

NA62 Results

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On behalf of the NA62 Collaboration



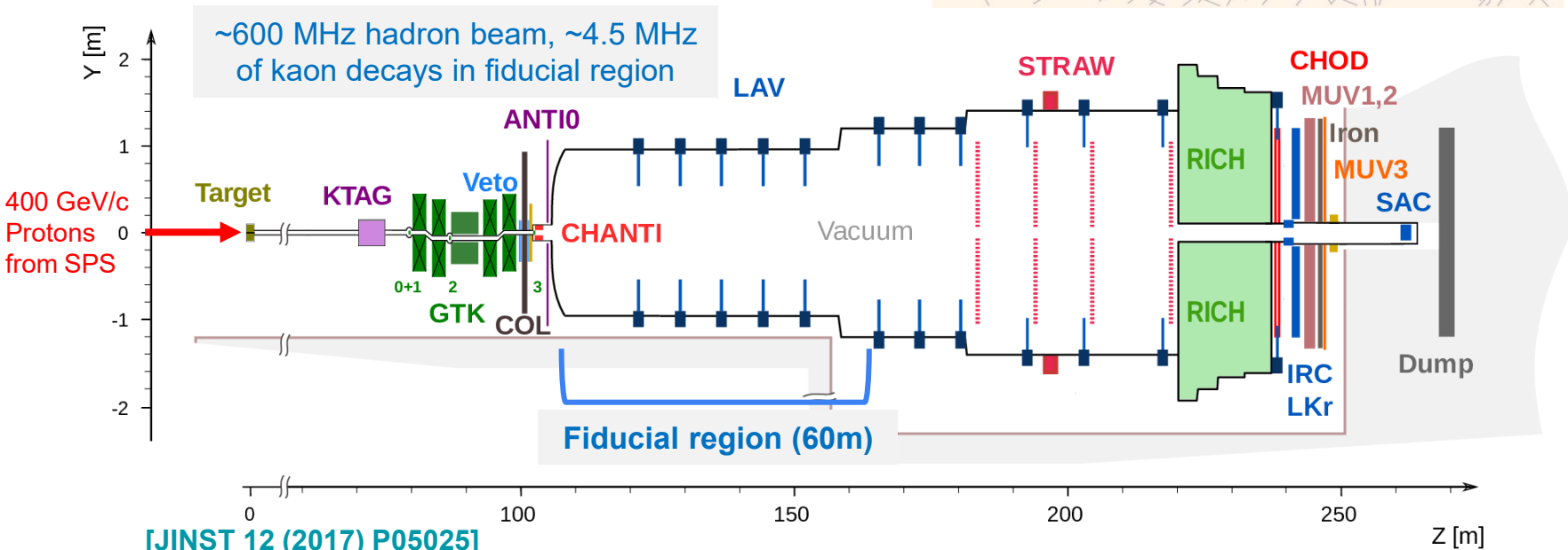
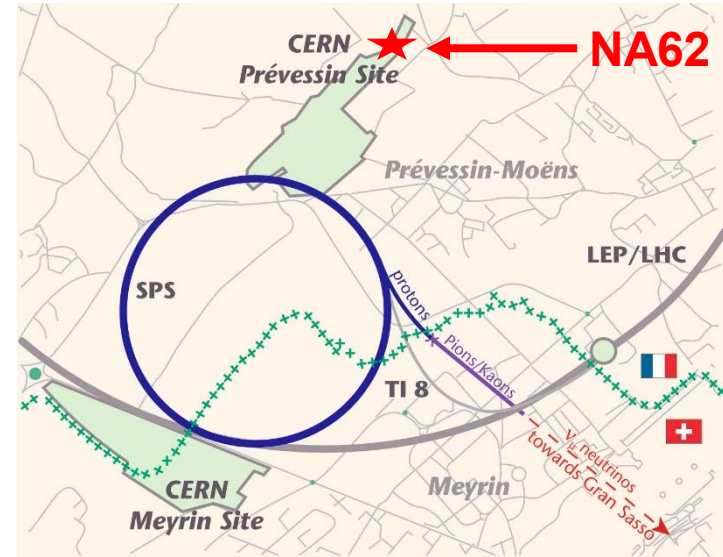
Lake Louise Winter Institute

March 1-7, 2026, Lake Louise, AB

The NA62 Experiment

Fixed target kaon decay experiment located at the CERN Prévessin site

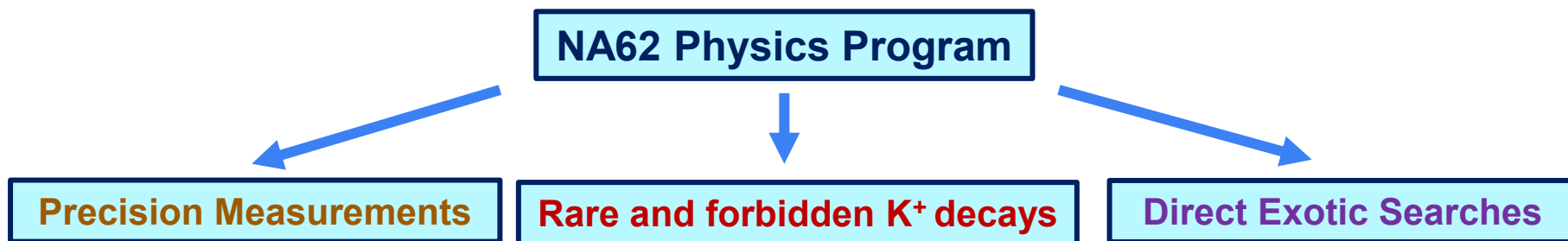
- ~250 collaborators from ~35 institutes
- 400 GeV/c proton beam from Super Proton Synchotron (SPS) directed at beryllium target
- Produces secondary 75 GeV/c kaon beam (70% π^+ , 23% p , **6% K^+**)



Physics at NA62

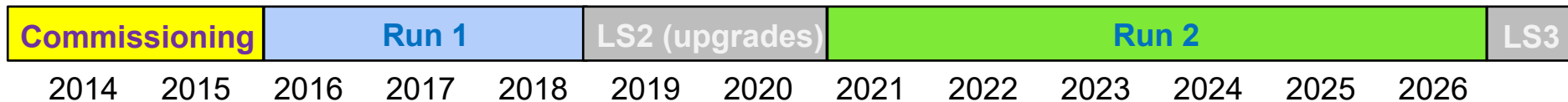
Primary goal: to measure rare decay $\text{Br}(K^+ \rightarrow \pi^+ \nu \bar{\nu})$

- Last year's update [\[LLWI 2025\]](#)
- New update this year (March 4)! [\[La Thuile 2026\]](#)



Recent highlights to be presented:

- 1) Measurement of the structure dependent $K^+ \rightarrow e^+ \nu \gamma$ decay (preliminary), [\[KAON25\]](#)
- 2) Measurement of the radiative $K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$ decay (preliminary), [\[KAON25\]](#)
- 3) Measurement of the $K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$ decay (preliminary), [\[KAON25\]](#)
- 4) Search for heavy neutral leptons ($\pi^+ \rightarrow e^+ N$), [\[Phys.Lett.B 872 \(2026\) 140119\]](#)
- 5) Searches for hidden-sector X particle ($K^+ \rightarrow \pi^+ X$), [\[JHEP 11 \(2025\) 143\]](#)

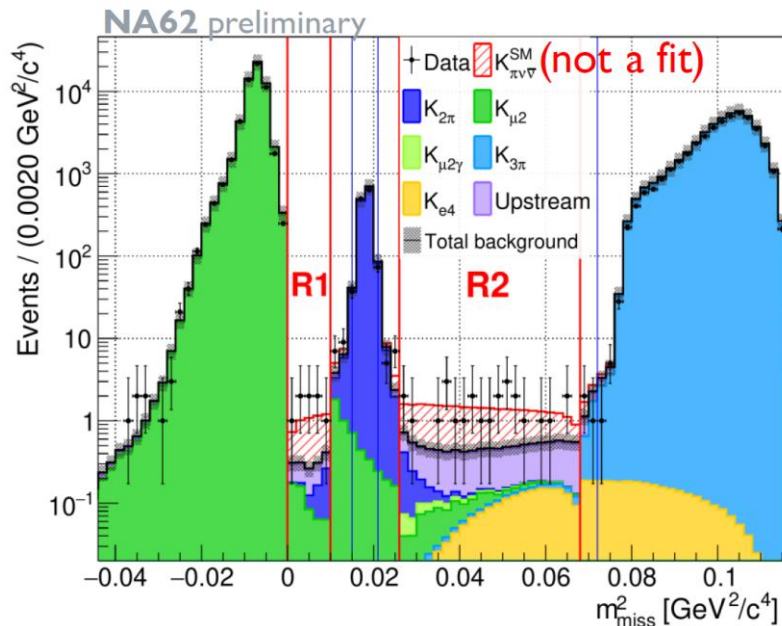


$K^+ \rightarrow \pi^+ \nu \bar{\nu}$: Improvements

	2021-2022 [JHEP 02 (2025) 191]	2023-2024 (this analysis)
$K^+ \rightarrow \pi^+ \pi^0 (\gamma)$	0.83 ± 0.05	1.19 ± 0.10
$K^+ \rightarrow \mu^+ \nu (\gamma)$	1.70 ± 0.47	1.39 ± 0.29
$K^+ \rightarrow \pi^+ \pi^+ \pi^-$	0.11 ± 0.03	0.24 ± 0.05
$K^+ \rightarrow \pi^+ \pi^- e^+ \nu$	$0.89^{+0.33}_{-0.27}$	$1.59^{+0.51}_{-0.43}$
Upstream	$7.4^{+2.1}_{-1.8}$	$7.4^{+2.8}_{-2.2}$
Background	$11.0^{+2.1}_{-1.9}$	$11.9^{+2.9}_{-2.3}$
$N(\pi \nu \nu, \text{exp})$	9.9 ± 0.3	22.9 ± 1.1

Increased statistics and improvements in background rejection:

- data-driven
 - Better π^0 rejection
 - Lower μ^+ mis-identification rate
- estimated with MC
- fully data-driven
 - Improved upstream background rejection



For 2023-2024 dataset:

- Expected SM signal: 22.9 ± 1.1 , (assuming $\text{BR} = 8.4 \times 10^{-11}$)
- Estimated background: $11.9^{+2.9}_{-2.3}$
- Observed: **33**

