Dark Sector Search Complementarity at the FPF

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Multiple probes of light DM models

Extra mediator generally required to ensure relic abundance

Mediators can couple to SM particles
→ visible mediator decays
→ modified SM scatterings

Long-lived particles

Neutrinos

Dark matter

Millicharged particles

credit: Felix Kling

Model: gauged hadrophilic U(1)'s

V couples to B or B – 3τ

Complex scalar DM charged under gauge group

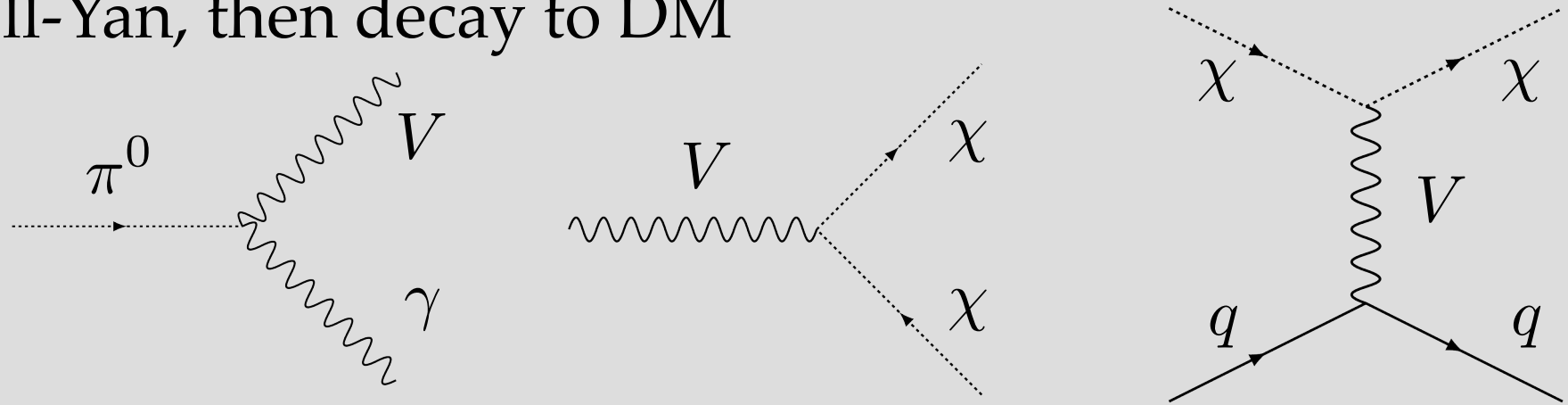
$$g_V V^\mu \left(\tfrac{1}{3}\bar{q}\gamma_\mu q - 3\bar{\tau}\gamma_\mu\tau - 3\bar{\nu}_\tau\gamma_\mu P_L\nu_\tau + (iQ_\chi\bar{\chi}^*\partial^\mu\chi + \text{ h.c.}) \right)$$

Constraints from anomaly-induced rare decays (B) or neutrino non-standard interactions (B – 3τ)

Not probed by electron beam dumps or DM-electron scattering Batell, Feng, Trojanowski 2101.10338

