Report of

the 2004 KEK PS External Review Committee

June 7-8, 2004
Seminar Room, Building 4, KEK, Tsukuba, Japan

Final Report

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Satoshi Ozaki: Committee Chairman

Introduction

The 2004 External Review Committee of the KEK 12 GeV Proton Synchrotron (PS) Program met on June 7-8, 2004 in the Seminar Room of Building 4 in the High Energy Accelerator Research Organization (KEK). The members of the External Review Committee and names of its Referees are listed in Appendix 1. The Committee appreciates the valuable contribution by Referees, who, by mail, provided their expert evaluation on specific experiments as well as general comments which have been incorporated in this report. The agenda of the meeting is given in Appendix 2.

The charge to the Committee by the Director General of KEK is found in Appendix 3. The completion of the 50 GeV proton synchrotron at the Japan Proton Accelerator Research Complex (J-PARC), which is under construction in Tokai in a joint effort by KEK and JAERI, has been delayed by one year and now its commissioning is anticipated in 2008. Soon, KEK is compelled to dismantle some of the existing beam line equipment, radiation shielding, as well as detector systems, refurbish them, and transfer them to J-PARC in time for the commissioning in order to supplement the outfitting of the experimental halls and beam lines. KEK also has to provide manpower to complete the accelerator and experimental facility. These considerations, together with the natural thought that the experimental programs at the 12 GeV PS will move to the new and more powerful facility, lead to the inevitable conclusion that the operation of the 12 GeV PS at KEK will have to be shut down in the near future.

With this backdrop, this review was called (1) to evaluate the contributions the 12 GeV PS has made to the field of particle and nuclear physics since its commissioning more than 25 years ago, (2) to evaluate the accomplishments and progress of physics research programs at the PS during the past four years since the last review was performed in the year 2000, and (3) to evaluate the performance of the 12 GeV PS and the timing of the anticipated shut down. The Committee was also asked to comment on the transition plan for the experimental program and experimental facility from the 12 GeV PS at KEK to the 50 GeV PS at J-PARC. The particular operative question is whether the PS can be shut down, in the earliest case, at the end of the current Japanese Fiscal Year 2004 as has been discussed occasionally, or should the shut down be delayed to accommodate various programmatic needs.

Executive Summary

The KEK 12 GeV Proton Synchrotron (PS) Program since 1976:

Since its commissioning in 1976, the 12 GeV PS at KEK has successfully supported a highly productive physics program in Japan. For more than 25 years, the PS has operated well with good reliability in spite of the constraint of having limited aperture. This limited aperture has prevented the PS from taking advantage of the steadily increased booster intensity over the years. With many innovative steps the 12 GeV PS operations

group recently succeeded in increasing the average intensity for the fast extraction from $4x10^{12}$ ppp to $6x10^{12}$ ppp, the improvement that was essential for the successful run of the K2K experiment.

The experimental program of the 12 GeV PS can be divided into three periods, namely 1977 - 1984 (before TRISTAN), 1985 - 1998 (after the start of TRISTAN and before K2K), and the period since 1999 (after the start of the K2K experiment). During the first period, the PS was the only high-energy accelerator in Japan, and as such, it had supported a wide range of particle and nuclear physics experiments. Notable accomplishments in this period are an early determination of the upper limit for $K^+ \rightarrow \pi^+ \nu\nu$-bar and the rejection of the existence of barionium states.

During the second period (1985 – 1998), with the shift of emphasis in particle physics research to TRISTAN, nuclear, in particular hypernuclear physics and kaon decay physics dominated the PS program. The detection of double hypernuclei and success in the hypernuclear gamma spectroscopy are the notable achievements. In the kaon decay experiments, the committee noted the $K_L \rightarrow \mu e$ study. Also noted is the observation of the anti-protonic atom. This period also saw a considerable increase in the demand for the test beams for detector R&D work related to TRISTAN experiments as well as experiments at foreign laboratories.

The third period (1999 to date) is the subject of this External Evaluation, and is marked by the K2K (KEK-to-Kamioka) experiment, the first accelerator based neutrino oscillation program in the world and the first PS based large scale international collaboration that placed the KEK 12 GeV PS on the map of the world. In order to achieve the goal of delivering 10^{20} protons on target as soon as possible, the PS-PAC authorized the allocation of 2/3 of available beam time to K2K with fast extraction and 1/3 for other experiments with slow extraction. It was unfortunate that the accident at the SuperKamiokande detector after two and a half years of running shut the experiment down. The detector was reconfigured and repaired within one year and it is now almost reaching the original goal in the amount of data collected. Other experiments were run using the remainder of the available time with significant accomplishments as detailed later.

As a whole, the KEK 12 GeV PS has made significant contributions to the field of particle and nuclear physics as noted below:

- Provided the foundation for the advancement of high energy physics in Japan.
- Advanced frontier of strangeness nuclear physics, the unique accomplishment worldwide.
- Pioneered work on the accelerator based neutrino oscillation, providing conclusive evidence with the disappearance experiment.
- Established the best upper limit, some at the time of the measurements, on various kaon decay modes and symmetry conservation.

The Performance of the 12 GeV PS Accelerator since the Year 2000:

The KEK PS complex consists of a 750 keV Cockcroft-Walton H^- ion source, a 40 MeV linac, a 500 MeV rapid-cycling synchrotron (booster), and a 12 GeV synchrotron. It provides a 500 MeV proton beam from the booster and 12 GeV protons to the users. The complex was completed in 1976.

