Short Minutes of the BVR 53

Meetings of 24 – 28 January 2022

1 Meetings of the Committee

closed meetings:	Wednesday, January 26, from 16:00 – 17:15 Thursday, January 27, from 15:30 – 19:30
present:	L. Baudis D. Bryman G. Colangelo (Wed) C. Curceanu B. Filippone (chair) G. Greene C. Hoffman P. Kammel St. Passaggio M. Ramsey-Musolf (Wed) P. Riedler B. Sauer A. Signer (secretary) U. Uwer
beam time coordinator:	St. Ritt
ex officio:	K. Kirch
apologies:	G. Colangelo (Thu) M. Ramsey-Musolf (Thu)

2 New Proposals

In addition to beam requests for ongoing experiments and student practicals, two new proposals, an LoI and several test-beam requests were submitted. This lead to a substantial over-subscription of all three beamlines.

R-22-01.1: Studies of rare pion decays (PIONEER) (D. Bryman, D. Hertzog, T. Mori *et al.*)

The PIONEER proposal aims to significantly improve the precision of the measurements of the rare pion decays $\pi^+ \to e^+ \nu(\gamma)$ (phase I) and $\pi^+ \to \pi^0 e^+ \nu$ (phases II and III). The theoretical motivations for these measurements as tests of the Standard Model are very strong and have become more urgent in recent years in connection with possible violations of lepton

universality and CKM unitarity.

This is an ambitious, long-term project with a strong collaboration. We note that πE5 at PSI is the only appropriate facility in the world for these measurements. We enthusiastically support this proposal with high priority and recommend two weeks of beam time in πE5 for beam studies to aid the design of the active target. To be compatible with other requests, the two weeks are scheduled early in the year, before the MEG beam time. We also recommend that PSI establish a technical review committee to monitor and guide the development of this project.

R-22-02.1: A next generation atomic physics and gravity experiment using muonium atoms (LEMING) (A. Soter *et al.*)

The LEMING group made promising progress in last year's beam time. They observed significant vacuum muonium flux emerging from SFHe and measured a 20% conversion rate from muon to muonium emitted into vacuum. They confirmed the fast diffusion model of muonium in SFHe and estimated the chemical potential.

The phase 1 objectives include characterization and optimization of the cold muonium beam, development of a horizontal muonium beam for interferometry, development of the muonium interferometer, and development of methods for spectroscopy. The committee endorses the phase 1 objectives and recommends approval.

Subsequent phases of the experiment will be evaluated based on results obtained. Because the realization of a gravity interferometer experiment requires the successful operation of a photon interferometer that is compatible with that proposed for muonium, progress on this effort will also be considered in the consideration of future phases.

We recommend that the group receive 2.5 weeks in πE1 in 2022 as requested.

R-22-03.1: Electrostatic Time Dilation (H. Landman *et al.*)

This experiment searches for a variation of the muon lifetime as a function of electrostatic potential. The theoretical motivation behind these attempts is unconvincing and requires significant speculative leaps (like the extension of the equivalence principle to electrodynamics), with the final outcome of dubious theoretical value. Even if the theoretical motivation were well-justified it is unlikely that the muon lifetime study is the most sensitive approach. The systematic errors were also not discussed, which could endanger the claim of the precision of the measurement. The use of several weeks of oversubscribed muon beam time does not appear to be a reasonable investment. Beam-time allocation is therefore not recommended.

Test: TIMESPOT Detectors (A. Cardini *et al.*)

This is a continuation of tests in 2019, 2020 and 1 week at πM1 is recommended.

Test: CMS diamond detectors (D. Hits *et al.*)

This test beam is recommended for 1 week in πM1 near the beginning of the cycle. The requested 2nd week is likely only possible if it is carried out in the June - August time frame and if an unused slot becomes available.

Test: muSR pixel (F. Meier *et al.*)

This test beam is recommended for πE5 assuming that it is included at the end-of-year Mu3e πE5 beam time and assuming that the Mu3e time is scheduled.

Test: UCN detectors (D. Ries *et al.*)

This test beam is recommended for the requested 2 weeks in UCN W, assuming it has no negative impact on the n2EDM experiment.

Test: UCN storage (D. Ries *et al.*)

The aim is to measure the storage property of an aluminium bottle as a function of energy. Assuming it has no negative impact on the n2EDM experiment, this test beam is recommended for the requested 2 weeks in UCN W.

