SUPER PARTNER MASSES & HIDDEN SECTOR RUNNING

A. Cohen
T. Roy
M. Schmaltz

Boston University

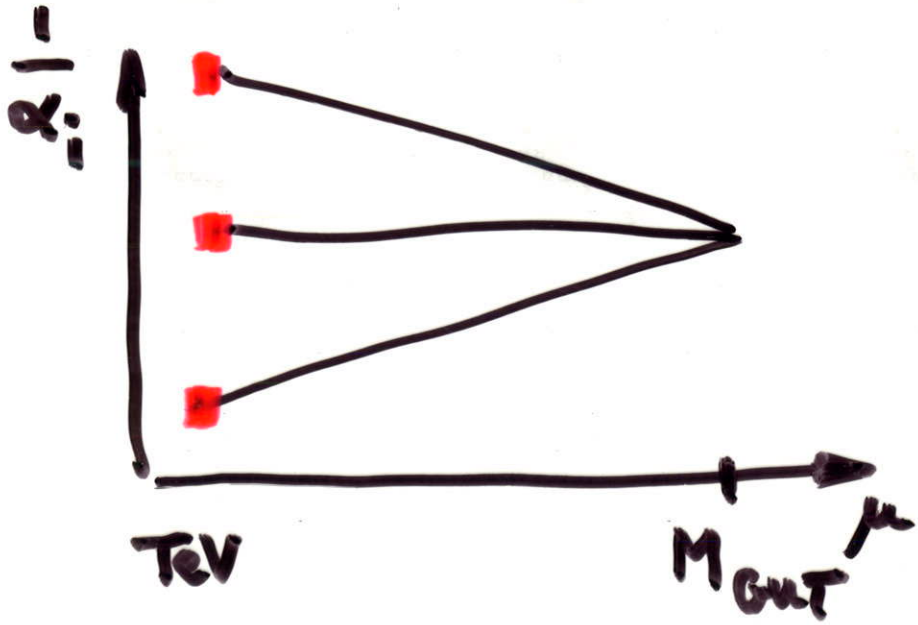
Outline

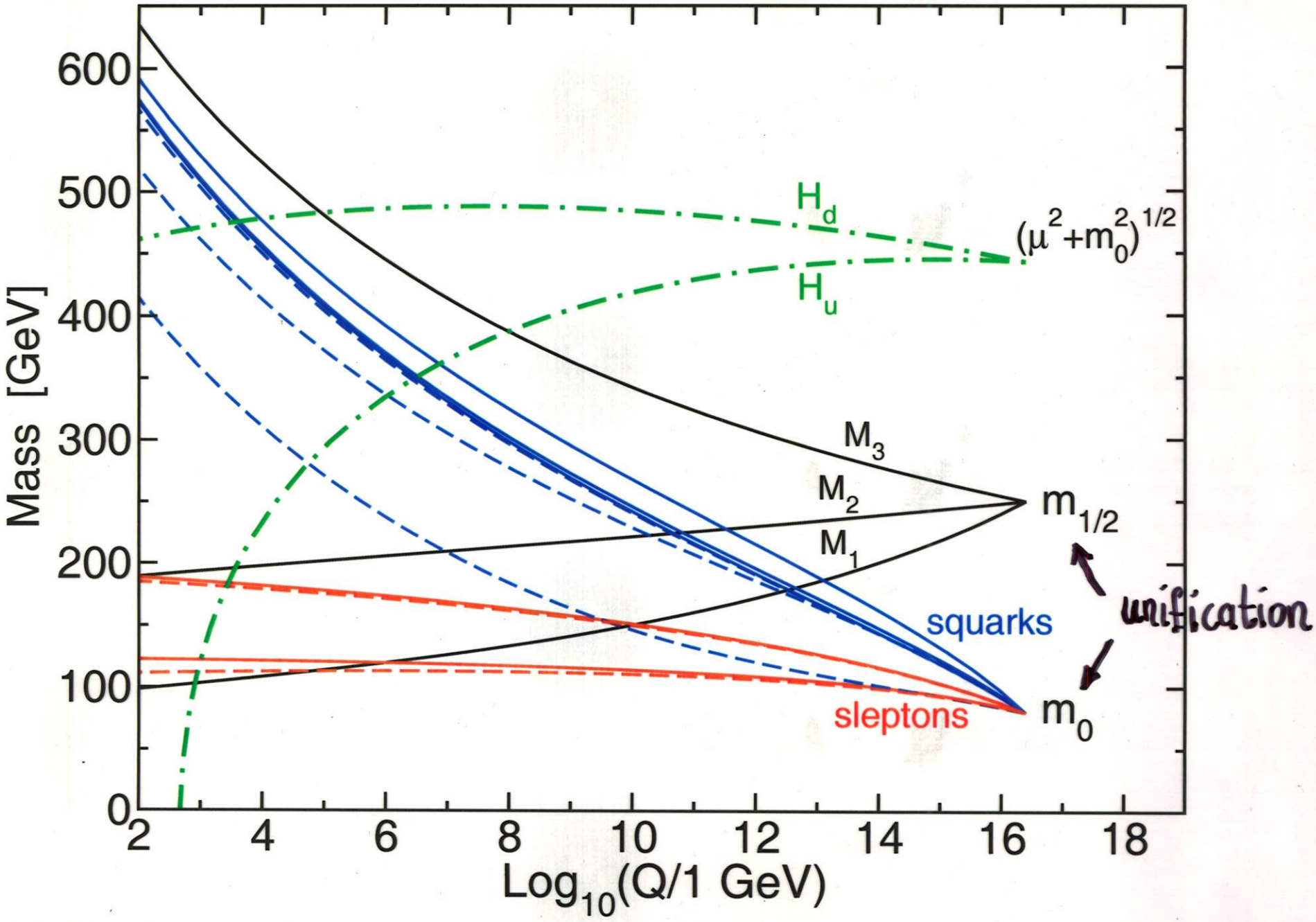
- the renormalization of superpartner masses in the MSSM
- hidden sector effects matter
- Scalar mass predictions
  → sum rules
- Summary

