NA62 status and prospects

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on behalf of the NA62UK collaboration

PPAP community meeting

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Outline:

- Physics at kaon experiments: $K \rightarrow \pi \nu \nu$ decays and beyond
- NA62 status, performance, UK involvement.
- Physics exploitation programme for 2021-2024.
- Overview of the recent results.
- Summary

Science & Technology Facilities Council

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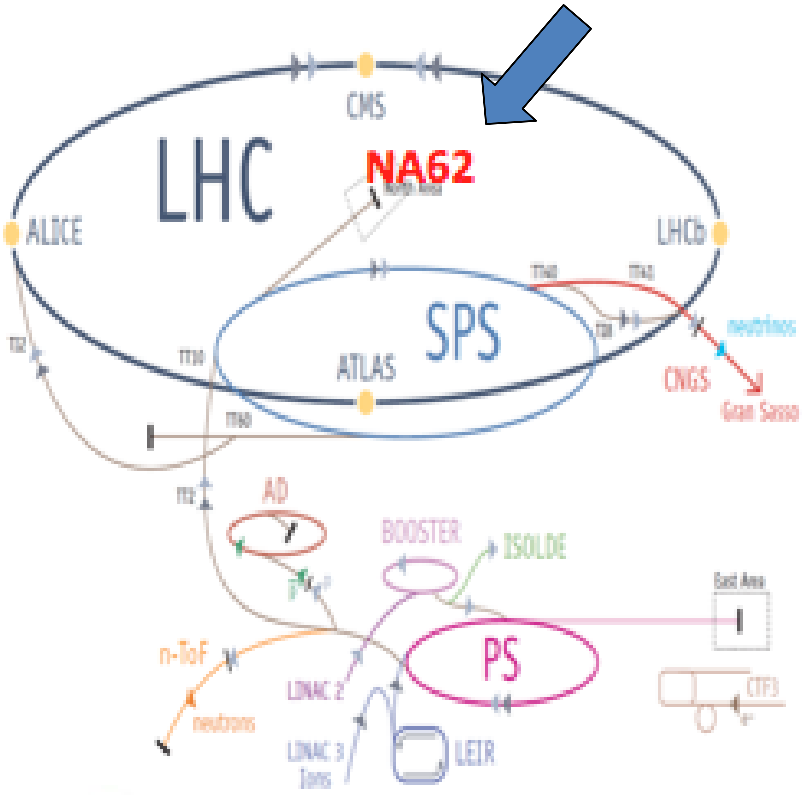
EXCELLENCE IN SCIENCE

CERN kaon experiments



Kaon decay-in-flight experiments at CERN:

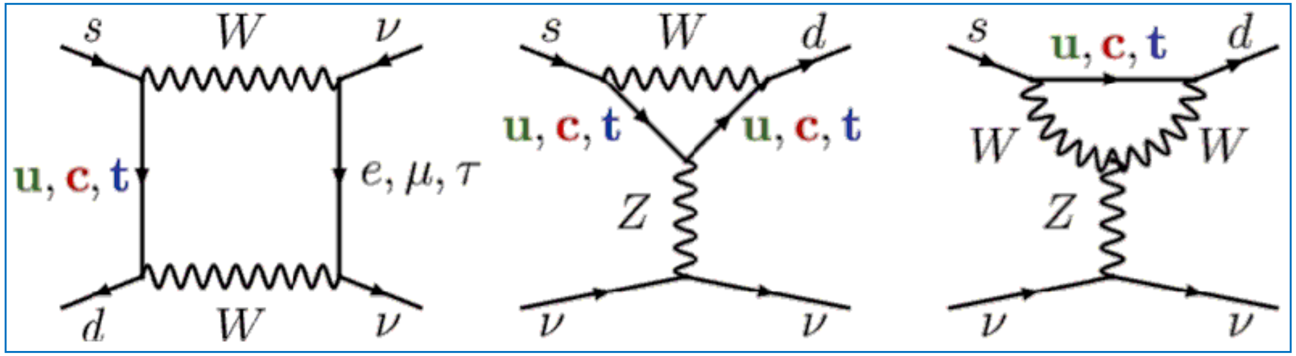
Earlier	NA31	
1997 ↓ 2001	NA48 (K_S/K_L)	$Re(\varepsilon'/\varepsilon)$ Discovery of direct CPV
2002	NA48/1 (K_S/hyperons)	Rare K_S and hyperon decays
2003 ↓ 2004	NA48/2 (K^+/K^-)	Direct CPV, Rare K^+/K^- decays
2007 ↓ 2008	$NA62_{R_K}$ (K^+/K^-)	$R_K = K^{\pm}_{e2}/K^{\pm}_{\mu 2}$
2014 ↓ ...	NA62 (K^+)	$K^+ \to \pi^+ \nu\bar{\nu}$, Rare K^+ and π^0 decays

NA62: currently ~200 participants, ~30 institutions.

NA62UK: Birmingham, Bristol, Glasgow, Liverpool--->Lancaster (12% of participants)

Rare kaon decays: $K \to \pi \nu \bar{\nu}$

SM: box and penguin diagrams



Ultra-rare decays with
the highest CKM suppression:

$A \sim (m_t/m_W)^2 |V_{ts}^* V_{td}| \sim \lambda^5$

- Hadronic matrix element related to a measured quantity ($K^+ \to \pi^0 e^+ \nu$).
- Exceptional SM precision.
- Free from hadronic uncertainties.
- Measurement of $|V_{td}|$ complementary to those from $B-\bar{B}$ mixing or $B^0 \to \rho\gamma$.

SM branching ratios
Buras et al., JHEP 1511 (2015) 033

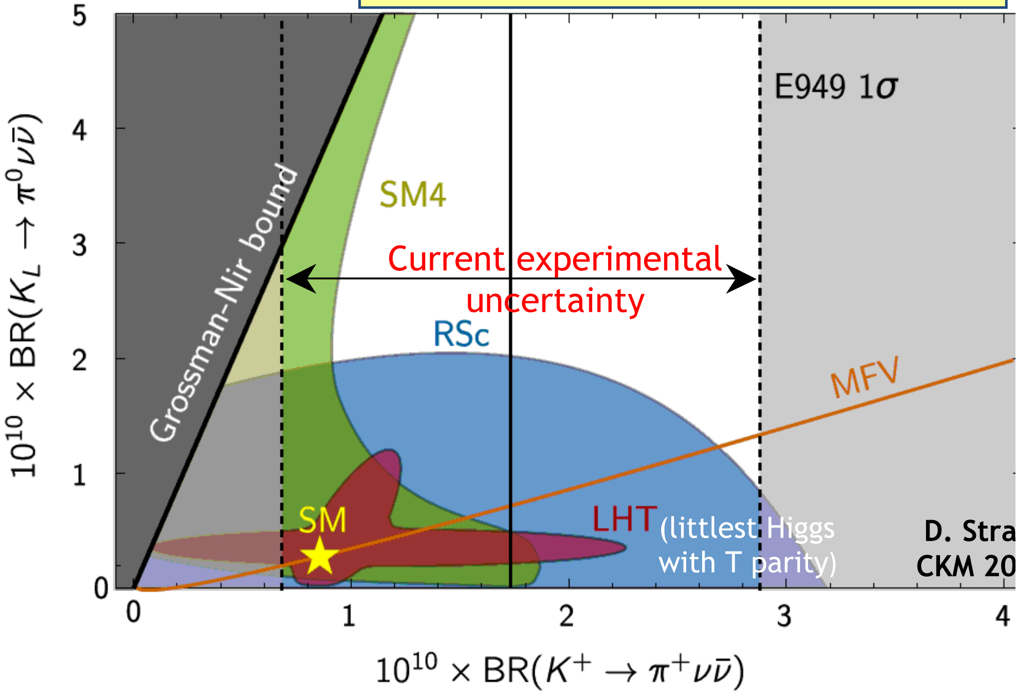
Mode	$BR_{SM} \times 10^{11}$
$K^+ \to \pi^+ \nu \bar{\nu}(\gamma)$	8.4±1.0
$K_L \to \pi^0 \nu \bar{\nu}$	3.00±0.31

The uncertainties are largely parametric (CKM)

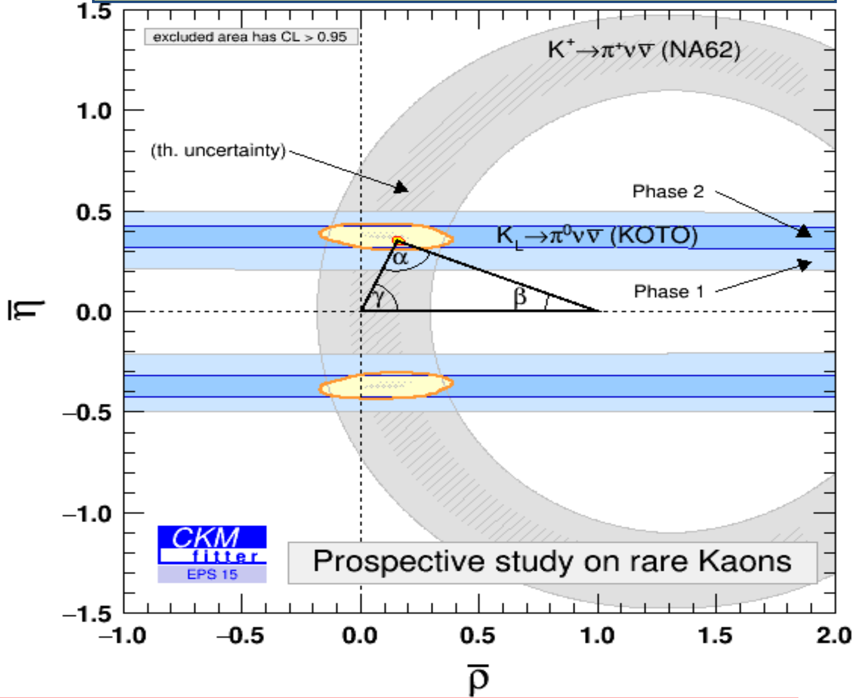
Theoretically clean,
almost unexplored,
sensitive to new physics.

$K \to \pi\nu\bar{\nu}$: experiment vs theory

BR($K_L \to \pi^0\nu\bar{\nu}$) vs BR($K^+ \to \pi^+\nu\bar{\nu}$)



CKM unitarity triangle with kaons



NA62 aim: collect O(100) SM $K^+ \to \pi^+\nu\nu$ decays using a novel decay-in-flight technique.

NA62 broad physics programme(I)

NA62 approach allows for a broad physics programme:

Signature: high momentum K^+ (75GeV/c) → low momentum π^+ (15–35 GeV/c).

Advantages: max detected K^+ decays/proton ($p_K/p_0 \approx 0.2$);
efficient photon veto (>40 GeV missing energy)

Un-separated beam (6% kaons) → higher rates, additional background sources.

❖ **NA62 Run 2016–2018: focused on the "golden mode" $K^+ \to \pi^+ \nu\nu$.**

- ✓ Several measurements at nominal SES~10^{-12}: $K^+ \to \pi^+ A'$, $\pi^0 \to \nu\nu$.
- ✓ A few measurements do not require extreme SES: $K^+ \to \ell^+ N$, …
- ✓ Sensitivities to most rare/forbidden decays are limited but still often world-leading (~10^{-10} to ~10^{-11}).
- ✓ Proof of principle for a broad rare & forbidden decay programme.

NA62 broad physics programme(II)

❖ **NA62 Run 2021–2024**: **continue physics exploitation**, make the most of previous investments.
Commitment of UK groups to NA62 physics programme.

[Presented at Physics Beyond Colliders workshops, CERN, Sep 2016 & Mar 2017]

- ✓ Existing apparatus with improved trigger logic.
- ✓ Evaluate incremental changes for optimal efficiency.
- ✓ Further $K^+\to\pi^+\nu\nu$ data collection.
- ✓ Rare/forbidden K^+ and π^0 decays at $SES\sim10^{-12}$:
  - K^+ physics: $K^+\to\pi^+\ell^+\ell^-$, $K^+\to\pi^+\gamma\ell^+\ell^-$, $K^+\to\ell^+\nu\gamma$, $K^+\to\pi^+\gamma\gamma$, …
  - π^0 physics: $\pi^0\to e^+e^-$, $\pi^0\to e^+e^-e^+e^-$, $\pi^0\to3\gamma$, $\pi^0\to4\gamma$, …
  - Searches for LFV/LNV: $K^+\to\pi^-\ell^+\ell^+$, $K^+\to\pi^+\mu e$, $\pi^0\to\mu e$, …
- ✓ Beam dump with $\sim10^{18}$ POT: hidden sector (long-lived HNL, DP, ALP).

UK-led recent results and prospects on exotics:

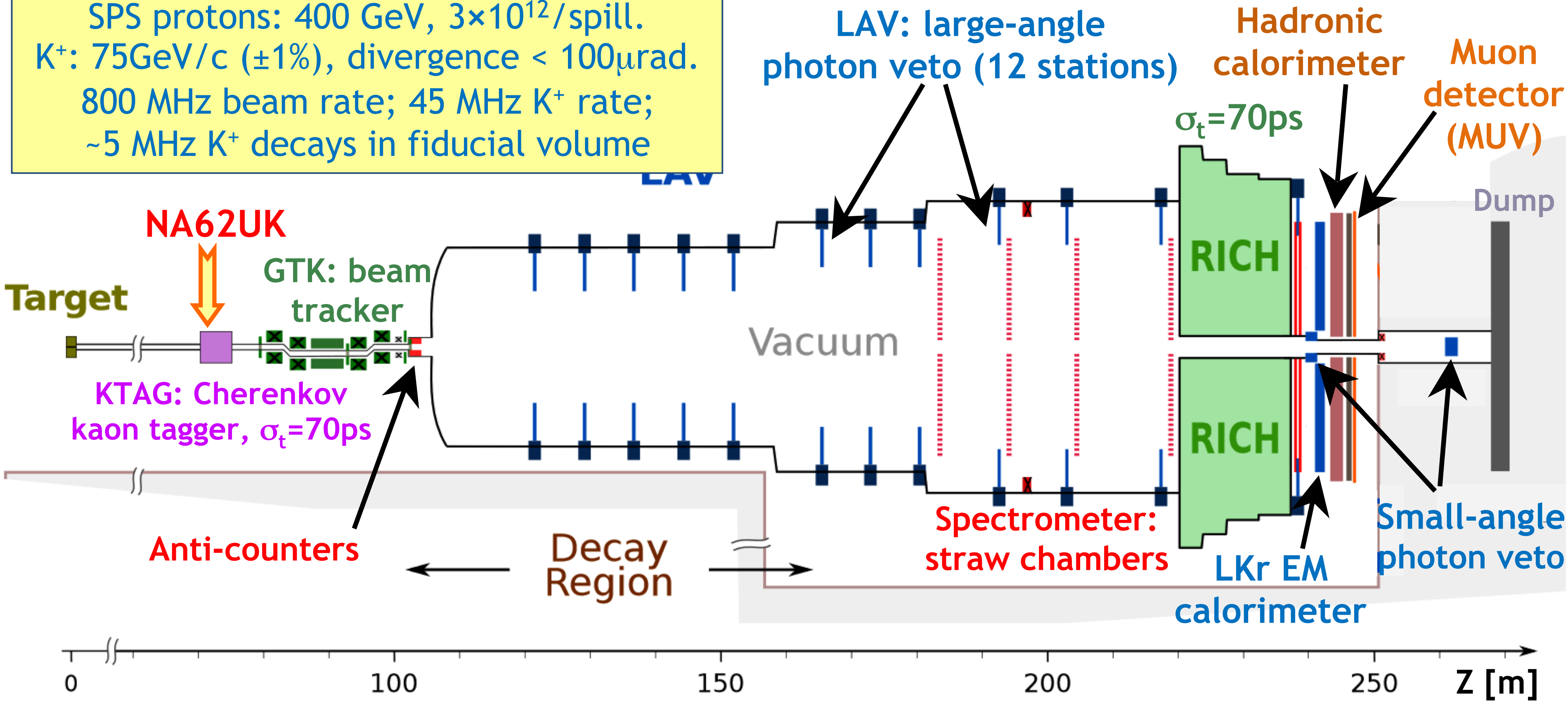
1. Searches for heavy neutral leptons: $K^+\to\mu^+\nu$
2. Searches for heavy neutral leptons: $K^+\to e^+\nu$
3. **3-tracks** K^+ decays

