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7th International Conference on New Frontiers in Physics – Kolymbari 2018

General Treatment of the Monopole Production Cross Sections by Drell-Yan and Photon Fusion for Three Spin Models

coming soon to journals near you...

Study of Monopole Production Mechanisms via photon fusion and/or Drell-Yan
processes: a comparative novel study

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Monopole Field Theories

The Dirac Monopole: this is the truest attempt at creating the dual sister to the point like electron. The monopole enters the field theory as a matter field in a U(1) gauge theory.

$$\mathcal{L}(\mathcal{A}_\mu, \phi_{(i, \mu)})$$



$$(e, m_e, S = \frac{1}{2})$$

Standard QED



$$(g(\beta), M, S = ?)$$

Monopole Field
Theory by Analogy



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Variations on QED

$S = 0$: Scalar Quantum Electrodynamics

Monopole as a scalar field obeying a
U(1) gauged **Klein Gordon equation**

$S = \frac{1}{2}$: Dirac Quantum Electrodynamics

Monopole as a spinor field obeying a
U(1) gauged **Dirac equation**

$S = 1$: Lee-Yang Field Theory

Monopole as a vector field obeying a U(1)
gauged **Klein Gordon equation** with a gauge
fixing parameter and ghosts

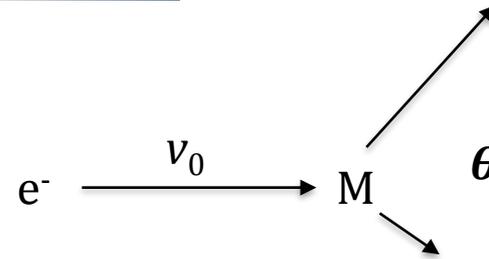


Boost Dependent Coupling

Rutherford (classical) scattering:

$$\frac{d\sigma}{d\Omega} = \left(\frac{eg}{c\mu v_0}\right)^2 \sum_{\chi} \frac{1}{4\sin^4(\frac{\chi}{2})} \left| \frac{\sin(\chi) d\chi}{\sin(\theta) d\theta} \right|$$

$\theta \ll 1$  $\frac{d\sigma}{d\Omega} = \left(\frac{eg}{2\mu v_0 c}\right)^2 \frac{1}{(\theta/2)^4}$



v_0 is the **relative velocity** of the electron with respect to the monopole (or equivalently vice versa)

Suggest some effective coupling
of the type

$$\frac{g}{c} \rightarrow \frac{e}{v_0}$$

when monopoles interact with
SM matter fields.



Heads Up

All analytical forms hold in both the boost-dependent and –independent cases

$$\beta = \left(1 - \frac{4M^2}{s}\right)$$

Whenever you see $g(\beta)$, I mean $g(\beta) = g$ in the independent case, and $g(\beta) = g\beta$ in the dependent case.

Alternatively,

$$g^2(\beta) = g^2 \beta^{2\delta}, \quad \delta = 0, 1$$

$$\alpha_e = \frac{e^2}{4\pi} \mapsto \alpha_g(\beta) \equiv \frac{g^2(\beta)}{4\pi}$$



Lee-Yang Field Theory

GAUGE FIXING PARAMETER
(covariance, renormalizability)

KINETIC AND MASS TERMS

$$\mathcal{L} = -\xi(\partial_\mu W^{\dagger\mu})(\partial_\nu W^\nu) - \frac{1}{2}(\partial_\mu \mathcal{A}_\nu)(\partial^\nu \mathcal{A}_\mu) - \frac{1}{2}G_{\mu\nu}^\dagger G^{\mu\nu} - M^2 W_\mu^\dagger W^\mu + ig\mathcal{A}_\mu W_\nu^\dagger \widetilde{W}^{\mu\nu} \\ - ig\widetilde{W}_{\mu\nu}^\dagger \mathcal{A}^\mu W^\nu - g^2 \mathcal{A}_\mu \mathcal{A}^\mu |W|^2 + g^2 (\mathcal{A}_\mu W^\mu)(W_\nu^\dagger \mathcal{A}^\nu) - ig\kappa F^{\mu\nu} W_\mu^\dagger W_\nu.$$

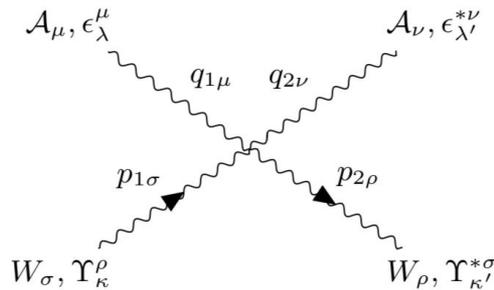
COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON

MAGNETIC MOMENT TERM
(Highly divergent, introduces
ghosts (negative metric), extra
graphs)

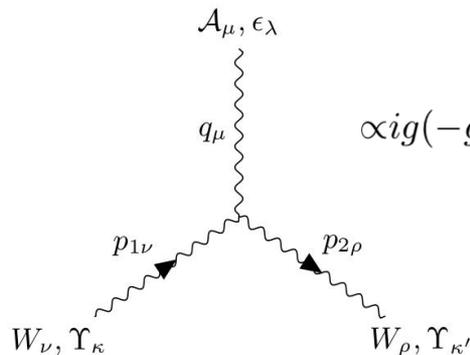
Lee-Yang Field Theory

$$\mathcal{L} = -\xi(\partial_\mu W^{\dagger\mu})(\partial_\nu W^\nu) - \frac{1}{2}(\partial_\mu \mathcal{A}_\nu)(\partial^\nu \mathcal{A}_\mu) - \frac{1}{2}G_{\mu\nu}^\dagger G^{\mu\nu} - M^2 W_\mu^\dagger W^\mu + ig\mathcal{A}_\mu W_\nu^\dagger \widetilde{W}^{\mu\nu} - ig\widetilde{W}_{\mu\nu}^\dagger \mathcal{A}^\mu W^\nu - g^2 \mathcal{A}_\mu \mathcal{A}^\mu |W|^2 + g^2 (\mathcal{A}_\mu W^\mu)(W_\nu^\dagger \mathcal{A}^\nu) - ig\kappa F^{\mu\nu} W_\mu^\dagger W_\nu.$$

**COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON**



$$\propto -2ig^2(g^{\mu\nu}g^{\sigma\rho}) + ig^2(g^{\mu\sigma}g^{\nu\rho} + g^{\mu\rho}g^{\nu\sigma})$$

