

Measurement of Anti-Matter Reaction in LArTPC using Accelerator Beam for GRAMS Experiment

Hinako Taniguchi(Waseda University)

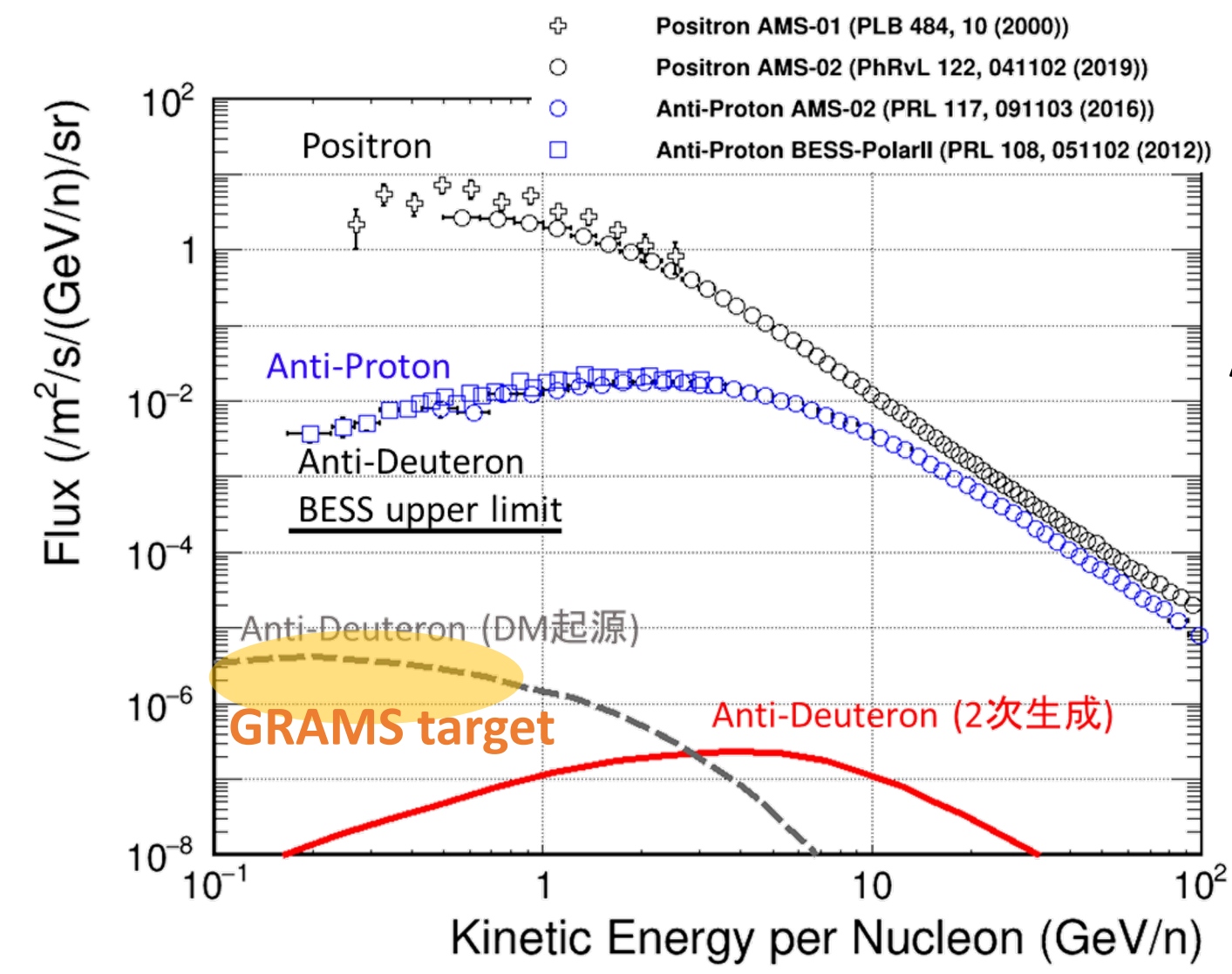


GRAMS (Gamma-Ray and AntiMatter survey)

Observation experiment of cosmic ray antiparticles and MeV- γ rays using balloon-borne LArTPC @ 40 km above Antarctica

Two physical targets

- ✓ Anti matter search (Anti-Proton/Deuteron/Helium) → Indirect dark matter search
- ✓ MeV- γ ray from SNR/BH/neutron star/Galaxy Center observation → Elucidation of heavy element synthesis process

