Cosmology And The ILC

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Cosmology Sessions Summary
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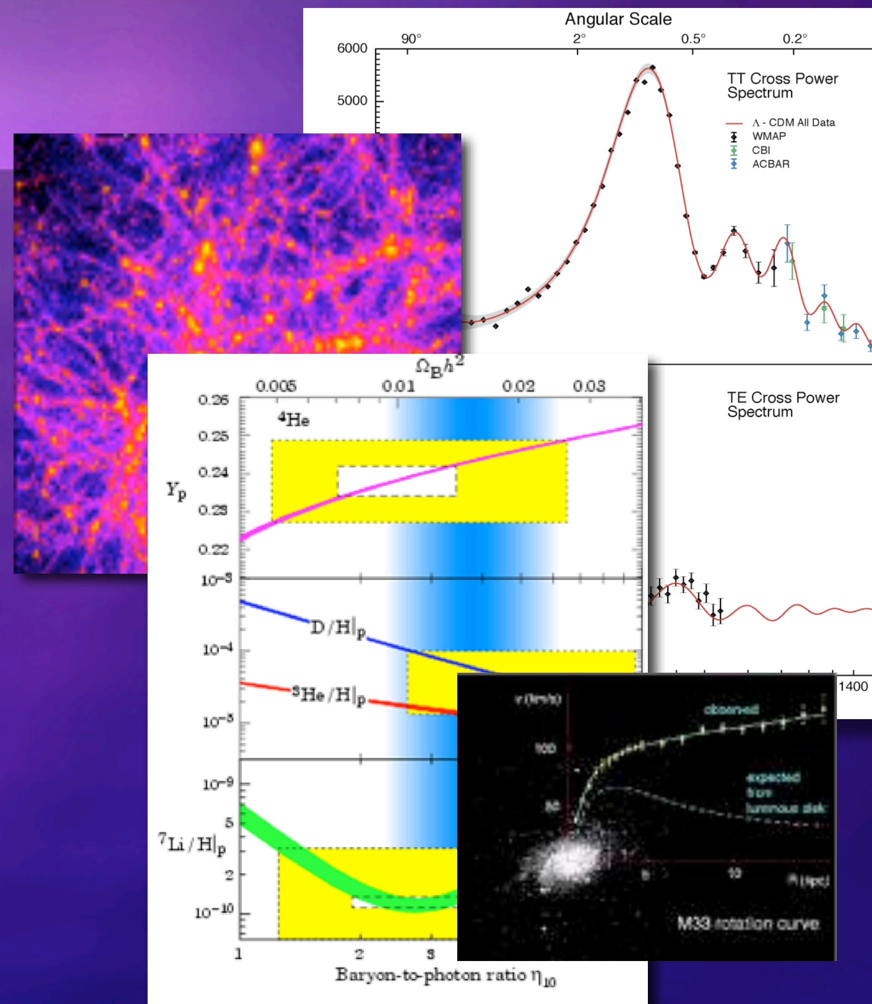
Dark Matter

- Evidence from a wide range of astrophysical observations including rotation curves, CMB, lensing, clusters, BBN, SN1a, large scale structure

- Still no (reliable) indications of dark matter's particle nature



The Particle Nature of Dark Matter

Axions, Neutralinos, Gravitinos, Axinos, Kaluza-Klein States, Heavy Fourth Generation Neutrinos, Mirror Particles, Stable States in Little Higgs Theories, WIMPzillas, Cryptons, Sterile Neutrinos, Sneutrinos, Light Scalars, Q-Balls, D-Matter, Brane World Dark Matter,…

A virtual zoo of dark matter candidates have been proposed over the years. 100's of viable dark matter candidates.

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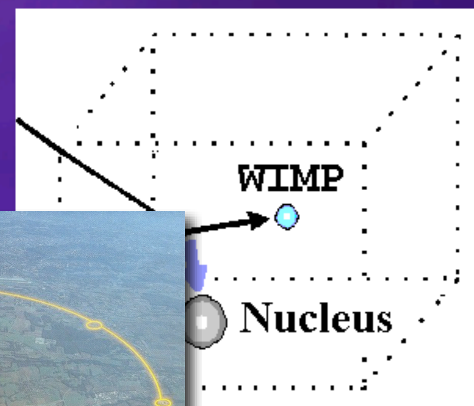
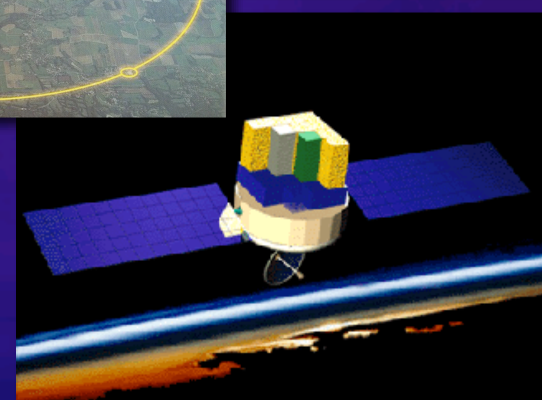
Michael Ramsey-Musolf, Ted Baltz, Larry Wai, Csaba Balazs

Andrew Noble

How To Search For Dark Matter

- •Collider Searches
- •Direct Detection
- •Indirect Detection





How To Search For Dark Matter

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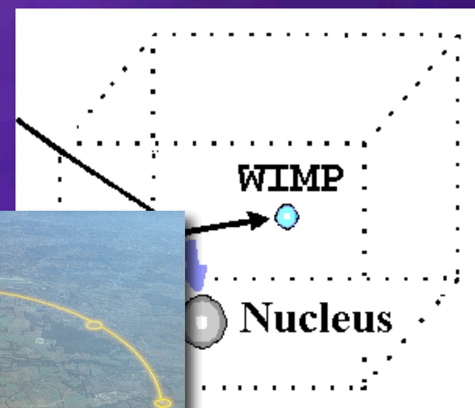
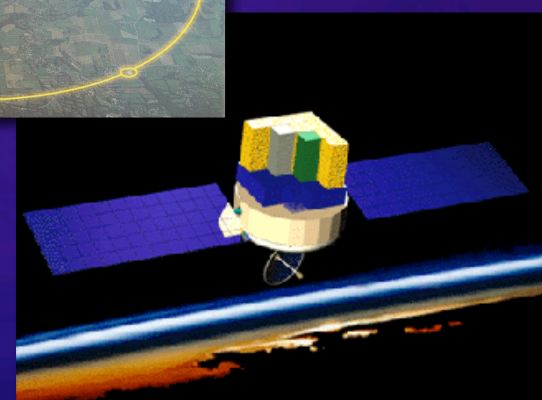
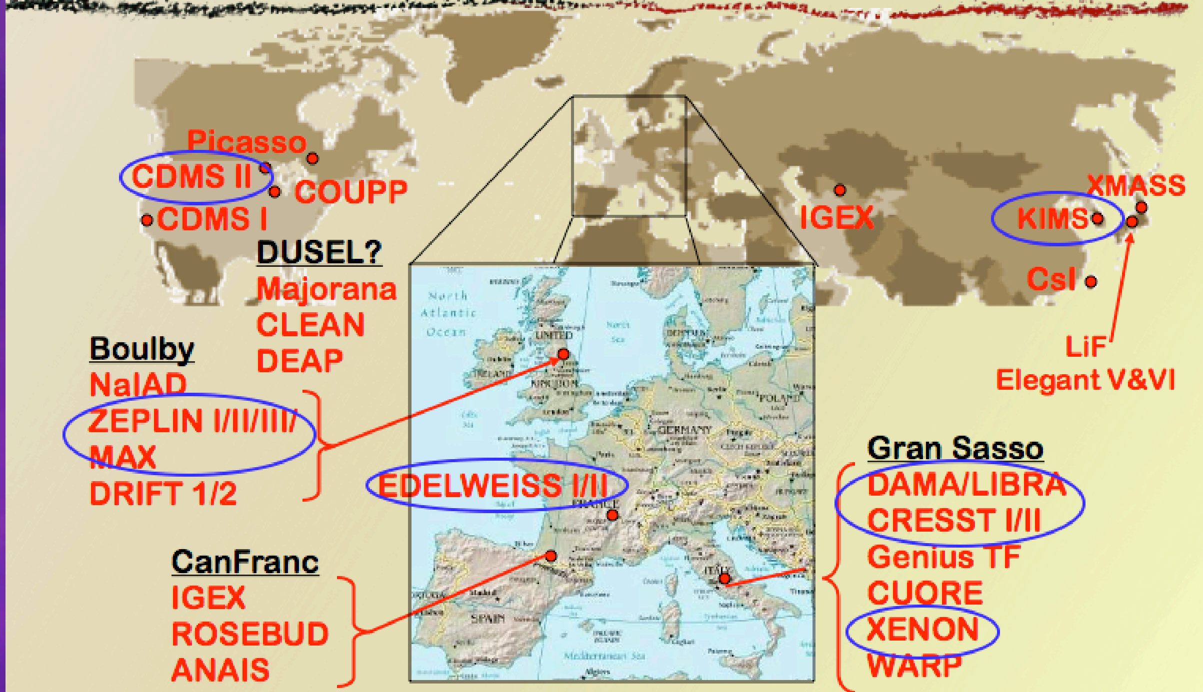
- Direct Detection
- Indirect Detection



