Jets @ high Q^2
Status report

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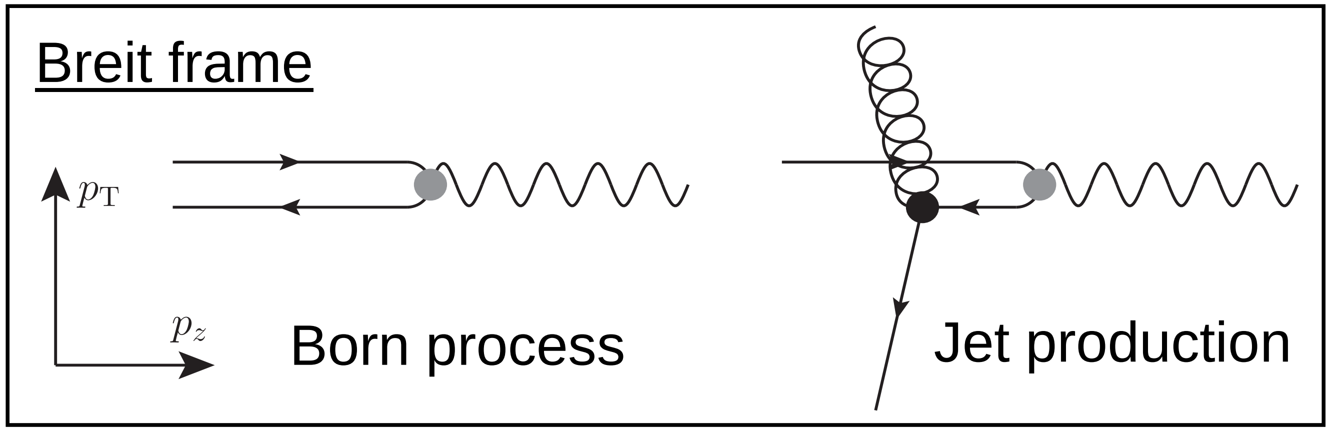
H1 Collaboration Meeting, September 2013
Liverpool, 11 September 2013

Jet production in *ep* scattering

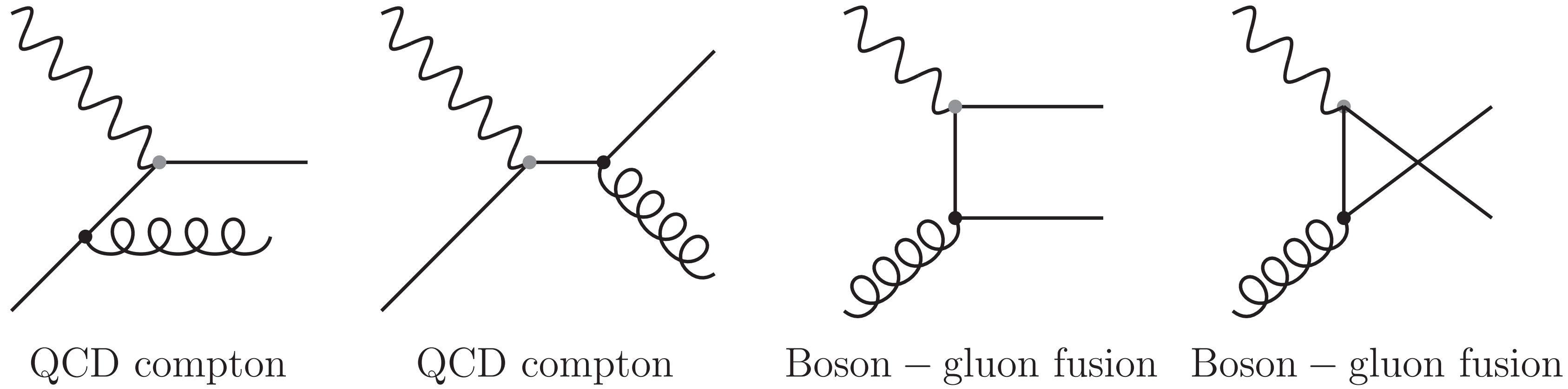
Breit frame of reference

$$2x_{\mathrm{Bj}}p + k = 0$$

- Only hard QCD processes generate considerable p_T in the Breit frame



Jet production in DIS in leading-order



Jet cross section calculable in pQCD

$$\sigma_{\mathrm{jet}} = \sum_{n} \sum_{a=q,\bar{q},g} \left[\sigma_{n,a} \otimes f_a\right] (1 + \delta_{\mathrm{had}})$$

- Expansion in orders of $\alpha_s(\mu_r)$ with $n \geq 1$
- Hadronization effects with correction factor
- Coefficients available up to next-to-leading order

Jet production directly sensitive to α_s

Phase space of measurement

Measurement phase space (MPS)	Extended phase space (EPS)
Neutral current phase space	**Neutral current phase space**
150 < Q^2 < 15000 GeV^2	100 < Q^2 < 40000 GeV^2
0.2 < y < 0.7	0.08 < y < 1.0
Jet acceptance	**Jet acceptance**
-1.0 < η_{lab} < 2.5	-1.5 < η_{lab} < 2.75
Inclusive Jet	**Inclusive Jet**
7 < p_T^{jet} < 50 GeV	p_T^{jet} > 3 GeV

MPS: Dijet ($n_{jet}\geq 2$)	MPS: Trijet ($n_{jet}\geq 3$)	EPS: Dijet ($n_{jet}\geq 2$)	EPS: Trijet ($n_{jet}\geq 3$)
5 < p_T^{jet} < 50 GeV		3 < p_T^{jet} < 50 GeV	
M_{12} > 16 GeV			
7 < $\langle p_T \rangle_2$ < 50 GeV	7 < $\langle p_T \rangle_3$ < 30 GeV	3 < $\langle p_T \rangle_2$ < 50 GeV	3 < $\langle p_T \rangle_3$ < 30 GeV
0.006 < ξ_2 < 0.316	0.01 < ξ_3 < 0.50	0.0 < ξ_2 < 1.0	0.0 < ξ_3 < 1.0

Phase space of final data points

Extended phase phase used only for migrations in unfolding

Schematic definition of migration matrix

Simultaneous unfolding

NC DIS, inclusive jet, dijet and trijet

Covariance matrix V_y

takes statistical correlations of observables into account

Individual unfolding schemes

- E, J_1, J_2, J_3 studied in detail
- Are optimized separately using MC

Matrices B_i

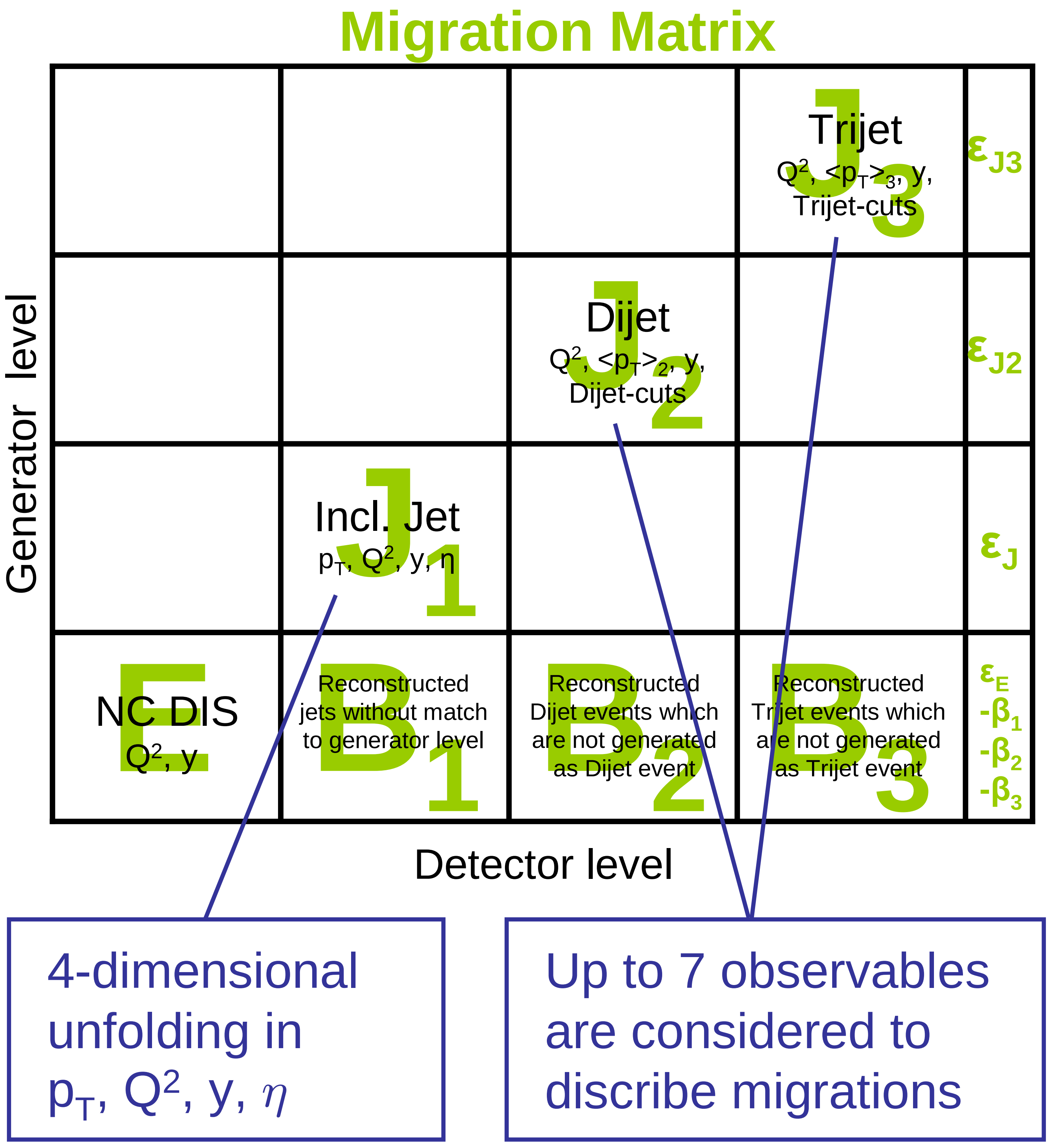
Constrain reconstructed but not generated contributions

Two MC generators

Django and Rapgap

Phase space is enlarged

in all variables where migrations are relevant



Problem with uncertainties after unfolding

Systematic uncertainties

Alternative unfolding matrix is determined for every source of systematic uncertainty

- Jet energy scale (JES)
- Remaining cluster energy scale (RCES)
- Electron angle (E_θ)
- Electron energy (E_e)

Uncertainty is propagated analytically

- using linear error propagation formulae to generator level distribution

Uncertainties show large fluctuations (O(%))

