

# Colored Resonances with Tao

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TaoFest  
5/14/2026



# Colored Resonances at LHC

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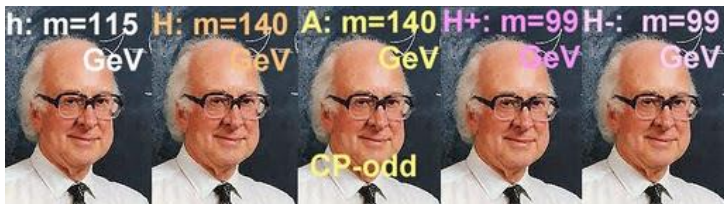
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Physics Department  
High Energy Phenomenology Group

Preliminary Examination

arXiv:1010.4309, with T. Han and I. Lewis  
arXiv:11\*\*.\*\*\*, with T. Han, I. Lewis, and T. Wang  
arXiv: [2306.00079](https://arxiv.org/abs/2306.00079) , with T. Han, I. Lewis, H.K. Liu, X. Wang

06/15/2011

# LHC Era?



*The Curtain Rises.....*


*..... For Particle Discoveries*




# COLORED RESONANCES CLASSIFICATION



# LHC Era

- Data Driven  Model
- Independent Simplest topology
- and largest rate Simplest
- topology: resonances Largest rate:
  - Strong interactions  
QCD machine

# LHC Era

- Data Driven  Model
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# Parton Luminosities

Hadronic production cross section:

$$\sigma(S) = \sum_{ij} \int \frac{dL_{ij}}{d\tau} d\tau \sigma(\hat{s})$$

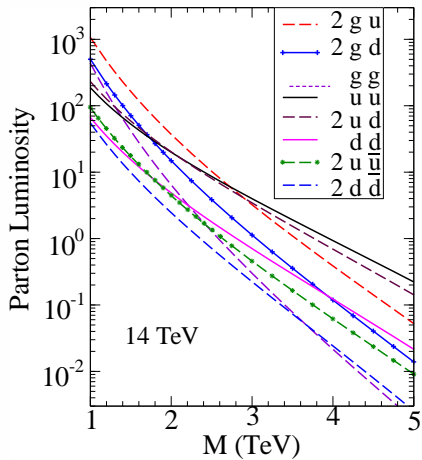
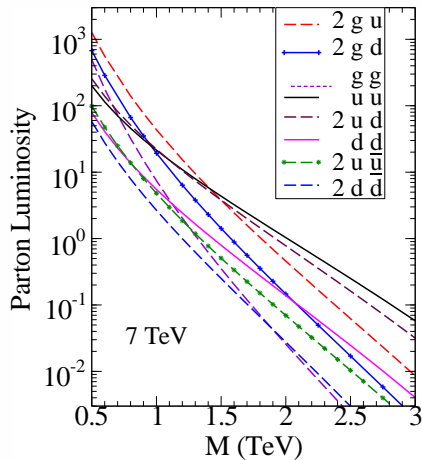
$\hat{s}$  is partonic c.m. energy squared

$S$  is hadronic c.m. energy squared

$$\tau = \hat{s}/S = x_1 x_2$$

$$\frac{dL_{ij}}{d\tau} = (f_i \otimes f_j) = \int_{\tau}^1 \int_{\tau/x_1}^1 f_i(x_1) f_j(x_2) \delta(x_1 x_2 - \tau)$$

