Recent Changes in the 500 MeV Cyclotron's Central Control System to Reduce Beam Downtime and Beam On/Off Transitions

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Abstract

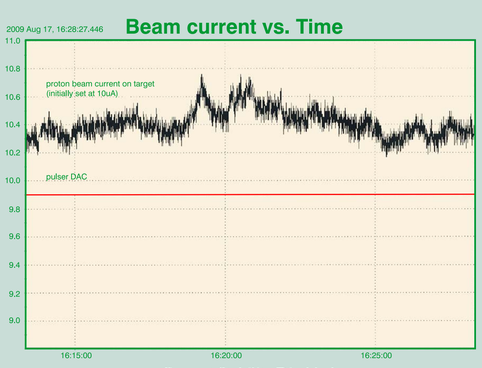
Recently at TRIUMF there has been an effort to reduce the downtime of scheduled beam and to reduce the number of on/off transitions on the radioactive ion beam (RIB) targets. In these pursuits, the 500 MeV cyclotron's Controls Group identified and proposed certain areas of improvement. Working with the Beam Delivery and Operations Group improvements have been developed and now run in production mode. This paper will detail the introduction of three software measures that resulted in beam delivery enhancements. Specifically, 1) a more stable beam current, 2) a more centered beam, and 3) a new concept called "soft trips". Together these measures reduce the number of beam trips, shorten beam recovery times, reduce thermal shocks on the RIB target, and simplify accelerator operation.

Introduction

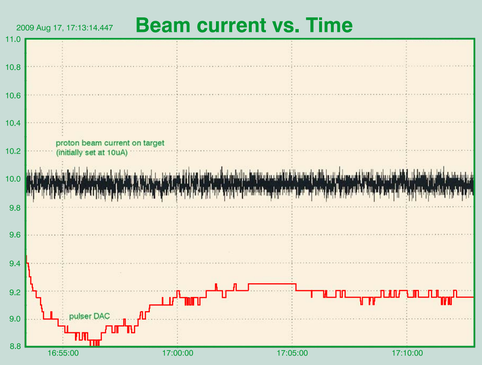
- RIB production is of increasing importance at TRIUMF.
- A 500 MeV proton beam is directed onto a target to produce RIB.
- RIB production is improved by running the proton beam current's amplitude close to the target's proton current limit.
- RIB targets are damaged by overheating (too much proton current) and thermal cycles (proton beam on/off transitions).
- RIB target protect trips result from the proton beam exceeding the target's proton current limit (overcurrent trip), and other conditions.
- Overcurrent trips are seen as a leading cause of thermal cycles.
- Current stability allows running proton beam current amplitude closer to the target's proton current limit without causing overcurrent trips.
- RIB target protect trips are also caused by the proton beamspot drifting off target.
- Proton beam position stability was identified as a means to reduce these beamspot drifting trips.
- In the past, beam trips always caused a full termination of beam delivery and this did not cause a problem on any of the beam lines.
- A wide variety of events cause trips and they now result in a problem for RIB targets.
- The concept of "soft trips" was introduced to lessen the thermal cycles caused by full beam trips.
- The "soft trip" approach was implemented on the RIB target's overcurrent protect trips.

Beam Current Stability

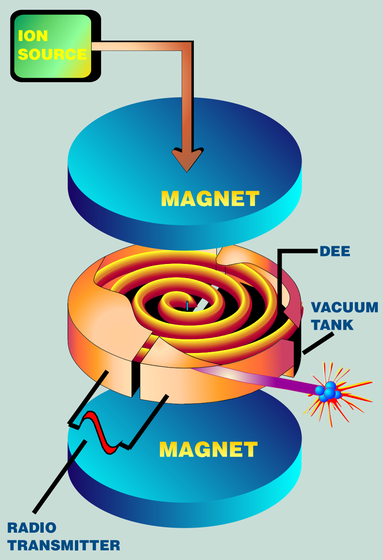
- RIB production increases with increased proton beam current on target (until damage sets in).
- Target damage occurs if the target gets too hot (too much proton beam) and with thermal cycling (beam going off).
- The challenge is to keep the proton beam current stable, near the target current limit, and not trip off (thermally cycle the target) if the current goes too high.
- Closed-loop feedback put on the proton beam current to stabilize it.
- An injection line electrostatic device (pulser) quickly adjusts the current.
- Stabilization works well.
- Less overcurrent trips.
- Proton beam current now runs closer to the target current limit.
- Other beamline currents fluctuate more than before.



Current Stability Disabled



Current Stability Enabled



Beam Position Stability

- Due to instabilities, the proton beamspot occasionally drifts off the RIB target causing misalignment.
- Movement of the beamspot may lead target protection interlocks to turn off the beam.
- Misalignment of the proton beam on the RIB target negatively affects target heating.
- Position stability control was implemented to avoid beam misalignment trips and to stabilize target heating.
- Beam position is inferred from target protect plate readings of the beam halo.
- Horizontal and vertical steering magnets are used to steer the beam to the desired position.
- Only slow drifts are corrected.
- Five target/dumps have position stability control running in production mode.
- Mechanical polarity switches prevent a full range of feedback control on some targets.

Soft Trips

- Interlock trips on beam delivery have until recently fully stopped the beam (a beam trip).
- New requirements for RIB target operation call for minimizing RIB target thermal cycles.
- A new concept of staged beam trips has been implemented and is called "Soft Trips".
- The first implementation of a soft trip has been on proton beam overcurrent trips.
- Overcurrent trips are now staged to initially reduce the proton beam current but not turn it off.
- Soft trips have reduced the thermal cycles and the overall downtime.
- Cyclotron operation is easier with soft trips due to easier recovery from machine protection issues.

Summary

- Three software applications have been developed to improve RIB target performance.
- Proton beam current stability significantly reduces the risk of overcurrent trips.
- Proton beam position stability decreases the number of misalignment trips.
- Soft trips reduce the severity of thermal cycles and shorten recovery times.
- All these applications now run in production time.
- Operations, Beam Delivery, Targets, and the Control Groups are all pleased with the three new enhancements.

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