亞灣微中子振盪實驗。我們計畫參與反微中子探測器內的壓克力圓筒的設計、建造與運轉，數據截取系統與電腦數據儲存系統。由於臺大有個十分活躍的高能物理實驗組，且臺灣也有很好的工業技術用以支持大亞灣微中子振盪實驗的研發。此外臺灣與香港和大亞灣地緣上如此鄰近，正是參與此一世界級的重要實驗以發現標準模型下的第三種混合角的良機。

計畫摘要(英)：

Discovery of bi-maximal neutrino mixings at end of last century, i.e. the observation of solar and atmospheric neutrino oscillations, shows that

the Standard Model of particle physics is incomplete. The remaining unmeasured mixing angle sin2 2 13 < 0.15 is small, and holds the key to the observability of CP violation in the lepton sector. To measure this mixing angle, a collaboration has been formed between China, US, Russia and Hong Kong, and Taiwan. A large antineutrino detector will be deployed inside a mountain 1800 m from the reactors in Daya Bay, China, using the overburden to suppress backgrounds, and two near detectors to help control systematic uncertainties. The Daya Bay neutrino oscillation experiment is a forefront research in the frontier of particle physics.

This 3-year subproposal plans to operate a prototype liquid scintillator detector with cosmic ray vetoes in an underground test facility at the Aberdeen tunnel in Hong Kong, in collaboration with University of Hong Kong, Chinese University in Hong Kong, and Lawrence Berkeley Laboratory and proceed the next step towards the construction of Daya Bay neutrino oscillation experiment. We plan to participate the design, construction and operation of the acrylic vessels for the anti-neutrino detectors, VME-based DAQ system and online PC-cluster for data taking, as well as physics and background simulation and analysis. Since NTU has a strong and active HEP group and Taiwan is also a good technology base for detector development for Daya Bay neutrino oscillation experiment. The close proximity between Taiwan, Hong Kong and Daya Bay is an ideal opportunity to participate such a world class experiment to discover the last mixing angle 13 in the Standard Model of leptons.

計畫編號：BN04-05
計畫名稱：推動粒子理論和實驗之聯結
計畫主持人：何小剛
計畫摘要(中)：

為使我們能在大強子對撞機（LHC）時代起到重要作用，這一子計畫將著重建立理論與實驗的聯結並系統地研究與質量起源相關之重味夸克、弱電對稱破缺和微中子等粒子物理前瞻課題。我們希望能延續 B 物理領域理論與實驗攜手並進的成功經驗，並推廣到主計畫下之各個實驗計畫。

子計畫一的第一物理目標是用 CMS 偵測器對第四代夸克 b’ 在弱赫格斯作用機制涵蓋質量範圍進行探測。這一方向也是本子計畫早

期物理分析目標。我們也會對赫格斯粒子的 CP 特性及其他粒子進行研究並回饋到我們的實驗計畫中。

子計畫二將參與日本 KEK 的 B-工廠之升級計畫。升級後的 B-工廠將產生更多的研究 B 物理之數據，進而開啟新的發現新物理之空間。我們將進一步加強與實驗組之合作，著重 B 衰變中 CP 破缺、夸克混合，和現今熱門的重味強子譜等進行研究。

主計畫下有兩個與微中子相關之實驗，子計畫三之探測微中子第三個混合角 $\theta 13$ 的微中子實驗，和子計畫四之 τ 再現探測實驗。我們將進一步研究能預言微中子質量和混合之模型，以及這些模型提供由輕子數不守恆而解釋宇宙中重子數不守恆之可能性。也將研究 sterile 微中子之效應和宇宙射線中微中子的產生機制。

當然理論研究也有它自身的生命力，因此我們將不侷限於研究只與主計畫實驗相關之課題，而將把研究方向擴展到標準模型之外的模型建構，自然界中各類相互作用之統一理論，新的 un-粒子研究，以及與宇宙澎漲相關的黑暗能量與黑暗物質之粒子物理研究。

本子計畫將同時把建立團不同層次研究人力資源作為重要目標。我們希望能在近期徵聘到兩到三位高水準研究人員進行與對撞機物理和新物理之研究。

計畫摘要(英)：

The LHC will turn on in 2008. Together with several currently running and planned experiments, many of the outstanding problems of modern particle physics may soon find their answers. To play a more significant role in this exciting period, this Subproposal (SP) aims at building up the Theory-Experiment link, to unify the current frontiers in heavy flavor, electroweak symmetry breaking (EWSB) and neutrino physics. We wish to emulate the success of the B physics support to Belle, and extend to other experiments under the main proposal: CMS Analysis (SP-1); From Belle to SuperBelle (SP-2); Daya Bay Neutrino Oscillation Experiment (SP-3); and NuTel — A Neutrino Telescope in Taiwan for τ Appearance (SP-4).

The main goal of LHC is to understand the mechanism for EWSB, hence mass generation. The initial physics goal of SP-1 is to pursue the search for the 4th generation b’ quark with the CMS detector covering the whole mass range allowed by weak Higgs mechanism. This is one of

the strengths of our theory faculty, with this steppingstone, we will be able to study any type of new heavy particle thereafter. The CP properties of Higgs boson, and other possible new physics effects will also be pursued with LHC data, and feedback on our future experimental program.

B physics is our strong suit, where we have made significant contributions to Belle, such as strong theoretical input to the two best possible indications for new physics, B decay to baryons, and effects of 4th generation quark. SP-2 joins the B-factory upgrade at KEK, to open up further opportunities for discovery. We will emphasize on CP violation, quark mixing in B decays, as well as the new hot topic on heavy hadron spectroscopy.

With recent dramatic progress in neutrino physics, SP-3 pursues 13, the 3rd neutrino mixing angle, and SP-4 develops the novel NuTel neutrino telescope to study appearance, even detect possible AGN source for UHECR. Whether 13 is zero or not is of fundamental importance, since CP violation in neutrino oscillations depends on it. We have independently proposed the tri-bi-maximal mixing which explains current data well and predicts 13 to be zero before. We will focus on models for neutrino mass and mixing, their implications for leptogenesis, sterile neutrinos, and cosmic neutrino production mechanisms.

The above directions all come back to the Question of Mass. This proposal will link different experimental efforts to provide better synthesis of our understanding. Theory work certainly has a life of its own, therefore we will also work on a broader range of theoretical topics, such as model building beyond SM, unification of forces in Nature, unparticles, dark energy and dark matter in particle context.

In theoretical studies, quality manpower at critical mass is necessary. This proposal aims at planning to gradually build up several layers of research staff. In the initial stage we will aim at recruiting 2 to 3 high caliber researchers working in the areas of collider and beyond SM physics. This effort will therefore put NTU in a better position to compete for hosting the NCTS.