Into the dark sector: New probes and model-building

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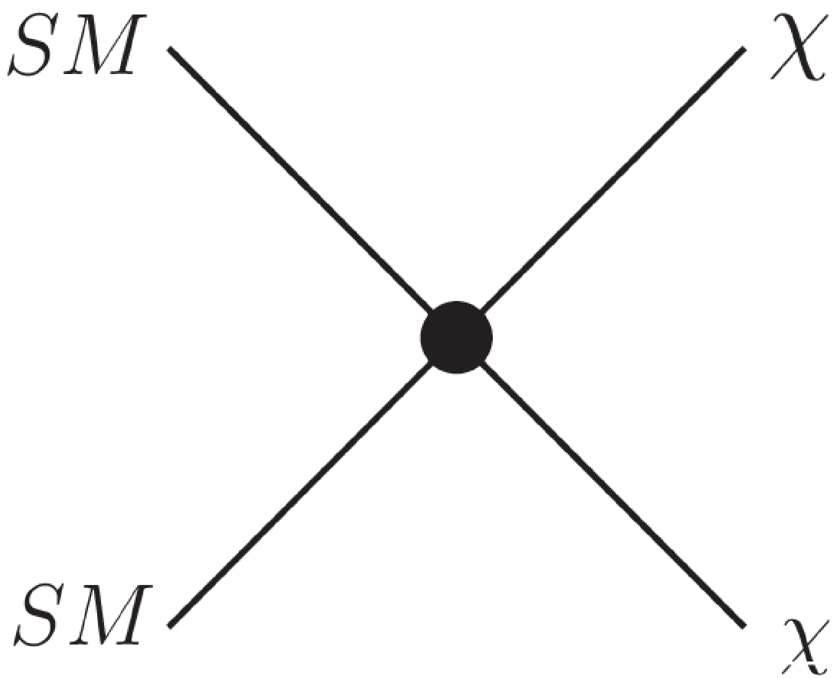
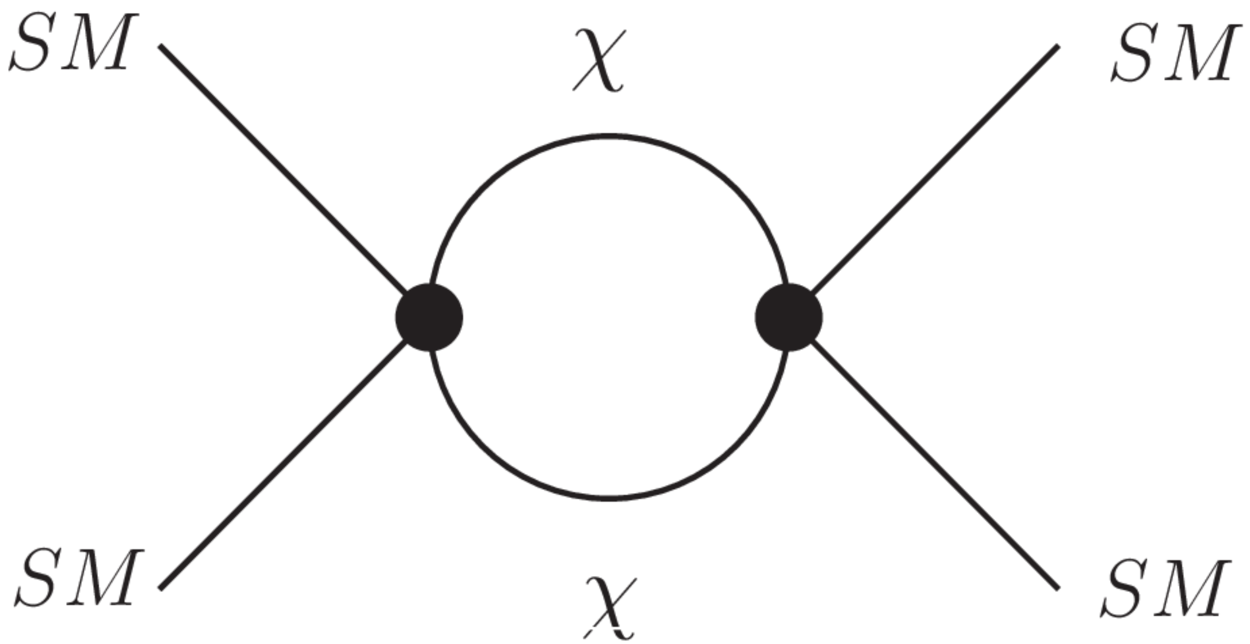
Related references:
JHEP 1704 (2017) 088
PRL 120 (2018), 131801
1710.00850 (with P. Brax, G. Pignol)

