Short Minutes of the BVR 56

Meetings of 10 – 12 February 2025

1 Meetings of the Committee

closed meetings:	Tuesday, February 11, from 09:00 – 12:15 Wednesday, February 12, from 09:00 – 12:00
present:	S. Bacca L. Baudis D. Bryman G. Colangelo C. Curceanu F. Farget B. Filippone (chair) C. Hoffman M. Iodice M. Jentschel P. Kammel M. Ramsey-Musolf P. Riedler B. Sauer A. Signer (secretary) U. Uwer
beam time coordinator:	St. Ritt
ex officio:	K. Kirch
apologies:	none

2 New Proposals

While there were no new proposals for this year, two test-beam requests and one LoI were submitted in addition to the requests of the approved experiments. This led to a substantial overbooking, in particular in πE1. In 2026, πM1 will be closed early for the long shut down, but the proton machine should run until end of 2026.

LoI: Pionic Helium (M. Hori *et al.*)

This group submitted a letter of intent aimed at studying metastable pionic helium synthesized in a superfluid helium target. The ultimate goal is an accurate measurement of the π^- mass with a relative precision of 10^{-9} with implications for the muon antineutrino mass.

No beam request was made this year but the plan is to use the πE5 beam line in the future. To reduce pile-up effects, a modification of the timing structure of the cyclotron beam is suggested, briefly chopping the proton beam. They also request that beam tests be carried out to characterize the π^- beam of momentum 50–60 MeV/c regarding its time structure, intensity, and e^- and μ^- contamination.

Although this proposal is interesting it may be difficult to schedule in πE5 due to high-priority projects coming online. Nevertheless, it would be worthwhile to consult the accelerator group to determine the feasibility of the proposed beam extinction. A more comprehensive proposal, including a thorough discussion of the motivation would be needed for further consideration.

Test: MicroTPC (C. Gustavino *et al.*)

This is a detector test of a so-called microTPC built from a package of microRWELL detectors. The detector is foreseen for an experiment at CERN to search for the X17 Atomki signal. The goal of the test is to characterize the 3D tracking performance of the microRWELL detector with an enlarged drift area. The request of 1 week at πM1 is supported.

Test: RadMap (M. Losekamm *et al.*)

This experiment aims to test radiation detectors designed to fly on the International Space Station. The test is to be undertaken using pions in πM1. The committee recommends the requested 1 week at πM1 but for scheduling reasons the test needs to run in the middle of the cycle.

3 Progress Reports and Beam Requests

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

The collaboration reported on the progress of the data taking in recent years in terms of accumulated muons on target, showing the success of 2022 and 2023. Unfortunately, in 2024 most of the allocated beam time was lost due to a failure of the cryoplant that prevented the operation of the beam transport line to MEG II.

During the 4 weeks in 2024 where MEG II could take data, the experiment ran well, despite some minor problems. A LXe leak developed in the calorimeter (with the Xe successfully recovered) and was subsequently fixed. Additionally, an unrelated incident involving a faulty gate valve resulted in a loss of 34 litres of xenon. However, sufficient xenon was available to compensate for the loss. The successful and stable operation of the CDCH was also noted.

The collaboration is almost ready to unblind the combined analysis of the 2021 and 2022 data while simultaneously working on the analysis of the 2023 data. In addition, two ancillary measurements were made. First, the process $^7\mathrm{Li}(p, e^+e^-)\,^8\mathrm{Be}$ was studied using the Cockcroft

Walton. No significant excess of events was observed, excluding the X17 Atomki observation at 94% CL. Further investigations are planned to make distinct studies of the two resonances at 17.6 and at 18.1 MeV. Second, using calibration data taken for 9 days at low photon energy ($E_\gamma > 14\,\mathrm{MeV}$) and low muon beam rate ($\sim 10^6$/sec) a search $\mu \to e + \gamma$+ALP was performed.

The collaboration's request for beam time has been motivated by the projected sensitivity. With the assumption of full beam time assignment at πE5 for the years 2025 and 2026 the experiment would reach the sensitivity goal of 6×10^{-14} before the HIPA shutdown at the end of 2026. The committee recognizes the importance of collecting as much data as possible to fully exploit the experiments good condition. Thus, the committee recommends 26 weeks of beam time for MEG II, with 3 weeks reserved at the beginning for Mu3e.

