Compositeness limits from dijet angular distribution in RunIIa

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Compositeness model

- model 10 from Iain Bertram's code
- Eichten-Lane 4-q contact interaction (left handed, positive interference)
- gives LO predictions on parton level
- integrates over appropriate phase space and gives cross section $d\sigma/d\chi$ for each particular bin in χ
- RunI analysis used NLO corrections from JETRAD
- NLO corrections not yet applied in my analysis
- no detector smearing included
- model with constant systematic error

RunII data

- RunI - integrated luminosity $L = 94\,\mathrm{pb}^{-1}$ at $\sqrt{s} = 1.8\,\mathrm{TeV}$
- RunIIa

$$L = 500\,\mathrm{pb}^{-1} \quad \text{at} \quad \sqrt{s} = 1.96\,\mathrm{TeV}$$
$$L = 2\,\mathrm{fb}^{-1} \quad \text{at} \quad \sqrt{s} = 1.96\,\mathrm{TeV}$$

- same cuts as in RunI

$$|\eta_{jet}| < 3\,, \qquad \chi < 11\,, \qquad \cos\vartheta^* < 5/6\,, \qquad |\eta^*| < 1.2$$

$$\chi = \frac{1 + |\cos\vartheta^*|}{1 - |\cos\vartheta^*|}\,, \qquad \eta^* = -\log\left(\tan\frac{\vartheta^*}{2}\right)$$

- two scenarios

$$\sigma_{sys} = 5\% \quad \text{and} \quad \sigma_{sys} = 10\%$$

- 'data' scattered only by statistical errors

Comp. limits in RunI

- from ratio $R_\chi = N_{\chi<4}/N_{4<\chi<\chi_{max}}$
- Bayesian technique

$$P(\Lambda|R_\chi) \propto P_{prior}(\Lambda)\, P(R_\chi|\Lambda)$$

- theory predicts for particular scale Λ the ratio R_χ^Λ

$$P(R_\chi|\Lambda) \propto \frac{1}{\sigma}\exp\left[-\frac{\left(R_\chi - R_\chi^\Lambda\right)^2}{2\sigma^2}\right]$$

- limit Λ_{limit} at particular confidence level CL

$$\frac{\int_{\Lambda_{limit}}^{\infty} P(\Lambda|R_\chi)\,\mathrm{d}\Lambda}{\int_{\Lambda_{min}}^{\infty} P(\Lambda|R_\chi)\,\mathrm{d}\Lambda} = CL$$

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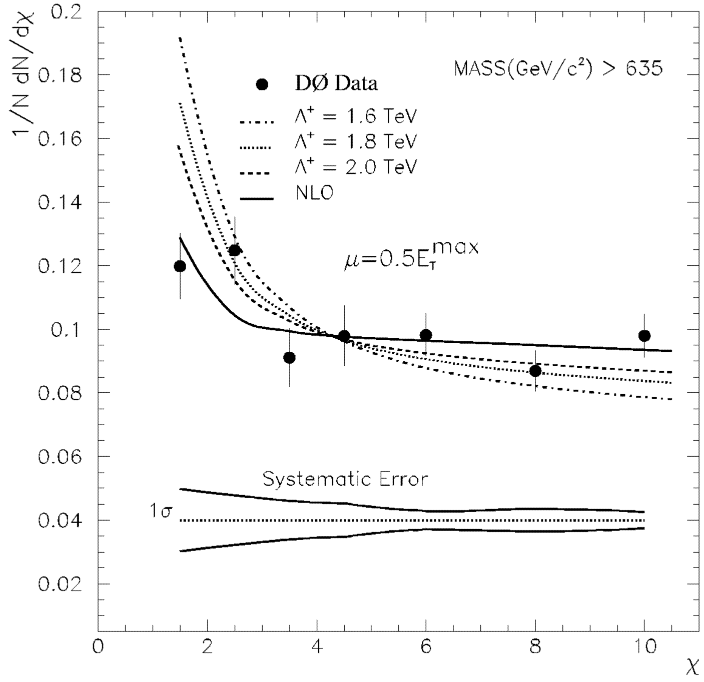


FIG. 2. Data compared to theory for different compositeness scales. See text for how compositeness is calculated for NLO predictions. The errors on the points are statistical and the band represents the correlated $\pm$ 1 σ systematic uncertainty.