Proposal 1: Virtual effects from Dark Matter

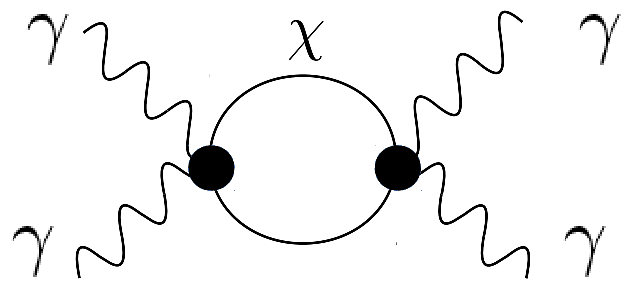


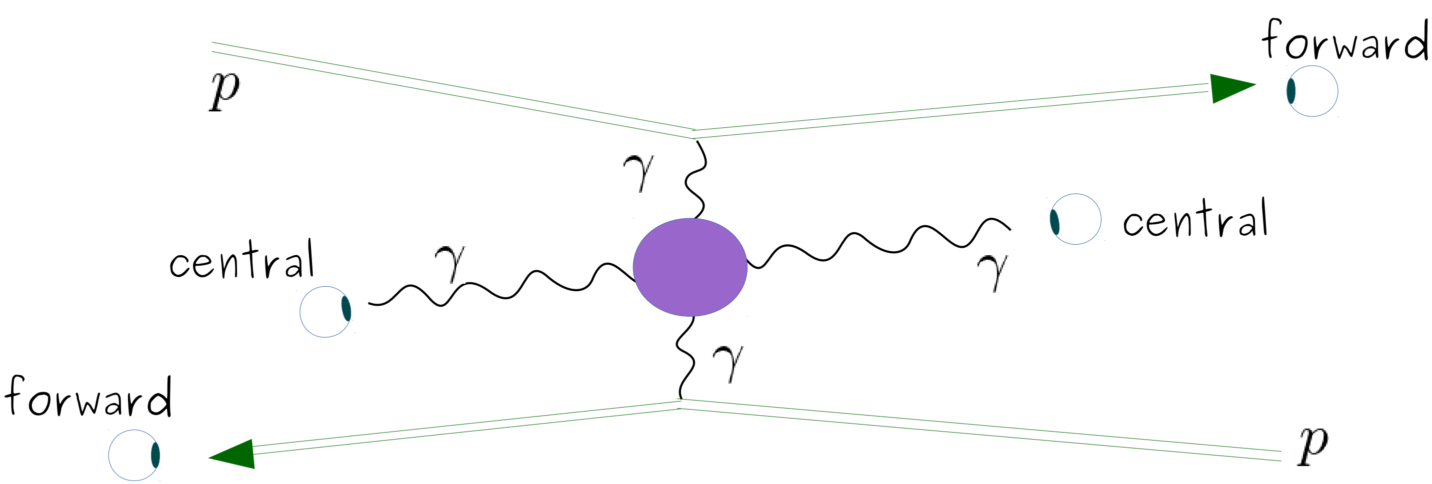
Proposal 1: Virtual effects from Dark Matter



Proposal 1: Virtual effects from Dark Matter

1a. From polarizable/polarized dark particles $\frac{1}{\Lambda^2}\phi^2(F^{\mu\nu})^2,\ \frac{1}{\Lambda^4}\partial_\mu\phi\partial_\nu\phi F^{\mu\rho}F_\rho^{\ \nu},\ \ldots$





Scalar case already done... [SF 17']

Proposal 1: Virtual effects from Dark Matter

...But calculation/simulation could be done for fermion DM too.

Box diagrams from polarized Dirac DM: $\bar{\Psi}\sigma_{\mu\nu}\Psi F^{\mu\nu}, \bar{\Psi}\gamma_5\sigma_{\mu\nu}\Psi\tilde{F}^{\mu\nu}$,

