New Physics with early LHC data?

Supermodels!

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with

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ROADMAP TO LHC

Early data

run 0. 0.9 - 7 TeV 0 pb^{-1}

Nov '09 → Feb '10

run 1.a. 7 TeV 10's of pb^{-1}

Feb - May '10

run 1.b. 9-10 TeV few 100 pb^{-1}

Jun - Oct '10

R. Tenchini :

"First step is not relevant for anything."

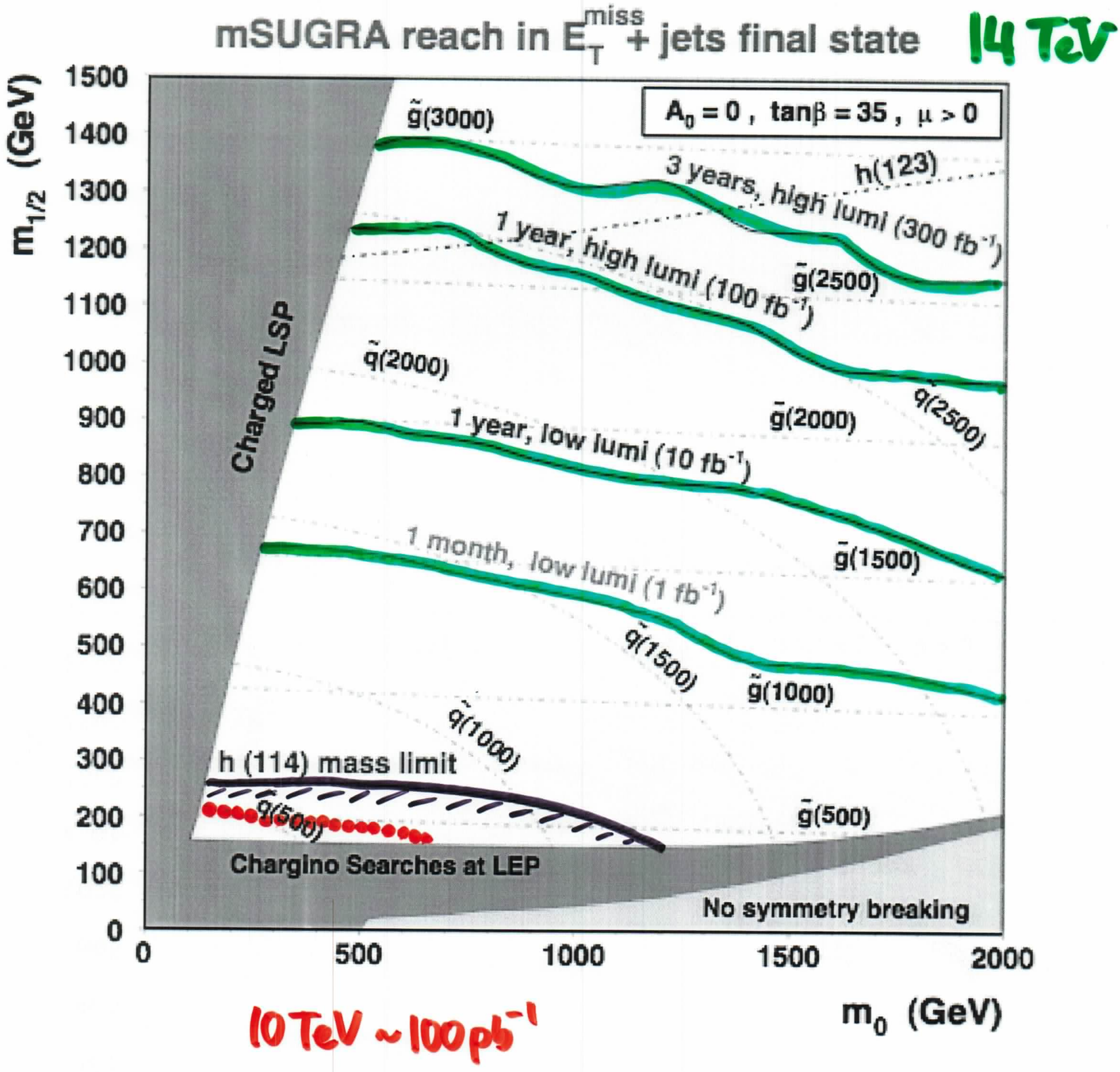
except supermodels

assume pessimistically...

7–10 TeV

- $10\ pb^{-1}$ "low"
- $100\ pb^{-1}$ "high"

of usable luminosity



mSUGRA reach in E_T^{miss} + jets final state
14 TeV
$A_0 = 0$, $\tan\beta = 35$, $\mu > 0$
$m_{1/2}$ (GeV)
m_0 (GeV)
$\tilde{g}$(3000)
3 years, high lumi (300 fb^{-1})
h(123)
1 year, high lumi (100 fb^{-1})
$\tilde{g}$(2500)
$\tilde{q}$(2000)
$\tilde{g}$(2000)
$\tilde{q}$(2500)
1 year, low lumi (10 fb^{-1})
1 month, low lumi (1 fb^{-1})
$\tilde{g}$(1500)
$\tilde{q}$(1500)
$\tilde{g}$(1000)
$\tilde{q}$(1000)
h (114) mass limit
$\tilde{q}$(500)
$\tilde{g}$(500)
Charged LSP
Chargino Searches at LEP
No symmetry breaking
10 TeV ~ 100 pb^{-1}

