



Improved particle identification with pixelated, precision-timing photodetectors



Principal Investigator(s): David Jaffe

List of the proposal participants:

Angelo Di Canto, Yifan Jin, Alexander Kiselev, Martin Purschke, Babak Azmoun

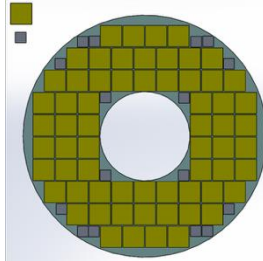
ECA eligibility: No

Proposal term from: Oct-26 to: Sep-28

Annual funding: FY27 \$250,000 FY28 \$250,000



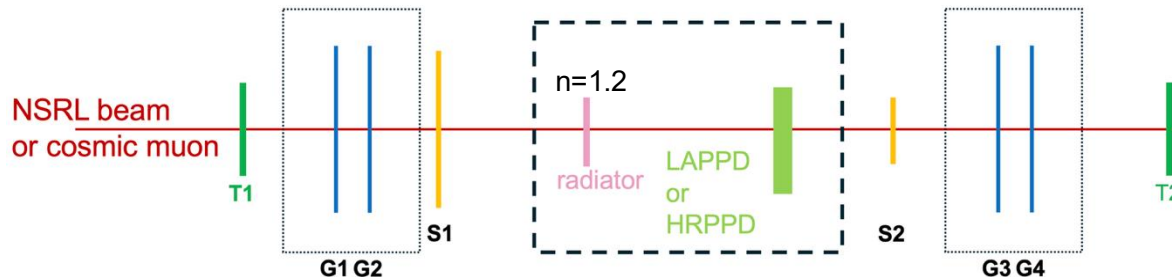
Description of the LDRD Proposal



Belle II Aerogel Ring-Imaging Cherenkov (ARICH) detector will require new photosensors for the upgrade in the early 2030's. We propose to use High Rate Picosecond Photo-Detectors (HRPPD) ($12 \times 12 \text{ cm}^2$) and Large Area Picosecond PhotoDetectors (LAPPD) ($20 \times 20 \text{ cm}^2$) to **augment the ARICH with time-of-flight (TOF)** capability.

The HRPPD and LAPPD have achieved **17 ps** and **30 ps** time resolution for **single photons**. Improvement in time resolution (currently 125 ns) will also reduce random beam backgrounds for RICH-based PID.

We will quantitatively evaluate key performance of an upgraded ARICH (RICH + TOF) using a prototype containing an HRPPD or LAPPD with the NSRL proton beam.



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

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 or LAPPD.

Description of the LDRD Proposal

Timeline and deliverables:

FY27

- Fabrication of prototype assembly with HRPPD.
- Commissioning of prototype and DAQ with cosmic ray muons.
- Development of Geant4 simulation.
- Measurements at NSRL to characterize HRPPD performance in terms of time resolution, Cherenkov photon yield and angular resolution.
- Development of combined RICH and TOF reconstruction software.
- Contribute to both the Technical Design Report (2027) for the Belle II upgrade and a proposal to DOE HEP for the US contribution to the Belle II upgrade.
- Technical publication on HRPPD results.

FY28

- Rent an LAPPD and incorporate into prototype assembly
- Measurements at NSRL to characterize LAPPD performance.
- Use simulation and combined RICH+TOF reconstruction to extrapolate to the performance of the upgraded ARICH.
- Technical publication on LAPPD performance.

Almost all components, including electronics and DAQ, are in hand, except an LAPPD.

We intend to first commission at NSRL using parasitic running (Martin Purschke has recent experience) to ensure efficient operation during dedicated NSRL beam time.

Intellectual Merit Summary

Assuming a **30 ps** time resolution **per track** for an HRPPD or LAPPD with readout electronics and 14 ps time resolution of the Belle II event start time, we expect **5 σ** separation between kaons and pions up to about 2 GeV/c, kaons and protons up to 3.3 GeV/c using just TOF.

The performance of Belle II ARICH on PID could be significantly enhanced. We project that an upgraded ARICH would be equivalent to **an increase of 5% to 10% statistics** for heavy flavor measurements at Belle II.

Return on Investment or Potential Future Funding

- Initiate relevant and complementary proposals to U.S.-Japan Science and Technology Cooperation Program in HEP (**fall 2026**).
- Participate in the proposal to DOE HEP by the US Belle II institutions for the planned upgrade of the Belle II detector. It is anticipated that funding from DOE HEP would be available in **FY2029**.

The Broader Impact on the Laboratory

- This proposal will further US leadership in scientific discovery with the current Belle II experiment. **BNL is the lead laboratory for Belle II.** We expect the successful results of this proposal allow BNL to assume a prominent role in the upgrade of the Belle II detector which is planned for 2032-3.
- HRPPD is also chosen as photosensor for pfRICH at ePIC. Synergistic with EIC PID efforts would facilitate this beam test project and contribute to both experiments.

