

Enabling Stage-V Cosmology by Extending Spectroscopic Surveys into the Near-Infrared



Principal Investigator: Juan Estrada (IO)

List of the proposal participants and their organizations:

(IO) Justine Haupt, Sven Herrmann, Paul O'Connor, Giovanni Pinaroli, Paul Stankus

(Physics) Anze Slosar,

Proposal term from: FY27-FY29

Annual funding: \$600k/year

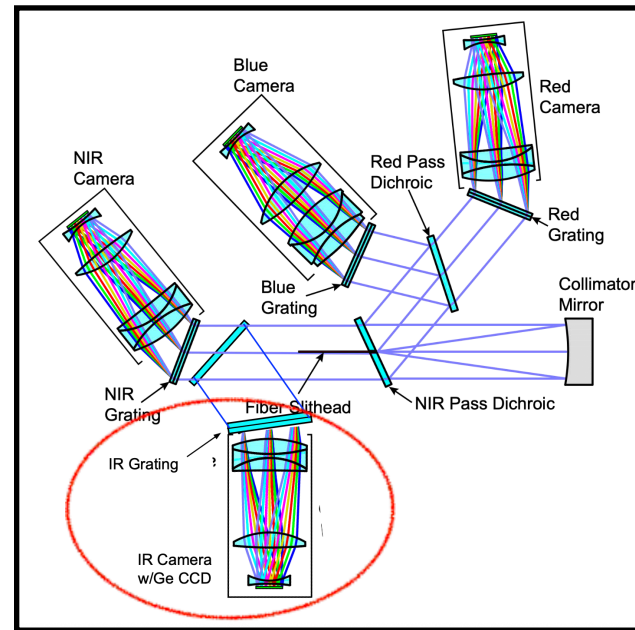


Spec-S5 and the new IR channel



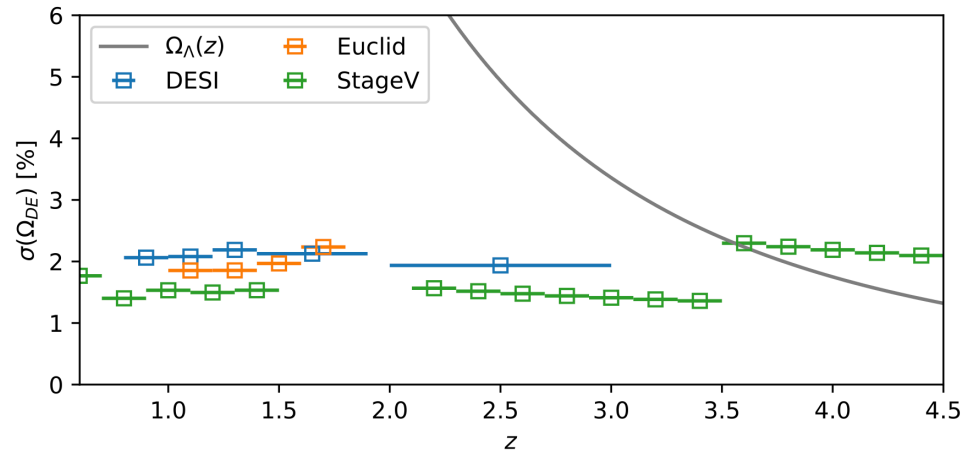
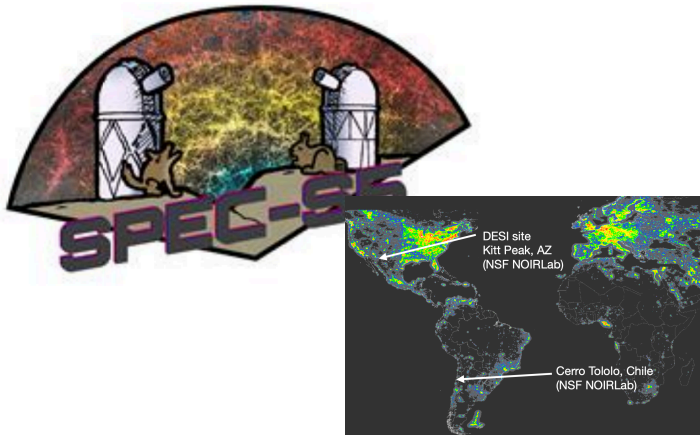
Upgrading two existing 4-m/6-m wide-field facilities, each with a highly multiplexed spectroscopic instrument measuring the spectra of 13,000 astronomical targets. Spec-S5, which builds and improves on DESI, more than 10× gain in spectroscopic capability. A critical scientific capability in the post-Rubin and post-DESI era for advancing cosmology, fundamental physics, and astrophysics in the 2030s. *Science Driver 1: Fundamental Physics at $z > 2$* .

