Baryonic Higgs @ LHC

Juri Smirnov
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Many thanks to: Michael Dürr and Pavel Fileviez Perez

arXiv:1704.03811

Why is the Proton stable?

- SM accidental symmetry
- What about BSM?
- Can stability be understood more fundamentally?
- Ansatz: Baryon number as local symmetry
- Spontaneously broken

$$\mathcal{O}_{6+n} = \frac{c_{6+n}(v_B)^n}{\Lambda^{2+n}} \times (u_R u_R d_R e_R)$$

for n=3 and $c_9 \approx 1$

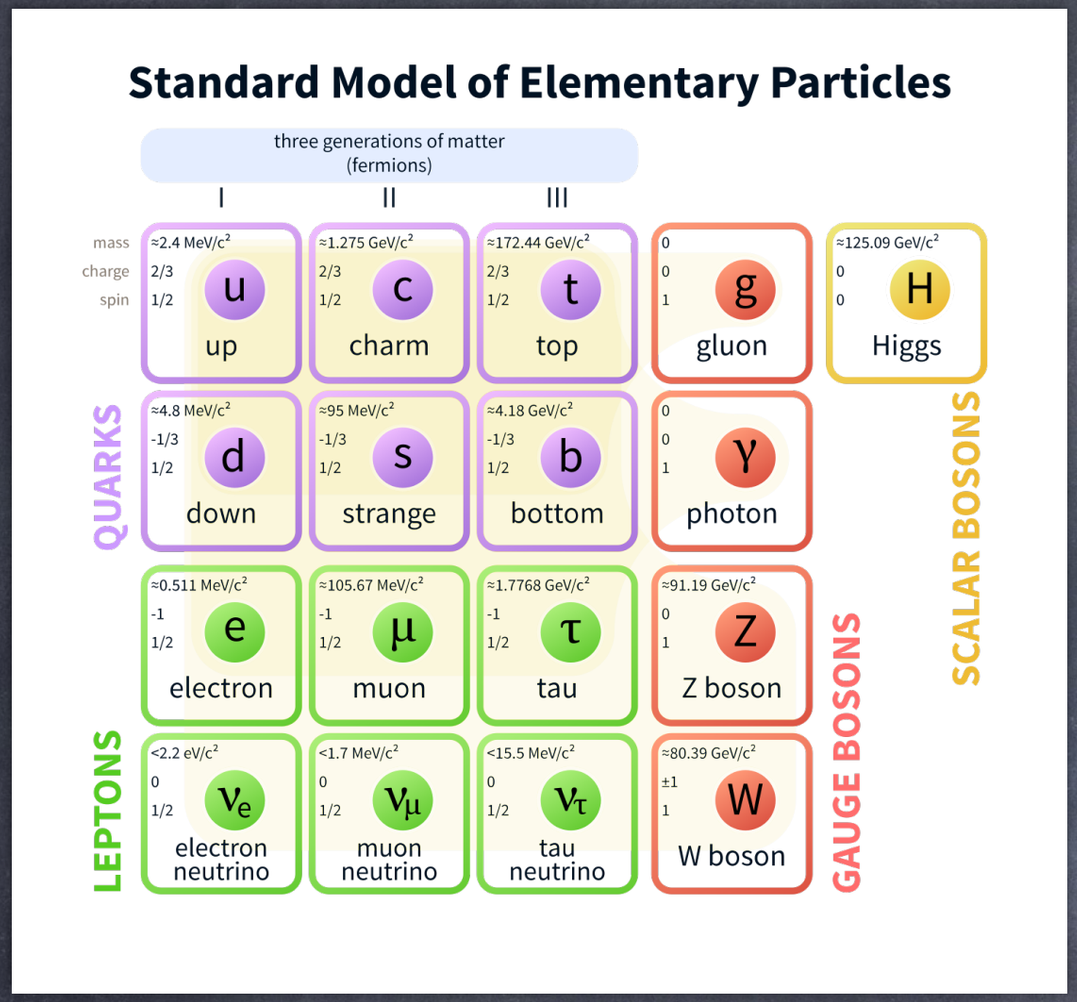
$$\Rightarrow \Lambda > 10^4 \text{ TeV}$$

Low Scale Unification: Talk by Sebastian Ohmer
Full Story: Talk by Michael Dürr

JHEP 1108 (2011) 068

Pavel Fileviez Perez, Mark B. Wise

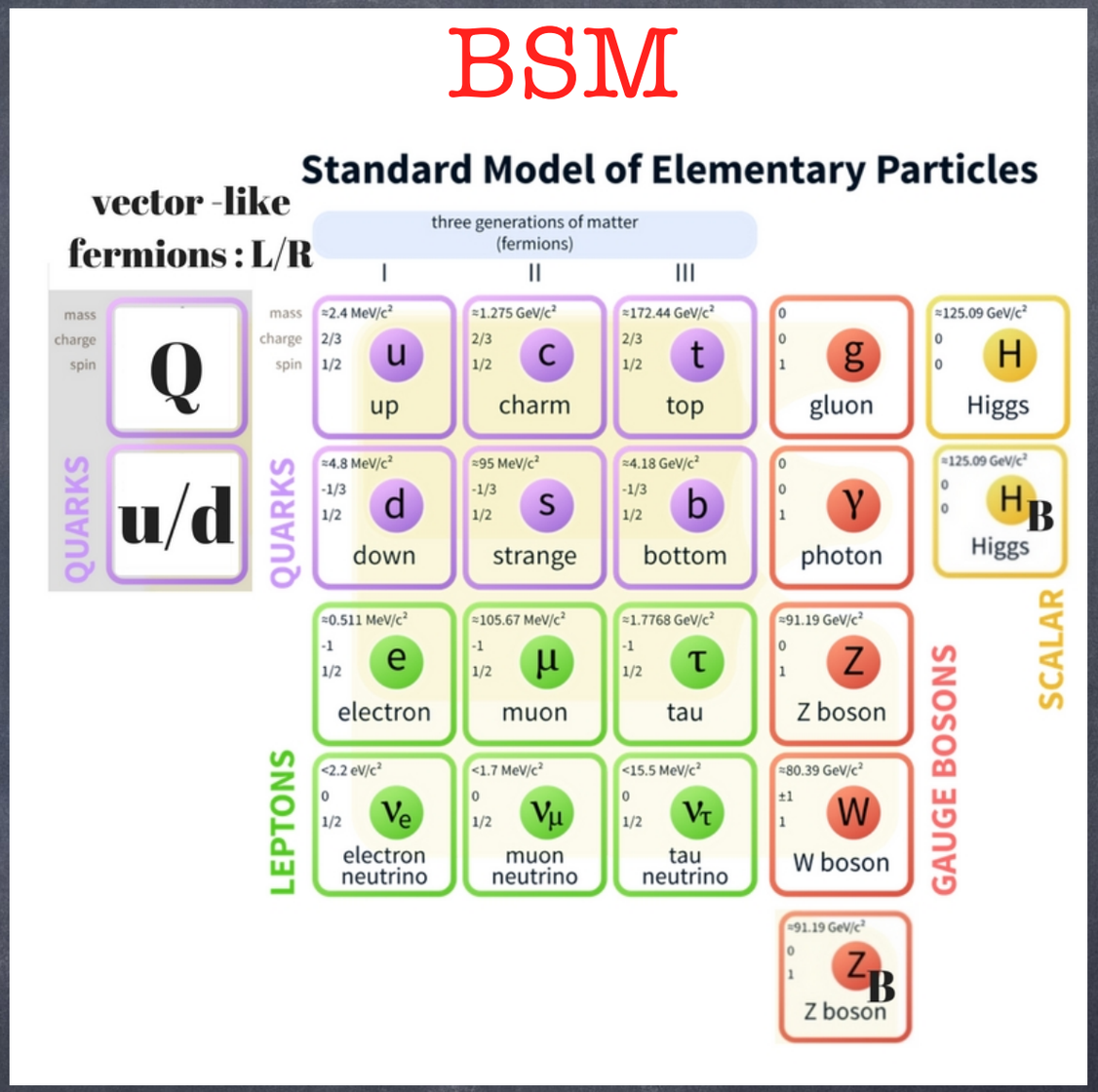
Matter and Gauge Symmetry



$$SU(3)_c \times SU(2)_L \times U(1)_Y$$

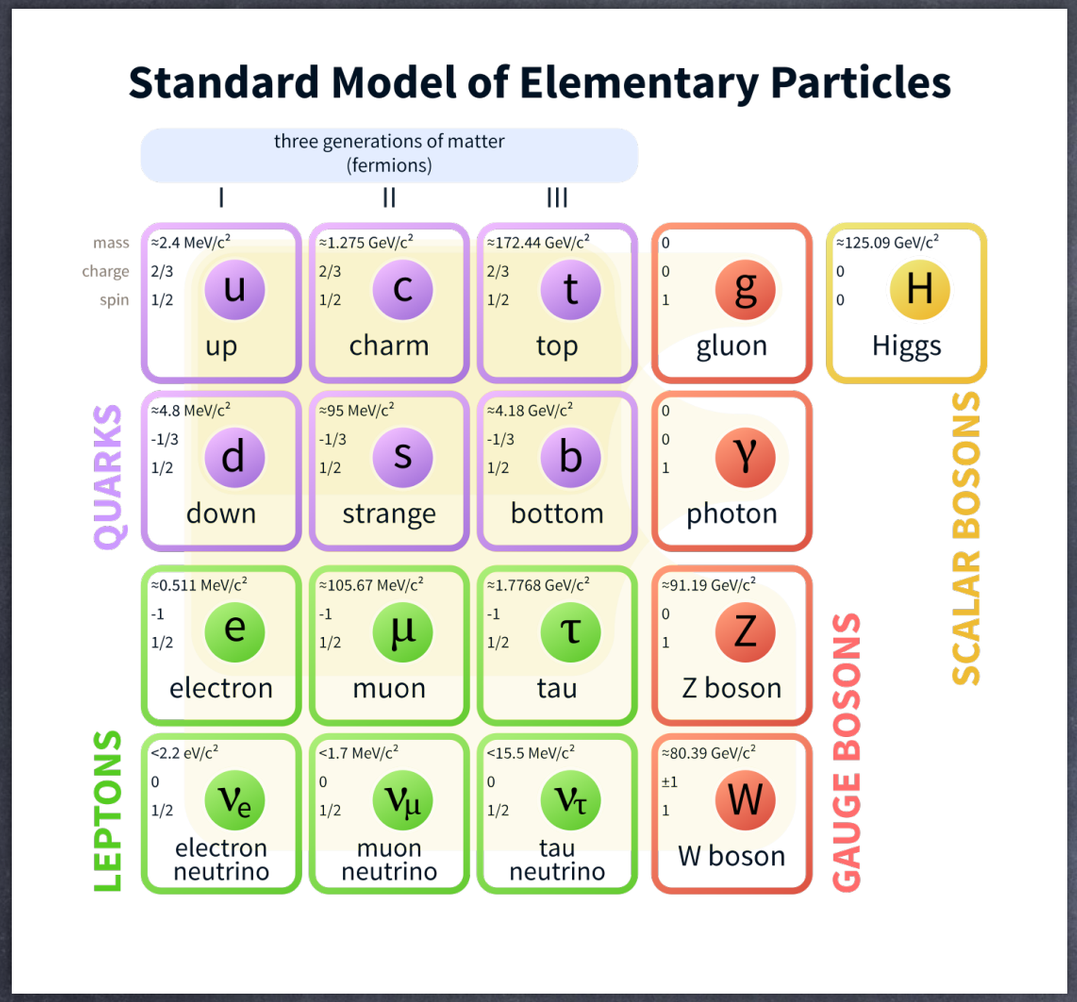
$$SU(3)_c \times U(1)_{\mathrm{em}}$$

BSM



$$U(1)_B \times SM$$

Matter and Gauge Symmetry



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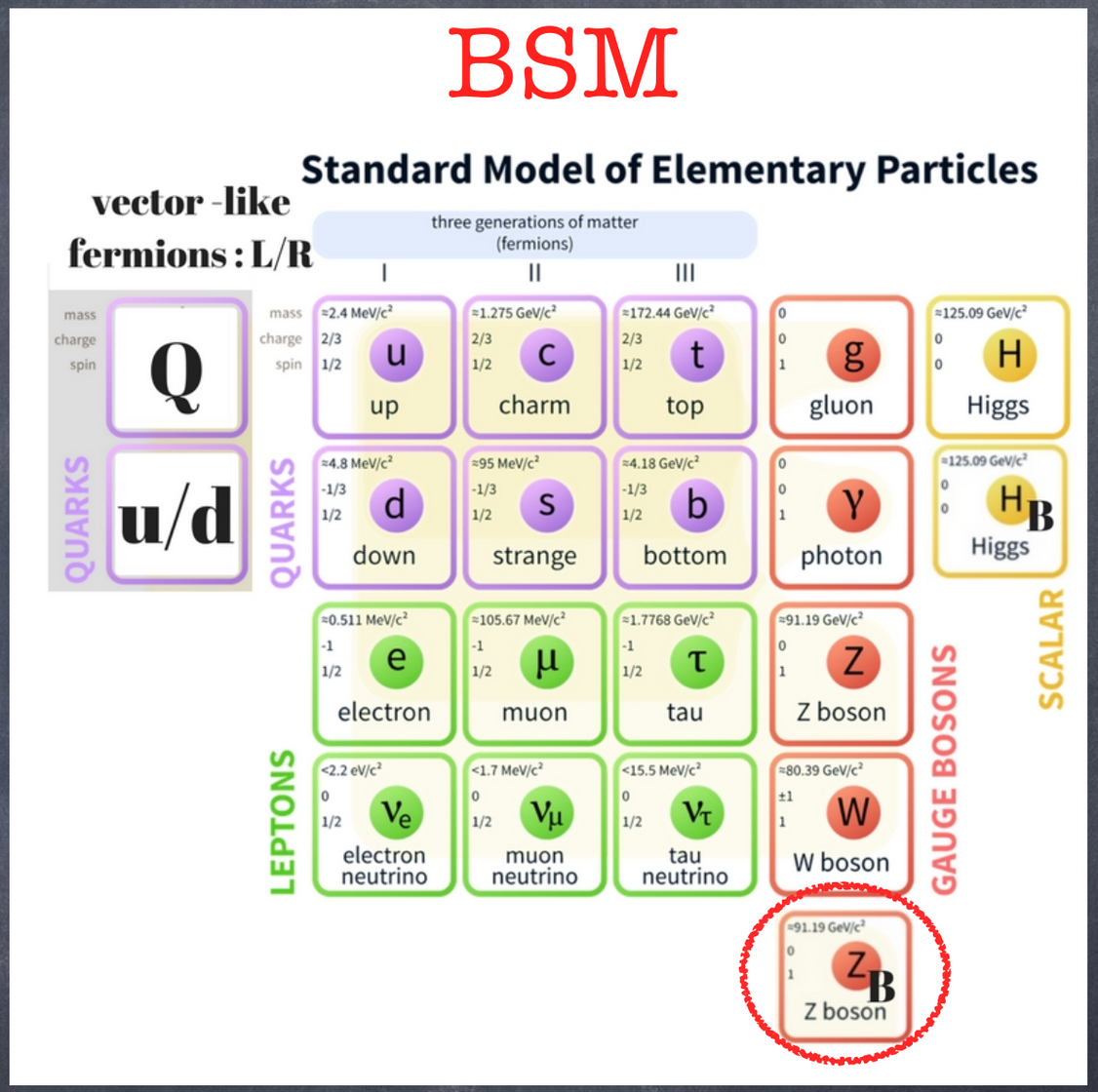

