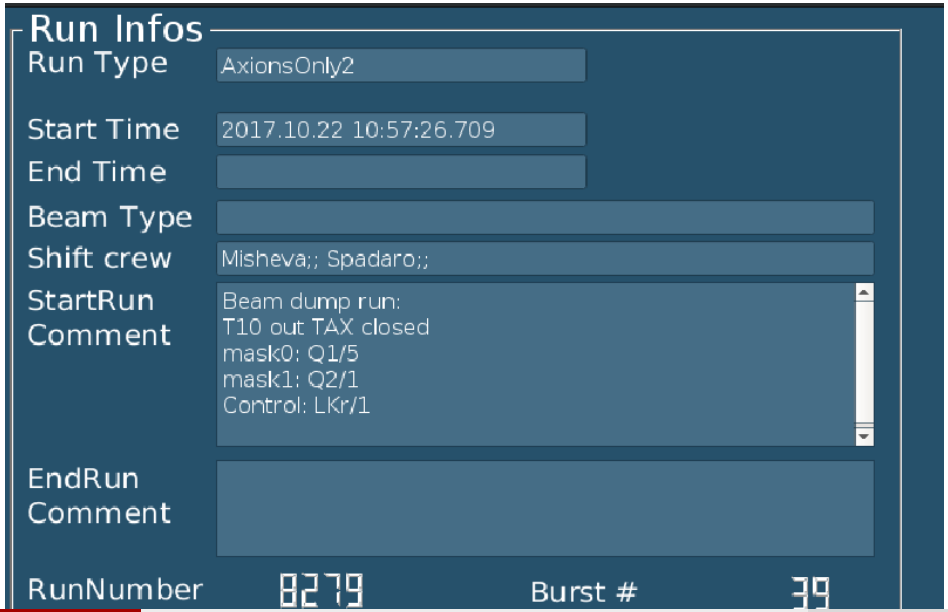
Long lived particles at NA62

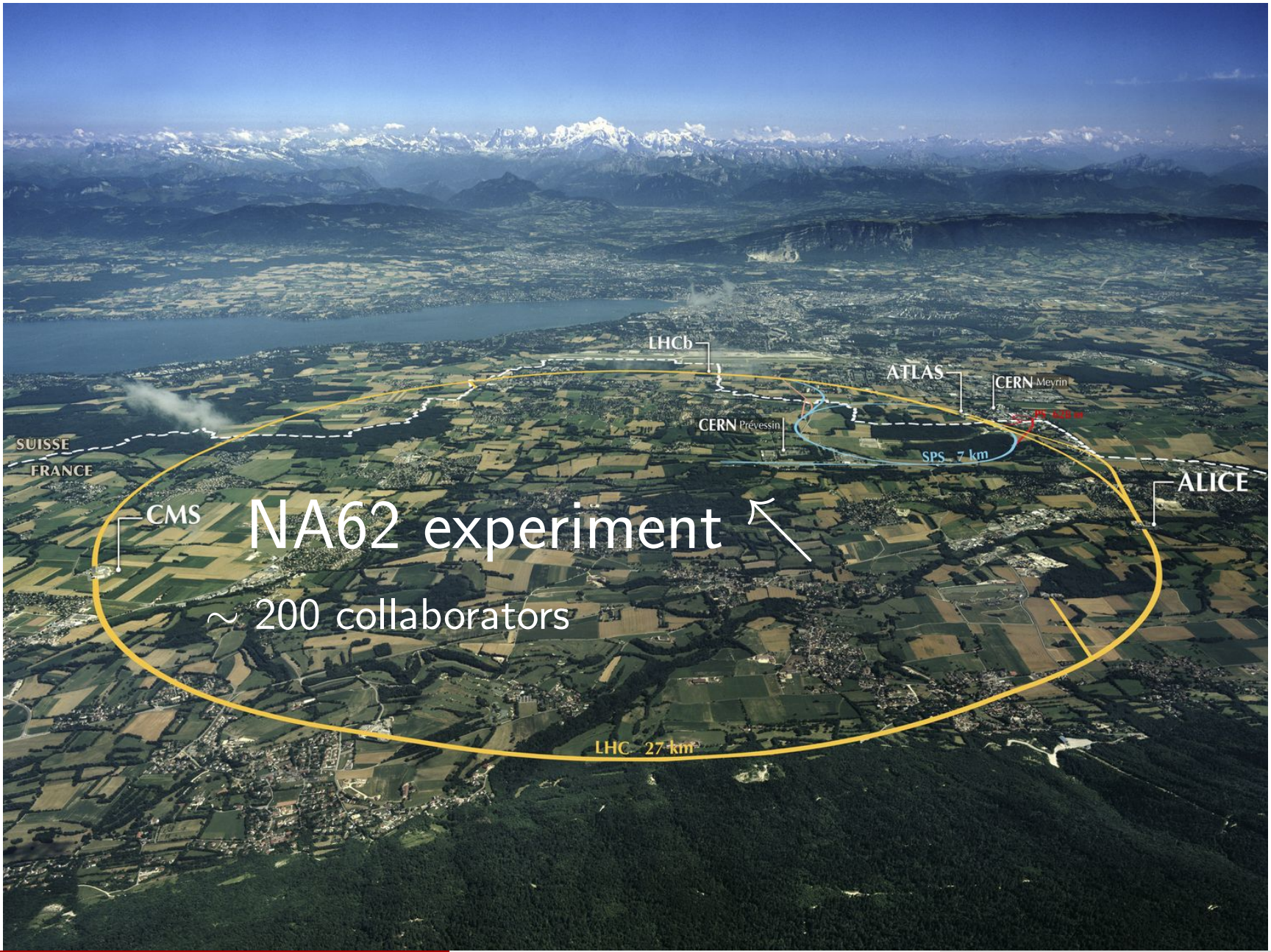
(disclaimer: NA62 is not a 'dedicated LLP experiment')

Babette Döbrich (CERN) for the NA62 collaboration

LLP at LHC, 18/05/2018



Journey to the "inner circle" :-)



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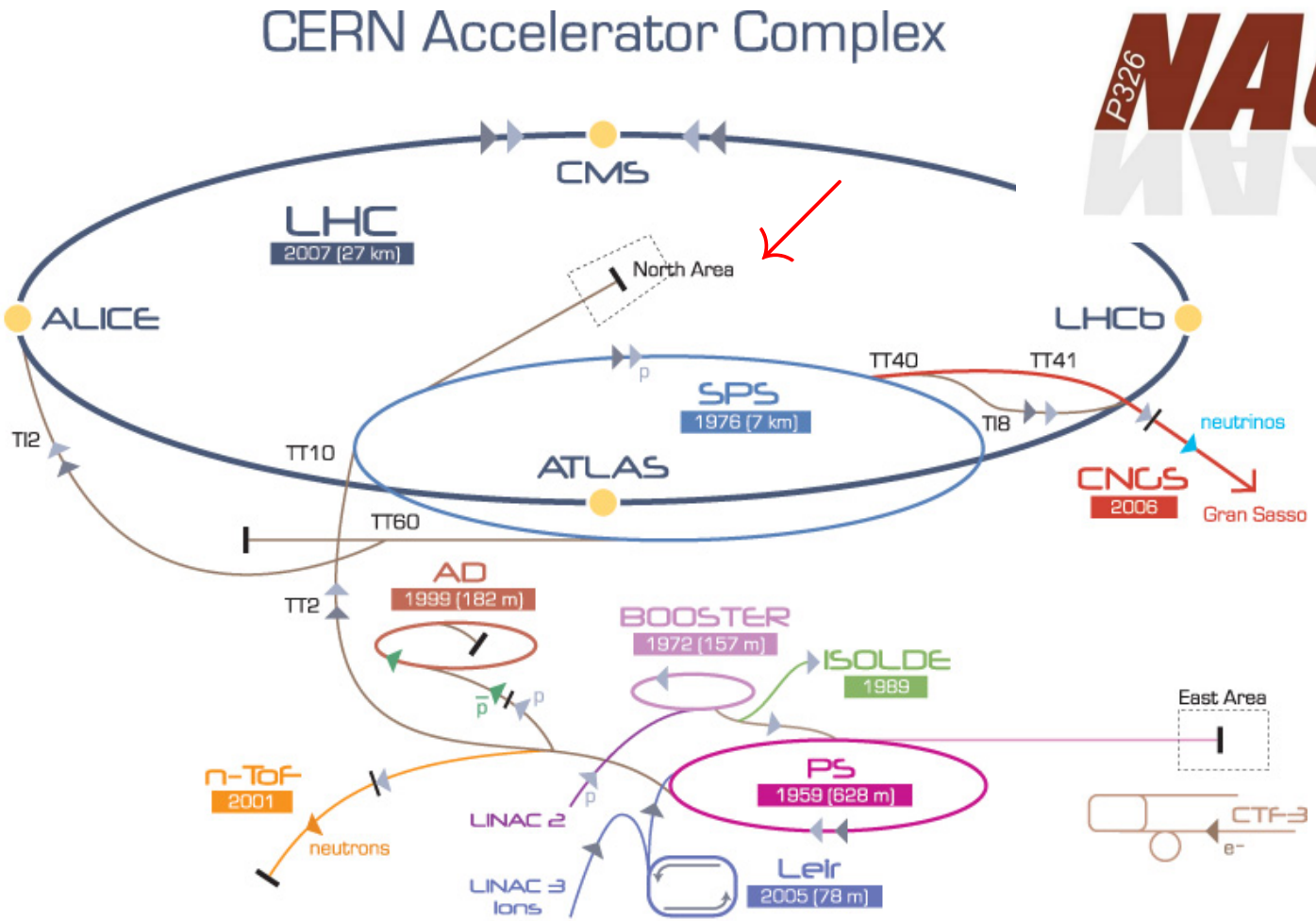
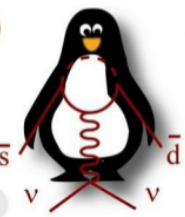