# Parton Luminosities

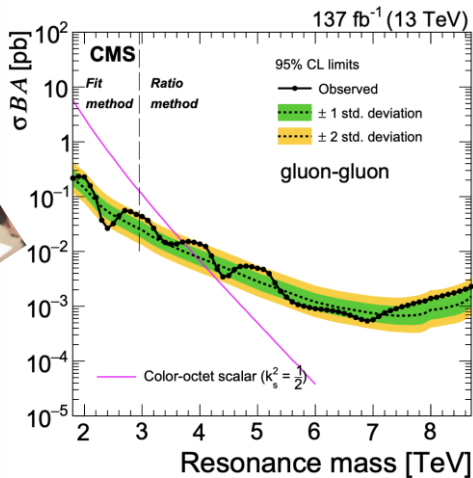
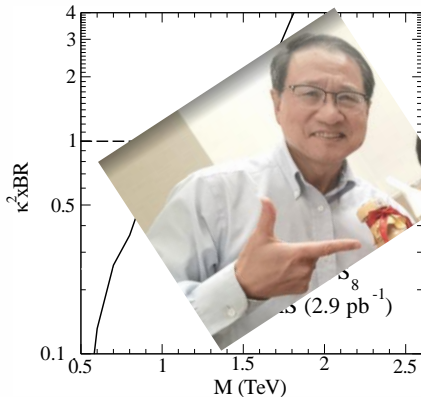


# Summary Table

**Table:** Summary for resonant particle names and their quantum numbers

Particle Names (leading coupling)	$J$	$SU(3)_C$	$ Q_e $	$B$	Related models
$E_{3,6}^{(\mu)} (uu)$	0(1)	<b>3</b> , $\bar{\mathbf{6}}$	$\frac{4}{3}$	$\frac{2}{3}$	scalar/vector diquarks
$D_{3,6}^{(\mu)} (ud)$	0(1)	<b>3</b> , $\bar{\mathbf{6}}$	$\frac{1}{3}$	$\frac{2}{3}$	scalar/vector diquarks; $\tilde{d}$
$U_{3,6}^{(\mu)} (dd)$	0(1)	<b>3</b> , $\bar{\mathbf{6}}$	$\frac{2}{3}$	$\frac{2}{3}$	scalar/vector diquarks; $\tilde{u}$
$U_{3,6}^{*(\mu)} (ug)$	$\frac{1}{2}(\frac{3}{2})$	<b>3</b> , $\bar{\mathbf{6}}$	$\frac{2}{3}$	$\frac{1}{3}$	excited $u$ ; quixes; stringy
$D_{3,6}^{*(\mu)} (dg)$	$\frac{1}{2}(\frac{3}{2})$	<b>3</b> , $\bar{\mathbf{6}}$	$\frac{1}{3}$	$\frac{1}{3}$	excited $d$ ; quixes; stringy
$S_8 (gg)$	0	<b>8</b> <sub>S</sub>	0	0	$\pi_{TC}$ , $\eta_{TC}$
$T_8 (gg)$	2	<b>8</b> <sub>S</sub>	0	0	stringy
$V_8 (u\bar{u}, d\bar{d})$	1	<b>8</b>	0	0	axigluon; $g_{KK}$ , $\rho_{TC}$ ; coloron
$V_8^\pm (u\bar{d})$	1	<b>8</b>	1	0	$\rho_{TC}^\pm$ ; coloron
$V_1 (u\bar{u})$	1	<b>1</b>	0	0	$Z'$

# bounds figures



# Dijet Resonances



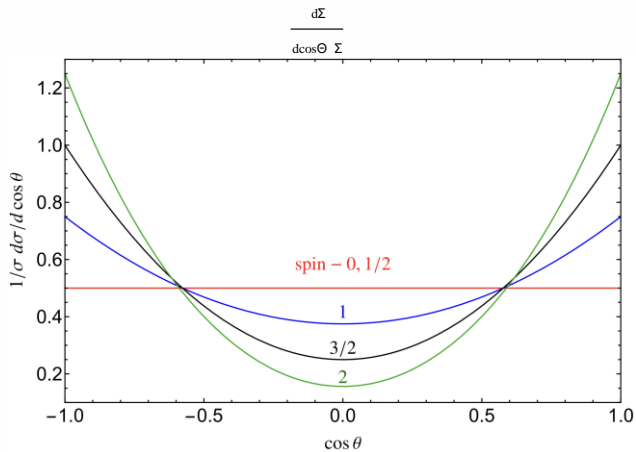
Zhen Liu (UW-Madison)