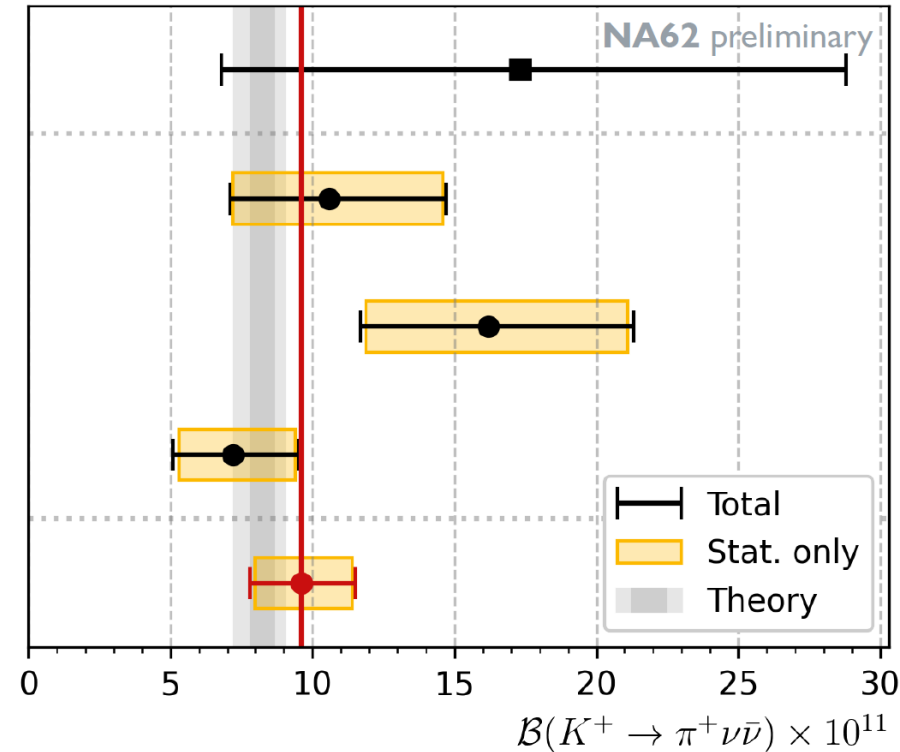
$K^+ \rightarrow \pi^+ \nu \bar{\nu}$: Updated Result

Newest combined result: $\text{Br}(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (9.6_{-1.8}^{+1.9}) \times 10^{-11}$

For 2016-2024 dataset:

- Expected SM signal: 43 ± 1 ,
(assuming $\text{BR} = 8.4 \times 10^{-11}$)
- Estimated background: 30_{-3}^{+4}
- Observed: **84**

	BNL
	[PRD 79 (2009) 092004]
	NA62 2016-2018
	[JHEP 06 (2021) 093]
	NA62 2021-2022
	[JHEP 02 (2025) 191]
	NA62 2023-2024
	[La Thuile 2026]
	NA62 combined
	this result



Observed significance $>6\sigma$, result compatible with SM

More to come with 2025-2026 dataset!

$K^+ \rightarrow e^+ \nu \gamma$: Motivation

Direct measurement of V , A model-dependent couplings:

$$\frac{d^2\Gamma(K e_{2\nu} SD^\pm)}{dx dy} = \rho_{SD^\pm}(x, y) = \frac{G_F^2 |V_{us}|^2 \alpha}{64\pi^2} M_K^5 [(V + A)^2 f_{SD^+}(x, y) + (V - A)^2 f_{SD^-}(x, y)]$$

$$x = \frac{2E_\gamma}{m_K}; y = \frac{2E_e}{m_K};$$

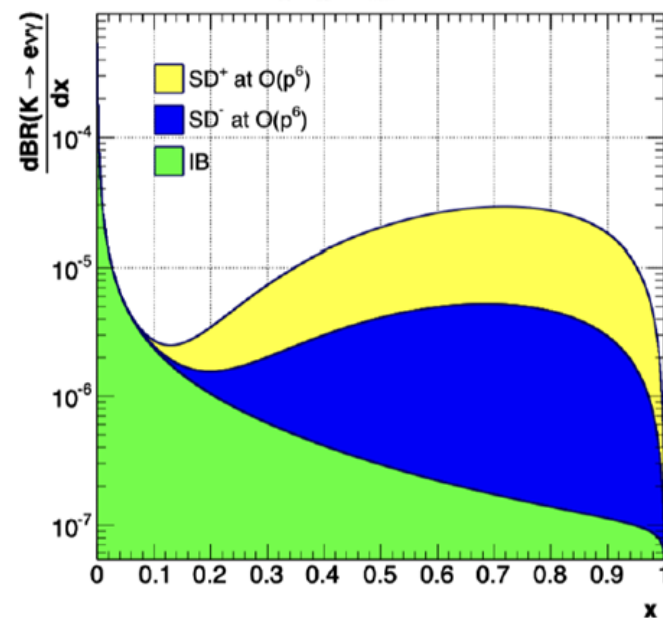
in K^+ rest frame

$$f_{SD^+}(x, y) = (1 - x)(x + y - 1)^2 \quad f_{SD^-}(x, y) = (1 - x)(1 - y)^2$$

Predictions of $BR(K^+ \rightarrow e^+ \nu \gamma)$ in units of 10^{-5} in (a) the ChPT at $O(p^4)$, (b) the ChPT at $O(p^6)$, (c) the LFQM

Model	Cut	IB	SD ⁺	SD ⁻	INT ⁺	INT ⁻	Total
(a)	$x = 0.01$	1.65×10^{-1}	1.34	1.93×10^{-1}	6.43×10^{-5}	-1.10×10^{-3}	1.70
	$x = 0.1$	0.69×10^{-1}	1.34	1.93×10^{-1}	6.43×10^{-5}	-1.10×10^{-3}	1.60
(b)	$x = 0.01$	1.65×10^{-1}	1.15	2.58×10^{-1}	6.22×10^{-5}	-1.21×10^{-3}	1.57
	$x = 0.1$	0.69×10^{-1}	1.15	2.58×10^{-1}	6.22×10^{-5}	-1.21×10^{-3}	1.47
(c)	$x = 0.01$	1.65×10^{-1}	1.12	2.59×10^{-1}	4.33×10^{-5}	-1.29×10^{-3}	1.54
	$x = 0.1$	0.69×10^{-1}	1.12	2.59×10^{-1}	4.33×10^{-5}	-1.29×10^{-3}	1.44

[Phys. Rev D77 (2008) 014004]



SD^- component beyond kinematical region of the analysis, focus on SD^+

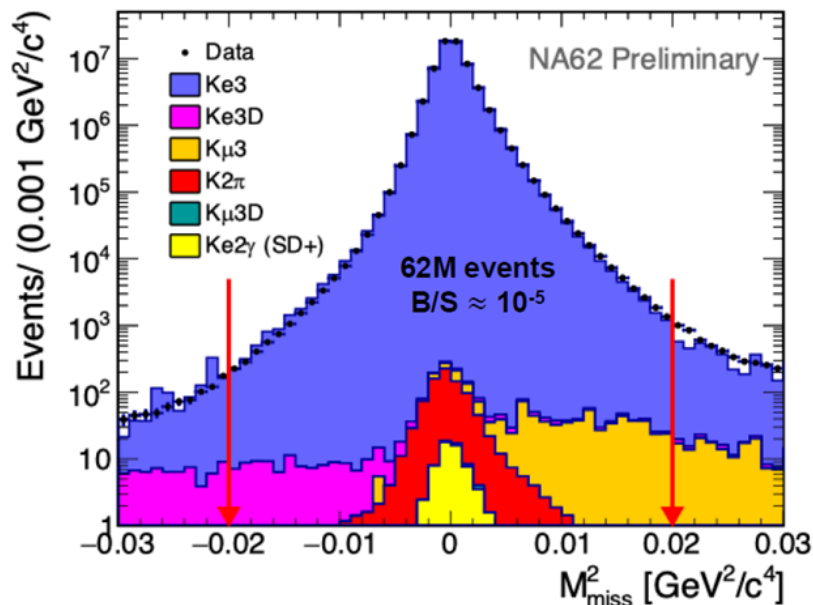
$K^+ \rightarrow e^+ \nu \gamma$: Analysis Strategy

Measure BR from yields in signal selection normalized to K_{e3} selection using observable $M_{miss}^2 = (P_K - P_e - P_\gamma)^2$ in 2017-2018 data ($N_K \approx 2.9 \times 10^{10}$):

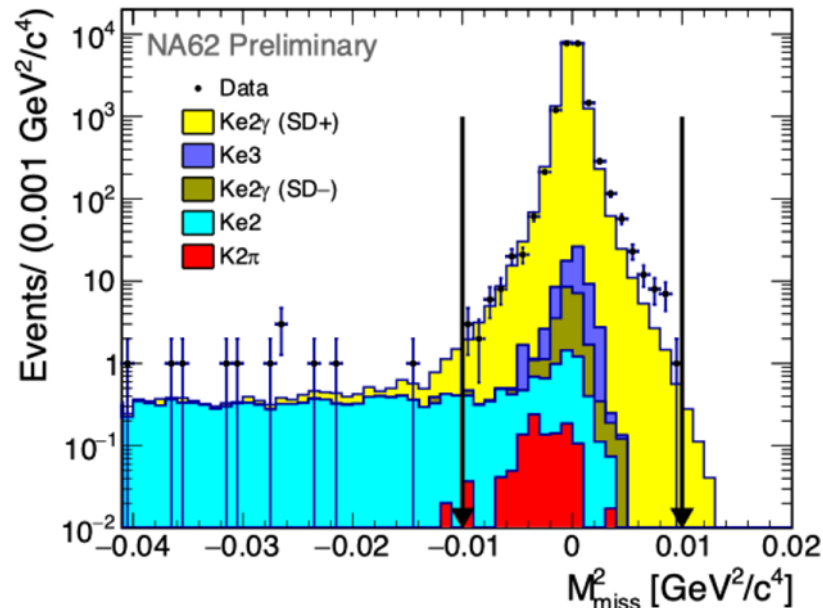
$$Br[K_{e2\gamma}(SD^+)] = \frac{N_{Ke2\gamma}^{obs} - N_{Ke2\gamma}^{bkg}}{N_{Ke3}^{obs}} \cdot \frac{Acc_{Ke3}}{Acc_{Ke2\gamma}} \cdot \frac{\epsilon_{Ke3}^{Trg}}{\epsilon_{Ke2\gamma}^{Trg}} \cdot BR(K_{e3}) \cdot BR(\pi^0 \rightarrow \gamma\gamma)$$

- Select single good e^+ track matched to GTK kaon, radiative γ reconstructed in LKr
- **NA62 signal region: $X > 0.2$, $Y > 0.93$** to reject K_{e2} , K_{e3} , $K_{2\pi}$ backgrounds
- Trigger efficiencies measured with MC and data using K_{e3} normalization selection

Normalization (K_{e3})



Signal ($K_{e2\gamma}SD^+$)



