Search for 4-jet Decay Modes from Colored Resonances in $p\bar{p}$ Multijet Channels at CDF at sqrt(s) = 1.96 TeV

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Introduction

- How do we find new particles?
  - Direct observation, recoil (positron, muon, antiproton)
  - Missing energy (neutrino)
  - Extra energy (neutron, π^0)

- New method: Monte Carlo comparison of decay products
  - Predict new particle and compute its decay modes and σ
  - Take data, model background
  - Compare SM with prediction MC. Do you see a resonance?

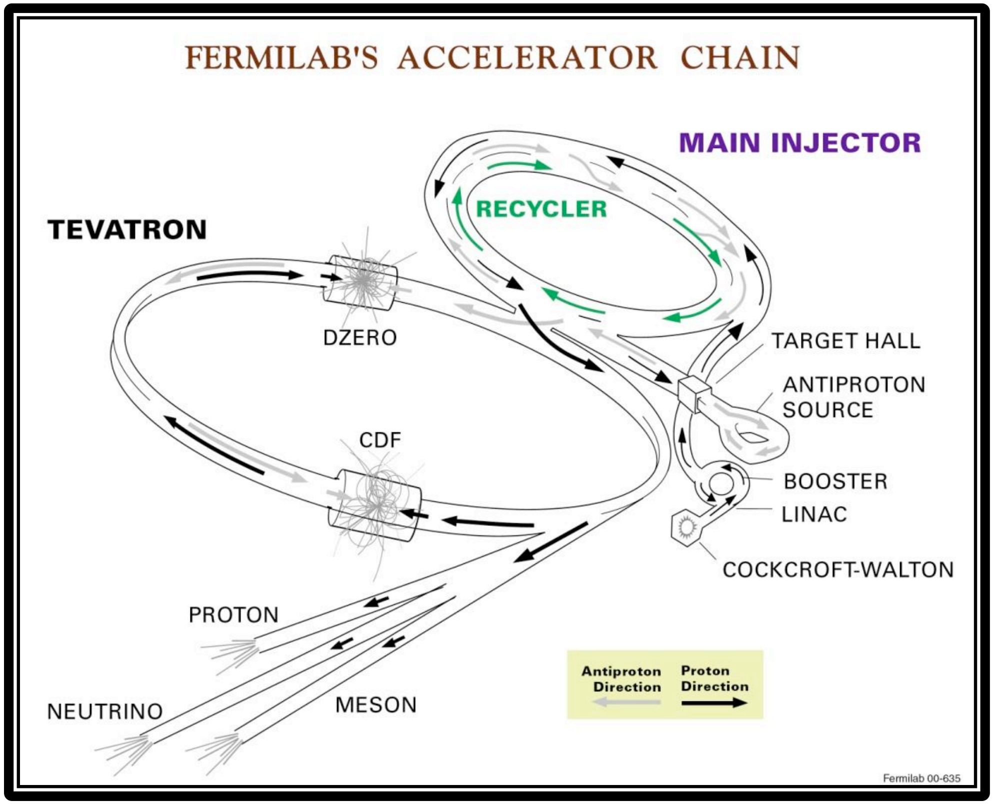

Figure 1. The Tevatron Beamline

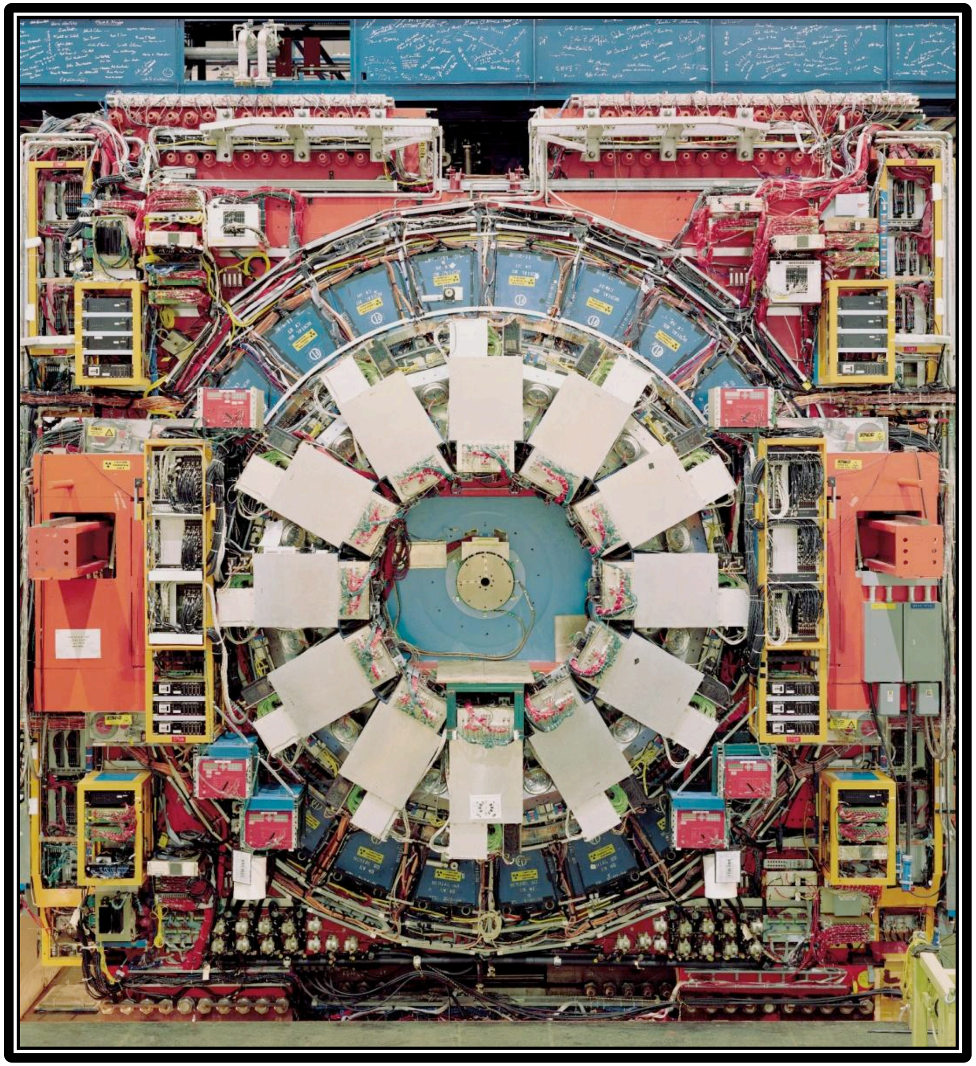

Figure 2. Collider Detector at Fermilab: Hermetic Tracker/Identifier

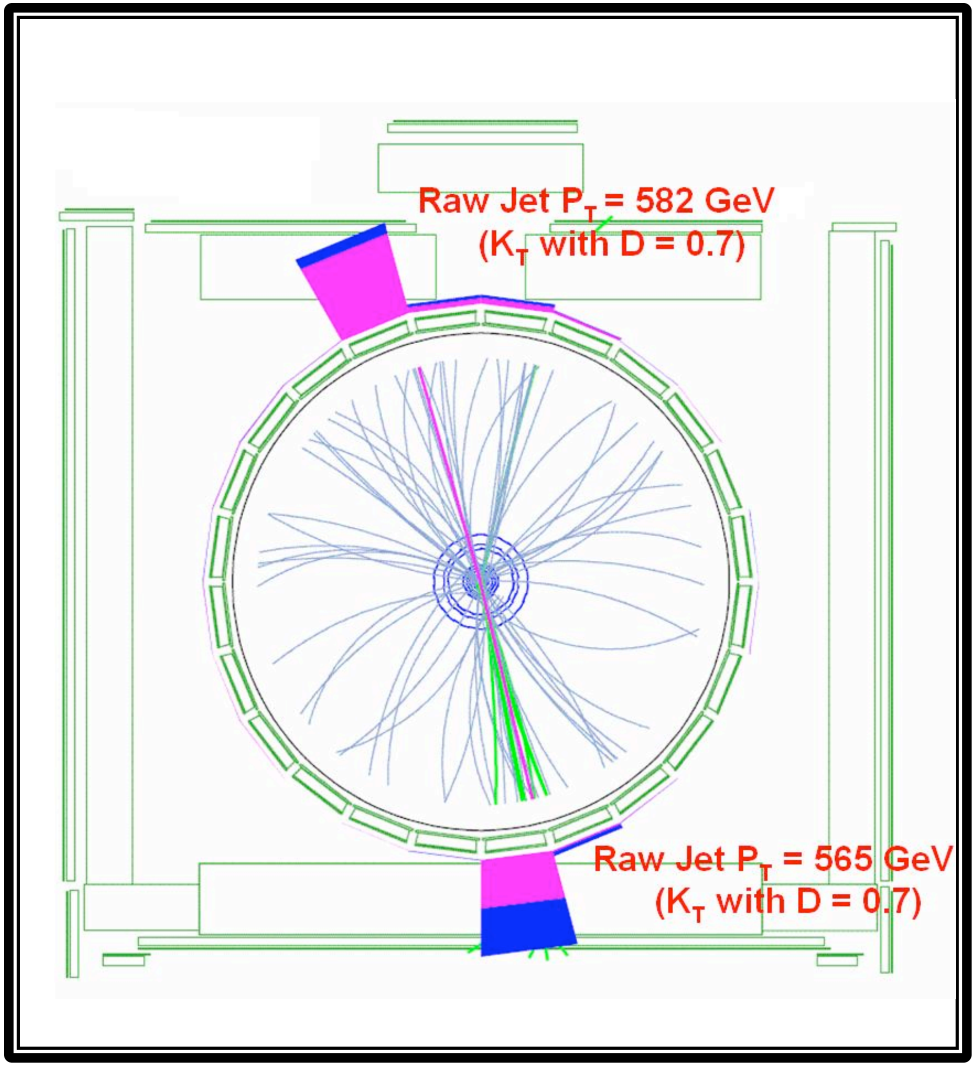

