CONSTRAINING NEW COLOURED MATTER FROM R_{32} AT THE LHC [1403.7411]

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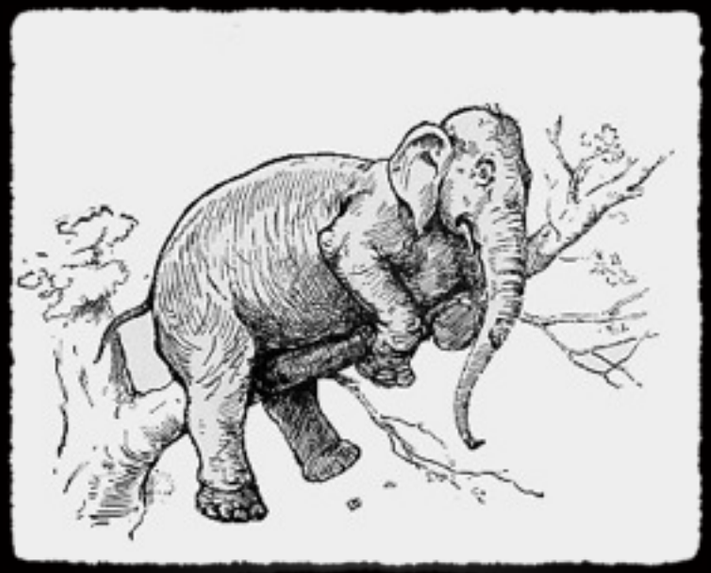
Where is new physics hiding?

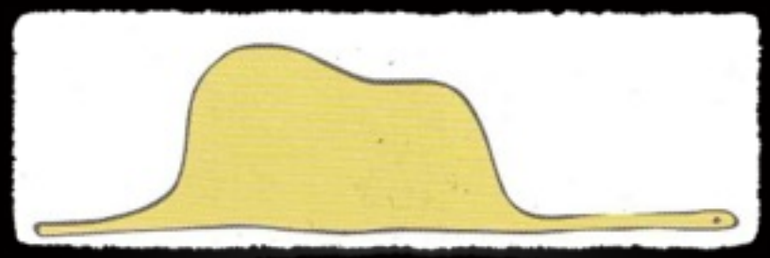
- Best (TeV-scale) motivation: EWSB
  - New coloured states? (cancel top-loop)
  - EWSB directly from coloured states? [1403.4262]
- Regardless: how well is QCD known experimentally at high(est) energies?
- New states hiding where we don’t expect them?

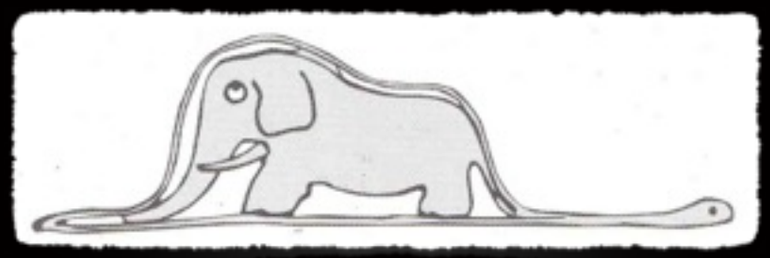


1905 book illustration

How could it be seen?

- Resonance/bump (di-jet)?





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- What if no LO contribution to process?
  - Indirect effects: running of α_s
  - Modification of PDFs?
- Not something new: Berger et al. [1010.4315]

Our ‘model independent’ elephant

- What is the context of interest?
- E.g. new fermions ‘X’ without quark mixing
  - Can only be pair-produced
  - No visible or ‘useful’ decays
    (at least 4-body final states anyway)
- ‘Model independent’ vs ‘specialised search’ tradeoff

Virtual effects

Modification of α_s

$$\beta(\alpha_s) \equiv \mu \frac{\partial \alpha_s}{\partial \mu} = -\frac{\alpha_s^2}{2\pi}\left(b_0 + \frac{\alpha_s}{4\pi}\, b_1 + \ldots\right)$$

$$b_0 = 11 - \frac{2}{3} n_f - \frac{2}{3}(2 n_X T_X)$$

$$b_1 = 102 - \frac{38}{3} n_f - 10\,(2 n_X T_X)\left(1 + \frac{C_X}{5}\right)$$

$$n_{\text{eff}} \equiv 2 n_X T_X$$

- n_X : number of X, T_X : trace normalisation, C_X: Casimir
- Majorana ‘gluino’ : $n_{\text{eff}} = 3$, Dirac decuplet : $n_{\text{eff}} = 15$

$$\frac{\alpha_s(Q)}{\alpha_s^{SM}(Q)} \approx 1 + \frac{n_{\text{eff}}}{3\pi}\alpha_s(m_X)\log\left(\frac{Q}{m_X}\right), \qquad \text{for } Q \geq m_X$$

