Inelastic Dirac Dark Matter

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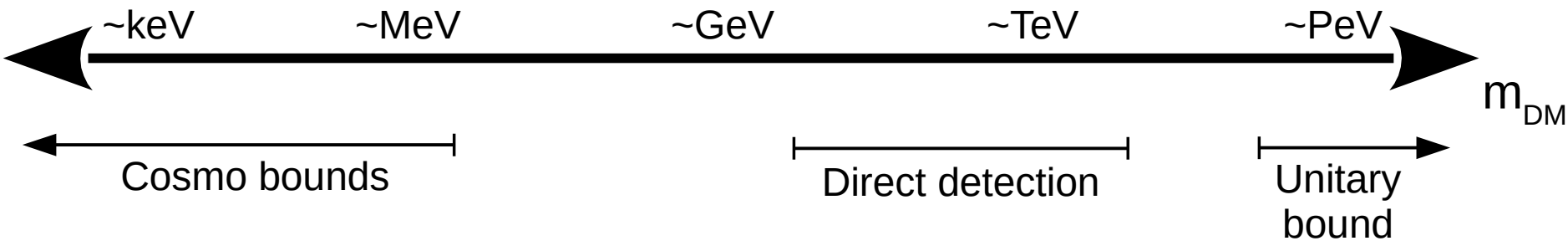
Thermal Dark Matter

- Nature of Dark Matter is one of the main open questions in modern physics
- Strong theoretical and experimental effort made to answer this question



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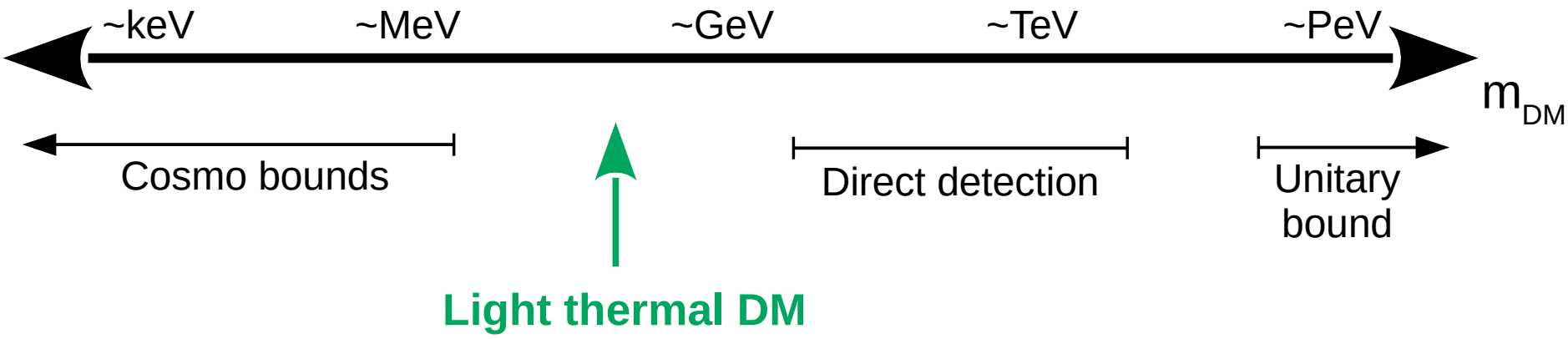


Inelastic Dirac Dark Matter (i2DM)

- New $U(1)_D$ with dark photon kinetically mixing with the hypercharge gauge boson

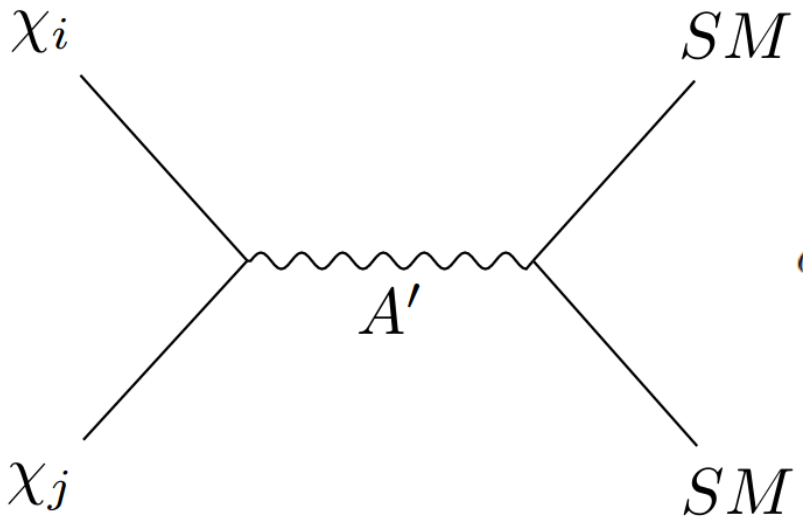
$$\mathcal{L} \supset -\frac{\epsilon}{2c_W} F_D^{\mu\nu} B_{\mu\nu}$$