Technical details

- question of prior probability distribution
- in RunI analysis

  flat distribution in $\gamma = 1/\Lambda^2$ with cut on minimum scale $\Lambda_{min} = 1\,\mathrm{TeV}$
- in this analysis

  probability that maximize the 'entropy'

$$P_{prior}(\Lambda) \propto \exp\left(-\Lambda/\mu\right) \qquad \text{with scale} \quad \mu = 2\,\mathrm{TeV}$$

  cut on minimum scale is $\Lambda_{min} = 0.2\,\mathrm{TeV}$
- integrals calculated numerically after substitution

$$l = \frac{\Lambda - \Lambda_{min}}{\Lambda + \mu - 2\Lambda_{min}}$$

  using values of posterior probably $P(\Lambda|R_\chi)$ in 512 points equidistant distributed over the whole interval $\langle 0, 1)$

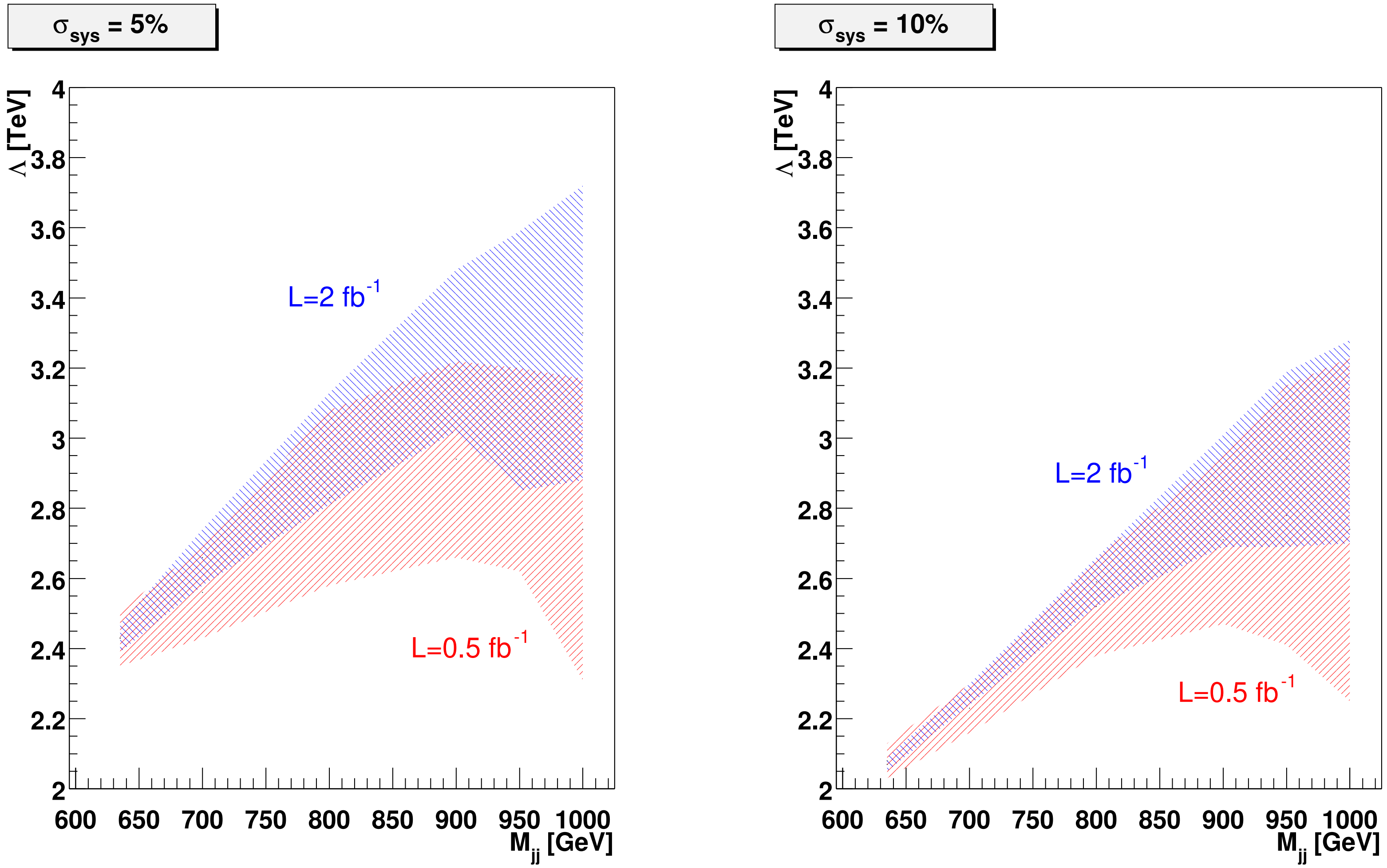
Limits in RunII from R_χ

- RunI limit based on measured ratio $R_\chi = 0.506$ is $\Lambda = 2.1\,\text{TeV}$
- RunIIa predictions

