Unitarity based techniques for higher-order QCD Part II

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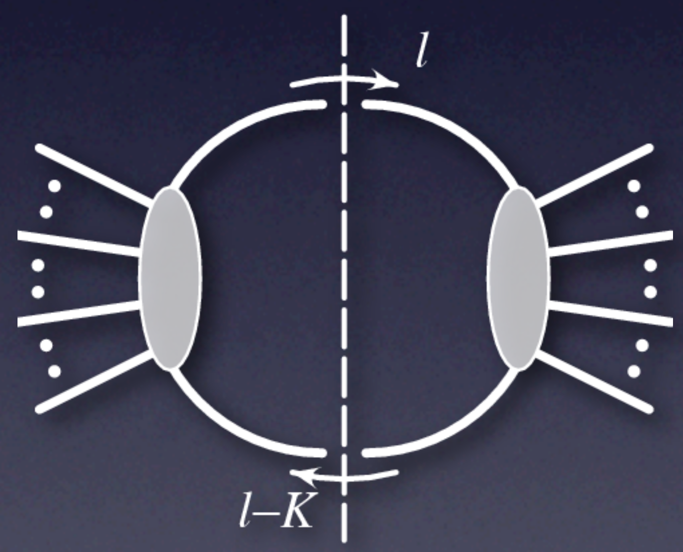
Overview

- Pierpaolo has already given an overview of Unitarity techniques.
- Describe the automation of Unitarity based approaches.
- Results that can be achieves using these techniques.

Unitarity & On-shell methods

- Want to avoid using gauge dependent quantities, use only on-shell amplitudes.
- Unitarity: "Glue" together trees to produce loops.



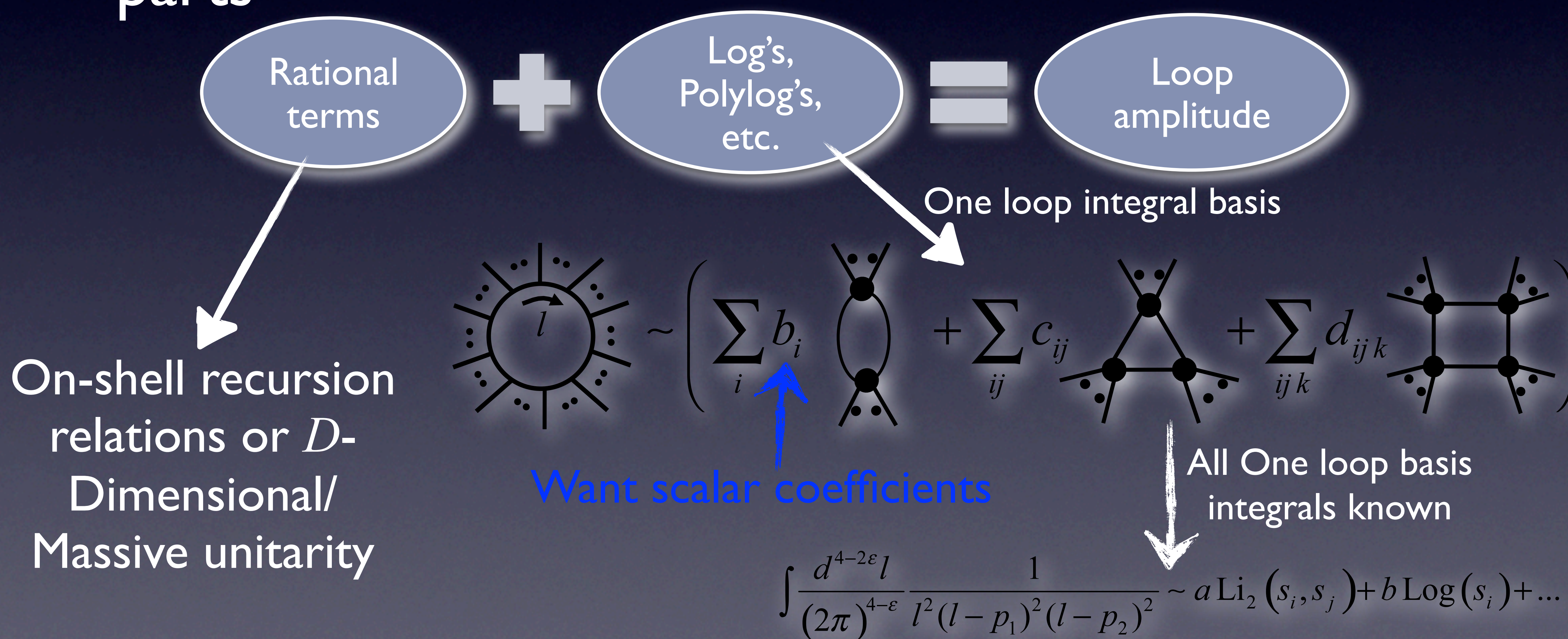
- Efficient methods for computing trees lead to efficient computation of loops.

