Physics cases under study

Search	Physics case	Analysers	Available POT, 10^{17}	Comment
Exotic decays to μμ	Dark photon, ALP fermionic, Dark Scalar	**T. Spadaro**, B. Dobrich, A. Kleimenova	~7.0 [2016/17/18]	Parasitic trg
Exotic decays to πμ	HNL	L. Iacobuzio [UK]	~2.2 [2016/17/18]	Parasitic trg
Exotic decays to charged particles	Dark photon, ALP fermionic, Dark Scalar, HNL	**G. Lanfranchi**	~0.25 [2017+2018]	Beam dump
Exotic decays to πe, ee	HNL	--	0.05 [2016]	Planned trg in 2018
$\pi^0 \rightarrow$ A'(inv) γ	Dark photon invisible	**T. Spadaro, M. Mirra**	2016 data, trigger ννν	**completed**
ALP → γγ	Photon-coupled ALP	**T. Spadaro**, B. Dobrich	0.25 [2017+2018]	Beam dump
Relevant additional activity				
LKr trigger study	ALP->gg	BD, J. Jerhot	0.25 [2017+2018]	Beam dump
Beam G4 MC	All	M. Rosenthal	9 10^{12} POT-equivalent	Beam dump

Obviously 2018 on-going: statistics of individual cases might change

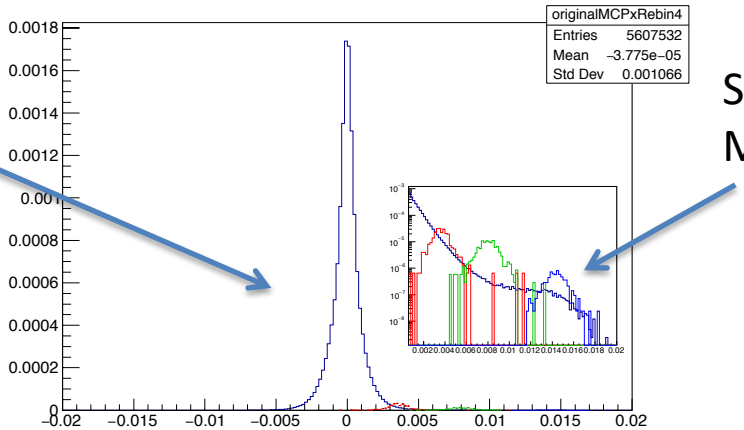
Search for A' to invisible

- Analysis totally Italian
- Detect dark photons, feebly coupled to SM γ via: $L = \varepsilon A^{\mu\nu} F_{\mu\nu}$
- Produce dark photons from the decay chain: $K^+ \rightarrow \pi^+\pi^0$, $\pi^0 \rightarrow A' \gamma$

$$\mathrm{BR}\left(\pi^0 \to A'\gamma\right) = 2\epsilon^2 \left(1 - \frac{m_A^2}{m_{\pi^0}^2}\right)^3 \times \mathrm{BR}\left(\pi^0 \to \gamma\gamma\right)$$

- Assume invisible decay of the A' (or extremely long-lived A')
  - Signature: one photon, **missing mass** peaking around the A' mass

