Non-accelerator Flavour Physics

KAON & MUON EXPERIMENTS

WARWICK
THE UNIVERSITY OF WARWICK

Angela Romano, University of Warwick

PPAP Meeting, 16-17 July 2026

Outline:

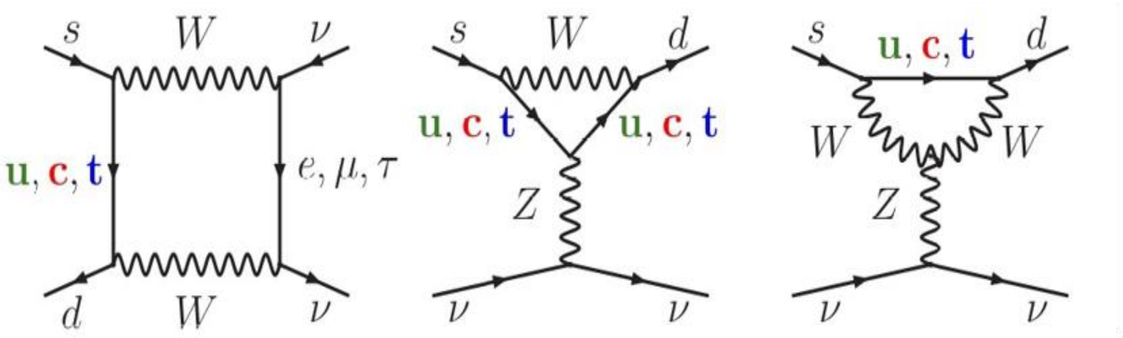
- Current kaon experiments: NA62 at CERN, KOTO at J-PARC
- Next-generation Kaon experiment: KOTO II
- Muon experiments: g-2 and Mu2e at FNAL, Mu3e at PSI

Muon slides provided by Joe Price, U. of Liverpool

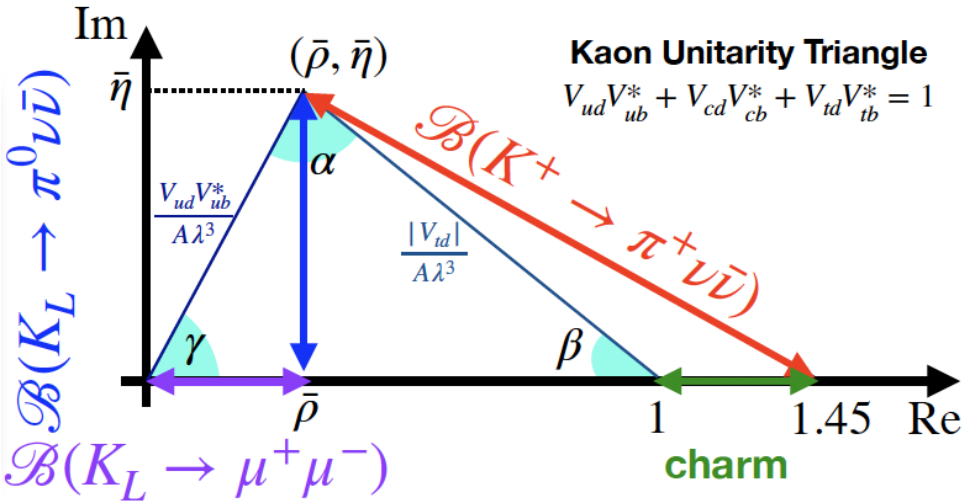
UK leadership at the precision frontier:
current achievements and future opportunities

$K \to \pi\nu\bar{\nu}$ in the Standard Model & Beyond

Ultra-rare Flavour Changing Neutral Current (s→d) process



Electroweak Box & Penguin (one-loop) diagrams



Highly suppressed in SM:

- ✓ Quadratic GIM suppression ~ $(m_{top}/m_W)^2$
- ✓ Maximum CKM suppression (BR ~$|V_{ts}^*V_{td}|^2$)

Exceptionally clean SM predictions:

- ✓ dominant SD contribution
- ✓ hadronic matrix from $K^+ \to \pi^0 e^+ \nu_e$

Sensitive to new physics scales beyond direct collider reach

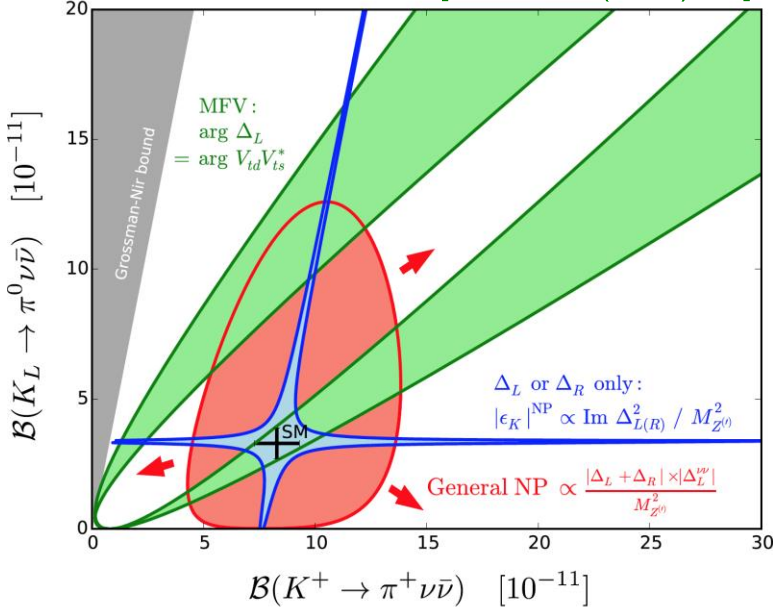
SM Predictions: irreducible theory uncertainty few %

[Buras et al. EPJC 82 (2022) 7, 615]

$K^+ \to \pi^+\nu\bar{\nu}$	$(8.60 \pm 0.42) \times 10^{-11}$
$K_L \to \pi^0\nu\bar{\nu}$	$(2.94 \pm 0.15) \times 10^{-11}$

New Physics: correlations btw charge and neutral mode significantly change for different NP models →
[EPJ C76 (2016) no.4 182]

[JHEP1511(2015)166]



Charged and neutral modes provide complementary information on the flavour structure of new physics

NA62 $K^+ \to \pi^+ \nu \bar{\nu}$: from Discovery to Precision

$>3\sigma$ $K^+ \to \pi^+ \nu \bar{\nu}$ evidence

NA62 Run 1: 2 x 10^{18} protons on target (PoT) delivered

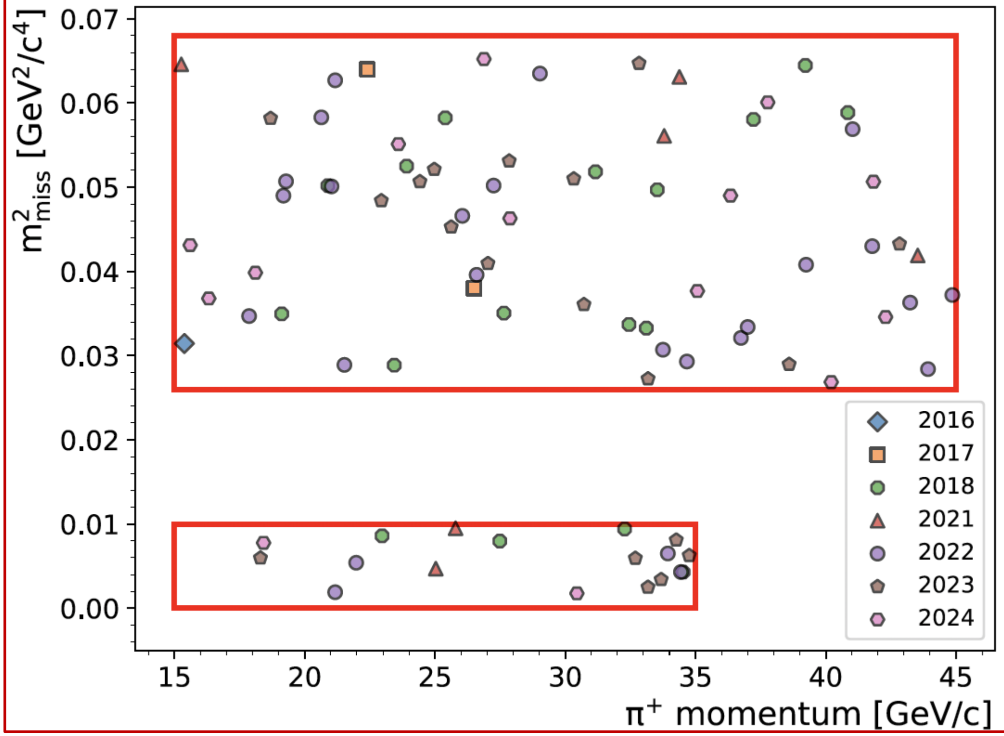
NA62 Run 2: ~8 x 10^{18} PoT → beam stop August 3rd

Commissioning	2016	2017	2018	LS2	2021	2022	2023	2024	2025	2026
	45 days	160 days	217 days	upgrades	85 days	215 days	150 days	204 days	200 days	

$K^+ \to \pi^+ \nu \bar{\nu}$ observation: the rarest decay measured at 5σ significance

NA62:
300 participants from 32 institutions
focused on $K^+ \to \pi^+ \nu \nu$ measurement to **15%** precision
Strong UK leadership at all levels
UK groups: Birmingham, Bristol, Glasgow, Lancaster, Warwick

Combination 2016-18 + 2021-24 data

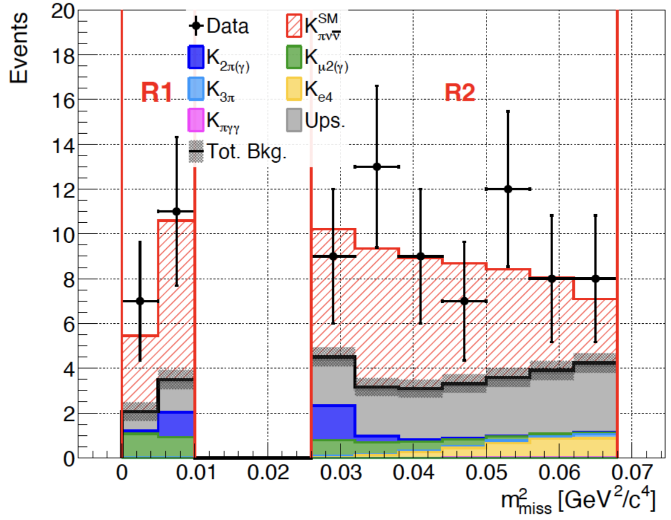


FLAVOUR PHYSICS | NEWS

The kaon stays on script

2 June 2026

1D projection with differential background predictions & SM signal expectation* with $\mathscr{B}_{SM} = 8.4 \times 10^{-11}$ [not a fit]:



Combined NA62 2016-2024 result

Expected SM signal	$N^{SM}_{\pi\nu\nu} = 43 \pm 1$
Expected background	$N_{bg} = 30^{+4}_{-3}$
Observed	$N_{obs} = 84$

From discovery to a precision probe of Flavour Physics

$$\mathscr{B}_{16-24}(K^+ \to \pi^+ \nu \bar{\nu}) = \left(9.6^{+1.9}_{-1.8}\right) \times 10^{-11}$$

The full NA62 dataset will define the charged-kaon benchmark for the next generation of flavour experiments

$K^+ \to \pi^+ \nu \nu$ results: [PLB791(2019)156, JHEP11(2020)042, JHEP06(2021)093, JHEP02(2025)191]

NA62 Broad Flavour Programme

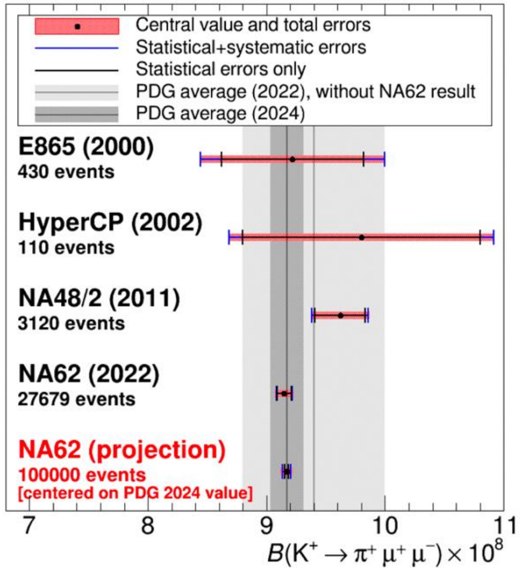
NA62 has collected data from 2016 until 2026 → world's largest multi-purpose sample of K^+ decays