SUPERSymmetry

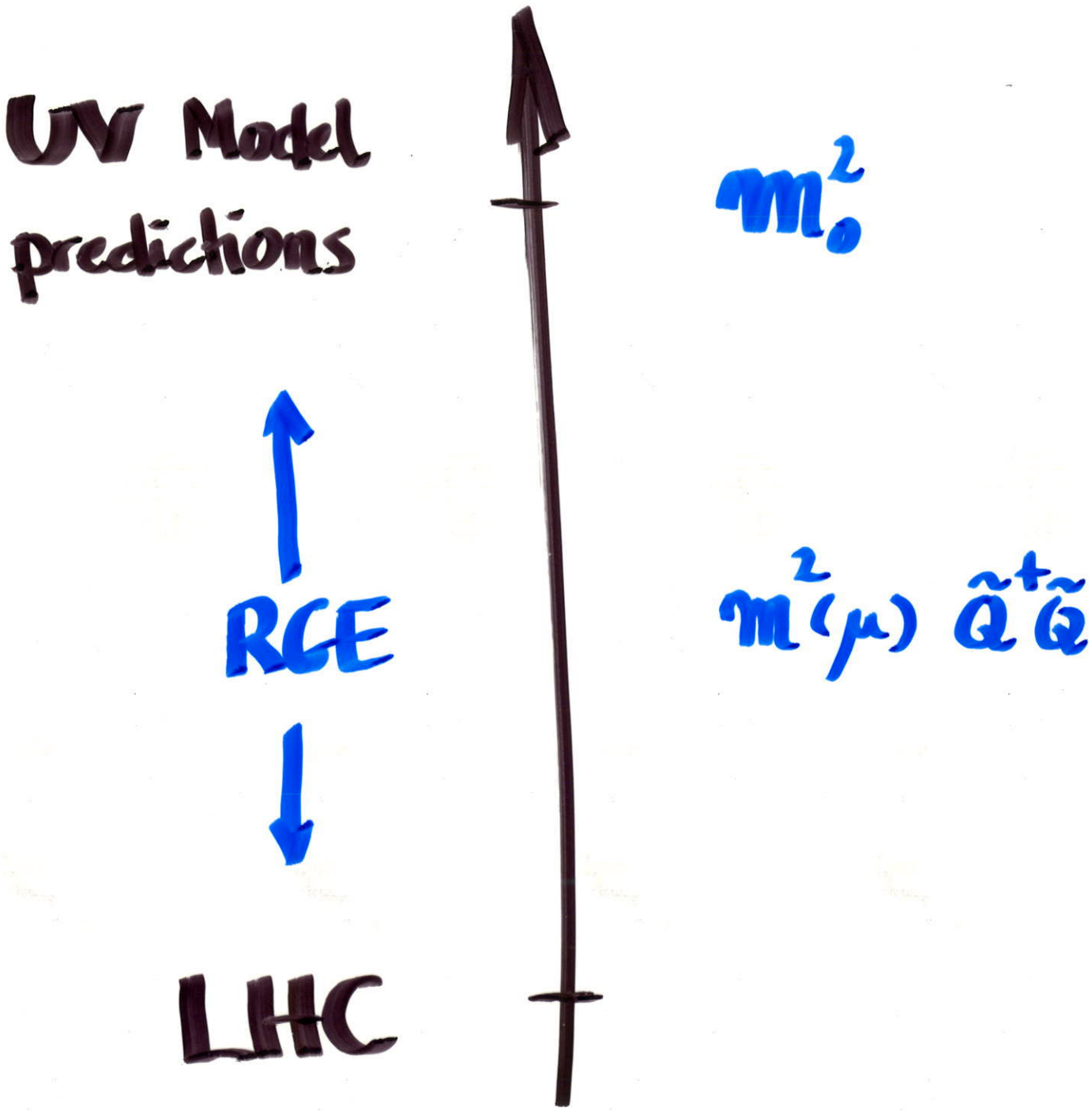
attractive because

- higgs naturalness
- dark matter
- gauge coupling unification




Mass [GeV]
600
500
400
300
200
100
0
2
4
6
8
10
12
14
16
18
Log10(Q/1 GeV)
Hd
Hu
(μ2+m02)1/2
M3
M2
M1
squarks
sleptons
m1/2
m0
unification

SOFT MASS RUNNING



MSSM running "state of the art"

- ~~3~~ 2 loop running
- 1 loop matching at { TeV / M_{GUT}
- automated:
  - Isajet
  - Softsusy
  - Spheno
  - Suspect
  - ⋮
- relic abundance, $b \to s\gamma$, ...

Dynamical Susy breaking

$\langle X_F \rangle = F$ ← "hidden sector"