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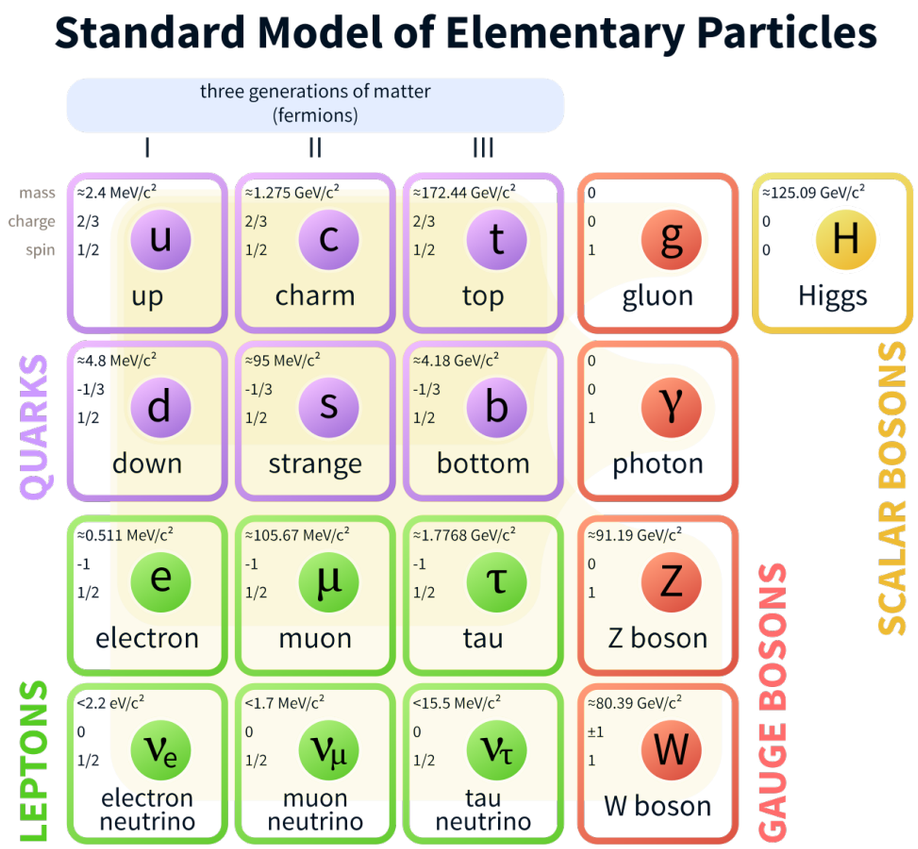

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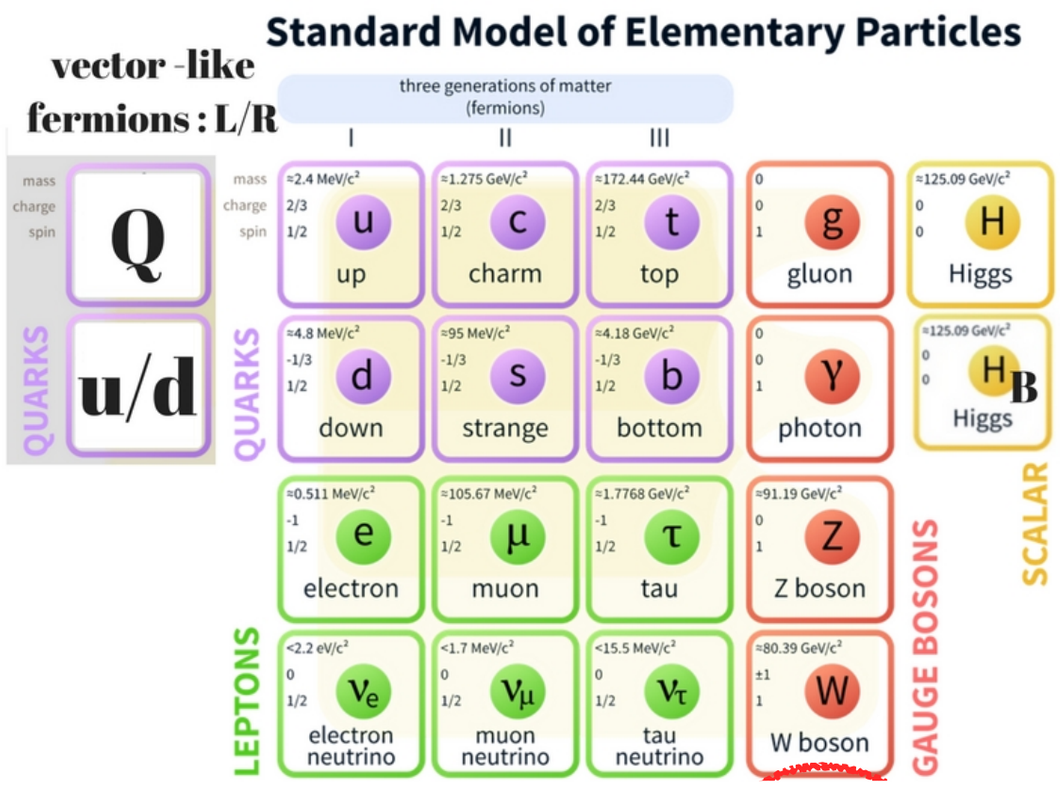
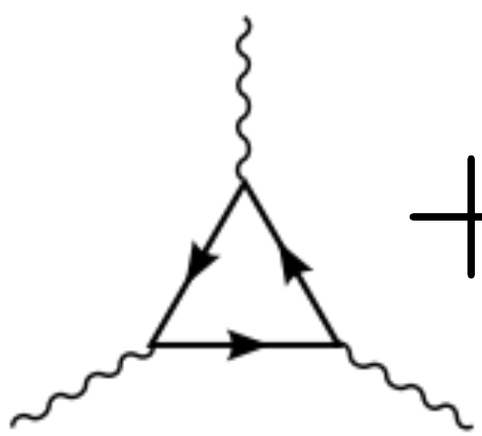
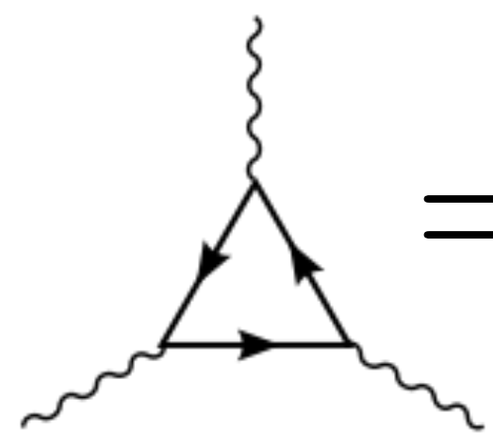


$$\sum_{\text{SM}}$$

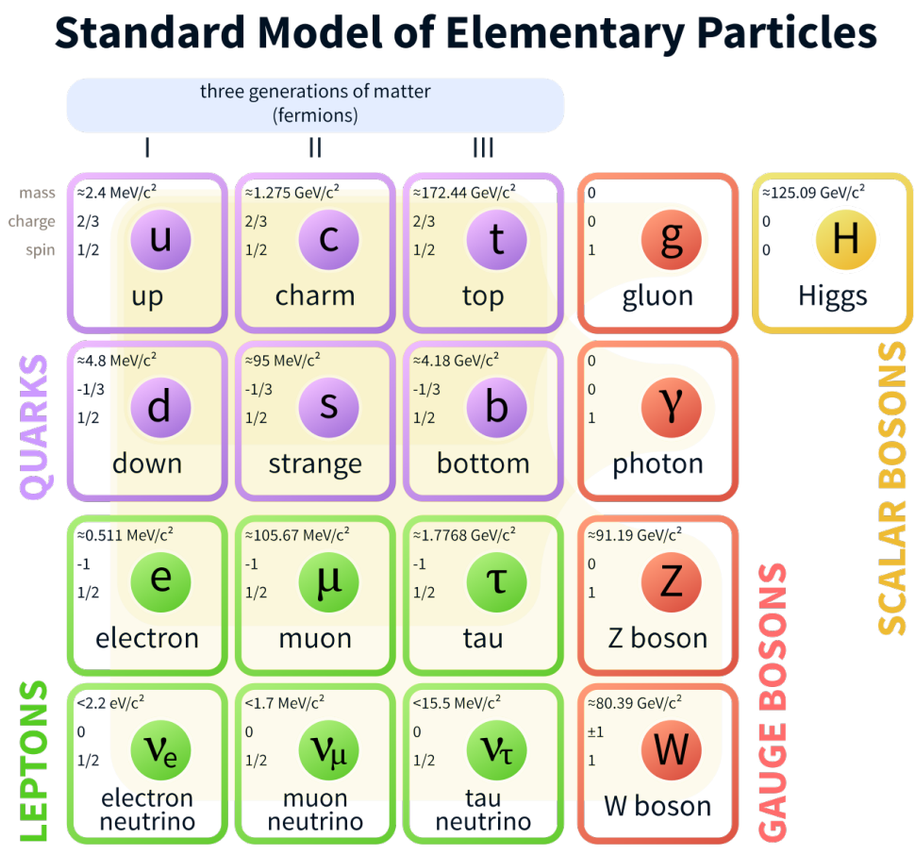


$$+ \sum_{\text{NEW}}$$



$$= 0$$

Matter and Gauge Symmetry



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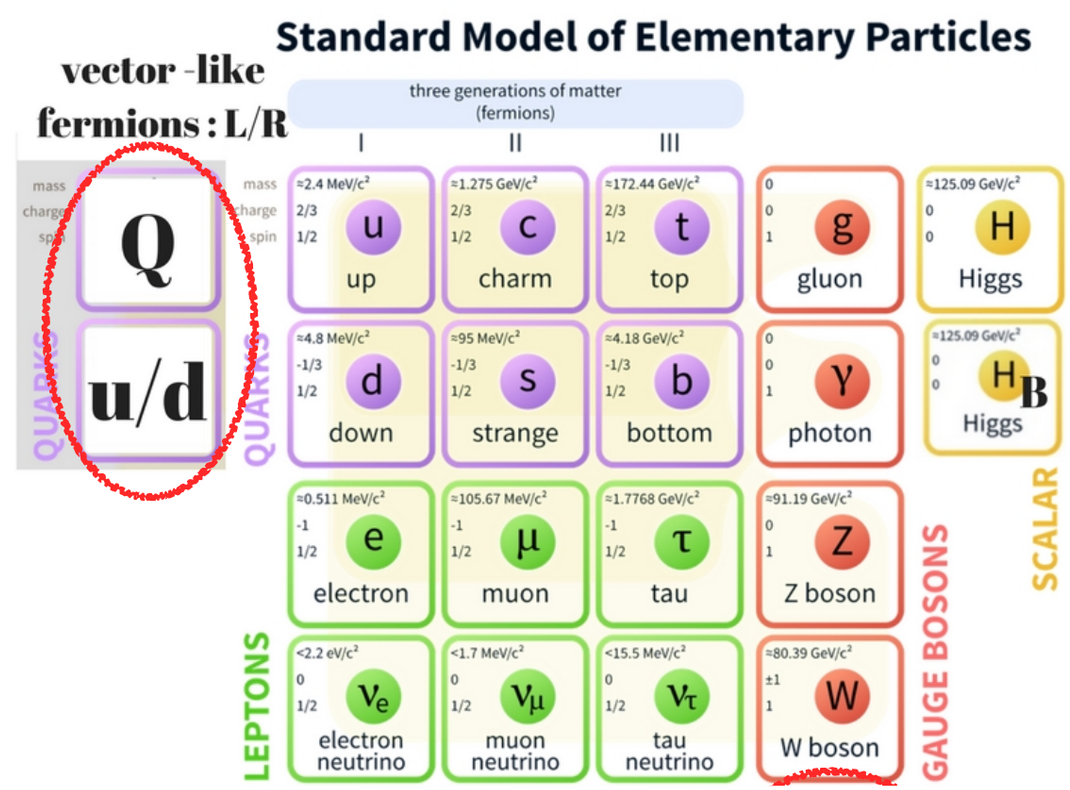

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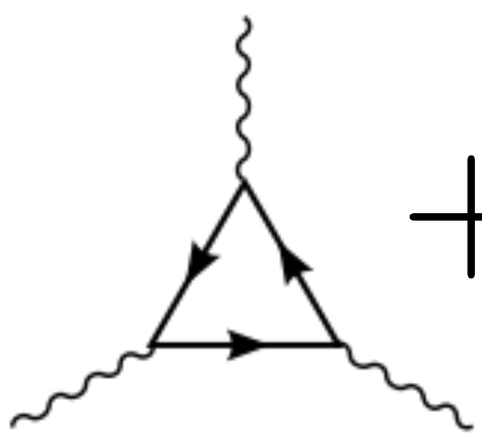