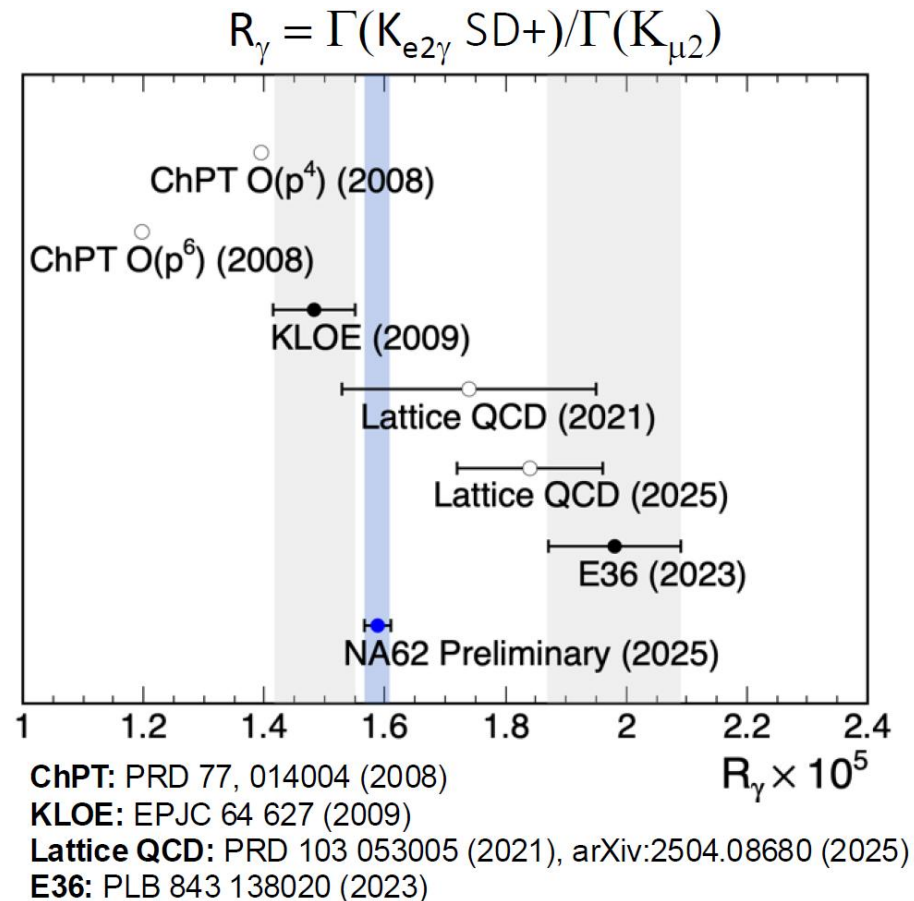
$K^+ \rightarrow e^+ \nu_\gamma$: Preliminary Results

Kinematic region: $P_e > 200 \text{ MeV}/c, E_\gamma > 10 \text{ MeV}$ in K^+ rest frame	$\Gamma(K_{e2\gamma} SD^+)/\Gamma(K_{\mu 2}) [10^{-5}]$
KLOE	$1.483 \pm 0.066 \pm 0.013$
E36	1.98 ± 0.11
NA62 Preliminary	1.59 ± 0.02

Most precise measurement of SD^+ amplitudes to date (~1% precision):

- Measurements and theoretical predictions computed in KLOE kinematic region: $P_e > 200 \text{ MeV}/c$ and $E_\gamma > 10 \text{ MeV}$ (in K^+ rest frame)
- PDG 2024 average:

$$R_\gamma = (1.62 \pm 0.22) \times 10^{-5}$$



$$\text{BR}[K_{e2\gamma}(SD^+)] = (0.466 \pm 0.003_{\text{stat}} \pm 0.003_{\text{sys}} \pm 0.004_{\text{ext}}) \times 10^{-5} = (0.466 \pm 0.006) \times 10^{-5}$$

$K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$: Motivation

Comparison of $\text{Br}(K_{3\pi\gamma})$ predicted by ChPT at $O(p^4)$ vs measurement by OKA collaboration (2019) in intervals of photon energy (kaon rest frame)

E_γ^* [MeV]	$\mathcal{B}_{\text{ChPT}}(K_{3\pi\gamma})$ [Zeit.Phys.C 76 (1997) 301]	$\mathcal{B}_{\text{OKA}}(K_{3\pi\gamma})$ [Eur.Phys.J.C 79 (2019) 296]
10–20	$(4.36 \pm 0.04) \times 10^{-5}$	
20–30	$(1.43 \pm 0.01) \times 10^{-5}$	
30–40	$(4.93 \pm 0.05) \times 10^{-6}$	$(5.17 \pm 0.34) \times 10^{-6}$
40–50	$(1.44 \pm 0.01) \times 10^{-6}$	$(1.55 \pm 0.12) \times 10^{-6}$
50–60	$(2.69 \pm 0.03) \times 10^{-7}$	$(3.5 \pm 0.5) \times 10^{-7}$
60–70	$(1.36 \pm 0.02) \times 10^{-8}$	$(1.1 \pm 0.6) \times 10^{-8}$
10–70	$(6.46 \pm 0.06) \times 10^{-5}$	
30–70	$(6.65 \pm 0.05) \times 10^{-6}$	$(7.1 \pm 0.4_{\text{stat}} \pm 0.3_{\text{syst}}) \times 10^{-6}$

Previous measurement of $\text{Br}(K_{3\pi\gamma})$ performed by OKA collaboration using clean sample of 450 events

- Missing measurement in low photon energy intervals

Goal: First measurement of $\text{Br}(K_{3\pi\gamma})$ in previously unobserved energy intervals

$K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$: Analysis Strategy

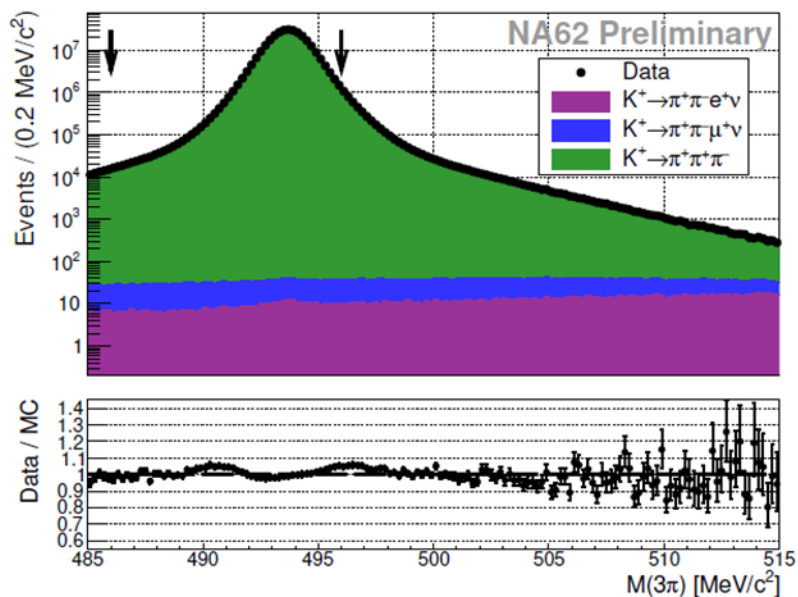
Measure BR from yields in signal selection normalized to $K_{3\pi}$ selection using invariant mass of decay products $M(3\pi\gamma)$ in 2017-2018 data

- Select exactly one good 3-track vertex reconstructed by STRAW matched to GTK kaon using Multitrack trigger (efficiency > 90%)
- **Signal region: $M(3\pi\gamma) \in (486, 496) \text{ MeV}/c^2$**
- Additional kinematic selections applied to reduce $K_{3\pi}$ background

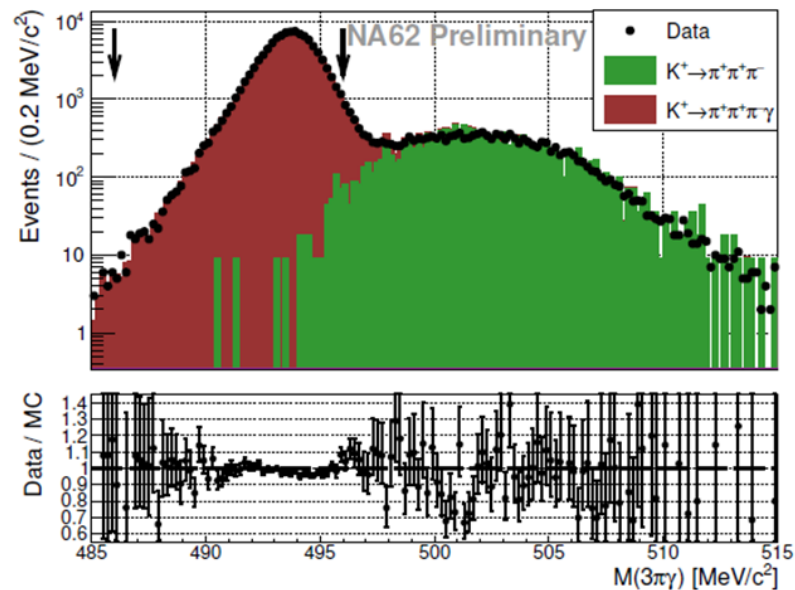
Acceptance $K_{3\pi}$:
 $(7.354 \pm 0.001_{\text{Stat}})\%$

Effective N_K :
 $(7.3997 \pm 0.0013_{\text{Stat}} \pm 0.0319_{\text{Ext}}) \times 10^{10}$

Normalization ($K_{3\pi}$)



Signal ($K_{3\pi\gamma}$)

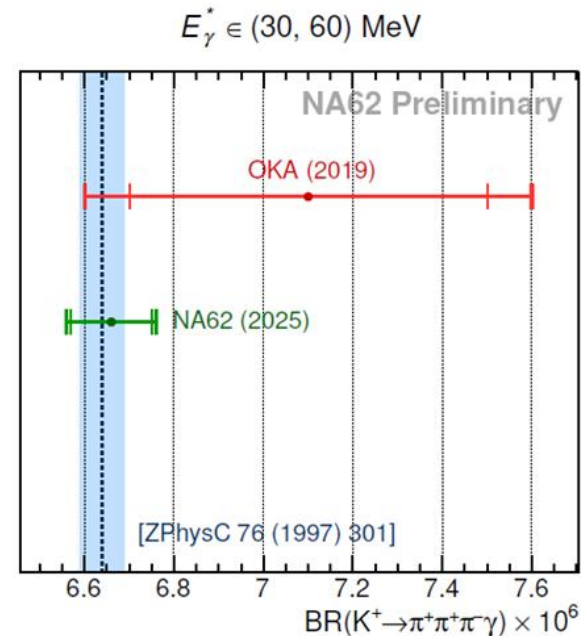
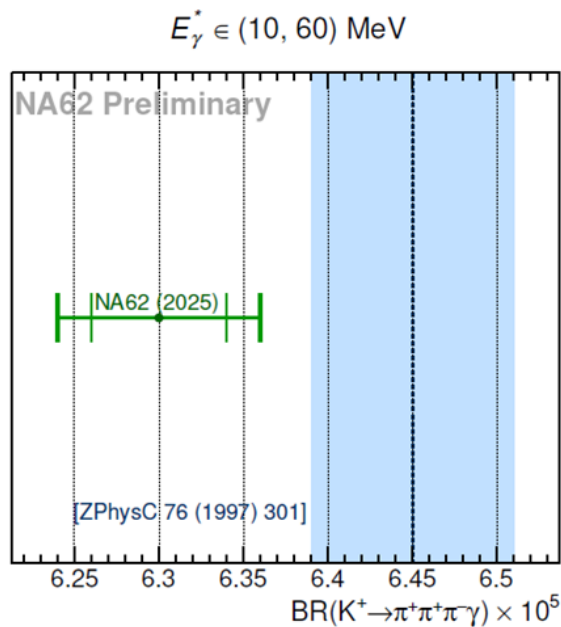


