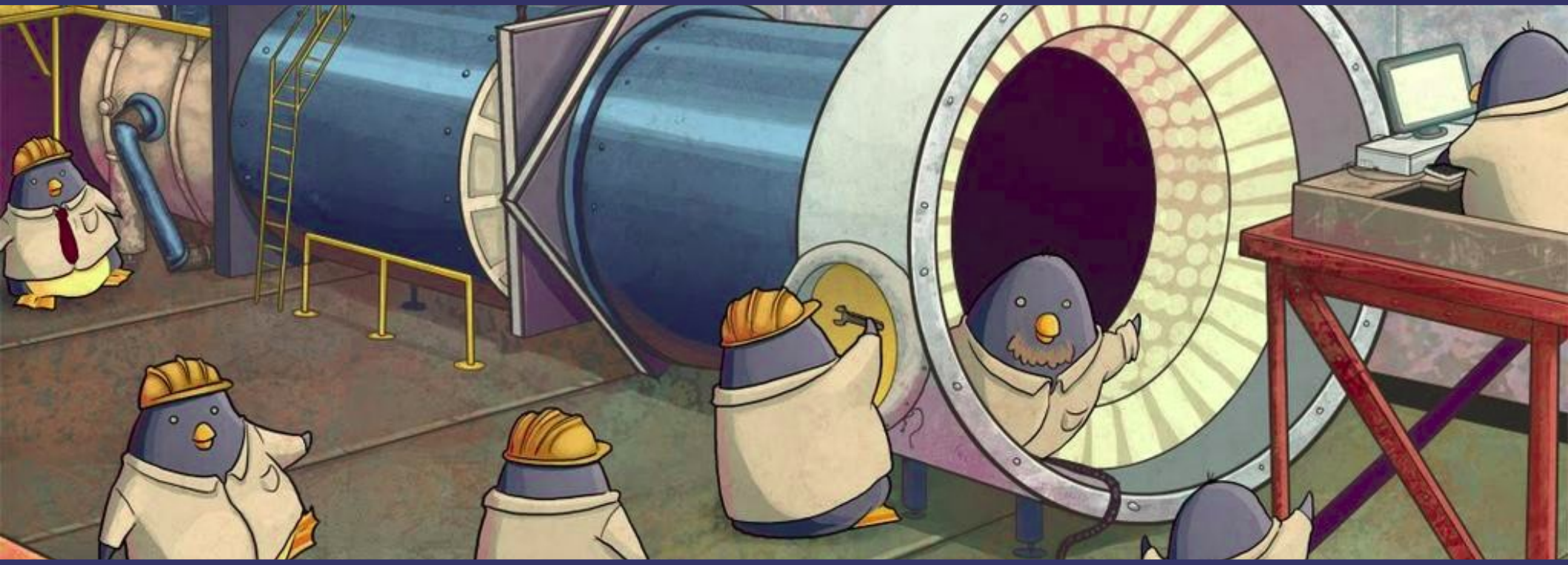
24th High-energy physics international conference in Quantum Chromodynamics



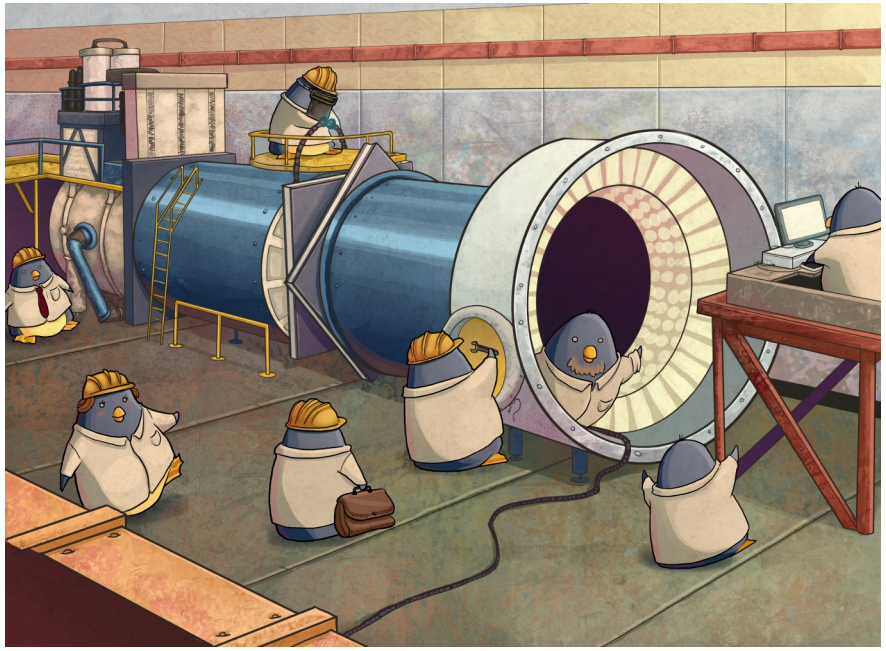
Search for π^0 decays to invisible particles at NA62

Alina Kleimenova
(Université catholique de Louvain)
on behalf of NA62 Collaboration

