KEK/J-PARC-PAC 2023-11
January 24th 2024

J-PARC Program Advisory Committee

for the Nuclear and Particle Physics Experiments

at the J-PARC Main Ring

Minutes of the 36th meeting held
19(Wed.)-21(Fri.) July 2023

OPEN SESSION:

1. Welcome and J-PARC Center Report: T. Kobayashi (J-PARC/KEK)
2. J-PARC Accelerator Status & Plan: Y. Sato (J-PARC/KEK)
3. Mandate to the Committee: N. Saito (KEK)
4. E11/E65 (T2K) : Beamline and ND upgrade status and plan:
   T. MATSUBARA (J-PARC/KEK)
5. E11/E65 (T2K) : SK and analysis status and plan:
   L. Berns (Tohoku Univ.)
6. E14(KOTO): T. Nomura (J-PARC/KEK)
7. E21(COMET): S. Mihara (J-PARC/KEK)
8. E34(g-2/EDM): T. Mibe (J-PARC/KEK)
9. E56/E82(JSNS2, JSNS2-II): T. Maruyama (J-PARC/KEK)
10. E71(NINJA) : T. Fukuda(Nagoya Univ.)
11. MLF Particle and Nuclear Physics Programs: N. Saito (KEK)
12. Study of Discrete Symmetries in Polarized Epithermal Neutron Optics:
    H. Shimizu (Nagoya Univ.)
13. Fundamental Physics with Pulsed Cold Neutrons: K. Mishima (J-PARC/KEK)

14. Report by expert committee of neutron programs at MLF:
H. Nanjo (Osaka Univ.)

15. Hadron Facility & Plan: H. Takahashi (J-PARC/KEK)

16. E16 Measurement of Spectral Change of Vector Mesons in Nuclei:
S. Yokkaichi (RIKEN)

17. E70 Ξ hypernuclear spectroscopy: T. Gogami (Kyoto Univ.)

18. E73 Lifetime measurement of ${}^{3}_{\Lambda}H$: Y. Ma (RIKEN)

19. Measurement of Anti-Matter Reaction in Liquid Argon Time Projection Chamber (LArTPC): M. Tanaka (Waseda Univ.)

20. Beam Time Schedule in 2022 T. Komatsubara (J-PARC/KEK)

CLOSED SESSION:

Present: P. Achenbach (Mainz), V. Cirigliano (Washington), M. Endo (KEK), L. Fields (FNAL), H. Ishino (Okayama), D. Jaffe (BNL),K. Joo (Connecticut), T. Kawabata (Osaka), C. Lazzeroni (Birmingham),

K. Luk (Berkeley), K. Miyabayashi (Nara), H. Ohnishi (Tohoku),M. Oka (JAEA), K. Yorita (Waseda), R. Yoshida (Chair, Argonne),

N. Saito (KEK-IPNS Director),

T. Komatsubara (KEK-IPNS Deputy Director) andT. Kobayashi (J-PARC Director)

1. PROCEDURAL REPORT

The minutes of the 35th J-PARC-PAC meeting (KEK/J-PARC-PAC 2023-7) were approved.

2. LABORATORY REPORT

2-1 Welcome and J-PARC Center Report (Takashi Kobayashi, J-PARC Center Director)

The J-PARC Director, Takashi Kobayashi discussed the recent beam power history at MLF and MR. Stable operation of > 500 kW for NU and ~ 60 kW for HD before the MR upgrade was achieved. The MR upgrade was started in FY2021, and the commissioning of the upgraded MR was started in FY2022. The MR high power study of 750kWeq pulse acceleration this April was successful. However, Kobayashi reported that the full-fledged user operation was delayed ~ 1 year due to several initial failures and fires at J-PARC. He then summarized the circumstances of the two fires, one on April 25th at the MR power supply and the other on June 22nd at the HD power supply. He also showed the history of the accelerator shutdown and resumption after the first fire. The history and resumption plan of the current shutdown due to the second fire was presented. According to the plan, MLF and NU operations will resume this Autumn; the HD resumption date will depend on preventive measures that are determined to need to be deployed. Kobayashi summarized the actual beam operation time for JFY2023 before the summer; and indicated the operation prospect for JFY2023, considering the shutdown period in January 2024 due to the air conditioning replacement at MLF as well as the recent electricity cost trends. LI/RCS/MLF is being planned to operate until the end of March. MR can also operate until around the end of March and will include beam time in Nov./Dec./early Feb. to complete the programs for NU/HD that were planned before summer as well as 1.5 cycles in addition. Kobayashi presented the budget request for JFY2024. The request includes 8 cycles of operation and 0.5 cycles of accelerator study and facility constructions (g-2/EDM, Pol-n (MLF), and Muon microscope) for J-PARC, accelerator power upgrade, beam upgrade, and near detector facility construction for Hyper-K.

Kobayashi finally discussed the improvement of the user environment, in particular, the improvement of transportation at the J-PARC site and the progress in the J-PARC access road construction.

