The ratio of the inclusive 3-jet cross section to the inclusive 2-jet cross section at $\sqrt{S} = 7$ TeV.

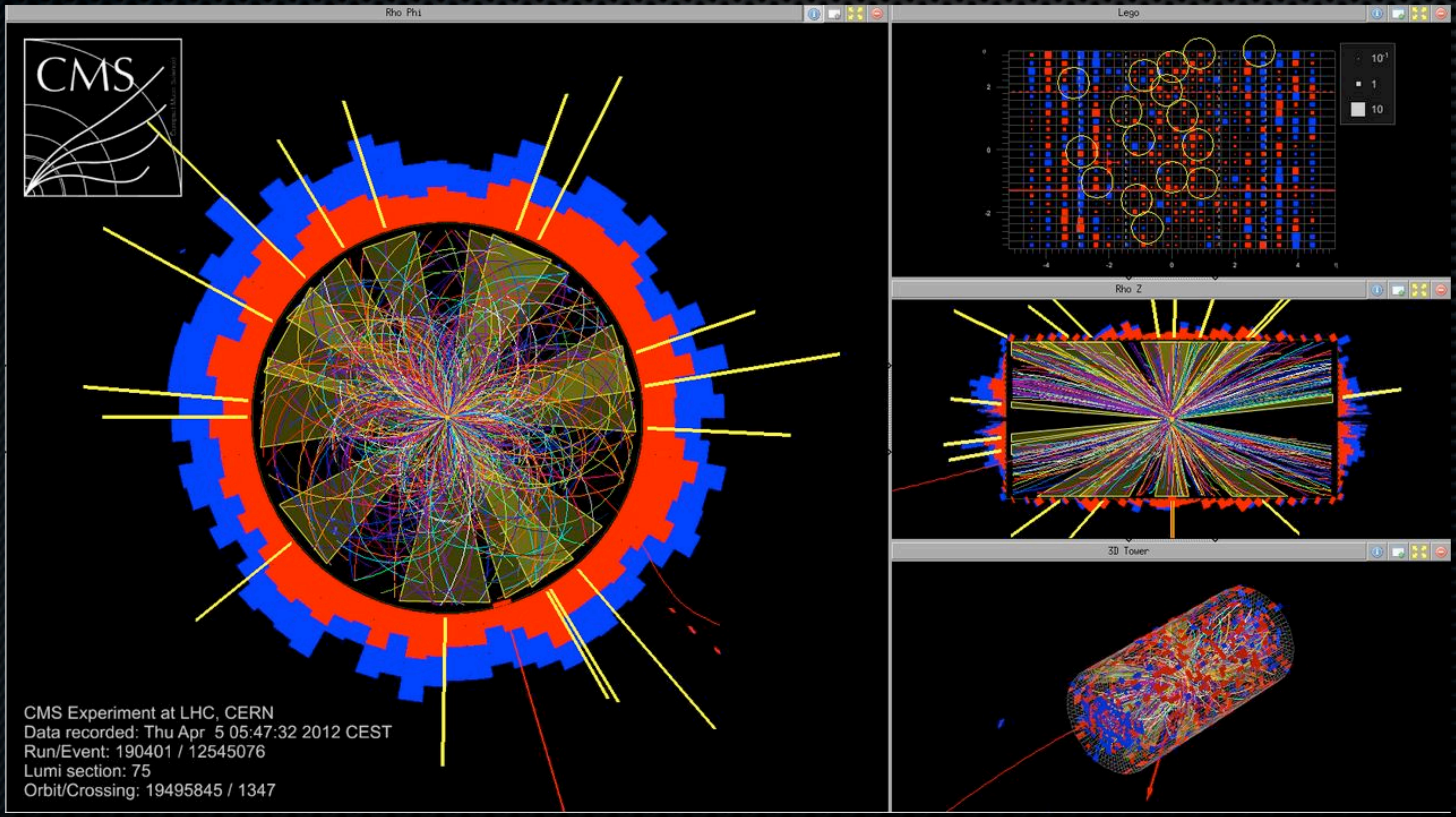
Nathaniel Davies
Adele D’Onofrio

GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN

CMS

The compact muon solenoid

$$\begin{cases} \int L dt = 5.0\, fb^{-1} \\ < p_{T1,2} > \in [0.42, 1.39]\; TeV \\ \alpha_s(M_Z) = 0.1148 \pm 0.0014(exp) \pm 0.0018(PDF)^{+0.0050}_{-0.0000}(scale) \end{cases}$$