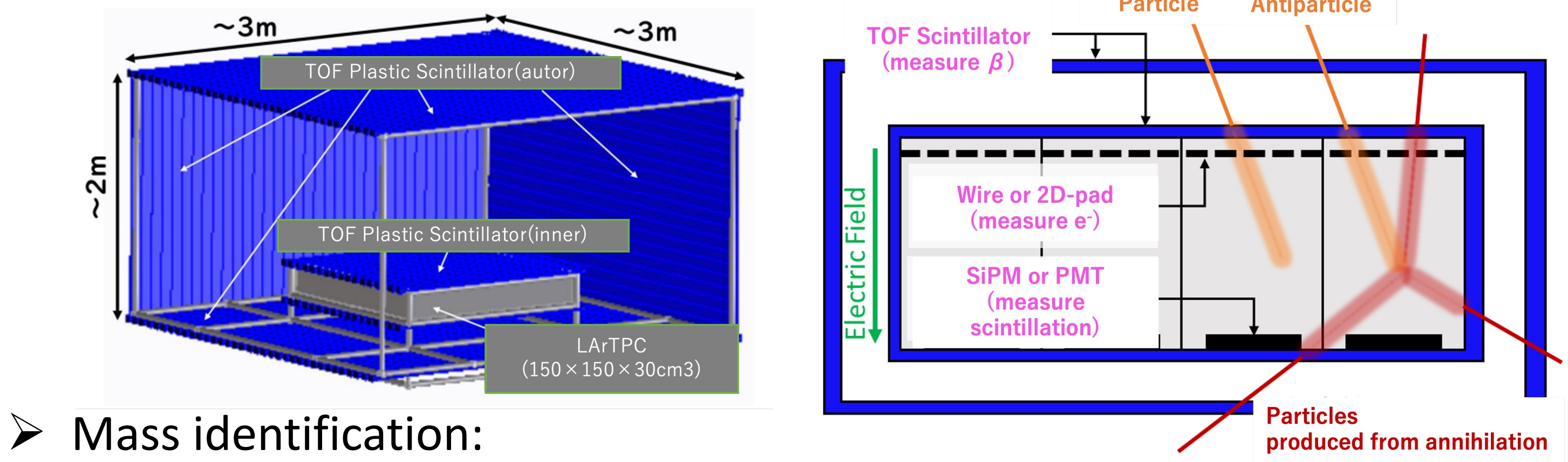


- Anti-particle Flux Positron/Anti-Proton Flux: Well known by other experiments
- Anti-Deuteron Flux: Not yet observed
- Secondary-induced fluxes are suppressed on the order of 10² at the low energy side
- ➔ If observed at low energy side, indirectly suggest DM!

Detection principle

- Two-layer TOFs ⇒ β measurement
- LArTPC = tracking calorimeter
- Electron signal: Anode pad ⇒ Two-dimensional position information
- Optical signal: PMT/SiPM ⇒ Drift time acquisition

Particle	Rigidity [MeV/n]	Momentum [MeV/c]
Anti proton	100-300	450-800
Anti deuteron	100-300	900-1600

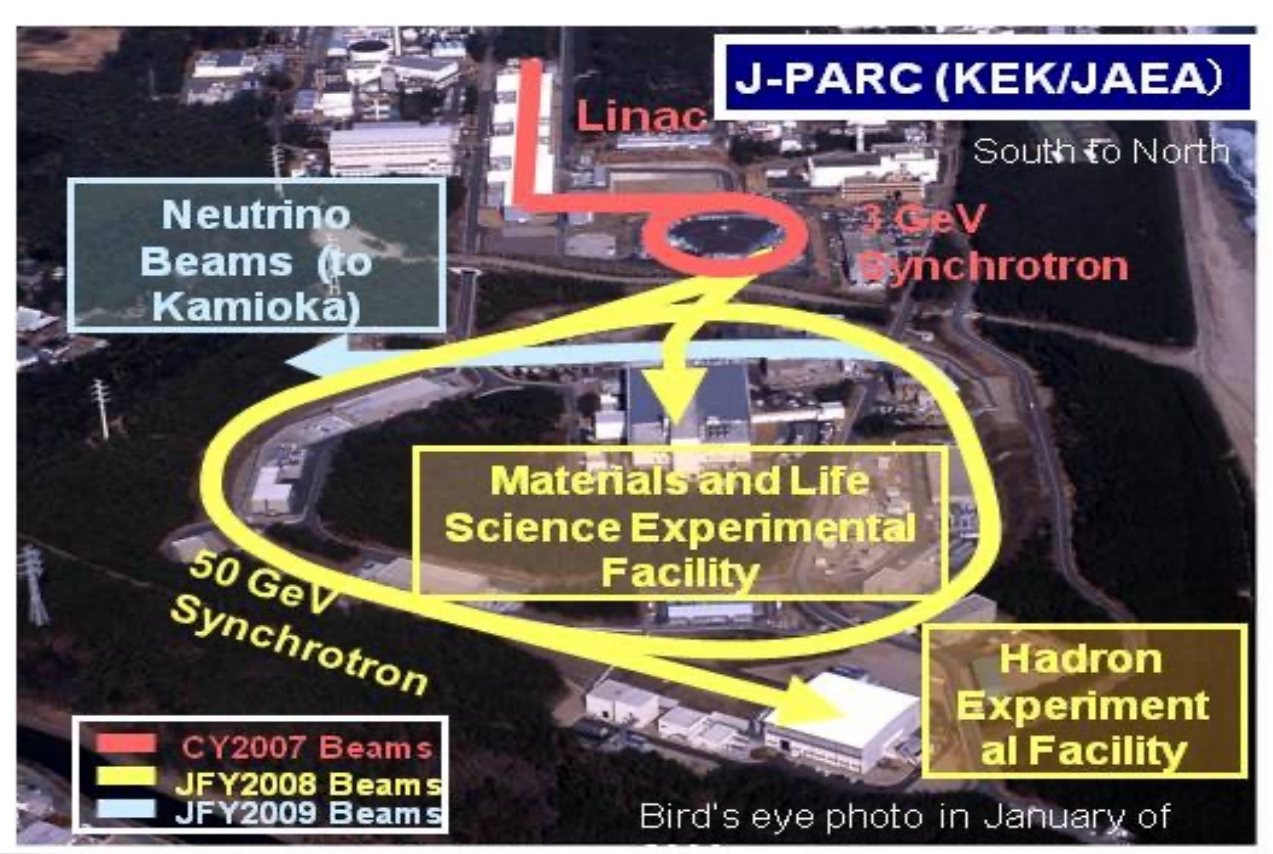


- Mass identification: At the same velocity β , the dE/dX and track length vary with mass
- Charge identification: Antiparticles are nucleus-captured and emit hadrons (mainly π)

