Constraints on the light gluino mass from the global analysis of hadronic data

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PDF=parton distribution function

If light gluinos (or other new color-charged particles) exist, can the PDF fits (CTEQ) to the data (DIS, Drell-Yan process, jets,...) constrain them?

History of the light gluino (LG) models ($m_{\tilde{g}} = 0 \sim 30$ GeV)

- ✓ Proposed in mid-70's (Fayet, Farrar)
- ✓ Discussed in the early 1990's as a means for explaining apparent slower running of α_S from the scales of a few GeV to M_Z
- ✓ May appear in some SUSY models as the lightest superpartner (LSP)
- ✓ May appear in some gauge-mediated SUSY-breaking models
- ✓ $m_{\tilde{g}} \lesssim 6$ GeV ruled out by the LEP data (?; see below)
- ✓ Berger, Harris, Kaplan, Sullivan, Tait, Wagner (2000):

  gluino ($m_{\tilde{g}} = 12 - 16$ GeV)
  + bottom squark ($m_{\tilde{b}} = 2 - 5.5$ GeV)
  = enhanced b-quark cross sections at the Tevatron;
  enhanced $B - \bar{B}$ mixing

- ✓ Recent activity to rule out such $m_{\tilde{g}}$ by LEP groups (see below)

Light gluino in the previous PDF fits

Assumptions: $m_{\tilde{g}} \lesssim 1.5$ GeV or $3 < m_{\tilde{g}} < 5$ GeV; $m_{\tilde{q}} \gtrsim 100$ GeV

Earlier fits (Roberts, Stirling; Blümlein, Botts; Rückl, Vogt; 1993-1994) find massless gluinos to be allowed by the data

C.S. Li, P. N., C.-P. Yuan, H.-Y. Zhou (1998) found that the LG model is disfavored in the fit to a subset of the CTEQ4 data
(for $\alpha_S(M_Z) = 0.118$)

In those analyses, only DIS and vector boson production data were used (no NLO contributions from the gluinos to the hard cross sections)

Current study

Assumptions: $m_{\tilde{g}} \geq 0.7$ GeV; bottom squark contributions to the studied observables are small (not included in this analysis)

A series of fits to the CTEQ6 set of data for varying $m_{\tilde{g}}$ and $\alpha_S(M_Z)$

