HIDDEN PHOTONS IN AHARONOV-BOHM-TYPE EXPERIMENTS

PAOLA ARIAS R.
USACH

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IN COLLABORATION WITH

- Joerg Jaeckel (Heidelberg U)
- Benjamin Koch (PUC)
- Christian Diaz & Marco Aurelio Díaz (PUC)
- Javier Redondo, (Zaragoza U)
- More info on arXiv:1603.01282 [hep-ph] (To appear in PRD)

OSCILLATION BETWEEN PHOTONS AND HIDDEN PHOTONS

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}G_{\mu\nu}G^{\mu\nu} - \frac{\epsilon}{2}F_{\mu\nu}G^{\mu\nu} + j_\mu A^\mu$$

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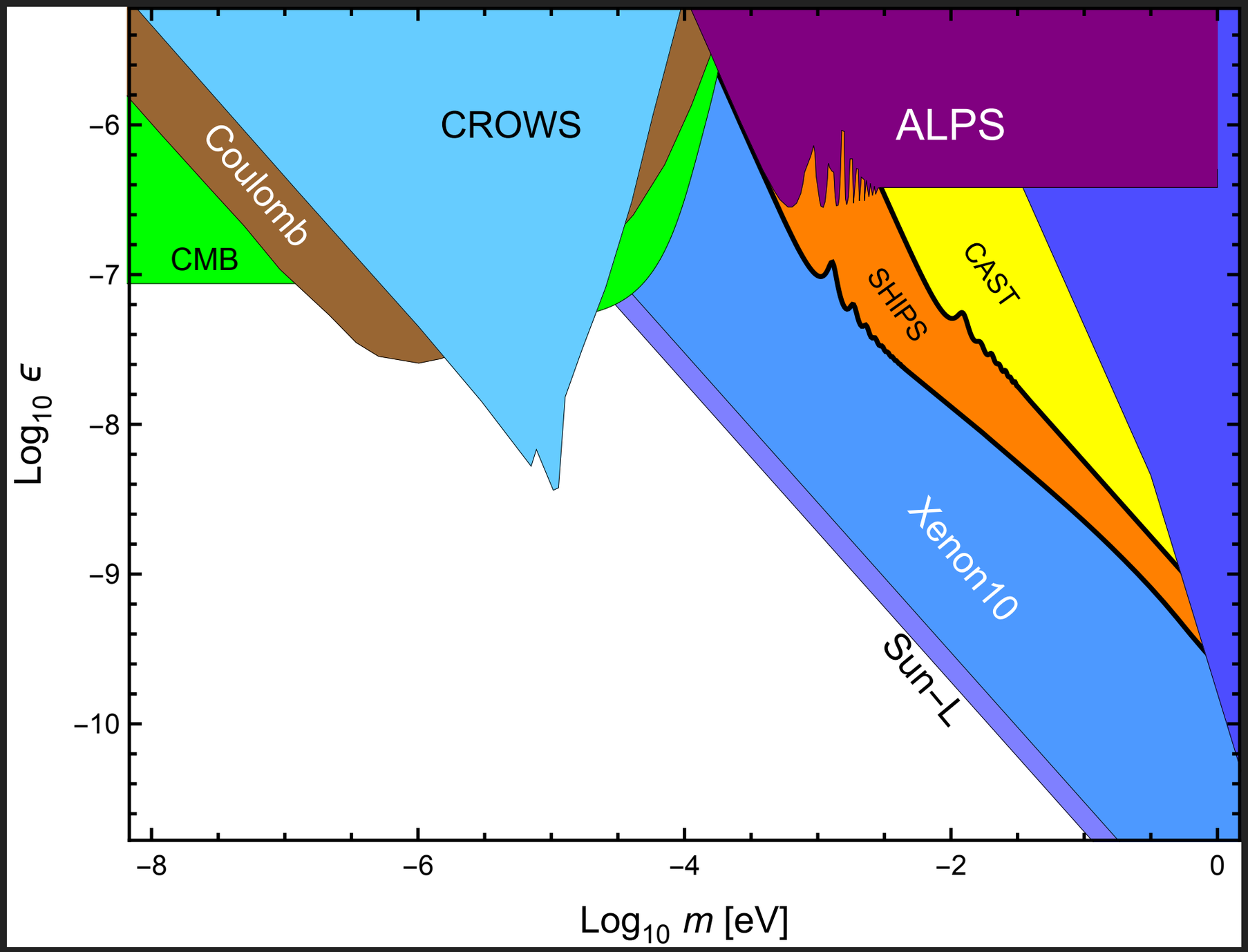
The orthogonal state $S^\mu = X^\mu + \epsilon A^\mu$

is sterile.

STATUS OF THE HIDDEN PHOTON SEARCH



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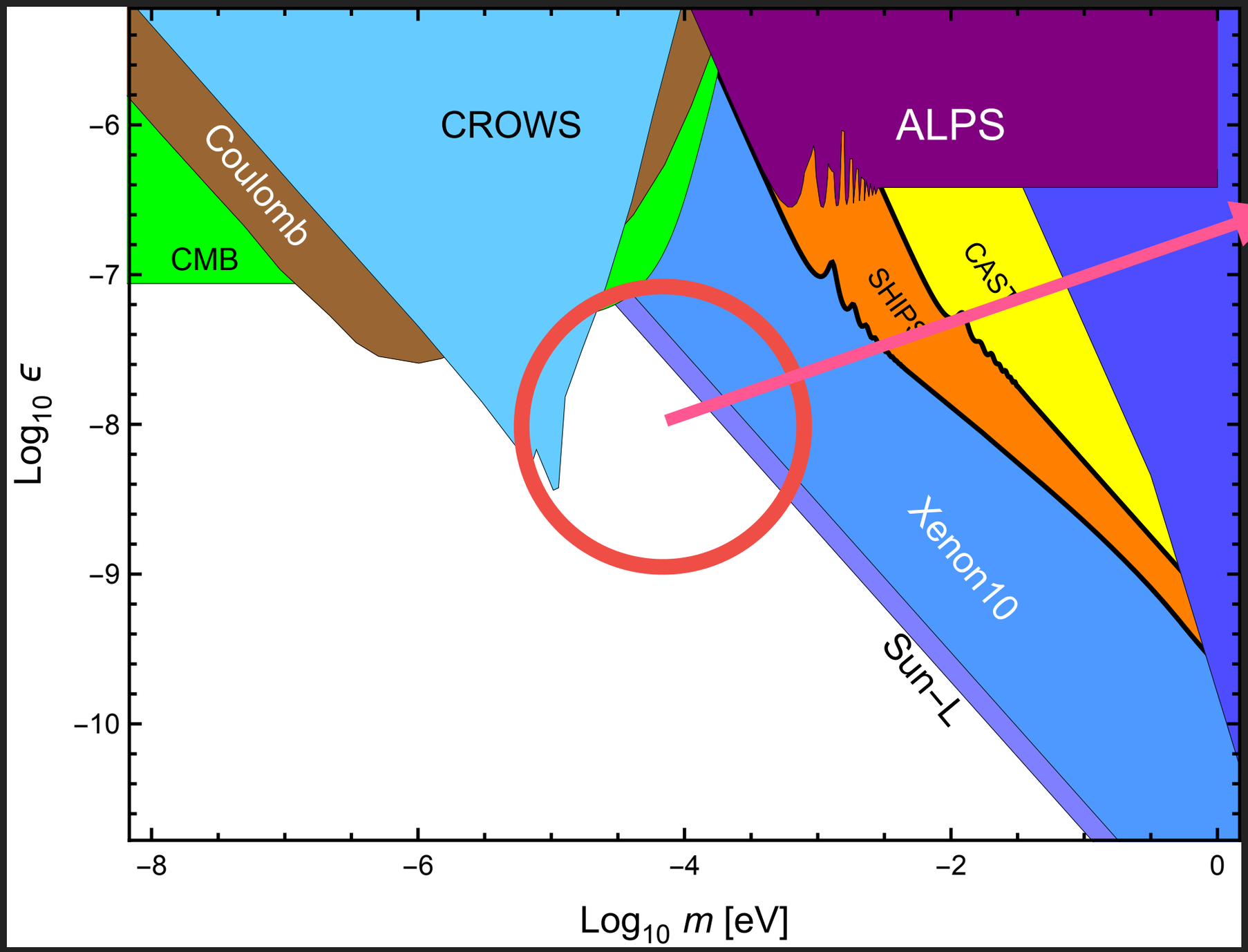

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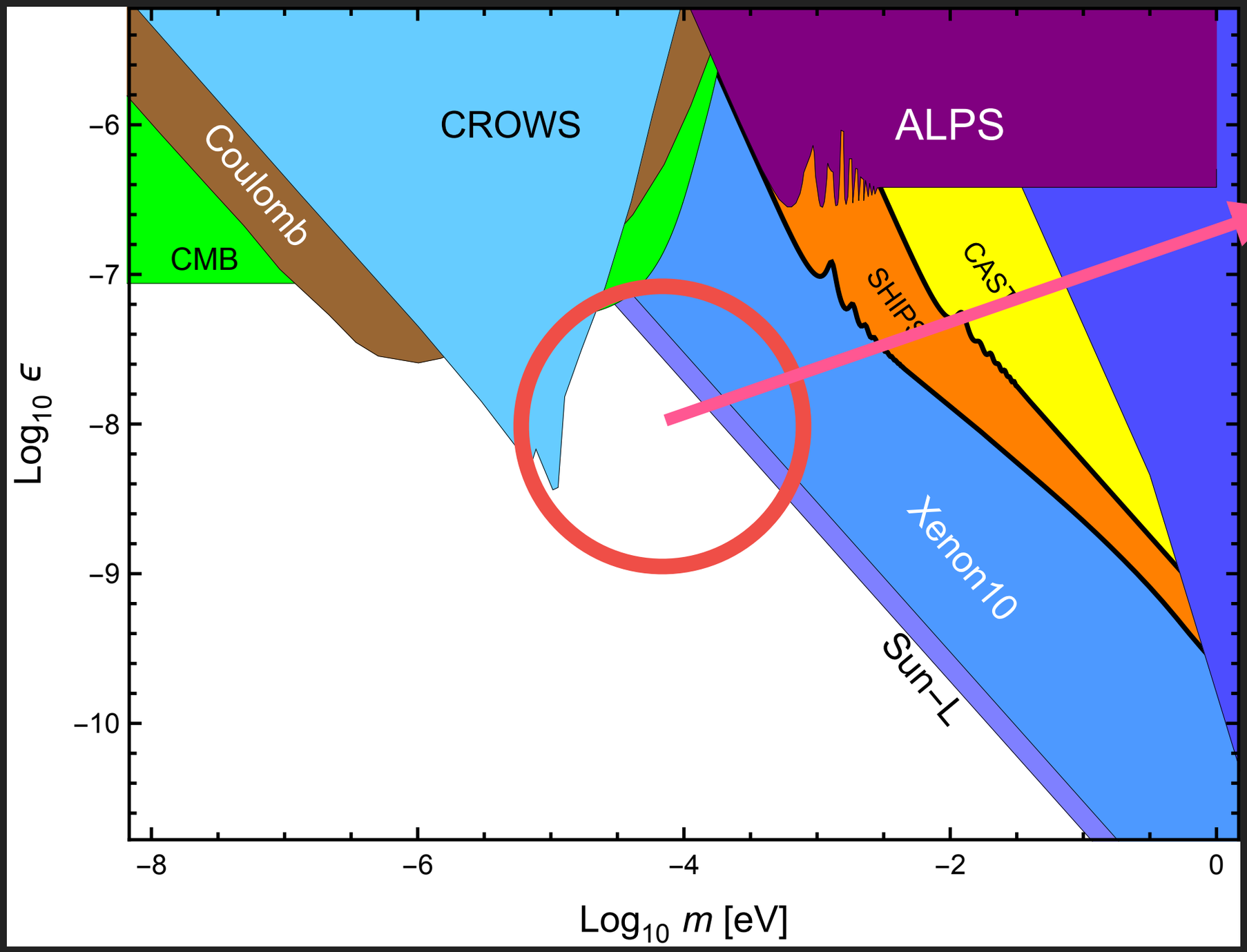

