KEK/J-PARC-PAC 2019-16
Aug. 12, 2019

**J-PARC Program Advisory Committee**
**for the Nuclear and Particle Physics Experiments**
**at the J-PARC Main Ring**

Minutes of the 28th meeting held
16(Tue.)-18(Thu.) July 2019

**OPEN SESSION**:

1. Welcome and J-PARC Center Report: N. Saito (J-PARC/KEK)
2. J-PARC Accelerator Status & Plan: F. Naito (J-PARC/KEK)
3. Mandate to the committee: K. Tokushuku (KEK)
4. T2K(E11)/T2K-II(E65) Status and Plan: F. Sanchez (Geneva)
5. T2K(E11)/T2K-II(E65) Status and Plan 2: Y.Nakajima (ICRR-Tokyo)
6. E56 (Sterile Neutrino Search): T. Maruyama (J-PARC/KEK)
7. E14 (KOTO): K. Shiomi (J-PARC/KEK)
8. E21(COMET): Y. Kuno (Osaka)
9. E34(g-2/EDM): T. Mibe (J-PARC/KEK)
10. E61(NuPRISM/TITUS): M.Ishitsuka (TUS)
11. FIFC Report : S. Uno (KEK)
12. E70 (Spectroscopic Study of Ξ-hypernucleus, $^{12}_{\Xi}$Be via the $^{12}$C($K^-$, $K^+$) Reaction): T. Nagae (Kyoto)
13. Hadron Hall & SX Beam Status, Schedule and Target R&D Plan: H. Takahashi (J-PARC/KEK)
14. E16 (Measurement of Spectral Change of Vector Mesons in Nuclei): S. Yokkaichi (RIKEN)
15. E57 (Strong Interaction Induced Shift and Width of Kaonic Deuterium): J. Zmeskal (SMI-ÖAW)
16. E40 (Measurement of the Cross Sections of Σp Scattering): K. Miwa (Tohoku)
17. E03 (Measurement of X-ray from $\Xi^-$ Atom): T.Yamamoto (JAEA)

18. E42 (H dibaryon): J.K. Ahn (Korea)

19. E72 (Search for a Narrow $\Lambda^*$ Resonance using the $p(K^-, \Lambda)\eta$ Reaction with the hypTPC Detector): K. Tanida (JAEA)

20. P74 (Direct Measurement of the ${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}H$ Lifetimes using the ${}^{3,4}He(\pi^-,K^0){}^{3,4}_{\Lambda}H$): A. Feliciello (INFN Torino)

21. P73 (${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}H$ Mesonic Weak Decay Lifetime Measurement with ${}^{3,4}He(K^-,\pi^0){}^{3,4}_{\Lambda}H$ Reaction): F. Sakuma (RIKEN)

22. K1.8/K1.8BR Request Summary & K1.8 Floor Plan (mid-term): M. Ukai (J-PARC/KEK)

23. Beam Time Schedule in 2018-2021: T. Kobayashi (J-PARC/KEK)

**CLOSED SESSION**:

Present: I. Adachi(KEK), N. Aoi (RCNP-Osaka), M. Blanke (KIT), D. Harris (FNAL), Y. Itow (Nagoya), F. Le Diberder (CNS/IP2N3/LAL), A. Ohnishi (YITP-Kyoto), S. Kettell (BNL), R. Kitano (KEK), M. Kuze (Tokyo Inst. of Tech.), J. Pochodzalla (Mainz), H. Tamura (Tohoku), A. W. Thomas (Adelaide), K. B. Luk (Berkley), R. Yoshida (Chair, JLab), K. Tokushuku (KEK-IPNS Director), T. Kobayashi (KEK-IPNS Deputy Director) and N. Saito (J-PARC Director)

## 1. PROCEDURAL REPORT

The minutes of the 27th J-PARC-PAC meeting (KEK/J-PARC-PAC 2019-10) were approved.

## 2. LABORATORY REPORT

### 2-1 Welcome and J-PARC Center Report (Naohito SAITO, J-PARC Center Director)

The J-PARC Director, Naohito Saito, welcomed the PAC members. As an introduction to J-PARC, he presented an overview of the accelerator and the experimental facilities, as well as the science at J-PARC. He mentioned the operational status of J-PARC. The Main Ring(MR) operation was suspended because of a failure of a magnet in 3-50 beam-transport line. Saito also mentioned the MR power upgrade plan to 1.3MW, which will be realized by (1) rapid cycle operation of 1.16 sec with new MR power supplies, high gradient RF cavities, improved collimator system, and rapid cycle pulse magnets for

injection and extraction, and (2) more protons per pulse with improved RF power, more RF systems, and feedback system stabilizing the beam. Saito reported a successful beam operation with 1 MW equivalent power for Material and Life Science Facility (MLF) for 10.5 hours straight. Saito explained that the high-power beam operation is beneficial for the MLF projects such as industrial and fundamental physics users with neutron and muon sources. He mentioned there are also particle physics projects at MLF: sterile neutrino search JSNS2 (E56), precise measurement of muon g-2/EDM (E34) and neutron fundamental physics, e.g. measurements of its life time and EDM.

Saito explained a recent action, status and plan at KEK in regard to J-PARC projects. The J-PARC upgrade for Hyper-Kamiokande has been the highest priority in the KEK Project Implementation Plan. KEK and J-PARC submitted J-PARC near future projects to Japan Science Council Master Plan 2020. These are MR and neutrino facility upgrades to realize 1.3MW beam power operation, Hadron hall extension, COMET Phase-II facility construction, muon g-2/EDM facility construction, construction of MLF second target station, and operation of J-PARC with sufficiently available beam time for users. He explained that there were strong supportive recommendations to J-PARC projects from J-PARC International Advisory Committee (IAC) held on March 4,5 in 2019, and 1st KEK Scientific Advisory Committee (SAC) held on March 23,24 in 2019. He also mentioned the budget request from KEK to MEXT for JFY2020 which covers operation for 6.5 cycles, power supply upgrade for higher repetition rate, and as KEK responsible part of Hyper-Kamiokande project, beam power upgrade to 1.3MW and facility for the intermediated detector to be used in the future Tokai-to-Hyper-Kamiokande experiment.