2-2 J-PARC Accelerator Status (Yoichi Sato, J-PARC/KEK)

Yoichi Sato gave an operation summary of Main Ring (MR) and MLF since the last PAC meeting. Operation in this period was suspended a few times due to machine problems. However, they successfully confirmed that the requirements for beam qualities have been

achieved. They demonstrated 766kW equivalent (2.17×10^{14} ppp) beam operation with an estimated beam loss of 840 W (2.4×10^{12} ppp) by carefully optimizing the MR three-fold symmetry. The beam repetition cycle in this FX tuning was 1.36 sec. In late April they succeeded in 535kW FX operation for T2K with vacuum scrubbing. They are already on track to achieve > 750kW beam power. SX operation at 8GeV for COMET was carried out in order to provide the beam to COMET Phase-α with an extraction efficiency of about 99% and a spill duty factor of about 76%. They also confirmed good beam extraction efficiency, above 99.5%, for SX at 30GeV although the spill duty factor was about 45%, which was worse than the previous value of 53% achieved in 2021 at 51kW.

Sato reported on the status of the MR power upgrade plan toward 1.3MW. They have set 7 milestones to reach the goal; 1) magnet power supply upgrade to reduce the repetition cycle from 2.48 sec. to 1.32 sec, 2) installation of 2nd harmonic RF cavities, 3) RF system upgrade, 4) reduction of the repetition cycle from 1.32 sec. to 1.16 sec., 5) installation of new collimators, 6) injection / fast extraction system upgrade, and 7) beam monitor upgrade. Among these they already achieved 1), 2), 3), 5), and 6) and the rest will be realized before 2028 to reach 1.3MW beam power.

Sato also summarized two machine issues that caused beam interruption in 2023. One was a failure of high-field FX septum magnets. Three septum magnets, SM30, 31, and 32 were restored in order to restart stable MR operation in late January 2023. The coils of the three magnets will be replaced. The other was a fire of the main quadrupole magnet power supply (QDN) that happened on 25th April. The cause of this fire was found to be a transformer used in the power supply whose specification did not satisfy the actual operating condition. They changed the initial-charging method in the power supply to bypass the problematic circuit and successfully restored the operation. Thanks to these measures they have achieved FX/SX beam performance as described above.

Sato concluded his presentation by showing the operation plan for JFY 2023. They aim to achieve 750kW operation in FX step by step with vacuum scrubbing while confirming the residual dose in maintenance days. In SX operation, they anticipate achieving 65-80kW beam by reducing the beam repetition cycle from 5.2 sec. to 4.24 sec. It is mandatory to reduce beam loss to this end. He also mentioned the plan to reach the FX beam power of 1.3MW. They plan to realize this by optimizing the operation point and correction magnet system as well as upgrading the beam dump capacity to 30kW.

2-3 Welcome and Mandate to the Committee (Naohito SAITO, KEK IPNS director)

The director of the Institute of Particle and Nuclear Studies (IPNS), Naohito Saito, welcomed the PAC members. He first introduced the organizational structure of the IPNS which covers a wide range of science research. The updated timeline for various ongoing and future projects and status of various task-force meetings was also reported.

Saito explained that two fire incidents had occurred at MR in April and at Hadron Experimental Facility in June and that a comprehensive approach was required rather than simple counter measures for each specific failure. He pledged to work responsibly with JAEA to solve these problems and to aim for the early resumption of beam operation. After the final report of the incident to the local governments is submitted and then accepted, beam recovery is aimed for MLF and MR-FX first, and SX operation may be delayed due to hardware replacements which will take more time.

Prospect of electricity price and beam time was explained. Electricity unit price has decreased to 20 yen/kWh level since last April and beam can be delivered until the end of this fiscal year if the current unit price continues. Based on this situation already allocated beam time to FX and SX will be completed by middle of February and 1.5 months can be allocated before the end of this fiscal year. Three-month operation is expected in the next fiscal year before summer shutdown.

Saito shared the excited news on COMET Phase-α that COMET experimental hall had successfully received the first beam in February. Status of two reviews on Muon g-2/EDM and KOTO was reported. He also announced that the PAC chair, Rikutaro Yoshida will step down and expressed appreciation for his great efforts for the last six years. Taku Yamanaka will take over as chair from the next meeting.

Two new proposals regarding neutron physics at MLF were submitted to this PAC meeting. One Letter of Intent (LoI) was also submitted. No Technical Design Report (TDR) for Stage-2 request was submitted and thus Facilities Impact and Financial Committee (FIFC) meeting was not held for this PAC meeting.

Saito requested the PAC to evaluate the new proposals along with requests for Stage-1 status and Stage-2 approval to provide recommendations to the IPNS and J-PARC directors. He also requested assessments of the progress in the ongoing experiments as well as any advice on the run plan from this autumn to the next summer.

2-4 Hadron Facility Status and Plan (Hitoshi Takahashi, J-PARC/KEK)

Hitoshi Takahashi reported on the status and plan of the Hadron Experimental Facility. The report included a summary of recent beam time, the result of the first beam commissioning of the new primary beam line, and the R&D status of the rotating target.

First, he summarized the beam operation of the recent SX run. The operation with the energy of 8 GeV was carried out in two periods, last February and March. During these periods, the first beam commissioning of the new primary beam line (C-line) and the COMET Phase-α program were conducted, and they successfully passed the facility inspection for the radiation facility license. The operation of the accelerators was relatively stable during the user time, except for the long (5.6 days) beam stop due to the MR QDN power-supply failure.

