

The NA62 experiment

Alina Kleimenova

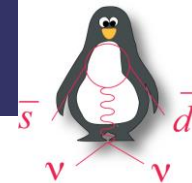
(EPFL, Lausanne)

on behalf of NA62 Collaboration

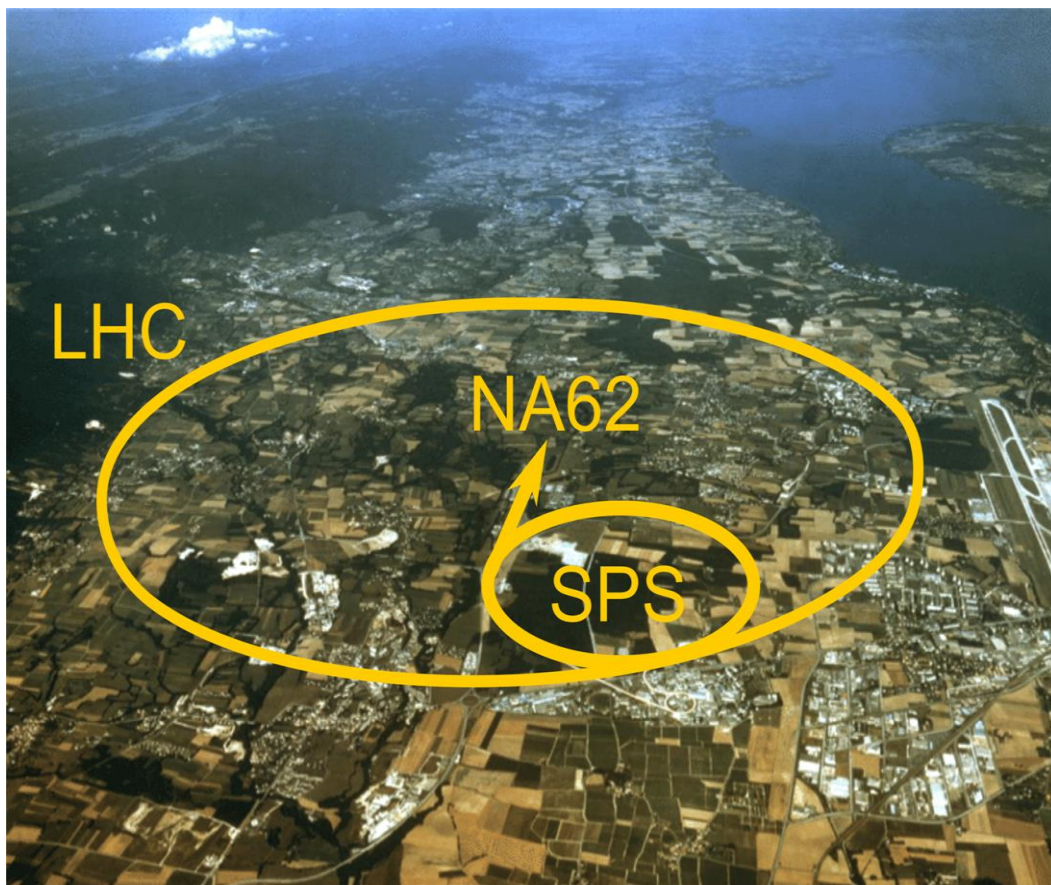
EPFL



Sursee 2023, 16th June



The NA62 experiment



NA62 is a fixed-target experiment at CERN SPS

Main goal: measure $\mathcal{B}(K^+ \rightarrow \pi^+ \nu \bar{\nu})$ with 10% precision using kaon-in-flight technique

Current theoretical prediction:

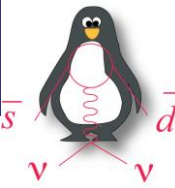
$$\mathcal{B}(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = 7.73(61) \times 10^{-11}$$

[\[arXiv:2105.02868\]](https://arxiv.org/abs/2105.02868)

