Radiological Safety Analysis Document for Charge Proton Radius (PRad) experiment in Hall B

This Radiological Safety Analysis Document (RSAD) will identify the general conditions associated with running the Charge Proton Radius (PRad) experiment in Hall B, and controls with regard to production, movement, or import of radioactive materials.

1 Description

The run of Charge Proton Radius (PRad) experiment, E12-11-106, may take place in spring-summer of 2016 in the experimental Hall-B. The PRad run will use a detector located on the Space Frame of the Hall-B. The setup will use the Hybrid Calorimeter (HyCal) with GEM detector mounted on its face. This calorimeter was previously used in PRIMEX experiment. The experiment will use windowless cold hydrogen gas target located downstream of the tagger magnet. The target density will be of the order 10^{18} atoms/cc. The length of the cell is 4 cm. The cell has openings for the beam passage. The diameter of the openings is 4 mm. Between the target and detectors there will be large 5-meter-long vacuum chamber with downstream diameter of about 2 m. The downstream end of the vacuum chamber has a 0.063"-thick aluminum window with an opening in the center. There is a 1.375" beam pipe attached to the center of the window. The beam passes through this pipe going through central hole of the calorimeter. Downstream of the calorimeter all the way to the Faraday cup there will be 3" beam pipe. There will be continuous vacuum in the beam line with no windows anywhere.

There are two different beam configurations.

In calibration configuration the tagged photon beam produced by 2.2 GeV electrons incident on 10^{-5} r.l. radiator will be used. The beam current will be 0.1 nA. The electron beam will be dumped in the tagger dump. The calorimeter will be placed directly into the photon beam. The photon beam will be stopped in the calorimeter.

In production configuration the electron beam with energies of 1.1 and 2.2 GeV will be used. The beam current will be of the order of 10 nA. The beam will be dumped in the Faraday cup. There will be halo counters mounted on the upstream and downstream sections of the beam line. They will be included in the machine fast shutdown system (FSD) to terminate beam delivery in case of missteered beam hitting anything along the beam line.

The run times approved for this experiment are 3 PAC days at 1.1 GeV and 3 PAC days at 2.2 GeV beam energies.

2 Summary and Conclusions

The PRad experimental runs as planned are not expected to produce significant levels of radiation at the site boundary. However, it will be continuously monitored by the Radiation Control

Department (RCD) to ensure that the site boundary goal is not exceeded. Residual activation from the experiment is expected to be low; however, beam tune up procedures and occasional beam missteerings may cause Radiation Areas and possibly High Radiation Areas in the Hall. Activation of radiators, collimators and beam line hardware must be considered. As specified in Sections 4 (4.2) and 7, the manipulation and/or handling of radiators, targets and beam line hardware (potential radioactive material), the transfer of radioactive material, or modifications to the beam line after the initial assembly must be reviewed and approved by the RCD. **Adherence to this RSAD is vital.**

3 Calculations of Radiation Dose at the Boundary

The radiation budget for a given experiment is the amount of radiation that is expected at site boundary as a result of a given set of experiments. This budget may be specified in terms of mrem at site boundary or as a percentage of the Jefferson Lab design goal for dose to the public, which is 10 mrem per year. The Jefferson Lab design goal is 10% of the DOE annual dose limit to the public, and cannot be exceeded without prior written consent from the RCD Head, the Director of Jefferson Lab, and the Department of Energy.

Calculations of the contribution to Jefferson Lab's annual radiation budget that would result from running under a broad variety of conditions typical of Hall B operations indicate that the contribution from this experiment will be negligible. With this expectation, we have not carried out calculations for the specific running conditions of this experiment.

This expectation will be verified during the run by using the active monitors at the Jefferson Lab site boundary. If it appears that the radiation budget will be exceeded, RCD will require a meeting with the experimenters and the Head of the Physics Division to determine if the run conditions are accurate and to assess what actions may reduce the dose rates at site boundary. If the site boundary dose approaches or exceeds 10 mrem during any calendar year, the run program will stop until a resolution can be reached.

4 Radiation Hazards

The following controls shall be used to prevent the unnecessary exposure of personnel and to comply with Federal, State, and local regulations, as well as with Jefferson Lab and the Experimenter's home institution policies.

