DESY Summer School - Students Session

A Comparison of the WHIZARD and ALPGEN event generators

Dirk Rathlev
Supervisor: Jürgen Reuter

Georg-August-Universität Göttingen

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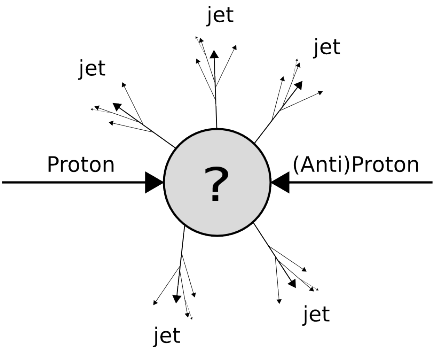
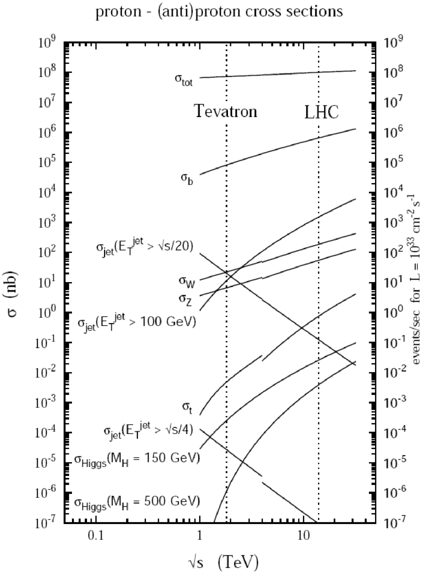
Outline

Scattering processes at hadron colliders

- scattering of composite particles
- QCD $\Rightarrow$ non-perturbative effects
- complicated event topology
- large background



Cross sections



Factorization

- different QCD effects at different time/energy scales
- nuclear force inside the proton/antiproton
- partonic scattering process
- jet formation and hadronization

$$\mathrm{d}\sigma(pp \to X) = \sum_{i,j,k} \int \mathrm{d}x_i \, \mathrm{d}x_j f_i^p(x_i, \mu^2) f_j^p(x_j, \mu^2) \mathrm{d}\sigma(ij \to Y_k) P(Y_k \to X)$$

- f_i^p from measurements (DIS, ...)
- $\mathrm{d}\sigma(ij \to Y_k)$ from perturbative QCD
- $P(Y_k \to X)$ from shower/hadronization models

Hard scattering

- already at leading order lots of diagrams
- get matrix elements by algebraic or numerical methods
- phase space integral has high dimensionality $\Rightarrow$ use Monte Carlo methods

WHIZARD and ALPGEN event generators

ALPGEN

- collection of (hard coded) processes
- widely used, for example in LHC calculations
- mainly QCD amplitudes
- specialized and optimized for hadron colliders

WHIZARD 2

- relatively new
- general purpose generator: hadron/electron collider, BSM signals, ...
- much more flexible due to house made scripting language $\Rightarrow$ (almost) no hard coding needed
- different models can be chosen (and easily implemented): full standard model, pure QCD, MSSM, ...

Our task

- compute total cross sections with both programs
- compare them to each other
- compare QCD predictions to full standard model calculation
- basic process: $pp \to b\overline{b} + n$ jets

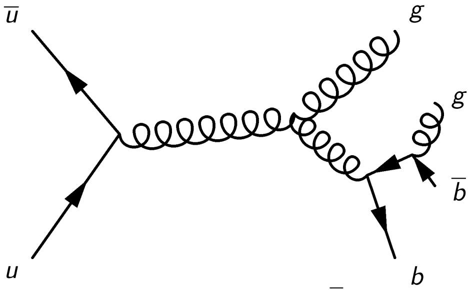
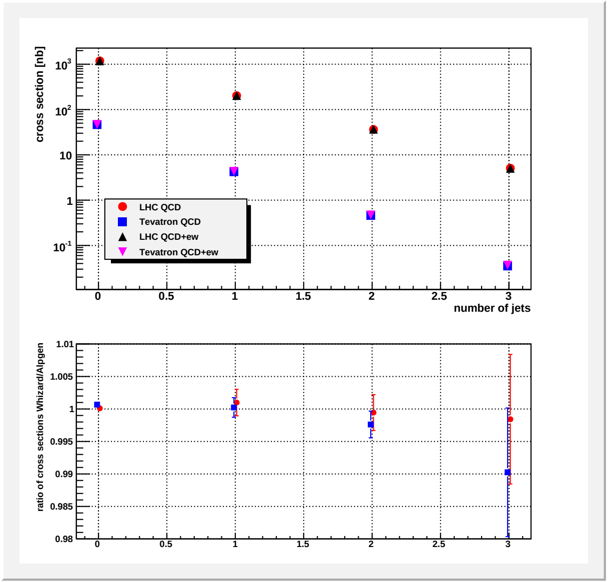
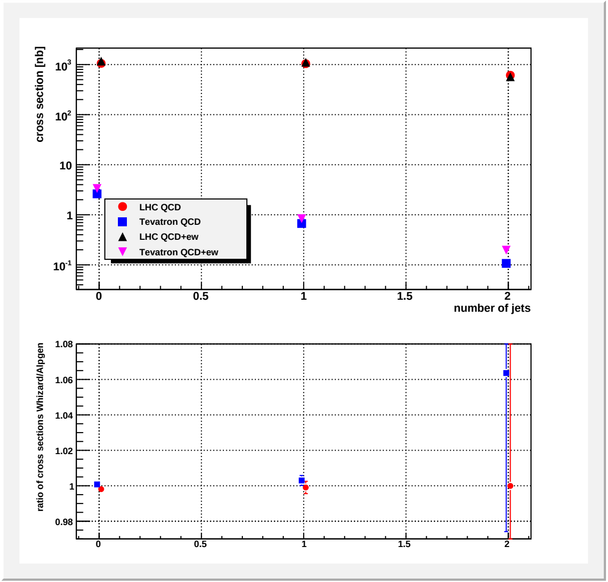