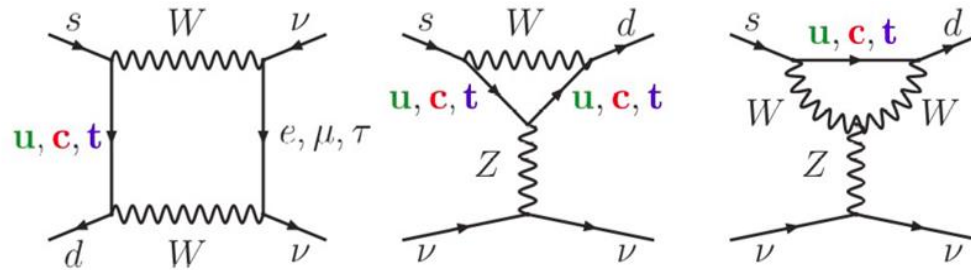
~30 institutes, ~200 participants from: Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, GMU-Fairfax, Ferrara, Firenze, Frascati, Glasgow, Lancaster, **Lausanne**, Liverpool, Louvain, Marseille, Mainz, Moscow, Munich, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Torino, TRIUMF, Vancouver UBC



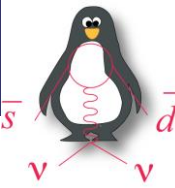
Joined this year!



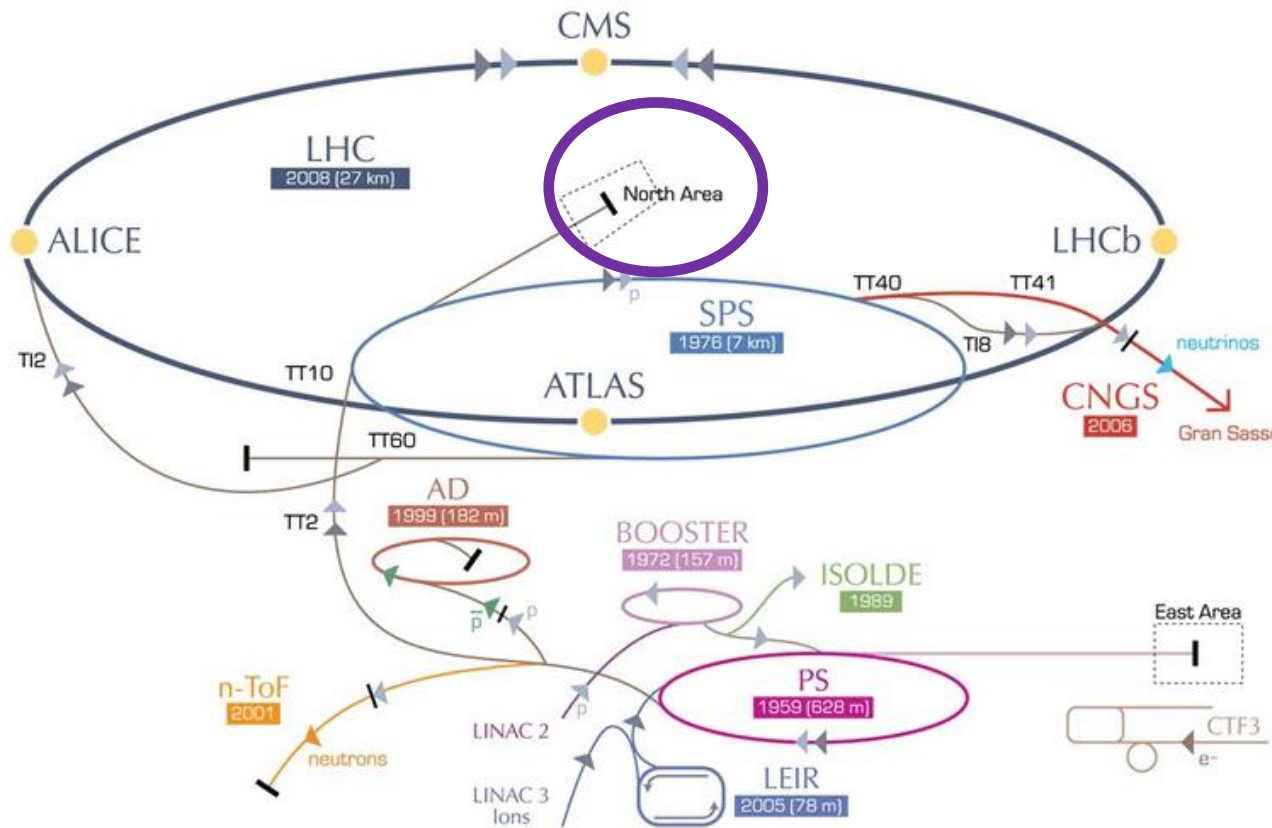
$$K^+ \rightarrow \pi^+ \nu \bar{\nu}$$



- **Extremely suppressed:** $s \rightarrow d \nu \bar{\nu}$ flavour-changing neutral current transition forbidden at tree level
- **Clean theoretical prediction** with intrinsic theory uncertainty $\sim 3\%$
- **Very high sensitivity to new physics:** unique probe in flavour physics to reach a model independent $\mathcal{O}(100 - 1000)$ TeV mass scale. BR can be enhanced by up to a factor of 2 in various NP models



