Early Spin Measurements at the LHC

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Based on work in collaboration with
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work in progress

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Outline

- Introduction and Basic Idea
- An Example: Top at Tevatron
- Gluino at LHC
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Introduction and Basic idea

- Solving the hierarchy problem usually requires some SM partners to cancel the quadratic divergence in SM.
- A leading example is SUSY. Experimentally to confirm it, one wants to determine the spins of the new particles.
- The standard way to do this is through the spin correlation; Many studies in the literatures

  A. J. Barr; P. Meade, M. Reece; J. M. Smillie, B. R. Webber; L. T. Wang, I. Yavin, ...

  This workshop – Talks of J. Lykken, S. Thomas and M. Graesser

  May work for light sleptons or high statistics.

Introduction and Basic idea

- What we are emphasizing is that a proper use of the rate information is extremely helpful in the early determination of the spin.

- The basic observation is that the cross sections of particles with different spin will differ significantly in many cases.

- Experimentally one will estimate the cross section and mass of the new particle. In most situations, this would immediately imply the spin.

- Method works best when one production mechanism dominants, e.g. color octets at LHC.

Introduction and Basic idea

- Initially test most reasonable hypotheses

  – color octet if $M \sim 1$TeV, $\sigma \gtrsim$ pb

  – no fine-tuned mass degeneracies that could confuse results. (Works even then, but more effort needed)

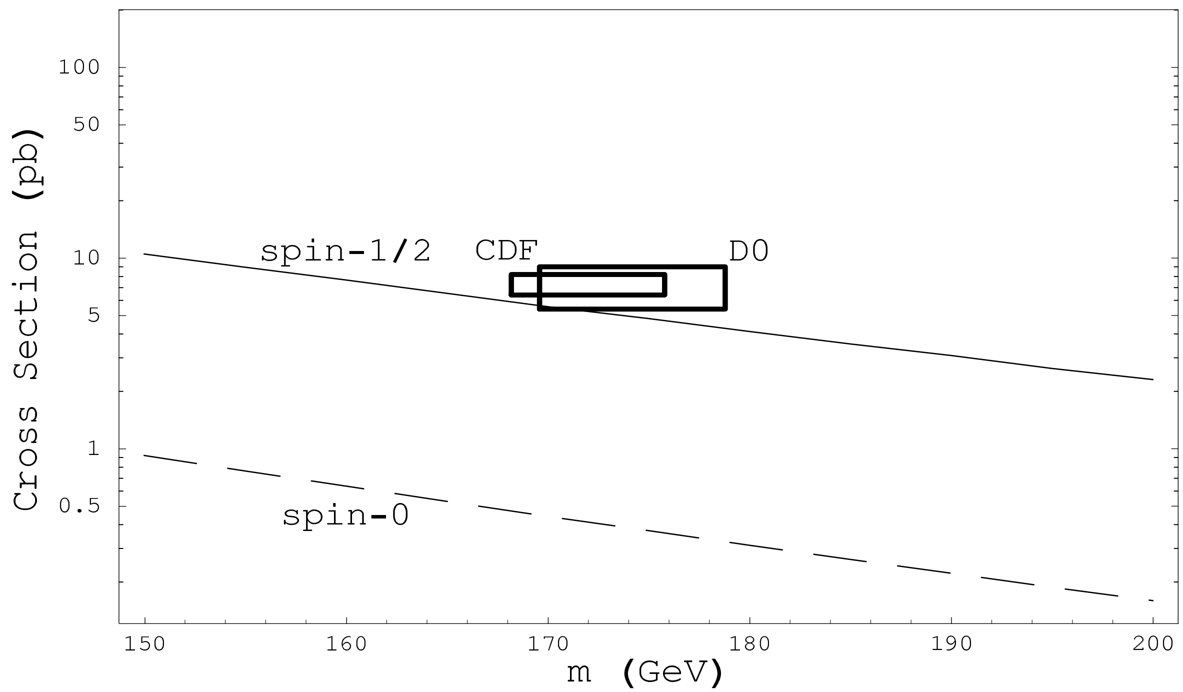
- Then later repeat with more alternatives