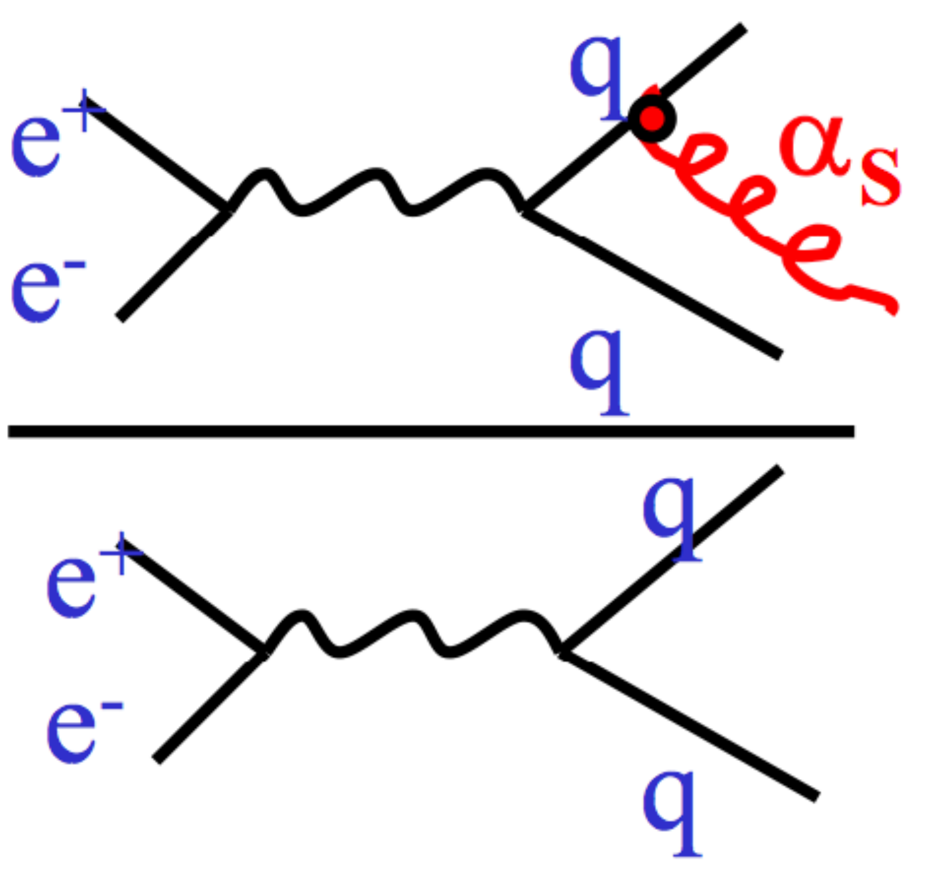


CMS Experiment at LHC, CERN
Data recorded: Thu Apr 5 05:47:32 2012 CEST
Run/Event: 190401 / 12545076
Lumi section: 75
Orbit/Crossing: 19495845 / 1347

Why is this measurement interesting?

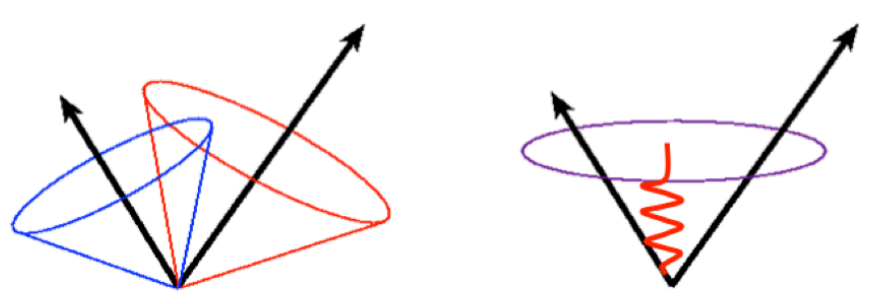
- It is a test of a property of *QCD* referred to asymptotic freedom: the ratio R_{32} is proportional to the strong coupling constant;
- The ratio is independent on luminosity;

$$\mathrm{R}_{32} = \frac{\sigma(q\bar{q}\rightarrow 2jets)}{\sigma(q\bar{q}\rightarrow 3jets)}$$



