Perspectives in Particle Physics

Joachim Kopp
KET Strategy Meeting
Bad Honnef, 18. November 2016

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The LHC: Flagship for the Coming Decades

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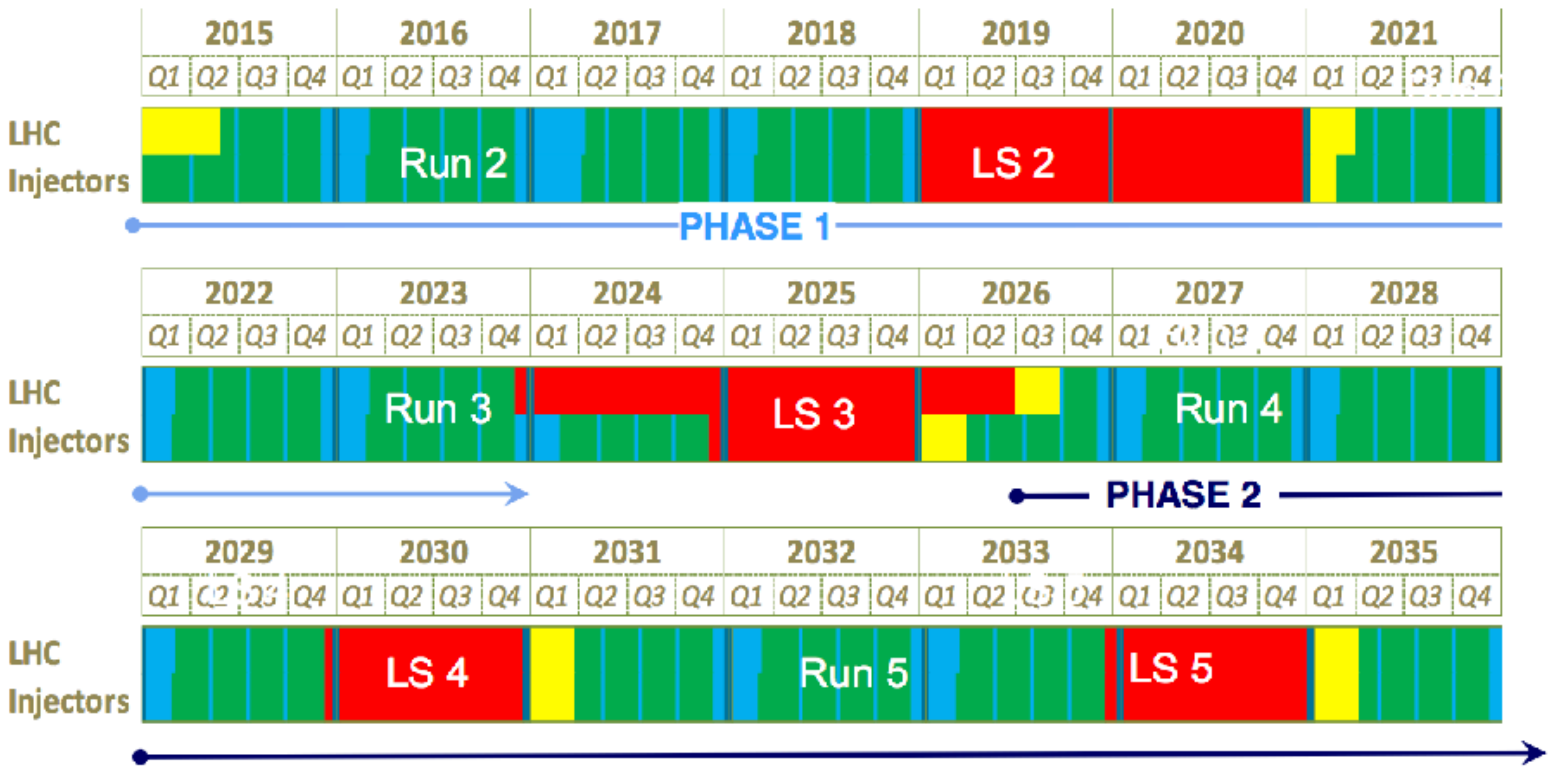

Source: LHC Commissioning web page

Perspectives Beyond the LHC

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- Energy Frontier: Future colliders
  - Very long-term
  - Extremely expensive
    barring a technological quantum leap (CLIC, plasma wakefield?)

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- **Energy Frontier:** Future colliders
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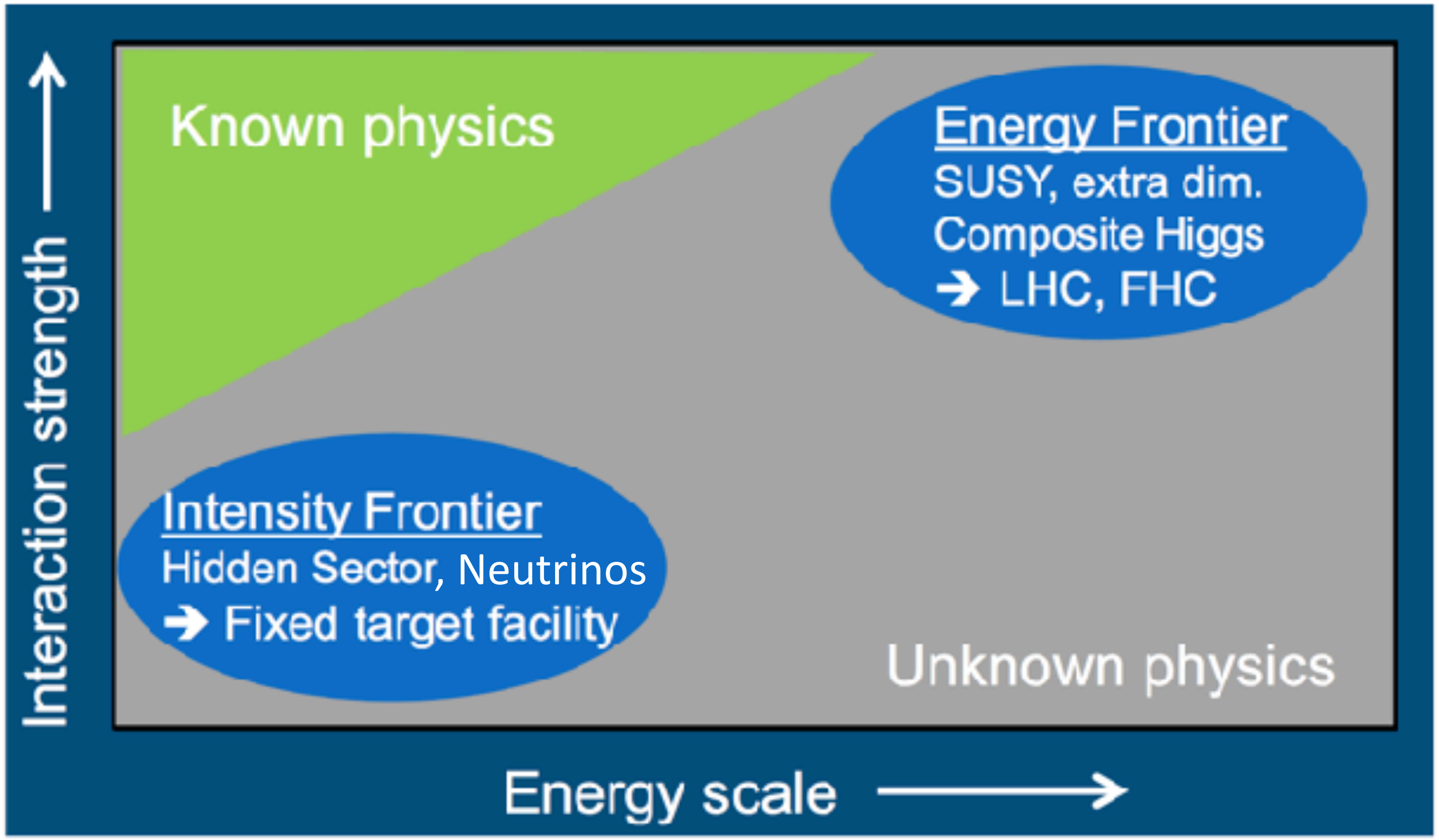
- **Intensity Frontier**



graphics based on SHiP collaboration 2015

Opportunities at the Intensity Frontier

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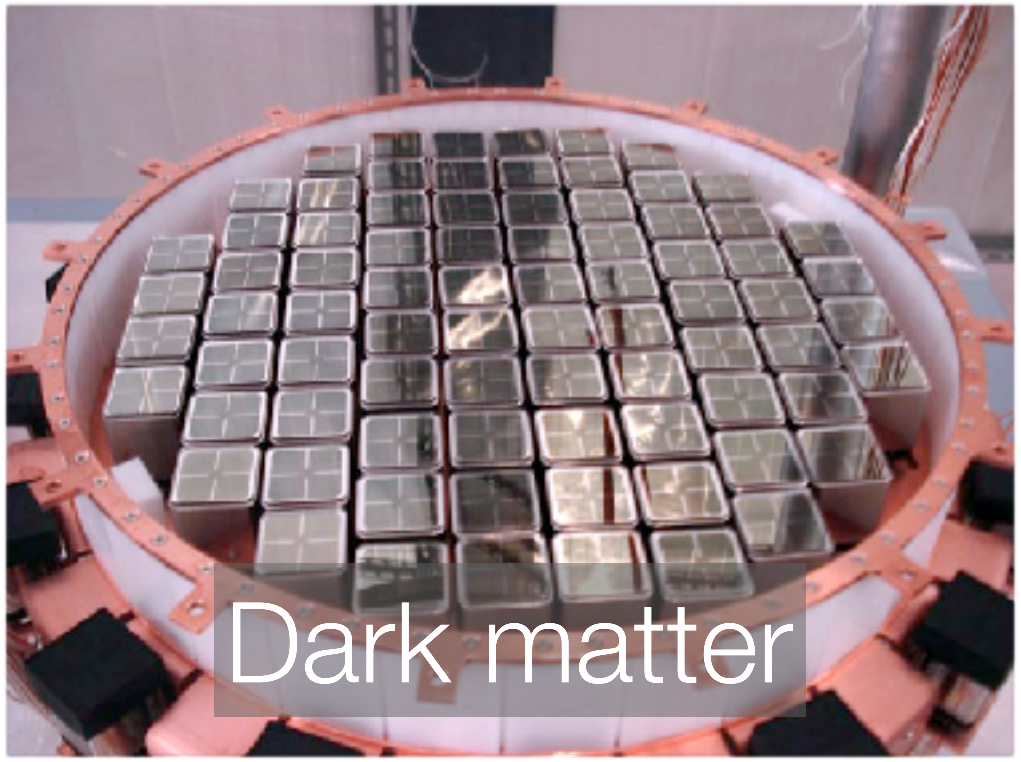

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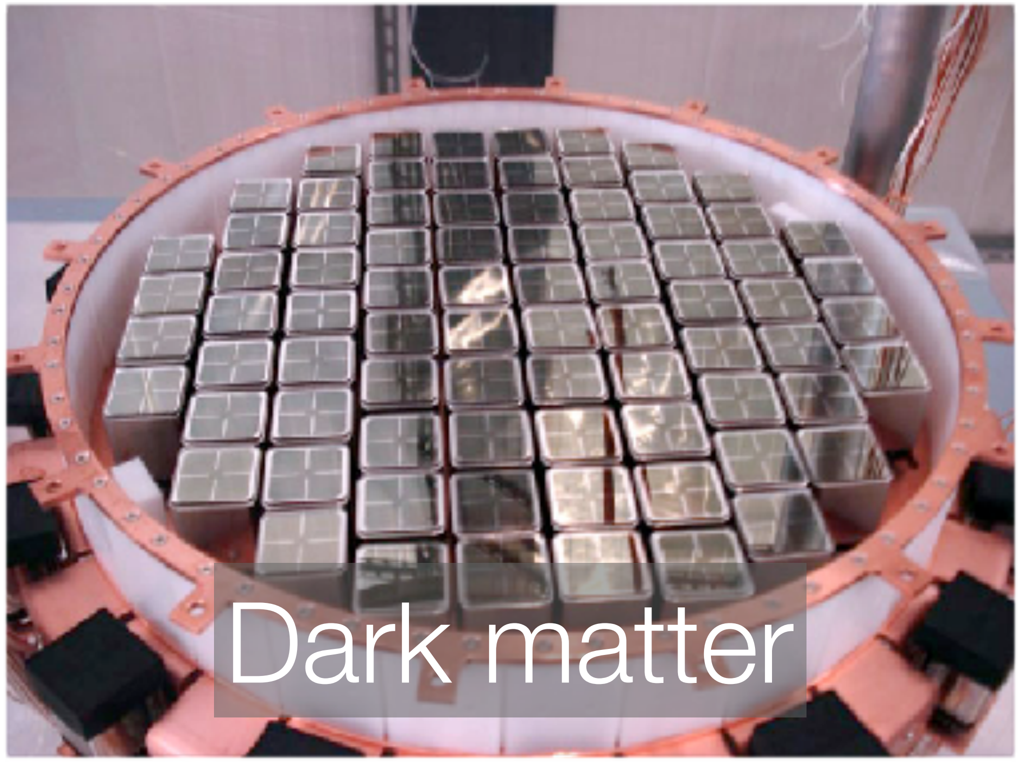

