European Strategy for Particle Physics

PARALLEL 7 / **BSM**

New Gauge Forces

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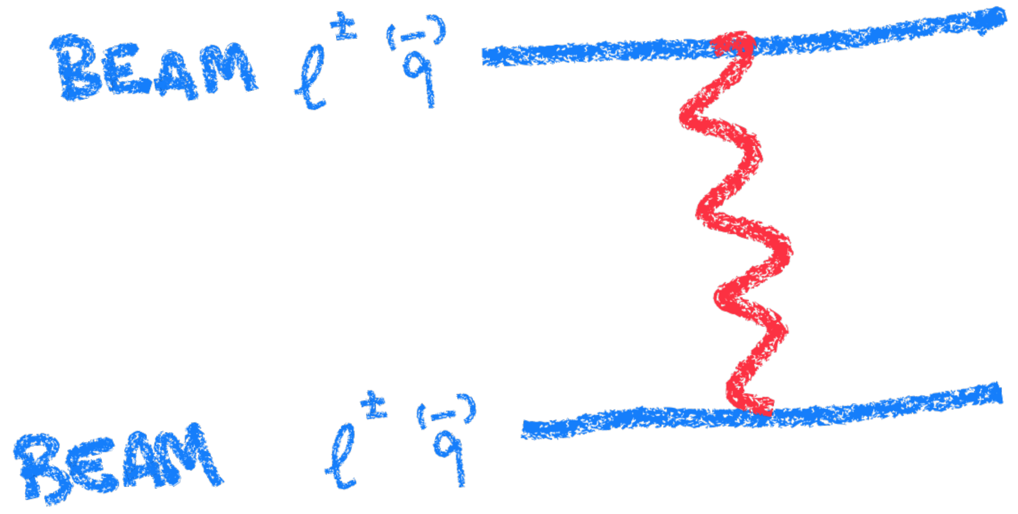
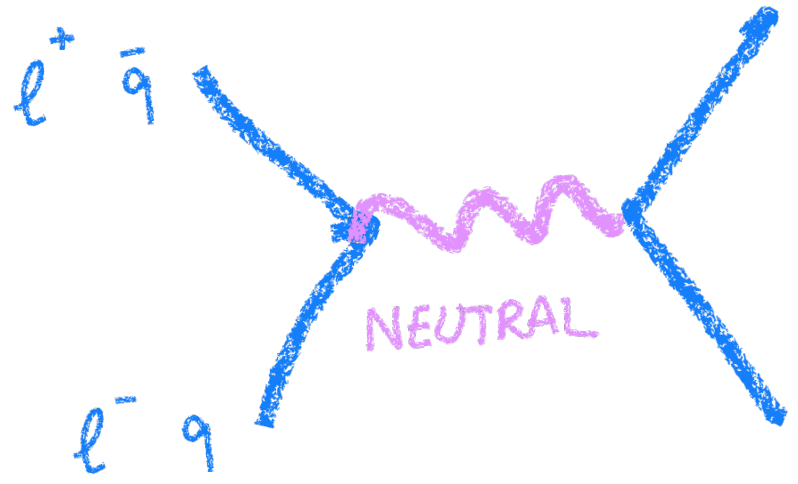
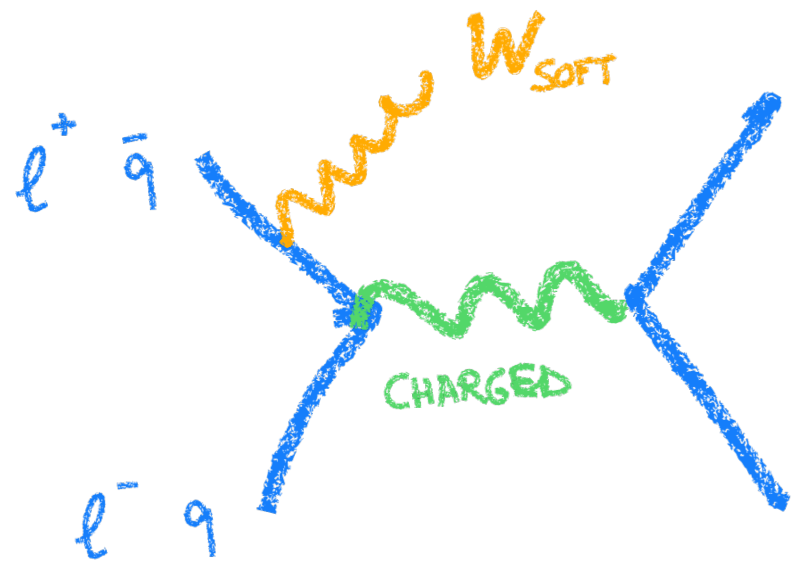
New forces

Major distinction between new force coupled to the beam at tree-level

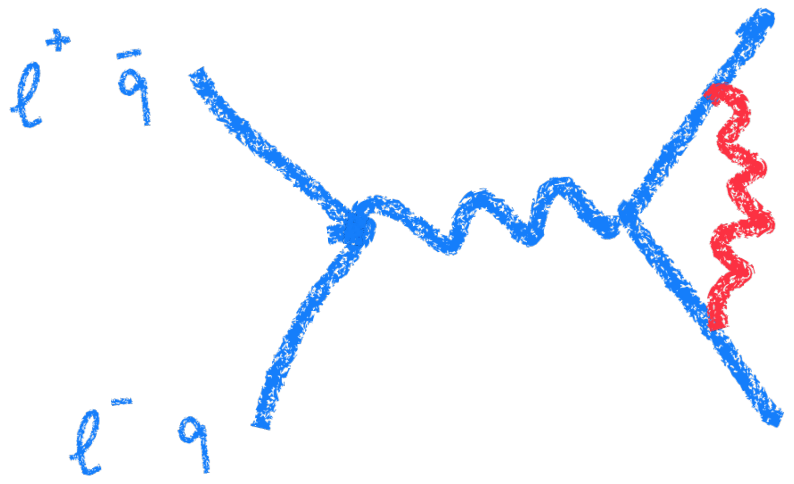


both charged and neutral

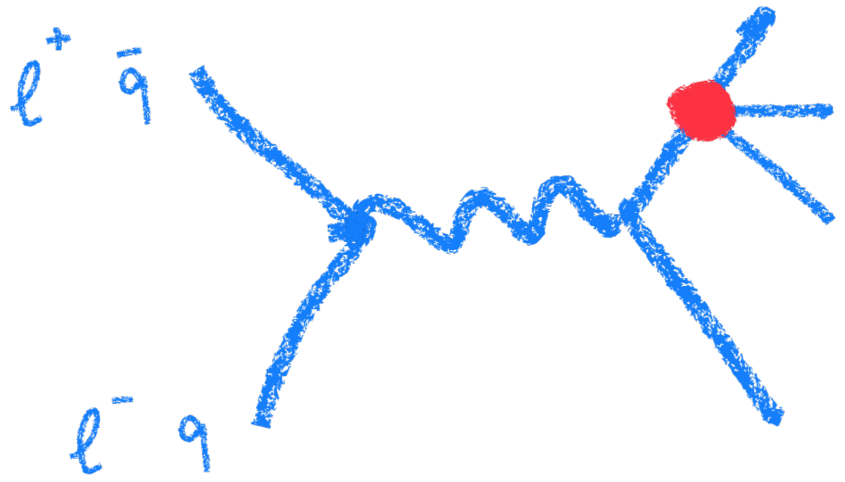




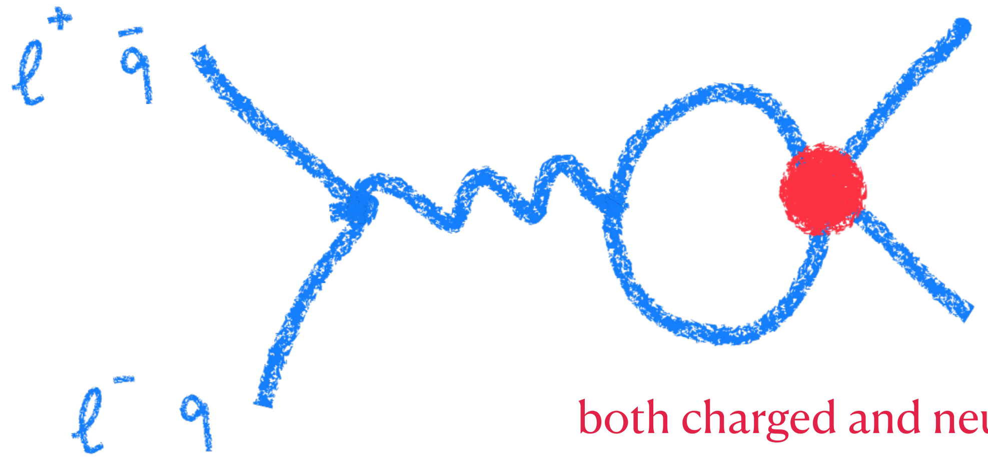
and new force not coupled to the beam at tree-level



both charged and neutral



both charged and neutral



both charged and neutral

Y' gauge boson

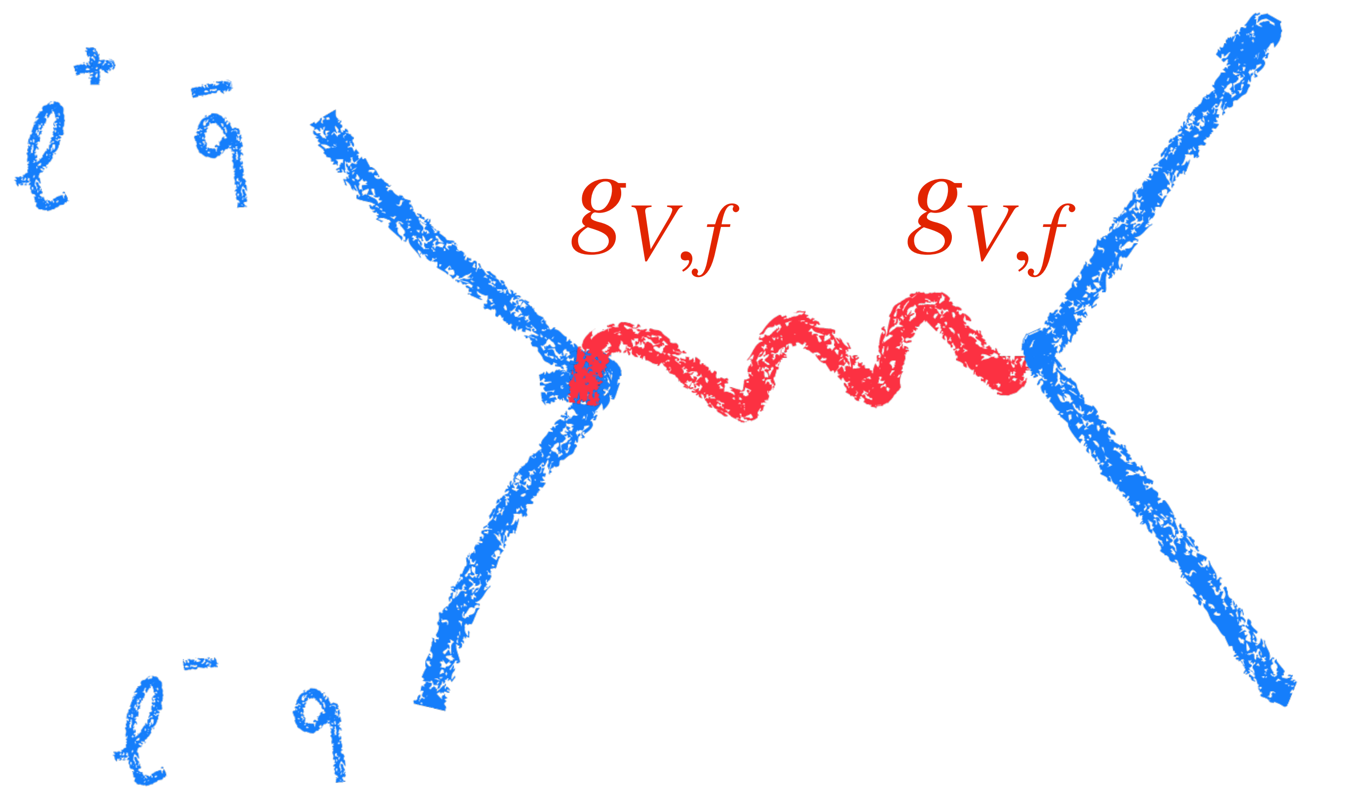
The Y-Universal Z' is selected instead of one of the standard benchmarks (such as the Sequential or $B-L$ models) for several reasons. It has comparable couplings to quarks and leptons, allowing for a fair comparison between hadron and lepton colliders. Its couplings are flavour-diagonal, making the model safely compatible with flavour constraints. When integrated out at tree-level, it generates only the universal operator $\mathcal{O}_{2B}$ in the SM EFT, with coefficient $c_{2B}/\Lambda^2 = g_{Z'}^2/(g_1^4 M^2)$. Since the sensitivity to $\mathcal{O}_{2B}$ is available for all colliders [39], a straightforward and rigorous assessment of the indirect reach is possible for the Y-Universal Z' model, while additional input would be needed for the standard benchmarks.

