Gravitino Production in Early Universe

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In collaboration with
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30.07.07, SUSY07, Karsluhe

This Talk

- Gravitinos are produced from scalar, i.e. inflaton, decay via gravitational effects.
- Direct and perturb. - different from thermal/preheating production.
- This talk clarifies underlying physics.
  - How generic it is?
  - How significant (for cosmology)?

(talk by Takahashi for inflation models)

Gravitino: overview

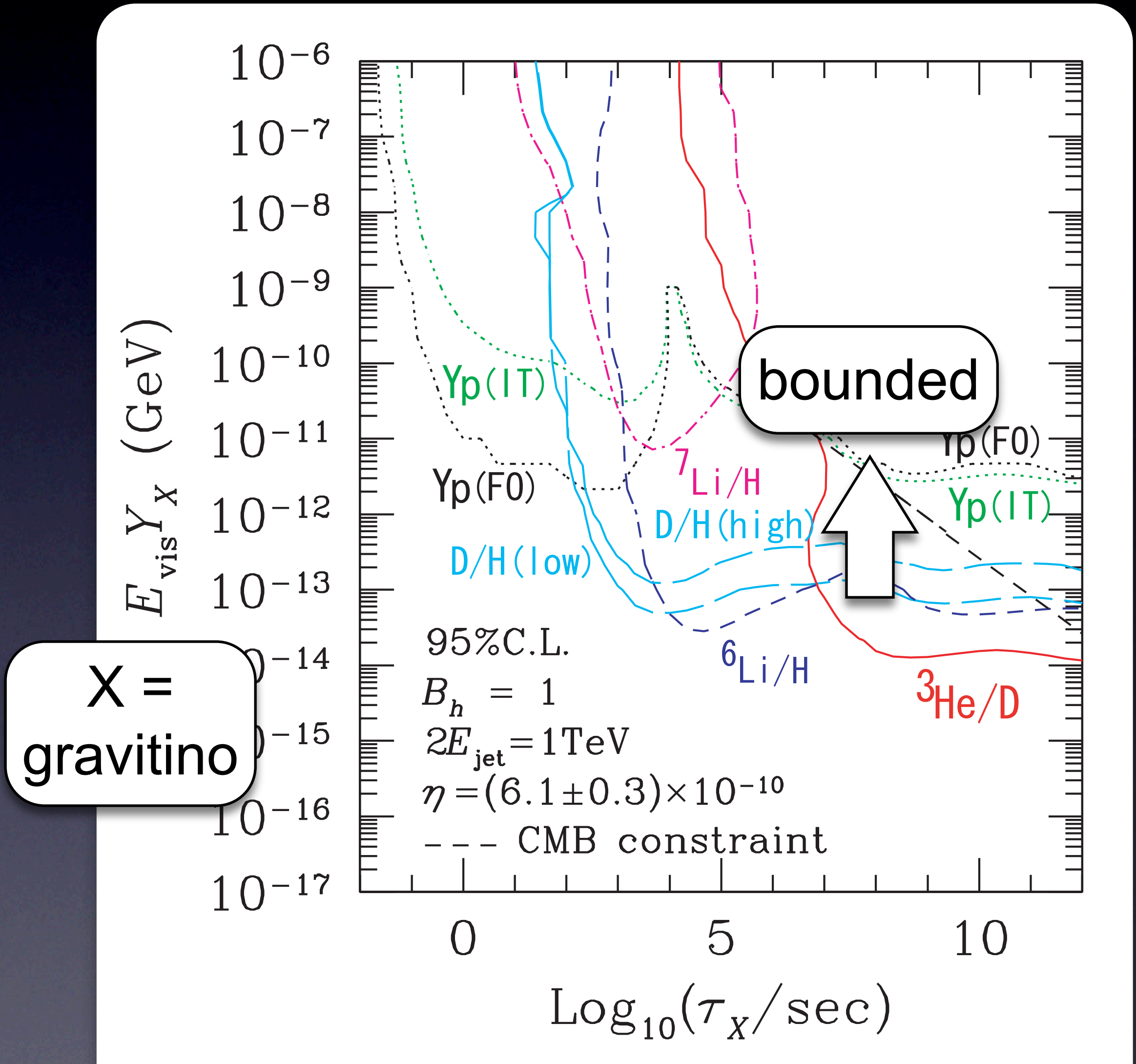
- R-parity odd
- Massive below SUSY breaking scale
- Absorb goldstino (fermion of ~~SUSY~~ field)
- Decay is Planck-suppressed

SUGRA = global SUSY + gravity

SM	SUSY
B, W, g	$\widetilde{B}, \widetilde{W}, \tilde{g}$
ℓ, e, q, d, u	$\tilde{\ell}, \tilde{e}, \tilde{q}, \tilde{d}, \tilde{u}$
H_u, H_d	$\tilde{H}_u, \tilde{H}_d$
graviton	gravitino

Gravitino Spoils SBBN

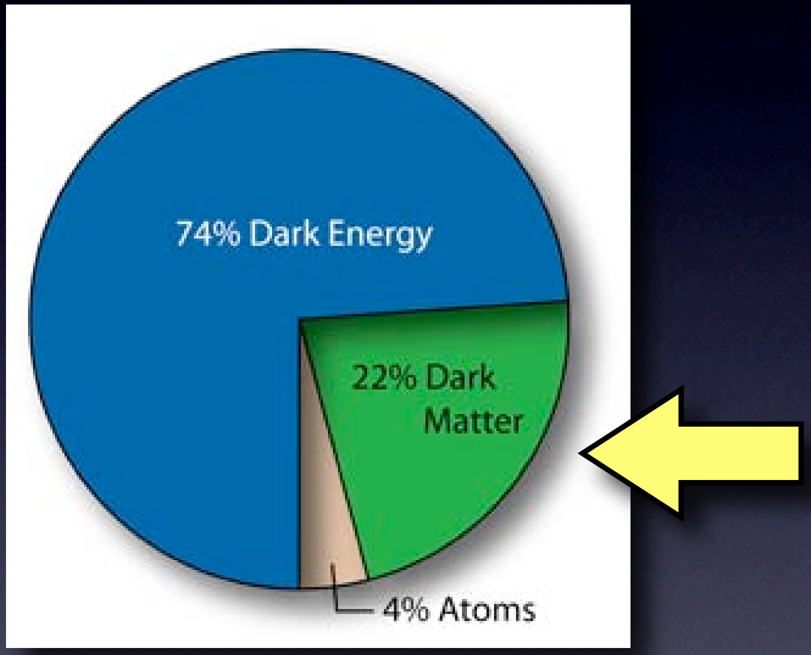
- BBN is spoiled by unstable gravitino



[Kawasaki,Kohri,Moroi]