The kaon factory



In the CERN SPS North Area the K12 extraction line provides an extremely intense kaon beam

400 GeV/c **primary protons** (3.3×10^{12} p/pulse)

400 mm **Be target**

75 GeV/c unseparated secondary hadrons beam (π, p, K)

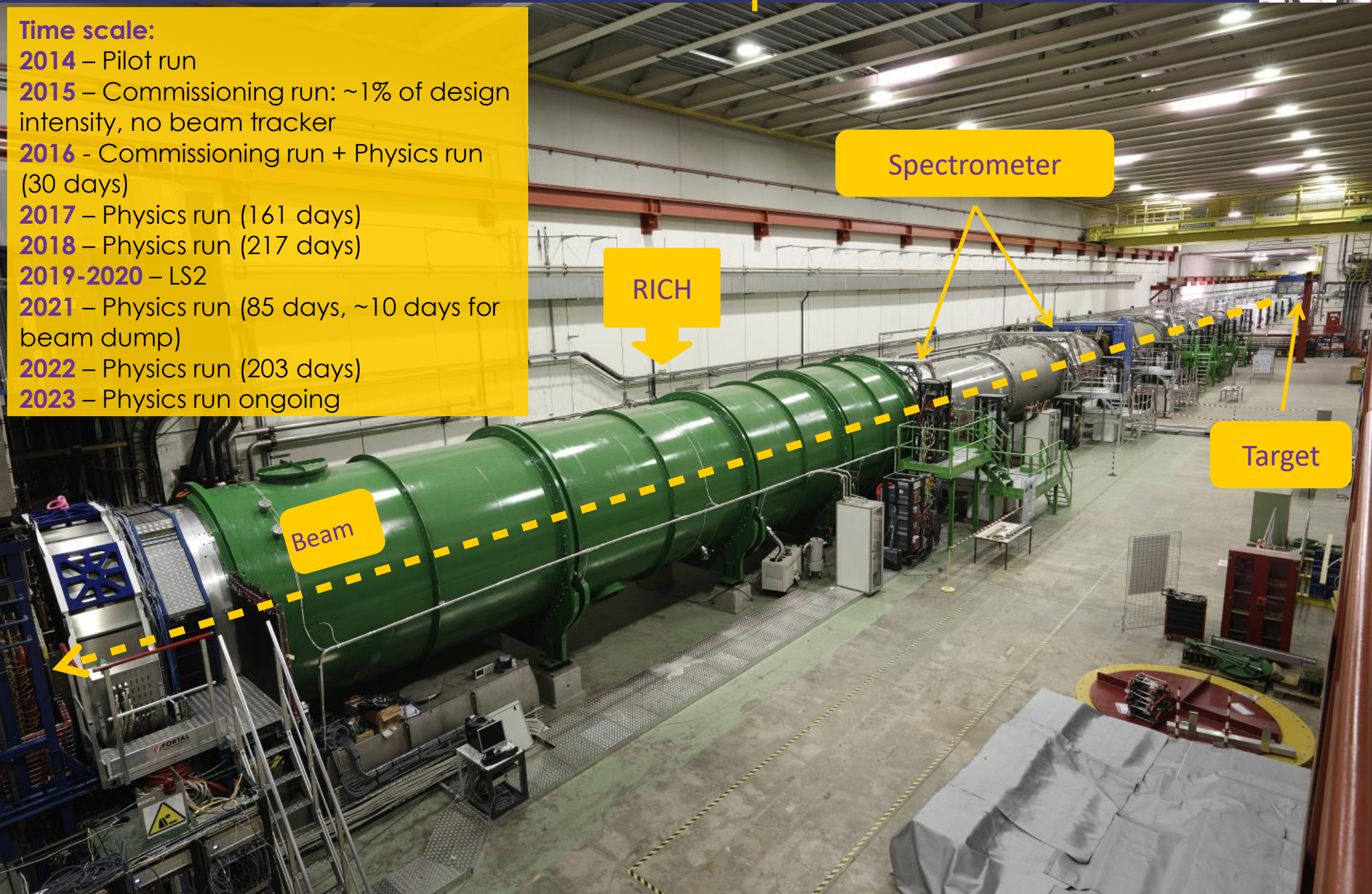
750 MHz total particle rate in secondary beam: 45 MHz of K^+ (6%)