Figure: One example for $p\overline{p} \to b\overline{b} + 2$ jets.

$pp \to b\bar{b} + n$ jets



$pp \to t\bar{t}b\bar{b} + n$ jets



full results

n	experiment	σ[nb] (WHIZARD)	σ[nb] (ALPGEN)	rel. diff.	σ[nb] (WHIZARD SM)
		$pp \to b\bar{b} + n$ jets			
0	LHC	1185.72(12)	1185.59(60)	0.22	1188.33(59)
	Tevatron	46.511(4)	46.48(2)	1.26	47.078(4)
1	LHC	202.6(1)	202.4(2)	0.5	203.3(3)
	Tevatron	4.244(5)	4.243(4)	0.28	4.342(5)
2	LHC	36.26(8)	36.28(6)	0.14	36.76(8)
	Tevatron	0.4598(9)	0.4609(3)	1.18	0.4740(10)
3	LHC	5.07(5)	5.080(8)	0.17	5.04(5)
	Tevatron	0.0352(4)	0.03559(4)	0.98	3.68(2)
		$pp \to t\bar{t} + n$ jets			
0	LHC	489.19(6)	489.1(4)	0.25	489.724(6)
	Tevatron	5.5459(8)	5.547(4)	0.30	5.5798(8)
1	LHC	392.9(4)	393.4(6)	0.69	395.0(4)
	Tevatron	1.282(2)	1.2822(5)	$2.7 \cdot 10^{-4}$	1.286(1)
2	LHC	0.1987(2)	0.1986(2)	0.41	0.1997(2)
	Tevatron	$0.21003(9) \cdot 10^{-3}$	$0.2098(2) \cdot 10^{-3}$	1.20	$0.2224(2) \cdot 10^{-3}$
3	LHC	todo	0.0798(1)	todo	todo
	Tevatron	todo	$0.02787(3) \cdot 10^{-3}$	todo	todo
		$pp \to t\bar{t}b\bar{b} + n$ jets, cross sections $\times 10^{-6}$			
0	LHC	1055(2)	1057(1)	0.83	1170(2)
	Tevatron	2.618(4)	2.616(3)	0.24	3.352(5)
1	LHC	1041(3)	1042(2)	0.44	1111(5)
	Tevatron	0.6699(16)	0.66790(98)	1.11	0.837(2)
2	LHC	todo	612(7)	todo	todo
	Tevatron	0.107(9)	0.1006(2)	0.78	0.197(27)
		$pp \to b\bar{b}b\bar{b} + n$ jets, cross sections $\times 10^{-3}$			
0	LHC	138.18(5)	138.07(9)	0.77	145.29(7)
	Tevatron	1.2229(4)	1.2235(8)	0.64	1.3574(4)
1	LHC	42.02(6)	41.95(4)	1.13	42.99(9)
	Tevatron	0.221(1)	0.2213(2)	0.72	0.234(3)
2	LHC	6.1(3)	8.876(7)	11.54	6.9(4)
	Tevatron	0.24(1)	0.02486(3)	0.94	0.021(4)

Conclusion and Outlook

results:

- good agreement between ALPGEN and WHIZARD (so far)
- some processes have significant electroweak contributions

next steps:

- more complicated processes, e. g. $pp \to WQ\overline{Q} + n$ jets
- higher jet multiplicities $\Rightarrow$ need more computing power, probably optimizations in WHIZARD
- differential quantities

Thank you! Any questions?