C-AD

Radiation

Safety

Committee

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Subject: CeCPoP Radiological Issues

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This is part of the on-going review of CeCPoP which is requesting approval for a low power beam test before the ARR is conducted for full power commissioning.

1 Watt Low Power Exemption Request

E.T. Lessard lead the discussion of the 1 Watt exemption request with a Powerpoint presentation[1]. The layout of the CeCPoP is shown in Figure 1. Additional examples and blowups of sections can be found in the previous minutes on CeCPoP[2].

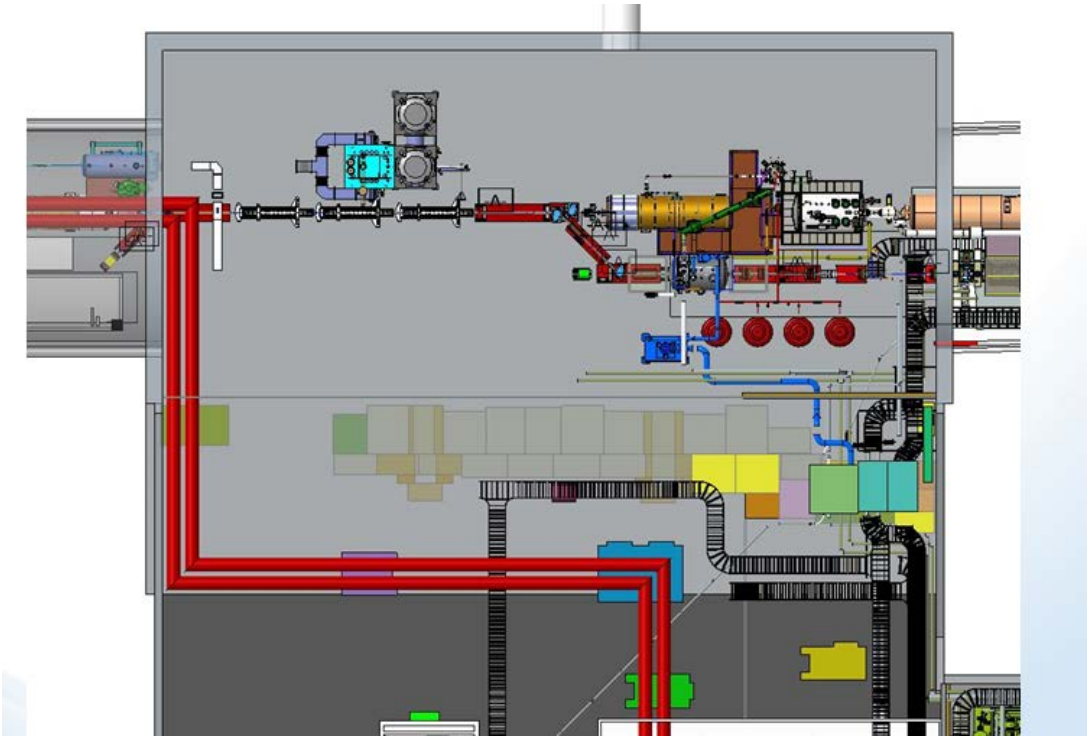

Figure 1: Layout of CeCPoP in RHIC IR2. Preliminary locations of portions of LEReC are shown at the upper left hand side.

[1] E.T. Lessard, "ASE Controls and Bases for Radiation Safety for 1 W Low Power Test at CeC PoP", Nov. 13, 2015

[2] RSC Minutes, Oct. 16, 2015; http://www.c-ad.bnl.gov/esfd/RSC/Minutes/10_16_15Minutes.pdf

The SBMS requires an IRR to be conducted for exemption requests. The IRR is scheduled for Dec. 21 and 22 and the LESHC is scheduled for Dec. 10, 2015. The authorization documents for the full power test and controls for the low power testing exemption will be reviewed at both meetings. The plan is to receive approval near the start of the RHIC cooldown for the low power testing and have ARR items completed and subsequent approval by early March. The documents and are listed below:

- Draft CeC PoP Safety analyses
- Draft version of a new RHIC ASE
- Draft OPM 2.5.2 RHIC ASE Procedure
- Draft CeC PoP Low Power Test Plan
- Draft Low Power Test Exemption USI
- Draft OPM 2.5.2.2 CeC ASE Procedure

The proposed controls for the low power exemption are:

- Draft RHIC ASE Implemented
- Simultaneous operation in the common transport with RHIC beam will only occur with yellow beam[3] or with the electron beam centered in the abort gap.
- Bunch charge from a single laser pulse onto the photocathode will not exceed 10 nC .
- Repition rate less than 1 Hz.
- An RSC reviewed and approved means to reduce the beam power using the laser, beam energy and repetition rate to less than 1 Watt averaged over an hour.
- Procedure to measure polarity with sign-off and procedure with sign-off to test transport at low power if one of the dipoles has had work conducted that could have changed the polarity if performed incorrectly.
- CeCPoP dipoles in series

RSC approved means to limit the electron beam power averaged over one hour to 1 Watt could remove restriction on the 1 Hz and the 10 nC per laser pulse from the gun. More review on this needs to be conducted.