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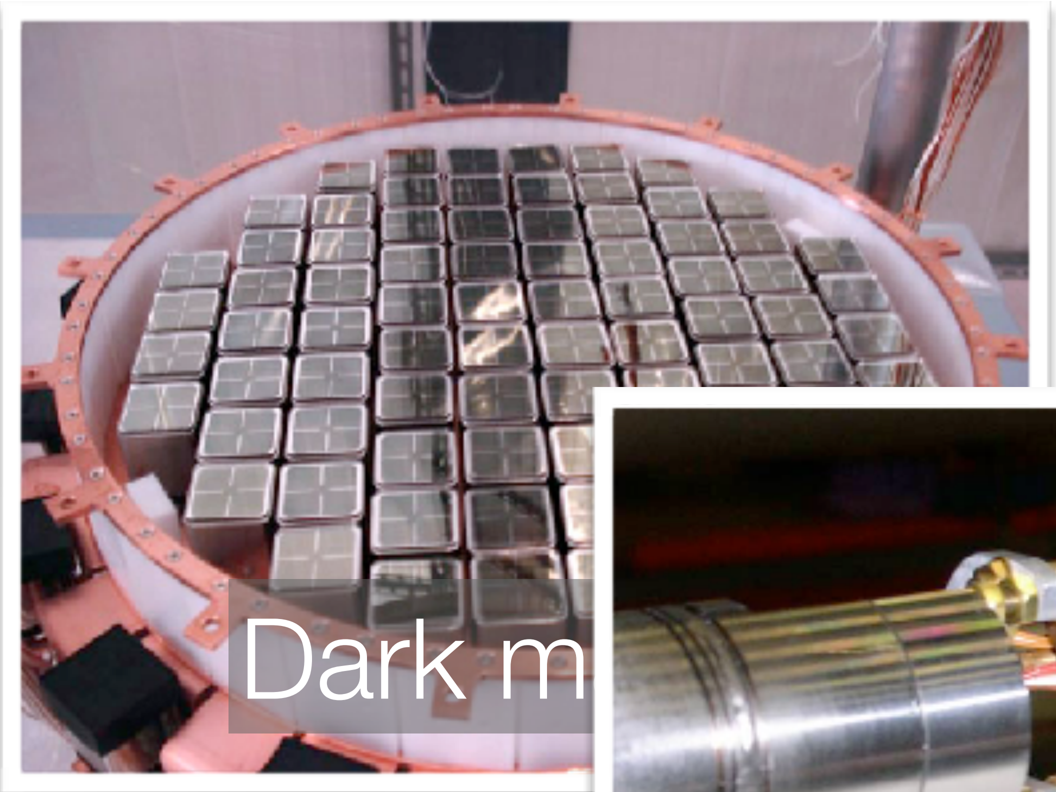

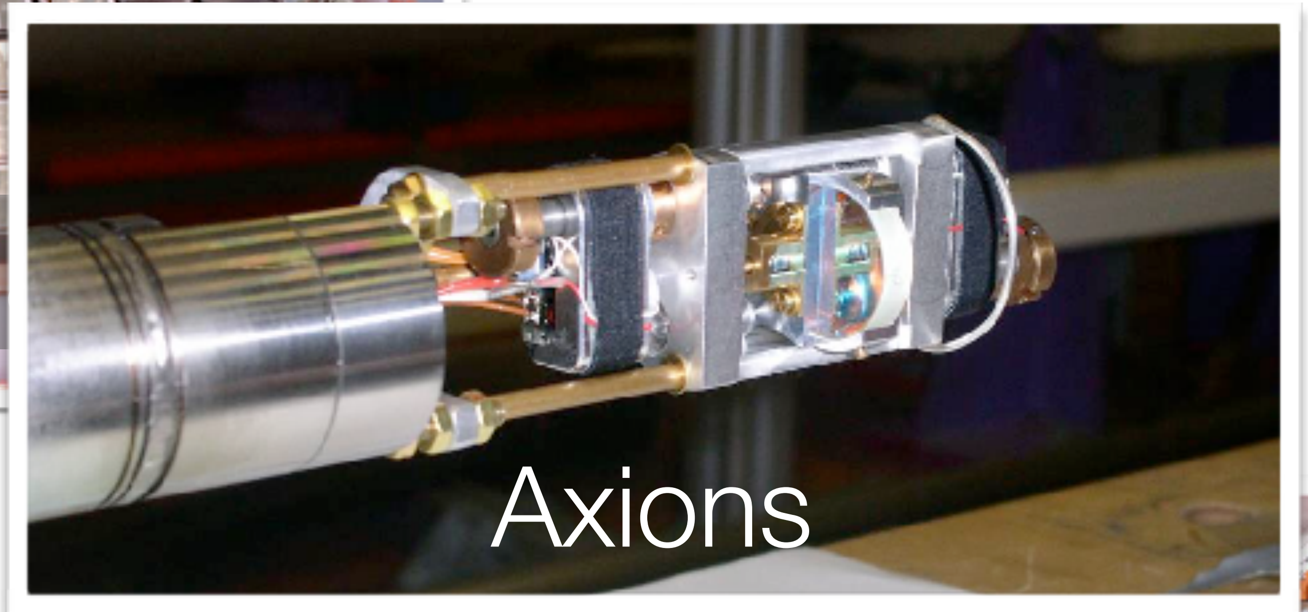

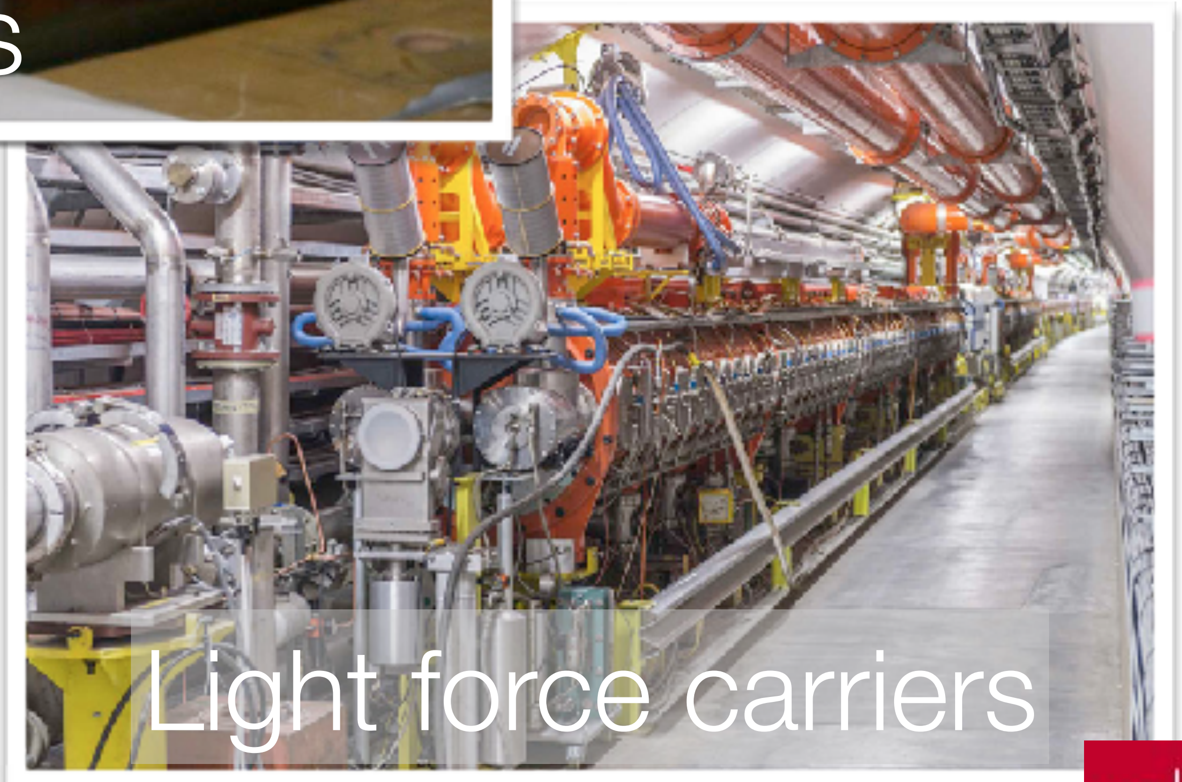

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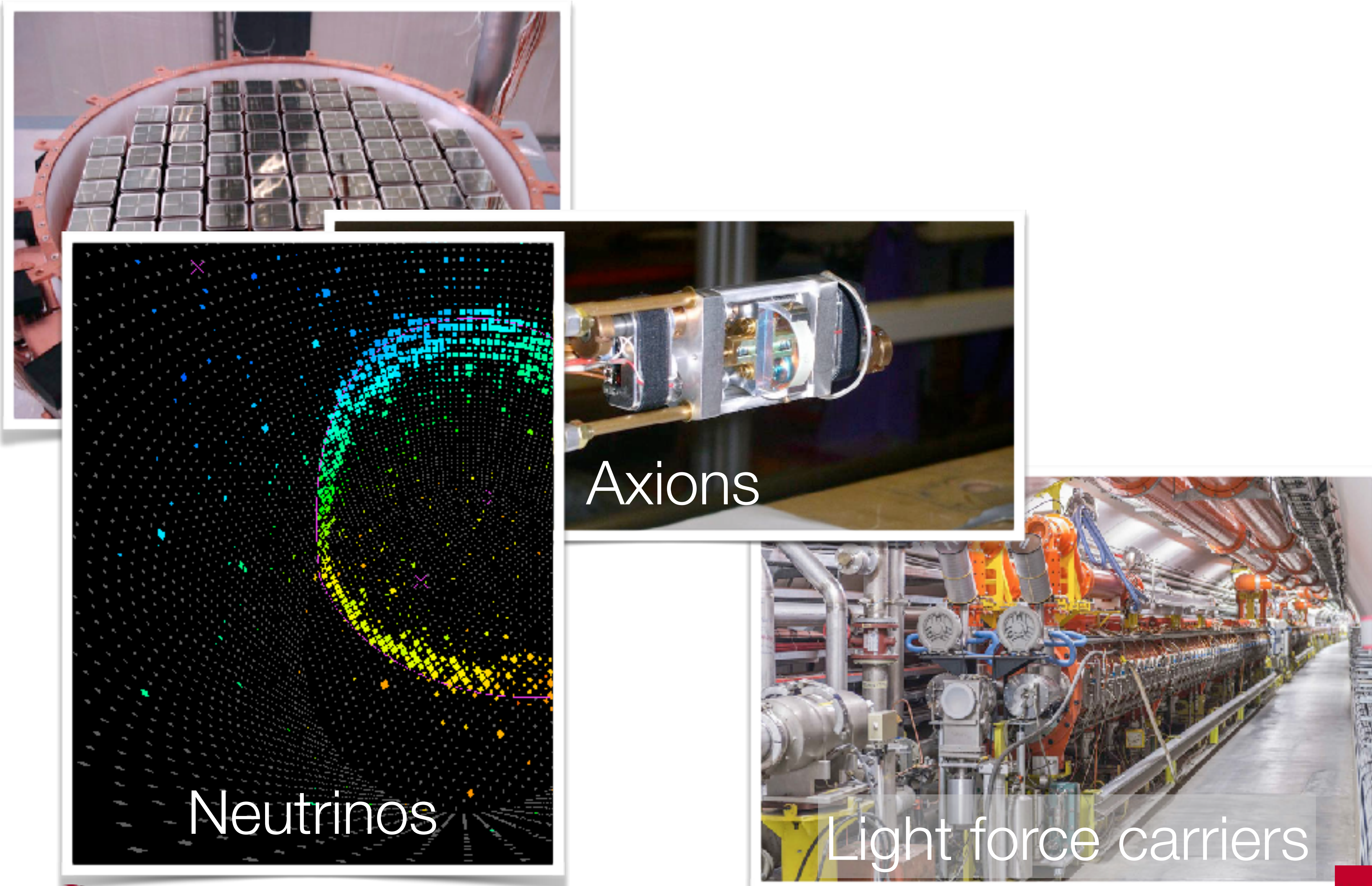

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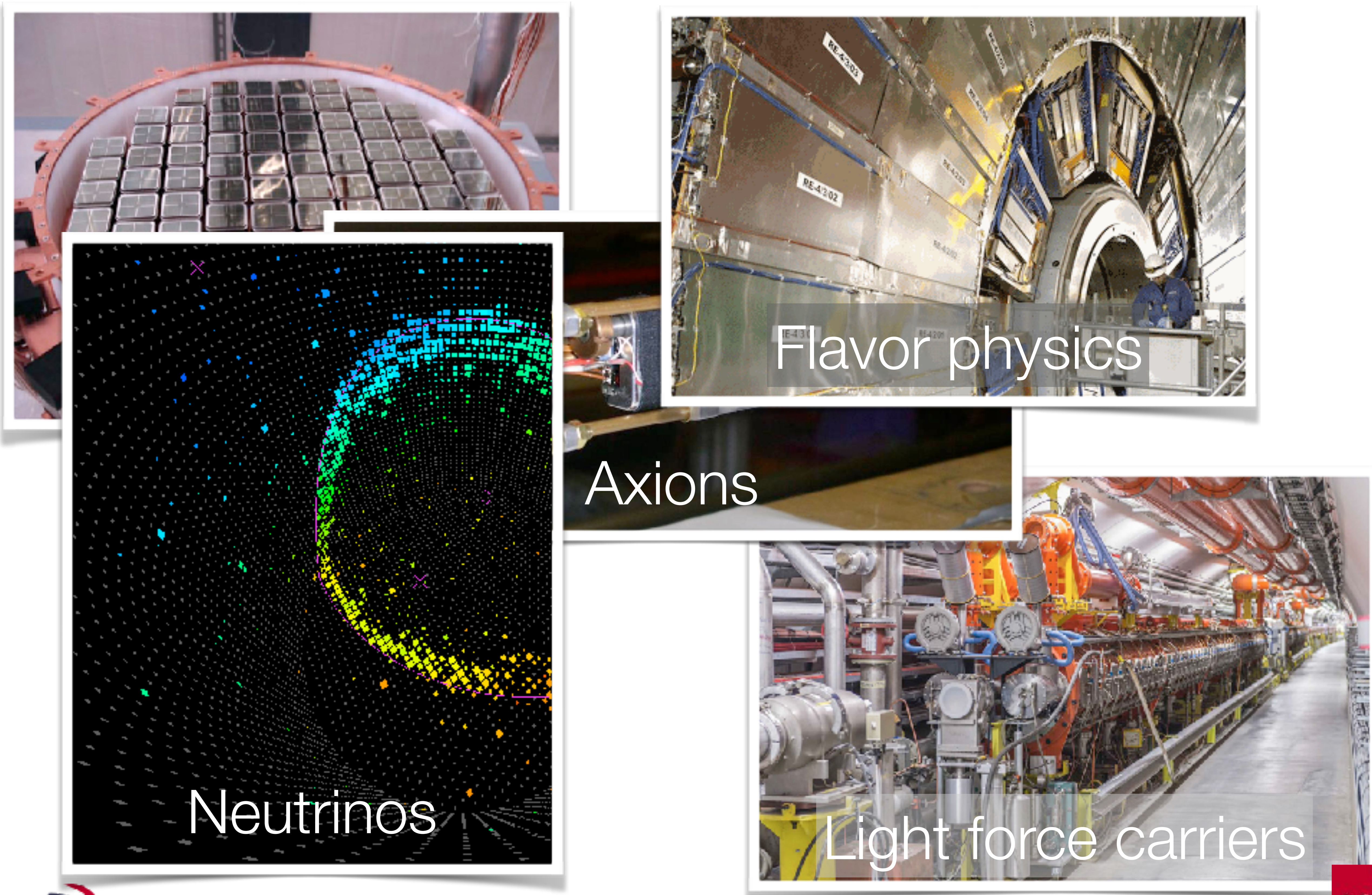

