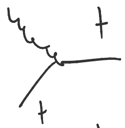
Discussion Session #3, December 10, 2020

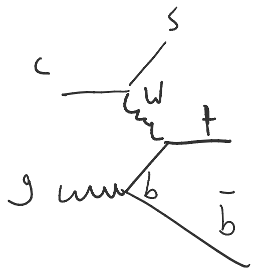
Thursday, December 10, 2020 2:16 PM

Dominant graphs for any SM process @ LHC

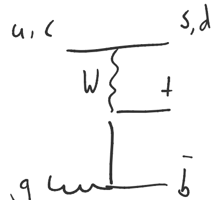
1.) single top+X (t-channel vs. s-channel)



no top in proton PDF ; W+b must come from $g, u, d, c, s, \bar{u}, \bar{d}, \bar{c}, \bar{s}$ PDFs

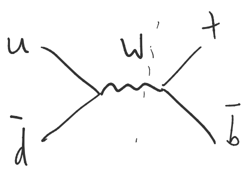


$\Rightarrow$



single-top, t-channel

s-channel ;



suppressed compared to t-channel

gluon PDF vs. $\bar{d}$ PDF

W decay to $l\nu$, $u\bar{d}$, $c\bar{s}$, ($t\bar{b}$?)

Kinematically suppressed

$\sigma\left(pp \to W^{(*)}\right)$ – on-shell vs. virtual

$W \to f_1 f_2$

$$\frac{1}{s - m_W^2} \qquad \frac{1}{s - m_W^2 + i m_W \Gamma_W}$$

$m_W \sim 80.4$ GeV

$\Gamma_W \sim 2$ GeV $\to 50\times\ \Gamma_W$ away.

$m_t \sim 173$ GeV

Distinguishing s-channel vs. t-channel

veto additional jets for isolating s-channel

after identifying $t + b$, no more jets in event.

Why no 7 TeV measurement of triple boson production?

$\mathcal{L}^{int}_{7 TeV} = 5\ fb^{-1}$

$\sigma_{VVV,\ t\bar{t}V} \sim 0.1 - 1$ pb $\Rightarrow$ Nevents ~ 1000, before applying cuts + branching

Consider $t\bar{t}Z$: $Z \to \underline{q\bar{q}}$ (70%), $\nu\nu$ (20%), $\tau\tau$ (3%), $ee + \mu\mu$ (6%)

Two universal remarks about quark final states:

$ee + \mu\mu$ (6%)

Two universal remarks about quark final states:

① Bad energy resolution, much less preferred to reconstruct a resonance

② Always contaminated by additional ISR / FSR gluon emission.

$Br(Z \to e^+e^- \text{ or } \mu^+\mu^-) \sim 6\%$

$\Rightarrow$ $\underline{N_{events} \sim 60}$ in the $Z \to e^+e^- / \mu^+\mu^-$ decay

Apply $B(t \to bW) \sim 100\%$, $B(W \to \ell\nu) \sim 2/9$

$N_{events} \sim \underline{12}$ for $5\ fb^{-1}$ at $\sqrt{s} = 7$ TeV

$\underline{1200}$ for $500\ fb^{-1}$

Higgs @ 7 TeV

Discovered in diphoton + 4ℓ.

Leading production gluon fusion

Sub-leading production VBF, VH, $t\bar{t}h$

$\sigma_{7TeV}(gg \to h) \sim 20$ pb

$\sigma_{7TeV}(pp \to hjj) \sim 2$ pb.

$m_h = 125$ GeV $Br(h \to b\bar{b}) \sim 60\%$

compared to $Br(h \to \gamma\gamma) \sim 0.228\%$ orders of magnitude difference

$Br(h \to ZZ^*) \sim 2.64\%$, but

$Br(h \to 4\ell) \sim 2 \cdot 10^{-4}$

---

b-tagging helps distinguish light flavor + gluon jets from b-quark initiated.

Any analysis: balance two aspects for maximum significance

$\sigma_{sig} \sim \dfrac{N_S}{\sqrt{N_B}}$, maximize N_S, minimize N_B.

Issue with $h \to b\bar{b}$ as discovery,

tree-level background $(\mathcal{O}(\alpha_s^2))$ for $pp \to b\bar{b}$.

$\sigma_{SM}(pp \to b\bar{b}) \sim 1\%$ of $\sigma_{pp}^{tot} \sim 1$ nb.

7 TeV vs. $\sigma_{SM}(pp \to h \to b\bar{b}) \sim 20\text{pb} \cdot 0.6 \sim 12$pb.

$\sigma_{sig} \sim \dfrac{12\text{ pb} \cdot L \cdot \epsilon_{sig}}{\ldots} = \dfrac{12 \cdot \text{pb}\ L\ \epsilon_{sig}}{\ldots}$

$$\sigma_{sig} \sim \frac{12\,pb \cdot L \cdot \epsilon_{sig}}{\sqrt{800\,nb\, L\, \epsilon_{back}}} = \frac{12 \cdot pb \quad L\ \epsilon_{sig}}{\sqrt{8 \cdot 10^5\, pb \cdot L\ \epsilon_{back}}}$$