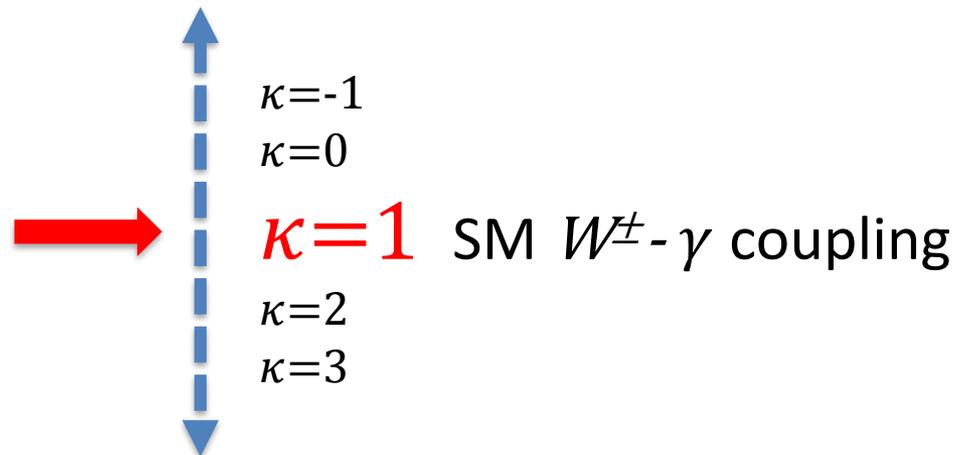


$$\propto ig(-g^{\nu\mu}(-\kappa p_2 + \kappa p_1 + p_1)^\rho - g^{\mu\rho}(p_2 + \kappa p_2 - \kappa p_1)^\nu + g^{\rho\nu}(p_1 + p_2)^\mu)$$



A New Phenomenological Parameter κ

$$\mathcal{L}_\kappa \propto -ig\kappa F_{\mu\nu} W^{\dagger\mu} W^\nu$$



In the *Standard Model*, such a term appears naturally through the coupling of physical bosons in rotated

$$SU(2) \times U_Y(1) / U_{em}(1).$$

- Unitary
- Renormalizable
- No ghosts or gauge fixing

T. D. Lee Phys Rev 128.899 (1973)
 Tupper & Samuel Phys Rev D 23.9 (1981)
 Mikaelian, Samuel & Sahdev Phys Rev Lett 43.746 (1979)



Asside: The Standard Model $\kappa = 1$

The Higgs Sector of the Standard Model Lagrangian

$$\mathcal{L}_{EW} = -(\mathcal{D}_\mu \Phi)^\dagger (\mathcal{D}^\mu \Phi) - \frac{\lambda}{2} \left(\Phi^\dagger \Phi - \frac{\mu^2}{\lambda} \right)^2 - \frac{1}{4} F_{\mu\nu}^a F^{\mu\nu,a} - \frac{1}{4} G_{\mu\nu} G^{\mu\nu}$$

$$\mathcal{D}_\mu = \partial_\mu - i \frac{g}{2} \tau^a A_\mu^a - i \frac{g'}{2} B_\mu$$

The physical fields appear through the relations

$$\begin{pmatrix} A_\mu^{(em)} \\ Z_\mu \end{pmatrix} = \begin{pmatrix} \cos \theta_W & \sin \theta_W \\ -\sin \theta_W & \cos \theta_W \end{pmatrix} \begin{pmatrix} B_\mu \\ A_\mu^3 \end{pmatrix} \qquad W_\mu^+ = \frac{1}{\sqrt{2}} (A_\mu^1 + i A_\mu^2)$$

Through the process of **Spontaneous Symmetry Breaking**, coupling terms between the boson W^\pm and the photon $A^{(em)}$ naturally generate the $\kappa = 1$ scenario.



Observable Significance

- **MAGNETIC MOMENT** (to 1st order)

Gyromagnetic ratio

$$\mu_M = \frac{g(\beta)}{2M} (1 + \kappa) \hat{S}, \quad \hat{S} = 1$$

Quadrupole moment (to 1st order)

$$Q_E = \frac{-g(\beta)\kappa}{M^2}$$

- **DISTINCT KINEMATIC DISTRIBUTIONS**

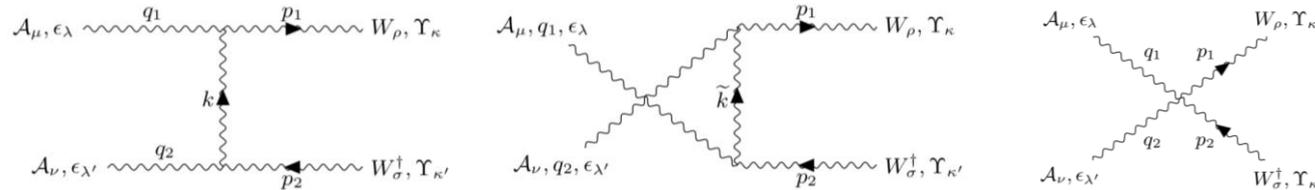
the shapes of which change with κ though the Feynman rules

$$\frac{d\sigma}{d\Omega} = \frac{1}{64\pi^2 s} \frac{|p_1|}{|q_1|} |\overline{\mathcal{M}}|^2$$

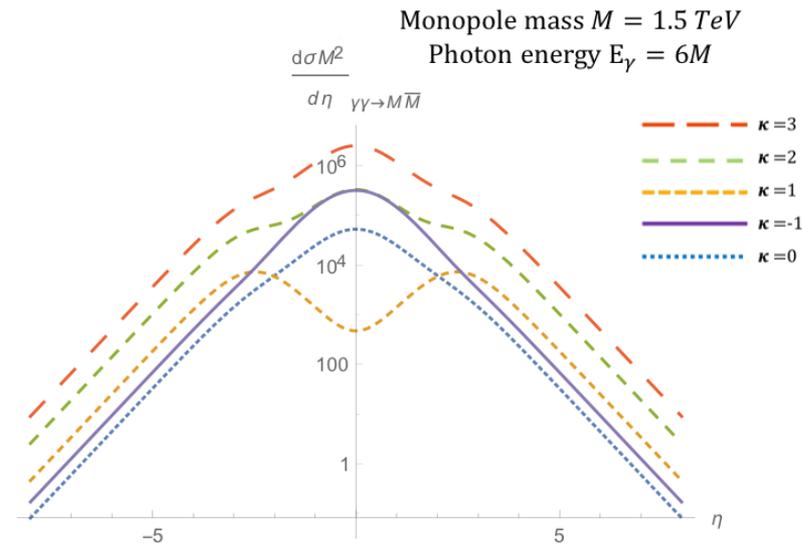
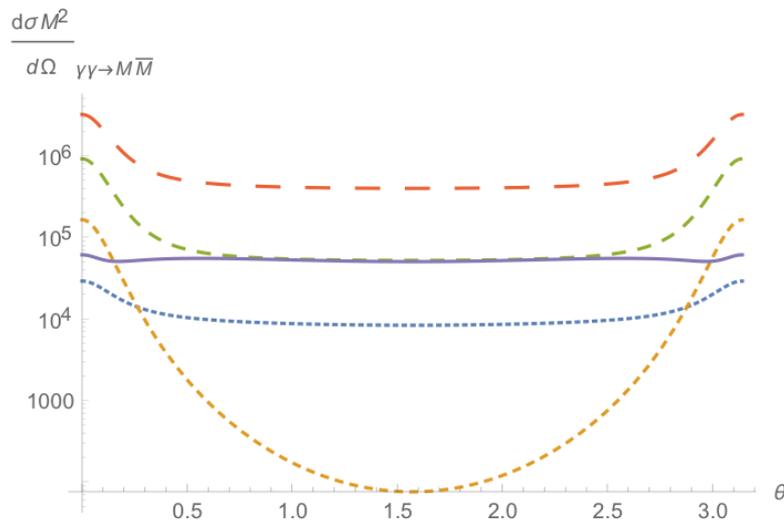


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Vector Monopole Production by Photon Fusion



Spin-1 monopole production by Photon Fusion (β independent)



This became an experimental test because as E_γ increases, the SM value becomes very distinctive.



