PSMNP Portorož, April 15 2013

Too light color octet in the minimal SO(10) GUT ?

Michal Malinský

IPNP, Charles University in Prague

based on

Phys.Rev.D *81 035015 2010*

85 095014 2012

87 085020 2013

in collaboration with

Stefano Bertolini (SISSA & INFN Trieste)
and Luca di Luzio (KIT Karlsruhe)

Outline / conclusions

Minimal SO(10) GUT:

Either

we should see a scalar color octet @ LHC

or

we should see proton decay @ Hyper-Kamiokande

Minimal SO(10) GUT

SO(10) broken by 45, rank reduced by 126

Buccella, Ruegg, Savoy 1980, Yasuè 1981, Anastaze, Derendinger, Buccella 1983, Babu, Ma 1985

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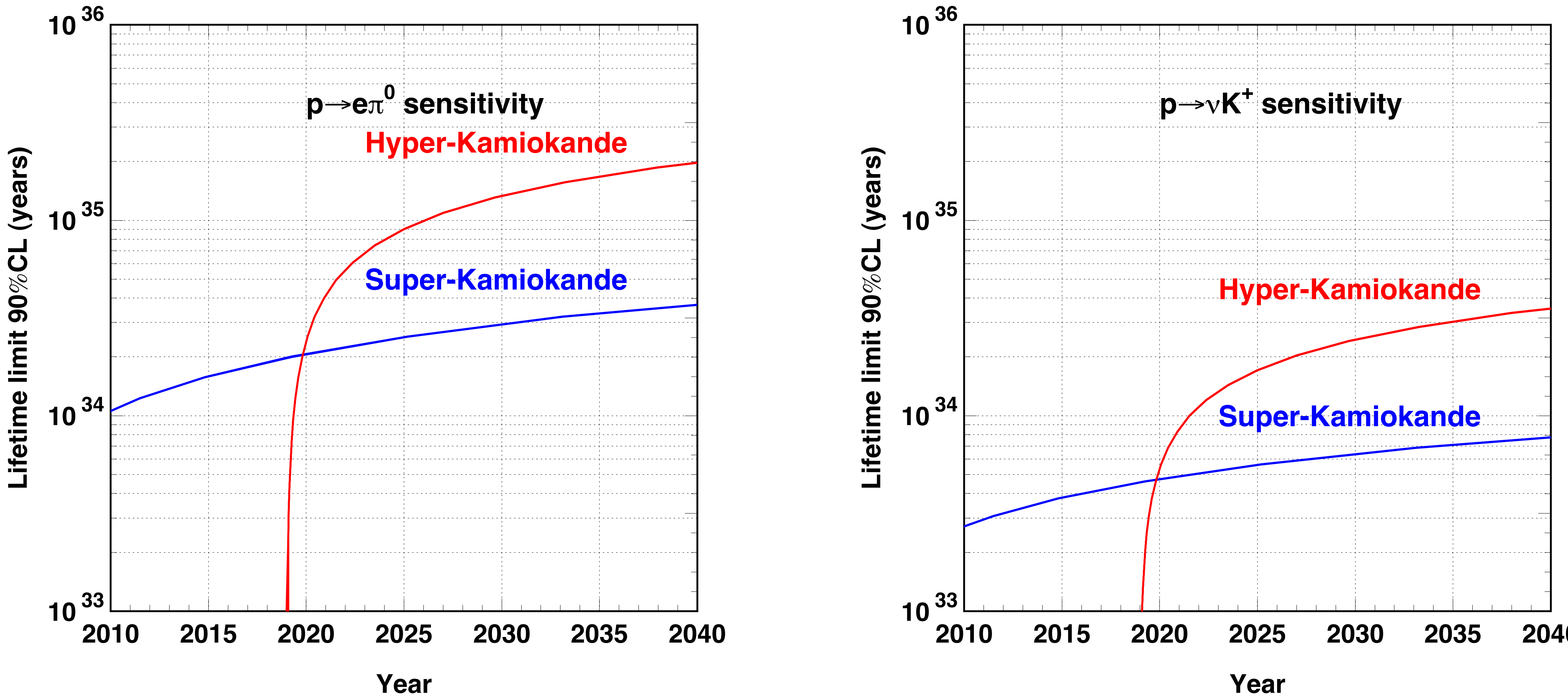
Calculable?

Testable?

Proton lifetime calculations in GUTs

Optimistic scenario: Hyper-Kamiokande @ around 2020



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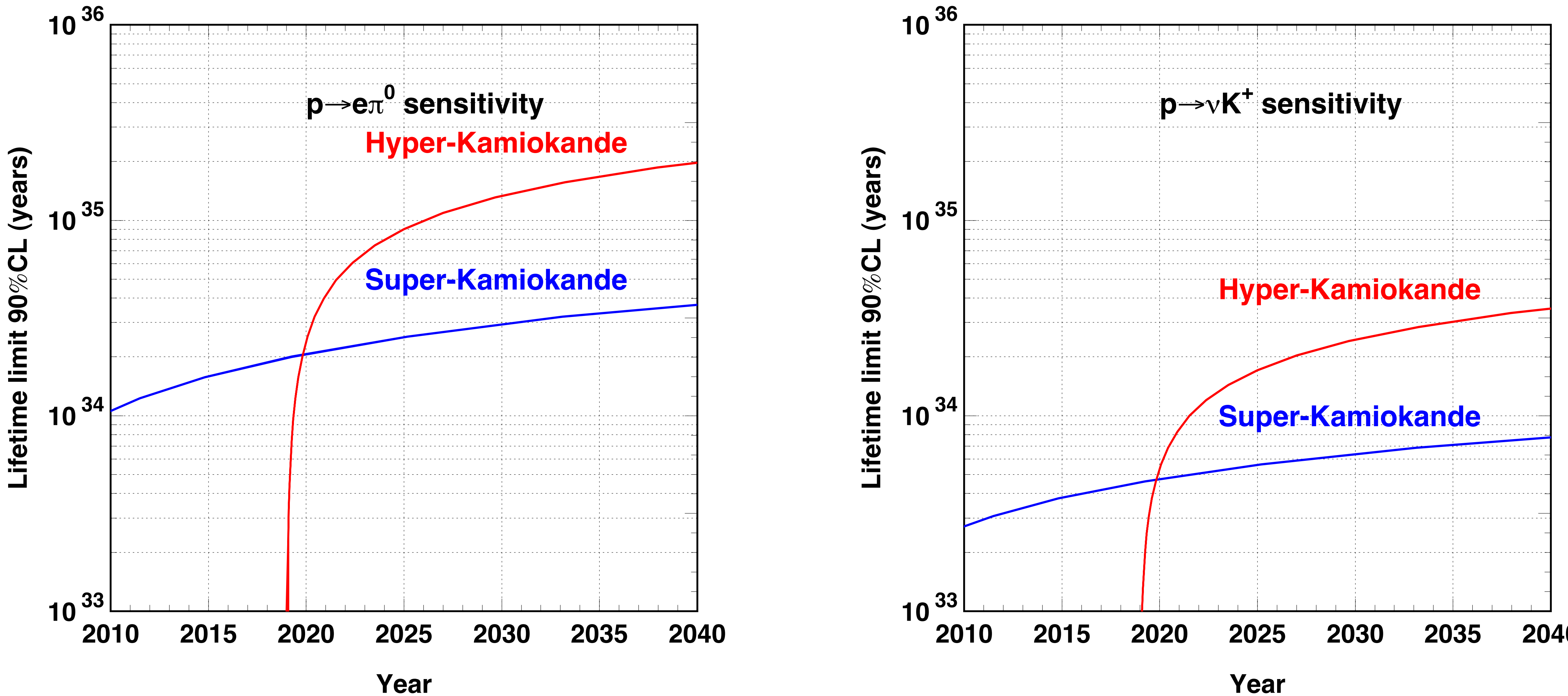