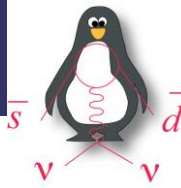
The NA62 experiment



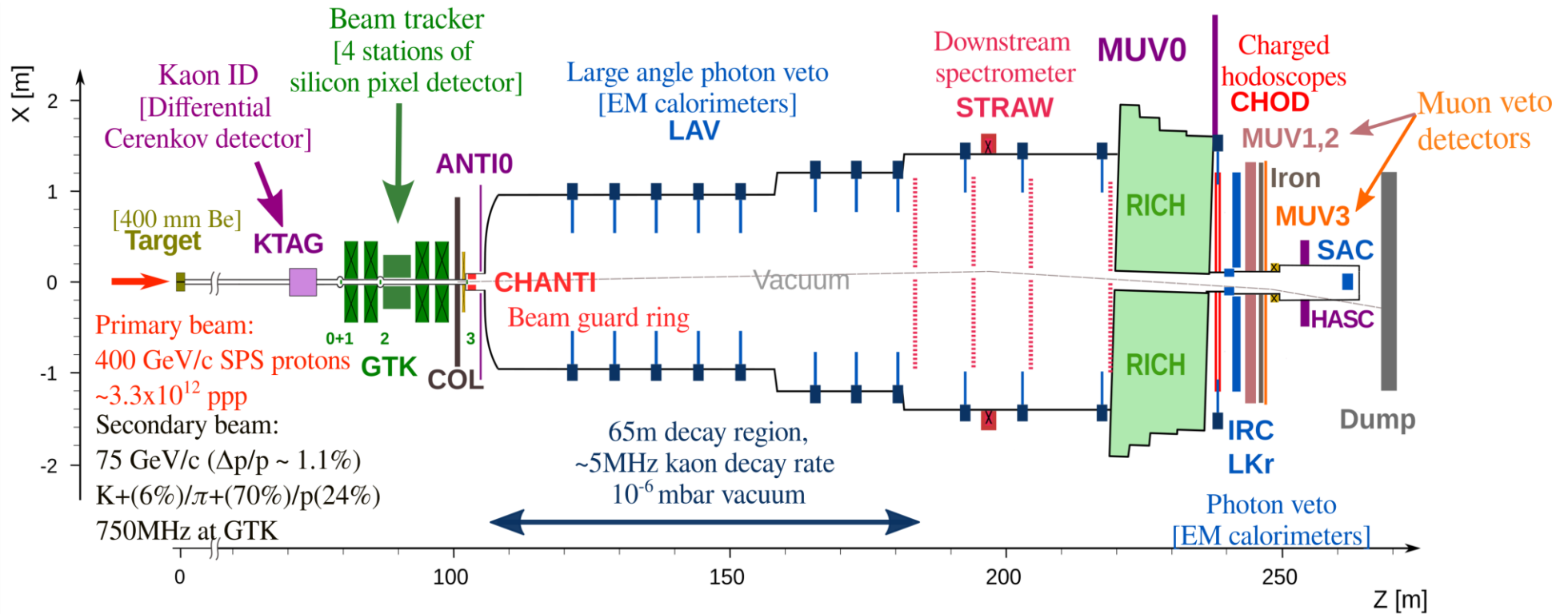
Time scale:

- 2014** – Pilot run
- 2015** – Commissioning run: ~1% of design intensity, no beam tracker
- 2016** - Commissioning run + Physics run (30 days)
- 2017** – Physics run (161 days)
- 2018** – Physics run (217 days)
- 2019-2020** – LS2
- 2021** – Physics run (85 days, ~10 days for beam dump)
- 2022** – Physics run (203 days)
- 2023** – Physics run ongoing



