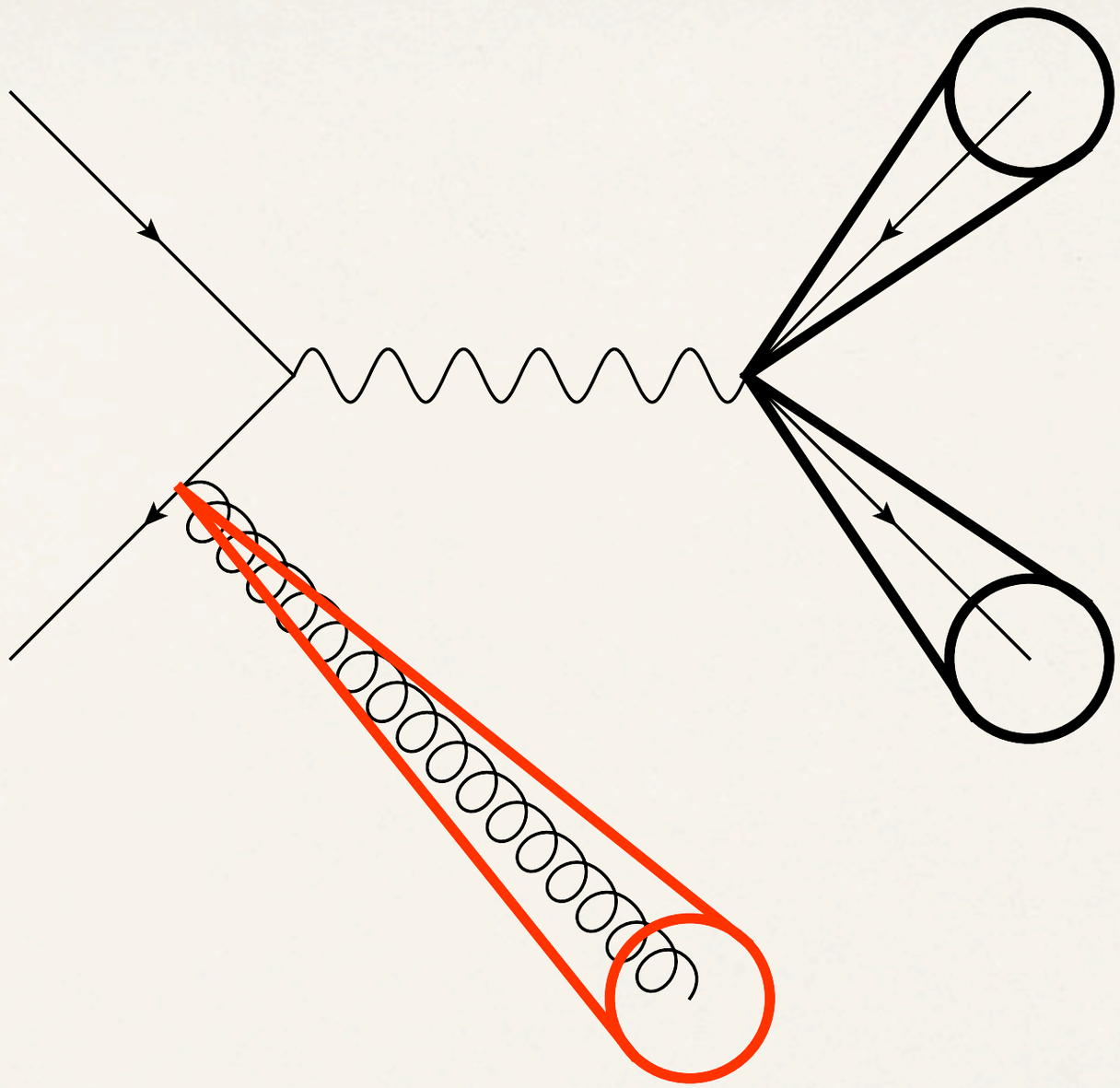

ISR Tagging

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Boost 2011, Princeton

Based on 1101.0810

Outline

- Introduction & Motivation
- Tagging an ISR Jet
- Uses of an ISR Jet
- Conclusion

Takeaway

- Initial state radiation (ISR) is normally a nuisance.
  - It can contaminate jets, and makes sorting out combinatorics hard.
- However,
  - When ISR produces a jet it can often be tagged (through methods we introduce).
  - By investigating an ISR jet we can learn valuable information about the event which produced it.

Introduction & Motivations

Busy Final States

- The LHC will, hopefully, allow us to produce and study particles from physics beyond the SM.

