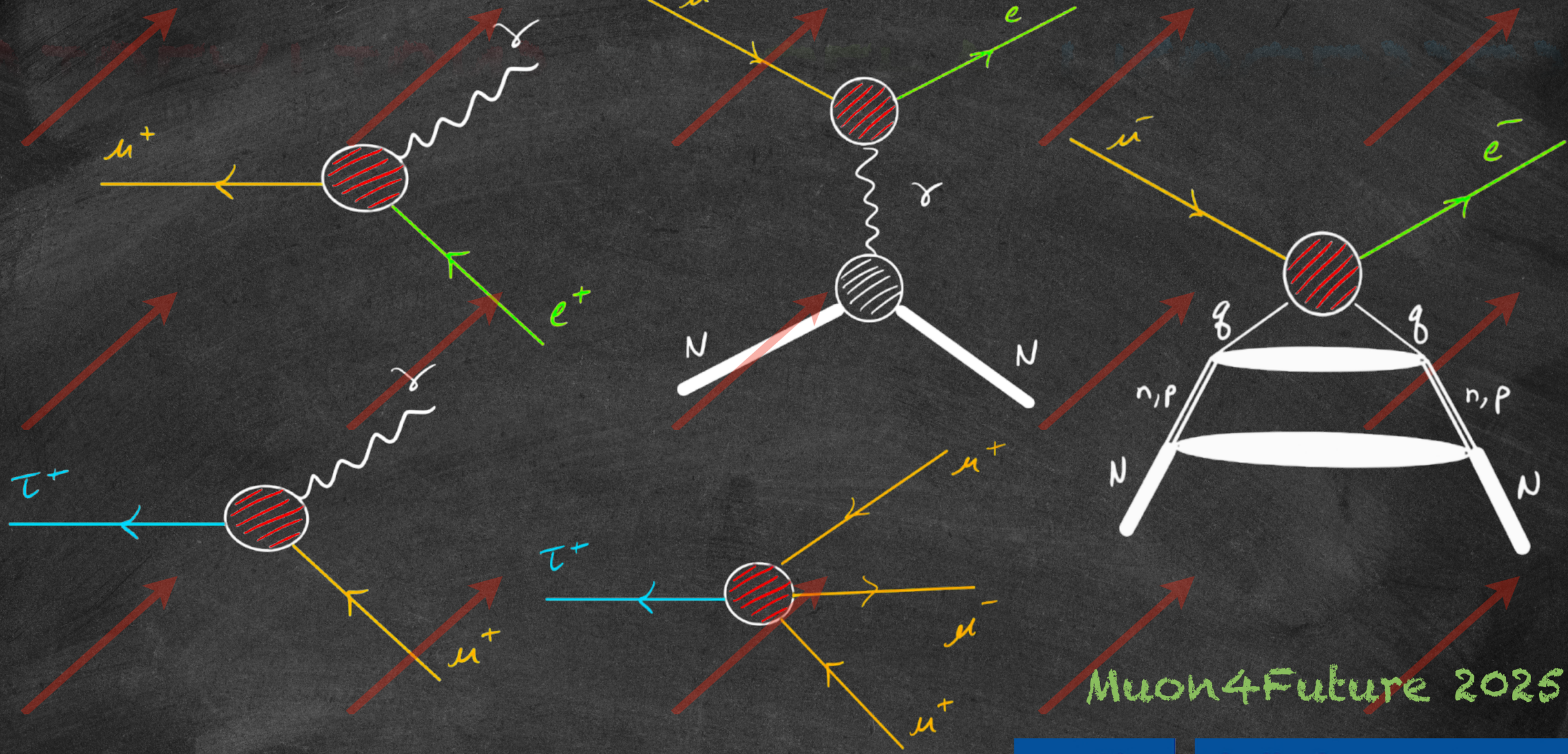
FUNDAMENTAL SYMMETRY VIOLATIONS IN CLFV PROCESSES



Muon4Future 2025

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basic idea

- CLFV provides a unique window into tests of spacetime symmetries

- Lorentz and CPT violation associated with flavor-changing processes largely unexamined

- We use CLFV measurements to probe these violations, setting hundreds of first constraints

muon and tau decays	V. A. Kostelecký, E. Passemar, **NS**, PRD 106, 076016 (2022)
mu-to-e in nuclei	V. A. Kostelecký, W. P. McNulty, E. Passemar, **NS**, 2501.05986

effective description

$$\mathscr{L}_{\mathrm{LV}} \supset -b_\mu \bar{\psi}\gamma_5\gamma^\mu\psi$$

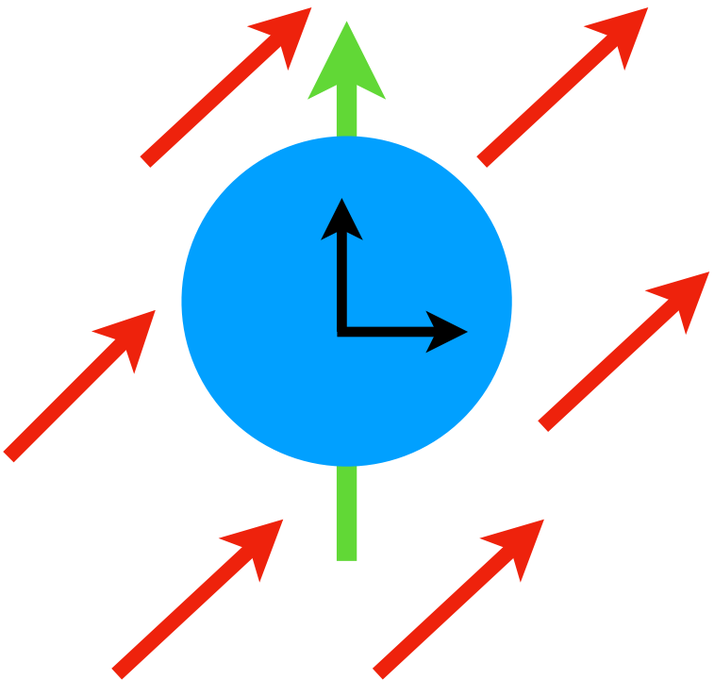
background field
EFT coefficient

SM fermion bilinear
(CPT odd)

full extension of
Standard Model

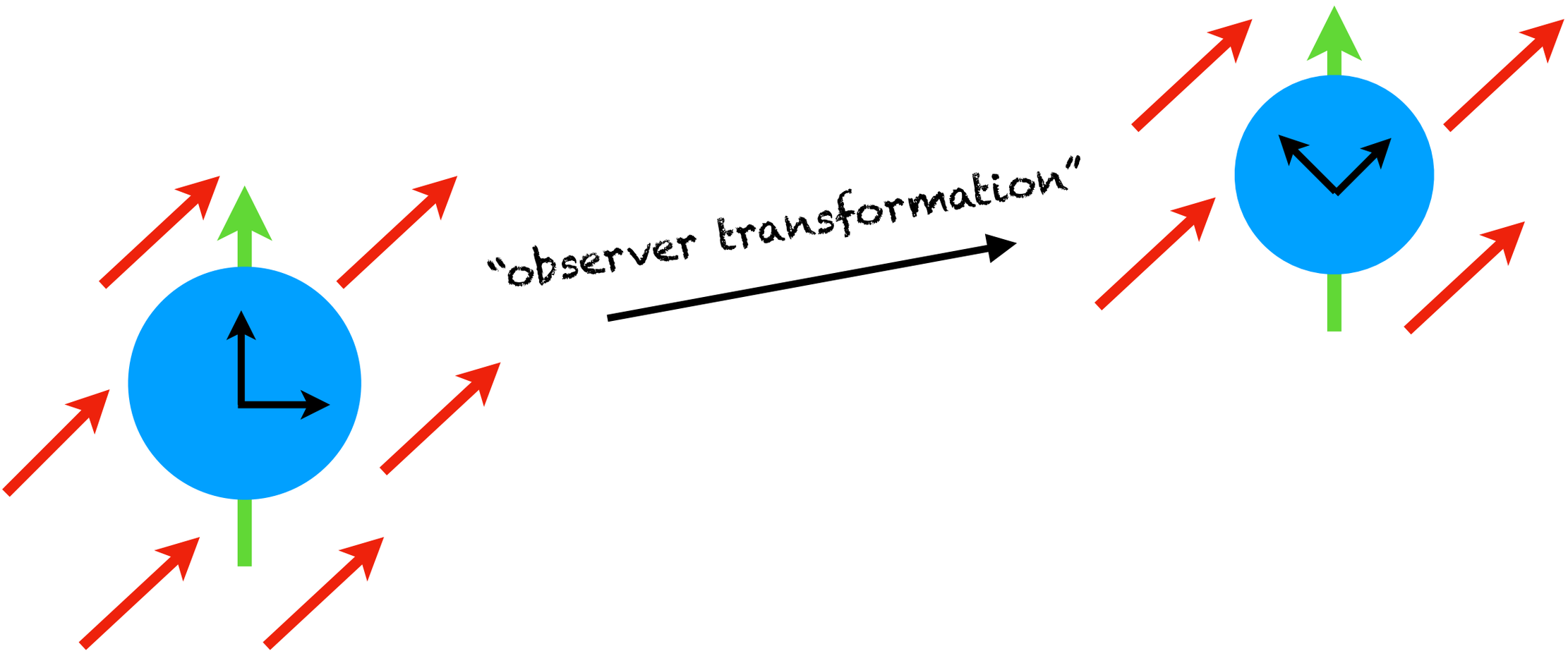
D. Colladay, V. A. Kostelecky,
PRD 55, 6760 (1997); PRD 58, 116002 (1998)