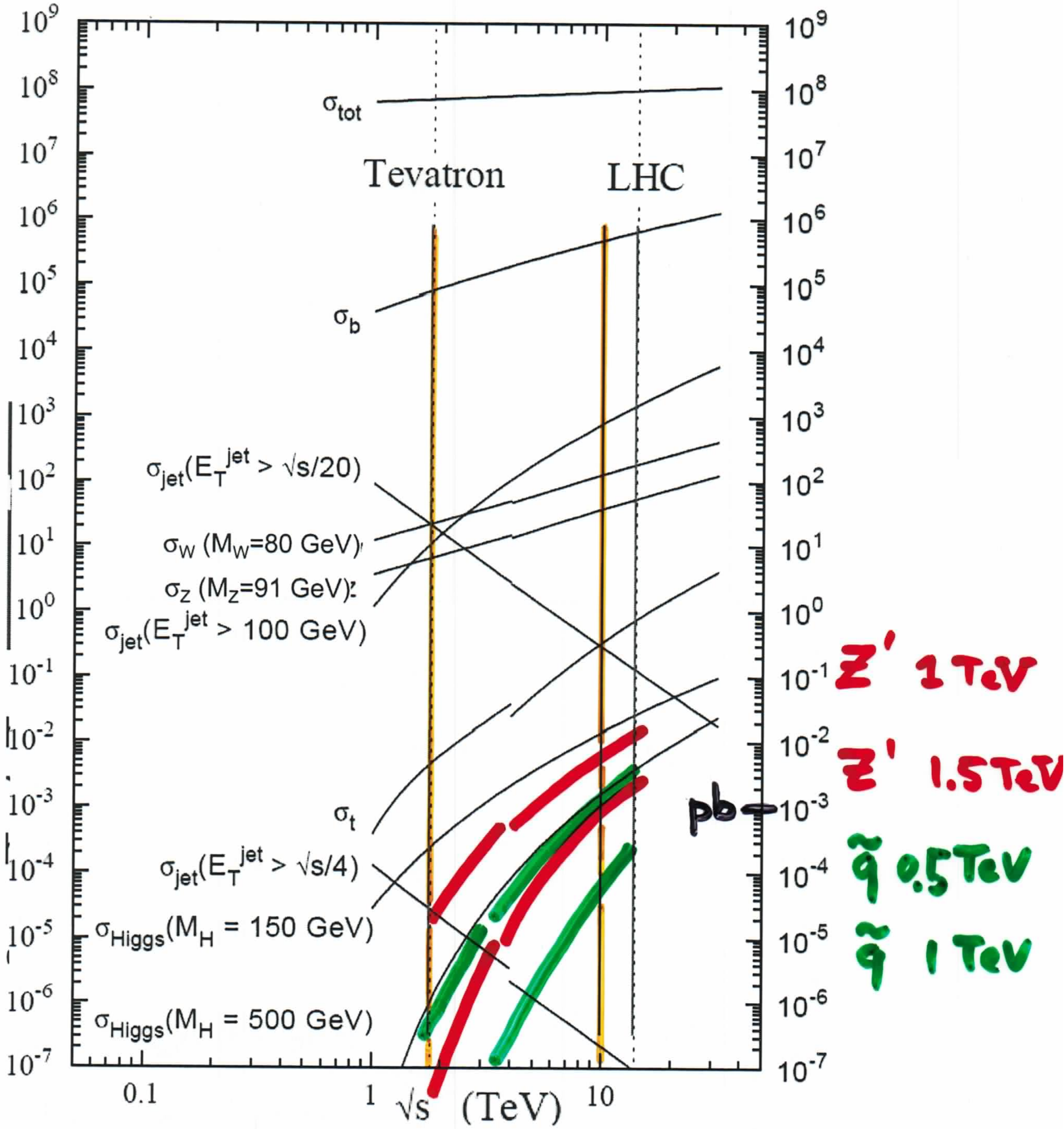
Early discovery needs ...

"easy" signature (leptons, ...)

A. $N^{LHC}_{events} \gtrsim 10$

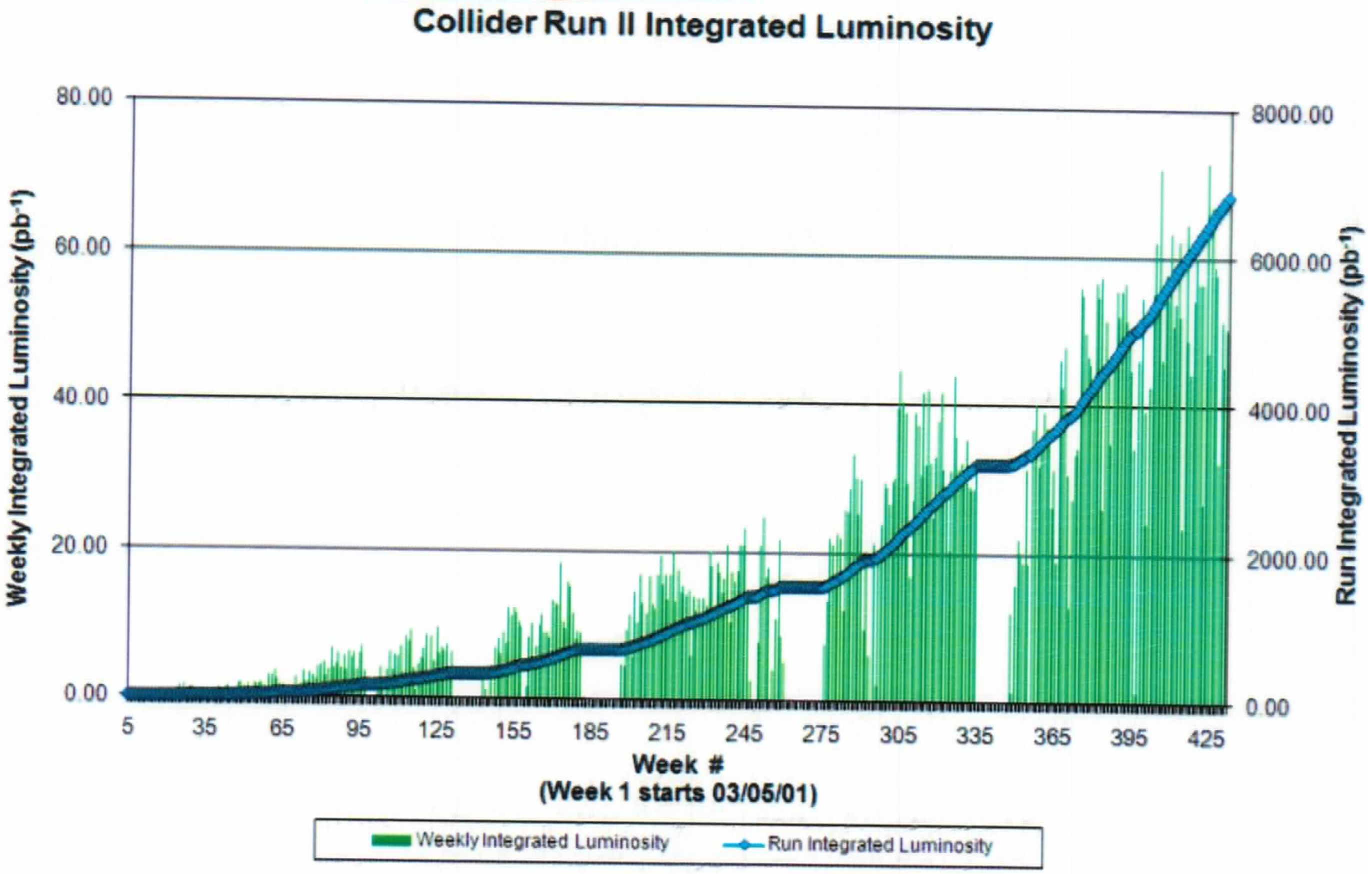
$$\Longrightarrow \sigma \cdot Br. \gtrsim \begin{cases} 1\,pb & \text{"low"} \\ 0.1\,pb & \text{"high"} \end{cases}$$