3 Progress Reports and Beam Requests

R-99.05.2: Search for $\mu^+ \to e^+ \gamma$ (MEG II) (T. Mori, A. Baldini *et al.*)

MEG II remains at the forefront of the laboratory's muon physics program. Despite the persisting pandemic, 2021 was a breakthrough year for the collaboration. MEG II ran in physics mode for the first time with all detector components in stable operational conditions and the full readout and trigger chains in place. The last part of the allocated time in the experimental area was used, as planned, for calibrating the LXe calorimeter and monitoring the stability of its photo-detectors through the charge exchange reaction $\pi^- p \to \pi^0 n$.

The existing drift chamber (CDCH) was successfully operated in 2021 for the whole year, with no broken wires. It operated with stable currents at nominal gain and at beam intensities up to the nominal MEG II value. This is largely due to the use of the gas mixture that had been optimized at the end of 2020.

Further progress includes the trigger with all components successfully installed and commissioned. Also the final release of all versions of the WaveDreamBoard have been produced and installed. In addition, the DAQ efficiency as well as the the position resolution in the LXe calorimeter were improved.

The main area of concern remains the persistent degradation with beam of the photon detection efficiency (PDE) of the multi-pixel photon counter (MPPC) used for scintillation

light detection on the inner surface of the LXe calorimeter. Annealing has been proven effective in regaining the MPPC PDE to its original level, but this cure will have to be applied at the beginning of each data-taking year. For 2022 two annealing approaches are planned: warm water circulation in the nitrogen refrigeration pipes of the detector and Joule heating.

The committee supports the adoption of due care in the first implementation of this delicate procedure, but encourages the collaboration to make an earlier start. We request a report on the outcome of the first months of annealing not later than April.

INFN has granted the collaboration full funding for the construction of a new drift chamber (CDCH2). The design is finalized, using thicker 50 μm diameter Al wires, Ag coated but not 'ultrafinished' as well as strict control of the humidity in all phases of construction, transport and operation. The material procurement is under way, and all tools, infrastructure and workforce for constructing the new chamber are in place. The delivery of CDCH2 at PSI is expected in time for the 2023 run, although a final decision on which chamber to use from then on will be taken only after the experience gained in this year's run.

Preliminary estimates of the detector performance show significant improvements over the first phase of MEG, but also a significant loss relative to the upgrade goals, in particular for the calorimeter energy resolution, with consequent impact on the projected overall sensitivity.

The committee recommends initial approval for 24 weeks. Before deciding on the remaining 3 weeks of requested beam time, PSI – in consultation with the committee – requests a report in September on detector performance and expected sensitivity for the 2022 run time.

R-05-03.1: Measurement of the neutron EDM (n2EDM) (B. Lauss, G. Pignol *et al.*)

The n2EDM experiment has made good progress since their previous report. The thermohouse is finished and working close to the desired temperature stability. All aspects of the magnetic field system have met or exceeded their specifications for the experiment.

Progress has also been made on the other components of the experiment that are necessary to finish the construction. The precession cell is being fabricated and the DAQ system is progressing well. The vacuum tank is complete but its magnetism is not fully tested. The Cs magnetometers are constructed but will need installation and calibration. The Hg magnetometer design is not yet finalised. This appears to be the limiting critical component, but in fact other parts of the experiment need to be finished on a similar time scale. Compared to the BVR52 n2EDM report the completion of these components has slipped by a few months. This should not be a serious problem, but extra resources might need to be devoted to some subprojects in the coming year. The UCN guides and switch are still to be completed and tested. The new annealing procedure for the moderator is very promising.

While the flapper vacuum failure in the UCN source is not a limiting problem in its present condition, a progressive failure could have serious implications for the n2EDM experiment. As the UCN source is obviously essential for this experiment, we strongly encourage the collaboration to work with PSI to start the design process for a UCN insert replacement as soon as possible and report to the BVR next year on its progress.

R-08-01.2: Search for muon catalysed d^{3}He fusion (P. Kravchenko *et al.*)

This experiment is measuring the rate for muon-catalyzed $d\,^3$He fusion, which is of astrophysical interest, using the MuSun detector. The group took data in 2021 but the muon beam rate was lower than anticipated so they are requesting 4 weeks of data taking in 2022 in πE1. We recommend 4 weeks of beam in autumn 2022 immediately preceded by one week to prepare the target gas. This should conclude data taking for this experiment, and we look forward to a successful measurement.