Abundance Bounded

- BBN is spoiled by unstable gravitino
- Overclose universe by stable LSP
- Initial gravitino abundance to be constrained



$$m_X Y_X \lesssim 4.4 \times 10^{-10} \mathrm{GeV}$$

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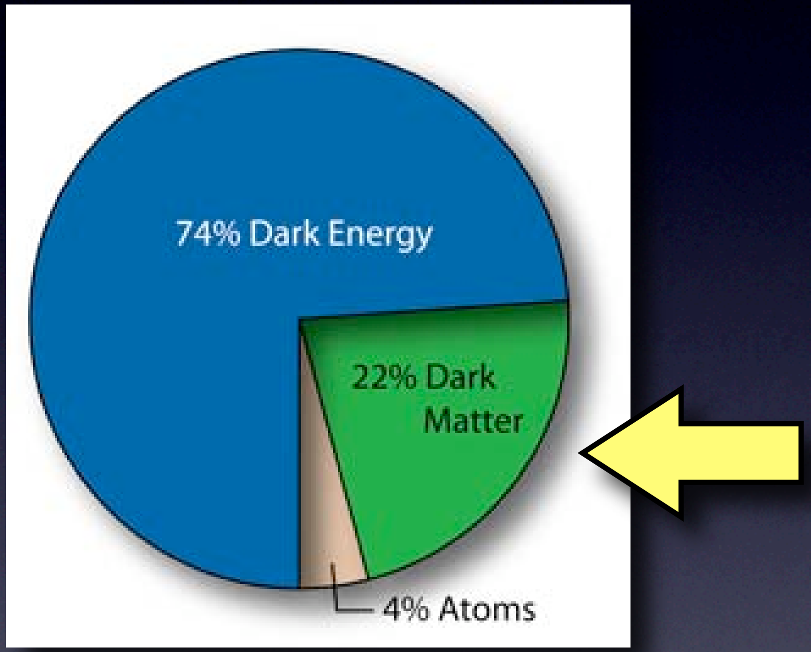


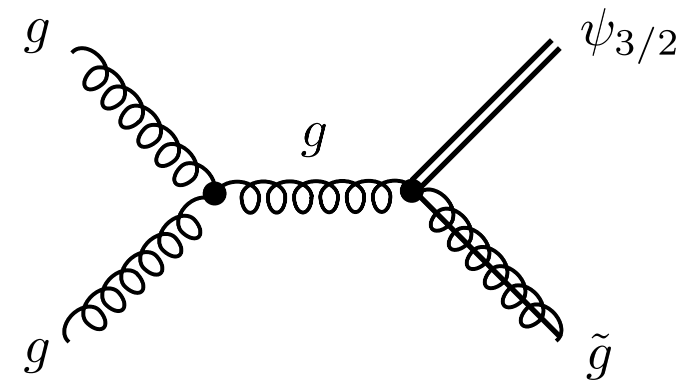
Production?

$$m_X Y_X \lesssim 4.4 \times 10^{-10}\mathrm{GeV}$$

Thermal Production

- Thermal scattering of SM/SUSY particles
- Increase as $T_R \nearrow$

ex. $g + g \to \tilde{g} + \psi_{3/2}$



$$Y_{3/2}^{(th)} \sim 10^{-12} \left(\frac{T_R}{10^{10}\mathrm{GeV}} \right)$$

up to corrections

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cf. BBN bound

$$Y_{3/2} \lesssim 10^{-(15-16)}$$

for gravity-mediation

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up to corrections

Thermal Production

- Thermal scattering of SM/SUSY particles
- Increase as $T_R \nearrow$
- Total decay rate of inflaton should be suppressed.

$$c \sim 1/M_P$$

- Gravity effects should affect reheating

ex. $g + g \to \tilde{g} + \psi_{3/2}$

cf. BBN bound

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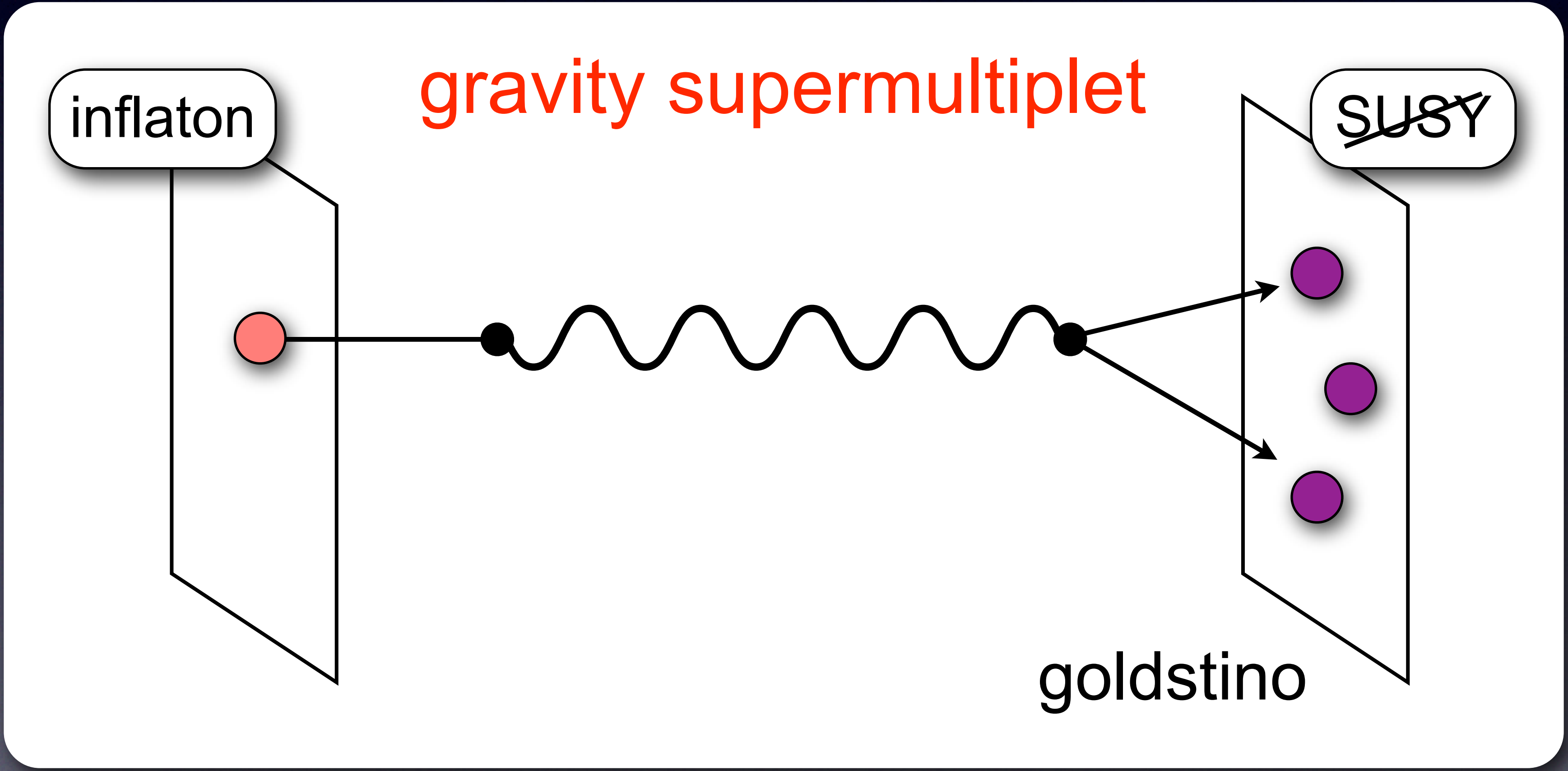
Gravitational Interaction