Precise Lepton Universality tests with $K^+\to\pi^+\ell^+\ell^-$ decays (>100k candidates per mode expected)	Updated R_K measurement (expect >1M $K^+\to e^+\nu$ candidates)	Upper limits on BRs of LFV/LNV K^+ and π^0 decays ~ $O(10^{-11}\text{-}10^{-12})$

$K^+\to\pi^+\mu^+\mu^-$

Final dataset (2016-2026) projection

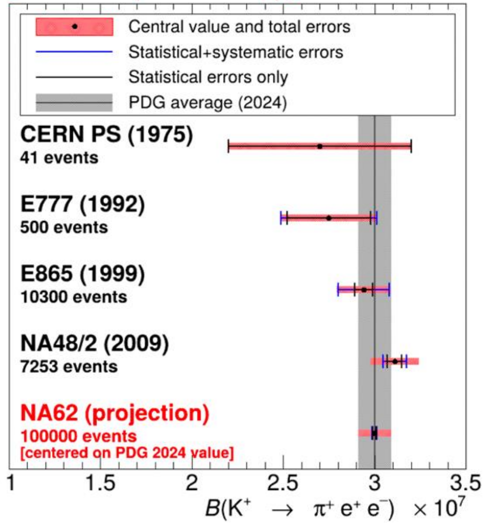
- >100k $K^+\to\pi^+\mu^+\mu^-$ candidates
- Negligible background
- Assume same systematic uncertainty as $\pi\mu\mu$ result (0.3%)



$K^+\to\pi^+e^+e^-$

Final dataset (2016-2026) projection

- >100k $K^+\to\pi^+e^+e^-$ candidates
- Negligible background
- Assume same systematic uncertainty as $\pi\mu\mu$ result (0.3%)
- Same external error as NA48/2 [from $BR(\pi^0\to e^+e^-\gamma)$]



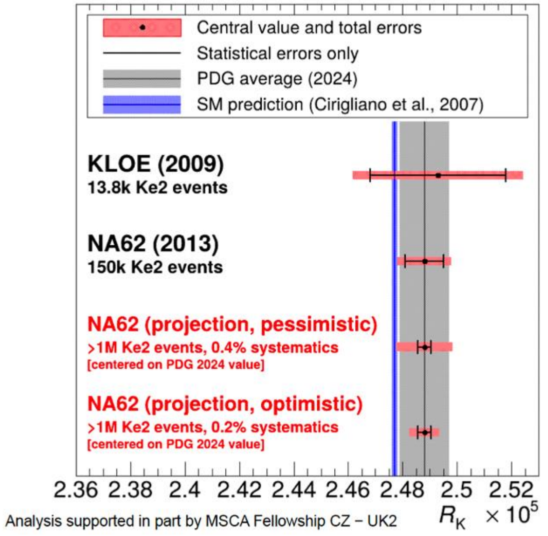
$R_K = K^+\to e^+\nu/K^+\to\mu^+\nu$

Novel technique [no dedicated data taking]: select $K_{\mu2}$ decays with μ decays within RICH → both $K_{\ell2}$ from same (PNN) trigger line

Analysis well advanced

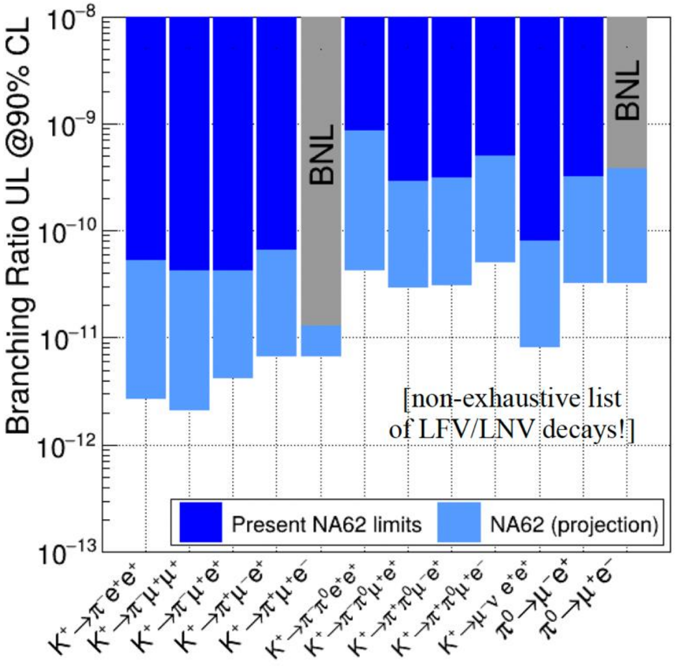
Statistics: >1M Ke2 candidates (Run1 only)

Systematic uncertainty: work in progress

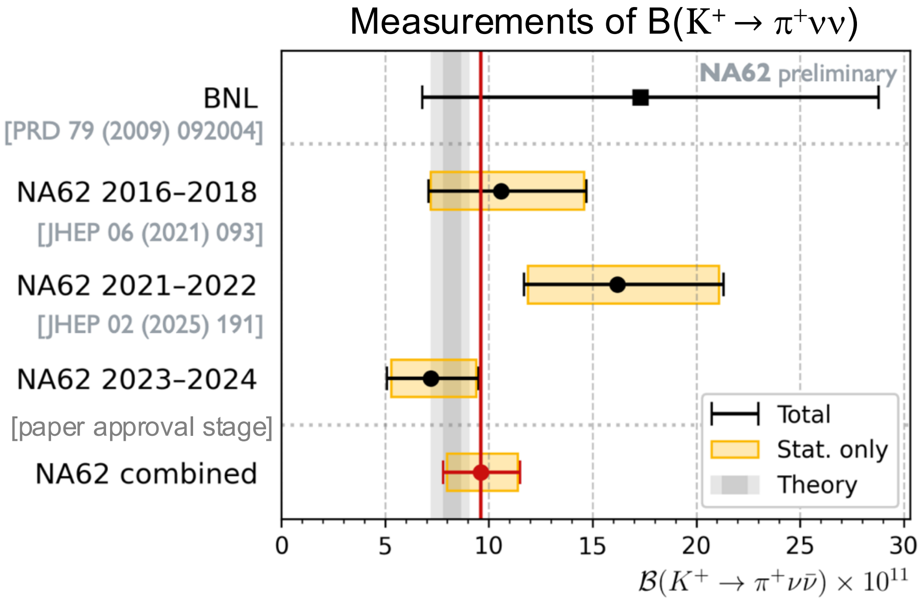


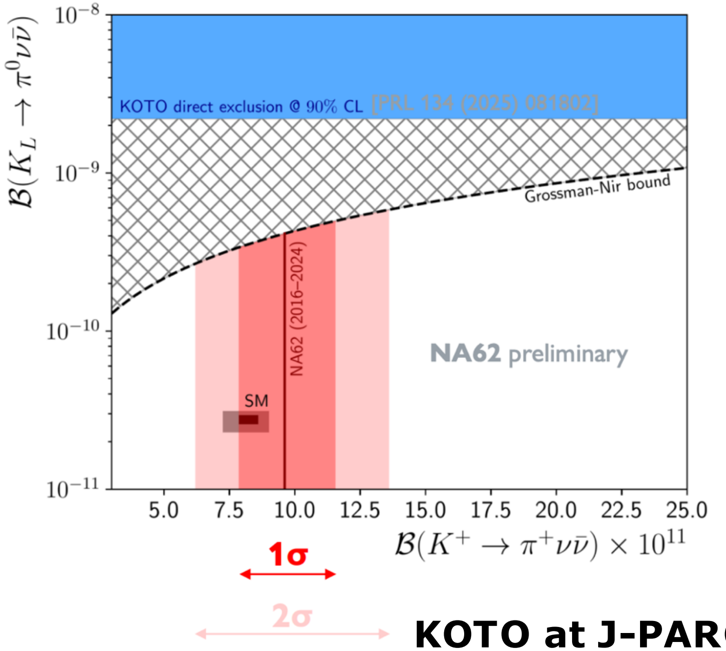
LFV/LNV decays

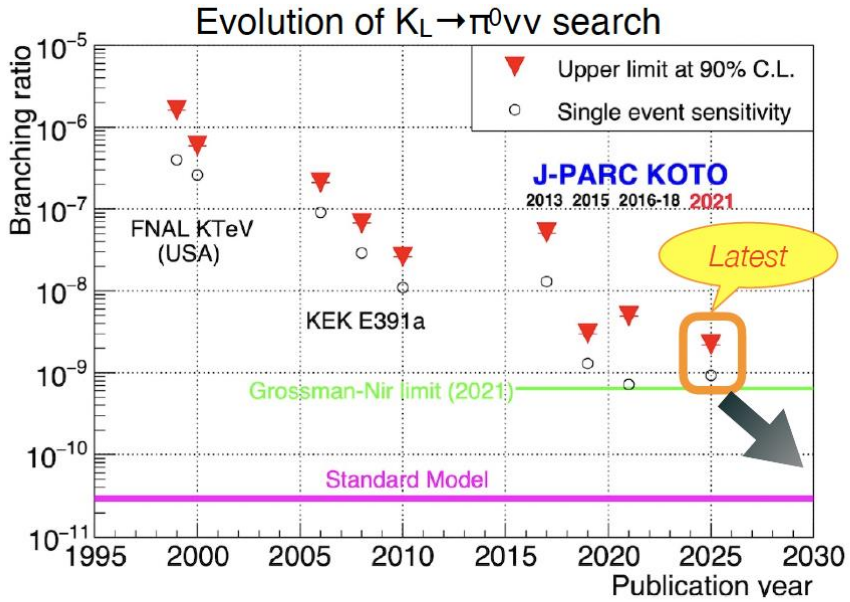
Final dataset (2016-2026) projection:



$K \to \pi\nu\nu$: Global Picture







NA62 at CERN:

- First observation of ultra-rare $K^+ \to \pi^+\nu\nu$ decay
- Smallest BR ever measured at > 5σ significance
- $B(K^+ \to \pi^+\nu\nu)$ measured to < 20% precision
- Aim at 15% precision measurement with legacy analysis

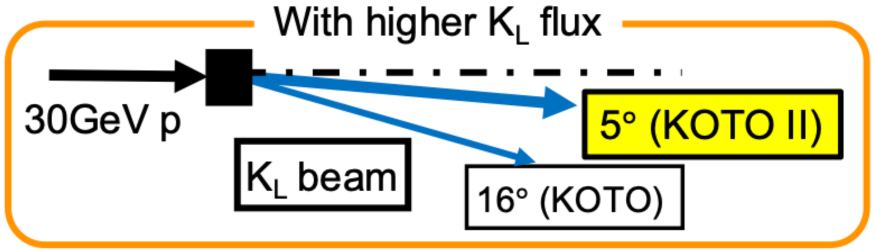
KOTO at J-PARC:

- Current world-leading search for $K_L \to \pi^0\nu\nu$
- Latest result: $\mathcal{B}(K_L \to \pi^0\nu\bar{\nu}) < 2.2 \times 10^{-9}$ (90% C.L.)
- Validate the exp technique required for neutral mode
- Aim to reach SES $\sim 10^{-10}$ and Grossman-Nir bound by 2028

Following the observation of $K^+ \to \pi^+\nu\nu$, the next major experimental challenge is the discovery and measurement of $K_L \to \pi^0\nu\nu$

