Short Minutes of the BVR 51

Meetings of 27 – 29 January 2020

1 Meetings of the Committee

closed meetings:	Tuesday, January 28, from 9:00 – 12:30 Wednesday, January 29, from 9:00 – 12:30
present:	L. Baudis D. Bryman 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 A. Amato
apologies:	M. Ramsey-Musolf P. Riedler

2 New Proposals

Apart from the requests of n2EDM, MEG II, Mu3e and MUSE, two new proposals were received. Furthermore, several test beam requests were made, one with a letter of intent which might lead to a full proposal at the UCN facility. The requests made for πE1, πE5 and πM1 would lead to a substantial overbooking.

R-20-01.1: Ordinary Muon Capture as Probe of Properties of Double Beta Decay (D. Zinatulina *et al.*)

This new proposal considers using ordinary muon capture as a way to constrain the nuclear matrix elements needed to interpret the results from on-going and future searches for neutrinoless double beta decay ($0\nu\beta\beta$). The group proposing this experimental campaign is not only experienced, but has led the way in establishing the muon capture technique for $0\nu\beta\beta$

investigations, as documented in their recent publications. In the proposal, measurements of muon capture on ^{136}Ba and ^{76}Se are planned which are of particular importance for $0\nu\beta\beta$ experiments with ^{136}Xe and ^{76}Ge. This will be the starting point of a 3 year program with measurements of several other nuclei also being planned.

The anticipated systematic studies will establish a database, which could become a standard to compare with the variety of detailed model calculations. While the question of nuclear matrix elements will not be decided by a single experiment, muon capture provides unique constraints which should be fully exploited. The committee sees this as an opportunity for PSI to play an important role in this issue of critical importance to nuclear and particle physics and recommends allocation of the requested beam time.

R-08-01.3: Search for muon catalysed d^{3}He fusion (P. Kravchenko *et al.*)

This experiment aims to measure the rate for muon-catalyzed d^{3}He fusion utilizing the MuSun detector and an optimized target gas. Measurement of this rate would be of some astrophysical interest. The committee recommends approval of the request of 4 weeks in πE1, but notes that scheduling issues in πE1 require running this experiment earlier than requested. The committee also believes that the experiment could benefit from more sophisticated analysis procedures.

Test: Search for Neutron to Mirror-Neutron (N.J. Ayres *et al.*)

The possibility of a mirror sector to the Standard Model has been suggested more than 50 years ago. The existence of such a sector could result in neutron to mirror-neutron oscillations which would appear as neutron disappearance. A manifestation of this phenomenon could be a magnetic field dependence of the UCN storage time. Some recent storage experiments with ultracold neutrons have been interpreted to support this notion. PSI has a unique opportunity to check this interpretation using existing UCN hardware on the UCN West 1 beam port. The committee considers this to be a good use of the UCN facility, as long as there is no adverse impact on n2EDM activities. It recommends the allocation of approximately 1 month of beam time to be scheduled compatible with other UCN activities.

Test: HVMAPS Sensors (M. Fritsch *et al.*)

The provisional allocation of 1 week at πM1 is put at the end of the year and conditional on the chip being available.

Test: CMS Diamond Detectors (D. Hits *et al.*)

These tests are a continuation from last year. In view of the overbooking only 1 week at πM1 can be granted.

Test: PIMice Mice Irradiation (L. Desorgher *et al.*)

A similar request was made already last year, but the irradiation of the mice did not work as planned. Two separate weeks at πM1 are allocated. As last year, it is the collaboration's responsibility to follow ethical guidelines.

Test: RWELL Sensors (M. Poli Lener *et al.*)

This request to use the πE1 beam for the whole year parasitically is not practicable and the committee believes that PSI is not the right place for these tests.

Test: MuEDM Tests (P. Schmidt-Wellenburg *et al.*)

These tests are a part of a long-term investigation towards a possible experiment to improve the sensitivity to the muon electric dipole moment and is of strategic relevance to PSI. The request of 1 week at πE1 is approved.

Test: RADEM (PIF) (W. Hajdas *et al.*)

The request for two slots of 1 week each at πM1 is granted.

Test: COMET/NA62 (H. Nishiguchi *et al.*)

The request of 1 week at πM1 is approved.

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

This is a continuation of tests in 2019 and 1 week at πM1 is granted.

Test: PSEC-Micromegas (L. Sohl *et al.*)

One week at πE1 is granted.

Test: Muonium (A. Soter *et al.*)

This request is of particular importance as it might lead to a fundamental experiment at PSI on testing the weak equivalence principle with 2^{nd} generation antimatter, in form of the muonium system. The prerequisite for this is a cold, mono-energetic and parallel muonium beam. The basic idea is that muonium ejected from superfluid helium will have these characteristics, similar to the behaviour observed with hydrogen impurities.