ANALYTICAL FORMS for Photon Fusion

ANALYTICAL FORM of the DIFFERENTIAL CROSS SECTION

$$\begin{aligned} \frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=1}}{d\Omega} = & \frac{\alpha_g^2(\beta)\beta}{16(\beta^2-1)^2 s_{\gamma\gamma}(\beta^2\cos^2(\theta)-1)^2} \left(48\beta^8 + \beta^6(\kappa-1)^4\cos^6(\theta) \right. \\ & - 144\beta^6 + 2\beta^4(3\kappa^4 + 28\kappa^3 + 42\kappa^2 - 4\kappa + 79) - 2\beta^2(11\kappa^4 + 60\kappa^3 + 58\kappa^2 + 12\kappa + 35) \\ & + \beta^4(24\beta^4 + 2\beta^2(\kappa^4 + 12\kappa^3 - 10\kappa^2 - 20\kappa - 7) + 9\kappa^4 - 36\kappa^3 + 22\kappa^2 + 28\kappa + 1) \cos^4(\theta) \\ & - \beta^2(48\beta^6 + 2\beta^4(\kappa^4 + 4\kappa^3 - 34\kappa^2 - 28\kappa - 55) \\ & - 4\beta^2(3\kappa^4 - 42\kappa^2 - 8\kappa - 29) + 35\kappa^4 - 44\kappa^3 - 78\kappa^2 - 12\kappa - 29) \cos^2(\theta) \\ & \left. + 29\kappa^4 + 44\kappa^3 + 46\kappa^2 + 12\kappa + 21 \right) \end{aligned}$$

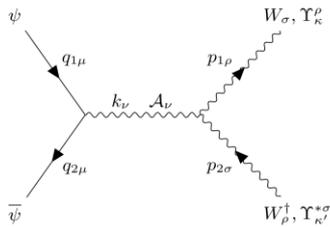
THE UNITARY SOLUTION: $\kappa=1$

$$\frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=1}}{d\Omega} = \frac{\alpha_g(\beta)^2\beta}{2s_{\gamma\gamma}(\beta^2\cos^2(\theta)-1)^2} (3\beta^4(\cos^4(\theta) - 2\cos^2(\theta) + 2) + \beta^2(16\cos^2(\theta) - 6) + 19)$$

$$\rightarrow \frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=1}}{d\Omega} \xrightarrow{s_{\gamma\gamma} \rightarrow \infty} \frac{\alpha_g^2(\beta)}{2s_{\gamma\gamma}(\cos^2(\theta)-1)^2} (3\cos^4(\theta) + 10\cos^2(\theta) + 19)$$

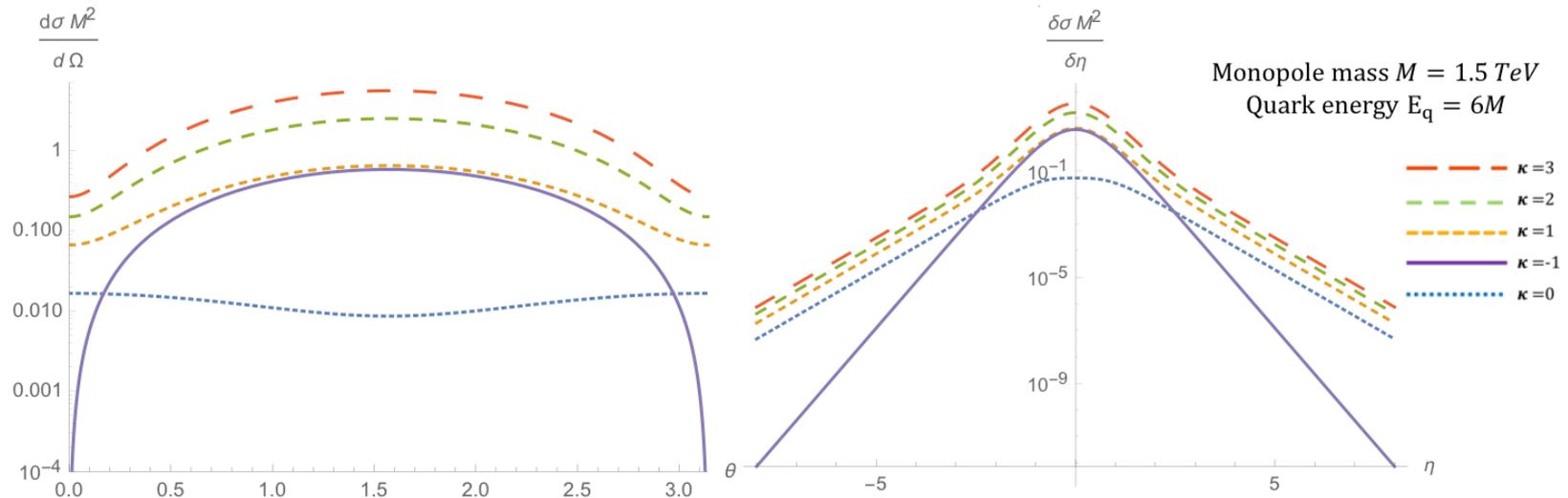


Vector Monopole Production by Drell-Yan



This became an experimental test because as E_q increases, the SM value becomes very distinctive.

Spin 1 monopole production by Drell-Yan (β independent)



ANALYTICAL FORMS for Drell-Yan

ANALYTICAL FORM of the DIFFERENTIAL CROSS SECTION

$$\frac{d\sigma_{q\bar{q} \rightarrow M\bar{M}}^{S=1}}{d\Omega} = \frac{5\beta^3 \alpha_e \alpha_g(\beta)}{288(\beta^2 - 1)M^2} \left(3\beta^4(\cos^2 \theta - 1) + \beta^2(2\kappa^2(\cos^2 \theta + 1) + 8\kappa - 4\cos^2 \theta + 8) \right. \\ \left. + 2\kappa^2(\cos^2 \theta - 3) - 8\kappa + \cos^2 \theta - 5 \right)$$

THE “UNITARY” SOLUTION: $\kappa=1$

$$\frac{d\sigma_{q\bar{q} \rightarrow M\bar{M}}^{S=1}}{d\Omega} = \frac{5\beta^3 \alpha_e \alpha_g(\beta)}{288(\beta^2 - 1)M^2} \left[3\beta^4(\cos^2 \theta - 1) + \beta^2(18 - 2\cos^2 \theta) + 3\cos^2 \theta - 19 \right]$$

This is non-unitary as an isolated process, in the absence of other contributing processes, also arising naturally in the SM.