Review if restrictions on 1 Hz and 10 nC from gun per laser pulse can be removed.

(Ck-CeCPoP-Pinayev and Beavis-Nov. 20, 2015-1001)

Review if restrictions on blue and yellow RHIC beam and electron beam in common transport section can be removed.

(Ck-CeCPoP-Pinayev and Beavis-Nov. 20, 2015-1002)

Review lower energy limit for RHIC beams during test. At present it is assumed that the lower

[3] This restriction may be too conservative but the project has not provided details of what occurs when the blue ion and electron beam collide. This should be calculated so unnecessary restrictions can be removed.

limit is the nominal injection energy with a proton equivalent energy of 20 GeV or greater.

(Ck-CeCPoP-Pinayev and Beavis-Nov. 20, 2015-1003)

The electron beam in the abort gap could encounter at most 1% of the blue beam. The centering of the beam in the abort gap will be established and monitored by an experimental physicist on duty during operations.

The robustness of the means to place and maintain the electron bunches in the abort gap must be reviewed. **(Ck-CeCPoP-Pinayev and Beavis-Nov. 24, 2015-1004)**

The safety basis for the low power testing was found to be reasonable. The statement that the abort-gap hadrons are normal chronic RHIC losses is questionable. The losses for abort gap hadrons and interactions of the hadrons in the abort gap with the electrons may not create losses at the same location. A justification with more details should be provided for this evaluation.

(CK-CeCPoP-Nov. 20, 2015-A. Dress & I. Pinavey-1005)

It was noted that the laser SOP has been approved and laser interlocks are in place. There was a question of whether there is an alarm if the fan fails in 1002A. This is an ODH issue and the safety section will address this concern.

The assurance methods for the low power testing were discussed. The term the CeC PoP experimental physicist refers to more than one qualified physicist. The committee did not see the value of resigning the check-off list after seven days of non-operations of CeC. Most of the interlocks and shielding for IR2 and adjacent sectors are required for RHIC operations. The RSC typically requires a new checklist if a radiation source has not operated for 4-6 weeks. The committee has always left this vague to allow judgement based on complexity and activities that have beeen conducted while the machine is down.

CeC Safety Envelope

1. Electron energy limited to 25 MeV. This is the hardware limit of the machine.
2. Low power electron beam dump shall be reviewed and approved by the RSC with limits on combination of beam power and energy.
    - The low power beam dump can be a combination of beam dump and associated shielding. The present dump with no associated shielding is approved for 2000 Watts of 2 MeV beam and 30 Watts of 25 MeV beam averaged over an hour. These limits are for radiation protection and not machine protection. The 25 MeV beam power limit is established by conservative calculations of the residual activity reaching 100 mrads/hr at a foot immediately after beam is turned off and the IR posted as a Radiation Area. **(CK-CeCPoP-Nov. 20, 2015-A. Dress & I. Pinavey-1006)**
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    - Access to the IR will require the RCT to conduct surveys before entry by personnel. Once there are adequate radiation measurements to establish controls near the low power beam dump are adequate then the requirement for surveys can be re-evaluated. **(CK-CeCPoP-Dec. 10 2015-C. Naylor& D. Beavis-1007)**

3. The high power beam dump shall be reviewed and approved by the RSC along with associated shielding. The maximum allowed power on the beam dump will be 8500 Watts.
    - The dump, barriers, and shielding for the beam dump will limit exposure to less than 100 mrads/hr for the radiation area. A High Radiation Area can exist around the beam dump inside an appropriate barrier with dose rates to 1,000 mrads/hr.
    - Delays in access can be used to allow the residual activity to decrease to the allowed levels. After one hour the dose rates should decrease to 30% of the dose rates at beam off. For short beam runs of a few hours the dose rate after an hour is of the order of 3% the saturated residual dose rate.
    - Access to IR will require RCT to make surveys until a satisfactory configuration is established.
    - With self-shielding ignored the beam dump will reach 100 mrads/hr at a foot with 1.3 Watts of 25 MeV beam. This is expected to be conservative.
4. **RSC review and approval of a phased approach to the high power beam dump. (CK-CeCPoP-Nov. 20 2015- D. Beavis& Lessard-1008)**
5. Shielding inspected and under configuration control.
6. Access Control System (ACS) in functional tests current and operating for relevant radiation hazards.
7. Allowed configuration of RHIC beam concurrent with the electron beam
    - 12 yellow bunches of less than 10^9 ions
    - Or Electron beam in abort gap with reviewed/approved means
    - Or determine that the above two controls are unnecessary
    - **(see checklist item 1002 above)**

