

U.S.-Japan Cooperation Program: Advanced Electron and Positron Source Concepts

JLAB-KEK-SLAC Collaboration
September 11, 2023



U.S.-Japan Cooperation Program

- The *U.S.-Japan Science and Technology Cooperation Program in High Energy Physics* is a collaborative R&D program jointly funded by the DOE Office of Science and KEK.
 - “Proposals submitted to this U.S.-Japan Laboratory Announcement should support current HEP experiments or **technology development** of mutual interest to U.S.-Japan collaborations. Seed funding requests for new ideas to incubate and **develop new accelerator** and detector systems for application in this time scale will also be considered.”

Advanced Electron and Positron Source Collaboration



KEK-JAPAN



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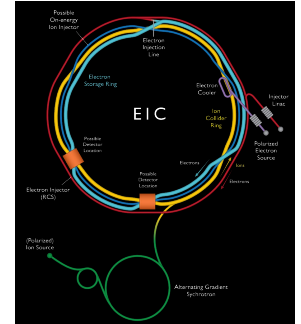
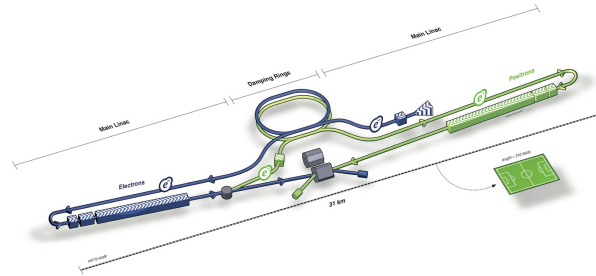
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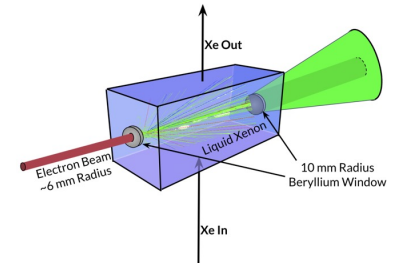
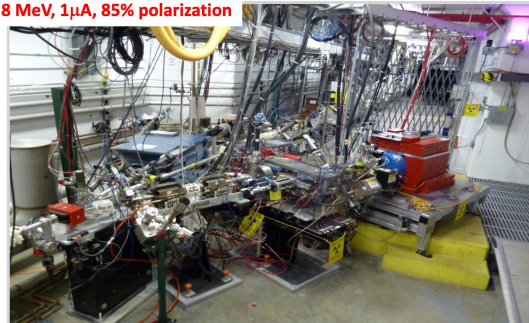
Advanced Electron and Positron Sources R&D

Advanced Electron and Positron Source Concepts has a broad scope.

- Source R&D for planned colliders:
 - ILC
 - EIC
- R&D for new initiatives:
 - Polarized positrons at JLAB.
- R&D for novel concepts:
 - Liquid Xenon target.



8 MeV, 1 μ A, 85% polarization







Our Proposal

Our proposal included 6 R&D topics and a duration of 3 years:

1. 400 kV Polarized Electron Source
2. Solid Target Fatigue Studies
3. Positron Target Concepts
4. Positron Capture Section
5. Beam Dynamics
6. Accelerating Structures

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- ~~4. Positron Capture Section~~
5. Beam Dynamics 
- ~~6. Accelerating Structures~~

However, we were awarded funding for 1 year and can only address some of these topics. The funding does not support scientific labor.

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- ~~4. Positron Capture Section~~
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The reviewers of our proposal encouraged us to re-apply for 2024 cycle with a “more focused” proposal.

Topic 1: 400 kV Polarized Electron Source

In 2010, JLAB and KEK developed a 200 kV inverted insulator for DC gun.

Now, updated specifications demand a 400 kV insulator to meet requirements for 300 kV operation.

Carlos Hernandez-Garcia (JLAB) and Masahiro Yamamoto (KEK) are collaborating with Kyocera (Japan) on new insulator design.



