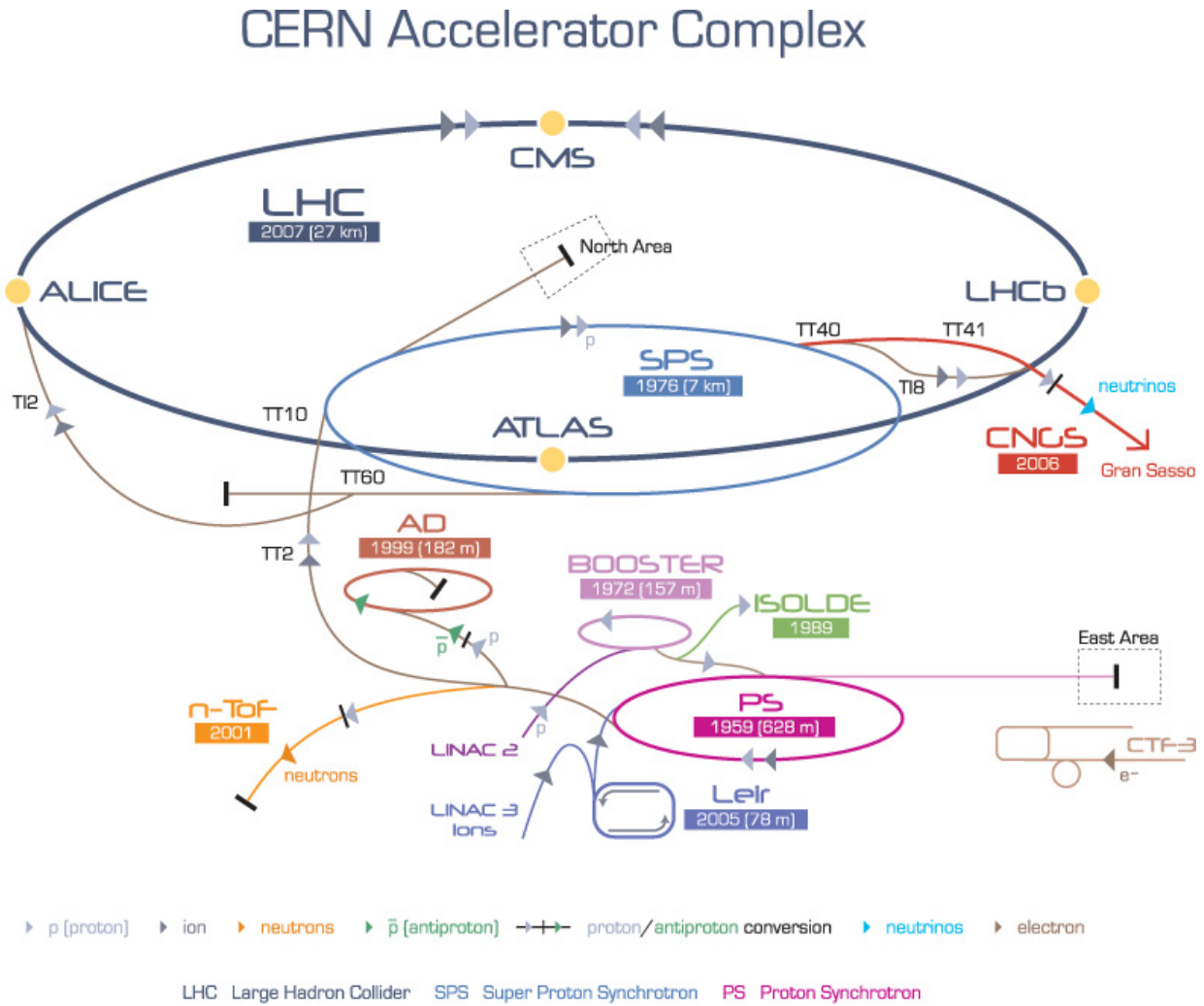
Results and Status of NA62

with emphasis on weakly coupled BSM particles

Babette Döbrich (CERN) for the collaboration

Thessaloniki, 16/05/17

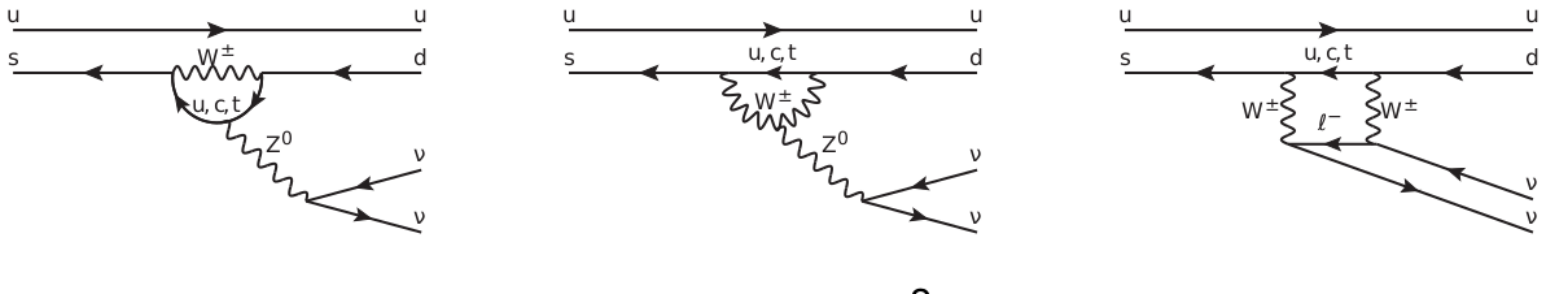
CERN North Area



CERN North Area

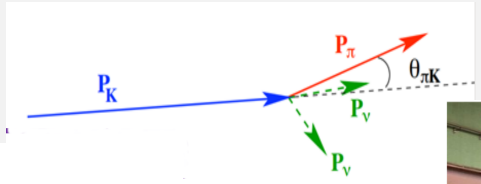
$\sim$ 200 participants from Birmingham, Bratislava, Bristol, Bucharest, CERN, Dubna, Fairfax, Ferrara, Firenze, Frascati, Glasgow, Liverpool, Louvain, Mainz, Merced, Moskow, Napoli, Perugia, Pisa, Prague, Protvino, Roma I, Roma II, San Luis Potosi, Sofia, Torino, TRIUMF, Vancouver UBC