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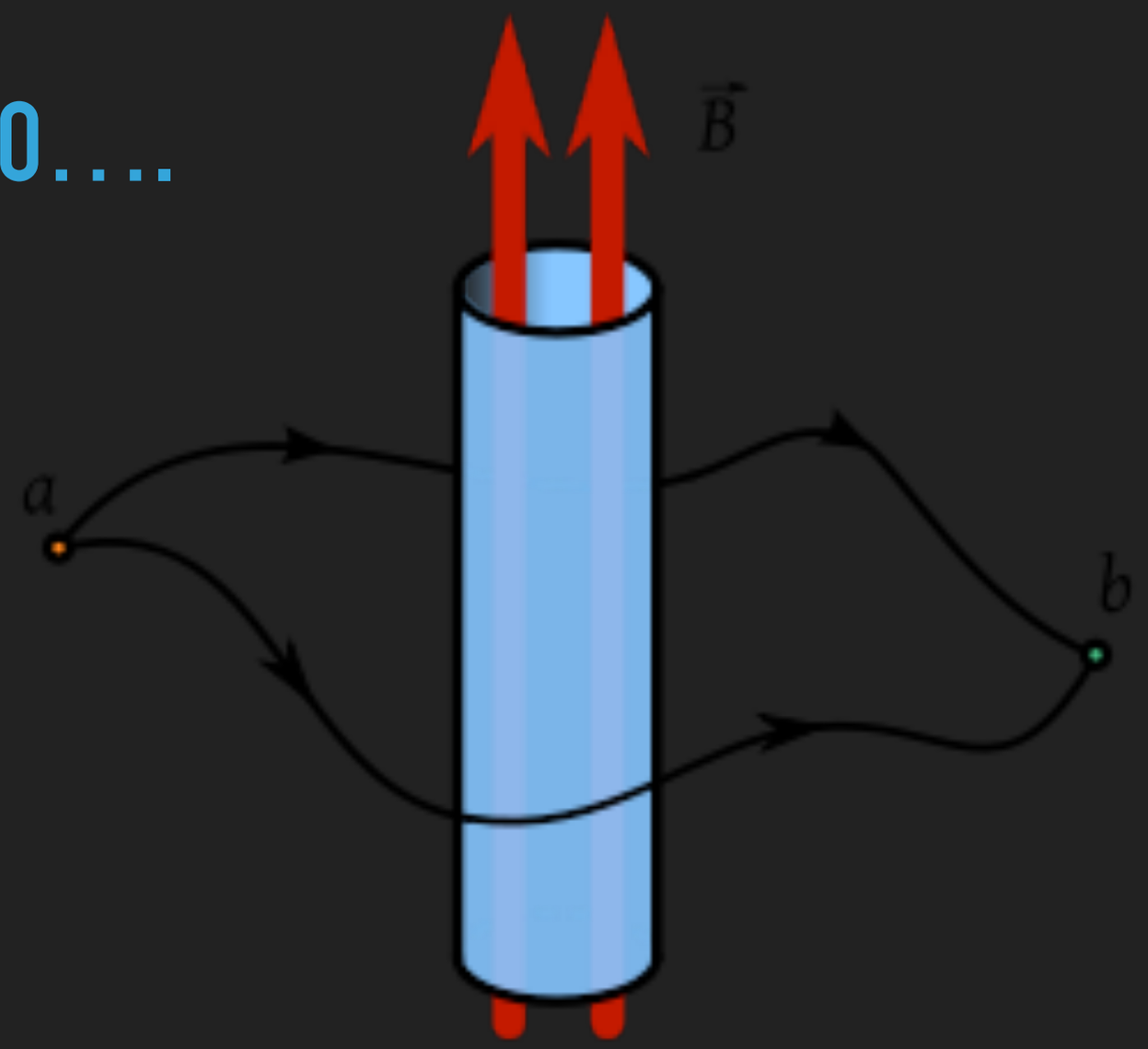
$r \sim 1/m_{\gamma'} \sim \mathrm{mm}$

ABOUT 2 YEARS AGO....



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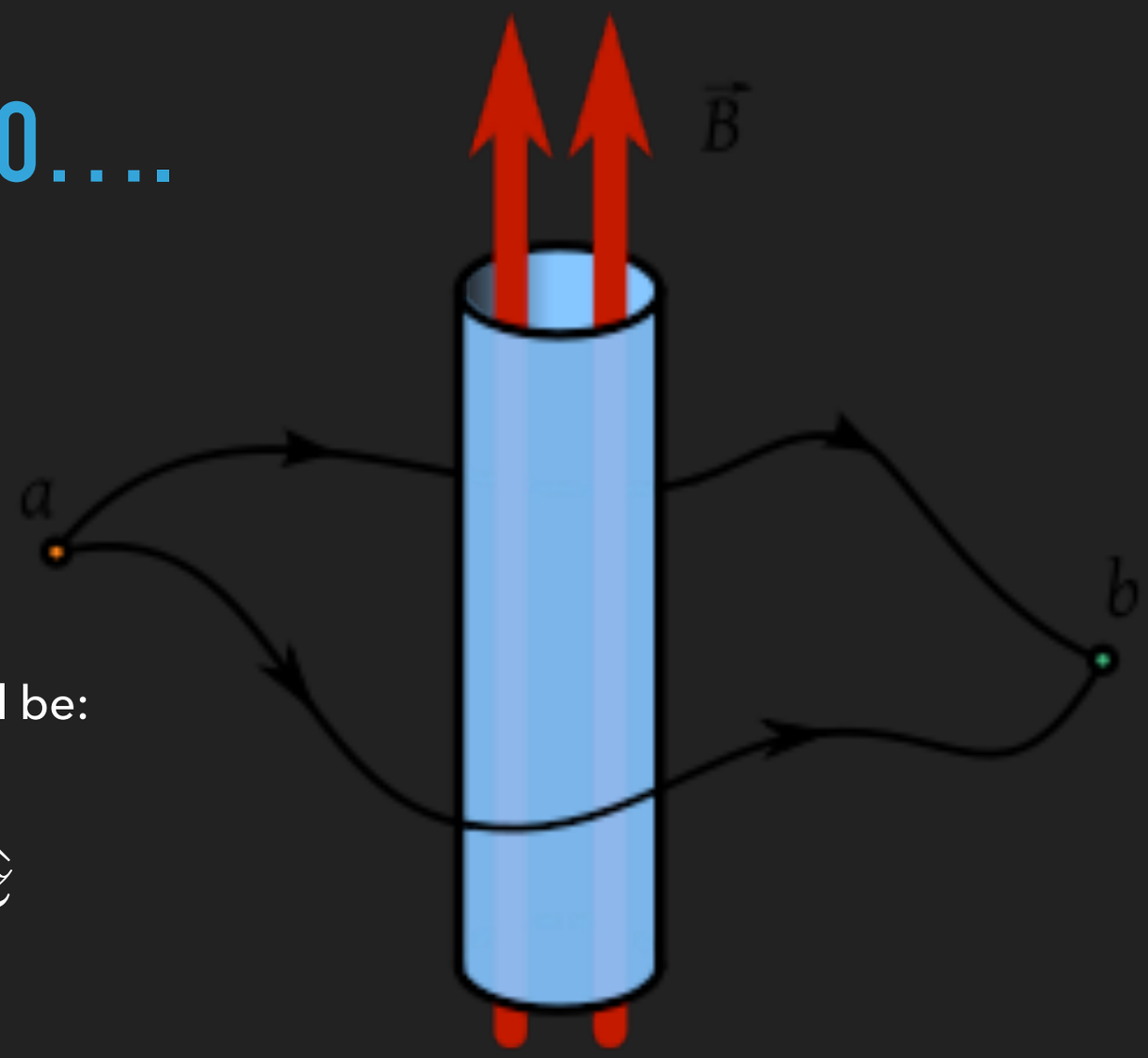

the produced magnetic field will be:

