Dark Matter and Dark Sectors

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Recap the 2020 ESPP document highlighting the progresses
→ Trigger french contributions for 2025 ESPP
→ Open discussions for the 2024 IRN Terascale meeting

ESPP Preparation 1rst meeting, 04 octobre 2024

2019 ESPP section layout

❑ **20 pages**

Recap the 2020 ESPP document highlighting the progresses
→ Trigger french contributions for 2025 ESPP

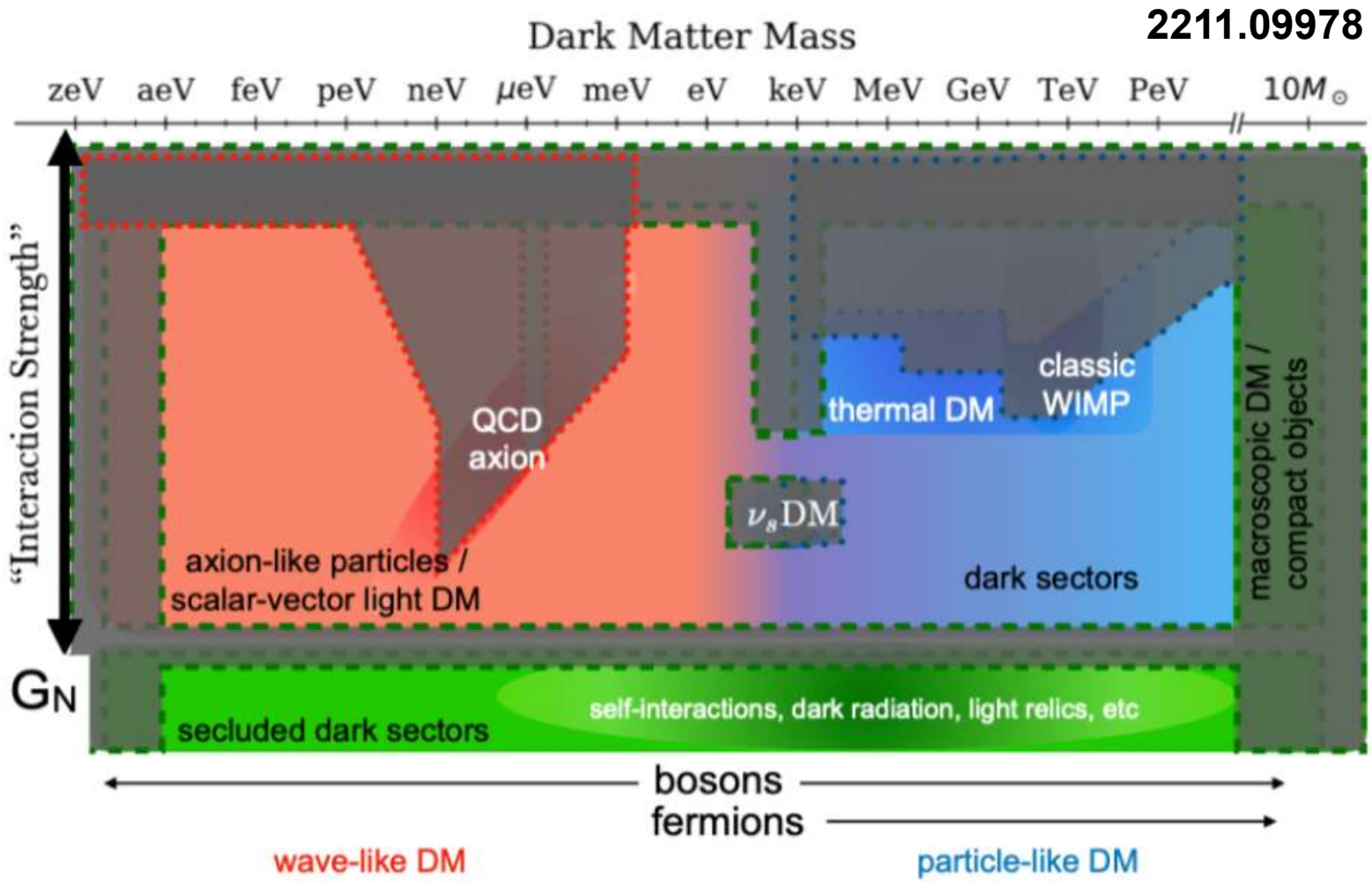
Select few vanilla models

Potential French contrib.
- …

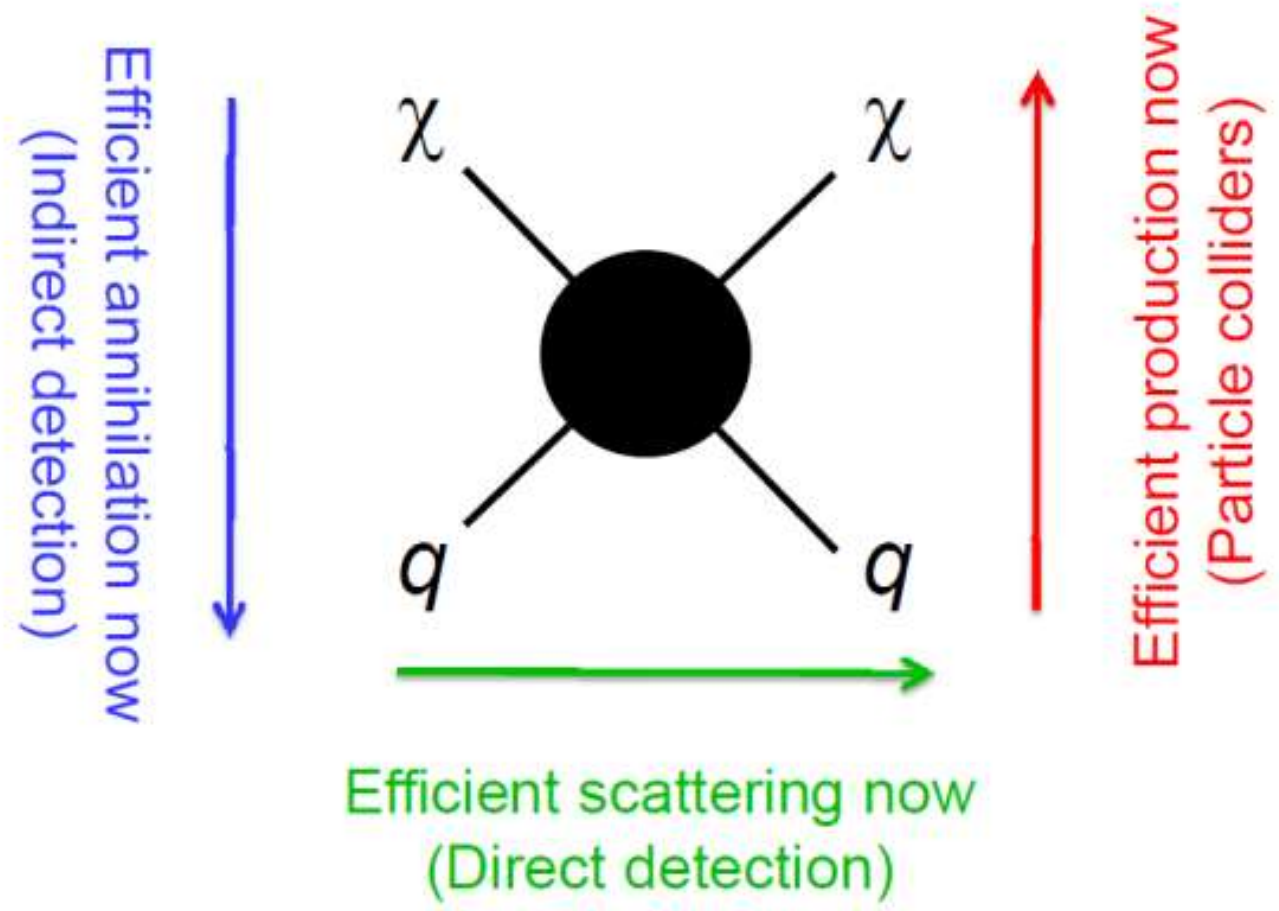
- 2021-22 Snowmass (2209.0742, 2210.01770, 2211.07027, 2211.09978)
- "*Dark Matter*" M. Cirelli et al.: 500 pages (2406.01705)