In order to meet the requirements of the K2K experiment (in total 1×10^{20} protons-on-target), the performance was upgraded during 1998 to 1999. The integrated number of protons-on-target, recorded by the experiment, already has almost reached its goal in fiscal year 2003. This is very impressive and the team should be congratulated on this achievement.

The PS complex is operating efficiently with a fractional down-time which is less than 10%. This is comparable to the down-time of the 26 GeV CERN Proton Synchrotron (CERN PS) which is about 5%. The fraction of time used for setting-up and machine studies is about 10% which is reasonable and nearly the same number as observed at the CERN PS. The total time scheduled for operation per year is close to 6000 hours, which is comparable to the 5000 to 6500 hours per year of the CERN PS, depending on the physics program. The remaining 2800 hours allow for proper maintenance of the accelerator complex, its infrastructure and official holidays. This time span includes the cool-down time after an extended running period which is required for the maintenance of important components that have become radio-active due to unavoidable beam losses.

The performance goal of the KEK PS was achieved by a number of well-targeted measures to increase the intensity and the reliability, and to reduce the losses in the accelerators. This quickly led to an increase of about a factor of 1.5 to 2 in the delivered intensity of fast extracted beams when compared to the period before 1999.

These measures included well justified hardware upgrades of key booster components (magnet power supply, RF cavities and RF power amplifiers) and careful re-engineering of the vacuum envelope of the PS, resulting in a reduction of the impedance seen by the beam which significantly reduced the losses at transition. Furthermore, extensive machine studies were made to improve the tuning of the accelerators and to raise beam stability limits. A prominent example is the introduction of white noise in the RF, which produced an increase in the space charge threshold by bunch lengthening.

KEK PS Particle Physics Program since the Year 2000:

The recent KEK program in particle physics has addressed frontier issues in its neutrino and kaon experiments. The results obtained are significant and the experience gained in their pursuit will be extremely valuable for the next generation of neutrino and kaon studies to be carried out at J-PARC. The much higher flux of neutrinos and kaons attainable at J-PARC will improve the experimental sensitivity and could lead to major discoveries. The neutrino and kaon experiments carried out at KEK in recent years include: E362, E246, E470, and E391a.

The above particle physics program is viewed as an outstanding success. The neutrino experiment (E362), K2K, has pioneered an accelerator based long baseline neutrino oscillation experiment. It made very important measurements regarding the neutrino oscillations, confirming with a 99.99% confidence level the neutrino oscillation discovered by SuperKamiokande. This is a major success of the KEK-PS experimental program in recent years. The K2K experiment will also provide very useful neutrino cross-section measurements. The kaon experiment, E246, searched for T-violation in $K_{\mu 3}$ decay using a precise measurement of transverse muon polarization, and obtained the best bound to date. Another kaon experiment, E391a, is currently taking data, aiming at searching for the CP violating $K_L \rightarrow \pi^0 \nu\nu$-bar decay with sensitivity at the level of 10^{-10}. These kaon experiments provide valuable information regarding backgrounds for some of the most interesting future kaon experiments imaginable. The experience gained from those efforts will prove extremely valuable for J-PARC.

KEK PS Hadron and Hyperon Program since the Year 2000:

The physicists running strangeness physics experiments at the KEK 12 GeV PS have taken full advantage of its capability to deliver an outstanding set of results over the past five years even with limited beam availability. The Japanese physicists heading this effort are to be commended for taking a world leadership role in the field. The γ-ray spectroscopy research was a giant step forward; the Hyper-ball is a superb technical success and the precision data obtained are of major importance in hypernuclear physics. The Σ^+-p scattering measurement and its relation of the spin-orbit potential plus the Σ-nucleus repulsive potential demonstration are important contributions to strangeness physics and our effort to understand the baryon-baryon interaction. The non-mesonic weak decay of the Λ hypernuclei experiments have resolved a decade-long puzzle in hypernuclear physics, suggesting that the kaon exchange plays a crucial role in the meson exchange picture of the hyperon-nucleon interaction. The discovery of the Nagara event ${}^{\Lambda\Lambda}{}^{6}$He is considered by some the most significant result of the past 5 years in hypernuclear physics. The observation of the excess dileptons in p-C and p-Cu reactions gave a first hint of the medium modification of vector mesons in nuclei. The observation of possible signatures for deeply bound kaonic states in light nuclei and their interpretation is especially tantalizing; one would certainly urge additional time for an experiment to provide clear confirmation prior to any permanent shutdown of the KEK PS. In any case, the record at KEK in strangeness physics since 2000 is unequaled.

Conditionally Approved Experiments and Approved Experiments Awaiting for Beam Time at 12 GeV PS:

Three experiments have been conditionally approved by PAC for future KEK beam time:

1) E548: Study of Kaonic Nuclei by the (K^-, p) Reactions and Search for the Kπ bound state in Kaon Induced Reaction
2) E549: Confirmation of Nuclear Kaonic State and Search for its Excited State
3) E559: High Resolution Spectroscopy of Pentaquark Θ^+

Of these proposals, E549 is a clear follow-up to E471, and should run to confirm the existence of deeply bound, narrow kaonic states before the KEK PS closes. E548 is an interesting exploratory experiment, if time is available, although one cannot argue that its need to run is as pressing as that of E549. Given the high profile nature of pentaquark physics at this time, KEK should make a supreme effort to explore its production mechanism and spectroscopy before the KEK PS closes. For both E549 and E559 experiments, their physics importance is very high and also the time is of the essence.