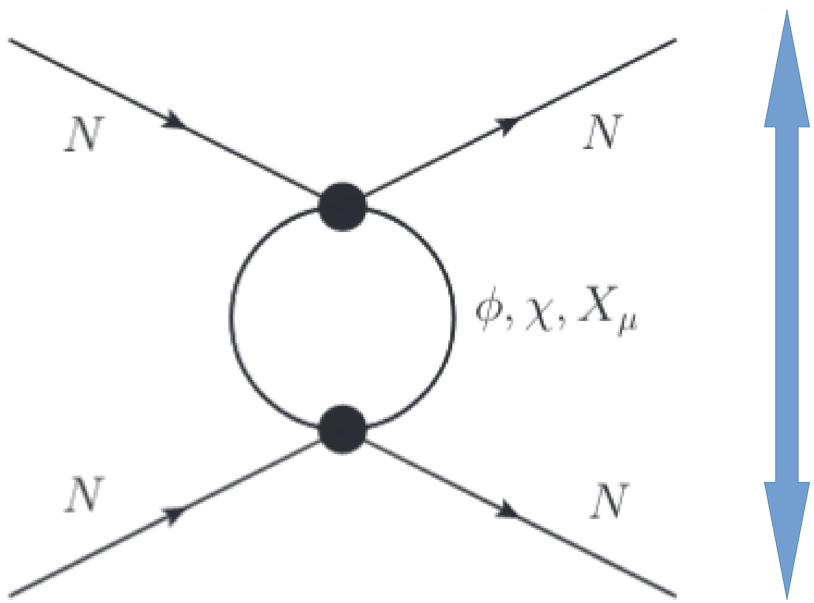
Bubbles from polarizable Majorana DM:

$\bar{\Psi}\Psi(F)^2$ 7 $\mathcal{O}^{1/2}_{7a}$	$i\bar{\Psi}\gamma_\mu\partial^\nu\Psi(F.F)^{\mu\nu}$ 8 $\mathcal{O}^{1/2}_{8a}$	$i\bar{\Psi}\gamma_\mu\partial^\mu\Psi(F)^2$ 8 $\mathcal{O}^{1/2}_{8b}$
$i\bar{\Psi}\gamma_5\Psi(F\tilde{F})$ 7 $\mathcal{O}^{1/2}_{7b}$	$\bar{\Psi}\gamma_5\gamma_\mu\partial^\nu\Psi(F.\tilde{F})^{\mu\nu}$ 8 $\mathcal{O}^{1/2}_{8c}$	$\bar{\Psi}\gamma_5\gamma_\mu\partial^\mu\Psi(F\tilde{F})$ 8 $\mathcal{O}^{1/2}_{8d}$

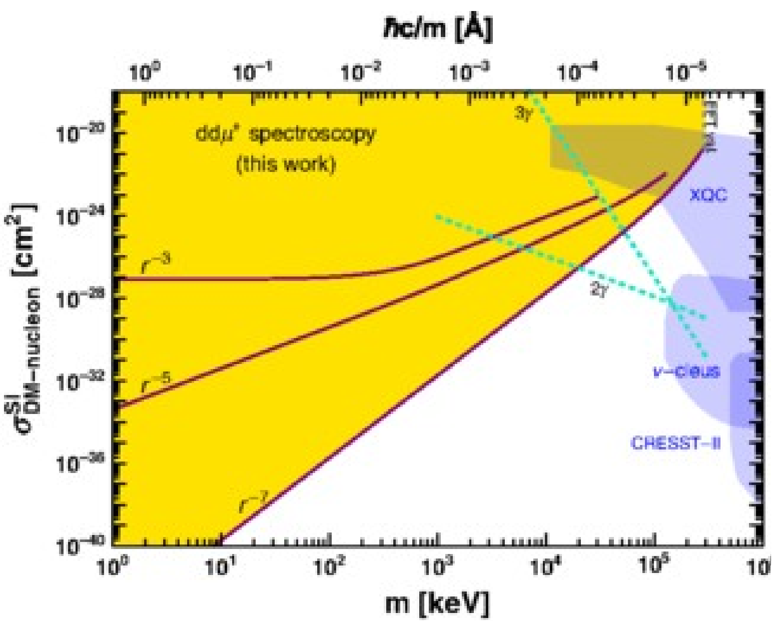
$pp \to p\gamma\gamma p$ data are being collected and are under analysis. Thus there will be the possibility to put actual bounds on DM using this process.

Proposal 1: Virtual effects from Dark Matter

1b. From dark particles coupled to nucleons $\frac{1}{\Lambda}\bar{N}N\phi^2, \ \frac{1}{\Lambda^2}\bar{N}\gamma^\mu N\bar{\chi}\gamma^\mu\chi, \ , \ldots$



Casimir–Polder force



Spin-independent case already done. Is only for scalar and vector channels and constrained by molecular spectroscopy and neutron scattering.

