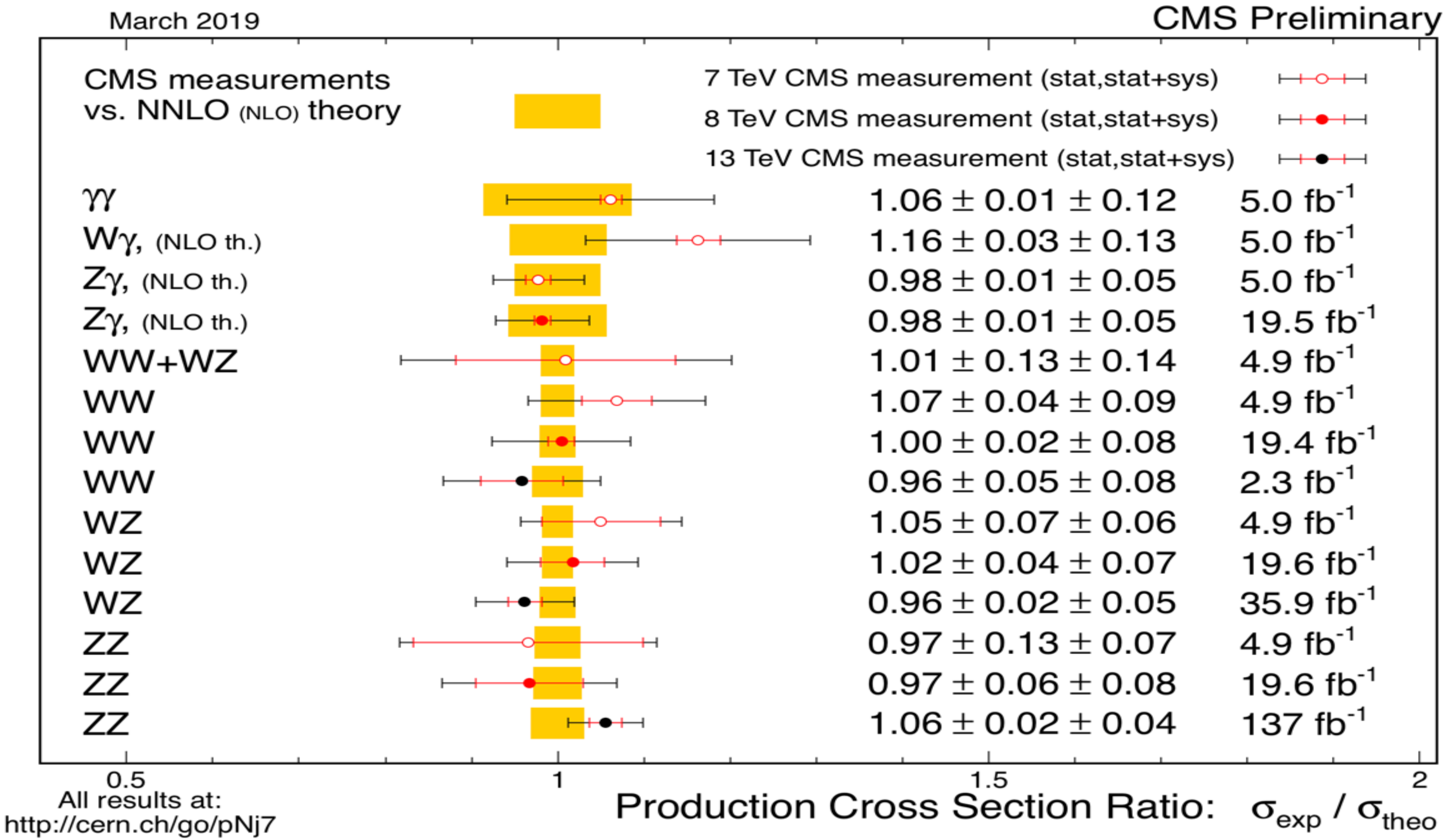
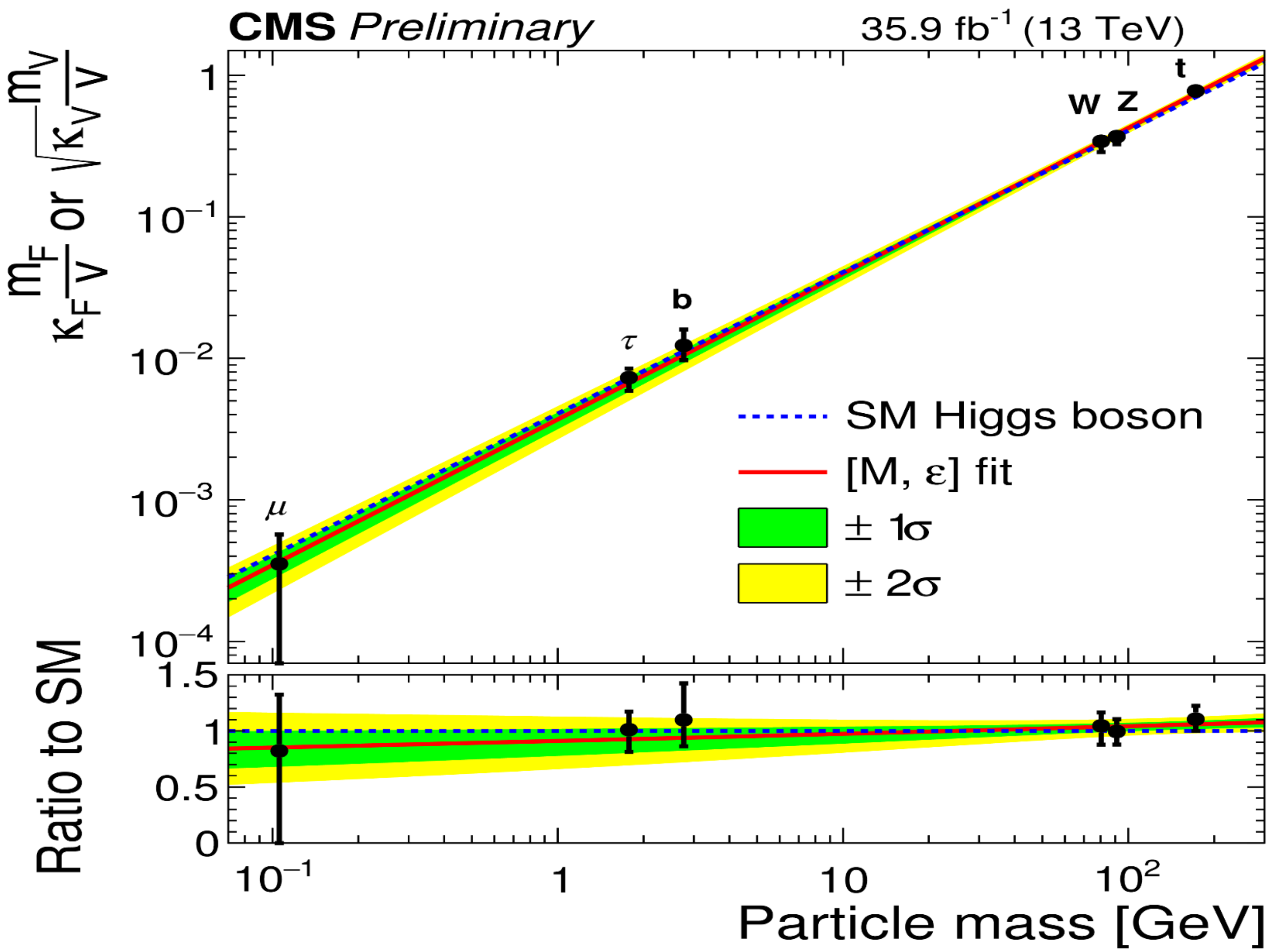
CHARGE CONSERVATION AND EMERGENT GRAVITY

