1 TopBESS unitarity limits expressed via b_L, b_R, g''

I will study unitarity limits in the following scenarios:
Scenario 1) $p = 1$, $b_L = 0$ limit
Scenario 2) $p = 1$, $b_L = b_R = b$ limit
Scenario 3) $p = 0$, $b_L = 0$ limit

1.1 $\pi^+\pi^- \to \pi^+\pi^-$

To express unitarity limits directly in variables b_R, g'', we show allowed regions in these parameters in Fig. 1. All partial waves are included, evaluated at two different energies $\sqrt{s} = 1.0$ TeV and $\sqrt{s} = 2.5$ TeV and superimposed.

We get from here a limit on g'' valid for $|b_R| \geq 0.015$

$$g'' \quad \geq \quad 4, \tag{1}$$

which is not as strict as the low energy limit $g'' \geq 10$.

For $|b_R| \leq 0.015$ we can see an interesting structure which has its origin in the unitarity violation in the peak region ($\sqrt{s} = 1.0$ TeV) of a_1 partial wave. This unitarity violation extends for $b_R = 0$ to very large values of g'' and is a small one (see Fig.2a) and disappeares if one uses exact tree level ρ resonance widths calculated by CompHEP (Fig. 2b). Nevertheless, if we do not ignore this violation, we can display it also in variables b_L, b_R and thus place a lower limit on them. For $p = 0$ (the most conservative case as hinted by Fig.1f), $g'' = 10$ we get (Fig. 3)

$$|b_L| \quad \geq \quad 0.005, \tag{2}$$
$$|b_R| \quad \geq \quad 0.008 \tag{3}$$

1.2 $t\bar{t} \to t\bar{t}$

To express unitarity limits directly in variables b_L, b_R, we show allowed regions in these parameters for $\sqrt{s} = 2.5$ TeV in Figs. 4a,b. We get from here

$$\begin{aligned} |b_L, b_R| \quad &\leq \quad 1.4 \\ |b_L, b_R| \quad &\leq \quad 0.15 \end{aligned} \tag{4}$$

for $g'' = 10$ and $g'' = 100$, respectively.

1.3 $t\bar{b} \to t\bar{b}$

To express unitarity limits directly in variables b_L, b_R, we show allowed regions in these parameters for $\sqrt{s} = 2.5$ TeV in Figs. 5a,b for $g'' = 10$ and $g'' = 100$, respectively. These limits are not stricter than the limits of Eq. 4.

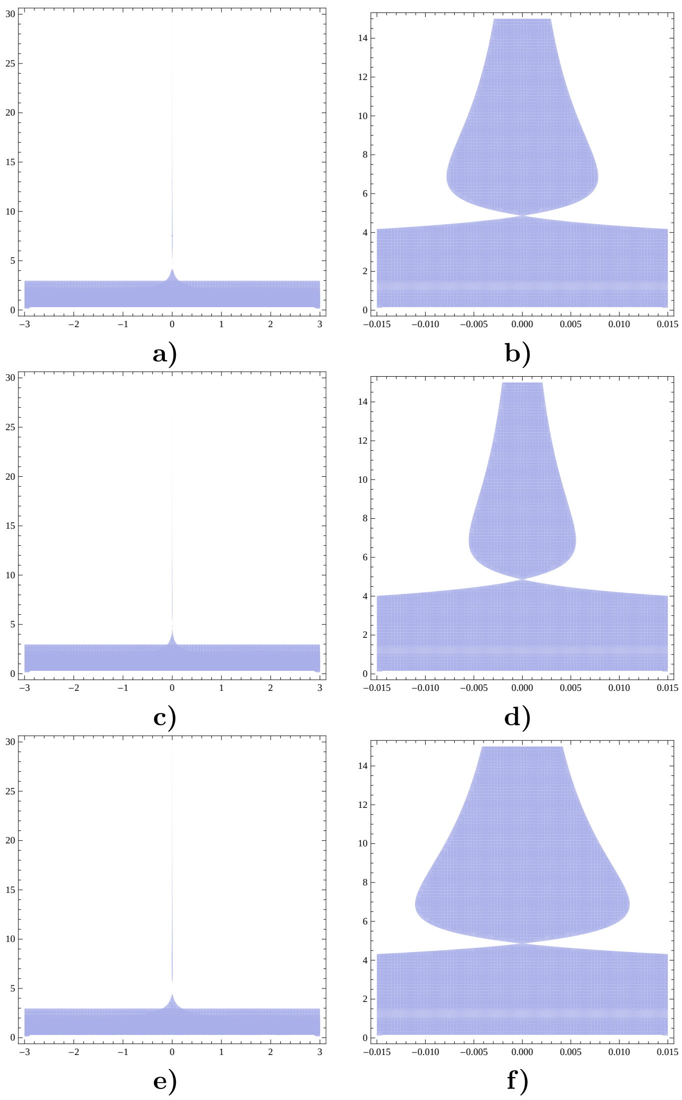
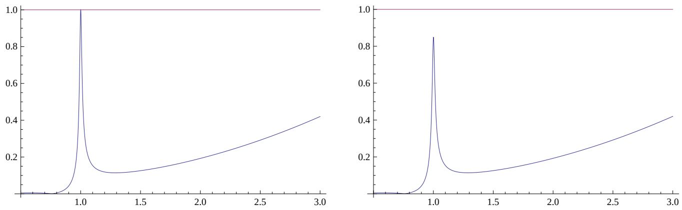