background violates Lorentz inv.



= system/expt. = coordinates $= \vec{b}$

background violates Lorentz inv.



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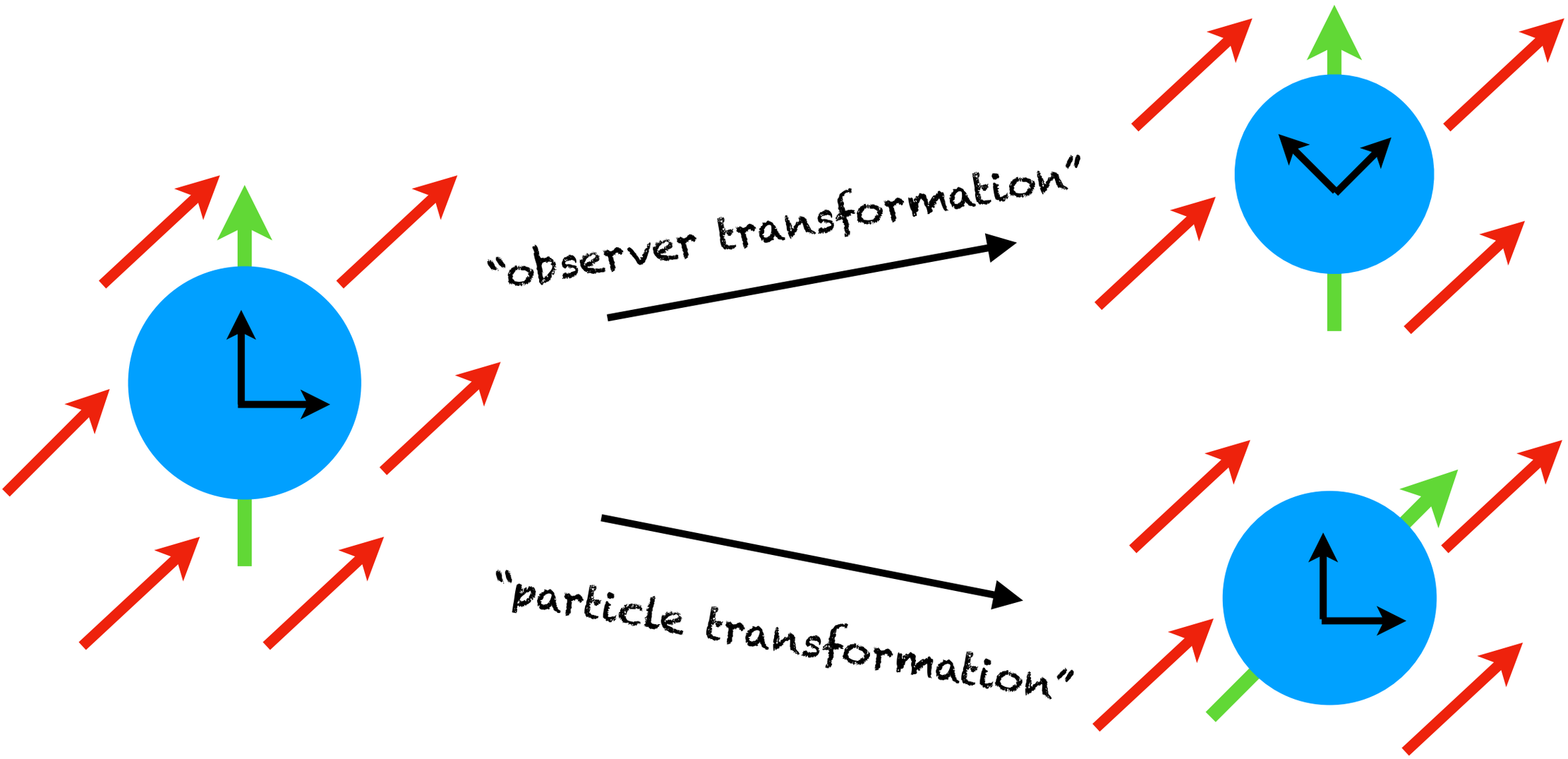
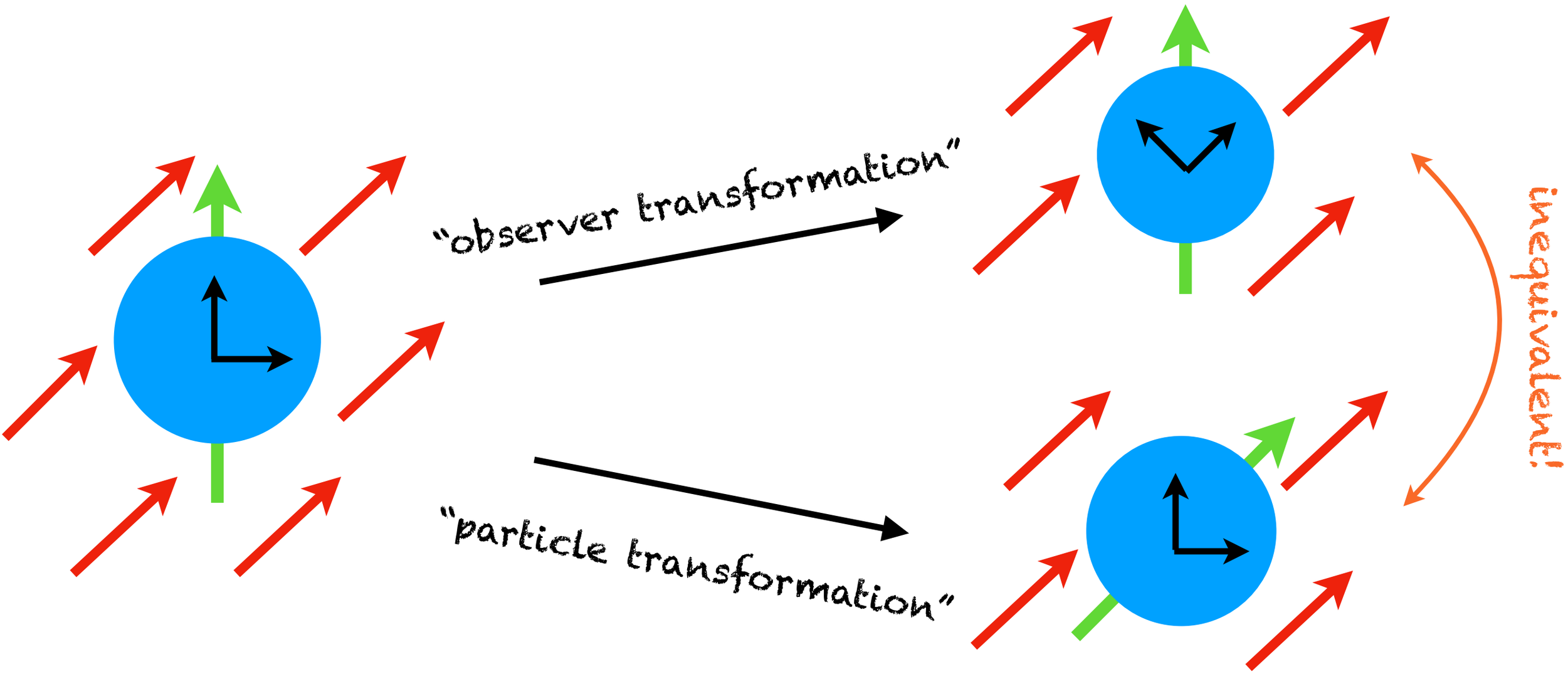
background violates Lorentz inv.



