Using Selection Criteria to Optimize Analysis in High Energy Physics

Comparing Methods to Find New Particles

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Outline

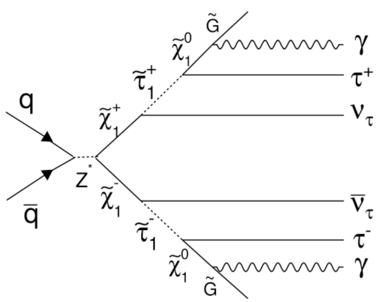
- Overview
  - Motivation for using selection criteria to find new particles
- Using Selection Criteria (Cuts)
- Comparing Different Approaches
  - Single Criterion
  - Two Criteria
- Results

Motivation

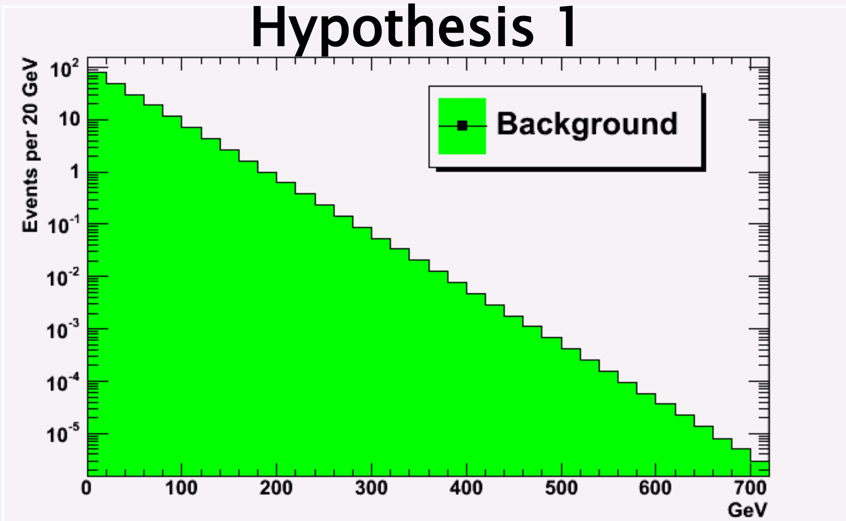
- We want to be more sensitive to new particles in High Energy Physics
- Huge amount of collisions at colliders such as LHC means lots of data to look through
- Many ways to look for new particles
  - However, most are dominated by Standard Model particle “Backgrounds”
  - In some places, new particle “Signal” dominates the Background
- Higher sensitivity means we can better distinguish between Signal and Background, giving stronger results
- Using selection criteria allows us to be the most sensitive to new particles in these regions

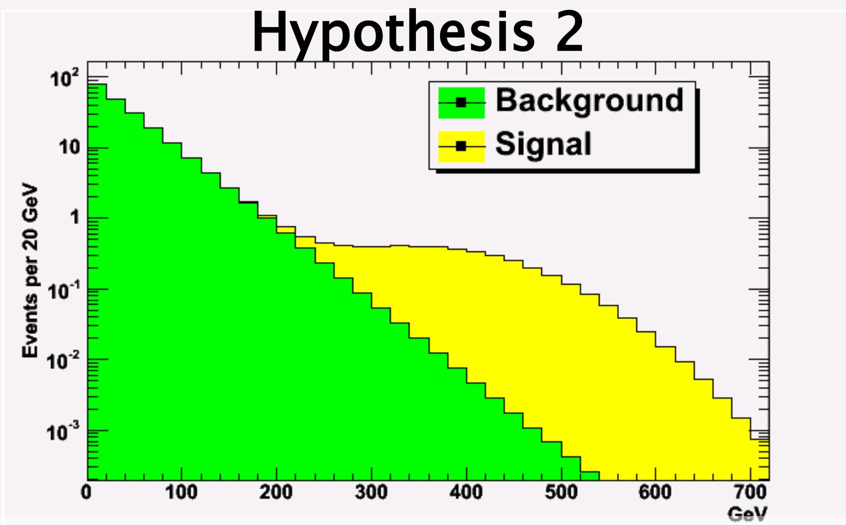
The Data We Used

- Data is from a diphoton search for supersymmetry at Fermilab[1]



- A typical, simple search involves counting
  1. Number of Background events expected
  2. Number of Signal events expected
  3. How many events are observed in the experiment
- Add up observed events to determine which hypothesis is more consistent with data



