# Closeout Report

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| **Applicant/Institution:** | Hampton University |
| **Street/City/State/Zip:** | 100 E. Queen Street, Hampton, VA 23668 |
| **Project Title:** | Collaborative Research: Equipment for and Running of the PSI MUSE Experiment |
| | |
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| | |
| **Agency:** | DOE Office of Science, Medium Energy Nuclear Physics, Early Career Award |
| **DOE Program Office:** | Office of Nuclear Physics |
| **DOE Program Officer:** | Dr. Gulshan Rai |
| **DOE Award number:** | DE-SC0012589 |
| | |
| **Start Date:** | September 1, 2014 |
| **End Date:** | February 29, 2016 |
| **Reporting Period:** | September 1, 2014 - February 29, 2016 |
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| **Previous Reports:** | No previous reports |

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# 1 Executive Summary

The R&D funding from this award has been a significant tool to move the Muon Scattering Experiment (MUSE) at the Paul Scherrer Institute in Switzerland forward to the stage of realization. Specifically, this award has enabled Dr. Michael Kohl and his working group at Hampton University to achieve substantial progress toward the goal of providing beam particle tracking with Gas Electron Multiplier (GEM) detectors for MUSE experiment. Establishing a particle detection system that is capable of operating in a high-intensity environment, with a data acquisition system capable of running at several kHz, combined with robust tracking software providing high efficiency for track reconstruction in the presence of noise and backgrounds will have immediate application in many other experiments, as well as potential applications in medical physics and national security.

# 2 Goals and Accomplishments

The goals of the project were focused on preparing the existing Gas Electron Multiplier (GEM) telescope at PSI to meet the specifications of the MUSE experiment. This required full characterization of the GEMs and establishing their routine operation at a series of MUSE test beam times at PSI, along with a modification of the GEM telescope for the final geometry with upgraded cabling and electronics. One main task has been the further development of the GEM data acquisition system to increase the readout speed, which is still continuing. Various options had been conceived which were investigated in further detail in the course of this award. A most likely path toward achieving the design specification of the GEM operation at MUSE, along with a fallback path to mitigate risks has been developed. Some modest investments were made by acquiring latest-generation Multi-Purpose Digitizer (MPD) modules and new, more powerful VME controllers.

The proposed plan had been to implement 32-bit and 64-bit block transfer. It had further been planned to explore the gain in readout speed by splitting the data acquisition system up into one VME system per GEM element, and to implement and assess zero suppression. The actual sequence of activities has been revised in the course of this award and are reported in the next section.

# 3 Project Activities

## 3.1 GEM Operation at PSI

Dr. Kohl and his group have successfully constructed, commissioned and operated a set of GEM detectors for the OLYMPUS experiment, arranged as two telescopes each consisting of three triple-GEM elements to track forward-angle scattered leptons for the purpose of luminosity monitoring at OLYMPUS. The detectors have performed quite well with high efficiencies above 90%. Spatial resolutions of the GEM chambers have been found around 75 $\mu$m. One telescope has been relocated to PSI where it has been serving as beam particle tracker of the secondary beam at the piM1 beamline for the MUSE experiment. The other telescope has been relocated to Hampton to allow for further developments of the readout system and the analysis software.

In the course of this award, the GEM telescope at PSI has been operated at MUSE test beamtimes in December 2014, June-July 2015, and December 2015. During the first two beamtimes the GEM telescope has been successfully characterized in terms of efficiency maps and resolution studies for all three beam species $e$, $\pi$, and $\mu$. The beam flux could be varied between a few kHz up to 1 MHz. Operation at even