[SF 18']

Proposal 1: Virtual effects from Dark Matter

But spin-dependent case is also well-motivated. Comes from interactions of the form

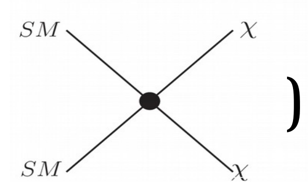
$$\frac{1}{\Lambda}\bar{N}\gamma_5 N\mathcal{O}_{DS}\,,\,\frac{1}{\Lambda}\bar{N}\gamma_5\gamma_\mu N\mathcal{O}_{DS}\,,\,\frac{1}{\Lambda}\bar{N}\sigma_{\mu\nu}N\mathcal{O}_{DS}$$

Experimentalists from ILL (Grenoble) have shown interest because it motivates the development of a new experiment based on polarized ^{3}He.

There may also be bounds from stellar energy loss to evaluate

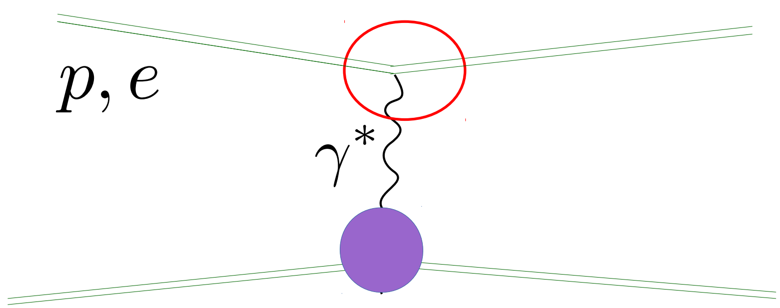
[1205.1776. (Raffelt)]

Proposal 2: Dark Matter fluxes

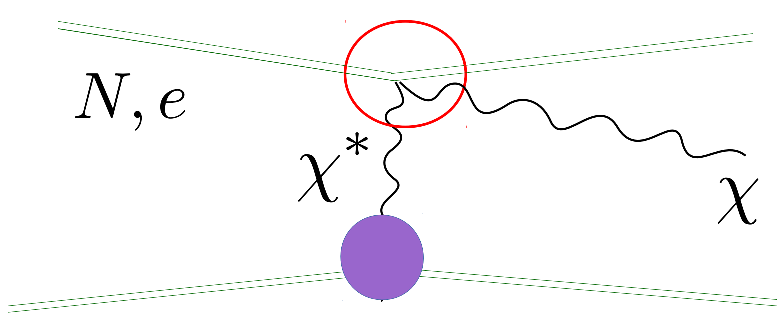
Back to tree-level ()

Low-energy Dark Matter effective theory: $\bar{N}\Gamma^A N \bar{\chi}\Gamma'_A\chi\ ,\ \ e^-\Gamma^A e^+\bar{\chi}\Gamma'_A\chi$

In analogy with the Weizsacker-Williams equivalent photon approximation



We expect a Dark Matter flux from nucleons, electrons...