General strategy

- Dark matter search covers a wide coupling – mass range



Particle-like DM general strategy



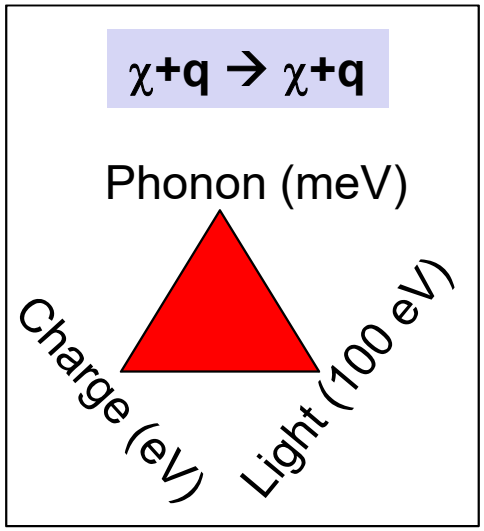
Complementarity of 3 experimental approaches

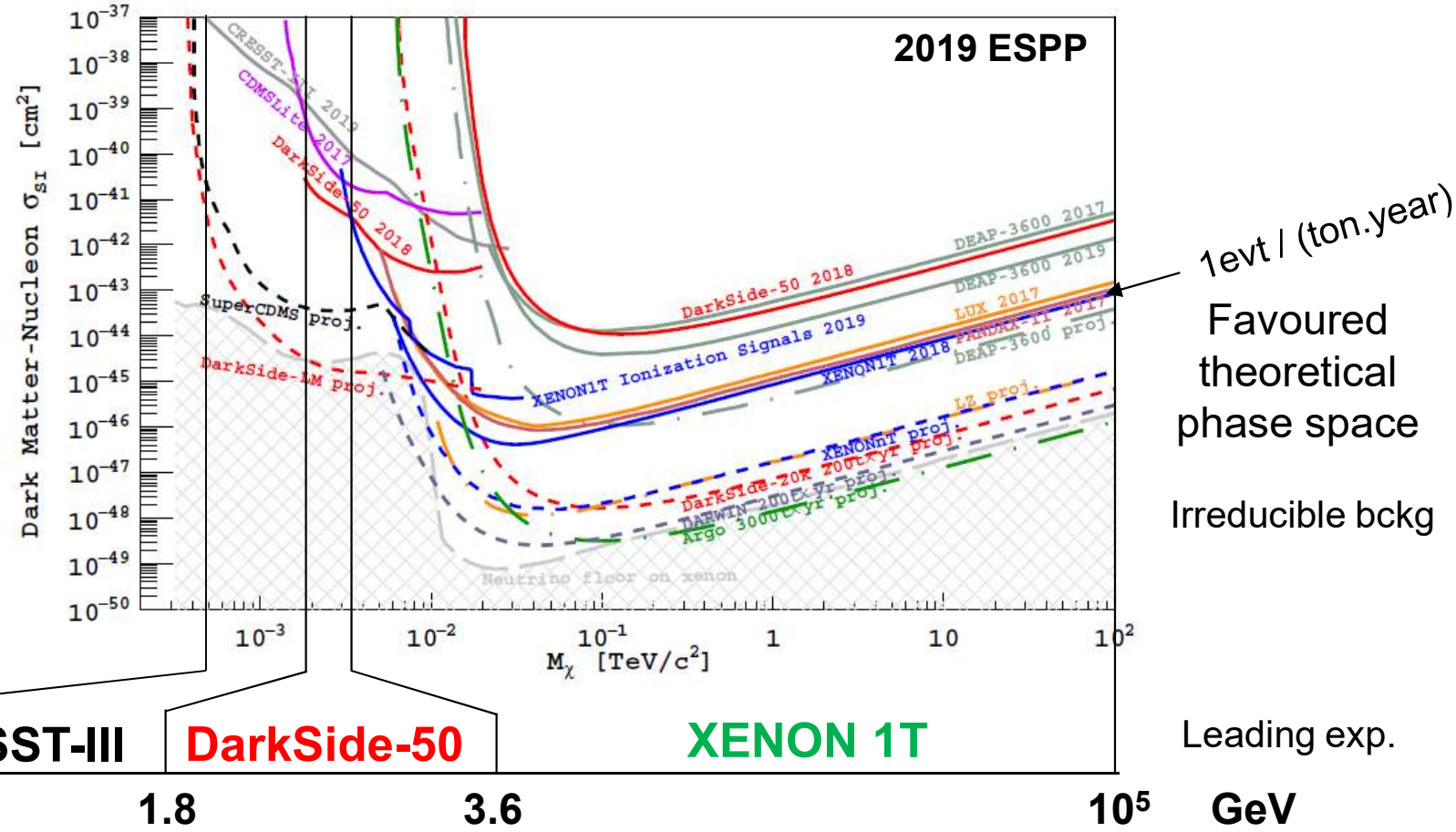
WIMP Direct Detection 2020

9.2 Astrophysical Probes of Dark Matter . . . . . .

❑ Spin independent (SI) DM-Nucleon cross-section

- Double phase TPCs filled with LAr or LXe lead the race 1.8 GeV → 100 TeV
- Other technologies (mK cryo) contribute below