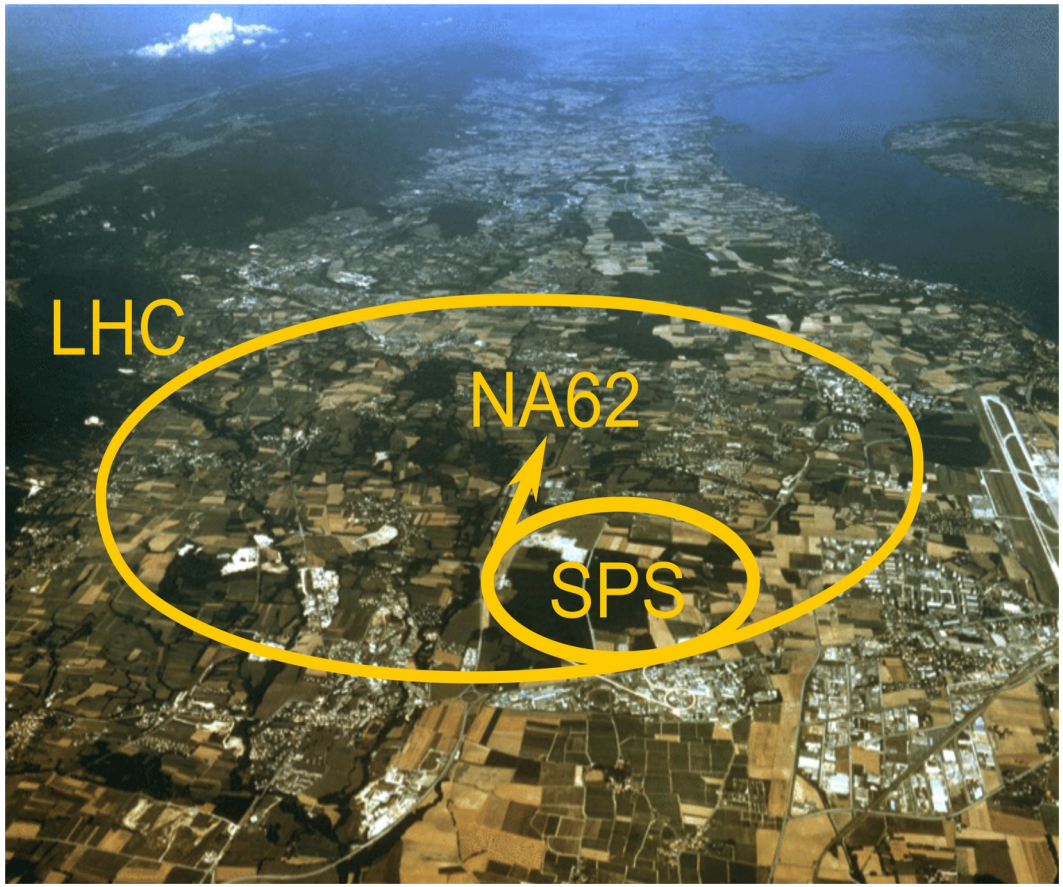
QCD 2021, 5th July

Outline

- The NA62 experiment at the CERN SPS
- Exotics searches in NA62:
  - Searches for π^0 decays to invisible
- Summary



The NA62 experiment



~30 institutes, ~200 participants from:

Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, GMU-Fairfax, Ferrara, Firenze, Frascati, Glasgow, Lancaster, Liverpool, Louvain, Mainz, Moscow, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Sofia, Torino, TRIUMF, Vancouver UBC

NA62 – fixed target kaon experiment at CERN SPS

Main goal: measurement of the BR($K^+ \to \pi^+ \nu\bar{\nu}$) with 10% precision using novel kaon-in-flight technique.

Theoretical prediction:

$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (8.4 \pm 1.0) \times 10^{-11}$

[Buras et al., JHEP11(2015)033]

Experimental result before NA62:

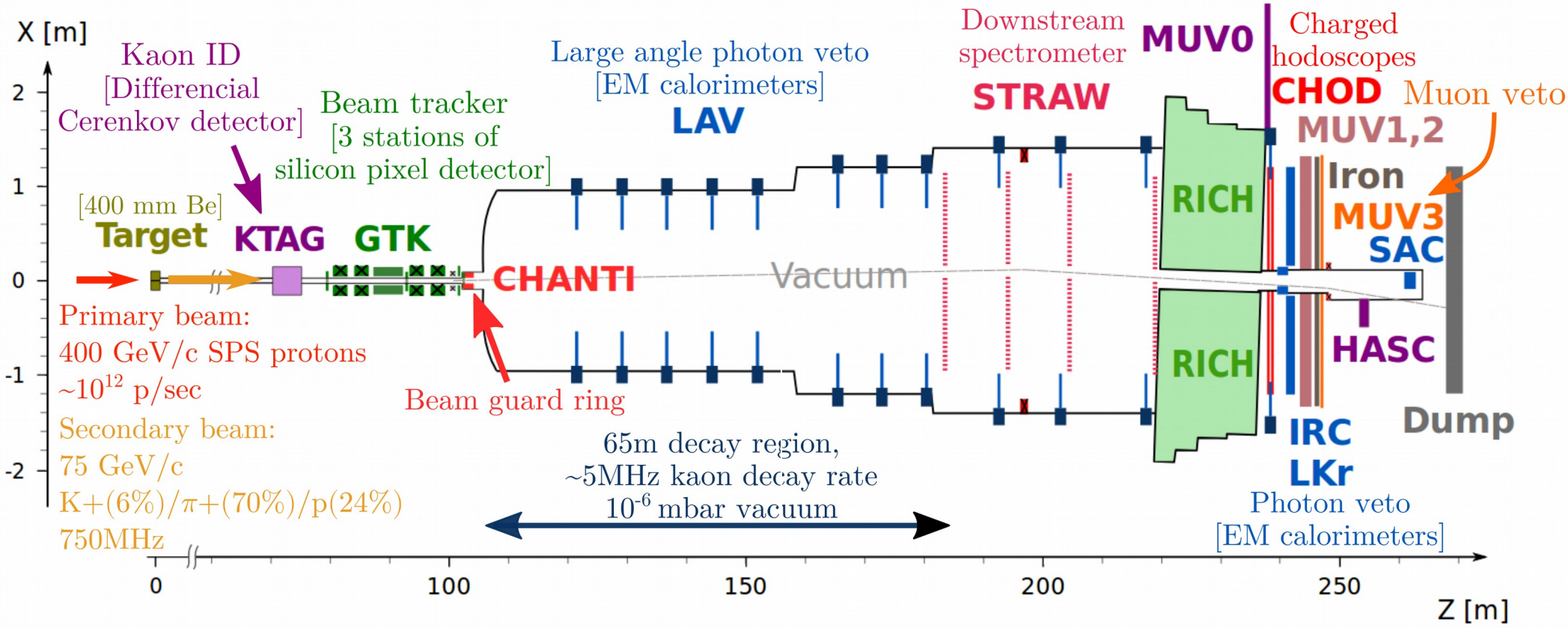
$BR(K^+ \to \pi^+ \nu\bar{\nu}) = (17.3^{+11.5}_{-10.5}) \times 10^{-11}$

[Phys. Rev D 79, 092004 (2009)]

Broader physics program:

- Rare/forbidden kaon decays
- Searches for **exotic particles** in kaon decays and in beam dump mode