Dirac Quantum Electrodynamics

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \overline{\psi}(i\not{D} - m)\psi - i\frac{1}{4}g(\beta)\kappa F_{\mu\nu}\overline{\psi}[\gamma^\mu, \gamma^\nu]\psi$$

KINETIC AND MASS TERMS

**COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON**

**MAGNETIC MOMENT TERM
(Highly divergent)**

$$\kappa = \frac{\tilde{\kappa}}{M}$$

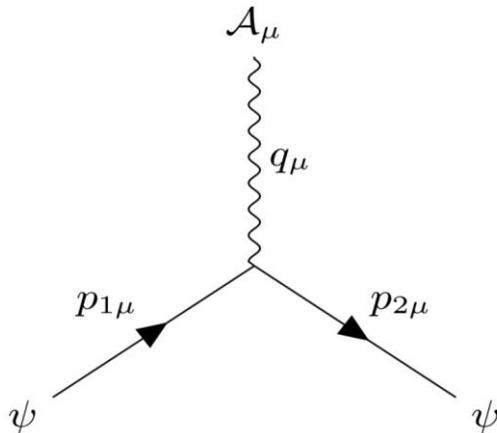


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Dirac Quantum Electrodynamics

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + \bar{\psi}(i\not{D} - m)\psi - i\frac{1}{4}g(\beta)\kappa F_{\mu\nu}\bar{\psi}[\gamma^\mu, \gamma^\nu]\psi$$

COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON



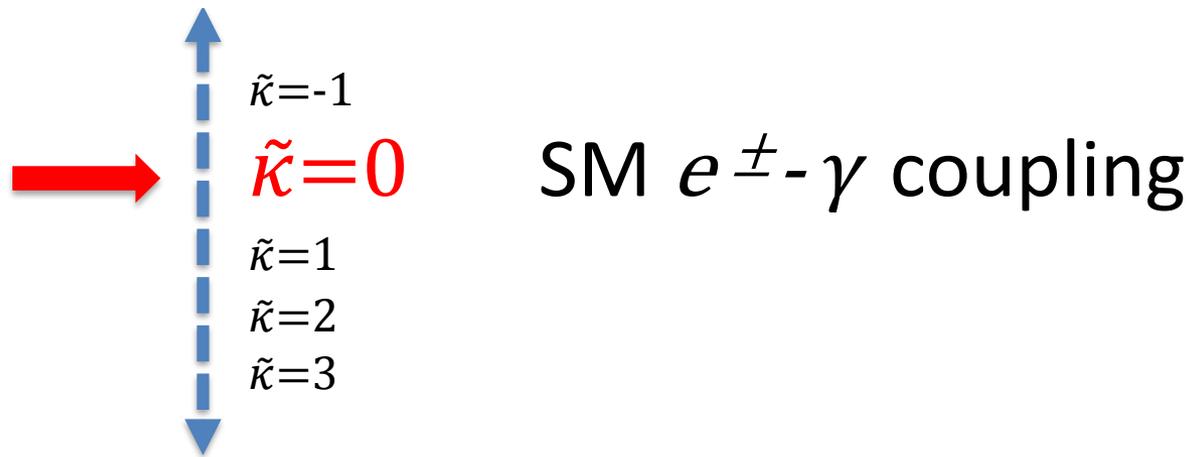
$$\propto -ig(\beta)\gamma^\nu - i\kappa\frac{1}{2}g(\beta)q_\mu[\gamma^\mu, \gamma^\nu]$$

$$\kappa = \frac{\tilde{\kappa}}{M}$$



A New Phenomenological Parameter κ

$$\mathcal{L}_\kappa \propto -i \frac{1}{4} g(\beta) \kappa F_{\mu\nu} \bar{\psi} [\gamma^\mu, \gamma^\nu] \psi$$



In the *Standard Model*, such a term appears through spin interactions in minimally coupling

QED

- Unitary
- Renormalizable

$$\kappa = \frac{\tilde{\kappa}}{M}$$



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Observable Significance

- **MAGNETIC MOMENT** (to 1st order)

Magnetic Moment

$$\mu_M = \frac{g(\beta)}{2M} 2(1 + 2\tilde{\kappa})\hat{S}, \quad \hat{S} = \frac{1}{2}$$

the parameter κ has dimensions

$$\kappa = \frac{\tilde{\kappa}}{M}$$

- **DISTINCT KINEMATIC DISTRIBUTIONS**

the shapes of which change with κ though the Feynman rules

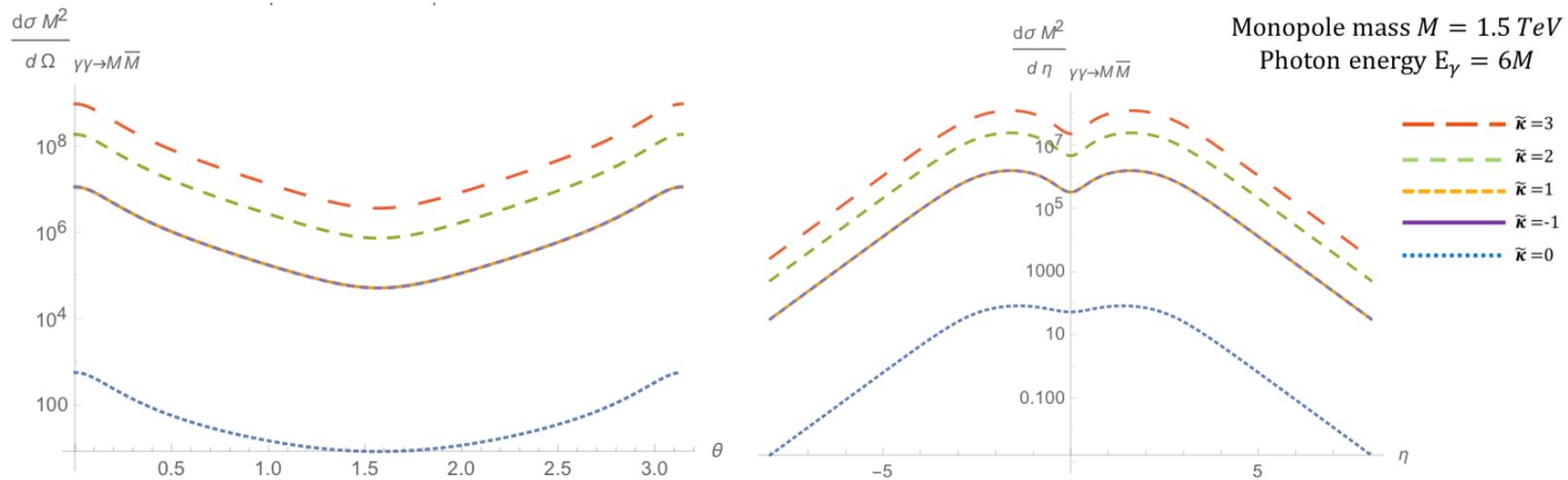
$$\frac{d\sigma}{d\Omega} = \frac{1}{64\pi^2 s} \frac{|p_1|}{|q_1|} |\overline{\mathcal{M}}|^2$$



