



FY27 NPP LDRD Type B Pre-Proposal

Improved particle identification with pixelated, precision-timing photodetectors

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FY27 NPP LDRD Type B Pre-Proposal

Proposal title: Improved particle identification with pixelated, precision-timing photodetectors

Primary Investigator: David Jaffe

Other Investigators: Angelo Di Canto, Yifan Jin, Alexander Kiselev, Martin Purschke

This is not a cross-directorate proposal.

Proposal Term: 2 years From: 1 Oct 2026 To: 31 Sept 2028

FY27 NPP LDRD Type B Pre-Proposal

Proposal title: Improved Particle IDentification with pixelated, precision-timing photodetectors

Brief abstract: The Belle II Aerogel Ring-Imaging Cherenkov (ARICH) detector will require new photosensors as part of the upgrade to Belle II slated for the early 2030's. We propose to employ pixelated, precision-timing photodetectors* HRPPD and LAPPD to augment the ARICH with time-of-flight (TOF) capability. TOF will provide excellent PID for low-momentum charged particles, complementing RICH-based PID at higher momentum. The improvement in time resolution will reduce random backgrounds for RICH-based PID making the upgraded ARICH more robust as the higher instantaneous luminosity increases as forecast. We will quantitatively evaluate key performance characteristics of an upgraded ARICH using a prototype containing an HRPPD & LAPPD with the NSRL proton beam. We project that an upgraded ARICH would be equivalent to an increase of 5% to 10% statistics for heavy flavor measurements at Belle II.

Program: DOE HEP

Return on Investment: U.S.-Japan Science and Technology Cooperation Program in HEP (fall 2026) and Belle II detector upgrade to be proposed to DOE HEP

Broader impact on the activities at the laboratory: Increases the scope the existing Belle II effort at BNL. Synergistic with EIC PID efforts.

Total planned funding in FY27 and FY28 is \$199k and \$187k, respectively.

*HRPPD = High Rate Picosecond PhotoDetector, LAPPD = Large Area PPD

Description of the LDRD(1/2)

The Belle II ARICH provides charged particle identification (PID) via proximity-focused Cherenkov-ring-imaging in the forward direction at the asymmetric e^+e^- SuperKEKB collider. The current ARICH photosensors are no longer produced and thus unavailable for the planned Belle II upgrade. We propose to replace them with a mix of HRPPD (120x120 mm²) and LAPPD (200x200 mm²) photosensors which have both superior time and spatial resolution compared to the current detector to improve RICH performance and enable PID by time-of-flight (TOF). The HRPPD and LAPPD have achieved [17 ps](#) and [30 ps](#) time resolution for single photons, respectively.

Assuming a 30 ps time resolution per track for an HRPPD/LAPPD with readout electronics and 10 ps time resolution of [the Belle II event start time](#), we expect 5σ separation between kaons and pions (protons) up to about 2(3.4) GeV/c using TOF. The sub-ns time resolution of the upgraded ARICH should yield a substantial reduction in random background compared to the effective time resolution of the current ARICH of [~125 ns](#).

We will construct a prototype consisting of a radiator and an HRPPD and LAPPD to evaluate both the TOF and RICH performance of an upgraded ARICH. We will investigate the Cherenkov photon yield and angular and temporal resolution for charged particles traversing the radiator and extrapolate these results to compare to the current ARICH. We will also evaluate the timing resolution provided by Cherenkov light produced by charged particles traversing the glass window of HRPPD and LAPPD.

The prototype will be simulated using Geant4 for comparison with measurements to enable reliable extrapolation to the upgraded ARICH and to develop reconstruction software that can combine RICH and TOF capabilities.

