

# Spin Measurements with Metastable Charged Particles

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Daniel Stolarski

Work in progress with  
Peter Graham, Kiel Howe,  
and Surjeet Rajendran





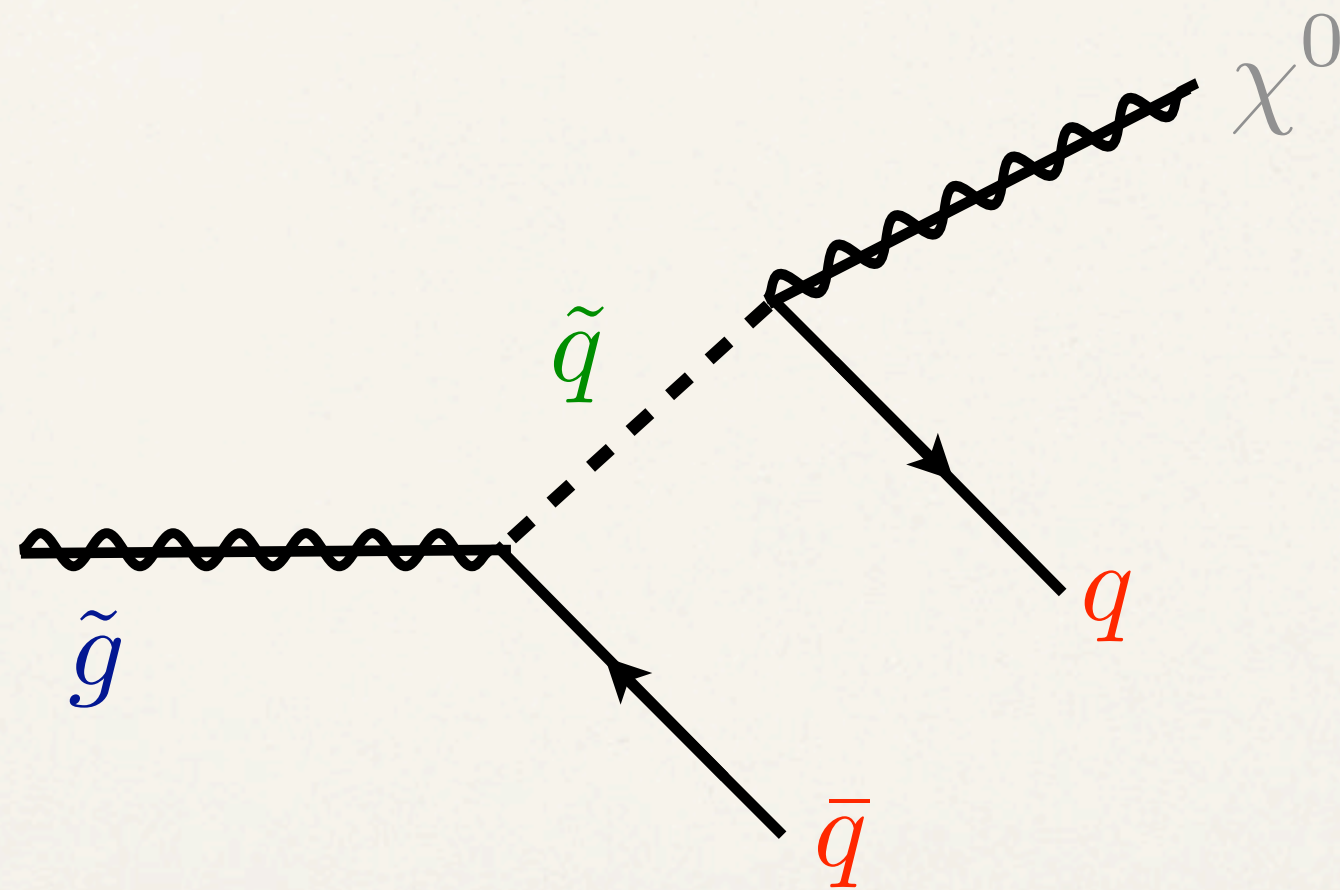
# Probing High Scale Physics

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- ✧ LHC era has started
- ✧ Can the LHC explore scales *above* the electroweak scale?
- ✧ Decays of long lived particles can (muon, proton)

# Color Octet Example

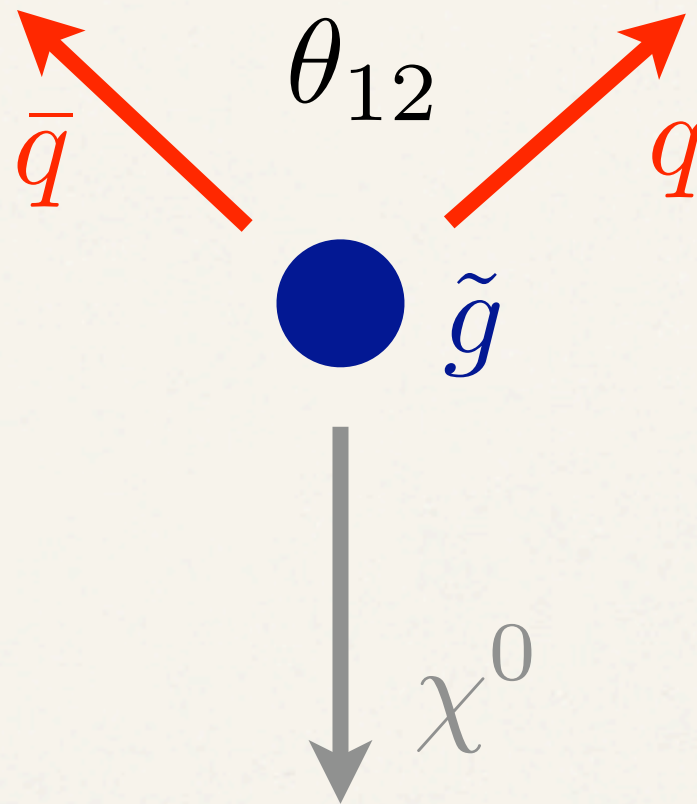
- ✧ Take 8 under color, neutral under E&M as example