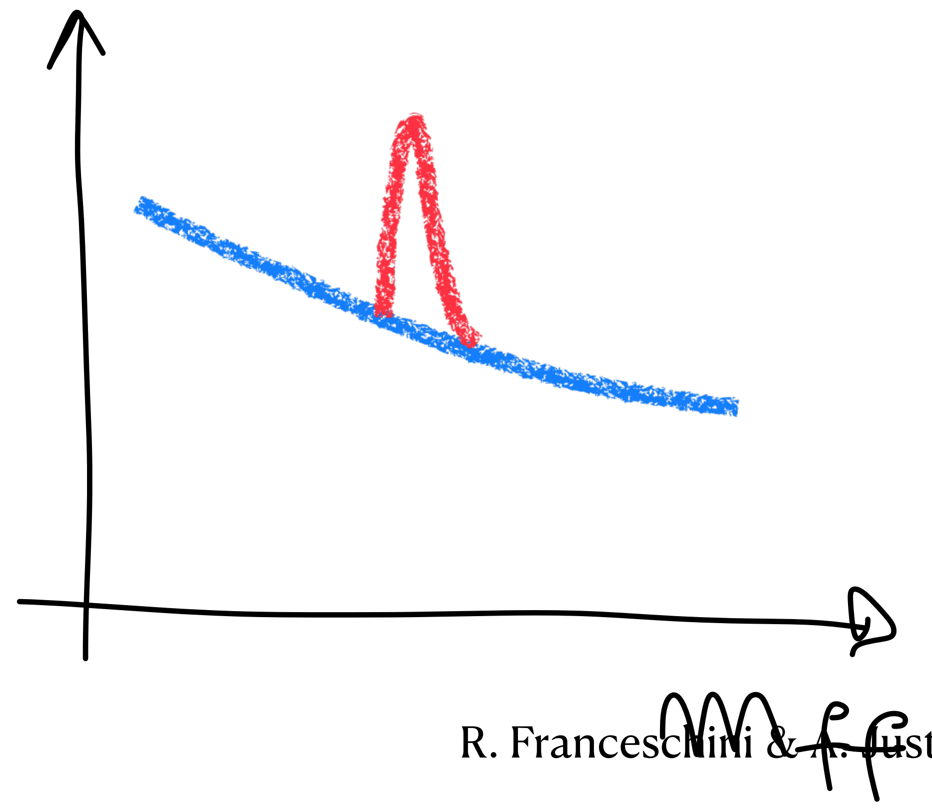
Briefing Book 2019

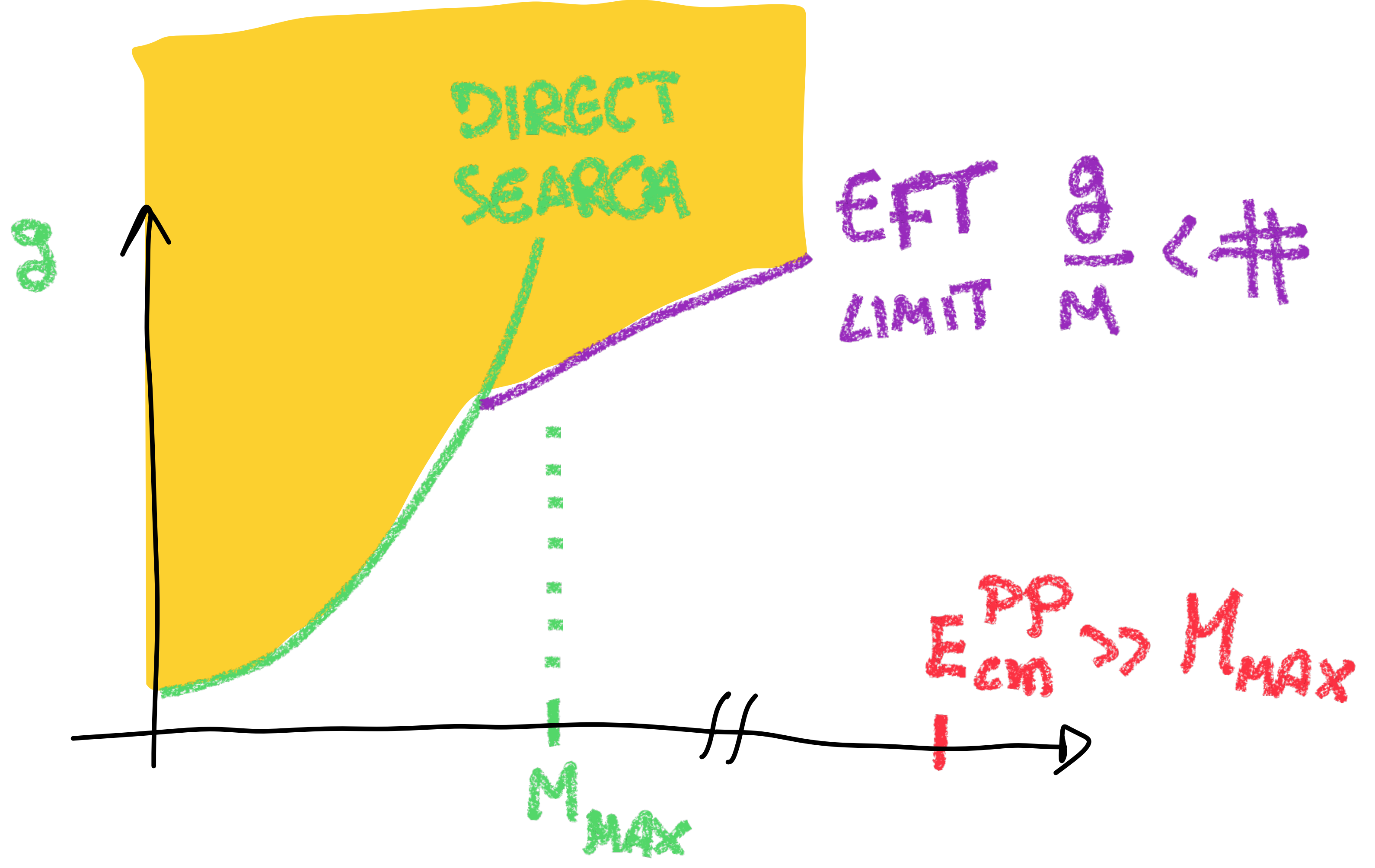
Bounds at hadron colliders

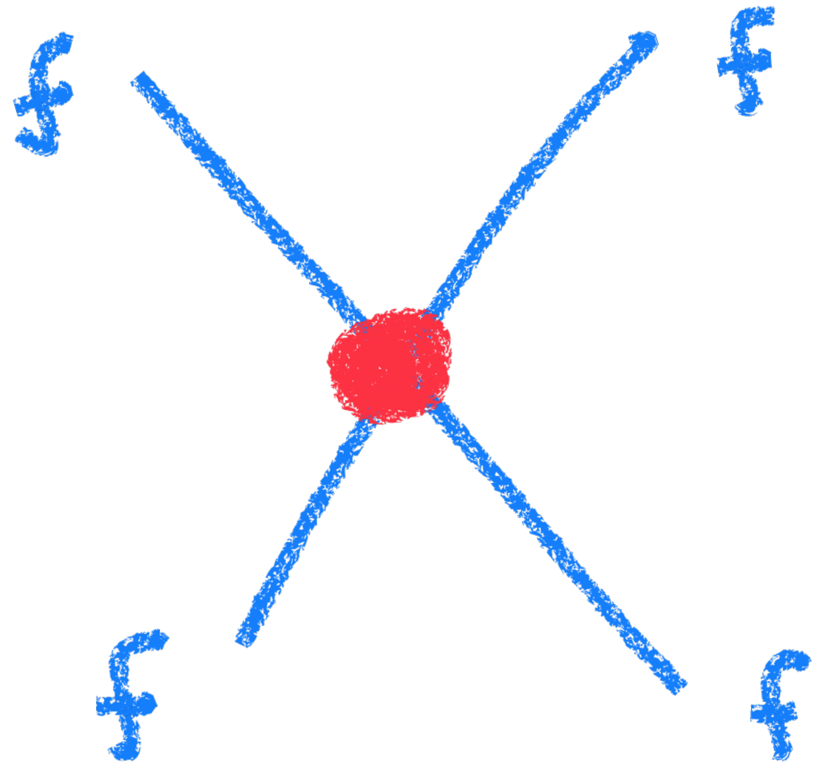
tree-level coupling to the beams

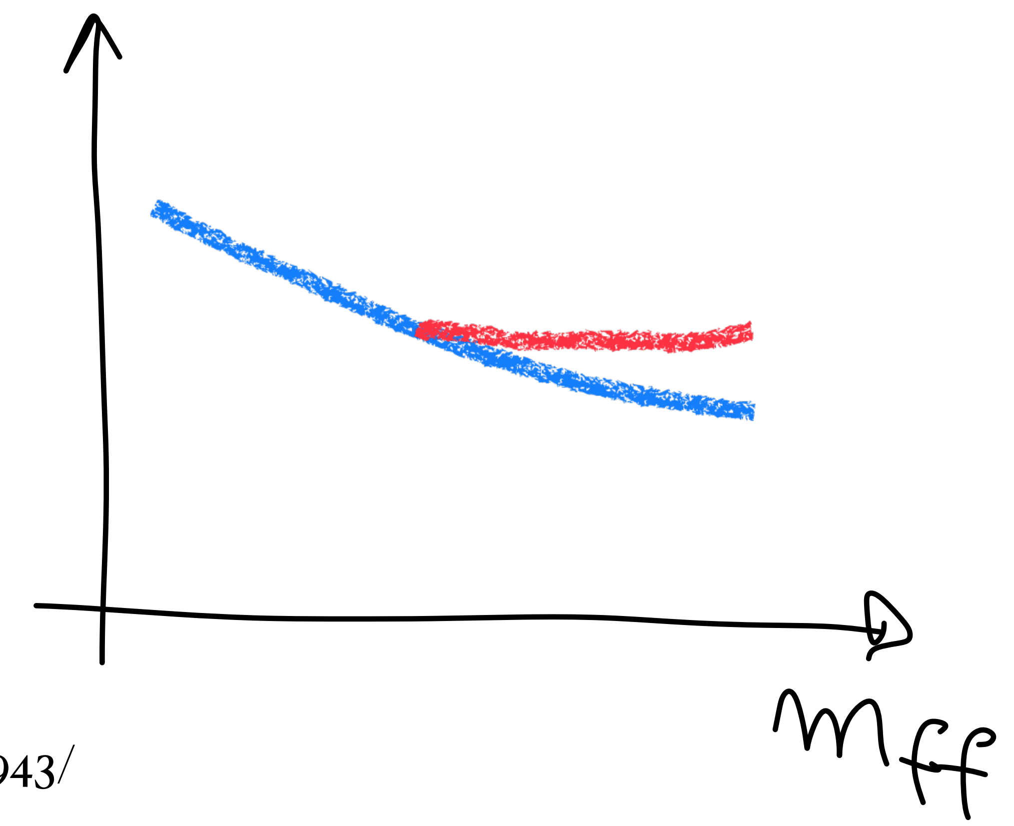
$$Y': \qquad g_{Z'}/g_1 \equiv 6\cdot g_{V,q_L} = -3\cdot g_{V,d_R} = \frac{3}{2}\cdot g_{V,u_R},$$
$$g_{Z'}/g_1 \equiv -2g_{V,\ell_L} = -g_{V,e_R}.$$