$$\vec{B} = B_0 \theta(R - r)\hat{z}$$

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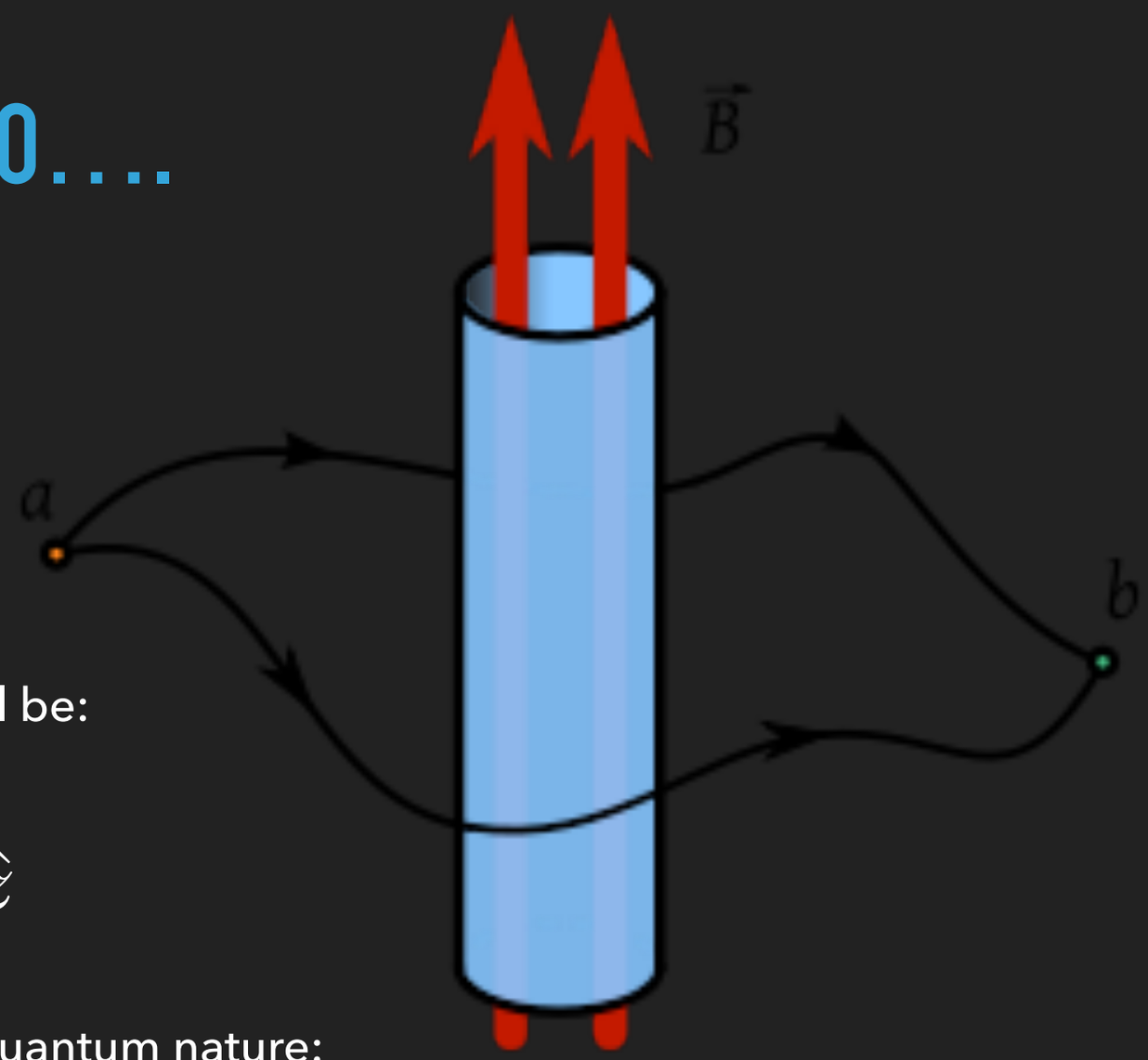

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$$\Delta\varphi = e \oint_C \vec{A} \cdot d\vec{\ell} = e\Phi_0$$

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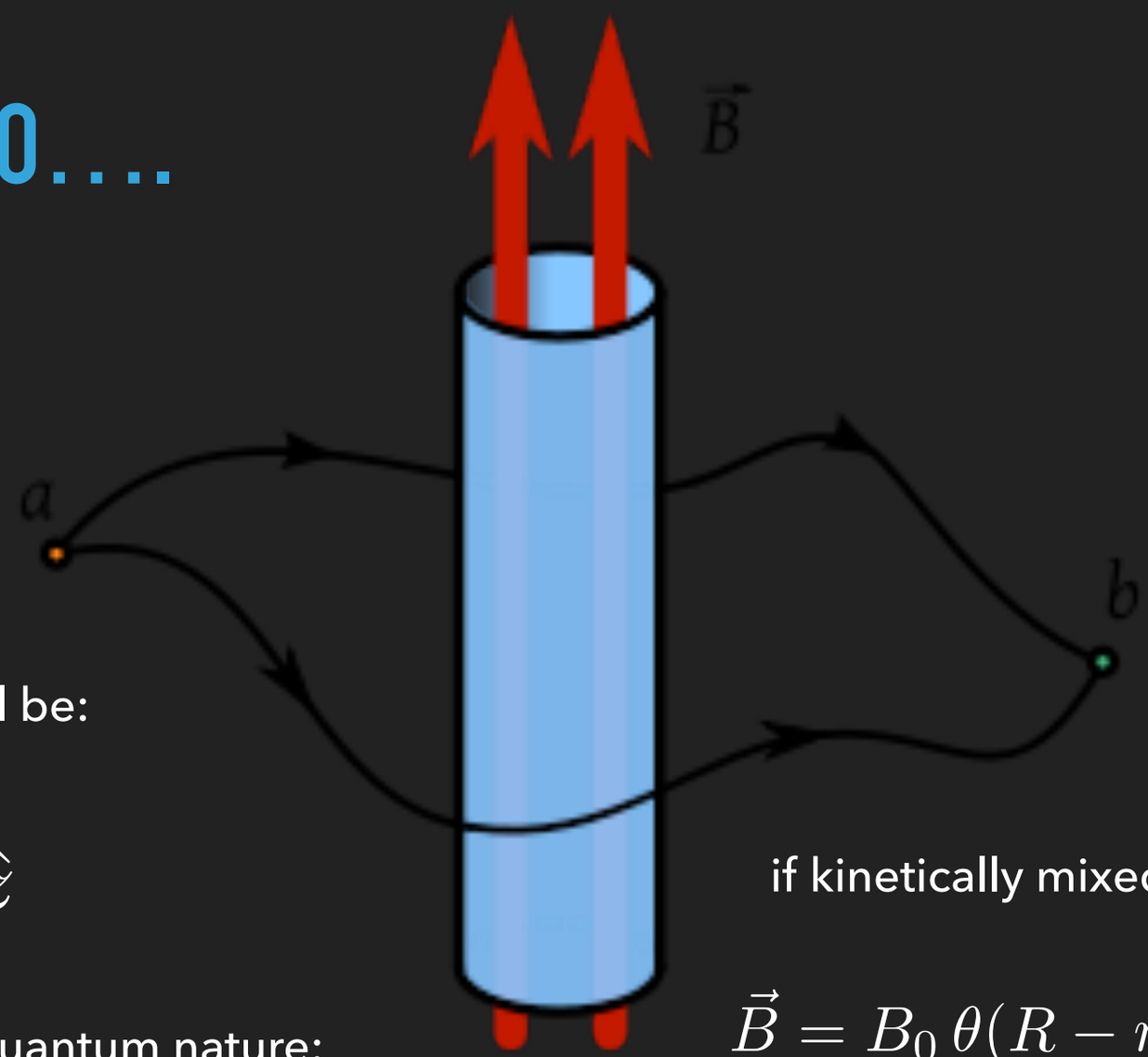

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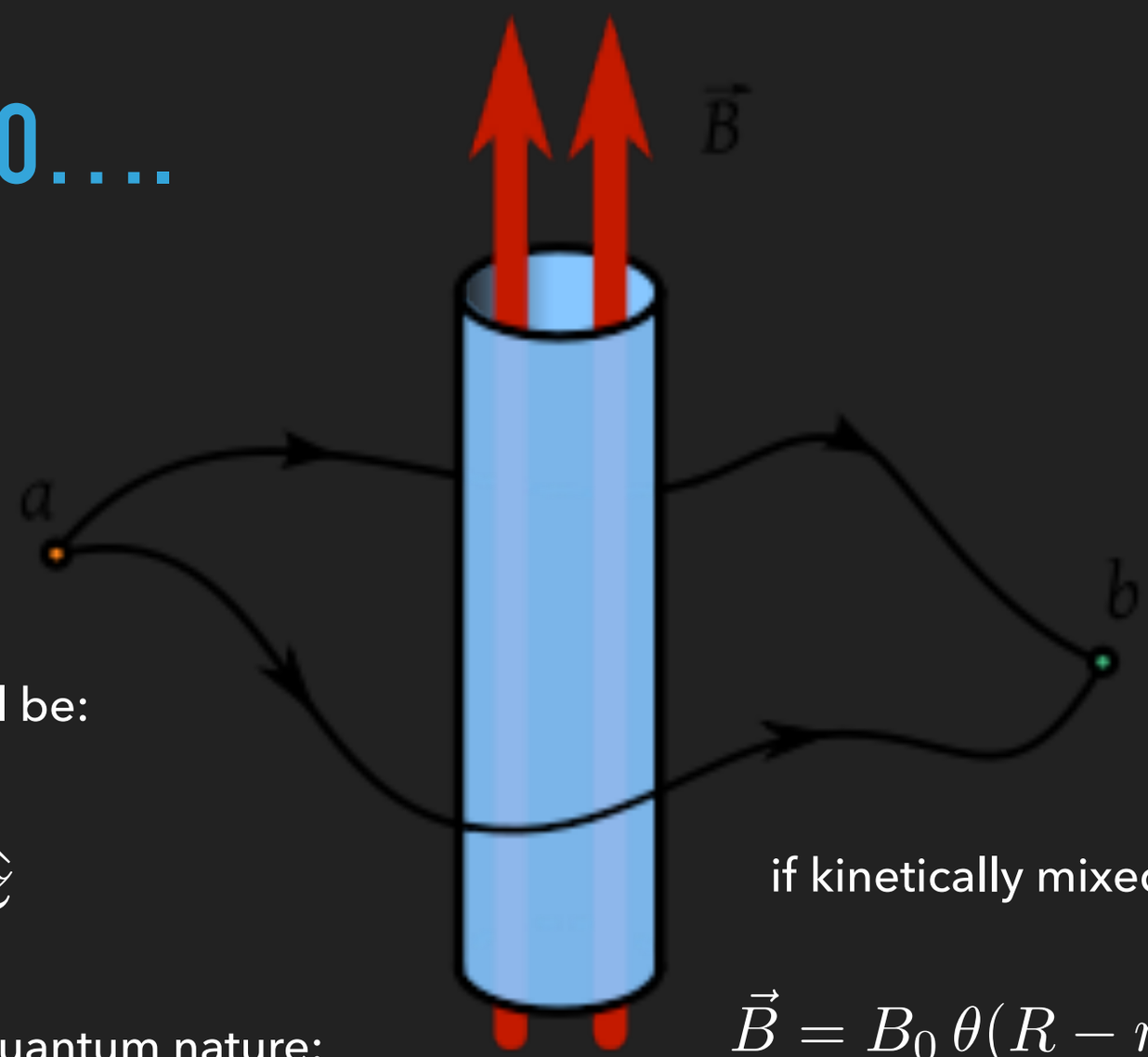

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LIMITED SENSITIVITY OF AN EXPERIMENT

