A DISTRIBUTED BEAM LOSS MONITOR BASED UPON ACTIVATION OF OXYGEN IN DEIONISED COOLING WATER

TUPA37

NAPAC 2022

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ABSTRACT

- We propose a novel beam loss detection scheme whereby activation of deionised cooling water is used to observe elevated radiation around the APS storage ring.
- Based on radioactivation of oxygen within deionised cooling water by gamma rays above 10 MeV and neutrons above 15 MeV.
- Losses would be detected using a gamma ray detector monitoring deionised water flow out of the accelerator enclosure.

MOTIVATION

- In order to diagnose accelerator faults, protect people and equipment, ionising radiation monitors ('loss monitors') have been used as diagnostics for accelerators all around the world [1].
- We propose a novel detection scheme whereby activation of deionised cooling water is used to observe elevated radiation around the APS storage ring.

THEORY

- Cooling water activation of deionised water at light source facilities does not present a significant hazard to human health.
- A few principal activation reactions of light nuclei in deionised cooling water may be usable as a distributed loss monitor [2]. In particular, we consider the reactions $^{16}\mathrm{O}(\gamma,n)^{15}\mathrm{O}$ and $^{16}\mathrm{O}(n,p)^{16}\mathrm{N}$.
- Properties of both reactions are summarised in Table 1 [3, 4].

Table 1: Properties Of Radioactivation Reactions In Water.

Reaction	Threshold (MeV)	Half-life (s)	Ref.
$^{16}\mathrm{O}(\gamma,n)^{15}\mathrm{O}$	15.67	124	[3], Table XXXIIa
$^{16}\mathrm{O}(n,p)^{16}\mathrm{N}$	10.4	7.13	[4]

- We would plan to detect gamma rays as decay products of these reactions.
- $^{15}\mathrm{O}$ decays via positron emission to $^{15}\mathrm{N}$. Positron annihilates with an electron to produce a pair of 511 keV gamma ray photons [5].
- Disintegration of $^{16}\mathrm{N}$ emits gamma ray photons of energy 6.13 MeV (68.8%) and 7.12 MeV (4.7%) [4].

MONITOR LAYOUT

- Essentially, deionised water for the storage ring is served by a centralised 'primary' system, which distributes water to multiple 'secondary' systems around APS. The connection between the primary and secondary systems are illustrated schematically in Fig. 1 below.

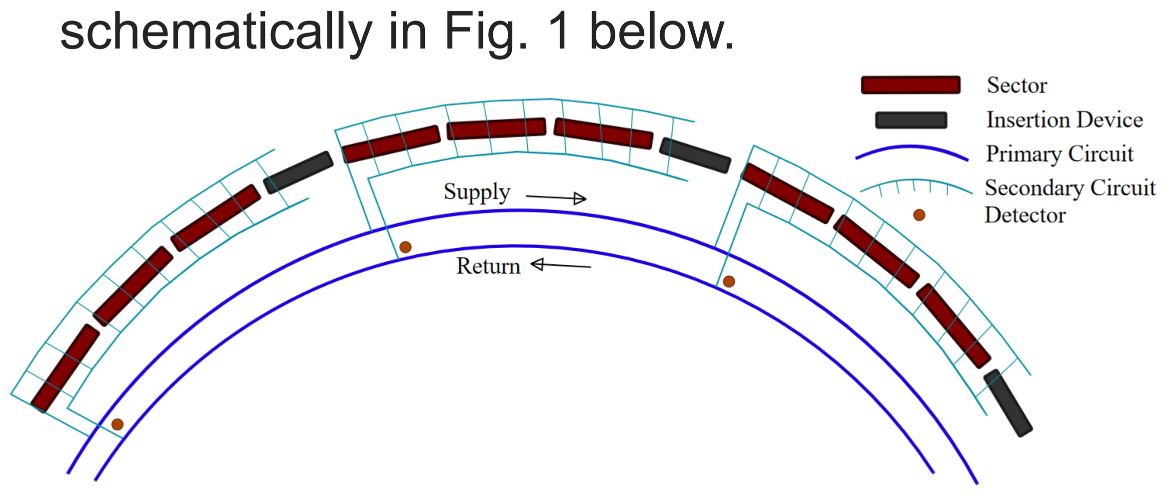

Figure 1: Schematic illustration of primary and secondary water systems. With approximately one secondary system per machine sector, detectors can be placed at each connection to the primary circuit to provide segmented coverage of the entire ring. Short flexible hoses supply and return water from individual accelerator and front-end components.

- We are principally interested in the 'secondary' circuit, supplying water to the accelerator magnets.

WATER MANIFOLDS

- A photo of the system within the tunnel is illustrated in Fig. 2 [6].

Figure 2: Photo of the APS storage ring within the accelerator enclosure [6]. Prominent in this image are the flexible tubing (aqua) serving individual accelerator components, connected to the water manifold at the ceiling. The fire sprinkler piping (painted red) is also visible along the ceiling. [Adapted under CC BY-NC-SA 2.0 license from Ref. [6].]

- In order to maintain pressure along the secondary circuit, diameter of deionised water piping gradually reduces from 4" to 1" diameter along a sector.
- Distribution manifold is more than 1 m away from the centreline of the accelerator. Radiation field at this location is estimated to be four orders of magnitude lower than near the accelerator centreline [7].

PROPOSED EXPERIMENT

- We consider a proposed experiment using the APS storage ring. Propose positioning a gamma ray detector outside the accelerator enclosure at the locations indicated in Fig. 1.
- Assume a staged approach. Initially, one might use a handheld survey meter to determine a proposed detector location along the water line, in particular as it relates to shielding of the accelerator enclosure.
- A comparison of a few different sectors around the ring could be instructive. For instance, we could compare the storage ring injection straight to a sector on the other side of the ring.
- Compare the performance of such a detector to existing point detector loss monitors (Cherenkov loss monitors, area radiation monitors).
- Expect that activation of cooling water provides benefit in having a detection scheme that effectively 'flattens the curve' of a full electron beam loss. Expect that mixing of water within the pipe will spread out the volume of activated water as it arrives at a detector. A complementary and different way to measure the full energy deposited at different locations around the ring.

SUMMARY

- We propose a novel detection scheme whereby activation of deionised cooling water is used to observe elevated radiation around the APS storage ring.
- Based on radioactivation of deionised cooling water by gamma rays and neutrons above about 10 MeV.
- Losses detected using a gamma ray detector monitoring deionised water flow out of the enclosure.

OUTLOOK

- We propose a staged experimental plan to test the feasibility of the concept.
- We anticipate that this could be used to provide a segmented, distributed loss monitor system covering the accelerator components closest to locations where radiation is generated.

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