- Two nearly degenerate Dirac fermions, one charged (χ_2) and one neutral (χ_1) under $U(1)_D$
- Higgs-like mechanism breaks $U(1)_D$, causing fermions to mix

Relic abundance in i2DM

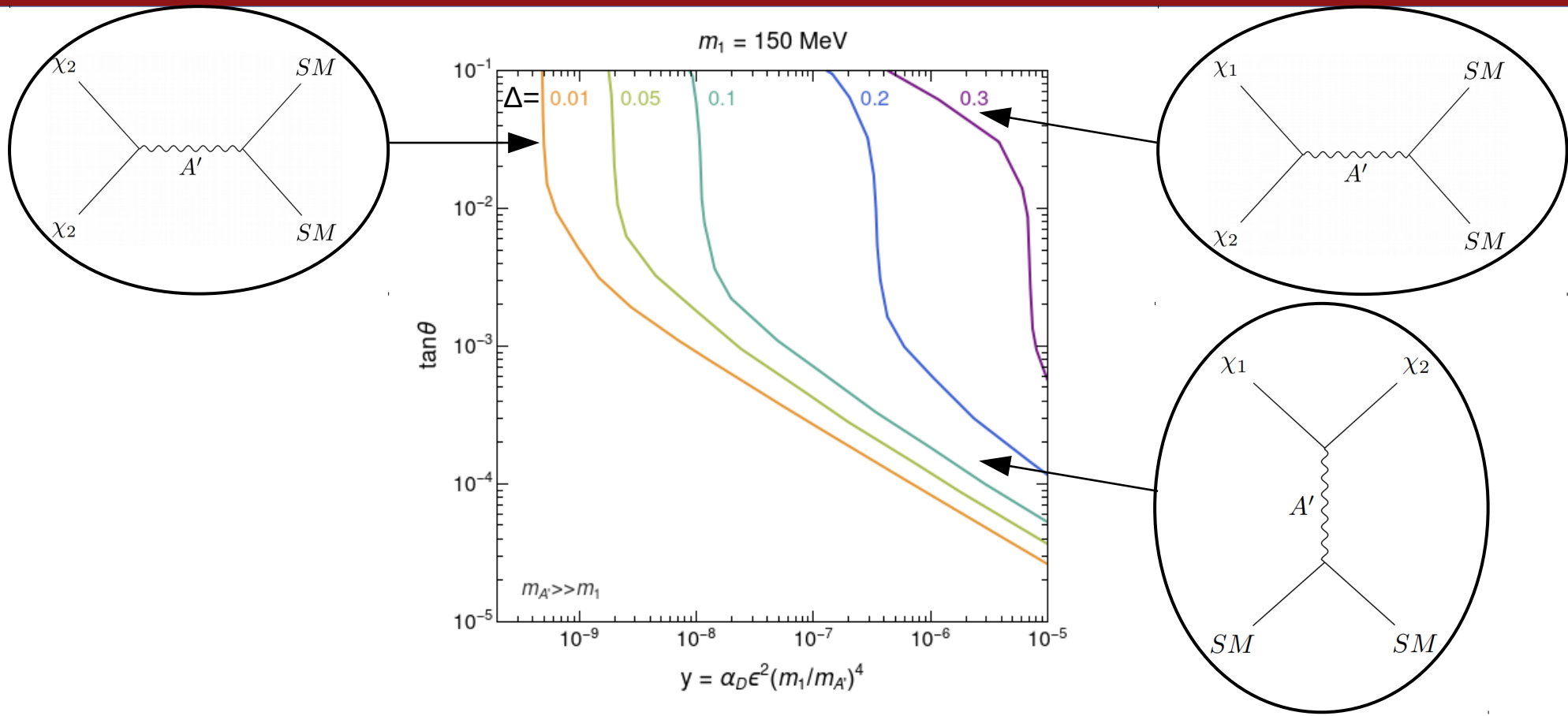
- Hierarchy in (co-)annihilation processes

$$\mathcal{L} \supset -g_D A'_\mu (c_\theta^2 \bar{\chi_2} \gamma^\mu \chi_2 + s_\theta c_\theta \bar{\chi_1} \gamma^\mu \chi_2 + s_\theta^2 \bar{\chi_1} \gamma^\mu \chi_1)$$



