Summary of activities in

NLO multi-leg working group

June 20, 2007

Les Houches 07 wishlist

process ($V \in \{Z, W, \gamma\}$)	# groups working on
1. $pp \to V\,V$ jet	2
2. $pp \to t\bar{t}\,b\bar{b}$	1
3. $pp \to t\bar{t} + 2$ jets	
4. $pp \to W\,W\,W$	1
5. $pp \to V\,V\,b\bar{b}$	
6. $pp \to V\,V + 2$ jets	
7. $pp \to V + 3$ jets	
8. $b\bar{b}b\bar{b}$	1
9. $gg \to W^*W^*$ (NLO, 2 loops)	?
10. EW corrections to VBF	1
11. NNLO to VBF, $t\bar{t}$, Z/γ+jet, W+jet	

progress

- change in philosophy:
  - more automatisation
  - more modular tools:
    - loop integrals: public database

      $\rightarrow$ "Les Houches Accord on master integrals"
    - real radiation: automated dipole subtraction
      (T. Gleisberg)

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      → "Les Houches Accord on master integrals"
    - real radiation: automated dipole subtraction (T. Gleisberg)
- better methods:

  → "learn, discuss, compare"

"new" approaches

- on-shell recursion for multi-leg tree level amplitudes (Weinzierl)

"new" approaches

Comparison for Born amplitudes

(Weinzierl)

n	4	5	6	7	8	9	10	11	12
Berends-Giele	0.00005	0.00023	0.0009	0.003	0.011	0.030	0.09	0.27	0.7
Scalar	0.00008	0.00046	0.0018	0.006	0.019	0.057	0.16	0.4	1
MHV	0.00001	0.00040	0.0042	0.033	0.24	1.77	13	81	—
BCF	0.00001	0.00007	0.0003	0.001	0.006	0.037	0.19	0.97	5.5

CPU time in seconds for the computation of the n gluon amplitude on a standard PC (2 GHz Pentium IV), summed over all helicities.

M. Dinsdale, M. Ternick and S.W., JHEP 0603:056, (hep-ph/0602204);

C. Duhr, S. Höche and F. Maltoni, hep-ph/0607057.

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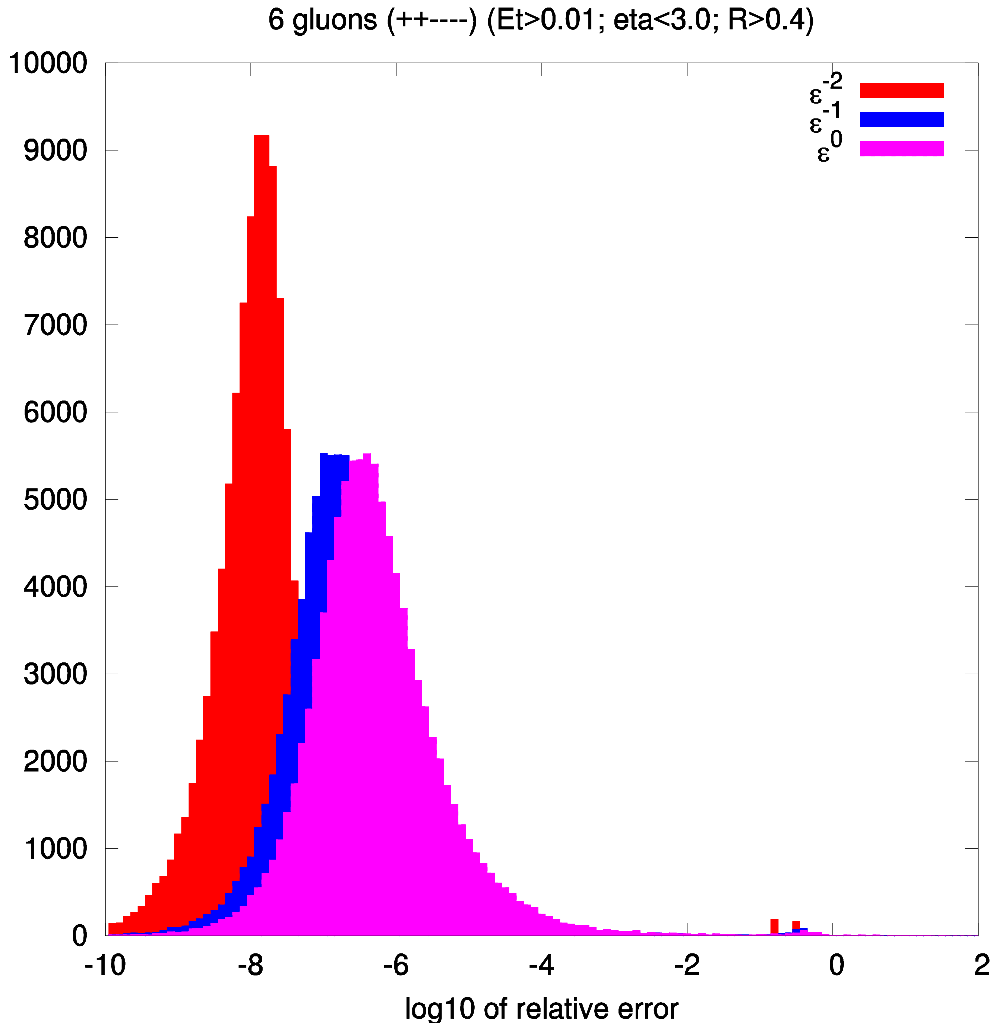
- similar approach: "unitarity method goes numerical" (Giele)