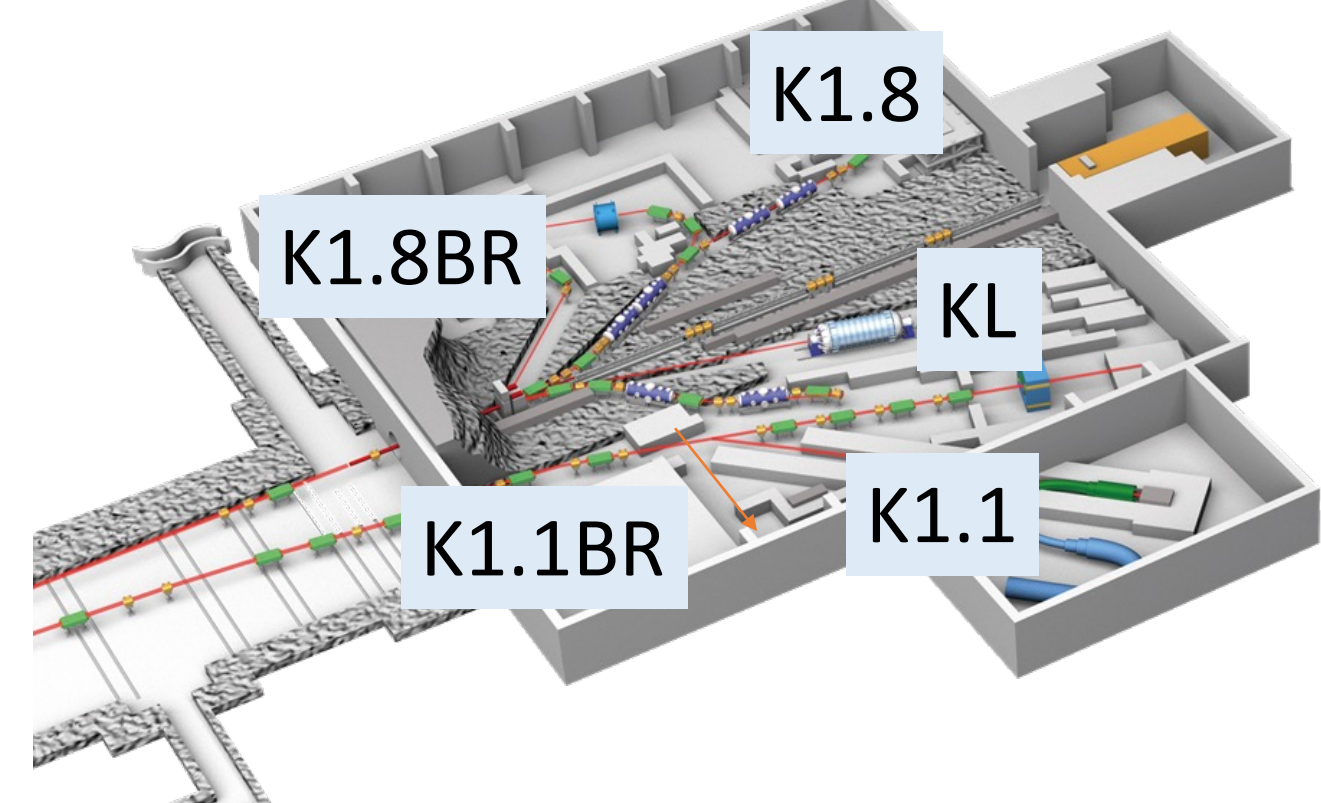
J-PARC

(Japan Proton Accelerator Research Complex)

- High Intensity Proton Beam Facility
- Tokai-mura, Ibaraki, Japan
- Three Accelerators
- Three Experimental Facilities



Hadron Experimental Facility



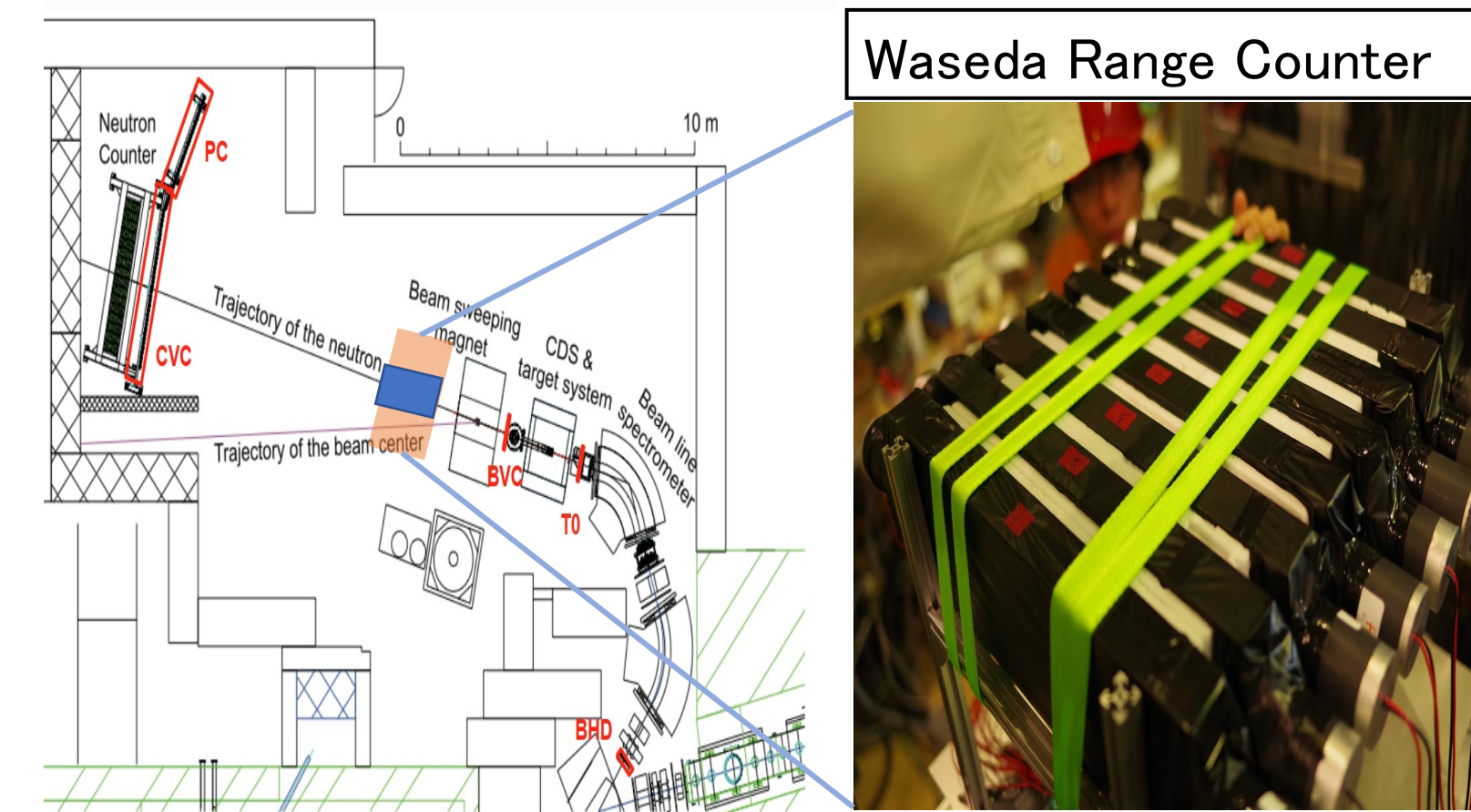
- Primary proton beam is irradiated to a fixed target and secondary particles are transported
- Five beamline configurations
 - K1.8BR beamline: kaon-, anti proton: Well observed; anti deuteron: Not well observed; Maximum momentum 1.1 GeV/c
- ➔ Ideal momentum for GRAMS!