Durmuş Demir

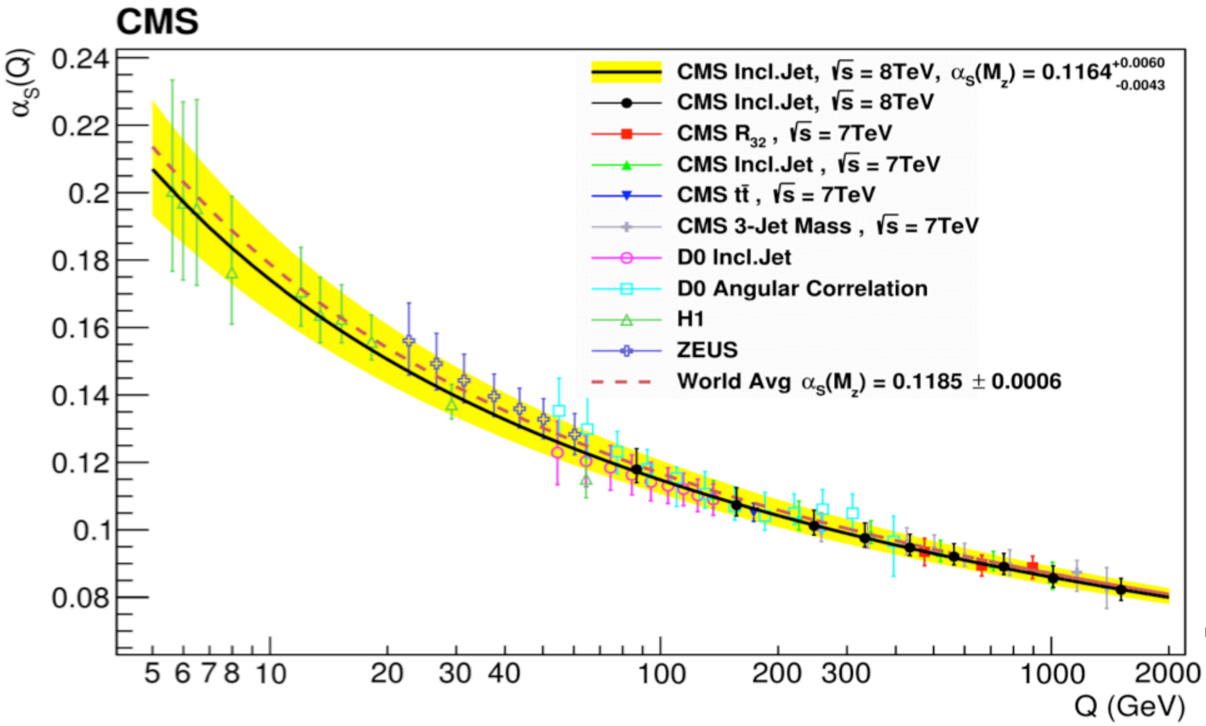
Production x-sections follow the SM:

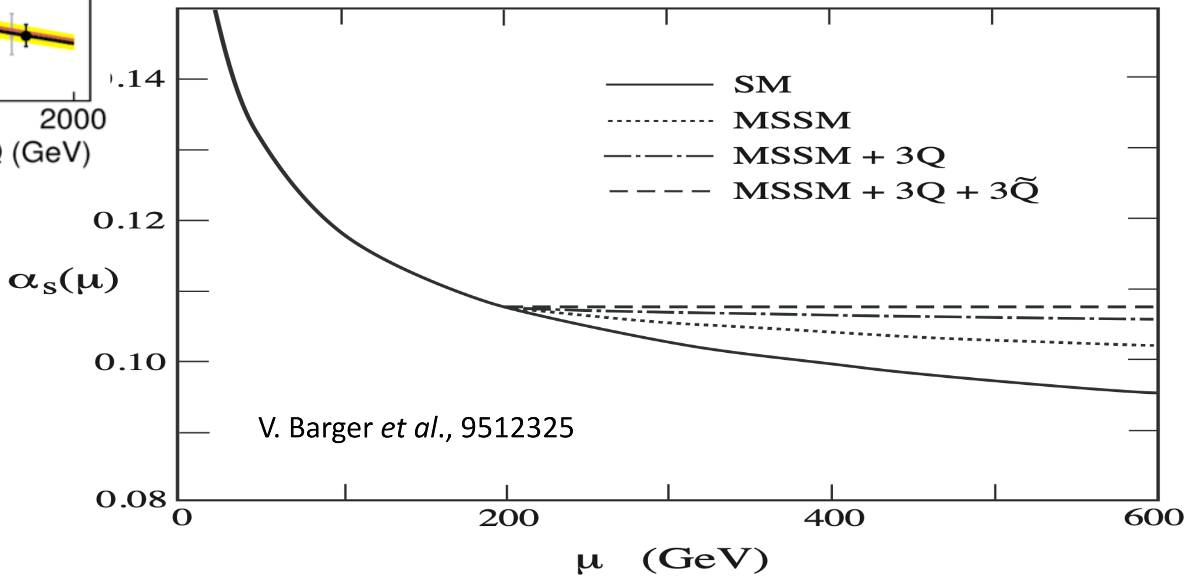


Higgs couplings follow the SM:

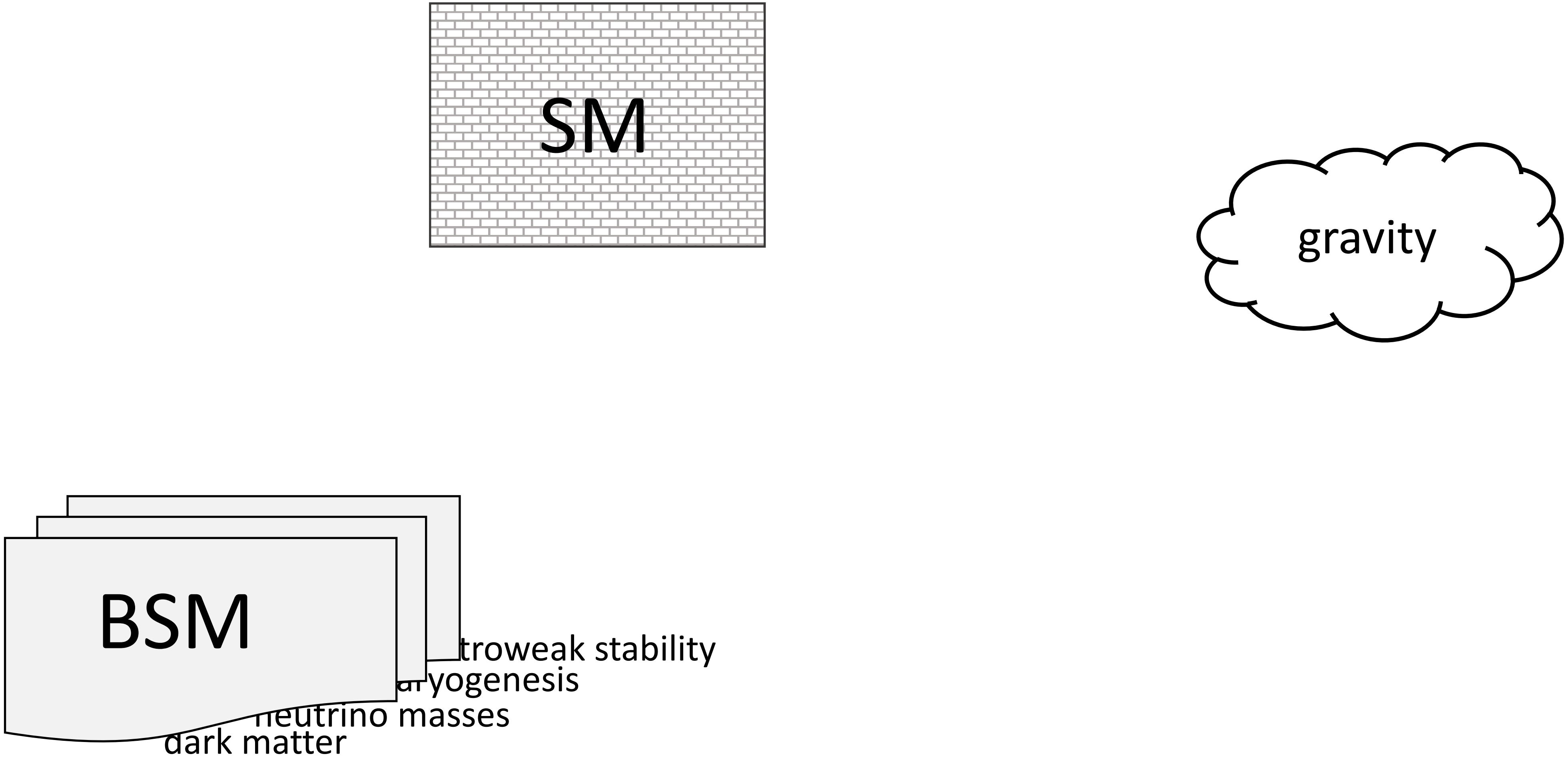


There exist no new colored particles in the TeV domain:

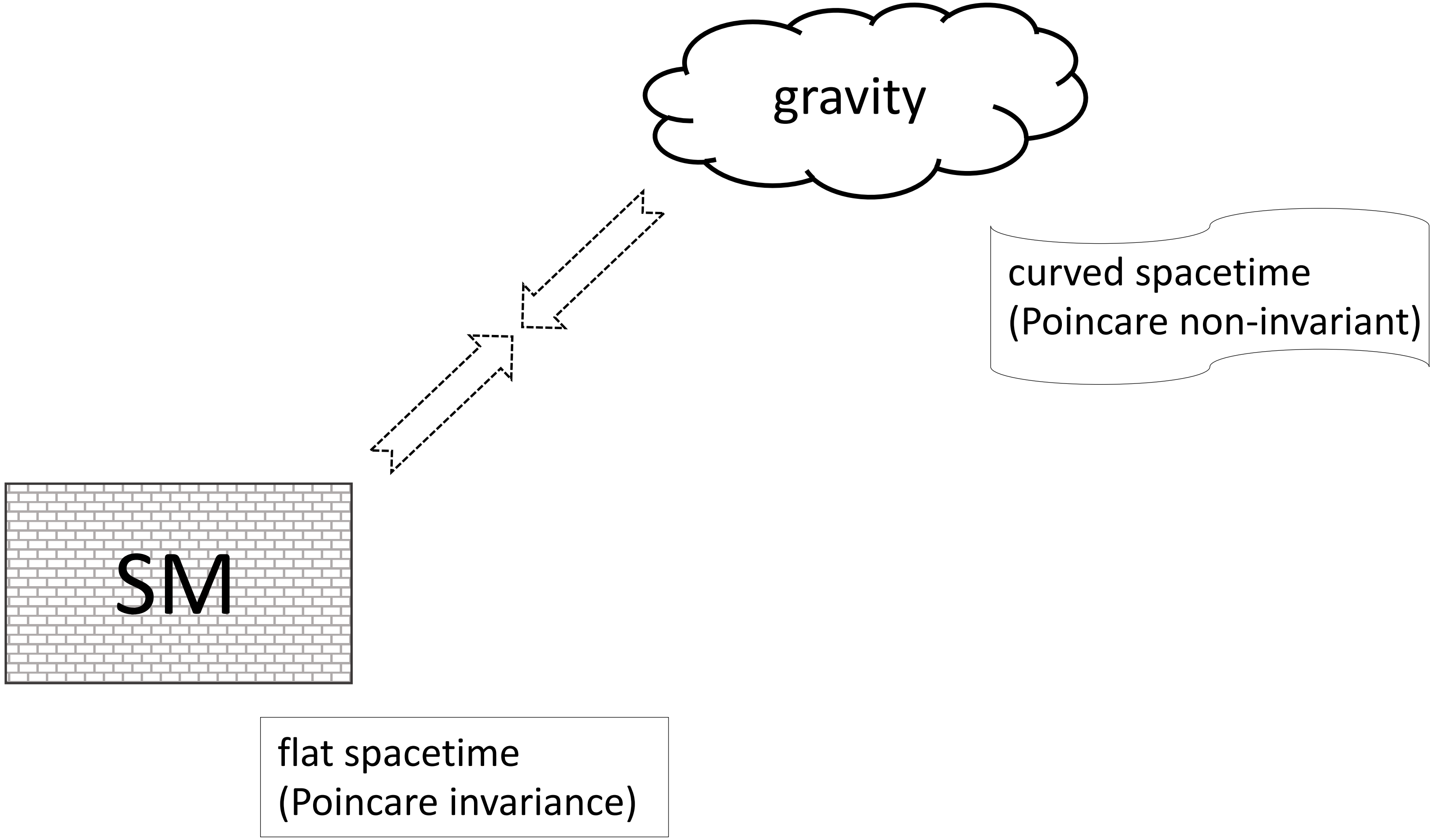




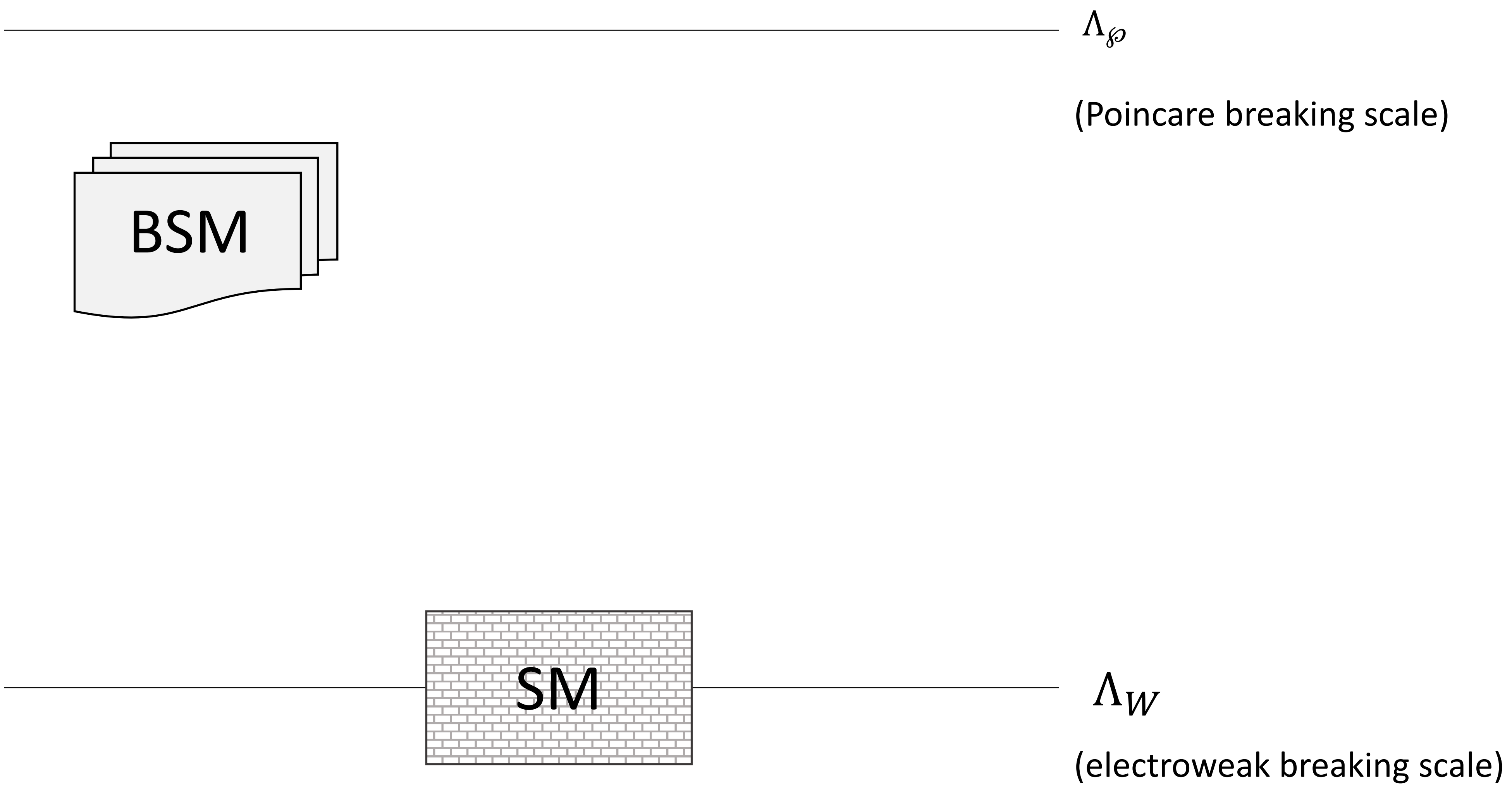
But, the SM still needs be extended for various physical reasons:

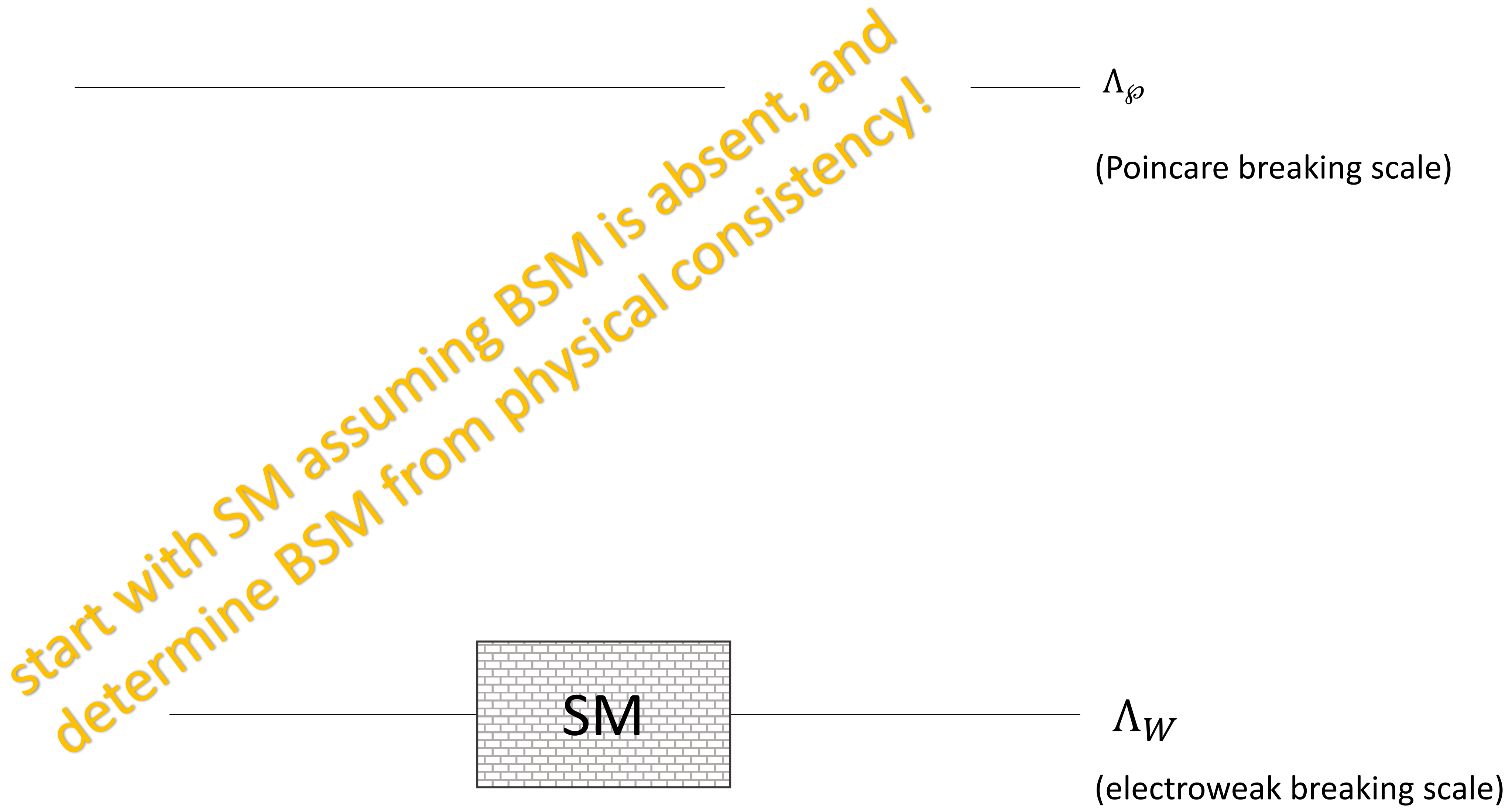


Reconciling SM with GR is an intricate problem.

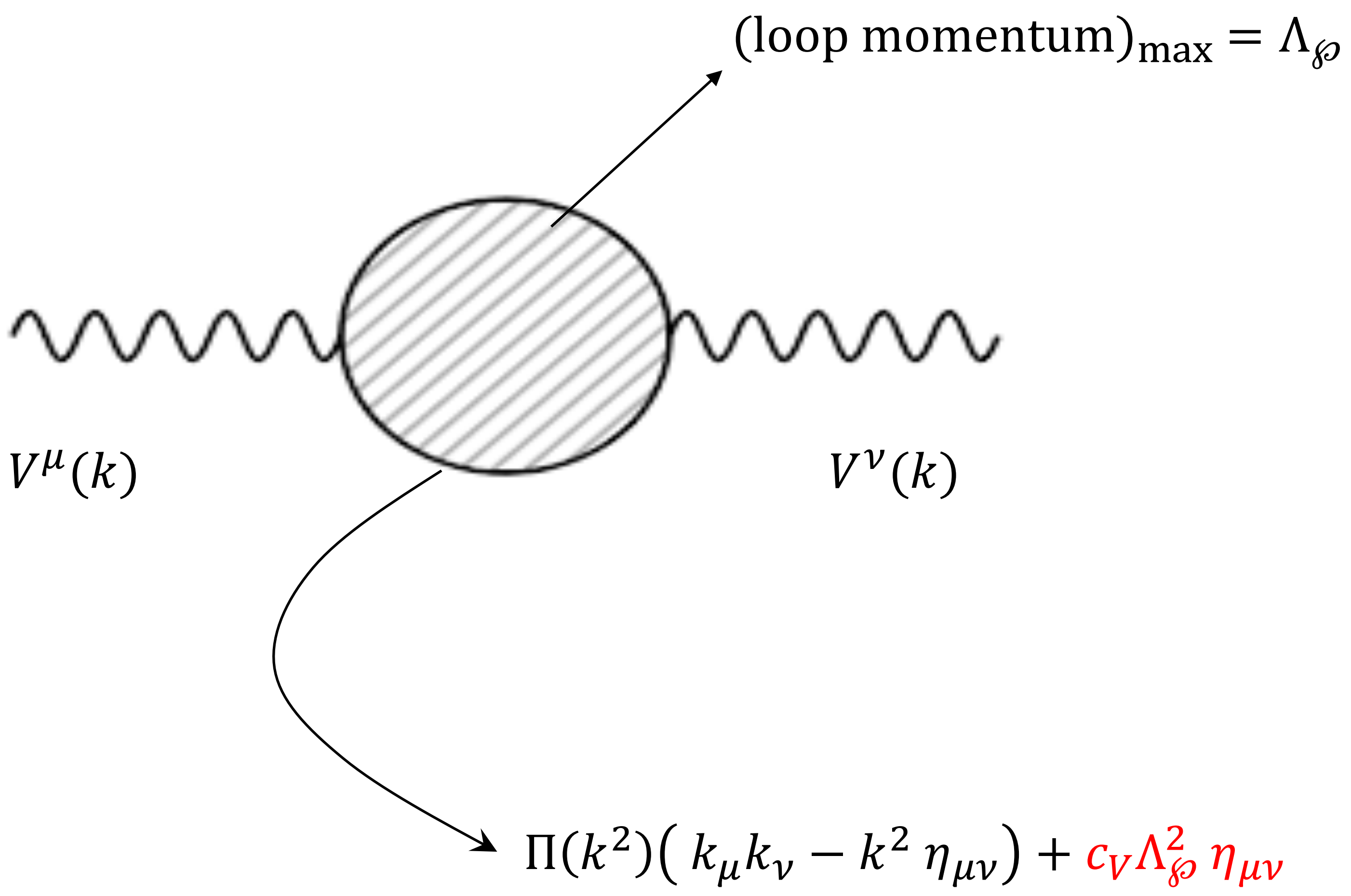


(Wald, arXiv:0907.0416, '09)


$\Lambda_{\wp}$
(Poincare breaking scale)
BSM
SM
Λ_W
(electroweak breaking scale)

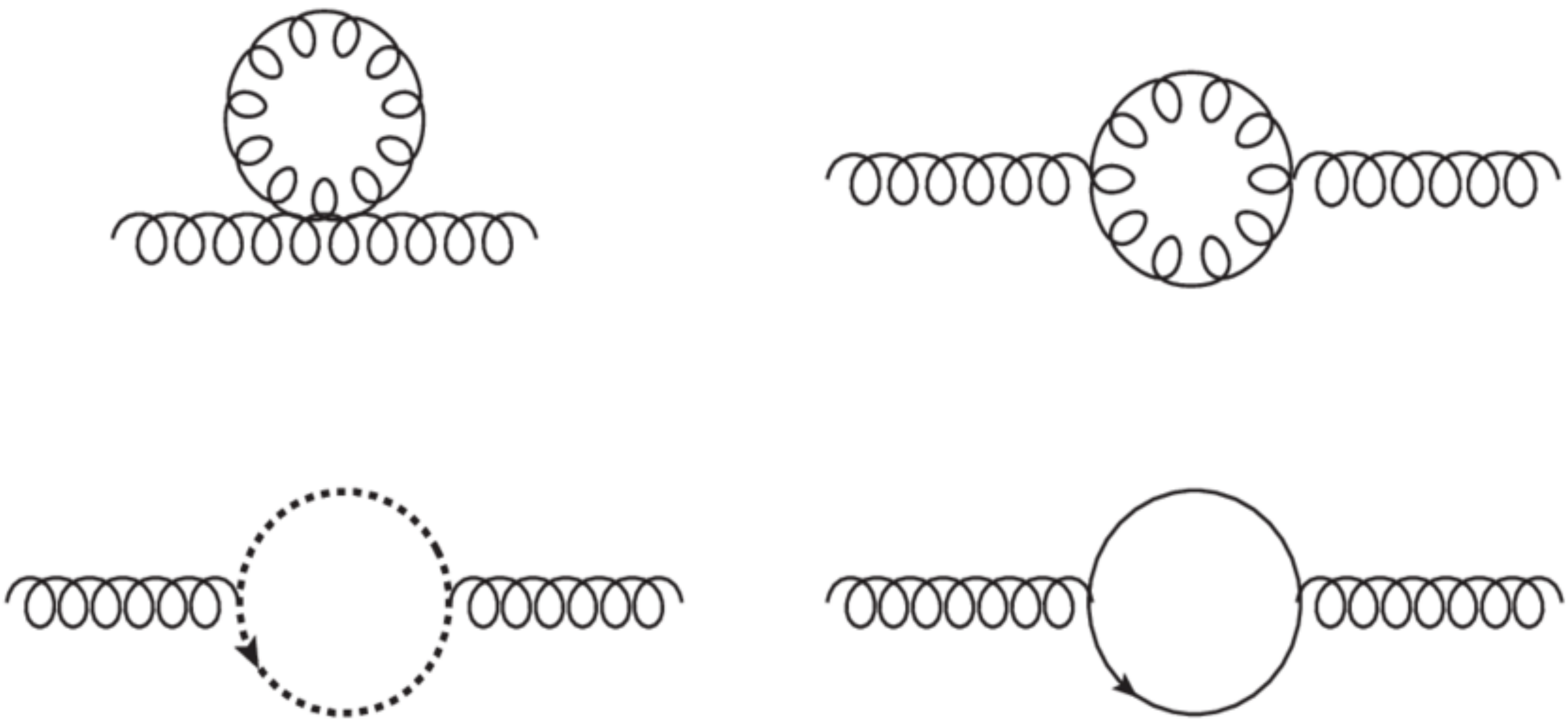

start with SM assuming BSM is absent, and
determine BSM from physical consistency!
$\Lambda_{\wp}$
(Poincare breaking scale)
SM
Λ_W
(electroweak breaking scale)