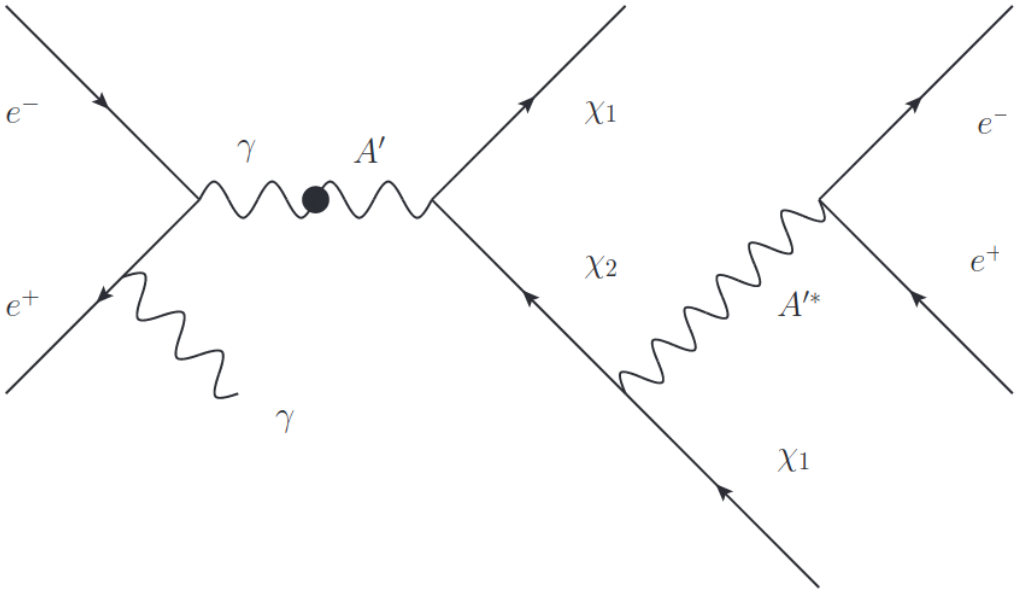
$$\sigma v \propto \epsilon^2 \alpha_D \left(\frac{m_1}{m_{A'}} \right)^4 \equiv y$$

Relic abundance in i2DM



i2DM at colliders

- Lifetime to long to give observable signals at colliders
- Mono-ɣ seaches by BaBar $\longrightarrow \epsilon < 10^{-3}$