Beam Test @K1.8BR Beamline, J-PARC

Purpose: Validation of anti-particle identification methods

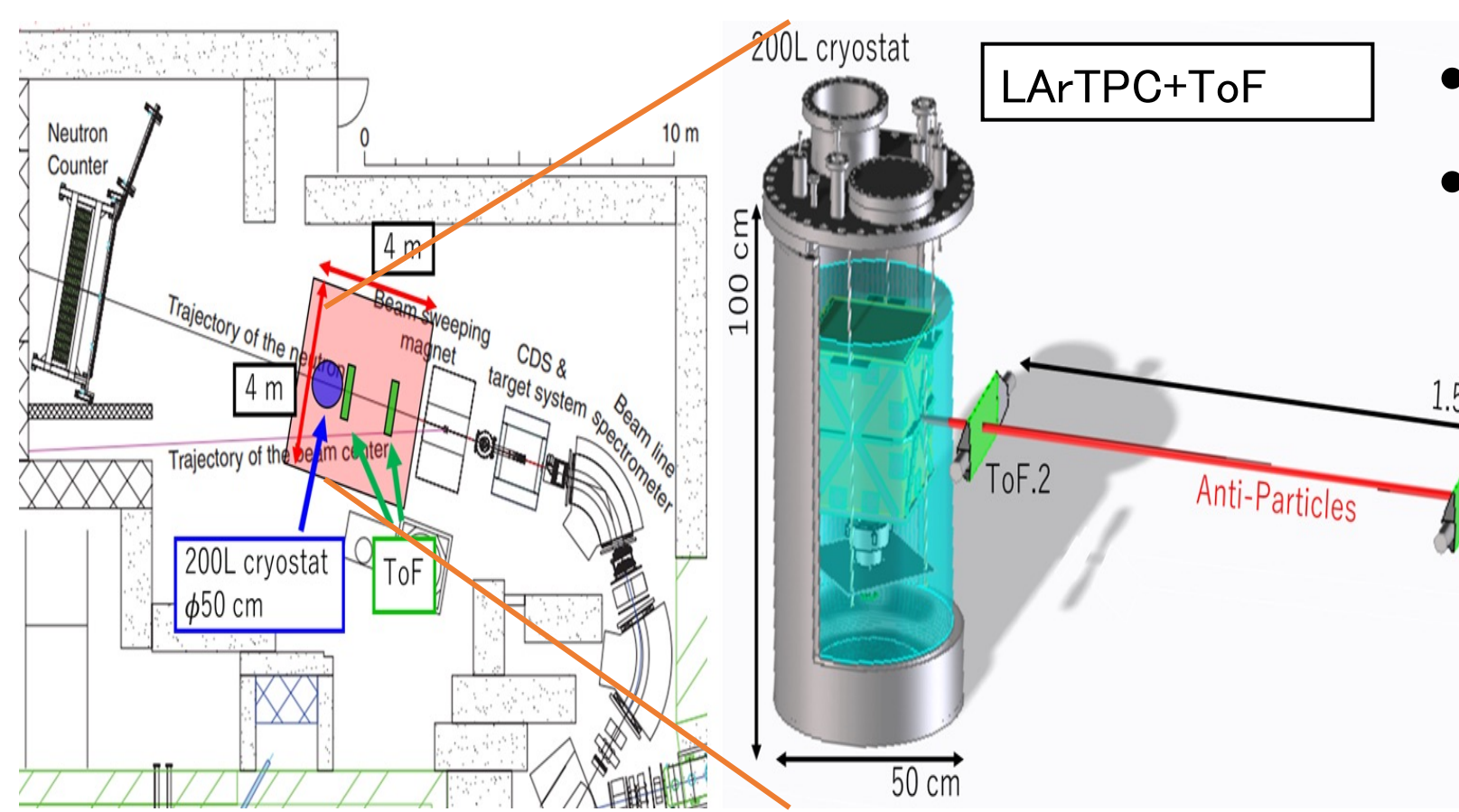
Strategy: Two steps

- ✓ Phase-1: Verification of antideuteron rate



- June 2023 Implementation
- Particle identification: dE/dX + ToF
- Observation of (anti-)deuteron stop events by Waseda Range Counter