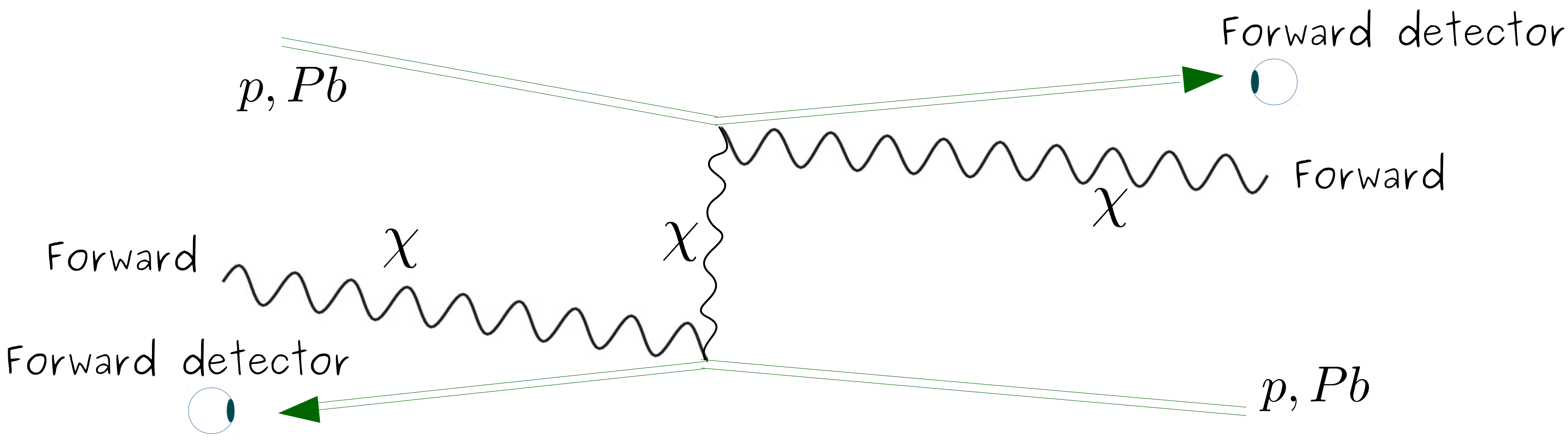


$\rightarrow$ A nice calculation to do

Proposal 2: Dark Matter fluxes

What can we study when knowing these DM fluxes?

Central exclusive DM production

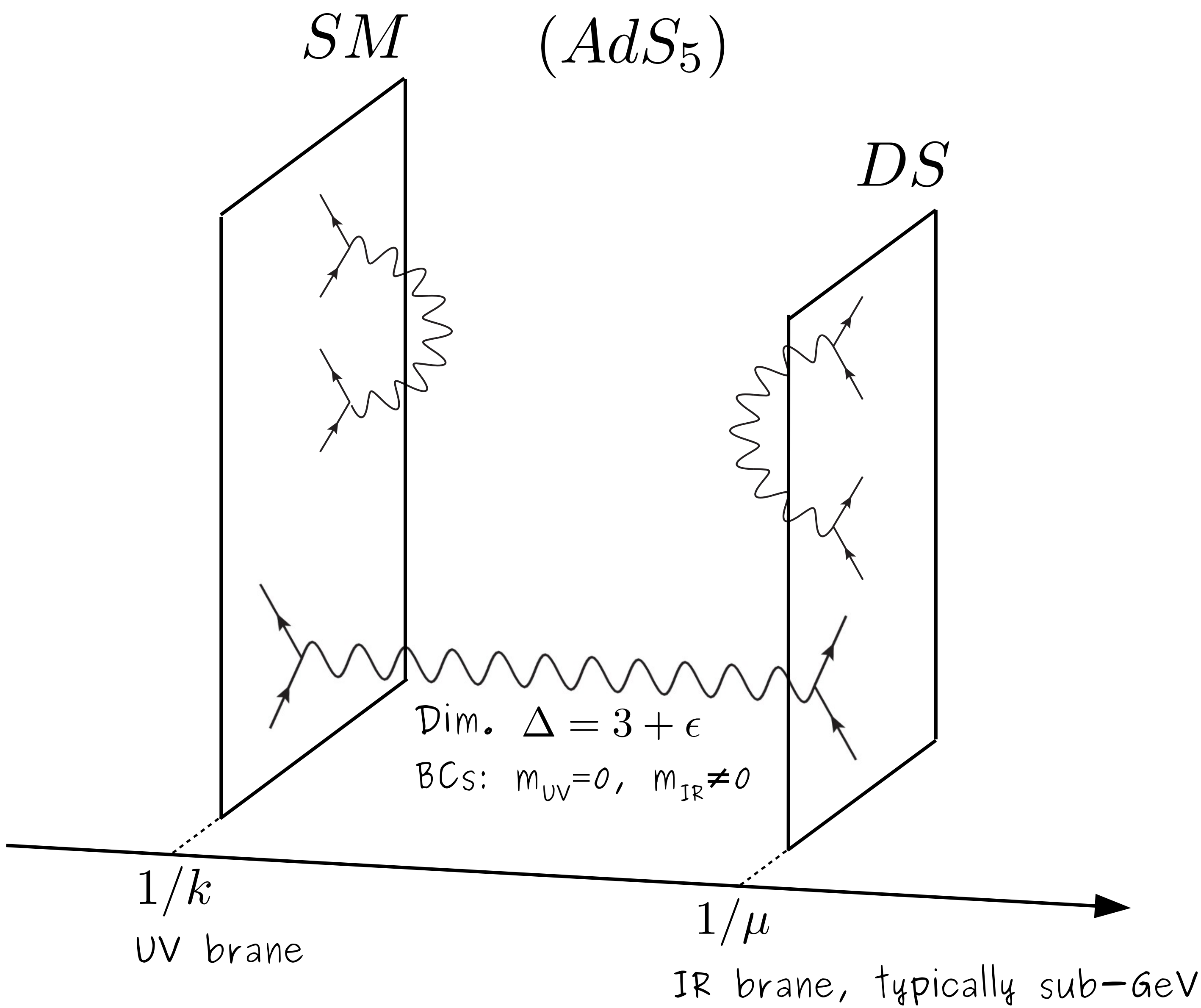


p-p: $\sqrt{s_{\gamma\gamma}^{\max}}$=4.5 TeV, large pileup. Needs timing detectors to be efficient (cf C. Royon)