Next generation cosmic survey is Spec-s5. Very likely the next project in Cosmic Frontier. Will explore the high-redshift universe ($z > 2$).



For getting into the redshift desert ($1.4 < z < 2.5$) IR is essential

The new instruments will need an IR channel on the spectrograph. 23 spectrographs per telescope (567 fibers each). *BNL has already started getting ready to start testing Ge CCDs for spec-s5. Sensors arriving next week!!!*



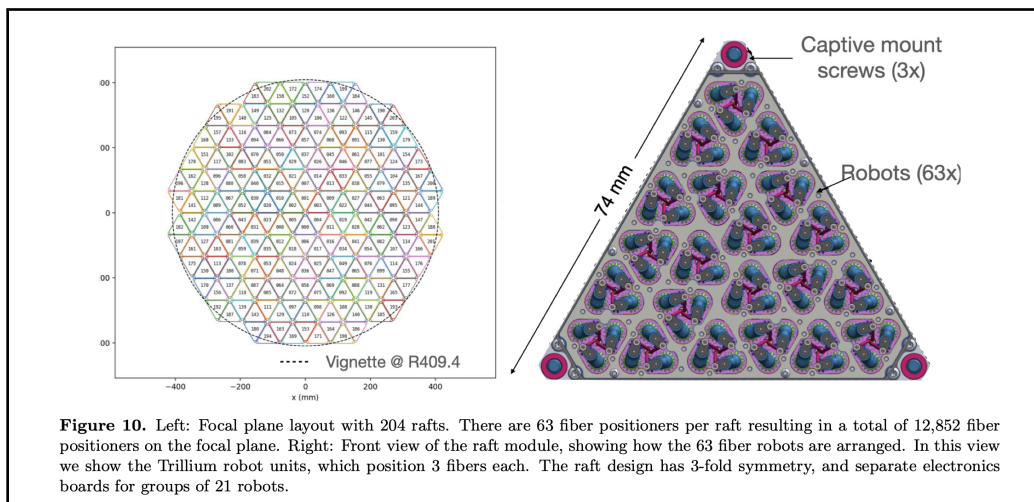
• **BAO measurements at better than 0.1**

measurement of the BAO parameter at these redshifts will allow tests of dark energy models that mimic a cosmological constant at low redshift or otherwise cause deviations in the expansion history at early times and thus evade detection by the lower redshift, Stage 4 dark energy probes. Given current capabilities, only BAO measurements from a large spectroscopic sample can be used to constrain the expansion history in this era. The impact of this BAO measurement relative to the dark energy content is described in the supporting Snowmass paper (Ferraro et al. 2022) and presented in Figure 1. [Anze Slosar]



DES-II/SPEC-S5 flows naturally from our LSST work. Spec-S5 will select galaxies from LSST. DESI will be crucial to support lensing science via helping with redshift distribution (A.Slosar)