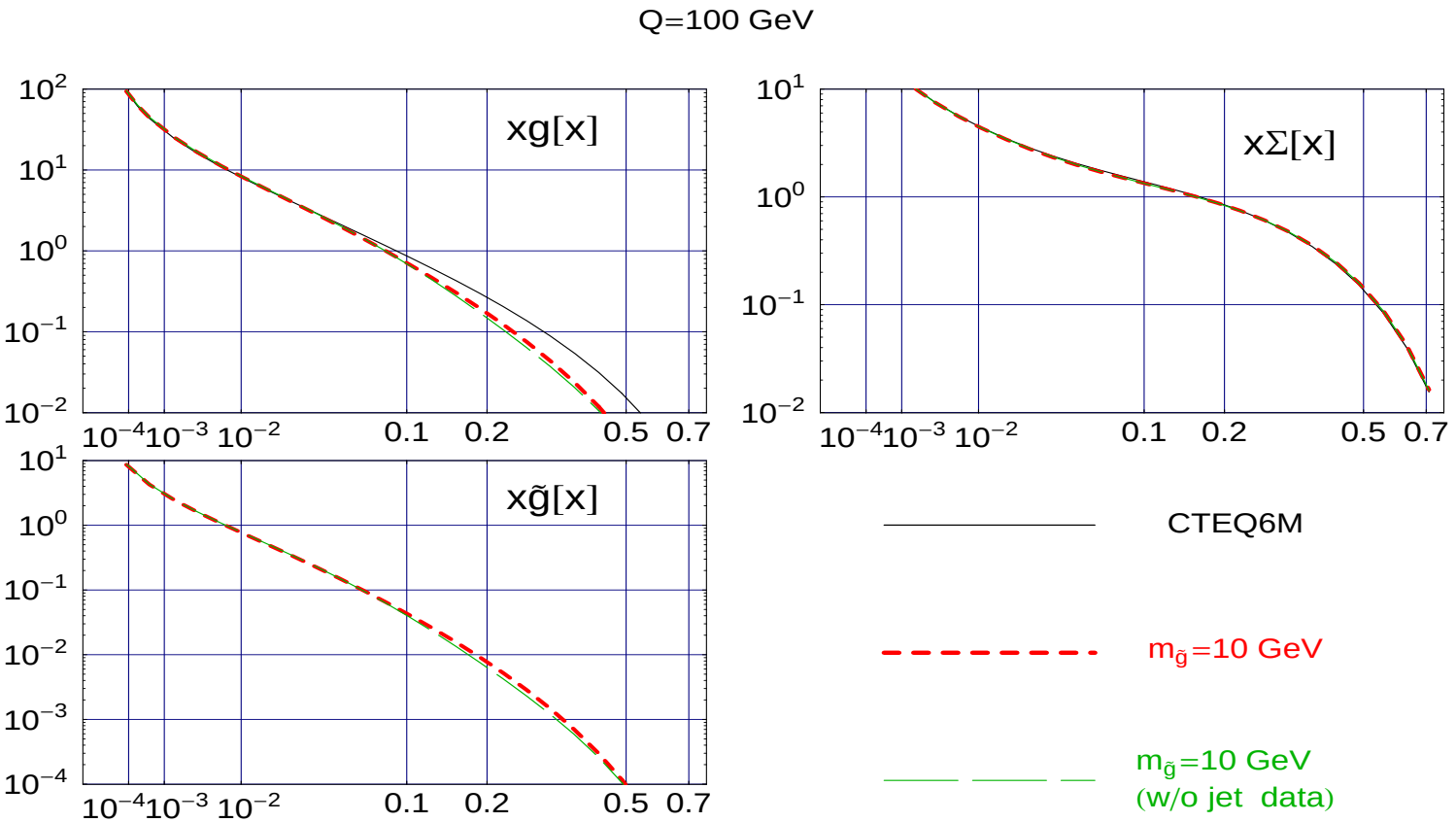
Quantative constraints on $m_{\tilde{g}}$ from the PDF error analysis

All Standard Model contributions are evaluated at NLO

$\tilde{g}$ contributions to the PDF evolution and jet production evaluated at the Born level (sufficient because $\tilde{g}(x) \ll q(x),\ g(x)$)

Tevatron jet data is included

Gluon, singlet, and gluino distributions ($xg(x)$, $x\Sigma(x)$, and $x\tilde{g}(x)$) for $\alpha_S(M_Z) = 0.118$



- ✓ $\tilde{g}(x) \ll g(x), \Sigma(x)$
- ✓ Strong depletion of the gluons at $x \gtrsim 0.05$
- ✓ Tevatron jet data are crucial for constraining $m_{\tilde{g}}$

The major effect of $\tilde{g}$: slower running of α_S (implemented to NLO in our analysis)

$$\mu\frac{\partial}{\partial\mu}\,\alpha_S(\mu) \;=\; -\left[\beta_0\frac{\alpha_S^2}{2\pi}+\beta_1\frac{\alpha_S^3}{2^3\pi^2}+\ldots\right],$$

