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**Title:** Experimental overview about LANL contributions to the Electron-Ion Collider

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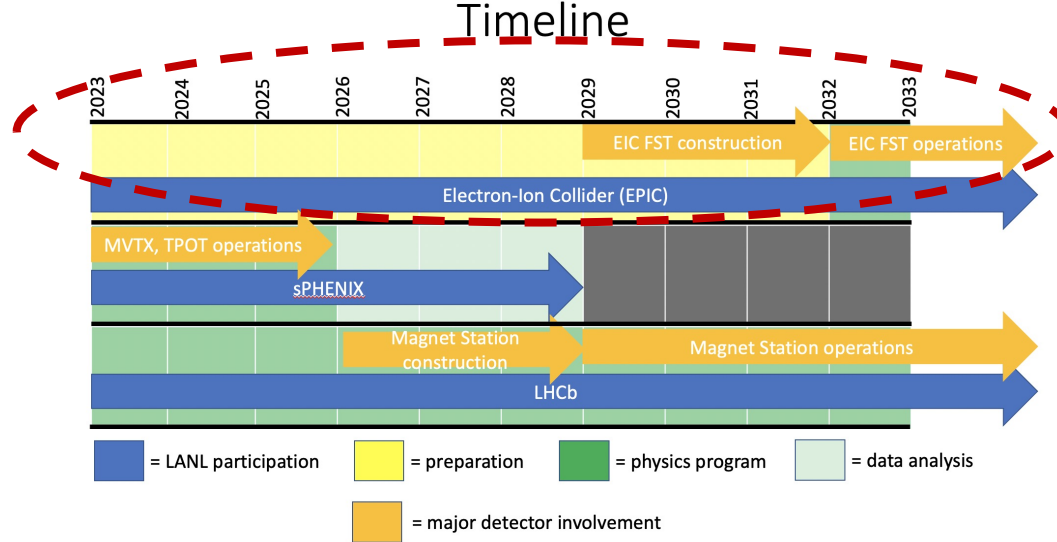


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# Experimental overview about LANL contributions to the Electron-Ion Collider

Xuan Li, P-3

# What we would like to request



- The LANL team is interested in designing and building the Forward Silicon Tracker (FST) for the EIC. We would like to support 0.5 FTE staff, 1.0 FTE postdoc in FY23 for
  - Silicon detector R&D.
  - FST technical design.
  - Associated heavy flavor physics studies.

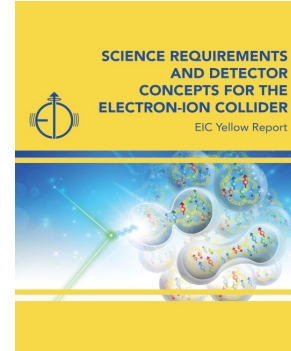


# What have been done at LANL for the EIC

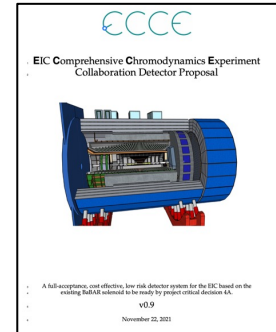
- An EIC LDRD from Oct. 2019 to Sep. 2022, has been funded with \$5M by the LANL LDRD office with PI: Ivan Vitev (Theory), Co-PI: Xuan Li (Experiment) and 15+ staff/engineers/postdocs.
- Through this LDRD project at LANL, **we have established LANL as a major contributor (leader) for the physics and detector developments of the EIC:**
  - Three conveners in three ECCE working groups, X. Li is the EPIC tracking working group co-convenor and C.P. Wong (PD) is the EPIC heavy flavor and jet working group co-convenor.
  - LANL is the first team in the EIC community to develop a series of heavy flavor physics studies to explore the hadronization process.
  - We have led the EIC forward silicon vertex/tracking detector design and carried out advanced silicon sensor R&D.
  - LANL team made significant contributions to the EIC YR, ECCE detector proposal (selected as the EIC detector reference design) and 5+ peer reviewed publications/proceedings.