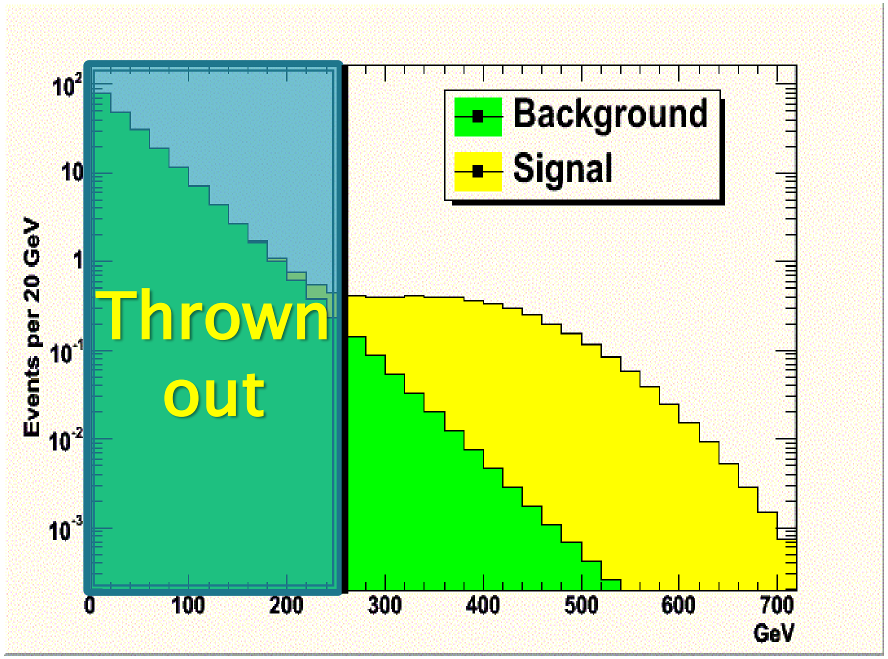


1. Eunsin Lee, TAMU Ph.D. Thesis (2010), PRL 104

Using Selection Criteria (Cuts)

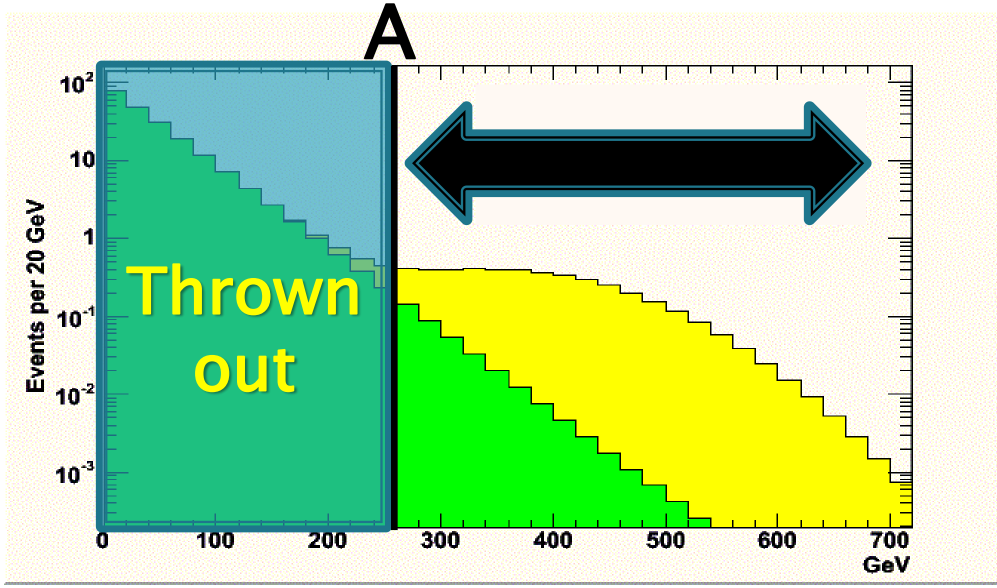
Selection Criteria

- Selection criteria are used to optimize searches
  - Select only events that pass certain criteria
  - New particles easily pass them
  - Few Background events also pass



