PION PROPERTIES UNDER STRONG MAGNETIC FIELDS

MAXIMO COPPOLA

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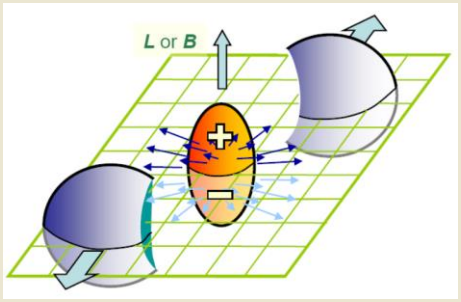
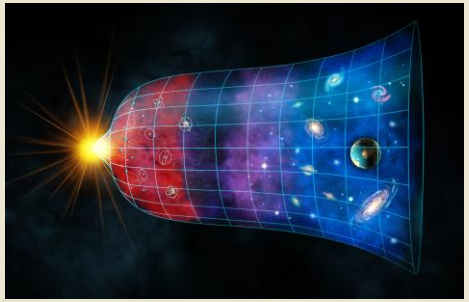
MAGNETIC PION-TO-VACUUM AMPLITUDES

Strong magnetic fields on QCD matter:

Magnetars



Heavy Ion Collisions



Early Universe

In $\vec{B} = B\hat{z}$, new axial and vector pion decay constants appear (similar for π^0)

Fayazbakhsh+ 1306.2098

Bali+ 1805.10971

Coppola+ 1810.08110

$$H^{-}_{\mu,L} = H^{-}_{\mu,V} - H^{-}_{\mu,A} = \langle 0|\, \bar{\psi}_u\, \gamma^\mu (1-\gamma_5)\, \psi_d |\pi^-\rangle$$

<u>Four</u> independent form factors arise when hadronizing quark currents (restricted by $\mathcal{C},\mathcal{P},\mathcal{T}$: $f_{\pi^0}^{(A2)} = 0$)

$$H^{\pm}_{\mu,L} = \left[\epsilon^{\mu\nu\alpha\beta} F_{\nu\alpha} D_\beta \frac{f_{\pi^\pm}^{(V)}}{2B} - D^\mu f_{\pi^\pm}^{(A1)} + iF^{\mu\nu} D_\nu \frac{f_{\pi^\pm}^{(A2)}}{B} - F^{\mu\nu} F_{\nu\alpha} D^\alpha \frac{f_{\pi^\pm}^{(A3)}}{B^2}\right] \sqrt{2}\, \langle 0|\Phi_{\pi^\pm}|\pi^\pm\rangle$$

PION MASSES AND DECAY CONSTANTS

Coppola+ 1802.08041

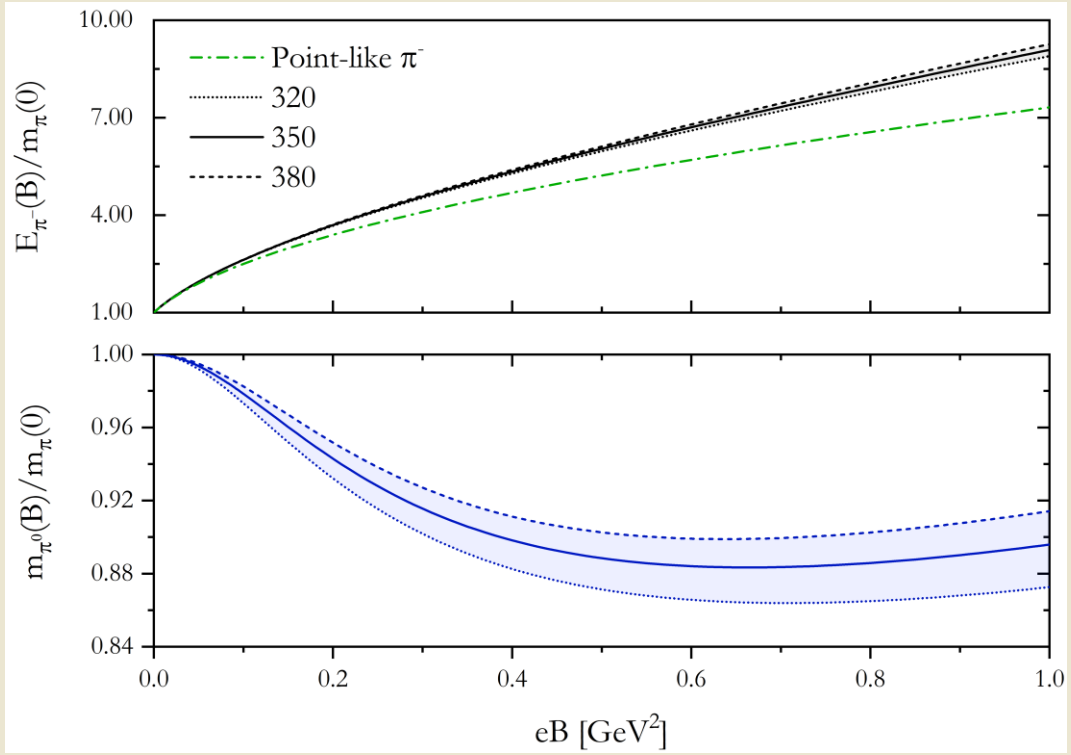
Coppola+ 1907.05840

Nambu-Jona—Lasinio model: $\mathcal{L}_{\rm NJL} = \bar{\psi}\left(-i\not{D} + m_0\right)\psi - G\left[(\bar{\psi}\,\psi)^2 + (\bar{\psi}\,i\gamma_5\vec{\tau}\,\psi)\right]$