$K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$: Preliminary Results

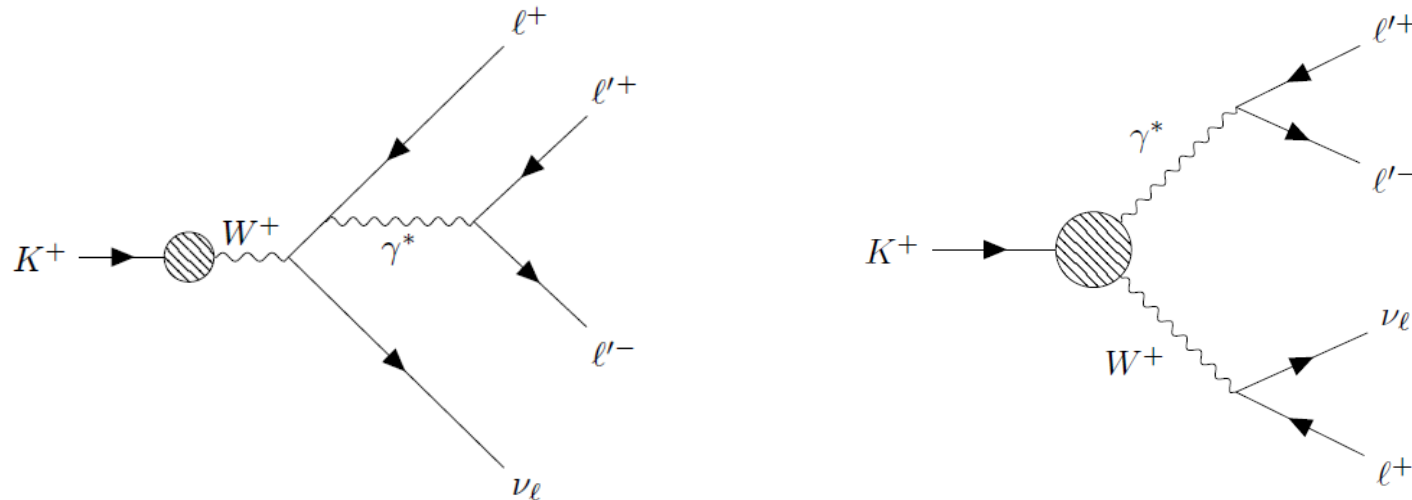
Good agreement with theoretical prediction

- Percent level precision achieved
- Can further reduce statistical uncertainty using full dataset (2021-2026)

E_γ^* [MeV]	$\mathcal{B}_{\text{NA62}}(E_\gamma^*)$ Preliminary	$\mathcal{B}_{\text{Theory}}(E_\gamma^*)$ [ZPhysC 76 (1997) 301]	$\mathcal{B}_{\text{OKA}}(E_\gamma^*)$ [EPJC 79 (2019) 1]
10–20	$(4.22 \pm 0.05) \cdot 10^{-5}$	$(4.36 \pm 0.04) \cdot 10^{-5}$	
20–30	$(1.42 \pm 0.02) \cdot 10^{-5}$	$(1.43 \pm 0.01) \cdot 10^{-5}$	
30–40	$(4.86 \pm 0.09) \cdot 10^{-6}$	$(4.93 \pm 0.05) \cdot 10^{-6}$	$(5.17 \pm 0.34) \cdot 10^{-6}$
40–50	$(1.53 \pm 0.05) \cdot 10^{-6}$	$(1.44 \pm 0.01) \cdot 10^{-6}$	$(1.55 \pm 0.12) \cdot 10^{-6}$
50–60	$(2.80 \pm 0.31) \cdot 10^{-7}$	$(2.69 \pm 0.03) \cdot 10^{-7}$	$(3.5 \pm 0.5) \cdot 10^{-7}$
60–70		$(1.36 \pm 0.02) \cdot 10^{-8}$	$(1.1 \pm 0.6) \cdot 10^{-8}$
10–60	$(6.30 \pm 0.06) \cdot 10^{-5}$	$(6.45 \pm 0.06) \cdot 10^{-5}$	
30–60	$(6.66 \pm 0.10) \cdot 10^{-6}$	$(6.64 \pm 0.05) \cdot 10^{-6}$	
30–70		$(6.65 \pm 0.05) \cdot 10^{-6}$	$(7.1 \pm 0.4_{\text{stat}} \pm 0.3_{\text{sys}}) \cdot 10^{-6}$



$K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$: Motivation



$K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$ remains the only unobserved $K^+ \rightarrow \ell^+ \nu \ell^+ \ell^-$ decay

- Dominated by SD contribution (~30% IB component)
- Most challenging background: $K^+ \rightarrow \pi^+ \pi^+ \pi^-$ ($\text{Br} = (5.583 \pm 0.024)\%$)
- Requires efficient PID to ensure low $\pi^\pm \rightarrow \mu^\pm$ misidentification probability, complete kinematic information of decay products, and high-intensity experiment to ensure sufficient statistics

➔ NA62 experiment ideal for measuring $K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$

$K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$: Analysis Strategy

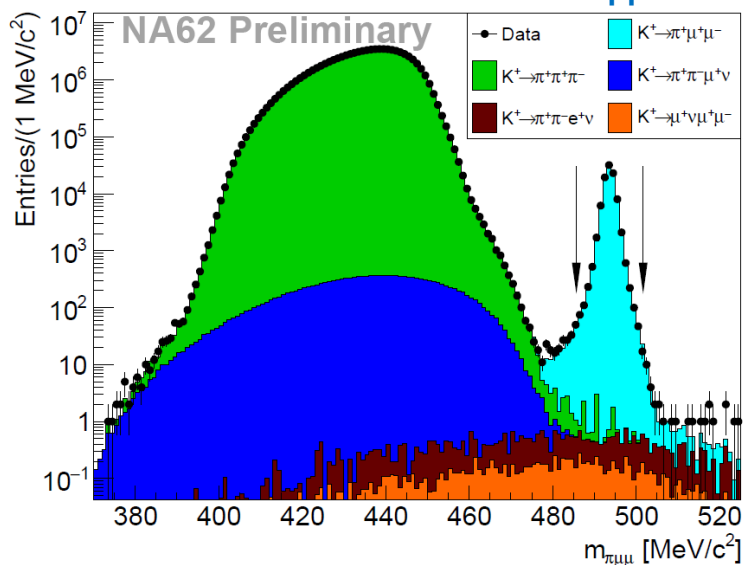
Measure BR from yields in signal selection normalized to $K_{\pi\mu\mu}$ selection using observable $M_{miss}^2 = (P_{K^+} - P_{\mu^+} - P_{\mu^+} - P_{\mu^-})^2$ in full Run 1+2 data (2017-2024)

$$BR[K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-] = \frac{N_D - N_B}{A_S \times N_K} \quad A_S = (3.821 \pm 0.004_{\text{Stat}}) \times 10^{-2}$$

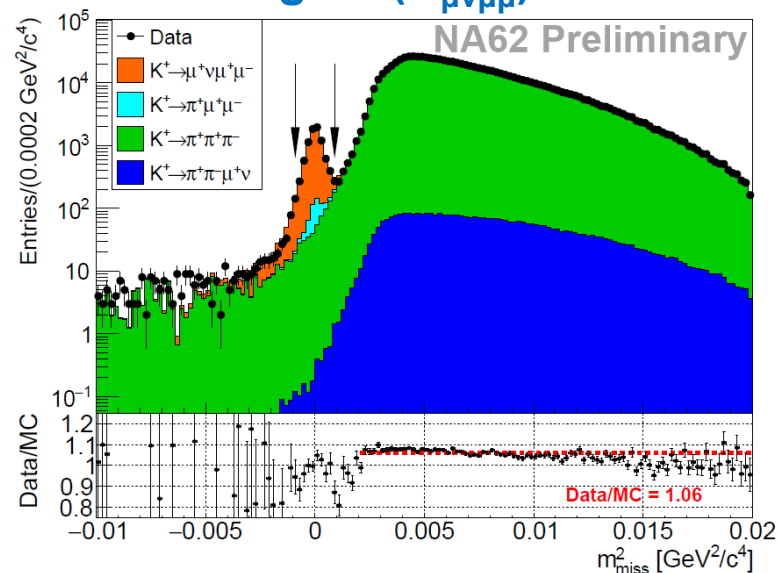
$$N_K = (1.475 \pm 0.005_{\text{Stat}}) \times 10^{13}$$

- Select single good downstream three-track vertex with Dimuon trigger, reject vertices compatible with $K^+ \rightarrow \mu^+ \nu$ decay
- Background contamination estimated with simulated data
- Signal acceptance A_S calculated assuming decay density from $O(p^6)$ ChPT prediction

Normalization ($K_{\pi\mu\mu}$)

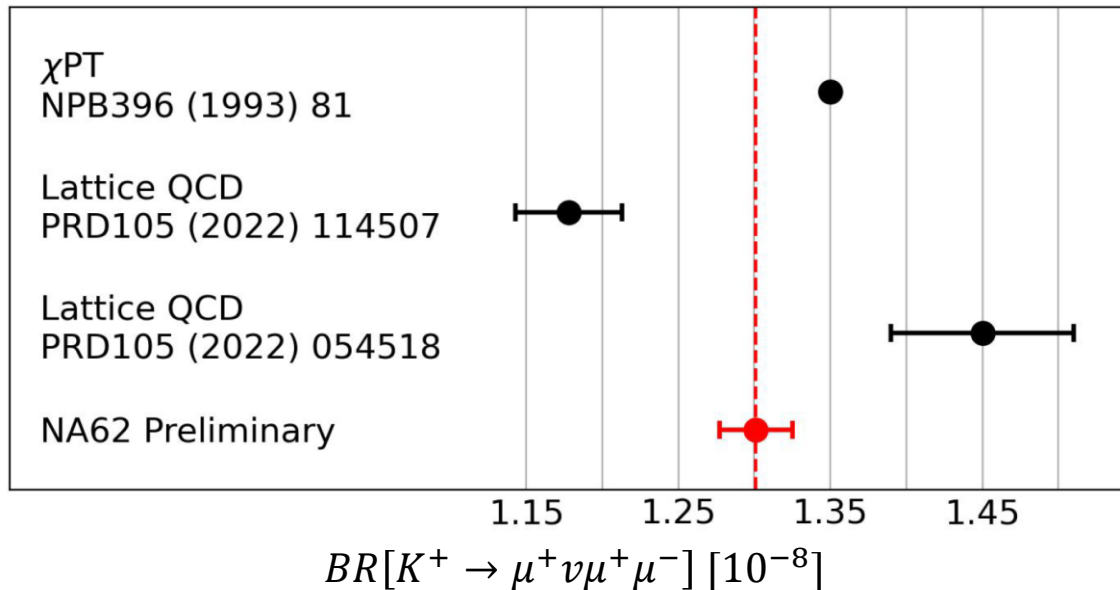


Signal ($K_{\nu\mu\mu\mu}$)



$K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$: Preliminary Results

$$BR[K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-] = (1.301 \pm 0.017_{\text{Stat}} \pm 0.012_{\text{Syst}} \pm 0.012_{\text{Ext}}) \times 10^{-8} = (1.301 \pm 0.024) \times 10^{-8}$$