Detector overview

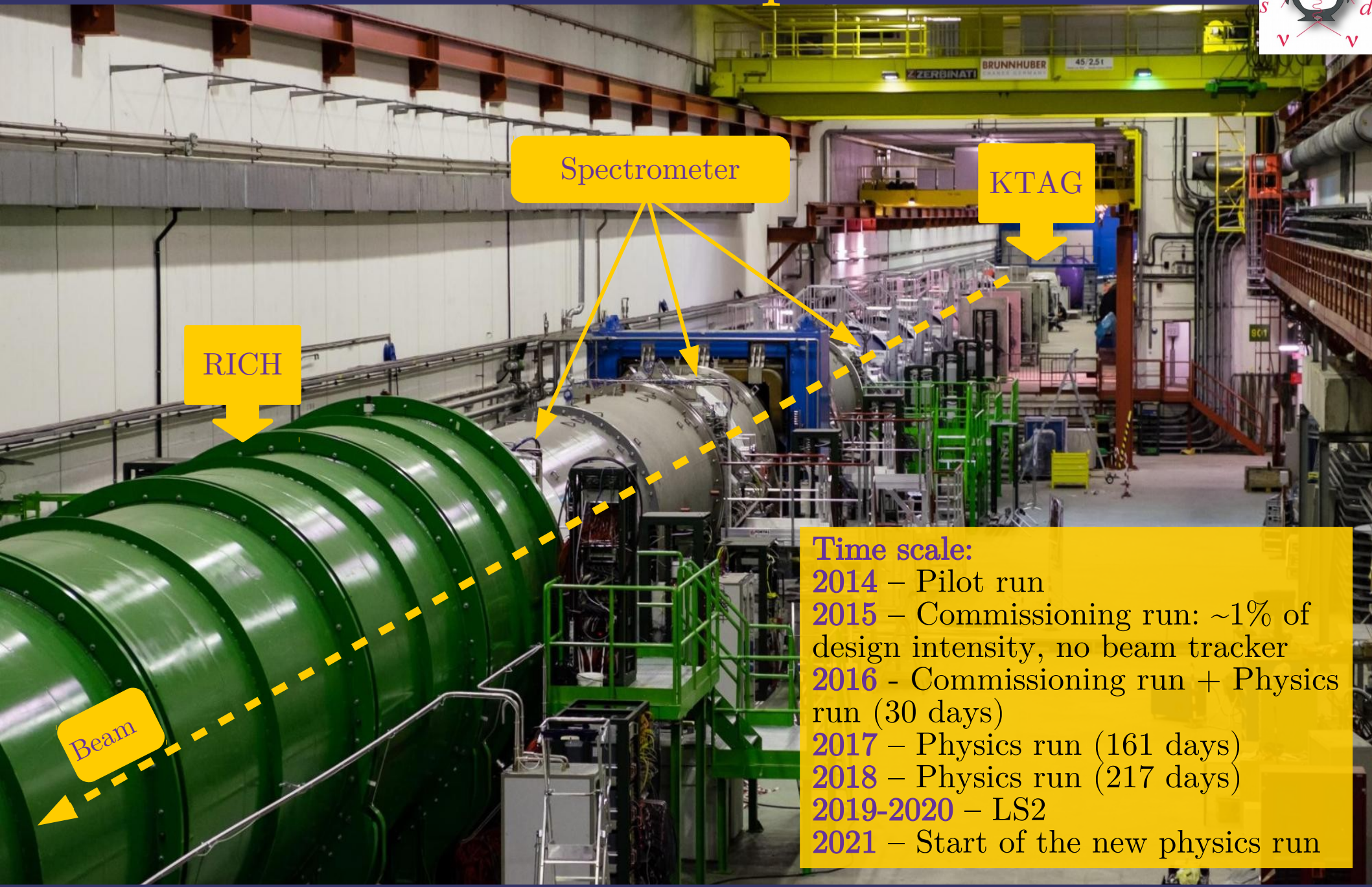


Performances:

- GTK-KTAG-RICH time resolution: $O(100$ ps$)$
- $O(10^4)$ background suppression from kinematics
- $O(10^7)$ muon rejection for 15 $<p(\pi^+)<$ 35 GeV
- $O(10^8)$ π^0 rejection of for $E(\pi^0)>$ 40 GeV

[NA62 Detector Paper, JINST 12 (2017), P05025]

The NA62 experiment

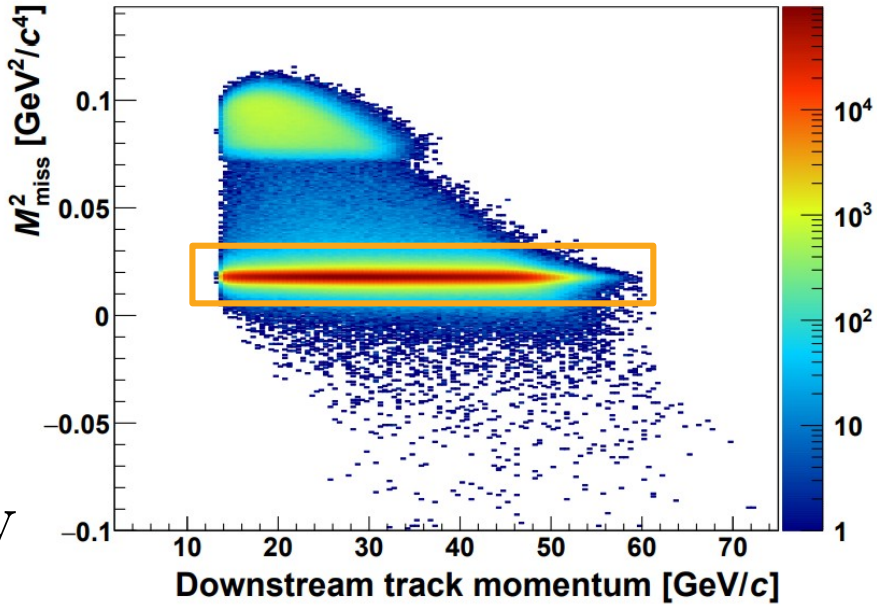


Time scale:
2014 – Pilot run
2015 – Commissioning run: ~1% of design intensity, no beam tracker
2016 - Commissioning run + Physics run (30 days)
2017 – Physics run (161 days)
2018 – Physics run (217 days)
2019-2020 – LS2
2021 – Start of the new physics run