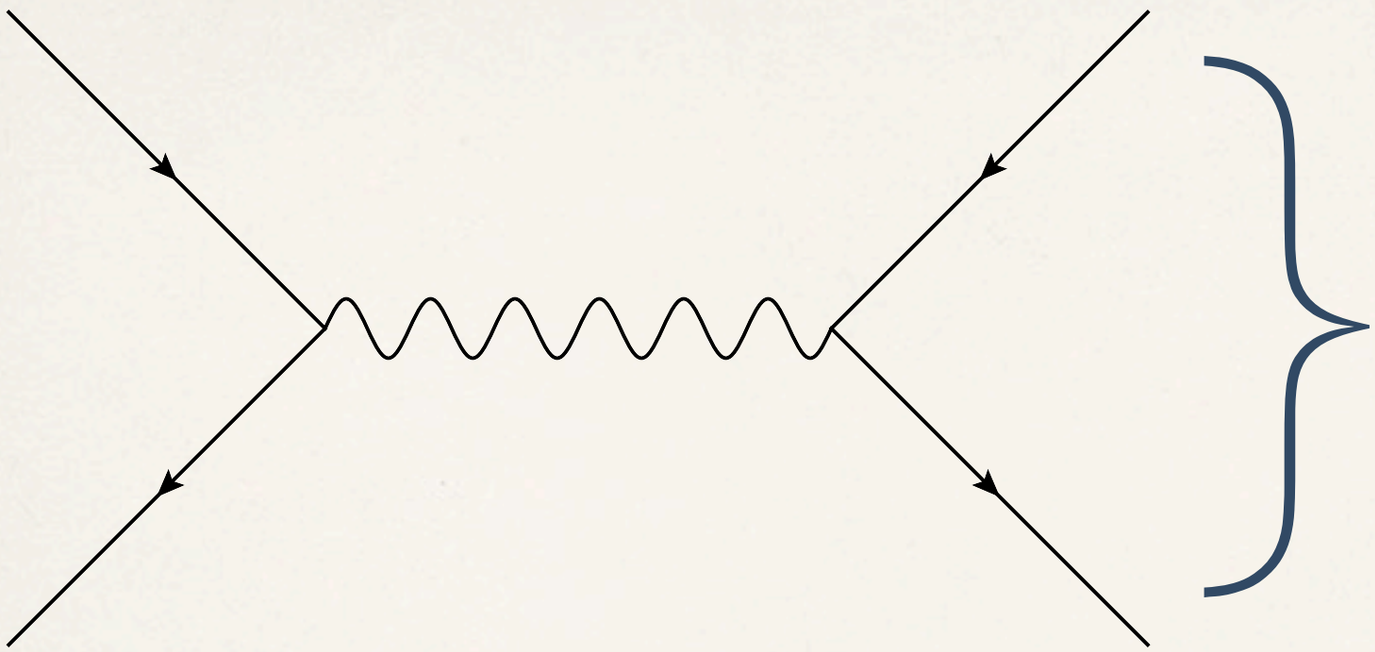
- Even at leading order the decay processes of these new particles can yield busy final states

