

# CPU performance improvements in MadGraph

Implementing helicity recycling

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## Traditional calculation

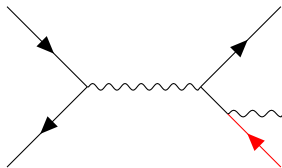
- Express matrix element in terms of Lorentz vectors
- Computation goes like  $N^2$

## Spinor formalism

- Express matrix element in terms of spinors
- Computation goes like  $N$

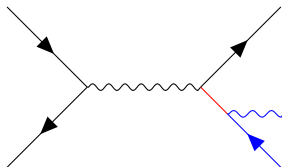
$N$  is number of diagrams

# Helicity Recycling: External Spinor



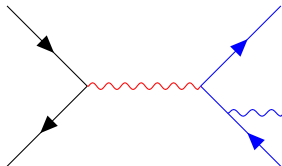
- The amplitude is the sum of all possible helicity combinations
- Each leg can be helicity  $+1$  or  $-1$
- There are 16 possible combinations where red leg has helicity  $+1$
- Aim of project: Only call spinors function once per helicity and store it as number

# Helicity Recycling: Internal Wavefunction



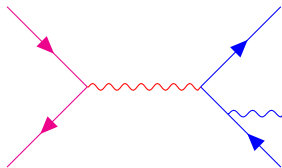
- MadGraph recursively calculates internal wavefunctions
- For 8 helicity combinations red line has same value
- Aim of project: Only call internal wavefunction once and store it as number

# Helicity Recycling: Internal Wavefunction 2



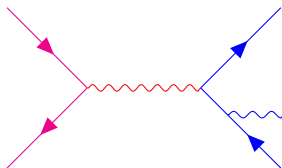
- MadGraph recursively calculates internal wavefunctions
- For 4 helicity combinations red line has same value
- Aim of project: Only call internal wavefunction once and store it as number

# Helicity Recycling: Amplitude



- Finally combin red internal wavefunction with magenta legs
- This gives the final amplitude for the diagram
- Can't recycle this

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## Helicity filtering

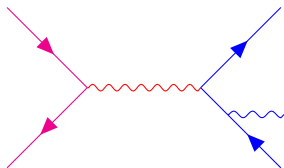
- Not all helicity combinations contribute
- Must avoid these combinations

|                  | $gg \rightarrow t\bar{t}$ | $gg \rightarrow t\bar{t}g$ | $gg \rightarrow t\bar{t}gg$ | $qq \rightarrow t\bar{t}g$ |
|------------------|---------------------------|----------------------------|-----------------------------|----------------------------|
| Matrix reduction | 55%                       | 47%                        | 31%                         | 49%                        |
| Overall Speed-up | 12%                       | 23%                        | 23%                         | 11%                        |

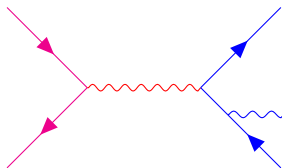
Table:  $t\bar{t}$  production

- Using AMD Opteron 6278 (8 years old)
- Speed-up for  $gg \rightarrow t\bar{t}gg$  not as big as expected
- Calls to amplitudes (rather than wavefunctions) dominate  $gg \rightarrow t\bar{t}gg$
- So far we are only recycling wavefunctions





- Magenta part introduces factor of  $\bar{\psi}\gamma^\mu\psi$
- This factor is the same for identical helicities
- Can we recycle it?



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## Preliminary results

|                  | $gg \rightarrow t\bar{t}$ | $gg \rightarrow t\bar{t}g$ | $gg \rightarrow t\bar{t}gg$ |
|------------------|---------------------------|----------------------------|-----------------------------|
| Matrix reduction | 69%                       | 70%                        | 63%                         |
| Overall Speed-up |                           | 26%                        | 50%                         |

- MadGraph calculates matrix elements by looping over all possible helicity combinations
- We can reduce the number of times external spinors and internal wavefunctions are calculated
- Gives 20-25% speed-up for computationally involved processes
- May also be possible to partially recycle amplitudes too

Thanks!