New Scientific Opportunities with the TRIUMF ARIEL e-linac

Wednesday, 25 May 2022 - Friday, 27 May 2022

TRIUMF

ARIEL TRIUMF Stony Brook University

Book of Abstracts

Contents

1

(Welcome)

2

ARIEL Accelerator Overview

Author: Thomas Planche[1]

[1] *TRIUMF*

Corresponding Author: tplanche@triumf.ca

I will present a brief overview of TRIUMF's accelerator complex, focusing particularly on the ARIEL facility and its high-power electron accelerator: the e-linac. I will detail its design parameters, review the current performance of the machine, and show how the DarkLight experiment could be integrated into our beamlines.

Attendance:

Contact Email:

Scheduling Constraints:

3

PERLE@Orsay: A novel facility for ERL development and applications in multi-turn configuration and high-power regime

Author: Achille Stocchi[None]

Corresponding Author: achille.stocchi@ijclab.in2p3.fr

The development of ERLs has been recognized as one of the five main pillars of accelerators R&D in support of the European Strategy for Particle Physics (ESPP). The ERL Roadmap Panel recognized PERLE project as "a central part of the roadmap for the development of energy-recovery linacs", with milestones to be achieved by the next ESPP in 2026.
PERLE at Orsay is a project aiming at the construction of a novel ERL machine for the development and application of the energy recovery technique in multi-turn configuration, large current and large energy regime. It will operate in a 3-turns mode, first at 250 MeV, then upgraded to 500 MeV with 20mA beam current. Such challenging parameters make PERLE a unique multi-turn ERL facility operating at an unexplored operational power regime (10MW), studying and validating a broad range of accelerator phenomena, paving the way for the future larger scale ERLs.
PERLE machine opens a new frontier for the physics of "the electromagnetic probe". It will be the first ERL dedicated to Nuclear Physics for studying the eN interaction with radioactive nuclei. PERLE is also the necessary demonstrator for the future HEP machine (LHeC / FCC-eh) (same technological choices & beam parameters). PERLE could also host elastic ep scattering experiments and experiments on Nuclear Photonics using inverse Compton scattering gammas.
In this seminar we will present the PERLE project focusing on the challenges on accelerators physics and presenting the possible physics applications. We will also show the project structuration in an international collaboration and a timeline for the TDR phase and the following staged construction steps toward the PERLE machine at its nominal performances.

Attendance:

Contact Email:

Scheduling Constraints:

4

Low-energy electron scattering facilities in Japan - SCRIT for exotic nuclei and ULQ2 for proton and stable nuclei-

Author: Toshimi Suda[None]

Corresponding Author: suda@lns.tohoku.ac.jp

I will introduce low-energy electron scattering facilities for nuclear physics that we have constructed in Japan.
1) SCRIT facility at RIKEN RI Beam Factory
(SCRIT : Self-Confining Radioactive-isotope Ions Target)
the world's first electron scattering facility dedicated to short-lived exotic nuclei. Ee = 150 - 300 MeV, q = 80 - 300 MeV/c.
Luminosity ~ 1027 /cm2/s with NRI ~ 108/s.
ISOL (Photofission), electron storage ring, large-acceptance spectrometer.
2) ULQ2 facility at Tohoku
(ULQ2 : Ultra-Low Q2)
Ee = 10 - 60 MeV.
60-MeV e-linac, twin spectrometers with 4k-ch silicon strip detectors.
keyword : Proton charge (magnetic) radius. Nuclear charge form factor at extremely low q.
I will discuss the facility details, current status, and the physics program to be pursued at these facilities, including a ground-breaking new physics opportunity, recently pointed out [1], to determine the RMS radii of the neutron distribution of exotic nuclei at SCRIT and of stable nuclei at ULQ2.
references
1) H. Kurasawa and T. Suzuki, Prog. Theor. Exp. Phys., 2019, 113D01, https://doi.org/10.1093/ptep/ptz121
H. Kurasawa, T. Suda and T, Suzuki, Prog. Theor. Exp. Phys., 2021, 013D02, https://doi.org/10.1093/ptep/ptaa177
H. Kurasawa and T. Suzuki, Prog. Theor. Exp. Phys. 2022 023D03, https://doi.org/10.1093/ptep/ptac008

