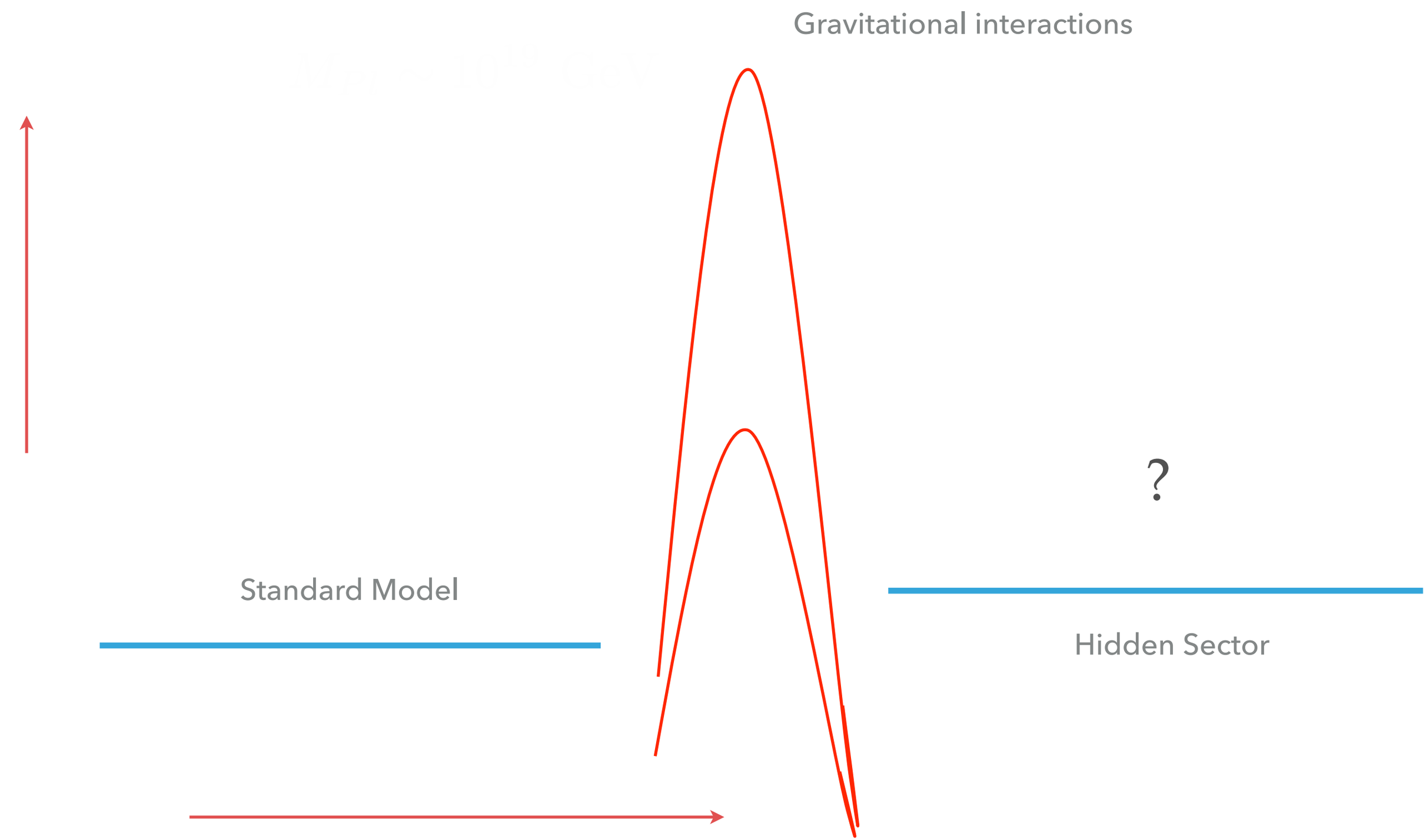
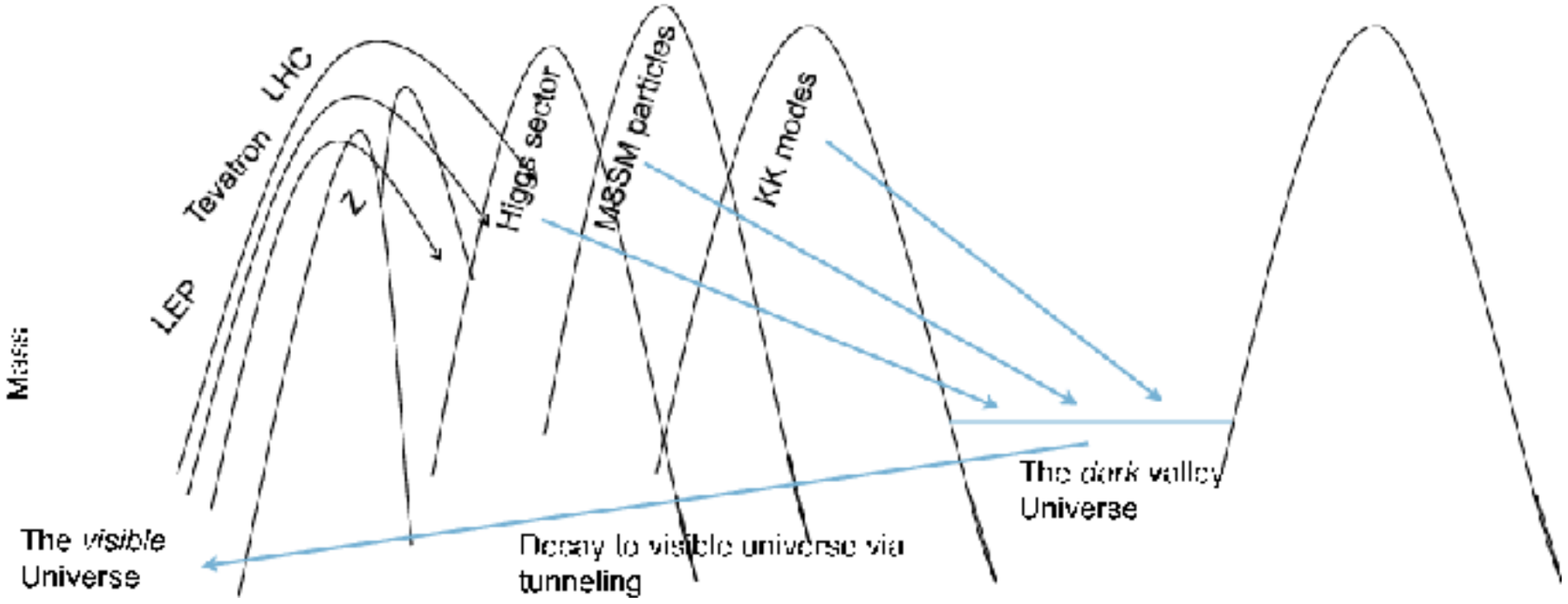
K. ZUREK

THE FIP/HIDDEN SECTOR/VALLEY PARADIGM: OPPORTUNITIES AND CHALLENGES

SUPER-WEAKLY INTERACTING



A SHIFT AWAY FROM FOCUS ON EVER HIGHER ENERGIES



Hidden Valley Paradigm

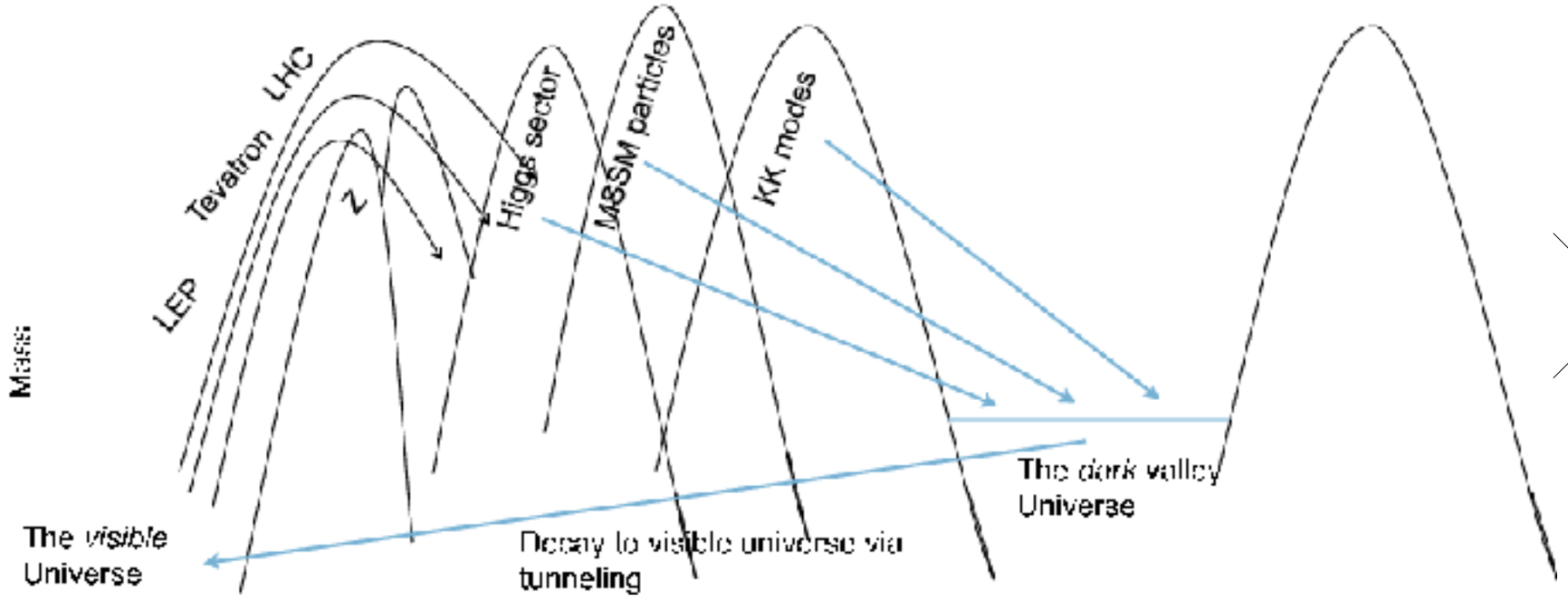
TOWARDS LIGHTER STATES

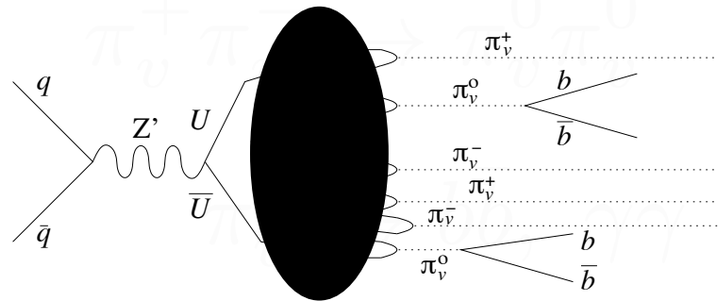
A Hidden Sector Need Not Solve the SM's Problems

But naturally provides a DM candidate

e.g. a stable dark pion

no weak force





Hidden Valley Paradigm

Hidden Sectors

Standard Model → Connector → Hidden Valley

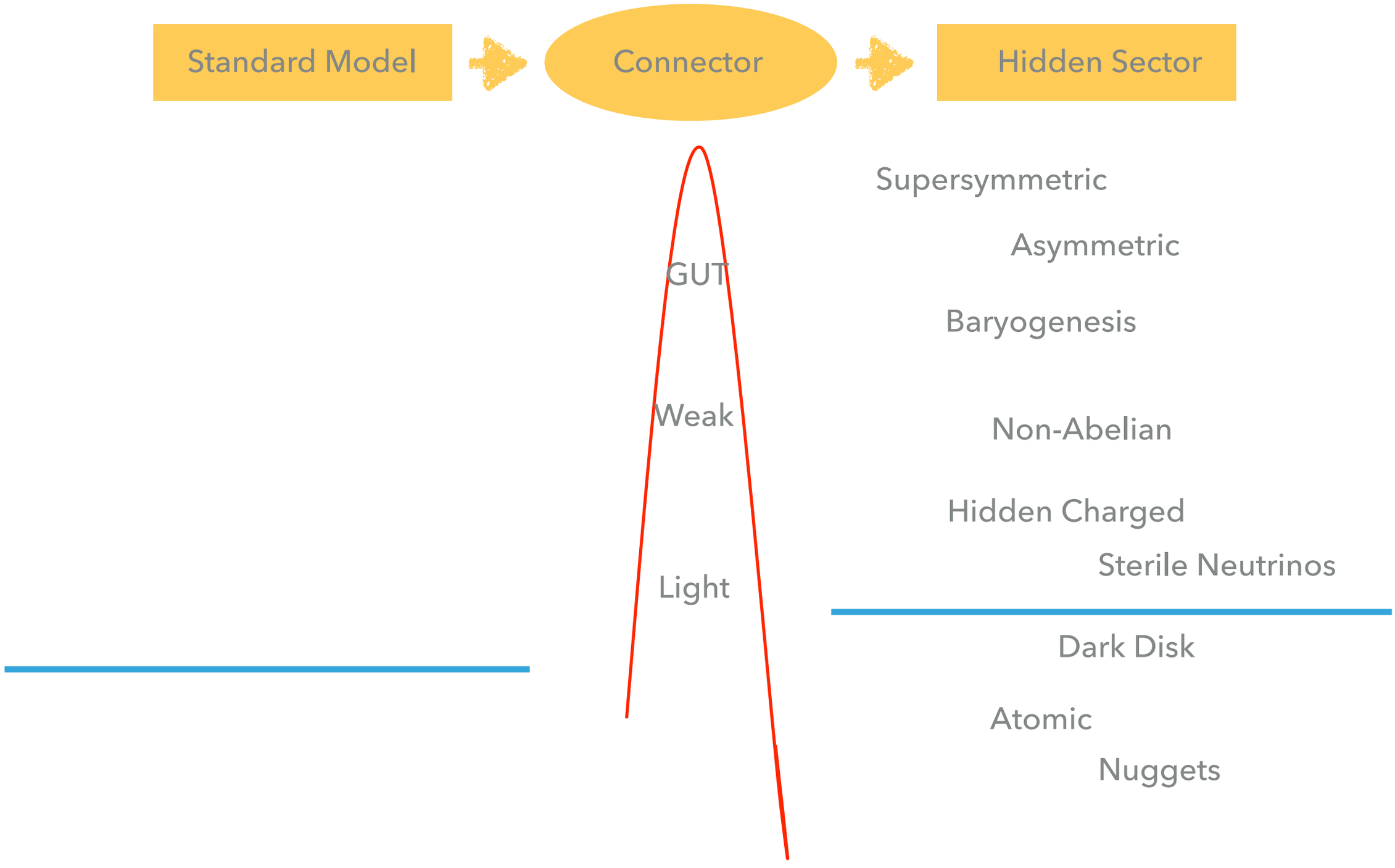
e: electric charge
p: baryon number
nu: lepton number