- ✓ Phase-2: Validation of anti-particle identification methods by LArTPC+TOF

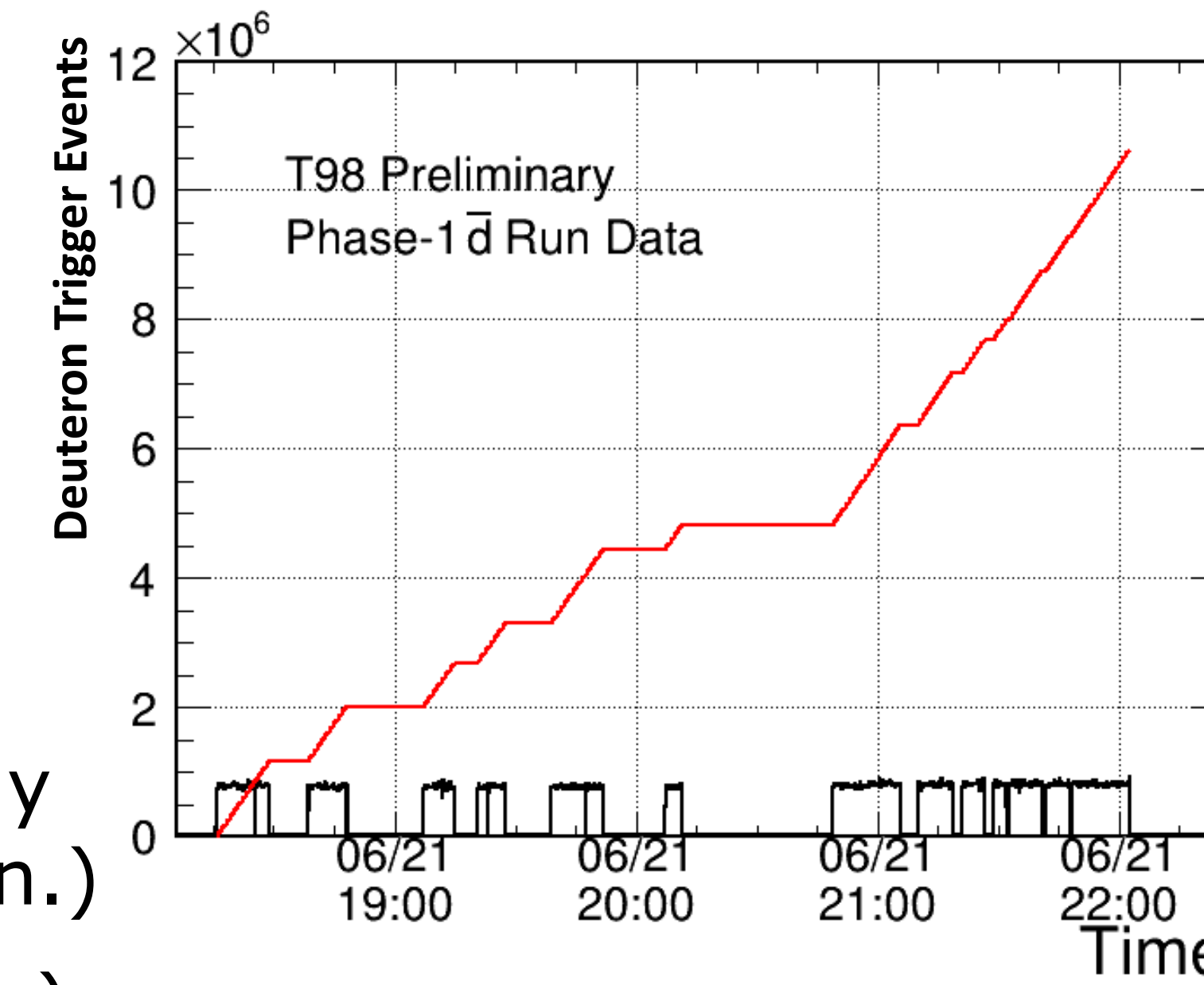


- Proposal 2024 January
- Observation of antiparticle reaction
- LArTPC: particle tracking + calorimeter
- ToF : Measure Velocity β

Phase-1 Beam Timeline

2023 6/19-21

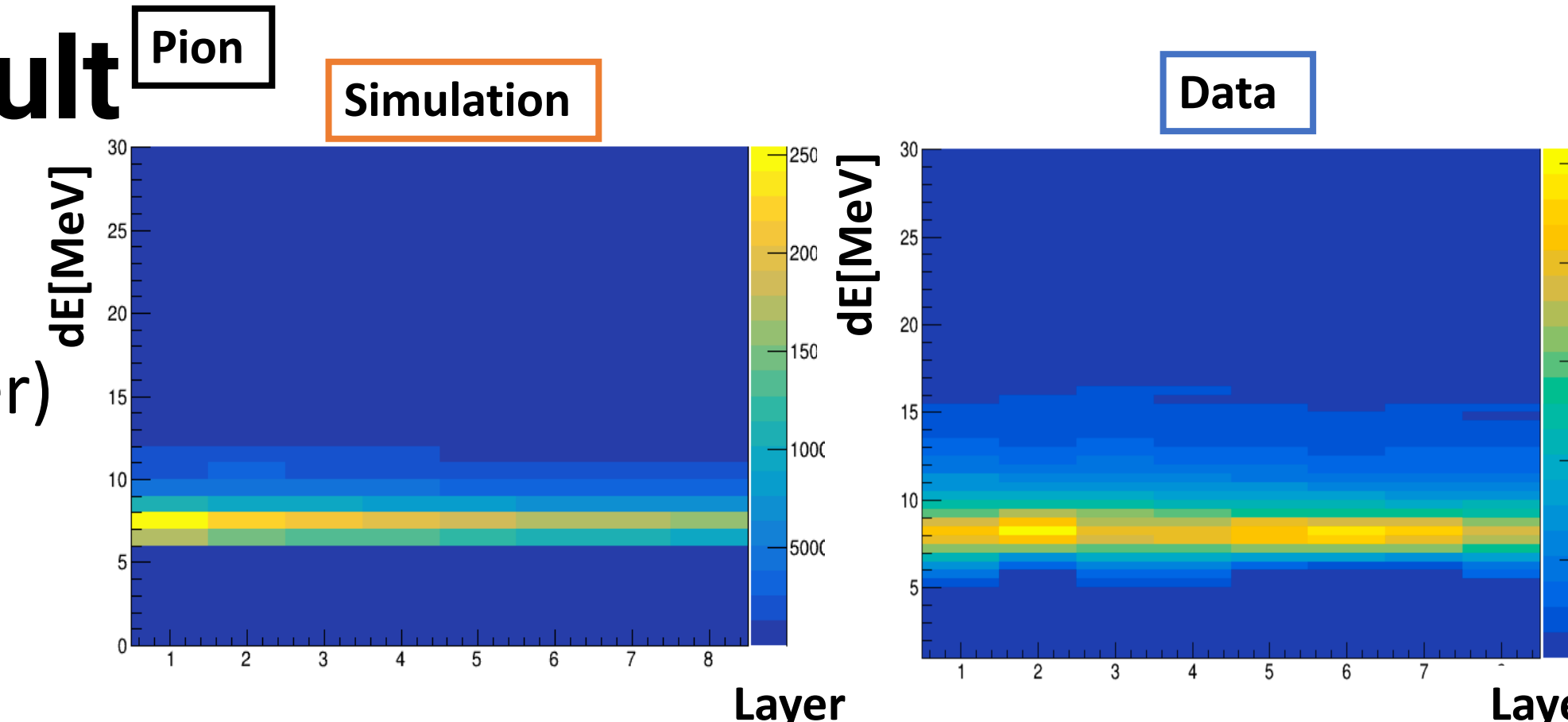
- shot beam Trigger/Gate timing check
- Reproducibility of K- beam
- Positive beam tune Kaon+, Proton, Deuteron (15min. each)
- Anti Proton tune & Rate study (12min.)
- Anti deuteron hunt (120min.)