  – color triplet, etc

  – special mass splittings (return to this later in the talk)

Consider Simple Example: Top at Tevatron

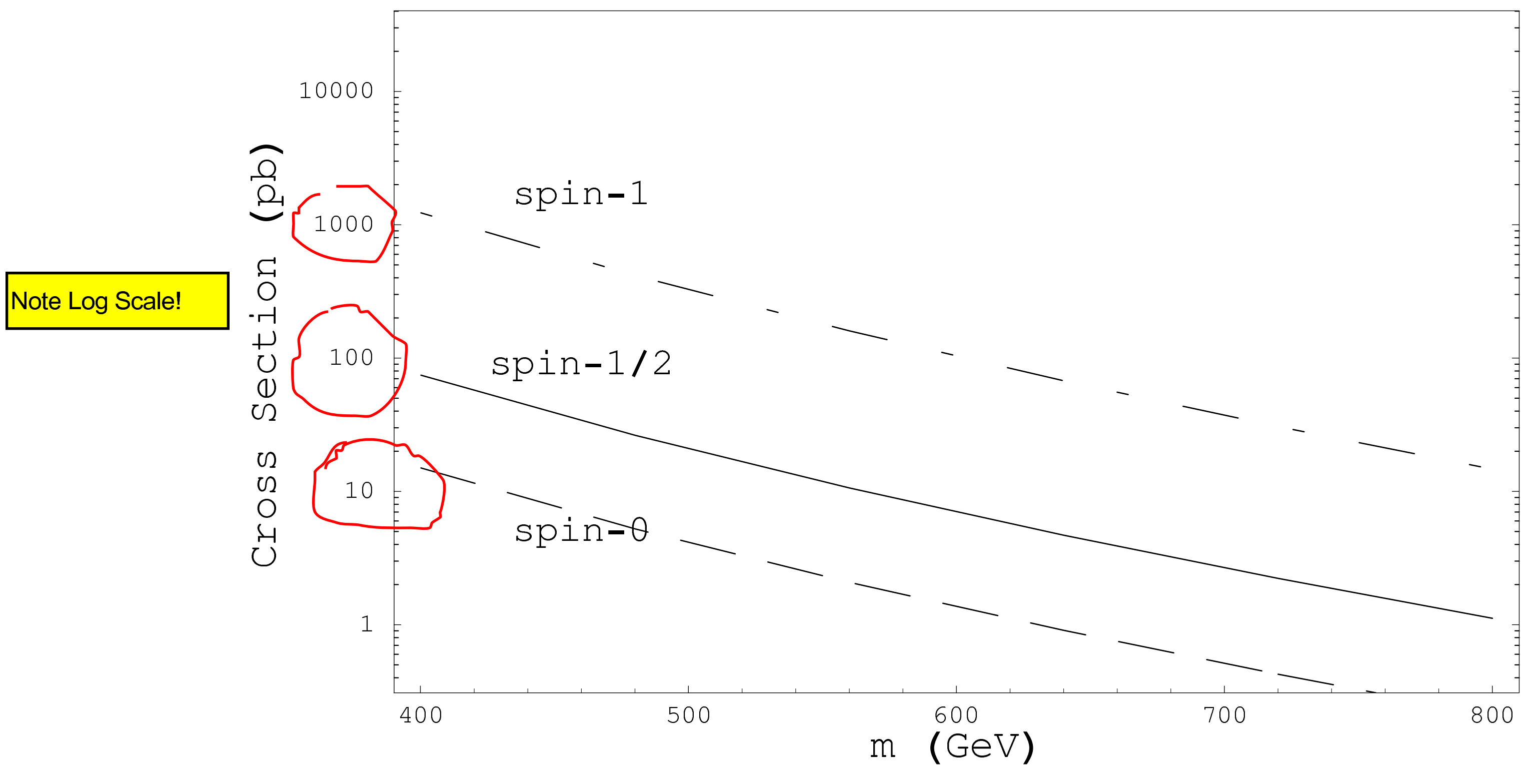
- The cross section at Tevatron



- Large differences in the cross section between spin-$\frac{1}{2}$ and spin-0. $\Longrightarrow$ Spin of top was measured by $\sigma + M$.