Z'
Leptoquarks
SUSY Particles
Higgs
X-Dims

Strongly or Weakly Coupled
Dark Photons
Dark Higgs
Dark SU(N)
N flavors
ADM
Sterile Neutrinos

When a Hidden Sector Particle is (quasi-)Stable, there is (potential for) a dark matter candidate

BROAD RANGE OF MODELS



BROAD RANGE OF MODELS

Standard Model → Connector → Hidden Sector

GUT

Weak

Light

pure glue, light flavors, heavy flavors, quirky asymmetric dark matter, Strongly Interacting Massive Particle (SIMP), Wess-Zumino-Witten SIMP

MeV DM, WIMPless, Anomalies: PAMELA, ATIC, Fermi I, Fermi II, Fermi III, DAMA, CDMS, Cogent

Darkogenesis, Xogenesis, Hylogenesis, Cladogenesis, ADM from Leptogenesis, Dark Affleck-Dine

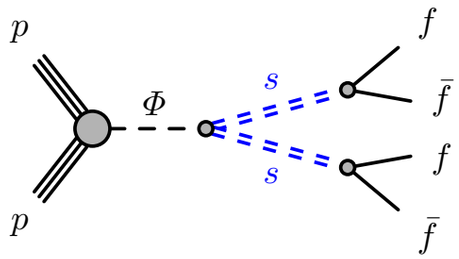
Dark photons, Freeze-in, WIMPless miracle

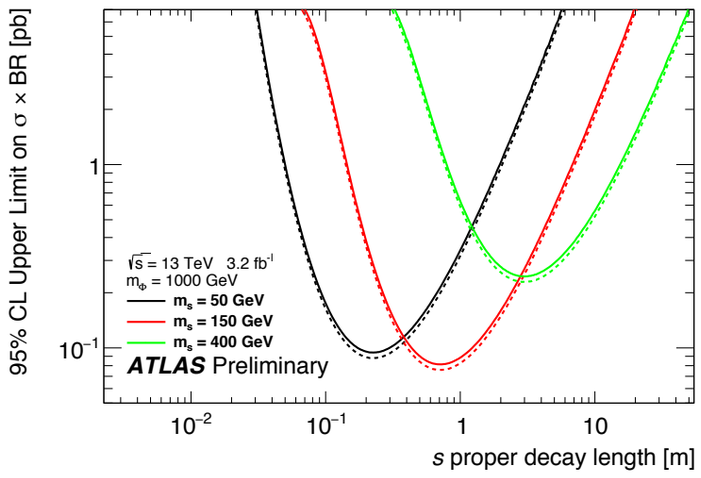
Mirror Matter, Atomic Matter, Self-Interacting Dark Matter, Magentic, Dark Anapole and EDMs

Dark Disk – Killing the Dinosaurs

BROAD RANGE OF SIGNATURES

Standard Model → Connector → Hidden Sector





LHC

GUT

Weak

Light

Supersymmetric

Asymmetric

Baryogenesis

Non-Abelian

Hidden Charged

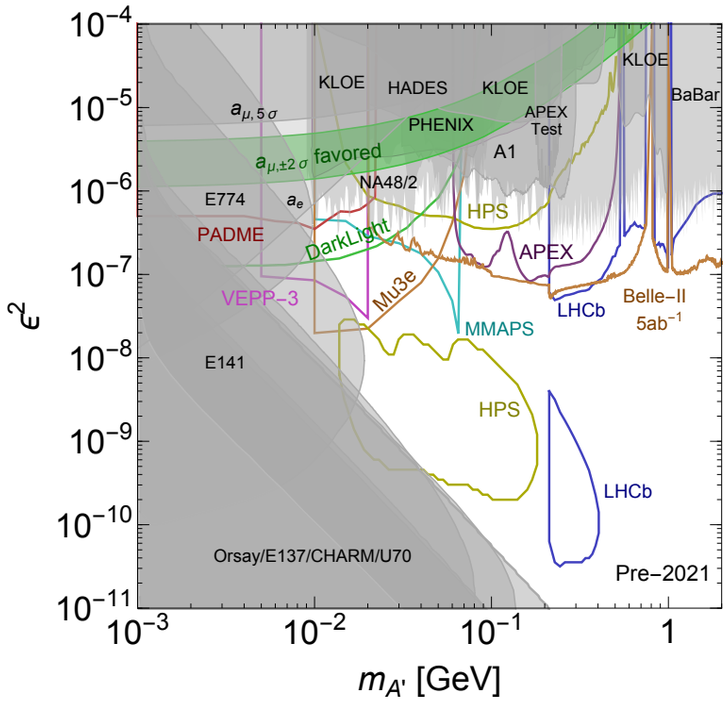
Dark Disk

Atomic

Nuggets

BROAD RANGE OF SIGNATURES

Standard Model → Connector → Hidden Sector



Low Energy / Intensity

Weak

Light

GUT

Supersymmetric

Asymmetric

Baryogenesis

Non-Abelian

Hidden Charged

Dark Disk

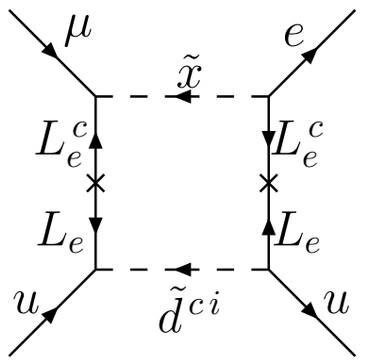
Atomic

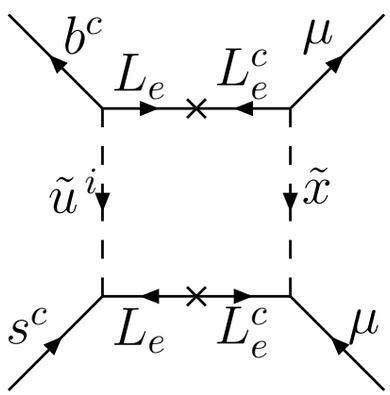
Nuggets

Dark Sectors community report 1608.08632

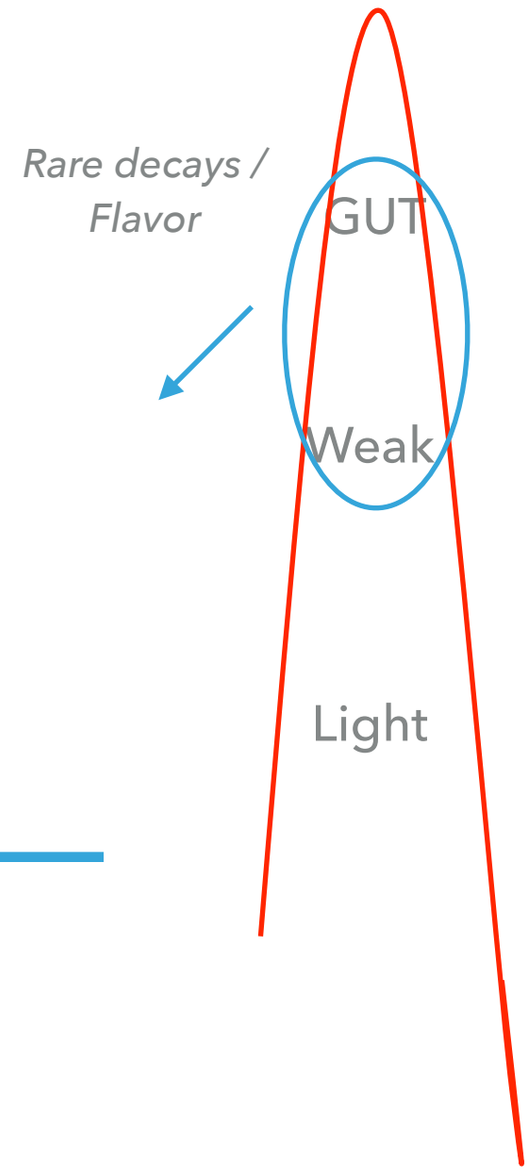
BROAD RANGE OF SIGNATURES

Standard Model → Connector → Hidden Sector





Rare decays / Flavor



Supersymmetric

Asymmetric

Baryogenesis

Non-Abelian

Hidden Charged

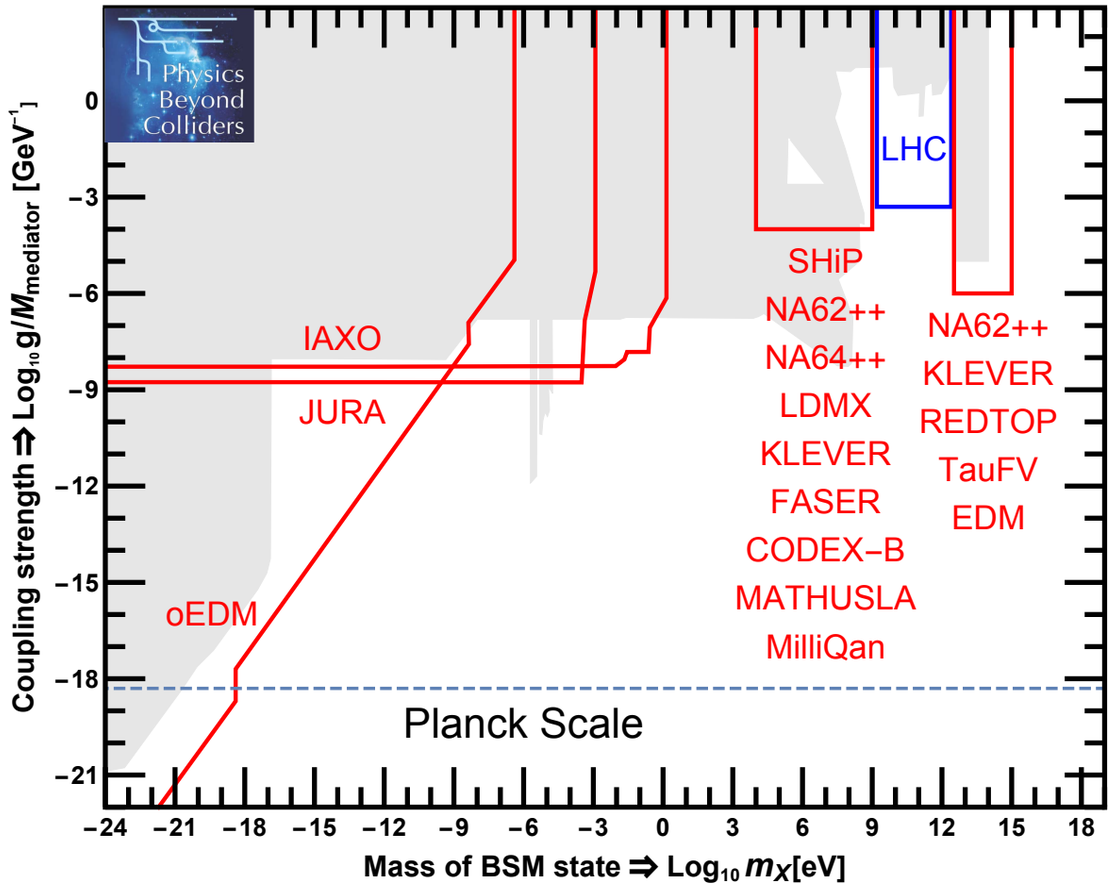
Dark Disk

Atomic

Nuggets

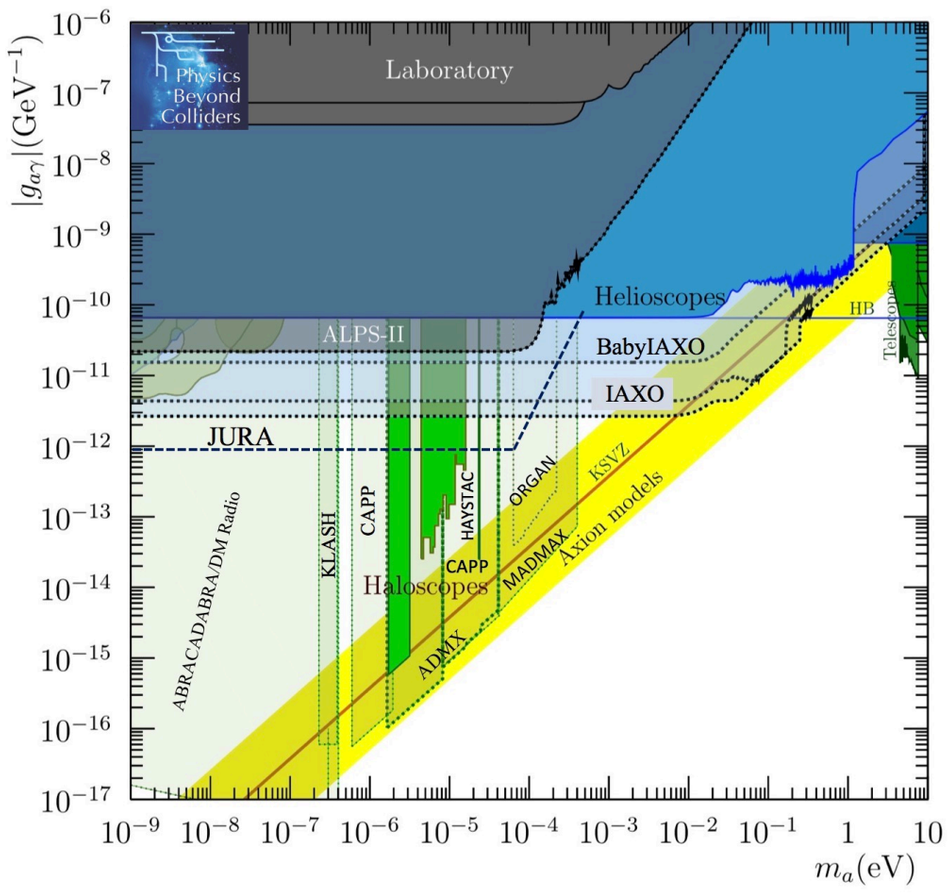
RELAXING THE MOTIVATION....