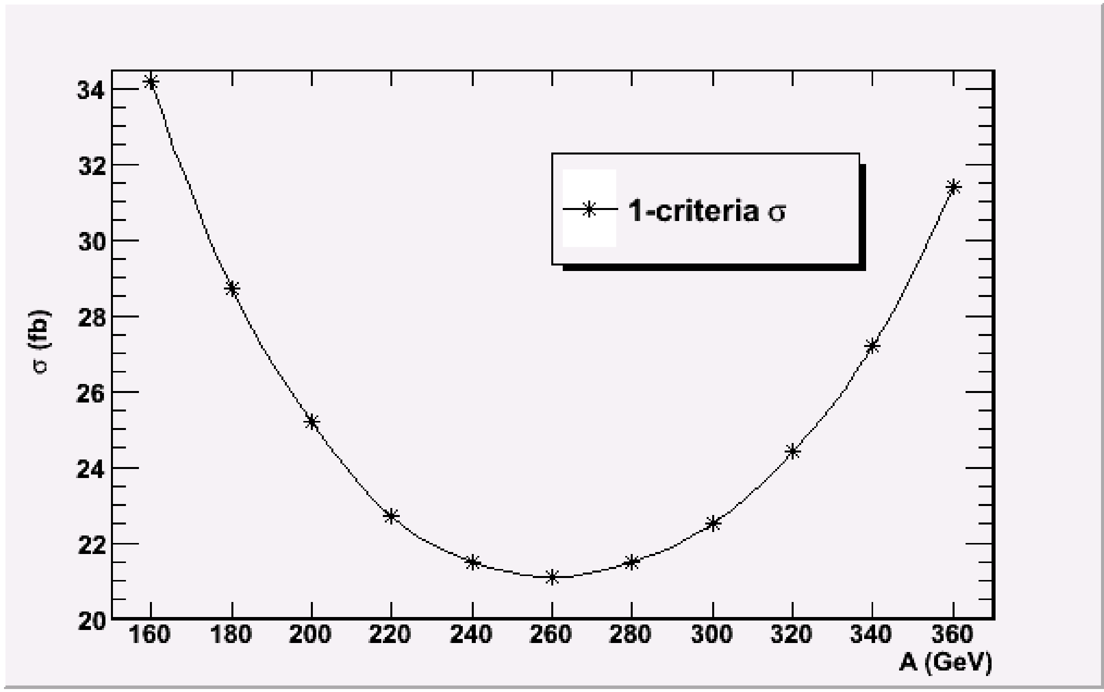
Single Selection Criterion

- Creates a single set of data starting at A
  - Throw out all events that do not pass our criterion, count events from A→∞
    - Lowering the value of A adds in more background, more signal
    - Raising value of A takes out background, but also signal
  - We look at data that is most sensitive to signal



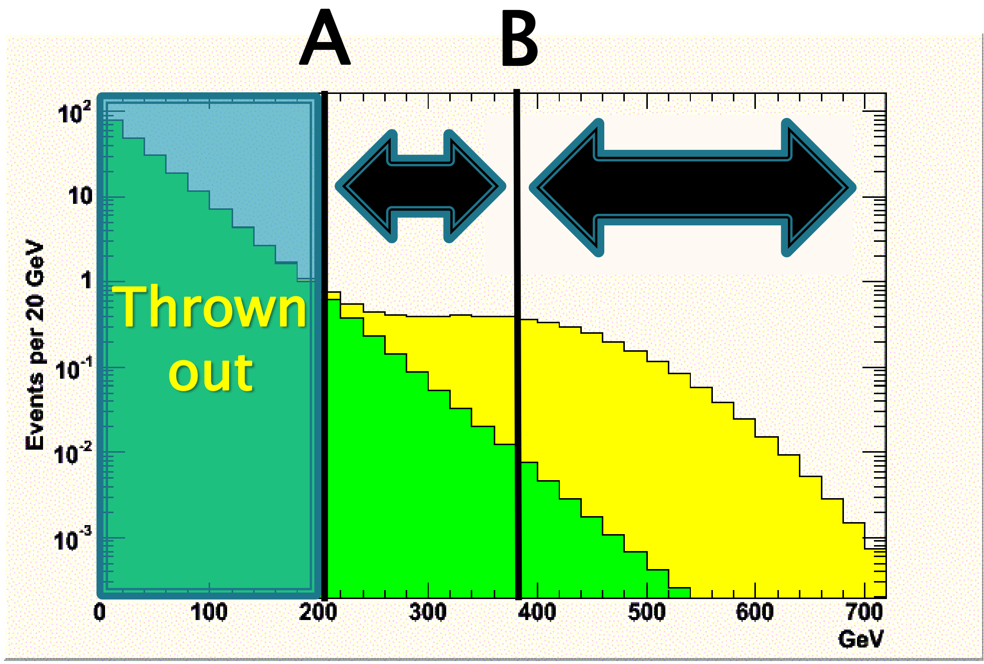
Single Criterion in Experiment

- Cross section, σ, is a quantitative measure of sensitivity
  - Lower σ, better sensitivity
  - Higher σ, worse sensitivity
- Vary A to optimize sensitivity
- Can we get better sensitivity by doing a more sophisticated analysis?