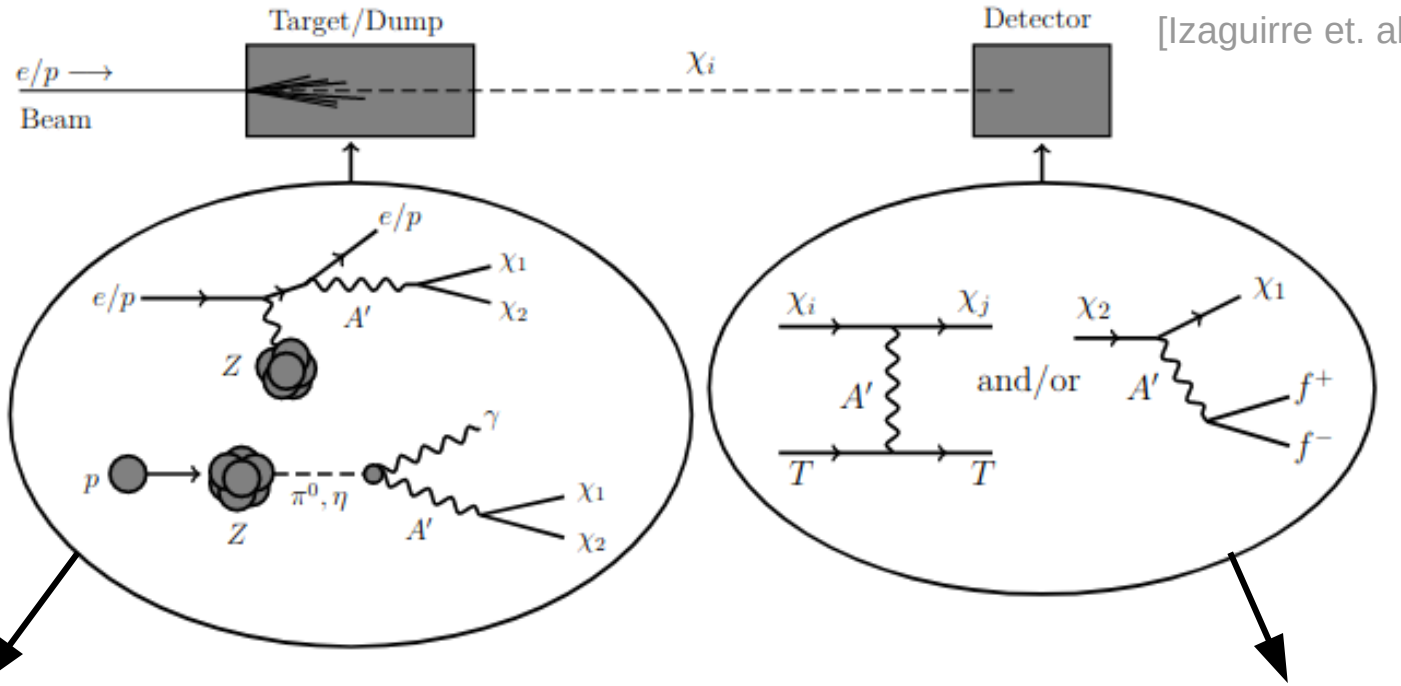


$$\Gamma \approx \frac{4y\alpha_{EM}s_\theta^2 c_\theta^2}{15\pi} m_1 \Delta^5$$

$$(m_e \ll m_1 \ll m_{A'})$$

$$c\tau \sim 10^4 - 10^{16}\text{m}$$

I2DM at fixed target experiments



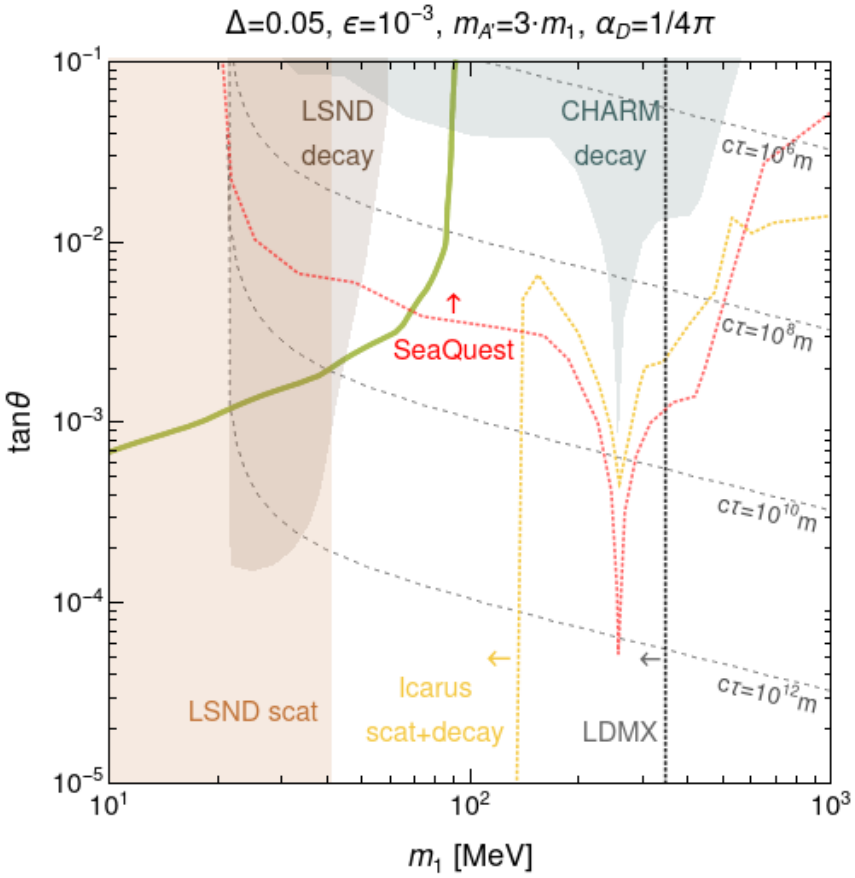
[Izaguirre et. al. 1703.06881]