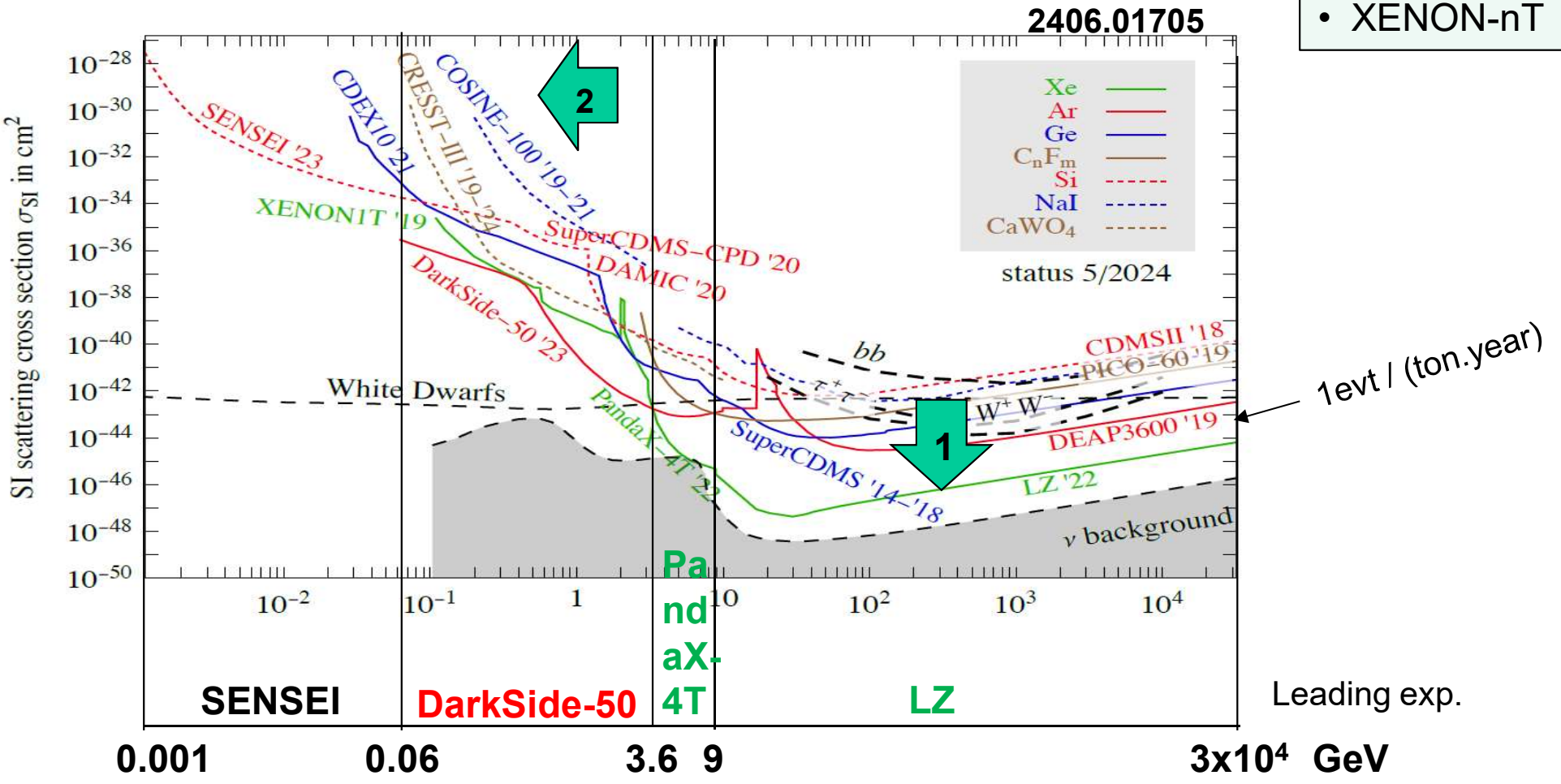


WIMP Direct Detection 2024

❑ Spin independent (SI) DM-Nucleon cross-section

- Double phase TPCs leading the race 0.06 GeV (inc. Migdal) → 100 TeV
- Other technologies (low T CCD) push to very low DM mass

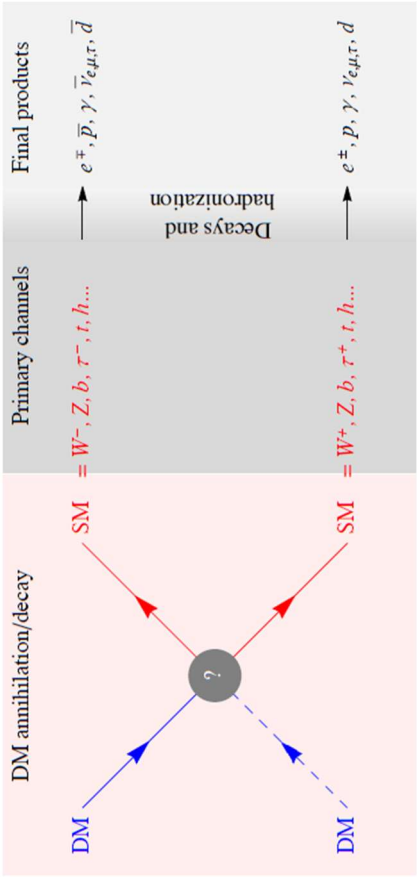
Potential French contrib.
- DAMIC
- DarkSide
- Tesseract
- XENON-nT