Searches for $\pi^0 \to$ invisible

- $\pi^0 \to \nu\nu$ is not forbidden due to neutrino non-zero masses
- BR($\pi^0 \to \nu\nu$) in the SM is O(10^{-24}) $\to$ any observation will be an indication of the new physics
- Current experimental limit is 2.7×10^{-7} at 90% CL from BNL

  [Phys. Rev. D 72 (2005) 091102]



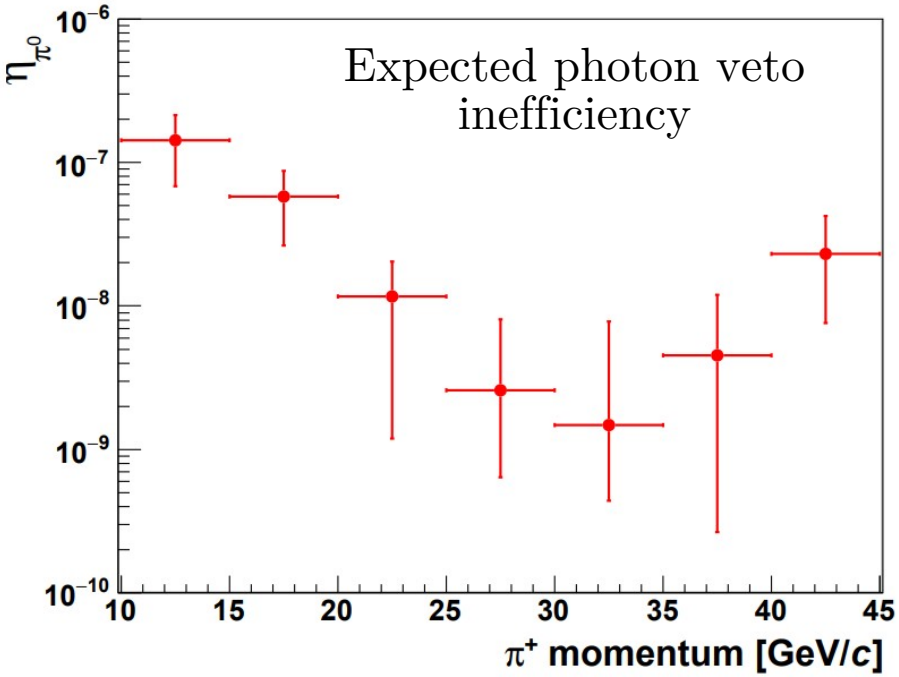
The hermetic photon veto of NA62 allows for the search in the kaon decay chain:

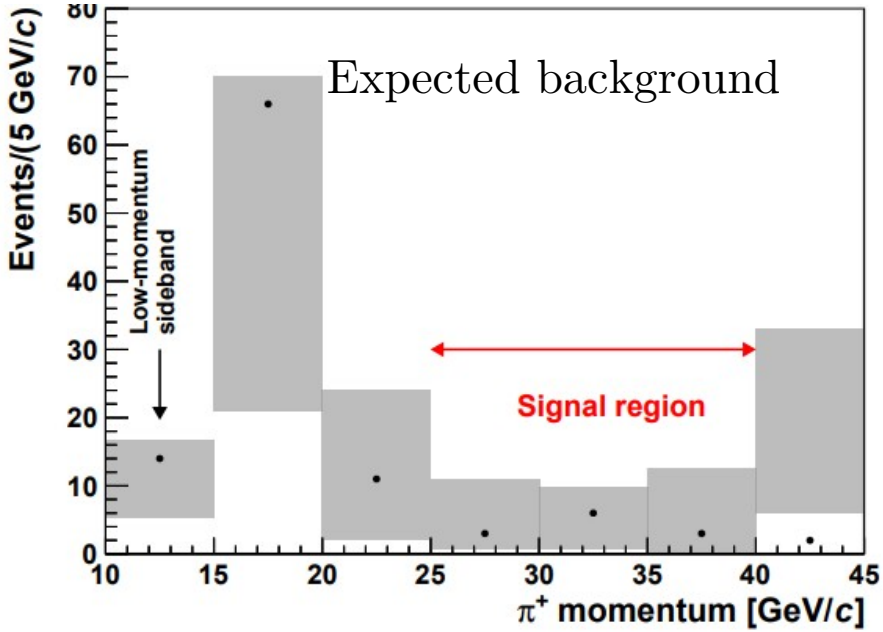
$$K^+ \to \pi^+\pi^0(\gamma), \pi^0 \to invisible$$

[J. High Energ. Phys. 2021, 201 (2021)]

Analysis strategy

- Select $K^+ \to \pi^+\pi^0$ decays
- Normalization on $\pi^0 \to \gamma\gamma$
- Main background, $\pi^0 \to \gamma\gamma$ with 2 lost photons, evaluated using tag and probe technique
- Counting experiment in the region
  - $25 < p < 40$ GeV/c and
  - m^2_{miss} in [0.015,0.021] GeV2/c4





Result:

$$\mathrm{BR}(\pi^0 \to inv) \leq 4.4 \times 10^{-9}\ at\ 90\%CL$$

An improvement of a factor 60 compared to the previous experimental result!

[J. High Energ. Phys. 2021, 201 (2021)]

