Open bottom production at NNLO+NNLL

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Open bottom production

- A wealth of data from the Tevatron and S$p\bar{p}$S on open bottom production
- Processes considered:

  $p\,\bar{p} \to b + X$

  $\left(\hookrightarrow B \;/\; \mu \;/\; J/\psi \;/\; \psi(2S)\right)$

  $p\,\bar{p} \to 2b + X$

  $\left(\hookrightarrow 2B \;/\; 2\mu\right)$
- Previous comparisons to theory: NLO(+NLL)

  Cacciari, Greco, Nason (1998)
- Consistently found data/theory $\approx 1.5 - 2$
  (initially data/theory ≈ 3 before theory improvements)
- We can do better: NNLO+NNLL!
- Calculations were performed using C++ library STRIPPER

Addressing the Tevatron 'excess'

- Many measurements find ratio data/theory > 1
- Not always clear from individual measurements, but pattern appears when considering many measurements
- Idea: 'average' many measurements
- Rigorous combination not feasible (by us)
- But: rough estimate sufficient for our purposes
- $\Rightarrow$ Simple weighted average with conservative error estimate

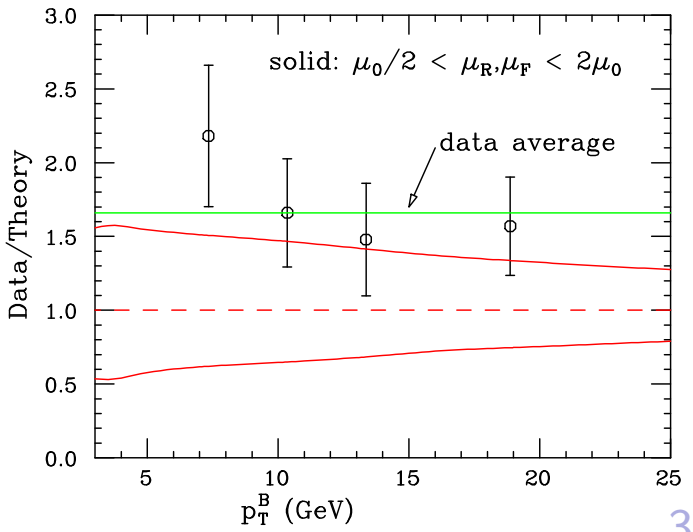
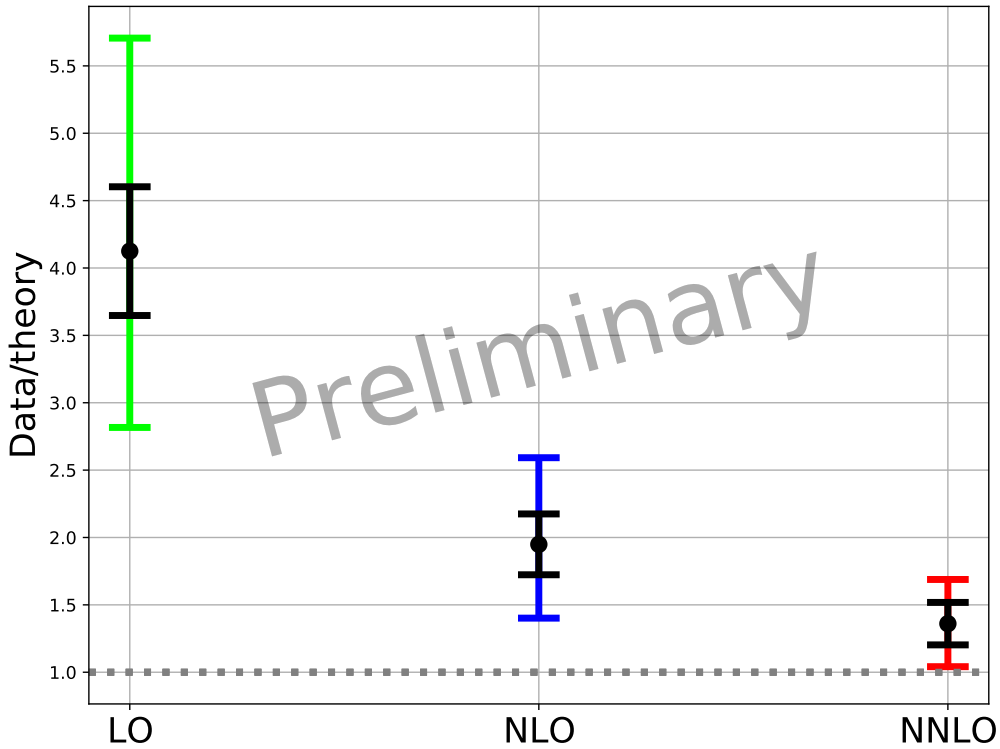


