

Closeout Report

Applicant/Institution: Hampton University
Street/City/State/Zip: 100 E. Queen Street, Hampton, VA 23668
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Principal Investigator: Dr. Michael Kohl
Postal Address: Physics Department, Hampton University, Hampton, VA 23668
Telephone Number: (757) 727-5153
Email: kohlm@jlab.org

Administrative contact: Alisa Rodgers
Telephone Number: (757) 727-5363
Email: alisa.rodgers@hamptonu.edu

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1 Introduction

This DOE Early Career Award has enabled Dr. Michael Kohl to take on and expand his leadership roles in several projects such as TREK@J-PARC, OLYMPUS@DESY, MUSE@PSI, and in the experimental program in Hall C at Jefferson Lab.

Dr. Kohl has key leadership roles in several experimental projects that have synergistic connections in multiple ways, in terms of the science goals, the technological expertise, and the training opportunities. Dr. Kohl has served as spokesman and is the present physics coordinator of the OLYMPUS experiment at DESY in Hamburg, Germany, which aims to definitively determine the effect of two-photon exchange in elastic lepton-proton scattering by comparing the positron-proton and electron-proton elastic cross sections [1, 2, 3, 4]. He has co-initiated the MUSE experiment at PSI in Villigen, Switzerland, to shed light on the proton radius puzzle by simultaneously measuring the proton charge radius with elastic scattering of muons and electrons of either charge, which will determine a possible lepton flavor dependence of the scattering process and at the same two-photon exchange effects independently [5]. Dr. Kohl is co-spokesperson of the TREK/E36 experiment [6, 7, 8] at J-PARC in Tokai, Japan, which uses positively charged stopped kaon decays to investigate the universality of the charged lepton couplings and to search for new light neutral particles in the mass region up to 200 MeV/c², which could be connected to established anomalies in particle physics (such as the muon anomalous magnetic moment and the proton radius puzzle), and provide an explanation for dark matter. Through his joint appointment as staff scientist at Jefferson Lab, Dr. Kohl has also lead roles in the Jefferson Lab program, here as co-spokesperson for the proposed measurement of the neutron electric form factor with recoil neutron polarimetry and deuterium target at high momentum transfer (C-GEN, E12-11-009). He is also a principal investigator of the DarkLight experiment (C12-11-008) in preparation at the Low-Energy Recirculator Facility (LERF) at Jefferson Lab to search for a dark photon as a mediator particle of dark matter [9, 10]. He is responsible for the lepton tracker based on Gas Electron Multiplier (GEM) detectors [11] for the DarkLight phase-I apparatus, which has recently been funded by NSF through a consortium MRI grant together with MIT.

Dr. Kohl has developed expertise for GEM detectors through his involvement in OLYMPUS, where he and his group have constructed forward-angle GEM tracking telescopes for luminosity monitoring at OLYMPUS. After completion of OLYMPUS running these telescopes have been relocated to PSI where they serve as beam particle trackers for the MUSE experiment, representing a key instrument to enable the needed precision of MUSE. Using GEM detectors for tracking in high-rate environments has also been considered for TREK and C-GEN.

Dr. Kohl has successfully accomplished several items:

- (i) Preliminary results from SANE (E08-003) at Jefferson Lab: Former HU graduate student Anusha Liyanage has pursued her PhD research on SANE. Her analysis of the elastic ep scattering data has resulted in the extraction of the proton electric-to-magnetic form factor ratio from double spin asymmetries at the highest momentum transfer to date. The results are almost final and a publication is in preparation.
- (ii) Approval of TREK/E36 for running, preparation of simulation and analysis: the TREK experiment has been stage-II approved in fall 2013, has been mounted on the hall floor from November 2014 to April 2015, has been commissioned in April-June 2015 and is scheduled to run in fall 2015. The group has contributed significantly with simulations and magnetic field map calculations, has investigated the sensitivity of TREK to new light neutral particles, and contributed substantially to the mounting and commissioning of the experiment.
- (iii) Running of OLYMPUS and analysis: Under Dr. Kohl's leadership as spokesman, the OLYMPUS experiment has completed data taking beginning of 2013; calibrations and analysis have been well underway,

with results to be expected in the course of 2015.

(iv) Operation of GEM detectors at OLYMPUS and MUSE: The GEM telescopes built for OLYMPUS luminosity monitoring with forward-angle ep elastic scattering have been operated successfully, have meanwhile been relocated to PSI, and have been re-commissioned as beam particle trackers for the PSI secondary beams for MUSE.

(v) Trained and prepared postdocs and graduate students for their future careers. Two postdocs from Dr. Kohl's group (Dr. Juergen Diefenbach and Dr. Peter Monaghan) have found permanent academic positions. Two former graduate students of the group have graduated and received their PhD degrees in nuclear physics (Dr. Anusha Liyanage and Dr. Ozgur Ates).

In particular, this award has enabled Dr. Kohl to pursue the TREK project (Time Reversal Experiment with Kaons) at J-PARC, which he has been leading and advancing as International Spokesperson. Originally proposed as a search for time reversal symmetry violation [6], the project has evolved into a precision test of lepton flavor universality in the Standard Model along with sensitive searches for physics beyond the Standard Model through a possible discovery of new particles such as a sterile neutrino or a neutral gauge boson from the hidden sector in the mass region up to $300 \text{ MeV}/c^2$ [7]. Experiment TREK/E36, first proposed in 2010, has been mounted between November 2014 and April 2015, and commissioning with beam has been started in April 2015, with production running anticipated in early summer and late fall 2015. It uses the apparatus from the previous KEK/E-246 experiment with partial upgrades to measure the ratio of decay widths of leptonic two-body decays of the charged kaon to $\mu\nu$ and $e\nu$, respectively, which is highly sensitive to the ratio of electromagnetic charged lepton couplings and possible new physics processes that could differentiate between μ and e , hence breaking lepton flavor universality of the Standard Model. Through the searches for neutral massive particles, TREK/E36 can severely constrain any new physics scenarios designed to explain the proton radius puzzle [12, 13].

2 Description of Dr. Kohl's Working Group

Dr. Kohl has been a faculty member at Hampton University in the Experimental Nuclear Physics Group since January 2008 in joint appointment as a staff scientist at Jefferson Lab (Hall C). In summer 2013 he has been awarded tenure.

Dr. Kohl's present group includes two postdoctoral researchers, and two graduate students pursuing a PhD in experimental nuclear physics. Dr. Anusha Liyanage has joined the group as a postdoc in fall 2013 for the Optional Practical Training (OPT) after graduating in Dr. Kohl's group in summer 2013. She has since been supported under the NSF grant PHY-1207672. Her main focus is on optimizing the operation and data acquisition of the existing GEM telescopes, and the analysis and calibration of GEM data from OLYMPUS and from ongoing MUSE test experiments. She has succeeded Dr. Juergen Diefenbach who left the group in April 2013 to accept a permanent position as research scientist at Mainz University.

Dr. Narbe Kalantarians has joined Dr. Kohl's group as a senior postdoc in August 2014. He is presently co-funded to 50% between Dr. Kohl's Early Career Award and Jefferson Lab. He has served as a postdoc in the group of Dr. Eric Christy on Jefferson Lab related tasks such SHMS wire chamber construction and analysis of structure functions. His main focus in Dr. Kohl's group is on the preparation and running of the TREK/E36 experiment at J-PARC, and on the DarkLight phase-I experiment under preparation at Jefferson Lab. He will play a significant role in the construction effort of the lepton tracker for DarkLight phase-I.

Two graduate students are presently funded under Dr. Kohl's present grants: Bishoy Dongwi has been

working on the TREK/E36 experiment at J-PARC supported by Dr. Kohl's DOE Early Career Award. He is now in his 4th year of the program and has passed the PhD qualifying exam in spring 2014. He has been visiting J-PARC for extended periods for preparation, running and analysis of TREK/E36. Bishoy has been contributing by developing a Geant4 simulation of the full TREK/E36 setup. Jesmin Nazeer has joined Hampton University and Dr. Kohl's group as a new graduate student in fall 2014. She is presently supported by Dr. Kohl's NSF award PHY-1207672. Her focus will be on the DarkLight experiment.

3 Training and Career Advances

Most importantly and in achieving one of the goals of the Early Career support, PI Dr. Michael Kohl has been awarded tenure and promotion to Associate Professor at Hampton University in a continued joint appointment with Hall C at Jefferson Lab in 2013.

