Quirky Folded Supersymmetry

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- Quirk v.s. folded SUSY
- Quirky Signal at LHC ?
    - excited state
    - low lying state (more detail study)
    - energy lost (not well understood)
- Summary and out look

An old question : What will LHC find ?

Theoretical Well motivated :

Extra-Dim, TC, Little Higgs, SUSY ….

Collider Motivated :

Z', W', Hidden Valley, Quirk, ….

Quirk

- new strong interaction $SU(N)$

new fermion $Q,\ \overline{Q}$

$$\Lambda_s \ll M_Q$$

Little hierarchy problem

LH, SUSY → Top partner has color under $SU(3)_{SM}$

(No need of new strong dynamic)

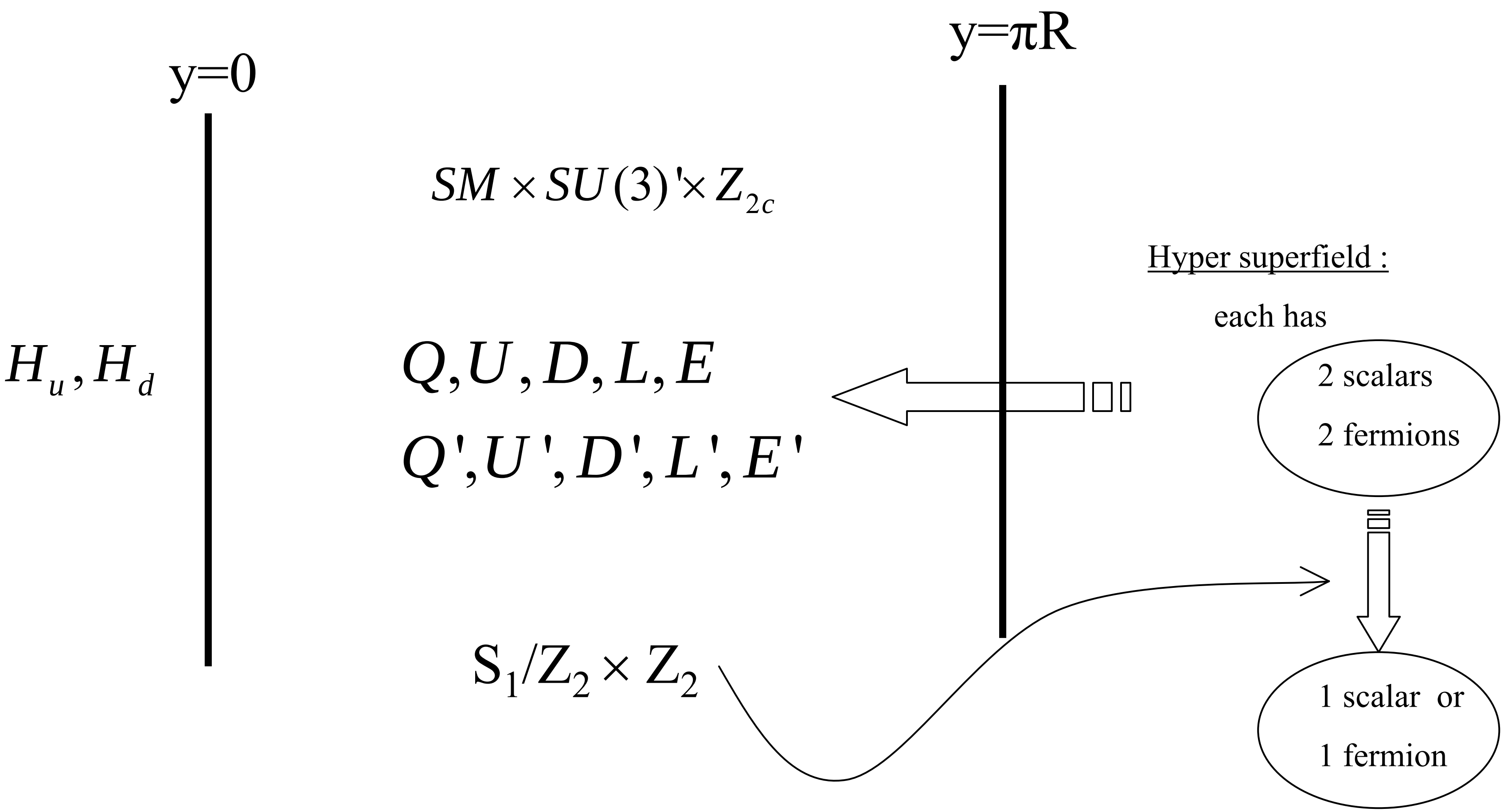
Alternative with discrete symmetry :