Gluino at LHC

- The cross sections for gluino and other spin candidates



- These cross sections are essentially determined by the spin and color structure.

Some discussion

- There are uncertainties in the calculated cross section: higher order QCD corrections and scale dependence. However the ratios of the cross sections depend less on them.

- For example, consider the mass of a new color octet to be $M = 800$GeV. If we choose scales $\mu_F = \mu_R = M_Z$, then the cross section for the spin-$\frac{1}{2}$ and spin-1 are given by

$$\sigma_{pp\to\tilde{g}\tilde{g}} \approx 2.8\text{pb}, \quad \sigma_{pp\to g_V g_V} \approx 24.1\text{pb}. \quad \text{ratio} \approx 8.5$$

- For scales $\mu_F = \mu_R = M$

$$\sigma_{pp\to\tilde{g}\tilde{g}} \approx 0.95\text{pb}, \quad \sigma_{pp\to g_V g_V} \approx 7.79\text{pb}. \quad \text{ratio} \approx 8.2$$

Some discussion

- For the same production rate, particles with different spin must have different mass. However, determination of the mass may not be trivial.
- In special cases may need further efforts to untangle the degeneracy. Usually the mass difference ΔM between the color particle and the invisible particle can be determined, for example from the P_T distribution. After fixing both the rate and ΔM, can we find any observable differences in the kinematical distributions, e.g., H_t, $\not{E}_T$, m_{ij}, ΔR_{ij} ... ?
- Yes, in principle.
- Then we can fit these distributions to the data and resolve the "degeneracy".