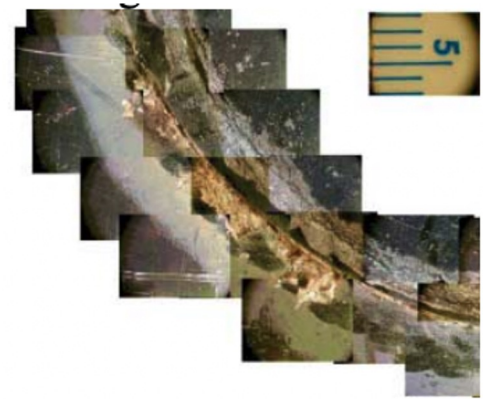
200 kV insulator for ILC/CEBAF

Topic 2: Solid Target Fatigue Studies

Targets for positron sources degrade over time. One particular area of concern is the boundary between the tungsten target and copper heatsink.

KEK will prepare W-Cu connection samples for testing at KEK and JLAB.

KEK will perform strain-stress and thermal-stress tests on the samples and analyze the results.



Degraded section of SLC positron target
V. Bharadwaj, et al. WPAH019 PAC 2001

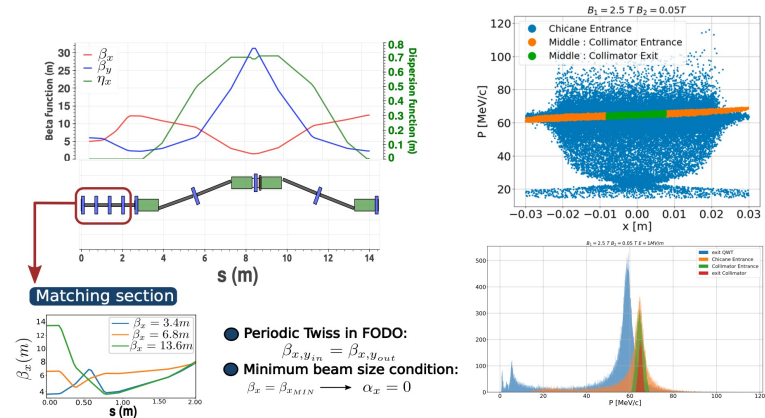
Topic 3: Positron Source Beam Dynamics

Start-to-end simulations are critical for optimizing positron source performance. We need accurate estimates of positron yield and beam parameters such as emittance.

Start-to-end simulations involved many components and codes (CST, GPT, Elegant, etc).

Andriy Ushakov (JLAB) will use models provided by KEK of SuperKEKB and ILC sources for CST and beam dynamics calculations. The results of these simulations will be validated against KEK results. Next, these tools and simulations will be used to design and optimize the JLAB positron source.

Beam size optimization



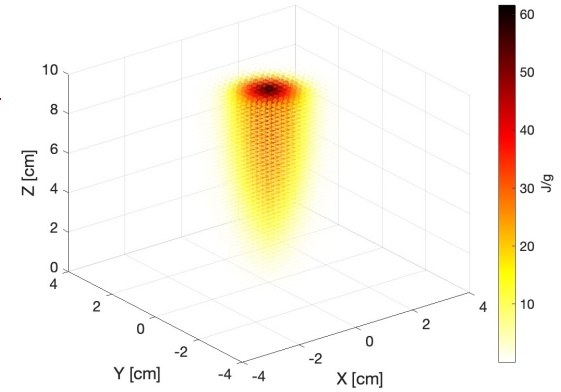
Sami Habet: Optimization of CW Polarized Positron Source for JLAB, LCWS2023

Topic 4: Liquid Xenon Target Modeling

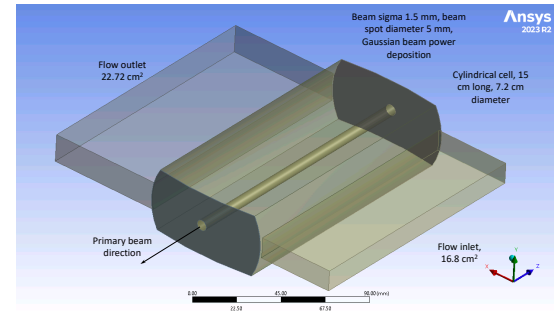
In 2022, we began to study a new concept for a positron target: liquid xenon (LXe).

