

Polarized Source Development for the Chiral Belle Upgrade at SuperKEKB

Alexandre Beaubien, PhD candidate

University of Victoria

The Belle II collaboration

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University
of Victoria



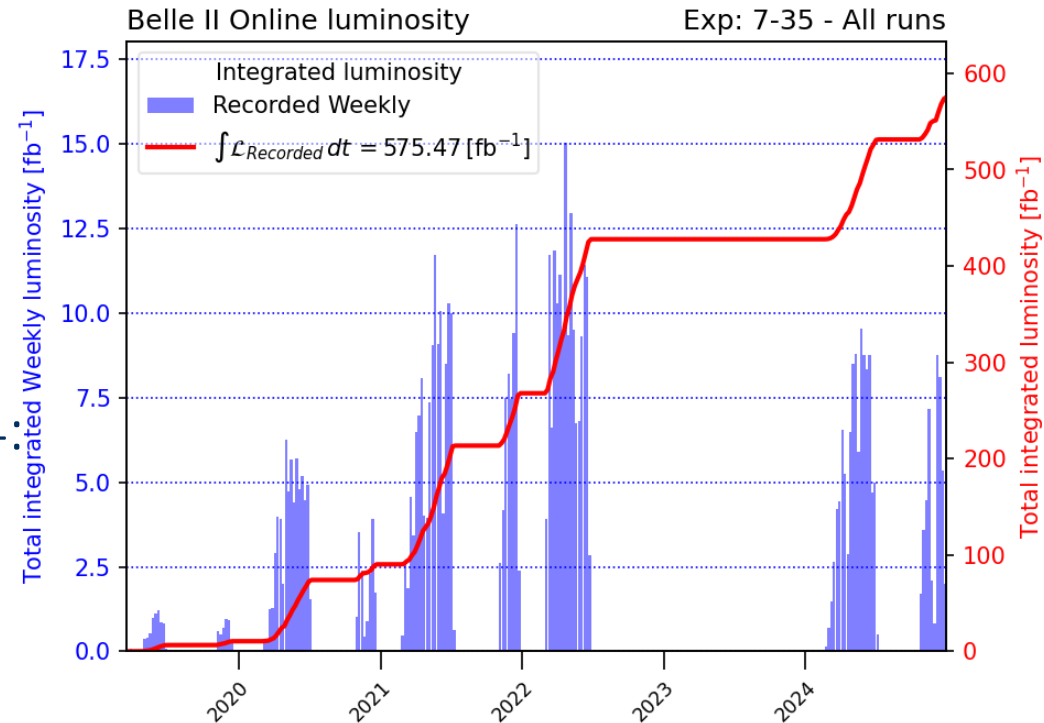
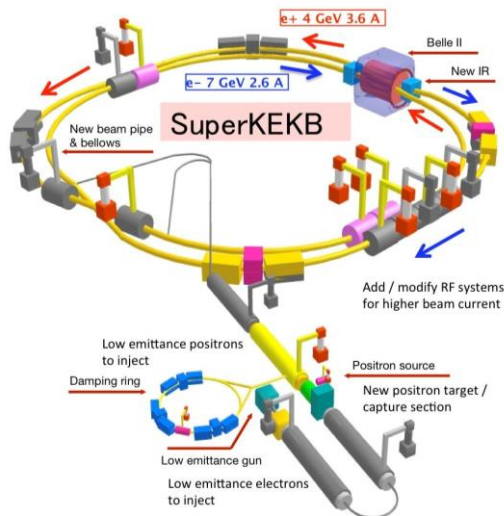
SuperKEKB



SuperKEKB e^+e^- collider,
 $\sqrt{s} = 10.58 \text{ GeV}$ energy

Highest **luminosity** record
 since 2020

Broke the record again in 2024:
 $5.1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$!



Process	σ	N [10^6]
$e^+e^- \rightarrow \tau^+\tau^-$	0.919	528.86
$e^+e^- \rightarrow c\bar{c}$	1.329	764.80
$e^+e^- \rightarrow B\bar{B}$	1.05	536.21*

Chiral Belle Upgrade to SuperKEKB



Get more Physics out of Belle II by *polarizing* the *electron beam*

Increases sensitivity to many measurements

e.g.: world leading measurements *tau g-2*, *tau Michel parameters*, *neutral current couplings* and *running of weak mixing angle*

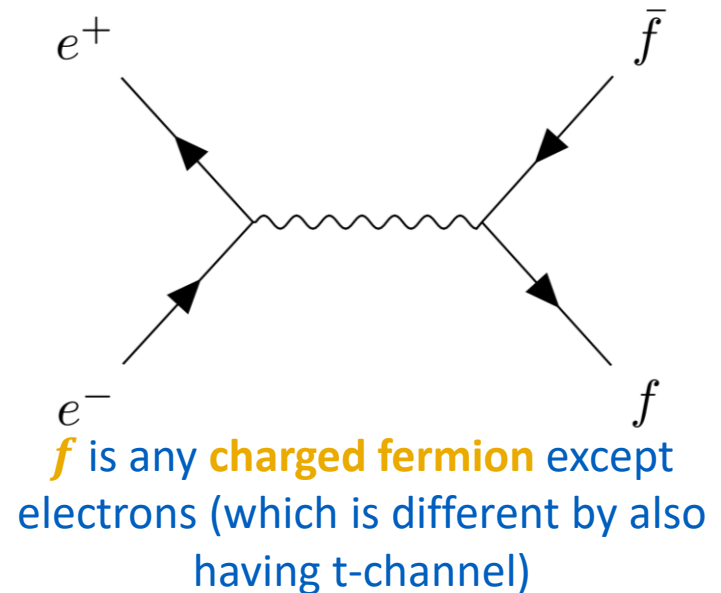
See *Savino Longo's Chiral Belle talk* for in depth description!

$$\Lambda_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \propto \frac{sG_F}{\alpha} g_A^e g_V^f \langle P_e \rangle$$

For s-channel processes

$$\Lambda_{LR} \propto T_3^f - Q_f \sin^2 \theta_W$$

$$g_V^f = T_3^f - 2Q_f \sin^2 \theta_W \quad g_A^f = T_3^f$$



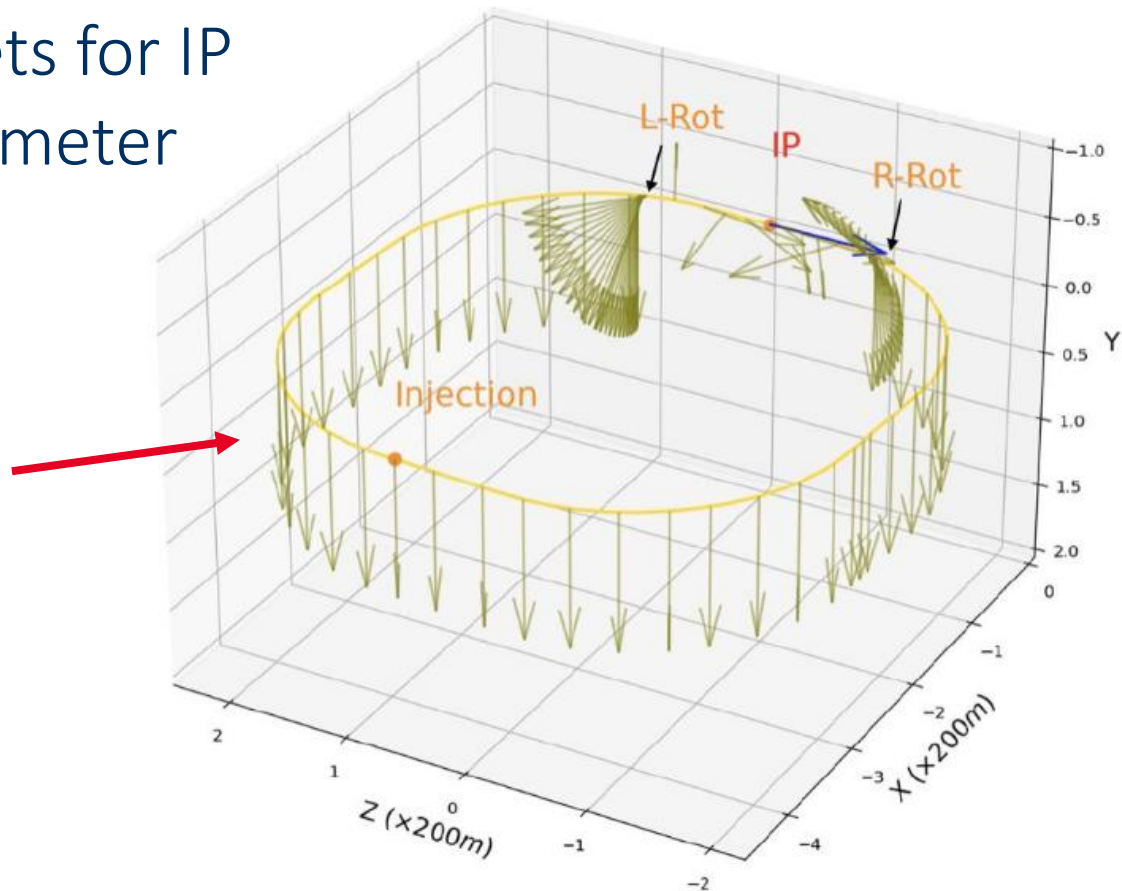
Chiral Belle Upgrade to SuperKEKB



Polarized beams require upgrading SuperKEKB with:

1. *Source for polarized electrons*
2. Rotation magnets for IP
3. Compton polarimeter