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

The n2EDM experiment has made tremendous progress in the past year and is now very close to starting data collection. The Cs magnetometer array is the main hardware system still to be completed. The aim is to have half of the system completed in 2025, with the remainder ready for the 2026 data run. This requires time consuming testing for magnetic contamination, but appears feasible. The collaboration has made great strides in increasing the stored neutron number, with reasonable plans to address the remaining shortfall. Other technical issues seem straightforward to address. The committee recommends the full beam-time request be approved.

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

The MUSE experiment made considerable technical progress in 2024 towards their goal of determining the proton charge radius from elastic scattering of electrons and muons. The systematic variation of flavour and charge provides a unique check on a wide range of physics including the study of radiative corrections and details of two-photon exchange. Hence, this remains an interesting and important experiment.

In the last year MUSE operated with a very high uptime and efficiency as they acquired 6×10^9 additional scattering events to complement their 3×10^9 events from the previous 2 years. This leaves a further 6×10^9 events to be collected to reach their design goal. While progress continues on understanding data quality and performing the detailed blinded analysis, the committee noted that the workforce size committed to analysis is less than optimal. With some minor hardware improvements the experiment appears to be ready to acquire the remaining data with high efficiency. The committee recommends that MUSE be given a total of 22 weeks at πM1, split into two blocks, to hopefully complete their data taking goals.

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

Mu3e has reached a significant milestone with the successful assembly of the first complete vertex MuPix detector with an improvement in the yield of tested chips. As a result, the

vertex detector #1 is now ready for installation into the test cage and for commissioning with cosmic rays. Furthermore, the committee acknowledges the remarkable progress made in services and infrastructure installation during the unexpected πE5 downtime caused by the helium cryomodule failure in 2024. The collaboration is requesting a six-week engineering run of the detector, incorporating the vertex detector #1, a complete SciFi tracker, and several downstream SciTile modules. This engineering run would, for the first time, integrate numerous critical detector components, services, beam properties, cooling and the readout system into a comprehensive test. Notably, it would serve as a final verification of the innovative MuPix system with valuable information for the construction of the final vertex detector #2 and the outer central tracker. Prior to the 2025 beam time allocation, the committee requests two status updates from the Mu3e collaboration:

1. A demonstration of four-plane cosmic tracks in the test cage setup with vertex detector #1 along with a detailed installation and commissioning schedule of the detector in πE5. Both of these reports are expected by the end of March.

2. A report should be submitted before the planned beam time on the status of the experiment relative to the installation plan to ensure that the new detector is ready for efficient operation. The details needed in the second report and the due date will be presented in the detailed subcommittee report.

Beam-time allocation of 3 weeks at πE5 is contingent on readiness demonstrated in these reports. The additional request of 1 week in πM1 is recommended.

With respect to the 2026 program, the committee acknowledges the significant progress but remains concerned about the tight and highly critical timeline. Consequently, scheduling decisions for 2026 will depend on Mu3es readiness at BVR 57. The committee reaffirms its full support for Mu3e as a future flagship experiment at PSI.

R-14-02.1: Development of High Intensity Muon Beams (muCool) (A. Antognini *et al.*)

In 2024, the muCool experiment made substantial progress towards the extraction of thermal μ^+ through a small orifice. The primary objectives included demonstrating mixed cooling in the presence of the required He gas refilling flow and investigating the extraction process. Overcoming the challenges associated with extraction necessitated a significant upgrade, effectively requiring a near-complete redesign of the muCool experiment. Through innovative and dedicated efforts, the team successfully completed this major upgrade project. However, the final target used in the test run did not fully meet the specified criteria in several aspects. The committee acknowledges the considerable progress made but requests that the collaboration demonstrates and, in a readiness report, documents the stable operation of the entire experimental system at least one week prior to the allocated beam time. It recommends approval of 3 weeks in πE1, contingent to the condition mentioned above.

R-19-01.1: Laser Spectroscopy of Muonium (MuMass) (P. Crivelli *et al.*)

MuMass is an experiment that aims to improve the precision of the 1S-2S transition measurement in muonium, leading to an improved determination of the muon mass while providing several related QED tests. As this experiment currently runs in the LEM area, it is outside the purview of this committee, but it is strongly endorsed. The physics addressed by MuMass is of great interest and future running may be requested in πE1. Thus the committee should remain informed about the progress and plans for this experiment.