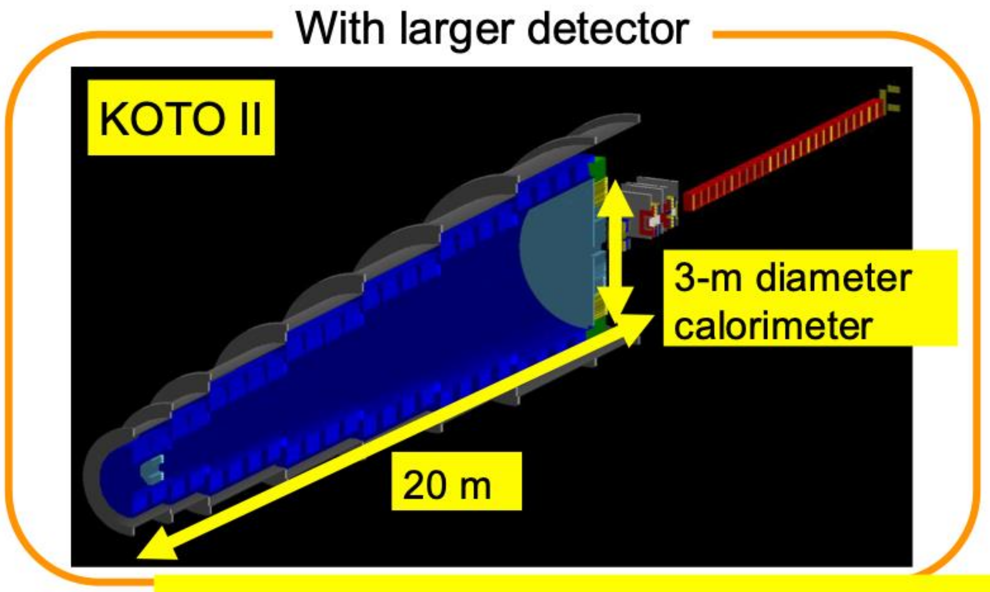
- $K_L \to \pi^0\nu\nu$: directly CP-violating decay
- SM branching ratio: $\sim 3 \times 10^{-11}$
- Not yet observed

KOTO II: from search to precision measurement



[arXiv: 2501.14827]

Based on KOTO experimental concept with improved sensitivity

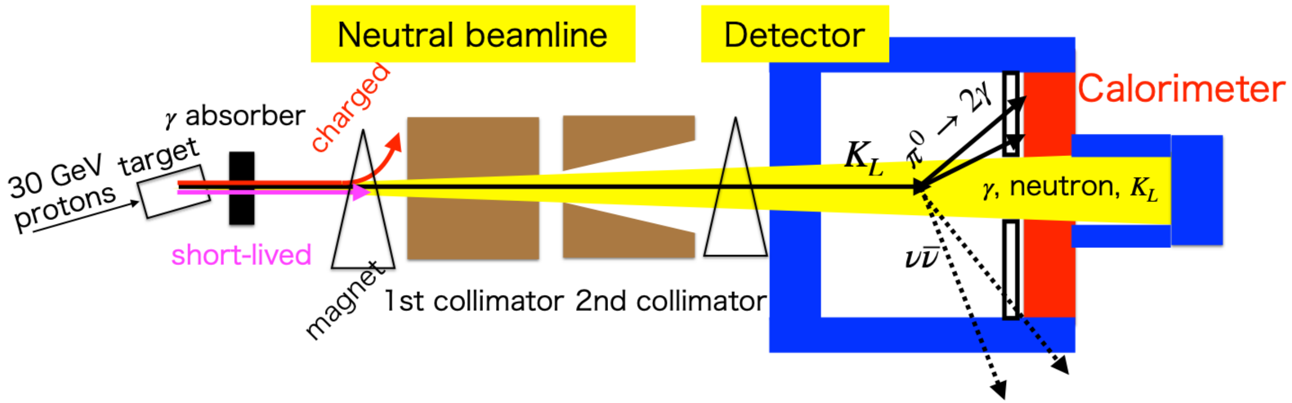


Upgraded detectors to improve background suppression

New beam line → $1.1 \times 10^{7}\ K_L$ / 2×10^{13} POT

Improvements wrt KOTO:

× 3 higher K_L momentum: longer decay volume larger acceptance → new exp. area



Summary of sensitivity and impact:

Signal (branching fraction : 3×10^{-11})	S	35.3 ± 0.4
Background	B	40 ± 2.7
Single event sensitivity	$(3 \times 10^{-11})/S$	8.5×10^{-13}
Signal-to-background ratio	S/B	0.89
Significance of the observation	$S/\sqrt{B}$	5.6σ
90%-C.L. excess / deficit	$1.64 \times \sqrt{S+B}$	14 events
	$1.64 \times \sqrt{S+B}/S$	40% of SM
Precision on branching fraction	$\sqrt{S+B}/S$	25%
Precision on CKM parameter η	$0.5 \times \sqrt{S+B}/S$	12%

* A running time of 3×10^{7} s is assumed in the calculation.

Aiming to run in mid 2030's in Hadron Hall extension

Expect 35 SM $K_L \to \pi^0\nu\nu$ events (40 background), ~25% precision on branching fraction

Sensitive to NP with >40% deviation from SM at 90% C.L.

KOTO II will open the precision frontier in ultra-rare neutral-kaon decays

KOTO II: UK Leadership & Roadmap

PPAP Roadmap 2021: *UK leadership in current kaon experiments recognised; investment in the future kaon programme recommended.*

KOTO II Physics proposal approved at J-PARC PAC (https://arxiv.org/abs/2501.14827)
→ J-PARC E107 experiment
KOTO II collaboration formed with KEK as host institution

UK Leadership:
- UK is a founder member of the KOTO II collaboration
- UK Co-Spokesperson and Speaker's Bureau
- UK Leadership of software, detector and physics working groups

Growing UK community building on expertise developed through NA48 and NA62

KOTO II workshop Mainz, September 2025

UK groups: Birmingham, Edinburgh, Glasgow, Lancaster, Liverpool, Manchester, Warwick

KOTO II ROADMAP

2026-2028 Design, detector R&D, prototyping and TDR

↓

2030-2034 Detector construction, installation and commissioning

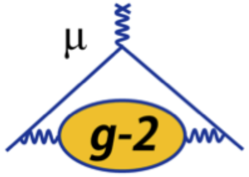
↓

From 2035 Physics data taking and exploitation

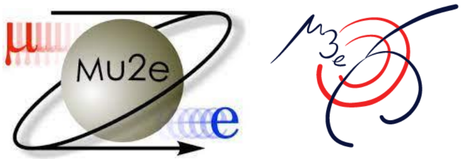
KOTO II provides a clear route for sustained UK leadership in rare-kaon physics into the 2030s & beyond

Muon Physics in the UK - summary

- STFC funded experiments
  - **g-2** (*Fermilab*)
  - **Mu2e** (*Fermilab*)
  - **Mu3e** (*PSI*)



DIPOLE MOMENTS



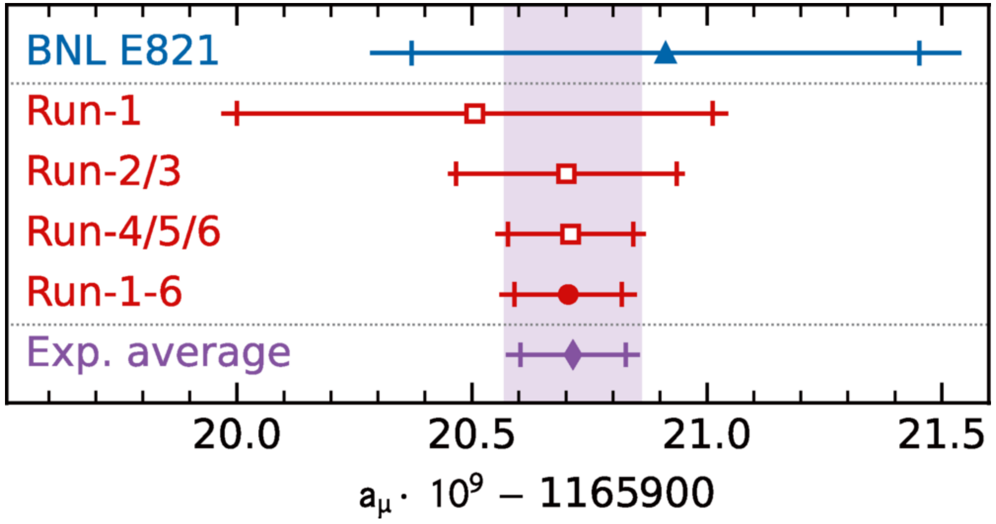
CLFV: CHARGE LEPTON FLAVOUR VIOLATION

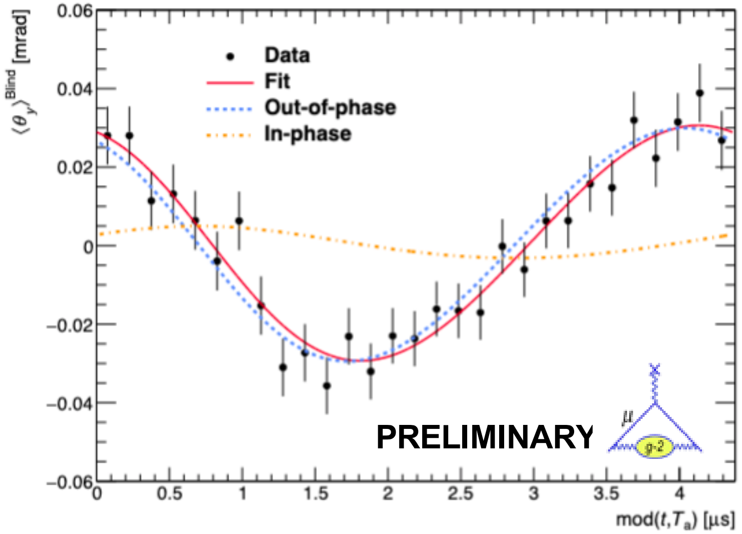
- ~40 staff/post-docs across 9 institutes in the UK
- Additional experiments
  - **DIPOLE MOMENTS**: muonE (*CERN*), KLOE (*DAFNE*), muEDM (*PSI*), g-2 (*J-PARC*)
  - **CLFV**: COMET (*J-PARC*), MEG-II (*PSI*)

University of BRISTOL
The Cockcroft Institute of Accelerator Science and Technology
Imperial College London
Lancaster University
UNIVERSITY OF LIVERPOOL
MANCHESTER 1824 The University of Manchester
UNIVERSITY OF OXFORD
Science & Technology Facilities Council Rutherford Appleton Laboratory
UCL

Fermilab g-2 experiment

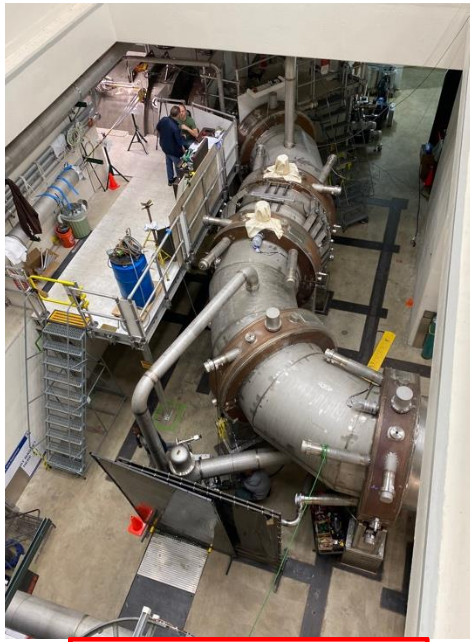
- Data taking 2017 – 2023. All data now analysed
- Measured the anomalous magnetic dipole moment (a_μ) to 127ppb – reached target precision!
- Published Sept 2025: Phys. Rev. Lett. **135**, 101802





- World's most sensitive direct muon EDM search - expected Aug 2026
- Look for out of phase tilt in e^+ angle $\langle\theta_y\rangle$
- Uses UK-built tracking detectors, UK-lead analysis
- BSM Lorentz- and CPT- violation searches to follow

Mu2e – summary and status



Transport solenoid

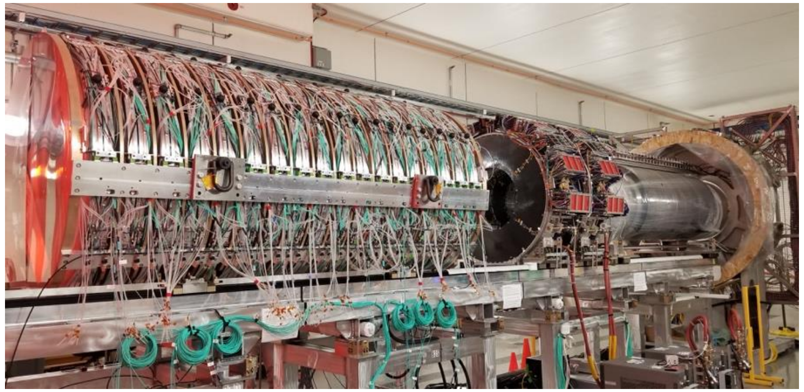
Production solenoid

Rate of Muon conversion

$$R_{\mu e} = \frac{\boxed{\Gamma(\mu^- + \mathrm{Al} \to e^- + \mathrm{Al})}}{\boxed{\Gamma(\mu^- + \mathrm{Al} \to \nu_\mu + \mathrm{Mg})}}$$