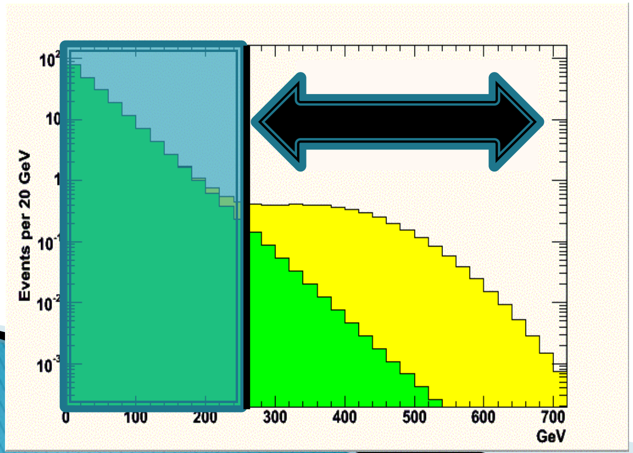
Two Selection Criteria

- Data is placed into two sets
  - Count events from A→B and B→∞
- This is a more sophisticated analysis
  - Does being more sophisticated translate to being more sensitive?
  - Systematic errors can be introduced, we'll deal with the simplest case without them in this talk

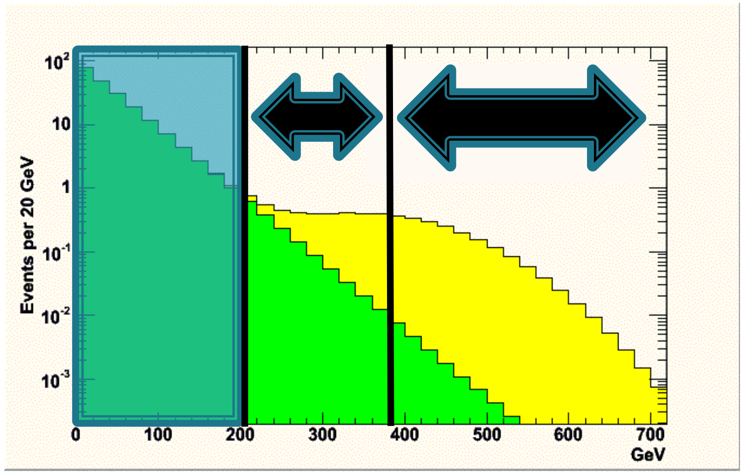


Main Question

- Is it better to do one or two separate sets of independent criteria?
  - If we use two selection criteria, can we become more sensitive to new particles?.....Yes, will show!
  - Is using two selection criteria always more sensitive than using a single selection criterion?.....Surprisingly no, will show!