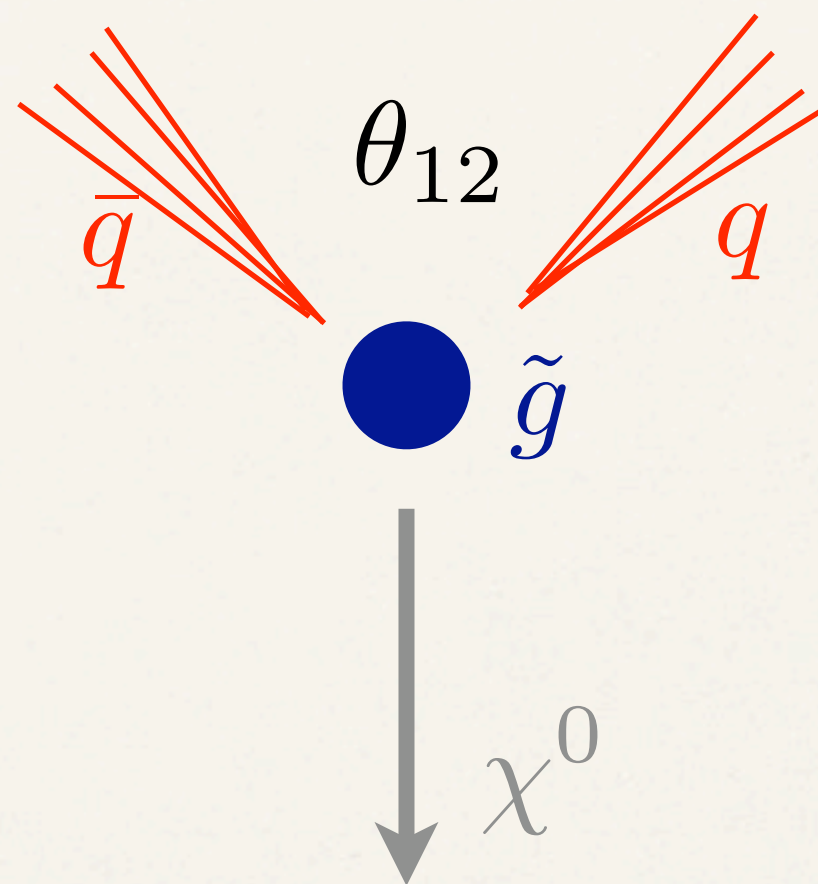
# Three Body Decay

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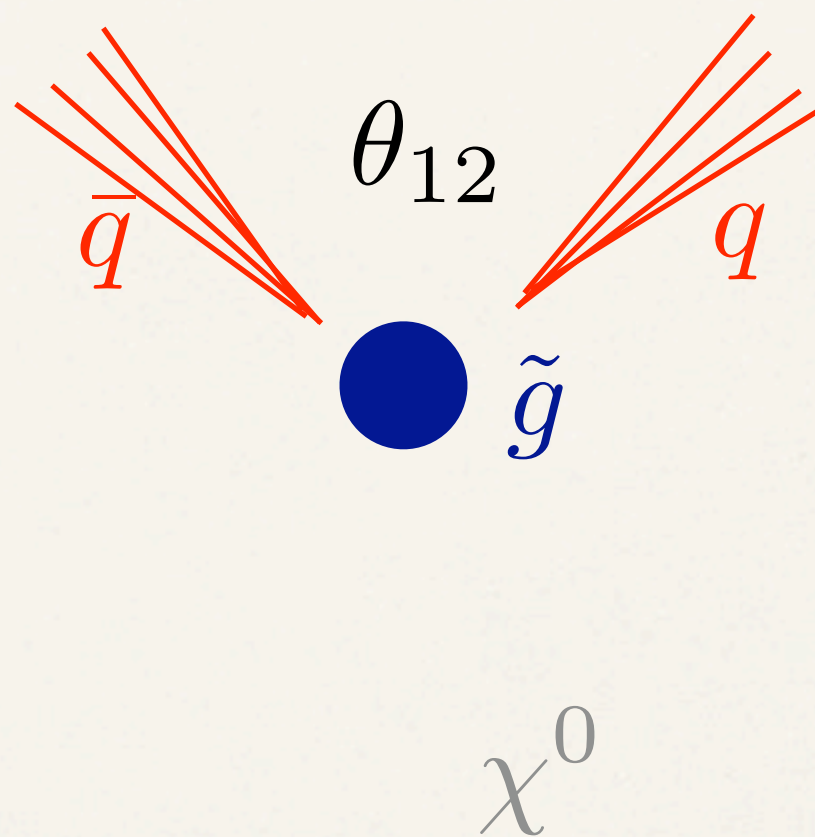
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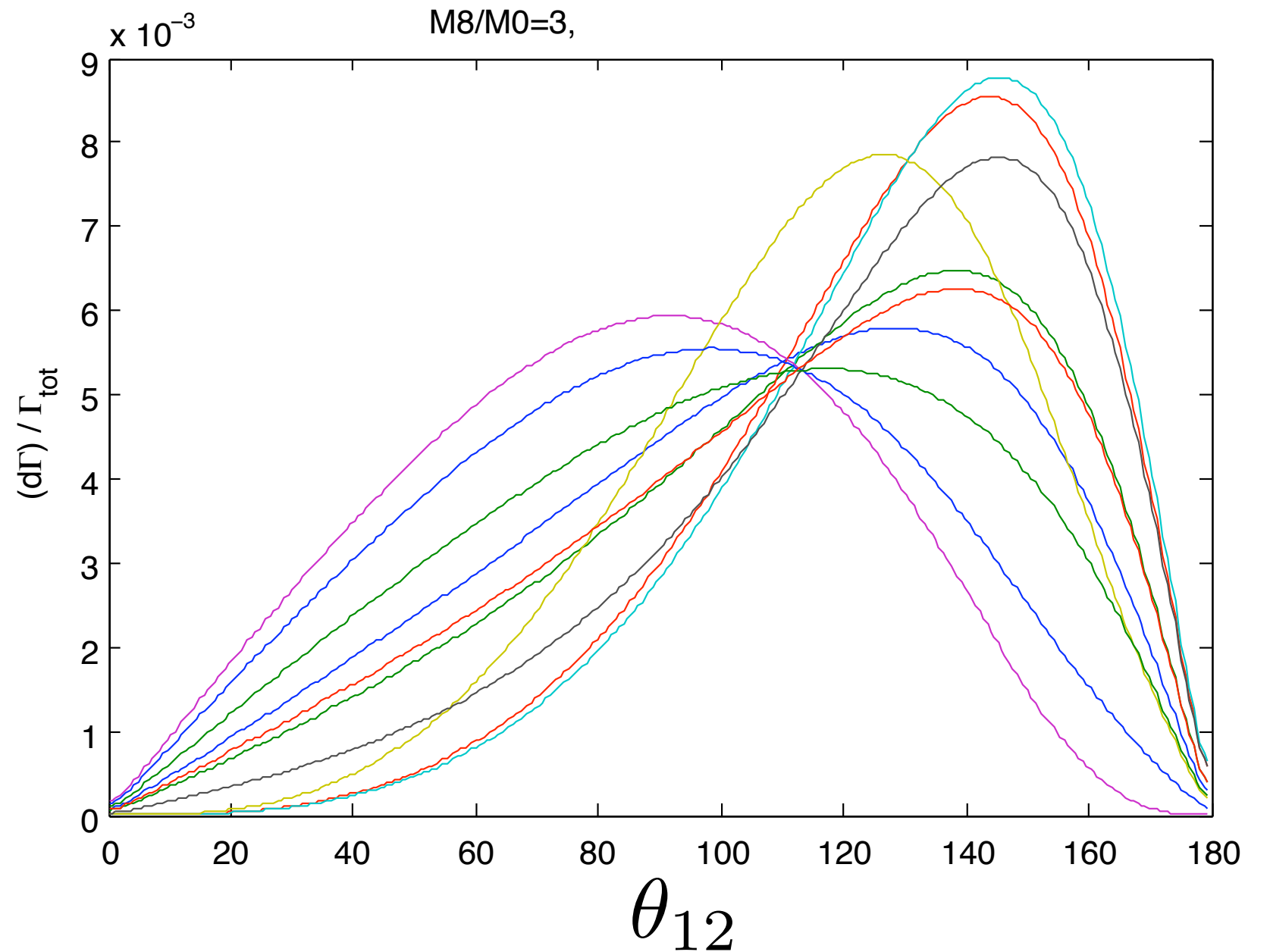
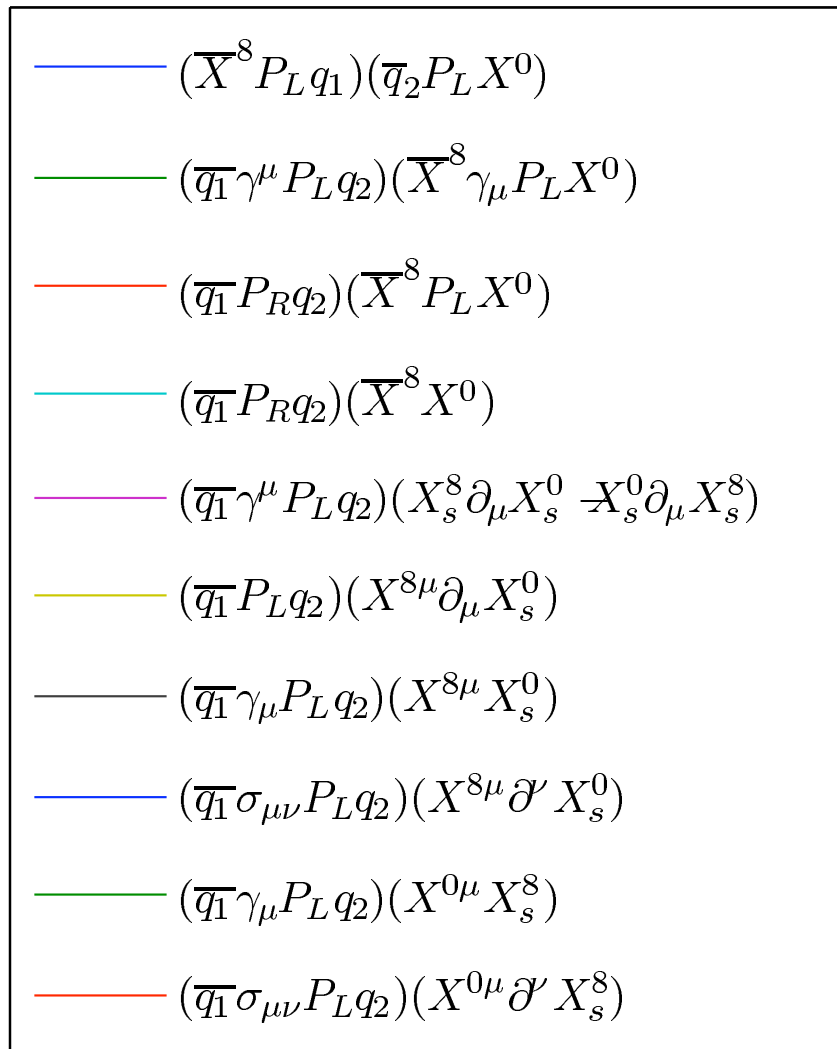