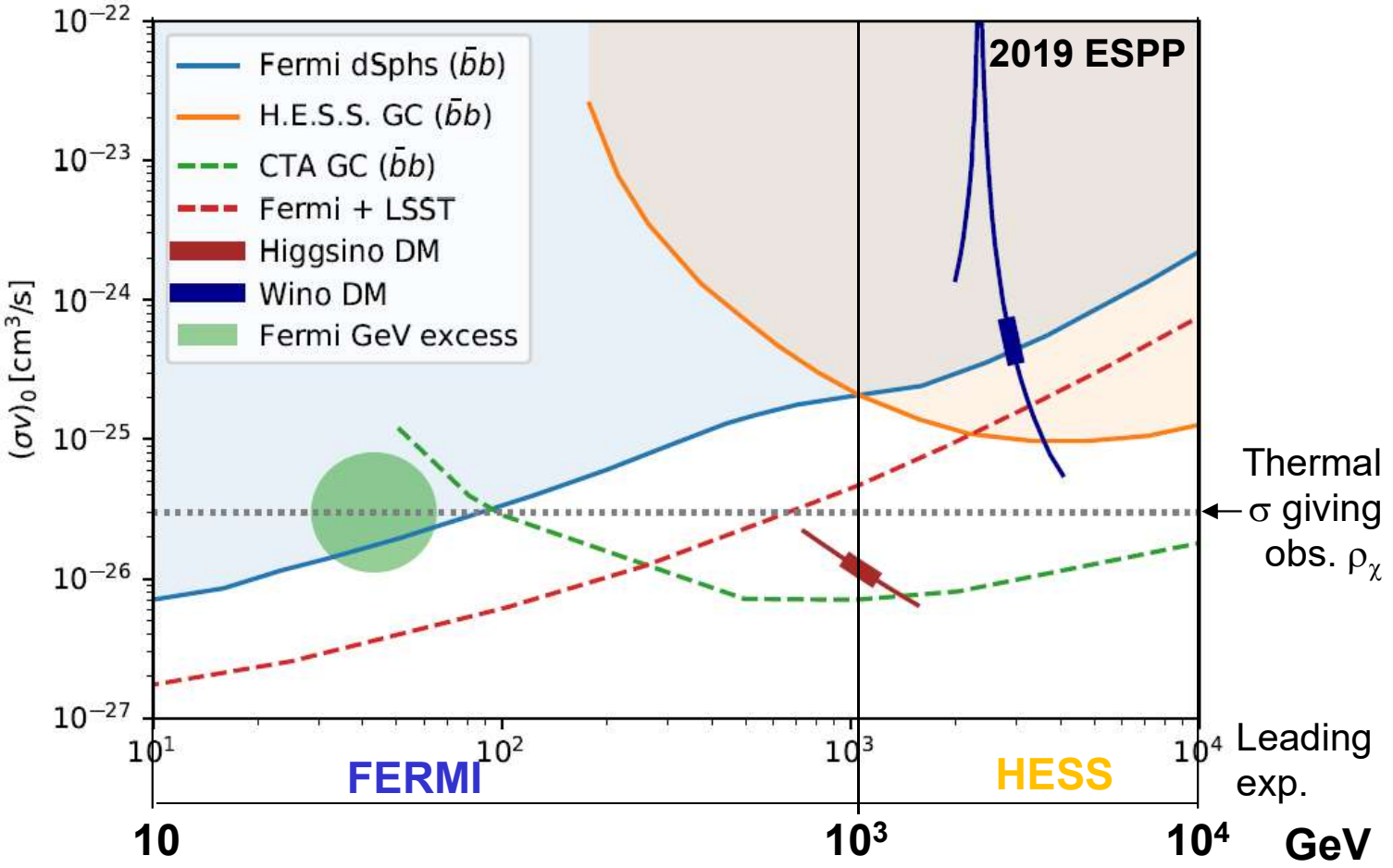


Indirect Detection 2020

❑ Weak scale DM annihilation cross-section

- Focus on the GeV-TeV DM mass range
- Cleanest constraints from γ-rays observations (most sensitive channel $\chi\chi \rightarrow bb$)