scalar mass

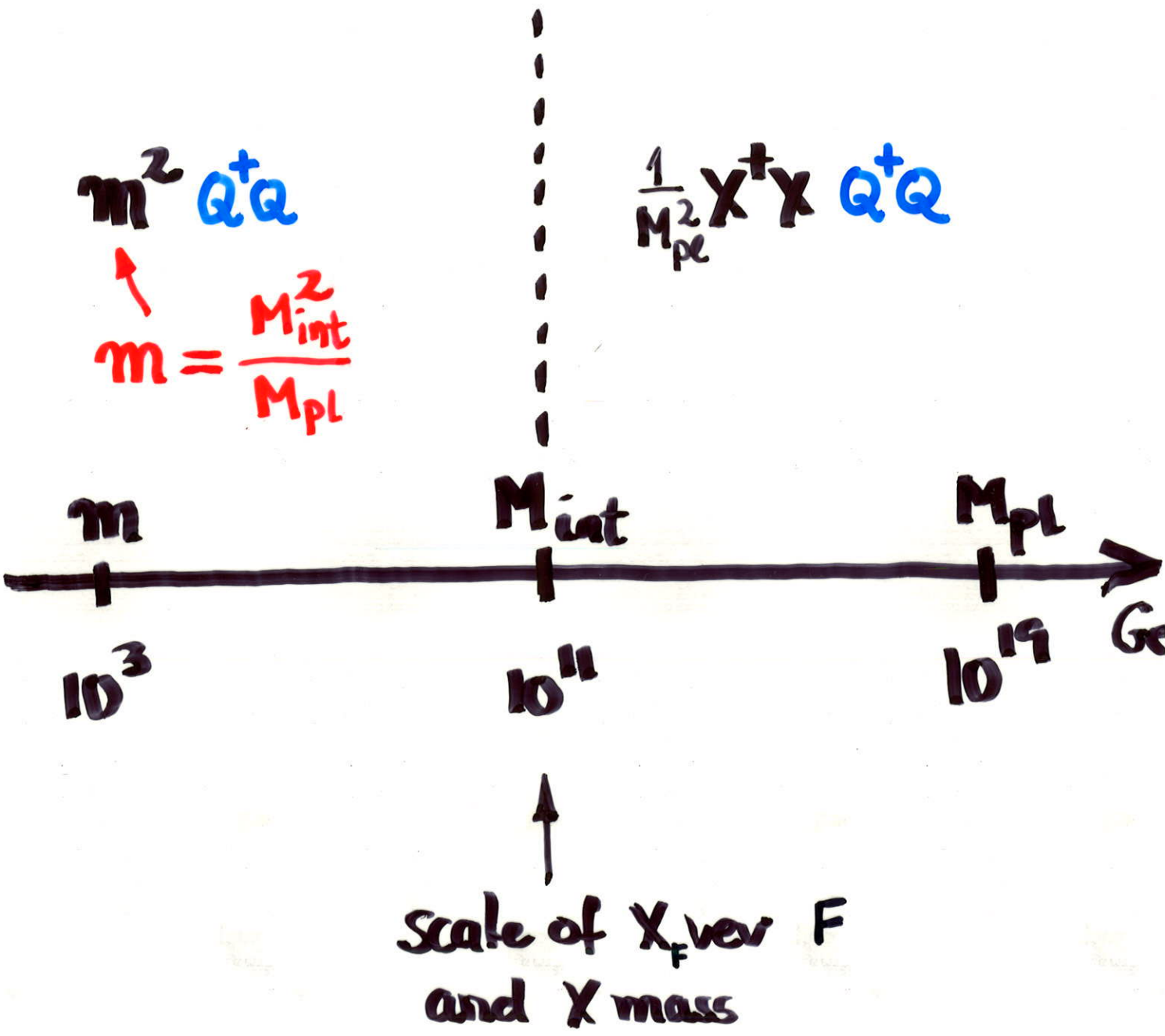
$$\int d^4\theta \; \frac{X^\dagger X \, Q^\dagger Q}{M^2} \Rightarrow m^2_{\tilde{Q}} = \frac{F^2}{M^2}$$

gaugino mass

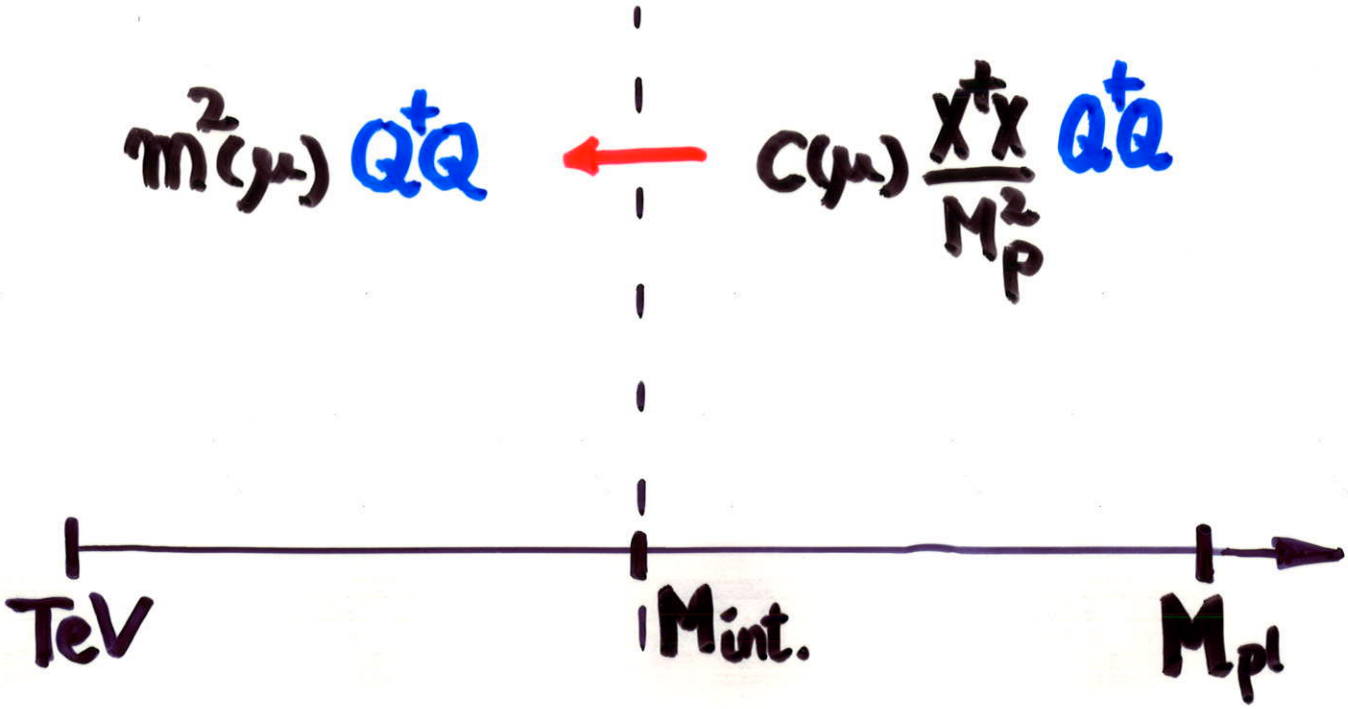
$$\int d^2\theta \; \frac{X \, WW}{M} \Rightarrow m_{\tilde{g}} = \frac{F}{M}$$