$K \to \pi\nu\bar{\nu}$: motivation and state of art



- Very rare FCNC decay, theory prediction:
  $(K \to \pi\nu\bar{\nu}) = (8.4 \pm 1.0) \times 10^{-11}$ Buras et al. JHEP 1511, 33
- experiment at BNL, E949 (2008), stopped Kaons:
  $\mathrm{BR}(K \to \pi\nu\bar{\nu}) = (17.3^{+11.5}_{-10.5}) \times 10^{-11}$ Phys. Rev. D 79, 092004
- NA62 goal: measure at 10% level with 10% signal acceptance in ~ 2 years of data (decay in flight) $\Rightarrow$ ($10^{13} K^+$ in fiducial volume)
- BR sensitive to new physics & correlated with flavor observables

NA62 rationale

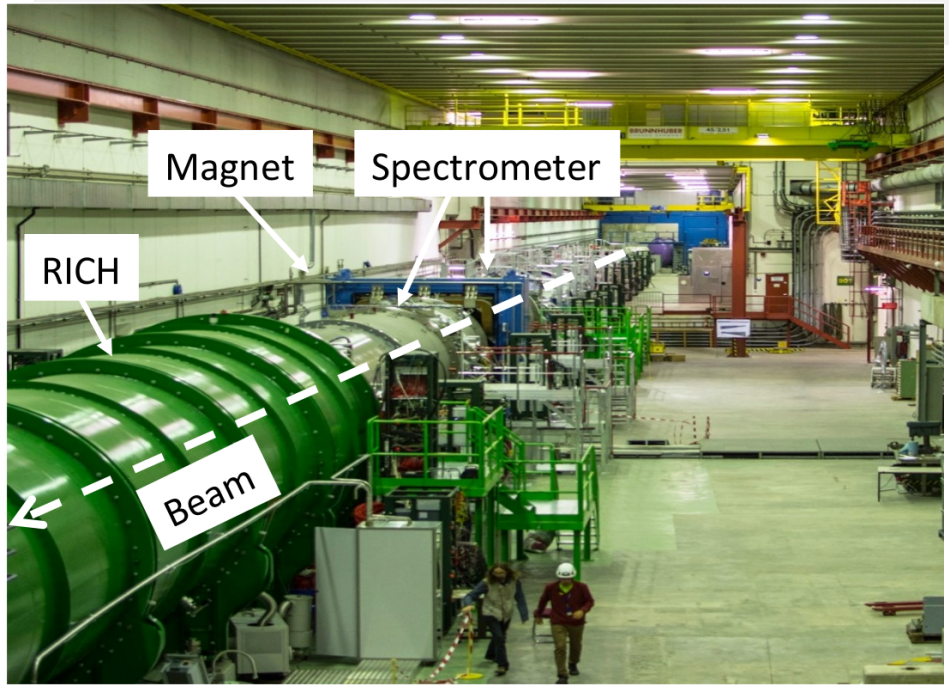


A Kaon's life:

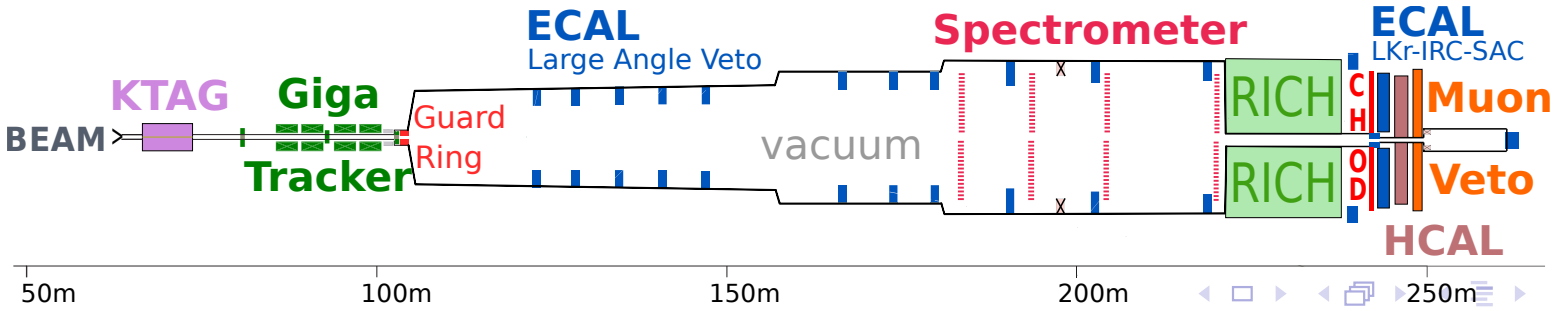
- BR($K \to \pi^+\pi^0$) $\simeq$ 0.21
- BR($K \to \mu^+\nu$) $\simeq$ 0.64
- BR($K \to \pi^+\pi^-\pi^+$) $\simeq$ 0.06

Detector system

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



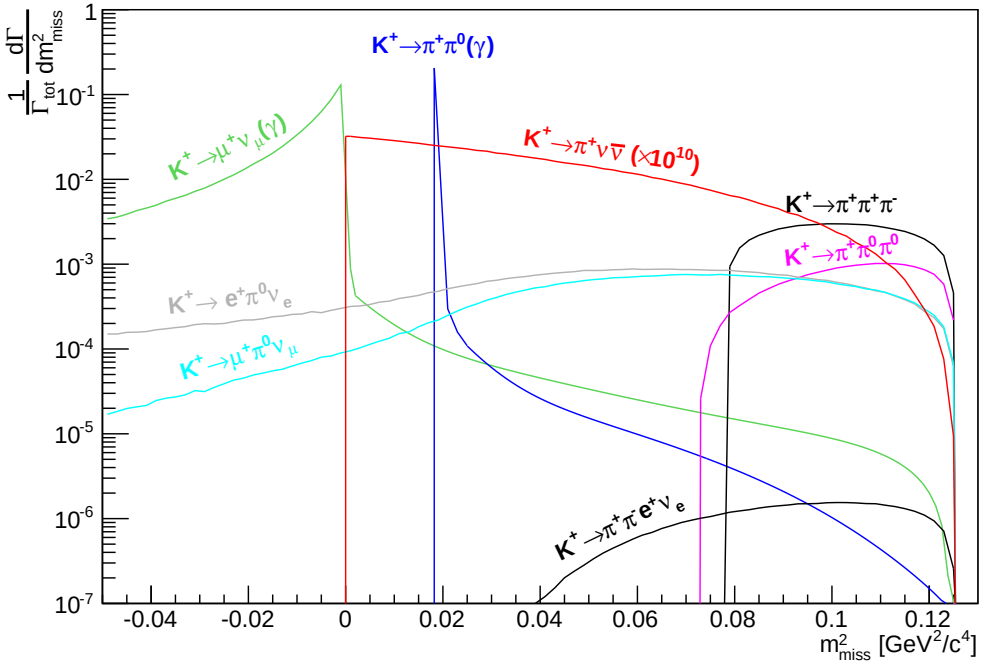
unseparated 750 MHz beam at GTK3
(6.6 % Kaons at 75 GeV, 1 % bite)