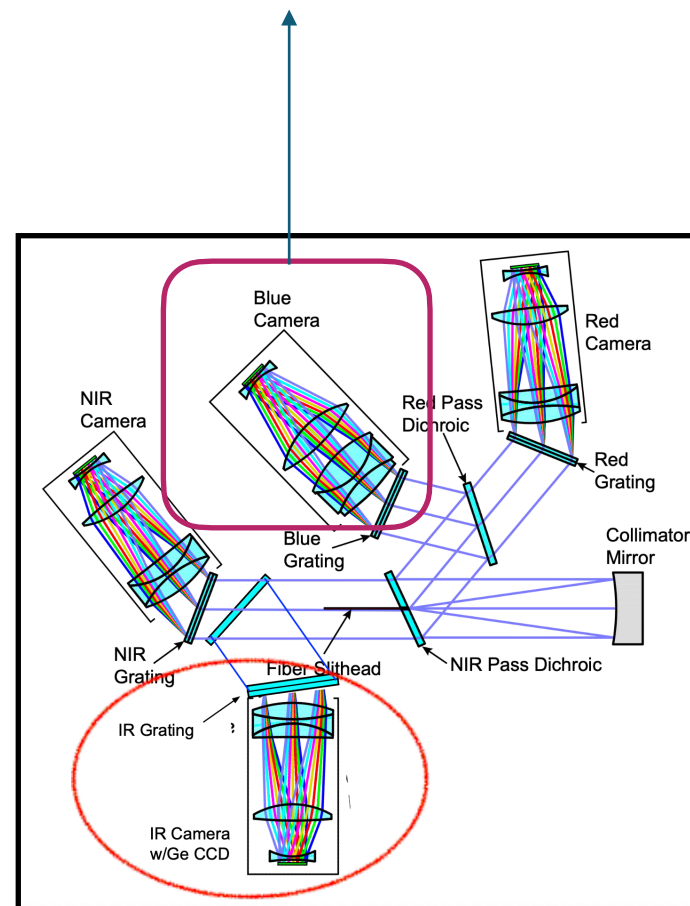
Other upgrades



Fiber positioners with 6.2 mm center-to-center pitch. This is a significant reduction from the DESI state-of-the-art 10.4 mm minimum pitch. Development by LBNL.

The IR channel is a new subsystem that aligns well with our capabilities and is where we have already started working. Critical enabling component for the spec-S5 science.

The blue channel will have a low-noise CCD (most likely a MAS-CCD), which has been developed by LBNL+FNAL. We (BNL) are ready to contribute with packaging, electronics, and integration.



Spec-S5 prototype is planned.

- To reduce commissioning time and risk for the full spec-s5 project, we have been considering a prototype deployment of a few rafts in the 4m telescope in Chile (Blanco) in ~ 2030. (~\$10M)
- Additionally, this prototype/pathfinder will do very interesting science (LSST follow-up).
- BNL is already participating in the planning for this. At the moment, we are focusing on the testing of the Ge CCDs fabricated by MIT-LL.

We propose to design, prototype, and validate the infrared (IR) camera for the Spec-S5 spectrograph, and to deploy it as part of the Spec-S5 prototype instrument planned for 2030.

The IR arm introduces a new capability for Spec-S5 and poses the highest technical risk in the spectrograph design. Its IR detector and camera subsystem are novel, with no direct heritage from previous DOE cosmology instruments. This proposal is therefore a risk-reduction effort for Spec-S5, focusing IR camera during the project's early phase.

Focused system-level integration, prototyping, and risk reduction for the Spec-S5 IR camera.

HOW DOES THE PROPOSED RESEARCH ENHANCE THE LAB STRATEGY

This project directly advances Brookhaven National Laboratory's strategic objective to make **high-impact contributions to next-generation scientific instrumentation for flagship DOE experiments. Spec-S5 is a priority future facility for the Office of High Energy Physics and the Cosmic Frontier program.**

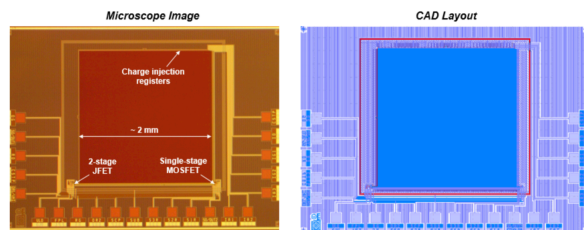
BNL strongly involved in LSST and are planning to shift towards Spec-S5 as the next target. Now it is time to develop base technologies, but the roadmap will involve getting Physics heavily involved in a few years with science. They hate it doing instrumentation without analysis involvement (Anze Slosar)

This effort will position **BNL as an indispensable enabling partner for Stage-V cosmology** at a stage when design decisions will have a lasting impact on cost, performance, and feasibility.

We are **already starting a small effort on device packaging/testing for the IR channel in spec-s5.** This will make it a full IR-channel effort.