4.1 Beam in the Hall

When the Hall status is Beam Permit, there are potentially lethal conditions present. Therefore, prior to going to Beam Permit, several actions will occur. Announcements will be made over the intercom system notifying personnel of a change in status from Restricted Access (free access to the Hall is allowed, with appropriate dosimetry and training) to Sweep Mode. All magnetic locks on exit doors will be activated. Persons trained to sweep the area will enter by keyed access (Controlled Access) and search in all areas of the Hall to check for personnel.

After the sweep, another announcement will be made, indicating a change to Power Permit, followed by Beam Permit. Run-Safe boxes will indicate "OPERATIONAL" and "UNSAFE". IF YOU ARE IN THE HALL AT ANY TIME THAT THE RUN-SAFE BOXES INDICATE "UNSAFE", IMMEDIATELY HIT THE BUTTON ON THE BOX.

Controlled Area Radiation Monitors (CARMs) are located in strategic areas around the Hall and the Counting House to ensure that unsafe conditions do not occur in occupiable areas.

4.2 Activation of Target and Beam line Components

All radioactive materials brought to Jefferson Lab shall be identified to the RCD. These materials include, but are not limited to radioactive check sources (of any activity, exempt or non-exempt), previously used targets or radioactive beam line components, or previously used shielding or collimators. The RCD inventories and tracks all radioactive materials onsite. The RCD will survey all experimental setups before experiments begin as a baseline for future measurements.

The RCD will coordinate all movement of used targets, collimators, and shields. The RCD will assess the radiation exposure conditions and will implement controls as necessary based on the radiological hazards.

There shall be no local movement of activated target configurations without direct supervision by the RCD. Remote movement of target configurations shall be permitted, providing the method of movement has been reviewed and approved by the RCD.

No work is to be performed on beam line components, which could result in dispersal of radioactive material (e.g., drilling, cutting, welding, etc.). Such activities must be conducted only with specific permission and control of the RCD.

5 Incremental Shielding or Other Measures to be Taken to Reduce Radiation Hazards

As it is mentioned in Section 1, there will be halo counters mounted on the upstream and downstream sections of the beam line. They will be included in the machine fast shutdown system (FSD) to terminate beam delivery in case of missteered beam hitting anything along the beam line. This measure is directed on prevention of electron beam steering errors that would lead to possible activation of the beam line components during the beam delivery.

6 Operations Procedures

All experimenters must comply with experiment-specific administrative controls. These controls begin with the measures outlined in the experiment's Conduct of Operations Document, and also include, but are not limited to, Radiation Work Permits, Temporary Operational Safety Procedures, and Operational Safety Procedures, or any verbal instructions from the Radiation Control Department. A general access RWP is in place that governs access to Hall B and the accelerator enclosure, which may be found in the Machine Control Center (MCC); it must be read and signed by all participants in the experiment. Any individual with a need to handle radioactive material at Jefferson Lab shall first complete Radiation Worker (RW I) training.

The RCD will commission a Quick Access Monitoring System for the PRad experiment. Once approved by RCD, this system will allow access to the hall **during Controlled Access only** without a manual radiation survey, in accordance with Safety System Operator instructions. The monitoring panel for the Quick Access system is just outside the access gate to the hall. The beacon on the panel shall be tested prior to entry by pressing the test button. At that time, the SSO will allow access to the hall by authorized personnel. The attached addendum to this RSAD describes the monitoring scheme of this system, and gives an overview of the restrictions on access and work while using the QAS. These are summarized as follows:

- No entry to roped off radiation areas without a radiation survey
- No hands-on beamline maintenance anywhere in the hall without a radiation survey
- No access to the beamline between the space frame and CLAS12 detector without a survey
- A full survey of the hall shall be conducted prior to a change to Restricted Access

The attachment shows areas covered by the system and restricted zones.

There shall be adequate communication between the experimenter(s) and the Accelerator Crew Chief and/or Program Deputy to ensure that all power restrictions on the radiator and the target are well known. Exceeding these power restrictions may lead to excessive and unnecessary activation, contamination, and personnel exposure.

No scattering chamber or downstream component may be altered outside the scope of this RSAD without formal Radiation Control Department review. Alteration of these components (including the exit beamline itself) may result in increased radiation production from the Hall and a resultant increase in site boundary dose.

Any requested changes outside of the experimental parameters submitted for the RSAD evaluation (i.e., current, energy, target material, target thickness, run time) for this experiment shall require a formal review by the RCD, and a new revision to the RSAD.