Rate of Muon Capture

- Mu2e searches for **CLFV** via a muon conversion to an electron
- Need to measure muon conversion rate and muon capture rate
- All detectors installed in the hall – DAQ/Cosmic test runs ongoing
- UK responsible for stopping target monitor (capture rate) + DAQ
  - 2 run co-ordinators from the UK



Tracker and Calorimeter

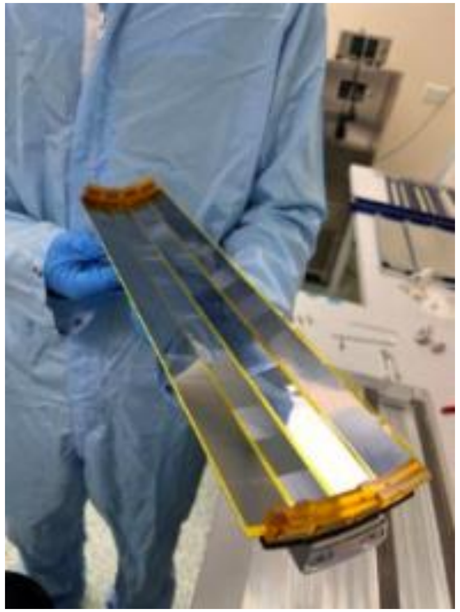
- Final solenoid (detector solenoid) arrives this month First physics run end of 2027 before PIP-II shutdown
- 2027 data: Sensitivity improves worlds best CLFV limit by factor of 30 – discovery potential!
- 2030-34 data, (post PIP-II): further sensitivity × 300, to reach goal of 10,000 improvement

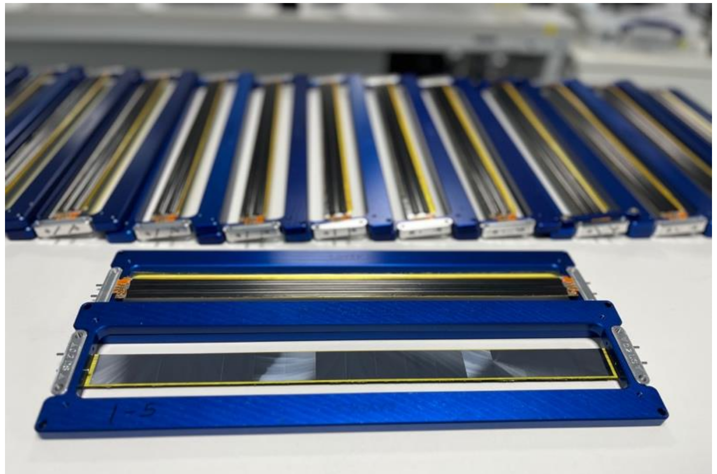
Mu3e

Search for CLFV via $\mu^+ \rightarrow e^+e^+e^-$

- UK responsible for clock-and-reset system and HV-MAPS outer pixel tracker
- Lowest mass fast pixel tracker (~0.1%X0 per layer)
- 17/18-chip pixel ladders produced in Oxford & 4-ladder modules assembled in Liverpool
- First outer tracking layers installed in Mu3e this August
- Gradual increase of detector acceptance and CLFV sensitivity
- 8 weeks of beam commissioning data in 2026
- ~30 week physics run in 2027 (Phase-0, central detector) → will surpass the SINDRUM limit very fast

- Completion of Phase-1 programme in 2030-2032 after High Intensity Muon Beam upgrade
- Mid 2030s Mu3e upgrade for Phase-2
- Multiple UK coordinating positions: physics, tracker (production, installation and overall), DQ, MC





Ladders produced in Oxfords

Summary

KAON Programme:

- UK has played a leading role in experimental kaon physics for several decades
- NA62 achieved the first observation of $K^+ \to \pi^+ \nu\nu$ and is delivering a broad programme of precision measurements and searches for new physics
- The next frontier is the discovery and precision measurement of $K_L \to \pi^0 \nu\nu$
- KOTO II brings together the international kaon community to address this challenge
- The UK is already playing a leading role in establishing KOTO II and its physics programme

Muon Programme:

- UK has 9 institutes with 40 staff working on dedicated muon physics experiments
- g-2 experiment published measurement of a_μ, reaching precision goal of 127ppb
- New results imminent for muon EDM measurement at Fermilab muon g-2 experiment – UK lead
- Mu2e and Mu3e are at/entering commissioning phase, begin physics data taking next year
- Both will reach full sensitivity in the second phase of running, 2030-34
- STFC funding key part of muon programme in the UK, with additional experiments broadening UK muon expertise

STRATEGIC OPPORTUNITY

❖ Maintains UK leadership in kaon and muon precision measurements
❖ Provides long-term opportunities for detector R&D, students and early-career researchers
❖ Complements collider, neutrino programmes in the search for new physics

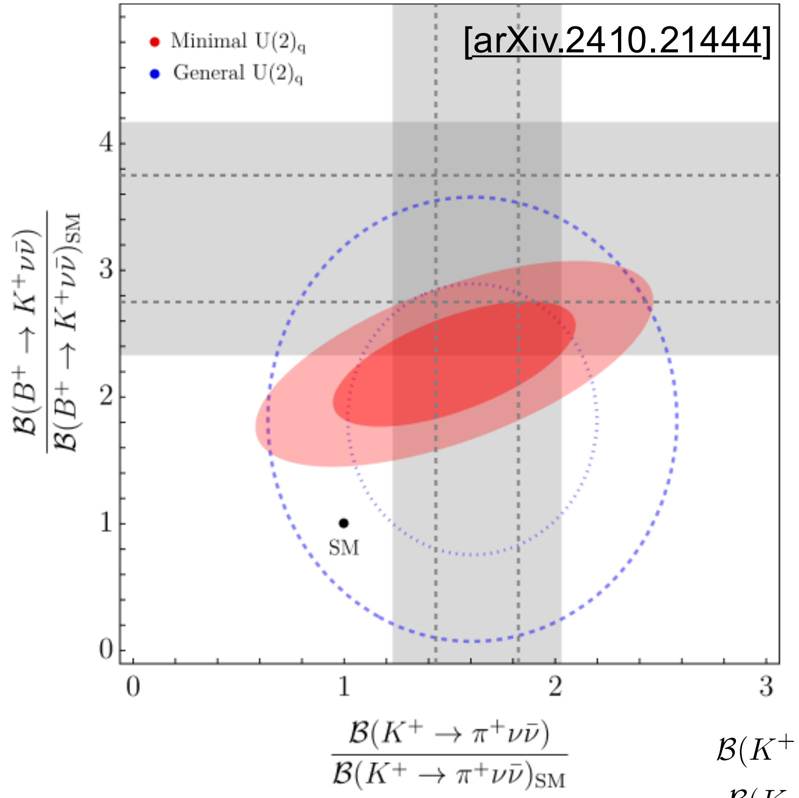
SPARES

Angela Romano, University of Warwick

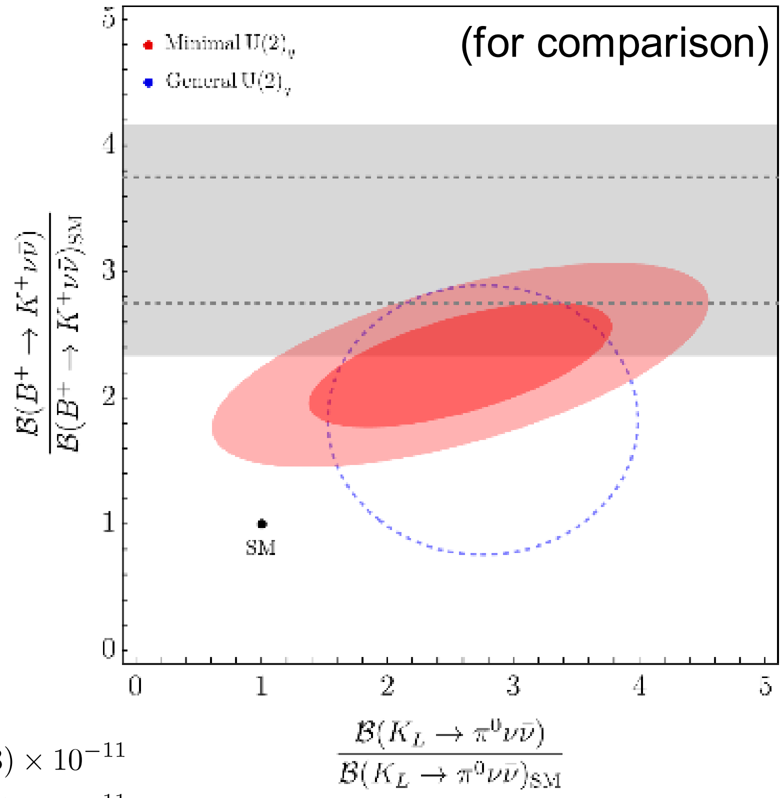
PPAP Meeting, 16-17 July 2026

Probing third-generation New Physics

- EFT with dimension-six semileptonic operators built in terms of SM fields
- Minimally-broken $U(2)^5$ flavour symmetry acting on the lightest two SM families
- Reduce the number of relevant operators and free parameters
- Using 5 parameters analyse a large set of observables that includes direct searches, EWPO, FCNC
- Key role of the two neutrino modes in determining the allowed parameter space

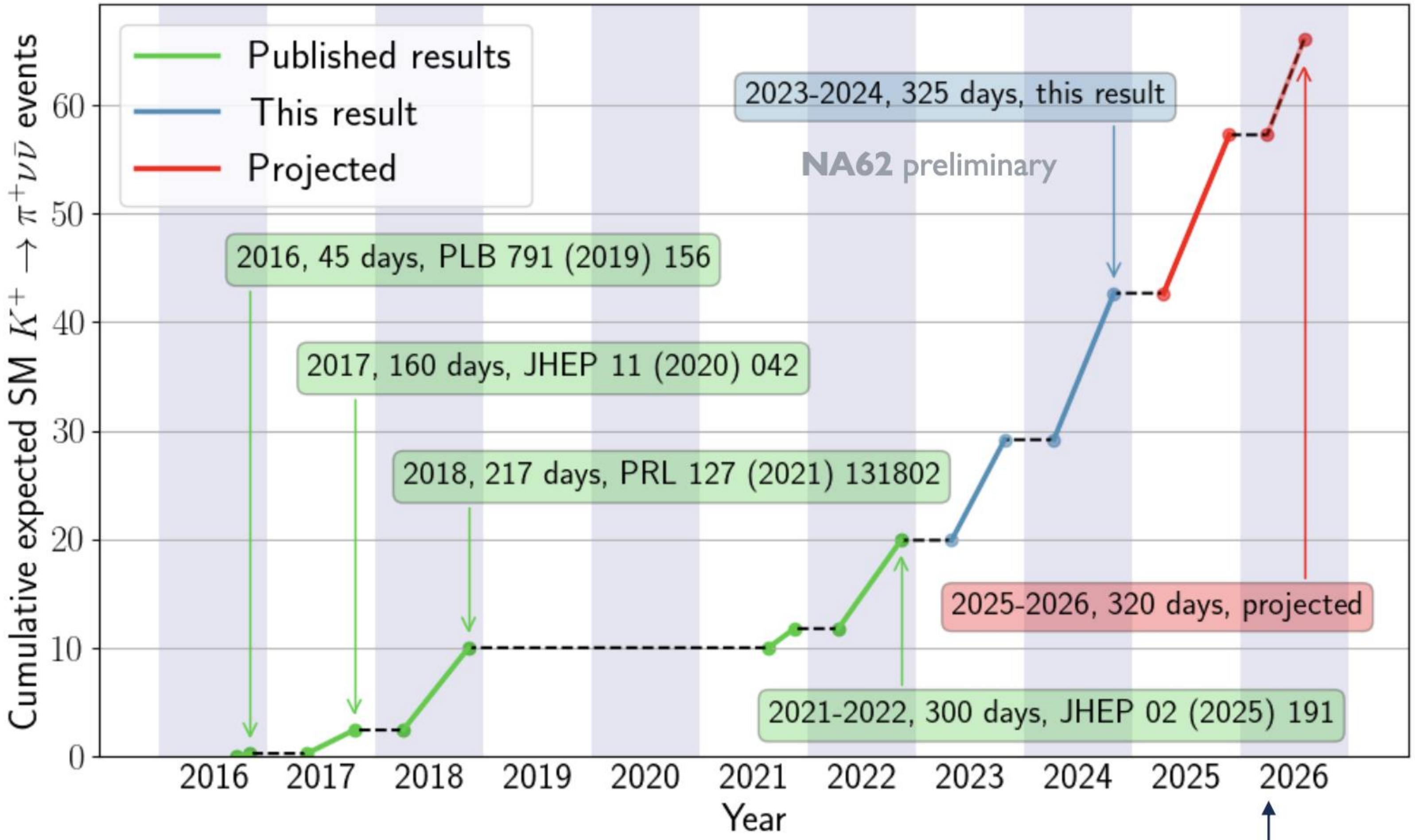


$$\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu})^{SM} = (8.09 \pm 0.63) \times 10^{-11}$$
$$\mathcal{B}(K_L \to \pi^0\nu\bar{\nu})^{SM} = (2.58 \pm 0.30) \times 10^{-11}$$