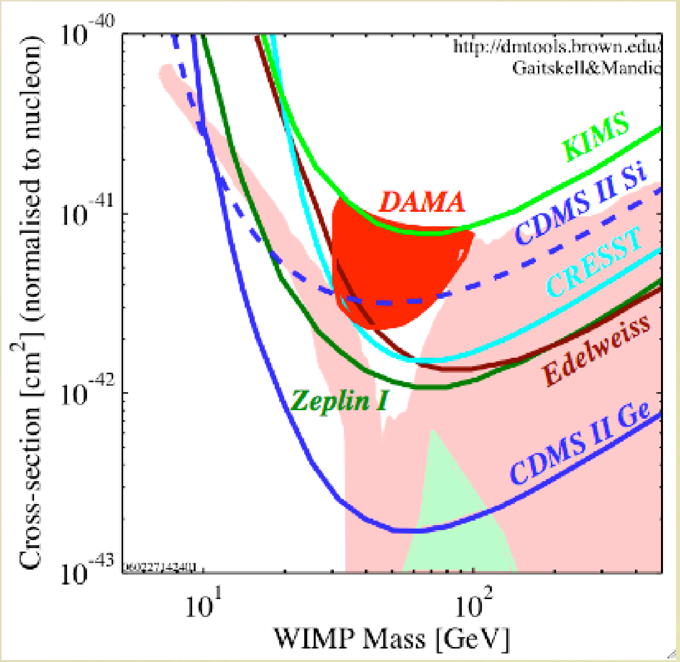


"No single approach is going to solve this problem"
-Joe Lykken

Direct Detection WIMP Experiments Worldwide



Where Do We Stand?



Presently the best limit for WIMP-nucleon cross-section come from the CDMS II experiment.

1.6×10^{-43} cm^2 at 60 GeV

Exclude large regions of SUSY parameter space under some frameworks.

A. Bottino et al., 2004 in light pink

J. Ellis et al. 2005 in light green

Super-CDMS

25 kg - 150 kg - 1 ton of ultra-cold Ge detectors

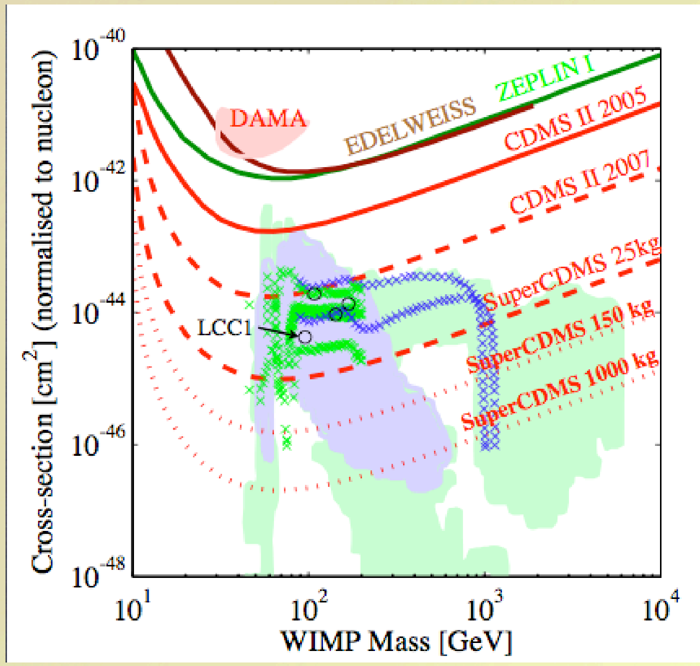
Move from Soudan to SNOlab

Reduce muon flux by 500

Reduce HE neutron flux by >100

CDMS II ZIPs:
3" diameter x 1 cm ⇒ 0.25 kg Ge

SuperCDMS ZIPs:
3" diameter x 1" ⇒ 0.64 kg Ge



Indirect Detection

Gamma ray detectors

- *Space (20MeV-300GeV)*
  - *GLAST*
- *Ground (>100GeV)*
  - *VERITAS*
  - *HESS*
  - *MAGIC*

Neutrino detectors

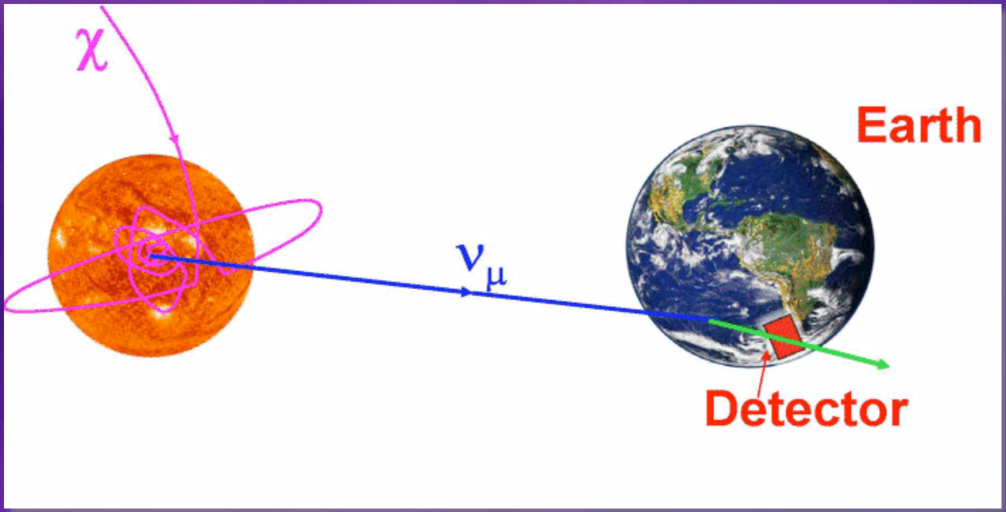
- *Underground (>5MeV)*
  - *Super-Kamiokande*
- *Undersea/ice (>20GeV)*
  - *AMANDA/ ICECUBE*
  - *ANTARES*