- To focus on new states at the weak scale, as solutions to the hierarchy problem
- Where do we look?



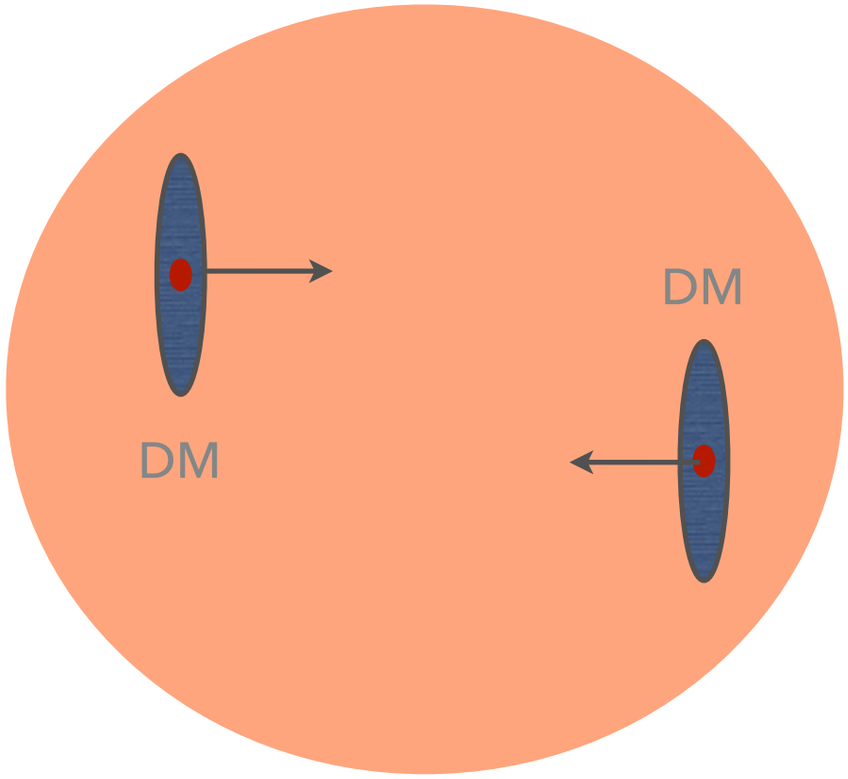
RELAXING THE MOTIVATION....

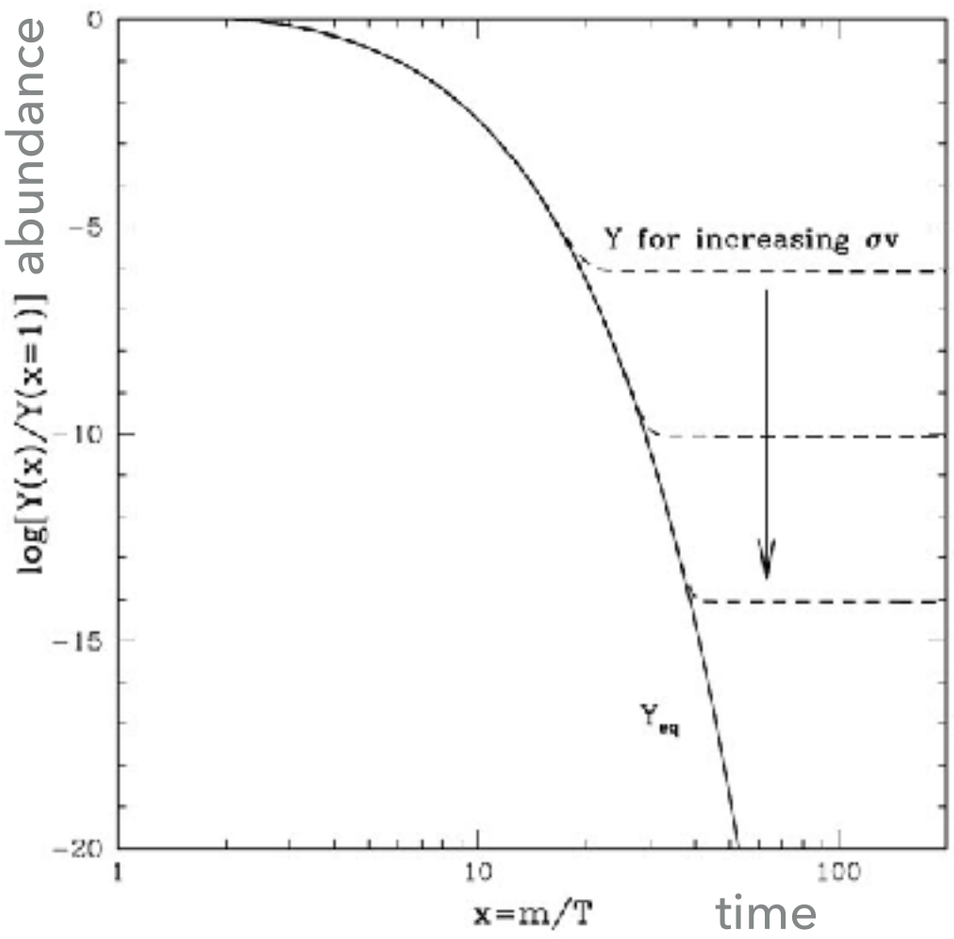
- To focus on new states at the weak scale, as solutions to the hierarchy problem
- Where do we look?
- One powerful motivation is dark matter, and its relic density
- And, to satisfy cosmological constraints on dark sectors



NEW IDEAS IN DARK MATTER THEORY

- Old paradigm: weak scale dark matter (with relic density fixed by freeze-out)

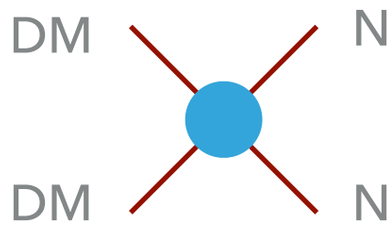




$$\rho_{DM} = \rho_{obs} \quad \Rightarrow \quad \langle \sigma v \rangle \simeq 3 \times 10^{-26}\ \mathrm{cm}^3/\mathrm{s}$$

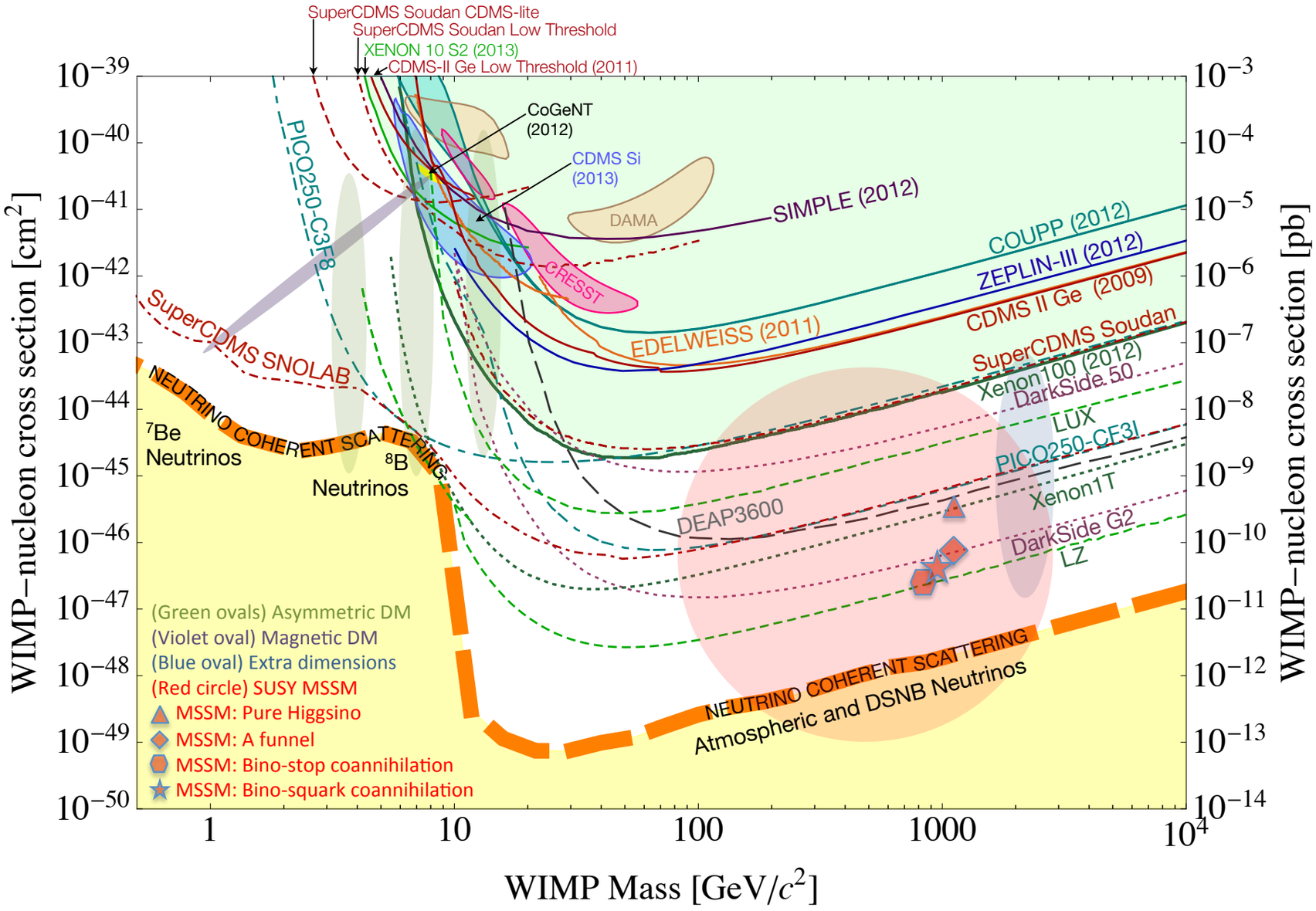
Kolb and Turner

WEAK SCALE PARADIGM: PREDICTIVE TARGETS

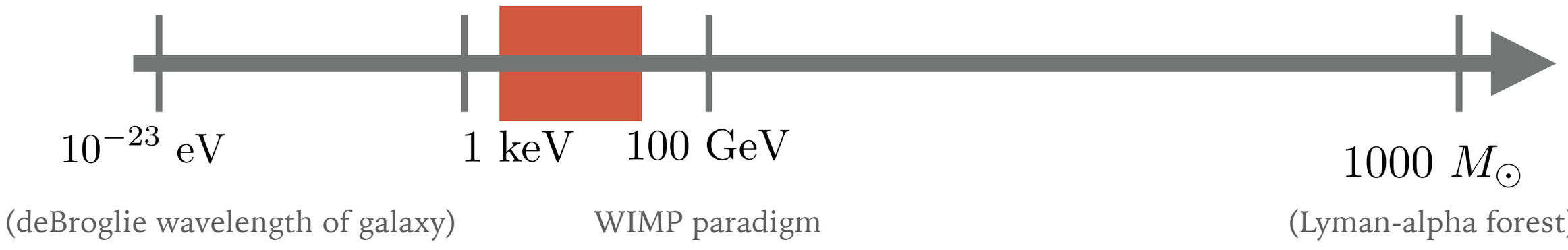


Z-boson interacting dark matter: ruled out

Higgs interacting dark matter: active target



LIGHT HIDDEN SECTOR/VALLEY DARK MATTER

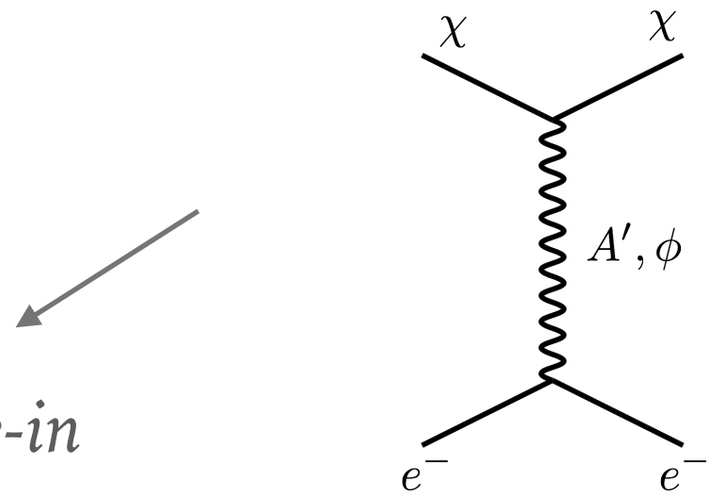


- Abundance may still be set by (thermal) population from SM sector

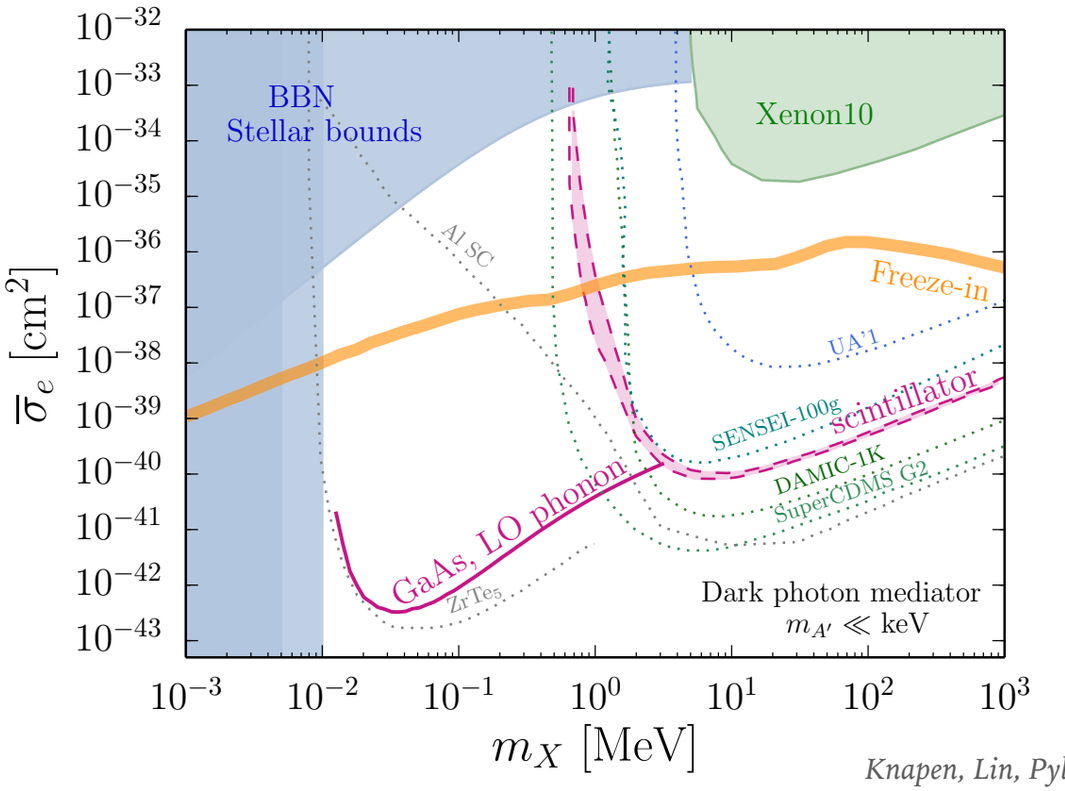
$$\sigma_{wk} v_{fo} \simeq \frac{g_{wk}^4 \mu_{XT}^2}{4\pi m_Z^4} \frac{c}{3} \simeq 10^{-24} \frac{\mathrm{cm}^3}{\mathrm{s}} \left(\frac{100\ \mathrm{GeV}}{M} \right)^2$$