L	$\sqrt{s}$ [TeV]	M_{jj} *cut*	$\Lambda\ (\sigma_{sys} = 5\%)$	$\Lambda\ (\sigma_{sys} = 10\%)$
$94\,\text{pb}^{-1}$	1.8	635 GeV	2.31 ± 0.23 TeV	2.02 ± 0.12 TeV
$500\,\text{pb}^{-1}$	1.96	635 GeV	2.43 ± 0.08 TeV	2.08 ± 0.05 TeV
		700 GeV	2.56 ± 0.13 TeV	2.23 ± 0.07 TeV
		800 GeV	2.83 ± 0.25 TeV	2.52 ± 0.14 TeV
		900 GeV	2.94 ± 0.28 TeV	2.71 ± 0.24 TeV
		950 GeV	2.91 ± 0.29 TeV	2.78 ± 0.37 TeV
		1000 GeV	2.74 ± 0.43 TeV	2.74 ± 0.49 TeV
$2\,\text{fb}^{-1}$	1.96	635 GeV	2.43 ± 0.04 TeV	2.07 ± 0.02 TeV
		700 GeV	2.66 ± 0.08 TeV	2.27 ± 0.03 TeV
		800 GeV	2.97 ± 0.16 TeV	2.59 ± 0.07 TeV
		900 GeV	3.25 ± 0.23 TeV	2.85 ± 0.16 TeV
		950 GeV	3.22 ± 0.37 TeV	2.94 ± 0.25 TeV
		1000 GeV	3.30 ± 0.42 TeV	2.99 ± 0.29 TeV

Mean values of compositeness limit are shown (averaged over different experiments), the errors correspond to 1σ deviation of one experiment.

Limits in RunII from R_χ



RunII compositeness limits as a function of a cut on dijet mass M_{jj} (assuming 5% and 10% systematic error). Filled regions correspond to 1σ deviation of one experiment.

Limits from angular dist.

- the R_χ ratio does not contain the whole information
- method for determination of compositeness limits using all data points
- normalization of the distribution introduces statistical dependence between the data points in measured dijet angular distribution
- number of entries in each particular bin is independent
- theory predicts number of entries in given bin $\widetilde{N}_i = \widetilde{N}_i(\Lambda)$

$$P\left(\{N_i\}|\Lambda\right) = \prod_i P_i\left(N_i|\Lambda\right)$$

$$P_i\left(N_i|\Lambda\right) \propto \frac{1}{\sigma_i}\exp\left[-\frac{\left(N_i - \widetilde{N}_i\right)^2}{2\sigma_i^2}\right] \quad \text{with} \quad \sigma_i = \sqrt{\widetilde{N}_i + \sigma_{sys}^2\widetilde{N}_i^2}$$

- probability that one observe normalized angular dist. $\{n_i\}$ in theory Λ

$$P\left(\{n_i\}|\Lambda\right) = \int_0^\infty \mathrm{d}N\; P\left(\{n_1 N, n_2 N, \ldots, n_{N_{max}} N\}|\Lambda\right)$$