Jet reconstruction

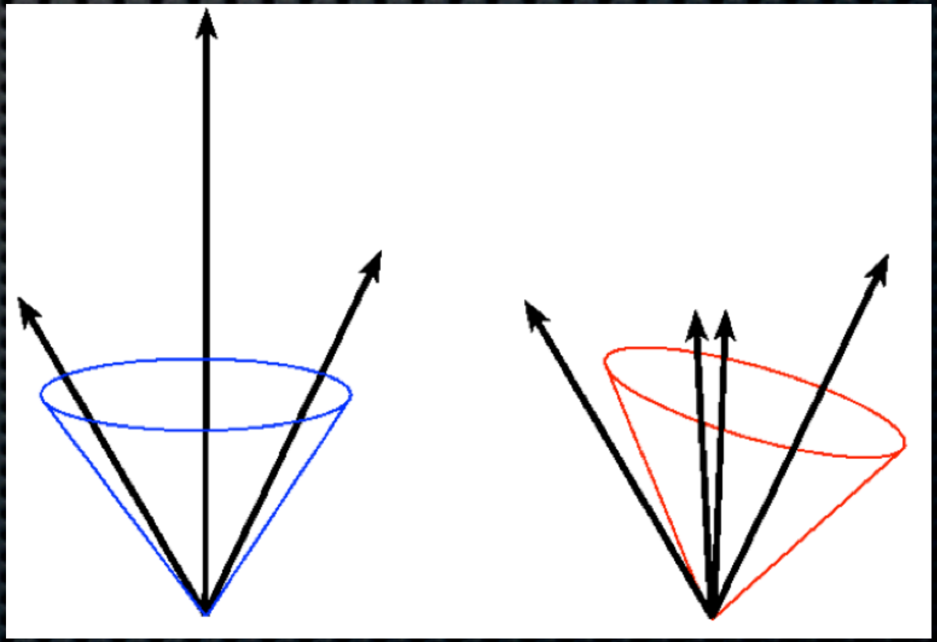
Infrared and collinear safe anti-Kt clustering algorithm with a size parameter of 0.7;