NA62 status and UK involvement

NA62 collaboration, JINST 12 (2017) P05025

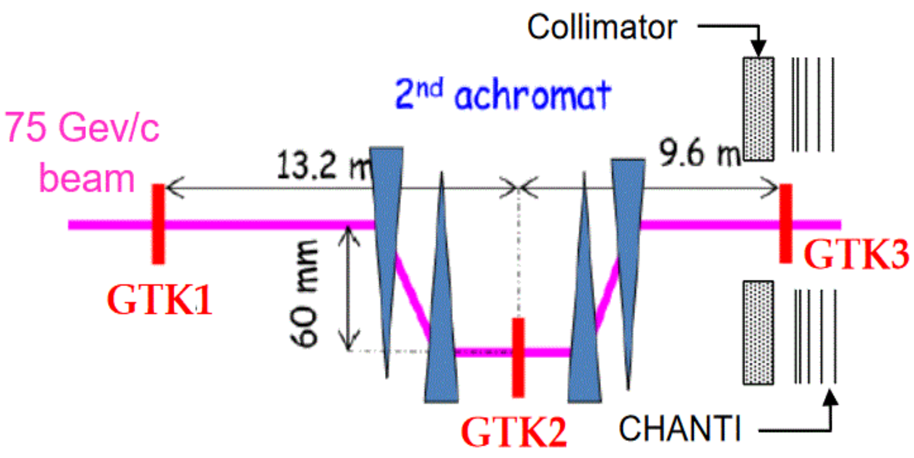
The NA62 detector

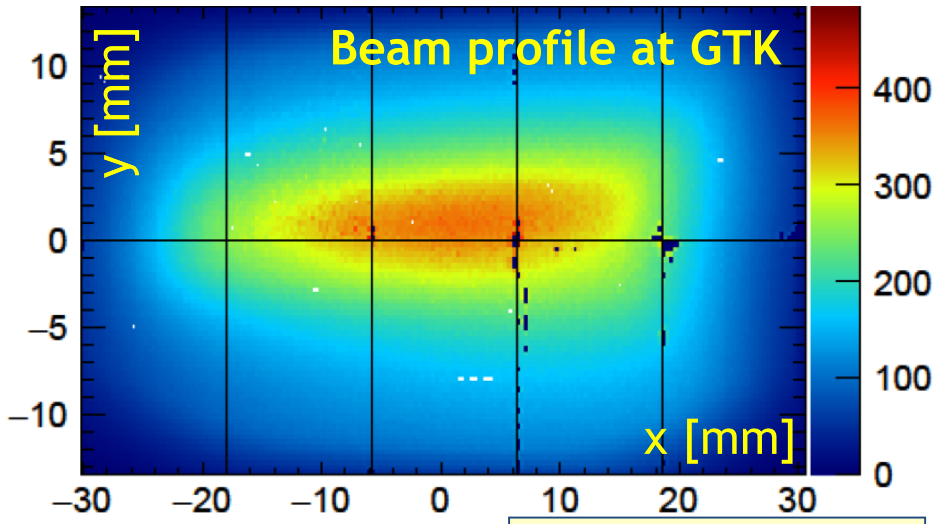
Un-separated hadron ($p/\pi^+/K^+$) beam.
SPS protons: 400 GeV, 3×10^{12}/spill.
K^+: 75GeV/c (±1%), divergence < 100μrad.
800 MHz beam rate; 45 MHz K^+ rate;
~5 MHz K^+ decays in fiducial volume

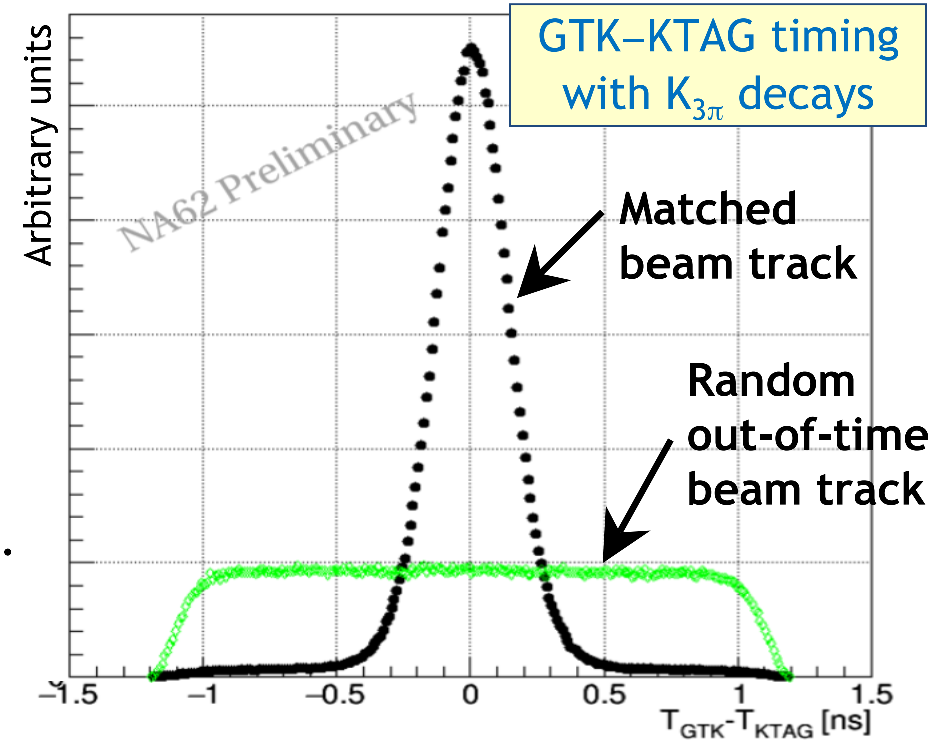


- Expected single event sensitivity for K^+ decays: **BR~10^{-12}**.
- Measured kinematic rejection factors (limited by beam pileup & MCS tails): 6×10^{-4} for $K^+\to\pi^+\pi^0$, 3×10^{-4} for $K\to\mu^+\nu$.
- Hermetic photon veto: measured $\pi^0\to\gamma\gamma$ decay suppression = 1.2×10^{-7}.
- Particle ID (RICH+LKr+HAC+MUV): ~10^{-7} muon suppression.

Beam tracker: the Gigatracker







Tracker design:

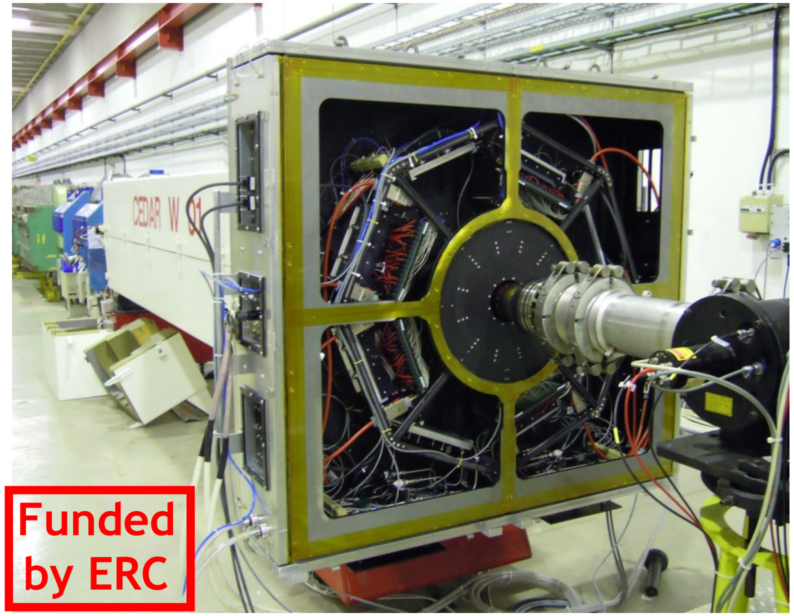
- ❖Three Si pixel stations in the beam.
- ❖Operation at beam rate up to **800 MHz**.
- ❖In total, **54k** pixels (**300×300 μm²**).
- ❖Thickness: **<0.5% X_0** per station.

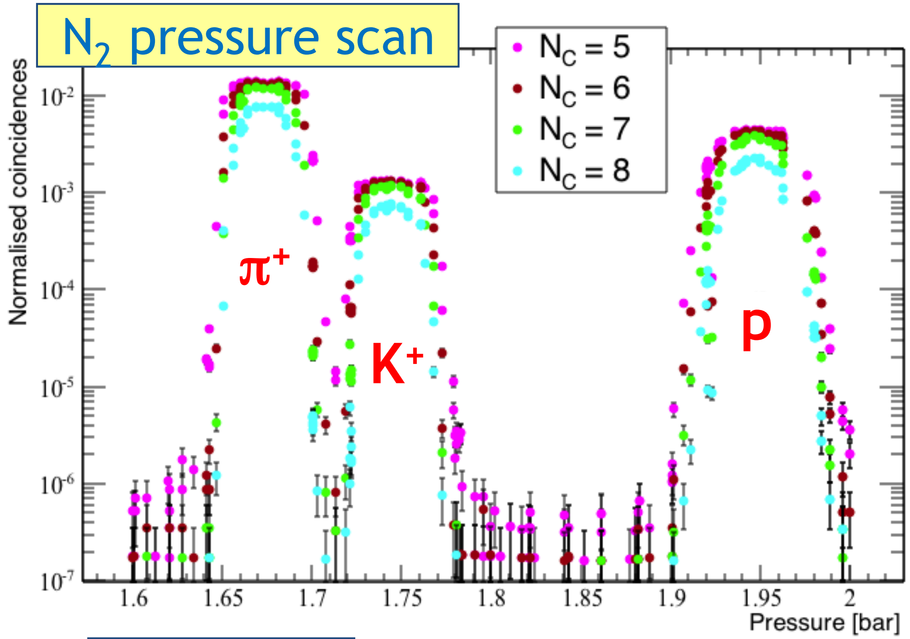
Performance at 40% beam intensity:

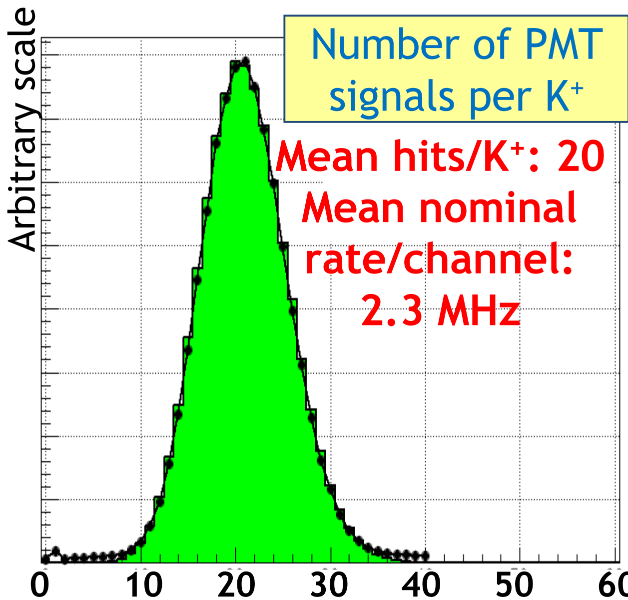
- ❖Track reconstruction efficiency: **75%**.
- ❖Time resolution **$\sigma(t_{BeamTrack}) \approx$ 100 ps**.
- ❖Beam track mis-tagging probability: **1.7%**.
- ❖Spatial matching: beam/downstream track intersection, **$\sigma_{CDA} \approx$ 1.5 mm**.

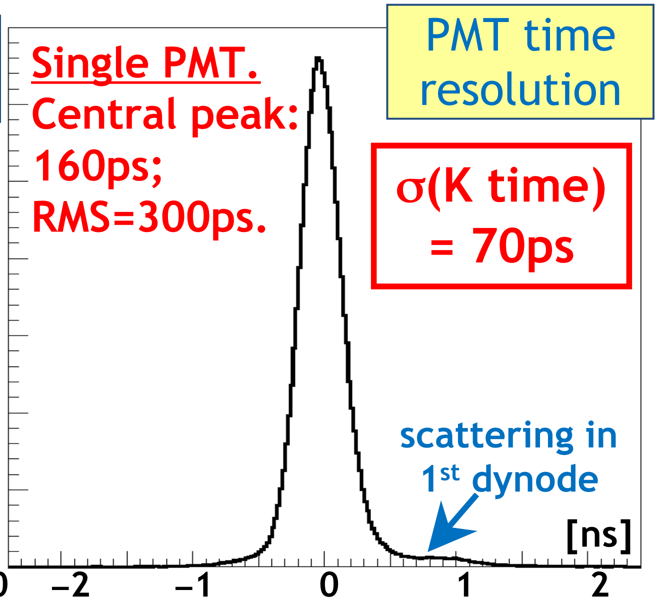
KTAG operation

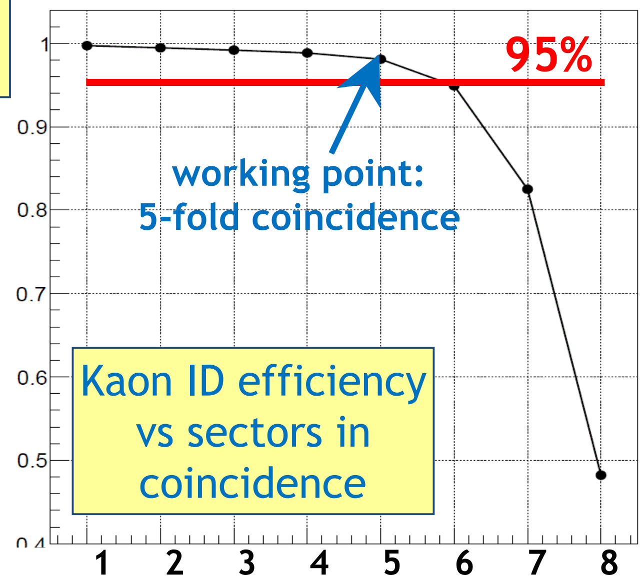
The first NA62 detector to be commissioned; performance exceeds specifications











UK participation in NA62

UK participation in NA62 from 2011:

- ✓ Capital funding and manpower for detector construction and operation from ERC / EU and Royal Society Grants.
  (manpower: 6 postdocs, 1 RS fellow, academic time)

- ✓ Soon after, STFC contribution with M&O costs.

- ✓ **Now in exploitation mode**: supported by STFC Particle Grant.
- ✓ **Extremely good value for STFC investment**:
  M&O, 1 postdoc, 2 Rutherford fellows, travel, some academic time.

- ✓ Strong, wide-spread leadership.

NA62: UK contributions

Hardware and trigger:

- full responsibility for the **KTAG subdetector**;
- full responsibility for the Run Control system;
- development and operation of L0 muon+hodoscope+RICH trigger;
- development and operation of the **high-level software trigger**;
- **GRID infrastructure, software, data processing**;
- DCS system.

Leadership in the physics exploitation:

- Flagship analysis: $K^+ \to \pi^+ \nu\nu$;
- Detector performance studies with data;
- Rare decays and forbidden studies:
- Analyses of "old" NA48/NA62 data.