Production: dark bremsstrahlung or meson decay

Signal: decay to leptons or scatter of detector material

I2DM at fixed target experiments

- Current limits from neutrino experiments LSND and CHARM constrain larger portion of parameter space
- Future experiments like SeaQuest, SBN and LDMX will probe remaining space



Conclusion

- Thermal Dark Matter in the MeV-GeV range
- New model: inelastic Dirac Dark Matter
- i2DM exhibits novel production mechanism: coscattering
- In order to reproduce the relic density, the dark partner has to be extremely long-lived
- Can by fully probed by near future fixed-target/missing energy experiments

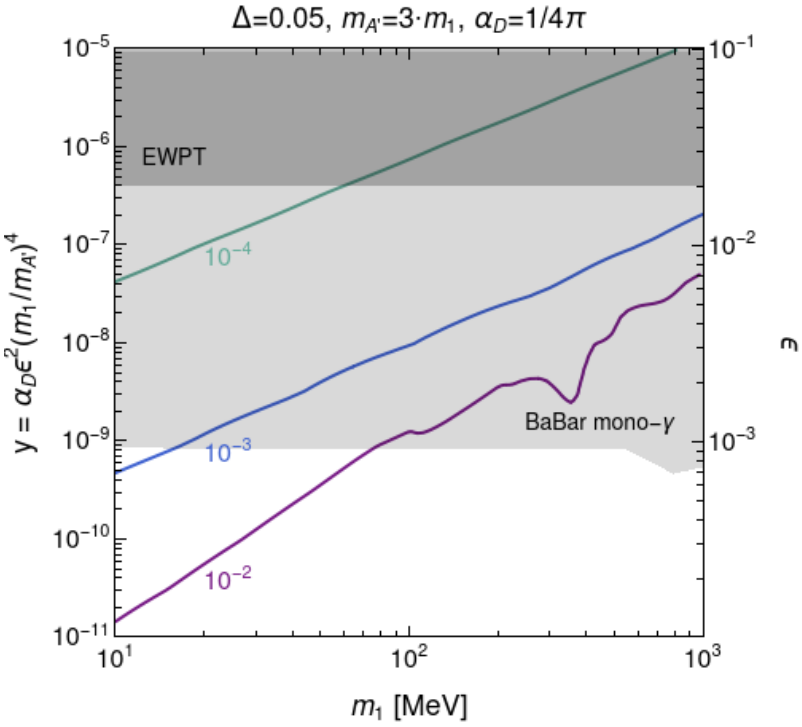
Back-up

i2DM at colliders

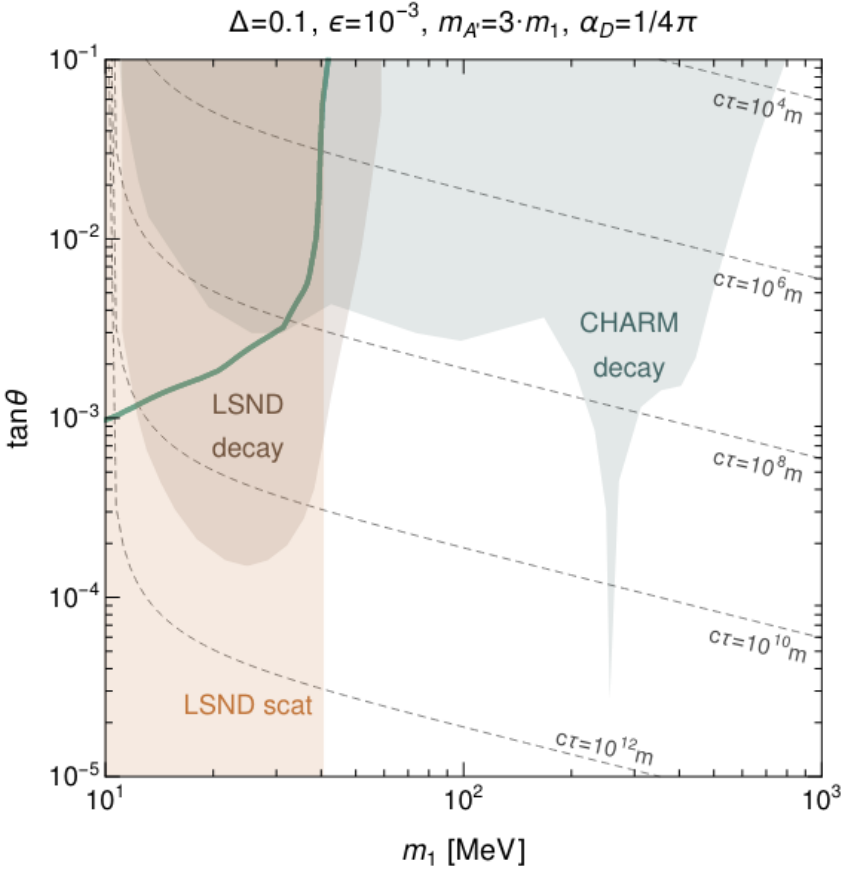
- Lifetime to long to give observable signals at colliders
  - EWPT
  - Missing energy (mono-ɣ)