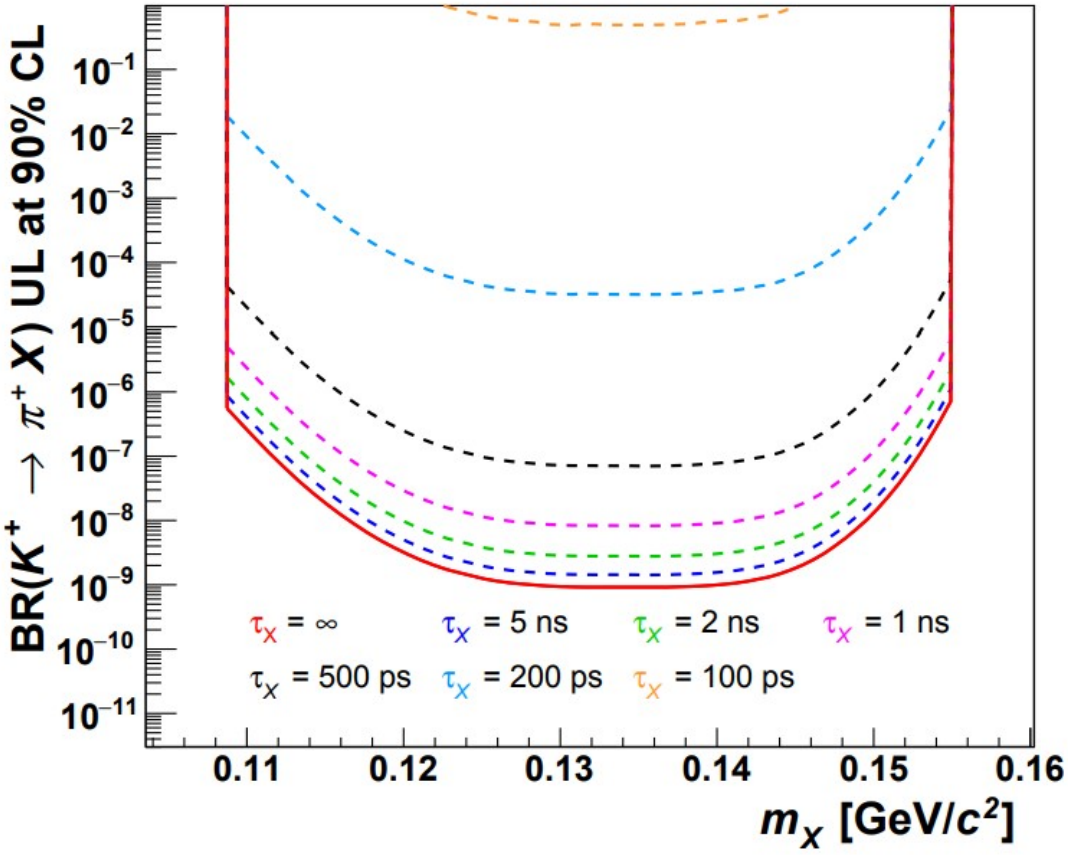
Search for $K^+ \to \pi^+ X$ with $m_X \sim m_{\pi 0}$

Model independent limit:

$$\mathrm{BR}(K^+ \to \pi^+ X) = \frac{N_s}{N_{K^+} \times R(m_X) \times \varepsilon_{sel} \times \varepsilon_{trig}}$$

$R(m_X)$ is the acceptance of cut on m^2_{miss} which depends on mass hypothesis

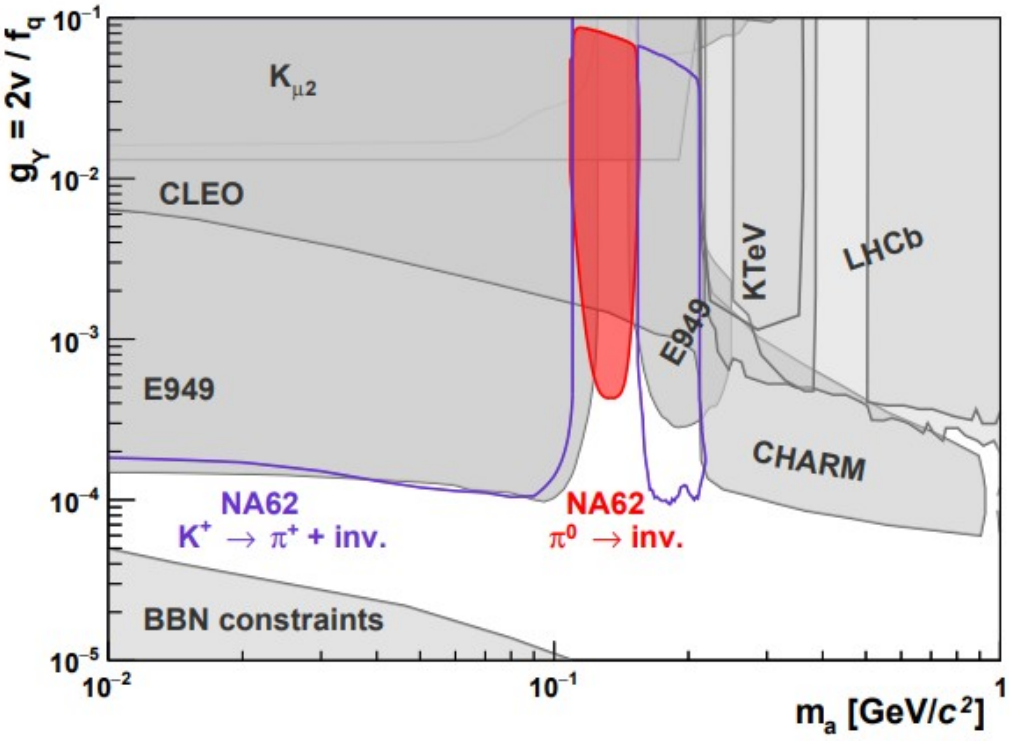
If X decays to visible particles inside the NA62 apparatus, the acceptance is reduced and UL is weaker



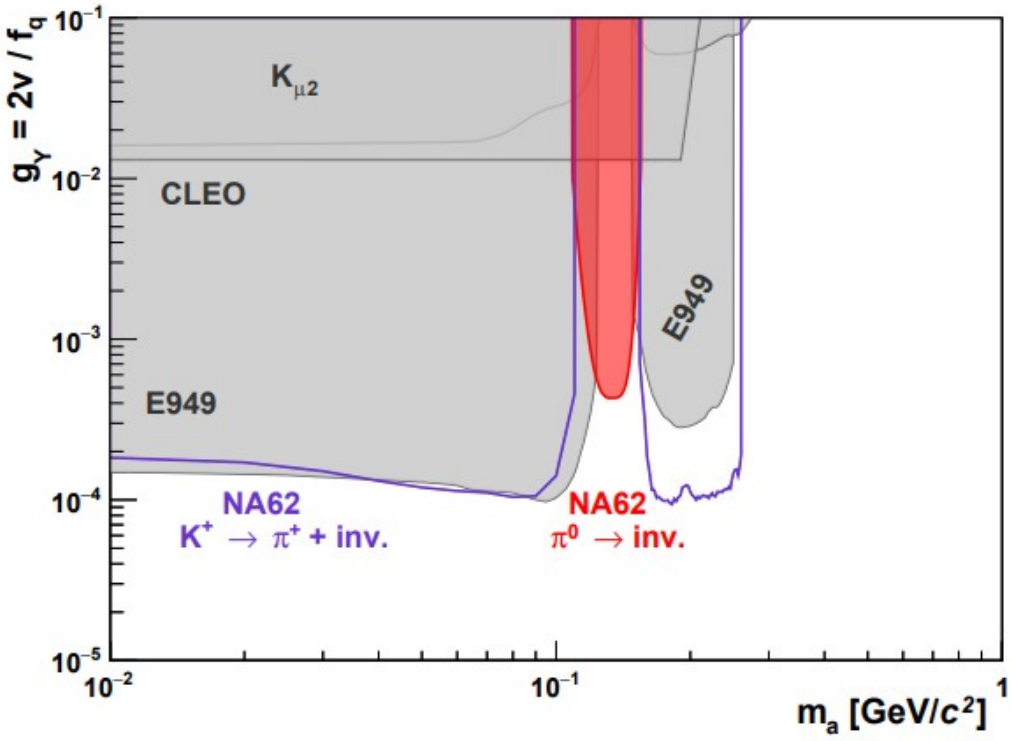
[J. High Energ. Phys. 2021, 201 (2021)]