Dr. Kohl has also been a successful mentor to his students and postdocs. Former Hampton University graduate student Ozgur Ates was supported by the NSF group grant PHY-1002644 until spring 2010. From summer 2010 until fall 2011 he was funded under Dr. Kohl's NSF/MRI grant PHY-0959521 for the GEM telescope construction, for spring and summer 2012 under Dr. Kohl's DOE Early Career Award DE-SC0003884, and from fall 2012 - spring 2014 under Dr. Kohl's regular NSF award PHY-1207672. He graduated in May 2014 with the dissertation "*GEM Luminosity Monitors for the OLYMPUS Experiment to Determine the Effect of Two-Photon Exchange*" and is now a postdoc in medical physics at the Medical College of Wisconsin.

Former Hampton University graduate student Anusha Liyanage was supported by JLab until graduating. She graduated in August 2013 with the dissertation "*Proton Form Factor Ratio, G_E^p/G_M^p from Double Spin Asymmetry*". Since September 2013 she has been funded as a postdoc under Dr. Kohl's NSF award PHY-1207672 for the OPT (Optional Practical Training).

Former Hampton University postdoctoral associate Dr. Peter Monaghan was funded under the NSF group grant PHY-1002644 until April 2011. He was funded under Dr. Kohl's DOE Early Career Award from May 2011 - July 2014. Dr. Monaghan has successfully found a tenure-track faculty position at Christopher Newport University in joint appointment as staff scientist at JLab, which he started in August 2014.

Former Hampton University postdoctoral associate Dr. Juergen Diefenbach was funded under Dr. Kohl's regular NSF grants PHY-0855473 and PHY-1207672. He has successfully found a permanent appointment as a research scientist at Mainz University in Germany, which he started in April 2013.

4 Proton Form Factor Ratio from Double Spin Asymmetry - E07-003 (SANE)

The Spin Asymmetries of the Nucleon Experiment (SANE), which aimed to measure the spin structure functions g_1^p and g_2^p with a dynamically polarized ammonia target for polarized protons, took simultaneously elastic scattering data in two configurations: In one mode, elastically scattered electrons were detected in BigCal, a large solid-angle electromagnetic calorimeter, with recoil protons detected in the High-Momentum Spectrometer (HMS) at high four-momentum transfer $Q^2 = 5.66 \text{ (GeV/c)}^2$ in coincidence. In the other mode, HMS was used to measure single-arm elastically scattered electrons at somewhat lower value of $Q^2 = 2.06 \text{ (GeV/c)}^2$. These data provide an important verification of the decline of the proton form factor ratio with Q^2 as observed in polarization transfer experiments. Dr. Kohl has supervised former Hampton University

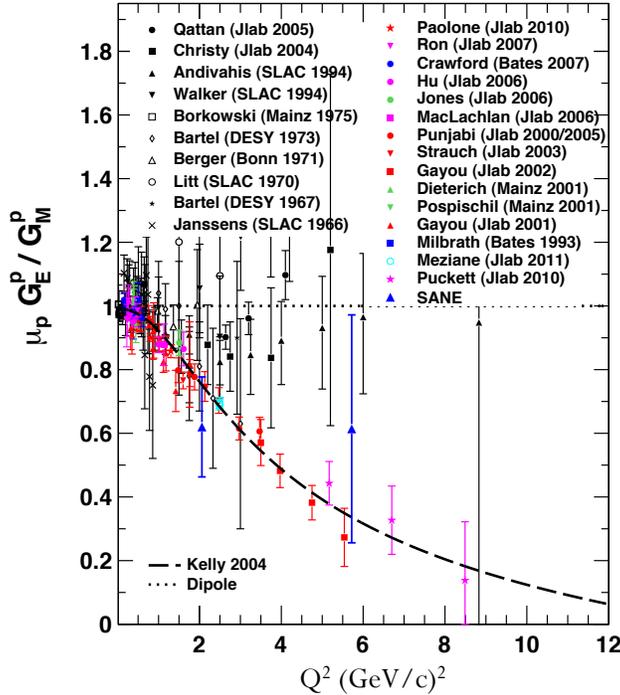


Figure 1: Preliminary result of the proton electric-to-magnetic form factor ratio $\mu_p G_E^p / G_M^p$ from the SANE experiment (blue triangles), together with previous data.

graduate student Anusha Liyanage in her analysis of the elastic data. Anusha graduated with her PhD in 2013 and is now a postdoc in the group in OPT (Optional Practical Training). The extracted form factor ratio from the double spin asymmetry with longitudinally polarized beam and polarized target confirms a decline of the ratio below unity, consistent with the recoil polarization data. Figure 1 shows the preliminary result. Detector calibrations and systematic error estimates are still being finalized. A publication of the final result is in preparation.

The kinematics of this experiment represent the highest four-momentum transfer ever covered with a polarized target. The analysis of the proton form factor ratio at high Q^2 , while statistics limited, demonstrates the feasibility of a dedicated polarized target experiment with optimized statistics, which is being considered in the Jlab community.

5 Status of TREK

The TREK (Time Reversal Experiment with Kaons) collaboration, with Dr. Kohl as International Spokesman, has been pursuing a staged approach in realization of the TREK experiment, the search for time reversal violation (E06) [6], by having proposed two additional measurements (test of lepton universality and search for heavy neutrinos, called E36) [7]. The two additional experiments are a new measurement of the $K_{e2}^+ / K_{\mu 2}^+$ branching ratio to test lepton universality and lepton flavor violation with a precision of 0.25%, improving the precision of the CERN/NA62 and KLOE experiments by nearly a factor two [14, 15]. The stopped-kaon method of TREK/E36 has completely different systematics. In the minimally super-symmetric extension of the Standard Model (MSSM), this ratio can deviate from the Standard Model value by as much as 1.3%

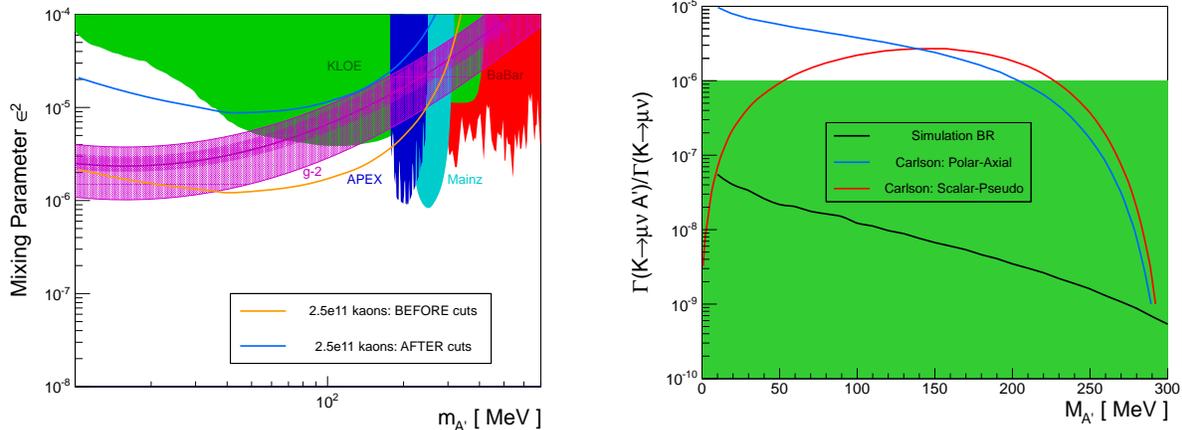


Figure 2: *Left*: Expected dark-photon exclusion limit for TREK/E36 from $K^+ \rightarrow \mu^+ \nu A' \rightarrow K^+ \rightarrow \mu^+ \nu e^+ e^-$ decays. *Right*: The expected exclusion limit for a light bosons with fine-tuned couplings [12, 13] (black curve) severely restricts the presently allowed, green region. The red and blue curves are the expected branching ratios to produce fine-tuned A' bosons that explain the proton radius puzzle.

and is thus an excellent probe of new physics beyond the Standard Model [16, 17, 18]. In addition, R_K is also sensitive to the neutrino mixing parameters within SM extensions involving a fourth generation of quarks and leptons [19] or sterile neutrinos [20]. The TREK apparatus is very suitable to measure both kaon decay channels with high statistics and excellent control of systematics. The second experiment is a search for heavy sterile neutrinos (N) in two-body kaon decays $K^+ \rightarrow \mu N$ (or eN). It was recently noticed that TREK/E36 also allows for a sensitive search for a dark photon or more generally of light neutral gauge bosons with non-universal couplings, which has relevance in view of new physics explanation of the proton radius puzzle [8, 12, 13]. Former postdoctoral associate Dr. Peter Monaghan has studied the sensitivity of the charged kaon decays in TREK/E36 to an observation of a dark photon to decay into e^+e^- in the final state, or more generally of a neutral gauge boson in the mass region up to $300 \text{ MeV}/c^2$ and found it to be competitive with other present dark photon searches, see Fig. 2 (left). Non-universal gauge bosons with preferred coupling to muons, as needed to explain the proton radius puzzle, can be completely ruled out by TREK/E36 if not seen within the approved amount of beamtime (Fig. 2 right panel).