All loop momenta are cut off at $\Lambda_{\wp}$. Then all the bosons, including the gauge bosons, acquire $\mathcal{O}(\Lambda_{\wp}^2)$ masses:



(D'Attanasio & Morris, hep-ph/9602156, '96)

(Peskin & Schroeder, QFT book, '95)



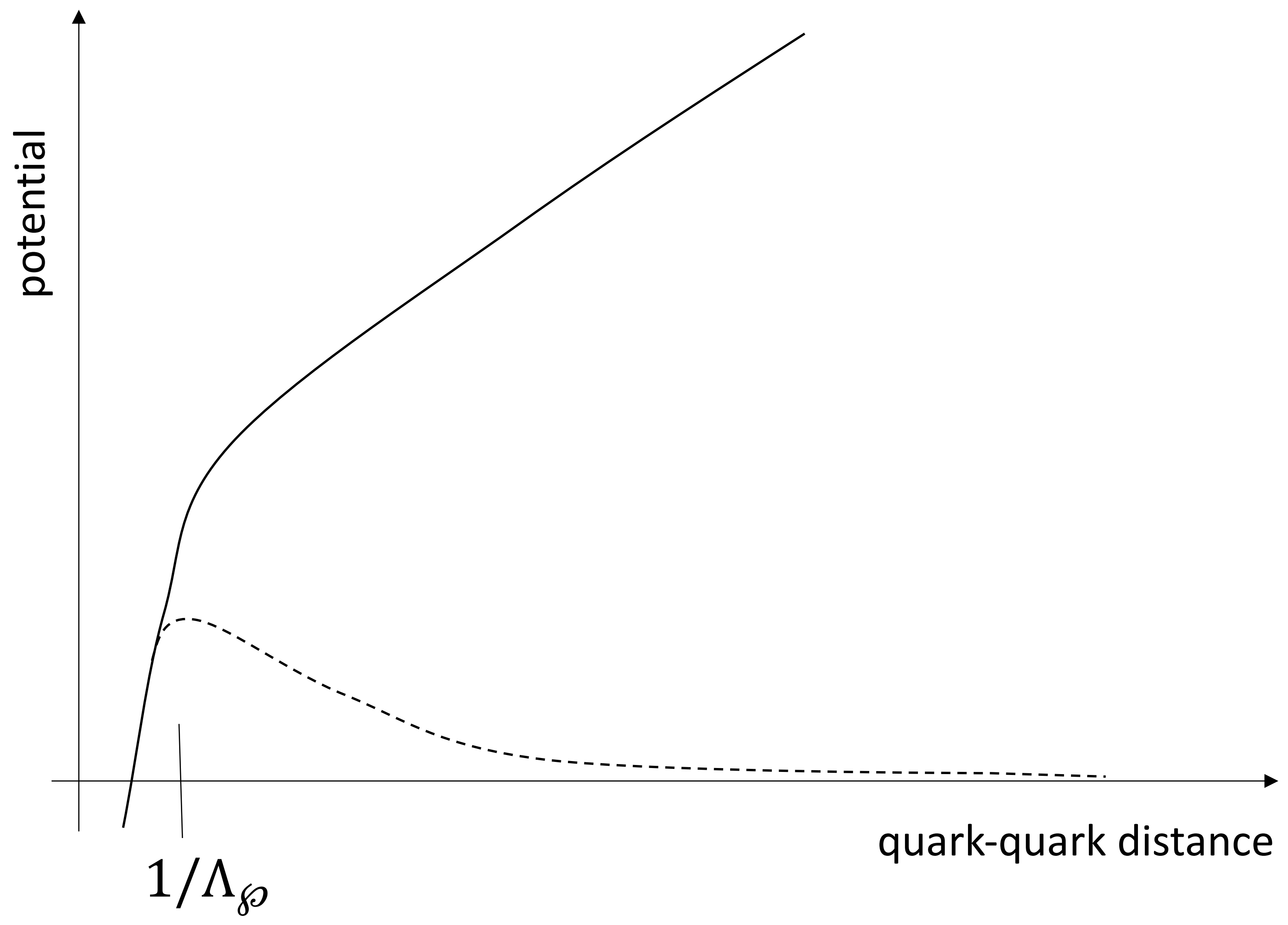
(Haque, 2014)

The SM effective action contains then a «hard mass term» for each gauge boson:

$$\delta S_V(\eta, \Lambda_{\wp}) = \int d^4x \, \sqrt{-\eta} \; c_V \, \Lambda_{\wp}^2 \, \mathrm{tr}\left[V_\mu \, V^\mu\right] \; + \; 0 \, . \log \Lambda_{\wp} \; + \; 0 \, . \text{(finite terms)}$$

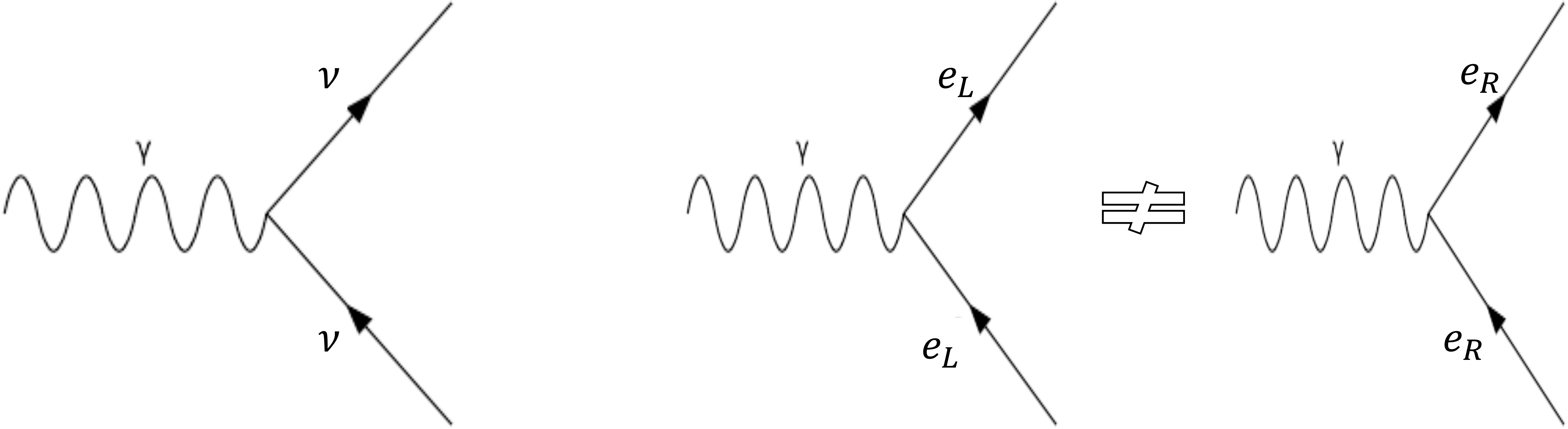
Gauge Boson (V^μ)	Loop Factor (c_V)	Broken Gauge Symmetry
$g_\mu^{a=1,\ldots,8}$	$c_g = \frac{21}{16\,\pi^2} g_s^2$	$SU(3)_C$
$W_\mu^{i=1,\ldots,3}$	$c_W = \frac{21}{16\,\pi^2} g_2^2$	$SU(2)_L$
B_μ	$c_B = \frac{39}{32\pi^2} g_Y^2$	$U(1)_Y$

Color breaking demolishes confinement and destructs therefore all the hadronic structures.



Isospin is broken explicitly and spontaneously (by $\langle H \rangle \neq 0$) . Electromagnetism is broken by $c_W \neq 2\, c_B$.

$$\tan 2\tilde{\theta}_W = \frac{(g_2^2 - g_Y^2)\, \langle H \rangle^2}{(g_2^2 - g_Y^2)\langle H \rangle^2 + 2(c_W - 2\, c_B)\Lambda_{\wp}^2} \tan 2\theta_W \implies \partial_\mu J^\mu \neq 0$$



(Okun&Voloshin, '77; Ignatiev&Joshi, '96)

How to prevent charge and color breaking (CCB)? How to sweep away $\delta S_V(\eta, \Lambda_{\wp})$?