Figure taken from *Is There a Significant Excess in Bottom Hadroproduction at the Tevatron?* (Cacciari and Nason, 2002)

Addressing the Tevatron 'excess'

- Average of 21 measurements
- Data published at b-quark level
- Fiducial cross sections with p_T cuts from 5 GeV to 56.6 GeV
- Ratio shows no (statistically significant) p_T-dependence

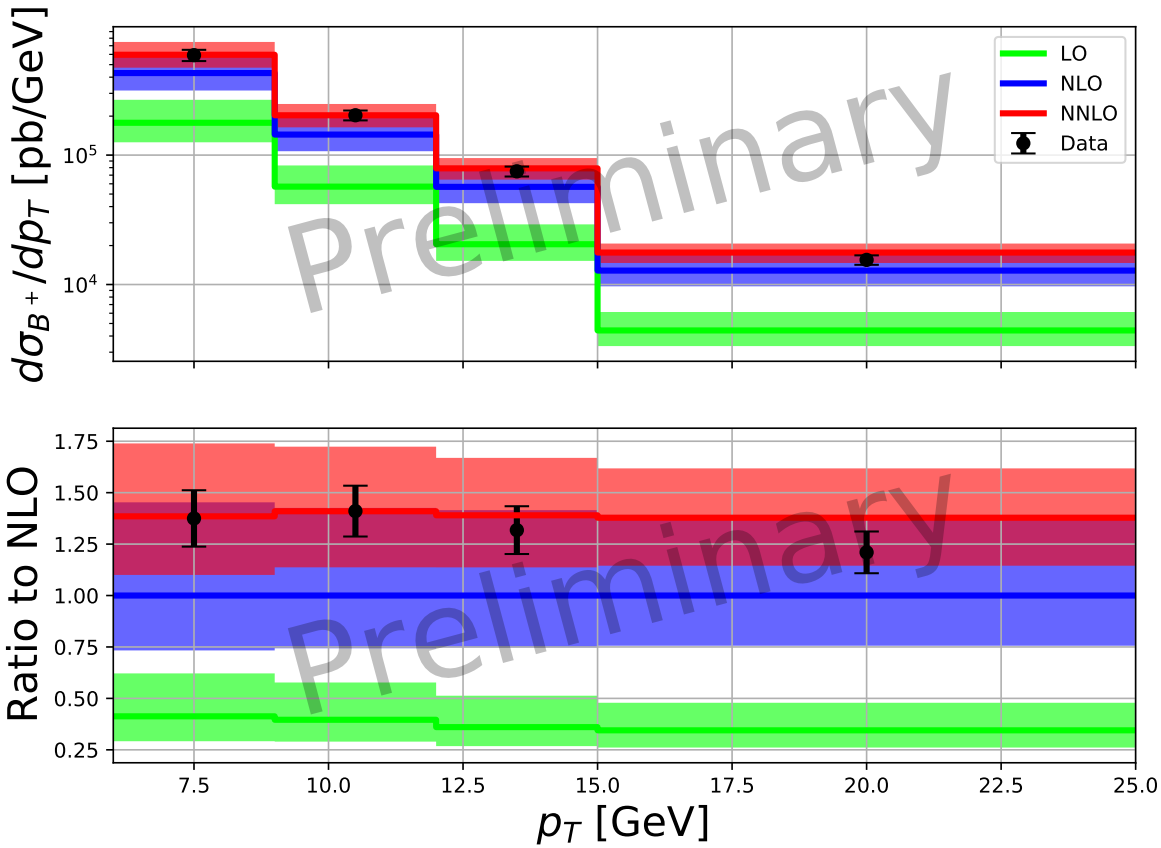


$$\text{NLO: } 1.95 \pm 0.23(\text{exp.})^{+0.64}_{-0.55}(\text{th.})$$
$$\text{NNLO: } 1.36 \pm 0.16(\text{exp.})^{+0.33}_{-0.32}(\text{th.})$$

Much better agreement at NNLO!