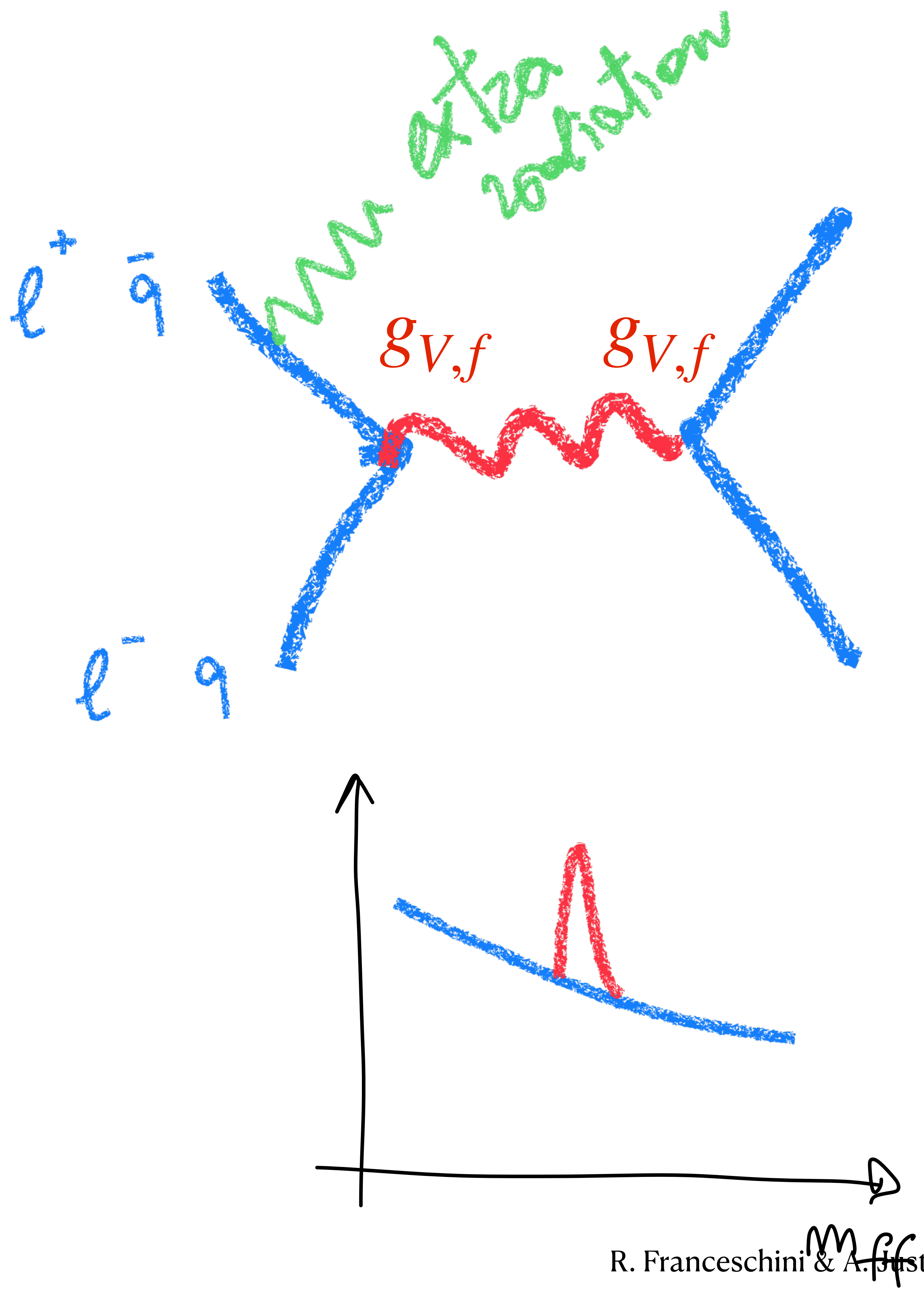


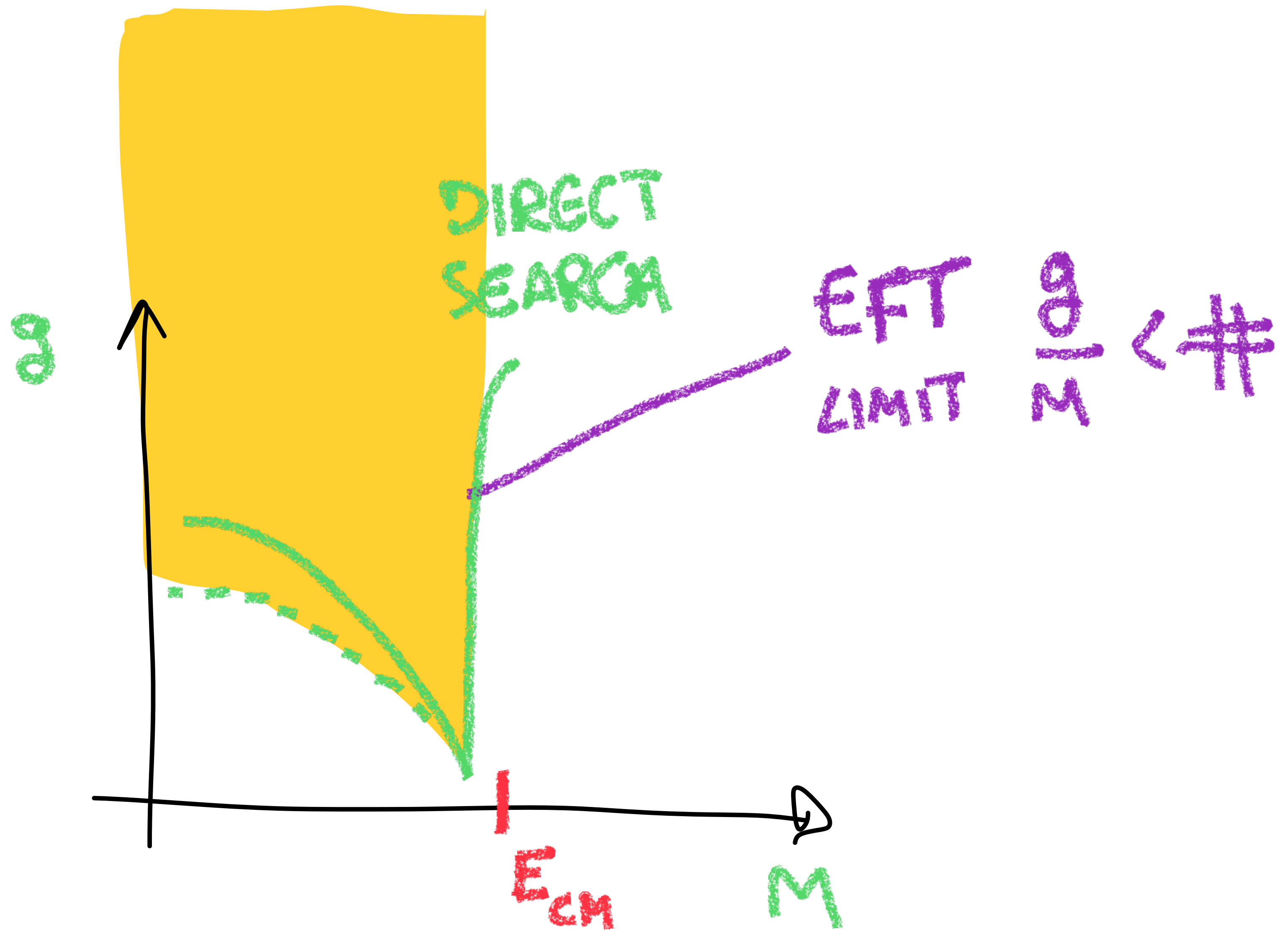


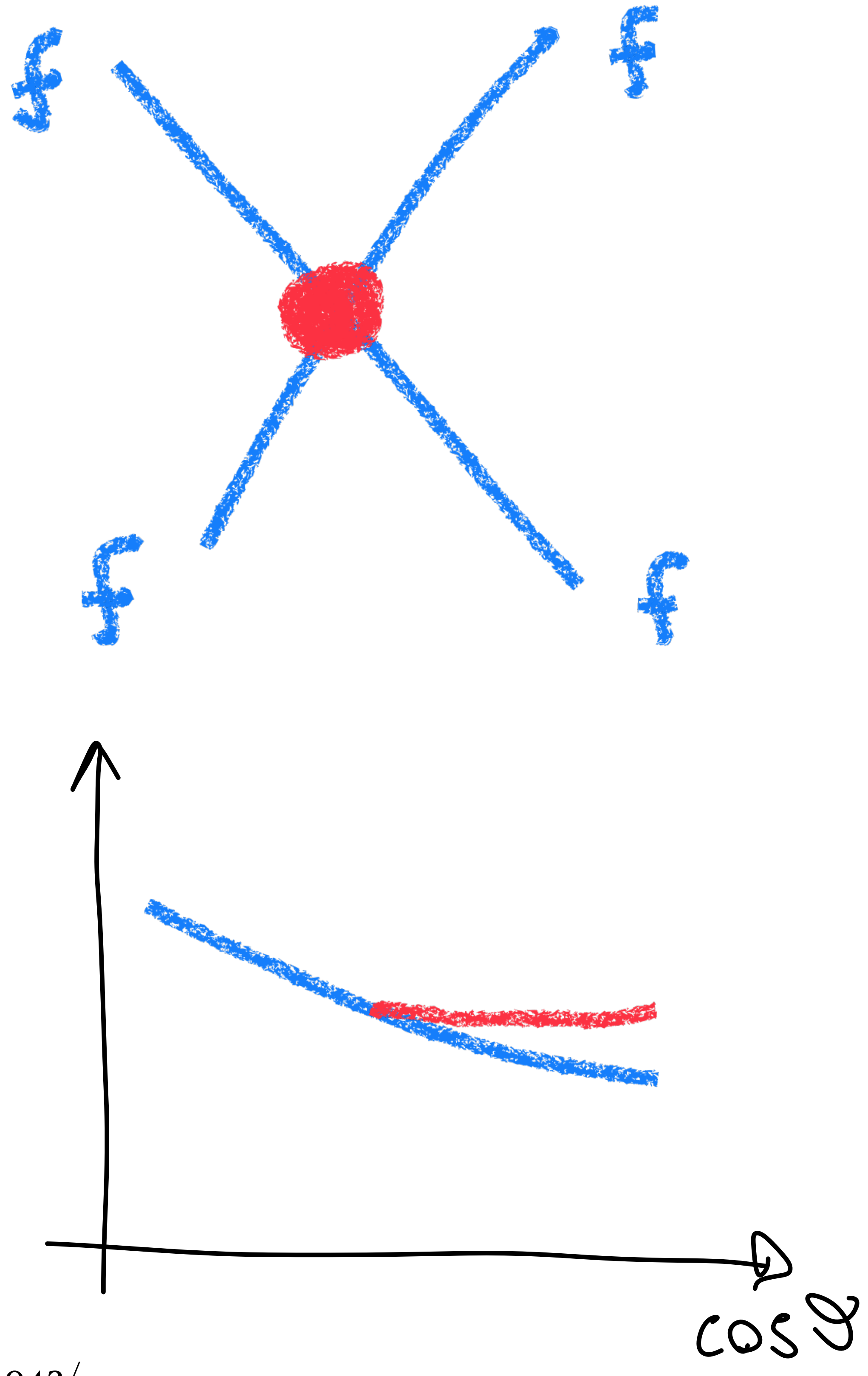


Bounds at lepton colliders

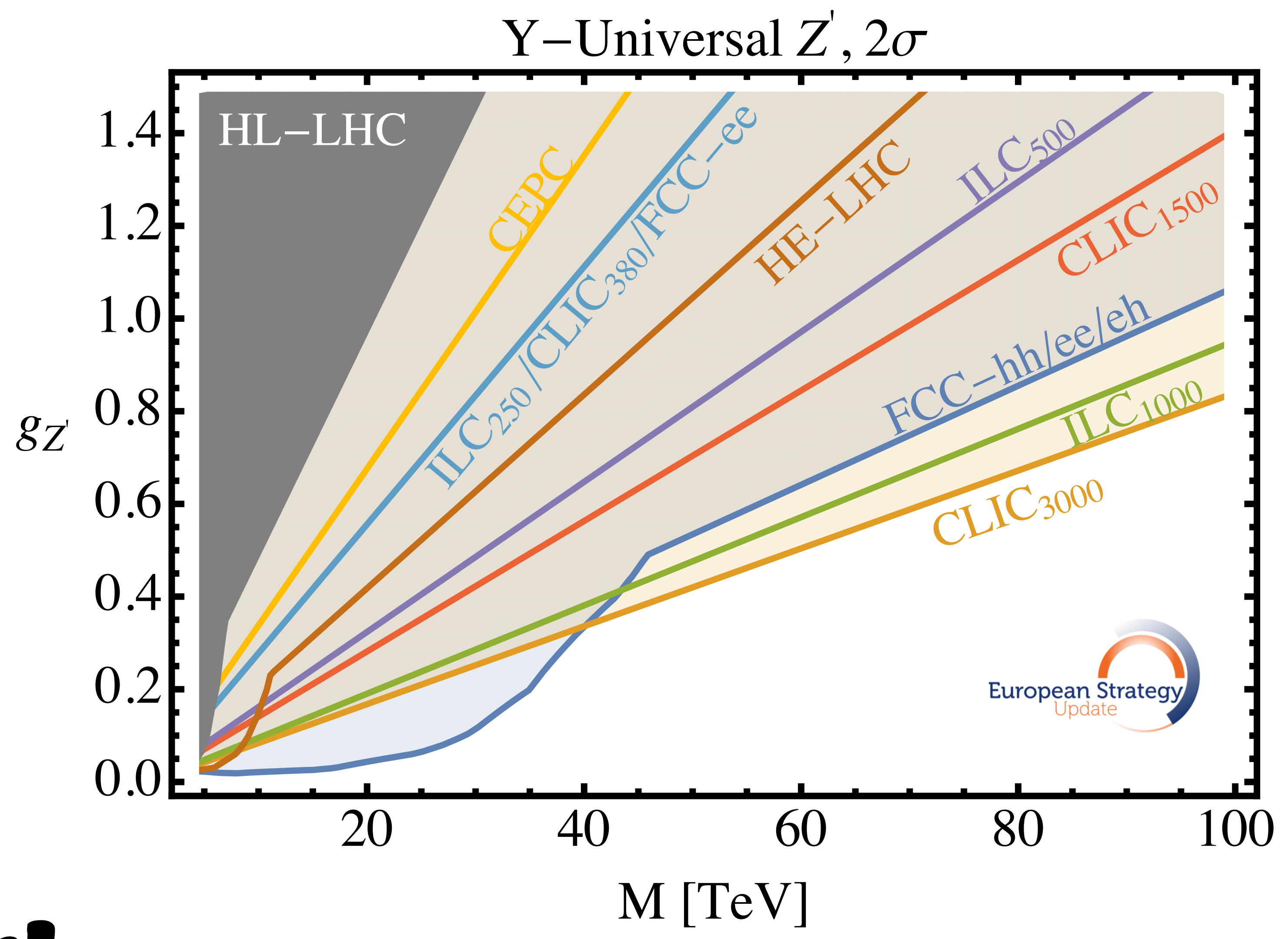
tree-level coupling to the beams





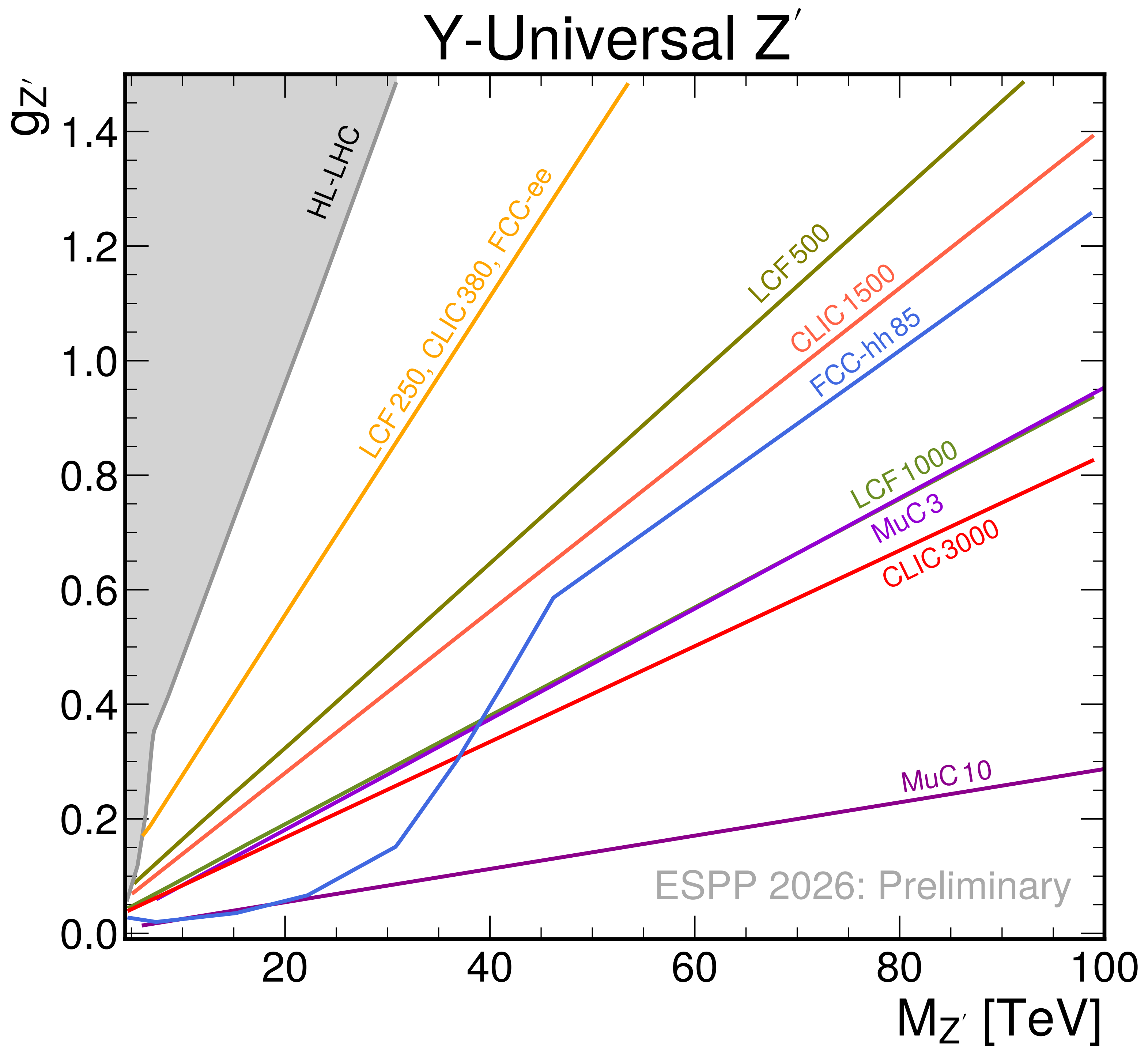


New Summary (in progress)



- Added muCol 3 TeV and 10 TeV (Abstract #207) and a rescaling of 100 TeV 30/ab FCChh to 85 TeV 30/ab (Abstracts #227 + #233 #241 #242 #247 #261)
- The rest is taken from 2019 Briefing Book
- Straight part of each bound from EFT bounds on c_{2B} from EW fit (e.g. PPG19, Snowmass 22, PPG25 …) → TBU

- Bottom line: Y-Universal Z' representative of gauge boson coupled to all fermions; Higher energy projects can bring the largest jump in sensitivity w.r.t. HL-LHC, up to O(10) stronger bound on the coupling
- Updates foreseen: Update-able from EW fit result from EW PPG, exploration of any difference from global ↔ single operator for this scenario in the updated fits
- Questions and things still to do: what happens when not coupled to beams? (partial answer in the next slides)



