The Unique Role of Future High-Energy pp Colliders

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CERN

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Ideology

HEP before the LHC

HEP before the F.C.

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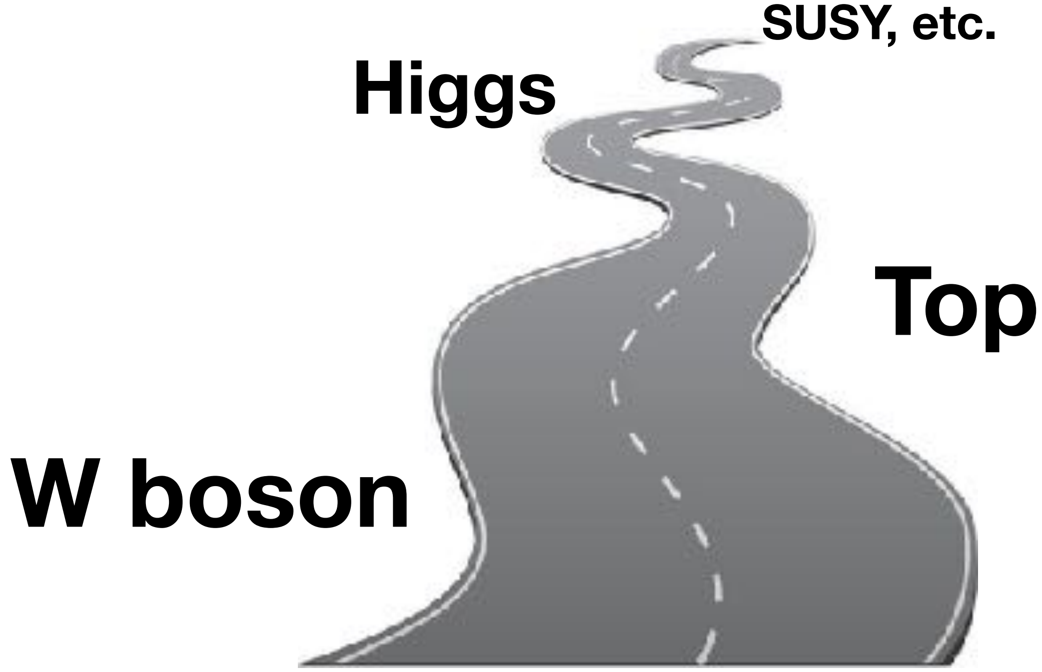

HEP before the F.C.

Particle physics is not **validation** anymore, rather it is **exploration of unknown territories ***

* Not necessarily a bad thing. Columbus left for his trip just because he had no idea of where he was going !!

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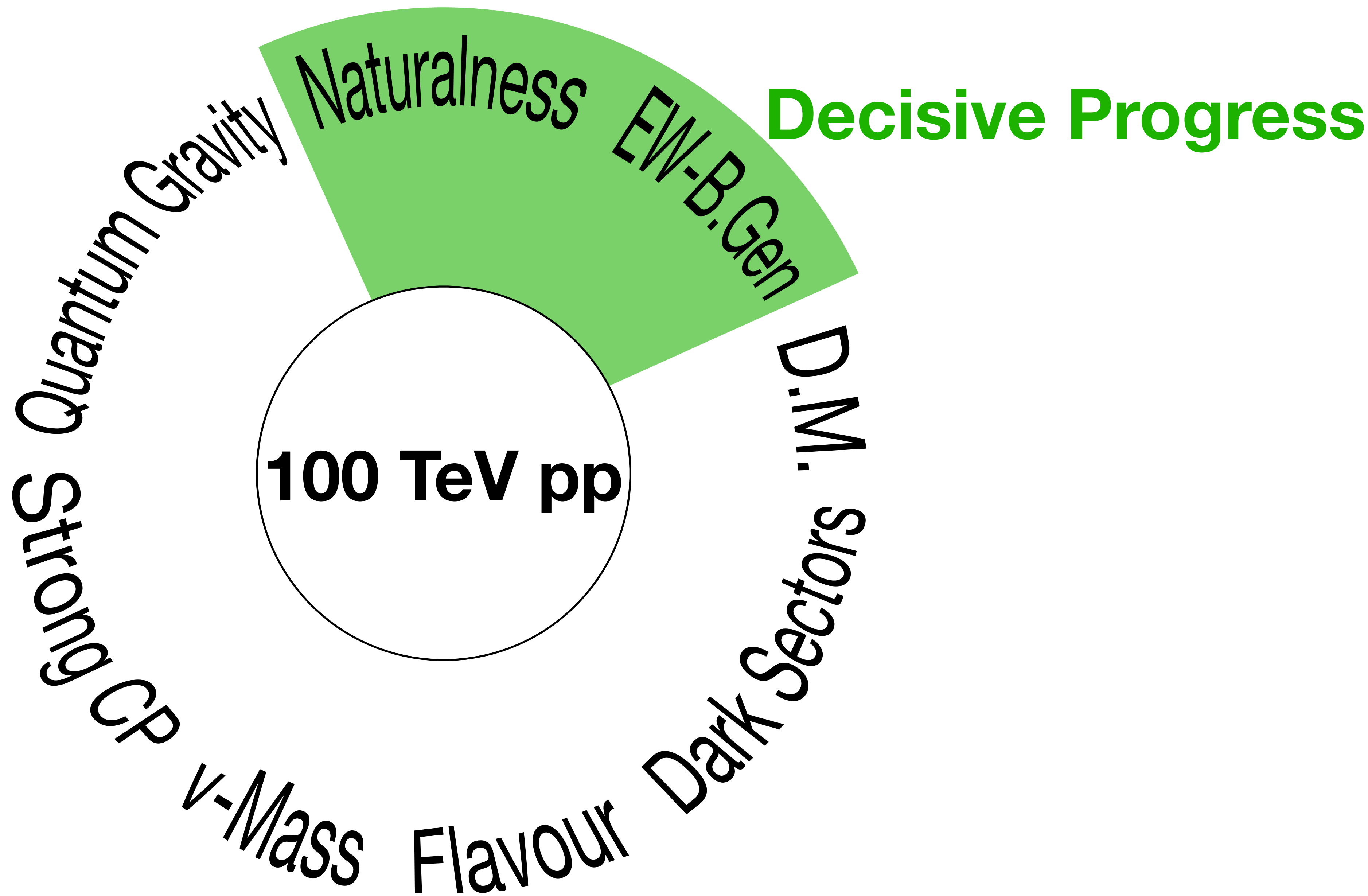

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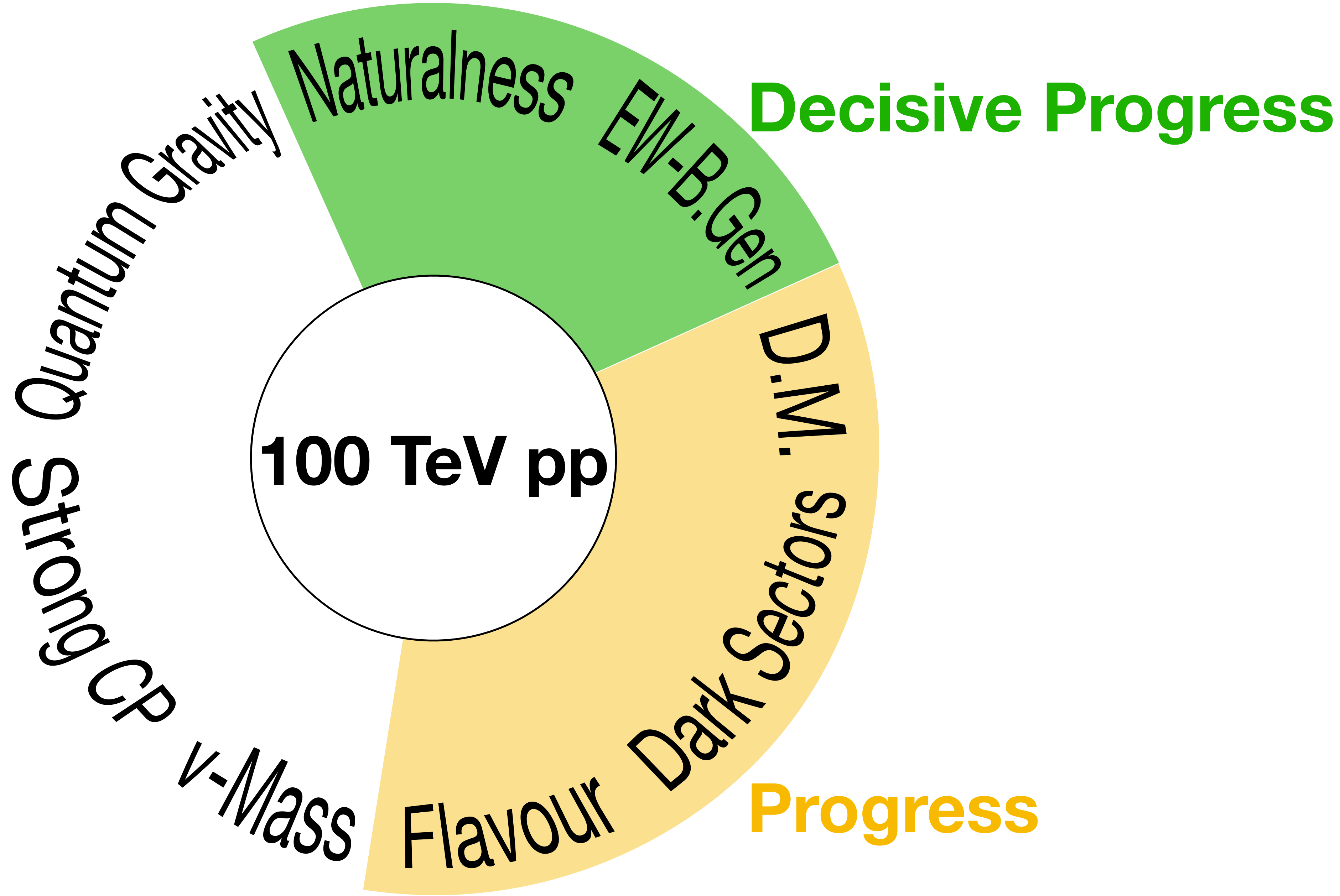