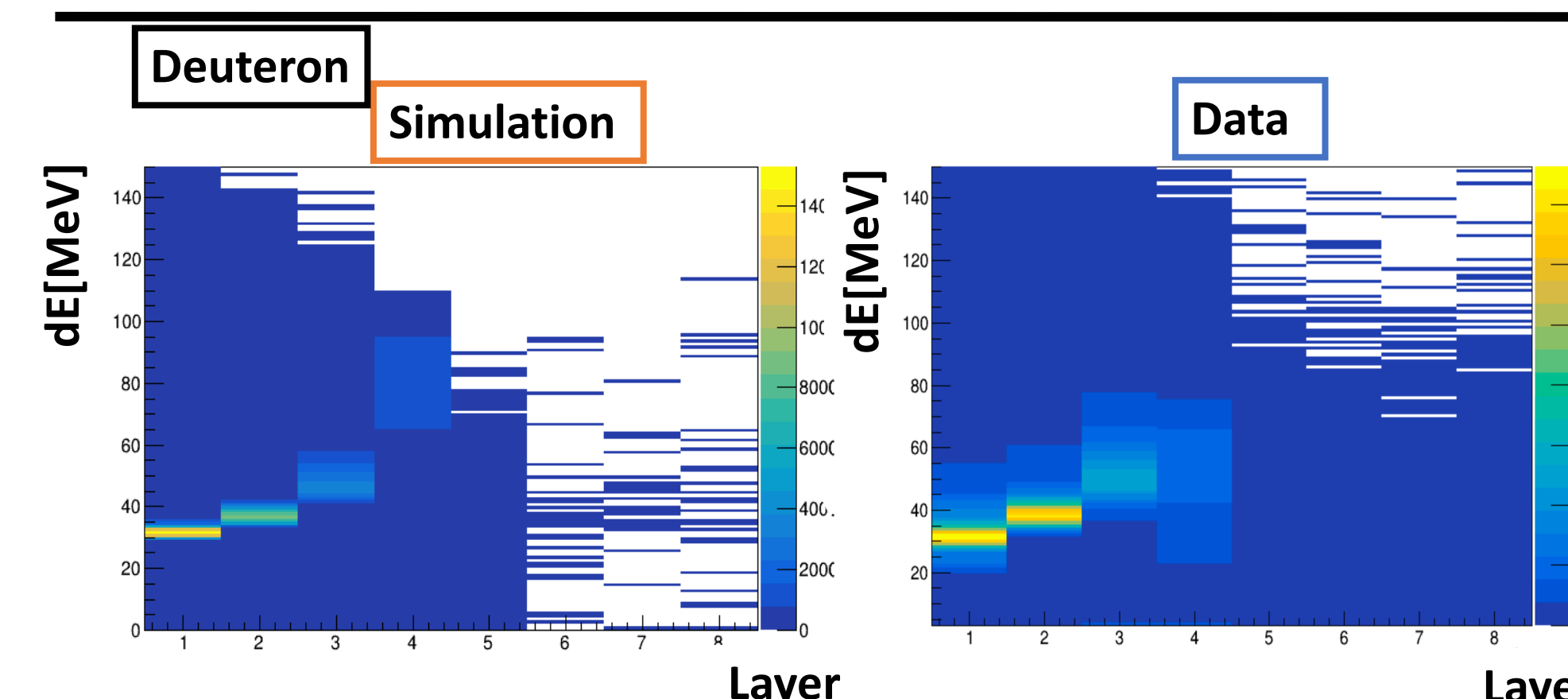
1. Phase-1 Result

➤ Positive Particle

- Response on Range counter(8-layer)
- Pion, Kaon, Proton: Passed by MIP
- Deuteron: Stopped at layer 4