In previous runs, several important ingredients to this technique have been established, including sufficient muonium formation yield below 0.3 K and background-free muonic detection at room temperature. During the requested beam time, important additional requirements for this technique will be tested, most critically efficient muonium emission from a superfluid helium surface. The committee recommends approval of the full requested beam time and expects to receive an experiment proposal for future sizeable beam assignments.

Test: PAD-Micromegas (M. Camerlingo *et al.*)

One week at πM1 is allocated.

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

One week at πM1 is allocated early in the year for the collaboration to be able to meet the NASA deadline.

Test: RPC Counters (G. Bencivenni *et al.*)

The request for 2 weeks at πE1 or πM1 is not well justified and only one week at πE1 is allocated.

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 physics goals remain at the forefront of PSI particle physics program. In 2019 MEG performed the foreseen interventions on the cylindrical drift chamber (CDCH) aimed at addressing the electrostatic instabilities that were affecting the internal layers in 2018. The procedure of over-stretching the chamber's wires and then removing the broken wires appears to have largely cured the targeted instabilities. The sealed chamber was then inserted in Cobra, HV powered and operated on the πE5 beam with the rest of the MEG II detector for about one month. However, the experiment suffered a series of unfortunate accidents to the beam transport solenoid (BTS), which eventually became inoperable on 20 November. This brought MEG's data taking to an abrupt end. Unfortunately, the collaboration also encountered additional problems with the CDCH and the LXe readout.

The CDCH suffers from the onset of intolerably high currents in a large portion of the chamber at HV values well below the chamber's nominal working point. The committee supports the MEG collaboration in its current effort to fully understand and properly address this issue before the construction of a new chamber. Use of the πE5 beam could be useful in achieving this goal, as well as to assess the robustness of any other aspect of the current chamber design and should be granted as much as possible subject to an assessment of MEG preparedness and compatibly with the needs and readiness of other groups (essentially: Mu3e). The main focus and goal is to achieve a solid understanding of the multiple issues affecting the current chamber in order to allow for the construction of a new robust one. As previously recommended by this committee and the experts review panel convened by PSI in Sep 2019, the collaboration should also concurrently investigate the possibility of a different choice of wires and prove it to be technologically viable and immune from the corrosion phenomena affecting the current chamber.

Regarding the LXe readout, two issues have come up: in the first case, the beam-induced gain loss for the conventional PMTs has been observed to occur at a rate (1.8%/day) that would quickly make it impossible to be compensated for by PMT HV adjustments. Secondly, a substantial and very quick SiPM (MPPC) photon detection efficiency degradation (0.08%/h) has been observed under standard MEG II beam conditions. Both these issues will need to be further studied on the πE5 beam and the committee supports a suitable beam allocation to MEG for these goals.

The procurement of the full set of WaveDream cards necessary to readout both LXe and CDCH is expected to occur in the course of the year. Even with optimized design of the cards there are noise issues, affecting in particular the energy resolution performance of the calorimeter. This needs to be addressed in the real experimental environment as soon as possible.

The repair of the BTS is currently underway and hopefully will be accomplished before beam time starts. A working BTS or the development of an alternative is a prerequisite for MEG to be eligible for beam assignment.

Given this complex spectrum of issues, the committee only provisionally recommends an an initial beam allocation for MEG of 19 weeks. Additional beam time at the end of the year could be allocated, subject to Mu3e and MEG readiness. This will be decided by the PSI management in consultation with the Mu3e and MEG subcommittees. Further details will be provided in the subcommittee report.

R-05-03.1: Measurement of the neutron EDM (P. Schmidt-Wellenburg, G. Pignol *et al.*)

The committee is profoundly pleased with the release of the now world-leading best limit for the neutron EDM. Following an intense period of analysis by two independent groups the data were unblinded late last year and a publication is imminent. With the completion of this round of analysis the collaboration is now intensely focused on completing construction of the new high-sensitivity experiment: n2EDM. In the last year, the final design of the major components has been completed and assembly, testing and commissioning is underway. The subcommittee was very impressed with the progress and the status of the facility during a guided tour. While a problem with the critical 6-layer metal shield has caused a delay of approximately 6 months, it is anticipated that construction of the full experimental setup will be largely completed in 2020, allowing data taking to begin in 2021. Further details will be provided in the subcommittee report.

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

MUSE is to be commended for making significant progress over the past year. During the 2019 run period, all detector systems have become operational and runs have been carried out with all target configurations. The liquid hydrogen target was also operated reliably and routinely. The collaboration has demonstrated the ability to install and remove the apparatus

in a relatively prompt and efficient fashion. We recommend that MUSE receives 16 weeks of beam time in one continuous session. We anticipate that this beam time will be used to fully commission all hardware components and demonstrate that MUSE will be ready for dedicated proton radius production running in 2021. The committee anticipates that this readiness will be documented in the January 2021 BVR 52 report on MUSE. For this report, MUSE should perform a sufficient degree of analysis on the 2019 and 2020 data, including all tracking, timing and PID systems as well as beam transport properties, to clearly demonstrate that they are of sufficient quality to provide a determination of the proton radius at the requisite level of sensitivity. MUSE should also present a clear analysis strategy that includes a suitable blinding scheme. Further details will be provided in the subcommittee report.