The earthquake in Northeastern Japan in March 2011 has delayed the J-PARC program by about a year. With the expected primary beam intensity growth, the J-PARC lab management has revised its mid-term strategies for the J-PARC Hadron Hall, reviewed at the PAC14 meeting in March 2012. KEK and IPNS (Institute of Particle and Nuclear Studies) have identified COMET ($\mu - e$ conversion experiment, the competitor of “mu2e” proposed at Fermilab), as a J-PARC flagship experiment that is now aimed to be built already in phase I of J-PARC, in combination with an also proposed high-momentum proton beamline (high-p). While TREK does not conflict with the planned high-p beamline when mounted on rails, it will conflict with COMET if the latter is constructed as a branch of the high-p beamline, which requires substantial shielding bunkers at the previously conceived location of the TREK experiment (K1.1BR). The timeline for COMET calls for a start of construction of the shielding walls in 2016. According to the PAC, the spatial conflict of the Time Reversal Violation Experiment with Kaons (E06) with COMET by the time when high beam power of $> 100 \text{ kW}$ is expected to become available (after 2015) will unfortunately prohibit execution of E06 in phase I of J-PARC. In phase II of J-PARC, the hadron hall will be extended but there are no detailed plans yet at this time concerning funding and schedule.

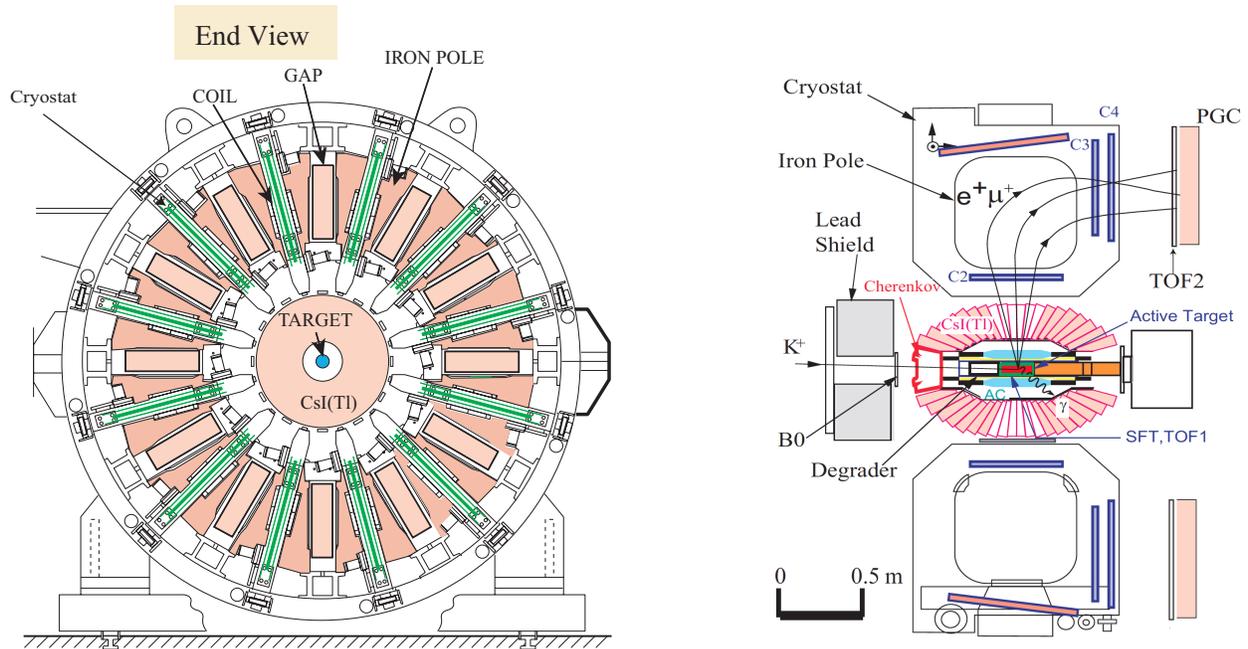


Figure 3: End and side views of the TREK/E36 setup. The momentum of charged particle and photons are determined by the toroidal spectrometer with the SFT+MWPCs (C2-C4) and the CsI(Tl) calorimeter, respectively. The spectrometer consists of 12 identical sectors. Charged particles π^+ , μ^+ , e^+ are discriminated by the combination of a time-of-flight measurement (TOF2-TOF1), an aerogel Cherenkov counter (AC), and a lead-glass Cherenkov counter (PGC).

On the other hand, it was stated by PAC14 in March 2012 that there would be a very good chance that E36 (test of lepton universality) will be mounted and run by 2015 before the construction schedule for COMET begins. The J-PARC / KEK / IPNS management have demonstrated their strong support for E36 since then. PI Dr. Kohl has successfully defended the TREK/E36 project at PAC15 in July 2012, which was subsequently stage-I approved by the IPNS/KEK directorate. The laboratory covered the cost for the transfer of the cryogenic system, as this would be used both for E36 as well as for COMET. The TREK collaboration has developed a detailed plan to use the given time window of opportunity to run E36 in 2014-2015, including a resource and manpower loaded schedule, and by minimizing cost and effort to prepare E36. Fund raising has been successful in Canada (an NSERC grant for UBC to construct the new TREK target which was renewed). Upon approval of E36 in summer 2012, additional funding requests have been submitted in Japan and in the US, here for the C1 GEM chambers in form of an NSF/MRI proposal in February 2013. The MRI request was not immediately funded, however, and so the collaboration started to develop plans for a fallback solution in case that C1 tracker would not be built, by considering a scintillating fiber tracker to spiral around the stopping target bundle. The TREK/E36 collaboration led by PI Dr. Kohl successfully convinced the PAC17 in September 2013 from the feasibility of TREK/E36 and achieved stage-II approval by the IPNS/KEK management. Additional funding proposals were submitted in Japan in fall 2013 and again in the US, where a revised NSF/MRI request for the construction of C1 GEM detectors has been resubmitted in January 2014. Unfortunately the C1 GEM detector could not be funded after all, so the fallback solution with the Spiraling Scintillating Fiber Tracker (SFT) has been pursued.

In May 2013, a radiation contamination accident happened at J-PARC unfortunately, which caused a halt of all operations at J-PARC until beginning of 2014. Major changes to the safety control procedures were

implemented. In February 2014, operations have begun to be gradually resumed. The Hadron Facility received first beam again only in April 2015, after the primary production target had been replaced and operations of the slow beam extraction to the Hadron Hall were re-approved. The E36 experiment has been mounted on the floor at K1.1BR from November 2014 - April 2015, followed by an engineering run in April-May 2015 and June 2015. Production running is anticipated in fall 2015. A total of three months of production running at the design intensity will be sufficient to achieve the goals of E36.

The anticipated contribution of Dr. Kohl's group at Hampton University to the TREK program has originally been the development of Gas Electron Multiplier (GEM) detectors. For E36, twelve planar GEM tracking detectors (C1) were proposed to be constructed, to provide more precise and redundant tracking information for charged particles. The design parameters for the C1 GEM chambers for TREK were determined, leveraging from the experience with OLYMPUS. The originally proposed cylindrical GEM chamber (C0) for TREK will not be required in E36, instead the space surrounding the stopping target inside the CsI calorimeter barrel will host a spiraling scintillating fiber tracker (also used as fallback since the funding for the C1 GEMs has failed), and an aerogel Cerenkov detection system for enhanced positron-muon discrimination for the lepton universality test. E36 will also not require the new active muon polarimeters required for TREK/E06. The CsI readout based on PIN diodes can remain unchanged. Unfortunately the GEM detectors for TREK were not funded. The group has instead focused on developing simulation and analysis code for the E36 experiment, and contributed substantially to the construction and commissioning of E36.