$$y = \frac{1}{2}\log\frac{(E+p_z)}{(E-p_z)}$$

$$p_T = \sqrt{(p_x^2 + p_y^2)}$$

$$p_T > 150\ GeV \qquad |y| < 2.5$$

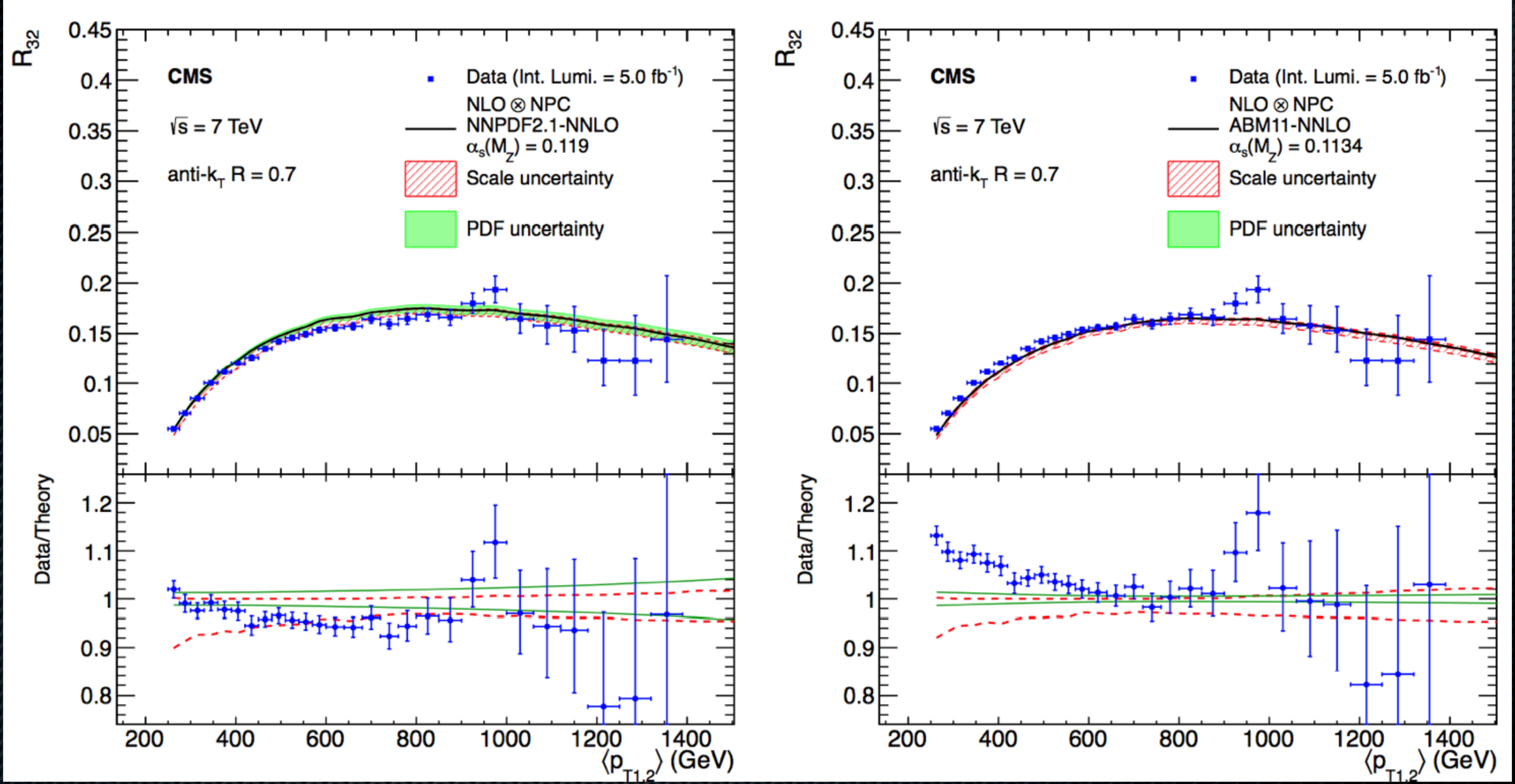


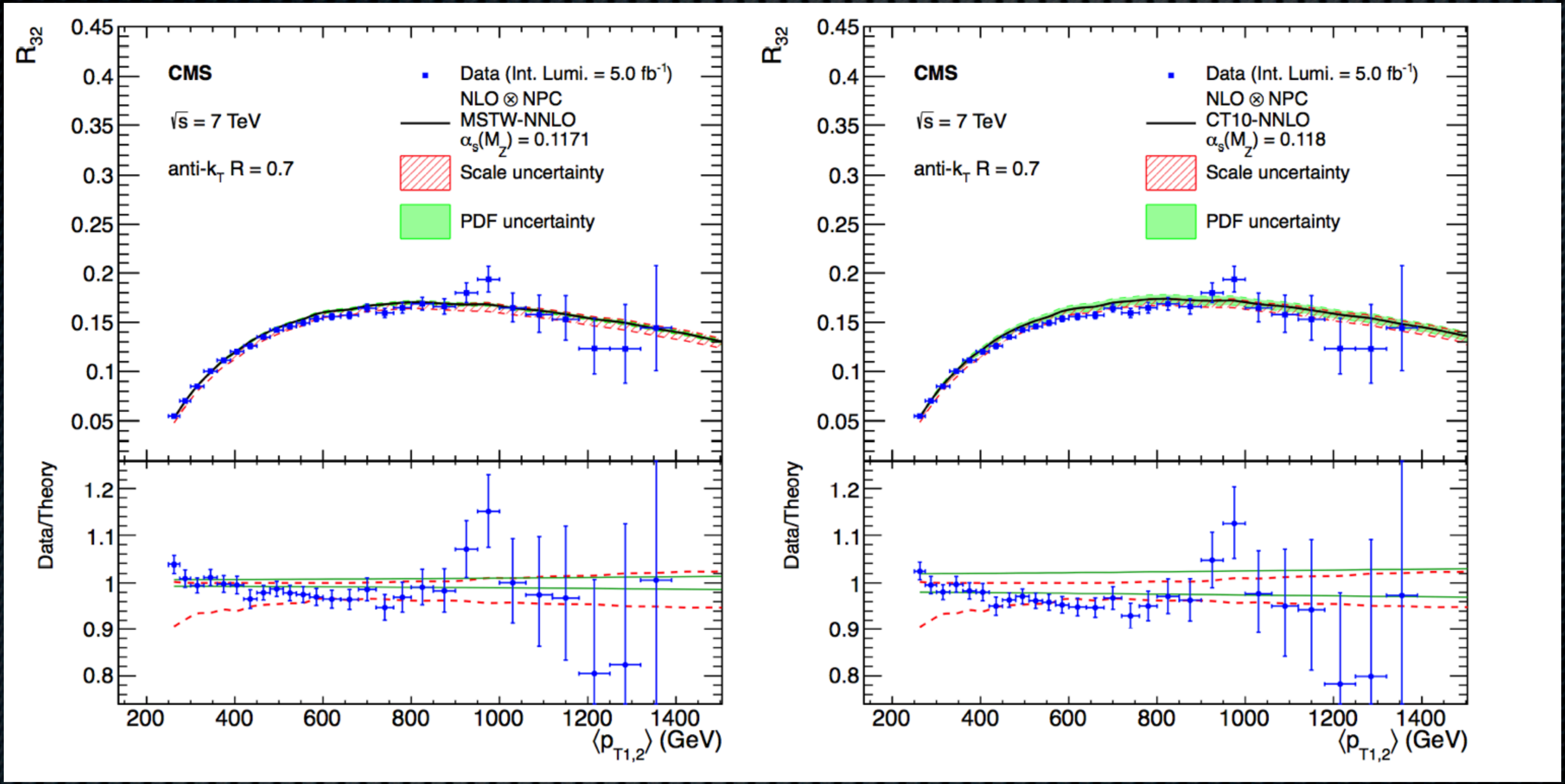
Calorimeters *vs* tracks

- ECAL;
- HCAL;
- identification criteria give us 99% efficiency in identifying genuine jets;
- Jet energy corrections are derived using simulated events;
- pile-up becomes negligible for jets with $p_T > 200GeV$.