Test Beam Facility:

A test beam facility, no doubt, is indispensable in proving the principle of an innovative detector, in finalizing a proposed detector component before mass production, and in calibrating completed detectors to confirm their performance characteristics. The KEK PS has provided such an opportunity since its start in 1976 for the PS experimental groups, international collaboration groups and others. It has also contributed to producing a number of scientific and technical papers for many years. This opportunity will be lost when the impending shut down of the PS will take place. Although a test beam facility is planned at J-PARC, commissioning of such a facility is some years away and also the scope is rather limited.

The committee was informed that a plan exists to build an alternative test beam facility at KEK by making use of the existing 8 GeV electron linac. The committee strongly recommends that it be built in a timely manner.

General Consideration and Recommendations:

The KEK 12 GeV PS has played a critical role in advancing Japanese particle and nuclear physics to international prominence. It provided opportunities to carry out pioneering experiments in particle physics, and to develop a unique and well instrumented hadron and hypernuclear physics program. Also the facility was instrumental in educating and training a large number of young physicists and students, many of them are now very active in the international arena. The number of experiments successfully completed, the number of physics papers published in refereed journals, and in particular the number of doctoral degrees acquired, based on the program at an accelerator facility, are very important measures for the success of the facility. In this regard, 12 GeV PS has an outstanding record of completing 119 experiments, publishing 279 physics papers, and letting 135 students attain the doctoral degree. The detailed statistics on these accounts, supplied to the Committee, are given in Appendix 4.

The J-PARC 50 GeV program is a natural continuation of the program at the KEK PS. Therefore, the promising experimental programs that were developed using the KEK PS must be transferred to J-PARC with further refinement. In addition, the new accelerator facility, with expected performance much higher than the current PS capability, will attract a new breed of experiments.

Although the neutrino experimental results from the K2K experiment could be improved with more statistics, considering that much higher fluxes, attainable at the J-PARC, will significantly improve the sensitivity and extend its reach into a domain where revolutionary discoveries are possible and that J-PARC will come on-line in 2008, the committee sees little need for a long extension of the program beyond the presently planned runs. The committee, however, notes that there is a critical need to complete the proposed near term data taking before the impending shut down of the 12 GeV PS in order to improve the systematic error on the present K2K experiment.

The 12 GeV PS is now at a very advantageous point to apply its power to a highly time critical investigation such as the investigation of pentaquark states (E559) and the confirmation of an interesting finding of the deeply bound kaonic nuclear states (E549). For the pilot experiment like E391a, it is important to establish the feasibility of data taking with low background before the shut down so that further investment and planning for the J-PARC experiment can be made with confidence. These considerations and an evaluation of the beam time needed to complete these critical experiments lead to the recommendation that the shut down of the 12 GeV PS should be delayed to the end of FY 2005 if not into FY 2006. It is the committee's judgment that the benefits from this extension clearly outweigh the pressure it might cause on the available resources.

A timely completion and commissioning of J-PARC with well equipped experimental halls must be the top priority of the Project Director. Although outside the purview of the J-PARC project, one hopes that a lot of thought has been given to maintaining the capability of the physicists who will utilize this outstanding facility once it becomes operational. One should not lose sight of the fact that it is the ingenuity and creativity of Japanese physicists which has placed Japan at the forefront of neutrino and strangeness nuclear physics for the past decade. Such talent, if squandered while waiting for J-PARC, will be next to impossible to restore.

Despite the overwhelming impression that J-PARC will be unmatched in the world, it is not without significant competitors. Injector proton synchrotrons for hadron colliders at BNL, CERN, and Fermilab have been upgraded in recent years to ensure a high performance of the colliders, and are now becoming available for fixed target programs at 10's to 100's of GeV. For instance, BNL is working towards RSVP (Rare Symmetry Violating Processes) program and CERN is organizing a large workshop this fall to study its future fixed target program. As to the neutrino beam program, all three laboratories have proposals for a high power proton driver in Mega-Watt range. Considering the worldwide situation, there is another reason to note that a timely completion of J-PARC is of critical importance.

Detailed Evaluation of the KEK PS Program

Neutrino Sector

E362: K2K Experiment

Known as K2K, this search for neutrino oscillation using neutrino beams form the KEK PS and the SuperKamiokande detector has been a flagship experiment of the KEK program, and has been a pioneering neutrino oscillation experiment with a long baseline of 250 km. Based on accumulated data samples taken in June 1999 to February 2004, K2K has observed 108 neutrino events contrary to the 150.9 (+11.6-10.0) expected events, and found the energy distortion characterized by neutrino oscillations. The null oscillation probabilities are found to be 0.33% in the ν_μ disappearance and 1.1% in the E_ν energy distortion. Combining both results, K2K has confirmed the neutrino oscillation discovered in the SuperKamiokande atmospheric neutrino observation with a 99.99 % confidence level. The K2K results provide important information regarding the pattern of neutrino masses and mixing. The high priority given by KEK to this experiment was well justified.