$$\text{Example}: \quad \tilde{g} \to t\bar{t}\chi_0 \to 6j + \chi_0$$

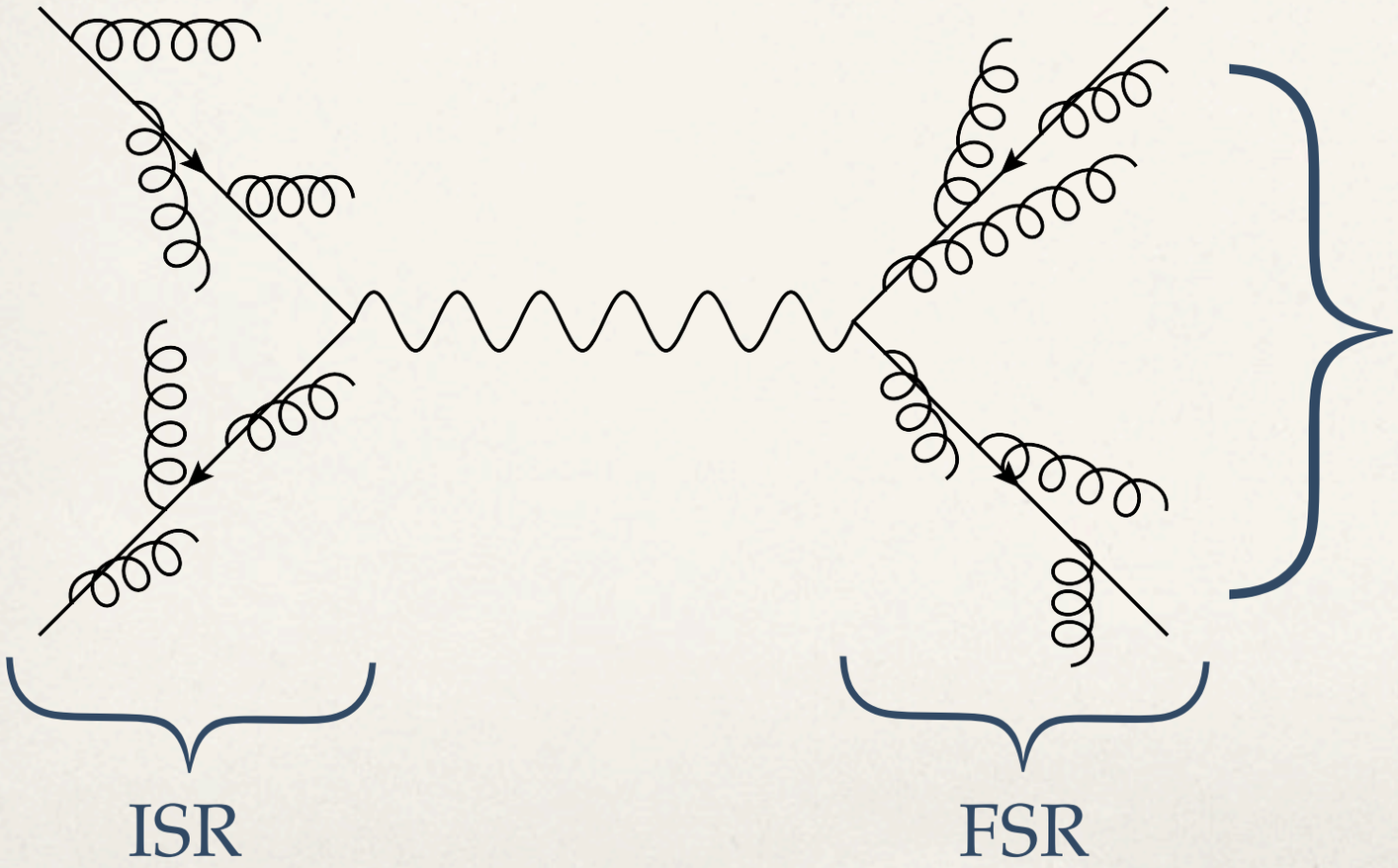
- However, what we observe in the detector is actually much more complicated than the leading tree level diagrams suggest.

Initial & Final State Radiation (ISR/FSR)

- This is because leading order tree level considerations neglect initial state radiation .
- Colored final state particles will emit soft/collinear radiation (FSR)
  - These emissions are together resolved as jets - a spray of radiation in one direction.
- In the same way, partons in the proton will emit soft/collinear radiation (ISR) before they scatter into/via new physics states