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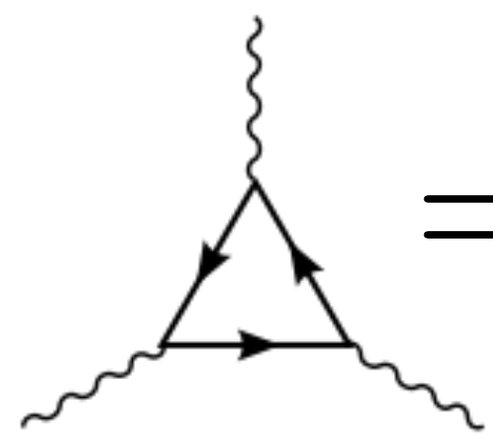

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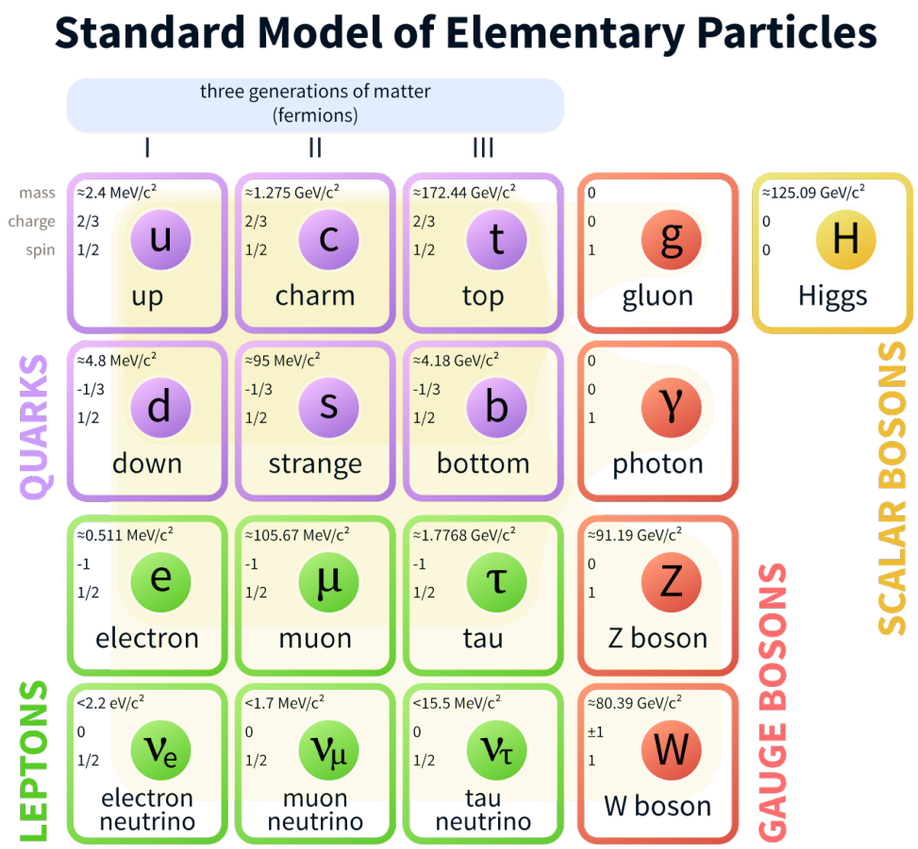
Matter and Gauge Symmetry



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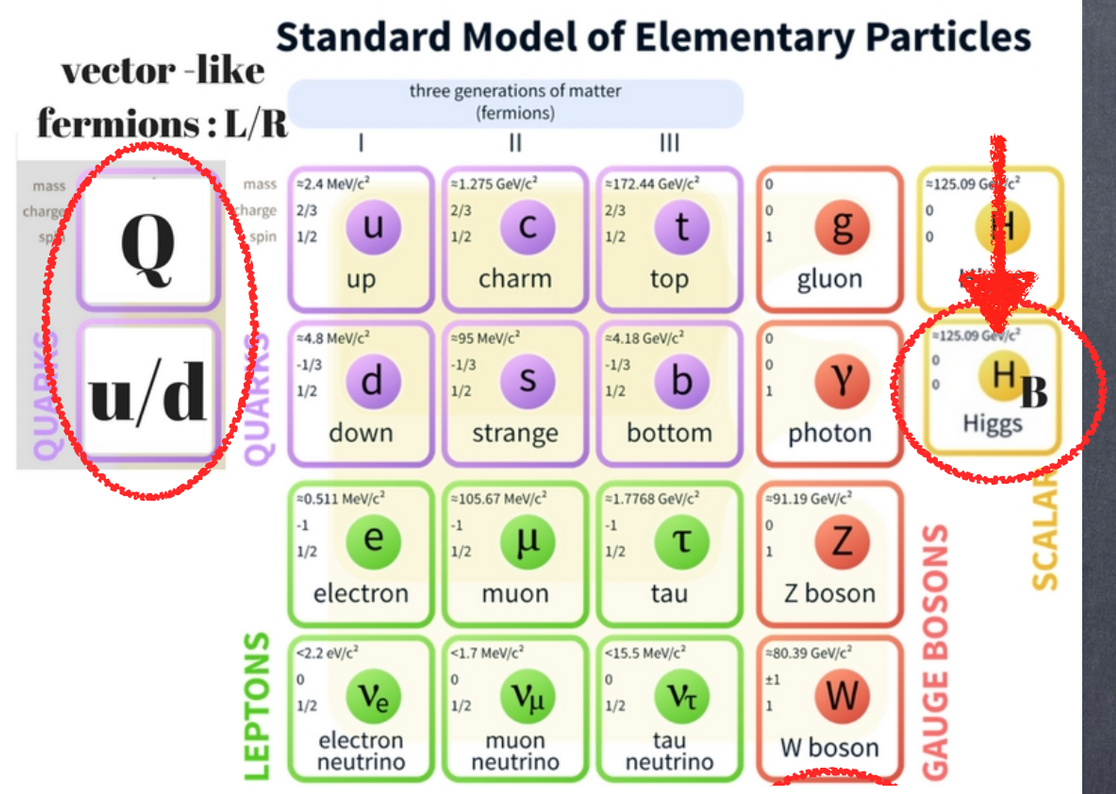

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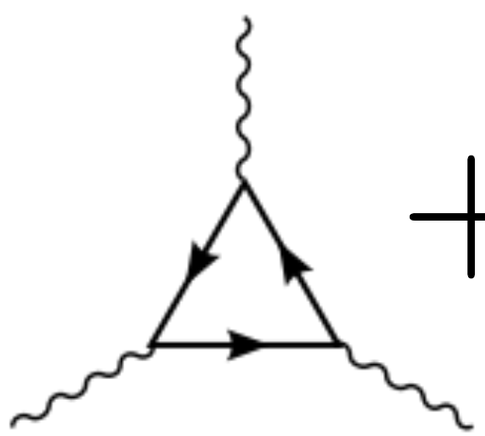

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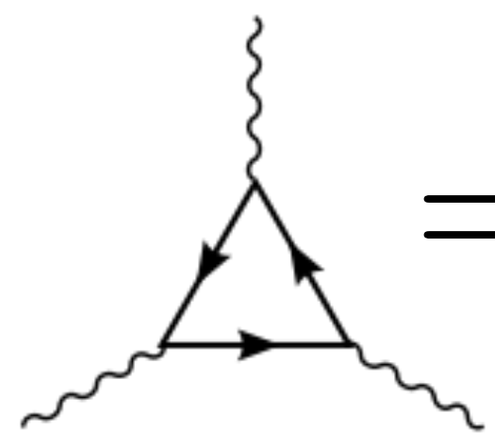

$$= 0$$

Particle Content

Table I. Particle content.

Field	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_B$
Fermions				
ℓ_L	1	2	$-1/2$	0
e_R	1	1	-1	0
q_L	3	2	$1/6$	$1/3$
u_R	3	1	$2/3$	$1/3$
d_R	3	1	$-1/3$	$1/3$
Q_L	3	2	Y_1	B_1
Q_R	3	2	Y_1	B_2
U_R	3	1	Y_2	B_1
U_L	3	1	Y_2	B_2
D_R	3	1	Y_3	B_1
D_L	3	1	Y_3	B_2
Scalars				
S_B	1	1	0	$B_2 - B_1$
H	1	2	$1/2$	0

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- Scenario I: $Y_1 = 1/6$, $Y_2 = 2/3$ and $Y_3 = -1/3$.
- Scenario II: $Y_1 = -5/6$, $Y_2 = -4/3$ and $Y_3 = -1/3$.
- Scenario III: $Y_1 = 7/6$, $Y_2 = 5/3$ and $Y_3 = 2/3$.

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$$B_2 - B_1 = \frac{1}{n_f} = 1/3$$

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$$B_2 - B_1 = \frac{1}{n_f} = 1/3$$

- Baryon Number forbids mixing with SM quarks
- This model could be potentially light

