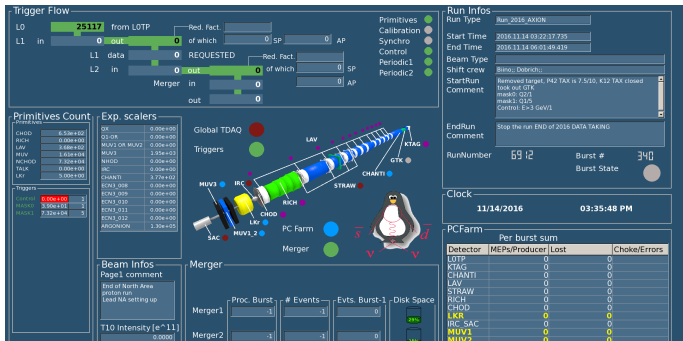


Heavy axion search with NA62

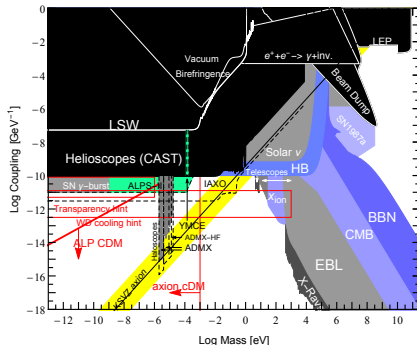
Babette Döbrich (CERN)

CERN/LAT, 29/03/17

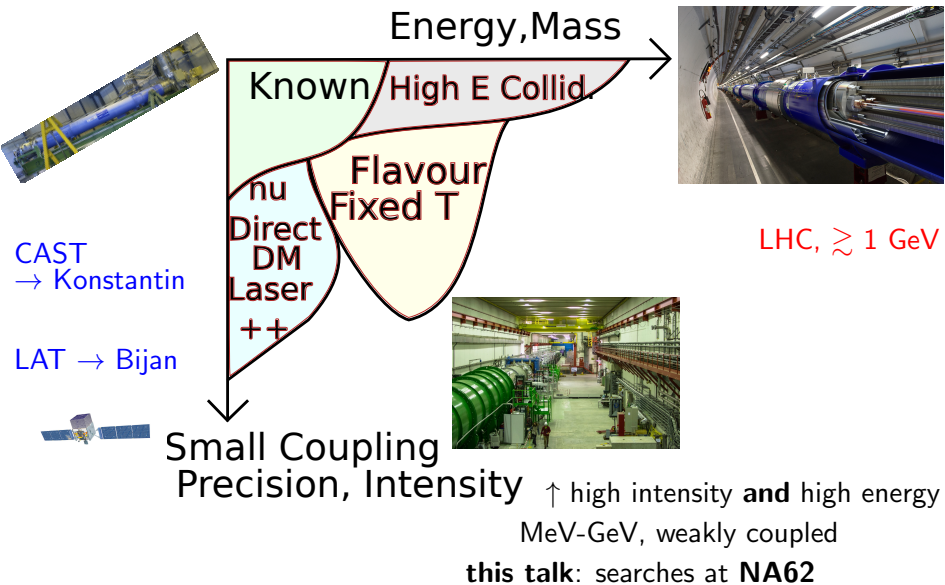


Axions and Axion-like particle, a brief bestiary

- Axions as solution for strong CP problem in QCD
- may be cold Dark matter in certain parameter range
- relevant band t.b. covered by direct DM searches (e.g. cavities)
- Axion-like particle: pseudoscalar, not connected to CP, e.g. interesting as Dark Matter mediator (see later)
- often shown: two-photon coupling ↙



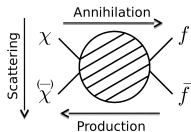
Instruments, reasons for axion/ALP searches



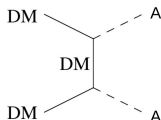
Why MeV-GeV? Why Axion-like?

Why MeV-GeV, very weakly coupled

- comparatively little explored (next slide)
- compelling phenomenology as 'Dark Matter mediators'



thermal
DM freeze out
exp. constraints:



DM can annihilate to
intermediate states
then to SM

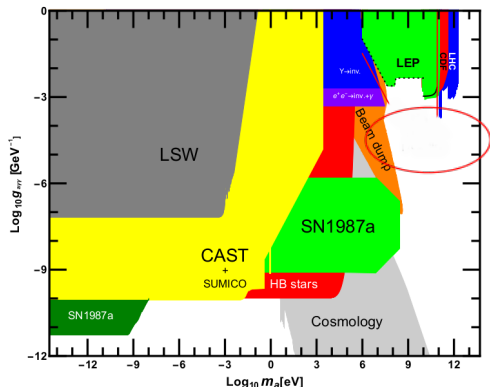
difficult to avoid overproduction (not enough decay)

why pseudoscalar \rightarrow th + pheno

- 1) fundamental scalar exists 2) natural in Higgs-sector extensions (Two Higgs doublet) 3) Nambu-Goldstone boson (axion)
- DM mediator: scattering through PS exchange is momentum suppressed; also coupling through spin, not mass [Freytsis & Ligeti, arXiv:1012.5317]