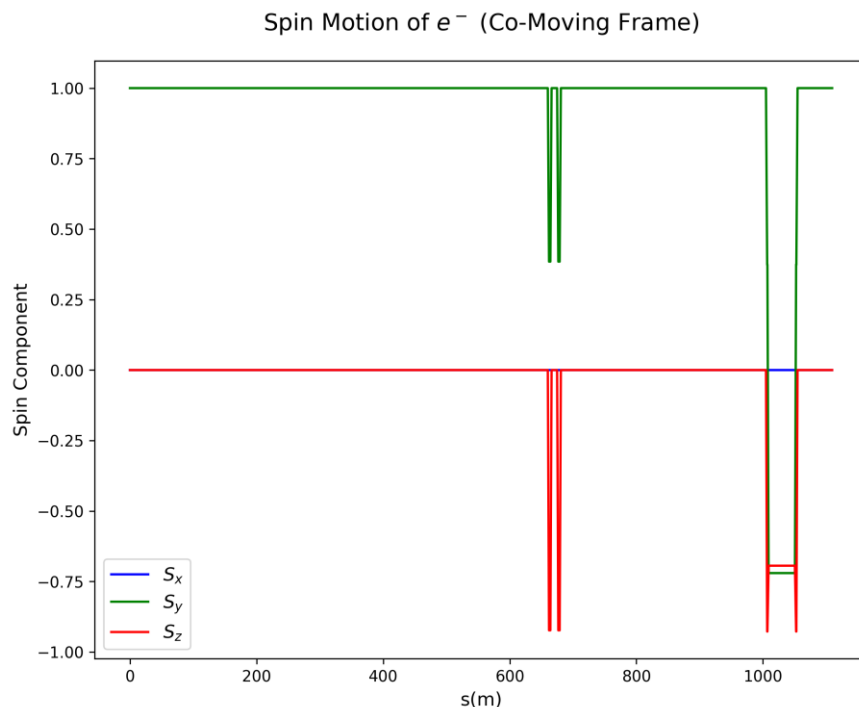
Transverse polarization is
the stable spin orientation
in storage ring



Beam Transportation Simulation

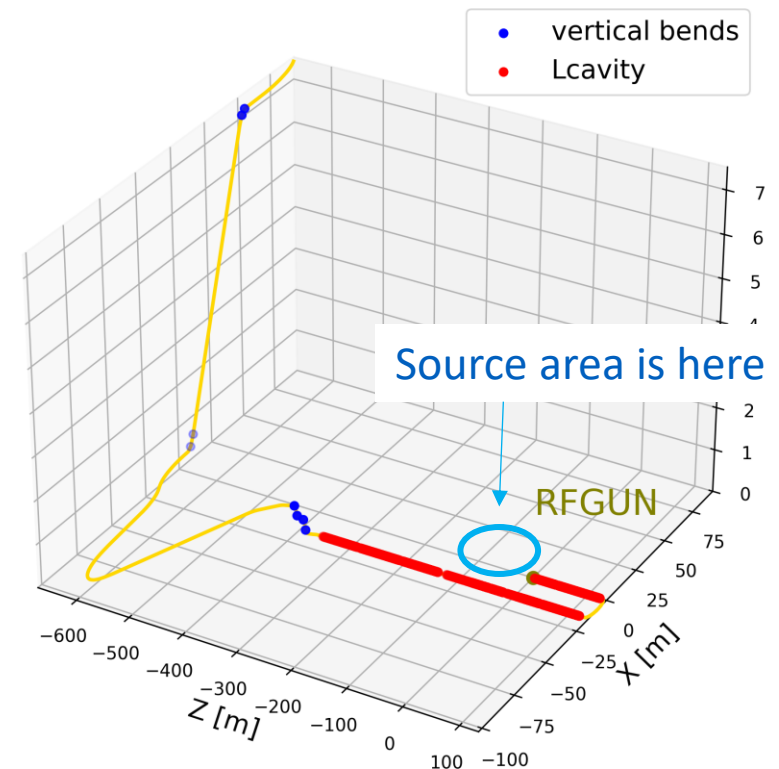


Simulations show that **transversally polarized** electrons injected into the Linac **maintain polarization** as it enters the High Energy Ring



Yuhao Peng, Univ. of Victoria

KEK Linac



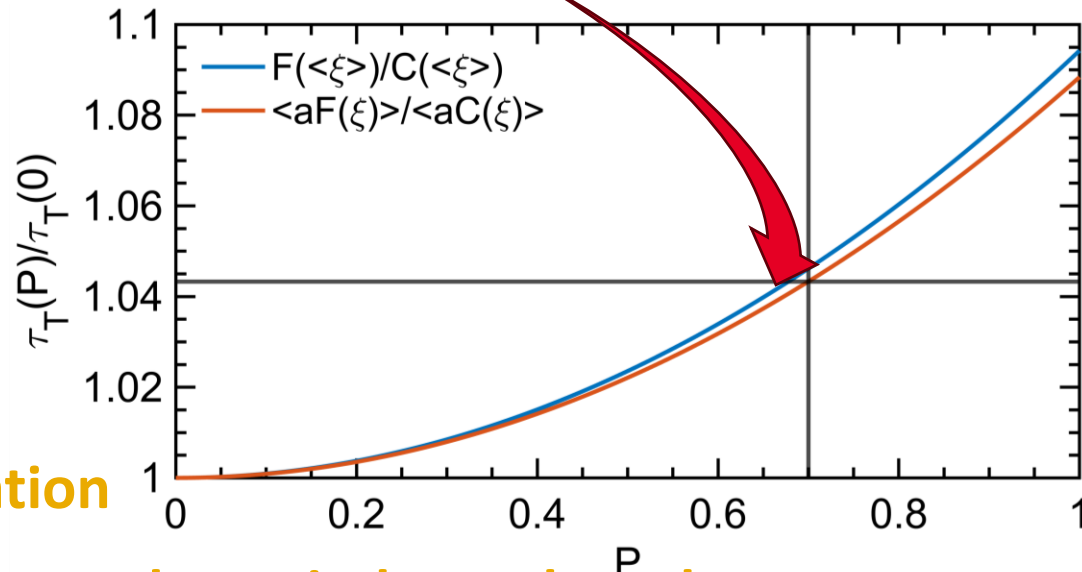


Proposed Touschek Lifetime Measurement: A First Step

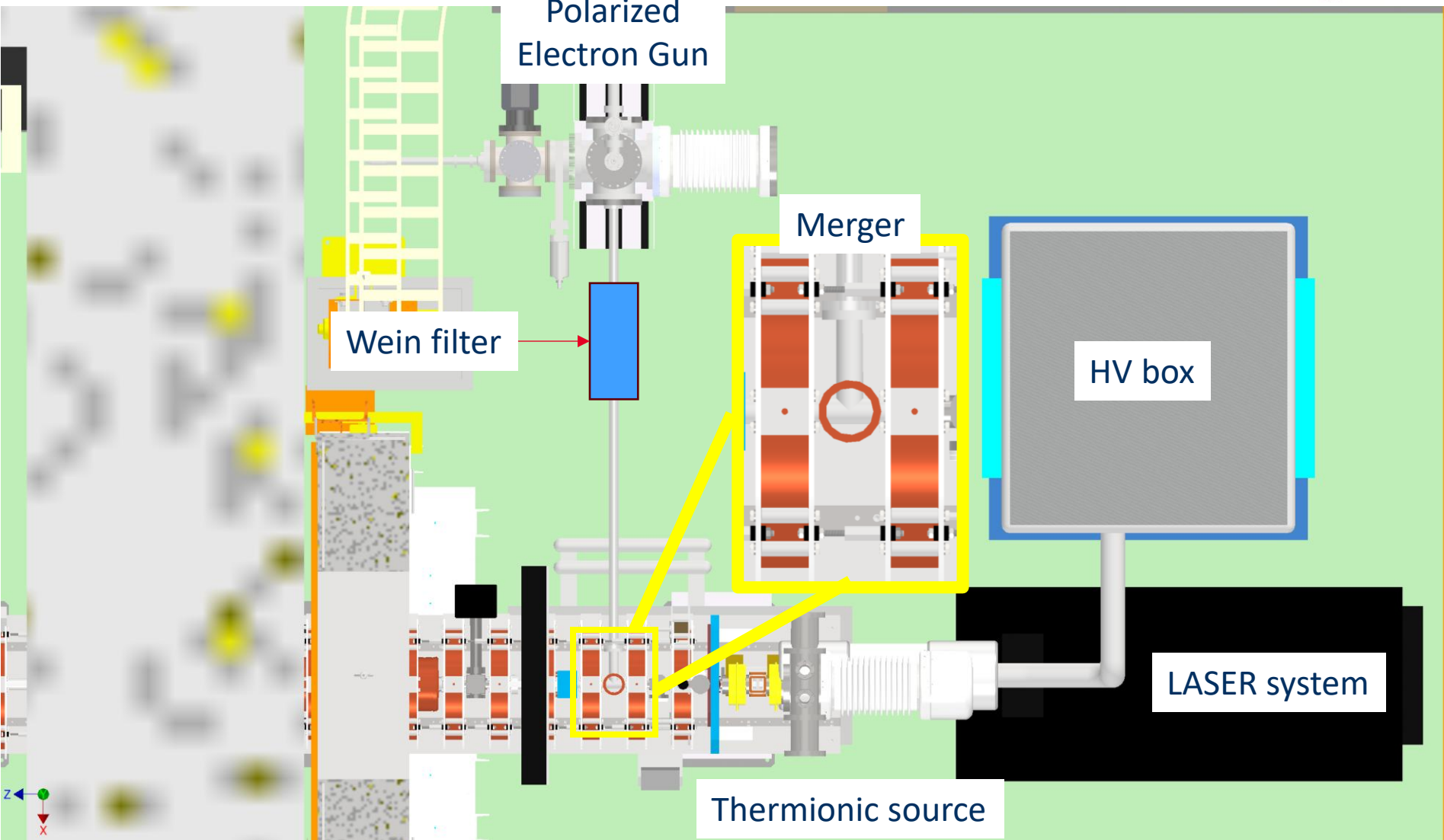
With **beam polarization** of **70%**, **Touschek lifetime** is expected to **increase by 4%**.