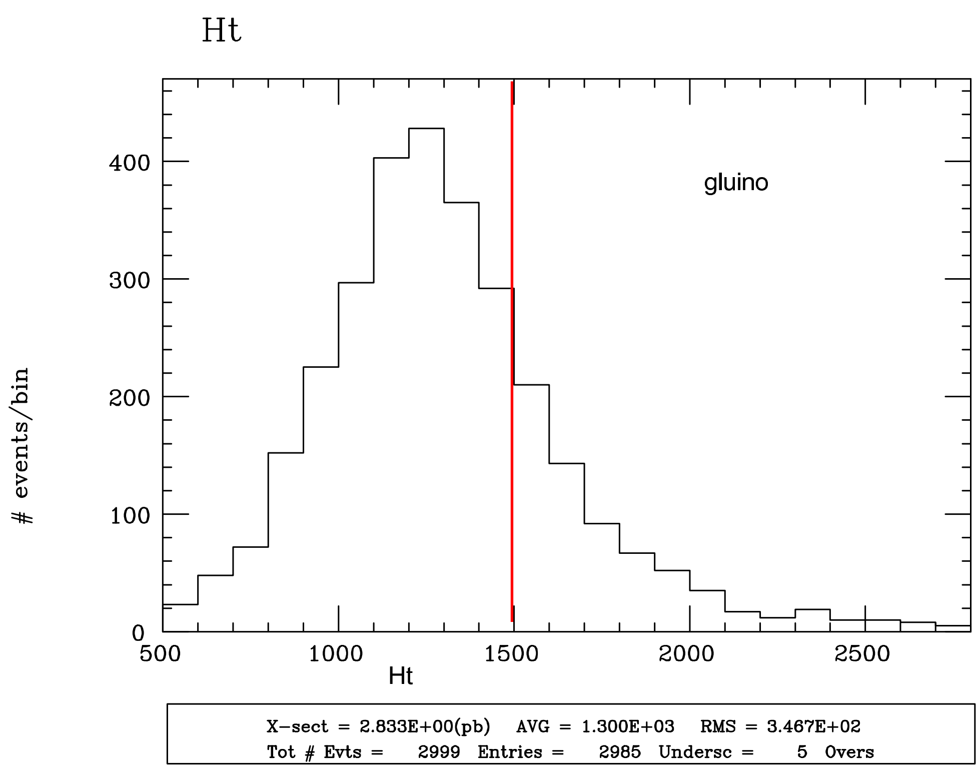
For example

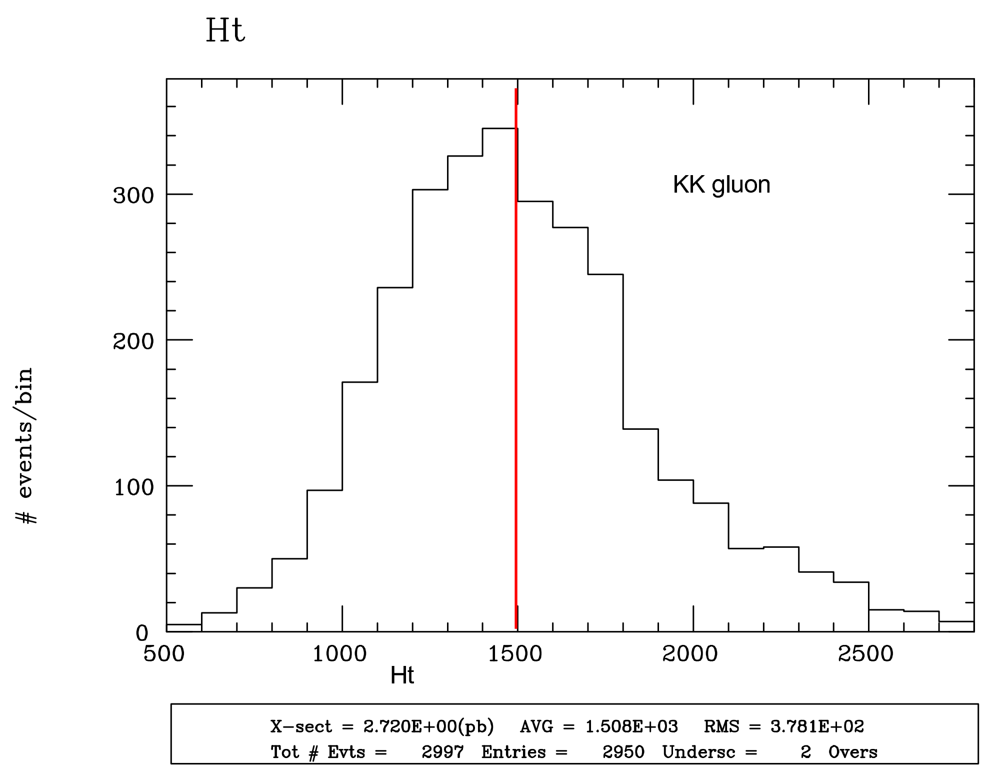
- Fix the production rate and $\Delta M = 660$GeV:

  Gluino with $M_{\tilde{g}} = 800$GeV, KK gluon with $M_{g_V} = 1100$GeV.

  Both of them undergo 3-body decay into 2 jets plus $\not{E}_T$.