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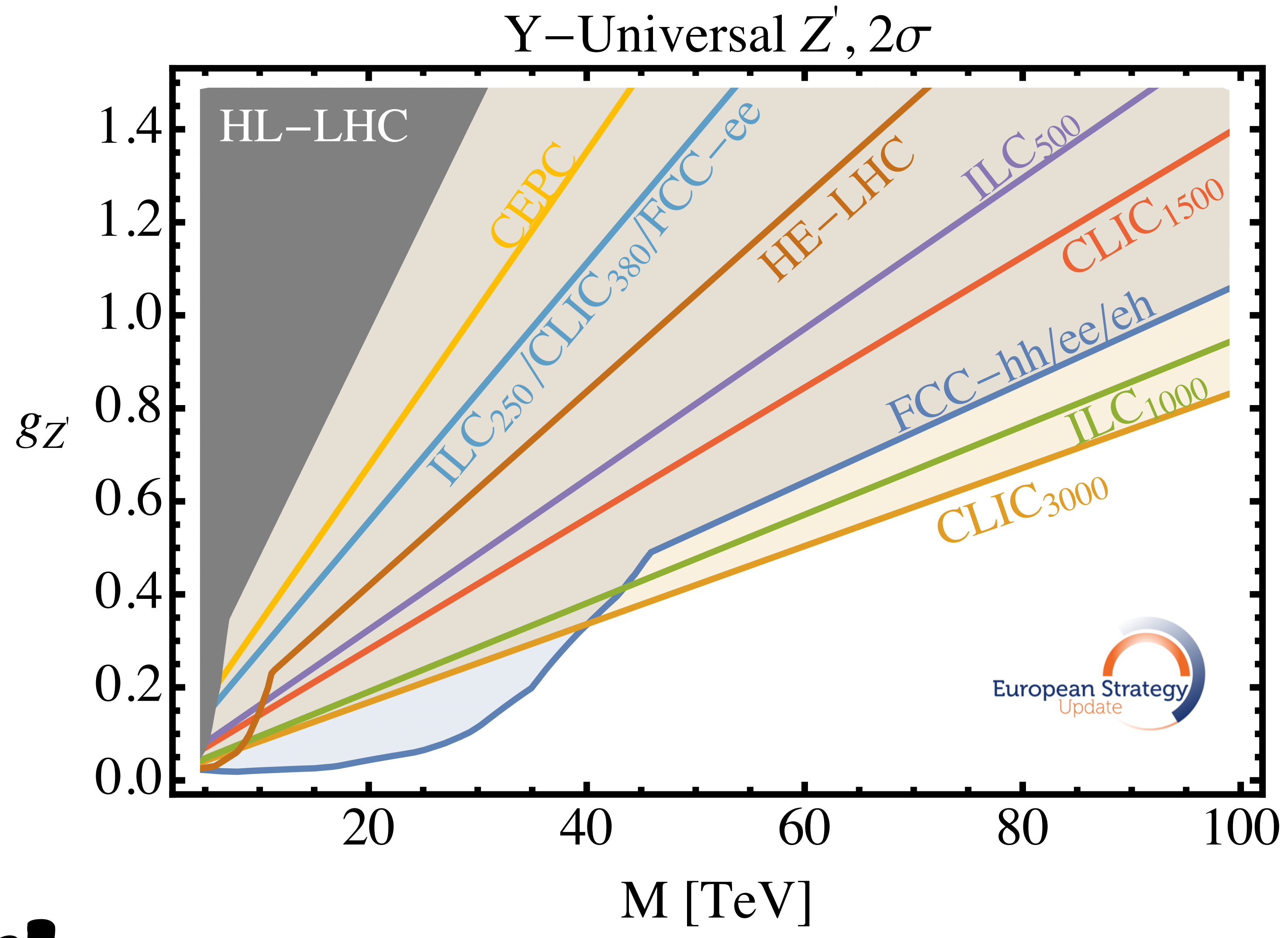

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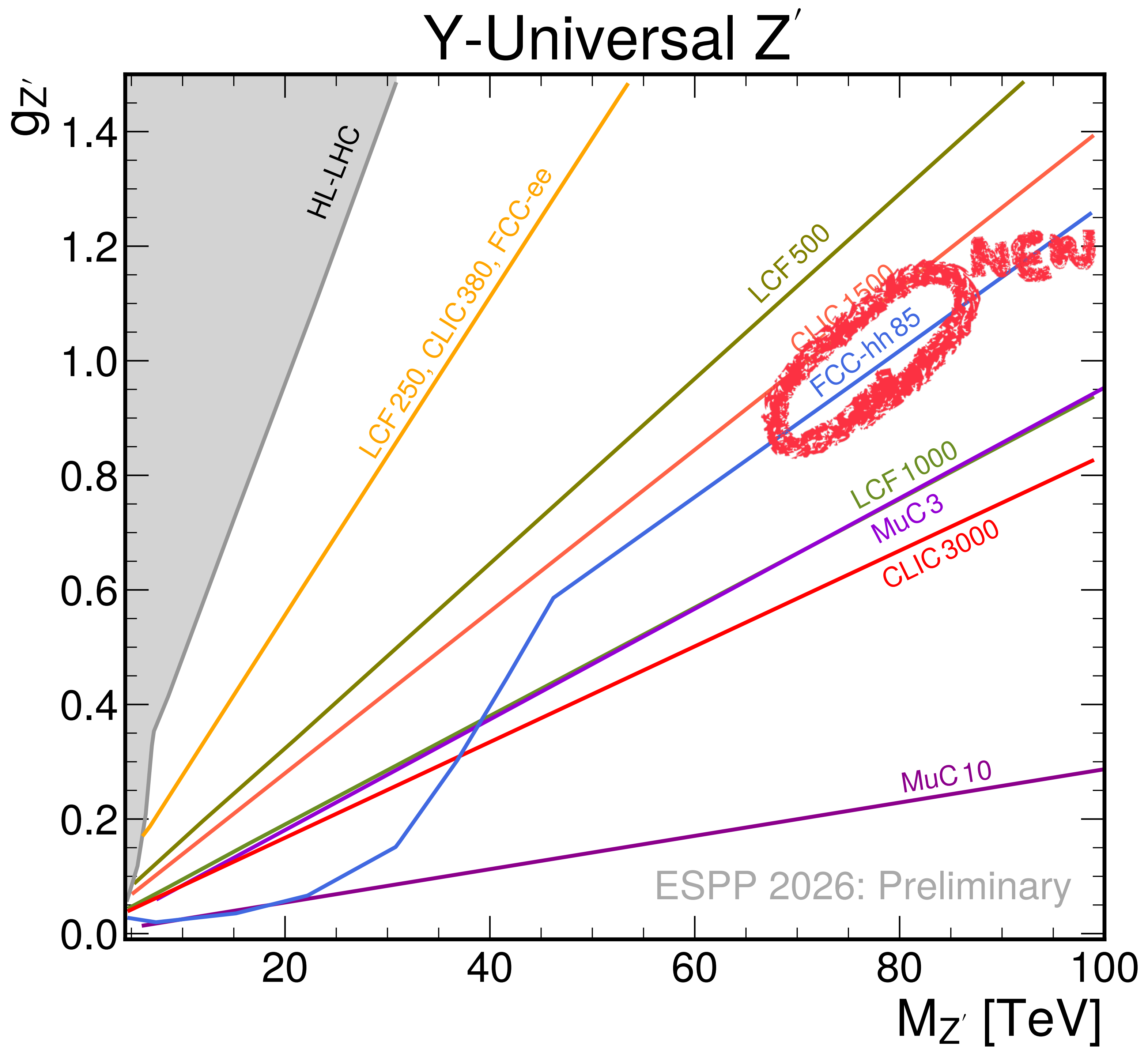

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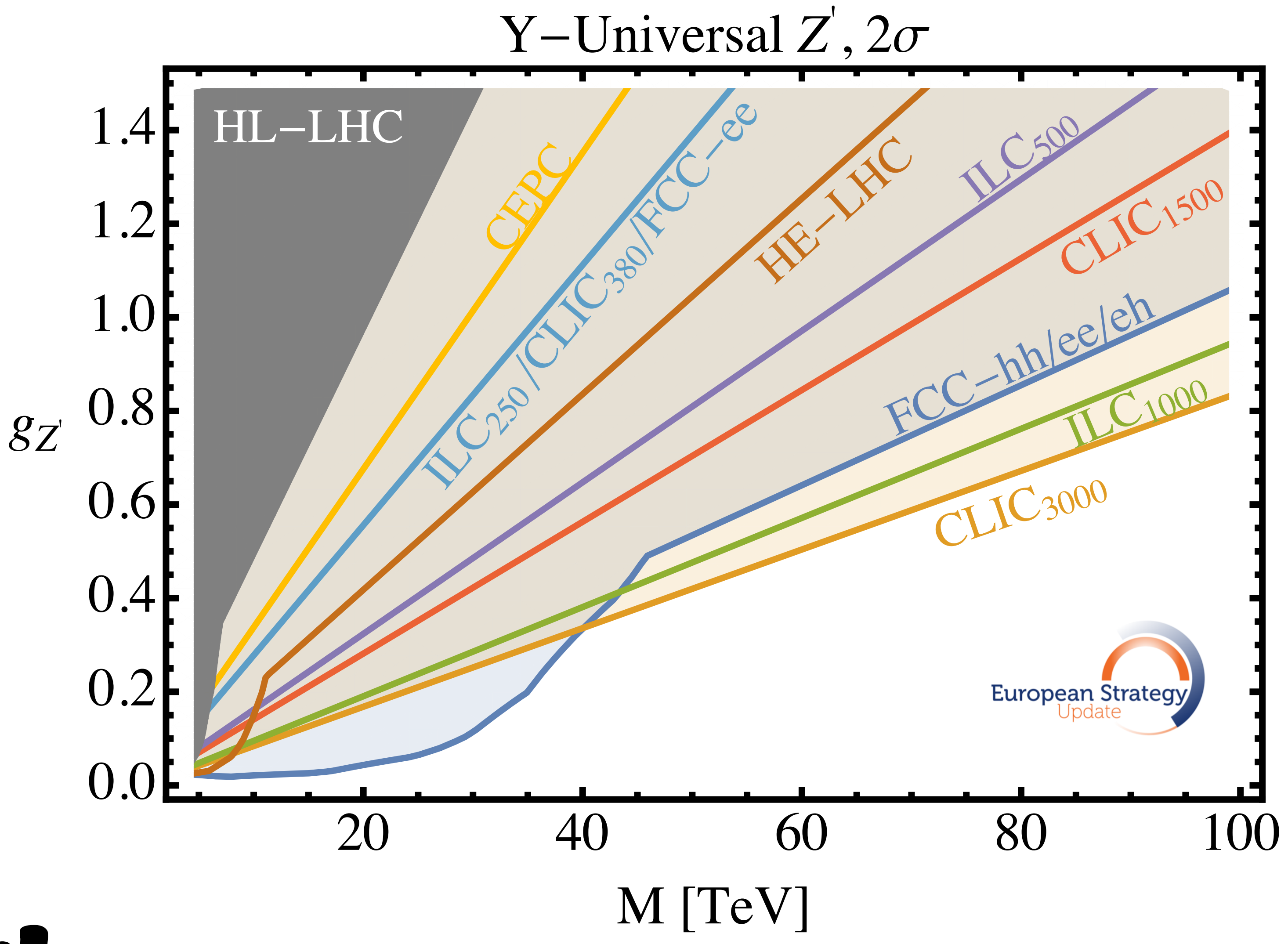

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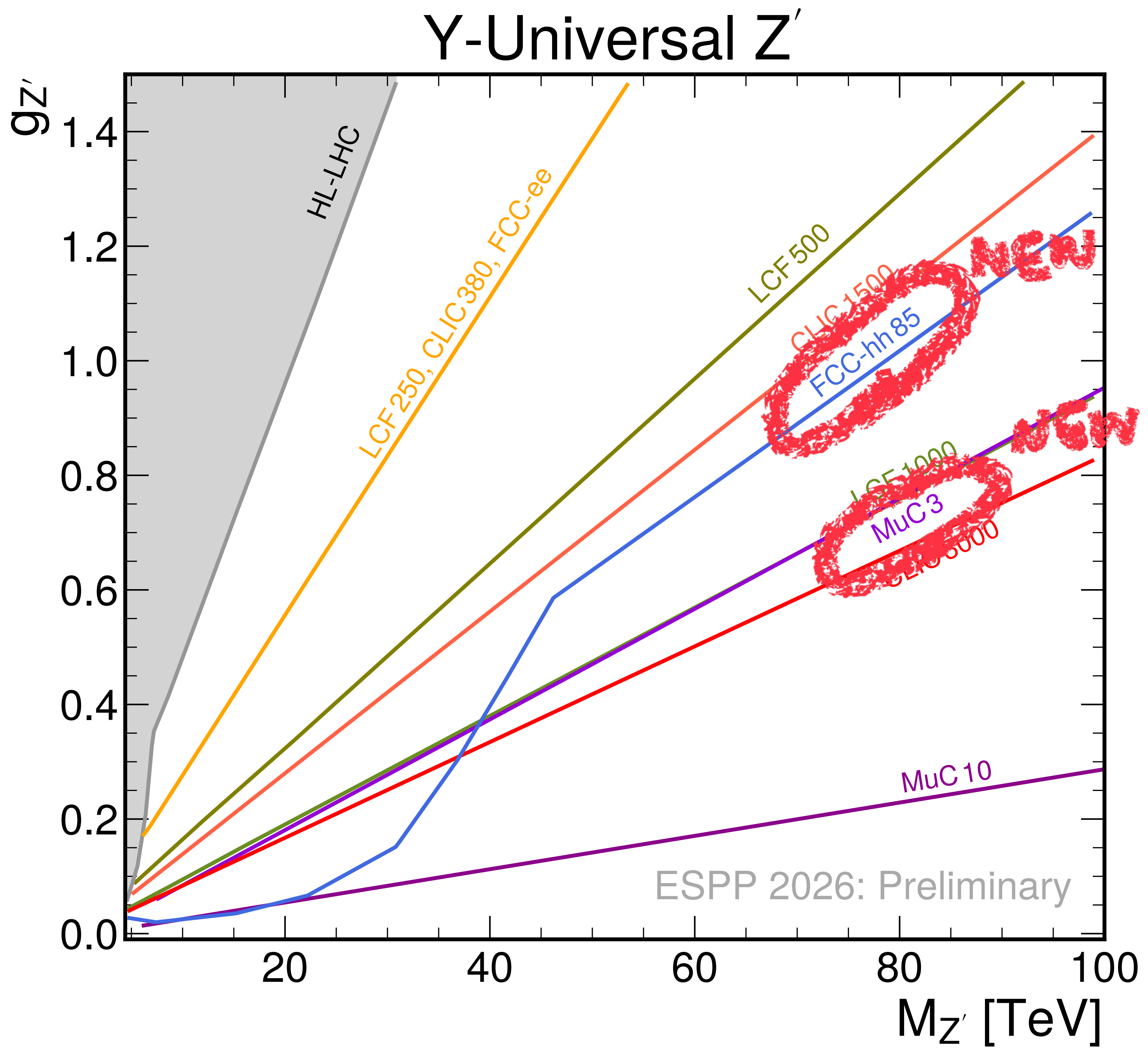