Figure 3. High Energy Dijet Event: Towers are Calorimeters

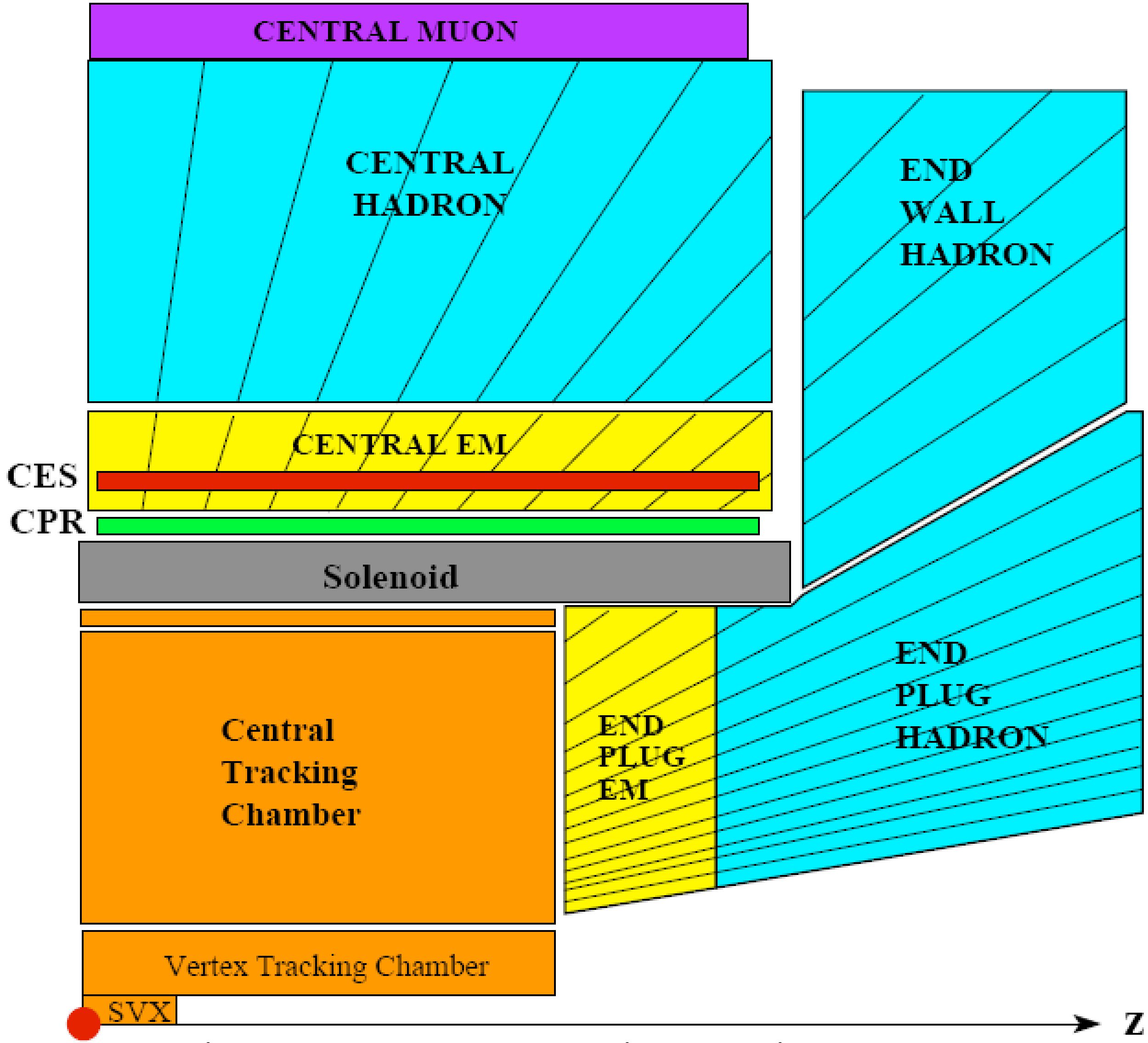

Figure 4. CDF Interaction Region Cutaway

Previous Work

- 1996. "*Colorons: Theory and Phenomenology.*" Simmons
- 1997. "*Search for New Particles Decaying to Dijets at CDF.*" CDF
- 1998. "*Evidence for 4 Jet Resonances.*" Kondo, Watanabe
- 2003. "*Phenomenology of Technihadrons in TCSM.*" Lane, Mrenna
- 2007. "*Massive Color Octet Bosons.*" Dobrescu, Kong, Mahbubani
- 2008. "*Dijet mass resonances.*" Hatakeyama, Bhatti, Harris
- 2008. "*Colored Resonances at the Tevatron.*" Kilic, Okui, Sundrum

Expected Phenomenology

- Massive Boson decays into intermediates, which decay into Dijets
- Same invariant mass (M_{jj}), low background $|Mjj - Mjj| \leq \frac{1}{x}(Mjj + Mjj)$