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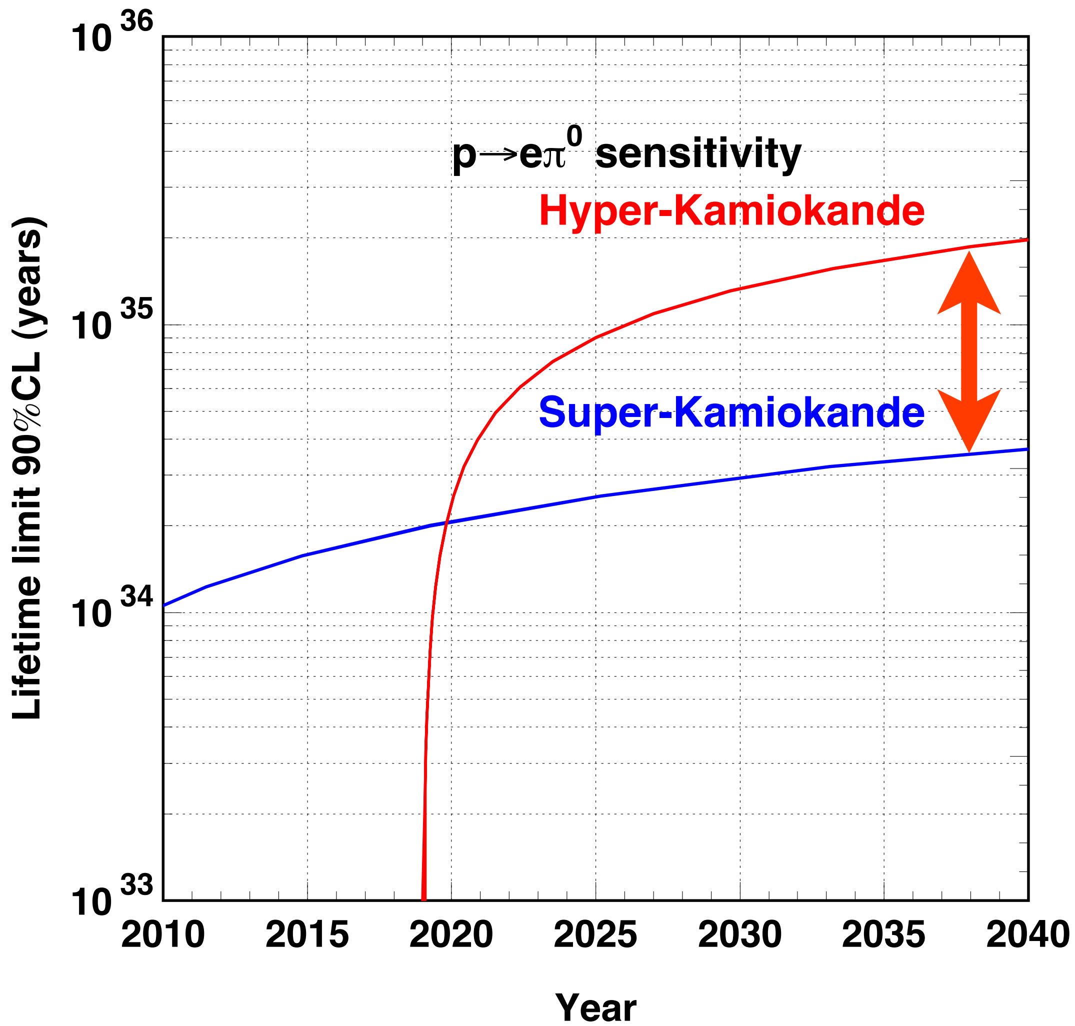

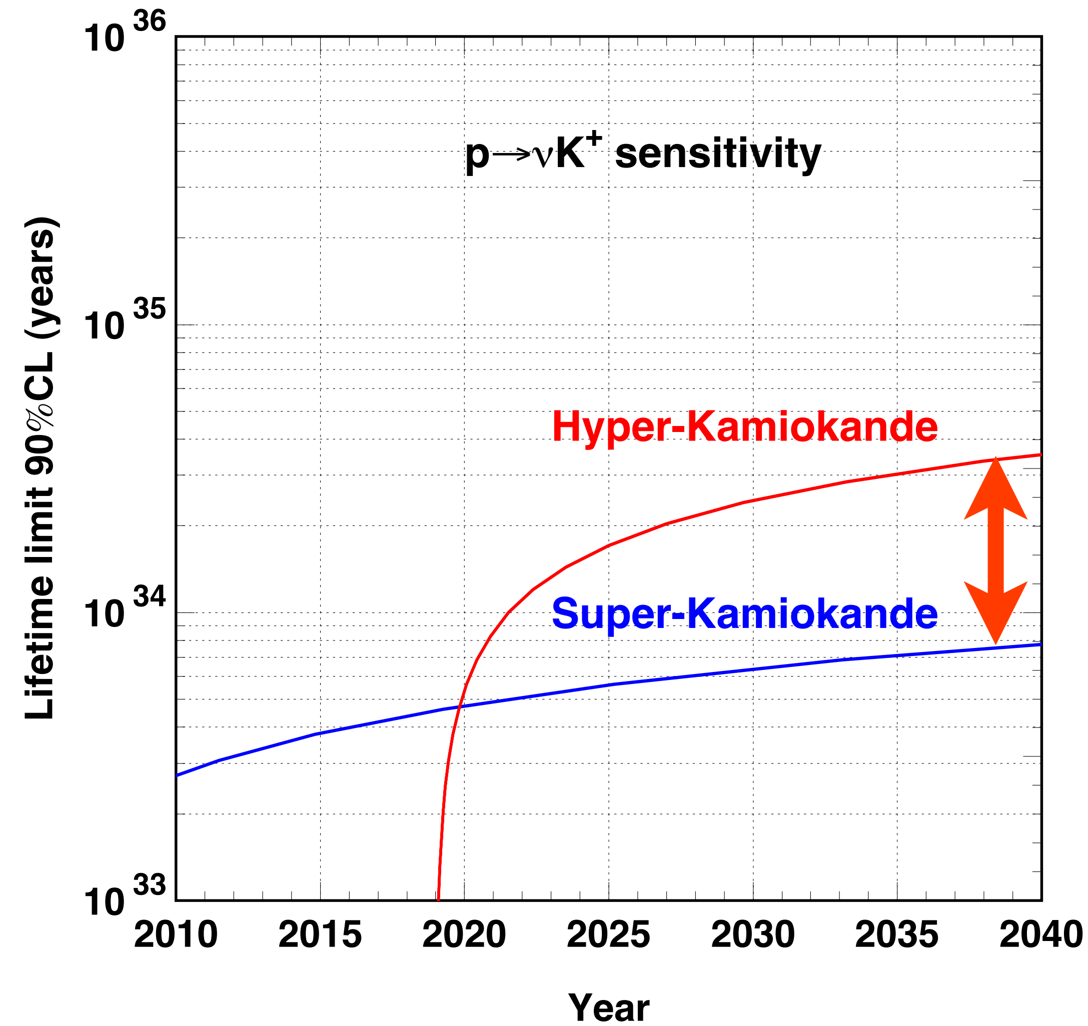

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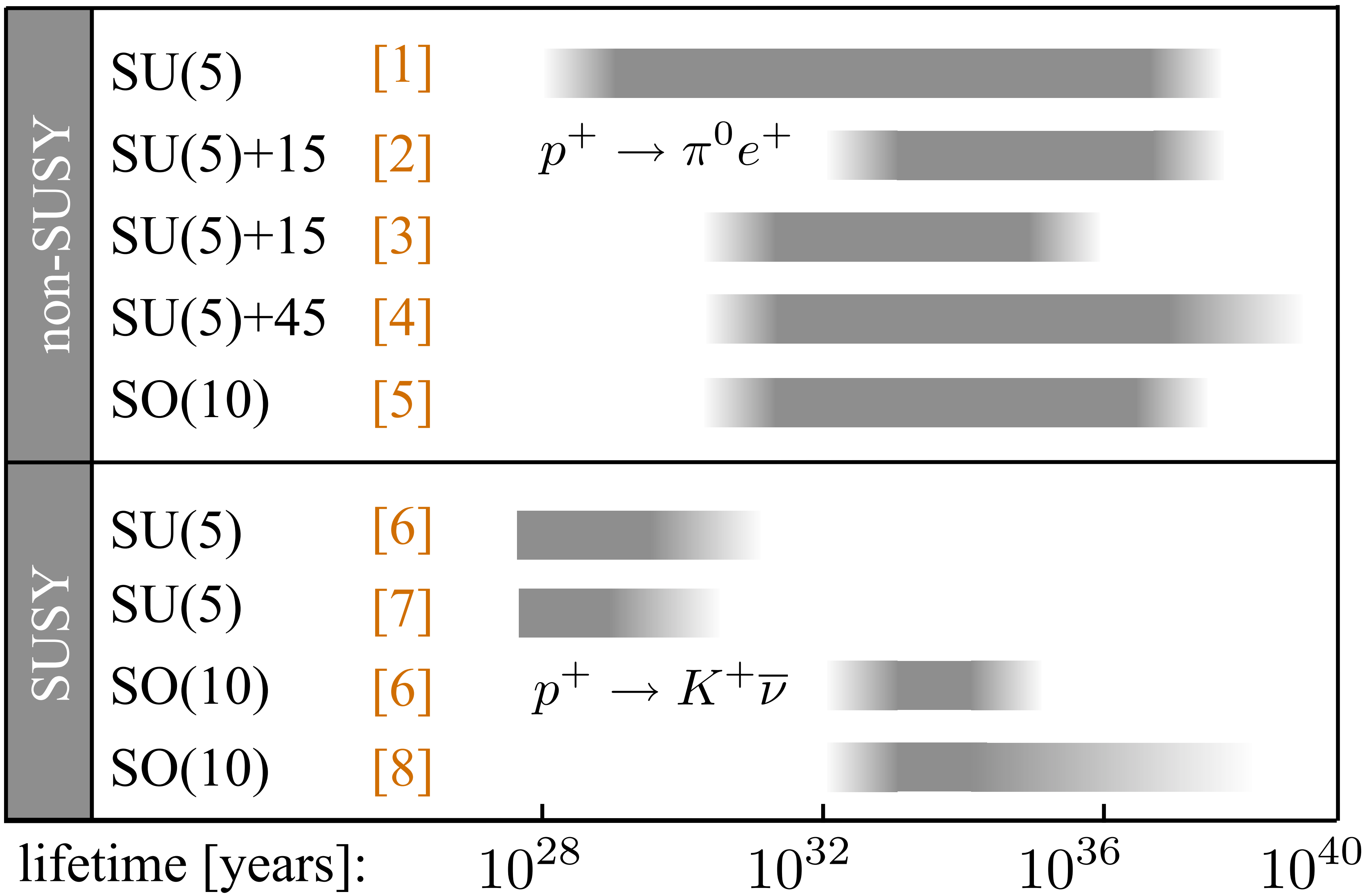
Accuracy of a **factor of few** in Γ_p needed to make a case !