## EIC YR



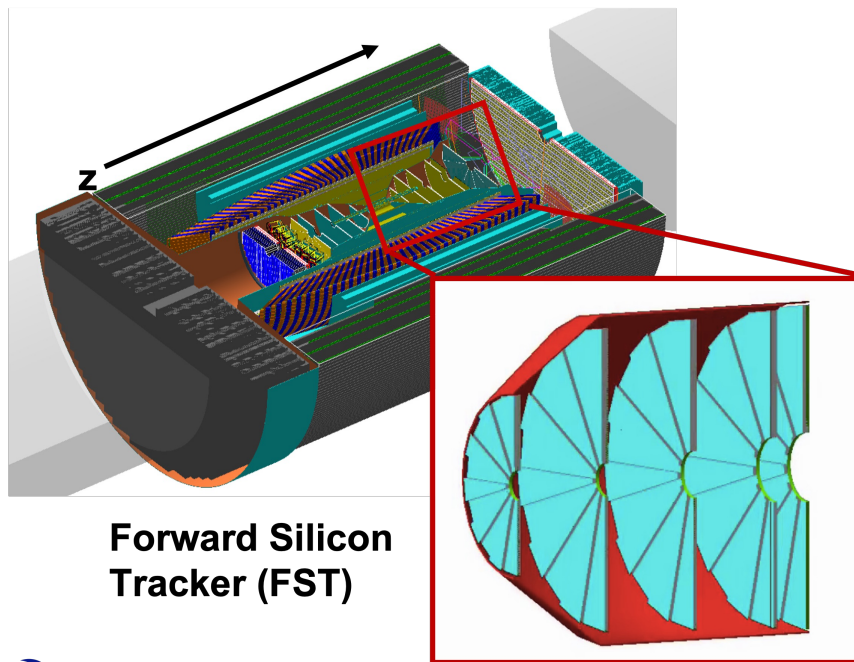
## ECCE proposal



# EIC Achievement – FST detector design and performance

- The FST conceptual design including the mechanical structure, cooling and cables has been implemented in the GEANT4 simulation.

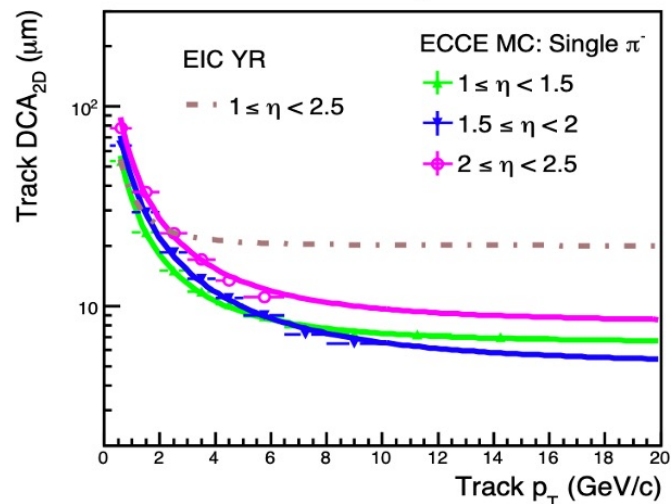
**LANL FST included in the EIC reference design.**



X. Li, C. Dean (former PD), M. Durham,  
C.P. Wong (PD), W. Sondheim

Tracking performance with the 1.4T Babar magnet

DCA<sub>2D</sub> resolution VS  $p_T$  in  $1 \leq \eta < 2.5$



# EIC Achievement – silicon sensor R&D progress

- Silicon R&D via single sensor and telescope setup has achieved first results.

X. Li, Y. Morales (PD), M. Durham, E. Renner, A. Navazo, W. Sondheim

## Single silicon sensor and telescope setup

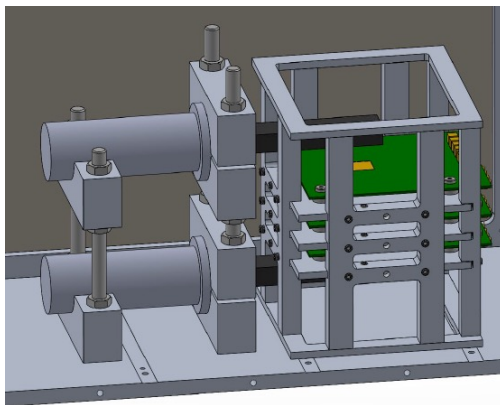
LV supply for  
LVDD, DVDD,  
AVDD, SUB  
and PWELL of  
the MALTA  
sensor