Cross Sections



$$N_{events} = L \cdot \sigma \cdot Br$$

Tevatron



$\approx 10^4\ pb^{-1}$ by 2010

($55\ pb^{-1}$/week !)

Early first discovery needs ...

B. $N^{LHC} \gtrsim N^{Tevatron}$

$\Longleftrightarrow \quad L \cdot \sigma \cdot \cancel{Br} \cdot \cancel{Eff}\Big|_{LHC} \gtrsim L \cdot \sigma \cdot \cancel{Br} \cdot \cancel{Eff}\Big|_{Tevatron}$

$$\Longleftrightarrow \quad \frac{\sigma^{LHC}}{\sigma^{TeV}} \gtrsim \frac{L^{TeV}}{L^{LHC}} = \begin{cases} \frac{10000}{10} = \underline{1000} & \text{"low"} \\ \frac{10000}{100} = \underline{100} & \text{"high"} \end{cases}$$

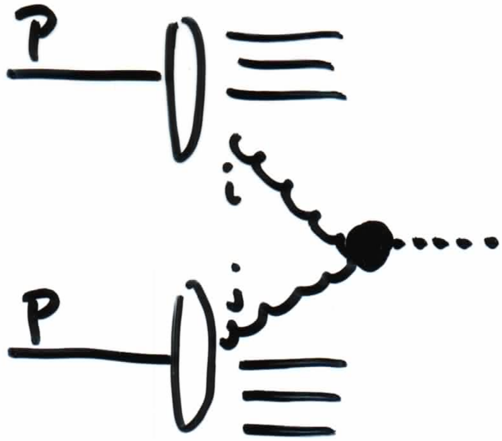
a useful formula for $\frac{\sigma_{LHC}}{\sigma_{TeV}}$:

$$\frac{d\sigma}{d\hat{s}} = \underbrace{\sum_{ij} \hat{\sigma}_{ij}(\hat{s})}_{\text{collider independent}} \underbrace{\int_0^1\!\!\int_0^1 dx_i\, dx_j\, f_i(x_i)\, f_j(x_j)\, \delta(\hat{s} - x_i x_j s)}_{\text{process independent}}$$

collider independent

process independent $\equiv \Omega_{ij}(s, \hat{s})$

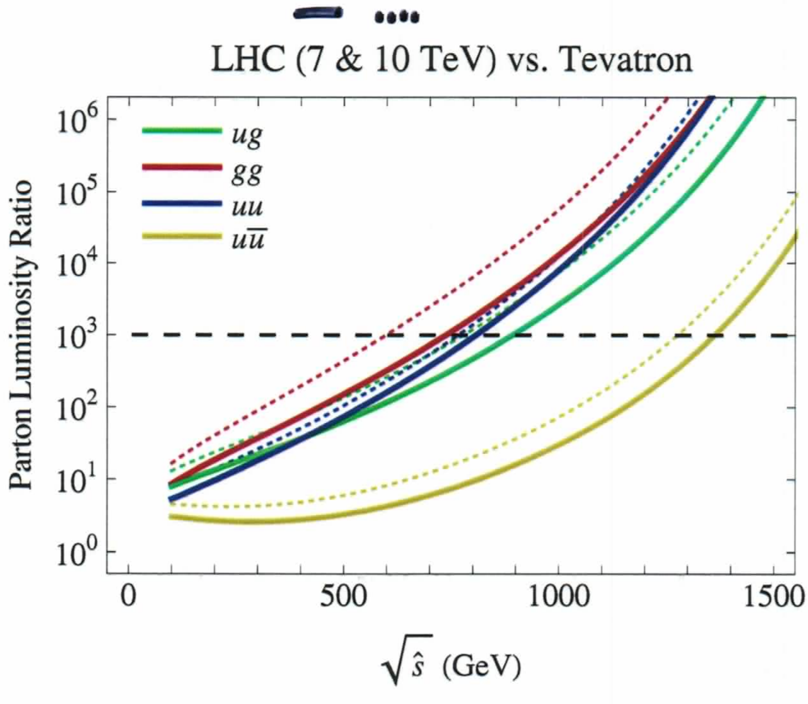
"parton parton luminosity"



$$\Rightarrow \quad \frac{\sigma_{LHC}}{\sigma_{TeV}} \approx \frac{\cancel{\hat{\sigma}}\ \Omega_{LHC}(s, \hat{s})}{\cancel{\hat{\sigma}}\ \Omega_{TeV}}$$

(assumed : single parton dominates, narrow $\hat{s}$ range)

$$\frac{\mathcal{L}^{LHC}}{\mathcal{L}^{TeV}}$$



LHC wins for

- large mass
- gg, gq, qq

Early discovery requires...