During the upcoming data-taking runs, it is quite important to improve the understanding of systematic errors and to increase the significance of the K2K results. Therefore, the following proposals should be finalized: at least 6 months normal run in 2004; at least 4 months more of beam exposure for more data in SciBar; beam alignment runs; and an anti-neutrino operation study. These runs can also provide more measurements of low energy neutrino interactions with $E_\nu < 1$ GeV where the neutrino oscillation parameters give a strong distortion in the energy spectrum.

In addition to its outstanding physics results, the experience gained will be extremely valuable for the next generation T2K (Tokai-to-Kamioka) experiment that will use a much more intense neutrino beam and the well understood and tested SuperKamiokande detector. That effort will significantly advance neutrino physics and should get underway as soon as possible.

K-decay Sector

E246: Search for T-Violating Transverse Muon Polarization in $K^+_{\mu 3}$ Decay using Stopped Kaons
E470: Branching Ratio Measurement of $K^+ \rightarrow \pi^+\pi^0\gamma$ Direct Emission

This experiment searched for T-violation in $K_{\mu 3}$ decays via a transverse muon polarization measurement. Such an effect is extraordinarily small in the Standard Model, but could be induced in interesting extensions that provide new sources of CP violation. The experiment improved the bound on such an effect by a factor of 3 which is the world-record to date. On top of that, it should be noted that E246 has established a precise measurement for transverse muon polarization in $K^+ \rightarrow \pi^0\mu^+\nu$. This experimental

group has also explored a number of other kaon physics topics including direct photon emission in $K^+ \rightarrow \pi^+\pi^0\gamma$.

In most of its measurements, E246 was statistics limited. Additional kaon flux would have improved the results significantly. The experiment really requires a much more intense beam. However, in order to access $P_T \sim 10^{-4}$ which is the goal at J-PARC, obtaining a systematic uncertainty of $\delta P_T < 10^{-4}$ is essential. Having demonstrated their ability to reduce systematic backgrounds, this experiment is ideal for the high flux that will be provided at J-PARC. The possible order of magnitude sensitivity improvement in the muon transverse polarization attainable at that facility will explore interesting potential new sources of CP violation beyond the Standard Model.

E391a: Study of $K_L \rightarrow \pi^0\nu\nu$-bar

This experiment was designed to search for $K_L \rightarrow \pi^0\nu\nu$-bar with sensitivity $O(10^{-10})$, i.e, about three orders of magnitude beyond existing bounds. Even at that level, it falls short by about an order of magnitude of Standard Model expectations. For that reason, it has been viewed as a pilot program to search for new physics and to better understand backgrounds. The latter point is very important, since measurement of this rare decay will be extremely difficult; but the payoff for eventually measuring it is very high. It will provide the cleanest known manifestation of CP violation in the Standard Model and together with B physics studies could unveil new sources of CP violation. The expertise obtained in this endeavor will be very valuable for future pursuits at Brookhaven (the KOPIO experiment) and an envisioned higher statistics study at J-PARC.

Hadron Sector

E325: Study of Chiral Property of Dense Nuclear Matter through Measurements of Meson Mass Modification in Medium

This experiment addresses the issue of meson mass modification within the nuclear medium – the partial restoration of QCD chiral symmetry in dense nuclear matter – by bombarding nuclear targets of different atomic mass with 12 GeV protons to produce π, ρ, and ω mesons within the nucleus and then measuring their spectral shape by detecting electron-positron pairs from the decaying mesons. The data taken in 2000-2002 with high statistics strengthen their previous results published in 2001, indicatingthe excess of e^+e^- pairs below the ω-meson peak in carbon and copper nuclei. A possible origin of this excess is the modification of the ρ-meson inside the nucleus. Detailed analyses of the dispersion relation of the in-medium ρ-meson and of the in-medium properties of the ϕ-meson are under way. The data would be the best experimental evidence of the medium modification of mesons in nuclei among other attempts in hadron-nucleus and nucleus-nucleus collisions. Judgment on the implication of the experiment must await final analysis of the full data set and the consequent interpretation of the data, which should be made the experimental team's top priority.

Nuclear Physics with Strangeness Sector

E373: Double Strange Nuclei by Emulsion Hybrid Method
E522: Search for H-dibaryon Resonance via $^{12}C(K^-, K^+\Lambda\Lambda$ and Study of Ξ^-N Interactions

This experimental group constructed a hybrid system of Scintillating-fiber bundle tracker and emulsion, which is highly sensitive, precise and has been productive in finding double strange nuclei and a possible H-dibaryon candidate. E373 addresses the characterization of the hyperon-hyperon interaction by stopping Ξ's in a nuclear emulsion to form ΛΛ hypernuclei. The existence of such bound systems indicates an attractive interaction, and the size of the binding energy provides information about the strength of the interaction. There was no unique interpretation for the first event, the so-called Demachi-Yanagi event, but the second event, Nagara-event does have a unique interpretation as $^{6}_{\Lambda\Lambda}$He; the production and decay of a double-Λ hypernucleus ($^{6}_{\Lambda\Lambda}$He) were confirmed from kinematical analysis. The results give a mass for the nucleus indicating a weakly attractive Λ-Λ interaction. The reported result has excited theorists around the world. Despite suggestions by many that such an experiment was not an optimum means to search for ΛΛ hypernuclei, a truly important result was obtained. In E522, they have measured the invariant mass spectrum of ΛΛ in $^{12}C(K^-, K^+ \Lambda \Lambda)$ reactions and observed an enhancement (2.7 standard deviations) near the threshold, which may be the unstable H-dibaryon. No clear distinction between evidence for an unstable H dibaryon and an attractive final-state ΛΛ interaction was established. One awaits the final result from the experiment and its interpretation.

