EPS-HEP 2025 Conference

6 -11 July 2025, Palais du Pharo, Marseille

Observation of the decay $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ and measurement of its branching ratio by the NA62 experiment at CERN

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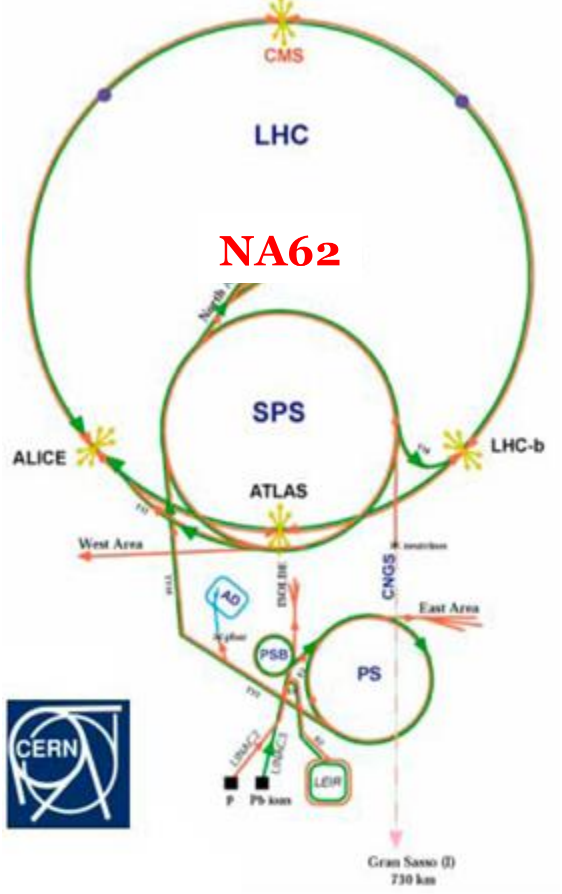
on behalf of the NA62 Collaboration

The NA62 experiment

High precision fixed-target Kaon experiment at CERN SPS

300 participants from 30 institutions



NA62 Beam line & detectors

NA62 primary goal: Measure BR($K^+ \to \pi^+\nu\bar{\nu}$)

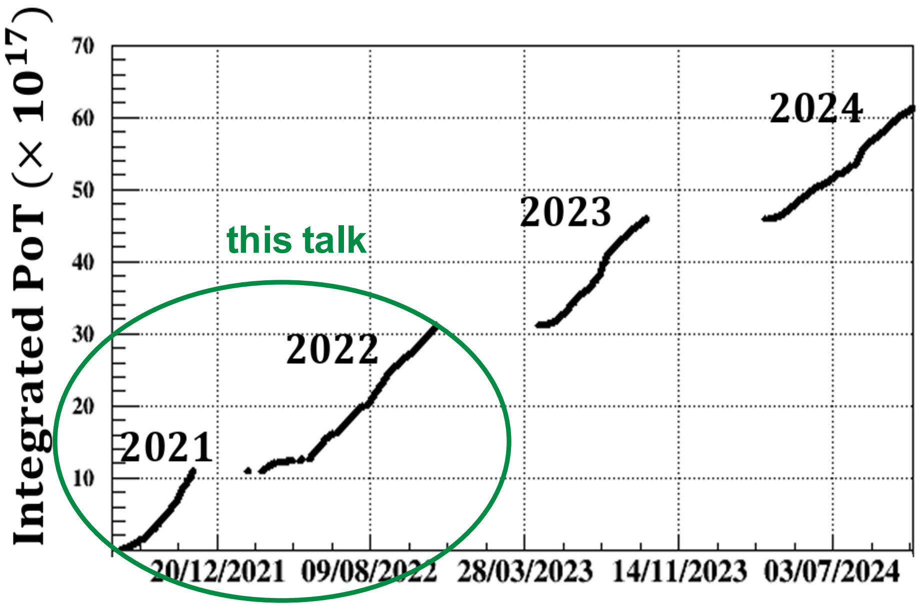
Novel K^+ decay-in-flight technique

Run1 results: [PLB791(2019)156, JHEP11(2020)042, JHEP06(2021)093]

NA62 Timeline & Datasets

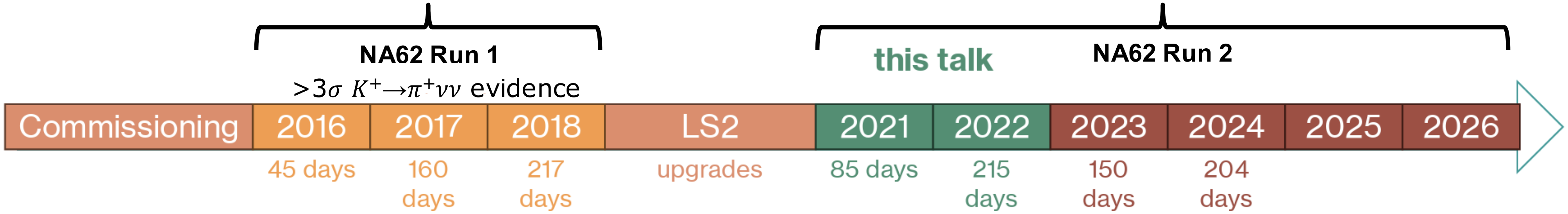
NA62 Run 1 (2016-2018):
- 22 x 10^{17} protons on target (PoT) delivered
- 0.9 x 10^6 spills collected

NA62 Run 2 (2021-present):
- ~1.5 x 10^6 spills collected



NA62 Timeline

- 2008 - Physics Approval
- 2009 - 2014: Detector R&D, Installation 2015 Commissioning
- 2016 – 2018: NA62 Run 1
- 2021 – 2026: NA62 Run 2



NA62 Physics Programme

NA62

Flavour Physics

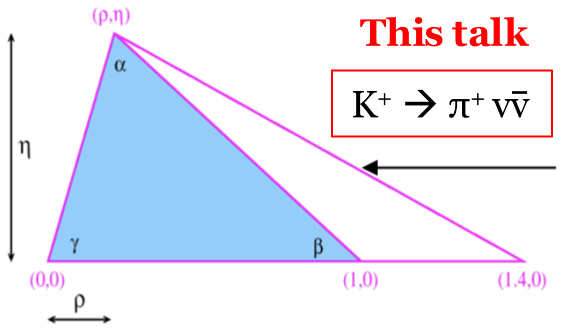
- Search for NP at the EW scale with sizeable coupling to SM particles via indirect effects in loops: Golden mode: $K^+ \to \pi^+ \nu\nu$;
- χPT and Lepton Universality tests - Precision measurements of K^+ decays
- Searches for lepton flavour and number violation (LFV, LNV) - Rare and forbidden decay analysis

Hidden Sector

- Search for NP below the EW scale (MeV-GeV range) feebly-coupled to SM particles via direct detection of long-lived particles: HNL, Dark Photon, ALP..

Neutrino Physics

- Experimental proof of principle of Neutrino Tagging technique using NA62 layout



This talk

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

$K^+ \to \pi^+ \gamma\gamma$

$K^+ \to \pi^0 e^+ \nu\gamma$

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

$K^+ \to \pi^\pm \mu^\mp e^+$

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

$K^+ \to \mu^- \nu e^+ e^+$

$K^+ \to \pi^- \pi^0 e^+ e^+$

$\dots$

$K^+ \to \pi^+ X$

$K^+ \to l^+ N$

$K^+ \to \pi^+ aa, a \to e^+ e^-$

Talk by V. Duk on 07/07 (T07)

$A' \to l^+ l^-$

$N \to \pi^\pm l^\mp$

$\dots$

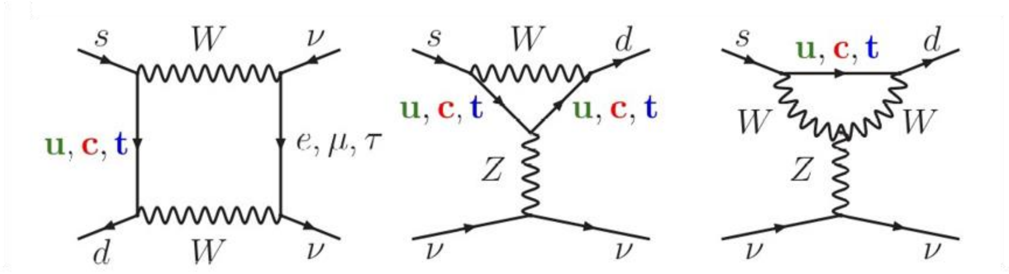
NA62 dump configuration Talk by I. Rosa on 07/07 (T09)

$K^+ \to \mu^+ \nu_\mu$

Talk by M. Perrin-Terrin on 11/07 (T03)

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

Box & Penguin (one-loop) diagrams



- ✓ FCNC process forbidden at tree level
- ✓ Highly CKM suppressed (BR ~ $|V_{ts}{}^*V_{td}|^2$)
- ✓ Extraction of V_{td} with minimal (few %) non-parametric uncertainty

Theoretically very clean:

- ✓ dominant short-distance contribution
- ✓ hadronic matrix element extracted from precisely measured BR($K^+ \to \pi^0 e^+ \nu_e$)

- SM predictions: differences in calculation from choices of CKM parameters, theory uncertainty few %

	[Buras et al. EPJC 82 (2022) 7, 615]	[D'Ambrosio et al. JHEP 09 (2022) 148]
$K^+ \to \pi^+\nu\bar{\nu}$	$(8.60 \pm 0.42) \times 10^{-11}$	$(7.86 \pm 0.61) \times 10^{-11}$
$K_L \to \pi^0\nu\bar{\nu}$	$(2.94 \pm 0.15) \times 10^{-11}$	$(2.68 \pm 0.30) \times 10^{-11}$

- Experimental status:

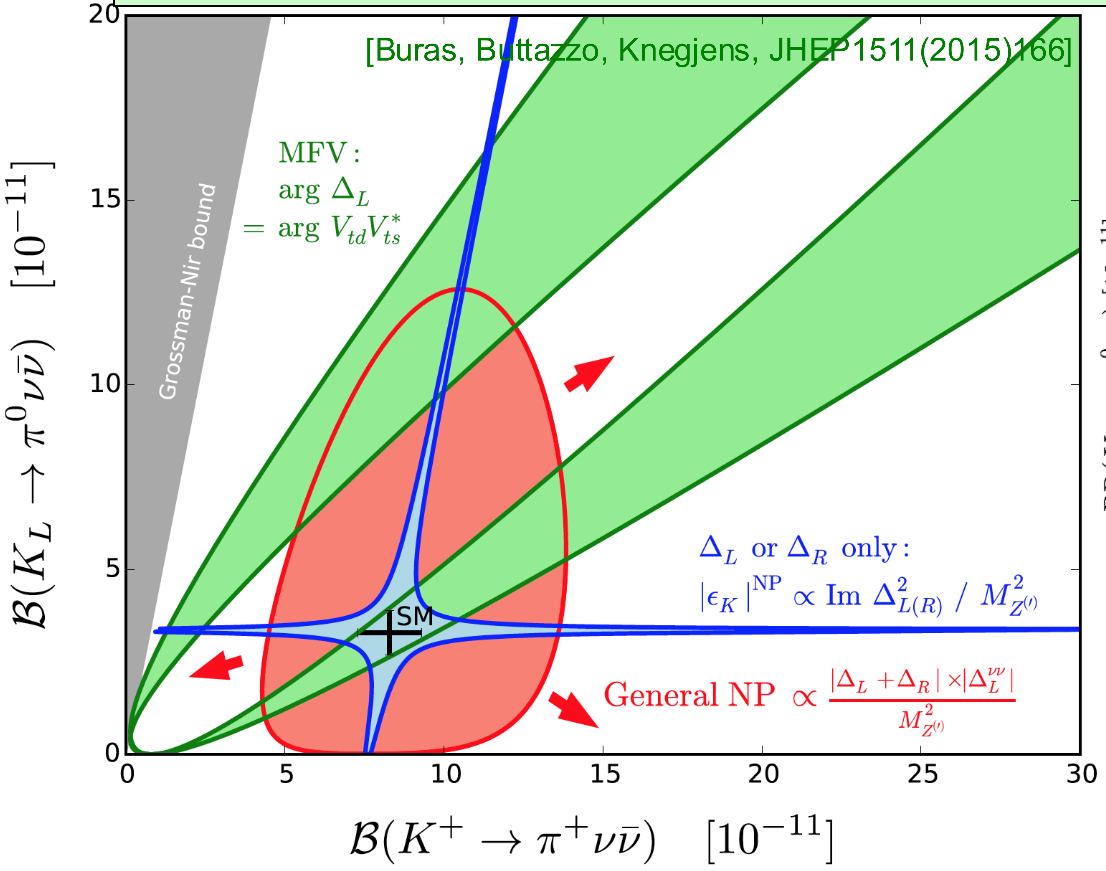
$K^+ \to \pi^+\nu\bar{\nu}$ NA62: $\left(10.6^{+4.1}_{-3.5}\right) \times 10^{-11}$ [16-18 data JHEP 06 (2021) 093]; THIS TALK [21-22 data+16-18]

$K_L \to \pi^0\nu\bar{\nu}$ KOTO: $< 2.2 \times 10^{-9}$ [21 data PRL 134, 081802]

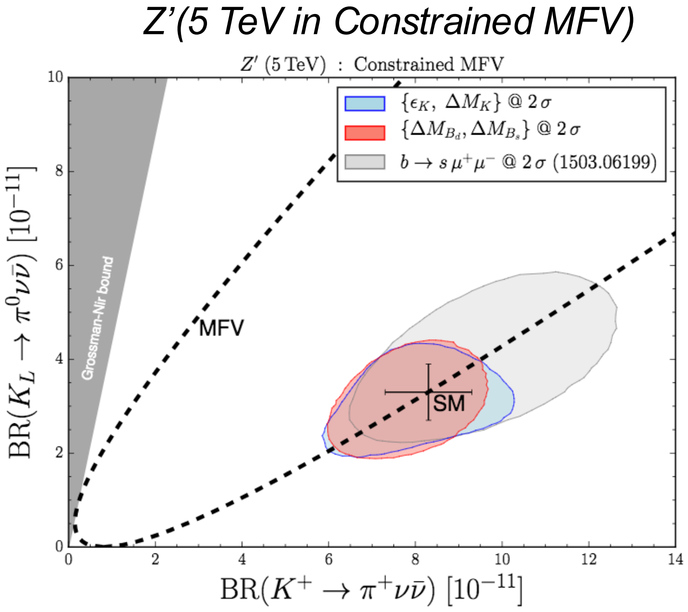
K→$\pi\nu\bar{\nu}$ and New Physics

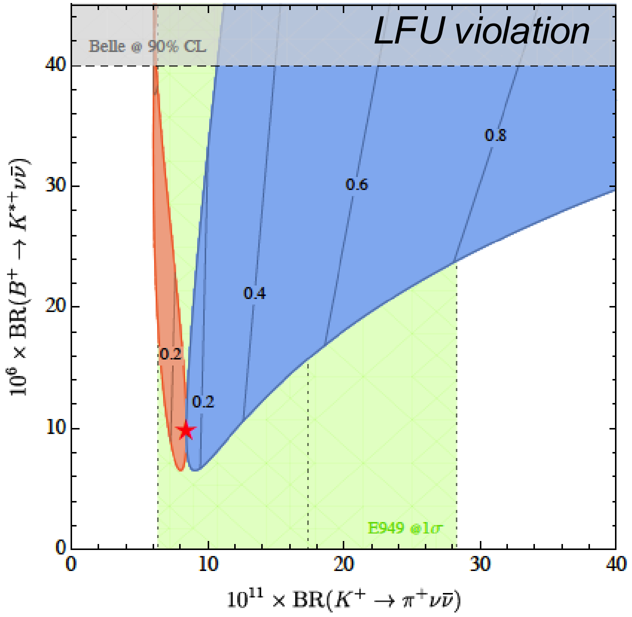
Indirect searches of NP with high precision studies of rare K decays