Search for $K^+ \to \pi^+ a$, a=ALP

BC10 in PBC*: universal coupling to quark and lepton fields $f_q = f_l$



ALP decays to visible SM particles



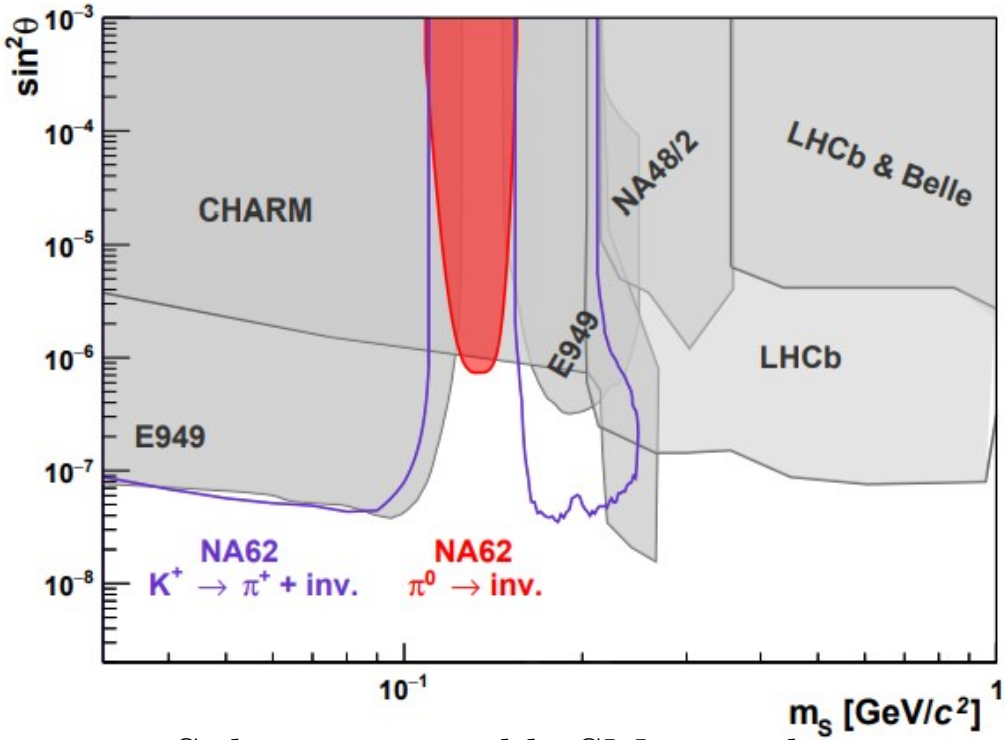
ALP decays to invisible particles or it is long-lived

* [PBC-BSM report, arXiv:1901.09966] [J. High Energ. Phys. 2021, 201 (2021)]

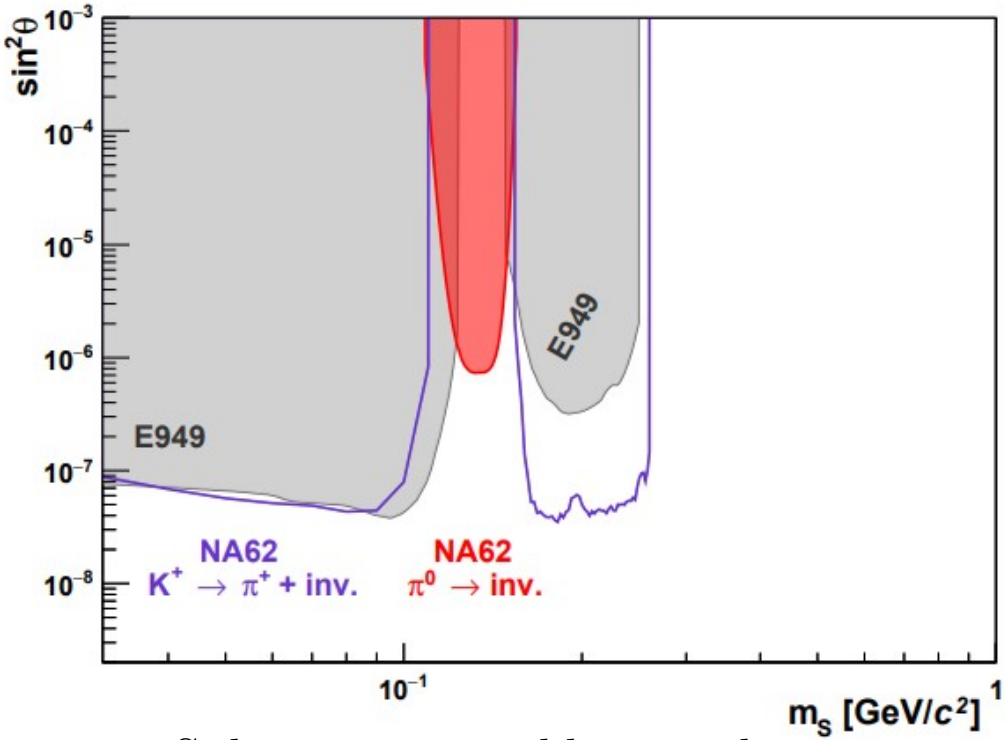
Search for $K^+ \to \pi^+ S$, S=scalar

BC4 in PBC*: Higgs mixing model

$$L_{scalar} = -(\mu S + \lambda S^2) H^\dagger H, \lambda = 0, \mu = sin\theta$$