Major leadership roles:

- **Physics coordination**;
- **Computer coordination**;
- **Run coordinators**: 3 out of 12 (in 2017);
- **Editorial Board** membership: 4 out of 10;
- **Conference Committee** chair.
- **LFV, $\pi^+\nu\nu$ WGs coordination**;
- **High-level trigger coordination**;
- 2 out of 4 **PBC representatives;**

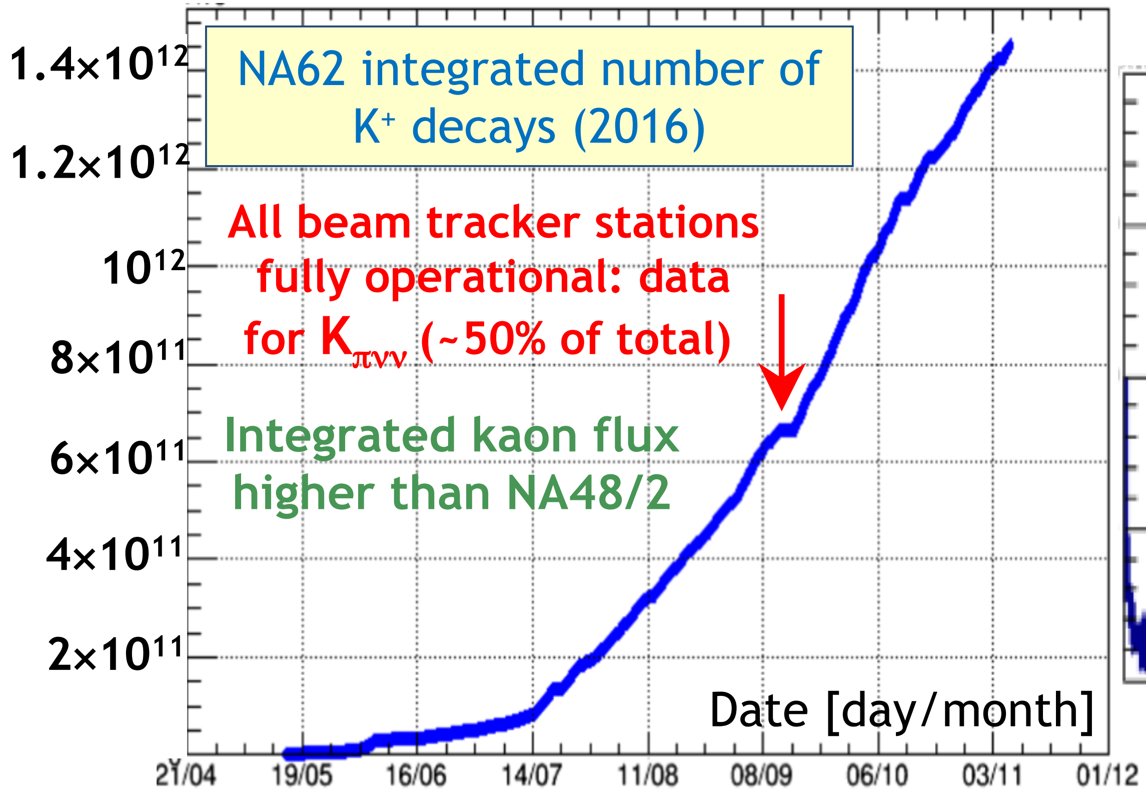
UK groups have been consistently responsible for **>50%** of the physics output of NA62

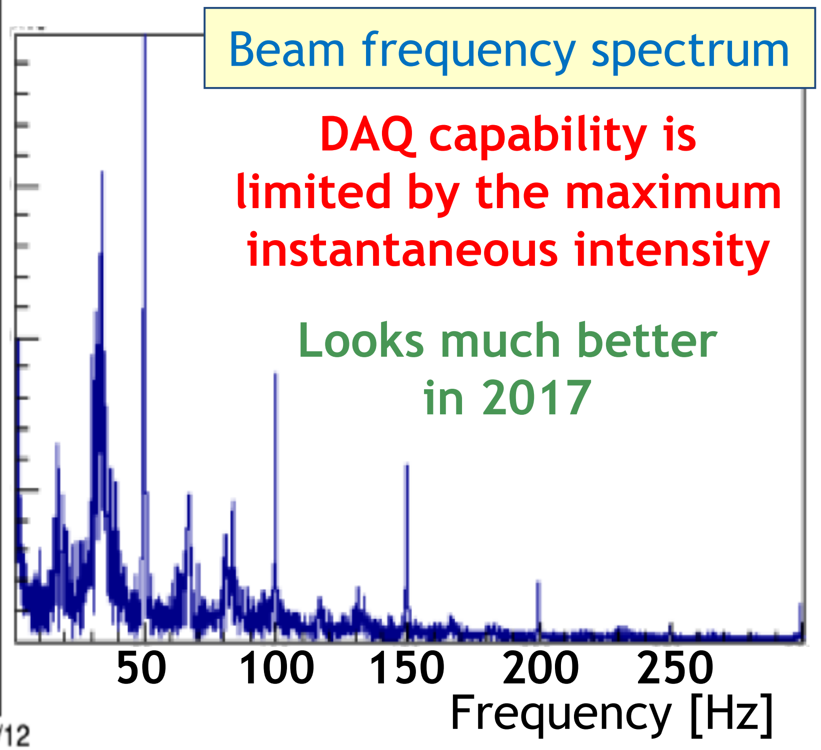
Data collection

- Commissioning run **2015**: minimum bias (~1% intensity) and **$K_{\pi\nu\nu}$ test** data.
  - ✓ Most systems commissioned and meet the design requirements
- First high intensity run: **3 May – 14 November 2016**
  - ✓ Data collection at **~40%** of the nominal intensity (limited by beam quality)
- Long (~6 months) runs in **2017** (started in May) and **2018**

Reached sensitivity of ~1 SM $K_{\pi\nu\nu}$ event with the **2016** data

High intensity run in 2016

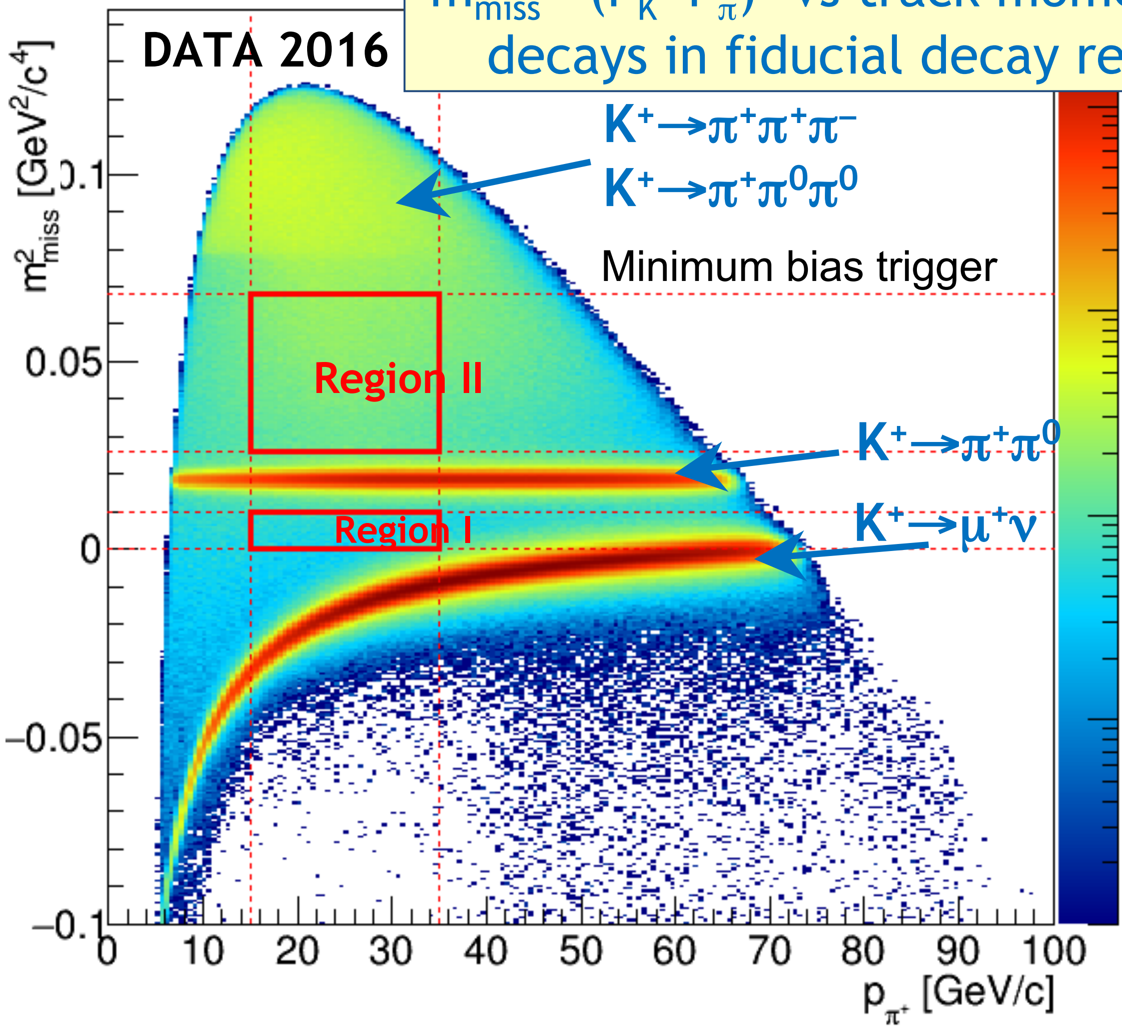




- Stable data collection at ~40% of the nominal intensity; limited by beam structure, including the 50 Hz harmonics.
- Simultaneous data taking for $K_{\pi\nu\nu}$ and **rare/exotic decays**.
- Extrapolation to end of 2018 (12 months of live time): 7×10^{12} K^+ decays.
- With improved extraction and incremental improvements in efficiency, the target of 10^{13} K^+ **decays** by end of 2018 is reachable.

$K_{\pi\nu\nu}$ signal region definition

$m_{miss}^2=(P_K-P_\pi)^2$ vs track momentum; decays in fiducial decay region



Analysis done in 3D space:
m^2_{miss}, m^2_{miss}(RICH), m^2_{miss}(no GTK)

Main K^+ decay modes (>90% of BR) rejected kinematically.

Design kinematical resolution on m_{miss}^2 has been achieved ($\sigma=1.0\times10^{-3}$ GeV^4/c^2).

Measured kinematical background suppression:

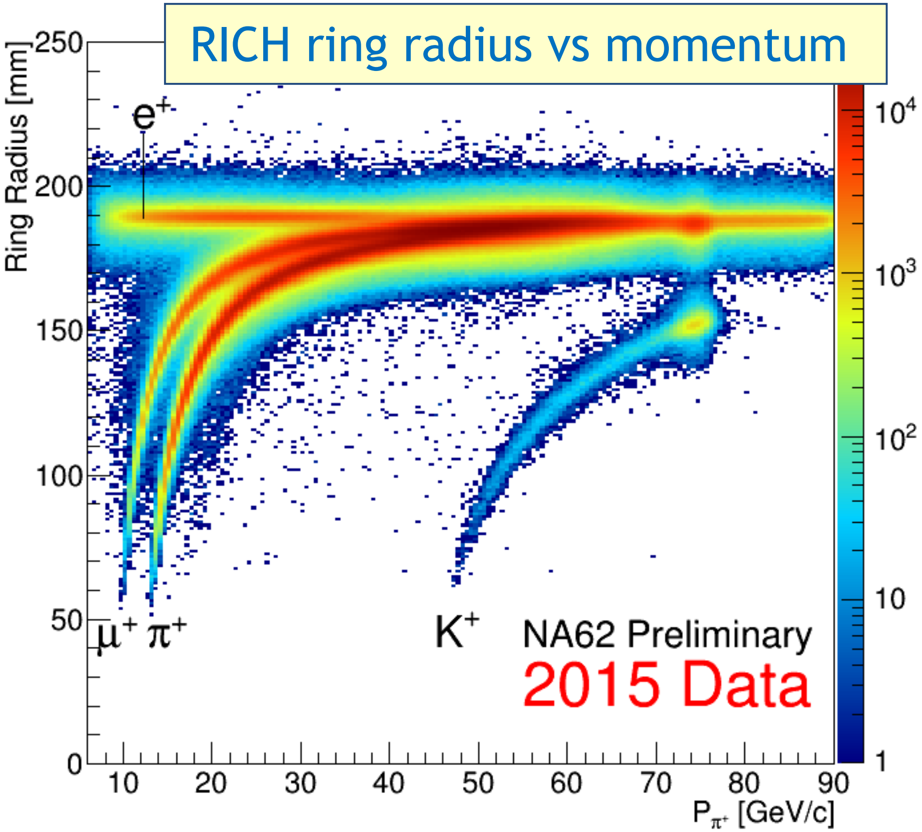
✓$K^+\to\pi^+\pi^0$: 6×10^{-4};
✓$K^+\to\mu^+\nu$: 3×10^{-4}.

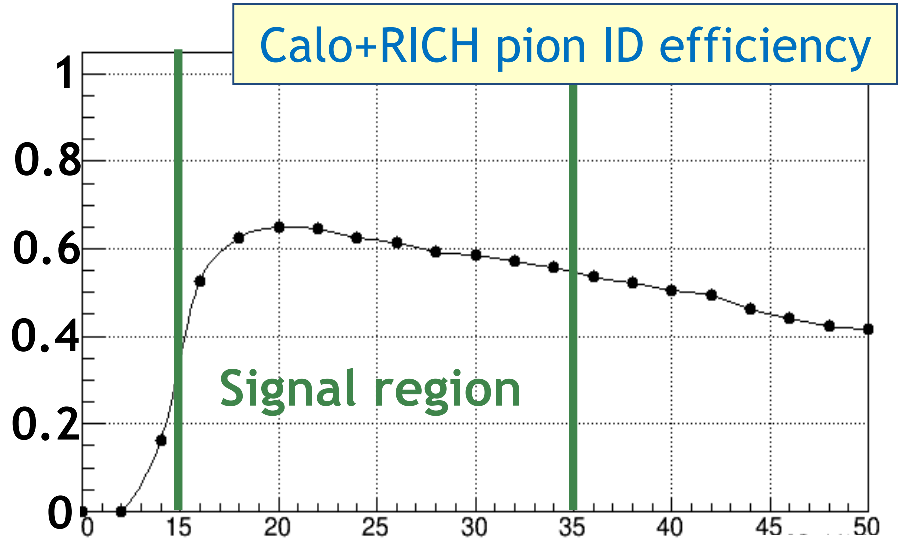
Further background suppression:

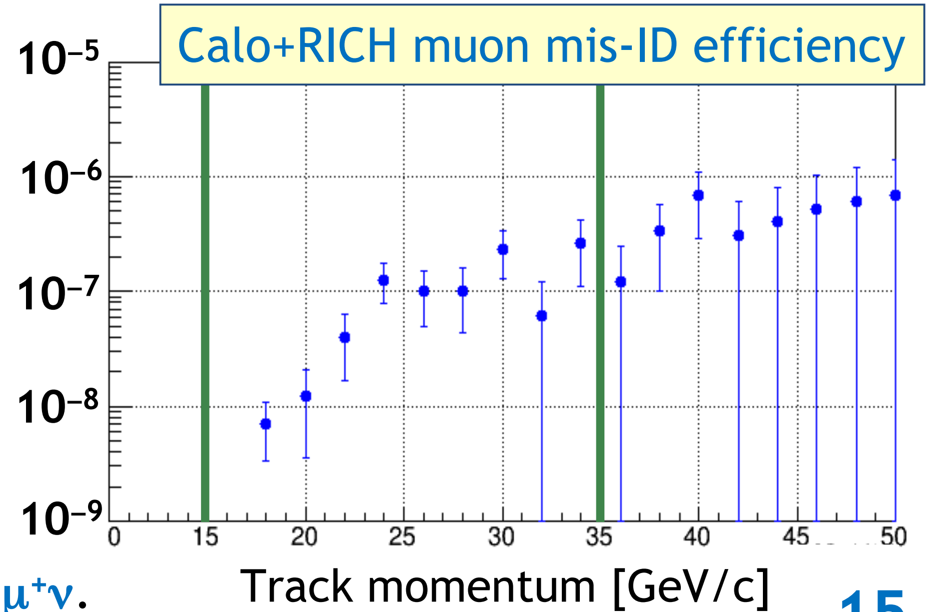
✓PID (calorimeters & Cherenkov detectors): μ suppression $<10^{-7}$.