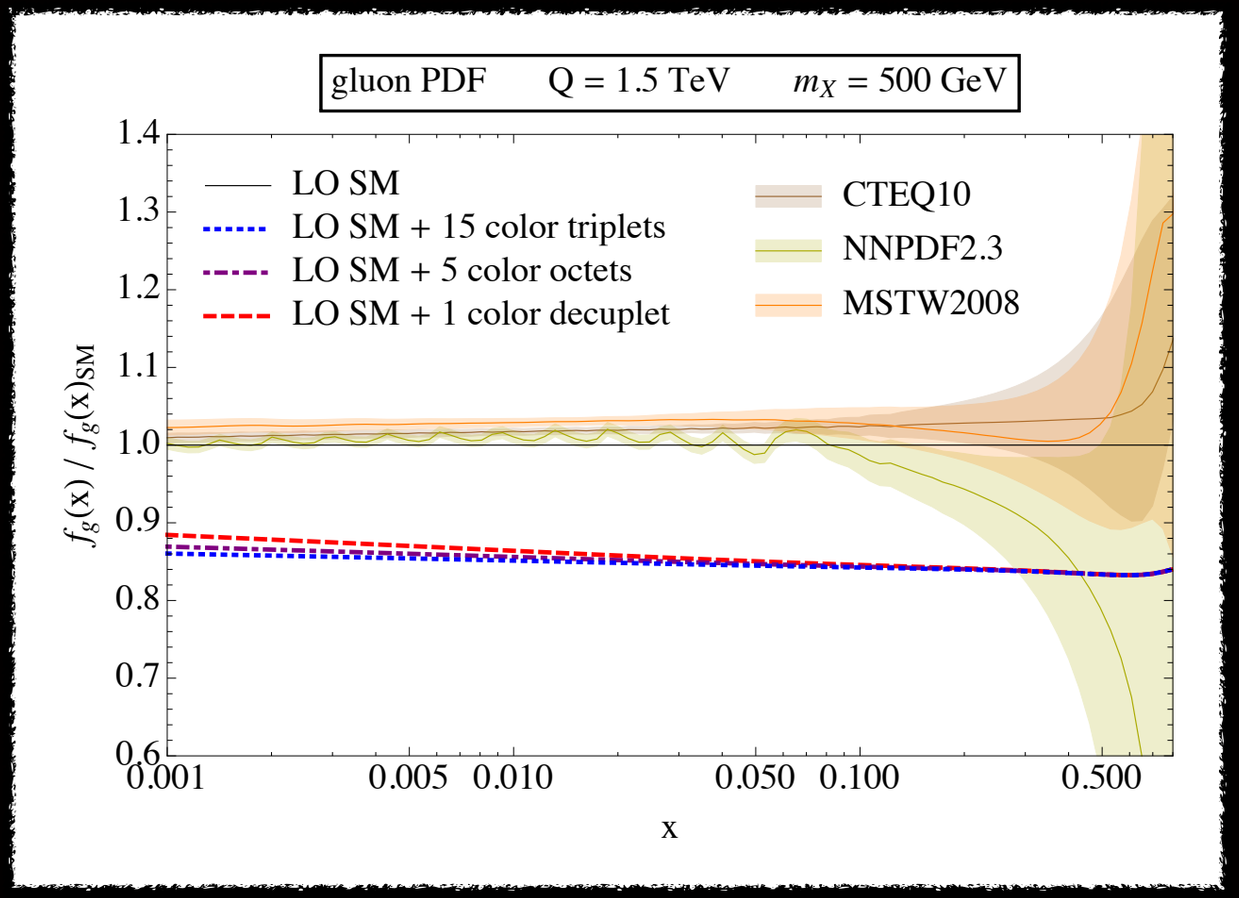
Modification of PDFs

- New or modified splitting functions :
  P_{gg}, P_{xg}, P_{gx}, P_{xx}
- Main effect on gluon PDF (and large-x in valence PDF)

$$\frac{f_g(x,Q)}{f_g^{SM}(x,Q)} \approx 1 - \frac{n_{\text{eff}}}{3\pi}\alpha_s(m_X)\log\left(\frac{Q}{m_X}\right)$$

x-independent!