Twin, folded SUSY

→ Top partner has color under **new** SU(3)

A new Quirky particle that plays a role in EW symmetry breaking.

folded supersymmetry



The orbifolding conditions are chosen in such a way that

<u>Zero modes</u>

$$\{Q, U, D, L, E\} \Longrightarrow \text{1 fermion each (SM)}$$

Scherk-Schwarz

$$-$$

$$\{Q', U', D', L', E'\} \Longrightarrow \text{1 scalar each}$$

("superpartner" in MSSM)

Real superpartner are heavy : mass ~1/R ~ 5-10 TeV

Low energy effective 4D theory has :

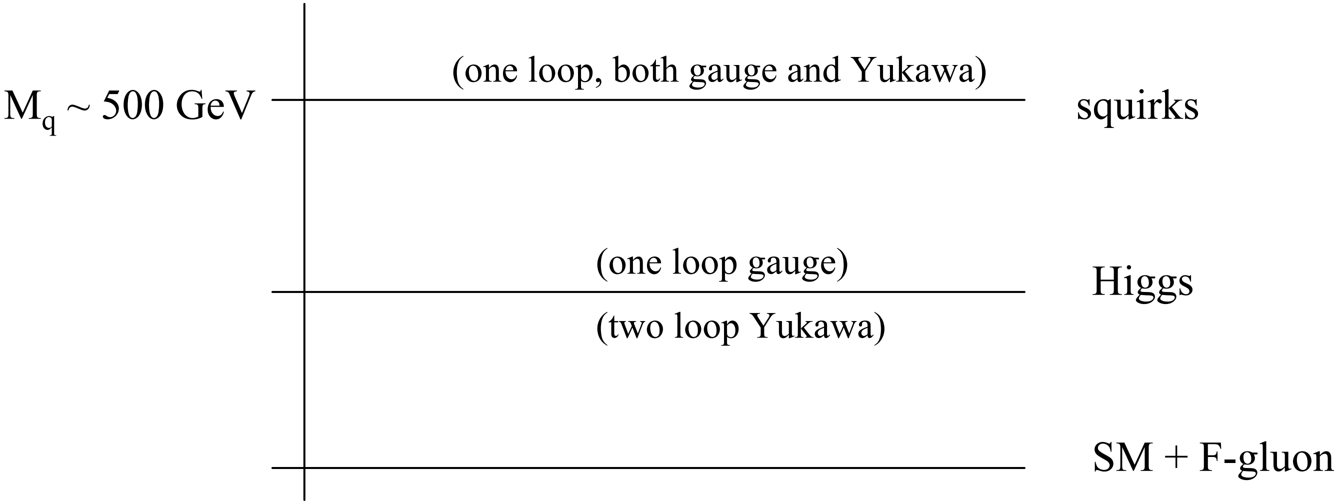
SM + {F-gluon, F-sparticles}

(quirky sector)