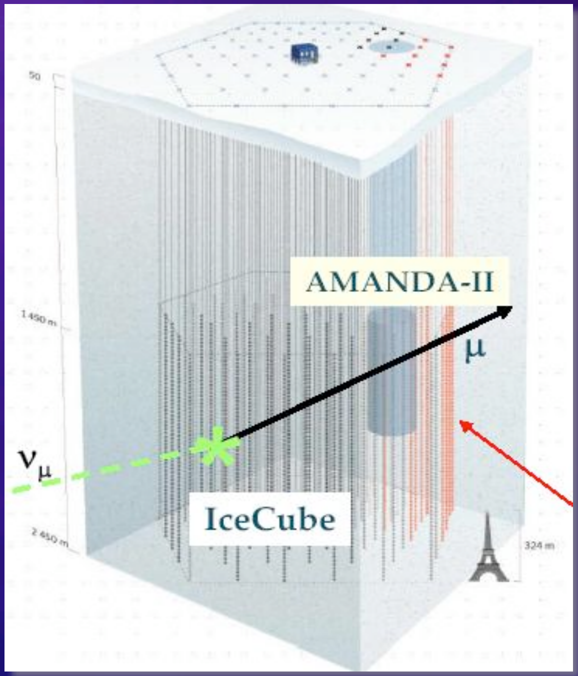
Anti-Matter detectors

- *Space*
  - *PAMELA*
  - *AMS*

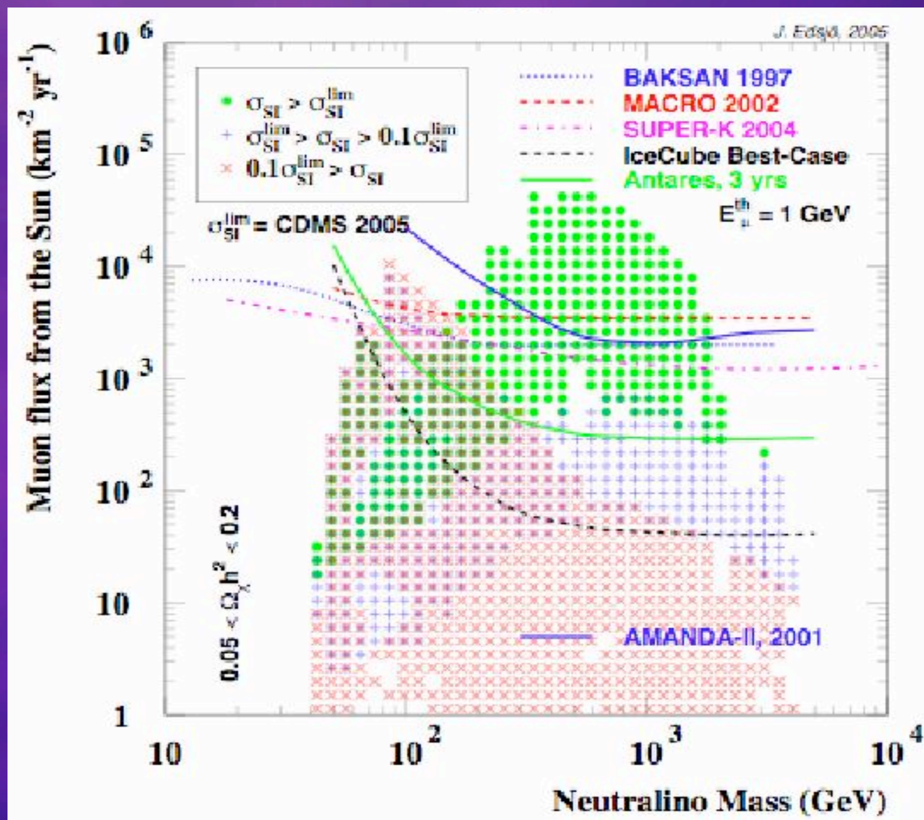
Gamma Ray Detectors

Dark Matter With Neutrinos

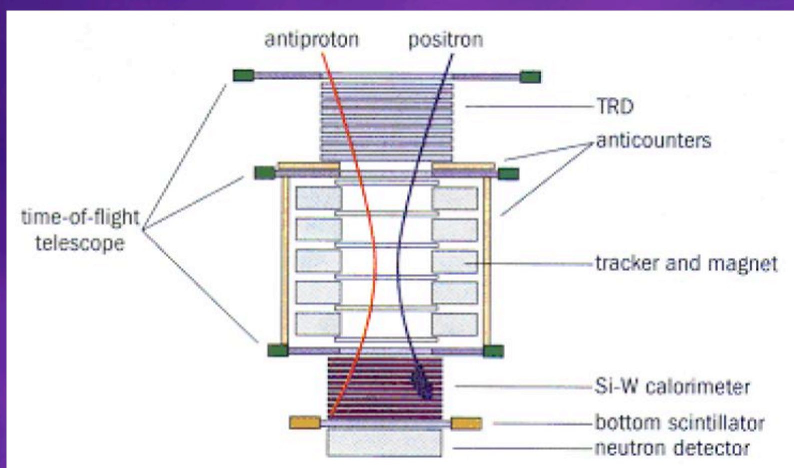


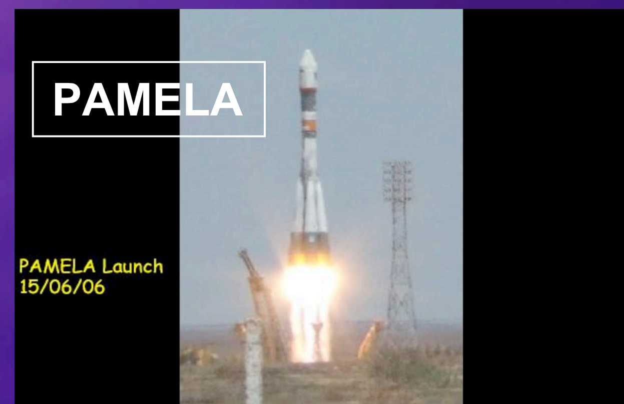


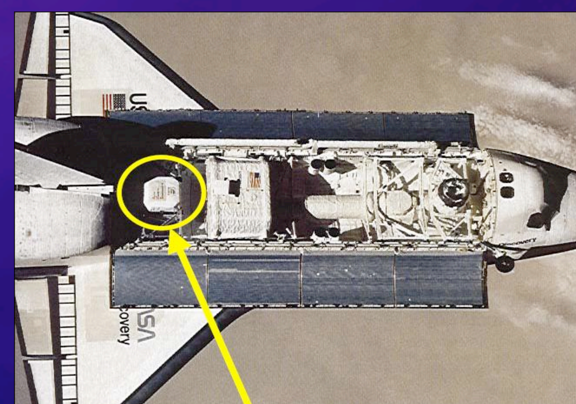
Solar WIMP Sensitivity



Anti-Matter Detectors

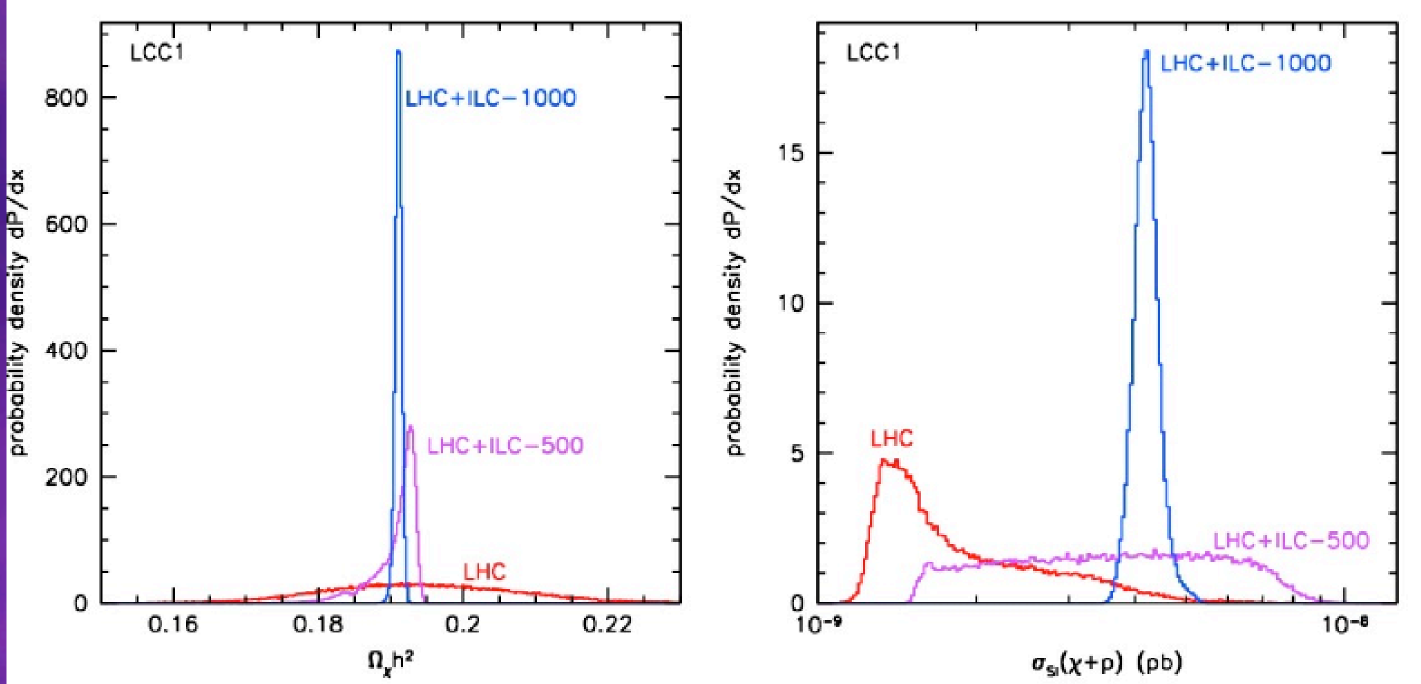






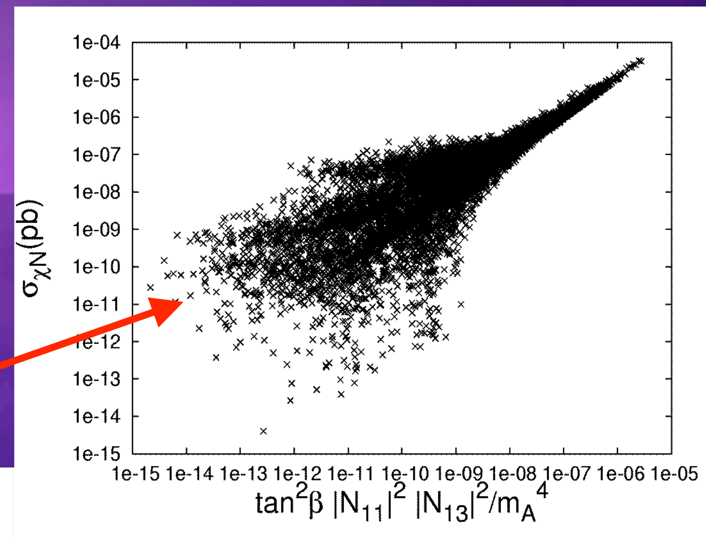
AMS-1

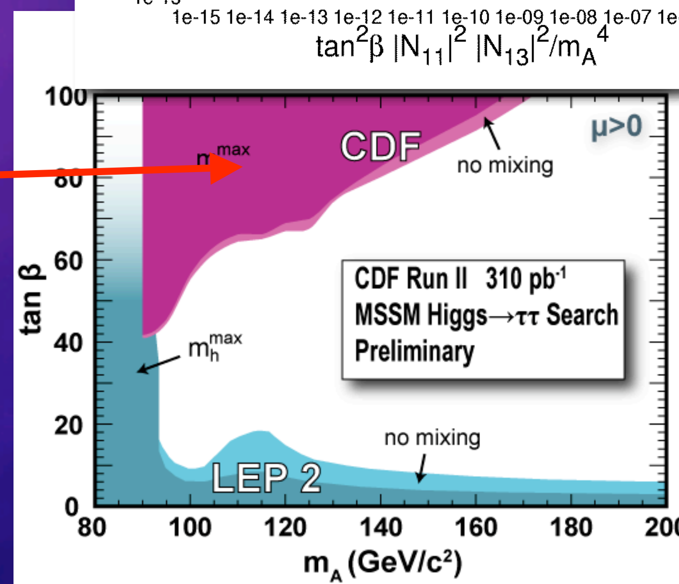
Collider/Cosmology Synergy