Measurement of systematic uncertainties

- unfolding less than 1%;
- detector smearing;
- JES: 1.2%;


R$_{32}$
CMS
$\sqrt{s}$ = 7 TeV
anti-k$_T$ R = 0.7
Data (Int. Lumi. = 5.0 fb^{-1})
NLO ⊗ NPC
NNPDF2.1-NNLO
$\alpha_s(M_Z)$ = 0.119
Scale uncertainty
PDF uncertainty
Data/Theory
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
1.2
1.1
1
0.9
0.8
200
400
600
800
1000
1200
1400
⟨p$_{T1,2}$⟩ (GeV)
R$_{32}$
CMS
$\sqrt{s}$ = 7 TeV
anti-k$_T$ R = 0.7
Data (Int. Lumi. = 5.0 fb^{-1})
NLO ⊗ NPC
ABM11-NNLO
$\alpha_s(M_Z)$ = 0.1134
Scale uncertainty
PDF uncertainty
Data/Theory
⟨p$_{T1,2}$⟩ (GeV)


R_{32}
CMS
$\sqrt{s}$ = 7 TeV
anti-k_T R = 0.7
Data (Int. Lumi. = 5.0 fb^{-1})
NLO ⊗ NPC
MSTW-NNLO
$\alpha_s(M_Z)$ = 0.1171
Scale uncertainty
PDF uncertainty
Data/Theory
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
1.2
1.1
1
0.9
0.8
200
400
600
800
1000
1200
1400
$\langle p_{T1,2} \rangle$ (GeV)
R_{32}
CMS
$\sqrt{s}$ = 7 TeV
anti-k_T R = 0.7
Data (Int. Lumi. = 5.0 fb^{-1})
NLO ⊗ NPC
CT10-NNLO
$\alpha_s(M_Z)$ = 0.118
Scale uncertainty
PDF uncertainty
Data/Theory
$\langle p_{T1,2} \rangle$ (GeV)

Using the *NNPDF2.1 PDF* set, we can propagate uncertainties of PDF to the fits for each value of $\alpha_s(M_z)$

The result of a fit to the region of 420-1390 GeV is $\alpha_s(M_z) = 0.1148 \pm 0.0014(exp)$.

