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DarkLight Commissioning Plan

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1 Introduction

After installation of the DarkLight experiment into the e-Linac, along with the new magnets required for beam transportation downstream of it, several stages of commissioning must be performed. The optics and new collimator must be commissioned with and without a target in place. Then the DarkLight dipole spectrometers must be commissioned at a range of energies to test the linearity of the magnetic field and its mapping to operating conditions. Finally, a new optical setup suitable for 30 MeV running with a dense target will be installed, and these optics too must be tested and understood.

2 Purpose

The objectives of this commissioning exercise are:

1. To ensure that the installed optics can be used to safely guide the beam from the DarkLight target to the dump in a range of running conditions
2. To determine the absolute calibration of the experiment's spectrometers by comparison to elastically scattered electrons
3. To test the experiment's detectors in situ and ensure the data acquisition systems work as expected

Radiation safety surveys will also be done during commissioning to validate the experiment's FLUKA simulations and confirm that DarkLight does not pose a radiation hazard to personnel.

3 System to Be Commissioned

DarkLight and the new beamline elements that support it are described in detail in Document-242966: DarkLight Experiment Facility Hazard Analysis and Safety Review. All newly installed components will need to be commissioned.

4 Commissioning team

The commissioning team is composed of:

- Laura Miller: Experiment equipment commissioning coordinator;

- Stephanie Rädel: Beamline equipment and beam commissioning co-ordinator;

and their delegates:

- Mike Hasinoff and Katherine Pachal, for experiment equipment
- Thomas Planche and Laura Miller, for beamline equipment and beam

and other delegates as may be appointed. Laura Miller will be the head of the commissioning team. Responsibilities are defined in Document-108335: E-Linac Commissioning Plan.

5 Pre-requisites

Beam delivery with the e-Linac must be possible at the range of low energies and currents defined for commissioning, as well as at high energy and high duty factor as appropriate for data taking. All beam requirement criteria are defined in Document-244079: DarkLight @30 MeV: Beam Properties Requirements.

All new remotely-controlled beamline components must be integrated into EPICS. Names of the new components need to be communicated to e-Linac team. Controls for the target ladder must be completed.

6 Acceptance Criteria

Commissioning will be complete when the following criteria are met:

- The beam is successfully transported to the dump by the new optics, as measured by the beam dump current, collimator current reading, BPMs and the beam loss monitors. This must hold for the commissioning optics as well as, finally, the physics optics.
- Current readout from the collimator works as expected
- The magnetic field to beam energy calibration for the spectrometers has been determined for various beam energy points ranging between 10 and 25 MeV
- Radiation surveys show no doses that could endanger personnel when running at the most intensely radiation generating setting (high energy and high current on a tantalum target; i.e., physics running).

7 Safety

All members of the commissioning team shall conform to sections 4 and 5.2 of Document-108335: E-Linac Commissioning Plan.

All members of the team shall conform to existing safety requirements in the e-Hall and surrounding areas. Work permits will be used appropriately for any work taking place in the e-Hall.

RPG surveys of potentially affected areas will take place during experiment commissioning and during the initial physics runs once the high-energy optics configuration is installed. The team proposes that RPG surveys should be conducted during the following beam and target configurations:

- Commissioning optics, 30 MeV beam energy, carbon target
- Commissioning optics, 10 MeV beam energy, carbon target
- Standard optics, 30 MeV beam energy, tantalum target.

In each configuration, the dose levels should be monitored at intermittent steps in beam power as it is ramped up to the maximum power per configuration. Intermediate energy steps in the commissioning stage can also be surveyed at request of the lab or of RPG.

8 Equipment commissioning before taking beam

Tests of all installed equipment will be conducted before any beam is delivered through the new installation. Key points to be checked and the member of the commissioning team responsible for those checks are:

- Turn on EMQs and verify they are working, properly controlled, and polarities are correct [L. Miller]
- Turn on experiment spectrometers and verify that they are working, properly controlled, and polarities are correct [L. Miller]
- Calibrate cameras and ensure they are properly integrated with diagnostics [L. Miller, S. Rädel]
- Test controls for target ladder [L. Miller with S. Rädel]
- Verify readout from all new diagnostics is working correctly [S. Rädel]

9 Procedure for commissioning the new optics

Running with the target out of the beamline, cycle through the requested beam kinetic energies. The order in which energies are tested does not matter for the validity of the commissioning, so they can be tested in whichever order is easiest for the e-Linac to deliver. This will likely mean starting at 30 MeV and proceeding in steps towards lower energies.

