

**SAMUEL ABREU**

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📌 Undergraduate/Master: Lisbon (IST)

📌 PhD: University of Edinburgh

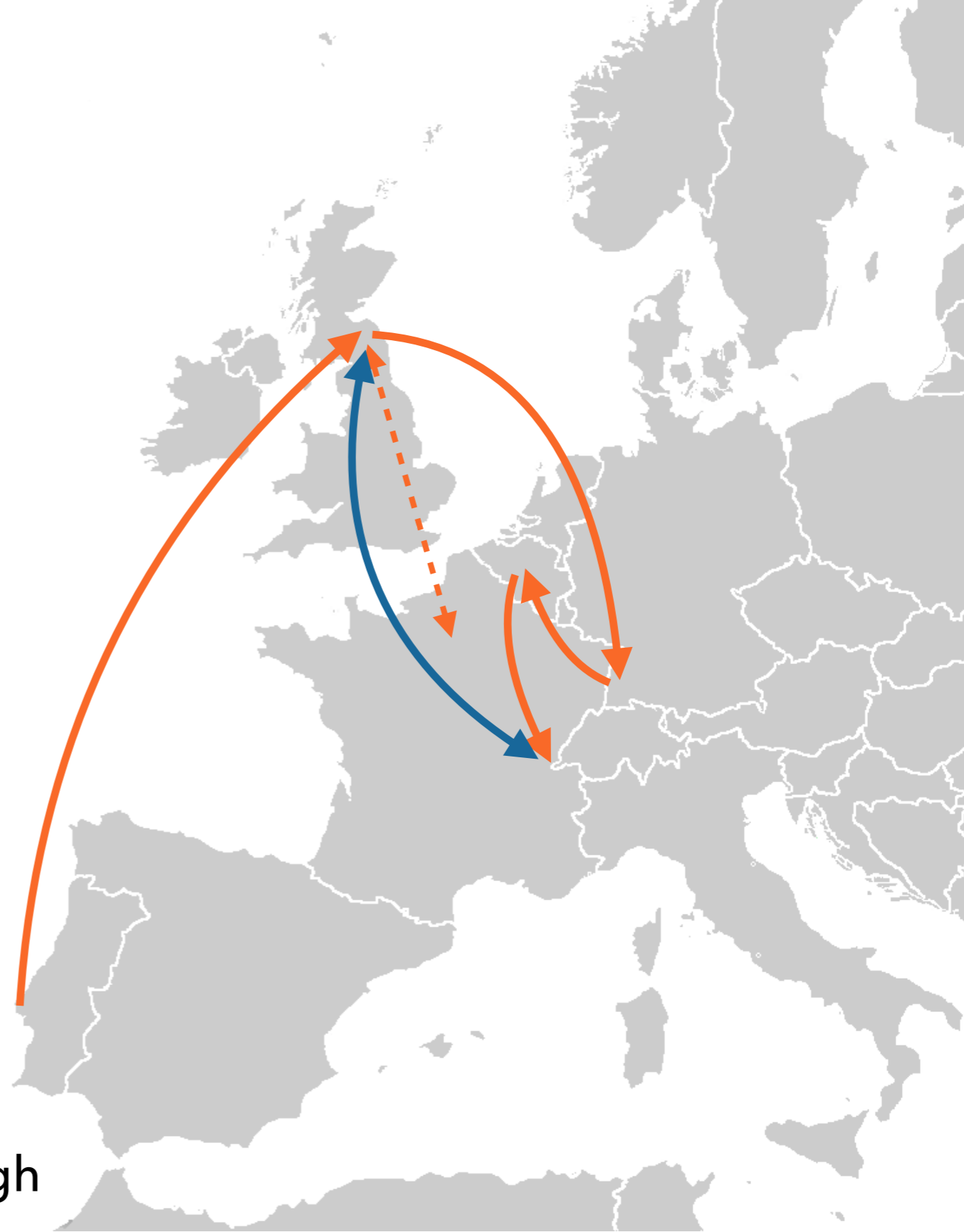
➔ One year at the CEA (Saclay)

📌 Postdoc 1: University of Freiburg

📌 Postdoc 2: UCLouvain

📌 Since 2020 at CERN: first as a fellow, now as staff

📌 On leave from the University of Edinburgh



THE UNIVERSITY  
of EDINBURGH

# Scattering amplitudes for collider phenomenology

$$\mathcal{A} = \text{[Diagram of a two-loop bubble diagram with external momenta } p_1, p_2, p_3, \dots, p_n \text{]} = \sum c_i I_i$$

## RATIONAL FUNCTIONS, THEORY SPECIFIC

- Analytic or numerical calculations
- Integration-By-Part relations, unitarity, ...