- We discuss inflaton decay in SUGRA
- Universal
  - SUSY breaking sector as well as inflaton inevitably couples to gravity.
- Less depend on details of model
  - Generic interaction rate

Gravity-Induced Inflaton Decay



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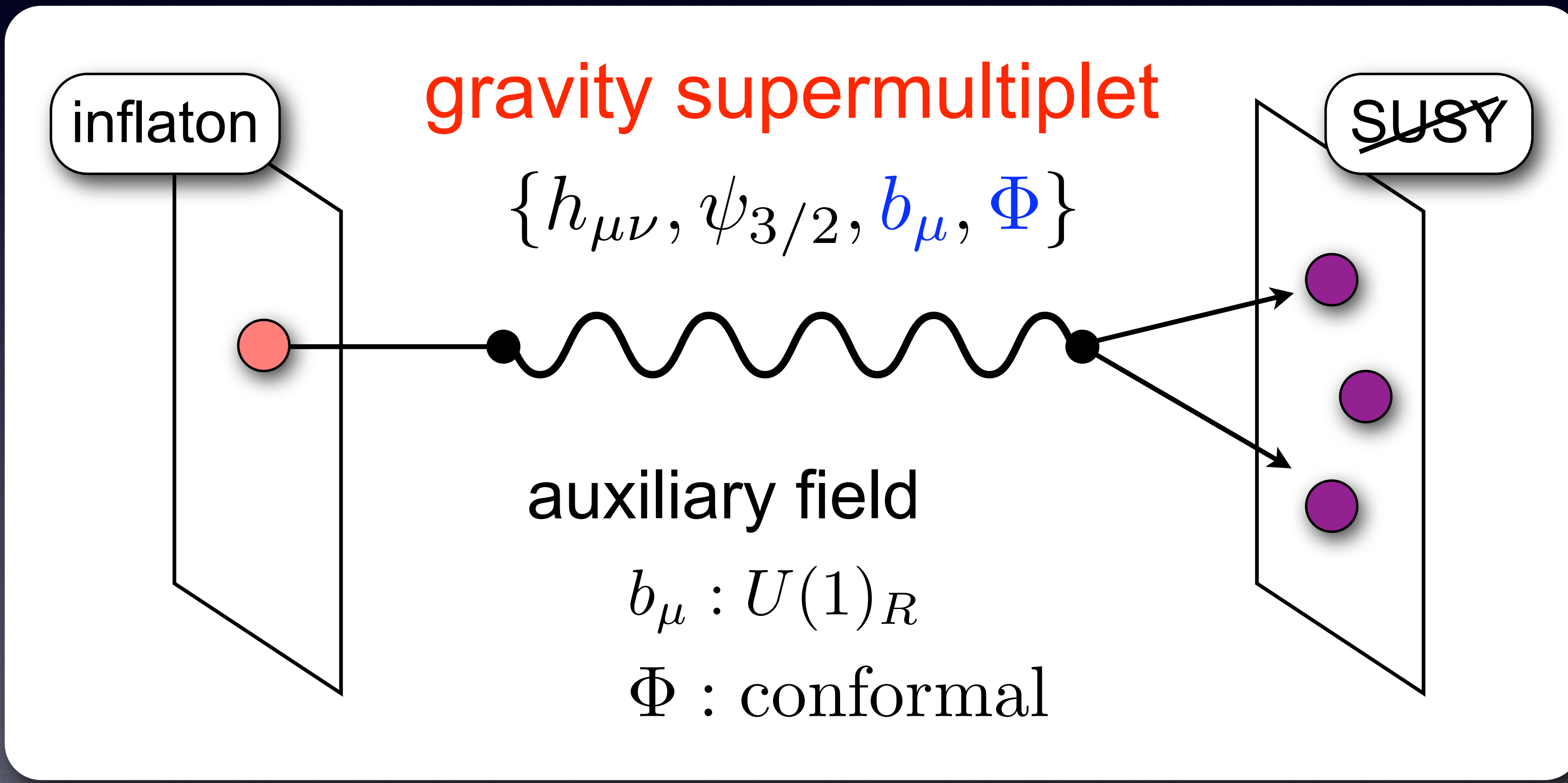

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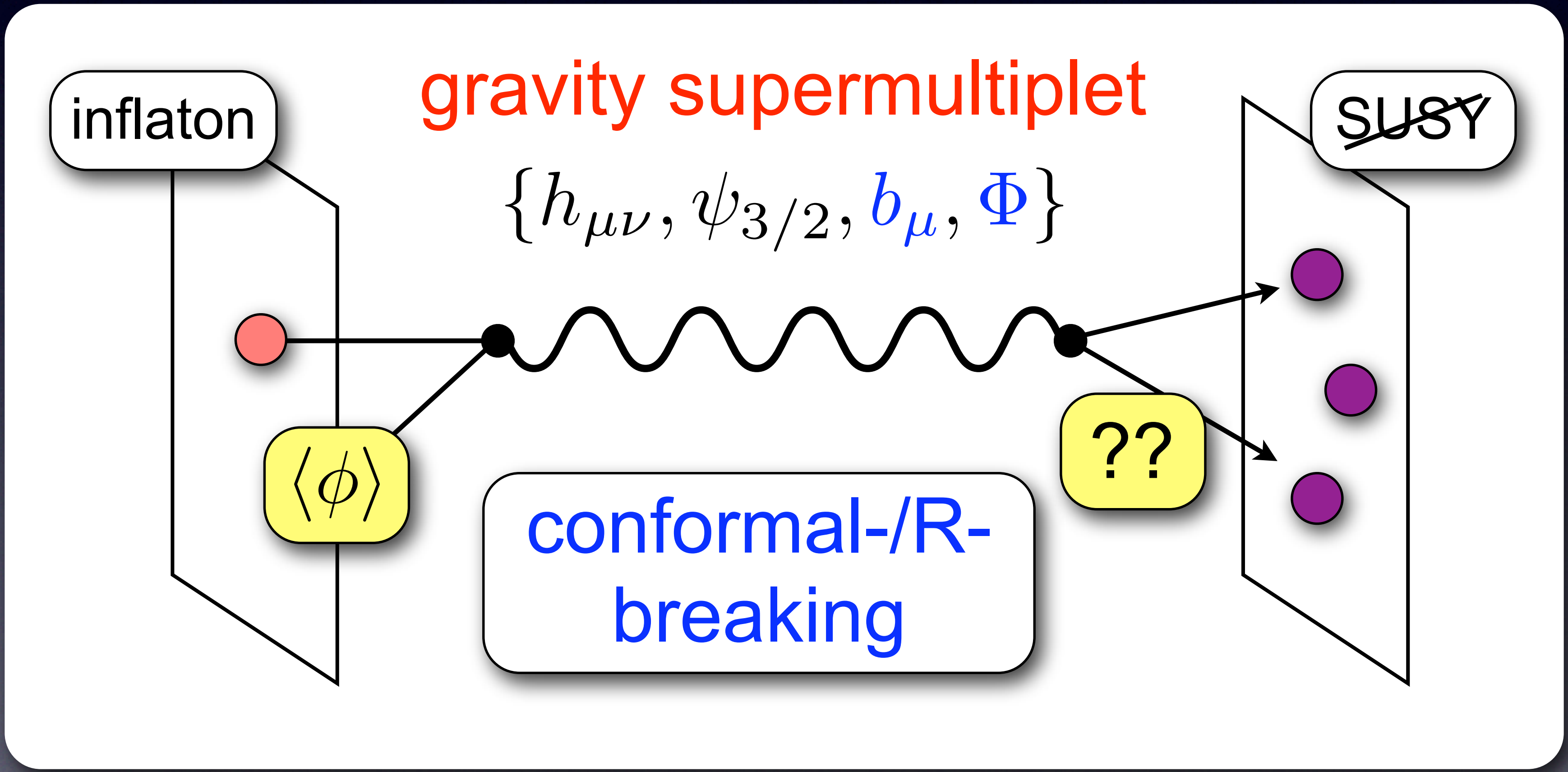
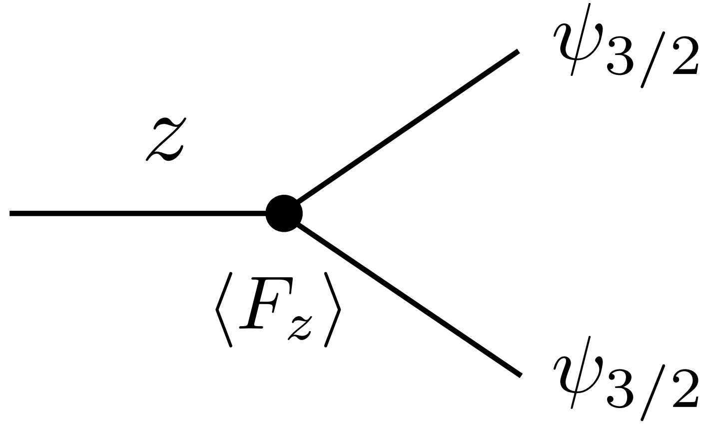