Spinor Monopole Production by Photon Fusion



Spin $1/2$ monopole production by Photon Fusion (β independent, dimensionless $\tilde{\kappa}$)



ANALYTICAL FORMS for Photon Fusion

ANALYTICAL FORM of the DIFFERENTIAL CROSS SECTION

$$\begin{aligned} \frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=\frac{1}{2}}}{d\Omega} &= \frac{\alpha_g^2(\beta)\beta}{4s_{\gamma\gamma}(\beta^2 \cos^2(\theta) - 1)^2} (-\beta^6 \kappa^4 s_{\gamma\gamma}^2 \cos^6(\theta) - 2\beta^4(\kappa^4 s_{\gamma\gamma}^2 + 4) \\ &+ \beta^2(48\kappa\sqrt{s_{\gamma\gamma} - \beta^2 s_{\gamma\gamma}} + 2\kappa^4 s_{\gamma\gamma}^2 + 32\kappa^2 s_{\gamma\gamma} + 8) - \beta^4 \cos^4(\theta)((2\beta^2 + 3)\kappa^4 s_{\gamma\gamma}^2 \\ &+ 8\kappa^2 s_{\gamma\gamma} + 4) + \beta^2 \cos^2(\theta)(2\beta^4 \kappa^4 s_{\gamma\gamma}^2 + 8\beta^2(5\kappa^2 s_{\gamma\gamma} + 1) - 48\kappa\sqrt{s_{\gamma\gamma} - \beta^2 s_{\gamma\gamma}} \\ &+ 3\kappa^4 s_{\gamma\gamma}^2 - 60\kappa^2 s_{\gamma\gamma} - 8) + (\kappa^2 s_{\gamma\gamma} - 2)^2), \end{aligned}$$

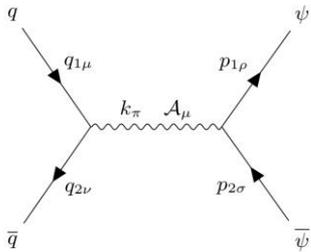
THE UNITARY SOLUTION: $\kappa=0$

$$\frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=\frac{1}{2}}}{d\Omega} = \frac{\alpha_g^2(\beta)\beta}{4s_{\gamma\gamma}(\beta^2 \cos^2(\theta) - 1)^2} (-8\beta^4 + 8\beta^2 - 4\beta^4 \cos^4(\theta) + 8\beta^4 \cos^2(\theta) - 8\beta^2 \cos^2(\theta) + 4)$$

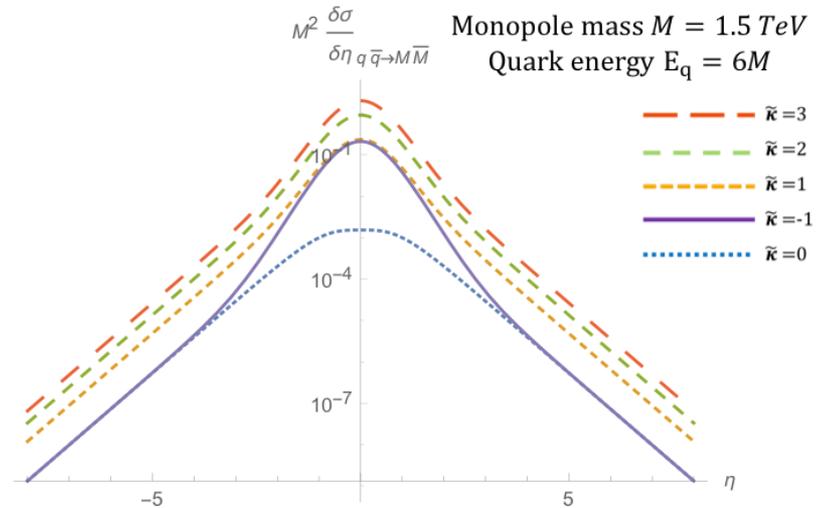
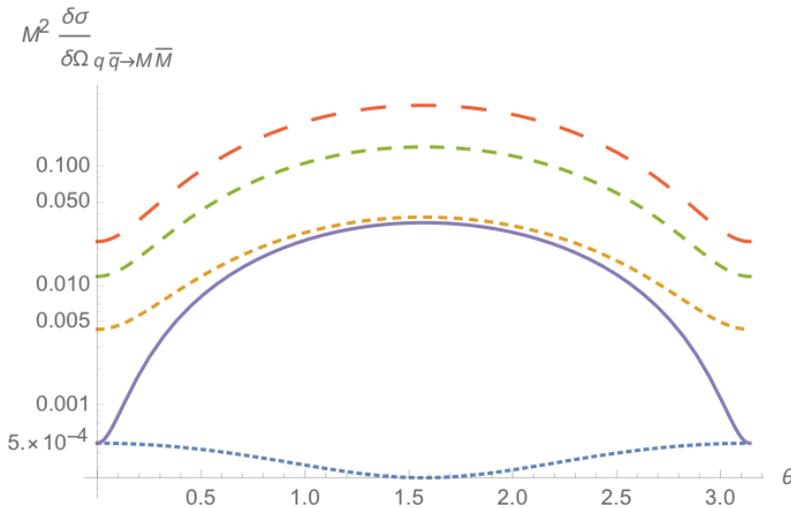
$$\rightarrow \frac{d\sigma_{\gamma\gamma\rightarrow M\bar{M}}^{S=\frac{1}{2}}}{d\Omega} \xrightarrow{s_{\gamma\gamma} \rightarrow \infty} \frac{\alpha_g^2(\beta)(1 - \frac{4M^2}{s_{\gamma\gamma}})^{\frac{1}{2}}}{s_{\gamma\gamma}(1 - \cos^2(\theta))} (\cos^2(\theta) + 1)$$



Spinor Monopole Production by Drell-Yan



Spin $1/2$ monopole production by Drell-Yan (β independent , dimensionless $\tilde{\kappa}$)