Measurement of charged ($K^+ \rightarrow \pi^+\nu\bar{\nu}$) and neutral ($K_L \rightarrow \pi^0\nu\bar{\nu}$) modes allows to **discriminate among different NP scenarios**



Correlations significantly change for different classes of NP models [EPJ C76 (2016) no.4 182]





[Isidori et al., Eur. Phys. J. C(2017)77: 618]

K→ $\pi\bar{\nu}\nu$ probes of unique sensitivity for NP models among B and K decays
(NP searches complementary/alternative to LHC)

$K^+ \to \pi^+ \nu\bar{\nu}$ Signal and Backgrounds

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

Kaon track + Pion track + nothing else

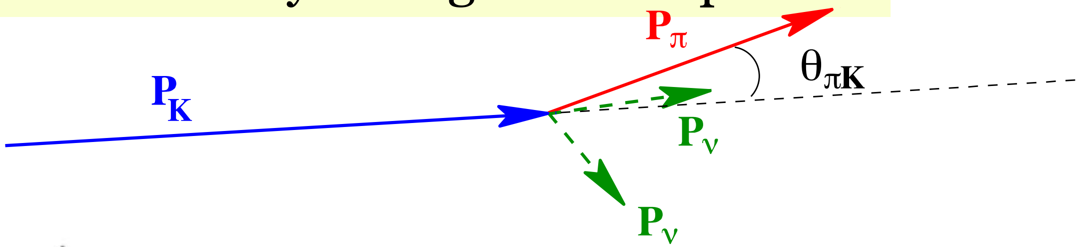
$$m^2_{miss} \approx m^2_K \left(1 - \frac{|p_\pi|}{|p_K|}\right) + m^2_\pi \left(1 - \frac{|p_K|}{|p_\pi|}\right) - |p_K||p_\pi|\theta^2_{\pi K}$$

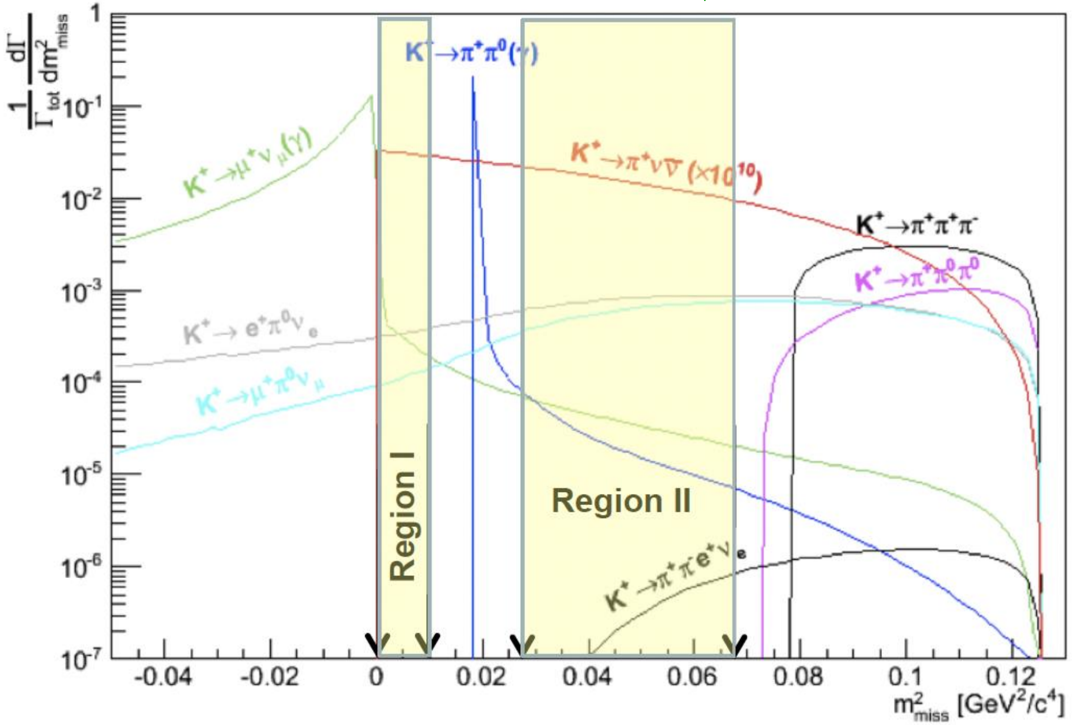
Main kaon decay backgrounds

Process	Branching ratio
$K^+ \to \mu^+ \nu_\mu(\gamma)$	63.6%
$K^+ \to \pi^+ \pi^0(\gamma)$	20.7%
$K^+ \to \pi^+ \pi^+ \pi^-$	5.6%
$K^+ \to \pi^+ \pi^- e^+ \nu_e$	4.2×10^{-5}

Sign & Bkg control regions kept blind throughout the analysis

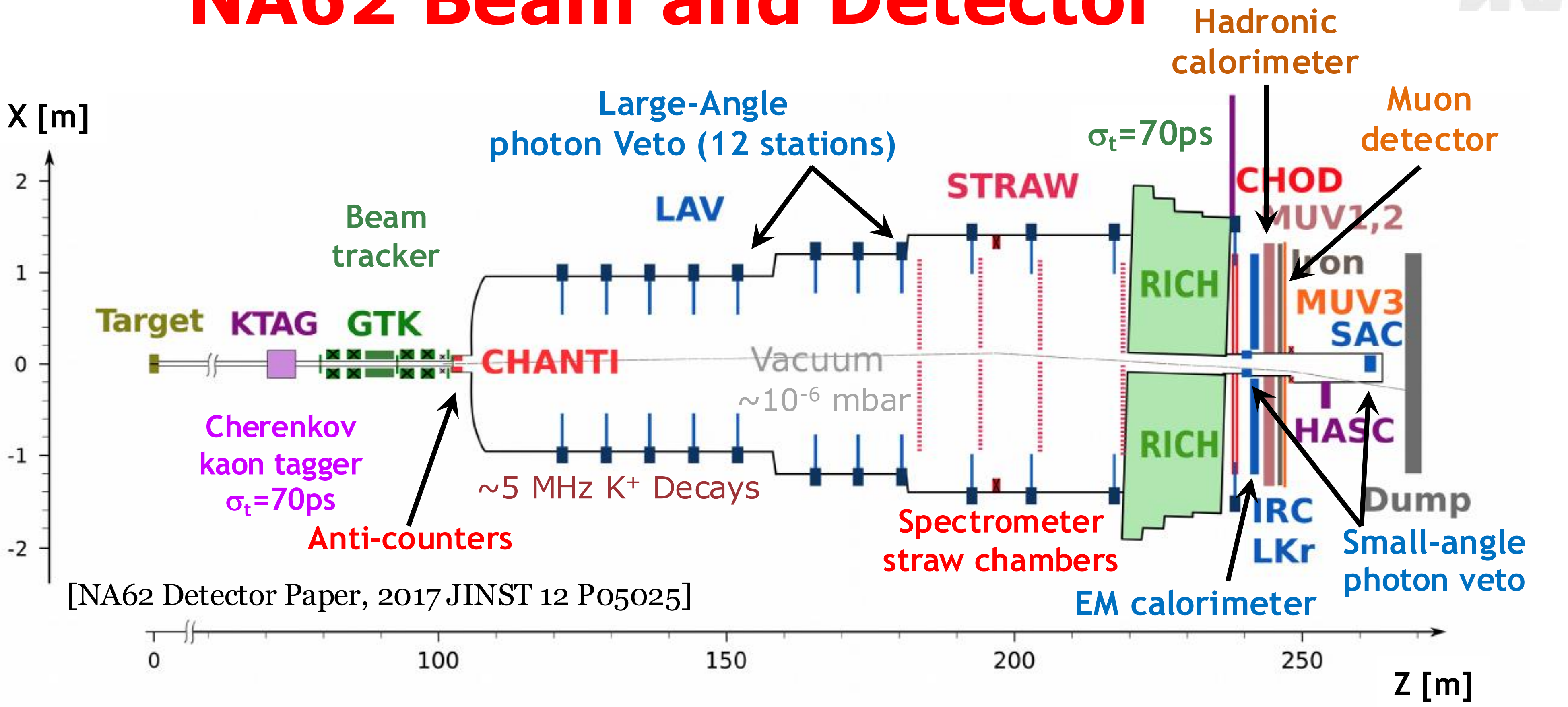
K+ decay-in-flight technique





Background rejection relies on **Kinematics** (15GeV/c < P_p < 35GeV/c ; m^2_{miss}) used in conjunction with **Particle ID**, **Veto systems** and **sub-ns timing**

NA62 Beam and Detector



- SPS protons on Be target (PoT): 400 GeV/c, ~10^{12} PoT/sec , ~3 sec/spill
- Un-separated hadron beam: π^+(70%)/K^+(6%)/p(24%)
- K^+: 75GeV/c (±1%), beam spread < 100μrad, (60 x 30) mm^2 transverse size
- 600MHz beam rate @GTK (~5MHz K^+ decays in 60 m fiducial volume)

Measurement Strategy

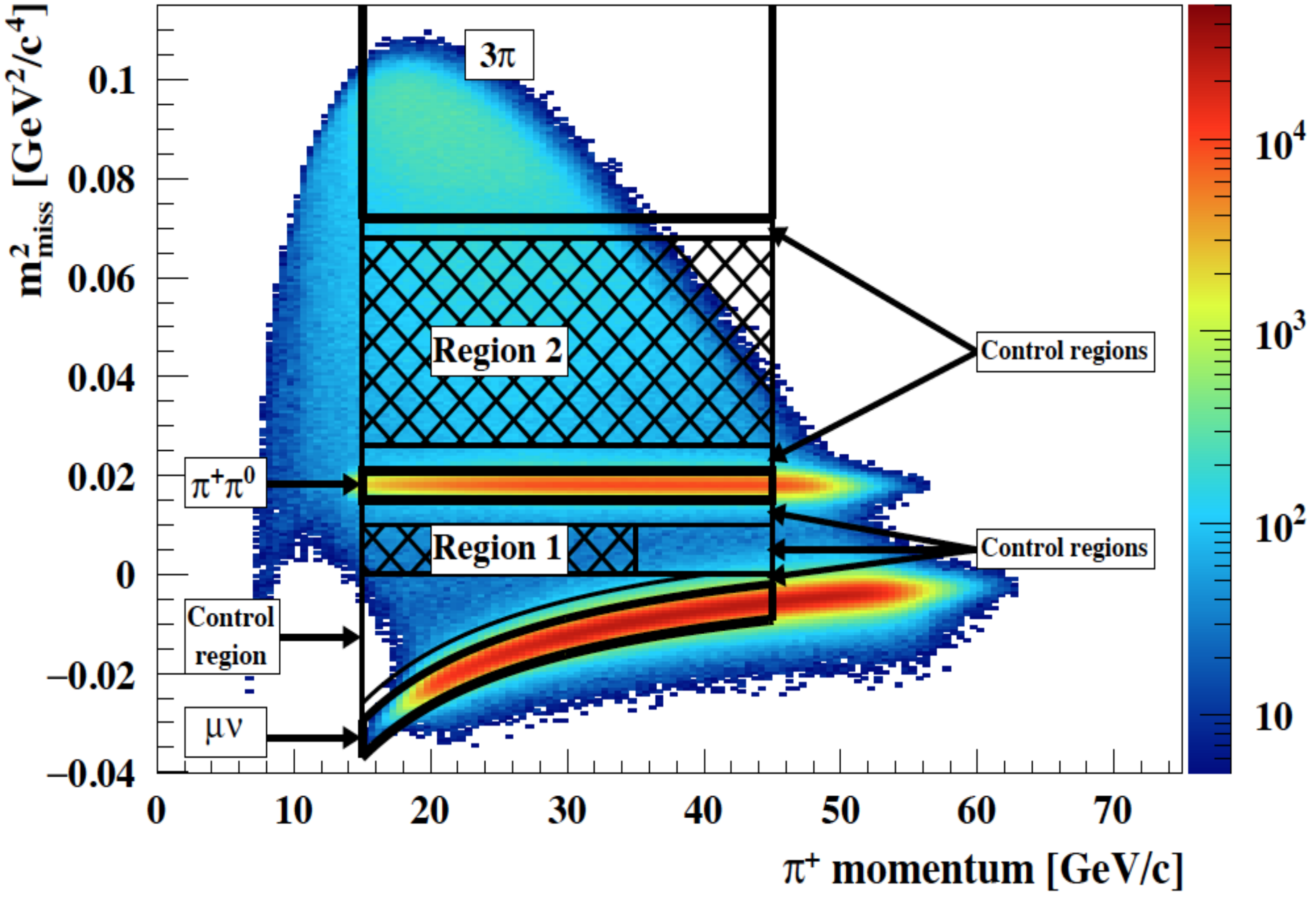
NA62 Performance keystones:

- O(100ps) Timing
- $\geq 10^3$ Kinematic bkg rejection
- $\geq 10^8$ Muon suppression (from $K^+ \to \mu^+\nu$)
- $\geq 10^8$ $\pi^0 \to \gamma\gamma$ suppression (from $K^+ \to \pi^+\pi^0$)

Signal selection:

- K^+ decays with 1 track in final state
- Definition of Region 1, Region 2
- PID, photon and multi-track rejections

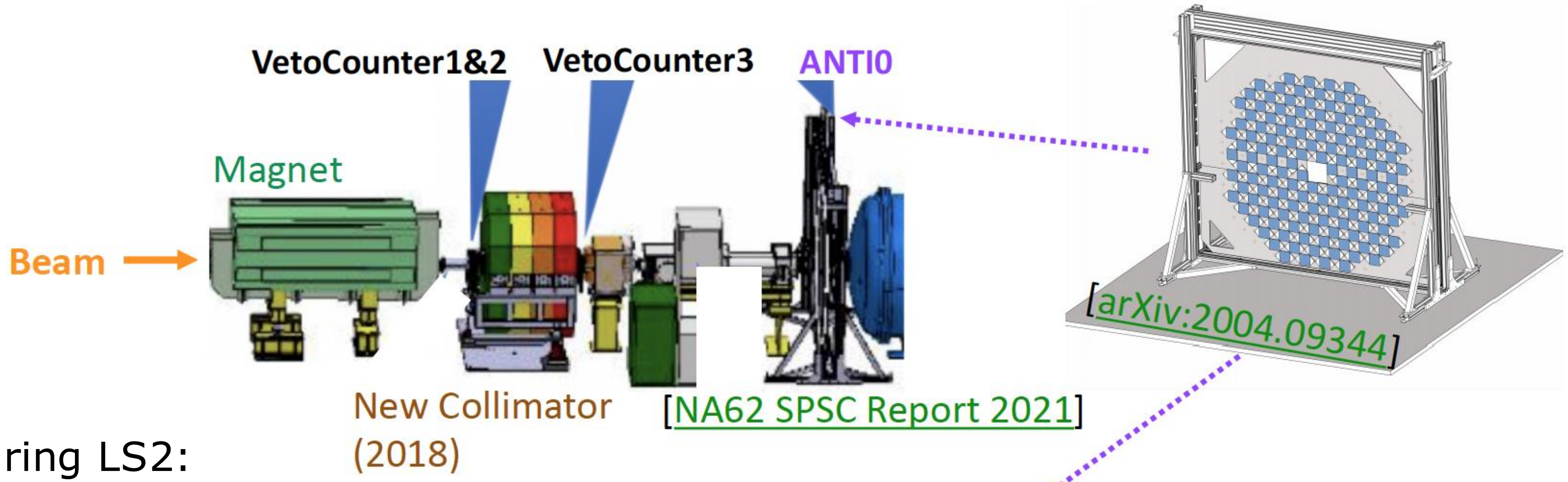
$m^2_{miss} = (P_K - P_\pi)^2$ [m_π mass hypothesis]