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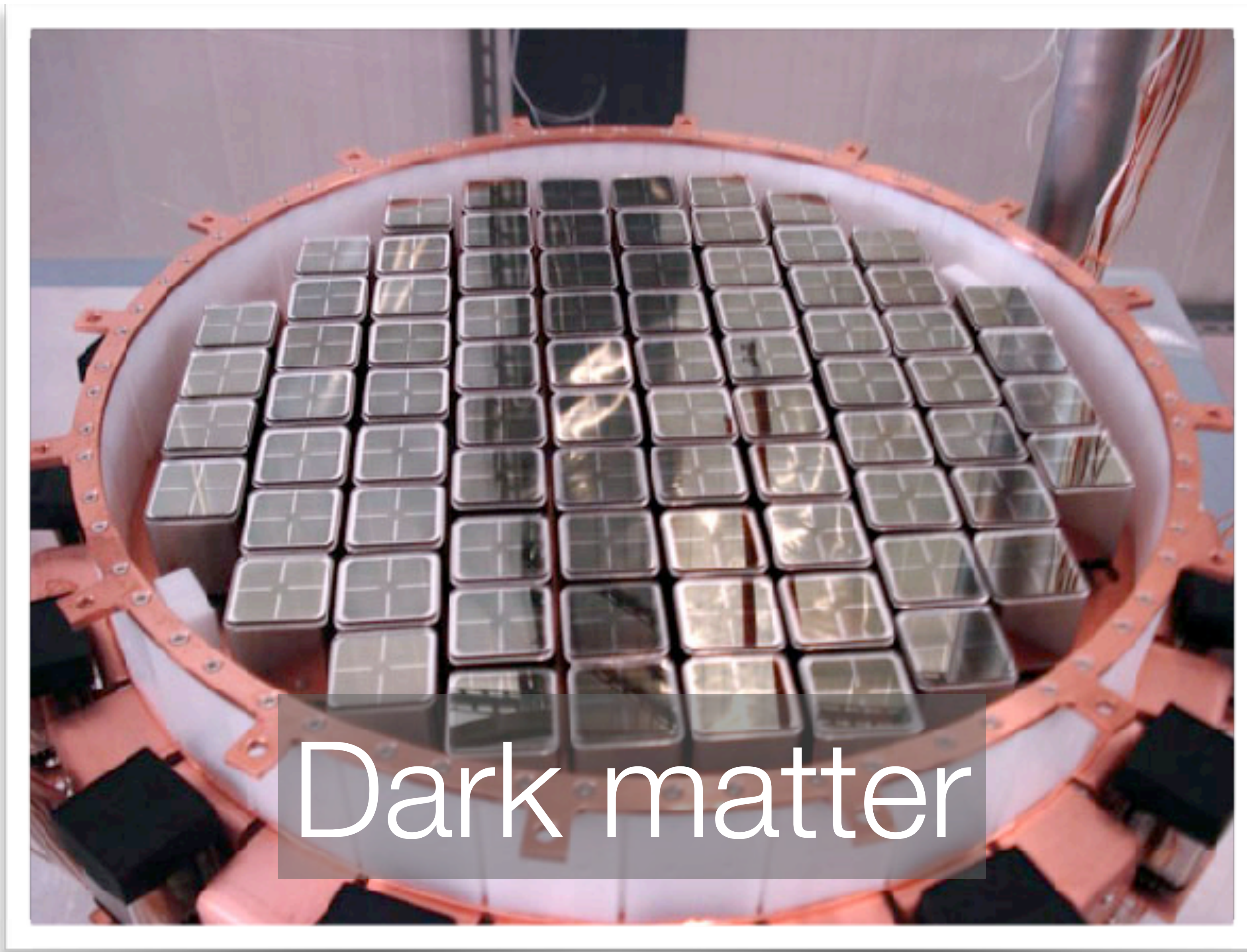
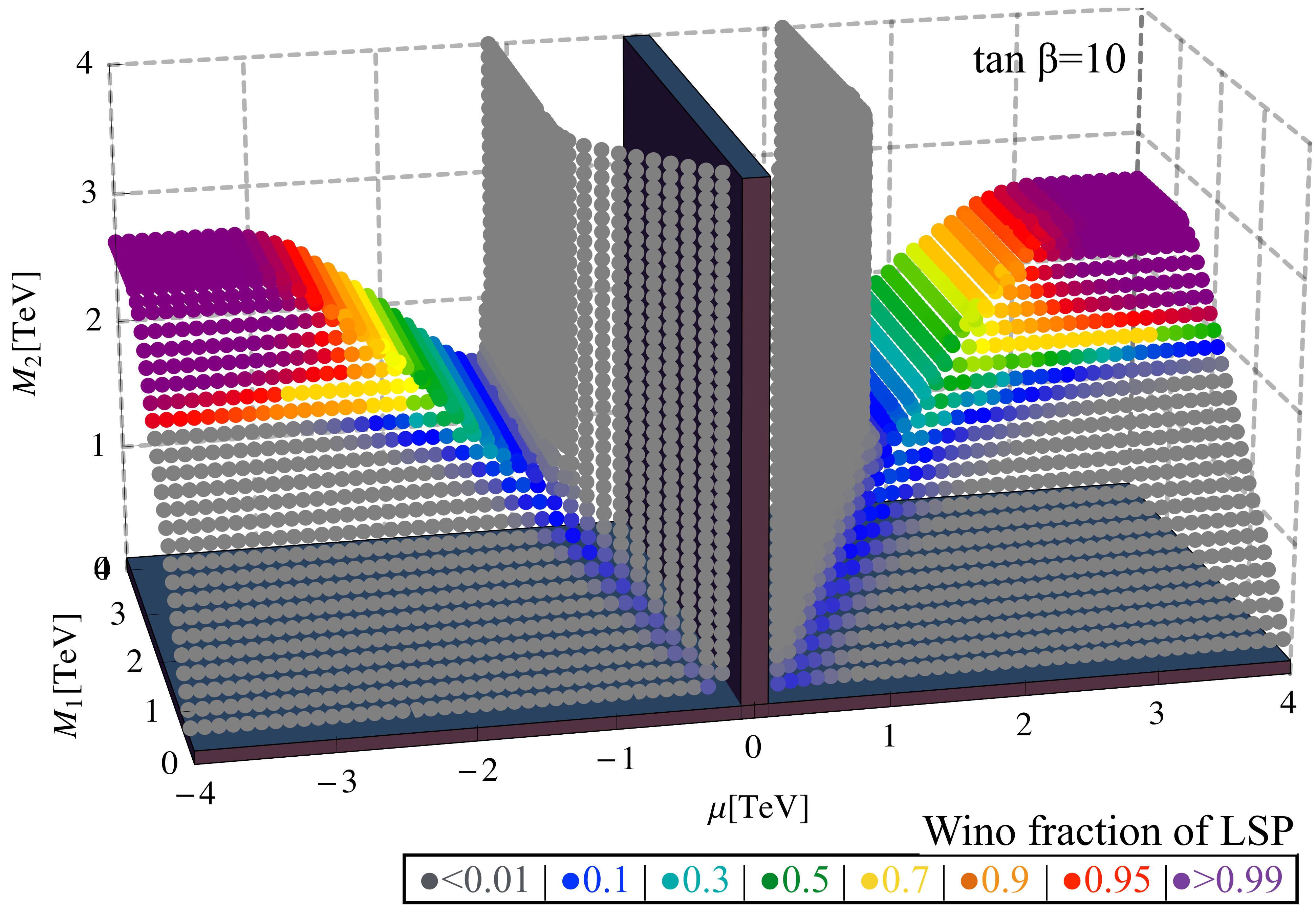


Cornering the WIMP



Bramante et al. 2015

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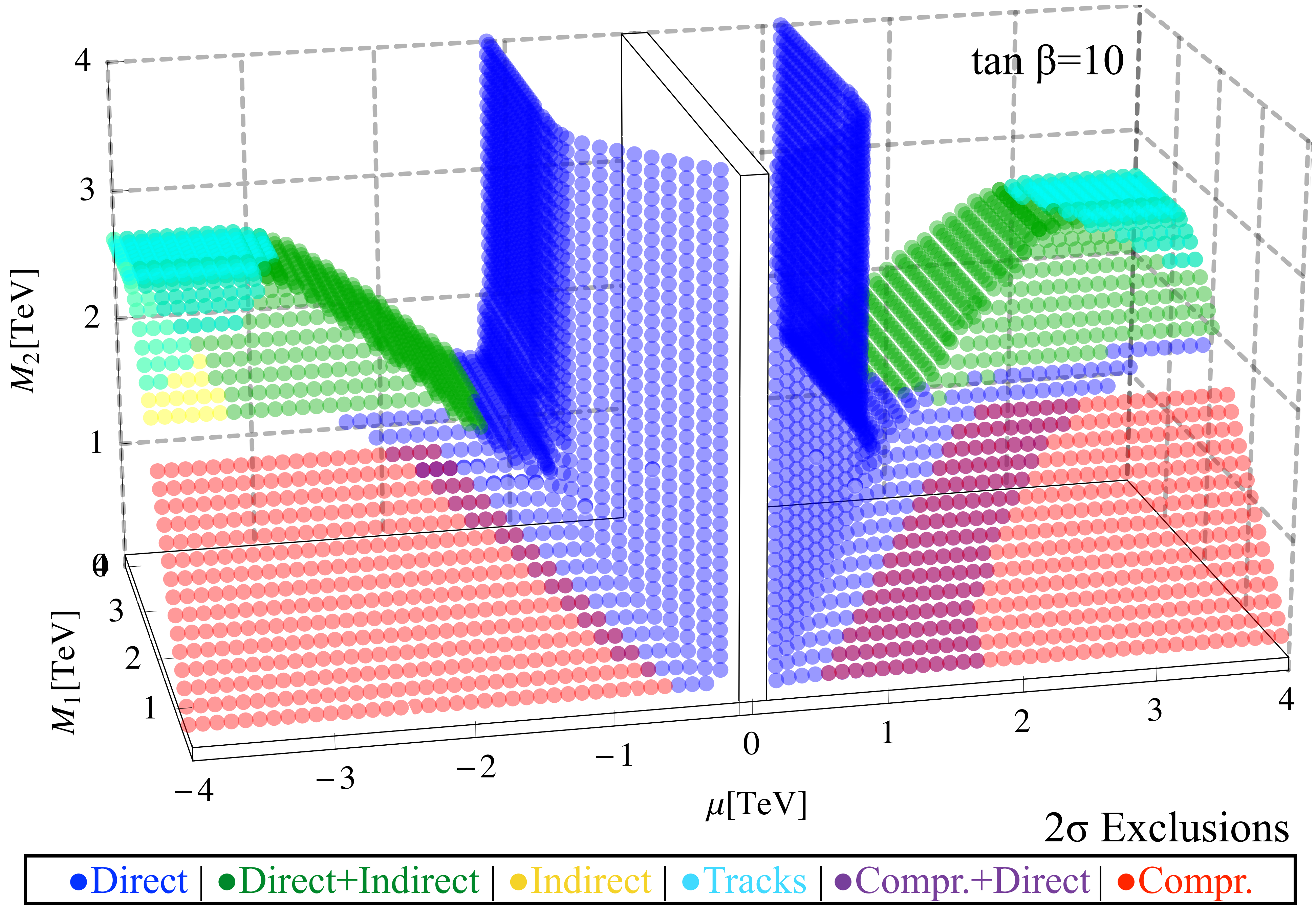

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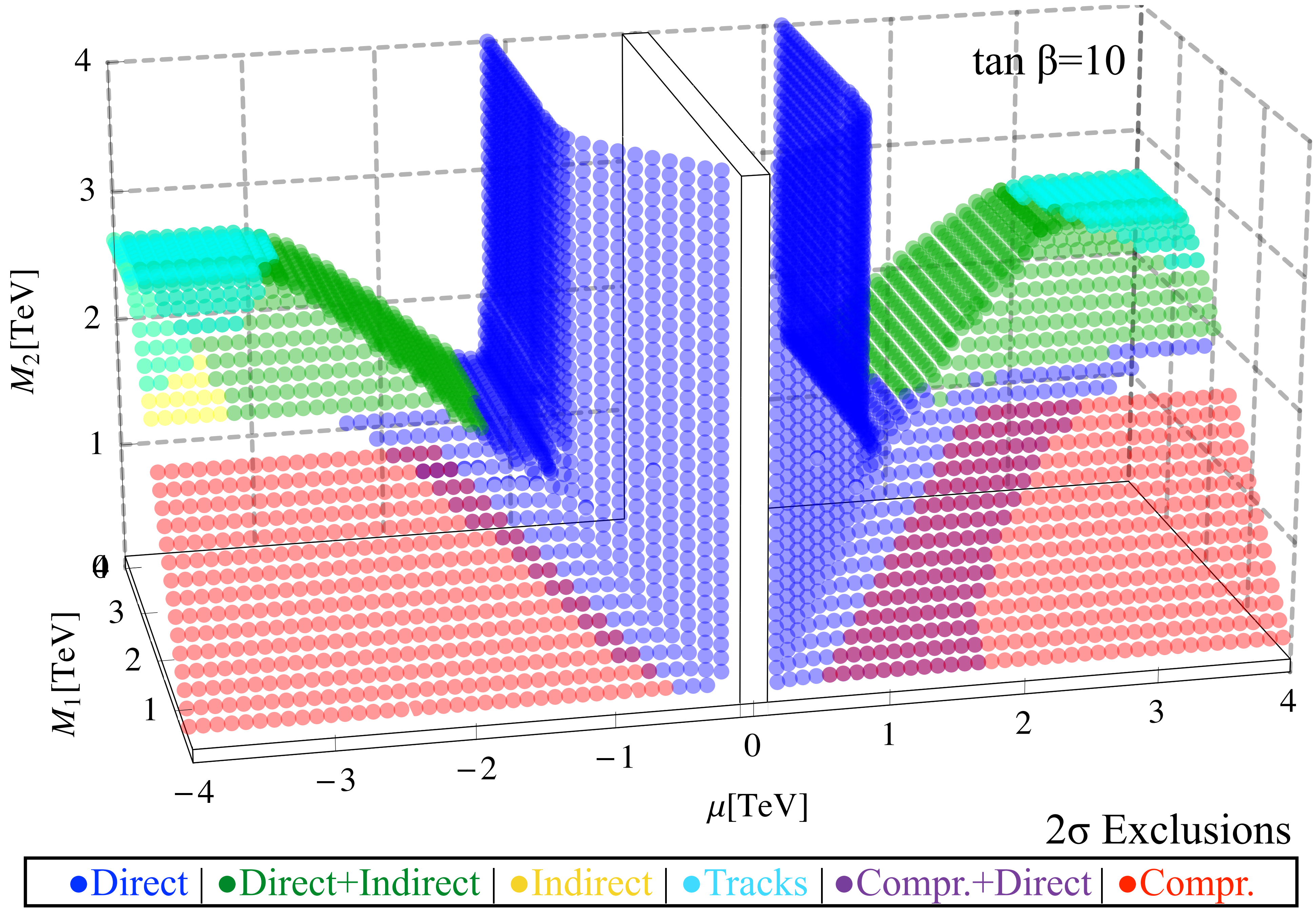