Pb-Pb: $\sqrt{s_{\gamma\gamma}^{\max}}$=160 GeV, no pileup, huge enhancement A^4= $O(10^9)$. Proton taggers unavailable. Could ZDCs provide enough information?

Pb-p: $\sqrt{s_{\gamma\gamma}^{\max}}$ =260 GeV, no pileup, A^2 enhancement. Interesting combination...

Proposal 3: A sub-GeV warped dark sector



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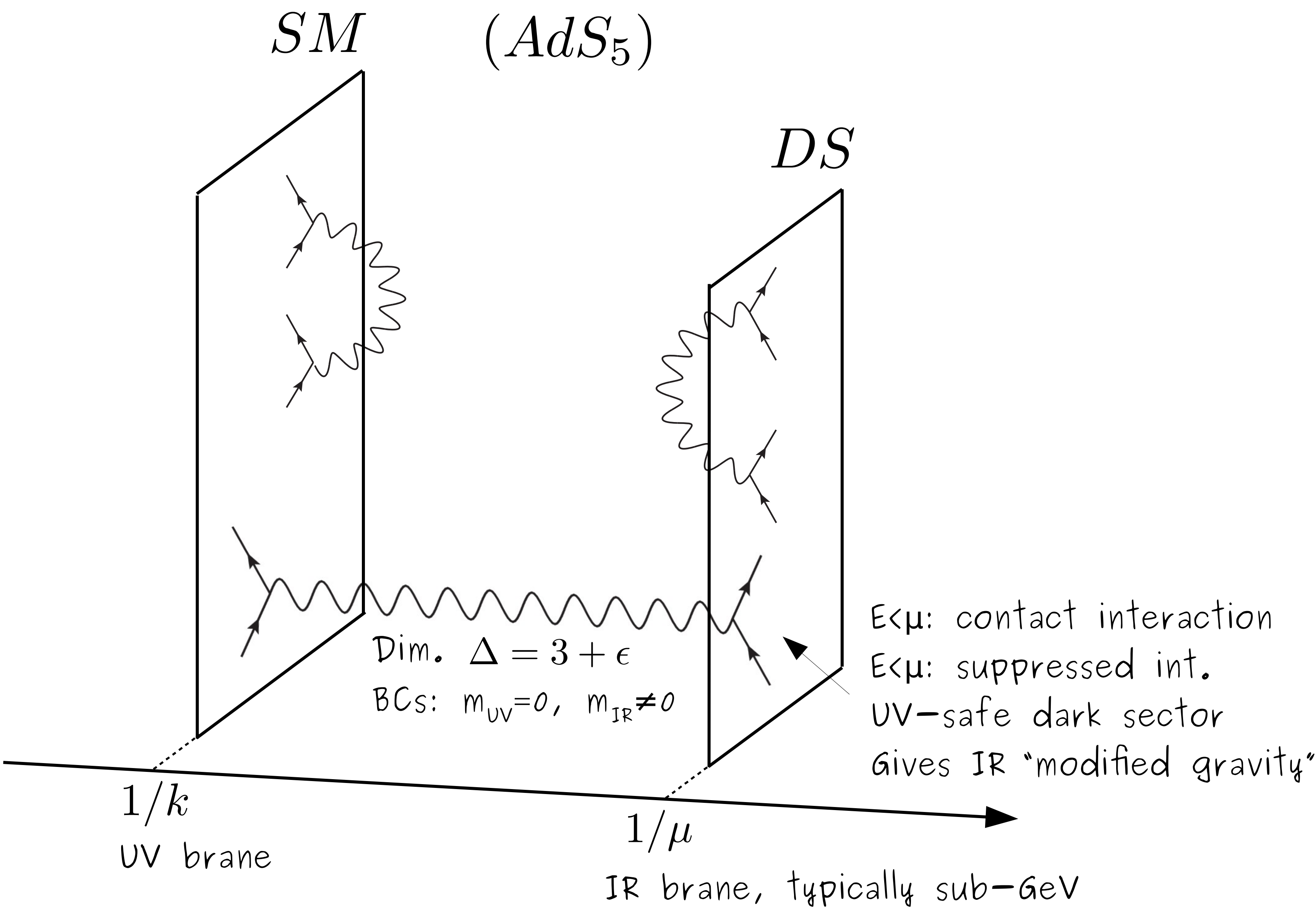

