Precision Calculations in Particle Physics

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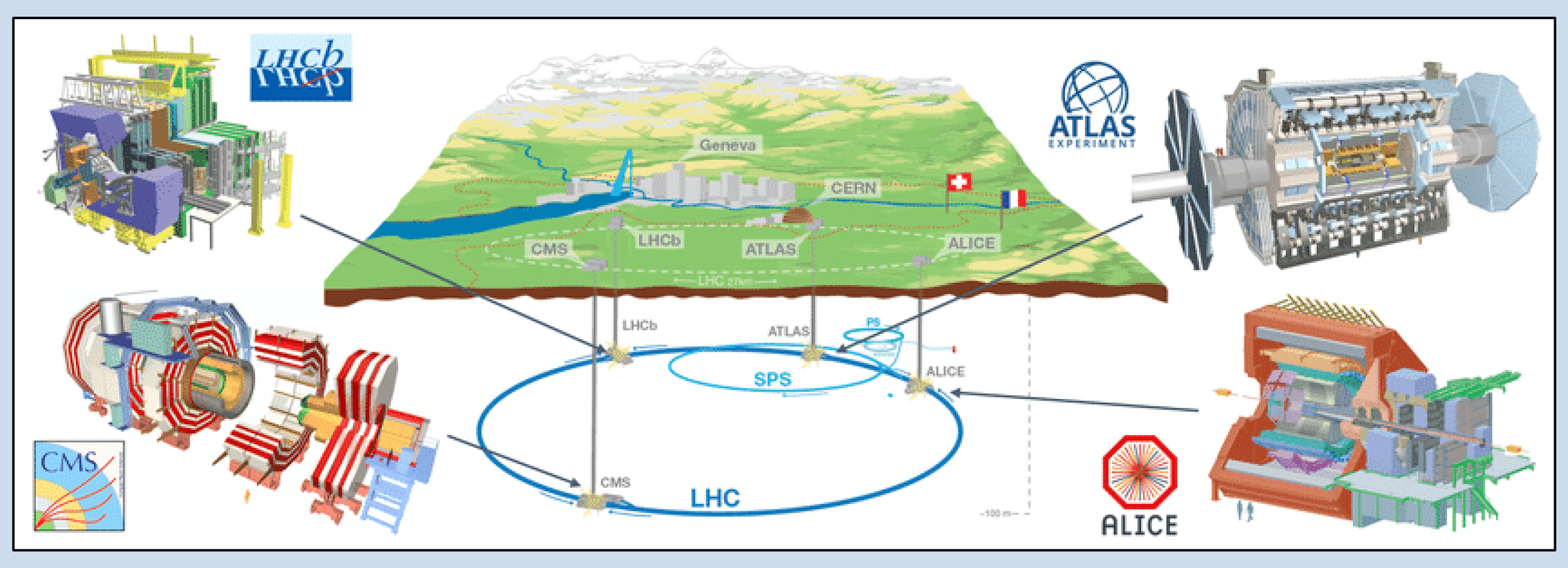
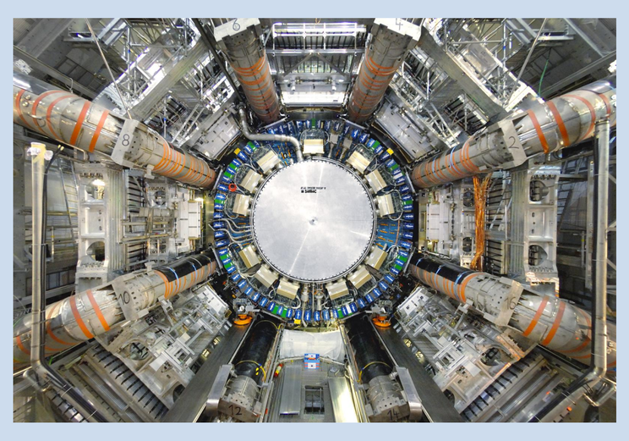
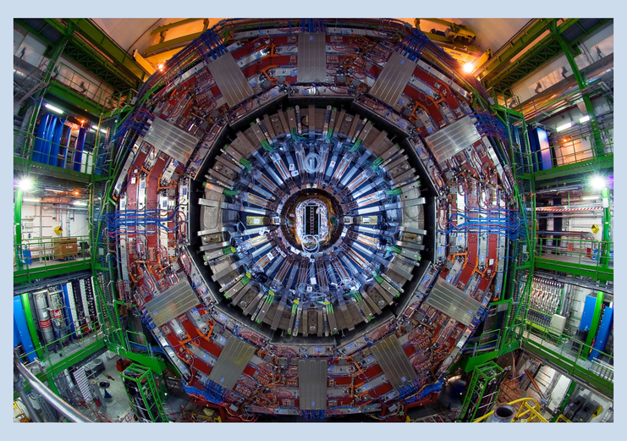
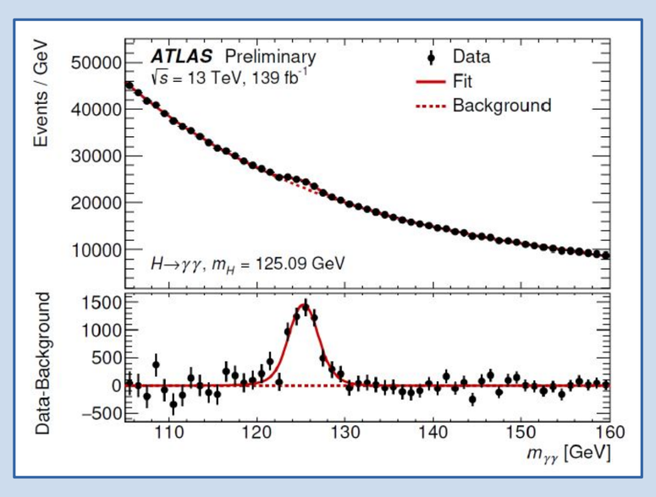
Standard Model