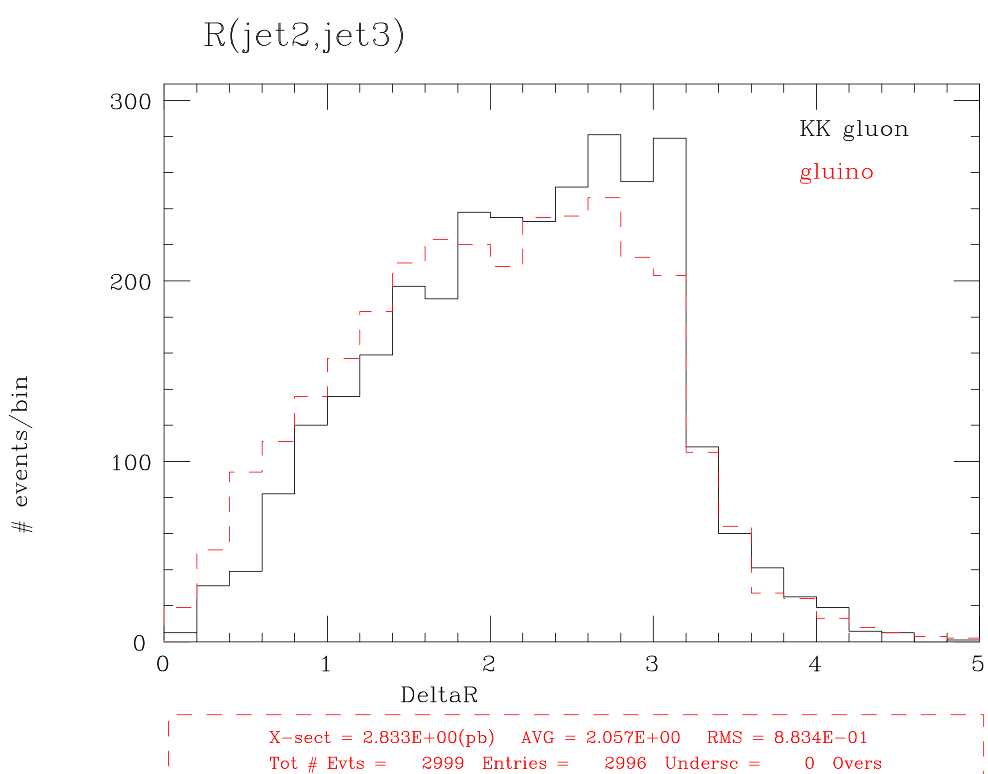
- The effective mass distribution

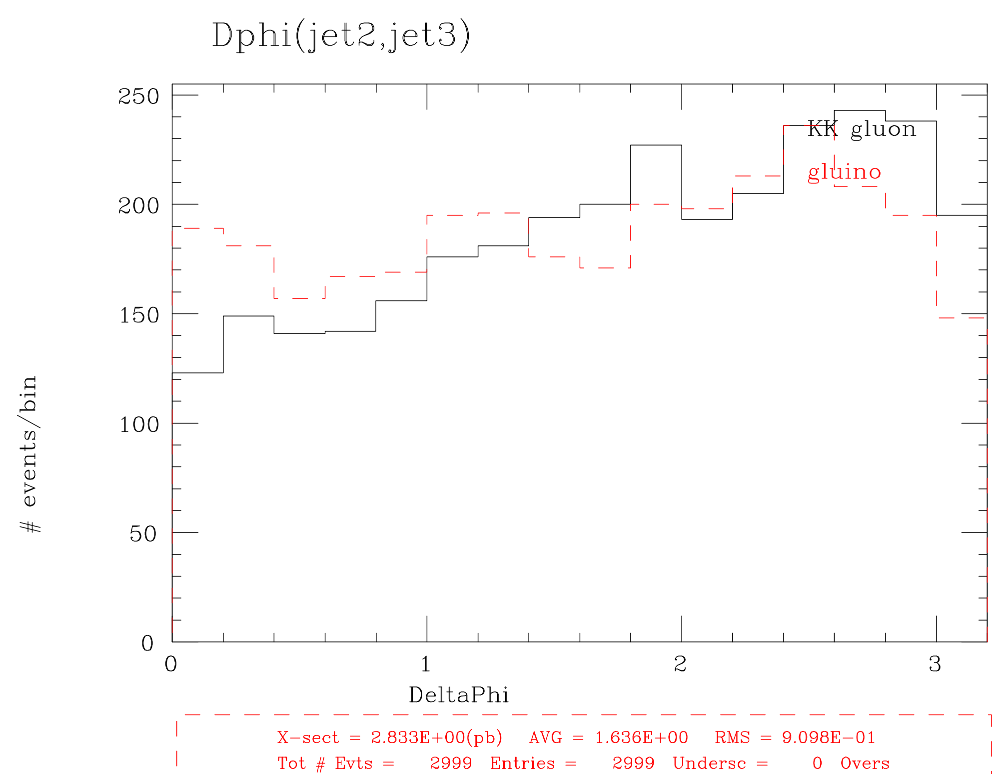


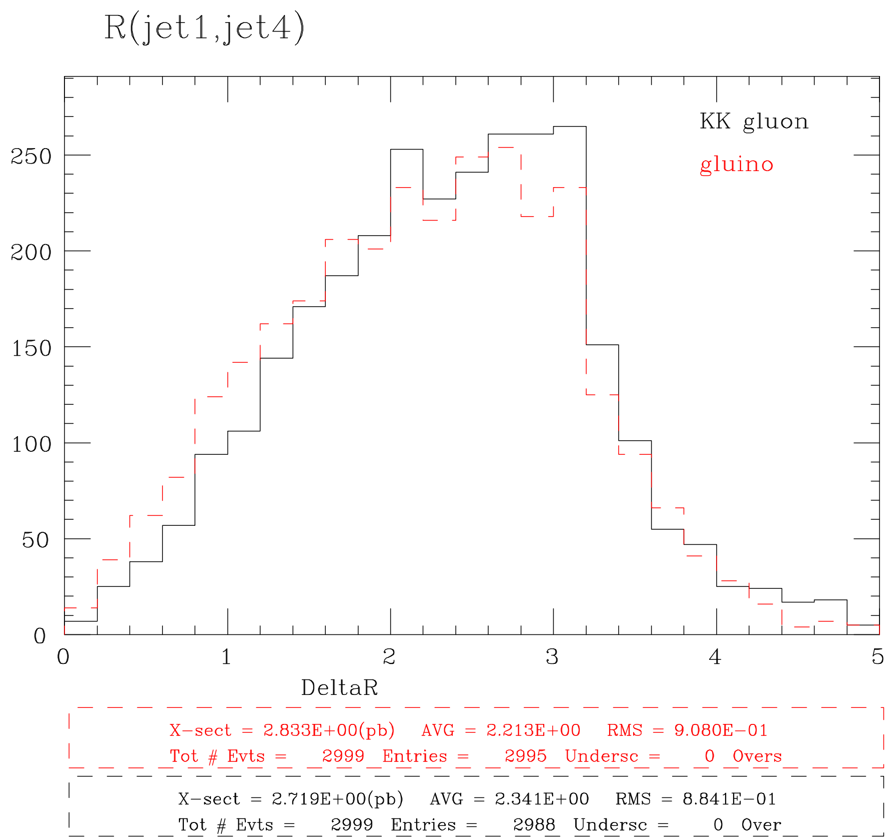


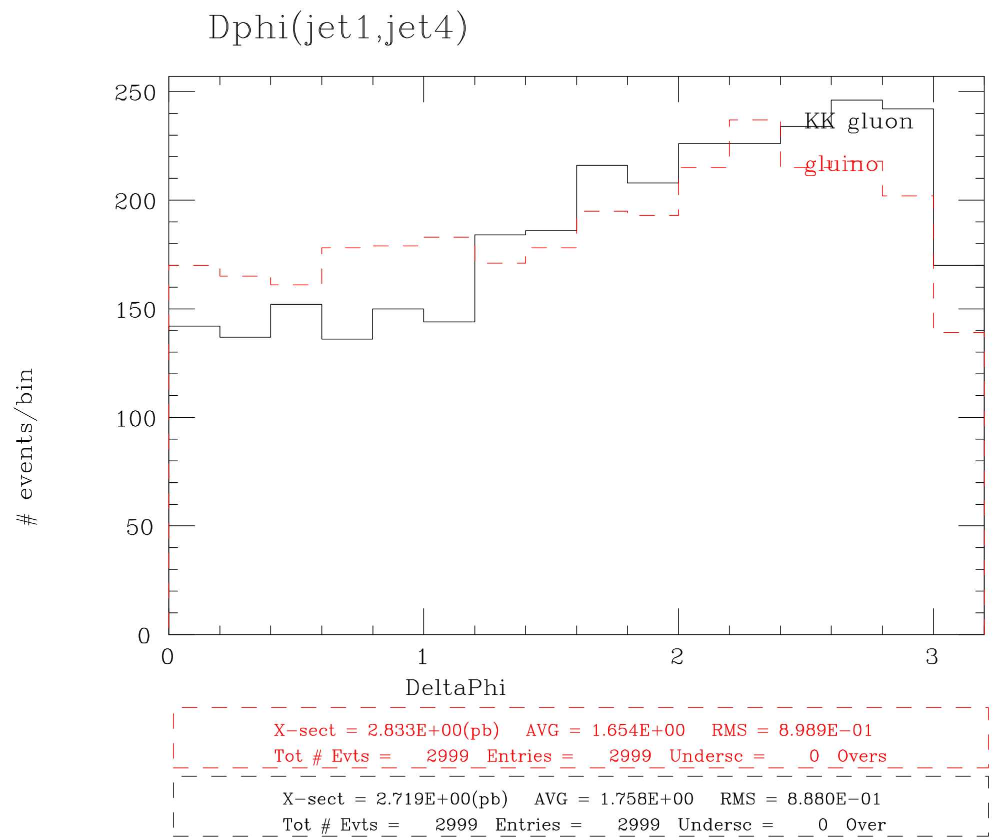