# Three Body Decay

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# Measuring Spin





# Possible Objections

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  - ❖ Can these events be seen experimentally?

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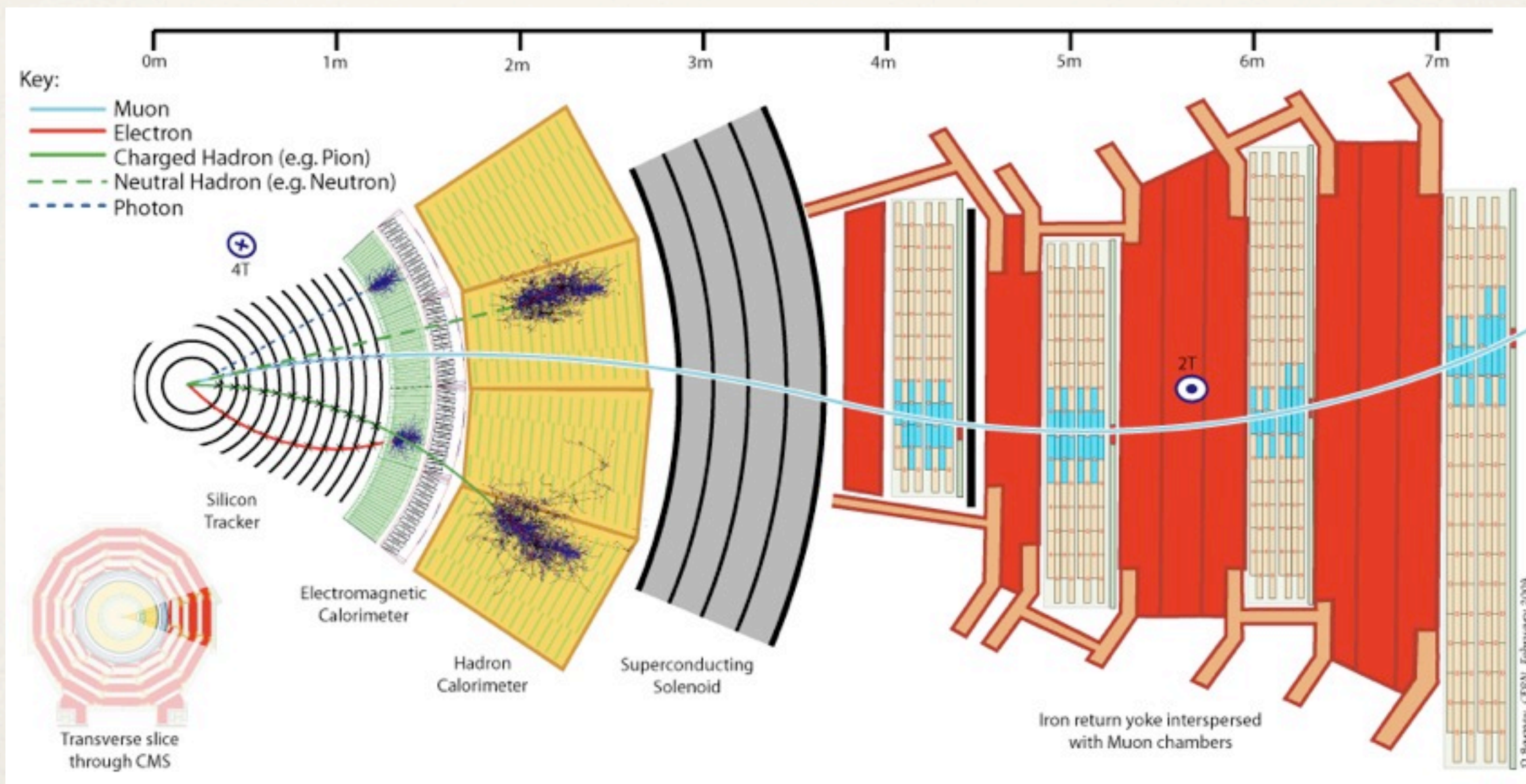
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- ✧ Particle is unpolarized, how do you measure spin?
- ✧ Are you just measuring properties of the hadron and not gluino?
- ✧ Are you a crazy theorist?
  - ✧ Can these events be seen experimentally?
  - ✧ Is it possible to measure angles in the a calorimeter?



# CMS and ATLAS

- ❖ Most useful particles will stop in HCAL

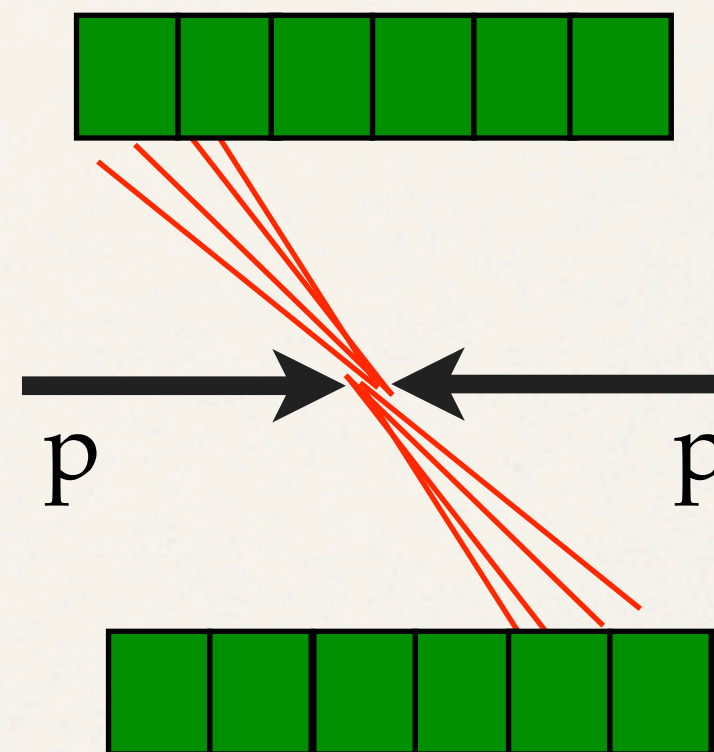




# CMS and ATLAS

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- ❖ Most useful particles will stop in HCAL
- ❖ Good transverse segmentation  
 $\Delta\eta \times \Delta\phi \sim 0.1 \times 0.1$