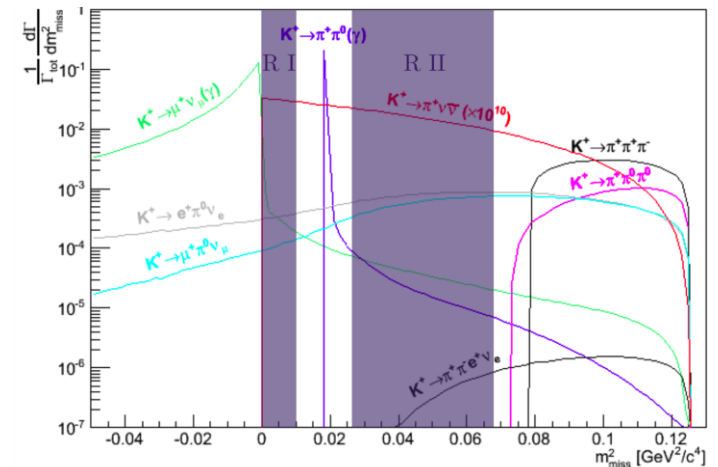


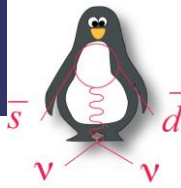
Detector overview



Performances:

- GTK-KTAG-RICH time resolution: $\mathcal{O}(100 \text{ ps})$
- $\mathcal{O}(10^4)$ background suppression from kinematics
- $\mathcal{O}(10^7)$ muon rejection for $15 < p(\pi^+) < 45 \text{ GeV}$
- $\mathcal{O}(10^8)$ π^0 rejection for $E(\pi^0) > 35 \text{ GeV}$





The NA62 Physics Program

Flavour

Hidden sector

Search for New Physics at the TeV scale with sizeable coupling to SM particles via indirect effects in loops:

Experiment main goal:
 $B(K^+ \rightarrow \pi^+ \nu \bar{\nu})$

Search for lepton flavour and number violation, rare and forbidden decays (HNL, LFV, LNV). Kaon precision physics.

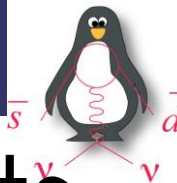
$K^+ \rightarrow \pi^\pm \mu^\mp e^+$
 $K^+ \rightarrow \pi^- l^+ l^+$
 $K^+ \rightarrow \pi^+ l^+ l^-$
 $K^+ \rightarrow \pi^- \pi^0 e^+ e^+$
 $K^+ \rightarrow \mu^- \nu e^+ e^+$
 $\pi^0 \rightarrow invisible$

Test of low-energy hadronic theories (e.g. χPT)

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

Search for New Physics below the EW scale (MeV-GeV) feebly-coupled to SM particles via direct detection of long-lived particles

Dark Photon (A'), Axion-Like Particle (a), Dark Scalar (S), Heavy Neutral Lepton (N):
 $K^+ \rightarrow \pi^+ X$
 $K^+ \rightarrow l N$
 $K^+ \rightarrow \pi^+ a a, a \rightarrow e e$
 $A' \rightarrow l l$
 $N \rightarrow \pi l$



$$\mathcal{B}(K^+ \rightarrow \pi^+ \nu \bar{\nu}) = (10.6_{3.4}^{+4.0} \pm 0.9_{syst}) \times 10^{-11}$$