Automation

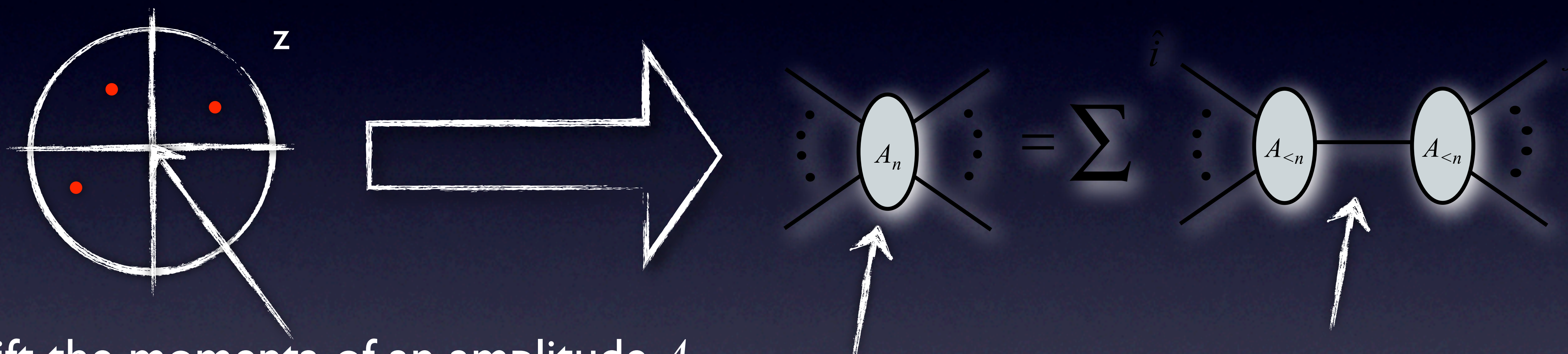
- There are many processes we want to compute for the LHC, which are made up of many subprocesses.
- Use computers to do the tedious work!
- **BlackHat** - an automated package for computing one-loop amplitudes.

Automating Unitarity

- Split the computation of the amplitude into two parts



On-shell recursion



Shift the momenta of an amplitude A_n by a complex parameter z. In terms of z the amplitude is a sum of poles.

(Britto, Cachazo, Feng, Witten)

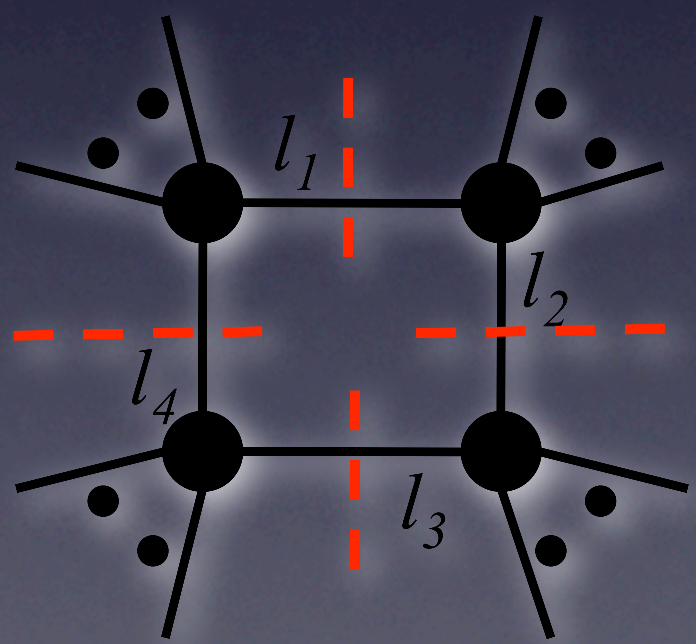
The unshifted amplitude, what we want

Build higher point amplitudes from lower point on-shell amplitudes.