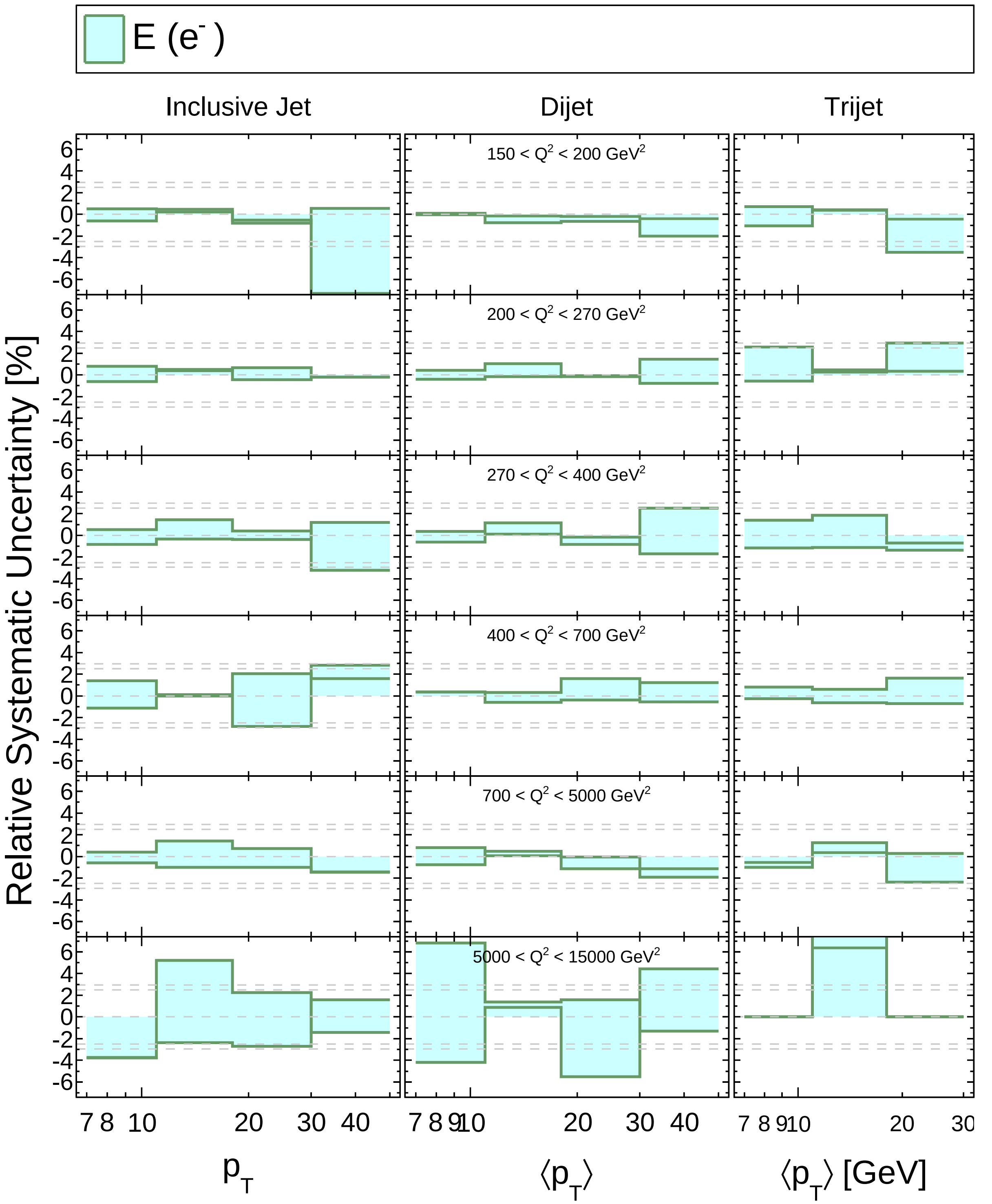
Unclear

Caused by

- limited data statistics?
- limited MC statistics? -> New MC production

Impact on fit

- Does fluctuation ‘mimic’ statistical fluctuation -> Causing large nuisacne parameters



New Monte Carlo production

New Rapgap and Django MC

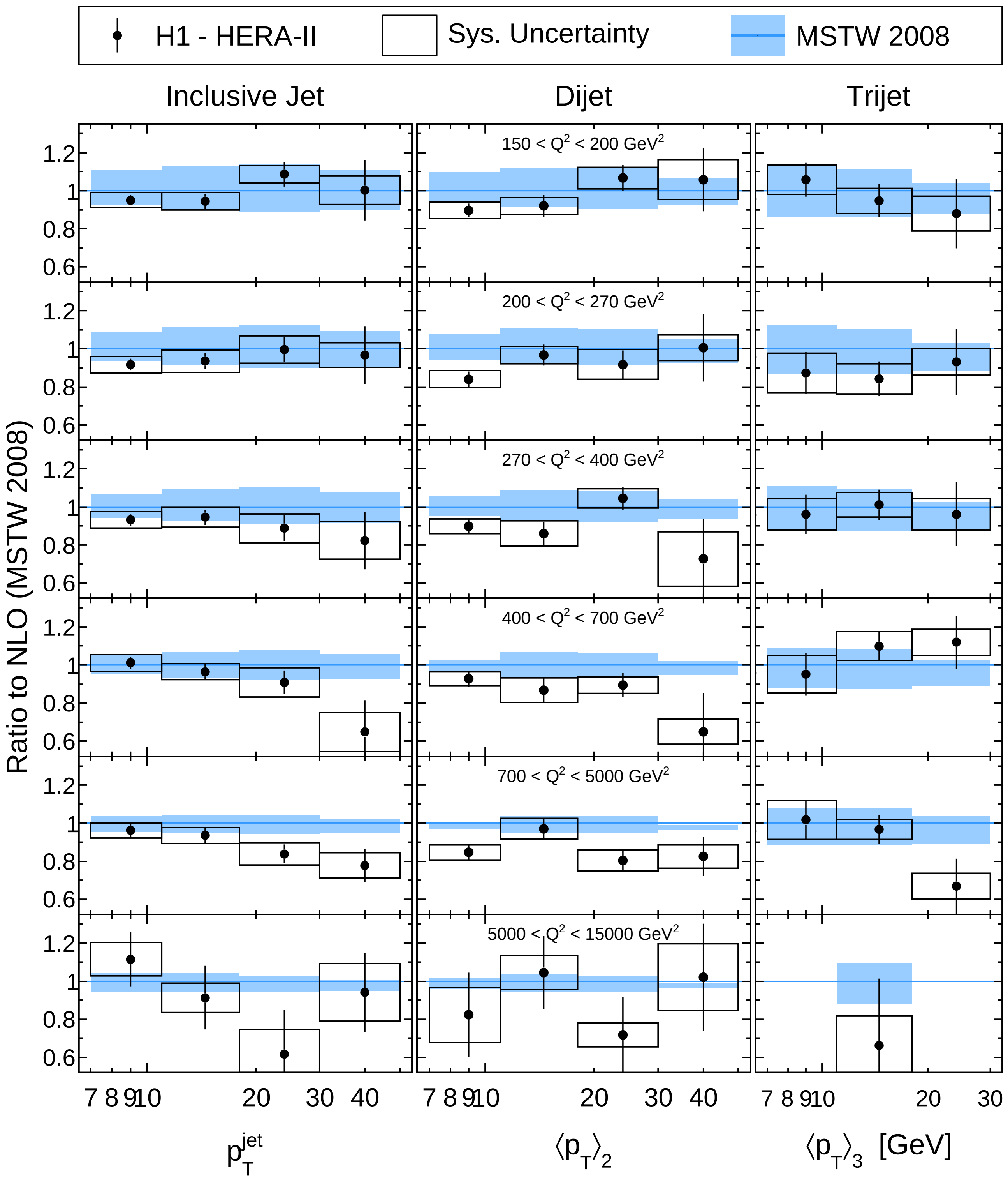
Huge statistics

- 40 fb^{-1} of MC data for every generator
- New controlplots very well consistent with old ones

Two Sim/Rec files corrupt

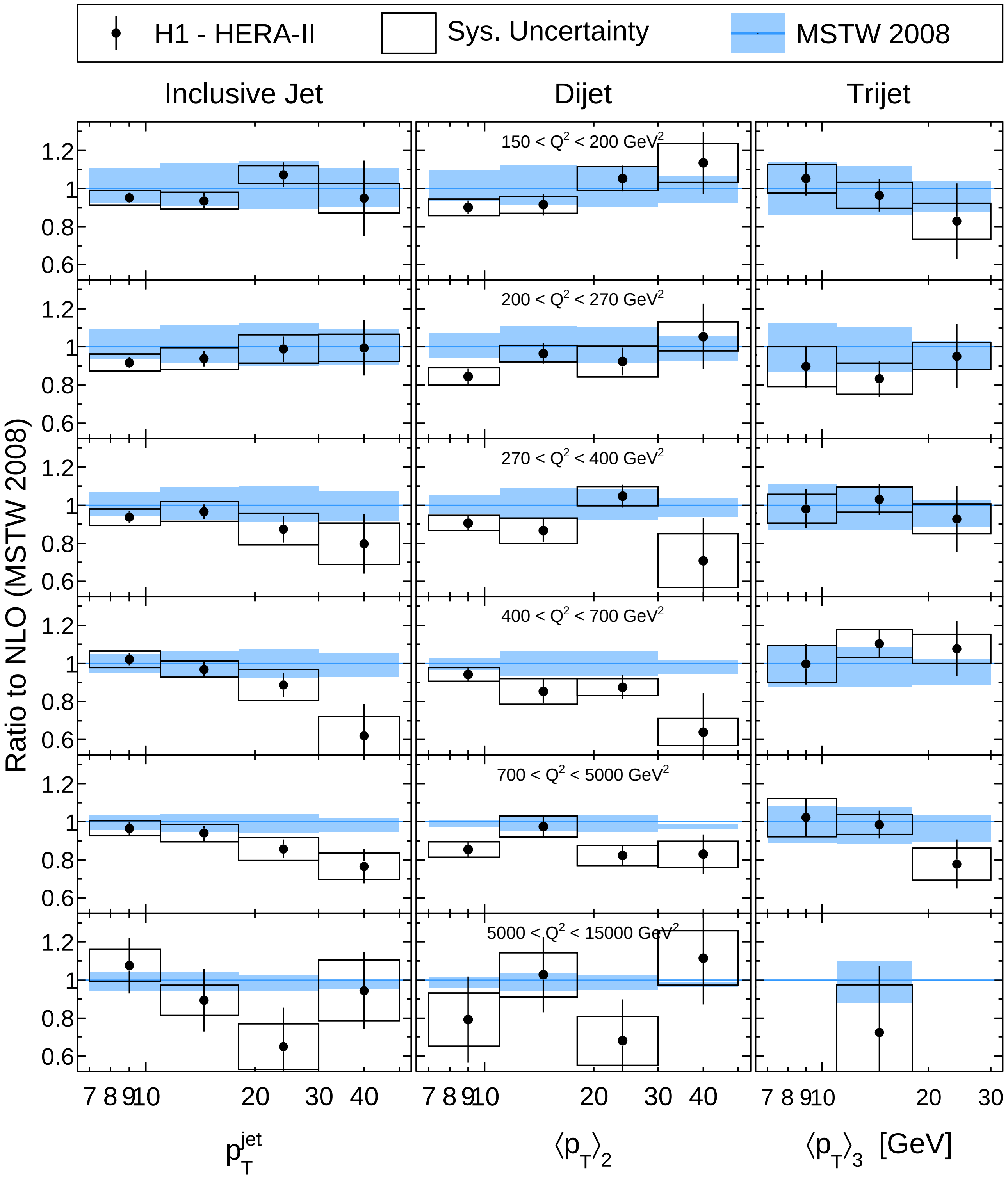
- Therefore today only: ‘almost-almost-closetovery-finalfinal2_4’ cross sections