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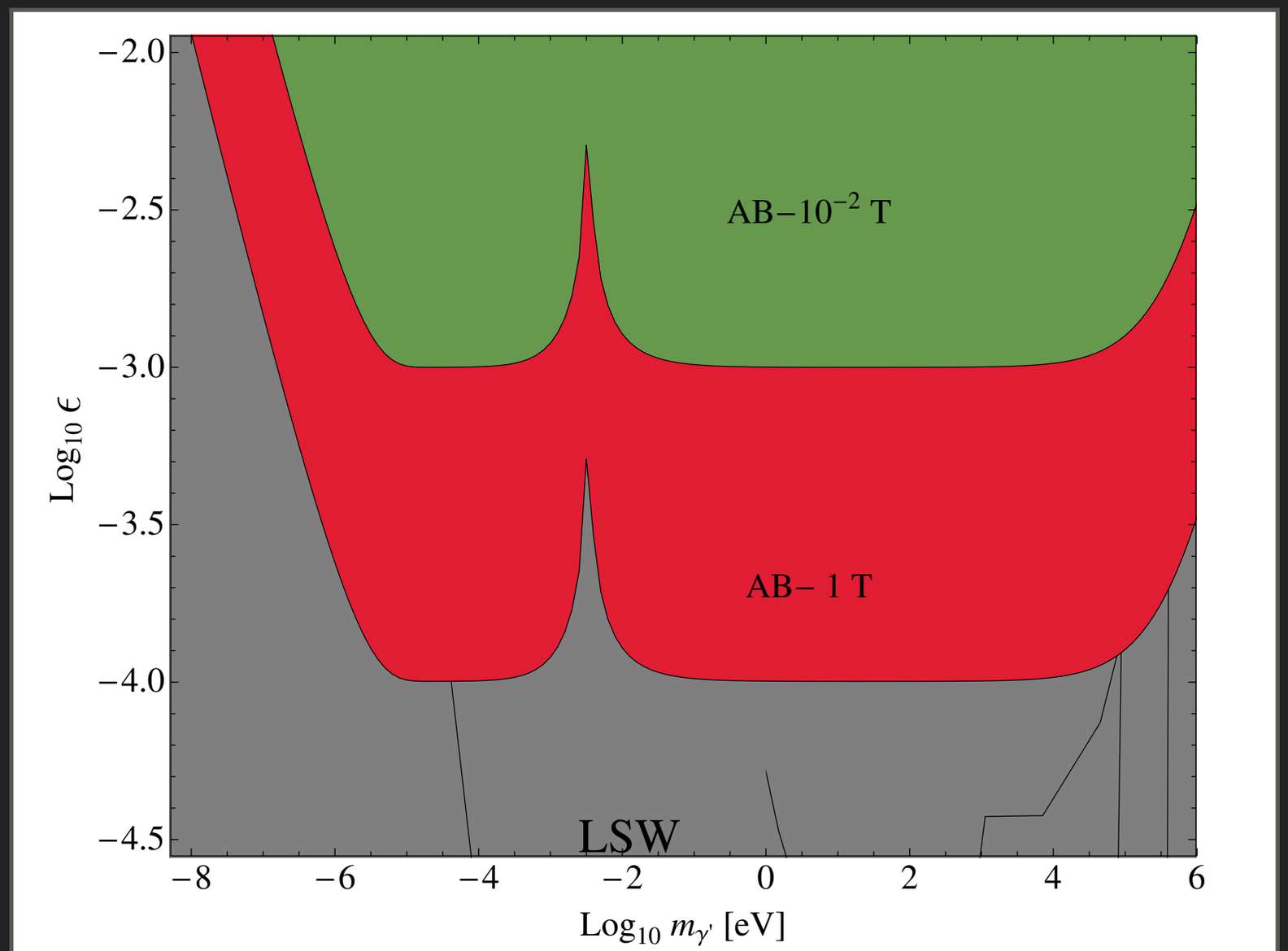
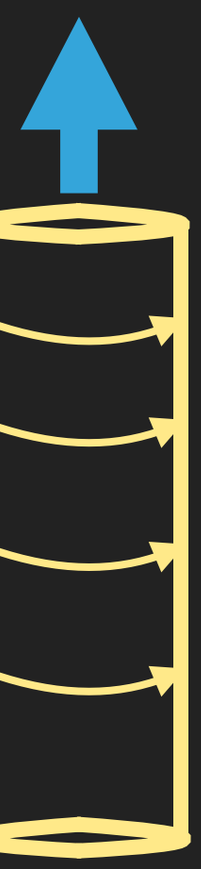


MAGNETIC FIELD LEAKS THROUGH THE SOLENOID

Light-shinning-through a superconductor



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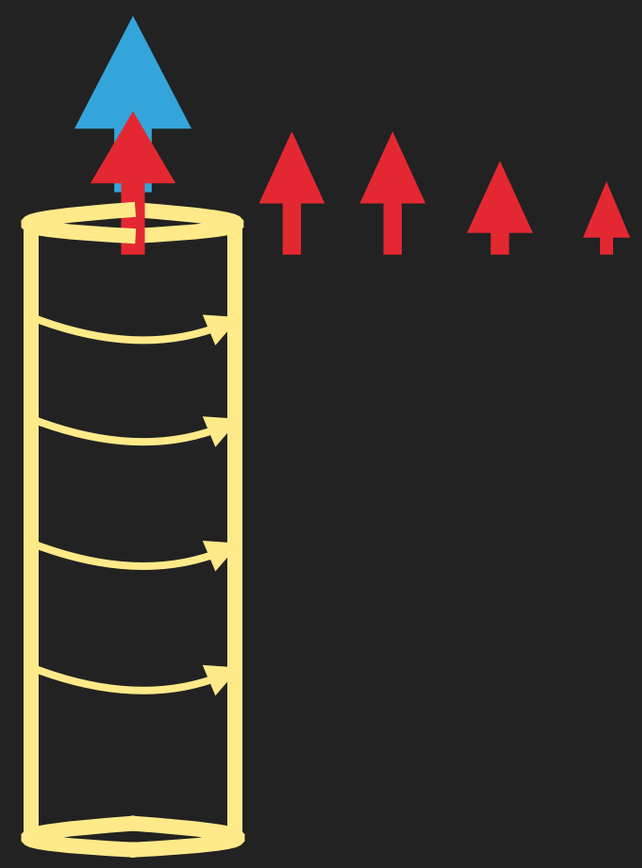

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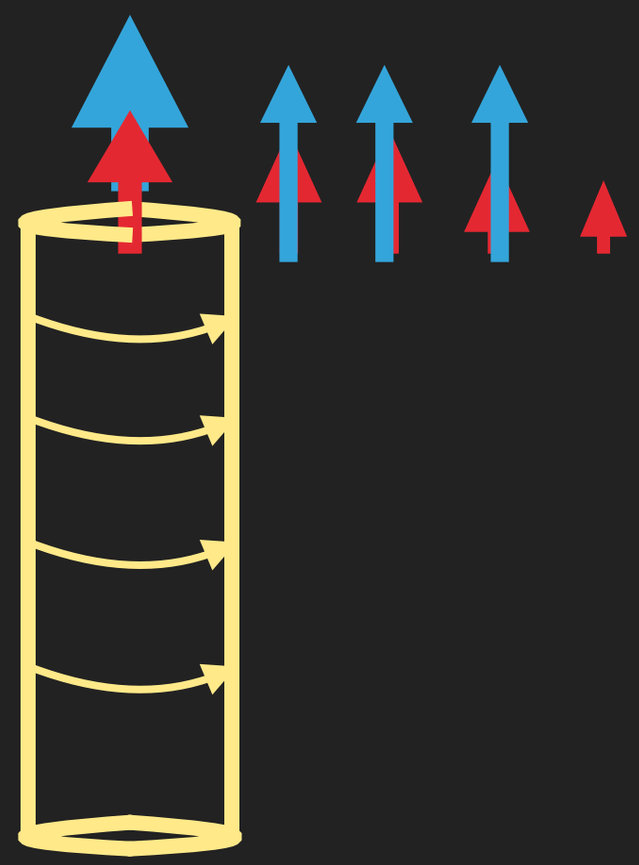

imperfections in the solenoid

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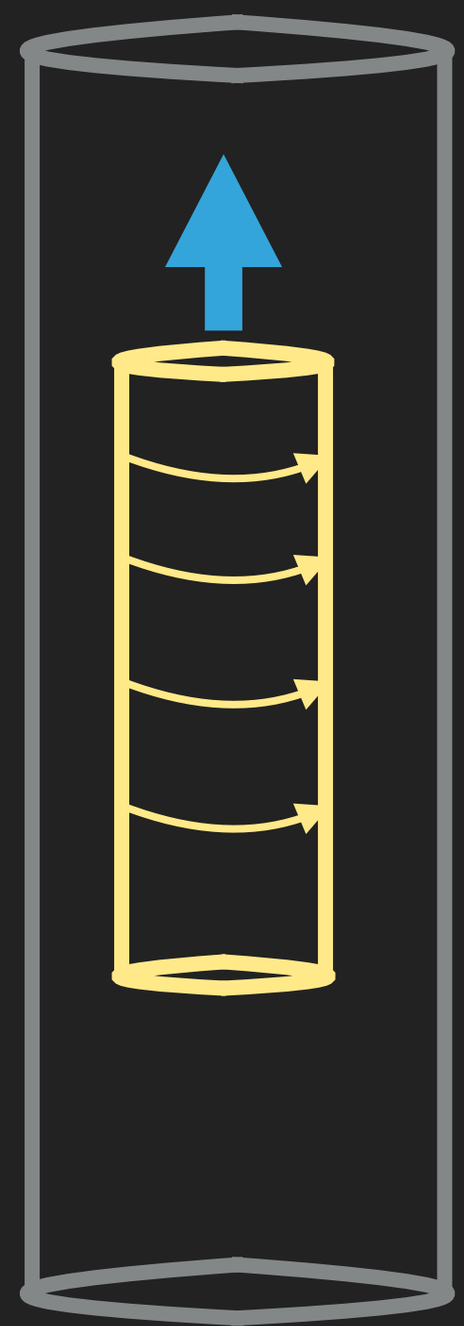