7 Decommissioning and Decontamination of Radioactive Components

Experimenters shall retain all targets and experimental equipment brought to Jefferson Lab for temporary use during the experiment. After sufficient decay of the radioactive target configurations, they shall be returned to the experimenter's home institution for final disposition. All transportation shall be done in accordance with United States Department of Transportation Regulations (Title 49, Code of Federal Regulations) or International Air Transport Association regulations. In the event that the experimenter's home institution cannot accept the radioactive material due to licensing requirements, the experimenter shall arrange for appropriate transfer of funds for disposal of the material. Jefferson Lab cannot store indefinitely radioactive targets and experimental equipment.

The Radiation Control Department may be reached at any time through the Accelerator Crew Chief (269-7050).

Approvals:

V. Vn — 5/12/2016

Radiation Control Department Head — Date

May 10, 2016

Hall B Rapid Access Configuration for the PRad Experiment

The Hall B Rapid Access System (RAS) has been out of service for several years due to the 12 GeV upgrade activities in Hall B. The hardware has now been restored. The hall would like to reinstate operation of the RAS to allow expedited access during Torus cooldown operations during experimental runs. However, the upcoming experiment, PRad, has a target/detector configuration that is somewhat different than the "standard" historical layout of the hall.

To accommodate this configuration, and provide good confidence in RAS sensitivity, we are reconfiguring probe placement somewhat for the PRad run.

The RAS system consists of 9 detectors coupled to three monitoring unit ratemeters, designated RM601, RM602 and RM603. Historically, the three detectors connected to RM601 were located in the upstream transport tunnel area shown below in figure 1. The layout of these probes was designed to limit the distance from a detector to anywhere on the beamline to be no more than about 10 feet, based on assessments of typical activation patterns.