6 Status of OLYMPUS

The OLYMPUS experiment [1, 2, 3, 4] aims to precisely measure the ratio of elastic e^+p and e^-p scattering cross sections to better than 1% total error for a beam energy of 2 GeV and a wide range of scattering angles. In the kinematic region covered by OLYMPUS the cross section ratio is expected to deviate from unity by as much as 5-10%, if the form factor discrepancy between Rosenbluth and recoil polarization measurements is caused by two-photon exchange.

The OLYMPUS experiment has been run in February and from October-December 2012 at the DORIS storage ring at DESY, Hamburg, Germany, which provided both electron and positron beams in excess of 100 mA at 2 GeV. Both the lepton and recoiling proton were detected in coincidence. The internal, unpolarized, isotopically pure hydrogen gas target was designed to deliver $3 \cdot 10^{15}$ atoms/s, corresponding to a luminosity of $2 \cdot 10^{33}/(\text{cm}^2\text{s})$. The OLYMPUS detector has largely been based on the previous BLAST apparatus from the MIT-Bates Linear Accelerator Center [21, 22, 23, 24], a toroidal spectrometer with excellent tracking capability over a wide range of scattering angles of $\approx 20^\circ - 80^\circ$ and $\pm 15^\circ$ out of plane. Several upgrades were implemented for OLYMPUS, in particular two redundant systems were added to measure the relative luminosity of electron and positron beams using forward-angle elastic lepton-proton and symmetric Møller/Bhabha scattering, respectively.

Preparations of the OLYMPUS experiment have begun upon approval in 2010 after securing the required funding from the US agencies DOE and NSF, DESY and the German agency DFG. The BLAST detector was transferred from MIT and reassembled at DESY in a park position. In summer 2011 it was brought into final position in the DORIS storage ring. The new internal hydrogen gas target has been designed and constructed at MIT with a 60 cm long target cell made by INFN Ferrara. The experiment was commissioned in 2011 in parallel with the regular DORIS synchrotron operation, with several dedicated beamtests before the first production data taking took place at the beginning of 2012. OLYMPUS has successfully taken data during two running periods in February 2012 and from October 2012 until January 2013. The integrated

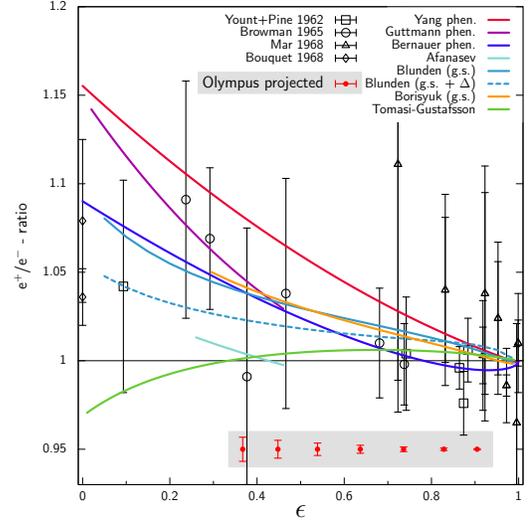
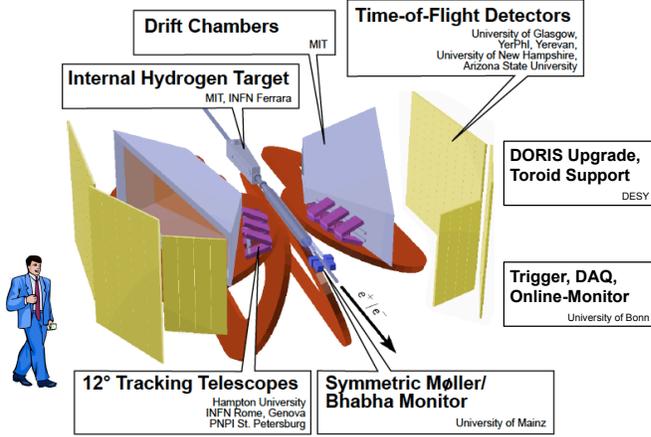


Figure 4: *Left:* Schematic layout of the OLYMPUS experiment with components labeled in the figure. *Right:* Projected precision of OLYMPUS for the e^+p to e^-p cross section ratio versus ϵ along with previous data [25] and various theoretical predictions [26, 27, 28, 29, 30, 31, 32], which have been evaluated for a constant beam energy of $E = 2$ GeV.

luminosity goal was exceeded with the data acquired. After the production running, detailed surveys of the target and detector geometry and of the magnetic field map were undertaken. Calibrations, data analysis and detailed simulations are now in full swing, using an integrated analysis framework. A total integrated luminosity of 3.6 fb^{-1} at a beam energy of 2.0 GeV is required to provide the statistical accuracy of $< 1\%$ up to $Q^2 \leq 2.2 \text{ (GeV/c)}^2$.

The schematic layout of OLYMPUS is shown on the l.h.s. of Fig 4. Of the original BLAST setup [21], the toroidal magnet, the wire chambers (WC) and the time-of-flight scintillators (TOF) have been used. Forward-angle elastic scattering luminosity monitoring systems have been constructed at Hampton University (GEM detector telescopes) and Petersburg Nuclear Physics Institute (multi-wire proportional chambers, MWPC). In addition, a symmetric Møller/Bhabha monitoring system has been developed at Mainz University. The trigger and data acquisition systems were provided by Bonn University. Figure 4 (r.h.s.) shows the projected statistical uncertainties for the e^+p to e^-p cross section ratio at a beam energy of 2.0 GeV as a function of virtual photon polarization along with previous data [25] and various theoretical expectations [27, 28, 29, 30, 31, 32]. The systematic uncertainties of the ratio are expected to be less than 1%.

7 GEM Detector Operation

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. The detectors have performed quite stable with high efficiencies above 90%. Spatial resolutions of the GEM chambers have been found around $75 \mu\text{m}$. The telescopes have been relocated to PSI in 2013 where they are now serving as beam particle trackers of the secondary beams for the MUSE experiment. Some detailed spatial variations of the efficiencies have been observed in the data which can be related to noise effects in the frontend readout

electronics. More detailed and systematic investigations are ongoing with the OLYMPUS data and now also with recent MUSE testbeam data at PSI.

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8 Research Metrics

8.1 Publications 2010-2015

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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. Mamyán, 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 ${}_{\Lambda}^{12}B$ hypernuclei,
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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. D'Ascenzo, 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. Khanefit, 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. O'Connor, 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).

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Precise Measurement of Deuteron Tensor Analyzing Powers with BLAST,

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S. Chernenko, E. Christy, M. Commisso, J.C. Cornejo, S. Covrig, S. Danagoulian, A. Daniel, A. Davidenko, D. Day, S. Dhamija, D. Dutta, R. Ent, S. Frullani, H. Fenker, E. Frlez, F. Garibaldi, D. Gaskell, S. Gilad, Y. Goncharenko, K. Hafidi, D. Hamilton, D.W. Higinbotham, W. Hinton, T. Horn, B. Hu, J. Huang, G.M. Huber, E. Jensen, H. Kang, C. Keppel, M. Khandaker, P. King, D. Kirillov, M. Kohl, V. Kravtsov, G. Kumbartzki, Y. Li, V. Mamyán, D.J. Margaziotis, P. Markowitz, A. Marsh, Y. Matulenko, J. Maxwell, G. Mbianda, D. Meekins, Y. Melnik, J. Miller, A. Mkrtchyan, H. Mkrtchyan, B. Moffit, O. Moreno, J. Mulholland, A. Narayan, Nuruzzaman, S. Nedev, E. Piasetzky, W. Pierce, N.M. Piskunov, Y. Prok, R.D. Ransome, D.S. Razin, P.E. Reimer, J. Reinhold, O. Rondon, M. Shabestari, A. Shahinyan, K. Shestermanov, S. Sirca, I. Sitnik, L. Smykov, G. Smith, L. Solovyev, P. Solvignon, R. Subedi, R. Suleiman, E. Tomasi-Gustafsson, A. Vasiliev, M. Vanderhaeghen, M. Veilleux, B.B. Wojtsekhowski, S. Wood, Z. Ye, Y. Zanevsky, X. Zhang, Y. Zhang, X. Zheng, and L. Zhu, Phys. Rev. Lett. **106**, 132501 (2011).