= system/expt. = coordinates $\nearrow = \vec{b}$

background violates Lorentz inv.

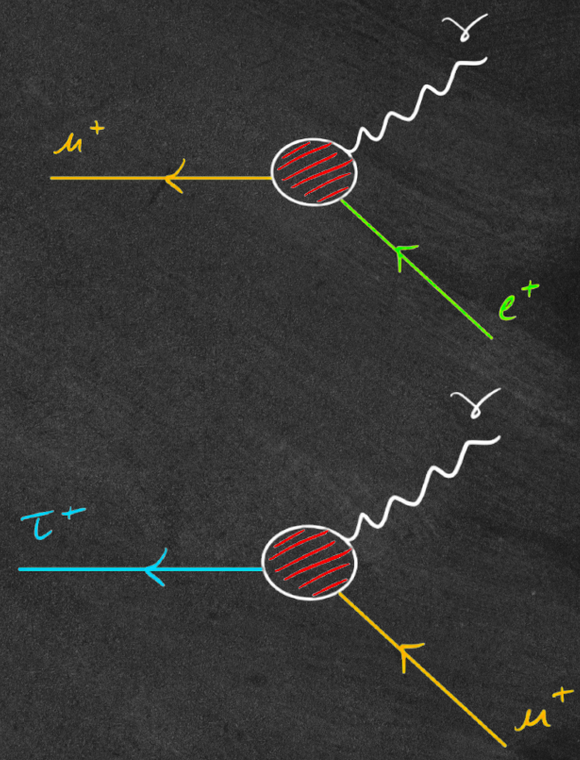


= system/expt. = coordinates $\nearrow = \vec{b}$

CLFV + LV operators

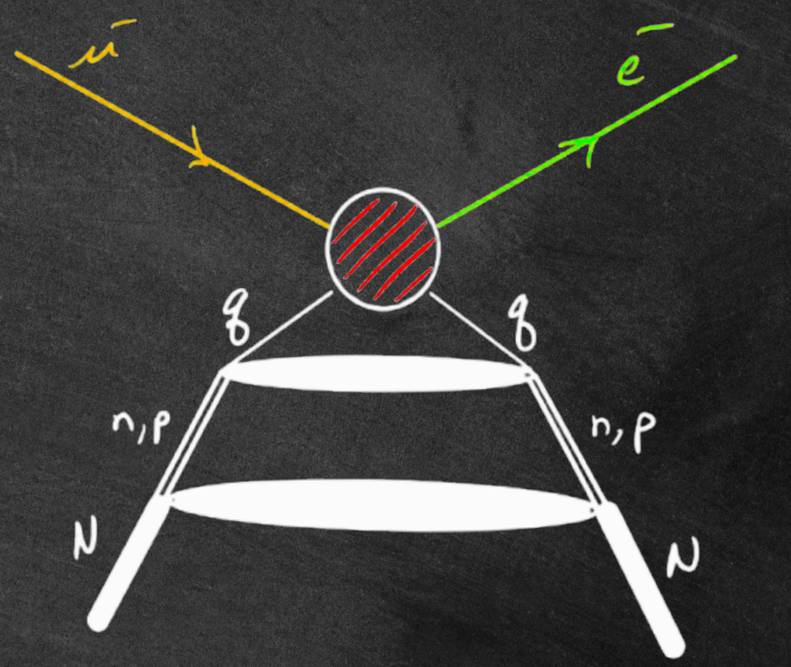
$d = 5$ lepton-photon

$$\mathcal{L}^{(5)}_{\psi_F} = -\frac{1}{2}(m_F^{(5)})^{\alpha\beta}_{AB} F_{\alpha\beta}\bar{\psi}_A\psi_B - \frac{1}{2}i(m_{5F}^{(5)})^{\alpha\beta}_{AB} F_{\alpha\beta}\bar{\psi}_A\gamma_5\psi_B$$
$$- \frac{1}{2}(a_F^{(5)})^{\mu\alpha\beta}_{AB} F_{\alpha\beta}\bar{\psi}_A\gamma_\mu\psi_B - \frac{1}{2}(b_F^{(5)})^{\mu\alpha\beta}_{AB} F_{\alpha\beta}\bar{\psi}_A\gamma_\mu\gamma_5\psi_B$$
$$- \frac{1}{4}(H_F^{(5)})^{\mu\nu\alpha\beta}_{AB} F_{\alpha\beta}\bar{\psi}_A\sigma_{\mu\nu}\psi_B$$



$d = 6$ lepton-quark

$$\mathcal{L}^{(6)}_{\psi\psi} = (k_{SS})_{ABCD}(\bar{\psi}_A\psi_B)(\bar{\psi}_C\psi_D) - (k_{PP})_{ABCD}(\bar{\psi}_A\gamma_5\psi_B)(\bar{\psi}_C\gamma_5\psi_D)$$
$$+ i\,(k_{SP})_{ABCD}(\bar{\psi}_A\psi_B)(\bar{\psi}_C\gamma_5\psi_D) + (k_{SV})^{\mu}_{ABCD}(\bar{\psi}_A\psi_B)(\bar{\psi}_C\gamma_\mu\psi_D)$$
$$+ (k_{SA})^{\mu}_{ABCD}(\bar{\psi}_A\psi_B)(\bar{\psi}_C\gamma_5\gamma_\mu\psi_D) + \frac{1}{2}(k_{ST})^{\mu\nu}_{ABCD}(\bar{\psi}_A\psi_B)(\bar{\psi}_C\sigma_{\mu\nu}\psi_D)$$
$$+ i\,(k_{PV})^{\mu}_{ABCD}(\bar{\psi}_A\gamma_5\psi_B)(\bar{\psi}_C\gamma_\mu\psi_D) + i\,(k_{PA})^{\mu}_{ABCD}(\bar{\psi}_A\gamma_5\psi_B)(\bar{\psi}_C\gamma_5\gamma_\mu\psi_D)$$
$$+ \frac{1}{2}i\,(k_{PT})^{\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_5\psi_B)(\bar{\psi}_C\sigma_{\mu\nu}\psi_D)$$
$$+ \frac{1}{2}(k_{VA})^{\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_\mu\psi_B)(\bar{\psi}_C\gamma_5\gamma_\nu\psi_D) + (k_{VV})^{\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_\mu\psi_B)(\bar{\psi}_C\gamma_\nu\psi_D)$$
$$+ (k_{AA})^{\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_5\gamma_\mu\psi_B)(\bar{\psi}_C\gamma_5\gamma_\nu\psi_D) + \frac{1}{2}(k_{VT})^{\lambda\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_\lambda\psi_B)(\bar{\psi}_C\sigma_{\mu\nu}\psi_D)$$
$$+ \frac{1}{2}(k_{AT})^{\lambda\mu\nu}_{ABCD}(\bar{\psi}_A\gamma_5\gamma_\lambda\psi_B)(\bar{\psi}_C\sigma_{\mu\nu}\psi_D) + \frac{1}{8}(k_{TT})^{\kappa\lambda\mu\nu}_{ABCD}(\bar{\psi}_A\sigma_{\kappa\lambda}\psi_B)(\bar{\psi}_C\sigma_{\mu\nu}\psi_D)$$



constraints

$\mu \to e + \gamma$ (MEG)