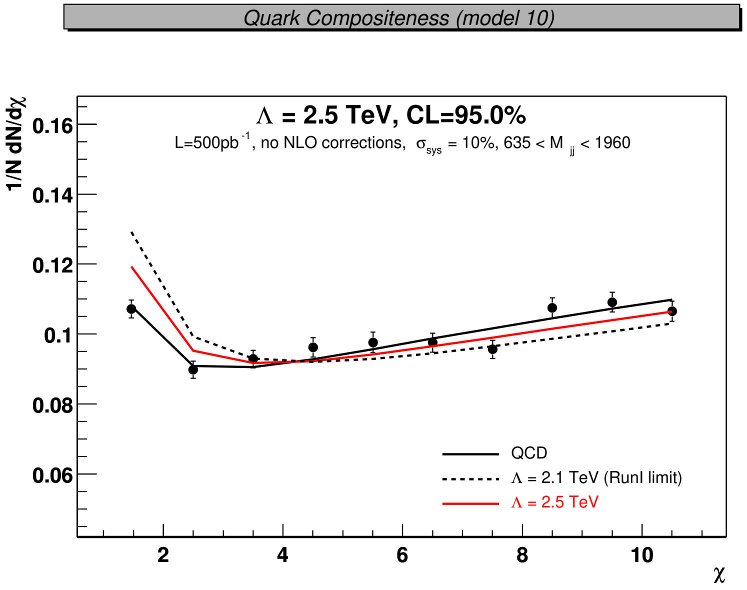
Technical details

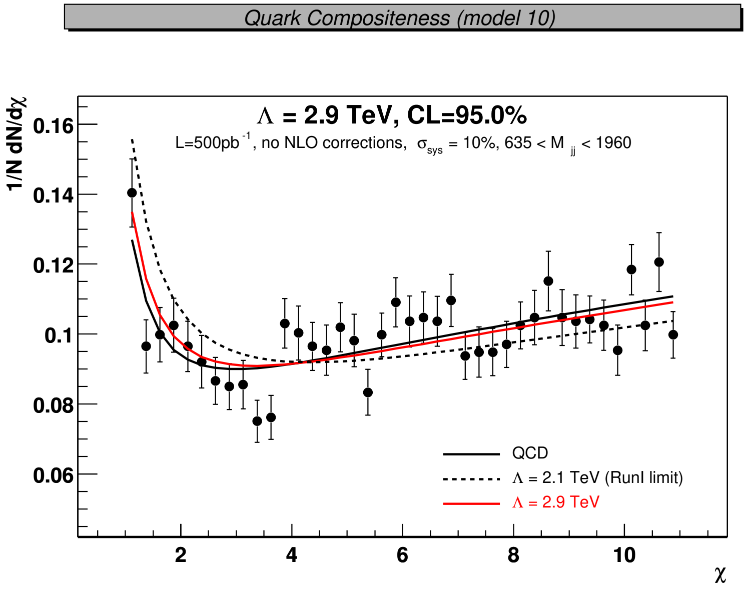
- the integral over N has Gaussian form
- can be performed analytically assuming $\widetilde{N}_i > 3\sigma_i$

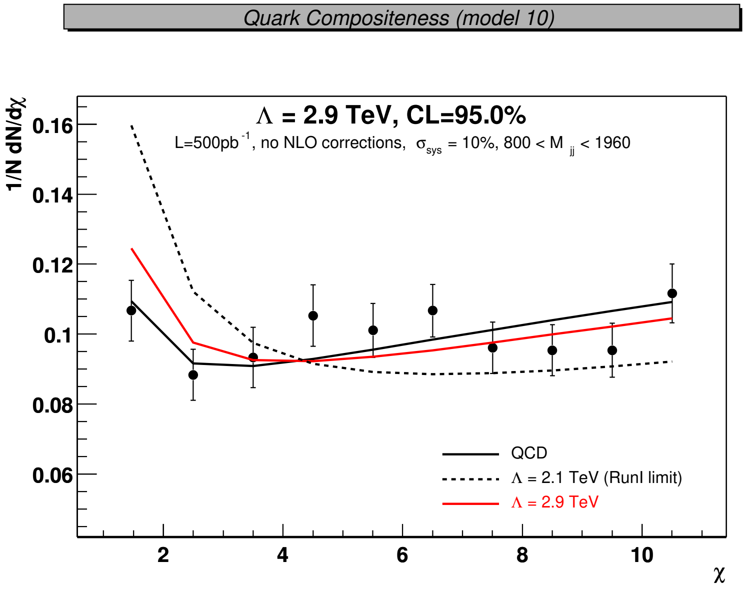
$$P\left(\{n_i\}\,|\Lambda\right) \propto \left(\prod_i \frac{1}{\sigma_i}\right) \frac{1}{\sqrt{\sum \frac{n_i^2}{2\sigma_i^2}}} \exp\left[\frac{\sum^2 \frac{n_i \widetilde{N}_i}{2\sigma_i^2}}{\sum \frac{n_i^2}{2\sigma_i^2}} - \sum \frac{\widetilde{N}_i^2}{2\sigma_i^2}\right]$$

