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Tong	Wu	$K_L^0 \to \gamma + dark\,photon(\bar{\gamma})$ Search at the J-PARC KOTO Experiment
Joseph	Redeker	Data Acquisition System Upgrade at KOTO
YU-CHEN	TUNG	Analysis Techniques for Neutron Background Suppression at KOTO
Keita	Ono	Thin scintillation counter with a new readout method for the KOTO experiment
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Opening

Overview of Kaon Physics

- Jason Aebischer
- University of Zurich

TBD.

Rare K Decays

Status of the NA62 experiment at CERN

- Cristina Lazzeroni
- University of Birmingham (GB)

The NA62 experiment is approved to take data until CERN long shutdown 3, with the main goal to collect of the order of 100 candidates $K^+ \to \pi^+\nu\overline{\nu}$ events and to measure the corresponding branching ratio with precision of the order of 10%. The experiment has resumed data taking in 2021 after CERN long shutdown 2, with an upgraded beam line, a new configuration of the kaon tracker (Gigatracker), new detectors installed upstream of the decay region to intercept early kaon decays, and a refurbished small angle hadronic calorimeter (HASC). The 2021 run has been devoted to commissioning both the beam line and the new detectors. Presently NA62 is running at an intensity 40% higher than that of the 2018 data taking, corresponding to the design intensity. The present status of NA62 and the future prospects are discussed.

Measurement of the very rare $K^+ \to \pi^+\nu\overline{\nu}$ decay at the NA62 experiment

- Francesco Brizioli
- CERN

The $K^+ \to \pi^+\nu\overline{\nu}$ decay, with a very precisely predicted branching ratio of less than 10^{-10}, is among the best processes to reveal indirect effects of new physics. The NA62 experiment reports the branching ratio measurement $\mathrm{BR}(K^+ \to \pi^+\nu\overline{\nu} = (10.6^{+4.0}_{-3.4}|_{\mathrm{stat}} \pm 0.9|_{\mathrm{syst}}) \times 10^{-11}$ at 68% CL, based on the observation of 20 signal candidates with an expected background of 7.0 events from the total data sample collected at the CERN SPS during 2016-2018. This provides evidence for the very rare $K^+ \to \pi^+\nu\overline{\nu}$ decay, observed with a significance of 3.4. This measurement is also used to set limits on $\mathrm{BR}(K^+ \to \pi^+ X)$, where X is a scalar or pseudo-scalar particle. The details of the full data analysis are reviewed.

Search for the $K_L \to \pi^0\nu\overline{\nu}$ decay at the J-PARC KOTO experiment

- Koji Shiomi
- KEK

The KOTO experiment at the J-PARC 30GeV Main Ring is dedicated to search for the rare decay $K_L \to \pi^0\nu\overline{\nu}$. In the previous analysis on data taken in 2016-18, we found three candidate events, which are statistically consistent with the background expectation. The main background source was the charged kaon contamination in the neutral beam. Since 2020, we have accumulated physics data with a new counter to detect the charged kaons. In this presentation, we will report analysis results of 2021 data which has a similar sensitivity as the 2016-2018 data.

Standard Model predictions for CP violating and rare Kaon decays

- Martin Gorbahn
- University of Livepool

The CP violating parameters ε_K and ε'/ε, as well as the branching ratio of the rare decay $K \to \pi\bar{\nu}\nu$ are highly suppressed in the Standard Model and particularly sensitive to flavour violating new physics. In this talk I will discuss the status of the Standard Model prediction of these observables using an improved organisation for the perturbation theory for the parameter ε_K based on work with J. Bord and E. Stamou. I will also present the relevant Lattice matching calculations performed in collaboration with S. Jager and S. Kvedaraite and the electroweak matching calculations performed in collaboration with E. Stamou and H. Yu. I will also give an outlook on how to improve the precision of these predictions in the future.

Lattice QCD calculations of rare kaon decays

- Xu Feng
- Peking University

In this talk, I will give a status report and prospects of lattice QCD studies of rare kaon decays.

Implications of $b \to s\mu\mu$ Anomalies for Future Measurements of $B \to K^{(*)}\nu\bar{\nu}$ and $K \to \pi\nu\bar{\nu}$

- Martin Novoa-Brunet
- INFN Sezione di Bari

We investigate the consequences of deviations from the Standard Model observed in $b \to s\mu\mu$ transitions for flavour-changing neutral-current processes involving down-type quarks and neutrinos. We derive the relevant Wilson coefficients within an effective field theory approach respecting the SM gauge symmetry, including right-handed currents, a flavour structure based on approximate $U(2)$ symmetry, and assuming only SM-like light neutrinos. We discuss correlations among $B \to K^{(*)}\nu\bar{\nu}$ and $K \to \pi\nu\bar{\nu}$ branching ratios in the case of linear Minimal Flavour Violation and in a more general framework, highlighting in each case the role played by various New Physics scenarios proposed to explain $b \to s\mu\mu$ deviations.

Strange processes in general 2HDM

- Girish Kumar
- National Taiwan University

We discuss new physics (NP) contribution to kaon mixing parameters ϵ_K and ΔM_K, direct CP violation ϵ'/ϵ parameter of $K \to \pi\pi$, and rare decays $K^+ \to \pi^+\nu\bar{\nu}$, $K_L \to \pi^0\nu\bar{\nu}$, and $K_{L,S} \to \mu^+\mu^-$ in context of general two Higgs doublet model (g2HDM). We focus on contribution of top related exotic couplings, and show that simultaneous presence of flavor conserving and flavor violating interactions leads to very large NP effects in kaon sector, while being consistent with stringent constraints from B-meson processes such as B-mixing, $B_s \to \mu\mu$, and $b \to s\gamma$. We stress on the importance of correlations between ϵ_K, $K \to \pi\nu\bar{\nu}$, and $B_s \to \mu\mu$ that can be exploited to distinguish the parameter space corresponding to a light (sub-TeV) or heavy (TeV) scale charged Higgs (H^+). One important implication of these correlations in g2HDM is that $K^+ \to \pi^+\nu\bar{\nu}$ is, in a rather counter intuitive fashion, more sensitive to a heavy H^+ as opposed to a light H^+.