Saito explained a plan of MR operation in the coming years. He explained that the decision to complete upgrade of MR power supplies in JFY 2021 is unchanged. He explained the plan in these three years; he mentioned that there will be no beam in JFY2021 because of installation of new MR power supplies.

Saito reported a recent growing collaboration with academia and industry. He also mentioned various activities such as international collaborations to study radiation damage. He summarized his talk after introducing J-PARC symposium and ceremony of the 10th anniversary of J-PARC scheduled in September 2019 .

**2-2 J-PARC Accelerator Status (Fujio Naito, J-PARC/KEK)**

Fujio Naito reported the status of J-PARC accelerator, mainly about the Main Ring (MR). He introduced two operation modes in MR; fast extraction mode (FX) and slow extraction mode (SX). In FX mode, protons are extracted to the neutrino experimental facility in a single turn. In SX mode, protons are extracted to the hadron experimental facility during 2 seconds continuously after de-bunching the beam. He reported the beam power history of MR. The beam power of 500 kW and 50 kW was successfully achieved for FX and SX modes, respectively. He mentioned that the MR operation scheduled in 2019 January-June period was suspended because of the trouble of B15D, which is a magnet in the 3-50 beam transport (3-50BT) line.

Naito reported the trouble of the B15D magnet in detail. A circumstantial evidence was found in a layer short-circuit caused by water leakage from a joint of the hollow conductor in the B15D coil. He also reported that an attempt is in progress to fabricate the coil using the conductor without any joints as a countermeasure. The coil production and assembly in the tunnel is scheduled until the end of September 2019. The B15D magnet will be ready before next beam operation. There are two more similar bending magnets in the 3-50BT although both of them are confirmed to have no problem at the moment. He explained a plan to replace them gradually in future.

Naito showed a summary of beam availability. The beam availability of the user operation in JFY2018 was 94.1%, 86.0% and 73.7% for MLF, Neutrino and Hadron experimental facility, respectively. For April 1st to May 1st 2019, it was 94.8% and 79.8% for MLF and Hadron experimental facility, respectively, while there was no beam operation for Neutrino experimental facility.

Naito reported the status of new MR magnet power supply system which is a major upgrade component to realize the rapid cycle operation necessary for beam power upgrade. Installation of new power supplies is scheduled in JFY2021. The first new power supply for a series of bending magnets was already examined with actual load of sixteen bending magnets in the MR tunnel. The second and third power supplies for bending magnets are under installation and assembling. In an examination test with actual load, 2-hours continuous operation was successfully achieved with 1.32 sec. repetition for the FX mode. Moreover, 11-hours continuous operation with 4.16 sec. repetition for the SX mode was successfully achieved with one-order better ripple noise compared to the current power supply system.

Naito reported an operation schedule and study plan for the period from October 2019 to March 2020. He showed a plan to start the operation in FX mode in November 2019. The accelerator team aims for user operation with beam power of 480 to 500 kW after machine studies and a vacuum scrubbing necessary to reduce outgassing from beam profile monitors newly installed in the MR tunnel. He also explained a plan for SX mode operation to reach 70kW beam power including a possible mitigation to suppress the instability during de-bunching of the beam.

**2-3 Mandate to the Committee (Katsuo TOKUSHUKU, KEK IPNS director)**

The director of the Institute of Particle and Nuclear Studies (IPNS), Katsuo Tokushuku, welcomed the PAC members.

Tokushuku reminded the committee of the general mandates and the approval process for proposals. Then reported the progress after the previous meeting and isses to be discussed in this meeting.

The stage-2 approval was given to the experiment E71, following the PAC's recommendation. No new proposal was received for this meeting and two Letters of Intent were received, as listed at the end of the minutes.

He reminded the committee that decision for the P73 and P74, both of which are for hyper-triton lifetime measurement is pending since the last PAC meeting. The E70 group submitted a revised TDR, which was reviewed by FIFC, challenging for the stage-2 approval. The E72 group would present their run plan following the request form the committee, asking for the stage-2 approval.

Tokushuku explained the J-PARC MR mid-term plan for the power upgrade has not changed. The long shutdown was scheduled in 2021 to install the new power supply system for MR magnets, to be ready for the high power operation in FY2022.

As explained in the last PAC, there are only 3-cycles in FY2019 because of the tight budget condition. These runs were originally assigned in April-June: one cycle for SX (hadron) followed by two cycles of the FX (neutrino) operation. Because of the water leak in a magnet in the transport line, as explained in the accelerator talk, the operation stopped in the middle of the SX run, remaining 14 days of beam time for the experiments in the hadron hall. The planned beam time will be re-allocated in the Nov-Mar period. It is decided that the MR operation will start with the FX mode and beams to the hadron hall will be delivered after the installation and commissioning of the new 80kW target and high-p beam line. The allocated beam time for the neutrino experiment is 61.5 days so that the FX operation will finish in the middle of February. After the commissioning of the new target and high-p beam line, the remaining beam time for the hadron experiment will be allocated.

KEK has recently submitted the FY2020 budget request to the MEXT, which include the budget for 6.5-cycle operation and an extra budget fort the MR power upgrade. The first priority of the labs is to complete the MR upgrade within FY2021. The decision by the government is expected in December.

He requested the committee to provide provisional recommendation on the run plan before the long shutdown expected in FY2022, considering the priority that which experiments to be completed. In the next PAC meeting when the FY2021 budget is known, the proposed schedule based on the recommendation will be shown and the committee will be asked to assess.

After several clarifications, the committee took note of the mandates. The tentative recommendation of the beam allocation for FY2021 is written in a separate section of the minutes.