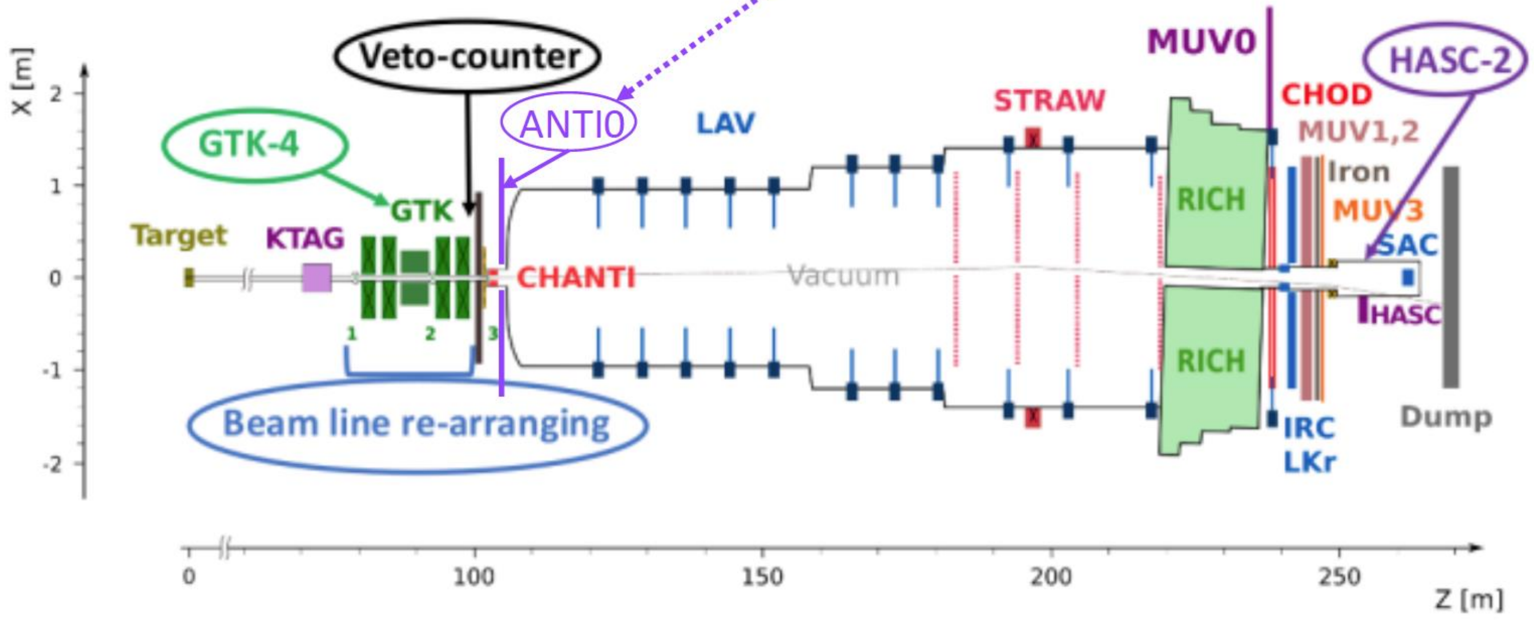
Signal and Control kinematic regions blinded during the analysis

Selection optimized in bins of π^+ momentum

NA62 Upgrades for 2021-22



- New detectors installed during LS2:
  - Additional 4th kaon beam tracker station (GTK-4)
  - New veto hodoscopes upstream of decay volume (Veto-counter, ANTI0)
  - Additional veto counters around downstream beam pipe (HASC-2)
- Beam intensity increased by ~35% wrt 2018 data taking [450 MHz → 600MHz]
- Improvements to trigger configuration



Single Event Sensitivity

Normalisation channel: $K^+ \rightarrow \pi^+\pi^0$

- Online trigger and offline selection in common for signal and normalization
- Different kinematic selection and rejection of activity additional to π^+ for signal

$$N_{\pi\nu\nu}^{SM}(p_i) = \frac{BR(\pi\nu\nu, SM)}{BR(\pi^+\pi^0, PDG)} \frac{\mathcal{A}(\pi\nu\nu)}{\mathcal{A}(\pi^+\pi^0)} D N_{\pi\pi}(p_i) \varepsilon_{trig}(p_i) \varepsilon_{RV}$$

- π momentum bin i → p_i
- 8.4×10^{-11} → $BR(\pi\nu\nu, SM)$
- Acceptances at 0 intensity → $\mathcal{A}$
- Selected $\pi\pi$ → $N_{\pi\pi}$
- 1-fraction of random signal losses due to photon/multiplicity veto → ε_{RV}
- $\pi\pi$ trigger downscaling factor → D
- Trigger efficiency → ε_{trig}

Single Event Sensitivity:
BR($K^+ \rightarrow \pi^+\nu\bar{\nu}$) for which the total number of expected events is 1

Single Event Sensitivity (2021-22)

π momentum bin i

8.4×10^{-11}

Acceptances at 0 intensity

Selected $\pi\pi$

1-fraction of random signal losses due to photon/multiplicity veto

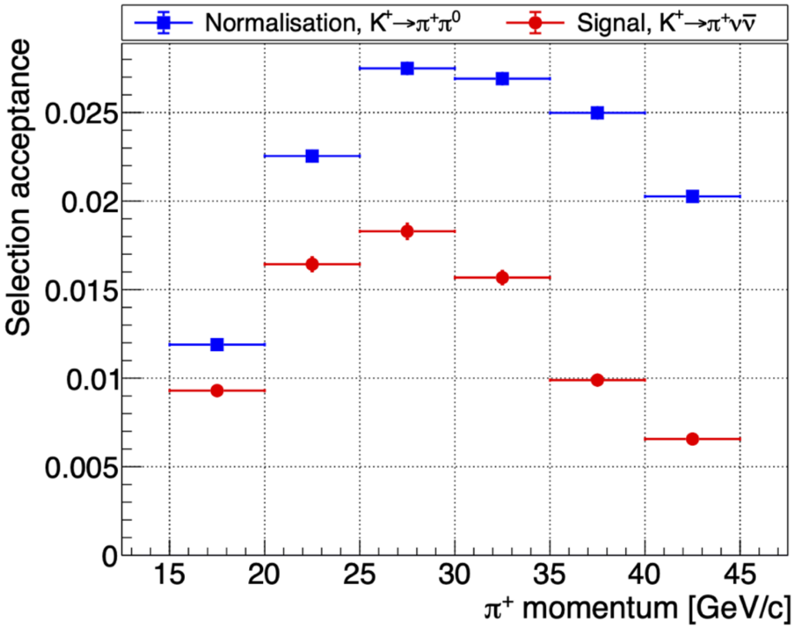
$$N^{SM}_{\pi\nu\nu}(p_i) = \frac{BR(\pi\nu\nu, SM)}{BR(\pi^+\pi^0, PDG)} \frac{\mathcal{A}(\pi\nu\nu)}{\mathcal{A}(\pi^+\pi^0)} D N_{\pi\pi}(p_i)\varepsilon_{trig}(p_i)\varepsilon_{RV}$$

$\pi\pi$ trigger downscaling factor

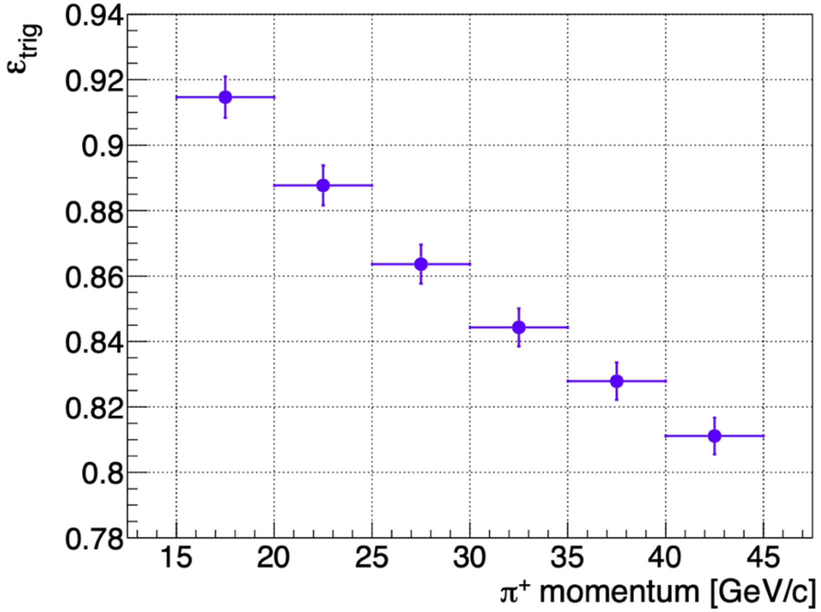
Trigger efficiency

1- ε_{RV} = probability of a signal event to be vetoed by accidental activity

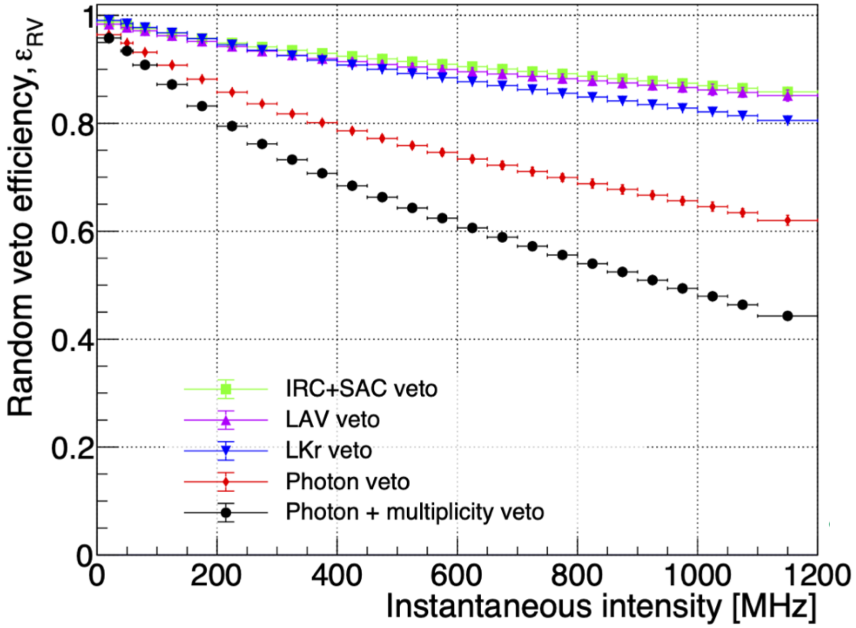
Acceptances vs π^+ momentum



Trigger efficiency vs π^+ momentum



Random veto efficiency vs π^+ momentum



Single Event Sensitivity (2021-22)

$N_{\pi\pi}^{\text{eff}}$	Effective number of normalisation events	$(1.953 \pm 0.005) \times 10^8$	
$A_{\pi\pi}$	Normalisation acceptance	$(13.410 \pm 0.005)\%$	→ +15% wrt Run1 (2016-18)
N_K	Effective number of K^+ decays $\quad N_K = \frac{N_{\pi\pi} D_0}{\mathcal{B}_{\pi\pi} A_{\pi\pi}}$	$(2.85 \pm 0.01) \times 10^{12}$	
$A_{\pi\nu\bar{\nu}}$	Signal acceptance	$(7.62 \pm 0.22)\%$	→ +20% wrt Run1 (2016-18)
$\varepsilon_{\text{trig}}$	Trigger efficiency ratio	$(85.9 \pm 1.4)\%$	→ x3 better precision wrt Run1
ε_{RV}	Random veto efficiency	$(63.2 \pm 0.6)\%$	→ comparable value to Run1
$\mathcal{B}_{\text{SES}}$	Single event sensitivity	$(8.48 \pm 0.29) \times 10^{-12}$	integrated in pion momentum 15-45 GeV/c, 2021+22 data
$N_{\pi\nu\bar{\nu}}^{\text{SM}}$	Number of expected SM $K^+ \to \pi^+ \nu\bar{\nu}$ events	9.91 ± 0.34	

Improvements wrt Run1 (2016-18) analysis:

- retuned selection and reconstruction
- new trigger configuration (common conditions lead to cancellation of systematics)

⇒ signal yield per SPS spill increased by 50%

⇒ ×2 better SES relative uncertainty

$$\mathcal{B}_{SES} = \frac{1}{N_K \varepsilon_{RV} \varepsilon_{trig} A_{\pi\nu\bar{\nu}}} \qquad N_{\pi\nu\bar{\nu}}^{exp} = \frac{\mathcal{B}_{\pi\nu\bar{\nu}}^{SM}}{\mathcal{B}_{SES}}$$

- $N_{\pi\nu\bar{\nu}}^{SM}$ per SPS burst: 2.5×10^{-5} in 2022
  - c.f. 1.7×10^{-5} in 2018

Assuming $\mathcal{B}_{\pi\nu\bar{\nu}}^{SM} = 8.4 \times 10^{-11}$:

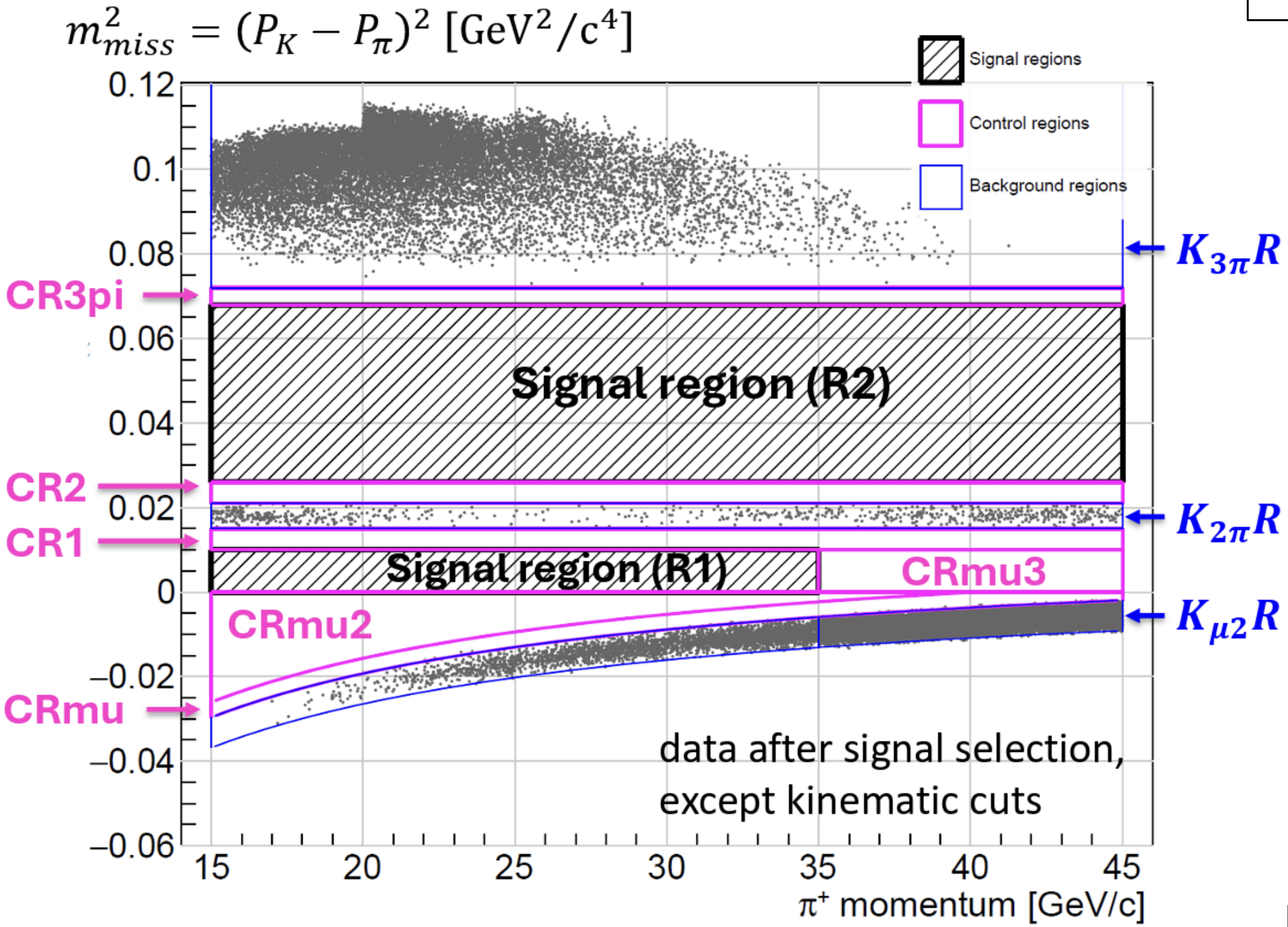
2021-22: $N_{\pi\nu\bar{\nu}} = \mathbf{9.91} \pm 0.34$

c.f. 2016–18 : $N_{\pi\nu\bar{\nu}} = 10.01 \pm 0.42$

Double expected signal by including 2021-22 data

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

m^2_{miss} vs π^+ momentum



2021-2022 Data: **Background regions, Control regions, Signal regions**

Background estimations in signal regions validated using control regions

Background	Events	
$K^+ \to \pi^+\pi^0(\gamma)$	0.83 ± 0.05	Data
$K^+ \to \mu^+\nu(\gamma)$	1.70 ± 0.47	Data
$K^+ \to \pi^+\pi^+\pi^-$	0.11 ± 0.03	Data MC
$K^+ \to \pi^+\pi^-e^+\nu$	$0.89^{+0.33}_{-0.27}$	MC
$K^+ \to \pi^+\gamma\gamma$	0.01 ± 0.01	MC
$K^+ \to \pi^0\ell^+\nu$	< 0.001	MC
Upstream	$7.4^{+2.1}_{-1.8}$	Data
Total	$11.0^{+2.1}_{-1.9}$	

Background estimates summed over R1 and R2

Signal Regions are blinded!