E419: Measurement of B(E2) in $^{7}_{\Lambda}$Li
E509: γ-ray Spectroscopy of Hyperfragments using Stopped K Method
E518: γ-ray Spectroscopy of $^{11}_{\Lambda}$B

Hyper-ball, a large-acceptance germanium detector array, was constructed and demonstrated that high-precision gamma spectroscopy of hypernuclei is feasible. It solved the technical problems associated with the severe background in such an experiment and obtained ~three orders of magnitude improvement in the energy resolution. In E419 and E518, gamma rays from $^{7}Li(\pi^+, K^+\gamma)^{7}_{\Lambda}$Li and $^{11}B\ (\pi^+, K^+\gamma)^{11}_{\Lambda}$B have been measured with dramatic improvement in resolution compared with the conventional methods and the level structure of the $^{7}_{\Lambda}$Li has been determined. Energy spacing of the ground state doublet of $^{7}_{\Lambda}$Li, which provides a measure of the strength of the spin-spin interaction between Lambda and a nucleon, has been investigated. Precise gamma ray measurement enabled Doppler shift analysis for the life-time of the excited state, suggesting possible modification of the core nucleus in $^{7}_{\Lambda}$Li. This finding may validate the theoretically based assertion from the 1960s that the addition of a Λ to a helium isotope should compress the nuclear core and increase the magnitude of the Coulomb energy in the hypernucleus relative to that in the associated core nucleus. The Hyper-ball has proven to be a major technical success. Additional efforts with other hypernuclei to confirm spin dependence of the Λ-N interaction obtained from $^{7}_{\Lambda}$Li are being carried out by the same group.

In E509, the feasibility of gamma ray spectroscopy also has been demonstrated for the stopped K^- method, which can produce a wide variety of hyperfragments with a higher rate. Moreover, the stopped K^- experiments are very relevant in investigating the important question of charge symmetry breaking through the production of mirror hypernuclei. The strength of the E2 ${}^{7}_{\Lambda}\mathrm{Li}\ (5/2)^+ \rightarrow (1/2)^+$ transition γ-ray was determined, which contains information regarding the hypernuclear production mechanism. A new γ-ray was observed which does not match any known γ-ray from light nuclei. Unfortunately, the beam time provided has not been sufficient to obtain definitive physics results, although it seems clear that the method does hold the promise of being a useful tool as advertised in the proposal. If beam time can be found for this experiment before the shutdown of the KEK PS, then these measurements are deserving of the additional shifts originally requested.

The first application of high-precision gamma ray spectroscopy with "Hyper-ball" has provided a vivid picture of Λ's in nucleus and has opened a new era of hypernucleus physics. It is strongly recommended to continue their efforts with the "Hyper-ball-2" and also at J-PARC.

E438: Study of Σ-Nucleus Potential by the (π^-, K^+) Reaction
E521: Production of Neutron-Rich Λ-Hypernuclei by the (π^-, K^+) Double-Charge Exchange Reaction

Inclusive (π^-, K^+) spectra with various target nuclei have been measured with very high-precision using the SKS magnetic spectrometer. From distorted-wave impulse approximation analysis, a strongly repulsive Σ^- nucleus potential with a non-zero size of the imaginary part has been demonstrated, which is consistent with the potential extracted from the former study of Σ-atom x-rays. This result will provide a strong constraint on parameterization of models of the Σ-nucleon interaction, whether one works within the framework of the OBE model or constituent quark model. Furthermore, the interpretation of these data in terms of the Σ-nucleus interaction in normal nuclear matter suggests that it is unlikely that Σ^- would appear within the core of a neutron star. This exploratory experiment was quite successful. An extension of this physics at J-PARC is encouraged.

From a missing mass analysis of the (π^-, K^+) reaction, the neutron-rich Λ hypernucleus ${}^{10}_{\Lambda}\mathrm{Li}$ has been observed in this pilot experiment E521. The Λ production rate for (π^-, K^+) was found to be about 3 orders of magnitude smaller than that for (π^+, K^+). No discrete ${}^{10}_{\Lambda}\mathrm{Li}$ peak was observed, probably due to the limited statistics obtained. Additional investigation is required to understand the reaction mechanisms. This is the first attempt to produce hypernuclei in the region of exotic nuclei, which opens a new region of nuclear physics.

E452: Spin-dependent Interaction in Σ^+p Scattering

This experiment addresses the physics of the Σ^+-proton interaction, in particular the strength of the spin-orbit interaction compared with that of the Λ-proton interaction, which is known to be very weak. The SCITIC (Scintillating Track Image Chamber) detector developed during the course of this experiment, appears to have been very successful. Analysis of the data is in progress, but preliminary results show a large left/right asymmetry in the Σ^+-P scattering experiment. Complete analysis of the full data set from E452 is awaited.