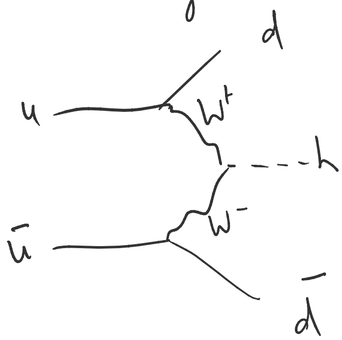
$$\sigma_{sig} = 0.05 \cdot \sqrt{L} \cdot \frac{\epsilon_{sig}}{\sqrt{\epsilon_{back}}}$$

$\sqrt{80000} \sim \sqrt{81} \cdot \sqrt{1000} \sim 9 \cdot 30 \sim 270$

$\frac{12}{270} = \frac{4}{90}$

If $\epsilon_{sig} \sim \epsilon_{back} \Rightarrow \sigma_{sig} = 5$ for $L = 10^4\ pb^{-1}$
$= 10\ fb^{-1}$

Sub-leading VDF

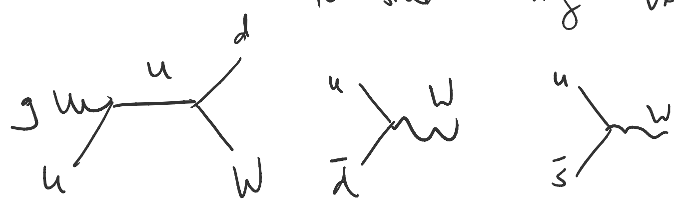


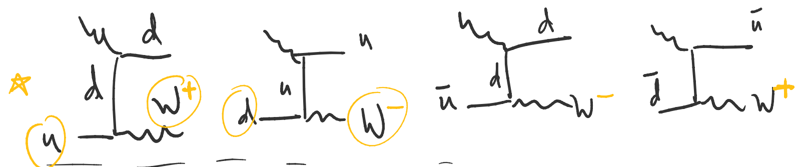
final state $h + jj$

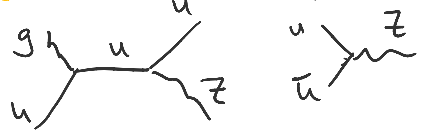
Roughly $\sigma_{VBF} \sim \frac{1}{10} \cdot \sigma_{gg}$ for any $\sqrt{s}$

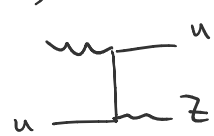
If σ_{gg} is observed with L_0, + all else is equal, then roughly need $100\ L_0$ to see σ_{VBF}.

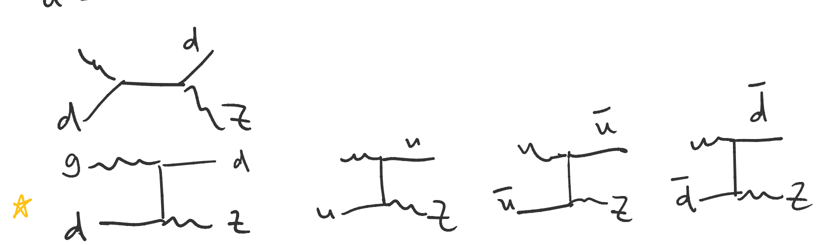
VBF efficiency $\epsilon^{sig}_{VBF} \sim 5\, \epsilon^{sig}_{gg}$, + backgrounds more under control $\Rightarrow$ 3-5x L_0 to start seeing VBF production.











$m_W < m_Z$ by ~ 10 GeV

$m_W < m_Z$

Inclusive vs. exclusive xsec.

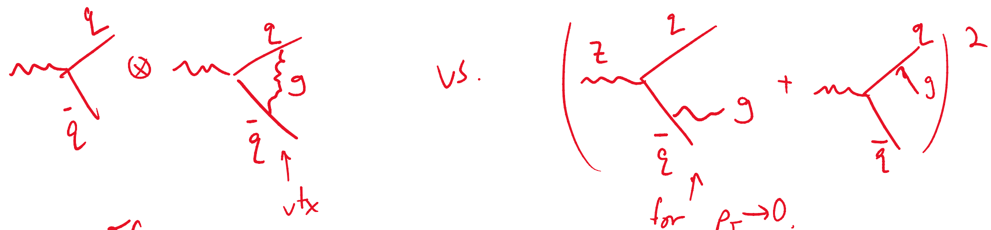
Z +jets ; $p_T(j) > 50$ GeV

↓ $Z+0$ jet ⇒ Z, no jet harder than 50 GeV

↑ $Z+1$ jet inclusive ⇒ Z, at least one jet harder than 50 GeV ~~but not a second~~

↑ ~~$Z+2$ jets inclusive ⇒ Z, at least two jets harder than 50 GeV~~

$Z \to q\bar{q}$, jet $= g$



If you evaluate sum $\sigma_{0\,jet} + \sigma_{1\,jet}$ to $\mathcal{O}(\alpha^2 \alpha_s)$ accuracy, then sum is <u>not</u> divergent.

Question!

How to get IR-safe cross sections with finite thresholds? What is behavior as threshold goes to 0? Where does log enhancement go?