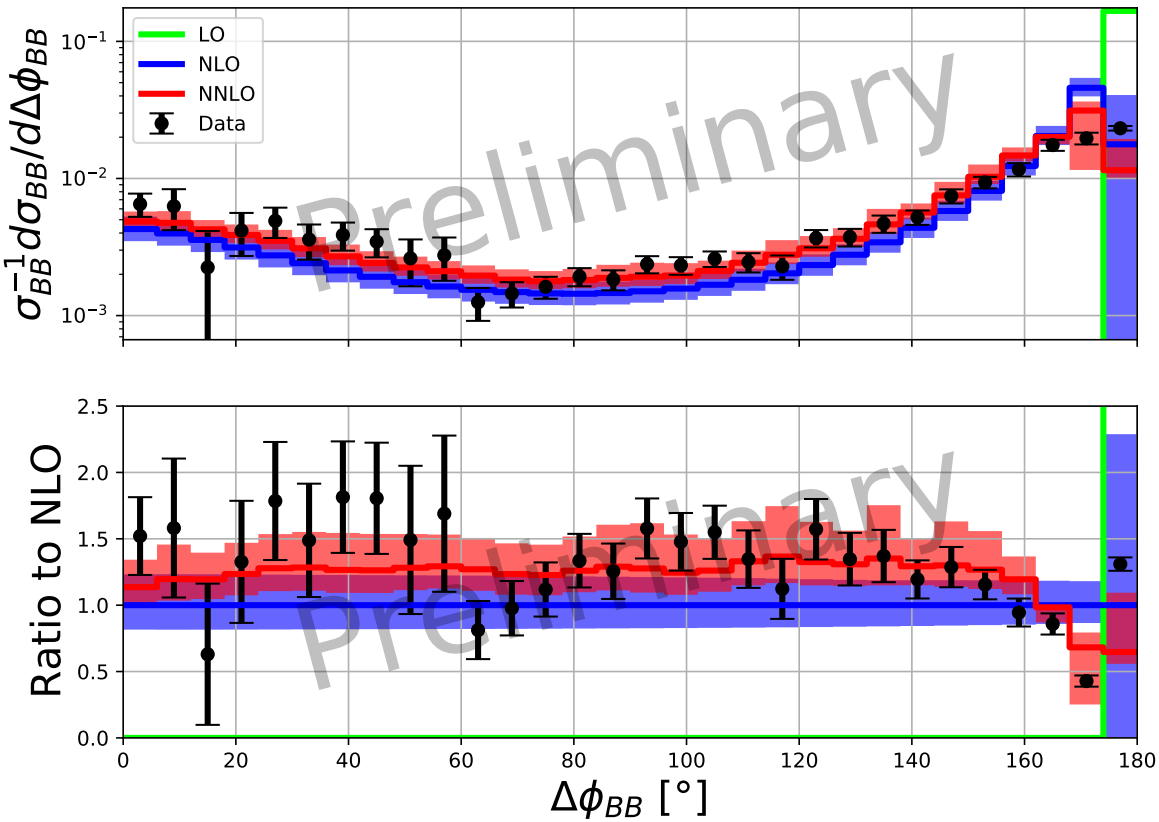
Differential measurement: B-hadron p_T

- CDF measurement of B^+ p_T spectrum Phys.Rev.D 75 (2007) 012010
- Large NNLO corrections
- Uncertainties reduced, but still quite large
- $\alpha_s(m_b) \approx 0.2$
  $\Rightarrow$ slow convergence



Differential measurement: *BB* angular correlation

- CDF measurement of *BB* azimuthal distribution Phys.Rev.D 71 (2005) 092001
- Significantly improved agreement at NNLO
- (Expected) slow convergence of last two bins
- NNLO nevertheless major improvement over NLO even here



What about resummation?

- All results so far involve fixed-order massive $b\bar{b}$ production
- Nothing new: b-quark-level NNLO predictions available for a while

  Catani, Devoto, Grazzini, Kallweit, Mazzitelli (2020)
- Also B-hadron-level NNLO using parton shower

  Mazzitelli, Ratti, Wiesemann, Zanderighi (2023)
- Real novelty of this talk: NNLL resummation
- Specifically: resummation of $\ln(p_{T,b}^2/m_b^2)$ at high p_T
- Essentially a straightforward extension of FONLL