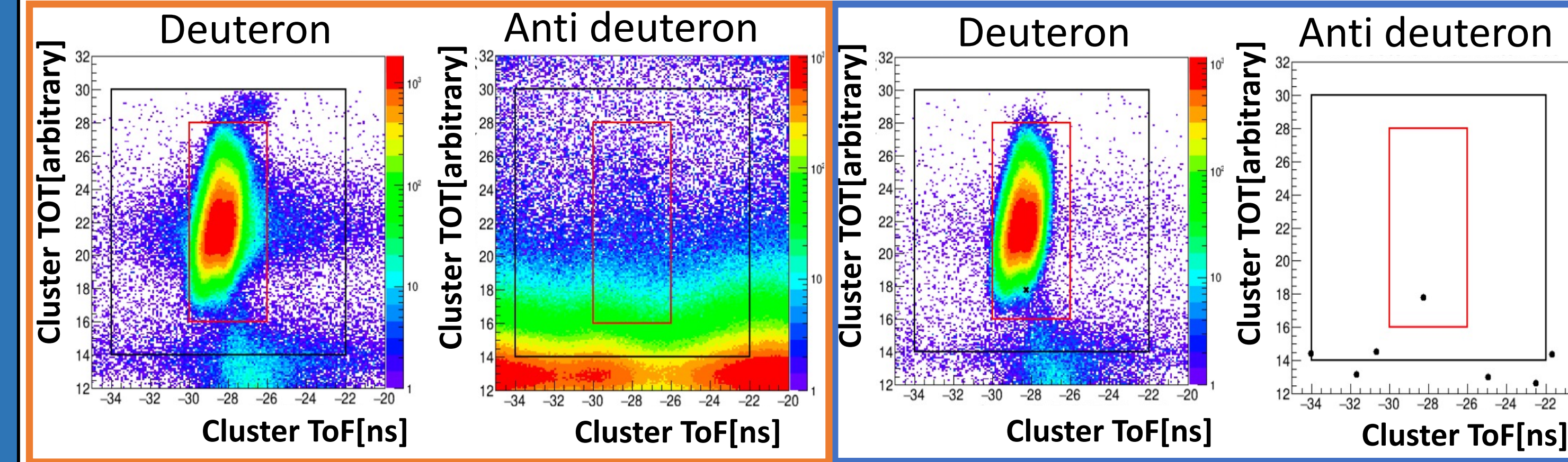
➔ Roughly consistent with Simulation!



2. Phase-1 Result

➤ Deuteron/Anti deuteron Particle Background elimination

by energy, drift chamber and trigger (TOF) matching.



We could not observe sufficient anti deuteron flux to make a proposal using anti deuteron beam for Phase 2.

Toward Phase-2

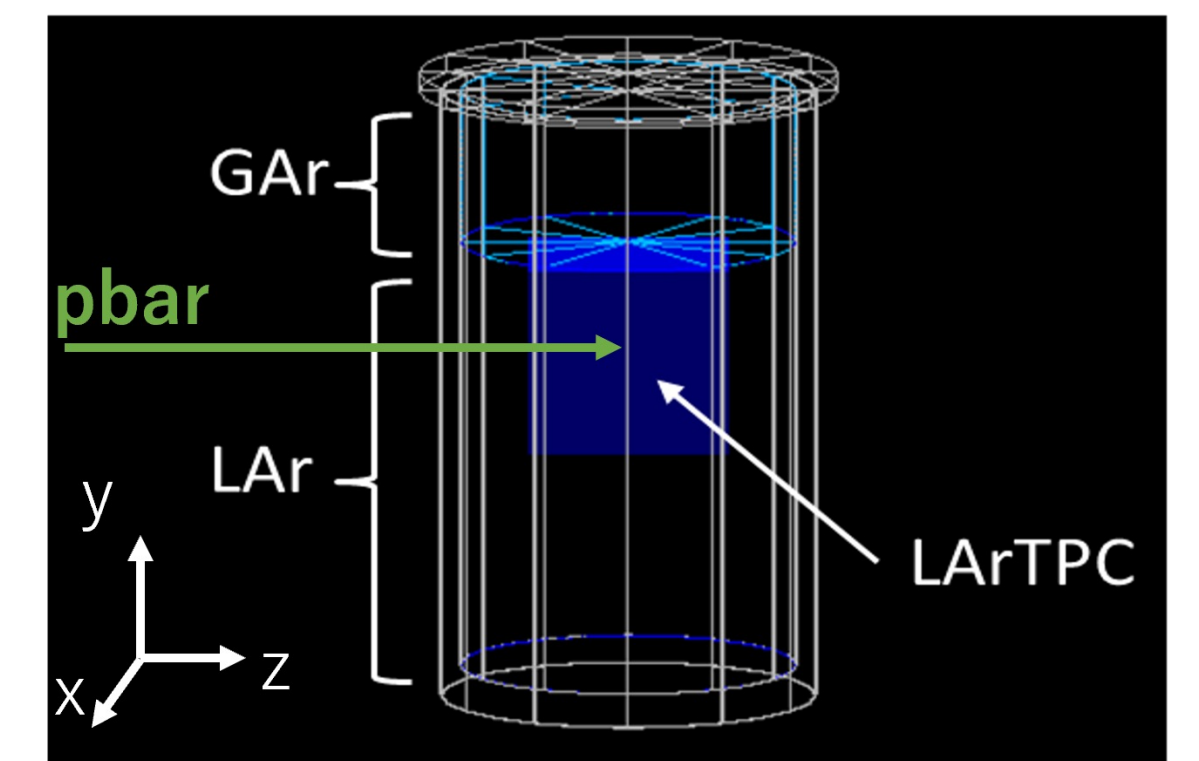
- To be proposed to J-PARC with Anti proton only
- Implemented in Geant4 Simulation