CP, T and CPT Violations

Direct CP violation in $K \to \pi\pi$ decay on the lattice with periodic boundary conditions

- Masaaki Tomii
- UConn

Since our recent publication on direct CP violation and the Delta I = 1/2 rule in $K \to \pi\pi$ decay which was made with G-parity boundary conditions, we have revisited this problem with a conventional lattice setup employing periodic boundary conditions and two lattice spacings to check our previous result and to improve the precision. We show that the physical amplitude, which corresponds to an excited state in this case, can be obtained reliably with the Generalized Eigenvalue Problem (GEVP) method. Not only are periodic boundary conditions cheaper and allow the use of existing ensembles to take the continuum limit, but they provide a straightforward path to introduce electromagnetism and strong isospin symmetry breaking, which will be needed in the near future. In this talk, we show our preliminary results on 24^3 and 32^3 lattices and discuss the prospect of the high-precision calculation of $K \to \pi\pi$ decay with periodic boundary conditions.

Two-loop Electroweak Corrections to ϵ_K

- Sandra Kvedaraite
- University of Cincinnati

The parameter ϵ_K measures CP violation in the neutral kaon system. It is a sensitive probe of new physics and plays a prominent role in the global fit of the Cabibbo-Kobabyashi-Maskawa matrix. As one of the first discovered sources of CP violation, it has been measured in experiment to per-mil precision. A simple re-parametrization of the effective Hamiltonian has been recently shown to drastically reduce the perturbative errors coming from the charm-quark corrections, making the electroweak corrections relevant. In this talk, I will present the two-loop electroweak corrections to ϵ_K.

A direct test of the T and CPT symmetries in transitions of neutral kaons with KLOE data

- Antonio Di Domenico
- Sapienza University of Rome and INFN-RM1

The comparison of neutral meson transition rates between flavour and CP eigenstates allows direct and model independent tests of time-reversal T and CPT symmetries. To date, direct T test measurements were only realized with entangled neutral B mesons. The same measurement principle was applied to ∼1.7 fb−1 KLOE data acquired at the DAΦNE e^+e^- collider, through ratios of rates of two classes of processes:$K_S K_L \to \pi^\pm e^\mp \nu, 3\pi^0$ and $K_S K_L \to \pi^+\pi^-, \pi^\pm e^\mp \nu$. In addition to this a straightforward extension to the case of CPT symmetry was performed providing us with the first model independent test of CPT symmetry violation in transitions of neutral kaons.

CKM Matrix

Leptonic and semileptonic kaon decays and neutral kaon mixing from lattice QCD

- Takashi Kaneko

- KEK

We review recent progress on the kaon (semi)leptonic decays and neutral kaon mixing from lattice QCD.

Kaon semileptonic form factors at the physical quark masses on large volumes in Nf=2+1 lattice QCD

- Takeshi Yamazaki
- University of Tsukuba

We present our results for the kaon semileptonic form factors calculated by using two sets of the PACS10 configuration, whose physical volumes are more than (10 fm)^4 at the physical light and strange quark masses in the lattice spacings of 0.063 and 0.085 fm. The configurations were generated using the Iwasaki gauge action and Nf=2+1 stout-smeared clover quark action. The form factors near zero momentum transfer can be calculated thanks to the large volume. Using our data, a stable interpolation of the form factors to zero momentum transfer is carried out. The value of $|V_{us}|$ is determined using the interpolated result of the form factors at zero momentum transfer. Our value of $|V_{us}|$ is compared with a prediction of the standard model estimated from the CKM matrix unitarity and with those determined using recent lattice results. We also evaluate the phase space integral using our form factors. The values of $|V_{us}|$ are determined with our results of the phase space integrals in six semileptonic decay processes, and they are compared with the one with the form factor at zero momentum transfer.

QED x QCD matching between the MS-bar and the RI schemes

- Francesco Moretti
- University of Liverpool

A systematic treatment of electromagnetic and strong corrections to the semi-leptonic decays is needed in order to have a precise determination of V_{us}. Under the presence of QED, the matrix element of the effective operator on the lattice has to be renormalised, thus requiring a matching to the continuum results. To this end, in collaboration with Dr. M. Gorbahn, Dr. S. Jäger and Mr. E. van der Merwe, we calculated the corresponding pertubative matching calculations and studied the different combined $O(\alpha\alpha_s)$ loop corrections. A particular emphasis of our work lies on different choices of renormalisation conditions, based on the definition of kinematics and suitable projectors, and the impact of these on the resulting matching coefficients. In particular, we have found that the renormalization conditions as defined and used in the literature thus far lead to extraneous and unnecessary QCD contributions that reflect in an artificial dependence on the lattice matching scale. We suggest improvements to rectify this problem and present the calculation for Leading-Log and Next-to-Leading-Log strong corrections to the electromagnetic contributions.

Sterile neutrinos in light of the Cabibbo-angle anomaly

- Teppei Kitahara
- Nagoya University

Based on recent developments in the lattice simulations and calculations of the radiative corrections to the charged-current interactions, the uncertainties for each component in the CKM matrix have been sophisticated. It is known that the first-row CKM unitarity is violated at 3 sigma level, implying a 3 sigma level deviation from the standard model prediction. This new deviation is called Cabibbo-Angle

Anomaly (CAA). These CKM components are mainly extracted from kaon, pion, and the superallowed beta decays. In this contribution, we point out that a MeV scale sterile neutrino can economically explain the CAA. We consistently investigate the sterile neutrino contributions to the kaon, pion, superallowed beta decays, and also the Fermi constant (muon decay). This contribution is based on an ongoing project collaborating with Kohsaku Tobioka.

Semileptonic Decays

A new $K_S \to \pi e \nu$ branching fraction measurement from KLOE-2

- Erika De Lucia
- INFN

The KLOE-2 Collaboration continues the KLOE long-standing tradition of flavour physics precision measurements in the kaon sector with a new $K_S \to \pi e \nu$ branching fraction measurement. Based on a sample of 300 million K_S mesons produced in $\phi \to K_L K_S$ decays recorded by the KLOE experiment at the DAΦNE e^+e^- collider, the $K_S \to \pi e \nu$ signal selection exploits a boosted decision tree built with kinematic variables together with time-of-flight measurements. A fit to the reconstructed electron mass distribution provides the signal yield, then normalised to $K_S \to \pi^+\pi^-$ decays. Data control samples of $K_L \to \pi e \nu$ decays are used to evaluate signal selection efficiencies. The combination with our previous BR($K_S \to \pi e \nu$) measurement, based on an independent data sample, allows the total precision to be improved by almost a factor of two, and a new derivation of $f_+(0)|V_{us}|$.

Covariant flavour effects in semileptonic K and D decays

- Nejc Kosnik
- Jozef Stefan Institute and University of Ljubljana

In this talk we present constraints on the left-handed dimension-6 interactions that lead to semileptonic and leptonic decays of K and D mesons, as well as pion and beta decays. We employ the flavour covariant description of the effective couplings, identify universal CP phases of New Physics and derive constraints from decay rates and CP-odd quantities. As a result we can predict maximal effects of such flavoured NP in D decays from stringent K decay constraints, and vice-versa.