Start with the rather trivial identity:

$$\delta S_V \equiv -I_V + \delta S_V + I_V$$

in which

$$I_V(\eta) = \int d^4x \sqrt{-\eta}\, \frac{c_V}{2} \mathrm{tr}\left[\mathrm{V}_{\mu\nu}\, \mathrm{V}^{\mu\nu}\right]$$

is a kinetic structure involving the loop factor c_V.

(DD, arXiv:1901.07244, ’19; arXiv:1605.00377, ‘16)

Now, expand the second I_V via by-parts integration and combine the result with $\delta S_V(\eta, \Lambda_\wp)$.
This leads to the renewed $\delta S_V(\eta, \Lambda_\wp)$:

$$\delta S_V(\eta, \Lambda_\wp) \equiv -I_V(\eta) + \int d^4x \sqrt{-\eta}\, c_V \mathrm{tr}[V^\mu(-D^2_{\mu\nu} + \Lambda^2_\wp\, \eta_{\mu\nu})V^\nu + \partial_\mu(V_\nu V^{\mu\nu})]$$

in which D_μ is gauge-covariant derivative, and

$$D^2_{\mu\nu} = D^2\eta_{\mu\nu} - D_\mu D_\nu - V_{\mu\nu}$$

is the usual inverse V_μ propagator.

The first step is to go to curved spacetime of a putative metric $g_{\mu\nu}$.
Thus, in view of the general covariance, let

$$\boldsymbol{\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}}$$

under which

$$\partial_\mu \rightarrow \nabla_\mu,\; D_\mu \rightarrow \mathcal{D}_\mu,\;\; D^2_{\mu\nu} \rightarrow \mathcal{D}^2_{\mu\nu} = \mathcal{D}^2 g_{\mu\nu} - \mathcal{D}_\mu \mathcal{D}_\nu - V_{\mu\nu}$$

so that $\delta S_V(\eta, \Lambda_\wp)$ changes to

$$\delta S_V(g, \Lambda_\wp) \equiv -I_V(g) \; + \int d^4x \sqrt{-g}\; c_V \mathrm{tr}[V^\mu(-\mathcal{D}^2_{\mu\nu} + \Lambda^2_\wp\, g_{\mu\nu})V^\nu + \nabla_\mu(V_\nu V^{\mu\nu})]$$

in which the covariant derivative ∇_μ, satisfying $\nabla_\mu\, g_{\alpha\beta} = 0$, is that of the the Levi-Civita connection

$${}^g\Gamma^\lambda_{\mu\nu} = \frac{1}{2}\, g^{\lambda\rho}(\partial_\mu g_{\nu\rho} + \partial_\nu g_{\rho\mu} - \partial_\rho g_{\nu\mu})$$

It is natural to associate the Poincare breaking scale $\Lambda_{\wp}$ to spacetime curvature.
It is thus conceivable to extend the metrical map

$$\boldsymbol{\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}}$$

by the curvature mape

$$\Lambda_{\wp}^2 \, g_{\mu\nu} \hookrightarrow R_{\mu\nu}({}^{g}\Gamma)$$

where $R_{\mu\nu}(\Gamma(g))$ is the Ricci curvature of the Levi-Civita connection.
These two maps do indeed nullify the problematic gauge boson mass action

$$\delta S_V(g,R) \equiv -I_V(g) + \int d^4x \sqrt{-g}\, \mathrm{c_V tr}\left[V^\mu\left(-\mathcal{D}_{\mu\nu}^2 + R_{\mu\nu}({}^{g}\Gamma)\right)V^\nu + \nabla_\mu(V_\nu V^{\mu\nu})\right]$$

$$\equiv -I_V(g) + I_V(g) = 0\,!$$

if c_V is held unchanged under curvature map! This seems to yield precisely what is sought! The CCB seems over !

It is natural to associate the Poincare breaking scale $\Lambda_{\wp}$ to spacetime curvature.
It is thus conceivable to extend the metrical map

$$\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}$$

by the curvature mape

$$\Lambda_{\wp}^2\, g_{\mu\nu} \hookrightarrow R_{\mu\nu}({}^{g}\Gamma)$$

where $R_{\mu\nu}(\Gamma(g))$ is ... e Levi-Civita connection.
These two maps ... oblematic gauge boson mass action

$$\delta S_V(g, R ... \sqrt{-g}\, c_V \mathrm{tr}\left[V^{\mu}\left(-\mathcal{D}_{\mu\nu}^2 + R_{\mu\nu}({}^{g}\Gamma)\right)V^{\nu} + \nabla_{\mu}(V_{\nu}V^{\mu\nu})\right]$$

$$\equiv ... I_V(g) = 0 \,!$$

if c_V is held unchanged under curvature map! This seems to yield precisely what is sought! The CCB seems over !

associating Poincare breaking with curvature is highly natural but these two maps contradict!

How to prevent contradiction ? How to make curvature approach work? One possibility is to replace the Levi-Civita connection ${}^{g}\Gamma^{\lambda}_{\mu\nu}$ by an "affine connection" $\Gamma^{\lambda}_{\mu\nu}$. Namely, assume now that the metrical map

$$\boldsymbol{\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}}$$

is followed by an «affine curvature map» of the form

$$\boldsymbol{\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)}$$

where $\mathbb{R}_{\mu\nu}(\Gamma)$ is the Ricci curvature of the affine connection $\Gamma^{\lambda}_{\mu\nu}$. These two maps now lead to

$$\delta S_V(g,\mathbb{R}) \equiv -I_V(g) \; + \int d^4x\, \sqrt{-g}\; \mathrm{c_V}\, \mathrm{tr}\Big[V^{\mu}\Big(-\mathcal{D}^2_{\mu\nu} + \mathbb{R}_{\mu\nu}(\Gamma)\Big)V^{\nu} + \nabla_{\mu}(V_{\nu}V^{\mu\nu})\Big]$$

$$\equiv \int d^4x\, \sqrt{-g}\; c_V \mathrm{tr}\Big[V^{\mu}\Big(\mathbb{R}_{\mu\nu}(\Gamma) \; - R_{\mu\nu}({}^{g}\Gamma)\Big)V^{\nu}\Big]$$

if c_V is held unchanged while $\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)$.

How to prevent contradiction ? How to make curvature approach work? One poss... ...eplace the Levi-Civita connection ${}^{g}\Gamma^{\lambda}_{\mu\nu}$ by an "affine connection" $\Gamma^{\lambda}_{\mu\nu}$. Namely, assume ... ...ical map

$$\boldsymbol{\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}}$$

is followed by an «affine curvature map» of the for...

$$\boldsymbol{\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)}$$

where $\mathbb{R}_{\mu\nu}(\Gamma)$ is the Ricci cur... ...e connection $\Gamma^{\lambda}_{\mu\nu}$. These two maps now lead to

$$\delta S_V(g, \mathbb{R}) \equiv - \ldots \sqrt{-g}\, c_V\, \mathrm{tr}\left[V^{\mu}\left(-\mathcal{D}^2_{\mu\nu} + \mathbb{R}_{\mu\nu}(\Gamma)\,\right)V^{\nu} + \nabla_{\mu}\left(V_{\nu}V^{\mu\nu}\right)\right]$$

$$\ldots \sqrt{-g}\; c_V \mathrm{tr}\left[V^{\mu}\left(\mathbb{R}_{\mu\nu}(\Gamma) \; - R_{\mu\nu}({}^{g}\Gamma)\,\right)V^{\nu}\right]$$

...eld unchanged while $\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)$.

$\log \frac{\Lambda_U}{\Lambda_W}$ must be held unchanged while $\Lambda^2_U\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)$!

How to prevent contradiction ? How to make curvature approach work? One possibility is to replace the Levi-Civita connection ${}^{g}\Gamma^{\lambda}_{\mu\nu}$ by an "affine connection" $\Gamma^{\lambda}_{\mu\nu}$. Namely, assume no… e metrical map

$$\eta_{\mu\nu} \hookrightarrow g_{\mu\nu}$$

is followed by an «affine curvature map» of the form

$$\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)$$

where $\mathbb{R}_{\mu\nu}(\Gamma)$ is the Ricci curv… …affine connection $\Gamma^{\lambda}_{\mu\nu}$. These two maps now lead to

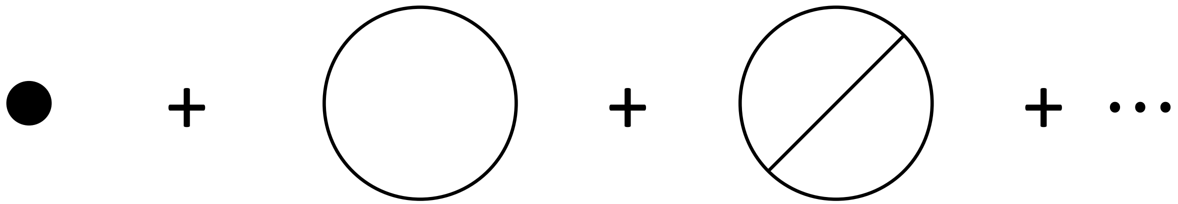
$$\delta S_V(g,\mathbb{R}) \equiv -I_V \ldots x\, \sqrt{-g}\, c_V\, \mathrm{tr}\left[V^{\mu}\left(-\mathcal{D}^2_{\mu\nu} + \mathbb{R}_{\mu\nu}(\Gamma)\right)V^{\nu} + \nabla_{\mu}(V_{\nu}V^{\mu\nu})\right]$$

$$\ldots x\, \sqrt{-g}\, c_V \mathrm{tr}\left[V^{\mu}\left(\mathbb{R}_{\mu\nu}(\Gamma) - R_{\mu\nu}({}^{g}\Gamma)\right)V^{\nu}\right]$$

CCB can be suppressed only if $\mathbb{R}_{\mu\nu}(\Gamma) \to R_{\mu\nu}({}^{g}\Gamma)$!

if c_V is held unchanged while $\Lambda^2_{\wp}\, g_{\mu\nu} \hookrightarrow \mathbb{R}_{\mu\nu}(\Gamma)$.