$m_\phi < \Lambda_{\rm SUSY}$

SUSY broken

z decays into
pair of gravitino

$$Z \to 2\psi_{3/2}$$



[ME,Hamaguchi,Takahashi;Kawasaki,Takahashi,Yanagida]

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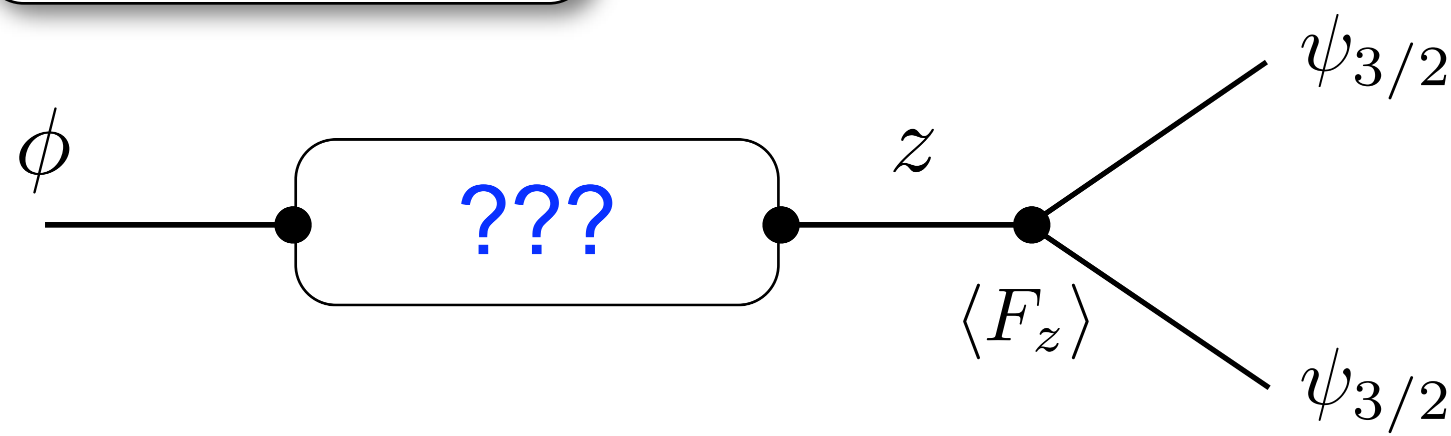

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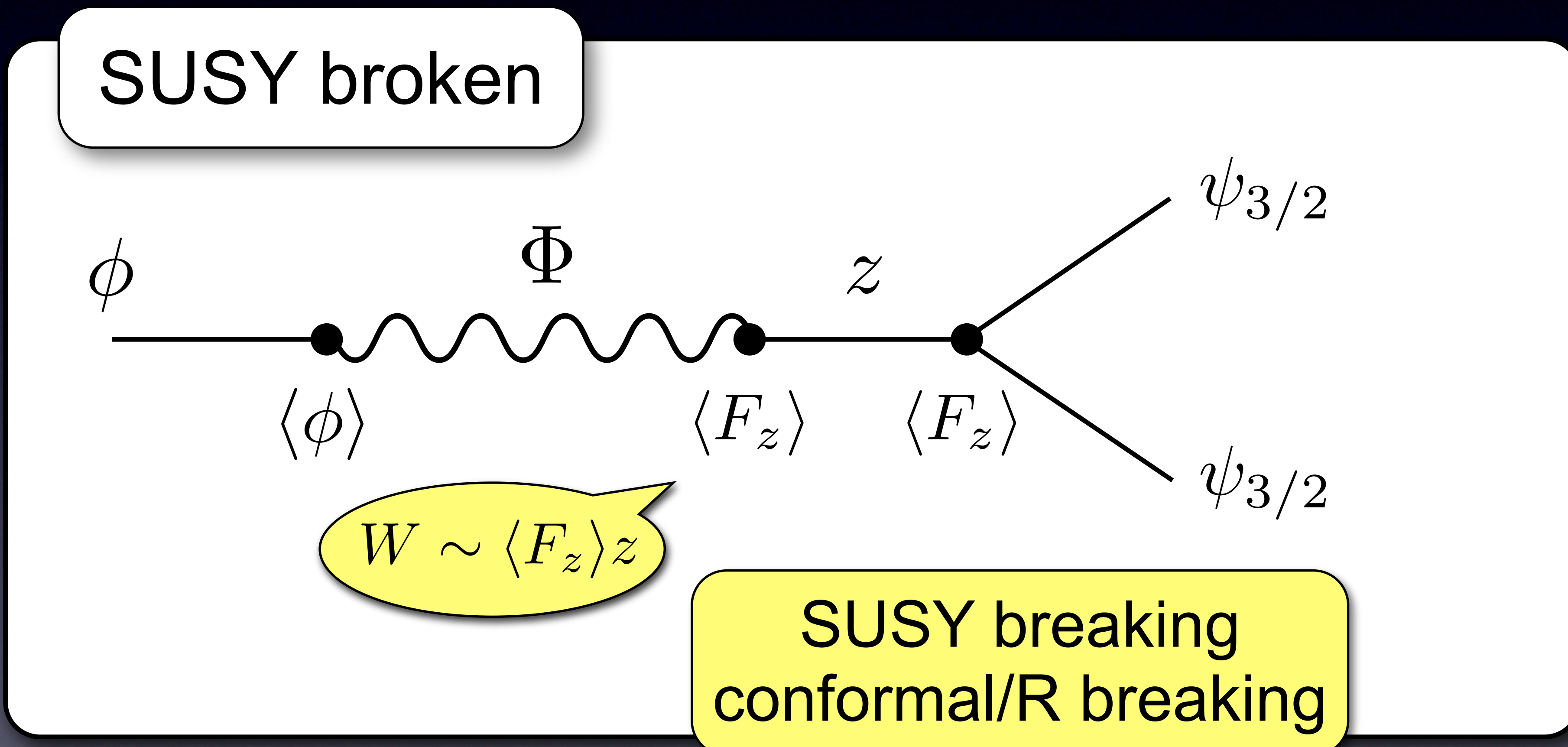