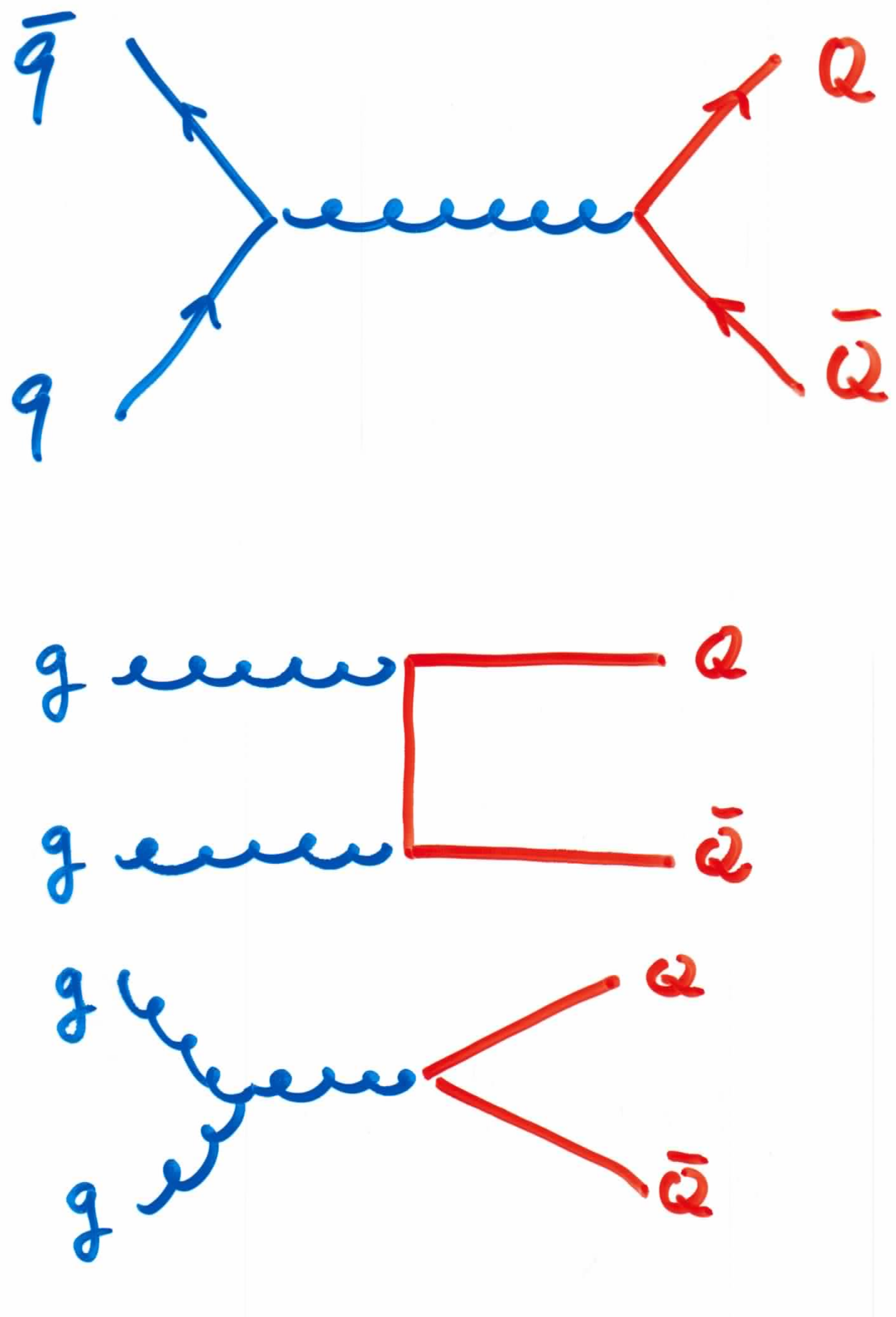
A. $N^{LHC} \gtrsim 10$ "some events"

$$\Rightarrow \quad \sigma \cdot Br \gtrsim \begin{cases} 1\ \text{pb} & \text{low} \\ 0.1\ \text{pb} & \text{high} \end{cases}$$

B. $N^{LHC} \gtrsim N^{Tev.}$ "beat Tevatron"

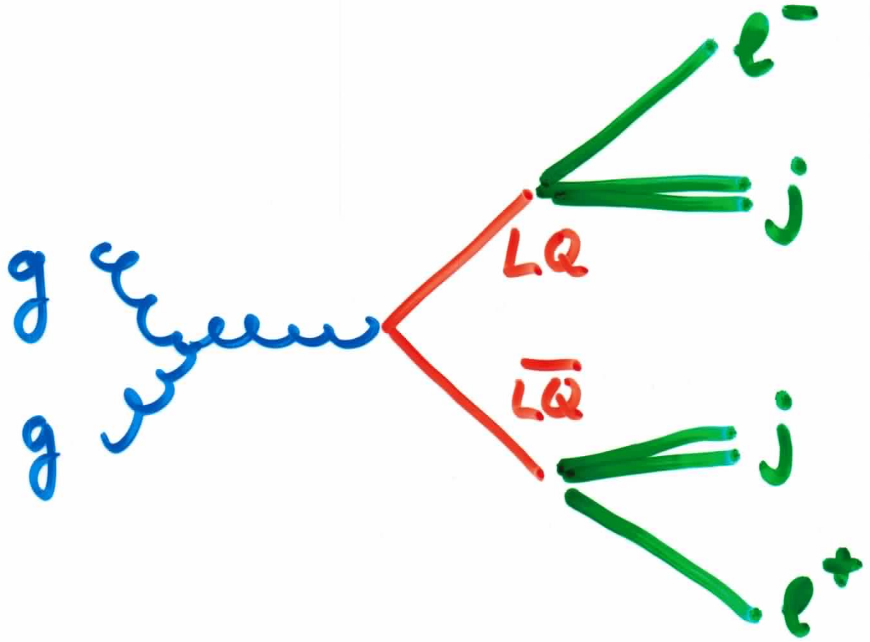
$$\Rightarrow \frac{\sigma^{LHC}}{\sigma^{Tev}} \approx \frac{\Omega^{LHC}}{\Omega^{Tev}} \gtrsim \frac{L^{Tev}}{L^{LHC}} = \begin{cases} 1000 & \text{low} \\ 100 & \text{high} \end{cases}$$