Colored

# Dijet Angular Distribution

- Helicity Amplitudes

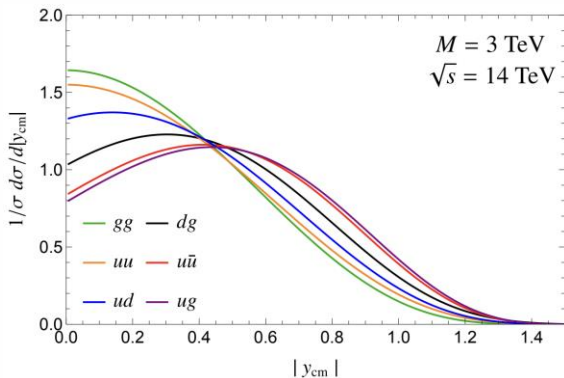


# Dijet Rapidity Distribution

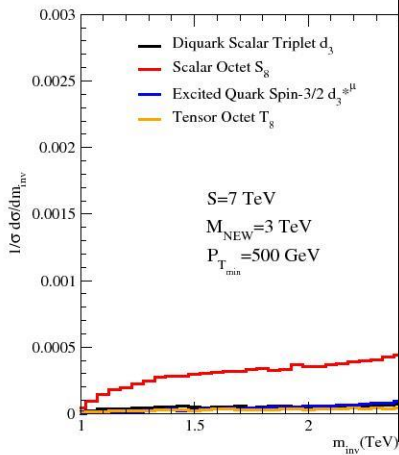
Events generating: FeynRules→UFO files→MadGraph5

The rapidity distribution of the whole system.

$$y = \frac{1}{2} \ln\left(\frac{x_1}{x_2}\right)$$



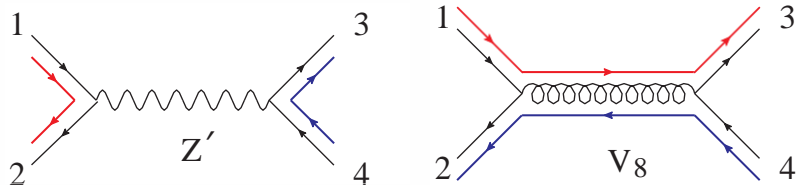
# Dijet Invariant Mass Distribution



# Color Flow and Hadronic Antenna

# Color Flow

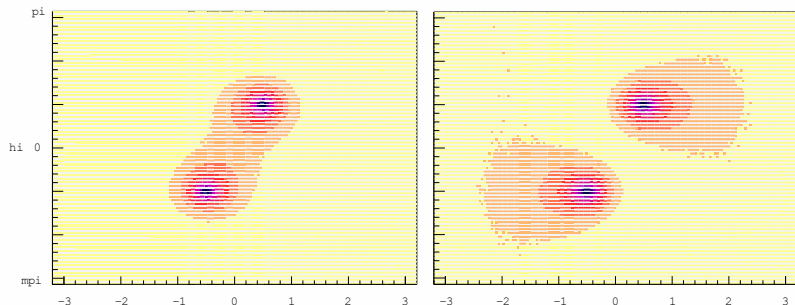
## Heuristic View



- Black lines are for Feynman diagrams
- Colored lines indicate the color flow

# Color Flow

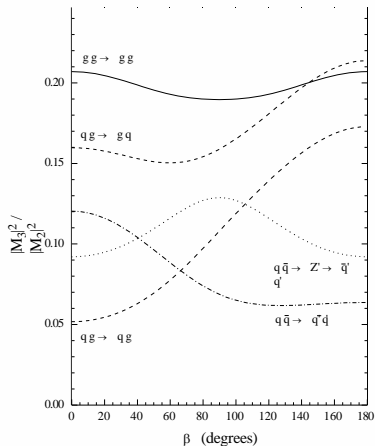
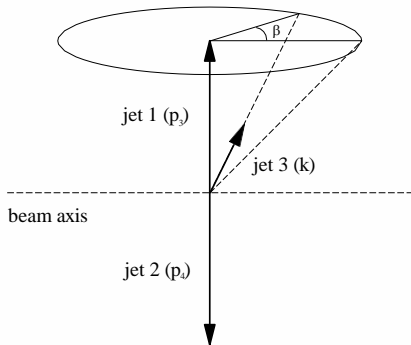
Jason Gallicchio and Matthew D. Schwartz, arxiv:1001.5027



