

KOTO-II at J-PARC:

first observation and measurement of the ultra-rare

$K_L \rightarrow \pi^0 \nu \nu$ and $K_L \rightarrow \pi^0 \ell^+ \ell^-$ decays

Key physics deliverables:

- ❖ Optimisation of design and physics sensitivity for the TDR.
- ❖ KOTO-II detector construction (the proposed UK deliverables are tracker and charged-particle veto detectors).
- ❖ Collection of the KOTO-II dataset.
- ❖ First observation and measurement of the ultra-rare “golden mode” $K_L \rightarrow \pi^0 \nu \nu$ decay and “silver modes” $K_L \rightarrow \pi^0 \ell^+ \ell^-$ decays.
- ❖ A comprehensive programme of rare K_L decay measurements.

Datasets and running/exposure time required:

KOTO-II dataset to be collected in 2034–41.

Financial costs are being evaluated for the submission of the KOTO-II Sol in Dec 2024. Crude estimate of the UK construction project cost: £3M.

Environmental costs are yet to be evaluated.

Dedicated submissions to EPPSU: a theory submission and an experiment submission to EPPSU are planned, both largely focused on the KOTO-II physics case.

Comparison with the current state of the art in the area:

CERN-NA62 experiment will complete a comprehensive K^+ decay programme by 2030, while LHCb will be making progress on rare K_S decay measurements. Ultra-rare K_L decays will remain the only unexplored area in kaon physics. KOTO-II will address this gap and will provide a crucial contribution to quark flavour physics.

Project's main advantages compared to competitor projects:

KOTO-II is the only ultra-rare K_L decay experiment currently planned.

Preferred location for the project:

KOTO-II will operate at the J-PARC laboratory (Japan).

Project timeline:

design phase (2025–27); construction (2027–33); data collection (2034–41); physics analysis (2034–43).

Main risks/obstacles for realisation of physics goals:

The main risk is KOTO-II experiment not achieving Stage 1 approval by the host laboratory. The outcome of the approval bid will be known by summer 2025. The decision will be determined primarily by the scientific merit and feasibility. The physics case for precision kaon physics is solid (as recognised by the European and UK roadmaps), and the technological challenges do not exceed those of HL-LHC.

Anticipated areas of UK involvement:

Detector design; construction of tracker and charged-particle veto; computing; physics analysis.

Total number of FTE/year required for construction/operation.

The FTE is being evaluated; a crude estimate is 5 FTE (RA) across the participating UK institutions.