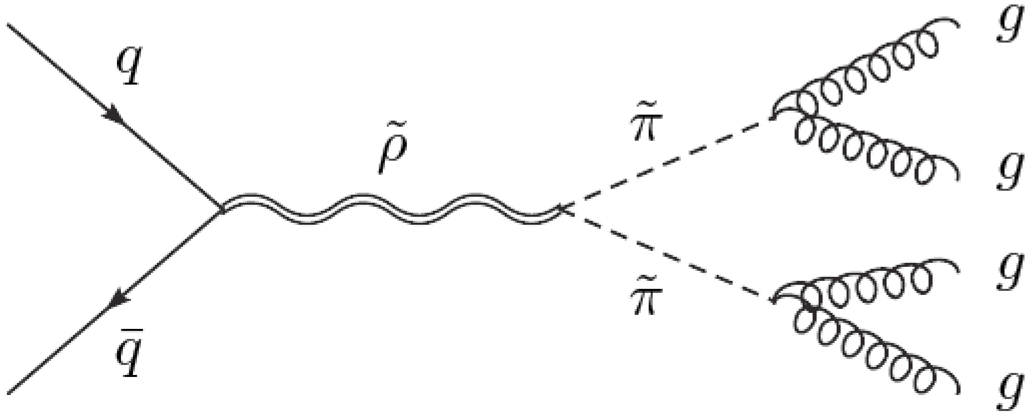

Figure 5. Feynman Diagram of Coloron Decay

Motivation

- Easier to find colorons at the Tevatron than the LHC
  - p-pbar gives larger cross section for q-qbar than pp
  - channel is qq dominated while background is gg dominated

- Existing bounds do not rule out a massive color octet boson with spin=1 case when boson has no electroweak charge or flavor.

- Challenge: “Exact limits on the discovery reach will depend on
  - a careful estimation of background
  - a realistic treatment of detector effects
  - a careful statistical definition of what is discoverable… ”

  - C. Kilic, T. Okui, R. Sundrum . JHEP 0807:038,2008

Methodology

- Phase 1: Model background (complete)
  - Multijet background is notoriously hard to model
  - Compare background models to small sub-sample of data
  - Give insight into possible cuts

- Phase 2: Increase Sensitivity (ongoing)
  - Find selection criteria to improve signal-to-noise ratio
  - Prove decay is discoverable within MC

- Phase 3: Compare 3.6 fb^{-1} of data (ongoing)
  - Look for 4-jet signal in available data, compare with MC
  - If there is a resonance: you just discovered a particle!
  - If not: set constraints on coloron mass & σ, cry a little…

Phase 1: Multijet Combinatorics

- We need to find two 2-jet decays in a 4 (or more) jet event
- CDF stores four-vectors for each jet, ordered by energy

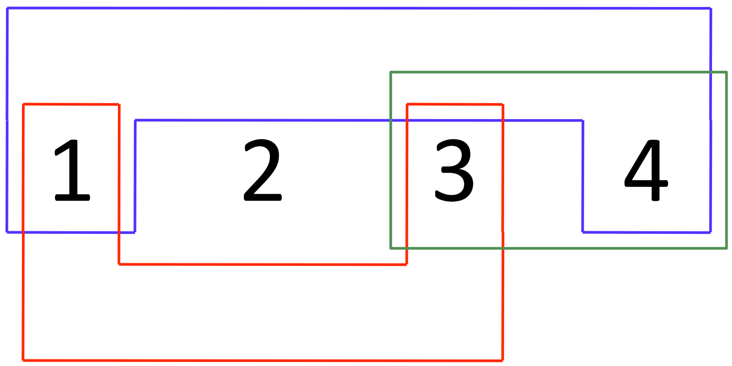

Figure 6. We must choose a "best matched pair" to consider Dijets

Phase 1: Kinematics Study

- Compared QCD from data against weighted-ALPGEN and PYTHIA (min=90) background
  - Simulates decay modes though brute force random solutions
  - Takes into account detector response, jet missmeasurement

- Global Cuts
  - $E_t[0] > 130$ && $E_t[1] > 40$ && $E_t[2] > 40$ && $E_t[3] > 40$ GeV
  - $\not{E}_t$ significance < 5 (removes cosmics)
  - $|\eta| < 2.4$ (selects only central hadron)
  - |zvertex| < 60 cm