✓Hermetic photon veto: suppression of $\pi^0\to\gamma\gamma$ decays $<10^{-7}$.

Identification with RICH & HAC







<u>Two independent PID measurements:</u>

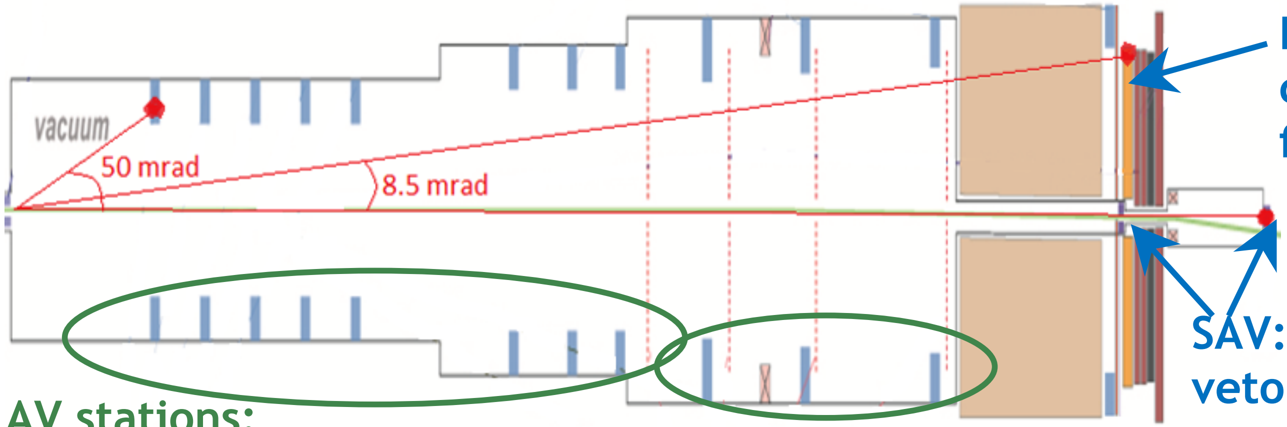
1) with calorimeters & muon detector: MVA technique used; $\varepsilon_\mu \div \varepsilon_\pi = 10^{-5} \div 80\%$,

2) with RICH: $\varepsilon_\mu \div \varepsilon_\pi = 10^{-2} \div 80\%$

in the signal momentum region.

Performance measured with $K^+ \to \pi^+\pi^0$, $K^+ \to \mu^+\nu$.

Photon rejection



LKr EM calorimeter: forward veto

SAV: small-angle veto (sampling calo)

12 Pb glass LAV stations: hermetic up to 50 mrad

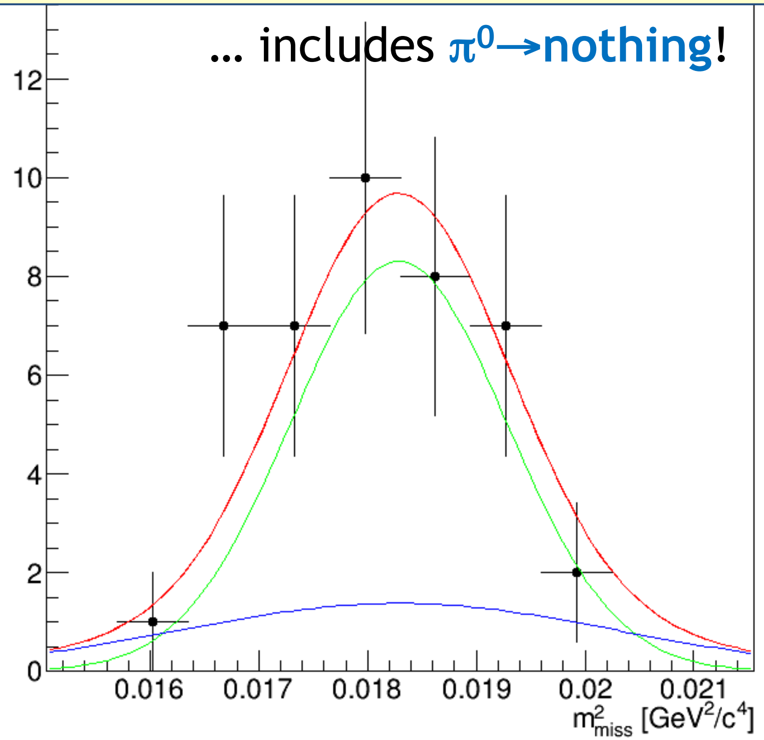
❖ Technique: EM calorimetry exploiting correlations between photons from $\pi^0 \to \gamma\gamma$ decays.

❖ Signal region: $p(\pi^+) < 35$ GeV/c, therefore $p(\pi^0) > 40$ GeV/c.

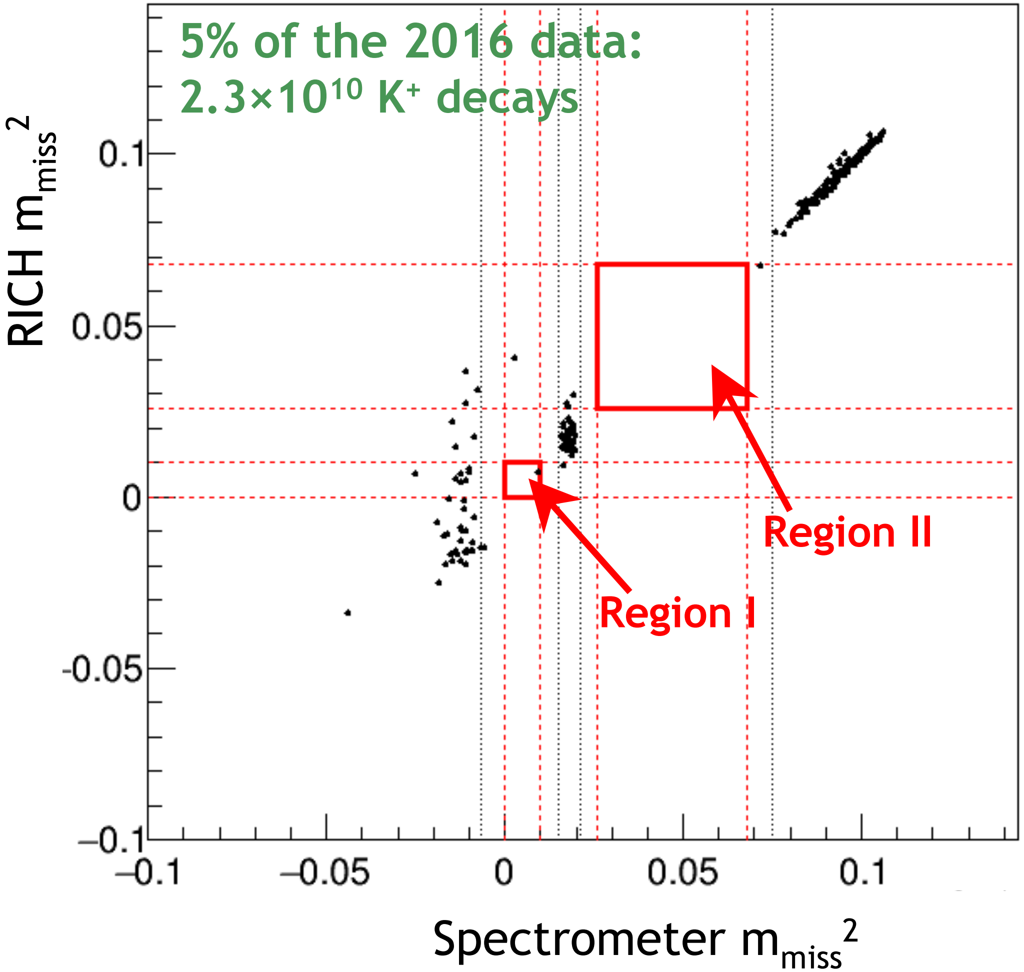
❖ Goal: $O(10^{-7})$ to $O(10^{-8})$ rejection of π^0 from $K^+ \to \pi^+\pi^0$ decays.

❖ Measured π^0 rejection factor with the $K_{\pi\nu\nu}$ selection: $\varepsilon = (1.2 \pm 0.2) \times 10^{-7}$. Accidental loss measured with $K_{\mu 2}$: 16% at 40% intensity, can be improved.

$m_{miss}^2 = (P_K - P_\pi)^2$: full $K_{\pi\nu\nu}$ selection



Data 2016: $K_{\pi\nu\nu}$ sample



$K^{\pm} \rightarrow \pi^{\pm}\nu\nu$ decay:

~50% of 2016 data is useful.

Analysis of 5% of this sample.

No events found in 3D-space.

in $K_{\pi\nu\nu}$ signal region.

- Expect 1.3 SM $K_{\pi\nu\nu}$ decays from total 2016 sample.
- Preliminary statement on background: B/S<0.9.
- Analysis in progress to increase signal acceptance and improve BKG suppression.

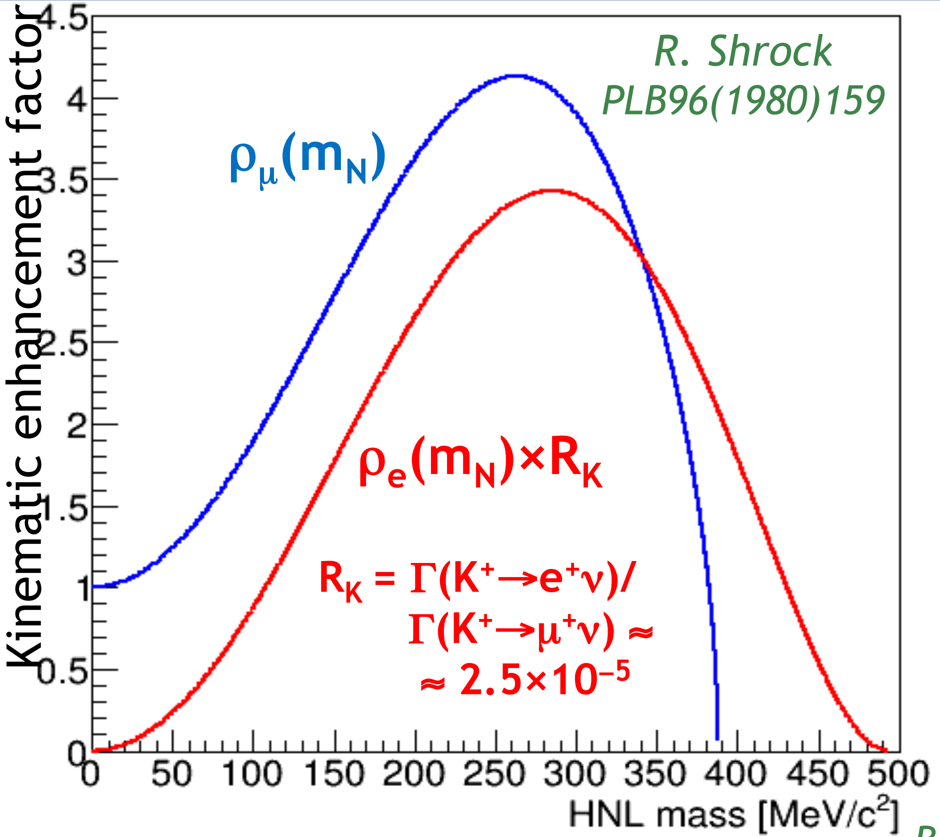
Recent & upcoming results
2007 and 2015-16 data samples

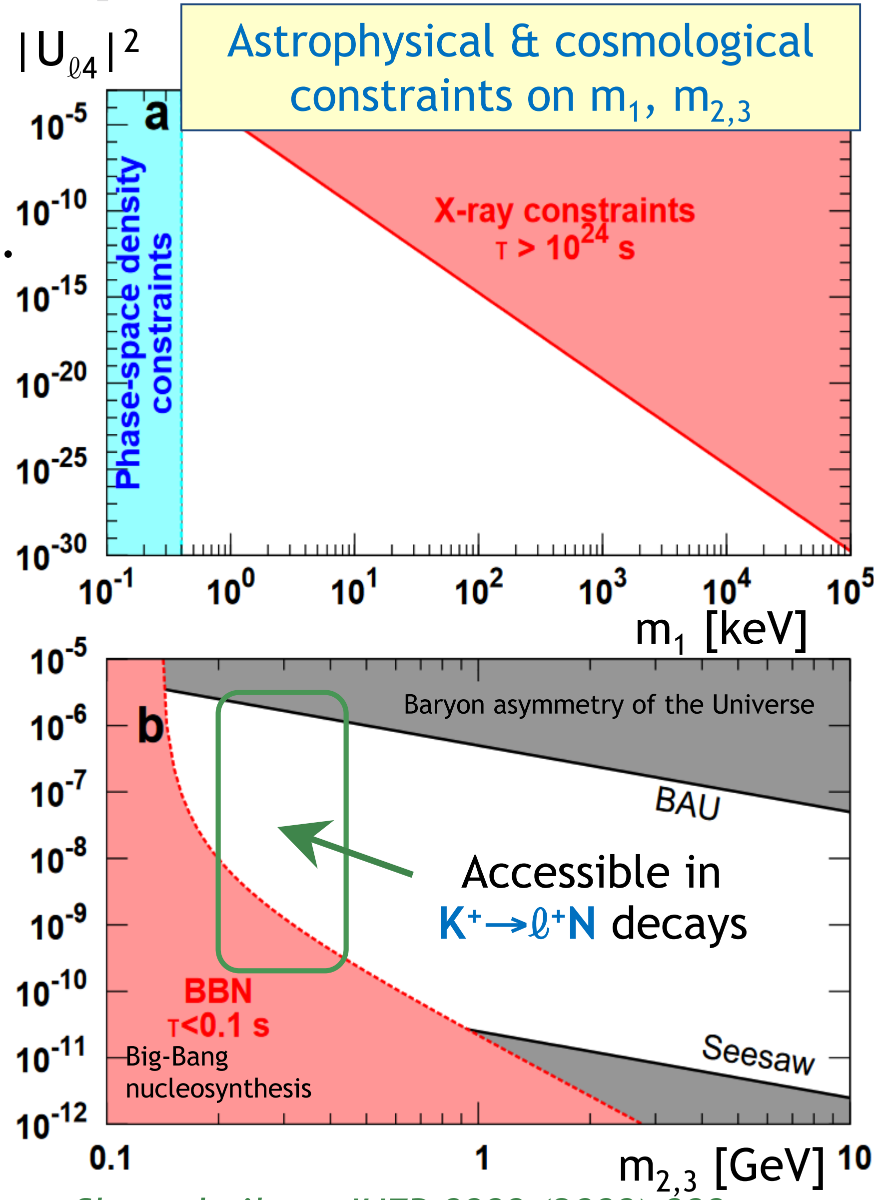
❖Searches for heavy neutral leptons: **$K^+ \to \mu^+ \nu$** [Birmingham]
❖Searches for heavy neutral leptons: **$K^+ \to e^+ \nu$** [Birmingham]
❖Prospects for **3-tracks K^+** decays [Birmingham, Bratislava]

Heavy neutral leptons in νMSM

Neutrino minimal SM (νMSM) =
SM + 3 right-handed neutral heavy leptons.
[Asaka et al., PLB 631 (2005) 151]
Masses: m_1~10 keV [DM candidate]; $m_{2,3}$~1 GeV.
HNLs observable via **production** and **decay**.

$$\Gamma(K^+\to\ell^+N) = \Gamma(K^+\to\ell^+\nu)\ \rho_\ell(m_N)\,|U_{\ell 4}|^2$$