Used to compute the rational parts of One-Loop amplitudes (Berger, Bern, Dixon, DF, Kosower)

Box Coefficients

- Generalized unitarity, cut the loop more than two times.
- Quadruple cuts in 4 dimensions freezes the box integral. (Britto, Cachazo, Feng)



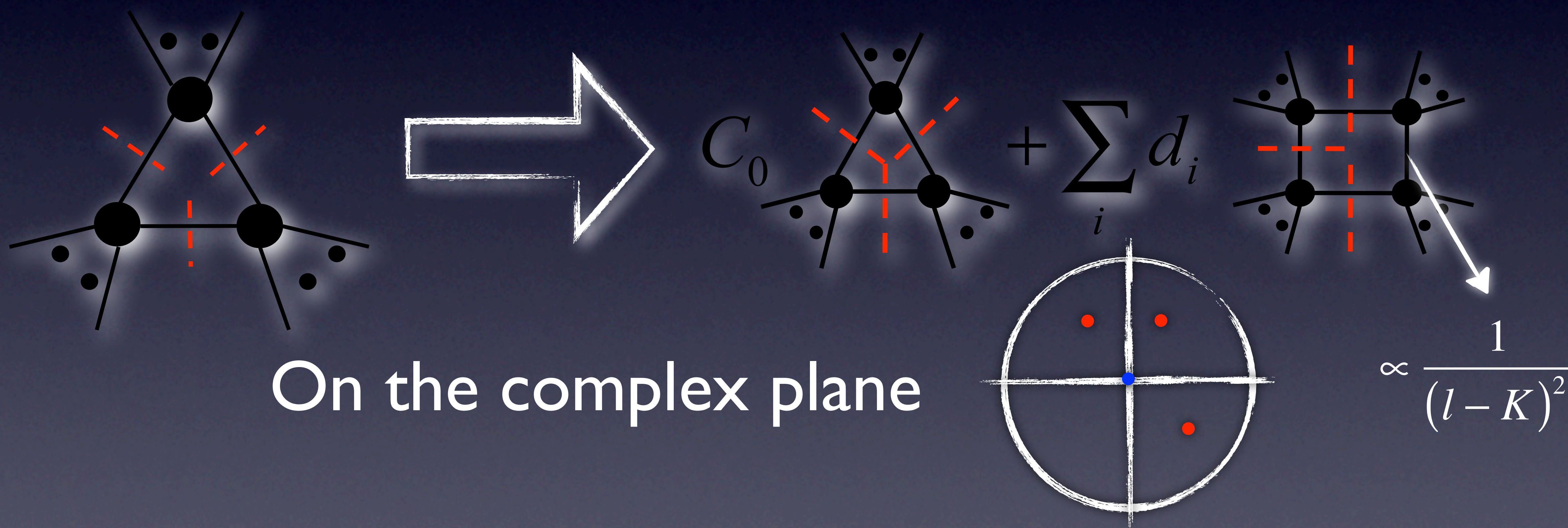
No free components in l^μ, fixed by 4 constraints in 4 dimensions.

$$d = \frac{1}{2}\sum_{a=1,2} A_1(l_a)A_2(l_a)A_3(l_a)A_4(l_a)$$

Generally requires complex momenta

Triangle Coefficients

- Triple cut has a single free parameter use this to isolate the triangle coefficient. (DF)



- Remove boxes by taking the infinite limit (analytical) or subtract poles (numerical). (Blackhat)

