PADME (future) sensitivity:

Axion-like particles and dark photons

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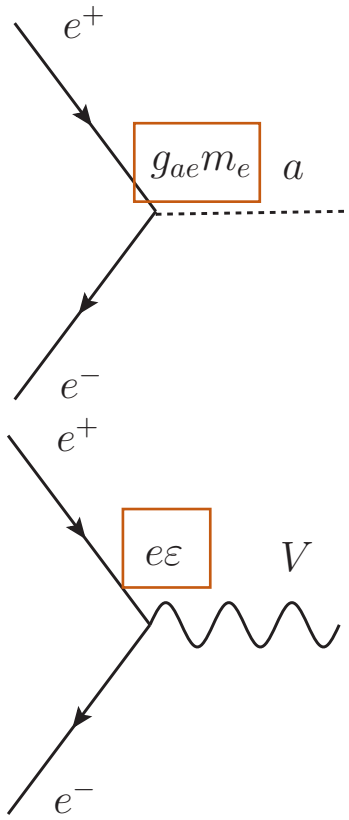
Feebly-Interacting Particles

- FIPs= "new neutral particle which interact with the SM via suppressed new interactions"
- Appear in various NP models aiming at dark matter, neutrino masses, strong CP problem, flavour etc …

SM operator		*Example FIPs*		
Scalar portal	$\lvert H\rvert^2 \quad (d=2)\,,$	$\lvert S\rvert^2$		
Vector portal	$F_{\mu\nu} \quad (d=2)\,,$	$F'^{\mu\nu}$	Dark photon	
Neutrino portal	$LH \quad (d=5/2)\,,$	N		
Axion portal / fermion portal	$\bar{f}_i\,\Gamma^\mu f_j \quad (d=3)$	$\partial_\mu a$	Axion-like Particle	
		$\Psi\Gamma_\mu\Psi$		

→ Can be produced with light SM fields, no need to high energy

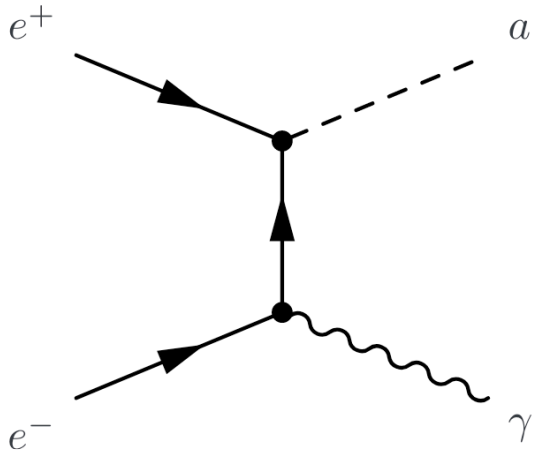
Dark photon/ALP production via electron coupling



- ALP and DP production via g_{ae}/ε at PADME

--> Associated production with a photon

→ Notice the dependence on the center of mass energy!



$$\sigma_{ae} \sim \alpha_{\mathrm{em}} g_{ae}^2 \frac{m_e^2}{2s} \log\left(\frac{s}{m_e^2}\right)$$

- Once produced we can observe the DP/ALP either visibly (a, $V \rightarrow e^+e^-$) or purely as missing mass if it decays invisibly