P326 NA62



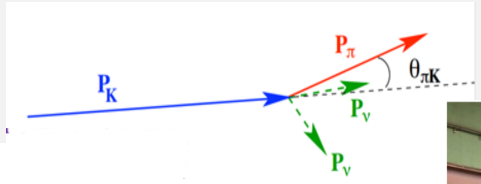
$$K^+ \to \pi^+ \bar{\nu} \nu$$

BR theory:

$$(8.4 \pm 1.0) \times 10^{-11}$$

Buras et al. JHEP 1511, 33

NA62 rationale

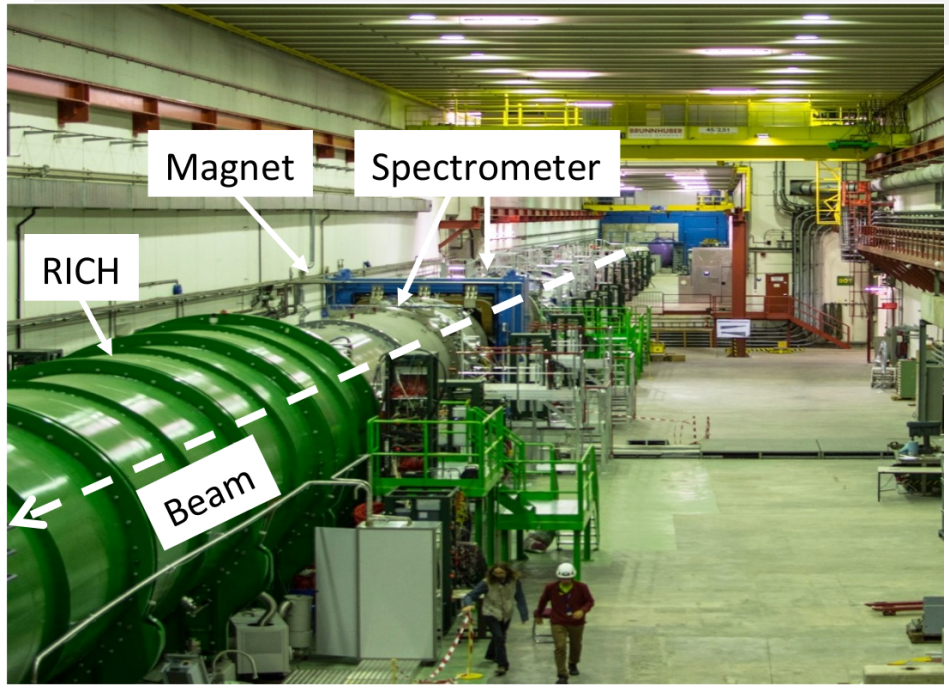


A Kaon's life:

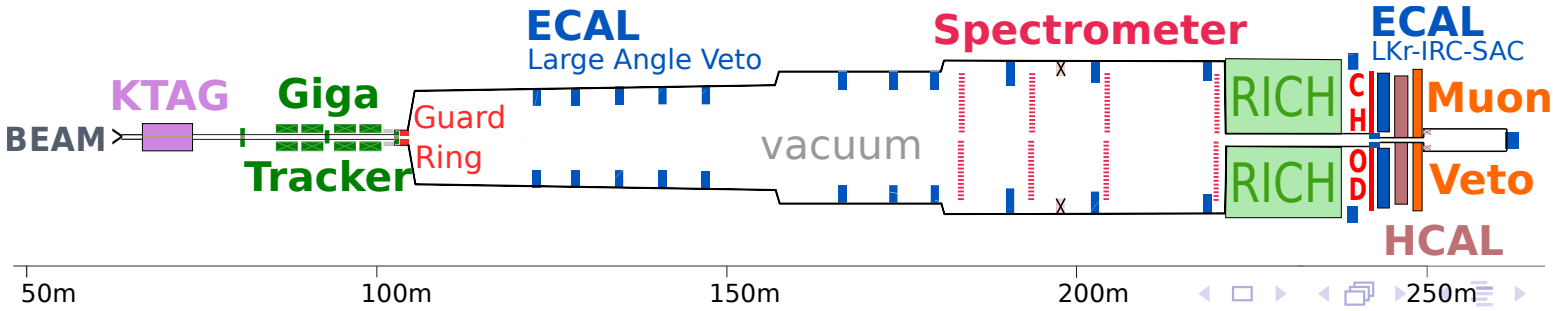
- $\mathrm{BR}(K^+ \to \pi^+\pi^0) \simeq 0.21$
- $\mathrm{BR}(K^+ \to \mu^+\nu) \simeq 0.64$
- $\mathrm{BR}(K^+ \to \pi^+\pi^-\pi^+) \simeq 0.06$

Detector system

- Kaon: KTAG, GTK, CHANTI
- Pion: STRAW, CHOD, RICH
- γ Vetoes: LAV, IRC, SAC, LKr
- MUV system: μ & Hadron



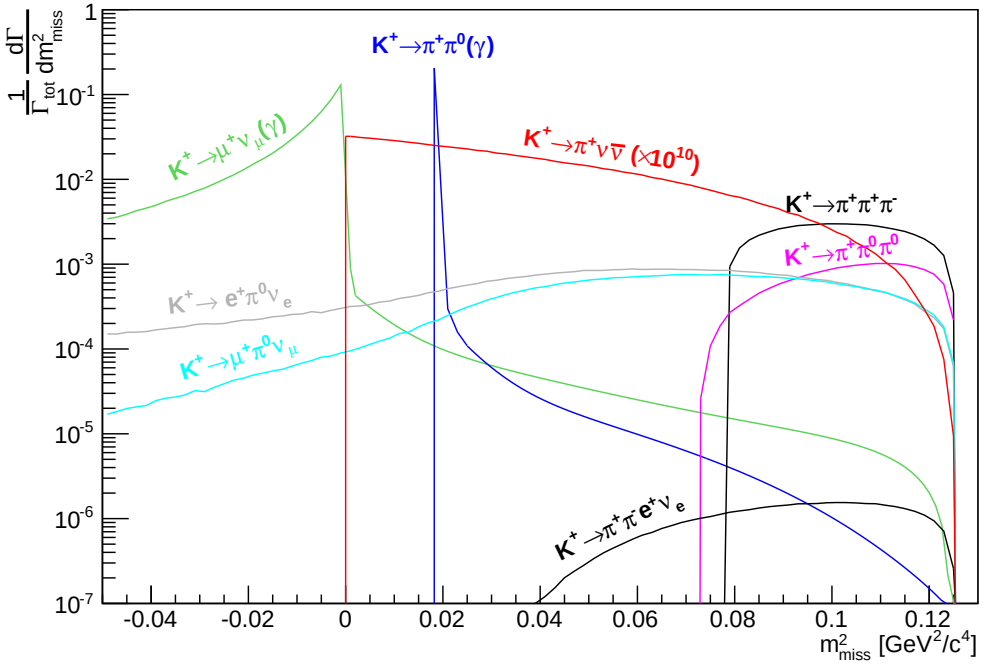
unseparated 750 MHz beam at GTK3
(6.6 % Kaons at 75 GeV, 1 % bite)

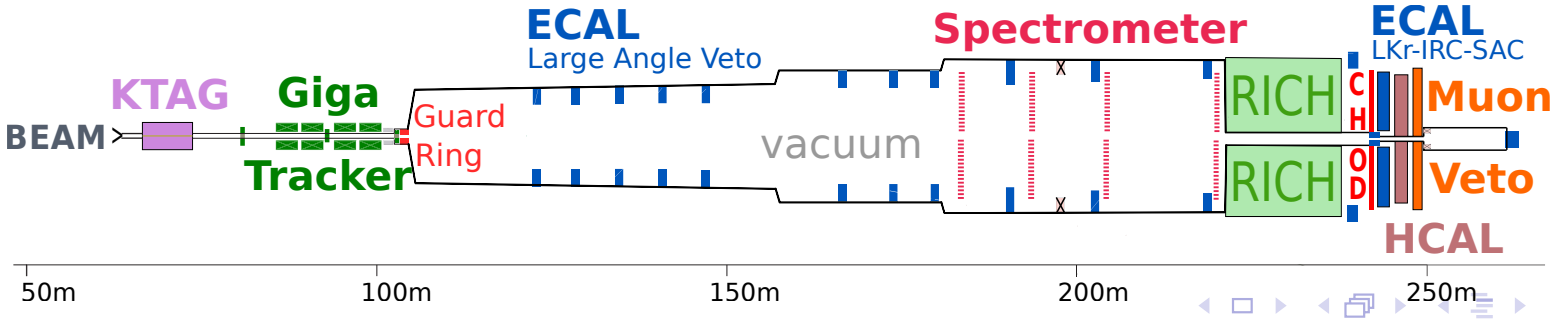


NA62 rationale II

↓ ↓ 2 signal regions

- $m^2_{\text{miss}} = (P_K - P_\pi)^2$
- 10^{12} background rejection!
- kinematic $\mathcal{O}(10^4)$
- high-efficiency veto: $\mathcal{O}(10^8)$ rejection of π^0 for $E(\pi^0) > 40\text{GeV}$
- particle ID μ vs π: rejection of $\mathcal{O}(10^7)$ for $15 < p_{\pi^+} < 35\text{GeV}$
- timing subdetectors $\mathcal{O}(100\text{ps})$