- Scaled ALPGEN & PYTHIA to data for shape comparison

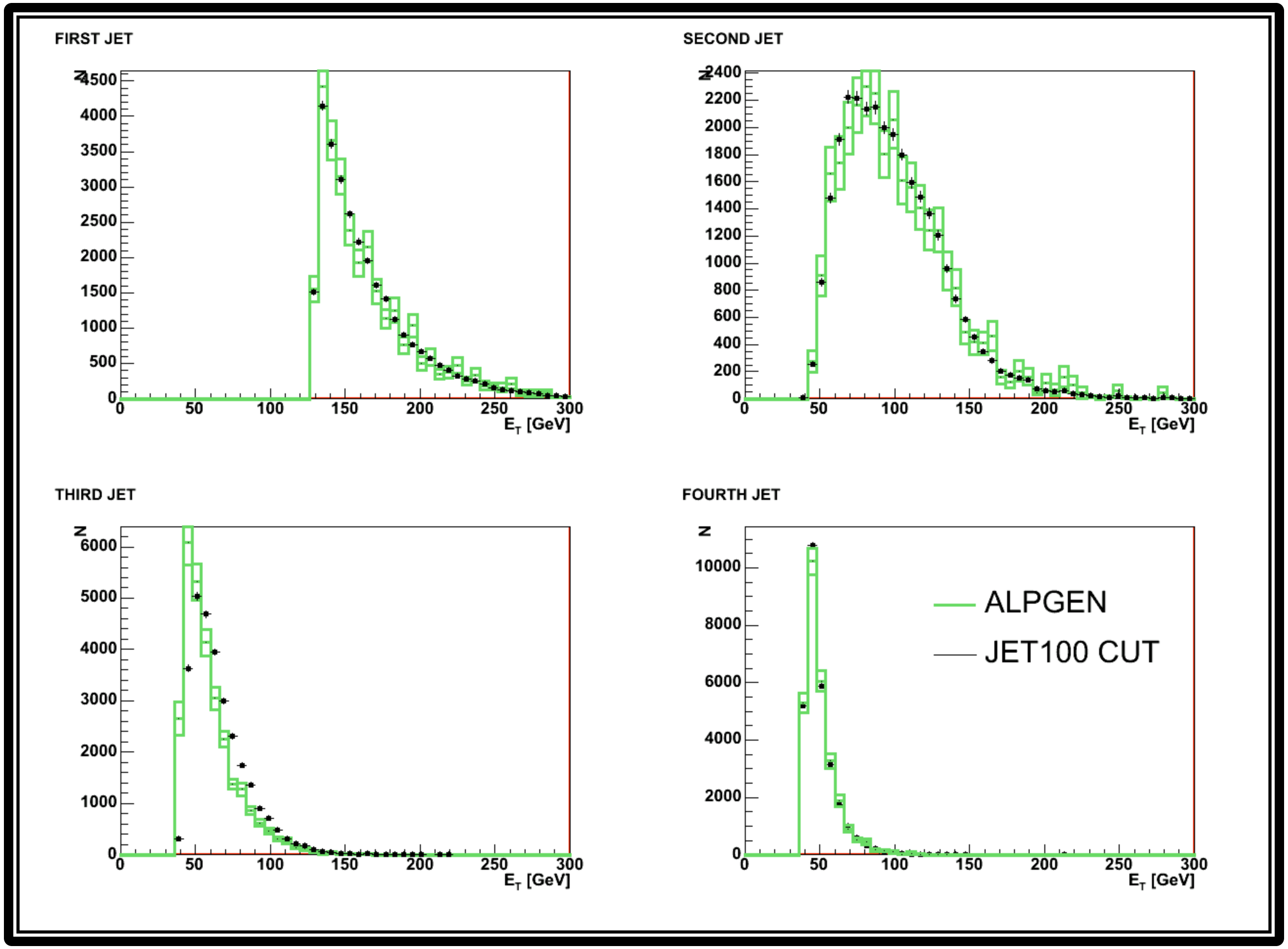

Figure 7. Comparison of Data and weighted-ALPGEN

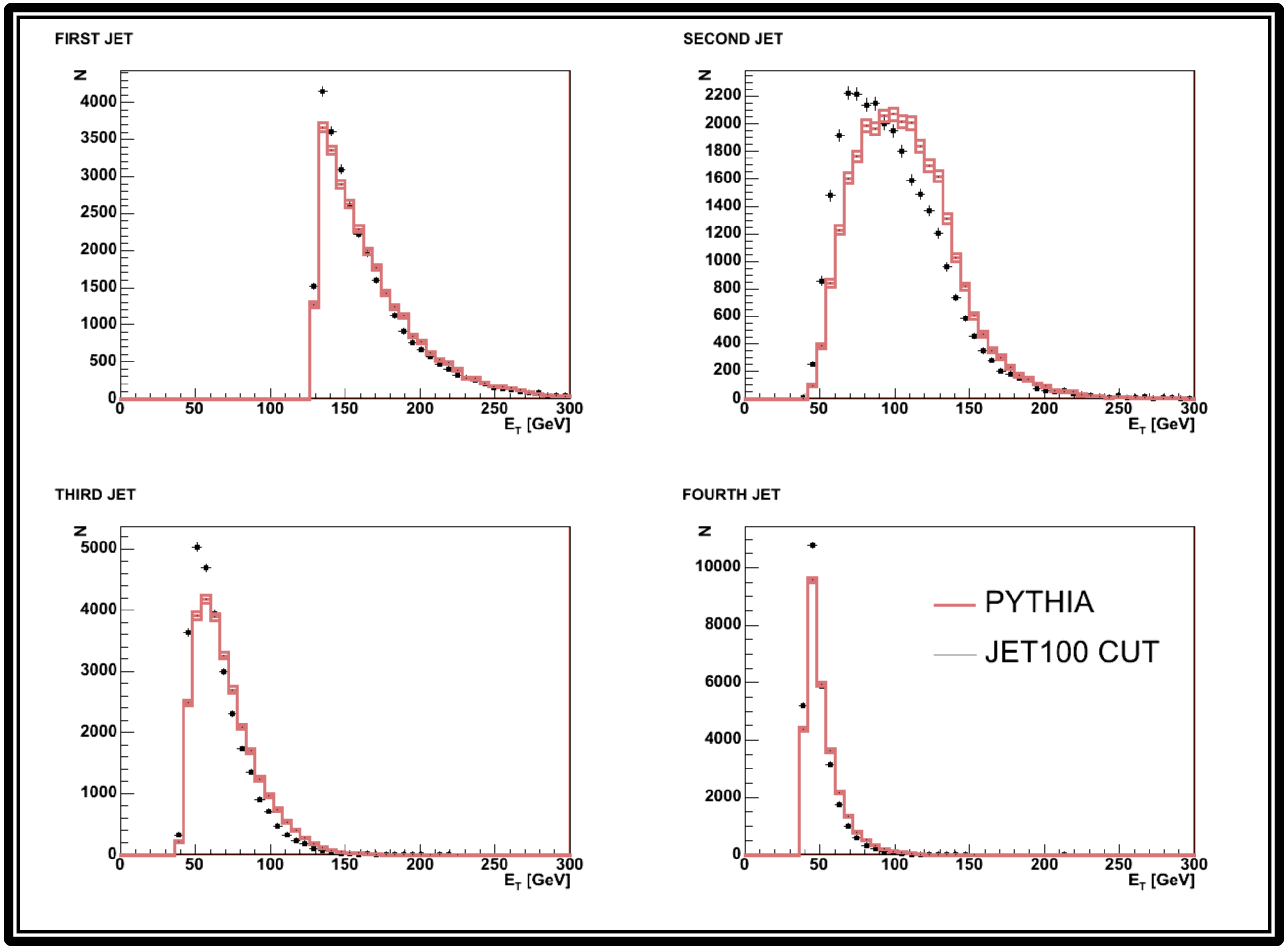

Figure 8. Comparison of Data and PYTHIA (min=90)

Phase 1: Multiplicity Study

- Compared number of jets per event from JET100 trigger against weighted-ALPGEN and PYTHIA (min=90) background

- Cuts
    - $E_t[0] > 130$
    - $\not{E}_t$ significance < 5 (removes cosmics)
    - $|\eta| < 2.4$ (selects only central hadron)
    - |zvertex| < 60 cm