Lowest order diagram for the production and decay of a Z′



Production of Z′ showing ISR/FSR

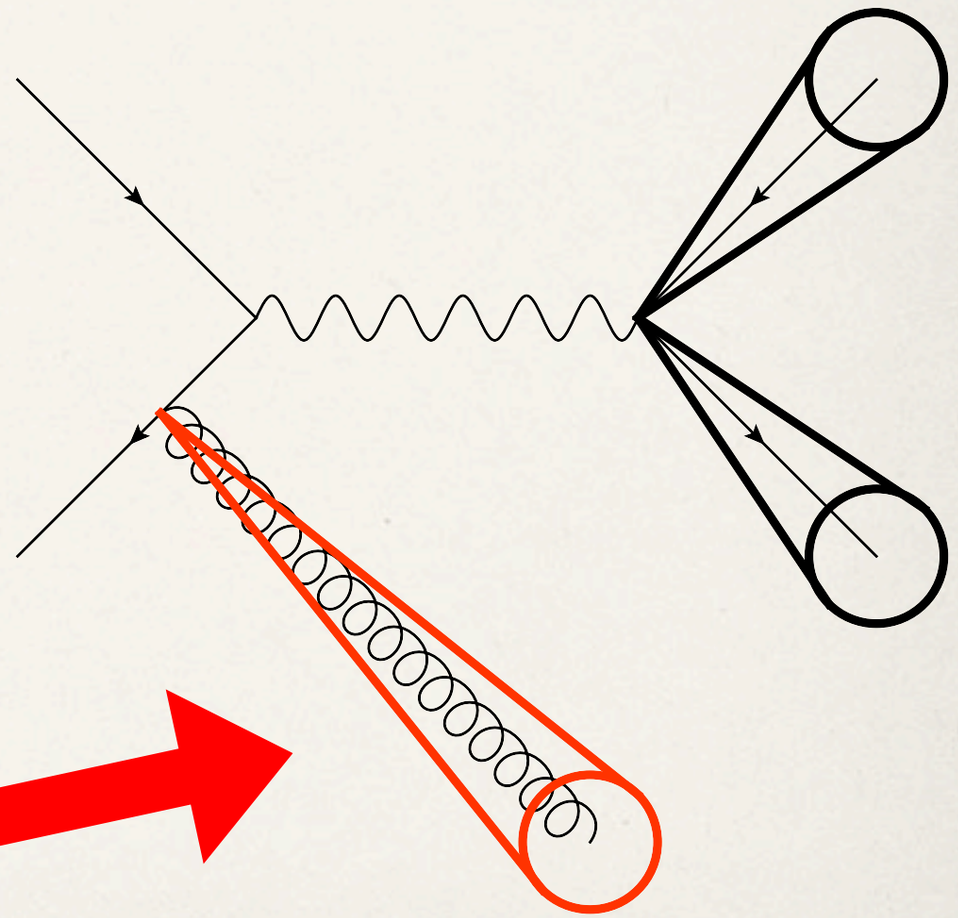
Effects of ISR

- We see ISR emissions as additional states in the detector.

- Basically, they can do two things

  1. Some emissions will spatially overlap with `signal' jets (motivation for jet topiary).

  2. Others will be assigned their own jets.



- So, if we can identify ISR jets on an event-by-event basis then we can do a better job at reconstructing new physics events.
  - This will be our goal.

- We'll see that we can even learn something new about BSM events.

Tagging an ISR Jet

Setup

- To tag an ISR jet we need to identify the criteria which distinguish it from FSR.

- These criteria are a little dependent on the event topology, although as we will see, adopting them from one process to another isn't too hard.

- Here we'll focus on the symmetric production of new physics states which decay into jets:

$$pp \rightarrow N_f J + 2\chi_1^0 + \mathrm{ISR}$$

where N_f=2(4) for di-squark and di-gluino production.

- In symmetric processes each jet should have a partner with roughly similar kinematics & color structure.
  - Look for unpaired jets
- Furthermore, the hard interaction distinguishes a region of rapidity which is more likely to be populated by FSR jets - outside this region jets more likely to come form ISR.

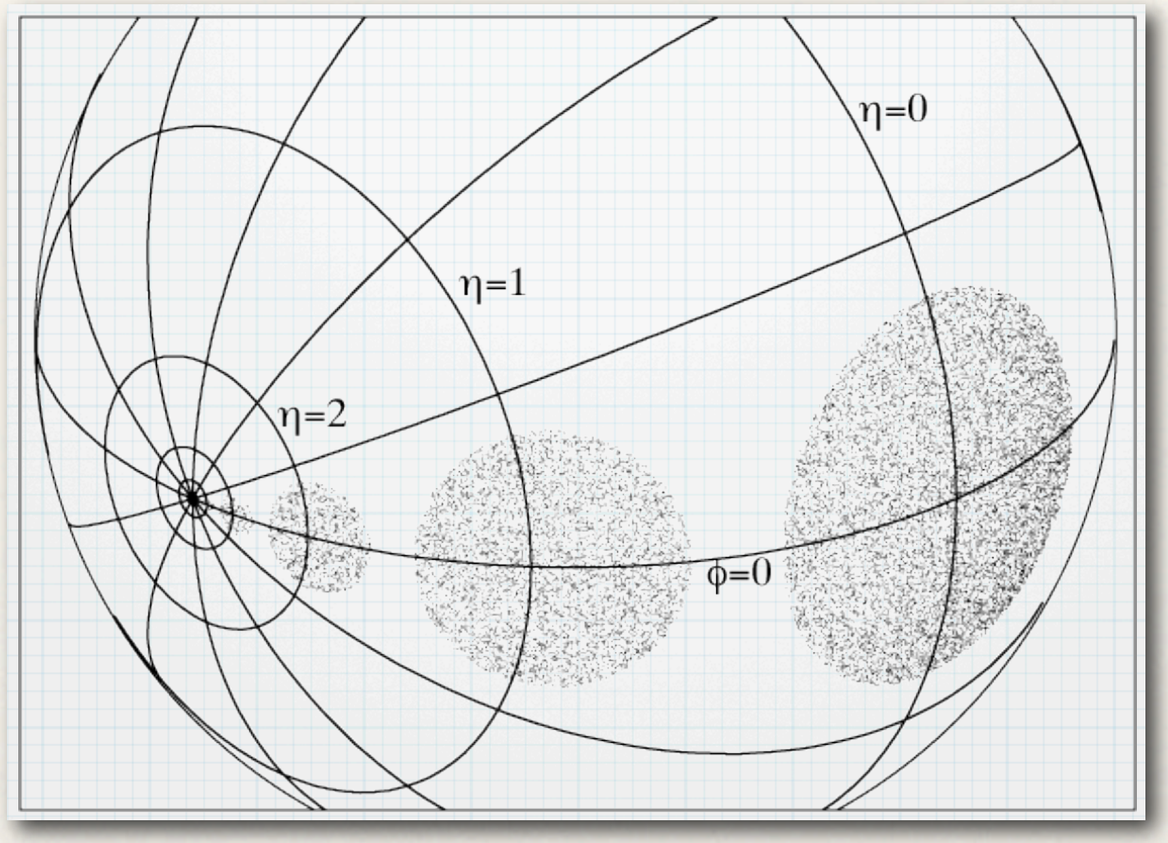


Figure stolen from John Conway's PGS talk: http://online.itp.ucsb.edu/online/lhco_c06/conway/