1 to 2 weeks
experiment

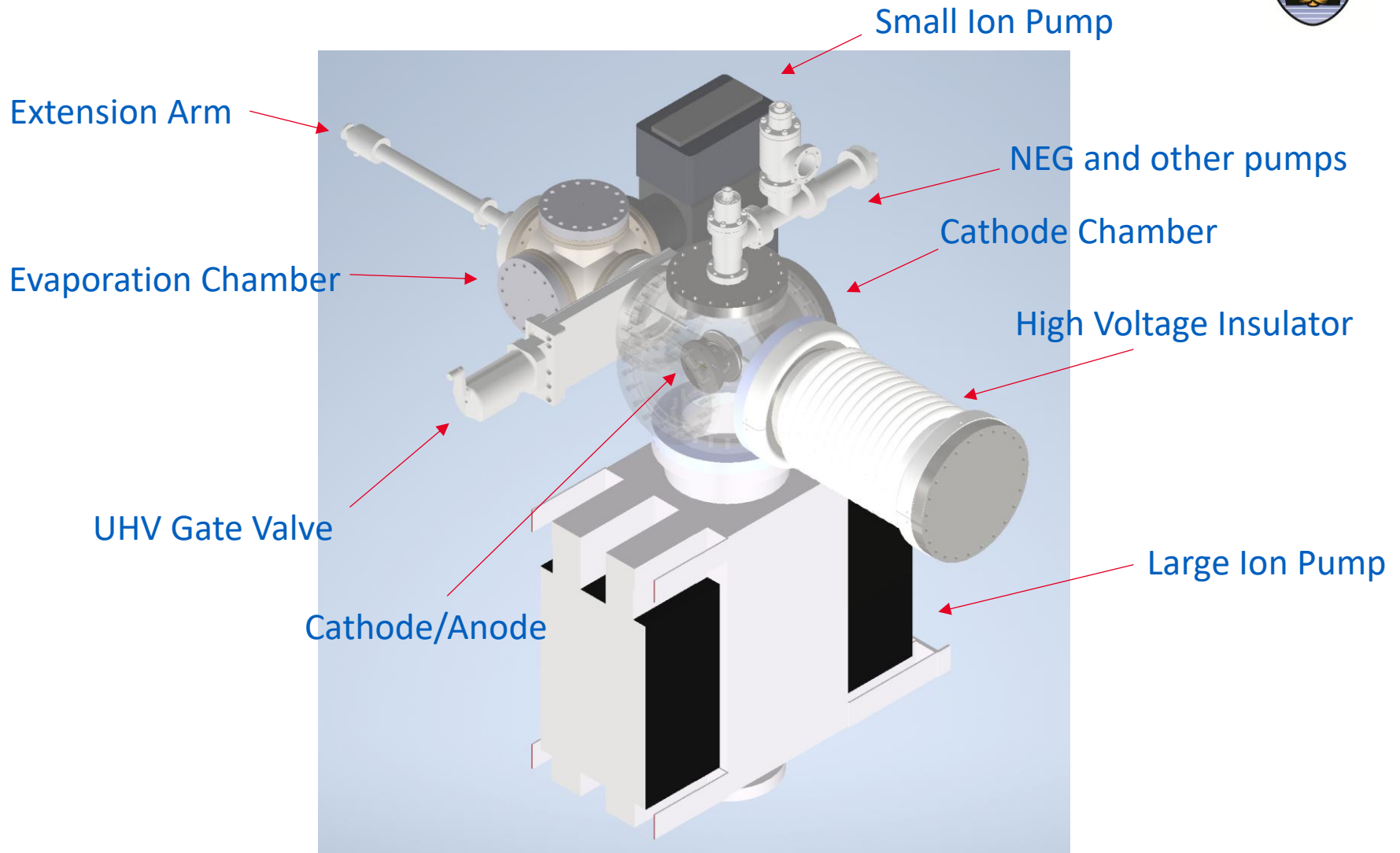
- Demonstrate the **feasibility** of the project
- Confirm **simulations** of polarized **beam transportation**
- Provide **valuable experience and new independent data** on **SuperKEKB** to precisely measure the beam energy, to improve our modelling of the accelerator, possibly help with getting to higher luminosity



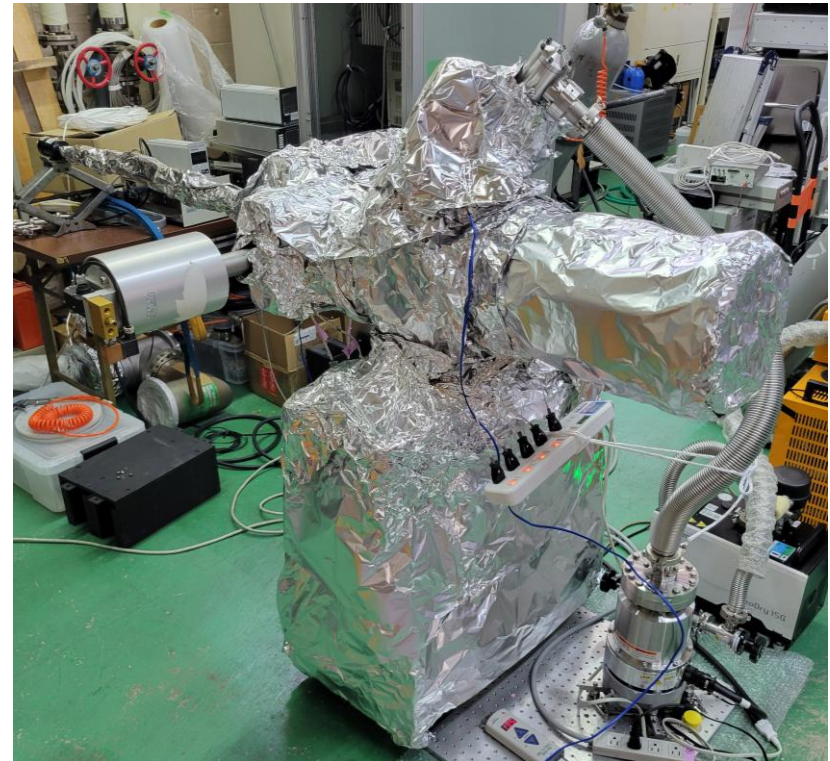
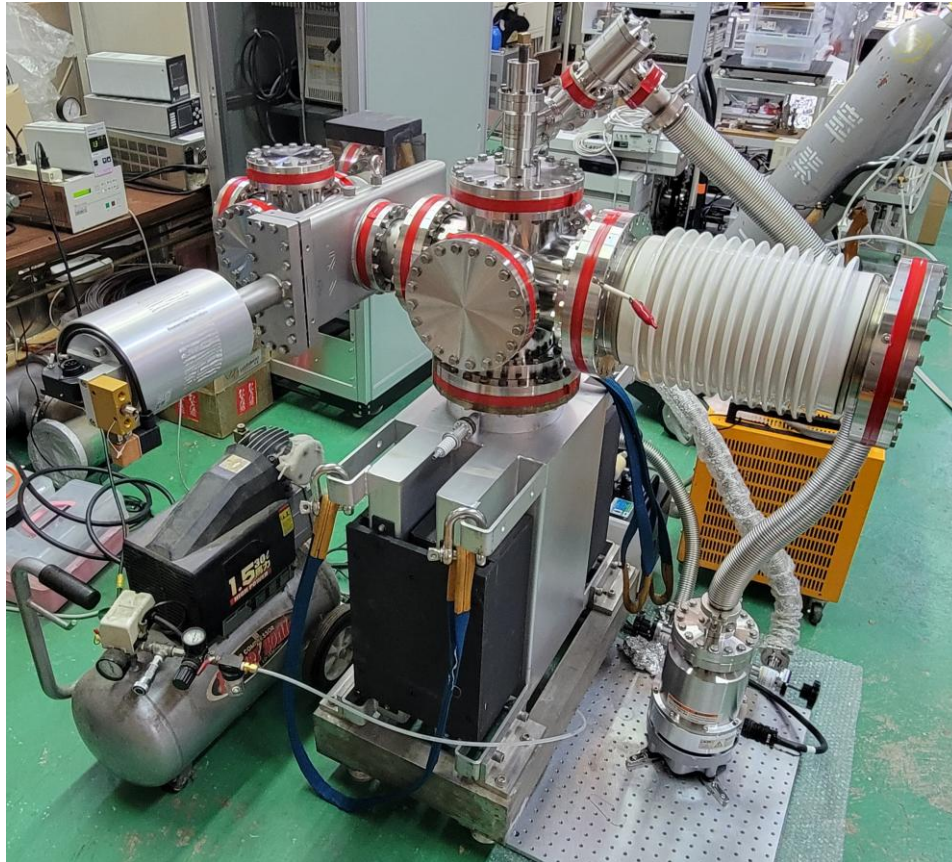
Conceptual Design