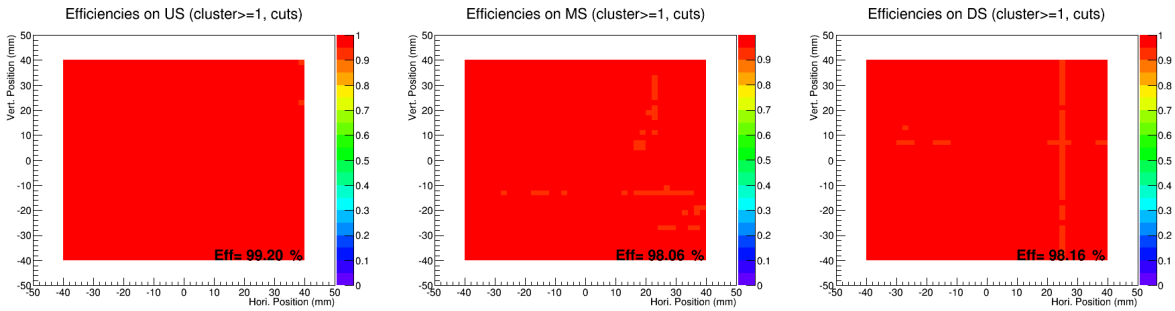


Figure 1: Efficiency maps for the three GEM elements. The candidate track is determined by two GEMs and projected to the third GEM to verify if a cluster has been observed at the projected locations.

higher flux up to 5 MHz will require segmented trigger detectors. The observed efficiencies were initially (as of spring 2015) unsatisfactorily low, which could be substantially improved to the 95-98% region by improving the analysis techniques in terms of cluster identification and candidate track reconstruction. More extensive measurements were performed in June-July 2015 to obtain efficiency maps at low and high flux. In the beamtimes of Dec. 2014 and summer 2015, before the modification of the cabling and electronics, we established efficiency maps, an example is shown in Fig. 1.

At high intensity the hit multiplicities were found to be significantly higher than at low intensity, which makes efficient and robust tracking harder. This task is still evolving. With a future segmented trigger, additional spatial information can be utilized to identify and suppress false hits in the GEMs. Further options to reduce the multiplicity per event is to infer timing information from acquiring multiple GEM samples. So far the GEM readout has been operated only in one-sample mode. To obtain timing information at least three APV samples need to be acquired per event, which is planned to be tested in a future test beamtime. While it had been considered already during this award to test zero suppression, it became a lower priority while managing many other issues and tasks in parallel. Zero suppression will be tested along with mutliple APV samples in an upcoming beamtime.

In summer 2016 the Hampton group has started to collaborate with the Super-Bigbite (SBS) collaboration at Jefferson Lab, where robust tracking under high-intensity conditions has been defined as a very similar goal.

## 3.2 Modification of the GEM Telescope

After the summer 2015 beamtime the group decided to re-assemble the telescope at PSI toward its final configuration. The previous distance between GEM elements in the OLYMPUS configuration was 30-40 cm. For MUSE, a distance of 8 cm between GEM elements is preferred. This required to re-orient the APV-25 frontend cards, which were mounted on the sides perpendicular to the GEMs for OLYMPUS, to be within the active planes of the GEM detectors, thus allowing smaller gaps. This required to renew the cabling scheme, in particular for the digital bus cable connecting all of the APVs of the setup. With the revised cabling scheme we decided to also upgrade the Multi-Purpose Digitizer (MPD) from v3.0 to v4.0. The MPD v3.0 had one HDMI-A socket for the digital, and two HDMI-B sockets for the analog signals. Unfortuntely, HDMI-B has not become a widely used industry standard and thus parts are very hard to be acquired. In the OLYMPUS configuration, the digital cable was 5 m flatband ribbon used as a bus cable to connect the set of 12 APV card at the GEMs, which was then converted to HDMI-A, using one HDMI-A cable to connect

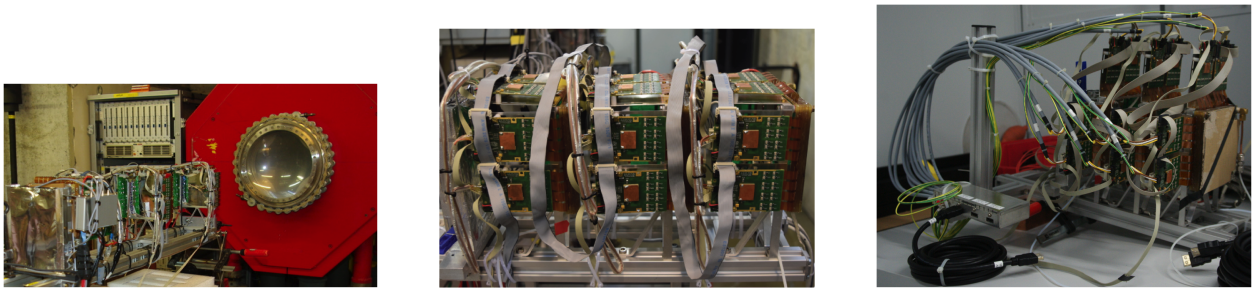

Figure 2: GEM telescope at PSI in May 2013 (left), June 2015 (middle), and June 2016 (right).

to the MPD v3.0. The analog cables were 25 m CAT-7 with a custom-made converter to HDMI-B close to the MPD module v3.0 at the VME crate.