First measurement of the $K^\pm \to \pi^0\pi^0\mu^\pm\nu$ decay

- Anna Korotkova
- JINR

The first observation of the decay $K^\pm \to \pi^0\pi^0\mu^\pm\nu$ (K00µ4) by the NA48/2 experiment at the CERN-SPS is reported. From 2437 selected signal candidates with 15% background contamination, the branching ratio of the decay is measured in the restricted kinematical space of the squared dilepton mass above 0.03 GeV2/c4 and extrapolated to the full kinematical space. The result is found to be in agreement with the R form factor from 1-loop Chiral Perturbation Theory.

Lepton Number Violation

Searches for lepton flavour and lepton number violating K+ decays at the NA62 experiment

- Jan Jerhot

- CP3 UCLouvain

The NA62 experiment at CERN collected world's largest dataset of charged kaon decays to di-lepton final states in 2016-2018, using dedicated trigger lines. Upper limits on the rates of several K+ decays violating lepton flavour and lepton number conservation, obtained by analysing this dataset, are presented.

Kaons at LHCb

- LHCb -
- -

Rare decays are fundamental probes for physics beyond the Standard Model, and the expanding LHCb program on strange physics provides unique and complementary information with respect to the beauty and charm sectors. Results of rare kaon decays at LHCb will be summarised and prospects for strange physics with LHCb Upgrade I, where the change in trigger strategy will allow for a much higher selection efficiency of kaon decays, will be outlined.

Radiative Decays

Radiative Kaon Decays

- Filippo Mazzetti
- Roma Tre University

With the huge improvement in the precision of lattice QCD results, increasingly QED corrections are included. In this talk the status of computations of rates for the decays K-to-lepton+neutrino+photon and K-to-lepton+neutrino+charged leptons together with a comparison with existing experimental results (see arXiv:2006.06358, 2012.02120, 2103.11331 and 2202.02833) will be presented. The comparison provides some interesting puzzles which would be useful to discuss in a general forum of kaon physicists.

Measurement of structure dependent radiative $K^+ \to e^+\nu\gamma$ decays using stopped positive kaons

- Suguru Shimizu
- Osaka University

The J-PARC E36 experiment is aiming at searching for the lepton universality violation by precisely measuring the ratio of the branching ratio of the $K^+ \to e^+\nu$ (K_{e2}) to $K^+ \to \mu^+\nu$ ($K_{\mu 2}$) decays. The E36 experiment was performed at J-PARC employing a stopped K^+ beam in conjunction with a 12-sector iron-core superconducting toroidal spectrometer. Charged particle momenta were calculated by reconstructing the tracks in the spectrometer. Particle discrimination between e^+ and μ^+ was carried out using an aerogel Cherenkov counters and a lead-glass Cherenkov counter, as well as by measuring the time-of-flight between TOF counters.

The peak structure due to the K_{e2} decays was successfully observed in the e^+ momentum spectrum. The structure-dependent radiative $K^+ \to e^+\nu\gamma$ ($K^{\rm SD}_{e2\gamma}$) events were selected by requiring one photon hit in the CsI(Tl) calorimeter. The experimental spectra were reproduced by the Monte Carlo simulation, which indicates a correct understanding of the detector acceptance. The $Br(K^{\rm SD}_{e2\gamma})$ value relative to $Br(K_{e2})$ was obtained by calculating the ratio of the $K_{e2\gamma}$ and K_{e2} yields corrected for their detector acceptances. A value of $Br(K^{\rm SD}_{e2\gamma})/Br(K_{e2}) = 1.12 \pm 0.07_{\rm stat} \pm 0.04_{\rm syst}$ was obtained, which is larger than the value inferred from a previous experimental result for $Br(K^{\rm SD}_{e2\gamma})/Br(K^+ \to \mu^+\nu)$.

Measurement of the radiative decay Ke3g at the NA62 experiment

- Mauro Piccini
- INFN - Perugia

The NA62 experiment at CERN reports results from the study of radiative kaon decay $K^+ \to \pi^0 e^+ \nu\gamma$ (Ke3g), using a data sample recorded in 2017-2018. The sample comprises O(100k) Ke3g candidates with sub-percent background contamination. Results with the most precise measurement of the Ke3g branching ratio, and T-asymmetry measurement in the Ke3g decay, are presented.

Measurement of the $K^+ \to \pi^0 \mu^+ \nu_\mu \gamma$ decay with OKA setup

- Victor Kurshetsov
- Institute for High Energy Physics

The $K^+ \to \pi^0 \mu^+ \nu\gamma$ (Km3g) decay has been measured with OKA setup at the RF-separated 17.7 GeV/c momentum kaon beam of the U-70 accelerater. The data was collected in two run in 2012-2013 yrs. and corresponds to the flux of 2.62e+10 "live" kaons entering the decay volume. More than 900 signal events was found in the "standard" Particle Data Group (PDG) region of 30-60 MeV energy of the emitted photon in the rest frame of the decaing kaon. Using 4.48e+06 events sample of normalization decay $K^+ \to \pi^0 \mu^+ \nu$ (Km3), the branching ratio B(km3g)/B(km3) was found to be (4.49+/-0.37(stat))e-4. This value can be transformed (PDG B(km3)=3.352%) to B(km3g)=(1.51+/-0.12(stat))e-5. Our results are preliminary, with systematic errors being estimated.

Radiative modes $K \to \pi\gamma^*\gamma^{(*)}$ and the $K \to \pi 4e$ decay

- Tomas Husek
- Lund University

We discuss radiative transitions of a kaon to pion and two photons. In particular, we have a close look at radiative corrections for the $K^+ \to \pi^+ \ell^+ \ell^-$ decays and present the branching ratio of the $K^+ \to \pi^+ e^+ e^- e^+ e^-$ process calculated for the first time at leading order in the Standard Model.

Study of the rare decay $K^+ \to \pi^+ \gamma\gamma$ at the NA62 experiment

- Artur Shaikhiev
- University of Birmingham

The NA62 experiment at CERN reports new preliminary results from an analysis of the decay $K^+ \to \pi^+ \gamma\gamma$ using the data sample collected with a minimum-bias trigger in 2016–2018. The decay sample is about 15 times larger than the previous largest one, which along with the improved di-photon mass resolution, leads to an unprecedented sensitivity. The measurement represents an important test of the theories describing low-energy dynamics. The analysis can be naturally extended to search for the $K^+\pi^+ + a, a \to \gamma\gamma$ process, where a is a short-lived axion-like particle.