**2-4 FIFC Report (Shoji UNO, IPNS, KEK)**

Shoji Uno presented a report from the Facilities Impact and Finance Committee (FIFC). He reported discussion at the 11$^{th}$ meeting held on June 4$^{th}$, 2019 at the Tsukuba campus. FIFC reviewed one experiment (E70) toward the stage-2 approval.

In the previous FIFC review meeting in December 2018, the FIFC had raised several questions and recommended to revise the TDR in order to provide enough information to judge the feasibility of the E70 experiment.

The E70 group answered the following four major questions,

1) Explain why the spectrometer for E70 (S-2S) have much better resolution than the previous one,
2) Show the schedule and goal of the R&D of the active fiber target,
3) Explain the DAQ/trigger system, and
4) Show the overall construction schedule.

Concerning the resolution of the spectrometer, an explanation based on the 1st order transfer matrix has been made. In addition, the $K^-$ beam momentum calibration method to achieve better resolution was shown. The active fiber target is an important sub-detector to improve the missing mass resolution. Expected performance and fabrication plan has been presented. E70 DAQ system is similar to that of E40, and there should be no issue.

A list of status and schedule of construction, beam test, and installation of each element of experimental apparatus has been shown in the revised TDR. The E70 group assumes the machine time after production target upgrade to 85kW, which seems well fitted to the schedule of J-PARC accelerator operation. In conclusion, questions raised in the previous FIFC review meeting have been reasonably answered, and the FIFC recognizes the technical feasibility of the E70 experiment, provided that everything goes well along the schedule shown by the group.

**2-6 Hadron Hall & SX Beam Status and Target R&D Plan (Hitoshi Takahashi, J-PARC/KEK)**

Hitoshi Takahashi presented the status of the Hadron Experimental Facility. The report included the status of recent beam time, the upgrade plan of the production target (T1), and the construction and commissioning plan of the high-p/COMET beam lines.

Takahashi showed the integrated beam power during the beam time from February to April, 2019. Because of the magnet trouble in the 3-50BT line, only 70% of the planned user beam time was available. The pilot run of the E57 experiment was performed, while the data taking of the E40 experiment could not be completed. This run was the first beam time after the installation of the beam-splitting magnet (Lambertson magnet) in the switching yard for the high-p beam line. The hadron group established a new beam optics to make the beam pass through the field-free hole in the magnet, which was the first step in high-p beamline commissioning.

Takahashi presented an upgrade plan for the T1 target. The next target will be an indirectly water-cooled type one capable of accepting the primary beam power of 95 kW in maximum for 5.2-sec. spill cycle. It is now in the final assembly stage and is planned to be installed in this Fall. Furthermore, another type of target is being developed for the

future use. It is a rotating "euro-coin" target composed of a nickel disk with a gold or platinum edge, and is directly cooled by water or He gas.

Construction work for the high-p/COMET beamlines is in progress. Takahashi showed several photographs of beamlines, including installed magnets and shielding in the branching section and high-p experimental area. He presented the construction schedule of the beamlines. The high-p beam is expected to be available in February, 2020. He introduced also a beam commissioning plan.

## 3. EVALUATIONS OF THE PROPOSALS AND STATUS OF THE ONGOING EXPERIMENTS

**E11/E65 (T2K and T2K-II)**

E11(T2K) is continuing to study neutrino oscillation with the ND280 near detector at J-PARC and the Super-K far detector. Experiment E65(T2K II) with Stage-1 status is the second phase of T2K with upgrades to ND280. The latest progress, plan and requests were presented in this PAC meeting.

The size of the collaboration has been growing slowly again since September 2017, and now totals ~500 members with CERN recently joining. New international co-spokesperson, and ND280 Technical Coordinator have come on board.

There have been many analysis and publication activities. Preliminary results based on data collected with $14.9 \times 10^{20}$ POT (neutrino mode) and $16.3 \times 10^{20}$ POT (anti-neutrino mode) through March 2018 were shown. T2K has obtained $3\sigma$ intervals in $\delta_{CP}$ for both neutrino mass hierarchies for the first time. They presented several measurements on cross-section of different types of neutrino interaction and the search for a light sterile neutrino. These findings are either published or in the pipeline for publication.

An analysis plan was presented. It included improvements of the oscillation analysis by reconstructing more events using new techniques, reduction of systematic errors by refining the flux modeling with better use of the replica target data, and measuring the energy dependence of the total interaction cross section by utilizing sub-systems of ND280 located at different off-axis angles. Joint oscillation analysis with NOvA and Super-K are being pursued with the goal of providing better results.

R&D of the new detector elements (SFGD, high-angle TPCs, and ToF) has been proceeding well. Also the project status of ND280 upgrade was reported as a follow-up of the previous PAC discussion. Now 70% of the funding is secured and no serious impact is foreseen for the construction schedule.

The ongoing effort of realizing a major upgrade of the Super-K detector was reported. Refurbishment consisting of fixing water leaks and replacing bad PMTs and calibration of the Super-K detector have been completed. Accounting for thermal effects the water level in the detector is steady. In addition, the detector is operating stably with water

transparency as good as before. The refurbished Super-K detector is ready to accept the neutrino beam from J-PARC.

Production of purified Gd-sulfate and preparation of a new water purification system for retaining the Gd-ions in water are ongoing. These two tasks are expected to be completed by the end of 2019, followed by recirculating pure water in the Super-K detector with the Gd-water system. After dissolving 13-tons of Gd-sulfate into the pure water to achieve a 0.02% Gd-sulfate concentration in about three months, commissioning of the SK-Gd detector will take place. The SK-Gd detector should be ready for the T2K beam by the beginning of October 2020.

Even with only a 0.02% Gd-sulfate concentration (the final goal is 0.2%), the ability to identify neutrons in the SK-Gd phase will be significantly improved. This will yield better knowledge of the characteristics of the final-state neutrons in neutrino interactions such as neutron multiplicity and directional correlation, which currently have large uncertainties. The improved information is useful for oscillation analysis and searches for supernova relic neutrinos.

