Short Minutes of the BVR 54
Meetings of 23 – 25 January 2023

1 Meetings of the Committee

closed meetings:	Tuesday, January 24, from 09:00 – 12:30 Wednesday, January 25, from 09:00 – 12:00
present:	G. Colangelo C. Curceanu B. Filippone (chair) G. Greene C. Hoffman P. Kammel St. Passaggio B. Sauer A. Signer (secretary) U. Uwer
beam time coordinator:	St. Ritt
ex officio:	K. Kirch
apologies:	L. Baudis D. Bryman M. Ramsey-Musolf P. Riedler

2 New Proposals

In addition to beam requests for ongoing experiments and student practicals, two Letters of Intent (LoI), four new proposals, and one test-beam request were submitted. This corresponds to a potential significant over-subscription of all three beamlines, in particular on πE1.

R23-01.1: tSPECT (M. Fertl *et al.*)

This LoI proposes to perform a new neutron lifetime experiment using a UCN storage bottle with precision competitive with previous results. As the neutron loading and storage used here differs from earlier experiments, this will be an important check on systematic effects.

For this year's request, the proponents plan to install their apparatus and test storage properties and systematics and optimize the use of UCN W1. The committee is pleased to see a new high-impact experiment being developed for PSI's intense UCN source and recommends the requested beam time, with the caveat that this activity should not interfere with the

commissioning and running of n2EDM. We look forward to a full proposal including lessons learned from this year's beam time.

R23-01.2: QUARTET (B. Ohayon *et al.*)

The QUARTET LoI proposes a feasibility study for high-precision measurements of 2p-1s transitions in light muonic atoms, using newly developed metallic magnetic calorimeter detectors. The QUARTET physics aims extend from an order of magnitude improvement of the nuclear radii extractions, to QED tests, and possible searches of new physics in a multi-year physics program. For 2023, the collaboration is proposing a test run to perform a first set of muonic atom measurements in realistic beam conditions. The energy calibration of the metallic magnetic calorimeters, a key-ingredient for the scientific program, will be performed using X- and gamma-ray sources, together with an X-ray tube.

The committee acknowledges the relevance of the physics case and of the innovative technology. It strongly encourages QUARTET to collaborate with the muX and MIXE collaborations to optimize their global data taking strategy. The committee is looking forward to a full technical proposal, based on the results from 2023 and recommends approval for 1 week of beam time at πE1.

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

This is a thorough, well-documented proposal by an expert collaboration. It has achievable objectives to make a two-orders-of-magnitude improvement in sensitivity to the muon EDM, to levels comparable to sensitivities that might be achieved by the muon $g-2$ experiments. Recent theoretical work allows for a much larger muon EDM than the simple linear mass scaling between muon and electron EDM implies.

The committee approves and strongly supports this worthwhile proposal. This experiment should be considered for additional yearly review in the coming years by a new subcommittee.

R-23-03.1: ReferenceRadii (T. Cocolios *et al.*)

This experiment proposes to use the muX/MIXE experimental concept to measure absolute nuclear radii over a range of isotopes for several medium to heavy nuclei. Progress in the theoretical precision will continue, but the impact of the proposed experiments on the theoretical understanding of nuclear structure calculations is at the moment difficult to asses. If this is seen as a long-term program, the organization of a theory workshop is recommended.

The committee recommends initial approval for 1 week of beam time at πE1 for a limited set of measurements in 2023.

R-23-04.1: UniKaon (U. Fahrendholz *et al.*)

UniKaon proposes to perform an experiment to determine the Birks' factor (which helps parameterize scintillation light emission from particle energy loss) for positive kaons in liquid scintillators. The goal is to provide input for proton decay searches based on $p \to K^+ \bar{\nu}$.

UniKaon plans to extract the Birks' factor for kaons from measurements with positive muon and pion beams, at kinetic energies of tens of MeV, complemented by measurements with proton beams elsewhere (INFN-LNL).

The committee takes note of the relevance of the proposed measurements, but points out that no realistic evaluation of the extraction of the kaon Birks' factor from the pion and muon data was included in the proposal. In addition, the experiment requested very low momenta ($\sim$30 MeV/c) pions, which have a very low rate due to their short lifetime. This aspect was not addressed in the proposal. Consequently, the committee does not approve the beam time request.

R-23-05.1: MuonFission (M. Niikura *et al.*)

The idea of this proposal is to use muon-induced fission to produce unstable muonic atoms. However, the beam request was withdrawn this year because the target is not available. A future proposal should provide a clear motivation for the experiment and also discuss the expected rates and backgrounds in more detail.

