Stop, chargino and neutralino searches in Run II & at the LHC

Csaba Balázs (Argonne National Laboratory)

— Constraints on CDM and the LSP

— Electroweak baryogenesis in the MSSM

— Combined astrophys constraints & collider implications

C.Balázs, M.Carena, C.E.M.Wagner PRD70 015007 (`04), hep-ph/041xxxx

H.Baer, C.Balázs JCAP0305:006

http://www.hep.anl.gov/balazs/Physics/Talks/2004/09-TeV4LHC

A Tevatron-LHC synergy written in the stars

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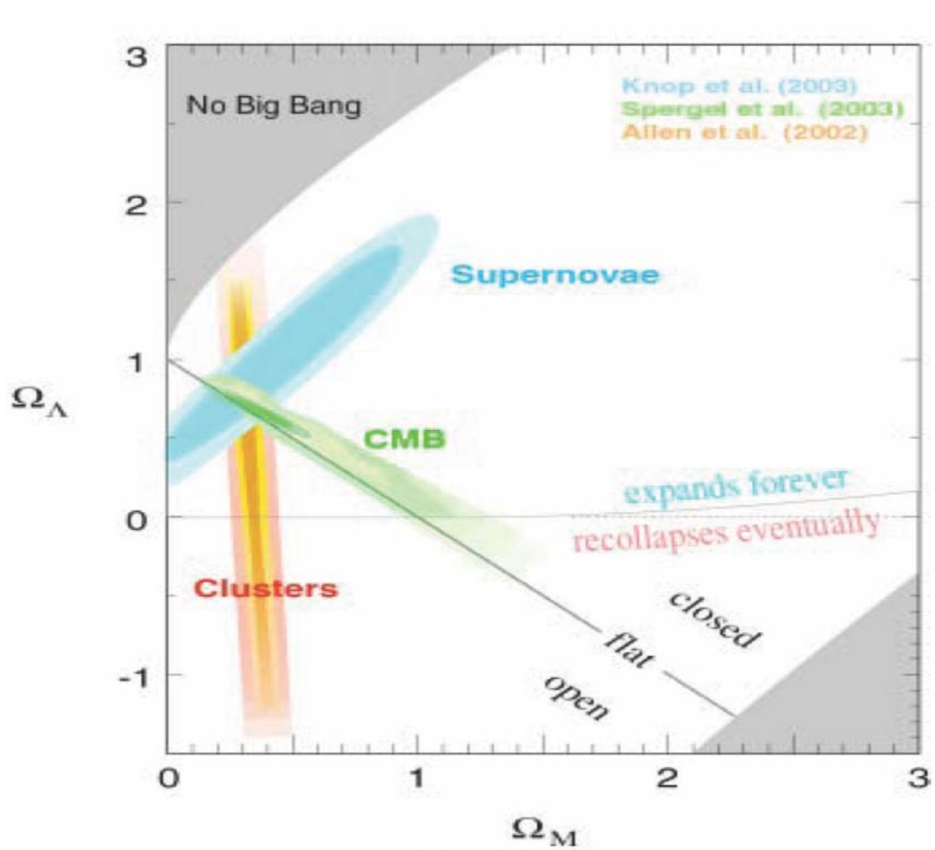
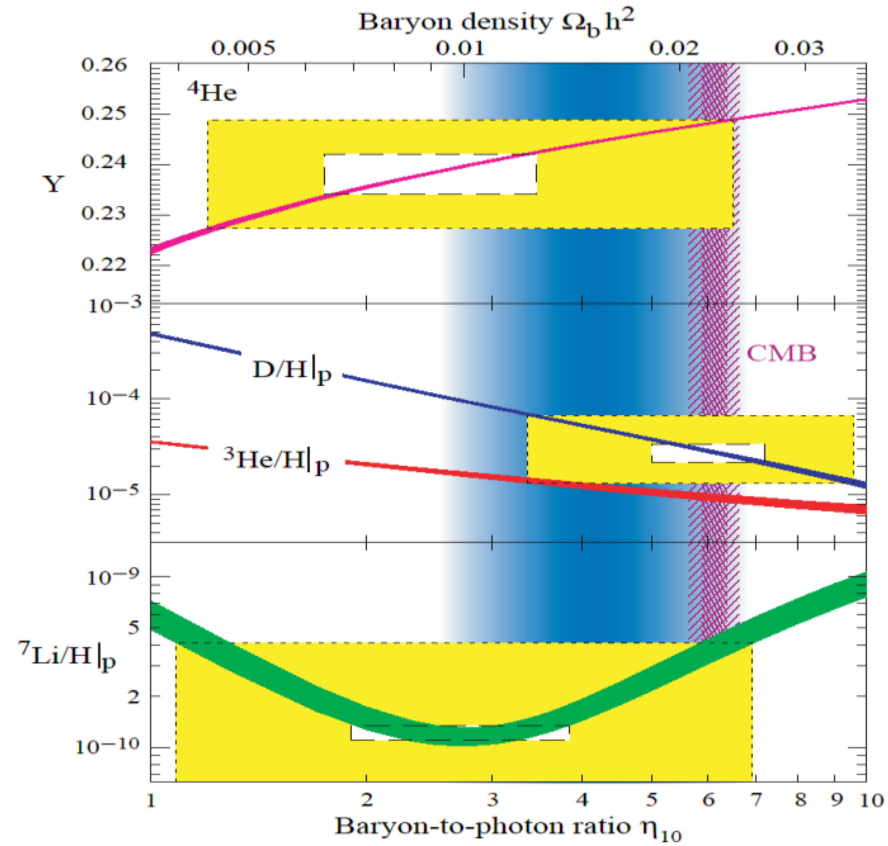
Why to turn to the stars?