Summary of Tagging Procedure

- **Tag (all `or' conditions)**
  - Take hardest N+1 jets. Look for those
    1. Distinguished in p_T
    2. Distinguished in rapidity
    3. Distinguished in m/p_T
- **Check (all `and' conditions)**
  - Require the candidate ISR jet
    1. Not be central
    2. Remain somewhat isolated in rapidity
  - Require that the implicit FSR jets be
    1. Close in p_T
    2. Central

Uses of an ISR Jet

What's ISR Tagging Good For?

- The most obvious use of ISR tagging is in resolving combinatorics. However, there are a number of other interesting possibilities:

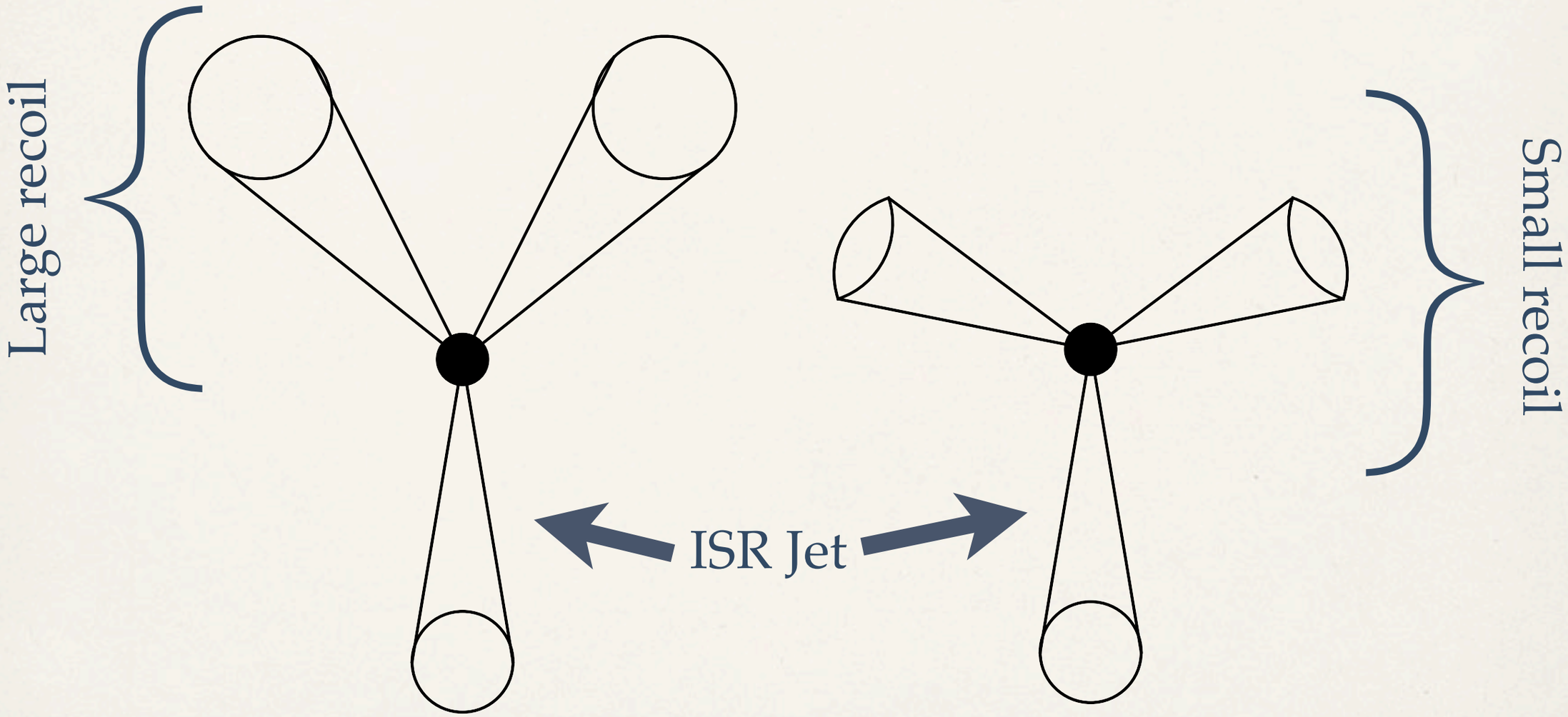
1. The ISR p_T can tell us about the scale probed in the interaction