Proton lifetime calculations in GUTs



[1] Georgi, Quinn, Weinberg, PRL 33, 451 (1974)
[2] Dorsner, Fileviez Perez, NPB 723, 53 (2005)
[3] Dorsner, Fileviez Perez, Rodrigo, PRD75, 125007 (2007)
[4] Dorsner, Fileviez Perez, PLB 642, 248 (2006)
[5] Lee, Mohapatra, Parida, Rani, PRD 51 (1995)
[6] Pati, hep-ph/0507307
[7] Murayama, Pierce, PRD 65. 055009 (2002)
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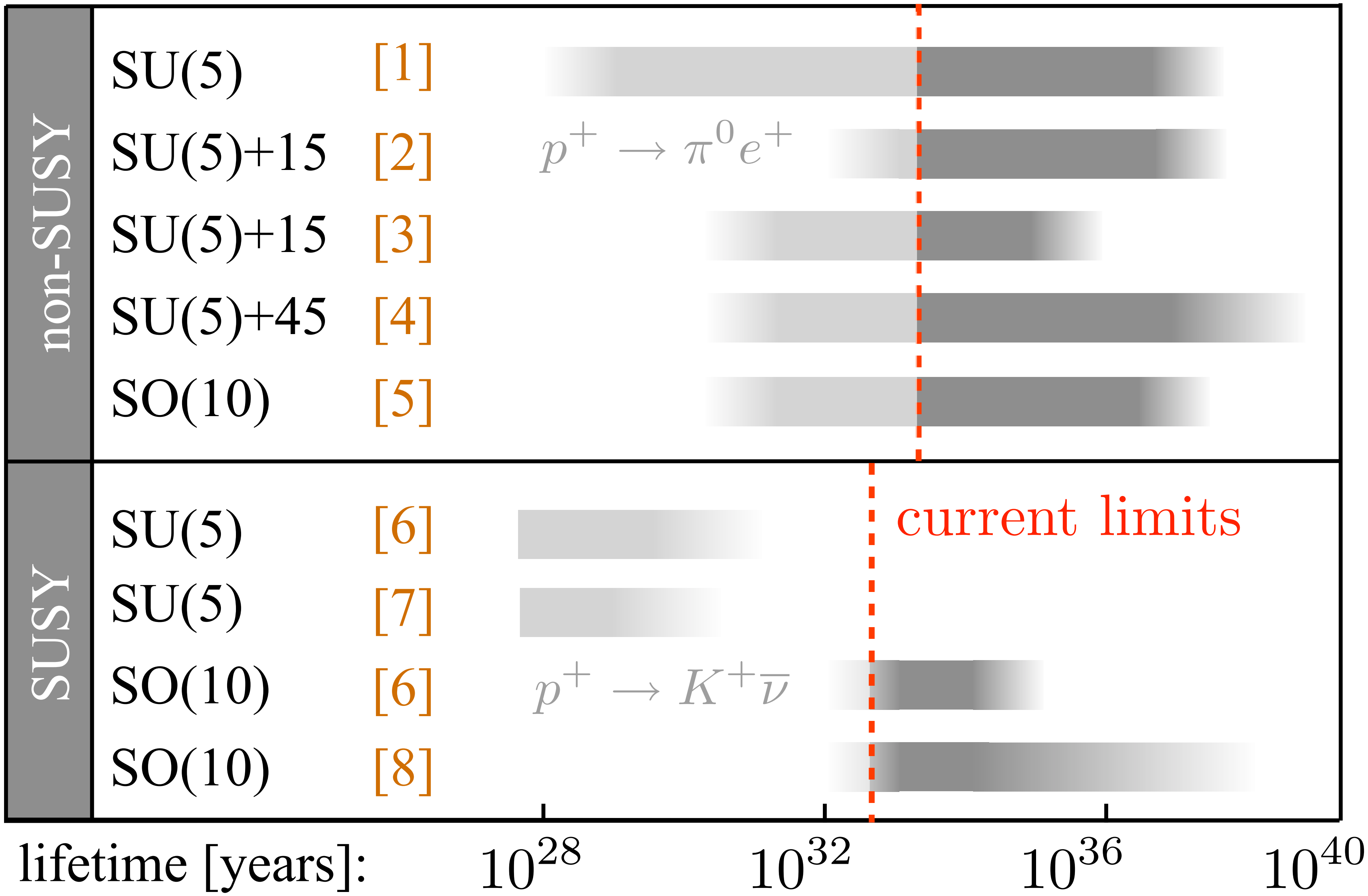

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Precision proton lifetime calculations in GUTs

Main theoretical uncertainties:

GUT scale determination

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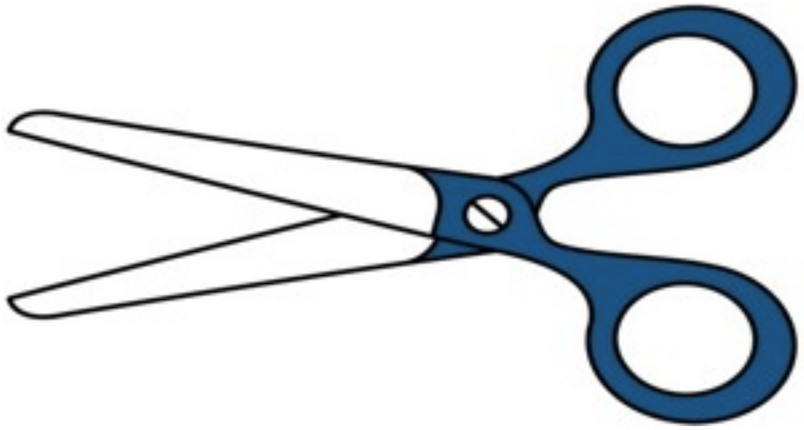

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easily half an order of magnitude uncertainty in M_G !

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- some channels more sensitive than others

Example:
$$\frac{g^2}{M_{1/6}^2} C_{ijk}\, \overline{u^c}\gamma^\mu d_i\, \overline{d^c_j}\gamma_\mu \nu_k \qquad C_{ijk} = (V_{d^c}^\dagger V_d)_{ji}(V_{u^c}^\dagger V_\nu)_{1k}$$

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- effective cut-off scale, SUSY thresholds, d=5 dressing,

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forget...

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$$V_{45} = -\frac{\mu^2}{2}(\phi\phi)_0 + \frac{a_0}{4}(\phi\phi)_0(\phi\phi)_0 + \frac{a_2}{4}(\phi\phi)_2(\phi\phi)_2\,,$$

$$\begin{aligned}V_{126} = &-\frac{\nu^2}{5!}(\Sigma\Sigma^*)_0 \\ &+ \frac{\lambda_0}{(5!)^2}(\Sigma\Sigma^*)_0(\Sigma\Sigma^*)_0 + \frac{\lambda_2}{(4!)^2}(\Sigma\Sigma^*)_2(\Sigma\Sigma^*)_2 \\ &+ \frac{\lambda_4}{(3!)^2(2!)^2}(\Sigma\Sigma^*)_4(\Sigma\Sigma^*)_4 + \frac{\lambda_4'}{(3!)^2}(\Sigma\Sigma^*)_{4'}(\Sigma\Sigma^*)_{4'} \\ &+ \frac{\eta_2}{(4!)^2}(\Sigma\Sigma)_2(\Sigma\Sigma)_2 + \frac{\eta_2^*}{(4!)^2}(\Sigma^*\Sigma^*)_2(\Sigma^*\Sigma^*)_2\,,\end{aligned}$$

$$\begin{aligned}V_{\rm mix} = &\frac{i\tau}{4!}(\phi)_2(\Sigma\Sigma^*)_2 + \frac{\alpha}{2\cdot 5!}(\phi\phi)_0(\Sigma\Sigma^*)_0 \\ &+ \frac{\beta_4}{4\cdot 3!}(\phi\phi)_4(\Sigma\Sigma^*)_4 + \frac{\beta_4'}{3!}(\phi\phi)_{4'}(\Sigma\Sigma^*)_{4'} \\ &+ \frac{\gamma_2}{4!}(\phi\phi)_2(\Sigma\Sigma)_2 + \frac{\gamma_2^*}{4!}(\phi\phi)_2(\Sigma^*\Sigma^*)_2\,.\end{aligned}$$

$$(\phi\phi)_0(\phi\phi)_0 \equiv \phi_{ij}\phi_{ij}\phi_{kl}\phi_{kl}$$

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$$(\phi\phi)_0 \equiv \phi_{ij}\phi_{ij}\,,\quad (\Sigma\Sigma^*)_0 \equiv \Sigma_{ijklm}\Sigma^*_{ijklm}$$

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The minimal SO(10) ~~blessing~~ nightmare

SO(10) broken by 45, rank reduced by 126

Scalar potential: $V = V_{45} + V_{126} + V_{\text{mix}}$

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???

