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Detectors with High Precision Timing at High Rates in Energy and Intensity Frontiers

We discuss detectors for MIPs(minimum ionizing particles) capable of timing precision to ±10's ps, simultaneously with rate capabilities exceeding 100's of MHz. Issues for defining a Figure of Merit(FOM) for timing scales as τdecay/√Nelectrons, and rate capability FOM scales inversely as τdecay. For optical transducers (SiPM, PMT, MCP-PMT), the timing precision is dominated by τrise, τdecay and inversely by S/N. Noise in the experiments from low energy photons/x-ray/n backgrounds scales inversely with Xo, an important consideration. Optical signals include scintillators with decay constants less than 2ns, Cherenkov radiators, and secondary emission detectors. Scintillators with high FOM include ZnO:Ga(GZO) (0.7ns decay), CdS:In (0.2 ns decay) and organic solid and liquid (with rad resistance) scintillators with decays less than 1 ns. SiPM and MCP-based detectors have risetimes shrinking to ˜100-20ps. We discuss scintillators, Cherenkov radiators(aerogels, quartz, Teflon AF, water, oils) and direct secondary emission detectors as precision timing and high rate detectors. Precision timing is becoming an important issue in particle, nuclear and medical physics. Signals with FW10%-10% Max < 25ns and segmentation to handle >200 pileup(PU) are advantageous in many future Colliders and upgrades. Similarly tagged neutrino beams (from kaons, pions or muon factories) and tagged kaon beams would benefit from MIP(minimum ionizing particles) rates exceeding 100's of MHz. The high track density and pile-up in high luminosity particle colliders are challenges for event reconstruction and analysis. Timing detectors must withstand 50 MRad and neutrons >3x1015 n/cm2. MIP pileup is a few percent in ˜1x1 cm2, ˜1m radially along η=0.

Energy Frontier: The case for adding a timing 4th dimension to calorimetry and tracking is becoming compelling. The high track density and pile-up in high luminosity particle colliders are challenges. Timing of MIP's has been shown by CMS and ATLAS to improve ETmiss resolution, and tag secondary vertices to ± few mm. It is estimated that the level of needed timing resolution is ˜30ps σt for 200 event pileup. Signals with FW10%-10% Max < 25ns and segmentation to handle >200 pileup(PU) are advantageous in many future colliders/upgrades. Timing detectors must withstand 50 MRad and neutrons >3x1015 n/cm2. MIP pileup is a few percent in ˜1x1 cm2, ˜1m radially along η=0. Luminosity measurements can exploit timing detector hardware for per bunch online luminosity measurements and for machine induced background measurements.

Intensity Frontier: time-of-flight is part of many fixed target experiments and factory-collider experiments at >100 MHz counting rates. Examples include: LHCb and Belle/BES-III TOF systems, Muon (g-2), μ->eγ, μ-to-e, and present and future rare K decay. Similarly tagged neutrino beams (from kaons, pions or muon factories) and tagged kaon beams would benefit from MIP(minimum ionizing particles) rates exceeding 100's of MHz. In the future, tagged neutrino beams to obtain purer beams of electron or muon neutrinos are being proposed, at >100 MHz counting rates.

Cosmic and Medical Frontiers: 10 ps precision TOF with GZO+SiPM could be in future high altitude balloon, satellite/space station, and speculatively eventually in moon-based experiments for cosmic rays. PET/SPECT benefit from ˜10ps timing.

Primary authors: Prof. WINN, David (Fairfield University); Prof. ONEL, Yasar (University of Iowa)

Presenter: Prof. WINN, David (Fairfield University)

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