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

The beam time request is rejected, since the proposal is essentially the same as last year. Still there is no clear theoretical motivation for this experiment.

Test: COMET (K. Oishi *et al.*)

COMET requests 3.5 days of beam time at πM1 to measure secondary particle production for a pion beam with momenta between 100 and 250 MeV/c stopped in a tungsten beam blocker. The aim is to validate and improve the GEANT4 simulation used to describe the beam blocking for the COMET experiment. The committee recommends the requested beam time.

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. Last year was a breakthrough year for the collaboration, with the number of stopped muons equaling the most productive of the MEG I data taking years. This should result in a sensitivity significantly better than that of the final MEG I published search.

The existing drift chamber was operated in a stable fashion up to $5 \times 10^7\,\mu$/s at nominal high voltage with the gas mixture optimized. Meanwhile, the construction of a backup drift chamber was started last autumn, with a currently projected delivery date to PSI in early 2024. Joule heat annealing of the LXe photon counters proved effective and safe for restoring

their efficiency to a value that is expected to allow the detector to be operated at the above muon stopping rate for ∼120 days of data taking. Remarkable improvements in DAQ efficiency relative to 2021 followed the installation of a new online server.

The projected sensitivity of MEG II at the current performance level of the whole detector should reach $\sim 10^{-13}$ at the end of 2023. The committee recommends a beam allocation of 27 weeks on the πE5 beamline for 2023 in order to fully exploit the currently achieved stable running conditions.

In addition to the productive muon run, the program to use protons from the Cockroft Walton accelerator on a Li target to study refute the 17 MeV 'Atomki anomaly' has been started. If the Atomki anomaly is real, 20 days of data taking would produce a 5σ effect.

More details will be provided in the separate subcommittee report.

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

Excellent progress has been made by the collaboration in magnetic field characterization and control. All aspects of the magnetic field system have met or exceeded their specifications for the experiment.

While progress has also been made on other fronts, the full experiment contains many complicated subsystems that will need to be fully integrated. We note that most of the milestones have slipped from their 2022 dates, some by more than six months. We feel the current milestones and the goal of taking physics data by the end of 2023 are realistic. We also note that it will require focus by the members of the collaboration to achieve the needed 500 days of data-taking, before the shut down at the end of 2026.

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

The scientific merit of the MUSE experiment remains high and the committee strongly recommends that it remain a priority for PSI. MUSE has made impressive progress in bringing its hardware into readiness for extended data collection. Particularly significant has been the extremely high reliability of the liquid hydrogen target and the installation of target chamber veto panels to reduce background produced by scattering from the target vacuum chamber supports. The successful operation of the straw tube tracker is significant. MUSE also reported a revised installation time of the apparatus of three weeks. This is somewhat longer than originally estimated. As a result, scheduling beam time in separate blocks would considerably reduce efficiency.

During the subcommittee review MUSE presented a comparison between beamline characteristics with exhaustive simulations. In general, these comparisons showed good agreement. MUSE documented this with a hardware readiness report as requested by BVR 53. Last year's BVR also requested an analysis report that would present an *"analysis of actual data ... of sufficient refinement that it produces a physics measurement that can be compared with theoretical expectations."* MUSE did present a detailed analysis report that described the beam simula-

tions and detector responses as well as a preliminary analysis of a set of blinded lepton-carbon data. While this was a useful step, the comparison between the theoretical cross sections, results from Monte Carlo calculations, and the extraction of blinded cross sections from electron and positron scattering showed very significant disagreements. The brief description of the blinding scheme left many open questions. The committee suggests that the collaboration prepare a detailed description of the blinding scheme, possibly for publication.

The committee recommends that MUSE receive 4 months of contiguous beam time in 2023. They should continue the analysis towards realistic hydrogen cross section extractions. The committee requests that MUSE present a report on this before next year's BVR.

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

The collaboration made impressive steps forward for all detector components and system integration. The year 2023 marks the transition from prototype development to mass production. The collaboration aims for a first working (partial) detector at the beginning of 2024, consisting of the inner vertex pixel layer, the full Scifi barrel and one side of the tile detector.