Coefficients	Constraint (GeV^{-1})
$(m_F^{(5)})^{TJ}_{\mu e}, (m_F^{(5)})^{JZ}_{\mu e}, (m_{5F}^{(5)})^{TJ}_{\mu e}, (m_{5F}^{(5)})^{JZ}_{\mu e},$ $(a_F^{(5)})^{TTJ}_{\mu e}, (a_F^{(5)})^{TJZ}_{\mu e}, (a_F^{(5)})^{JTJ}_{\mu e}, (a_F^{(5)})^{JTK}_{\mu e},$ $(a_F^{(5)})^{JJZ}_{\mu e}, (a_F^{(5)})^{JKZ}_{\mu e}, (a_F^{(5)})^{ZTJ}_{\mu e}, (a_F^{(5)})^{ZJZ}_{\mu e},$ $(b_F^{(5)})^{TTJ}_{\mu e}, (b_F^{(5)})^{TJZ}_{\mu e}, (b_F^{(5)})^{JTJ}_{\mu e}, (b_F^{(5)})^{JTK}_{\mu e},$ $(b_F^{(5)})^{JJZ}_{\mu e}, (b_F^{(5)})^{JKZ}_{\mu e}, (b_F^{(5)})^{ZTJ}_{\mu e}, (b_F^{(5)})^{ZJZ}_{\mu e},$ $(H_F^{(5)})^{TJTJ}_{\mu e}, (H_F^{(5)})^{TJTK}_{\mu e}, (H_F^{(5)})^{TJJZ}_{\mu e},$ $(H_F^{(5)})^{TJKZ}_{\mu e}, (H_F^{(5)})^{TZTJ}_{\mu e}, (H_F^{(5)})^{TZJZ}_{\mu e},$ $(H_F^{(5)})^{JKTJ}_{\mu e}, (H_F^{(5)})^{JKJZ}_{\mu e}, (H_F^{(5)})^{JZTJ}_{\mu e},$ $(H_F^{(5)})^{JZTK}_{\mu e}, (H_F^{(5)})^{JZJZ}_{\mu e}, (H_F^{(5)})^{JZKZ}_{\mu e}$	$< 6.0 \times 10^{-13}$
$(m_F^{(5)})^{TZ}_{\mu e}, (m_F^{(5)})^{JK}_{\mu e}, (m_{5F}^{(5)})^{TZ}_{\mu e}, (m_{5F}^{(5)})^{JK}_{\mu e},$ $(a_F^{(5)})^{TTZ}_{\mu e}, (a_F^{(5)})^{TJK}_{\mu e}, (a_F^{(5)})^{JTZ}_{\mu e}, (a_F^{(5)})^{JJK}_{\mu e},$ $(a_F^{(5)})^{ZTZ}_{\mu e}, (a_F^{(5)})^{ZJK}_{\mu e}, (b_F^{(5)})^{TTZ}_{\mu e}, (b_F^{(5)})^{TJK}_{\mu e},$ $(b_F^{(5)})^{JTZ}_{\mu e}, (b_F^{(5)})^{JJK}_{\mu e}, (b_F^{(5)})^{ZTZ}_{\mu e}, (b_F^{(5)})^{ZJK}_{\mu e},$ $(H_F^{(5)})^{TJTZ}_{\mu e}, (H_F^{(5)})^{TZTZ}_{\mu e}, (H_F^{(5)})^{JKTZ}_{\mu e},$ $(H_F^{(5)})^{JZTZ}_{\mu e}, (H_F^{(5)})^{TJJK}_{\mu e}, (H_F^{(5)})^{TZJK}_{\mu e},$ $(H_F^{(5)})^{JKJK}_{\mu e}, (H_F^{(5)})^{JZJK}_{\mu e}$	$< 6.4 \times 10^{-13}$

$\tau \to \mu + \gamma$

Coefficients	Constraint (GeV^{-1})
$(m_F^{(5)})^{TJ}_{\tau\mu}, (m_F^{(5)})^{TZ}_{\tau\mu}, (m_F^{(5)})^{JK}_{\tau\mu}, (m_F^{(5)})^{JZ}_{\tau\mu}$	$< 1.8 \times 10^{-9}$
$(m_{5F}^{(5)})^{TJ}_{\tau\mu}, (m_{5F}^{(5)})^{TZ}_{\tau\mu}, (m_{5F}^{(5)})^{JK}_{\tau\mu}, (m_{5F}^{(5)})^{JZ}_{\tau\mu}$	$< 2.0 \times 10^{-9}$
$(a_F^{(5)})^{TTJ}_{\tau\mu}, (a_F^{(5)})^{TTZ}_{\tau\mu}, (a_F^{(5)})^{TJK}_{\tau\mu}, (a_F^{(5)})^{TJZ}_{\tau\mu}, (b_F^{(5)})^{JTJ}_{\tau\mu}, (b_F^{(5)})^{JTK}_{\tau\mu}, (b_F^{(5)})^{JTZ}_{\tau\mu}, (b_F^{(5)})^{JJK}_{\tau\mu}, (b_F^{(5)})^{JJZ}_{\tau\mu}, (b_F^{(5)})^{JKZ}_{\tau\mu}, (b_F^{(5)})^{ZTJ}_{\tau\mu}, (b_F^{(5)})^{ZTZ}_{\tau\mu}, (b_F^{(5)})^{ZJK}_{\tau\mu}, (b_F^{(5)})^{ZJZ}_{\tau\mu}, (H_F^{(5)})^{JKTJ}_{\tau\mu}, (H_F^{(5)})^{JKJZ}_{\tau\mu}, (H_F^{(5)})^{JZTJ}_{\tau\mu}, (H_F^{(5)})^{JZTK}_{\tau\mu}, (H_F^{(5)})^{JZJZ}_{\tau\mu}, (H_F^{(5)})^{JZKZ}_{\tau\mu}, (H_F^{(5)})^{JZTZ}_{\tau\mu}, (H_F^{(5)})^{JZJK}_{\tau\mu}, (H_F^{(5)})^{JKTZ}_{\tau\mu}, (H_F^{(5)})^{JKJK}_{\tau\mu}$	$< 2.2 \times 10^{-9}$
$(a_F^{(5)})^{JTJ}_{\tau\mu}, (a_F^{(5)})^{JTK}_{\tau\mu}, (a_F^{(5)})^{JTZ}_{\tau\mu}, (a_F^{(5)})^{JJK}_{\tau\mu}, (a_F^{(5)})^{JJZ}_{\tau\mu}, (a_F^{(5)})^{JKZ}_{\tau\mu}, (a_F^{(5)})^{ZTJ}_{\tau\mu}, (a_F^{(5)})^{ZTZ}_{\tau\mu}, (a_F^{(5)})^{ZJK}_{\tau\mu}, (a_F^{(5)})^{ZJZ}_{\tau\mu}, (b_F^{(5)})^{TTJ}_{\tau\mu}, (b_F^{(5)})^{TTZ}_{\tau\mu}, (b_F^{(5)})^{TJK}_{\tau\mu}, (b_F^{(5)})^{TJZ}_{\tau\mu}, (H_F^{(5)})^{TJTJ}_{\tau\mu}, (H_F^{(5)})^{TJTK}_{\tau\mu}, (H_F^{(5)})^{TJJZ}_{\tau\mu}, (H_F^{(5)})^{TJKZ}_{\tau\mu}, (H_F^{(5)})^{TZTJ}_{\tau\mu}, (H_F^{(5)})^{TZJZ}_{\tau\mu}, (H_F^{(5)})^{TJTZ}_{\tau\mu}, (H_F^{(5)})^{TJJK}_{\tau\mu}, (H_F^{(5)})^{TZTZ}_{\tau\mu}, (H_F^{(5)})^{TZJK}_{\tau\mu}$	$< 2.5 \times 10^{-9}$