LIGHT HIDDEN SECTOR/VALLEY DARK MATTER

- Utilize DM Abundance and crossing symmetry as guide for interaction rates

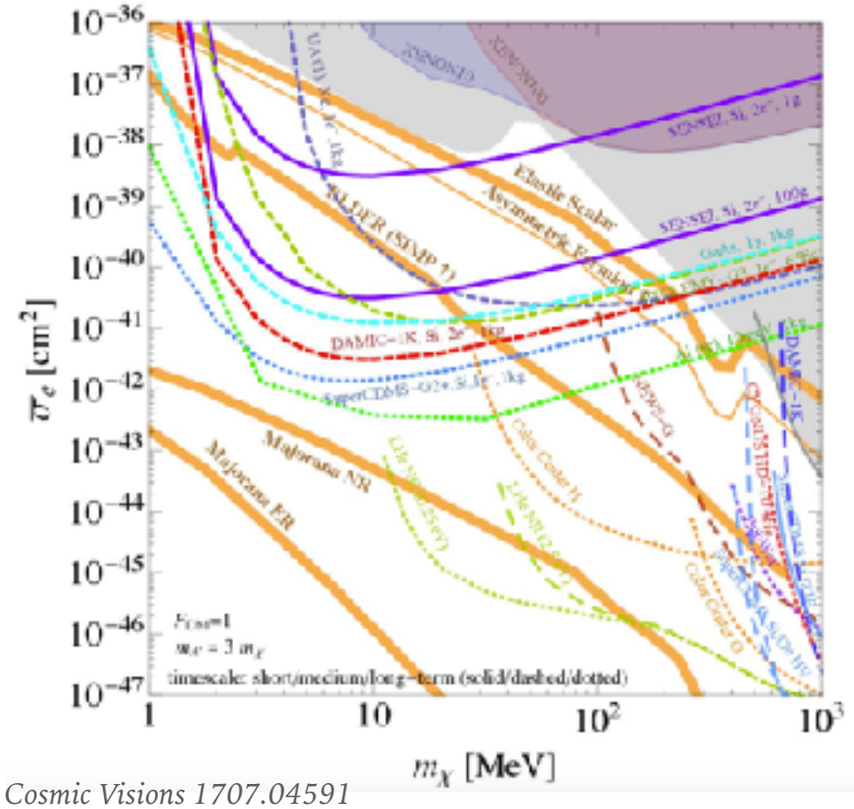


Freeze-in



Knapen, Lin, Pyle KZ 1712.06598

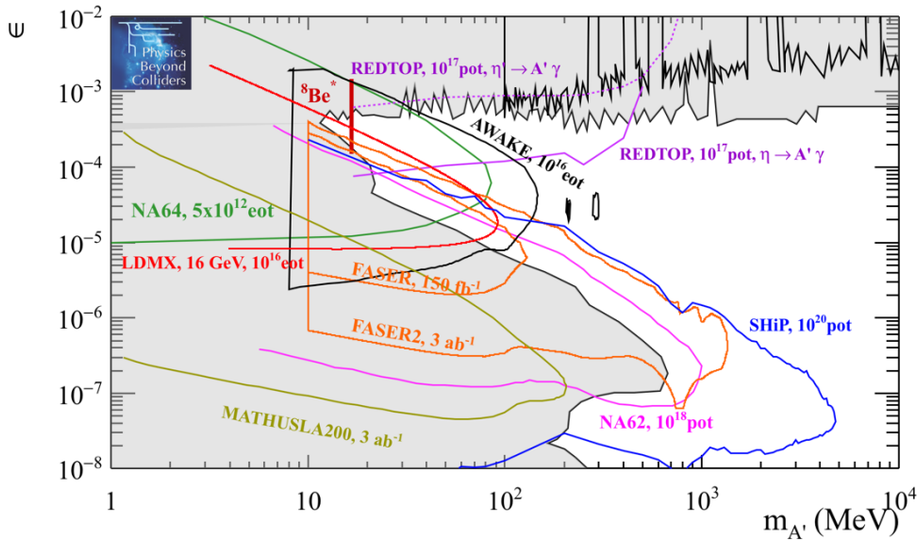
Asymmetric Dark Matter

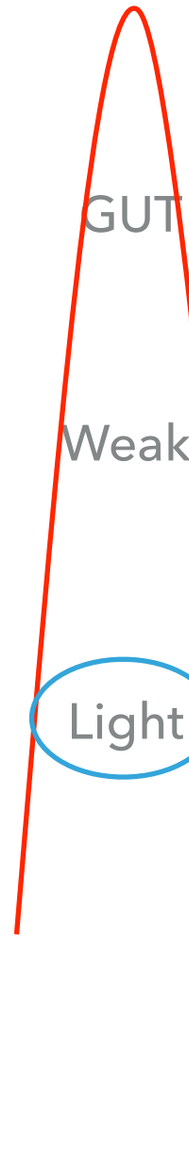


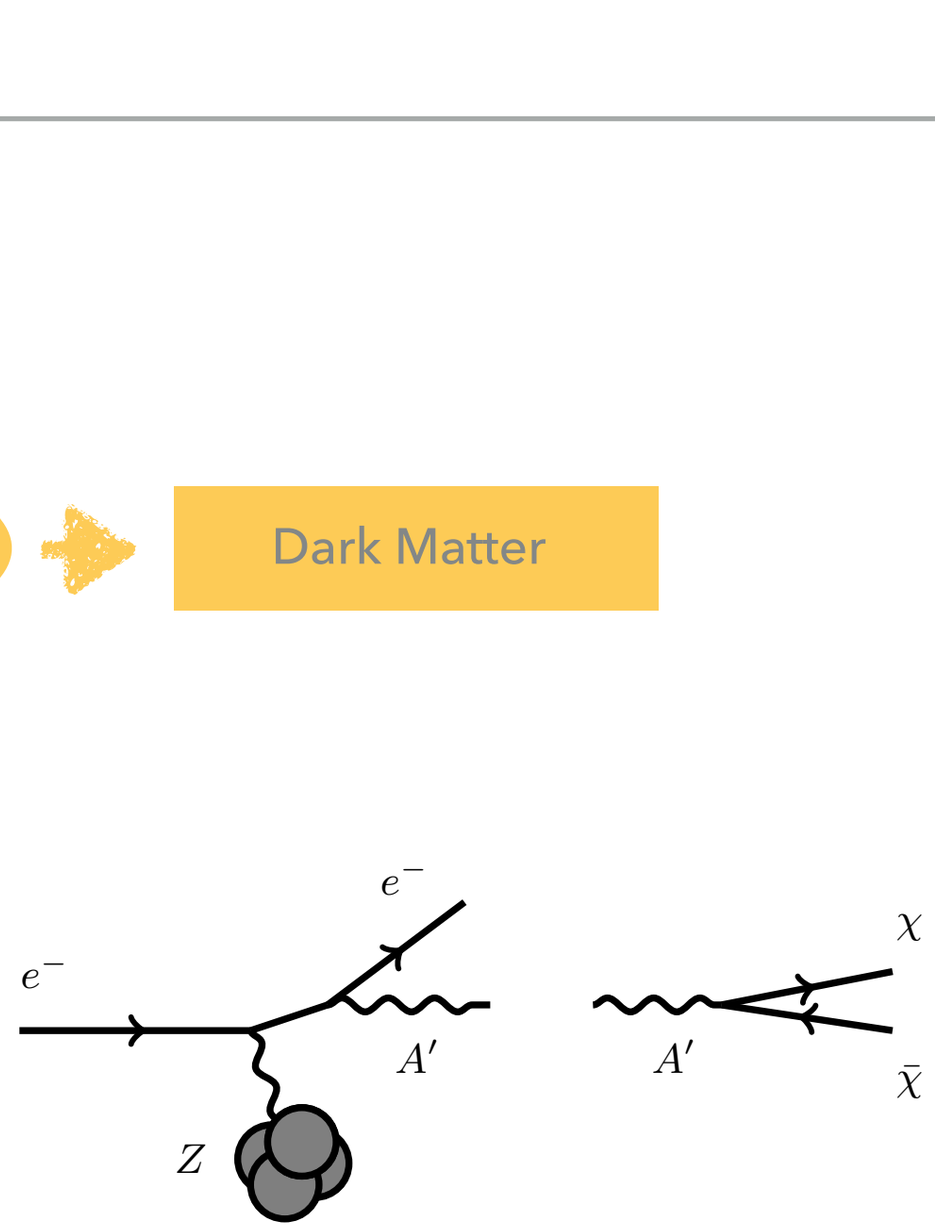
US Cosmic Visions 1707.04591

BROAD RANGE OF SIGNATURES

Standard Model → Connector → Dark Matter



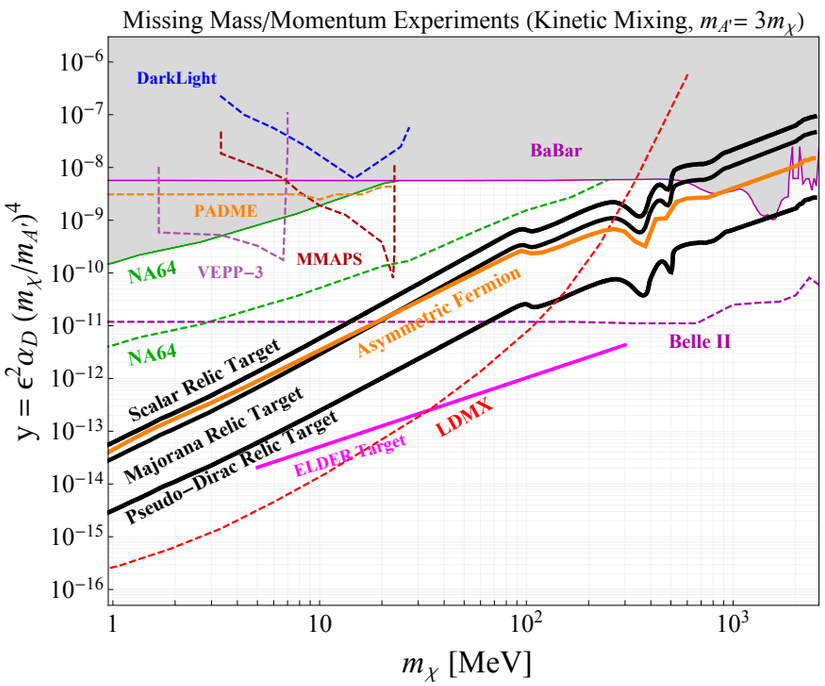




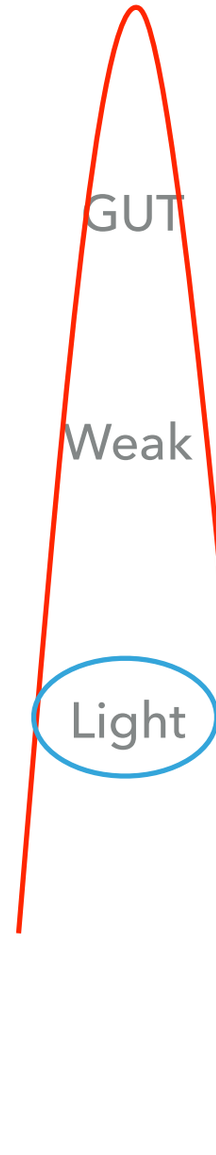
Light mediators yield large scattering cross-sections in direct detection