T2K is scheduled to receive 62 days of neutrino beam in FY2019. However, due to the magnet problem in the MR, T2K has no run time so far. It is planned to receive 61.5 days of beam in October 2019-February 2020 once the bending magnet in the transfer line is replaced.

To stay competitive with NOvA, T2K has requested $9.2\times10^{20}$ POT, which translates to ~120 days of beam time, in FY2020. With this POT, T2K expects to obtain about 100 events with neutrons in the final state. This gives a 10% stat error which is a factor of two improvement on current knowledge. If the allocated run time is limited by budget, ~52 days of beam would still provide important commissioning data for checking the performance of the SK-Gd detector for the T2K physics.

The PAC is pleased to see that T2K is maintaining momentum and continues to attract new members. The committee understands that a 52-day running period for checking the SK-Gd detector is important and that any additional running will improve results on CP violation. We are happy to see the efforts to improve cross-section modeling; we recommend that T2K engage more with the NINJA collaboration to make sure that NINJA measurements are effective in improving the understanding of neutrino-nuclear cross sections.

The PAC has received the report from the beamline review and we are happy to see the reviewers' conclusion that no serious unresolved technical problems remain. The PAC looks forward to receiving the review report on the ND280 upgrade; it is important that the ND280 schedule matches those of the MR and neutrino beamline.

## E14 (KOTO)

The E14 (KOTO) experiment searches for the CP-violating rare decay $K_L \rightarrow \pi^0 \nu \bar{\nu}$ at the J-PARC neutral beam line. Using the 2015 data, KOTO published a branching ratio upper limit of $3\times10^{-9}$ in 2019, which is two orders of magnitude above the SM prediction but a factor of 10 improvement over the previous KEK experiment. Below the indirect Grossman-Nir (G-N) bound of $1.5\times10^{-9}$, inferred from the corresponding charged kaon decay, there is room for new physics to contribute to this decay.

KOTO reported the status of the 2016-2018 data analysis. Features of this data set include additional thickness of Inner Barrel veto and new FPGA-based trigger/DAQ hardware. Also, a special run to collect a neutron-rich control sample was taken. New analysis techniques using deep learning on the pattern of CsI calorimeter hits and Fourier transformation of the CsI calorimeter waveforms largely reduce the hadron cluster background (0.07 events, compared to 0.24 in 2015). The single-event sensitivity (SES) of this data set is expected to be $7\text{-}8\times10^{-10}$. The group is finalizing the analysis with a plan to present results at Kaon2019 in September.

The 2019 data set was taken after completing detector upgrades in 2018. The CsI calorimeter was equipped with additional MPPC readout from the front face so that timing measurements can further discriminate between gamma- and neutron-generated signals. A 97% neutron reduction with 90% signal efficiency has been achieved. The expected radiation damage to the MPPCs seems acceptable. The new downstream charged veto counter inside the high vacuum beam pipe effectively reduces the backgrounds in the low Pt region. This data set has an estimated SES of $8\times10^{-10}$, bringing the total data set SES to $3\times10^{-10}$, well below the G-N bound.

A new iron wall is planned for installation in December 2019 to reduce the accidental background. In 2020 before the long shutdown in 2021, E14 requests at least 40 days of running time at 70 kW beam power to bring the SES of their total data set to $2\times10^{-10}$, reaching within an order of magnitude of the SM prediction.
The PAC congratulates KOTO on good progress on the detector upgrade and data analysis and encourages finalization of 2016-18 analysis results this fall. The PAC recognizes the importance of the target upgrade for 70kW SX beam power and encourages the lab to ensure enough MR study time to realize it. The PAC endorses the beam time request by E14.

## E21 (COMET)

The E21 (COMET) collaboration aims to observe charged lepton flavor violation (CLFV) through the μ to e transition in muonic Aluminum atoms, thereby allowing a probe of very high-energy scales for possible New Physics processes.

The focus of the status report presented to PAC was on Phase I of the program for which a TDR was submitted for publication in early 2019. The comments from the TDR referees are very positive and are being addressed.

A detailed status report was presented covering Trigger, DAQ, software, and analysis, in response to January PAC requests. The Triggers for the cylindrical drift chamber (CyDet)

and the straw tube tracker and calorimeter (StrEcal) are well advanced and tests started successfully at KEK, in February 2019. The DAQ system uses established technology that can handle a data flow of up to 1 GB/s, much larger than that originally foreseen (~40 MB/s). Tracking Software for CyDet and StrEcal follows a multi-prong approach involving a variety of algorithms, meant for crosschecks and comparison: preliminary performance results are encouraging. The offline software framework (ICEDUST, for Integrated Comet Experimental Data User Software Toolkit) is based on the software framework of ND280 (T2K). A sketch of the (blind) physics analysis was presented, either cut & count based, or likelihood based. For the latter the means to obtain the p.d.f. were briefly addressed.

In February 2019, the "extinction ratio issue" presented at July 2018 PAC meeting, was investigated, understood, and solved with a shift of the kicker timing, at the FX abort line. The PAC encourages the COMET group to perform the test in SX mode, at their earliest convenience.

Although the funding situation is deemed satisfactory, the evaluation of the needs for computing resources just started. To cover these needs, once well defined, care should be taken to ensure long term access to computing centers, for instance through computing MoU's.

A rough schedule was presented, with a commissioning starting in FY2023 that assumes that the COMET beam line is only completed by the end of FY2021. However, the shutdown foreseen for FY2021 may allow an earlier completion of the C-line by several months.

In light of the fact that the presentation was only on Phase I, and in light of the international competition which aims to start physics data-taking in early 2023, we recommend that Phase I of the experiment be ready to start by early 2023 at the latest. We recommend that the lab management and the collaboration produce a more detailed schedule to ensure a timely start.

Concerning Phase II, sensitivity studies, refinement and optimization are still underway and could not be presented at this PAC meeting.

Overall, the PAC congratulates the COMET collaboration for its steady progresses and achievements, notably for solving the "extinction ratio issue".