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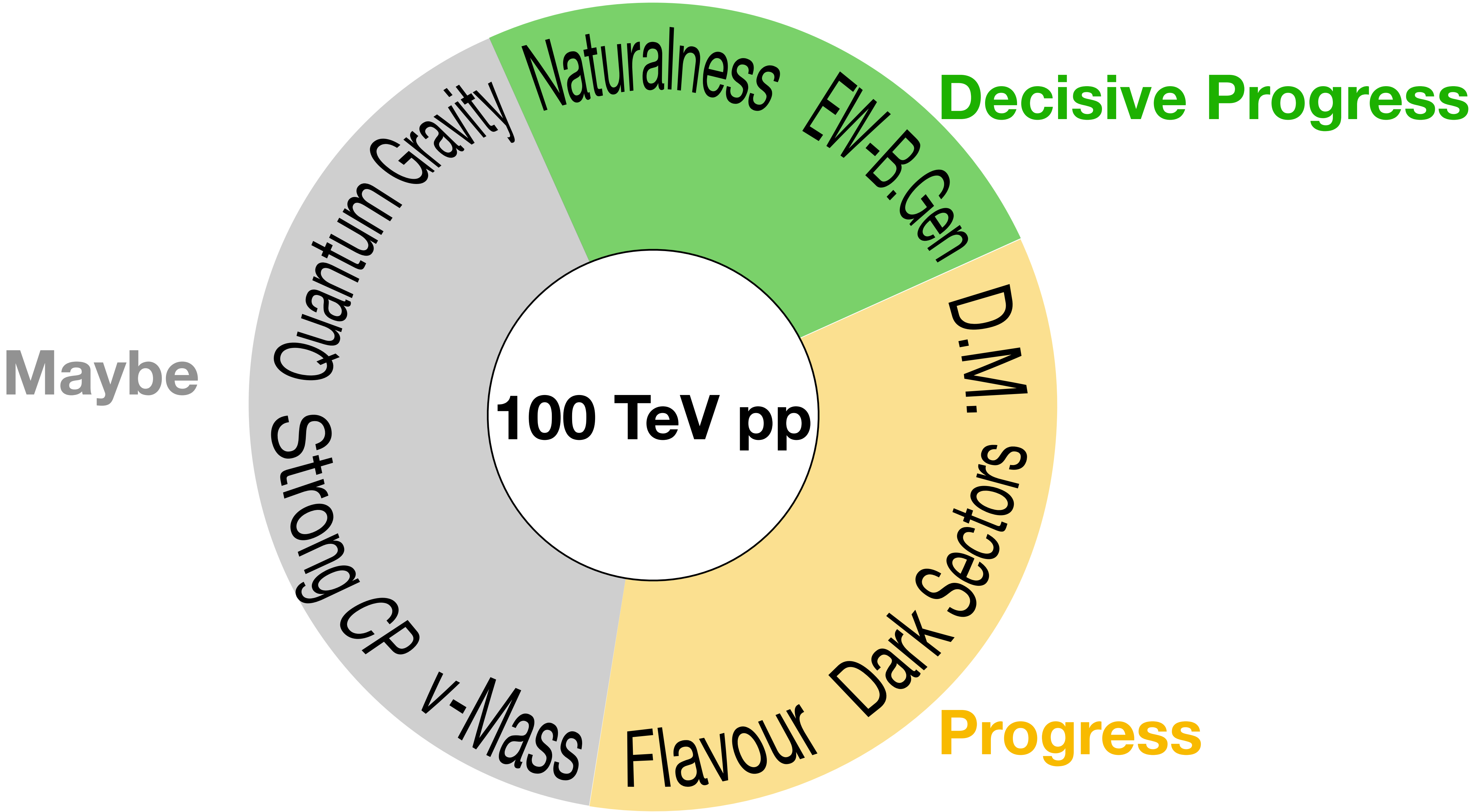

Naturalness

"Is m_H Unnatural?" $=$ "Is m_H Unpredictable?"

$$\left(m_H^2\right)_{Phys.} = \int_0^\infty F_{true}(E;\, g_{true})$$

UV Contribution

$$c\,{\Lambda_{\rm SM}}^2$$

$$= \int_0^{\Lambda_{\rm SM}} (\ldots) + \int_{\Lambda_{\rm SM}}^\infty (\ldots)$$

SM Contribution

$$\delta m_H^2 = \frac{3y_t^2}{8\pi^2}{\Lambda_{\rm SM}}^2$$

Fine Tuning: $\Delta \geq \frac{\delta m_H^2}{m_H^2} \simeq \left(\frac{126\,\mathrm{GeV}}{m_H}\right)^2\left(\frac{\Lambda_{\rm SM}}{500\,\mathrm{GeV}}\right)^2$

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Dramatic paradigm shift. E.g. Anthropic or Dynamical

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$$\Lambda_{\mathrm{SM}} \gtrsim 2\ \mathrm{TeV} \longrightarrow \Delta \gtrsim 10$$

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Partial Unnaturalness

$$\Delta \sim 100$$

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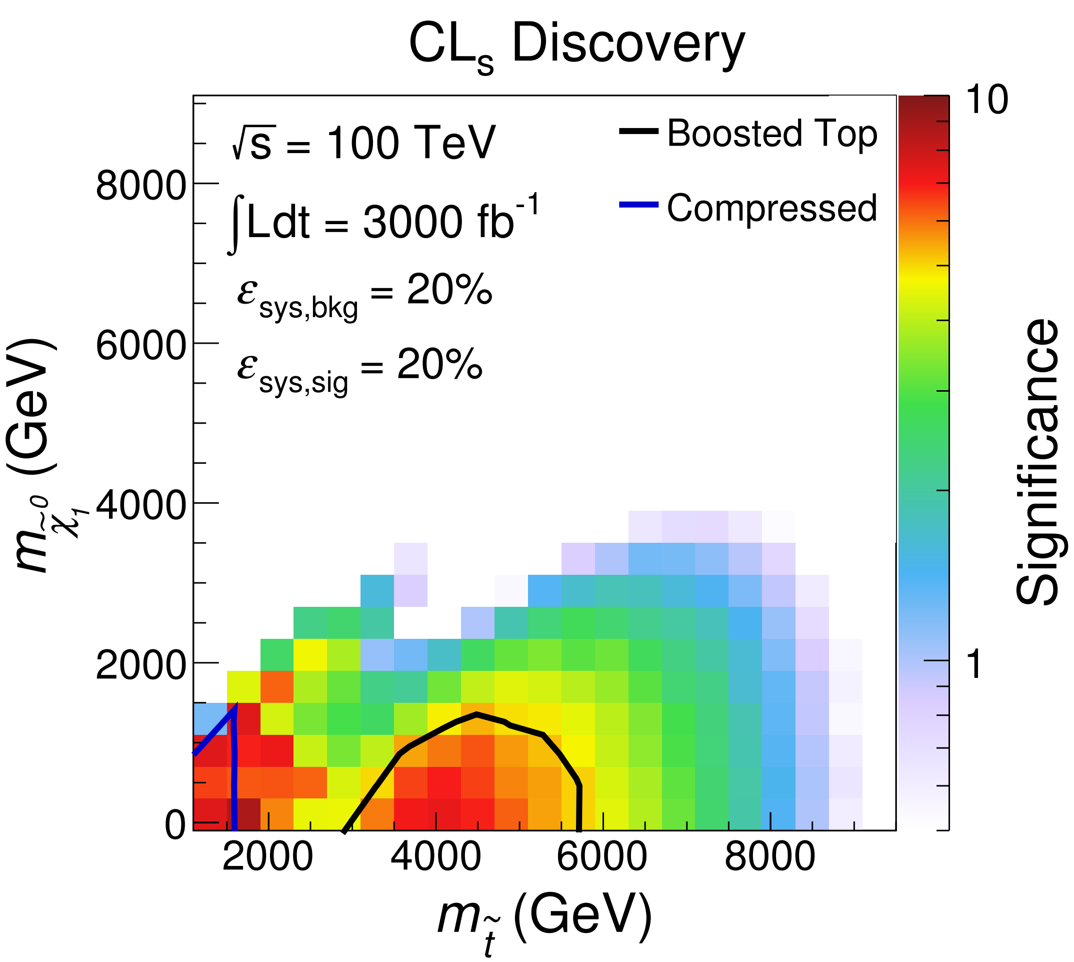
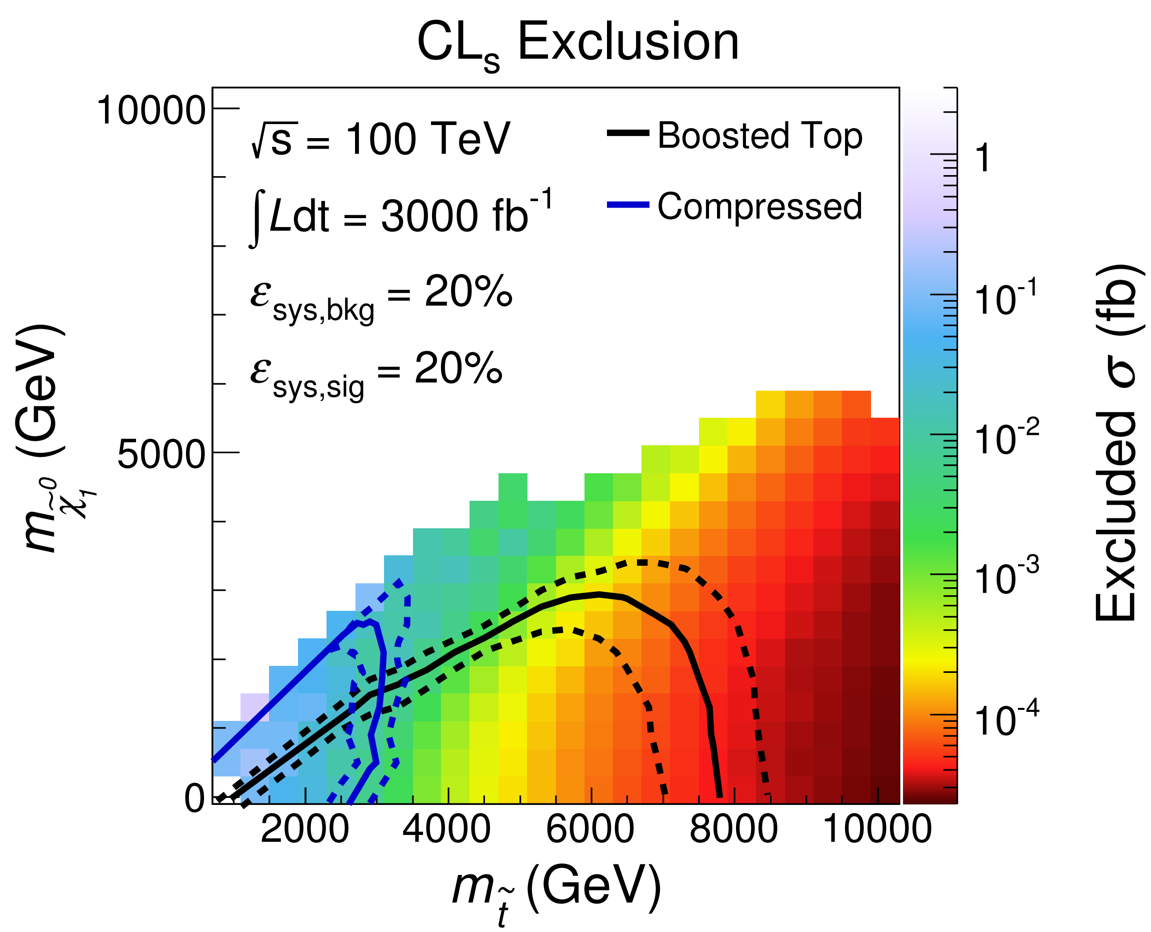
Need 5 TeV reach on ordinary Top Partners