LO computation with HOPPET



Other virtual corrections?

- Full virtual contribution?
  - Threshold effects!
  - 2-jets: Ellis & Ross [hep-ph/9708312]
- Unfortunately not evaluated…
  - …but perhaps not important

α_s and R_{32}

How to measure α_s (@LHC)

- Highest possible momentum transfer: low jet multiplicity
- Ratio to reduce uncertainties
  - Both theoretical & experimental
- Best candidate: R_{32}

Kinematic choice

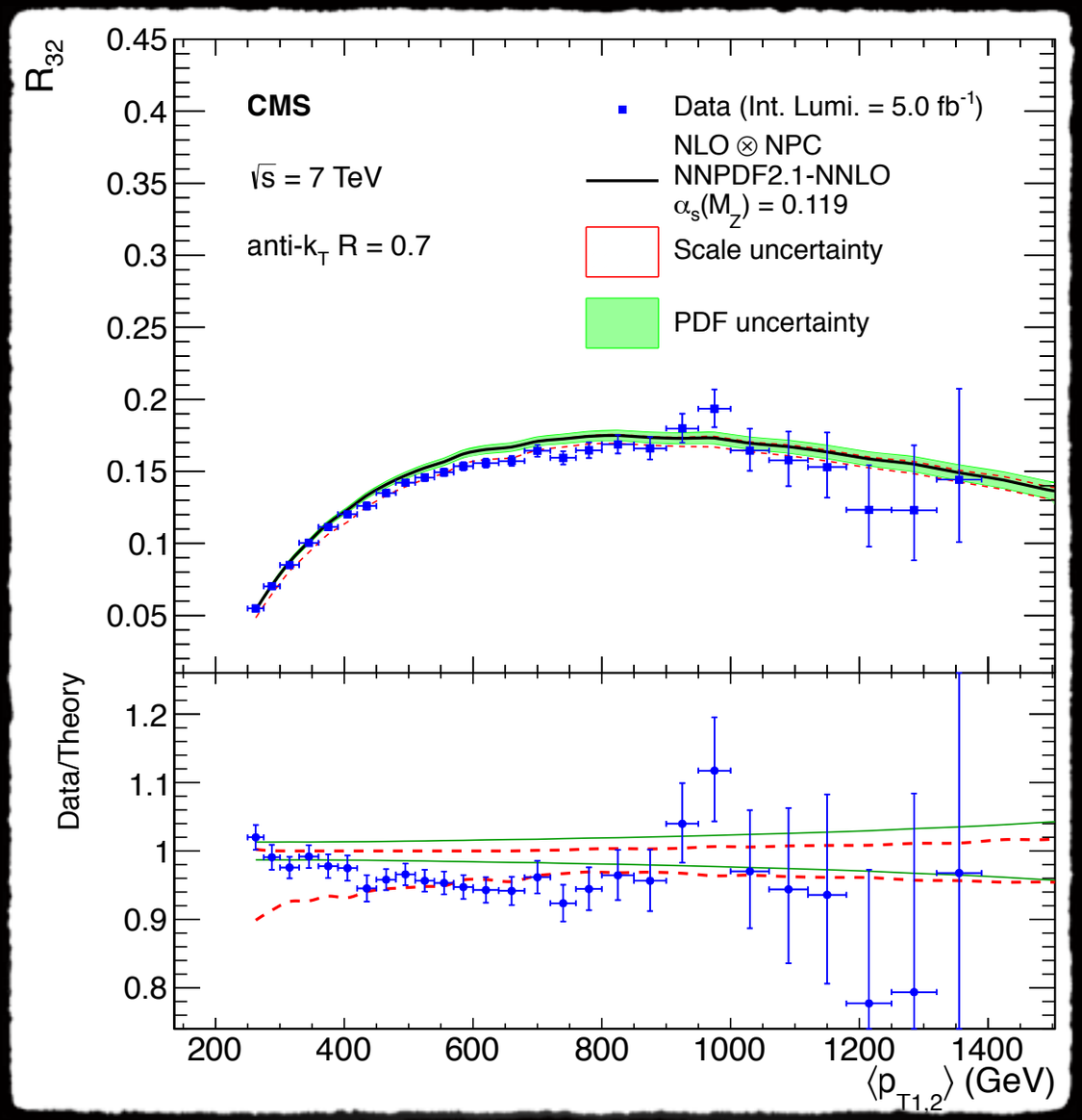
- Differential cross-section (discriminate large momentum transfer)
- Not-so-good choice: leading p_T
  - Mismatch of phase space between 3- and 2-jets
- Better choice (e.g. CMS): average two leading p_T