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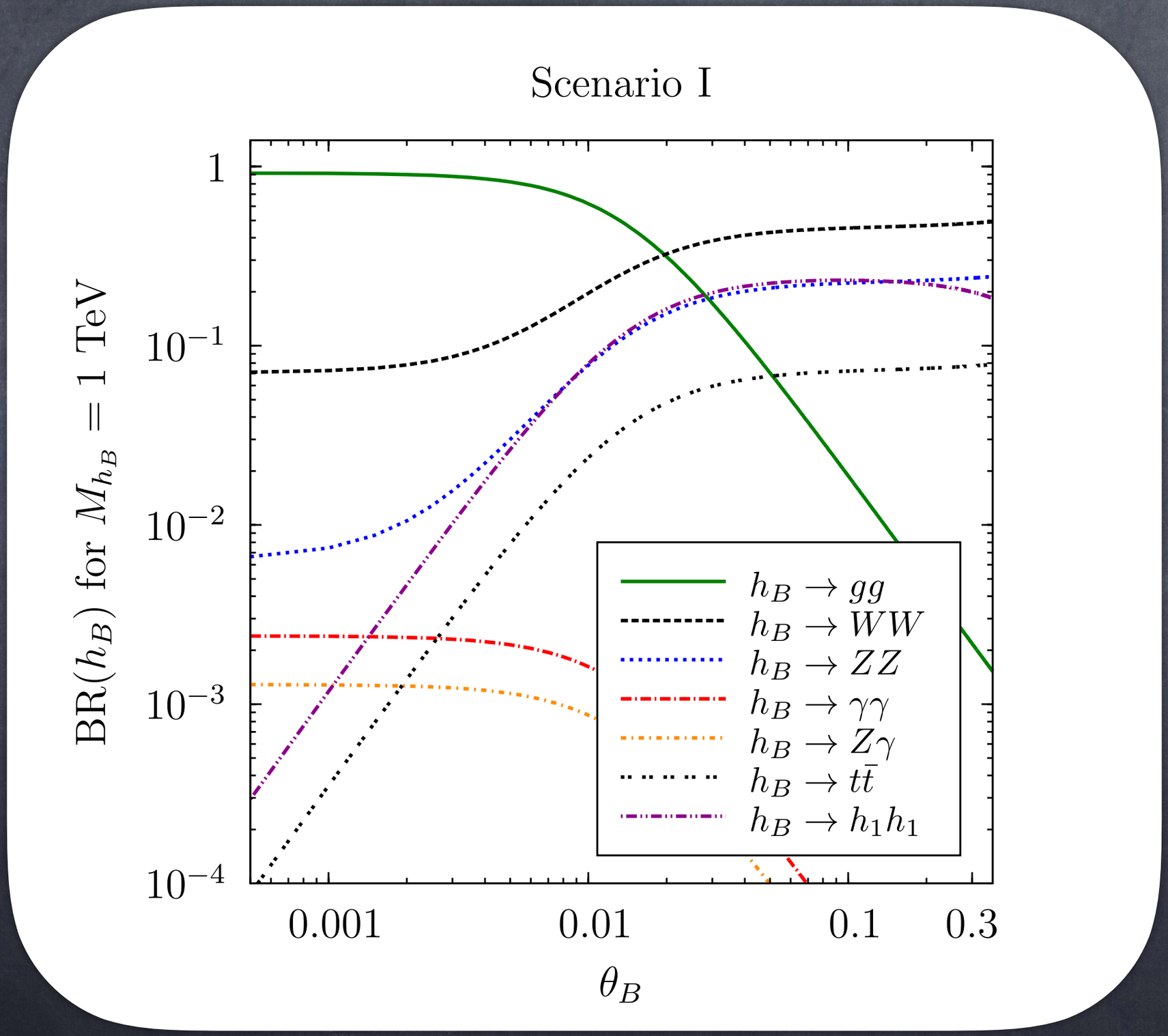
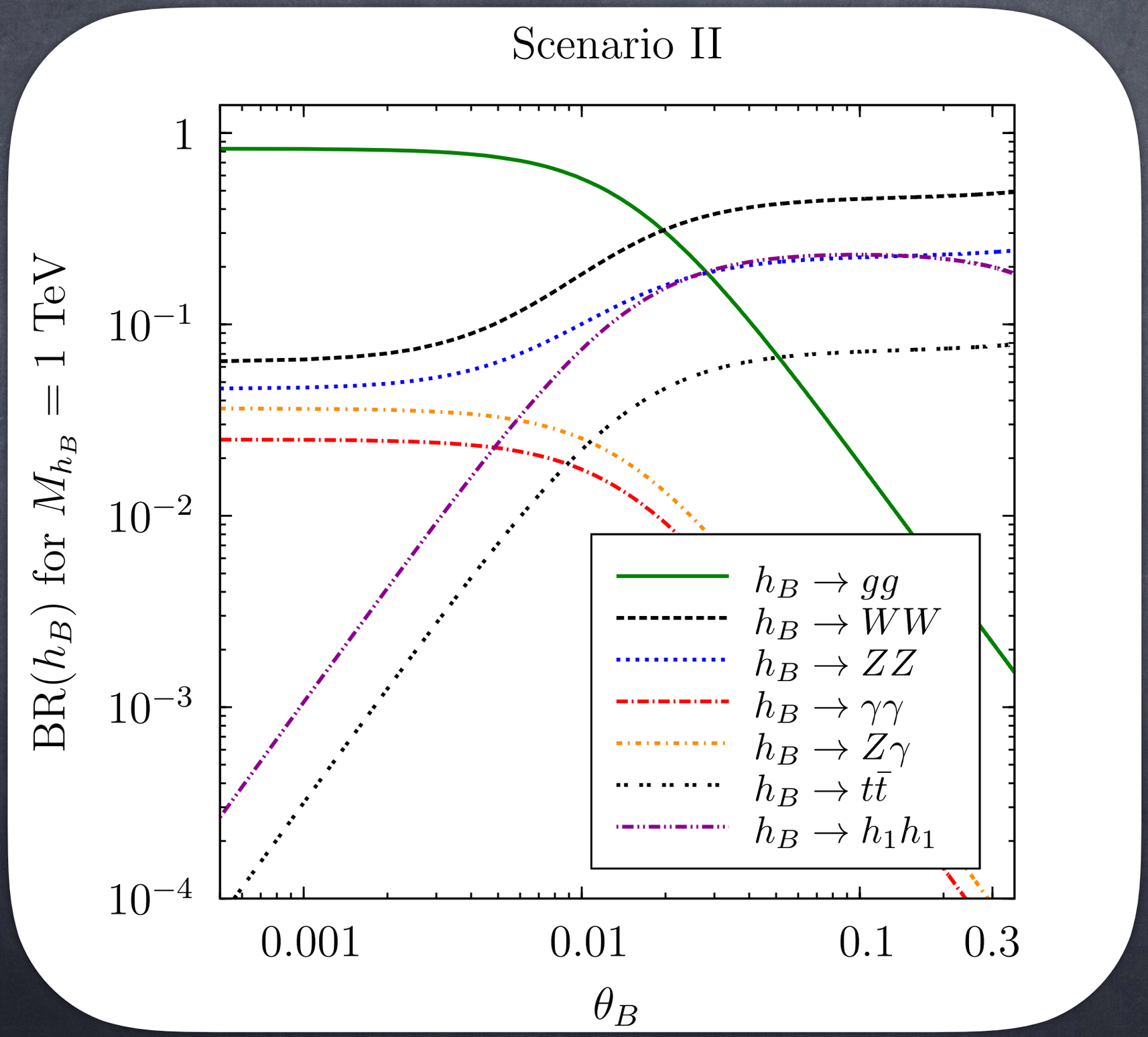
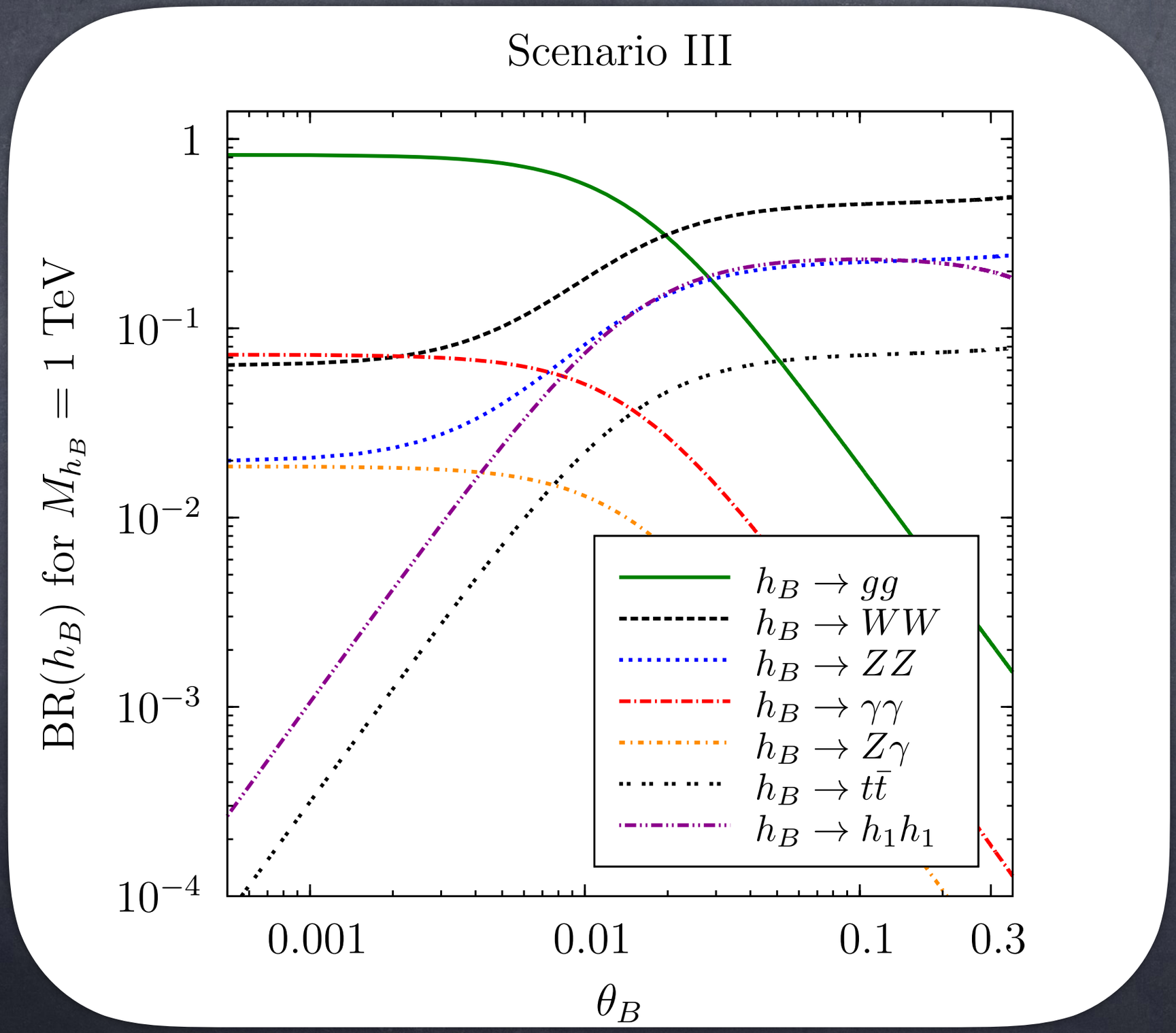
New Higgs


Scenario I
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
$\mathrm{BR}(h_B)$ for $M_{h_B} = 1$ TeV
0.001
0.01
0.1
0.3
θ_B
$h_B \to gg$
$h_B \to WW$
$h_B \to ZZ$
$h_B \to \gamma\gamma$
$h_B \to Z\gamma$
$h_B \to t\bar{t}$
$h_B \to h_1 h_1$

New Higgs


Scenario II
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.001
0.01
0.1
0.3
θ_B
$\mathrm{BR}(h_B)$ for $M_{h_B} = 1$ TeV
$h_B \to gg$
$h_B \to WW$
$h_B \to ZZ$
$h_B \to \gamma\gamma$
$h_B \to Z\gamma$
$h_B \to t\bar{t}$
$h_B \to h_1 h_1$

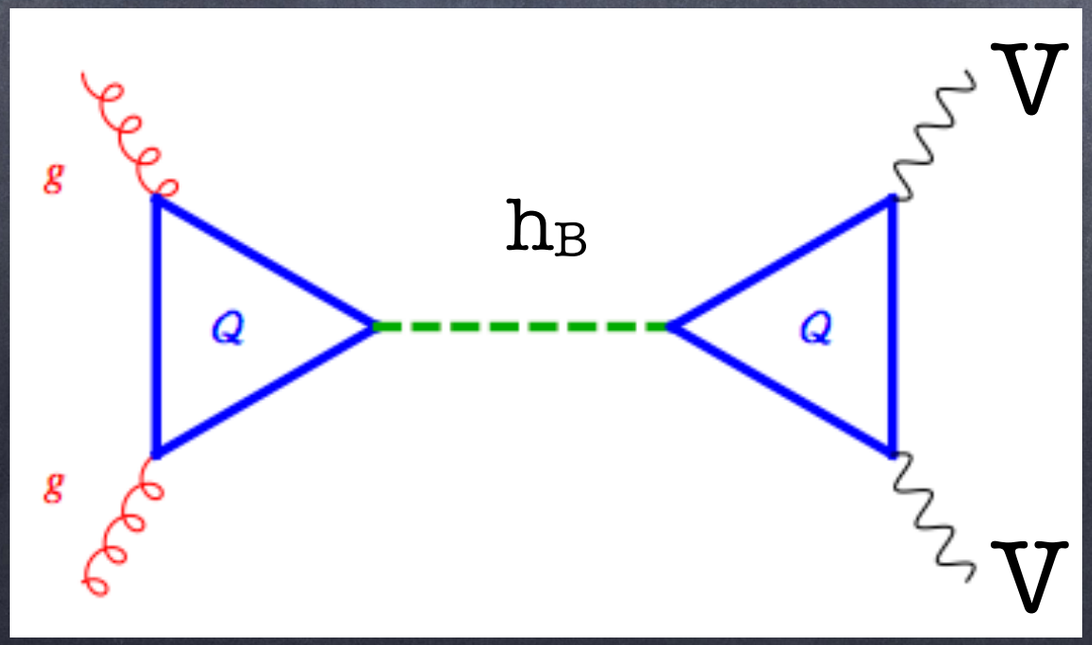
New Higgs


Scenario III
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0.001
0.01
0.1
0.3
θ_B
$\mathrm{BR}(h_B)$ for $M_{h_B} = 1$ TeV
$h_B \to gg$
$h_B \to WW$
$h_B \to ZZ$
$h_B \to \gamma\gamma$
$h_B \to Z\gamma$
$h_B \to t\bar{t}$
$h_B \to h_1 h_1$

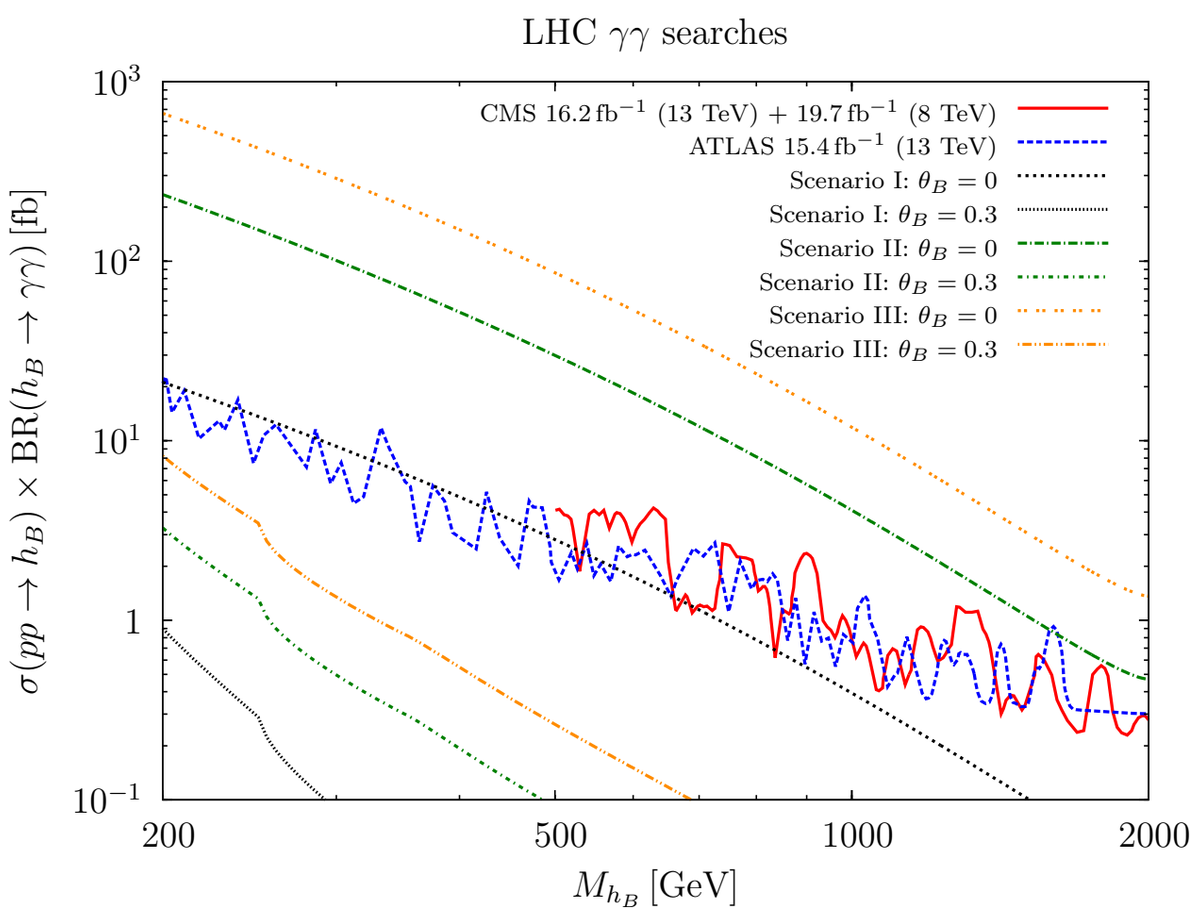
Assuming Baryonic Higgs is lighter than VLQs