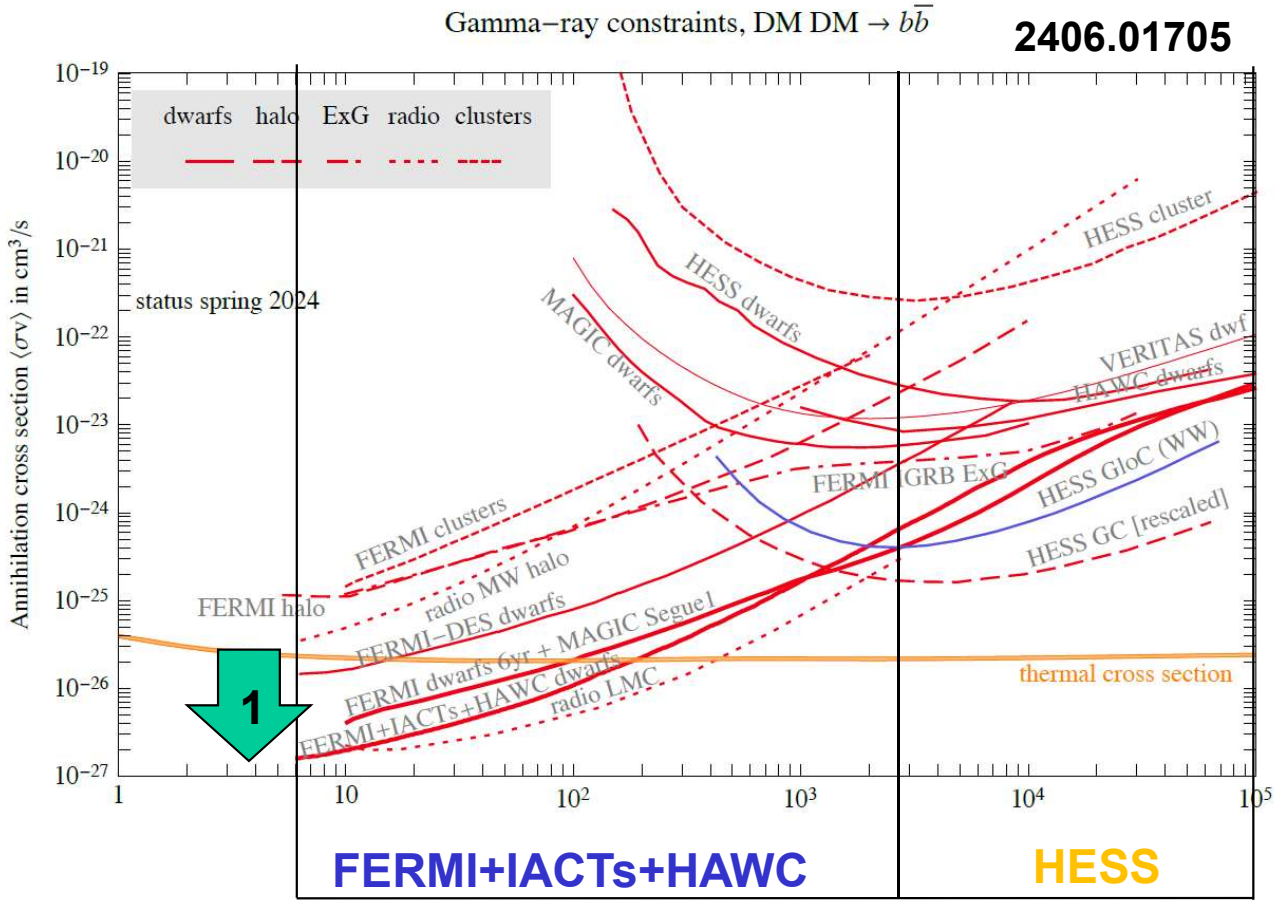




Indirect Detection 2024

❑ Weak scale DM annihilation cross-section

- Cleanest constraints still from γ-rays observations



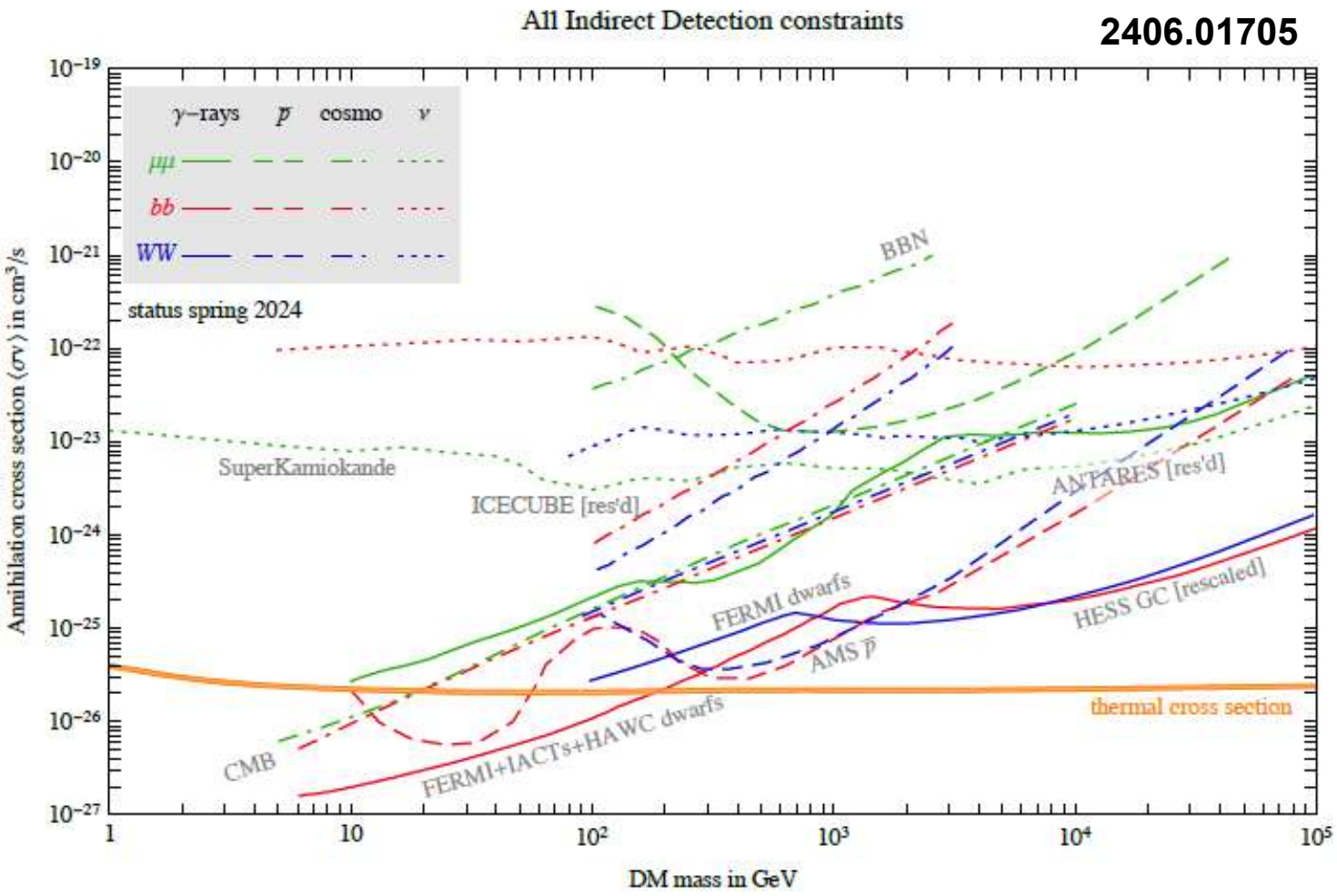
Thermal cross-section

Leading experiment

Indirect Detection 2024

❑ Weak scale DM annihilation cross-section

- More complete view with all the possible probes (beyond γ-rays)



Potential French contrib.
- HESS, CTA
- AMS
- KM3Net
- SuperK, HyperK

Colliders

9.3 Dark matter and Dark sectors at Colliders . . . . . .

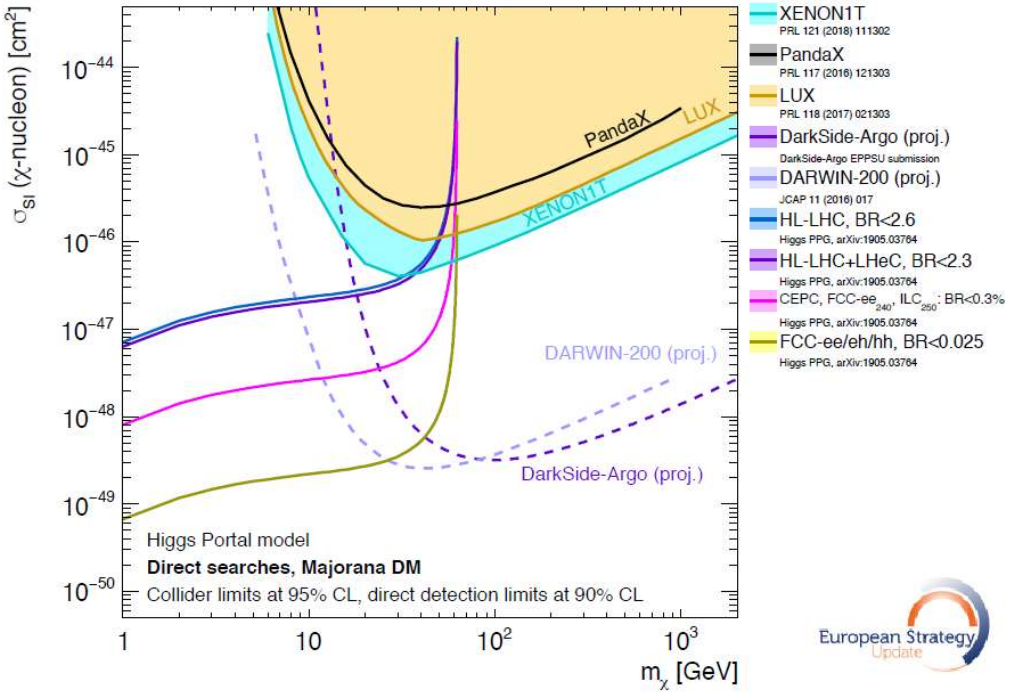
❑ σ_{SI} DM-Nucleon and DM annihilation cross-section