## E34 (g-2/EDM)

E34 presented responses to the previous PAC recommendations, including a more detailed schedule presentation. The experiment presented recent progress in R&D for the experiment. Laser ablated silica aerogels were installed in the U-line and initial tests confirm ionization of muonium produced in the aerogels. An RF coupler for the IH-LINAC and beam instrumentation were developed. A spiral injection test experiment was performed with an electron beam and seismic studies were made for the storage ring magnet. Silicon detector development has proceeded. The TDR was published in PTEP (May 2019), muon beamline commissioning with H- published in NIM**A937**:164. E34

reported that stage-2 approval was granted by the KEK-IMSS director and that the experiment was endorsed by the KEK Scientific Advisory Committee (SAC). E34 reported that a task force on the H-line building was appointed under the J-PARC center in April 2019.

The committee appreciated seeing the initial draft construction schedule, but would like to see the critical R&D milestones integrated into the schedule. The committee expects that this schedule is rather aggressive and expects that further negotiation with KEK management and budget pressure may lead to a somewhat less aggressive version.

The committee understands that E34 is considered to be the number three priority after the Main Ring power supply upgrade for J-PARC and the High Luminosity LHC upgrade. We understand that E34 is hoping to receive significant funding in FY2020. We look forward to hearing a more concrete integrated plans for schedule and budget in the coming meetings.

The committee is encouraged to see progress with the IMSS and KEK SAC. The committee is encouraged to see progress towards the H-line building.

**E61 (NuPRISM/TITUS)**

E61 proposes to build a movable kiloton water Cherenkov detector (IWCD) to be placed at a baseline O(km) for measuring the neutrino energy spectrum at various off-axis positions relative to the T2K and Hyper-K beam directions. The goal is to utilize these spectra to reduce systematic uncertainties related to the neutrino beam, interaction cross-section, and nuclear effects for oscillation measurements.

The PAC was informed that the detector concept of E61 has been adopted by the Hyper-K proto-collaboration. We heard about the marriage of NuPRISM and TITUS for constructing IWCD. E61 continues discussions with Hyper-K leaders on integrating into the Near Detector group of the Hyper-K proto-collaboration.

E61 has made good progress in developing the Multi-PMT sensor. Beam test of a water Cherenkov detector with 132 Multi-PMT modules by the Hyper-K proto-collaboration is planned at CERN. This replaced the proposal for the Phase-0 prototype at J-PARC.

E61 has explored four potential sites for the IWCD. E61 has identified a site for further exploration. The PAC did not find the justification for placing the IWCD on the SK direction rather than along the HK direction or on axis to be compelling. Our understanding is that a new review committee will be in place to review the construction phase of IWCD, and we encourage E61 to refine the scientific and placement arguments in preparation for that committee.

**E56 (Sterile Neutrino Search)**

The JSNS$^2$ experiment (E56) plans to search for eV scale sterile neutrinos with an improved stopped pion source compared to LSND.

JSNS$^2$ realized the risk of a failure to obtain PMTs from Double Chooz in time for a planned June 2019 run. This situation was mitigated with the development of a new plan to instrument the detector with fewer PMTs, scavenging spares from RENO and other experiments along with purchase of ~40 new PMTs with delivery expected in ~October. This new plan calls for PMT installation to complete by November, followed by filling and start of the physics run by the end of November. Simulations indicate that running with 96 10-inch PMTs as compared to the 192 8-inch PMTs in the TDR (28% less photocathode coverage) has a small impact on vertex and energy resolution. Missing from the presentation, were a detailed discussion of performance of the replacement PMTs, the plan for deployment of the PMTs, and a detailed schedule for delivery, characterization and installation of the PMTs.

JSNS$^2$ provided status updates on all detector systems. A test-installation of the acrylic vessel was performed in February. Liquid scintillator (LS) from RENO is stored at Kawasaki and shows no degradation in transparency or light yield over several months. Gd-LS was shipped from Daya Bay in July. No data on optical properties of the Gd-LS was presented. The PMT characterization system started operation in Tokai and a plot of the single photoelectron peak for some PMT(s) was shown. Electronics, data quality monitoring and slow control software have been successfully tested. University of Michigan plans electronics upgrades in late 2019. The LED calibration system has been shipped from the UK in March. No update on filling hardware or procedures was presented. It is expected that fire safety registration in the MLF will be achieved by October. Regular safety meetings are being held.

The PAC has some concern over the likelihood of achieving the very aggressive schedule shown for a physics run in November. The JSNS$^2$ check of LSND is important and unique, and therefore the SBN experiment timeline should not be the primary driver of the JSNS$^2$ schedule. Needless to say, the group has to be very cautious that a rushed schedule does not compromise safety or the overall physics goal of the experiment. The PAC recommends a timely assessment of the quality of the PMTs, plans for their characterization and development of acceptable performance criteria. The PAC would like to better understand the decision-making process that led to the choice to instrument the detector with half of the original number of PMTs: is a desire to meet very aggressive schedules leading to unoptimized choices in detector construction? Are the planned PMTs the best choice for the experiment? The PAC recommends analysis of the Gd-LS optical properties and performance and review of progress on filling equipment and procedures.

**E36 (Lepton Universality)**

E36's (Lepton Universality) main goal is to measure the ratio of branching ratios $Br(K^+ \rightarrow e^+ \nu_e)$ over $Br(K^+ \rightarrow \mu^+ \nu_\mu)$. The collaboration aims to match the current measurement precision (but with different systematics), which shows agreement with the Standard Model prediction at the 0.4% level. In light of the deviations from the Standard Model recently observed in lepton universality violating B decays, a timely completion of the analysis and publication of the results are extremely important.

During the PAC meeting the collaboration presented their results on the background (structure dependent) process $K^+ \rightarrow e^+ \nu_e \gamma$. This has turned out to require longer analysis than previously assumed; thus a full status report on the final analysis, and its corresponding publication plan, required after at PAC 26, were not provided. The PAC reiterates its concern about the slow progress towards completion of the analysis.