ANALYTICAL FORMS for Drell-Yan

ANALYTICAL FORM of the DIFFERENTIAL CROSS SECTION

$$\frac{d\sigma^{S=1/2}_{q\bar{q} \rightarrow M\bar{M}}}{d\Omega} = \frac{5\alpha_e\alpha_g(\beta)}{36s_{qq}} \left(\beta^3(\cos^2(\theta) - \kappa^2 s_{qq} \cos^2(\theta) - \kappa^2 s_{qq} - 1) + \beta(4\kappa\sqrt{s_{qq} - \beta^2 s_{qq} + 2\kappa^2 s_{qq} + 2}) \right)$$

THE UNITARY SOLUTION: $\kappa=0$

$$\frac{d\sigma^{S=1/2}_{q\bar{q} \rightarrow M\bar{M}}}{d\Omega} = \frac{5\alpha_e\alpha_g(\beta)\beta}{36s_{qq}} \left(\beta^2(\cos^2(\theta) - 1) + 2 \right)$$

*In fact, it **converges for all κ** but this is a happy coincidence. We know the non zero cases are non unitary for photon fusion.*

$$\rightarrow \frac{d\sigma^{S=1/2}_{q\bar{q} \rightarrow M\bar{M}}}{d\Omega} \xrightarrow{s_{\gamma\gamma} \rightarrow \infty} \frac{5\alpha_e\alpha_g(\beta)}{36s_{qq}} \left(\cos^2(\theta) + 1 \right)$$



Scalar Quantum Electrodynamics

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + (D^\mu\phi)^\dagger(D_\mu\phi) - M^2\phi^\dagger\phi$$

KINETIC AND MASS TERMS
COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON

NO MAGNETIC MOMENT TERM

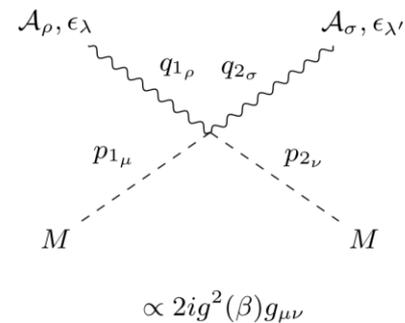
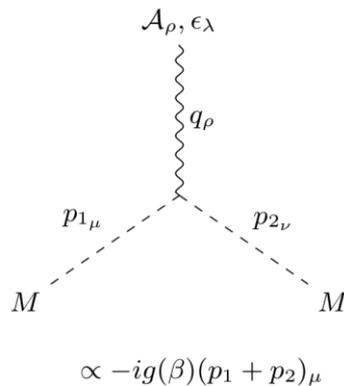


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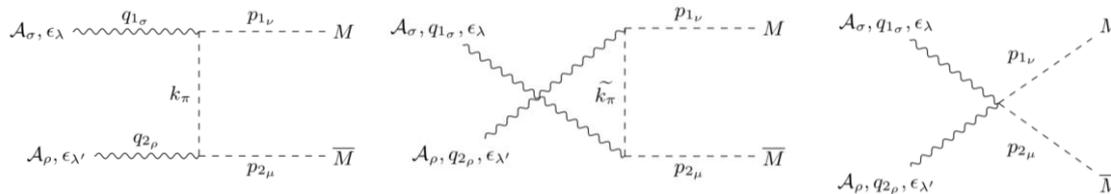
Scalar Quantum Electrodynamics

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + (D^\mu\phi)^\dagger(D_\mu\phi) - M^2\phi^\dagger\phi$$

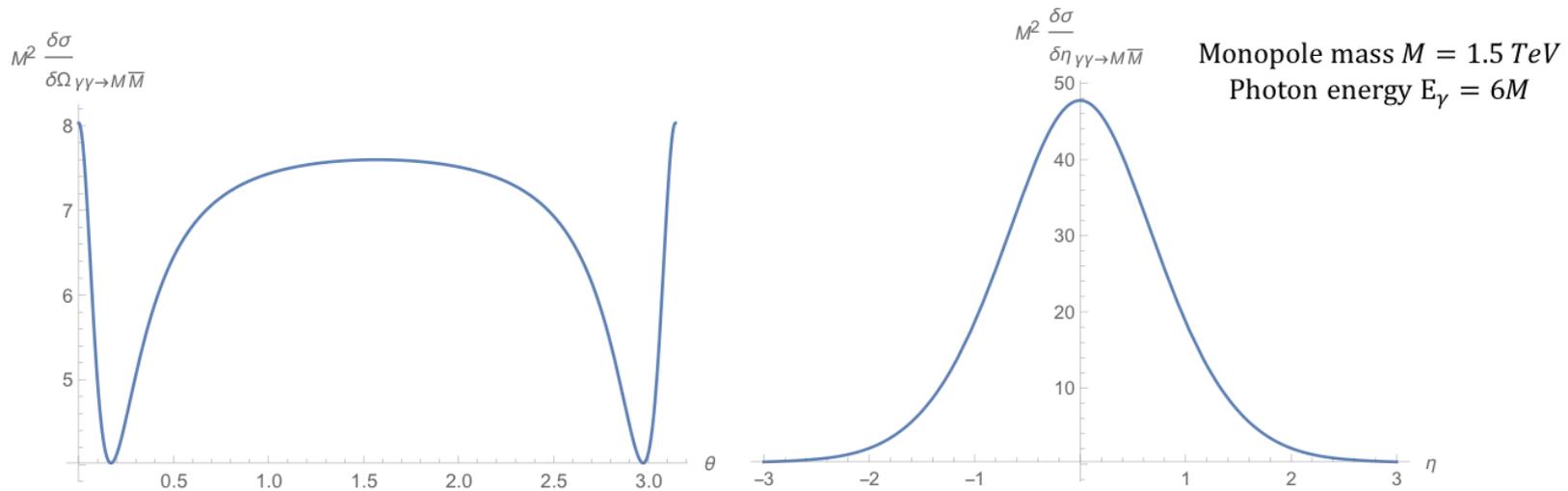
**COUPLING TERMS
BETWEEN THE MONOPOLE
AND THE GAUGE BOSON**



Scalar Monopole Production by Photon Fusion

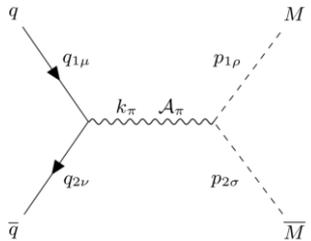


Spin 0 monopole production by Photon Fusion (β independent)