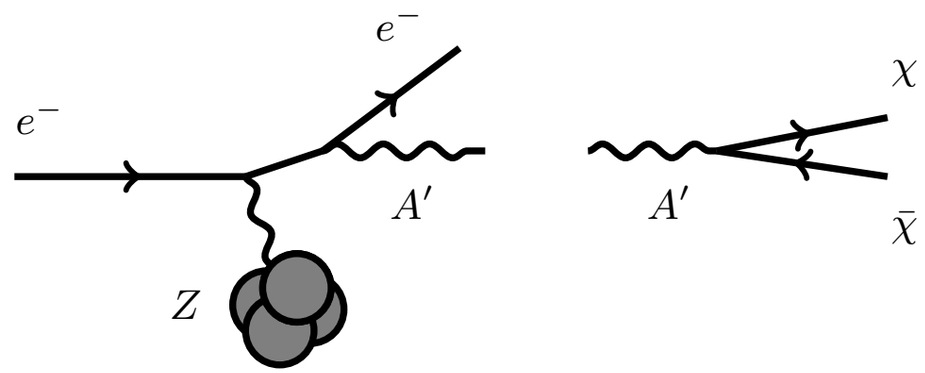
BROAD RANGE OF SIGNATURES

Standard Model → Connector → Dark Matter



Izaguirre, Krnjaic, Schuster, Toro

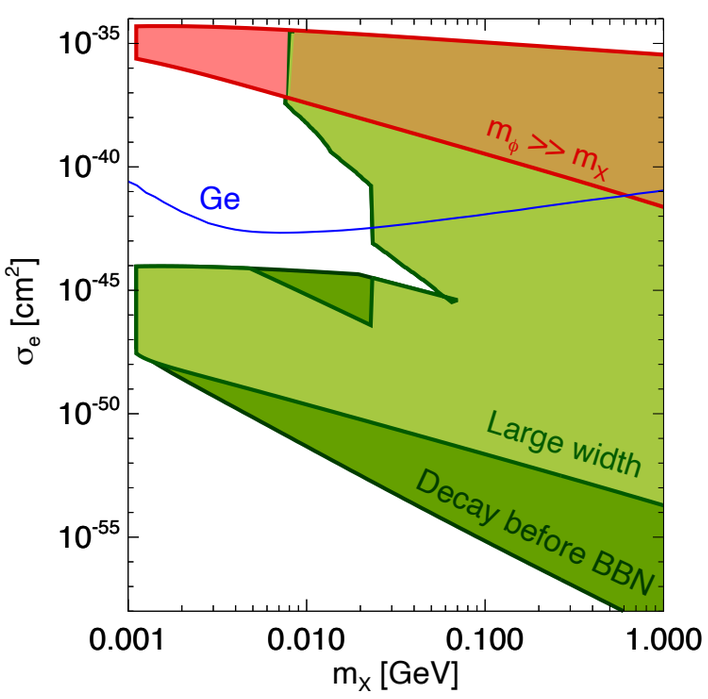




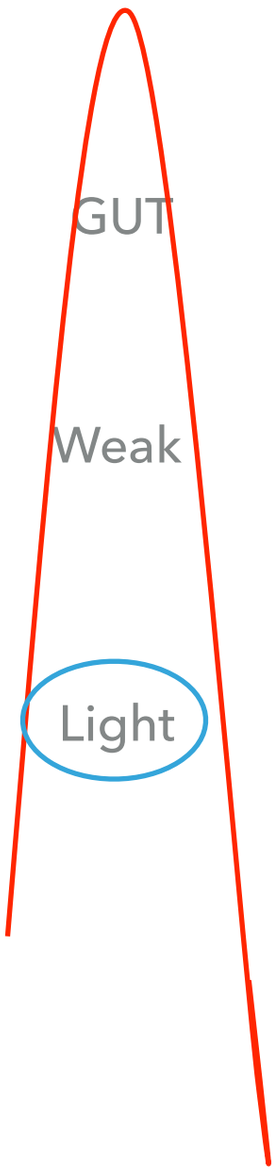
Light mediators yield large scattering cross-sections in direct detection

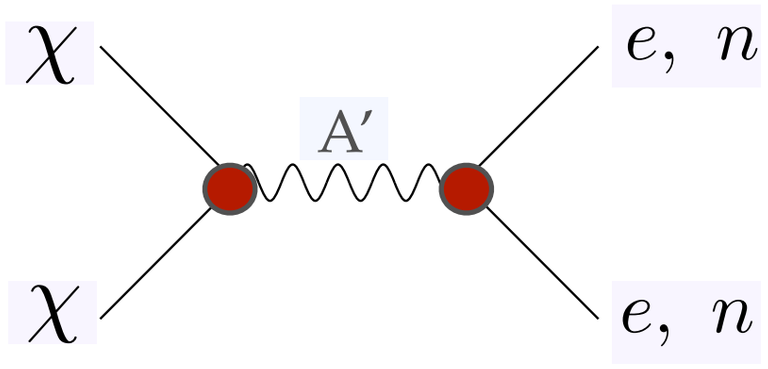
BROAD RANGE OF SIGNATURES

Standard Model → Connector → Dark Matter



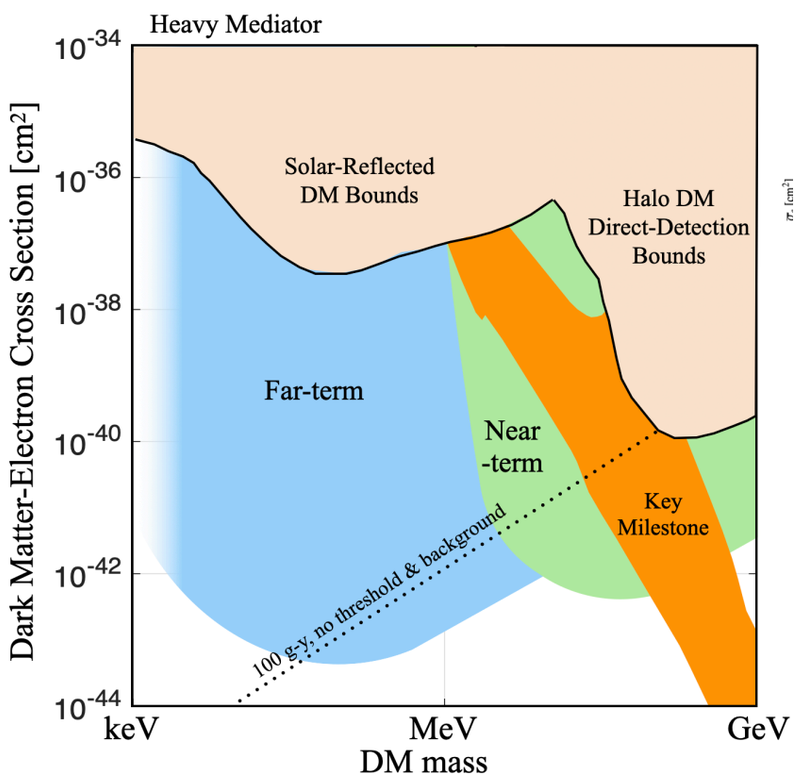
Lin, Yu, KZ 1111.0293

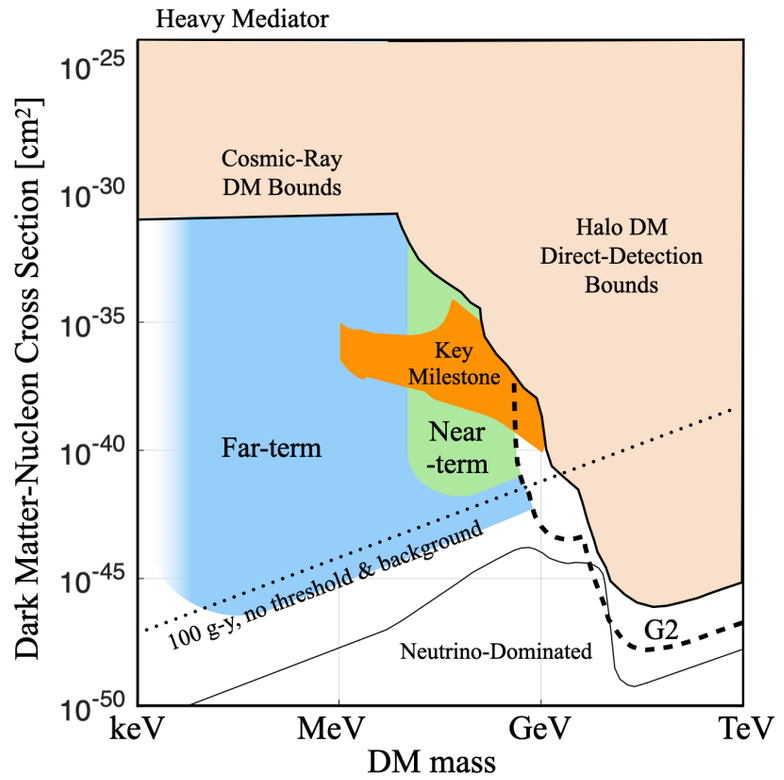


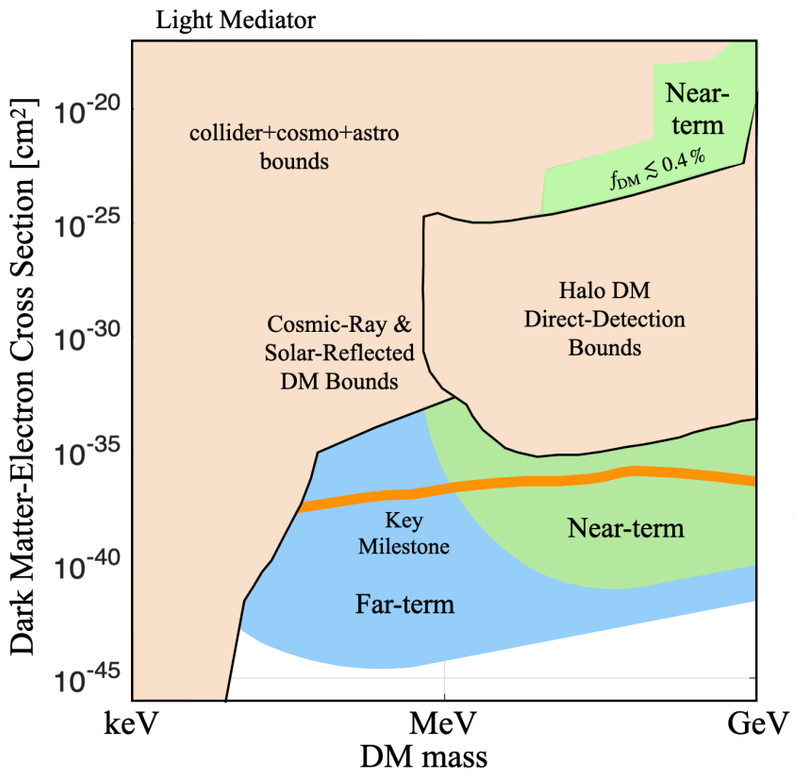


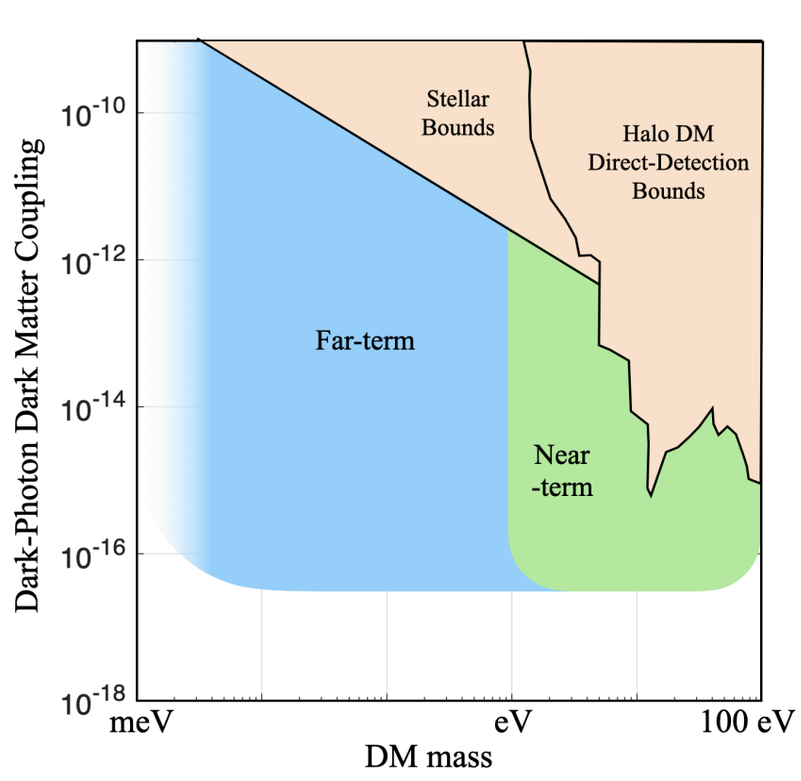
Light mediators yield large scattering cross-sections in direct detection