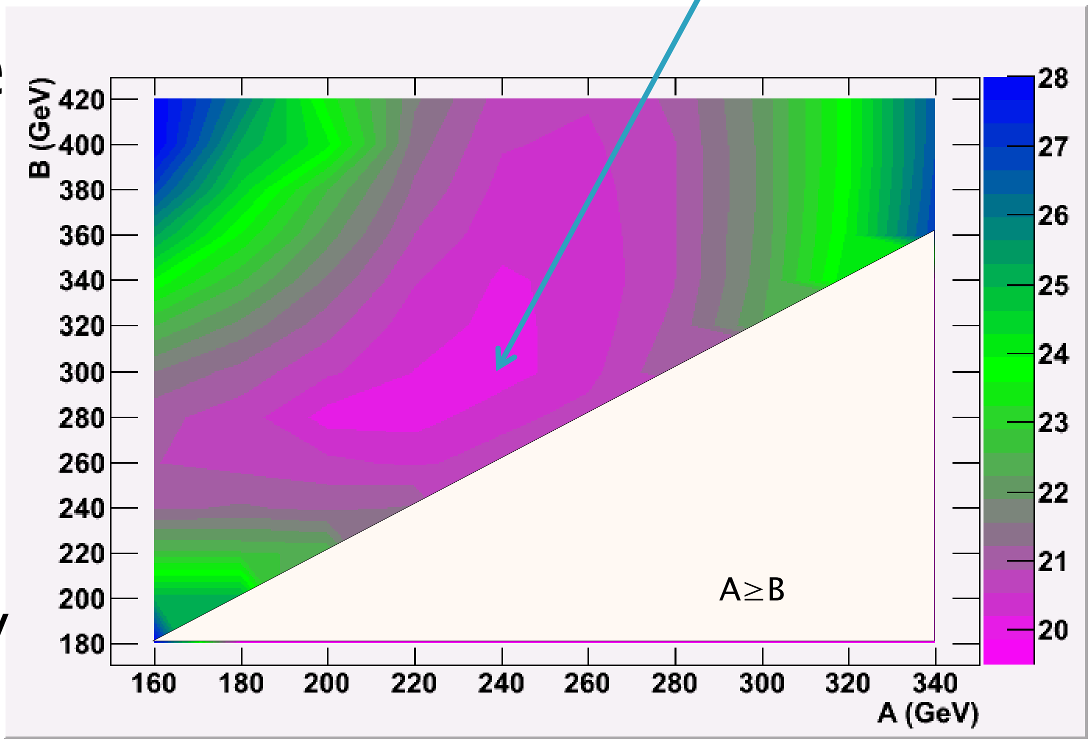
OR



Two Selection Criteria in Experiment

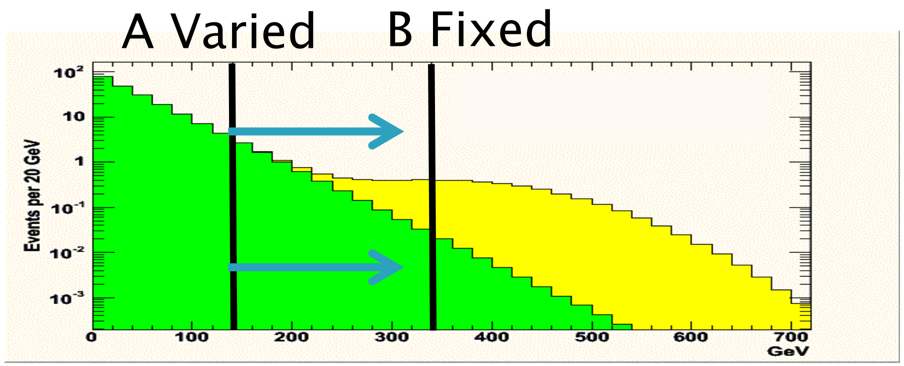
- Optimal criteria give lower σ than the optimal single criterion
  - ≈5% less in this particular experiment
    - More sensitive!
  - Varying A and B to optimize sensitivity

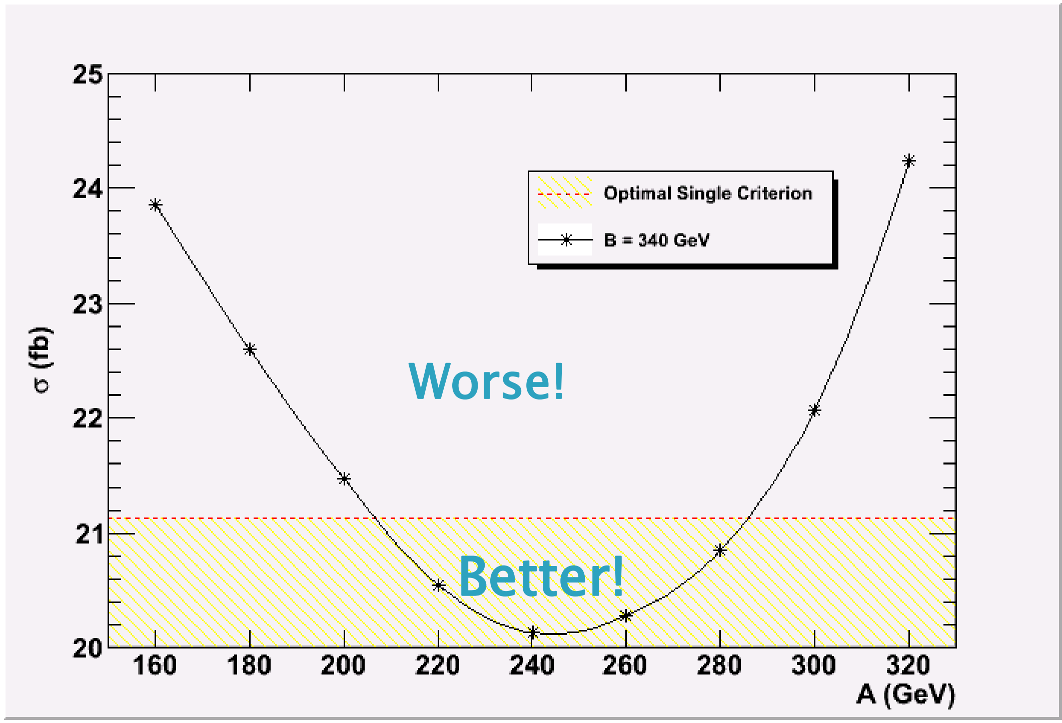
Minimum



Can it be Worse?

- Look at two criteria in one dimension to compare with an optimal single criterion
  - There is a region where two criteria are better
  - However, also regions where two criteria are worse!