The 30-GeV operation was originally planned for about one month from May to June but was rescheduled due to the fire incident in the MR D2 building on April 25th. The revised plan was from June 16th to the morning of June 22nd, but the beam time was interrupted by the fire incident in the Hadron power-supply building on June 22nd. The live ratio of the accelerator during the user time was very low (below 50%). The new beam optics was applied to the hadron primary beam lines, which eliminates the vertical dispersion at the beam-branching magnet, with the aim of reducing the spill microstructure in the B-line. The result was presented by the E16 group.

Takahashi also presented the R&D status of the new production target. The new target is a He-gas cooled rotating target and is expected to be capable of beam power of 150 kW or more. A gas bearing is under development for the longer lifetime and higher rotation speed. The realistic rotation tests of the gas bearing were performed using a dummy target disk with a real size and weight. Since one of the major concerns is the robustness of the gas-bearing system, especially for emergency cases, the vibration test assuming an earthquake was also carried out. The real vibration waveform that was observed in the Great East Japan Earthquake in 2011 in Hitachi city was used for the test. The tests were performed with 4 directions of the vibration, and the gas-bearing system passed all the tests. It is great progress for the rotation-system design.

3. EVALUATIONS OF THE PROPOSALS AND STATUS OF THE ONGOING EXPERIMENT

E11/E65 (T2K)

E11/65 (T2K) is an ongoing experiment that uses off-axis muon (anti-)neutrino beams produced at J-PARC, a near detector on-site, and the Super-K detector with a baseline of 298 km to study neutrino oscillation.

Upgrade of the neutrino beamline, capable of handling beam power up to 900 kW, was completed in 2022. The PAC congratulates the J-PARC beam group and T2K on the successful 3-day commissioning of the upgraded neutrino beamline in April 2023. No major issues were found. Before the fire in the MR PS transformer on April 25, the delivered proton beam with a repetition rate of 1.36s set a new T2K beam-power record of 540 kW. Once the problems of the readout of the horn thermocouple and the hardware of the primary beamline monitor are resolved, and the installation of a new monitor for the beam profile in the primary beamline are completed, commissioning of the neutrino beamline can be resumed. It will be ready for normal operation in November 2023.

We also congratulate the T2K Collaboration on making steady progress in upgrading ND280. This major upgrade will significantly reduce the systematic uncertainties of T2K's measurements. Since the last PAC meeting, two of the six ToF panels were installed and the assembled SFGD was commissioned at J-PARC. The latter detector will be installed in September of this year. The bottom HA-TPC was assembled and commissioned with cosmic-ray at CERN. It will be shipped to J-PARC in August and be installed in September. These three new subsystems and the SuperK-Gd detector will be ready for beam in November 2023. The top HA-TPC is expected to arrive onsite in February 2024 and be installed along with the remaining four ToF panels in March. The fully upgraded ND280 will be ready for data taking before the summer of 2024.

Besides the impressive progress in hardware, we have also heard a report on analysis. The first measurement of CC0π with data collected on- and off-axes has been submitted for publication. The analysis of CC coherent muon (anti-)neutrino interactions is being reviewed by the collaboration. A draft reporting the parametrization of the interaction model for oscillation analysis using cross-section measurements from T2K and other experiments is in preparation. The status of the ongoing 2023 oscillation analysis with more POT and refined handling of the Super-K detector systematic was shown. The plans for analyzing data acquired with the upgraded ND280 and SuperK-Gd were presented.

We were also informed about the status of the joint T2K-SK and T2K-NOvA analyses. Before carrying out the joint fit for extracting physics parameters, the two collaborations of each analysis are spending time in understanding potential systematic correlations

between the two experiments with different baselines, neutrino energies, and in the case of the T2K-NOvA analysis, detector technologies. For the T2K-NOvA analysis, the robustness studies are finished. The collaborations are reviewing the analysis method before performing the fit. For the T2K-SK analysis, the first data-fits performed and presented to both collaborations. The review process started within both collaborations. The PAC looks forward to receiving more news on the joint efforts between T2K and Super-K/NOvA in the next meeting.

We noted T2K's request of 3.5 cycles of beam before July 2024, in addition to the already approved beamtime (approximate 1 cycle) to be used for additional commissioning of the beamline, MR vacuum scrubbing and establishment of operation at a beam power of >750 kW. Out of the 3.5 cycle request, 1.5 cycles are for commissioning the SuperFGD, bottom HA-TPC and the ToF as well as collecting data with the existing near detectors and the SuperK-Gd detector. The other two cycles in JFY2024 are for data taking with the fully upgraded ND280. The PAC understands the desire of T2K to stay competitive with NOvA. In view of the other constraints and other requests, PAC recommends providing T2K one already-approved cycle for beam commissioning and an additional 2.3 cycles for commissioning the partially upgraded ND280 and amassing data before the summer shutdown in July 2024. See comments in the management section for further discussion of beam allocations.

E14 (KOTO)

The E14 (KOTO) experiment searches for the CP-violating rare decay $K_L \to \pi^0 \nu\nu$ at the J-PARC neutral beam line. With small theoretical uncertainties, the measurement of the branching ratio is a very sensitive probe of new physics beyond the Standard Model. At the meeting, KOTO reported the analysis status for 2021 data, and summarized the beam time activity in June 2023 and work plans for this summer.