R-12-01.2: Studying the "Proton Radius Puzzle" with μp elastic scattering (MUSE) (E. Downie, R. Gilman *et al.*)

The MUSE experiment made great progress in refining their apparatus in 2021 despite the very significant challenges generated by Covid. At the end of September, the apparatus was moved into the πM1 area and recommissioning began. In November, the hydrogen target was cooled down and approximately 5 weeks of production data at 115 MeV/c was taken.

Hydrogen target operation was hampered by control logic failures. The safety system demonstrated that it responds exactly as expected and provided a graceful failure mode. Still, the committee would like to be assured that PSI has reviewed and approved any mitigation strategies which have been implemented.

The straw tube trackers also suffered a serious failure due to a software issue. While the committee is pleased by the mitigation strategy that incorporates a hardware HV gas pressure interlock system, this is of sufficient concern that the committee believes it would be appropriate for PSI experts review the new interlock system.

Among other refinements to the apparatus was the expansion of the calorimeter and the repair of the PMT glue joints. All in all, the apparatus seems very close to meeting all the equipment requirements and is likely to be ready for data collection sometime in 2022.

In the BVR52 report the committee made a very specific recommendation that MUSE should perform a sufficient degree of analysis on real data. While MUSE has largely delivered on commissioning of all hardware components and has provided a thoughtful plan for personnel readiness, it has not yet provided the requested analysis of real data. The committee believes that it is incumbent on the collaboration to demonstrate that the data to be collected is capable of being analyzed to provide a physics result meeting the design goals of the MUSE project. This implies that, at a minimum, a limited data set of real data be analyzed to provide a physics measurement.

The committee therefore recommends that MUSE be allocated up to 18.5 weeks of beam time on πM1 in 2022, in two segments. However, the committee also recommends that no additional beam in 2023 be allocated until MUSE has presented an analysis of actual data. This analysis should be of sufficient refinement that it produces a physics measurement that can be compared with a theoretical expectation. More specifically, the committee asks that MUSE provide an updated hardware readiness report by 30 June 2022 and the analysis report, as described above, by 01 December 2022.

R-12-03.1: Search for the decay $\mu^+ \to e^+ e^- e^+$ (Mu3e) (A. Schoening, St. Ritt *et al.*)

The committee commends the Mu3e collaboration for achieving several milestones in 2021, including a first operation of the helium cooling system, several beam tests of sub-detectors, the verification that MuPix10 fulfills all specifications apart from corrections implemented in the final version MuPix11, and a successful first integration run with a partial Mu3e detector installed in the newly commissioned solenoid.

The beam could be focused on target, but significant beam intensity was lost upstream, which needs to be eliminated by further optimization of the compact muon beamline (CMBL) in 2022. A major goal for 2022 is readiness for mass production demonstrated by an integration run at the end of the year. This beam time will be prepared with extensive cosmics running performed with a new staging setup, where detectors can be installed, operated and cooled, thus providing an essential debugging and optimization platform.

The MuPix11 commissioning plan is very ambitious, from receiving chips at the end of April all the way to potentially employing MuPix11 ladders in the requested integration run in November. This integration run will serve as a milestone before starting mass production and involves a realistic detector installation with beam, where at least some prototypes of all detector systems are present and working. This requires significant electronics design and commissioning for the tile and SciFi subsystems, which were not operational during the 2021 beam time. In addition, recent irradiation tests indicated a dramatic increase of the dark current and noise in SIPMs used for tile and SciFi, requiring late-stage modifications. The committee would like to see simulations of the expected radiation dose for all critical detector elements including electronics. Moreover the effect of the increased dark-count rate on the SciFi performance should be simulated.

The committee recommends allocation of the two beam requests in πM1. However, there remains a conflict regarding the requested beam time in πE5 at the end of the year. To alleviate this, we recommend scheduling the CMBL studies at the beginning of the 2022 beam time.

While the committee considers the 4 weeks integration run an important milestone, it is in conflict with the MEG II request. To address this issue, the committee requests a report from Mu3e about the MuPix11 commissioning run by early July. Based on this and the reports from MEG II, the schedule in πE5 for the final weeks of 2022 will be coordinated by PSI.

R-16-01.1: Measurement of the charge radius of radium (MuX) (A. Knecht *et al.*)

We congratulate the MuX collaboration on the publication of the first physics results on the quadrupole moments of ^{185}Re and ^{187}Re. We are also pleased to see the improved understanding of the gas cell and the simulation of the transfer process, along with the proof-of-principle measurement with the $5\,\mu$g Au target. Since no muonic X-rays in ^{226}Ra were identified this measurement must be repeated, with improved radioactive targets.