- No direct connection to thermal DM → assumptions on the dark sector
  - It is possible to compare with direct and indirect searches …
  - … assuming e.g. Higgs portal (H → $\chi\chi$) or simplified model

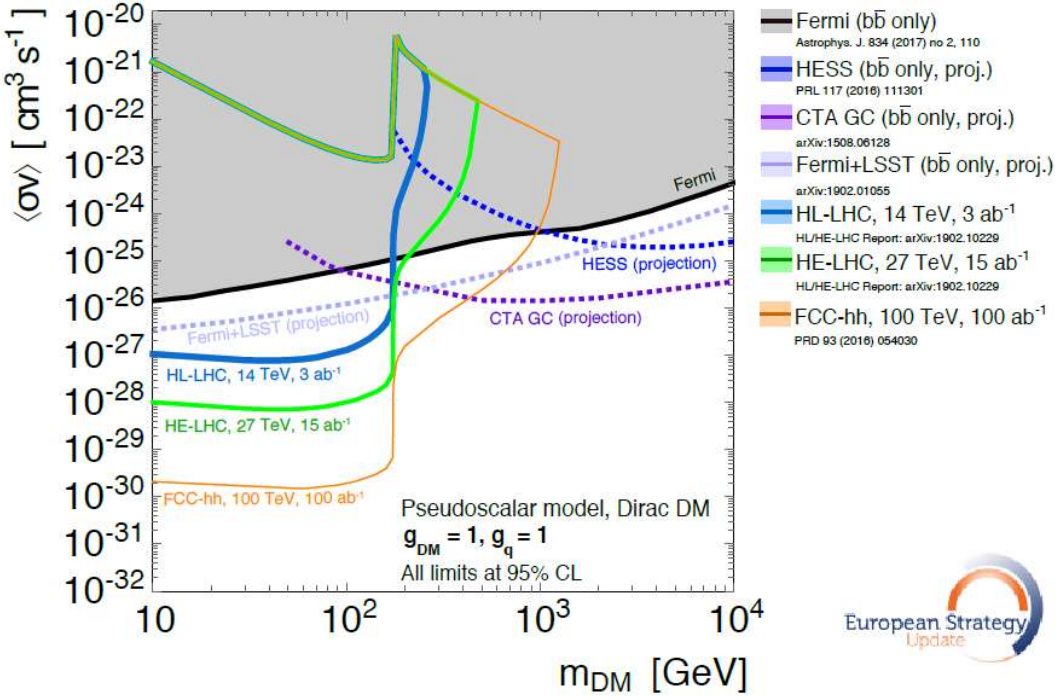
Potential French contrib.
- ATLAS
- CMS
- FCC

2019 ESPP

H → $\chi\chi$



gg → a (→$\chi\chi$) + X



Beam-dump, fixed-target

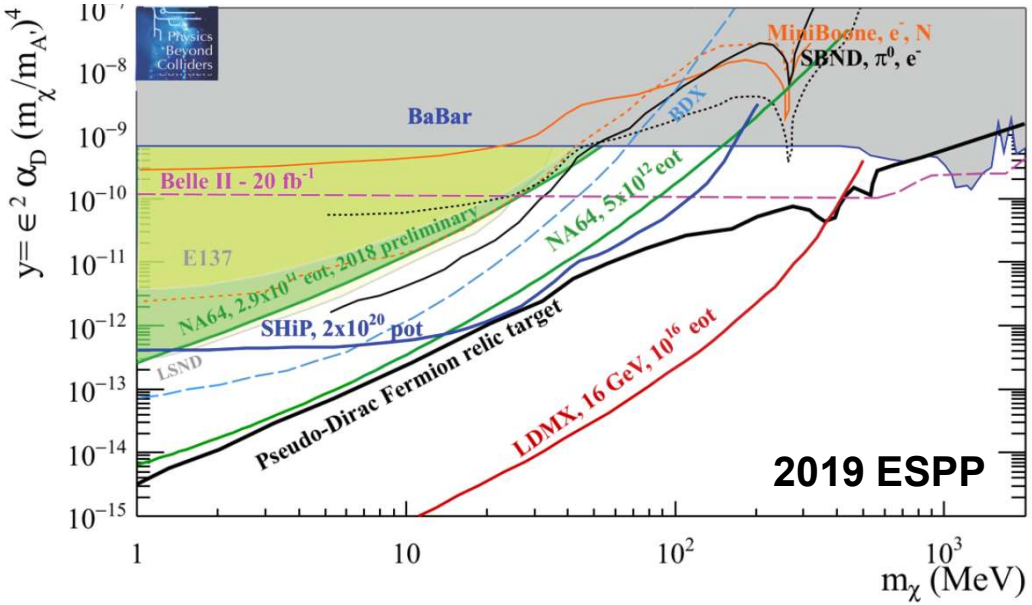
9.4 DM and DS at beam-dump and fixed-target experiments

Potential French contrib.
- ?

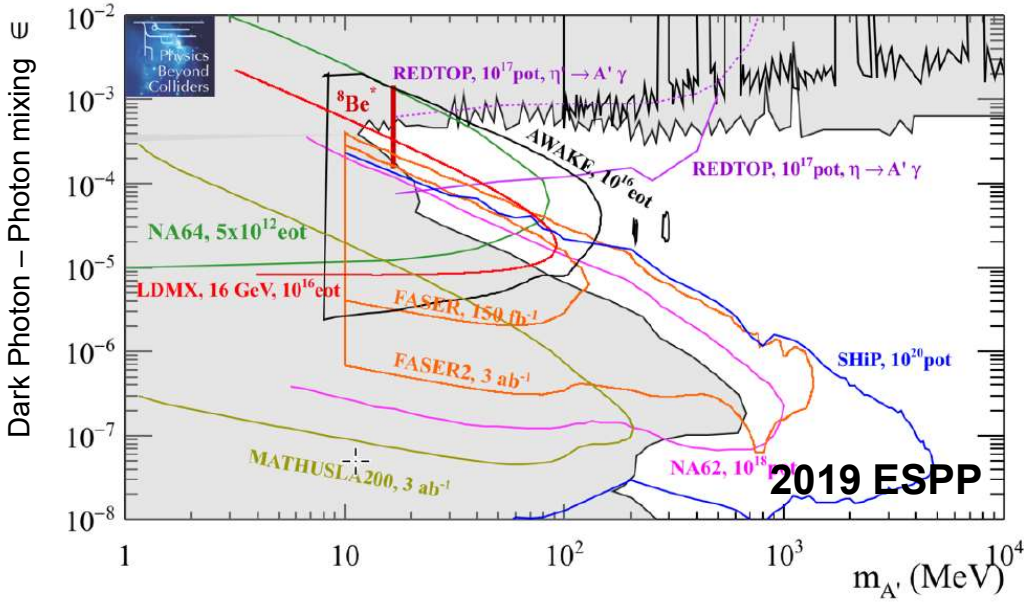
❑ Coupling – mass of DM or mediator candidate

