Run 2 Search for Long-Lived Massive Charged Particles at CDF

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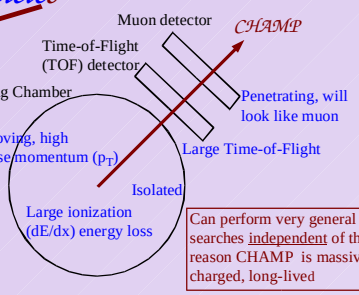
CHArged Massive Stable Particles

CHAMPs

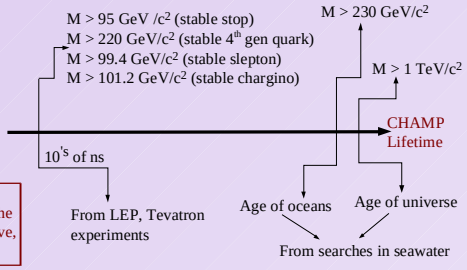
- Extensions to Standard Model predict the existence of new particles
- Particles can be:
  - Massive
  - Charged
  - Long-lived
- Such particles are called **CHAMPS**
- **Can exist in many types of models**
  - **NLSP (stau, stop, chargino in gauge mediated SUSY)**
  - **Stop in 5d SUSY theory (Barbieri, Hall, Nomura)**

Very Distinctive Signature

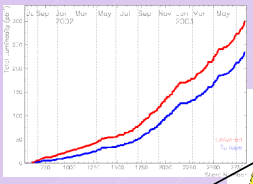


Can perform very general searches independent of the reason CHAMP is massive, charged, long-lived

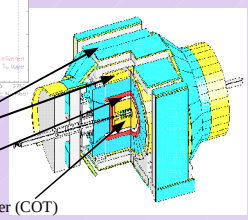
Existing CHAMP Mass Limits



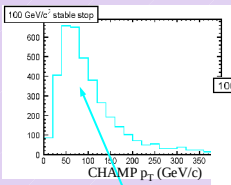
CDF Run 2



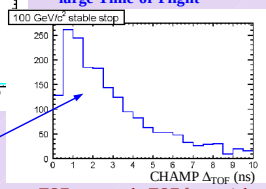
>225 pb^{-1} of $p\bar{p}$ collisions at $\sqrt{s}$ = 1.96 TeV on tape since summer 2001



Search Strategy



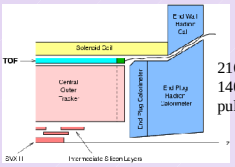
Look for events with high-p_T tracks that have:
- hits in muon chambers
- **large Time-of-Flight**



CHAMPS have: large p_T, large Δ_{TOF}

Δ_{TOF} = TOF measured - TOF for particle at c

TOF Detector



216 scintillator bars in cylinder
140 cm from beam
pulse readout by PMT's on both ends

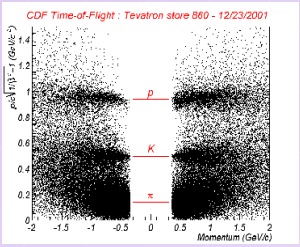
Measuring TOF

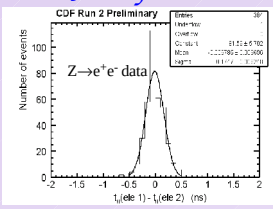
Two elements in measurement:
- Arrival time of high-p_T track at TOF detector
- Event interaction time t_0

Measured TOF = Arrival Time - Event Interaction Time

TOF Performance

Mass from TOF vs Momentum





For each leg, calculate a t_0 from arrival time at TOF and TOF expected from pathlength

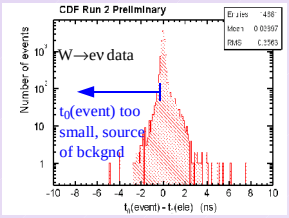
t_0(leg1) - t_0(leg2): res. ~ 175 ps

→ single leg res ~125 ps

Calculate t_0 from electron

Calculate t_0 from other tracks in event

When t_0(event) - t_0(ele) is negative:
- Calculated t_0(event) too small
- Produces large measured TOF
- Background to search