DM scattering

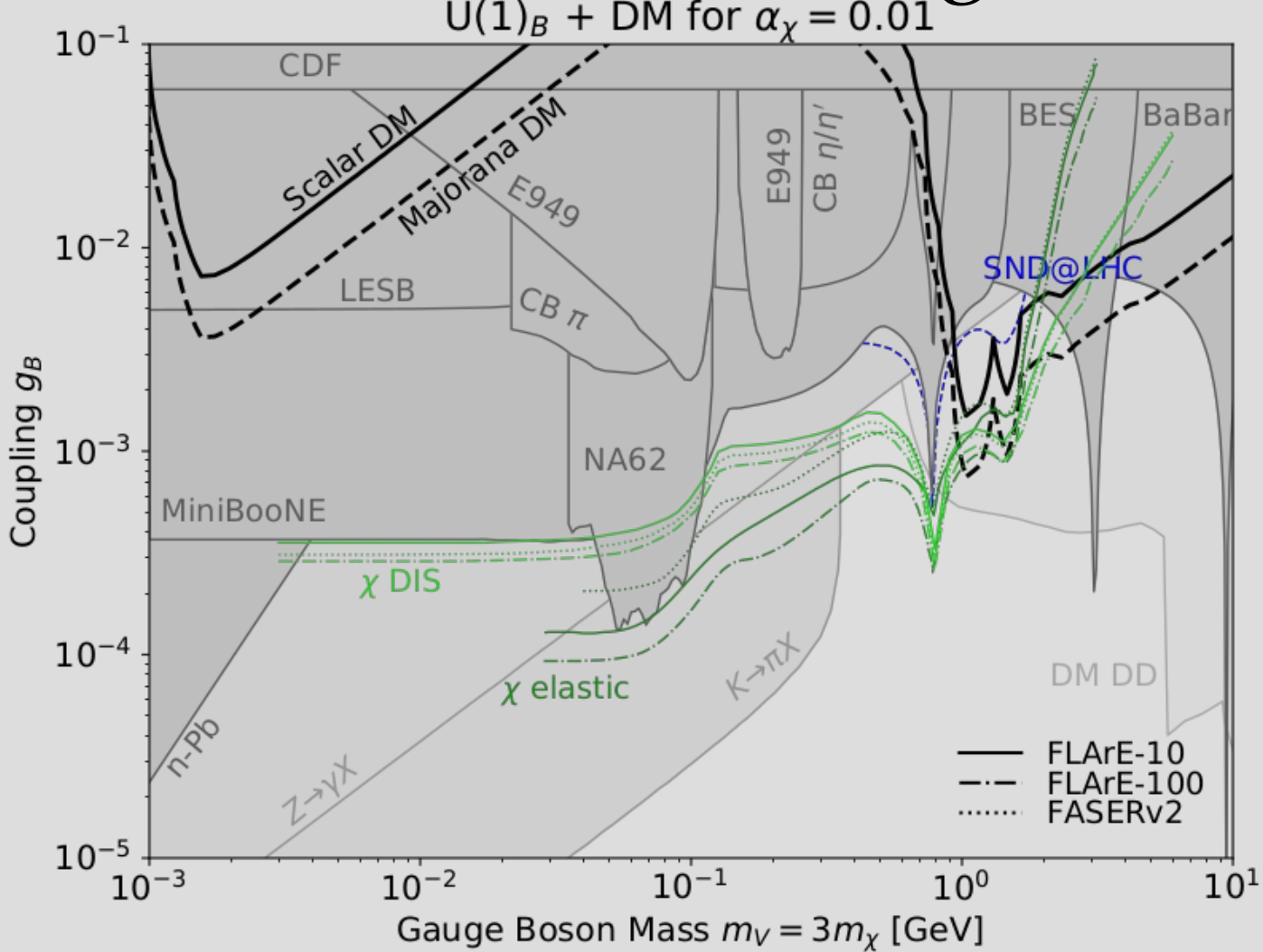
Produce V through meson decay, bremsstrahlung, and Drell-Yan, then decay to DM



DM subsequently scatters in dense detector, e.g. FLArE or FASERv2

Two regimes depending on momentum transfer: elastic and deep inelastic scattering Batell et al., 2107.00066