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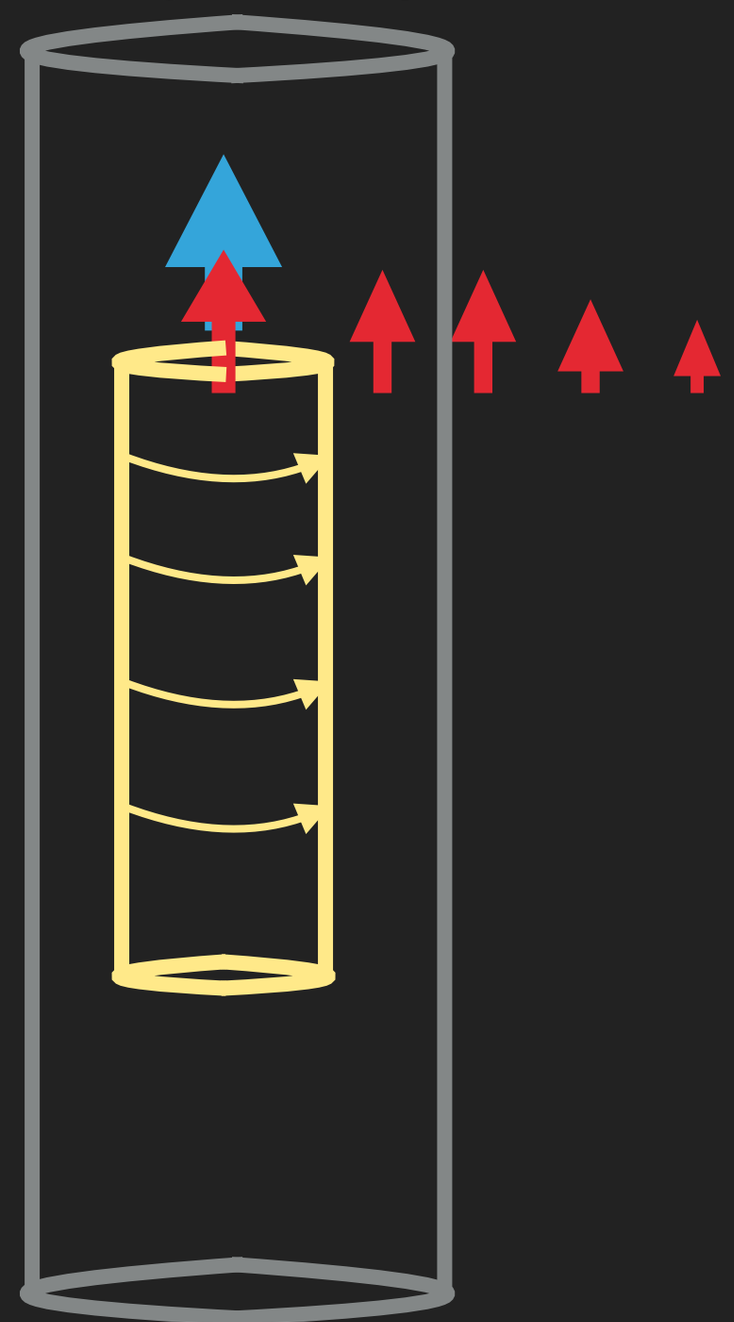

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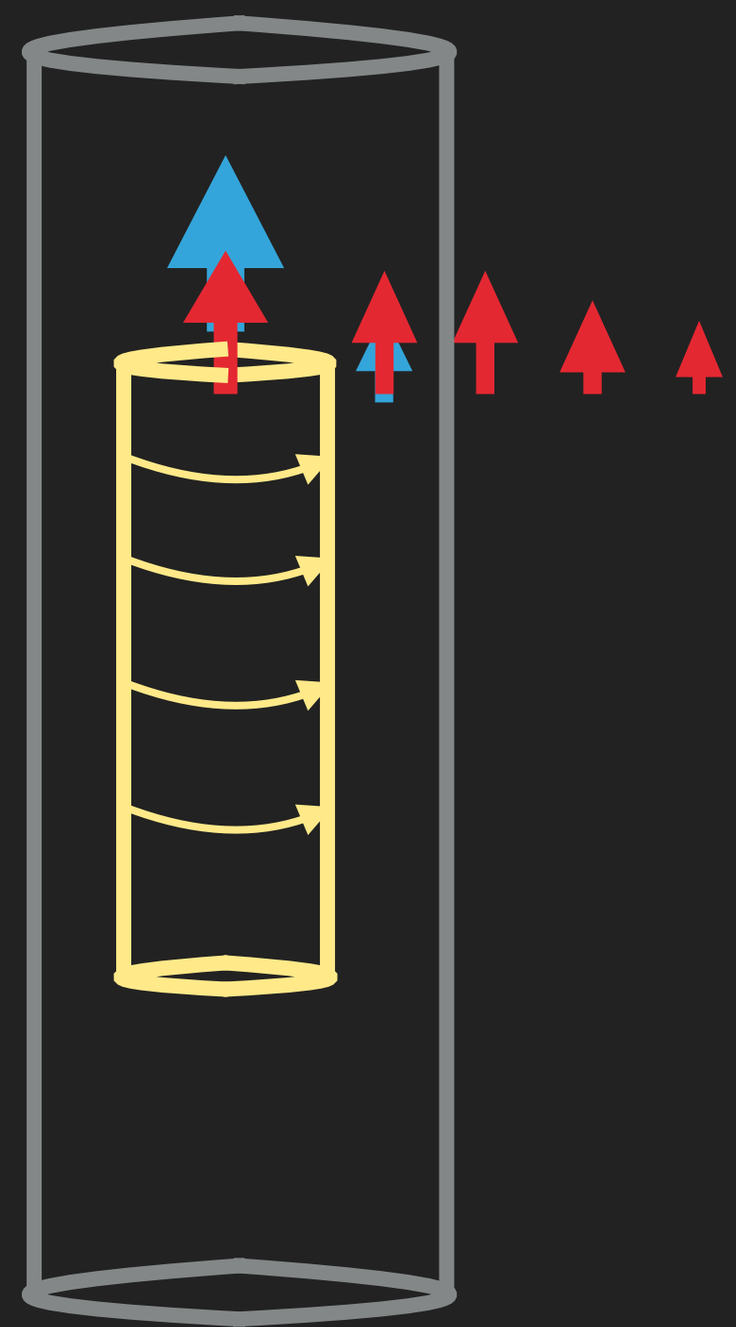
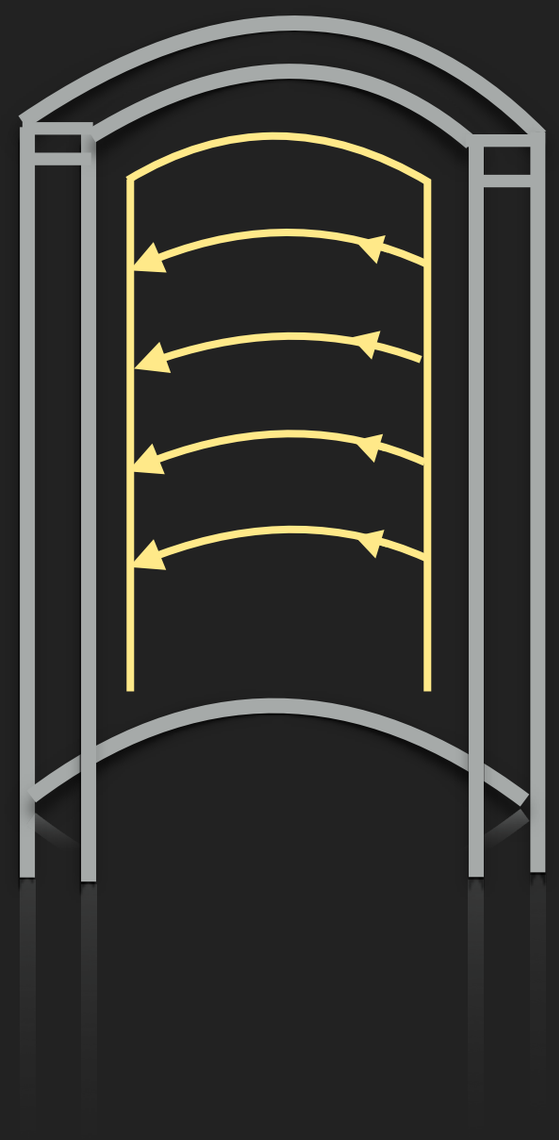


IN AND OUT SETUPS

Out setup:



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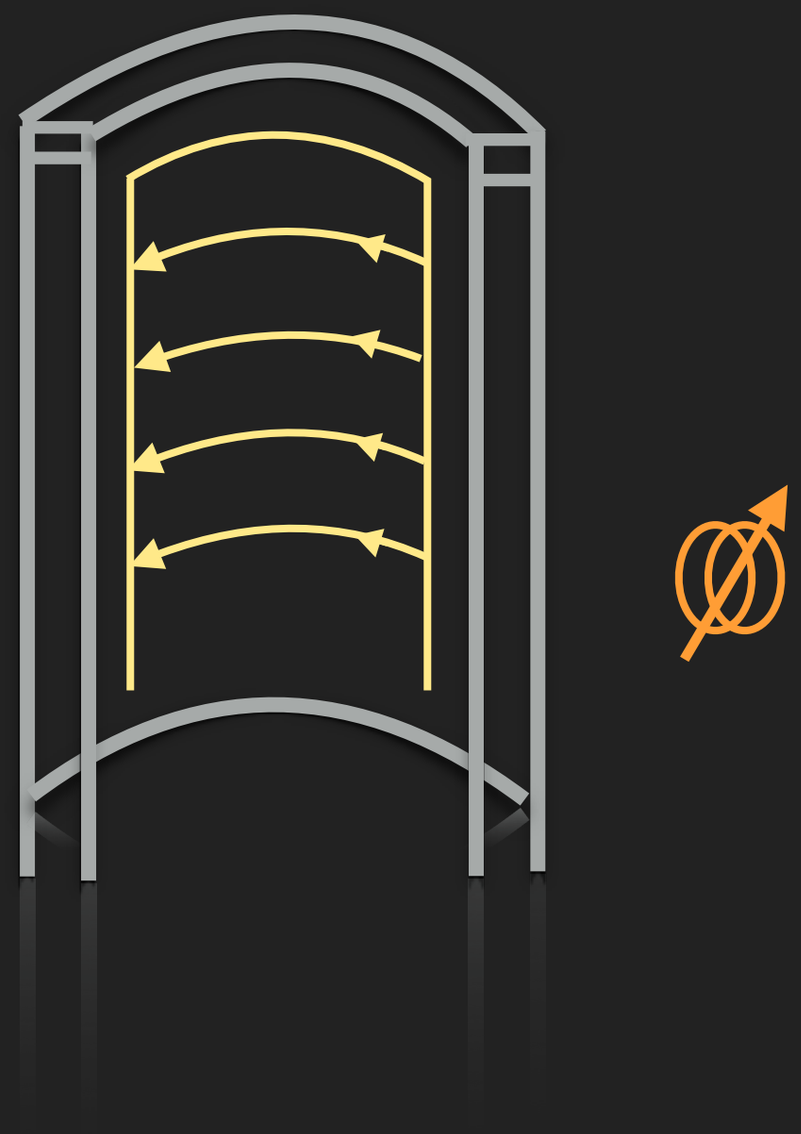

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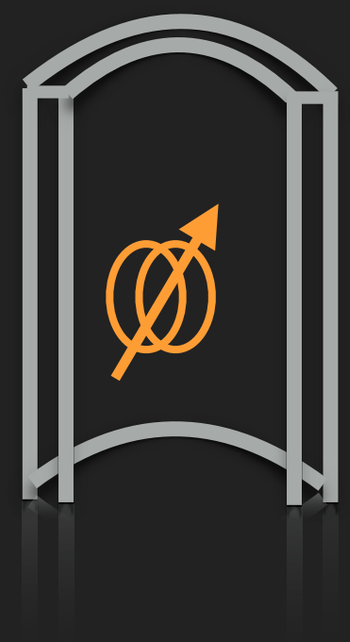