squirk

NO SUSY

Radiative corrections

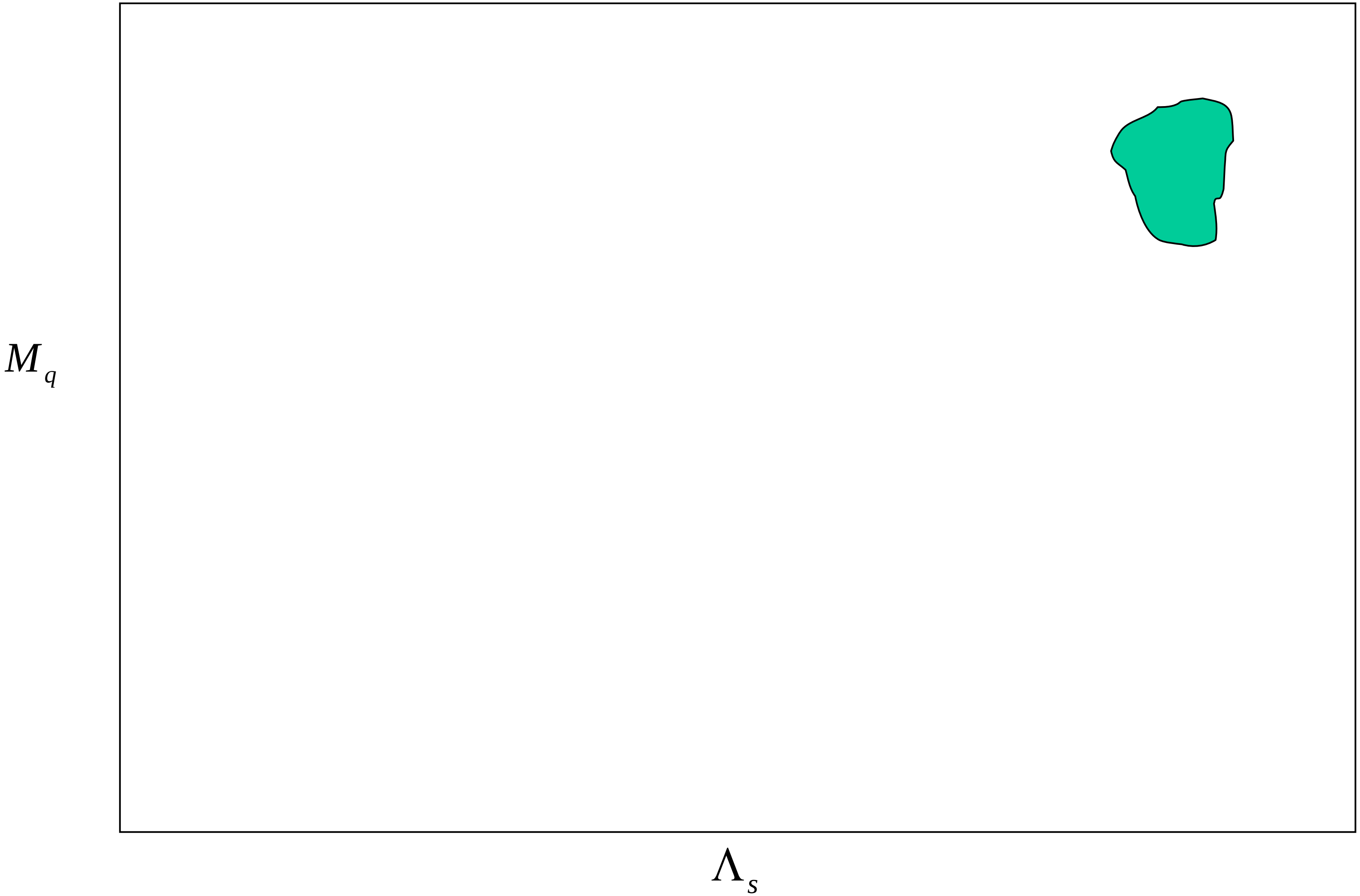


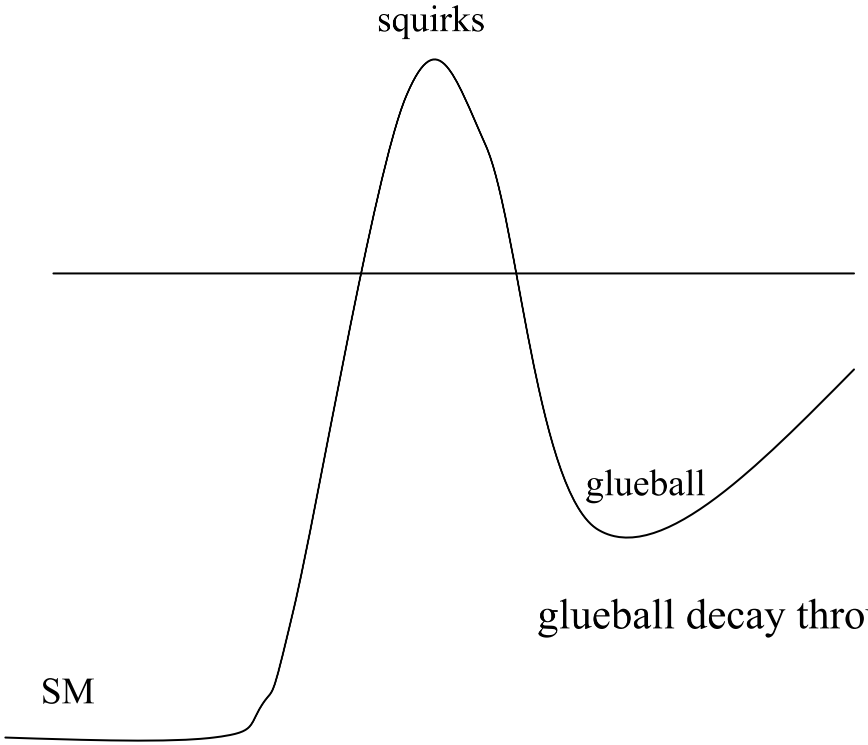
$$\Lambda_s \sim 5 \text{ GeV} << M_q$$

$$Z_{2c} \Rightarrow \Lambda_s \sim \Lambda_{QCD}$$

Collider Phenomenology

(focusing on F-squark)





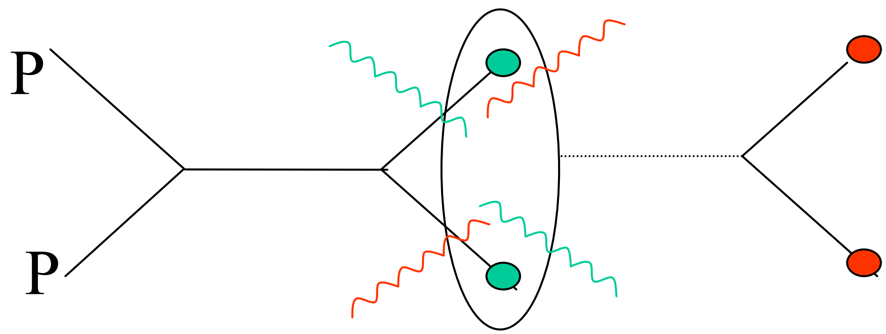
$E < M_q$ - hidden valley

glueball decay through $\sim \dfrac{F_{\mu\nu}^2 (H^2 \rightarrow