## FEYNMAN INTEGRALS, ONLY DEPEND ON KINEMATICS

- Complicated loop integrations
- (Poly)Logarithms and Elliptic functions
- Analytic/numerical approaches

◆ How to efficiently compute amplitudes?

- ✓ e.g., how to get an analytic expression

◆ How to efficiently evaluate amplitudes?

- ✓ Fast and stable, so that they can be used for phenomenology

# How to (for multi leg two-loop amplitudes):

$$\mathcal{A} = \text{Diagram} = \sum c_i I_i$$

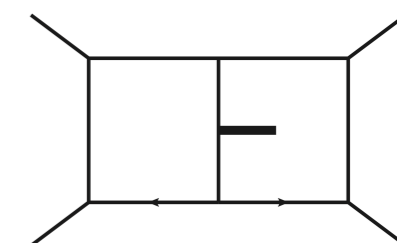
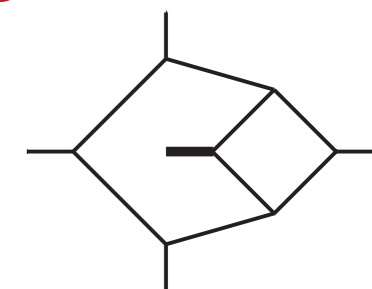
The diagram shows a two-loop amplitude represented as a grey circle with two white circles inside. Four external legs are shown with arrows:  $p_1$  and  $p_2$  on the left, and  $p_3$  and  $p_n$  on the right. A vertical ellipsis between  $p_3$  and  $p_n$  indicates additional legs.

## 1. Compute Feynman integrals and study their analytic structure

- ✓ Differential equations, discontinuities
- ✓ Coactions
- ✓ 'Pentagon functions'
- ✓ Generalised series expansions

Extract and classify analytic information

Fast and stable numerical evaluation



## 2. New approaches to the calculation of two-loop amplitudes

- ✓ Ansatz the result (with analytic information from integrals)
- ✓ Constrain ansatz with generalised unitarity ; finite-field evaluations
- ✓ Simplify result with algebraic geometry



Caravel

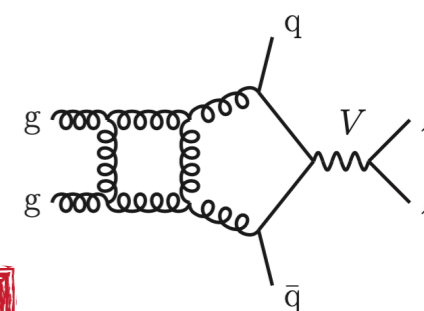
Result: 3-gluon amplitudes from  $\sim 10$ mins/phase-space point to  $\sim 1$ s!

# Generic tools for precision physics

## ◆ Multi-leg amplitudes (with B.Page and many other people)

- ✓ 4-graviton scattering at two-loops
- ✓  $\mathcal{N} = 4$  sYM and  $\mathcal{N} = 8$  SUGRA amplitudes
- ✓ 3-jet and 3-photon production
- ✓  $W+2$  jet production
- ✓ Next milestone:  $H+2$  jet production

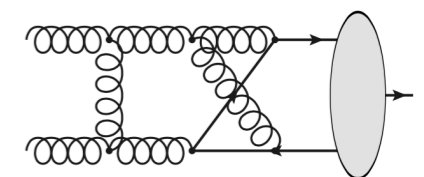
Used for pheno studies!