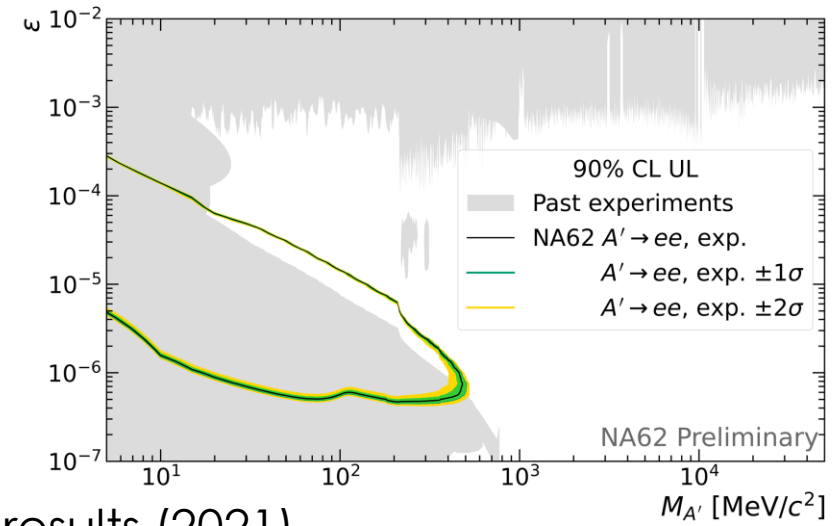
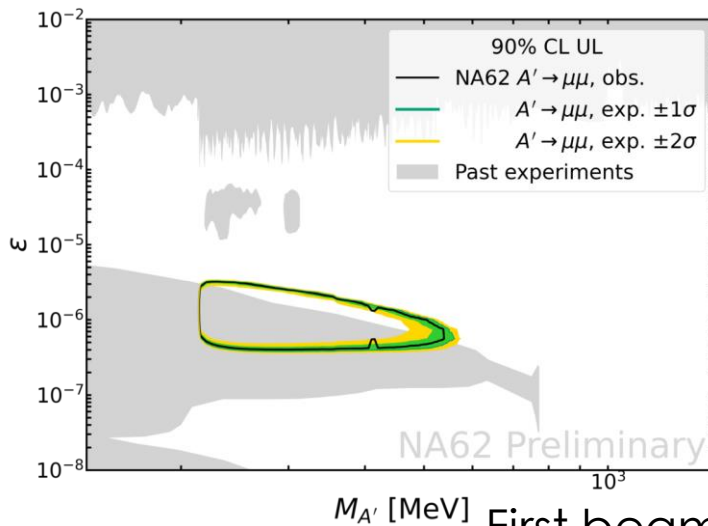
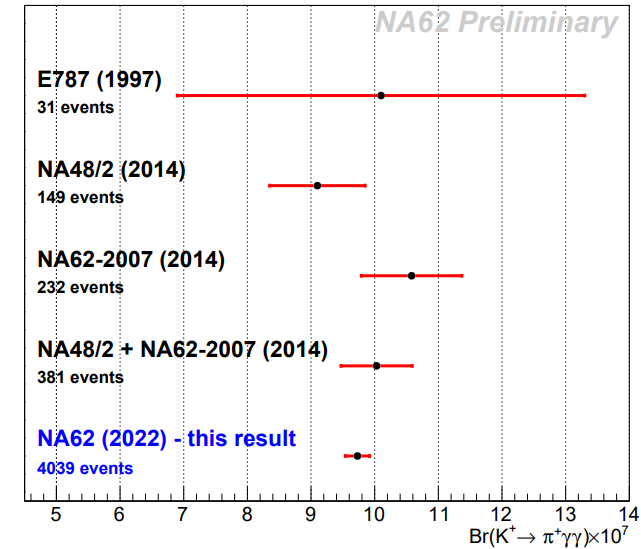
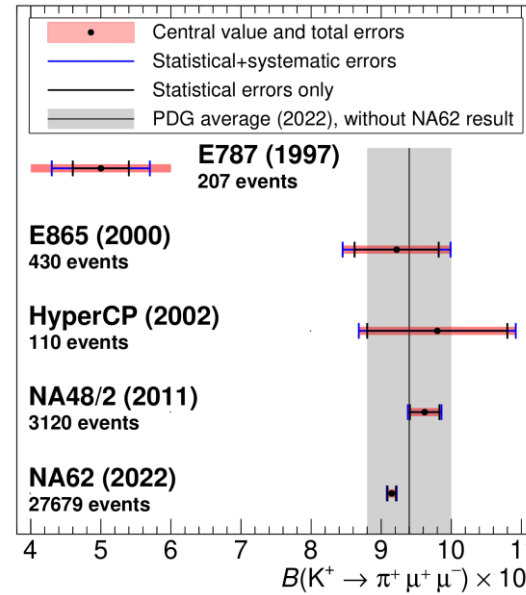
[JHEP06(2021)093]

A few results

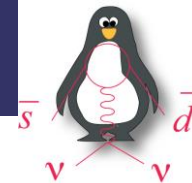
Channel	Background (2018)
$\pi^+ \pi^0$	0.75 ± 0.05
$\mu^+ \nu$	0.64 ± 0.08
$\pi^+ \pi^- e^+ \nu$	0.51 ± 0.10
$\pi^+ \pi^+ \pi^-$	0.22 ± 0.10
$\pi^+ \gamma \gamma$	< 0.01
$\pi^0 l^+ \nu$	< 0.001
Upstream	$3.30_{-0.75}^{+1.00}$
Total (2018)	$5.42_{-0.75}^{+1.00}$