Coherent Electron Cooling

V. Litvinenko presented[4] an overview of CeCPoP and provided details of radiological issues for run 16. The main parameters of the CeCPoP are given in Table 1. Initial operation is expected to be with 40 GeV gold beams. If the 22 MeV electron energy cannot be achieved then a lower energy would be used. It is expected that the electron-yellow beam cooling will not be useful for electrons below 10 MeV. However, tuning lower energy electrons to the beam stop may be attempted. The velocity of the yellow ion beam must be identical to the velocity of the electron beam. Table 2 provides a list of matching energies for the yellow Au beam and the electron beam. The nominal energies are 40 GeV/nucleon for Au and 21.95 MeV for the electrons. The experiment also intends to try other ion species. In run16 they hope to also try deuterons and protons. The parameters in Table 1 that are maximum values are repetition rate, average e-beam current, and electron beam power.

The potential losses and conditions for other ion species must be reviewed by the RSC or a subgroup before it can be used with electron beams. (CK-CeCPoP-Nov. 20 2015- I. Pinayev& D. Beavis-1009)

[4] V. Litvinenko, I. Pinayev, and J. Tuozzolo, "Coherent Electron Cooling in Run 16", Nov. 13, 2015

Table 1: Parameters for CeCPoP

Parameter	Value
Species in RHIC	Au^{+79} ions, 40 GeV/u
Relativistic factor	42.96
Number of particles in bucket	10^9
Electron energy	21.95 MeV
Charge per e-bunch	0.5-5 nC
Rep-rate	78.17 kHz
Average e-beam current	0.39 mA
Electron beam power	8.6 kW

Table 2: Matching Au (GeV/nucleon) and Electron beam Energies

Electron Beam, MeV	Ion beam, GeV
10	18.5
15	27.8
20	37
21.95	**40**
25	46.3

It was noted that the experiment may want to tune any energy achieved into the first dog-leg. This is in contrast to previous committee discussions. However, after reviewing rare magnet faults[5], routine beam losses and typical beam faults[6] there are no radiological issues for low energy transport past the first dipole. The main issue will be to monitor the routine losses levels and ensure that they do not exceed allowed values for exposure. **Monitor losses and report any issues to the RSC Chair (CK-CeCPoP-Nov. 20 2015- I. Pinayev& D. Beavis-1010)**

A conservative schedule was provided for evaluation of yearly losses. The number of hours is somewhat larger than that previously presented and has been used in the analysis of yearly environmental and exposure limits. The intended schedule for beam operations is presented in Table 3. It is anticipated that an Al beam dump with associated shielding will replace the Cu dump in March. There are 175 hours expected at high intensity. The radiation from this operation dominates the radiological issues.

[5] D. Beavis," Faults that Direct the CeCPoP Beam to the Side Wall Shielding", Nov. 12, 2015; http://www.c-ad.bnl.gov/esfd/RSC/Memos/11_12_15_CeCPoP.pdf
The rare magnet faults discussed in this memo are now considered to be non-credible faults or impossible.
[6] D. Beavis, "Dose Rates Out the Lateral Shielding of IR2 from CeCPoP Beam Losses", Nov. 12, 2015; http://www.c-ad.bnl.gov/esfd/RSC/Memos/11_12_15_LateralCeCPoP.pdf

Table 3: Operating Beam Hours, Beam Power, and Beam Dump Location for Run16

Month	Hours @ 1 W	Hours @ 6 kW	Note
January	0	0	Start-up, RF conditioning
February	320	0	To low power dump
March	350	0	To high power dump
April	325	25	To high power dump
May	300	50	Commissioning
June	250	100	Commissioning, experiment

The progress of previous open RSC items was presented. Progress has been made on many of the items and some are now closed. There does not appear to be any reason that they will not all be addressed on a reasonable timeframe.

The configuration of the abort gap and operation of the electron beam was presented. Checklist item 1004 above requests more details on the manner in which the timing is achieved and kept stable.