NA62 standard data-taking & parasitic BSM trigger lines

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

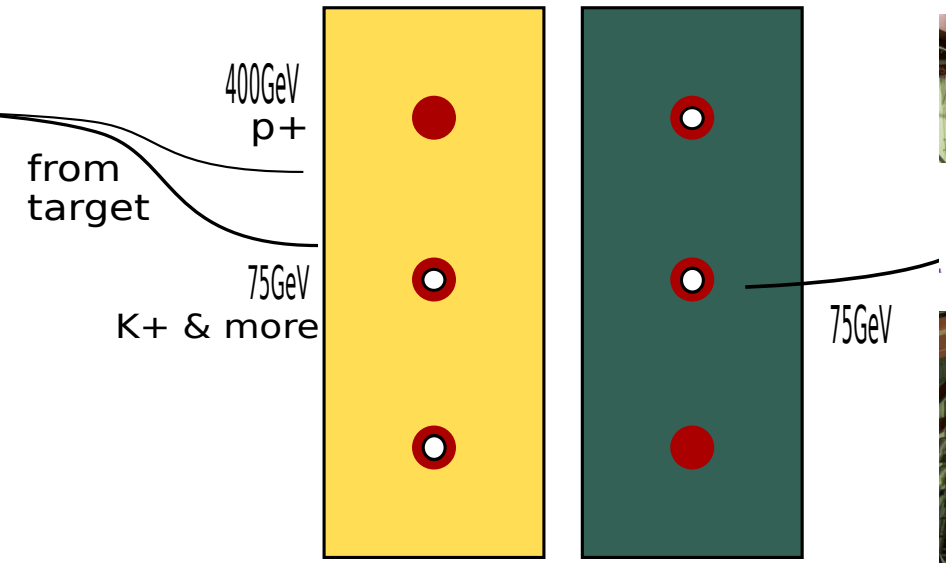
Run 2016: presented at this year's Moriond, and also

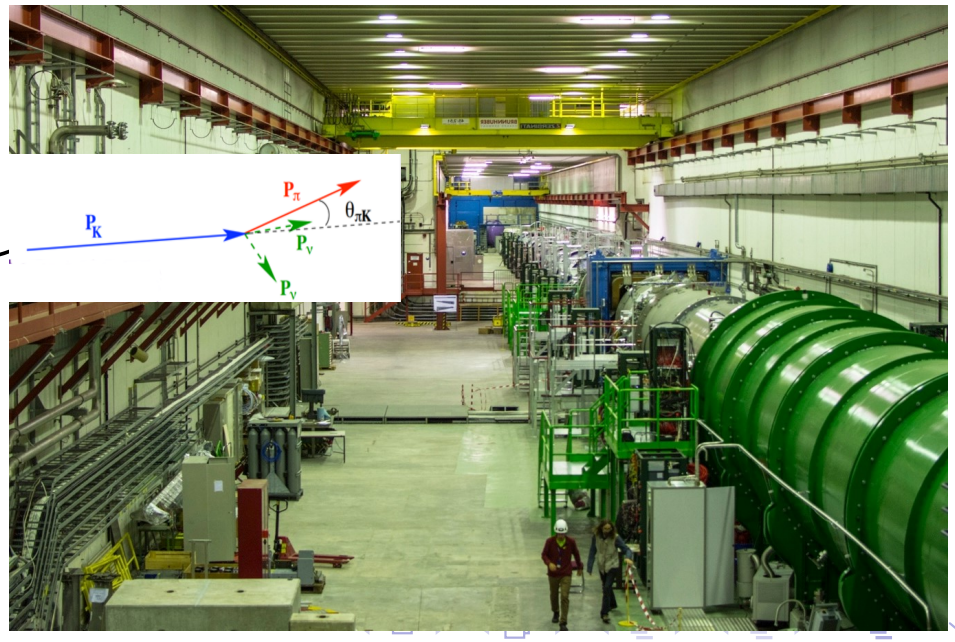
here: https://indico.cern.ch/event/714178/

Run 2017: $\sim 3 \times 10^{12}$ Kaon decays collected :-)

Run 2018: since mid April-November

then long shutdown expected

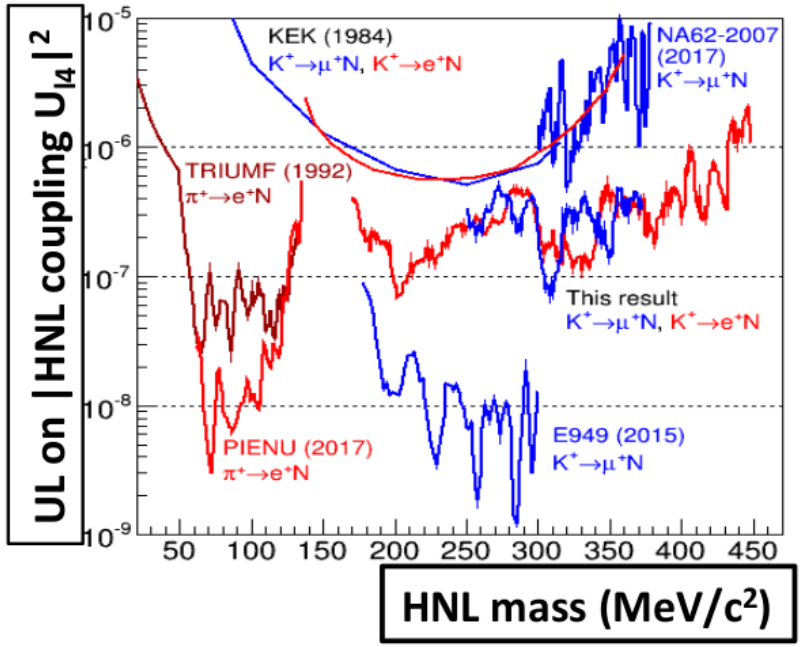


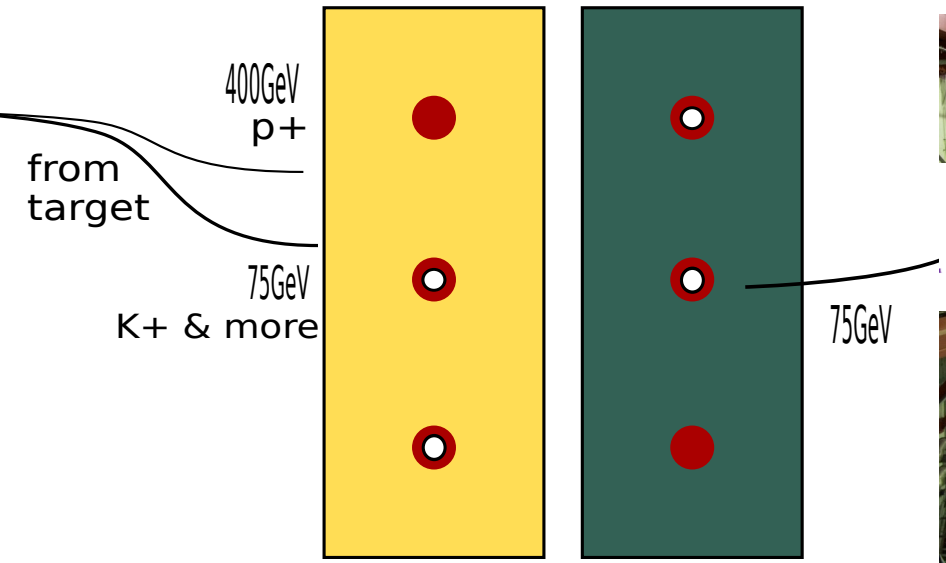


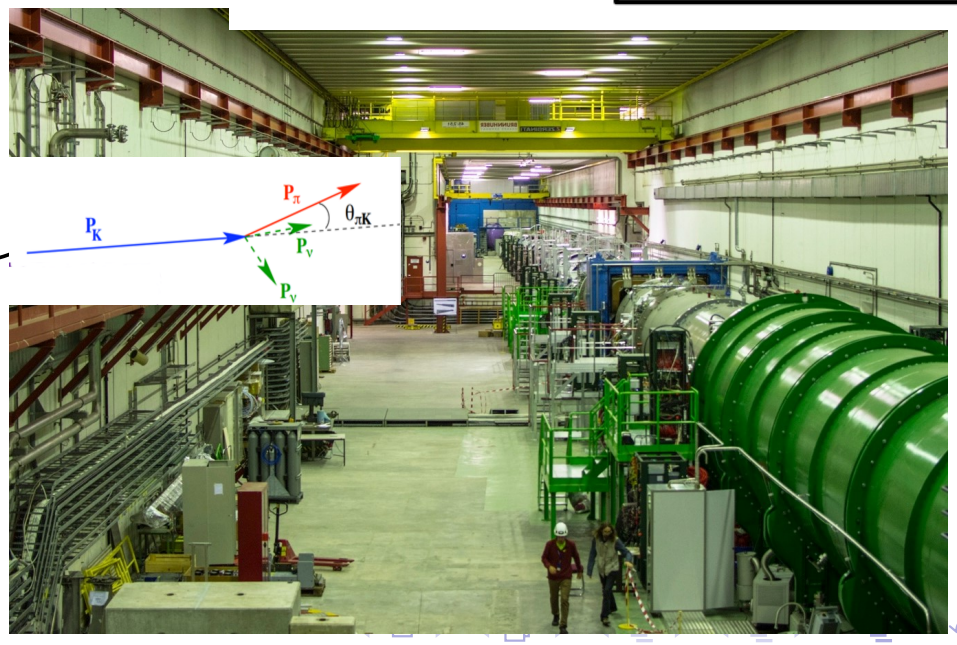
NA62 standard data-taking & parasitic BSM trigger lines

Trigger band width shared by $\pi^+\bar{\nu}\nu$
+ other Kaon & non-Kaon modes
example Kaon: $K^+ \to N + l^+$,