Hardly any effect on cross sections or uncertainties

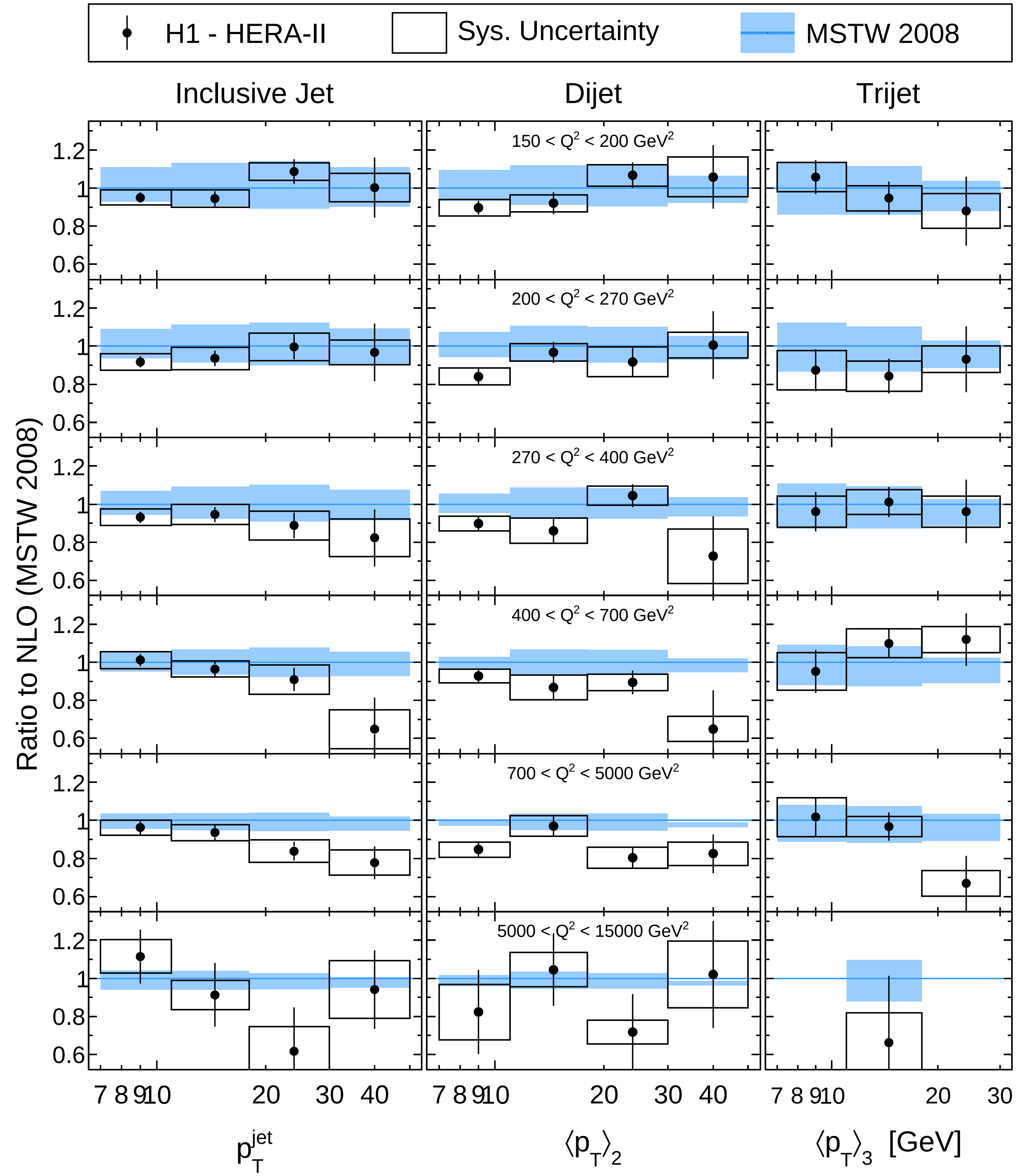


Comparison to old MCs ($\tau=10^{-6}$)

Using 'old MC'



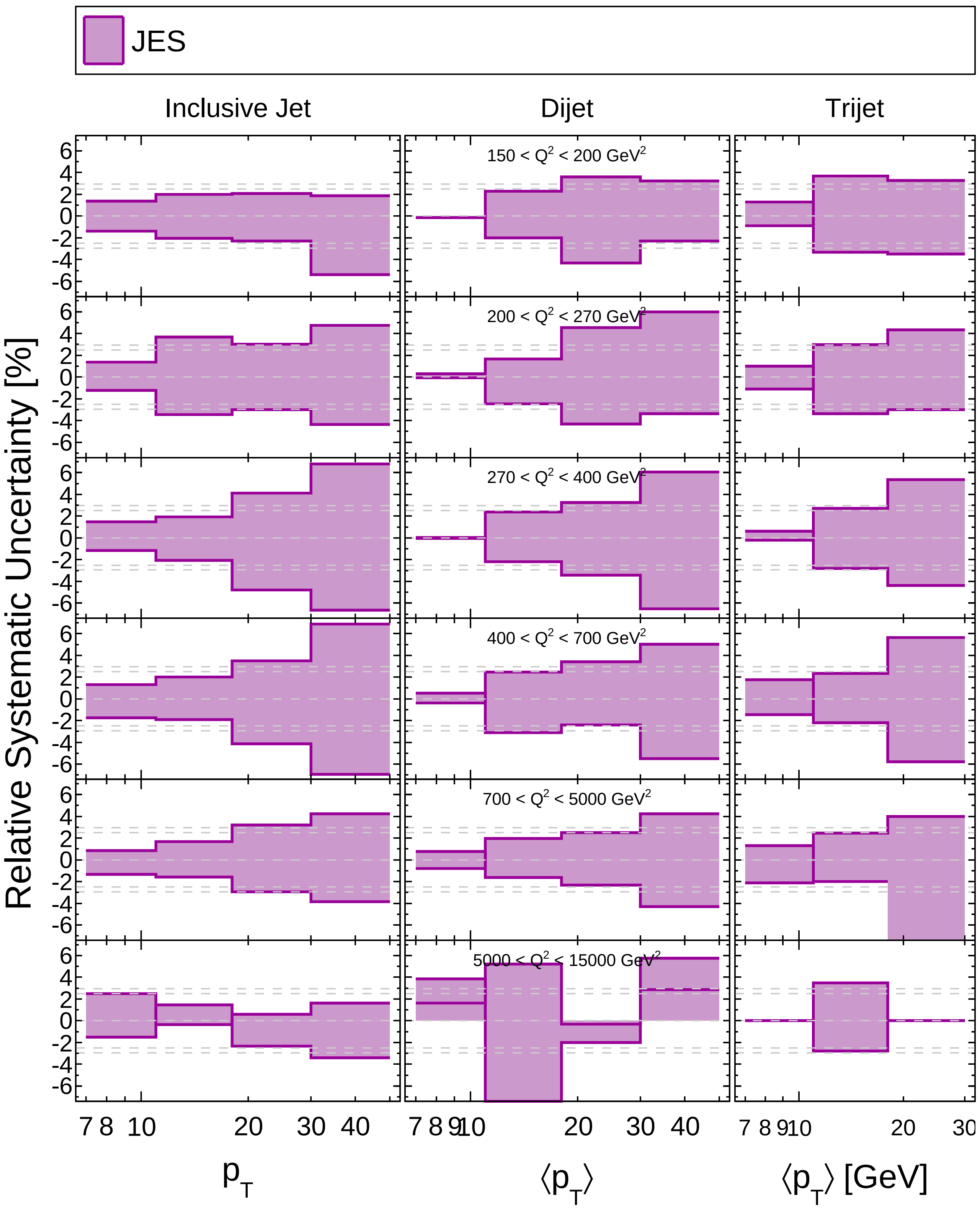
Using 'old+new MC'



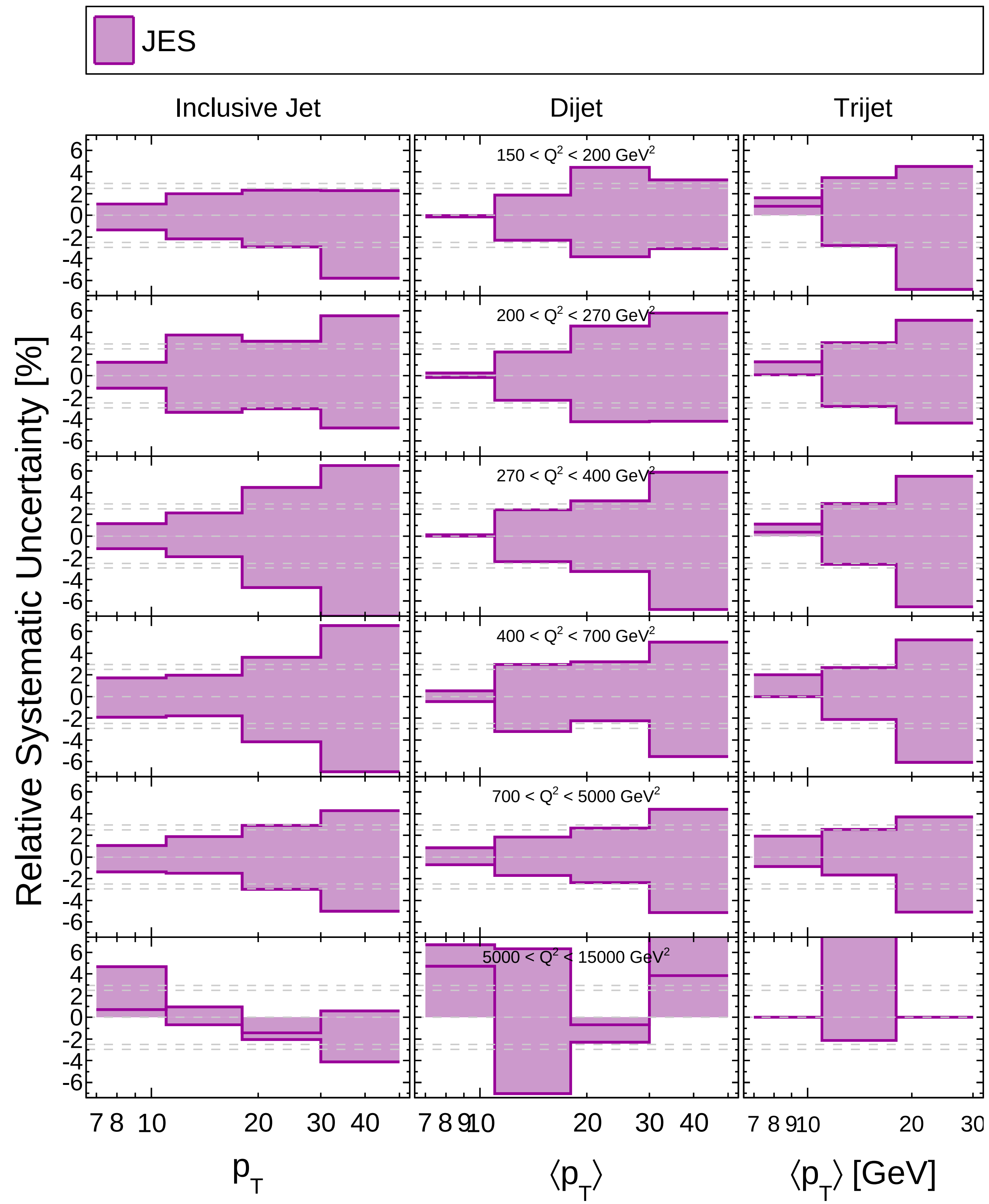
Overall picture does not change

Comparison of uncertainties

Using ‘old MC’

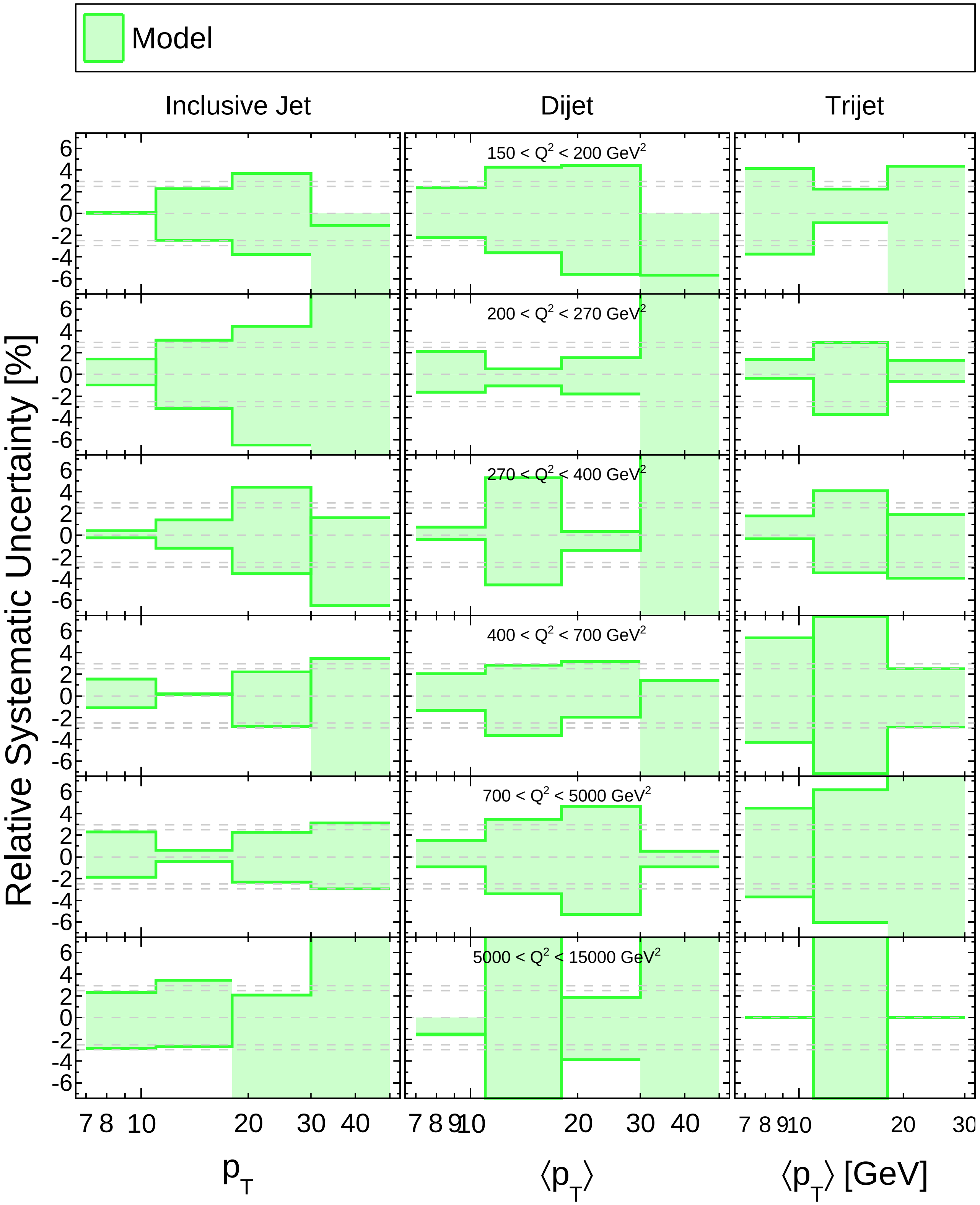


Using ‘old+new MC’