Experiments









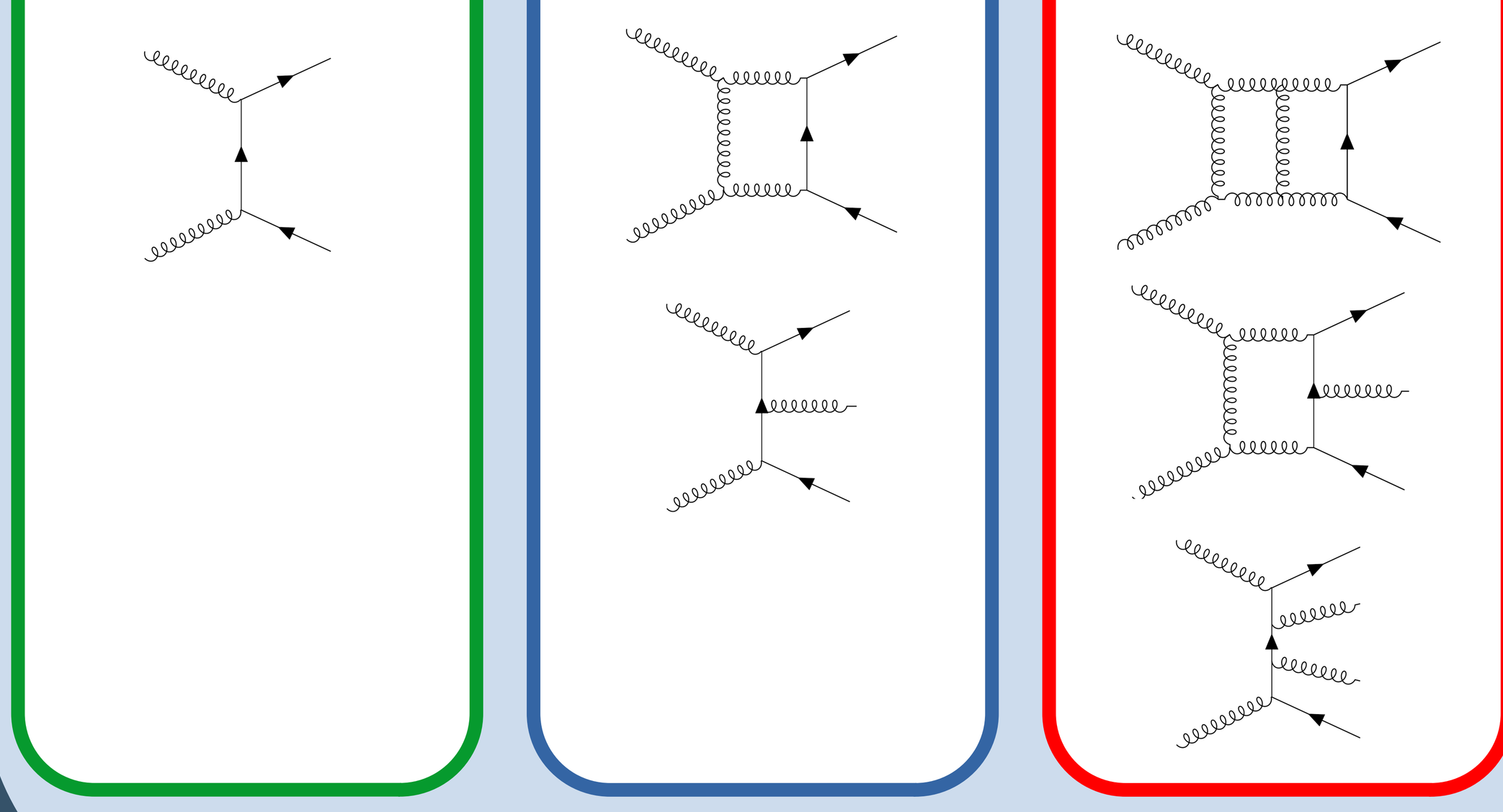
BSM?