Polarized Electron Gun



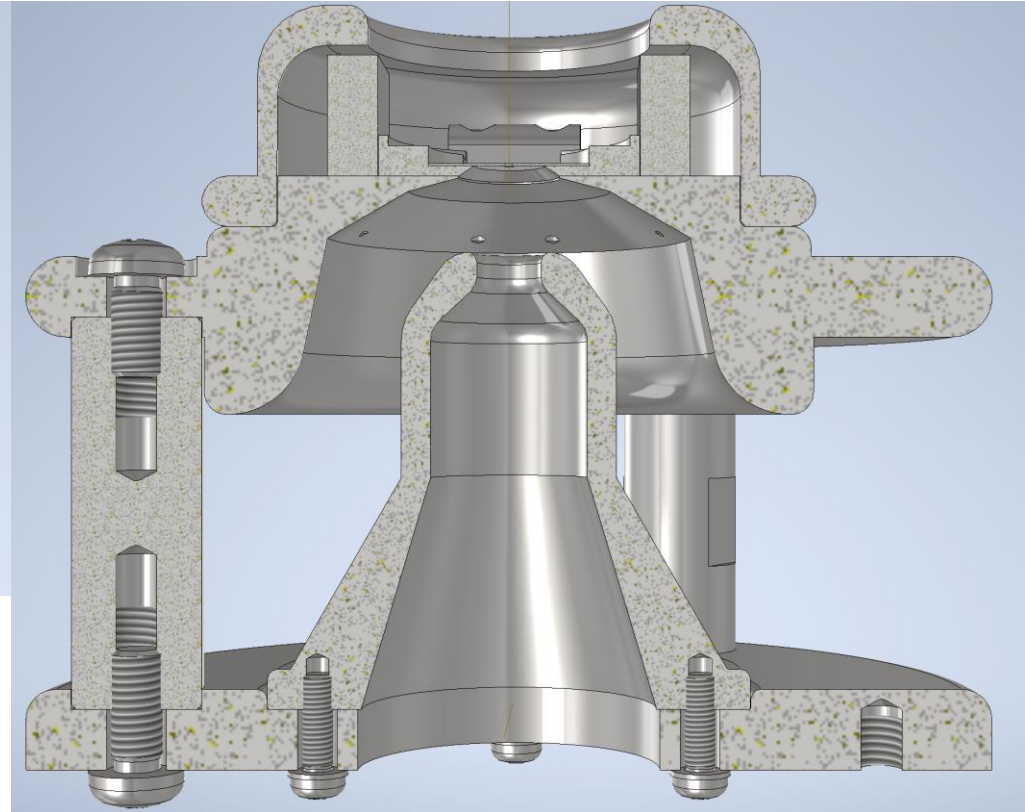
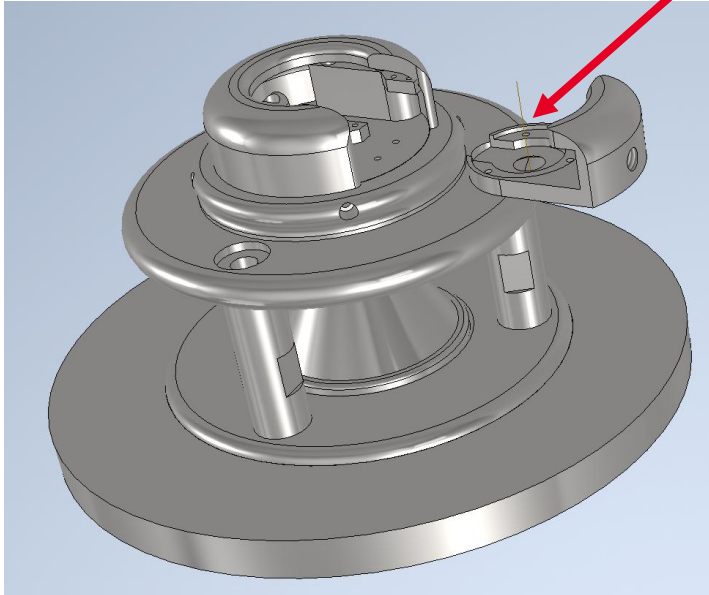
Building Vacuum Chamber & Baking



Cathode & Anode



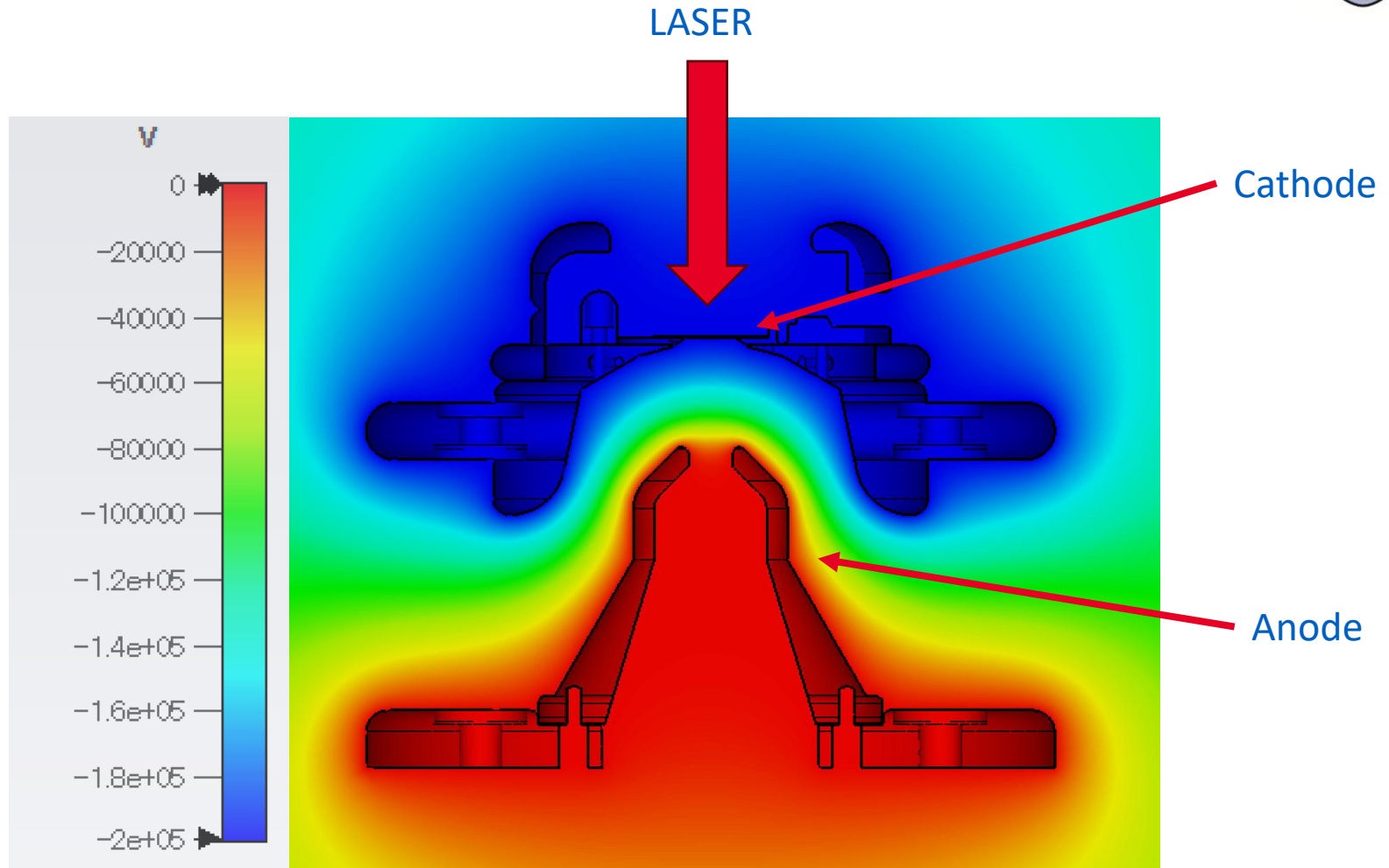
Cathode goes here



Use **p-doped GaAs** strained compensated superlattice cathode with CsO surface

Adapted from a design by N. Yamamoto;
Redesigned in part for low emittance at
200keV using Inventor