Statistics of $K_L \to \pi^0\pi^0$ (Kp2) Monte Carlo samples were increased by a factor of 3.7 thanks to the utilization of the Open Science Grid (OSG), and the systematic uncertainty was evaluated by propagating the uncertainties of the inefficiency corrections derived from 5γ data. After the correction, Kp2 background was updated as 0.087 event from previous 0.141 event. Systematic uncertainties due to hadron cluster background and η production in CV are evaluated using physics data with inverse neutron cuts, Al target control data, and Monte Carlo simulations. Studies on upstream π0 background are also in progress and uses 6γ samples with effects of photo nuclear interactions carefully

investigated. The total number of backgrounds is estimated to be 0.269 ± 0.040 (stat.) +0.053−0.069 (syst.) with the single event sensitivity of 8.0×10^{-10} for 2021 data. Although there are some remaining issues to be addressed, such as further estimation of $K_L\rightarrow3\pi^0$ background and the final determination of selection cuts, the collaboration expects to decide on opening the signal box in August.

During the beam time in June 2023, KOTO commissioned evaluated the new thinner UCV designed to reduce beam scattering as well as to achieve a better efficiency and obtained the expected performance. A new DAQ system was successfully operated, and physics data were taken stably with the event rate of 15K/spill, including 5γ data. However, due to limited beam availability, planned studies on the beam structure with new MR power supplies and the 4.2-second cycle were not completed and postponed.

In summary, the PAC congratulates the collaboration on the successful achievements to understand the backgrounds and the systematic uncertainties and is looking forward to seeing the analysis results. The PAC is pleased to see steady progress on new UCV and DAQ systems during the June beam time and encourages the installation of a sweeping permanent magnet (~0.87T) at the end point of the beam line to suppress charged kaon backgrounds by another factor of 10. The PAC recommends approval of the request for 60 days of running per year if it can be accommodated with concurrent running of experiments in other hadron hall beamlines. The PAC strongly endorses a ~1 month run with 80kW beam power before July 2024 to study the new beam structure and evaluate the performance with the newly installed sweeping magnet.

E21 (COMET)

COMET is an under-construction experiment with the goal of searching for a muon converting into an electron without emitting any neutrino after stopping inside an aluminum target.

The PAC heard a detailed report on the progress of Phase-α that is now nearly completed (only half of the allocated time was available). The proton beam line is ready and was tested with a low-intensity proton beam in the engineering run (Phase-α). Commissioning of the Transport Solenoid (MTS) was successfully performed at 1.5T and the support structure of the thermal shield was improved; commissioning at 3T is expected in the near future, including a confirmation that the instability of the power supply is resolved. The Pion Capture Solenoid (PCS) developed a coil insulation problem (ground fault) in August 2022. A method of eliminating the ground fault was established and construction

of the PCS has resumed. Cryogenic facilities have been successful in operation; here the Tritium contamination in the system will be checked and appropriate radiation control measures will be established if necessary. First results on the muon decay curve, the beam profile scan and the muon momentum spectrum were presented; the data analysis is in progress. Preparation towards Phases I and II was also reported: the detector construction is progressing steadily, and the software and simulation tools have advanced.

The PAC congratulates the J-PARC beam group on the job well done. The PAC congratulates the COMET collaboration on their impressive accomplishments and looks forward to hearing further progress and data results at the next PAC meeting. While the hardware tasks are proceeding rather well, we note that geopolitical issues continue to negatively impact the delivery of some detector subsystems. We acknowledge COMET's effort in finding alternative solutions and supply chains.

The PAC recommends accepting the COMET request to have 6.5 days beam time to complete Phase-α (transfer matrix measurement using the mask system and range counter measurement) before January 2024.

E34 (g-2, EDM)

E34 aims to perform precise measurements of the anomalous magnetic moment and electric dipole moment of the muon with a novel technique utilizing a cold surface-muon beam, muon acceleration and injection into a compact storage magnet.

In the meeting, the progress in the facility construction was explained. The collaboration has worked to meet the promised milestones for FY2023. PAC acknowledges the steady progress since the last meeting. For the muon source, the ionization test was performed, and initial commissioning data were collected. The muon cooling and acceleration system will be installed in S2 area for the beam time in FY2023. For the positron detector, the fabrication of quarter vane prototypes was completed. The beam injection test with electrons is in progress, aiming to finish in FY2023; the 80keV acceleration at S2 is requested for 2 weeks of beam time at MLF in FY2023. The extension of the H-line is in progress. In FY2023, KEK provided funding to carry out the engineering design of the building. The basic specifications of the building have been finalized. The design will be available by the end of FY2023.

The report of the IPNS Progress Review was also presented and explained in the meeting. A standing review committee was formed under IPNS, and the first meetings were held

on January 31 and February 8, to be followed annually. There are 4 general and 39 specific recommendations. The PAC is looking forward to hearing point-to-point responses to the recommendations and encourages E34 to continue their efforts to realize the experiment in a timely manner.