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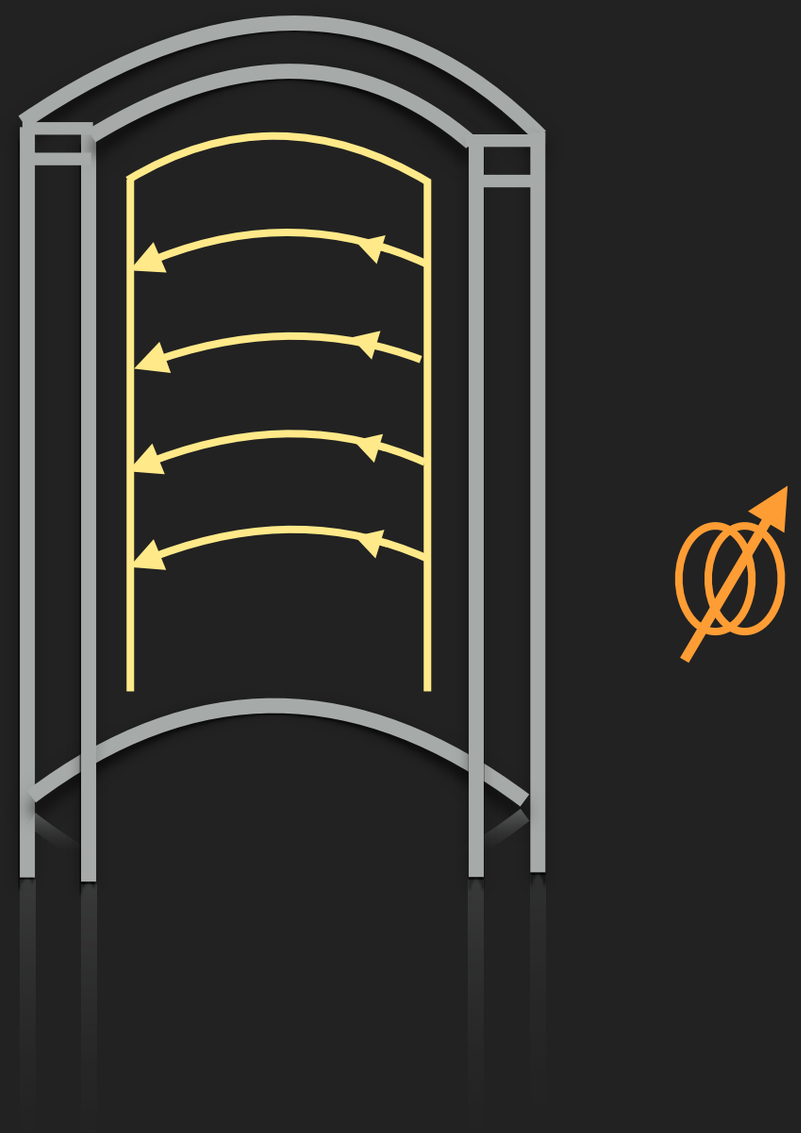

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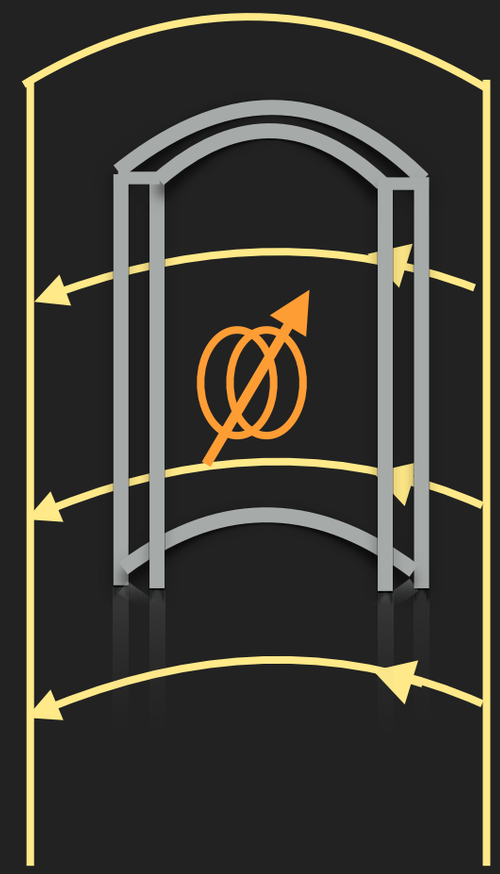
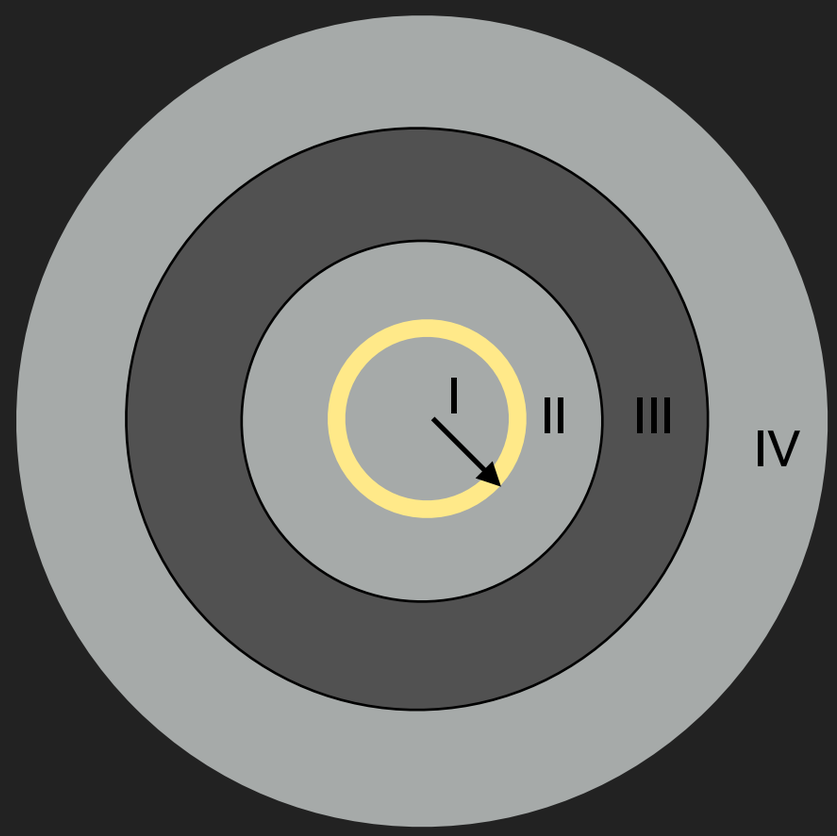


- In both setups we need to solve 2 Maxwell equations for each region:

$$\nabla^2 \vec{A} = -\vec{j} \quad ; \quad \left(\nabla^2 - m_{\gamma'}^2\right) \vec{X} = \epsilon \vec{j}$$



I) $\vec{j} = j_0\, \delta(R - r)\, \hat{\varphi}$

II) $\vec{j} = 0$

III) $\vec{j} = -M_L^2\, A_\varphi \hat{\varphi}$ $\qquad M_L \approx 1\,\mathrm{eV}$

IV) $\vec{j} = 0$

And then impose boundary conditions

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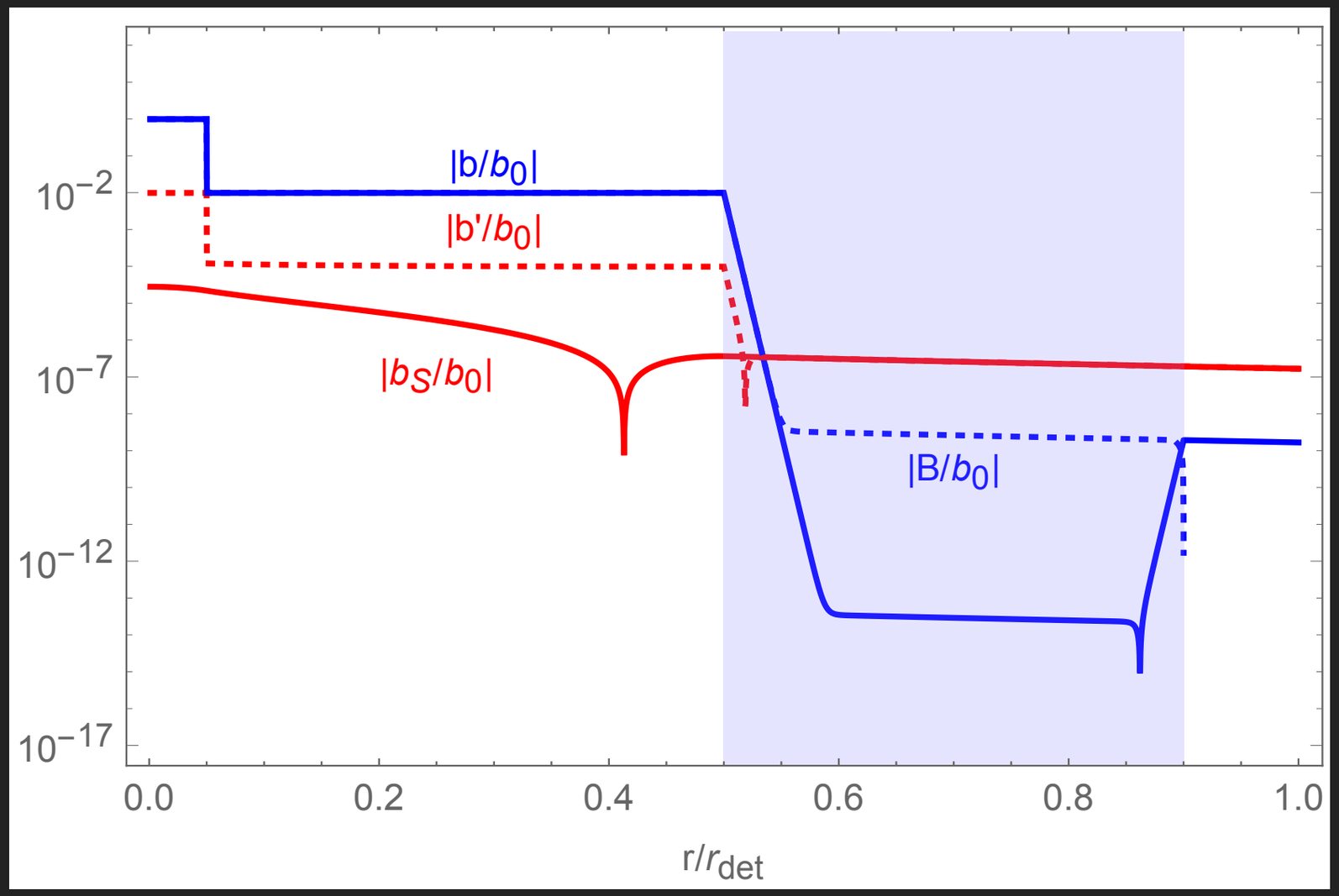