Acceleration Potential

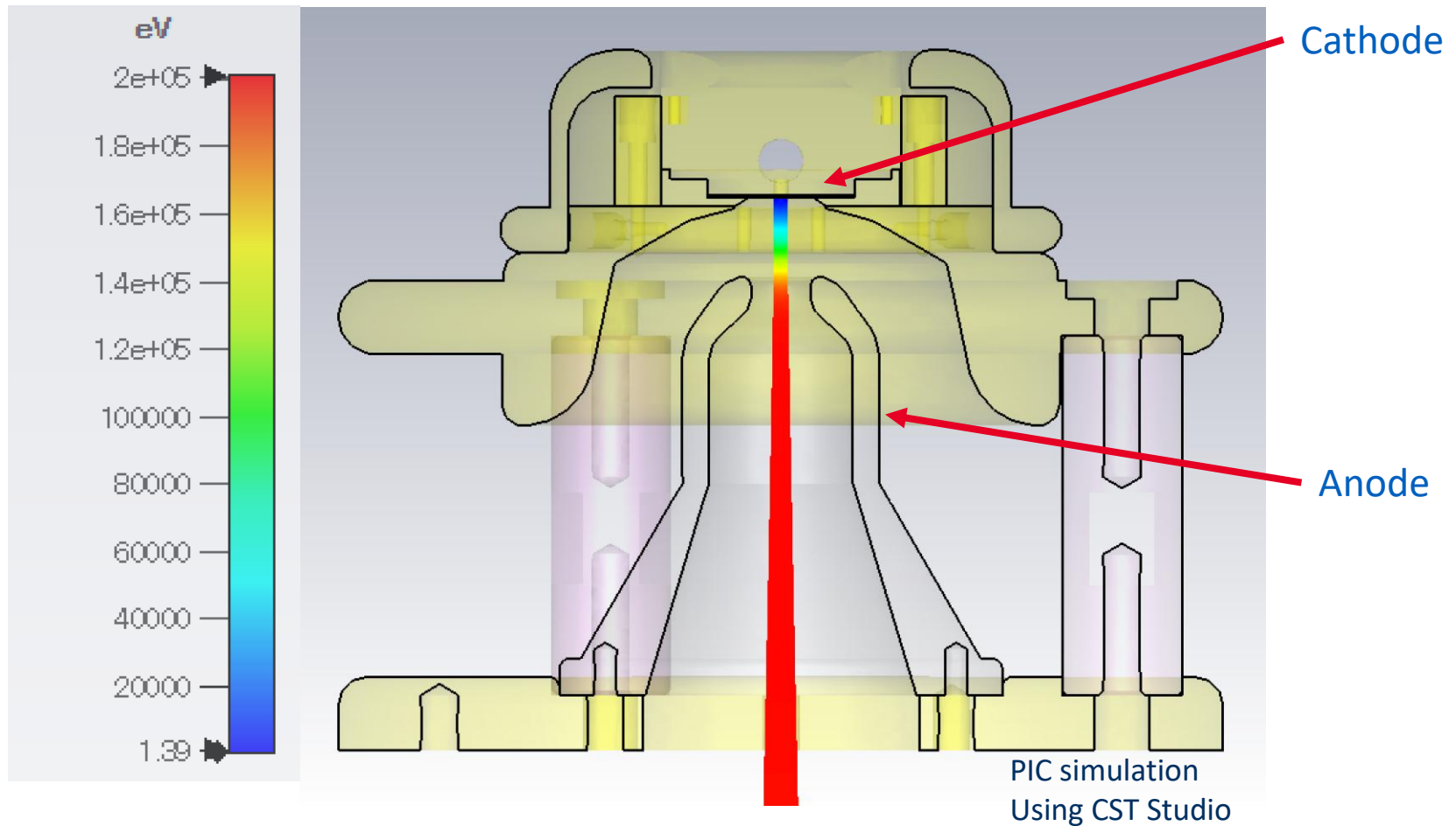


PIC simulation
Using CST Studio

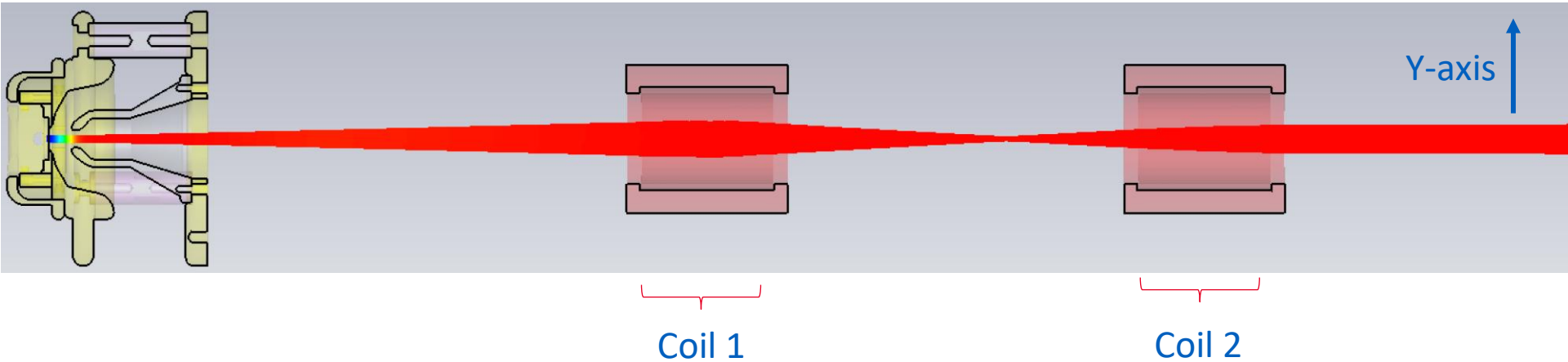
Beam trajectory



Anode geometry provides **lowest beam emittance**



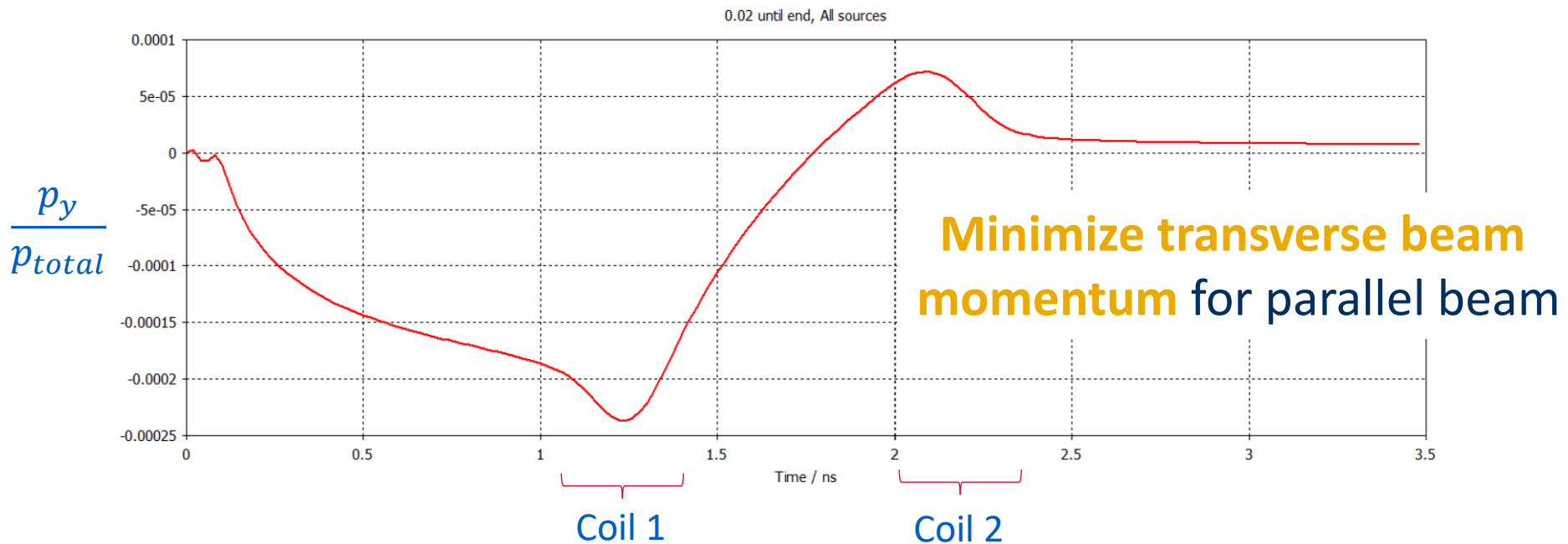
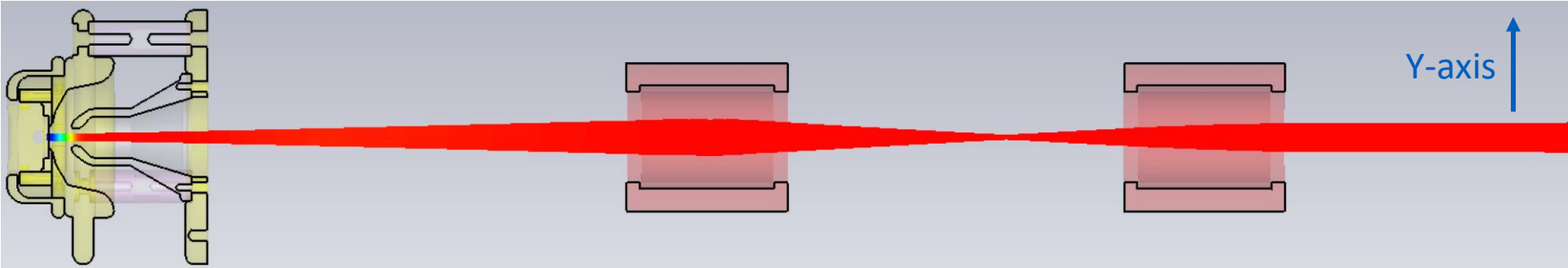
Focusing Magnet



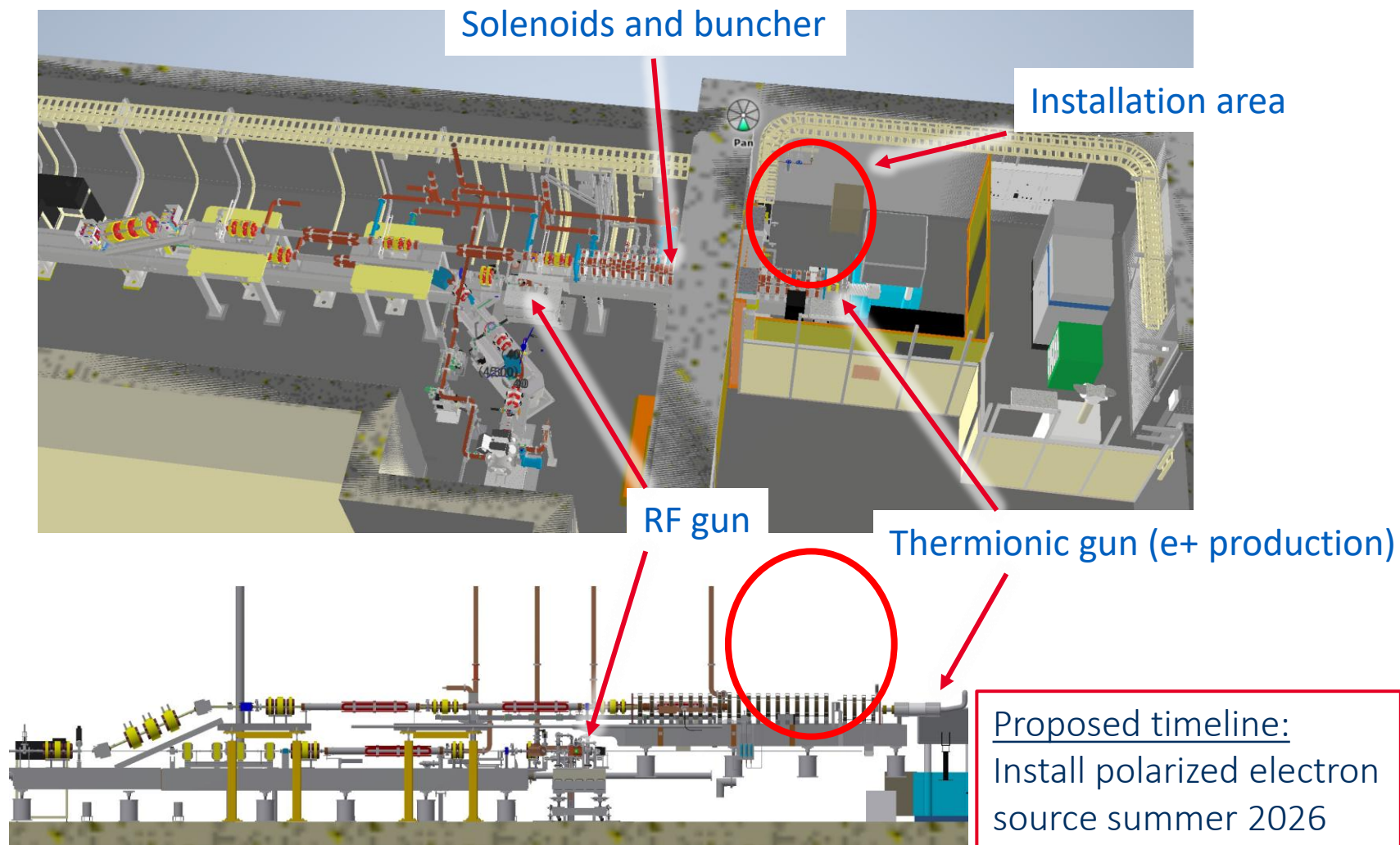
Create **parallel beam** for **long distance transportation** using **focusing magnets (coil with iron yoke)**