DAQ  
computer

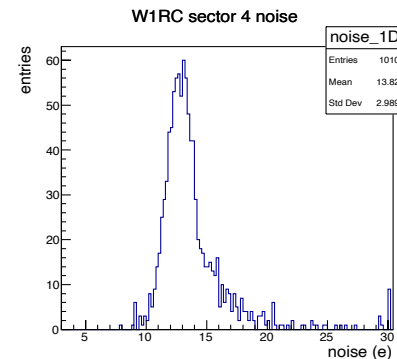
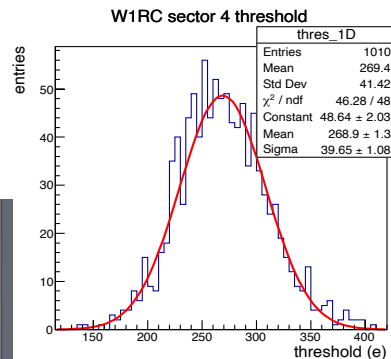
XILINX  
KC705 board

Router for FPGA  
and computer  
communication

MALTA sensor  
carrier board

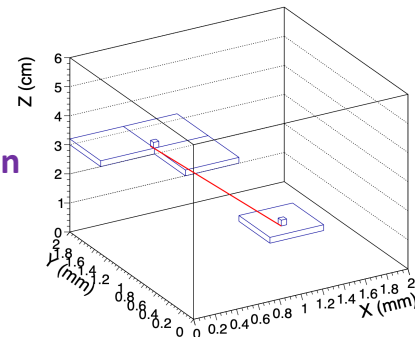


## Single sensor test



Event display 16

Track  
reconstruction in  
telescope tests



# EIC Achievement – EIC heavy flavor hadron/jet studies

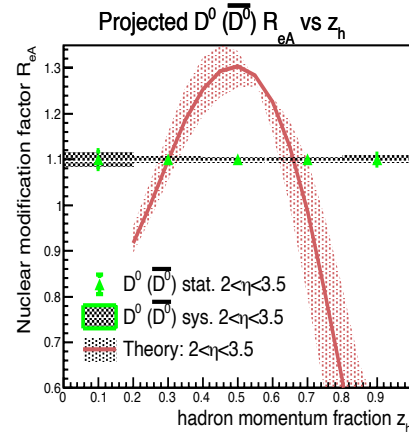
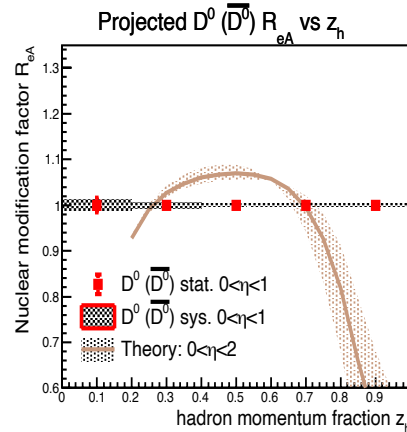
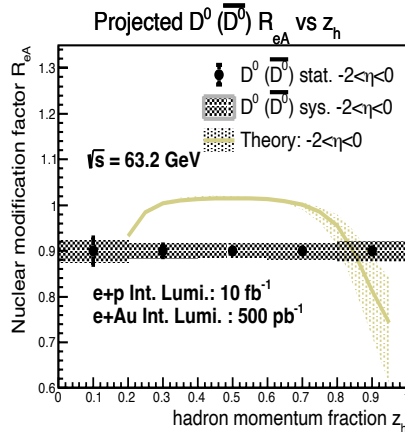
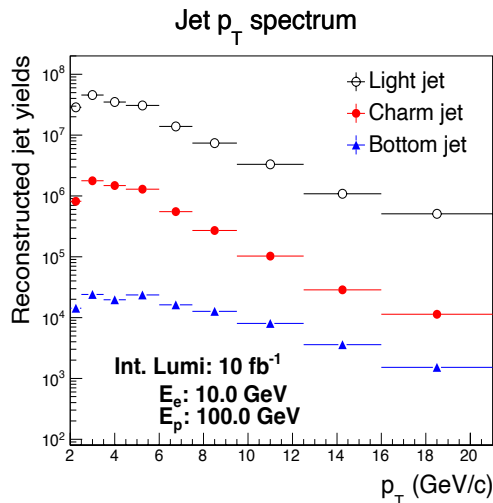
- With the developed full analysis chain, expanded the physics studies for both heavy flavor hadrons and jets with the integrated detector performance.
- The associated physics projection have been included the ECCE detector proposal, selected as the EIC detector reference.