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8.1.2 Conference proceedings

EM Form Factors and OLYMPUS,

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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,

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J.L. Hewett *et al.*,

Proc. of the 2011 workshop on Fundamental Physics at the Intensity Frontier, Rockville, MD, November 30
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M. Kohl,

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Moments of the Neutron g_2 structure function at Intermediate Q^2 ,

P. Solvignon *et al.*,

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Phys. Rev. D **81**, 034016 (2010).

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Studying the Proton “Radius” Puzzle with p Elastic Scattering,

Experiment Proposal, The MUon proton Scattering Experiment (MUSE) Collaboration, R. Gilman *et al.*,
arXiv:1303.2160v3 [nucl-ex]

DarkLight: A Search for Dark Forces at the Jefferson Laboratory Free-Electron Laser Facility,

Experiment Proposal, J. Balewski *et al.*, arXiv:1307.4432v2 [physics.ins-det]

Technical design report for the Paul Scherrer Institute Experiment R-12-01.1: Studying the Proton “Radius” Puzzle with p Elastic Scattering,

The MUon proton Scattering Experiment collaboration (MUSE),
Technical Design Report to Program Advisory Committee for Paul-Scherrer Institute, June 2012.

Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for heavy sterile neutrinos using the TREK detector system,

Progress Report of P36 to 15th Program Advisory Committee for J-PARC, June 2012.

A Proposal for the DarkLight Experiment at the Jefferson Laboratory Free Electron Laser,

The DarkLight Collaboration,

Experiment Proposal to Program Advisory Committee (PAC39) for Jefferson Lab, May 2012.

Studying the Proton “Radius” Puzzle with μp Elastic Scattering,

The MUSE Collaboration,

Proposal to Program Advisory Committee for Paul Scherrer Institute, February 2012.

Systematic Error Analysis of the Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$, The TREK/E36 Collaboration,

Addendum II to Proposal P36 Report to 13th Program Advisory Committee for J-PARC, January 2012.

Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for heavy sterile neutrinos using the TREK detector system,

The TREK/E36 Collaboration,

Addendum to Proposal P36 Report to 11th Program Advisory Committee for J-PARC, January 2011.

P36: Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for heavy sterile neutrinos using the TREK detector system,

The TREK/E36 Collaboration,

Experiment Proposal P-36 to the 10th Program Advisory Committee for J-PARC, June 2010.

8.2 Student and Staff Recognition 2010-2015

HU postdoctoral associate **Dr. Anusha Liyanage** attended the 2015 HU Research Day on April 9-10, 2015 and presented a poster with the title “The MUSE Experimental Setup”.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the DarkLight collaboration meeting at Arizona State University, Tempe, AZ, March 11-12, 2015.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the OLYMPUS collaboration meeting at Arizona State University, Tempe, AZ, March 9-10, 2015, and gave a presentation with the title “GEM analysis updates”.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the Geant4 simulation classes offered by Dr. Paul Gueye in spring 2015.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the MUSE collaboration meeting held at PSI on December 13-14, 2014, and gave a presentation with the title “GEM Analysis Updates”.

HU postdoctoral associate **Dr. Anusha Liyanage** traveled to PSI in Villigen, Switzerland from December 1-23, 2014 to participate in the test beam time for the MUSE experiment.

HU postdoctoral associate **Dr. Anusha Liyanage** presented the talk “Improved cluster finding in 2D GEMs” at the HU Nuclear Physics Group meeting on November 10, 2014.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the Gordon Conference on Photonuclear Reactions: From Quarks to Nuclei, Holderness School, Holderness, NH, August 10-15, 2014, and presented the poster “The MUSE Experimental Setup”.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the Workshop on Frontiers and Careers, MIT, Cambridge, MA, August 7-9, 2014. She chaired the session on “Form factors” and presented the talk “Measurement of the Proton Form Factor Ratio G_E/G_M from the Double Spin Asymmetry”.

HU postdoctoral associate **Dr. Anusha Liyanage** traveled to PSI in Villigen, Switzerland from June 14-30, 2014 to participate in the test beam time for the MUSE experiment.

HU postdoctoral associate **Dr. Anusha Liyanage** attended the MUSE Collaboration Meeting at George Washington University, Washington, DC, January 7-8, 2014.

HU postdoctoral associate **Dr. Anusha Liyanage** gave a presentation at the APS Fall Meeting of the Division of Nuclear Physics (DNP2013) in Newport News, October 23-26, 2013, with the title “*Proton Form Factor Ratio, G_{Ep}/G_{Mp} From Double Spin Asymmetries*”.

HU graduate student **Anusha Pushpakumari Liyanage** defended her PhD thesis on April 24, 2013, with the title “*Proton Form Factor Ratio, $\mu_p G_{Ep}/G_{Mp}$ From Double Spin Asymmetry*”.

HU graduate student **Anusha Pushpakumari Liyanage** attended the 2013 HU Research Day on April 18-19, 2013 and presented a poster with the title “*Measurement of the Proton Electric to Magnetic Form Factor Ratio with Polarized Beam and Target*”.

HU graduate student **Anusha Pushpakumari Liyanage** has been awarded a prize for Excellence in Scholarship for her paper titled “*Measurement of the Proton Form Factor Ratio G_{Ep}/G_{Mp} from Double Spin Asymmetries*”. This paper was submitted to the William & Mary Graduate Research Symposium 2013 and selected by a blinded independent panel of William & Mary faculty and Graduate Studies Advisory Board members. Anusha has been recognized at an Awards Luncheon on March 23, 2013 for her work.

HU graduate student **Anusha Pushpakumari Liyanage** has been admitted to the 2013 William & Mary Graduate Research Symposium at the College of William & Mary, Williamsburg, VA, March 23-24 2013, to give a presentation with the title “*Measurement of the Proton Electric to Magnetic Form Factor Ratio with Polarized Beam and Target*”.

HU graduate student **Anusha Pushpakumari Liyanage** gave a presentation at the Hall C winter workshop, Jefferson Lab, January 24-25, 2013, with the title “*Proton Form Factor Ratio G_E/G_M from Double Spin Asymmetries*”.

HU graduate student **Anusha Pushpakumari Liyanage** gave a presentation at the Experimental Nuclear Physics Group Seminar at Hampton University on December 4, 2012, with the title “*Proton Form Factor Ratio, G_{Ep}/G_{Mp} From Double Spin Asymmetries*”.

HU graduate student **Anusha Pushpakumari Liyanage** has been admitted to the prestigious symposium EDIT 2012 “*Excellence in Detectors and Instrumentation Technologies*” held at Fermi Lab, February 13 - 24, 2012.

HU graduate student **Anusha Pushpakumari Liyanage** has been speaker at the Hall C winter workshop, Jefferson Lab, January 13-14, 2012, “*SANE: Dilution Factor and Elastic Asymmetry from HMS*”.

HU graduate student **Anusha Pushpakumari Liyanage** presented “*SANE Experiment Extraction of the Proton Electric-to-Magnetic Elastic Form Factor Ratio with Polarized Beam and Target*” at the Annual Meeting of the Jefferson Lab Users Group, June 8, 2011 and won the first place in the poster contest, which resulted in a \$1,200 award.

HU graduate student **Anusha Pushpakumari** has been speaker at the 2011 April Meeting of the American Physical Society (APS), Anaheim, California, April 30 - May 3, 2011, with the contributed talk titled “*Measurement of the Proton Form Factor Ratio G_E/G_M from Double Spin Asymmetries*”. This activity was co-funded by the Jefferson Science Association, from where \$400 had been raised by Dr. Kohl.

HU graduate student **Anusha Pushpakumari** has been speaker at the Hall C winter workshop, Jefferson Lab, January 14-15, 2011, “*Proton Form Factor Ratio G_E/G_M from Double Spin Asymmetry with Polarized Beam and Target*”.

HU graduate student **Anusha Pushpakumari** has been admitted to the 2011 William & Mary Graduate Research Symposium at the College of William & Mary, Williamsburg, VA, March 25 - 26, 2011, to give a presentation “*Measurement of the Proton Electric to Magnetic Form Factor Ratio with Polarized Beam and Target*”.