DM scattering limits, $U(1)_B$

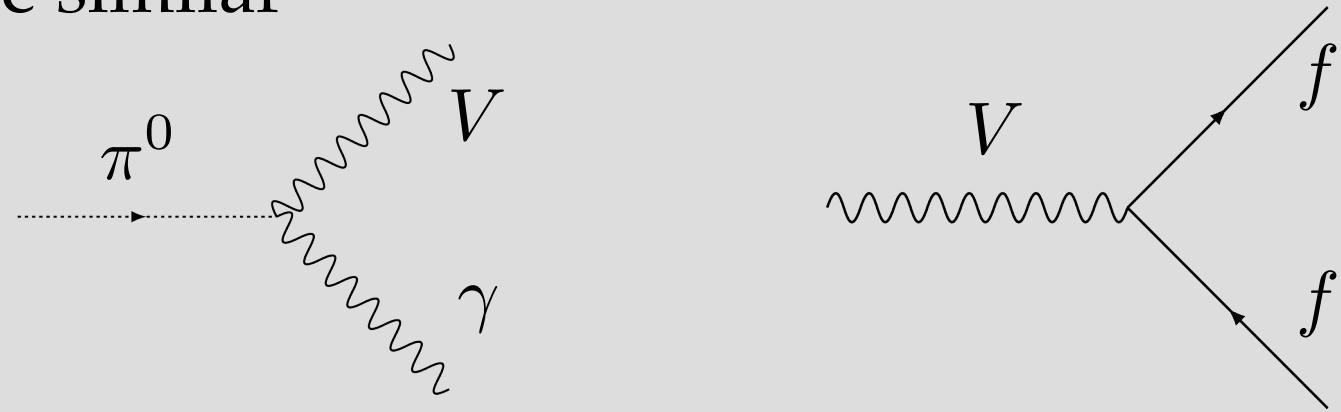


Kinematic cuts to remove neutrino backgrounds

Direct detection limits don't apply for closely related models, e.g. slightly inelastic or Majorana DM

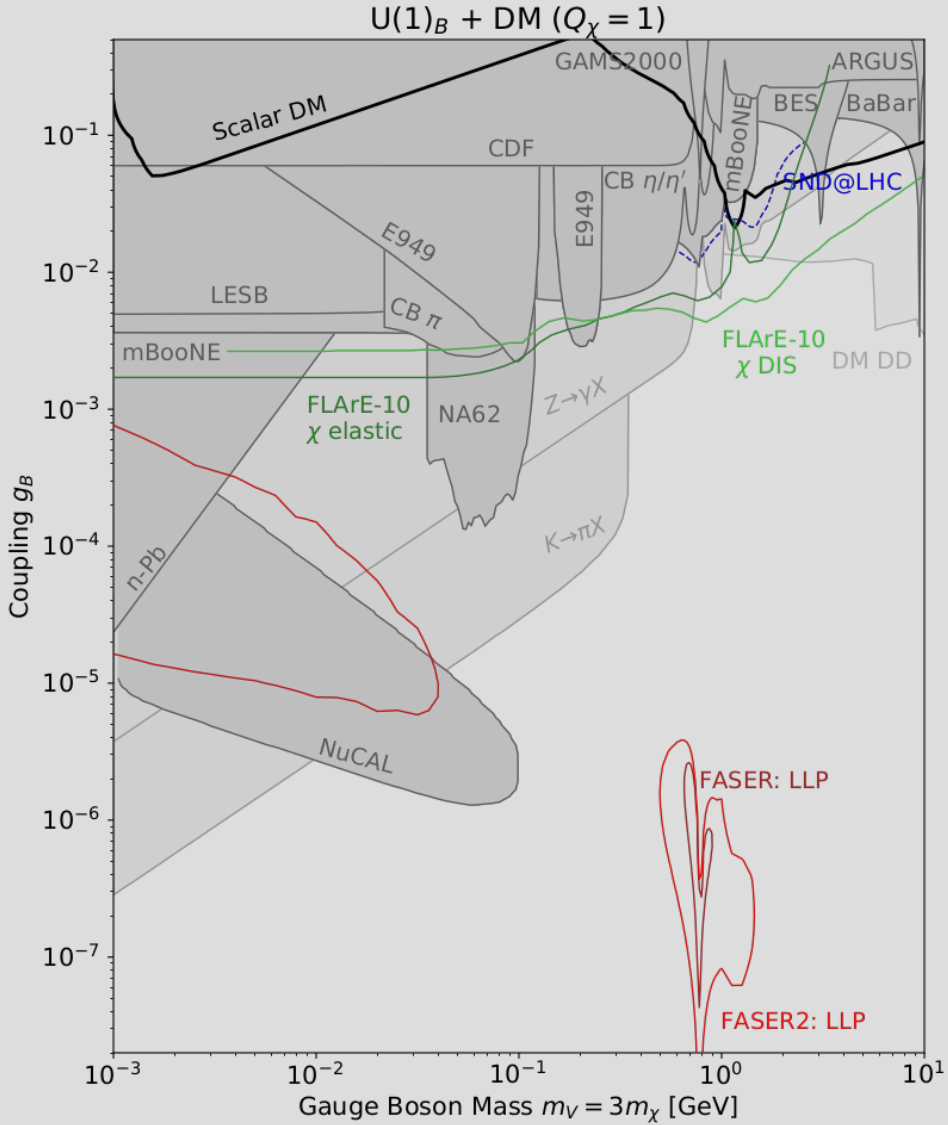
Visible mediator decays

Produce V as before, but decay to SM when dark and SM charges are similar



V mass below pion threshold: can decay to e^+e^- in the presence of some small kinetic mixing