Hidden magnetic field interaction

Hidden sterile magnetic field

Magnetic field propagation

Magnetic field Interaction

$$\epsilon = 0.01 \qquad \frac{m_{\gamma'}}{M_L} = \frac{1}{300}$$

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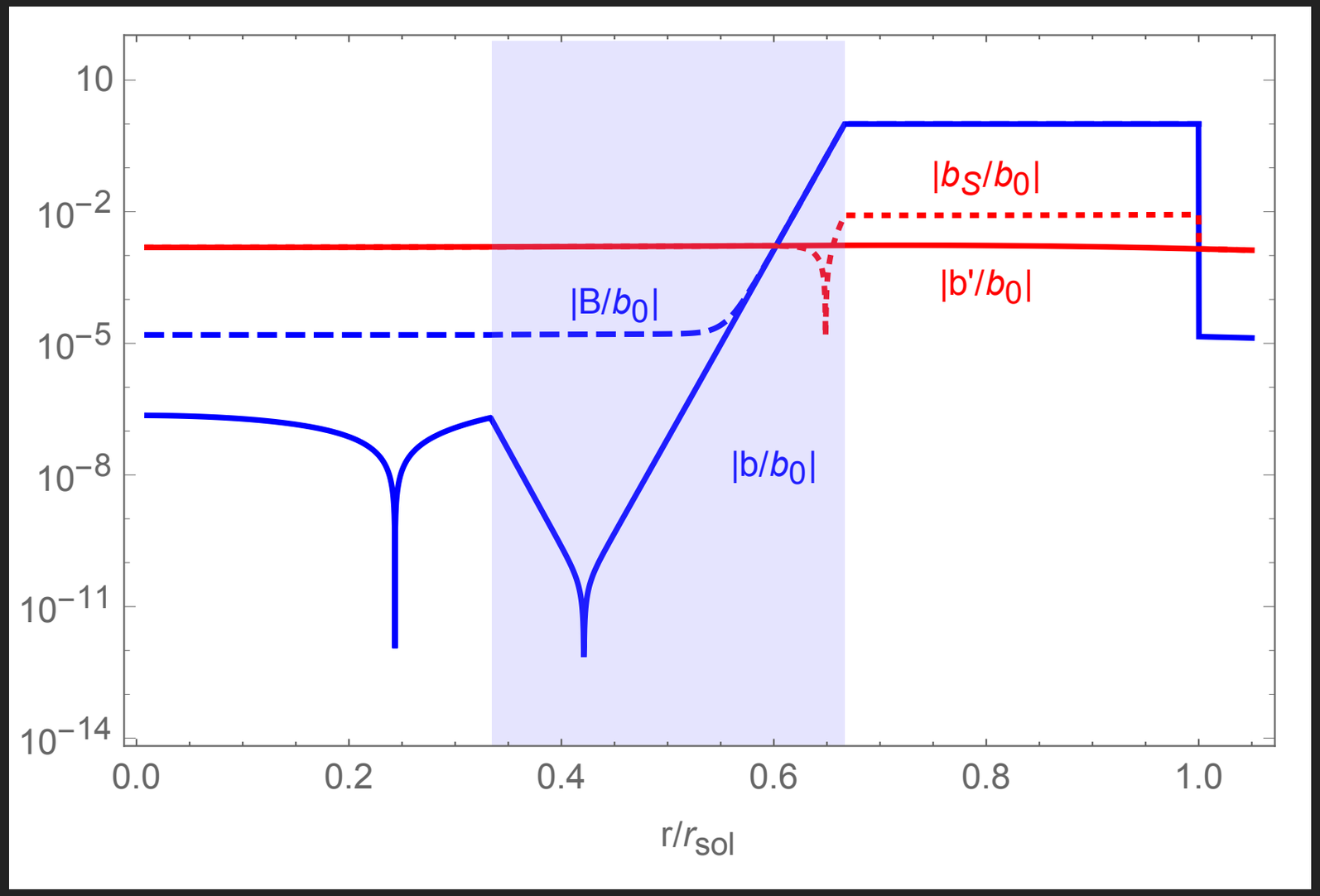

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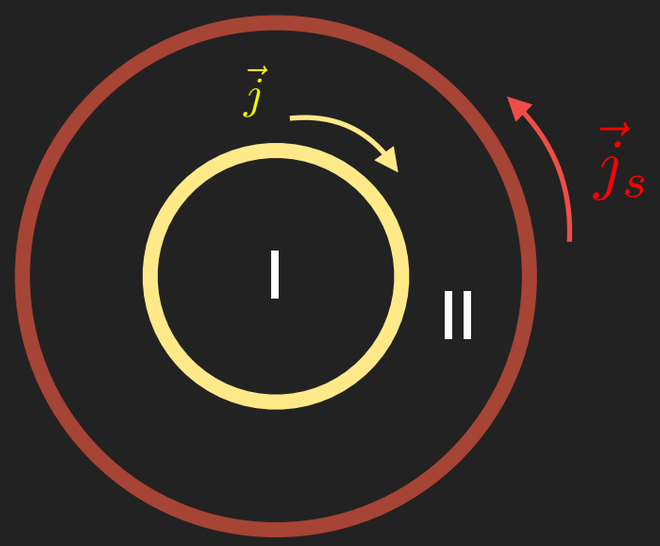
ANALYTICAL APROXIMATION

Cross check

FOR IDEAL SHIELDING, THE SC CURRENT IS ONLY SUPERFICIAL



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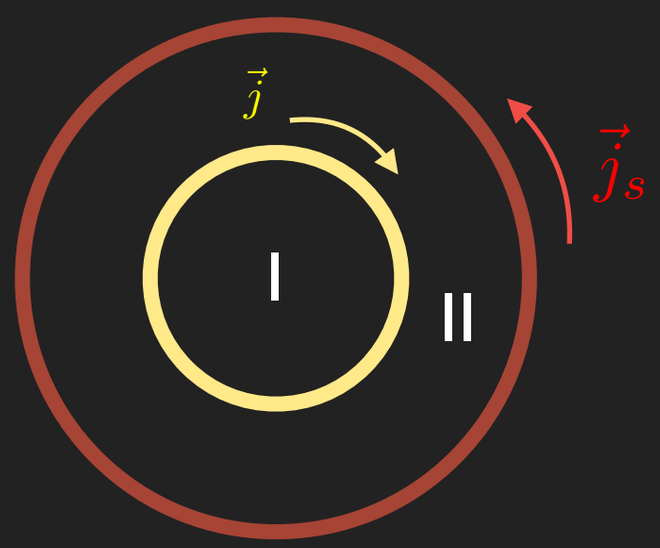

we obtain the superconducting current at leading order in ϵ

$$\int_I \vec{b} \cdot d\vec{a} + \int_{II} \vec{b} \cdot d\vec{a} = 0$$

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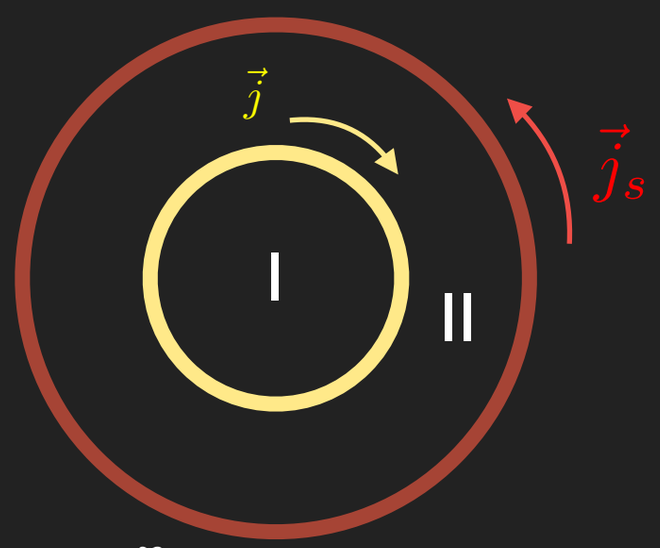

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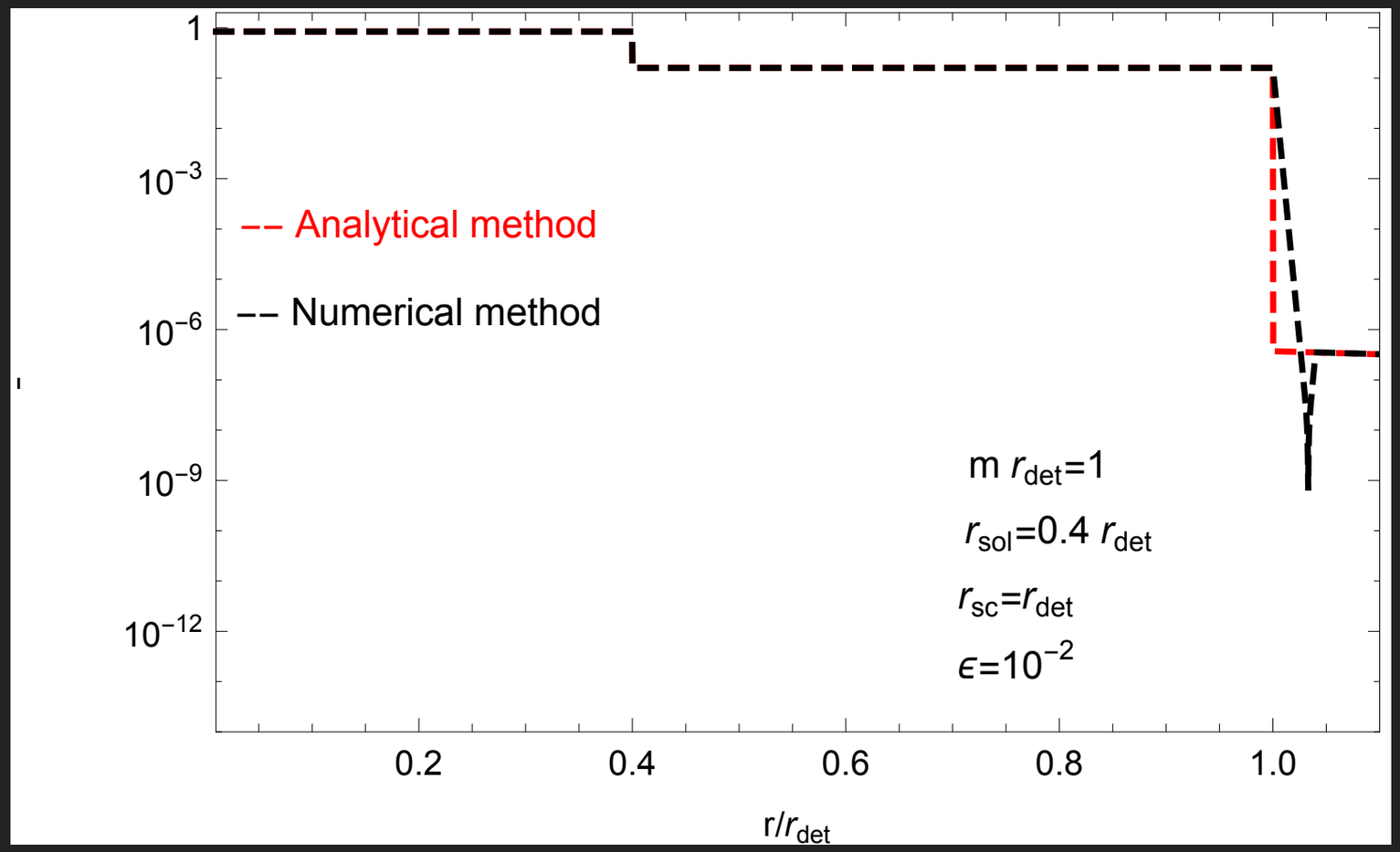
$$\frac{b_{\rm OUT}}{b_0} = \epsilon^2 \frac{r_{sol}}{r_{sc}} m_{\gamma'} \left(r_{sol} I_1(m_{\gamma'} r_{sc}) - r_{sc} I_1(m_{\gamma'} r_{sol}) \right) K_0(m_{\gamma'} r)$$