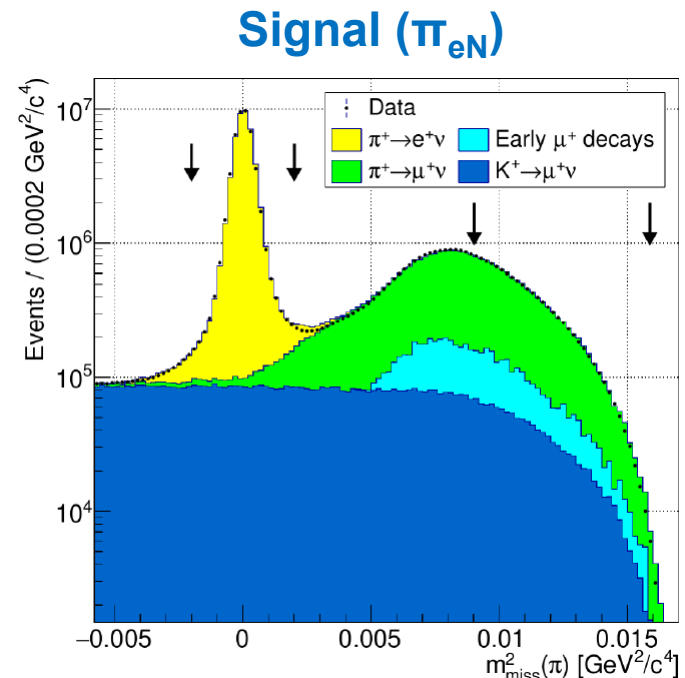
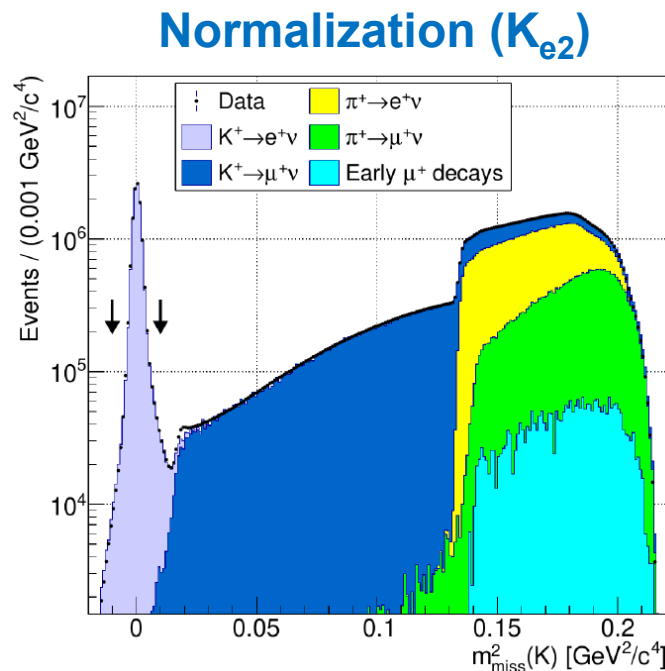
- Number of signal data candidates:
 $N_D = 8227$
- Number of background candidates:
 $N_B = 892 \pm 11_{\text{Stat}} \pm 54_{\text{Syst}}$
- Expected statistical uncertainty to remain $>1\%$ even with inclusion of 2025 and 2026 data

Three heavy neutral leptons (HNLs) predicted by extension of Standard Model (vMSM) to explain non-zero neutrino masses:

- HNLs with mass below $(m_{\pi^+} - m_e) = 139 \text{ MeV}/c^2$ can be produced in $\pi^+ \rightarrow e^+ N$ decays

$$\mathcal{B}(\pi^+ \rightarrow e^+ N) = \mathcal{B}(\pi^+ \rightarrow e^+ \nu_e) \cdot \rho(m_N) \cdot |U_{e4}|^2$$

- Search in mass range 95-126 MeV/c^2 using 2017-2024 data \rightarrow Set limits on $|U_{e4}|^2$
- Select single e^+ track in STRAW consistent with extrapolation to LKr and matched to GTK π^+ track using main $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ trigger, normalized to K_{e2} decays ($N_K = (19.02 \pm 0.08) \times 10^{12}$)

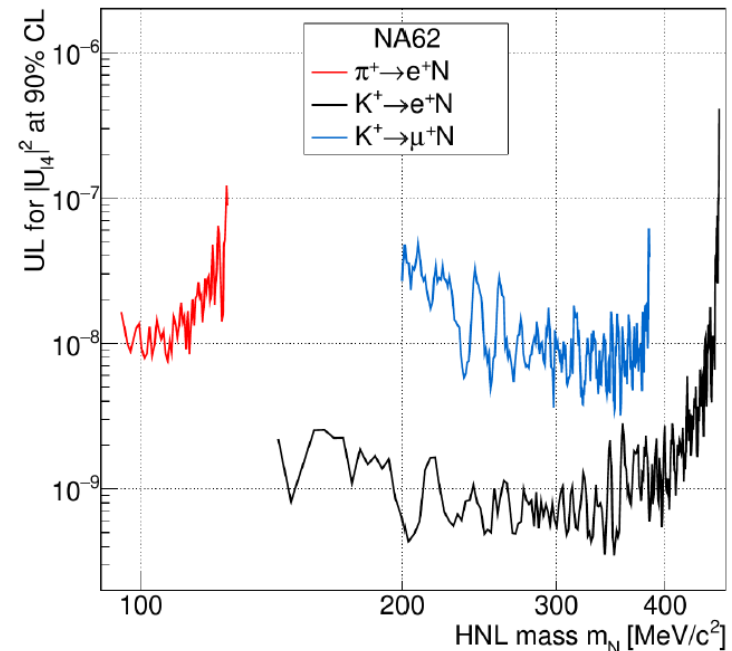
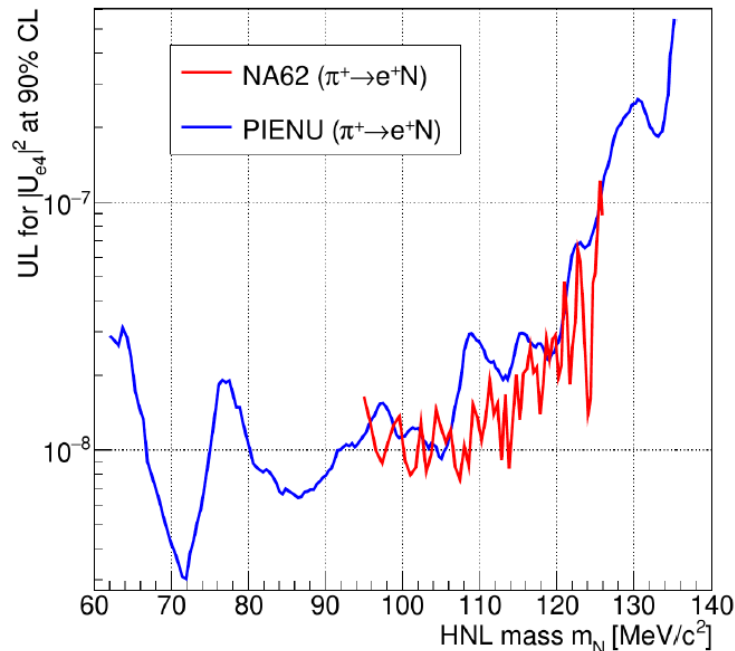


Expected number of signal events determined from single event sensitivity

$$N_S = \mathcal{B}(\pi^+ \rightarrow e^+ N) / \mathcal{B}_{\text{SES}}(\pi^+ \rightarrow e^+ N) = |U_{e4}|^2 / |U_{e4}|_{\text{SES}}^2$$

$$\mathcal{B}_{\text{SES}}(\pi^+ \rightarrow e^+ N) = \frac{1}{N_\pi \cdot A_N} \quad |U_{e4}|_{\text{SES}}^2 = \frac{\mathcal{B}_{\text{SES}}(\pi^+ \rightarrow e^+ N)}{\mathcal{B}(\pi^+ \rightarrow e^+ \nu_e) \cdot \rho(m_N)}$$

- Search performed in 63 mass hypotheses within HNL search region (95-126 MeV/c²)
- Upper limits at 90% CL set for mixing parameter $|U_{e4}|^2$



Constraints set on benchmark hidden-sector models from studies of rare kaon decays ($K^+ \rightarrow \pi^+ \nu \bar{\nu}$, $K^+ \rightarrow \pi^+ \mu^+ \mu^-$, $K^+ \rightarrow \pi^+ \gamma \gamma$, $\pi^0 \rightarrow$ invisible) using 2016-2022 data:

- **BC1 and BC2:** new $U(1)$ symmetry gauge boson A' (dark photon) interacts with SM fields through kinetic mixing:

$$\mathcal{L}_{\text{portal}} = -(\varepsilon/(2 \cos \theta_W)) F'_{\mu\nu} B^{\mu\nu}$$

- **BC4:** new scalar single S (dark scalar) interacts with SM Higgs doublet H :

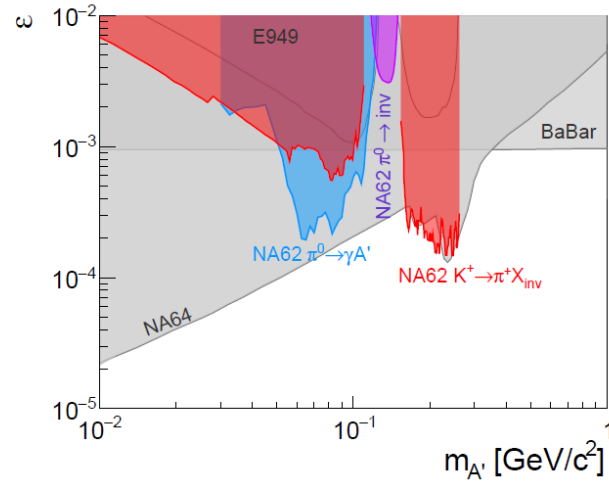
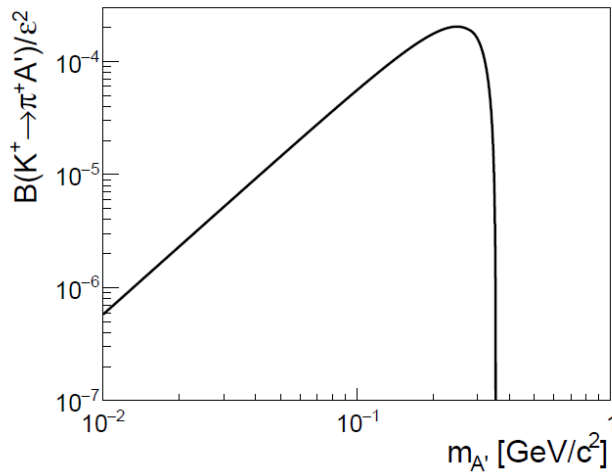
$$\mathcal{L}_{\text{portal}} = -\mu S H^\dagger H$$

- **BC10 and BC11:** axion-like particle a couples to SM fermions f and gauge bosons V :