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Ruled out in 1980's

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$$m^2_{(8,1,0)} = 2a_2(\omega_R - \omega_Y)(\omega_R + 2\omega_Y)$$
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Yasuè 1981, Anastaze, Derendinger, Buccella 1983, Babu, Ma 1985

$$\langle 45 \rangle = \begin{pmatrix} \omega_Y & & & & \\ & \omega_Y & & & \\ & & \omega_Y & & \\ & & & \omega_R & \\ & & & & \omega_R \end{pmatrix} \otimes \tau_2$$

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Aaarrrggh... tachyonic spectrum unless $\frac{1}{2} < |\omega_Y/\omega_R| < 2$

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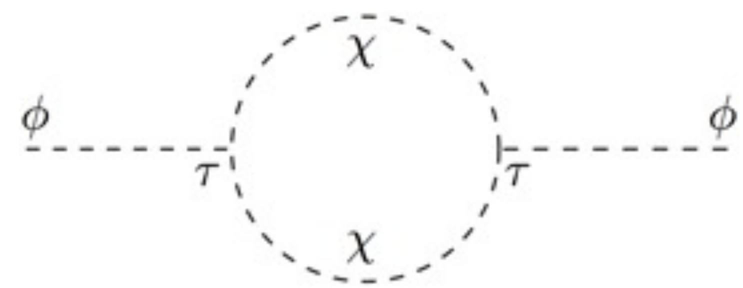
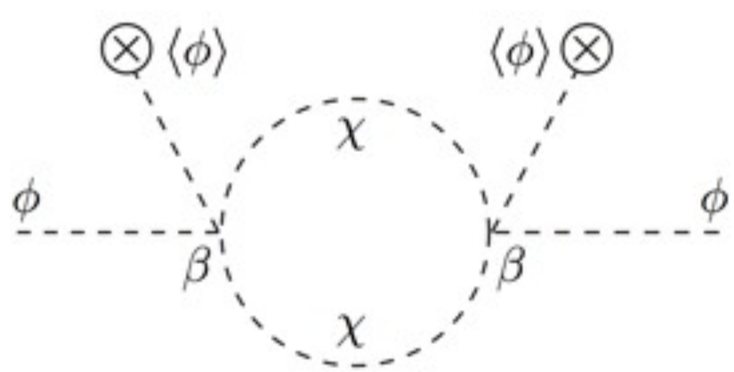
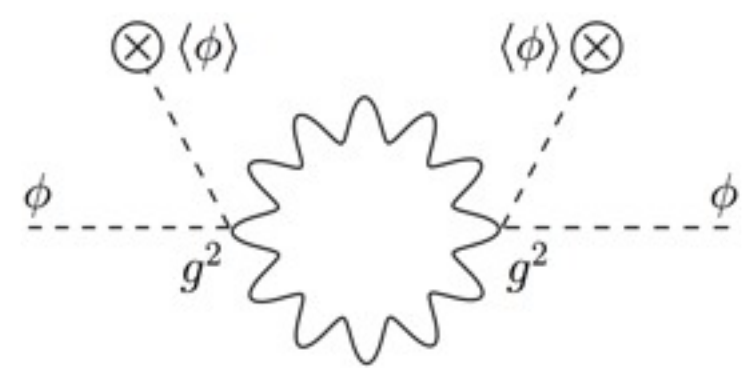
One-loop effective potential:







$$\Delta m^2_{(1,3,0)} = \frac{1}{4\pi^2}\left[\tau^2 + \beta^2(2\omega_R^2 - \omega_R\omega_Y + 2\omega_Y^2) + g^4\left(16\omega_R^2 + \omega_Y\omega_R + 19\omega_Y^2\right)\right] + \text{logs}\,,$$

$$\Delta m^2_{(8,1,0)} = \frac{1}{4\pi^2}\left[\tau^2 + \beta^2(\omega_R^2 - \omega_R\omega_Y + 3\omega_Y^2) + g^4\left(13\omega_R^2 + \omega_Y\omega_R + 22\omega_Y^2\right)\right] + \text{logs}\,,$$

Bertolini, Di Luzio, MM, PRD 81, 035015 (2010)

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Leading Planck-scale effects in M_G absent

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Towards a consistent & potentially realistic scenario

“Consistency is the last refuge of people without imagination”
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Two potentially realistic minimally finetuned & consistent options:

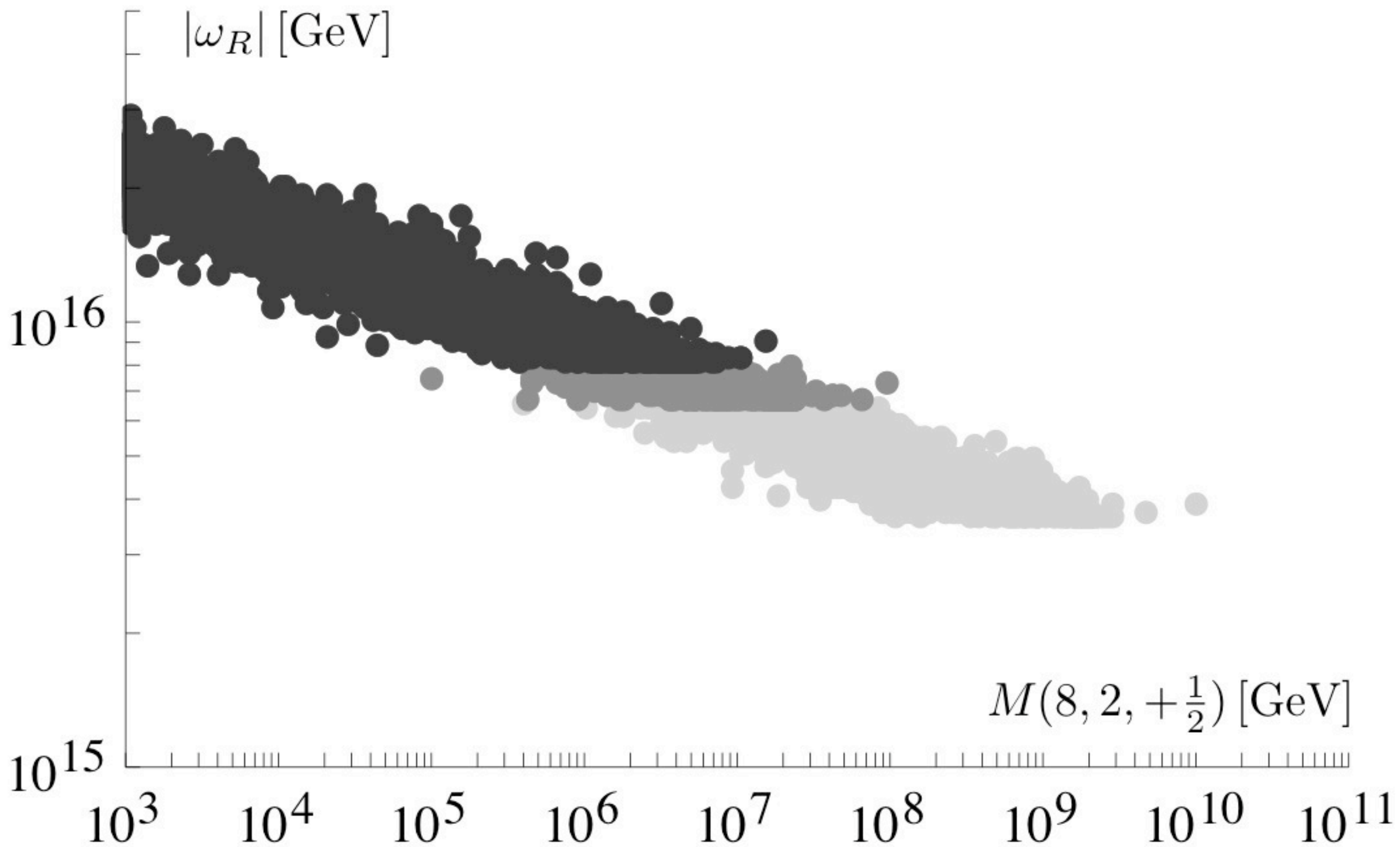
Case I: $(8, 2, +\frac{1}{2})$ Case II: $(6, 3, +\frac{1}{3})$

Bertolini, Di Luzio, MM, PRD85 095014 2012

Towards a realistic scenario

Case I: light $(8, 2, +\frac{1}{2})$

Bertolini, Di Luzio, MM, PRD 85, 095014 (2012)