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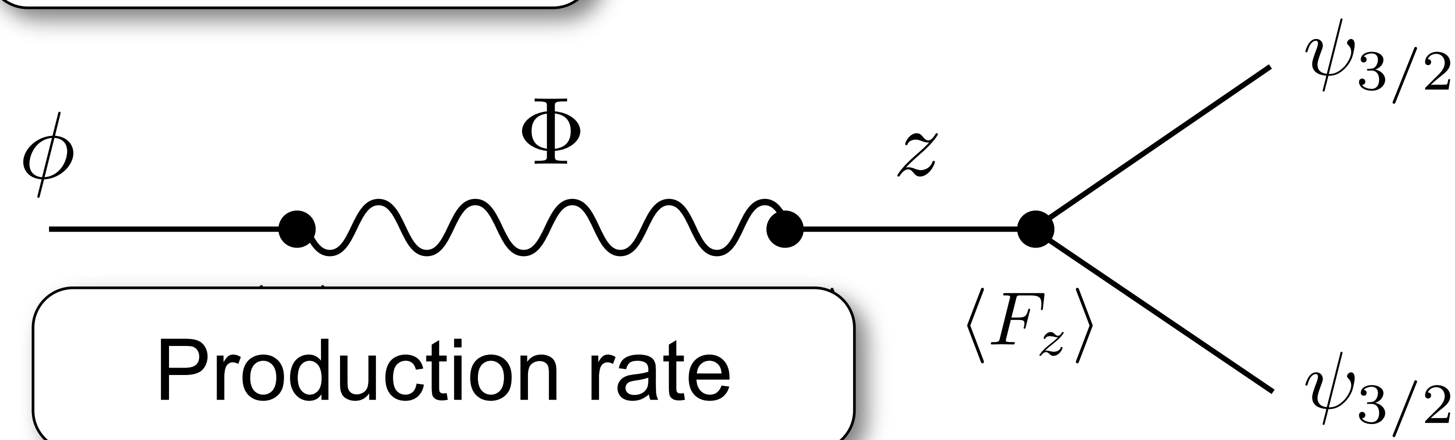

Production rate

$$\Gamma \simeq \frac{1}{32\pi} \left(\frac{\langle \phi \rangle}{M_P} \right)^2 \frac{m_\phi^3}{M_P^2}$$

[ME,Hamaguchi,Takahashi;Kawasaki,Takahashi,Yanagida]

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- Disaster of elementally-singlet Z
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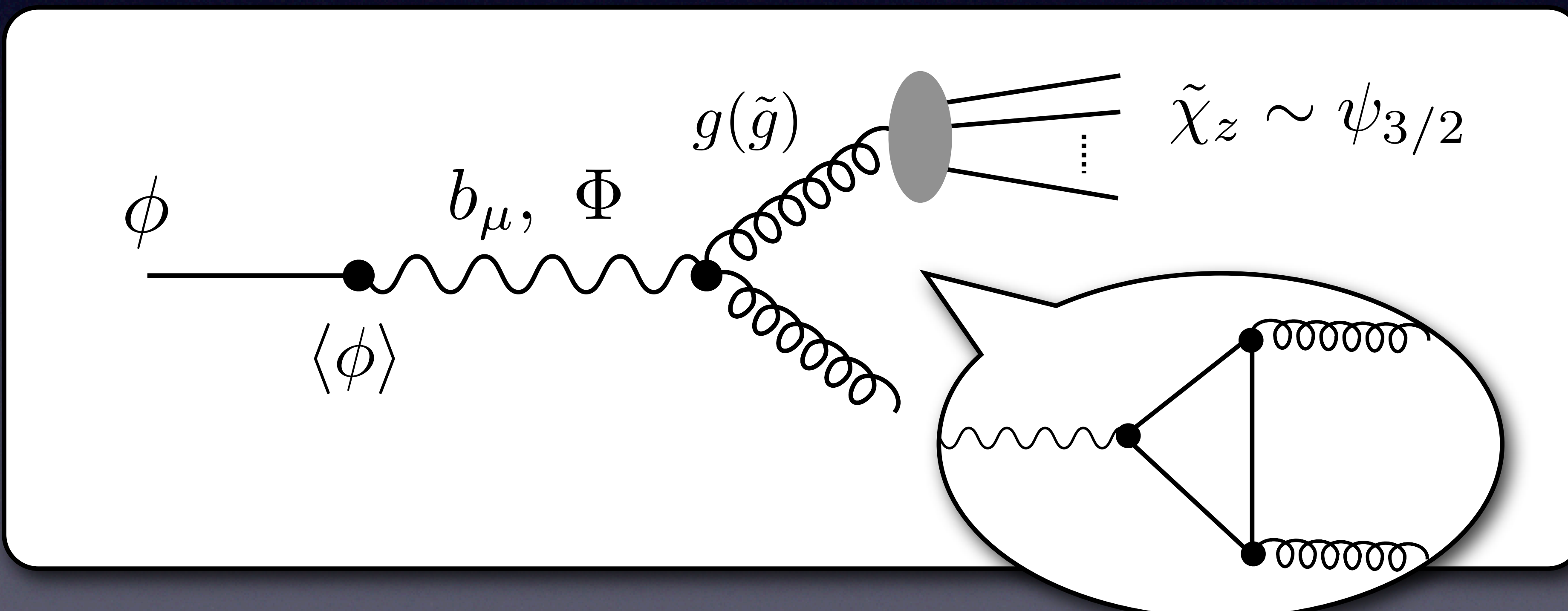
  - large gravitino production by $\delta K \sim |\phi|^2 zz$
- Assign gauge charge for Z (e.g. in DSB)

$m_\phi > \Lambda_{\rm SUSY}$

- Conformal-/R-symmetries are anomalous at quantum level (c.f. AMSB)