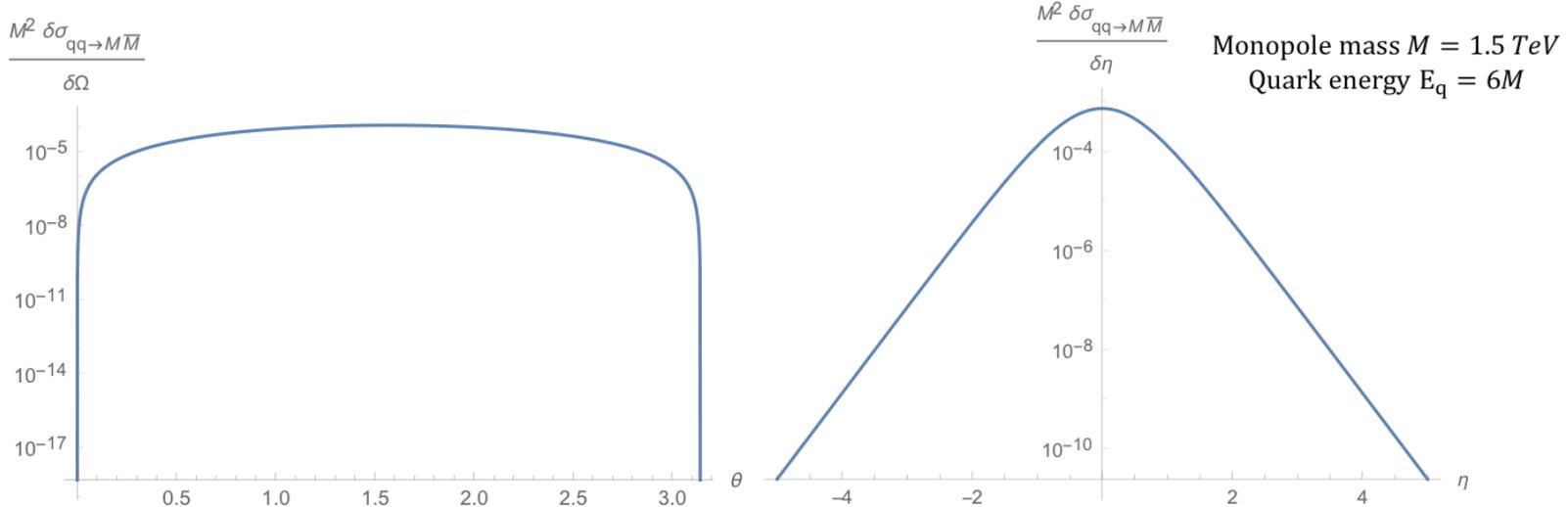
$$\frac{d\sigma_{\gamma\gamma \rightarrow M\bar{M}}^{S=0}}{d\Omega} = \frac{\alpha_g^2(\beta)\beta}{2s_{\gamma\gamma}} \left\{ 1 + \left[1 - \left(\frac{2(1-\beta^2)}{(1-\beta^2)\cos^2\theta} \right) \right]^2 \right\}$$

Scalar Monopole Production by Drell-Yan



$$\frac{d\sigma_{q\bar{q} \rightarrow M\bar{M}}^{S=0}}{d\Omega} = \frac{5\alpha_g(\beta)\alpha_e}{72 s_{qq}} \beta^3 (1 - \cos^2(\theta))$$

Spin 0 monopole production by Drell-Yan (β independent)



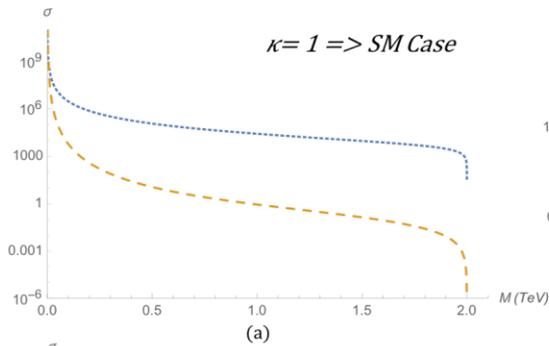
The Total Cross Section

**Integrating over the kinematic variables θ or η ,
we can compare the relative visibilities of
production.**

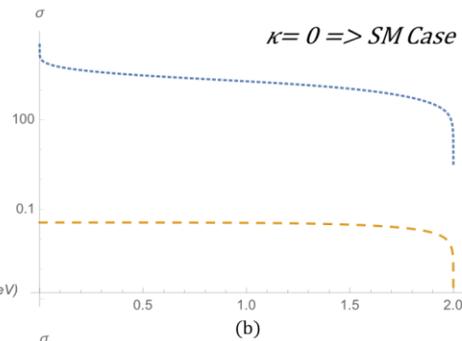


Photon Fusion vs Drell-Yan

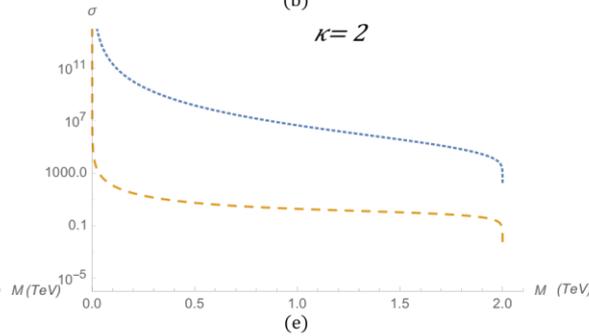
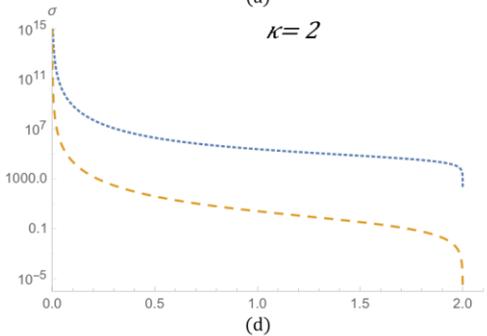
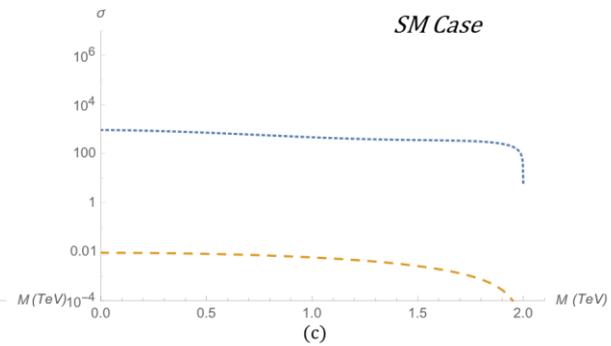
Spin 1 monopole production : Photon Fusion vs Drell-Yan (β independent) $\sqrt{s} = 4 \text{ TeV}$



Spin $\frac{1}{2}$ monopole production : Photon Fusion vs Drell-Yan (β independent) $\sqrt{s} = 4 \text{ TeV}$



Spin 0 monopole production : Photon Fusion vs Drell-Yan (β independent) $\sqrt{s} = 4 \text{ TeV}$