E56/E82 (JSNS^2, JSNS^2-II)

JSNS^2 (E56) is an experiment at the Materials and Life Science Experimental Facility at JPARC and is intended to be a direct test of the LSND anomaly. It was commissioned in 2020 and has taken data in 2021, 2022, and 2023. Beam power to the experiment has steadily increased over these data taking periods, and recently reached a record of 950 kW. A critical component of the JSNS^2 sterile neutrino analysis involves constraints of backgrounds using several sidebands. The experiment reported that progress has been made in understanding sidebands. They are also working on measurements of the neutrino flux using interactions with Carbon and a KDAR analysis. A new calibration technique using ^{252}Cf has also been developed. New electronics with extended dynamic range have been developed and tested in the experiment.

While JSNS^2 consists of only a near detector, JSNS^2-II (E82) is an upgrade of JSNS^2 that adds a far detector. The committee heard about progress in the installation of this new detector, which is larger, but nearly identical to the near detector. So far, 142 PMTs have been installed. Additional 33 PMTs that were expected from Double Chooz were not obtained due to customs issues. Hence, 30 PMTs have been ordered from Hamamatsu but will not arrive until February 2024. High voltage electronics and the acrylic tank have been delivered. Air conditioning has been installed but, due to delays in electrical lines installation, is currently run on a diesel generator. Data-taking with the far detector has been delayed from the original estimate and is currently foreseen to start in JFY2024.

The PAC would like to congratulate the collaboration for the steady progress on the installation of the far detector. However, we find that there is a lack of detail provided on the JSNS^2 sterile-neutrino analysis in the past several PAC meetings including this one. The PAC strongly encourages the collaboration to focus their effort on the sterile neutrino analysis and requests that they present a detailed progress report on the sterile neutrino analysis at the next PAC meeting. We also encourage the J-PARC directorate to investigate the situation with electrical lines for the far-detector air conditioning.

E71 (NINJA)

NINJA is aiming for the measurements of the charged-current neutrino interaction differential cross sections. Precise cross section measurements are critical to neutrino physics research, as they mitigate systematic uncertainties of the neutrino interactions with atomic nuclei. The advantage of using emulsion is the capability to identify low energy secondary particles including protons, pions, gammas and leptons with a good particle identification.

NINJA collaborators have already collected data with test experiments (T60, T66, T68 and T81) and presented physics results in several publications. The collaborators successfully took experimental data (E71a) from Nov. of 2019 to Feb. of 2020 with a total protons on target of 4.8e20. The experiment used 250 kg target mass containing water and iron as well as emulsion sheets. Neutrino interaction events are recorded in the emulsion sheet with the timing and position information obtained with the emulsion shifter and the scintillation tracker as well as the muon tracker (Baby MIND). The collaborators have completed emulsion scanning. Preliminary results were shown in the meeting without any physics interpretation. The PAC is looking forward to hearing the physics results in the form of double differential cross sections for muon's emission angle and momentum in the cases with presence or absence of pion/proton using the full data sample of E71a by the next PAC meeting.

The collaborators presented the preparation of the E71b in fall of 2023 to acquire 5.2e20 POT. The PAC congratulates the collaboration on the completion of the production of new emulsion sheets with the implementation of the refreshable large size AgBr crystal and the 2.5 times thickness that improves the track angular resolution.

The PAC commends the formation of a new joint working group of NINJA and T2K to reduce the cross section systematic errors of T2K with the NINJA’s data. The PAC strongly recommends collaborative studies and is looking forward to hearing the quantitative impact on systematic uncertainties next time.

P99 (Epithermal Neutrons)

The NOPTREX experiment aims to measure P and T odd (hence CP violating) correlations in the propagation of polarized neutrons through polarized nuclear targets. The triple correlation is built out of the neutron momentum, neutron spin, and the target spin polarization vector.

On theoretical grounds, the presence of close s- and p-wave resonances in the compound nucleus ^{139}La + n is expected to cause an amplification of P- and T-violating effects, through interference. Measurements of the P-violating asymmetry in the propagation of longitudinally polarized neutrons indeed indicate a strong enhancement compared to nucleon-nucleon scattering, due to the neutron-nucleus resonances. The proposed experiment aims to exploit this amplification to search for new sources of CP violation.

While the general principle is clear, the PAC could not fully assess the impact of the proposed experiment. Several questions arose, both concerning the physics reach and the status of R&D for detectors.

Concerning the motivation and impact of the experiment, it is highly desirable that the collaboration clearly benchmarks the relative sensitivity of NOPTREX compared to EDM searches in neutrons and atoms (such as ^{199}Hg). This can be phrased in terms of CP-violating pion-nucleon couplings, in as a model-independent way as possible. While some estimates were presented in the proposal and in the presentation to the PAC, several questions deserve further attention:

(i) what is the largest signal expected in NOPTREX, given the current bounds on neutron and ^{199}Hg EDMs?

(ii) in what sense is this experiment complementary to neutron and diamagnetic atom EDM searches? Can this be made concrete through a multi-dimensional analysis in terms of effective CP-violating couplings?

(iii) what is the impact of theoretical uncertainties in the neutron-nucleus matrix elements of the P- and CP-violating interactions?

(iv) what is the expected signal if the only source of CP violation is the Kobayashi-Maskawa phase in the Standard Model?