$$\chi^2/N_{dof} = \frac{22.0}{20}$$

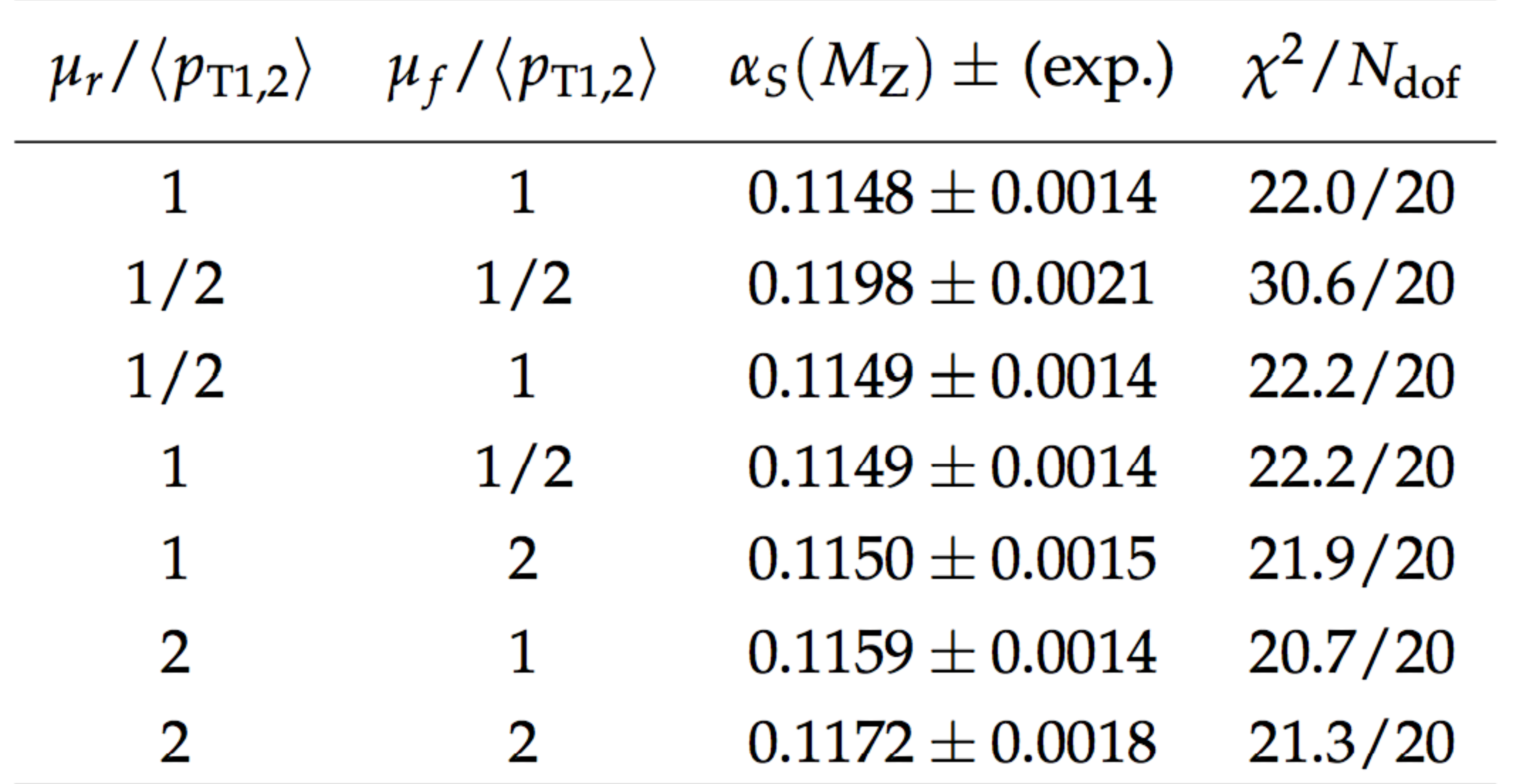
Theoretical uncertainies

- R_{32} is based on the next-to-leading-order perturbative QCD multiplied by a non perturbative factor;
- four different parton distribution function sets/ independent analysis;
- Non perturbative uncertainties: hadronization and multiparticle interactions -> 0.1% ;

Theoretical errors

- Contribution of PDFs to uncertainties: 100 replicas on NNPDF2.1;
- renormalization and factorization scales: they vary the default choice of $\mu_r = \mu_f =< p_{T1,2} >$ between $\frac{<p_{T1,2}>}{2}$ and $2 < p_{T1,2} >$ in six combinations;

Table 2: μ_r and μ_f



$\mu_r / \langle p_{\mathrm{T1,2}} \rangle$	$\mu_f / \langle p_{\mathrm{T1,2}} \rangle$	$\alpha_S(M_Z) \pm$ (exp.)	$\chi^2 / N_{\mathrm{dof}}$
1	1	0.1148 ± 0.0014	22.0/20
1/2	1/2	0.1198 ± 0.0021	30.6/20
1/2	1	0.1149 ± 0.0014	22.2/20
1	1/2	0.1149 ± 0.0014	22.2/20
1	2	0.1150 ± 0.0015	21.9/20
2	1	0.1159 ± 0.0014	20.7/20
2	2	0.1172 ± 0.0018	21.3/20

$$\boxed{\alpha_s(M_Z) = 0.1148 \pm 0.0014(exp) \pm 0.0018(PDF)^{+0.0050}_{-0.0000}(scale)}$$

The world average value is:

$$\alpha_s(M_Z) = 0.1184 \pm 0.0007$$

and it is also in agreement with the Tevatron and LHC results.

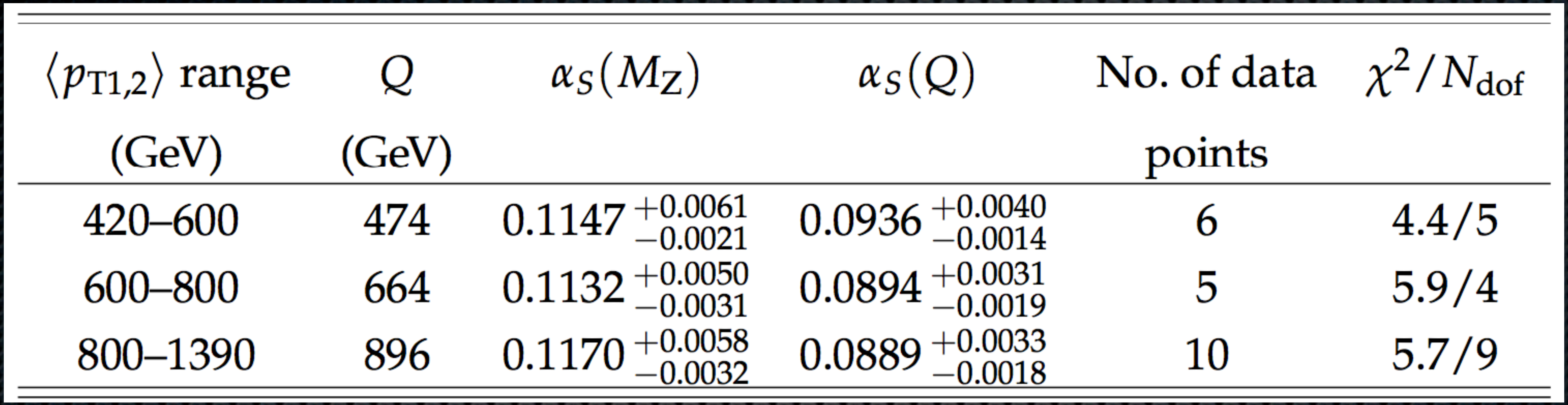
$$\alpha_s(M_Z) = 0.1148 \pm 0.0014(exp) \pm 0.0018(PDF)^{+0.0050}_{-0.0000}(scale)$$