Attendance:

Contact Email:

Scheduling Constraints:

5

Operation of an Energy Recovery Linac with an Internal Target

Author: Steve Benson[None]

Corresponding Author: felman@jlab.org

Operation of an Energy Recovery Linac with an Internal Target
Stephen V. Benson1 and David R. Douglas2
1Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA
2David R. Douglas Consulting, Yorktown VA 23690, USA

felman@jlab.org
Because an Energy Recovery Linac (ERL) decelerates and dumps the beam on each pass, beam degradation in the interaction region orders of magnitude larger than in a storage ring are tolerable in such a device, and some new types of Nuclear Physics experiments can be carried out. In 2016 an experiment was installed to test out this idea (the DarkLight experiment). The ERL used had previously been used for FEL applications where high peak current and a large growth in energy spread was present. For the internal target the machine setup required very small energy spread, and a large transverse emittance growth in the target. Additionally, the addition of a strong solenoid in the transport complicated the details of energy recovery. This presentation will describe how these new machine physics challenges were addressed.
Acknowledgement
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

Attendance:

Contact Email:

Scheduling Constraints:

6

ARIEL experiments and theory

Author: Petr Navratil[1]

[1] *TRIUMF*

Corresponding Author: navratil@triumf.ca

I will present an overview of experiments at TRIUMF ARIEL and ISAC facilities covering both the current and the future envisioned programs. I will also briefly review theory program at TRIUMF that relates to the ARIEL experimental program. I will highlight several recent experimental results from the nuclear astrophysics, nuclear structure, fundamental symmetries, and the sterile neutrino search. Finally, I will mention ongoing theoretical ab initio calculations of the proton capture on 7Li related to the X17 boson observation.

Attendance:

Contact Email:

Scheduling Constraints:

7

Status for beam and perspectives for applications at the SRF photoinjector of the Sealab facility

Author: Thorsten Kamps[None]

Corresponding Author: kamps@helmholtz-berlin.de

In the first part the talk rationalizes the SRF photoinjector design of the bERLinPRo/SEALab facility at HZB. A brief history ending at the current status of the experiments is given. The talk concludes then with scientific opportunities currently under consideration for beam applications.

Attendance:

Contact Email:

Scheduling Constraints:

8

MESA - A fully instrumented ERL facility for particle and nuclear physics experiments

Author: Florian Hug[None]

Corresponding Author: flohug@uni-mainz.de

MESA is a recirculating superconducting accelerator under construction at Johannes Gutenberg-Universität Mainz. It can be operated in either external beam or ERL mode and will be used for high precision particle and nuclear physics experiments and will be a fully instrumented ERL user facility with three major experiments after completion. The operating cw beam current and energy in EB mode is 0.15 mA with polarized electrons at 155 MeV. In ERL mode a polarized beam of 1 mA at 105 MeV will be available. In a later construction stage of MESA the beam current in ERL-mode shall be upgraded to 10 mA (unpolarized). Civil construction and commissioning of components like electron gun, LEBT and SRF modules are ongoing already. We will give a project overview including the accelerator layout including experimental setups, the current status and an outlook to the next construction and commissioning steps.

Attendance:

Contact Email:

Scheduling Constraints:

9

Discussion

10

A new light particle is being born

Author: Attila Krasnahorkay[None]

Corresponding Author: kraszna@atomki.hu

A few years ago we observed anomalous electron-positron angular correlations for the 18.15~MeV M1 transition of 8Be [1]. This was interpreted as the creation and decay of an intermediate bosonic particle with a mass of m0c2=16.70(35)(stat)(50)(sys) MeV, which is now called X17. The possible relation of the X17 boson to the dark matter problem triggered an enormous interest in the wider physics community. We then re-investigated the 8Be anomaly with an improved, and independent setup, and confirmed the signal of the assumed X17 particle [2,3].
We also observed a similar anomaly in 4He [4], which could be described also by the creation and subsequent decay of the same X17 particle. Our results agree well with the present ab initio calculations of Viviani et al., [5].