$\tau(p \to e^+\pi^0)_{\mathrm{SK},2011} > 8.2 \times 10^{33}$ years

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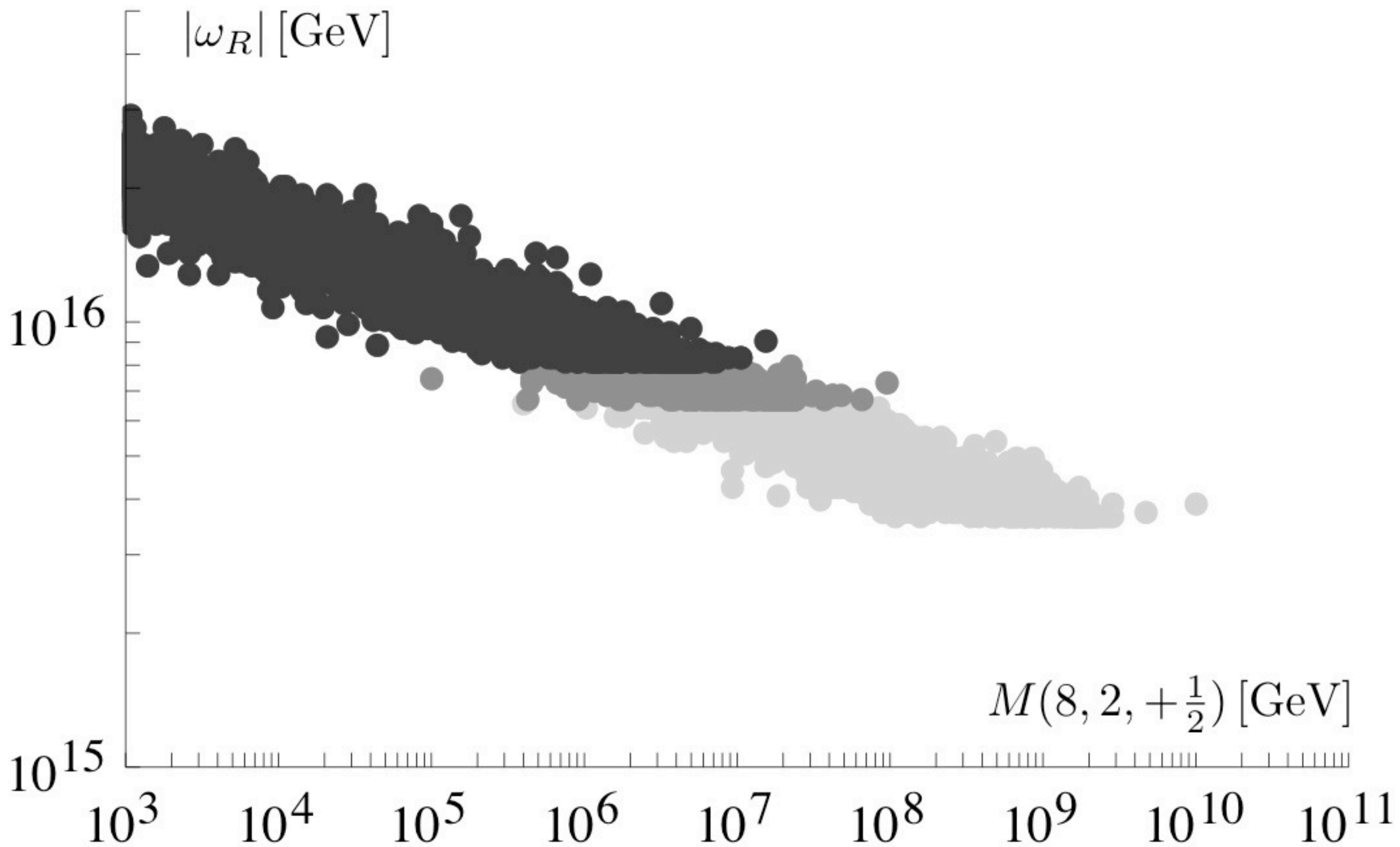
Towards a realistic scenario

Case I: light $(8, 2, +\frac{1}{2})$ **@ one loop** Bertolini, Di Luzio, MM, PRD 85, 095014 (2012)



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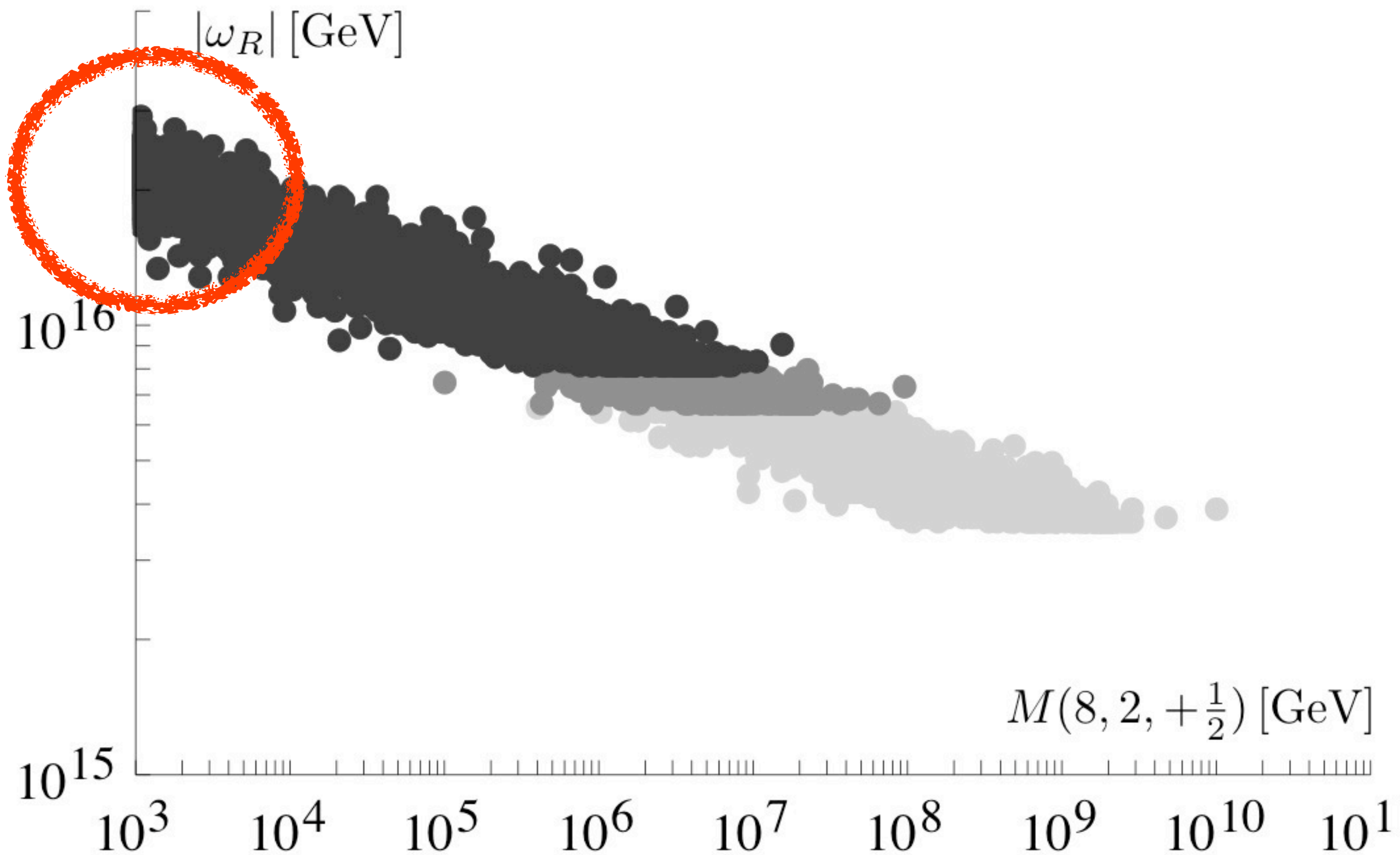

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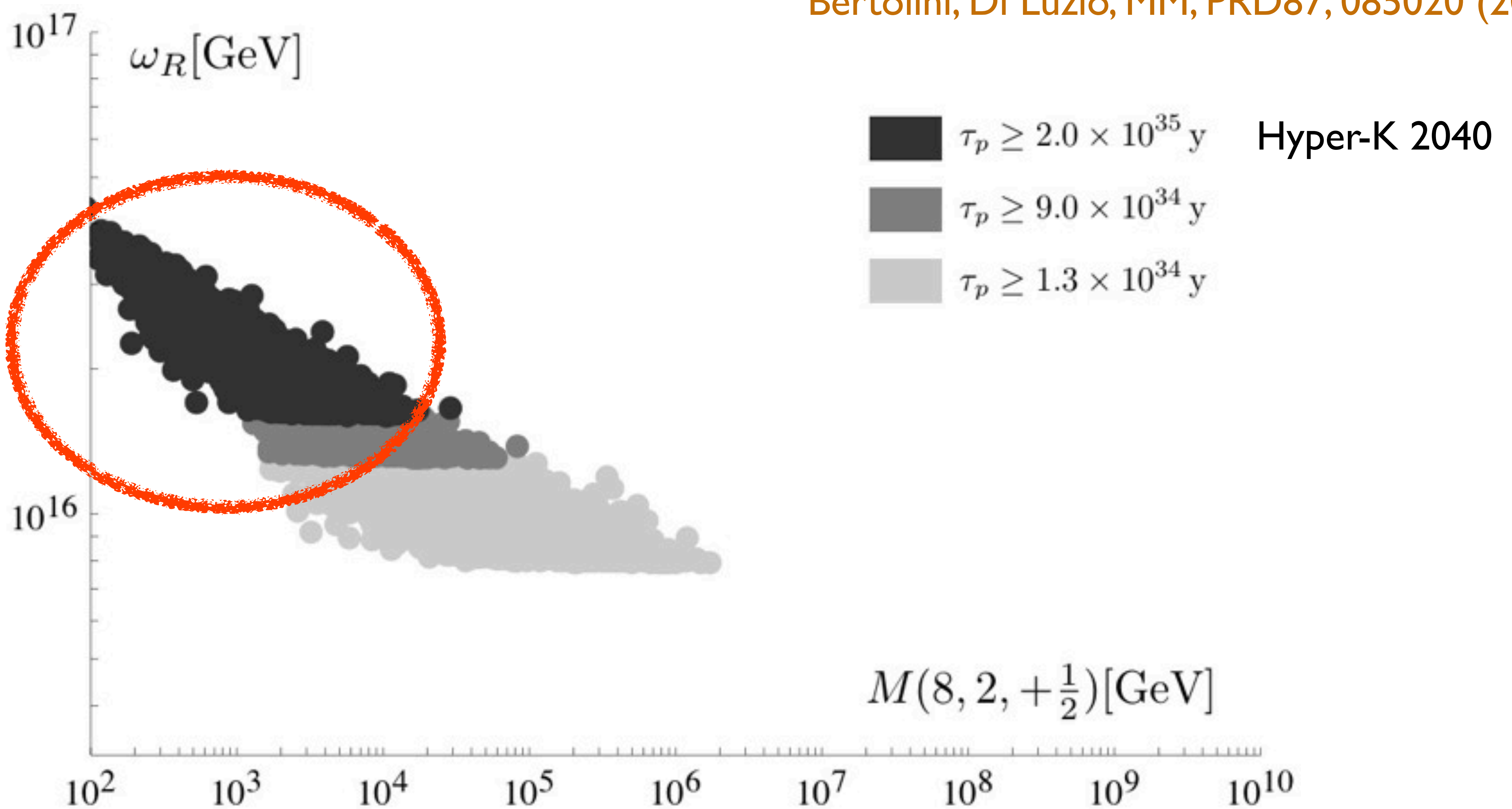