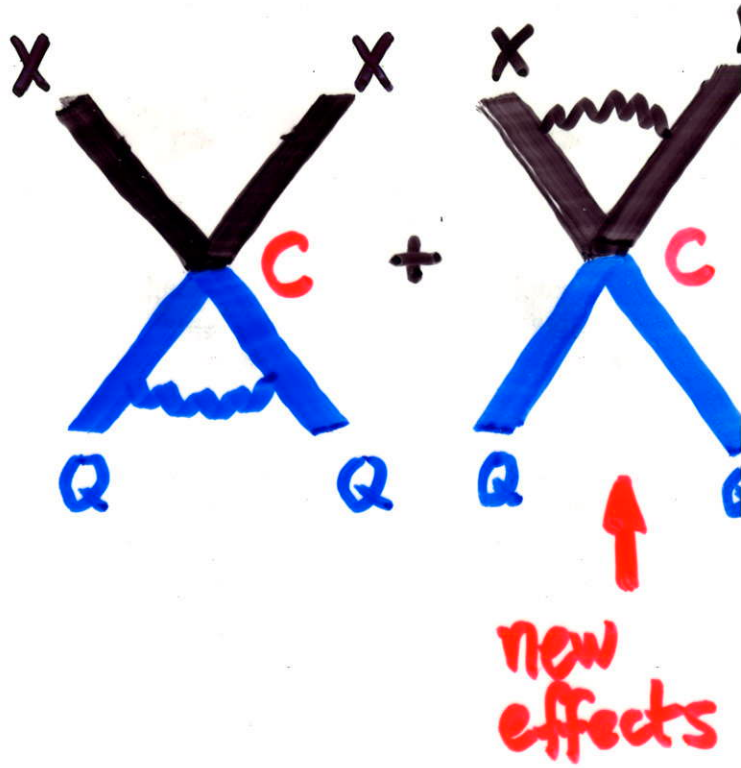
+ A terms, μ, B_μ ...

Scales in SUGRA

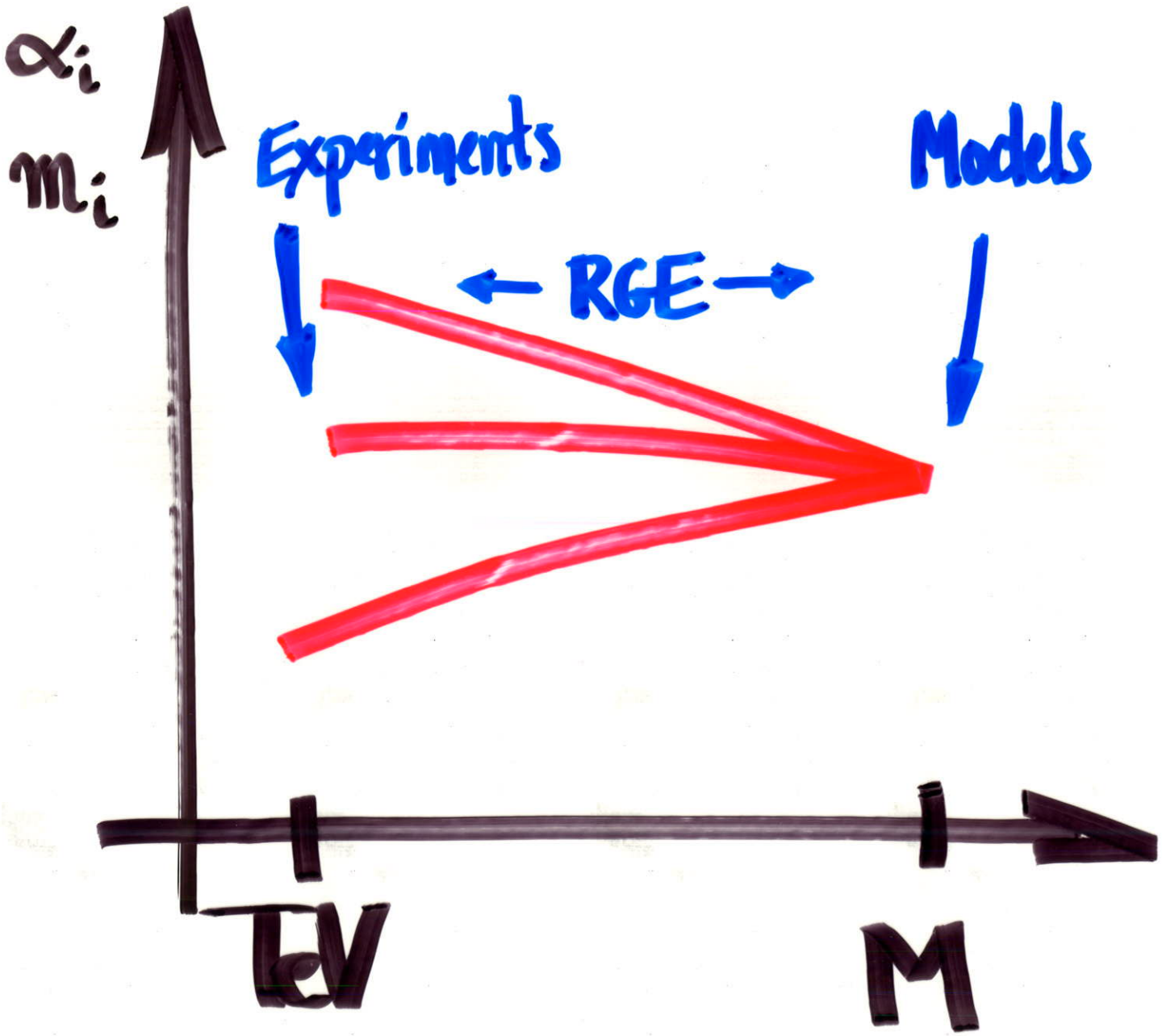


Running SUSY masses :





running ...