– Remarkable advance in astrophysics: precise, direct, independent observations, supporting each other → robust result





- Supernovae, WMAP, SDSS

$\Omega_M = 0.27 \pm 0.04$

$\Omega_\Lambda = 0.73 \pm 0.04$

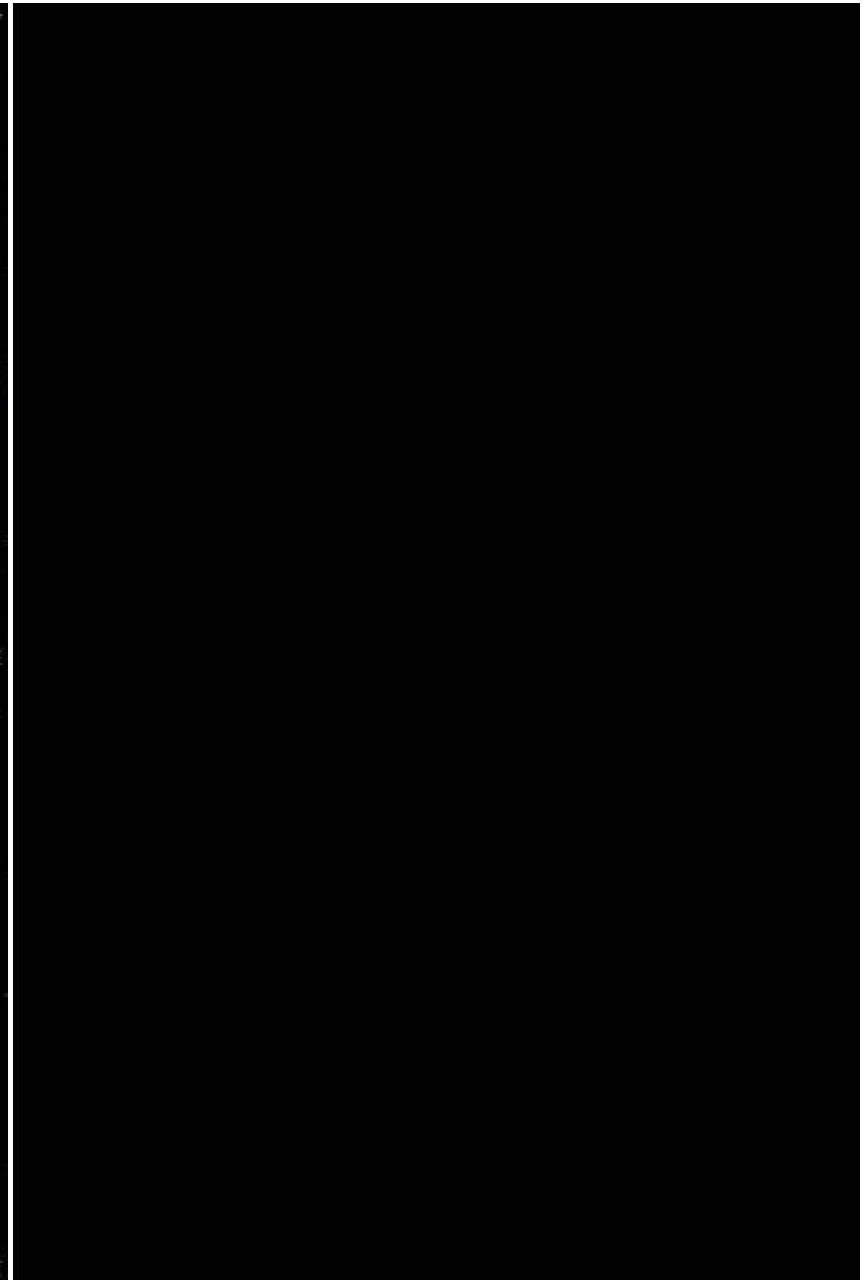
- BBN & CMB, cosmic concordance

$\Omega_b = 0.044 \pm 0.004 \Rightarrow$

$\Omega_{DM} = 0.22 \pm 0.04$

What's dark matter? (An astronomer's view)

Luminous matter



Dark matter

What's dark matter? (A particle physicist's view)