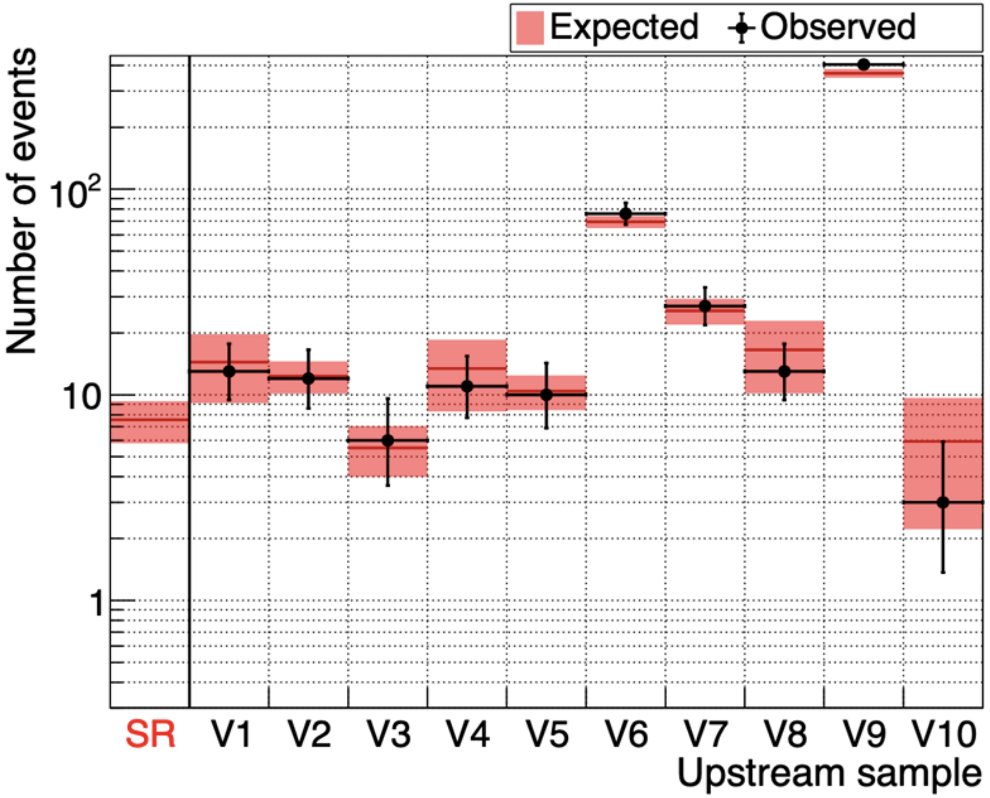
Background Validation

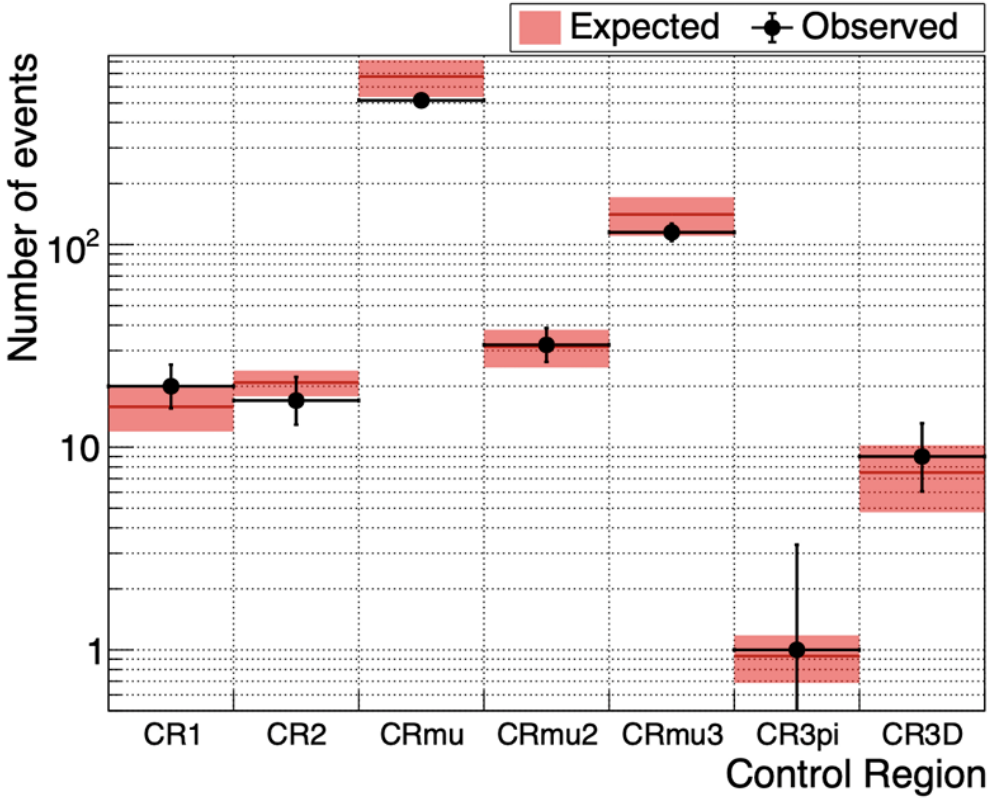
Upstream background validation

Sample accidental-enriched: “V3,4,5,6,9,10”
Sample interaction-enriched: “V1,2,7,8”
Signal region, masked: first bin “SR”

“K-decay” background validation

CR1, CR2: $K^+ \to \pi^+\pi^0(\gamma)$
CRmu, CRmu2, CRmu3: $K^+ \to \mu^+\nu(\gamma)$
CR3pi: $K^+ \to \pi^+\pi^+\pi^-$
CR3D: orthogonal to π^+ momentum, m^2_{miss} plane



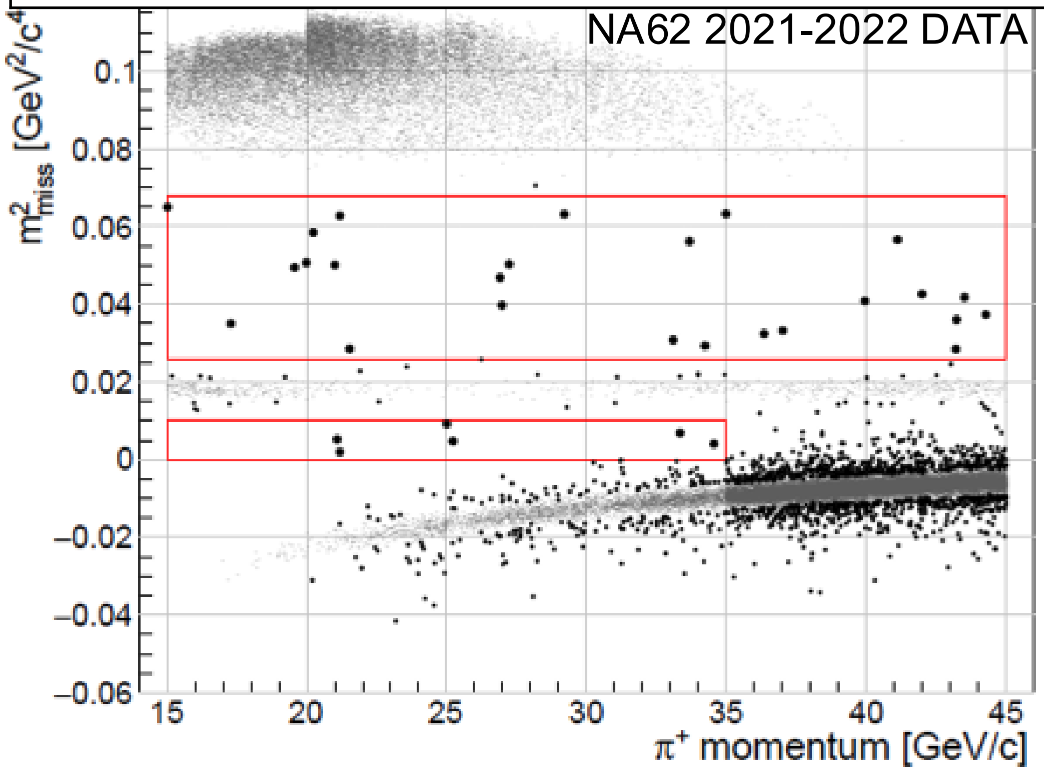


Upstream Validation: 10 independent samples enriched with different mechanisms

$K^{+}\rightarrow \pi^{+}\nu\bar{\nu}$ Result: 2021-2022

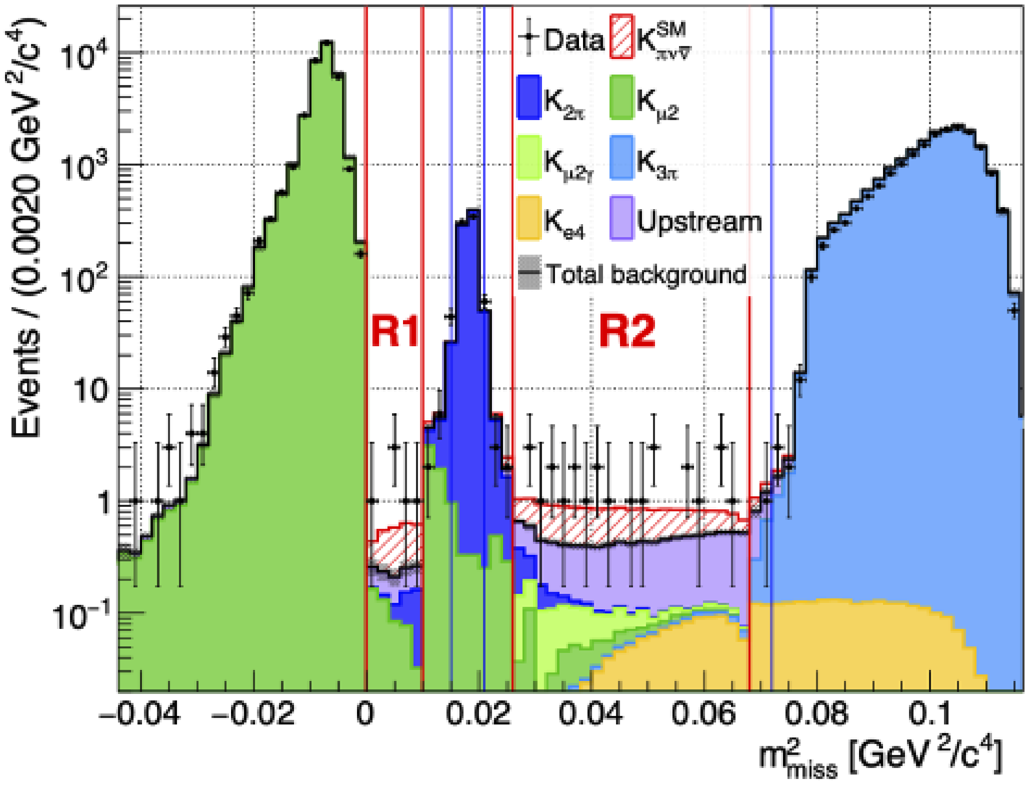
Expected SM signal: $N_{\pi\nu\bar{\nu}}^{SM} \approx 10$

Single Event Sensitivity	$(0.85 \pm 0.03) \times 10^{-11}$
Expected background	$11.0^{+2.1}_{-1.9}$
Observed	**31**



[JHEP02 (2025) 191]

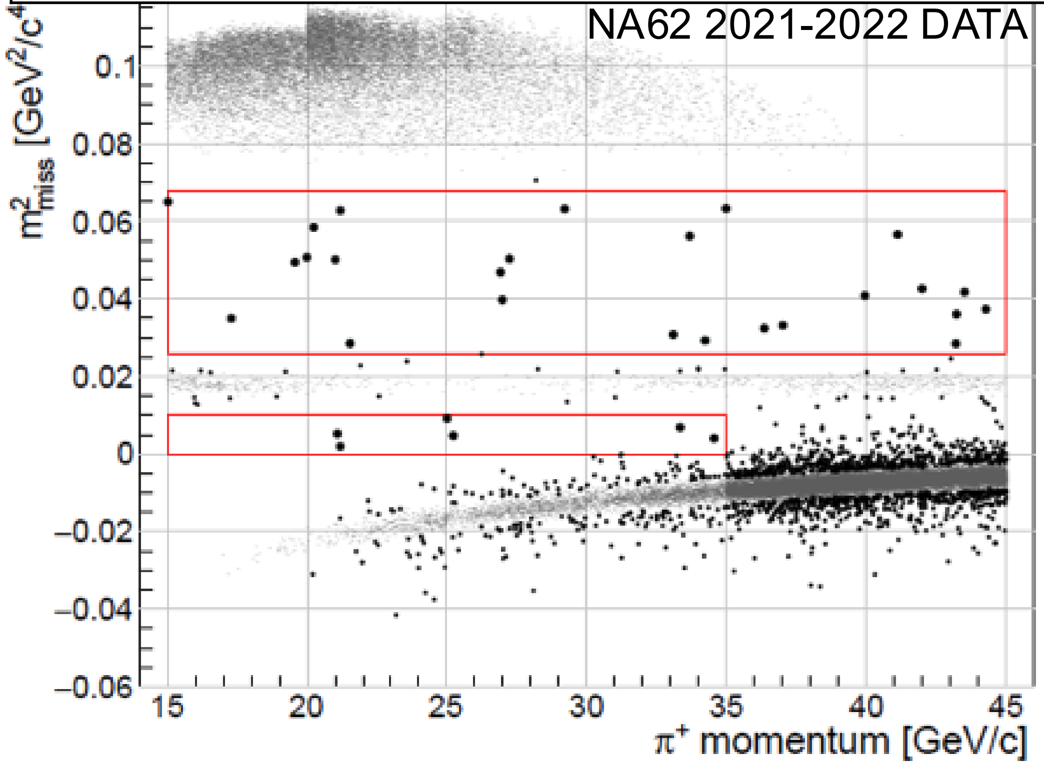
1D projection with differential background predictions & SM signal expectation [not a fit]:



$K^+ \to \pi^+\nu\bar{\nu}$ Result: 2021-2022

Expected SM signal: $N^{SM}_{\pi\nu\bar{\nu}} \approx 10$

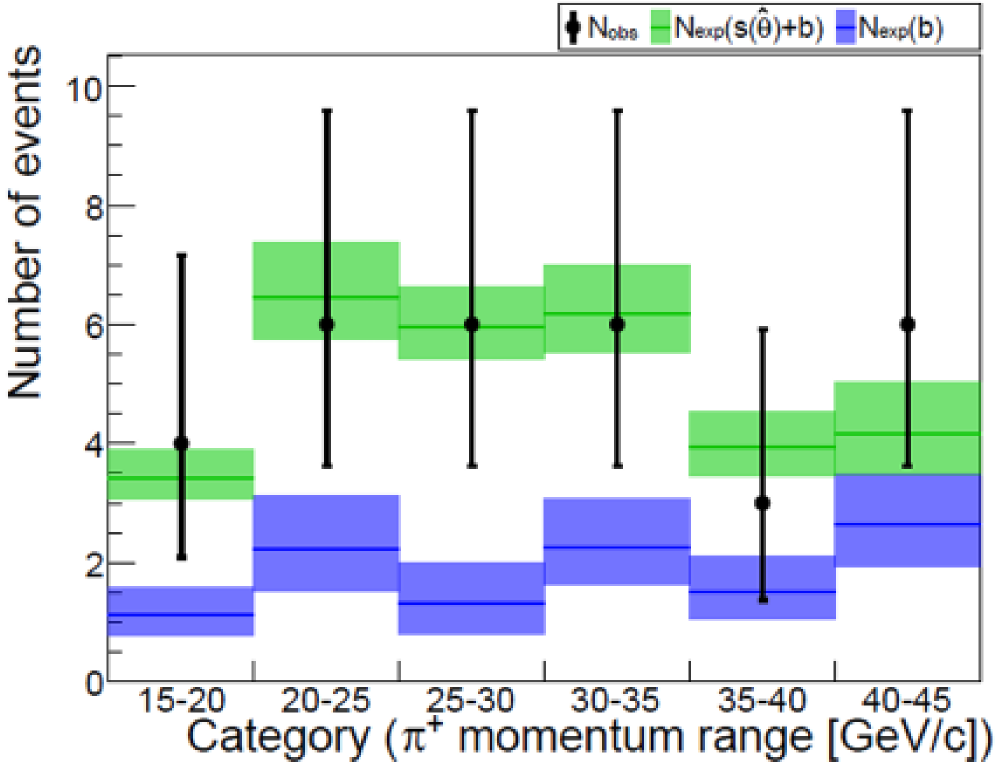
Single Event Sensitivity	$(0.85 \pm 0.03) \times 10^{-11}$
Expected background	$11.0^{+2.1}_{-1.9}$
Observed	**31**



[JHEP02 (2025) 191]

Fit to π^+ momentum with a profile likelihood ratio test statistics

$$\mathcal{B}_{2021-2022}(K^+ \to \pi^+\nu\bar{\nu}) = \left(16.2\ ^{+4.9}_{-4.3}\Big|_{\text{stat}}\ ^{+1.4}_{-1.4}\Big|_{\text{syst}}\right) \times 10^{-11}$$



$K^+ \to \pi^+ \nu\bar{\nu}$ Results: combined 2016-2022

Expected SM signal: $N^{SM}_{\pi\nu\bar{\nu}} \approx 20$

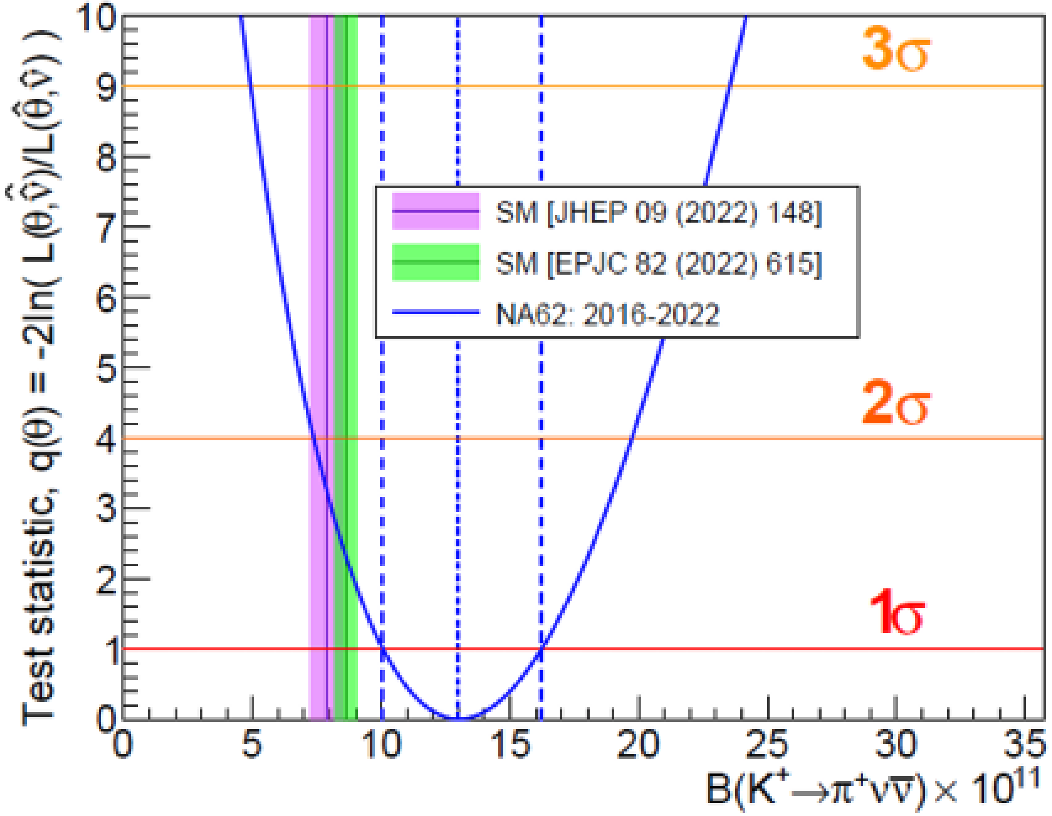
Expected background: $N_{bg} = 18^{+3}_{-2}$

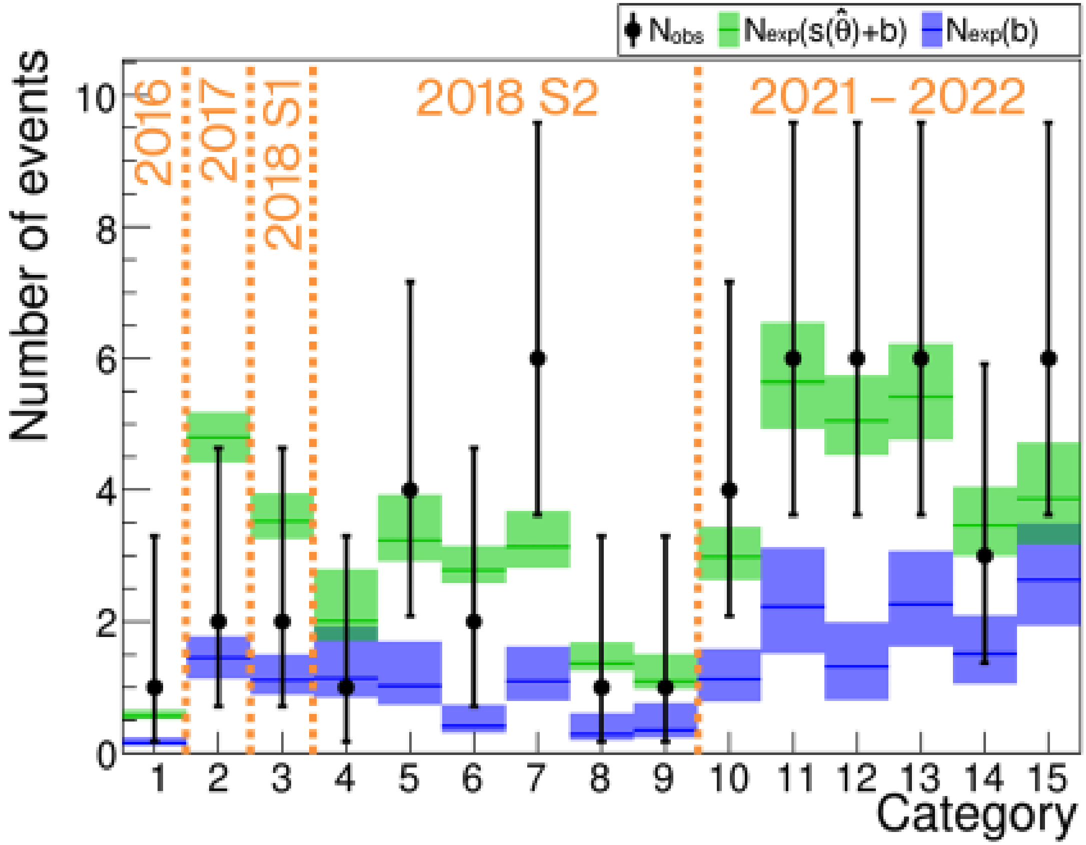
Observed: $N_{obs} = 51$

Background-only hypothesis p-value = 2×10^{-7}
⇒ significance $Z > 5$

$$\mathcal{B}_{2016-2022}(K^+ \to \pi^+ \nu\bar{\nu}) = \left(13.0\ ^{+3.0}_{-2.7}\Big|_{stat}\ ^{+1.3}_{-1.3}\Big|_{syst}\right) \times 10^{-11}$$

Combination 2016-18 + 2021-22 data

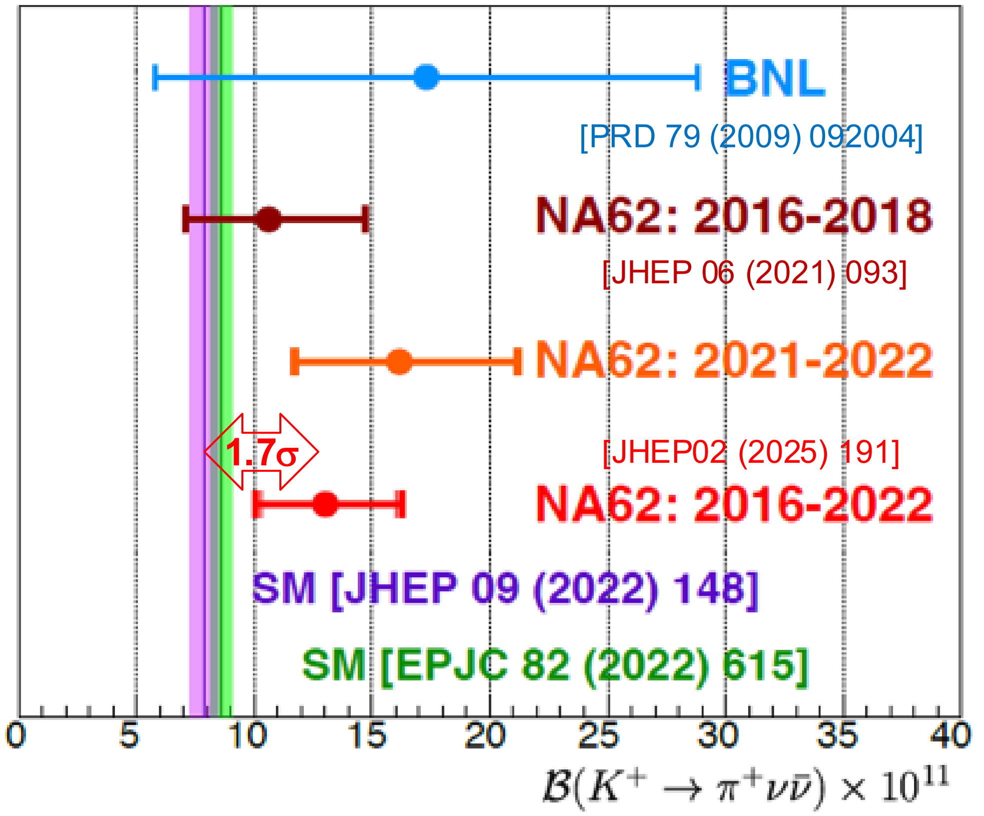


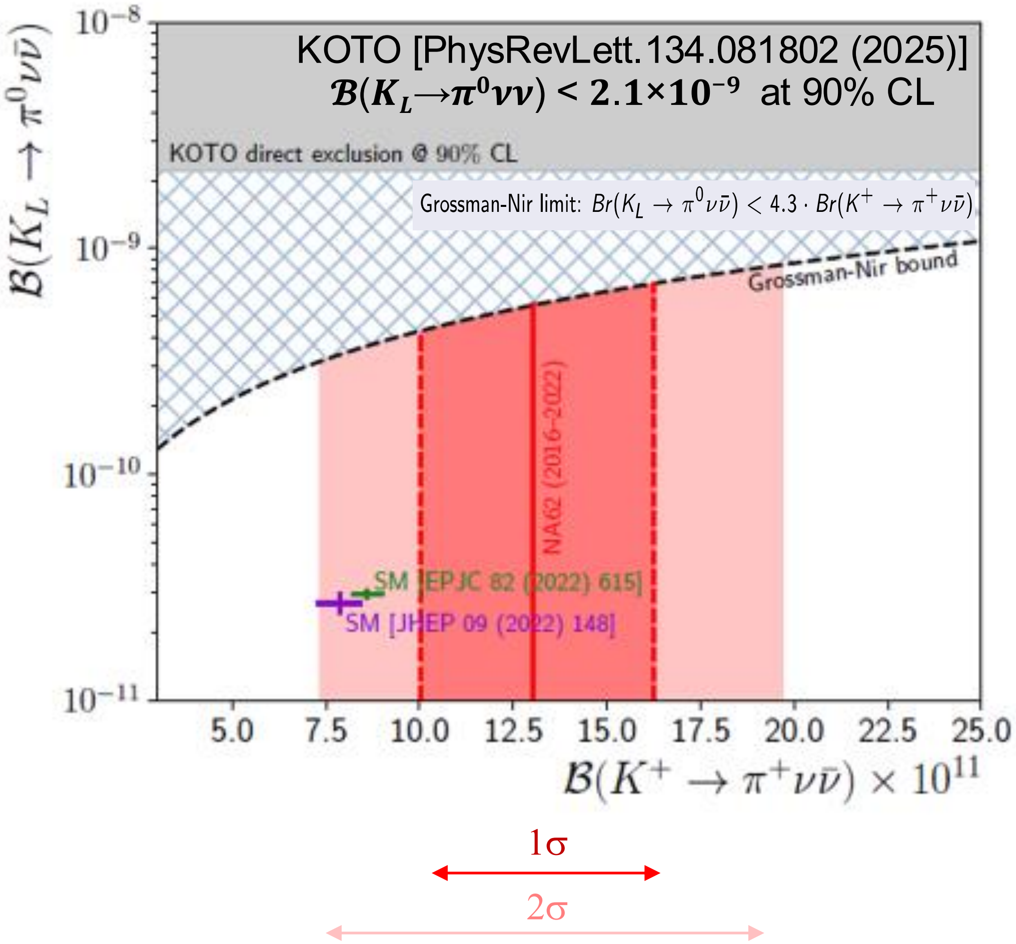


First observation of $K^+ \to \pi^+ \nu\bar{\nu}$ at 5σ [JHEP02 (2025) 191]

Result in Global Perspective

$$\mathcal{B}_{2016-2022}(K^+ \to \pi^+ \nu\bar{\nu}) = \left(13.0^{+3.3}_{-3.0}\right) \times 10^{-11}$$





- NA62 results are consistent
- Central value moved up (now 1.5-1.7σ above SM)
- Fractional uncertainty decreased: 40% → 25%
- Background-only hypothesis rejected with significance Z > 5