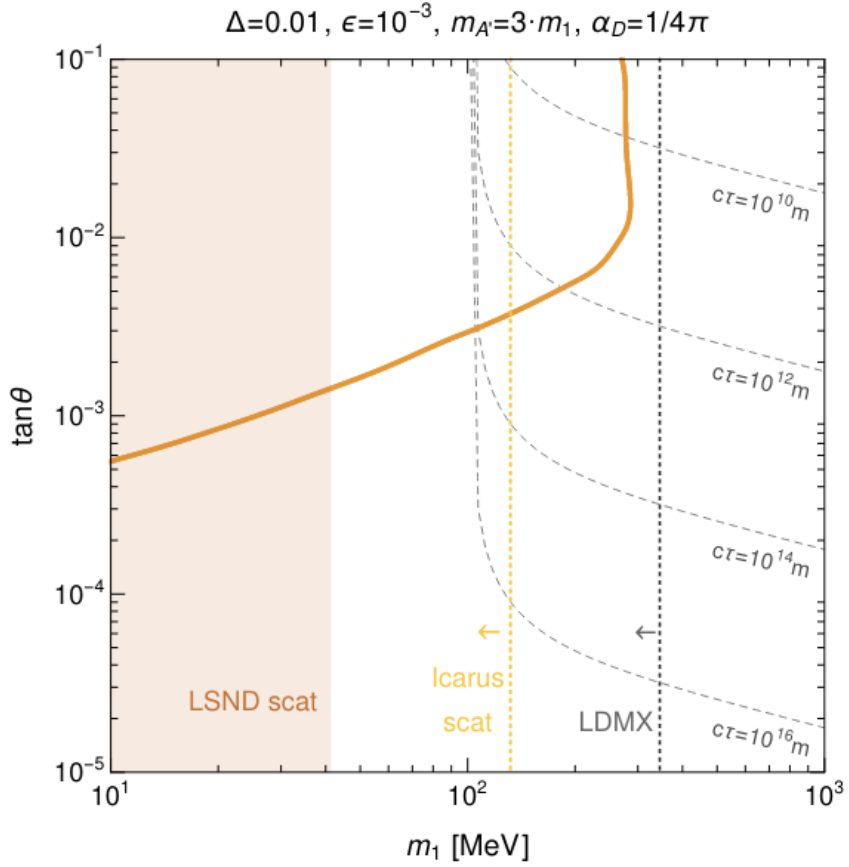
$$e^+e^- \to A'\gamma \to \chi_2\chi_2\gamma$$