The main plans for 2022 are to work towards improved targets using the conventional method, and in particular also to test an implantation method with a glassy carbon backing. This method might allow the collaboration to expand the measurements towards using low-Z

elements, starting with the stable ^{39}K isotope. A first implanted K target could be measured in 2022, as a feasibility test, together with the Au targets. If successful, ^{226}Ra as well as lower Z targets could potentially be measured in 2023.

The collaboration requests 3 weeks of beam time in 2022 in the πE1 area, ideally in conjunction with MIXE and R-20-01.1 to operate common Ge detectors. The committee recommends that MuX receive 2.5 weeks of beam time with a focus on Au target studies. The low-Z studies are recommended only if there is remaining time.

R-20-01.1: Ordinary muon capture as probe of properties of double beta decay (D. Zinatulina *et al.*)

The collaboration was strengthened and reported impressive progress for 2021. A new setup consisting of eight main Ge detectors was successfully used and the DAQ was upgraded into two independent data collection systems. Several preliminary spectra of nuclear gamma rays following muon capture demonstrate good detector performance and progress in the physics data analysis. In addition to the in-beam measurements, delayed gamma spectra of long lived nuclear states were observed in a low background set-up.

The collaboration plans to continue its program with the measurement of muon capture on ^{100}Mo, relevant for studying the nuclear response for neutrinoless double beta decay and astrophysical neutrino detection. The requested 2 weeks of data taking is recommended for approval with additional set-up time to be coordinated with the MuX experiment.

R-21-01.1: Search for neutron to mirror-neutron oscillations (N.J. Ayres *et al.*)

The n-n' experiment ran through a large part of 2021 using the UCN source, and the collaboration is to be commended for a successful data run. Data analysis is currently underway and the collaboration believes it has enough data to test for n-n' transitions at the requisite sensitivity over the desired parameter space.

The collaboration believes it would be useful to gather more detailed information concerning the magnetic field distribution, as well as the UCN distribution, over the storage volume. Hence, the collaboration would like to keep the apparatus in place in order to do additional field mapping. They also request 2 weeks of UCN production to measure the UCN distribution in order to validate the Monte Carlo velocity distribution simulations. The committee supports this beam time request under the condition that it does not interfere with n2EDM efforts.

R-21-02.1: Search for a muon EDM (P. Schmidt-Wellenburg *et al.*)

The muon EDM experiment presented a phased approach to ultimately achieve 3 orders-of-magnitude improvement in the sensitivity to the muon EDM. In the first phase, an existing magnet would be used to reach $3 \times 10^{-21}\,e$cm. The second phase would require a new superconducting magnet and detection hardware to reach $6 \times 10^{-23}\,e$cm. To begin the approach to phase 1, the collaboration has requested 2 weeks of beam time for testing a prototype of the muon entrance trigger concept and testing a prototype TPC muon tracker. While the proposal

has not reached approved status yet, the committee recommends 1 week in πE1 at the end of the cycle for testing the trigger concept and, if this is feasible for the collaboration, 1 week in July in πM1 for testing the TPC prototype.

R-21-03.1 Diamond anvil muon catalyzed fusion (A. Knaian *et al.*)

The committee is pleased to see the progress achieved by the collaboration during 2021, in particular the installation of the anvil setup at the πE1 beamline and the outcome of the measurements which were performed to characterize the various components of the setup. A series of improvements needed for the measurement were identified after the run.

The collaboration did not present a full technical design of the experiment and a proposal for measurements, as specifically requested at the BVR52. The committee reiterates the request for a proposal to be presented at the BVR54 which should include a detailed discussion of the technical design of the experiment and the status of the needed hardware. A main emphasis of the proposal should be a global assessment of the experiment's reach. This proposal should discuss the measured properties of the beam and background, define the analysis method, estimate signal and background from data and full Monte Carlo simulation and demonstrate the resulting sensitivity and uncertainties. Given that the experiment has not reached approved proposal status, the committee recommends allocation of 2 weeks of beam time.

4 Miscellaneous

Due to Covid the meeting was held remotely and extended to a full week.

5 Next Meeting

The next meeting (BVR 54) is again planned as a 3-day meeting and will take place from 23–25 January 2023 which will be extended to 27 January in case the meeting is remote. The deadline for proposals and beam time requests is 10 January 2023.

March 17, 2022 B. Filippone, A. Signer