$$\frac{b_{\rm IN}}{b_0} = \frac{\epsilon^2}{r_{sc}} \left(r_{sc} m_{\gamma'} I_0(m_{\gamma'} r) - 2 I_1(m_{\gamma'} r_{sc}) \right) \left(r_{sol} K_1(m_{\gamma'} r_{sol}) - r_{sc} K_1(m_{\gamma'} r_{sc}) \right)$$

COMPARISON NUMERICAL – ANALYTICAL



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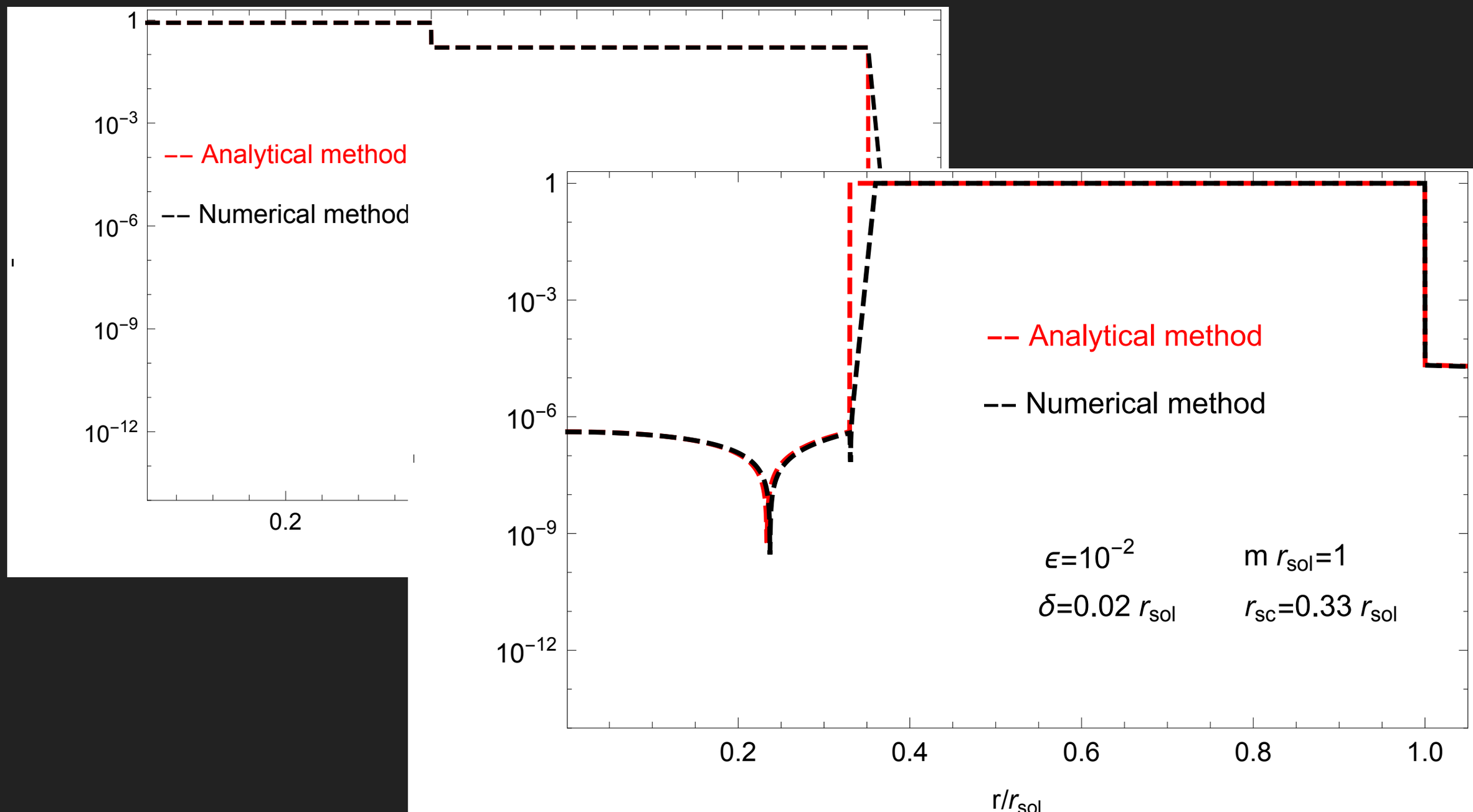

FINDING THE RIGHT GEOMETRY FOR 10^(-4) EV MASSES

We fix the solenoid radius $r_{sol} = 2\,\mathrm{cm}$

and optimize the position of the superconducting shielding using the analytical formula for HP masses $m_{\gamma'} = 10^{-4}\,\mathrm{ev}$

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WE ASSUME MAGNETOMETER SENSITIVITY $10^{-18}\,\mathrm{T}$

* co-magnetometers (PRL, 103 (2009), PRL 111 (2013)
* ferromagnetic needle PRL 116 (2016)

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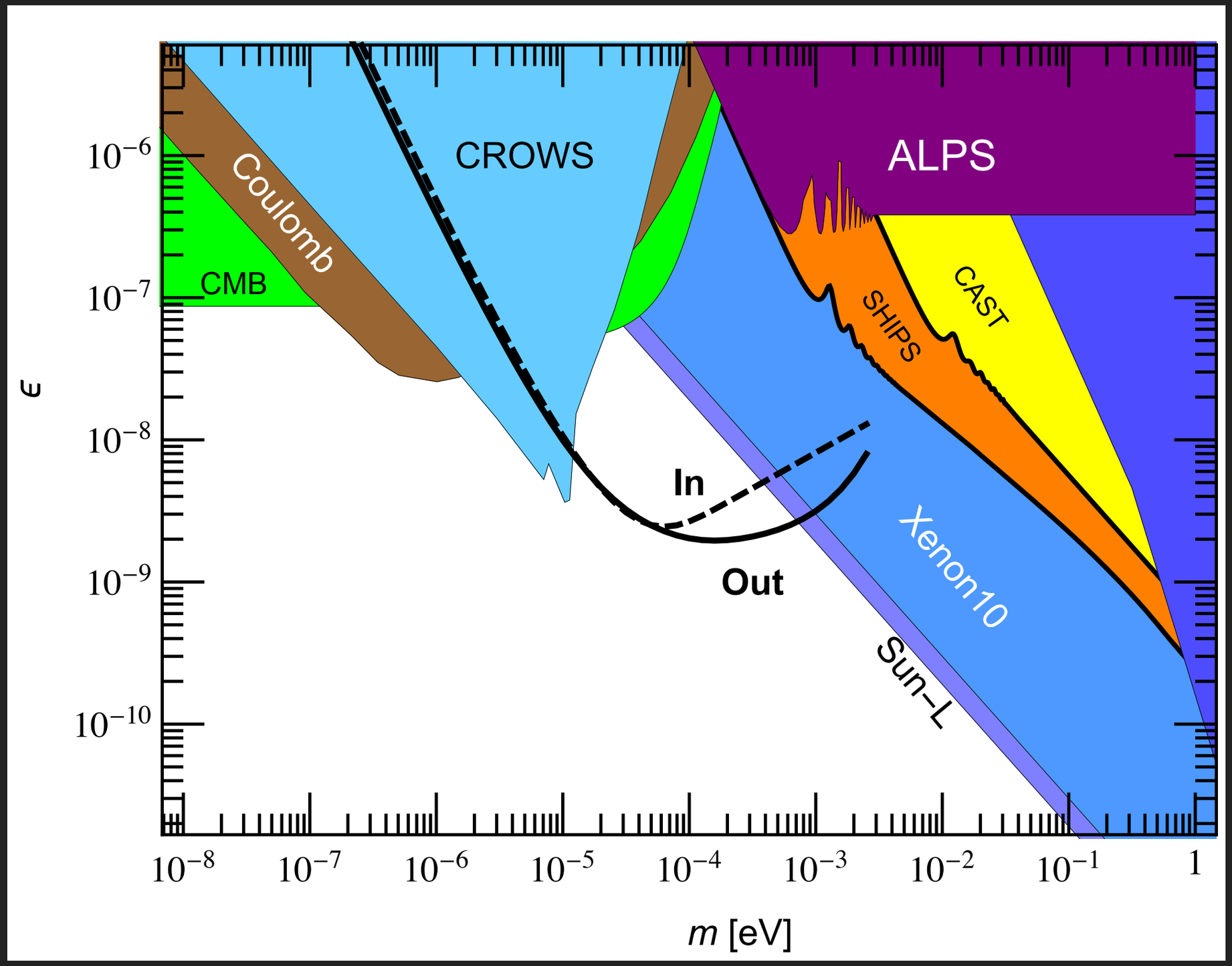

CONCLUSIONS

- Many experiments searching for WISP dark matter use intense magnets and superconducting shielding and highly sensitive magnetometers (CASPER, ARIADNE).

Thank you!

ACKNOWLEDGMENTS:

- FONDECYT GRANT 116150
- DICYT USACH