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

The committee remains strongly supportive of this important experiment in charged lepton flavour violation. The Mu3e collaboration reported significant progress on many aspects of the experiment and demonstrated excellent technical capabilities and creativity in the design of the detector components. During 2019, the design of most components has been finalized. The goal for 2020 is to build prototypes of all components and to commission them under realistic beam conditions. After about a year delay, the magnet is expected to be delivered in spring 2020 to PSI. Thus, the commissioning includes the installation of the magnet in the area, determining the properties of the Compact Muon Beam Line up to the experimental target as well as installing and taking beam data with a partially equipped detector inside the magnet. If successful, this aggressive program would be a tremendous step forward.

After successful tests, full production of all detector components is scheduled for 2021. As regards the Silicon pixel detectors, the collaboration has submitted its final prototype MuPix10 for production and also tested the ATLASpix3 demonstrator, as a promising alternative. High-intensity beam tests at PSI in 2020 will lead to a decision between the two candidates.

The critical path of the experiment is driven by the construction of the He cooling plant. A promising design based on high-speed turbo compressors has been identified. However, the full system construction will take until 2022. There is some concern that the novel concept of high He flow cooling of the fragile detector system cannot be tested before this date.

The committee approves the various beam tests as indicated in the beam schedule and endorses the high priority of commissioning of the full beamline with magnet. A final decision on weeks 46-51 will be made once more information on the Mu3e magnet commissioning timeline and updates on the MEG status become available. This will be decided by the PSI management in consultation with the Mu3e and MEG subcommittees. Further details will be provided in the subcommittee report.

R-14-02.1: High-brightness ultra-cold muon beam (MuCool) (A. Antognini *et al.*)

The committee commends the collaboration for their relentless and successful effort to construct a set-up that reached the required HV conditions for optimal combined transverse

and longitudinal μ^+ cooling. This, together with an improved detection system, led to a convincing demonstration of the combined cooling, on a faster time scale than achievable in separate cooling stages. Further analysis will study remaining differences between data and simulation. The committee wishes good success for the R&D planned for 2020 towards the challenging μ^+ extraction into vacuum.

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

The committee congratulates the MuX collaboration on the successful measurement campaign with the Miniball Ge array and the new Curium and Radium targets, prepared in Mainz with the electrodeposition and drop-on-demand printing methods. The collaboration was able to reduce the amount of organic contaminates in the targets and the background levels in the Ge detectors and to measure the number of muons that are transferred to the target. They have achieved sufficient statistics for detecting the muonic X-rays with the Curium target, while for Radium the analysis is ongoing. To catch up with the analysis effort, the collaboration does not request beam time in 2020.

R-16-02.1: Hyperfine splitting in muonic hydrogen and helium (HyperMu) (A. Antognini *et al.*)

The committee acknowledges the progress achieved by the collaboration in 2019. In particular, the collaboration successfully developed the detection system and demonstrated its performance during 10 days of beam time in November 2019. Preliminary studies of the target mechanism were prepared using CAD drawings and a prototype realised out of aluminium using a 3D printing techniques, which successfully passed first tests.

In 2019 the collaboration performed a beam test at πE5 and the committee is pleased to see that this alternative beam line, with some optimization, could in principle be used for the final experiment. The collaboration is developing three types of optical cavities requiring different technologies and production methods and the committee is looking forward to the results obtained from comparing their performance for optimal use in the experiment.

R-19-01.1: Muonium laser spectroscopy (Mu-Mass) (P. Crivelli *et al.*)

The group proposes to accurately measure the 1S-2S transition in muonium leading to a ppb determination of the muon mass, and perform related QED tests. Good progress has been made on developing the high power CW 244 nm laser system and demonstrating other experimental aspects required for the measurements. With further anticipated development, improvements of two orders of magnitude might be reached during the proposed 2020 run period in the LEM beam, with another order of magnitude potentially reachable in the future. While the beam request is for a beam outside the scope of the BVR, the committee is keen to see the experiment go ahead and recommends the allocation of the requested beam time.

4 Miscellaneous

Ben Sauer (Imperial College London) was welcomed as a new member of the BVR committee. Ana Teixeira presented a talk with the title “Flavour and searches for new physics: muons and neutrons at high intensities” during the open meeting on Tuesday afternoon.

5 Next Meeting

The next meeting (BVR 52) is again planned as a 3-day meeting and will take place from 25–27 January 2021. The deadline for proposals and beam time requests is 11 January 2021.

February 28, 2020 B. Filippone, A. Signer