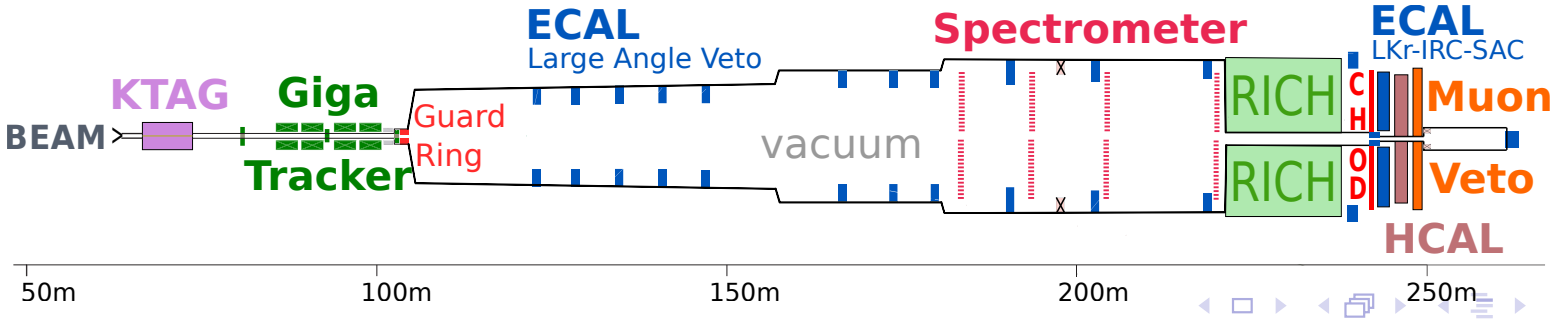


NA62 rationale II

↓ ↓ 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 $\mathcal{O}(100\text{ps})$

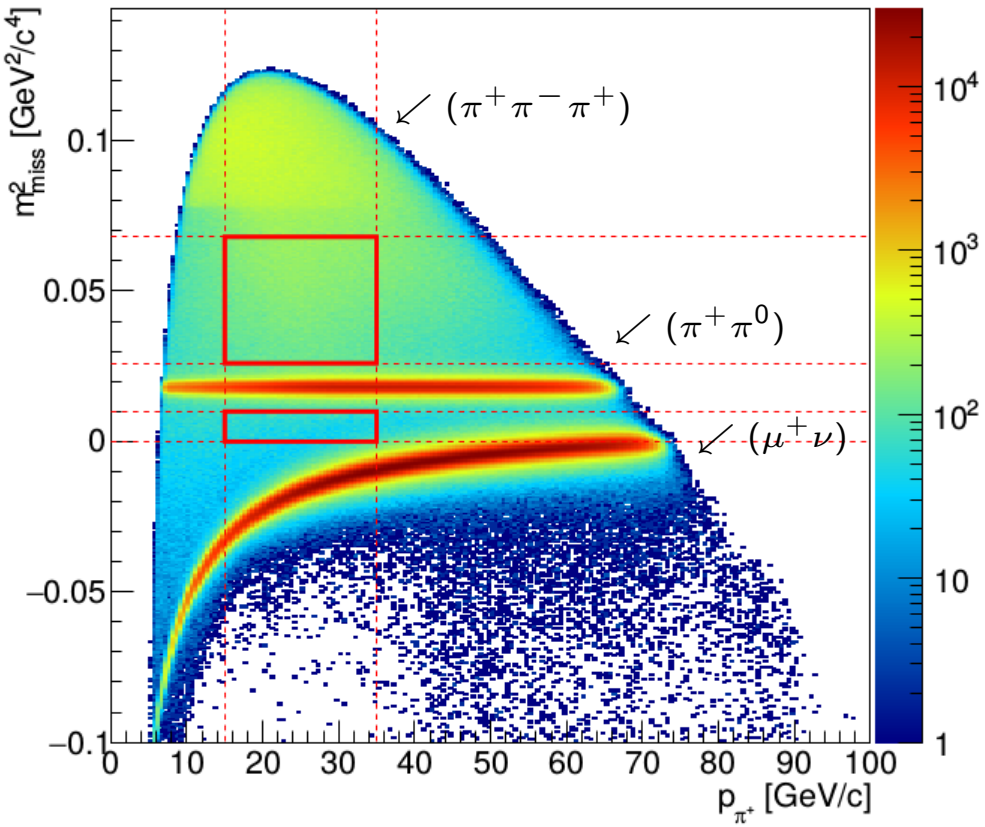




2016 $\pi\nu\bar{\nu}$ status

- CERN-SPSC-2017-013/SPSC-SR-208
- Preliminary analysis of $\sim$ **5% of 2016 data** ($\sim 2.3 \times 10^{10} K^+$ decays)
- Period starting September 15th

Data 2016



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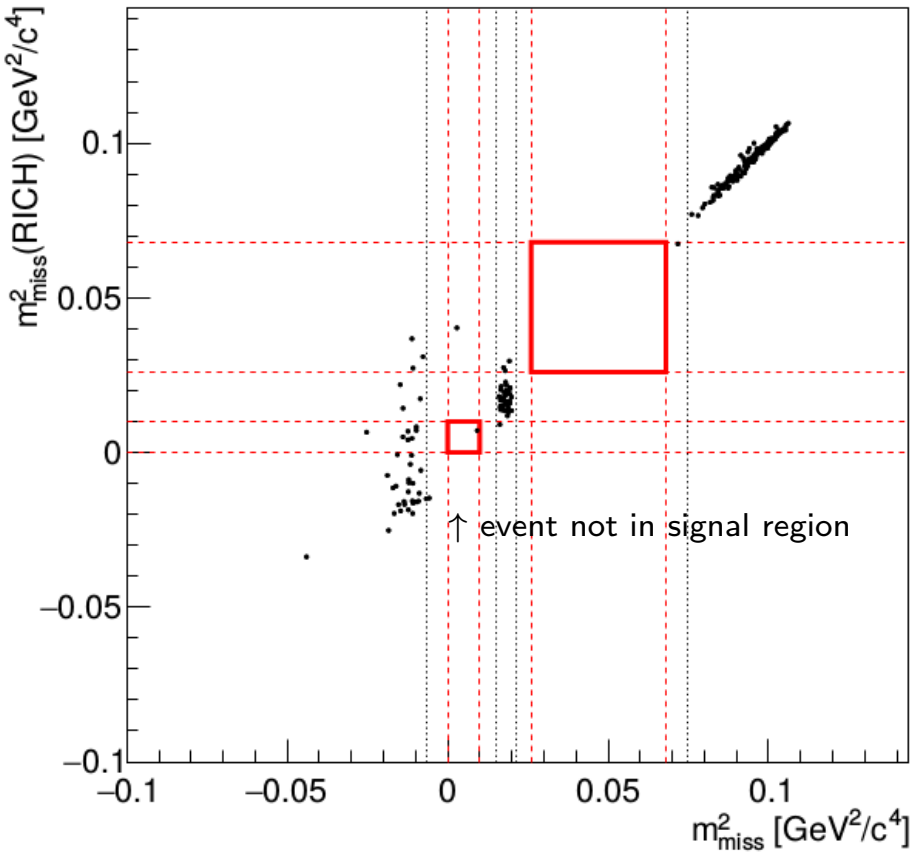
- Period starting September 15th
- 3-d $m^2_{\rm miss}$ supression of kinematic tails
- Signal efficiency and background rejection improvements possible