HU graduate student **Anusha Pushpakumari** has been speaker at the 2010 Fall Meeting of the American Physical Society (APS) Division of Nuclear Physics (DNP), Santa Fe, New Mexico, November 2-6, 2010, with the contributed talk titled “*Proton Form Factor Ratio G_E/G_M from Double Spin Asymmetry with Polarized Beam and Target*”. This activity was co-funded by the Jefferson Science Association, from where \$600 had been raised by Dr. Kohl.

HU graduate student **Ozgun Ates** has defended his PhD thesis on February 28, 2014, with the title “*GEM*”

Luminosity Monitors for the OLYMPUS Experiment to Determine the Effect of Two-Photon Exchange”.

HU graduate student **Ozgur Ates** gave a presentation at the APS Fall Meeting of the Division of Nuclear Physics (DNP2013) in Newport News, October 23-26, 2013, with the title “*Luminosity monitoring at OLYMPUS with forward-angle elastic scattering*”.

HU graduate student **Ozgur Ates** gave a presentation at the OLYMPUS Collaboration Meeting at DESY on October 17-18, 2013, with the title “*GEM luminosity measurements*”.

HU graduate student **Ozgur Ates** gave a presentation at the Experimental Nuclear Physics Group Seminar at Hampton University on October 1, 2013, with the title “*OLYMPUS GEM luminosity monitors*”.

HU graduate student **Ozgur Ates** attended the 2013 HU Research Day on April 18-19, 2013 and presented a poster with the title “*Studying Two Photon Exchange with OLYMPUS*”.

HU graduate student **Ozgur Ates** has visited DESY for a two-year period beginning March 27, 2011 until March 27, 2013 for preparation and running of the OLYMPUS experiment. This activity has been enabled by Dr. Kohl’s NSF and DOE grants.

HU graduate student **Ozgur Ates** has been admitted to give a presentation at the 77th Spring Meeting of the German Physical Society (DPG2013) in Dresden, Germany, March 4-8, 2013, with the title “*OLYMPUS Luminosity Monitoring*”.

HU graduate student **Ozgur Ates** gave a presentation at the Experimental Nuclear Physics Group Seminar at Hampton University on September 4, 2012, with the title “*GEM detectors for OLYMPUS at DESY and status of the experiment*”.

HU graduate student **Ozgur Ates** presented “*OLYMPUS Luminosity Monitoring*” at the Spring Conference of the German Physical Society (DPG) in Mainz, Germany, March 19-23, 2012.

HU graduate student **Ozgur Ates** presented a seminar talk “*OLYMPUS GEM Luminosity Monitors*” in the DESY Students’ Seminar series, December 8, 2011.

HU graduate student **Ozgur Ates** has been visiting DESY for a two-year period beginning March 27, 2011 for preparation and running of the OLYMPUS experiment. This activity has been enabled by Dr. Kohl’s NSF and DOE grants.

HU graduate student **Ozgur Ates** has given a talk at the HU Experimental Nuclear Physics Group Seminar on September 07, 2010 with the title “*Summer research at MIT*”.

HU graduate student **Ozgur Ates** has been speaker at Hampton University Research Day, Hampton, VA, February 18, 2010, with the talk titled “*Handling the OLYMPUS GEMs at MIT Bates, Manufacturing of*

the GEMs at the HU-GEM Lab and MC Simulation of GEMs by using Geant4".

HU graduate student **Jesmin Nazeer** attended the OLYMPUS collaboration meeting at Arizona State University, Tempe, AZ, March 9-10, 2015.

HU graduate student **Jesmin Nazeer** attended the DarkLight collaboration meeting at Arizona State University, Tempe, AZ, March 11-12, 2015.

HU graduate student **Jesmin Nazeer** attended the Geant4 simulation classes offered by Dr. Paul Gueye in spring 2015.

HU graduate student **Bishoy Dongwi** traveled to J-PARC and KEK two times (November 4, 2014 January 29, 2015 and February 17 April 14, 2015) to contribute to the construction of the TREK/E36 experiment at J-PARC.

HU graduate student **Bishoy Dongwi** remotely attended the TREK/E36 collaboration meeting at J-PARC, Tokai, Japan, May 8, 2015 and gave a presentation with the title "Acceptance study and optimum magnetic field determination".

HU graduate student **Bishoy Dongwi** attended the TREK/E36 collaboration meeting at KEK, Tsukuba, Japan, December 6, 2014 and gave a presentation with the title "Acceptance Study".

HU graduate student **Bishoy Dongwi** attended the HUGS2014 summer school, Jefferson Lab, June 1-20, 2014. He gave a HUGS seminar with the title "The TREK experiment at J-PARC".

HU graduate student **Bishoy Dongwi** remotely attended the TREK/E36 collaboration meeting at KEK, Tsukuba, Japan, May 8-9, 2014 and gave a presentation with the title "GEANT4 Tracking Element (C1-4) Simulation Using QT".

HU graduate student **Bishoy Dongwi** has passed the PhD qualifying exam in May 2014. His dissertation research will be focused on the TREK/E36 experiment at J-PARC in Japan, which is expected to run in 2015.

HU graduate student **Bishoy Dongwi** has visited KEK, Tsukuba, Japan from December 5-12, 2013 to attend the TREK/E36 collaboration meeting on Dec. 7-8, 2013, enabled by Dr. Kohl's DOE Early Career Award. He gave a presentation with the title "*GEANT4 Tracking Element Simulation*".

HU graduate student **Bishoy Dongwi** gave a presentation at the APS Fall Meeting of the Division of Nuclear Physics (DNP2013) in Newport News, October 23-26, 2013, with the title "*Gas Electron Multiplier Detectors for TREK at J-PARC*".

HU graduate student **Bishoy Dongwi** attended the 2013 HU Research Day on April 18-19, 2013 and presented a poster with the title “*The TREK/E36 Experiment at J-PARC*”.

HU graduate student **Bishoy Dongwi** has been admitted to the 2013 William & Mary Graduate Research Symposium at the College of William & Mary, Williamsburg, VA, March 23-24 2013, to give a poster presentation with the title “*Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ And Search for Heavy Sterile Neutrinos Using The TREK Detector System*”.

HU graduate student **Bishoy Dongwi** attended the Geant4 tutorial workshop at Jefferson Lab from July 9-13, 2012.

HU senior undergraduate student **Thoth Gunter** has attended the Geant4 tutorial workshop at Jefferson Lab from July 9-13, 2012.

HU junior students **Joshua McMahon** and **Miles Campbell** have been admitted to the Conference Experience for Undergraduates (CEU11) program at the 2011 fall meeting of the Division of Nuclear Physics of the American Physical Society, East Lansing, MI, October 26-29, 2011, with travel expenses and conference registration paid by the CEU. They presented the poster “*Gas Electron Multiplier Tracking Telescopes for OLYMPUS*” from work conducted at MIT-Bates Linear Accelerator and DESY.

On Dr. Kohl’s initiative, HU juniors **Joshua McMahon** and **Miles Campbell** were admitted to attend the 2011 DESY summer student program at DESY, Hamburg, Germany.

With Dr. Kohl’s support, 2010 Hampton REU/UniPhy students **Laura Havener** from University of North Carolina and **Matthew Anthony** from University of Notre Dame were re-admitted to the 2011 MIT Summer Student Research Program (MSRP) 2011 at MIT, Cambridge, MA after first attending the MSRP in 2010 through the Hampton REU/Uniphy program.

Laura Havener from University of North Carolina and Hampton REU participant in summer 2010 under supervision of Dr. Kohl, has been accepted to attend the graduate/PhD program in physics at Columbia University in New York, NY beginning in fall 2012.

Matthew Anthony from University of Notre Dame and Hampton REU participant in summer 2010 under supervision of Dr. Kohl, has been accepted to attend the graduate/PhD program in physics at University of Maryland, College Park, MD beginning in fall 2012.

Caroline Soffiati from Boston University and Hampton REU participant in summer 2010 under co-supervision of Dr. Kohl, has been accepted to attend the graduate/PhD program in physics at University of California, Berkeley, in Berkeley, CA beginning in fall 2012.

With Dr. Kohl’s help and support, **Laura Havener** from University of North Carolina and **Matthew Anthony** from University of Notre Dame have been re-admitted to the 2011 MIT Summer Student Research Program 2011 at MIT, Cambridge, MA.