The **Standard Model** (SM) is our best description of fundamental particles. It has been extensively tested through **experiments**, with extraordinary results. From the SM, **theoretical predictions** can be computed, which need to be more and more precise to match the accuracy of present and future measurements.

Predictions

$$\sigma = \sigma^0 + \left(\frac{\alpha_s}{2\pi}\right)\sigma^1 + \left(\frac{\alpha_s}{2\pi}\right)^2\sigma^2 + \mathcal{O}(\alpha_s^3)$$

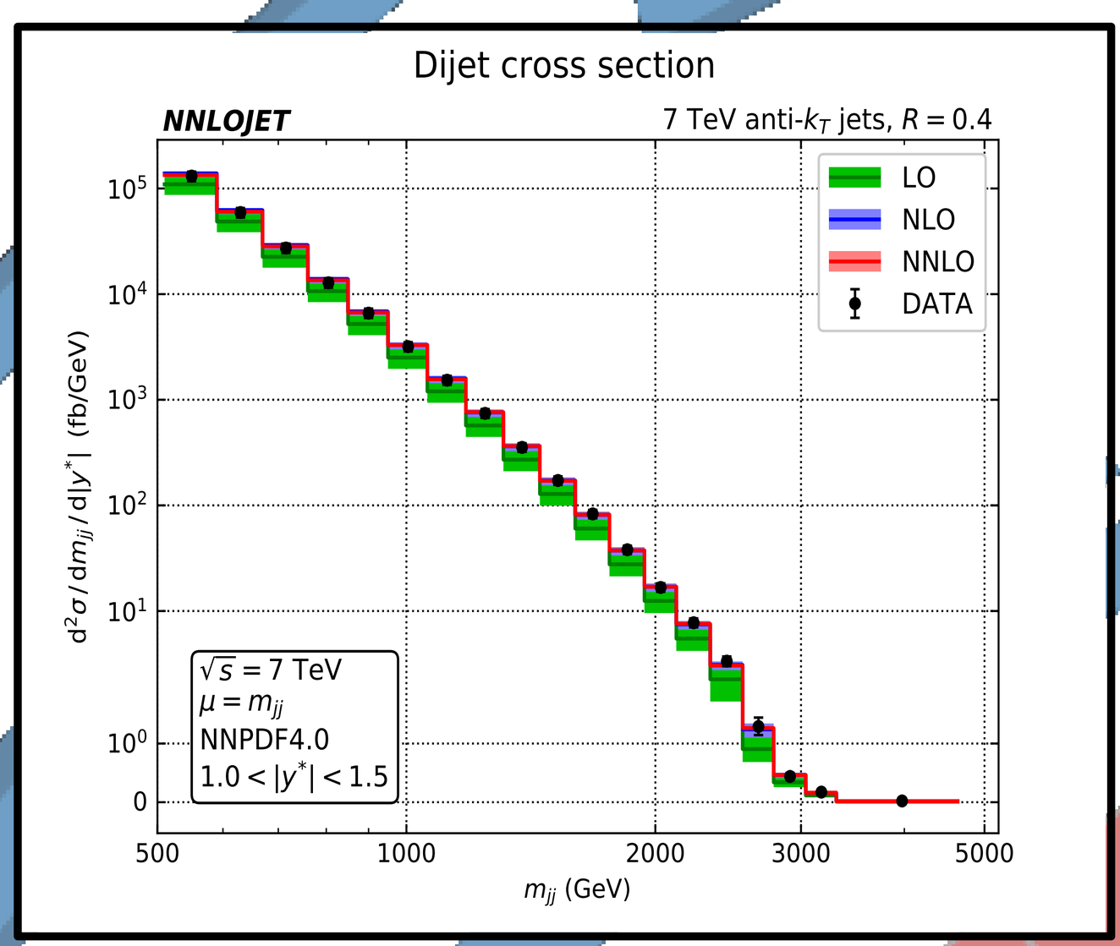
LO **NLO** **NNLO**

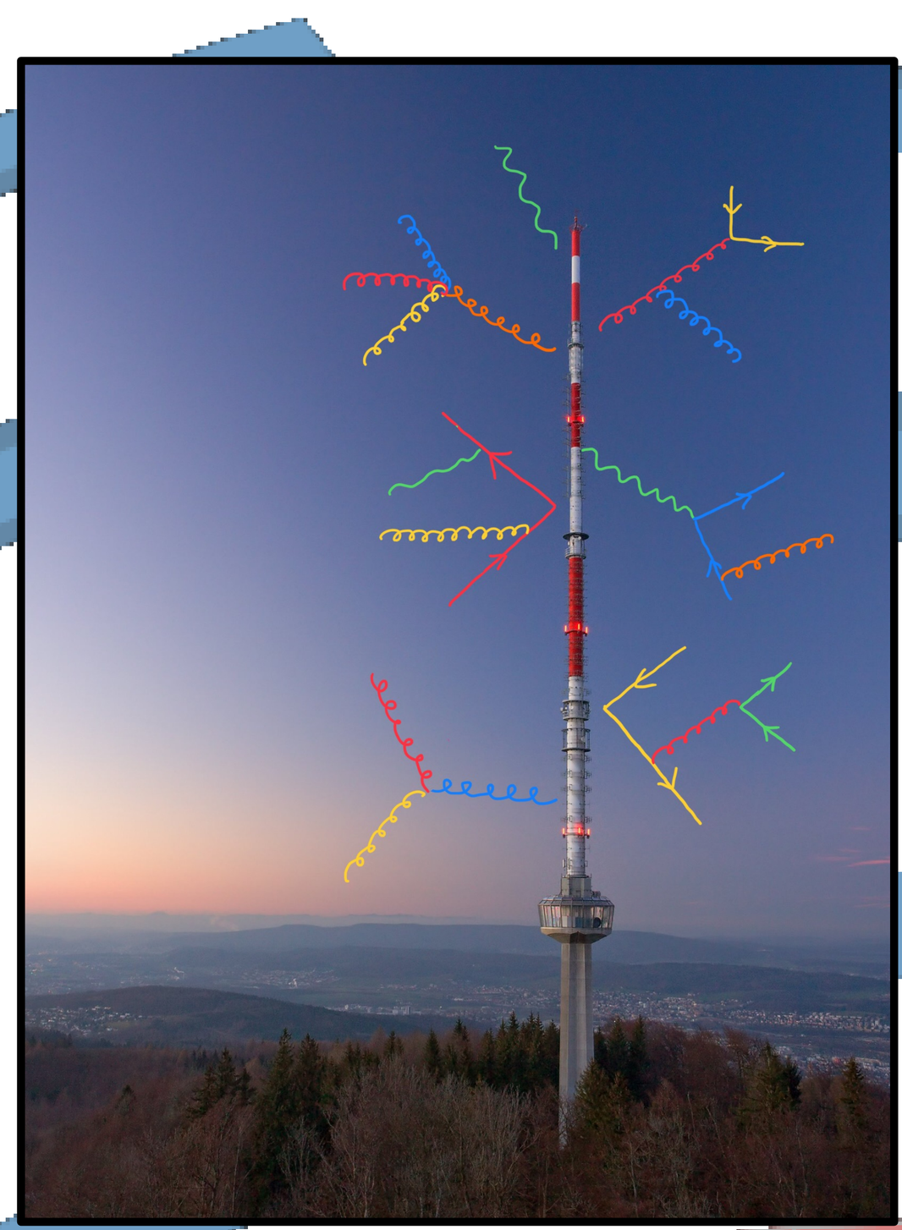


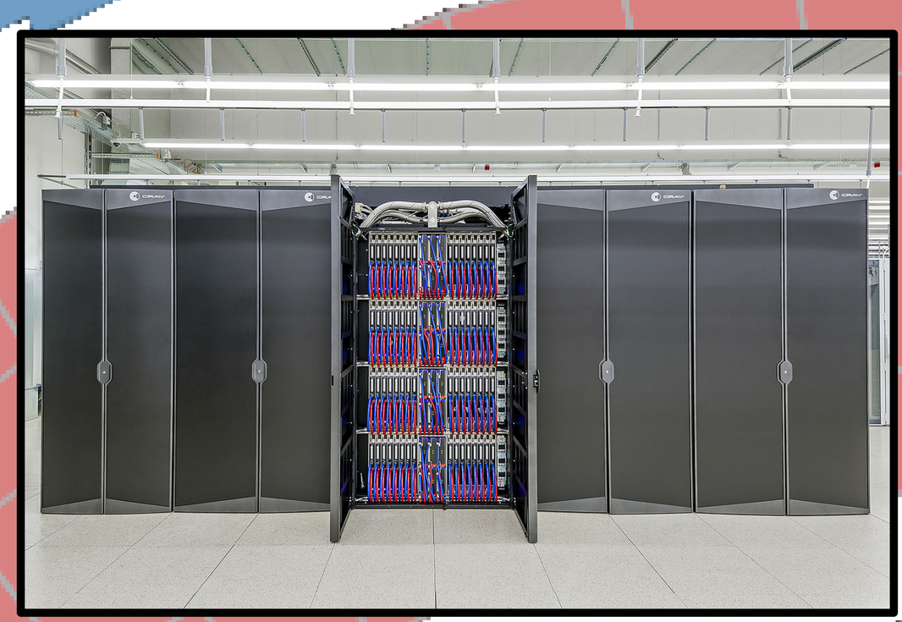
Monte Carlo Event Generator