The timeline of the collaboration is driven by the goal of a first physics run before the shutdown at the end of 2026. The committee recommends that the collaboration perform the tests and simulations needed for an informed decision on the optimal MuPix11 configuration. The schedule to produce, test and integrate all subcomponents is challenging and does not foresee contingency. Given the tight time constraints, a realistic plan with enough contingency to absorb unavoidable delays is crucial for the most efficient use of the time. The planning should accordingly be reviewed by the collaboration. In addition, the committee recommends a short mid-term subcommittee review, via zoom, during the summer.

The committee strongly endorses the beam requests for MuPix11 testing at πM1 and beam development and moderator tuning with beam monitors scanning the empty detector solenoid at the end of the πE5 beam period.

More details will be included in the subcommittee report.

R-14-02.1: muCool (A. Antognini *et al.*)

If successful, muCool could be an important part of the future HIMB, providing high intensity, small phase space muon beams for both particle physics and condensed matter studies. The committee strongly endorses this crucial development effort, but due to significant overbooking in πE1 cannot recommend the beam request for 2023. However the committee recommends that the collaboration perform a readiness review to present next year and anticipates recommending further running in 2024 with high priority.

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

The muX collaboration has pursued a program to study the 2p-1s muonic X-rays in high Z atoms. They reported successful measurements using implanted targets. Work continues on the development and refinement of other target preparation techniques. In particular, there

has been significant progress in the development of barium targets, which could be applicable to radium target development. The collaboration requests 2 weeks of beam time at πE1 in Sept/Oct to complete muX with its measurement of the charge radius of radium. The committee supports this request.

R-20-01.1: OMC4DBD (D. Zinatulina *et al.*)

By now, OMC4DBD has collected high quality data on several double beta-decay final-state nuclei. The analysis of the muon lifetime of low lying nuclear states is well advanced and has achieved good consistency. The partial capture rates, critical in the comparison with double beta-decay nuclear matrix elements, are expected to be published in 2023. The committee encourages the full evaluation of the rich data set already collected on the experimental side, and the study of their impact on reducing matrix element uncertainties on the theoretical side with high priority. The committee recommends 1 week of beam time at πE1 which should be pooled with other requests related to the muX/MIXE setup to optimize set-up time.

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

The committee acknowledges the progress achieved by the collaboration as outlined in the submitted report. They showed a preliminary Monte Carlo simulation that needs to be further refined. The committee strongly encourages the collaboration to demonstrate the sensitivity of their method and to characterize the systematic uncertainties, in particular in determining D-T sticking, by analyzing simulated data through their full analysis chain. Also, after discussions with PSI management, the committee strongly recommends to have at least one collaboration member based at PSI to support the experiment.

The committee notes that the deuterium-tritium measurement campaign depends upon safety issues associated with tritium target-management which are beyond the purview of this committee. Based on the technical progress and on the results of test measurements for the detector subsystem, the committee approves the experiment at PSI and recommends 3 weeks of data taking at the πE1 beamline in 2023, with the aim of performing a series of deuterium-deuterium muon fusion rate measurements at various temperatures and pressures.

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

The committee reiterates its strong support for the PIONEER experiment and acknowledges the high impact of their science case. It is seen as a long-term effort, preferably to run at πE5. For 2023 there is a request for beam studies at πE1. Since the situation at πE1 is difficult due to overbooking, the committee does not recommend it. However the committee does see a chance for a moderate amount of beam time at πE5 for PIONEER, before the shut-down at the end of 2026, to enable a careful development of the experiment in a realistic time frame. The committee recommends that a subcommittee perform a detailed review of PIONEER next year. For this, the collaboration should include a proposed schedule for hardware development

and commissioning plans. For 2023, the committee recommends 2 weeks of beam at πM1 for detector development.

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

For 2022, the LEMING experiment had to descope their program because the new custom dilution refrigerator did not arrive on time. Nevertheless, quality results and technical developments were achieved. The new cryogenic system has arrived now, so that the optimized setup can be installed to precisely measure properties of the muonium beam emitted from the superfluid helium surface. Other planned studies focus on the feasibility of a vertical target and the optimization of the electron detector. The committee recommends the allocation of 3 weeks at πE1. A brief status report one month before the beginning of the beam time is requested.

4 Miscellaneous

During the open meeting on Tuesday, A. Knecht gave an overview on the status of the IMPACT project. This includes the construction of two new high-intensity muon beamlines and would result in a shut-down of HIPA in 2027.

5 Next Meeting

The next meeting (BVR 55) is again planned as a 3-day meeting and will take place from 05–07 February 2024. The deadline for proposals and beam time requests is 22 January 2024.

March 23, 2023 B. Filippone, A. Signer