E462: Exclusive Measurement of the Non-Mesonic Weak Decay of $^{5}_{\Lambda}$He
E508: Coincidence Measurement of the Weak Decay of $^{12}_{\Lambda}$C

These experiments address the non-mesonic (Λ+N $\rightarrow$ N+N) weak decay of Λ hypernuclei, a baryon-baryon strangeness changing weak interaction processes. There has been a long standing puzzle where simple one-pion-exchange (OPE) model calculations predicted $\Gamma_n << \Gamma_p$, where $\Gamma_x = \Gamma(\Lambda + x \rightarrow n + x)$, while earlier experiments gave Γ_n/Γ_p _1. A definitive experimental measurement was demanded.

The experiment made use of most of the SKS magnetic Spectrometer, i.e. its large acceptance and fine resolutions for K^+ mesons in (π^+, K^+) reactions. They used ^{6}Li and ^{12}C as the target in order to obtain some information on the A dependence of the process. By requiring "back-to-back" configuration of produced nucleon pairs together with an appropriate energy cut, they have succeeded in measuring the Γ_n/Γ_p ratio to be close to 0.5 with small statistics and systematic errors. The results clearly exclude the naïve OPE model. There are two theoretical approaches in predicting the Γ_n/Γ_p ratio. One is a more sophisticated meson exchange model where the kaon and other heavier mesons are included. The other is based on a direct quark scattering model. Both predict Γ_n/Γ_p _ 0.5, agreeing with the data. Further study is needed to distinguish the two approaches. The proposed J-PARC experiment addresses this problem trying to measure the spin and isospin dependence in high statistics by comparing non-mesonic decays of $^{4}_{\Lambda}$He and $^{4}_{\Lambda}$H.

Other results with high statistics, such as the lifetimes of $^{5}_{\Lambda}$He and $^{12}_{\Lambda}$C Hypernuclei and the branching fraction to the pion (or $\Gamma_\pi/\Gamma_\Lambda$), began to constrain theoretical models. These results are to be published in 5 letter papers and 1 full paper. The committee is pleased to see the group's high activity in this field and strongly recommends an early start on the proposed experiment at J-PARC.

E471: Search for Strongly bound Kaonic System

It has been proposed theoretically that K^- could form a deeply bound state with light nuclei and even change the structure of the nucleus in a qualitative manner. The aim of this experiment is to search for such an exotic K-nucleus bound system with (K^-, n) and (K^-, p) reactions with stopping K^- in the ^{4}He target. In the former reaction, an indication of the deeply bound K^-ppn system with a binding energy of 174 ± 4 MeV with the width $\leq$ 25 MeV is observed. In the latter reaction, surprisingly a proton peak that corresponds

to a missing mass of around 3120 MeV was observed, giving a stronger indication of a bound K^-pnn system. If the results are verified, they will have a great impact on nuclear and hadron physics because it would open a new field of the dense multi-hadron/quark system with the strangeness as a catalyzer. Therefore, it is of great importance to carry out the confirmation experiment, the conditionally approved E549, before closing the KEK 12 GeV PS.

J-PARC Project

J-PARC Accelerator Overview

Generally the construction of the J-PARC accelerator complex is proceeding on schedule with the linac commissioning with beam in FY 2006. Namely, the civil construction is making good progress at the Tokai site with the target completion date in April 2005, in time for the beginning of the Linac and Rapid Cycling Booster Synchrotron installation. Development and fabrication of technical components for these accelerators also appear to be in good shape. As to the Main Ring, civil construction is scheduled to be completed in the summer of 2006 with partial beneficial occupancy available already in FY 2005. This will allow the installation of the ring components to begin in the fall of 2005. The Main Ring components are in various states of fabrication and proceeding very well. All together, there is no apparent technical concern that may impact the schedule of commissioning the 50 GeV PS in FY 2008.

The Committee was informed that the beam simulation through the accelerator system still takes a long time. Since the sound operations of the accelerator as well as the understanding of the beam loss, which can be caused by an accumulation of small errors, rely heavily on the beam simulation, a way must be found to speed up the beam simulation program. The beam loss is particularly critical for the high intensity accelerator at J-PARC because it can activate the accelerator components, making maintenance more difficult, and can lead to radiation damage if it becomes severe. Good beam simulation and good instrumentation, as most modern accelerators have practiced, are also the key to speedy commissioning of the accelerator system.

Facilities for Experiments at the J-PARC 50 GeV Accelerator

The highest priority experiment for particle physics at J-PARC, of course, is the long baseline neutrino oscillation experiment "T2K". The committee is pleased to hear that the budget for the neutrino beam line was restored, almost enabling an on schedule start of the experiment.

Budgetary constraints will limit initially the scale of the experimental hall. Construction of only one primary beam line with one target station will be possible even with a maximum recycling of existing beam line components from the KEK 12 GeV facility. Taking this into an account, the planned strategy for other nuclear and particle physics experiments, presented for the Day 1 program is well justified. The final decision

regarding which beam line will be constructed has to be left to the future PAC and will be based upon final approval of the Day-1 experiment.

Neutrino Experiment at J-PARC

T2K, the subsequent generation neutrino oscillation experiment using J-PARC and SuperKamiokande is the most advanced proposal to date. Although they use the same technology as conventional beams, several improvements in the neutrino beam line components and the front detector complex are required. The goal of the T2K proposal, establishing the framework of 3 flavor-mixing and searching for CP violation in the lepton sector, offers the physics potential of long baseline neutrino experiments for the coming ten years. Here the main focus is the sensitivity limit to the small mixing angle θ_{13}. This proposal is of high priority in J-PARC since the experiment is in competition with the US NuMi and the French Double-Chooz. The committee notes that if the J-PARC construction and the T2K detector construction are performed on schedule then the first neutrino beam will arrive at the SuperKamiokande in 2009 as planned in the proposal.