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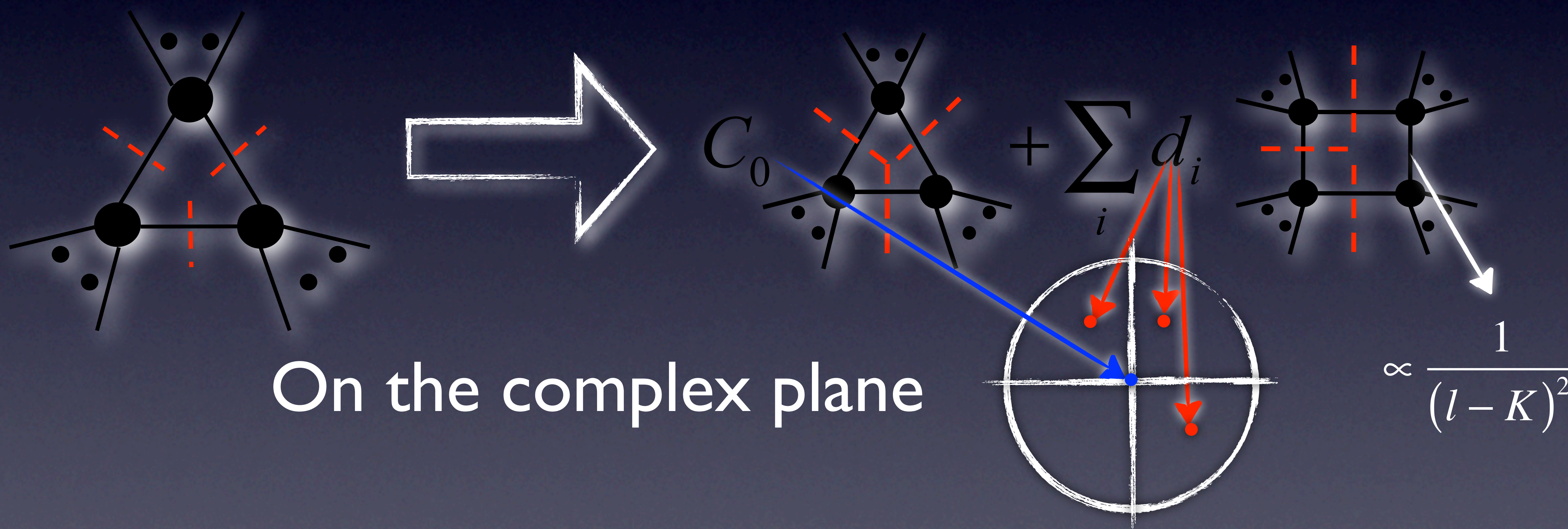
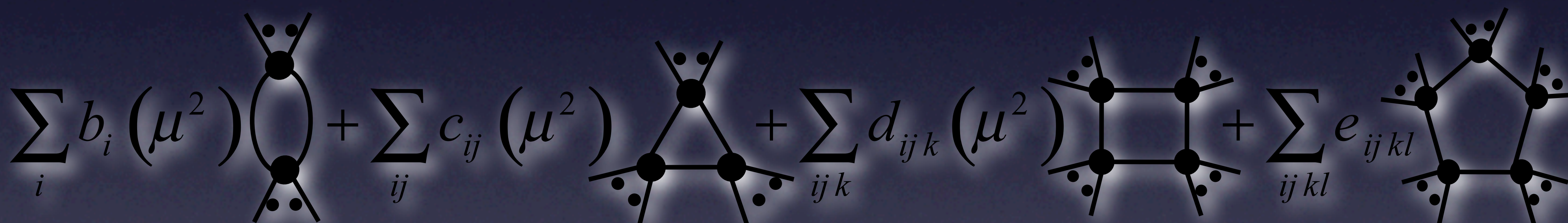


On the complex plane

- Remove boxes by taking the infinite limit (analytical) or subtract poles (numerical). (Blackhat)

D-Dimensional Unitarity

- Extend Unitarity to D-Dimensions, can now compute rational terms as well. (Giele, Kunszt, Melnikov) (Badger)
- Extended basis of structures,



- Extract coefficients in the same way as before but with an extra parameter, μ^2.

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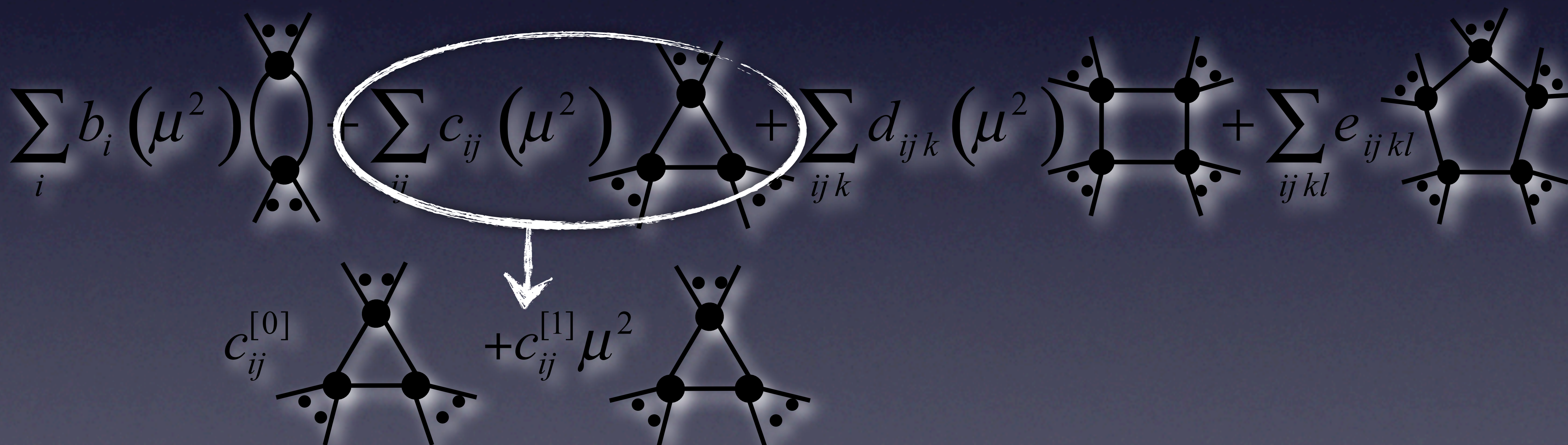