Concerning the experimental set up, more explanations are needed to judge if this proposal has a clear feasibility. Neither the meeting presentation nor the proposal document seem to contain quantitative descriptions about actual dimensions and performances of polarized target, spin filters and detectors. Many key components are in the design phase and not yet the construction phase. As an example, the type of spin-polarized target to be used is undecided. Both proposed methods, either using a low holding field with continuous DNP transfer or a high holding field at milli-Kelvin

temperatures in a “frozen-spin” mode, require substantial effort and resources for equipment fabrication and testing. This critical part of the experiment appears to be far from its realization. One other part of the experiment which appears to be in the preliminary planning phase is the choice of the target material. While ^{139}La is considered the preferred material due to the observed very high parity-violating asymmetries, this large enhancement factor might not be present for time-violating processes as pointed out in Sect. 4.5.1 of the proposal. As alternative candidates ^{117}Sn and ^{131}Xe- are mentioned in the proposal. The choice of target material determines the kind of equipment needed for the experiment. While the PAC appreciates the efforts that were made towards a design of this experiment, it considers the conceptual design of the full equipment incomplete. Without a complete conceptual design, the timelines for realization and the amount of necessary beamtime for setup and data taking remain unclear.

The PAC would like to request the expert panel to continue to work with the proponents. We look forward to hearing from the proponents and the expert panel when the proposal is considered to be ready for evaluation for Phase 1 approval recommendation.

P100 (Pulsed Cold Neutrons)

The P100 proposal contained six projects that utilize Pulsed Cold Neutrons at the MLF BL05 beamline. Before the PAC meeting, an expert review panel meeting was held, during which four out of the six projects were evaluated. During this PAC meeting, only two projects were discussed in open session: the neutron lifetime measurement and Neutron Interferometry projects. Unfortunately, two of the projects were discussed in neither the expert review and nor in the presentation to the PAC, although the documentation submitted contains some information. We make some comments below based on the presentation, the expert review, and the written material.

The neutron lifetime:

A free neutron decays with an average lifetime of 878.4 ± 0.5 s (PDG 2022). The neutron lifetime is a fundamental parameter that impacts areas of nuclear physics, particle physics, and cosmology. A precisely determined lifetime can be used to search for BSM (Beyond Standard Model) physics. The lifetime has been determined by counting the decays of cold neutrons in a beam, and measuring missing of ultra-cold neutrons (UCNs) confined in storage. Measured neutron lifetime values with the beam method (888.0 ± 2.0 s) and the storage method (878.4 ± 0.5 s) show significant discrepancy (more than 4.6σ). Measurements based on the storage method have so far reported the most precise values.

The proposed new beam method aims to reduce the uncertainty down to 1 s and provide the most precise experimental neutron lifetime value for the beam method as an important piece to solve the neutron lifetime puzzle. The PAC believes that a proposed new beam-based lifetime measurement, which would have very different systematic uncertainties from the existing beam measurements, with a precision of 1 s would be a timely and significant goal.

We note the concerns and comments of the expert review report:

1. The current measurement using the new proposed method is 898 ± 10(stat) ± (15-18) (syst) s. It is not clear whether the reduction of the current sensitivity down to the 1.0 s level as proposed is possible.

2. We need to better understand the details of systematic errors of the previous beam method(s). The systematic errors of the previous beam method(s) could have been significantly underestimated.

3. Moreover, as expressed in the presentation by the expert panel, while the whole project is of high relevance for nuclear physics and the standard model in general, the proposal needs further clarifications.

Neutron Interferometry, Search for short-range Gravity, neutron scattering:

The measurements, with a remarkable precision, of the phase determination in neutron interferometry is proposed, achieving a sensitivity of 20 mrad/20 min. This level of precision is one order of magnitude better than the previous measurement using a Si interferometer. The proponent emphasizes that the measurement will open a new window for the physics program in broad topics from nuclear physics to physics beyond the standard model, such as information on nucleon-nucleon or three-nucleon potentials and spin rotation in nuclei. A detailed discussion of the experiment, however, was not presented. This should include measurement principles, sensitivity, expected signal shape, final statistics, and so forth. The PAC recommends that the proponent collaborate with the expert panel to ensure a presentation of sufficient detail to the PAC is made in the future.

Concerning the envisioned study of non-standard short-range gravitational interactions, we note:

1. A prerequisite of this measurement is to understand neutron-matter interactions from known sources and to eliminate their effect. To reach the desired precision this amounts to determining the low-energy parameters for each species of nuclei in the target material separately. The PAC encourages further developments on precise determination of the n+A low-energy parameters from s-wave phase shifts covering the scattering lengths and the effective ranges.

2. For estimations of short-range gravity contributions, the proponents should also consider the Mott-Schwinger (MS) electromagnetic neutron-nucleus interactions, which also behave as ~O(exp(-ar)/r). They are a part of measured phase shifts and will interfere with any non-standard kind of interactions, especially because also the MS- scattering amplitude has a pronounced forward characteristic.

3. Precise measurements of neutron-nucleus scattering with phase shift analysis from high quality angular distributions will also serve to encircle electromagnetic short-/medium - range interactions like the MS interactions (non-relativistically amounting to a special kind of long–range spin-orbit interactions). This kind of investigation may be decisive for the quantitative determination of other beyond-BSM effects and interactions.

Preparatory research for EDM-Investigations:

The PAC recognizes the importance of nEDM investigations and supports further work on the preparation of such experiments at MLF. The issues raised by the expert panel should be the appropriate guidelines for the following steps.