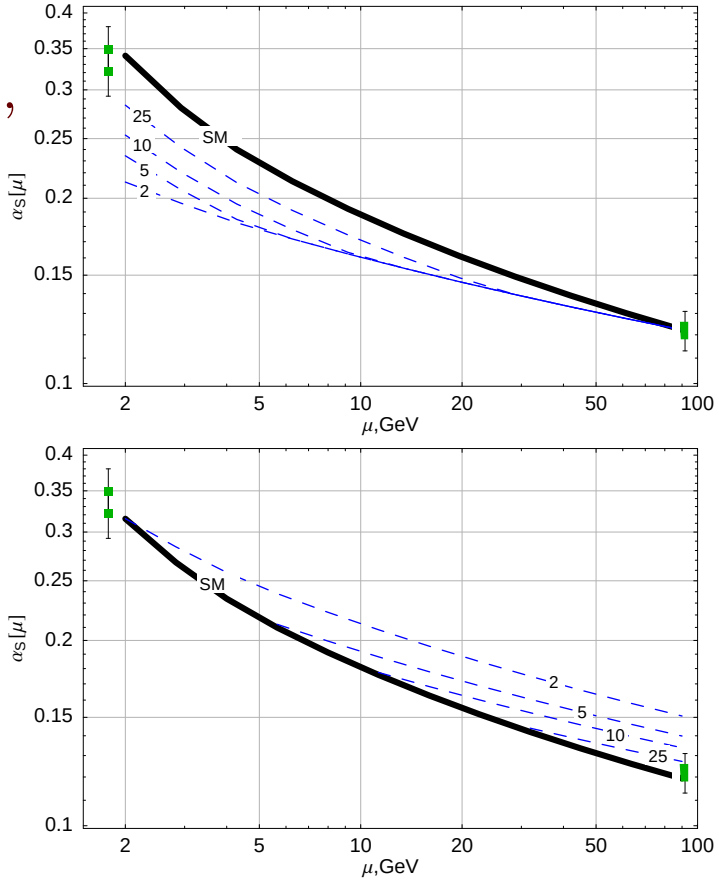
where

$$\beta_0 \;=\; 11-\frac{2}{3}n_f-2n_{\tilde{g}}-\frac{1}{6}n_{\tilde{f}}$$

n_f, $n_{\tilde{g}}$, $n_{\tilde{f}}$ are the numbers of active quarks, gluinos, and squarks

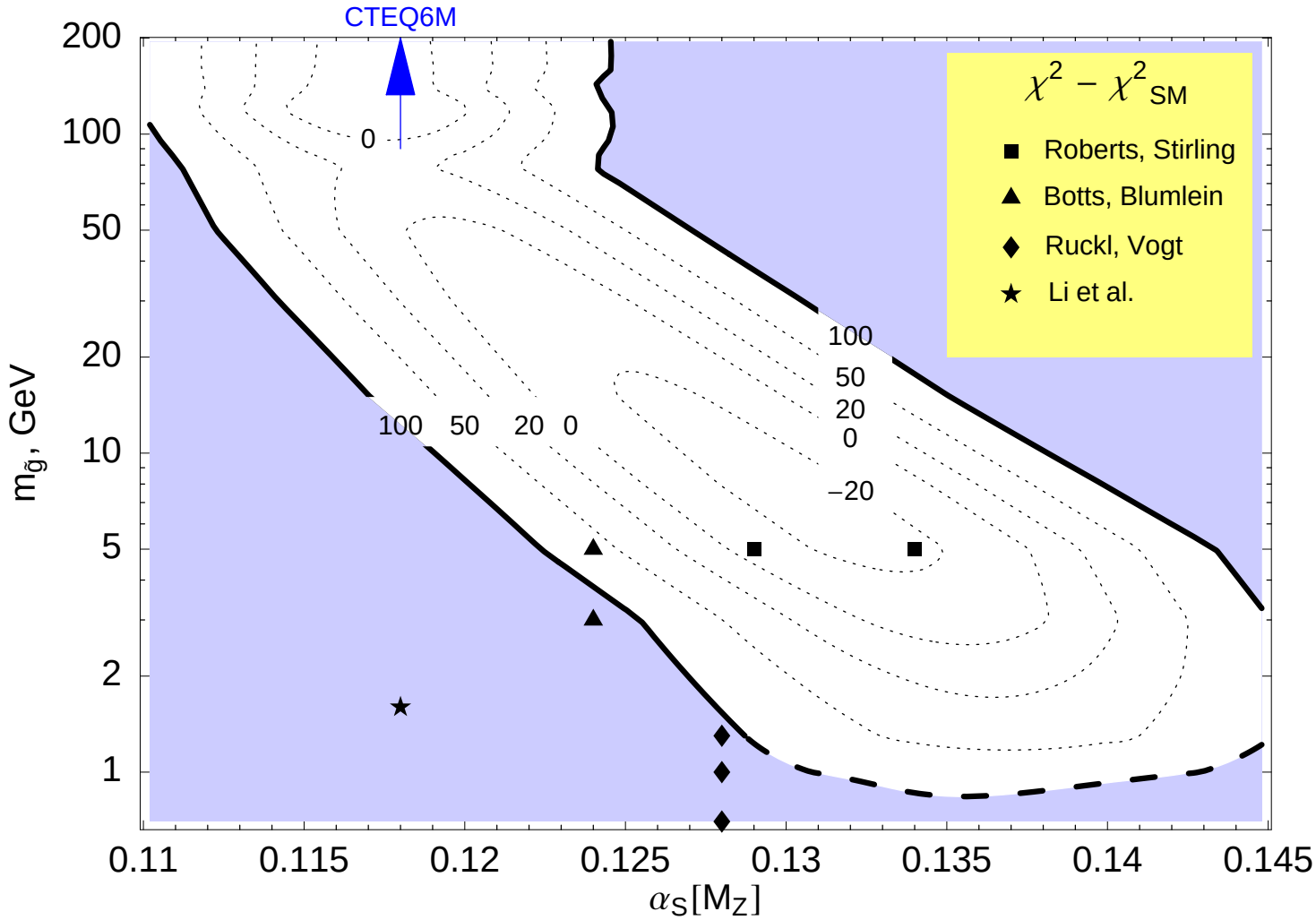
1 generation of gluinos contributes as 3 quark flavors