- **~ 325 Gauss*cm integrated B-field** per coil

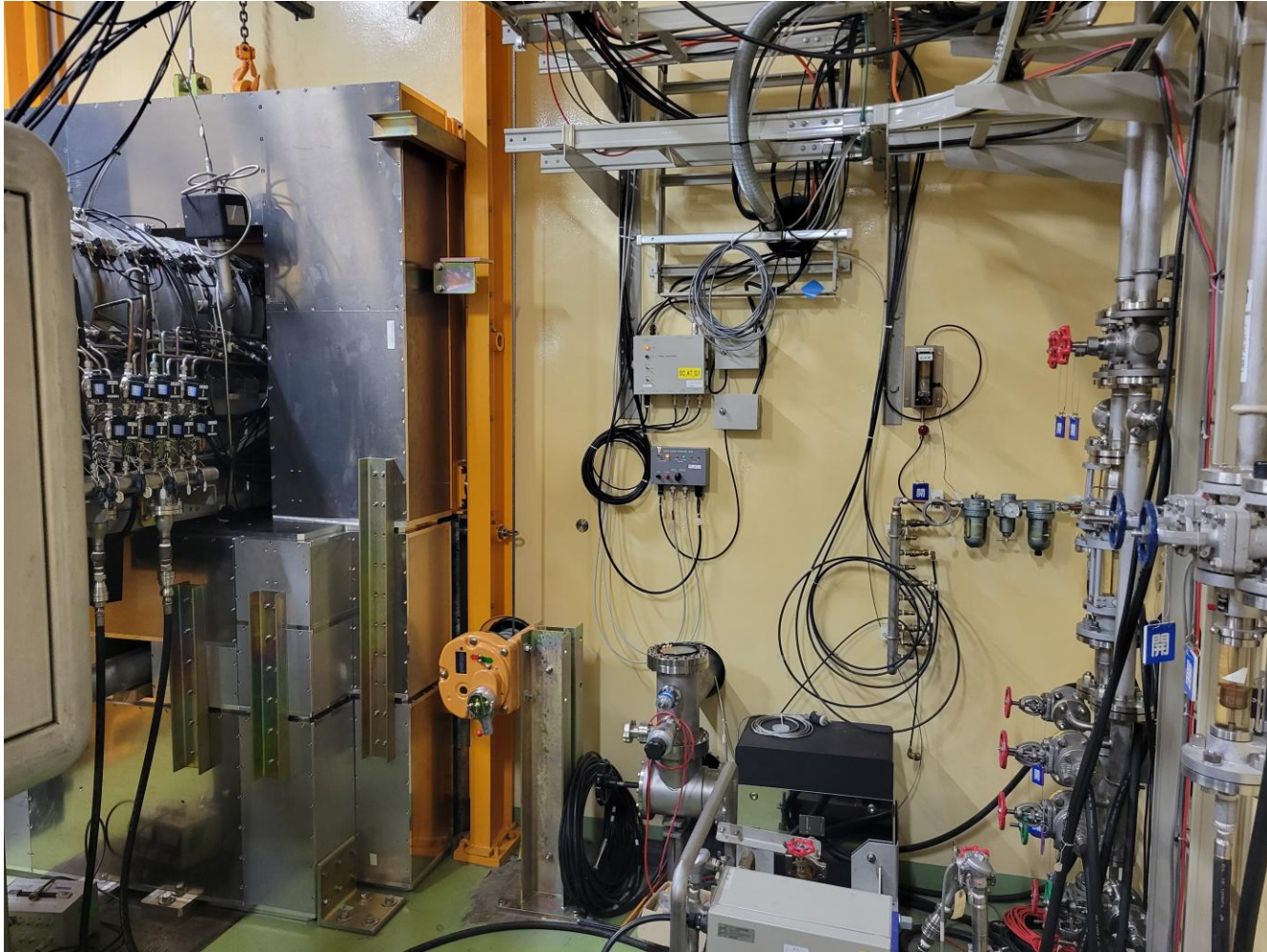
Focusing Magnet



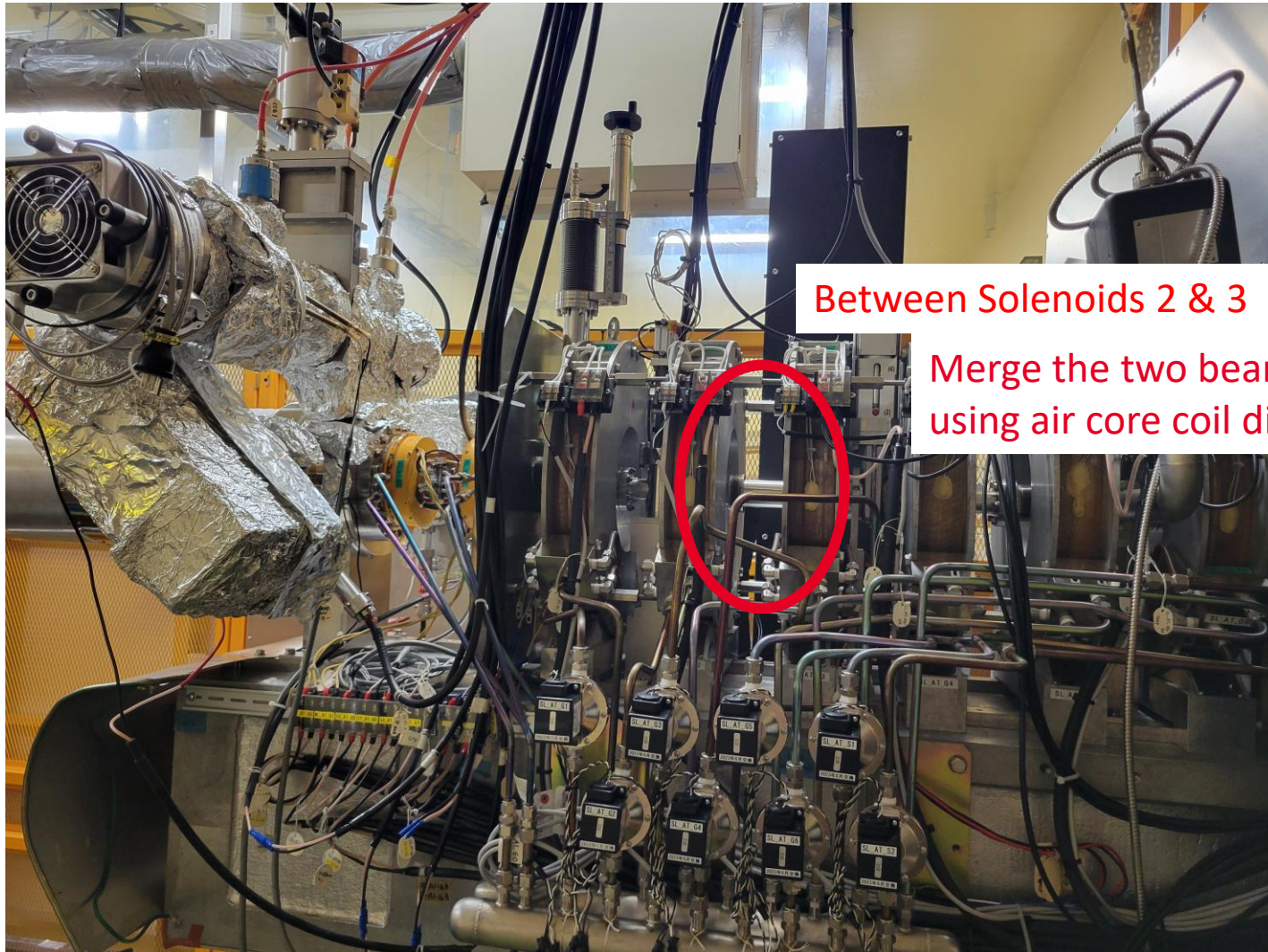
Source Room Available Area



Source Room



Merge Location



Between Solenoids 2 & 3

Merge the two beams
using air core coil dipole

Summary



1. Chiral Belle upgrade to SuperKEKB provides rich Physics program by polarizing electrons in High Energy Ring
2. Low emittance, transversally polarized electron source being developed in collaboration with KEK through KEK-TRIUMF Exchange program for early career researcher (EPECR)
3. Chamber and cathode/anode currently in construction
4. Final assembly and in-lab testing to be finished during summer 2025
5. Installation into the source area during summer 2026 (pending approval) – perform Touschek Lifetime measurement end of 2026

Backup



The Belle II Detector



General-purpose detector — Built like an onion around **interaction point (IP)**

7 sub-detectors

Also, a 1.5T magnet!