$$\begin{cases} \text{MSTW2008: } \alpha_s(M_Z) = 0.1141 \pm 0.0022(exp) \\ \text{CT10: } \alpha_s(M_Z) = 0.1135 \pm 0.0019(exp) \end{cases}$$

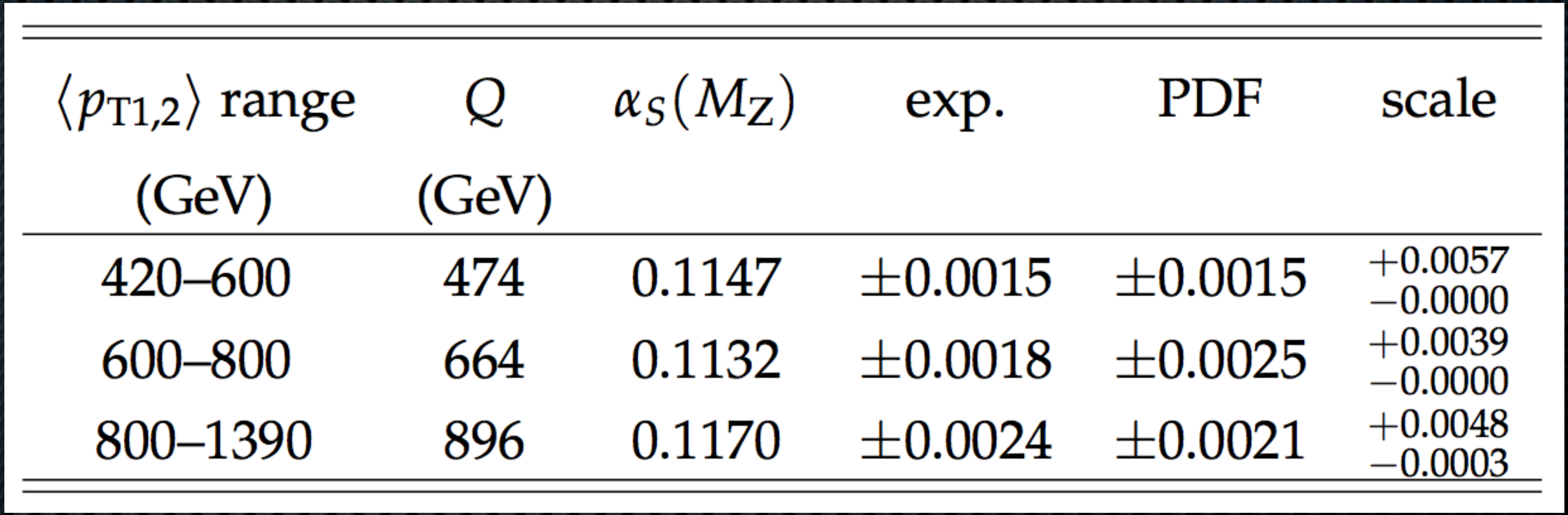
Roughly independent on NNLO or NLO

The ABM11 PDF set does not describe the data as well as the alternative PDF set

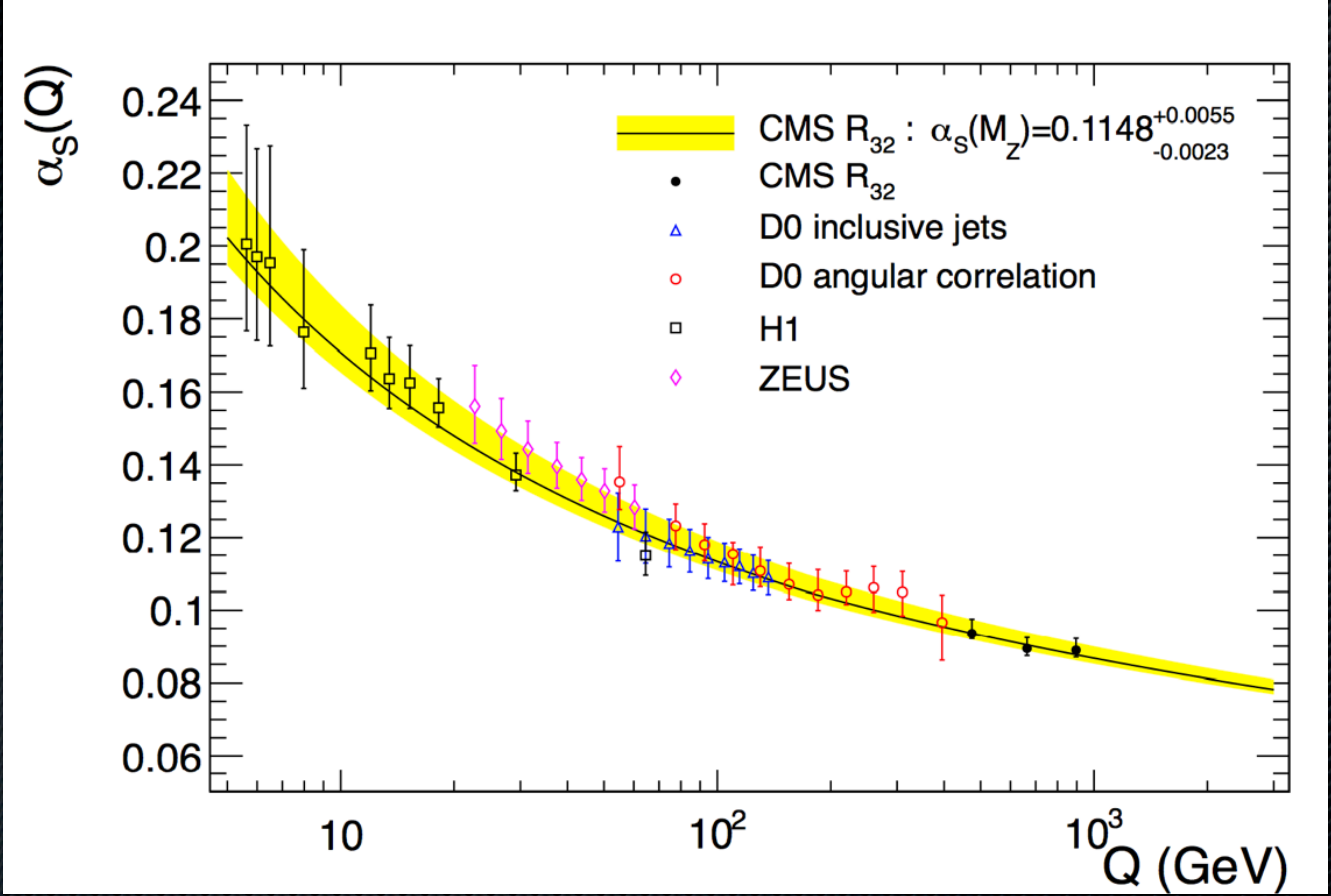
Table 3-4: three bins of momentum



$\langle p_{T1,2} \rangle$ range (GeV)	Q (GeV)	$\alpha_S(M_Z)$	$\alpha_S(Q)$	No. of data points	χ^2/N_{dof}
420–600	474	$0.1147^{+0.0061}_{-0.0021}$	$0.0936^{+0.0040}_{-0.0014}$	6	4.4/5
600–800	664	$0.1132^{+0.0050}_{-0.0031}$	$0.0894^{+0.0031}_{-0.0019}$	5	5.9/4
800–1390	896	$0.1170^{+0.0058}_{-0.0032}$	$0.0889^{+0.0033}_{-0.0018}$	10	5.7/9



$\langle p_{T1,2} \rangle$ range (GeV)	Q (GeV)	$\alpha_S(M_Z)$	exp.	PDF	scale
420–600	474	0.1147	±0.0015	±0.0015	$^{+0.0057}_{-0.0000}$
600–800	664	0.1132	±0.0018	±0.0025	$^{+0.0039}_{-0.0000}$
800–1390	896	0.1170	±0.0024	±0.0021	$^{+0.0048}_{-0.0003}$



Graph 3: the measurement of the strong coupling constant

Conclusions:

The ratio R_{32} has been measured for jets in the range $250 < \ < p_T > \ < 1390 GeV$ at LHC and the result agrees with QCD predictions at NLO.

The obtained result for the strong coupling constant is determined to be:

$$\alpha_s(M_Z) = 0.1148 \pm 0.0014(exp) \pm 0.0018(PDF)^{+0.0050}_{-0.0000}(scale)$$

The dominating error is theoretical and it agrees with the results from other experiments

Thank you for
your attention!