- No direct connection to thermal DM → assumptions on the dark sector
  - Dark sector mediator produced and decaying to DM or to SM particles
  - Generally sensitive in the keV – GeV DM mass range

Dark Photon mediator A' → χ



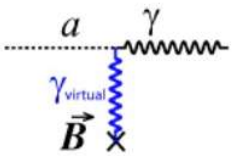
Dark Photon mediator A' → SM



Axion general strategy

9.5 Axions and ALPs . . . . . .

Main access through axion conversion to photon in a B-field

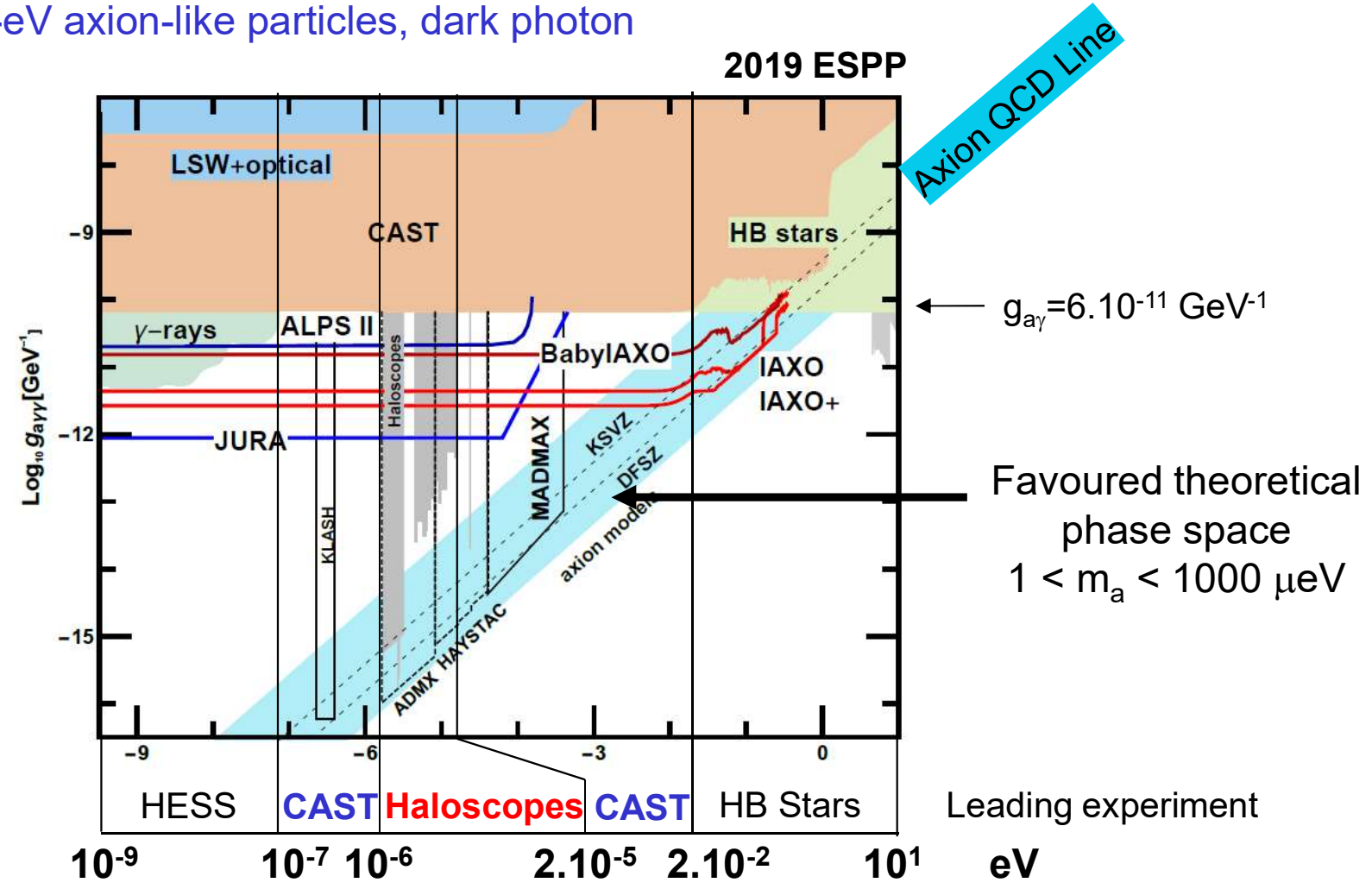


Light Shining through walls (LSW)	Helioscopes	Haloscopes
Lab produced → fully controlled setup	Solar axions	Relic DM axions
Low axion flux	Medium axion flux	High axion flux
Model independent	Mildly model dependent	Model dependent
ALP	QCD axion / ALP	QCD axion DM [1-1000 μeV]
e.g. ALPS II	e.g. CAST, (Baby)IAXO	e.g. MADMAX

Complementarity of 3 experimental approaches

Axion 2020

- **$g_{a\gamma}$ – m_a plane**
  - Increasingly attractive option : wave–like, unexplored phase space, new experimental ideas
  - Covers also sub-eV axion-like particles, dark photon