Heavy ALP parameter space

- mediator idea allows: **Pseudoscalar (Axion-like)**, Vector (Dark Photon), Scalar (Higgs-like), Neutrino (sterile Neutrinos)
- I will focus on ALPs but the NA62 exotics program is much richer
- weak coupling: high reaction rate, longer lifetimes, sufficient energy
→ Proton fixed target facility



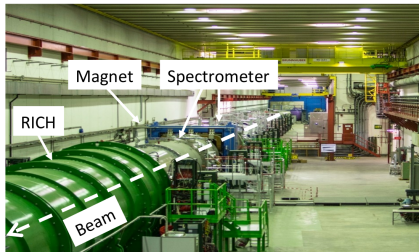
ALP coupled to two photons

taken from [Phys.Lett. B753,482]

$$\mathcal{L}_{\text{int,PS}} \sim g_{\phi\gamma} \phi F^{\mu\nu} \tilde{F}_{\mu\nu}$$

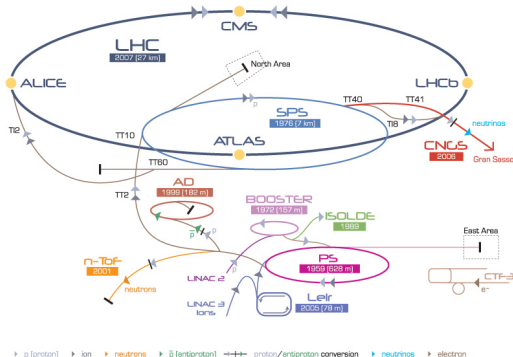
NA62 at CERN *see arXiv:1703.08501*

na62.web.cern.ch/NA62/



- NA62 wants to measure $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at CERN SPS, aim: BR at $\mathcal{O}(10\%)$ total uncertainty within ~ 2 years

CERN Accelerator Complex



The beam and detector of the NA62 experiment at CERN

The NA62 collaboration

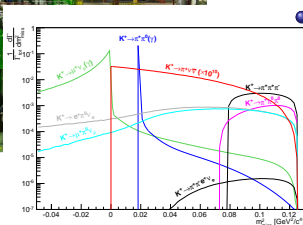
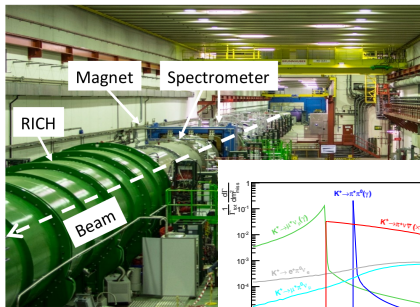
ABSTRACT: NA62 is a fixed-target experiment at the CERN SPS dedicated to measurements of rare kaon decays. Such measurements, like the branching fraction of the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay, have the potential to bring significant insights into new physics processes when comparison is made with precise theoretical predictions. For this purpose, innovative techniques have been developed, in particular, in the domain of low-mass tracking devices. Detector construction spanned several years from 2009 to 2014. The collaboration started detector commissioning in 2014 and will collect data until the end of 2018. The collaboration and detector components are described together with their early performance obtained from 2014 and 2015 data.

KEYWORDS: Large detector systems for particle and astroparticle physics.

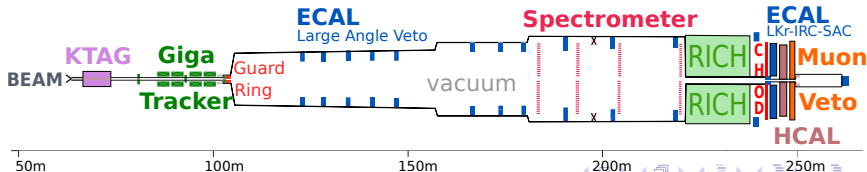
v1 [physics.ins-det] 24 Mar 2017

NA62 at CERN *see arXiv:1703.08501*

na62.web.cern.ch/NA62/

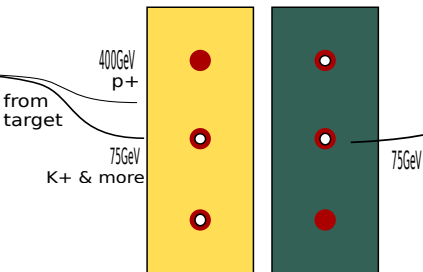


- NA62 wants to measure $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at CERN SPS, aim: BR at $\mathcal{O}(10\%)$ total uncertainty within ~ 2 years
- track 750 MHz beam ($6\% K^+$) at ~ 75 GeV: Particle ID, high-efficiency Veto + Kine