Names of Suggested BNL Reviewers

Four suggested reviewers:

Xin Qian

Craig Woody

Marc-Andre Pleier

Stefania Stucci

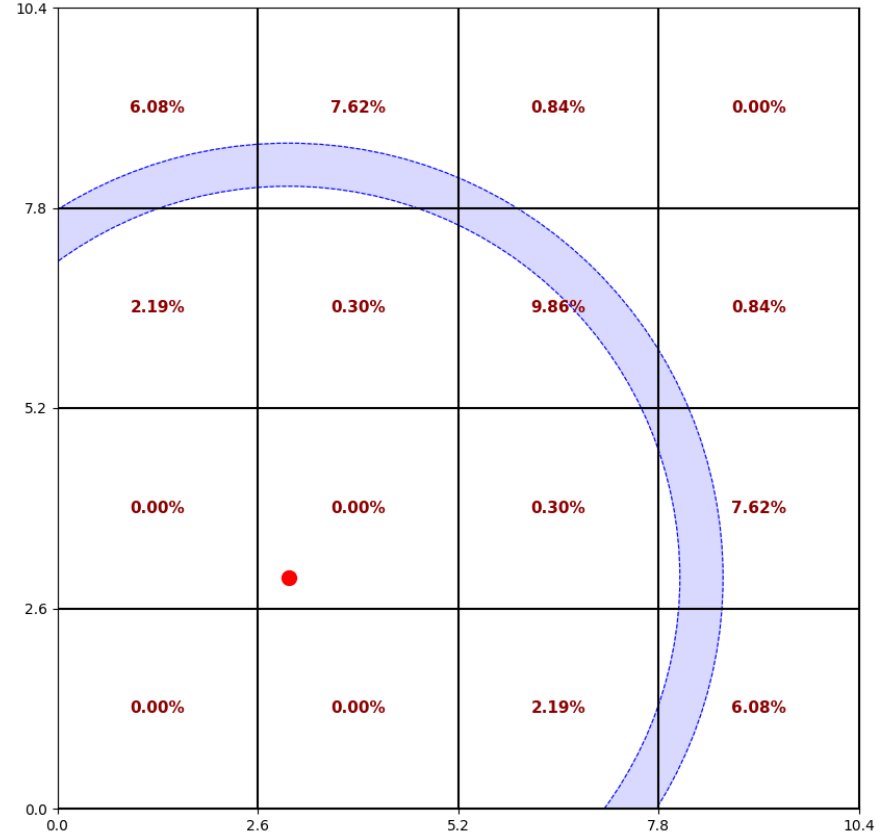
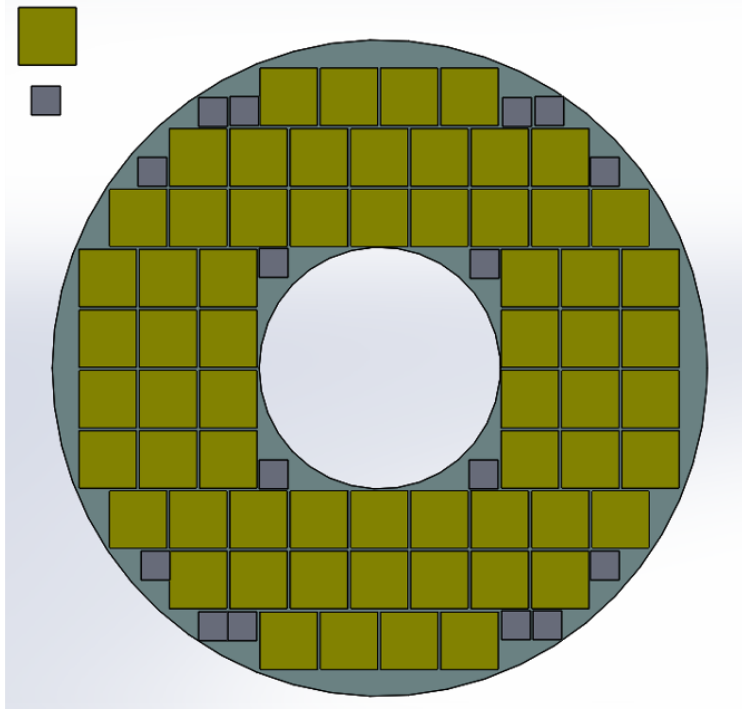
LDRD Funding Table from BOM