Background:
$K^+ \rightarrow \pi^+\pi^0$, $\pi^0 \rightarrow \gamma\gamma$

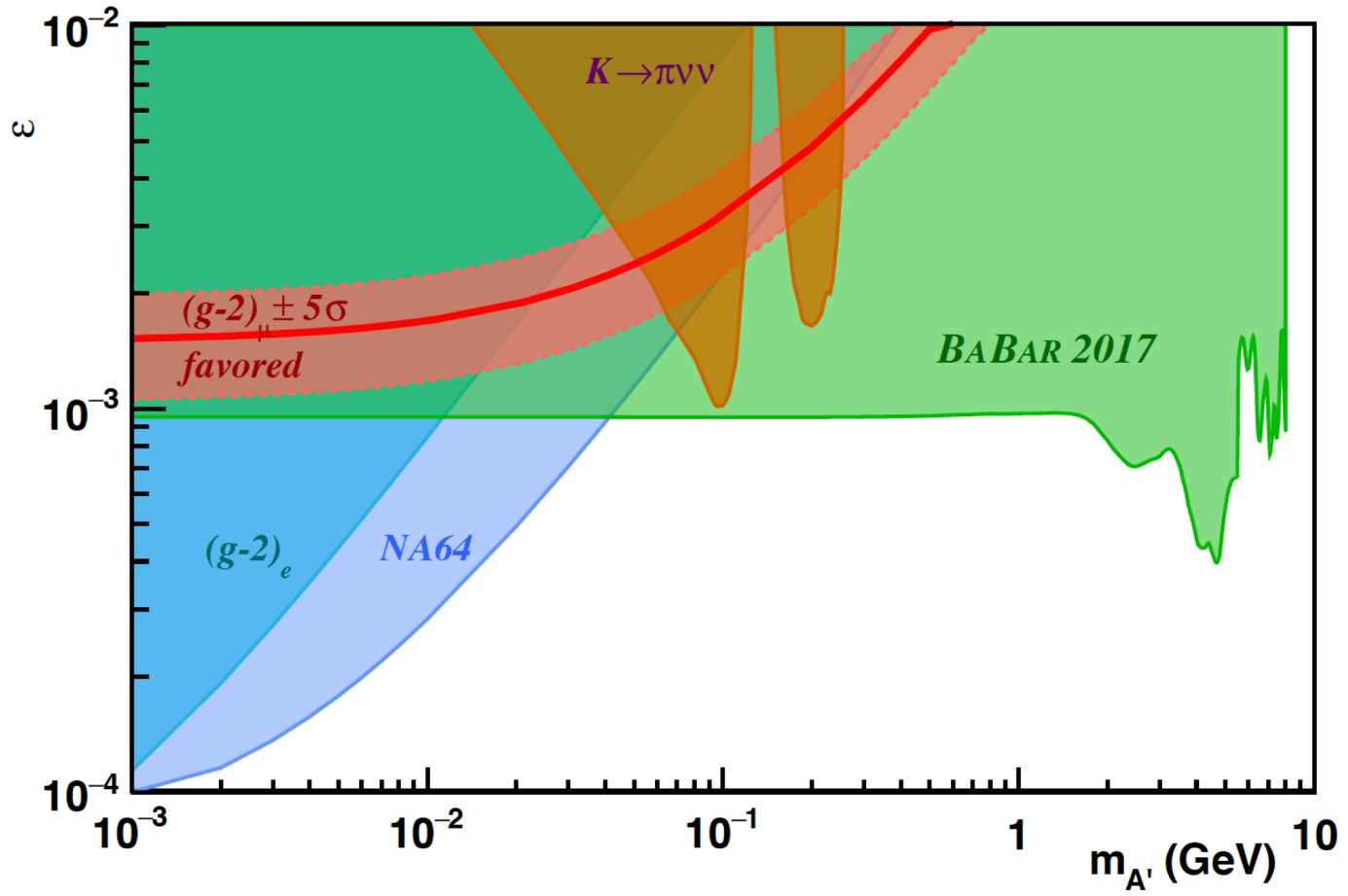


Signal MC, $\varepsilon = 5\times10^{-2}$
$M_{A'}$ = 30, 60, 90 MeV

Missing mass² (GeV²)