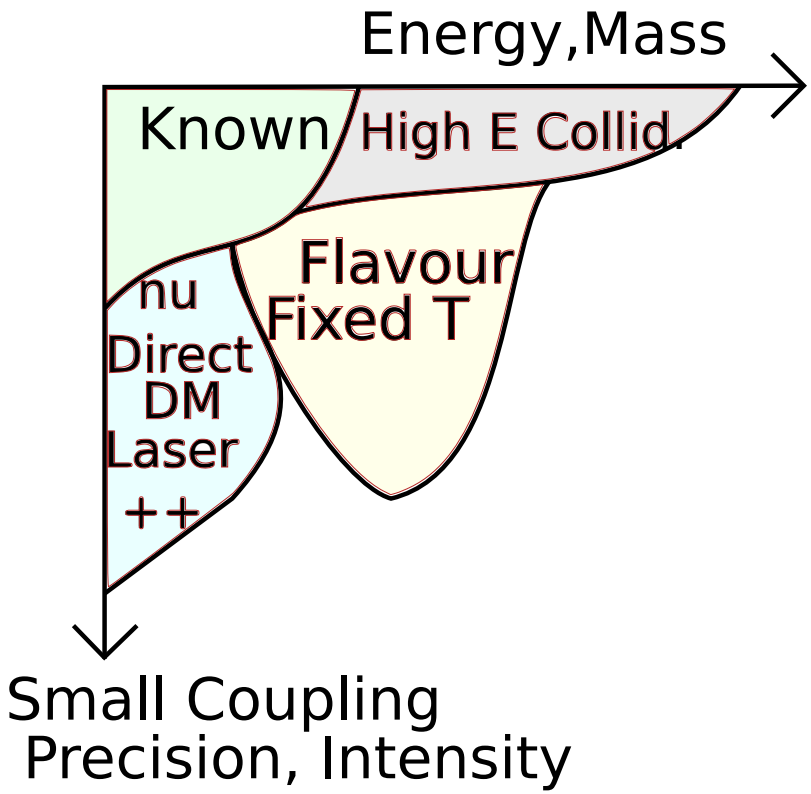
Data 2016, $\pi\nu\bar{\nu}$ trigger



expected Signal # (computed from ctrl trigger): 0.064, bkg: 0.052

BSM searches with K^+ beam: Dark Photon

- NA62 intense hadron beam opportunity for rare/forbidden decays + Dark Sector Physics



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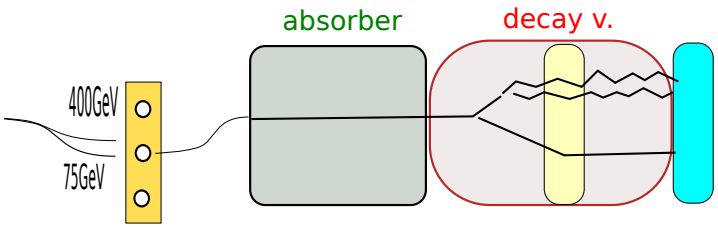
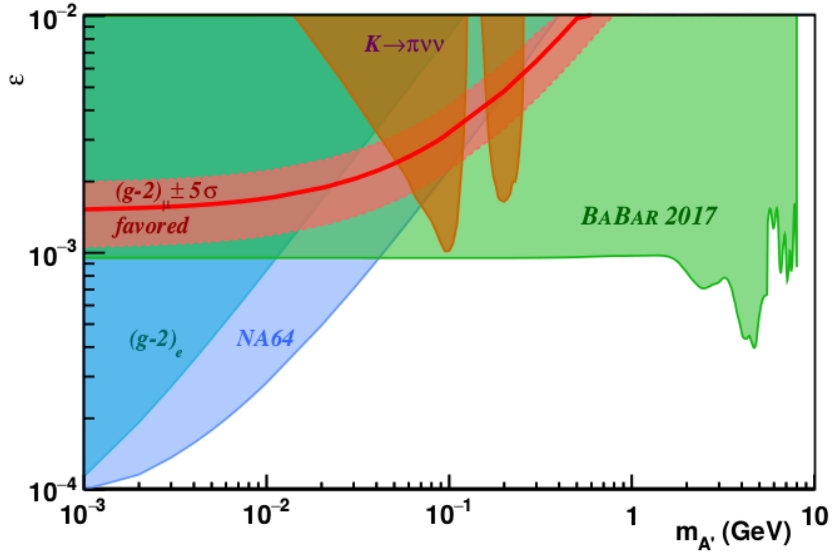
- Dark Photon $A' \rightarrow$ invisible sparked interest w interpretation of muon (g-2) anomaly
- NA62: utilize $K^+ \rightarrow \pi^0\pi^+$ with $\pi^0 \rightarrow A' + \gamma$



from [1702.03327]



- $\mathrm{BR}(\pi^0 \rightarrow A'\gamma) = 2\,\epsilon^2\left(1 - m'^2_A/m^2_{\pi^0}\right)^3 \times \mathrm{BR}(\pi^0 \rightarrow \gamma\gamma)$