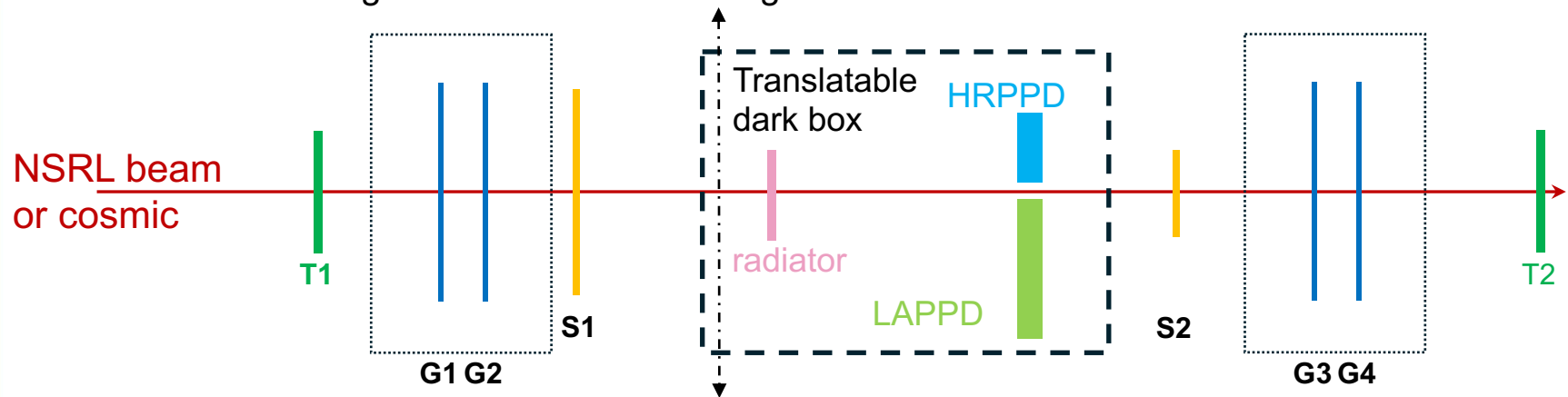
Description of the LDRD (2/2)

The prototype with an appropriate radiator (possibly UV-transparent acrylic, $n_r \cong 1.5$) will be exposed to a pencil proton beam at NSRL with energy up to 2.5 GeV to simulate the response to pions, kaons and protons with the aerogel radiator ($n_r \cong 1.05$) of the Belle II ARICH.

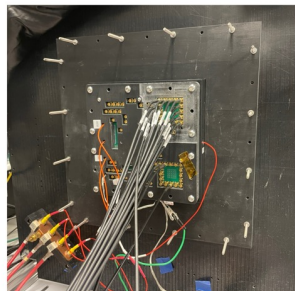
Translation of the dark box perpendicular to the incident NSRL beam will allow the beam to traverse the HRPPD or LAPPD glass window.

The apparatus will also be capable of tilting vertically to enable debugging and data acquisition with cosmic ray muons.

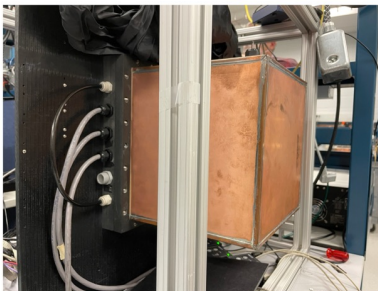
Almost all components, including electronics and DAQ, are in hand and planned for use in the pFRICH test beam setup at the CERN PS/SPS in summer 2026. We would need to procure an LAPPD and design and build the mounting structure.



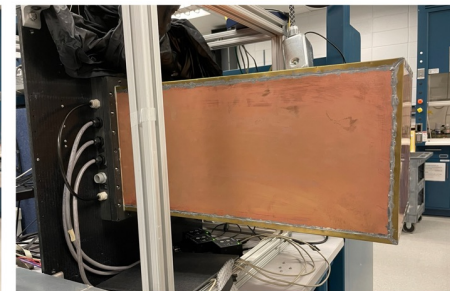
S1&S2 = trigger scintillators; G1-G4 = GEM trackers; T1&T2 = Photonis FT-16 MCP-PMTs for precision beam timing



rear side plate with a single HRPPD



front side with a short dark box



front side with a long dark box

LDRD milestones, deliverables, cost estimate

- FY27
 - Procure LAPPD
 - Fabricate prototype assembly with HRPPD
 - Develop Geant4 simulation
 - Measurements at NSRL to characterize HRPPD performance:
 - Time resolution
 - Cherenkov photon yield and angular resolution
- FY28
 - Incorporate LAPPD into prototype assembly
 - Measurements at NSRL to characterize LAPPD/HRPPD performance
 - Time resolution
 - Cherenkov photon yield and angular resolution
 - Develop combined RICH & TOF reconstruction
 - Extrapolation to upgraded ARICH performance
 - Preliminary cost estimate for upgraded Belle II ARICH

	FY27	FY28	
Postdoc	\$ 94,000	\$ 96,000	0.6 FTE (Y.Jin)
Technician	\$ 4,000	\$ 4,000	1 week
NSRL run	\$ 32,000	\$ 76,000	7h/FY27, 16h/FY28
Materials	\$ 11,000	\$ 11,000	
LAPPD	\$ 57,000	\$ -	
TOTAL	\$ 199,000	\$ 187,000	