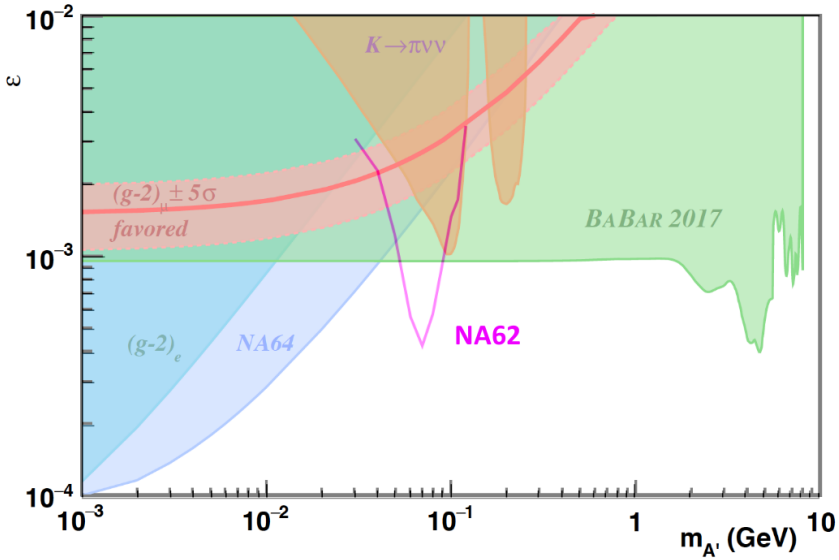
N: 'stable' Heavy Neutrino
2015 data: PLB 778 137 (2018)
based on $\sim 3 \times 10^8$ Kaon decays







NA62 standard data-taking & parasitic BSM trigger lines



from 2016 data:

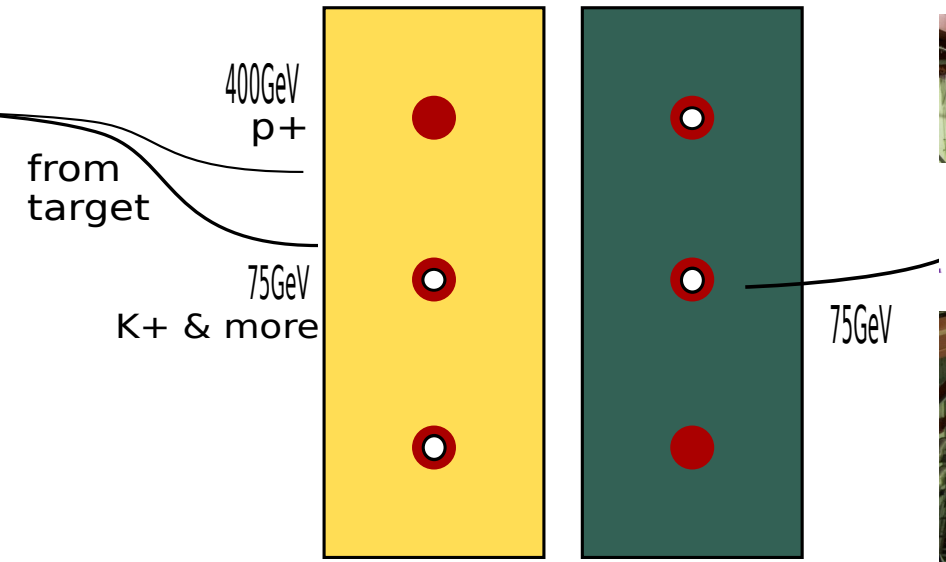
invisibly decaying Dark Photon

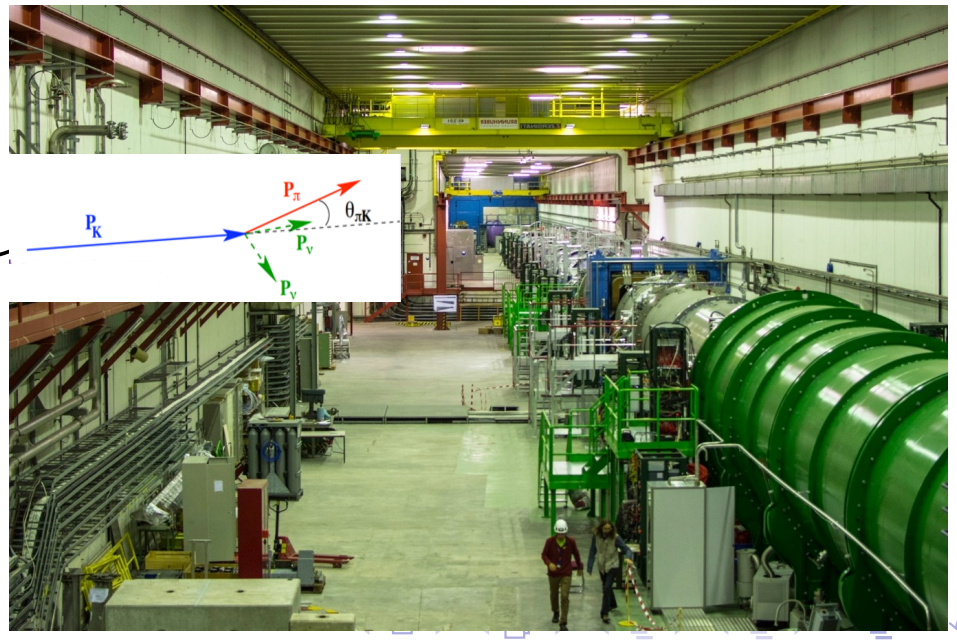
$K^+ \to \pi^0\pi^+$ with $\pi^0 \to A' + \gamma$

(prelim: paper in preperation)

search peak in missing mass of

$$m^2_{\text{miss}} = (P_K - P_\pi - P_\gamma)^2$$





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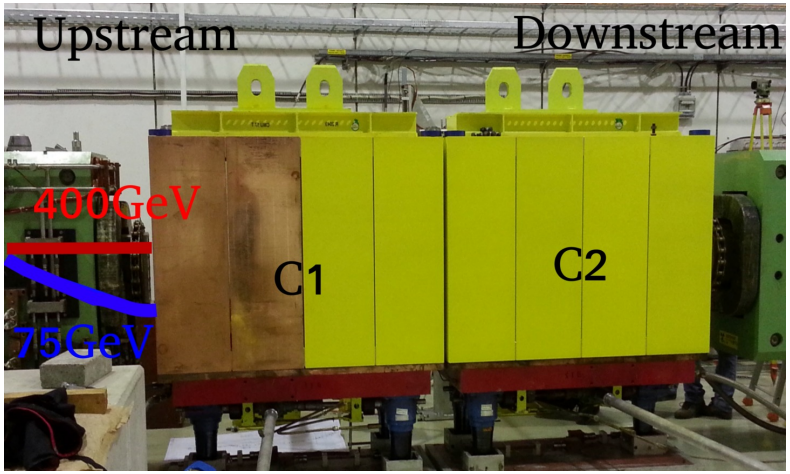


heavier BSM? other prod channels?
decay of long-lived?

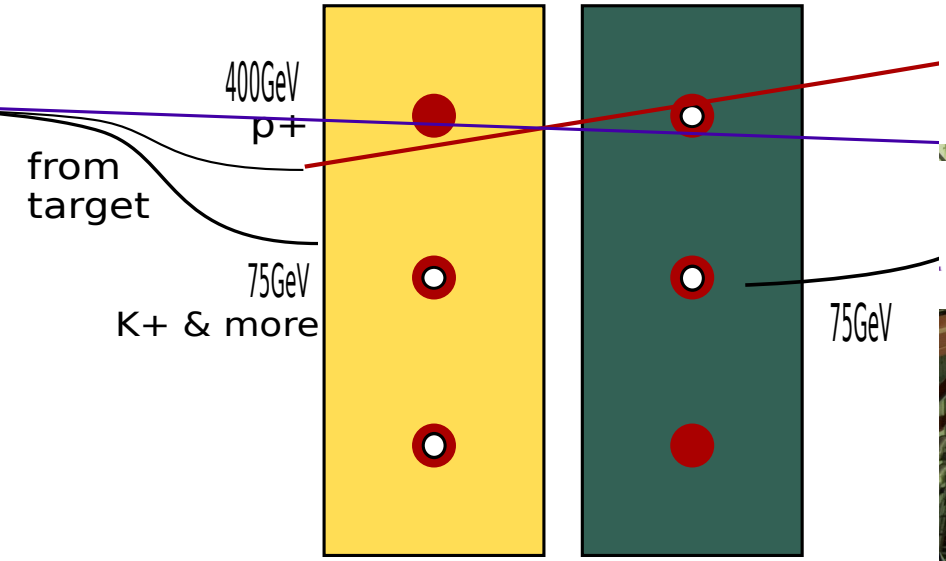
$\Rightarrow$ **upstream production**

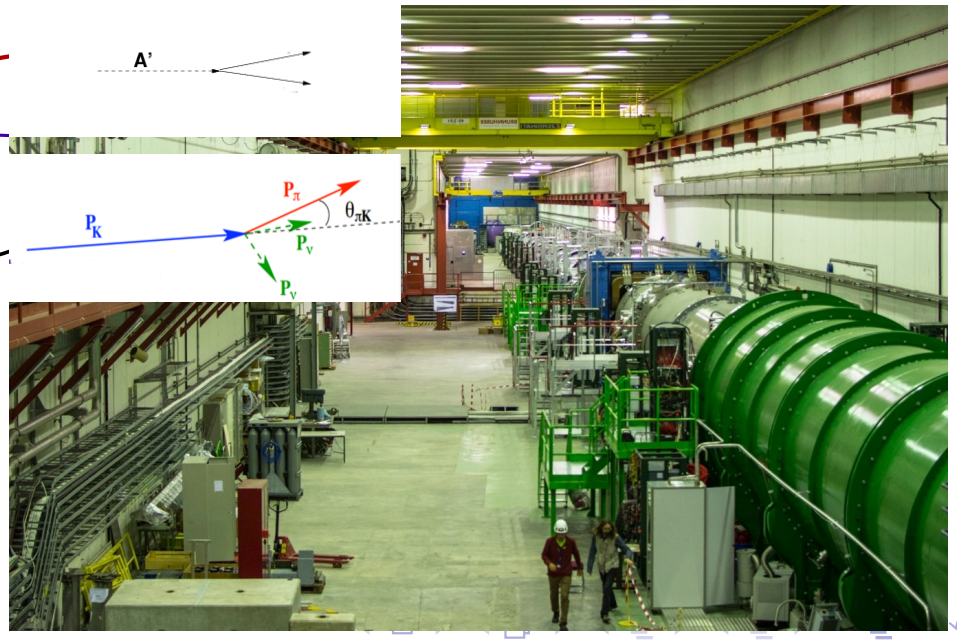
60 % meson decays & 40 % direct p prod.