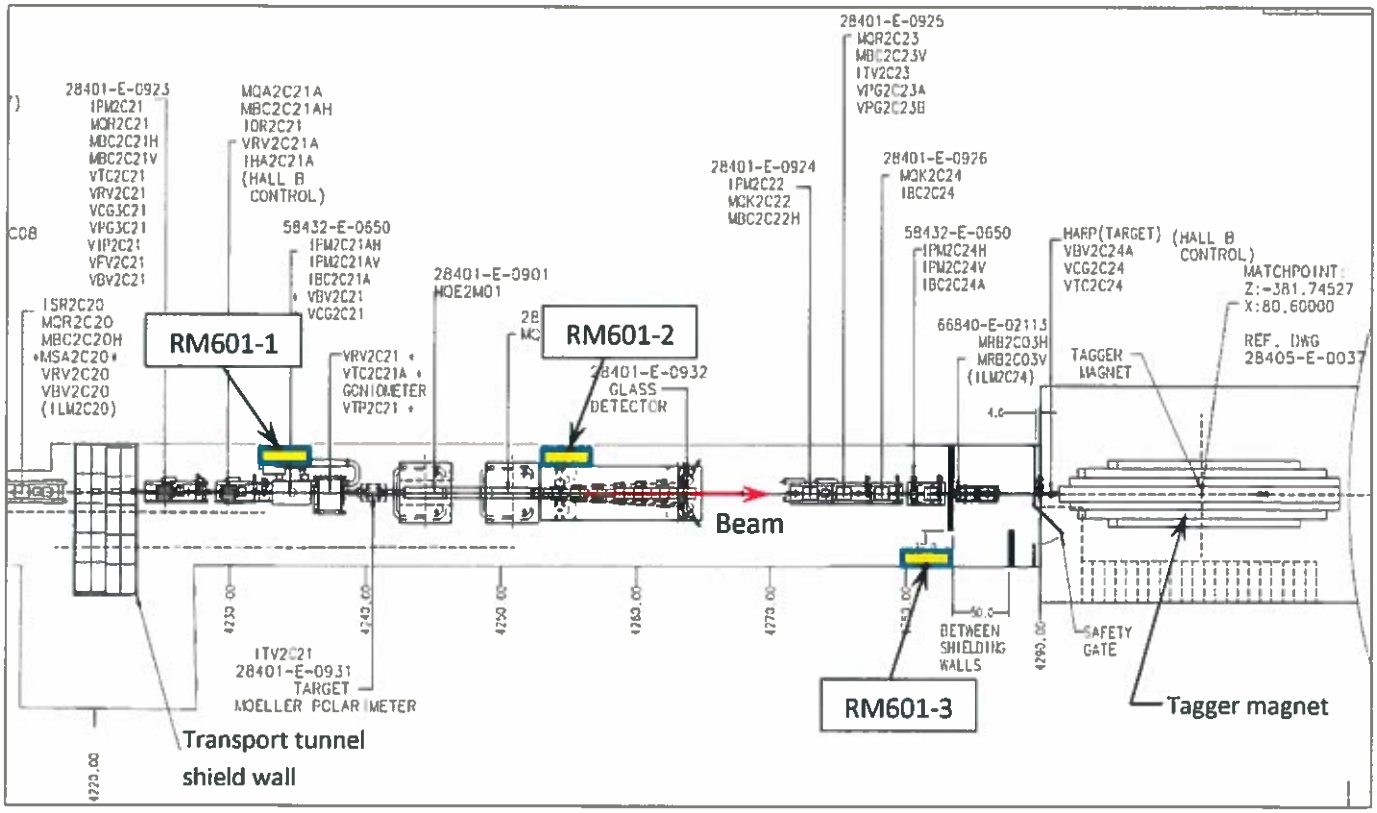


Figure 1; Locations of probes associated with RM601

In the new (temporary) configuration, these three detectors will be repositioned further downstream, in the area around the tagger magnet and PRad detector. The upstream transport tunnel area will be roped off and posted (conservatively) as a radiation area, requiring a radiation survey prior to entry, after beam operations.

The probes connected to RM602 will also be reconfigured somewhat. These probes historically have monitored the area of the second level of the space frame and the transport to the tagger dump. These detectors will be supplemented by the probes from RM601. The layout is designed to enhance sensitivity in areas with the most potential to experience beam loss/interaction. This optimized layout gives us good confidence in detection capability, and should allow for full use of the system with a brief commissioning period.

Figures 2 and 3 depict the new layout for the space frame area, shown in plan and elevation views, respectively.