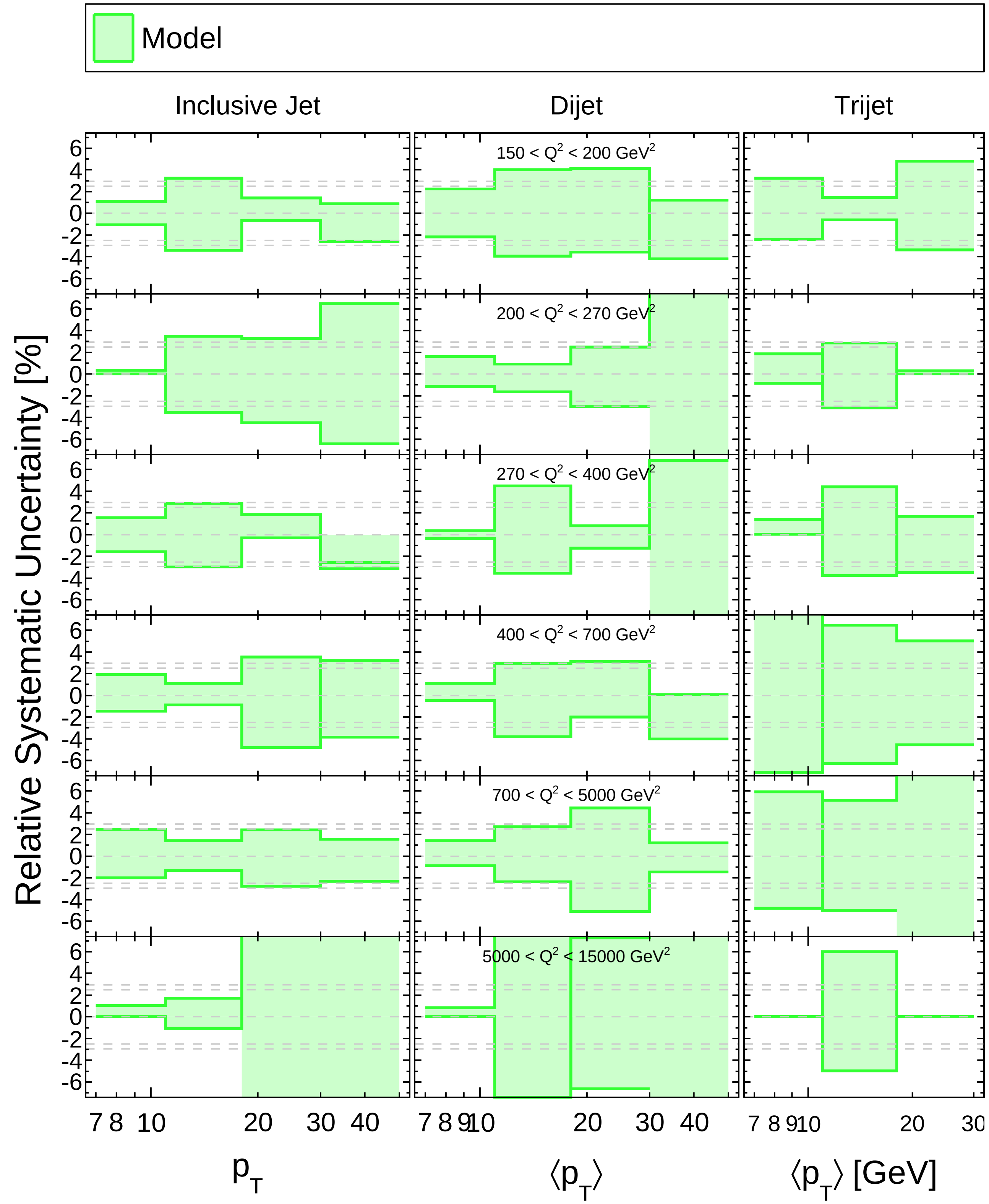


Model uncertainty

Using ‘old MC’



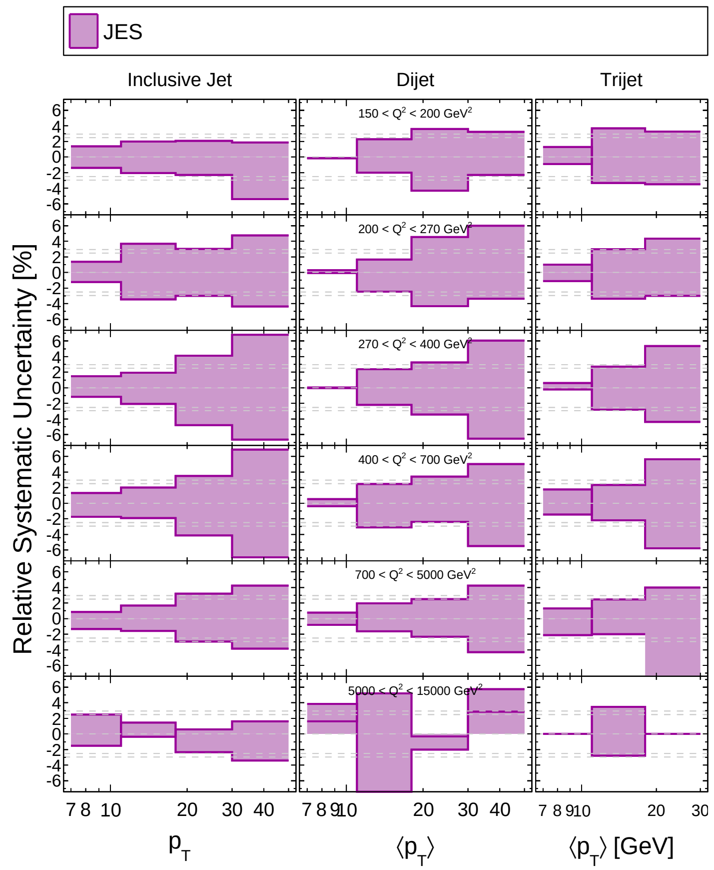
Using ‘old+new MC’



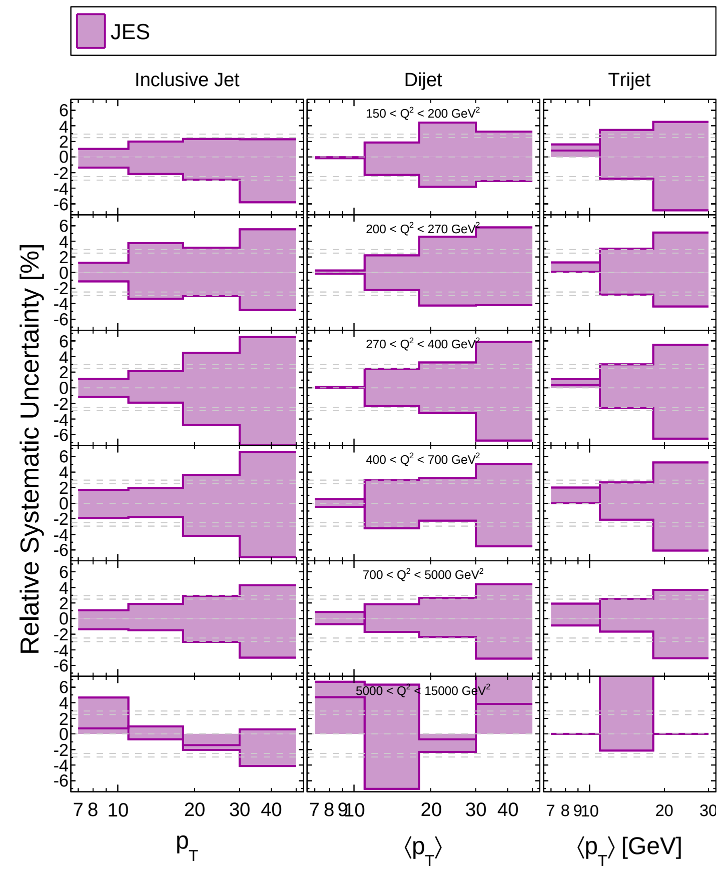
Some bins have quite different model uncertainties, but also large fluctuations/asymmetries

Conclusion on uncertainties

Using ‘old MC’



Using ‘old+new MC’



Results

- Size of systematic uncertainies does not change
- ‘Fluctuations’ are still present
- Quite consistent results (even for some ‘fluctuations’)
- Low-statistics bins (e.g. high-Q^2, high pT bins) have slight changes

Open questions

- Do we trust these uncertainties ?
- What is the potential impact on the fit?

Careful smoothing of uncertainties (by hand!)

Previously used 'smoothing' algorithm

1. Unfold data (with Dj+Rg) $\delta_{Data(Dj+Rg)}$
2. Unfold Django-pseudo-data with Rapgap
   - reduced dependence on limited data statistics
3. Unfold Rapgap-pseudo-data with Django
4. $$\delta\sigma = \frac{\delta\sigma_{Data(Dj+Rg)} + \delta\sigma_{Dj(Rg)} + \delta\sigma_{Rg(Dj)}}{3}$$

Only small effect on 'fluctuations'