Example: "stable" new quark

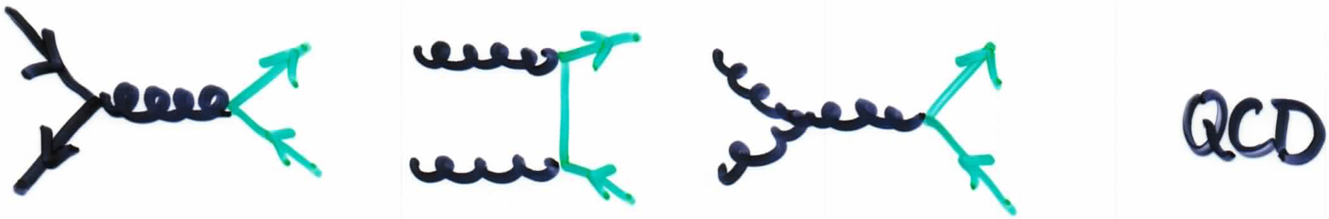


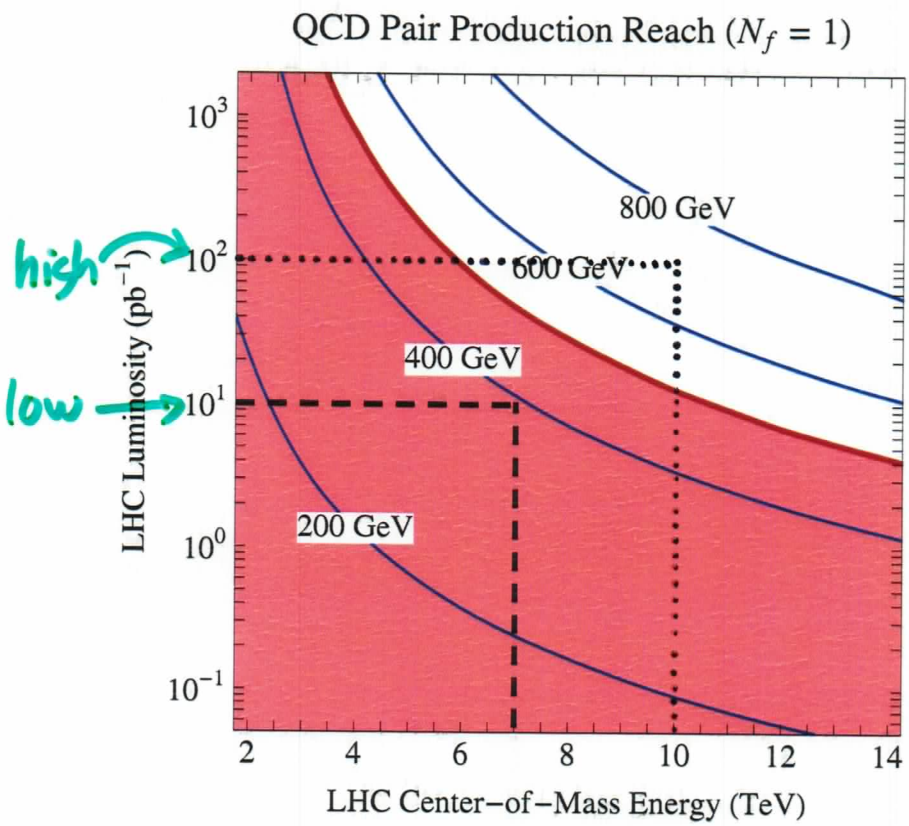
lepto-quark similar $LQ \to \mu q$

Leptoquark signature



New quarks


QCD


QCD Pair Production Reach ($N_f = 1$)
800 GeV
600 GeV
400 GeV
200 GeV
high
low
LHC Luminosity (pb^{-1})
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
2
4
6
8
10
12
14
LHC Center-of-Mass Energy (TeV)

We can do better !

Phase space for final particles

$$\prod_{i=1}^{n} \frac{d^3 p_i}{(2\pi)^3 2E_i} \Longrightarrow \left(1/16\pi^2 \right)^n$$

$\Longrightarrow$ single resonance production

(like Z @ LEP)

Classifying resonances

1. $q\bar{q}$ — Z' (W', g', Gr, ...)

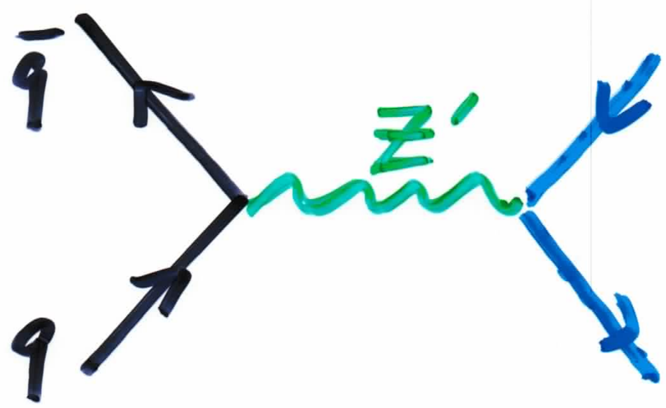
4. qq — diquark

3. gg — "higgs"

2. qg — excited quark

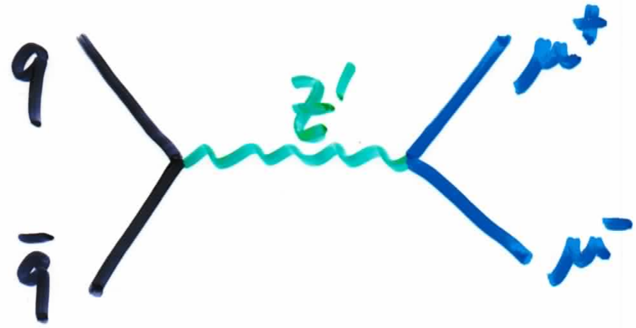
("higgs" and excited quark: $g_{eff} \approx \frac{1}{16\pi^2}$)

Example: $q\bar{q} \to Z'$



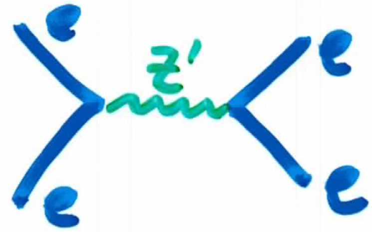
Decays: Z'

a.)