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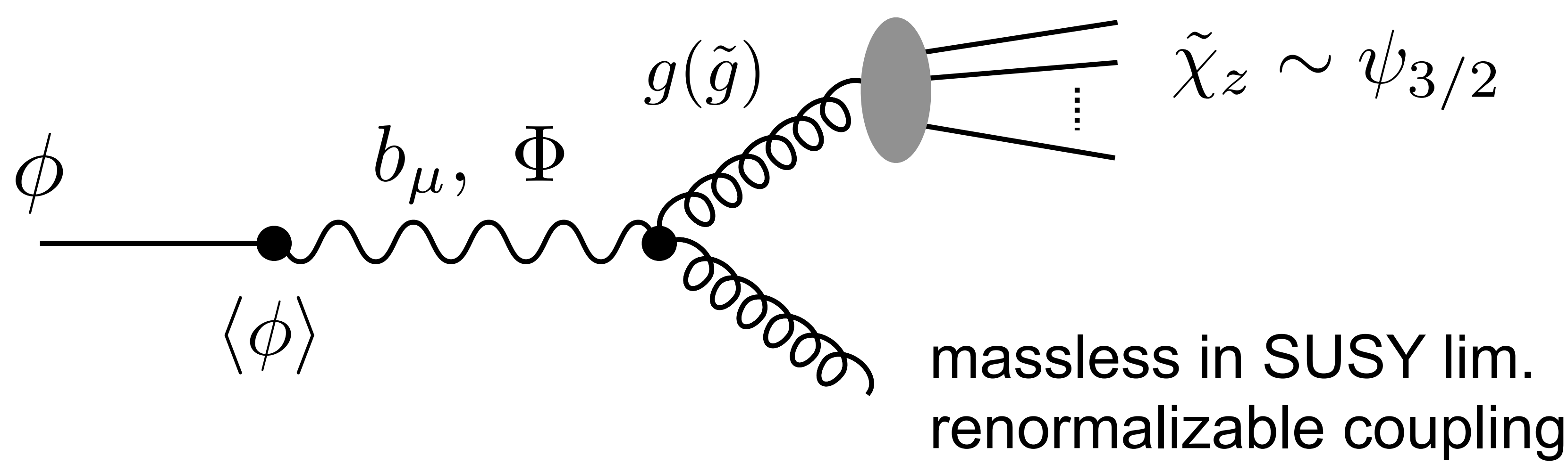

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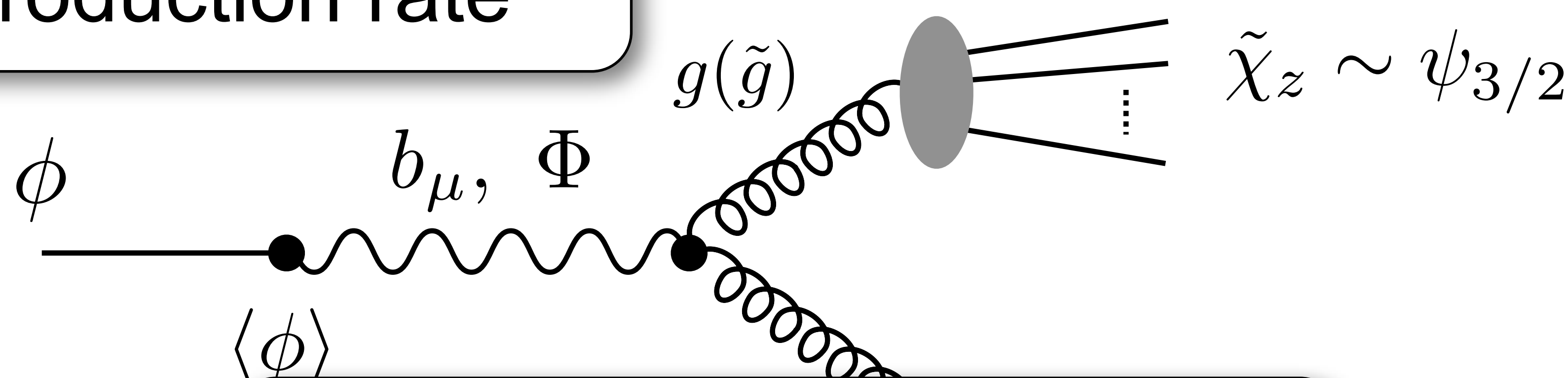

$$\Gamma \sim \frac{\alpha^2}{256\pi^3}\left(\frac{\langle\phi\rangle}{M_P}\right)^2 \frac{m_\phi^3}{M_P^2}$$

[ME, Takahashi, Yanagida]

Production Rate

- Gravitinos are produced as long as $\langle\phi\rangle \neq 0$
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[ME in collaboration w/. Hamaguchi,Kawasaki,Takahashi,Yanagida]

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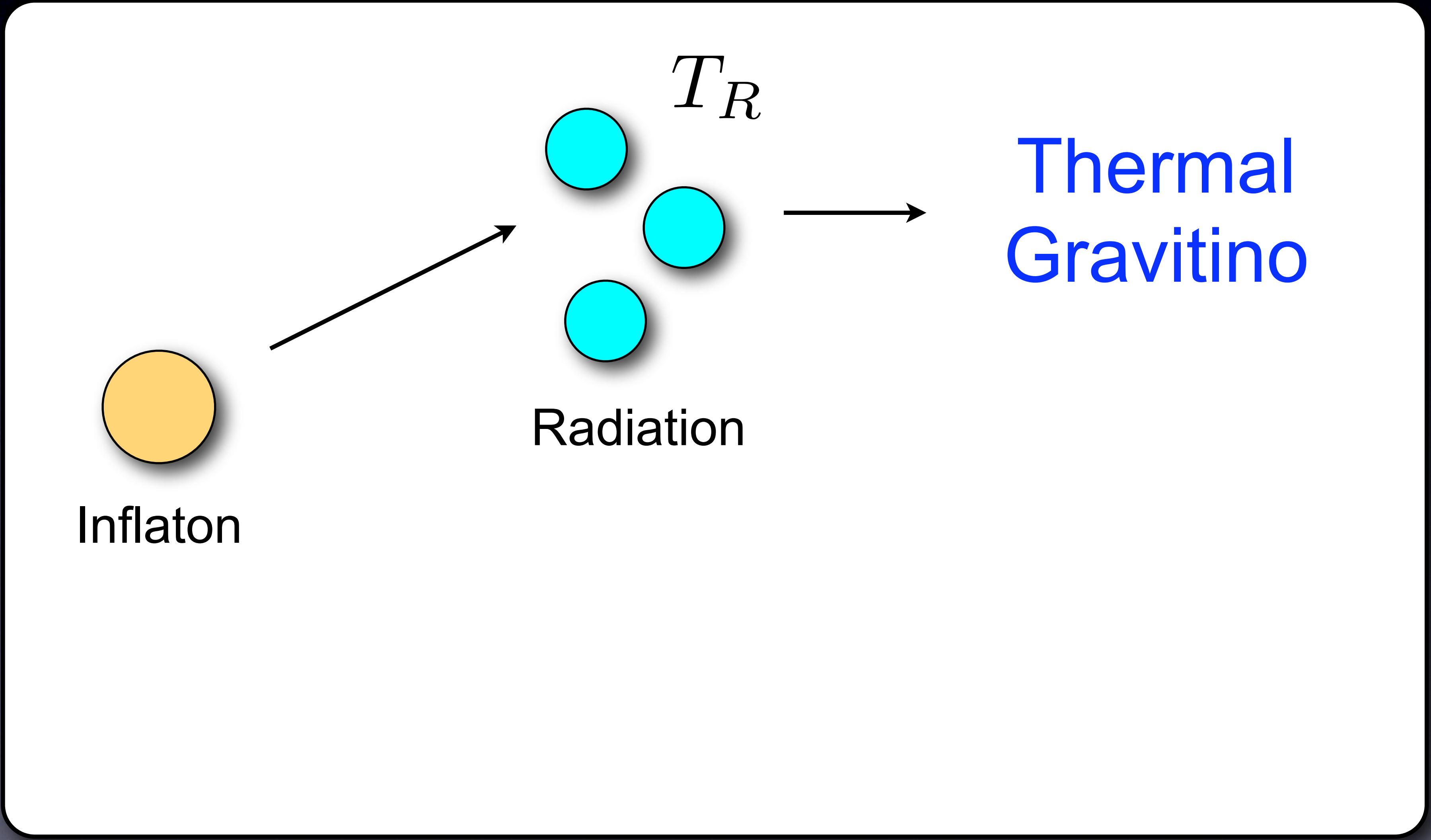
GENERIC