The muon p_T spectrum through NNLO+NNLL

- Study muons from B-hadron decays at 630 GeV S$p\bar{p}$S

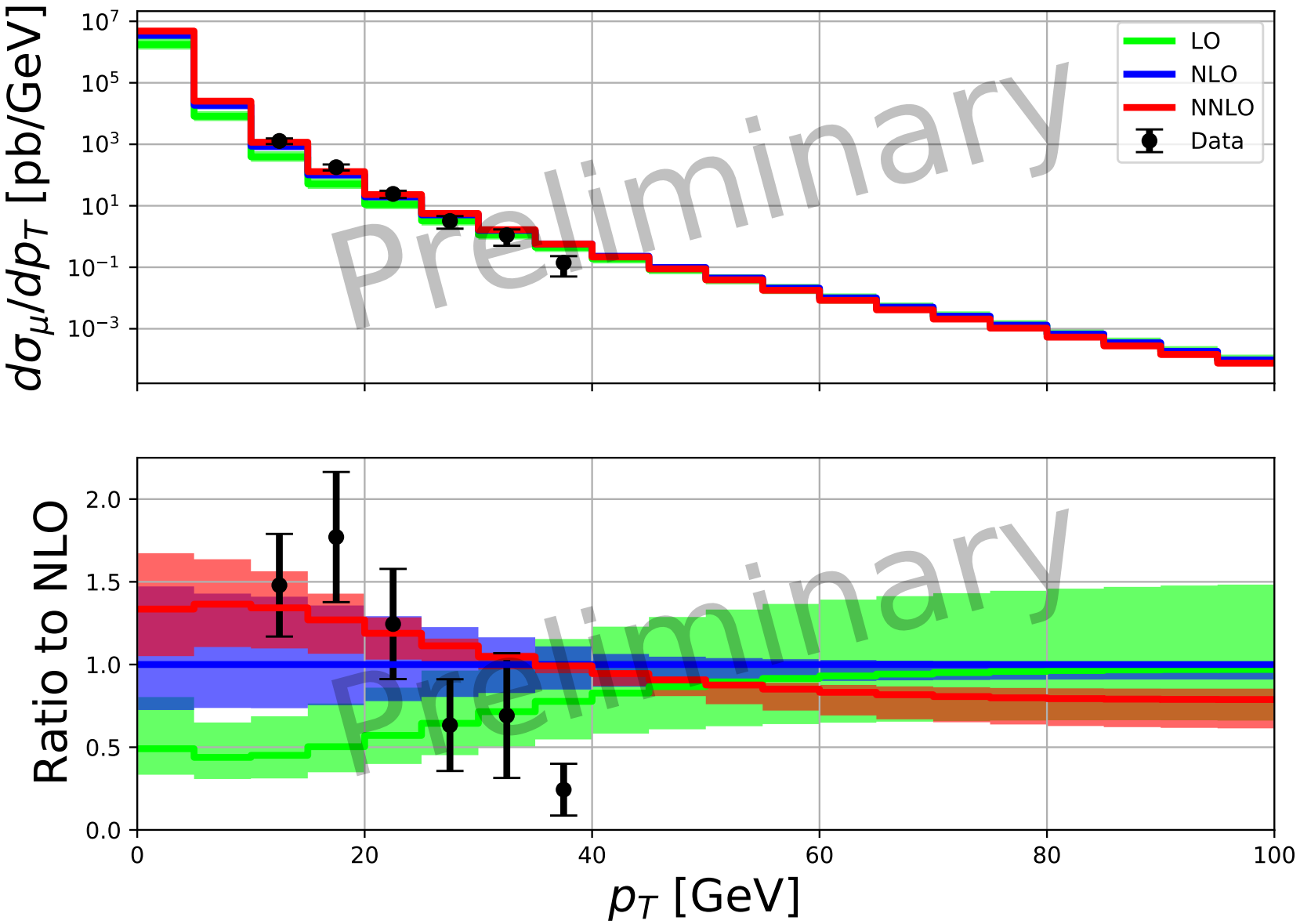
  Phys.Lett.B 256 (1991) 121

- Probes muons up to 40 GeV $\leftrightarrow$ b-quarks up to $\sim$ 80 GeV