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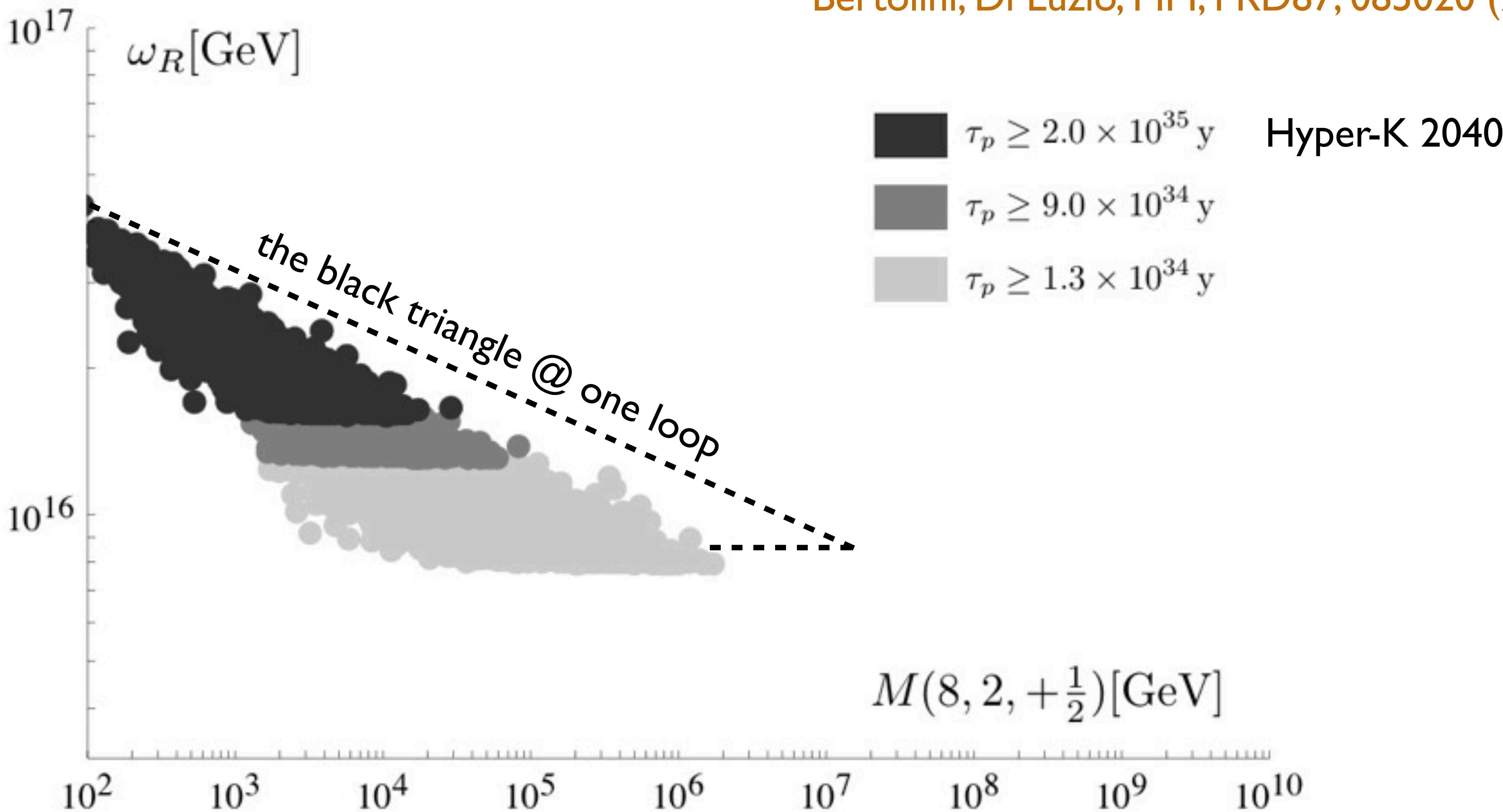

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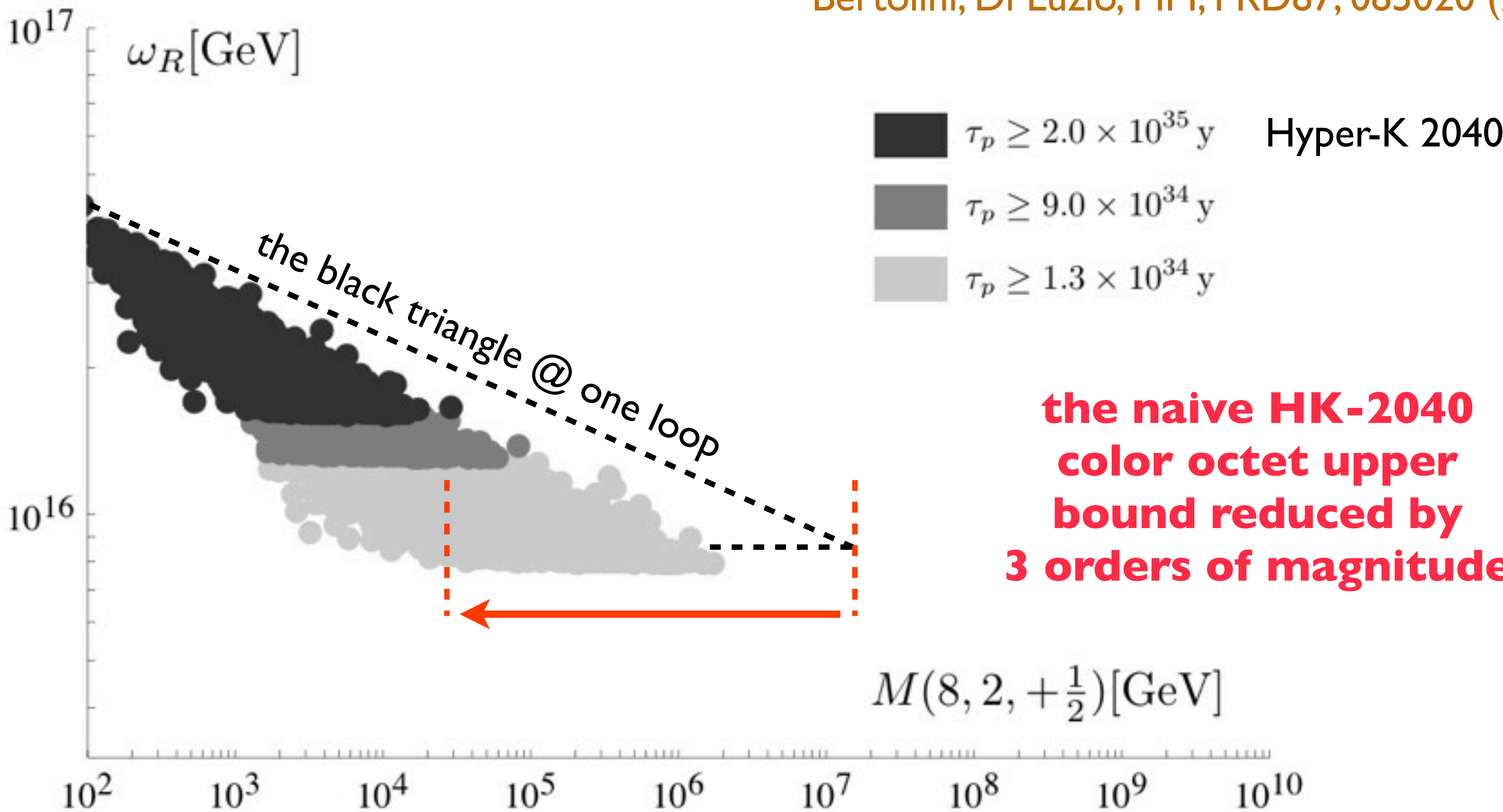
Case I: light $(8, 2, +\frac{1}{2})$ **@ two loops, improved proton decay**