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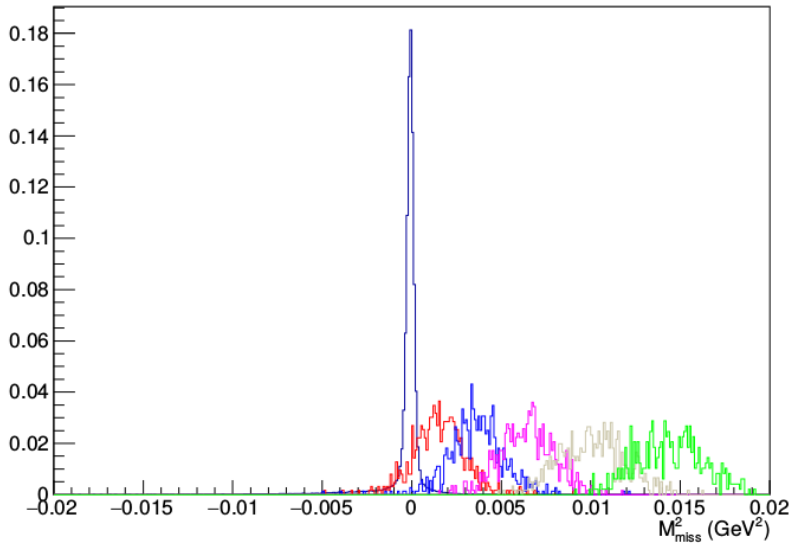
- search peak in missing mass of $m^2_{\text{miss}} = (P_K - P_\pi - P_\gamma)^2$

Monte Carlo for masses 40-120 MeV



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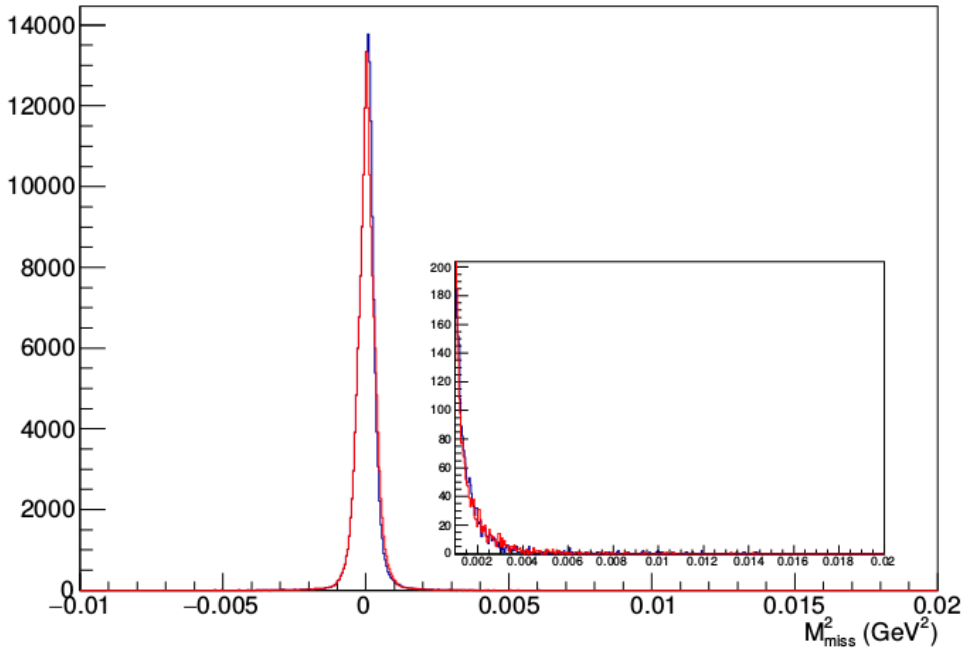
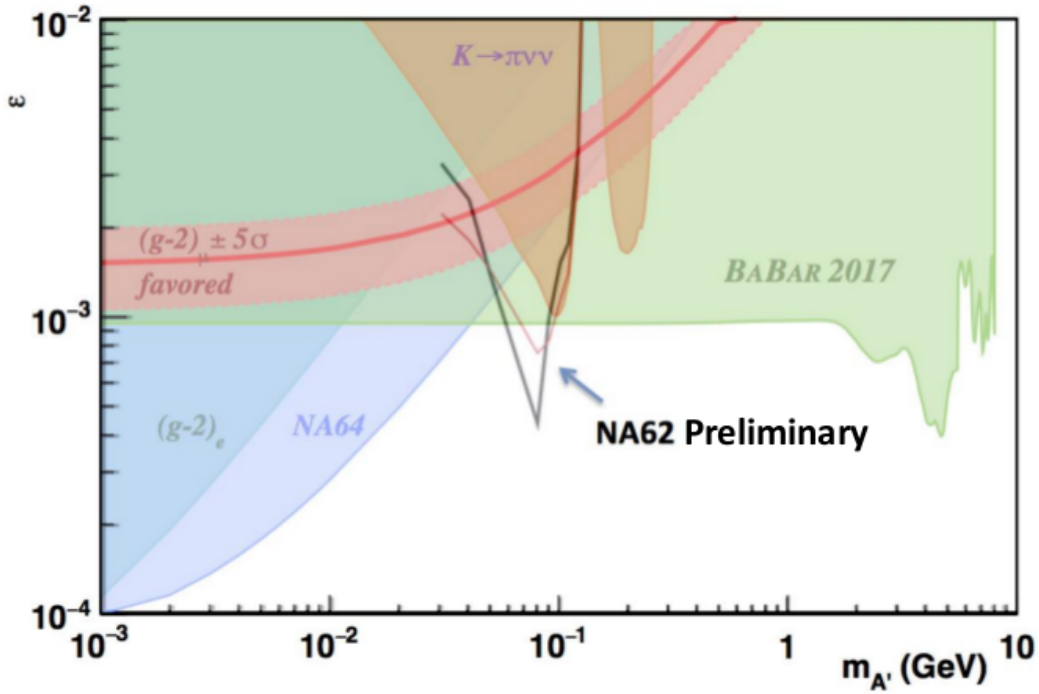
- search peak in missing mass of $m^2_{\text{miss}} = (P_K - P_\pi - P_\gamma)^2$
- data-driven background estimate (peak resolution mostly left-right-symmetric)