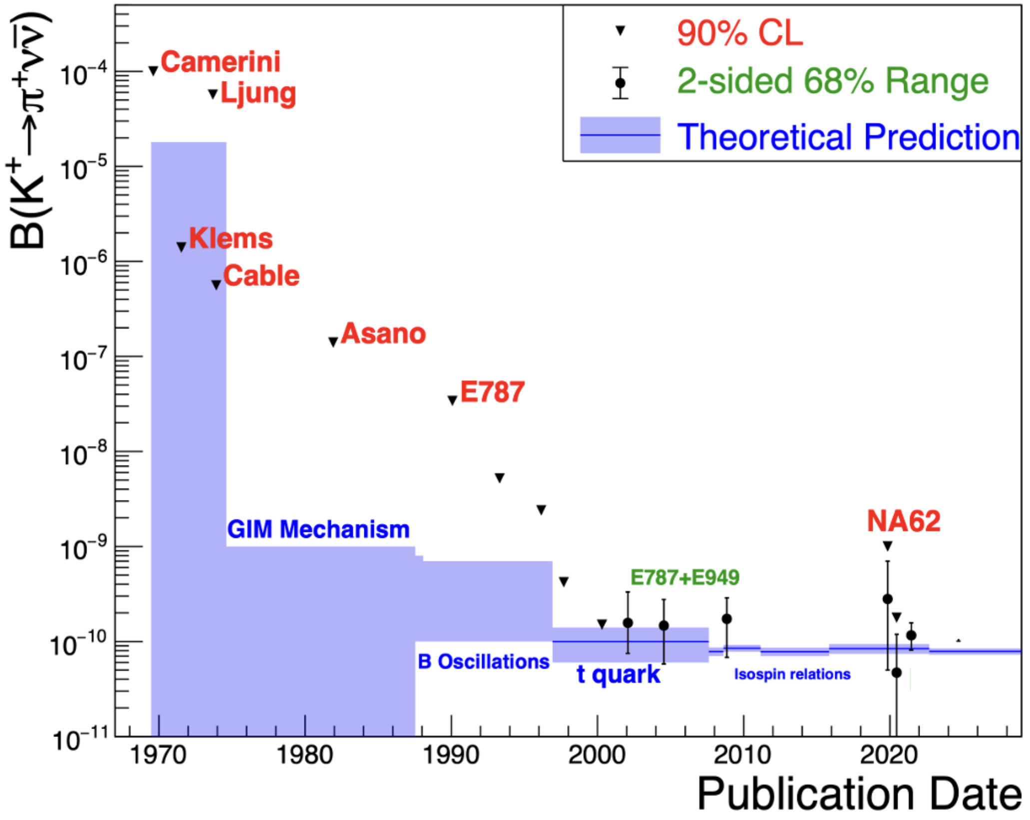
Conclusions

NA62 result on $K^+ \to \pi^+\nu\nu$ decay using 2021-22 dataset, combined with 2016-18

First observation of $K^+ \to \pi^+\nu\nu$ decay with 5σ rejection of background-only hypothesis

$$BR_{2016-22} = 13.0^{+3.3}_{-3.0} \times 10^{-11}$$ [JHEP 02 (2025) 191]

BR consistent with SM prediction within 1.7σ



- The long quest for $K^+ \to \pi^+\nu\nu$ has reached a very important step: the observation of the decay!
- **The rarest particle decay ever observed at 5 sigma level**
- NA62 2023-24 dataset of comparable size to 2016-22 one
- Analysis is ongoing
- NA62 will take data until LS3 (summer 2026)
- **Stay tuned!**

EPS-HEP 2025 Conference

6 -11 July 2025, Palais du Pharo, Marseille

SPARES

Angela Romano, University of Birmingham

on behalf of the NA62 Collaboration

WIP: 2023-24 $K^+ \to \pi^+ \nu\nu$ Data Analysis

- 2024 data-taking conditions lead to a slightly higher signal yield per spill:
  - lower signal loss due to random activity in veto detectors that compensates the lower number of normalization events
- increase of the overall expected signal yield, given the smoother and therefore more efficient collection of SPS spills

[2025 NA62 SPSC Report]

Dataset	2022	2023	2024
Number of spills $[10^3]$	326	363	519
$<$ Beam intensity $>$ [GHz]	0.57	0.48	0.41
$< N_{\pi\pi}/\text{spill} >$ $[10^2]$	4.9	4.7	4.4
N_K $[10^{12}]$	2.3	2.5	3.3
ε_{RV}	0.63	0.68	0.73
$N_{\pi\nu\nu}$	8	9	13
$N_{\pi\nu\nu}/\text{spill}$ $[10^{-5}]$	2.5	2.5	2.6
$B_{\text{total}}/N_{\pi\nu\nu}$	1.1	1.1	1.0

NA62 WORK-IN-PROGRESS

The addition of the 2023-2024 dataset is expected at least to double the signal yield of the already published 2016-2022 dataset, with the same level of relative background

Correlations with other meson decays

- New study of $K^+ \to \pi^+ \nu\bar{\nu}$ decay using NA62 2021–22 dataset, combined with 2016–18:

  [JHEP 02 (2025) 191]

- $\mathcal{B}_{16-22}(K^+ \to \pi^+ \nu\bar{\nu}) = (13.0^{+3.3}_{-3.0}) \times 10^{-11}$
- **BR consistent with SM prediction within 1.7σ**
- **Need full NA62 data-set to clarify SM agreement or tension, considering also correlations with other meson decay channels**

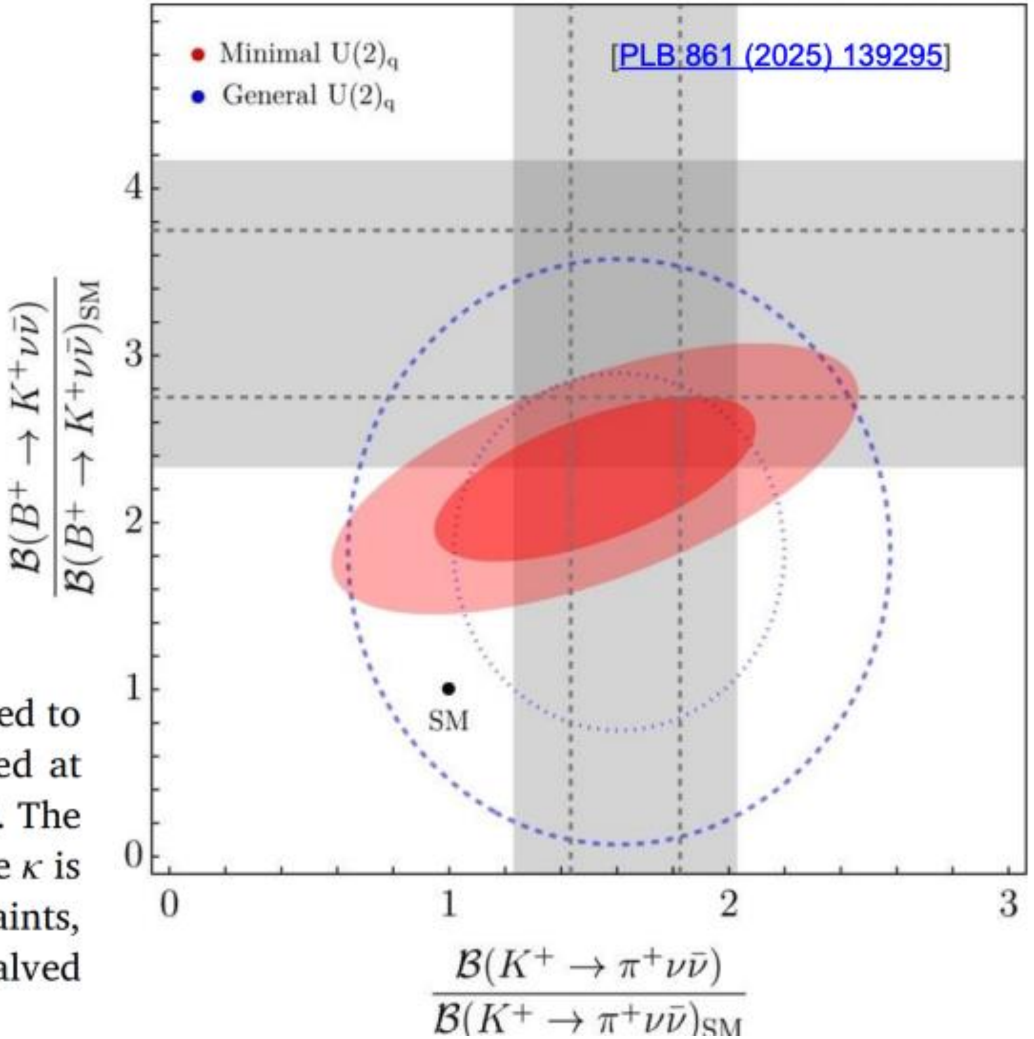
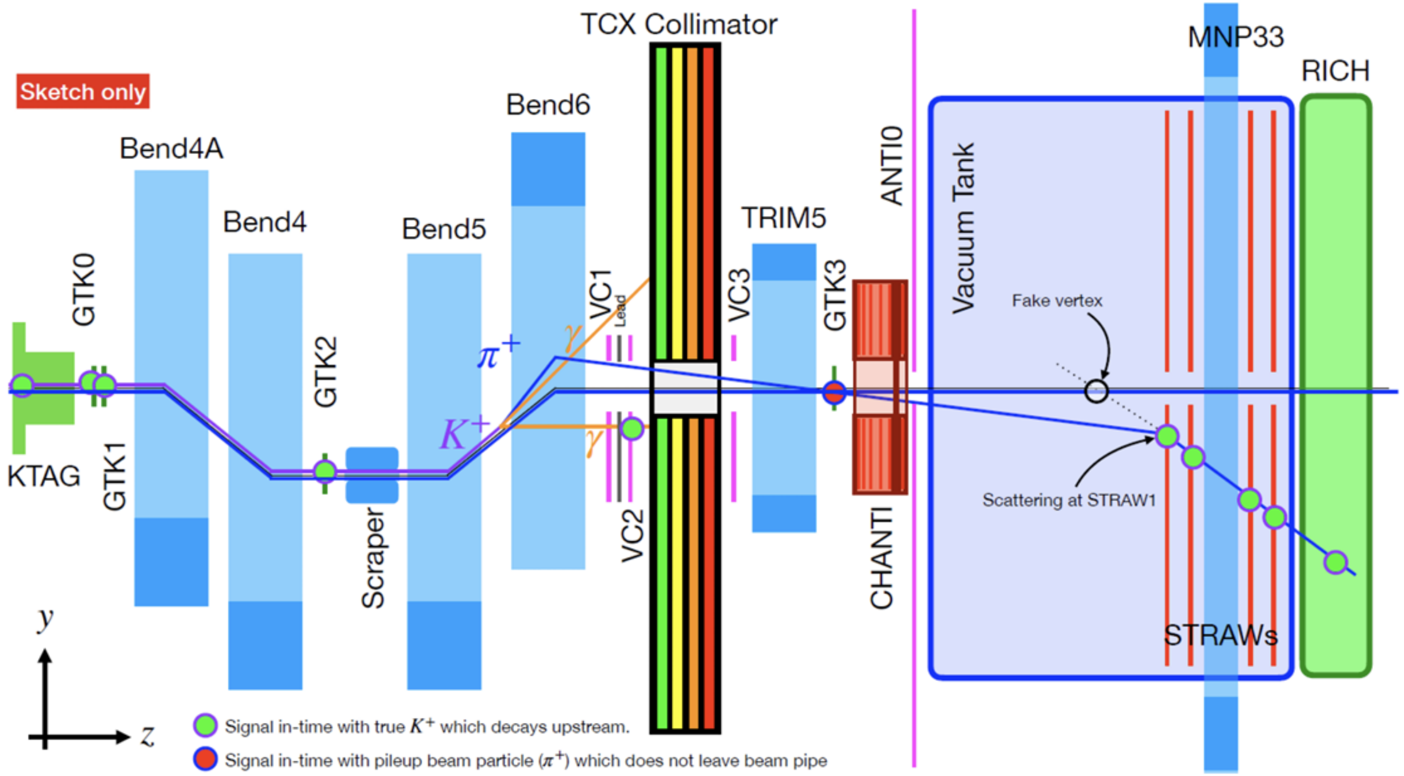


Fig. 6. Correlation between $\mathcal{B}(B^+ \to K^+ \nu\bar{\nu})$ and $\mathcal{B}(K^+ \to \pi^+ \nu\bar{\nu})$, normalized to their SM predictions. The red areas denote the parameter regions favored at 1σ and 2σ from a global fit in the limit of minimal $U(2)_q$ breaking ($\kappa = 1$). The dashed and dotted blue curves are 1σ and 2σ regions from a global fit where κ is a free parameter. The gray bands indicate the current experimental constraints, while the dashed gray lines highlight near-future projections assuming halved experimental uncertainties.

Upstream Background



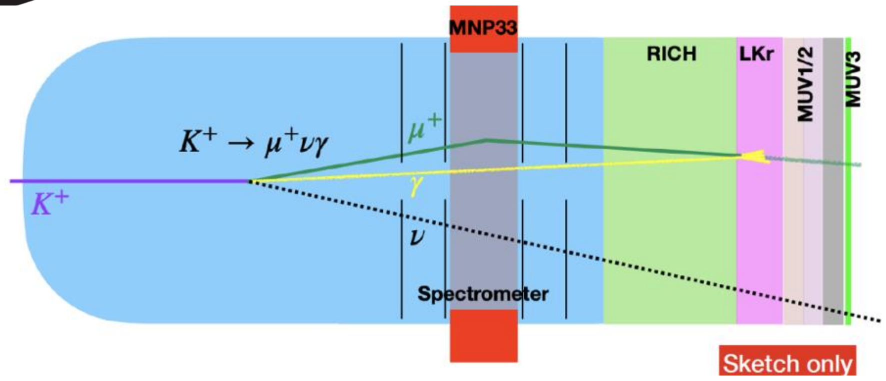
$$N_{bg} = f_{cda} \sum_i N_i \mathcal{P}_i^{match}$$

i	Bin in $(\Delta t, N_{GTK})$ plane
N	Upstream sample (inverted CDA cut)
f_{cda}	Scaling factor "bad-to-good" cda
$\mathcal{P}^{match}$	$K^+ - \pi^+$ mismatching probability

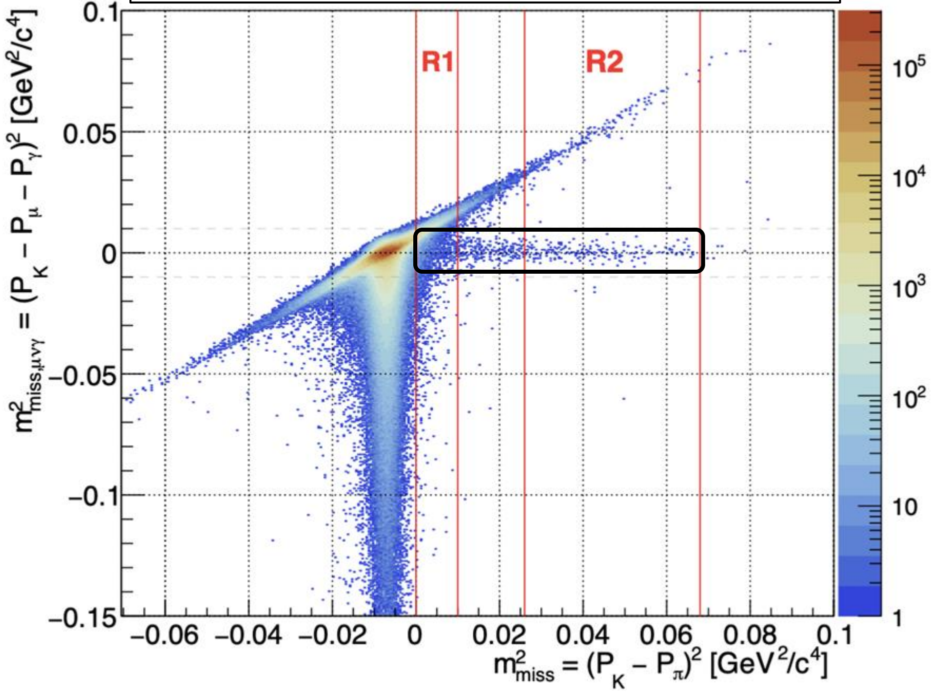
$$N_{bg}(Upstream) = 7.4^{+2.1}_{-1.8}$$

- Suppression: Δt (K^+, π^+), upstream vetoes (VC, CHANTI, ANTI0), BDT using spatial infos of K^+, π^+
- Estimation: Fully data-driven, "Upstream Reference Sample" contains all known generation mechanisms, bkg-to-signal probability estimated with data driven technique
- Validation: 10 independent samples enriched with different mechanisms

Background from $K^+ \to \mu^+\nu(\gamma)$



$(P_K - P_\mu - P_\gamma)^2$ vs $(P_K - P_\pi)^2$



Data Driven estimation

Not included in $K^+ \to \mu^+\nu$ tail if γ overlaps with μ at LKr ($\mu^+\gamma$ cluster mis-ID as π^+)

- Suppression: specific cuts on $(P_K - P_\mu - P_\gamma)^2$ and E_γ
- Estimation: control sample of events with signal in MUV3
- Validation: control sample with PID between μ and π

High momentum background (>35 GeV/c), relevant in 21-22 data (Calorimetric PID degraded at higher intensities)

Expected: $N_{bg}(K^+ \to \mu^+\nu\gamma) = \mathbf{0.82 \pm 0.43}$

- Before $K^+ \to \mu^+\nu\gamma$ veto: found excess of events at $p > 35\, GeV/c$ in Region 2 relative to 2016–18 data.
- Additional background identified and studied in data control samples & MC.
- $K^+ \to \mu^+\nu\gamma$ veto added to selection criteria for final analysis.