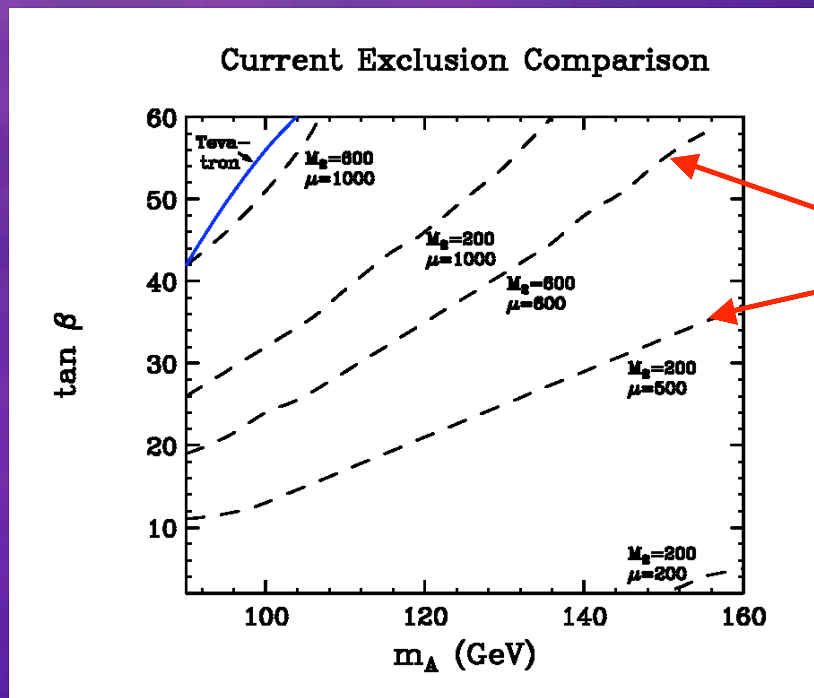
Direct Detection and the Tevatron

- Models with large cross sections are dominated by Higgs exchange, couplings to b, s quarks
- Large tan β, small m_A leads to a large elastic scattering rate
- MSSM Higgs searches at the Tevatron are also most sensitive to large tan β, small m_A





Direct Detection and Collider Searches

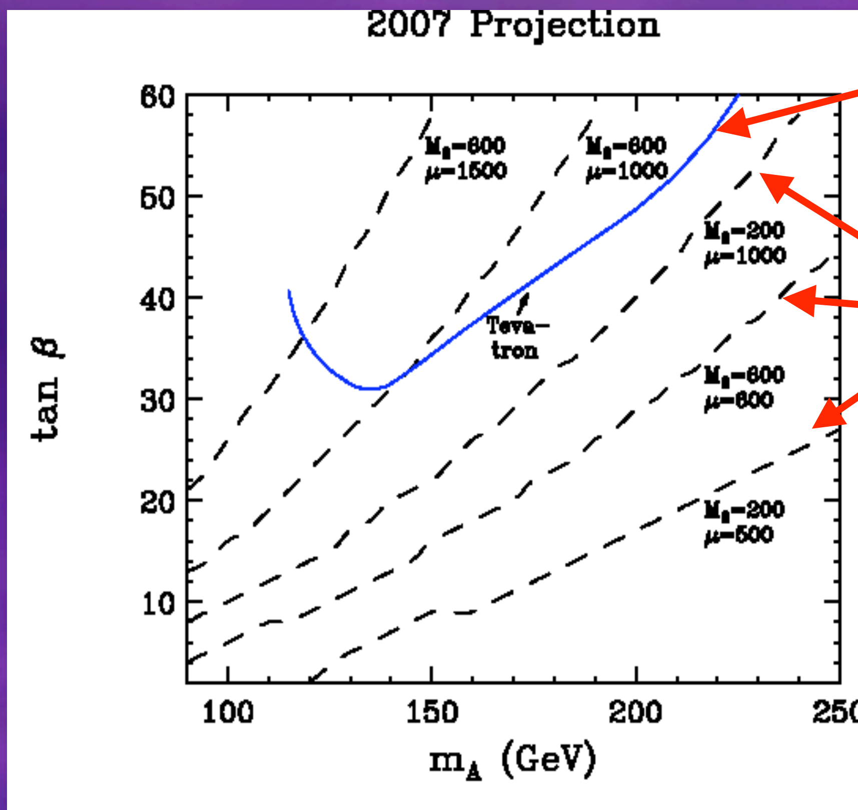


Current CDMS Limit

For a wide range of M_2 and μ, much stronger current limits on $\tan\beta$, m_A from CDMS than from the Tevatron