trigger 2017: $\mu\mu$ and μ + track

not requiring initial Kaon

both $\mathcal{O}(10^{17})$ POT in 2017



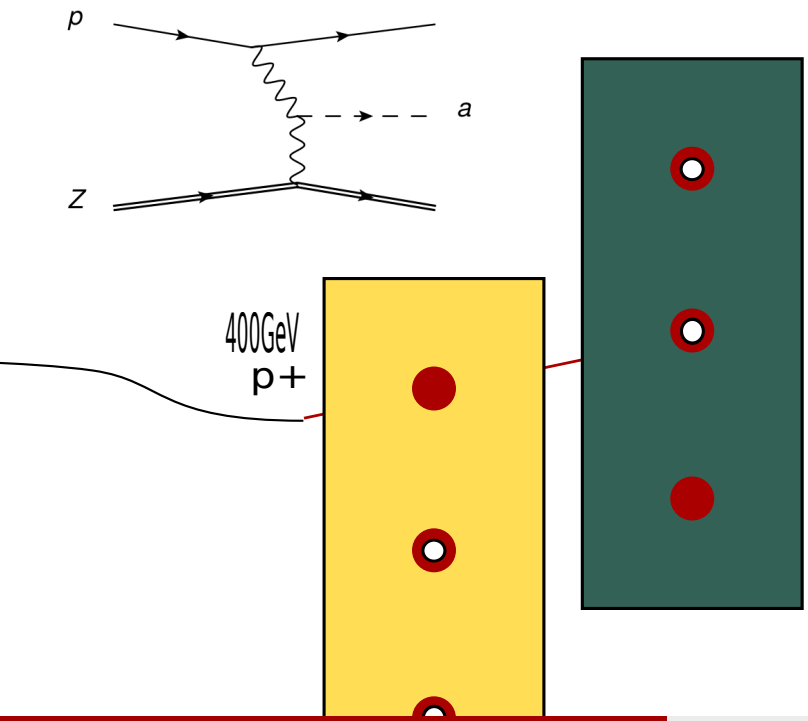


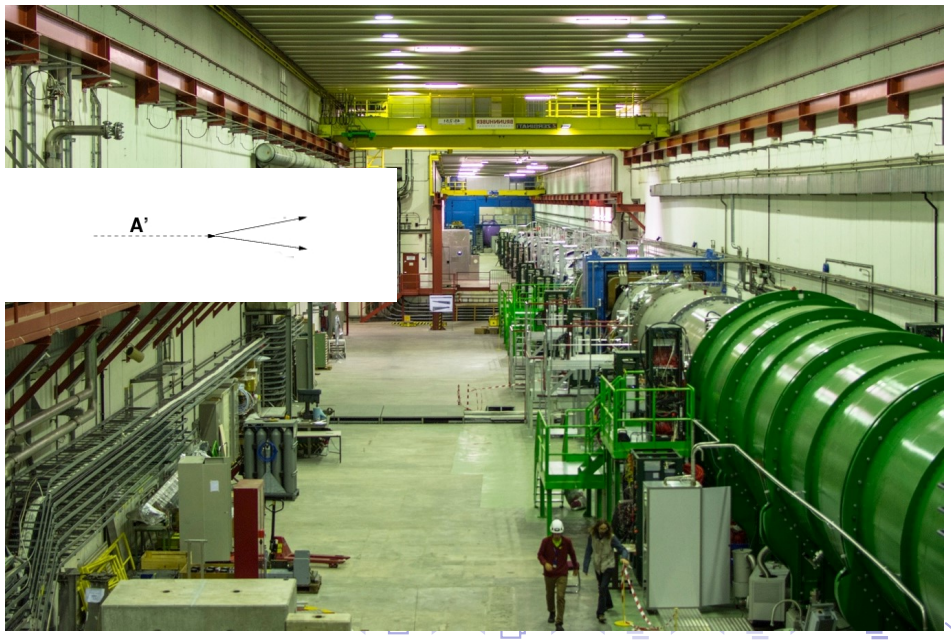
NA62 'pure' dump mode (no Kaon physics!)

from 2016/2017 data:

$\mathcal{O}(10^{16})$ POT from pure dump

critical for e.g. $\gamma\gamma$ final state





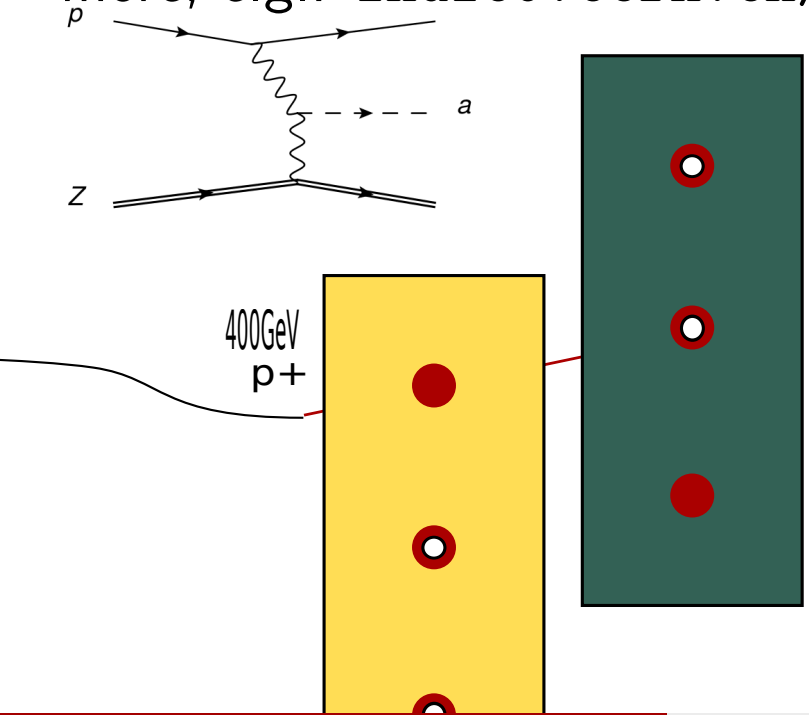
NA62 'pure' dump mode (no Kaon physics!)

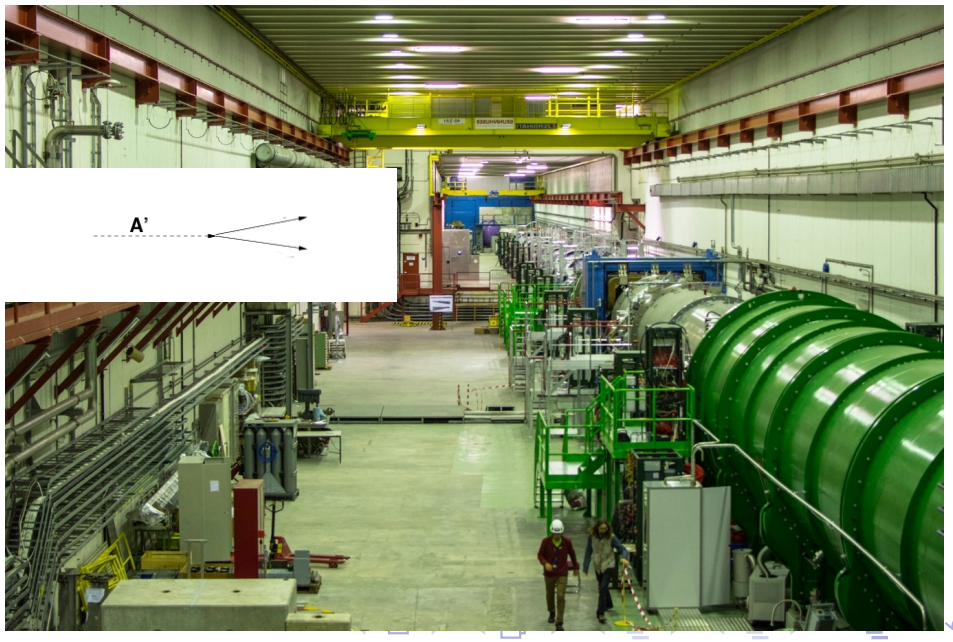
from 2016/2017 data:

$\mathcal{O}(10^{16})$ POT from pure dump
critical for e.g. $\gamma\gamma$ final state

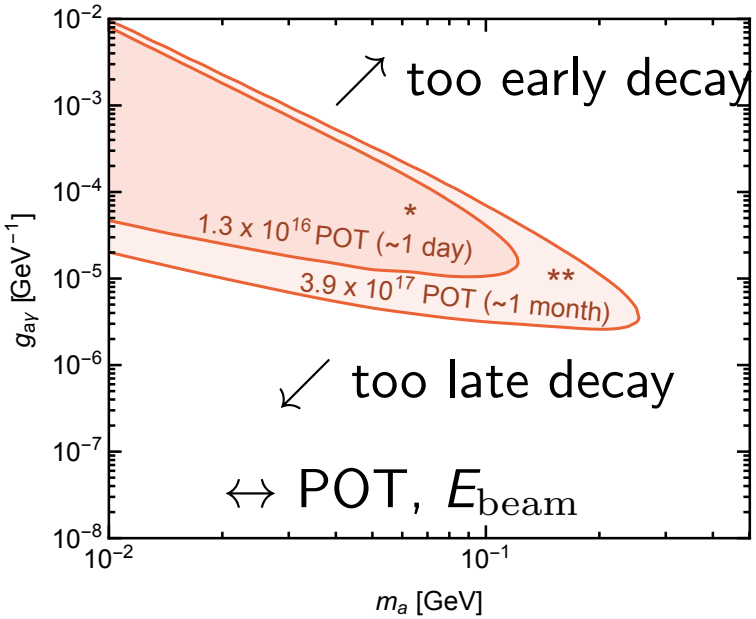
in future $\leq$ 2023 $\rightarrow \mathcal{O}(10^{18})$ POT
sensi to HNL, Dark Photon, ALP...