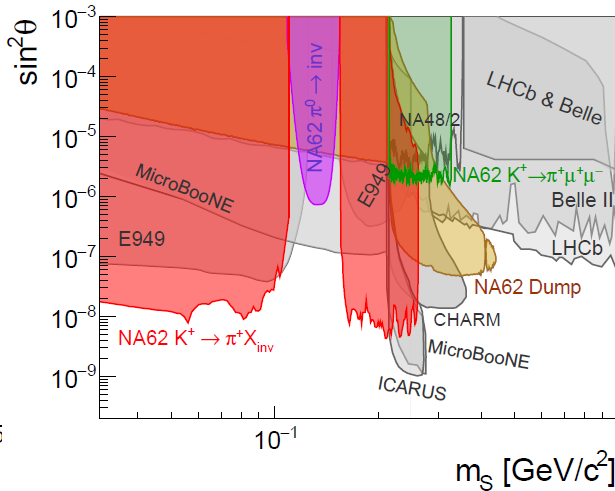
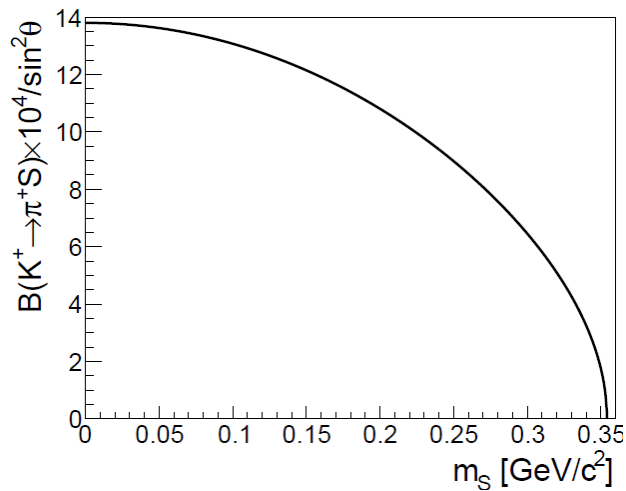
$$\mathcal{L}_{\text{portal},f} = (C_{ff}/(2\Lambda)) \partial_\mu a \bar{f} \gamma^\mu \gamma^5 f \quad \mathcal{L}_{\text{portal},V} = g^2 (C_{VV}/\Lambda) a V_{\mu\nu} \tilde{V}^{\mu\nu}$$

Benchmark	BSM particle (X)	Type	Coupling to SM	Search
BC1	dark photon (A')	vector	ε	$\mu^+ \mu^-$
BC2	dark photon (A')	vector	ε	invisible
BC4	dark scalar (S)	scalar	θ	invisible, $\mu^+ \mu^-$
BC4-inv	dark scalar (S)	scalar	θ	invisible
BC10	axion-like particle (a)	pseudoscalar	C_{ff} (to fermions)	invisible, $\mu^+ \mu^-$
BC10-inv	axion-like particle (a)	pseudoscalar	C_{ff} (to fermions)	invisible
BC11	axion-like particle (a)	pseudoscalar	C_{GG} (to gluons)	invisible, $\gamma \gamma$

$K^+ \rightarrow \pi^+ A'$ (BC2)



$K^+ \rightarrow \pi^+ S$ (BC4)

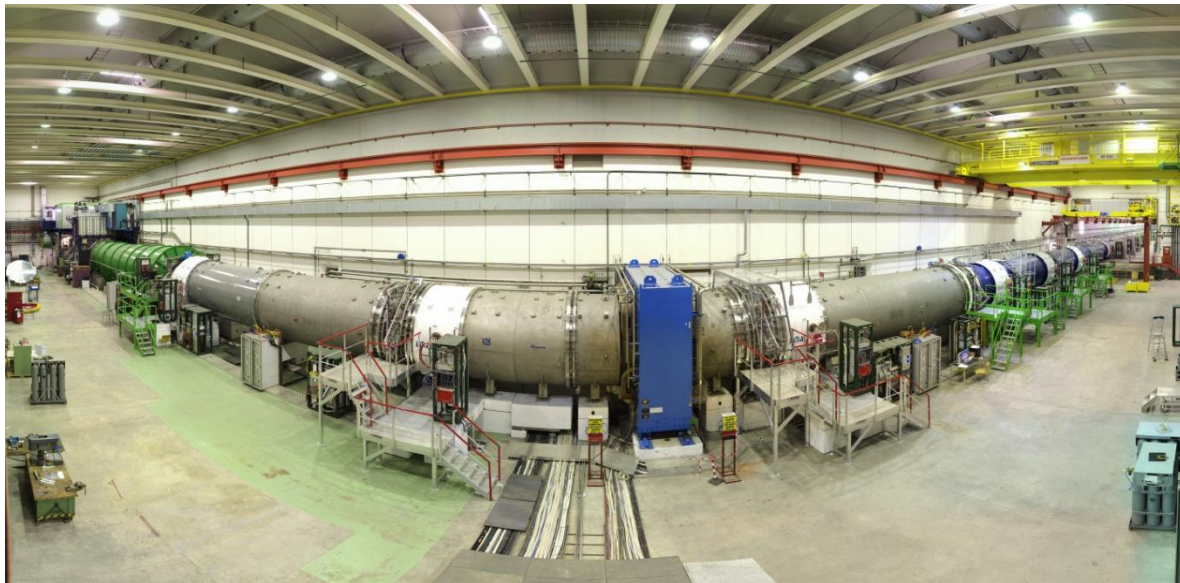


Summary

Many interesting physics results at NA62 (both preliminary and published)

- New update to $\text{Br}(K^+ \rightarrow \pi^+ \nu \bar{\nu})$
- Precision Measurements ($K^+ \rightarrow e^+ \nu \gamma$, $K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$)
- Rare and forbidden decays ($K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$)
- Direct exotic searches ($K^+ \rightarrow \pi^+ X$, $\pi^+ \rightarrow e^+ N$)
- And more to come...

Look forward to new results!



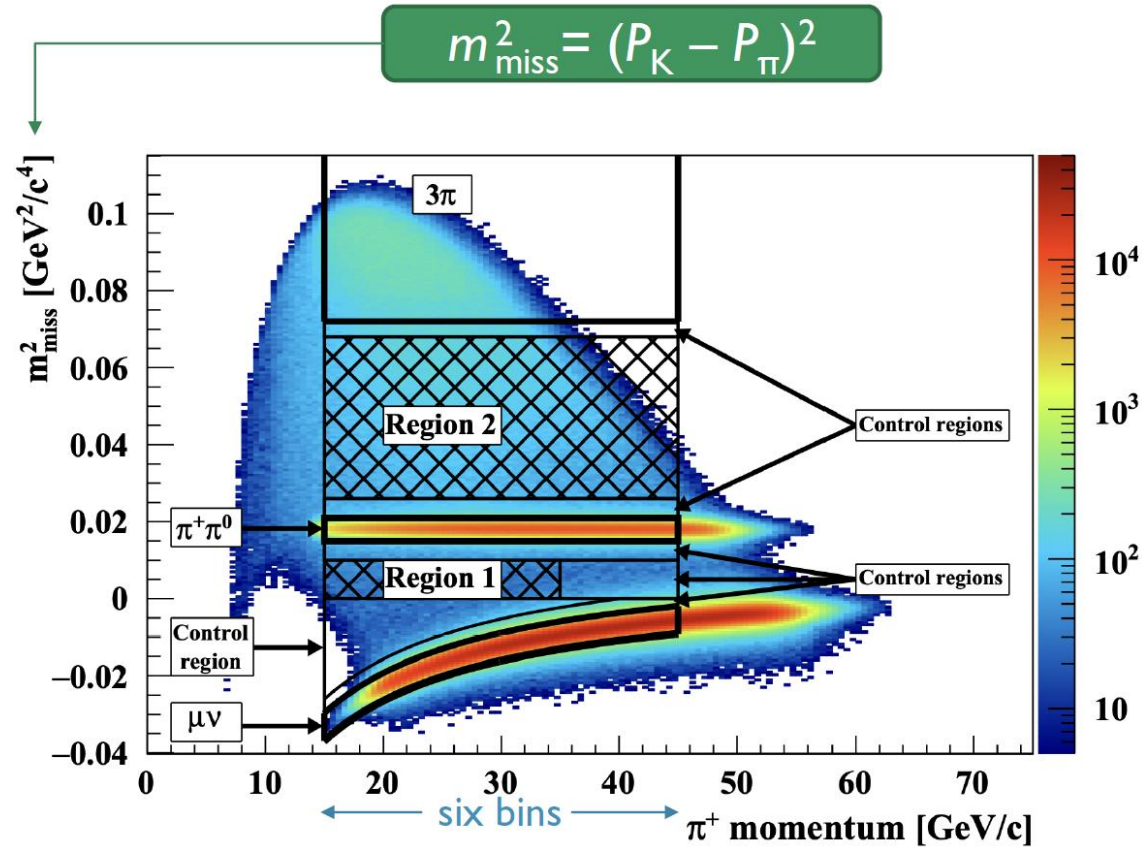
Backup

$K^+ \rightarrow \pi^+ \nu \bar{\nu}$: Kinematic Region

Main K^+ (bkg) decay modes	\mathcal{B}
$K^+ \rightarrow \mu^+ \nu$	64%
$K^+ \rightarrow \pi^+ \pi^0$	21%
$K^+ \rightarrow \pi^+ \pi^+ \pi^-$	5.6%
$K^+ \rightarrow \pi^+ \pi^- e^+ \nu$	4.3×10^{-5}
$K^+ \rightarrow \pi^+ \nu \bar{\nu}$	$O(10^{-10})$

Background rejection:

- $O(10^4)$ bkg suppression from kinematics
- $O(10^7)$ μ^+ rejection
- $O(10^8)$ π^0 rejection



$K^+ \rightarrow \pi^+ \nu \nu$: Signal Sensitivity

$$N_{\pi\nu\nu}^{\text{exp}} = N_{\pi\pi\pi} D \frac{\mathcal{B}(\pi\nu\nu)_{\text{SM}} A_{\pi\nu\nu}}{\mathcal{B}(\pi\pi\pi) A_{\pi\pi\pi}} \epsilon_{\text{trigger}} \epsilon_{\text{RV}}$$

Expected SM signal events

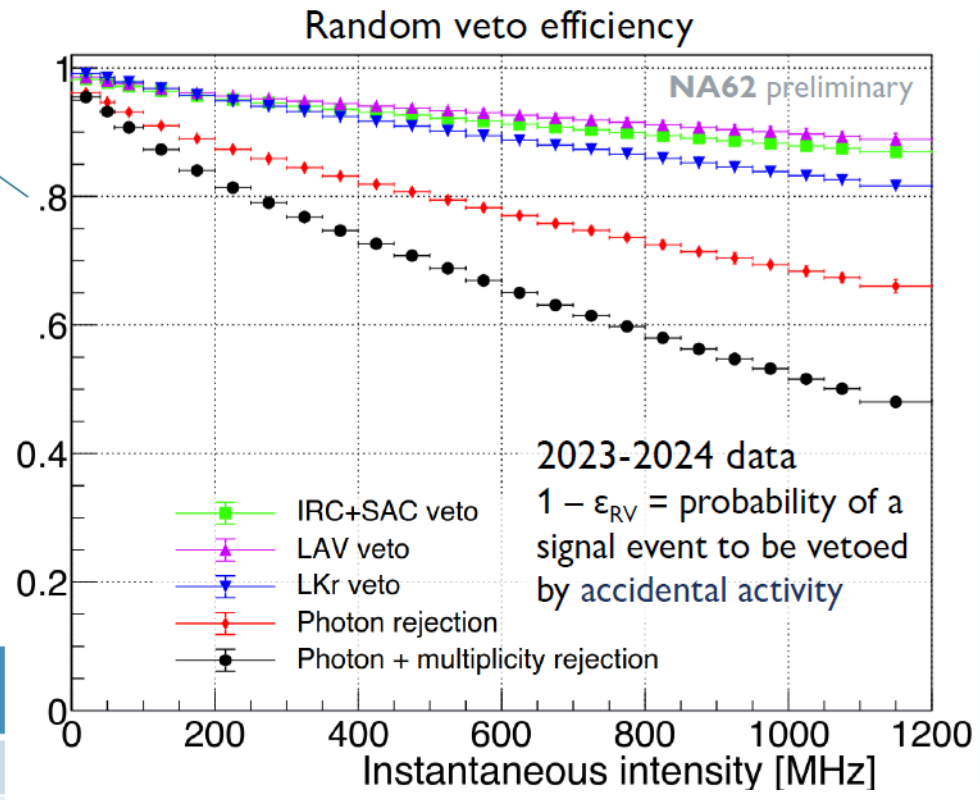
Trigger downscaling

External inputs

Trigger efficiency ratio

Normalization $K^+ \rightarrow \pi^+ \pi^0$ events

Selection acceptances



	2021-2022 [JHEP 02 (2025) 191]	2023-2024 (this analysis)
$N(\pi\pi)$	1.95×10^8	3.93×10^8
$A(\pi\pi)$	$(13.410 \pm 0.005) \%$	$(12.971 \pm 0.009) \%$
$A(\pi\nu\nu)$	$(7.62 \pm 0.22) \%$	$(7.36 \pm 0.33) \%$
$\epsilon(\text{trigger})$	$(85.9 \pm 1.4) \%$	$(86.4 \pm 1.2) \%$
$\epsilon(\text{RV})$	$(63.2 \pm 0.6) \%$	$(72.3 \pm 0.7) \%$
$N(\pi\nu\nu, \text{exp})$	9.9 ± 0.3	22.9 ± 1.1

$K^+ \rightarrow e^+ \nu \gamma$: Comparison to KLOE

Signal regions in K^+ rest frame:

NA62: $P_e > 230 \text{ MeV}/c$ and $E_\gamma > 50 \text{ MeV}/c$ (approx.)