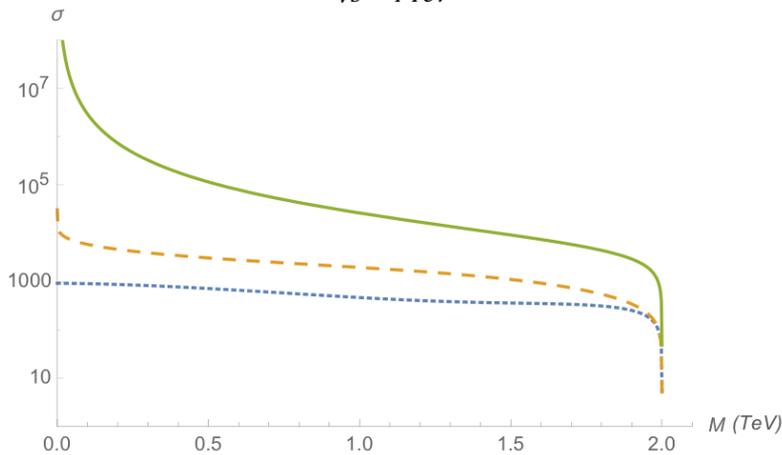
- - - Drell-Yan
. . . Photon Fusion

Photon Fusion clearly plays the dominant role

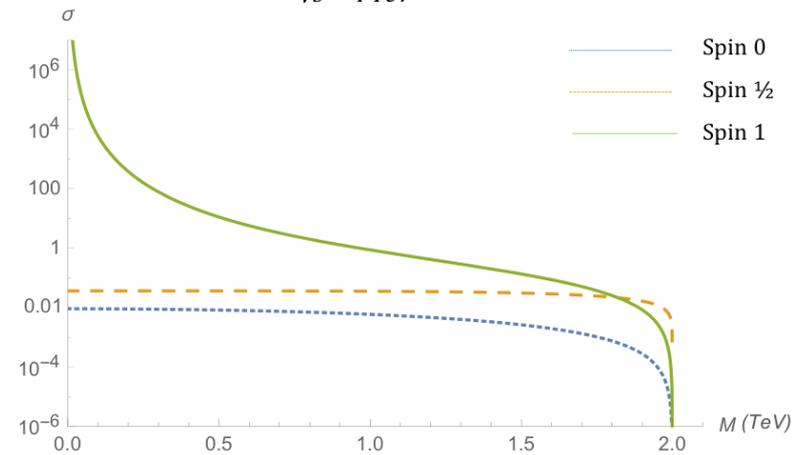


The Spin Models Stacked Up Against Each Other

Monopole production : Photon Fusion for 3 Spin Cases (β independent)
 $\sqrt{s} = 4 \text{ TeV}$



Monopole production : Drell-Yan for 3 Spin Cases (β independent)
 $\sqrt{s} = 4 \text{ TeV}$



In General, the Higher the Spin, the Larger the Cross Section over the Mass Range



Making Sense of the EFT with κ & $g(\beta)$

The perturbative approach holds strength despite using a **velocity dependent magnetic charge**, as long as the monopoles stay **slowly moving**.

$$\beta \ll 1 \quad \rightarrow \quad 2M \simeq \sqrt{s_{\gamma\gamma/qq}} + \mathcal{O}(\beta^2)$$

Note: $s_{\gamma\gamma/qq}$ follows a PDF distribution

*In SM cases, production at small β is **VERY VERY VERY** suppressed.*

For example:

$$\sigma_{\gamma\gamma \rightarrow M\bar{M}}^{S=1, \kappa=1} \stackrel{\beta \rightarrow 0}{\simeq} \frac{19 g^4}{8\pi s} \beta^5 \stackrel{\beta \rightarrow 0}{\rightarrow} 0 \quad (\text{spin} - 1 \text{ PF}),$$

Now leave $\beta \ll 1$, but require that the κ dependent coupling terms are small.

For example:

$$\begin{aligned} -i \frac{1}{4} g(\beta) \frac{\tilde{\kappa}}{M} F_{\mu\nu} \bar{\psi} [\gamma^\mu, \gamma^\nu] \psi &\rightarrow g \tilde{\kappa} \beta^2 < 1 \\ &\rightarrow \tilde{\kappa} \gg 1, \quad \beta \ll 1 \end{aligned}$$

*One then **requires** the absence of infrared divergences as $\beta \rightarrow 0$.*



Making Sense of the EFT with κ & $g(\beta)$

Spin-1 monopole production: the production cross section by Photon Fusion tends to a constant, and Drell-Yan production cross section vanishes.

$$(\kappa \beta g)^4 \beta \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{=}} |c_1| \quad \text{as by our definition} \quad \kappa g \beta^2 = |c_1|^{\frac{1}{4}} \beta^{\frac{3}{4}} \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{\rightarrow}} 0$$



$$\sigma_{\gamma\gamma \rightarrow M\bar{M}}^{S=1} \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{=}} \frac{29 c_1}{64 \pi s},$$

$$\sigma_{q\bar{q} \rightarrow M\bar{M}}^{S=1} \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{=}} |\alpha_e \frac{10 \sqrt{|c_1|}}{27 s} \beta^{\frac{5}{2}} \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{\rightarrow}} 0$$

Spin-1/2 monopole case, the same trends arise

$$(\tilde{\kappa} \beta g)^4 \beta \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{=}} |c'_1| \quad \text{as by our definition} \quad \tilde{\kappa} g \beta^2 = |c'_1|^{\frac{1}{4}} \beta^{\frac{3}{4}} \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{\rightarrow}} 0$$



$$\sigma_{\gamma\gamma \rightarrow M\bar{M}}^{S=\frac{1}{2}} \sim \pi \alpha_g^2(\beta) \beta \kappa^4 s = \frac{(\tilde{\kappa} g \beta)^4 \beta}{16 \pi M^4} s \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{=}} \text{finite},$$

$$\sigma_{q\bar{q} \rightarrow M\bar{M}}^{S=\frac{1}{2}} \sim \pi \alpha_e \alpha_g(\beta) \frac{10 \beta \kappa^2}{9} = \frac{5 \alpha_e}{18 M^2} (\tilde{\kappa} \beta g)^2 \beta \stackrel{\beta \rightarrow 0}{\underset{\kappa \rightarrow \infty}{\rightarrow}} 0.$$



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SUM-UP

ADDING THE κ PARAMETER

- *Adds a new phenomenological parameter κ*
- *Influences the different cross section distributions*
- *Constrains the theoretical fluidity in the search of a FT or EFT*

COMPREHENSIVE THEORETICAL MODELING OF SPIN-0, $\frac{1}{2}$,1 MONOPOLE PRODUCTION

COMING SOON...

Study of Monopole Production Mechanisms via photon fusion and/or Drell-Yan processes: a comparative novel study

S. Baines,¹ N.E. Mavromatos,¹ V.A. Mitsou,² J.L. Pinfeld,³ and A. Santra²



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SUM-UP

ADDING THE κ PARAMETER

- *Photon Fusion arises as the Dominant Process*
- *The higher the spin of the monopole, the higher the cross section*

THANKS FOR LISTERNING

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