Particle
Position
& Tracks

Pixel Detector (PXD)

Silicon Vertex Detector (SVD)

Central Drift Chamber (CDC)

Particle
Type

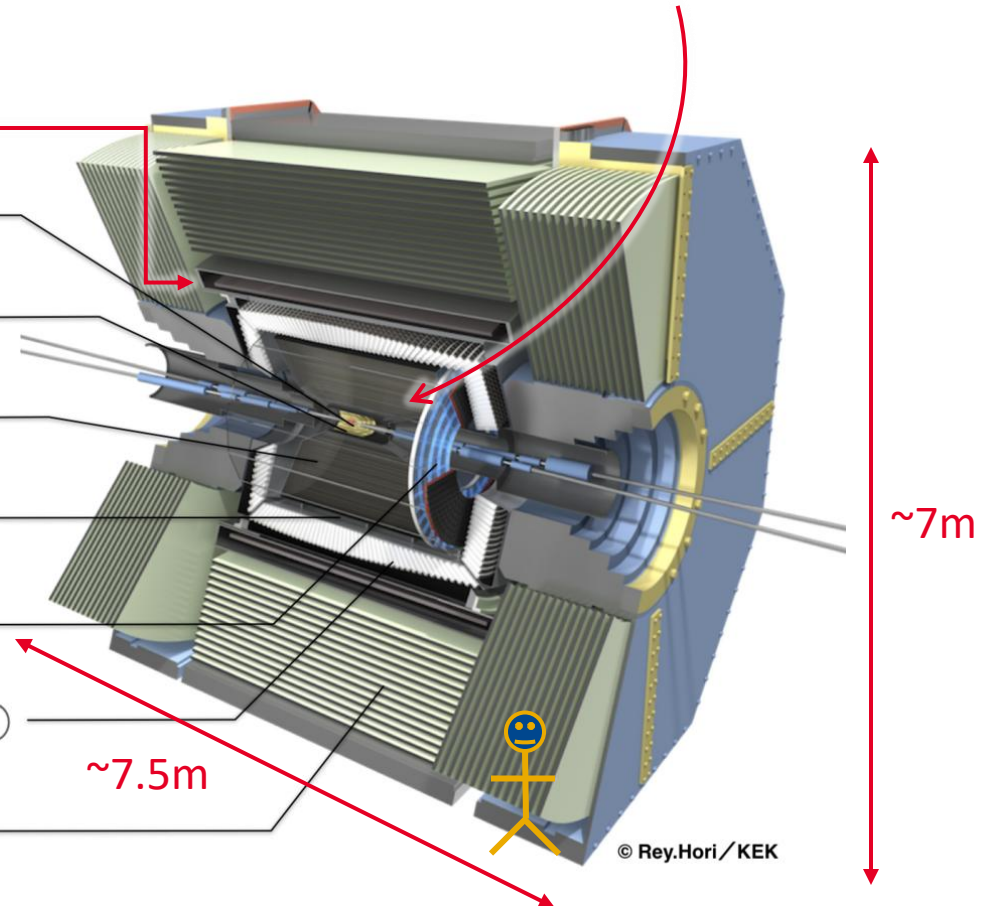
TOP counter (TOP)

Aerogel RICH counter (ARICH)

Particle
Energy

Electromagnetic Calorimeter (ECL)

K_L^0 /Muon Detector (KLM)