KLOE: $P_e > 200 \text{ MeV}/c$ and $E_\gamma > 10 \text{ MeV}/c$

To compare NA62 preliminary result with experimental status, $\text{BR}(K_{e2\gamma} \text{SD}^+)$ is extrapolated to KLOE kinematic region using:

$$F_{\text{NA62/KLOE}} = \frac{\text{Prob}(X > 0.2; Y > 0.93)}{\text{Prob}(E_\gamma > 10 \text{ MeV}; P_e > 200 \text{ MeV}/c)}$$

$$F_{\text{NA62/KLOE}} = 0.4616 \pm 0.0012^*$$

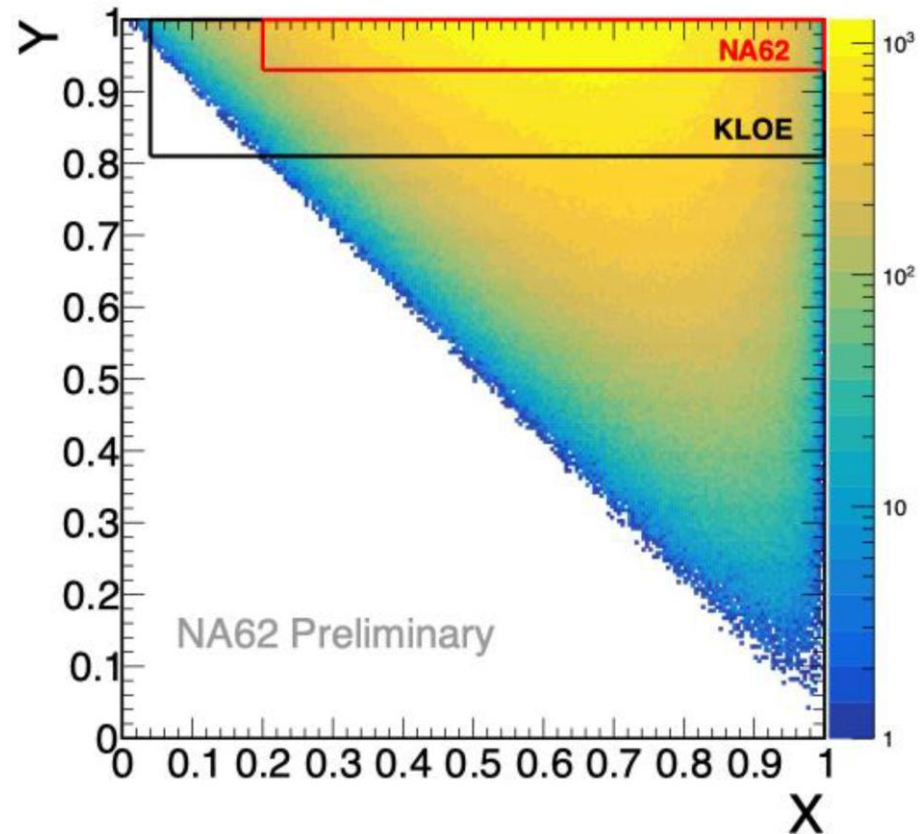
$$\text{BR}_{\text{KLOE}}(K_{e2\gamma} \text{SD}^+) = \text{BR}(K_{e2\gamma} \text{SD}^+) / F_{\text{NA62/KLOE}}$$

(*) due to uncertainty on the measured value of the slope λ

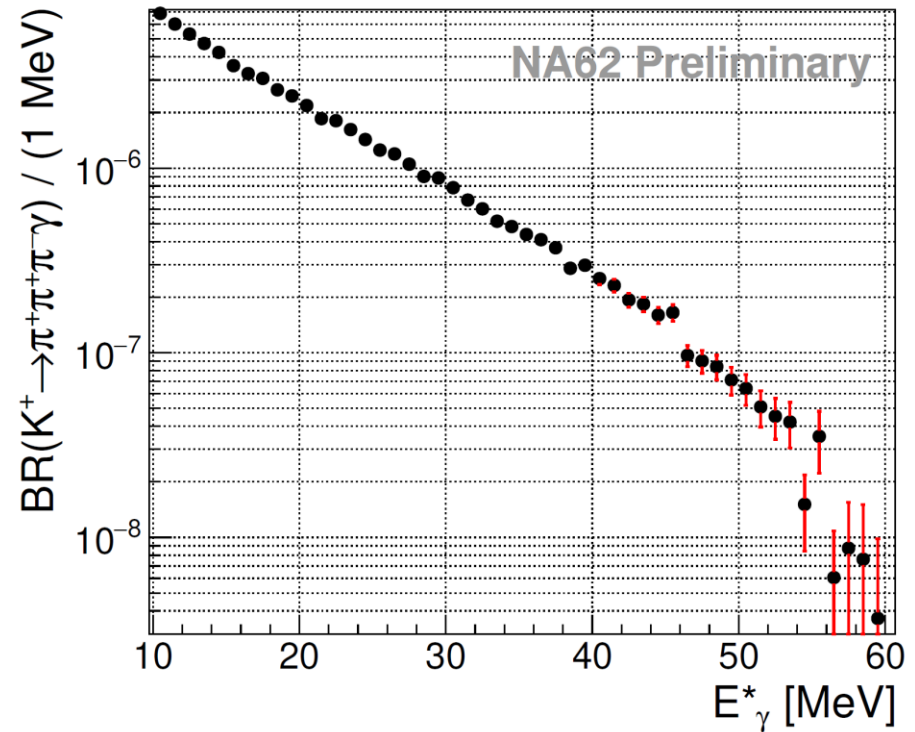
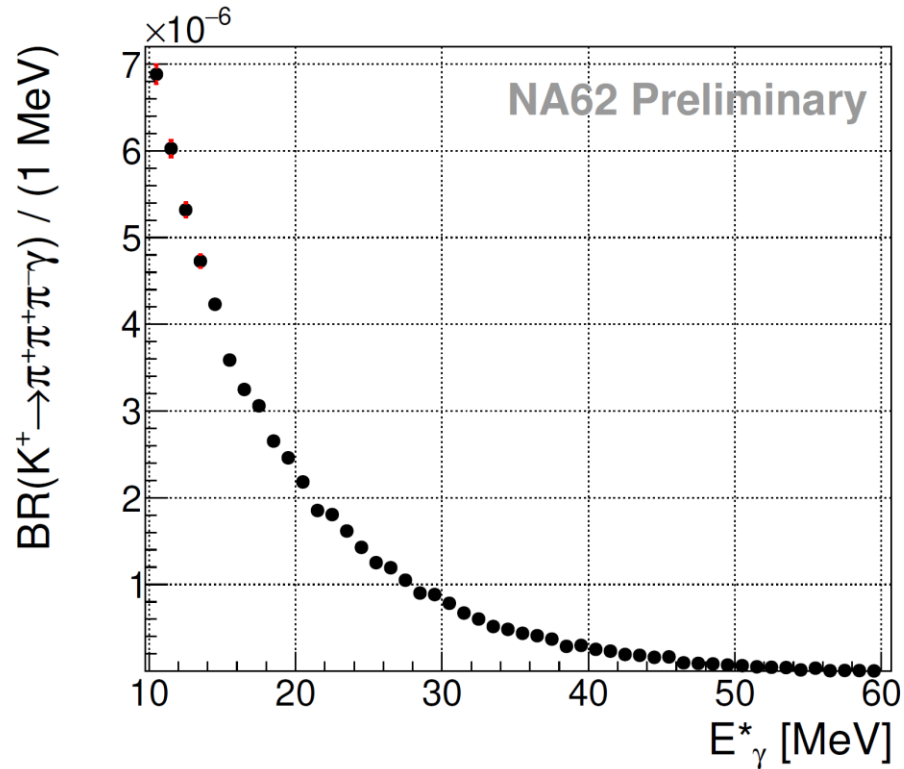
$$x = \frac{2E_\gamma}{m_K}; y = \frac{2E_e}{m_K};$$

in K^+ rest frame

$$\text{BR}_{\text{KLOE}}(K_{e2\gamma} \text{SD}^+) = (1.009 \pm 0.013) \times 10^{-5}$$