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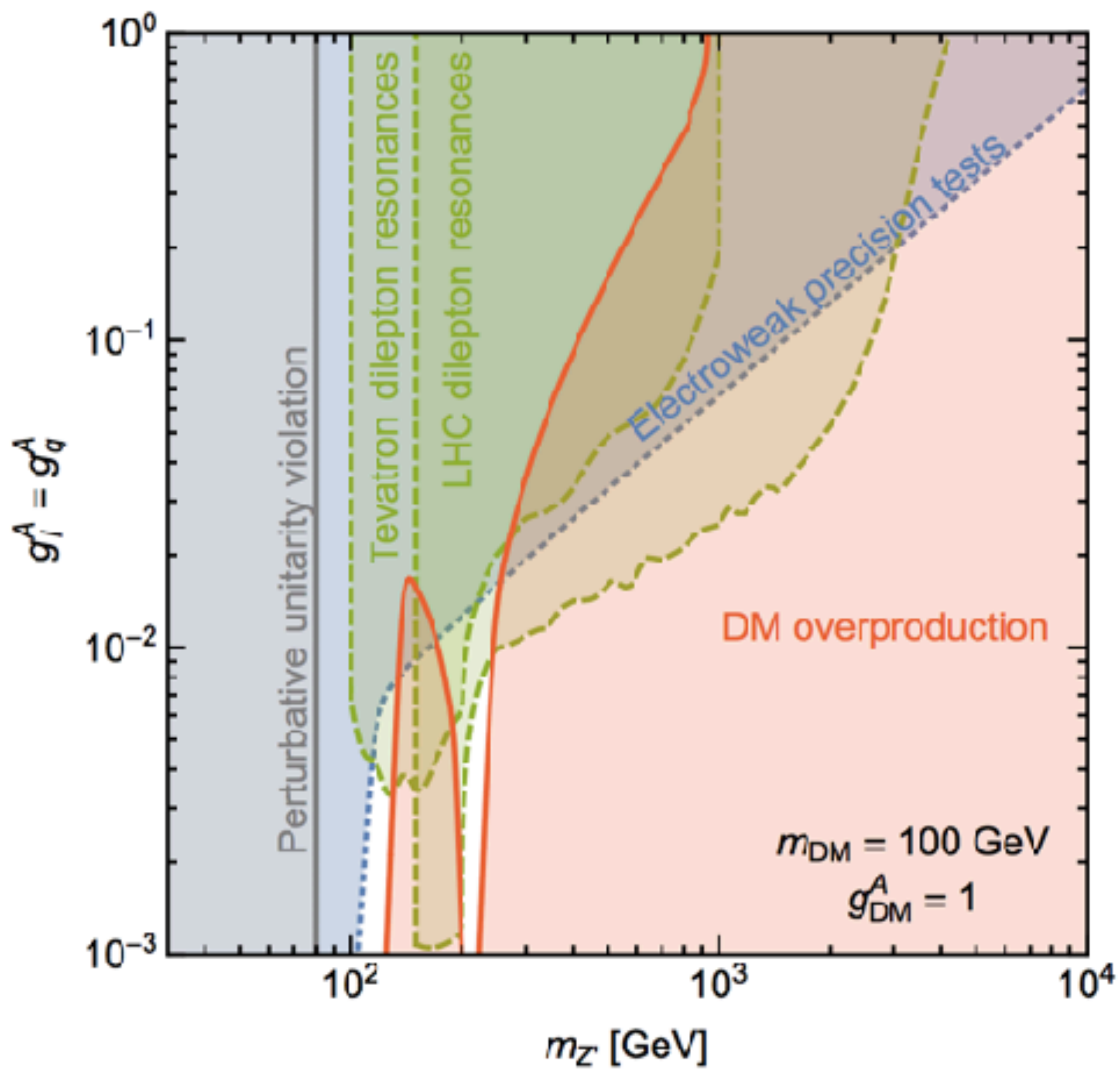
Opportunities at the Intensity Frontier

Dark Matter: Look for the Mediators!

Mediators of DM interactions often easier to detect than DM itself



Kahlhoefer Schmidt-Hoberg Schwetz Vogel, 2015
Vector+Axial (SM) + Axial (DM) coupling

Dark Matter Self-Interactions

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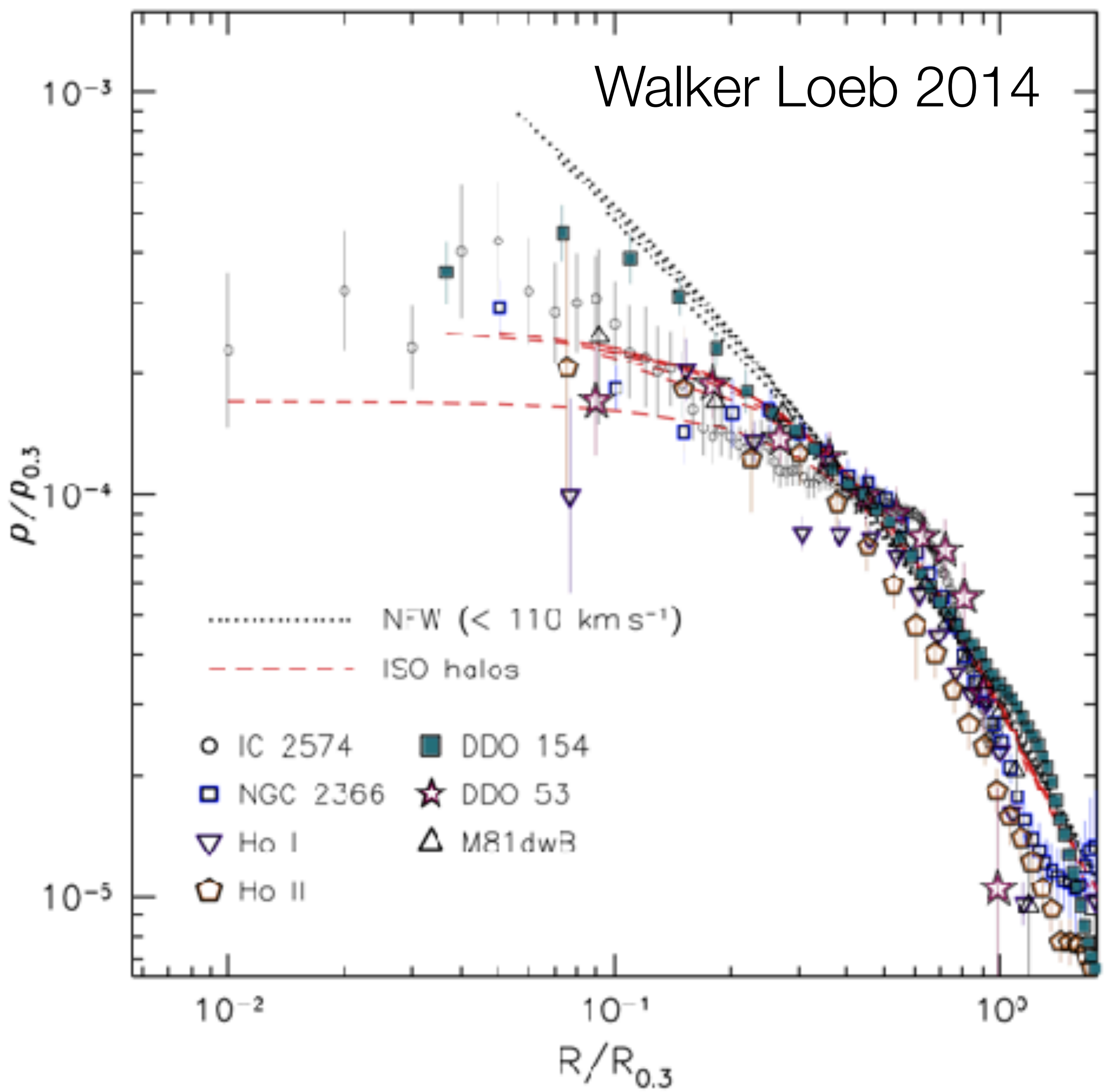

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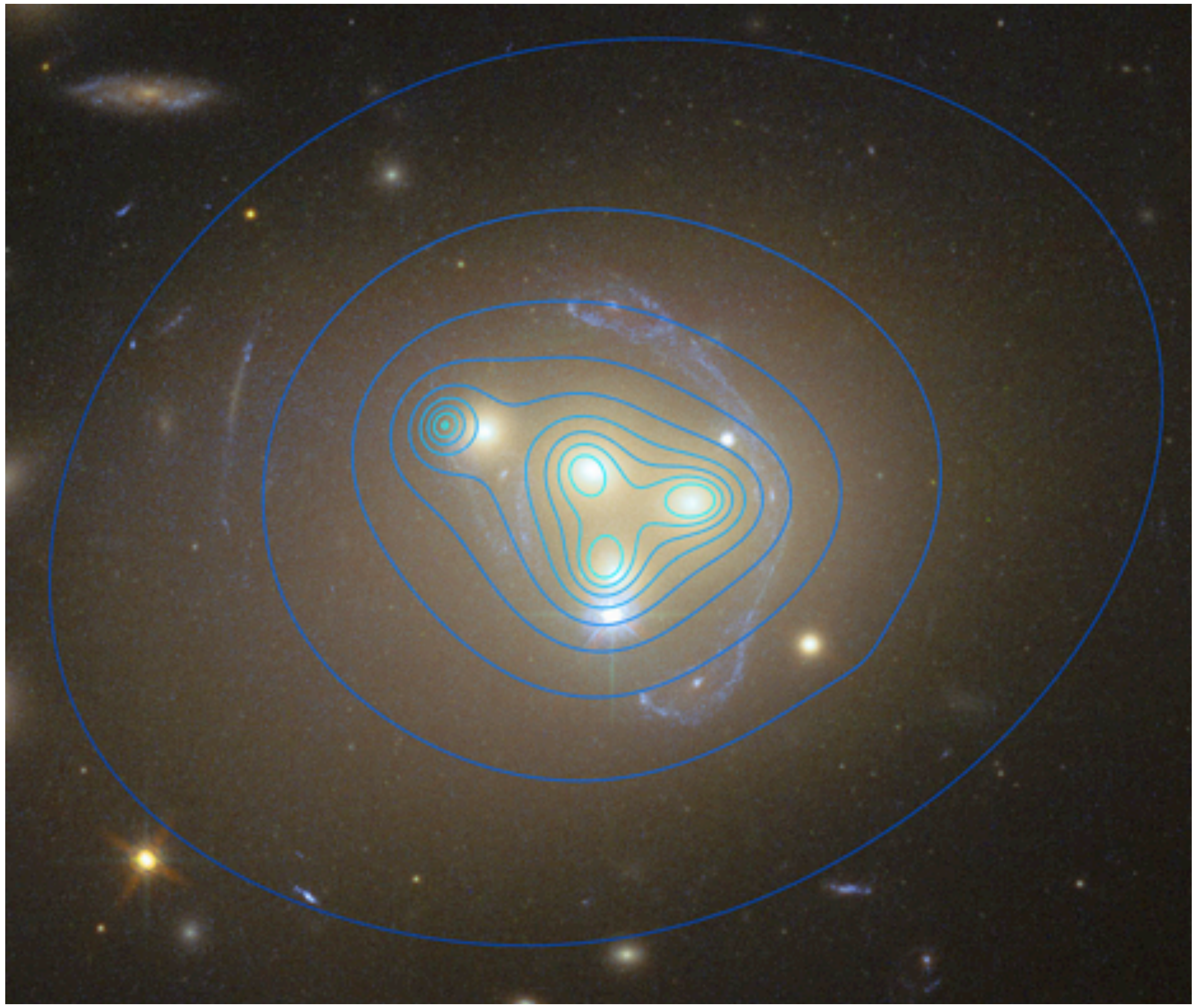