SUITE OF EXPERIMENTS TO SEARCH FOR LIGHT DARK MATTER IN DIRECT DETECTION

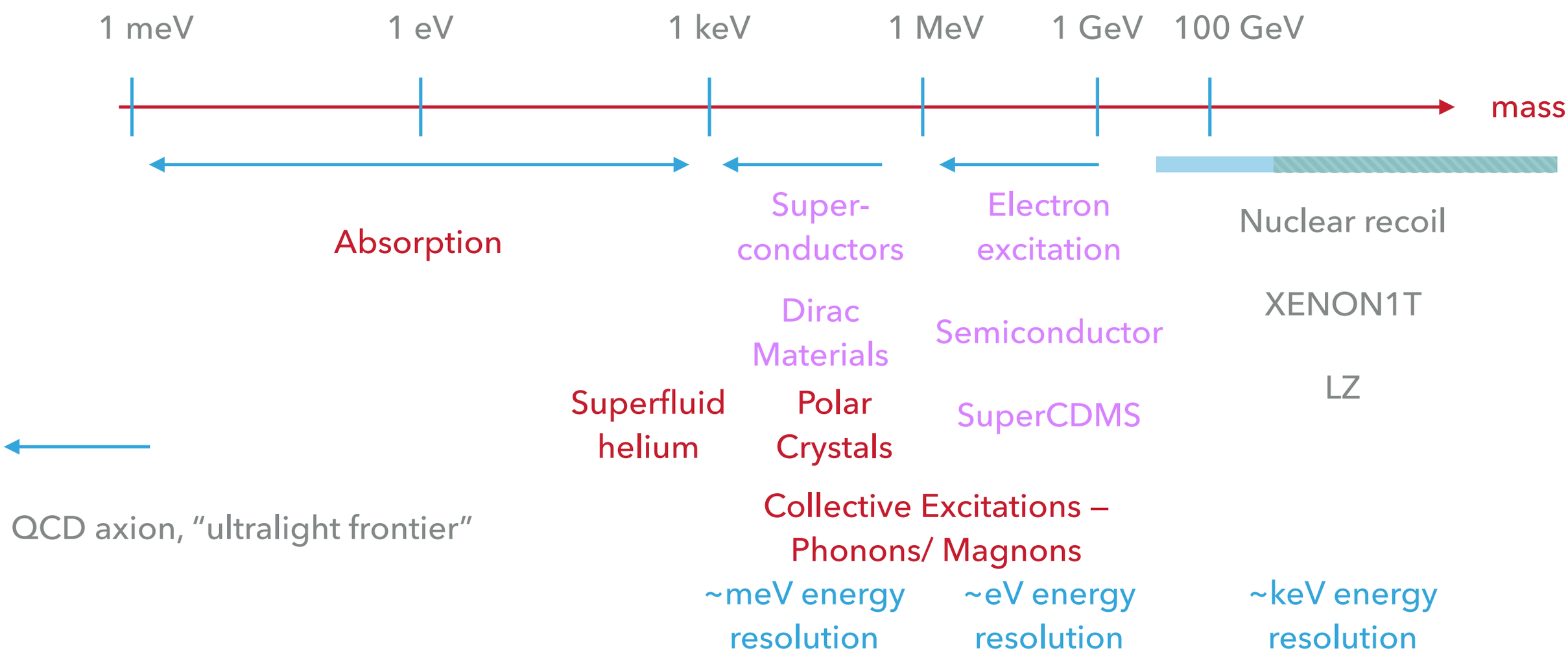




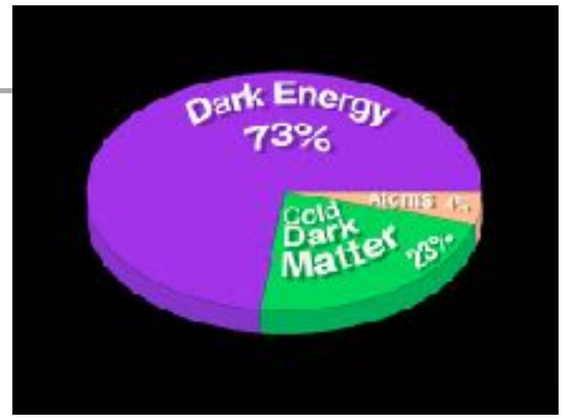




SUITE OF EXPERIMENTS TO SEARCH FOR LIGHT DARK MATTER IN DIRECT DETECTION

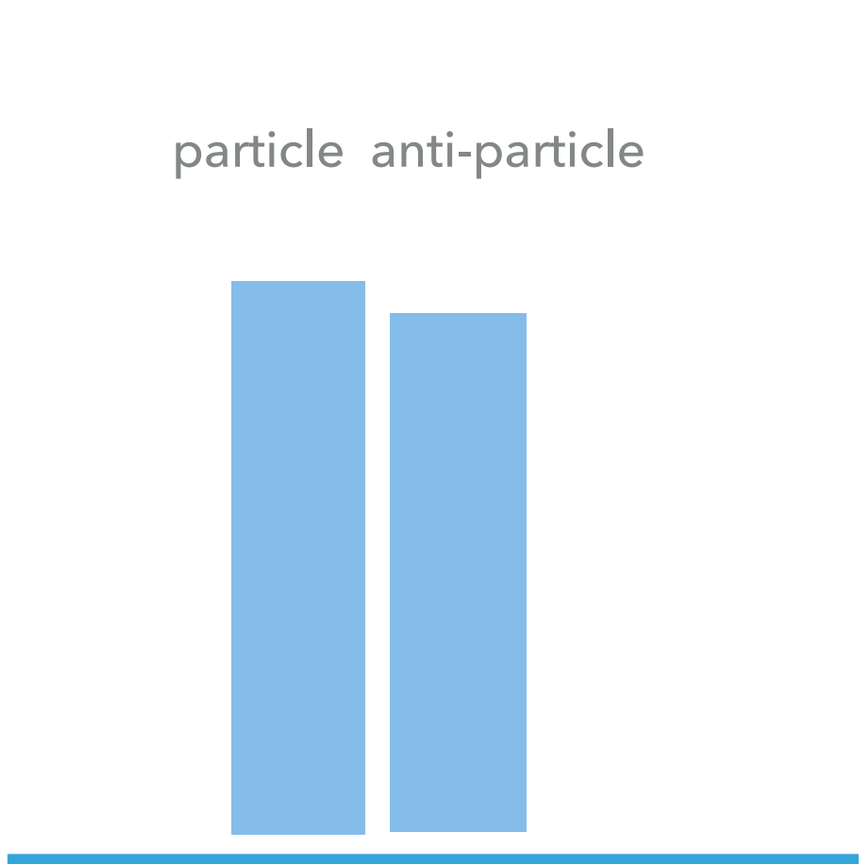


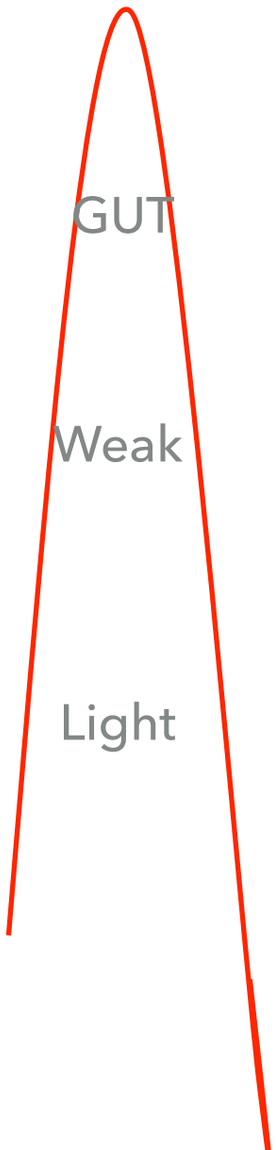
ASYMMETRIC DARK MATTER

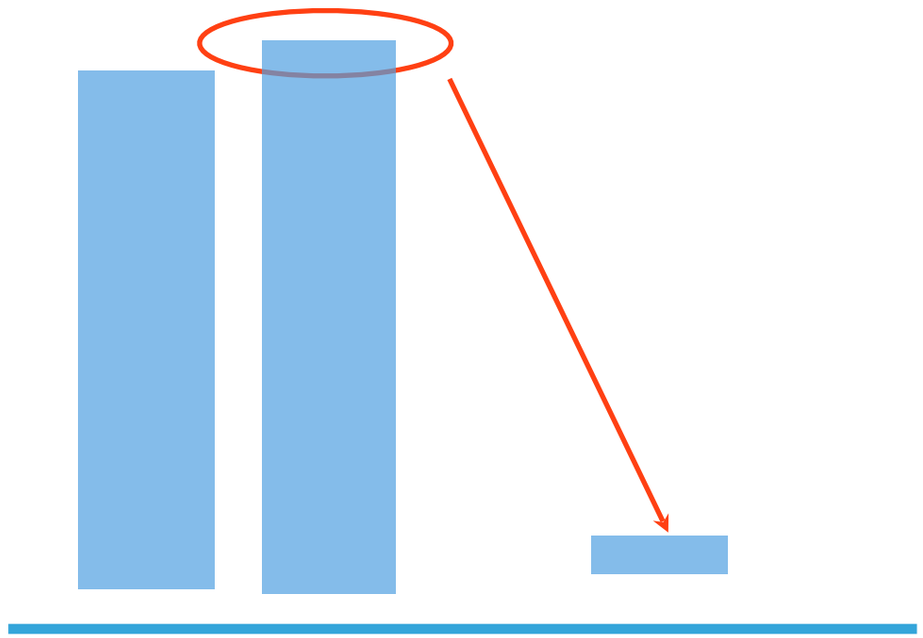


A concrete model of DM gives rise to a broad range of signals from a single, UV complete model

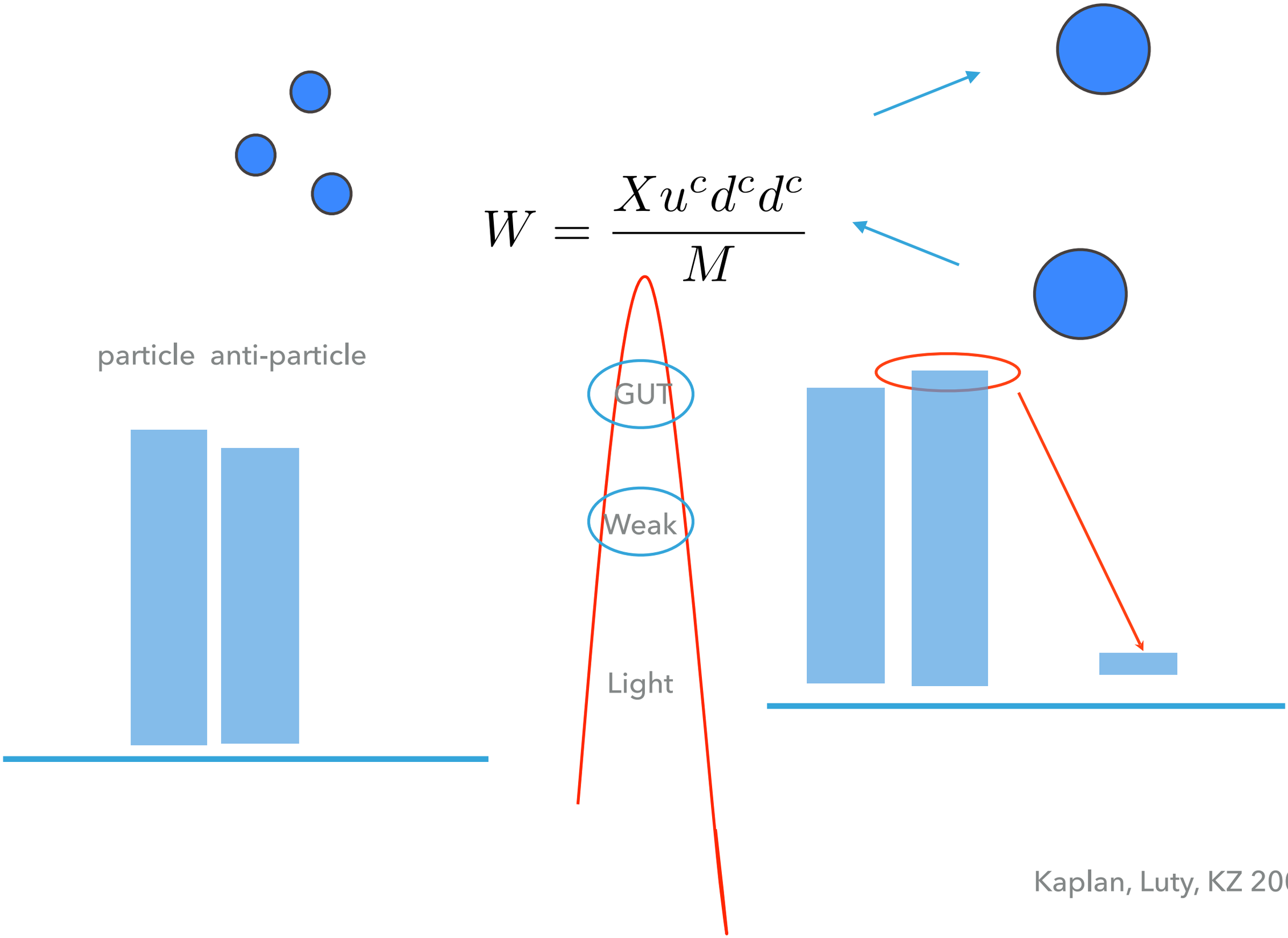
Standard Model → Connector → Dark Matter