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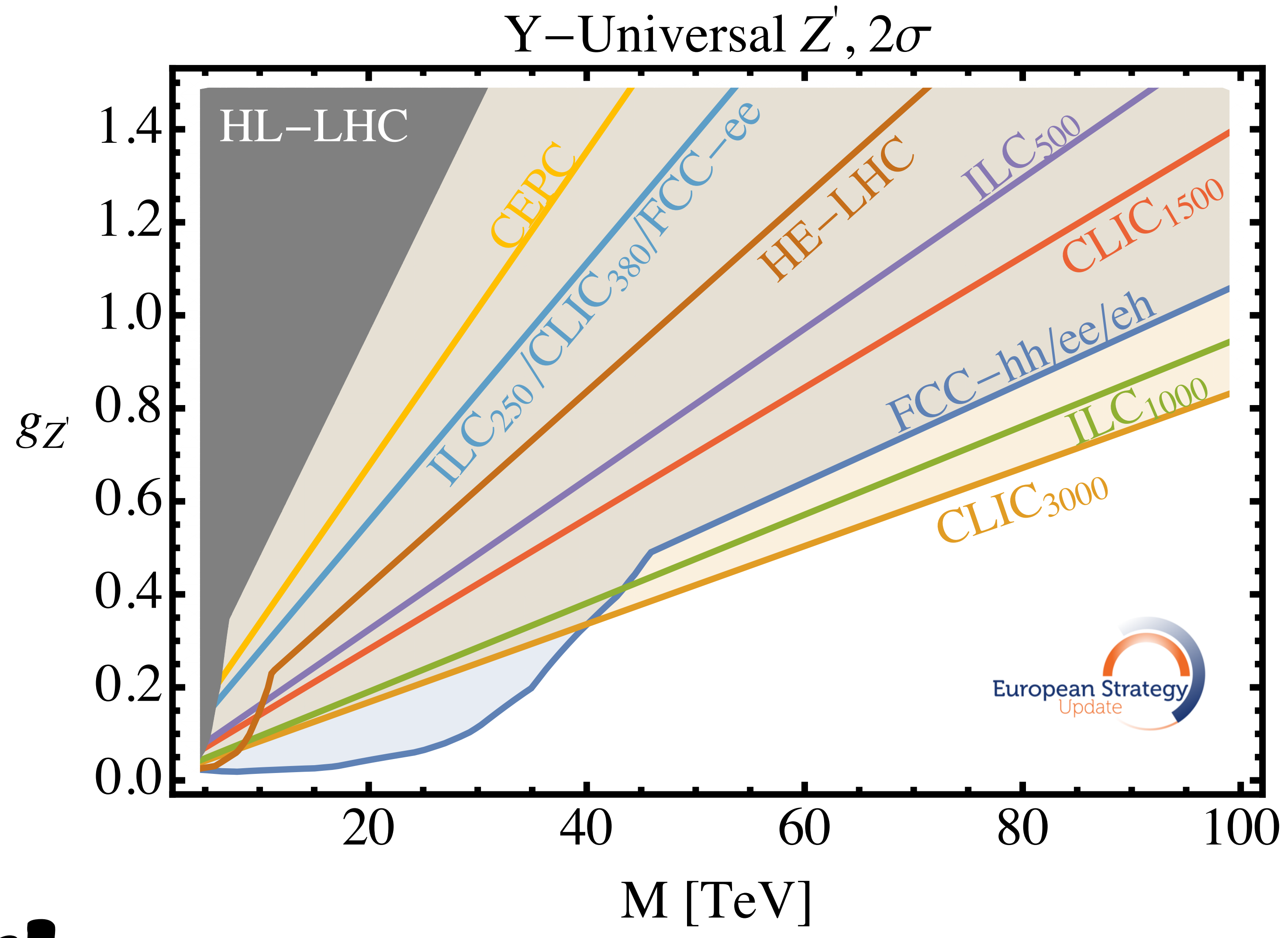

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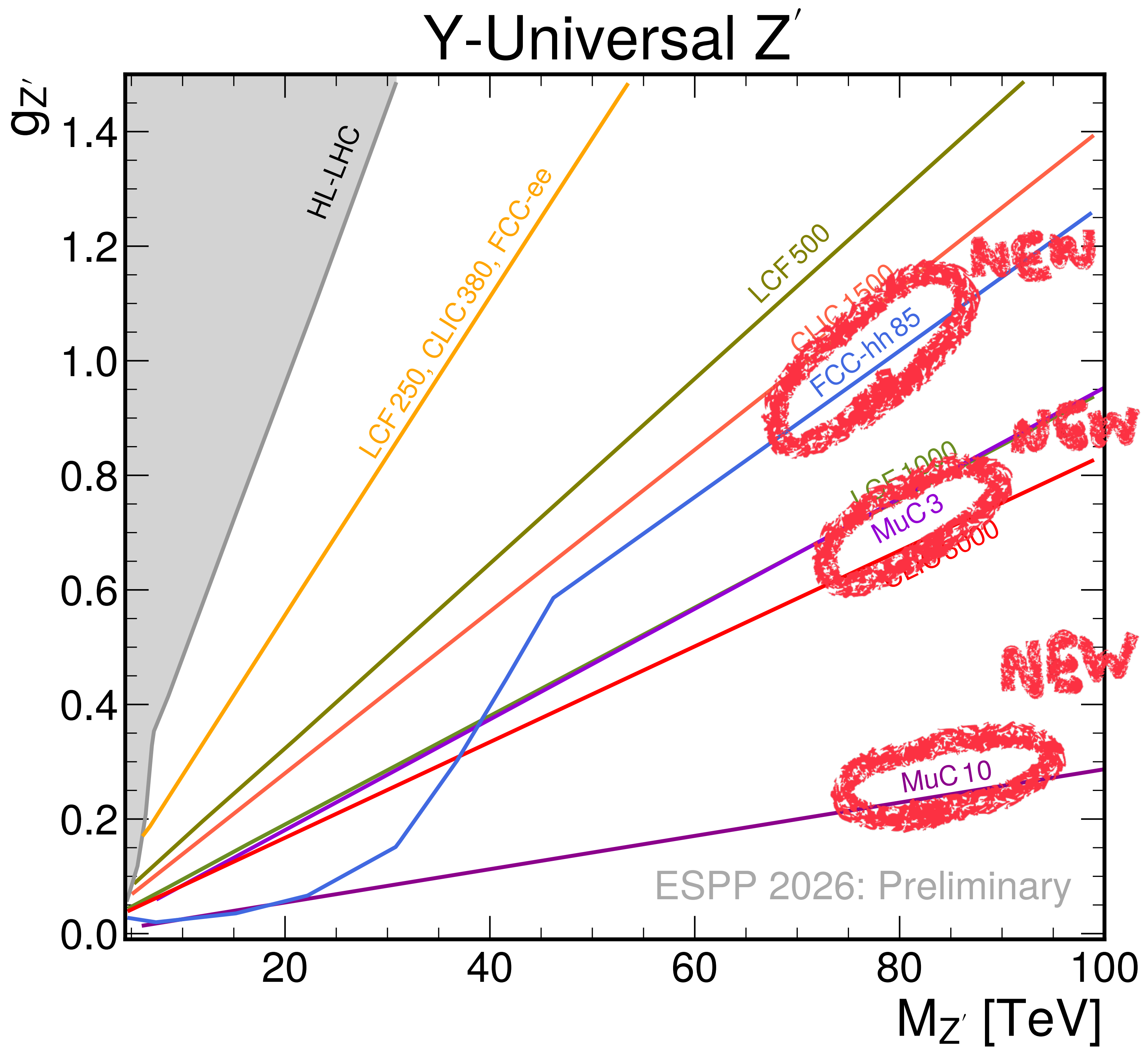
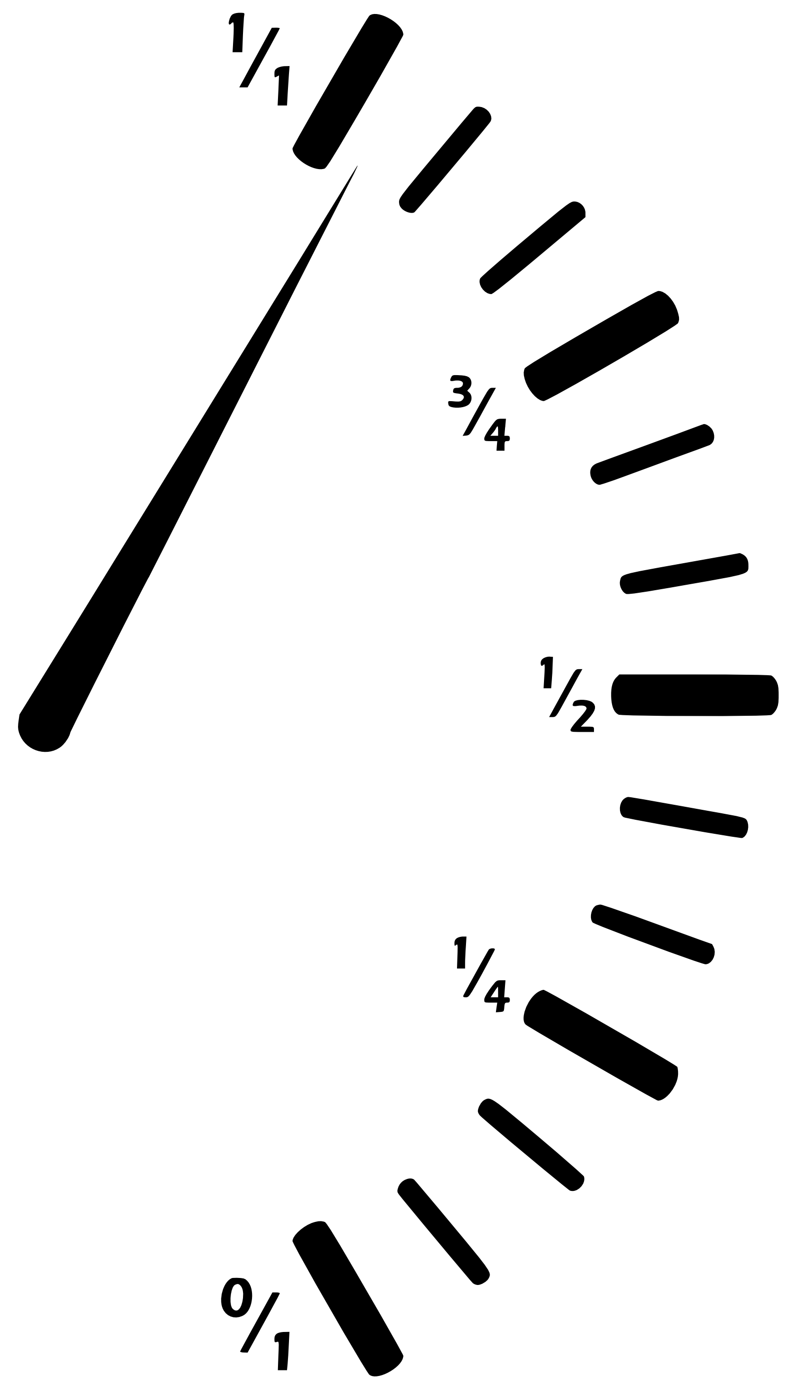
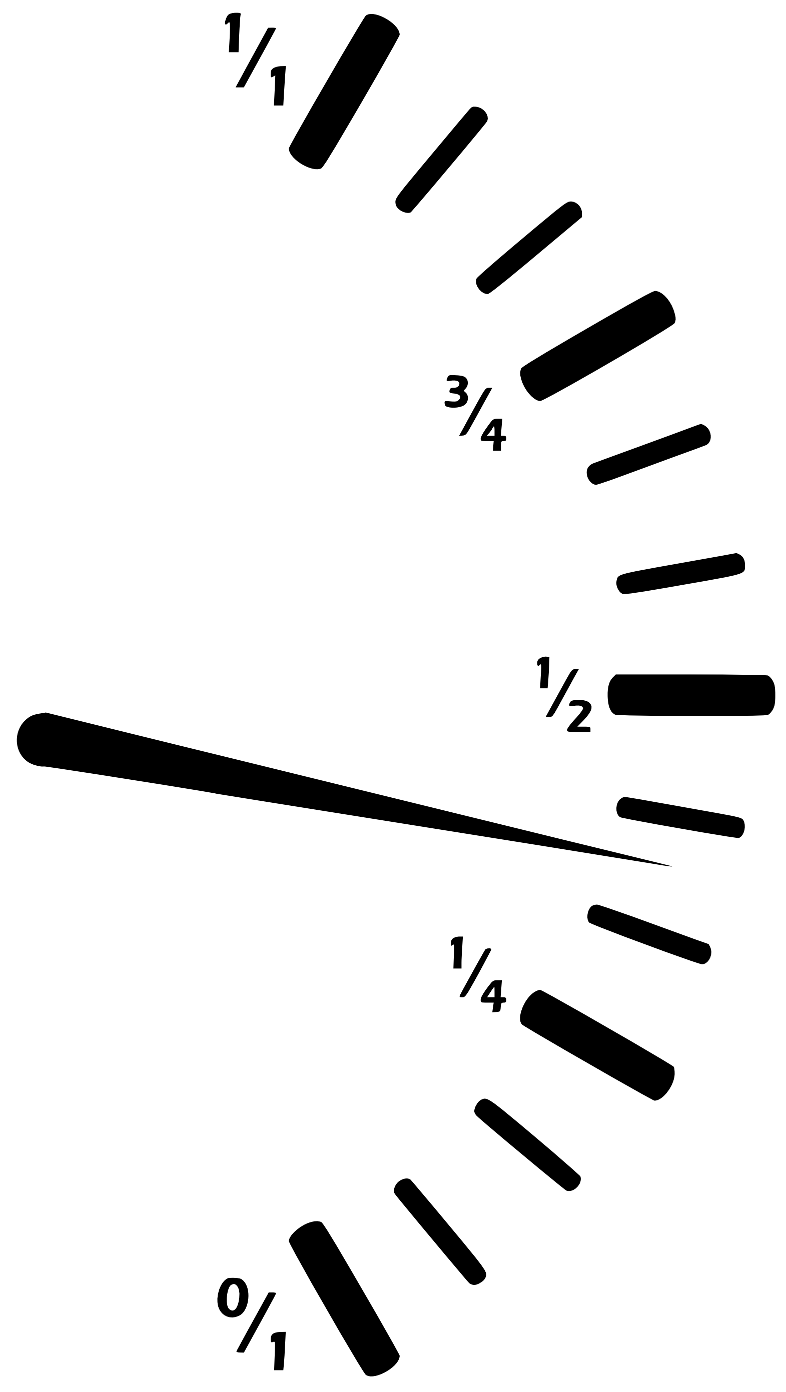