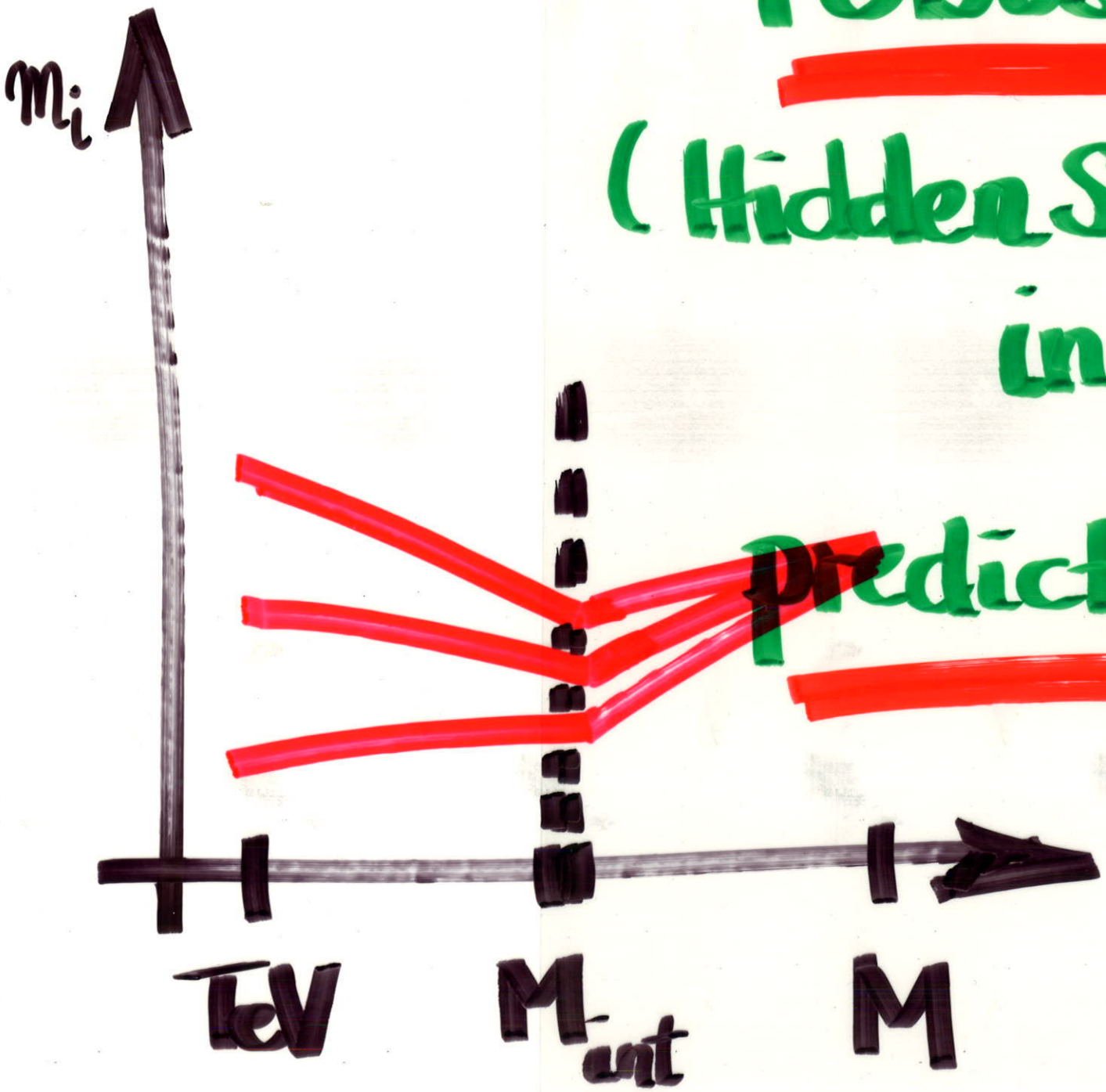
running, "corrected" Can we r

robust

(Hidden Sec

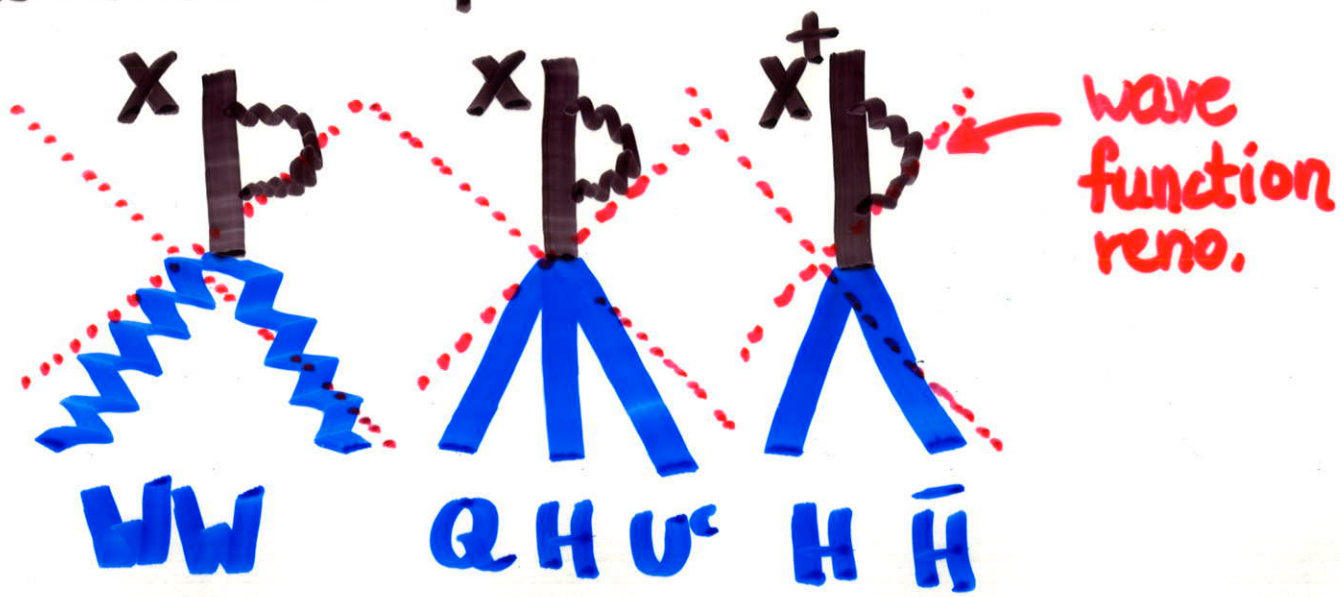
ind

predictio



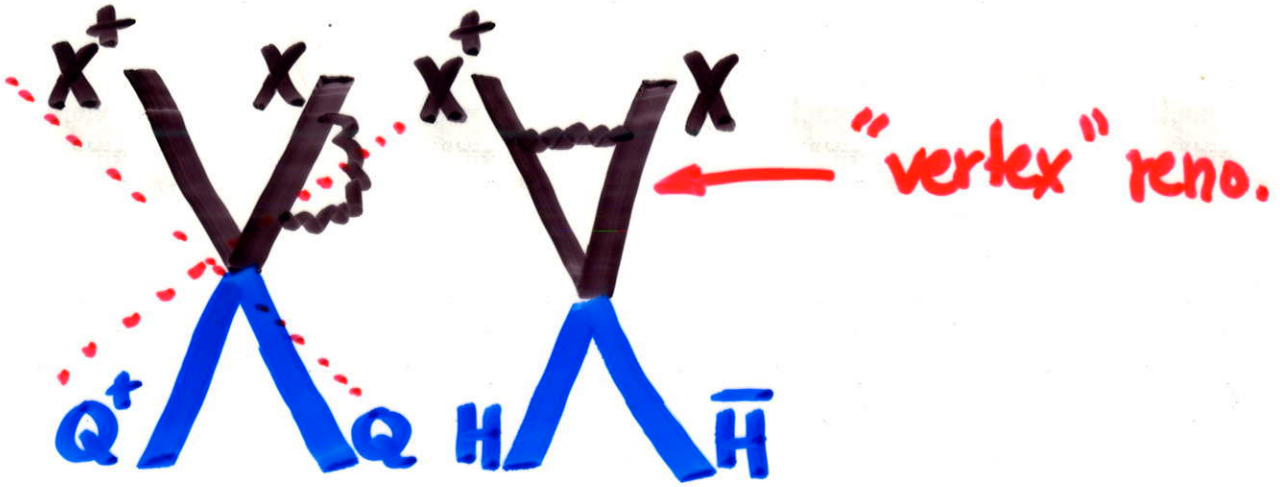
"trivial" effects

- chiral hidden operators



not renormalized in holomorphic basis

- real hidden ops



renormalized in holomorphic basis

Scalar masses

- universal running?
- no! but can parametrize hidden sector running
- $\Rightarrow$ sum rules

Universal hidden running ?

$$\# \frac{g^2}{16\pi^2}$$

$$\mu \frac{d}{d\mu} c_i = \gamma c_i$$