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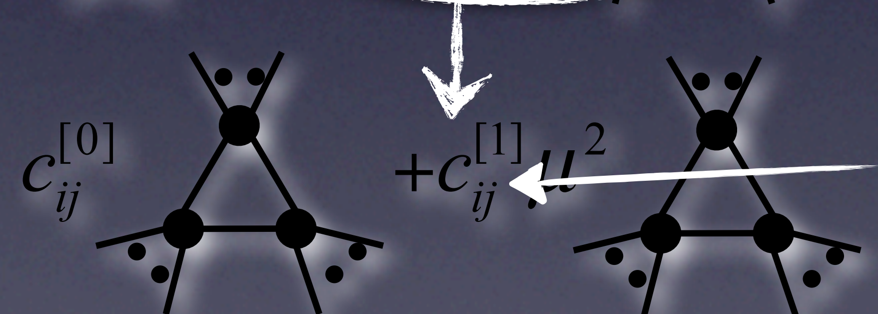


Rational piece

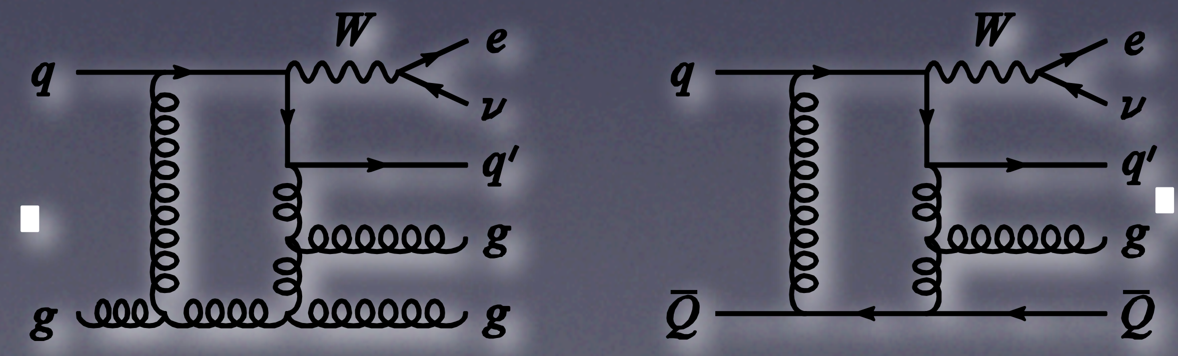
- Extract coefficients in the same way as before but with an extra parameter, μ^2.