Comparison: 6 gluons

- Time: 107 secs/10,000 events



- All other PT-helicity combinations identical results. (3+,3-) helicity amplitudes checked for singular contributions
- 3.0* slower as 5 gluons
- 11.0*slower as 4 gluons
- Increase in computer time is determined by growth of the number of coefficients.
- This is still development code with lots of internal checks, the final code will be faster
- On the other hand the (D-4)-part inclusion will double the cpu time

(semi-)numerical approaches

- semi-numerical:
  - GOLEM-approach: (Binoth)
    - stop algebraic tensor reduction before it causes trouble
    - analytical/numerical options
    - obtain rational parts as a by-product
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- purely numerical:
  - no tensor reduction, calculate loop integrals numerically (Nagy)

Les Houches Accord on MI's

needed by most of the approaches:

one-loop master integrals

Les Houches accord on Master Integrals:

- agreement on format to uniquely characterise the integral (LoopTools conventions)
- WIKI page where everybody can post previously unknown MI's
- hosted at http://durpdg.dur.ac.uk/hepdata/

  (put up by Jeppe Andersen)

Numerical Stability

"Numerical instabilities are like bad spots on an apple"
(Dave Soper)

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- where do the bad spots come from? (which type of singularity?)
- are they only on the surface of the apple?
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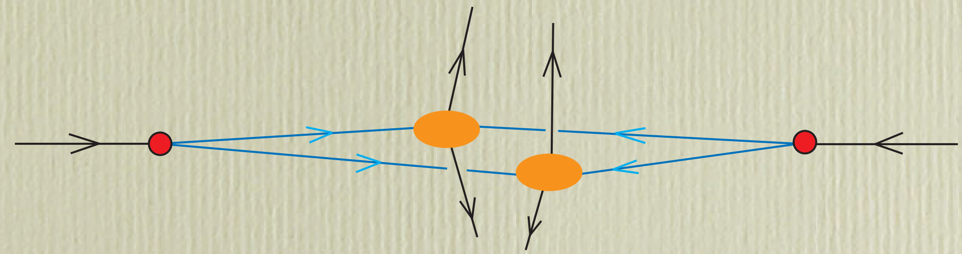
- if I make an apple cake:
  (integrate the amplitude over the phase space)
  - are the spots harmless? (smoothly integrable?)
  - can I cut out the bad spots and still have enough apple left for the cake? (drop or interpolate problematic phase space points if they are a negligible fraction of phase space)
  - if I cut the cake, do hidden bad spots suddenly show up? (how do kinematic cuts affect the numerical stability?)

disadvantages ...

Z.Nagy

- There can be problems from double parton scattering singularities.