The new MPD v4.0 has four HDMI-A front panels for the analog signals, replacing the two HDMI-B slots of MPD v3.0. Ideally only one HDMI-A cable directly connects four APVs with the HDMI-A front panel of the MPD. Realistically, the realization requires a conversion from HDMI to custom-format near the detector. It was decided to use industry-standard HDMI-A cables for the long distance from the VME crate to near the detectors, and to make short cable pieces from an HDMI-A patch panel to the APV cards on the detectors.

Initially, it was attempted to realize the new cabling scheme for an interim period, still with the MPD v3.0, which added in yet another adapter piece near the VME to convert to HDMI-B. Subsequently, the noise levels substantially increased compared to the original configuration. This was the status in spring 2016 at the end of this award. The new MPD v4.0 modules became only available in 2016. We decided to re-do the cabling, now using only one HDMI-A adapter. First tests have shown a significant reduction in noise, even compared to the original OLYMPUS configuration. Routine operation at low noise remains to be re-established in the upcoming December 2016 beamtime at PSI.

Figure 2 shows the PSI telescope as of May 2013 (still in OLYMPUS configuration), in June 2015 (elements moved as closely together as possible without changing the layout), and in June 2016 in the nominal configuration for MUSE.

### 3.3 Data Acquisition Speedup

The complication of the cabling and upgrade of the MPD, we could not yet establish the faster readout. However, we gave substantial consideration to this issue, which resulted in a clear path toward realization to meet the MUSE specification.

The group consulted with DAQ experts at MIT (with the DarkLight collaboration), and with the data acquisition group at Jefferson Lab in the context of the Super-Bigbite Spectrometer (SBS) project. The SBS aims to operate 50,000 GEM readout channels with the INFN electronics (APV+MPD) under similar conditions. In summer 2016, the Hampton group joined the SBS collaboration. There are similarities between the DAQ system established in Hampton and for the SBS based on very similar hardware, however there are also distinct differences which prevent simple copying of methods. However, the collaboration with SBS is used to exchange experience and strategies.

The second of the two OLYMPUS GEM telescopes, located in Hampton, has been prepared for phase-I of the DarkLight experiment in development at the Low-Energy Recirculator Facility at Jefferson Lab. The Hampton group has been collaborating with the MIT group who provided segmented scintillator paddles

for the DarkLight phase-I detector, along with a newly developed data acquisition system to read out the GEMs along with the scintillators using one VME crate. While this development happened only in summer 2016, i.e. outside the reporting period of this award, it is worth while mentioning the outline of what has been implemented, which serves as starting point for further development of the DAQ.

It is important to identify bottleneck in the data acquisition chain in order to implement improvements. One such bottleneck has been identified to be the chipset and driver that provides the communication between the VME master controller CPU and the VME bus. In the existing system, this bottleneck has limited the data rate to 5 MB/s corresponding to an event readout time of 1 ms. In order to meet the MUSE specification of 2 kHz with less than 20% deadtime, a factor 10 in readout speed needs to be achieved, corresponding to 100 $\mu$s per event or 50 MB/s data rate. This can be accomplished with a VME system operating in 64-bit block transfer mode. The present system of VME crate + controller (model GE V7768) and MPD v4.0 with the 2015 standard firmware supports 32-bit block transfer. Up to a factor 4 better performance has been observed with more recent models of VME controllers. The group has acquired two new VME controllers, a GE XVR-15 and a GE XVB602, both with a different VME chipset, more powerful CPUs and bigger memories. In collaboration with the MIT group, a linux kernel with improved chipset driver for VME support has been implemented recently. The new operating system requires a re-write of the frontend code to read out the MPD. This continues to be work in progress. We expect to see 15-20 MB/s from this improvement.