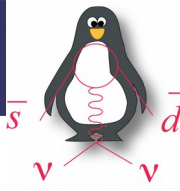


S decays to visible SM particles



S decays to invisible particles or it is long-lived

* [PBC-BSM report, arXiv:1901.09966]
[J. High Energ. Phys. 2021, 201 (2021)]

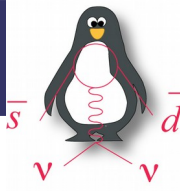


Summary

- The NA62 experiment is a powerful laboratory to make searches for exotic particles:
  - New limits on BR($\pi^0 \rightarrow$ invisible) using 2017 data:

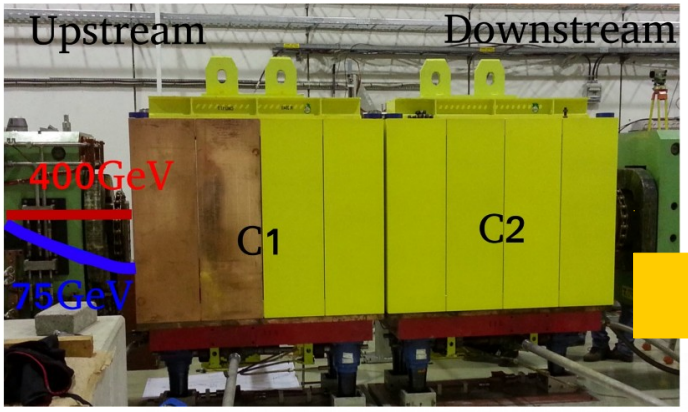
    BR($\pi^0 \rightarrow$ invisible) $< 4.4\text{x}10^{-9}$ at 90% CL
  - Factor of 60 improvement
- The NA62 experiment is ready for the new data taking in 2021 stating in July
  - Expect to take statistics at full beam intensity

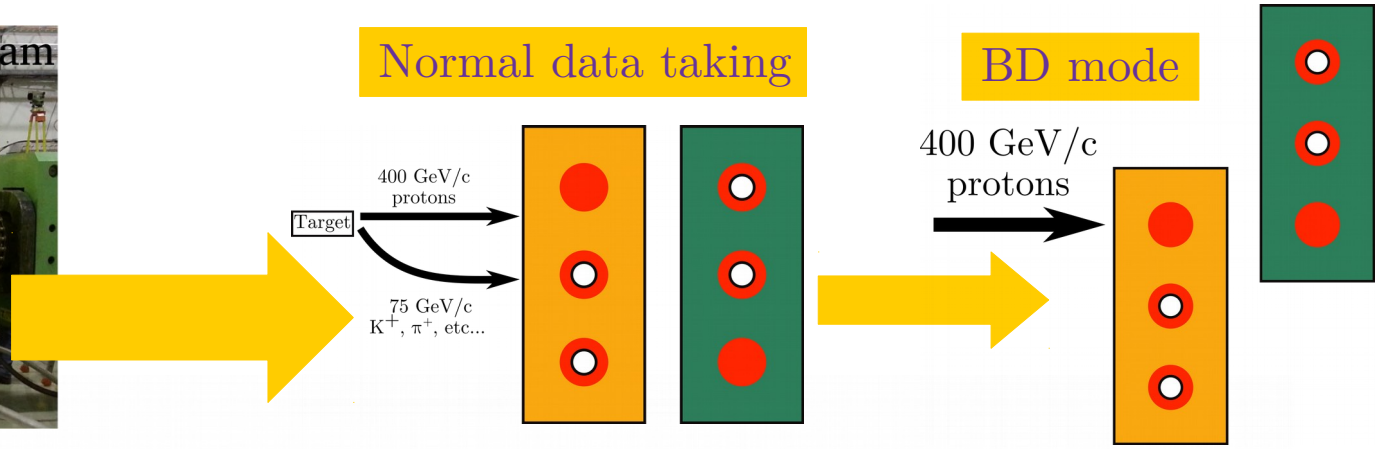

Thank you!