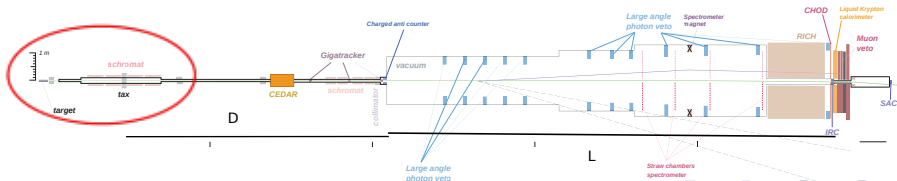


NA62 at CERN *see arXiv:1703.08501*

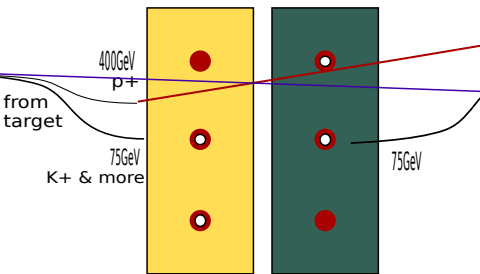
na62.web.cern.ch/NA62/



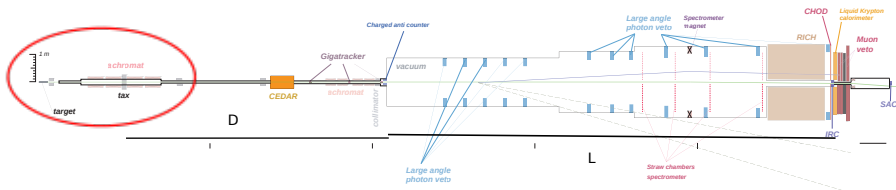
- NA62 wants to measure $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at CERN SPS, aim: BR at $\mathcal{O}(10\%)$ total uncertainty within ~ 2 years
- track 750 MHz beam (6% K^+) at ~ 75 GeV: Particle ID, high-efficiency Veto + Kine
- K^+ secondary from Beryllium target, large fraction of SPS protons continuously 'dumped'



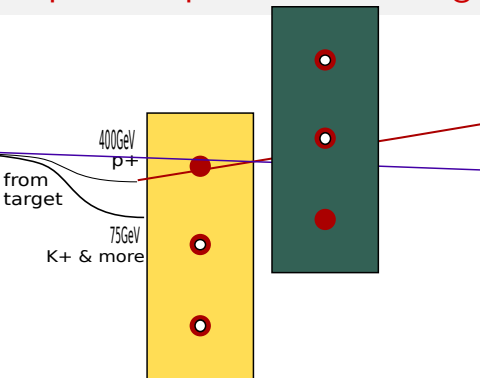
Upstream production of long-lived particles



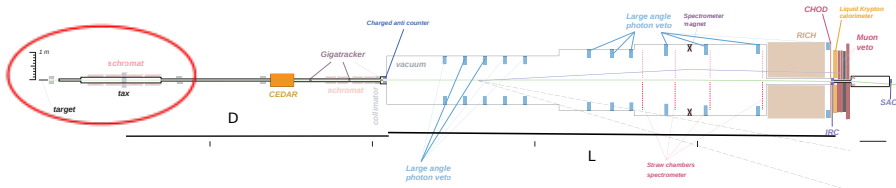
- long-lived, weakly-interacting particles produced along with nominal beam **directly**/ **decay**



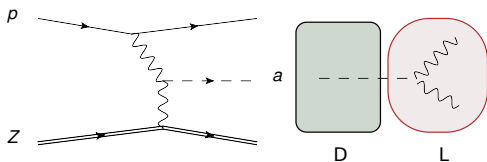
Upstream production of long-lived particles



- long-lived, weakly-interacting particles produced along with nominal beam **directly**/ **decay**
- possibility to dump complete beam by closing TAX ($\sim 10^{12}$ protons per effective second)
- in decay volume \rightarrow mostly muons from decays before TAX