The 32-bit block transfer can be further improved by a factor 2 by packaging the data from two APV cards into one 32-bit word (currently only one APV is handled at a time). This will require a modification of the firmware of the MPD, and the group is actively working with SBS and INFN on that frontier.

Lastly, the existing VME64x crate with new VME controllers and MPD v4.0 will support 64-bit block transfer. This will increase the data rate to 80 MB/s, which will be sufficient to meet the MUSE specifications.

The splitting of the VME system into three crates (one for each GEM) remains a fallback strategy to mitigate the risks associated with the implementation of the above steps.

Beyond the above, ideas are discussed to avoid the VME bus altogether for the readout, by accessing the MPD via ethernet or optical link. This is the route which is presently pursued by the SBS group at JLab. However, the timescale for this development exceeds that of the planned MUSE experiment, and it involves additional hardware and associated risks. For the purpose of meeting the MUSE specification, we hence decided for a more conservative, yet manageable approach as laid out above.

# 4 Opportunities for Training and Professional Development

This award has provided opportunity for one postdoc to take a lead role in the tasks of this project, operation of the GEM telescope and analysis of GEM data, the modification of the telescope toward its final configuration, and further development of the data acquisition system. In the course of the project the award budget was revised to provide two months of postdoctoral salary. The activities involved two extended visits to PSI by the postdoc, in December 2014 and in summer 2015, to work hands-on with the GEM telescope at PSI. The postdoc was also responsible for the operation and analysis of the GEM detectors. The PI was enabled to travel to PSI several times, for the Dec. 2014, summer 2015 and December 2015 beamtimes, and for the February 2015 and 2016 PAC meetings. The PI also undertook a visit at INFN in Rome to discuss details of the data acquisition. Both postdoc and PI attended the MUSE collaboration meeting in Washington, DC in October 2015, and the MUSE review meeting at the NSF Headquarters in Washington, DC in Feb. 2016.

# 5 Products

## 5.1 Publications 2014-2016

### 5.1.1 Refereed publications

*Polarization Transfer in Wide-Angle Compton Scattering and Single-Pion Photoproduction from the Proton,*
C. Fanelli, E. Cisbani, D. J. Hamilton, G. Salme, B. Wojtsekhowski, A. Ahmidouch, J.R.M. Annand, H. Baghdasaryan, J. Beaufait, P. Bosted, E.J. Brash, C. Butuceanu, P. Carter, E. Christy, E. Chudakov, S. Danagoulian, D. Day, P. Degtyarenko, R. Ent, H. Fenker, M. Fowler, E. Frlez, D. Gaskell, R. Gilman, T. Horn, G.M. Huber, C.W. de Jager, E. Jensen, M.K. Jones, A. Kelleher, C. Keppel, M. Khandaker, M. Kohl, G. Kumbartzki, S. Lassiter, Y. Li, R. Lindgren, H. Lovelace, W. Luo, D. Mack, V. Mamyan, D.J. Margaziotis, P. Markowitz, J. Maxwell, G. Mbianda, D. Meekins, M. Meziane, J. Miller, A. Mkrtchyan, H. Mkrtchyan, J. Mulholland, V. Nelyubin, L. Pentchev, C. F. Perdrisat, E. Piasetzky, Y. Prok, A.J.R. Puckett, V. Punjabi, M. Shabestari, A. Shahinyan, K. Slifer, G. Smith, P. Solvignon, R. Subedi, F.R. Wesselmann, S. Wood, Z. Ye, and X. Zheng,
Submitted to Phys. Rev. Lett.; arXiv:1506.04045v1 [nucl-ex].

*Performance test of a lead-glass counter for the J-PARC E36 experiment,*
Y. Miyazaki, S. Shimizu, S. Bianchin, C. Djalali, D. Gill, J. Jiang, M. Hasinoff, K. Horie, Y. Igarashi, J. Imazato, A. Ivashkin, M. Kohl, R. Narikawa, R. Pywell, S. Strauch, M. Tabata, A. Toyoda, H. Yamazaki, and T. Yoshioka,
Nuclear Instruments and Methods in Physics Research **A779**, 13-17 (2015).