Bertolini, Di Luzio, MM, PRD87, 085020 (2013)



the naive HK-2040 color octet upper bound reduced by 3 orders of magnitude

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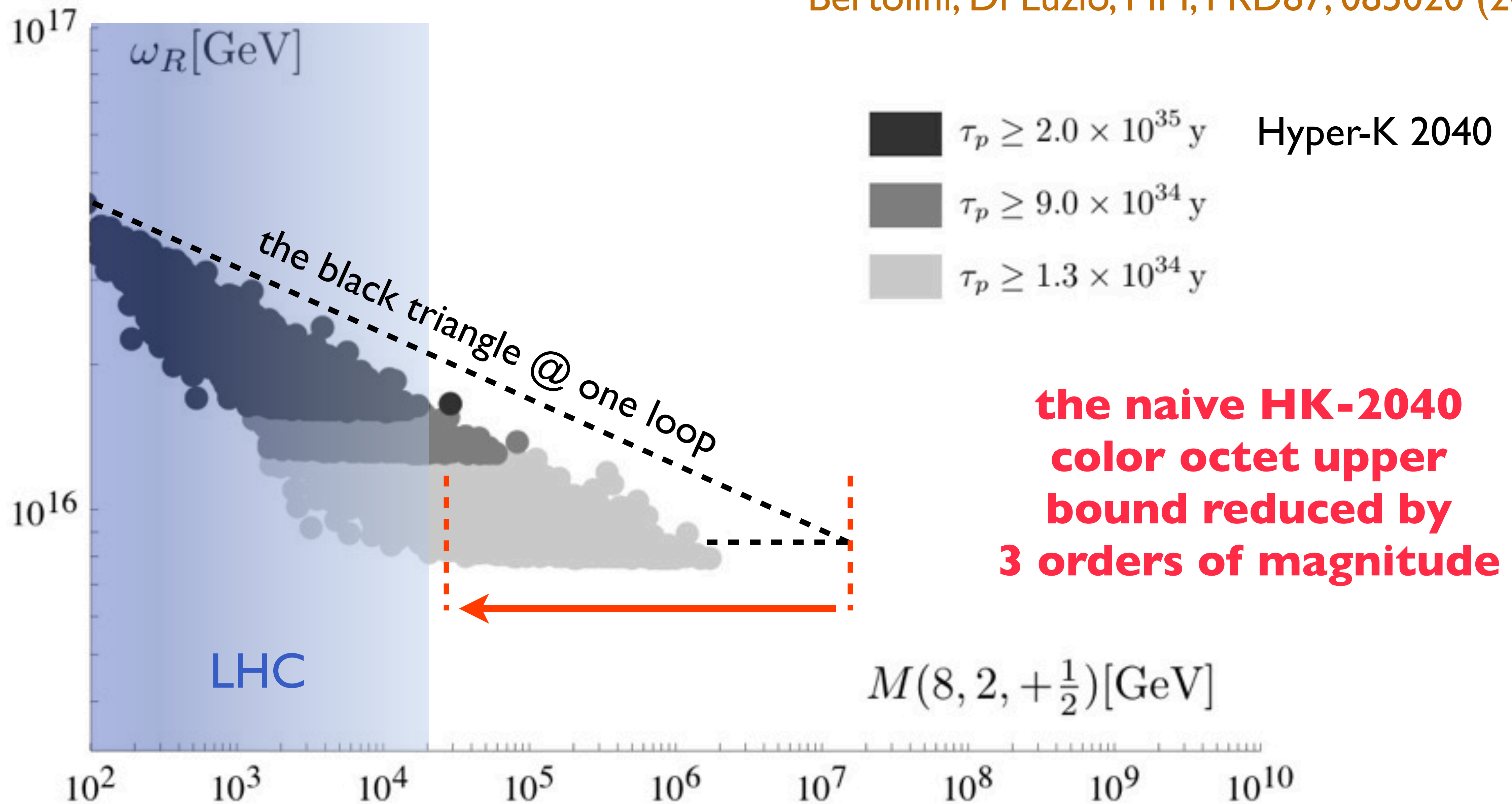


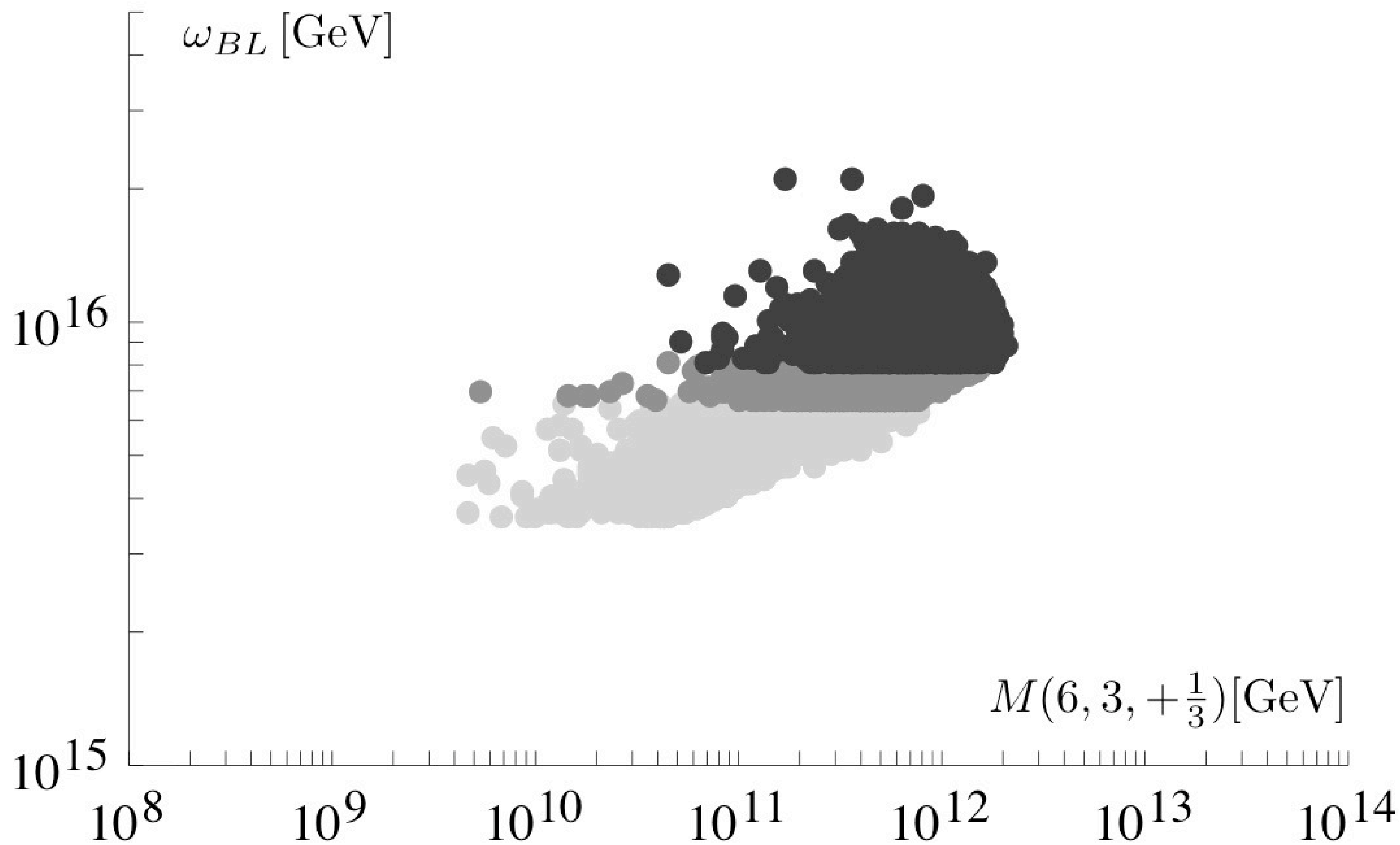
the naive HK-2040 color octet upper bound reduced by 3 orders of magnitude

CMS JHEP 1301, 013 (2013); ATLAS, JHEP 1301, 029 (2013)

Towards a realistic scenario

Case II: light $(6, 3, +\frac{1}{3})$

Bertolini, Di Luzio, MM, PRD 85, 095014 (2012)



$\tau(p \to e^+\pi^0)_{\mathrm{SK,2011}} > 8.2 \times 10^{33}$ years

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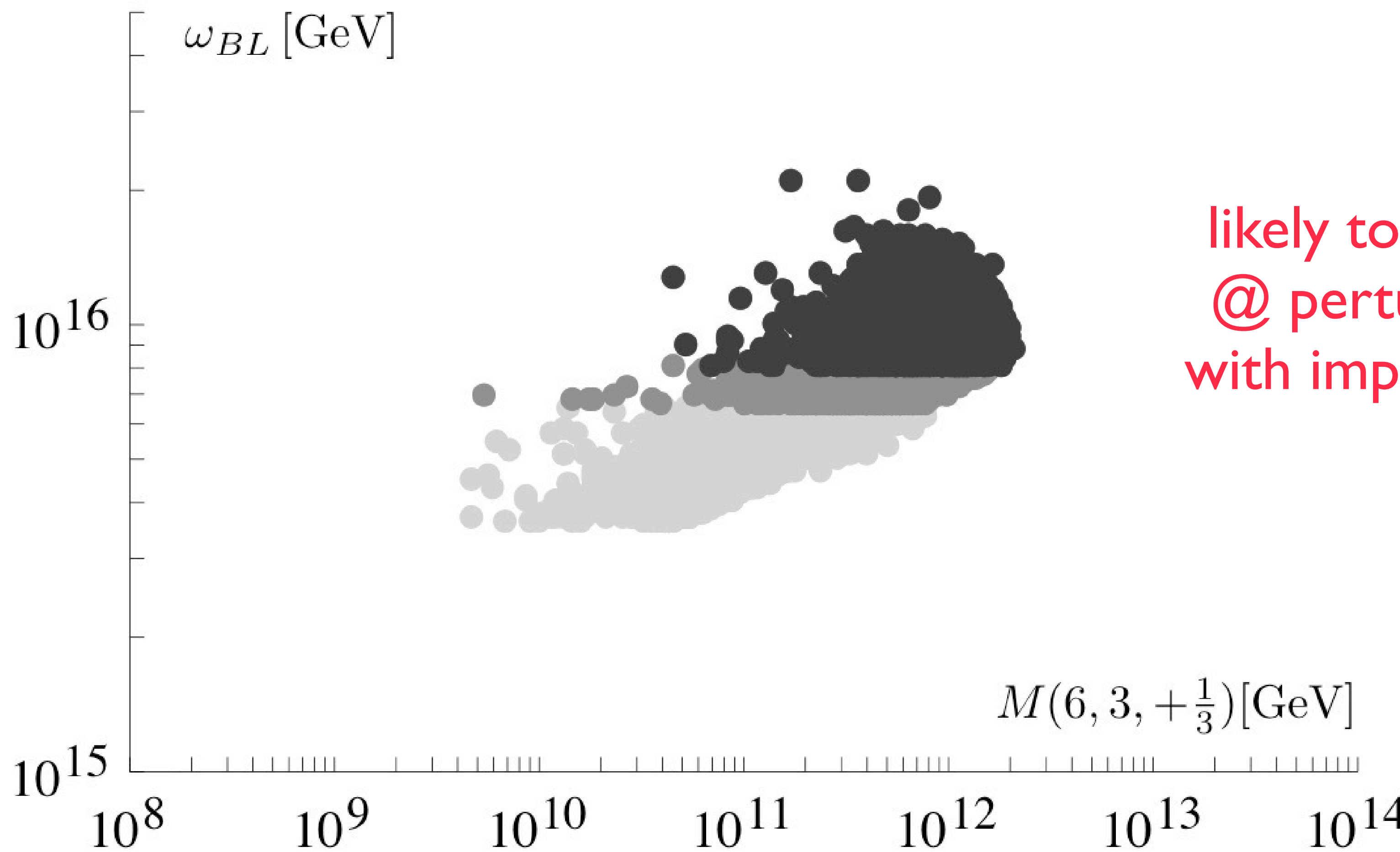

likely to be ruled out
@ perturbative level
with improved p-decay

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Conclusions / outlook

Minimal SO(10) GUT:

Either

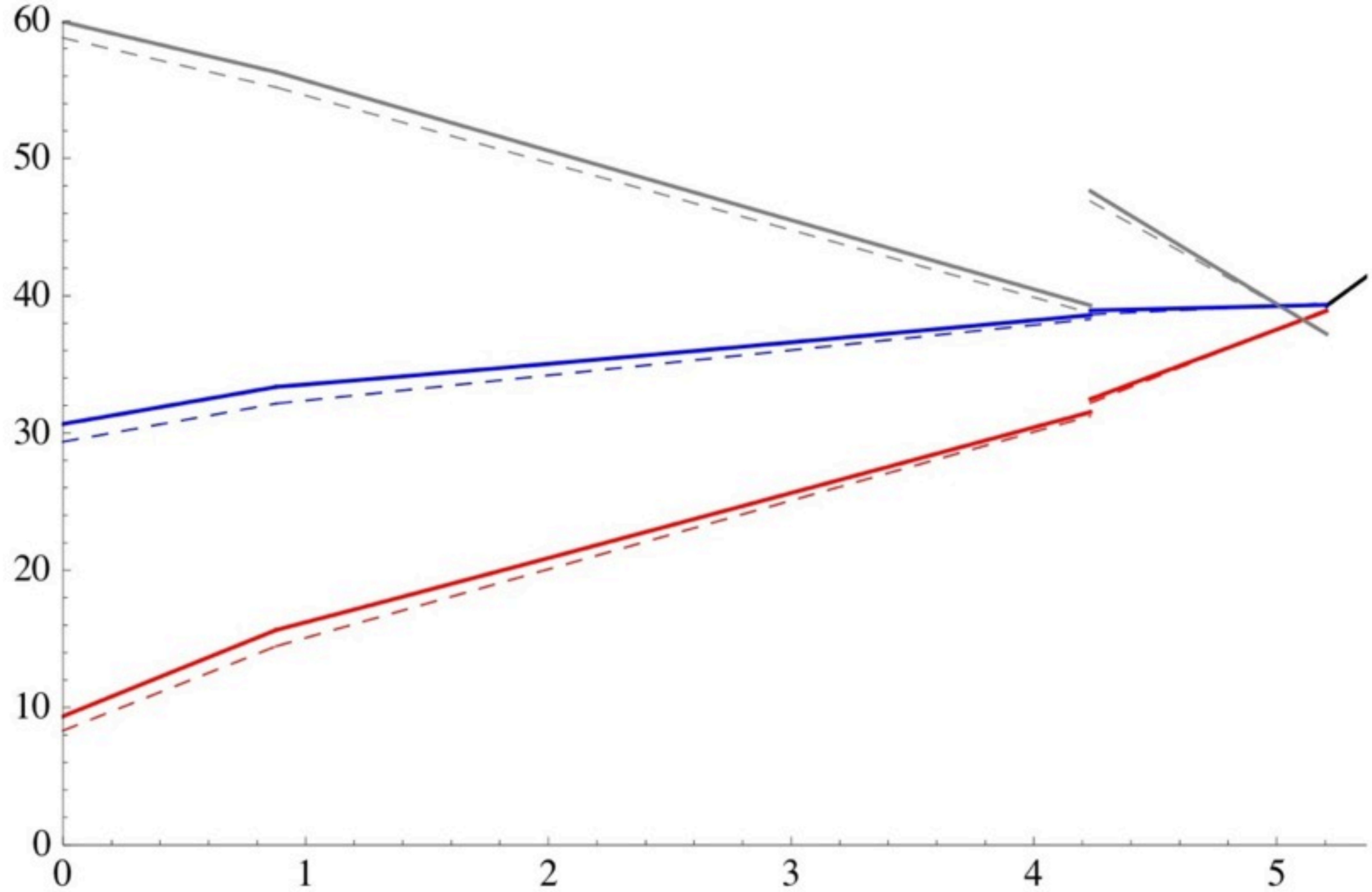
we should see a scalar color octet @ LHC

or

we should see proton decay @ Hyper-Kamiokande

Thanks for your kind attention!

Sample 2-loop running



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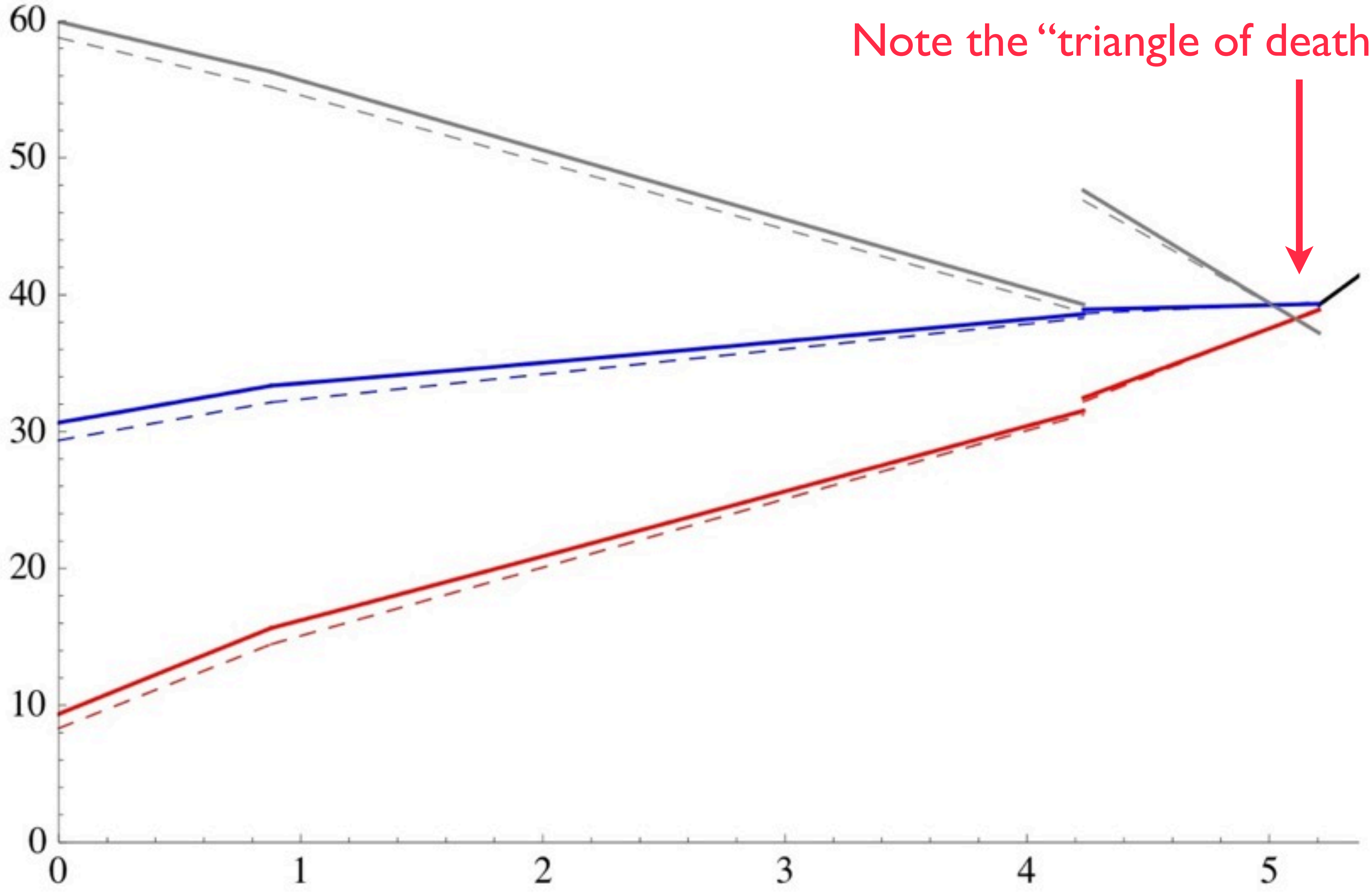

Note the "triangle of death"

Seesaw in non-SUSY SO(10)

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$\langle 16 \rangle$: renormalizable seesaw a la Witten

$$M_R \sim \alpha^2 \langle 16 \rangle^2 / M_G$$

+ predictive

- scale problem for $\langle 16 \rangle \ll M_G$

Witten 1980