– Known dark matter properties

- stable →

  u, d, ν, e, γ, g

- non-baryonic →

  ν, e, γ, g

- non-relativistic →

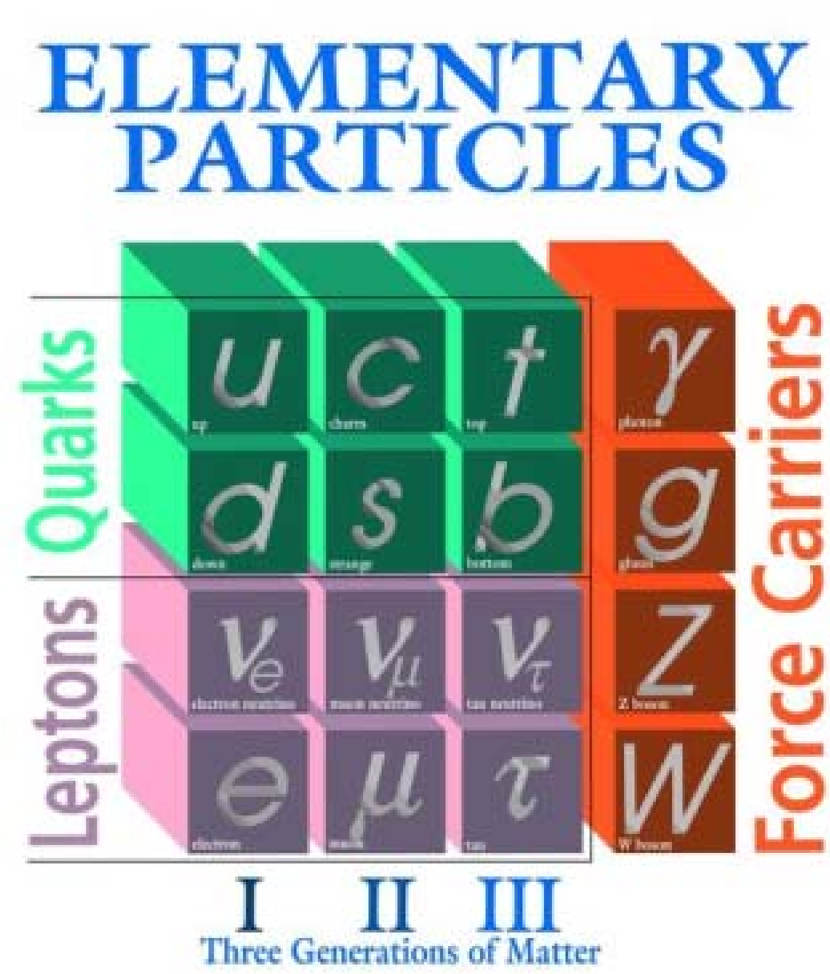
  e

- weakly interacting →

  new physics!

– Low energy supersymmetry with R parity → lightest supersymmetric particle

- stable, non-baryonic, heavy, weakly interacting



- cosmological properties of LSP make it an excellent CDM candidate
- LSP has to comply with the strong CDM limits

Matter-anti-matter asymmetry

– WMAP: $\frac{n_B}{n_\gamma} = (6.1 \pm 0.4) \times 10^{-10}$ → matter-anti-matter asymmetry