Data 2016



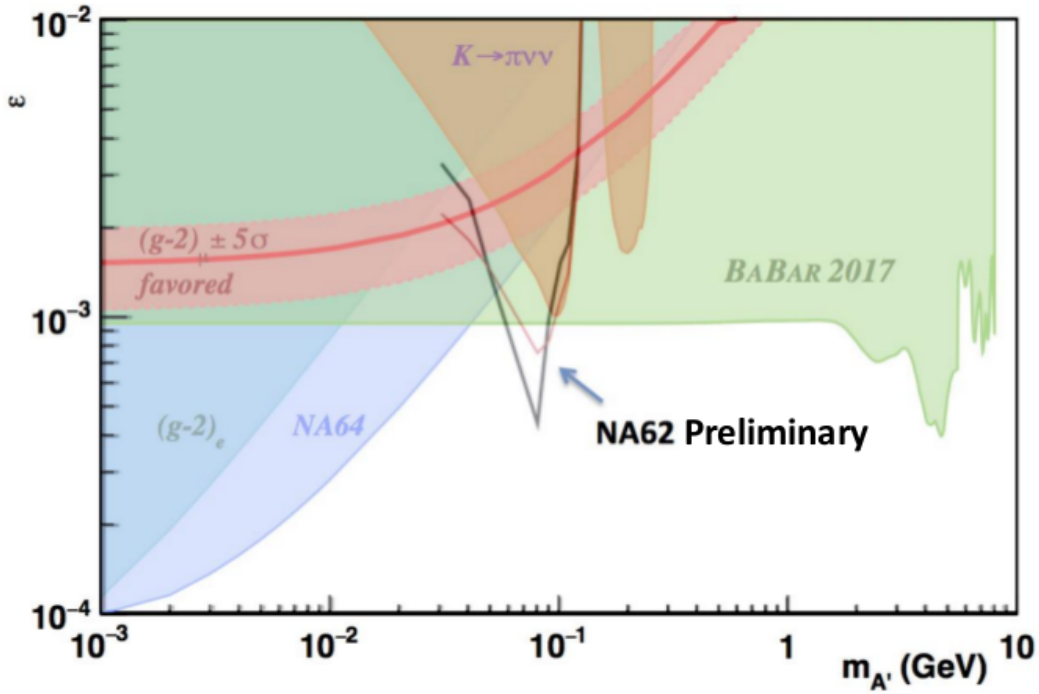
BSM searches with K^+ beam: Dark Photon

- no statistically significant excess observed in $\sim 1.5 \times 10^{10} K^+$ decays
- possibility to set limits at 90% confidence level

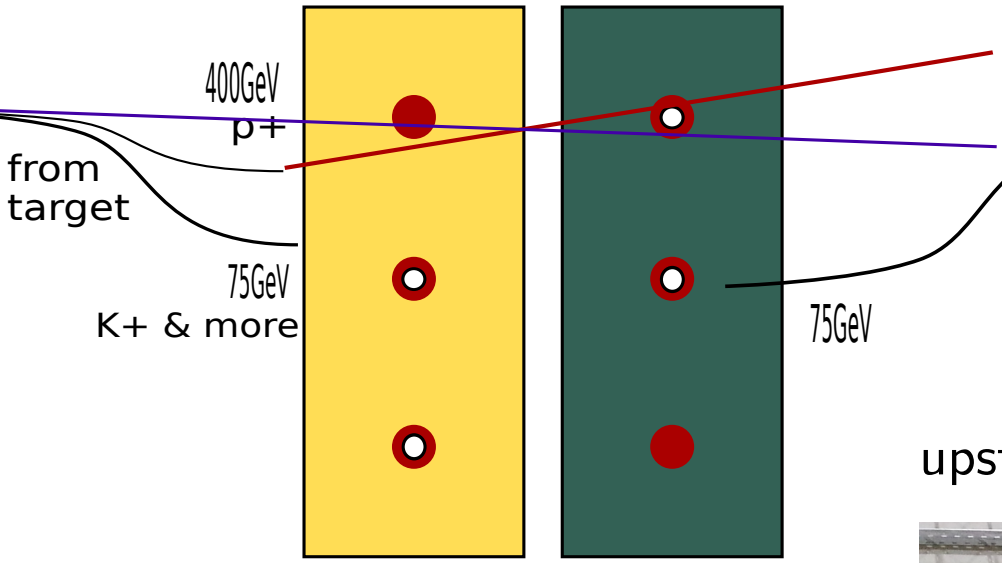


BSM searches with K^+ beam: Dark Photon

- no statistically significant excess observed in $\sim 1.5 \times 10^{10} K^+$ decays
- possibility to set limits at 90% confidence level
- further 2016 BSM with beam studies ongoing (e.g. Lepton-Number-Violating decays)
- more long lived (visibly decaying) 'Dark sector particles': 2016 'dump run'



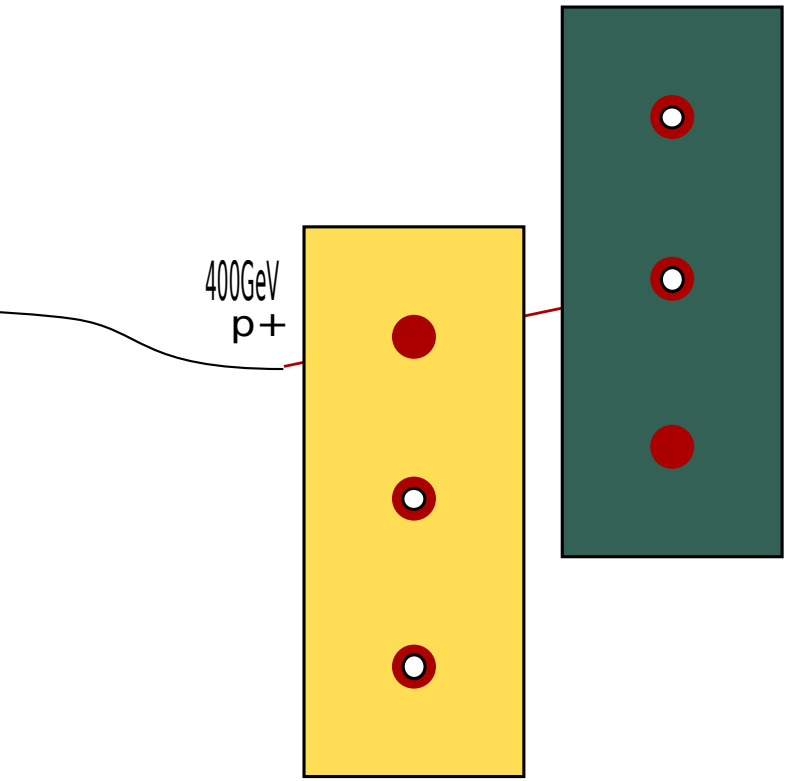
BSM without K^+ beam: Axion-like Particles