M. Carena, Hooper, P. Skands, PRL, hep-ph/0603180

Direct Detection and Collider Searches



3σ discovery reach, 4 fb^{-1}

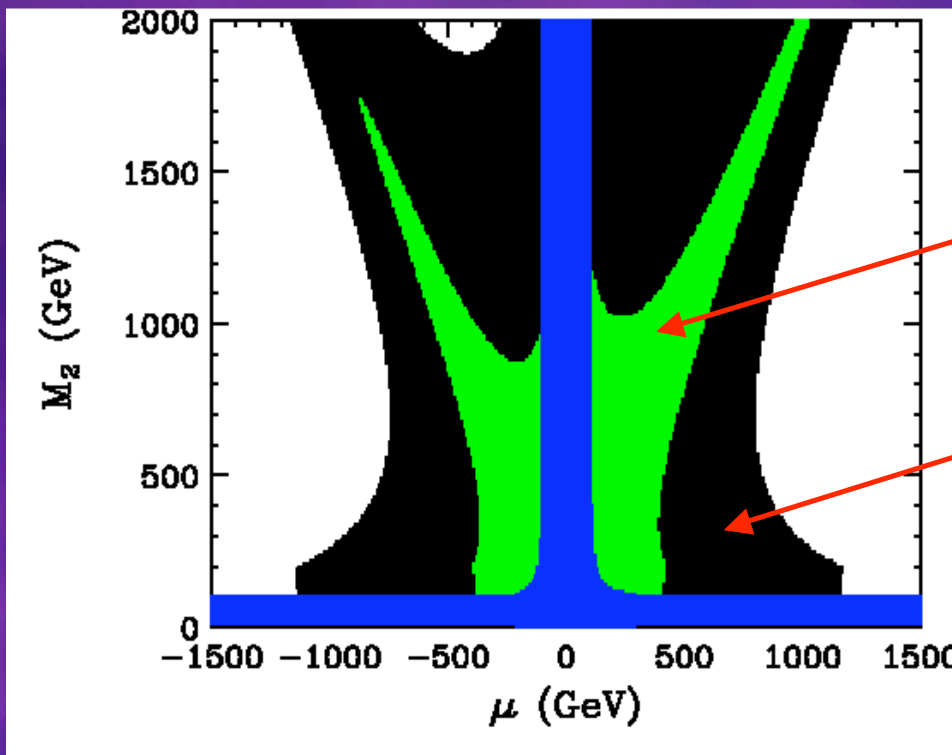
Projected 2007 CDMS Limit
(assuming no detection)

Limits from CDMS imply heavy Higgs (H/A) is beyond the reach of the Tevatron, unless LSP has a very small higgsino fraction ($\mu >> M_2$)

M. Carena, Hooper, P. Skands, PRL, hep-ph/0603180

Direct Detection and Collider Searches

Constrained heavy Higgs (A/H) discovery potential at the Tevatron (4 pb^{-1})



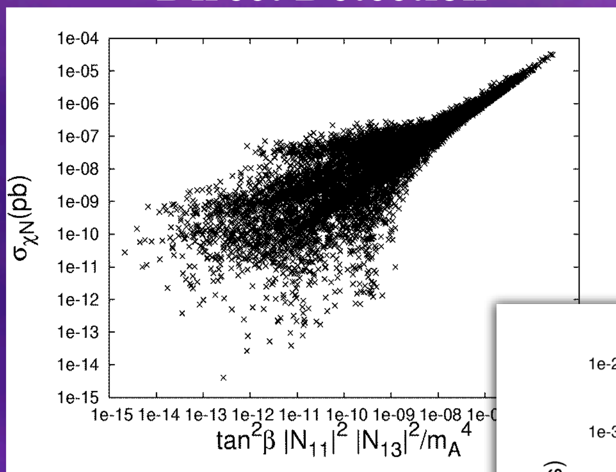
H/A discovery (3σ) not expected given current CDMS limits

H/A discovery (3σ) not expected given projected 2007 CDMS limits (assuming no detection)

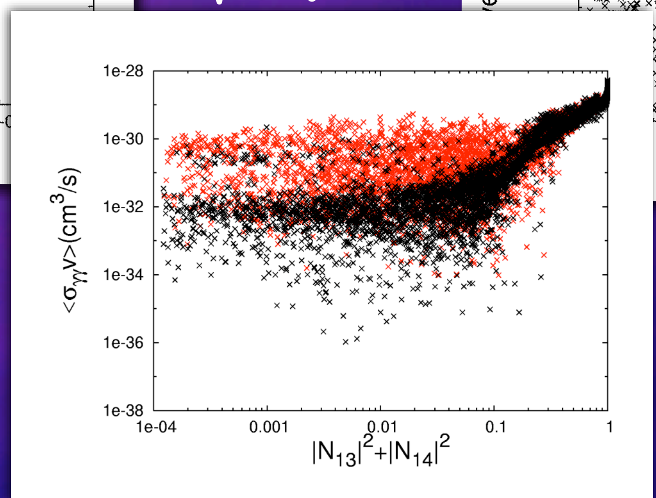
M. Carena, Hooper, P. Skands, PRL, hep-ph/0603180

SUSY Parameters From Astrophysics?