[ME in collaboration w/. Hamaguchi,Kawasaki,Takahashi,Yanagida]

Gravitino Produced



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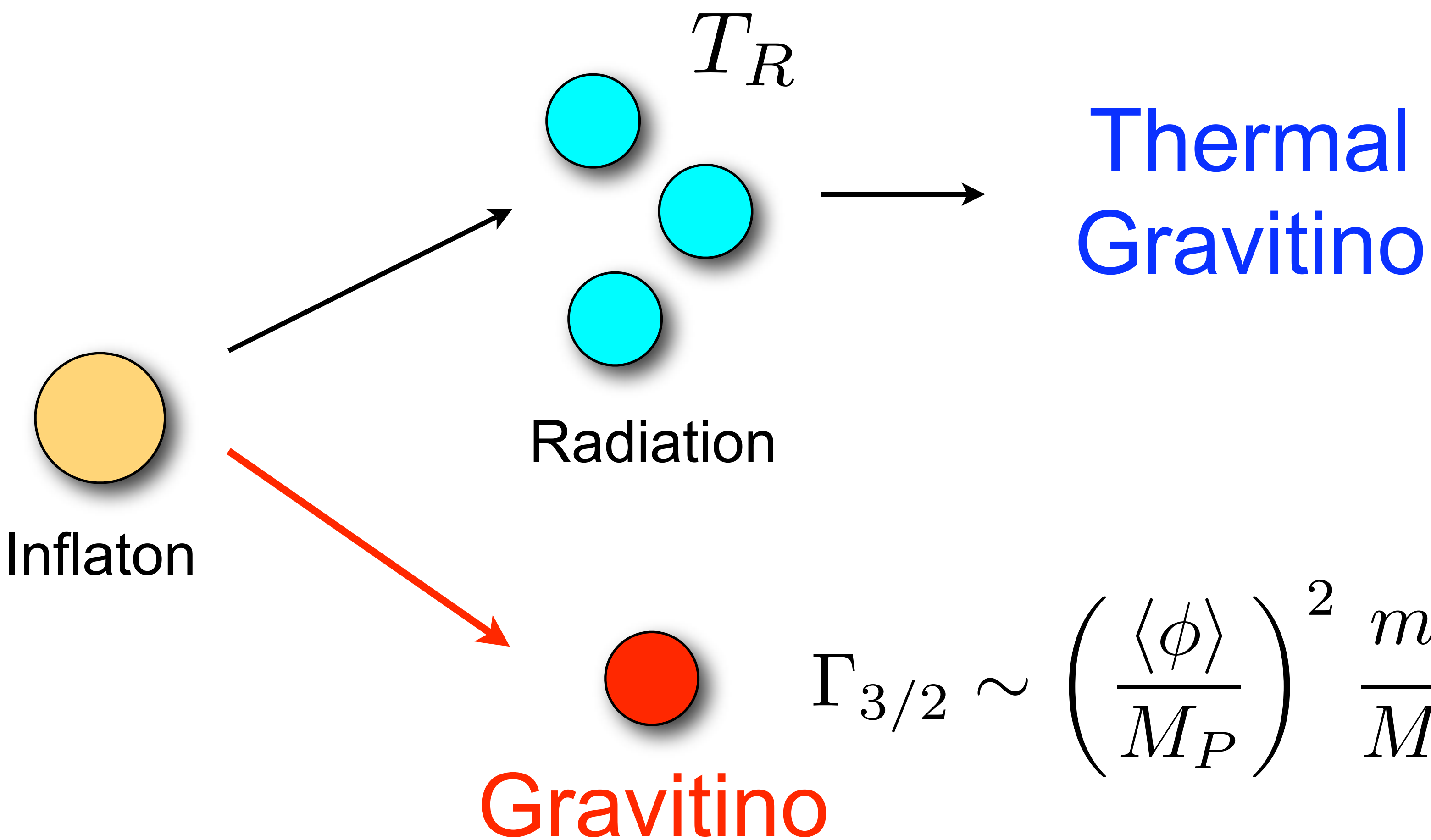
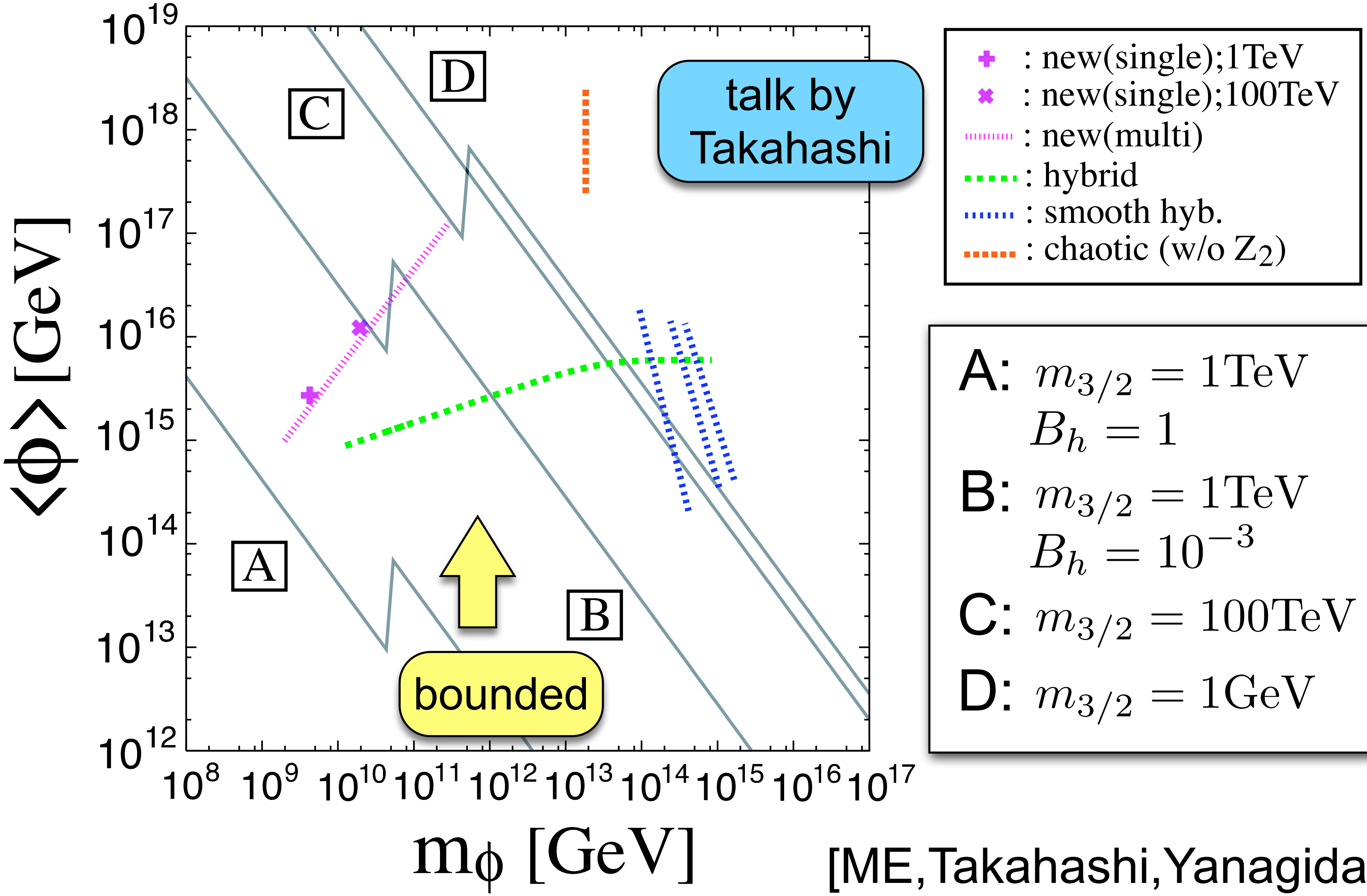


