A Novel Fast Response and Radiation-resistant Scintillator Detector for Beam Loss Monitor

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Abstract
At high luminosity era, beam loss monitor (BLM) with fast response and good radiation resistance is crucial for smooth and safe operation of collider. In this poster, we report the design and test results of a fast response and radiation-resistant scintillator detector as the beam loss monitor of high intensity beam, especially at low energy part such as RFQ. The detector is consistent of a 2cm x 2cm x 0.5cm LYSO crystal readout by a 0.6cm x 0.6cm Silicon photomultiplier (SiPM). The detectors we constructed have been tested with various radioactive sources. Results show that the detector has good sensitivity to photon and charged particles at energy range of tens of keV to several MeV with good linearity and energy resolution (23% for 60keV X-ray); Two detectors (one parallel to and the other perpendicular to the beam) are installed outside of the vacuum chamber shell of a 800 MeV electron storage ring. The details of the test and results will be introduced.

Why We Choose SiPM + LYSO Structure as BLM Detector
Due to high intensity of the beam, even a small amount of beam loss may cause serious damage to accelerator components. The ultimate goal of BLM system is to identify the loss level (and the loss location and time structure), to be able to protect the machine at uncontrolled loss, and if possible, to provide diagnostic information of the beam. Following requirements need to be satisfied by BLM detectors:

- Insensitve to magnetic field;
- Insensitve to secondary particles;
- Fast response;
- Excellent radiated-resistances;
- Cost efficiency;
- Sensitive to secondary particles;
- Sensitive to photon;
- Sensitive to charged particle;
- Radiation hardness 1MRad for 2MeV, 10MRad for 0.7keV electron.

For low energy (<10 MeV) but high intensity proton accelerator such as RFQ, BLM detector must be sensitive to photon, instead of electron, because of the large yield of γ-ray, as we can see from the simulation results.

Common BLM Detectors

<table>
<thead>
<tr>
<th>Detector</th>
<th>Type of Particle Detected</th>
<th>Sensitivity</th>
<th>Response Time</th>
<th>Radiation Hardness</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scintillator + PMT</td>
<td>photon, (neutron), charged particle</td>
<td>High</td>
<td>Depend on Scintillator</td>
<td>P55/1MRad</td>
<td>Expensive</td>
</tr>
<tr>
<td>PIN diodes</td>
<td>charged particle</td>
<td>Low</td>
<td>Fast</td>
<td>Good</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>Ionization Chamber</td>
<td>charged particle</td>
<td>Medium</td>
<td>Slow</td>
<td>Good</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>BF3 Counter Tube</td>
<td>neutron</td>
<td>Low</td>
<td>Slow</td>
<td>Good</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

Why BLM Detectors Must Be Fast and Radiation resistant?

- The detectors must be sensitive to photon and charged particles at energy range of tens of keV to several MeV with good linearity and energy resolution.
- Beam loss could be detected during the injection of the beam.
- Multi-hit in some event.
- Detector could response to the loss <50μs, upon the loss intensity.

Detector Design
- Using novel fast and radiation-resistant crystal scintillator, LYSO(20cm²/2cm x0.5cm);
- Read out by Silicon photomultiplier (SiPM) instead of PMT;
- The crystal was wrapped by Tyvek, to improve scintillation photon collecting efficiency.

- The read out circuit was designed with a 10x preamplifier and power supply filter circuit, to obtain better electronic performance.

Advantages
- Insensitve to magnetic field;
- Compact structure;
- Low noise;
- Fast response.

Summary and Outlook
- The design of a novel BLM detector is reported. The detector features fast response, radiation resistant, as well as insensitive to magnetic field.
- The detector has a large dynamic range, keeping good sensitivity and linearity to photon and charged particle at an energy range from tens of keV to several MeV;
- The detector could response to the beam loss quickly. Sensitive to the beam loss caused by the changing of the beam condition, it could provide more detail information than beam current for furthermore diagnosis of the beam;
- The detectors still have a good performance after exposing to high background of several MeV to hundreds of MeV electrons for two months;
- Plan to test it at high intensity proton accelerator of Accelerator Driven Sub-critical System of China (CADS) and China Spallation Neutron Source (CSNS) this year.