1 squark flavor contributes as 1/4 quark flavor (can be neglected)



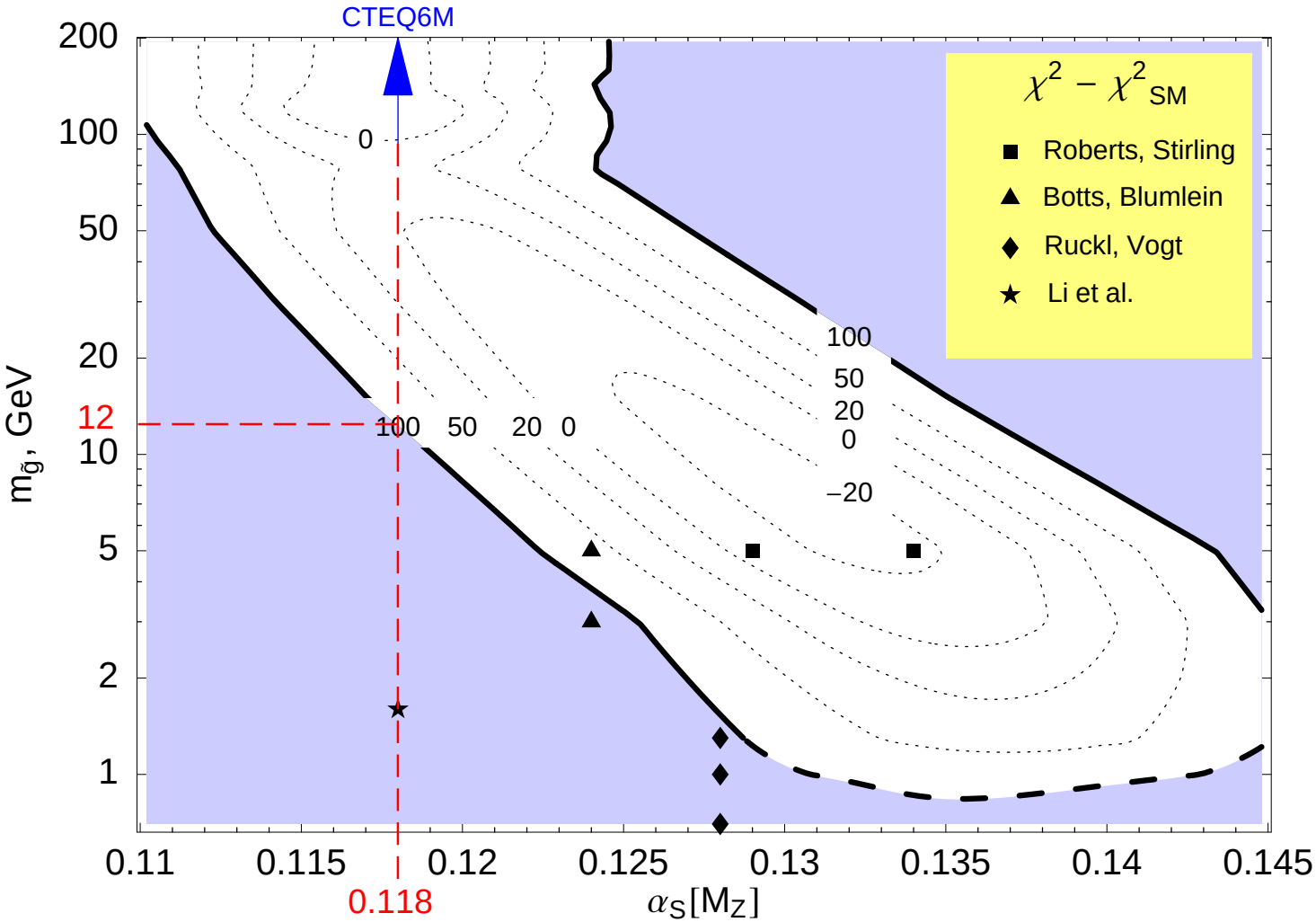
Slower running of α_S can be partially balanced by larger $\alpha_S(M_Z)$