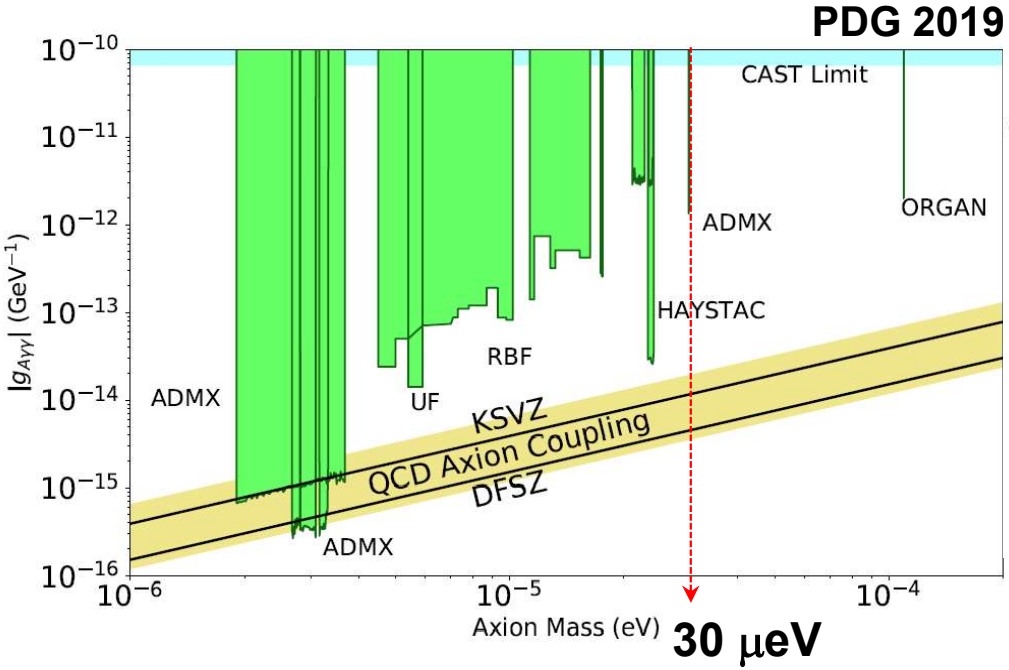


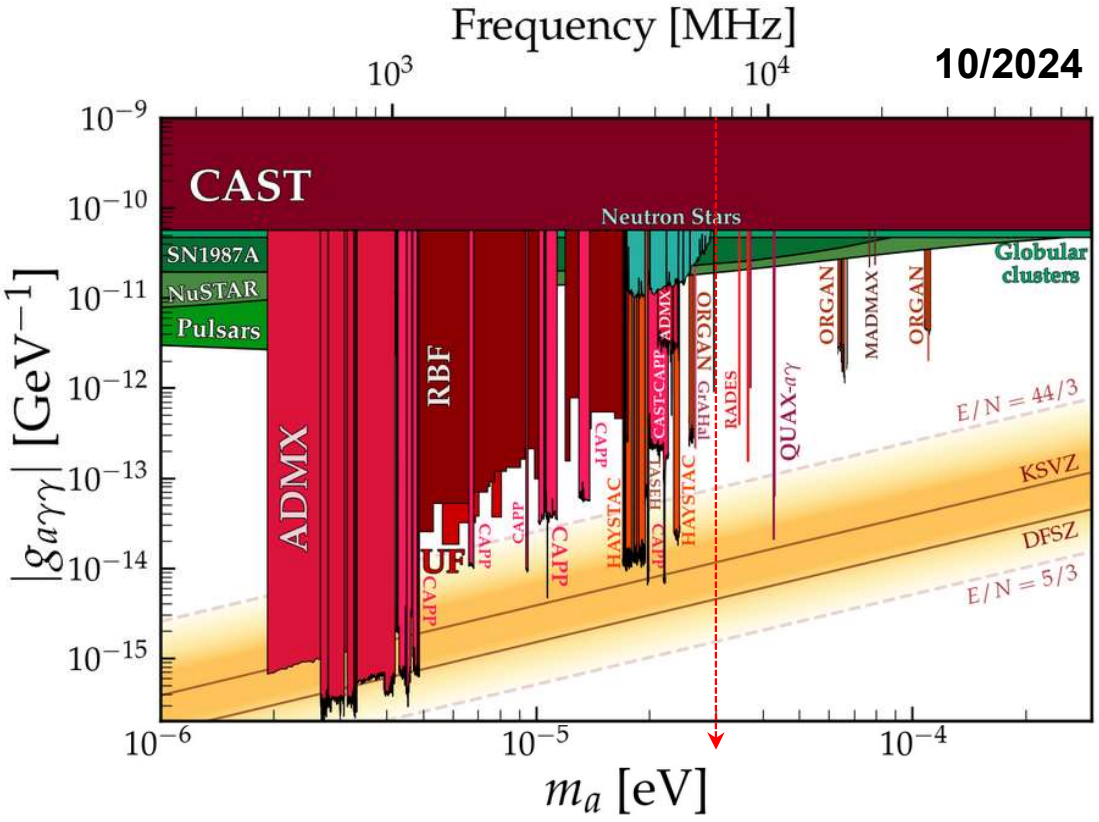
Axion 2024

Potential French contrib.
- MADMAX
- BabyIAXO
- GrAHal

❑ $g_{a\gamma}$ – m_a plane (haloscope region)

- New results with single resonant cavities (CAPP, ADMX, …) for $m_a < 30$ μeV
- First results beyond single cavity experiments (RADES, MADMAX, …) for $m_a > 30$ μeV





https://cajohare.github.io/AxionLimits/docs/am.html

New items

❑ Quantum sensors

- ECFA : R&D Roadmap for particle physics in 2021 → quantum sensors and emerging technologies
- DRD5 proposal: https://cds.cern.ch/record/2901426

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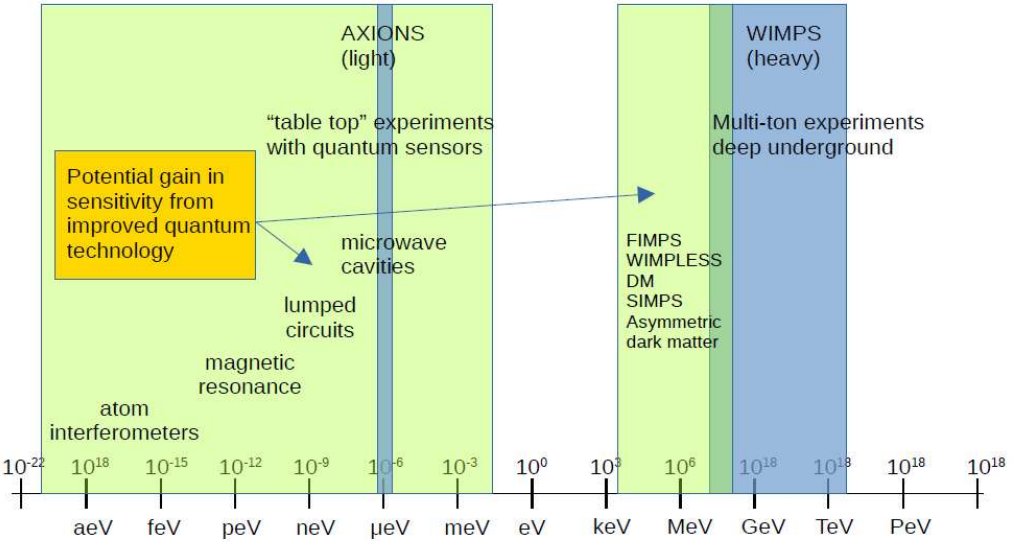

❑ Reinterpretation of WIMP / axion searches

- WIMP reinterpretation in LDM, ALPs, ν_S, dark photon, …
- Gravitational waves from axion haloscope →
- Transient event

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