The PAC recognizes the importance and the physics value of the P100 projects discussed in the expert review, in this PAC meeting, and presented in writing. The six projects were, however, presented at very different levels of detail. The objectives of the six projects also vary widely from fundamental measurements, to work in support of measurements planned elsewhere, or to developments of general tools. The PAC would like to ask the IPNS/JPARC management to work with IMSS to organize the proposals in such a way that PAC can recommend phase-1 approvals for well-defined experiments. PAC may also separately make comments on the potential of a science program with cold pulsed neutrons, if needed. In all cases, PAC concludes that further information is needed, and we ask the expert review committee to continue to work with the proponents. We look forward to hearing further presentations from the proponents and the expert panel when the appropriate stage has been reached.

E16 (VM in nuclei)

E16 aims to see the ϕ mass modification in medium to confirm partial restoration of chiral symmetry. The PAC appreciates the collaboration's achievement to complete full 8 detector modules construction and the implementation of the upgraded DAQ system to reduce deadtime as one of the countermeasures against the micro beam structure seen in 2020 and 2021 runs.

The PAC recognizes the collaboration's effort to do their best to understand and mitigate the micro beam structure effect under the reduced machine time due to the fire accidents. It is good to hear that the new beam optics setting zero-dispersion at the Lambertson septum magnet reduces the 5.2 microsec interval component down to about half of the previous observation. As for the 5 msec interval component, the adjustment of the power supplies at MR is expected to be effective. So far, the adjustment has been made on three pieces out of six of the same type power supplies, and the accelerator group will also adjust the remaining pieces. The PAC recommends giving E16 the requested beam time to encourage further study to solve the micro beam structure problem.

E70 (Cascade hypernuclei)

The E70 experiment will conduct the spectroscopy of $^{12}_{\Xi}$Be hypernuclei using the ^{12}C(K^-,K+) reaction to examine the ΞN interaction. E70 will improve missing-mass resolution to 2 MeV at FWHM, which is much better than those in the earlier experiments, BNL AGS-E885 and J-PARC E05, thanks to the newly commissioned S-2S spectrometer. A high statistics data set with good energy resolution should confirm the existence (or prove the non-existence) of a $\Xi/\Lambda\Lambda$ bound state in ^{12}Be.

The PAC congratulates E70 on the successful pilot run in June 2023. The active fiber target was nicely calibrated, enabling clear identification of particle trajectories. The five drift chambers worked effectively, achieving a good position resolution of 300 um on each detector plane. The trigger counters also performed well to distinguish kaons from protons and pions successfully. The PAC expects that E70 will validate the anticipated momentum resolution of the S-2S spectrometer through further refinements of off-line analysis.

E70 has remaining 7.5 days for detector commissioning not yet executed due to the truncated operation in the previous period. E70 requests 27.5 days for physics run after a 1-month analysis period after commissioning. Given the operational constraints and

other requests, the PAC recommends that E70 is allocated 1 cycle of data taking before the summer of 2024, after the previously allocated 7.5 days of the commissioning beam time have been taken.

E73 (hypertriton lifetime)

The PAC congratulates the collaboration for their successful demonstration of the identification of $^{4}_{\Lambda}$H and $^{3}_{\Lambda}$H hypernuclei, for their measurement of γ-decay from π^0, and the successful measurement of the $^{4}_{\Lambda}$H lifetime through directly tagging the π^- decay product. The PAC congratulates the collaboration for the imminent publication of the latter result. From the observed data of the $^{4}_{\Lambda}$H decay, the collaboration has estimated the precision of the $^{3}_{\Lambda}$H lifetime measurement as 20 ps (stat) and 20 ps (syst). The PAC recognizes the idea that the ratio of the production cross sections of $^{3}_{\Lambda}$H and $^{4}_{\Lambda}$H provides the binding energy, giving a better understanding of the structure of $^{3}_{\Lambda}$H

The PAC already recommended allocating a 25-days 80 kW beam time for E73 in JFY2023 even though the limited beam operation has not allowed execution. PAC recommends allocating 1 cycle of data taking to E73 before July 2024 at high priority.

T98 (LArTPC)

T98 seeks to establish the performance of a LArTPC for detecting antideuterons and antiprotons which is essential for launching the GRAMS project. During Phase-1, T98 has successfully taken sufficient antideuteron trigger data in June 2023 to determine the antideuteron rate in the K1.8BR beam line. A clear deuteron signal is observed, and analysis is ongoing to determine the antideuteron rate. It was also established in June that the beam can be collimated to reduce the incident particle flux on the LArTPC to be compatible with the maximum rate of the DAQ.

The PAC congratulates T98 for the efficient use of beam time and successful completion of the initial data-taking. We look forward to the T98's report at the next PAC on the results from the acquired data to establish the antideuteron rate in the K1.8BR beamline. The PAC expects the Phase-2 proposal of T98 will be forthcoming at the next PAC meeting.

