北京師範大學
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N-jettiness Subtraction

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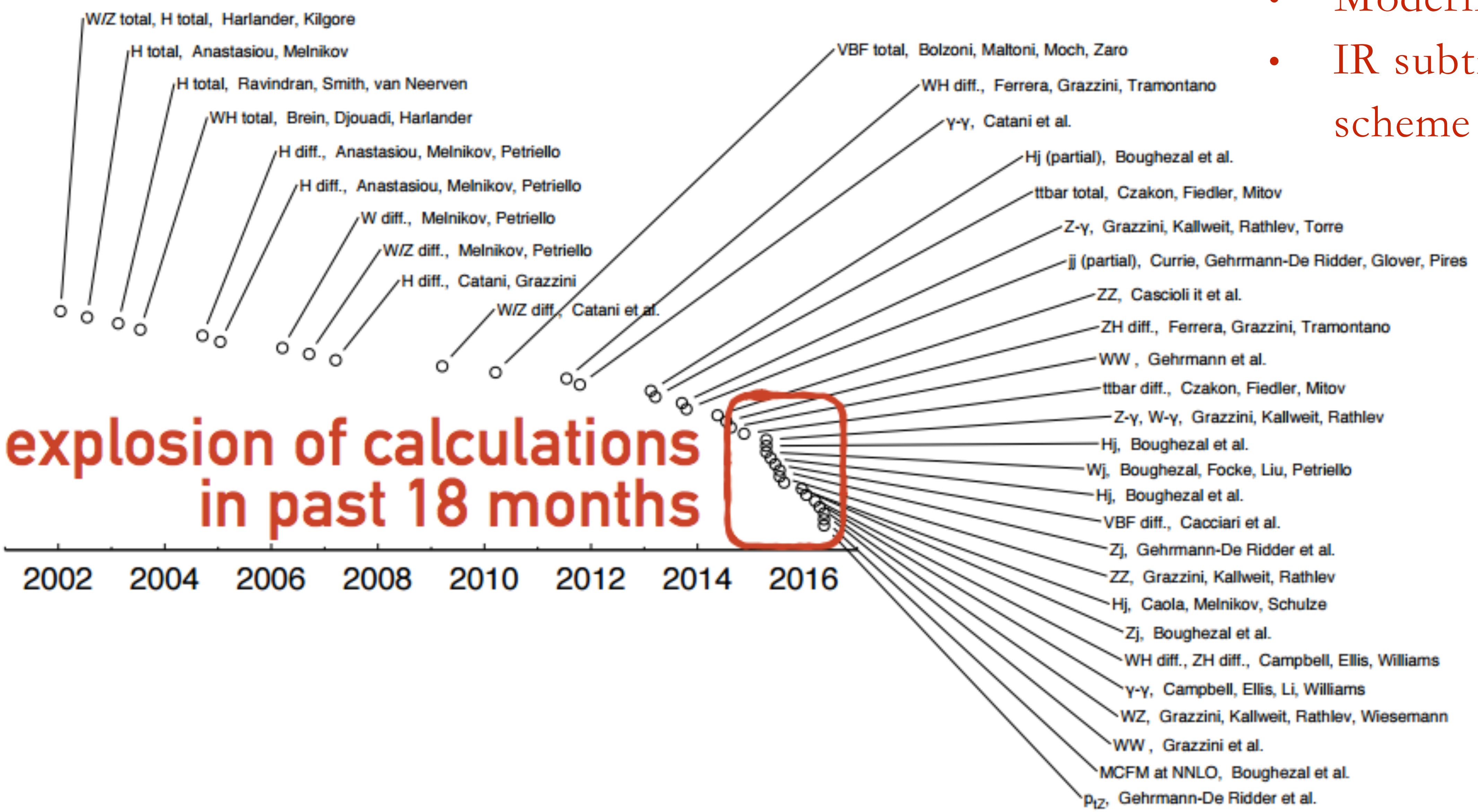
Current Status of NNLO Predictions



benefit from

- Modern amplitude
- IR subtraction scheme

Salam, LHCP '16

Current Status of NNLO Predictions

- Big progress in understanding IR in real corrections

$$\int \mathrm{d}z \frac{f(z)}{z^{1+a\epsilon}}$$

Local Subtraction:

$$\int \mathrm{d}z \frac{f(z) - f(0)}{z} + \int \mathrm{d}z z^{-1-a\epsilon} f(0)$$

- improved Sector Decomposition — Czakon; Boughezal,et. al.; Caola, et. al.
- antenna subtraction — Kosower; Gehrmann-De Ridder, et. al.