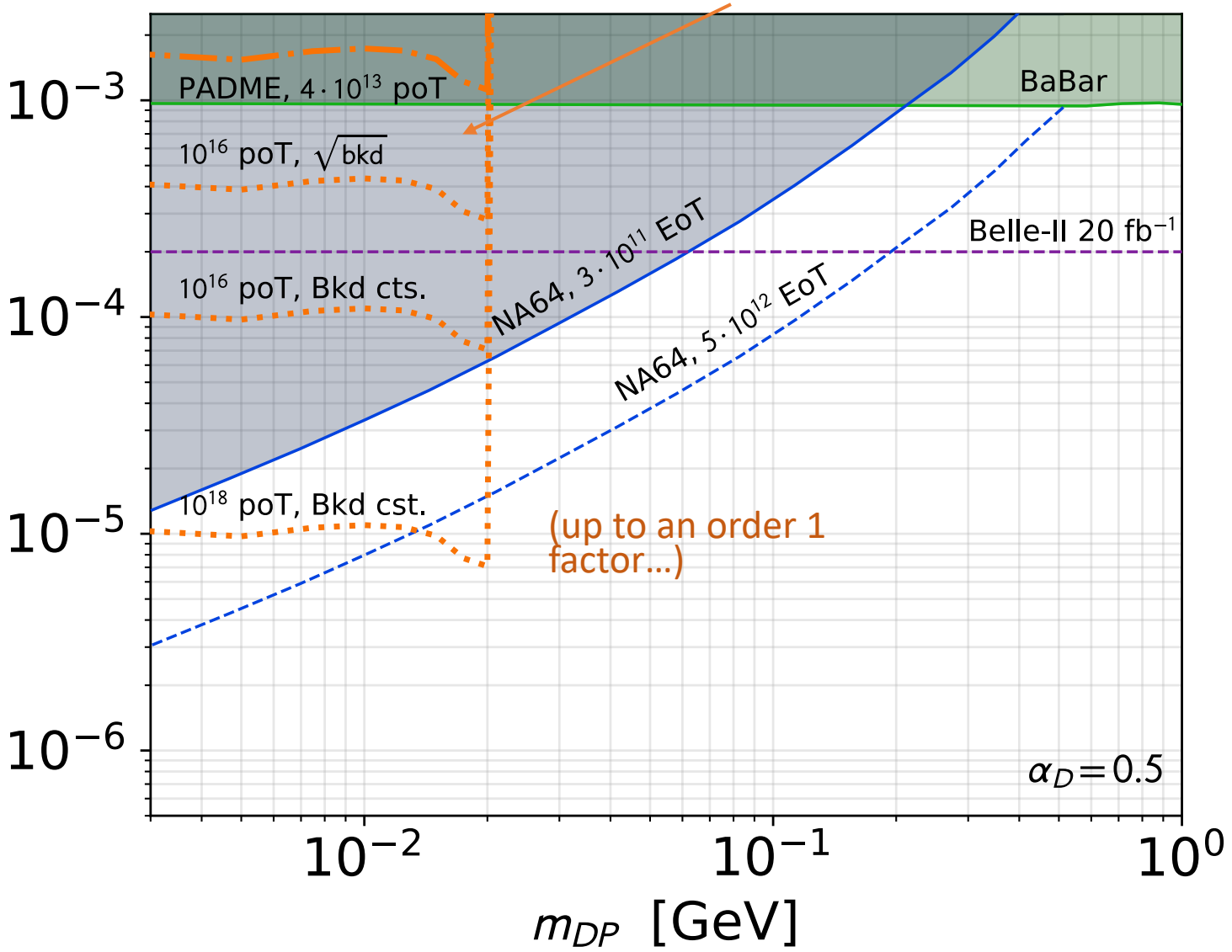
Invisible DP search at PADME

- The limit is background-dominated
  - → ~ 40k events at $4 \cdot 10^{13}$ poT
  - → ~ 10M events at 10^{16} poT
- "Bump search" so limit on signal event scales as

$$N_{lim} \sim g_{ae}^2 \sim \sqrt{bkd}$$

- Any reduction of the background will be useful
  - Show $\sqrt{bkd}$ limit and cst. limits (with bkd at the level of $4 \cdot 10^{13}$ poT)
- NA64, $5 \cdot 10^{12}$ EoT (limit for constant background) should be reached around 2024
  - Another order of magnitude at LDMX → ~10 years horizon