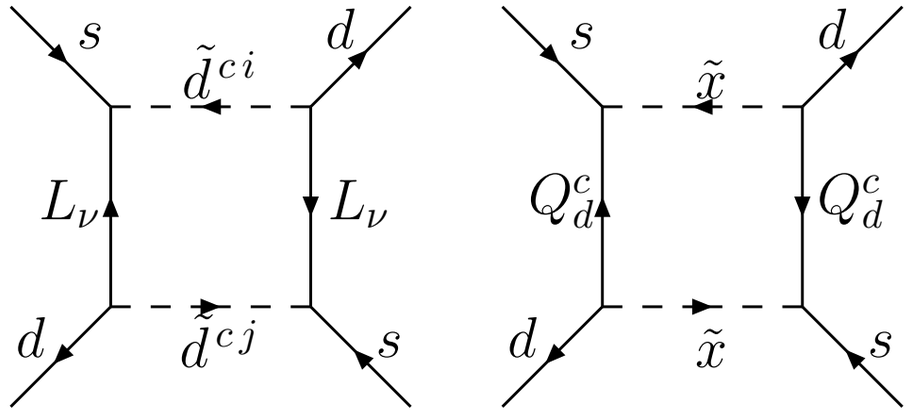


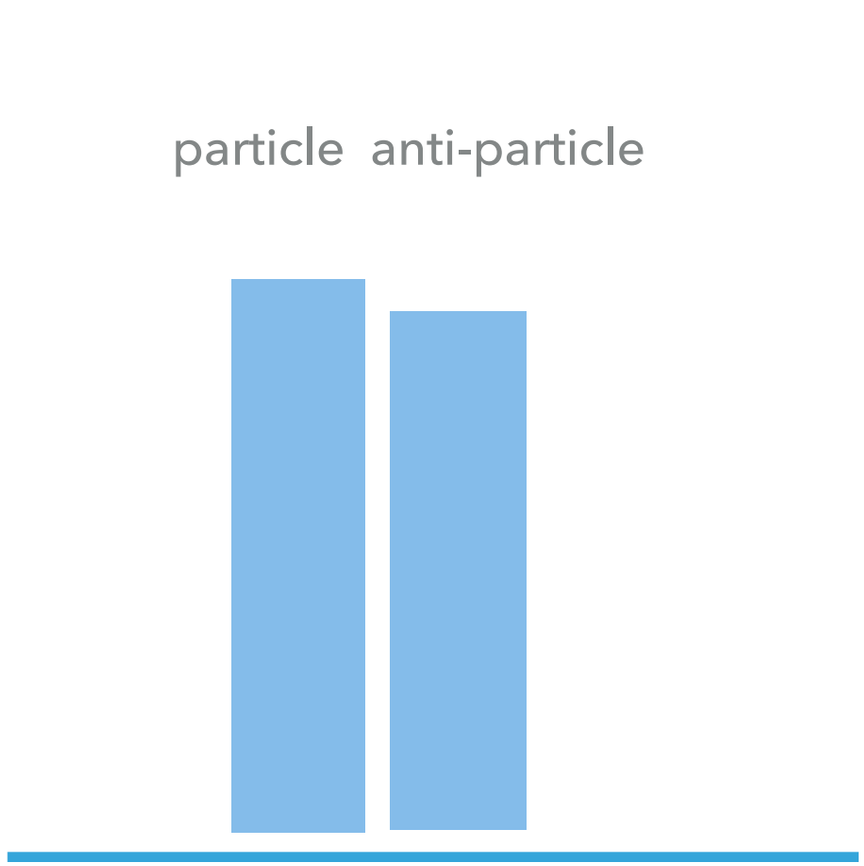


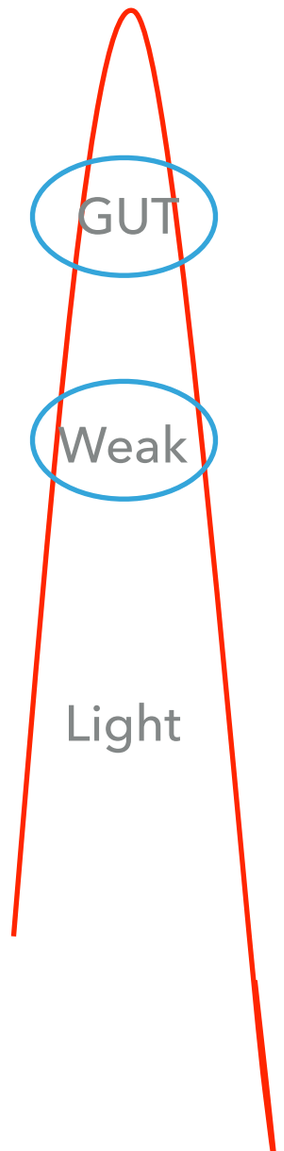
ASYMMETRIC DARK MATTER

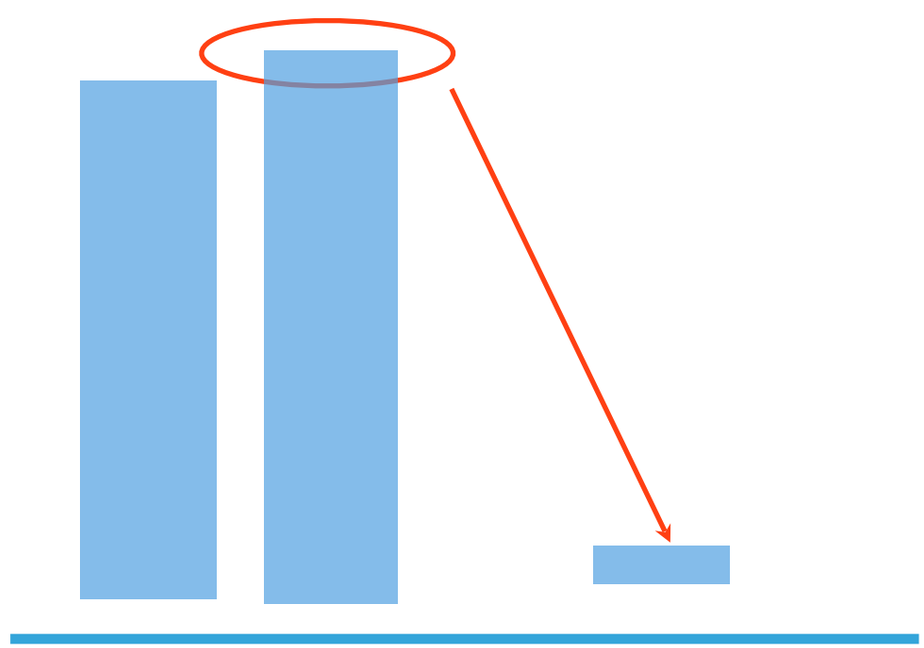


Kaplan, Luty, KZ 2009









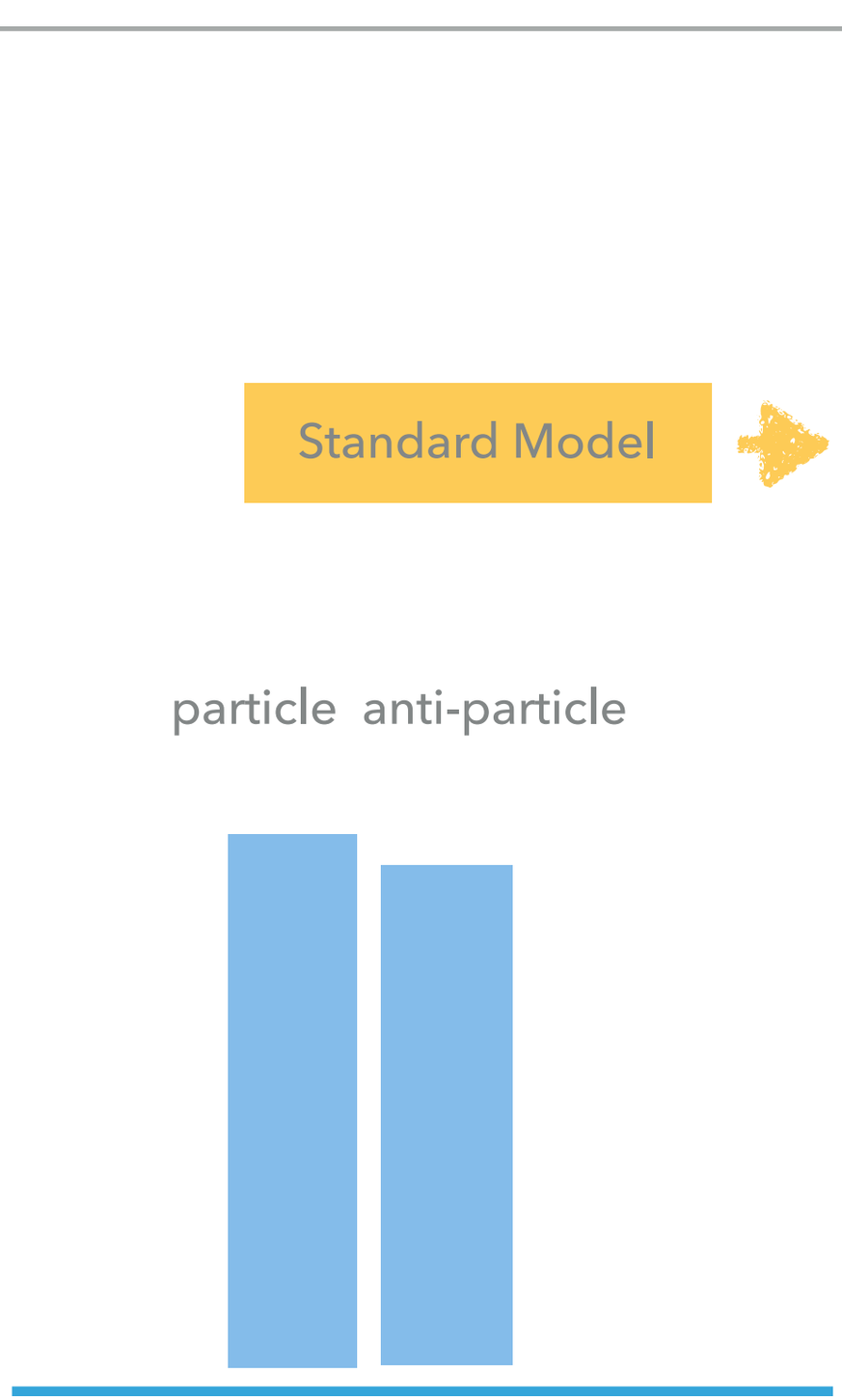
Kaplan, Luty, KZ 2009

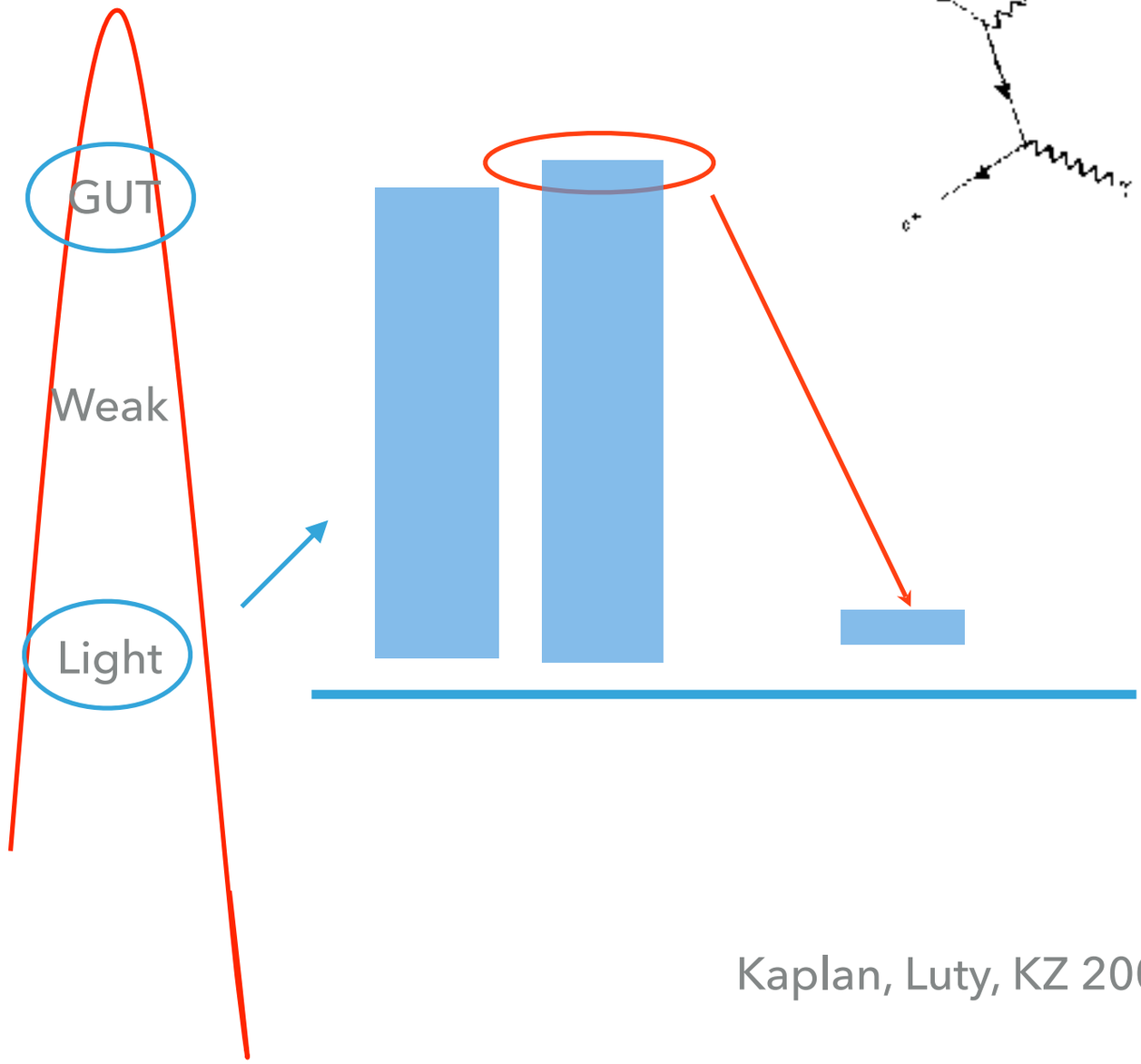
ASYMMETRIC DARK MATTER

Dark Forces Arise Naturally

Standard Model → Connector → Dark Matter

particle anti-particle



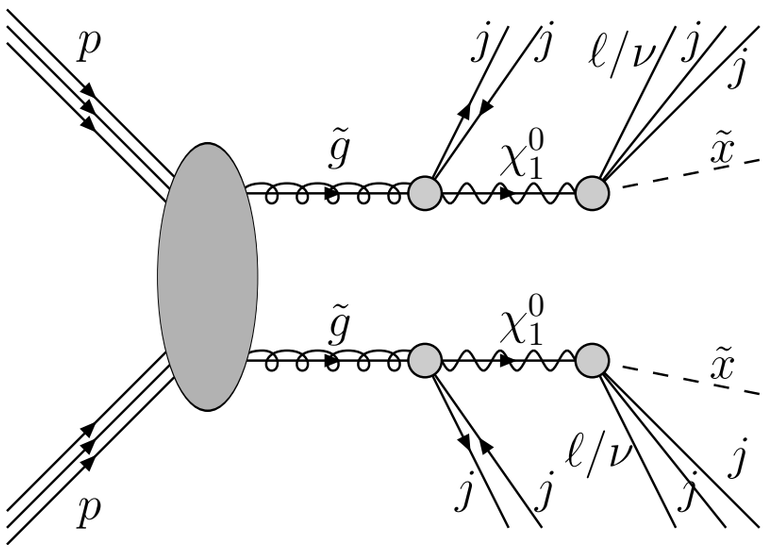


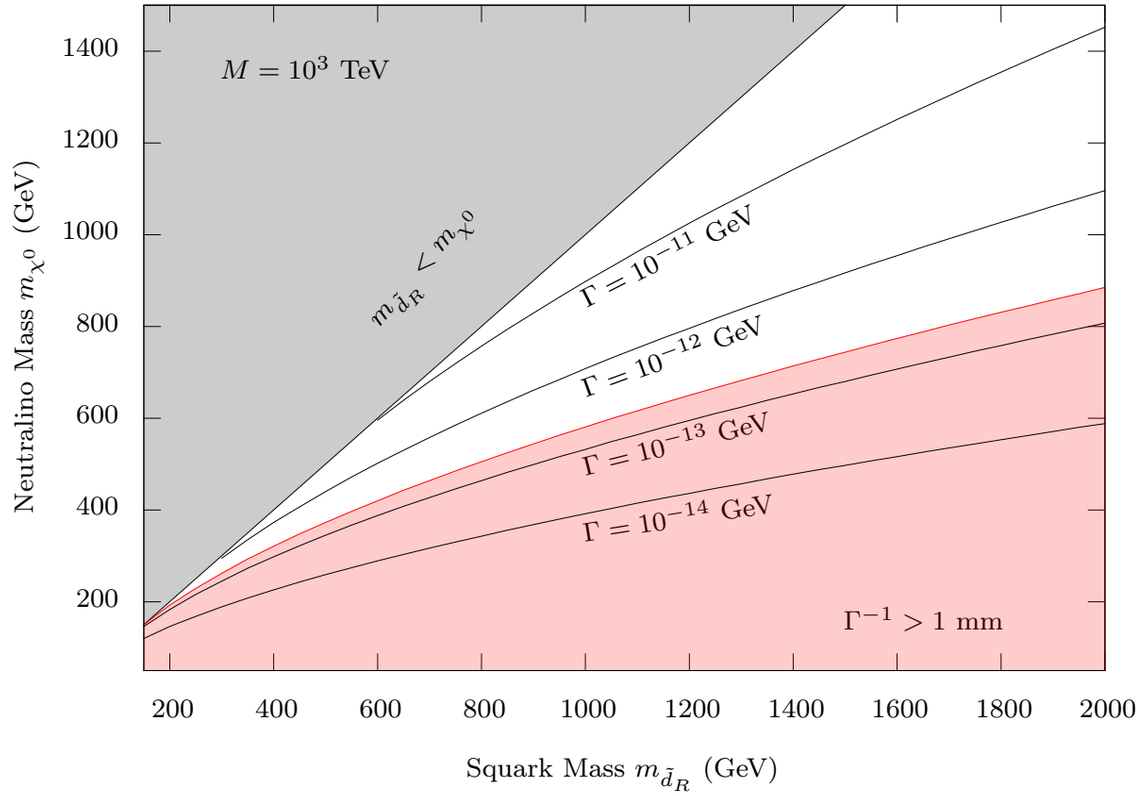
Kaplan, Luty, KZ 2009

GENERIC IR MODEL PRODUCES A PLETHORA OF SIGNALS

- At many mass scales
- In multiple different types of experiments

Kim, KZ 1310.2617

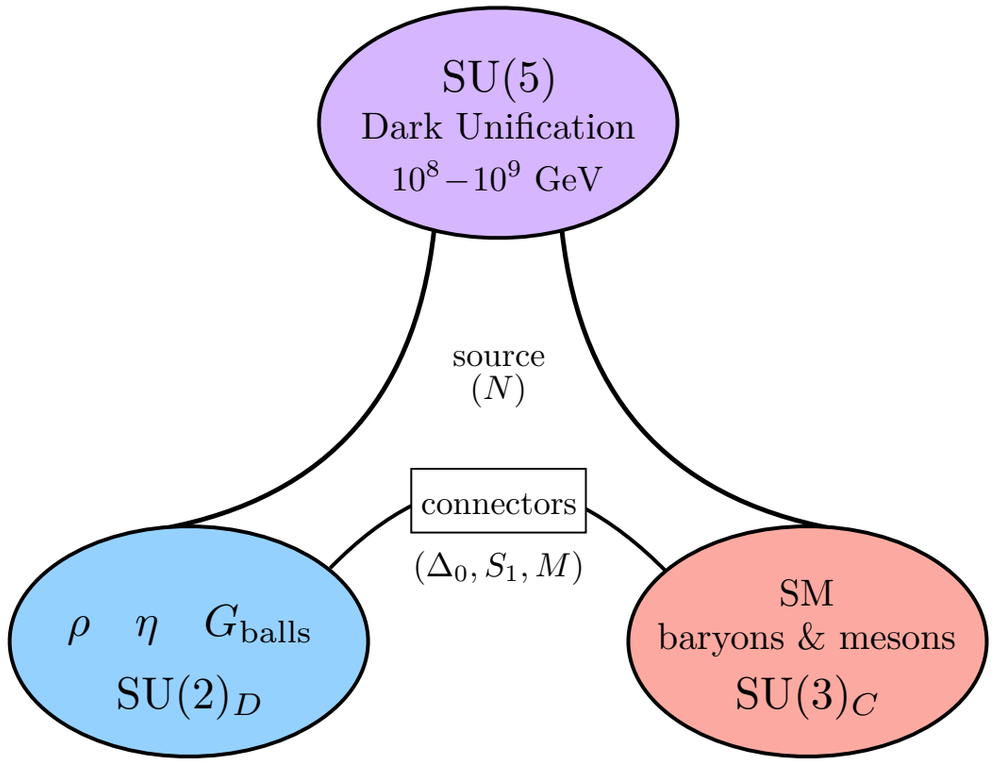




(a) $M = 1000$ TeV

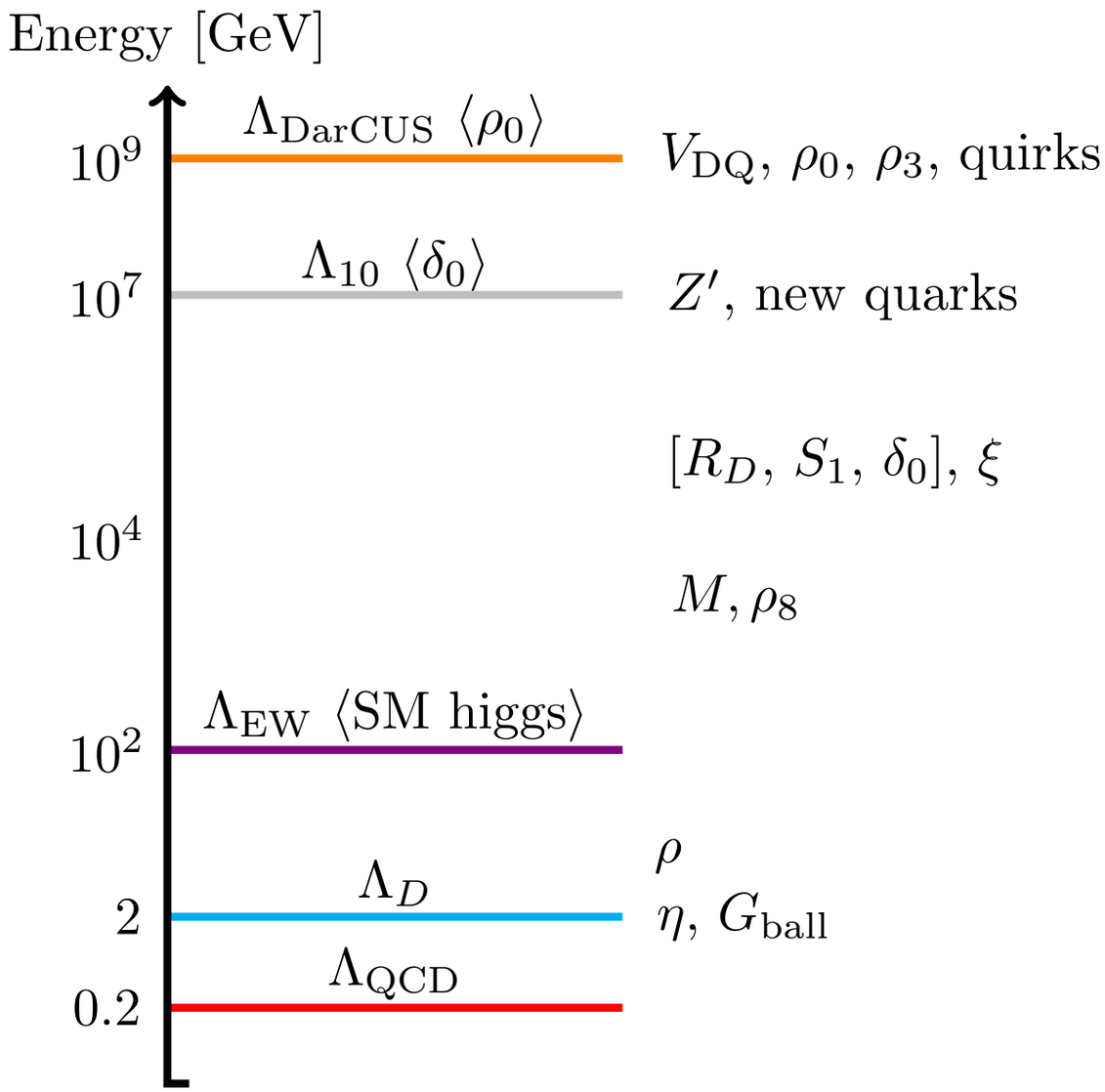
A UV COMPLETE THEORY OF ASYMMETRIC DARK MATTER

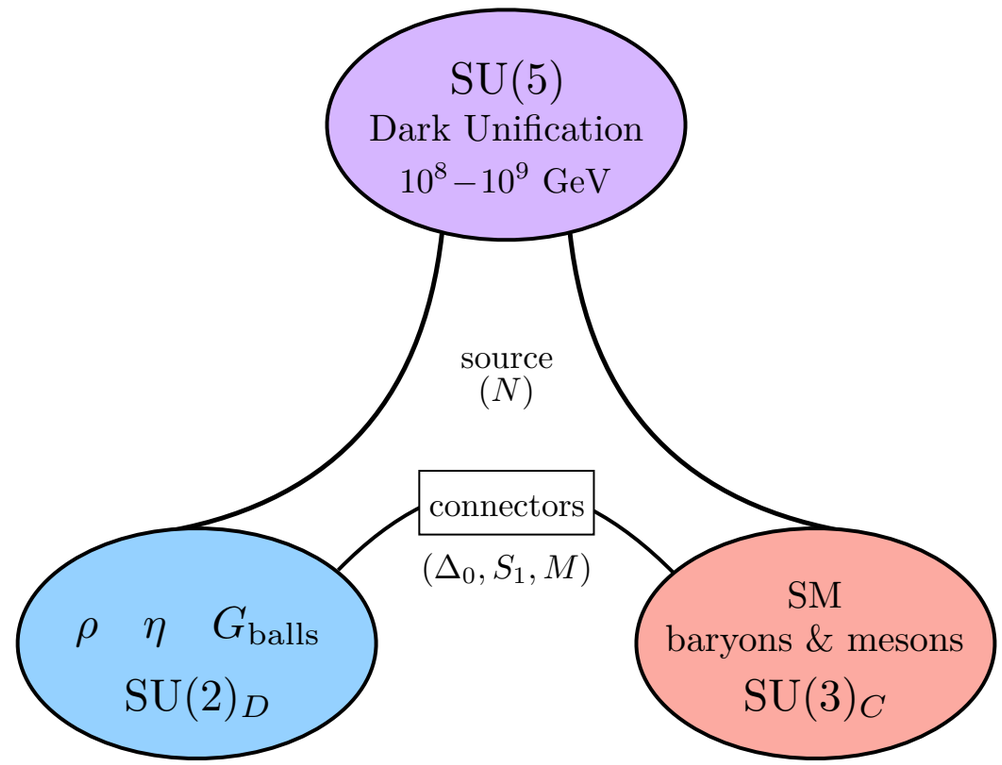
- In order to solve the cosmic coincidence problem, the DM mass should be close to the proton mass