$\tau \to e + \gamma$

Coefficients	Constraint (GeV^{-1})
$(m_F^{(5)})^{TJ}_{\tau e}, (m_F^{(5)})^{TZ}_{\tau e}, (m_F^{(5)})^{JK}_{\tau e}, (m_F^{(5)})^{JZ}_{\tau e}, (m_{5F}^{(5)})^{TJ}_{\tau e}, (m_{5F}^{(5)})^{TZ}_{\tau e}, (m_{5F}^{(5)})^{JK}_{\tau e}, (m_{5F}^{(5)})^{JZ}_{\tau e}$	$< 1.6 \times 10^{-9}$
$(a_F^{(5)})^{TTJ}_{\tau e}, (a_F^{(5)})^{TTZ}_{\tau e}, (a_F^{(5)})^{TJK}_{\tau e}, (a_F^{(5)})^{TJZ}_{\tau e}$	$< 1.9 \times 10^{-9}$
$(a_F^{(5)})^{JTJ}_{\tau e}, (a_F^{(5)})^{JTK}_{\tau e}, (a_F^{(5)})^{JTZ}_{\tau e}, (a_F^{(5)})^{JJK}_{\tau e}, (a_F^{(5)})^{JJZ}_{\tau e}, (a_F^{(5)})^{JKZ}_{\tau e}, (a_F^{(5)})^{ZTJ}_{\tau e}, (a_F^{(5)})^{ZTZ}_{\tau e}, (a_F^{(5)})^{ZJK}_{\tau e}, (a_F^{(5)})^{ZJZ}_{\tau e}$	$< 2.1 \times 10^{-9}$
$(b_F^{(5)})^{TTJ}_{\tau e}, (b_F^{(5)})^{TTZ}_{\tau e}, (b_F^{(5)})^{TJK}_{\tau e}, (b_F^{(5)})^{TJZ}_{\tau e}, (b_F^{(5)})^{JTJ}_{\tau e}, (b_F^{(5)})^{JTK}_{\tau e}, (b_F^{(5)})^{JTZ}_{\tau e}, (b_F^{(5)})^{JJK}_{\tau e}, (b_F^{(5)})^{JJZ}_{\tau e}, (b_F^{(5)})^{JKZ}_{\tau e}, (b_F^{(5)})^{ZTJ}_{\tau e}, (b_F^{(5)})^{ZTZ}_{\tau e}, (b_F^{(5)})^{ZJK}_{\tau e}, (b_F^{(5)})^{ZJZ}_{\tau e}, (H_F^{(5)})^{TJTJ}_{\tau e}, (H_F^{(5)})^{TJTK}_{\tau e}, (H_F^{(5)})^{TJJZ}_{\tau e}, (H_F^{(5)})^{TJKZ}_{\tau e}, (H_F^{(5)})^{TZTJ}_{\tau e}, (H_F^{(5)})^{TZJZ}_{\tau e}, (H_F^{(5)})^{TJTZ}_{\tau e}, (H_F^{(5)})^{TJJK}_{\tau e}, (H_F^{(5)})^{TZTZ}_{\tau e}, (H_F^{(5)})^{TZJK}_{\tau e}, (H_F^{(5)})^{JKTJ}_{\tau e}, (H_F^{(5)})^{JKJZ}_{\tau e}, (H_F^{(5)})^{JZTJ}_{\tau e}, (H_F^{(5)})^{JZTK}_{\tau e}, (H_F^{(5)})^{JZJZ}_{\tau e}, (H_F^{(5)})^{JZKZ}_{\tau e}, (H_F^{(5)})^{JZTZ}_{\tau e}, (H_F^{(5)})^{JZJK}_{\tau e}, (H_F^{(5)})^{JKTZ}_{\tau e}, (H_F^{(5)})^{JKJK}_{\tau e}$	$< 2.0 \times 10^{-9}$

(BaBar)

$\mu N \to eN$

$\times 10^{-12}$ GeV^{-1}

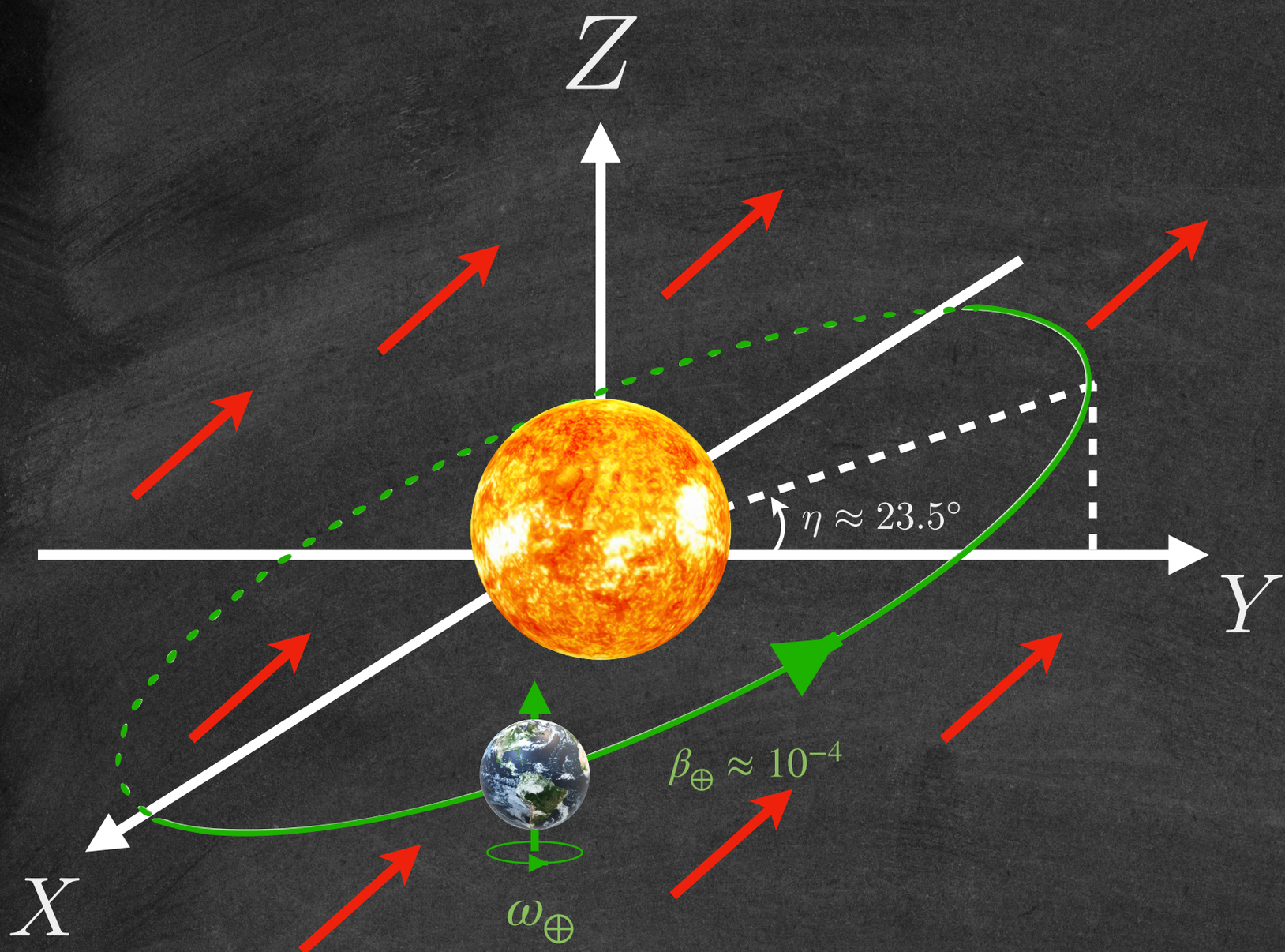
$\times 10^{-13}$ GeV^{-2}

"phase 1"