V mass of several hundred MeV: more exotic final states, e.g. three pions



Mediator decay limits

Minimum cut of 100 GeV on total energy of decay products for background rejection

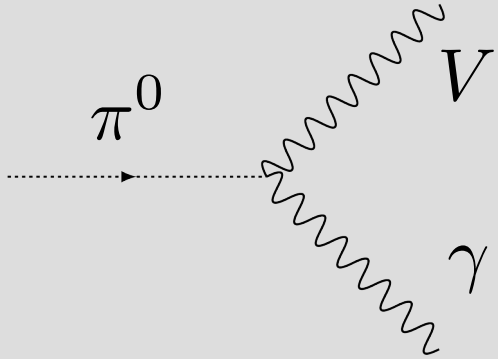
Extra power at FPF comes mostly from three pion decay, at much lower couplings than DM scattering

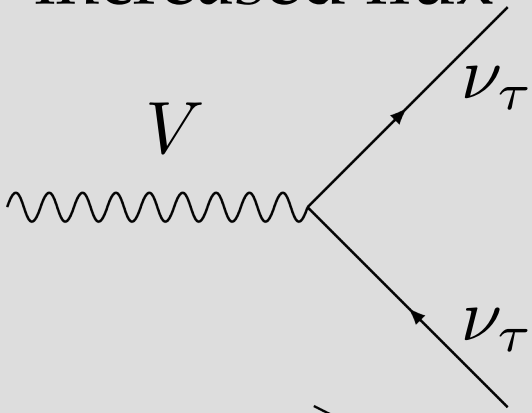
New parameter space can be probed at Run 3 with FASER!

Neutrino scattering

If V couples to neutrinos

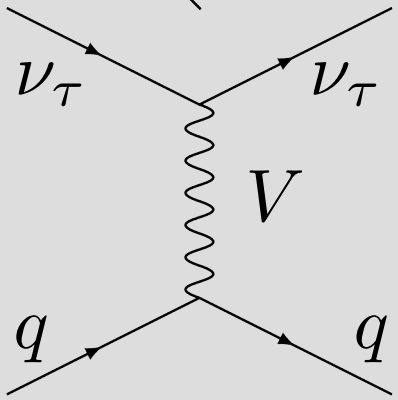
(1) More neutrinos from V decay → increased flux