Measurement of the rare decay $K^+ \to \pi^+ \mu^+ \mu^-$ at the NA62 experiment

- Michal Koval
- Charles University

The NA62 experiment at CERN reports results from the study of the flavour-changing neutral current decay $K^+ \to \pi^+\mu^+\mu^-$ decay, using a data sample recorded in 2017–2018 with a dedicated pre-scaled di-muon trigger. The decay is induced at the one-loop level in the Standard Model, and is well suited to explore its structure and, possibly, its extensions. The sample comprises about 27k signal events with negligible background contamination, and the presented analysis results include the most precise determination of the the branching ratio and the form factor.

RD Search for $K_S(L) \to \mu\mu\mu\mu$ at the LHC

- LHCb -
- -

The $K^0 \to 4\mu$ decays are very suppressed in the Standard Model, with expected branching fractions at the level of $10^{-14}$for the short-living kaon (K^0_S) and 10^{-13} for the long-lived kaon (K^0_L). Those branching fractions can be enhanced by mediators from Dark Sector Models and become potentially detectable by LHCb with its Run-II dataset, especially via the decays of the short-living K^0 meson (K^0_S). A search for the decays $K^0_{\mathrm{S(L)}} \to \mu^+\mu^-\mu^+\mu^-$ is performed using 5.6 fb^{-1} of pp collisions collected by the LHCb experiment during Run II of the Large Hadron Collider.

Hadron Physics

Kaonic atoms with SIDDHARTA-2 at the DAFNE collider

- Francesco Sgaramella
- INFN-LNF

The study of kaonic atoms plays a key role for the understanding of the low-energy quantum chromodynamics (QCD) in the strangeness sector, by allowing to directly access the antikaon-nucleus interaction at threshold. State-of-the-art X-ray detectors and suitable experimental technologies allow to perform kaonic atoms X-ray spectroscopy with unprecedented precision, providing fundamental results for the nuclear, particle and astrophysics research. To this end, the SIDDHARTA-2 experiment at INFN-LNF DAFNE collider is carrying on its data taking campaign, aiming at performing high precision X-ray spectroscopy of kaonic atoms, in particular the first measurement of kaonic deuterium X-ray transition to the fundamental level to completely solve the isospin-dependent antikaon-nucleon scattering length. The scientific case, the SIDDHARTA-2 experimental apparatus as well as the results obtained during the first phase of the experiment will be presented.

non-K flavor physics

Overview of Flavor Physics

- Gino Isidori
- University of Zurich

B Physics

- Takeo Higuchi
- Kavli IPMU

Rare decays at LHCb

- LHCb -
- -

Flavour-Changing Neutral-Current processes, such as decays mediated by $b \to sll$ transitions, are forbidden at the lowest perturbative order in the Standard Model (SM) and hence might receive comparatively large corrections from new particles in SM extensions. This talk highlights recent measurements from LHCb on $b \to sll$ transitions, including tests of lepton flavour universality and lepton flavour violation, as well as measurements of purely leptonic transitions.

Neutrino Physics

- Ken Sakashita
- KEK/J-PARC

Muon Physics

- Chris Polly
- -

Quantum Mechanics

Precision tests of Quantum Mechanics and CPT symmetry with entangled neutral kaons at KLOE

- Riccardo D'Amico
- University of Ferrara & INFN

The quantum interference between the decays of entangled neutral kaons is a very powerful tool for testing the quantum coherence of the entangled kaon pair state. The search for tiny decoherence and CPT violation effects, which may be justified in a quantum gravity framework, was performed. The studied process $\phi \to K_S K_L \to \pi^+\pi^-\pi^+\pi^-$ exhibits the characteristic Einstein–Podolsky–Rosen correlations that prevent both kaons to decay into $\pi^+\pi^-$ at the same time. The newly published result is based on data sample collected with the KLOE detector at DAΦNE and corresponds to an integrated luminosity of about 1.7 fb^{-1}, i.e. to $\sim 1.7 \times 10^9 \phi \to K_S K_L$ decays. From the fit of the observed time difference distribution of the two kaon decays, the decoherence and CPT violation parameters of various phenomenological models are measured. The results are consistent with no deviation from quantum mechanics and CPT symmetry violation. A stringent upper limit on the branching ratio of the $\phi \to K_S K_S, K_L K_L$ decay is also derived.

Can future observation of the living partner post-tag the past decayed state in entangled neutral K-mesons ?

- Antonio Di Domenico
- Sapienza University of Rome and INFN-RM1

Entangled neutral K mesons allow for the study of their correlated dynamics at interference and decoherence times not accessible in any other system. We find novel quantum phenomena associated to a correlation in time between the two partners: the past state of the first decayed kaon, when it was entangled before its decay, is post-tagged by the result and the time of the future observation of the second decay channel. This surprising "from future to past" effect is fully observable and leads to the unique experimental tag of the KS state, an unsolved problem since the discovery of CP violation [1]. General consequences of this effect and a novel kind of experimental studies possible in the KLOE-2 experiment at DAFNE will be also briefly discussed.

[1] J. Bernabeu and A. Di Domenico, PRD D 105, 116004 (2022)

Exotic Particles

Light new particles at the kaon experiments

- Kohsaku Tobioka
- Florida State University

Light new particles are compiling physics cases which are related to the most motivations of BSM physics. I will discuss the potential of the current kaon experiments to search for them, which is recently summarized in the whitepaper, arXiv:2201.07805. For the light particles, the tests through kaon decays are essential and complementary to the star-cooling bound, cosmological probes, and beam dump experiments. I will take a heavy QCD axion or axion-like particles as a representative benchmark to explore various opportunities of the kaon experiments.

Some Theoretical Aspects of Searches for Heavy Neutrino Emission in Kaon Decays

- Robert Shrock
- Stony Brook University

We discuss the theory underlying searches for heavy neutrino emission in two-body leptonic decays of charged pseudoscalar meson decays with specific application to $K^+_{\mu 2}$ and K^+_{e2} decays and current bounds.

Some of this material would involve updates from the recent paper that I wrote with Doug Bryman, Phys. Rev. D100, 073011 (2019) and developments since then. One aspect would be how lepton mixing and the presence of heavy neutrinos could give rise to apparent violation of e-mu universality.