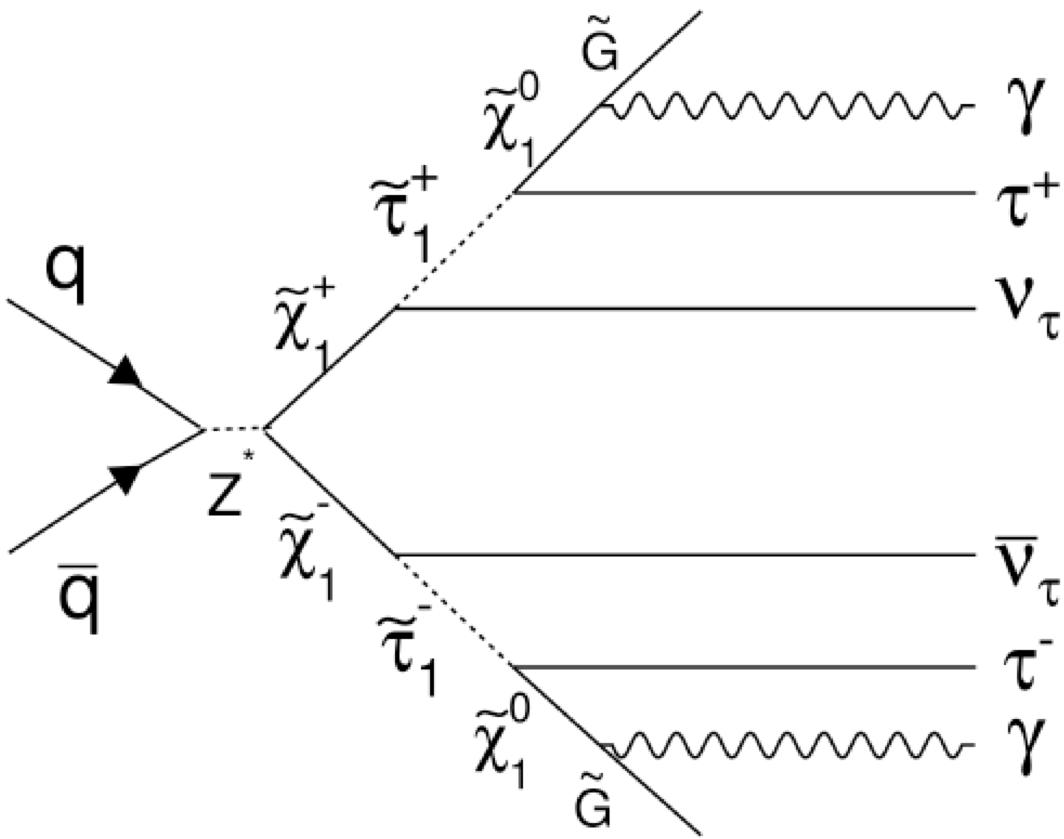


Conclusions

- Our sensitivity to new particles is improved when we use selection criteria
- We have determined that
  - Two criteria **CAN** be better than a single, optimized criterion
    - Need to look for a minimum!
  - Two criteria **CAN ALSO** give a worse result if used incorrectly

BACKUP SLIDES

Signal Events



Limit Calculator

- Example One-Cut input
  - 160
  - 1
  - -1 2.59 .0790 .1218 4.251 .3188
  - 0
- Example Two-Cut Input
  - 360
  - 2
  - -1 2.59 .0399 .1218 4.218 .3188
  - -1 2.59 .0391 .1218 .0326 .3188
  - 0