c\bar{c}, \tau\bar{\tau}, \text{ maybe } b\bar{b}\ )}{16\pi^2 M_q^2}$

Lifetime is $\sim (4\pi^2)^2 10^4 \dfrac{M_q^4 v^2}{\Lambda_s^7} \sim Km$

glueball is likely just missing energy

More interesting phenomenology… LHC $(E > 2\,M_q)$

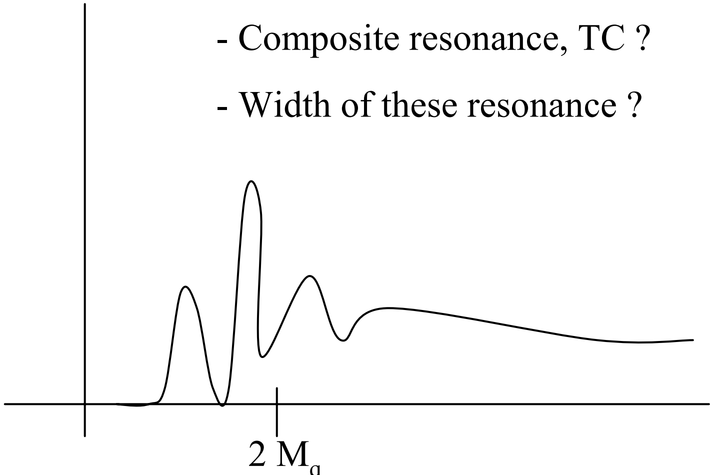


SM particles or F-glueballs

microscopic string

Low kinetic E

- Composite resonance, TC ?
- Width of these resonance ?