Search for Light Neutral Bosons in the TREK/E36 Experiment with Stopped K^+ Mesons

- Bishoy DH Dongwi
- LLNL

The Standard Model (SM) represents our best description of the subatomic world and has been very successful in explaining how elementary particles interact under the influence of the fundamental forces. Despite its far reaching success in describing the building blocks of matter, the SM is still incomplete; falling short to explain dark matter, baryogenesis, neutrino masses and much more. The E36 experiment was conducted at J-PARC in Japan, it was designed to test lepton universality, and it has additional sensitivity to search for light U(1) gauge bosons. Of particular interest is the muonic K^+ decay channel. Such $U(1)$ bosons could be associated with dark matter or explain established

muon-related anomalies such as the muon $g-2$ value, and perhaps the proton radius puzzle, and furthermore might help to resolve anomalies in excited ^{8}Be and ^{4}He decays. A realistic simulation study was employed for these rare searches in a mass range of 20 to 110 MeV/c^2. Preliminary upper limits for the A' branching ratio $\mathcal{B}r(A')$ extracted at 95% CL will be presented.

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Searches for the light invisible hypothetic pseudoscalar in $K^+ \to \pi^+\pi^0 P$ decay

- Alexander Sadovskiy
- Institute for High Energy Physics (Protvino)

Searches for the light invisible hypothetic pseudoscalar in the decay $K^+ \to \pi^+\pi^0 P$ are performed at the OKA detector exposed to 18 GeV/c RF separated beam of the U-70 PS for two alternative scenarios, namely for the pseudoscalar sgoldstino and for the axion. No signal is observed, the upper limits for the branching ratio of the decay are derived for both scenarios. The 90% CL upper limit for the case of sgoldstino is estimated to be in the region $3*10^{-5}$ to $2*10^{-6}$ for the sgoldsino mass from 40 to 200 MeV and for the case of axion the upper limit is changing from $2*10^{-5}$ to $2.5*10^{-6}$ for the axion mass from 20 to 200 MeV.

Search for Pair Production of Dark Particles in K_L^0 Decays at KOTO

- Chieh Lin
- University of Chicago

The $s \to d$ transition may result in more than one dark particle (X), and X can further decay to two photons if, for instance, it couples to a heavy quark loop. To date, this scenario has not been experimentally examined. With the KOTO detector, a signal is identified by requiring four final-state photons in the electromagnetic calorimeter and nothing else detected in the rest of the detector. The major background source is the $K_L^0 \to 3\pi^0$ decay with two fusion clusters, which are induced by two close photon hits in the calorimeter. Besides the cluster shower shape cuts, an algorithm exploiting the $K_L^0 \to 3\pi^0$ kinematic constraints is introduced to further reduce this background. With the data collected in 2018 June run, the single event sensitivity of $\mathcal{O}(10^{-7})$ – $\mathcal{O}(10^{-6})$ is achieved. In this presentation, the analysis method and the result will be given.

First results for searches of exotic decays with NA62 in beam-dump mode

- Patrizia Cenci
- INFN Perugia

The NA62 experiment at CERN can be run as a "beam-dump experiment" by removing the Kaon production target and moving the upstream collimators into a "closed" position. In 2021, more than 10^{17} protons on target have been collected in this way by NA62 during a week-long data-taking campaign. Using past experience, the upstream beam-line magnets were configured to sizably reduce background induced by "halo" muons. We report on the search for visible decays of exotic mediators from data taken in "beam-dump" mode with the NA62 experiment. Analysis results of this data will be presented, with a particular emphasis on Dark Photon Models.

Future Perspectives

$K \to \mu^+\mu^-$ as a Third Kaon Golden Mode

- Avital Dery
- Cornell University

The current effort to produce an independent picture of CKM measurements from kaon physics is centered around the two "golden modes", $K^+ \to \pi^+\nu\bar{\nu}$ and $K_L \to \pi^0\nu\bar{\nu}$. We have shown, that by measuring time dependence, $K \to \mu^+\mu^-$ can become a third golden mode, complementing the current program with an additional, theoretically clean observable. While in the total rate $K \to \mu^+\mu^-$ is dominated by long-distance physics, the measurement of CP violation in the interference of mixing and decay via the time dependent rate enables to extract the magnitude of the pure short-distance $K_S \to (\mu^+\mu^-)_{\text{CP-odd}}$ amplitude, which is predicted within the SM up to $\mathcal{O}(1\%)$ uncertainty. This kind of measurement would require a neutral beam with an $\mathcal{O}(1)$ dilution factor, $D = \frac{N_{K^0} - N_{\bar{K}^0}}{N_{K^0} + N_{\bar{K}^0}}$, with a detector placed close to the target, such that it is sensitive to $K_S - K_L$ interference effects. The experimental feasibility of such a next-generation machine, raising several interesting experimental challenges, has been investigated in a pilot study. If built, it would not only be able to measure CKM parameters from $K \to \mu^+\mu^-$, but also be sensitive to $\mathcal{O}(10)$ other decay modes of neutral kaons and hyperons into charged final states, opening up intriguing opportunities for further tests of the SM as well as probes of NP.

First thoughts on high intensity K_S experiment

- Radoslav Marchevski
- Weizmann Institute of Science

Recent theoretical developments showed that a measurement of the interference between $K_L \to \mu^+\mu^-$ and $K_S \to \mu^+\mu^-$ decays can be used to extract the CP violation parameter η with a theoretical precision of 1%. This turns the $K \to \mu^+\mu^-$ process into another golden rare kaon channel that can probe the CKM structure of the SM but also offers large sensitivity to contributions from physics beyond the Standard Model. A measurement of the $K_S - K_L$ interference effect ($BR_{eff} \sim 8 \times 10^{-10}$) to a few % precision is an extremely challenging task far beyond the reach of modern kaon physics experiments. The presented study is exploring the possibility to address the interference experimentally and outlines the challenges associated with such an ambitious project for the far future. A next-generation experiment at the intensity frontier is required that should be capable of collecting a large sample of $O(10^{14} - 10^{15})$ K_L and K_S decays. Challenges related to the beamline design and detector technology need to be overcome if we want to address this mode experimentally. A large background suppression of $K_S \to \pi^+\pi^-$ and radiative $K_L \to \mu^+\mu^-\gamma$ decays is imperative for a few % measurement, which would require excellent kinematic resolution and efficient photon detection. The first attempt at a possible experimental setup that could be used to measure this effect is presented. Last but not least, a huge number of neutral particles produced in such an experiment offers the possibility to study a plethora of other rare K_L, K_S decays as well as hyperon decays enhancing the physics motivation for such an initiative.

Lepton flavor violation experiment: PIONEER

- Elizabeth Worcester
- Brookhaven National Lab

A next-generation rare pion decay experiment, PIONEER, is motivated by several inconsistencies between Standard Model predictions and data pointing towards potential violation of lepton flavor universality. PIONEER will measure the charged-pion branching ratio to electrons vs muons (R_π), a quantity which is extremely sensitive to a wide variety of new physics effects, including those at very high mass scales, and which is theoretically predicted to a precision 15 times better than existing measurements. PIONEER has recently been approved by the Paul Scherrer Institute (PSI). Status and plans for PIONEER will be presented.