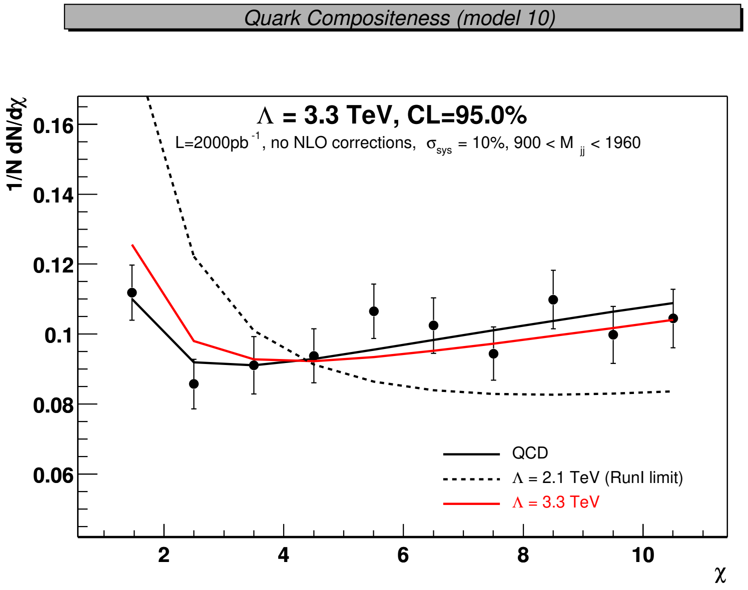
- using Bayesian technique, the limit on compositeness scale Λ can be obtained exactly in the same way as in the case of the ratio R_χ
- since σ_i is not proportional to $\widetilde{N}_i$ (due to statistical part) the results may slightly depend on the normalization of theory