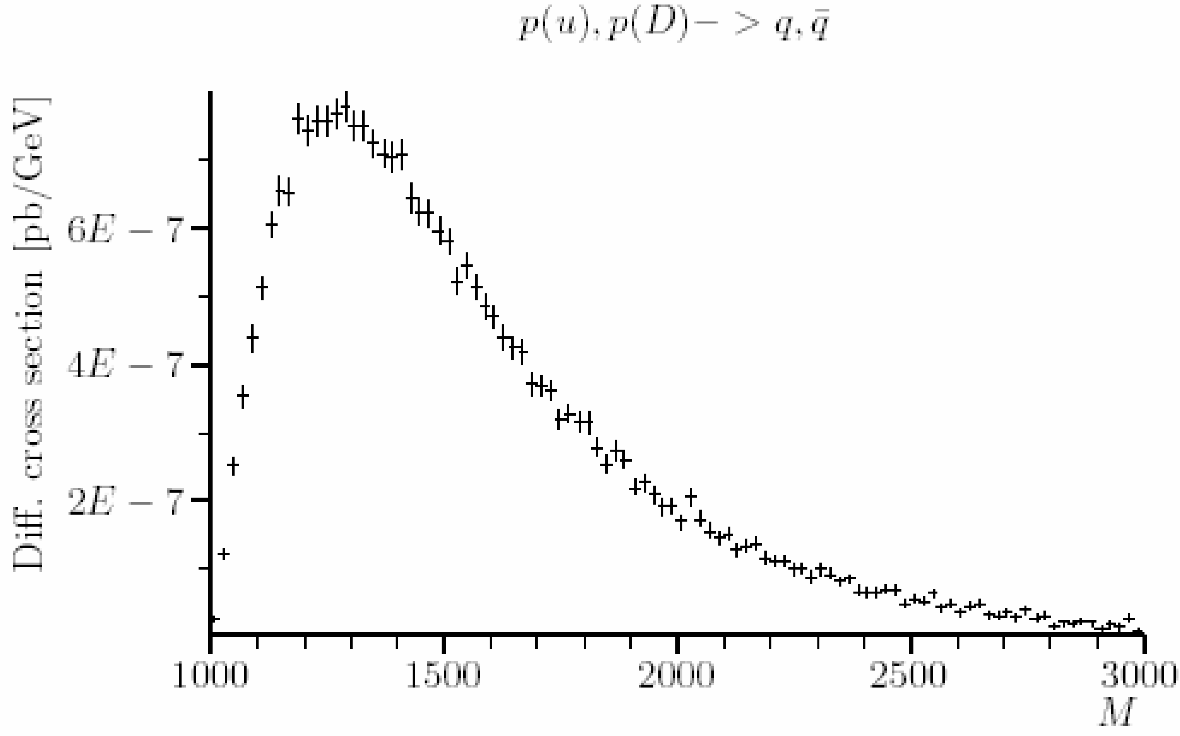


high kinetic E

- accessing 100s of "resonance", probing the continuum
- secondary collider

LHC will produce both low lying squirkonium and high excited bounded state

Mostly excited state : $kE \sim M_q >> \Lambda_s$



Then it is all about time scale

For $\Lambda_s = 5$ GeV and $M_q = 500$ GeV

Energy lost (radiation)	10^{-18} sec
Energy lost (glueball) (- Luty)	10^{-20} -- 10^{-17} sec
Annihilation from excited state	10^{-19} sec
Annihilation from low lying state	10^{-19} sec

prompt

No secondary vertex,

Can we probe the secondary collider ?

Depend on the dynamic of the strong int., we can have

- annihilation directly from excited state (continuum, hard to pick up signal)
- glueball emission is efficient (lot of missing energy)
- radiation dominate energy lost (being studied by Roni, etc..)