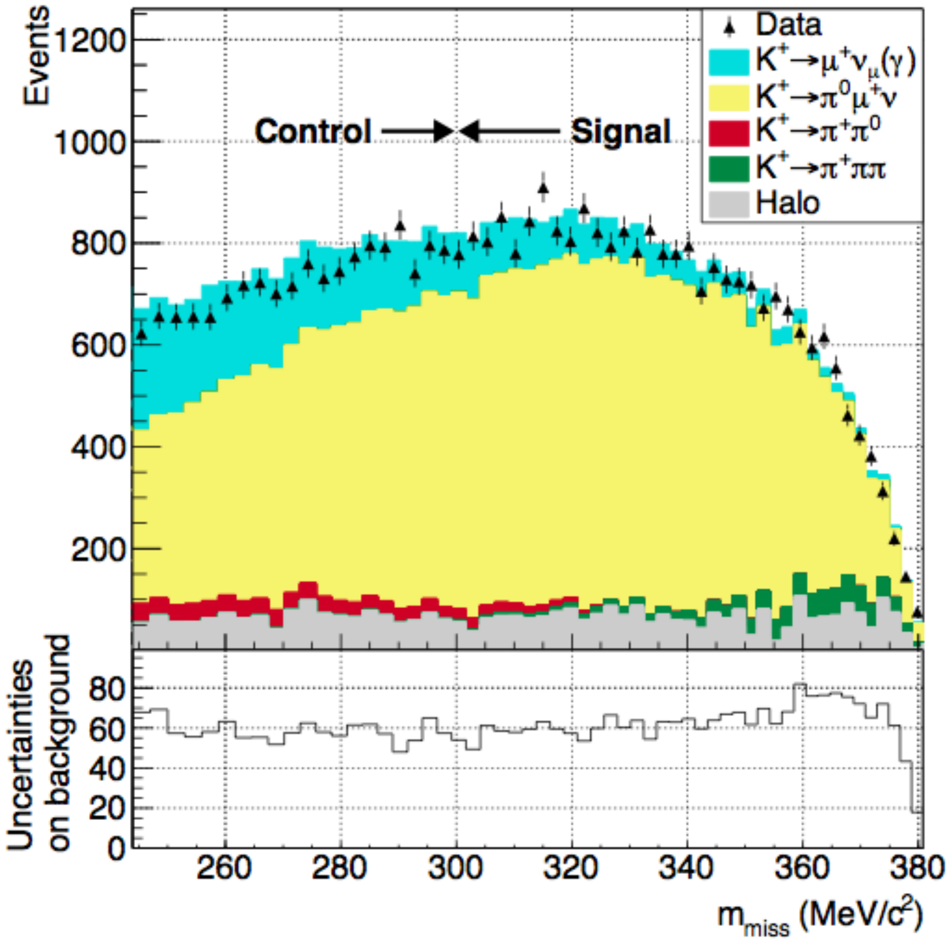




Shaposhnikov, JHEP 0808 (2008) 008
Boyarsky et al., Ann.Rev.Nucl.Part.Sci.59 (2009) 191

$K^+ \rightarrow \mu^+ N$: 2007 data sample

Only K^+ (43% of NA62 2007 data) due to higher muon halo rejection



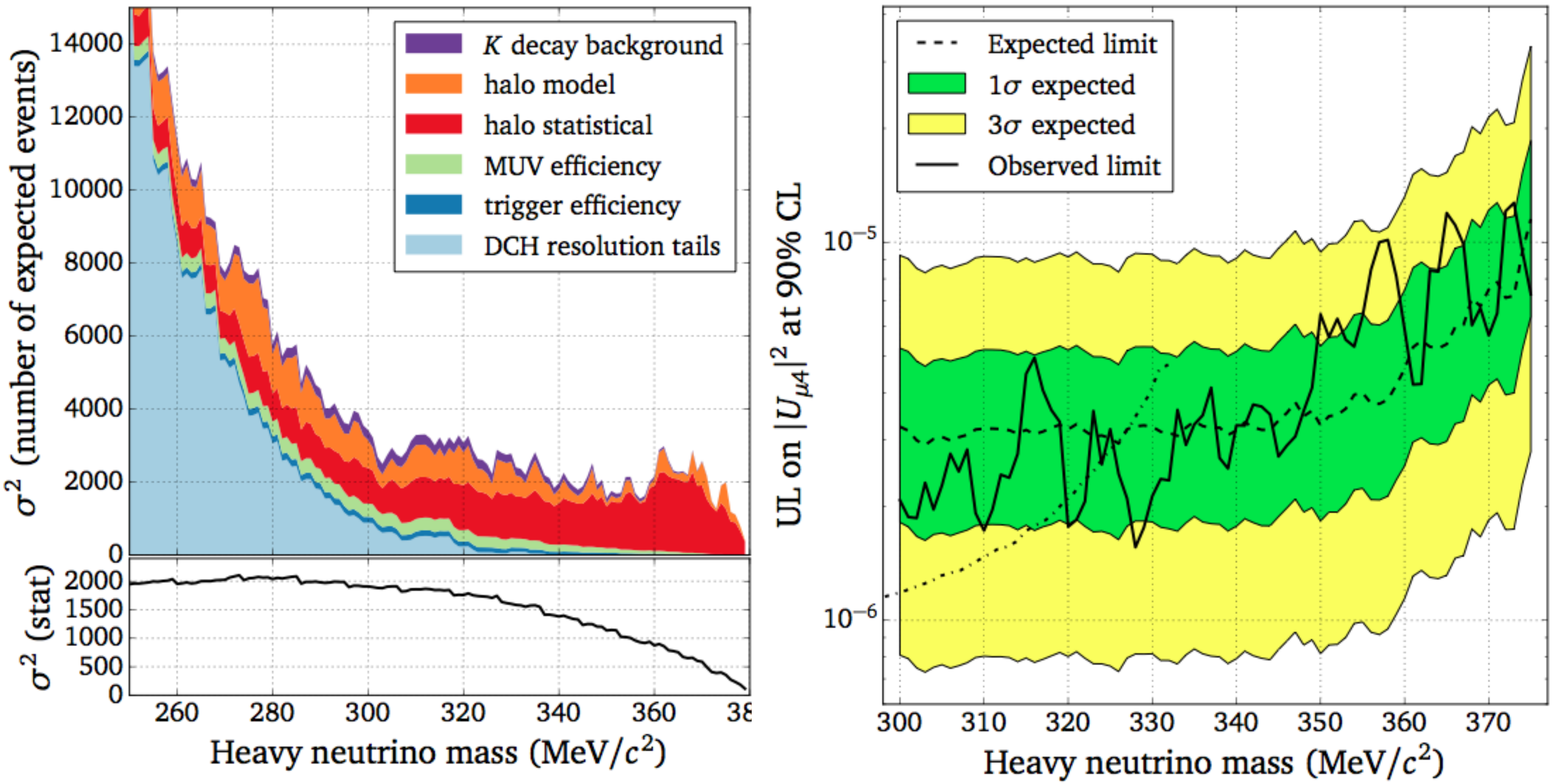
One well-reconstructed μ+ track.
Kinematic cuts to suppress halo

N(K) ~ 6 x 10^7 from K+ $\rightarrow \mu + \nu$
(trigger downscale D=150)

Data driven study of:
Halo background
Spectrometer resolution tails
Trigger efficiency
Muon ID efficiency
Dedicated MC simulation for:
Acceptance vs HN mass
HN peak resolution vs HN mass

HNL production search: results

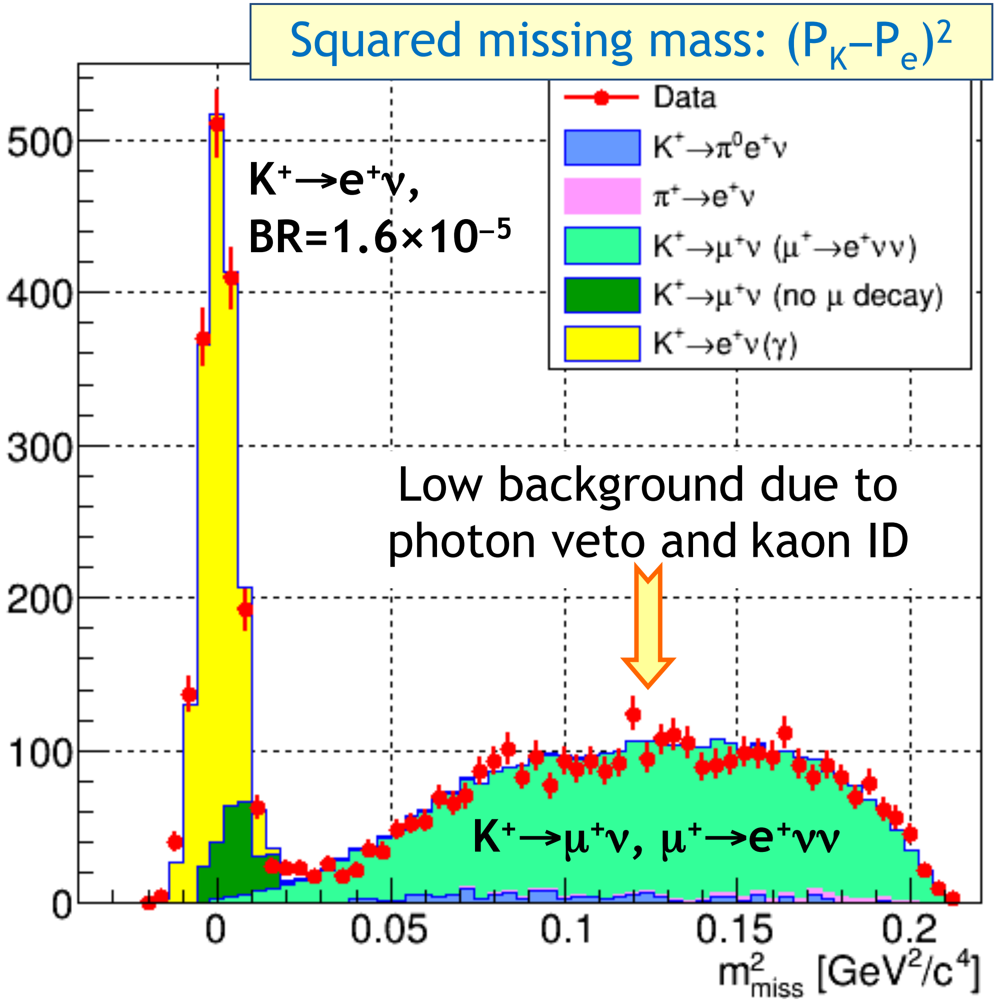
[arXiv: 1705.07510]

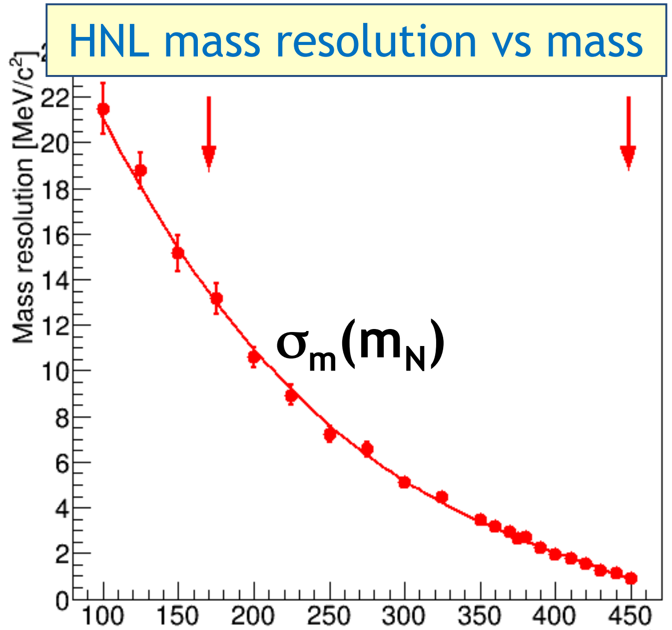


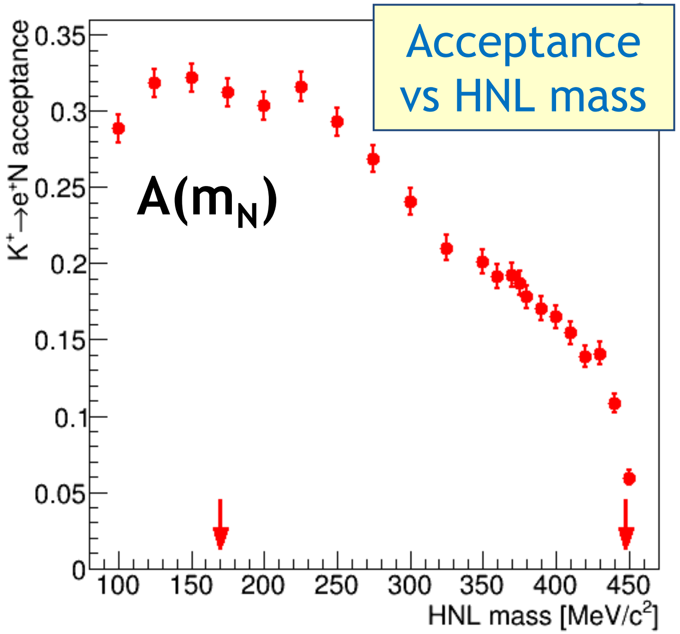
Limits on BR($K^+ \to \mu^+ N_4$) ~ 10^{-5}, limits on $|U_{\mu 4}|^2$ ~ 10^{-5} for M_N > 300 MeV/c^2

$K^+ \to e^+N$: 2015 data sample

- Minimum bias (1% intensity); 11k SPS spills in 2015.
- K^+ decays in fiducial volume: $N_K=(3.01\pm0.11)\times10^8$.
- Beam tracker not available: kaon momentum is estimated as the beam average.