The LXe target does not degrade over time, and it offers decent yield because it is a dense, high-Z material. Moreover, it is **non-toxic!**

With Silviu Covrig Dusa (JLAB), we will perform CFD studies using ANSYS Fluent to better understand the feasibility of this concept (e.g. What is the required flow rate for LXe? Will the windows survive?)



G4Beamline simulation of energy deposition in LXe.



3D model used for ANSYS Fluent CFD simulation.

Looking Ahead

- We are pleased to be awarded this Cooperation Grant for a timeline of 1 year (August 2023 – July 2024).
- The grant reviewers encouraged us to apply again for funding in 2024 with more focused R&D.
- **Goal for coming months:**
 - Determine which avenues of study will have the highest impact and develop a “more focused” proposal based on those concepts.

Tasks and Work Packages

400 kV inverted insulator development compatible with commercial high voltage cable

FY 2024 tasks:

- Q1
 - Present high voltage inverted geometry insulator R&D as invited speaker at the 14th International Vacuum Electron Sources Conference: IVESC2023, Tsukuba, Japan September 25-29, 2023.
 - Meet with KEK high voltage gun team, and with Kyocera engineers to discuss design and development of insulator (Meeting arranged for Sept 8 by Masahiro Yamamoto, KEK).
 - Perform initial insulator electrostatic design using CST FEA modeling software.
- Q2
 - Finalize insulator electrostatic design iterating with triple point junction shield electrostatic design to linearize potential along insulator while keeping the maximum gradient below 10 MV/m at 500 kV.
- Q3
 - Develop insulator engineering design iterating with electrostatic design.
- Q4
 - Finalize insulator engineering design package iterating with ME designers.

e⁺ Beam Dynamics Simulations

FY 2024 tasks:

- Q1
 - Calculations of magnetic fields in SuperKEK/ILC electron-driven positron source using CST Studio Suite
 - Tracking positron beam in magnetic field of e⁺ source (CST)
- Q2
 - Calculations of RF fields in capture accelerator of SuperKEK/ILC positron source (CST)
 - Tracking of positron beam in capture accelerator (CST)
 - Adding model of e⁺ capture section to General Particle Tracer (GPT)
- Q3
 - Beam tracking using GPT
 - Comparison of beam tracking results in CST and GPT
- Q4
 - Simulations of beam dynamics in the JLab e⁺ injector based on experience of modeling SuperKEKB/ILC e⁺ injector

- 400 kV polarized electron source
 - Support JLAB's development on HV insulator
 - JLAB want to compare insulator made by Japanese and US company
 - Contact Kyocera and develop prototype
- Solid target fatigue studies
 - Prepare W-Cu connection samples
 - Send part of them to JLAB
 - Strain-stress test and thermal test in Japan
 - Share test results in Japan and US
- Electron and positron injector beam dynamics
 - Support simulation at JLAB
 - Provide geometry and other settings
 - Share CST file and know-how

SLAC Tasks – 2023/2024

- Q1: Highly-resolved simulation of energy deposition in liquid xenon target using G4Beamline code.
 - Send results to Silviu Covrig Dusa (JLAB) for ANSYS Fluent CFD modeling.
- Q2: Prepare new grant proposal for FY2024 US-Japan Call. Evaluation of window materials (aluminum, beryllium) and geometries using G4Beamline and ANSYS Fluent.
- Q3: Engineering design of target chamber.
 - Send 3D model to JLAB for incorporation into CFD model.
- Q4: Prepare publication summarizing findings.