Following by low lying annihilation

First thing to do : find the annihilation signal

We assume the simplest possible case:

lost most of its energy before annihilation

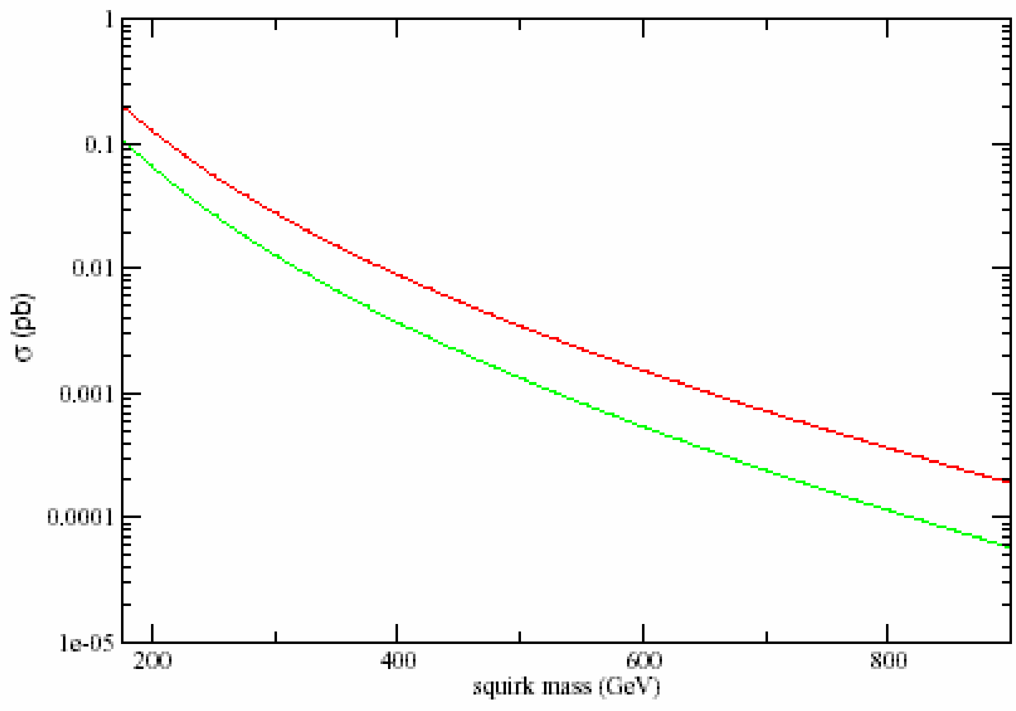
Production :

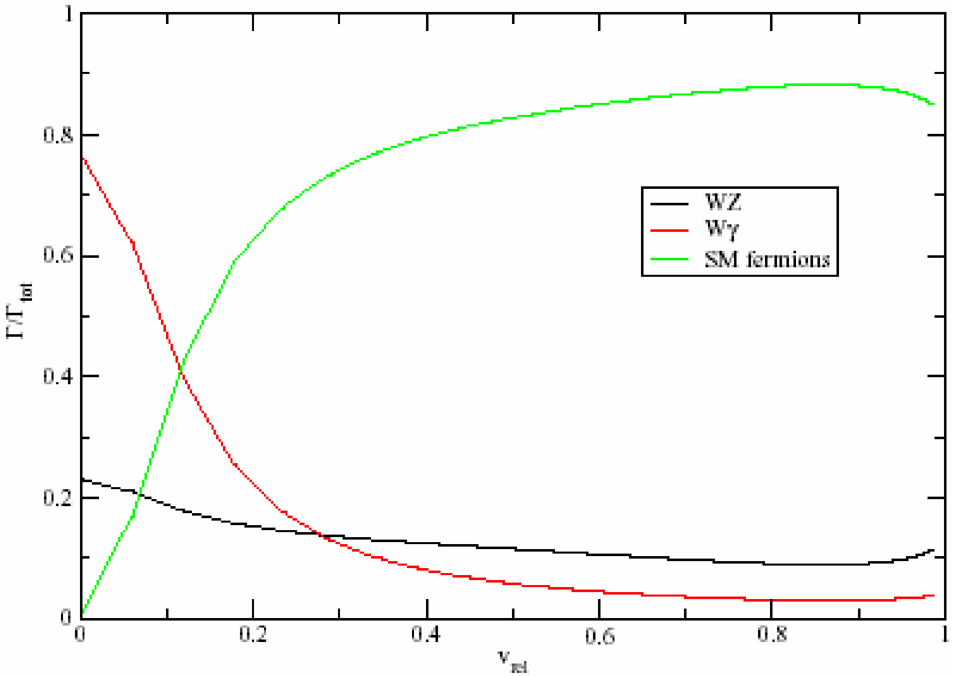
- neutral messon will dominantly decay to glueball, which is pure missing energy