Figure 1: $\pi^+\pi^- \to \pi^+\pi^-$: Allowed regions (white) in the b_R (horizontal axis) vs g'' (vertical axis) parametric space **a),b)** Scenario 1, **c),d)** Scenario 2, **e),f)** Scenario 3. Figs. **a,c,e** represent a total view, Figs. **b,d,f** a close-up view of the small b_R region. All partial waves are included and superimposed. $M_{V^0} = 1$ TeV. Unitarity is violated in the 'blue' area.



a) **b)**

Figure 2: $\pi^+\pi^- \to \pi^+\pi^-$: $|a_1|$ partial wave (vertical axis) as a function of $\sqrt{s}$ (horizontal axis) for $b_L = b_R = 0, g'' = 10, M_{V^0} = 1$ TeV. **a)** approximate widths **b)** exact tree-level widths

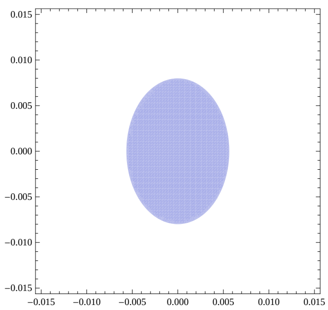
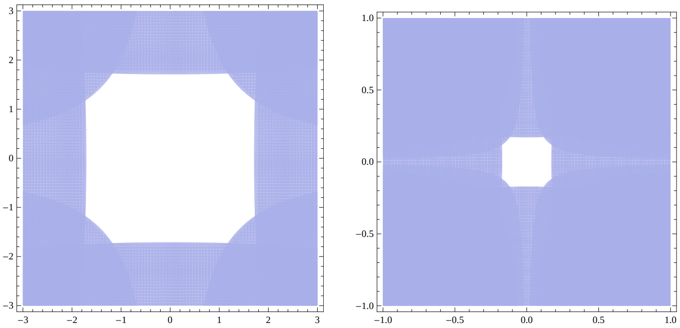
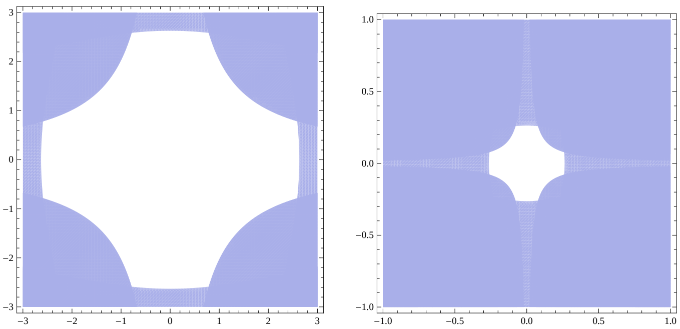


Figure 3: a_1 partial wave: allowed regions (white) in the b_L (horizontal axis) vs b_R (vertical axis) parametric space, $p = 0$, $g'' = 10$. $M_{V^0} = 1$ TeV. Unitarity is very slightly violated in the 'blue' area.



a) **b)**

Figure 4: $t\bar{t} \to t\bar{t}$: Allowed regions (white) in the b_L (horizontal axis) vs b_R (vertical axis) parametric space for **a)** $g'' = 10$ and **b)** $g'' = 100$. All partial waves are included and superimposed. $M_{V^0} = 1$ TeV. Unitarity is violated in the 'blue' area.



a) **b)**

Figure 5: $t\bar{b} \to t\bar{b}$: Allowed regions (white) in the b_L (horizontal axis) vs b_R (vertical axis) parametric space for **a)** $g'' = 10$ and **b)** $g'' = 100$. All partial waves are included and superimposed. $M_{V^0} = M_{V^+} = 1$ TeV. Unitarity is violated in the 'blue' area.