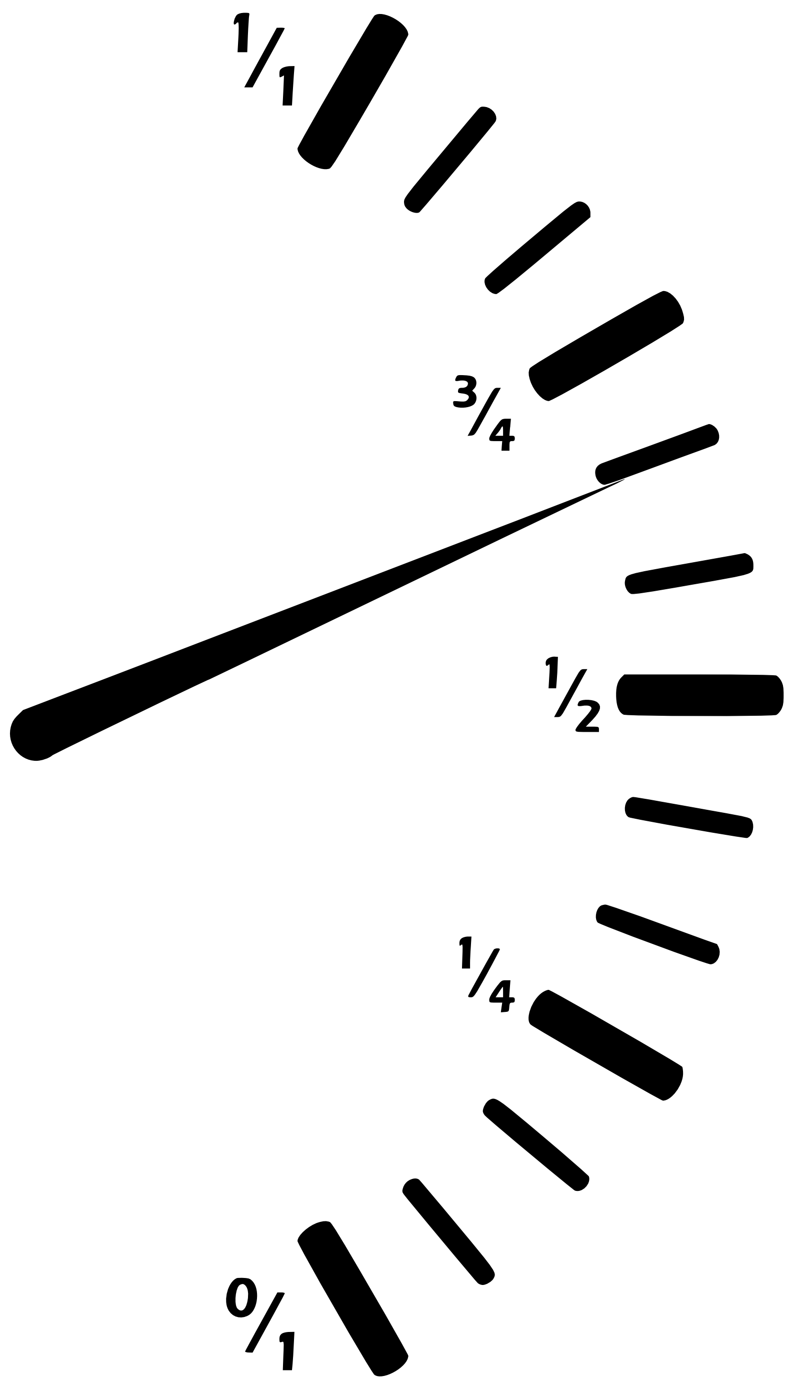
Many possible coupling choices



g_Q

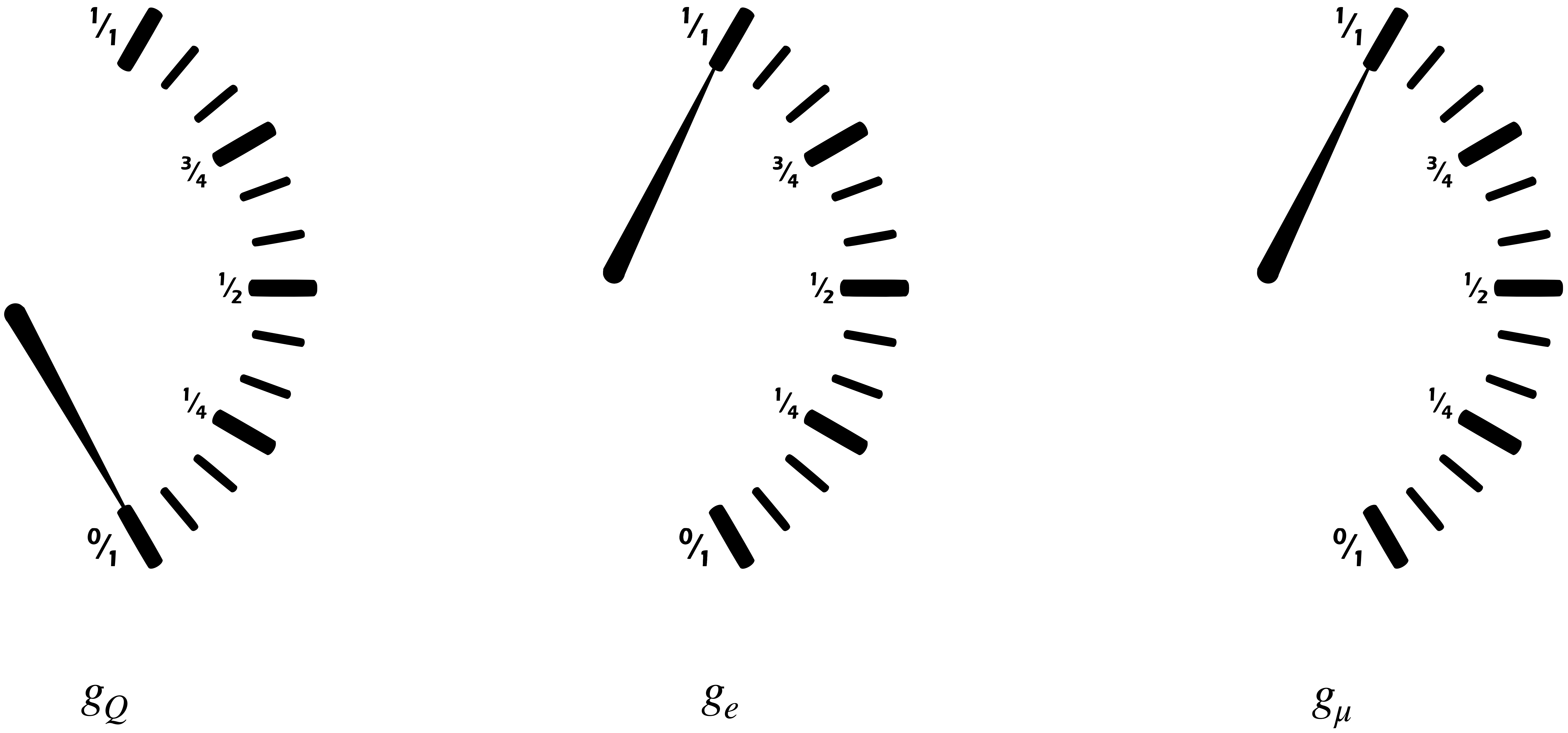


g_e



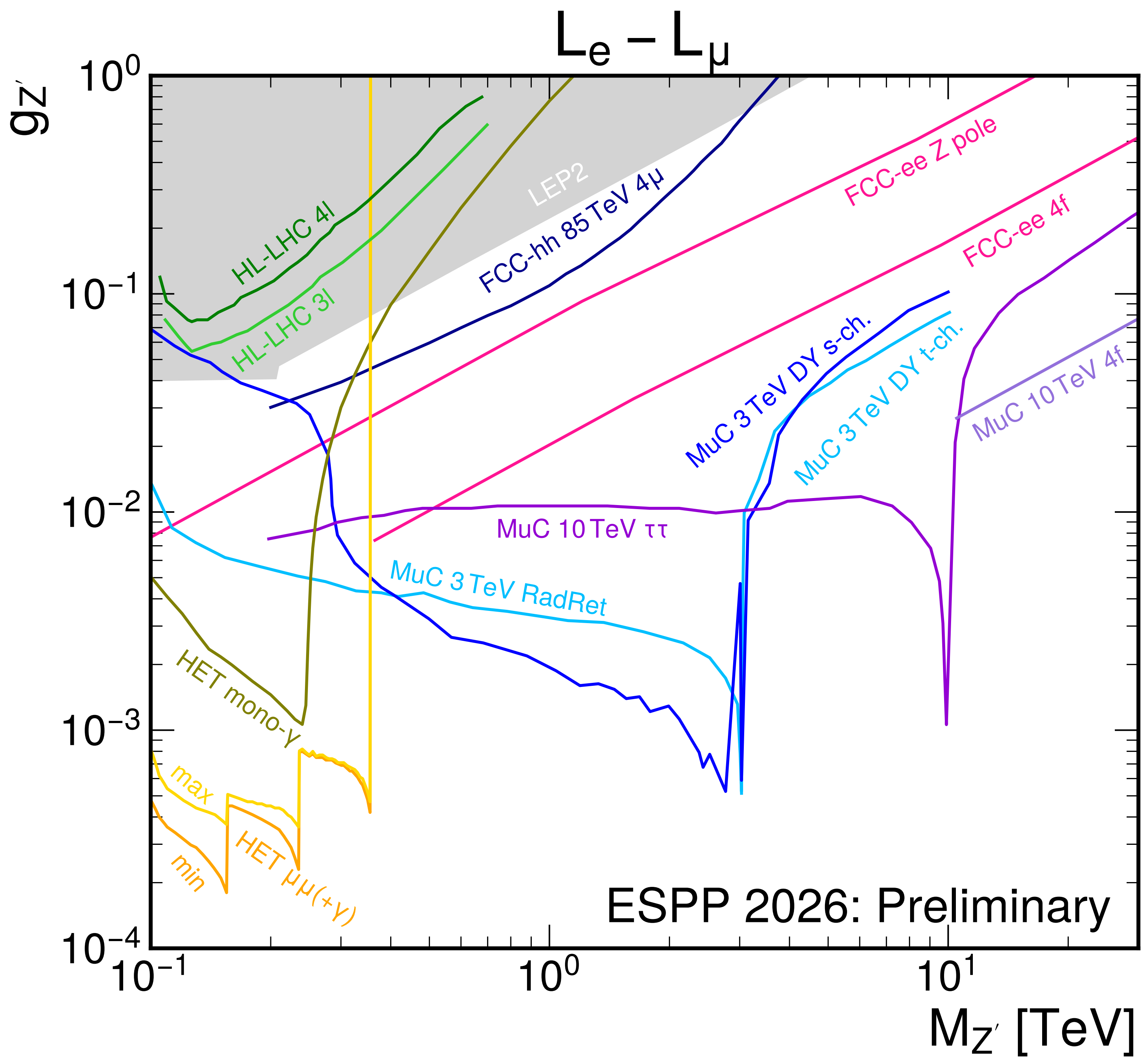
g_μ

$$L_e - L_\mu$$



Towards a summary plot

only lepton coupled at tree-level



- Higgs Electroweak Top factory (HET) 2412.14241, 2107.11194, 2410.12903 (FCCee 4f, $\ell\ell(+\gamma)$ + monoγ no det. sim, ILC Delphes monoγ). Harmonization and improvement needed.
- FCChh (no tree-level coupling to the beam) result from 2205.13552 for 100 TeV rescaled to 85 TeV
- MuC 2308.12804, 2205.13552 (EFT , direct 3 TeV, 10 TeV(TBU))

- Bottom line: lepton colliders very effective, very strong EFT bounds
- Thing to do: Harmonize lower energies e^+e^- information, try other scenarios in which beams are decoupled from the Z’

Conclusions

- ✱ The landscape of new gauge bosons is very rich. Extensive coverage requires extensive collider program(s).
- ✱Combination of indirect and direct search extends the reach significantly. All projects benefit of the combination of the two approaches. Higher energy machine probe higher masses and/or smaller couplings.
- ✱Tree-level production mechanism of on/off shell gauge bosons well explored and well represented by benchmarks à la Y'.
- ✱Possible to consider variations of tree-level coupled vectors (e.g. decay to vectors) to explore role of detectors.
- ✱Possible to consider more scenarios of vectors not coupled to the beams (e.g. no coupling to electrons, no coupling to muon, ...)

Thank you!

B-L vs Y'

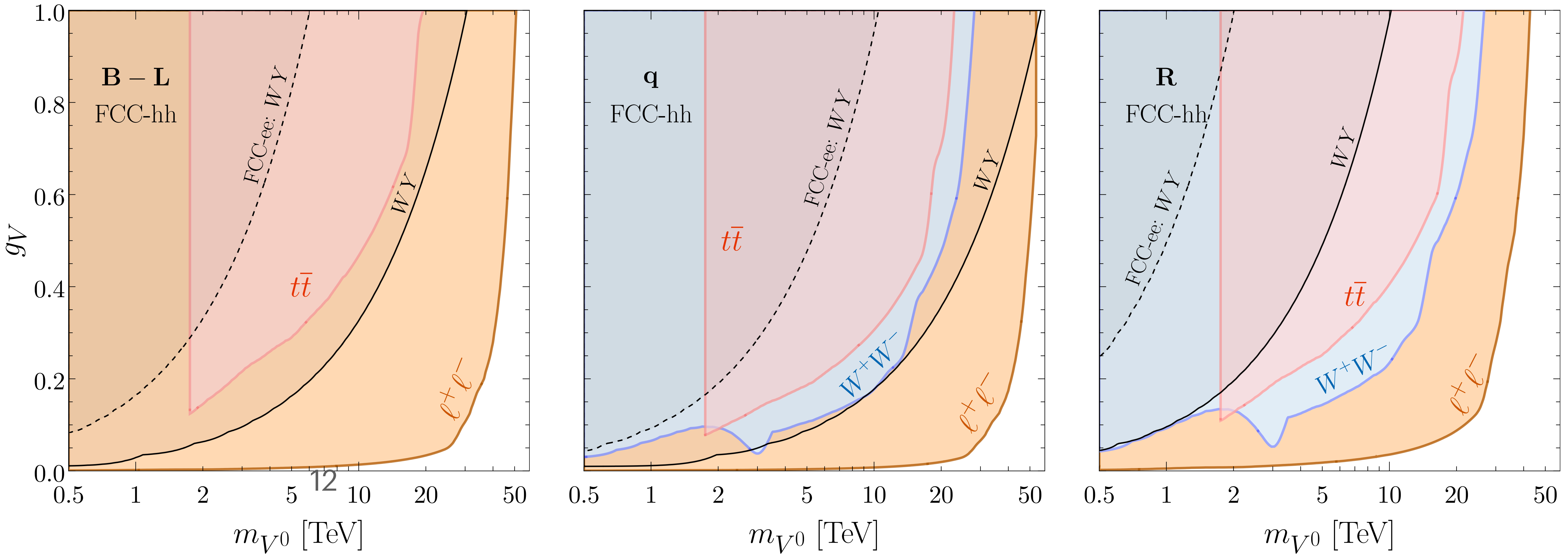
Also B-L has a O(1) coupling to both leptons and quarks, not too dissimilar from Y'

$$
\begin{aligned}
B-L: \quad g_{Z'} &\equiv 3\cdot g_{V,q_L} = 3\cdot g_{V,d_R} = 3\cdot g_{V,u_R},\\
-g_{Z'} &\equiv g_{V,\ell_L} = g_{V,e_R}.
\end{aligned}
$$