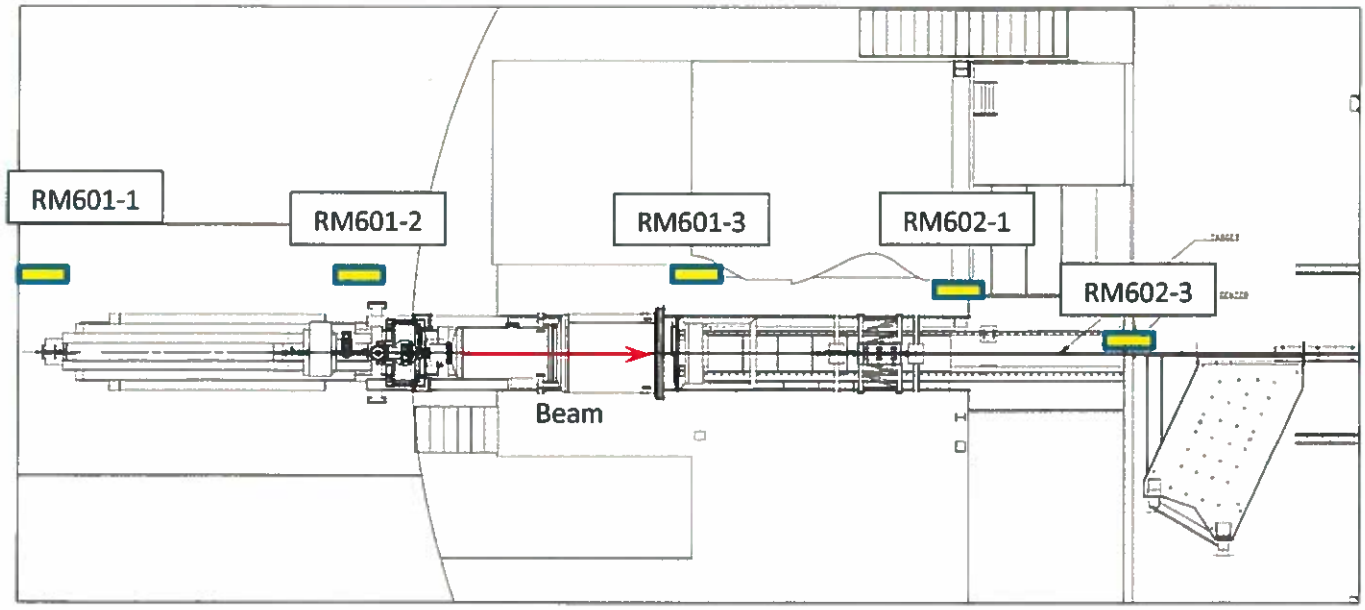


Figure 2; Probe Layout in Space Frame Area – Plan View

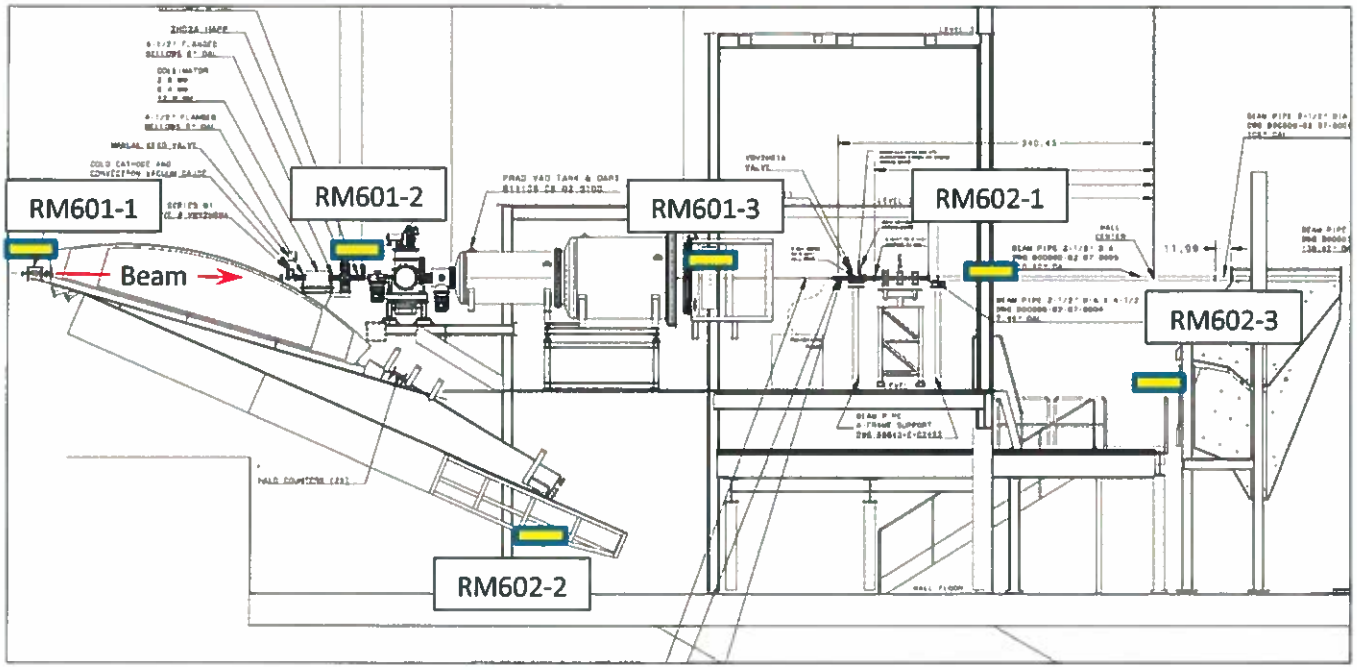


Figure 3; Probe Layout in Space Frame Area – Elevation View

The rationale behind this placement is as follows. Probe 601-1 is optimized for beam losses at the entrance to the tagger magnet, and activity associated with use of the HARP just upstream of the tagger magnet. Probe 601-2 covers the area in the vicinity of both the collimator box and the PRad target (collimators may not be used, depending on detector performance). Probe 601-3 covers the region near the large vacuum pipe exit window and detector area. Probe 602-1 and 602-3 cover the area of drift chamber downstream of the target and detector and the area just upstream of the torus magnet. Probe 602-2 covers the area of electron transport to the dump (this is the only detector in this area of the hall that remains in its old location).

The detectors that are associated with RM603 are remaining in their historical locations. These probes are shown in Figure 4.