*Experiments with the High Resolution Kaon Spectrometer at JLab Hall C and the new spectroscopy of* ${}^{12}_{\Lambda}B$ *hypernuclei,*
L. Tang, C. Chen, T. Gogami, D. Kawama, Y. Han, L. Yuan, A. Matsumura, Y. Okayasu, T. Seva, V. M. Rodriguez, P. Baturin, A. Acha, P. Achenbach, A. Ahmidouch, I. Albayrak, D. Androic, A. Asaturyan, R. Asaturyan, O. Ates, R. Badui, O. K. Baker, F. Benmokhtar, W. Boeglin, J. Bono, P. Bosted, E. Brash, P. Carter, R. Carlini, A. Chiba, M. E. Christy, L. Cole, M. M. Dalton, S. Danagoulian, A. Daniel, R. De Leo, V. Dharmawardane, D. Doi, K. Egiyan, M. Elaasar, R. Ent, H. Fenker, Y. Fujii, M. Furic, M. Gabrielyan, L. Gan, F. Garibaldi, D. Gaskell, A. Gasparian, E. F. Gibson, P. Gueye, O. Hashimoto, D. Honda, T. Horn, B. Hu, Ed V. Hungerford, C. Jayalath, M. Jones, K. Johnston, N. Kalantarians, H. Kanda, M. Kaneta, F. Kato, S. Kato, M. Kawai, C. Keppel, H. Khanal, M. Kohl, L. Kramer, K. J. Lan, Y. Li, A. Liyanage, W. Luo, D. Mack, K. Maeda, S. Malace, A. Margaryan, G. Marikyan, P. Markowitz, T. Maruta, N. Maruyama, V. Maxwell, D. J. Millener, T. Miyoshi, A. Mkrtchyan, H. Mkrtchyan, T. Motoba, S. Nagao, S. N. Nakamura, A. Narayan, C. Neville, G. Niculescu, M. I. Niculescu, A. Nunez, Nuruzzaman, H. Nomura, K. Nonaka, A. Ohtani, M. Oyamada, N. Perez, T. Petkovic, J. Pochodzalla, X. Qiu, S. Randeniya, B. Raue, J. Reinhold, R. Rivera, J. Roche, C. Samanta, Y. Sato, B. Sawatzky, E. K. Segbefia, D. Schott, A. Shichijo, N. Simicevic, G. Smith, Y. Song, M. Sumihama, V. Tadevosyan, T. Takahashi, N. Taniya, K. Tsukada, V. Tvaskis, M. Veilleux, W. Vulcan, S. Wells, F. R. Wesselmann, S. A. Wood, T. Yamamoto, C. Yan, Z. Ye, K. Yokota, S. Zhamkochyan, and L. Zhu, Phys. Rev. C **90**, 034320 (2014).

*The OLYMPUS Experiment,*
R. Milner, D. Hasell, M. Kohl, U. Schneekloth, N. Akopov. R. Alarcon, V.A. Andreev, O. Ates, A. Avetisyan,

D. Bayadilov, R. Beck, S. Belostotski, J.C. Bernauer, J. Bessuille, F. Brinker, B. Buck, J.R. Calarco, V. Carassiti, E. Cisbani, G. Ciullo, M. Contalbrigo, N. DAscenzo, R. De Leo, J. Diefenbach, T.W. Donnelly, K. Dow, G. Elbakian, D. Eversheim, S. Frullani, Ch. Funke, G. Gavrilov, B. Glaser, N. Gorrissen, J. Hauschildt, B.S. Henderson, Ph. Hoffmeister, Y. Holler, L.D. Ice, A. Izotov, R. Kaiser, G. Karyan, J. Kelsey, D. Khaneft, P. Klassen, A. Kiselev, A. Krivshich, I. Lehmann, P. Lenisa, D. Lenz, S. Lumsden, Y. Ma, F. Maas, H. Marukyan, O. Miklukho, A. Movsisyan, M. Murray, Y. Naryshkin, C. OConnor, R. Perez Benito, R. Perrino, R.P. Redwine, D. Rodriguez Pineiro, G. Rosner, R.L. Russell, A. Schmidt, B. Seitz, M. Statera, A. Thiel, H. Vardanyan, D. Veretennikov, C. Vidal, A. Winnebeck, and V. Yeganov,
Nuclear Instruments and Methods in Physics Research **A741**, 1-17 (2014).