Contour plot for $\delta\chi^2 = \chi^2\left[\alpha_S(M_Z), m_{\tilde{g}}\right] - \chi^2_{\text{CTEQ6M}}$



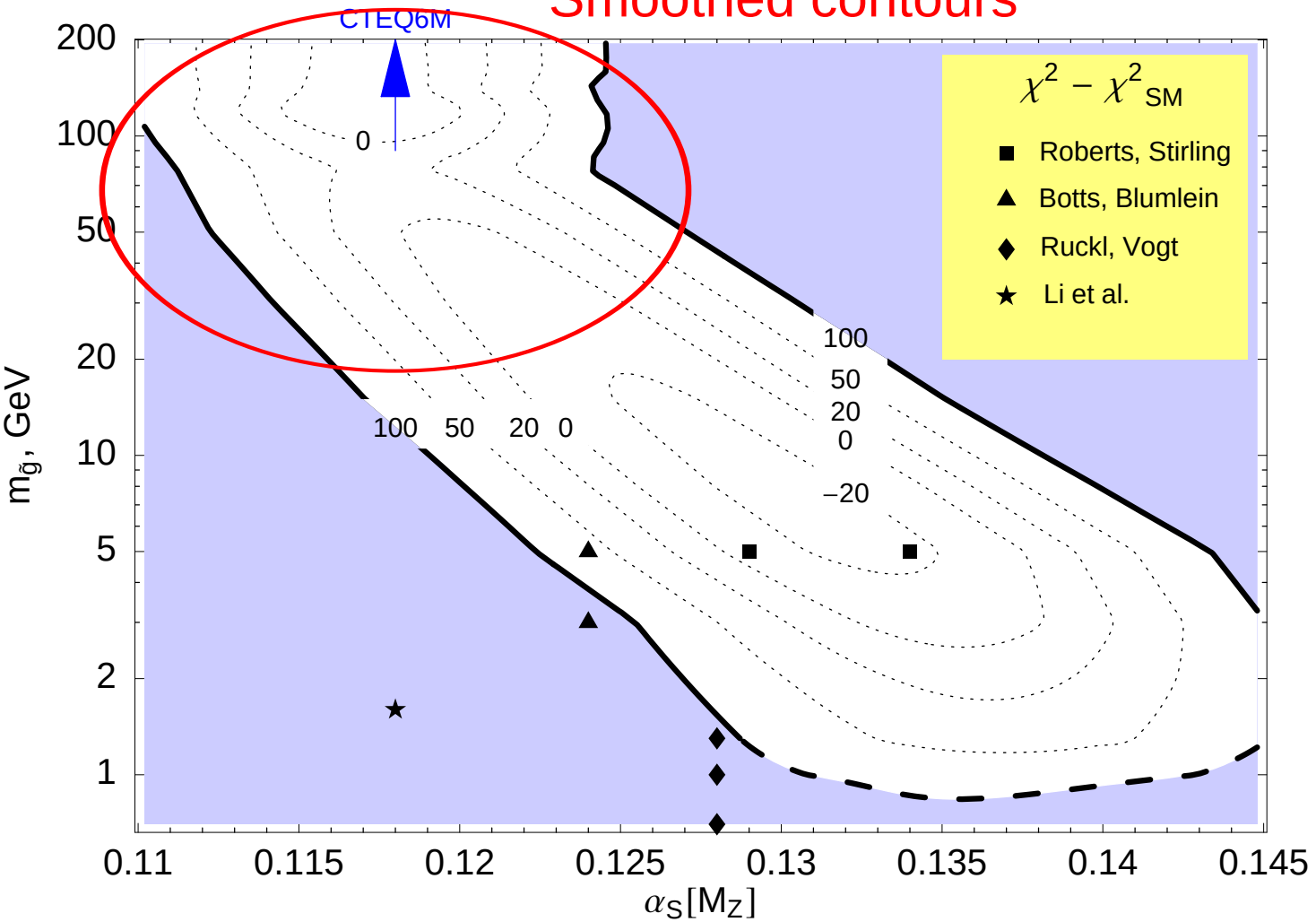
CTEQ6 tolerance criterion: fits with $\delta\chi^2 > 100$ are excluded (shaded area)