Automated NLO Results

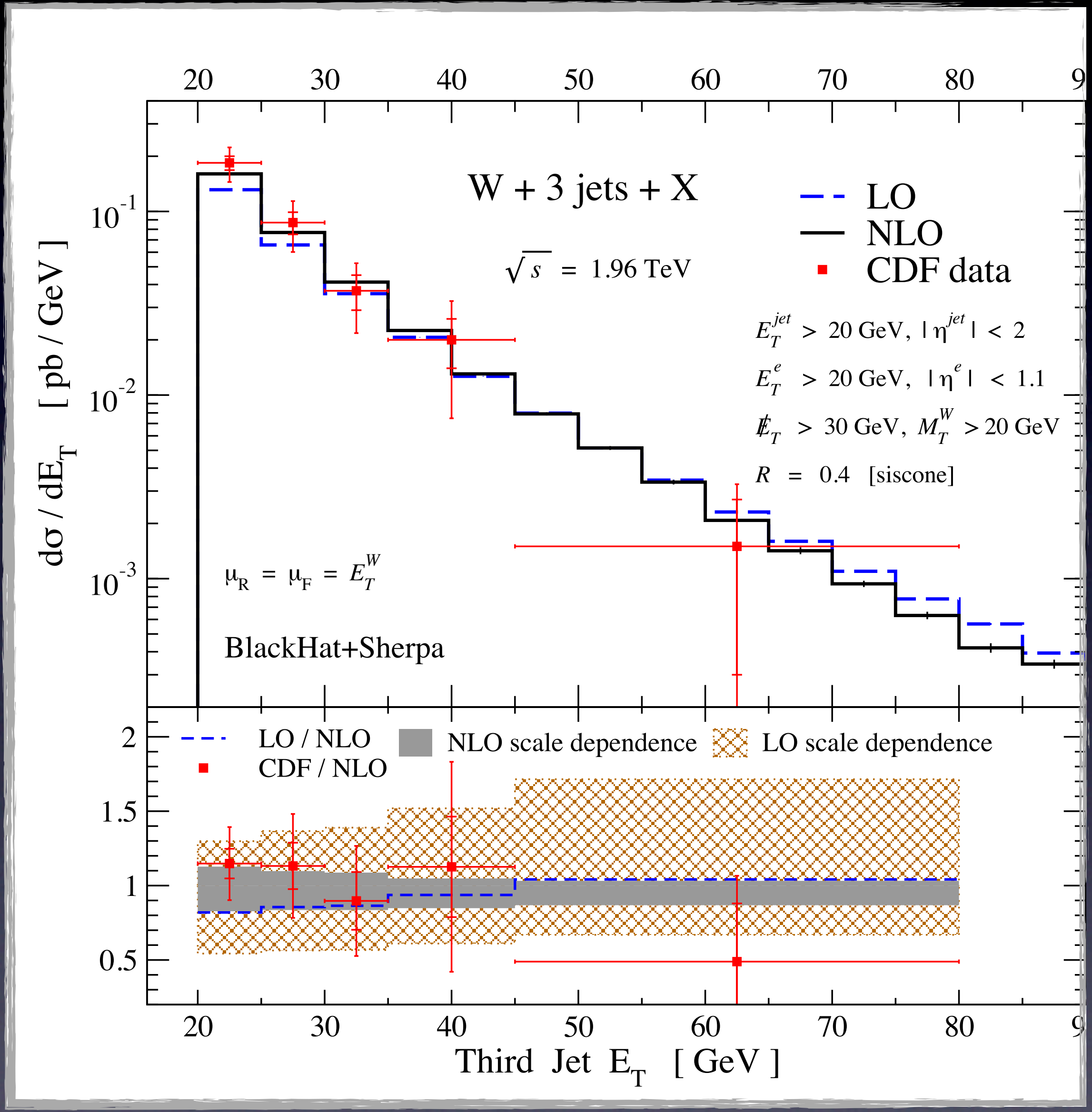
- Combine the real and virtual correction,

$$\sigma_n^{\mathrm{NLO}} = \int_n \sigma_n^{tree} + \int_n \sigma_n^{virt} + \int_{n+1} \sigma_{n+1}^{real}$$

- Many automated tools to produce the real piece e.g. Sherpa, Madgraph, ... etc.
- Used BlackHat+Sherpa for the computation of W+3 jets.