Naturalness

Stop to top + Neutralino:

[arXiv:1406.4512]





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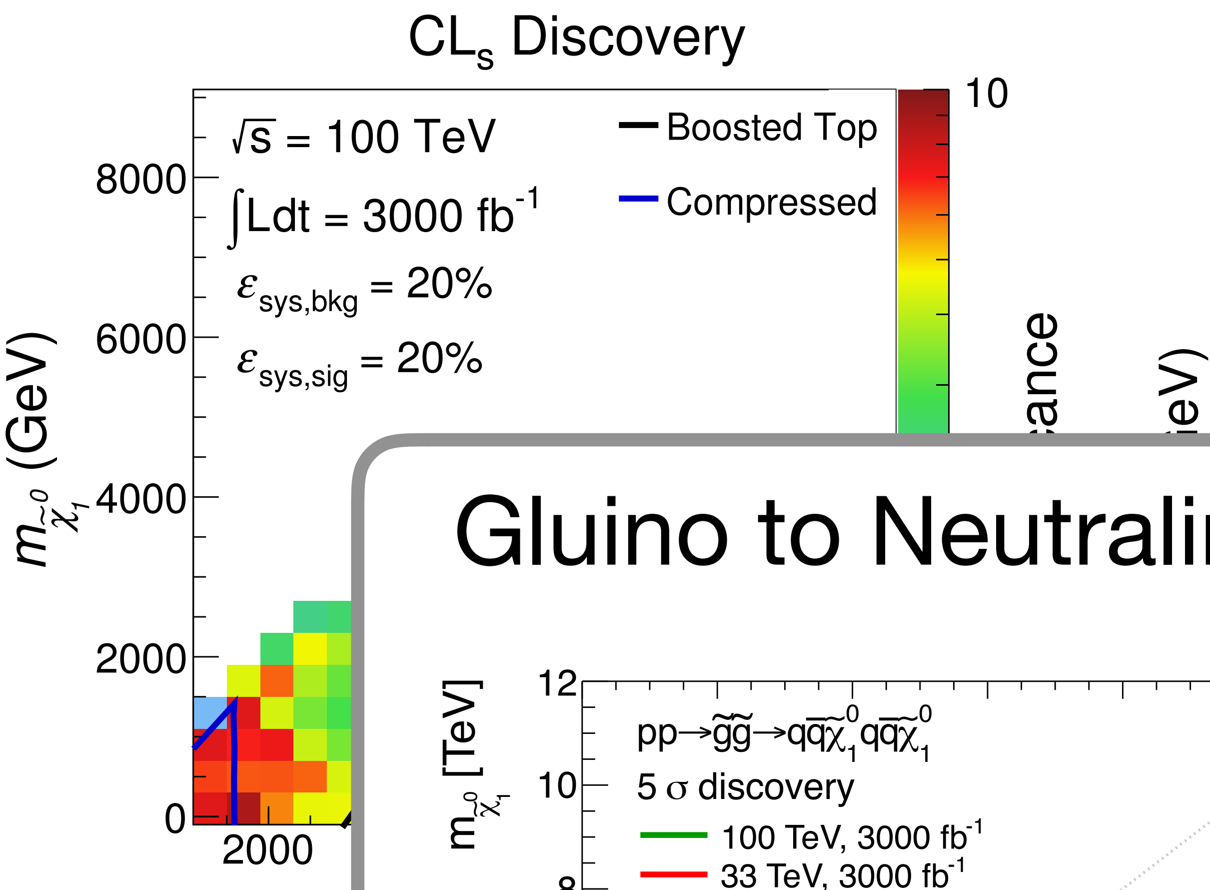
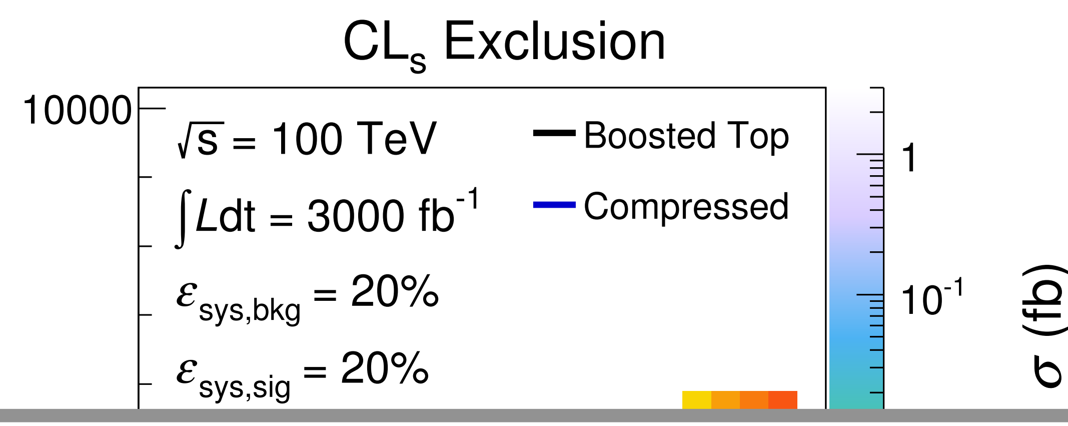
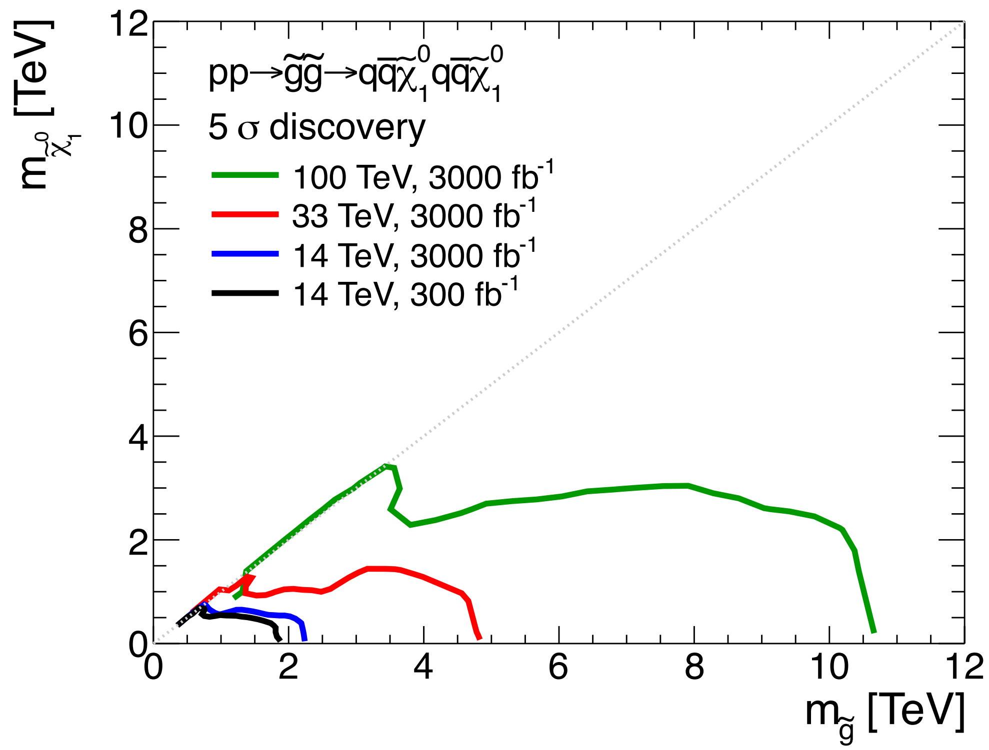
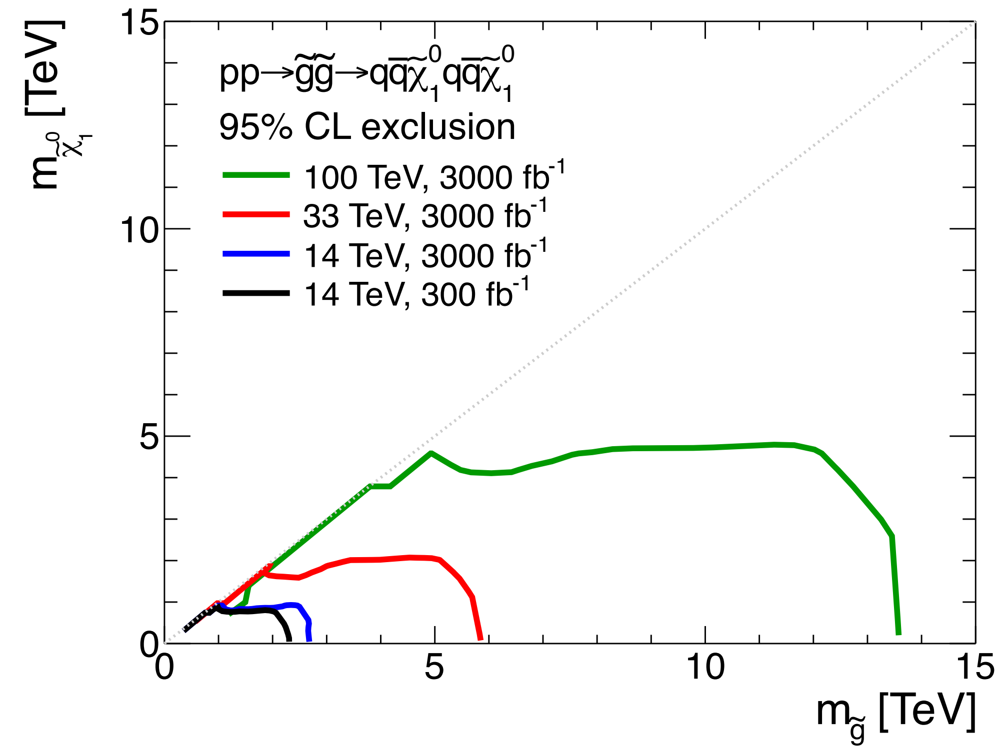




Gluino to Neutralino + q:

[arXiv:1606.00947]