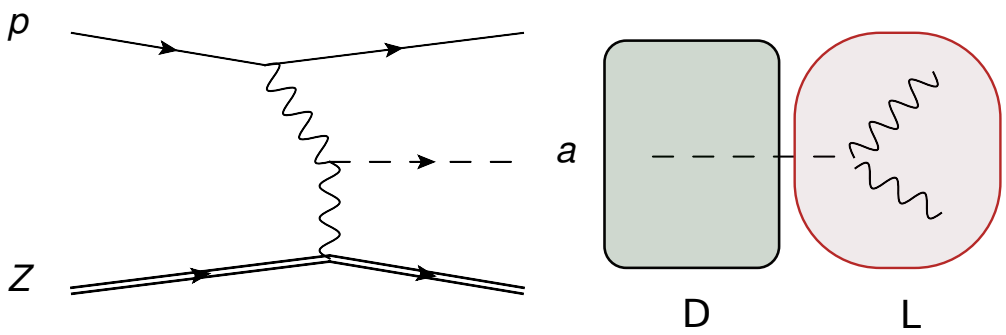
more, e.g.: `indico.cern.ch/event/608491/contributions/2457796/`





Detailed example: understanding ALP contours





[JHEP 1602, 018]

- production is not exactly forward (but not relevant for the moment)
- NA62: $d_{\rm target} \sim 105$m, $d_{\rm TAX} \sim 80$m, $L_{\rm tracker} \sim 65$m

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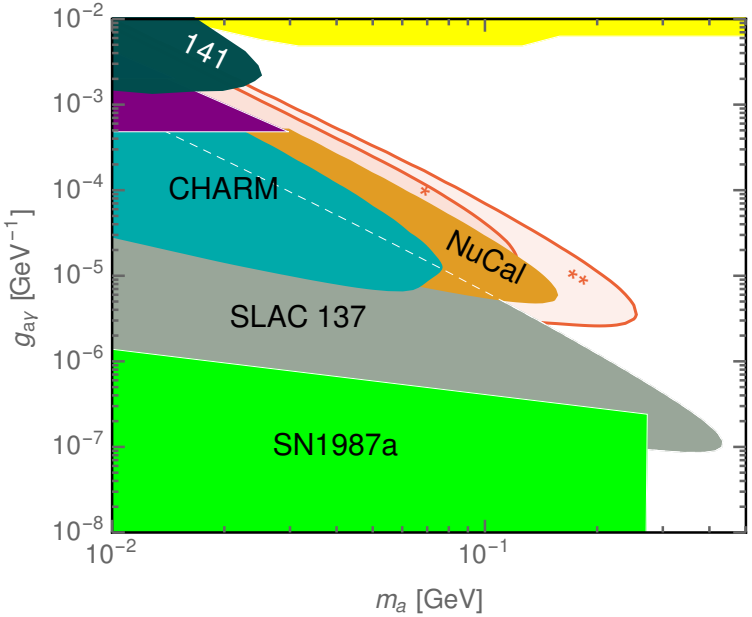

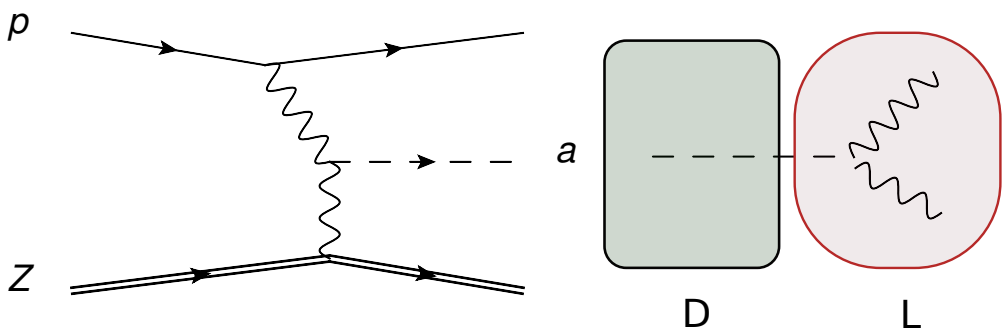

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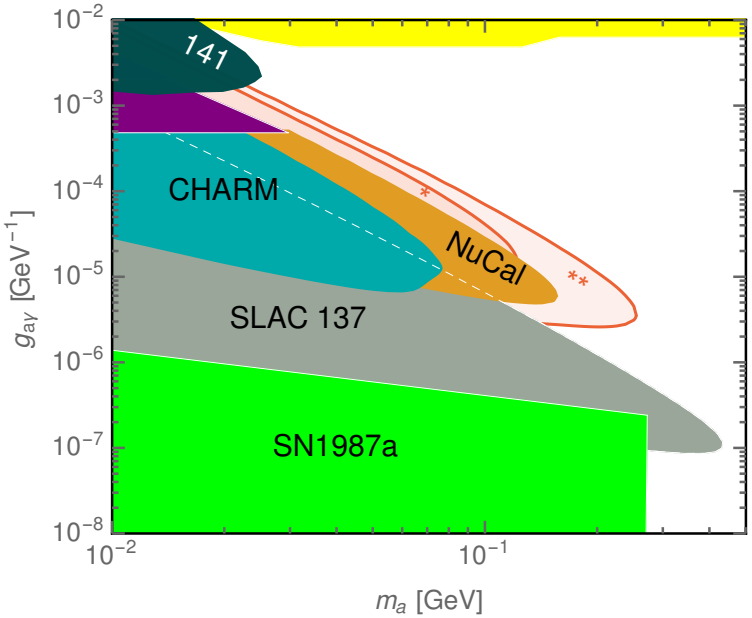
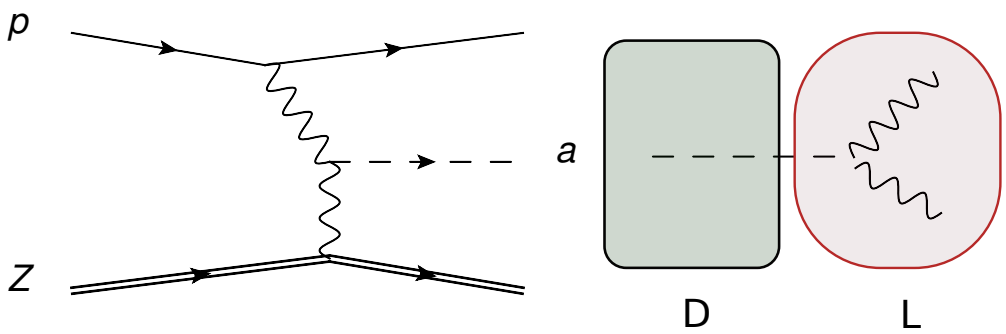
- CHARM: $d_{\mathrm{dump}} \sim 480$m, $L_{\mathrm{tracker}} \sim 35$m **but** offset 5m from beam-axis $\rightarrow A_{\mathrm{effective}} = 0.09 \rightarrow N_{\mathrm{POT,effective}} \sim 2 \times 10^{17}$
- NuCal: $d_{\mathrm{dump}} \sim 64$m, $L_{\mathrm{tr.}} \sim 23$m, $N_{\mathrm{POT}} \sim 2 \times 10^{18}$ **but** $E = 70$GeV

Detailed example: understanding ALP contours





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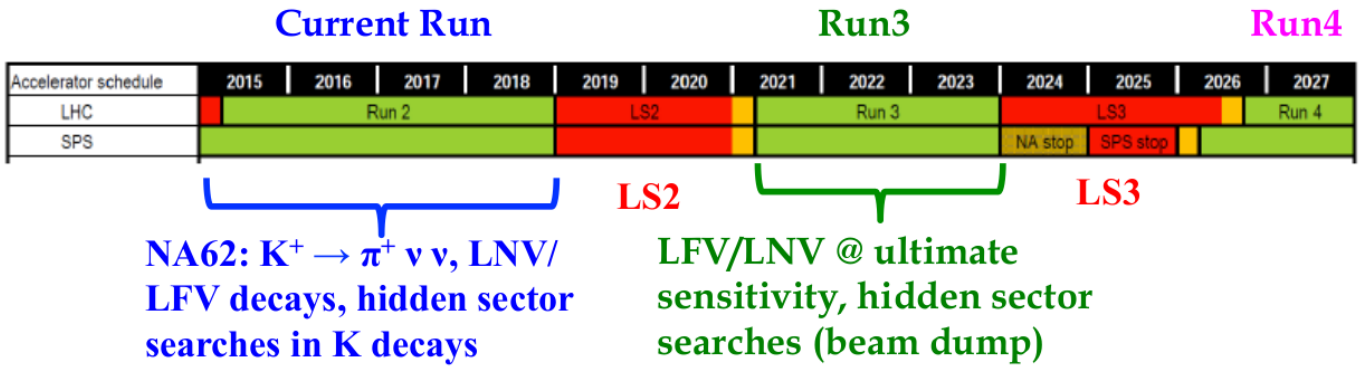
- NuCal: $d_{\mathrm{dump}} \sim 64$m, $L_{\mathrm{tr.}} \sim 23$m, $N_{\mathrm{POT}} \sim 2 \times 10^{18}$ **but** $E = 70$GeV
- general picture persists for two tracks $\rightarrow$ reason for parasitic triggers: complementary sensitivity also, e.g. for ALPs to $\mu\mu$ + others