Contour plot for $\delta\chi^2 = \chi^2\left[\alpha_S(M_Z), m_{\tilde{g}}\right] - \chi^2_{\text{CTEQ6M}}$ (cont.)



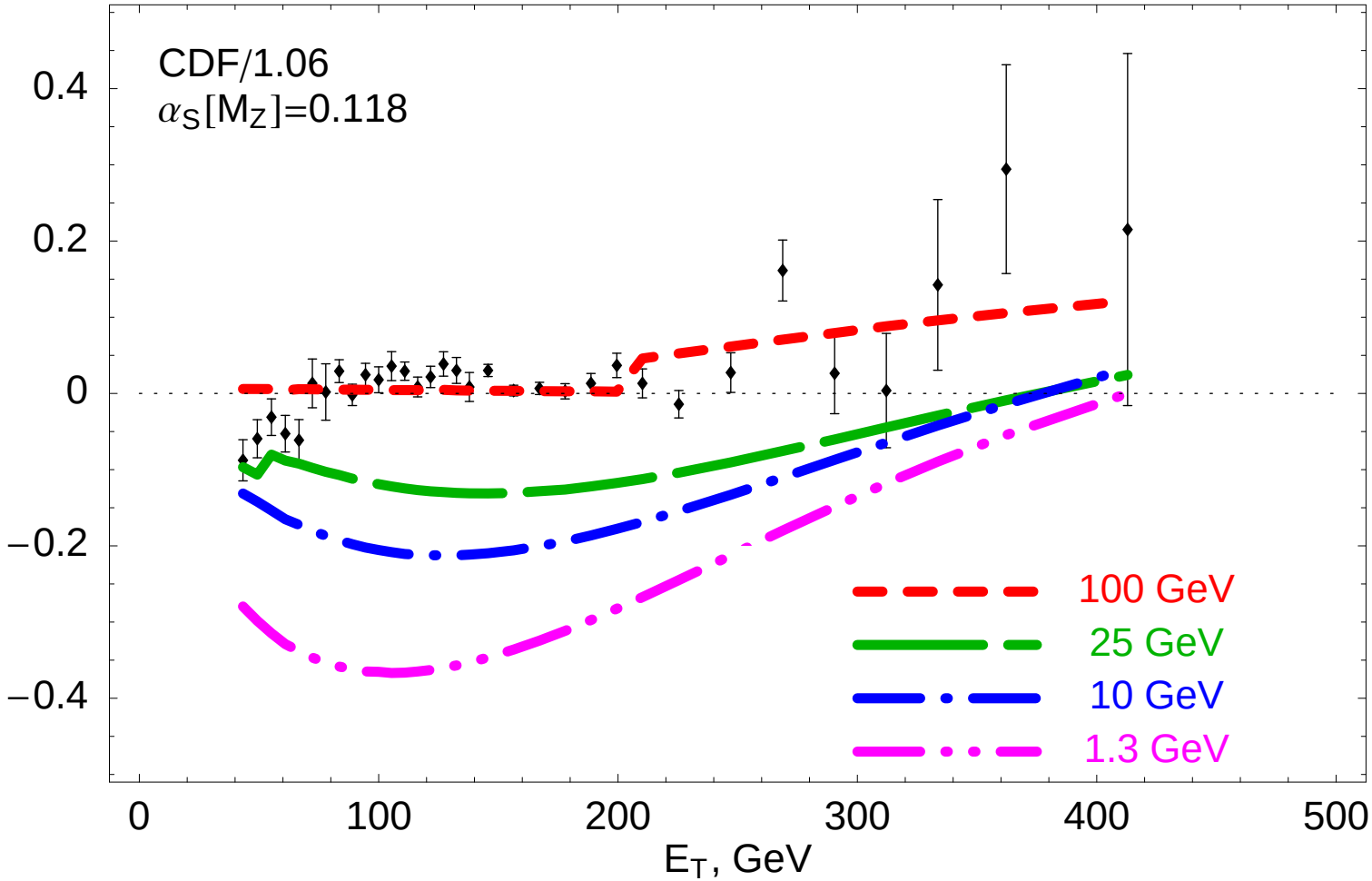
- ✓ $m_{\tilde{g}} > 12$ GeV at $\alpha_s(M_Z) = 0.118$
- ✓ lighter gluinos allowed for larger $\alpha_s(M_Z)$
- ✓ older fits for $m_{\tilde{g}} < 5$ GeV are excluded