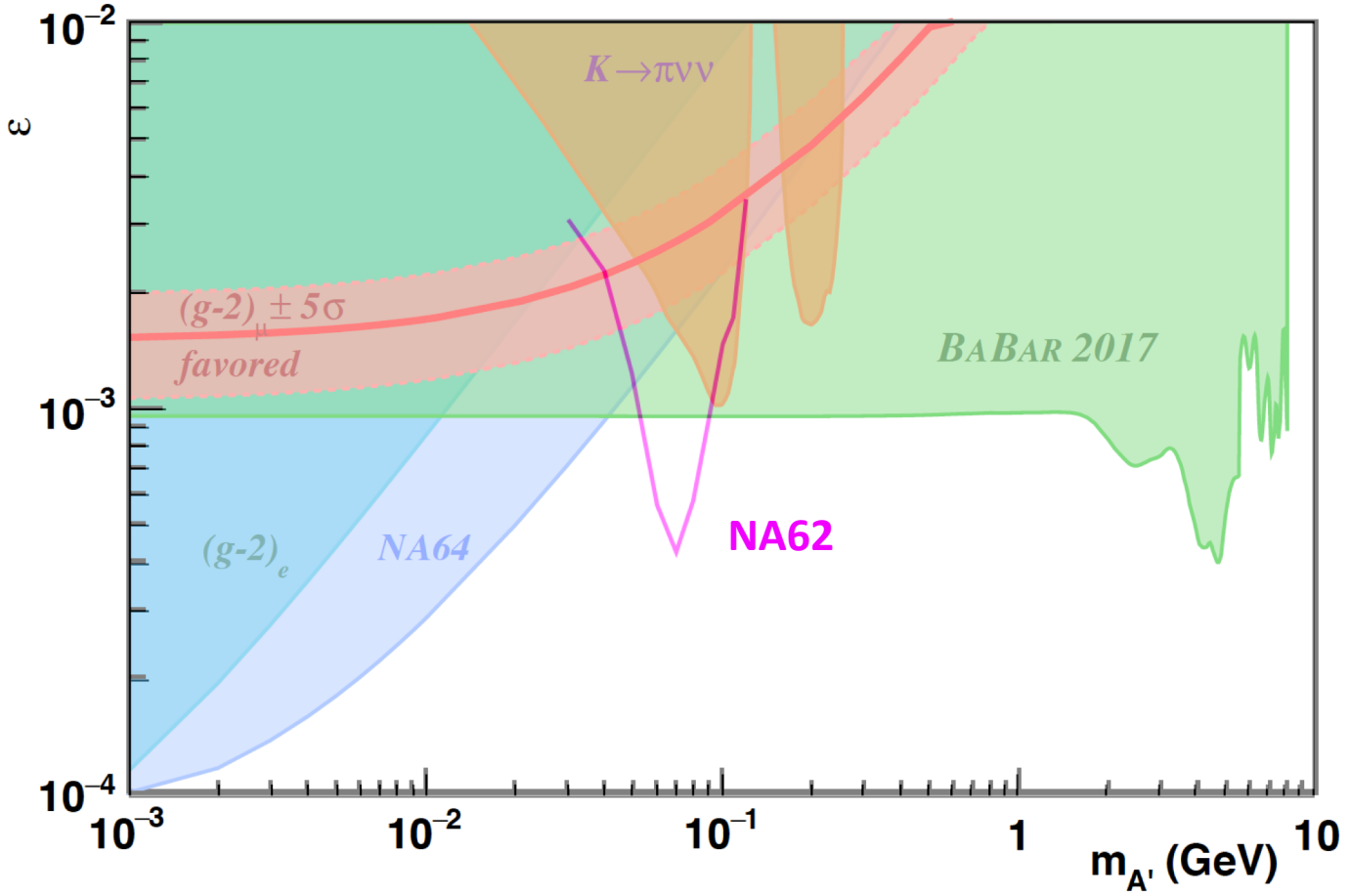
Status of A’ invisible searches

- Recent exclusion limits: NA64, Babar
- In future, expect results from Belle/Belle-II



Upper limit preliminary result

NA62 preliminary result: no signal observed, exclusion limit in an interesting region (10^{10} K^+ decays from 2016)



Status: analysis completed

10^{11} K^+ decays from 2016 data (10^{10} in the fiducial volume)

Final internal review in progress

Paper to be submitted within 2018

Other promising exotic analyses: ALP

$$\mathcal{L}_{\text{axion}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{DS}} + \frac{a}{4f_\gamma} F_{\mu\nu}\tilde{F}_{\mu\nu} + \frac{a}{4f_G}\text{Tr}G_{\mu\nu}\tilde{G}_{\mu\nu} + \frac{\partial_\mu a}{f_l}\sum_\alpha \bar{l}_\alpha\gamma_\mu\gamma_5 l_\alpha + \frac{\partial_\mu a}{f_q}\sum_\beta \bar{q}_\beta\gamma_\mu\gamma_5 q_\beta$$

- Minimal scenario with flavor-diagonal couplings to photons, quarks/leptons, gluons, etc.
- Three scenarios suggested [PBC definitions]:
  - **BC9**: Photon coupling dominance, parameters $\{m_a, g_{a\gamma\gamma}\}$
  - **BC10**: Fermion dominance, parameters $\{m_a, 1/f_l, 1/f_q\}$, to simplify $f_l = f_q$
  - **BC11**: Gluon dominance, parameters $\{m_a, 1/f_G\}$

For **BC10**:

– Toy-MC's

– Acceptance included

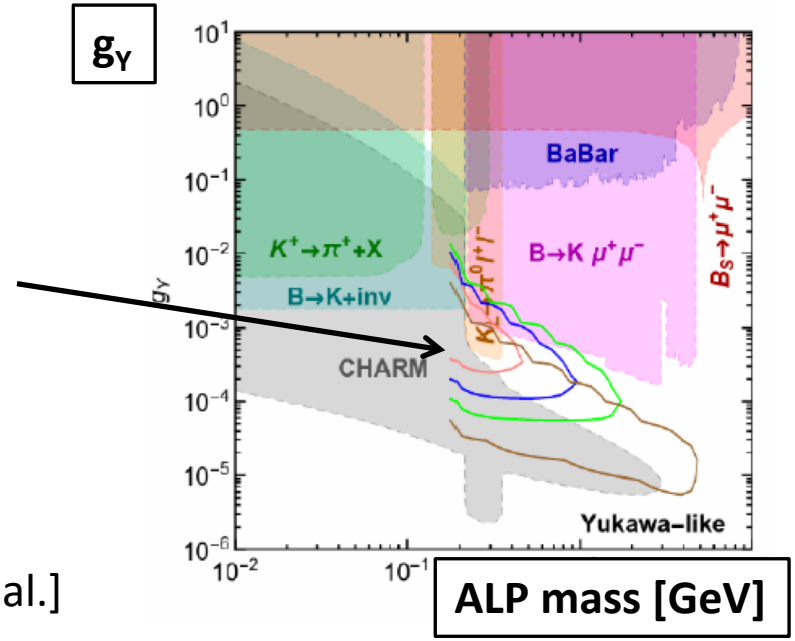
– **Provide curve for 10^{16}, 10^{17}, 10^{18} POT [NA62++]**

– Zero background ass.

Data analysis in progress [μμ]:

– ~2.5 10^{16} POT in beam dump mode [G. Lanfranchi]

– Up to 7x10^{17} POT in parasitic μμ trig [T. Spadaro, et al.]



Other promising exotic analyses: ALP

$$\mathcal{L}_{\text{axion}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{DS}} + \frac{a}{4f_\gamma} F_{\mu\nu}\tilde{F}_{\mu\nu} + \frac{a}{4f_G}\text{Tr}G_{\mu\nu}\tilde{G}_{\mu\nu} + \frac{\partial_\mu a}{f_l}\sum_\alpha \bar{l}_\alpha\gamma_\mu\gamma_5 l_\alpha + \frac{\partial_\mu a}{f_q}\sum_\beta \bar{q}_\beta\gamma_\mu\gamma_5 q_\beta$$

- Minimal scenario with flavor-diagonal couplings to photons, quarks/leptons, gluons, etc.
- Three scenarios suggested:
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  - **BC11**: Gluon dominance, parameters $\{m_a, 1/f_G\}$

For **BC9**:

– Toy-MC cross checked with NA62MC

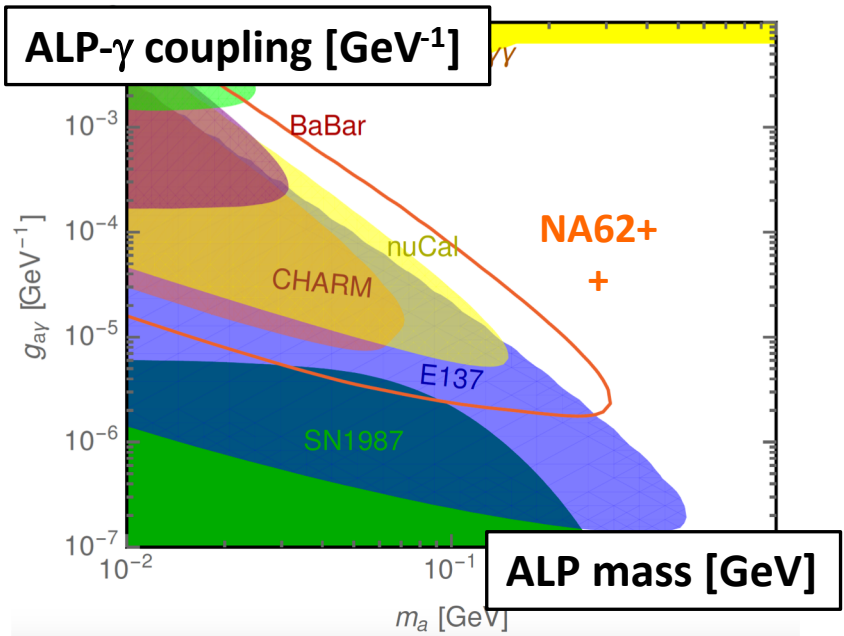
– Acceptance included

– **Curve for 10^{18} POT [NA62++, landscape updated]**

– Zero background ass.