LLPs at NA62 in a nut-shell

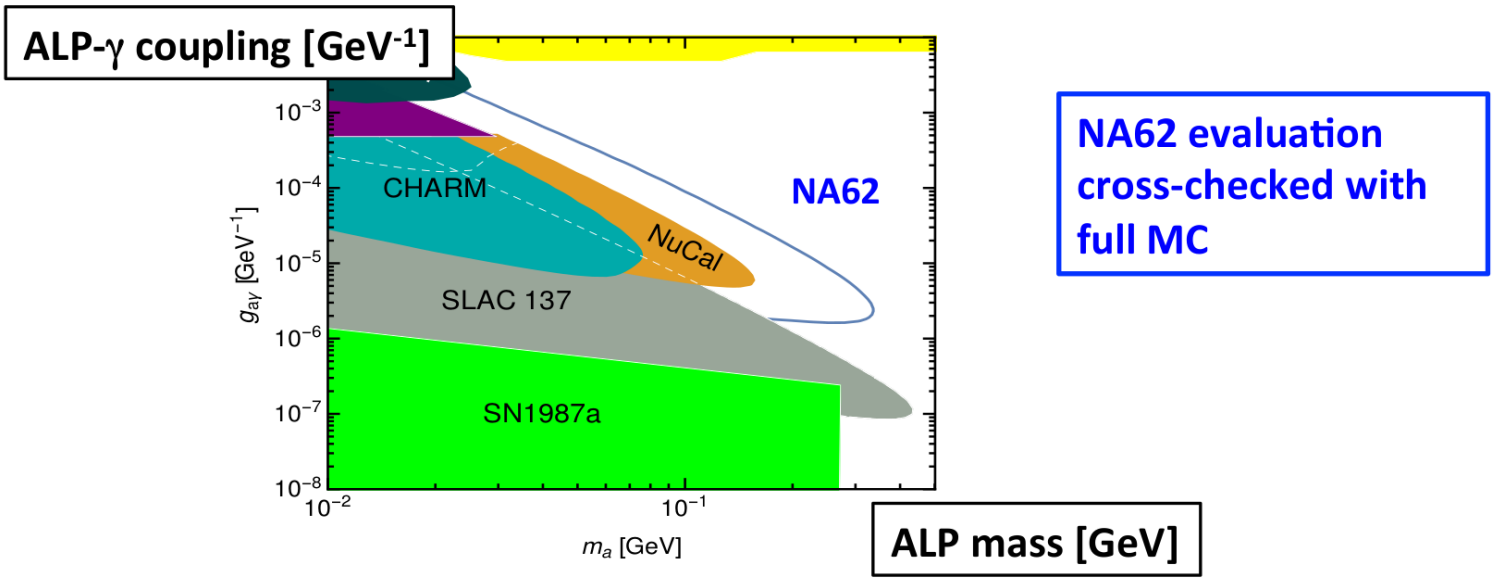
1. Parasitic to $\pi\nu\bar{\nu}$: invisible Dark Photons, heavy Neutrinos...
2. Trigger Parasitic to $\pi\nu\bar{\nu}$: $\mu\pi + \mu\mu$ away from beamline: sizable statistics $\mathcal{O}(10^{18})$ possible this year
3. dump-mode: sizable statistics $\mathcal{O}(10^{18})$ reserved for future, but some channels discovery potential with moderate statistics (e.g. ALP $\mathcal{O}(10^{16})$)



Under study / definition, interaction/synergy with the Physics Beyond Collider CERN initiative

$\Rightarrow$ In the following: "long-lived" prospects at $\mathcal{O}(10^{18})$ POT

ALPs coupled to photons

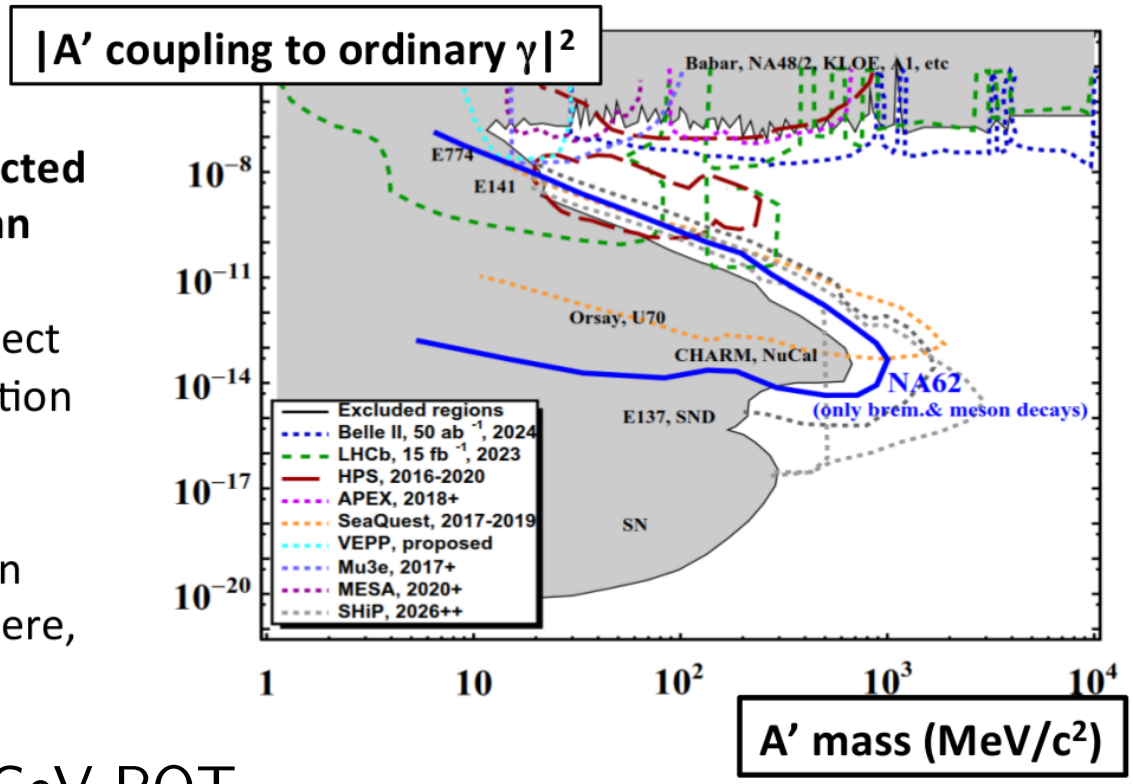


- Assume 10^{18} 400-GeV POT
- As in the detailed example given before: based on Primakov production and 0 background

Dark Photons

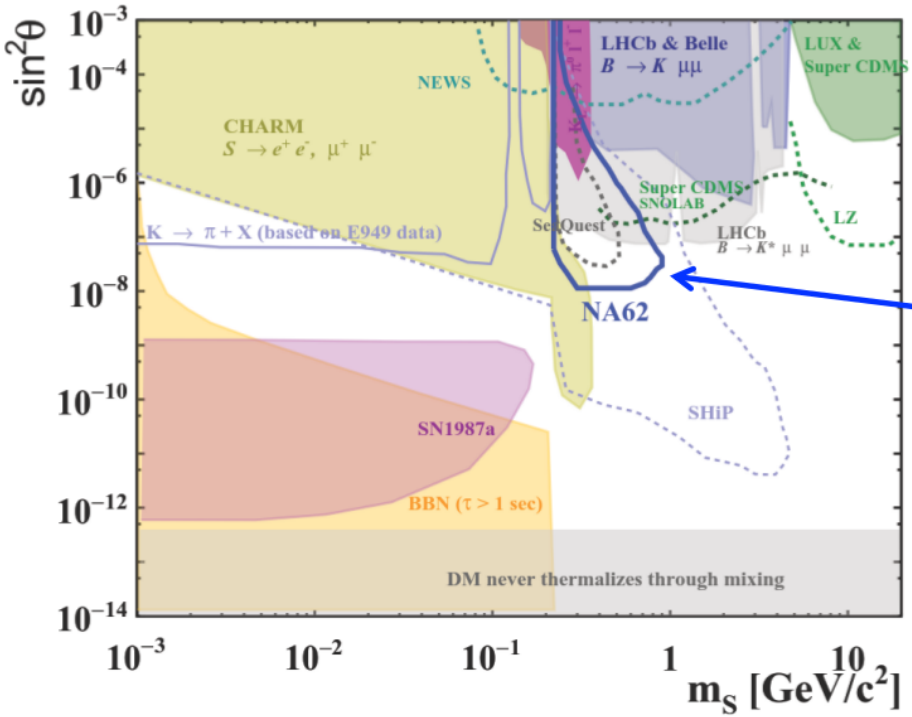
Sensitivity expected to be higher than shown:

1. including direct QCD production of A'
2. Including A' production in the dump (here, only target)



- Assume 10^{18} 400-GeV POT
- Study DP production (meson decays, bremsstrahlung) from interaction on target, search for ee, $\mu\mu$
- assume zero background, expected 90%-CL exclusion plot