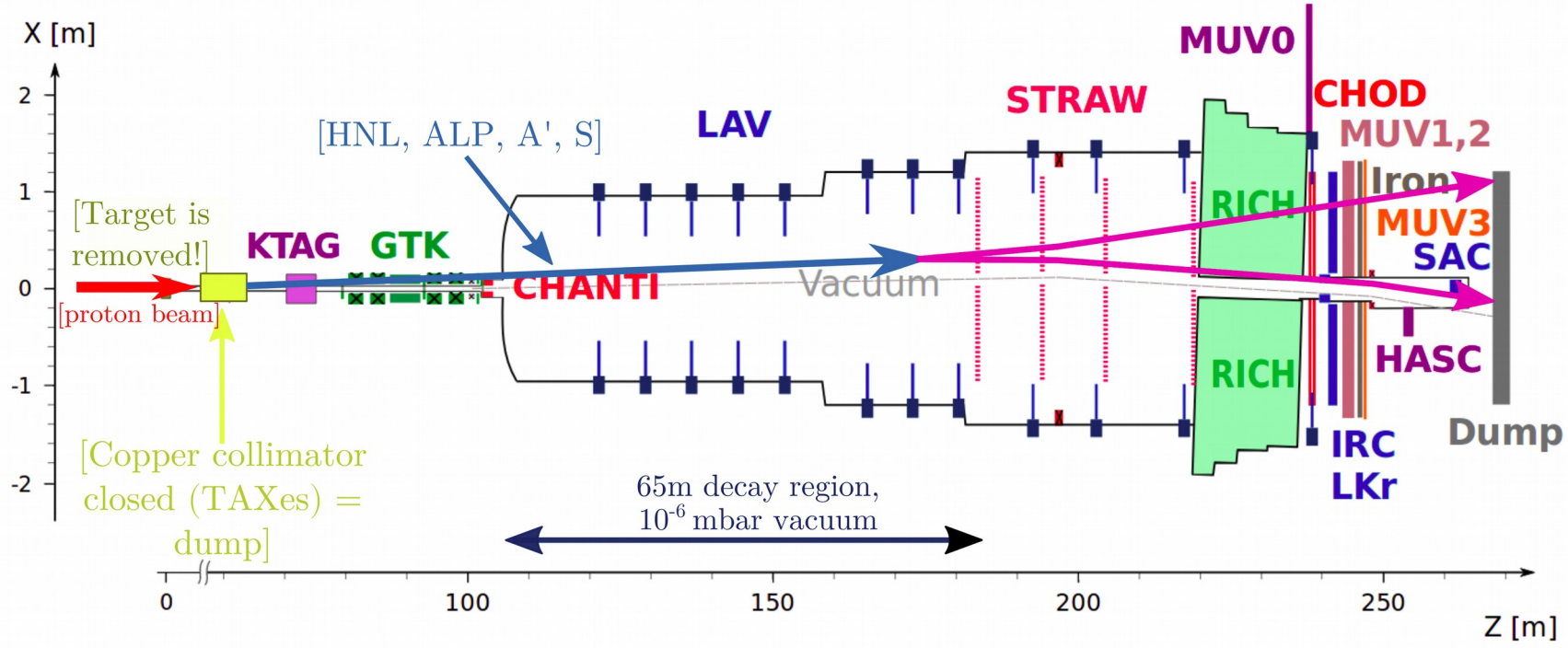


[Backup slides]

Beam dump mode of NA62

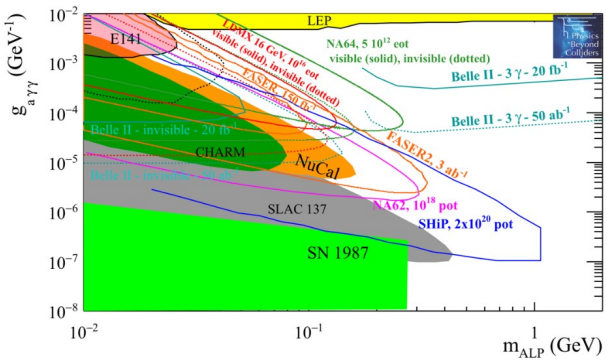






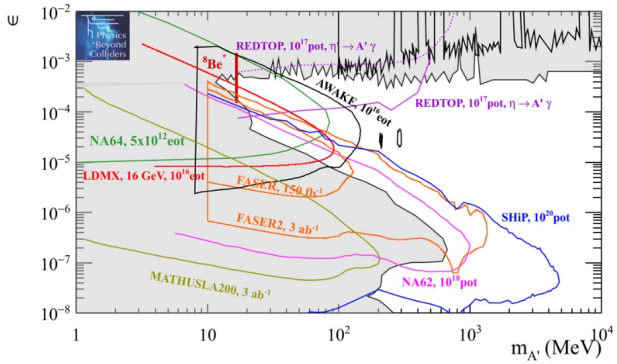
Future prospects 10-15 years scale

Coupling to SM photon



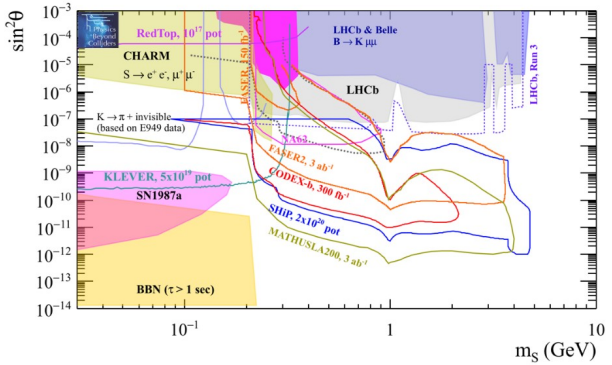
$a \to \gamma\gamma$

Mixing with SM photon



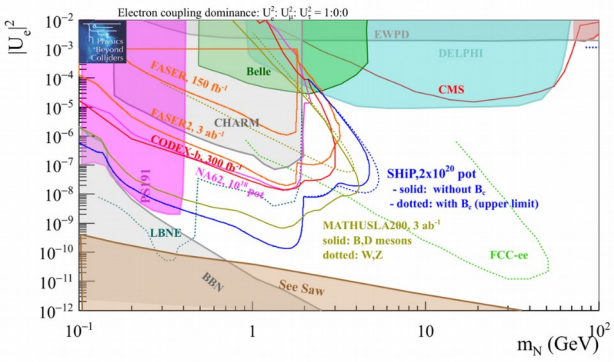
$A' \to ll$

Mixing with SM Higgs

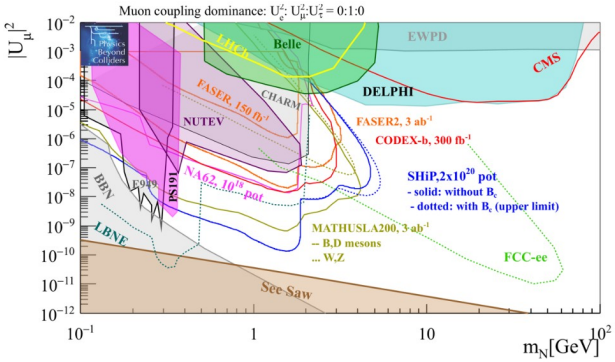


$S \to ll$

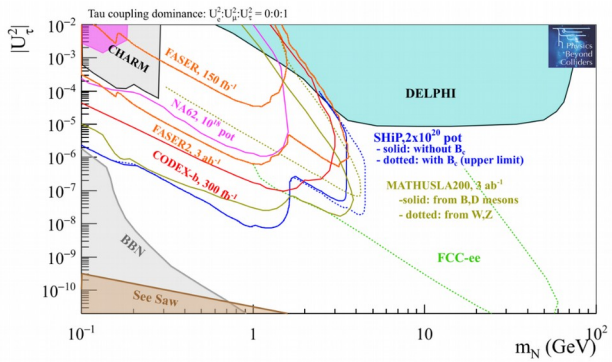
Electron coupling dominant



Muon coupling dominance



Tau coupling dominance



All HNL decays with at least two charged tracks are considered, assuming zero background

[PBC-BSM report, arXiv:1901.09966]

Search for π0 decays to invisible particles at NA62