Metastable Staus in the ILC-Detector

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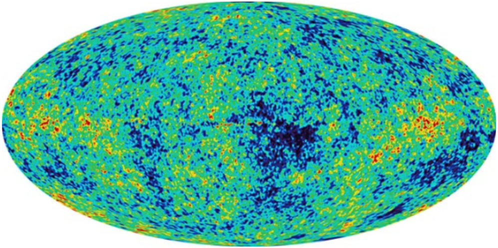
ILD Analysis Kickoff Meeting

January 24, 2008

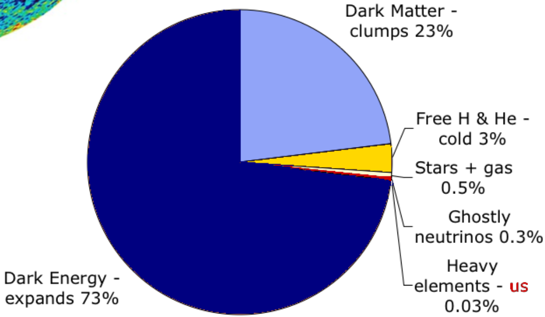
Dark Matter Relic Density: Ω_{DM}

WMAP: measurement of the anisotropies of the CMB background
$\longrightarrow$ Cold Dark Matter relic density: $\Omega_{DM} \approx 23\%$



Down below, the heavy elements of only 0.03%
$\rightarrow$ This is us !

Heavy gravitinos might explain the above CDM relic density.



Dark Matter & Supersymmetry

Large number of different scenarios - SUSY can be ...

- MSSM (mSUGRA): Minimal Supersymmetric Standardard Modell
- GMSB: Gauge mediatd SUSY Breaking
- AMSB: Anomaly mediated SUSY Breaking

GMSB & mSUGRA give gravitino masses of $\longrightarrow \quad m_{3/2} \approx eV \; \ldots \; TeV$,
One special GMSB scenario is very interesting: the SuperWIMP$^{\diamond}$ scenario
with a gravitino LSP† and a stau NLSP† - decay: $\widetilde{\tau} \rightarrow \tau \widetilde{G}$

Gravitino mass is determined by the SUSY breaking scale F, where the interaction is mediated from the 'hidden' to the 'observable' sector.

$$m_{3/2} = \frac{F}{\sqrt{3}} \cdot M_P \qquad \text{with:} \quad M_P \approx 2.4 \cdot 10^{18} \text{ Planck scale}$$

$^{\diamond}$WIMP: Weakly Interacting Massive Particle

†(N)LSP: (Next-to) Lightest Supersymmetric Particle

NLSP can only interact gravitationally with the Gravitino ($\widetilde{G}$)
→ not only weak, but 'superweak' interaction
→ $\widetilde{\tau}$-NLSPs: long-lived, heavy, and charged (i.e. strongly ionising)

Cosmological observations: nearly impossible to distinguish Gravitinos from WIMPS, but: LHC and ILC, both can discover the Gravitino.

→ if kinematically accesible, $\widetilde{G}$ can be observed via $\widetilde{\ell}$-decays!
Observables would be: $\widetilde{\tau}$-mass & -lifetime ($m_{\widetilde{\tau}}$, $t_{\widetilde{\tau}}$) and $\widetilde{G}$-mass ($m_{\widetilde{G}}$)

Advantages of long-lived particles ($\widetilde{\tau}$'s)

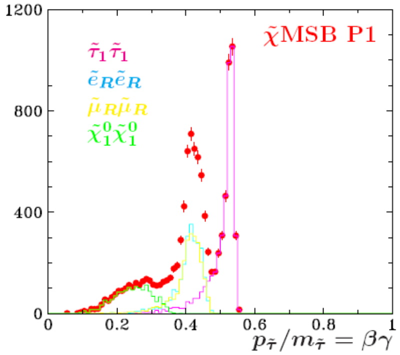
- will produce an anomal ionisation in the TPC ($\frac{dE}{dx}$) (← recognition)?
- may get stuck inside the detector $\Longrightarrow$ late decays

Disadvantages of late decays:

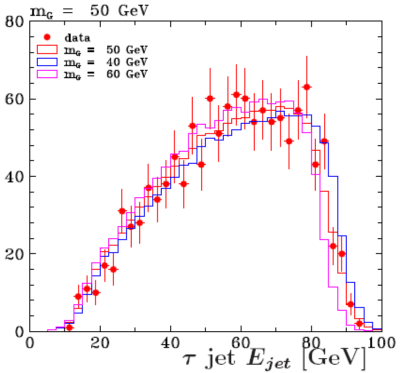
- cannot trigger on them (LHC),
- might decay during bunch breaks (ILC) and not get detected at all

Detecting Metastable staus: $\tilde{\tau}_1$, $\tilde{\tau}_2$

Momentum spectrum of $\tilde{\tau}$ leptons



$\tilde{\tau}$-jet energy spectrum ($\tilde{\tau}$-decays)



- Identify & record stopping staus via $\frac{dE}{dx} \propto \frac{1}{\beta^2}$ $\longrightarrow$ $\tilde{\tau}$ mass
  (record the location & time stamp with the TPC)
- wait for the decay: $\tilde{\tau} \rightarrow \tau \tilde{G}$: $\longrightarrow$ $\tilde{\tau}$ lifetime
- measure the τ recoil spectra: $\longrightarrow$ $\tilde{G}$ mass

Fundamental Problems with Late Decays

Unfortunately, a pulsed operation is forseen for the calorimeters:
2 ms sensitive - 198 ms idle - 2 ms sensitive - 198 ms idle - 2 ms sensitive - etc.

Works only well for beam-correlated physics,
but: one cannot record late decays this way! ...at least, one would not know to which bunch crossing the late event belongs.

In case, the LHC finds something that could potentially be a manifestation of a SUSY-model with $\widetilde{\tau}$-NLSPs (other late decays?)
$\Longrightarrow$ ILC/ILD has to be prepared to deal with this!

First Thoughts Towards Possible “Workaround”

Try locating the area precisely where the WIMP got stuck in the detector (presum. the cal.), using the TPC tracking and dE/dx information.

Try to be ready for changes in the readout system to accomodate these late decays... (keep calorimeter areas sensitive)

Maybe one can refine the readout such, that calorimeter wedges / parts that might contain a stuck sparticle can reamin sensitiv.

Summary - Gravitinos ($\widetilde{G}$) are:

- Interesting Dark Matter candidates
- Cannot be detected directly in astrophysical experiments, BUT: if kinematically accesible, should be observable via the decays of metastable sleptons (staus for now: $\widetilde{\tau}_1 \rightarrow \tau \widetilde{G}$)
- Need to revise the calorimeter readout system / idle time! ($\rightarrow$ adapted for late decays)
- Most importantly: "a fun phenomenology & signature" ☺

Thanks!