**E70 (Spectroscopic Study of Ξ-hypernucleus)**

The purpose of the E70 experiment is to study $\Xi^-$-hypernucleus ${}^{12}_{\Xi}Be$ through a missing mass study of the ${}^{12}C(K^-, K^+)$ reaction. The binding energies of the states in this nucleus provide information on the real part of the potential. This measurement complements studies of $\Xi^-$ hyperatoms, which probe – at least in heavy nuclei – the more neutron rich nuclear periphery of the nuclear wave function, and studies of two-body correlations in heavy ion reactions which reflect the $\Xi^-$-p two-body interaction. This information is important in understanding the generalized nuclear force models extended to the flavor SU(3) and also to reveal the roles of hyperons in the neutron stars.

E70 aims at a missing mass resolution of better than 2 MeV (FWHM). This is significantly better compared to the predecessor E05 where a resolution of about 5 MeV was achieved. An improved beam spectrometer with an additional water Cherenkov detector and an active scintillation fiber target are essential components of the improved setup. Questions raised previously by the FIFC concerning these new detectors were addressed in an updated TDR. The FIFC evaluated this document and concluded that the questions raised in the previous FIFC review meeting have been reasonably answered, and the FIFC recognizes the technical feasibility of E70.

The committee agrees with this assessment. The PAC does not find any problems and concerns to perform the experiment. It therefore recommends stage-2 approval. The PAC suggests, that the collaboration clarifies the responsibilities and carefully monitors the progress in the setting up stage in order to assure readiness after the long shut down in FY2021.

**E16 (Spectral Change of Vector Mesons in Nuclei)**

The aim of the E16 experiment is to carry out a systematic study of the spectral change of vector mesons, especially the φ-meson, in nuclei by measuring the $e^+e^-$ invariant mass distribution. It is especially important that this measurement will determine the spectrum as a function of the velocity of the meson and hence, to some extent, as a function of the time spent in the nucleus. The KEK E325 experiment observed the spectral change, and some model calculations predict the spectral change for vector mesons in hot and dense matter. Confirmation of such an effect is one of the important measurements in hot/dense QCD matter.

E16 reported the progress of preparation in this PAC meeting. The detector configuration of 6(SSD)+6(GTR)+4(HBD)+6(LG) will be ready in Jan. 2020, and the configuration of 6+8+6+6 is secured and will be ready in autumn 2020. The field mapping is being completed. The Taiwan collaborators joined E16, and several students have also joined E16. Collaboration with CBM has started, and a part of sensor & FEM for Run-1 will be provided by CBM. E16 requests the Run-0 beam time of 20 shifts (6.6 days) in Feb.-Mar. 2020 with the 6+6+4+6 configuration, and another 20 shifts in autumn 2020 with the 6+8+6+6 configuration.

The PAC recommends to allocate the Run-0 beam time as requested. At the same time, the PAC finds that the construction schedule is tight, and still encourages the E16 group to increase human resources. E16 is invited to deliver a report of the updated status in the next PAC meeting.

**E57 (SDD)**

E57 aims at the first measurement of X-rays from K-d atoms. A precision measurement of the shift and width of the 1s state by the strong interaction will provide unique information on the kaon-neutron interaction at threshold. Since K-p atomic X-rays were previously measured by some of the E57 collaborators, the K-d X-ray data enables separation of the scattering lengths for the $\bar{K}N$ isospin 0 and 1 channels. The collaboration proposed to run a pilot experiment with a hydrogen target prior to stage-2 approval, and the beam time for the pilot run was allocated in the last PAC meeting.

The pilot run was performed in February-April 2019 for 3-days commissioning and 3-days run with the hydrogen target. All the detectors worked well, and the kaonic helium X-rays were clearly identified with a background level as expected. As for the kaonic hydrogen X-rays, however, transitions from higher states were seen but the $K_\alpha$ line was not, indicating the X-ray yield significantly smaller than expected. The collaboration considers that it is likely caused by the smaller number of stopping kaons and losses of various efficiencies as well as a lower branching ratio for the $K_\alpha$ transition. The collaboration has decided not to request a beam time with the present detector setup and to study necessary improvements. The collaboration foresees a beam time request after the upgrade of the setup in near future.

The PAC evaluates highly the successful run of the pilot experiment which clarified that the X-ray yield was smaller than the original estimate. The collaboration is

encouraged to understand the reasons for the lower yield and, if appropriate, to upgrade the setup for a revised proposal.

**E40 (Σp)**

E40 aims to elucidate ΣN interactions by measuring differential cross sections of Σp elastic scattering and the $\Sigma^- p \rightarrow \Lambda n$ conversion reaction. E40 reported the results of the second production run in the 2019 spring term (February-April). While the analysis is still ongoing, it has demonstrated that the experiment is performing successfully. A total of 17 M $\Sigma^-$ and 40 M $\Sigma^+$ have been produced, 4500 $\Sigma^- p$ scattering events, 2400 $\Sigma^- p \rightarrow \Lambda n$ conversion events, and 2500 $\Sigma^+ p$ scattering events are observed. These numbers exceed those in previous experiments by about 2 orders of magnitude. All components of the detector system seem to work properly, most of the background processes and yields are understood, and there is almost no loss time in experimental side. The PAC congratulates E40 for the successful data taking.

E40 requests 14 days of $\Sigma^+ p$ production run and 1.5 days for startup. In the 2019 spring run, the half of the beam time of $\Sigma^+ p$ scatterings were unavailable due to accelerator trouble. While the number of $\Sigma^+ p$ scattering events is large compared with the previous experiments, it is still half of the original request and is not enough to determine the $^3S_1$ phase shift with 10% statistical error in the high momentum region of $p > 0.55$ GeV, which is necessary to confirm the quark Pauli-blocking mechanism of the $\Sigma^+ p$ repulsion.

The PAC understands and supports the E40 request of the beam time in JFY2019. The PAC also looks forward to seeing a finalization of the analyses, which could strongly constrain the ΣN interaction.