$\Gamma^{\lambda}_{\mu\nu}$ dynamics is set by curvature sector, and curvature sector stems from corrections to the vacuum and Higgs sectors:



$$\delta S_{OH}(\eta, \Lambda_{\wp}) = -\int d^4x \sqrt{-\eta}\, \{c_4\, \mathrm{str}[1]\Lambda_{\wp}^4 + c_m\, \mathrm{str}[m^2]\Lambda_{\wp}^2 + c_h\, \Lambda_{\wp}^2\, h^2\}$$

$$c_m = 2\, c_4 = \frac{1}{32\pi^2}$$

$$c_h = \frac{1}{32\pi^2\Lambda_W^2}\,(2\, m_h^2 + \mathrm{str}[m^2])$$

CCP

GHP

Employing the metrical and curvature maps, the vacuum and Higgs sectors lead to the curvature sector:

$$\delta S_{OH}(g,\mathbb{R}) = -\int d^4x \sqrt{-g}\, \{\frac{c_4}{16}\ \mathrm{str}[1](\mathbb{R}(g,\Gamma))^2 + \frac{c_m}{4}\, \mathrm{str}[m^2]\mathbb{R}(g,\Gamma) + \frac{c_h}{4}\, \mathbb{R}(g,\Gamma)h^2\}$$

$$\mathbb{R}(g,\Gamma) = g^{\mu\nu}\ \mathbb{R}_{\mu\nu}(\Gamma)$$

would be M_{Pl}^2 if it were not wrong in size ($\mathrm{str}[m^2] \sim \Lambda_W^2$) and sign ($\mathrm{str}[m^2] < 0$) !

Higgs-curvature coupling $\zeta = \frac{c_h}{2}$

Employing the metrical and curvature maps, the vacuum and Higgs sectors lead to the curvature sector:

$$\delta S_{OH}(g,\mathbb{R}) = -\int d^4x\,\sqrt{-g}\,\{\frac{c_4}{16}\,\mathrm{str}[1](\mathbb{R}(g,\Gamma))^2 + \frac{c_m}{\cdots}\cdots\mathbb{R}(g,\Gamma) + \frac{c_h}{4}\mathbb{R}(g,\Gamma)h^2\}$$

$$\mathbb{R}(g,\Gamma) = g^{\mu\nu}\,\mathbb{R}_{\mu\nu}(\Gamma)$$

would be M_{Pl}^2 if it were not wrong in size ($\mathrm{str}[m^2] \sim \Lambda_W^2$) and sign ($\mathrm{str}[m^2] < 0$) !

Higgs-curvature coupling $\zeta = \frac{c_h}{2}$

gravitational scale M_{Pl} necessitates a BSM sector!

The BSM sector must have requisite degrees of freedom to generate M_{Pl} correctly.

- BSM sector is spanned by scalars h', gauge fields V'_μ, fermions f', $\cdots$
- SM+BSM is spanned by scalars $\mathcal{H} = \{h, h'\}$, gauge fields $\mathcal{V}_\mu = \{V_\mu, V'_\mu\}, \cdots$
- BSM mass spectrum is $m' = \{m_{h'}\ , m_{V'}\ , m_{f'}\ , \cdots\}$
- SM+BSM mass spectrum is $\mathcal{M} = \{m_h\ , m_V\ , \ m_f\ , \ m_{h'}\ , m_{V'}\ , m_{f'}\ , \cdots\}$
- Then, fundamental scale of gravity takes the form

$$M_{Pl}^2 = \frac{1}{2}\left(c_{\rm m}\, {\rm str}[{\rm m}^2] + c_{m'}\, {\rm str}[m'^2]\right) \rightarrow \frac{1}{64\pi^2}\ {\rm str}[\mathcal{M}^2]$$

scale or stack of m' sets M_{Pl}

one-loop

The complete curvature sector, reinstated with BSM effects, can be put into the form:

$$\delta S(g,\mathbb{R}) = \int d^4x\,\sqrt{-g}\,\{-Q^{\mu\nu}\mathbb{R}_{\mu\nu}(\Gamma) + \frac{c_4}{16}\,\mathrm{str}[1]\big(\mathbb{R}(g,\Gamma)\big)^2 - c_V R_{\mu\nu}({}^g\Gamma)\mathrm{tr}[\mathcal{V}^\mu\mathcal{V}^\nu]\}$$

$$Q^{\mu\nu} = \left(\frac{M_{Pl}^2}{2} + \frac{c_4}{8}\,\mathrm{str}[1]\mathbb{R}(g,\Gamma)\right)g^{\mu\nu} + \mathcal{K}^{\mu\nu}$$

$$\mathcal{K}^{\mu\nu} = \frac{c_{\mathcal{H}}}{4}\mathcal{H}^2 g^{\mu\nu} - c_{\mathcal{V}}\,\mathrm{tr}[\mathcal{V}^\mu\mathcal{V}^\nu]$$

At last the $\Gamma^{\lambda}_{\mu\nu}$ dynamics! $\Gamma^{\lambda}_{\mu\nu}$ obeys the equation of motion:

$$^{\Gamma}\nabla_{\alpha}\, Q_{\mu\nu} = 0$$

Its solution is:

$$\Gamma^{\lambda}_{\mu\nu} = {}^{g}\Gamma^{\lambda}_{\mu\nu} + \frac{1}{2}\,(Q^{-1})^{\lambda\rho}\left(\nabla_{\mu}Q_{\nu\rho} + \nabla_{\nu}Q_{\rho\mu} - \nabla_{\rho}Q_{\mu\nu}\right)$$

this solution is actually a non-linear PDE for $\Gamma^{\lambda}_{\mu\nu}$ because $Q_{\mu\nu}$ involves the affine curvature $\mathbb{R}(g,\Gamma) \sim \partial\Gamma + \Gamma\Gamma$

Dropping $\mathcal{H}$ and $\mathcal{V}_\mu$ for simplicity and clarity, the curvature is found to satisfy the equation

$$\mathbb{R} = R - 3\nabla^2 \log(1 + \frac{2\mathrm{str}[1]\mathbb{R}}{M_{Pl}^2}) - \frac{3}{2}\nabla_\mu \log(1 + \frac{2\mathrm{str}[1]\mathbb{R}}{M_{Pl}^2})\nabla^\mu \log(1 + \frac{2\mathrm{str}[1]\mathbb{R}}{M_{Pl}^2})$$

$\mathbb{R}(g,\Gamma) \simeq R(\mathrm{g})$ for $\mathbb{R}(g,\Gamma) \ll M_{Pl}^2$

for $\mathbb{R}(g,\Gamma) \sim M_{Pl}^2$ non-linearities dominate!

At high curvatures gravity may deviate from EH form!