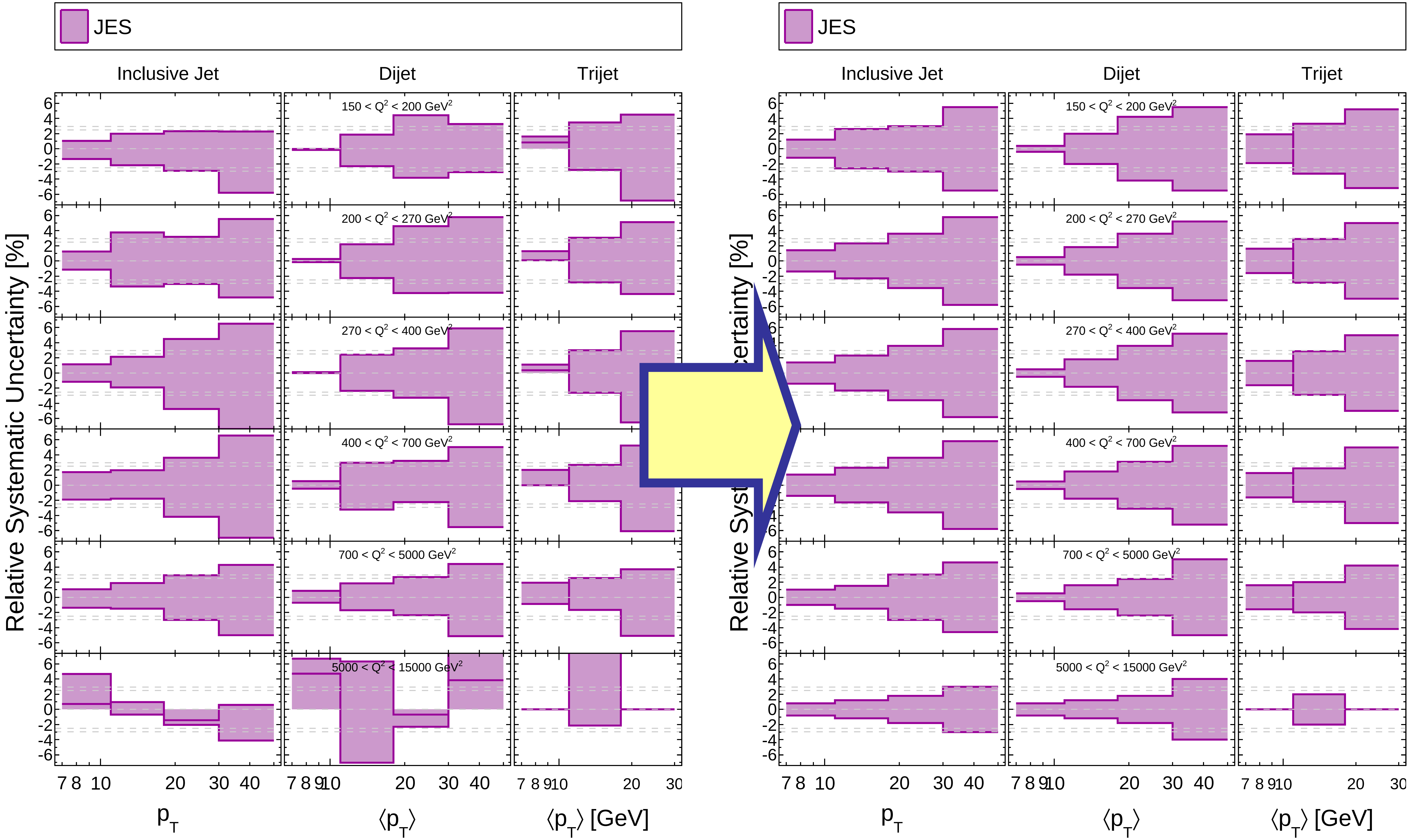
Now:

CAREFUL(!) smoothing of uncertainties by hand

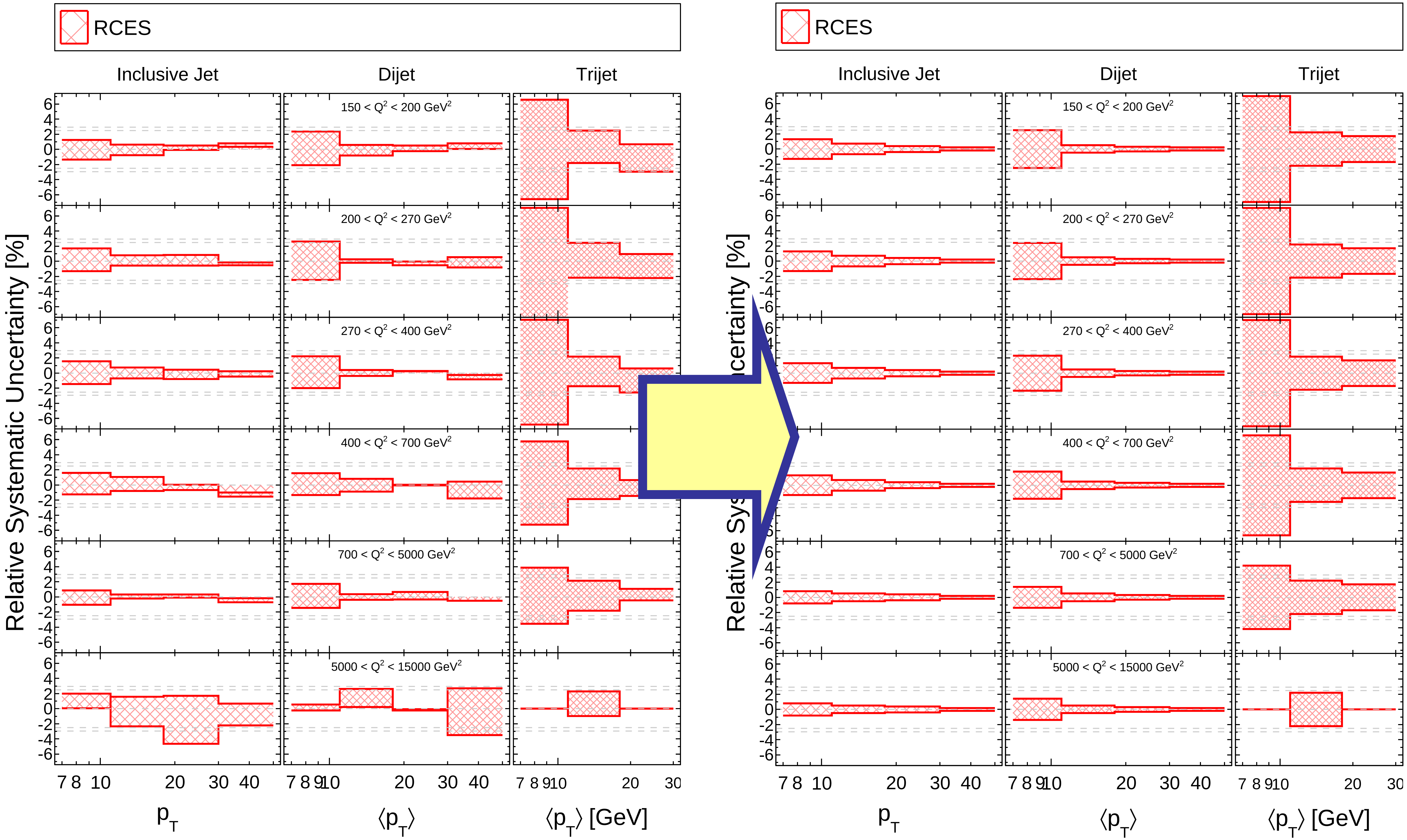
- e.g. average uncertainty in bins of similar phase space
- Consider Q^2 and p_T dependence of uncertainties
  - JES and RCES should have small dependence in Q^2
  - Electron uncertainties should hardly differ between different jet p_T bins
- Consider also uncertaities if bin-by-bin method would be used

2 x 3 macht 4 –
widdewiddewitt und 3 macht 9e !
Ich mach' mir die Fehler –
widdewidde wie sie mir gefallen ...

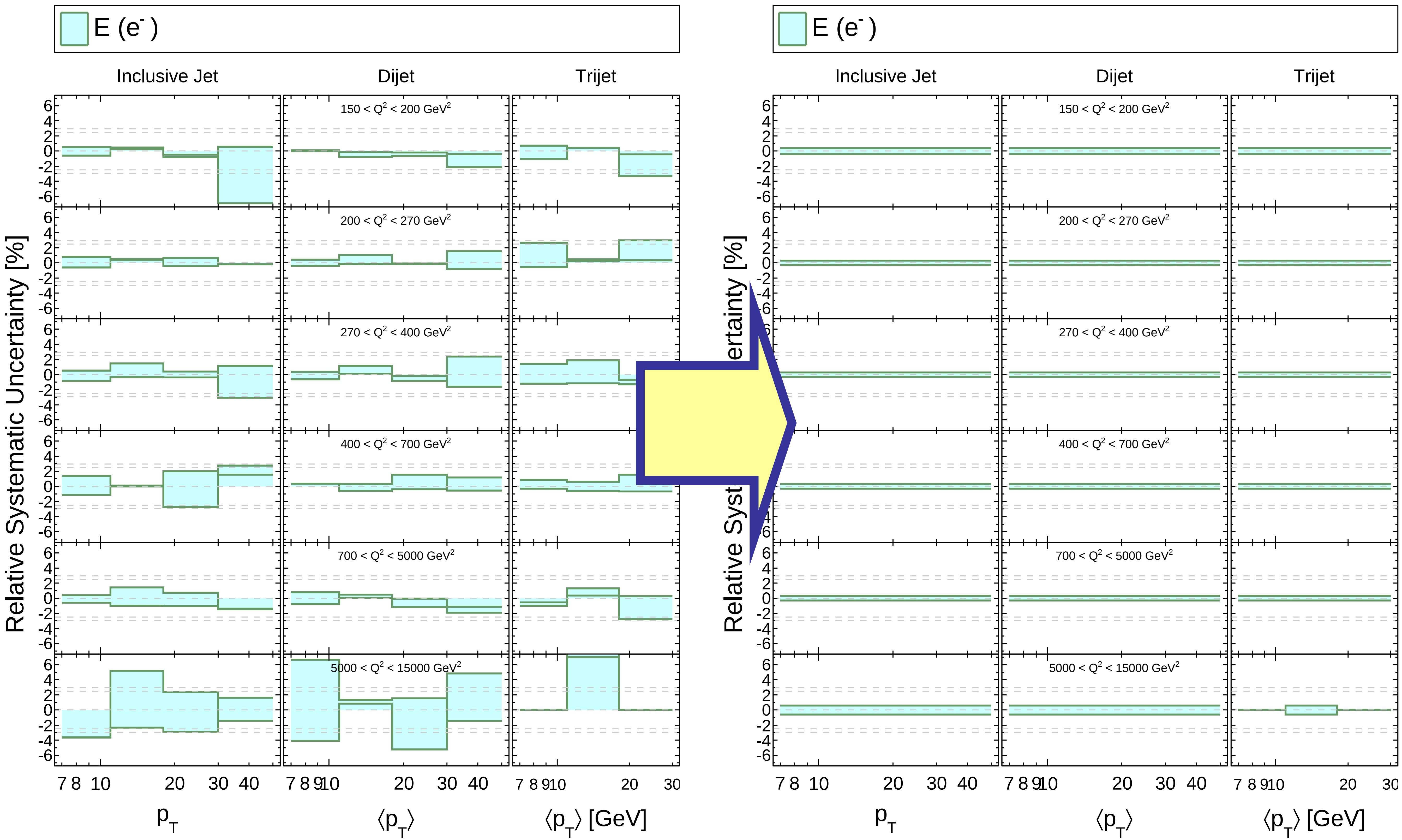
Before and after ‘smoothing’