High Intensity Kaon Experiments (HIKE) at the CERN SPS

- Matthew Moulson
- INFN Laboratori Nazionali di Frascati

The availability of high-intensity kaon beams at the CERN SPS North Area gives rise to unique possibilities for sensitive tests of the Standard Model in the quark flavor sector. Precise measurements of the branching ratios for the flavor-changing neutral current decays $K \to \pi\nu\bar{\nu}$ can provide unique constraints on CKM unitarity and, potentially, evidence for new physics. Building on the success of the NA62 experiment, plans are taking shape at CERN for a comprehensive program that will include experimental phases to measure the branching ratio for $K^+ \to \pi^+\nu\bar{\nu}$ to 5% and for $K_L \to \pi^0\nu\bar{\nu}$ to 20% precision. These planned experiments would also carry out lepton flavor universality tests, lepton number and flavor conservation tests, and perform other precision measurements in the kaon sector, as well as searches for exotic particles in kaon decays. We overview the physics goals, detector requirements, and project status for the next generation of kaon physics experiments at CERN.

Presented on behalf of the HIKE Project

KOTO step-2 at J-PARC toward measurement of branching ratio of $K_L \to \pi^0\nu\overline{\nu}$

- Hajime Nanjo
- Osaka University

We are designing the KOTO step-2 experiment at J-PARC aiming at the measurement of the branching ratio of the $K_L \to \pi^0\nu\overline{\nu}$ decay. We plan to extend the Hadron Experimental Facility at J-PARC to have the second production target. We use the K_L extraction angle of 5 degree to obtain larger K_L flux and harder K_L momentum spectrum while keeping the ratio of neutron and K_L fluxes. To realize the extraction angle, the detector is behind the primary beam dump. The KOTO step-2 detector has the longer decay volume and larger calrimeter radius to achieve larger decay probability and higher acceptance of the K_L decay. We designed the K_L beam line and the detector for the KOTO step 2, and evaluated the numbers of signal and backgrounds. We evaluated 40 signal events for the branching ratio of the standard model with 60 background events for the running period of 3×10^7 s. This corresponds to approximately 5-sigma discovery of the decay. We will present the design and evaluation, and the detector research toward the KOTO step 2.

The future prospects of kaon physics

- Jure Zupan
- University of Cincinnati

Poster

A new era of experimental studies on the $\overline{\mathrm{K}}$N interaction.

- Oton Vazquez Doce
- INFN (Frascati)

The strangeness sector of low-energy QCD faces a promising era with the arrival of precision data from new experimental approaches. The most recent and upcoming measurements of the $\overline{\mathrm{K}}$N interaction will be presented.

Two-particle correlation studies in momentum space (femtoscopy) have been recently demonstrated to be very sensitive to the effects of the final state strong interaction. Its application to K^-–p and K^0–p pairs produced in pp, p-Pb and Pb-Pb collisions by the ALICE Collaboration delivers unique information on the interaction and channel couplings. Femtoscopy measurements are now extended for the first time to Three-Body correlations, such as p–p–K^- and p–p–K^+, providing information on the genuine three-particle interaction.

Among more traditional approaches, the first measurement of the Kaonic Deuterium X-rays by SIDDHARTA2 will enable access to the isospin dependence of the interaction. Studies of K^- reactions in light nuclei at DAΦNE and J-PARC provide new measurements of cross sections at very low momentum and the identification and characterization of the $\overline{\mathrm{K}}$NN state.

The new data place stringent constraints and provide an updated scenario towards the description of the low-energy $\overline{\mathrm{K}}$N interactions and the understanding of the nature and structure of the $\Lambda(1405)$.

Nuclear resosnance effects in kaonic atoms

- Luca De Paolis
- Laboratori Nazionali di Frascati - INFN

The nuclear E2 resonance effect occurs when atomic de-excitation energy is closely matched by nuclear excitation energy. It produces an attenuation of some of the atomic x-ray lines from resonant versus normal isotope target. The investigation of the nuclear E2 resonance effect in kaonic ticklish atoms could provide important information about strong kaon nucleus interaction. In the past, only $K^- - {}^{98}_{42}Mo$ nuclear resonance effect was measured by G. L. Goldfrey, G- K. Lum and C. E. Wiegand at Lawrence Berkeley Laboratory, in 1975. The nuclear E2 resonance effect was observed, but 25 hours of data taking resulted not enough for a conclusive result. In four kaonic molybdenum isotopes (${}^{94}_{42}Mo$, ${}^{96}_{42}Mo$, ${}^{98}_{42}Mo$ and ${}^{100}_{42}Mo$), the nuclear E2 resonance effect is expected at the same transition and could be studied in DAΦNE during the SIDDHARTA-2 experiment. The aim is to exploit the negatively charged kaons emitted by the DAΦNE e^+e^- collider in the horizontal direction, not collected by SIDDHARTA-2. Four solid strip targets each enriched with one molybdenum isotope could be exposed to negatively charged kaons, using a germanium detector for x-ray transition measurements. A solid strip target of ${}^{92}_{42}Mo$, in which nuclear E2 resonance effect does not occur, would be used as a reference for standard yield transition. This experiment would provide first measurements of nuclear resonance effects in 4 isotopes of kaonic molybdenum, with needed precision for conclusive results, and a unique opportunity to study kaon-nucleus strong interaction in kaonic ticklish nuclei.

Heavy New Physics in Rare Kaon Decays

- Ulserik Moldanazarova
- Karaganda Buketov University

Rare and CP violating Kaon decays are an exceptional laboratory to test new physics. The phenomenology of Kaon physics has been studied in various heavy new physics models in the past and compared with collider searches. In arXiv:2104.10930 we derived, together J. Brod, F. Bishara and M. Gorbahn, the matching corrections for generic new physics models at one-loop level. In this talk we will show how this results can be applied to the Kaon sector. Using our publicly available tools, one can easily reproduce results of previous model calculations and also study the parameter constraints on simplified renormalisable models.

Online event selection and GPU-based waveform compression for the High Level Trigger of the KOTO experiment

- Mario Gonzalez
- Osaka University

The High Level Trigger (HLT) of the J-PARC KOTO experiment is currently undergoing a major upgrade. Event selection and data compression are needed to cope with the expected increase by a factor of 8 in data rates, coming from the ongoing accelerator upgrade and from upstream event selection being relaxed to allow more diverse data to reach the HLT. Event reconstruction and selection are performed in parallel on CPUs. Lossless waveform compression has been implemented on GPUs, where it performs two orders of magnitude faster than the CPU version that has been running in KOTO during past runs.