Continue

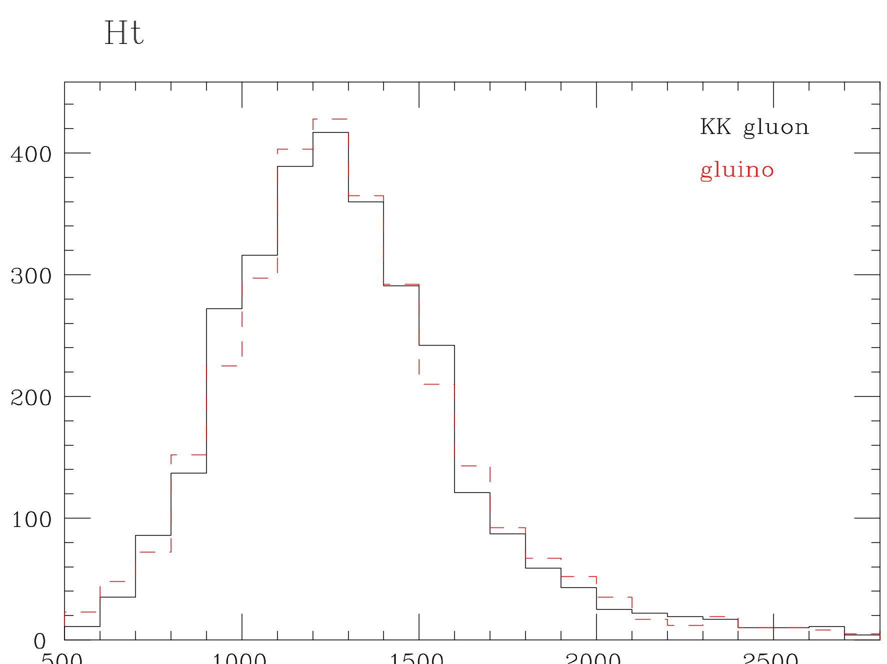
- Maybe ΔM can be adjusted so these peaks are closer? Probably can be dealt with also.
- Adjust LKP mass ($\Delta M = 560$GeV) in the KK gluon case such that H_t peak at the same position as the gluino case. We find differences in other distributions, e.g. ΔR and $\Delta\varphi$ both give distinguishable distributions:

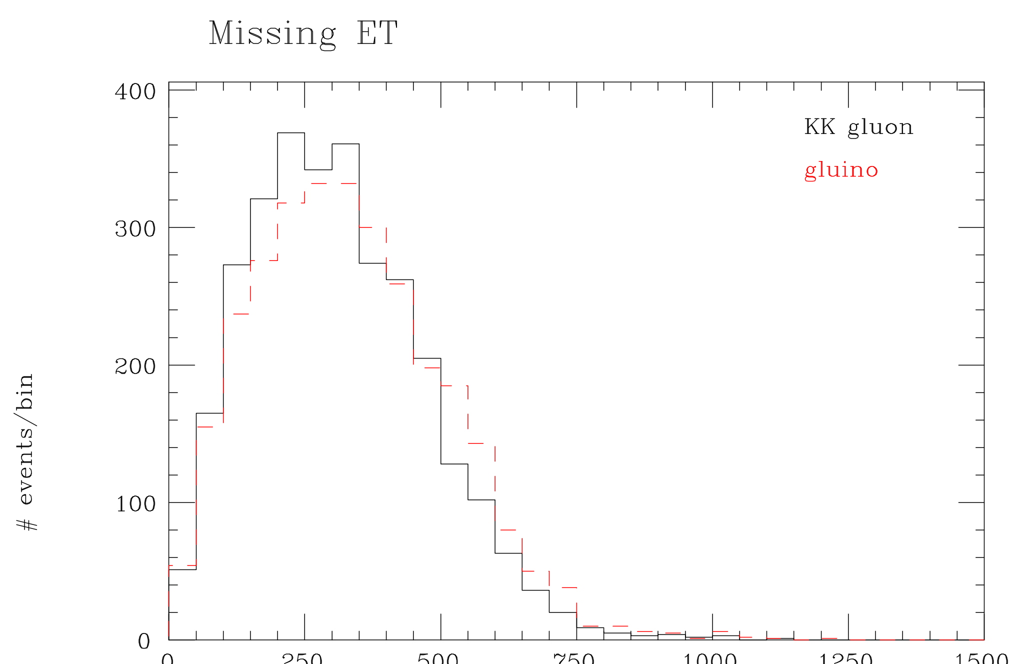





R(jet1,jet4)
KK gluon
gluino
DeltaR
X-sect = 2.833E+00(pb) AVG = 2.213E+00 RMS = 9.080E-01
Tot # Evts = 2999 Entries = 2995 Undersc = 0 Overs
X-sect = 2.719E+00(pb) AVG = 2.341E+00 RMS = 8.841E-01
Tot # Evts = 2999 Entries = 2988 Undersc = 0 Over


Dphi(jet1,jet4)
# events/bin
KK gluon
gluino
DeltaPhi
X-sect = 2.833E+00(pb) AVG = 1.654E+00 RMS = 8.989E-01
Tot # Evts = 2999 Entries = 2999 Undersc = 0 Overs
X-sect = 2.719E+00(pb) AVG = 1.758E+00 RMS = 8.880E-01
Tot # Evts = 2999 Entries = 2999 Undersc = 0 Over


Ht
KK gluon
gluino


Missing ET
events/bin
KK gluon
gluino

Summary

- The cross section information can be used to determine the spin early at LHC. 100pb^{-1}? The result can be checked later by examining the spin correlation.
- It works well in most "worlds", but may need more work for complicated situations. The detailed study is underway.