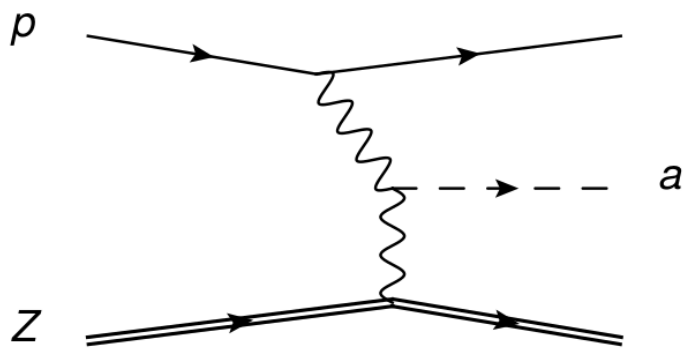
- nominal beam / weakly interacting from decay/ weakly interacting from direct production

upstream TAX system $\sim$ 80m before fiducial

BSM without K^+ beam: Axion-like Particles

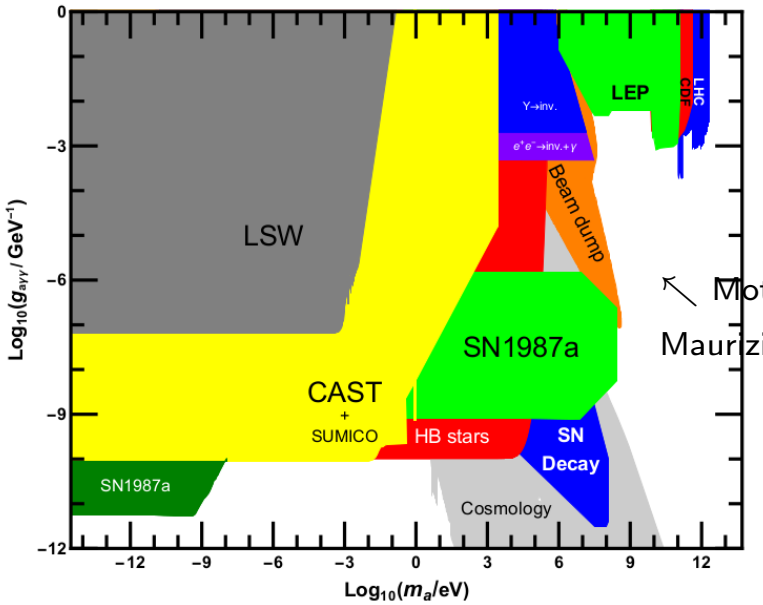


- nominal beam / weakly interacting from decay/ weakly interacting from direct production
- dump complete beam by closing collimator, removing Be target



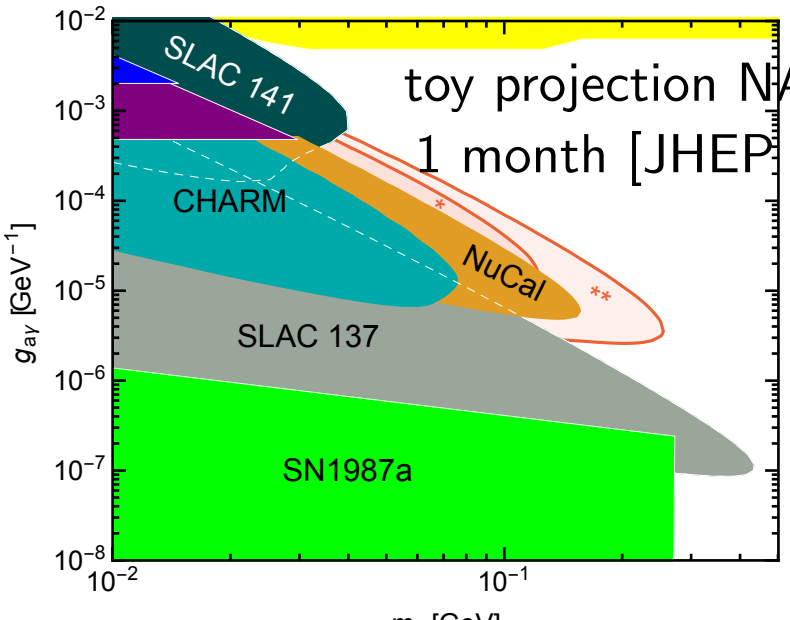
possibility of ALP production in collimator

BSM without K^+ beam: Axion-like Particles



[1702.02964]

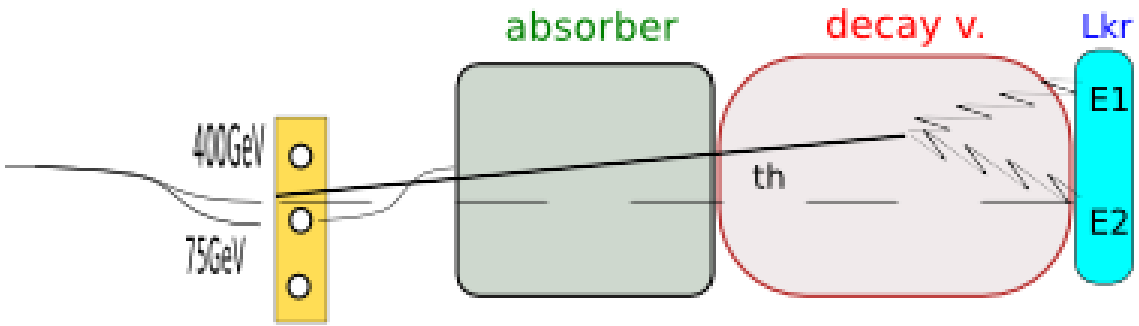
↖ Motivation see talks: Maurizio + Rocio

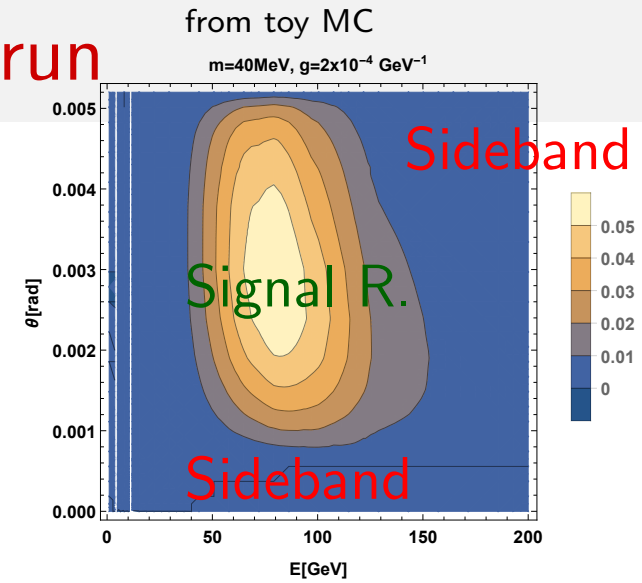


toy projection NA62 **1 day** + 1 month [JHEP 1602, 018]