(*)NA62 $K^+ \to \pi^+\nu\nu$ result from 2016-2022 datasets, updated plots in preparation

NA62 Prospects



- Current: 2016–2024
  - Expected SM* signal, $N^{SM}_{\pi\nu\bar{\nu}} = 43 \pm 1$
  - Expected background, $N_{bg} = 30^{+4}_{-3}$
  - Observed, $N_{obs} = 84$
- Full: 2016–2026
  - Expect ~**1/3 of data still to come** (2025+2026)
  - Improve BR precision further: from 20% towards 15%.
  - Study kinematic distributions (shapes).

NA62 Physics Programme

Precision measurements & rare decays

- $K^+ \to \pi^+\mu^+\mu^-$ [JHEP 11 (2022) 011]
- $K^+ \to \pi^+e^+\nu\gamma$ [JHEP 09 (2023) 040]
- $K^+ \to \pi^+e^+e^+e^+e^-$ [PLB 846 (2023) 138193]
- $K^+ \to \pi^+\gamma\gamma$ [PLB 850 (2024) 138513]
- $\pi^0 \to e^+e^-$ [Moriond2024]
- $K^+ \to \mu^+\nu\mu^+\mu^-$ [KAON2025]
- $K^+ \to e^+\nu\gamma$ [KAON2025]
- $K^+ \to \pi^+\pi^+\pi^-\gamma$ [KAON2025]

$K^+ \to \pi^+\nu\bar{\nu}$

- 2016 data [PLB 791 (2019) 156]
- 2017 data [JHEP 11 (2020) 042]
- 2018 data [JHEP 06 (2021) 093]
- 2021-2022 data [JHEP 02 (2025) 191]
- 2023-2024 [this talk]

Forbidden decays

- $K^+ \to \pi^-\ell^+\ell^+$ [PLB 797 (2019) 134794]
- $K^+ \to \pi\mu e$ & $\pi^0 \to \mu e$ [PRL 127 (2021) 131802]
- $K^+ \to \pi^-(\pi^0)e^+e^-$ [PLB 830 (2022) 132172]
- $K^+ \to \mu^-\nu e^+e^+$ [PLB 838 (2023) 137679]
- $K^+ \to \pi^0\pi\mu e$ [PLB 859 (2024) 139122]

Invisible particles

- $\pi^0 \to \gamma A'$ [JHEP 05 (2019) 182]
- $K^+ \to e^+N$ [PLB 807 (2020) 135599]
- $\pi^0 \to$ inv. [JHEP 02 (2021) 201]
- $K^+ \to \mu^+ +$ inv. [PLB 816 (2021) 136259]
- $K^+ \to \pi^+ +$ inv. [JHEP 11 (2025) 143]
- $\pi^+ \to e^+N$ [PLB 872 (2026) 140119]

Dump Mode

- $A' \to \mu^+\mu^-$ [JHEP 09 (2023) 035]
- $A' \to e^+e^-$ [PRL 133 (2024) 111802]
- $A' \to$ hadrons [EPJC 85 (2025) 571]

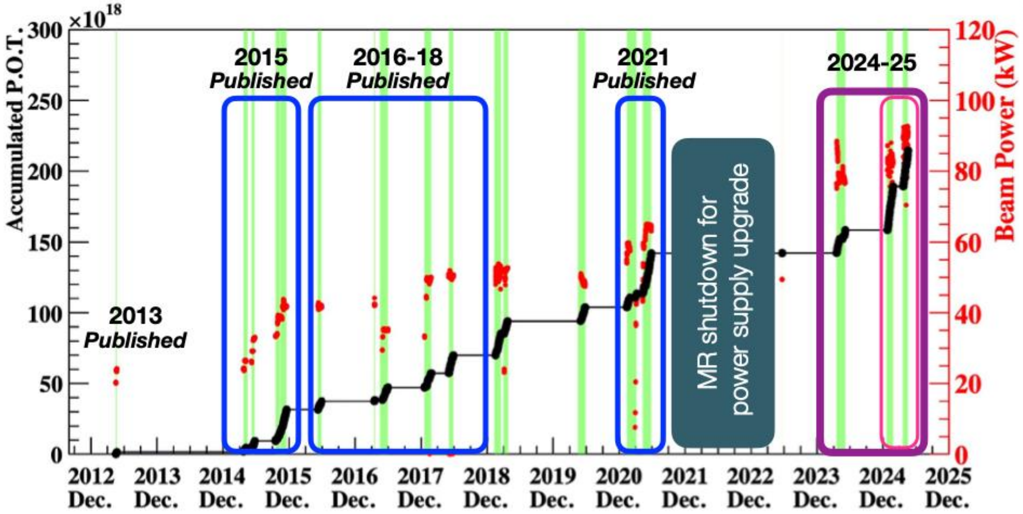
Neutrino Tagging: [PLB 863 (2025) 139345]

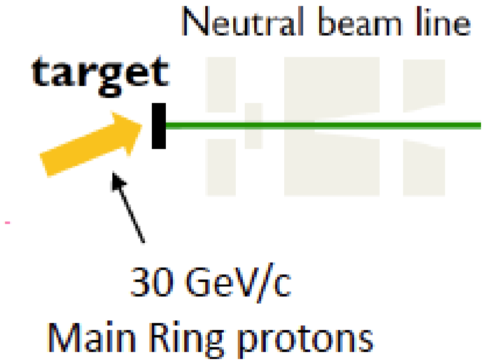
The KOTO Experiment

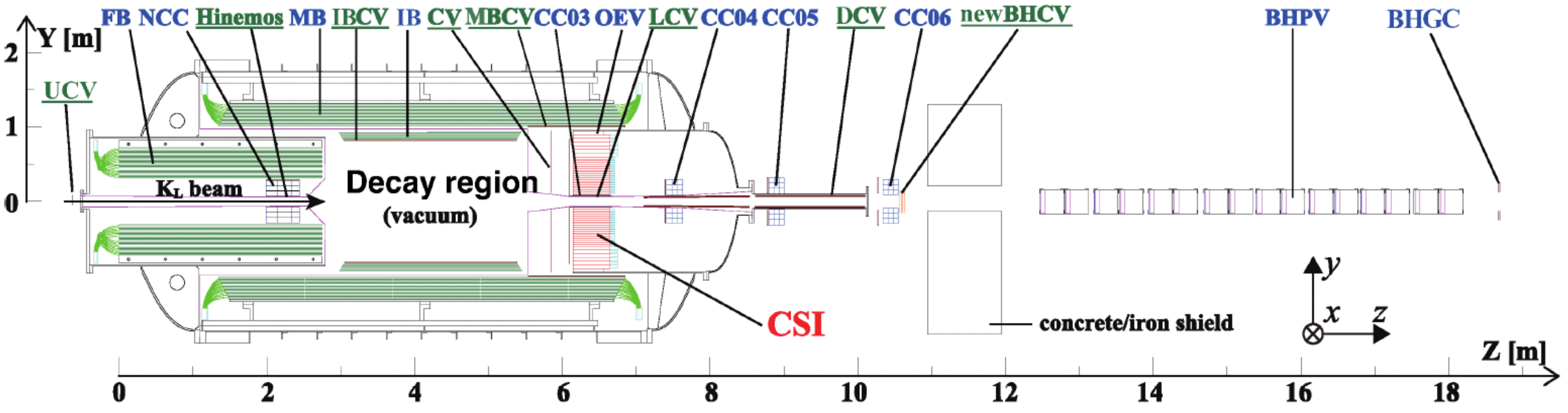
Search for $K_L \to \pi^0 \nu \bar{\nu}$ @ J-PARC

Primary 30 GeV/c protons on gold target located in HEF
Secondary neutral beam (K_L, neutrons, photons)
✓ beam angle ~16°, 7.8 μsr "pencil" beam
✓ K_L momentum peak: 1.4 GeV/c
✓ K_L flux: 2.1 x10^{-7} per proton on target
✓ Fiducial decay region ~3 m

PTEP 2017 (2017) 021C01
PRL 122 (2019) 021802
PRL 126 (2021) 121801
[PRL 134 (2025) 081802]







Lead-scintillator sandwich
Plastic scintillator counter
CsI Calorimeter from KTeV

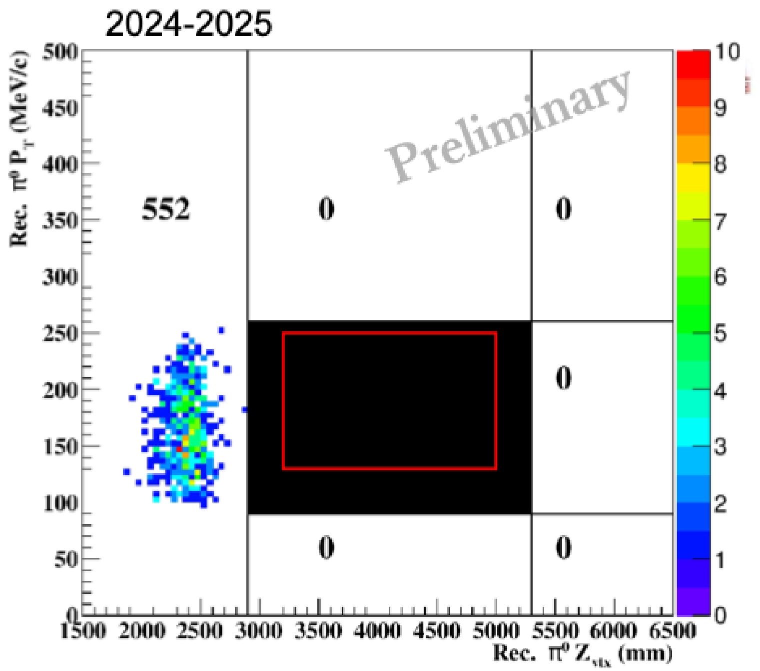
Hermetic photon detection & veto systems →