ESO/Massey et al., 2015

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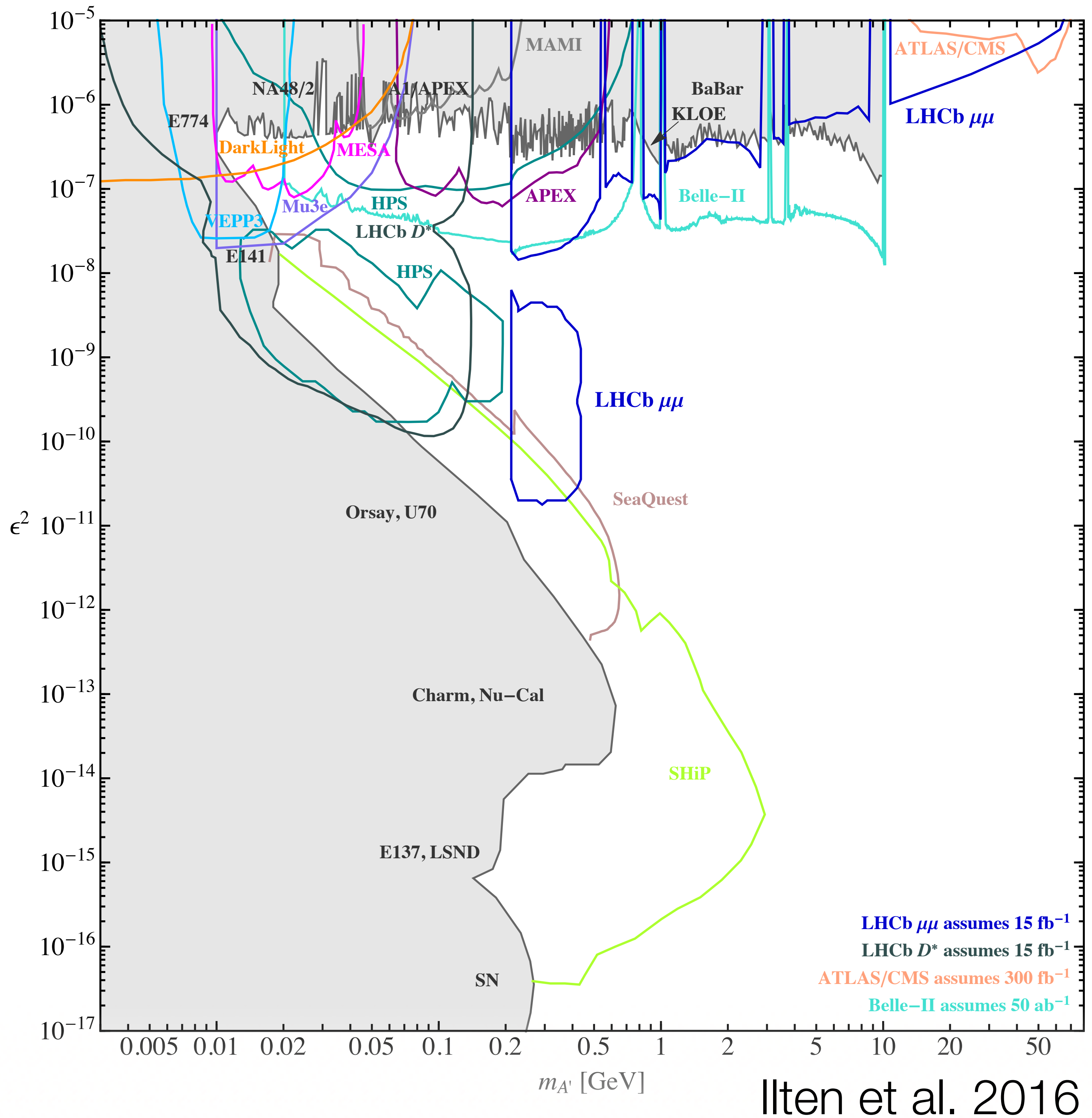
Dark Matter Self-Interactions

- Small scale DM structure deviates from predictions
  - Core vs. cusp and missing satellites problems
  - Baryon feedback or DM self-interactions? Jury is still out.
- Separation of DM and baryons in Abell 3278?
- Possible solution:
  DM self-interactions with $\sigma/m \sim 1\,\mathrm{cm}^2/\mathrm{g}$

Light Force Carriers: Searches



Ilten et al. 2016

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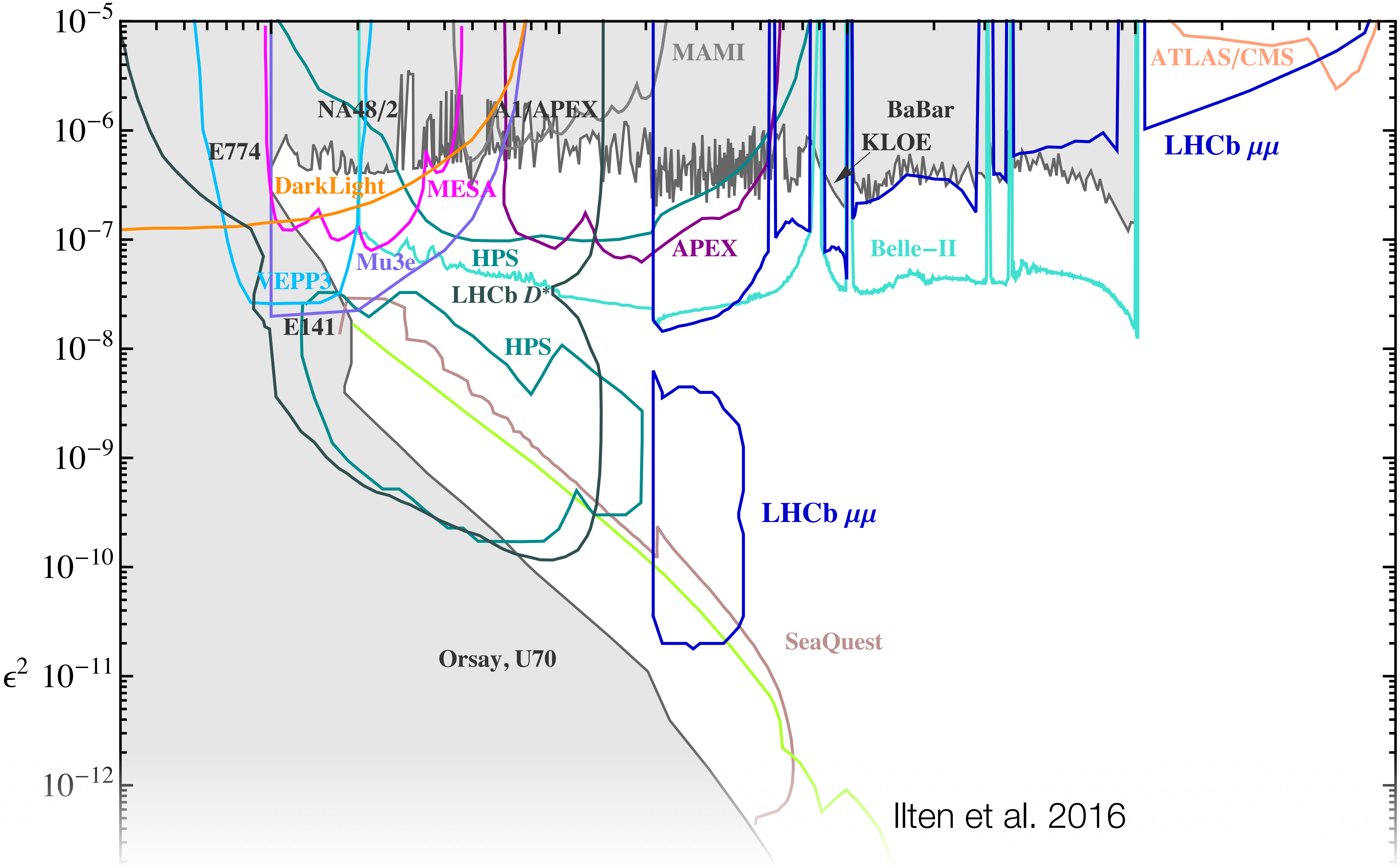

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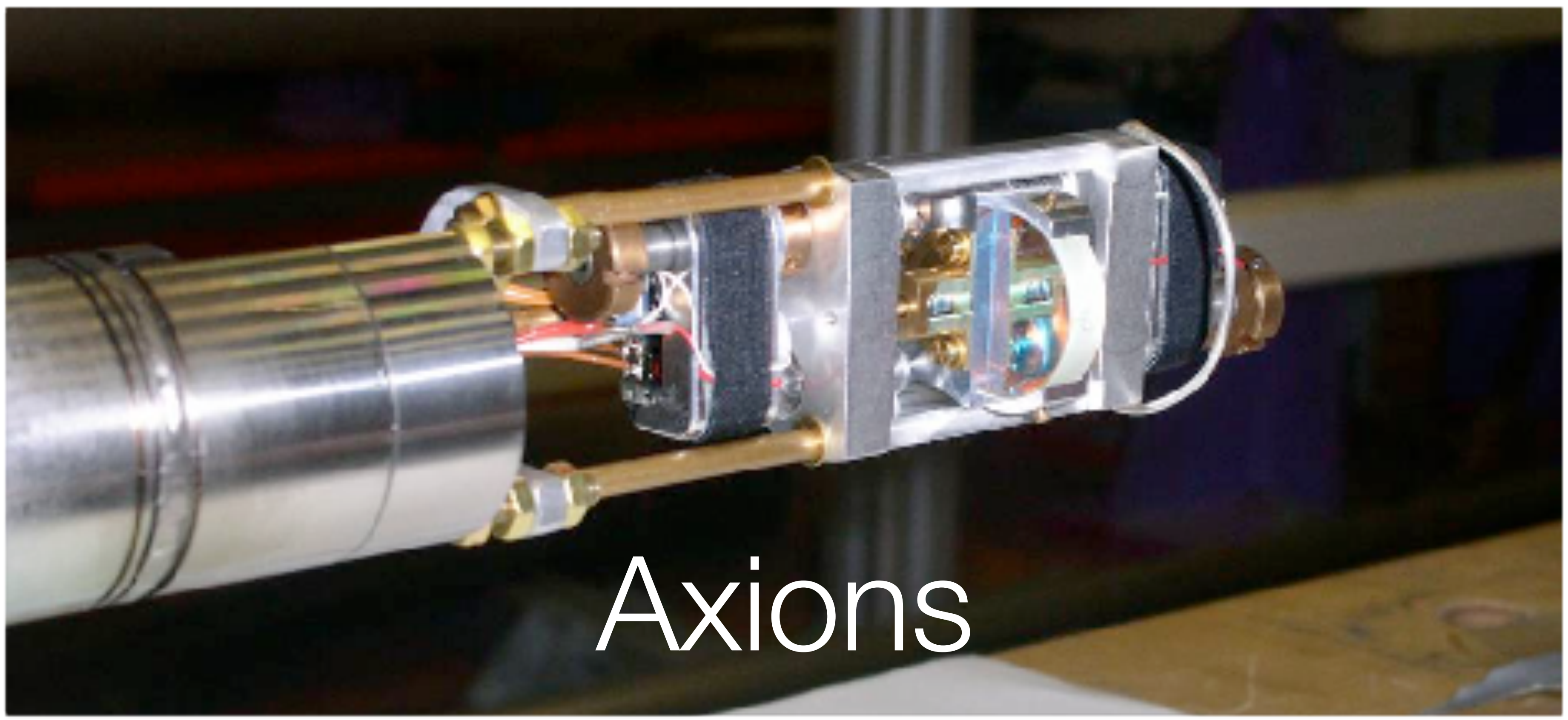

Axions: Motivation

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- QCD Lagrangian

$$\mathcal{L} \supset \theta\, F_{\mu\nu} \tilde{F}^{\mu\nu}$$

Violates CP;
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Peccei-Quinn solution

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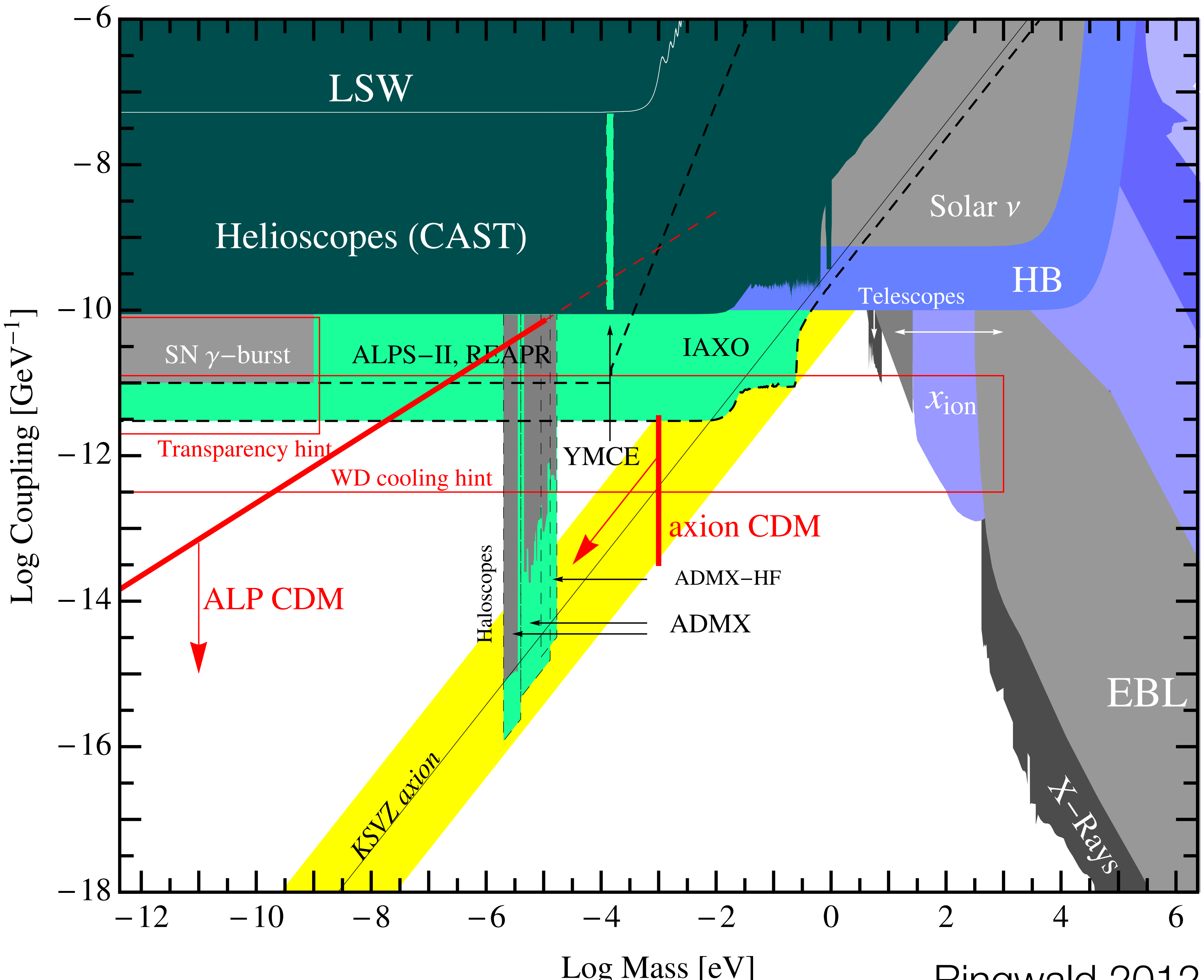
Peccei-Quinn solution