- lepto-, baryogenesis explains the origin of asymmetry
- baryogenesis: connected to weak scale → testable at colliders

0. earliest universe starts in a matter-antimatter symmetric phase
1. ~~B~~ is efficient before a thermodynamic phase transition
2. ~~C~~ & ~~CP~~ interactions allow to generate asymmetry
3. ~~T~~ preserves asym.: at phase transition Universe falls out equilibrium, and new vacuum B conserving (Sakharov conditions)

– Electroweak baryogenesis (EWBG)

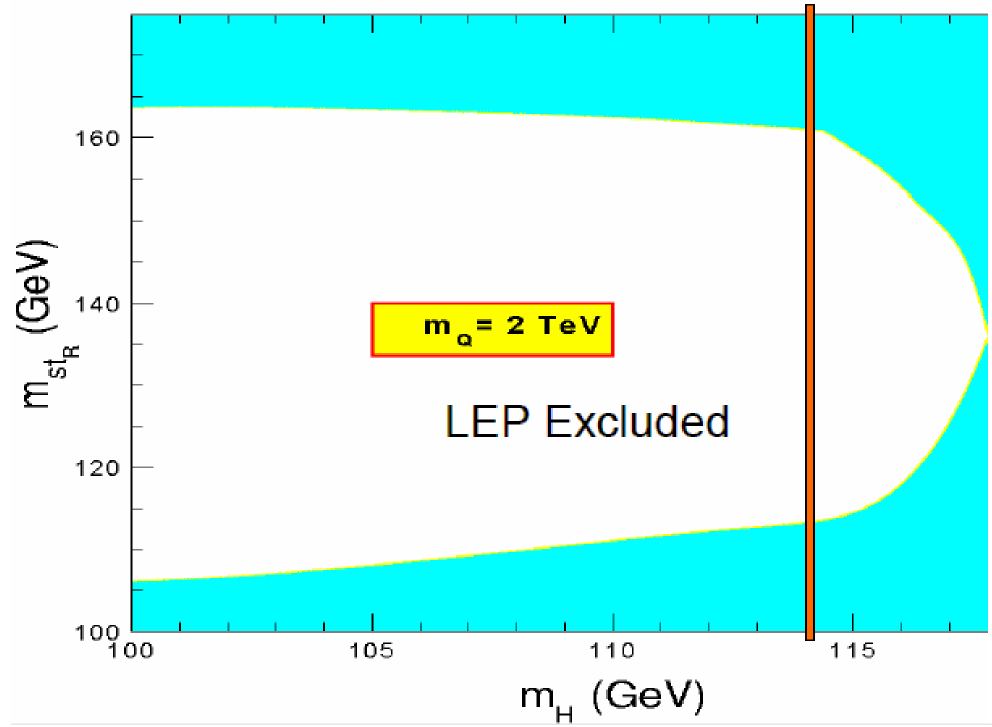
- SM can satisfy Sakharov conditions, if