Kaon Decay and Muon Experiment at J-PARC

The kaon program will be at the forefront of CP violation searches, both within the Standard Model framework and beyond it. The muon program also holds great promise. Building on the MECO effort at BNL, J-PARC studies of rare muon processes could extend the search for a muon number violation or study it in detail (if discovered by MECO). In addition, searches for a muon electric dipole moment (edm) (or deuteron edm), using storage ring technology, could nicely expand the J-PARC program. Having a world class set of particle physics experiments at J-PARC will also be important for its applied physics program. The particle physics experiments are very demanding and force human ingenuity to its limits, developing new technology and ideas. Those advancements should greatly help in any applied muon and neutron beam program at J-PARC.

Hadron Physics Experiments at J-PARC

The operation of J-PARC for hadron physics experiments remains several years in the future. Nonetheless, the hadron physics community responded enthusiastically to the Project Director's call for Letters of Intent in July 2002. Seven LOI's have been received, including those from internationally recognized spokespersons from around the world. The 50 GeV PS is clearly an attractive facility. One anticipates additional exciting proposals as the time for J-PARC operation approaches.

There are many subjects to be studied in the hadron physics at the J-PARC 50 GeV PS, ranging from hadron spectroscopy to dense hadronic matter and to the perturbative QCD. The recent discovery of the pentaquark and the ample data at RHIC on hot QCD matter let us anticipate new surprises in hadron physics in coming years, and the J-PARC 50

GeV PS should prepare for them. An appropriate selection of the experiments for Phase-1 will become a non-trivial but highly important issue.

Hypernuclear Physics at J-PARC

It is the ingenuity and creativity of Japanese physicists which has placed Japan at the forefront of strangeness nuclear physics for the past decade. This important activity should be and will certainly be continued in the 50 GeV PS right from the Day-1 experiments. New generation spectroscopy of the hypernuclei and the search for a new form of dense matter with strangeness are two of the key directions to be explored in the new facility.

As is the case with the hadron physics experiments, the operation of hypernuclear physics experiments at J-PARC is several years in the future, mid JFY 2008. Nonetheless, the strangeness physics community responded enthusiastically to the Project Director's call for Letters of Intent in July 2002. Six LOI's have been received, all of which appear to form a natural extension of the highly successful KEK 12 GeV PS program. One can anticipate new and even more exciting proposals as the time for operating J-PARC approaches.

Appendix 1

KEK-PS External Review 2004

June 7-8, 2004

List of Committee Members and Referees

(Titles and affiliations to be added)

The Committee Members

Satoshi Ozaki: chairman	BNL	ozaki@bnl.gov
Tetsuo Hatsuda:	U. Tokyo	hatsuda@phys.s.u-tokyo.ac.jp
Ken-ichi Hikasa:	Tohoku U.	hikasa@phys.tohoku.ac.jp
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Atsuto Suzuki:	Tohoku U.	neutrino@mx1.phys.tohoku.ac.jp
Yasushi Watanabe:	Tokyo Inst. of Technology	watanabe@hp.phys.titech.ac.jp

Referees

Benjamin Gibson:	LANL	bfgibson@lanl.gov
William Marciano:	BNL	marciano@bnl.gov
Stephen Myers:	CERN	stephen.myers@cern.ch

Appendix 2

KEK-PS External Review 2004

June 7-8, 2004
Seminar Hall, Building 4

Monday, June 7

8:30		Closed Session	
9:00	M. Kobayashi	Opening address	
9:05	K. Nakamura	Overview of KEK-PS Experiments	
9:40	K. Satoh	Overview of KEKPS Accelerator	
10:15		Coffee	
10:35	K. Nishikawa	E362	K2K Experiment
11:10	J. Imazato	E246	Search for T-Violation in Kμ3 Decay
		E470	Branching Ratio Measurement of $K^+ \rightarrow \pi^+\pi^0\gamma$
11:35	T. Inagaki	E391a	Study of $K_L \rightarrow \pi^0\nu\nu$-bar
12:00	J. Imazato	Facilities for Experiment at the J-PARC 50 GeV Accelerator	
		Lunch	
13:50	T. Kobayashi	Neutrino Experiment at J-PARC	
14:20	T. Komatsubara	Kaon Decay Experiments at J-PARC	
14:50	K. Nakazawa	E373	Double Strange Nuclei by Emulsion Hybrid Method
		E522	Search for H-dibaryon Resonance via $^{12}C(K^-,K^+\Lambda\Lambda)$ and Study of Ξ^-N interactions
15:15		Coffee Break	
15:35	S. Okada	E462	Exclusive Measurement of the Non-Mesonic Weak Decay of $^{5}_{\Lambda}He$
		E508	Coincident Measurement of the Weal Decay of $^{12}_{\Lambda}C$
16:00	H. Noumi	E438	Study of Σ-Nucleus Potential by the (π^-, K^+) Reaction
		E521	Production of Neutron-Rich Λ-Hyper-nuclei by the (π^-, K^+) Double-Charge Exchange Reaction
16:25	H. Tamura	E419	Measurement of B(E2) in $^{7}_{\Lambda}Li$
		E509	γ-ray Spectroscopy of Hyperfragments using Stopped K Method
		E518	γ-ray Spectroscopy of $^{11}_{\Lambda}B$
16:50	M. Ieiri	Test Experiments	
17:15		Closed Session	
19:00		Reception	