- Scaled ALPGEN & PYTHIA to data

- Compared ratio of MC to JET100

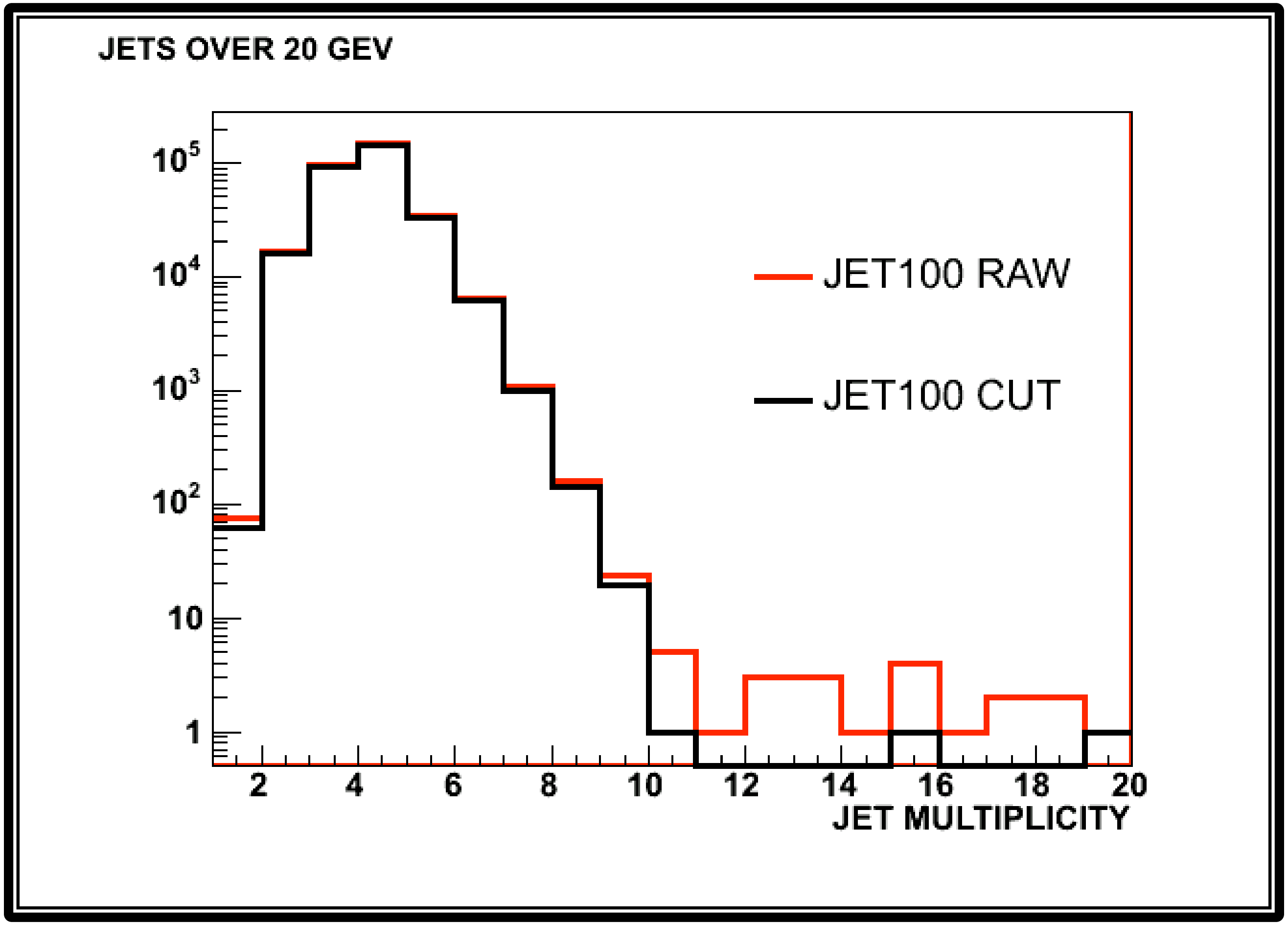

Figure 9. Comparison of Data and Data + Cuts

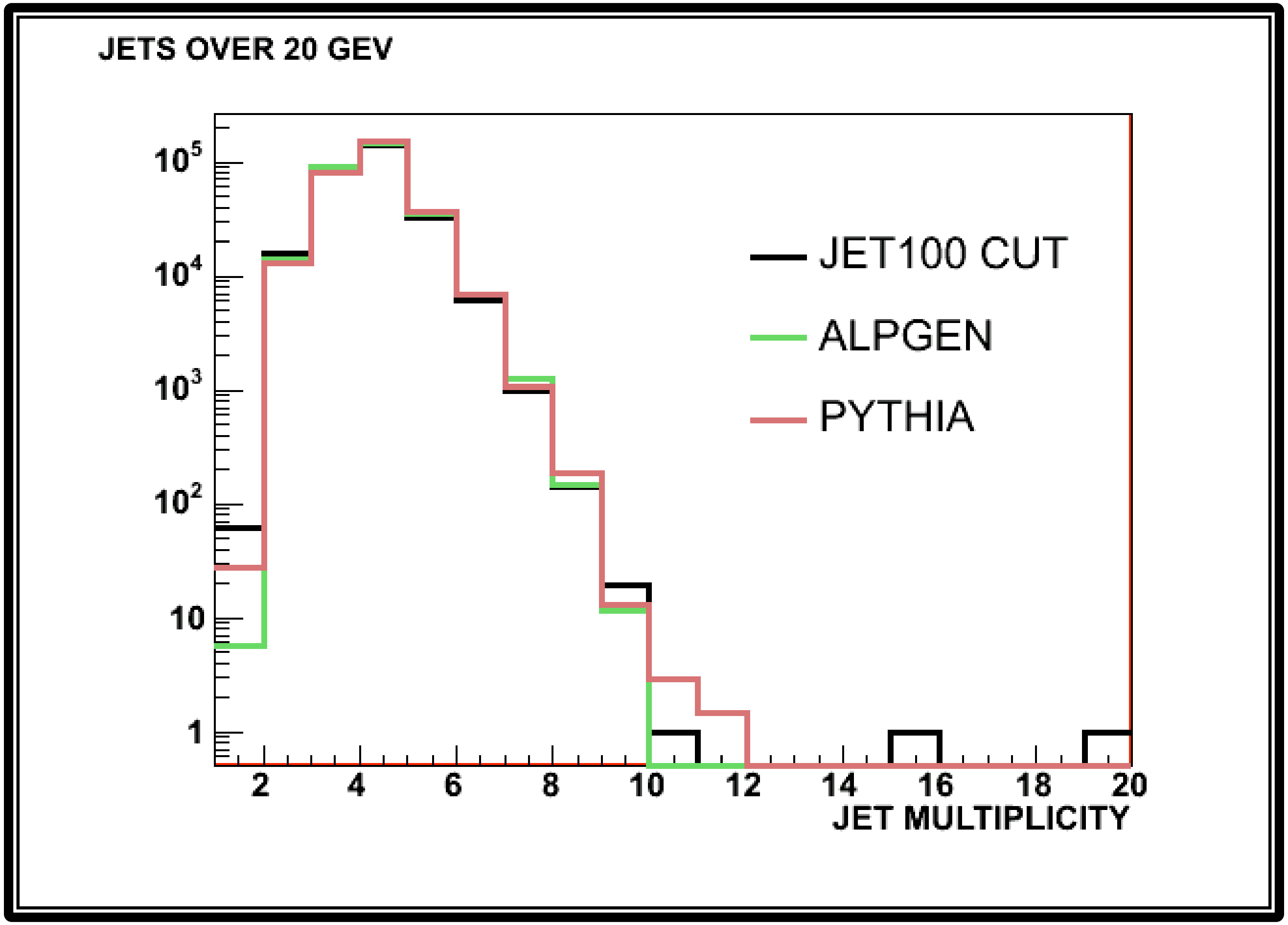

Figure 10. Comparison of Data and MC-background

Phase 1: Conclusions

- ALPGEN has better shape agreement
- We will need to optimize other kinematic variables
- MC agreement is a surprise, simulates multiplicity very well
- Optimistic we can use MC to model background

Phase 2: Optimization for M_{jj} + M_{jj} Resonance Sensitivity

- Pseudosignal MC events generated for $W^+ + W^-$
  - Production assuming M_W = 180 GeV
  - Require W's to decay hadronically into Dijets

- Background MC vs. Pseudosignal MC
  - Make Cuts on (Mjj + Mjj)/2 and |Mjj – Mjj|
  - Look for other ways to discriminate against background