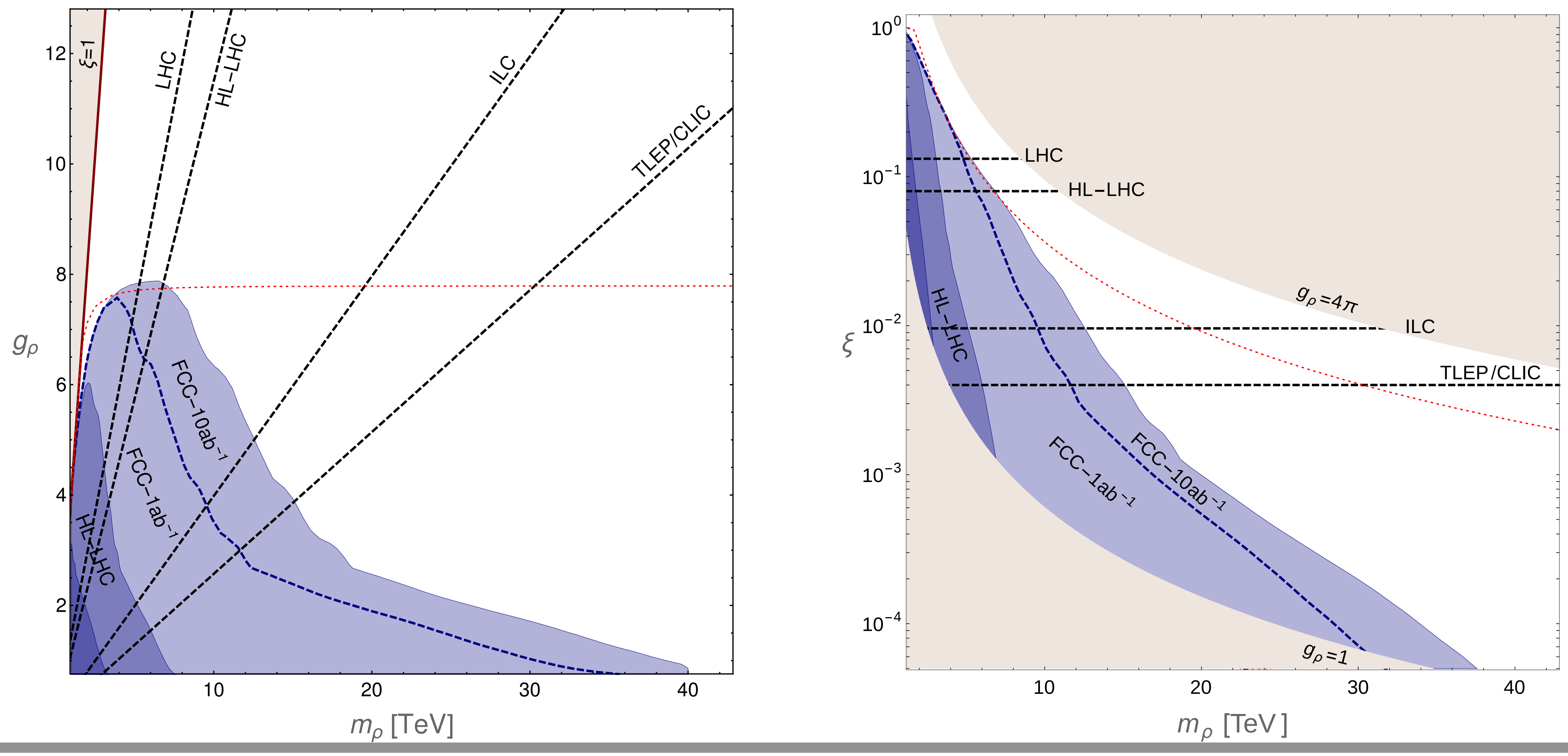




Naturalness

Spin-1 CH resonances (or V'):

[arXiv:1502.01701]



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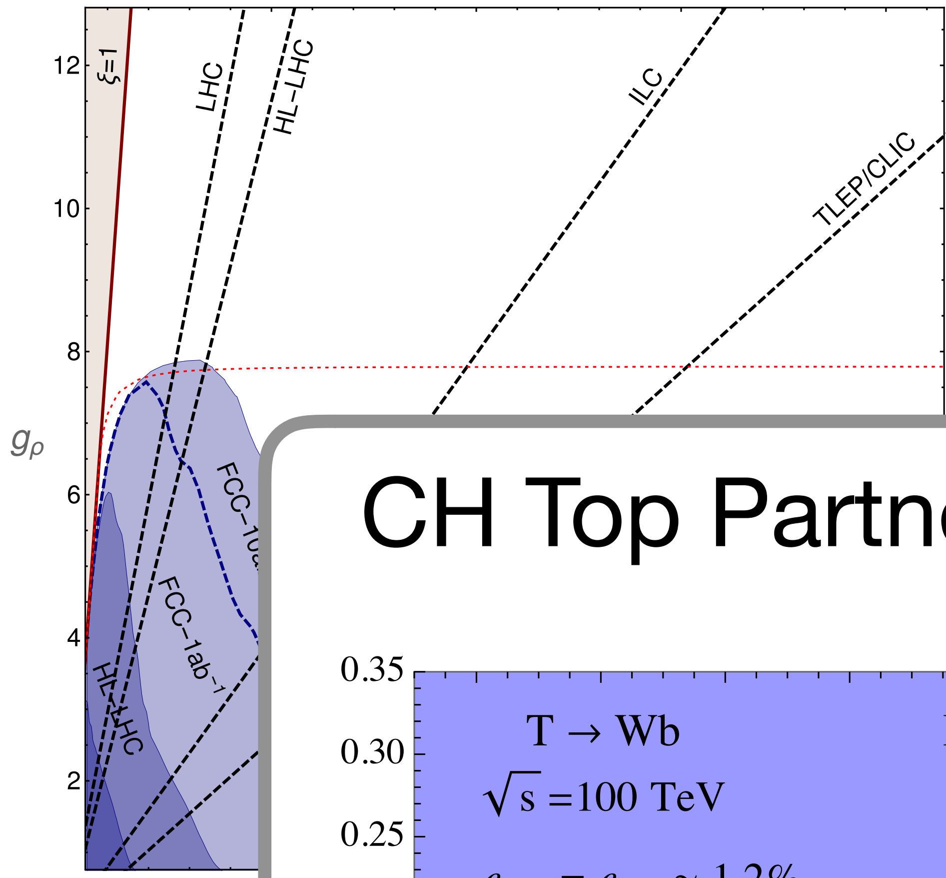
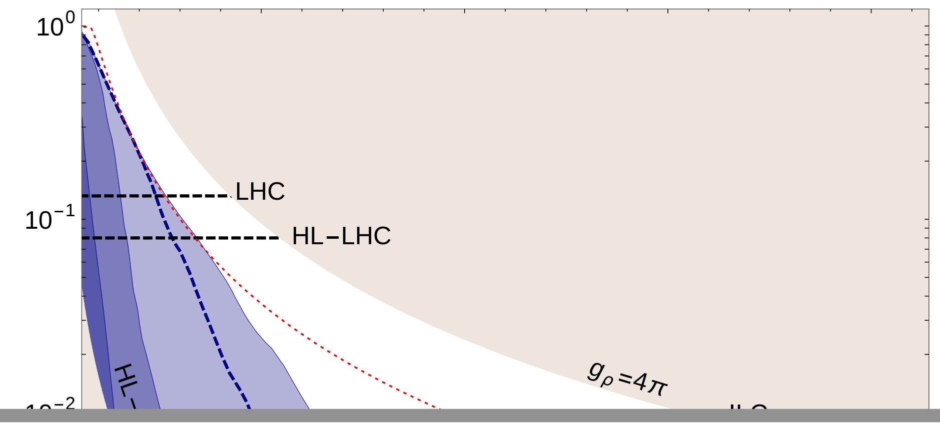
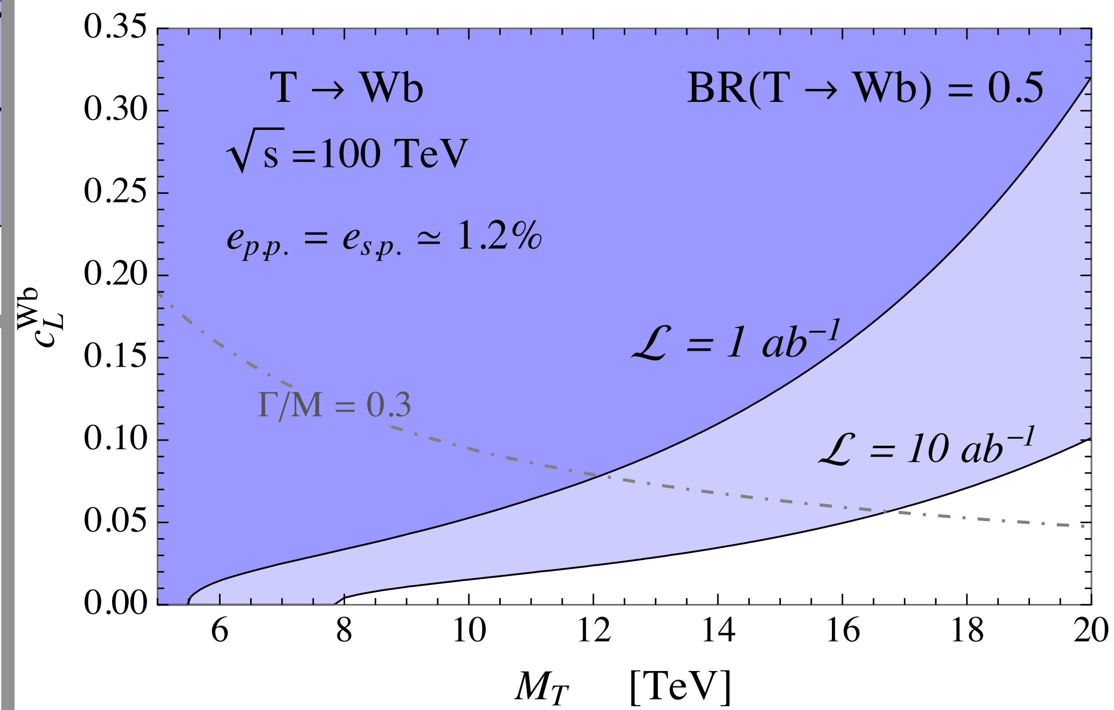
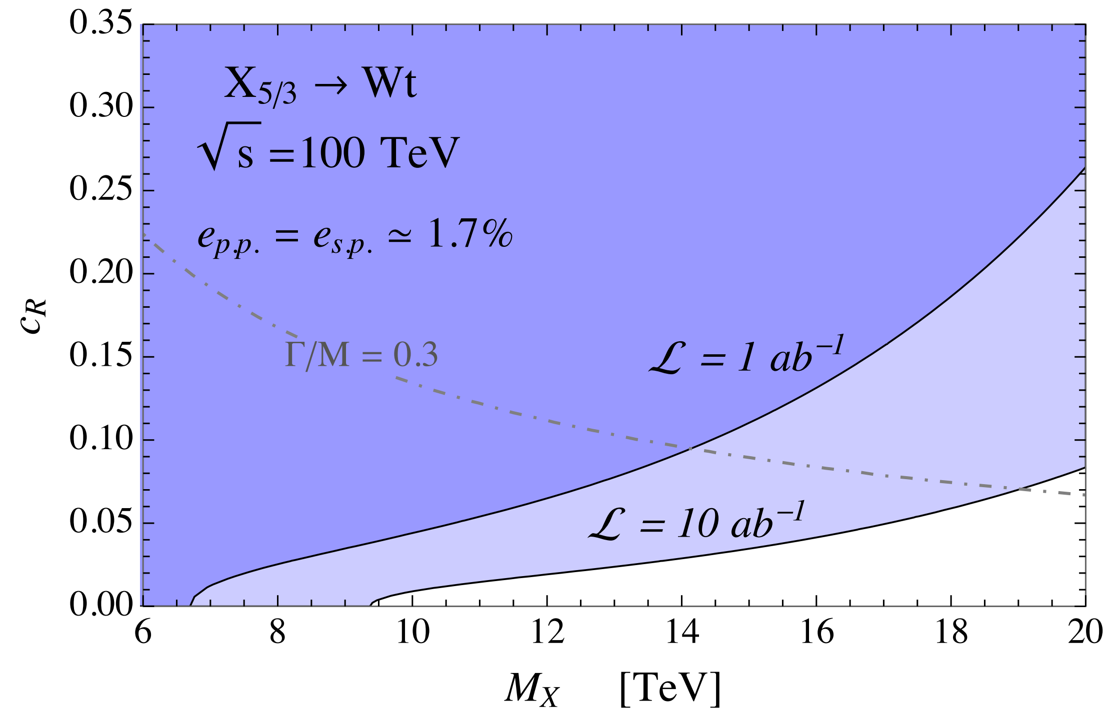