Very recently, the 11B proton capture reaction was used for exciting the 17.2 MeV broad (Gamma= 1.15 MeV) resonance in 12C and studying their internal pair creation decay. Significant anomalies were observed in the angular correlation of the electron-positron pairs, at three different bombarding energies, which provides kinematic evidence for the X17 particle and supports their vector boson and fifth force explanation.

[1] A.J. Krasznahorkay et al., Phys. Rev. Lett. 116 (2016) 042501.
[2] A.J. Krasznahorkay et al., J. Phys.: Conf. Series 1056 (2018) 012028.
[3] A.J. Krasznahorkay et al., Acta Phys. Pol. B 50 (2019) 675.
[4] A.J. Krasznahorkay et al., Phys. Rev. C 104 (2021) 044003.
[5] M. Viviani et al., Phys. Rev. C 105, (2022) 014001.

Attendance:

Contact Email:

Scheduling Constraints:

11

Status of IPC experiment at the Montreal Tandem

Author: Georges Azuelos[None]

Corresponding Author: georges.azuelos@umontreal.ca

At the Montreal Tandem accelerator, an experiment is being setup to measure internal pair creation in 8Be, using a Daphne experiment MWPC and the scintillator bars surrounding it, covering nearly 4-pi. The preamps and data acquisition hardware have been designed and tested. The target, mounted on an Al foil and water-cooled is in a section of the beamline made of C fiber. The experiment will focus on the measurement of the X17 in IPC of the 18.15 MeV state of 8-Be. Assuming the ATOMKI evaluation of the electron-pair production rate from X17, Geant4 simulation predicts observation of a clear signal after about 2 weeks of data taking with 2 uA proton beam. The IPC measurement could eventually be extended to other nuclei: 10B, 12C and 4He.

Attendance:

Contact Email:

Scheduling Constraints:

13

Fermilab g-2 result and prospects for MeV-scale new physics

Author: Rodolfo Capdevilla [None]

Corresponding Author: rcapdevilla@perimeterinstitute.ca

We study new physics scenarios that resolve the muon $(g-2)_\mu$ anomaly with only Standard Model singlet particles coupled to muons. Since such models are only viable in the MeV –TeV mass range and require sizable muon couplings, they predict abundant accelerator production through the same interaction that resolves the anomaly. We show that B-factories and high energy colliders can respectively probe the middle (0.1 - 10 GeV) and high mass (>10 GeV) regions of viable single masses. Searches for light singlets (<0.1 GeV) are better suited for fixed target experiments. We show that a combination of these experiments can cover nearly all viable singlets scenarios, independently of their decay modes.

Attendance:

Contact Email:

Scheduling Constraints:

15

Dark photon searches at accelerators

Author: Christopher Hearty[1]

[1] *U. British Columbia/IPP*

Corresponding Author: hearty@physics.ubc.ca

The dark photon could mediate interactions between dark matter particles, and, through its kinetic mixing with the standard model photon, interact with standard model particles. I will review recent results on accelerator-based searches for dark photons decaying visibly to standard model particles, or invisibly to dark matter. I will also briefly discuss projected sensitivities from current and proposed experiments.

Attendance:

Contact Email:

Scheduling Constraints:

18

New opportunities for the study of baryon-number violation with low-energy electron accelerators

Author: Susan Gardner[None]

Corresponding Author: svg@pa.uky.edu

The severity of the experimental limits on proton decay does not preclude the appearance of processes that break baryon number by two units at an appreciable rate, and their experimental signatures in low-energy experiments are so striking as to be "background free." I will consider the connections between various such processes and their implications, noting, e.g., that the observation of $e^- p \to e^+ \bar{p}$, along with that of $n\bar{n}$ oscillations, would point to the existence of neutrinoless double β decay — and thus to that of a Majorana neutrino.
Working within the context of minimal scalar models that permit no proton decay, I consider not only the experimental constraints on such new degrees of freedom but also event rates for baryon- and lepton-number violating processes at future accelerator facilities such as Ariel.