Goals for several electron-ion beam interactions were discussed. Some of these studies serve dual roles of documenting beam loss locations for radiation protection evaluation and to examine the impact of such interactions on the ion and electron beams. One such study will to place 6 blue bunches in the machine and to run the electron beam through one of the ion bunches. The impact on the electron beam on the one ion bunch will be compared to the other five bunches. Studies with a dual role or radiation protection shall be documented using the fault study procedure in the RSC procedure, OPM 9.1.9.

The use of APEX experiments for co-propagating ions and electrons was outlined.

Dipole fault scenarios were presented. The Chief Mechanical Engineer (CME) offered his evaluation of potential beam faults. Typically the committee accepts the evaluation of the CME for mechanical reliability and faults. After the meeting his evaluation of the fault scenarios of the diploes was accepted unless a member of the RSC objects. Turn to turn shorts are the most common but a rare failure. This would cause a decrease in the magnet bending power of 1.2% or 0.54 degrees for the electron beam. The worst credible coil short for this design is a pancake to pancake short that removes the maximum possible pancake to pancake turns. For this coil package 13 turns out of 84 or 15% could be eliminated causing the electrons to be miss-steered by 7 degrees. The electrons beam will aperture in the beam pipe in a short distance.

A maximal turn to turn short would cause the energy-matched ion beam to be miss-steered by 0.077 milli-radians. At 10 meters away the beam would be off axis by 0.76 mm. The beam would not aperture inside the IR. Any scrapping would occur at the high-beta quadrupoles. There is no expectation that any feedback systems in the RHIC machine will cause large beam losses.

The connection of the coil packages is designed in a manner that makes it not credible for a worker to mistakenly leave a top or bottom coil package not connected to the power supply. This fault would decrease the beading power by 50%. Cables are not used to connect the bottom to the top coil. Rather a threaded rod through an insulator is used with nuts to connect the upper and lower

coil packages. All the rare beam faults in footnote 5 are not considered credible. The maximum credible fault of 7 degrees miss-steering of the electron beam would be covered by the analysis of footnote 6.

Possible effects of coil shorts in the quadrupoles and trim coils were discussed. There is no impact on the ion beam and the electron beam faults would be covered by footnote 6. The two quadruples that require that the beam is a large size on the high power beam stop are monitored in the MPS to ensure the beam is large.

Low power testing at startup of the machine should find any existing shorts in the coils. Coil shorts are rare and multiple shorts are not considered credible in a five dipole system. Should a short develop during operations the time for the bending power to change will take sufficient time that the MPS should stop the beam. The concern is machine protection not radiation protection for personnel and the MPS can react to changes in a few tens of micro-seconds.

The initial MPS system will use two measures for electron beam permit. The Beam Position Monitors (BPMs also called buttons) can measure the electron beam position to a few microns. The trajectory of the electrons will have a defined narrow window (a few mms) in which the electron beam permit will be satisfied. The MPS will also use current monitors to measure the transmission of the beam. Transmission below an acceptable threshold will pull the electron beam permit. In addition loss monitors will be used as the system progresses. However, the beam loss monitors are not as fast as the Beam Position Monitors (BPMs) and current monitors.

The experiment is highly motivated to ensure that the MPS is properly setup and functional. Initial low power beam will be used to establish that the system functions as designed. Detected failures in the beam transport in position or transmission will cause the electron beam permit to be pulled. If the MPS should fail to do its intended job the beam can punch a hole in the vacuum system. A vacuum failure would cause several days of downtime to the RHIC program but the CeCPoP would be off for the rest of the running period. The process to re-bake the vacuum chambers requires CeCPoP magnets to be split. This process would be too lenghty to complete during the RHIC run. The importance of a successful CeCPoP is a very high and motivates the Project to ensure the MPS is functioning properly.

The MPS is designed to be a fast system in order to protect the machine. The method to create a beam fault in the shortest time would be a phase or amplitude shift in one of the three RF systems. The electron beam would most likely be lost at the first dipole bend.

During the meeting it was mistakenly said there is a portion of the beam pipe between the undulators that had an OD or 1 inch. These pieces of pipe are not part of the final vacuum system and the pipe dimensions are as discussed by I. Pinayev. The undulator vacuum chamber is a square that has internal sides of 29 mm and is rotated about the beam axis by 45 degrees and is not a limiting aperture for the RHIC beam.

Rare Magnet Faults

D. Beavis presented the portion of his talk[7] on rare magnet faults. Since the presented faults are no longer considered credible the interested reader can read the PowerPoint file or footnote 5.

CC:

Present
RSC
RSC Minutes File
A. Drees

[7] D. Beavis, "Radiological Open Issues", Nov. 13, 2015