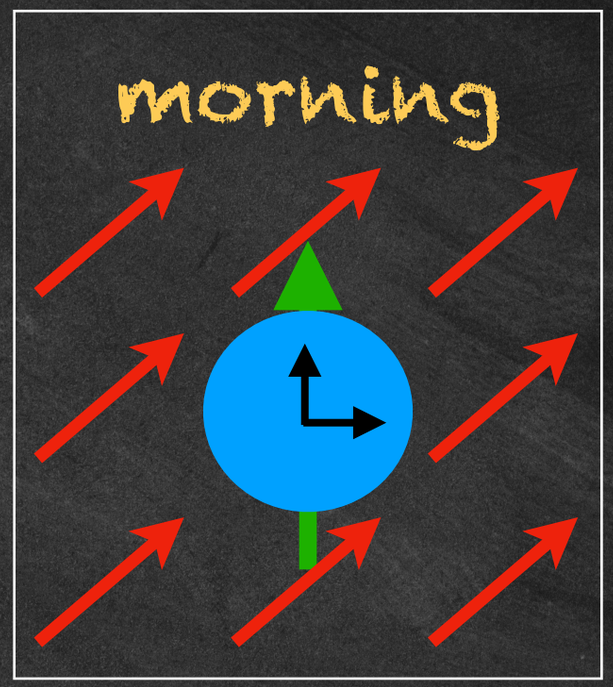
Coefficients	SINDRUM II	COMET	Mu2e
$\lvert(m_F^{(5)})^{TJ}_{\mu e}\rvert, \lvert(m_{5F}^{(5)})^{TJ}_{\mu e}\rvert$	< 8	< 1	< 0.2
$\lvert(m_F^{(5)})^{TZ}_{\mu e}\rvert, \lvert(m_{5F}^{(5)})^{TZ}_{\mu e}\rvert$	< 8	< 0.9	< 0.2
$\lvert(a_F^{(5)})^{TTJ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{TTJ}_{\mu e}\rvert$	< 6	< 1	< 0.2
$\lvert(a_F^{(5)})^{TTZ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{TTZ}_{\mu e}\rvert$	< 6	< 0.9	< 0.2
$\lvert(a_F^{(5)})^{JTJ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{JTJ}_{\mu e}\rvert$	< 6	< 1	< 0.2
$\lvert(a_F^{(5)})^{JTK}_{\mu e}\rvert, \lvert(b_F^{(5)})^{JTK}_{\mu e}\rvert$	< 8	< 1	< 0.2
$\lvert(a_F^{(5)})^{JTZ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{JTZ}_{\mu e}\rvert$	< 8	< 0.9	< 0.2
$\lvert(a_F^{(5)})^{ZTJ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{ZTJ}_{\mu e}\rvert$	< 8	< 1	< 0.2
$\lvert(a_F^{(5)})^{ZTZ}_{\mu e}\rvert, \lvert(b_F^{(5)})^{ZTZ}_{\mu e}\rvert$	< 7	< 0.9	< 0.2
$\lvert(H_F^{(5)})^{TJTJ}_{\mu e}\rvert, \lvert(H_F^{(5)})^{JZTK}_{\mu e}\rvert$	< 7	< 1	< 0.2
$\lvert(H_F^{(5)})^{TJTK}_{\mu e}\rvert, \lvert(H_F^{(5)})^{JZTJ}_{\mu e}\rvert$	< 6	< 1	< 0.2
$\lvert(H_F^{(5)})^{TJTZ}_{\mu e}\rvert, \lvert(H_F^{(5)})^{JZTZ}_{\mu e}\rvert$	< 6	< 0.9	< 0.2
$\lvert(H_F^{(5)})^{TZTJ}_{\mu e}\rvert, \lvert(H_F^{(5)})^{XYTJ}_{\mu e}\rvert$	< 6	< 1	< 0.2
$\lvert(H_F^{(5)})^{TZTZ}_{\mu e}\rvert, \lvert(H_F^{(5)})^{XYTZ}_{\mu e}\rvert$	< 7	< 0.9	< 0.2

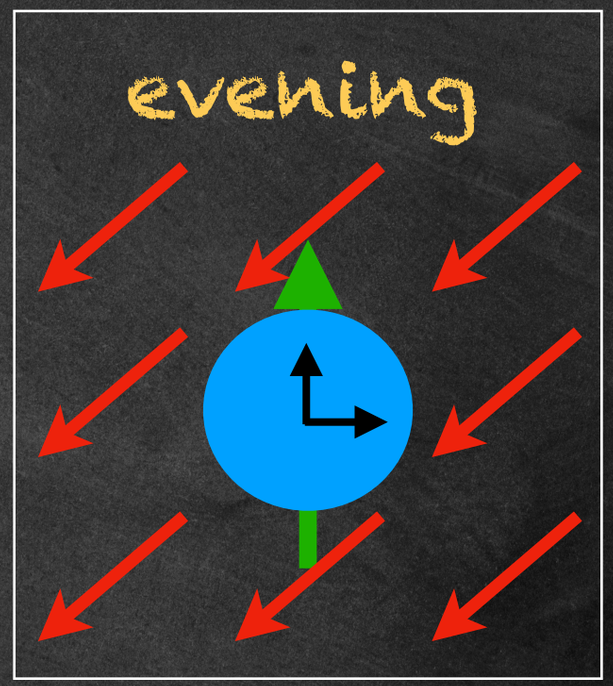
Coefficients	SINDRUM II	COMET	Mu2e
$\lvert(k_{SV}^{(6)})^{T}_{uue\mu}\rvert, \lvert(k_{SA}^{(6)})^{T}_{uue\mu}\rvert$	< 6	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{J}_{uue\mu}\rvert, \lvert(k_{SA}^{(6)})^{J}_{uue\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{Z}_{uue\mu}\rvert, \lvert(k_{SA}^{(6)})^{Z}_{uue\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{T}_{dde\mu}\rvert, \lvert(k_{SA}^{(6)})^{T}_{dde\mu}\rvert$	< 6	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{J}_{dde\mu}\rvert, \lvert(k_{SA}^{(6)})^{J}_{dde\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{Z}_{dde\mu}\rvert, \lvert(k_{SA}^{(6)})^{Z}_{dde\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{SV}^{(6)})^{T}_{sse\mu}\rvert, \lvert(k_{SA}^{(6)})^{T}_{sse\mu}\rvert$	< 10	< 2	< 0.4
$\lvert(k_{SV}^{(6)})^{J}_{sse\mu}\rvert, \lvert(k_{SA}^{(6)})^{J}_{sse\mu}\rvert$	< 15	< 2	< 0.4
$\lvert(k_{SV}^{(6)})^{Z}_{sse\mu}\rvert, \lvert(k_{SA}^{(6)})^{Z}_{sse\mu}\rvert$	< 15	< 2	< 0.4
$\lvert(k_{VS}^{(6)})^{T}_{uue\mu}\rvert, \lvert(k_{VP}^{(6)})^{T}_{uue\mu}\rvert$	< 30	< 4	< 0.8
$\lvert(k_{VS}^{(6)})^{T}_{dde\mu}\rvert, \lvert(k_{VP}^{(6)})^{T}_{dde\mu}\rvert$	< 30	< 4	< 0.7
$\lvert(k_{ST}^{(6)})^{TJ}_{uue\mu}\rvert, \lvert(k_{ST}^{(6)})^{JZ}_{uue\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{ST}^{(6)})^{TZ}_{uue\mu}\rvert, \lvert(k_{ST}^{(6)})^{XY}_{uue\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{ST}^{(6)})^{TJ}_{dde\mu}\rvert, \lvert(k_{ST}^{(6)})^{JZ}_{dde\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{ST}^{(6)})^{TZ}_{dde\mu}\rvert, \lvert(k_{ST}^{(6)})^{XY}_{dde\mu}\rvert$	< 7	< 1	< 0.2
$\lvert(k_{ST}^{(6)})^{TJ}_{sse\mu}\rvert, \lvert(k_{ST}^{(6)})^{JZ}_{sse\mu}\rvert$	< 15	< 2	< 0.4
$\lvert(k_{ST}^{(6)})^{TZ}_{sse\mu}\rvert, \lvert(k_{ST}^{(6)})^{XY}_{sse\mu}\rvert$	< 15	< 2	< 0.4
$\lvert(k_{VV}^{(6)})^{TT}_{uue\mu}\rvert, \lvert(k_{VA}^{(6)})^{TT}_{uue\mu}\rvert$	< 20	< 4	< 0.7
$\lvert(k_{VV}^{(6)})^{TJ}_{uue\mu}\rvert, \lvert(k_{VA}^{(6)})^{TJ}_{uue\mu}\rvert$	< 25	< 4	< 0.7
$\lvert(k_{VV}^{(6)})^{TZ}_{uue\mu}\rvert, \lvert(k_{VA}^{(6)})^{TZ}_{uue\mu}\rvert$	< 25	< 4	< 0.7
$\lvert(k_{VV}^{(6)})^{TT}_{dde\mu}\rvert, \lvert(k_{VA}^{(6)})^{TT}_{dde\mu}\rvert$	< 20	< 4	< 0.7
$\lvert(k_{VV}^{(6)})^{TJ}_{dde\mu}\rvert, \lvert(k_{VA}^{(6)})^{TJ}_{dde\mu}\rvert$	< 20	< 4	< 0.7
$\lvert(k_{VV}^{(6)})^{TZ}_{dde\mu}\rvert, \lvert(k_{VA}^{(6)})^{TZ}_{dde\mu}\rvert$	< 20	< 4	< 0.7
$\lvert(k_{VT}^{(6)})^{TTJ}_{uue\mu}\rvert, \lvert(k_{VT}^{(6)})^{TJZ}_{uue\mu}\rvert$	< 25	< 4	< 0.7
$\lvert(k_{VT}^{(6)})^{TTZ}_{uue\mu}\rvert, \lvert(k_{VT}^{(6)})^{TXY}_{uue\mu}\rvert$	< 25	< 4	< 0.7
$\lvert(k_{VT}^{(6)})^{TTJ}_{dde\mu}\rvert, \lvert(k_{VT}^{(6)})^{TJZ}_{dde\mu}\rvert$	< 20	< 4	< 0.7
$\lvert(k_{VT}^{(6)})^{TTZ}_{dde\mu}\rvert, \lvert(k_{VT}^{(6)})^{TXY}_{dde\mu}\rvert$	< 20	< 4	< 0.7