Attendance:

Contact Email:

Scheduling Constraints:

19

Light MeV-scale dark matter at accelerators

Author: Adam Ritz[None]

Corresponding Author: aritz@uvic.ca

Over the past decade, a growing effort using accelerators and direct detection has explored the parameter space of light thermal relic dark matter models in the MeV-GeV range and their associated dark force mediators. I will briefly review the current status, focussing on the lower end of this mass window, and discuss theoretical scenarios, astrophysical and cosmological constraints, and potential future targets.

Attendance:

Contact Email:

Scheduling Constraints:

20

Lepton Flavor Universality

Author: Douglas Bryman[1]

[1] *UBC/TRIUMF*

Corresponding Author: doug@triumf.ca

An overview of searches for violation of lepton flavor universality will be presented with focus on low energy precision probes using pions, kaons, tau leptons, and beta decays related through unitarity tests of the CKM quark mixing matrix. The current status and future prospects including the new PIONEER rare pion decay experiment will be discussed.

Attendance:

Contact Email:

Scheduling Constraints:

21

Proton Radius: A Puzzle or a Solution!?

Author: Ulrich Jentschura[None]

Corresponding Author: ulj@mst.edu

The proton radius puzzle is known as the discrepancy of the proton radius, obtained from muonic hydrogen spectroscopy (about 0.84fm), and the proton radius obtained from (ordinary) hydrogen spectroscopy by the Paris group, who measured a number of transitions in atomic hydrogen, involving highly excited states (which led to a radius of 0.88fm). Recently, a number of measurements of hydrogen transitions by the Munich (Garching) groups (2S-4P), by the spectroscopy group at the University of Toronto (2S-2P_1/2), and by the group at Colorado State University (2S-8D), have led to transition frequency data which is consistent with the smaller proton radius, pointing to a possible,

purely experimental, resolution of the proton radius puzzle. In the talk, we will discuss a complete reevaluation of the irreducible two-loop vacuum-polarization correction to muonic hydrogen energy levels. This calculation addresses one of the most challenging contributions relevant for the proton radius puzzle. We also give an overview of the general theoretical status of the theory of the Lamb shift in simple atomic systems. A comparison of the raw data for the Sachs G_E form factor of the proton, from the PRad and Mainz collaborations, reveals that the situation in regard to scattering experiments might be less clear than currently thought, raising the question whether or not the proton radius puzzle has been conclusively solved, and opening up interesting experimental possibilities at TRIUMF ARIEL.

Attendance:

Contact Email:

Scheduling Constraints:

22

Discussion

Authors: Jeffery Martin[1]; Jeffery Martin[1]

[1] *The University of Winnipeg*

Corresponding Authors: jeffery.w.martin@gmail.com, j.martin@uwinnipeg.ca

Attendance:

Contact Email:

Scheduling Constraints:

23

The MESA science program: dark matter and more

Author: Luca Doria[None]

Corresponding Author: doria@uni-mainz.de

The Mainz Energy recovery superconducting accelerator MESA will allow precise measurements in hadron and nuclear physics, as well as exciting opportunities in dark matter searches. Three experiments will be built around this new and unique facility: MAGIX, P2, and DarkMESA. In this talk, the MESA science program will be presented, with focus on dark matter and new physics searches.

Attendance:

Contact Email:

Scheduling Constraints:

24

Science Program at the S-DALINAC

Author: Norbert Pietralla[None]

Corresponding Author: pietralla@ikp.tu-darmstadt.de

The Superconducting-Darmstadt linear accelerator (S-DALINAC) is operational at the Technische Universität Darmstadt and represents the major research instrument at its institute for nuclear physics.
Its research program focuses an precision studies of photonuclear reactions with real and virtual photons at low momentum transfers and impacts on various fields ranging from nuclear structure physics and nuclear astrophysics to support for searches beyond the standard model as well as detector and accelerator technology [1].
We present a few research examples and indicate current initiatives for future experimental opportunities.
[1] N. Pietralla, Nucl. Phys. News 28, No.2, 4 (2018).