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

The committee applauds the collaboration for their extensive program of planning and modelling, along with the success of their 2024 beam time. The muEDM experiment has started a period of hardware construction, with the ambitious goal of a first muon EDM measurement in 2026. Some parts of the experiment can be tested off-line, with four tests planned which require muons. These are 1) a test of injection into spiral orbits. This is a verification of the magnetic correction coils which modify the solenoid field. The success of this test will allow testing of 2) the muon spin orientation using a stopping target, and 3) the stopping efficiency of the kicker which puts muon into a trapped orbit and 4) the cylindrical helix $e^{\pm}$ tracking system. The committee recommends 2 weeks of beam time in πE1, leaving the collaboration to determine which tests are most critical for the experiment.

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

The committee acknowledges the substantial advancements made by MuFusE (formerly Anvil) in 2024. During the two-week beam period at πE1, MuFusE successfully completed various cycles of cryostat cooling, liquid hydrogen loading, ultra-high pressure compression, and data acquisition. The collaboration achieved a record pressure of 930 MPa, more than four times higher than any previous experiment, while ensuring safe tritium operations in compliance with PSI and Swiss regulatory requirements. The experiment produced various high-statistics data sets, with strong evidence of muon catalyzed fusion events. The committee encourages the collaboration to complete the data analysis and to publish initial results. For 2025, MuFusE proposes an extended measurement campaign focusing on deuterium-tritium fusion-rate measurements spanning over a broader range of temperatures, densities, and isotopic fractions with various technical improvements. The committee recommends allocating 3 weeks of beam time at πE1 in 2025.

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

The committee reiterates its strong support of the PIONEER experiment. The experiment was already approved for operation at PSI and due to the high-impact science case is seen as a long-term future flagship experiment at πE5. The committee congratulates the collab-

oration on the impressive progress since the last meeting on several fronts: simulation and analysis, beam characterisation, R&D on the active target (ATAR) and tracker, the two explored calorimeters (LYSO vs. LXe), as well as on the electronics and DAQ. The committee is also pleased to see a solid collaboration structure in place, and the decision trees based on key performance parameters. The committee looks forward to the readiness of the three (ATAR + 2 calorimeter) demonstrators at BVR 57, and would appreciate seeing a plan for how and when the collaboration will decide between the LXe and LYSO crystal calorimeter.

The PIONEER collaboration requests one week at πE5 to directly measure the phase space of the beam and inform several aspects of the downstream detector design. The committee recognizes the importance of this test but can only support it in 2025, if MEG II is unable to use the beam. The committee requests a readiness report for the phase-space beam test by early June. If no beam time at πE5 can be allocated in 2025, an allocation in 2026 will have high priority.

The collaboration also requests one week at πM1, prior to the student practicum, to test the new LYSO calorimeter with tapered crystals in the beam for the first time. This will provide valuable data towards the selection between the two calorimeter techniques. This request is approved.

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

The LEMING group has made good progress in the development of an experiment to study gravitational free fall of cold muonium atoms. They have observed muonium beam emission through micron-wide slits and developed an interferometer prototype. In addition they commissioned a cryogenic silicon strip detector prototype and detected low-energy atomic electrons from a field emission gun using a transition edge detector. Monte Carlo simulations for diffusion and surface emission processes of muonium in SFHe have also been developed. The committee recommends 3 weeks of beam time in 2025 in the πE1 area to demonstrate methods for muonium interferometry on the micron scale and to commission the system to be used for initial LEMING measurements. Following this run, it is expected that a TDR will be prepared along with a new proposal.

R23-01.1: Precision measurement of the neutron lifetime (τSPECT) (M. Fertl, D. Ries *et al.*)

This experiment uses a large UCN magnetic trap to make precise measurements of the lifetime of the free neutron. In the last year the collaboration demonstrated enhanced UCN densities with a sophisticated UCN loading scheme and acquired sufficient statistics to provide a measurement with a 1 s uncertainty. Because the neutron loading, storage, and detection used here differ from earlier experiments, this will be an important check on systematic effects. The committee had some concerns regarding the size of workforce for operating the experiment as well as doing a detailed and thorough analysis. The committee recommends the requested

beam time and expects the collaboration to continue working closely with n2EDM for allocating the available UCN with priority given to the successful operation and running of n2EDM.