Theory: Z. Liu, H. Li, I. Vitev et al.

Experiment: X. Li et al.

## Reconstructed heavy flavor jets

Submitted for publication, arXiv:2207.10632





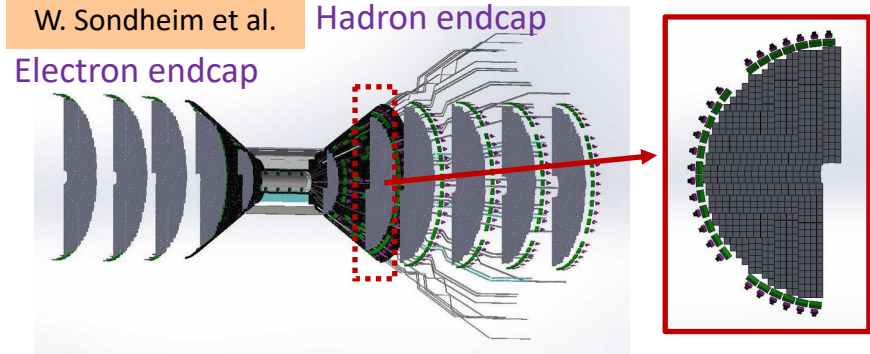
# EIC Achievement – additional contributions

- LANL EIC physics and detector studies supported by this DR project have been included in the submitted ATHENA and ECCE detector proposals and evolving in the EPIC detector technical design.
- The LANL FST design has been integrated into the EIC generic silicon detector design, which is part of the EIC eRD111.
- Additional EIC background studies, which include the synchrotron radiation and beam gas contributions, are underway and will be completed soon. Will update the tracking performance accordingly.

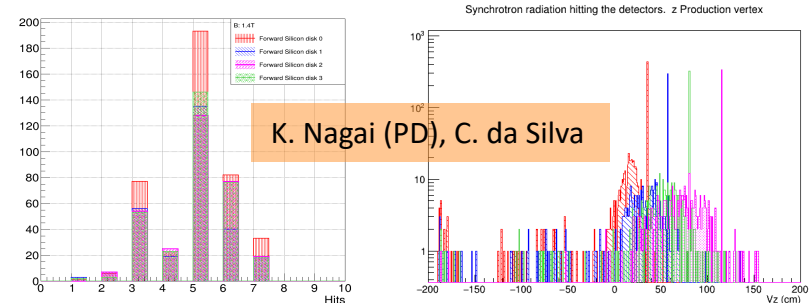
LANL team



## EIC generic silicon detector design

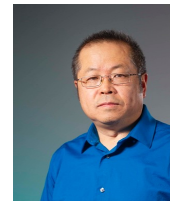


## Hits from sync. background in the FST



# Continuous efforts for the EIC

- In addition to the **LANL EIC LDRD project**, there are parallel small-scale EIC R&D projects at LANL:
  - sPHENIX+EIC AI based HF real time trigger development supported by DOE NP in FY22-23 (PI: M. Liu).
  - EIC project R&D work for silicon tracking detector mechanical design: eRD111 (W. Sondheim) and AC-LGAD silicon technology R&D: eRD112 (X. Li) is ongoing at LANL.
- We plan to continue leading and playing a major role in the EIC for heavy flavor physics developments, the EIC silicon tracking detector technical design, detector R&D and construction for the EIC.