Limit extracted from 1501.01867:
Resonant feature not completely present

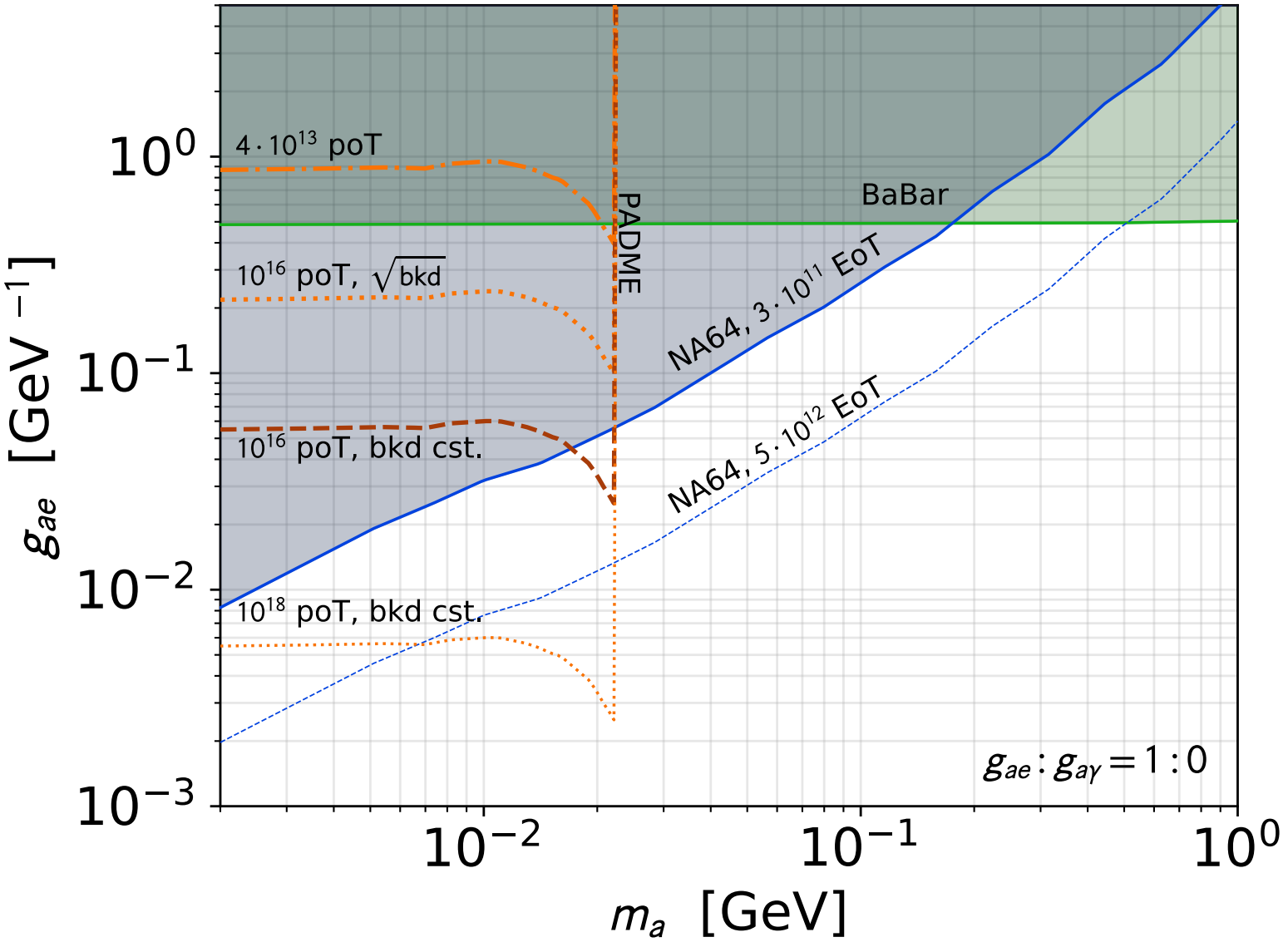


ALP search at PADME in missing mass

- PADME typically probes the electron coupling, focus on electrophilic ALPs
- For an ALP and DP production shares a (mostly) similar phenomenology