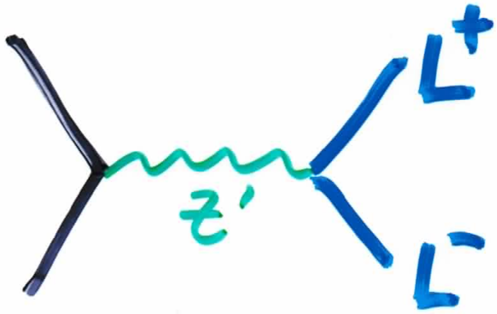


LEP II bounds

$m_{Z'} > 5$ TeV

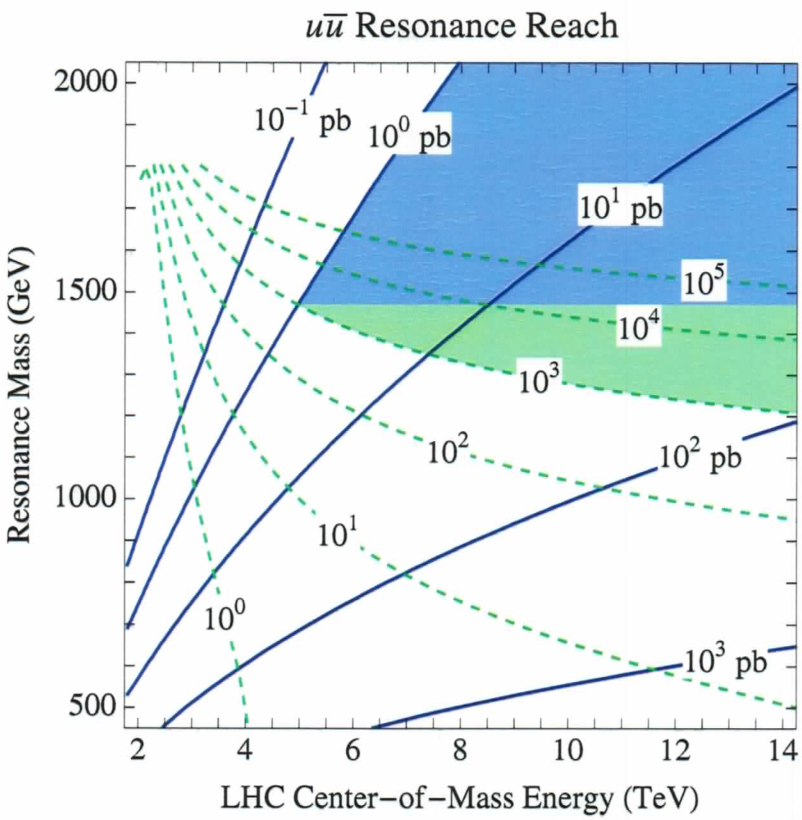


b.)



new "stable" lepton

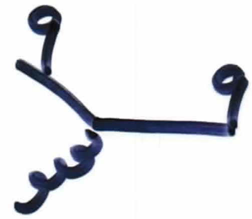
Z′ production



(ignore anomalies
branching fract's.)

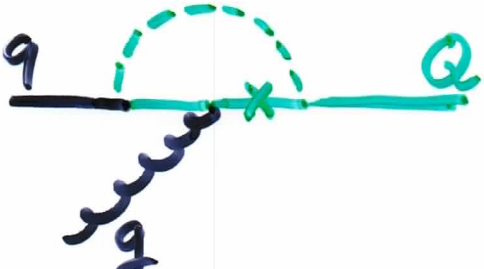
qg: excited quark gauge invariance

$$q^\dagger i \not{D} q$$



$$\frac{1}{\Lambda} Q^\dagger \sigma^{\mu\nu} G_{\mu\nu} q$$

weakly coupled example:

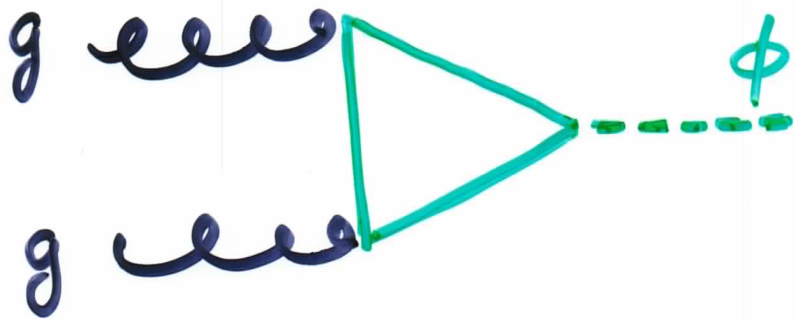


$$\sim \frac{1}{16\pi^2} \frac{1}{M}$$

g_{eff}

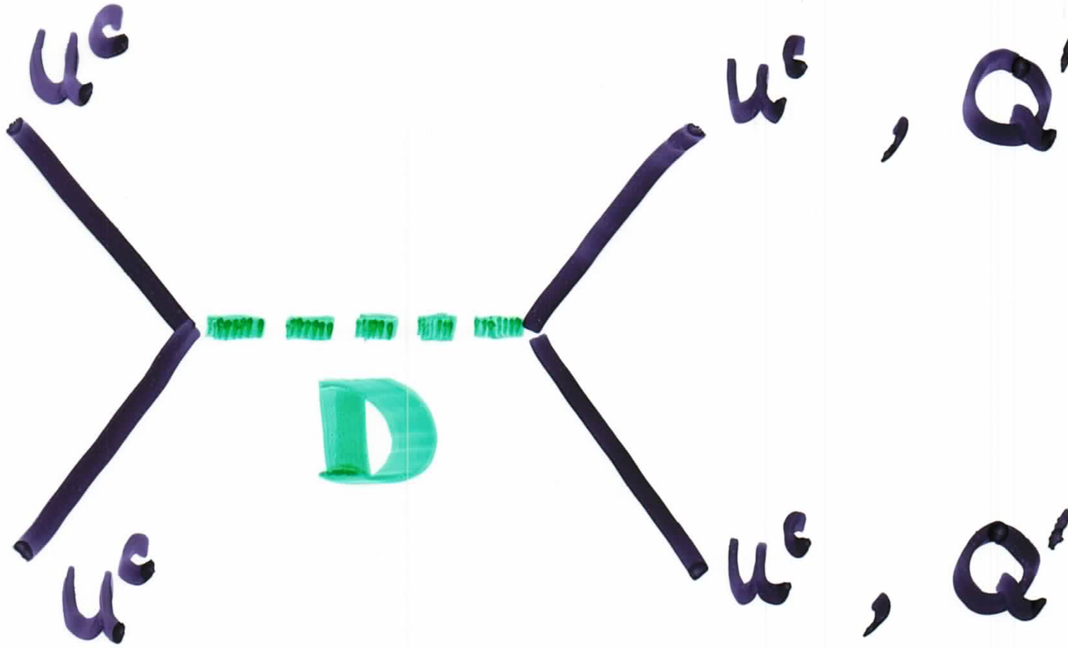
TeV

gg: "higgs"