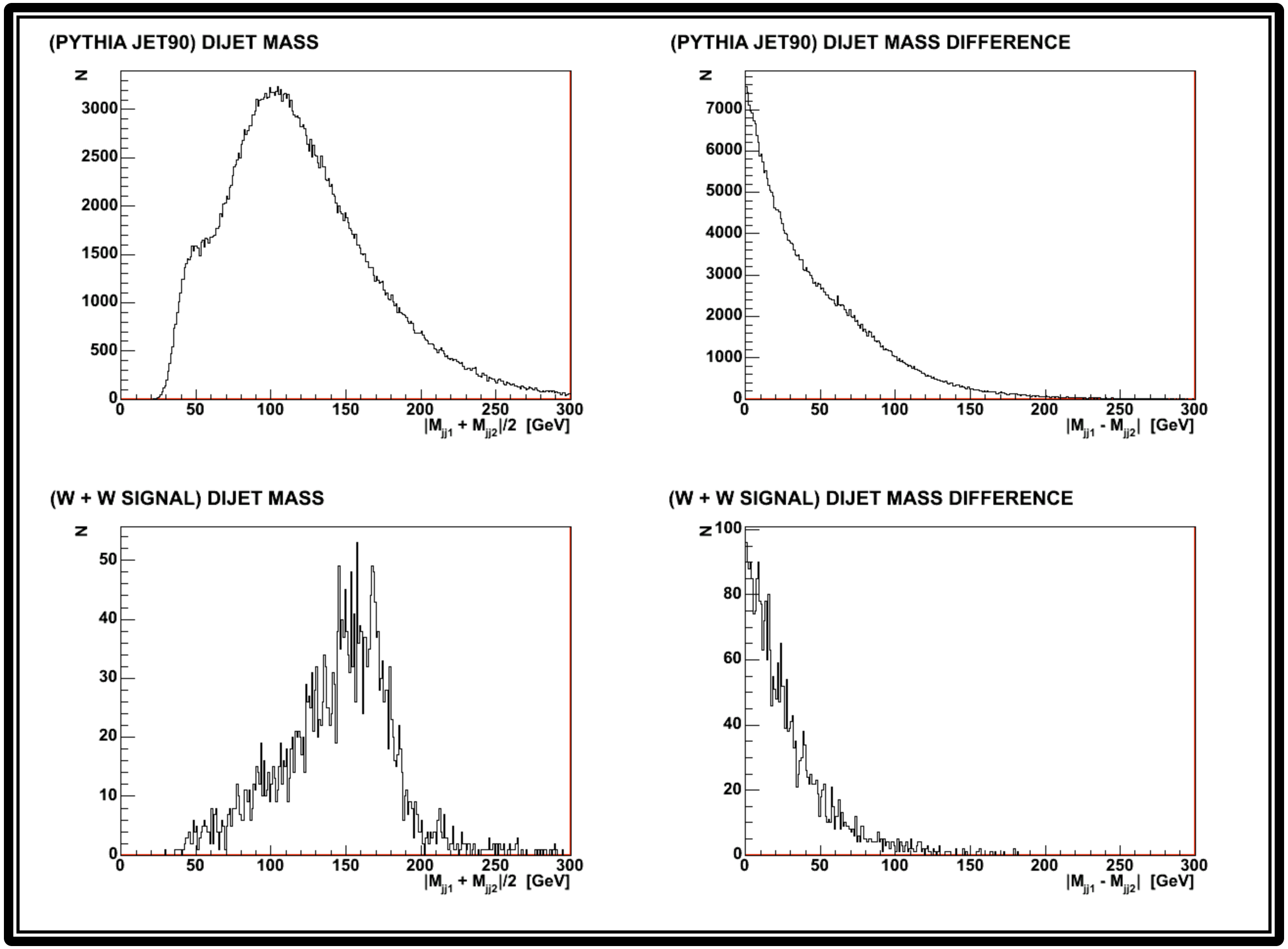

Figure 11. Pseudosignal MC and Background MC

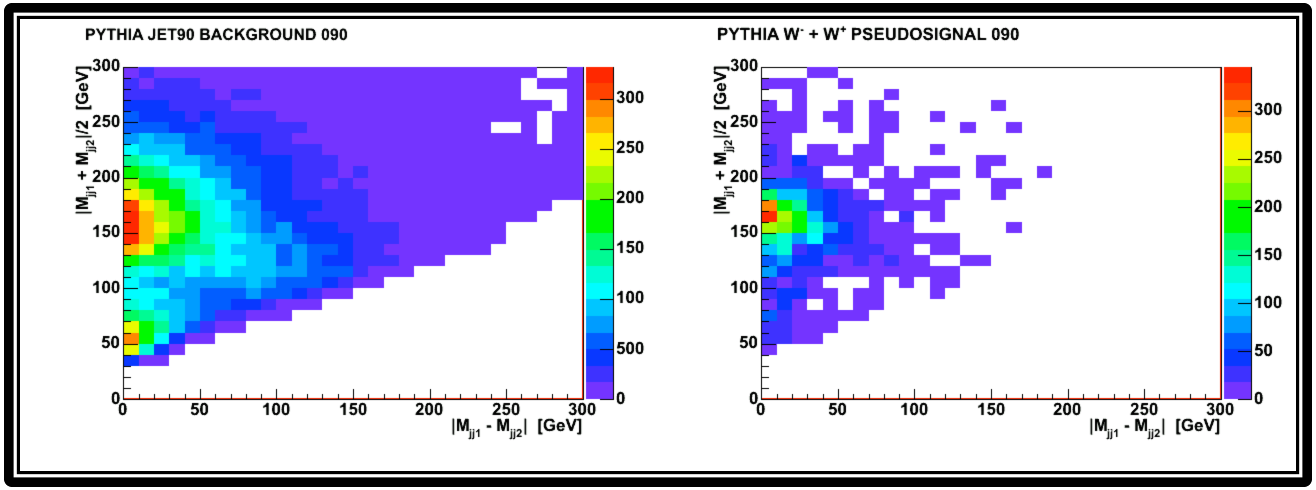

Figure 12. $|M_{jj} - M_{jj}|$ vs. $|M_{jj} + M_{jj}|/2$ for Several Leading Jet E_t Cuts