At last the $\Gamma^{\lambda}_{\mu\nu}$ dynamics! It will now be possible to determine if $\Gamma^{\lambda}_{\mu\nu}$ does ind… approach to ${}^{g}\Gamma^{\lambda}_{\mu\nu}$. In this regard, $\Gamma^{\lambda}_{\mu\nu}$ obeys the equation of motion:

$$ {}^{\Gamma}\nabla_{\alpha}\, Q_{\mu\nu} = 0 $$

Its solution is:

$$ \Gamma^{\lambda}_{\mu\nu} = {}^{g}\Gamma^{\lambda}_{\mu\nu} + \frac{1}{\ldots} \ldots {}_{\nu}Q_{\rho\mu} - \nabla_{\rho} Q_{\mu\nu}) $$

GR is guaranteed if $\Gamma^{\lambda}_{\mu\nu}$ contains no geometrical degrees of freedom beyond ${}^{g}\Gamma^{\lambda}_{\mu\nu}$!

this solution is actually a partial differential equation for $\Gamma^{\lambda}_{\mu\nu}$ because $Q_{\mu\nu}$ involves the affine curvature $\mathbb{R}(g,\Gamma) \sim \partial\Gamma + \Gamma\Gamma$

At last the $\Gamma^{\lambda}_{\mu\nu}$ dynamics! It will now be possible to determ... $^{\lambda}$. does indeed approach to ${}^{g}\Gamma^{\lambda}_{\mu\nu}$. In this regard, $\Gamma^{\lambda}_{\mu\nu}$ obeys the equation of motion:

$$ {}^{\Gamma}\nabla_{\alpha}\, Q_{\mu\nu} = 0 $$

Its solution is:

$$ \Gamma^{\lambda}_{\mu\nu} = $$

... and this happens if

$$ str[1] = 0 $$

or equivalently

$$ n^{(b)}_{SM+BSM} = n^{(f)}_{SM+BSM} $$

...n is actually a partial ...ential equation for $\Gamma^{\lambda}_{\mu\nu}$ because $Q_{\mu\nu}$ involves the affine curvature $\mathbb{R}(g,\Gamma) \sim \partial\Gamma + \Gamma\Gamma$

$\Gamma^{\lambda}_{\mu\nu}$ does indeed approach to ${}^{g}\Gamma^{\lambda}_{\mu\nu}$! Indeed, with $\mathrm{str}[1] = 0$, the affine connection takes an algebraic form

$$\Gamma^{\lambda}_{\mu\nu} = {}^{g}\Gamma^{\lambda}_{\mu\nu} + \frac{1}{2}\left(\left(\frac{M_{Pl}^2}{2}g + \mathcal{K}\right)^{-1}\right)^{\lambda\rho}\left(\nabla_{\mu}\mathcal{K}_{\nu\rho} + \nabla_{\nu}\mathcal{K}_{\rho\mu} - \nabla_{\rho}\mathcal{K}_{\mu\nu}\right)$$

$$= {}^{g}\Gamma^{\lambda}_{\mu\nu} + \frac{1}{M_{Pl}^2}\left(\nabla_{\mu}\mathcal{K}_{\nu\rho} + \nabla_{\nu}\mathcal{K}_{\rho\mu} - \nabla_{\rho}\mathcal{K}_{\mu\nu}\right) + \mathcal{O}\left(\frac{\nabla\mathcal{K}^2}{M_{Pl}^4}\right)$$

involves only the scalars $\mathcal{H}$ and gauge bosons $\mathcal{V}_{\mu}$ in SM+BSM!

Corresponding to the affine connection, the affine curvature takes the form

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}(\frac{\nabla^2\mathcal{K}}{M_{Pl}^2})$$

so that the notorious CCB gauge-boson mass action becomes

$$\delta S_V(g,\mathbb{R}) \equiv \int d^4x\, \sqrt{-g}\, c_V \mathrm{tr}\left[V^\mu\left(\mathbb{R}_{\mu\nu}(\Gamma) - R_{\mu\nu}({}^{g}\Gamma)\right)V^\nu\right] = 0 + \int d^4x\, \sqrt{-g}\, c_V \mathcal{O}(\frac{\nabla^2\mathcal{K}}{M_{Pl}^2})$$

no contribution to scalar
and gauge boson masses!

Corresponding to the affine connection, the affine curvature takes the form

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}\left(\frac{\nabla^2 \mathcal{K}}{M_{Pl}^2}\right)$$

so that the notorious CCB gauge-bos ... on becomes

CCB is suppressed !

$$\delta S_V(g, \mathbb{R}) \equiv \int d^4x \sqrt{-g} \ldots V^{\mu}\left(\mathbb{R}_{\mu\nu}(\Gamma) - R_{\mu\nu}({}^{g}\Gamma)\right)V^{\nu}\Big] = 0 + \int d^4x \sqrt{-g}\, c_V \mathcal{O}\left(\frac{\nabla^2 \mathcal{K}}{M_{Pl}^2}\right)$$

no contribution to scalar
and gauge boson masses!

Corresponding to the affine connection, the affine curvature t… …rm

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}(\frac{\nabla^2 \mathcal{K}}{M_{Pl}^2})$$

so that the notorious CCB …

$$\delta S_V(g, \mathbb{R}) \ldots]V^\nu] = 0 + \int d^4x \sqrt{-g}\, c_V \mathcal{O}(\frac{\nabla^2 \mathcal{K}}{M_{Pl}^2})$$

symmetry-restoring emergent gravity

or briefly

«symmergent gravity»

no contribution to scalar
and gauge boson masses!

With the affine curvature

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}(\frac{\nabla^2\mathcal{K}}{M_{Pl}^2})$$

the complete curvature sector takes the form

$$\delta S(g,\mathbb{R}) = \int d^4x\,\sqrt{-g}\,\{-\mathrm{Q}^{\mu\nu}\mathbb{R}_{\mu\nu}(\Gamma) + \frac{c_4}{16}\,\mathrm{str}[1]\big(\mathbb{R}(g,\Gamma)\big)^2 - c_{\mathcal{V}} R_{\mu\nu}({}^{g}\Gamma)\mathrm{tr}[\mathcal{V}^{\mu}\mathcal{V}^{\nu}]\}$$

$$= \int d^4x\,\sqrt{-g}\,\{-\frac{M_{Pl}^2}{2}\,R(g) - \frac{c_{\mathcal{H}}}{4}\,R(g)\,\mathcal{H}^2 + \mathcal{O}\left(\frac{\mathcal{K}\nabla^2\mathcal{K}}{M_{Pl}^2}\right)\}$$

With the affine curvature

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}\left(\frac{\nabla^2\mathcal{K}}{M_{Pl}^2}\right)$$

complete curvature sector takes the form

$$\delta S(g,\mathbb{R}) = \int d^4x\,\sqrt{-g}\,\{-\mathrm{Q}^{\mu\nu}\mathbb{R}_{\mu\nu}(\Gamma) + c \ldots (\mathbb{R}(g,\Gamma))^2 - c_V R_{\mu\nu}({}^{g}\Gamma)\mathrm{tr}[\mathcal{V}^{\mu}\mathcal{V}^{\nu}]\}$$

$$= \int d^4x\,\sqrt{-g}\,\{ \ldots \frac{\ldots}{2} R(g) - \frac{c_{\mathcal{H}}}{4} R(g)\,\mathcal{H}^2 + \mathcal{O}\left(\frac{\mathcal{K}\nabla^2\mathcal{K}}{M_{Pl}^2}\right)\}$$

GHP is gone !

With the affine curvature

$$\mathbb{R}_{\mu\nu}(\Gamma) = R_{\mu\nu}({}^{g}\Gamma) + \mathcal{O}\left(\frac{\nabla^2\mathcal{K}}{M_{Pl}^2}\right)$$

complete curvature sector ta... ...n

$$\delta S(g,\mathbb{R}) = \int \cdots g \left\{-\mathrm{Q}^{\mu\nu}\mathbb{R}_{\mu\nu}(\Gamma) + \frac{c_4}{16}\,\mathrm{str}[1]\big(\mathbb{R}(g,\Gamma)\big)^2 - c_V R_{\mu\nu}({}^{g}\Gamma)\mathrm{tr}[\mathcal{V}^{\mu}\mathcal{V}^{\nu}]\right\}$$

$$= \int d^4x\,\sqrt{-g}\left\{-\frac{M_{Pl}^2}{2}\,R(g) - \frac{c_{\mathcal{H}}}{4}\,R(g)\,\mathcal{H}^2 + \mathcal{O}\left(\frac{\mathcal{K}\nabla^2\mathcal{K}}{M_{Pl}^2}\right)\right\}$$

symmergent gravity is exact Einstein gravity!

no higher-curvature terms !

Symmergence left behind only logarithmic UV-sensitivities. Nevertheless, the equivalence relation

$$\log\frac{\Lambda_{\wp}}{\Lambda_W} = \frac{1}{2\epsilon} + \log\frac{\mu}{\Lambda_W}$$

enables passage to dimensional regularization! Independence from μ leads to RGE's.

Flat Spacetime	Curved Spacetime
$\mathrm{SM}(\psi, \eta, \Lambda_{\wp}^2, \log\Lambda_{\wp})$ $\oplus$ $\mathrm{BSM}(\psi', \eta, \Lambda_{\wp}^2, \log\Lambda_{\wp})$	$\mathrm{SM}(\psi, g, \mathbb{R}, \log\mu)$ $\oplus$ $\mathrm{BSM}(\psi', g, \mathbb{R}, \log\mu)$

Gravity is incorporated into the SM in such a way that:

CCB is suppressed; GHP is neutralized; BSM is specified; Dim. Reg. is recovered.

There exist numerous problems to be investigated:

- What is the high curvature limit? Are there BH solutions?
- Is there an underlying SUSY? Can it have a say on the CCP?
- Is inflation a scalar field? Or, is it a vector?
- Can Poincare breaking be made dynamical?
- How to characterize various BSM phenomena?
- …

Thank You