- relatively more smooth integrand
- but still numerically challenging at NNLO
- conceptually hard to implement

Current Status of NNLO Predictions

- Big progress in understanding IR in real corrections

$$\int \mathrm{d}z \, \frac{f(z)}{z^{1+a\epsilon}}$$

Global Scheme:

$$\int \frac{f(z)}{z}\theta(z > z_0) - f(0)\frac{z_0^{-a\epsilon}}{a\epsilon} + \ldots$$

Power corrections, vanishes as z_0 -> 0. Can be added systematically

Moult et.al.; Boughezal, et. al.

- qT subtraction ($W/H \cdots$) Catani et. al.
- jet mass (top quark physics) Gao et. al.
- N-jettiness scheme (generic jet process) Boughezal, et. al.; Gaunt, et. al.

achieves the most NNLO calculations so far

- numerical challenging
- conceptually easy to implement

N-jettiness scheme

- the N-jettiness observable   Stewart, Tackmann, Waalewijn

$$\mathcal{T}_N = \sum_k \min \{ w_a \, n_a \cdot q_k \, , w_b \, n_b \cdot q_k \, , w_i \, n_i \cdot q_k \, , \ldots \, , w_N \, n_N \cdot q_k \}$$

N	the minimum number of jets required
n_i	light-like vectors along beam or jet axes
q_k	final state partons ' 4-momenta
w_k	arbitrary positive weight

N-jettiness scheme

- the N-jettiness observable Stewart, Tackmann, Waalewijn

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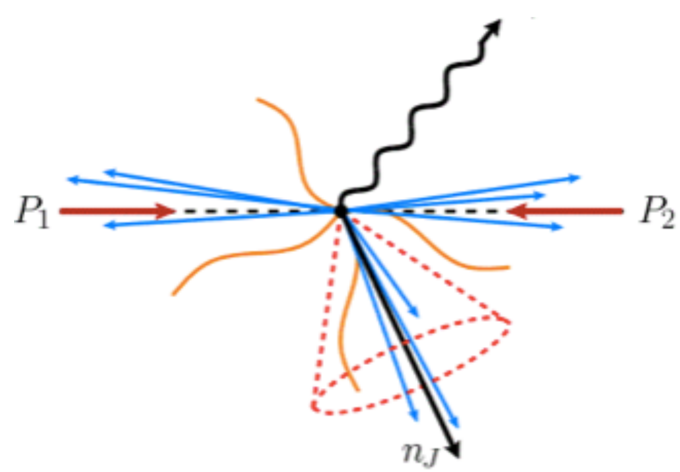

- 2-loop, soft+collinear contributions
- simple calculation using EFT
- all components known to 2-loop
- universal (almost)
- power corrections vanish as $\mathcal{T}_N \to 0$

$$\mathrm{Tr}[H \cdot S_N] \otimes B_a \otimes B_b \otimes J_i + \dots$$

jet: Becher and Neubert, Becher and Bell

beam: Gaunt, Stahlhofen, Tackmann

soft: Boughezal, XL and Petriello

$\mathcal{T}_N \to 0$

$$\int \frac{f(z)}{z}\theta(z > z_0) - f(0)\frac{z_0^{-a\epsilon}}{a\epsilon} + \dots$$

N-jettiness scheme

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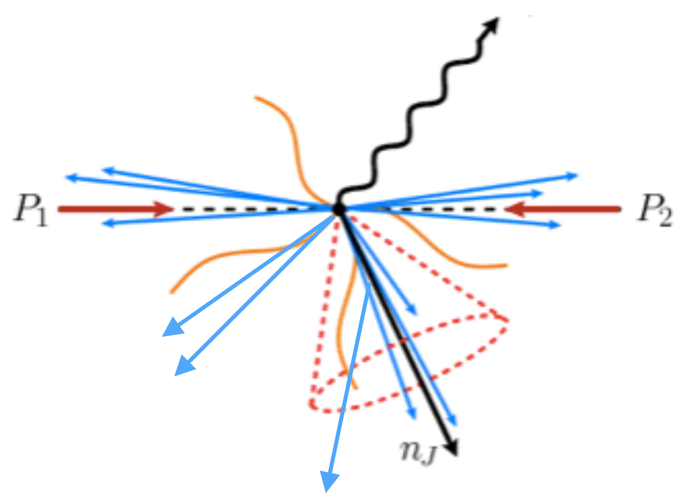
- at least N+1 hard radiations
- NNLO reduces to NLO N+1j
- known NLO results/methods/tools



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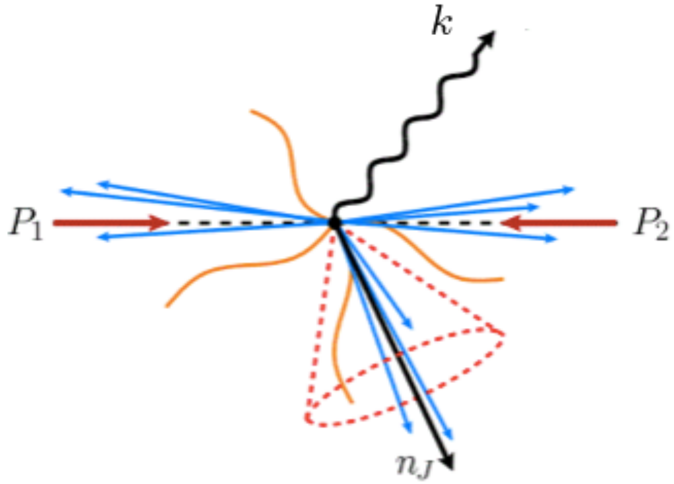
$$\int \frac{f(z)}{z}\theta(z > z_0) - f(0)\frac{z_0^{-a\epsilon}}{a\epsilon} + \dots$$

N-jettiness scheme

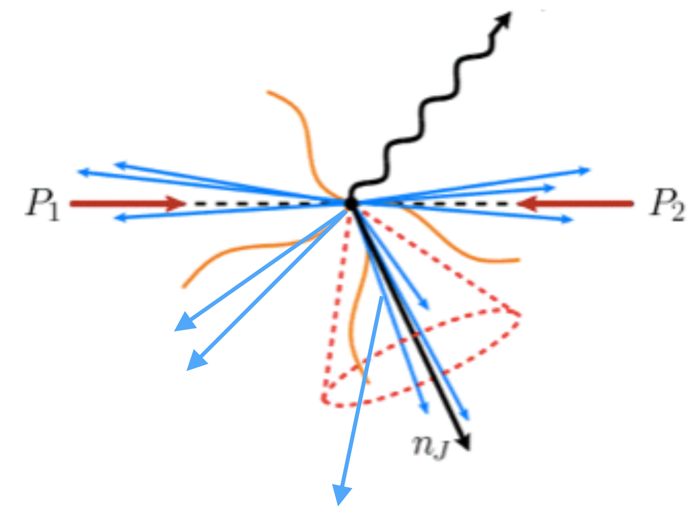
- N-jettiness as an NNLO scheme

Boughezal, Focke, XL, Petriello; Gaunt, Stahlhofen, Tackmann, Walsh

$$\mathcal{T}_N = \sum_k \min\{w_a\, n_a \cdot q_k\,, w_b\, n_b \cdot q_k\,, w_i\, n_i \cdot q_k\,, \ldots\,, w_N\, n_N \cdot q_k\}$$



- generate phase space and measure T_N
- introduce a small T_{cut}
- $T_N > T_{cut}$: NLO N+1j
- $T_N < T_{cut}$: EFT @ NNLO



$\mathcal{T}_N \to 0$

large

$$\mathrm{Tr}[H \cdot S_N] \otimes B_a \otimes B_b \otimes J_i + \ldots$$

NLO N+1j

N-jettiness scheme

- 0-jet
  - Color singlet production at NNLO in MCFM

Boughezal, Campbell, Ellis, Focke, Giele, XL, Petriello, Williams

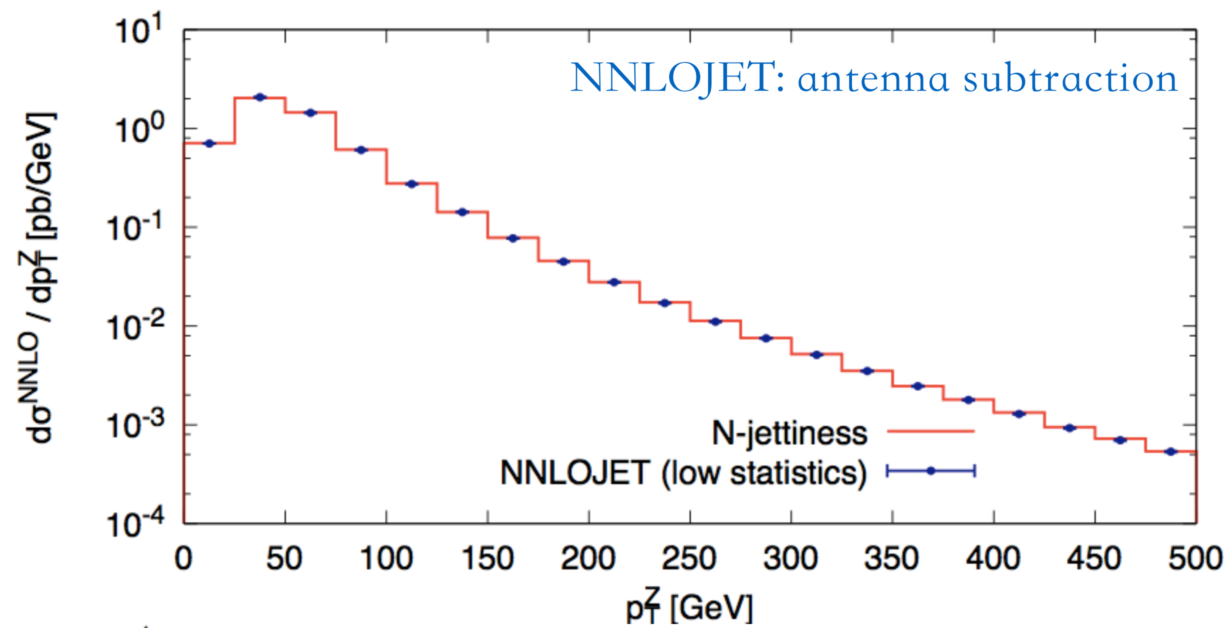
- 1-jet
  - H/V + 1-jet
  - DIS + 1-jet

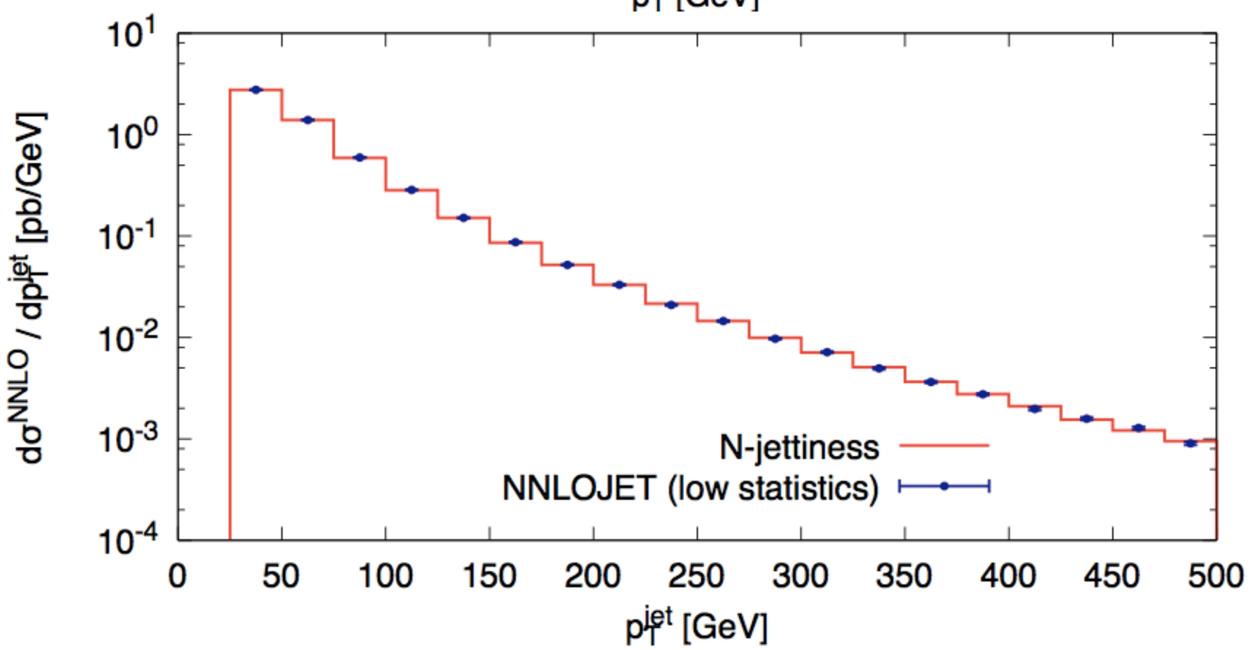
Boughezal, Focke, XL, Petriello;
Boughezal, Focke, Giele, XL, Petriello;
Boughezal, Campbell, Ellis, Focke, Giele, XL, Petriello
Campbell, Ellis, Williams

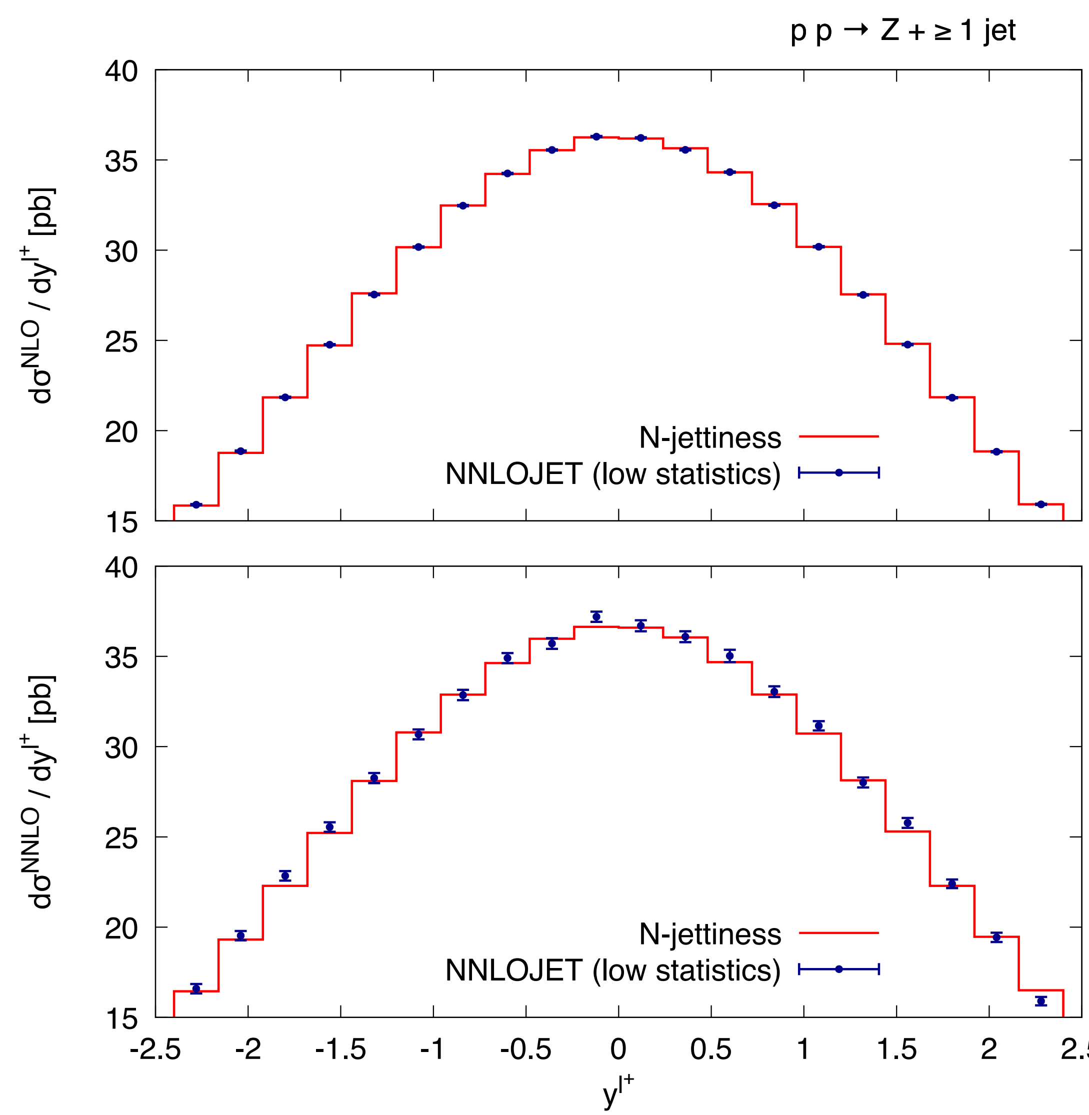
Ablof, Boughezal, XL, Petriello

N-jettiness scheme

- Good agreement between independent calculations





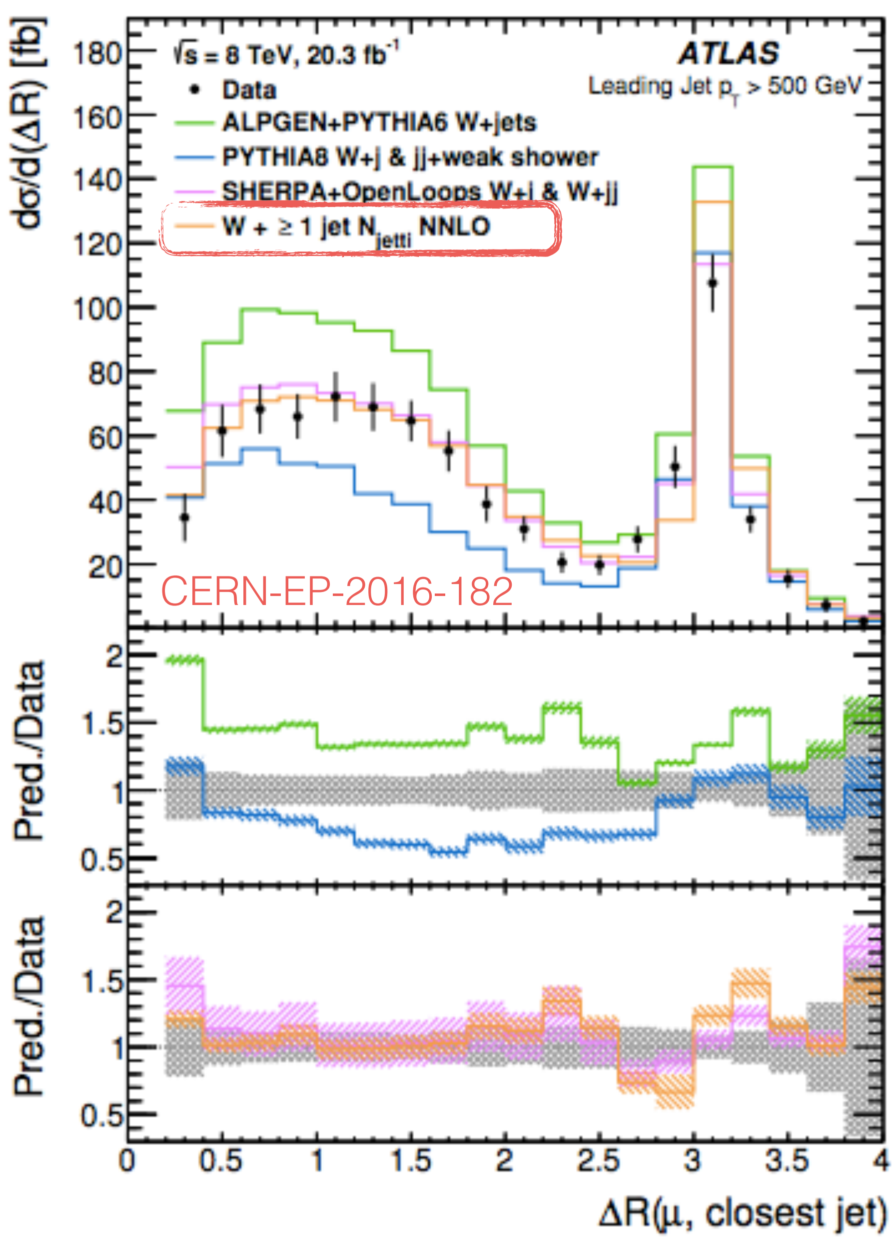


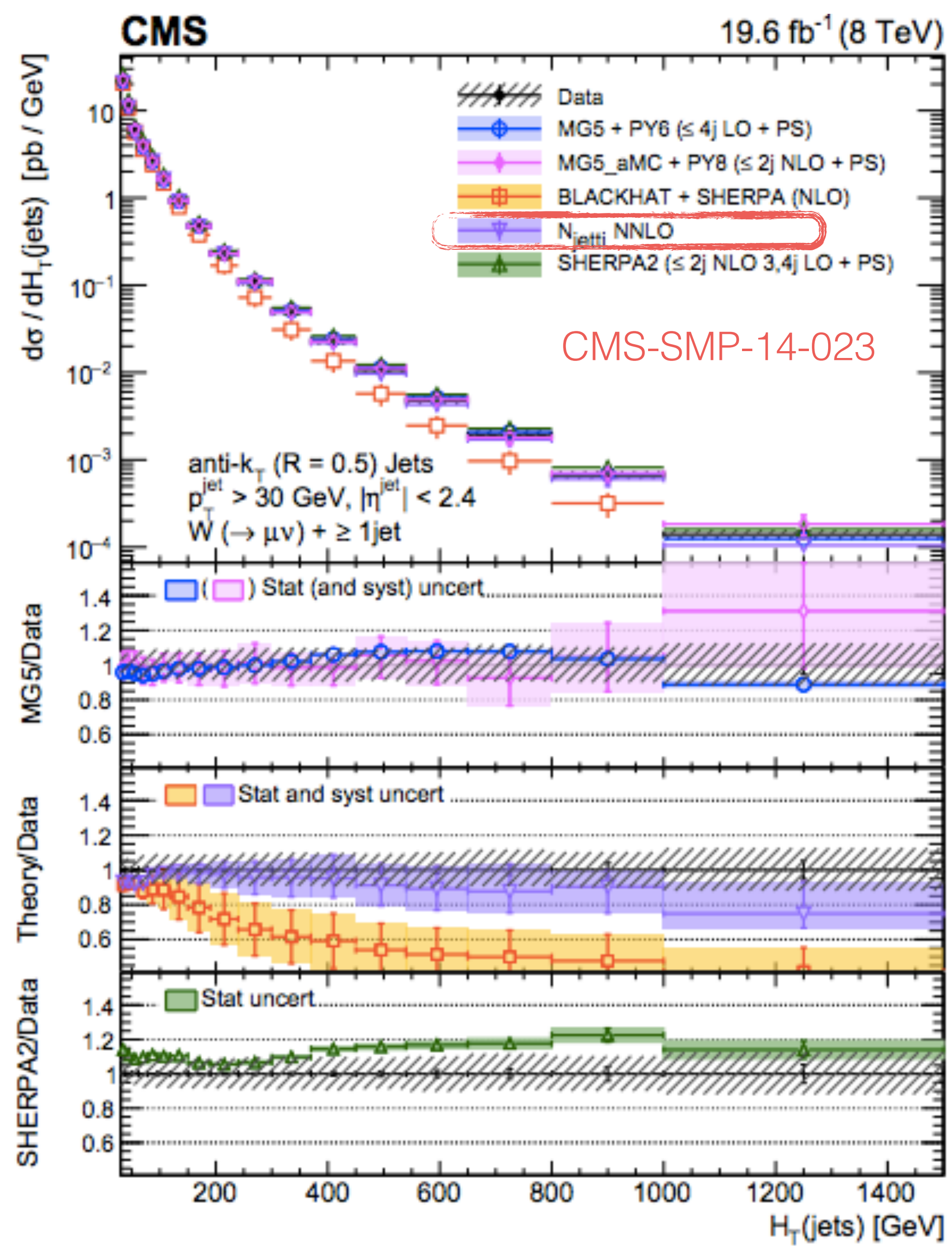
Boughezal, Campbell, Ellis, Focke, Giele, XL, Petriello

Gehrmann-De Ridder, Gehrmann, Glover, Huss, Morgan

N-jettiness scheme

- Good agreement with data





- Improved agreements with all measured distributions

Bougezhal, XL, Petriello

N-jettiness scheme

- Systematic to improve the convergence
  - Power corrections

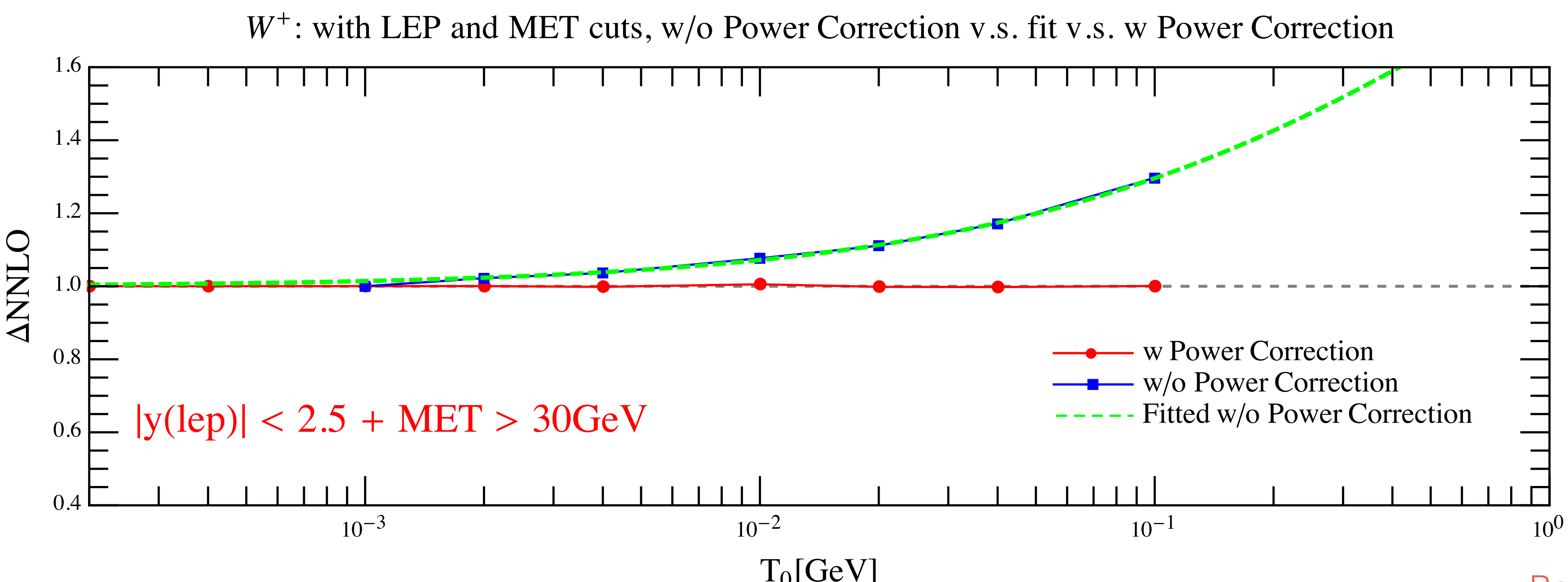
$$\mathrm{Tr}[H \cdot S_N] \otimes B_a \otimes B_b \otimes J_i + \ldots$$

$$\alpha_s^2 \, \tau_{cut} C_{23} \log^3(\tau_{cut})$$

Moult et.al.; Boughezal, XL, Petriello

N-jettiness scheme

- Systematic to improve the convergence
  - including power corrections substantially improves the convergence



Bougezhal, XL, Petriello

N-jettiness scheme

- Systematic to improve the convergence
  - including power corrections substantially improves the convergence
  - Other ways to improve: efficient phase space generator, choose reference vectors to minimize the power corrections $\cdots$

Conclusions

- N-jettiness scheme is proved to be successful for NNLO calculations and has been applied to various 0-jet and 1-jet productions at the LHC

- The convergence of the scheme can be systematically improved by adding the power corrections

- More to come

Thanks