At each energy, perform the following steps:

1. Adjust the current to the EMQs immediately before the dump to their appropriate values as specified in Document-243187: Beam optics for DL commissioning runs.
2. Use all available diagnostics to verify that the beam position is as expected and beam losses are within the 1 W/m maximum specified for beam protection. This may require recommissioning the beam loss monitors for the new beamline configuration (see procedure specified in Document-158347: Commissioning Plan for the e-Linac MPS BLM.) If the beam loss is higher than expected from simulation, adjust the beam position or permanent magnet positions.
3. Record the readout current from the collimator to use for calibration
4. Perform a radiation survey of the highest-risk low occupancy area (directly on top of e-Hall roof over dump) to ensure that radiation safety requirements met as expected.

While the spectrometer commissioning is ongoing with the target in place, repeat steps 1-4 to continue to monitor beam losses and radiation doses.

When the experiment is ready to move from commissioning to data taking, the permanent magnet configuration in the optics will need to be modified to support 30 MeV running on a tantalum target. The new optics will not be run at low energies, but steps 1 through 4 above should be repeated with the target out and with the target in at nominal energy with the new optics.

10 Beam commissioning for the DarkLight spectrometers and detectors

Commissioning will require the ARIEL electron beam to be operated at five beam kinetic energies, i.e. $(\gamma - 1)mc^2$, of 10, 15, 20, 25, and 30 MeV. The beam will strike a 1 µm carbon target. At all of these energies the requested current will be around 1–5 µA. The experiment many request a higher or lower current depending on the performance and count rate of the detectors and the data acquisition system. The actual value for the current is not very important for these measurements, as long as it is low. The duty factor should be high. All beam requirements for the commissioning phase are given in more detail in Document-244079: DarkLight @30 MeV: Beam Properties Requirements.

The experiment requires energy to be known to an accuracy of 0.1 MeV (approximately percent level), as described in the beam requirements document. Beam energy will be measured and reported by the e-Linac. The DarkLight experimental team will verify these numbers where possible against known features in the electron spectra, but will take the values from the e-Linac as the nominal energy in all cases.

The experiment does not require beam current to be precisely known during the commissioning stage, when the beam currents will be too low to be assessed with the available e-Linac monitoring equipment. During commissioning, it is sufficient to simply turn down the current until the measured rates are manageable to the DarkLight detectors, then examine relative rates at different settings. During physics data taking, the current will be much higher (about 200-300 µA). At this stage, the microamp-level precision with which the e-Linac reports the peak current will be sufficient for DarkLight's physics measurements. The values from the e-Linac will be taken as the nominal current by the experiment.

Again, the order in which energies are tested does not matter for the validity of the commissioning, so they can be tested in whichever order is easiest for the e-Linac to deliver. This will likely mean starting at 30 MeV and proceeding in steps towards lower energies.

Commissioning will proceed through the following steps:

1. Stage 1: both magnet power supplies will be cabled with the same polarity, which bends electrons into the detectors. It may be necessary to open the e-Hall to adjust the position of the detectors based on the results of the measurements. Step through the requested beam kinetic energies, and at each energy perform the following steps:

    - Vary the current in the spectrometer magnets through a range of -20, -10, 0, +10, and +20% of the nominal magnet current for the given energy (that is, the current that would place the elastic peak in the center of the magnet acceptance). This will sweep the electrons elastically scattered from the carbon target across the face of the detectors to verify the calibration of the magnet current and linearity of the spectrometer response. If the GEM detectors are found to NOT be on the focal plane of the spectrometer it may be necessary to access the e-Hall and adjust the GEM positions.

- Set the magnet current, of both magnets, to position the elastic peak from carbon scattering towards the high momenta region of the GEM detectors. Collect data to look for the inelastic peaks, which will be at lower energies. For these measurements, it would be useful to know the incident electron beam current.
- Adjust the magnet current, of both magnets, to detect the Møller electrons.

2. Stage 2: reverse the polarity of the positron arm magnet such that electrons are deflected downwards and positrons are bent into the detectors. This can be done either on the connections to the spectrometers in the e-Hall or from the power supplies on the roof. Step through the requested beam kinetic energies, and at each adjust the magnets to look for coincident events in the 20° and 36° spectrometers arising from Bethe-Heitler scattering from carbon.

The experiment has requested 300 hours of commissioning beam for these studies. Time in which stable beam is delivered on the commissioning target will count towards this quota.

11 Commissioning Record

Upon execution of the plan described in section 10, a Commissioning Report will be produced.