Search for contact interactions using the inclusive jet p_T spectrum in $p\,p$ collisions at $\sqrt{s} = 8$ TeV

Greg Myers[1], Harrison Prosper[1], Suman Beri[2], Supriya Jain[3]
[1]Florida State University
[2]Panjab University
[3]SUNY, Buffalo

8 August, 2013

Outline

qq Contact Interactions

- Goal: Search for evidence of quark compositeness using the recently measured $\sqrt{s} = 8$TeV inclusive jet p_T spectrum (CMS AN AN-12-223), set a limit on mass scale, Λ
- We will compare contact interaction (CI) signal plus QCD cross sections calculated at next-to-leading-order (NLO) to the measured spectrum.
- In this talk we present our signal models and discuss PDF uncertainties.

Signal Models

- Signal Lagrangian (`arXiv:1202.5535 [hep-ex]`):

$$\mathsf{L}_{qq} = \frac{2\pi}{\Lambda^2}\left[\eta_{LL}\left(\bar{q}_L\gamma^\mu q_L\right)\left(\bar{q}_L\gamma_\mu q_L\right) + \eta_{RR}\left(\bar{q}_R\gamma^\mu q_R\right)\left(\bar{q}_R\gamma_\mu q_R\right) + 2\eta_{RL}\left(\bar{q}_R\gamma^\mu q_R\right)\left(\bar{q}_L\gamma_\mu q_L\right)\right]$$

Model	η_{LL}	η_{RL}	η_{RR}
LL	± 1	0	0
RR	0	0	± 1
VV	± 1	± 1	± 1
AA	± 1	∓ 1	± 1
V-A	0	± 1	0

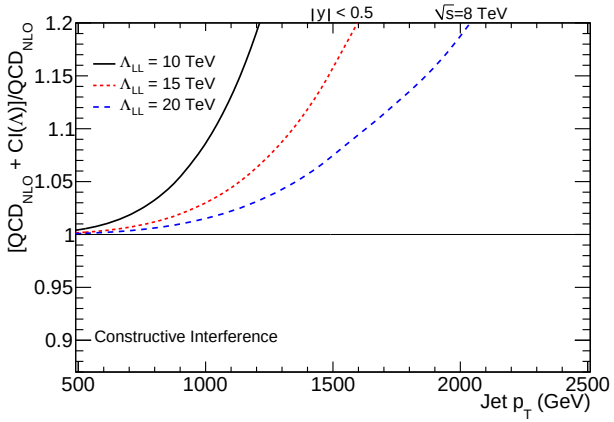
- NLO Signal model calculated using CIJET 1.0 program from J. Gao (`arXiv:1301.7263 [hep-ph]`)
- Inclusive jet cross section in one p_T bin:

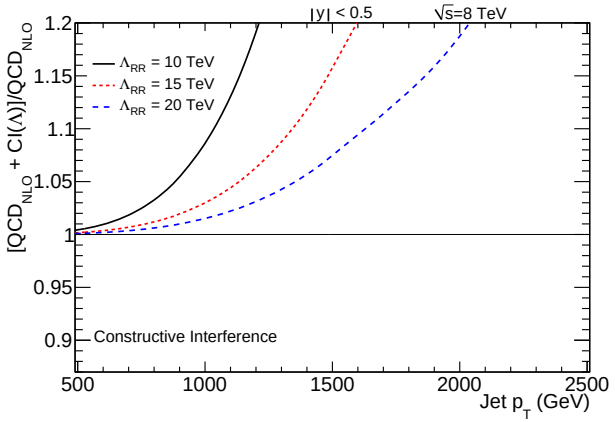
$$\sigma = \sigma_{QCD} + \sigma_{CI}$$

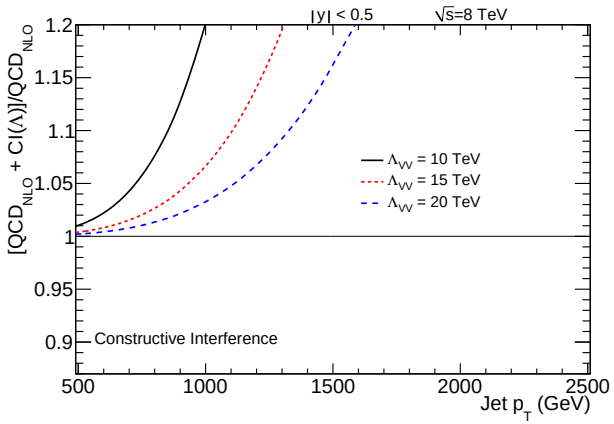
$$\sigma_{CI} = \frac{1}{\Lambda^2}\left(B + B' \ln r\right) + \frac{1}{\Lambda^4}\left(A + A' \ln r\right)$$

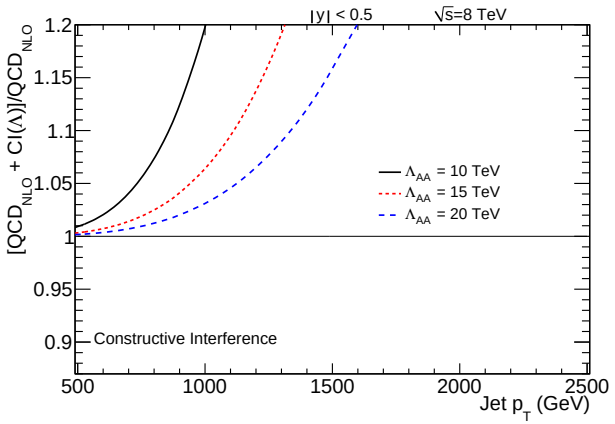
- $r = \frac{\Lambda}{\mu_0}$
- CIJET 1.0 allows us to calculate A, A', B, and B' coefficients in each p_T bin for each model.
- At leading order: $A' = B' = 0$

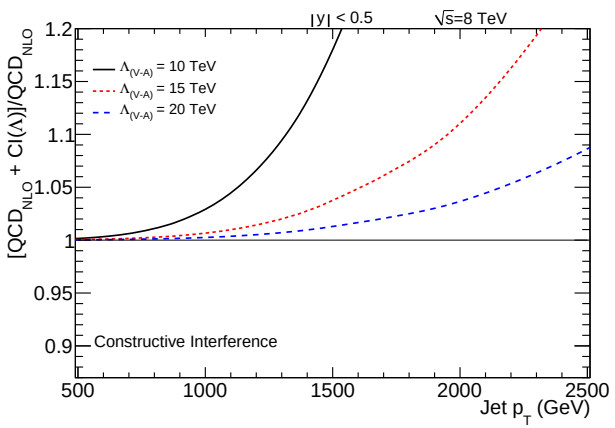
- We consider both constructive and destructive interference for each model
- For each model, choice of Λ, PDF set, interference mode, and choice of factorization scale (μ_f) and renormalization scale (μ_r) we plot: $\frac{\sigma_{QCD}+\sigma_{CI}}{\sigma_{QCD}}$
- The following plots were made using the central member of the CT10nlo PDF set and by choosing $\mu_f = \mu_r = 1$

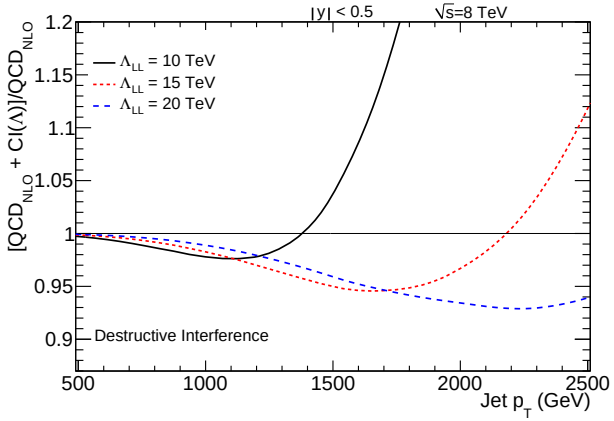

|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_LL = 10 TeV
Λ_LL = 15 TeV
Λ_LL = 20 TeV
Constructive Interference
Jet p_T (GeV)

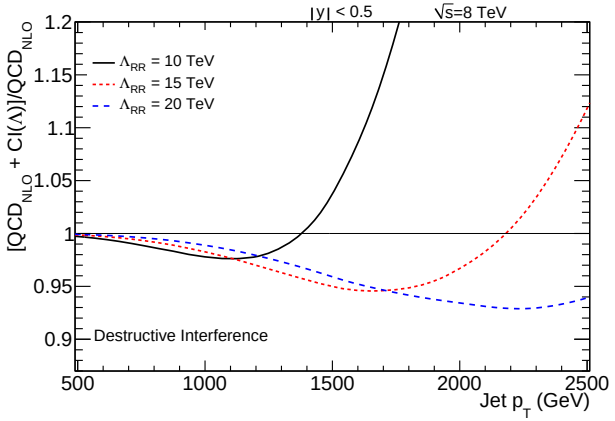

|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_RR = 10 TeV
Λ_RR = 15 TeV
Λ_RR = 20 TeV
Constructive Interference
Jet p_T (GeV)

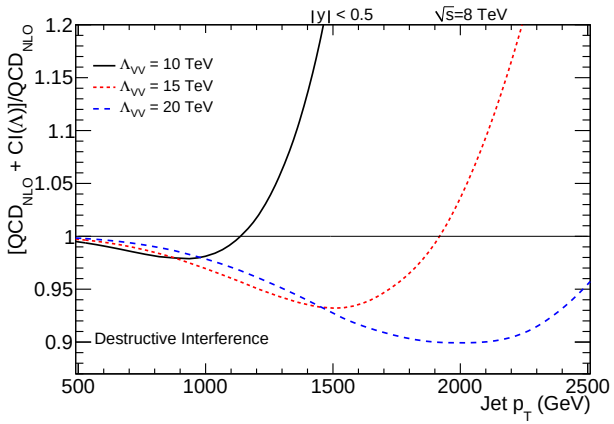

|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_VV = 10 TeV
Λ_VV = 15 TeV
Λ_VV = 20 TeV
Constructive Interference
Jet p_T (GeV)

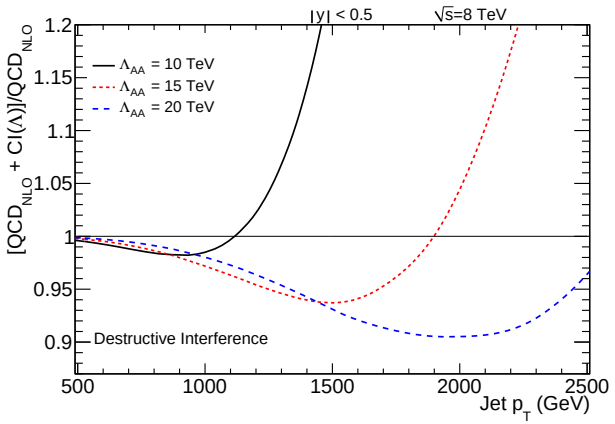

|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_AA = 10 TeV
Λ_AA = 15 TeV
Λ_AA = 20 TeV
Constructive Interference
Jet p_T (GeV)

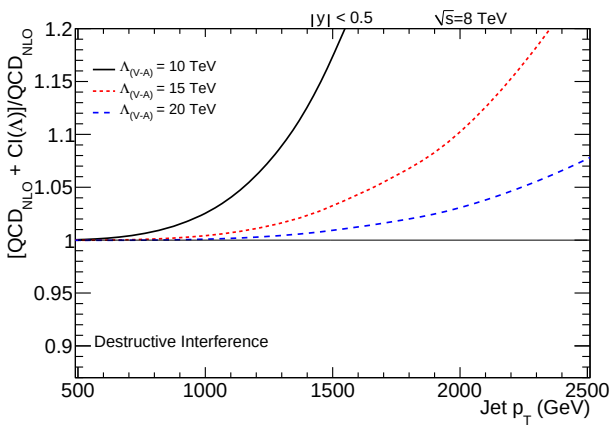

|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_(V-A) = 10 TeV
Λ_(V-A) = 15 TeV
Λ_(V-A) = 20 TeV
Constructive Interference
Jet p_T (GeV)


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_LL = 10 TeV
Λ_LL = 15 TeV
Λ_LL = 20 TeV
Destructive Interference
Jet p_T (GeV)


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_RR = 10 TeV
Λ_RR = 15 TeV
Λ_RR = 20 TeV
Destructive Interference
Jet p_T (GeV)


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_VV = 10 TeV
Λ_VV = 15 TeV
Λ_VV = 20 TeV
Destructive Interference
Jet p_T (GeV)


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_AA = 10 TeV
Λ_AA = 15 TeV
Λ_AA = 20 TeV
Destructive Interference
Jet p_T (GeV)


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_(V-A) = 10 TeV
Λ_(V-A) = 15 TeV
Λ_(V-A) = 20 TeV
Destructive Interference
Jet p_T (GeV)

Accounting for PDF uncertainties

- Following the procedure outlined here: `https://mstwpdf.hepforge.org/random/`
- The variance in an observable, F, is computed as follows:

$$\Delta F = \frac{1}{2} \sum_{k=1}^{n} \left| F(S_k^+) - F(S_k^-) \right| R_k$$

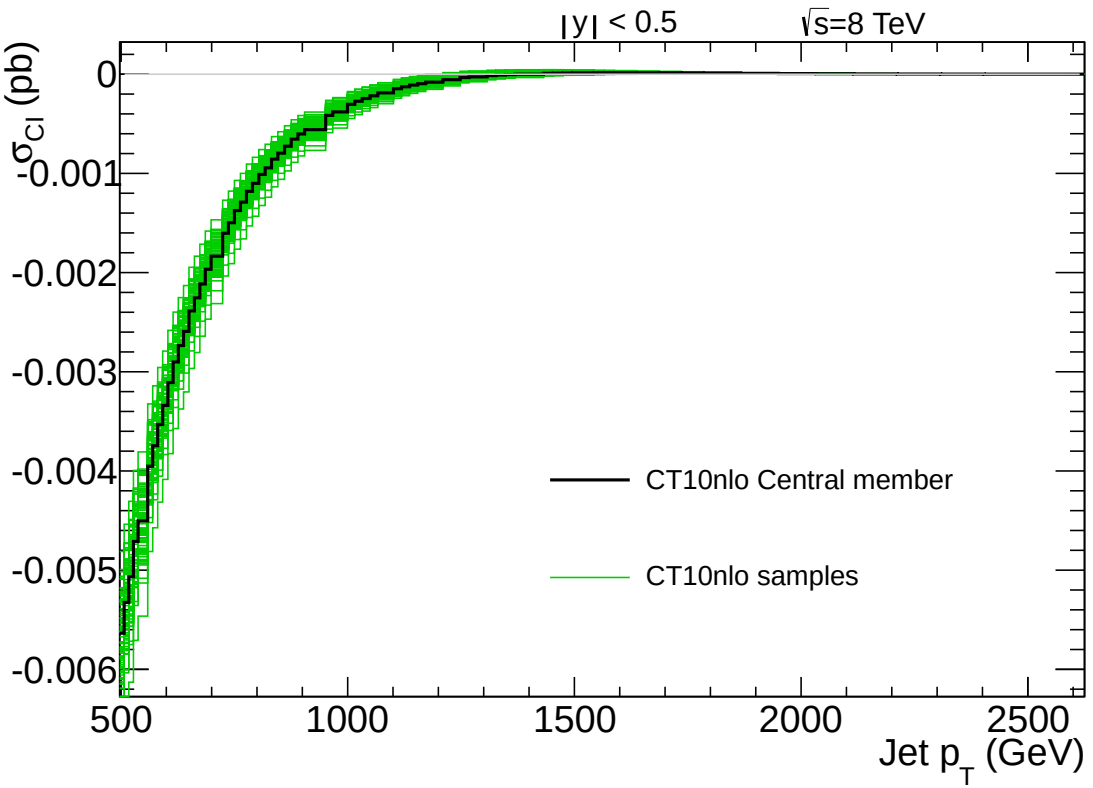
where R_k is a random number generated from a Gaussian distribution with a mean of 0 and σ of 1,

$S_k^{\pm}$ are the $\pm$ variations in the kth free parameter,

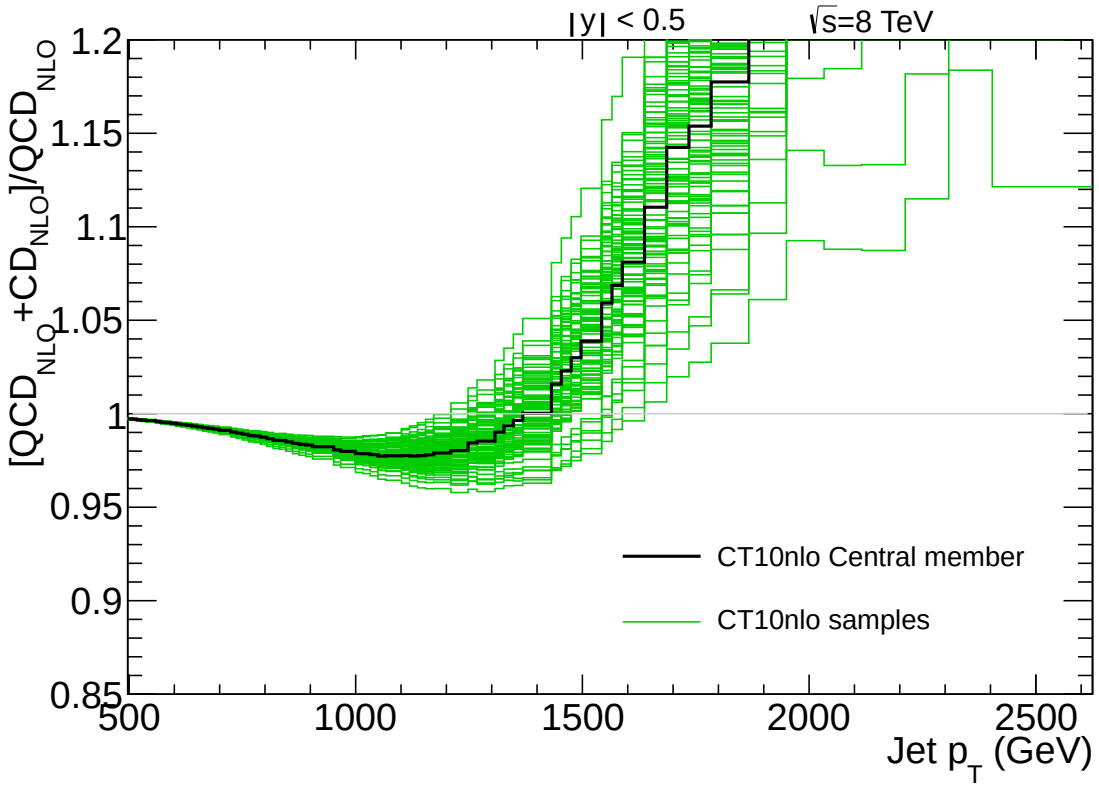
and n is the number of non-central members in the PDF set ($n = 26$ for CT10nlo). The same set of n random numbers is used for all bins, all models.

Signal Uncertainty (CT10nlo)

- Λ =10 TeV, $\mu_f = \mu_r = 1$, LL Model, Destructive Interference
- 100 ΔF's calculated using 100 different sets of 26 random numbers

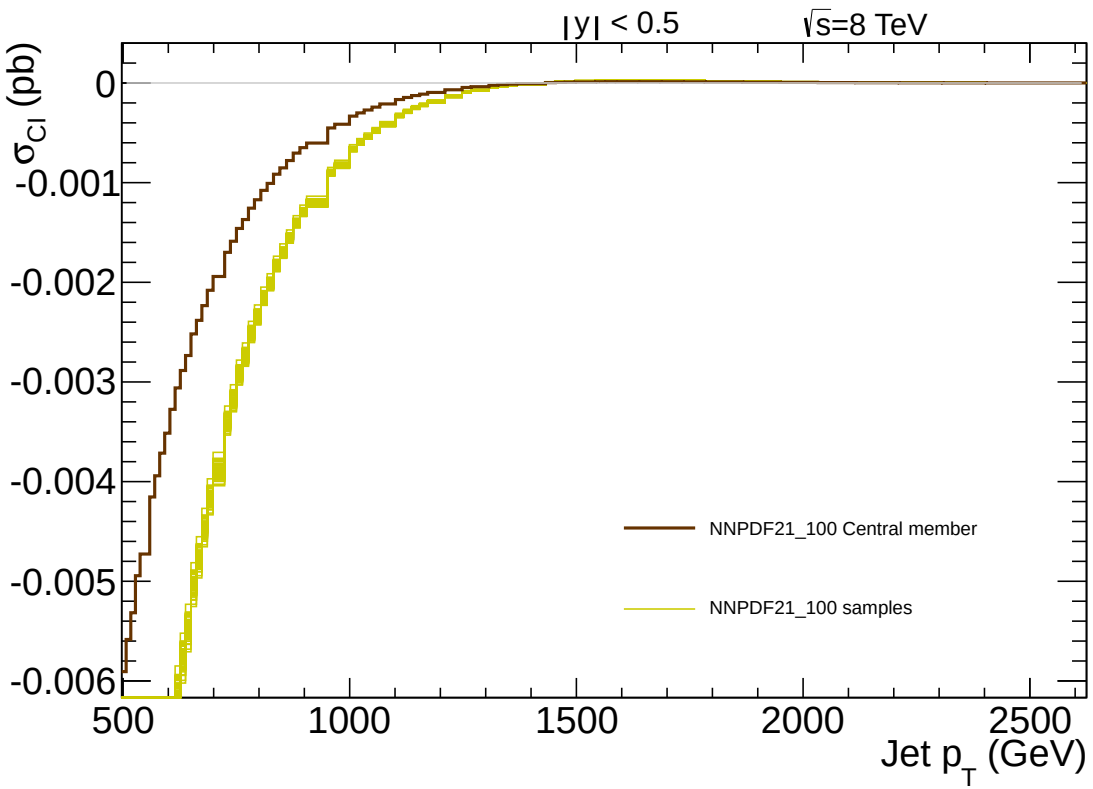


Signal Uncertainty (CT10nlo)

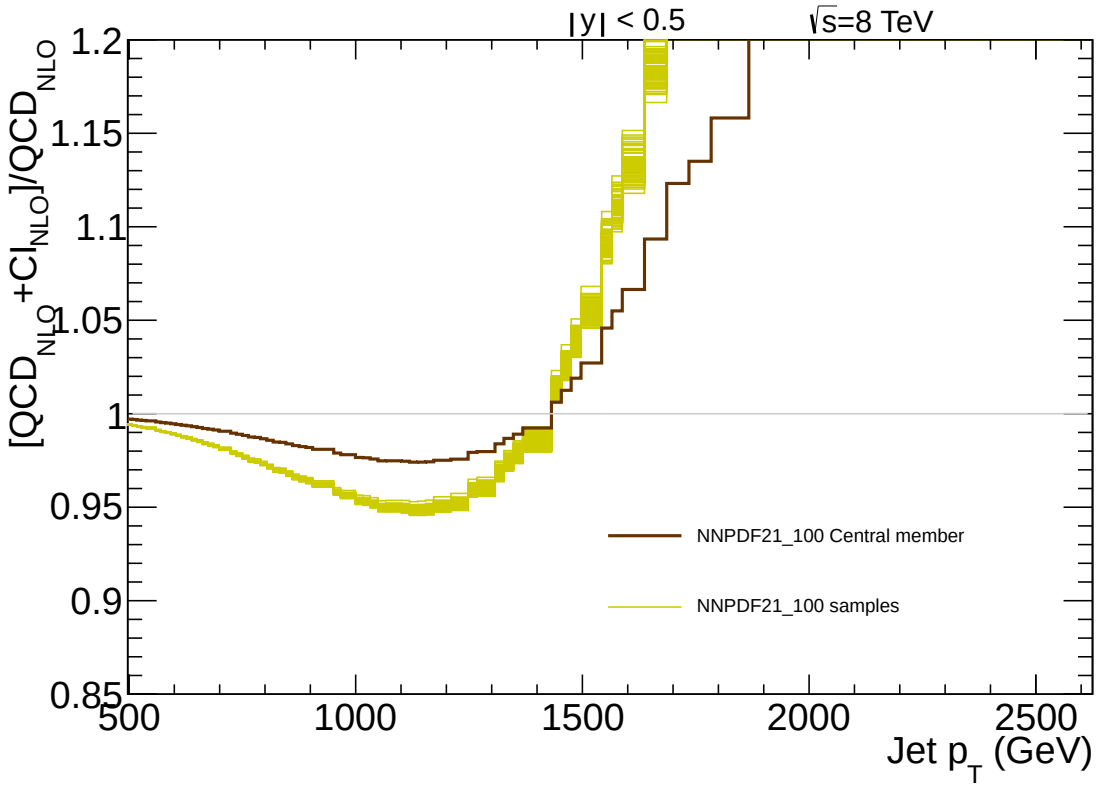


Signal Uncertainty (NNPDF21_100)

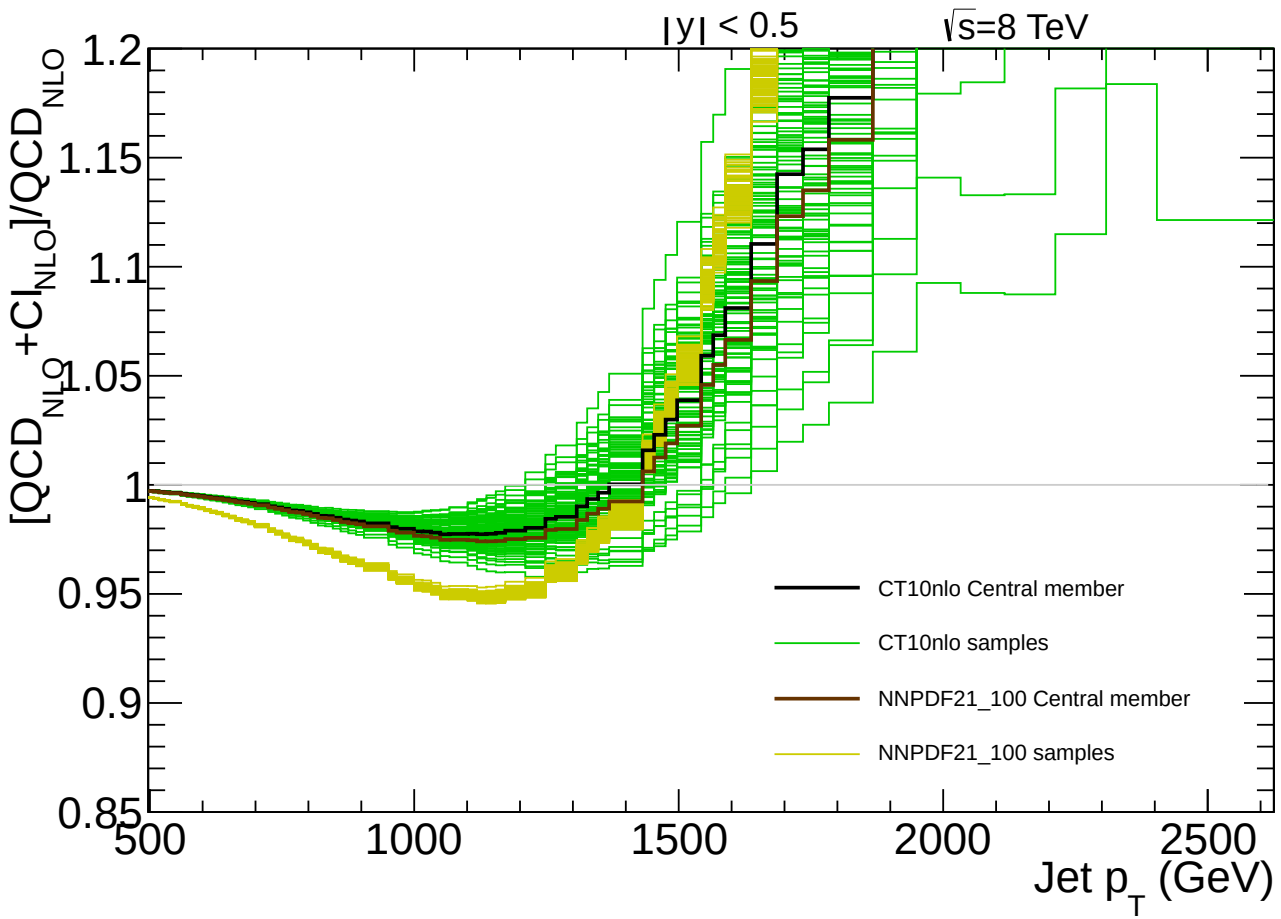
- Λ =10 TeV, $\mu_f = \mu_r = 1$, LL Model, Destructive Interference
- Here we use 100 different PDF members provided in NNPDF21_100 set.



Signal Uncertainty (NNPDF21_100)



NNPDF21_100 and CT10nlo Uncertainty

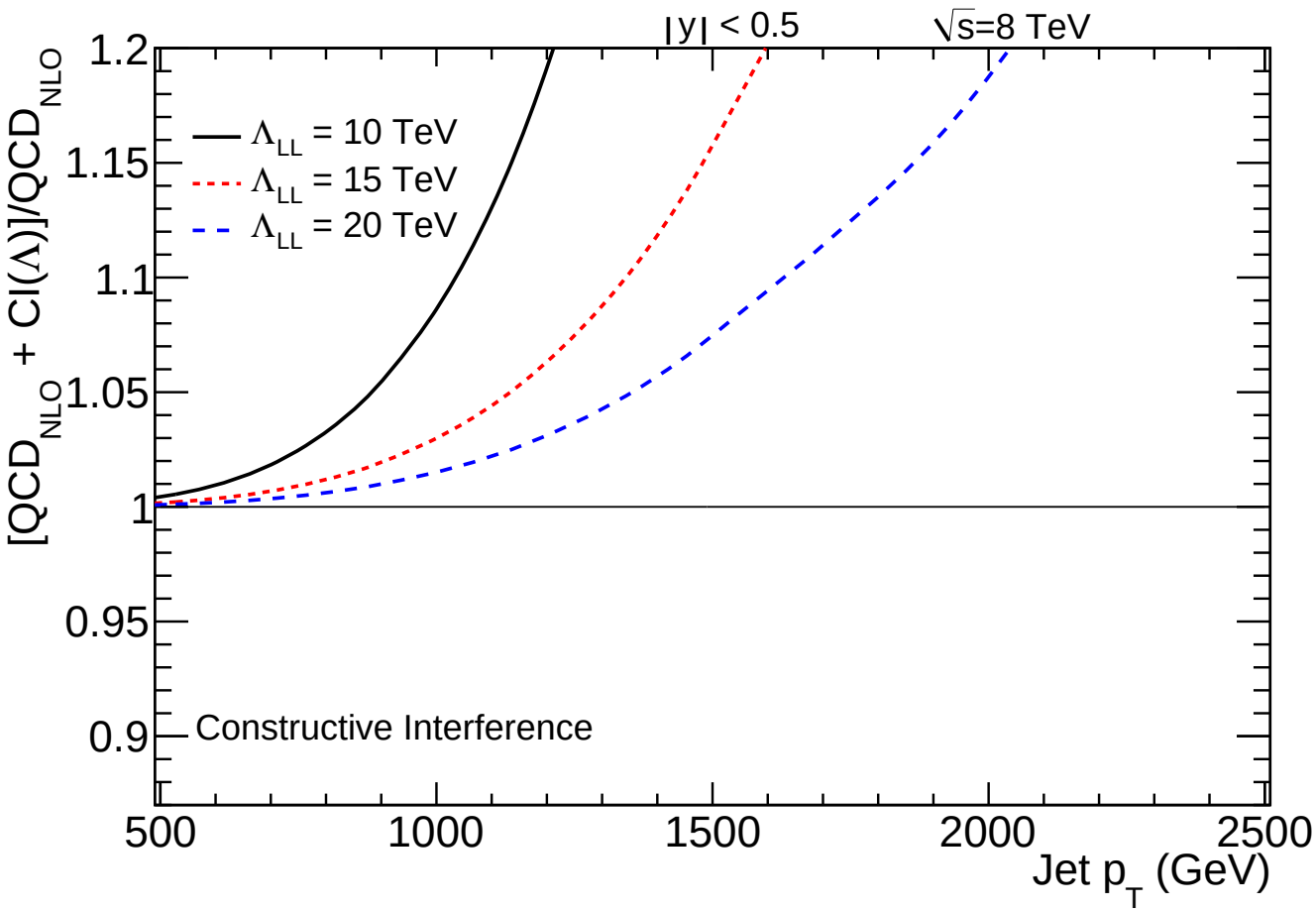


Looking Forward

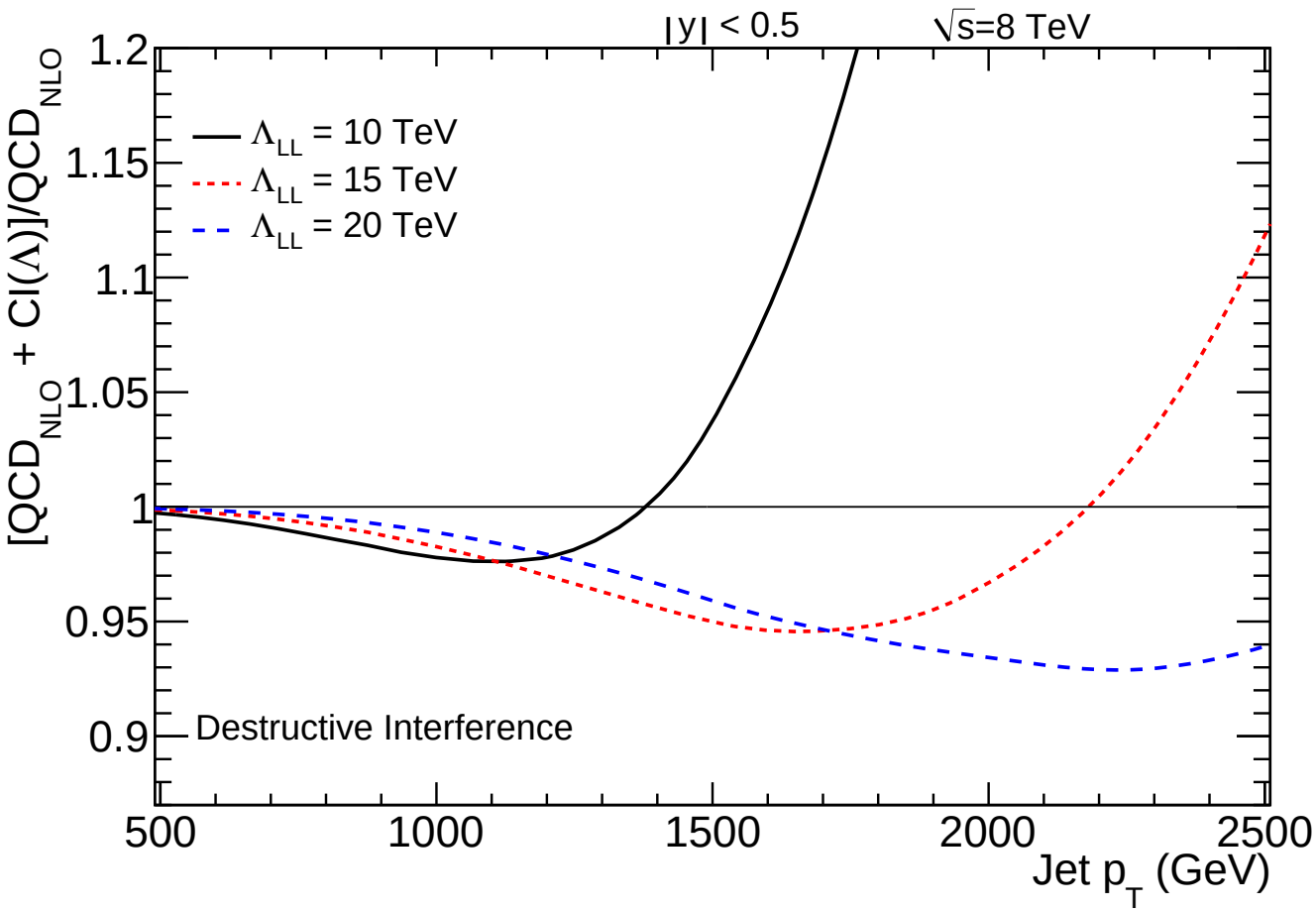
- Account for jet energy resolution (JER) and jet energy scale (JES) uncertainty
- Include MSTW PDF set
- Compare QCD + CI with data
- Obtain expected Bayesian limits on Λ, and later observed limits.

Backup Slides

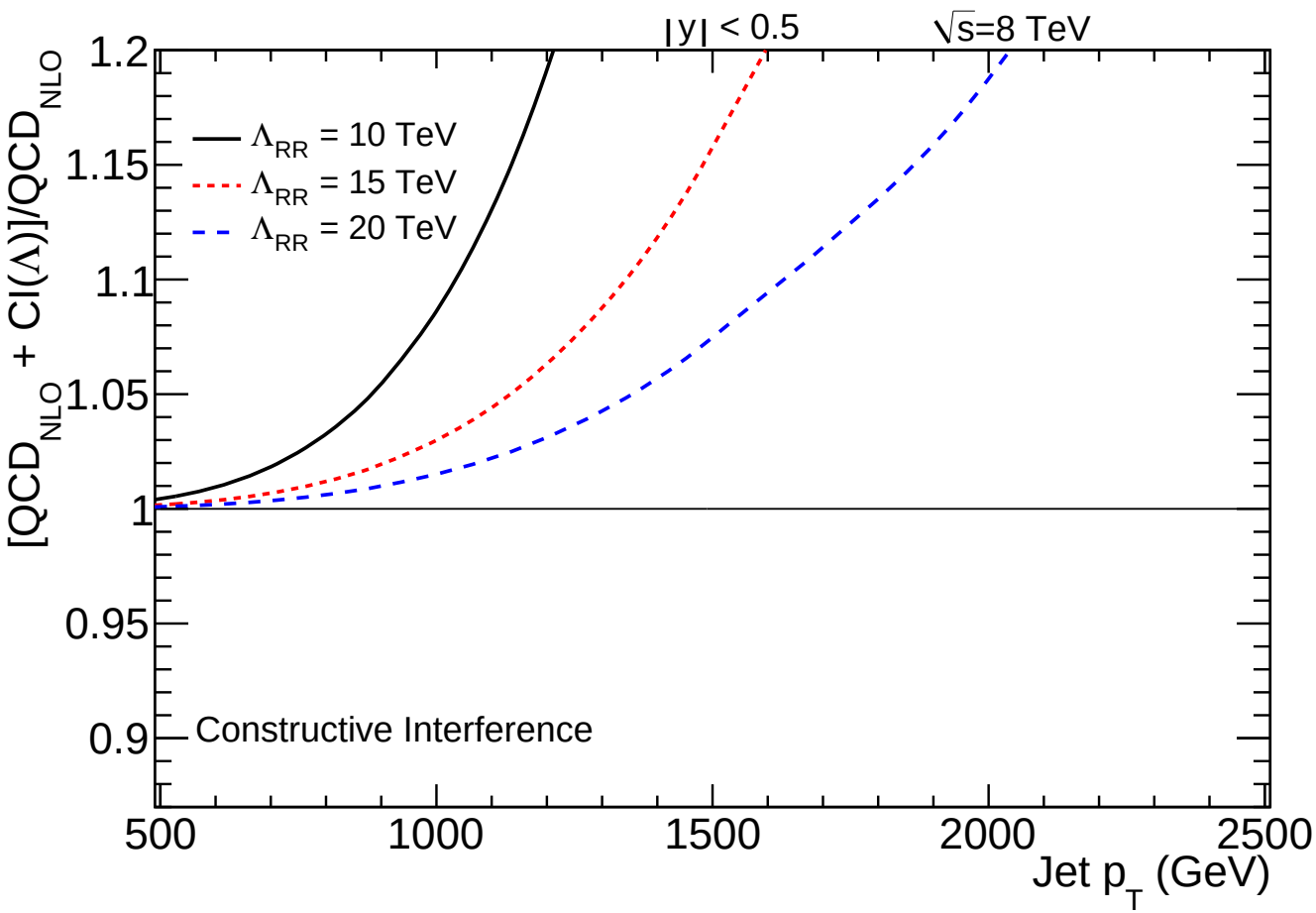
LL Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_LL = 10 TeV
Λ_LL = 15 TeV
Λ_LL = 20 TeV
Constructive Interference
Jet p_T (GeV)
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500

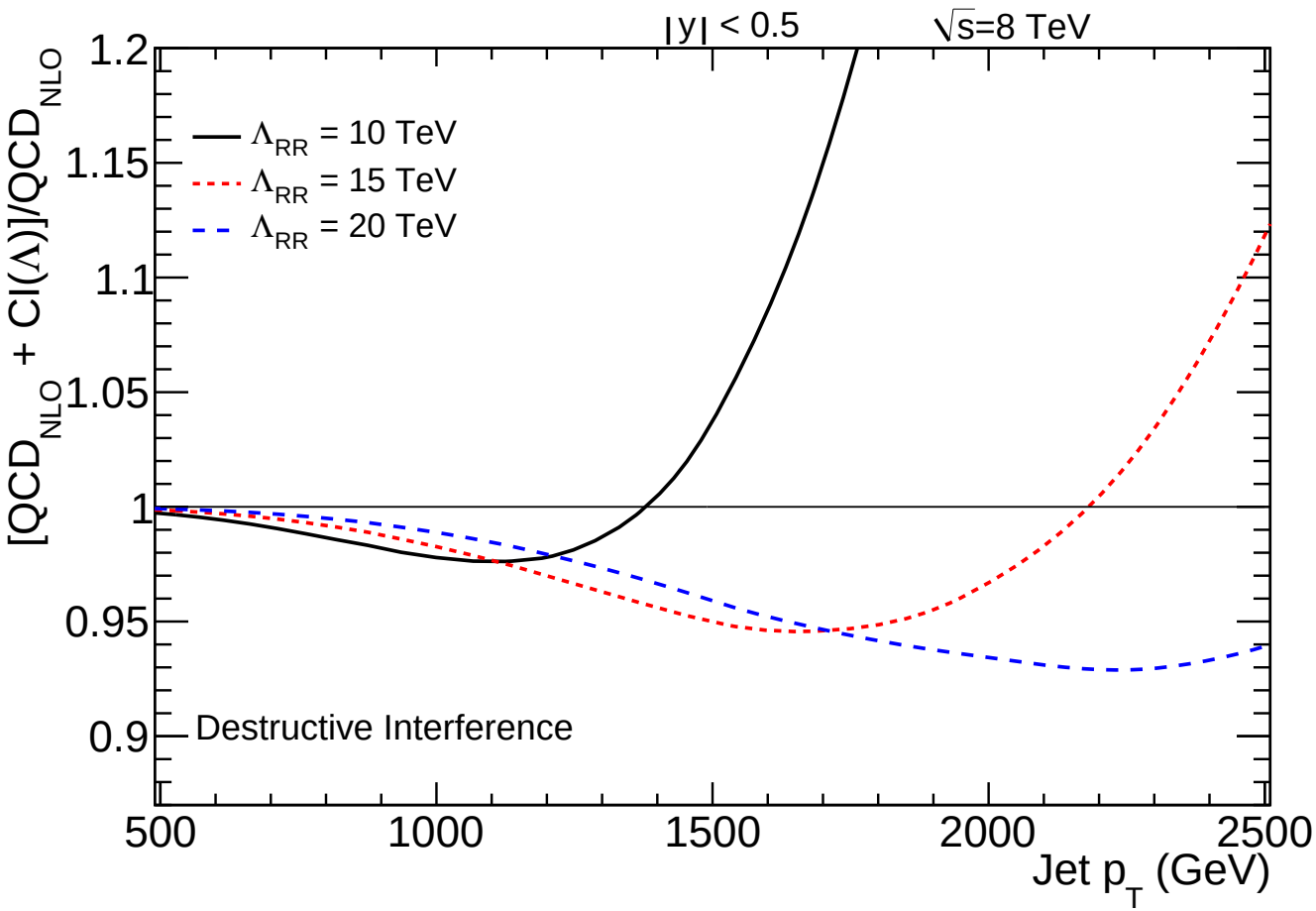
LL Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_LL = 10 TeV
Λ_LL = 15 TeV
Λ_LL = 20 TeV
Destructive Interference
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500
Jet p_T (GeV)

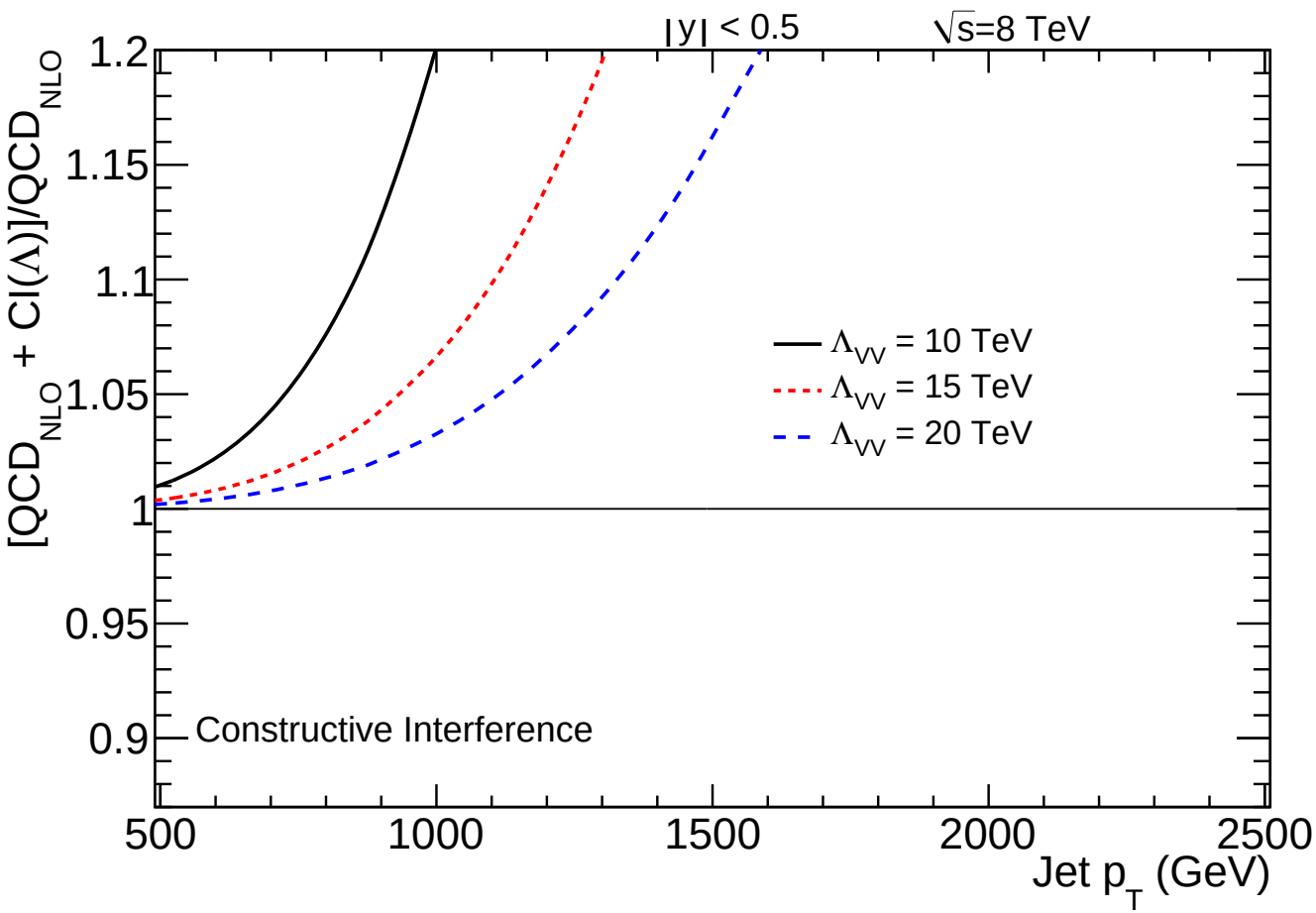
RR Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_RR = 10 TeV
Λ_RR = 15 TeV
Λ_RR = 20 TeV
Constructive Interference
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500
Jet p_T (GeV)

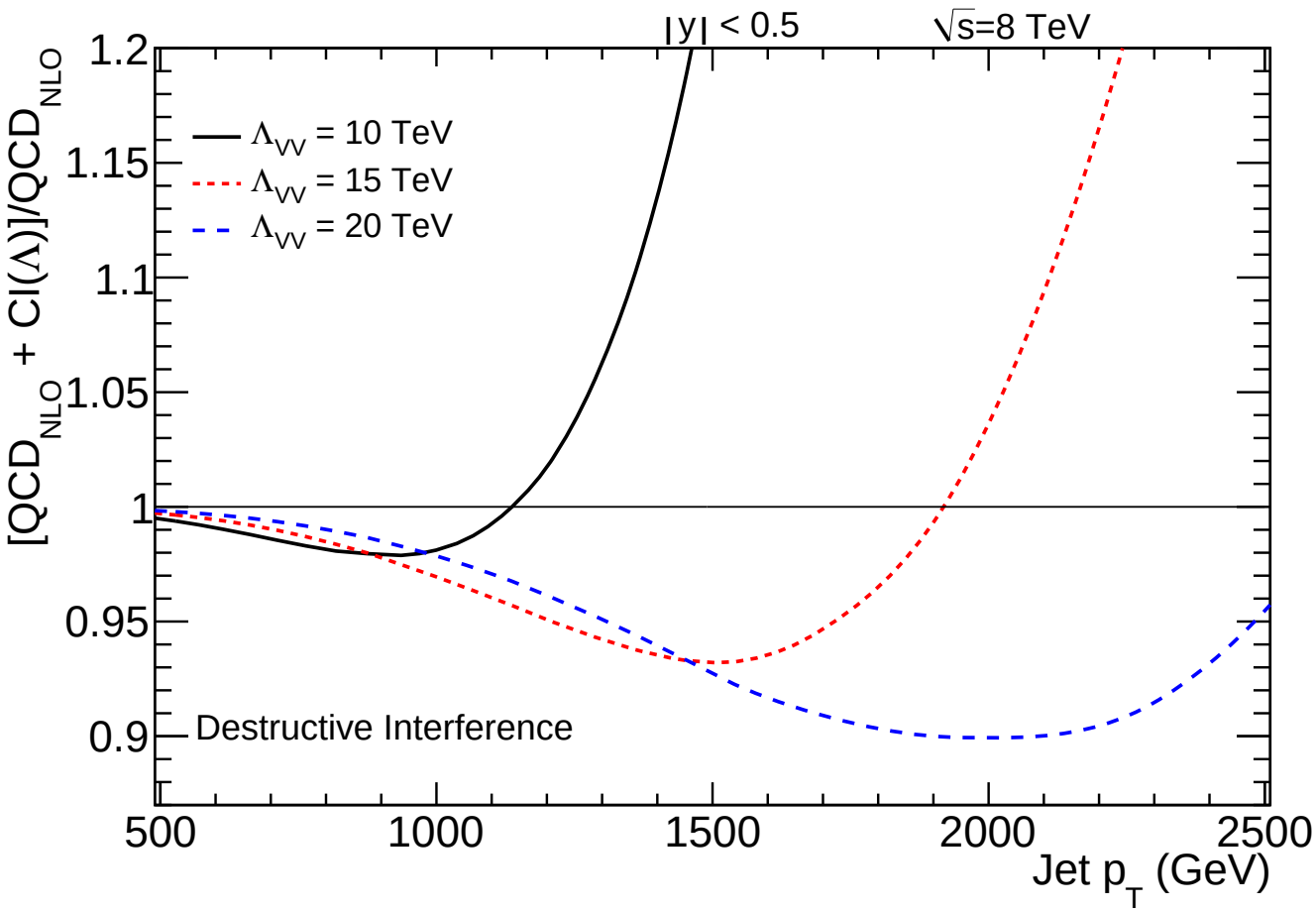
RR Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_RR = 10 TeV
Λ_RR = 15 TeV
Λ_RR = 20 TeV
Destructive Interference
Jet p_T (GeV)
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500

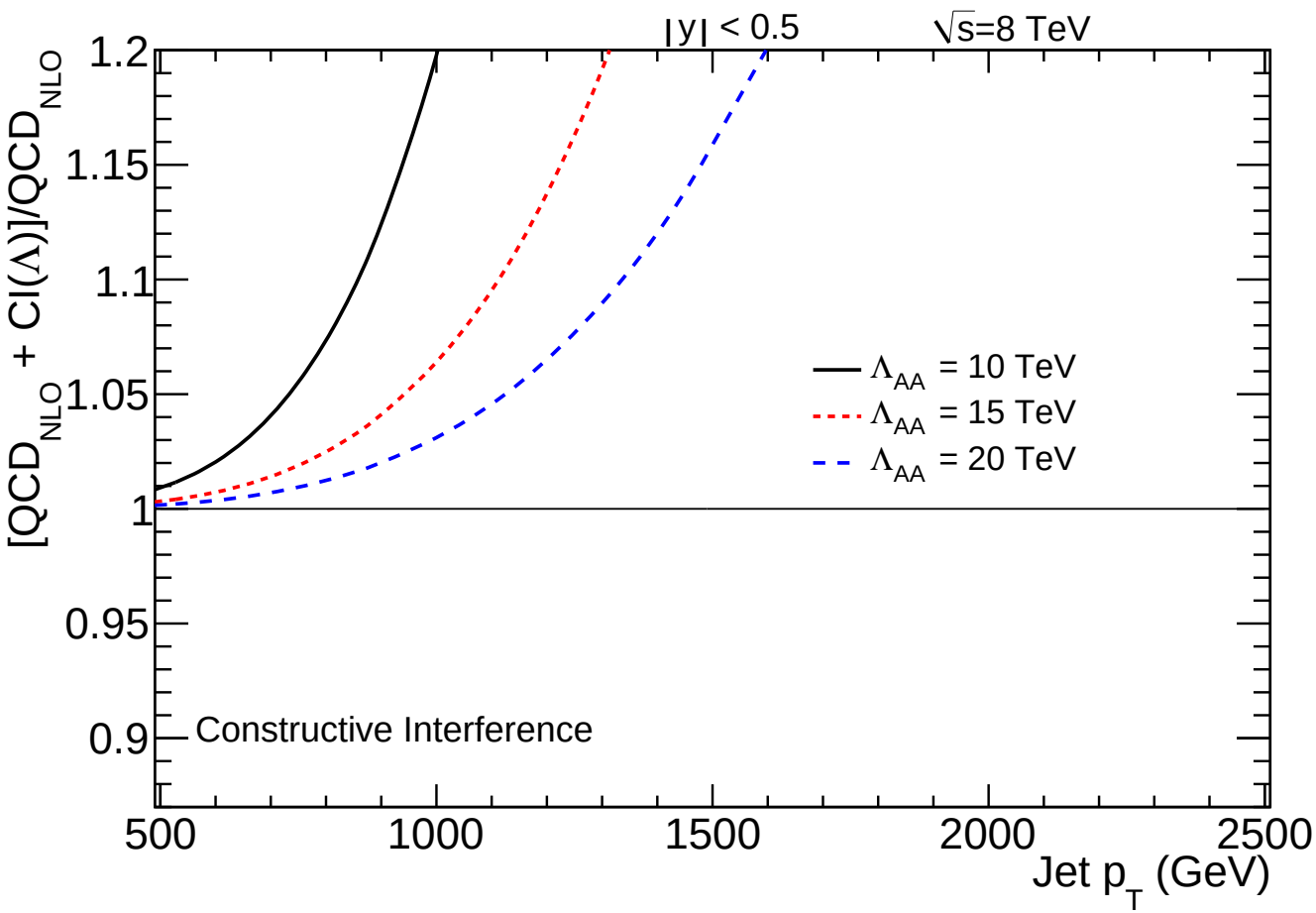
VV Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
1.2
1.15
1.1
1.05
1
0.95
0.9
Λ_VV = 10 TeV
Λ_VV = 15 TeV
Λ_VV = 20 TeV
Constructive Interference
500
1000
1500
2000
2500
Jet p_T (GeV)

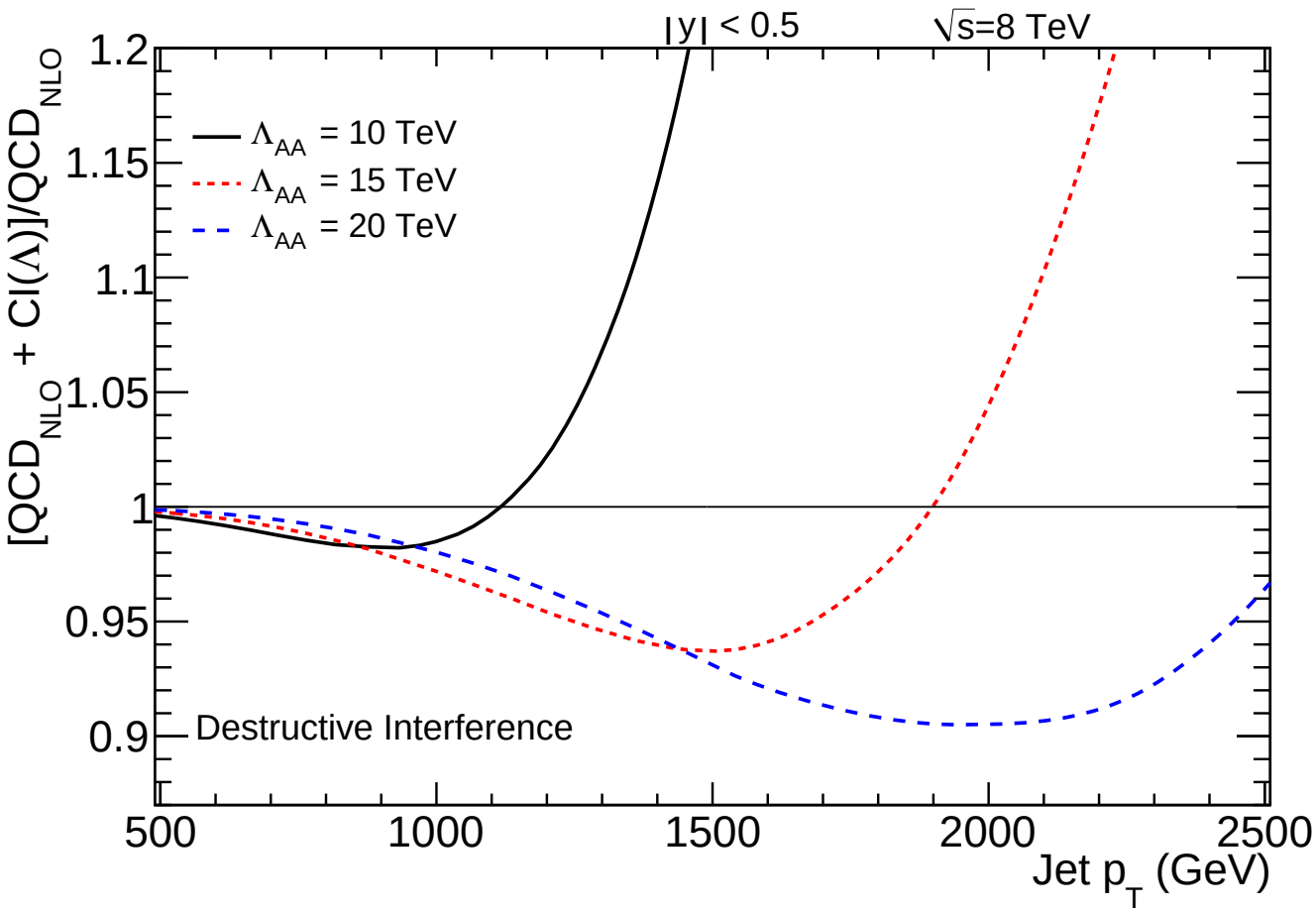
VV Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_VV = 10 TeV
Λ_VV = 15 TeV
Λ_VV = 20 TeV
Destructive Interference
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500
Jet p_T (GeV)

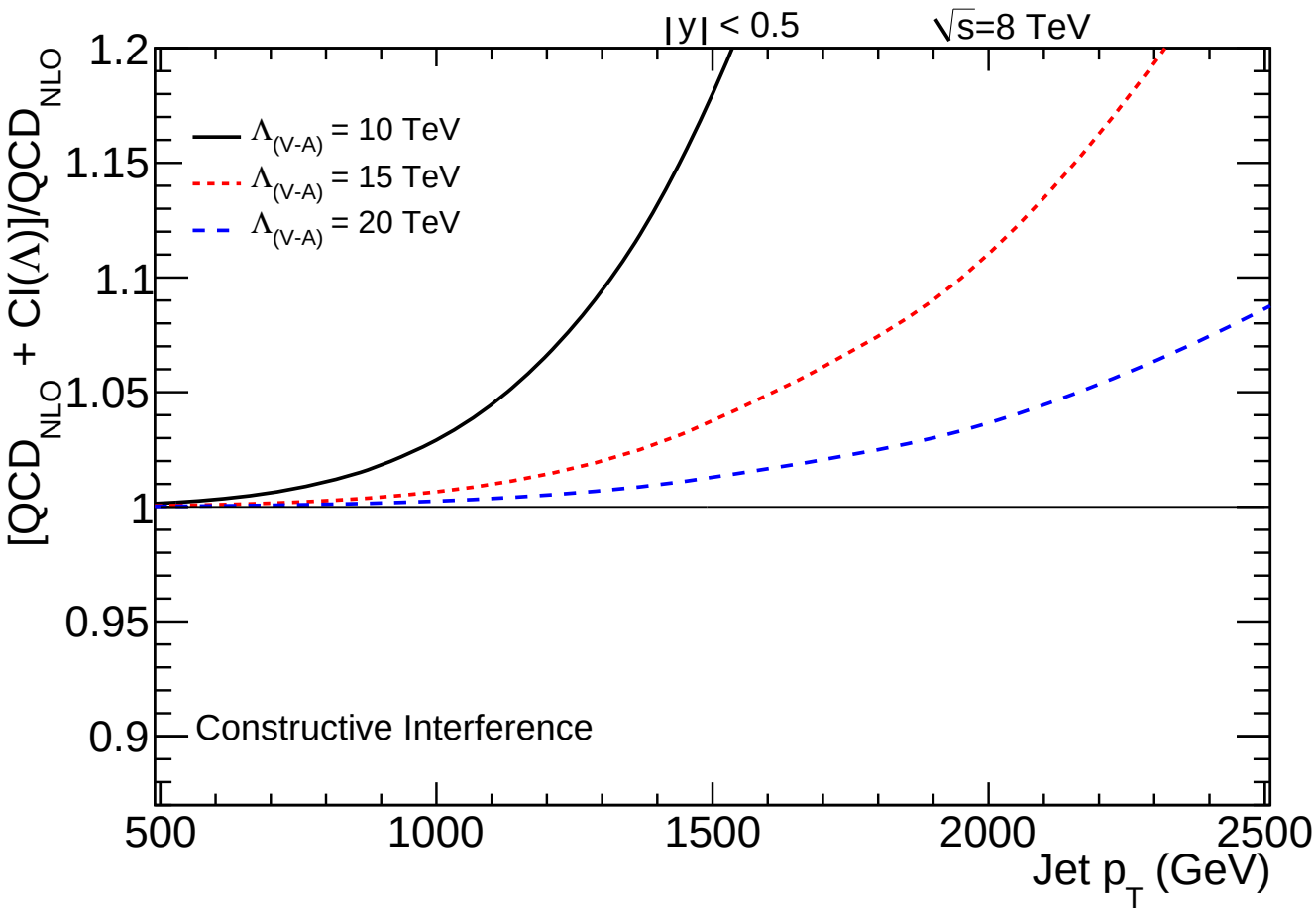
AA Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
1.2
1.15
1.1
1.05
1
0.95
0.9
Λ_AA = 10 TeV
Λ_AA = 15 TeV
Λ_AA = 20 TeV
Constructive Interference
500
1000
1500
2000
2500
Jet p_T (GeV)

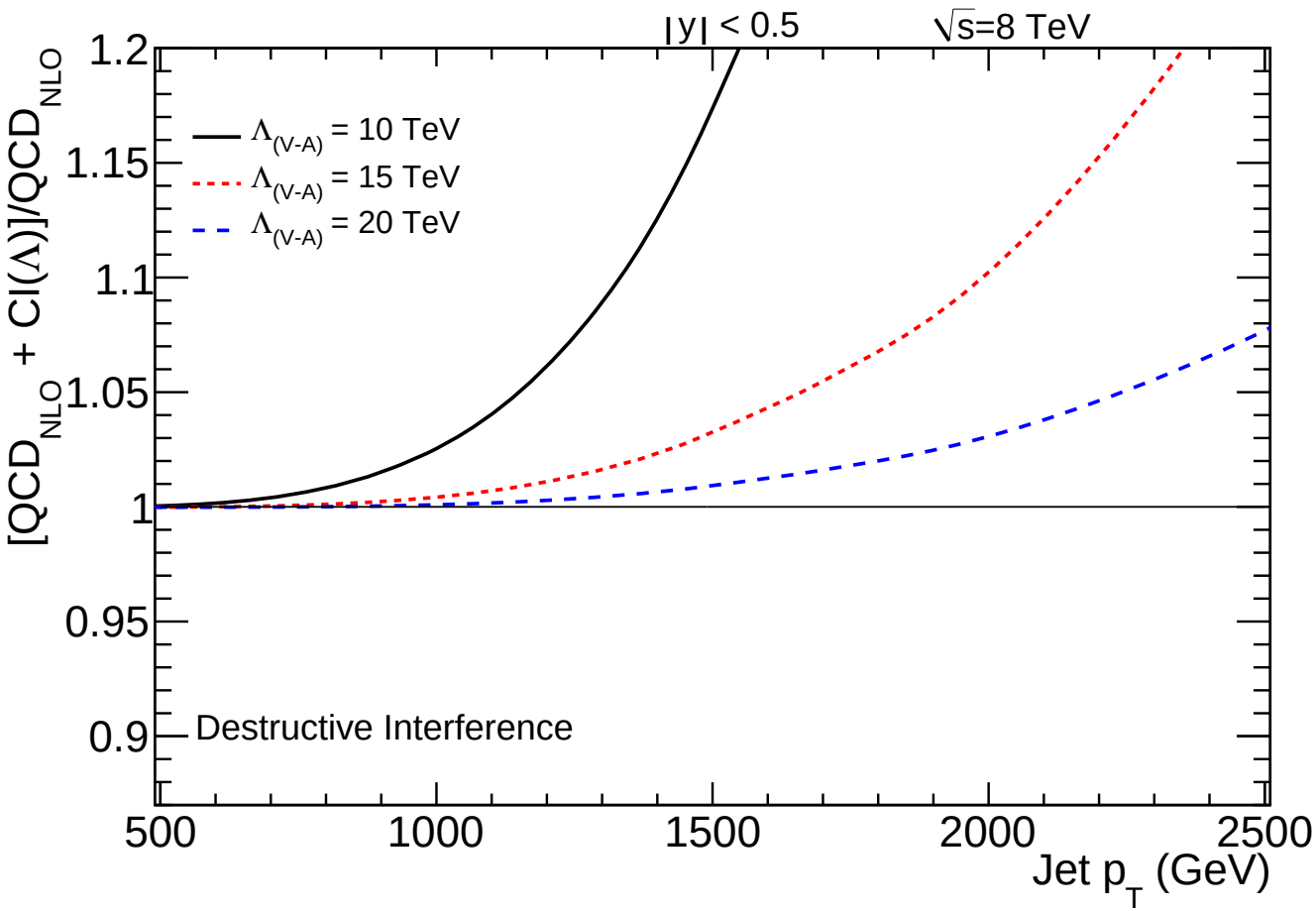
AA Model


|y| < 0.5
√s=8 TeV
[QCD_NLO + CI(Λ)]/QCD_NLO
Λ_AA = 10 TeV
Λ_AA = 15 TeV
Λ_AA = 20 TeV
Destructive Interference
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500
Jet p_T (GeV)

V-A Model


|y| < 0.5
√s=8 TeV
Λ(V-A) = 10 TeV
Λ(V-A) = 15 TeV
Λ(V-A) = 20 TeV
Constructive Interference
[QCD_NLO + CI(Λ)]/QCD_NLO
Jet p_T (GeV)
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500

V-A Model


|y| < 0.5
√s=8 TeV
Λ(V-A) = 10 TeV
Λ(V-A) = 15 TeV
Λ(V-A) = 20 TeV
Destructive Interference
[QCDNLO + CI(Λ)]/QCDNLO
Jet pT (GeV)
1.2
1.15
1.1
1.05
1
0.95
0.9
500
1000
1500
2000
2500