MY CUBICLE IS SURROUNDED BY LOUD IDIOTS WHO MAKE IT IMPOSSIBLE FOR ME TO CONCENTRATE ON MY WORK.

DID YOU CREATE A PRESENTATION ON WHY YOU COULDN'T DO THE PRESENTATION YOU'RE SUPPOSED TO BE DOING?

WOULDN'T IT HAVE BEEN JUST AS EASY TO CREATE THE ACTUAL PRESENTATION?

I'M HOPING TO USE THIS ONE MORE THAN ONCE.
No CHAMPs at DØ

Flip Tanedo

Presenting: 0809.4472

7 December 2009
Physics 7661, Fall 2009
Collider Physics

Cornell University
WTF is a CHAMP

Kobe Bryant
- 4x NBA CHAMPion
- 2009 NBA Finals MVP
- 2008 NBA MVP
- 11x NBA All-Star
- 2x scoring CHAMPion
- 1997 Slam Dunk CHAMPion

Game-winning buzzer-beating 3-point shot last Friday against the Miami Heat. LAL 108, MIA 107.
WTF is a CHAMP

Experimentalist definition

- Long-Lived **Charged Massive Particle**
- **Massive Metastable Charged Particle**
- **Heavy Stable Charged Particle**
- **Charged Massive Stable Particles**

Summary: charged shit that makes it out of the collider before decaying
WTF is a CHAMP

Standard Model examples

- Approximately conserved quantum number
e.g. electron, proton

- Suppressed effective coupling
e.g. muon (e.g. $\mu \rightarrow e\gamma$... man, I hate that process)

- Suppressed phase space
e.g. neutron (I know: not charged, STFU)
WTF is a CHAMP
Theorist’s definition

- **GMSB**: gravitino LSP, so NLSP may be charged e.g. third-generation sfermion (stau)
- **AMSB**: with $M_2 \ll M_1 \ll M_3$, small splitting between $\chi^+$ and $\chi^0$
- **Focus point CMSSM**: $M_{1,2} \gg \mu$, degenerate Higgsino LSP and Higgsino-like NLSP
- **Split-SUSY**: very large squark mass metastable gluino
WTF is a CHAMP
Collider definition

Let’s make some simplifying assumptions

- Only consider electric charge
- Colored charges are a different story (R-hadron)
- Also assume CHAMPs are pair produced
  i.e. ignore cascade decays (for simplicity)

Pair production: LEP gives a model-independent-ish
$M > 100 \text{ GeV}$ bound from $Z \rightarrow (\text{CHAMP})^2$
WTF is a CHAMP
Collider definition

Signature looks just like a heavy muon

- Muon chamber hit with associated ECAL tracks
  1. Large invariant mass (& high $p_T$)
  2. Slow velocity (time of flight measurement)

Time of flight? We can measure that?
The Muon System

Different times of flight for particles at different polar angles are compensated for by varying cable lengths since the front-end electronics do not allow such timing adjustments.

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Cuts and BG

- 2 “muons” with $p_T > 20$ GeV
- At least one track is ‘collimated’ ($E_T, p_T$)
  Reducible BG: mesons
- Acolinear, outward moving muons
  Reducible BG: cosmic rays (very bad!)
- Sufficiently close to the beamline
  Reducible BG: $B_s$, beam halo, cosmic rays
- Irreducible BG: mismeasurements
Background Simulation

- Randomly combine separate distributions of invariant mass and velocity
  Central tracker is independent of muon chamber

- **Velocity BG**: ‘events’ invariant mass in Z peak: 70 - 110 GeV, passes other cuts
  This is why the pair production assumption is useful

- **Invariant mass BG**: negative velocity events

- **Subtle**: modeling BG from the data itself.
  Chosing randomly from separate data sets gives us decorrelated background simulation.
Data vs. Monte Carlo

\[ \frac{1 - \bar{v}}{\sigma_{\bar{v}}} \]
(a) 
DØ 1.1 fb$^{-1}$

<table>
<thead>
<tr>
<th>Charged Gaugino Mass [GeV]</th>
<th>Observed Cross Section Limit</th>
<th>Expected Cross Section Limit</th>
<th>NLO Cross Section Prediction</th>
<th>NLO Cross Section Uncertainty</th>
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<tr>
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### Table: E.g. Stau CHAMP

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<td>0.7</td>
<td>1.6 ± 0.8</td>
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<td>0.1</td>
<td>1.7 ± 1.0</td>
<td>1</td>
</tr>
<tr>
<td>300</td>
<td>0.004</td>
<td>1.9 ± 0.7</td>
<td>3</td>
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Red line is the prediction for some arbitrary CHAMP model

Above the blue line is excluded

This intersection is the lower bound on the CHAMP mass

**e.g. Stau CHAMP**

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<td>1.7 ± 0.6</td>
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e.g. Gaugino CHAMP

DØ 1.1 fb$^1$

Observed Cross Section Limit
Expected Cross Section Limit
NLO Cross Section Prediction
NLO Cross Section Uncertainty
In some regions, LHCb might be able to do better due to particle ID. E.g. medium-lived particles that decay inside the detector.
Bethe-Bloch

Signatures depend on interaction with detector

\[
\langle -\frac{dE}{dx} \rangle = \frac{Kz^2 Z}{A\beta^2} \left( \frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\text{max}}}{I^2} \right) - \beta^2 - \frac{\delta}{2}
\]

- Energy loss is almost independent of CHAMP mass
- So we can use the tracking system and treat CHAMP as \( \mu \)
- \( p \) measurement in central tracker + \( \beta \) measurement from \( \mu \) system = \( m \) measurement
- But: software assumes \( \beta = 1 \), track fit is poor for \( \beta < 0.75 \)
  Can treat \( \beta \) as an additional fit parameter, good to \( \beta > 0.5 \)
Other CHAMPs

- UED with KK-parity
- RS with GUT-parity
- DSB (quantum numbers)
- Leptoquarks
- Additional generations
- Magnetic Monopoles
CHAMP Cosmology

- Hard to get a viable dark matter CHAMP

- Strong constraints from, e.g., BBN, CMB, ... CHAMP decay injects energetic particles into the plasma, abundance of light elements

- A CHAMP @ LHC would require model building to dilute its early universe density
Other Ideas

• Slepton trapping in water tanks
  Feng hep-ph/0405278 (colliders)
  Byrne hep-ph/020252 (cosmic rays)

• R-hadrons: CHAMPs + quarks
  Interactions with nuclei mainly due to quark. Can swap quarks, change electric charge.
Happy Winter Break!

References

• DØ, 0809.4472
• CDF note 8701
• Fairbairn et al, hep-ph/0611040
• Raklev, 0908.0315
• Feng & Smith, hep-ph/0409278