M. Liu



W. Sondheim



X. Li



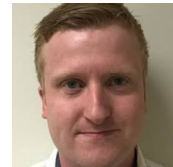
A. Navazo (Post-bac)



C.P. Wong (PD)



Y. Morales (PD)



C. Dean (Former PD)



K. Nagai (PD)



# Summary

- The LANL LDRD project has established and secured LANL's leadership role in the EIC physics and detector developments.
- Deliverables of this LANL LDRD project align well with the timeline of the new DOE facility - the EIC.
- We have developed a diverse workforce, which includes students, postdocs, scientists and engineers at different career stages and with different expertise to carry out various tasks for the EIC project.
- We would like to seek DOE supports to continue our work for the EIC: silicon detector R&D; silicon tracker construction and operation; heavy flavor physics development and data analysis.

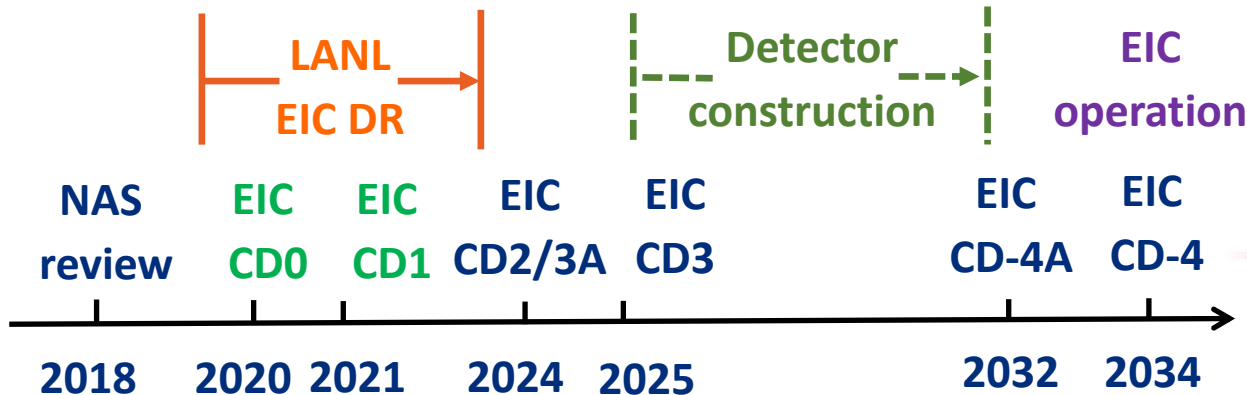
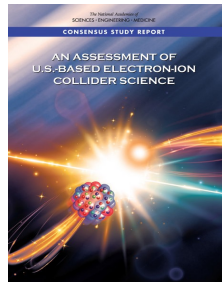


# Backup



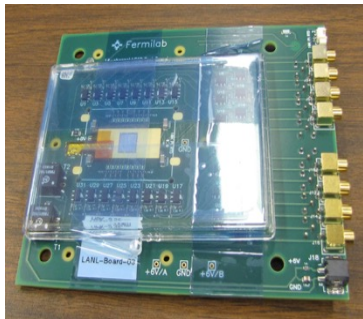
# Current LANL EIC studies are supported by LDRD

- An EIC DR (20200022DR), Oct. 2019 to Sep. 2022, have been funded with \$5M by the LANL LDRD office with PI: Ivan Vitev, Co-PI: Xuan Li and 15+ staffs/engineers/postdocs.
- Through this EIC project at LANL, we have explored hadronization processes and their medium modifications using heavy flavor hadron and jet probes at the EIC; carried out detector R&D for advanced silicon technologies and completed the conceptual design for a forward silicon tracking detector to meet the EIC heavy flavor and jet physics requirements.