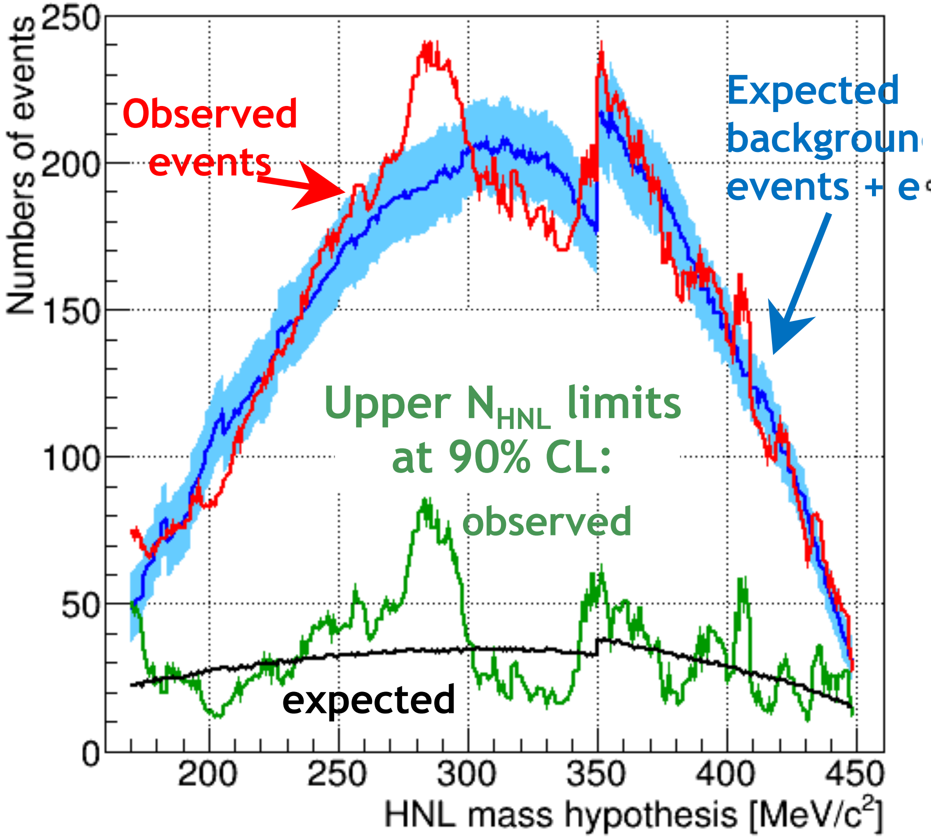


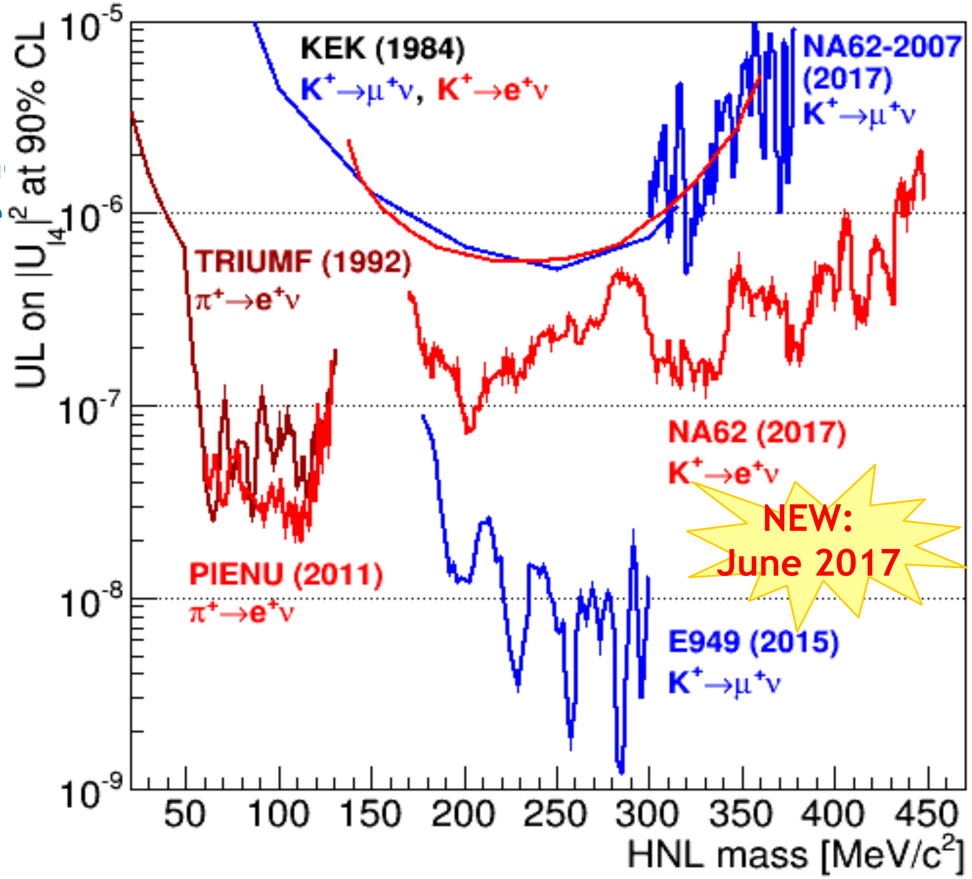




HNL production search: results

- HNL mass scan: $170\ MeV/c^2 < m_N < 448\ MeV/c^2$, mass step = $1\ MeV/c^2$.
- Signal search window for each mass hypothesis: $\pm 1.5\sigma_m$.
- Background estimate: polynomial fits to mass spectra outside signal window.

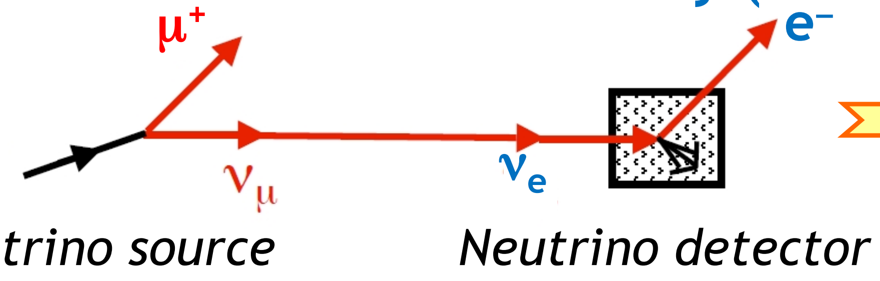




- Local signal significance never exceeds 3σ: **no HNL signal** is observed.
- Reached 10^{-6}–10^{-7} limits for $|U_{e4}|^2$ in the 170–$448\ MeV/c^2$ mass range.
- Major improvement foreseen with high intensity NA62 2016 data.

LVF/LNV programme

Neutrino oscillations discovery (1998)



First non-SM phenomenon:

1) Lepton Flavour Violation;
2) non-zero neutrino mass.

New physics scenarios involving **LFV**:

- ✓ Neutrino is a **Majorana fermion** (identical to antineutrino)
- ✓ Heavy (possibly sterile) neutrino states
- ✓ **Supersymmetry** with R-parity violation or RH neutrinos

Astrophysical consequences:

- ✓ Dark matter, nucleosynthesis, Supernova evolution, ...

❖ Search for forbidden states with lepton pair (**ee**, **μμ**, **μe**):

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

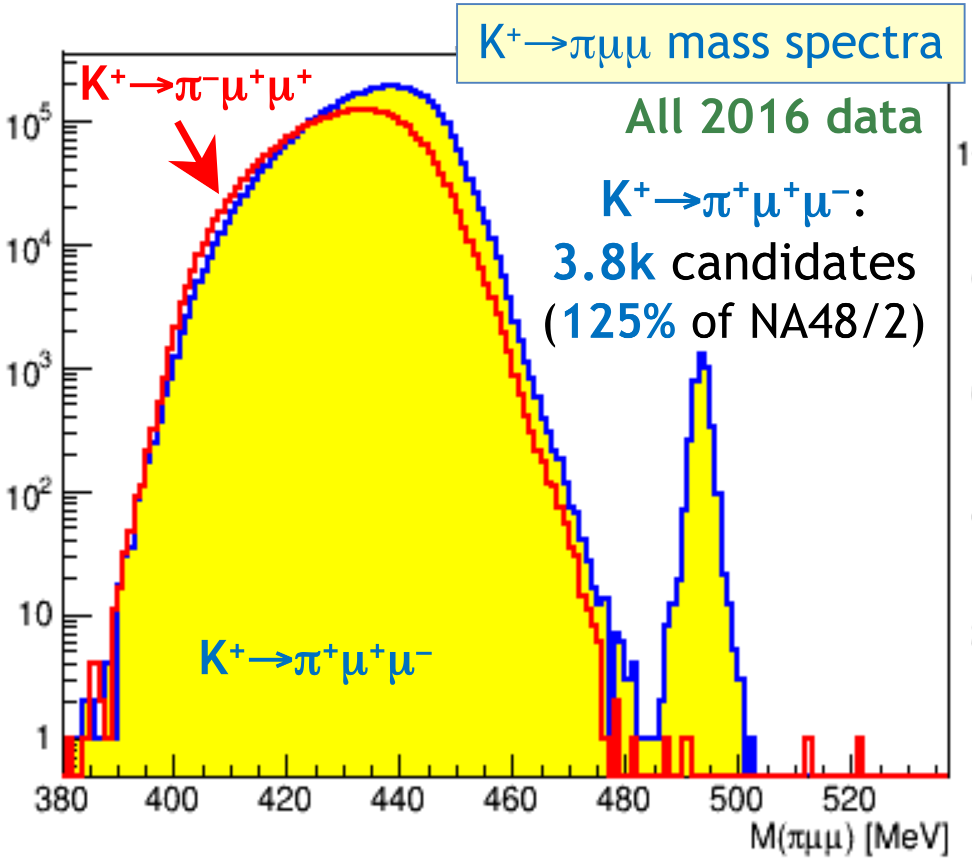
$$K^+ \to \mu^-\nu e^+e^+$$
$$K^+ \to e^-\nu\mu^+\mu^+$$

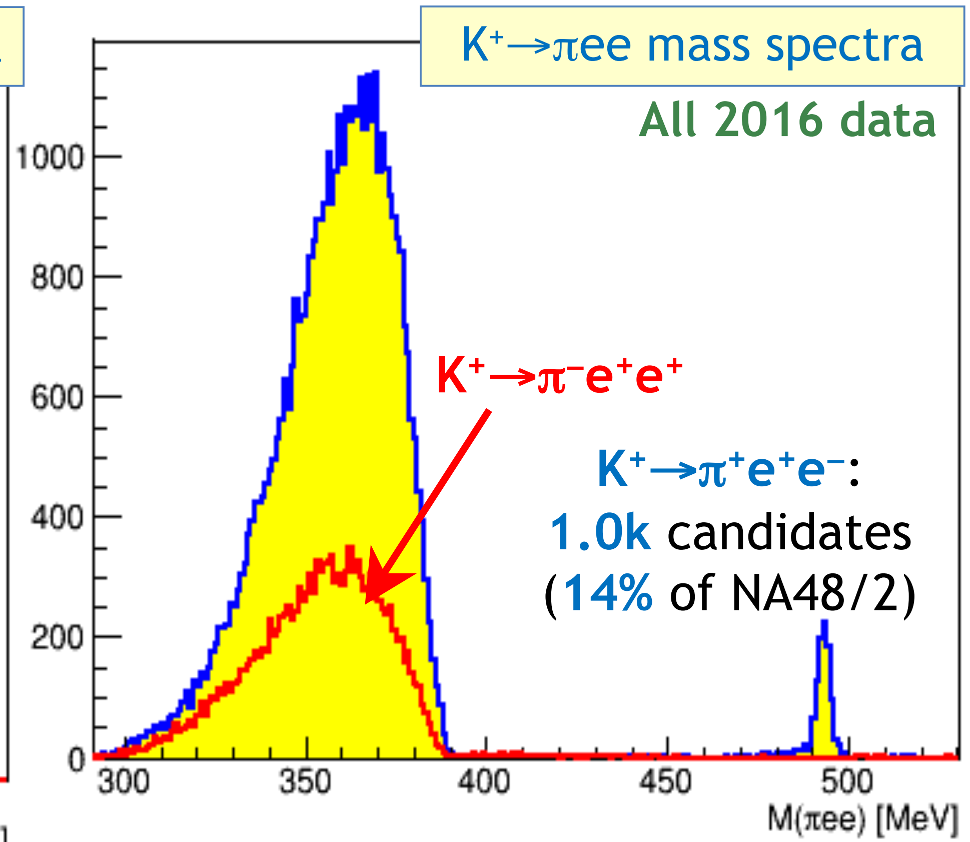
$$K^+ \to \pi^+\pi^0, \quad \pi^0 \to \mu^+e^-$$
$$K^+ \to \pi^+\pi^0, \quad \pi^0 \to \mu^-e^+$$

Data 2016: 3-track sample

<u>Lepton flavour and number conservation tests:</u>

❖Dedicated trigger streams for **3-track decays with leptons**.
❖Improved resolution, veto and PID: lower backgrounds wrt NA48/2.
❖Expect to improve world limits on LFV/LNV K^+ and π^0 decays.



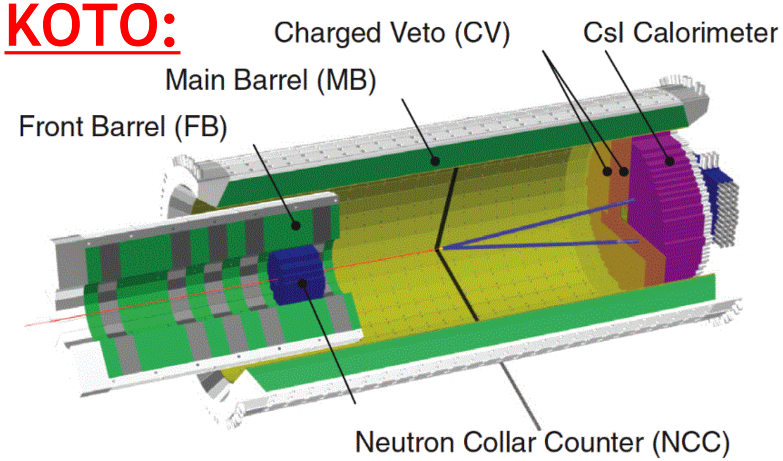


The far future and Summary

Beyond 2024

- Need to measure both $BR(K^+\to\pi^+\nu\nu)$ vs $BR(K_L\to\pi^0\nu\nu)$: affected differently by NP.
- In the next few years, we expect:
  - ✓ NA62 @ CERN to measure $BR(K^+\to\pi^+\nu\nu)$ to 10%;
  - ✓ KOTO @ J-PARC to observe a few $K_L\to\pi^0\nu\nu$ events.
- A new, possibly multi-purpose, K_L experiment at CERN focussed on $K_L\to\pi^0\nu\nu$, with $SES\sim0.5\times10^{-12}$ is under consideration for Run 4 (2026–2029).

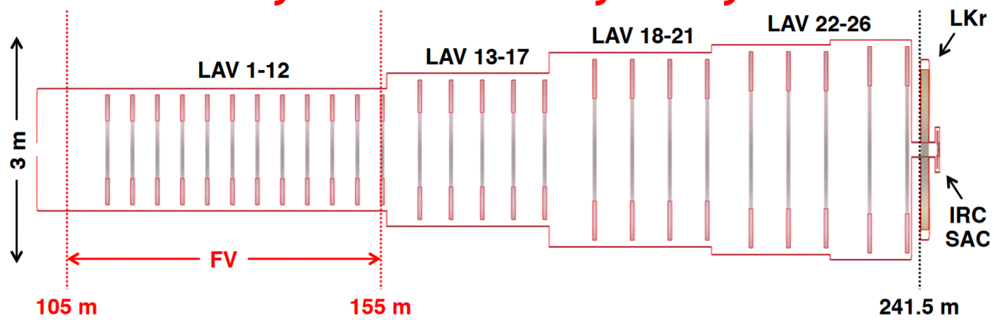
KOTO:



- 30 GeV protons (300 kW); $\langle p_{KL}\rangle=2$ GeV/c;
- Proposal: $SES=8\times10^{-12}$ (~4 SM evts) with S/B=1.4 in three years.
- Short (100h) run in 2013: $SES=1.3\times10^{-8}$;
- Observed 1 event, expected 0.36; *[CKM2014]*
- Collected ×20 more data in 2015;
- Intention (no proposal): upgrade to 100 SM evts.

KLEVER @ CERN:

feasibility and sensitivity study



- 400 GeV protons; $\langle p_{KL}\rangle\sim100$ GeV/c: complementary approach to KOTO.
- 60 SM events in 5 years with S/B≈1.
- Protons required: 5×10^{19} (NA62×10): target area & transfer line upgrade.
- Re-use NA62 infrastructure and parts of detector (LKr calorimeter; muon system).

Summary

UK participation in NA62 from 2011:

- ✓ Capital funding and manpower for detector construction and operation from ERC Advanced and Royal Society Grants.
  M&O costs from STFC.
- ✓ **Now in exploitation mode**: supported by STFC Particle Grant.
- ✓ **Extremely good value for STFC investment**
- ✓ Strong UK leadership overall, and **in physics analysis.**

NA62 run 2015–2018:

- ✓ Detector performance is close to design parameters
- ✓ Large dataset at **40%** of nominal intensity collected in 2016
- ✓ Expect **O(1) SM $K_{\pi\nu\nu}$** events sensitivity in **2016** (~50% of total dataset).
- ✓ Currently taking data at **50%** of nominal intensity
- ✓ **Focused on the $K_{\pi\nu\nu}$ measurement** (**SES~10^{-12}**).