$$\Rightarrow \quad c_i(\mu) = \left(\frac{\mu}{M}\right)^{\gamma} c_i(M)$$

i-independent !

$\Rightarrow$ mass ratios OK (?)

Universal hid. run ?

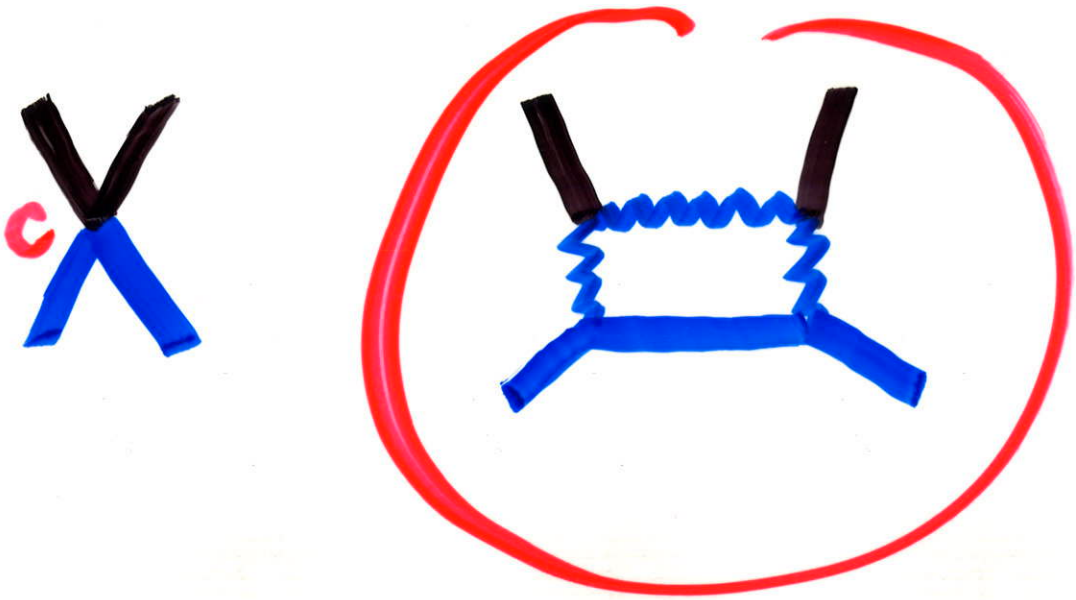
$$\mu \frac{d}{d\mu} c_i = \gamma_i^{hidden} c_i + \gamma_i^{MSSM} c_i$$

$$\Rightarrow \quad \left(\frac{\mu}{M}\right)^{\gamma_{hid.}} c_i(M) \left(\frac{\mu}{M}\right)^{\gamma_i^{MSSM}}$$

universal known

$\Rightarrow$ mass ratios ok (?)

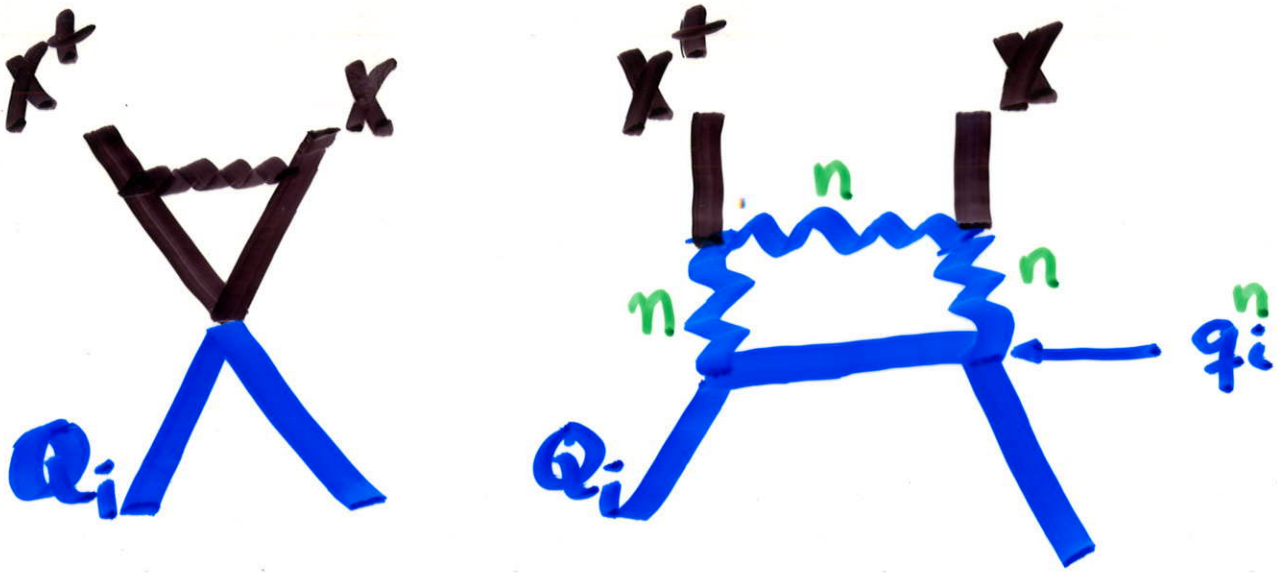
MSSM renormalization is NOT of this form