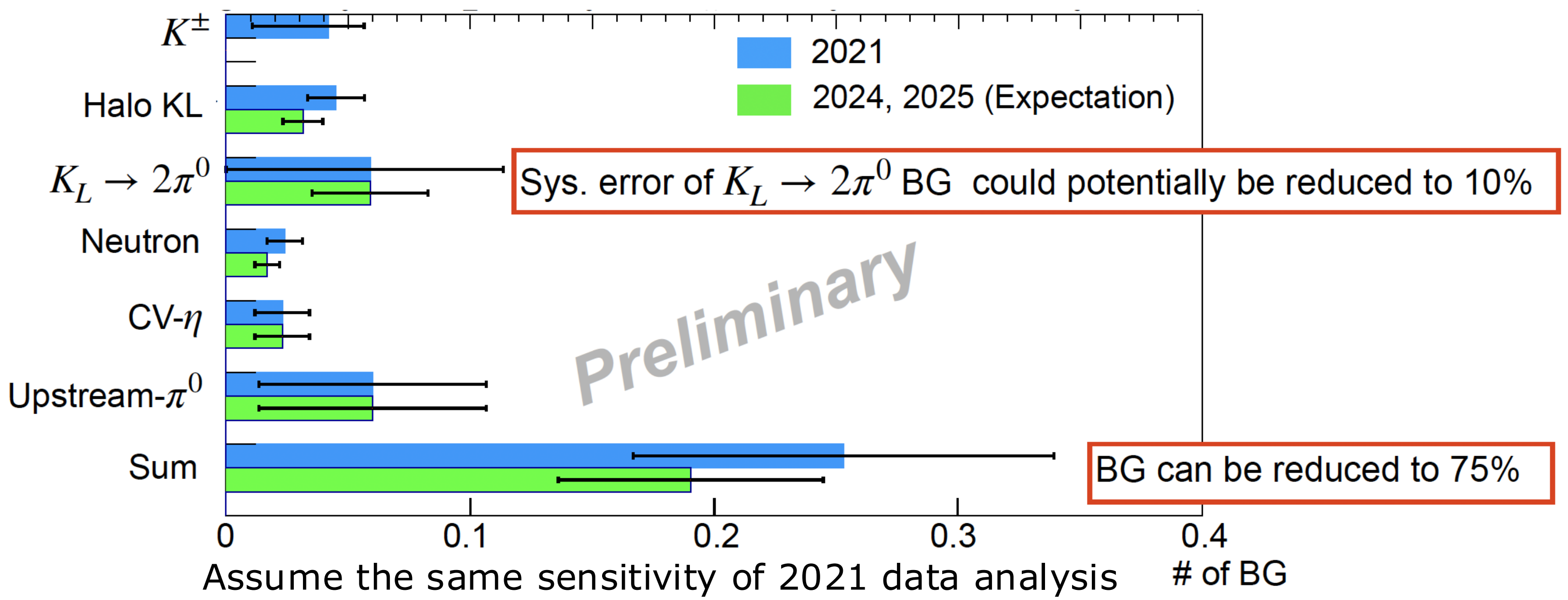
Signal: 2 photons from π^0
+ nothing else in detector

KOTO Prospects

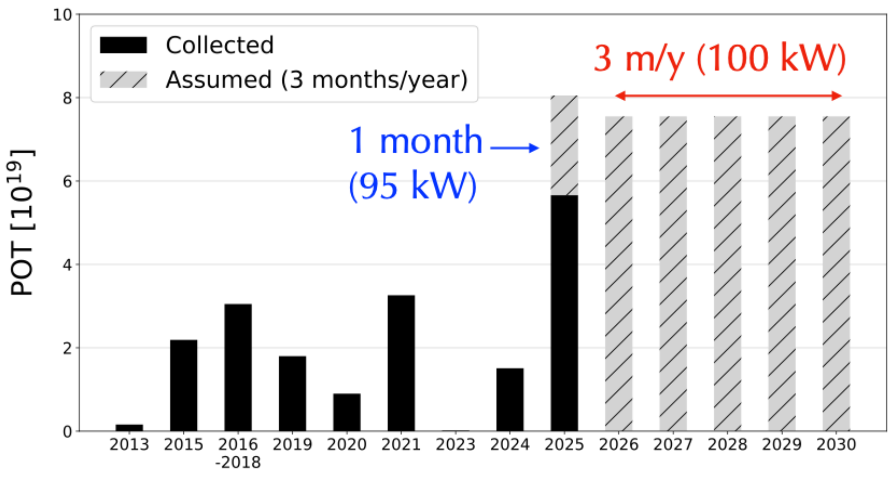
KOTO upgrades (2021-23)
- ✓ Upstream Charged Veto
- ✓ Permanent magnet at the end of beam-line
- ✓ DAQ system

Analysis of KOTO 2024-25 data
- ✓ x2 statistics of 2021 data
- ✓ expected bkg improvement wrt 2021 data analysis





Assume the same sensitivity of 2021 data analysis



Accumulated POT will reach ×10 more than 2021 data around 2028

Improved conditions for $K_L \to \pi^0\nu\nu$ search thanks to the upgrades

KOTO: broader programme

Taken in our standard trigger mixing
Special trigger (run) required

Other K_L decay search @ KOTO

EM: γ or e^+/e^-

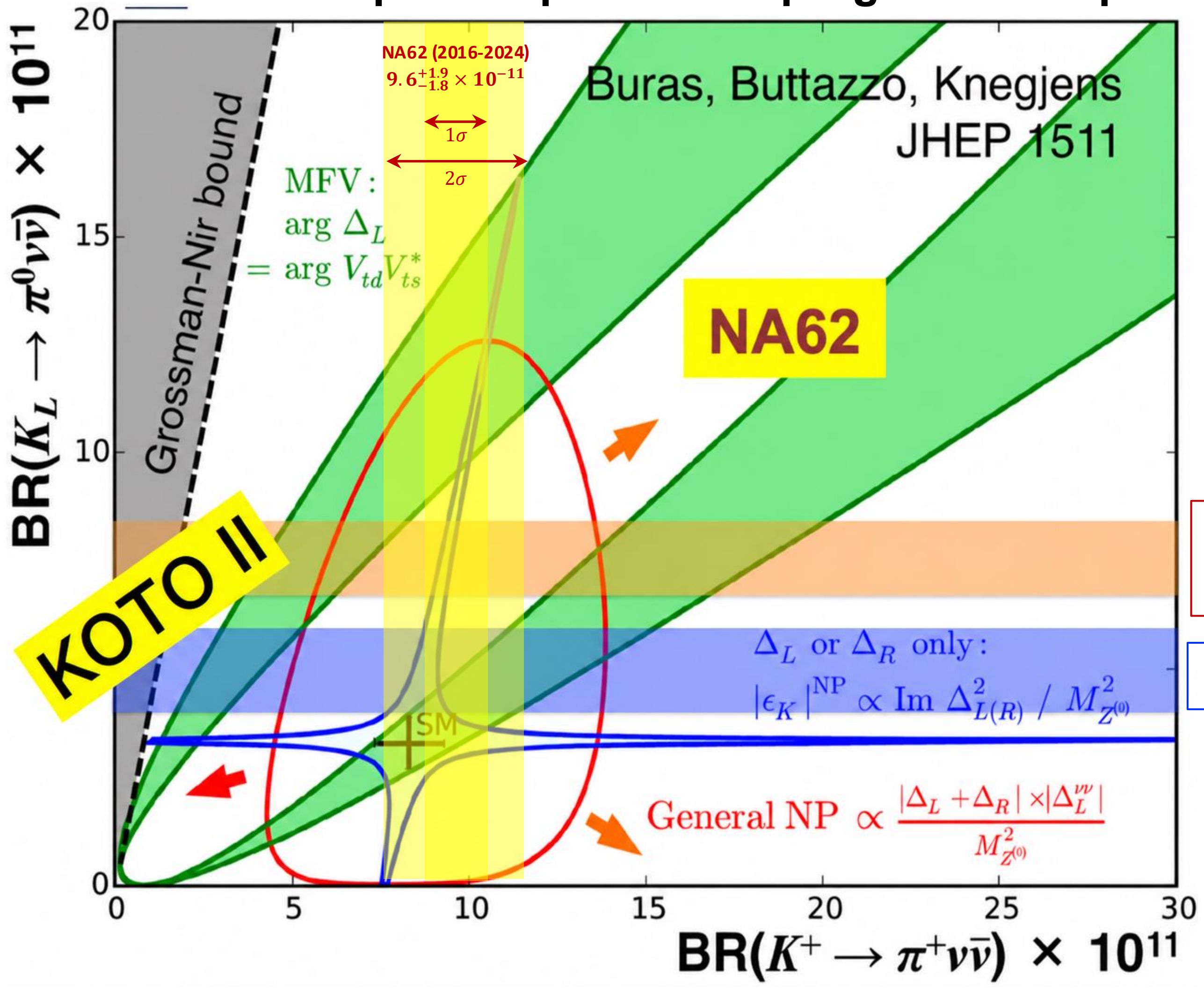
- **1γ** $K_L \to \gamma\bar{\gamma}$: Dark photon search
  - SES=2.9×10^{-8} (2 hours run), expected N_{BG}=12.7, observed 13 => BR<3.5×10^{-7} (90% CL)

Preliminary

- **2γ** $K_L \to \pi^0 X$ (X: invisible)
  - Simple byproduct of $K_L \to \pi^0\nu\bar{\nu}$ analysis
- **3γ** $K_L \to \pi^0\gamma$: Violating Lorentz invariance
  - (2016-18 data) SES=7.1×10^{-8}, estimated N_{BG}=0.34, No events observed, BR<1.7×10^{-7} (90% CL)
- **4γ** $K_L \to \pi^0\pi^0 X$ (X: invisible)
- **4γ** $K_L \to XX, X \to 2\gamma$
  - (2018 data) N_{BG}=0.61, No events observed.
  - BR<(1-4)$\times10^{-7}$ (M_X: 40-110MeV/c^2), BR<(1-2)$\times10^{-6}$ (M_X: 210-240MeV/c^2)
- **6γ** $K_L \to \pi^0\pi^0 X, X \to 2\gamma$
  - (2018 data) Maximal SES=4.5×10^{-9} in Mx=155-190MeV/c^2 *Preliminary*
  - (2021 data) Analyzing; Results coming soon
- **6EM** $K_L \to \pi^0 4e$
  - (2018 data) No events observed, BR<4.1×10^{-7} (90% CL)
- **4EM** $K_L \to \pi^0 e^+e^-$ … trial data accumulation in 2024 *Preliminary*
- **3EM** $K_L \to \gamma e^+e^-$ and/or $K_L \to \gamma A, A \to e^+e^-$ … data accumulation in 2025

KOTO II: Impact & Global picture

A complete experimental programme requires both the charged and neutral modes



- 100kW beam, 3×10^7 s = 6.3×10^{20} P.O.T
- SES: 8.5×10^{-13}, S/B=0.9
- 35 SM signal / 40 background events
  - → 5.6σ observation
- ΔB/B = 25% for SM value of branching fraction

Example
250% deviation from SM

70% deviation from SM

KOTO II sensitivity:

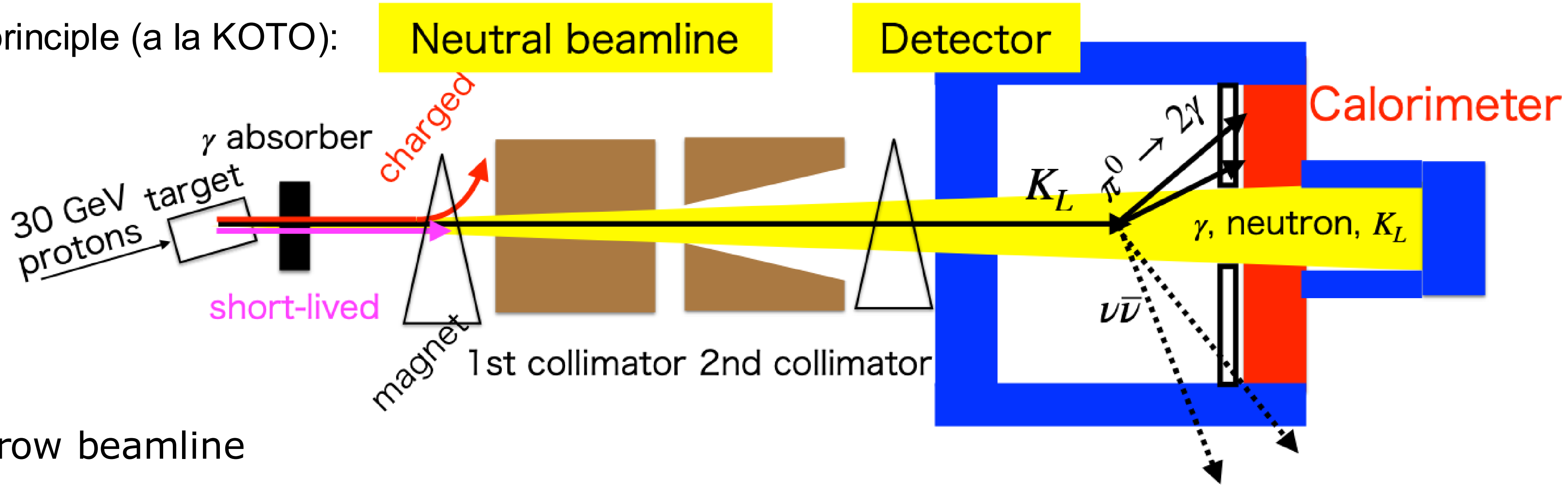
deviations of ~40% from the SM can be probed at 90% C.L.