NNLOJET is a **Monte Carlo Event Generator** which implements the **antenna subtraction** method to organize and communicate between the different layers of the calculation.

```
!##############################################!
!##                                          ##!
!##                 NNLOJET                  ##!
!##                                          ##!
!##                               RUNCARD    ##!
!##############################################!

PROCESS  GJ

  collider = pp
  sqrts = 13000
  jet = antikt[0.4]
  jet_exclusive = .false.
  jet_recomb = V4
  photon_isolation = etsum[R=0.4, ETmax_const=10, ETmax_epsilon=0.0042, ET_threshold=0]
  photon_fragmentation = BFG2
  decay_type = 2

END_PROCESS

RUN  RRa  ! <--- this is the JOB name
  PDF = NNPDF31_nnlo_as_0118_mc[0]
  tcut = 1d-8
  iseed   = 16
  reset_vegas_grid = .true.
  angular_average  = .false.
  multi_channel    = .false.
  !multi_channel    = 2

  !warmup     = 20000[10]
  production = 10000[10]
END_RUN

PARAMETERS
  MASS[H]  = 125.09
  WIDTH[H] = 0.004029643852
  MASS[Z]  = 91.1876
  WIDTH[Z] = 2.4952
  MASS[W]  = 80.385
  WIDTH[W] = 2.085
  MASS[t]  = 173.21
  WIDTH[t] = 1.41
  MASS[b]  = 4.18
  MASS[c]  = 1.275
  MASS[tau]  = 1.77
  SCHEME[ALPHA]  = FIX
```