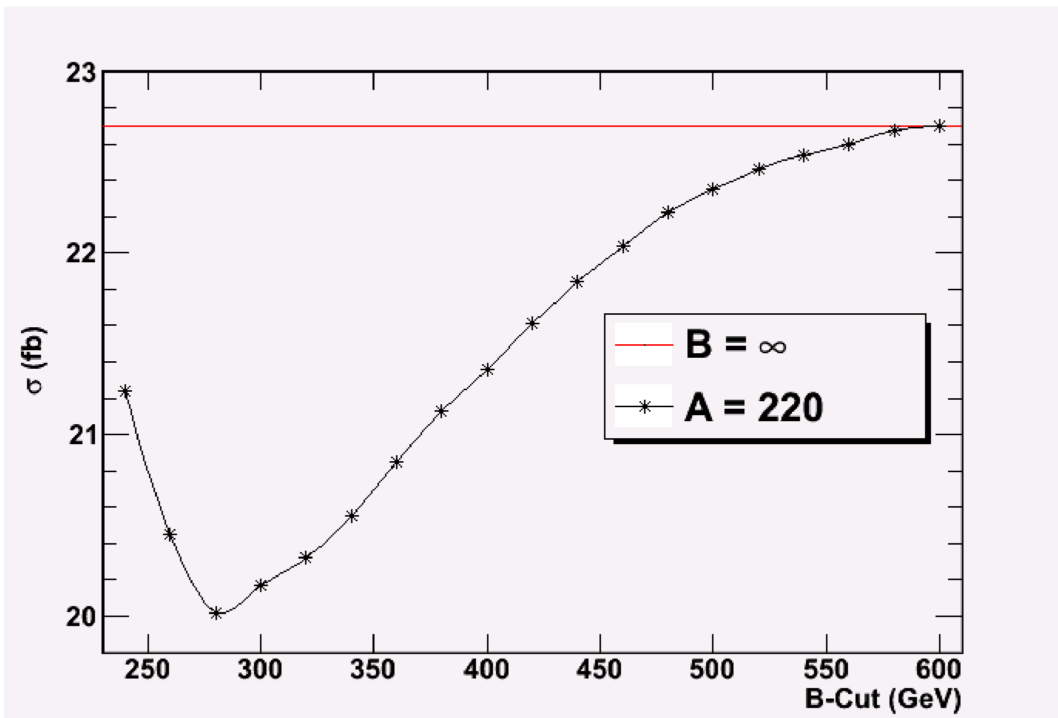
Expected Cross Sections

- N_{events} = Luminosity * $\sigma_{production}$ * Acceptance
- Find 95% confidence limits on $\sigma_{production}$
  - Taking cuts allows us to optimize expected σ
  - $$\sigma^{95}_{expected} = \sum_{N_{obs}=0} Poisson(N_{obs}) * \sigma^{95}(N_{obs})$$
- Used improved Limit Calculating program[1]