May find New Physics or severely constrain it

Charged + neutral modes distinguish the flavour structure of new physics

KOTO II: Experimental Principle

Experimental principle (a la KOTO):

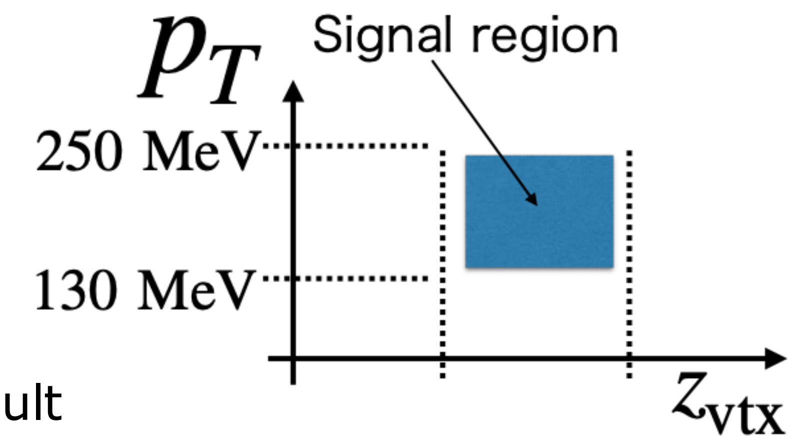


Long, narrow beamline

Signal: π^0 ($\to\gamma\gamma$) + nothing else
Higher p_T of π^0 (due to two missing neutrinos)

Detector:

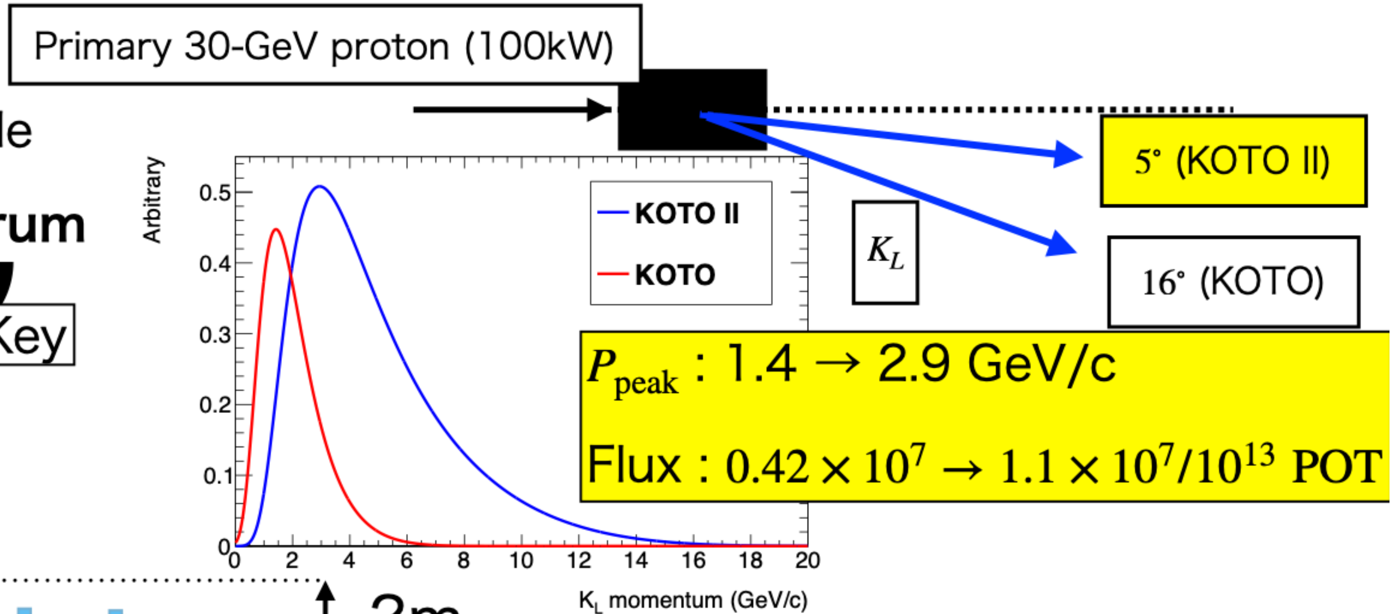
- Calorimeter to detect 2γ
  - Reconstruct π^0 assuming Z vertex on beam axis
- Hermetic veto counters
  - Need to cover beam hole where detector operation is difficult

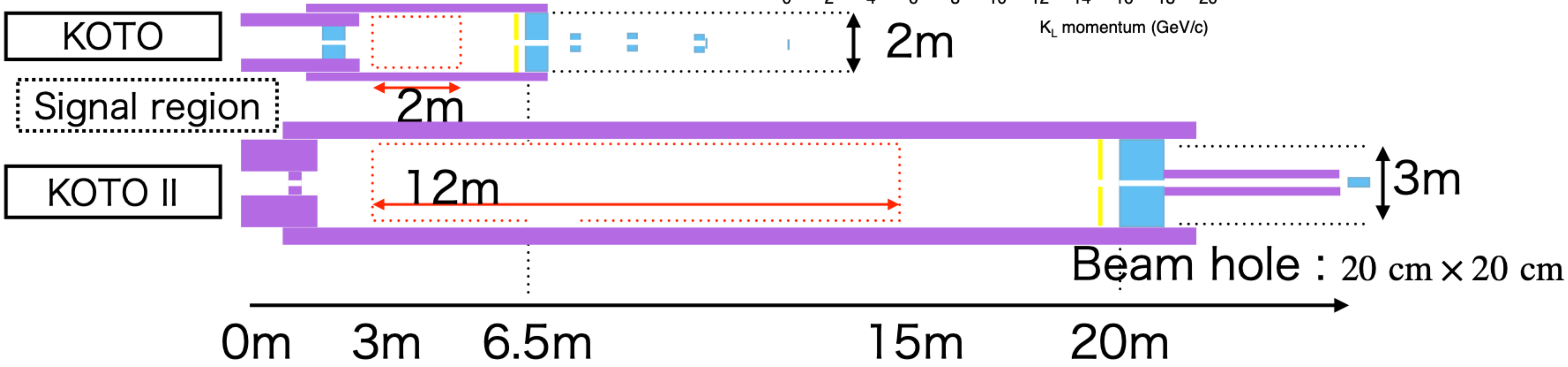


KOTO II: Sensitivity Improvements

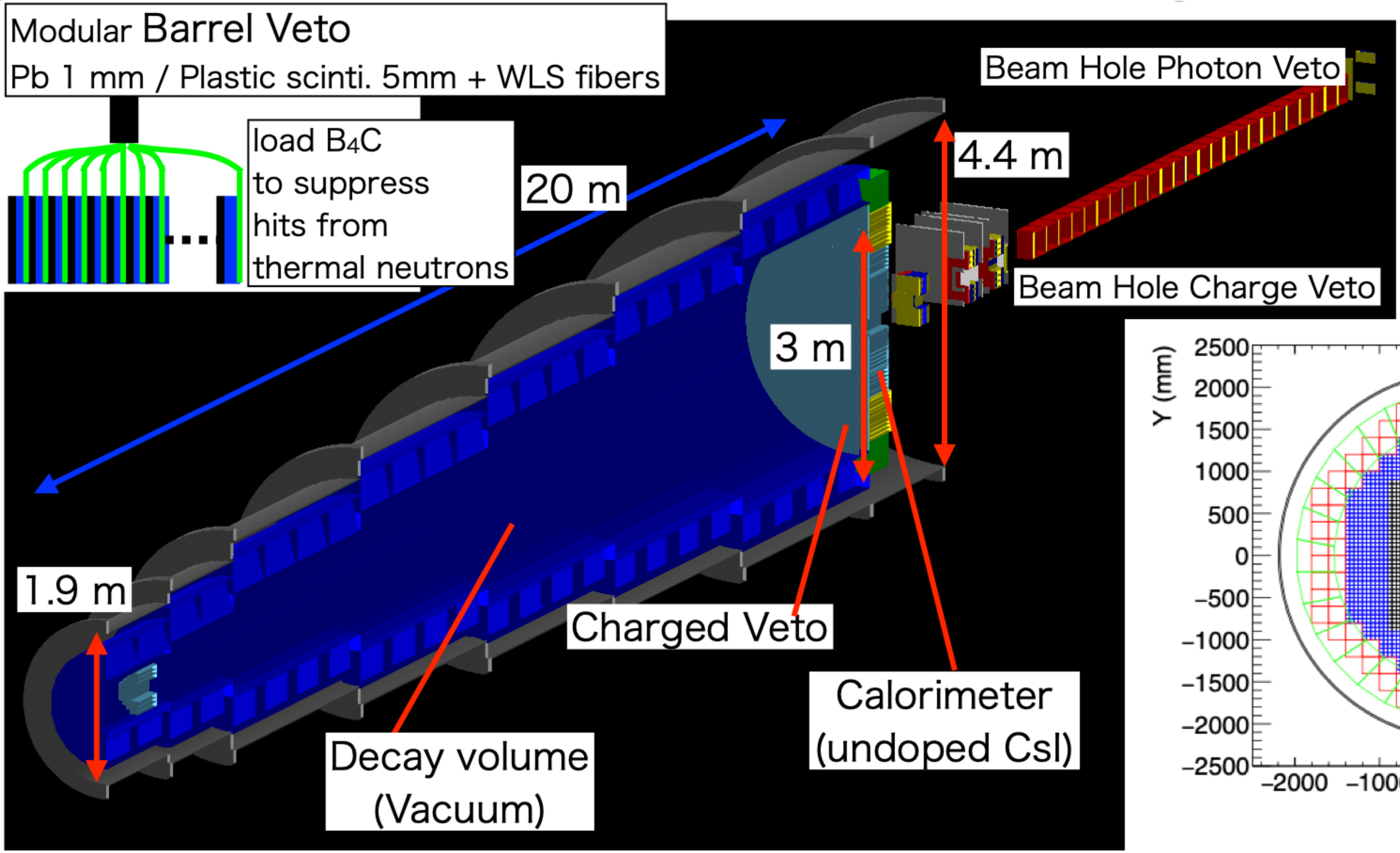
Key factors to improve the sensitivity:

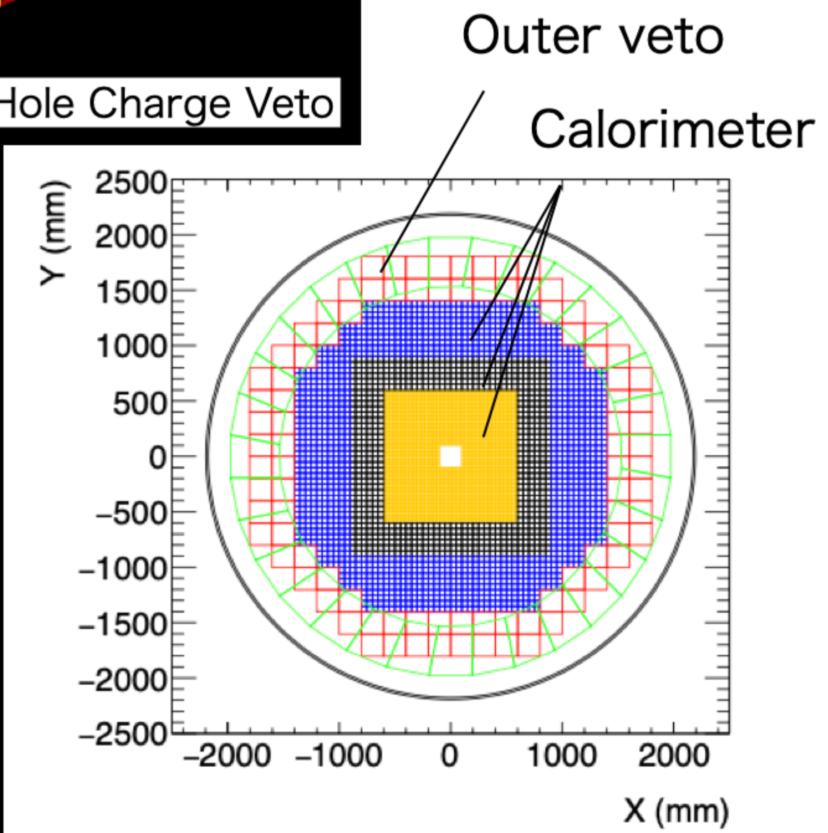
- More K_L
  - Use forward production angle
    - $\times$ 2.6 flux + **harder spectrum**
- More signal acceptance
  - Longer decay volume
  - Larger calorimeter