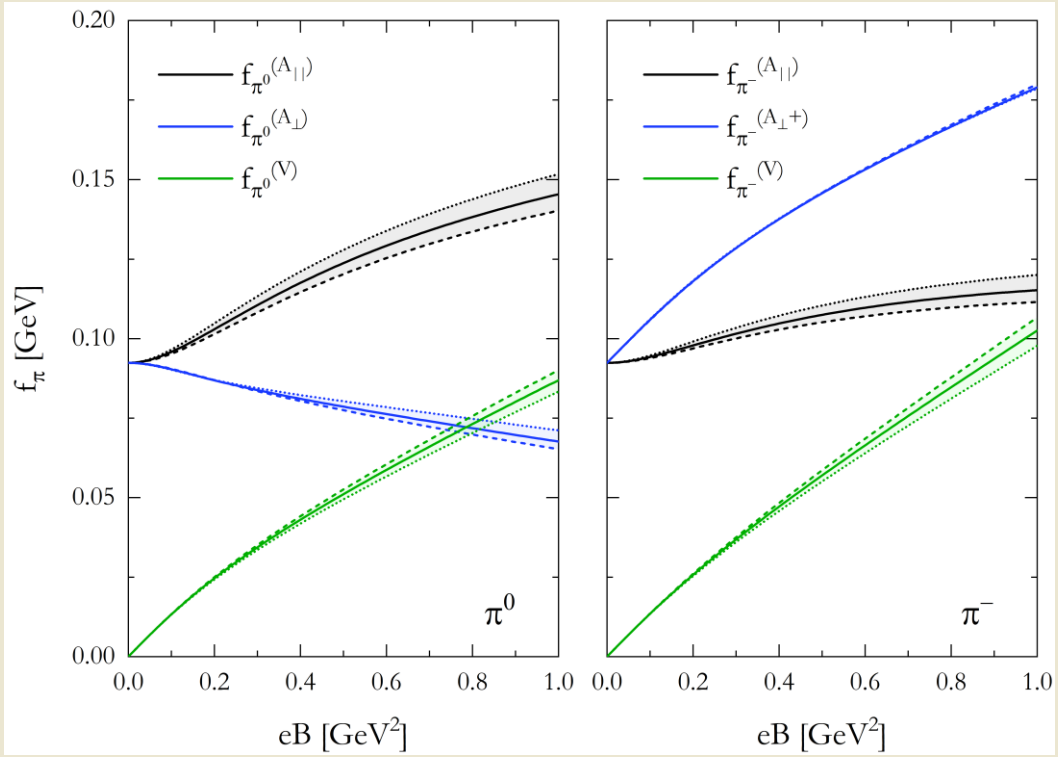
Reg: MFIR-3D

Three parametrizations

Pion masses



Pion decay constants



- π^0 is diagonal in Fourier basis $E_{\pi^0} = \sqrt{m_{\pi^0}^2 + u_{\pi^0}^2 q_\perp^2 + q_3^2}$
- π^- is diagonal in **Ritus** basis $E_{\pi^-} = \sqrt{m_{\pi^-}^2 + (2n+1)eB + q_3^2}$

Some convenient definitions:

$$f_{\pi^0}^{(A_\parallel)} \equiv f_{\pi^0}^{(A1)}\,, \quad f_{\pi^0}^{(A_\perp)} \equiv f_{\pi^0}^{(A1)} - f_{\pi^0}^{(A3)}\,, \quad f_{\pi^-}^{(A_\perp\pm)} \equiv f_{\pi^-}^{(A1)} \pm f_{\pi^-}^{(A2)} - f_{\pi^-}^{(A3)}$$

CHARGED PION LEPTONIC DECAY

Coppola+ 1810.08110

Coppola+ 1910.10814

Coppola+ 1908.10765

We obtain a model-independent expression for the $\pi^- \to l^- \bar{\nu}_l$ decay width (using different gauges)

$$\Gamma_l^-(B)\Big|_{\substack{n_{\max}=0 \\ m_l=0}} = \frac{G_F^2 \cos^2\theta_c}{\pi} \frac{B_e^2}{E_{\pi^-}} \left[1-\left(1+\frac{E_{\pi^-}^2}{2B_e}\right) e^{-E_{\pi^-}^2/(2B_e)}\right] \left| f_{\pi^-}^{(V)} - f_{\pi^-}^{(A2)} + f_{\pi^-}^{(A3)} \right|^2$$

For $B > m_{\pi^-}^2 - m_l^2$ and $B \gg m_l^2$, $n = 0$ and $m_l \sim 0$ approximately

- Decay strengthened by B (1000 times at $eB = 1\ \mathrm{GeV}^2$).
- **No helicity-supression in $\vec{B}$!**
- Ratio Γ_e/Γ_μ dramatically enhanced by B ($\sim$0.5 at $eB = 1\ \mathrm{GeV}^2$).
- Anisotropic angular distribution of outgoing $\bar{\nu}_l$ for large B.