1. ~~B~~ at quantum level ← in SM anomalies only conserve B–L
2. there's enough ~~CP~~ in CKM ← not satisfied in SM: new ~~CP~~ physics!
3. EW phase transition strongly first order ← in SM: $m_h < 40$ GeV

Baryogenesis in the MSSM

— Possible if

1. anomalies violate B (✓)
2. there's enough $\not{CP}$ ↔
   μ, M_i and/or A_t has
   (relative) complex phases
3. EW phase trans'n 1st order →
   constraints on stop sector
   $m_{\tilde{t}_1} < m_t$, $m_{\tilde{t}_2} \gtrsim 1$ TeV,
   $0.3 < |X_t| / m_{\tilde{Q}_3} < 0.5$,
   constraints on Higgs sector
   $m_h \lesssim 120$ GeV



Carena, Seco, Quiros, Wagner 2002

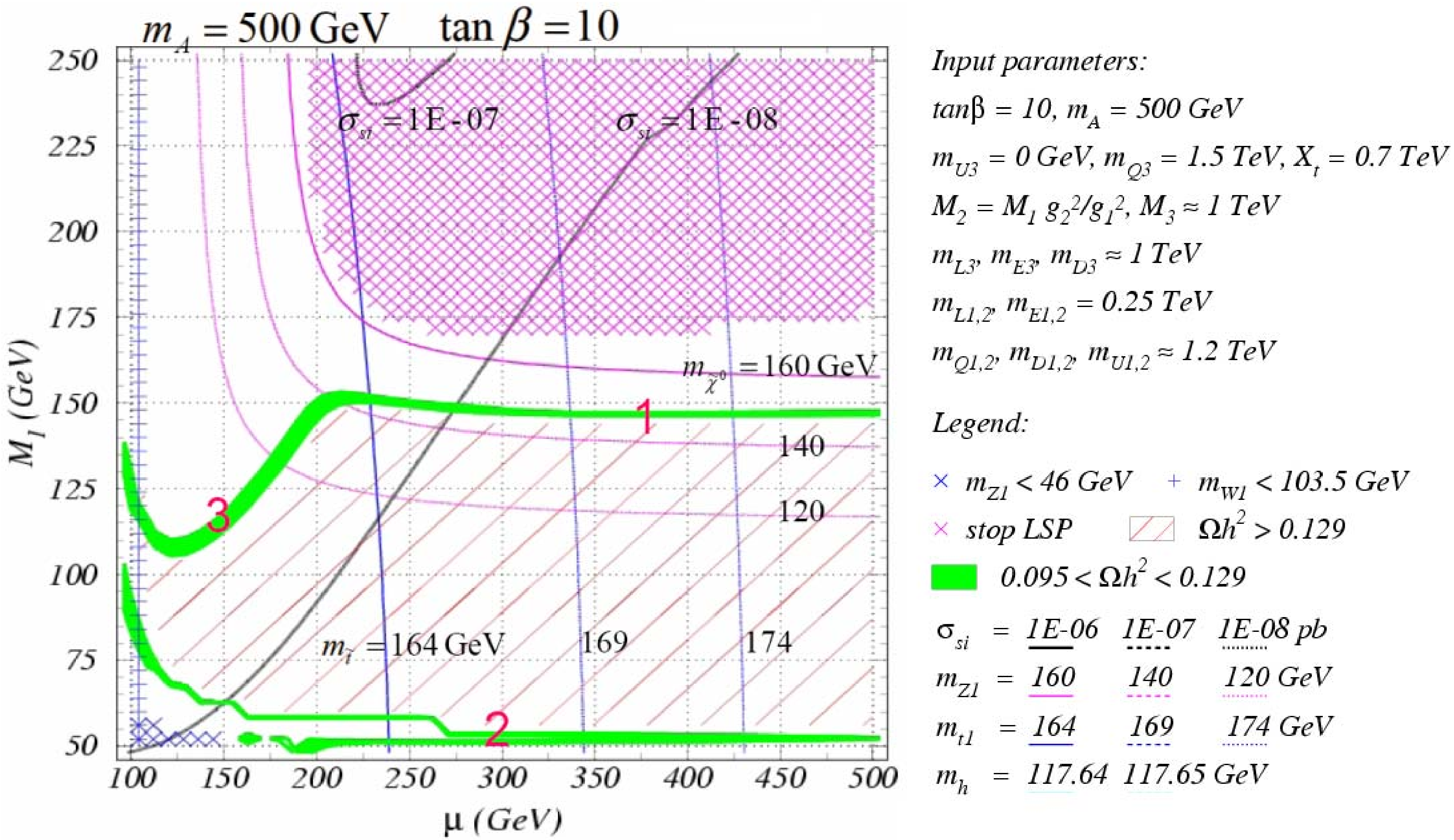
- scenario is already severely constrained by the LEP 2 Higgs lower limit:

  $114.4 \text{ GeV} < m_h$

- Does it survive the stringent WMAP limits?

Dark matter & baryogenesis in the MSSM

– Simultaneous requirement of EW baryogenesis & neutralino DM pinpoints the viable MSSM regions Davidson et al., Boehm et al. 1999



Balazs,Carena,Wagner 2004

Collider implications

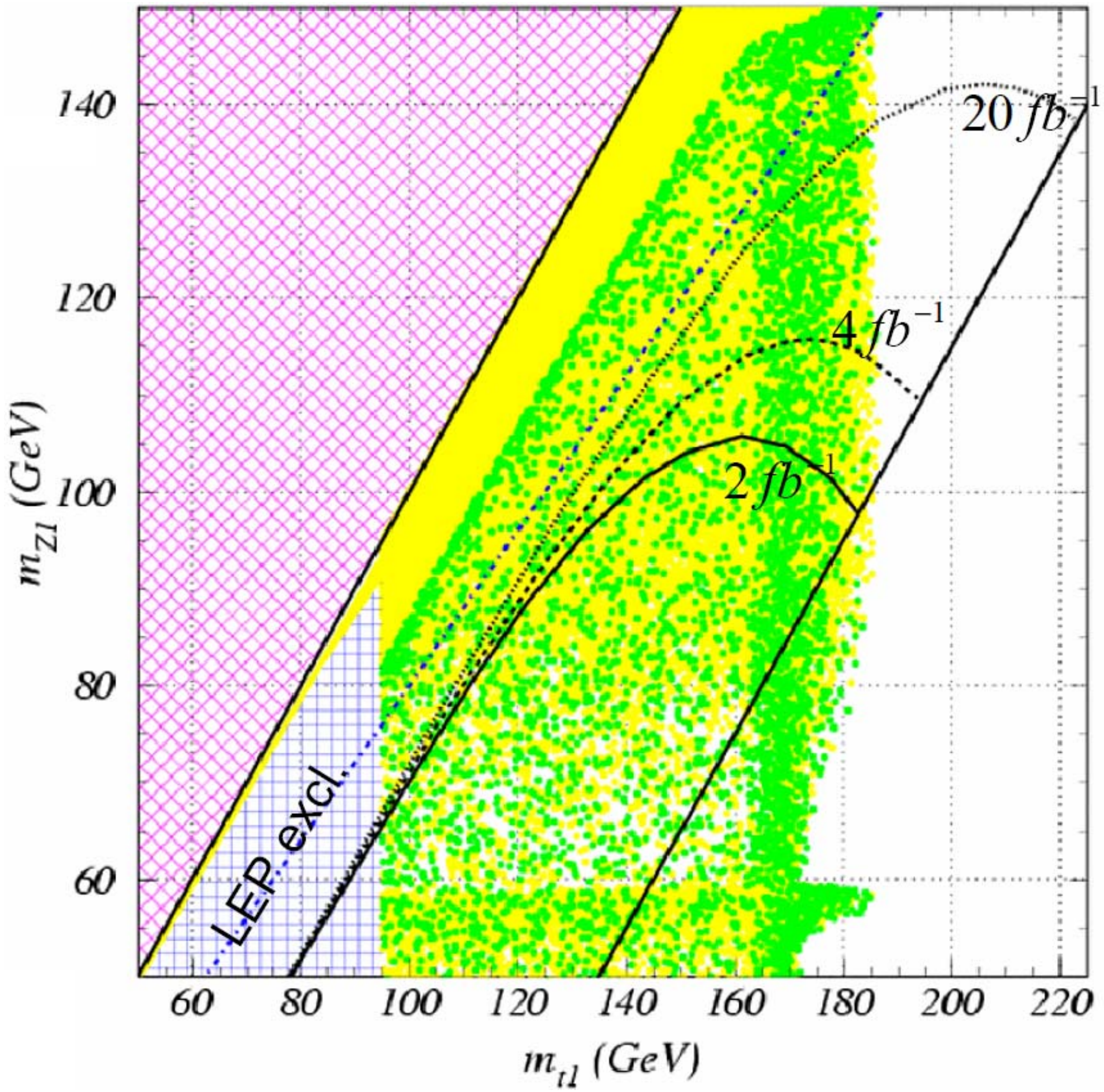
— If $m_{\tilde{t}_1} < m_{\tilde{Z}_1} + m_W + m_b \rightarrow$
$\tilde{t}_1 \rightarrow c\,\tilde{Z}_1 \; (= c\,\not{E}_T)$ dominant