Compositeness limits









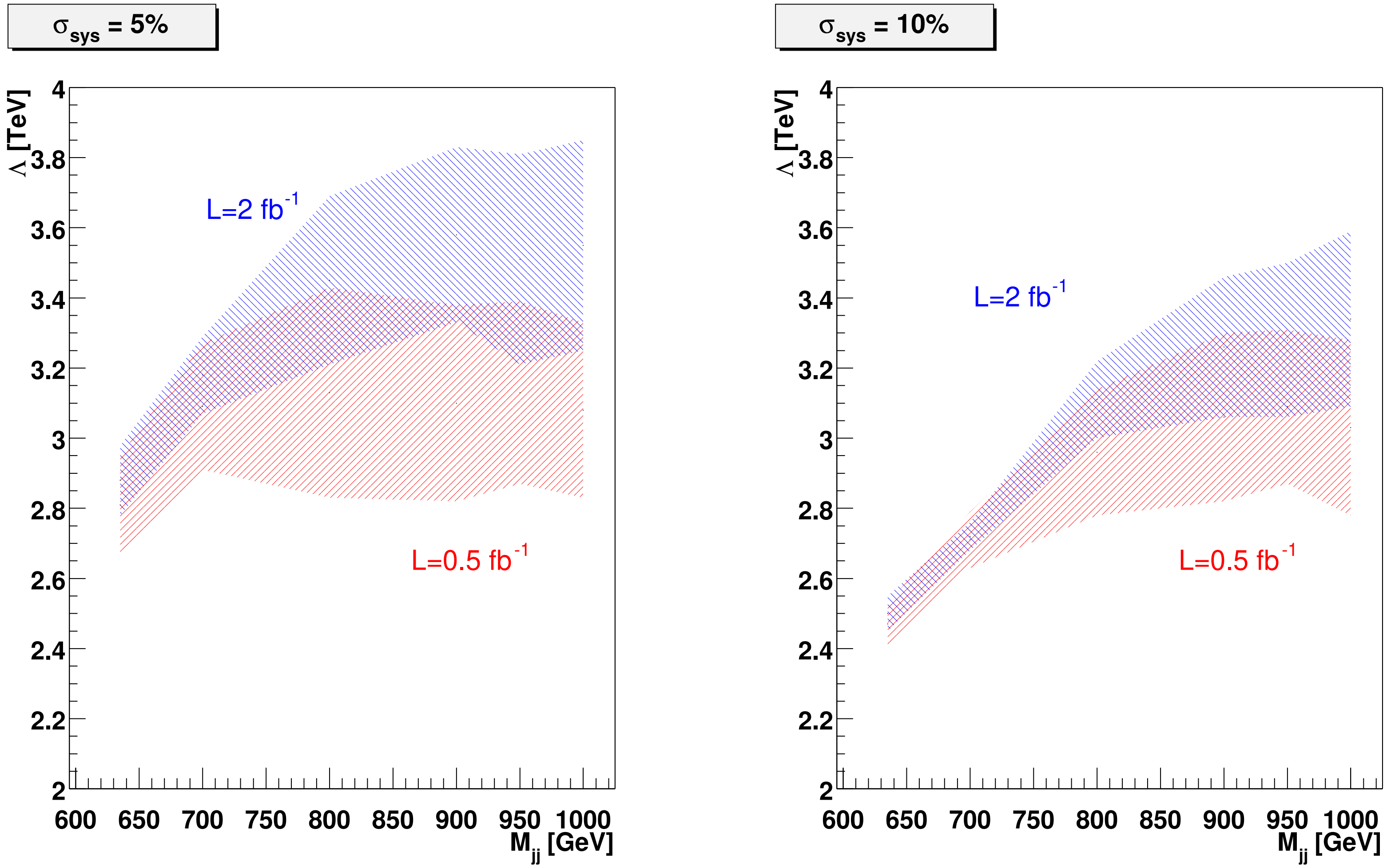
Compositeness limits

▷ RunII predictions

L	$\sqrt{s}$ [TeV]	M_{jj} *cut*	Λ ($\sigma_{sys} = 5\%$)	Λ ($\sigma_{sys} = 10\%$)
$94\,\mathrm{pb}^{-1}$	1.8	635 GeV	2.51 ± 0.20 TeV	2.36 ± 0.15 TeV
$500\,\mathrm{pb}^{-1}$	1.96	635 GeV	2.81 ± 0.14 TeV	2.47 ± 0.06 TeV
		700 GeV	3.09 ± 0.18 TeV	2.71 ± 0.08 TeV
		800 GeV	3.13 ± 0.30 TeV	2.96 ± 0.18 TeV
		900 GeV	3.10 ± 0.28 TeV	3.06 ± 0.24 TeV
		950 GeV	3.13 ± 0.26 TeV	3.09 ± 0.22 TeV
		1000 GeV	3.08 ± 0.25 TeV	3.03 ± 0.25 TeV
$2\,\mathrm{fb}^{-1}$	1.96	635 GeV	2.88 ± 0.10 TeV	2.50 ± 0.05 TeV
		700 GeV	3.18 ± 0.11 TeV	2.72 ± 0.04 TeV
		800 GeV	3.45 ± 0.24 TeV	3.11 ± 0.11 TeV
		900 GeV	3.58 ± 0.25 TeV	3.26 ± 0.20 TeV
		950 GeV	3.51 ± 0.30 TeV	3.28 ± 0.22 TeV
		1000 GeV	3.55 ± 0.30 TeV	3.34 ± 0.25 TeV
$15\,\mathrm{fb}^{-1}$	1.96	1000 GeV	4.09 ± 0.23 TeV	3.73 ± 0.17 TeV

Mean values of compositeness limit are shown (averaged over different experiments), the errors correspond to 1σ deviation of one experiment.

Limits in RunII



RunII compositeness limits as a function of a cut on dijet mass M_{jj} (assuming 5% and 10% systematic error). Filled regions correspond to 1σ deviation of one experiment.

Summary

- ▷ **General rule.** *Keep statistical errors roughly on the same level as systematic errors.*
- ▷ **Large statistical variations** *of the scale limit* Λ *in different 'experiments'*
- ▷ *putting down the* **systematic errors** *is not that important issue*

Compositeness limits from R_χ

L	$\Lambda\ (\sigma_{sys} = 5\%)$	$\Lambda\ (\sigma_{sys} = 10\%)$
$0.5\,fb^{-1}$	$2.9\,\mathrm{TeV}$	$2.8\,\mathrm{TeV}$
$2\,fb^{-1}$	$3.3\,\mathrm{TeV}$	$3.0\,\mathrm{TeV}$

Compositeness limits *from whole dijet angular distribution*

L	$\Lambda\ (\sigma_{sys} = 5\%)$	$\Lambda\ (\sigma_{sys} = 10\%)$
$0.5\,fb^{-1}$	$3.1\,\mathrm{TeV}$	$3.0\,\mathrm{TeV}$
$2\,fb^{-1}$	$3.5\,\mathrm{TeV}$	$3.3\,\mathrm{TeV}$
$15\,fb^{-1}$	$4.1\,\mathrm{TeV}$	$3.7\,\mathrm{TeV}$

- ▷ No need to wait till the end of RunIIa, $0.5\,fb^{-1}$ is enough to obtain interesting physics results