→ Bound on ϵ



Results for different mass splittings



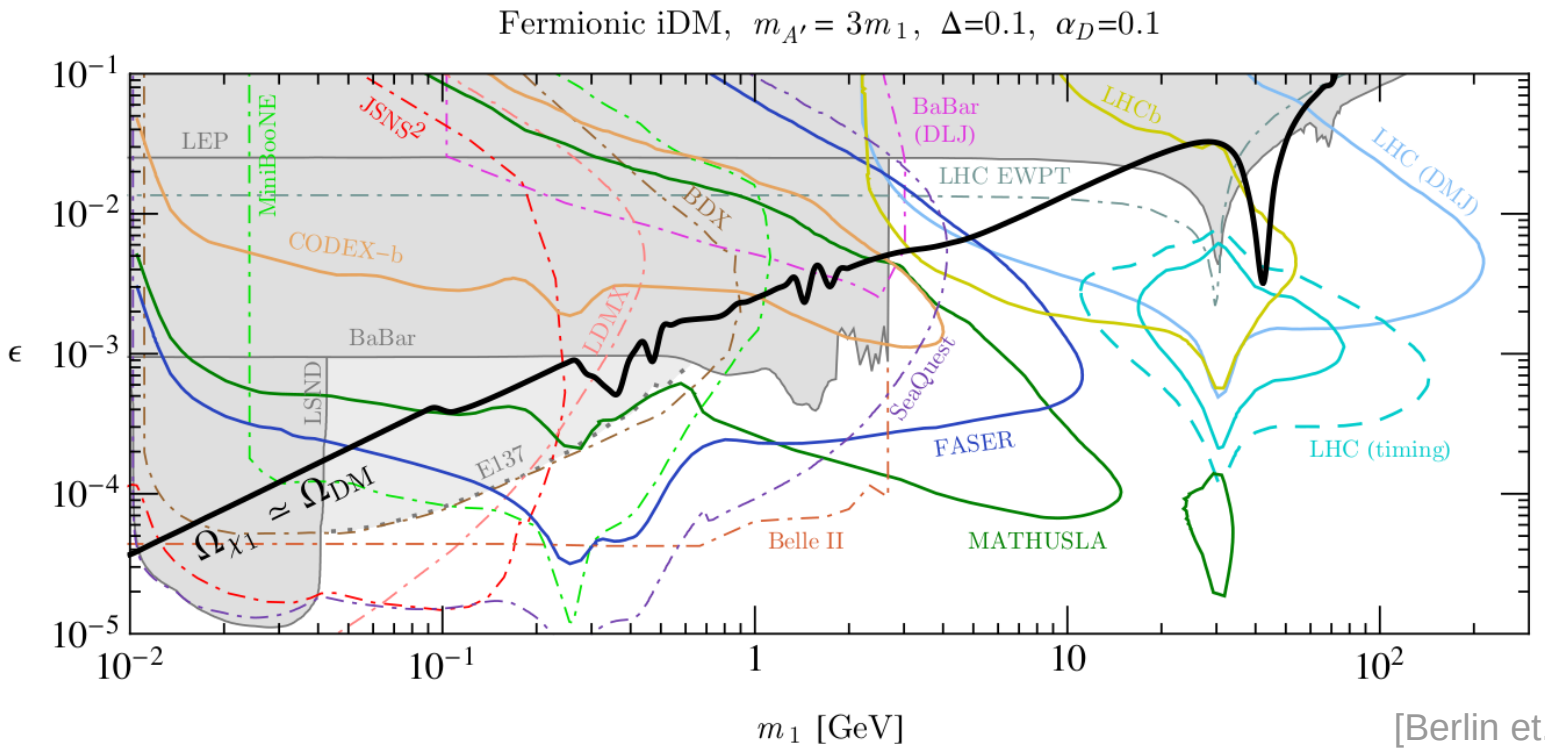


Fixed target experiments

- Current constraints:
  - LSND: 800Mev proton beam experiment with detector at 30m
  - CHARM: 400GeV proton beam experiment with detector at 480m
  - Ohters: MiniBooNE, NuCal, NA62 → less sensitive
- Near future experiments:
  - SeaQuest: 120GeV proton beam with decay volume from 5-12m
  - SBN: 8/120GeV proton beam with multiple detectors (SBND, MicroBooNE and Icarus)
  - LDMX: Electron beam dump looking for missing energy signal