**E03 (X-ray from $\Xi^-$ Atom)**

This experiment, which will be performed on the K1.8 beamline, aims to measure the shift and width of a $\Xi^-$ bound in an atomic orbit in Fe, using the $(K^-,K^+)$ reaction. The absorption is estimated to be such that the Ξ will be absorbed by the nucleus when it reaches the n=5 atomic level. The physical importance of the measurement is that the shift will give information on the sign and depth of the strong nuclear potential in the nuclear surface. The degree of attraction is not only important for its own sake but as a benchmark for calculations of massive neutron stars. Estimates of the absorption suggest a width for n=5 of order 4 keV with a shift of a similar size. A width of order 4 keV is the level required in order that the experiment can readily resolve the state.

The collaboration proposed a staging approach; in Phase 1 they plan to observe the upper transition (n=7→6) with 10% of the total requested beam time in order to make the world-first observation of Ξ-atomic X-rays, although no new physics information is expected to be obtained from this transition. However, this run also has a chance to observe the physically important transition (n=6→5) if the n=5 state has a width less than 1 keV.

Tests carried out suggest that the estimates of the background level are reliable and the PAC supports the beam tuning request as well as the Phase 1 request for 19.5 plus 3 days

commissioning before the long shutdown in FY2021. This run, which is expected to yield 10% of proposed statistics , should observe the n=7 to 6 transition (~172 keV) and, provided the width of the n=5 level is near or below 1 keV, is also expected to allow an initial determination of the shift of the n=5 level.

**E42 (H dibaryon)**

The E42 experiment aims to observe the H-dibaryon, S=-2 and B=2 six quark state (uuddss), in the $^{12}C(K^-, K^+)H$ reaction. It will employ a newly constructed detector system, the "Hyperon Spectrometer" consisting of a superconducting Helmholtz magnet and a time projection chamber (HypTPC), together with the existing KURAMA spectrometer system at the K1.8 beam line. The experiment can measure the ΛΛ, Λpπ$^-$ and Ξ$^-$p final states with a good mass resolution (~1 MeV) and high statistics. This will allow searches for the H dibaryon over a wide mass range including the mass around the NΞ threshold predicted by a recent lattice QCD calculation. The existence and the mass of the H-dibaryon would make a great contribution to our understanding of low-energy QCD and the nature of hadrons. The E42 experiment received stage-2 approval in July 2017.

In the present PAC meeting the collaboration reported the present status of the preparations. A long-term test of the superconducting Helmholtz magnet was successful and a field mapping was carried out, showing a field distribution as good as expected. A cosmic-ray test of the HypTPC in the superconducting magnet was performed, giving a good spatial resolution with the magnetic field. Prototype counters of the TPC Hodoscope and the water Cherenkov detector have been tested. The apparatus will be ready at the K1.8 beam line in early 2020. The collaboration requests a commissioning beam time for 5 days and a physics run beam time for 25 days (60 kW case) in 2 months after the commissioning in the late 2020.

The PAC is happy to hear their steady progress in preparation. The PAC supports the E42 request of running before the long shutdown in FY2021.

Considering possible floor plans, however, the interval between the commissioning and the physics run of E42 may need to be shortened (to about one month). The PAC would like to hear whether such a schedule is realistic or not. The collaboration will be required to make all the apparatus completely ready well in advance and to confirm their performance, particularly the mass resolution of 1 MeV, based on realistic test data before the beam time. The run plan will be discussed in the next PAC meeting based on the readiness of the experiment.

**E72 ($\Lambda^*$ Resonance)**

E72 aims to observe a narrow Λ resonance around 1665 MeV, just above the Λη threshold and to determine its spin and parity. The existence of this resonance is conjectured on experimental ground, but is not established, yet. Earlier data suggest its spin-parity would either be $3/2^+$ (P wave) or $3/2^-$ (D wave). If confirmed, this would indicate that the resonance is exotic.

Following January 2019 PAC request, E72 plan is to proceed in two phases.

The first phase (2 days of data taking, and 6 days for commissioning) is meant to establish firmly the existence of a spin 3/2 resonance, by measuring the differential cross sections of the $p(K^-, \Lambda)\eta$ reaction, around threshold, with ~734 MeV/c $K^-$ beam at K1.8BR line, after completion of the E42 experiment. The Monte Carlo simulation presented demonstrates that 2 days are sufficient to reach the goal of this discovery phase (5 sigma significance).

Assuming the first phase leads to a discovery, the second phase (19 additional days of data taking) is meant to determine the spin-parity of the resonance, through the angular dependence of the Λ polarization. In January 2019, the PAC asked for a detailed discussion of the actual analysis on the spin and parity to understand precisely why 21 days of data taking were needed to perform the measurement. The PAC expects that a Monte Carlo analysis will be presented in a timely way to justify the length of the data-taking period needed to establish the parity of the resonance (5 sigma significance).

The request to PAC is for a stage-2 approval. As stated previously, the PAC believes that there is no technical issue that preempts performing the experiment. Notwithstanding the above reservation concerning the length of the second phase – it can be evaluated later - the PAC recommends a stage-2 approval.

**P73 ($^{3}_{\Lambda}H$ and $^{4}_{\Lambda}H$ mesonic weak decay lifetime measurement with $^{3,4}$He($K^-,\pi^0$) $^{3,4}_{\Lambda}H$)**

The lightest strange baryonic nuclear system is the hypertriton, $^3_\Lambda$H, and found to be just bound. Its small Λ binding energy $B_\Lambda$ of only 130 keV found in emulsion studies implies that the Λ hyperon has a rather extended wave function. The combination of such a small binding energy on one side and, on the other hand, a $^3_\Lambda$H lifetime significantly shorter than the Λ lifetime, as reported recently by some heavy-ion collision experiments (STAR@RHIC, HypHI@GSI and ALICE@LHC) presents one of the most intriguing puzzles in hypernuclear physics, the so-called “hypertriton puzzle”.