4. GENERAL REMARKS AND RECOMMENDATIONS

The PAC heard with concern about the fire incidents that occurred on April 25 and June 22. We were happy to hear that there were no injuries or serious damage beyond the

components (a transformer and a polarity changer) that were the causes of the fires. However, these and some other smaller issues have prevented the full commissioning of the Main Ring for user operations thus far. While the MR returned to operation in June after the first fire, the second fire, that happened shortly thereafter currently prevents J−PARC from operation. The operation can only resume after receiving permission from local authorities, which will consider the matter after J-PARC submits a full report of the incident. The report is planned to be ready at the end of August. With this permission, MR may return to operation for NU; however, because the second fire was in a power supply for the HD beam line, an investigation and preventive maintenance of all power supplies are planned. It is not yet clear when the full maintenance will be completed, so that the estimated time of resumption of beam to the Hadron Experimental Facility (HEF) is not yet established. The two incidents are both electrical in nature, but apparently not related, the former being a design flaw (which has been corrected) in a newer installed equipment, and the latter being likely due, at least partially, to the aging of the equipment. PAC notes that the aging infrastructure is an on-going concern and encourages the laboratory to maintain a robust set of preventive maintenance activities.

Although the commissioning of the upgraded MR remains incomplete, the PAC congratulates the laboratory in achieving the acceleration of a 750 kWeq pulse, with good prospects of establishing 750 kW user operation within JFY2023 and delivering 8-GeV bunched SX for COMET, which succeeded in achieving much of the aims of its test phase (phase-α). In addition, 30-GeV SX with 5.2-s cycle at 50 kW with extraction efficiencies of 99.5% was demonstrated. PAC was also pleased to hear that steady progress is being made towards the aim of 1.3-MW beam power in 2028. In the Hadron Hall, the current target can handle the 80-kW beam power planned for the near future (current maximum 50 kW) while a new target capable of handling >150 kW is being developed.

We turn now to the recommendation of the assignment of available beamtime from the end of the current shutdown, mid-November 2023, to the summer shutdown 2024. Given the uncertainty of the start of the HEF operation, as well as the interruption for the air-conditioner renewal in MLF, which will interrupt the beam for about 1 month, and some pause requirements for data taking in the beam requests, we believe it is not too useful to give any details about the sequence and timing of specific activities. Instead, we give priorities and recommended timing allocations.

With much of the work recommended in the last PAC not completed, the first priorities remain the same as at the last PAC meeting. These are the full establishment of the FX and SX beam operations, followed by the neutrino beam commissioning (T2K request of ~1 cycle), what remains of the COMET phase-α(6.5 days), S2-S spectrometer commissioning (E70 request of 7.5 days), and high momentum beam tests (E16 request). We believe these can be largely achieved within the period corresponding to the already allocated beamtime after mid-November 2023 beam start and mid-February 2024. It is likely, however, that these activities require approximately one extra week beyond the mid-February allocation.

Next, we discuss the allocation of the 4.5 cycles of new beam planned to be made available to users between mid-February and the summer shutdown in July 2024. This 4.5 cycles will likely be somewhat shortened (by ~0.2 cycles) by the residual work from the first priority items discussed in the previous paragraph, making the availability of beam closer to 4.3 cycles.

Beam requests to this PAC (beyond the first-priority items discussed above) are as follows: T2K (1.5 cycles for detector commissioning with data taking in parallel + 2 cycles of data taking with new ND280; total of 3.5 cycles), E73 (1.15 cycles of data taking), E70 (1.25 cycles of data taking). These three requests cannot run concurrently since they take place in NU, K1.8Br and K1.8 beamlines respectively. The request from KOTO of ~1 cycle of data taking with the new magnet can run concurrently with E70 or E73. This amounts to almost 6 cycles of requests compared to 4.3 cycles available.

The PAC recommends that the laboratory balance the need to make progress in the HEF program in view of the planned HEF extension in 2026, with the needs of T2K to commission the new configuration and take as much data as possible. The PAC recommends that T2K be allocated 2.3 cycles to be shared between detector commissioning and data taking. E73 and E70 are recommended to be allocated 1 cycle each for data taking with higher priority on E73. KOTO can take data during the E70 and E73 allocations.

The PAC emphasizes that given the uncertainties of the HEF availability and various requirements from the experiments, the above discussion does not imply a chronological order. We recommend the laboratory to devise a detailed schedule to accomplish the program discussed above when the constraints become better known.

Good news is that the electricity price has reversed its steep rise since last April and is now back down to the level of one year ago. It is to be hoped that this trend will continue so that longer operation at J-PARC becomes possible. PAC was happy to hear that J-PARC continues to make improvements on the environment for the users such as new transportation options and continued progress on the direct access road.

5. DATES FOR THE NEXT J-PARC PAC MEETING

The next J-PARC PAC meeting will be held around the middle of January, 2024.

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

- Minutes of the 35th J-PARC PAC meeting held on 23-25 Jan., 2023 (KEK/J-PARC-PAC 2023-7)
- Proposals:
    - Study of Discrete Symmetries in Polarized Epithermal Neutron Optics (NOPTREX: Neutron Optical Parity and Time-Reversal Experiment)(KEK/J-PARC-PAC 2023-9)
    - Fundamental Physics with Pulsed Cold Neutrons (KEK/J-PARC-PAC 2023-10)
- Letter of Intent:

Study of the bump structure at 1680 MeV by the $\pi^- p \to \eta n$ reaction at p_π=0.7 to 1.2 GeV/c (KEK/J-PARC-PAC 2023-8)