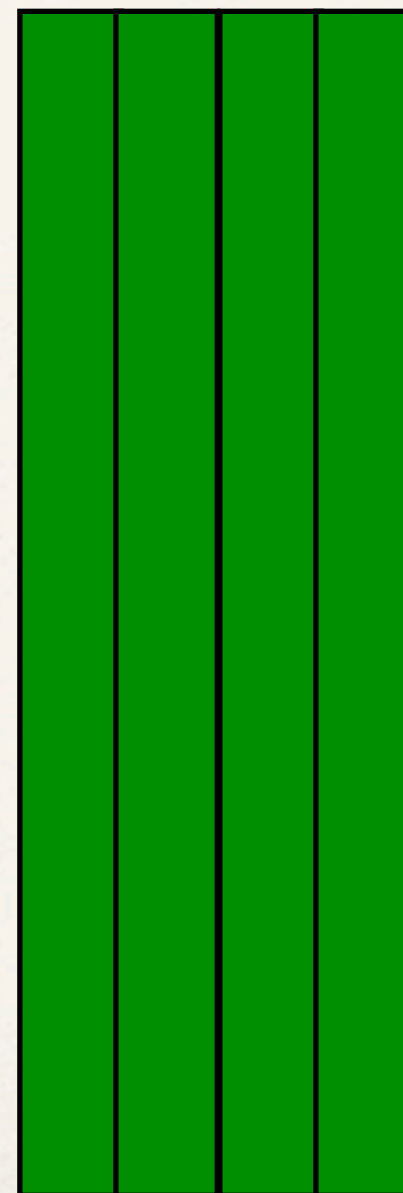




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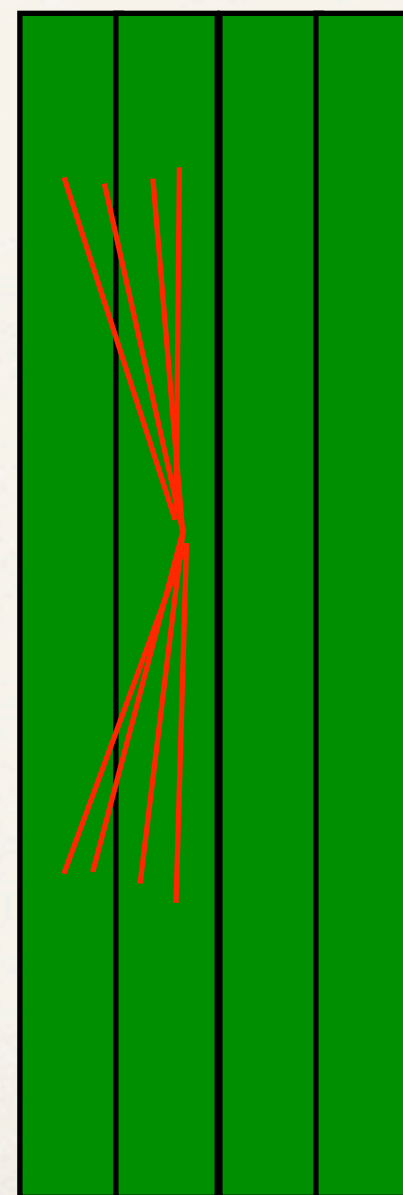
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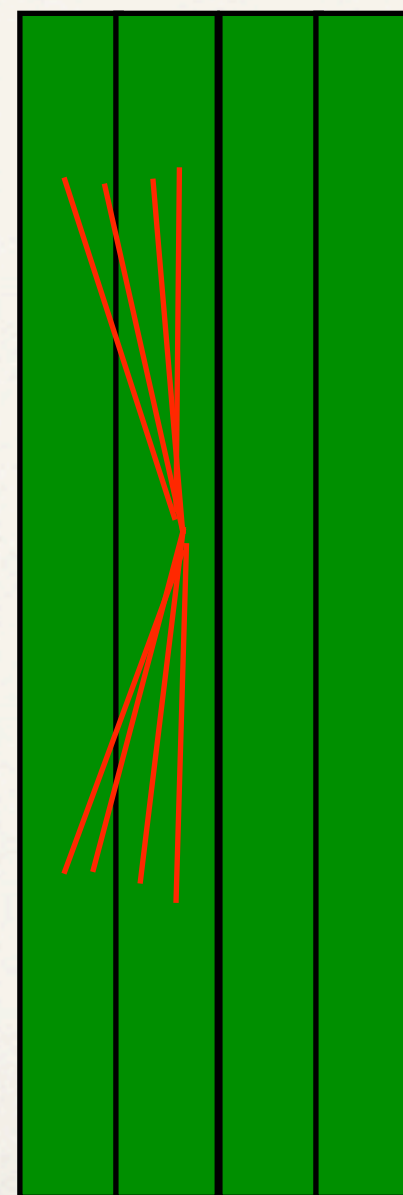




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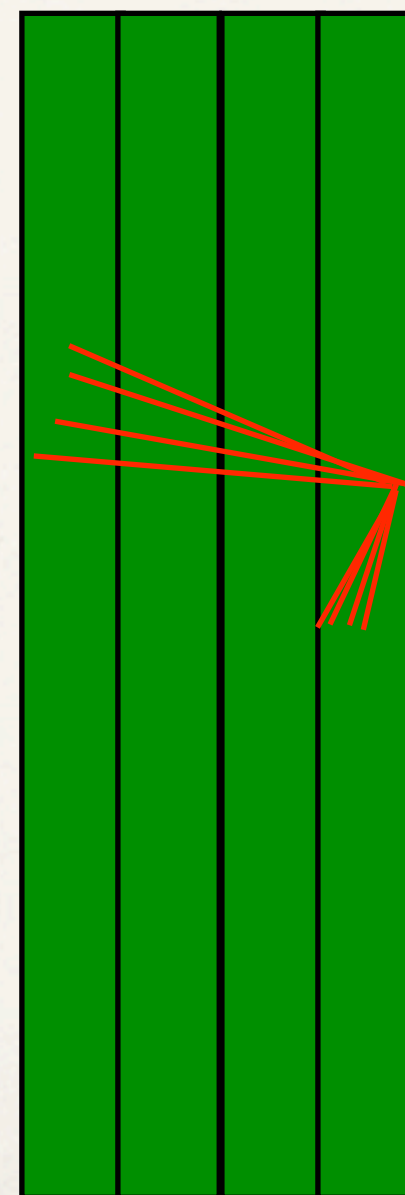
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- ❖ Look for decays in transverse plane



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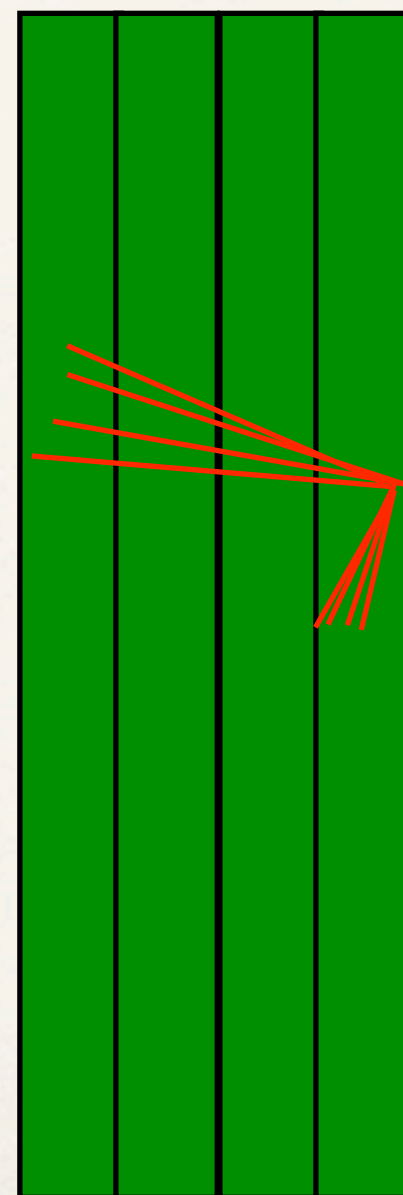