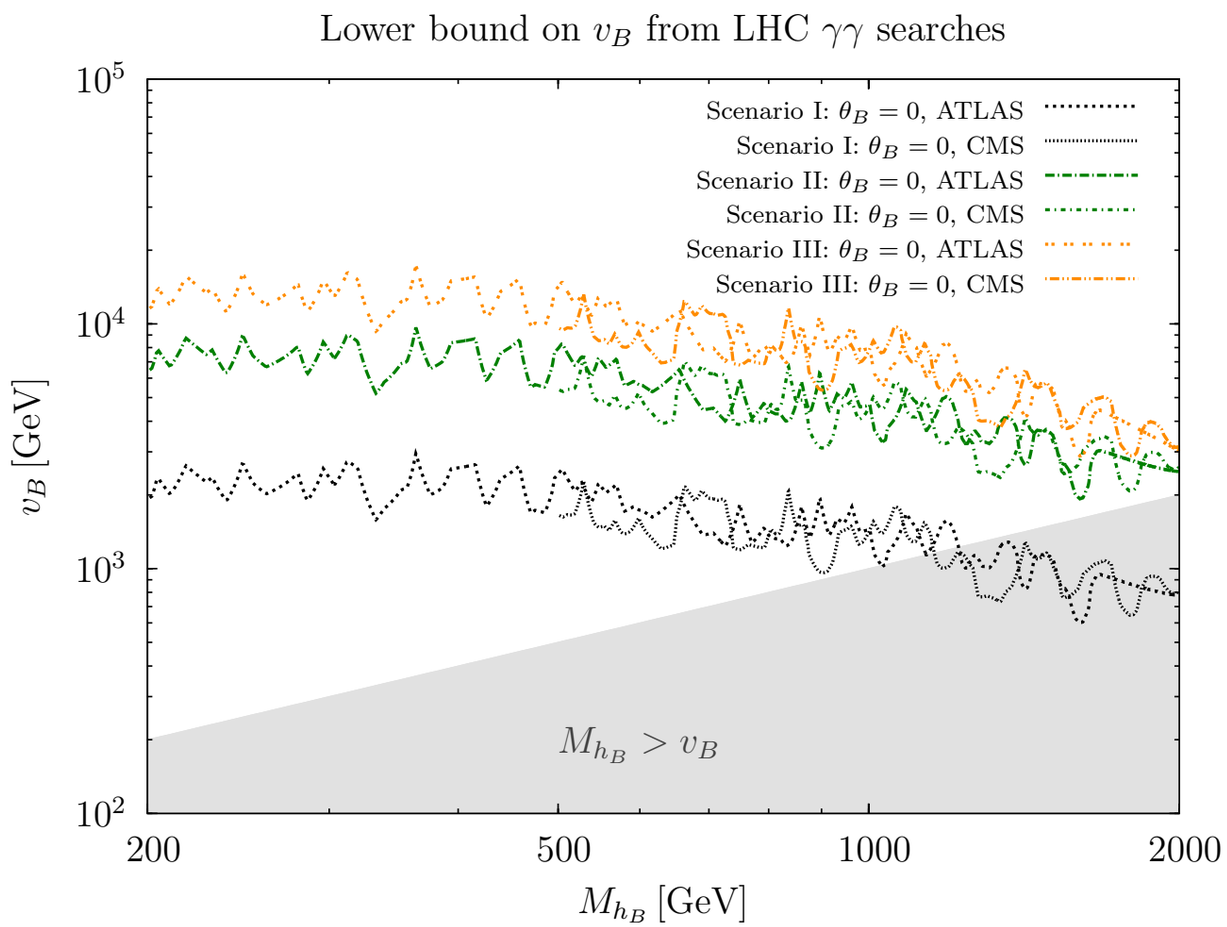
$$\sigma\left(pp \to h_B\right) = \frac{C_{gg}}{s M_{h_B}} \Gamma\left(h_B \to gg\right).$$

$$\sigma_{VV} \equiv \sigma(pp \to h_B) \times \mathrm{BR}(h_B \to V\,V) \approx \frac{C_{gg}}{s} \frac{2\,\alpha_s^2\,M_{h_B}^2\,n_f^2}{9\pi^3 v_B^2} \mathrm{BR}(h_B \to V\,V)\,.$$