## ◆ Towards 6-point scattering at two loops (with P.Monni, B.Page)

## ◆ Quarkonium production at NNLO (with M. Becchetti, C. Duhr, M. Ozelik)

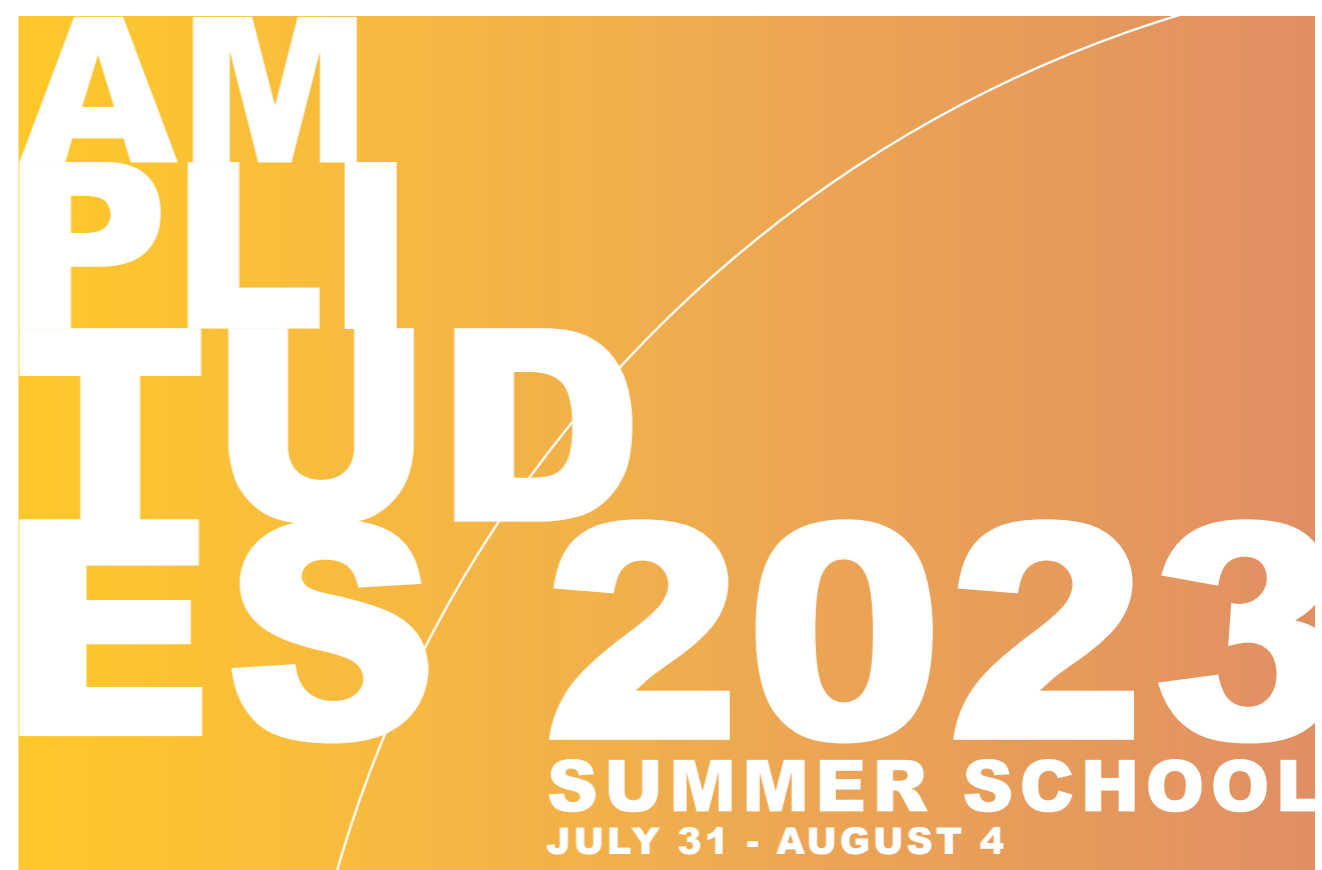
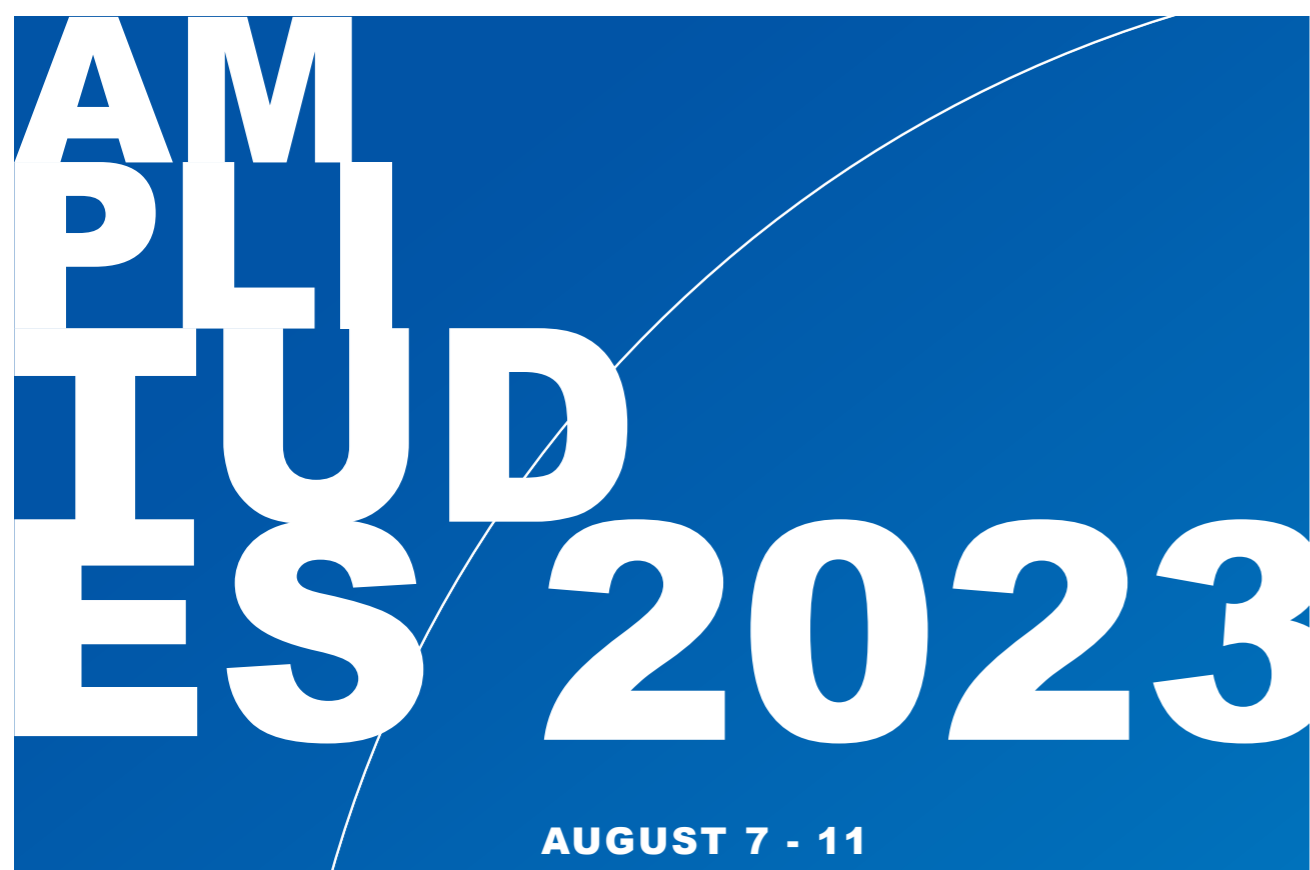
- ✓ Simple kinematics, but massive propagators  $\rightsquigarrow$  elliptic integrals
- ✓ Analytics and high-precision numerics, ready for pheno



## ◆ Rho parameter at 4 loops (with A.Behring, A.McLeod, B.Page)

- ✓ Which type of functions appear?

## ◆ Improve fixed order prediction with resummation: soft and beam functions for jet-veto in Higgs production (with J.Gaunt, P.Monni, L.Rottoli, R.Szafron)



with Andrew McLeod, Ben Page, Lorenzo Tancredi

**Registration opens soon!**

- ◆ Organiser of TH Colloquium: if you have suggestions, please get in touch!
  - ✓ Together with C. Caprini, A. Zhiboedov
- ◆ Get in touch if you have any questions/suggestions about the twiki!

**THANK YOU!**