Junior students **Laura Havener** from University of North Carolina and **Matthew Anthony** from University of Notre Dame have been admitted to the Conference Experience for Undergraduates (CEU10) program at the 2010 fall meeting of the Divisions of Nuclear Physics of the American Physical Society, Santa Fe, NM, November 2-6, 2010. The award came with \$100 partial support toward travel expenses, covers the conference fee of \$125 and includes 4 nights of accommodation. Laura and Matt presented a poster on their research conducted at MIT in summer 2010 under supervision of Dr. Michael Kohl.

Taumi Daniels from the Department of Atmospheric Sciences, Hampton University, received his PhD in 2012 with the dissertation *The Analysis of an Imaging Passive Infrared Fourier Transform Spectrometer for Airborne Detection of Wake Vortices*, which was co-refereed by Dr. Kohl.

HU postdoctoral associate **Juergen Diefenbach**, “*Parity Violating Electron Scattering with A4 at MAMI*”, Talk presented at HU Experimental Nuclear Physics Group Seminar, Hampton University, September 21, 2010.

HU postdoctoral associate **Juergen Diefenbach**, “*Lumi GEMs status update*”, Talk presented at OLYMPUS collaboration meeting at DESY, Hamburg, Germany, November 1-2, 2010.

HU postdoctoral associate **Dr. Juergen Diefenbach**, “*OLYMPUS testbeam at DESY*”, Talk presented at OLYMPUS collaboration meeting at DESY, Hamburg, Germany, January 24-25, 2011.

HU senior postdoctoral associate **Dr. Peter Monaghan** attended the TREK/E36 Collaboration meeting held at the High-Energy Research Organization (KEK) in Tsukuba, Japan, December 7- 8, 2013.

HU senior postdoctoral associate **Dr. Peter Monaghan** has started a tenure-track faculty position at Christopher Newport University in August 2014 in joint appointment with Jefferson Lab.

HU senior postdoctoral associate **Dr. Peter Monaghan** remotely attended the TREK/E36 collaboration meeting at J-PARC, Tokai, Japan, May, 2014 and gave a presentation with the title “Calculation of a New Magnetic Field Map”.

HU senior postdoctoral associate **Dr. Peter Monaghan** remotely attended the TREK/E36 collaboration meeting at J-PARC, Tokai, Japan, December 6, 2014 and gave a presentation with the title “Magnetic Field Map”.

HU senior postdoctoral associate **Dr. Peter Monaghan** gave a presentation at the APS Fall Meeting of the Division of Nuclear Physics (DNP2013) in Newport News, October 23-26, 2013, with the title “*Extracting the Proton Longitudinal Structure Function Moments from World Data*”, based on his recent publication P. Monaghan *et al.*, “*Moments of the Longitudinal Proton Structure Function F_L from Global Data in the Q^2 Range $0.754.50(\text{GeV}/c)^2$* ”, Phys. Rev. Lett. **110**, 152002 (2013).

HU senior postdoctoral associate **Dr. Peter Monaghan**, “*Moments of the Longitudinal Proton Structure Function F_L from World Data*”, Invited talk, 5th Workshop of the APS Topical Group on Hadronic Physics, Denver, CO, April 10-12, 2013.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** traveled to J-PARC and KEK four times (October 25 – November 7 and December 1-19, 2014; January 14-29 and March 28 – April 7, 2015) to contribute to the construction of the TREK/E36 experiment at J-PARC.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** is initiator and organizer of the “Workshop on Final State Nucleons for Neutrino-Nucleus Interactions”, Jefferson Lab, Newport News, VA, May 14-15, 2015.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** attended the APS April Meeting in Baltimore, MD, April 1-14, 2015, and presented a talk with the title “DarkLight Invisibles”.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** gave the invited Jefferson Lab Pizza Seminar with the title “(Semi-)Inclusive Deuteron Data and Extraction of Neutron Structure Functions”, March 18, 2015.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** remotely attended the DarkLight Collaboration Meeting at Arizona State University, Tempe, AZ, March 11-12, 2015, and gave a presentation with the title “Invisible Search”.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** attended the Hall C Winter Collaboration Meeting, JLab, Newport News, VA, January 15, 2015, and gave a presentation with the title “SHMS Drift Chambers Update”.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** attended the TREK/E36 collaboration meeting at J-PARC, Tokai, Japan, on December 6, 2014, and gave a presentation with the title “TREK-E36 Scalers Study”.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** remotely attended the DarkLight Collaboration Meeting at Jefferson Lab, December 2, 2014, and gave a presentation with the title “Invisible Search”.

HU senior postdoctoral associate **Dr. Narbe Kalantarians** attended the DarkLight Collaboration Meeting at Jefferson Lab, August 26, 2014.

8.3 Presentations/Conferences 2010-2015

8.3.1 Seminars and Colloquia

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.

Two-Photon Exchange and the Role of OLYMPUS,
M. Kohl,
Invited seminar, PRISMA Colloquium and Seminar of the Graduate School, Johannes Gutenberg- Univer-

sität Mainz, Mainz, Germany, November 27, 2013.

Das geheimnisvolle Proton,

M. Kohl,

Invited seminar, Institut f. Kernphysik, Johannes Gutenberg-Universität Mainz, Mainz, Germany, May 14, 2013.

A framework of low-energy precision experiments,

M. Kohl,

Invited seminar talk at the Nuclear Physics Seminar at Ohio University, Athens, Ohio, September 18, 2012.

The OLYMPUS Experiment at DESY, M. Kohl,

Invited Colloquium, presented at University of Saskatchewan, Saskatoon, Canada, March 10, 2011.

Fundamental Symmetries and Time Reversal Invariance,

M. Kohl,

Colloquium at Hampton University (Dean's Colloquium Series), November 11, 2010.

8.3.2 Presentations at Conferences and Workshops

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 $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for a heavy sterile neutrino using the TREK detector system,

M. Kohl,

Invited talk in the 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 (MESON2014), 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.

The Proton Radius Experiment (PRad) at Jefferson Lab,

M. Kohl,

Invited talk, 10th European Research Conference on “Electromagnetic Interactions with Nucleons and Nuclei” (EINN2013), Pafos, Cyprus, Oct. 28 - Nov. 2, 2013.

Two-Photon Exchange,

M. Kohl,

Invited talk, 10th European Research Conference on “Electromagnetic Interactions with Nucleons and Nuclei” (EINN2013), Pafos, Cyprus, Oct. 28 - Nov. 2, 2013.

Investigating the charge of the proton,

M. Kohl,

Invited talk, 2013 Fall Meeting of the APS Division of Nuclear Physics (DNP2013), Newport News, VA, Oct. 23-26, 2013.

Status of the OLYMPUS experiment,

M. Kohl,

Contributed talk, 2013 Fall Meeting of the APS Division of Nuclear Physics (DNP2013), Newport News, VA Oct. 23-26, 2013.

E36: Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ and Search for a heavy sterile neutrino using the TREK

detector system,

M. Kohl,

Invited open session talk, 18th Program Advisory Committee meeting for J-PARC, KEK, Tsukuba, Japan
Sept. 25-27, 2013.

Muon Elastic Scattering with MUSE at PSI,

M. Kohl,

Poster presented at the International Nuclear Physics Conference (INPC2013), Florence, Italy, June 2-7,
2013.

Probing Two-photon Exchange with OLYMPUS,

M. Kohl,

Talk presented at the International Nuclear Physics Conference (INPC2013), Florence, Italy, June 2-7, 2013.

Form Factors with Electrons and Positrons,

M. Kohl,

Invited lecture series, HUGS2013 summer school at Jefferson Lab, May 28 - June 14, 2013

Wed May 29 2:00 - 3:00 pm, Part I: Overview and introduction

Wed May 29 3:15 - 4:15 pm, Part II: Proton form factor measurements

Thu May 30 10:15 - 11:15 am, Part III: Neutron form factor measurements

Thu May 30 2:15 - 3:30 pm, Part IV: Theoretical interpretation of nucleon form factors

Fri May 31 9:00 - 10:00 am, Part V: Deuteron form factor measurements

Fri May 31 1:00 - 2:00 pm, Part VI: The proton charge radius puzzle

The E36 Experiment at J-PARC,

M. Kohl,

Contributed talk at the APS April meeting, Denver, Colorado, April 13-16, 2013.

The TREK/E36 Experiment at J-PARC,

M. Kohl,

Contributed talk at the "Workshop to Explore Physics Opportunities with Intense, Polarized Electron Beams
up to 300 MeV" (PEB2013), MIT, Cambridge, MA, March 14-16, 2013.