Test station for GeCCD@BNL

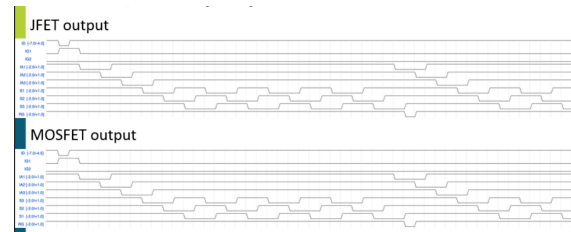
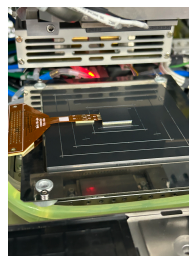


256x256 sensors arriving next week from MIT-LL.



CCD readout system getting ready. Jan 2026 (G. Pinaroli)

CCD packaging at IO (Jan 2026). D Pinelli et al.



CCD clocking sequence for Ge CCD, Feb 2026 (E. Tamura)

THE RESEARCH TEAM

Instrumentation Department brings together the full range of expertise and infrastructure required to deliver this critical Spec-S5 subsystem, including detector characterization, low-noise readout electronics, cryogenic systems, opto-mechanical design, and end-to-end spectrograph integration.

Physics will also be heavily involved in data analysis from the prototype (A.Slosar).

Juan (new to the BNL team is a DESI builder)

Leverage of in-house cryogenic facilities, readout systems, and optical test capabilities that enable rapid prototyping and system-level validation.

Proven record of delivering detector subsystems of comparable complexity and risk (LSST CCD rafts for the LSST camera). That effort closely parallels the proposed work, involving sensor evaluation, readout and thermal design, and successful mechanical and electrical integration at scale.

The team will ***collaborate closely with MIT Lincoln Laboratory on Ge CCD*** evaluation and with Spec-S5 and DESI partners responsible for spectrograph optics, fiber systems, and instrument controls. The existing Ge detector activity within the department provides additional technical depth, while this project remains.

WHY BNL and Why NOW!

Brookhaven National Laboratory is already playing an active role in early Spec-S5 technology planning, but for the moment is very small.

This LDRD effort extends the effort from device-level evaluation to the construction and validation of a complete IR camera subsystem for the spectrograph, including detector readout, mechanical integration, and cryogenic solution. Make BNL a key player driving this important sub-system for spec-s5.

Urgency : The technical architecture and detector choices for Spec-S5 are being defined now, engagement at this stage is essential. Decisions made in the near term will set the performance, cost, and risk envelope for the full facility and will be difficult to revisit later. The roles are being defined now, this is the time to demonstrate the support and commitment.

By anchoring this work at BNL, the Laboratory provides continuity from early technology assessment through system-level implementation, ensuring that lessons learned during detector evaluation are efficiently translated into a deployable instrument for the Blanco-based Spec-S5 prototype. This timely engagement positions BNL to contribute meaningfully to the next major cosmology experiment, rather than entering after critical design choices have already been fixed.

Builds on BNL involvement in LSST Camera (Instrumentation) and Cosmology (Physics). It also takes advantage of cryogenics, integration, and Ge detector efforts here!

Draft LDRD Funding Table

Effort/year (\$490k/year)

- *Sci (~0.2), Professional (~0.4), Tech (~0.3)*
- *Design, build, test cryo and electronics*

M&S (\$100k/year):

- *electronics adapter, controller for new sensors*
- *packaging parts*
- *sensor*

(The spec-s5 prototype is planned at ~\$10M, when it comes time to install the spectrographs for this project in 2030 we will be ready with a solution)



Summer 2042

The New York Times

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David Guttenfelder/The New York Times

FROM PHOTONS TO COSMOLOGY

How Spec-S5 and LSST turned faint galaxies into fundamental insight *The unprecedented marriage of the Spec-S5 spectroscopic survey with the imaging power of LSST has delivered what cosmologists long chased: a decisive measurement that confirmed evolving dark energy.*

THE SILICON AND GERMANIUM BEHIND THE BREAKTHROUGH

Every key sensor passed through Brookhaven

Behind the cosmic headlines lies a terrestrial triumph.

Critical detector technologies—spanning silicon sensors for visible channels and germanium sensors for the infrared—were developed at Brookhaven National Laboratory.

The germanium infrared channel proved decisive, opening access to the high-redshift universe where dark energy's evolution could finally be disentangled from cosmic structure growth.

ARGENTINA WINS FIFTH STAR!

Mateo Messi Scores Winning Goal in World Cup Final.

Mateo Messi Lifts the Trophy