➤ Consideration of Incident Momentum

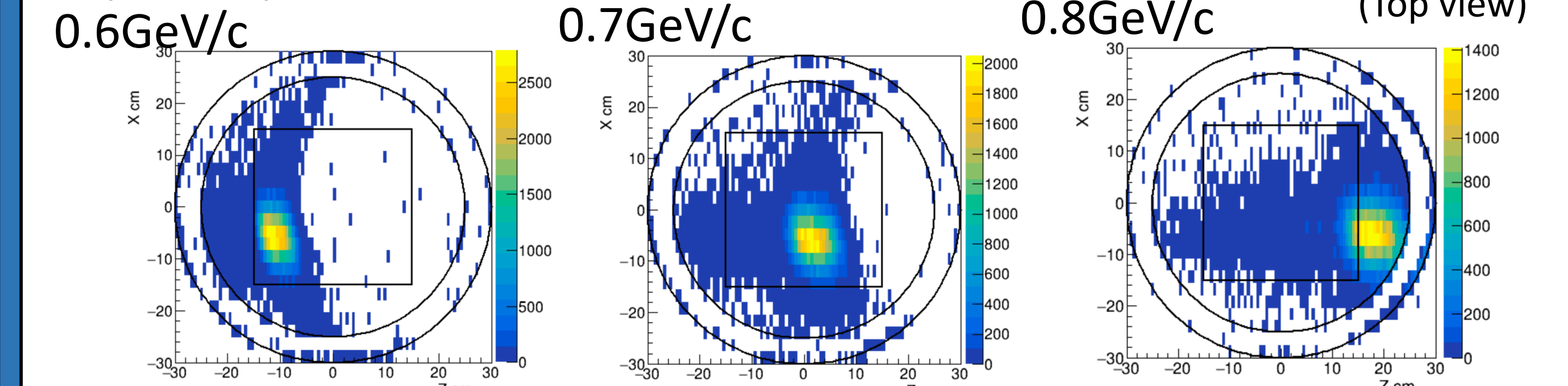
- Reflects Phase-1 beam profile data

Setup

- LArTPC setup Cryostat, GAR, LAr and LArTPC
- Front Detectors: TOFs, Drift chamber and Aerogel Cherenkov



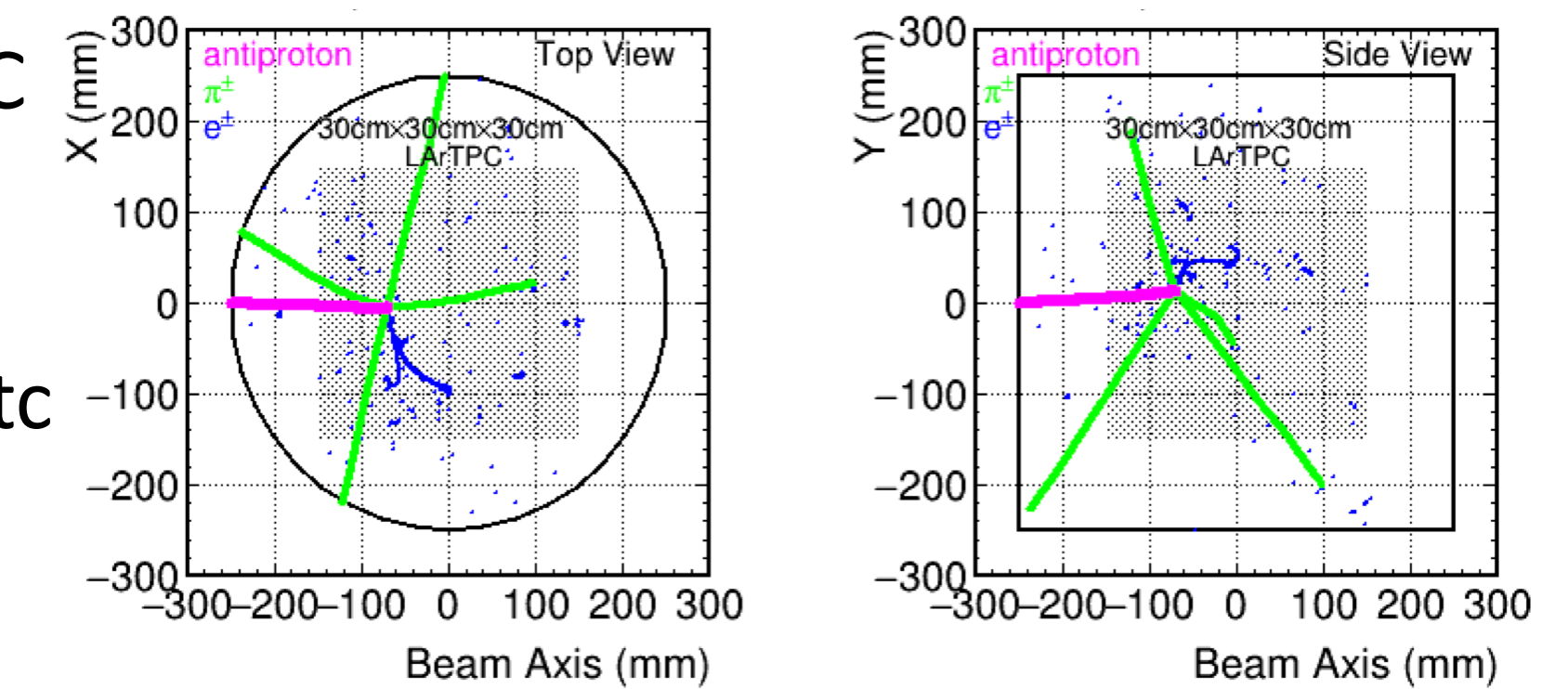
Captured point distribution



➔ For 0.7 GeV/c beam, Anti proton stops around the center of LArTPC.

➤ Expected Signal at LArTPC

- Secondary particles: Some pions and electron-positrons etc



Summary and Future Prospects

- The GRAMS experiment is a balloon/satellite experiment utilizing a LArTPC with one of its goals to indirectly search for dark matter.
- Verification of the antiparticle identification method in stages of Phase-1 and Phase-2 at the J-PARC experimental facility.
- In Phase-1, a sufficient amount of anti deuteron flux was not obtained. In Phase-2, only anti protons will be studied.
- Advancing Simulation, TPC R&D and Electronics readouts for Phase-2.