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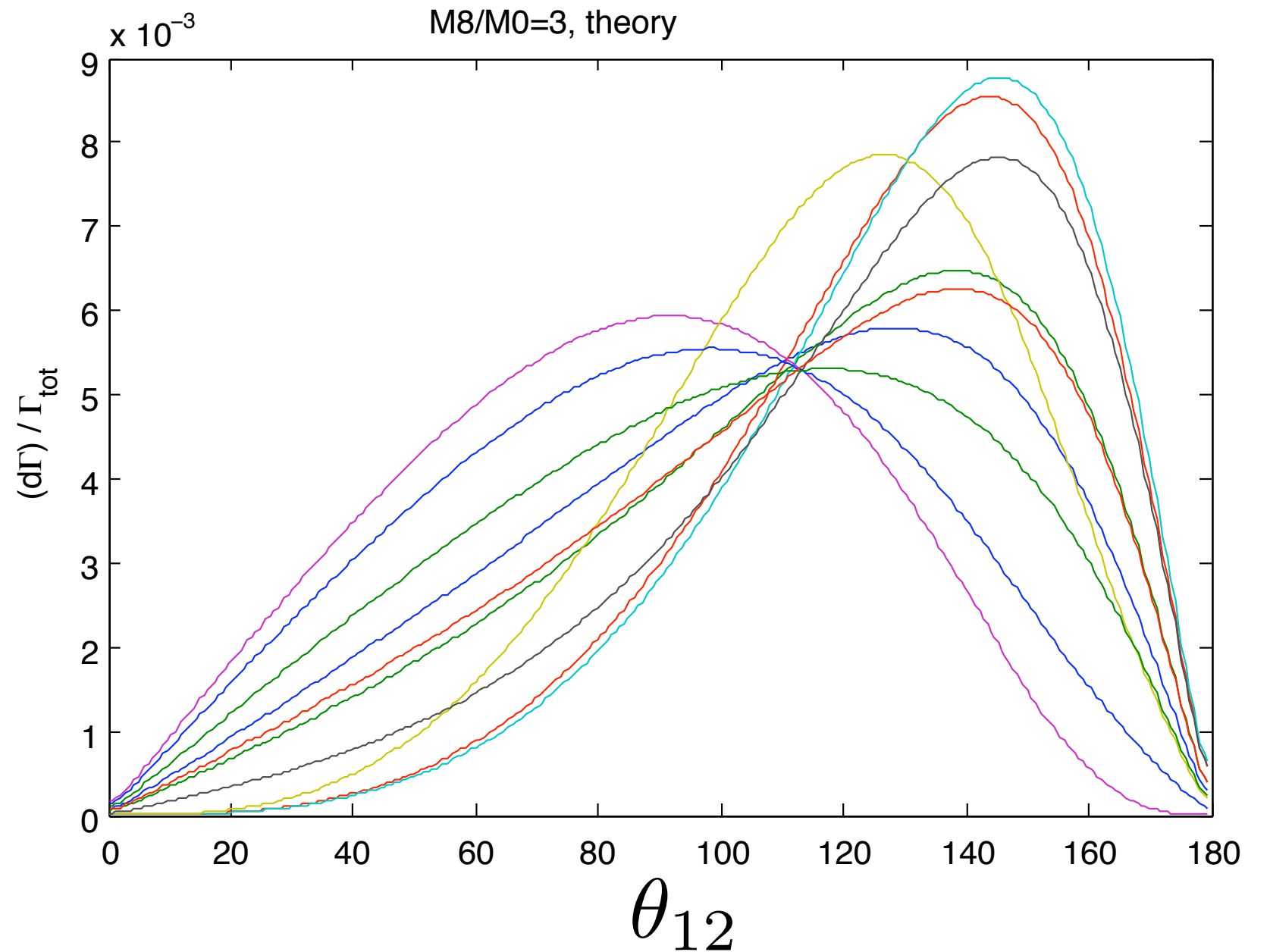
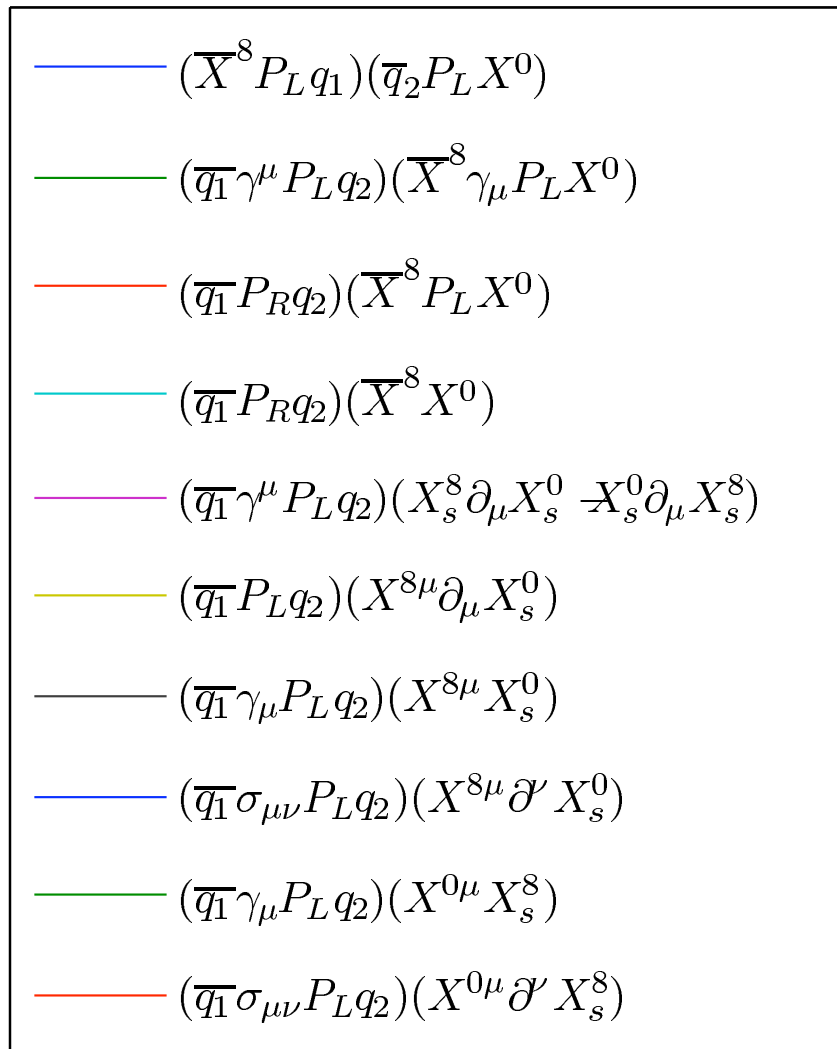
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$$\Delta\theta \sim 30^\circ$$