$K_L^0 \to \gamma + dark\,photon(\bar{\gamma})$ Search at the J-PARC KOTO Experiment

- Tong Wu
- National Taiwan University

We present the study of massless dark photons in the decay of $K_L^0 \to \gamma\bar{\gamma}$ in the J-PARC KOTO experiment. The massless dark photon ($\bar{\gamma}$) is different from the massive dark photon because it does not mix directly with ordinary photons, but it could interact with SM particles through direct coupling with quarks. In some theoretical predictions, the $\mathcal{BR}(K_L^0 \to \gamma\bar{\gamma})$ can be as large as $\mathcal{O}(10^{-3})$, which is well within the sensitivity of KOTO. Because of the lack of kinematic constraints, searching for $K_L^0 \to \gamma\bar{\gamma}$ could be challenging, but the hermetic veto system of KOTO provides a unique opportunity to probe for this decay. In this presentation, we will present the preliminary results of the study based on data collected in 2020.

Data Acquisition System Upgrade at KOTO

- Joseph Redeker
- University of Chicago

In this presentation, the new KOTO data acquisition (DAQ) system upgrade is discussed. The new system is a pyramid style architecture, composed of all new homemade optical fiber centers (OFC) modules with high-speed ports which gather and build the event from over 4000 channels. It will be able to handle up to 30,000 triggers per second with minimal loss in the near future, which is a factor of six more than current rates. This will allow KOTO to handle a higher intensity KL beam, as well as open up the possibility of adding new physics triggers such as $K_L \to \pi^0 e^+ e^-$. Additionally, the new architecture simplifies our data handling and allows for greater flexibility in adding late level trigger conditions because the event building is done before the data is sent to the server. This system is robust, flexible and easily scalable in the future so that KOTO can open up our trigger to more interesting physics and provides a foundation for moving forward to KOTO Step-2.

Analysis Techniques for Neutron Background Suppression at KOTO.

- YU-CHEN TUNG
- National Taiwan University

Neutron was the largest background source before in the rare $K_L \to \pi^0\nu\overline{\nu}$ search at KOTO. It was caused by the neutron from the beam directly entering the CsI calorimeter and producing two photon-like clusters. Through these years, we made several improvements in the analysis and detector that successfully suppressed the neutron background to a negligible level. In this poster, I will present the analysis techniques for neutron background suppression, including the deep learning neural network for pattern classification and Fourier frequency analysis on the raw digital waveform.

Thin scintillation counter with a new readout method for the KOTO experiment

- Keita Ono
- Osaka University

The KOTO experiment at J-PARC is dedicated to search for the rare decay $K_L \to \pi^0\nu\bar{\nu}$. In the 2016-2018 data analysis, we found that some background events were caused by decay of charged kaons in the beam. To reject this background, we are developing a new charged particle detector. It uses a 0.2mm-thick plastic scintillator. The scintillation light escaping from the surface without total reflection is collected by 12-μm-thick aluminized mylar and is read out by multiple PMTs on the side. In my talk, I will introduce the design and performance such as efficiency and light yield evaluated in a beam test we will perform in July.

Development of a PMT base used for an in-beam charged particle detector for the J-PARC KOTO experiment

- Ayumu Kitagawa
- Osaka University

The J-PARC KOTO experiment is searching for the rare decay $K_L \to \pi^0\nu\bar{\nu}$ that breaks CP symmetry. In data acquired in 2016-2018, the source of the largest background was a small amount of charged K in the beam. To reduce this background, we are developing a charged particle detector to be installed at the upstream end of the KOTO detector. Light leaking from a 0.2mm thick plastic scintillator is reflected by an aluminized mylar and read out by PMT array. In this presentation, I will report on the development of the PMT base to ensure reliable operation in vacuum and in a high rate environment of the detector.

Measurement of residual mu+ polarization in various scintillating materials to search for T-violating mu+ polarization in $K^+ \to \pi^0\mu^+\nu$ decay

- Keito Horie
- Osaka University

Time reversal symmetry has long been a subject of interest from pre-modern physics time, since it implies the reversibility of motion. In the $K^+ \to \pi^0\mu^+\nu$ (Kmu3) decay, the transverse muon polarization (P_T) is defined as the polarization component perpendicular to the decay plane. A non-vanishing value of P_T provide clear evidence for T-violation under the condition that spurious effects

from final state interactions are negligibly small. We are now proposing a new T-violation experiment to achieve delta $P_T \sim 10^{-5}$ at the J-PARC Hadron Hall without using a magnetic spectrometer. The most important characteristics of the new experiment is the measurements of the muon momentum vector, the pi^0 momentum vector, and the muon polarization by the same highly segmented sequential electro-magnetic calorimeter surrounding the K^+ stopping target. Here it should be noted that one of key issues in the experiment is the choice of a scintillation material which can preserve the muon spin polarization for a reasonably long time [1]. A test experiment to measure the residual muon polarization in a CeF3 scintillating crystal was performed using a 100% polarized muon beam at J-PARC MLF. In the longitudinal field of 140 Gauss, the muon polarization in CeF3 was obtained to be 90% at room temperature. In the zero-field measurement, the muSR pattern due to a stable F-mu -F diamagnetic state without forming muonium was successfully observed. We concluded that the residual polarization in CeF3 is high enough to perform the new T-violation experiment [1].

References 1) S. Shimizu et al., Nucl. Instrum. Methods A 945 (2019) 162587; K. Horie et al., Nucl. Instrum. Methods A 1037 (2022) 166932.

Evidence for the Chiral WZW anomaly in the coherent production of $(K^+\pi^0)$-system by K^+ beam on copper nuclei.

- Vladimir Obraztsov
- Institute for High Energy Physics (IHEP), Protvino

The experiment is performed at the "OKA" setup exposed to 18 GeV RF separated K^+ beam of the U-70 PS. On the statistics of $\sim 1.7 \times 10^8$ interactions of positively charged kaons on copper nuclei, coherent events of the K^+ π^0 system production are selected. The cross sections for the Coulomb and coherent strong components and their interference in the region of the K*(892) meson are measured. The partial width for the decay $K^*(892) \to K^+\gamma$ is determined. When studying the mass spectrum of the K^+ π^0 system, an effect which can be interpreted as the interference of the chiral anomaly and the K*(892) s-channel amplitudes is found. This gives an estimate for the ratio of the observed amplitude of the chiral anomaly to the theoretical one: Aexp/Ath = 0.9 ± 0.24(stat.) ± 0.3(syst.).