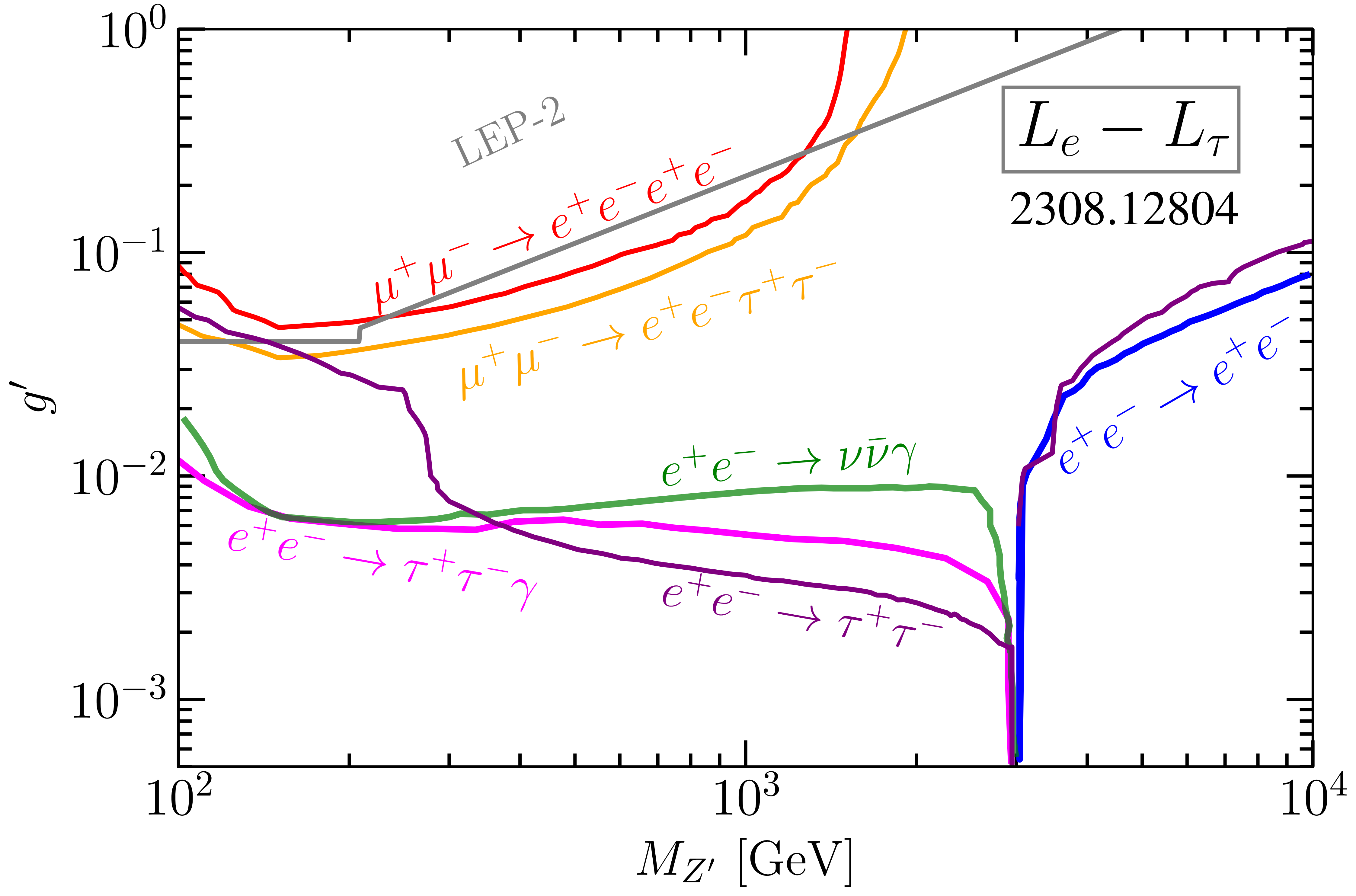
$$
\begin{aligned}
Y': \quad g_{Z'}/g_1 &\equiv 6\cdot g_{V,q_L} = -3\cdot g_{V,d_R} = \frac{3}{2}\cdot g_{V,u_R},\\
g_{Z'}/g_1 &\equiv -2g_{V,\ell_L} = -g_{V,e_R}.
\end{aligned}
$$

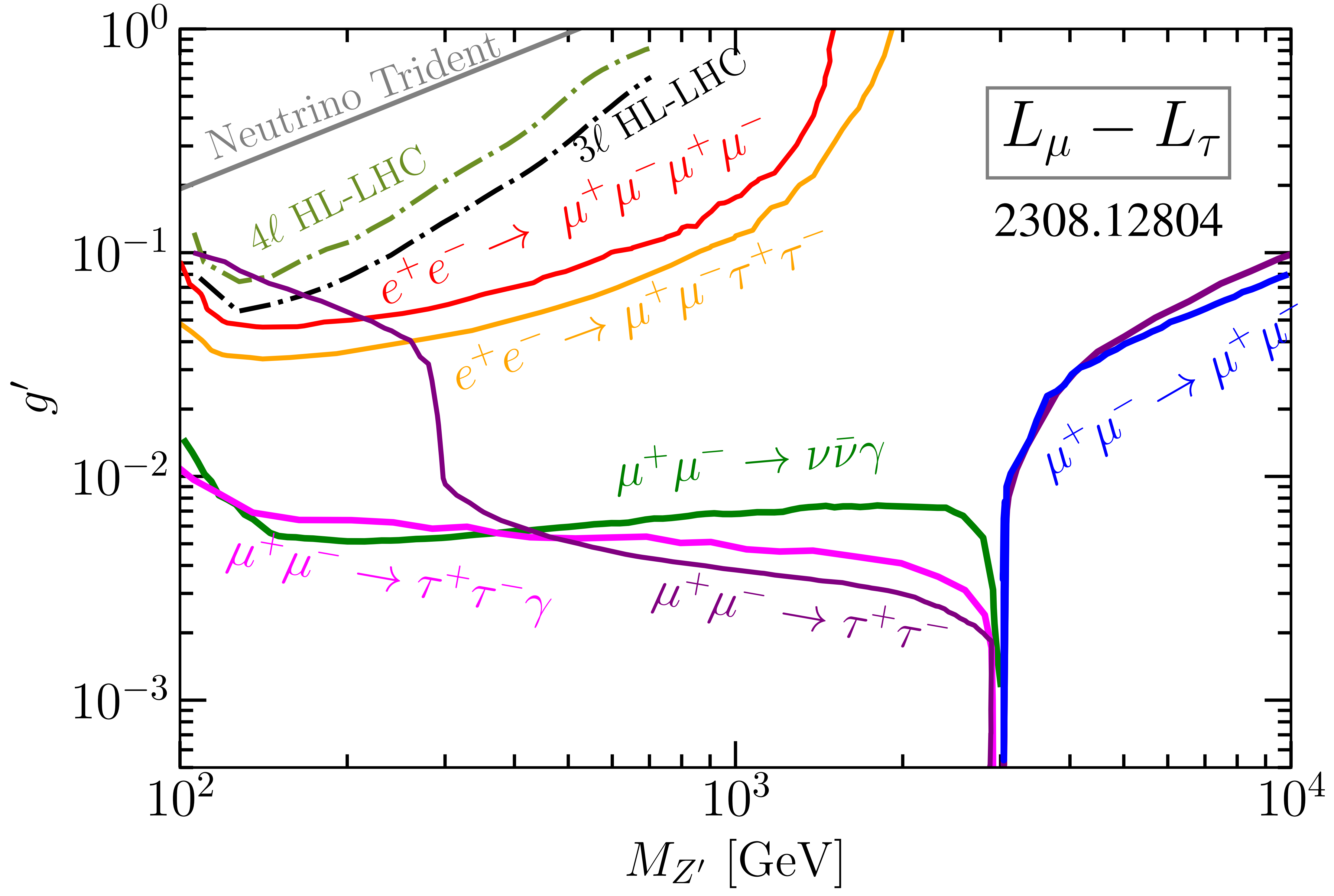
Field	$U(1)_{B-xL}$	$U(1)_R$	$U(1)_{q+xu}$
$Q_L=(u_L,d_L)^T$	$1/3$	0	$1/3$
u_R	$1/3$	$-1/3$	$x/3$
d_R	$1/3$	$1/3$	$(2-x)/3$
$L_L=(\nu_L,e_L)^T$	$-x$	0	-1
e_R	$-x$	$1/3$	$-(2+x)/3$
H	0	$-1/3$	$(x-1)/3$