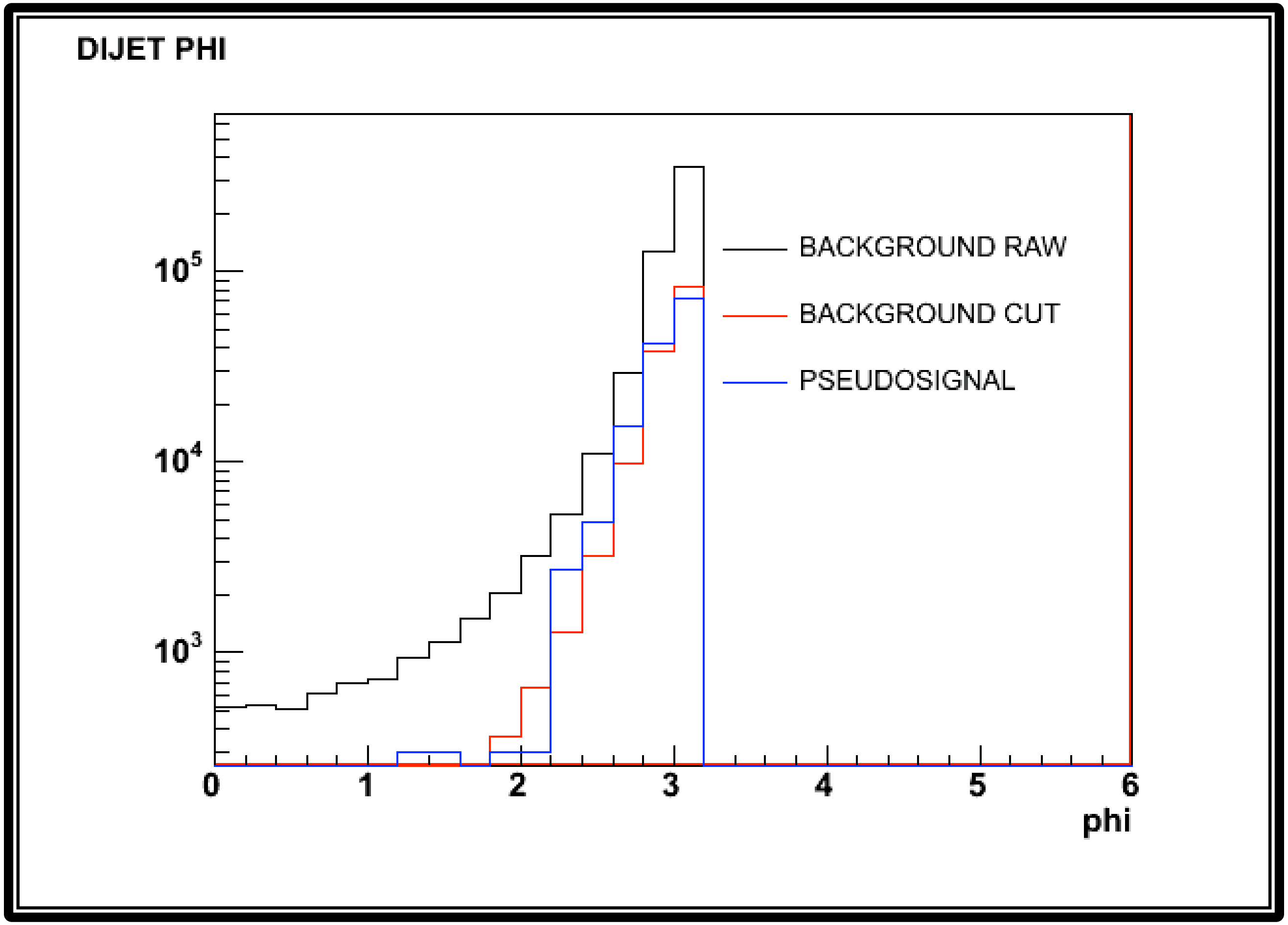

Figure 13. Dphi for Pseudosignal MC and Background MC

Phase 3: Comparison of Predicted Distribution to 3.6 fb^{-1}

- Final step in analysis
- Compare cut-MC with SM and Multijet Data
  - Look for signal in Multijet data
  - Compare data with Multijet SM prediction and look for excess
  - $\int L\, dt = 3.6 fb^{-1}$
- Stay tuned!

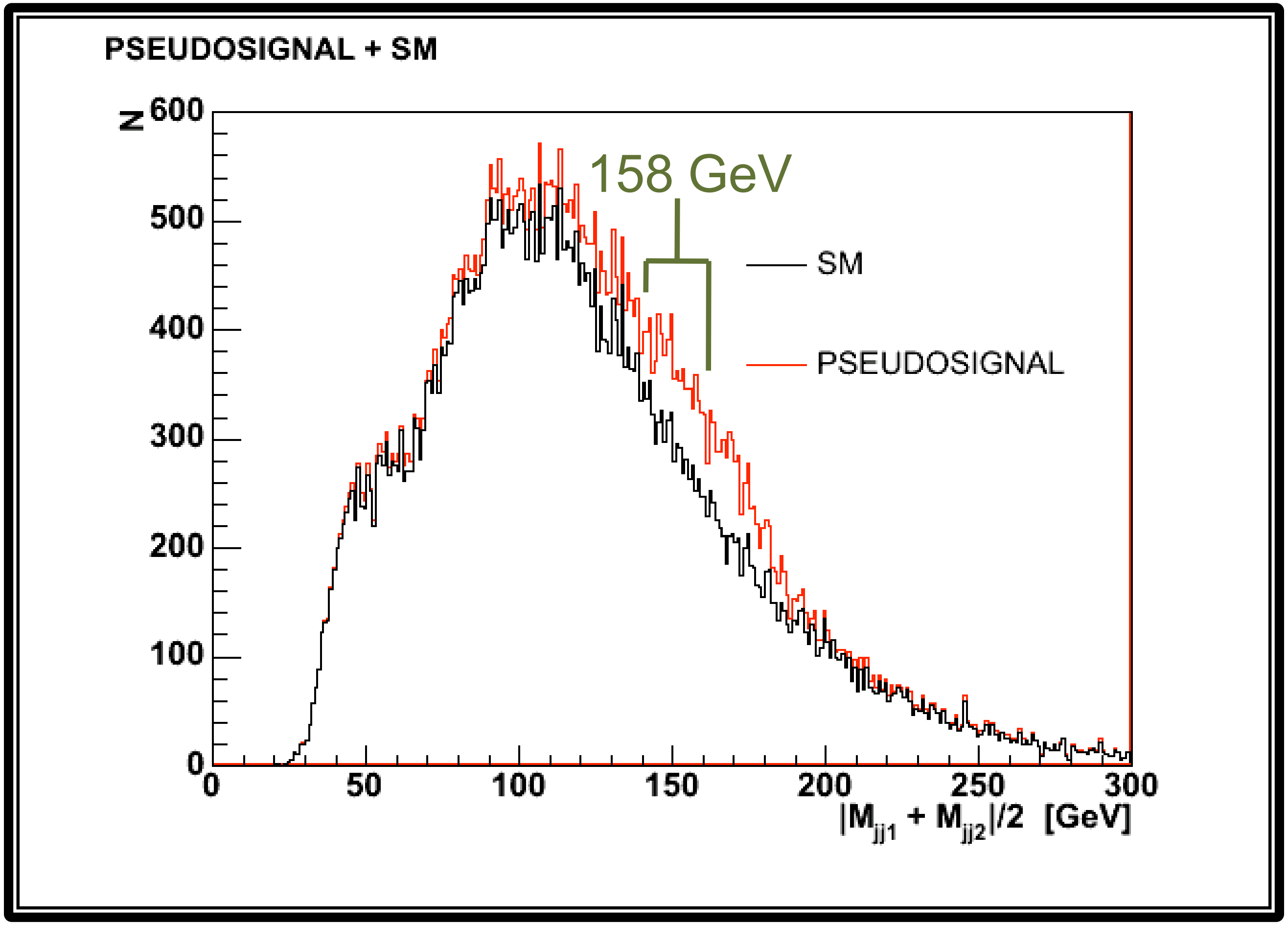

Figure 14. Resonance in MC. Coloron Might Look Like This.

Acknowledgements

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CDF

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U.S. DEPARTMENT OF ENERGY

Coloron Phenomenology. E.H. Simmons

- proposes an extension to strong gauge group
- predicts eight new flavored massive bosons termed “colorons”
- predicts lightest coloron mass above 150 GeV

Search for New Particles Decaying to Dijets at CDF. CDF

- survey using 106 pb^{-1}
- $\eta < 2.0$ && $-2/3 <= \cot\theta <= 2/3$
- restricts coloron mass above 200 GeV

Evidence for 4 Jet Resonances. K. Kondo, T. Watanabe

- result of 6 jet analysis in 1997
- requires 240 GeV < M_{jj} + M_{jj} < 480
- dijet resonances at (120,125), 115, (140,145), and 175 GeV

Phenomenology of Technihadrons in TCSM. K. Lane, S. Mrenna

- different model: topcolor-assisted technicolor straw man
- assumes massless partons, includes full propagator structure
- lightest coloron confined, restricts mass above ‘several’ TeV

Massive Color Octet Bosons. B. Dobrescu, K. Kong, R. Mahbubani

- predicts coloron observation at CDF below 350 GeV with $1fb^{-1}$
- case 1: spin = 1 decays into two dijets with similar inv. mass
- case 2: spin = 0 decays into b-bbar, smaller cross section

Colored Resonances at the Tevatron. C. Kilic, T. Okui, R. Sundrum

- model-independent study only considers gluon-coloron mixing
- demonstrates resonance is consistent with previous bounds
- paper outlines search strategy for 350 and 600 GeV cases