- $\Rightarrow \ln(p_{T,b}^2/m_b^2) \sim 6$

- Resummation effects expected to be large

The muon p_T spectrum through NNLO+NNLL



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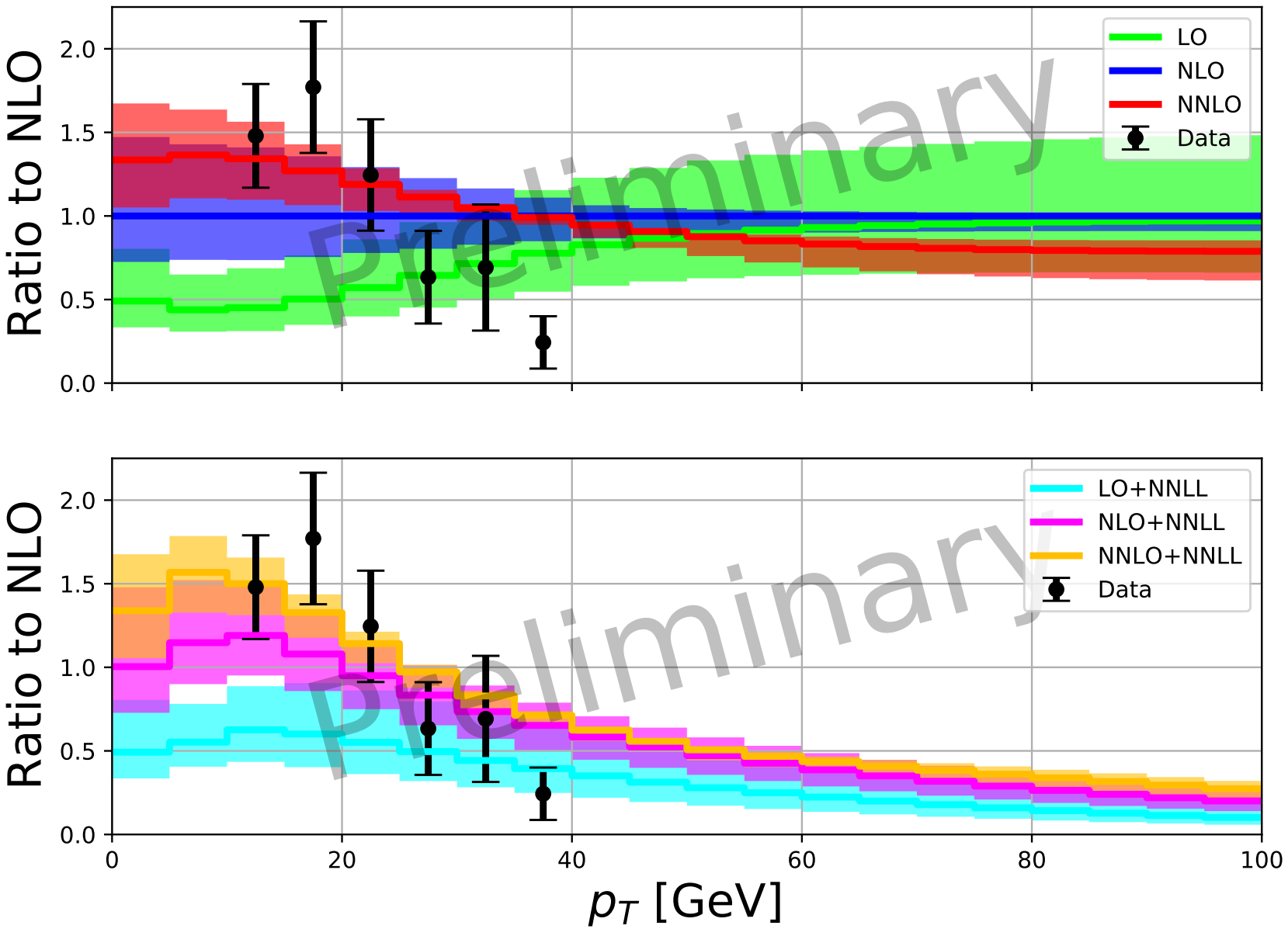