$N_{obs} = 20$ 3.4σ evidence for $K^+ \rightarrow \pi^+ \nu \bar{\nu}$

[JHEP11 (2022) 011]

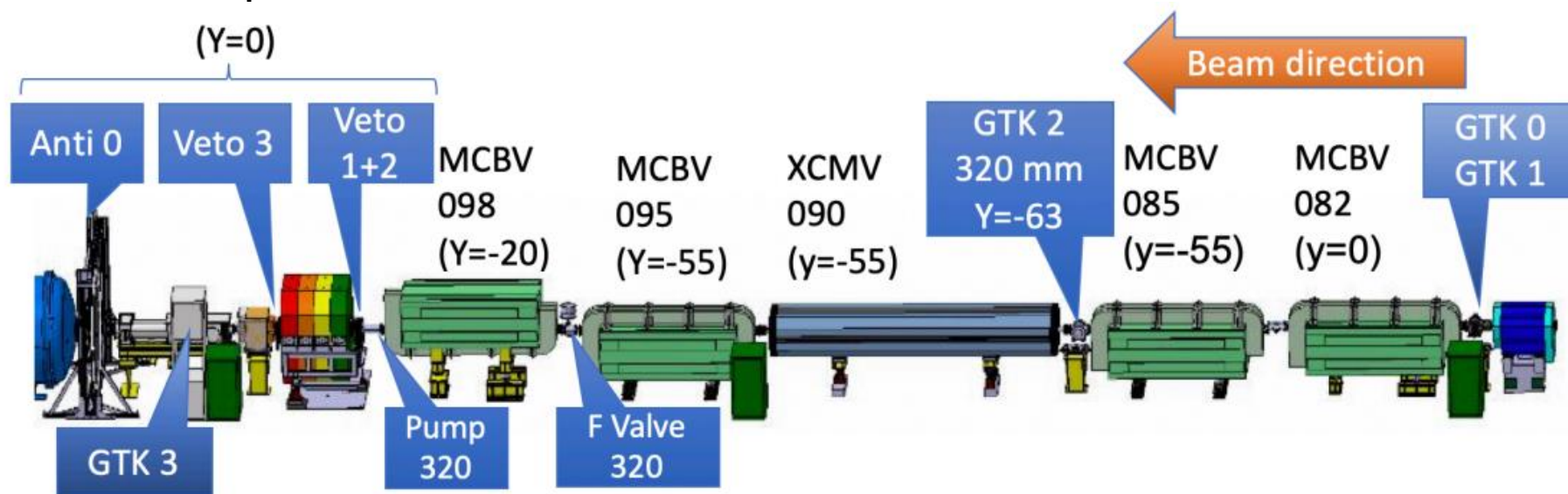


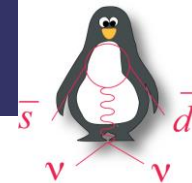
First beam dump results (2021)



Run 2 upgrade

- For background reduction in $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ analysis: re-built 2nd achromat optimized for background rejection, 4th GTK station (GTK0), VetoCounter before/after last collimator, 2nd HASC module
- Anti0 hodoscope for muon background reduction in dump mode





Run 2 upgrade



GTK0



HASC1+new HASC2



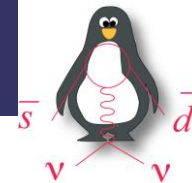
VetoCounter1,2



VetoCounter3



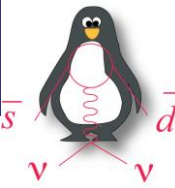
Anti0



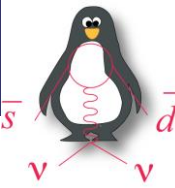
Summary

- Experiment restarted operation in 2021. Data taking from 2021 to LS3.
- Broad physics programme to be explored in Run2, and many results from Run1.
- Plans for longer term high-intensity kaon beam experiments [[HIKE LoI](#)].

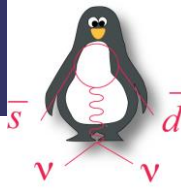




Thank you!



Backup slides



NA62 in beam dump mode