R23-02.1: Charge radii measurements of light nuclei using muonic X-rays (QUARTET) (B. Ohayon, N. Paul, L. Gastaldo *et al.*)

QUARTET aims to perform high-precision 2p to 1s X-ray transition measurements in various light muonic atoms (from Li to Ne), pioneering the use of metallic magnetic calorimeter (MMC) detectors in exotic atom spectroscopy. In 2024, they successfully conducted a two-week data acquisition campaign at πE1, utilizing Li, Be, and B targets. The experiment demonstrated high operational stability, with the MMC detector system running stably for over 90% of the available beam time and implemented advanced calibration techniques. A preliminary analysis indicates that the statistical precision of the 2024 data set should allow for a substantial improvement in the charge radii determination of the studied isotopes.

For 2025, QUARTET proposes to measure the 2p to 1s transitions in C, N, and O isotopes, aiming for an order-of-magnitude improvement in charge radii determination. This measurement campaign will utilize newly fabricated MMC detectors with enhanced absorber thickness.

The committee acknowledges QUARTETs significant progress in 2024, commends the collaboration for its technical advancements and recommends a careful data analysis to extract radii from the 2024 measurements. The committee supports 1.5 weeks in πE1 and recommends that the group submits a readiness report for the new detector to PSI in advance of the beam time.

R-23-03.1: Charge radii measurements of medium to heavy nuclei using muonic X-rays (ReferenceRadii) (T. Cocolios *et al.*)

The goal of the ReferenceRadii project is to apply muonic X-ray spectroscopy to doublets or triplets of isotopes to determine their absolute charge radii and help benchmark laser spectroscopy measurements. The main experimental challenges include producing the appropriate targets and performing precise energy calibrations in the energy range of the various isotopes.

The committee congratulates the collaboration on their recent achievements and on proving the feasibility of using implanted targets with potassium and gold. We look forward to the radius extraction of ^{35}Cl and ^{37}Cl and to the analysis of the data on the other isotopes collected in 2023 and 2024. The committee is also interested in seeing the results from the lead-gold-water target used as calibration lines for the heavy element investigations at BVR 57.

The collaboration requests 2 weeks of beam time at the πE1 beam line with the MIXE experimental setup to study the muonic X-rays of the isotope triplet ^{137,138,139}La. This would represent a sensitive benchmark for laser spectroscopy via absolute measurement. The argument to use the data for constraining nuclear models of proton emission of ^{114}La was less convincing, as measurements are taken many neutron numbers away.

The committee acknowledges the scientific impact of the proposal for nuclear structure and the importance of absolute measurements obtained with muonic spectroscopy. However, due to

the high demand on the πE1 beamline, no beam time could be granted in 2025. The committee anticipates a new beam request for 2026 that includes the expected improved apparatus and we look forward to seeing the first results from the analysis of the existing data.

R-16-02.1 Hyperfine splitting in muonic H and He (HyperMu) (R. Pohl, A. Anognini *et al.*)

During the focused reviews on Monday Feb 2, the committee heard from the CREMA (Charge Radius Experiment with Muoninc Atoms) collaboration about their plans for future running. Their near-term goal is to measure the hyperfine splitting in atomic hydrogen to $\sim$ 1ppm, providing important information on nuclear structure effects (including the Zemach radius) that would allow improved tests of QED. This is a well-motivated experiment with a strong collaboration that has made significant technical progress on the challenging high-power laser system, a multi-pass cavity to enhance the photon fluence and the X-ray detection system. The collaboration indicated that they are likely to ask for 8 weeks of beam time in 2026 for this measurement in πE5, which is, of course, in high demand. The committee strongly supports this effort and looks forward to the CREMA beam request at BVR 57.

4 Miscellaneous

Sonia Bacca, Fanny Farget, and Michael Jentschel were welcomed as new members of the BVR committee. Last year's BVR 55 was the final committee meeting for Geoff Greene. This year, there were extended reviews on Monday for MuEDM, Mu3e, and PIONEER with a shorter session for MEG II and HyperMu.

5 Next Meeting

The next meeting (BVR 57) is again planned as a 3-day meeting and will take place from Tuesday to Thursday, 03–05 February 2026. The deadline for proposals and beam-time requests is 16 January 2026.

March 17, 2025 B. Filippone, A. Signer