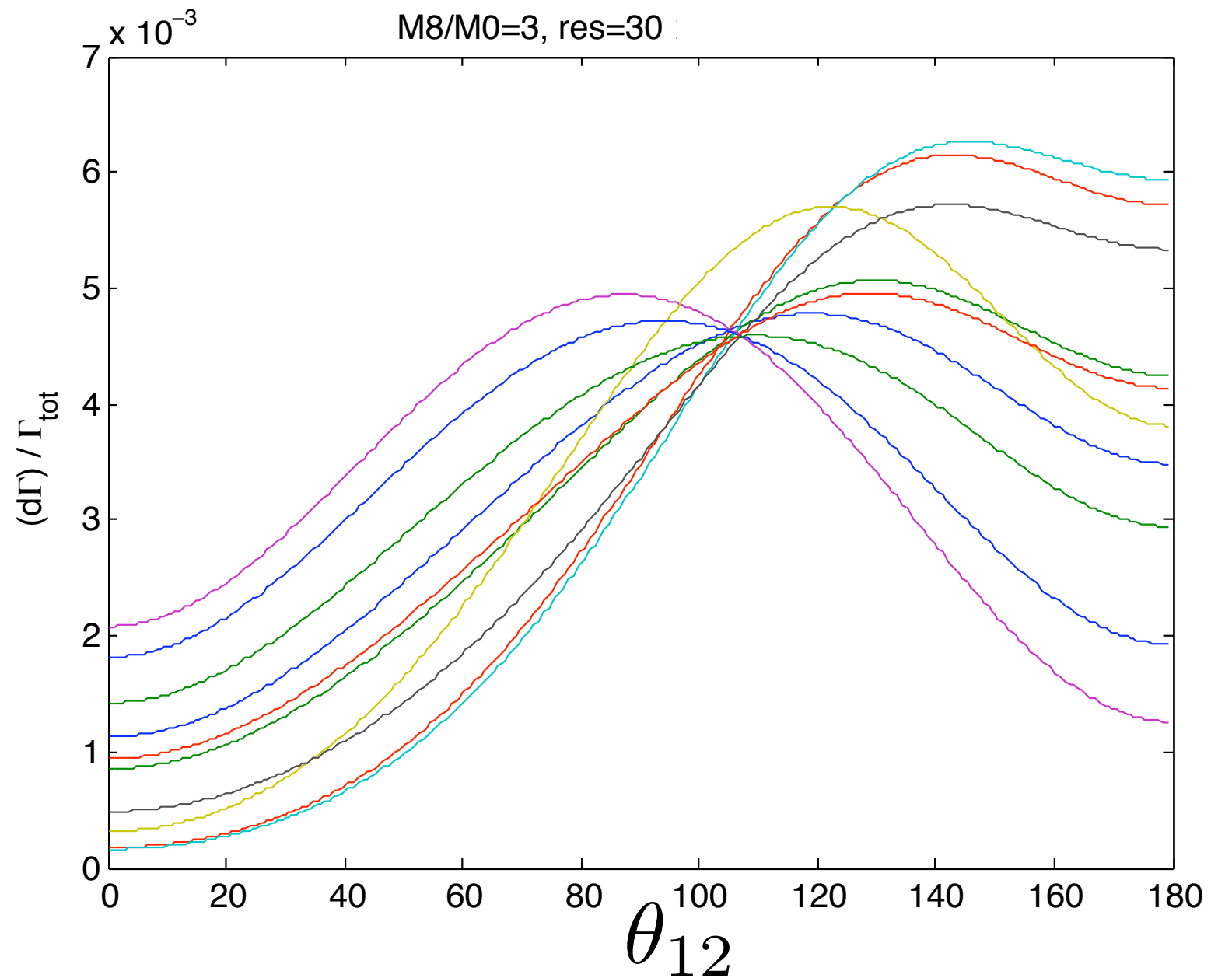
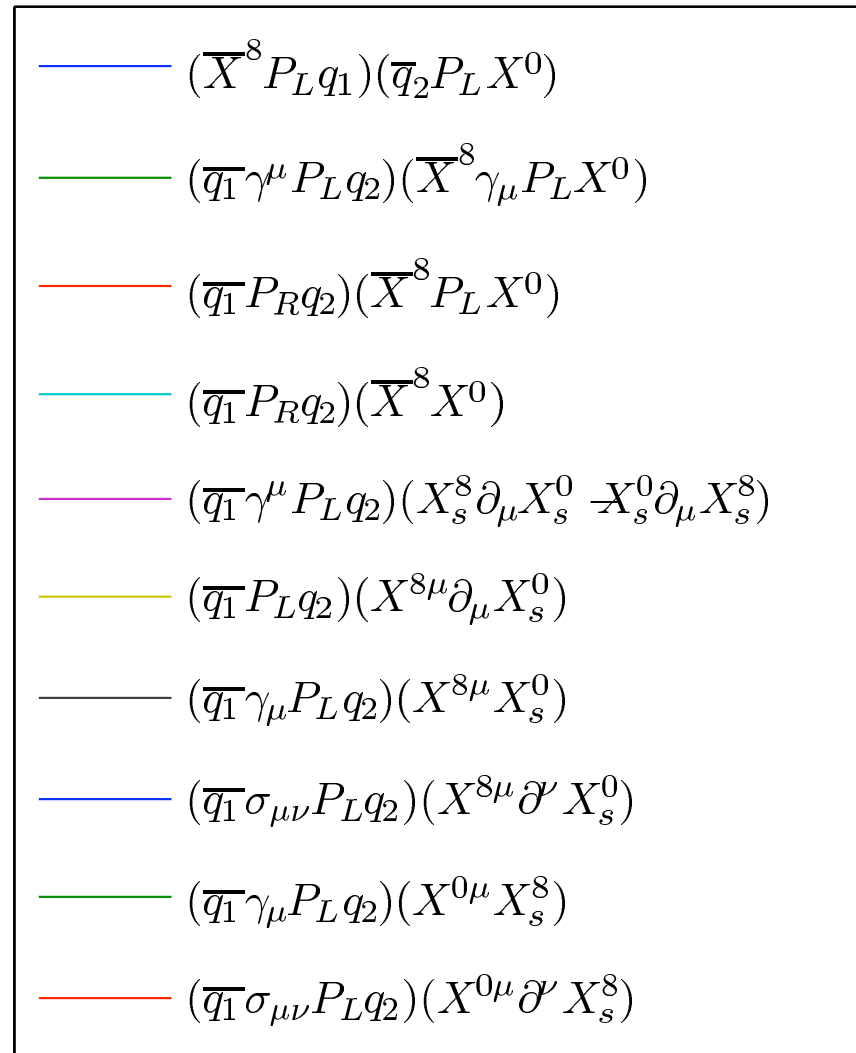