$$\Rightarrow \dot{c}_i \not\propto \gamma\, c_i$$

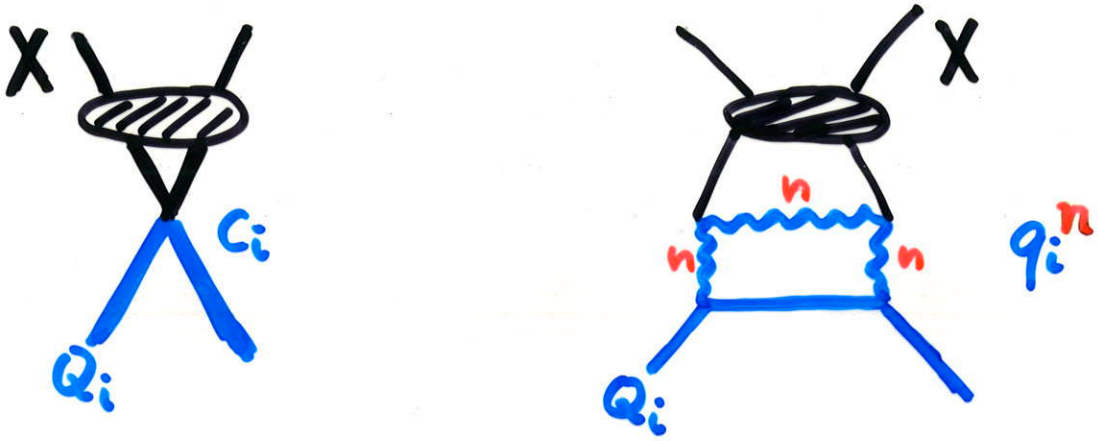
not multiplicative!

• non-trivial effects



$$\dot{c}_i = \gamma c_i - \sum_{n=1}^{3} q_i^n g_n^6 \omega^2$$

or, more generally ...



$$\dot{C}_i = \gamma C_i - \sum_{n=1}^{3} q_i^n g_n^6 G$$

$$C_i(t) = e^{-\int^t \gamma} C_i(t_0) + \sum_n q_i^n \int g_n^6 G e^{-\int \gamma}$$

$$C_i(\mu) = Z\left(\frac{\mu}{M}\right) C_i(M) + \sum_{n=1}^{3} q_i^n N_n(\mu, M)$$

$\Rightarrow$ 4 unknowable parameters from hidden sector

$\Rightarrow$ can form <u>sum rules</u> to eliminate them!

Example: Universal $C_i(M) = C_0$

MSUGRA
SO(10) GUT

$$m_i^2 = m_0^2 + \sum_{n=1}^{3} q_i^n N_n$$

5 masses $\tilde{Q}\tilde{U}\tilde{D}\tilde{L}\tilde{E}$, 4 unknowns

$\Rightarrow$ prediction

$$m_{\tilde{Q}}^2 - 2m_{\tilde{U}}^2 + m_{\tilde{D}}^2 - m_{\tilde{L}}^2 + m_{\tilde{E}}^2 = 0$$

(true at M_{int} and at TeV scale)

Hidden Sector indep. Prediction (GUTs)

$$m_{\tilde{Q}}^2 - 2m_{\tilde{u}}^2 + m_{\tilde{D}}^2 - m_{\tilde{L}}^2 + m_{\tilde{E}}^2 = 0$$

+ gaugino mass unification

2nd generation?

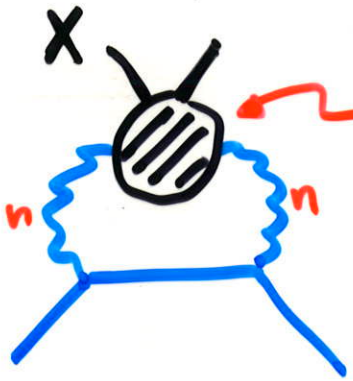
identical (flavor universality, FCNC's)

3rd generation?

$\lambda_t, \lambda_b, \lambda_\tau, \ldots$

new unkown moments

Example: gauge mediation



messenger sector

$$\Rightarrow C_i(M) = \sum_{n=1}^{3} q_i^n M_n(M)$$

$$m_i^2 = \sum_{n=1}^{3} q_i^n (M_n + N_n)$$

messenger physics

hidden running

$\Rightarrow$ 2 predictions

$$m_{\tilde{Q}}^2 - 2m_{\tilde{u}}^2 + m_{\tilde{D}}^2 - m_{\tilde{L}}^2 + m_{\tilde{E}}^2 = 0$$

$$3(m_{\tilde{u}}^2 - m_{\tilde{D}}^2) - m_{\tilde{E}}^2 = 0$$

"general gauge mediation"