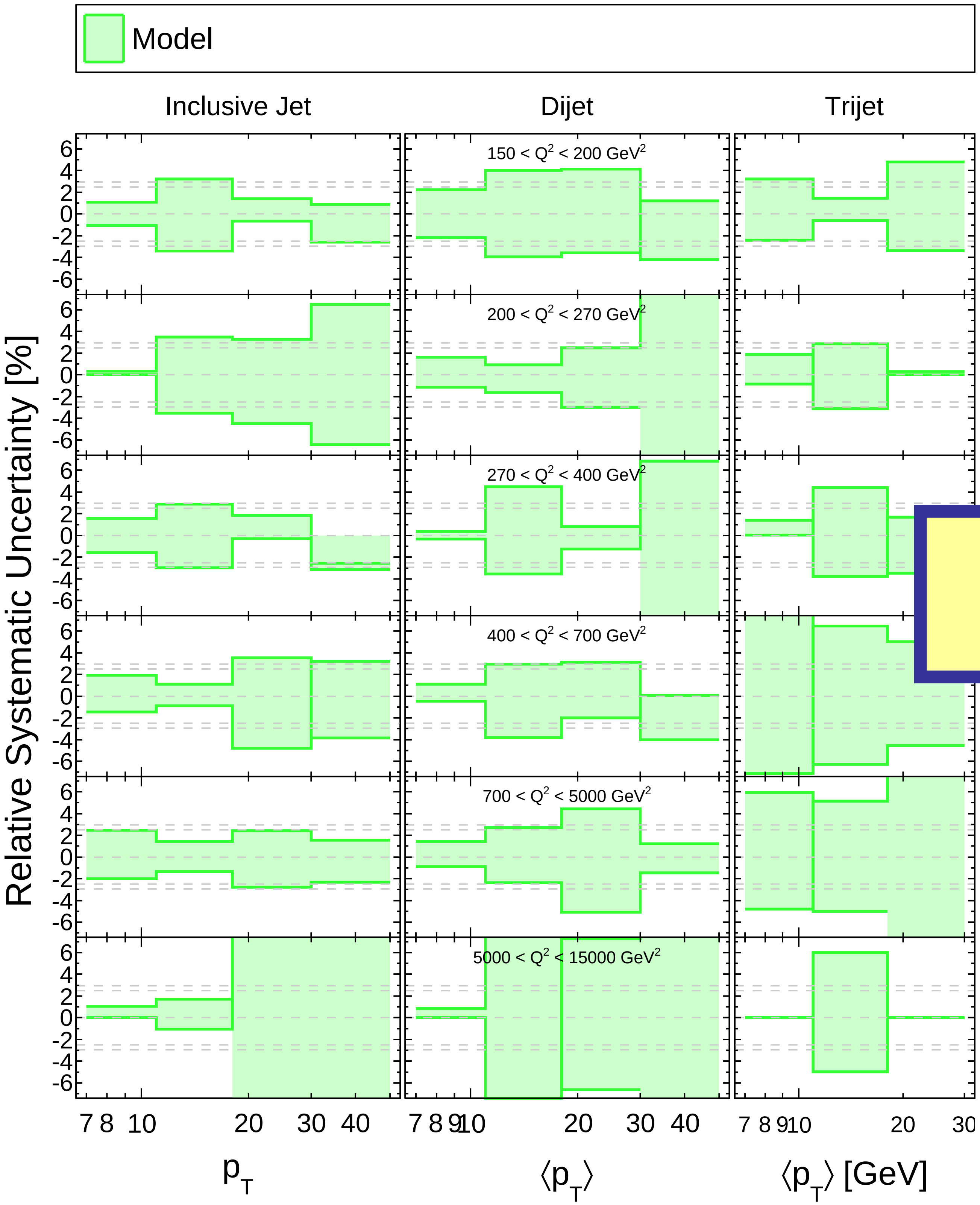
Before and after ‘smoothing’

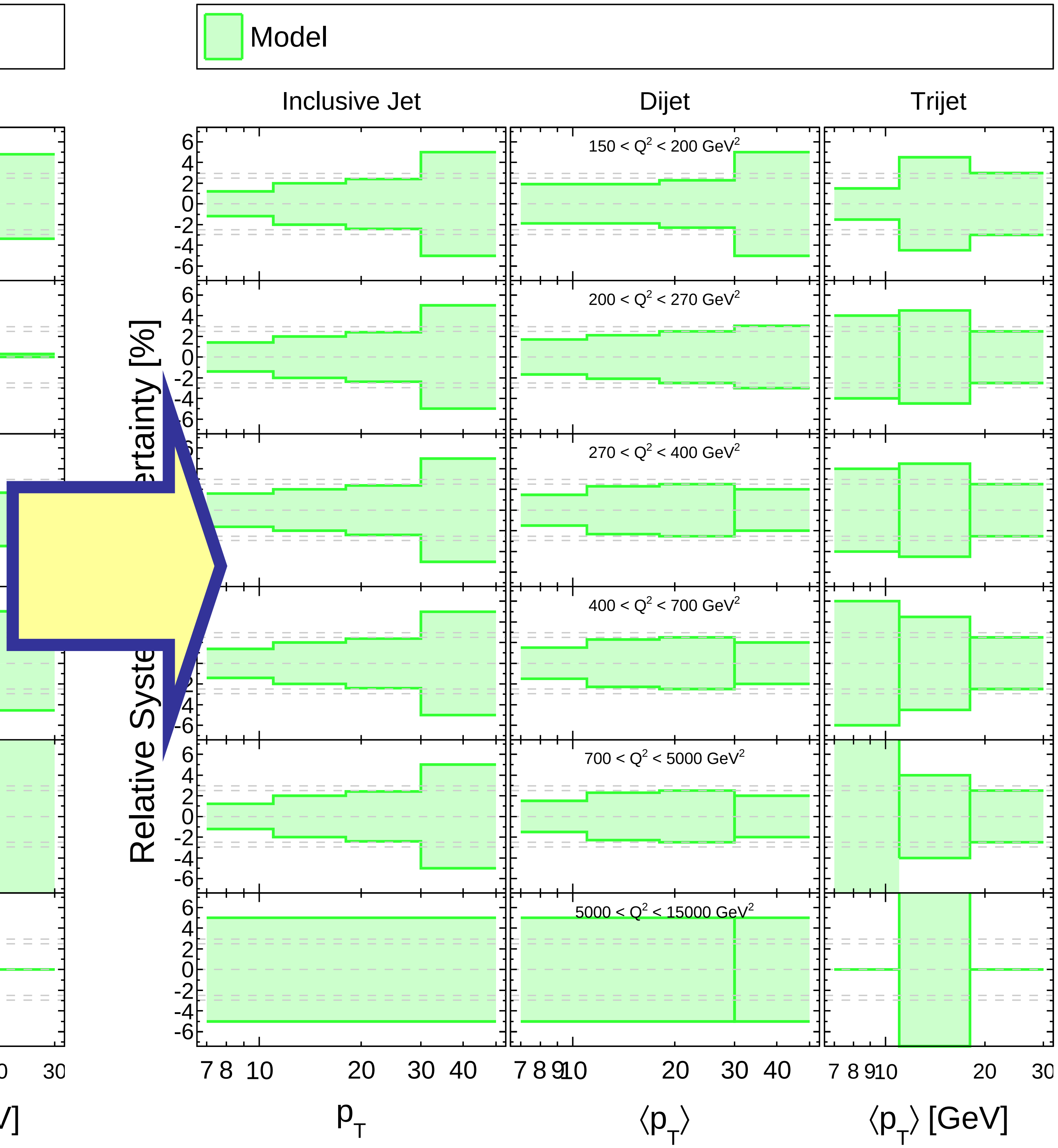


Before and after 'smoothing'



Before and after 'smoothing'





Impact on alpha_s

Unsmoothed data set	Smoothed data set
Inclusive Jet	**Inclusive Jet**
0.1175 +/- 0.0022 (exp) @ chi2/ndf = 1.342	0.1176 +/- 0.0022 (exp) @ chi2/ndf = 1.408
Dijet	**Dijet**
0.1136 +/- 0.0023 (exp) @ chi2/ndf = 1.261	0.1137 +/- 0.0024 (exp) @ chi2/ndf = 1.396
Trijet	**Trijet**
0.1168 +/- 0.0019 (exp) @ chi2/ndf = 1.002	0.1165 +/- 0.0019 (exp) @ chi2/ndf = 1.347
Multijet	**Multijet**
0.1179 +/- 0.0017 (exp) @ chi2/ndf = 1.251	0.1182 +/- 0.0018 (exp) @ chi2/ndf = 1.400
eps(HFS) = 0.202 +/- 0.627	eps(HFS) = 0.326 +/- 0.876
eps(JES) = 0.422 +/- 0.603	eps(JES) = 0.677 +/- 0.739
eps(LArNoise) = 0.292 +/- 0.933	eps(LArNoise) = 0.347 +/- 0.977
eps(Norm) = 1.531 +/- 0.759	eps(Norm) = 1.517 +/- 0.779

- ‘Smoothing’ has no significant influence on fit
- Large nuisance parameters are not caused by ‘fluctuations of system. uncertainties’
- Results change more significantly if uncertainies are treated as ‘fully correlated’ (backup)

Study: Include systematic uncertainties in Unfolding Covariance matrix (based on old MC)

Regularized unfolding using Tunfold

- Find hadron level x by analytic minimization of χ^2

$$\chi^2(x,\tau) = (y - Ax)^T V_y^{-1} (y - Ax) + \tau^2 (x - x_0)^T (L^T L)(x - x_0)$$

- Include Systematic uncertainty in

  V: V-> V_{stat}+V_{sys}

  - Only JES and RCES (the largest systematic uncertainties) (technical limitations)
- Correlated, uncorrelated, 50:50, …

Systematic uncertainty will be included in Covariance matrix of result

Cannot be disentangled from statistical uncertainty

Systematic uncertainties in unfolding

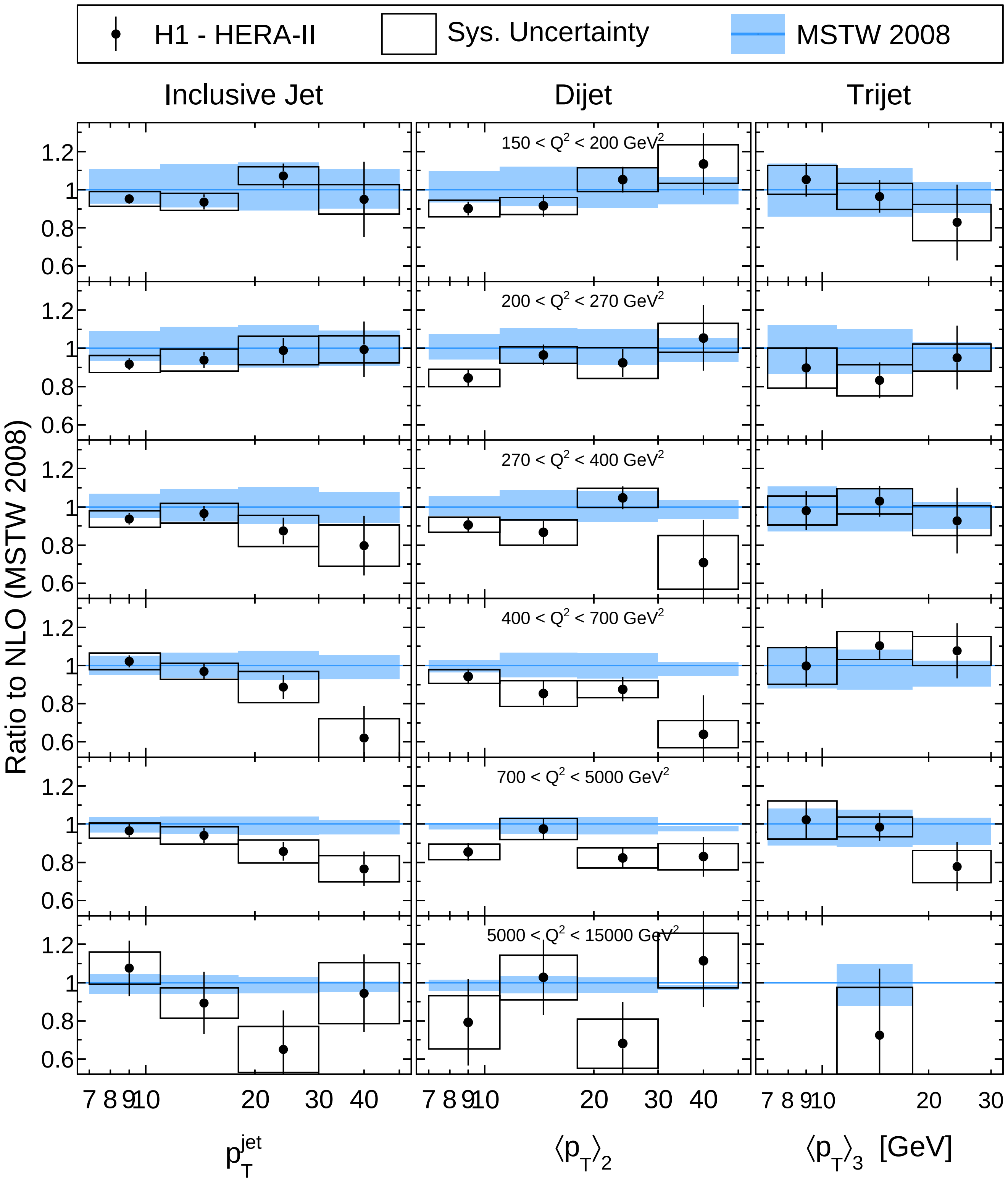
	Referenz	JES and RCES in V	JES and RCES in V	JES and RCES in V
Uncertainty treatment		Correlated	Uncorrelated	half correlated, half uncorrelated
tau	10^{-6}	10^{-6}	10^{-6}	10^{-6}
Chi2a in unfolding	3306.7	3219.8	2685.35	2388.76