# Realistic Plot



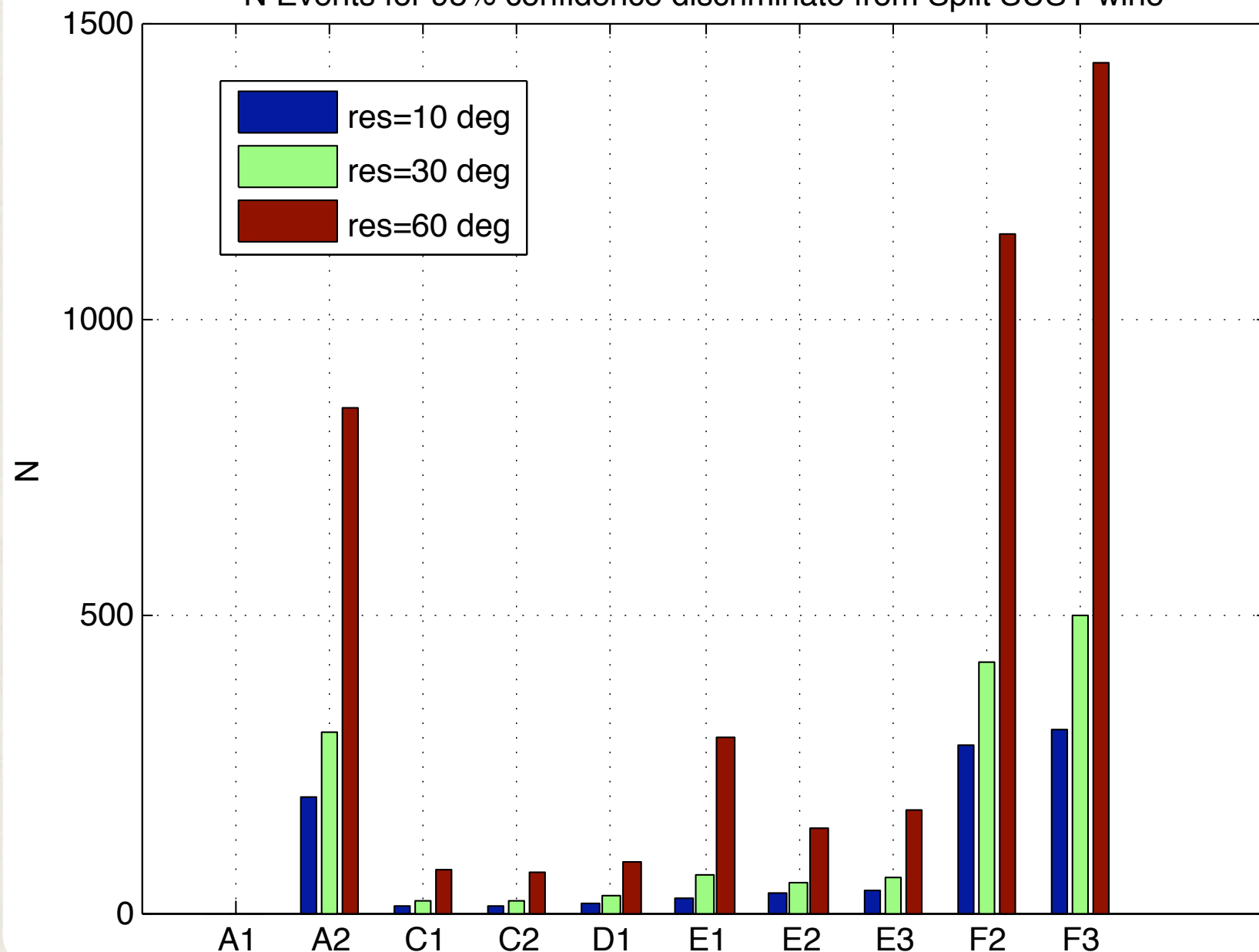


# Realistic Plot



# Discriminating Operators

N Events for 95% confidence discriminate from Split SUSY wino



<span style="color: blue;">—</span>	$(\overline{X}^8 P_L q_1)(\overline{q}_2 P_L X^0)$
<span style="color: green;">—</span>	$(\overline{q}_1 \gamma^\mu P_L q_2)(\overline{X}^8 \gamma_\mu P_L X^0)$
<span style="color: red;">—</span>	$(\overline{q}_1 P_R q_2)(\overline{X}^8 P_L X^0)$
<span style="color: cyan;">—</span>	$(\overline{q}_1 P_R q_2)(\overline{X}^8 X^0)$
<span style="color: magenta;">—</span>	$(\overline{q}_1 \gamma^\mu P_L q_2)(X_s^8 \partial_\mu X_s^0 - X_s^0 \partial_\mu X_s^8)$
<span style="color: yellow;">—</span>	$(\overline{q}_1 P_L q_2)(X^{8\mu} \partial_\mu X_s^0)$
<span style="color: black;">—</span>	$(\overline{q}_1 \gamma_\mu P_L q_2)(X^{8\mu} X_s^0)$
<span style="color: blue;">—</span>	$(\overline{q}_1 \sigma_{\mu\nu} P_L q_2)(X^{8\mu} \partial^\nu X_s^0)$
<span style="color: green;">—</span>	$(\overline{q}_1 \gamma_\mu P_L q_2)(X^{0\mu} X_s^8)$
<span style="color: red;">—</span>	$(\overline{q}_1 \sigma_{\mu\nu} P_L q_2)(X^{0\mu} \partial^\nu X_s^8)$



# Conclusions

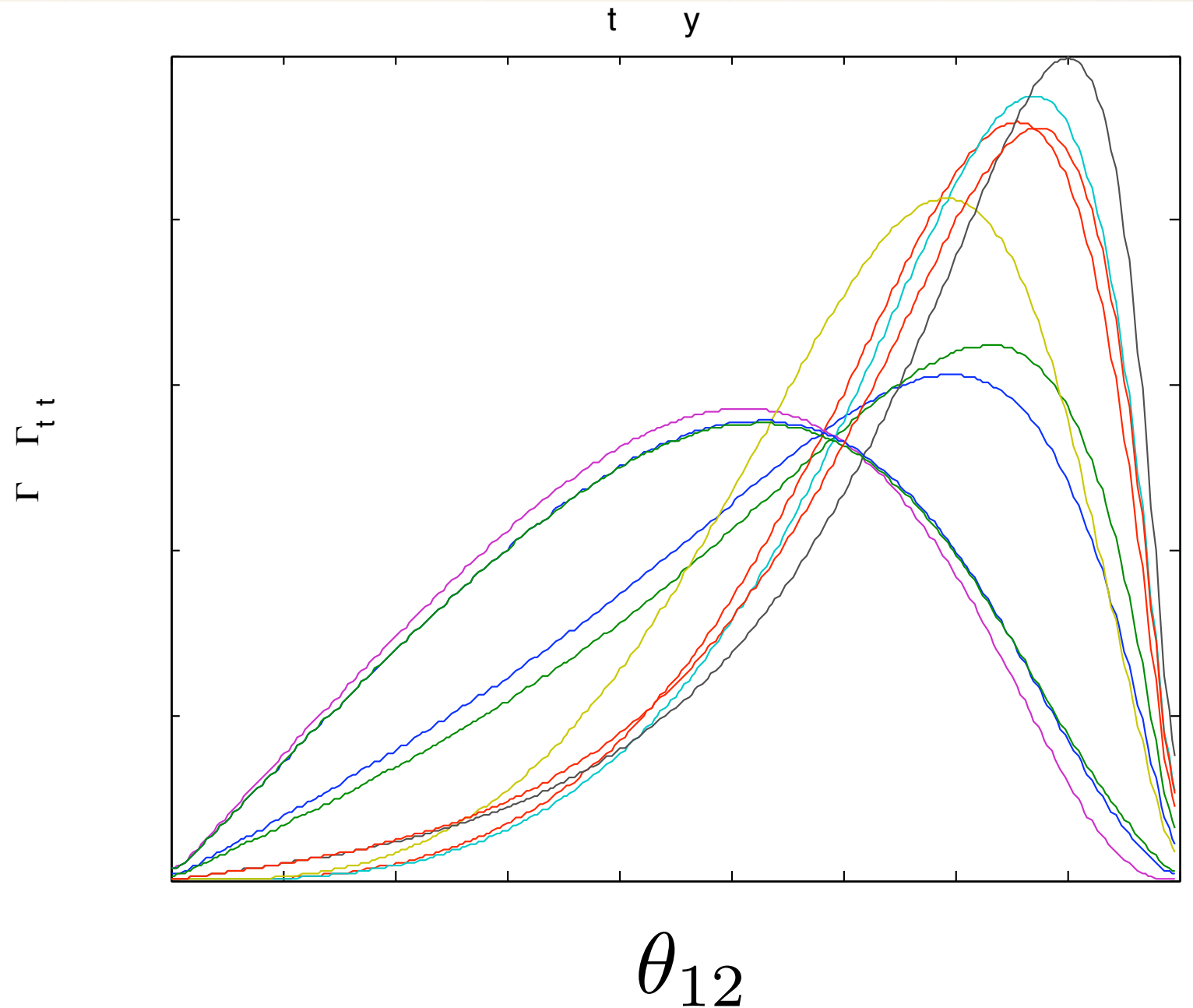
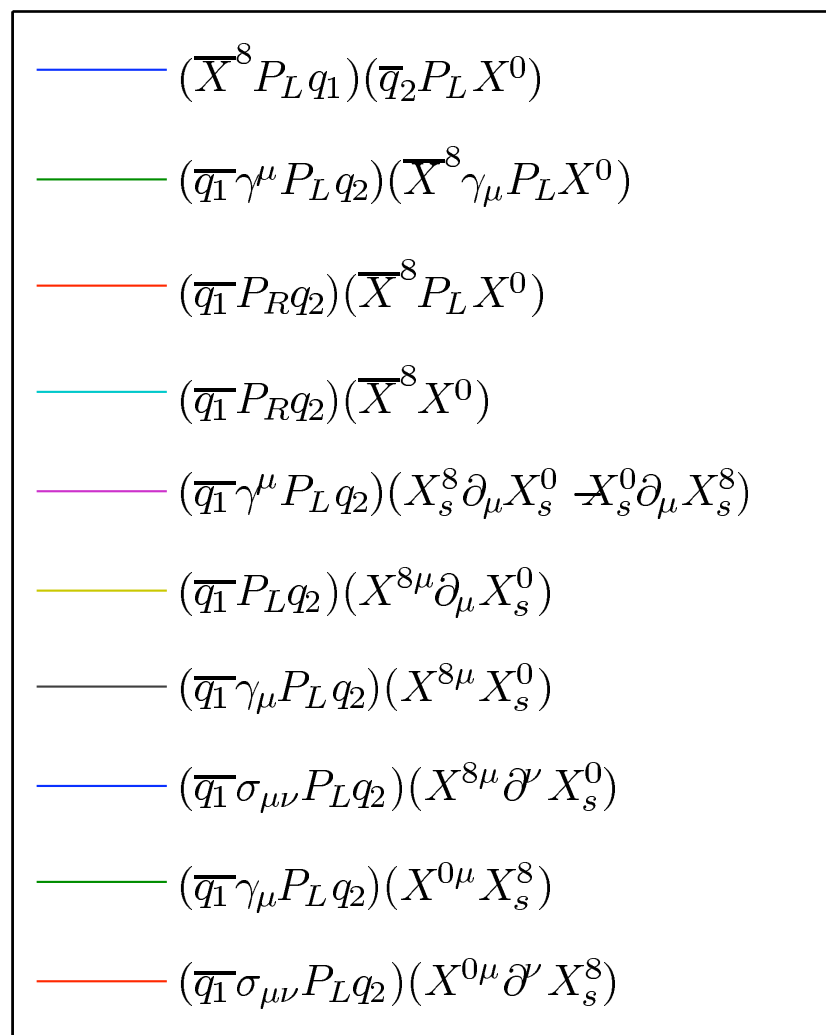
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- ✧ Very high scales can be probed by measuring decays of long lived charged particles
- ✧ Lorentz structures of decay operators can be distinguished by measuring 3 body decay properties
- ✧ While not designed to do so, LHC detectors can make this measurement
- ✧ With a few hundred events, can distinguish many models apart