Attendance:

Contact Email:

Scheduling Constraints:

25

Illuminating the Dark Photon with DarkLight

Author: Ethan Cline[None]

Corresponding Author: ethan.cline@stonybrook.edu

The search for a dark photon holds considerable interest in the physics community. Such a force carrier would begin to illuminate the dark sector. Many experiments have searched for such a particle, but so far it has proven elusive. In recent years the concept of a low mass dark photon has gained popularity in the physics community. Of particular recent interest is the ^8Be and ^4He anomaly, which could be explained by a 17 MeV mass dark photon. The proposed Darklight experiment would search for this potential low mass force carrier at ARIEL in the 10-20 MeV e^+e^- invariant mass range. This talk will focus on the experimental design and physics case of the Darklight experiment.

Attendance:

Contact Email:

Scheduling Constraints:

26

New experiments on resonances near threshold

Author: Wolfgang Mittig[None]

Corresponding Author: mittig@nscl.msu.edu

Four types of recent and ongoing experiments will be described: Resonances near threshold in the 10Be+proton system, search for dark decay in 11B and 6He (ongoing), the
pair creation in the 7Li+p and the X17 boson (ongoing), and multi-particle decay near threshold.

Attendance:

Contact Email:

Scheduling Constraints:

27

Electrodisintegration of 16O and determination of astrophysical S-factors of the inverse reaction

Author: Ivica Friščić[1]

[1] *University of Zagreb, PMF-FO*

Corresponding Author: ifriscic@phy.hr

After more than five decades of experimental effort the rate of ⊠ on 12C radiative capture at astrophysical energies (⊠⊠⊠ ~ 0.3 MeV above threshold) is not determined with desired precision and it is a cause of the largest uncertainty contribution in modeling of evolution of massive stars and underlying nucleosynthesis. By using the windowless gas jet target and modern energy-recovery linear accelerators (ERLs, CBETA at Cornell, NY, USA and MESA in Mainz, Germany) to reach high luminosity, a high precision measurement of the electron scattering on 16O nucleus would provide a method to determine the rate of the ⊠ on 12C radiative capture for energy range ⊠⊠⊠ < 2 MeV with a superb precision compared to previous experiments [1]. The feasibility of this method still needs to be studied. This could be done in a moderate luminosity experiment at existing electron accelerator sites by measuring the rate at ⊠⊠⊠ > 2 MeV where the cross section is much larger.

[1] I. Friščić, T. W. Donnelly, and R. G. Milner, Phys. Rev. C 100, (2019) 025804

Currently supported by:
Croatian Science Foundation under the project IP-2018-01-8570 and European Union's Horizon 2020 research and innovation program under the grant agreement 101038099.

Attendance:

Contact Email:

Scheduling Constraints:

28

Closeout

30

Search for Light Neutral Bosons in the TREK/E36 Experiment

Author: Bishoy Dongwi[None]

The Standard Model (SM) represents our best description of the sub- atomic world and has been very successful in explaining how elementary particles interact under the influence of the fundamental forces. Despite its far reaching success in describing the building blocks of matter, the SM is still incomplete; falling short to explain dark matter, baryogenesis, neutrino masses and much more. The E36 experiment was conducted at J-PARC in Japan, it was designed to test lepton universality, and it has additional sensitivity to search for light U(1) gauge bosons. Of particular interest is the muonic K+ decay channel. Such U(1) bosons could be as- sociated with dark matter or explain established muon-related anomalies such as the muon g − 2 value, and perhaps the proton radius puzzle. A realistic simulation study was employed for these rare searches in a mass range of 20 MeV/c2 to 110 MeV/c2. Preliminary upper limits for the A′ branching ratio Br(A′) extracted at 95% CL will be presented.