Background from $K^+ \to \pi^+\pi^0$

Data Driven estimation

- Background suppression based on kinematics and photon vetoes
- Fraction of kinematic tails in SR region estimated on data on a sample selected tagging positively the π^0 via photons detected in the calorimeter
- Number in SR evaluated as

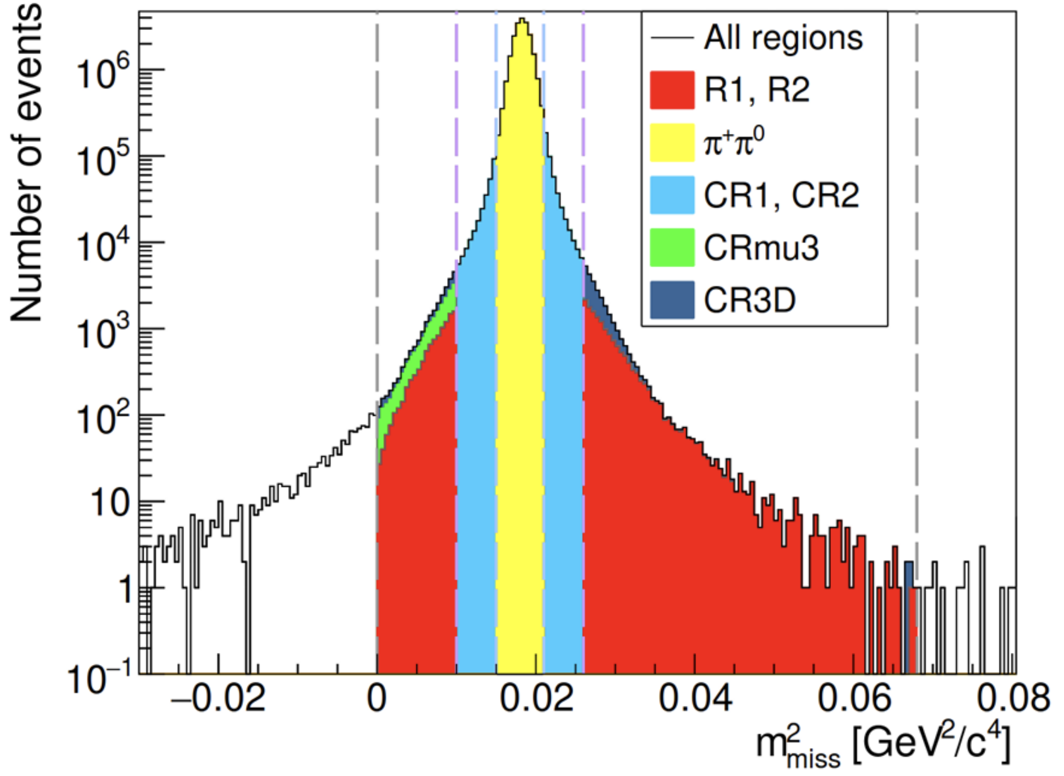
Events in $\pi^+\pi^0$ region after selection

$$N_{\pi^+\pi^0}(SR) = N(\pi^+\pi^0)\, f_{\pi^+\pi^0}(SR)$$

$K^+ \to \pi^+\pi^0$ events in signal region

Ratio of events in $\pi^+\pi^0$ region to signal region, measured on control sample

kinematic tail fraction



*CR3D: CR orthogonal to the π^+ momentum, m^2_{miss} plane

Background from $K^+ \to \mu^+ \nu$

- Background suppression based on kinematics and pion identification (RICH & Calo)
- Fraction of kinematic tails in SR region estimated on data on a sample selected tagging positively muons via Calorimetric ID.
- These muons must fake a pion: RICH π^+ selection applied to CS
- Number in SR evaluated as

Events in $\mu^+\nu$ region after selection

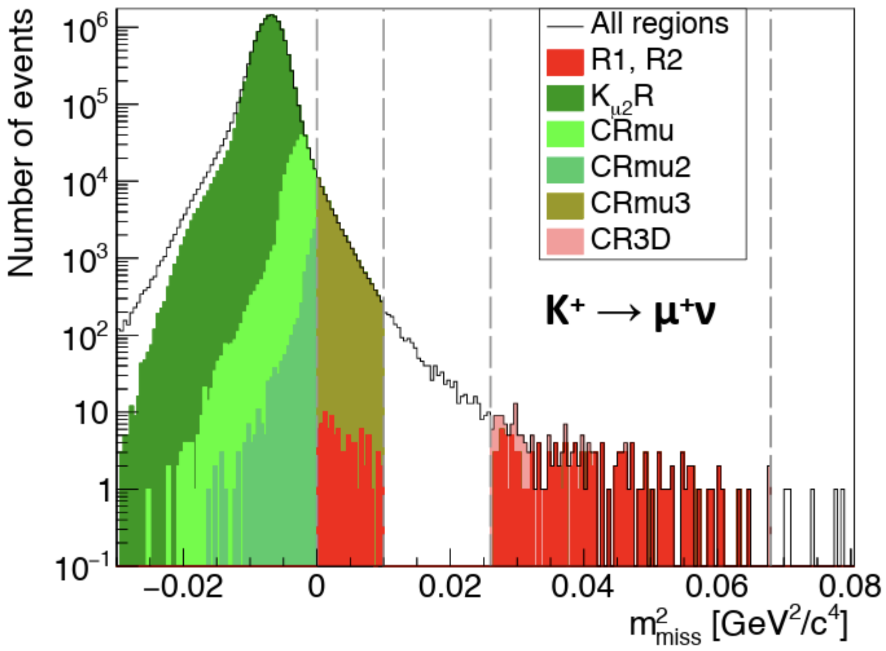
$$N_{\mu\nu}\ (SR) = N(\mu^+\nu)\ f_{\mu\nu}\ (SR)$$

$K^+ \to \mu^+\nu$ events in signal region

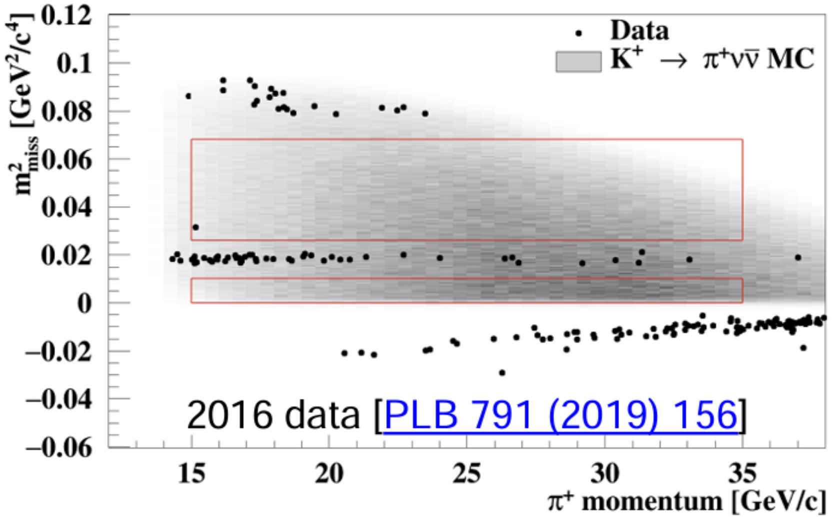
Ratio of events in $\mu^+\nu$ region to signal region, measured on control sample

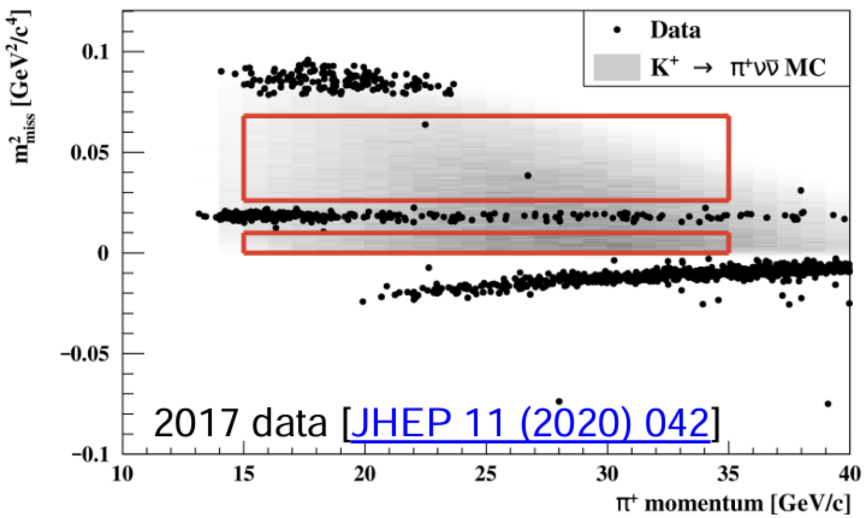
kinematic tail fraction

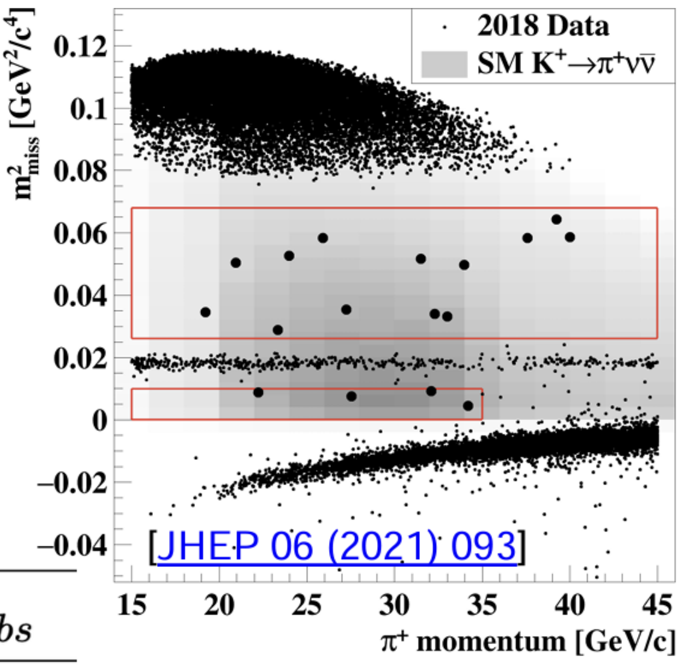
Data Driven estimation



NA62 $K^+ \to \pi^+ \nu\nu$ Results: 2016-2018







Data-taking year	[Reference]	N_{bg}	$N^{SM,exp}_{\pi\nu\bar{\nu}}$	N_{obs}
2016	[PLB 791 (2019) 156]	$0.152^{+0.093}_{-0.035}$	0.267 ± 0.020	1
2017	[JHEP 11 (2020) 042]	1.46 ± 0.33	2.16 ± 0.13	2
2018	[JHEP 06 (2021) 093]	$5.42^{+0.99}_{-0.75}$	7.58 ± 0.40	17
2016–18	[JHEP 06 (2021) 093]	$7.03^{+1.05}_{-0.82}$	10.01 ± 0.42	20

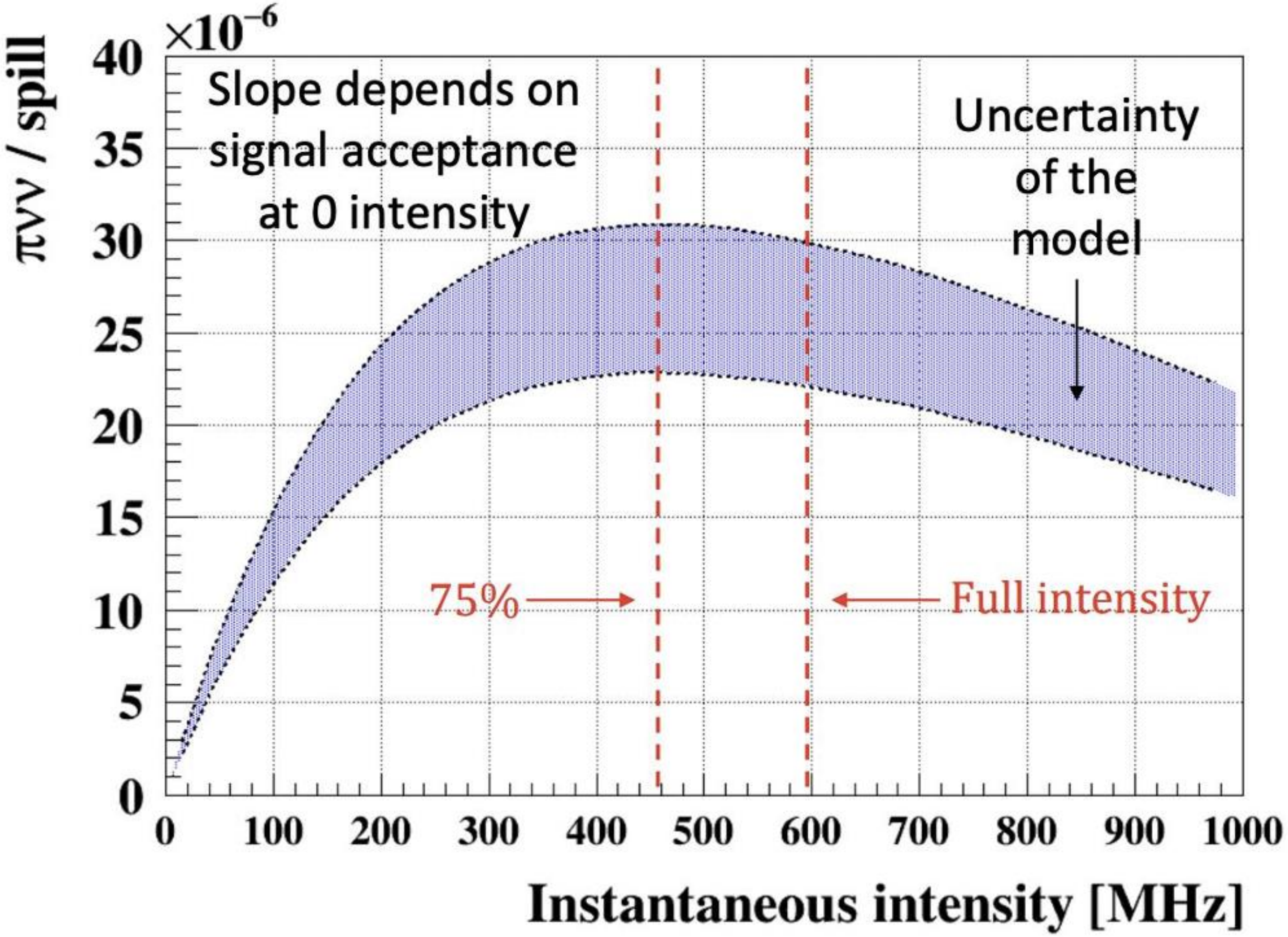
$N^{SM,exp}_{\pi\nu\bar{\nu}}$ assumes: $\mathcal{B}^{SM}_{\pi\nu\bar{\nu}} = 8.4 \times 10^{-11}$