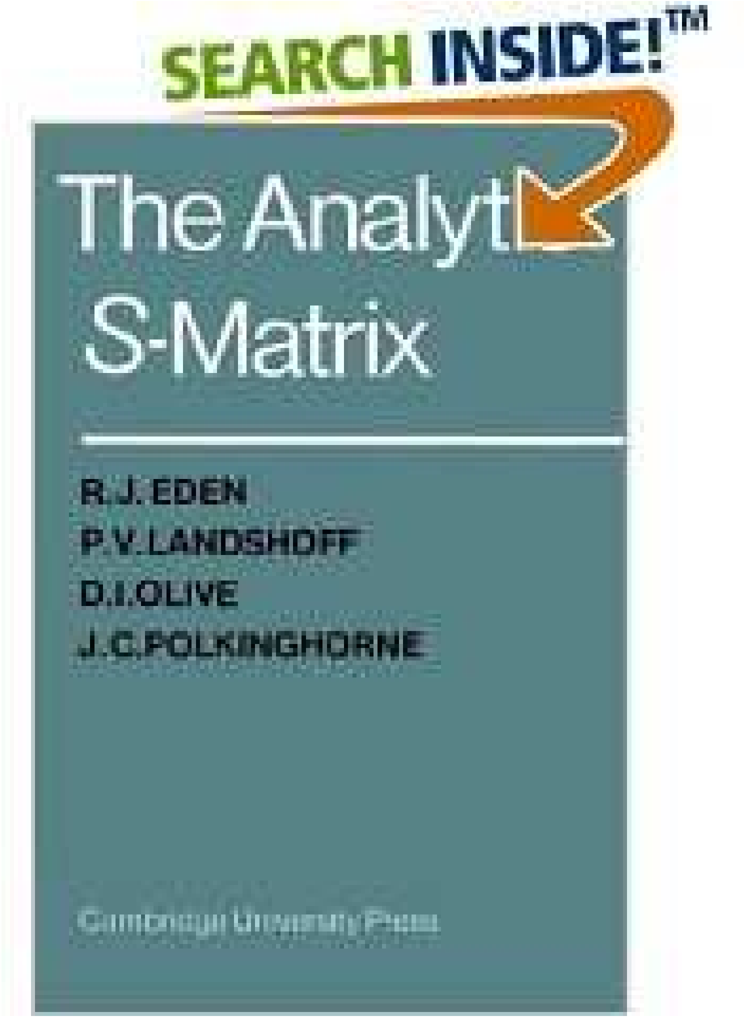


- This starts at $N = 6$.

Numerical Stability

- plan: dedicated section in the proceedings on different types of singularities (Giele et al)
- agreement on information that would be useful in a publication:
  - amplitudes in analytical form: give numerical value at certain phase space point(s) such that others can compare
  - integrated amplitudes/cross sections: statements about numerical behaviour
    - what fraction of phase space shows instabilities ?
    - how have they been dealt with ?

Revenge of the Analytic S-matrix



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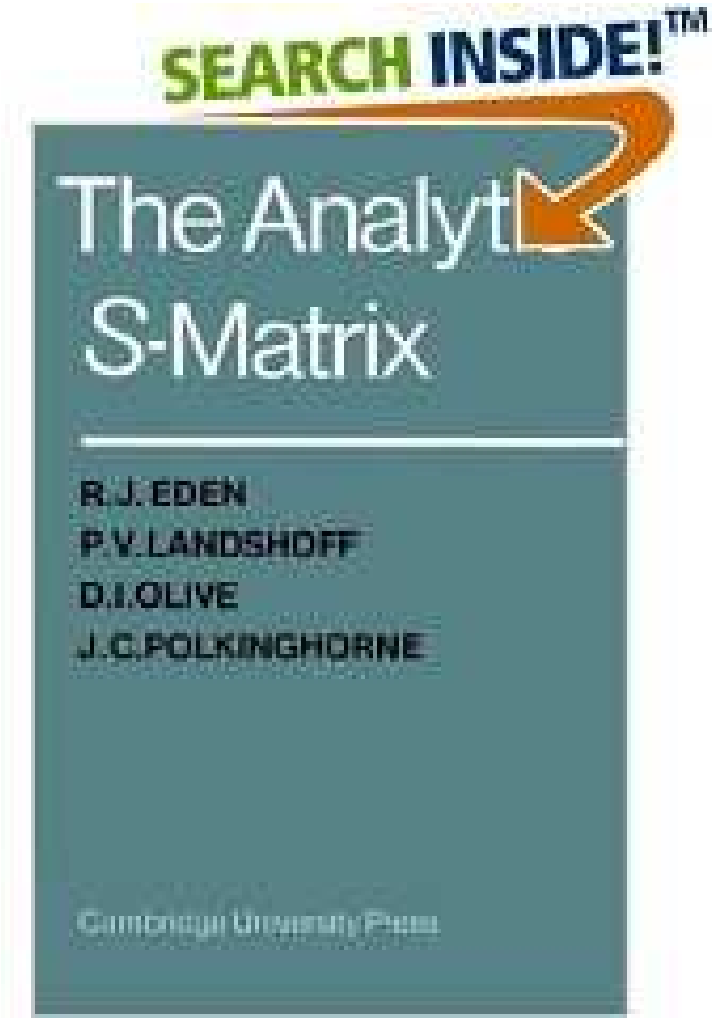

rediscover the sixties !