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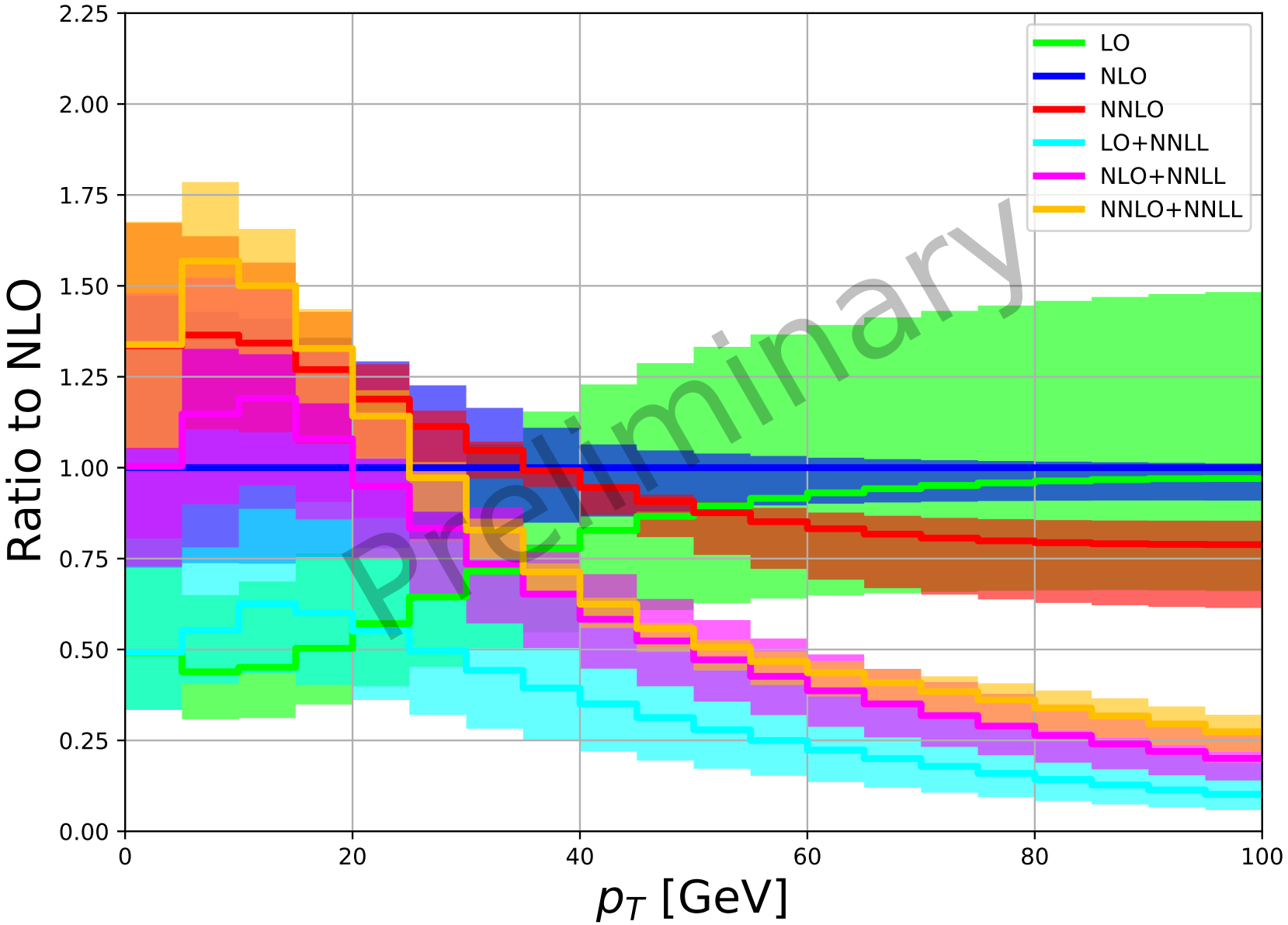