The precision channels: 2-Gamma

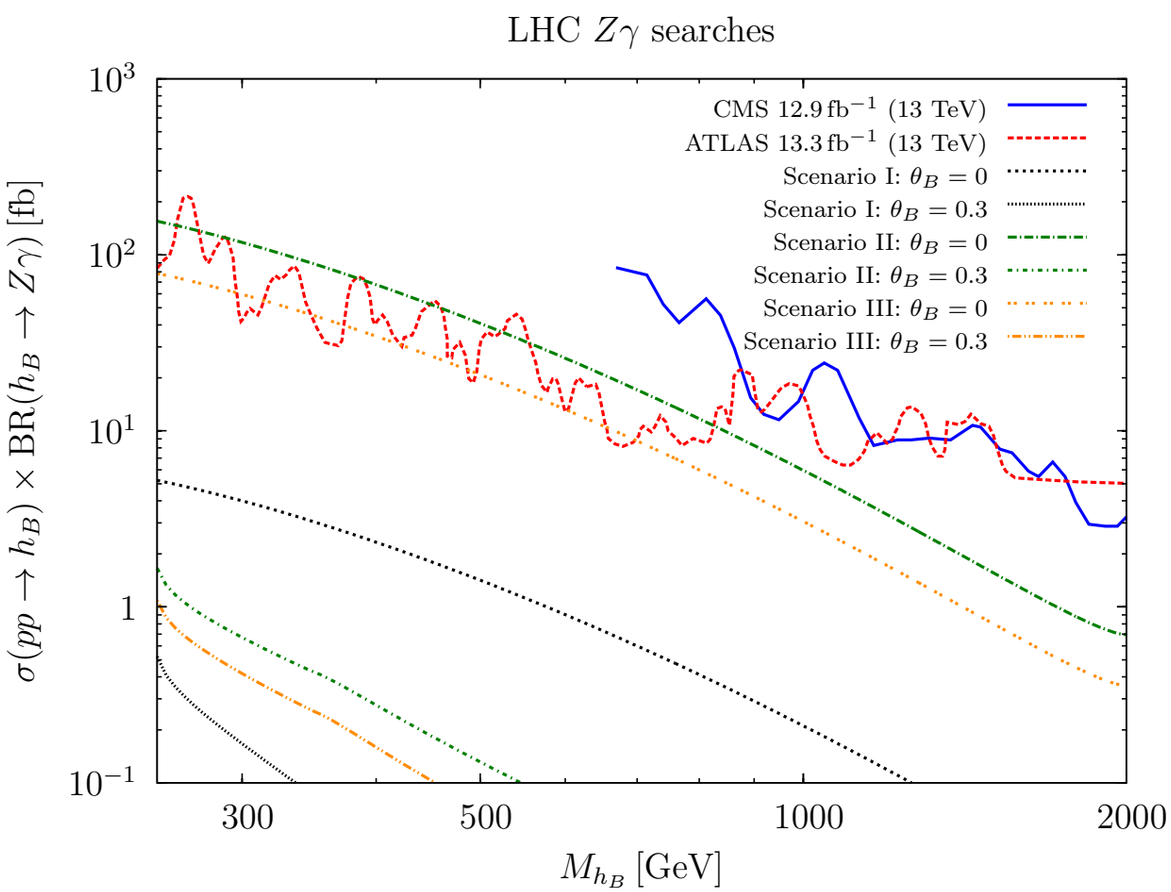


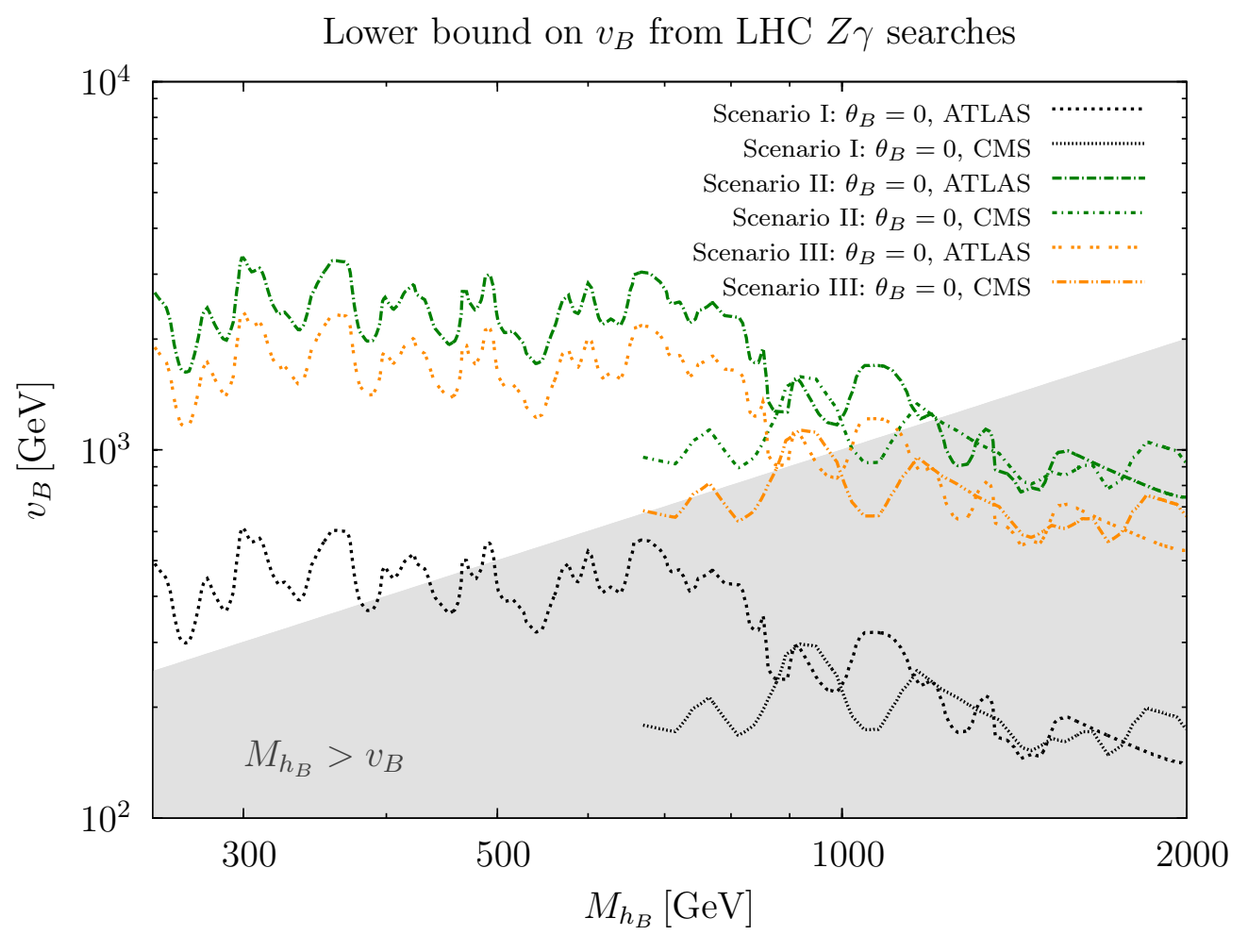


$v_B = 2$ TeV
$m_Q = 1$ TeV

I) $v_B > 1$ TeV
II) $v_B > 2.3$ TeV
III) $v_B > 3$ TeV

And Z-Gamma

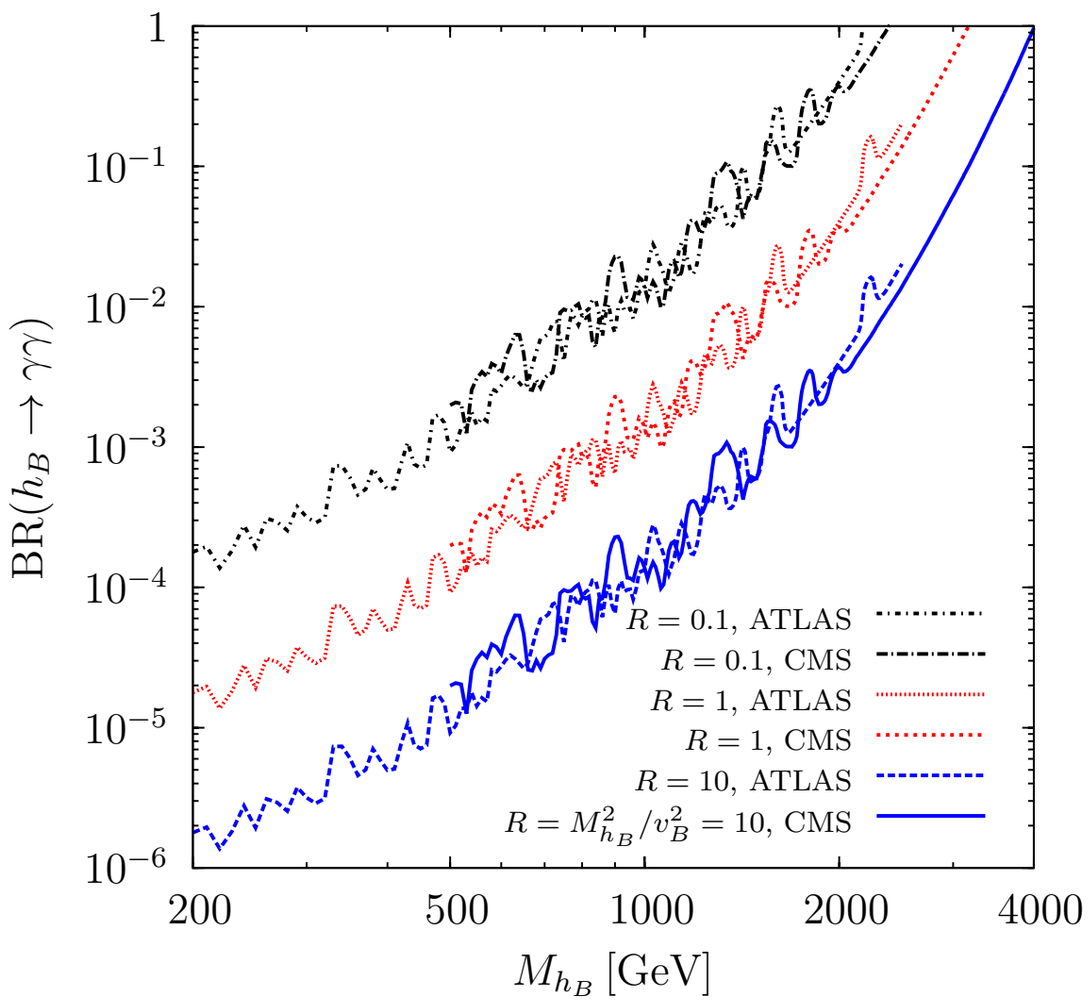


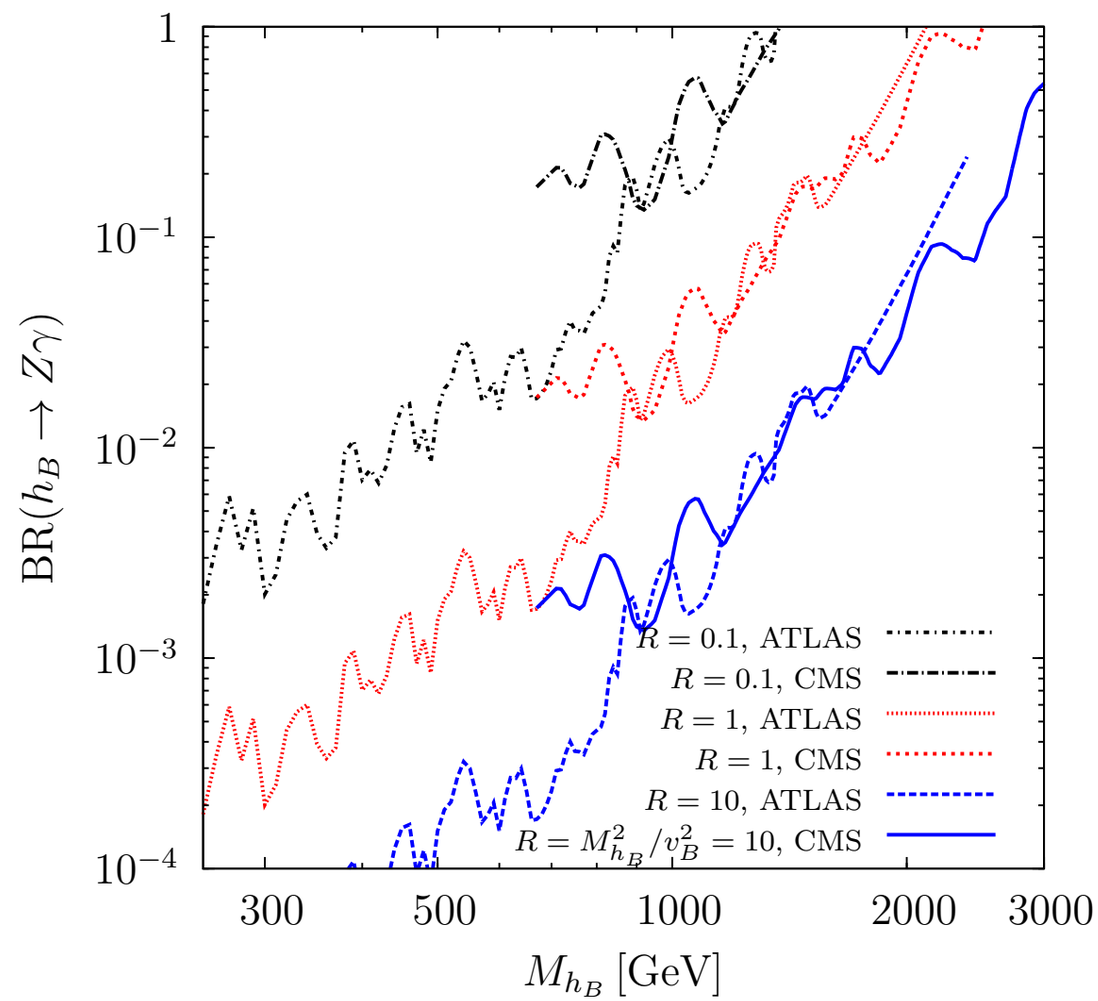


$v_B = 2$ TeV

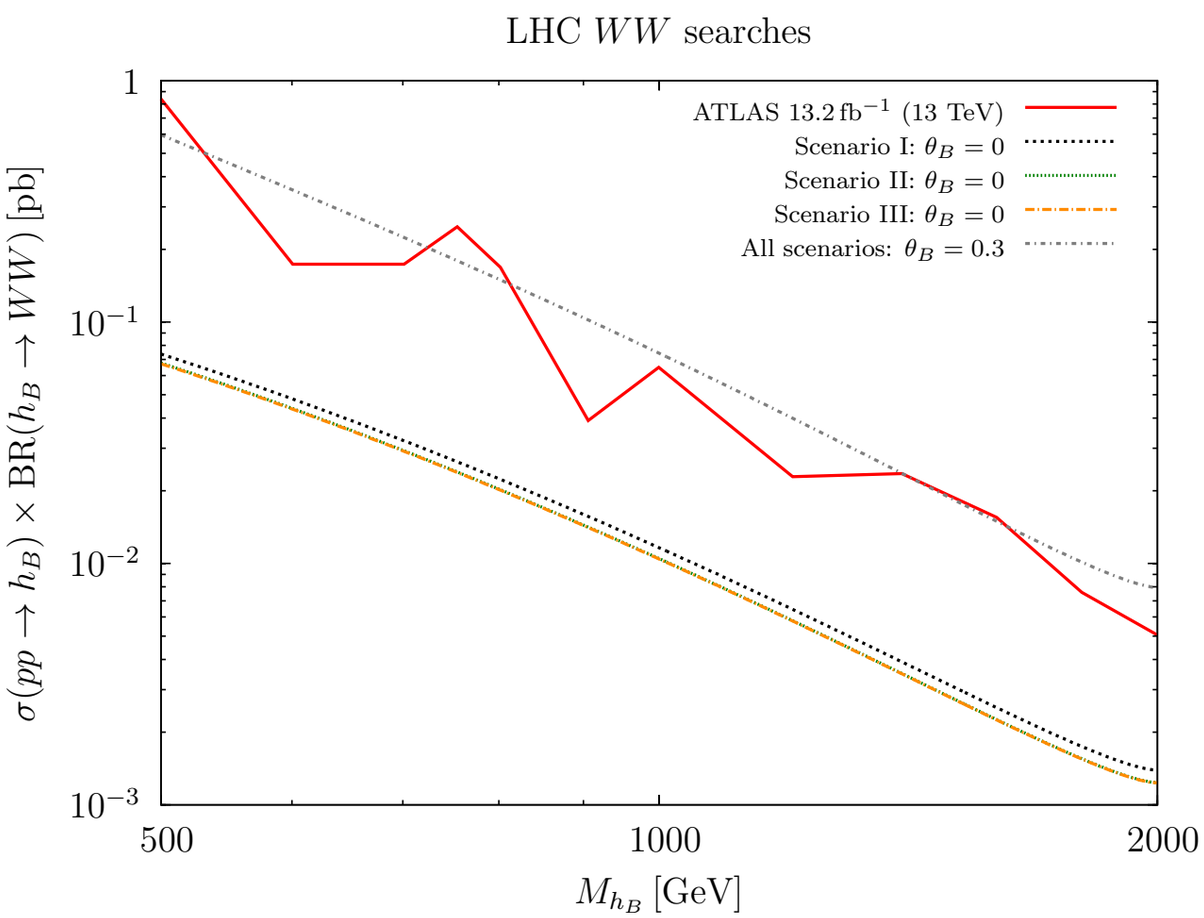
$m_Q = 1$ TeV

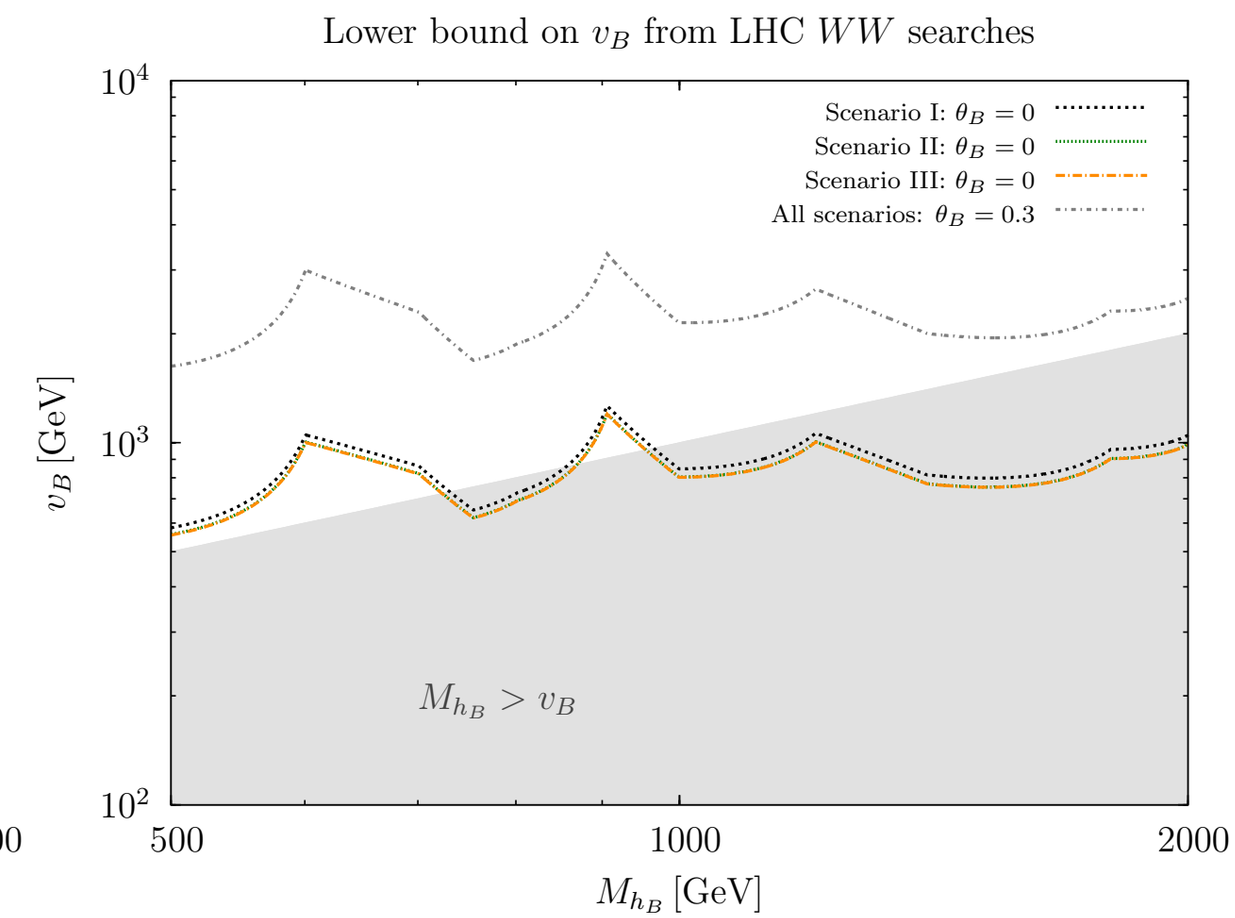
The precision channels: Model Independent