P73 aims at a novel precision measurement of the $^3_\Lambda$H lifetime which does not rely on the decay vertex distribution like in the heavy ion studies. Instead, P73 intends a direct measurement of the decay time distribution in the $^3$He($K^-,\pi^0$)$^3_\Lambda$H reaction. The decay time is determined event-by-event by the time difference between the production vertex of the hypernucleus and its decay vertex. A γ-ray from the decay of the associated $\pi^0$ is used as a tag for event selection.

The committee appreciates the effort made by the P73 collaboration to provide rather advanced simulations and error estimates. The J-PARC PAC understands the importance of the hypertriton lifetime measurement. The experiment is very timely and should, therefore, be performed soon. P73 is relying essentially on existing equipment.

The committee recommends a 7 days pilot experiment with a $^4$He target to demonstrate the feasibility of this measurement. Before allocating running time for this test, the PAC asks the collaboration to provide by November 2019 a concise proposal which confirms the readiness for running by the end of the fiscal year 2019 and which will be discussed by the next PAC in Jan 2020.

**P74 (Direct measurement of the ${}^{3}_{\Lambda}H$ and ${}^{4}_{\Lambda}H$ lifetimes using the $^{3,4}$He($\pi^-$,$K^0$) ${}^{3,4}_{\Lambda}H$ reactions)**

Like the P73 experiment, the P74 collaboration also aims at a direct measurement of the hypertriton lifetime. The P74 collaboration uses the $^{3,4}$He($\pi^-$,$K^0$)$^{3,4}{}_{\Lambda}$H reaction to produce this lightest hypernucleus. As in the case of P73, the hypertriton lifetime will be determined from the decay time distribution.

The committee appreciates the improved Monte Carlo calculations presented by the collaboration. The simulations nicely demonstrate that the $^{3,4}$He($\pi^-$,$K^0$)$^{3,4}{}_{\Lambda}$H reaction studied by P74 has potentially less background, since the missing mass can be used as a selection criterion.

The PAC welcomes the effort of P74 to introduce a new spectroscopic method, the ($\pi^-$,$K^0$) reaction, which may open the possibility to study neutron rich hypernuclei in future at J-PARC. However, in view of the timeliness of the hypertriton lifetime measurement, the committee believes, that it should be performed as soon as possible at J-PARC. Given the readiness of P73 and in view of the present time schedule for setting up the K1.1 beamline required by P74, the committee suggests that one should postpone the decision on P74. A decision on the present P74 proposal, as it stands, will be considered once the outcome of the P73 proposal becomes clear.

## 4. General Remarks and Recommendations

The committee was pleased to hear the steady progress made towards the MR power upgrade planned for JFY2021. The committee recommends that the Laboratory make every effort to keep to the schedule of start-up of the upgraded MR in April 2022 in view of the urgency of many important scientific questions to be addressed with the upgraded machine. Operations after April 2022 should then return as quickly as possible, and at as close to the full utilization of 9 cycles per year as we recommended last time. The

"Eurocoin" target development should keep pace such that the target does not become the bottleneck in delivering beam power to the hadron hall in years following the upgrade. The committee was also happy to hear about high momentum beamline progress with availability for both high-p and existing beams in February 2020, and with the C-line for COMET to be complete as early as the end of JFY 2021.

The committee heard that shorts in a bending magnet in the transfer line caused a premature stop of the MR experimental program in the Spring 2019. While this was unfortunate, the committee was pleased to hear the prospects of repair and the schedule was such that the planned experimental program in JFY2019 can still be carried out in full within the fiscal year. There is a small number of additional operations days needed for the hadron hall due to the abrupt interruption of the experimental program. Also a few additional days of operation is desirable in view of the evolving scientific program since the last meeting. The committee recommends the laboratory to make strong efforts to secure funds for this relatively minor additional running, as this will lead to optimized usage of experimental time before the long shutdown in JFY2021. The committee was happy to see that the laboratory also recognizes the importance of sufficient time for machine studies and tuning, after the installation of the new production target, toward establishing the beam power of 70kW and beyond for the hadron experiments in 2020. The committee was pleased to hear that, in view of the mode of the failure of the magnet in question, further replacement of coils of similar type over the next months and years is being planned. The committee encourages further investigations of possible systematic failures of this type in the accelerator infrastructure due to aging or other factors.

JFY2020 is the last opportunity for data taking prior to the shutdown in JFY2021. The committee recommended last time that available operations should be at least 6 cycles. We are pleased to find that there is a request for 6.5 cycles that is being considered. After consideration of various boundary conditions, the committee recommends tentatively that, unless there is a severe curtailment of operations compared to the request, that at least 2 cycles should be used for the hadron program in FY2020 and the rest for the neutrino program. We will need to revisit this when the budget and other factors are better known. We recommend that effort should be made to complete the three experiments currently pending in the K1.8 beamline before the FY2021 shutdown.

## 5. DATES FOR THE NEXT J-PARC PAC MEETING

The next J-PARC PAC meeting will be held January 16-18, 2020.

**6. FOR THIS MEETING, THE J-PARC PAC RECEIVED THE FOLLOWING DOCUMENTS:**

- Minutes of the 27th J-PARC PAC meeting held on 16-18 January, 2019 (KEK/J-PARC-PAC 2019-10)
- Technical Design Reports
  - Technical Design Report for E70 (KEK/J-PARC-PAC 2019-11)
- Reports
  - Report on J-PARC Neutrino Beam Line Upgrade Technical Review Round 2 (KEK/J-PARC-PAC 2019-12)
  - Addendum to Direct measurement of the $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H lifetimes using the $^{3,4}$He($\pi^-$,$K^0$)$^{3,4}_{\Lambda}$H rections (KEK/J-PARC-PAC 2019-15)
- Letter of Intent
  - Search for a $K^-K^-$pp double kaonic nucleus using the $d(K^-,K^0)$ reaction with the HypTPC detector (KEK/J-PARC-PAC 2019-13)
  - Letter of Intent for the Systematic Study of the Kaonic Nuclear Bound Stataes at K1.8BR in J-PARC Hadron Hall (KEK/J-PARC-PAC 2019-14)