Effect of low-energy neutrons on accidental counting rate in the KOTO experiment

- Toru Matsumura
- National Defense Academy of Japan

The KOTO experiment is dedicated to observe the $K_L^0 \to \pi^0\nu\bar{\nu}$ decay using the 30-GeV proton beam at J-PARC. So far, we have achieved the world's highest sensitivity of branching-ratio measurement on the order of 10^{-10} by using the main CsI calorimeter and hermetic VETO counters covering the entire solid angle. For further sensitivity improvement, suppressing the signal loss due to accidental counts of the VETO counters is one of the issues to overcome. A simulation study shows that about half of the counting rate of Front-Barrel VETO counter is stemmed from "delayed photons", which is produced by the (n, γ) reaction due to the thermal neutrons moderated in the KOTO detector. In this report, focusing on the low-energy neutrons, we discuss the contribution to the accidental count caused by the delayed photons and its suppression method.

A three-dimensional sampling electromagnetic calorimeter for the KOTO2 experiment with the future extension of J-PARC Hadron Facility

- YoungJun Kim

- Korea University

We present a Geant4-based simulation study of the three dimensional (3D) electromagnetic sampling calorimeter (ECAL). The 3D ECAL model consists of alternating layers of scintillator strips and Pb sheets to measure the energy and incidence angle of high energy photons. We obtained energy deposits in individual strips using Geant4 simulations and reconstructed incidence photon angles using a XGBoost model with boosted decision trees. We then tested the performance of the incidence angle measurement using pre-shower hit information on the 3D ECAL. This incidence angle measurement could advance a high-rate K_L measurement at the future KOTO experiment. We will discuss preliminary results of the 3D ECAL design study with special emphasis on the photon reconstruction performance.

Baryon number violation from confining New Physics

- Mathew Thomas
- Indian Institute of Science Education and Research, Thiruvananthapuram

The detection of neutron-antineutron oscillation will be a discovery of fundamental importance in particle physics and cosmology. Models predicting them, usually, assume weak couplings at the scale of the experiment, although Nature has been quite evasive regarding the issue. Acknowledging this, we discuss a non-perturbative mechanism, generated by confining New Physics in a linear moose, resulting in the low-energy baryon number violating effects within the reach of terrestrial and Neutron Star measurements.

Effective theory for universal seesaw model ,FCNC and CP violation

- Takuya Morozumi
- Hiroshima University

The universal seesaw model based on $SU(2)_L \times SU(2)_R \times U(1)$ explains the hierarchy of the six quarks. The model includes five vector like quarks which masses are heavier than the breaking scale of $SU(2)_R$. We integrate the heavy vector like quarks and derive the effective theory with one up type vector like quark in addition to the quarks of the standard model. We report the phenomenology of the model including the flavor mixing, FCNC from the higher dimensional operators, and CP violation.

Lepton Number Violation without and with muon g-2 anomaly

- George W.S. Hou
- National Taiwan University

The general two Higgs doublet model (g2HDM) that possesses extra Yukawa couplings provide rich phenomena in flavor physics. Muon flavor violation appears very promising, where mu -> e gamma and mu to e conversion on nuclear, together with tau -> mu gamma all provide promising probes with discovery potential. Considering the muon g-2 anomaly, in particular the one-loop solution in g2HDM, the implication of the extra Yukawa coupling $\rho_{\tau\mu}$ being 20 times the tau Yukawa coupling in Standard Model has very strong implications, which would bring in a renaissance of muon physics: all the above-mentioned modes become very promising, including the observability of muon electric dipole moment with PSI proposal. Also, mu to e conversion on nuclei could in principle measure diagonal extra quark couplings.

Reduction of charged kaon background in the KOTO experiment

- Ryota Shiraishi
- Osaka University

The KOTO experiment at J-PARC is searching for new physics that breaks the CP symmetry by using the rare $K_L \to \pi^0\nu\bar{\nu}$ decay mode. In the analysis of the data collected from 2016 to 2018, the largest background was caused by decays of charged kaons produced at the collimator in the beam line. To reject this background, an in-beam charged particle detector was installed at the upstream end of the KOTO detector in 2020. Using charged kaon samples collected in 2021, inefficiency of the charged particle detector was estimated to be less than 10%. Based on this performance, the background from charged kaons in the 2021 data set was estimated. For further reduction of the charged kaon background in the future, we are developing a new detector, and preparing a magnet to be installed at the downstream edge of the beam line. In this talk, I will present the performance of the charged particle detector and future plans to improve rejection capability.

Estimation of Hadron shower background in KOTO 2019 - 2021 data

- Katsushige Kotera
- Osaka University

One of the keys for the $K_L \to \pi^0\nu\bar{\nu}$ search is to suppress the backgrounds caused by hadron showers in the KOTO CsI calorimeter. We developed three methods to discriminate the hadron showers from gamma showers. The methods use 1) pulse shape of signals, 2) shower shape on the calorimeter, and 3) depth of the showers in the calorimeter. We report the discrimination power of these methods and the estimated backgrounds in latest data taken at in 2019 - 2021.

Investigating the Strong Interaction with Kaonic Atoms - The SIDDHARTA-2 Experiment

- Marlene Tuechler
- Stefan Meyer Institute

The theoretical models representing the low-energy, non-perturbative regime of QCD show significant differences in their description of the antikaon-nucleon interactions at threshold. Experimental input is needed to constrain them, which can be provided by the SIDDHARTA-2 experiment. The apparatus is located at the DAFNE collider at LNF in Italy, and aims to precisely measure the 2p-1s transition in kaonic deuterium atoms. The strong interaction between the kaon and nucleons induces an energy shift and broadened width to the kaonic deuterium ground state, which can be directly observed via X-ray spectroscopy of the kaonic atoms and allow, in combination with the kaonic hydrogen results of SIDDHARTA, for the extraction of the isospin-dependent antikaon-nucleon scattering lengths. SIDDHARTA-2 implements newly developed X-ray detectors in the form of Silicon Drift Detector arrays with an energy resolution of approximately 150 eV at 6 keV. The apparatus was installed at DAFNE in 2019, and first preparatory runs were performed which concluded in a successful measurement of kaonic helium. The apparatus and first results will be presented and discussed.

Study of Weak Basis Invariant in the Universal Seesaw Model using Hilbert Series

- Albertus Panuluh
- Hiroshima University

Universal Seesaw Model is a model which explains the mass hierarchy of the quark sector. This model introduces vector-like quarks. The top quark mass is generated in the electroweak scale and the other quarks mass is generated using a seesaw-like mechanism. The invariant theory is useful method for constructing a weak basis invariant. We study the weak basis invariant (WBI) using Hilbert Series (HS) and apply it to Universal Seesaw Model.