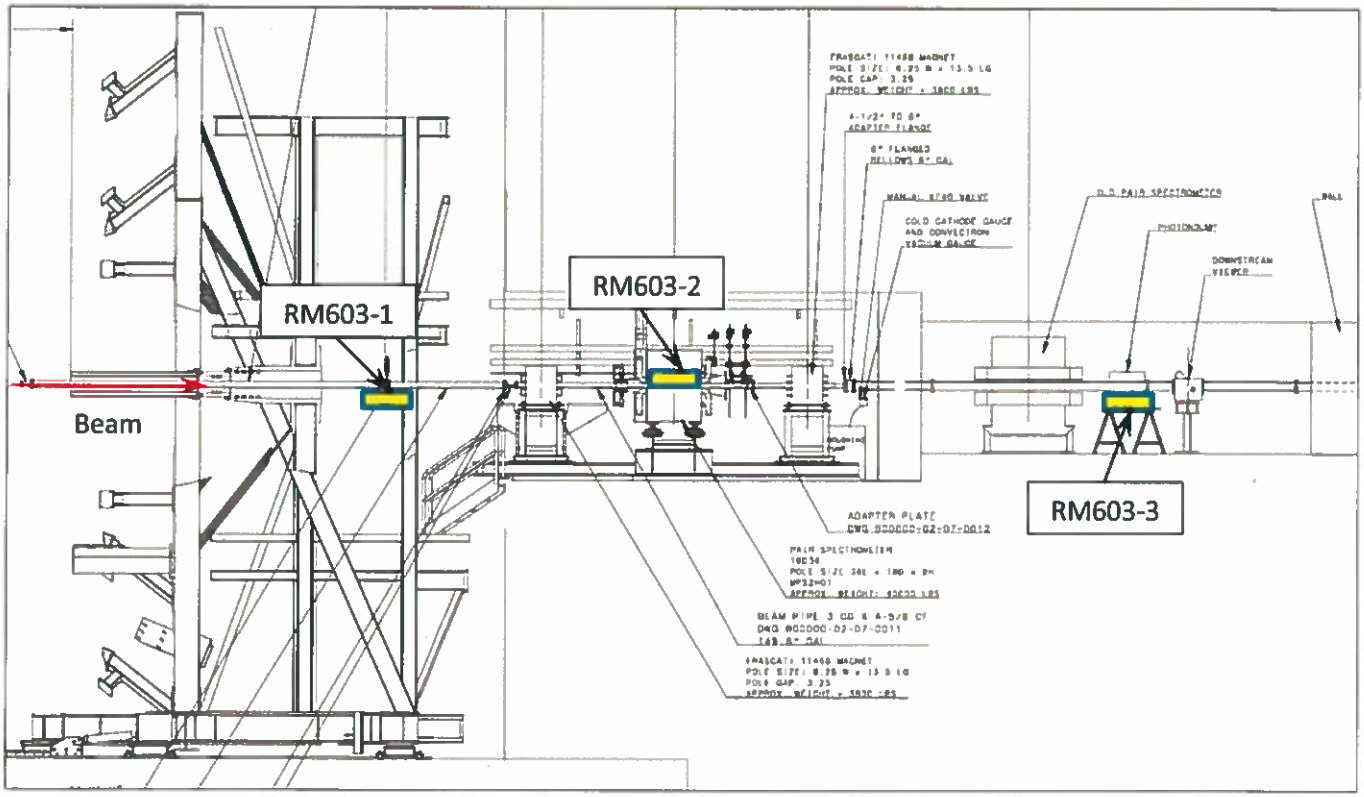


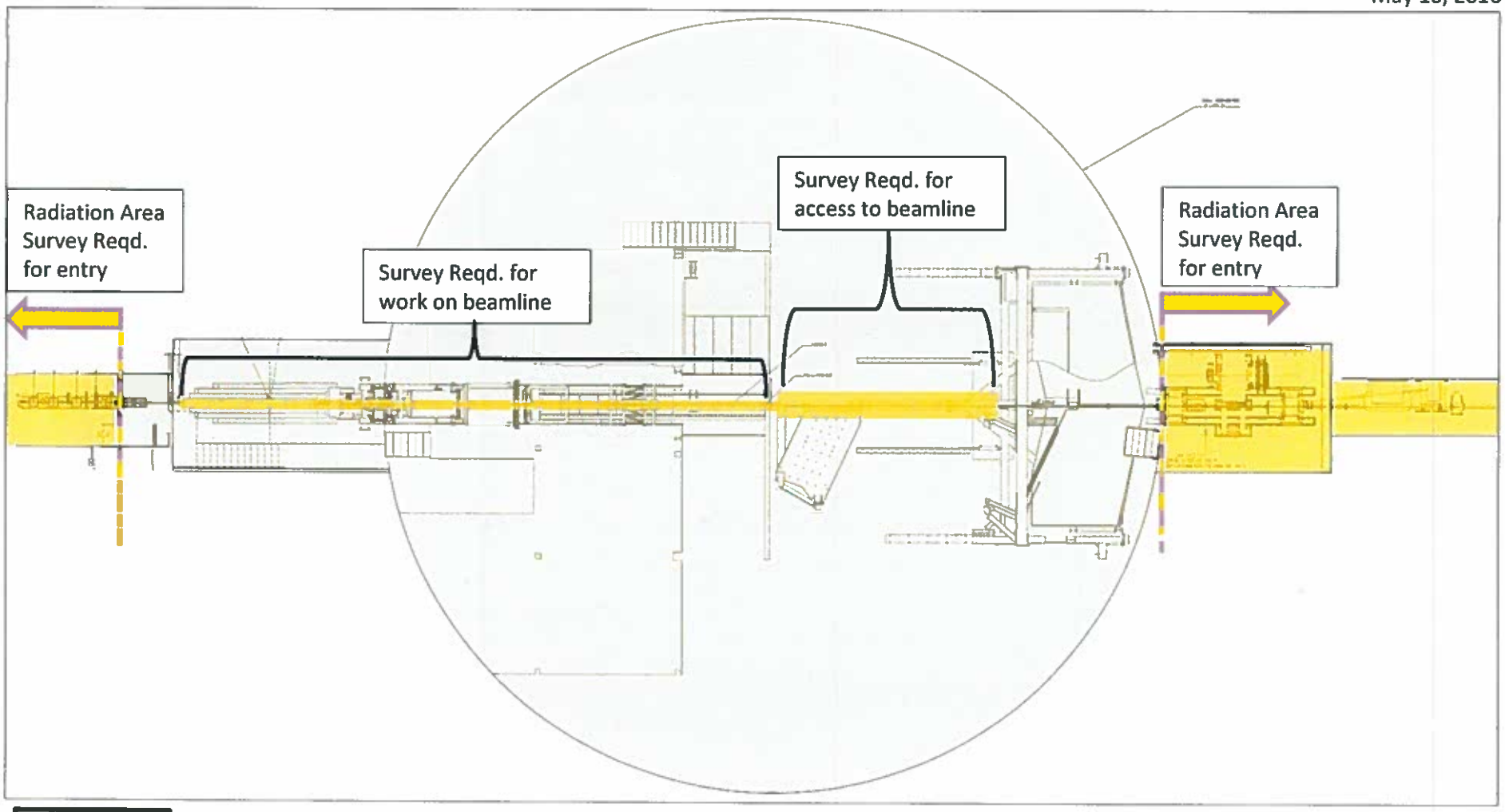
Figure 4; Probe Placement in Downstream Transport Region

Configuration of the System During PRad

Due to the removal of the probes upstream of the tagger magnet, and because the hall has little concern with rapid access downstream of the CLAS12 detectors, both the upstream and downstream transport tunnels will be roped off and posted as radiation areas. In the case of the downstream tunnel area, these detectors will be active, however the trip setpoints for detectors in the dump tunnel will be raised so they will not create a RAS beacon actuation in the event of radiation dose rates consistent with the posting in this area. This will allow commissioning data to be accumulated without undue delays. The setpoints will be adjusted so that dose rates approaching high radiation area levels would cause a RAS beacon actuation. RM603-1 will be operated at its historically determined setpoint. Both upstream and downstream posted regions will require a radiation survey for entry upon access to the hall during the experiment.

Given the relatively low beam current, thin target and small total power involved in the PRad run, potential for significant activation during the experiment is small. The additional probe density provided in the space frame area gives assurance of high RAS sensitivity for this region. The RadCon department will conduct surveys in the hall, when feasible, parasitically to other access needs, in order to provide a quality assurance check that detector coverage is satisfactory. As has been normal practice in the past, any work on beamline hardware in the region covered by the RAS will require a survey of that area. This includes the area around the beamline in the overhead, between the space frame and CLAS12.

Overall configuration and summary of the access protocol are given below.



Area covered by Rapid Access System

Areas requiring survey prior to entry/work

Rope boundary for radiation area