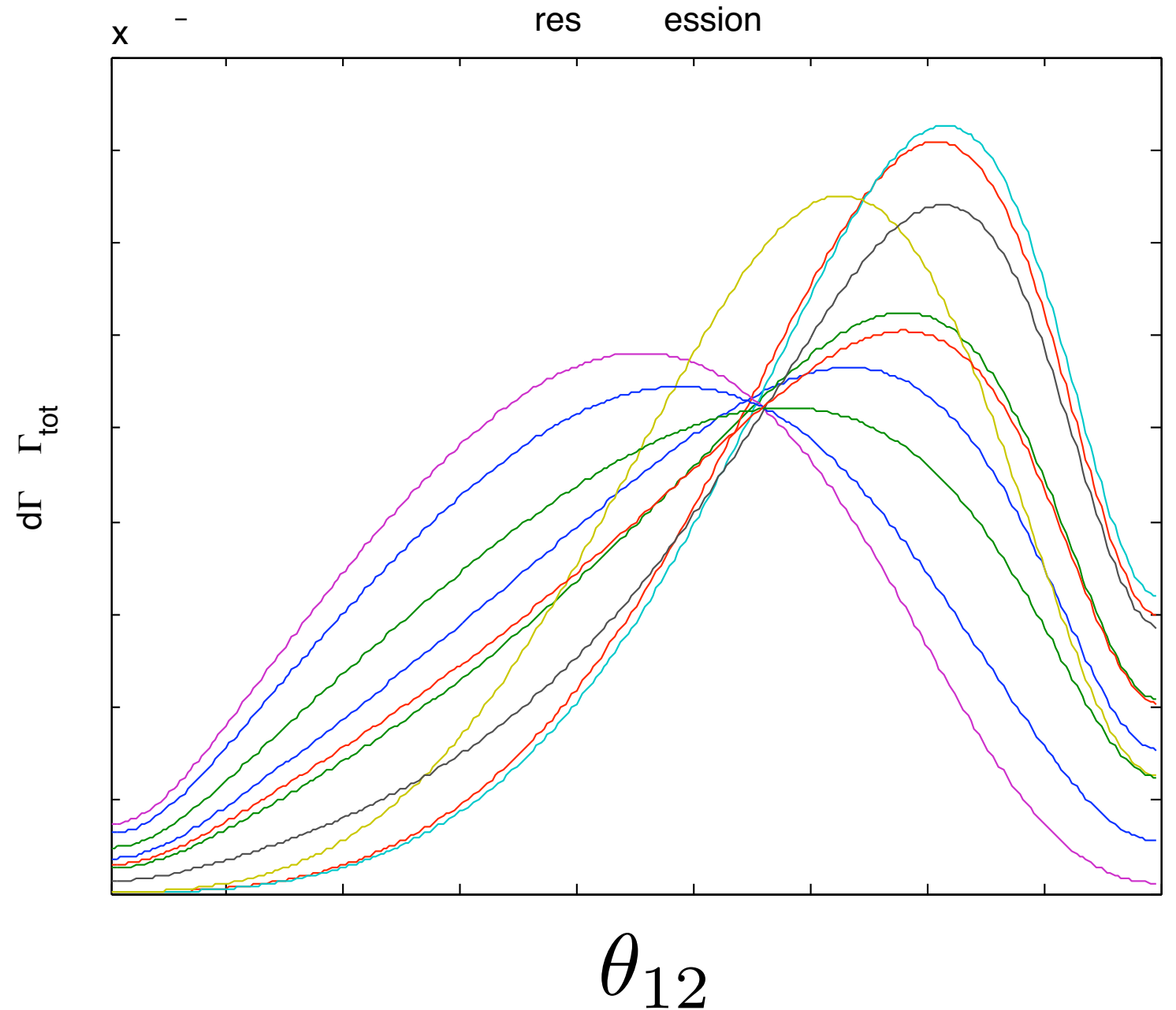
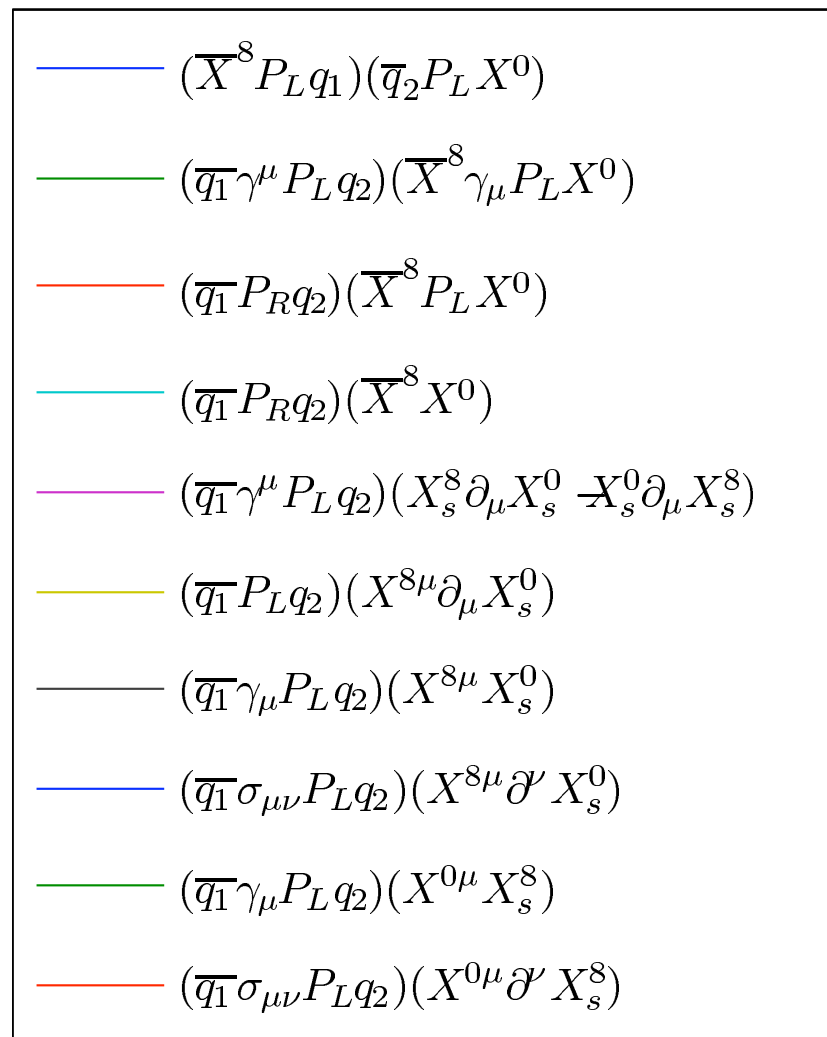
Thank You



# Varying Mass



# Better Resolution





# Worse Resolution