At larger mixing: WW

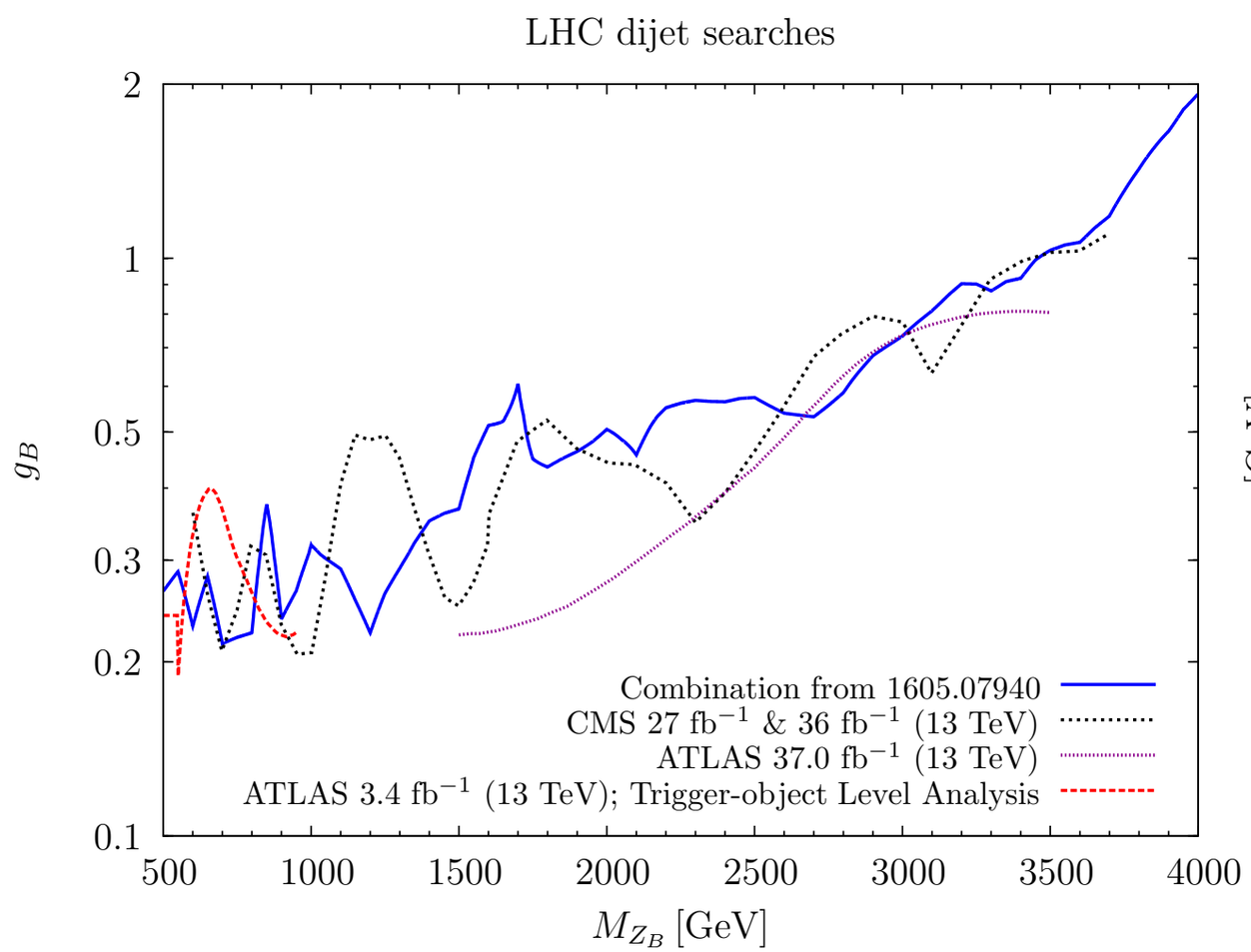


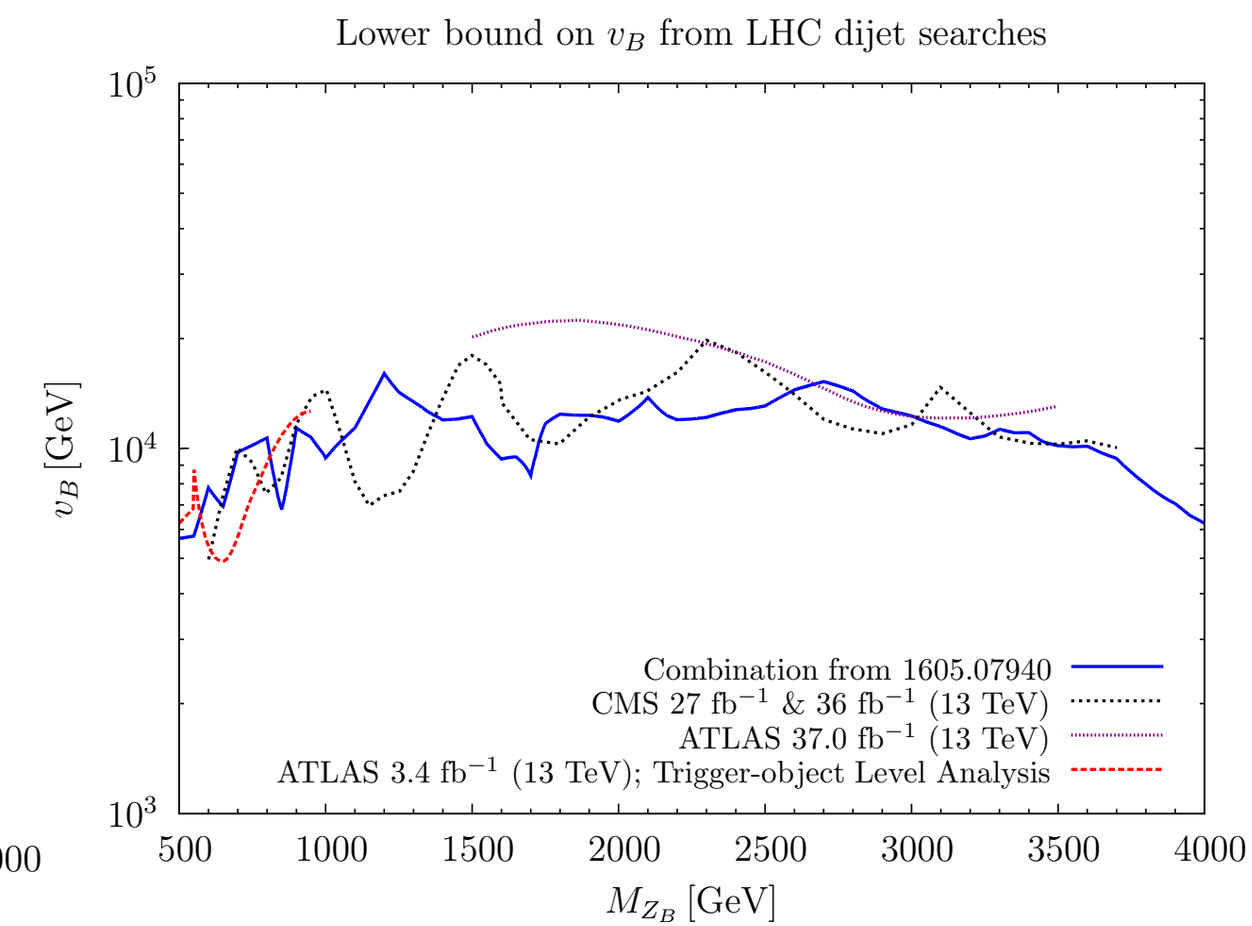


v_B = 2 TeV
m_Q = 1 TeV

I),II),III) v_B > 2 TeV

Di-jet searches for the Z_B

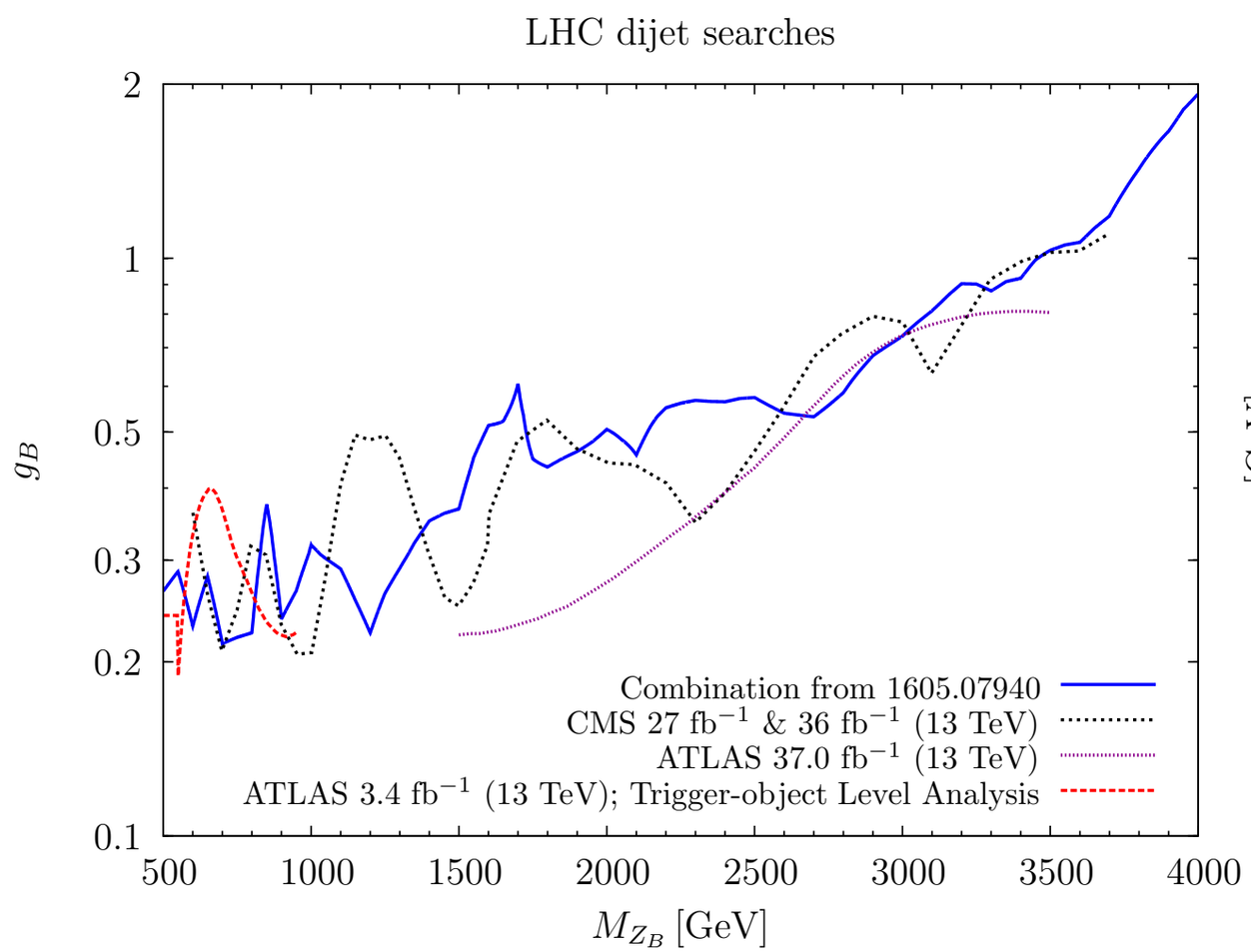


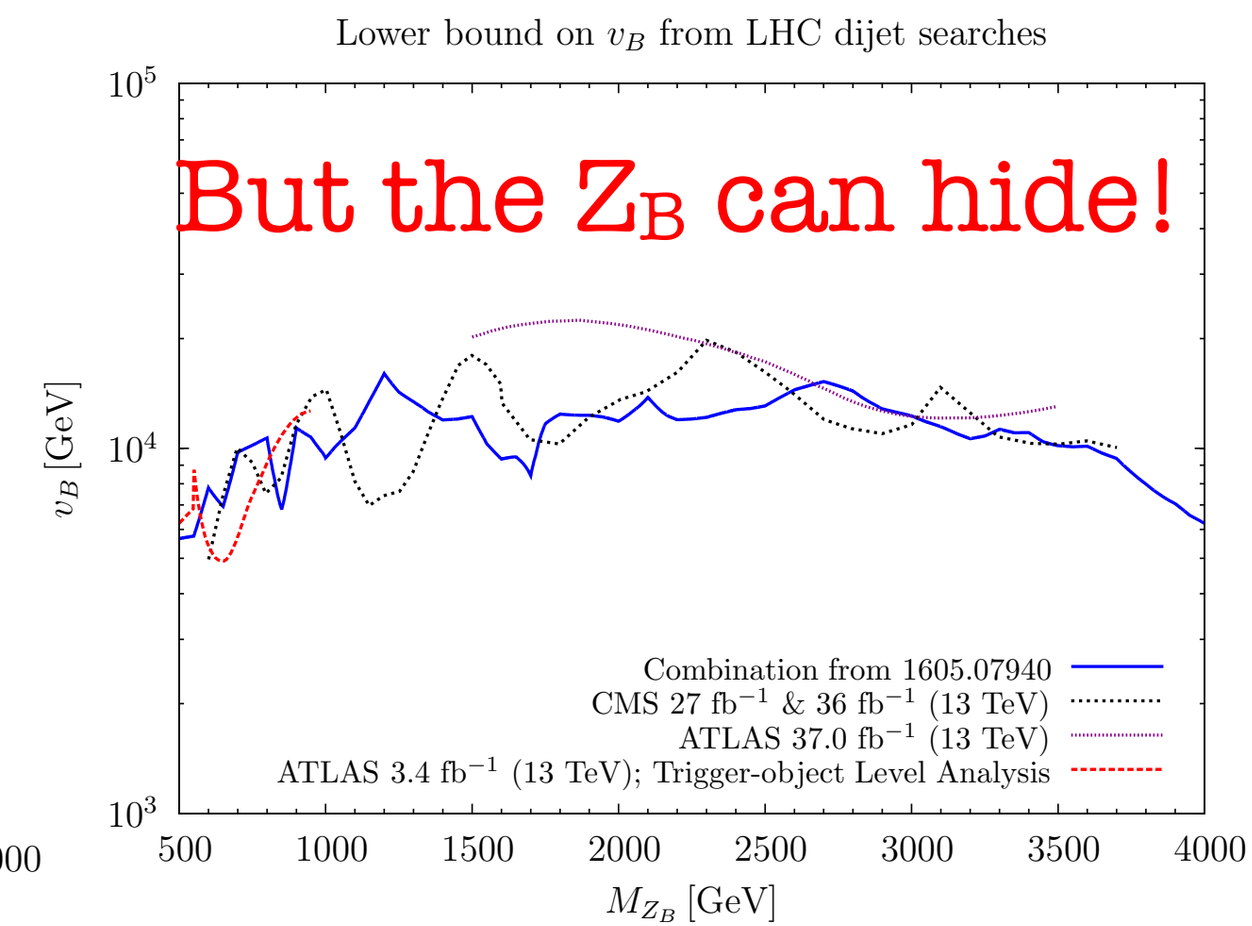


If $M_{ZB} > 0.5$ TeV

$v_B > 3.4$ TeV

Di-jet searches for the Z_B





But the Z_B can hide!