- we focus on first two generation charged messon.

$$pp \to W \to u\bar{d}, \bar{u}d$$

(~ 10 fb)





Low lying annihilation ($v_{rel} << 1$):

W-γ dominate

$$W \to l\nu$$

- if ν is the only missing energy, reconstruct W
- the decay width is small

$$\sim M_q \alpha_w^2 \alpha_s^3 / 18 \sim \frac{\Lambda_s^2}{M_q} \frac{\alpha_w^2}{18\pi} \ll \Lambda_s$$

- if energy resolution << Λ_s , we can probe multiple peaks
- But large energy lost contributes more missing P_T

$$\text{Missing} \quad \not{P}_T \sim \frac{\text{total energy lost}}{\sqrt{n}}$$

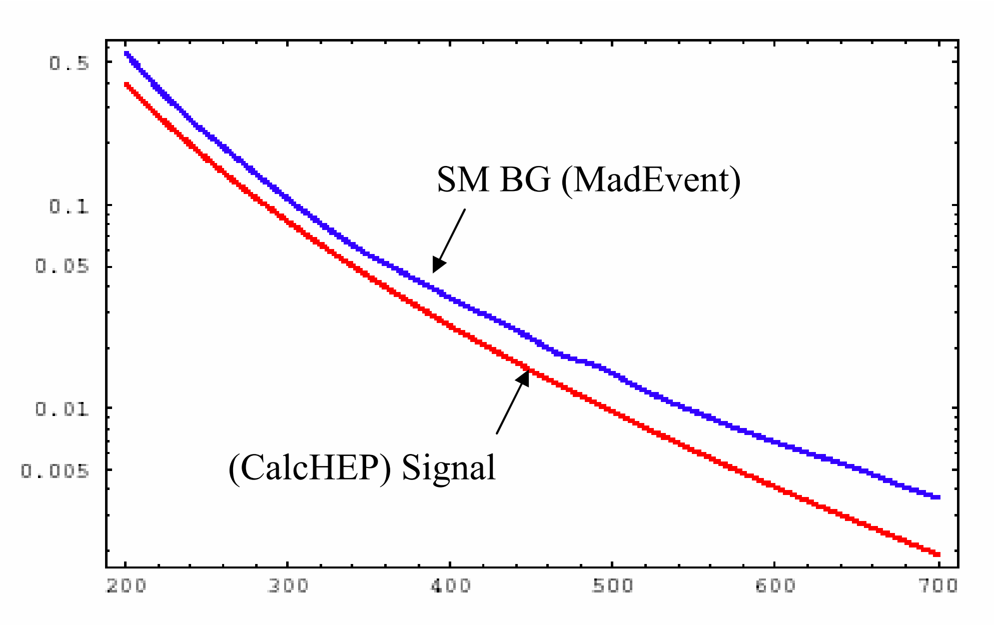
Best scenario : Mostly radiation $\quad n \sim \frac{M_q^2}{\Lambda_s^2} \quad \Rightarrow \quad \not{P}_T \sim \Lambda_s \sim 5 \text{ GeV}$

Worst scenario : Mostly glueball $\quad n \sim \frac{M_q}{\Lambda_s} \quad \Rightarrow \quad \not{P}_T \sim \sqrt{M_q \Lambda_s} \sim 100 \text{ GeV}$

We take the worst case scenario. Expect the width will be smeared by these missing energy to about 100 GeV

Use invariant mass of W-γ to be $\left|m_{W\gamma} - 2M_q\right| < 100$ GeV

to reduce SM background



5σ Reach : 600 GeV for 100 fb^{-1}

$$\frac{signal}{\sqrt{BG}} = 5$$

Conclusion

- Folded-SUSY solves the LEP paradox without the usual stop.
- The collider signature of this class of models is very different from the traditional supersymmetric models.

- Out look- More to be done in order to reveal the quirky behavior
  - How efficient is glueball emission ?
  - energy resolution of the low lying peaks $\Rightarrow \Lambda_s$
  - Is glueball really just missing energy ? Search for secondary collider.