Statistical combination: $\mathcal{B}(K^+ \to \pi^+\nu\bar{\nu}) = (10.6^{+4.0}_{-3.4}|_{stat} \pm 0.9_{syst}) \times 10^{-11} @ 68\%\ CL$

Background-only hypothesis: $p = 3.4 \times 10^{-4} \Rightarrow$ significance = 3.4σ

Optimum NA62 Intensity

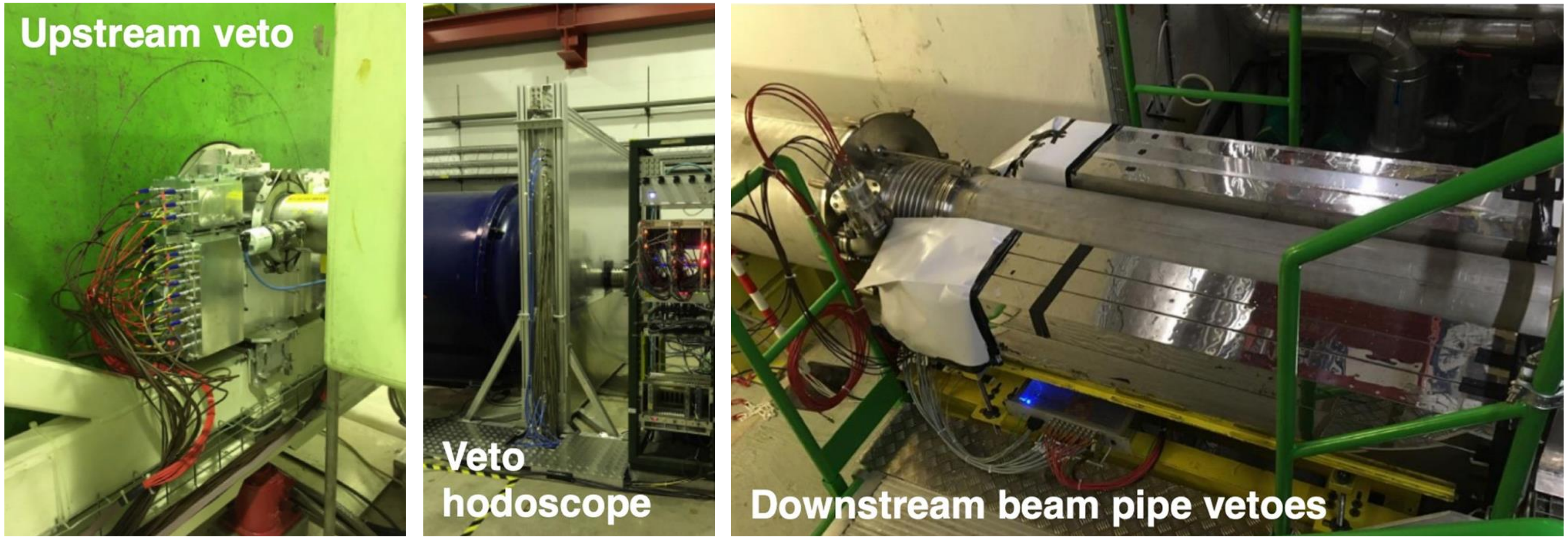
Selected signal yield vs intensity



- Saturation of expected signal yield with intensity. Mainly due to:
  - Paralyzable effects from TDAQ dead time and trigger veto windows.
  - Offline selection, due to veto conditions.
- Main sources of uncertainty for model:
  - Online time-dependent mis-calibrations.
  - Fit uncertainty.
- **From August 2023 operate at optimal intensity** (~75% of full) to maximise $\pi\nu\nu$sensitivity
  - Maximise signal yield
  - lower expected background
  - Higher DAQ efficiency

Studies of **2021—22 data** at high intensity **were crucial** to establish optimal intensity

NA62 Run 2 Data Taking

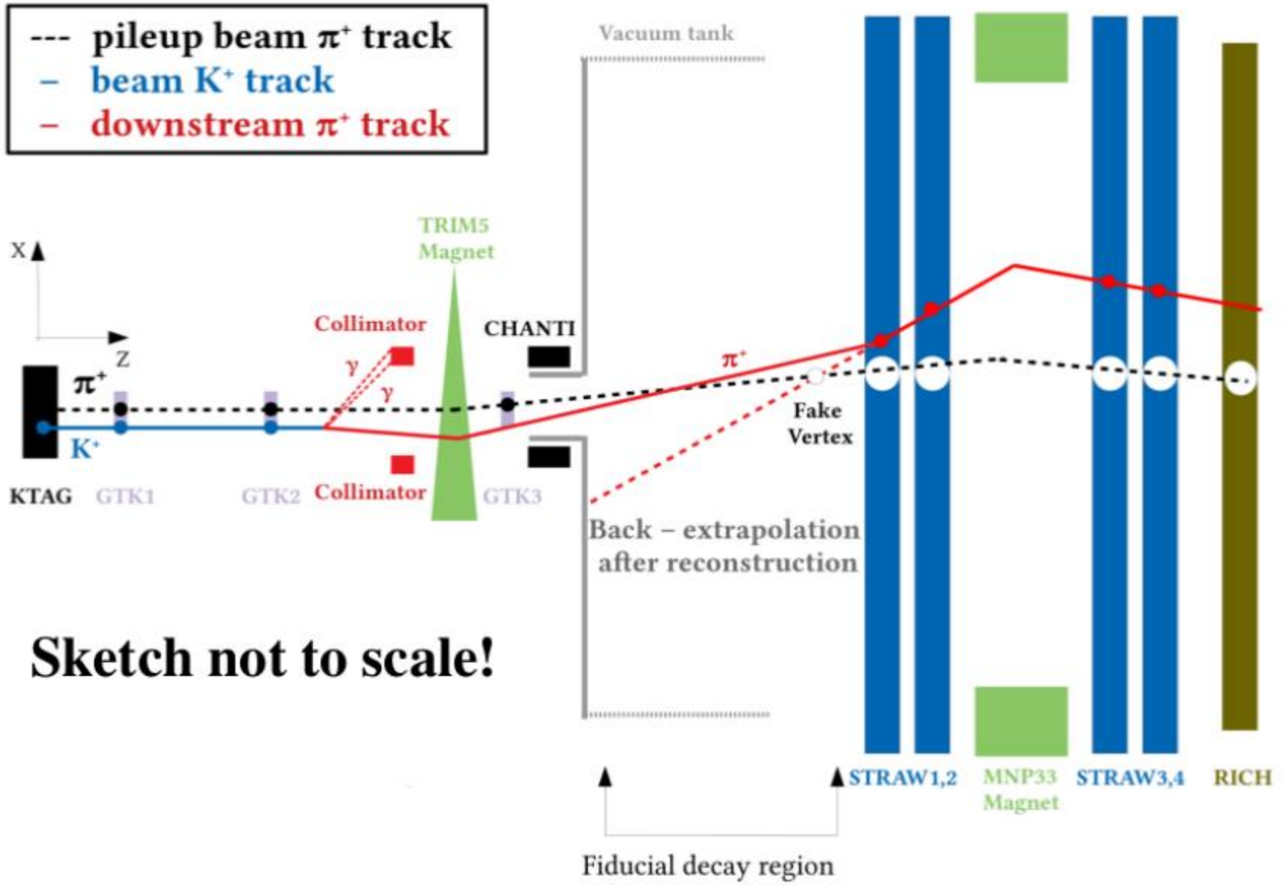


New detectors installed for NA62 Run2 (2021 – 2026)

- The kaon decay-in-flight technique is firmly established
- Improved trigger: beam intensity increased by ~35% wrt Run 1
- $K^+ \to \pi^+ \nu\bar{\nu}$ measurement in a low-background, high-acceptance regime
- Analysis of 2021-2022 combined datasets presented here

Expect to measure BR($K^+ \to \pi^+ \nu\bar{\nu}$) at O(15%) precision by LS3

Upstream Background

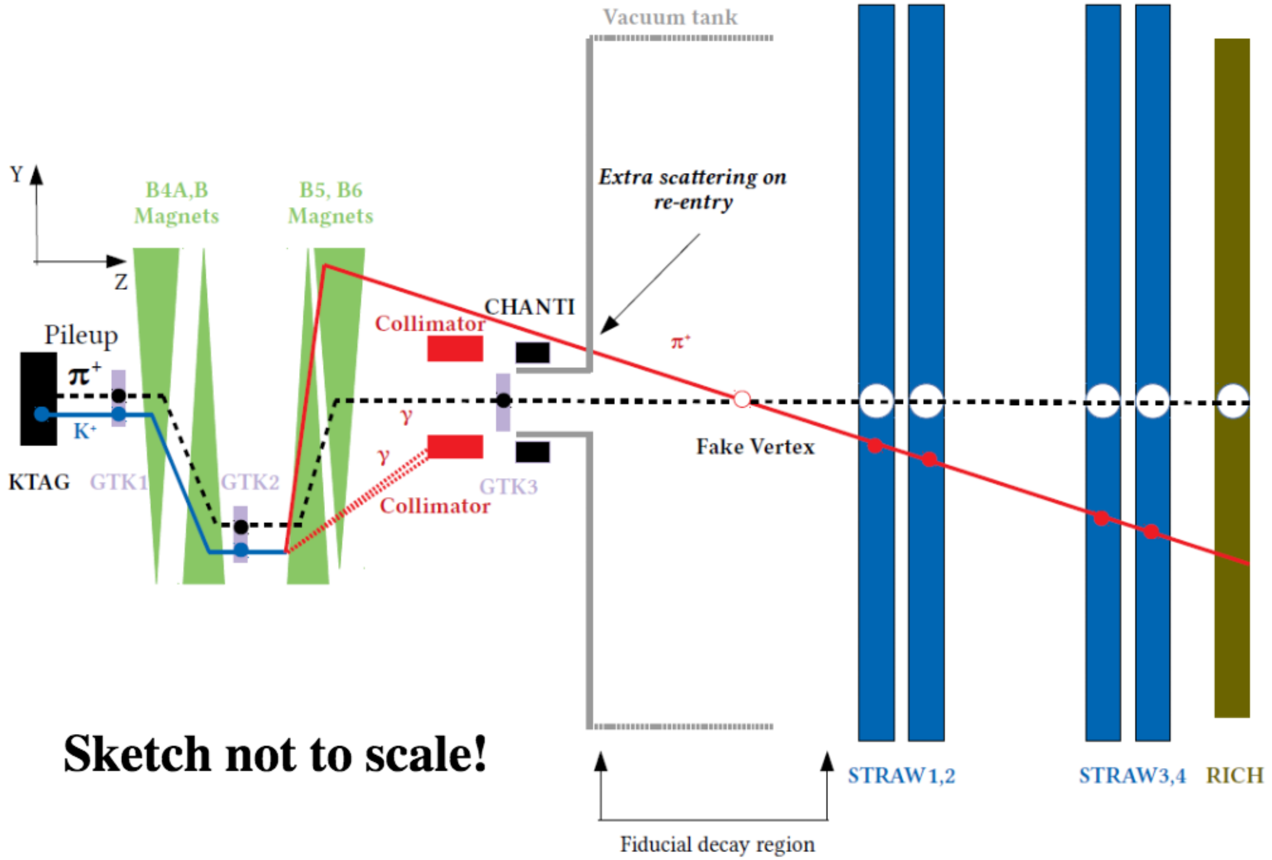


Kaon decays upstream the FV
→ only π^+ enters FV and scatters in first STRAW chamber
In-time pileup beam particle (in GTK) generates a fake decay vertex inside the FV

Upstream Background

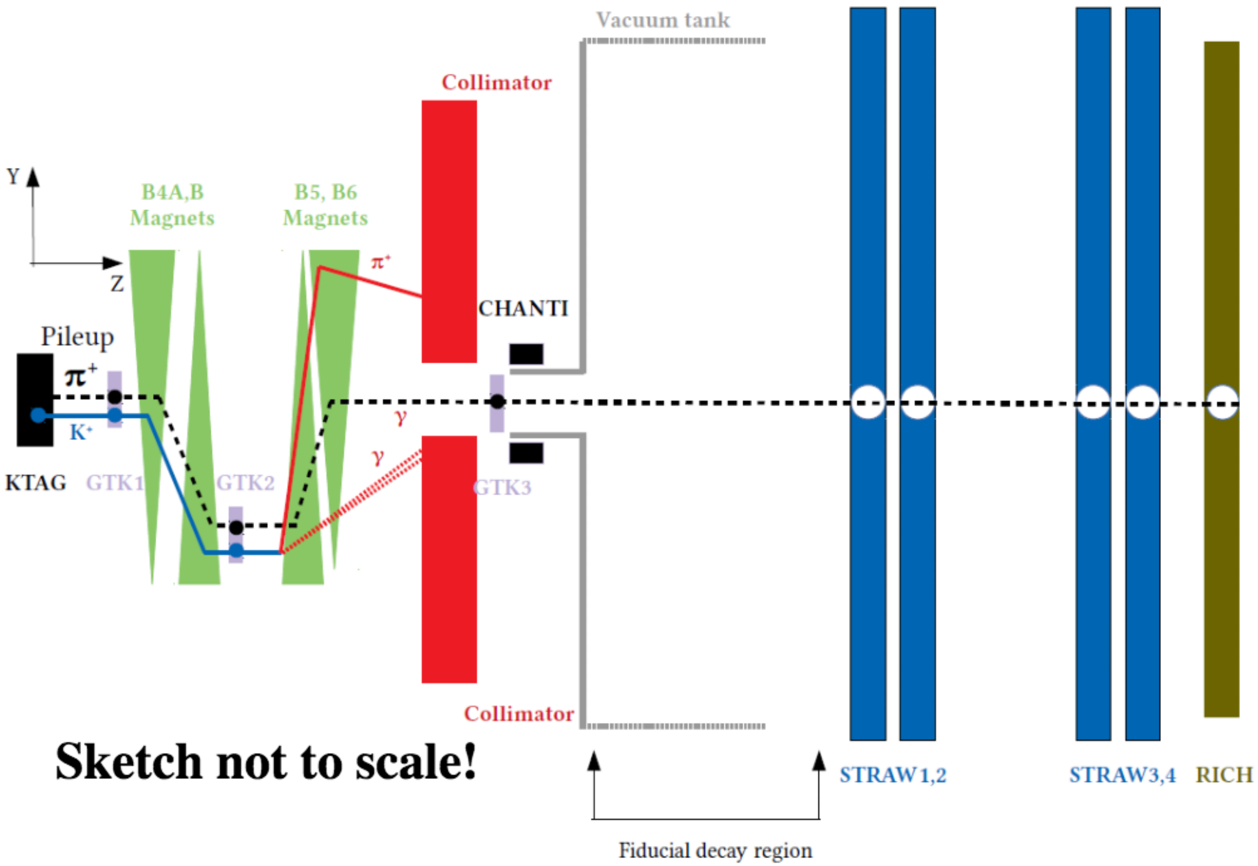
Replacement of the final collimator against Upstream events (June 2018)

Upstream Background



A particular upstream event in the OLD COL configuration

Upstream Background



The same upstream event in the NEW COL configuration