**Figure:** Accumulated pT after showering a particular partonic phase space point 3 million times.

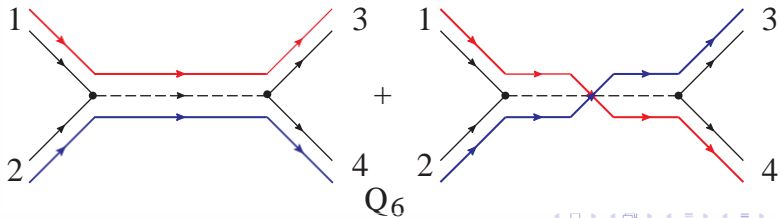
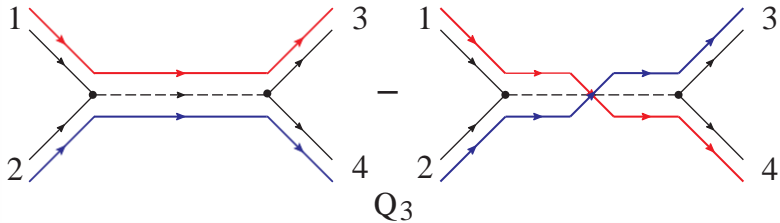
# Color Flow

John Ellis, Valery A. Khoze and W. James Stirling, arxiv:hep-th/9608486

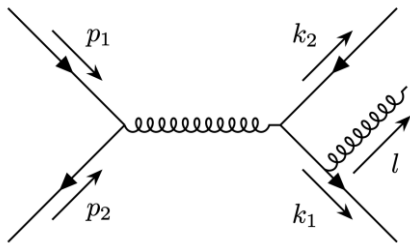


## Color Flow

## Sextet v.s. Triplet



## Interference Pattern

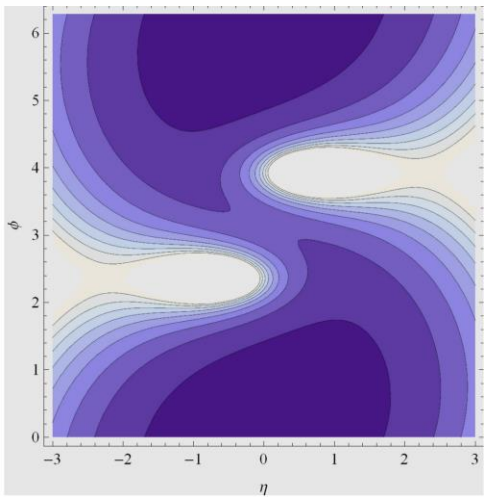
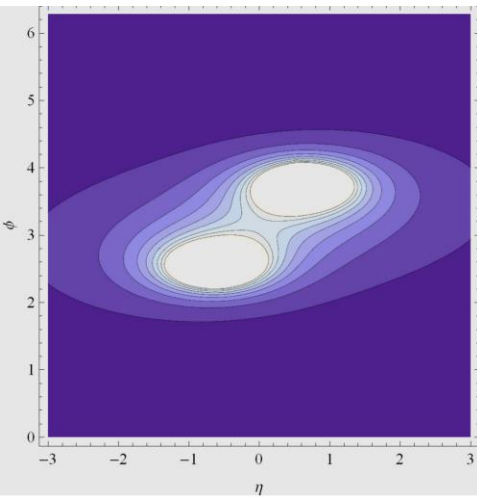