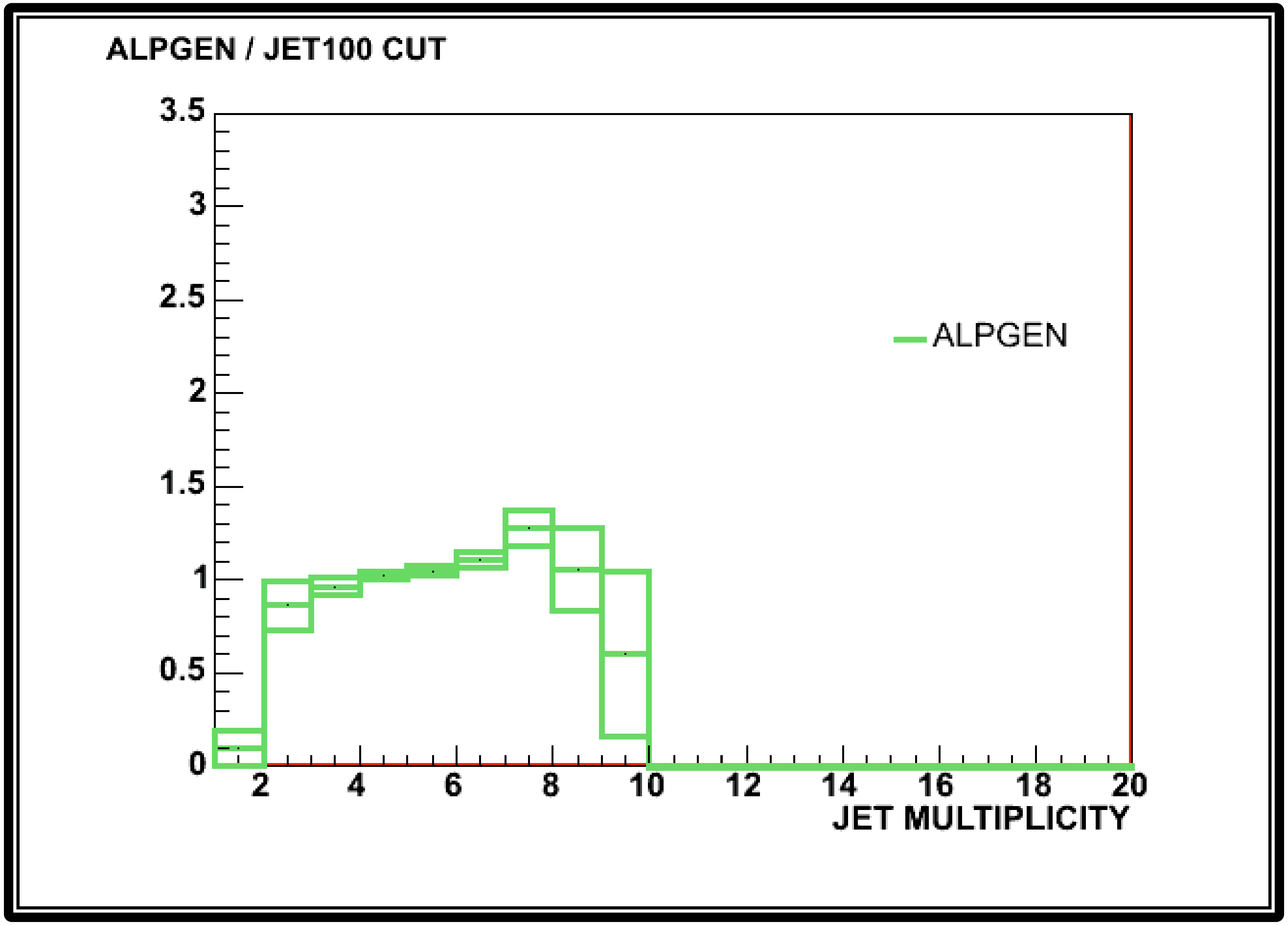
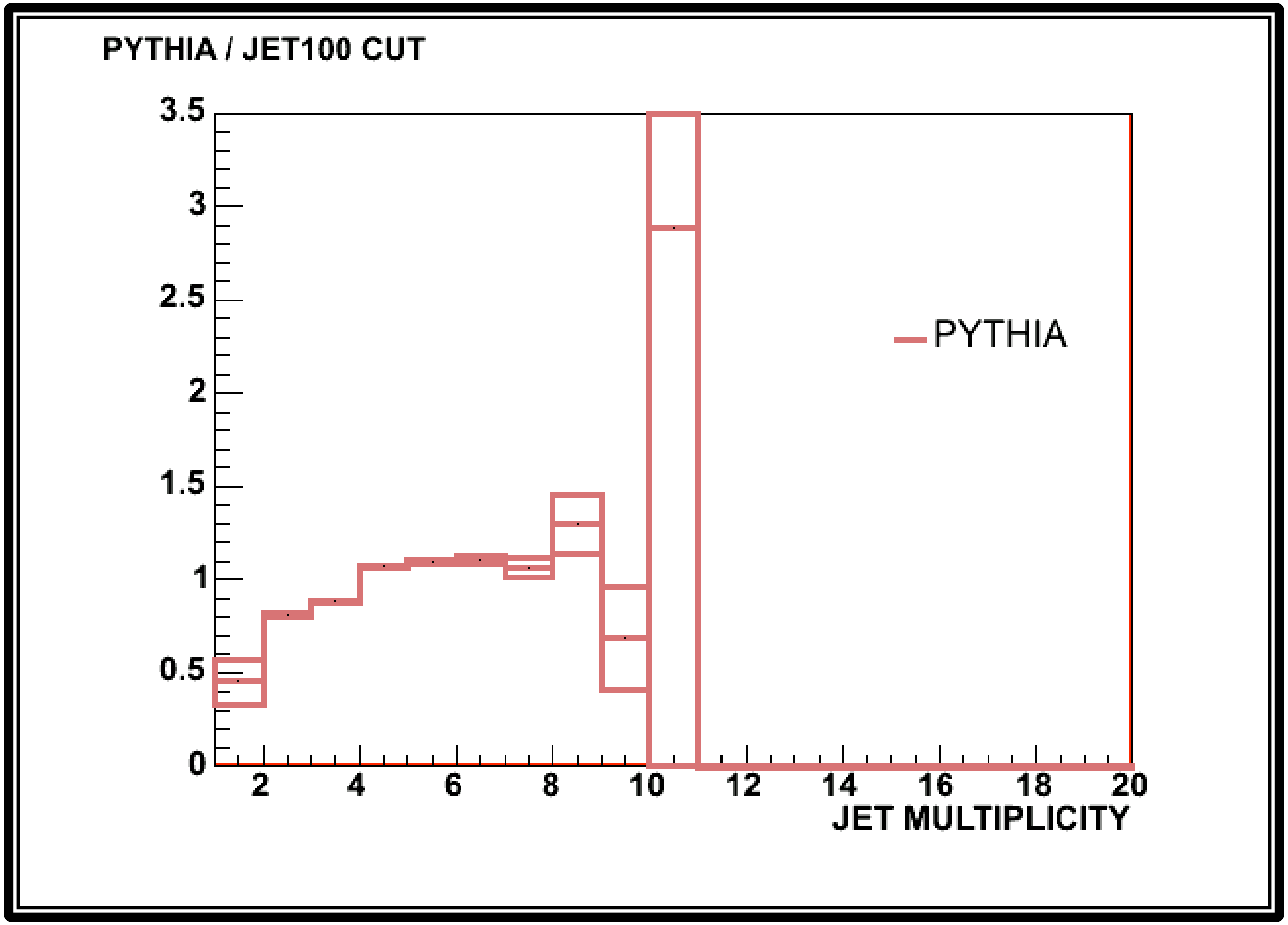

ALPGEN / JET100 CUT
3.5
3
2.5
2
1.5
1
0.5
0
ALPGEN
2
4
6
8
10
12
14
16
18
20
JET MULTIPLICITY

Figure 15.


PYTHIA / JET100 CUT
3.5
3
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JET MULTIPLICITY
PYTHIA

Figure 16.