2. ISR p_T can also tell us about the initial states (valence quark/sea quark/gluon)

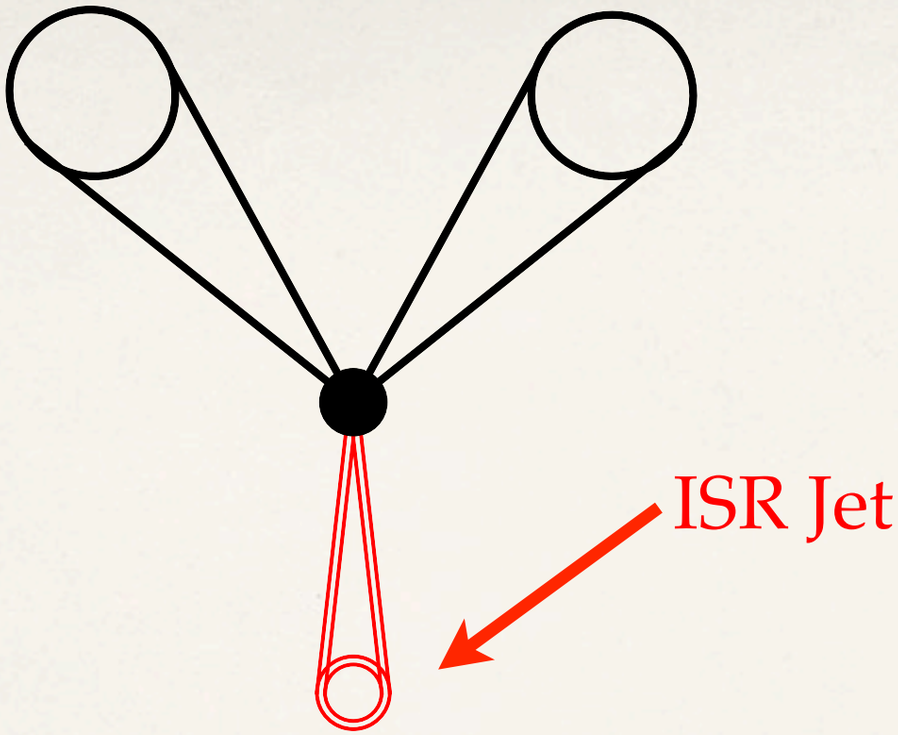
3. Curiously, requiring an ISR tag is a good signal/background discriminant

4. We can make use of a cute trick and measure the recoil of FSR against ISR, and thus infer the mass of the BSM system produced.

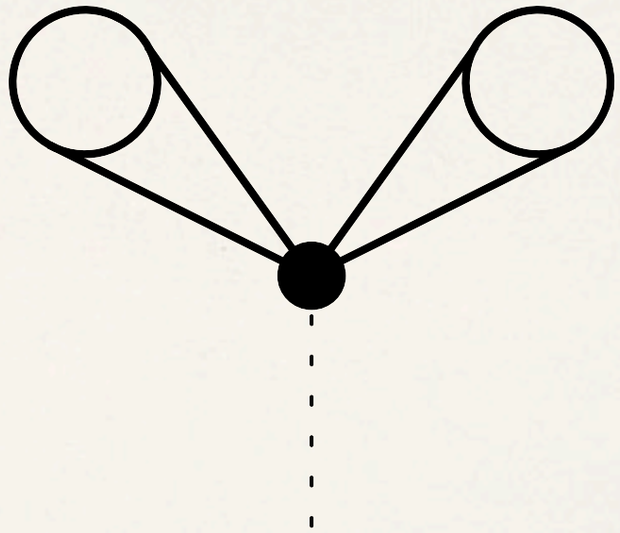
Starting Configuration



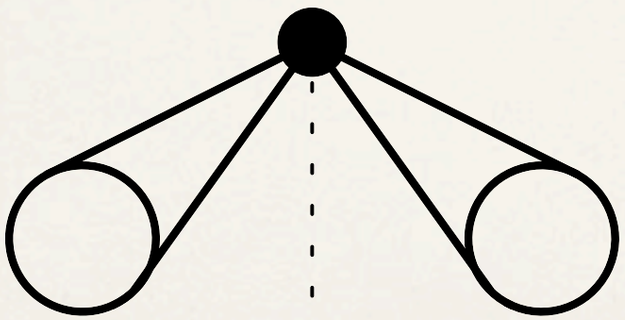
Note: In our system there is missing energy - the above picture is only true on average - i.e. there is no exact balance