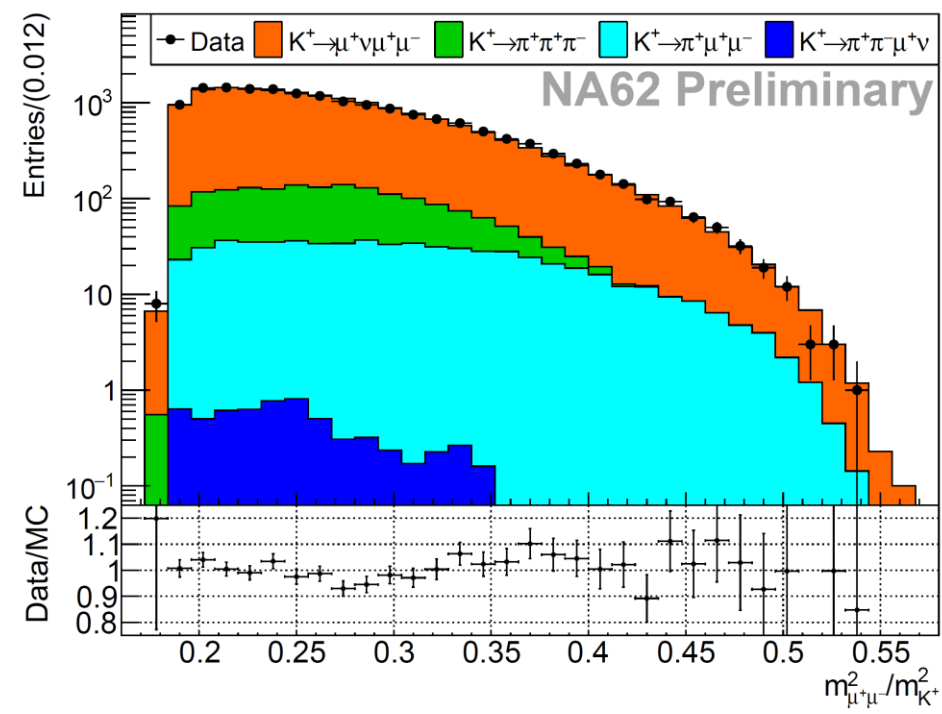
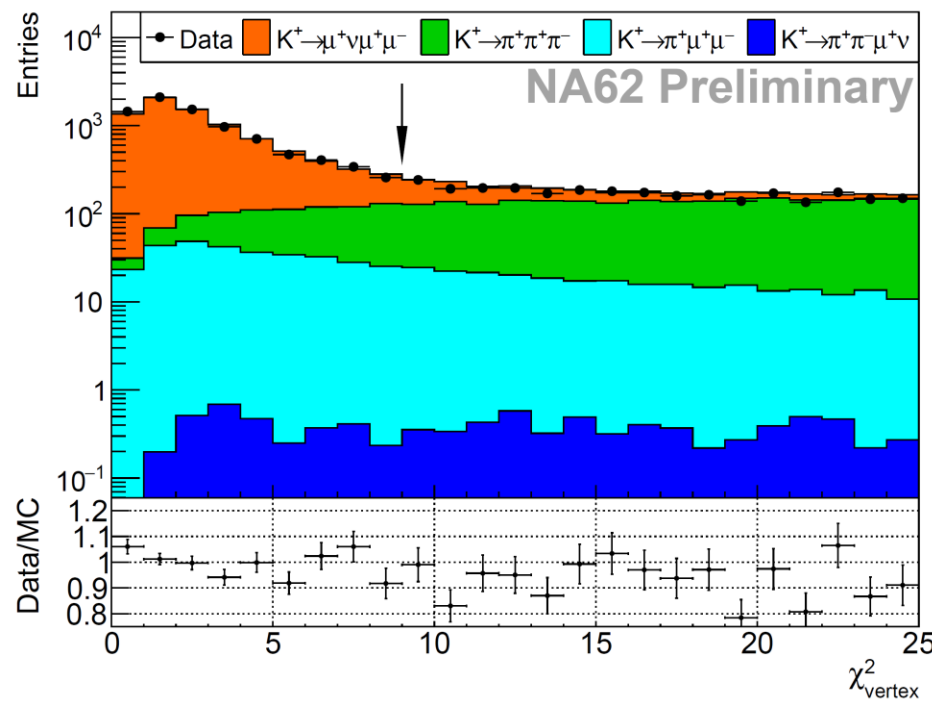


$K^+ \rightarrow \pi^+ \pi^+ \pi^- \gamma$: BR Distribution



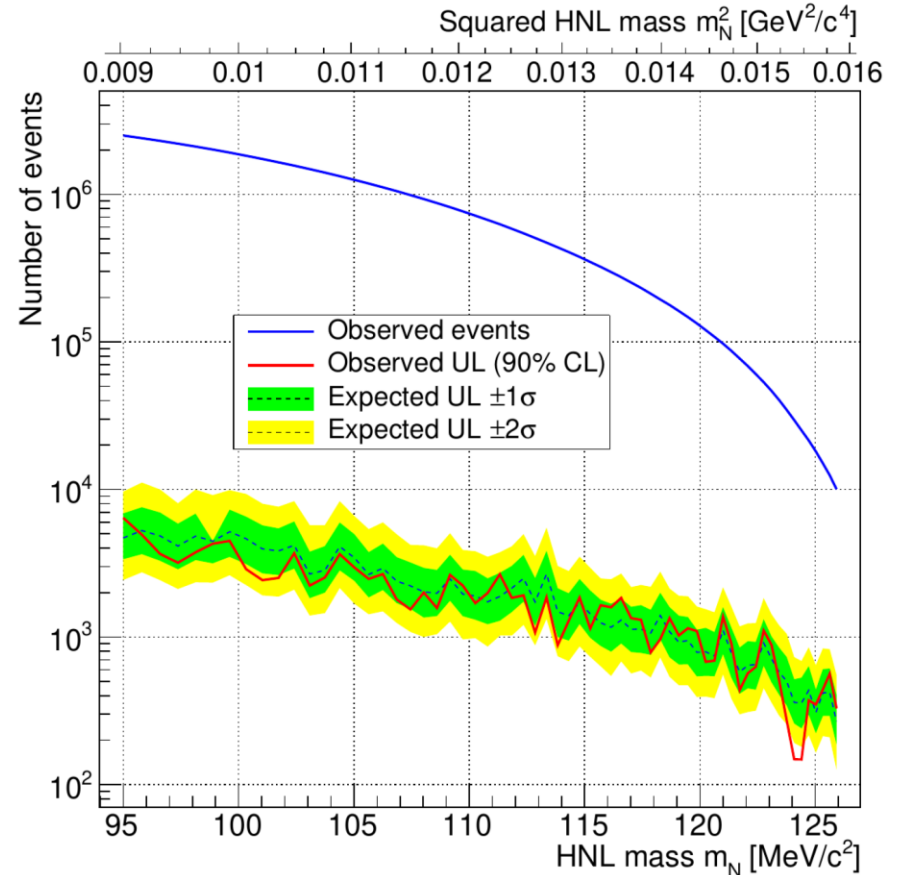
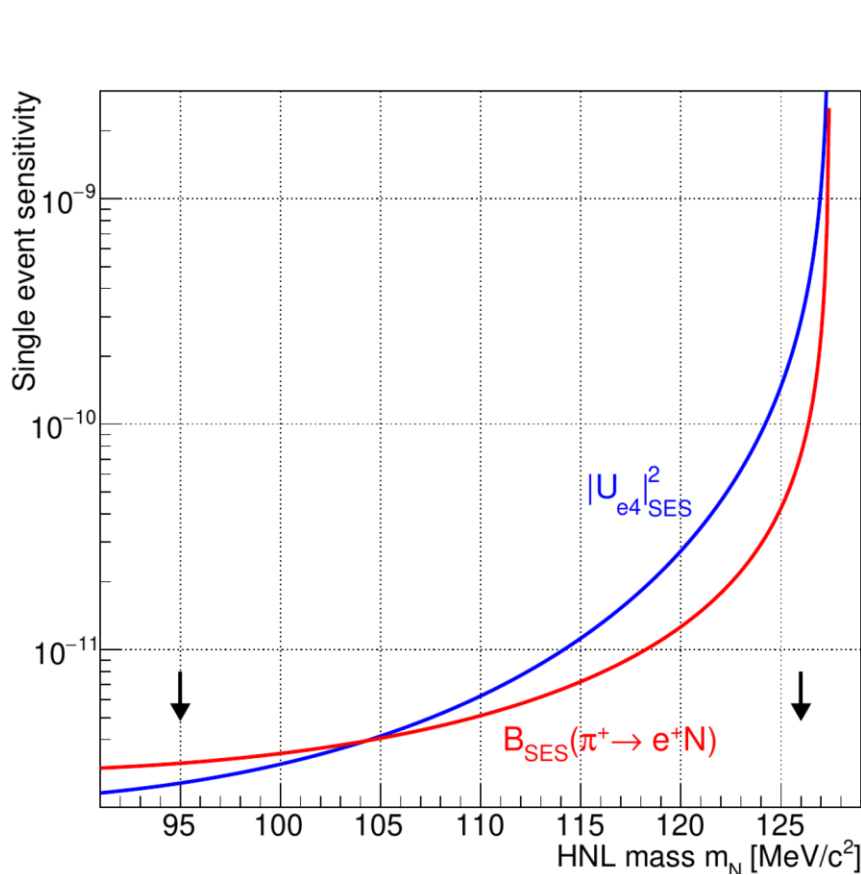
***Uncertainties are statistical only**

$K^+ \rightarrow \mu^+ \nu \mu^+ \mu^-$: Signal and Background Validation



- Cut value of $\chi^2 < 9$ applied in common selection
- $m^2_{\mu^+ \mu^-}$ spectrum has two entries per event due to ambiguity in μ^+

$\pi^+ \rightarrow e^+ N$: SES and N_{obs} vs m_N



$$\mathcal{B}_{\text{SES}}(\pi^+ \rightarrow e^+ N) = \frac{1}{N_\pi \cdot A_N}$$

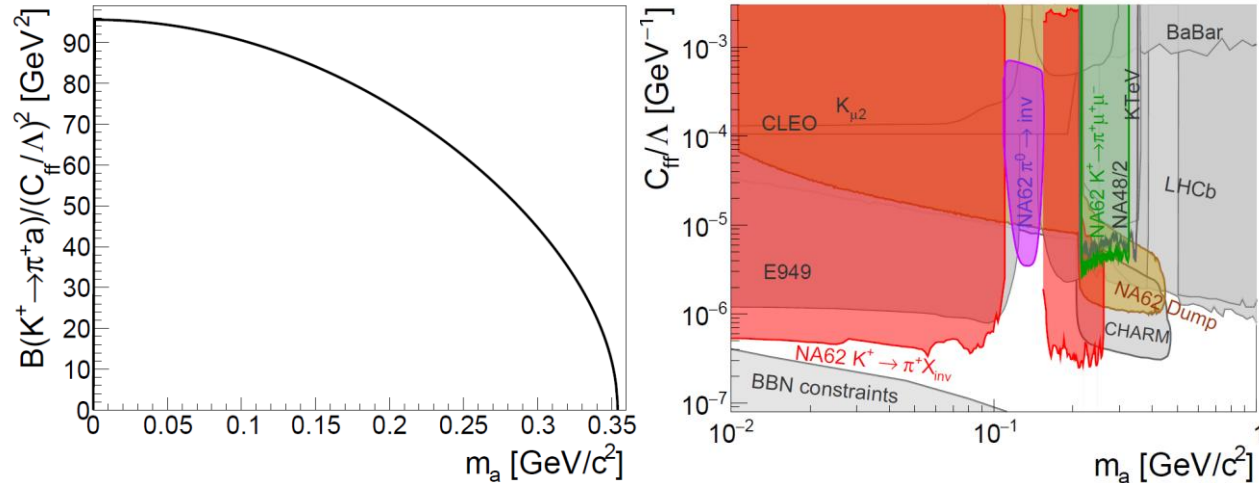
$$|U_{e4}|_{\text{SES}}^2 = \frac{\mathcal{B}_{\text{SES}}(\pi^+ \rightarrow e^+ N)}{\mathcal{B}(\pi^+ \rightarrow e^+ \nu_e) \cdot \rho(m_N)}$$

$$N_\pi = \frac{N_{\text{SM}}^\pi - N_{K\mu 2}^\pi}{A_e^\pi \cdot \mathcal{B}(\pi^+ \rightarrow e^+ \nu_e) + A_\mu^\pi \cdot \mathcal{B}(\pi^+ \rightarrow \mu^+ \nu_\mu)}$$

$$N_{K\mu 2}^\pi = N_K \cdot A_{K\mu 2}^\pi \cdot \mathcal{B}(K^+ \rightarrow \mu^+ \nu_\mu)$$

$K^+ \rightarrow \pi^+ X$: BC10 and BC11 Constraints

$K^+ \rightarrow \pi^+ a$ (BC10)



$K^+ \rightarrow \pi^+ a$ (BC11)