1. Developed by Dr. Joel Walker, Sam Houston State University

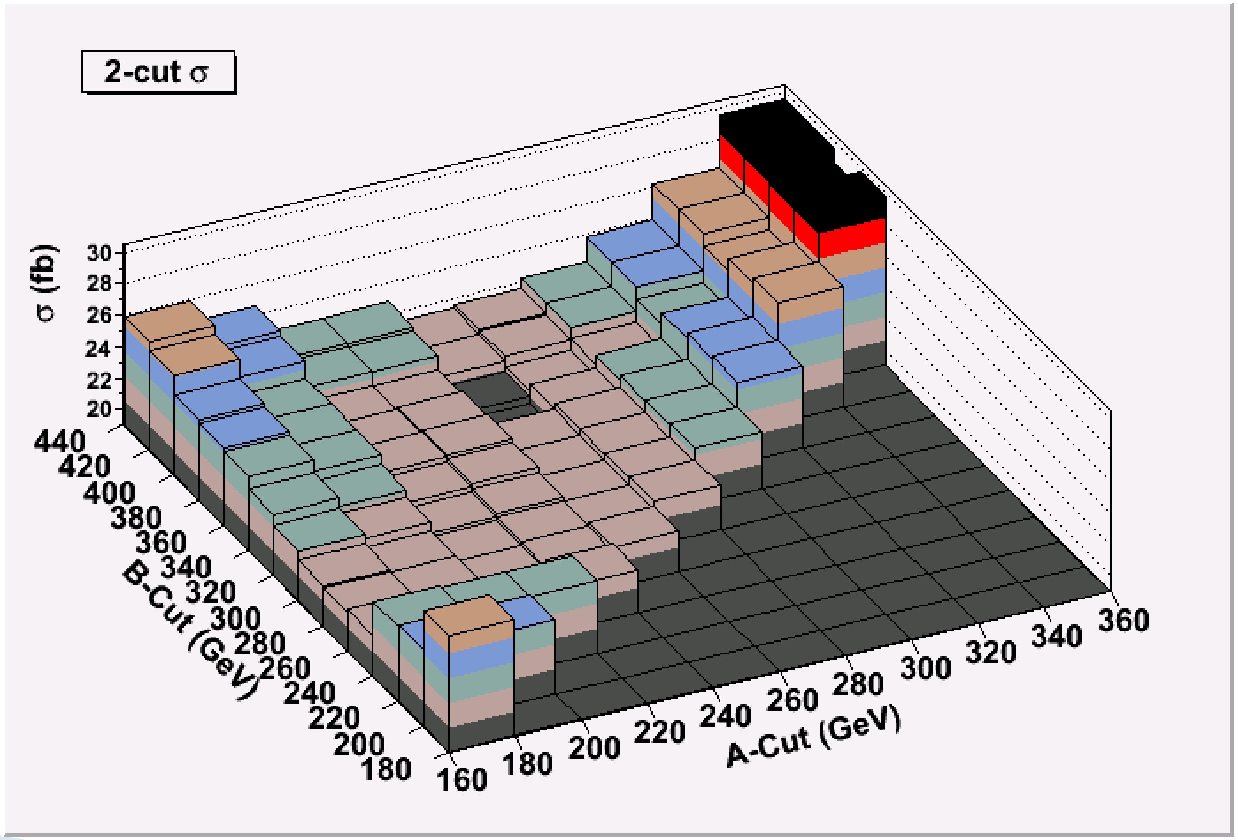
Splitting Single Cut into Two

- If you take a single cut and place a B cut in it, you will always improve your sensitivity
  - Possibly not much better, but never worse



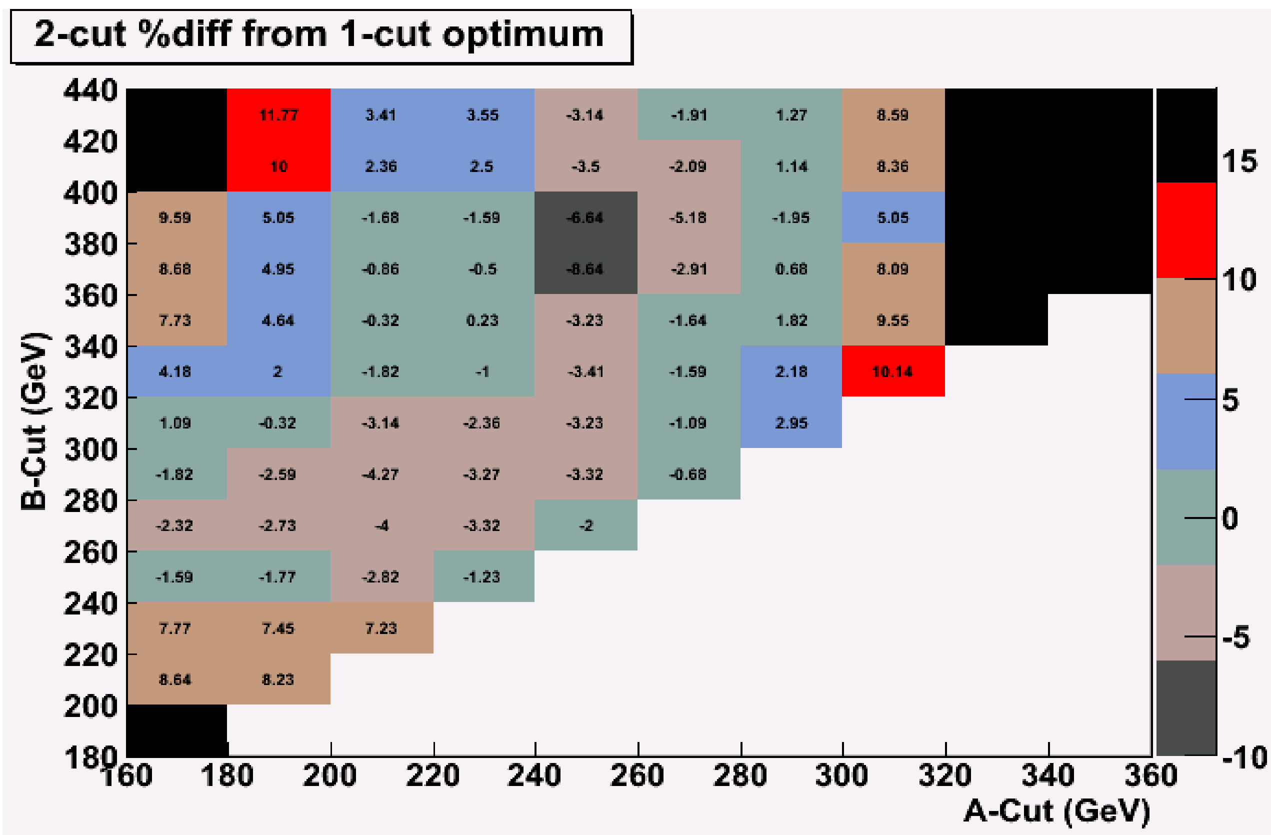
Binned Value Two-Cut

- The optimal cuts give 20.1 fb at A:240 B:360



Percentage Decrease

- Two cuts can be used to improve the optimal expected limit
  - Able to achieve slightly under 10% decrease (8.64%)



Acceptance

- $A_{signal} = \frac{N_{events}^{passing\ requirements}}{N_{events}}$
- Related to signal by a scaling factor