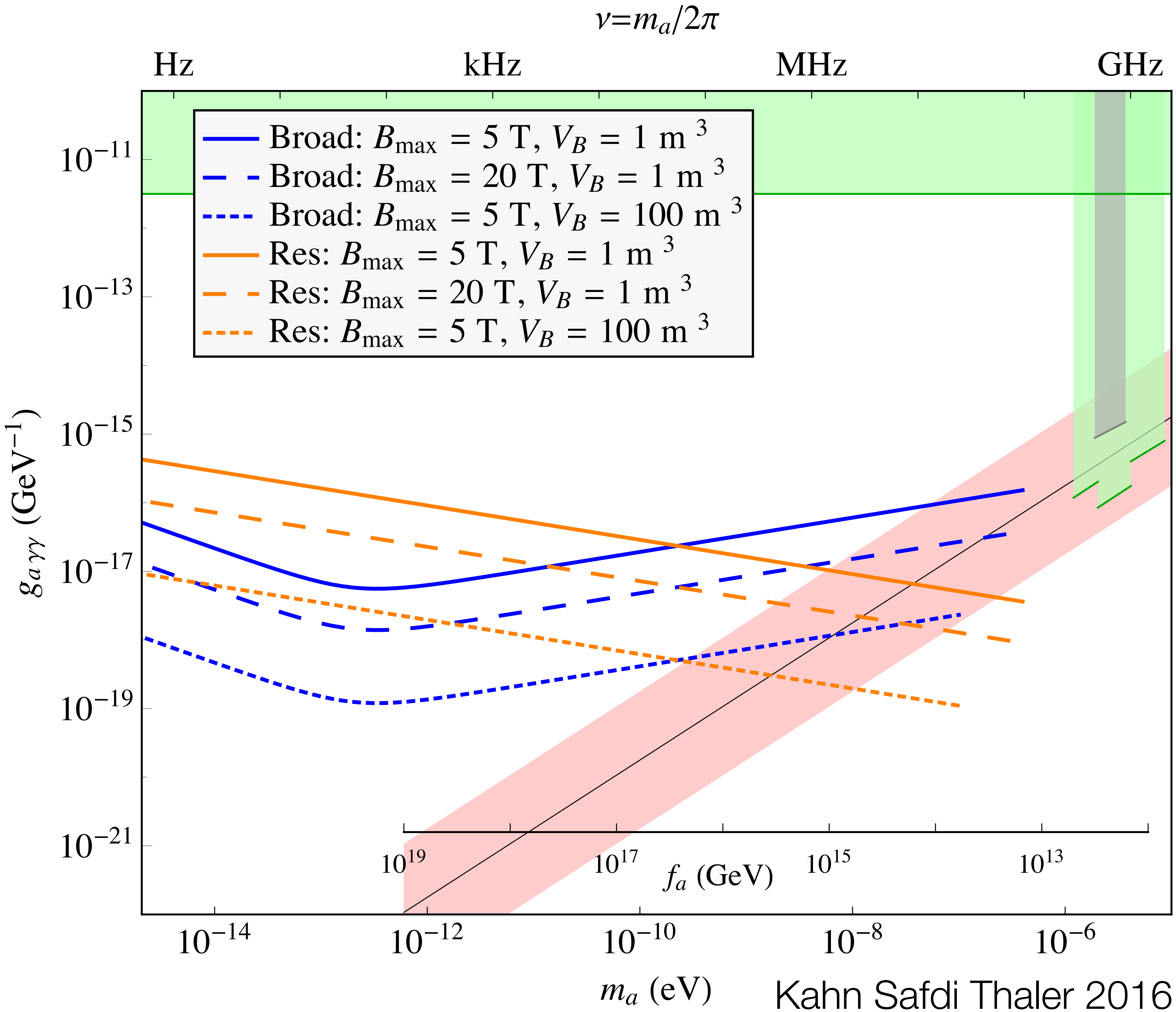
- Vev of axion a cancels θ
- Axion is an excellent dark matter candidate

Axions: Searches



Ringwald 2012

Axions: New Ideas



Kahn Safdi Thaler 2016

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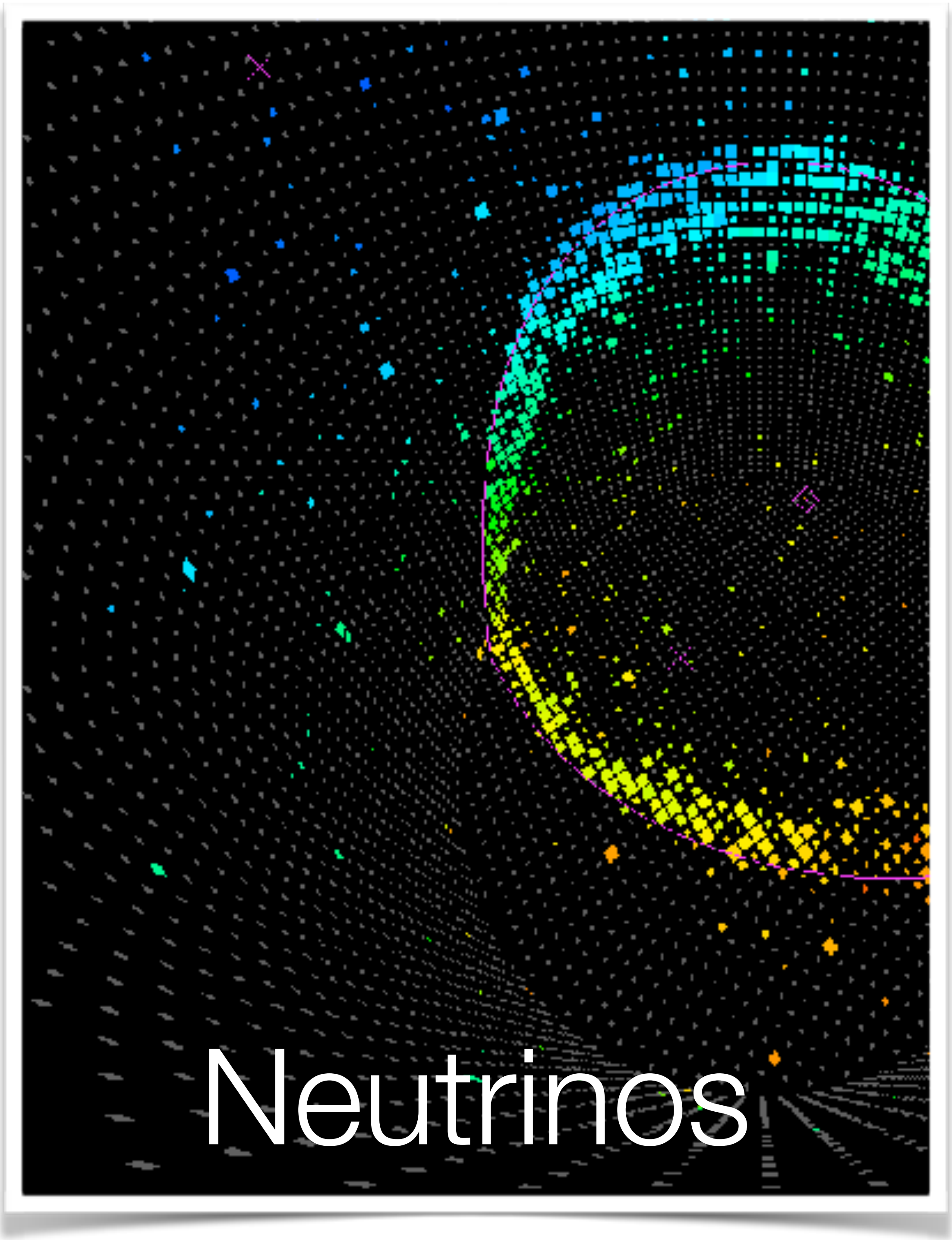
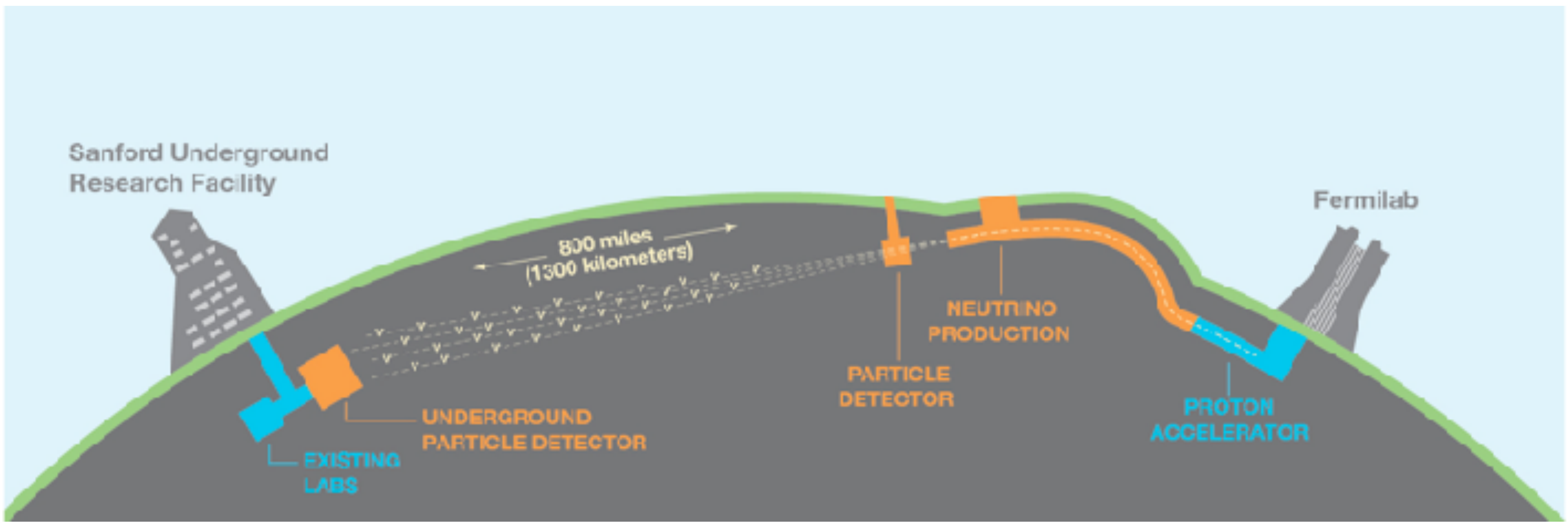
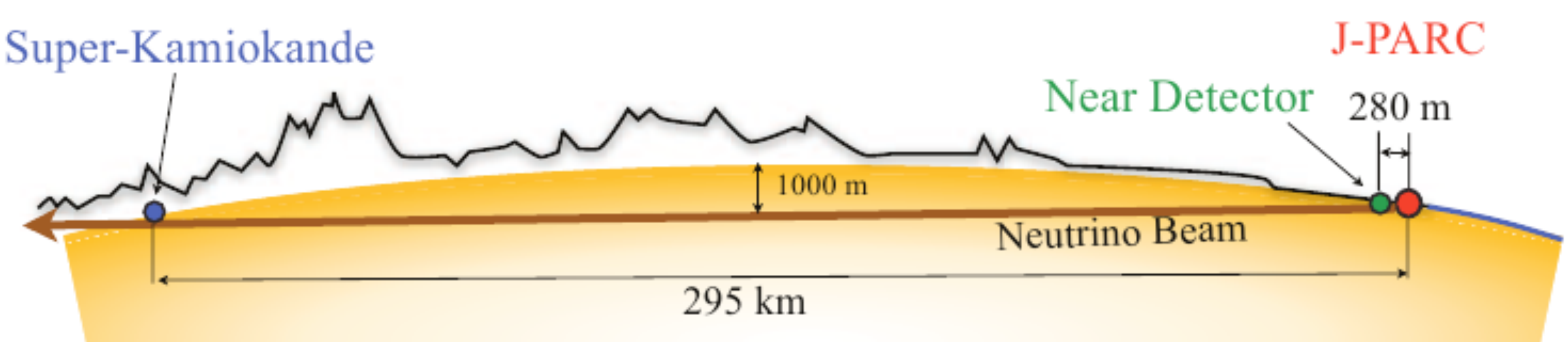


Neutrinos: T2(H)K and DUNE

- DUNE: US HEP flagship
  - Liquid argon technology (forward-looking)



- T2K/T2HK: Next in a long line of Japanese successes
  - Water Čerenkov technology (well established)



DUNE and T2(H)K: Physics Goals

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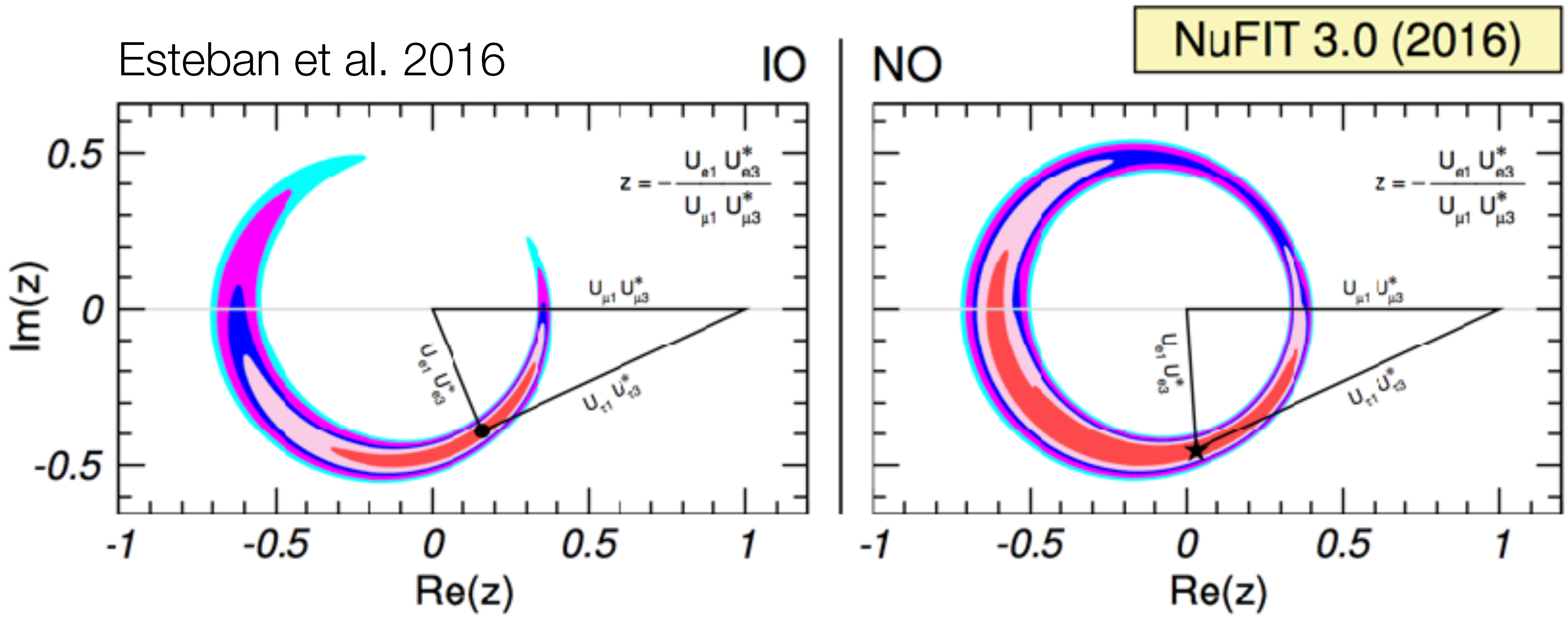
☑ Measure leptonic CP phase