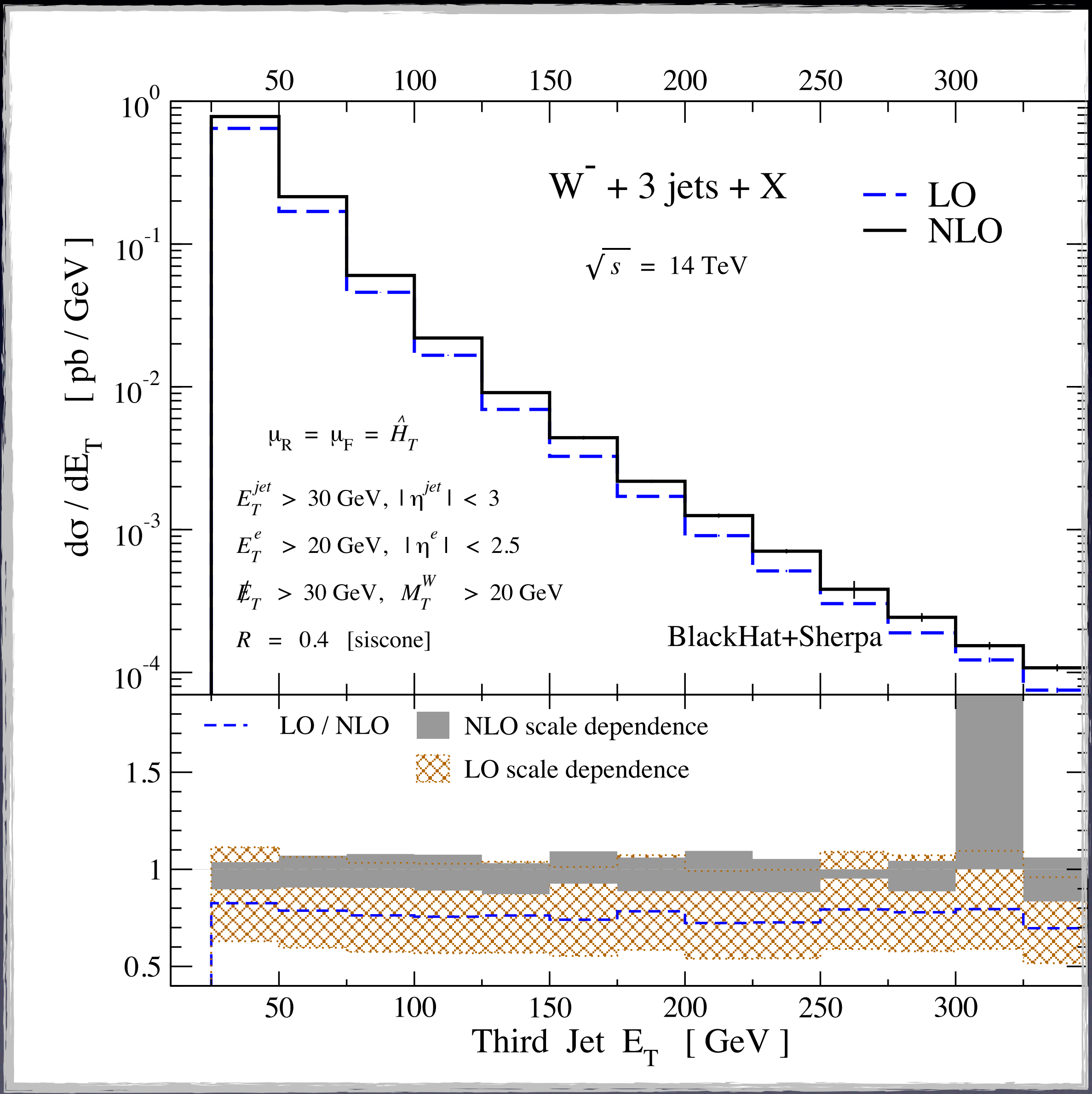


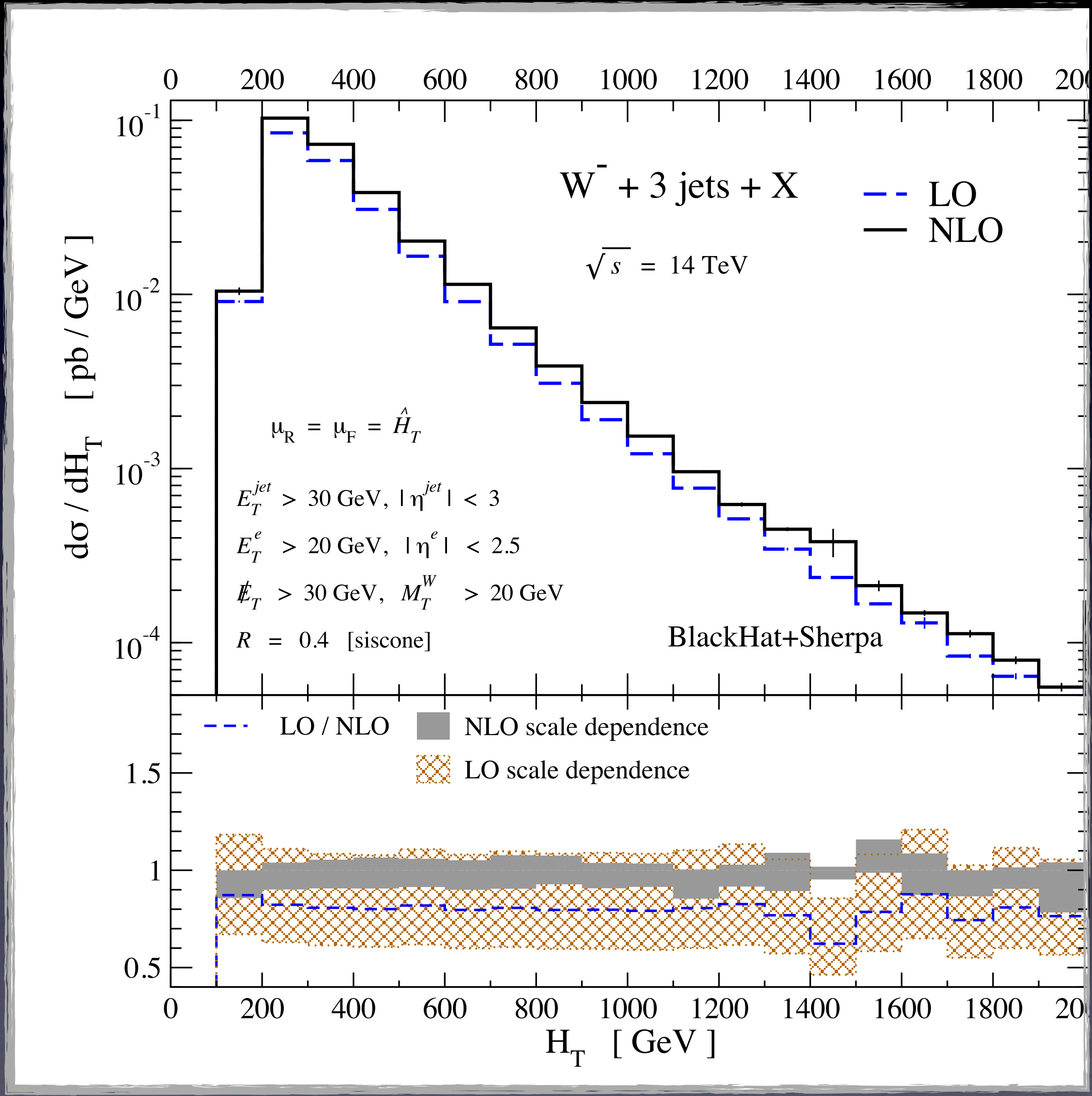
W+3 jets at the Tevatron



- Good agreement with Tevatron data. (arXiv:0711.4044)
- Reduced scale dependance at NLO.

W+3 jets at the LHC

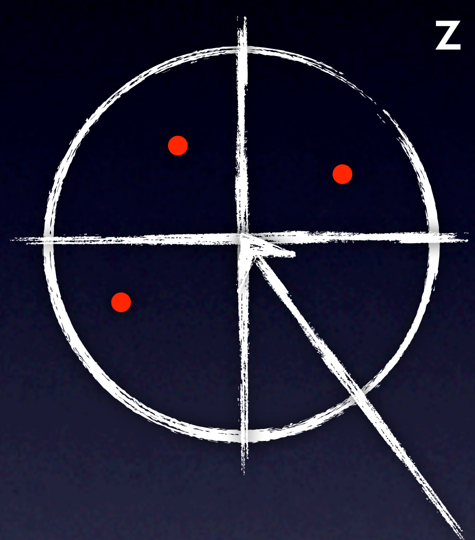




Conclusions

- Automated NLO computations are now a reality. A number of programs are being produced.
- The techniques used are completely general. Not restricted to any specific theory.