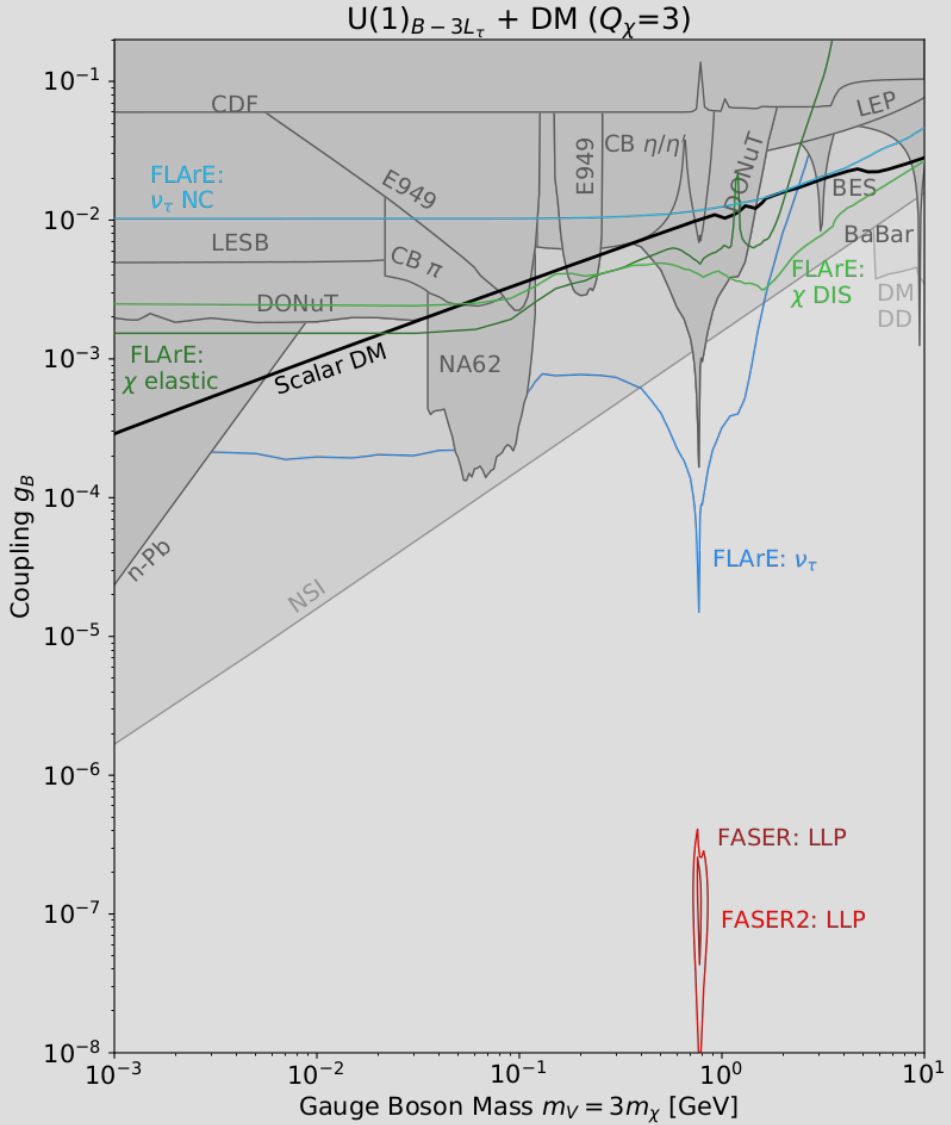




(2) Neutral current scattering through V

Has to be visible over NC scattering from other neutrino flavors





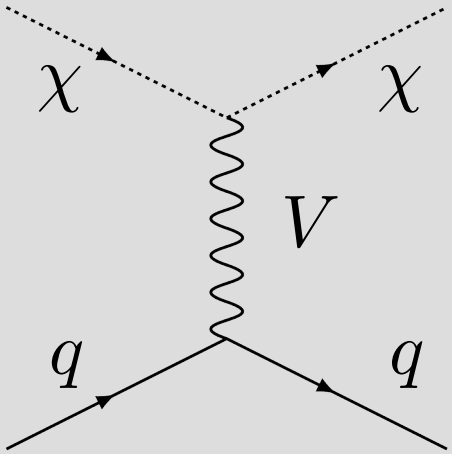
Neutrino scattering, $U(1)_{B-3\tau}$

Neutrino flux from V decay more forward than that from SM decays → shape analysis to mitigate flux uncertainty

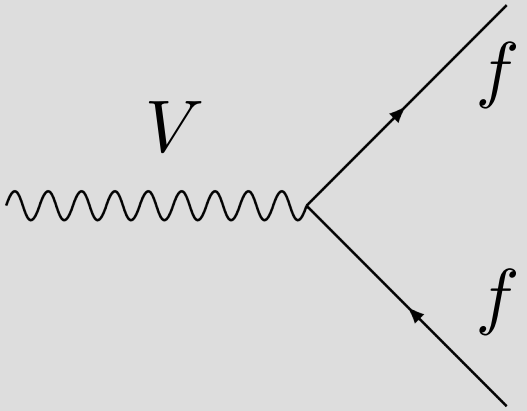
Peak in sensitivity when V can mix with ω, ϱ mesons

Less sensitivity from NC events

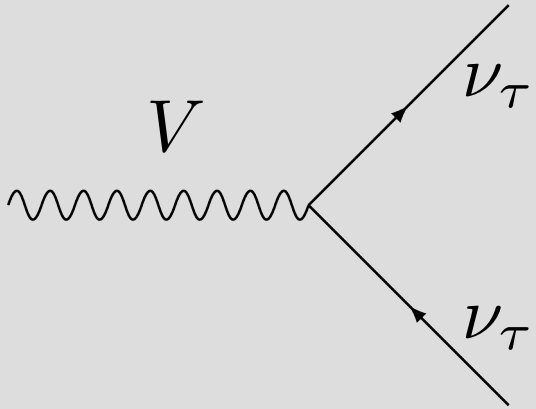
Summary



DM scattering



Visible decays



Neutrino flux

FPF experiments give *complementary* probes of models of light dark sectors