$$\mathcal{M}_{2 \rightarrow 3} \sim g_s \frac{\varepsilon(l) \cdot q}{l \cdot q} \mathcal{M}_{2 \rightarrow 2}$$

$$[k_i k_j] = \frac{k_i \cdot k_j}{l \cdot k_i l \cdot k_j}$$

$$\frac{|\mathcal{M}_{2 \rightarrow Q_3^* \rightarrow 3}|^2}{|\mathcal{M}_{2 \rightarrow Q_3^* \rightarrow 2}|^2} \propto g_s^2 \left\{ [p_1 k_1] + \frac{8}{9} ([p_2 p_1] + [k_2 k_1]) - \frac{1}{9} ([p_2 k_1] + [k_2 p_1]) + \frac{1}{81} [p_2 k_2] \right\}$$

$$\frac{|\mathcal{M}_{2 \rightarrow Q_6^* \rightarrow 3}|^2}{|\mathcal{M}_{2 \rightarrow Q_6^* \rightarrow 2}|^2} \propto g_s^2 \left\{ [p_1 k_1] + \frac{1}{3} ([p_2 k_1] + [k_2 p_1]) + \frac{4}{15} ([p_2 p_1] + [k_2 k_1]) + \frac{1}{9} [p_2 k_2] \right\}$$





## Interference Pattern Cut

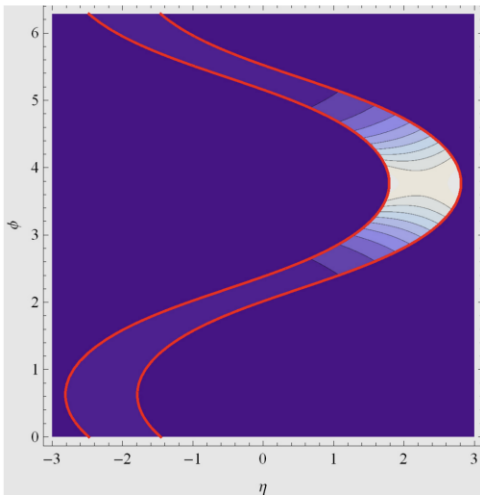
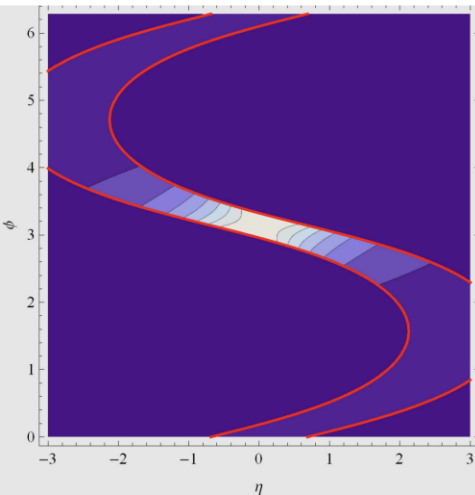
$$[k_i k_j] = \frac{k_i \cdot k_j}{l \cdot k_i l \cdot k_j}$$

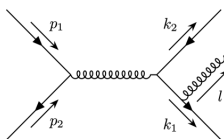
$$[p_A p_B] = \frac{p_A \cdot p_B}{p_A \cdot l - p_B \cdot l} \left( \frac{1}{p_B \cdot l} - \frac{1}{p_A \cdot l} \right)$$

$$\frac{p_A \cdot p_B}{|p_A \cdot l - p_B \cdot l|} \geq \frac{h_T}{l_T} \Rightarrow |p_A \cdot l - p_B \cdot l| \leq \frac{l_T}{h_T} p_A \cdot p_B$$