$$\Gamma_{3/2} \sim \left(\frac{\langle \phi \rangle}{M_P} \right)^2 \frac{m_\phi^3}{M_P^2}$$

Inflation Models



[ME,Takahashi,Yanagida]

Moduli Decay

- mass of scalar is light
  - $Y_{3/2}$ REDUCED
- VEV is at Planck scale
  - $Y_{3/2}$ INCREASES
- Very low reheating temperature
  - $Y_{3/2}$ INCREASES
- Problem becomes much WORSE

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- mass of scalar is light
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Gravitino production is serious

- Very low reheating temperature
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Natural Reheating

- Inflaton decays into MSSM sector w/o introducing special couplings by hand.
- Tree-level processes

  Majorana neutrino mass (leptogenesis)

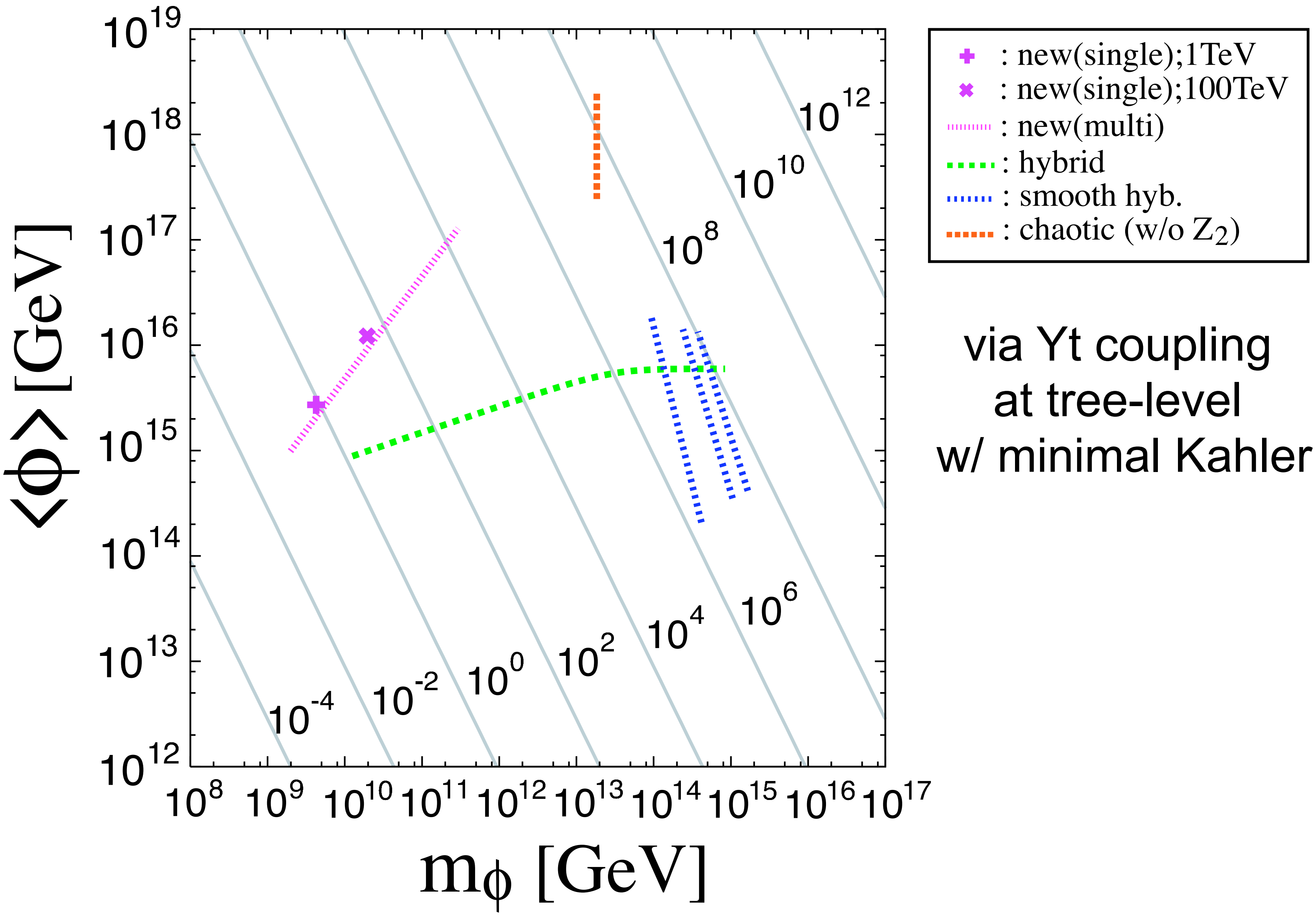
  Top Yuakwa coupling w/ $K \sim |\phi|^2 |Q|^2$
- Gluon(ino) production via anomalies
- Universe may be reheated.
  (ex. string-inspired inflation)

Summary

- Gravitinos are produced via gravitational effects.
- We obtained generic production rates.
- Crucially change conventional picture of reheating process.
- Inflation/moduli models are constrained.

  (see talk by Takahashi for inflation)
- Universe may be reheated naturally.

STOP



via Yt coupling
at tree-level
w/ minimal Kahler

Relaxation of Problem

- Vanishing VEV: symmetries at vac.

  cf. most inf. models do NOT

    but chaotic w/ Z2

- Dilution: introduce new fields

  gravitino/LSP again, so NOT really solved

- Special SUSY breaking: need discussion