Update 11. 09. 13: WARNING !!!
Systematic unceraintny was added twice in unfolding (once for up/down variation)
This gives an increased uncertainty of 1.4142…

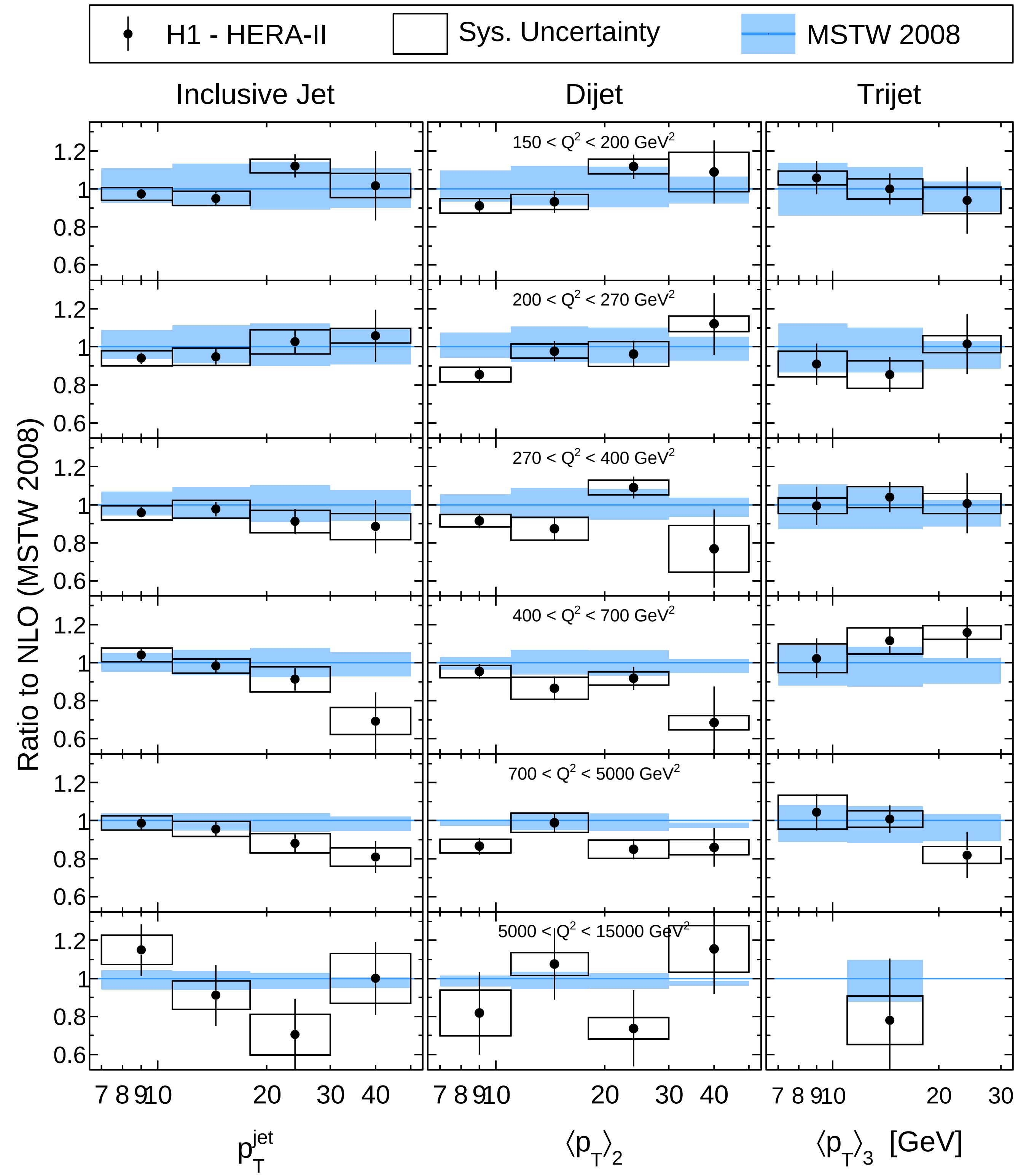
If there is a visible effect, this should be even increased !!!

Systematic uncertainties in unfolding

Reference

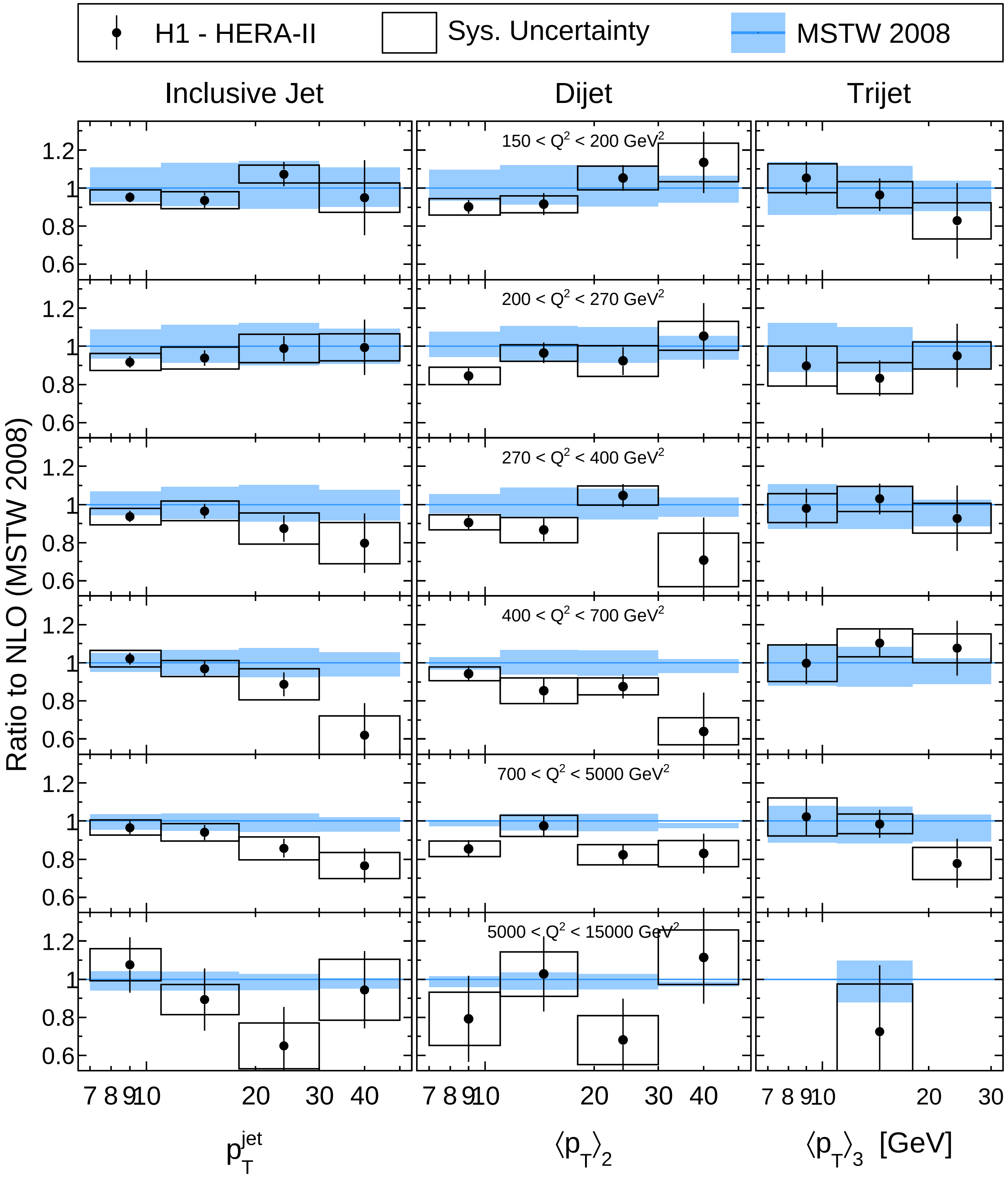


JES and RCES as correlated

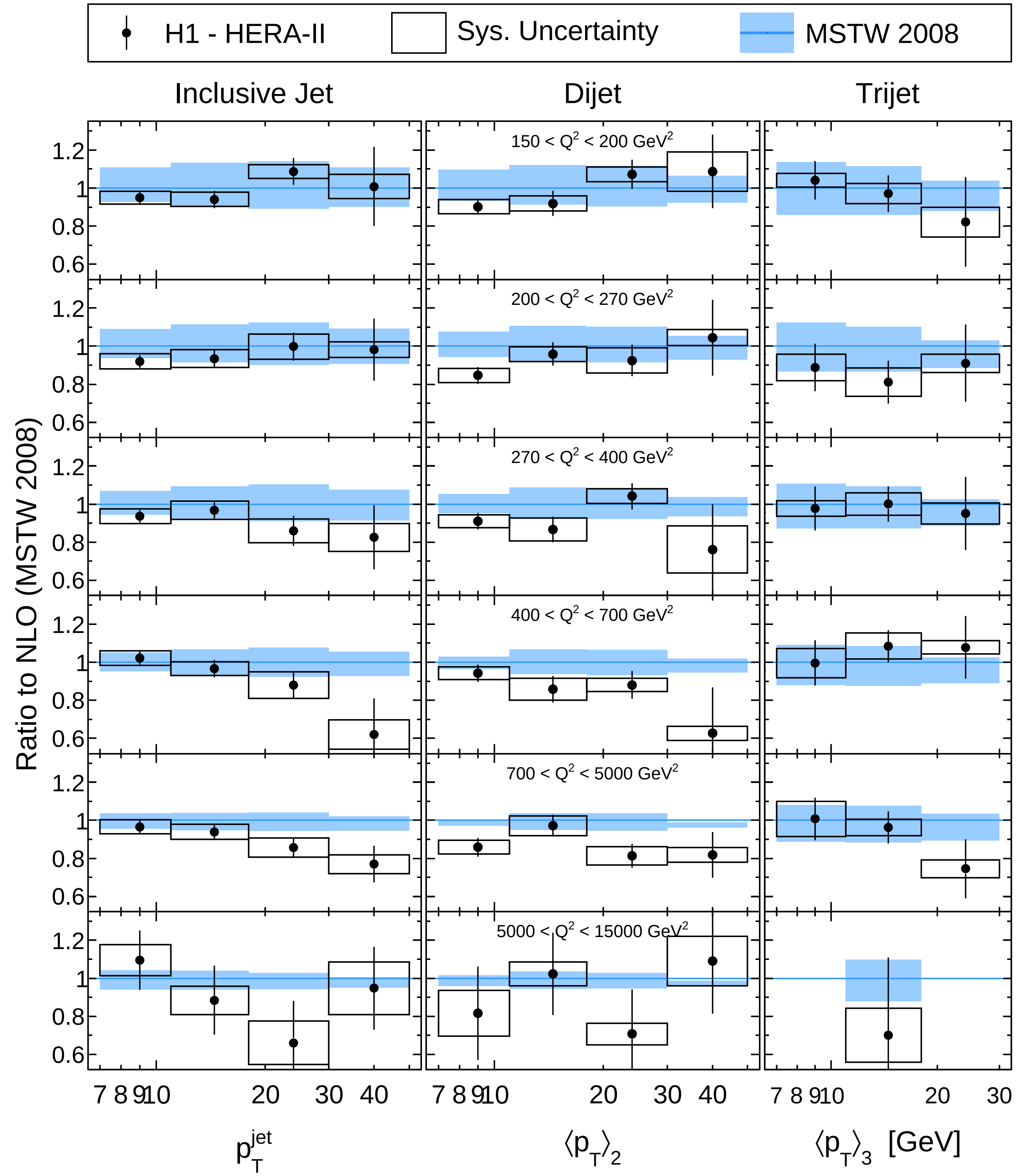


Systematic uncertainties in unfolding

Reference



JES and RCES as uncorrelated



Effect in α_s-fit

	Sys in α_s-fit uncorrelated	Sys in α_s-fit (50:50)	Sys in α_s-fit correlated (rel.)	Sys in α_s-fit correlated (abs.)
Inclusive Jet	0.1168 +/- 0.0021 chi2/ndf = 1.372	0.1176 +/- 0.0022 chi2/ndf = 1.386	0.1180 +/- 0.0022 chi2/ndf = 1.475	0.1178 +/- 0.0023 chi2/ndf = 1.529
Dijet	0.1135 +/- 0.0022 chi2/ndf = 1.260		0.1134 +/- 0.0023 chi2/ndf = 1.500	0.1129 +/- 0.0024 chi2/ndf = 1.462
Trijet	0.1171 +/- 0.0016 chi2/ndf = 0.748	0.1176 +/- 0.0017 chi2/ndf = 0.797	0.1179 +/- 0.0018 chi2/ndf = 0.878	0.1180 +/- 0.0020 chi2/ndf = 0.892
Multijet	0.1181 +/- 0.0016 chi2/ndf = 1.179	0.1184 +/- 0.0017 chi2/ndf = 1.290	0.1186 +/- 0.0017 chi2/ndf = 1.454	0.1177 +/- 0.0019 chi2/ndf = 1.457
Multijet Norm	0.1165 +/- 0.0006 chi2/ndf = 1.519	0.1165 +/- 0.0007 chi2/ndf = 1.614	0.1166 +/- 0.0007 chi2/ndf = 1.738	0.1164 +/- 0.0007 chi2/ndf = 1.731