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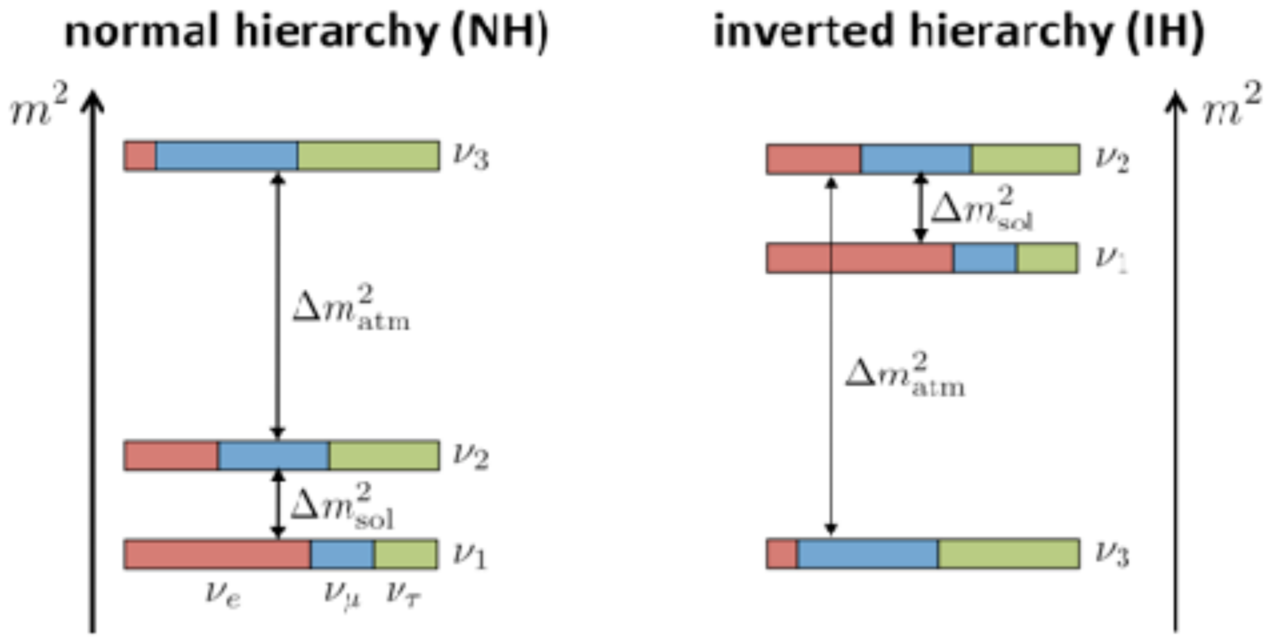

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- ☑ Supernova neutrinos
  - HyperK: $\bar{\nu}_e + p \to e^+ + n$ $\quad \nu + e^- \to \nu + e^-$
    $\nu_e + {}^{16}\mathrm{O} \to e^- + {}^{16}\mathrm{F}^{(*)}$ $\quad \bar{\nu}_e + {}^{16}\mathrm{O} \to e^+ + {}^{16}\mathrm{N}^{(*)}$
  - DUNE: $\nu_e + {}^{40}\mathrm{Ar} \to e^- + {}^{40}\mathrm{K}^{(*)}$ $\quad \bar{\nu}_e + {}^{40}\mathrm{Ar} \to e^+ + {}^{40}\mathrm{Cl}^{(*)}$
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- ☑ New physics in the neutrino sector

New Physics in Neutrino Oscillations

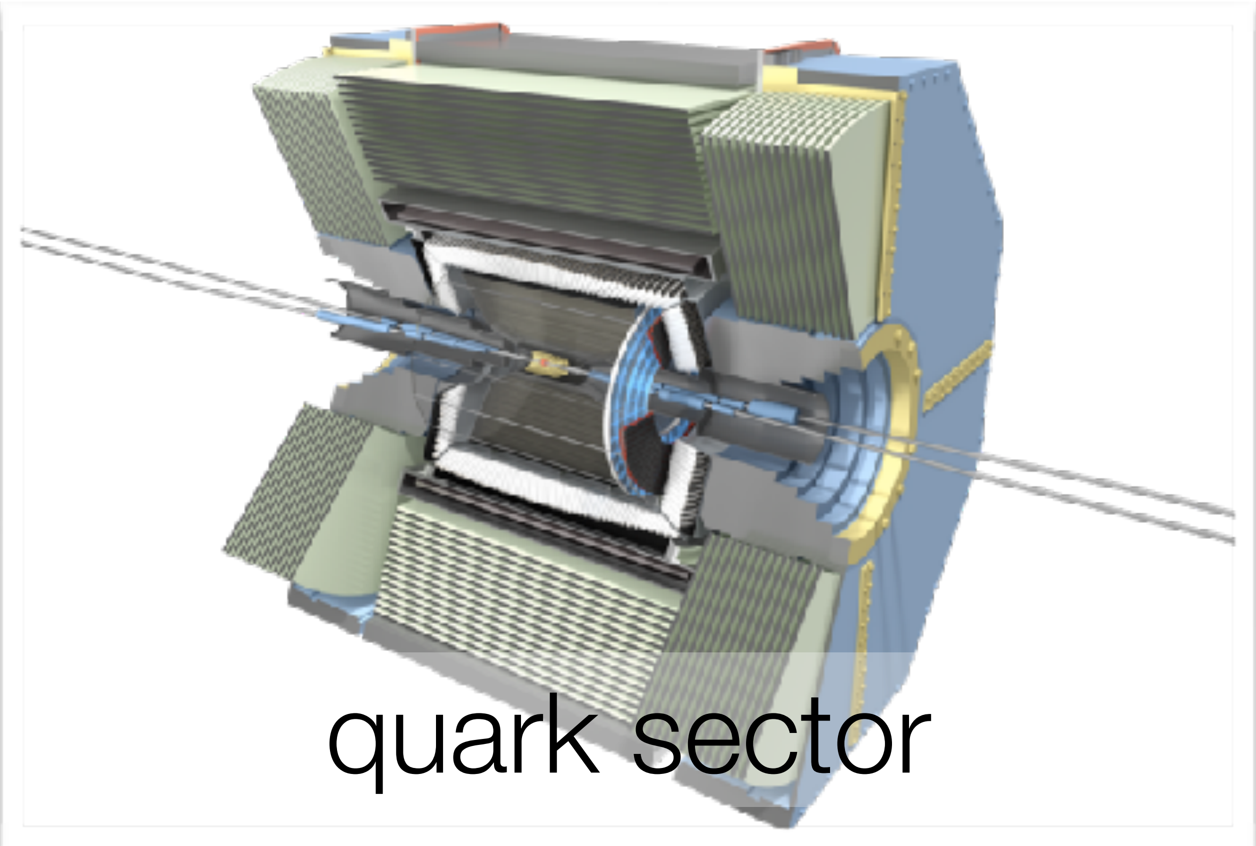
- The neutrino portal to a singlet sector

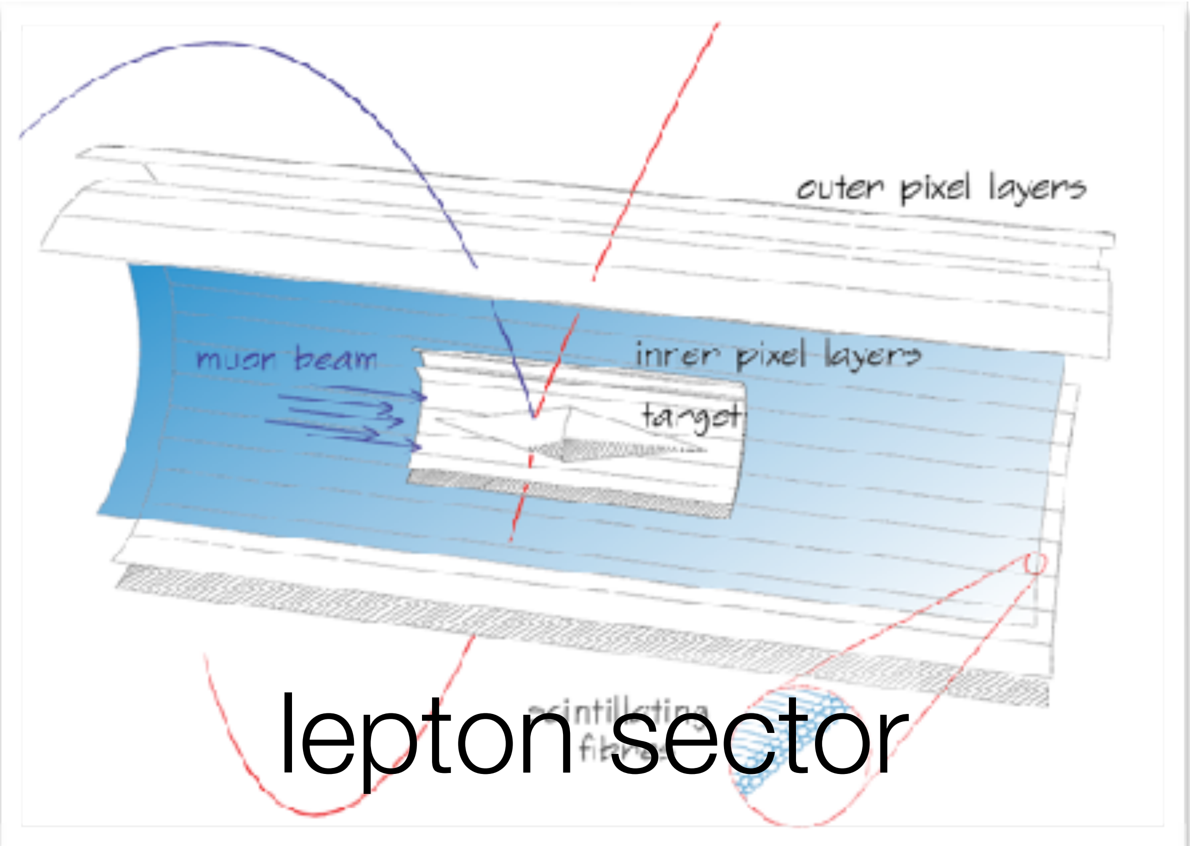
$$\mathcal{L} \supset y\,\bar{L}\tilde{H}N + h.c.$$

- Possible phenomenological consequences
  - non-unitary mixing matrix at low energy $U \to (\mathbb{1} - \alpha)U$
  - oscillations into sterile states

- Non-standard neutrino interactions
  - new neutrinophilic interactions with non-trivial flavor structure
  - light mediators
  - coupling via singlet N
- Complementary to charged LFV

Flavor physics





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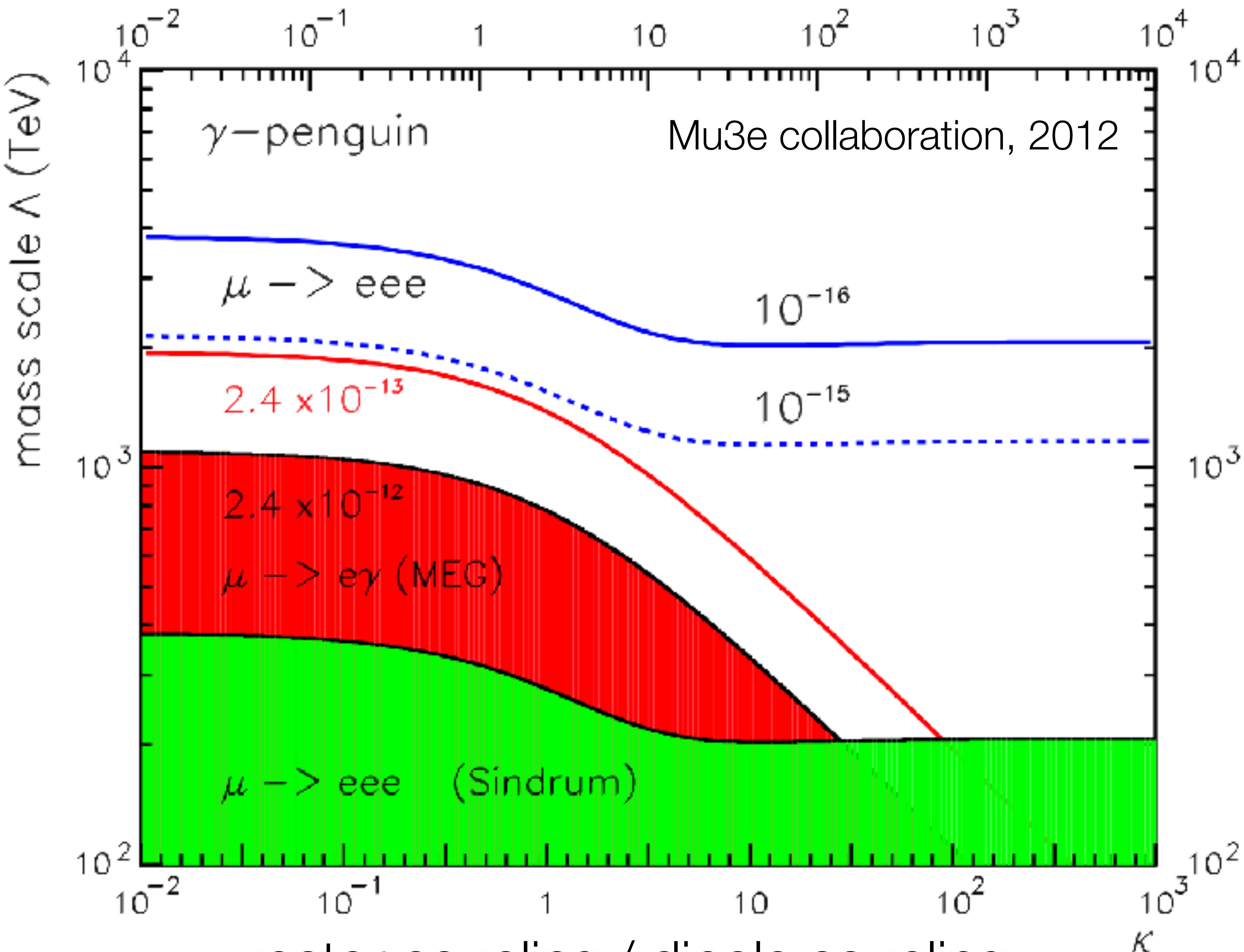