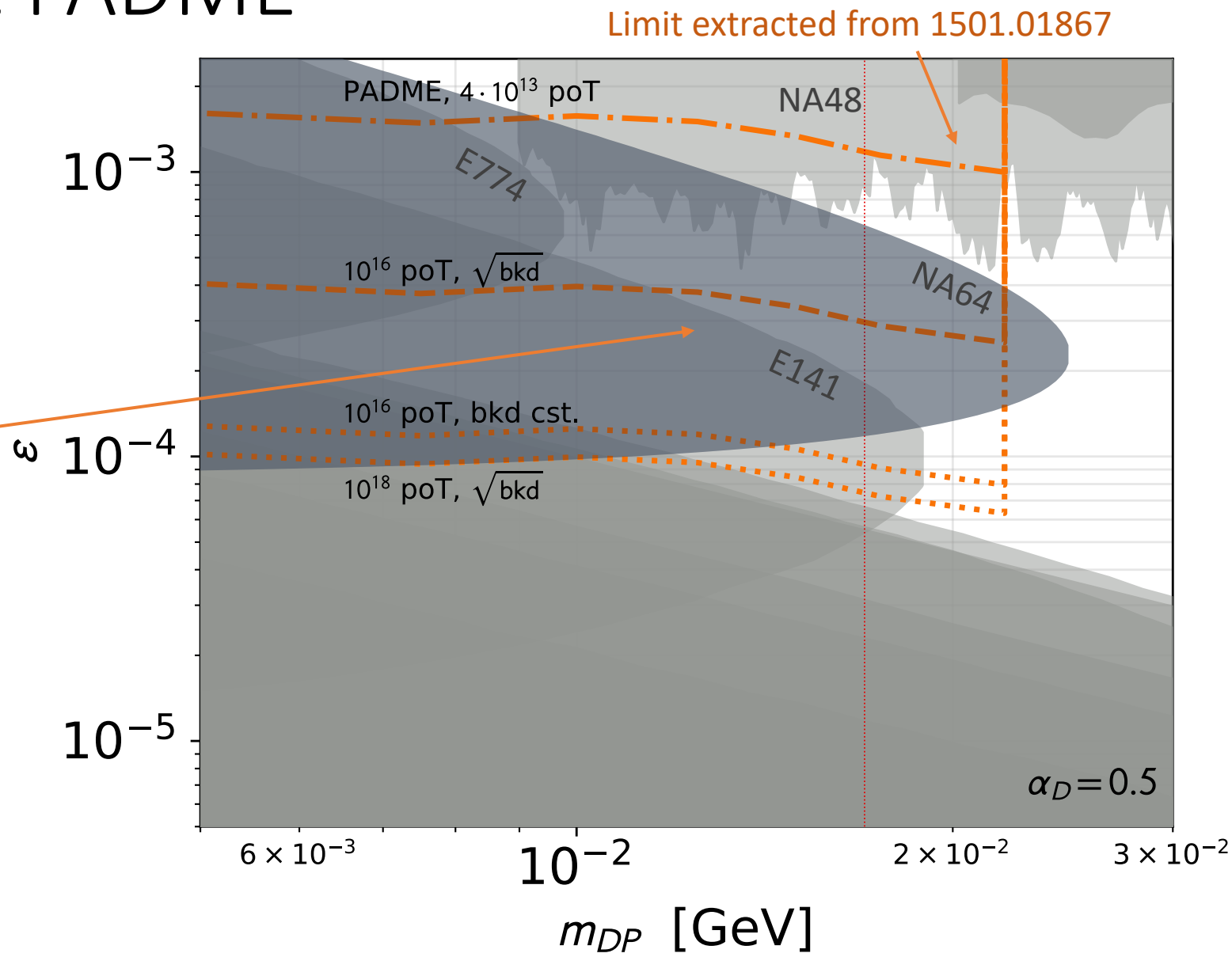
$$g_{ae} m_e \longleftrightarrow \sqrt{4\pi\alpha}\ \varepsilon$$