If $M_{ZB} > 0.5$ TeV

$v_B > 3.4$ TeV

Alternative: VLQs are lighter than the Baryonic Higgs

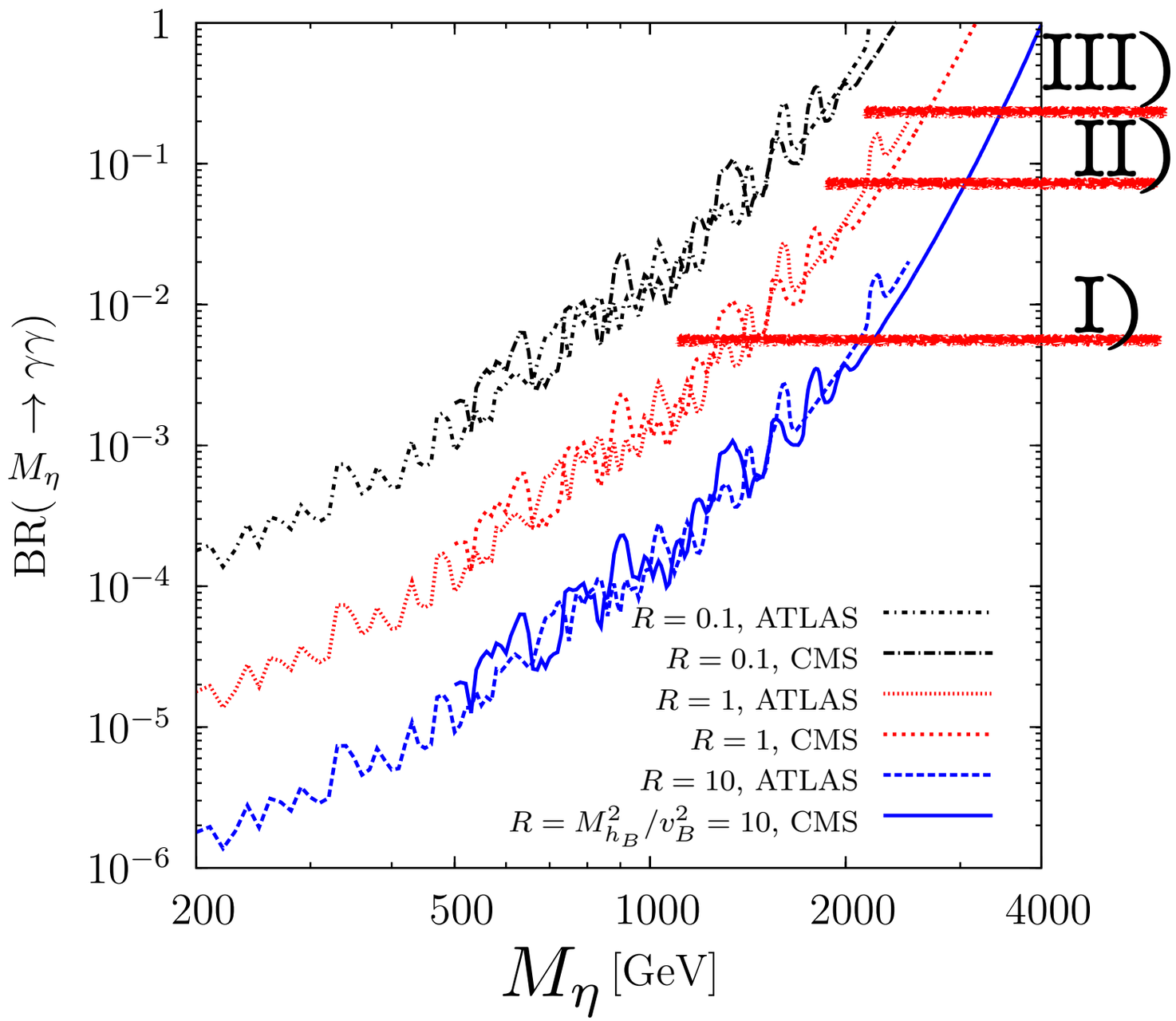
$$R \times \bar{R} = (1,1)_0 + (8,1)_0$$

spin-0 resonance
pseudo scalar, color singlet

$$\Gamma(\eta \to gg) = \frac{8}{3} d_2 \alpha_s(M_Q)^2 \frac{|R_1(0)|^2}{M^2} = \frac{1}{6} d_2 \alpha_s(M_Q)^2 \left(\frac{4\alpha_s(M_Q)}{3} \right)^3 2 y_Q v_B$$

$$R = \frac{M_{h_B}^2}{v_B^2} \approx 1 \Rightarrow \Gamma(\eta \to gg) \approx \Gamma(h_B \to gg)$$

The precision channels: Model Independent



III)

II)

I)

Photon Branching:

Scenario I) 0.5 %

Limit about 1.4 TeV

$v_B > 700$ GeV

Scenario II) 8 %

Limit about 2.2 TeV

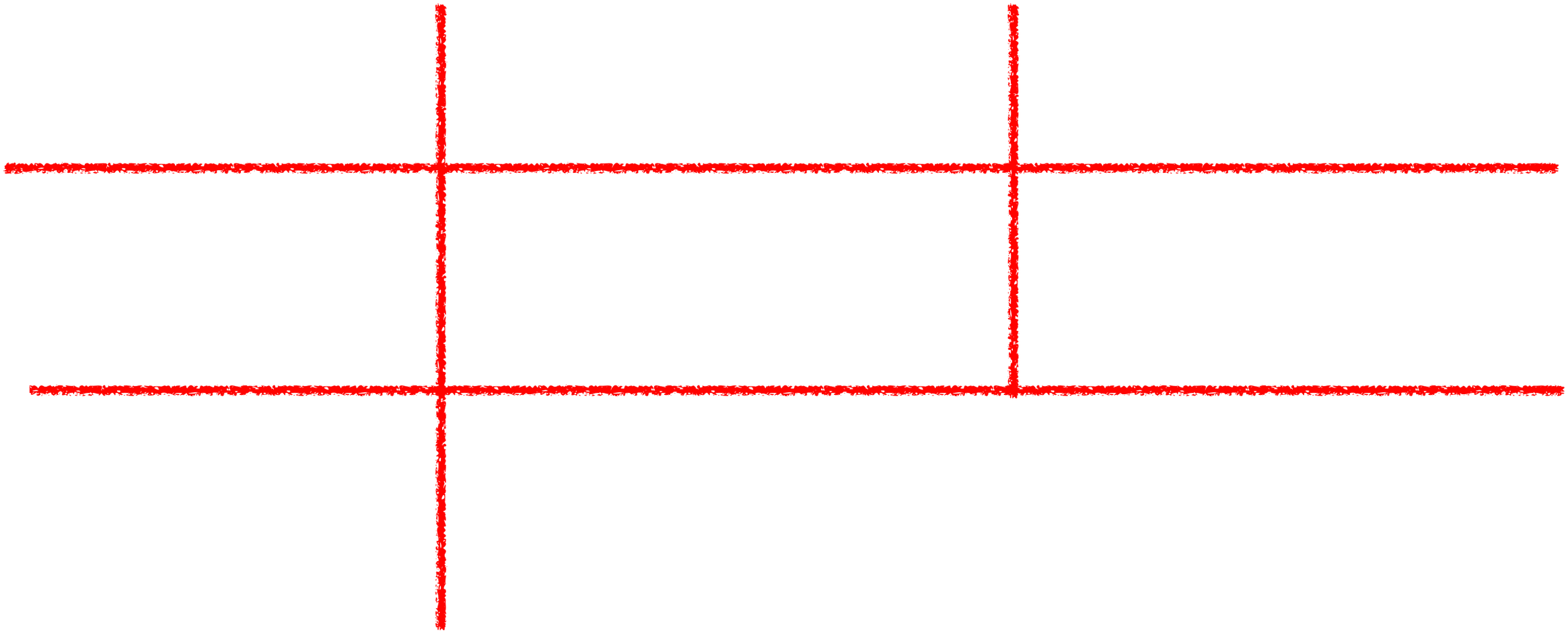
$v_B > 1.1$ TeV

Scenarion III) 20%

Limit about 2.6 TeV

$v_B > 1.3$ TeV

The Model Space



Heavy Z_B : v_B > 3.4 TeV

The Model Space

Light Z_B:

Heavy Z_B : $v_B > 3.4$ TeV

The Model Space

Light Z_B:	Large Scalar Mixing	
$M_{HB} < 2\ M_Q$		

Heavy Z_B : $v_B > 3.4$ TeV

The Model Space

Light Z_B:	Large Scalar Mixing	
$M_{HB} < 2\ M_Q$	$v_B > 2$ TeV	

Heavy Z_B : $v_B > 3.4$ TeV

The Model Space

Light Z_B:	Large Scalar Mixing	Small Scalar Mixing
$M_{HB} < 2\ M_Q$	$v_B > 2$ TeV	

Heavy Z_B : $v_B > 3.4$ TeV

The Model Space

Light Z_B:	Large Scalar Mixing	Small Scalar Mixing
$M_{HB} < 2\ M_Q$	$v_B > 2$ TeV	I) $v_B > 1.0$ TeV II) $v_B > 2.3$ TeV III) $v_B > 3.0$ TeV

Heavy Z_B : $v_B > 3.4$ TeV

The Model Space

Light Z_B:	Large Scalar Mixing	Small Scalar Mixing
$M_{HB} < 2\ M_Q$	$v_B > 2$ TeV	I) $v_B > 1.0$ TeV II) $v_B > 2.3$ TeV III) $v_B > 3.0$ TeV
$M_{HB} > 2\ M_Q$		

Heavy Z_B : $v_B > 3.4$ TeV

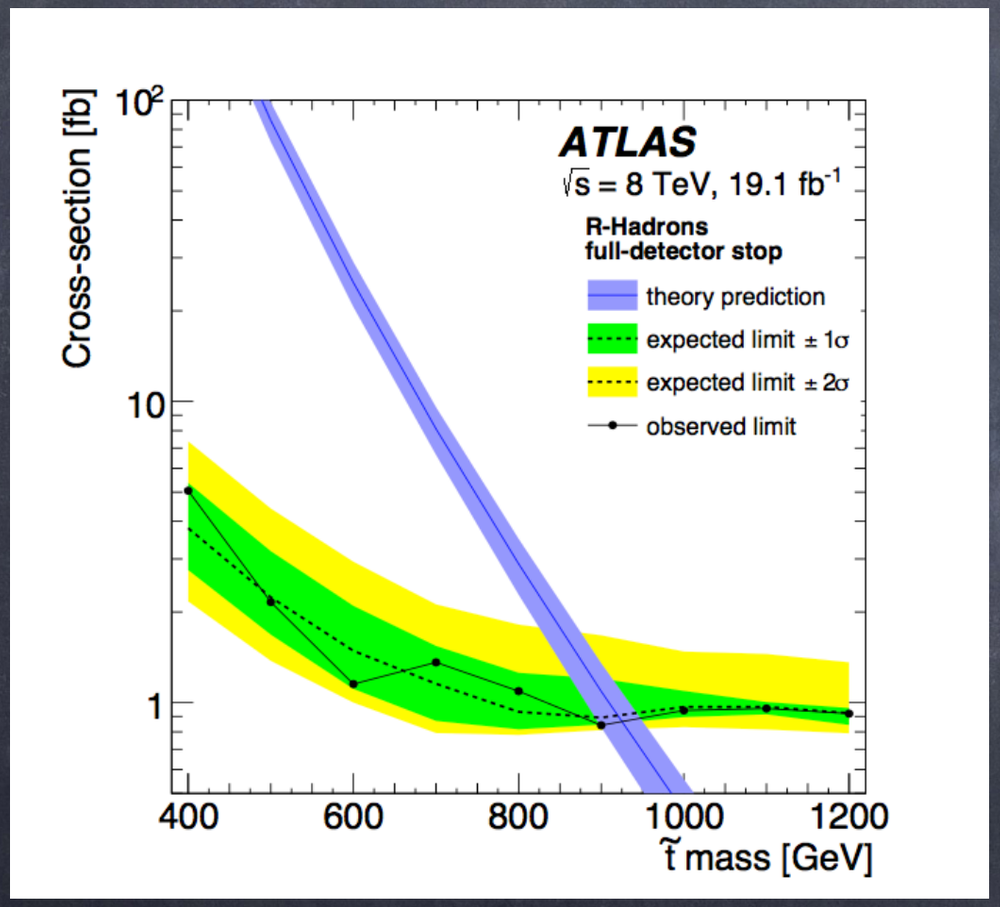
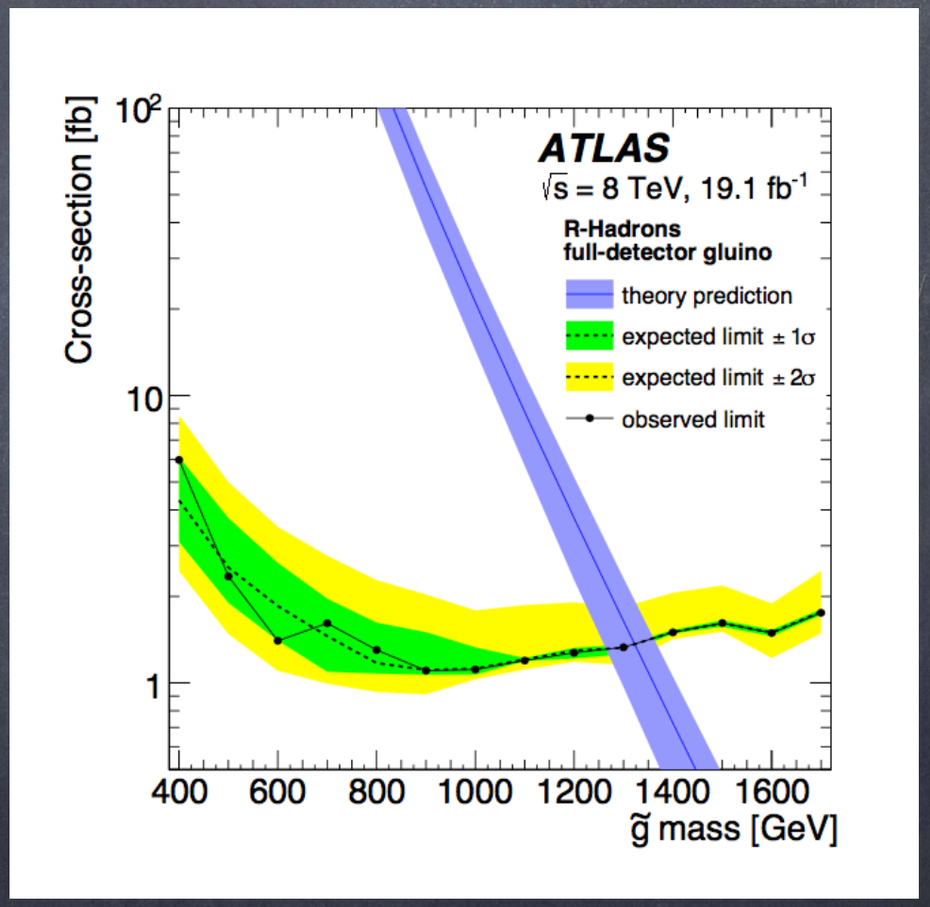
The Model Space

Light Z_B:	Large Scalar Mixing	Small Scalar Mixing
$M_{HB} < 2\ M_Q$	$v_B > 2$ TeV	I) $v_B > 1.0$ TeV II) $v_B > 2.3$ TeV III) $v_B > 3.0$ TeV
$M_{HB} > 2\ M_Q$		I) $v_B > 0.7$ TeV II) $v_B > 1.1$ TeV III) $v_B > 1.3$ TeV

Heavy Z_B : $v_B > 3.4$ TeV

Summary

- We study a model class with local Baryon Number
- Theoretically motivated by proton stability
- New Higgs is unavoidable
- Baryonic Higgs search gives the strongest bounds in the “nightmare” scenario ($g_B << 1$)
- Approach provides also bounds on new scalar meson resonances
- Discovery sets upper bound on symmetry breaking scale!

Thank you!

Stable Charged Particles