Data analysis:

– **$2.5\text{x}10^{16}$ POT beam dump [T. Spadaro, et al.]**



Neutrino portal

$$\mathcal{L}_{\text{vector}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{DS}} + \sum F_{\alpha I}(\bar{L}_\alpha H) N_I$$

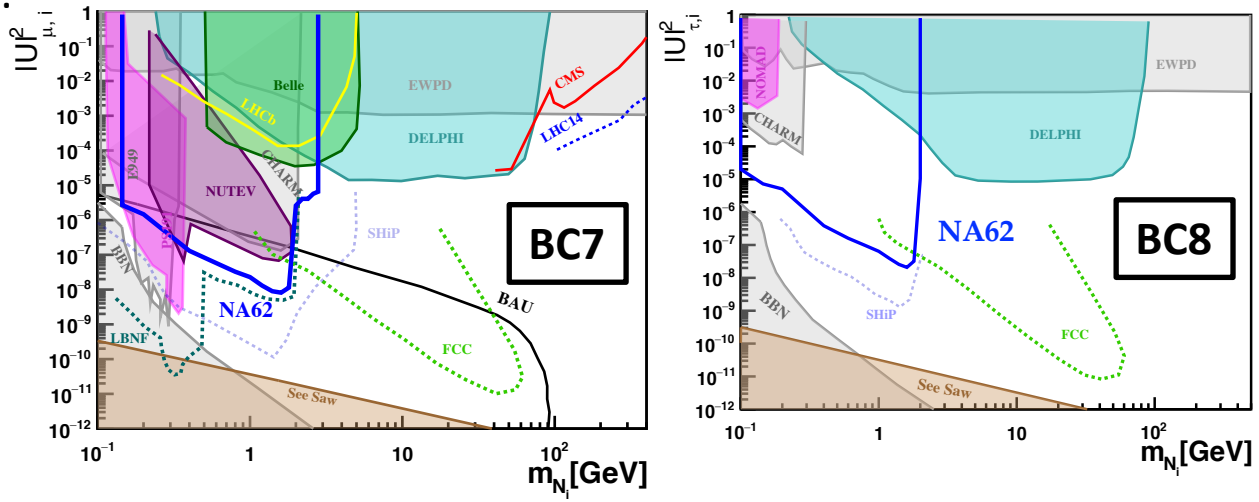
- Neutrino portal, the DS Lagrangian can include both Dirac or Majorana types + expanding the H around the vev for the physical 125 GeV Higgs (h) and diagonalizing the mass matrix gives the mixing of ν and N with a matrix U
- Three scenarios suggested [Gorbunov, Shaposhnikov, JHEP10 015(2017)]:
  - **BC6**: $U^2e : U^2\mu : U^2\tau$ = 52: 1 : 1, normal hierarchy of active neutrino masses
  - **BC7**: $U^2e : U^2\mu : U^2\tau$ = 1: 16 : 3.8, normal hierarchy of active neutrino masses
  - **BC8**: $U^2e : U^2\mu : U^2\tau$ = 0.061: 1 : 4.3, normal hierarchy of active neutrino masses

Projections from G. Lanfranchi:

– Toy-MC/NA62MC

– **Curves for 10^{18} POT**

– Zero background ass.



Data analysis in progress:

– ~2x10^{17} POT πμ parasitic [T. Spadaro, others]

– ~2x10^{16} POT beam dump [G. Lanfranchi]

The “Lepton Flavour WG”

LNV	**$K^+ \to \pi^- e^+ e^+ / \pi^- \mu^+ \mu^+$**	**UK**
SM/EXO	**$K^+ \to \pi^+ \mu^+ \mu^-$**	**UK, Prague**
SM	**$K^+ \to e \nu \gamma$**	**IT (R. Piandani)/UK**
SM/EXO	**$K^+ \to e^+ \nu \mu^+ \mu^-$**	**IT (D. Soldi)**
SM	**$K^+ \to \pi^+ \gamma\gamma$**	**UK**
SM/EXO	**$K^+ \to e^+ \nu\nu\nu$**	**Louvain/JINR**
LFV	**$K^+ \to \pi \mu e$**	**Louvain/UK**
LFV/EXO	**$K^+ \to e \nu$ / $K^+ \to \mu \nu$**	**CERN**
EXO	**$K^+ \to e \nu$, $K^+ \to \mu \nu$**	**UK**
SM	**$K^+ \to \pi e \nu \gamma$**	**IT (F. Brizioli)**

+ General contributions:

trigger efficiency (D. Soldi, et. al.),
detector efficiency (all Italian subdetector groups)
general analysis tools

Highlighted examples

Select >3000 K^+ → $e\nu\gamma$ decays, background ~5% vs PDG value from 1000 evts (R. Piandani)

Select O(100) K^+ → $e\nu\mu^+\mu^-$ decays in 2017 data, % bkg vs PDG value with 30% error (D. Soldi)

Can improve by x3 on BR(K^+ → $\pi^0 e\nu\gamma$) and T-violation asymmetry wrt PDG (F. Brizioli)