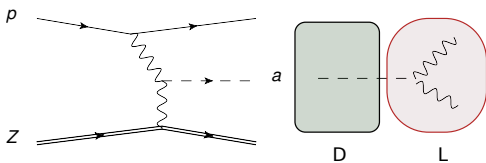
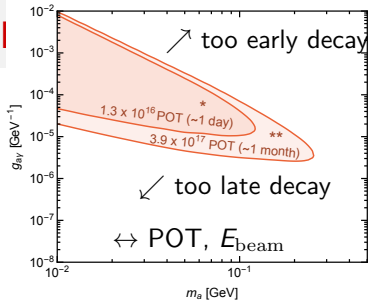


Example: Axion-like particle production from TAX



- pseudoscalar ALP created by photon fusion
- copper TAX \rightarrow coherent Z^2 enhancement with charge

particle production from TAX

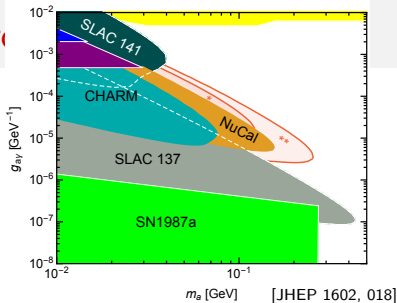


- pseudoscalar ALP created by photon fusion
- copper TAX \rightarrow coherent Z^2 enhancement with charge
- decay length $\gamma\beta\tau$, ALP lifetime $\tau \sim 1/(g_{a\gamma}^2 m_a^3)$
- the projected limits fold as input: 1. the differential cross-section for production, 2. coincidence and acceptance in EM calorimeter, 3. probability to decay within the decay volume

Example: Axion-like particle pro

red: ★ 1 day (toy projection)

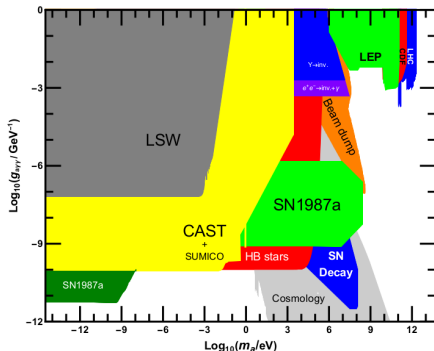
red: ★★ 1 month (toy projection)



- pseudoscalar ALP created by photon fusion
- copper TAX → coherent Z^2 enhancement with charge
- decay length $\gamma\beta\tau$, ALP lifetime $\tau \sim 1/(g_{a\gamma}^2 m_a^3)$
- the projected limits fold as input: 1. the differential cross-section for production, 2. coincidence and acceptance in EM calorimeter, 3. probability to decay within the decay volume
- NA62 → small d , large E : one day runtime as ‘dump’ is sensitive to new physics (90% confidence at 0 background)

Relevance to LAT, cf. e.g. 1702.02964

rather complementary regions probed
if mass where known, synergies are likely :-)



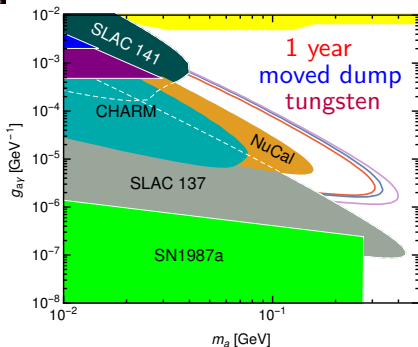
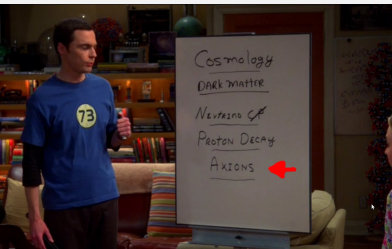
↑ ALP to gamma conversion
in B-field of galaxy
but non-observation of gamma ray burst
see 1609.02350 for LAT sensi

← fixed target (e.g. NA62)
but also, e.g. B-factories

energy loss by ALP emission
← reduce length of ν burst

← ALP prod. in SN ($m = \text{core } T$)
 g small → collapse not perturbed
photon decay $\gamma \gtrsim 10 \text{ MeV}$
easily improved by LAT upon SN

Thank you for your interest!



- with NA62 experiment: parasitically to $K^+ \rightarrow \pi^+ \nu \bar{\nu}$, search for weakly coupled MeV to GeV sectors, e.g. axion-like particles (DM mediator?)
- extended program for Dark Photons, Heavy Neutral Leptons, see e.g. *link: presentation to PBC*
- many analyses ongoing with data collected in 2015/2016
- 2017 data taking starts in May, priority on $\pi^+ \nu \bar{\nu}$ but with room for 'Exotics'
- proposing a longer such datataking after next long shutdown with conditions optimized to exotics