CH Top Partners:

[arXiv:1409.0100]



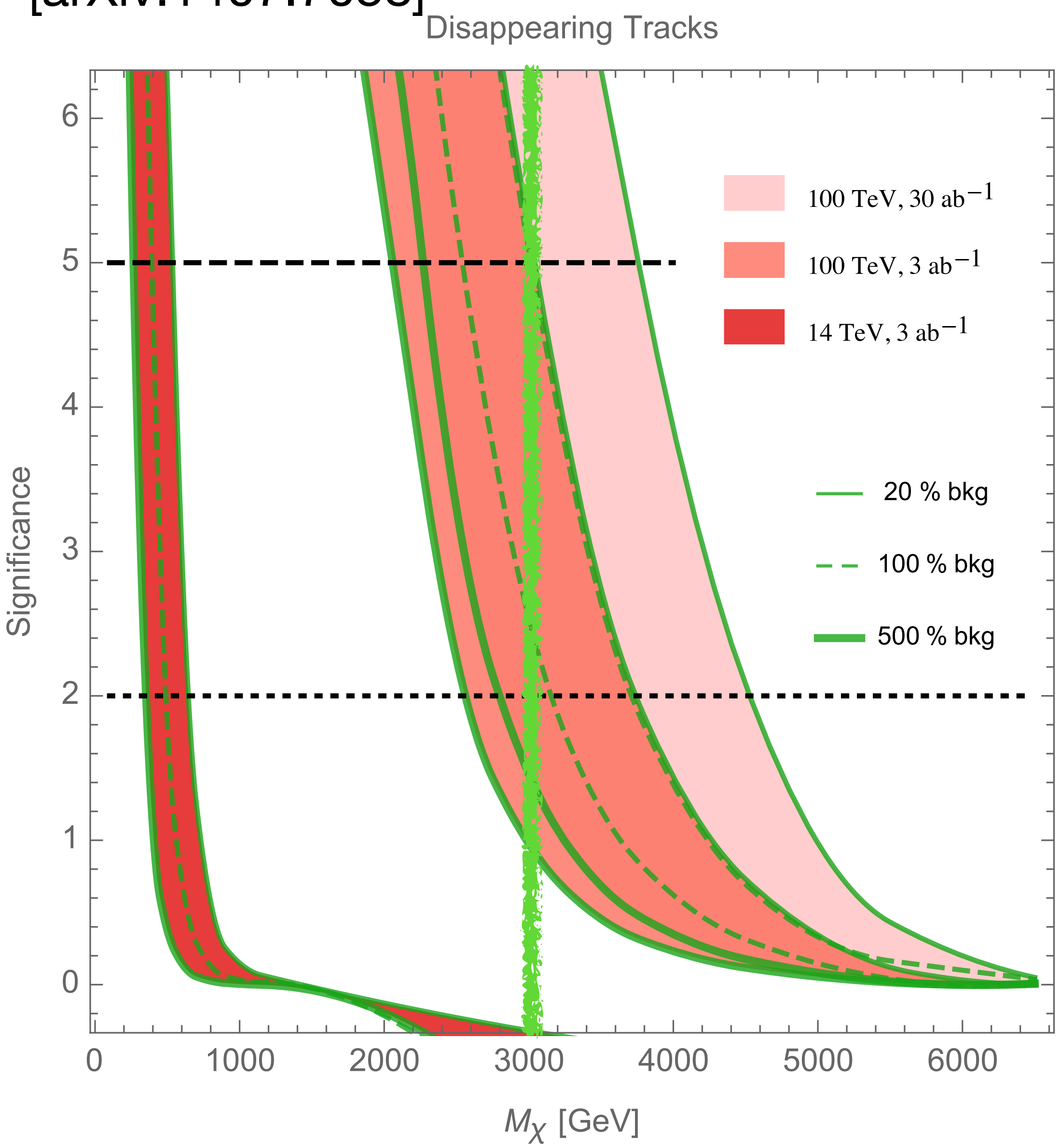


Dark Matter

100 TeV can probe WIMP DM unaccessible to current and future Direct Detection

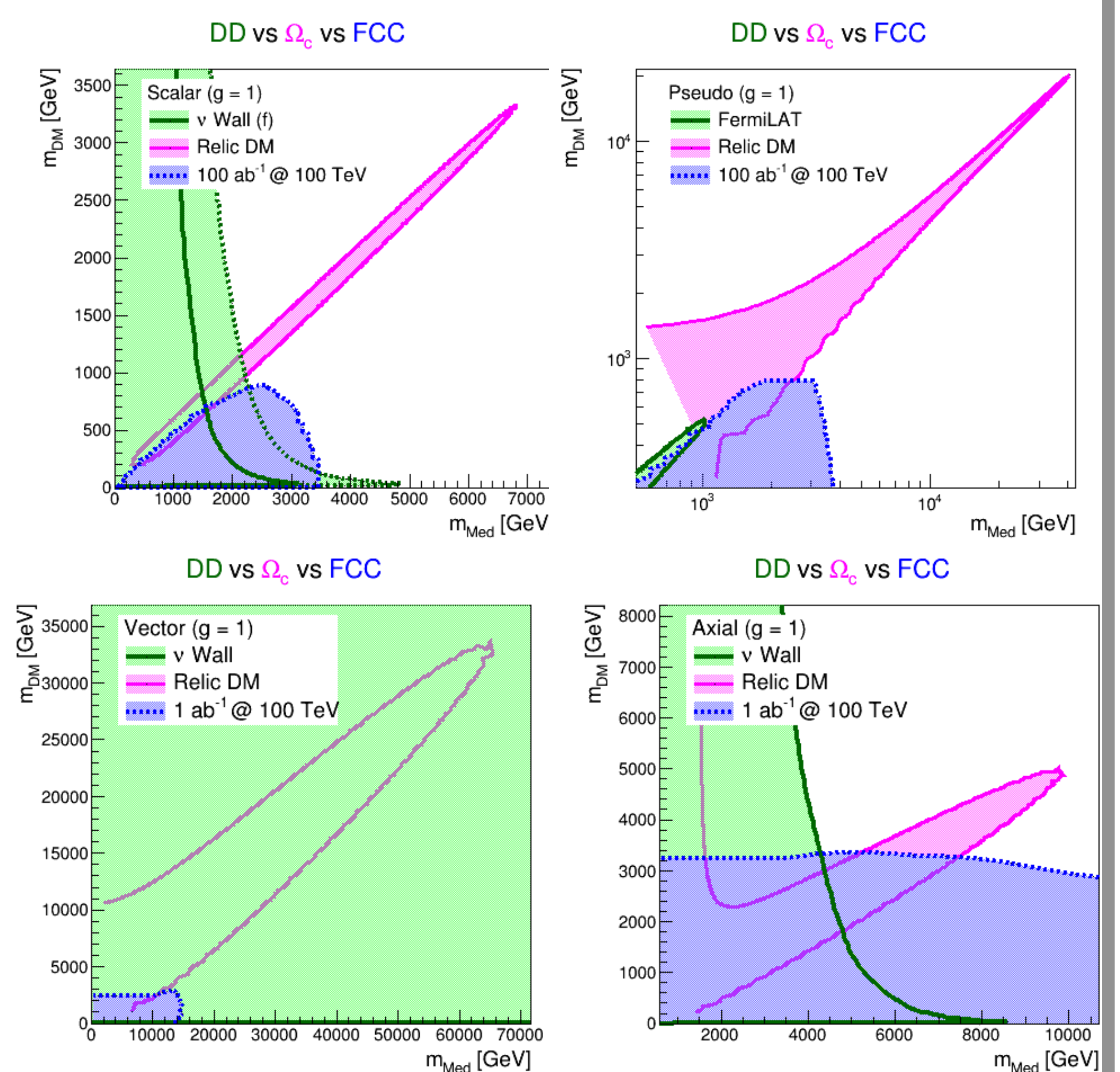
Wino DM. (disappearing tracks:)

[arXiv:1407.7058]



Crossing neutrino wall:

[arXiv:1606.00947]



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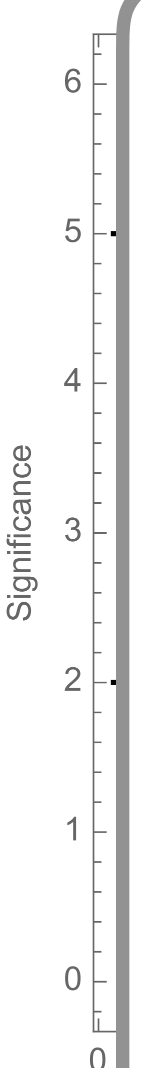