  - e.g. used in $N=8$ Supergravity computations.

On-shell recursion



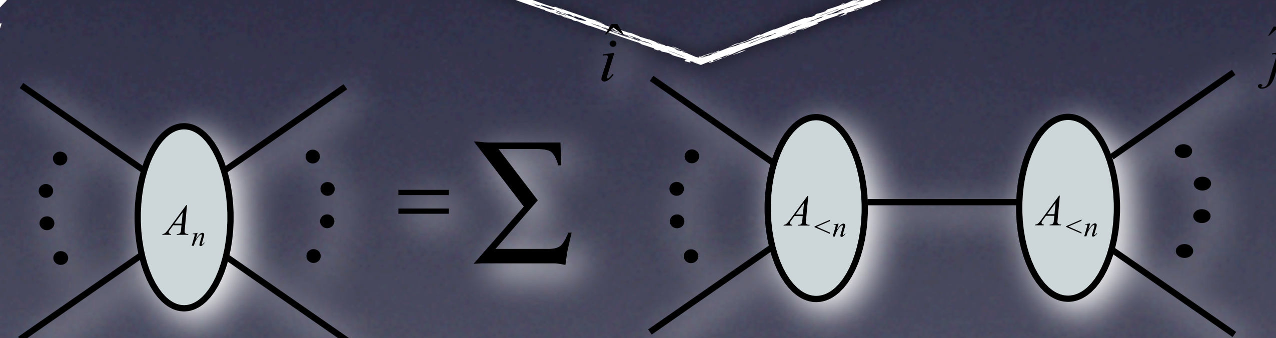
Shift the momenta of an amplitude A_n by a complex parameter z. In terms of z the amplitude is a sum of poles.

(Britto, Cachazo, Feng, Witten)

The unshifted amplitude, what we want

$$A_n(0) = -\sum_{\text{poles}} \text{Res}_z \frac{A_n(z)}{z}$$

Relate to factorization



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