time-dependent signals

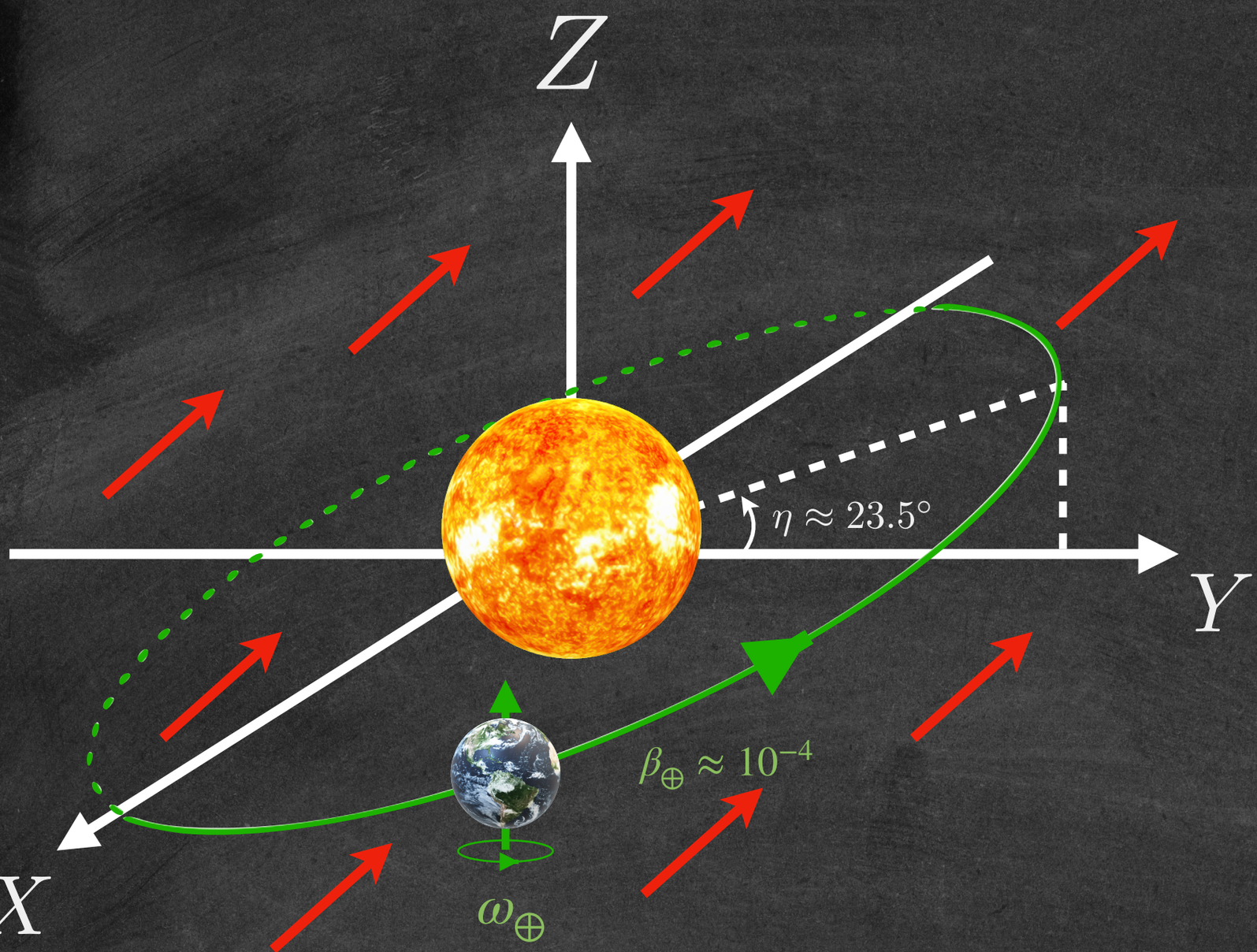


lab frame

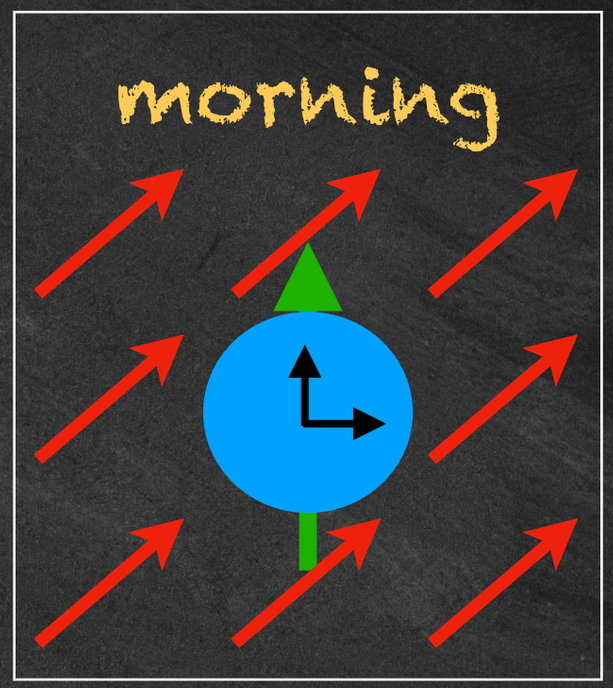


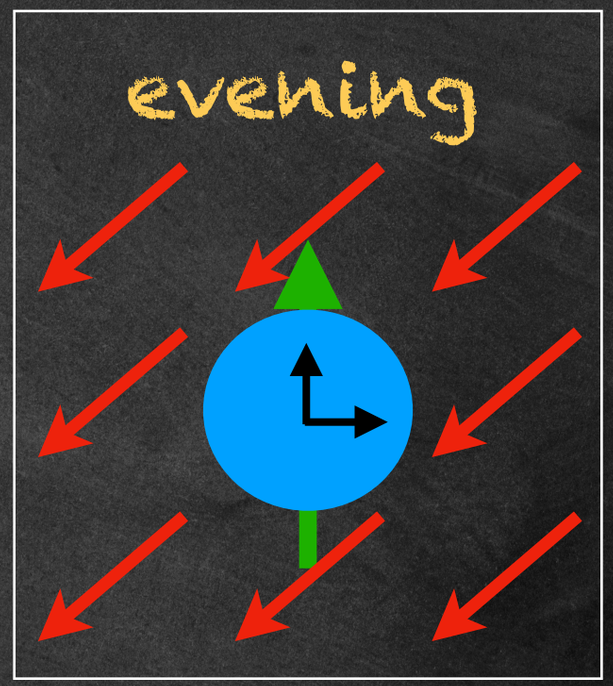


time-dependent signals



lab frame





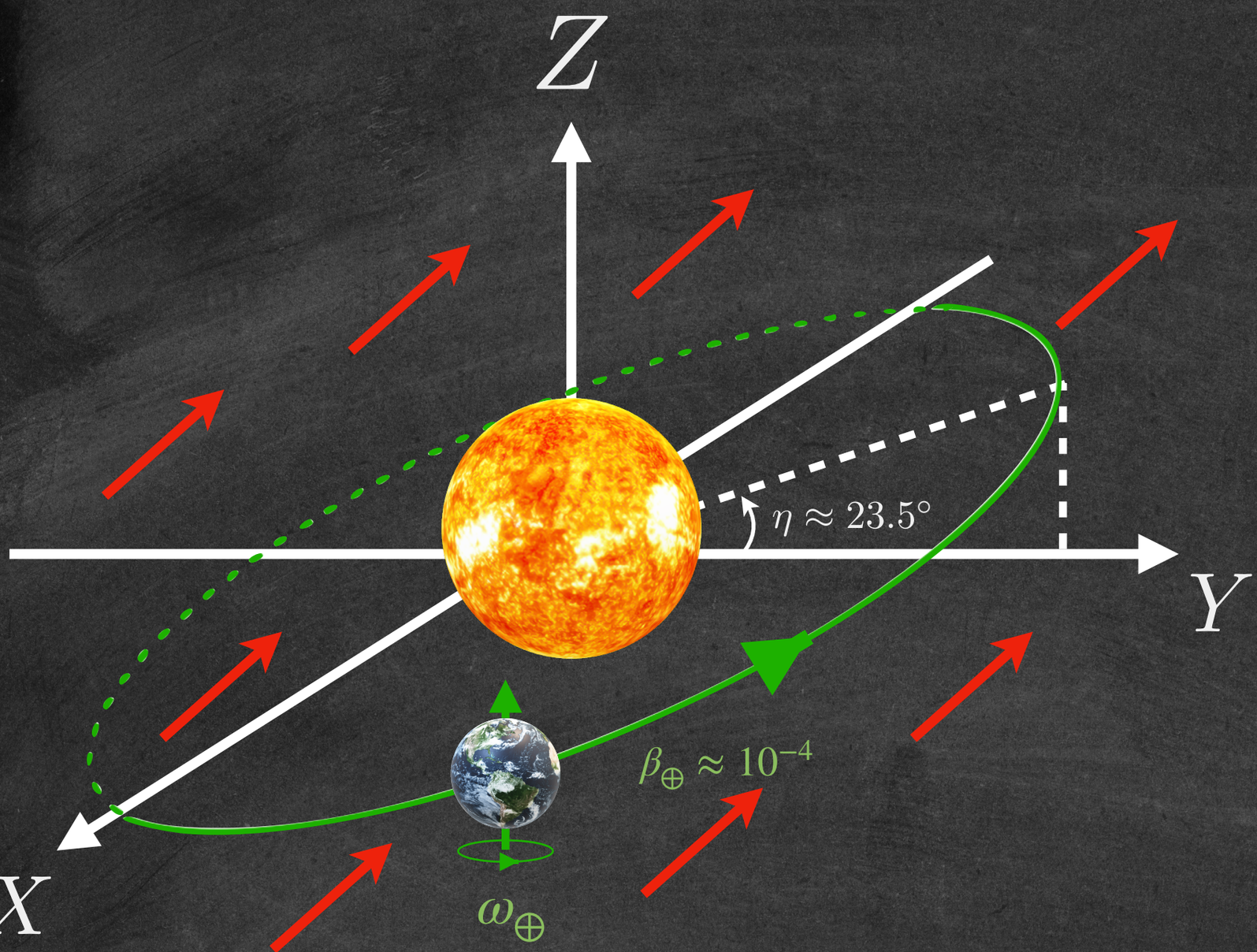
colatitude event time

e.g.

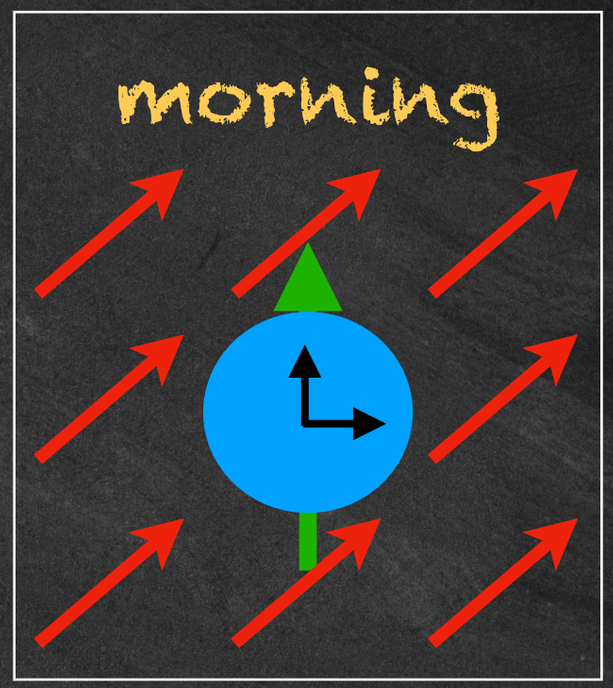