KOTO II: Detector (Base Design)





$K_L \to \pi^0 \ell^+ \ell^-$ in the Standard Model

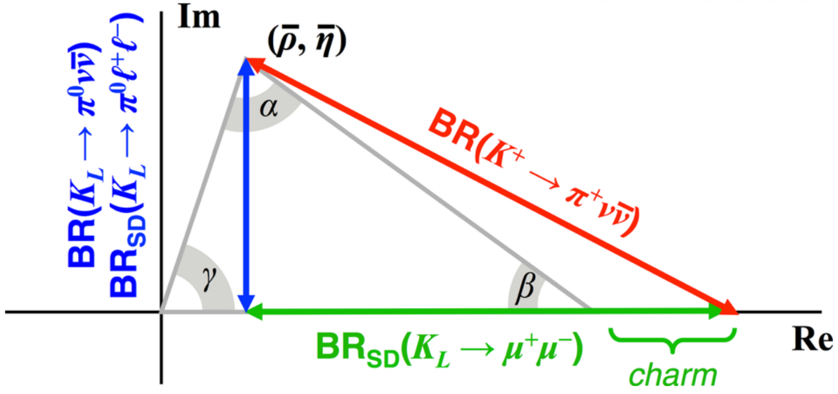
Contributions from long-distance physics

- SD CPV amplitude: γ/Z exchange
- LD CPC amplitude from 2γ exchange
- LD indirect CPV amplitude: $K_L \to K_S$

- $K_S \to \pi^0 \ell^+ \ell^-$ will help reducing theoretical uncertainties, measure $|a_S|$
  - measured NA48/1 with limited statistics
  - planned by LHCb Upgrade
- $K_L \to \pi^0 \ell^+ \ell^-$ can be used to explore helicity suppression in FCNC, give unique access to SD BSM effects in the photon coupling via the tau loop

[arXiv:hep-ph/0404127,arXiv:hpe-ph/0404136, arXiv:hep-ph/0606081]
[arXiv:0705.2025, arXiv:1812.00735, arXiv:1906.03046, https://indico.cern.ch/event/1196830/]

$K_L \to \pi^0 \ell^+ \ell^-$ CPV amplitude constrains UT η



$$\mathcal{B}(K_L \to \pi^0 e^+ e^-) = 3.54^{+0.98}_{-0.85} \left(1.56^{+0.62}_{-0.49}\right) \times 10^{-11}$$
$$\mathcal{B}(K_L \to \pi^0 \mu^+ \mu^-) = 1.41^{+0.28}_{-0.26} \left(0.95^{+0.22}_{-0.21}\right) \times 10^{-11}$$

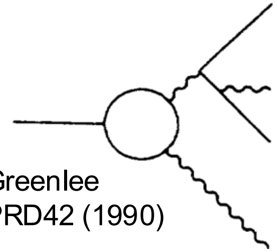
(2 sets of values corresponding to constructive (destructive) interference btw direct and indirect CP-violating contributions)

Experimental bounds from KTeV: **$BR(K_L \to \pi^0 e^+ e^-) < 28 \times 10^{-11}$**
$BR(K_L \to \pi^0 \mu^+ \mu^-) < 38 \times 10^{-11}$

Phys. Rev. Lett. 93 (2004) 021805
Phys. Rev. Lett. 84 (2000) 5279–5282

Main background: $K_L \to \ell^+ \ell^- \gamma\gamma$
- Like $K_L \to \ell^+ \ell^- \gamma$ with hard bremsstrahlung

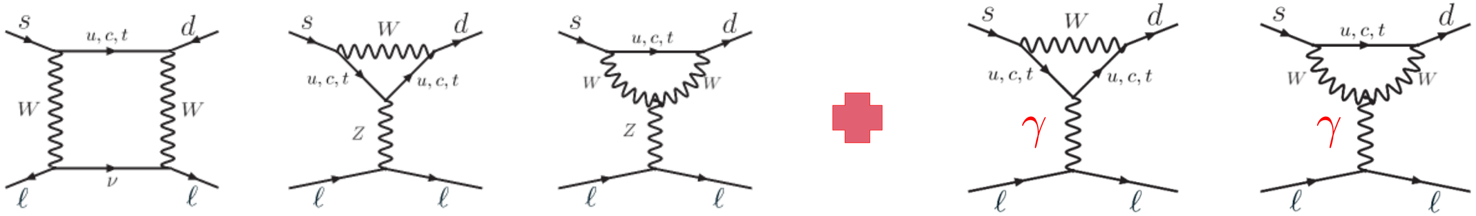
$BR(K_L \to e^+ e^- \gamma\gamma) = (6.0 \pm 0.3) \times 10^{-7}$ $E_\gamma^* > 5$ MeV
$BR(K_L \to \mu^+ \mu^- \gamma\gamma) = 10^{+8}_{-6} \times 10^{-9}$ $m_{\gamma\gamma} > 1$ MeV



Greenlee PRD42 (1990)

$K_L \to \pi^0 \ell^+ \ell^-$ and New Physics

[D'Ambrosio, Iyer, Mahmoudi, Neshatpour 2206.14748, 2311.04878, 2404.03643]

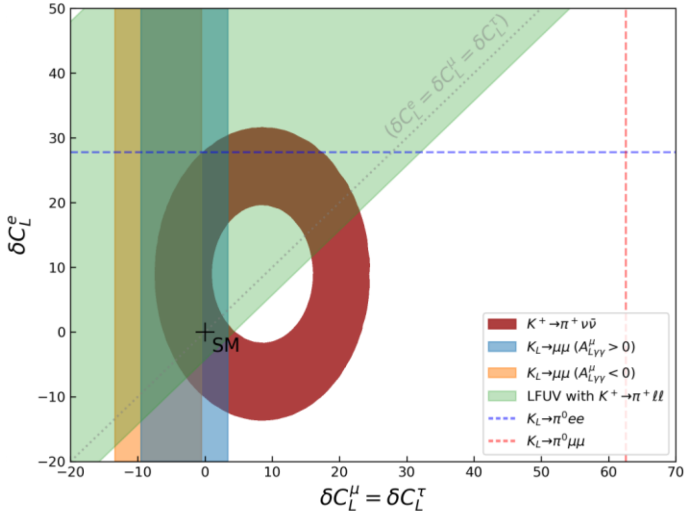


Access to photon coupling Can be used to explore helicity suppression in FCNC decays, give unique access to SD BSM effects in γ coupling via τ loop

We assume NP contributions of the charged and neutral leptons related to each other by the SU(2)$_L$ gauge symmetry and we work in the chiral basis

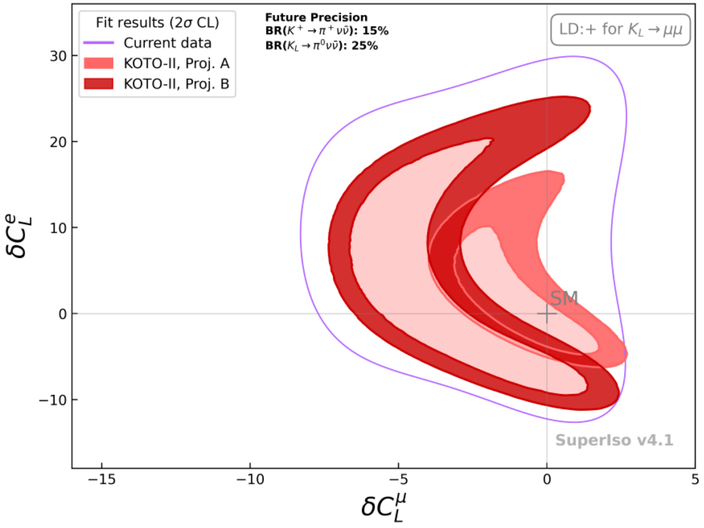
$$\delta C_L^\ell \equiv \delta C_9^\ell = -\delta C_{10}^\ell \qquad \delta C_L^e \neq \delta C_L^\mu = \delta C_L^\tau$$

Lepton Flavour Universality Violation:



Bounds from individual observables:

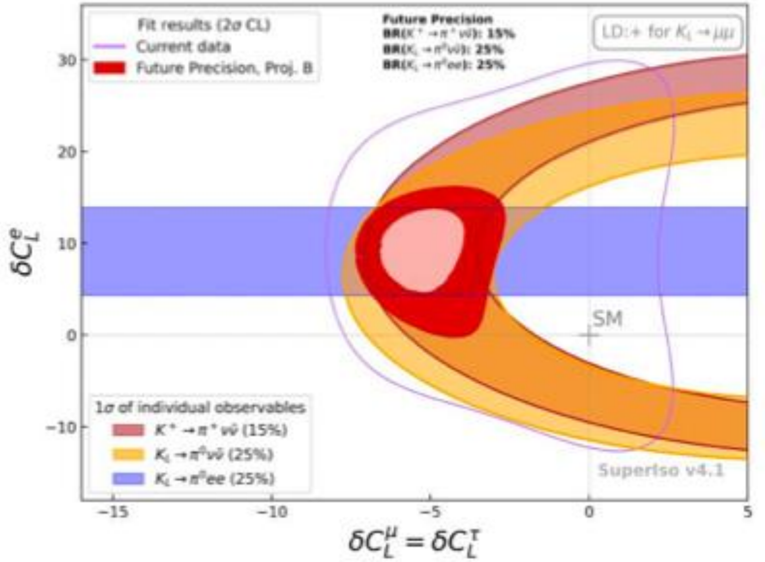
Coloured regions: 68% CL measurements
Dashed lines: 90% upper limits



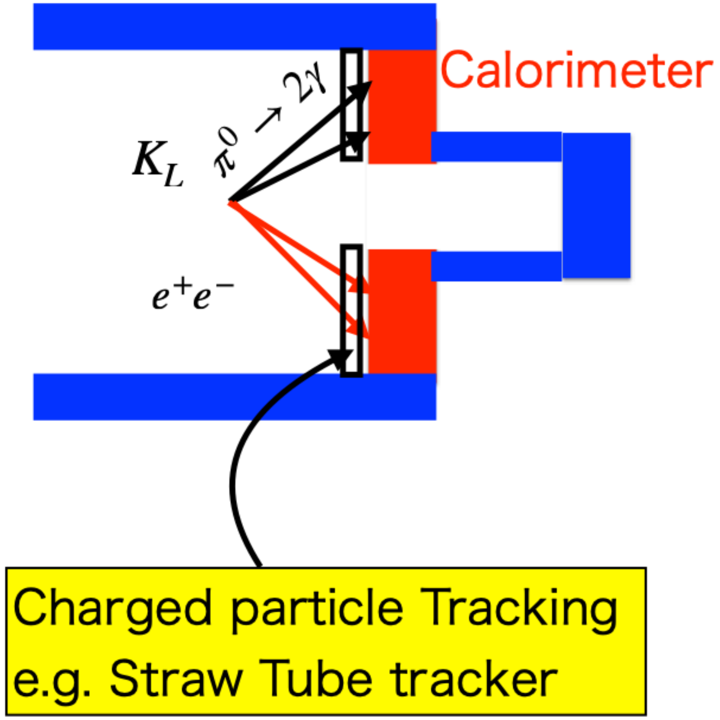
Projec on A
Observables already measured are kept, others assumed at their SM values, all with target precision of KOTO-II

Projec on B
All measurements give current best-[t point with target precision of KOTO-II

Impact on LFUV tests
$s \to d\ell\ell + s \to d\nu\bar\nu$



Measurement of $K_L \to \pi^0 \ell^+ \ell^-$ in KOTO II



- $K_L \to \pi^0 e^+ e^-$
- Additional charged particle tracker (Two layers)
- Vertex reconstruction with the two tracks
  $\to$ Better resolution
- Reconstruct K_L and π^0 with better resolution
  - BG : $K_L \to e^+ e^- \gamma\gamma$
- 3.6σ observation is expected in KOTO II
  $\to$ Discussion of further improvement
- $K_L \to \pi^0 \mu^+ \mu^-$ is also under study.

Compatibility with neutrino channel is under study
Probably, a second phase of KOTO II with dedicated tracking