$$R_{32}\left(\langle p_{T1,2}\rangle\right) \equiv \frac{\mathrm{d}\sigma^{n_j\geq 3}/\mathrm{d}\left\langle p_{T1,2}\right\rangle}{\mathrm{d}\sigma^{n_j\geq 2}/\mathrm{d}\left\langle p_{T1,2}\right\rangle}$$

  - Also identifying it with renorm. scale (uncertainty!)

PDF uncertainty

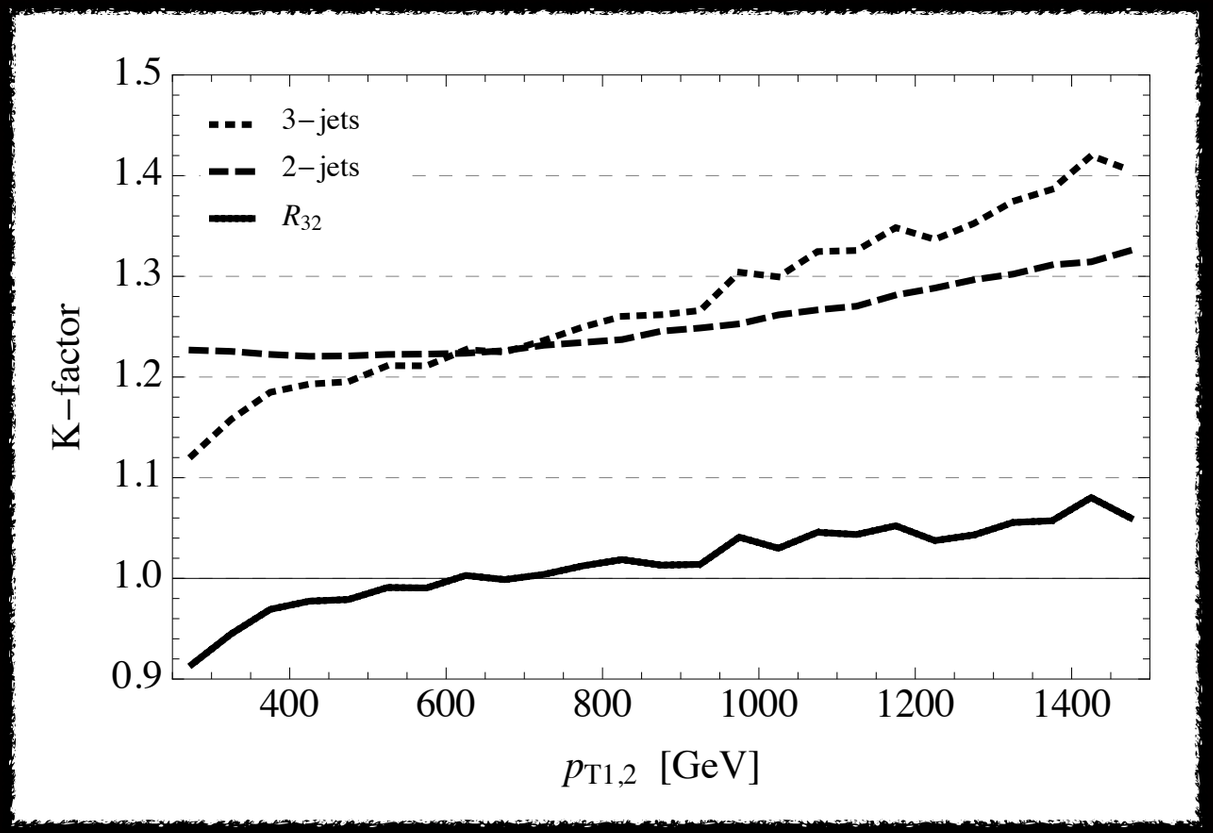
- Cancellation in ratio
  - Reduced uncertainty
  - Change in gluon PDF will also tend to cancel
  - Plus initial gluons <u>not main contribution</u>



from CMS [<u>1304.7498</u>]