- This is not explained in the standard theories of ADM
- One natural way to do it is to have a common origin for both dark and visible mass scales, which suggests unification



Murgui, KZ 2112.08374

A UV COMPLETE THEORY OF ASYMMETRIC DARK MATTER



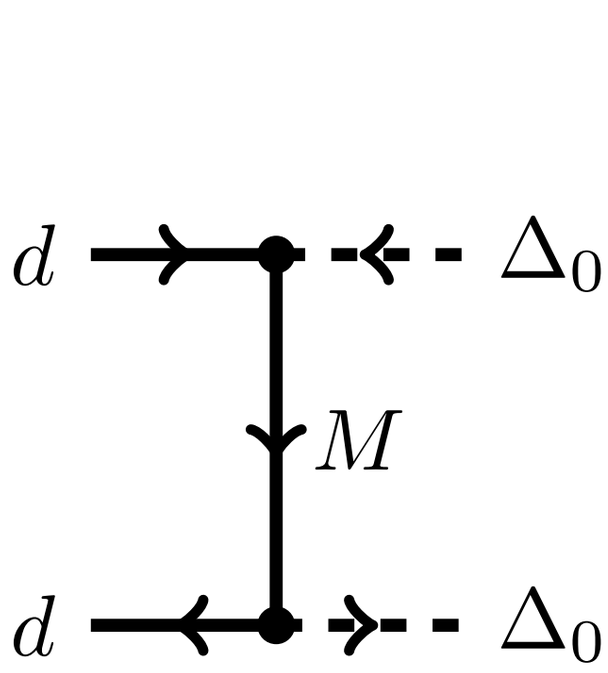


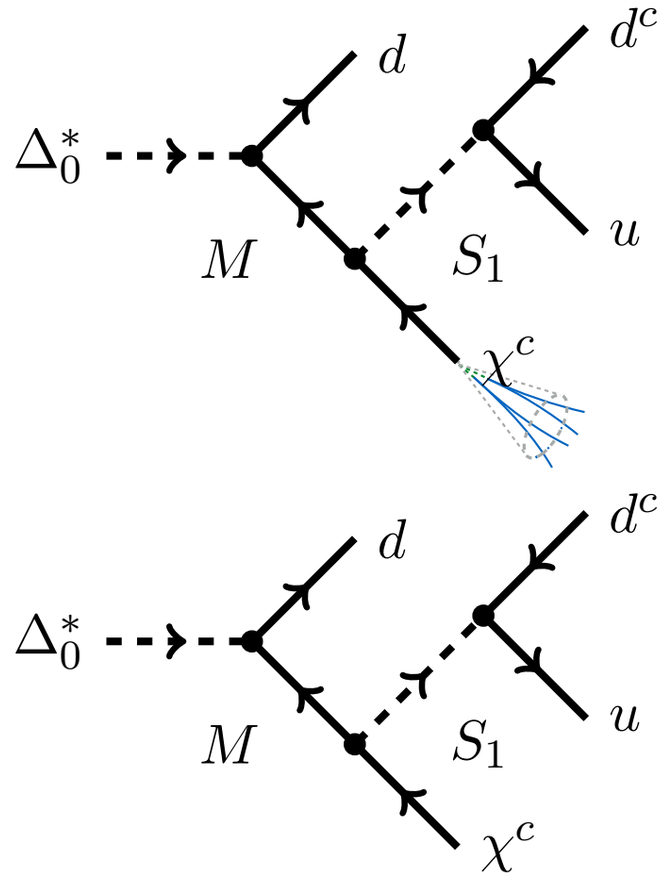
Murgui, KZ 2112.08374

Multiple mass scales and states

HIDDEN VALLEYS WERE MOTIVATED TOP DOWN BUT ENGINEERED BOTTOM UP

- Here, we generate the whole panoply
- Connector particles that decay promptly to MET + jets, Pairs of displaced vertices, as well as semi-visible jets





CONCLUSIONS

- There is no *single* way to search for signatures of hidden sectors
- In general, UV complete models feature multiple signatures
- Light dark matter detection, prompt and displaced decays at collider, searches for light states at intensity machines, flavor, even extending to gravitational wave signatures
- Moving forward, we are working to optimize reach from existing experiments