Prospects in BSM physics at FCC, #242 from 2407.11117

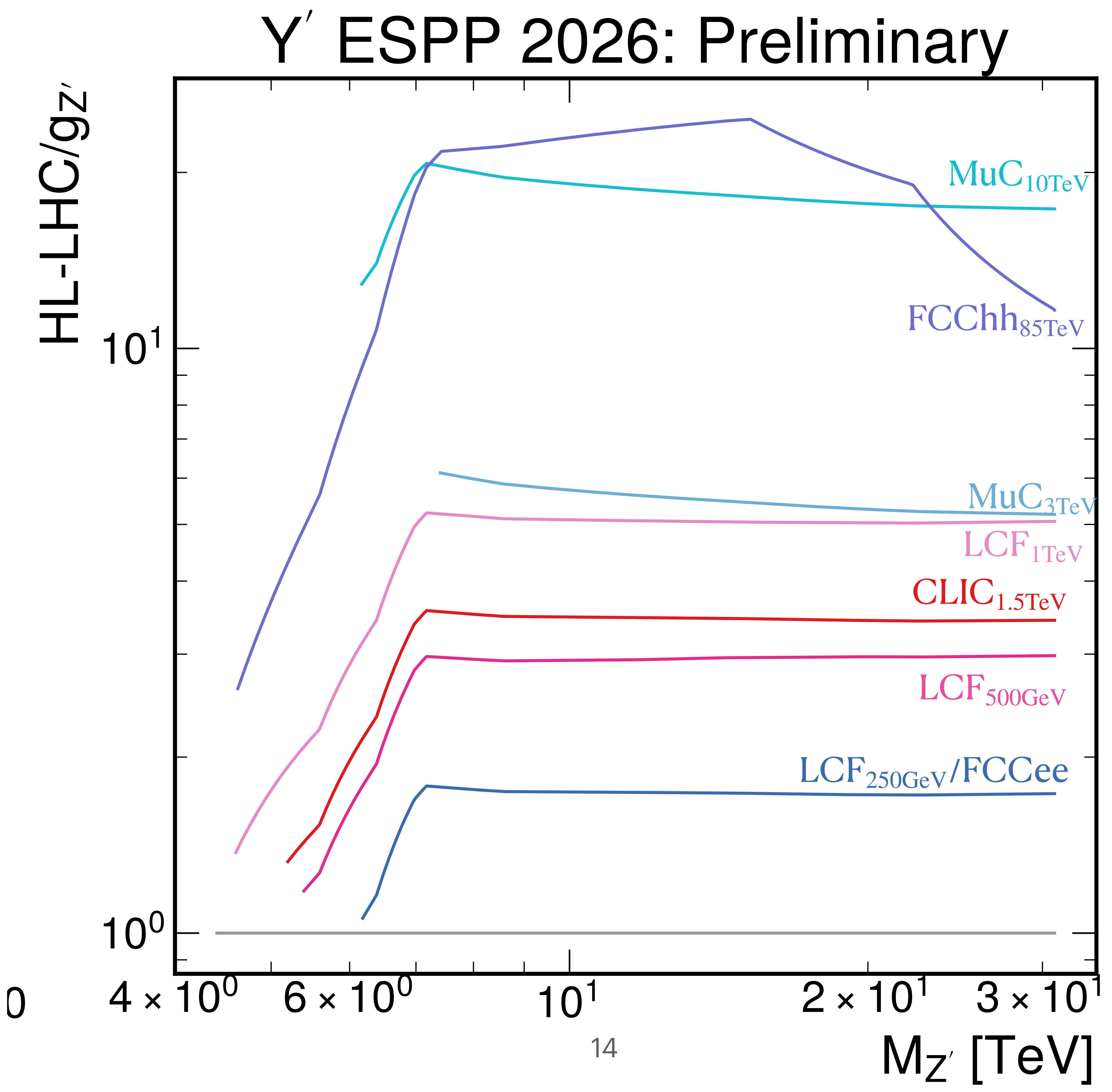


Unfriendly L

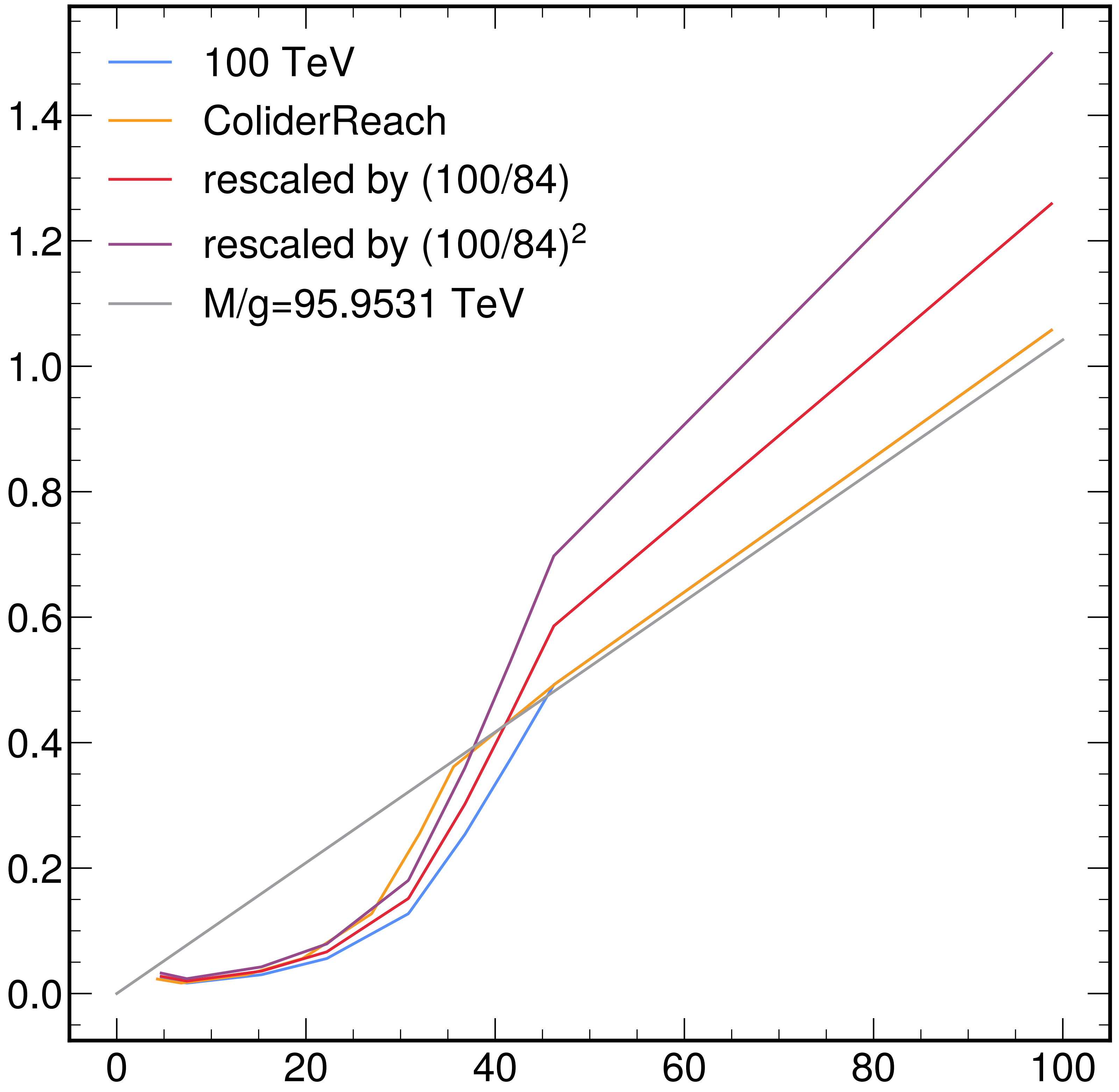




Ratio of reach w.r.t HL-LHC



Y' 84 TeV from 100 TeV limits

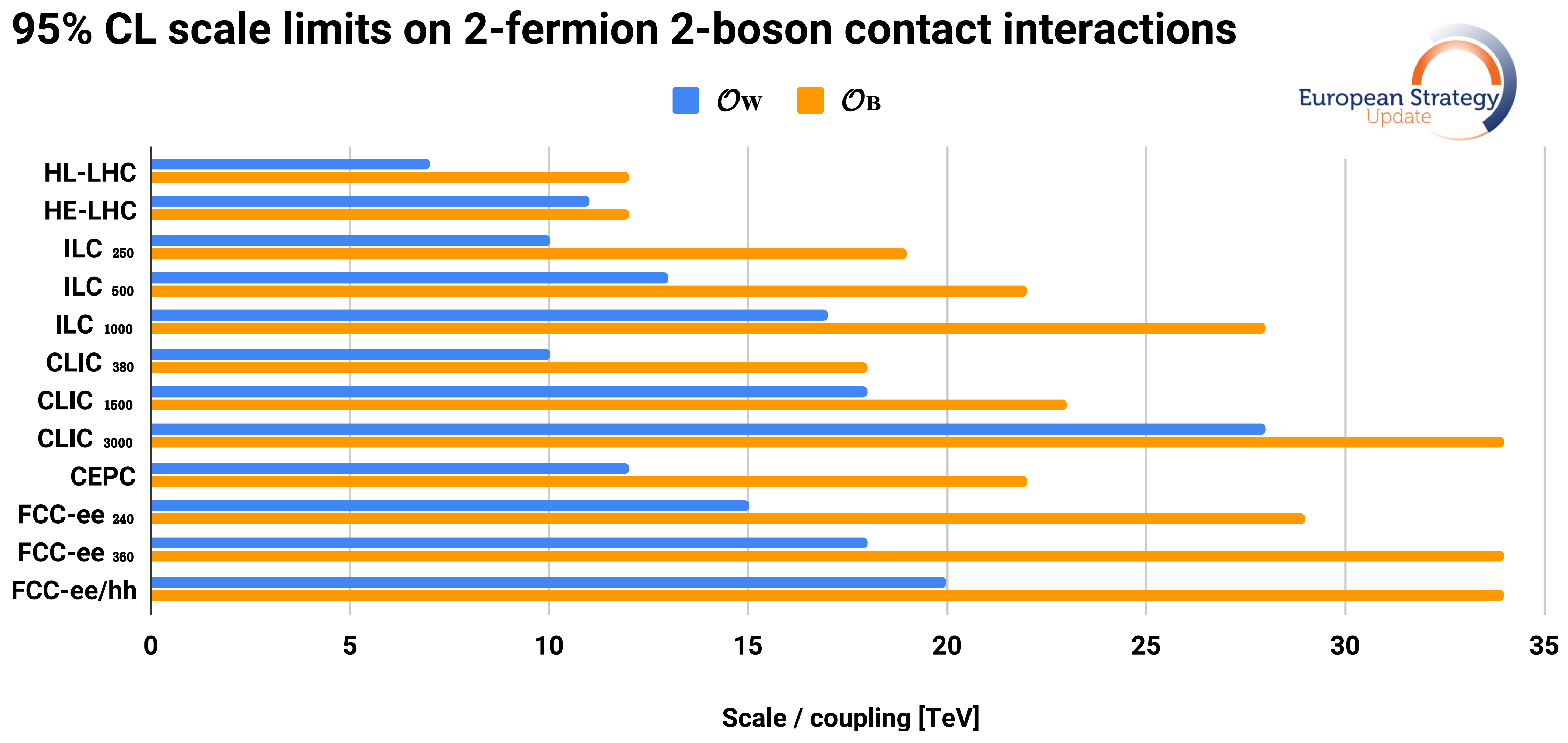


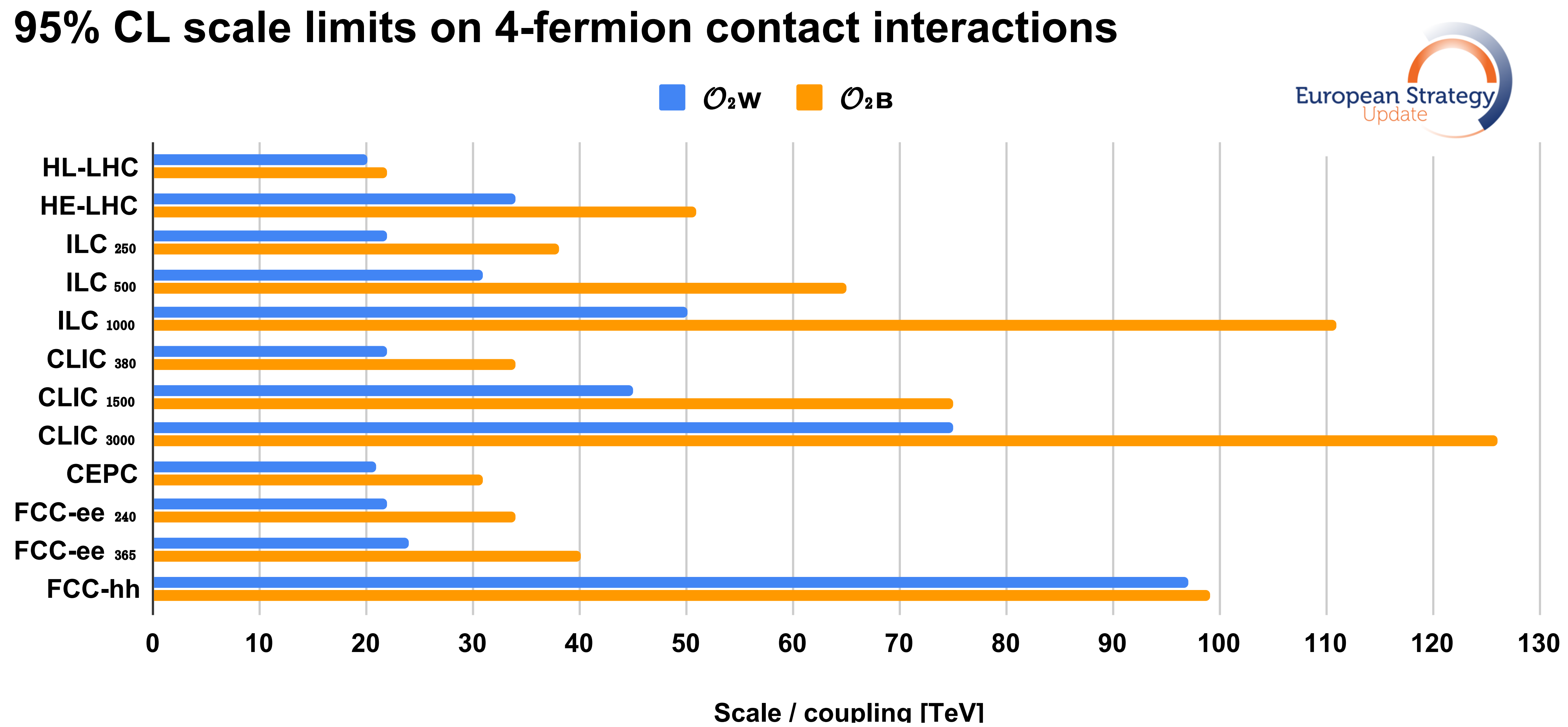
2019 EW fit FCC combined dominated by 100 TeV hadron machine M/g ~ 95 TeV

COLLIDERREACH line is very close to the $(100/84)^2$ rescaling in the direct search segment, so we can rescale by g~$(100/84)^2$ in the direct reach and g~(100/84) in the EFT range and call it the 84 TeV bound.

arXiv:1905.03764v3 arXiv:2206.08326v5

C_{2B} comparison Briefing Book vs Snowmass





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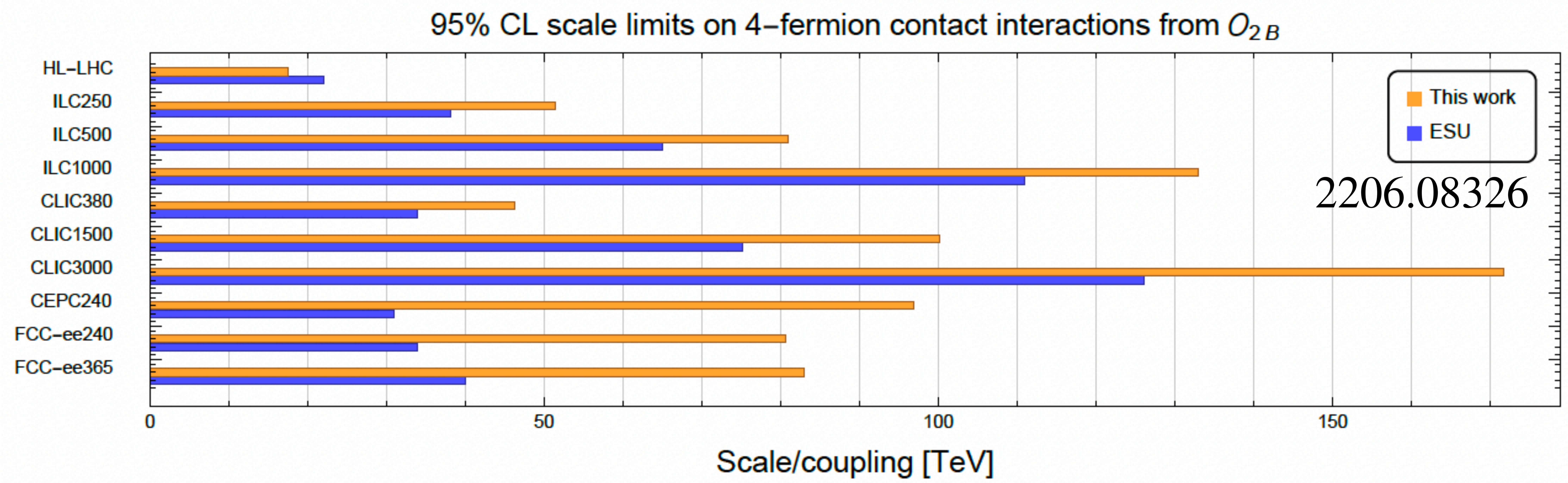
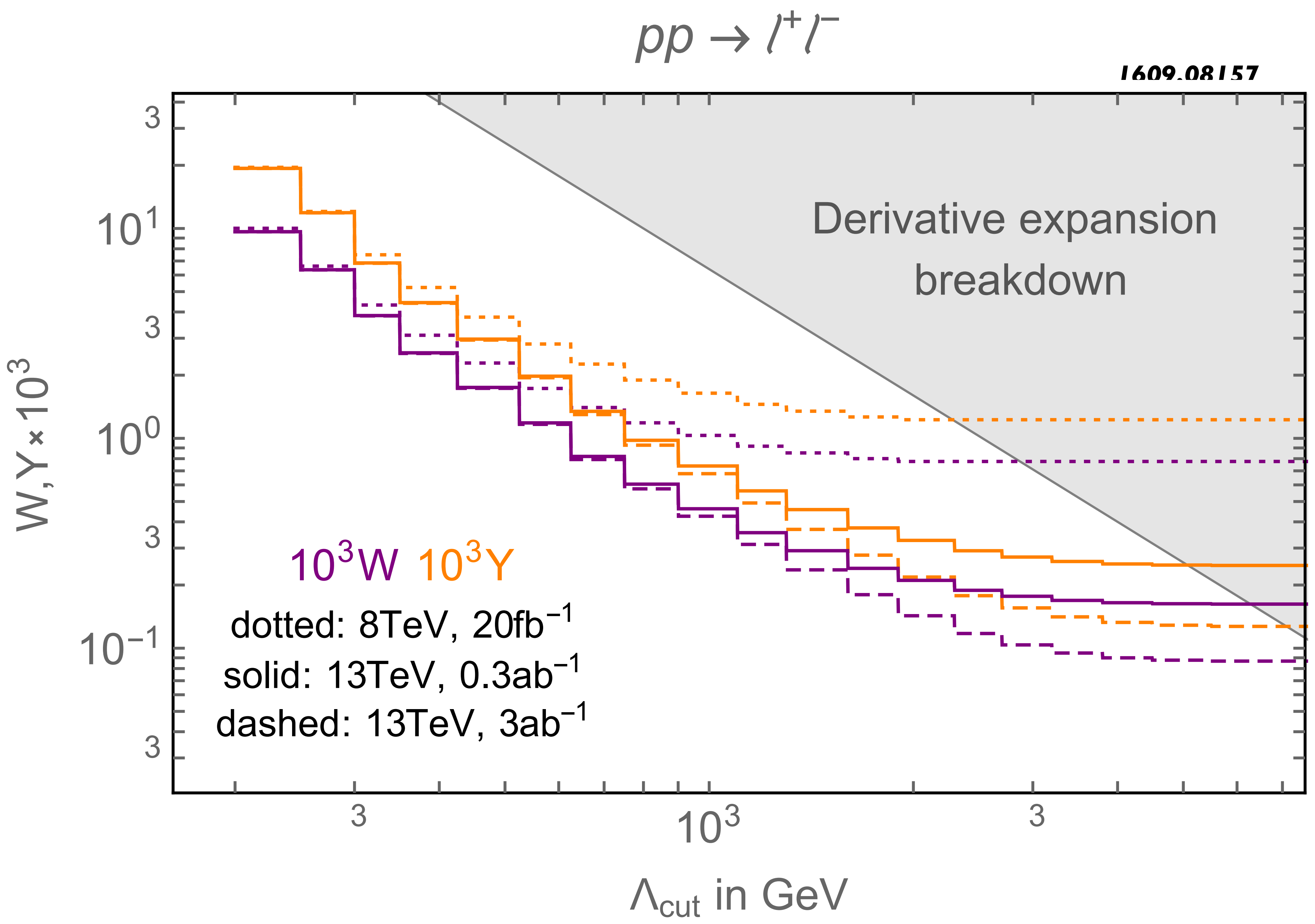


The ESU fits made use of only inclusive cross section times branching ratio measurements (or even ratios thereof), omitting precious kinematic information, like Higgs transverse momentum distribution, which could reveal higher sensitivity to New Physics but requires more detailed estimates of the theoretical uncertainties.

Rescaling of 100 TeV 30/ab to 84 TeV 30/ab

84 TeV @ 30/ab



$$Y_{95\%} \sim \frac{g^2}{m^2} \sim \frac{E_0^2/E^2}{\sqrt{\mathscr{L}}}$$

1609.08157		LEP	ATLAS 8	CMS 8	LHC 13		100 TeV	ILC	TLEP	ILC 500 GeV
luminosity		2×10^7 Z	19.7 fb^{-1}	20.3 fb^{-1}	0.3 ab^{-1}	3 ab^{-1}	10 ab^{-1}	10^9 Z	10^{12} Z	3 ab^{-1}
NC	W×10^4	[−19, 3]	[−3, 15]	[−5, 22]	±1.5	±0.8	±0.04	±3	±0.7	±0.3
	Y×10^4	[−17, 4]	[−4, 24]	[−7, 41]	±2.3	±1.2	±0.06	±4	±1	±0.2
CC	W×10^4	—	±3.9		±0.7	±0.45	±0.02	—	—	—

$$LHC13 : 10 \times \mathscr{L} \to 1/2Y$$

TABLE II. *Reach on W and Y from different machines with various energies and luminosities. The bounds from neutral DY are obtained setting the unconstrained parameter to zero. Bounds from LEP are extracted from [42], marginalizing over Ŝ and T̂. Bounds from Z-peak ILC [52] and TLEP [53] are from Ref. [39]. Bounds from off-peak measurements of $e^+e^- \to e^+e^-$ at lepton colliders are extracted from [54].*

Mapping Luminosities		
	100 TeV	**13 TeV**
ab^-1	10.0	0.17
ab^-1	30.0	0.51
ab^-1	20.0	0.34

	100 TeV	**13 TeV**	**Mismatch**
Y*10^4	0.040	2.37	58%
Y*10^4	0.025	1.50	-37%
Y*10^4	0.034	1.99	-16%

Thank you!
Thank you!
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