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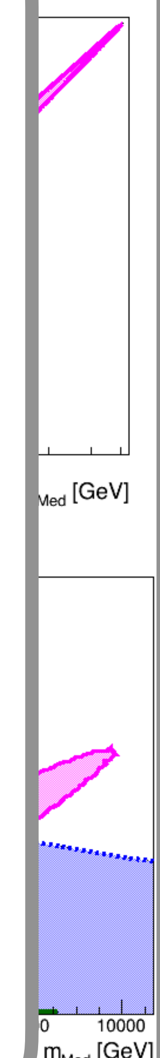
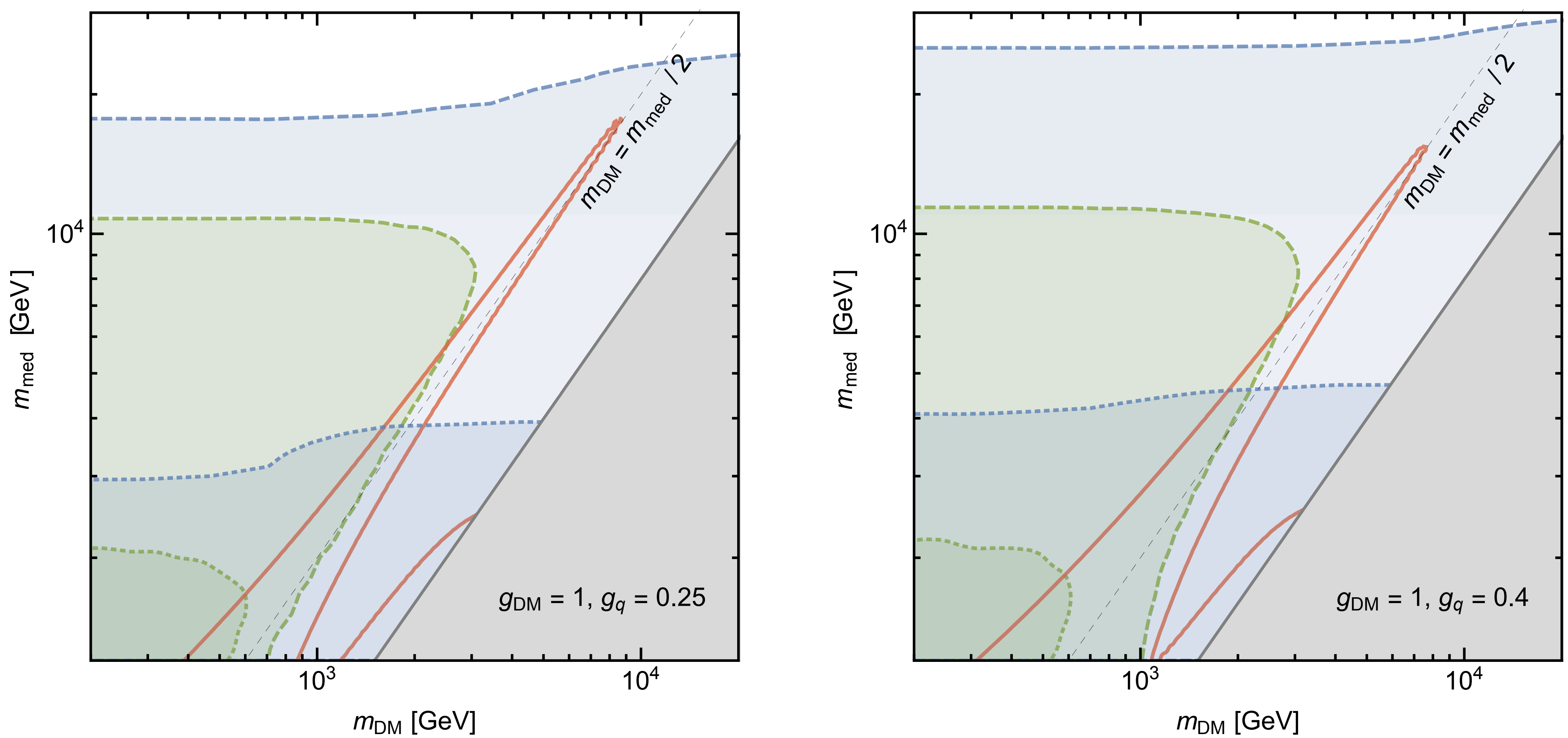


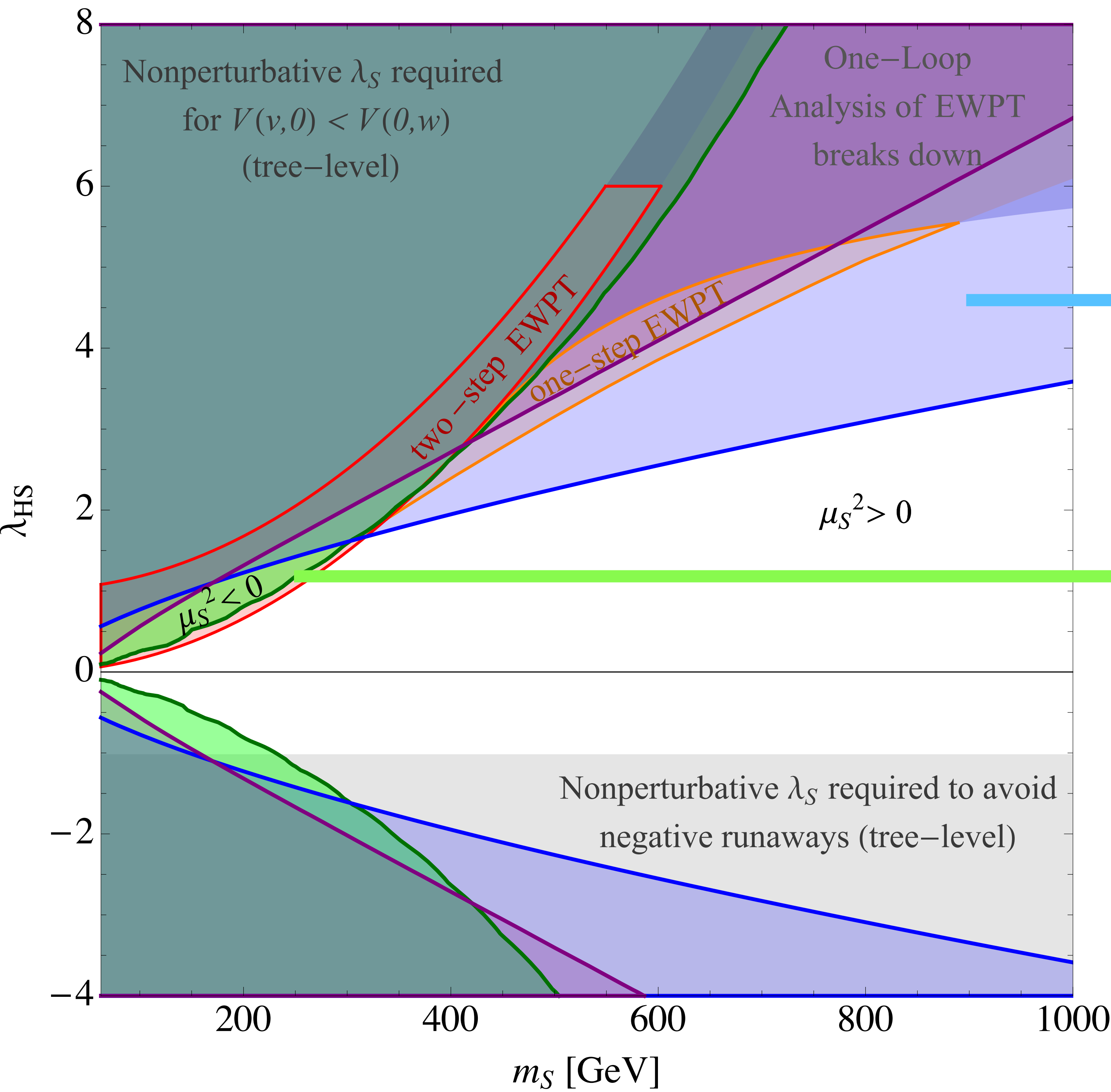
Further improve with mediator searches [arXiv:1606.00947]



axial-vector model, relic in red

EW Baryogenesis

Direct reach on new states **and few-percent 3H coup.** can probe **strong first order EW phase transition**



Z2-odd singlet (nightmare scenario?)

[arXiv:1409.0005]

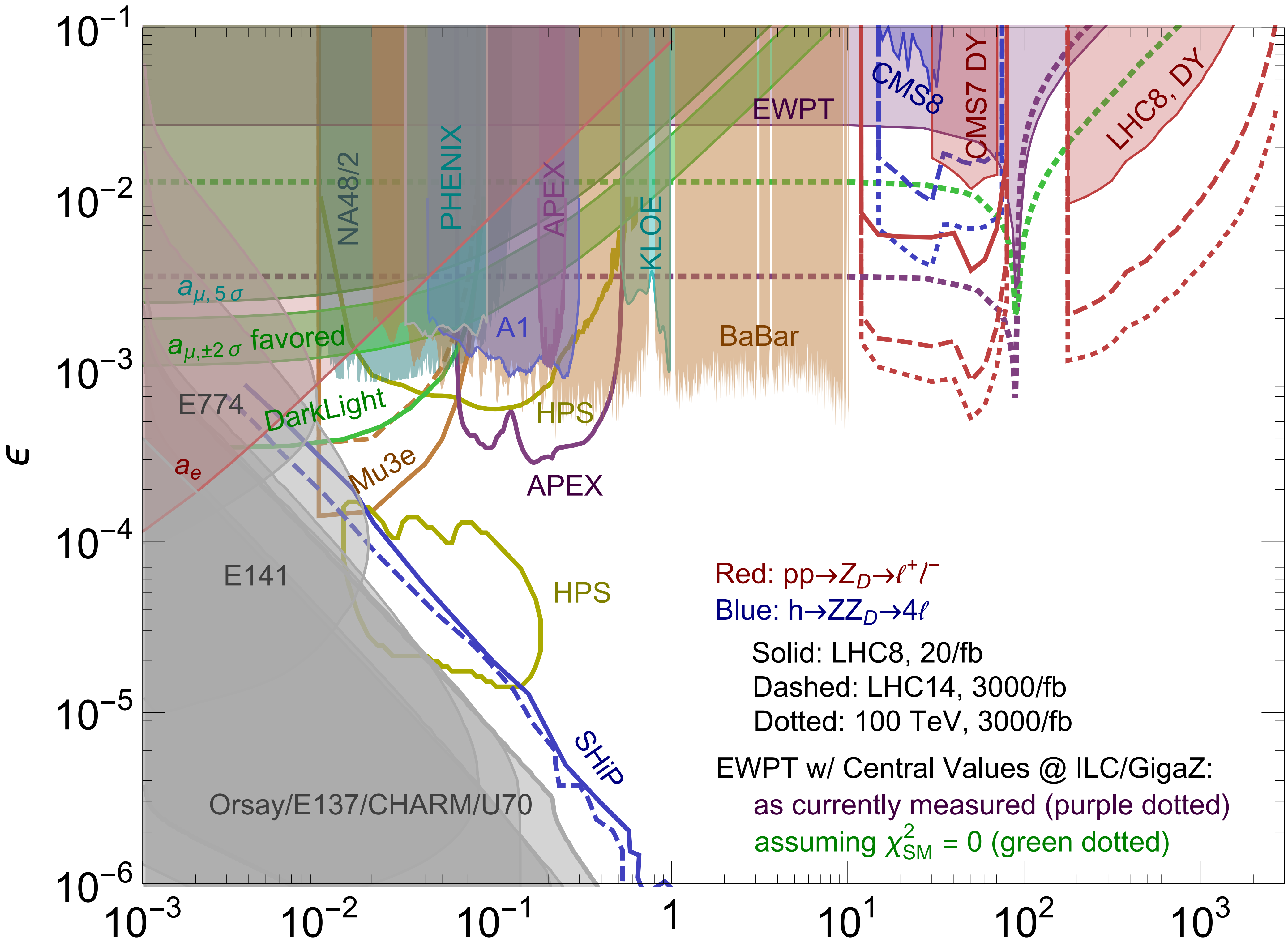
$$\delta g_{3H}/g_{3H} \sim 3, 4\%$$

Direct singlet search (VBF h*->SS)

Intensity/Accuracy Frontier @ 100 TeV

Huge "low-mass" rate allows to produce Dark Sec. part. ...