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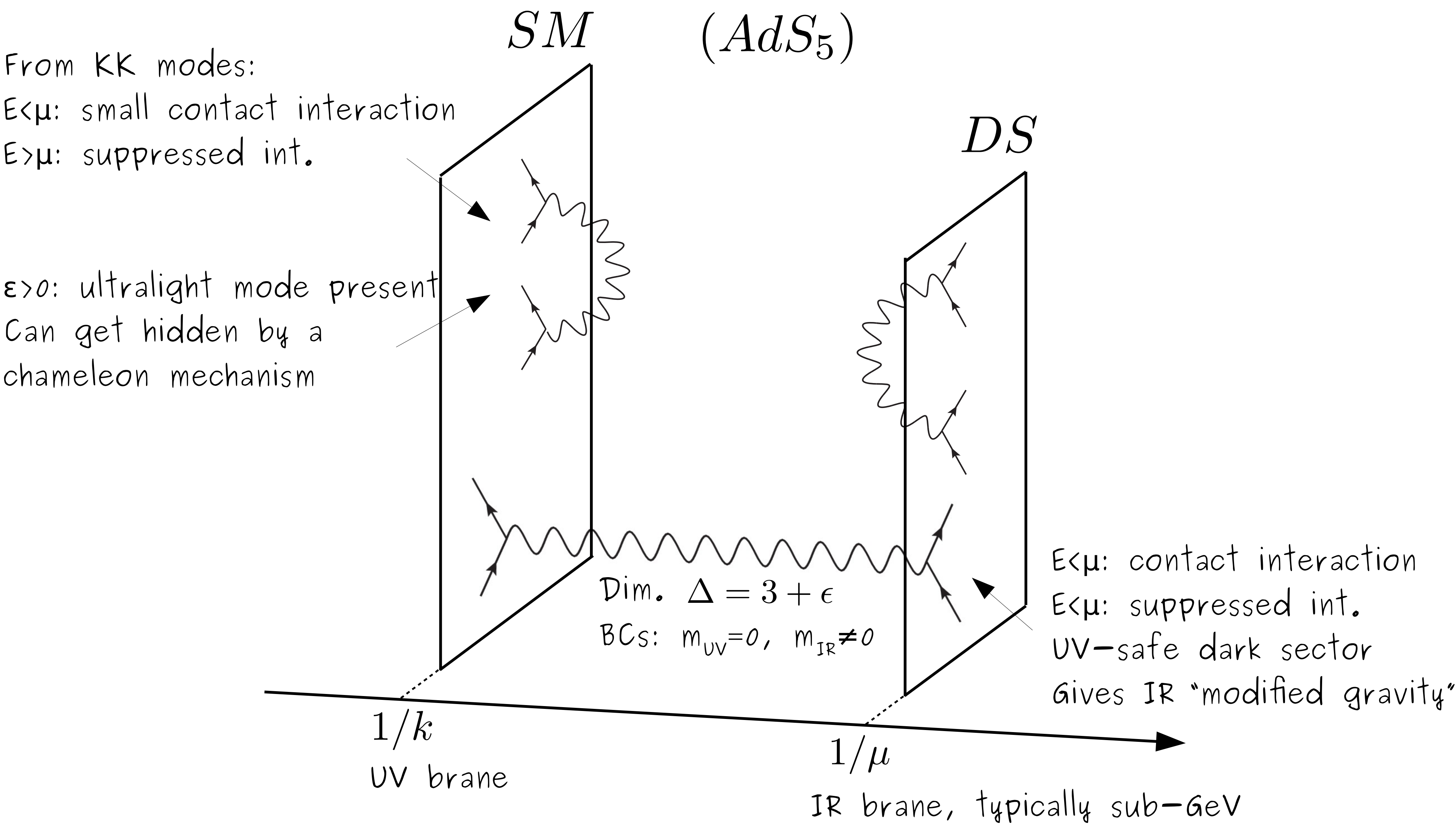