Smoothed contours



✓ Contours smoothed in the region $m_{\tilde{g}} \sim 50 - 200$ GeV and $\alpha_s(M_Z) \sim 0.118$ (dominated by the Tevatron jet data)

(Data-CTEQ6M)/CTEQ6M and (SUSY-CTEQ6M)/CTEQ6M for the CDF jet data



$m_{\tilde{g}} \sim 100$ GeV slightly improves description of high-E_T jet data

Comparison with LEP results

- Global analysis:
  - ✓ $m_{\tilde{g}} > 12$ GeV for $\alpha_S(M_Z) = 0.118$
  - ✓ theoretically clean (one-scale inclusive observables only)
  - ✓ no assumptions about the stability of the superpartners
- Z boson width measurement *(P. Janot, 2003)*
  - ✓ $m_{\tilde{g}} > 6.3$ GeV at $\alpha_S(M_Z) = 0.118$
- Search for stable hadronizing gluinos
  - ✓ $m_{\tilde{g}} > 18$ GeV *(DELPHI, 2003)*; $m_{\tilde{g}} > 26.9$ GeV *(ALEPH, 2003)*
  - ✓ Does not apply if superpartners decay through R-parity violating channels *(Berger, Sullivan, 2003; Clavelli, Stremnitzer; 2003)*
- $m_{\tilde{g}} > 30 - 40$ GeV from the analysis of jet shape variables *(DELPHI, 2002)*
  - ✓ Multi-scale observables
  - ✓ Too optimistic theoretical errors?

Conclusions

- ✓ Model-independent constraints on new color-octet particles (gluinos)
- ✓ New features of our analysis
  - ◇ A fit to the complete CTEQ6 data set
  - ◇ SUSY contributions to Tevatron jet production cross sections
  - ◇ CTEQ error analysis
- ✓ Allowed gluino parameter space
  - ◇ $m_{\tilde{g}} > 5$ GeV for $\alpha_S(M_Z) < 0.122$
  - ◇ $m_{\tilde{g}} >$12 GeV for $\alpha_S(M_Z) = 0.118$
  - ◇ older fits for $m_{\tilde{g}} < 5$ GeV are excluded
- ✓ Competitive with LEP constraints
- ✓ Potential for the PDF analysis to constrain new physics in the next decade

(Data-CTEQ6M)/CTEQ6M and (SUSY-CTEQ6M)/CTEQ6M for the DØ jet data and $\alpha_S(M_Z) = 0.118$ (Preliminary)