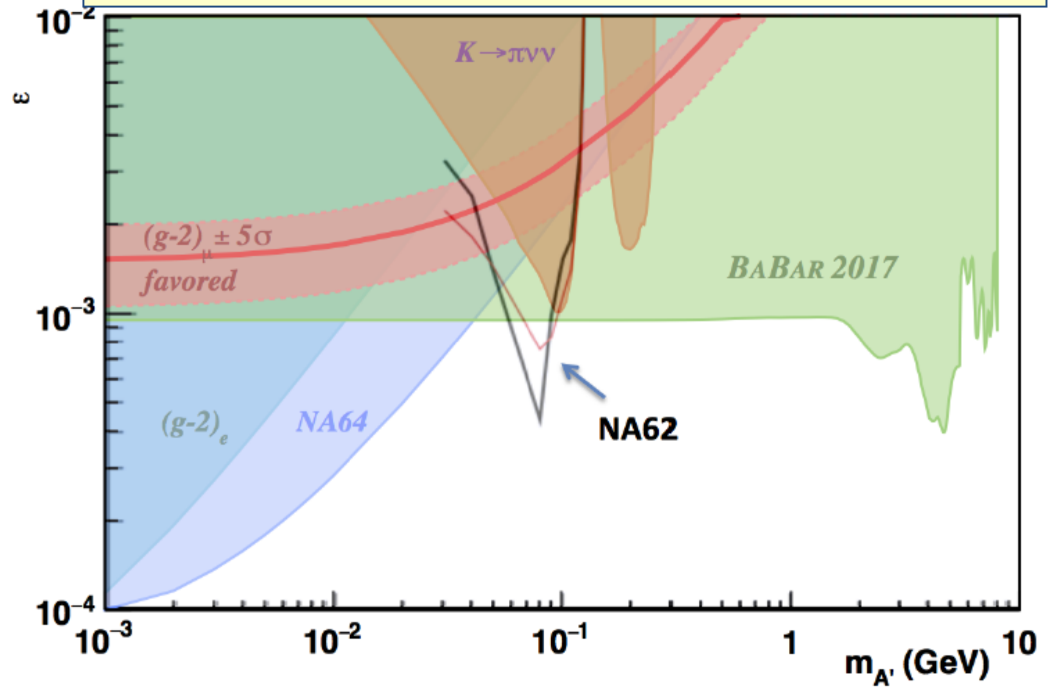
NA62 run 2021–2024:

- ✓ **Continue physics exploitation**: make the most of investments.
- ✓ extensive rare decay and beam dump programme with existing detector.

Backup

Data 2016: related studies

Expected DP exclusion limits



Dark photon search in $K^+\to\pi^+\pi^0$, π^0-

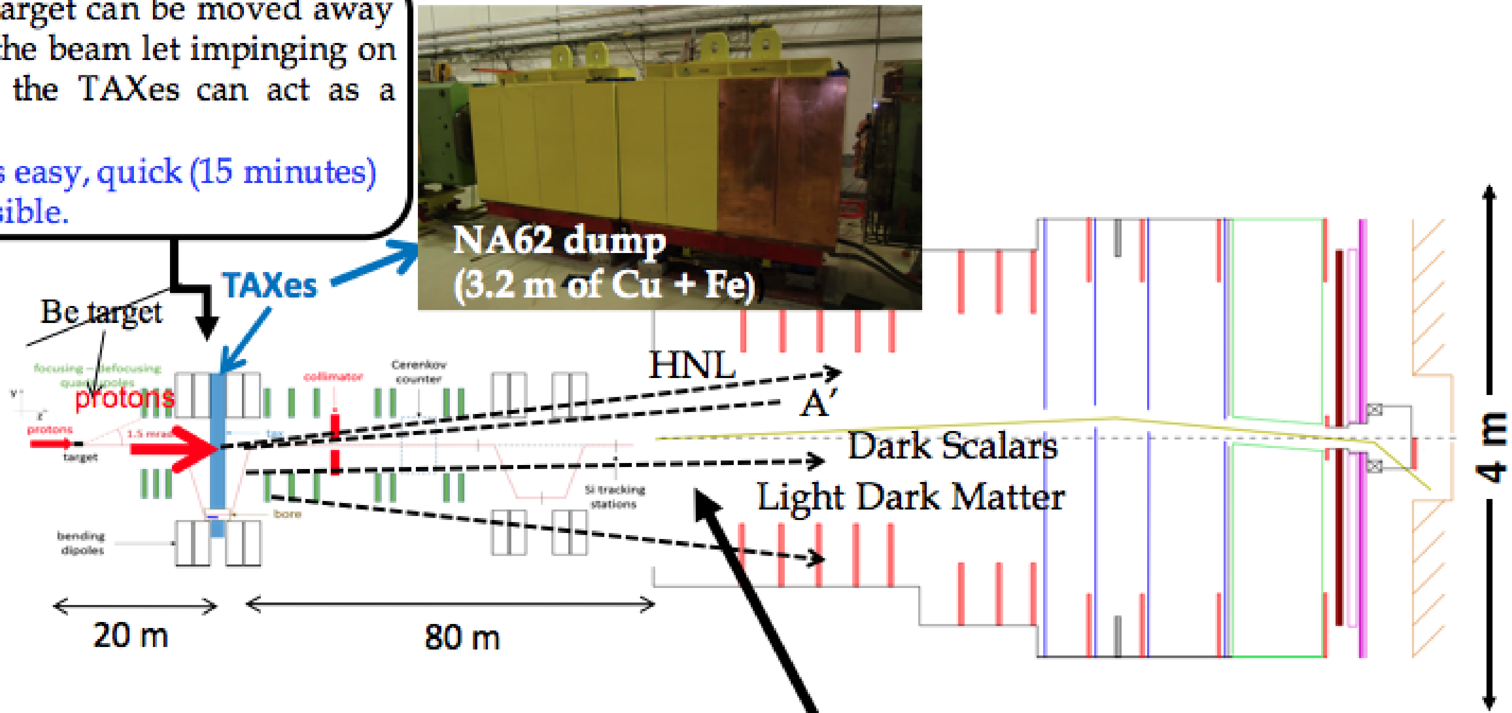
look for invisible A' decays;
peak search in $(P_K-P_\pi-P_\gamma)^2$ spectrur
data-driven background estimate;

Expect improvement over the world data with **5%** of the 2016 sample.

Improvement on **BR($\pi^0\to$invisible)** over the current limit of 2.7×10^{-7} is also possible.

NA62 in dump operation mode

In dump mode the target can be moved away from the beam and the beam let impinging on the copper. Hence: the TAXes can act as a dump (2x10.7 λ_I).
→ this operation is easy, quick (15 minutes) and fully reversible.

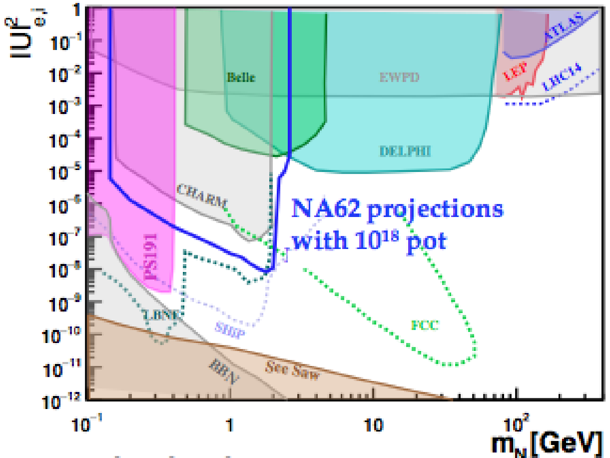


Heavy Neutral Leptons, Dark Photons, Dark scalars, and ALPS can be originated by charm, beauty and photons produced in the interaction of protons with the dump.

The expected sensitivity is evaluated assuming zero background.
Backgrounds to be considered: scattering of halo muons, accidentals.
Proof-of-principle: 2016 data.
Searches for dark photon and axion production at target: prospects are being evaluated.

NA62 sensitivity dump mode

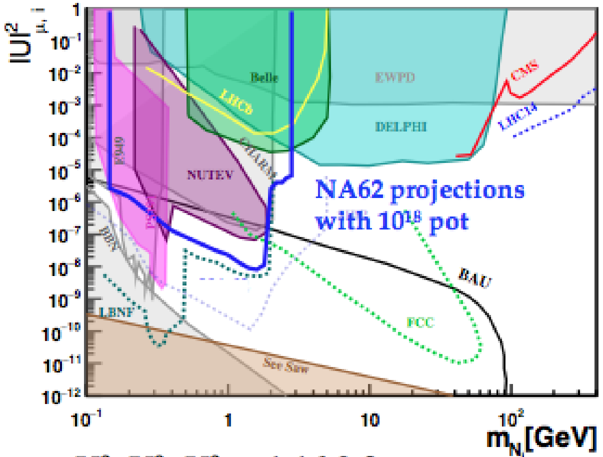
Scenario 1



$U^2_e : U^2_\mu : U^2_\tau = 52:1:1$

Normal hierarchy of active **ν** masses

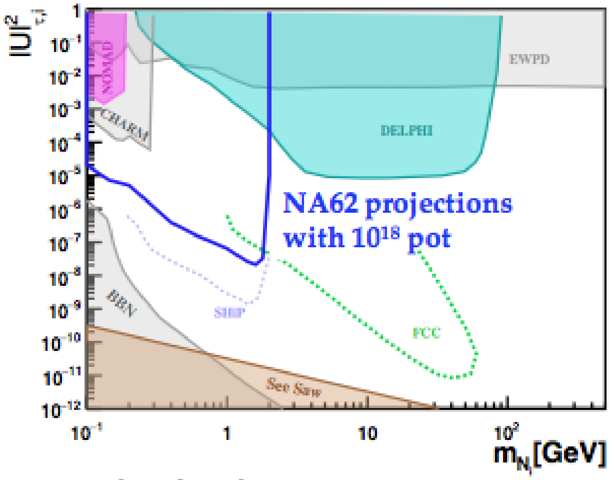
Scenario 2



$U^2_e : U^2_\mu : U^2_\tau = 1:16:3.8$

Normal hierarchy of active **ν** masses

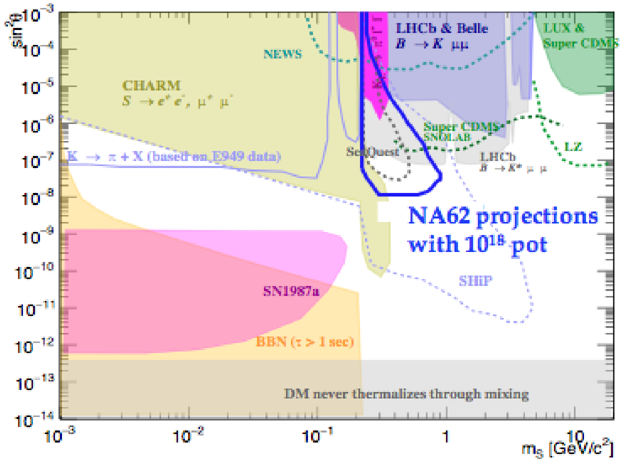
Scenario 3



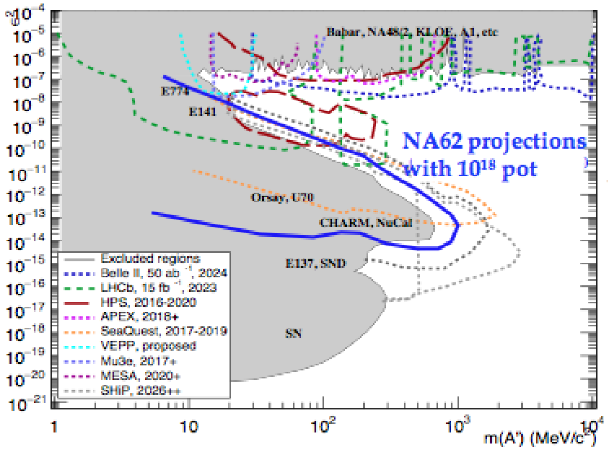
$U^2_e : U^2_\mu : U^2_\tau = 0.061:1:4.3$

Normal hierarchy of active **ν** masses

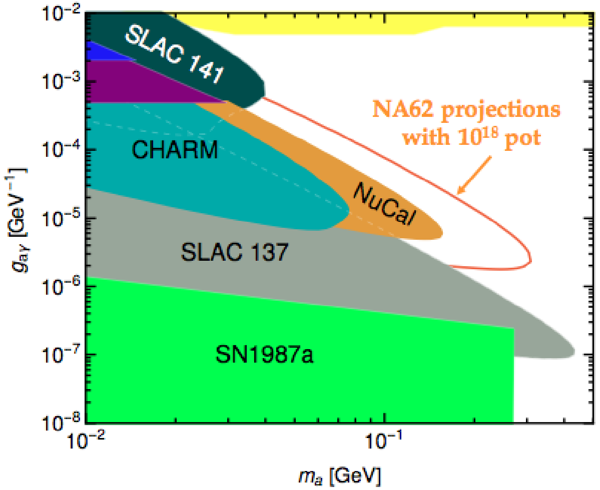
Dark Scalar:



Dark Photon:

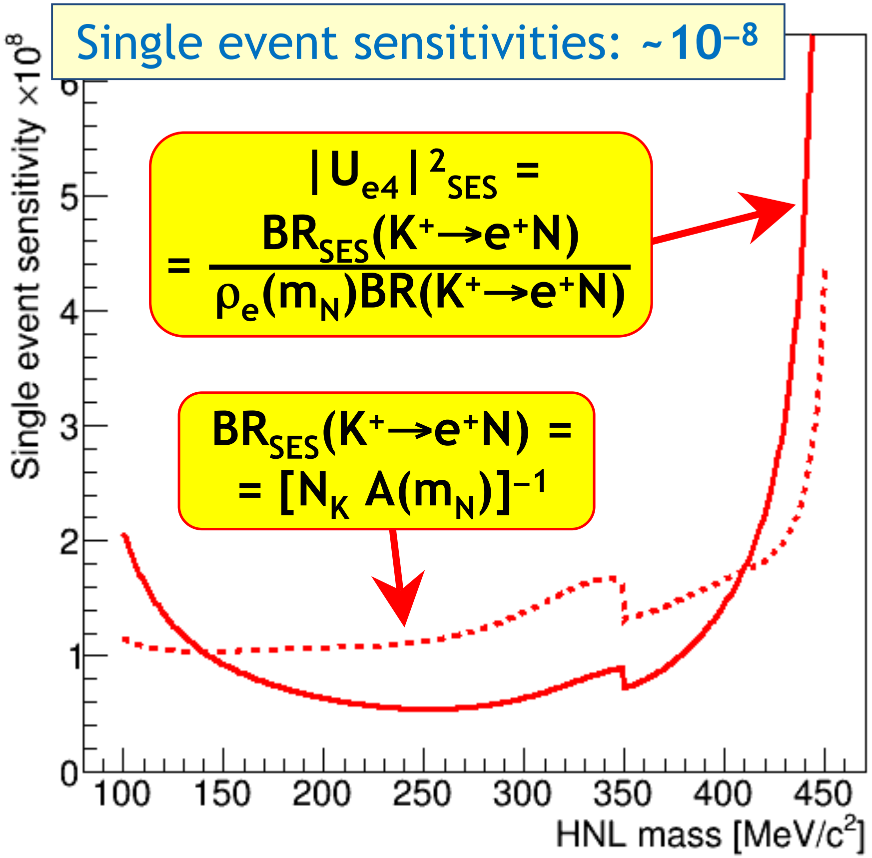


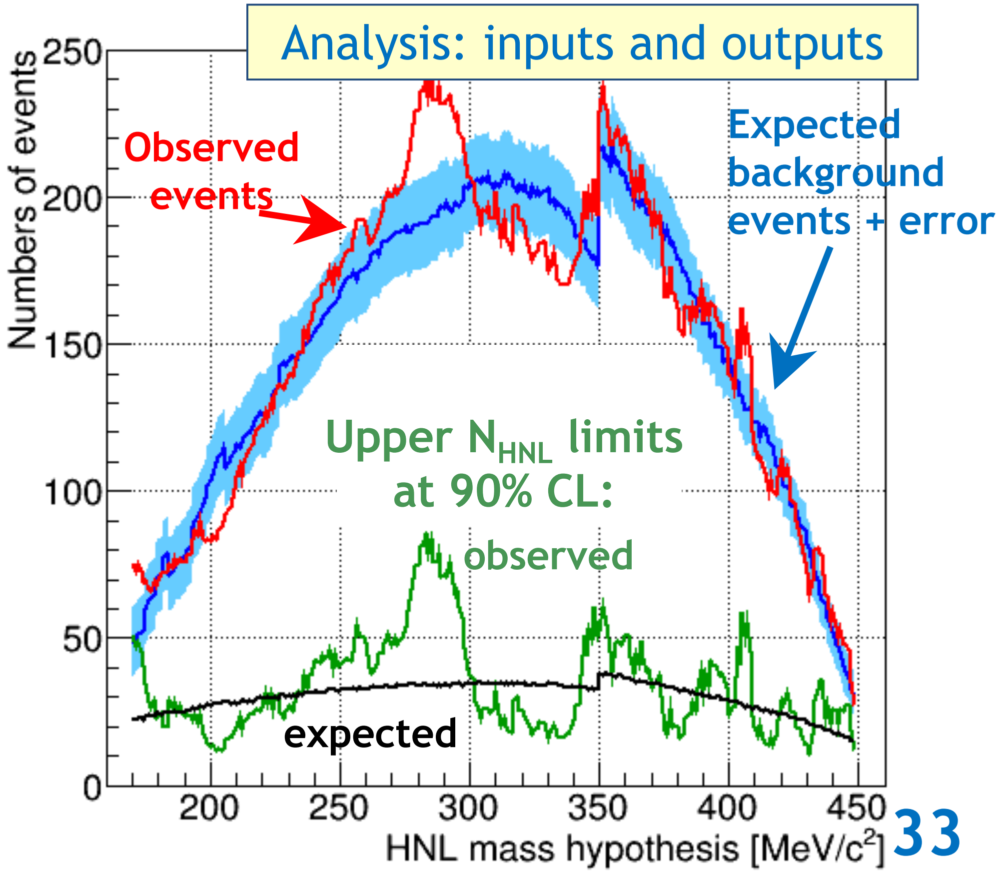
ALPs:



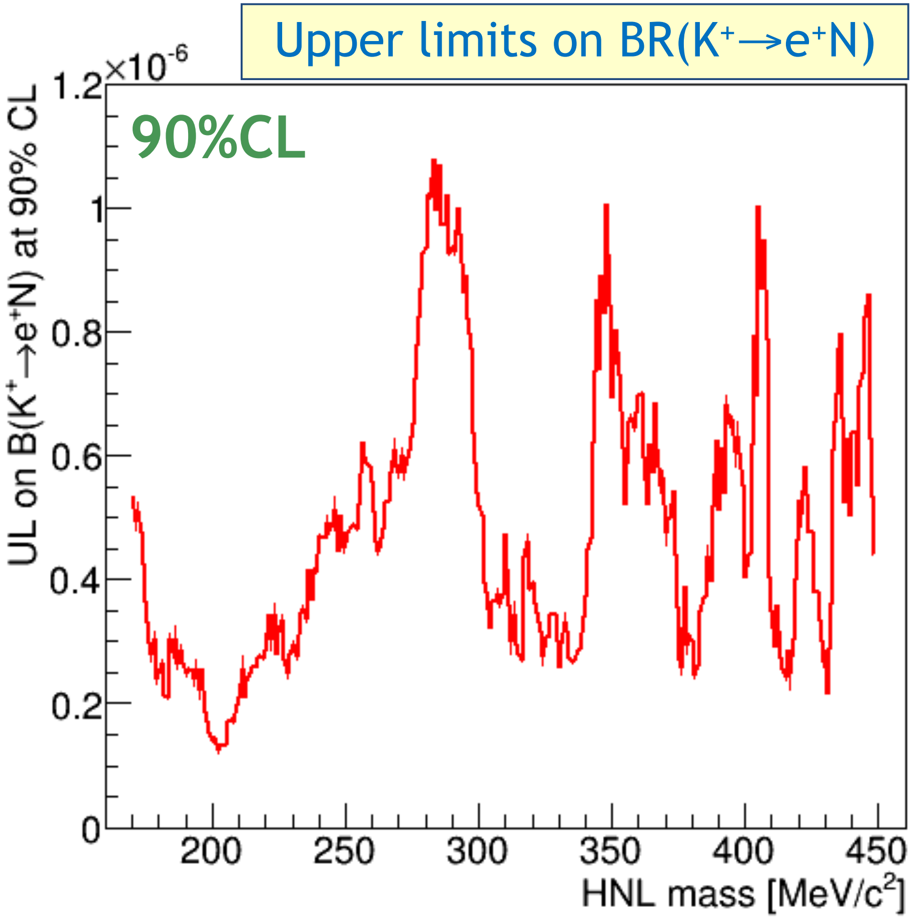
Search for HNL production signal

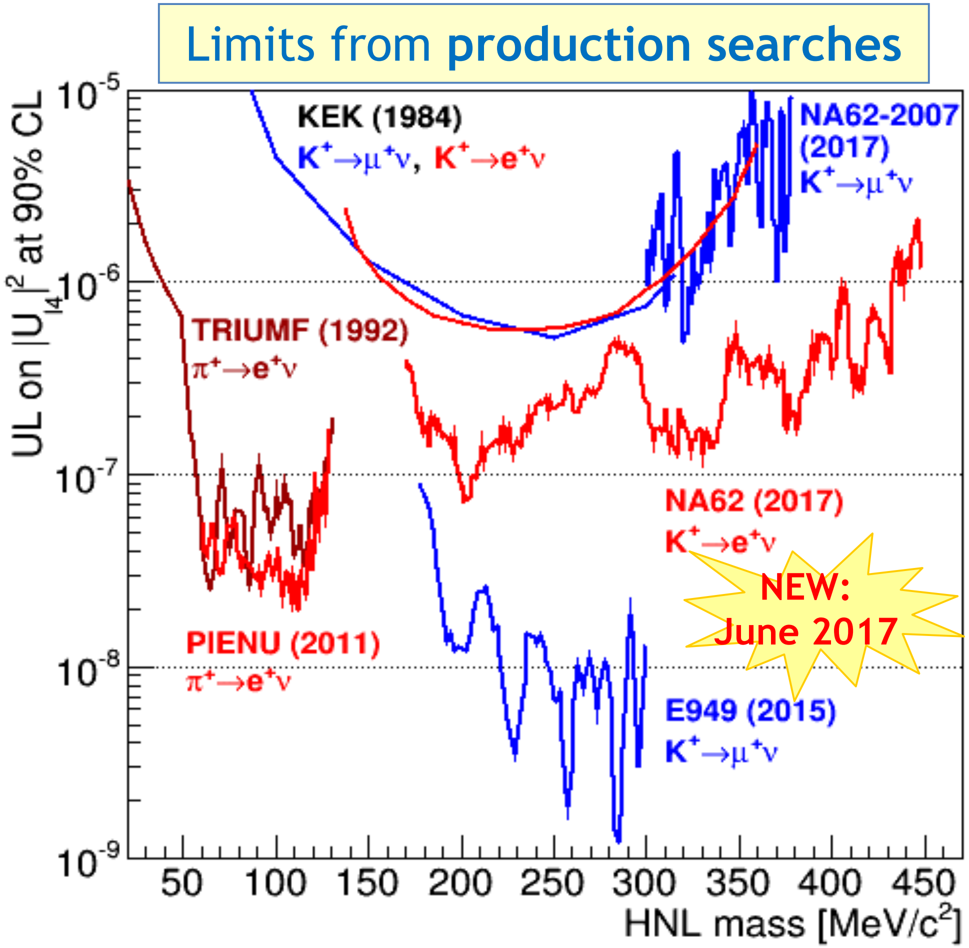
- HNL mass scan: $170\ MeV/c^2 < m_N < 448\ MeV/c^2$, mass step = $1\ MeV/c^2$.
- Signal search window for each mass hypothesis: $\pm 1.5\sigma_m$.
- Background estimate: polynomial fits to mass spectra outside signal window.
- Background statistical errors estimated with dedicated MC simulation.
- For each m_N, frequentist confidence intervals for N_{HNL} obtained from numbers of observed and expected events and their uncertainties.





HNL production search: results

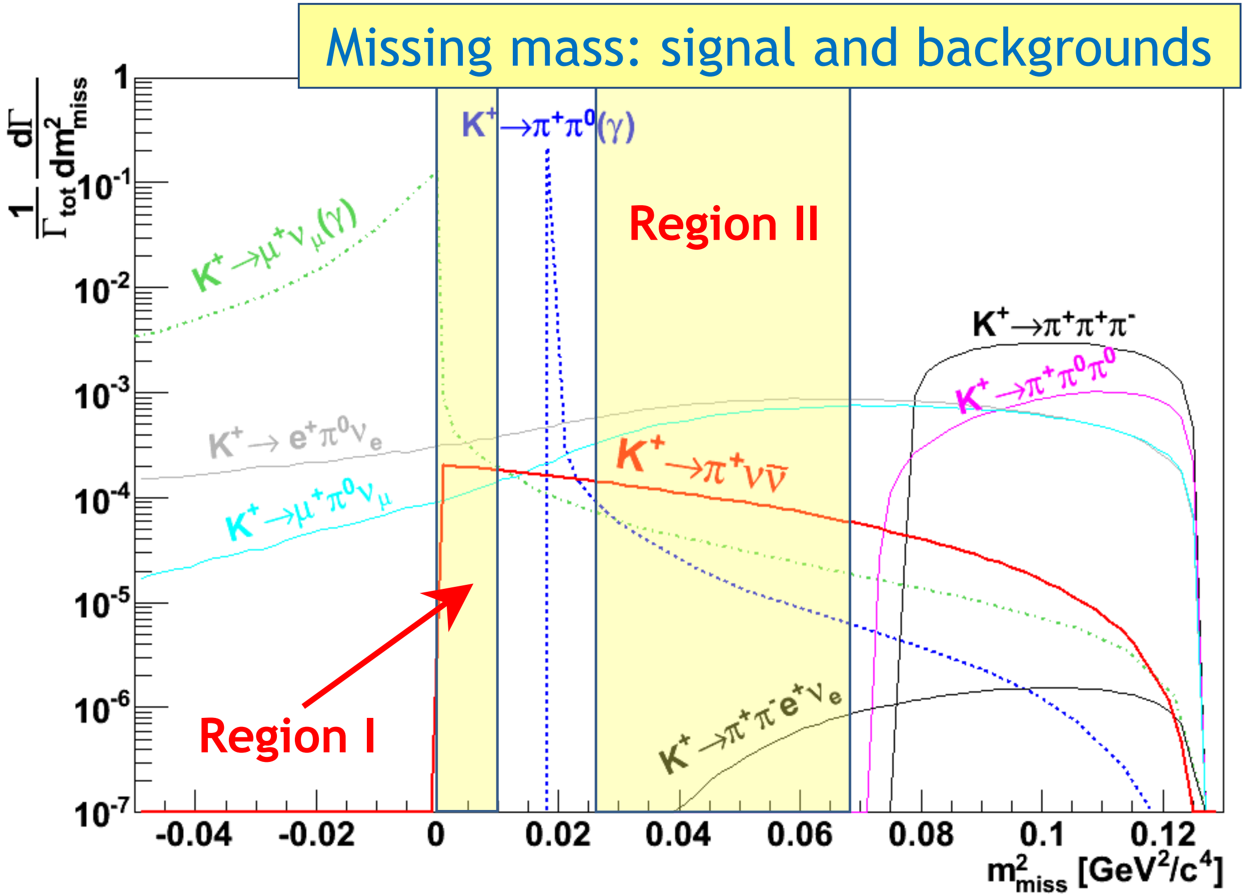




- Local signal significance never exceeds 3σ: **no HNL signal** is observed.
- Reached 10^{-6}–10^{-7} limits for $|U_{e4}|^2$ in the 170–448 MeV/c^2 mass range.
- Major improvement foreseen with high intensity NA62 2016 data.

Backup

$K_{\pi\nu\nu}$ kinematics



92% of total **BR(K⁺)**:

- ❖ Outside the signal kinematic region.
- ❖ Signal region is split into **Region I** and **Region II** by the $K^+ \to \pi^+\pi^0$ peak.

8% of total **BR(K⁺)** including multi-body:

- ❖ Span across the signal region (not rejected by kinematic criteria).
- ❖ Rejection relies on hermetic photon system, PID, sub-ns timing.

$K_{\pi\nu\nu}$ selection

- PNN trigger: RICH, CHOD signals and LAV, MUV and LKr vetos at L0; KTAG, LAV and STRAW at L1

- Single π^+ topology, $15 < P_\pi < 35$ GeV/c
- K/π matching in time (KTAG/GTK vs CHOD/RICH)
- K/π matching in space (GTK and STRAW track)

- Fiducial decay region: $110/115 < Z_v < 165$ m and Z_v vs π position at STRAW (remove early decays; CHANTI against interactions in GTK3)

- Particle ID (Cherenkov, calorimeters, muon veto)
- Photon veto

- Signal regions: 2 regions in m^2_{miss} vs $P_{\pi+}$ shown on next slide
Analysis done in 3D space: m^2_{miss}, m^2_{miss}(RICH), m^2_{miss}(no GTK)
(kinematical suppression for $\pi^+\pi^0$ and $\mu^+\nu$ measured on data with events selected using calorimeters)

$K_{\pi\nu\nu}$ 5% of 2016 sensitivity

Normalization: $K^+ \rightarrow \pi^+\pi^0$ (in $\pi^+\pi^0$ region before γ rejection on minimum bias events)

5% of 2016 statistics:

N(K decays) ~ 2.3 x 10^{10}

N(normalization) = 3.3 x 10^8

Acceptance (normalization) ~ 7%

Acceptance signal ~ 3.3%

N(Expected $\pi\nu\nu$) ~ 0.064 assuming SM branching ratio

N(K decays) ~ 2.3 × 10^{10} [5% 2016 statistics]

Process	Expected Events	Branching ratio
$K^+ \rightarrow \pi^+\pi^0$	0.024	0.2066
$K^+ \rightarrow \mu^+\nu$	0.011	0.6356
$K^+ \rightarrow \pi^+\pi^+\pi^-$	0.017	0.0558
Early Decays	< 0.005	

NA62 & SHiP design parameters

Primary beam for both NA62 and SHiP: 400 GeV/c SPS protons

	NA62 (running experiment)	SHiP (proposal)
Years of operation	3	5
POT per SPS spill	3×10^{12}	4×10^{13}
POT total	5×10^{18}	2×10^{20}
Decay volume (m^3)	260 m^3	1780 m^3
Decay volume distance to target	104–183 m	64–124 m
Decay volume pressure (bar)	10^{-9} bar	10^{-6} bar
Halo muon rate in spectrometer	6 MHz	few kHz
Straw chamber area	$0.06\text{m} < R < 1.05\text{m}$	$R_1 = 5\text{m}$, $R_2 = 10\text{m}$

… but a crucial aspect is the background rejection capability!

LFV in $K^{\pm}$ and π^0 decays

Mode	UL at 90% CL	Experiment	Reference
$K^+ \to \pi^+ \mu^+ e^-$	1.3×10^{-11}	BNL E777/E865	PRD 72 (2005) 012005
$K^+ \to \pi^+ \mu^- e^+$	5.2×10^{-10}	BNL E865*	PRL 85 (2000) 2877
$K^+ \to \pi^- \mu^+ e^+$	5.0×10^{-10}		
$K^+ \to \pi^- e^+ e^+$	6.4×10^{-10}		
$K^{\pm} \to \pi^{\mp} \mu^{\pm} \mu^{\pm}$	1.1×10^{-9}	CERN NA48/2	PLB 697 (2011) 107
$K^+ \to \mu^- \nu e^+ e^+$	2.0×10^{-8}	Geneva-Saclay	PL 62B (1976) 485
$K^+ \to e^- \nu \mu^+ \mu^+$	no data		
$\pi^0 \to \mu^+ e^-$	3.6×10^{-10}	FNAL KTeV	PRL 100 (2008) 131803
$\pi^0 \to \mu^- e^+$	3.6×10^{-10}		

* CERN NA48/2 sensitivities for these three modes are similar to those of BNL E865

Expected NA62 single event sensitivities:
~10^{-12} for $K^{\pm}$ decays, ~10^{-11} for π^0 decays.

- ❖ NA62 is capable of improving on all these decay modes.
- ❖ Sensitivity will depend on the trigger selectivity.