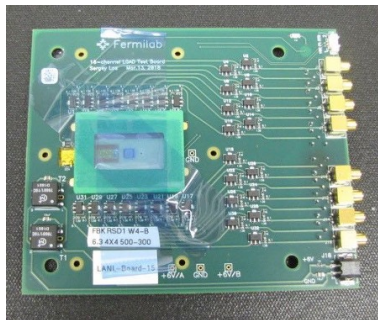


# All prototype sensors have been delivered to LANL

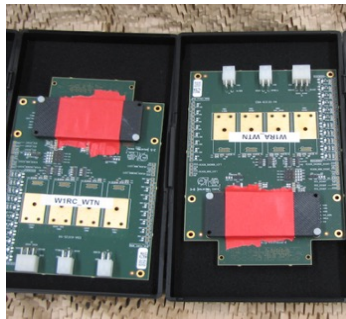
**LGAD sensor**



**AC-LGAD sensor**



**MALTA sensor**



- All prototype sensors have been delivered to LANL.
- Bench test configuration for LGAD/AC-LGAD/MALTA has been completed, and sensor characterization scan is ongoing.

Name	Technique	Pixel Size	Integration Time	Thickness per layer	External collaborators
LGAD or AC-LGAD	Low Gain Avalanche Diode	Towards 100 X 100 $\mu m^2$	< 100 ps	< 1% $X_0$ per layer	UC Santa Cruz FNAL
Radiation hard MAPS (MALTA)	180 nm commercial HV-MAPS	36.4 X 36.4 $\mu m^2$	< 5 ns	< 0.5% $X_0$ per layer	CERN FNAL

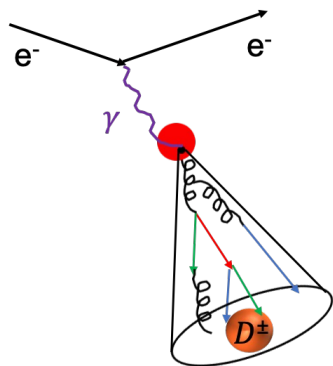


# Project outcomes – EIC heavy flavor hadron/jet updates (II)

- New physics observable explored to study the hadronization process: Jet substructure of light and charm jets in e+p simulation.

X. Li

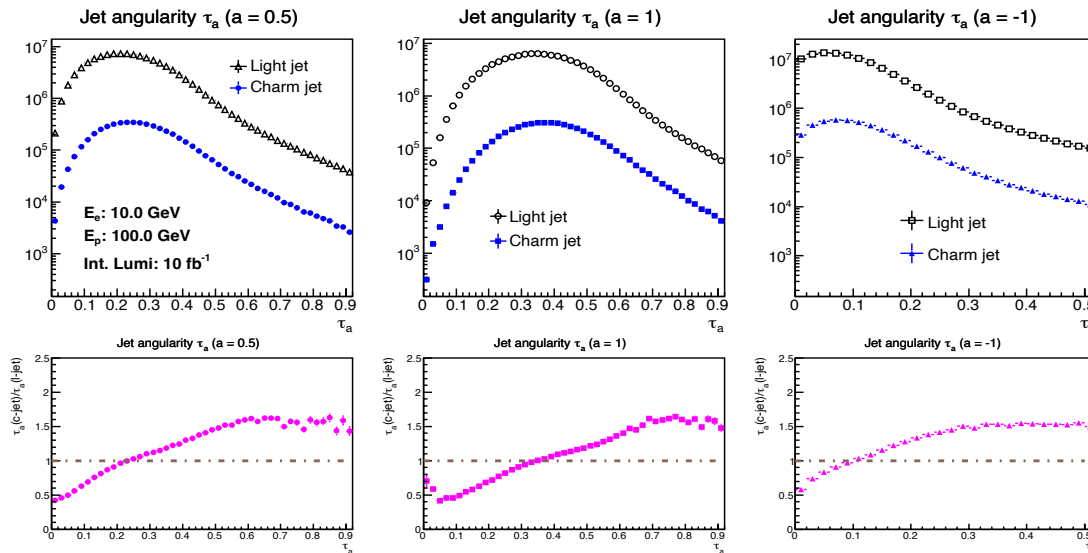
$$e^- + p \rightarrow e^- + jet(D^\pm) + X$$



Jet angularity:

$$\tau_a \equiv \tau_a^{pp} \equiv \frac{1}{p_T} \sum_{i \in J} p_T^i (\Delta \mathcal{R}_{iJ})^{2-a}$$

Updated studies with latest EIC detector performance



- Evidence of parton shower (potentially fragmentation) differences between light and heavy flavor quarks. Studies to extract medium effects in e+A collisions are underway.