Conceptual Design of the Gun



Evaporation Chamber

Activation $\sim 10^{-9}$ Pa

Cathode Chamber

Gun $\sim 10^{-10}$ Pa

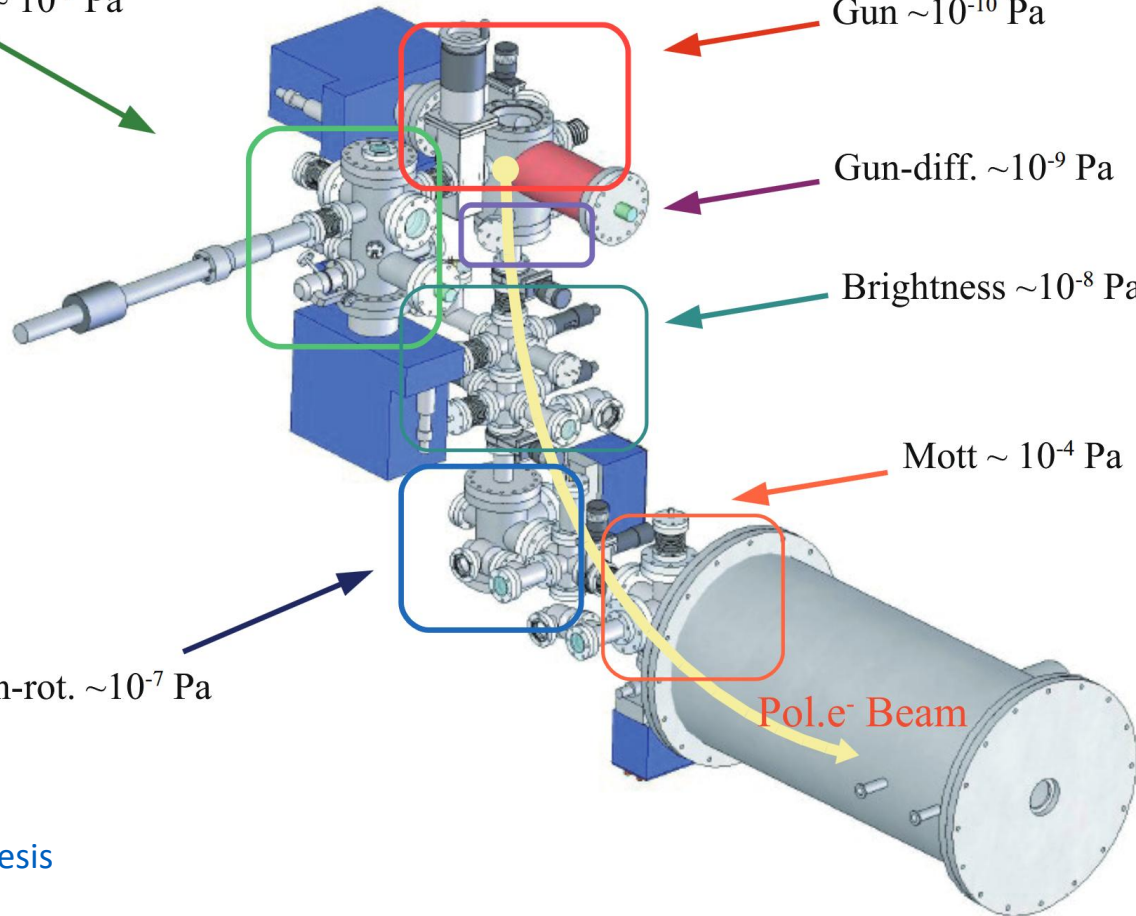
Gun-diff. $\sim 10^{-9}$ Pa

Brightness $\sim 10^{-8}$ Pa

Mott $\sim 10^{-4}$ Pa

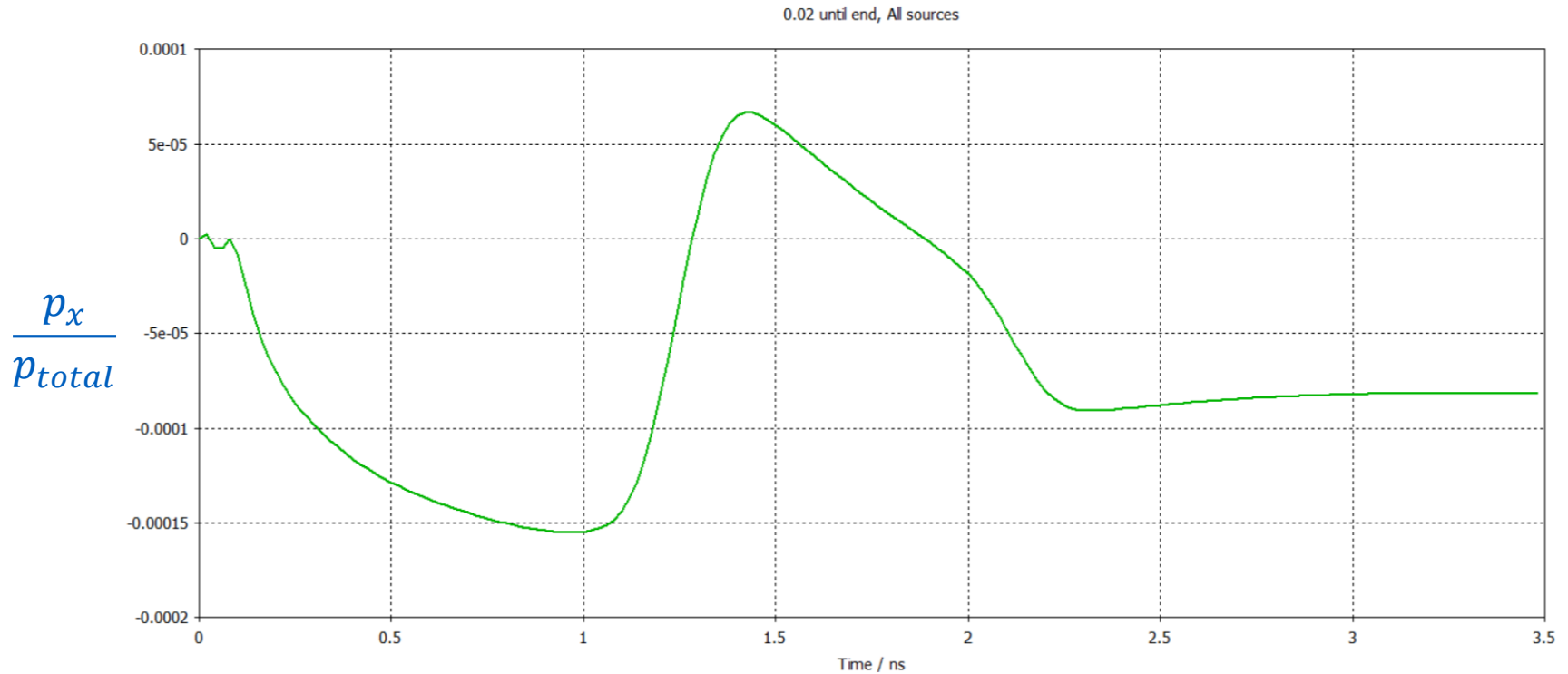
Spin-rot. $\sim 10^{-7}$ Pa

Pol.e⁻ Beam

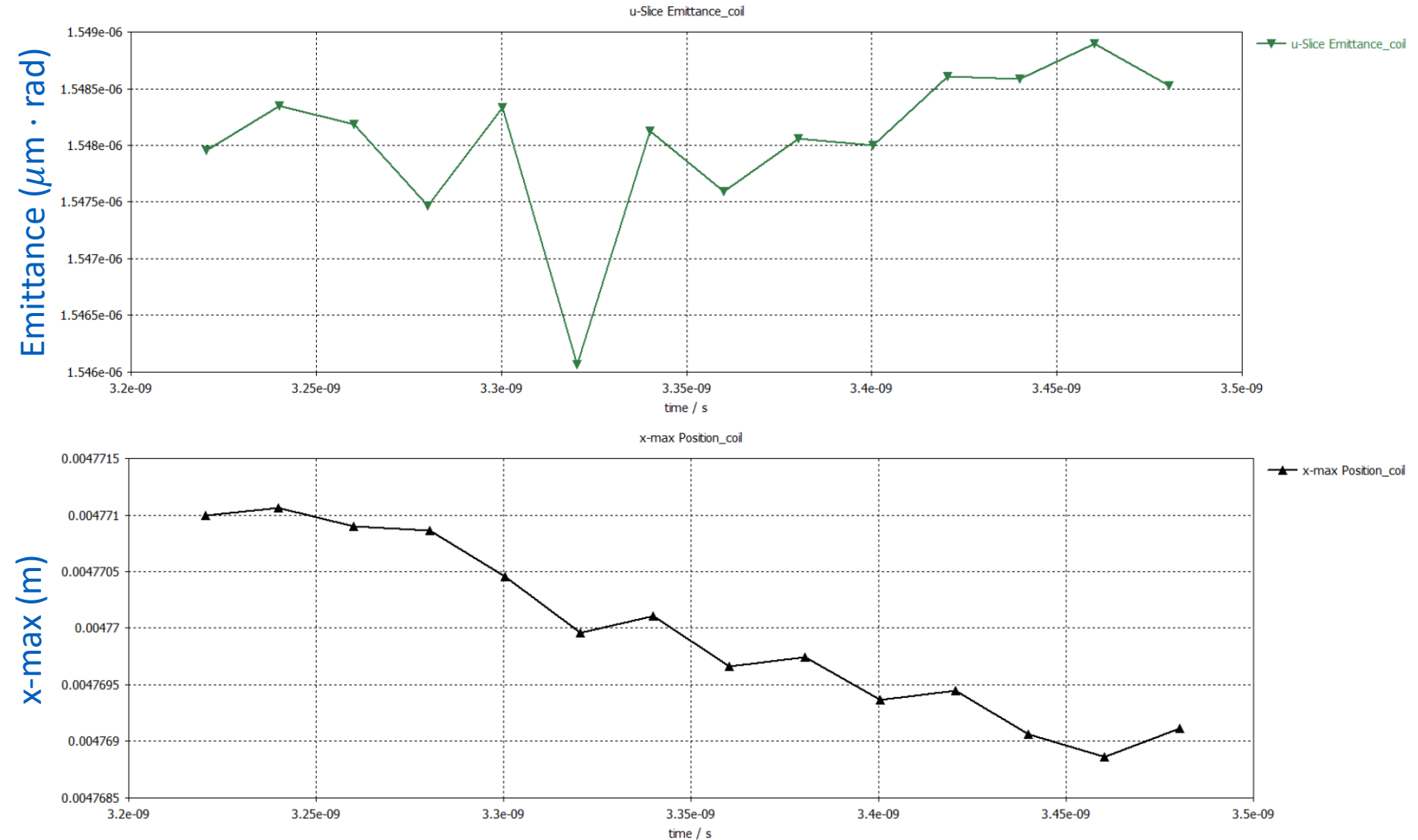


N. Yamamoto, PhD Thesis

Momentum x



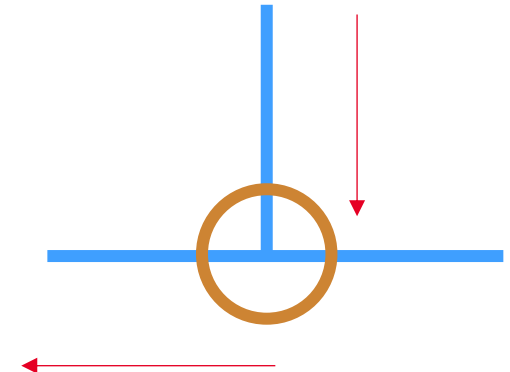
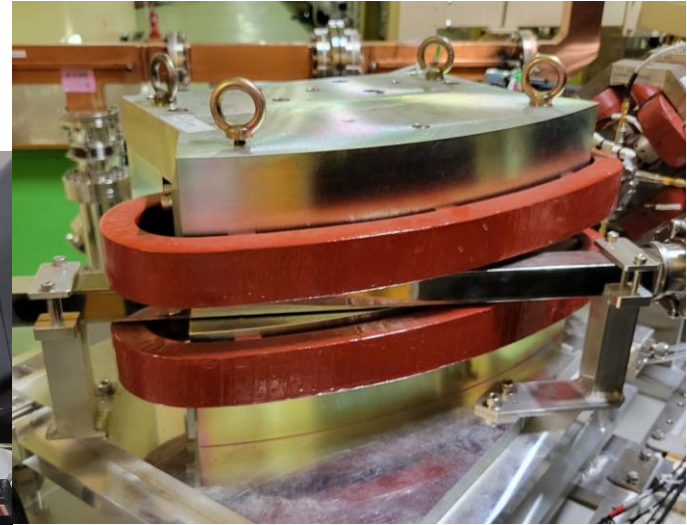
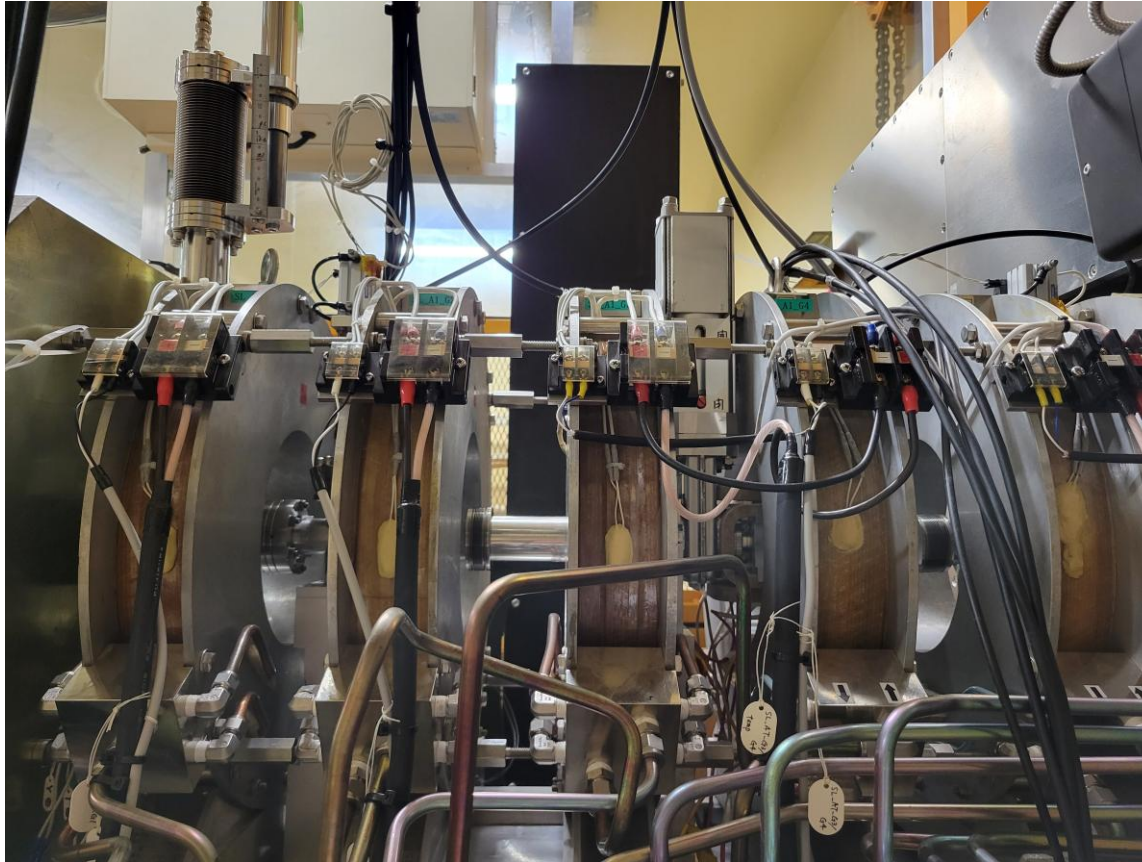
Simulation Results



RF Gun Area



Dipole Magnet



Spin Polarization Considerations



GaAs creates **longitudinally polarized** electrons.

Use **Wein filter** to obtain **transversally polarized** electrons.