Investigating the Charge of the Proton,

M. Kohl,

Invited plenary talk at the 77. Spring Conference of the German Physical Society (DPG2013), Dresden,
March 4-8, 2013.

Status of the OLYMPUS experiment,

M. Kohl,

Invited talk in the open session of the 74. Physics Research Committee (PRC) meeting at DESY-Zeuthen,
Germany, November 8-9, 2012.

The OLYMPUS experiment at DESY,

M. Kohl,

Invited talk at the International Workshop “The Proton Radius Puzzle”, European Center for Theoretical Studies (ECT), Trento, Italy, October 29 – November 2, 2012.

GEMs for MUSE,

M. Kohl,

Talk presented at the Technical Review meeting for the Muon Scattering Experiment MUSE, Paul-Scherrer Institute (PSI), Villigen, Switzerland, July 24, 2012.

P36: Measurement of $\Gamma(K^+ \rightarrow e^+\nu)/\Gamma(K^+ \rightarrow \mu^+\nu)$ Search for a heavy sterile neutrino using the TREK detector system,

M. Kohl,

Invited talk in the open session presented at the 15. PAC meeting for J-PARC at KEK, Tsukuba, Japan, July 13-15, 2012.

Status report of P36,

M. Kohl,

Talk presented in the closed session at the 15. PAC meeting for J-PARC at KEK, Tsukuba, Japan, July 13-15, 2012.

Muon scattering at PSI; Summary of Experiments (summary talk)

M. Kohl,

Two talks presented at the International Symposium “Experimental and theoretical aspects of the proton form factors”, St. Petersburg, Gatchina, Russia, July 9-11, 2012.

Muon-proton scattering at PSI,

M. Kohl,

Invited talk presented at the International Conference on Precision Physics of Simple Atomic Systems (PSAS2012) in Eltville, Germany, June 10-15, 2012.

Status of OLYMPUS,

M. Kohl,

Closed session report presented at the 73. PRC meeting at DESY, Hamburg, Germany, April 26, 2012.

The TREK Program at J-PARC,

M. Kohl,

Contributed talk and a poster presented at the Workshop on Fundamental Physics at the Intensity Frontier, Rockland, MD, Nov. 30 - Dec. 2, 2011.

OLYMPUS,

M. Kohl,

Invited talk presented on October 25, 2011 at the 72. Physics Research Committee Meeting, DESY, Ham-

burg, Germany, October 25-26, 2011.

BLAST and OLYMPUS Programs,

M. Kohl,

Invited talk at Int. Conference “Partons in Nucleons and Nuclei (PINAN2011)”, Marrakech, Morocco, September 26-30, 2011.

Overview of the OLYMPUS Experiment,

M. Kohl,

Invited talk at the Workshop on Radiative Corrections, MIT, Cambridge, MA, July 30, 2011.

The TREK program at J-PARC,

M. Kohl,

Contributed talk presented on May 2, 2011 at APS April Meeting, Anaheim, California, April 30 - May 2, 2011.

The OLYMPUS Experiment at DESY,

M. Kohl,

Contributed talk presented on April 13, 2011, at Int. Conf. “Deep Inelastic Scattering (DIS2011)”, Newport News, April 11-15, 2011.

OLYMPUS update,

M. Kohl,

Invited talk presented on January 15, 2011, Hall C Users meeting, Jefferson Lab, Newport News, VA, January 14-15, 2011.

Status of the OLYMPUS Experiment at DESY,

M. Kohl,

Contributed talk presented at 12th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon, College of William and Mary, Williamsburg, Virginia, USA, May 31 - June 4, 2010.

IncAs - Inclusive Asymmetries from Vector-Polarized Deuterium for a Precise Determination of G_nM at Intermediate Momentum Transfer,

M. Kohl,

Talk presented at the Workshop on High Luminosity Polarized Targets for the 12 GeV Era (Joint Hall A & C Meeting), June 17-18, 2010.

Elastic Form Factors of the Nucleon: A Long Story (To Be Continued!),

M. Kohl,

Invited talk presented at the International Symposium “Challenges in Nuclear Physics 2010” on the Occasion of Achim Richter’s 70th Birthday, Darmstadt, Germany, October 14-15, 2010.

A Trek to TREK,

M. Kohl,
Contributed talk at the 2010 Fall Meeting of the APS Division of Nuclear Physics, Santa Fe, New Mexico, USA, Nov. 2-6, 2010.

8.3.3 Presentations at Collaboration Meetings

*The Neutron Electric Form Factor at Q^2 up to 7 GeV^2 from the Reaction $^2\text{H}(e, e'n)^1\text{H}$ via Recoil Polarimetry
Status of GEN,*

M. Kohl,
Talk at the E12-11-009 (GEN) collaboration meeting, Jefferson Lab, October 22, 2013.

*E36 status,
Byproduct searches,
C1 GEM chamber,*

M. Kohl,
Three talks presented at the TREK Collaboration meeting, KEK, Tsukuba, March 25-26, 2013.

Status of OLYMPUS,

M. Kohl,
Talk presented at the Proton Radius Experiment (PRad) Collaboration meeting, Jefferson Lab, December 12, 2012.

*C1 GEM chamber
Possible byproduct physics "Searches in K^+ decays"*

M. Kohl,
Two talks presented at the TREK Collaboration meeting, TRIUMF, Vancouver, Canada, November 8-9, 2012.

Time of Flight,

M. Kohl,
Talk presented at the OLYMPUS Collaboration meeting, DESY, Hamburg, Germany, October 18-19, 2012, 2012.

GEM Chamber Developments,

M. Kohl,
Talk presented at TREK Collaboration Meeting at TRIUMF, Vancouver, BC, Canada, November 5, 2011.

*Summary of the Workshop on Radiative Corrections; Detector Calibration and Plans for October Test Run;
Lumi Telescope Installation,*

M. Kohl,
three talks presented at OLYMPUS Collaboration Meeting at DESY, Hamburg, Germany, September 8-9, 2011.

GEM Luminosity Monitor,

M. Kohl,
Talk presented at OLYMPUS Collaboration Meeting at DESY, Hamburg, Germany, June 27-28, 2011.

C1 and B0 GEMs,
M. Kohl,
Talk presented at TREK collaboration meeting at KEK, Tsukuba, Japan, February 19-20, 2011.

Luminosity Monitors; Physics Update,
M. Kohl,
Two talks presented at OLYMPUS Collaboration Meeting at DESY, Hamburg, Germany, January 24-25, 2011.

OLYMPUS update,
M. Kohl,
Talk presented at the Hall C Users Meeting, Jefferson Lab, Newport News, VA, January 14-15, 2011.

Status of TREK and Strategic Outlook; Update on GEMs,
M. Kohl,
Two talks presented at TREK Collaboration Meeting at KEK, Tsukuba, Japan, October 30-31, 2010.

Status and Plans for the Forward Elastic Scattering Luminosity Monitor,
M. Kohl,
Talk presented at the OLYMPUS Technical Review Meeting at DESY, Hamburg, Germany, August 30-31, 2010.

Status of the Forward Elastic Scattering Luminosity Monitor,
M. Kohl,
Talk presented at OLYMPUS Collaboration Meeting at DESY, Hamburg, Germany, June 28-29, 2010.

Status of the Forward Elastic Scattering Luminosity Monitor,
M. Kohl,
Talk at OLYMPUS Collaboration Meeting at DESY, Hamburg, Germany, April 26-27, 2010.

9 Student Tracking Information

Student: **Wenting Tan**
Date Entered Graduate school: August 2010
Date Joined Group: January 2011
Funding source: DOE
Degree Program: Masters
Date Degree Awarded: 2014
Advisor: M. Kohl, from fall 2011 E. Christy

Student: **Bishoy Dongwi**

Date Entered Graduate school: August 2011

Date Joined Group: September 2011

Funding source: DOE

Degree Program: PhD

Date Degree Expected: 2017

Advisor: M. Kohl

Student: **Ozgun Ates**

Date Entered Graduate school: August 2007

Date Joined Group: September 2007

Funding source: NSF

Degree Program: PhD

Date Degree Awarded: 2014

Advisor: M. Kohl

Student: **Anusha Liyanage**

Date Entered Graduate school: August 2006

Date Joined Group: September 2007

Funding source: JLab

Degree Program: PhD

Date Degree Awarded: 2013

Advisor: M. Kohl