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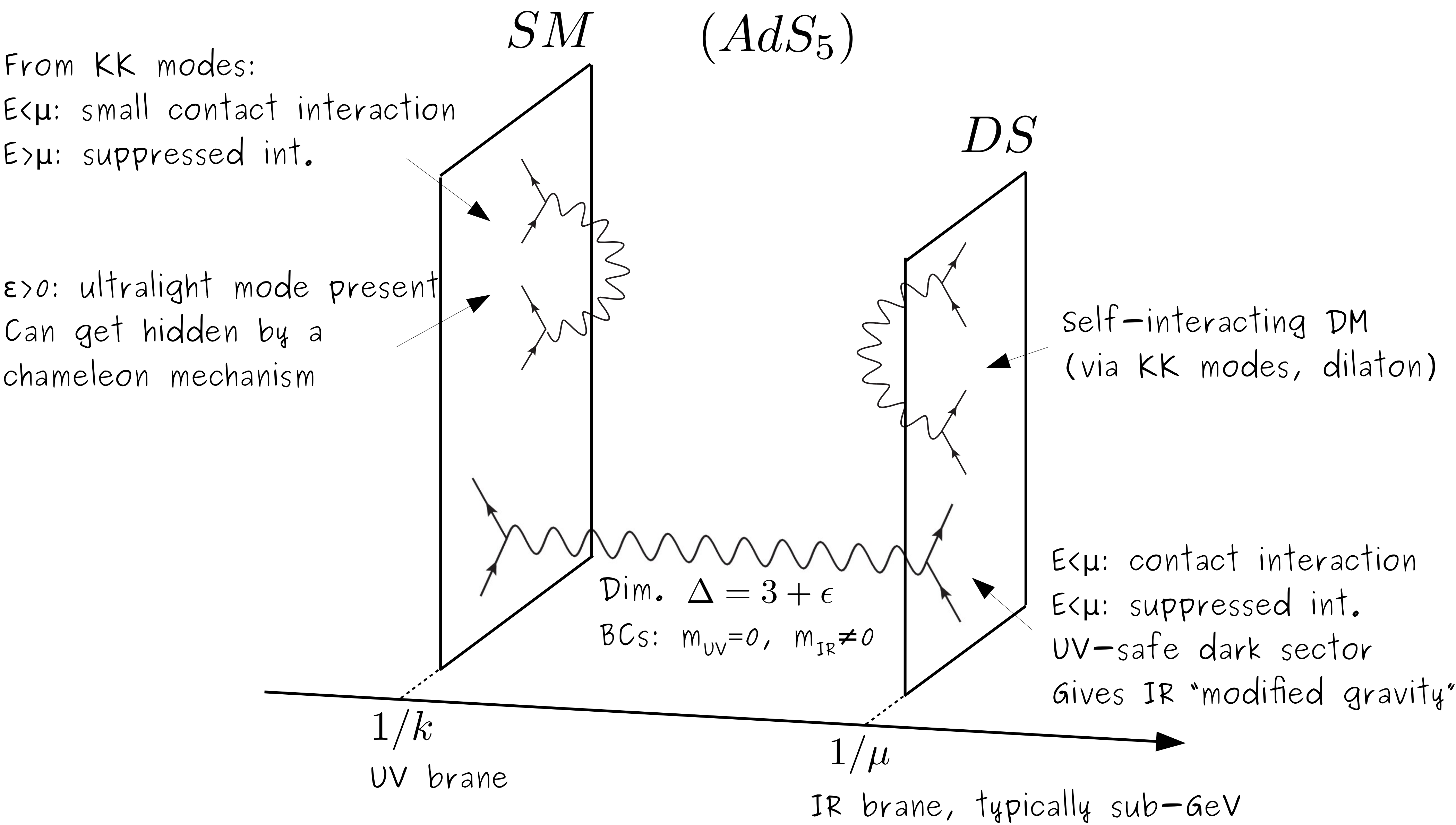

Proposal 3: A sub-GeV warped dark sector

A first letter about this project is already in progress. But many follow ups are possible. Aspects to investigate:

→ Collider bounds (MET and visible continuum).

→ Meson decays

→ The brane chameleon effect

→ Non-integer fifth force from KK modes (can also be done in the 4D dual)

→ Direct detection, indirect detection

→ Cosmology

→ Implications for future experiments like FASER, DUNE etc

→ Self-interacting dark matter

→ Other consequences of having a light dilaton in the dark sector

Summary

- Proposal 1: Virtual effects from Dark Matter (light-by-light scattering, fifth forces,...)
- Proposal 2: Dark Matter fluxes and their consequences
- Proposal 3 : A sub-GeV warped dark sector

THANKS