Tuesday, June 8

8:30	S. Nagamiya	J-PARC Project Overview	
9:00	Y. Yamazaki	J-PARC Accelerator Overview	
9:30	K. Nakai	E452	Spin-dependent Interaction in Σ^+p Scattering
9:55		Coffee Break	
10:15	M. Iwasaki	E471	Search for Deeply Bound Kaonic Nuclear State
10:40	H. En'yo	E325	Study of Chiral Property of Dense Nuclear Matter through Measurement of Meson Mass Modification in Medium
11:05	T. Nagae	Hypernuclear Physics at J-PARC	
11:35	H. En'yo	Hadron Physics Experiments at J-PARC	
		Lunch	
14:00		Closed Session	

Appendix 3

KEK
HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION
1-1 OHO, TSUKUBA-SHI
IBARAKI-KEN, 305-0801 JAPAN
http://www.kek.jp/

April 15, 2004

Dr. Satoshi Ozaki
Special Assistant to the Laboratory Director for
Accelerator Projects
Brookhaven National Laboratory
PO Box 5000
Upton NY 11973-5000
USA

Dear Dr. Ozaki,

We are delighted that you have accepted our invitation to chair the External Review Committee of experiments at the KEK 12-GeV PS (Proton Synchrotron) to be held at High Energy Accelerator Research Organization (KEK) in Tsukuba, Japan, on June 7 - 8, 2004. KEK will support your air fare and local expenses to visit KEK to attend the committee meeting. We will select the committee members in consultation with you.

Part of the purposes of the committee is to review and evaluate (i) the operation and performance of the 12-GeV PS, (ii) scientific achievements of the completed experiments, and (iii) status of the running experiments, over the period from the last external review in December 2000 through the present.

As you know, KEK is now constructing J-PARC (Japan Proton Accelerator Research Complex) at Tokai in collaboration with JAERI (Japan Atomic Energy Research Institute). As the construction proceeds, KEK has to consider the shutdown and decommissioning of the 12-GeV PS in near future, and the current scientific activities at the 12-GeV PS must be moved to the high-intensity 50-GeV Proton Synchrotron at J-PARC. In view of this, we would also like to ask the committee to discuss and review the 12-GeV PS shutdown scenario and the plan to move the scientific activities from the 12-GeV PS to the J-PARC 50-GeV PS.

Documents necessary for review, such as the summary of experimental programs and copies of selected publications, will be sent to you and committee members at least two weeks before the meeting.

Thank you again for accepting our invitation. I am looking forward to seeing you in June at KEK.

Sincerely,

Y. Totsuka

Yoji Totsuka, Director General
KEK

Appendix 4

Statistics on the Number of Experiments, Publications, and Doctorates

In Table 1, the number of experiments are summarized for each category of (High Energy Physics, Nuclear Physics, and Chemistry), and for each period (first period, second period, and third period). Hadron physics experiments in the first and second periods are classified as High Energy Physics, because mostly those people belonging to high-energy physics community conducted these experiments, while in the third period hadron physics experiments are classified as Nuclear Physics because mostly those people belonging to the nuclear physics community conducted these experiments.

In the second set of four tables (Table 2), the number of Doctoral degrees, physics papers, and technical papers from High Energy Physics, Nuclear Physics, and Chemistry are classified. Then, each of the categories is further divided into three periods.

In Table 3, the number of Doctoral degrees, physics papers, and technical papers from each of the experiments, reviewed by the Committee, are presented.

Table 1

Number of Experiments by Category

	High Energy Physics	Nuclear Physics	Chemistry
Total	36	72	11
First period	25	13	3
Second period	7	42	5
Third period	4	16	3

Table 2

Doctoral Degrees, Physics and Technical Papers Produced in the KEK PS Program

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	135	279	114
High Energy Physics	72	109	63
Nuclear Physics	60	149	48
Chemistry	3	21	3

High Energy Physics

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	72	109	63
First period	43	74	45
Second period	8	20	6
Third period	21	15	12

Nuclear Physics

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	60	149	48
First period	11	28	4
Second period	35	97	35
Third period	14	23	9

Chemistry

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Total	3	21	3
First period	1	3	0
Second period	1	8	3
Third period	1	10	0

Table 3

Experiments Reviewed by this Committee

	Doctoral Degrees	Physics Papers published in refereed Journal	Technical Papers
Neutrino Physics			
E362	8	4	3
K Decay Experiment			
E246/E470	12	8	8
E391a	1	3	1
Hadron Physics and Neutron Physics (Except Hypernuclear Physics)			
E325	4	2	2
E443	2	7	3
Hypernuclear Physics			
E373	2	4	2
E419	1	4	0
E438	1	1	0
E452	3	2	1
E462/E508	1	2	0
E471	0	1	1
E518	0	0	0
E521	0	0	0
E522	0	0	0
Kaonic Hydrogen X-Ray Experiment			
E546	1	10	0