vector coupling / dipole coupling

Conclusions

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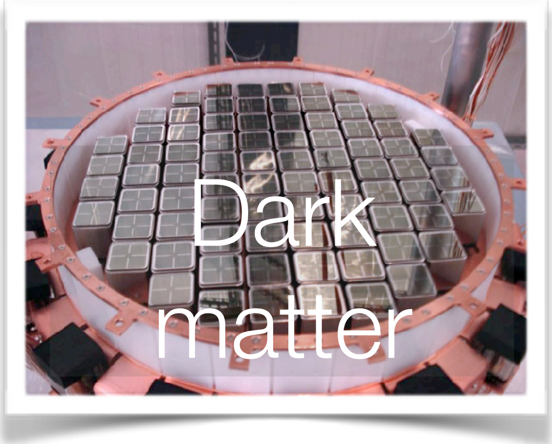
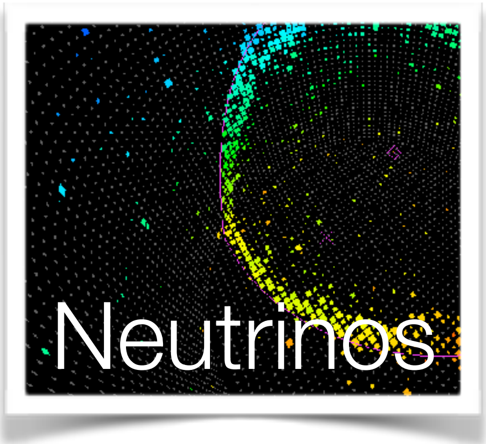
☑ Possibly game-changing opportunities





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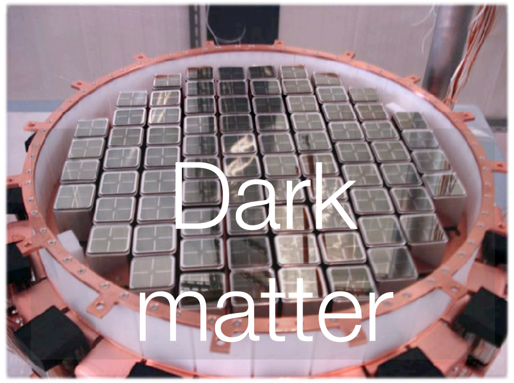

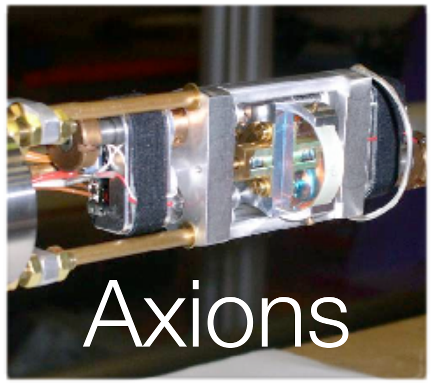

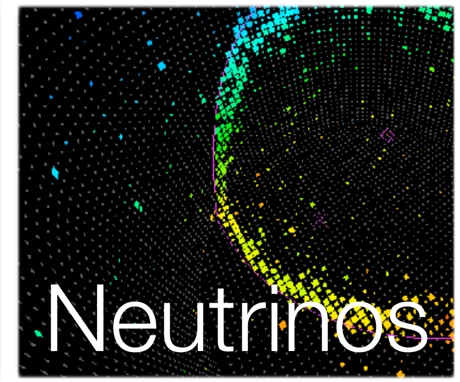

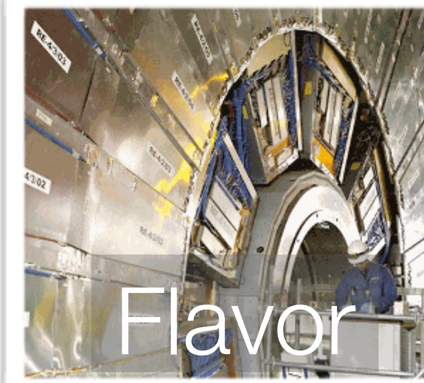

☑ Maintain diversity

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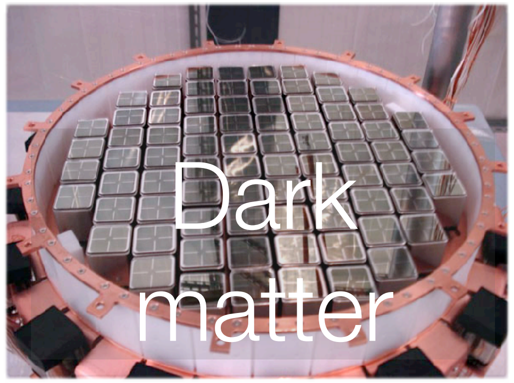

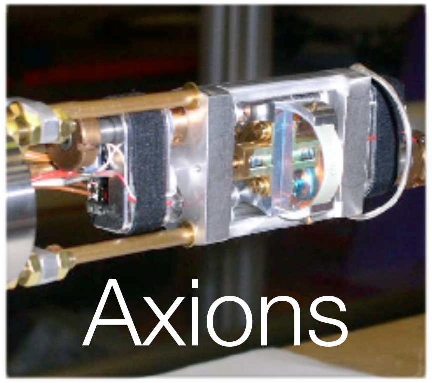

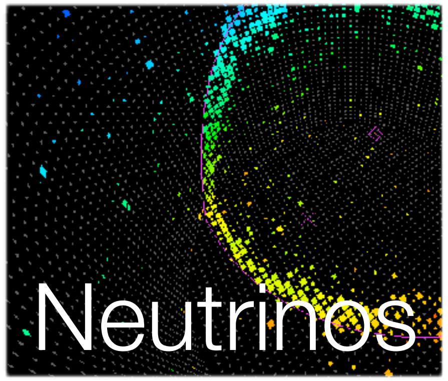

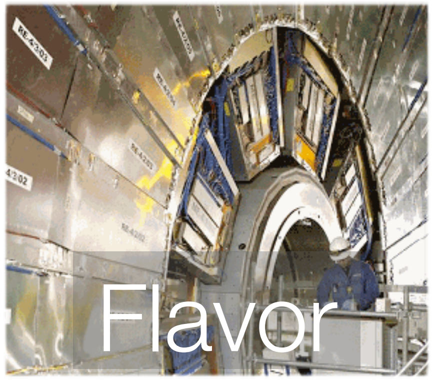

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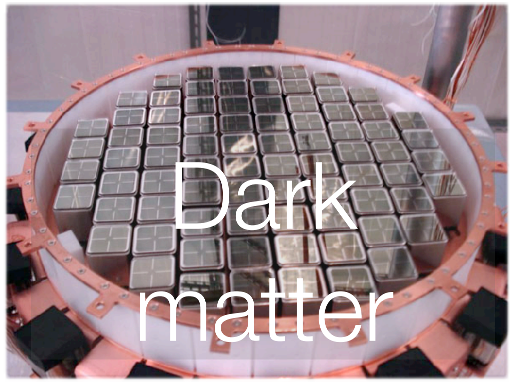

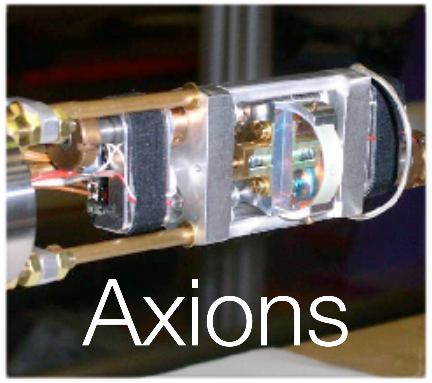

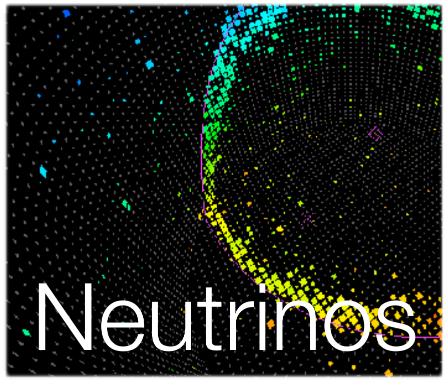

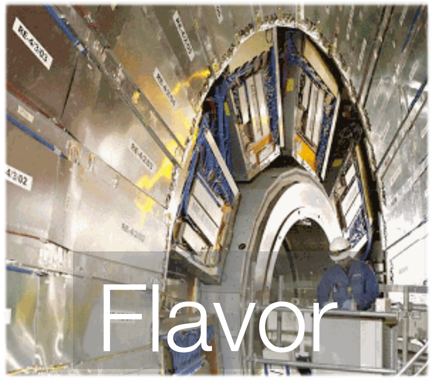

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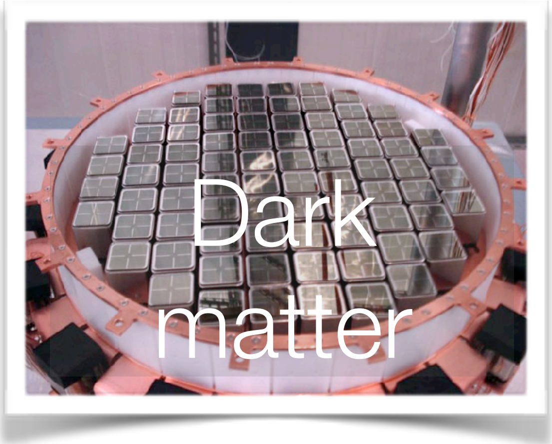

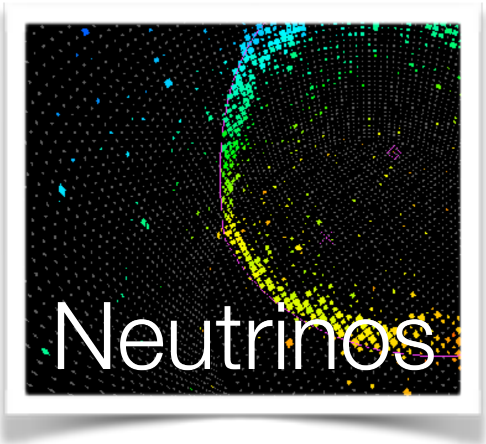

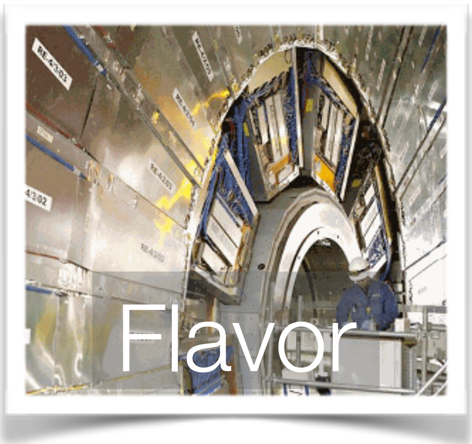

- Maintain diversity
- Discoveries often follow technological breakthroughs

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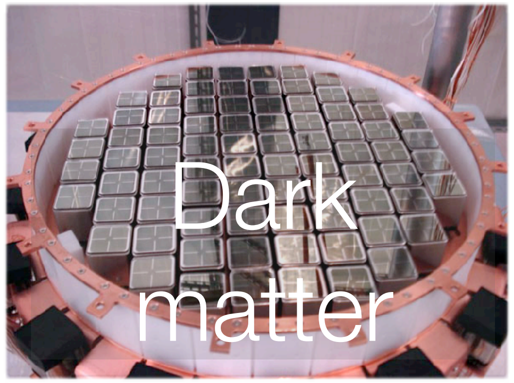

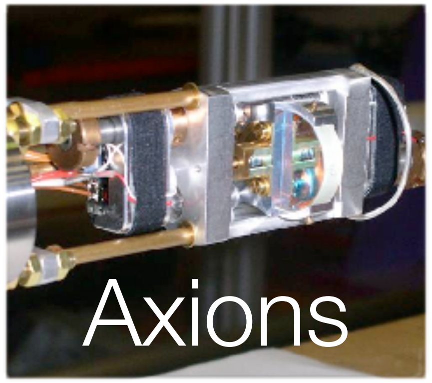

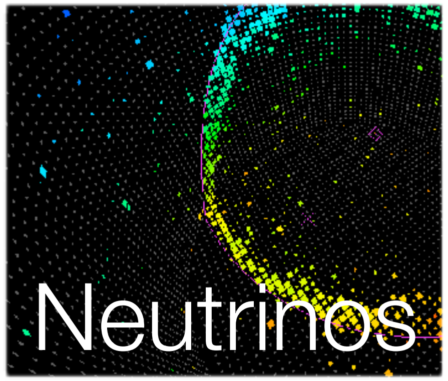

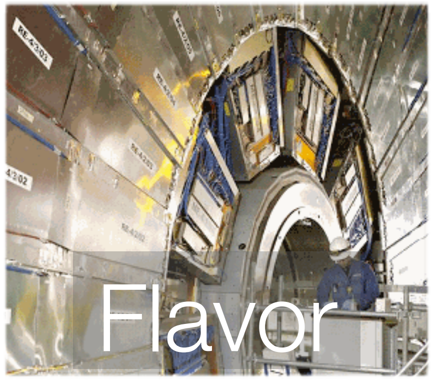

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