	Sys in Unfolding V Uncorrelated	Sys in Unfolding V (50:50)	Sys in Unfolding V Correlated
Inclusive Jet	0.1168 +/- 0.0021 chi2/ndf = 1.447	0.1180 +/- 0.0021 chi2/ndf = 1.429	0.1183 +/- 0.0020 chi2/ndf = 1.509
Dijet	0.1137 +/- 0.0022 chi2/ndf = 1.218	0.1148 +/- 0.0022 chi2/ndf = 1.455	0.1151 +/- 0.0022 chi2/ndf = 1.677
Trijet	0.1167 +/- 0.0016 chi2/ndf = 0.860	0.1178 +/- 0.0015 chi2/ndf = 0.870	0.1182 +/- 0.0015 chi2/ndf = 0.878
Multijet	0.1177 +/- 0.0015 chi2/ndf = 1.222	0.1188 +/- 0.0015 chi2/ndf = 1.347	0.1194 +/- 0.0014 chi2/ndf = 1.483
Multijet Norm	0.1164 +/- 0.0006 chi2/ndf = 1.424	0.1175 +/- 0.0006 chi2/ndf = 1.545	0.1179 +/- 0.0006 chi2/ndf = 1.691

For JES/RCES 50:50 was commonly used: No significant difference there
Inclusion of sys. uncertainties in unfolding is an equally valid approach

Summary

Status

- Reason for fluctuations in systematic uncertainty remains unclear
  - It is not MC statistics, not Data statistics …
- Fluctuations of sys. uncertainties do not have bad influence on fit results
  - Some smoothing may be reasonable, but not too much
- Systematic uncertainties can also be included in covariance matrix, which enters unfolding
  - Systematic uncertainties cannot be disentangled after unfolding from statistical uncertainties
  - No visibly preferred effect on cross sections
  - Treatment seems to be equally valid, as using systematic uncertainties in a similar way in α_s-fit
  - Uncertainties on α_s may come out to be slightly smaller

Plans

- As soon as remaining new MCs are sim-rec'd and oo'd,
  data will be unfold'd, cross-section'd and fitt'd
  - Final cross sections
- Final fits are also ahead
- Writing paper
- T0 planned on 17. October (optimistic, but possible)

Correction of detector effects using regularized unfolding

Detector effects

- Acceptance and efficiency
- Migrations due to limited resolution

Aim

- Cross section on hadron level
- Direct matrix inversion of A often not possible

Detector response

$$y = A \cdot x$$

- Measured vector y
- Hadron level vector x
- Detector response matrix A
- Covariance matrix V_y

Regularized unfolding using Tunfold (JINST 7 (2012) T10003)

- Find hadron level x by analytic minimization of χ^2

$$\chi^2(x,\tau) = \underbrace{(y - Ax)^T V_y^{-1} (y - Ax)}_{\text{Matrix inversion: } \chi^2_A} + \underbrace{\tau^2 (x - x_0)^T (L^T L)(x - x_0)}_{\text{Regularization: } \chi^2_L}$$

- Find stationary point ($\partial\chi^2/\partial x = 0$) by solving analytically as function of x
- 'True' hadron level can be determined directly

$$x = (A^T V_y^{-1} A + \tau^2 L^2)^{-1} A^T V_y^{-1} y =: By$$

- τ (and L) are free parameters

Correlation matrix

Covariance matrix

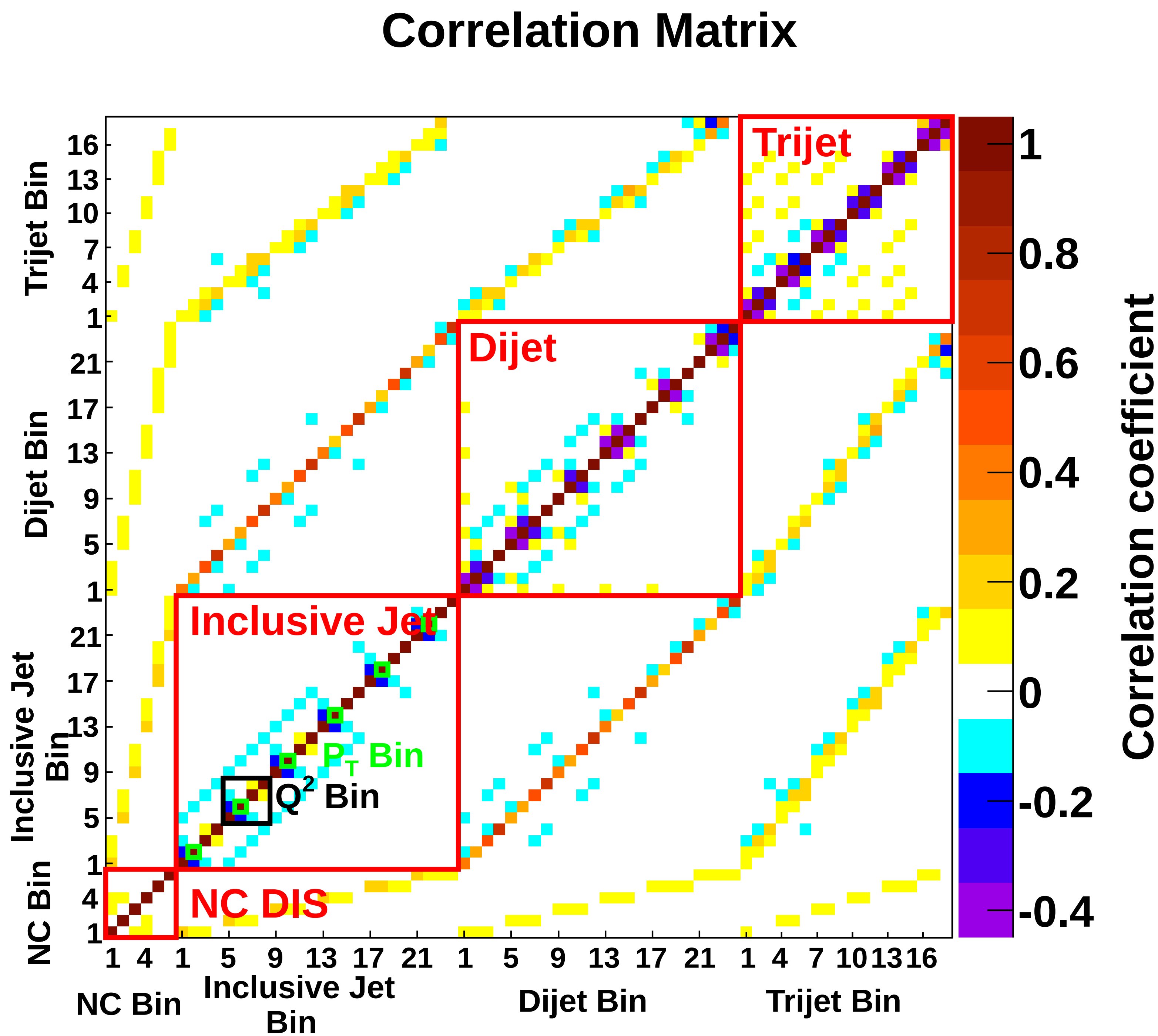
Obtained through linear error propagation of statistical uncertainties

Correlations

- Resulting from unfolding
- Physical correlations
  - Between measurements
  - Within inclusive jet

Useful for

- Cross section ratios
- Combined fits
- Normalized cross sections



Correlation matrix is employed for correct error propagation for norm. cross sections

All sys. uncertainties fully correlated (model 50%:50%)

```
Fit_SysCorrMod05_MC13prel2/log.1.txt:446:xxac  alpha_s   = 0.1181 +/- 0.0022 (exp)  @   chi2/ndf =  1.539
Fit_SysCorrMod05_MC13prel2/log.123.txt:651:xxac  alpha_s   = 0.1189 +/- 0.0017 (exp)  @   chi2/ndf =  1.534
Fit_SysCorrMod05_MC13prel2/log.2.txt:446:xxac  alpha_s   = 0.1146 +/- 0.0024 (exp)  @   chi2/ndf =  1.528
Fit_SysCorrMod05_MC13prel2/log.3.txt:434:xxac  alpha_s   = 0.1174 +/- 0.0022 (exp)  @   chi2/ndf =  1.275

Fit_SysCorrMod05_MC13prel2/log.123.txt:638:xxe---------------------------------------------------------------
Fit_SysCorrMod05_MC13prel2/log.123.txt:639:xxe  eps(HFS)  =     0.230   +/- 0.537       Corr to as: 0.515
Fit_SysCorrMod05_MC13prel2/log.123.txt:640:xxe  eps(JES)  =     0.387   +/- 0.456       Corr to as: 0.264
Fit_SysCorrMod05_MC13prel2/log.123.txt:641:xxe  eps(LArNoise) =         0.534   +/- 0.992       Corr to as: 0.172
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Fit_SysCorrMod05_MC13prel2/log.123.txt:643:xxe  eps(The)  =     0.228   +/- 0.940       Corr to as: -0.106
Fit_SysCorrMod05_MC13prel2/log.123.txt:644:xxe  eps(IDe)  =     1.375   +/- 0.891       Corr to as: 0.020
Fit_SysCorrMod05_MC13prel2/log.123.txt:645:xxe  eps(Norm) =     1.790   +/- 0.735       Corr to as: 0.755
Fit_SysCorrMod05_MC13prel2/log.123.txt:648:xxe  eps(Model) =    -0.027  +/- 0.421       Corr to as: 0.116


Fit_SysCorrMod05_MC13prel2SmoothHand/log.1.txt:446:xxac  alpha_s   = 0.1191 +/- 0.0023 (exp)  @   chi2/ndf =  1.531
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:651:xxac  alpha_s   = 0.1201 +/- 0.0019 (exp)  @   chi2/ndf =  1.653
Fit_SysCorrMod05_MC13prel2SmoothHand/log.2.txt:446:xxac  alpha_s   = 0.1149 +/- 0.0026 (exp)  @   chi2/ndf =  1.672
Fit_SysCorrMod05_MC13prel2SmoothHand/log.3.txt:434:xxac  alpha_s   = 0.1166 +/- 0.0021 (exp)  @   chi2/ndf =  1.496

Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:638:xxe---------------------------------------------------------------
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Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:640:xxe  eps(JES)  =   0.587   +/- 0.627       Corr to as: 0.383
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:641:xxe  eps(LArNoise) =       0.622   +/- 0.991       Corr to as: 0.142
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:642:xxe  eps(Ee)   =   0.136   +/- 0.996       Corr to as: 0.061
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:643:xxe  eps(The)  =   0.182   +/- 0.991       Corr to as: 0.089
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:644:xxe  eps(IDe)  =   1.292   +/- 0.901       Corr to as: 0.010
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:645:xxe  eps(Norm) =   1.595   +/- 0.773       Corr to as: 0.666
Fit_SysCorrMod05_MC13prel2SmoothHand/log.123.txt:648:xxe  eps(Model) =  0.642   +/- 0.543       Corr to as: 0.041
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