# Hadronic Interferometer

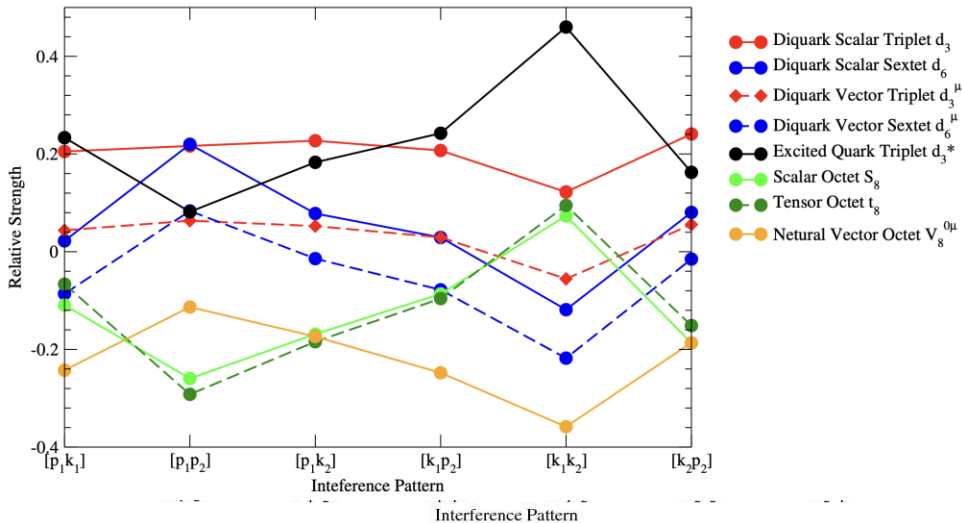
Cut



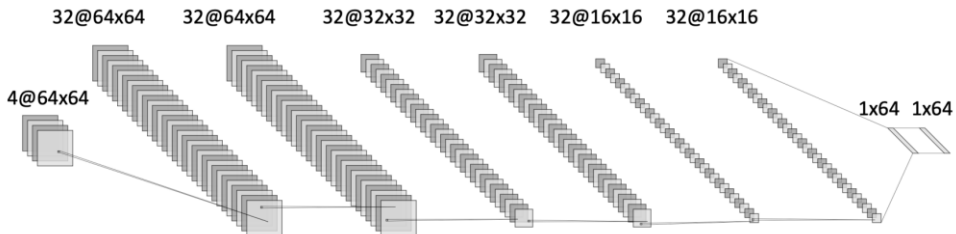


# Hadronic Interferometer

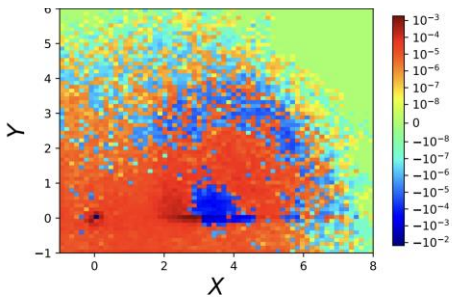
Result



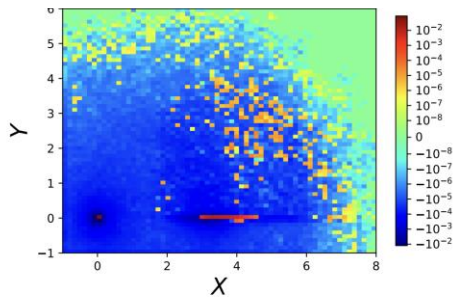
# New Era



Input    Convolution    Max-Pool    Convolution    Max-Pool    Convolution    Max-Pool