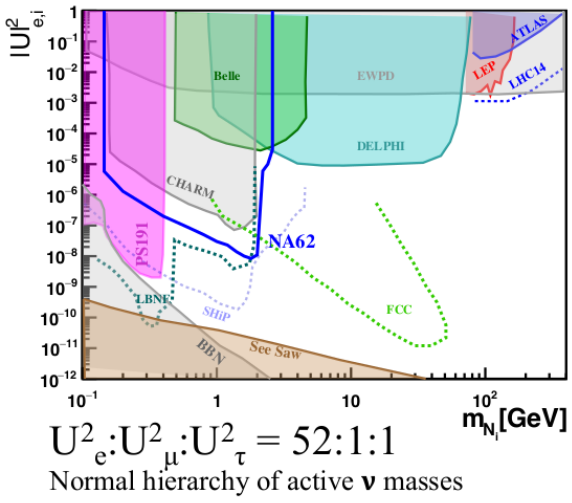
Dark Scalars



NA62 projected sensitivity dominated by beauty production

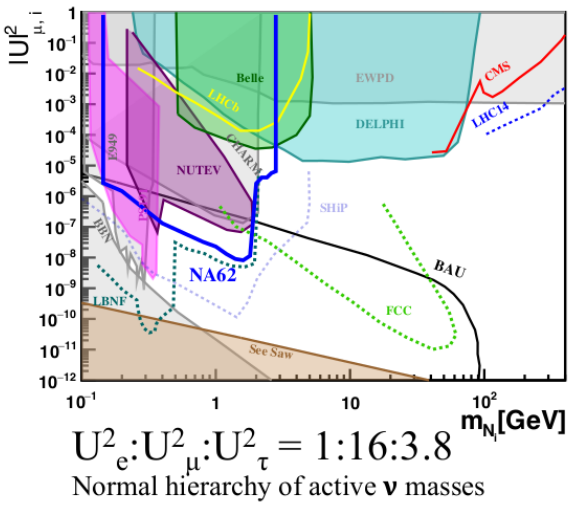
- Assume 10^{18} 400-GeV POT
- sensivity to hidden scalars charged decays search for ee, $\mu\mu$, $\pi\pi$, KK two-track final states originating at the TAX
- assume zero background, expected 90%-CL exclusion plot

HNLs



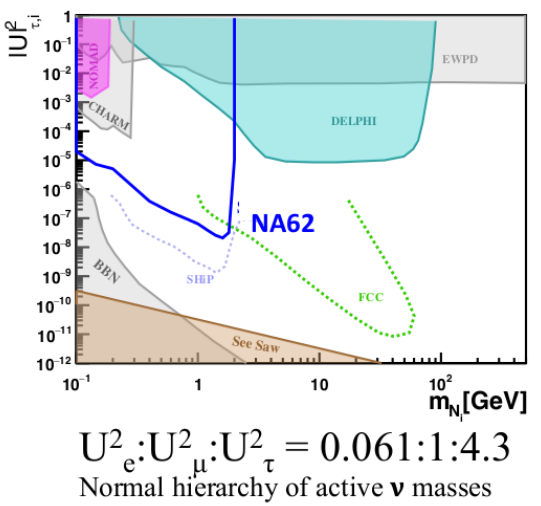
$U^2_e : U^2_\mu : U^2_\tau = 52:1:1$

Normal hierarchy of active ν masses



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

Normal hierarchy of active ν masses

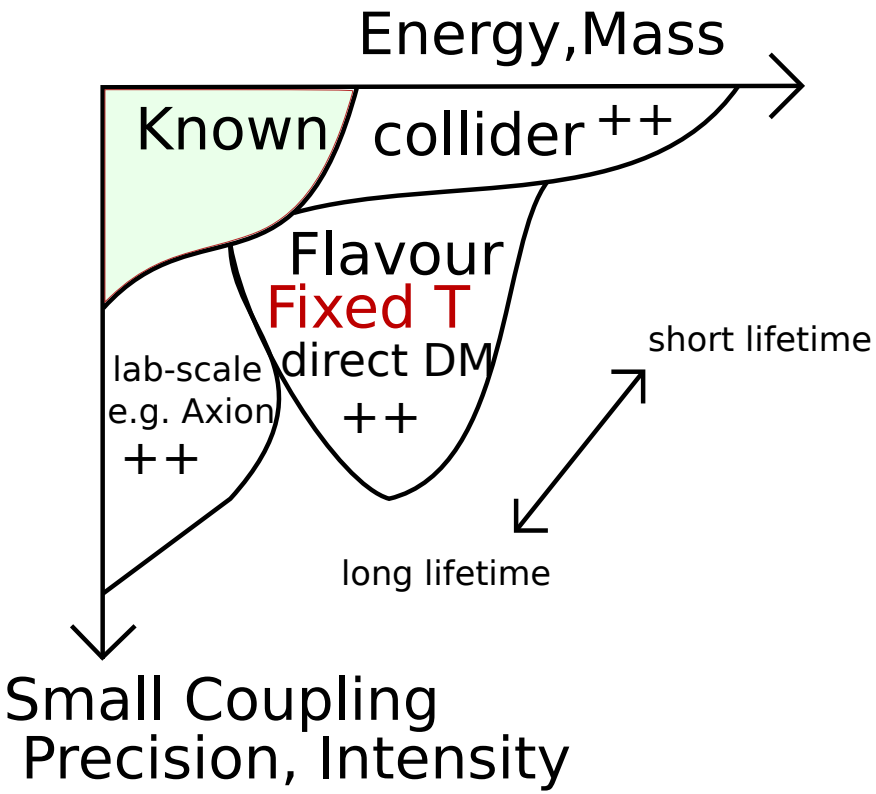


$U^2_e : U^2_\mu : U^2_\tau = 0.061:1:4.3$

Normal hierarchy of active ν masses

- Assume 10^{18} 400-GeV POT: search for two-track final states originang at the TAX sensivity includes open channels, assuming 0 background
- separately address 3 extreme coupling scenarios [Shaposhnikov, Gorbunov arXiv:0705.1729v2]
- assume zero background, evaluate expected 90%-CL exclusion plot

Let's explore the unknown together :-)



NA62: 2016 data analyzed for $K^+ \to \pi^+ \bar{\nu}\nu$, 2017 analysis on the way, 2018 data taking ongoing.

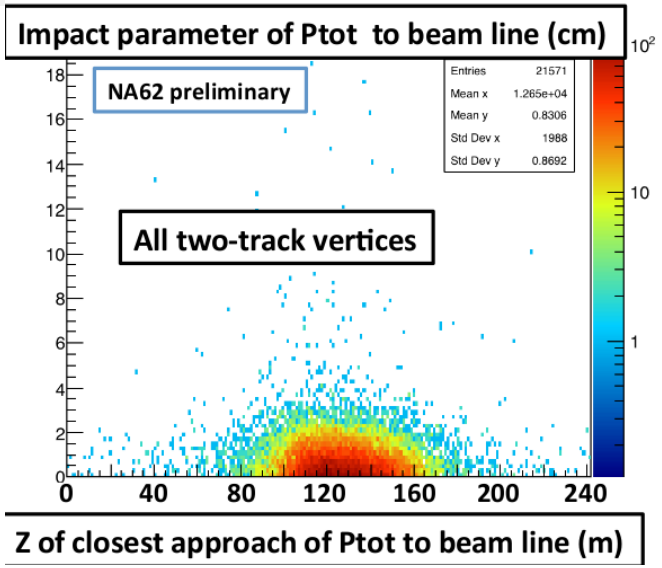
In addition,

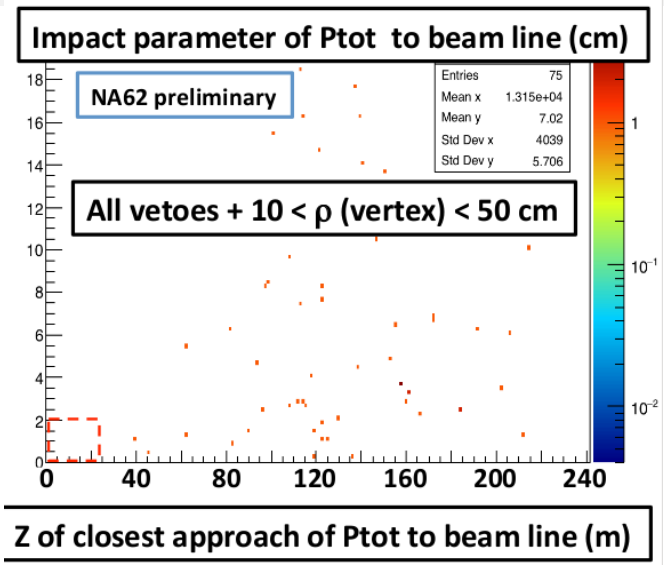
- before LS2: $\pi\bar{\nu}\nu$-parasitic triggers/searches + short dedicated beam-dump runs
- after LS2, a year-long data taking would provide sensitivity to various LLPs

Thank you for your attention!

Backup

Background rejection: 2016 data $\mathcal{O}(10^{15})$ POT





- Track quality (association with CHOD, LKr hits in time) + acceptance (CHOD, LKr, MUV3)
- Vertex quality: two-track-distance $<$ 1cm, vertex-position $105 < z < 165$ m
- further veto (rhs): $E_{\mathrm{LKr,additional}} < 2$ GeV; IRC, SAC, LAV no hits with $\pm$ 5ns, CHANTI no candidate within $\pm$ 5ns
- no events in signal region at TAX even with standard K^+ beam at $\mathcal{O}(10^{15})$ POT, background rejection OK for $\mathcal{O}(10^{15})$ POT in standard conditions and $4 \times \mathcal{O}(10^{15})$ in dump