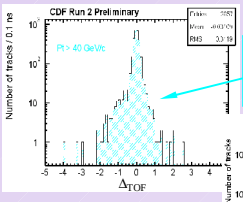
Data Sample

- 53 pb^{-1} (March 2002 to Dec. 2002) recorded by high-p_T central muon trigger (≥ 1 central muon, p_T > 18 GeV/c)
- Cosmics removed using COT timing (look for tracks moving toward center of detector from outside)
- Divide tracks into 3 categories
  - Signal region tracks: p_T > 40 GeV/c. Search for signal among these
  - Control region tracks: 20 GeV/c < p_T < 40 GeV/c. Used to estimate background in signal region
  - t_0 tracks: p_T < 20 GeV/c. Use only these to calculate event t_0. Must come from same vertex as signal or control track
- Signal and control region tracks required to be reconstructed as muons

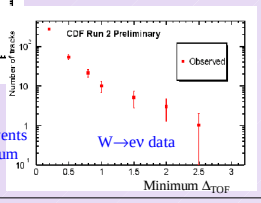
Signal region event: Event with at least one signal region track

Control region event: Event with at least one control track, no signal tracks

Background Estimate

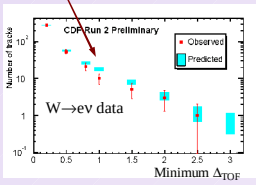


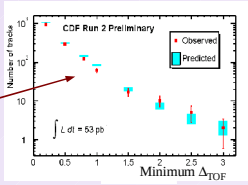
Δ_{TOF} for "candidate" events in W→eν data. Large Δ_{TOF} from instrumental effects



Treat as a counting experiment: # of events above some minimum value of Δ_{TOF}

At small values of Δ_{TOF} (background dominated), find ratio of events in control region to events in signal region. Use to estimate # of background events in signal region at large Δ_{TOF}. Procedure tested with other physics samples and within high-p_T muon control sample





Systematic uncertainty on expected background comes from the precision with which procedure is tested in the high-p_T muon control sample

Control1: 20 GeV/c < p_T < 30 GeV/c

Control2: 30 GeV/c < p_T < 40 GeV/c

Use ratio of Control1 to Control2 at small Δ_{TOF} to predict # of events in Control2 at large Δ_{TOF}

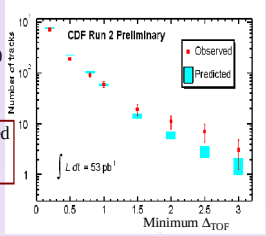
Results

Optimal cut: Δ_{TOF} > 2.5 ns (From high-p_T muon control region and signal Monte Carlo)

In signal region of high-p_T muon data,

2.9 ± 0.7 ± 3.1 events expected

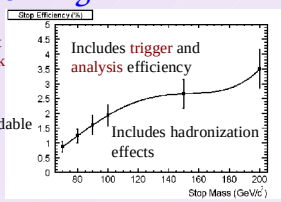
7 events observed



Setting Limits

Set limit in context of stable stop quark pair production

Results easily extendable to other models



Use combination of data, Monte Carlo to estimate efficiency

Generate stable stop Monte Carlo at several stop masses

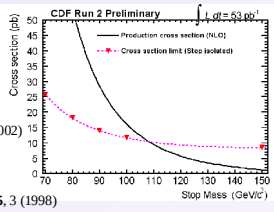
Estimate reconstruction efficiencies from W→eν data

Final Mass Limit

Limit on Stable Stop Mass: 107 GeV/c²

Previous best stable stop limit: 95 GeV/c²
ALEPH, Phys. Lett. **B357**, 5 (2002)

Theory (NLO) cross section at $\sqrt{s}$ = 1.96 TeV

Beenaker *et al*, Nucl Phys. **B515**, 3 (1998)

Berger, Klasen, Tait, Phys. Rev. **D59**, 074024 (1999)