$$\sim \frac{1}{16\pi^2} \frac{1}{M}$$

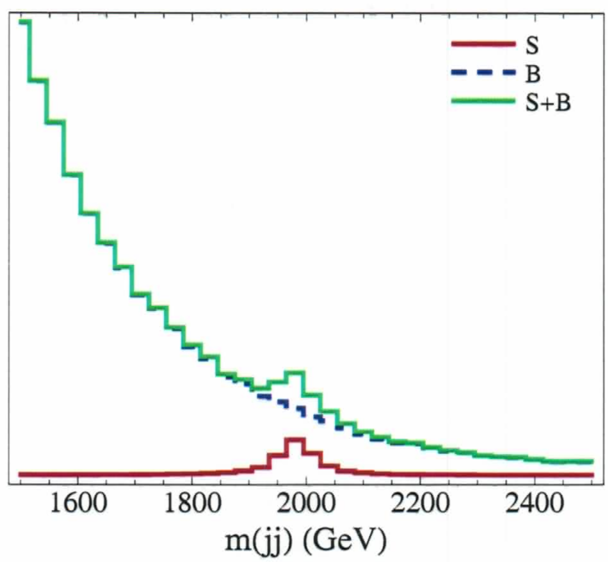
diquarks



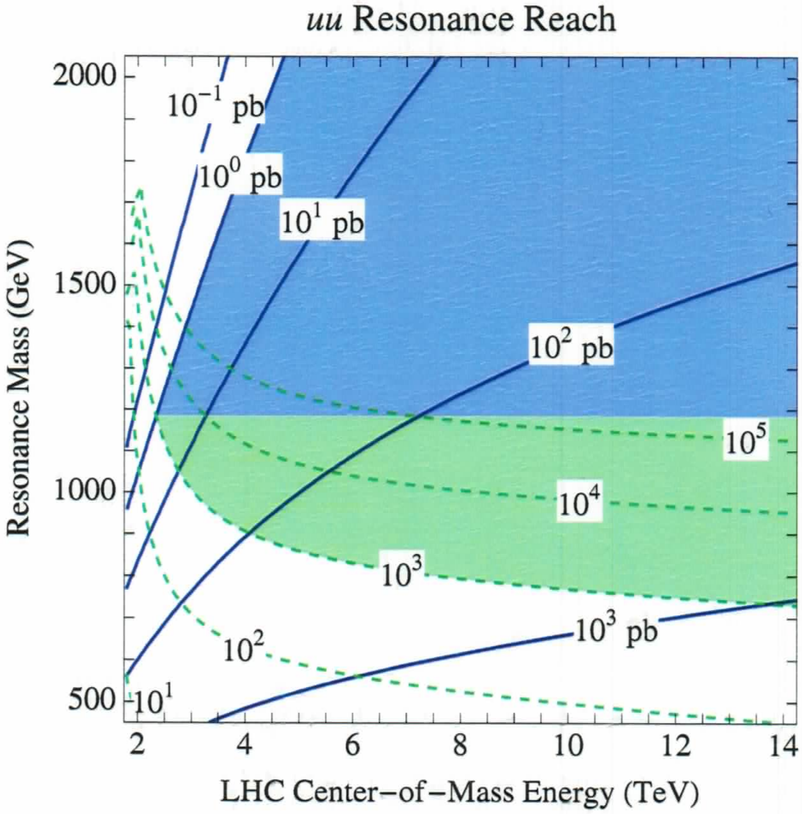
diquarks

∞ - luminosity

di-jets

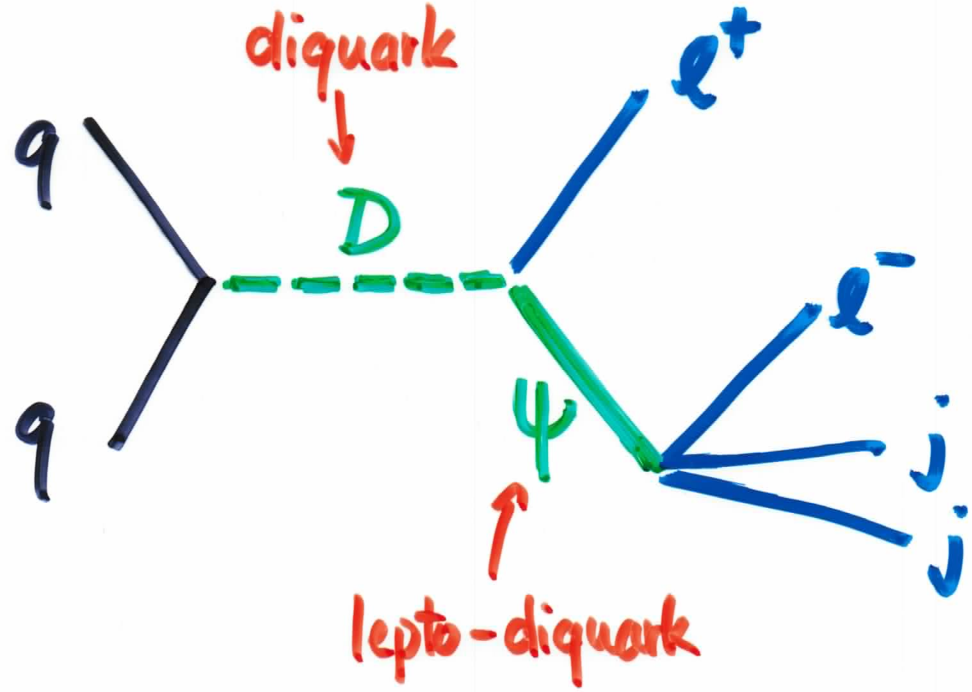


diquark production



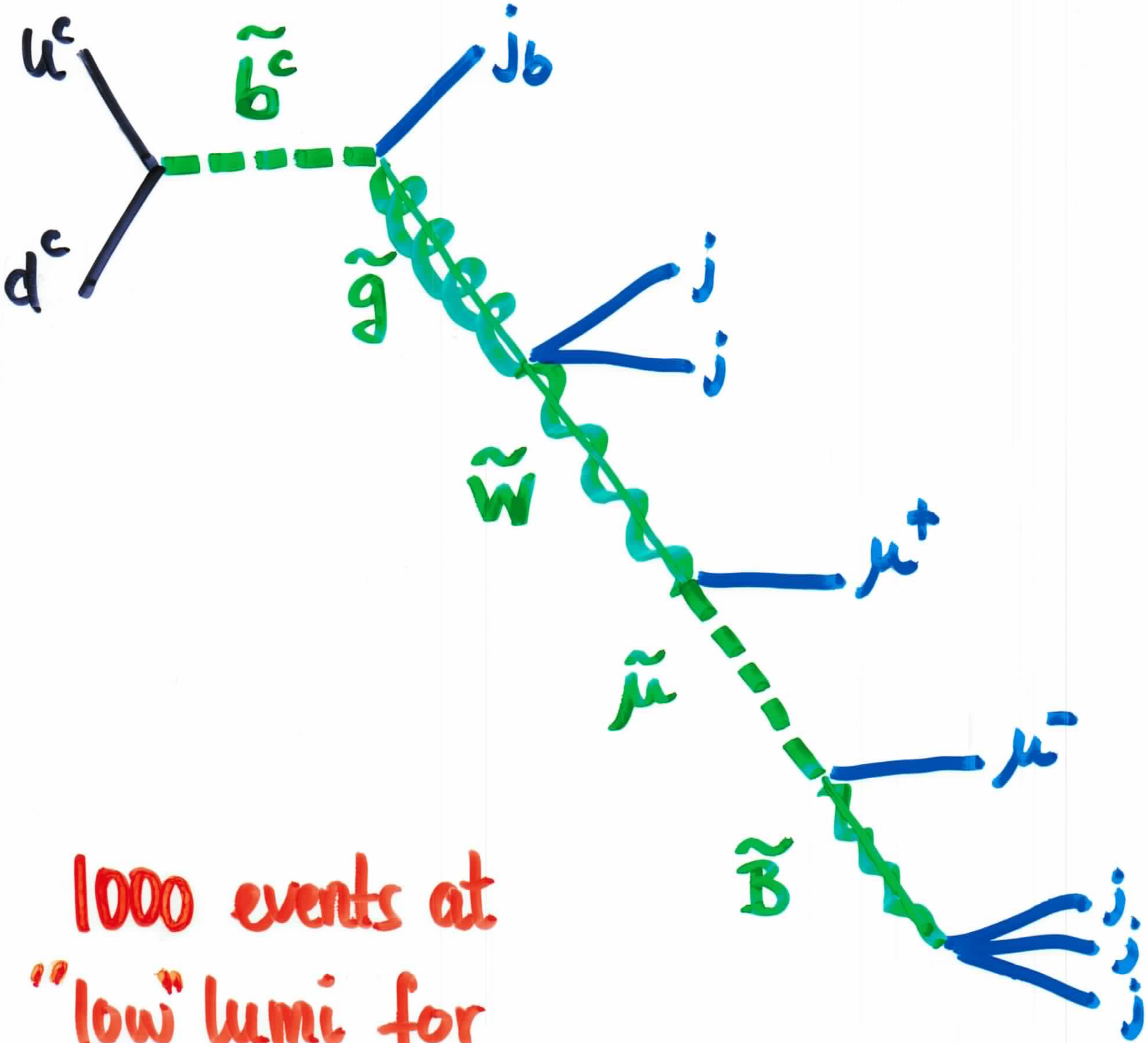
a true supermodel!

Diquark decays



Squark as diquark in $MSSM_{\not R}$

$$W = U^c D^c B^c$$



1000 events at "low" lumi for

$M_{\tilde{b}^c} = 1$ TeV

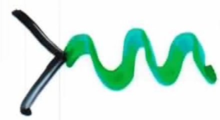
Conclusions

- no reach for MSUGRA, gM, higgs, little Higgs
  even with 100 pb^{-1}

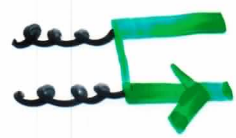
- big difference between 100 & 10 pb^{-1}

100 pb^{-1}

Z'



stable quark
leptoquark



10 pb^{-1}

diquark

↑ truly super