$$R_{\mu e} = R_{\mu e}(\chi, \psi, \omega_\oplus T_\oplus)$$

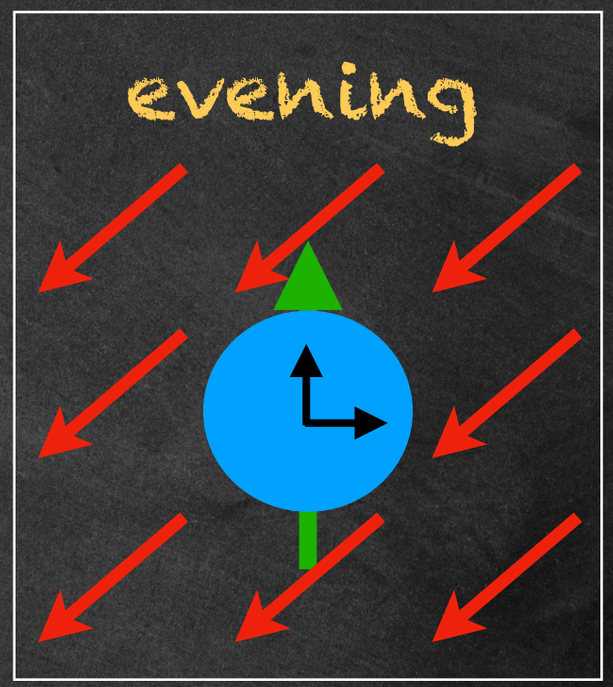
beam direction

time-dependent signals



lab frame





colatitude event time

e.g.

$$R_{\mu e} = R_{\mu e}(\chi, \psi, \omega_\oplus T_\oplus)$$

beam direction

never tested!