Attendance:

Contact Email:

Scheduling Constraints:

31

Theoretical study of the 3H(p, e+e-)4He and 3He(n,e+e-)4He processes and the X17 anomaly

Author: Michele Viviani[1]

[1] *INFN-Pisa*

Corresponding Author: michele.viviani@pi.infn.it

A rather puzzling anomaly has been recently observed in the emission of electron-positron pairs in the 7Li(p,e+e-)8Be and 3H(p,e+e-)4He reactions [1,2]. This anomaly has been interpreted as the signature of a particle not foreseen in the standard model of particle physics (hereafter X17 boson) with mass M=16.8 MeV. The X17 boson could be a mediator of a fifth force, characterized by a strong coupling suppression of protons compared to neutrons [3]. This scenario can explain, at least partially, the long standing anomaly of the magnetic moment of muon found experimentally. In this contribution, we present an ab-initio study of the 3H(p, e+e-)4He and 3He(n,e+e-)4He processes [4]. We first analyze the pair production as a purely electromagnetic process in the context of a state-of-the-art approach to nuclear strong-interaction dynamics and nuclear electromagnetic currents, derived from chiral effective field theory (chiEFT). Next, we examine how the exchange of a hypothetical low-mass boson would impact the cross section for such a process. We consider several possibilities, that this boson is either a scalar, pseudoscalar, vector, or axial particle.

We also provide an overview of an experiment probing pair production in the 3He(n,e+e-)4He at the n_TOF facility at CERN, currently in preparation [5]. We discuss also of other experimental searches of the X17 boson in nuclear reactions, as that performed by the MEG collaboration at PSI (Switzerland), which are currently repeating the 7Li(p,e+e-)8Be experiment, or as in the 2H(p,e+e-)3He and 2H(n,e+e-)3H reactions, proposed in order to test the "protophobicity" of X17.

[1] A. J. Krasznahorkay et al., Phys. Rev. Lett. 116, 042501 (2016)
[2] A. J. Krasznahorkay et al., Phys. Rev. C 104, 044003 (2021)
[3] J. L. Feng et al., Phys. Rev. Lett. 117, 071803 (2016)
[4] M. Viviani et al., Phys. Rev. C 105, 014001 (2022)
[5] E. Cisbani et al. CERN-INTC-2021-041 (2021) [https://cds.cern.ch/record/2766541]

Attendance:

Remote

Contact Email:

michele.viviani@pi.infn.it

Scheduling Constraints:

33

Lepton universality test with MUSE at PSI

Author: Michael Kohl[1]

[1] *Hampton University*

Corresponding Author: kohlm@jlab.org

Lepton universality (LU) typically refers to the lepton coupling,
which is considered to be the same for e and mu if the interaction is
electroweak according to the Standard Model, and it is hence a compelling
probe for New Physics.
The same principle of universal electroweak lepton interaction leads
to the expectation that lepton scattering yields are equal for e and mu
under the same kinematic condition. The mere mass difference between
e and mu affects kinematic quantities (such as the relation between
scattering angle and Q^2), and the lepton mass dependence of elastic
cross sections for leptons scattered from structured and pointlike
objects are taken into account.
By comparing e+, e-, mu+, and mu- scattering yields, two-photon
exchange (TPE) effects, universal or not, can be separated from the
general lepton universality test of the e/mu yield ratio.
With its separable mixed beams of e+/mu+ and e-/mu-, respectively, the
MUSE experiment at PSI is not only designed to measure the proton
charge radius with four lepton species, but is also uniquely suited to
probe TPE and LU, while benefitting from partial cancellations of
certain shared systematics.
An overview will be given of the MUSE experiment, the sensitivity, and the present status.

This author is presently supported by NSF grants PHY-1812402 and PHY-2113436.

34

Proceedings Template

Corresponding Author: ethan.cline@stonybrook.edu

Template for the workshop proceedings

Attendance:

Contact Email:

Scheduling Constraints: