Karlsruhe Institute of Technology

New developments in the APPLfast project

PhysTeV 2023 Workshop | École de Physique des Houches, Les Houches, France

Lucas Kunz | 15/06/2023

KARLSRUHE INSTITUTE OF TECHNOLOGY

Old Interface

- Grids generated based on NNLOJET modules 1 as MC
- Two publications:
  - $\alpha_s(\mathrm{M_Z})$ fits based on HERA DIS data [1906.05303]
  - jet production at LHC (inclusive and dijet) [2207.13735]
- $\Rightarrow$ see talk by Klaus Rabbertz (right before this one)

New Interface

- Interface adapted to use modules 2 of NNLOJET
  - better colour sampling
  - full colour dijet code
  - printout of intermediate results during production step
    $\Rightarrow$ workflow can better detect problematic phase space points
  - more flexible decomposition of logarithmic scale coefficients
    $\Rightarrow$ no need for „magical numbers“ in scale setup any more

```
        muf = 1.0 * mll          mur = 1.0 * mll
        muf = 0.5 * mll          mur = 0.5 * mll
        muf = 2.0 * mll          mur = 2.0 * mll
        muf = 1.0 * mll          mur = 0.5 * mll
        muf = 0.5 * mll          mur = 1.0 * mll
        muf = 1.0 * mll          mur = 2.0 * mll
        muf = 2.0 * mll          mur = 1.0 * mll

!       muf =             mll    mur =             mll
!       muf =  90.0171313005     mur =  90.0171313005
!       muf =  54.5981500331     mur =  54.5981500331
!       muf = 148.4131591026     mur = 148.4131591026
!       muf =  54.5981500331     mur =  90.0171313005
!       muf =  90.0171313005     mur =  54.5981500331
!       muf = 148.4131591026     mur =  90.0171313005
```

Dijet full colour

- Two different dijet full colour data sets produced for testing:
  - CMS at 7 TeV, anti-kt, R=0.6
  - double differential in $m_{12} \in [260.0, 5040.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - ATLAS at 13 TeV, anti-kt, R=0.4
  - double differential in $m_{12} \in [260.0, 9066.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - $\Rightarrow$ plots shown on the following slides

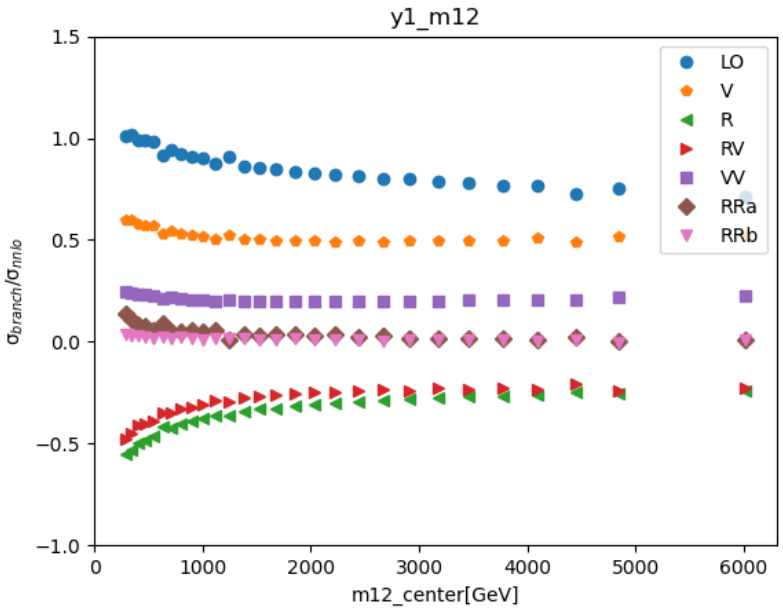
Dijet full colour

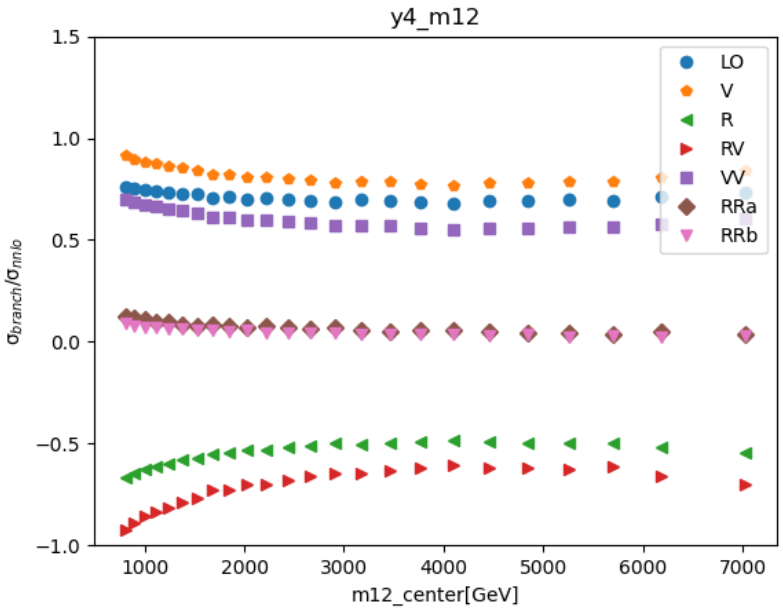
- Two different dijet full colour data sets produced for testing:
  - CMS at 7 TeV, anti-kt, R=0.6
  - double differential in $m_{12} \in [260.0, 5040.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - ATLAS at 13 TeV, anti-kt, R=0.4
  - double differential in $m_{12} \in [260.0, 9066.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - $\Rightarrow$ plots shown on the following slides

Dijet full colour

- Two different dijet full colour data sets produced for testing:
  - CMS at 7 TeV, anti-kt, R=0.6
  - double differential in $m_{12} \in [260.0, 5040.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - ATLAS at 13 TeV, anti-kt, R=0.4
  - double differential in $m_{12} \in [260.0, 9066.0]$ and $y^* \in [0.0, 3.0]$
  - PDF set: NNPDF31 nnlo as 0118
  - $\Rightarrow$ plots shown on the following slides

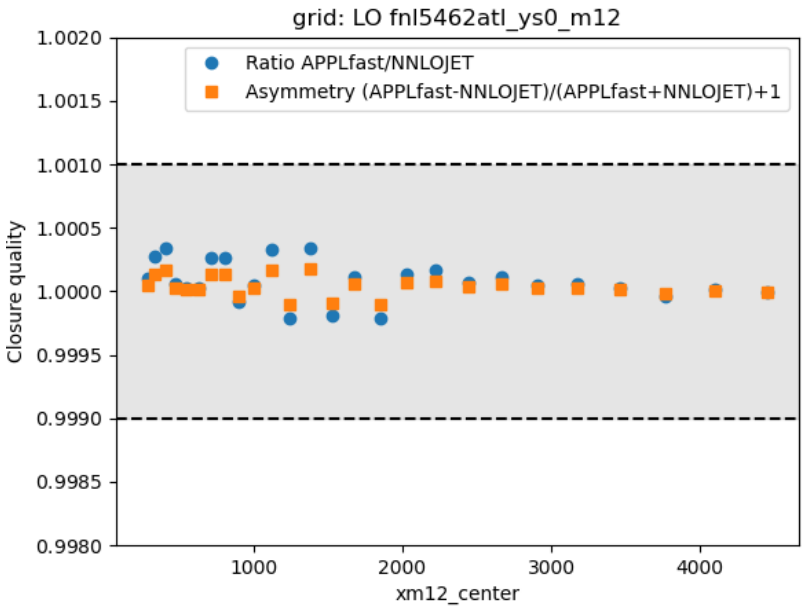
Dijet full colour - channels

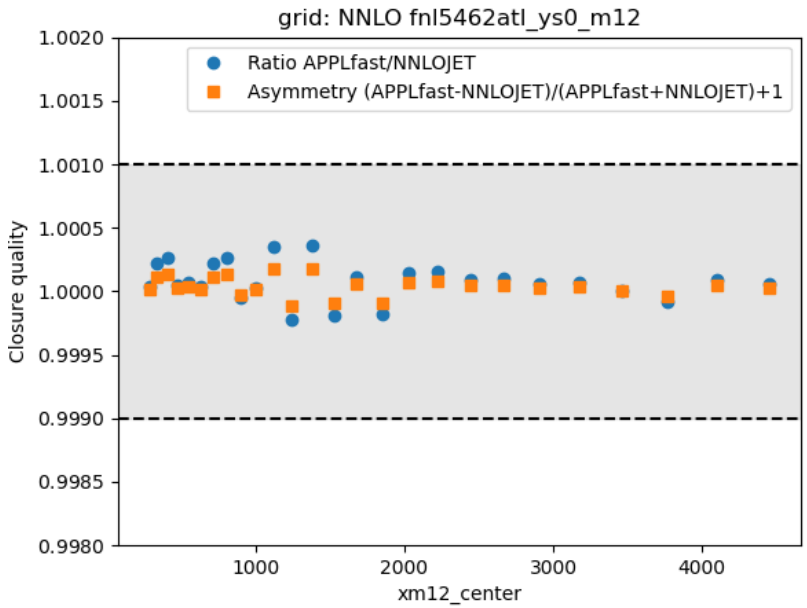




Plot of relative contributions of different channels shows large cancellations between real and virtual parts for higher y^*

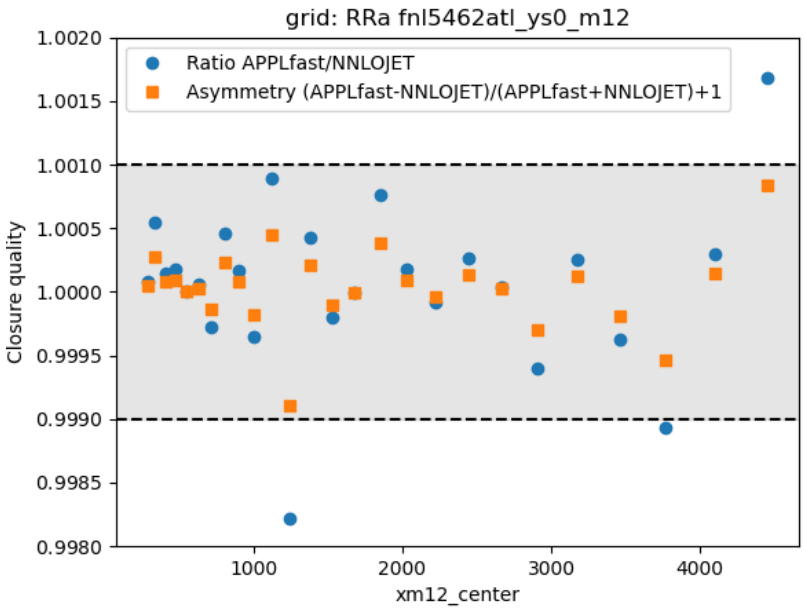
Dijet full colour - closure

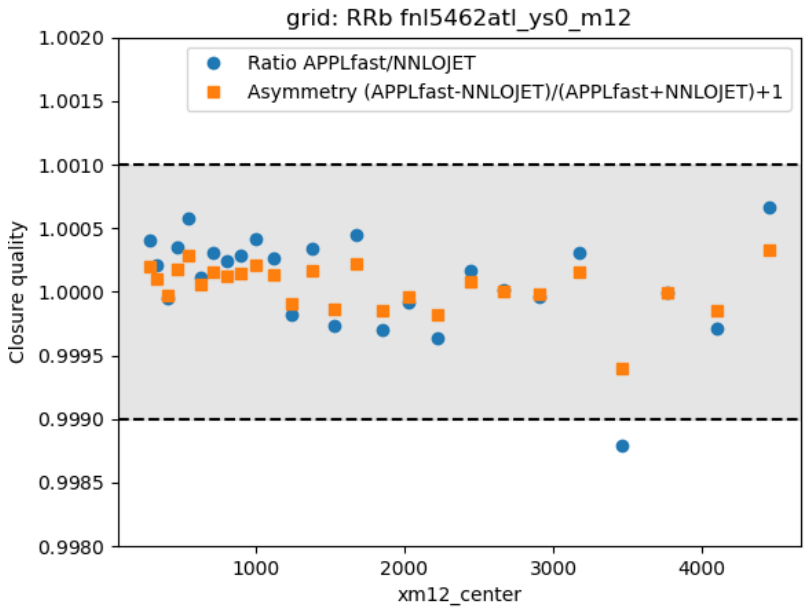




Overall we find good closure at sub-permille accuracy

Dijet full colour - closure





Even the most problematic channels (double real) show nice behaviour

Dijet full colour - runtimes

	Event	Jobs	neval	Tot Time	Cross section	Error
LO	$0.5*10^9$	27*8	$108*10^9$	$4.7*10^3$h	5.249331E+08	1.315478E+04
V	$8*10^6$	28*8	$1.792*10^9$	$3.6*10^3$h	4.089646E+08	1.072727E+05
R	$4*10^6$	84*8	$5.088*10^9$	$22.9*10^3$h	-3.296991E+08	2.205647E+05
	$10*10^6$					
VV	$15*10^6$	55*8	$6.006*10^9$	$4.8*10^3$h	2.200059E+08	7.435571E+04
RV	$0.67*10^6$	100*8	$1.1952*10^9$	$41.6*10^3$h	-3.385389E+08	8.122503E+05
	$1.7*10^6$					
RRa	$0.69*10^6$	300*8	$1.656*10^9$	$116*10^3$h	5.278204E+07	2.521830E+06
RRb	$3.75*10^6$	81*8	$3.436*10^9$	$19*10^3$h	2.386325E+07	1.117482E+06
	$11.2*10^6$					

	LO	*NLO*	*NLO_only*	*NNLO*	*NNLO_only*
Number of evaluations	$108*10^9$	$\sim 114.9*10^9$	$\sim 6.9*10^9$	$\sim 127.2*10^9$	$\sim 12.3*10^9$
Cross-section	5.249331E+08	6.041986E+08	7.926550E+07	5.623109E+08	-4.188771E+07
error	1.315478E+04	4.835966E+05	2.452676E+05	2.886867E+06	2.876399E+06

Dijet full colour - runtimes

TABLE 1.1: Profiling data for NNLOJET rev5918, nnlo-bridge v0.0.40

Subprocess	Runtime [s]	Incl. bridge + fastNLO [s]		Incl. fastNLO [s]	
LO	0.658	0.086	13.01%	0.053	7.98%
V	2.383	0.621	26.08%	0.535	22.46%
R	6.259	2.536	40.52%	1.950	31.15%
NLO	9.300	3.243	34.87%	2.538	27.29%
VV	6.999	0.379	5.42%	0.327	4.67%
RV	57.732	5.912	10.24%	4.624	8.01%
RRa	114.915	40.565	35.30%	31.452	27.37%
RRb	114.430	40.256	35.18%	32.395	28.31%
NNLO	303.376	90.355	29.78%	71.336	23.51%

TABLE 1.2: Profiling data for NNLOJET rev6591, nnlo-bridge v0.0.46

Subprocess	Runtime [s]	Incl. bridge + fastNLO [s]		Incl. fastNLO [s]	
LO	0.696	0.092	13.20%	0.062	8.91%
V	2.154	0.124	5.77%	0.082	3.83%
R	12.407	1.040	8.38%	0.605	4.88%
NLO	15.257	1.256	8.23%	0.749	4.91%
VV	9.710	0.201	2.07%	0.142	1.46%
RV	180.825	4.014	2.22%	2.387	1.32%
RRa	159.221	4.188	2.63%	2.341	1.47%
RRb	183.860	5.993	3.26%	3.659	1.99%
NNLO	548.873	15.652	2.85%	9.278	1.69%

Dijet full colour - runtimes

Subprocess	Runtime [s]	Incl. bridge + fastNLO [s]		Incl. fastNLO [s]	
LO	0.696	0.092	13.20%	0.062	8.91%
V	2.154	0.124	5.77%	0.082	3.83%
R	12.407	1.040	8.38%	0.605	4.88%
NLO	15.257	1.256	8.23%	0.749	4.91%
VV	9.710	0.201	2.07%	0.142	1.46%
RV	180.825	4.014	2.22%	2.387	1.32%
RRa	159.221	4.188	2.63%	2.341	1.47%
RRb	183.860	5.993	3.26%	3.659	1.99%
NNLO	548.873	15.652	2.85%	9.278	1.69%

leading colour

Subprocess	Runtime [s]	Incl. bridge + fastNLO [s]		Incl. fastNLO [s]	
LO	0.730	0.096	13.16%	0.065	8.88%
V	2.157	0.124	5.76%	0.082	3.82%
R	12.359	0.597	4.83%	0.582	4.71%
NLO	15.246	0.817	5.36%	0.729	4.78%
VV	20.731	0.369	1.78%	0.251	1.21%
RV	1700.880	13.607	0.80%	7.994	0.47%
RRa	672.888	17.629	2.62%	9.689	1.44%
RRb	696.900	22.719	3.26%	14.008	2.01%
NNLO	3105.745	55.141	1.78%	32.671	1.05%

full colour

Subprocess	Runtime [s]	Incl. bridge + fastNLO [s]		Incl. fastNLO [s]	
LO	0.676	0.010	1.52%	0.010	1.00%
V	0.691	0.021	2.99%	0.014	2.01%
R	0.971	0.068	7.04%	0.040	4.12%
NLO	2.338	0.099	4.23%	0.064	2.74%
VV	1.084	0.017	1.55%	0.011	1.06%
RV	10.086	0.179	1.77%	0.103	1.02%
RRa	14.809	0.244	1.65%	0.144	0.97%
RRb	15.282	0.319	2.09%	0.192	1.26%
NNLO	43.599	0.858	1.97%	0.514	1.18%

full colour with optimised colour sampling

Dijet full colour - runtimes

- bridge and fastNLO make up negligible amount of runtime ($\sim 1\%$)
- overall @ NNLO: FC with optimisation $<$ LC $<$ FC
- better momentum caching in NNLOJET brought additional speedup:
  - 24% for LC
  - 11% for FC
  - 18% for FC with optimised colour sampling
- $\Rightarrow$ ready for mass production in reasonable time

Next steps

- finalize validation of NNLO code
  - optimize workflow and runtime
  - make sure closure works in all channels
  - reproduce results in [2207.13735]
- calculate dijet differential distributions at full colour
- $\alpha_s(\mathrm{M_Z})$ determination from LHC data
- provide setup for further developments and calculations

Thank you for your attention!