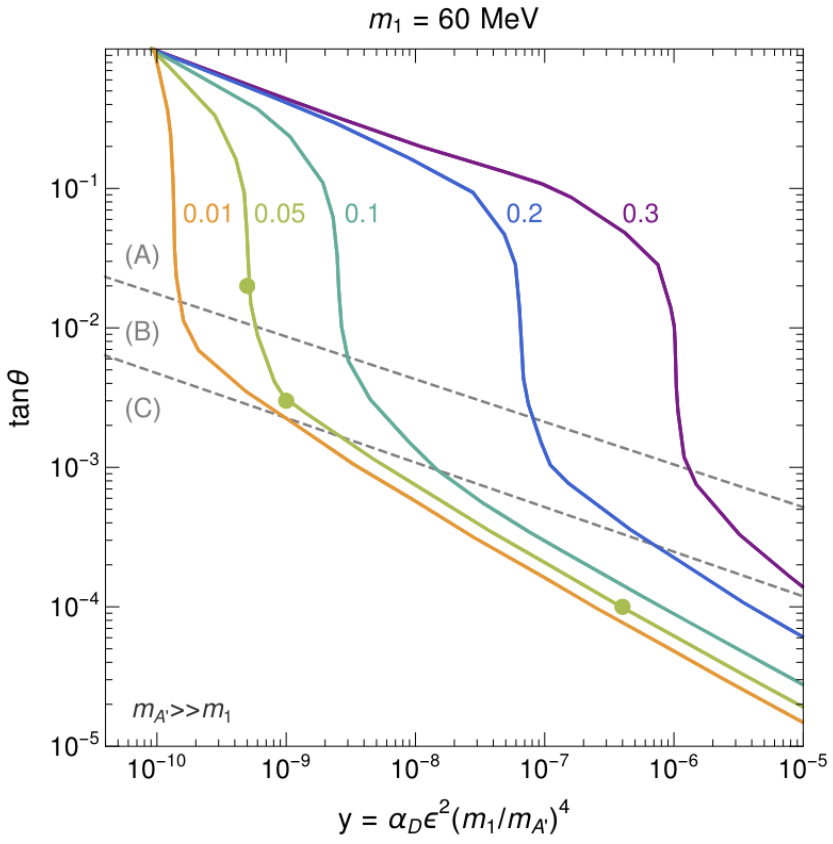
LLP experiments at LHC

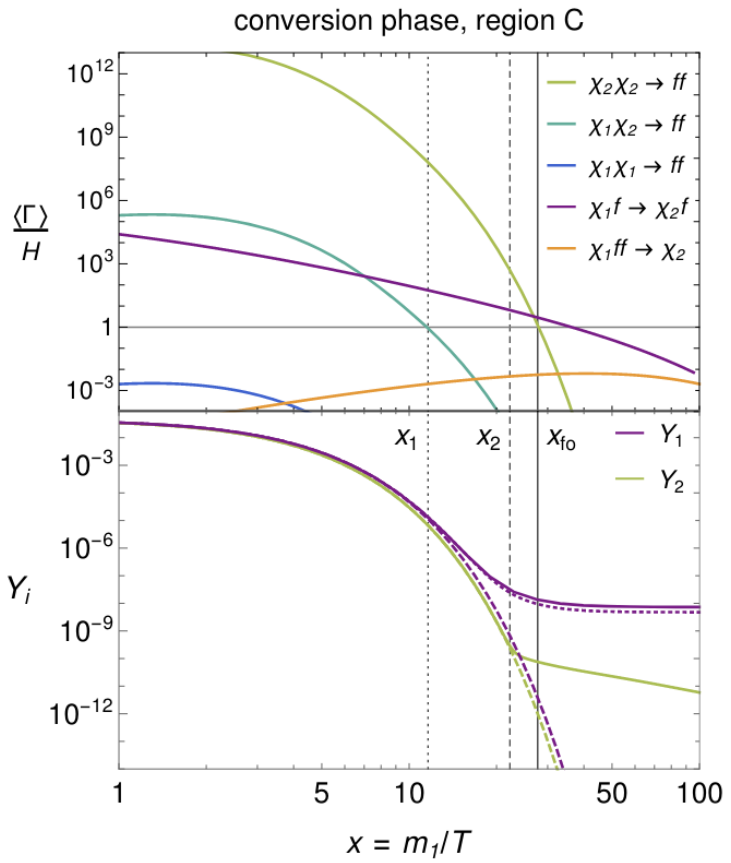
Sensitivity of some proposed LLP experiments at LHC for iDM



[Berlin et.al. 1810.01879]

Kinetic equilibrium





Cosmological bounds

- For m>1GeV, QCD phase transition should be taken into account carefully
- For m<10MeV, strong bounds from Δn_{eff}
- Within this range, other probes like CMB and BBN don’t reach parameter space where relic abundance is reproduced