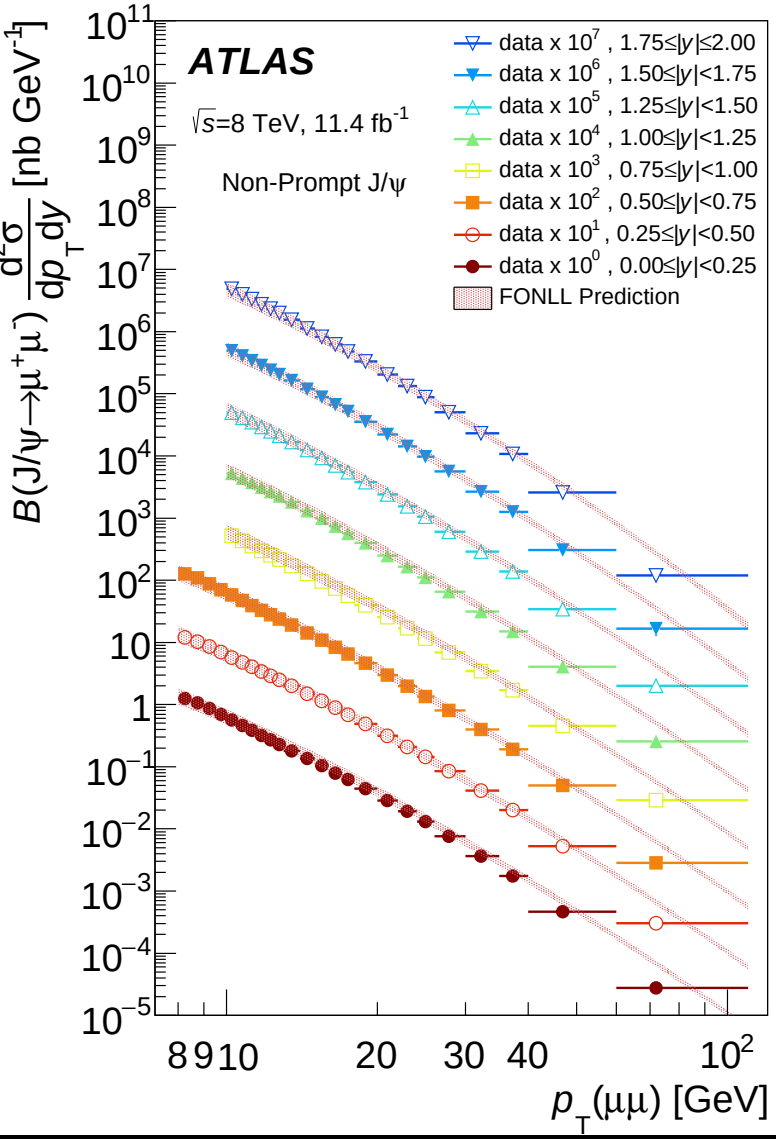
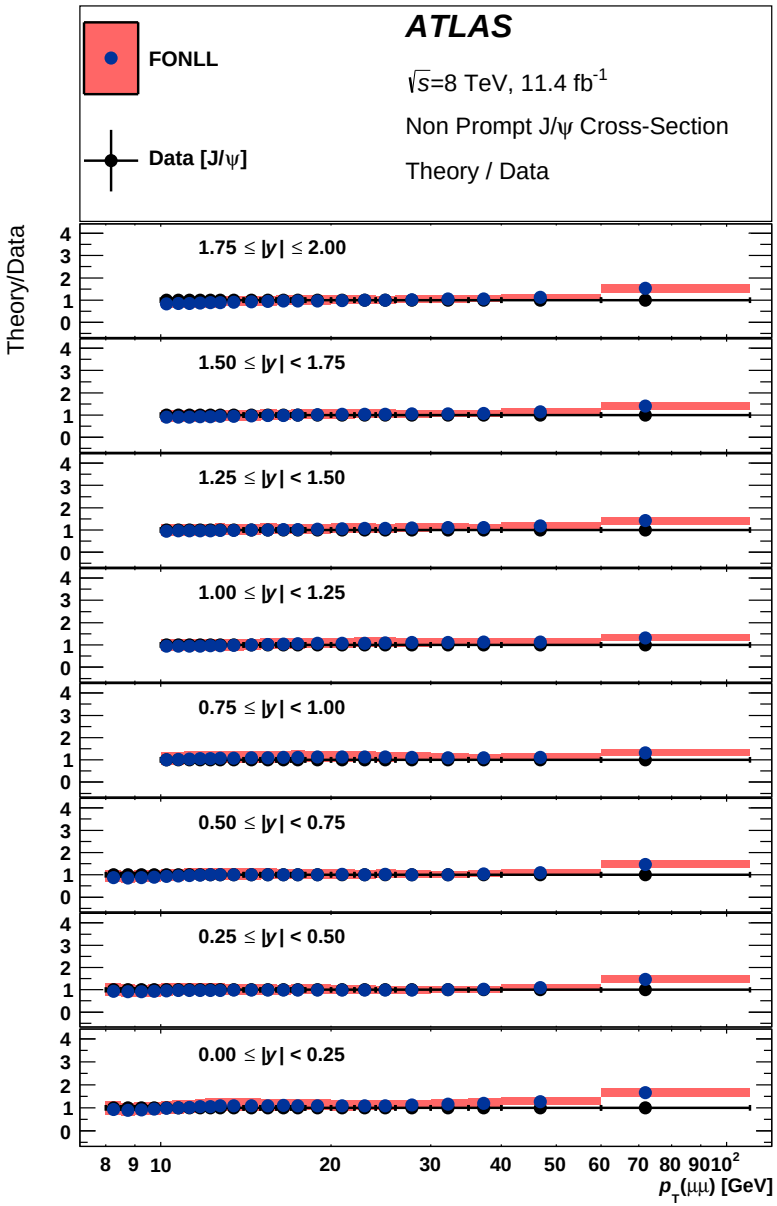