- observable at Tevatron if
$m_{\tilde{t}_1} - m_{\tilde{Z}_1} > 30$ GeV (dep. $\mathcal{L}$)
- if $m_{\tilde{t}_1} \lesssim 1.25\, m_{\tilde{Z}_1} \Rightarrow$
$\tilde{t}_1$ - $\tilde{Z}_1$ coannihilation
Tevatron doesn't trigger !

— If $m_{\tilde{t}_1} > m_{\tilde{Z}_1} + m_Z + m_b \rightarrow$
Higgs resonance region

- 3-body decay
Tevatron has no reach for $\tilde{t}_1$!
- if $m_{\tilde{W}_1} \lesssim 130$ GeV
$\tilde{W}_1$ can be seen via 3-leptons

— LHC will detect $\tilde{Z}_1$, $\tilde{W}_1$ in full para. space but trigger settings similar for $\tilde{t}_1$



Balazs, Carena, Wagner 2004

— A lepton-lepton collider can cover the $\tilde{t}_1$-$\tilde{Z}_1$ coannihilation region

Summary

— Dark matter seems to be out there & neutralinos are excellent candidates

- strong astrophysical constraints have to be satisfied!

— EWBG is a testable scenario explaining matter-anti-matter asymmetry

- strong astro- and collider constraints implied

— Simultaneous EWBG & CDM is viable in the MSSM

- combined constraints select narrow regions of the MSSM

— The Tevatron-LHC synergy written in the sky:

- Tevatron has a chance to find a light stop chargino and neutralino, but it should try to trigger for a small $\tilde{t}_1$-$\tilde{Z}_1$ mass gap to increase its chance
- even if the Tevatron misses a light stop the LHC should learn the lesson and trigger for a small $\tilde{t}_1$-$\tilde{Z}_1$ mass gap
- maybe a LC is needed to fully cover the $\tilde{t}_1$-$\tilde{Z}_1$ coannihilation region, or: can the Tevatron/LHC do it? a study necessary!