- nominal beam / weakly interacting from decay/ weakly interacting from direct production
- dump complete beam by closing collimator, removing Be target
- data set November 2016: $\sim 2.5 \times 10^{15}$ POT, triggering with ECAL ≥ 3 GeV
- Reconstructing NA62 Spectrometer to veto charged Halo μ up to 400 GeV
- for Axion-like-particle search, this is competitive statistics

Axion-like Particles from 2016 dump run





- **problem:** photon is not tracked: know only E_1, E_2, d in Ecal, need to impose mass or decay point to discriminate
- **mitigation:** only extend beyond existing limits at small l_d: decay in absorber $\sim \exp(-l_{\mathrm{abs}}/l_d)$, $l_d = \gamma\beta\tau \sim \frac{E_a}{m}\frac{64\pi}{m^3 g^2}$
- yields the ALPs in reach **highly boosted** $E_a = E_{\gamma 1} + E_{\gamma 2}$
- their barycenter enclose a (computable) non-zero **angle** θ
- compare **charged sample in side-band**, deduce **expected background in signal region** $\rightarrow$ optimization of signal efficiency for (g, m) in full MC on the way

Thanks for listening :-)

- NA62 detectors fully working, 2017 run commenced yesterday! :-)
- 2017 $\pi\nu\bar{\nu}$ will profit from improvements on analysis method, and 'more beam'
- Dark photon $\rightarrow$ invisible $\Rightarrow$ competitive preliminary result
- Axion-like particles from dump run under investigation (many other Dark Sector searches possible, visibly decaying DP, HNLs...)
- exciting prospects for $\pi\nu\bar{\nu}$ the next two years and beyond

$\leftarrow$ Prevessin, today

Thessaloniki, today $\rightarrow$

Additional slides

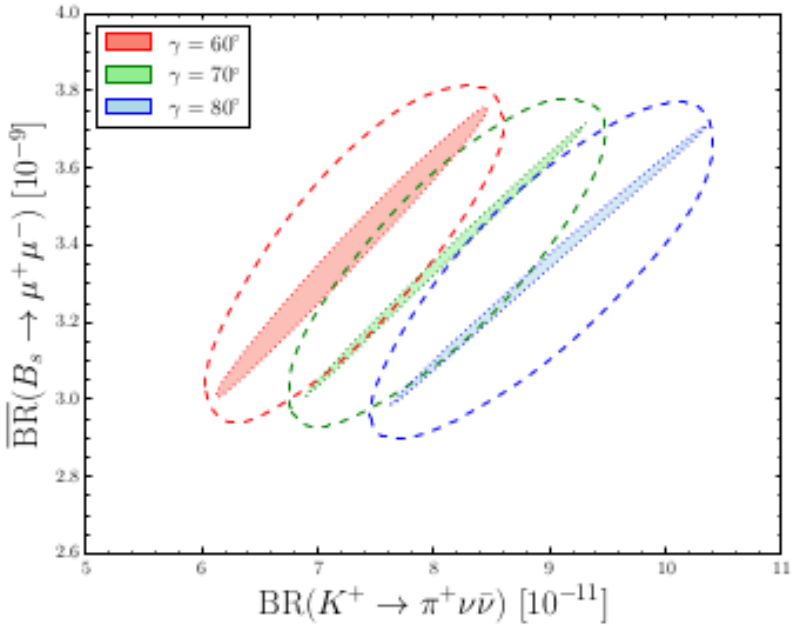
$K \to \pi\nu\bar{\nu}$

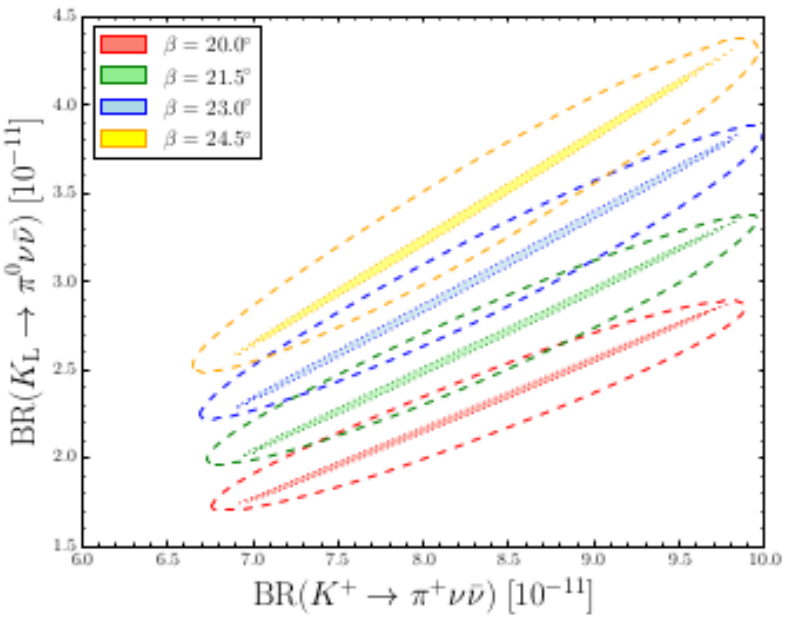
- pure theoretical uncertainty is very small (short distance physics):

$$(K \to \pi\nu\bar{\nu}) = (8.4 \pm 0.3) \times 10^{-11} \left(\frac{|V_{cb}|}{0.0407}\right)^{2.8} \left(\frac{\gamma}{73.2}\right)^{0.74}$$ Buras et al. JHEP 1511, 33

- opportunity to put the SM under unprecedented scrutiny

filled regions using only uncertainties of $|V_{ub}|, |V_{cb}|$





$K \to \pi\nu\bar{\nu}$ 2016 run

Signal

- $N_{\pi\nu\bar{\nu}}^{exp} = D^{ctrl} N_{\pi\pi}^{ctrl} \frac{Br_{\pi\nu\bar{\nu}}}{BR_{\pi\pi}} \frac{A_{\pi\nu\bar{\nu}}}{A_{\pi\pi}} \epsilon^{trig}$
- normalization: $(K \to \pi^+\pi^0)$ ctr. trigger data passing signal selection except photon rejection
- Acceptance factor from MC, D is downscaling factor
- $\epsilon^{trig} \sim 85\%$ (preliminary, measured from data)
- SES below 10^{-9}

Background

- $(K \to \pi^+\pi^0) \to 0.024$
- $(K \to \mu^+\nu) \to 0.011$
- $(K \to \pi^+\pi^-\pi^+) \to 0.017$