#### 5.1.2 Conference proceedings

*EM Form Factors and OLYMPUS,*
M. Kohl for the OLYMPUS collaboration,
Proc. 13th International Workshop on Production, Properties and Interaction of Mesons (MESON2014), Cracow, Poland, May 29 June 3, 2014, EPJ Web Conf. 81 (2014) 01006, DOI: 10.1051/epjconf/20148101006.

*The Muon Scattering Experiment (MUSE) at PSI and the proton radius puzzle,*
M. Kohl for the MUSE Collaboration,
Proc. 13th International Workshop on Production, Properties and Interaction of Mesons (MESON2014), Cracow, Poland, May 29 June 3, 2014, EPJ Web Conf. 81 (2014) 02008, DOI: 10.1051/epjconf/20148102008.

*Muon Elastic Scattering with MUSE at PSI,*
M. Kohl for the MUSE collaboration,
Proc. Int. Nuclear Physics Conference (INPC2013), Florence, Italy, June 2-7, 2013, EPJ Web Conf. 66 (2014) 06010, DOI: 10.1051/epjconf/20146606010.

*Probing two-photon exchange with OLYMPUS,*
OLYMPUS Collaboration (M. Kohl for the OLYMPUS collaboration),
Proc. Int. Nuclear Physics Conference (INPC2013), Florence, Italy, June 2-7, 2013, EPJ Web Conf. 66 (2014) 06009, DOI: 10.1051/epjconf/20146606009.

### 5.2 Presentations/Conferences 2014-2016

#### 5.2.1 Seminars and Colloquia

*Status of TREK, OLYMPUS, MUSE, DarkLight, C-GEN*,
M. Kohl,
Hampton University Nuclear Physics Group Seminar, Hampton, VA, September 15, 2015.

*The Proton Charge Radius Puzzle and the MUSE Experiment,*
M. Kohl,
Invited Department seminar at INFN Rome, La Sapienza University Rome, Rome, Italy, January 26, 2015.

*The dark side of light,*
M. Kohl,
Invited colloquium Tel Aviv University, Tel Aviv, Israel, January 4, 2015.

*Form Factors with Electrons and Positrons*,
M. Kohl,
Invited lecture series at The Hebrew University of Jerusalem, Jerusalem, Israel, Dec. 30, 2014 /Jan. 6, 2015.

*The dark side of light,*
M. Kohl,
Invited colloquium The Hebrew University of Jerusalem, Jerusalem, Israel, December 29, 2014.

*The Proton Radius Puzzle How can it be resolved?*
M. Kohl,
Invited seminar, The College of William and Mary, Williamsburg, Virginia, USA, September 26, 2014.

*Investigation of two-photon exchange with the OLYMPUS experiment*,
M. Kohl,
Invited seminar, Trinity College, Dublin, Ireland, September 9, 2014.

*What is so puzzling about the electric charge of the proton?*, M. Kohl,
Invited seminar, Joint Experiment-Theory Seminar, Technical University Darmstadt, Darmstadt, Germany, June 10, 2014.

*What is so puzzling about the electric charge of the proton?*,
M. Kohl,
Invited Colloquium, Physics Colloquium at Hampton University, Hampton, VA, February 13, 2014.

*The TREK program at J-PARC*,
M. Kohl,
Invited seminar, Particle Physics Seminar at Tel Aviv University, Tel Aviv, Israel, January 1, 2014.

*A framework of low-energy precision experiments,*
M. Kohl,
Invited seminar Joint Nuclear Physics Seminar at Hebrew University of Jerusalem, Jerusalem, Israel, December 30, 2013.

#### 5.2.2 Presentations at Conferences and Workshops

*TREK @ J-PARC: Beyond the Standard Model with Stopped $K^+$*,
M. Kohl,

Invited talk presented at the KL2016 Workshop at Jefferson Lab, Newport News, VA, Feb. 1-3, 2016.

*Progress of the TREK/E36 experiment at J-PARC*,
M. Kohl,
Contributed talk presented at the 2015 APS Division of Nuclear Physics Fall Meeting (DNP2015), Santa Fe, New Mexico, Oct. 28-31, 2015.