Resource Category	DESCRIPTION	FY27	FY28
050	Salary - Scientific	0	0
051	Salary - Research Assoc	87,135	90,113
050	Salary - Professional	0	0
050	Salary - Technical	10,394	7,039
050	Salary - Management & Admin.	0	0
	Total FTEs	0.85	0.83
TOTAL SALARY/WAGE & FRINGE		97,529	97,152
	various Contracts - Low Value	0	25,000
280	Foreign Travel	0	0
290	Domestic Travel	0	0
	various Purchases	20,000	10,250
TOTAL MSTC		20,000	35,250
	493 Other Research Machines	45,000	34,000
TOTAL OTH-CHRGs		45,000	34,000
TOTAL DIRECT COSTS		162,529	166,402
251	Electric Distributed (Electric Power Burden)	975	972
700/701/481	Organizational Burden	11,606	11,561
TOTAL ORGANIZATIONAL BURDEN		12,581	12,533
745	Procurement (Material Handling)	1,400	2,468
735	G&A Burden	0	0
730	Common Institutional Support	73,490	68,598
722	Safeguards & Security Assess	0	0
TOTAL LABORATORY BURDEN		74,890	71,065
705	LDRD Burden	0	0
TOTAL PROGRAM COSTS		250,000	250,000
740	Full Cost Recovery	0	0
TOTAL PROGRAM COSTS		250,000	250,000

Labor Band	Name	FY27		FY28	
		FTE	Amount	FTE	Amount
RA1	Yifan Jin	0.80	87,135	0.80	90,113
TECH2	TBD	0.06	10,394	0.04	7,039

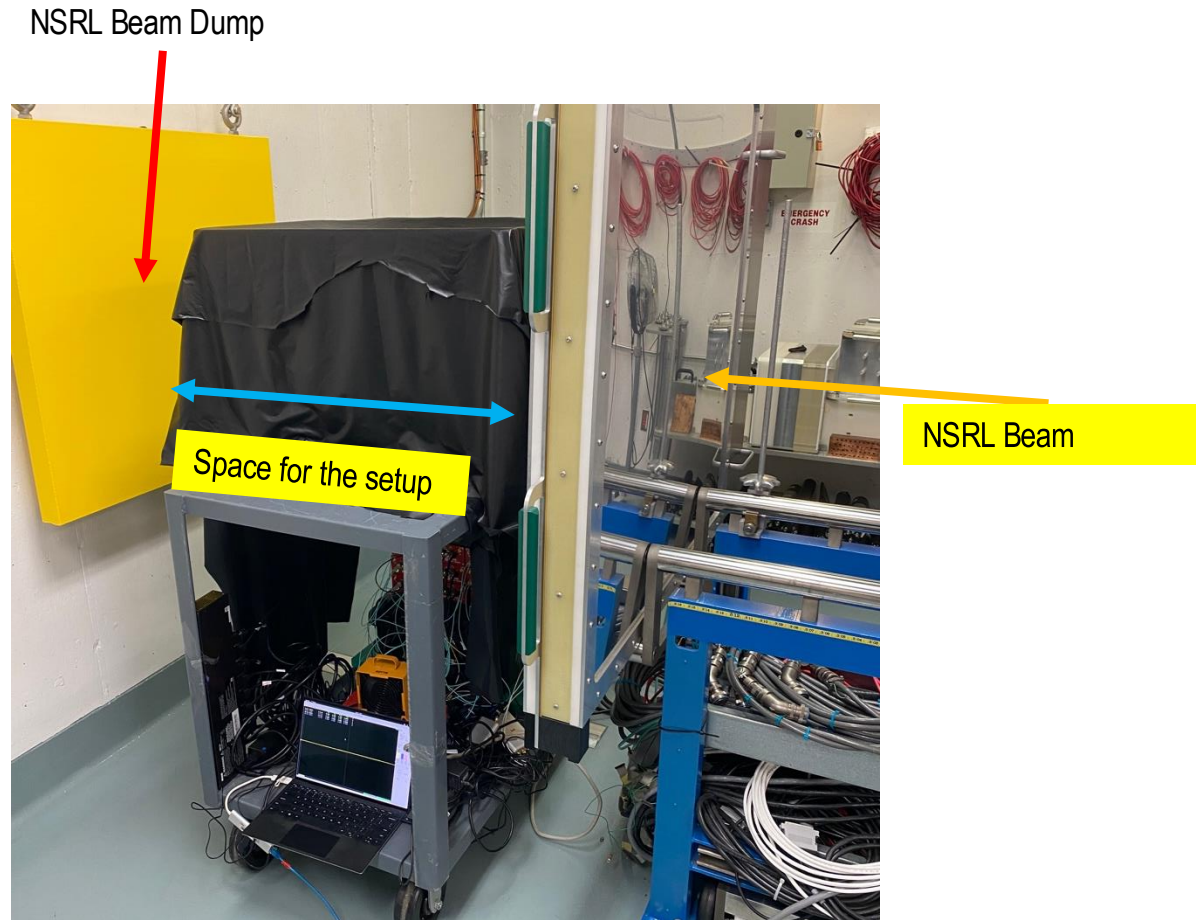
Backup

Backup



Using protons with 2 GeV kinetic energy, for a 5-mm thick radiator with $n=1.2$, if the separation between radiator and HRPPD is 8 cm, the ring on HRPPD has outer radius 5.6 cm and inner radius 5.1 cm. Number of generated Cherenkov photons is 86. At Belle II ARICH, ring dimension is ~ 6 cm.

Backup



This is the actual setup by one of the participants (M. Purschke). We already have the expertise to run test beams at the NSRL.