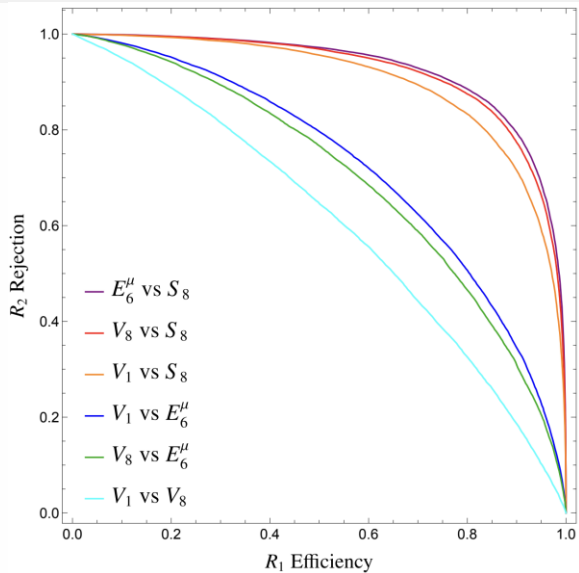


(a)  $V_1 - V_8$



(b)  $V_1 - S_8$

# New Era



Colored



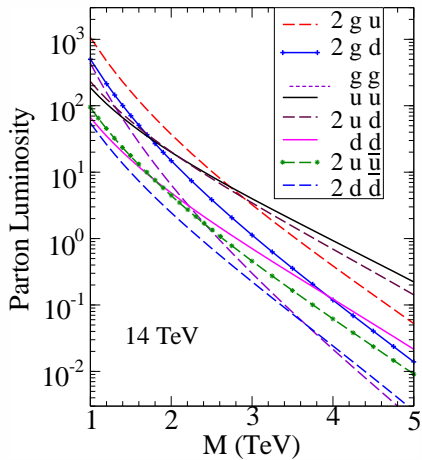
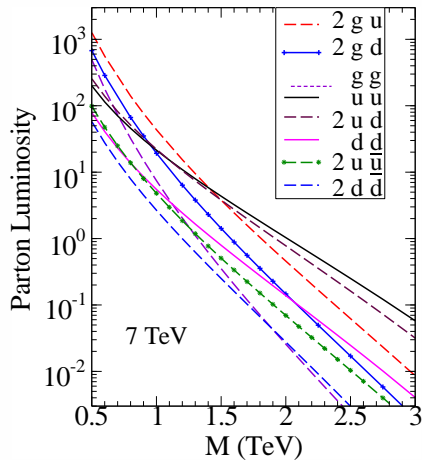
# Summary

- We performed a data-driven study for color resonances at the LHC
- We classified possible color resonances at LHC
- Bounds are put according to early LHC data
- Extract mass, spin information of possible colored resonances.
- Explored on how to get color structure of different resonances.

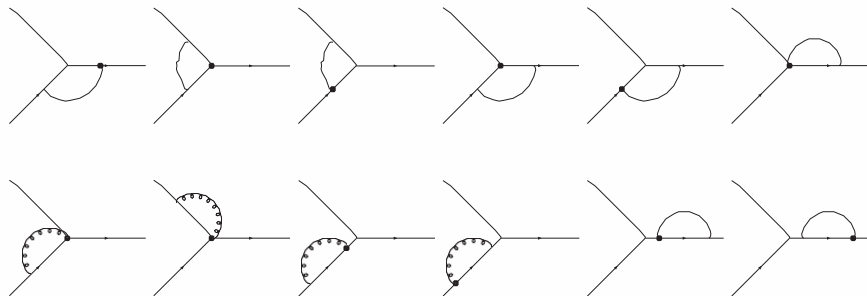


# Sextet Fermion NLO Calculation

# Parton Luminosities

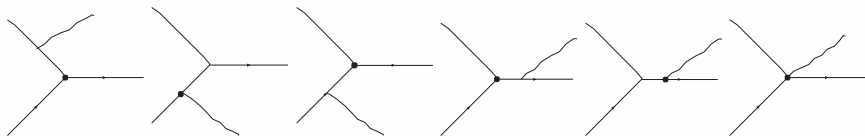


## Sextet Fermion NLO



- Dimensional regulation  $d = 4 - 2\epsilon$
- $\overline{MS}$  scheme
- UV divergences are canceled by renormalization

# Sextet Fermion NLO



- Soft divergences are canceled by real gluon emission
- Collinear divergences are canceled by PDF universal counter terms