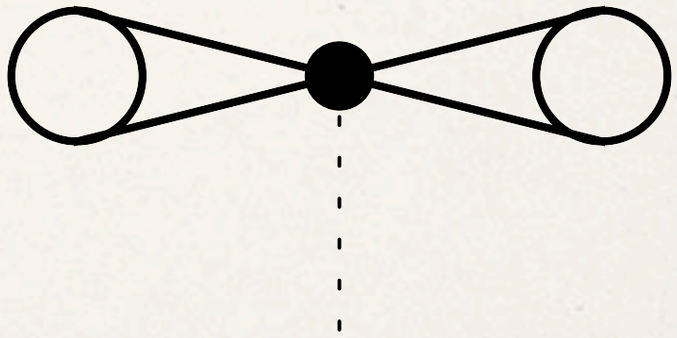
Pre-boost



Under boost



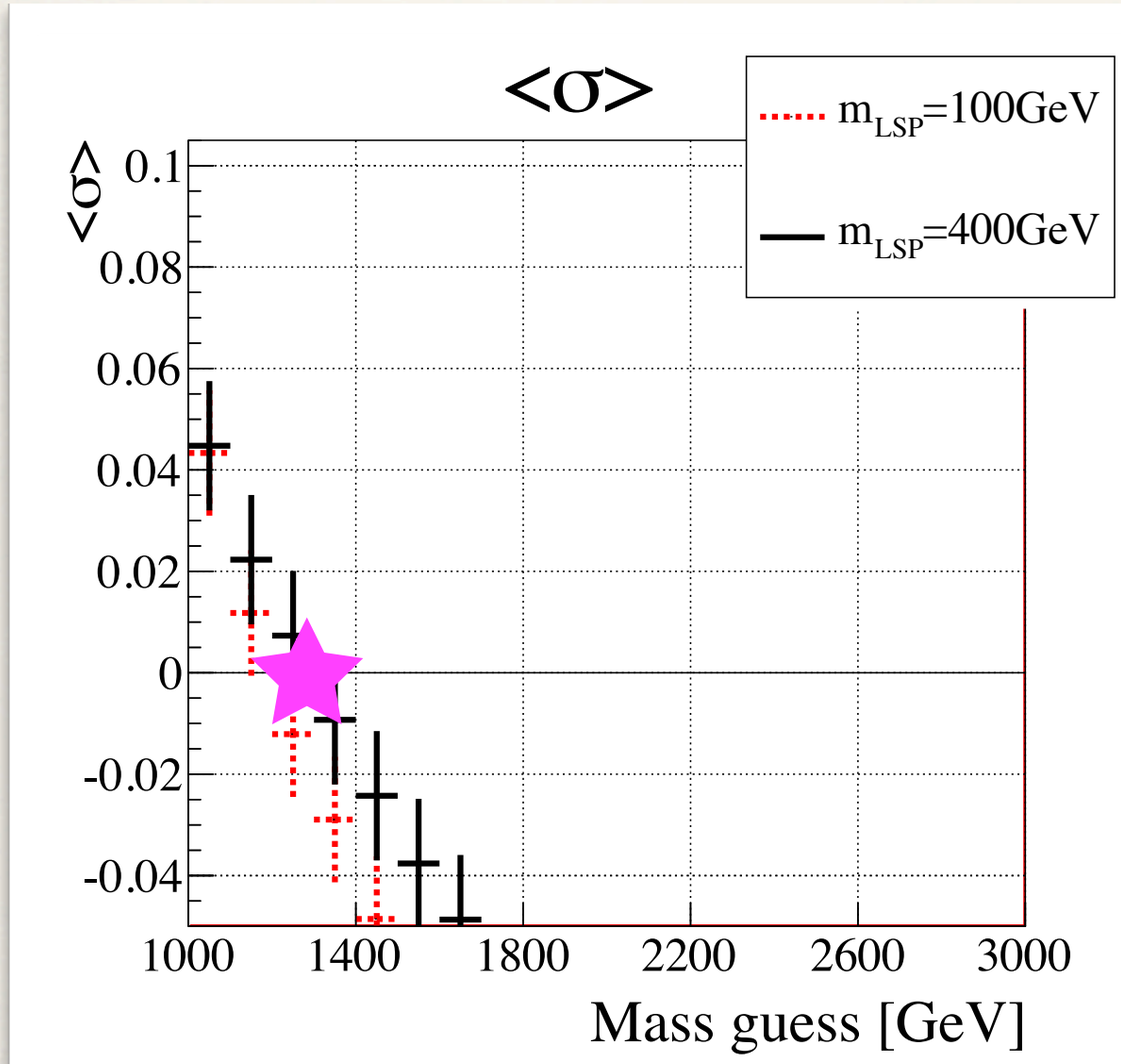
Over boost

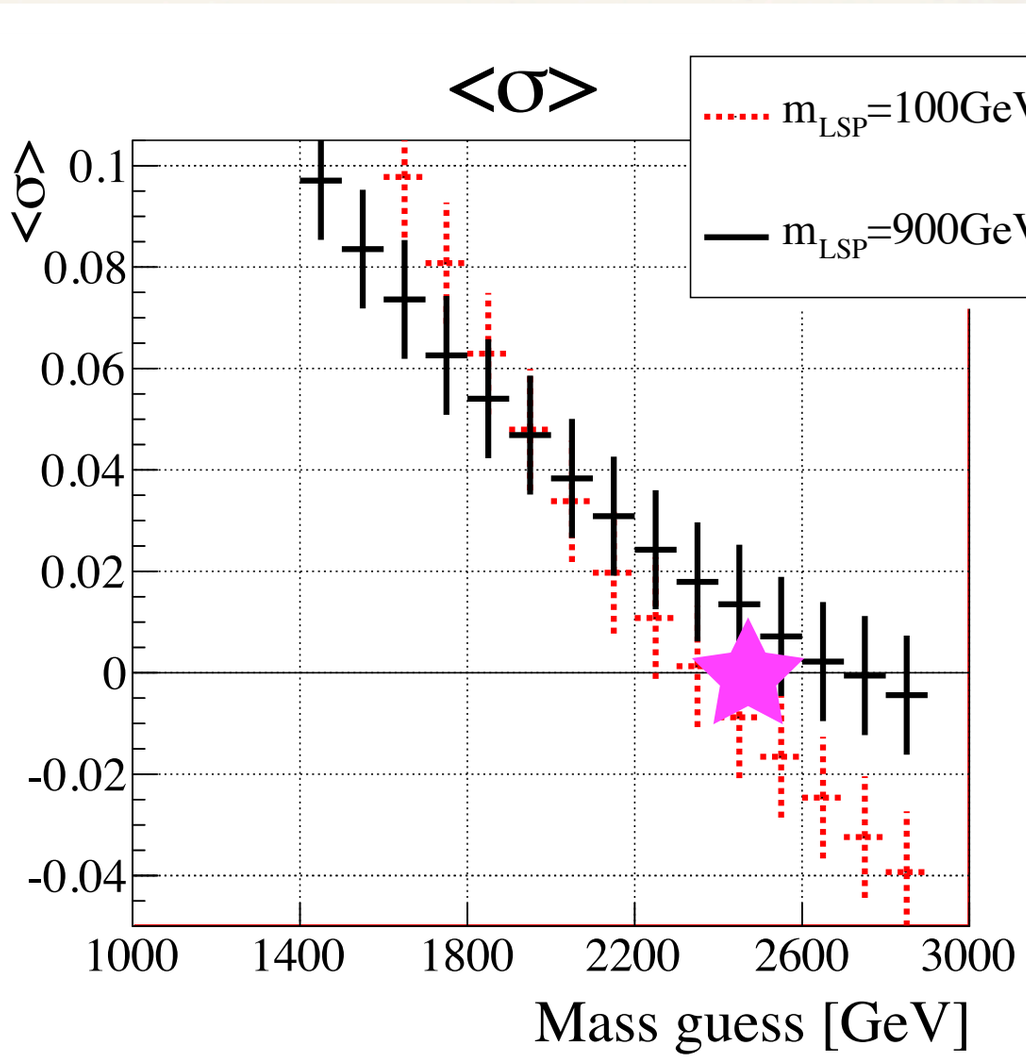


Correct boost

Main Result

m_{Glunio} = 0.5 (1.0) TeV for left (right) plots





★ } Where we expect ⟨σ⟩ = 0

- Just to emphasize what happened
  - On the previous page, for a 1 TeV gluino with a 900 GeV LSP we were able to infer the presence of 2.5 TeV physics from four dinky (p_T ~50 GeV) FSR jets and ISR. Not bad!

Future Directions & Conclusion

Future Directions

- We were able to get pretty far with a simple minded ISR tagger based on only three observables.

- Surely a more accurate tagger can be made, and it would be interesting to think of what could be added.

  - Especially interesting to think of how to adapt it to even busier environments.

Conclusions

- In looking for new physics at the LHC, we'll have to contend with initial state radiation (ISR).

- Not only can we mitigate its effects when it contaminates `signal' jets (through jet topiary), here we have shown that we can reliably tag jets as having come from ISR.

- This not only improves combinatorics - we saw we can actually derive new information from ISR jets to improve our understanding of BSM events.

Backup Note

- How do we know we're tagging ISR and not something else?
  - After all, technically ISR is not very well defined especially when you have color connections between the initial and final states.
- Answer: Use the LL parton shower definition of ISR
  - When you simulate events with ISR find a tagging rate (X), when you simulate without ISR you get another tagging rate (Y). As long as X >> Y you can be confident you're tagging mostly ISR.
  - Note: Even if we add in ME/PS matching the rates, distributions don't change much compared to LO+PS -> This gives us added confidence in our results.