Dark photon:
[arXiv:1412.0018]



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Dark photon from H-portal:
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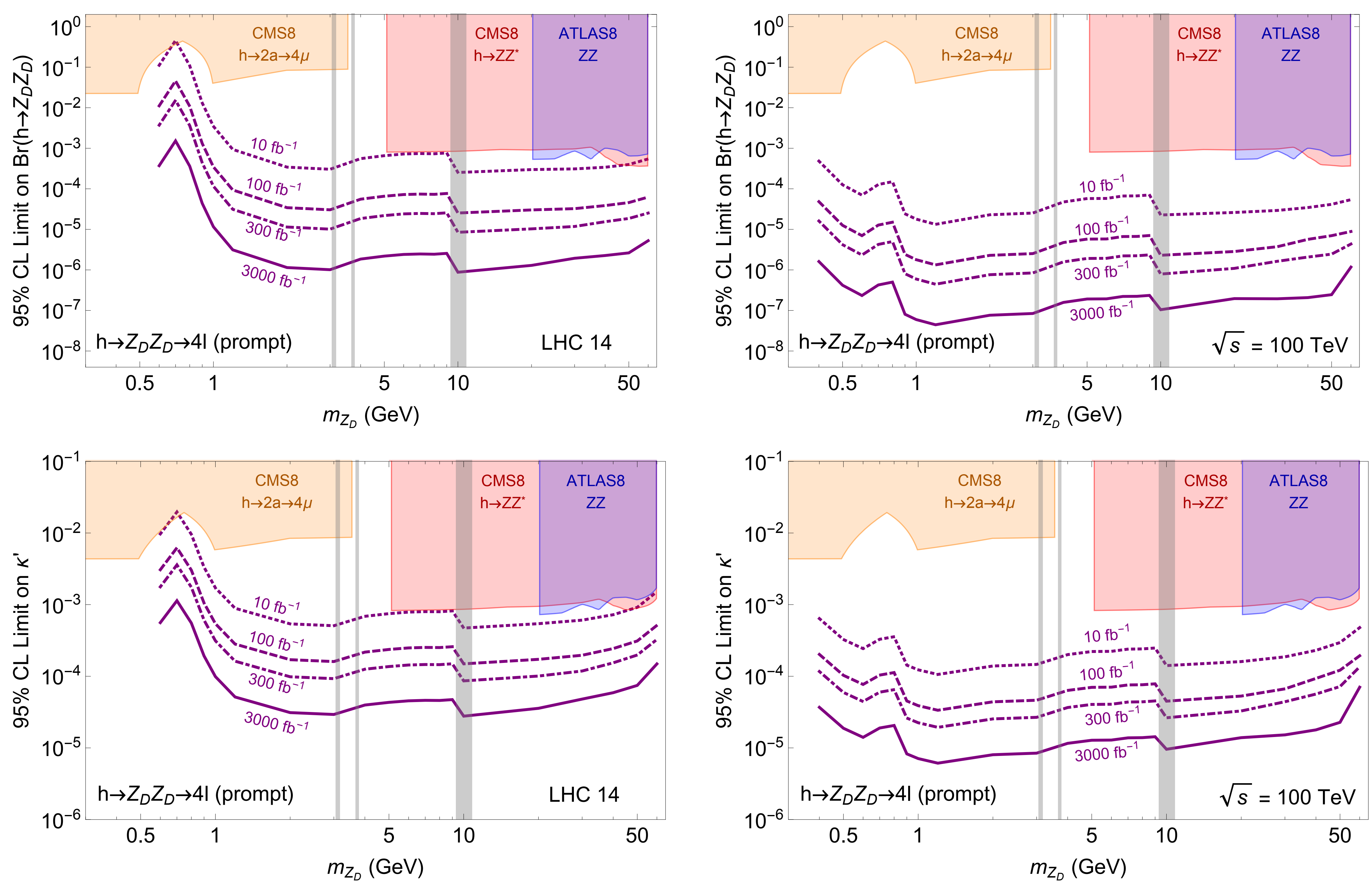

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[arXiv:1412.0018]

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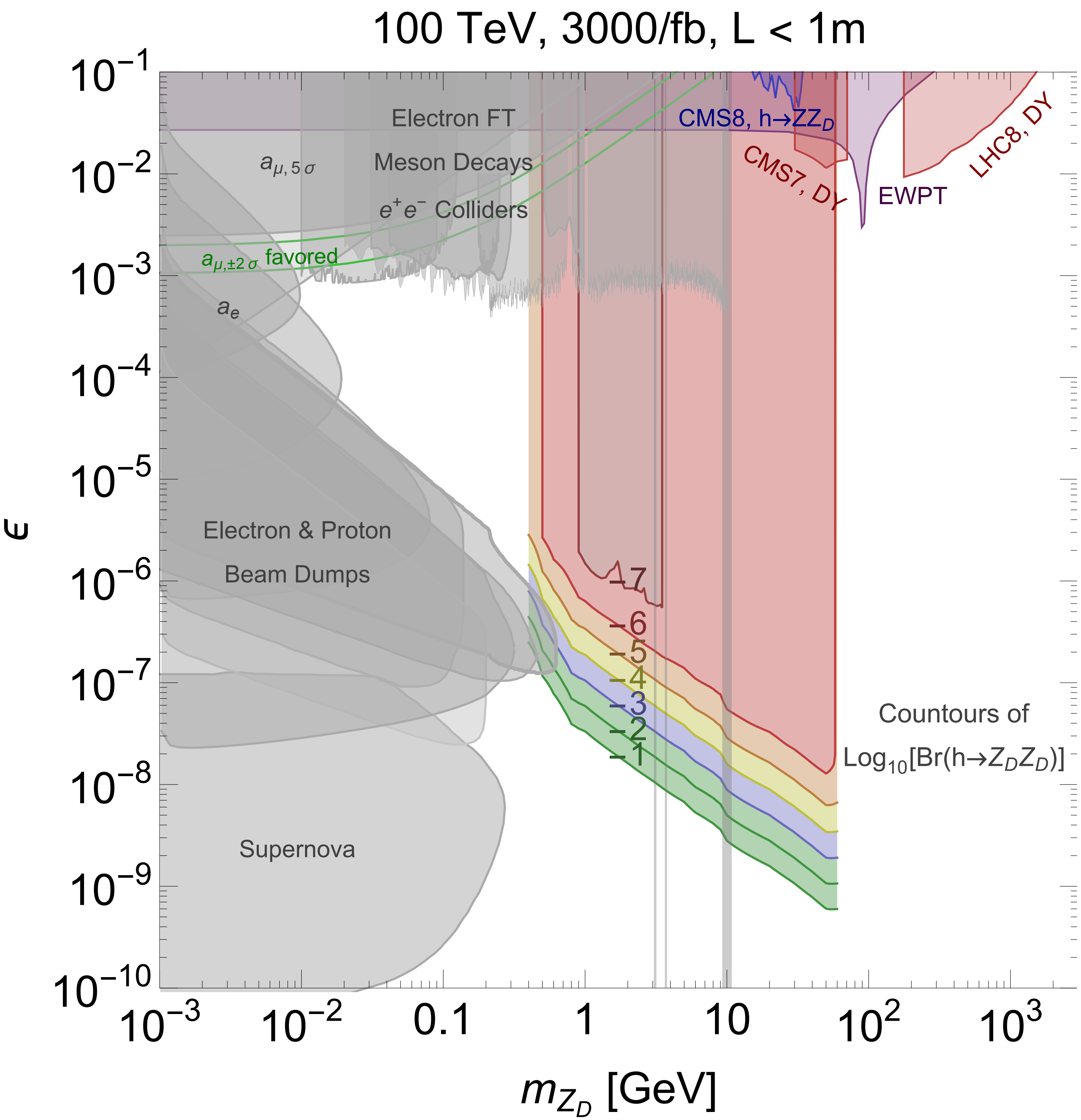
[arXiv:1412.0018]

Long-Lived DP:
[arXiv:1412.0018]



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… and many SM particles as well (10^{10} Higgs, 10^{12} tops, …)

Accuracy performances still to be fully assessed.
Known examples include:

- H-trilinear @ 3-4%, thanks to high rate (**Unique**)
- Top Yukawa @ 1% from ttH/ttZ [arXiv:1507.08169]

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Under investigation:

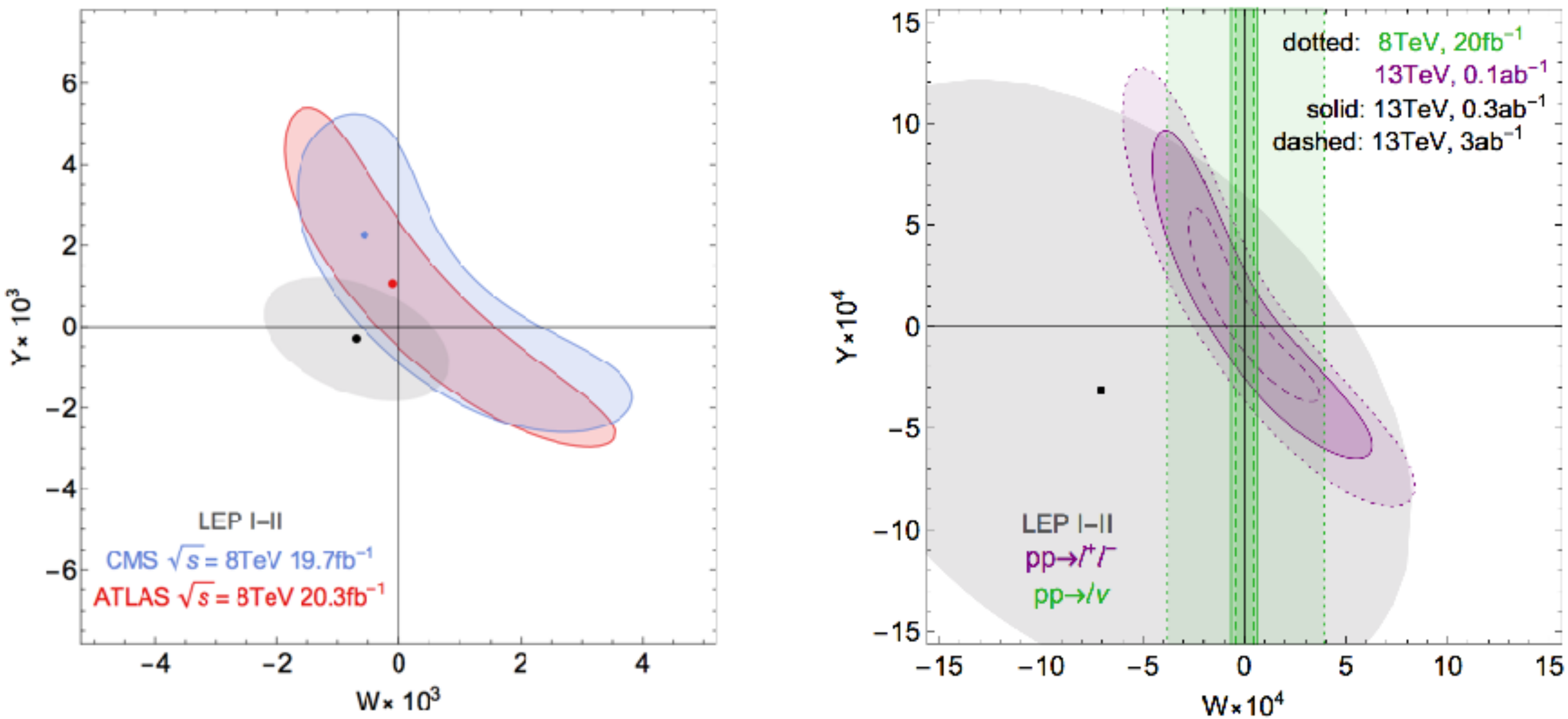
- Flavour Physics?
- Top FCNC? (e.g. BR(Zq)~10^{-7})
- Light Yukawa from Exotic Exclusive H decays?

Energy **and** Accuracy Frontier @ 100 TeV

Enhanced indirect NP effects in high mass tails

No need of extreme accuracy for indirect NP probe

EWPT @ hadron colliders: (W and Y oblique par.s) [arXiv:1609.08157]



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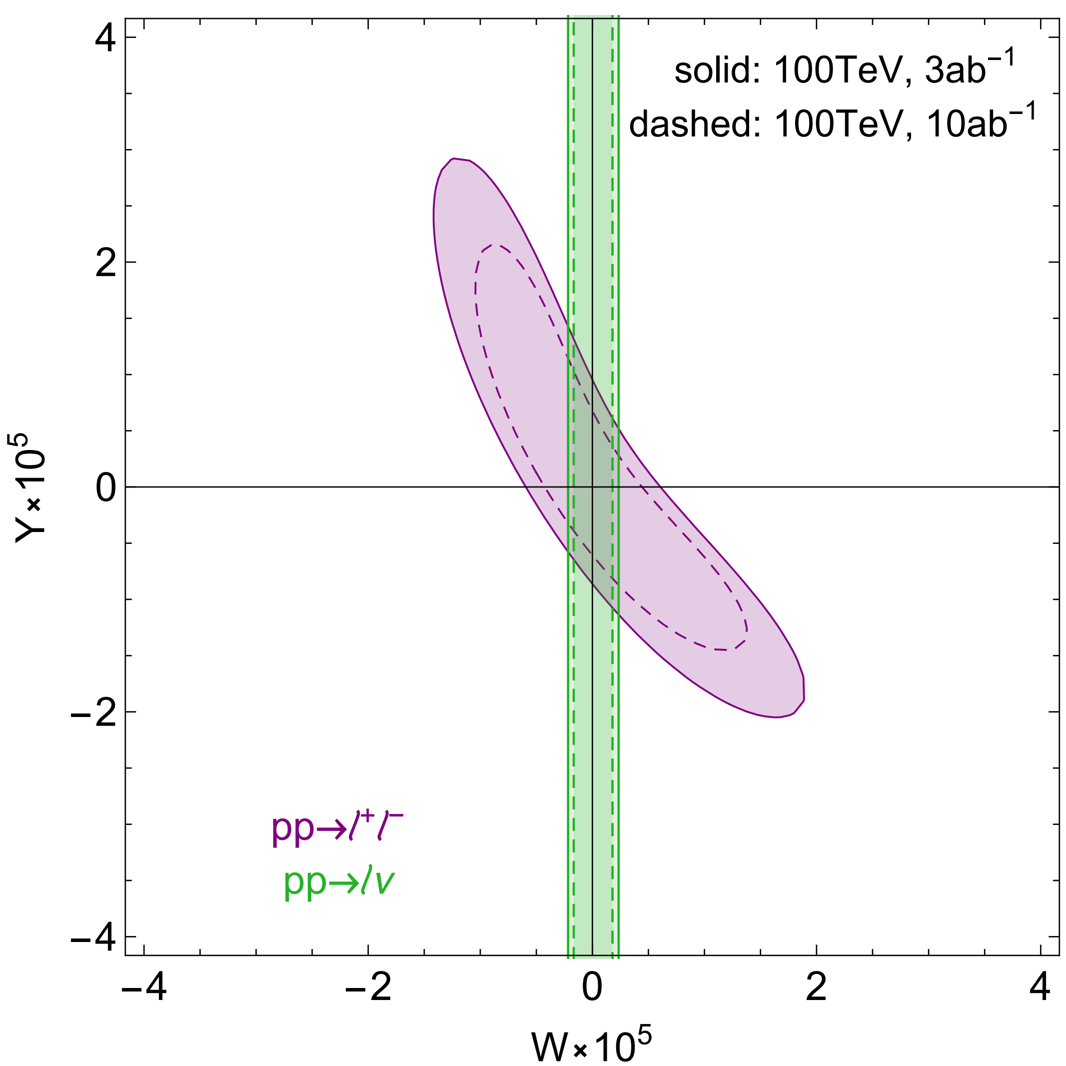

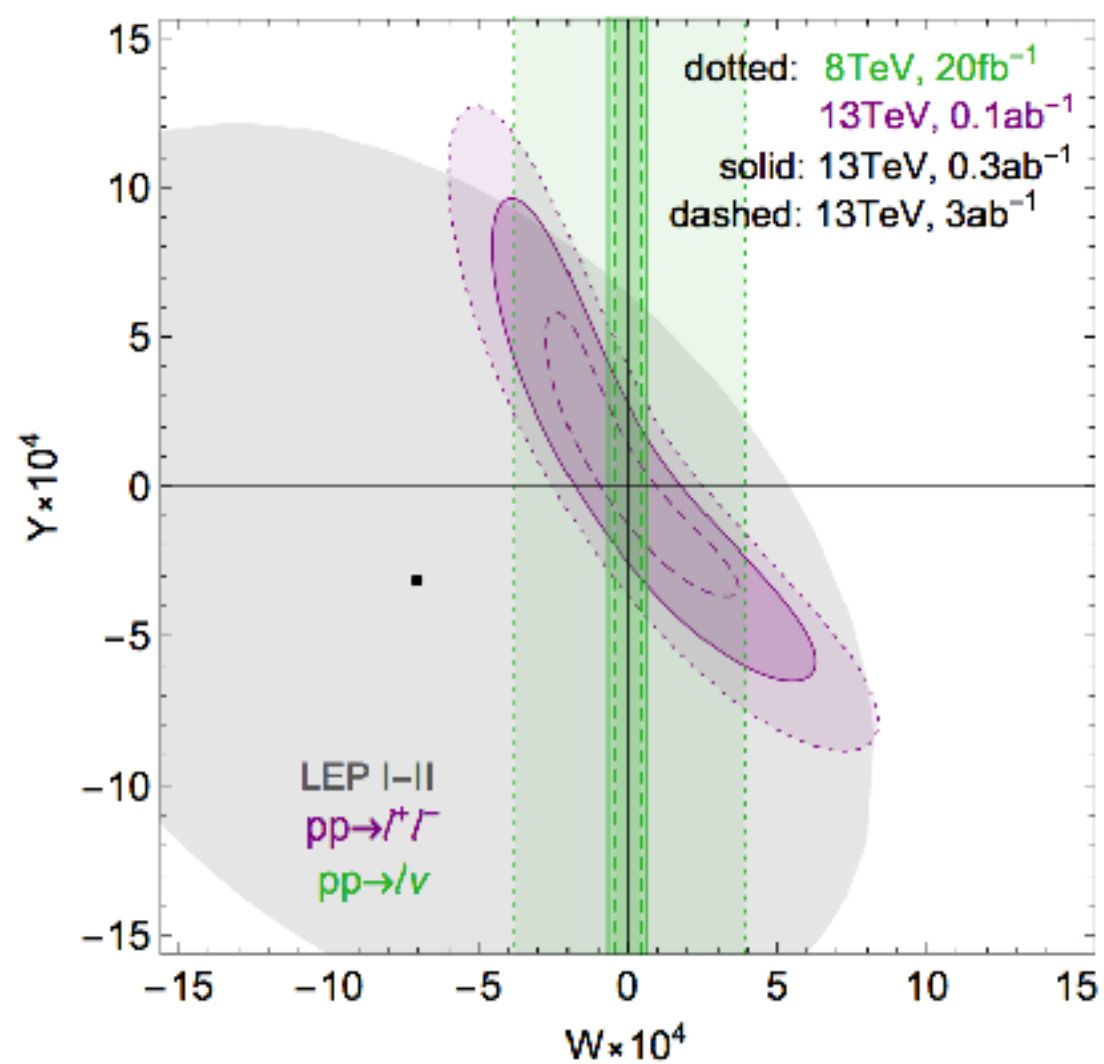

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Only CLIC@3TeV can be competitive:

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

Energy **and** Accuracy Frontier @ 100 TeV

Enhanced indirect NP effects in high mass tails

No need of extreme accuracy for indirect NP probe

- EWPT @ hadron colliders: (W and Y oblique par.s) [arXiv:1609.08157]
- Other example is top couplings from HE ttW/ttZ [arXiv:1511.03674]
- Diboson final states or boosted Higgs under exploration

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But, **we must dream !**