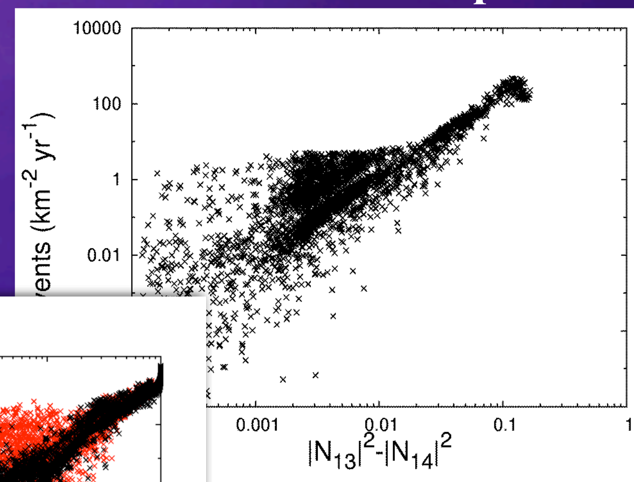
Direct Detection



γ-Rays + e+

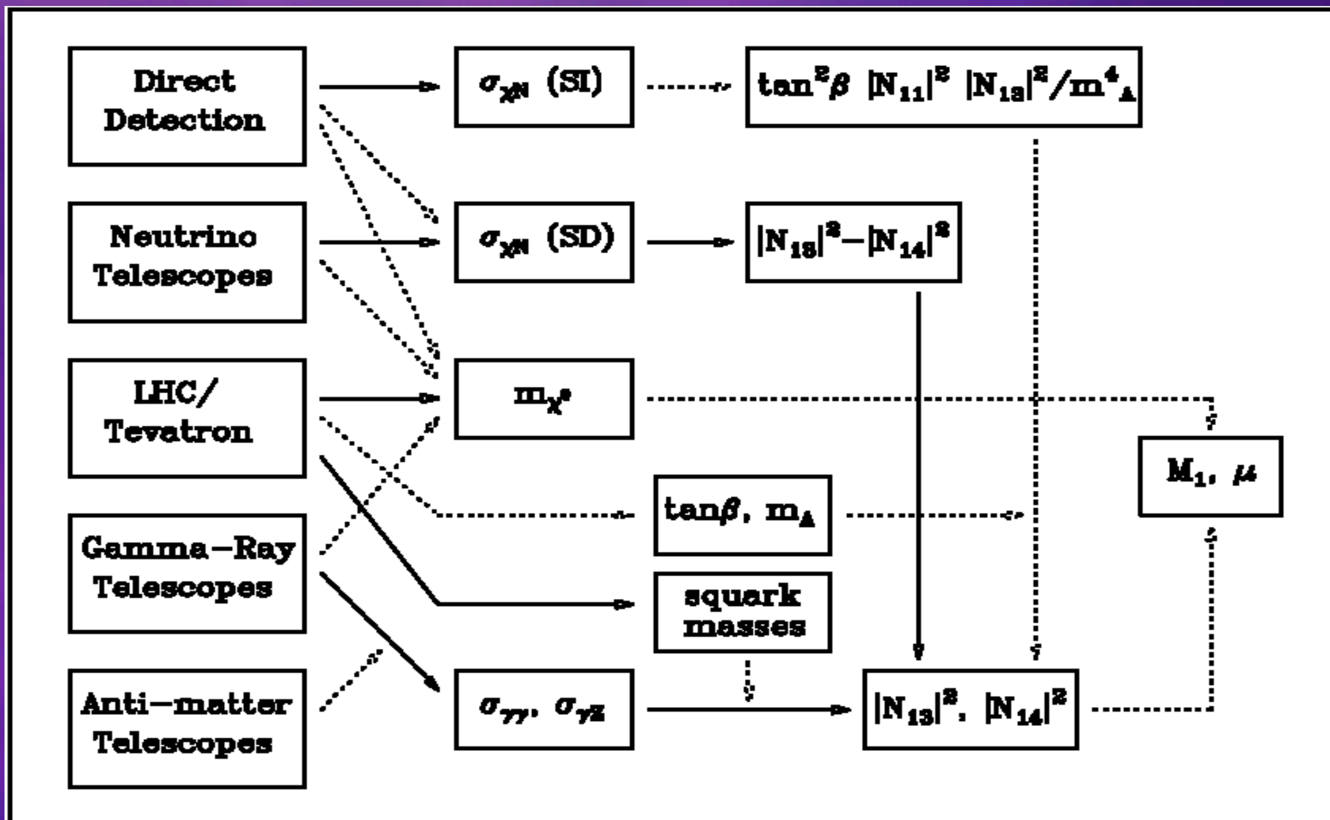


Neutrino Telescopes



Hooper and A. Taylor, hep-ph/0607086

Putting It All Together



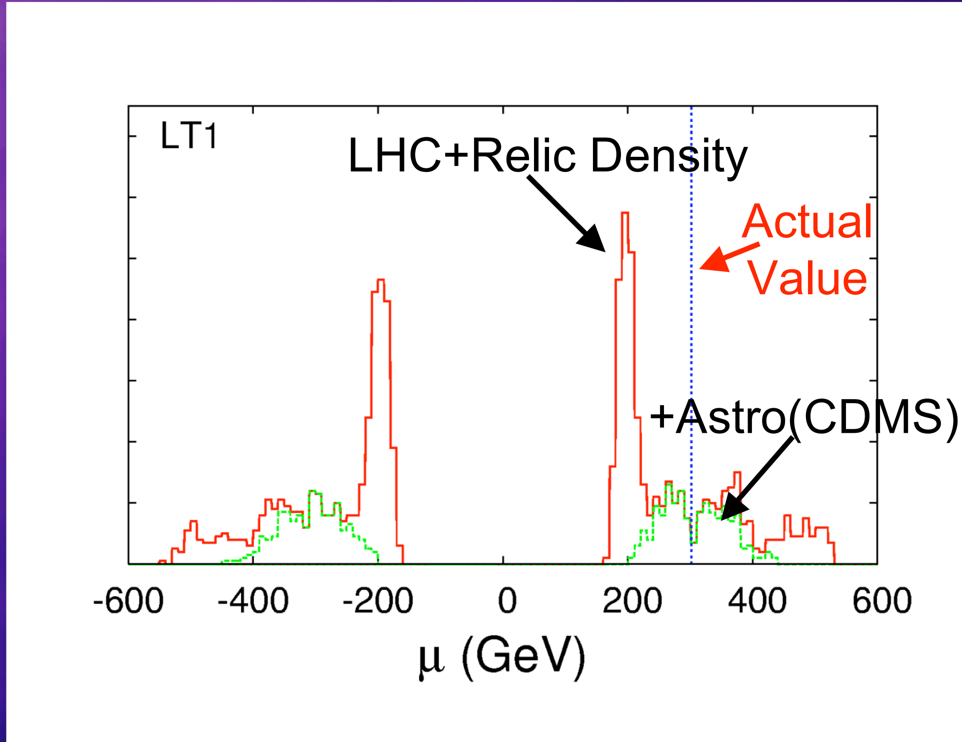
Combining LHC With Astrophysics

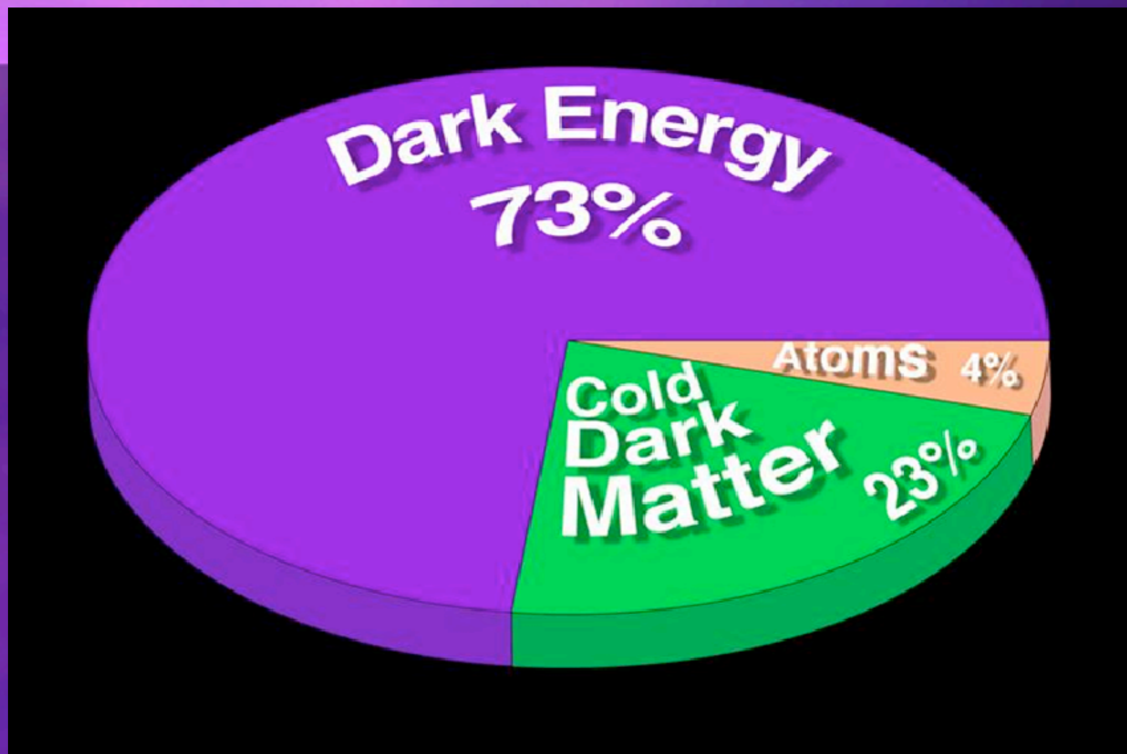
Benchmark model LT1:

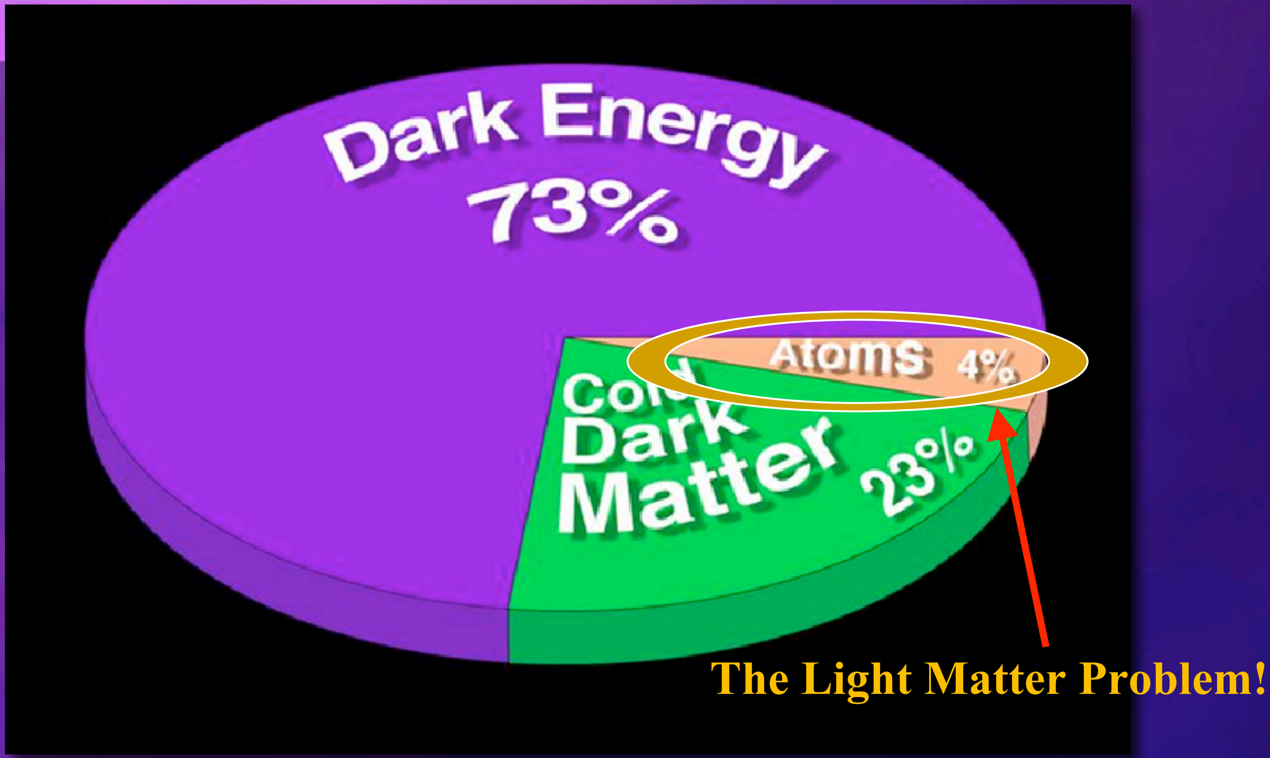
M_2=120 GeV, μ=302 GeV,
m_A=352 GeV, $\tan\beta$=56,
1700 GeV squarks

LHC: m_χ= 59 ± 10%,
m_{squark}=1700 ± 10%,
$\tan\beta$=56 ± 15%,
m_A=352 ± 1%

Astro: $\sigma_{\chi N}$=$7 \cdot 10^{-8}$ pb x/÷ 2,
R_ν < 10 yr^{-1},




Dark Energy
73%
Atoms 4%
Cold
Dark
Matter
23%



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The Light Matter Problem!

The Electroweak Scale and the Origin of the Baryon Asymmetry

•Electroweak baryogenesis is one of the most attractive possibilities for origin of the baryon asymmetry

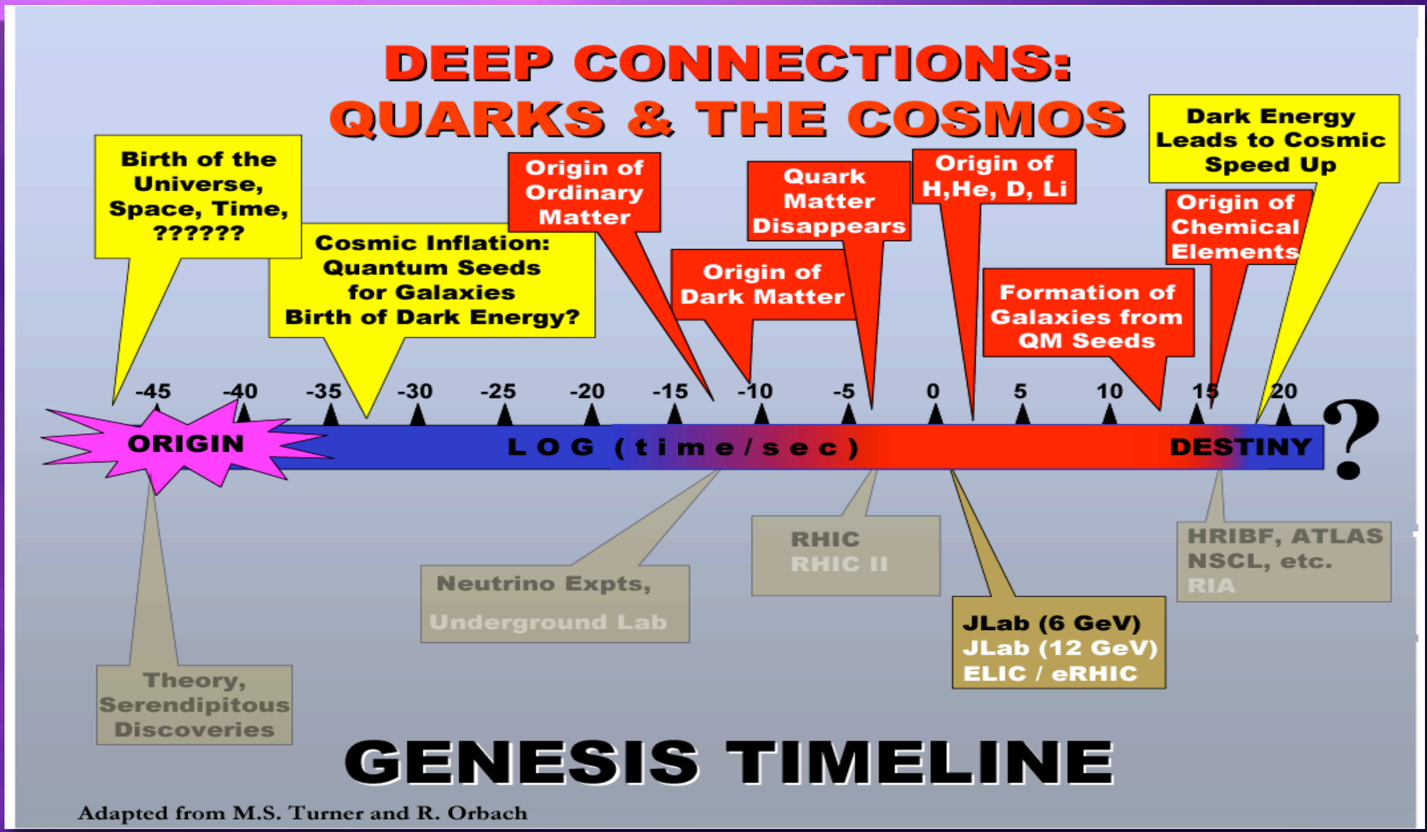
•Although too little CP-violation is present in the SM to generate baryon asymmetry, it can be generated (for example) in the MSSM

•Strong first order phase transition requires $M_{stop} < M_{top}$ in the MSSM, although not as restrictive in the nMSSM and other extended Higgs sector models

•Neutralinos and charginos can play critical roles - ILC very important!