But what about the LHC?

ATLAS study: J/ψ's from B-hadron decays

Eur.Phys.J.C 76 (2016) 5, 283





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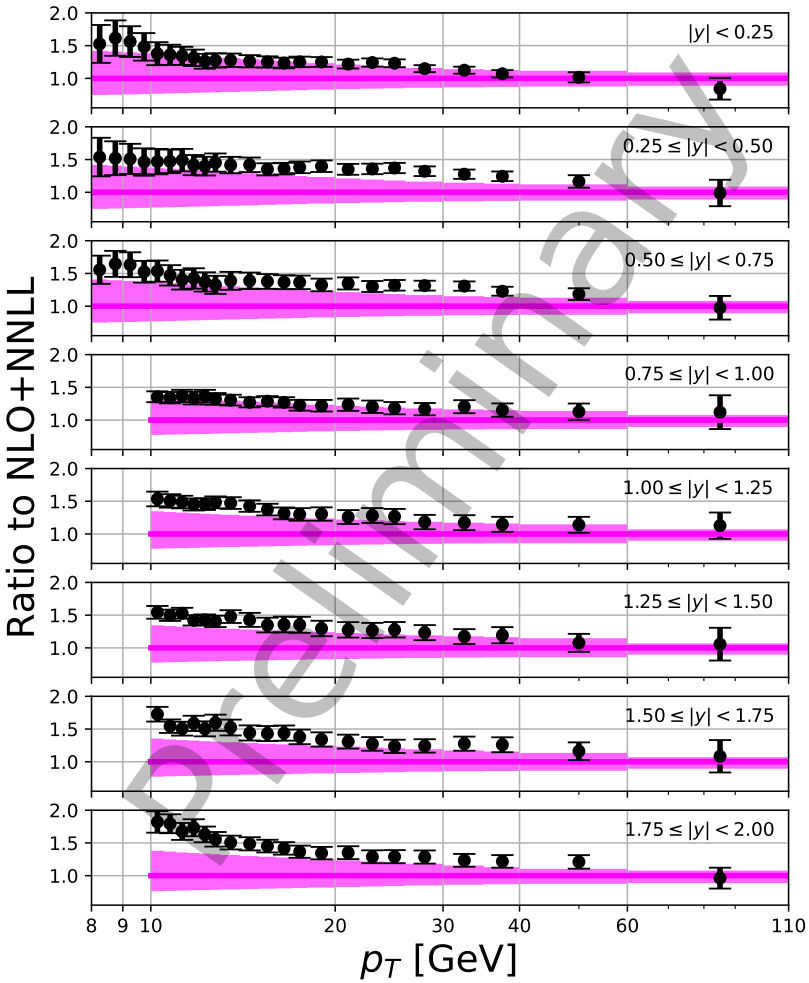

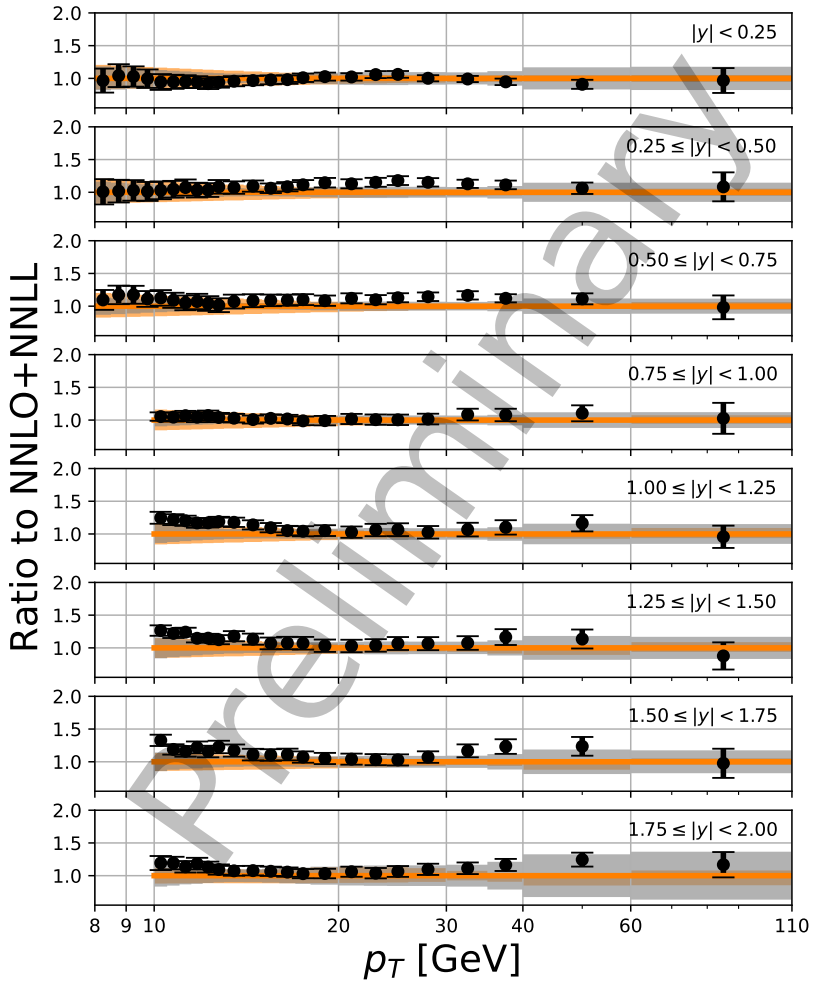

Conclusion & outlook

- First NNLO+NNLL calculation of open bottom at hadron colliders
- NNLO corrections essentially get rid of the old Tevatron 'excess'
- NNLO+NNLL improves agreement with Tevatron, S$p\bar{p}$S and LHC data
- Much smaller uncertainties than at NLO+NLL
- LHC prediction shown just an early example: many interesting measurements made over the years. More results to come!