*Development of GEMs at Hampton University*,
A. Liyanage,
Contributed talk presented at the 2015 APS Division of Nuclear Physics Fall Meeting (DNP2015), Santa Fe, New Mexico, Oct. 28-31, 2015.

*GEM detectors for MUSE*,
M. Kohl,
Talk at Mini-Workshop on the MUSE experiment at PSI, Villigen, Switzerland, July 22-24, 2015.

*E36: Measurement of* $\Gamma(K^+ \to e^+\nu)/\Gamma(K^+ \to \mu^+\nu)$ *and Search for a heavy sterile neutrino using the TREK detector system,*
M. Kohl,
Invited talk in te Open Session at the 20th Program Advisory Committee meeting for J-PARC, July 15-17, 2015, J-PARC, Tokai, Japan.

*Status of the TREK/E36 experiment at J-PARC,*
M. Kohl,
Contributed talk, APS April meeting, Baltimore, Maryland, April 11-14, 2015.

*Status of the TREK/E36 experiment at J-PARC,*
M. Kohl,
Contributed talk at the 2014 Joint APS/JPS Division of Nuclear Physics Fall Meeting (HAW2014), Waikoloa, Big Island, Hawaii, Oct. 7-11, 2014.

*Recent results in two-photon exchange,*
M. Kohl,
Invited talk at the Gordon Research Conference on Photonuclear Reactions (from quarks to nuclei), Holderness, NH, August 10-15, 2014.

*The TREK experiment at J-PARC,*
M. Kohl,
Invited talk, Proton Radius Puzzle Workshop, Mainz, June 2-6, 2014.

*EM Formfactors and OLYMPUS,*
M. Kohl,
Invited talk at the 13th International Workshop on Meson Production, Properties and Interaction (ME-

SON2014), Cracow, Poland, May 29-June 3, 2014.

*Studying Two Photon Exchange with OLYMPUS,*
M. Kohl,
Poster presented at the 2014 HU Research Day on April 17-18, 2014.

*MUSE Beamline Detectors,*
M. Kohl,
Talk at the MUSE Technical Review Meeting, PSI, Villigen, Switzerland, Jan. 25, 2014.

*The MUSE experiment at PSI,*
M. Kohl,
Invited talk, International Workshop XLII on Gross Properties of Nuclei and Nuclear Excitations "Hadrons from Quarks and Gluons", Hirschegg, Kleinwalsertal, Austria, January 12-18, 2014.

#### 5.2.3 Presentations at Collaboration Meetings

*GEMs for MUSE*,
M. Kohl,
Talk presented at the MUSE collaboration meeting, George Washington University, Washington, DC, September 1-2, 2016.
*GEMs for MUSE*,

*GEM Updates at HU*,
A. Liyanage,
Talk presented at the MUSE collaboration meeting, George Washington University, Washington, DC, September 1-2, 2016.

*GEMs for MUSE*,
M. Kohl,
Talk presented at the MUSE collaboration meeting, George Washington University, Washington, DC, October 8-9, 2015.

*GEM Lepton Tracker Update*,
M. Kohl,
Talk presented at the DarkLight collaboration meeting, MIT, Cambridge, MA, September 2, 2015.

*Analysis and Simulation Framework*,
M. Kohl,
Talk at the TREK/E36 collaboration meeting, J-PARC, Tokai, Japan, May 8, 2015.

*GEM detectors*,
M. Kohl,
Talk presented at the DarkLight collaboration meeting, Arizona State University, Tempe, AZ, March 11-12, 2015.

*GEM chambers  Plans to improve and finalize GEM setup*,
M. Kohl,
Talk presented at the MUSE collaboration meeting, PSI, December 13-14, 2014.

*Analysis and Simulation Framework*,
M. Kohl,
Talk at the TREK/E36 collaboration meeting, J-PARC, Japan, December 6, 2014.

*GEM lepton tracker update*,
M. Kohl,
Talk presented at the DarkLight collaboration meeting, JLab, Newport News, December 2, 2014.

*Lepton Tracker for phase-I DarkLight*,
M. Kohl,
Talk presented at the DarkLight collaboration meeting, JLab, Newport News, August 26, 2014.

*E12-11-009 Charter*,
M. Kohl,
Talk at the E12-11-009 (GEn) collaboration meeting, Jefferson Lab, August 25, 2014.