(See talks by Michael Ramsey-Musolf, Csaba Balazs, Marcela Carena)

Colliders And The Early Universe



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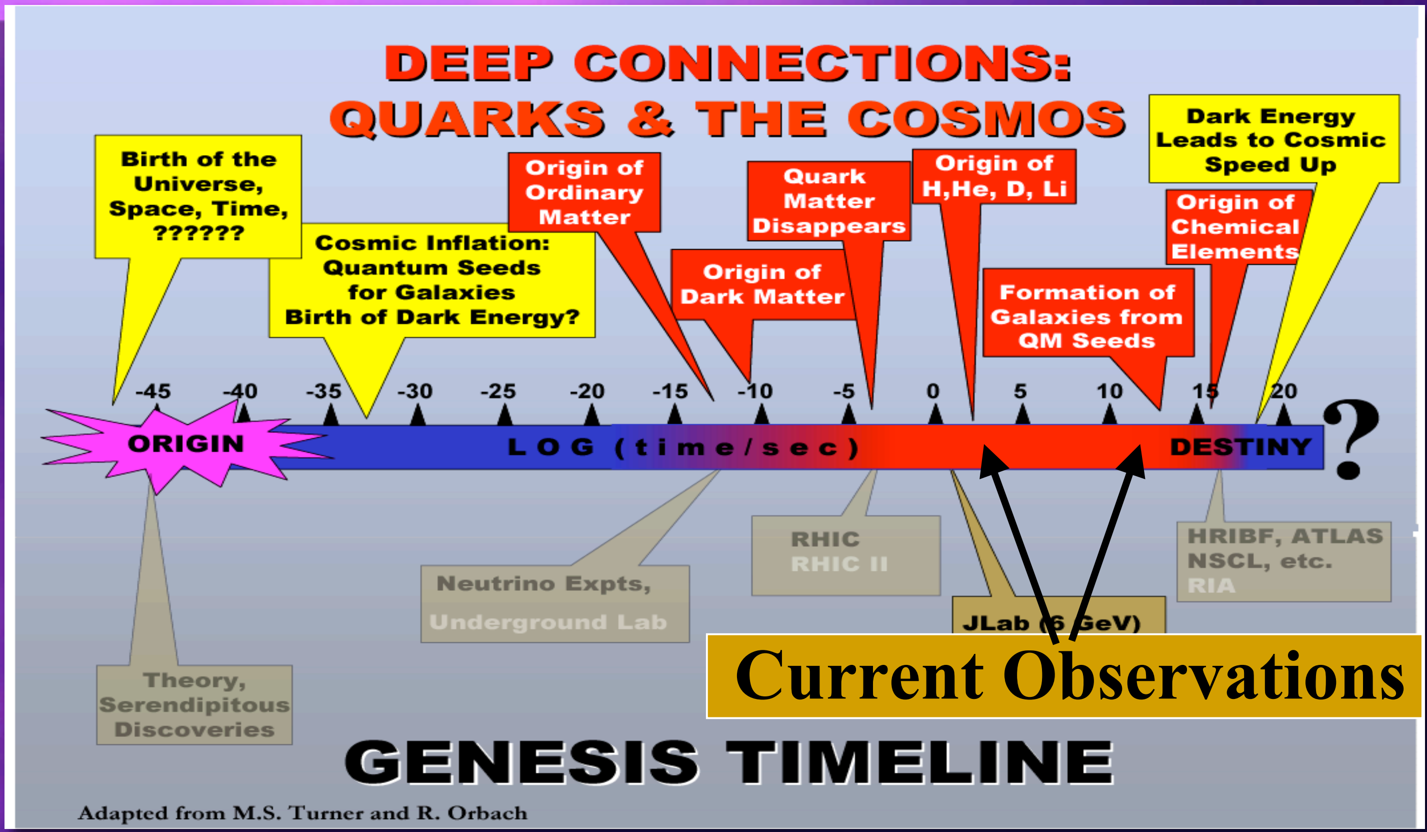
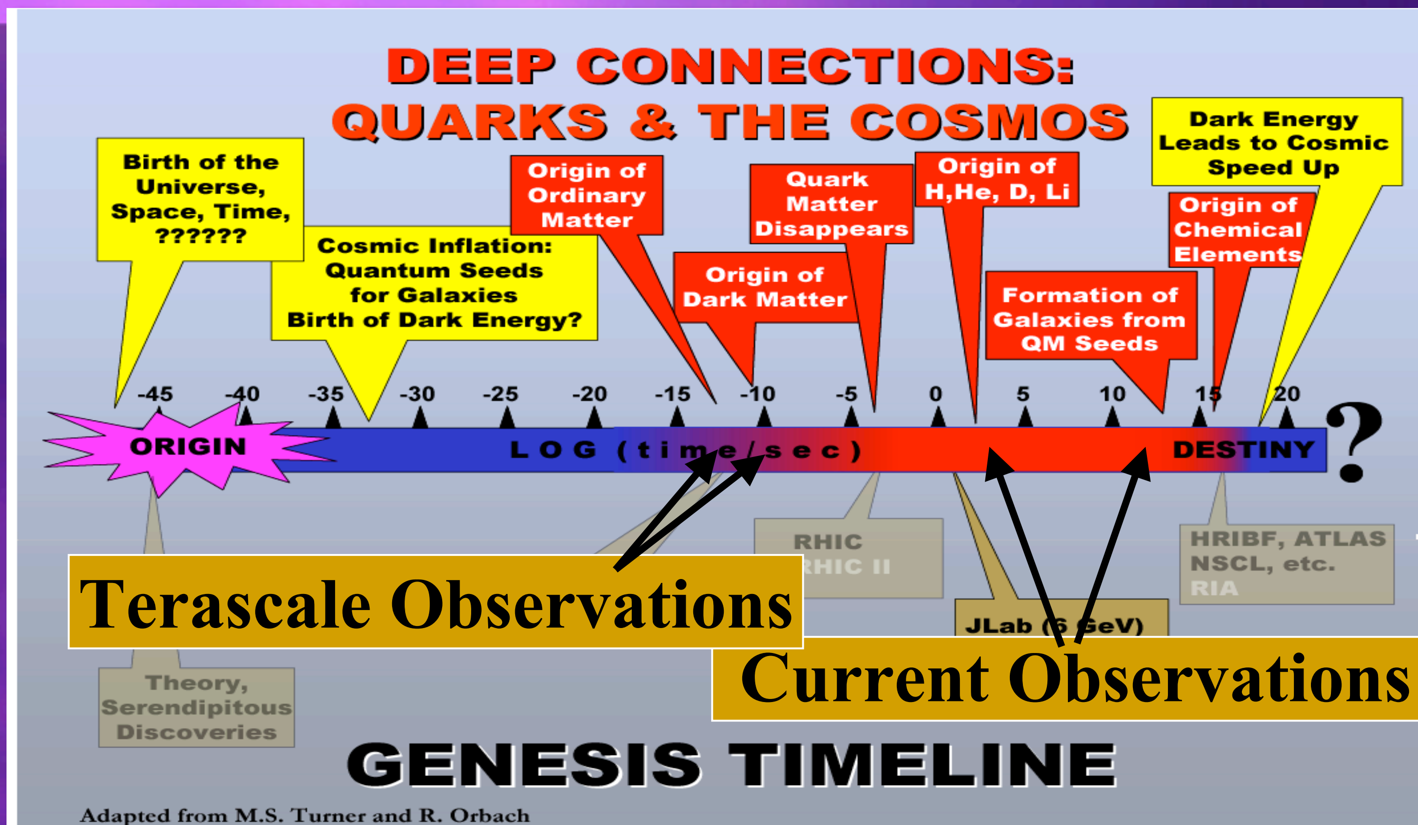


Colliders And The Early Universe



All-Natural Particle Accelerators

- Astrophysical accelerators are known to accelerate particles to at least ~10^{20} eV (~10^{20} eV neutrino $\Rightarrow$ ~300 TeV CM), but far smaller numbers of events can be observed (low luminosity)

- Opportunity to study particles over kpc/Mpc/Gpc baselines

- Provides a natural complementarity to collider experiments

Summary

•Collider/Cosmology complementarity is extremely powerful

•LHC/Tevatron, direct and indirect dark matter searches are each very promising, but will not fully solve the dark matter problem

•An ILC would likely enable us to determine the particle identity of the dark matter observed in our galaxy and elsewhere

•Origin of baryon asymmetry may be tied to EW scale physics

•Cosmic accelerators provide an opportunity to study particles with energies beyond the reach of the LHC, and over exceedingly long baselines

Let's use all of the tools we have to solve the puzzles of the terascale!