- Notice the resonant enhancement ~ 10x in signal



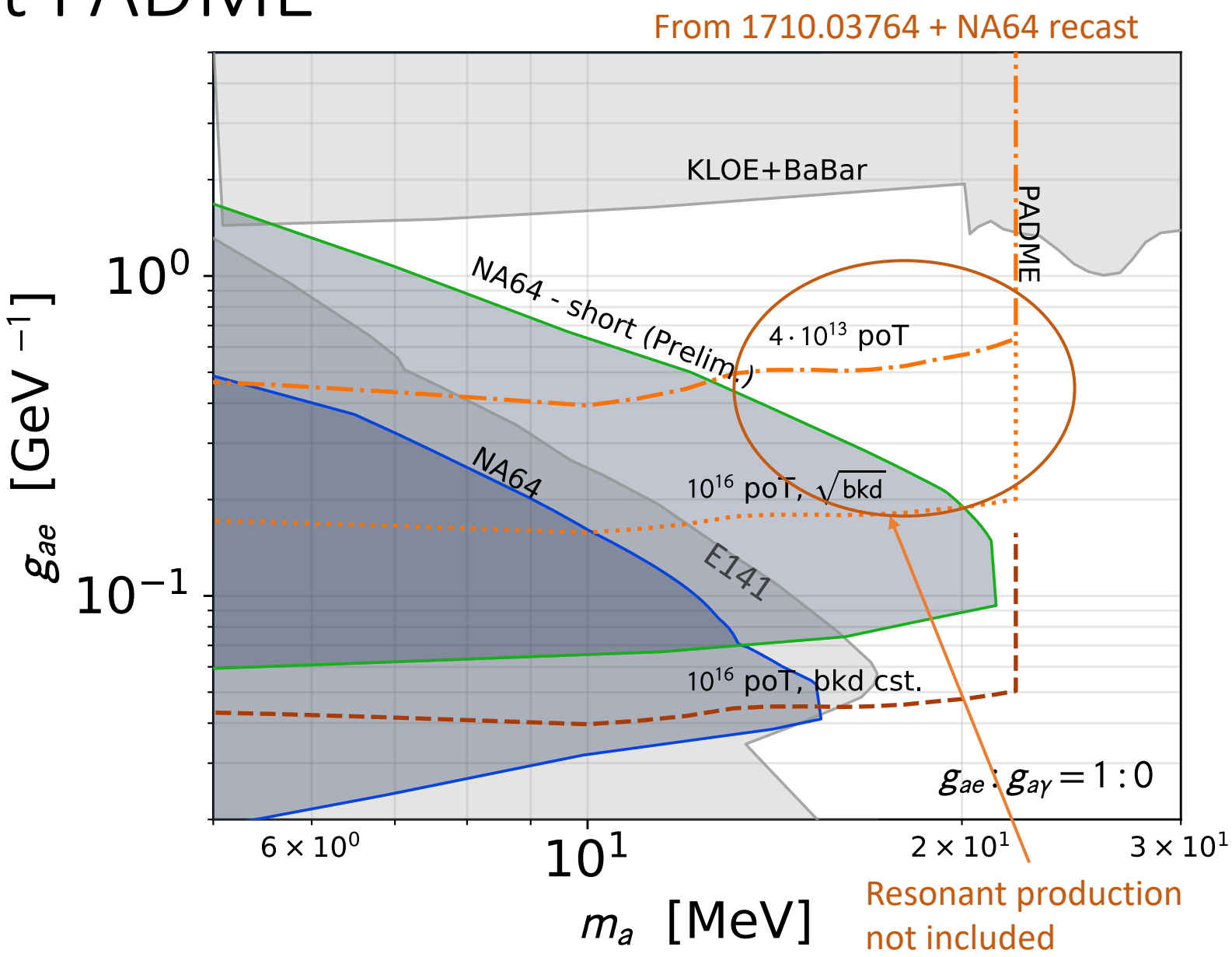
DP visible decay at PADME

- Recent NA64 limits for X17 boson.
  - Uses a different analysis, 1912.11389, than the ”main” NA64 experiment, based on a purely beam dump setup.
  - Use a 17cm tungsten calorimeter as target
- Region in the top-left corner in conflict with $(g-2)_e$



ALP visible decay at PADME

- Main difference with dark photon: no NA48 limits (from $\pi^0 \to \gamma V$ decays)
- Two different NA64 analysis
  - Include recast of which focused on X17 boson
- Excellent prospects for PADME → this misses the resonant production