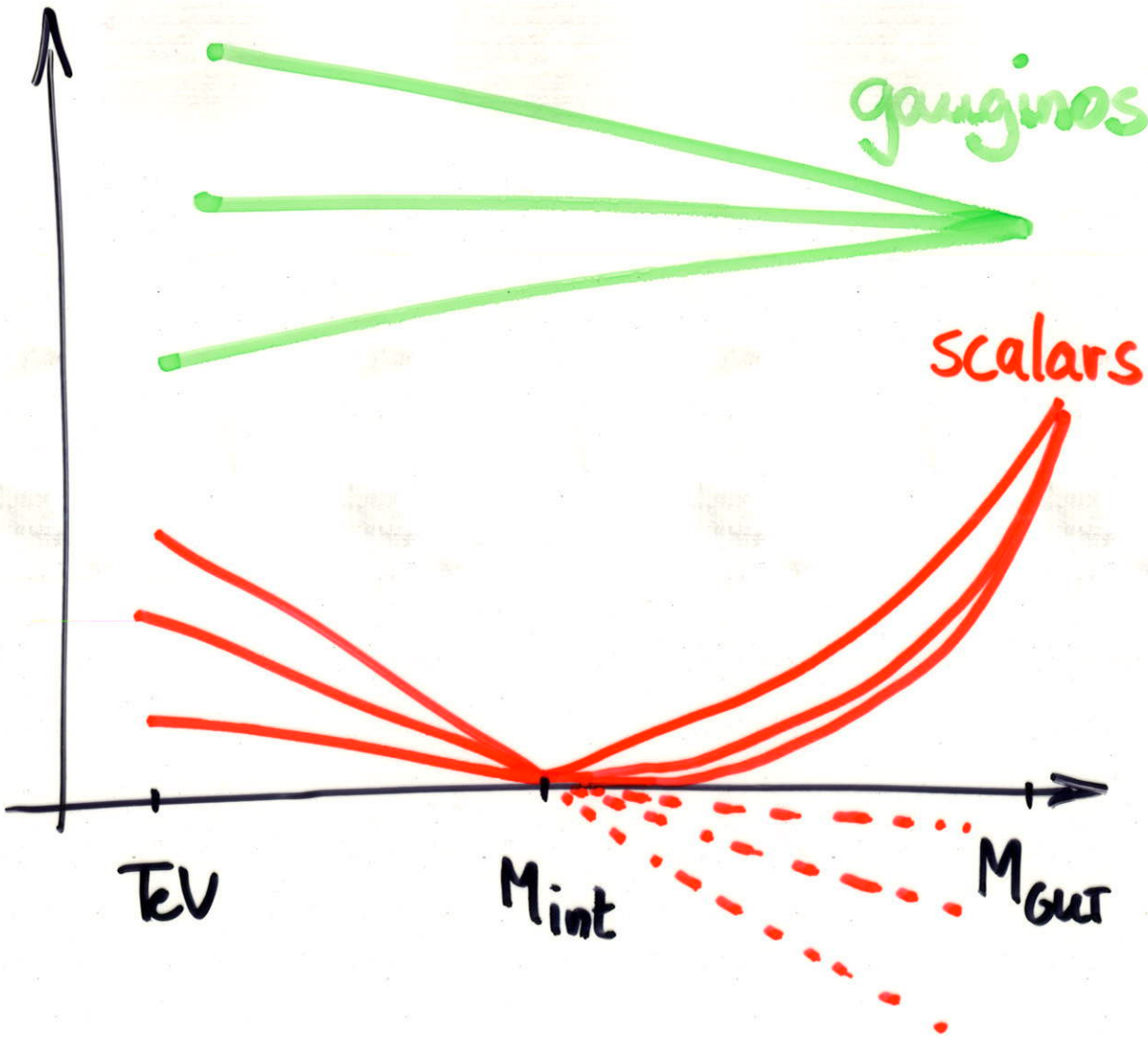
Meade, Seiberg, Shih

Example : strongly coupled h.s.

$$\dot{c}_i = \gamma\, c_i + \text{MSSM loops}$$

γ ← large positive

$$\Rightarrow m_i^2(M_{int}) \approx 0$$



SUMMARY

Linear X - soft masses are not renormalized

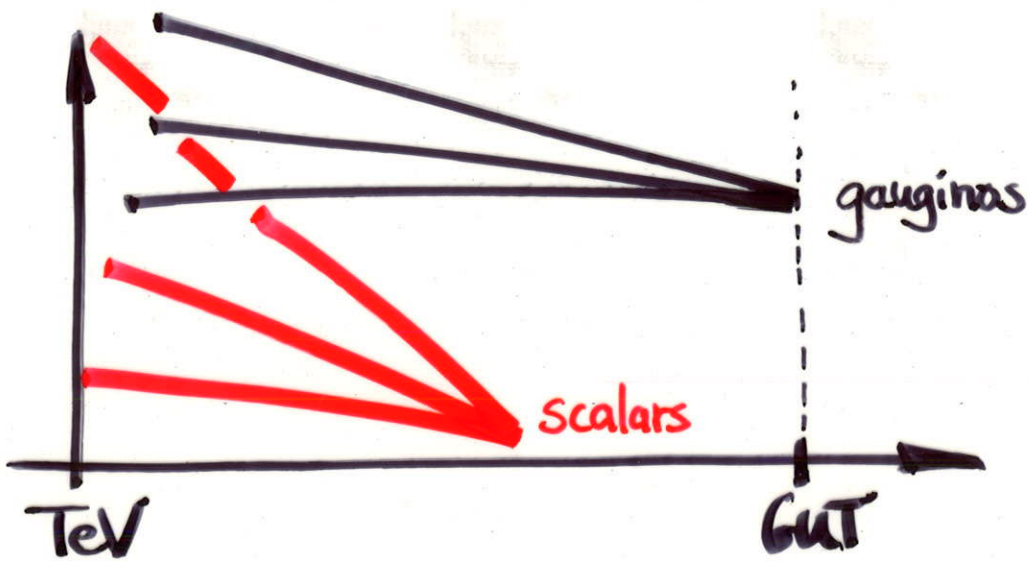
$X^\dagger X$	$Q^\dagger Q$	scalar	affected
$X^\dagger X$	$H_u H_d$	$B\mu$	affected
$X^\dagger$	$H_u H_d$	μ	
X	$Q H_u U^c$	A-term	
X	WW	gaugino	

Conclusions

- scalar mass predictions are sensitive to unknown hidden sector physics

- hidden sector independent sum rules

GUT, gM: $\tilde{Q}^2 - 2\tilde{U}^2 + \tilde{D}^2 - \tilde{L}^2 + \tilde{E}^2 = 0$

gM: $3(\tilde{U}^2 - \tilde{D}^2) - \tilde{E}^2 = 0$

- model dependent "predictions"