New Physics Searches at Fermilab

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Summary

1. Search For Neutral, Long-Lived Particles at CDF
   - Introduction
   - Model
   - Results

2. Search for Charged, Long-Lived Particles at D0
   - Introduction
   - Model
   - Results

3. Search for non-SM Pairs Decaying Hadronically
   - Introduction
   - Model
   - Results
CDF and D0 Are Still Alive

CDF and D0 still have active collaborations that are producing results in interesting and competitive areas:

- **New physics particles with long lifetimes:** Differing collision energies changes the boost.
- **Low mass resonances in hadronic decays:** Higher collision energies increases backgrounds.
- **Asymmetric production resulting from $p\bar{p}$ collisions:** (NOTE: Ongoing $A_{fb}$ studies are not in this talk)
SUSY and Axigluons Also Not Dead Yet

...but may be on its last legs.

Three New Physics Searches:

1. **SUSY/GMSB**: $\gamma$-delay from neutral, long-lived particles

2. **SUSY/GMSB**: muon-like (but not muon) from charged, long-lived particles

3. **Axigluons**: Low-mass 4j resonances from axigluons
$\gamma_{\text{delayed}} + E_T$: Intro

**Signature:**

SM $\gamma$s are expected to be produced promptly from $p\bar{p}$ collisions. **New physics** could be seen if lifetime $\mathcal{O}(\text{ns})$.

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**Backgrounds:**

- **(BLUE):** $\gamma$ correctly paired w/ vertex from which it originated
- **(RED):** $\gamma$ paired w/ wrong vertex
- **(YELLOW):** Cosmic Rays
γ_{delayed} + E_T: Model

7 Parameters Define the Model:

- Right Vertex Gaussian (Mean, RMS, Norm.)
- Wrong Vertex Gaussian (Mean, RMS, Norm.)
- Cosmics Uniform (Norm.)

Data-driven fit to sidebands:

- $-7 < t_{corr} < 2$ ns
- $20 < t_{corr} < 80$ ns
- $-3.5 < t_{corr} < 3.5$ ns (no vertex sample)
\( \gamma_{\text{delayed}} + E_T \): Results

**Expected:** 286 ± 24

**Observed:** 322, Agreement to +1.2\( \sigma \)
Muon-like Resonances: Intro

**Signature:**
Muon-like charged particles that traverse the full D0 detector before decaying (lifetime $\mathcal{O}(25 - 1000) \text{ ns}$), but with differing ionization energy loss ($dE/dx$) due to slower speeds.

**Background:**
- Primarily $W \rightarrow \mu \nu_{\mu}$ for single-muon events
- Primarily $Z \rightarrow \mu \mu$ for two-muon events
Muon-like Resonances: Model

Signals:
- Stau Leptons
- Top squark
- Charginos

Model:
MC background modelling, then Boosted Decision Tree (BDT) discrimination
Muon-like Resonances: Selected BDT Results
Muon-like Resonances: Limit Results

- **Gaugino-Like Chargino Mass [GeV]**
  - Observed Limit
  - Expected Limit
  - Expected ± 1 SD
  - Expected ± 2 SD
  - NLO Prediction
  - NLO Uncertainty
  - Observed Limit
  - Expected Limit
  - Expected ± 1 SD
  - Expected ± 2 SD
  - NLO Prediction
  - NLO Uncertainty

- **Higgsino-Like Chargino Mass [GeV]**
  - Observed Limit
  - Expected Limit
  - Expected ± 1 SD
  - Expected ± 2 SD
  - NLO Prediction
  - NLO Uncertainty

- **Stau Lepton Mass [GeV]**
  - Observed Limit, no CF
  - Expected Limit, no CF
  - Expected ± 1 SD
  - Expected ± 2 SD
  - NLO Prediction
  - NLO Uncertainty

- **Top Squark Mass [GeV]**
  - Observed Limit
  - Expected Limit
  - Expected ± 1 SD
  - Expected ± 2 SD
  - NLO Prediction
  - NLO Uncertainty

Search For Neutral, Long-Lived Particles at CDF
Search for Charged, Long-Lived Particles at D0
Search for non-SM Pairs Decaying Hadronically
Low mass 4j Resonances: Intro

**Signature:**
- Light axi-gluon models have not yet been ruled out. One could decay to low-mass colored particles, then to pairs of jets.
- ATLAS ruled out [100, 150] GeV. There are no limits below 100 GeV.

**Background:**
Dominated by QCD multijet production.
Used data-driven fit to observed $m_{jj}$ spectrum.
Low mass 4\(j\) Resonances: Model

Signals:
- \(m_Y\): 50, 100, 125, 200, 400 GeV/c\(^2\)
- \(m_X\): 170, 200, 325, 400, 500 GeV/c\(^2\)

Model:
Do a parametric functional fit to the observed \(m_{jj}\) spectrum. This assumes QCD background has a smooth shape without features.
Low mass 4j Resonances: Limit Results

- **(Left)** 50 – 100 GeV/c^2 excluded for non-resonance case
- **(Right)** wide exclusion for m_X resonance case
Links

- **Charged Massive Long-lived Particles:**
  [http://www-d0.fnal.gov/Run2Physics/WWW/results/final/NP/N12D/](http://www-d0.fnal.gov/Run2Physics/WWW/results/final/NP/N12D/)
- **Four jets:**