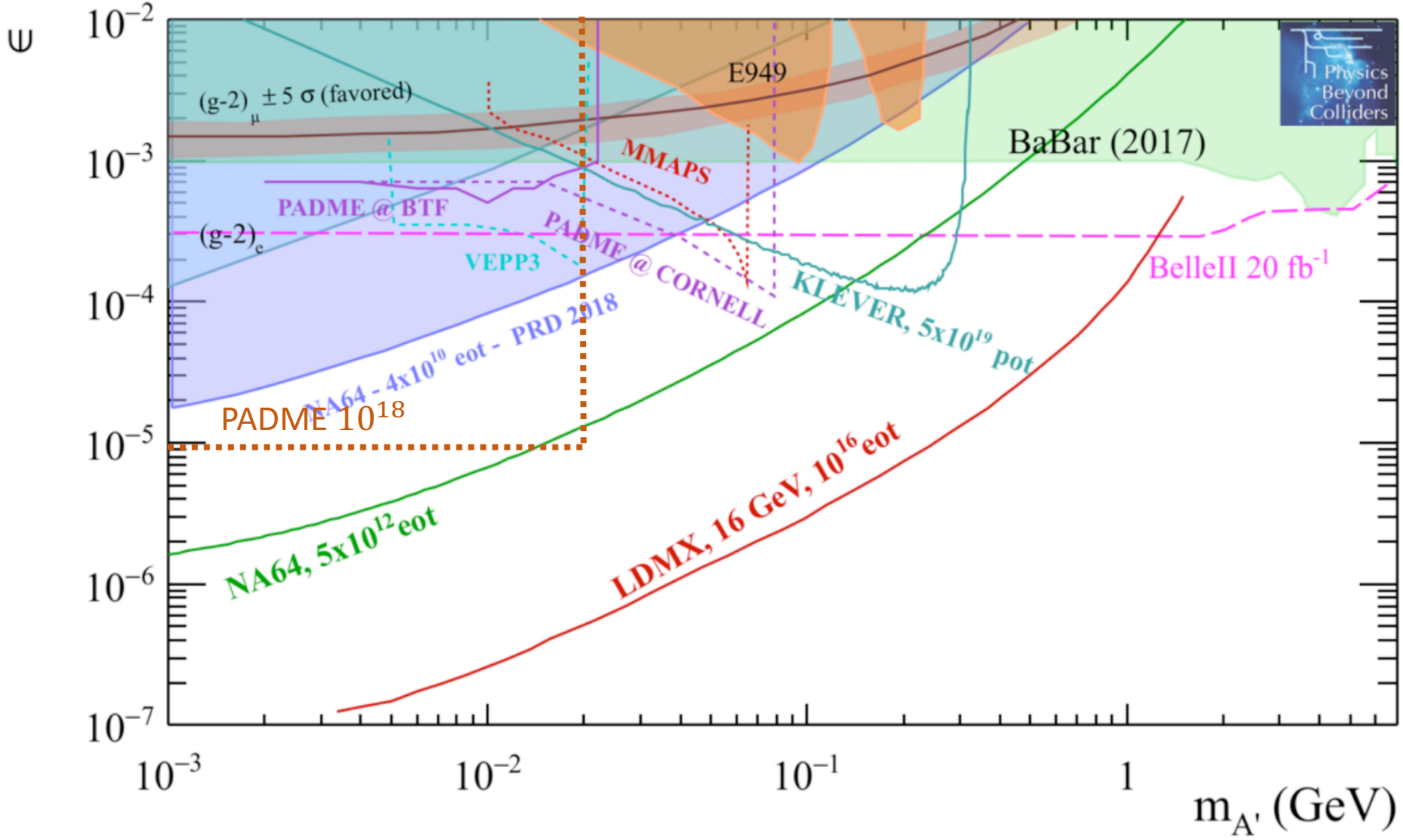


Conclusions

- Prospects for PADME without energy increases of DAΦNE
- In order to be competitive, $\sim 10^{16}$ positrons on target needed, background reduction is critical
- One exception: visible ALP, $a \rightarrow e^+e^-$ searches → good mid-term prospects
- Varying the beam energy to sit on resonance could dramatically help search → factor x10 increases in signal for same background
- In invisible decay searches, not many upcoming experiment in a 10 years time frame

Backup slides

The big picture, dark photon invisible



The big picture, dark photon visible