R32@NLO

- Cancellation of K-factors between 3- and 2-jets: R32 (almost) simply proportional to α_s



Computed with NLOJet++

- Still possibility for ‘bad’ (or ‘good’) surprises in presence of new physics (thresholds)

R_{32}: good determination of α_s

- Sensitive to high pT
- Insensitive to PDF uncertainties
- Small K-factor
- Showering only affecting overall normalisation (possible extra uncertainties, though)

Experimental constraints

Experimental values

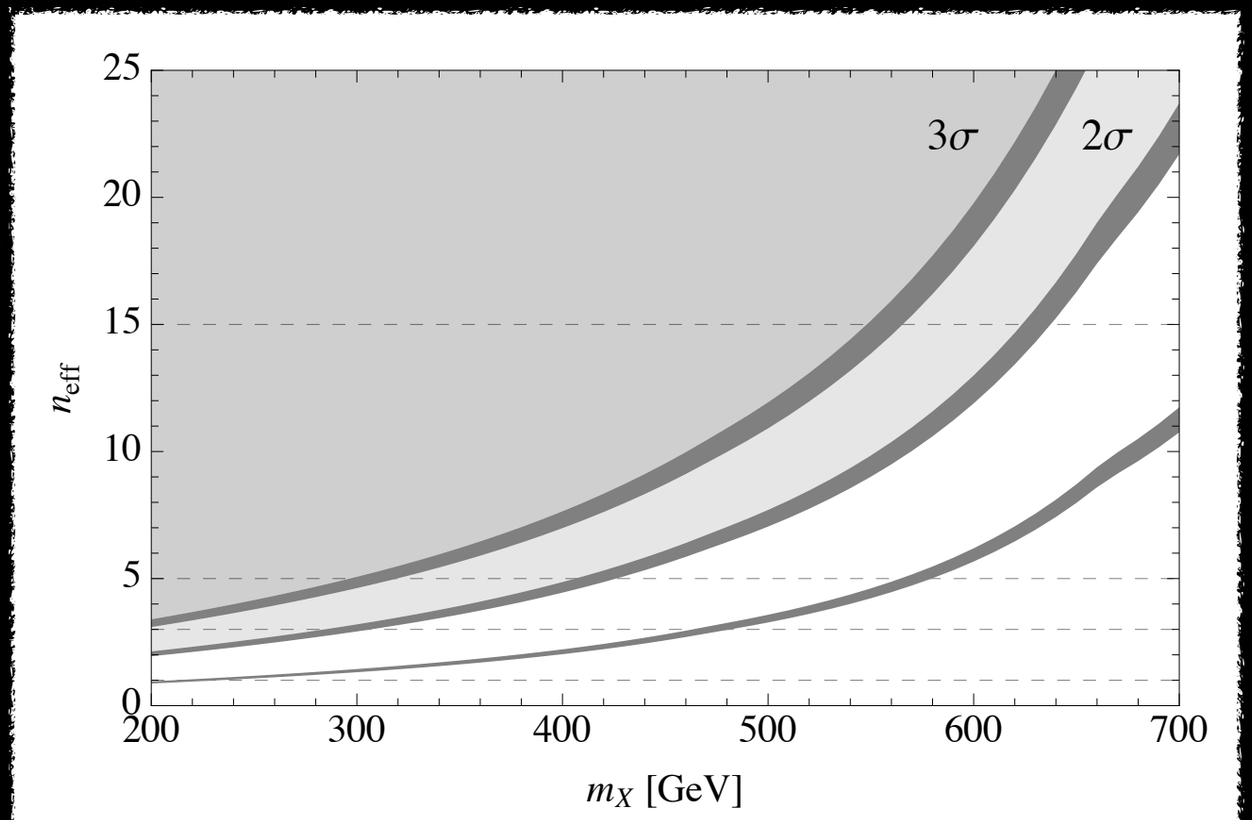
- ATLAS [conf]: $\alpha_s(M_Z) = 0.111$
  ± 0.006 (exp.) $+0.016/-0.003$ (theory)
- CMS [1304.7498]: $\alpha_s(M_Z) = 0.1148$
  ± 0.0014 (exp.) ± 0.0018 (PDF) ± 0.0050 (theory)

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

- Full data (correlations) for R_{32} not available

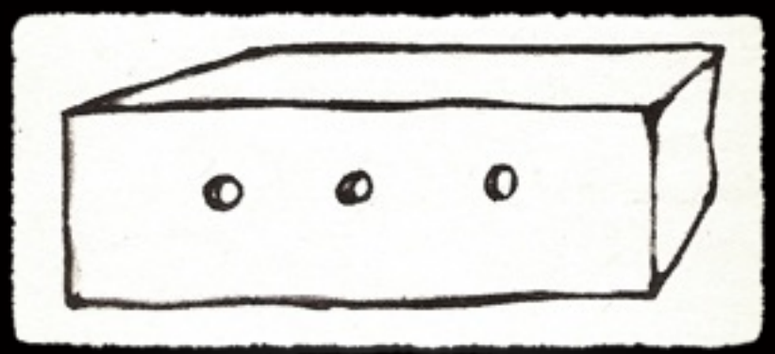
Constraining new coloured matter

- Using directly CMS measurement of α_s



Conclusions

- New coloured matter ‘invisible’ in direct searches:
  potentially interesting limits from pure QCD observable R_{32}
  - Hard to avoid
  - Depends (at LO) only on n_{eff} (and m_X):
    ‘model independent’
- Let’s hope something is in the box!



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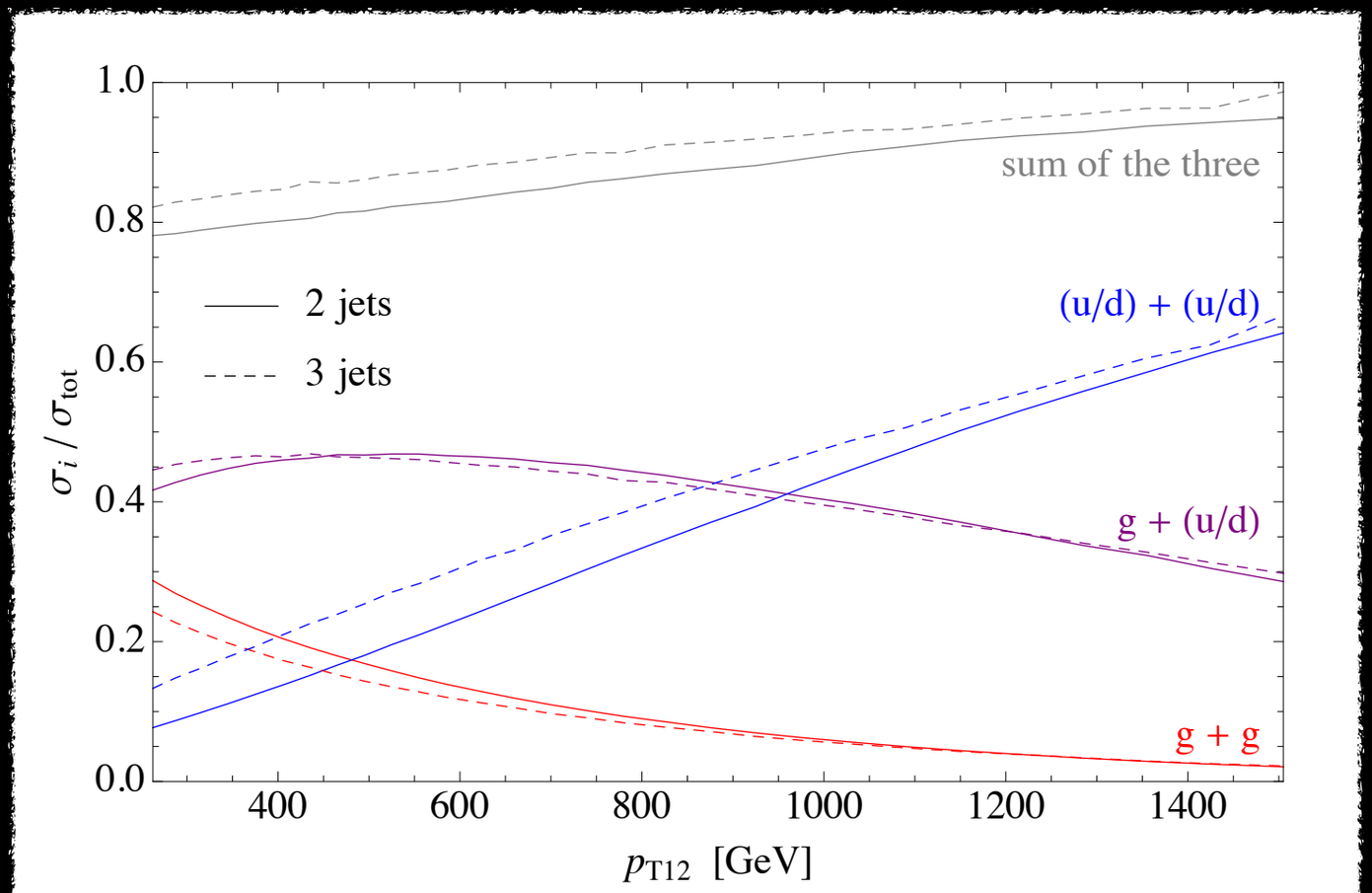
Extras

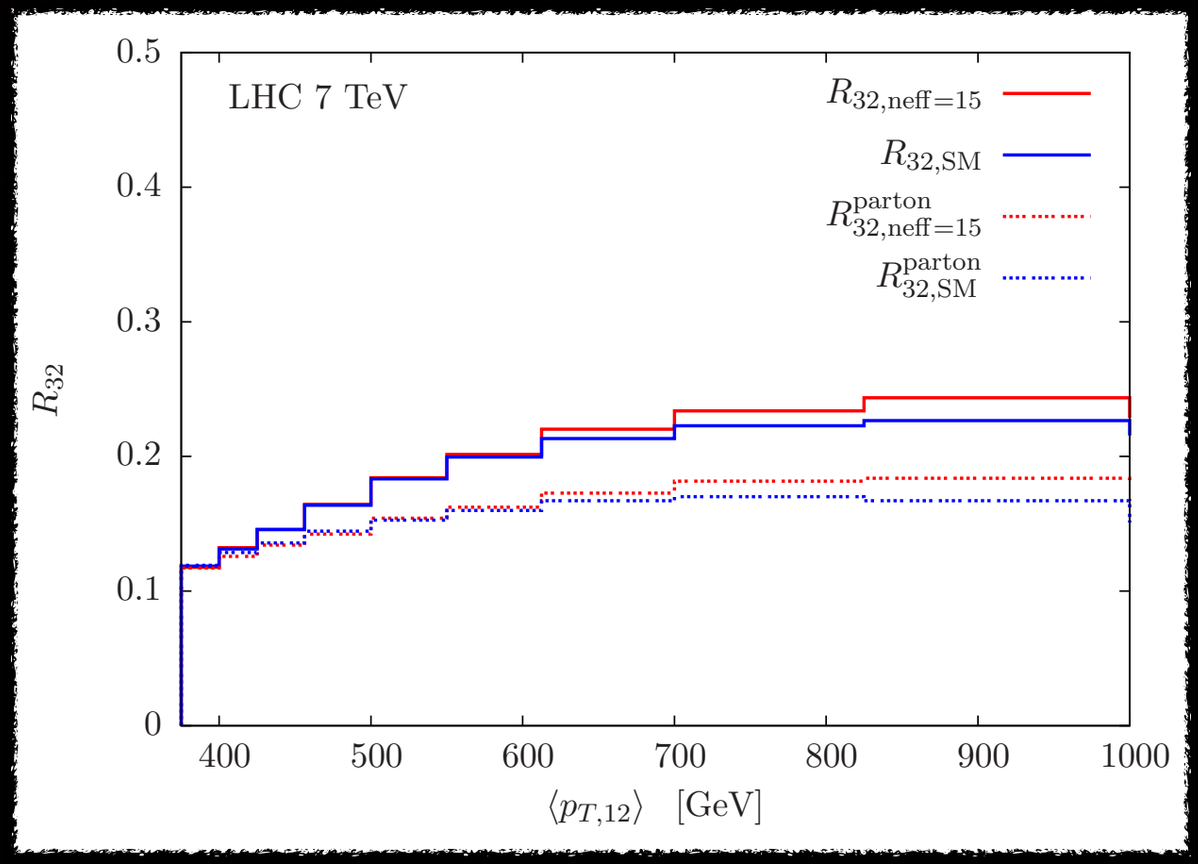
Modification of gluon PDF?

- Initial gluons sub-leading at large p_T anyway



Influence of showering

- New physics effect unchanged



- Possible underestimation of related uncertainty by CMS (5-10%: Höche & Schönherr [1208.2815])