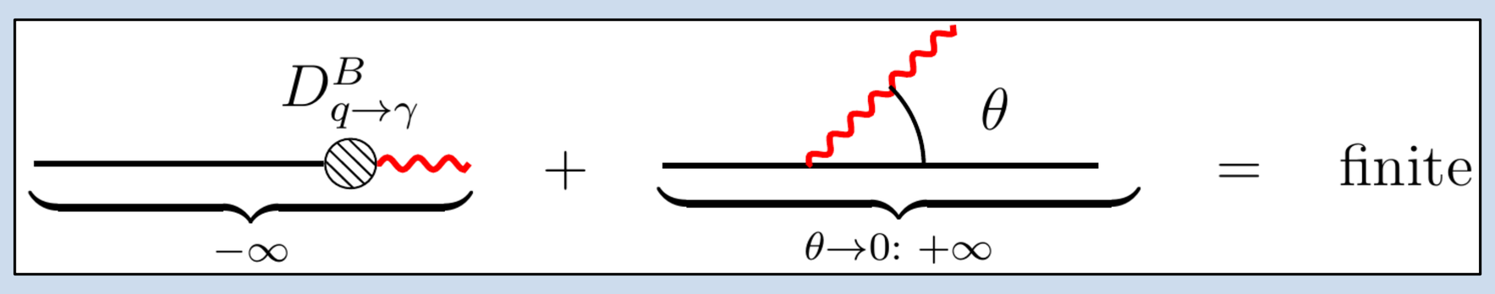




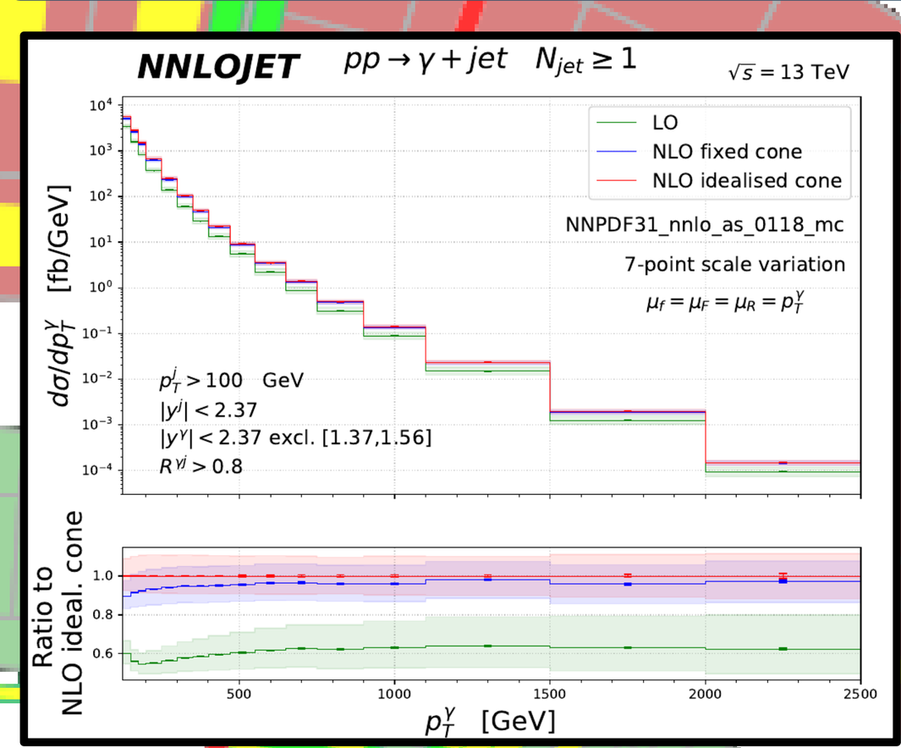
We obtain our predictions performing multi-dimensional phase space integrations using the **Vegas algorithm**. Due to the very complicated integrand structure, powerful **computing resources** are needed to perform this integration with **high precision**. A typical NNLO calculation requires a computation time of **10 000 CPU days**.

Identified Final-State Particles

In some processes the observed final-state particle is produced during hadronization. The corresponding contribution to the cross section is called **fragmentation** contribution and it is described by **fragmentation functions.** These functions absorb some of the singularities we encounter in our calculations:

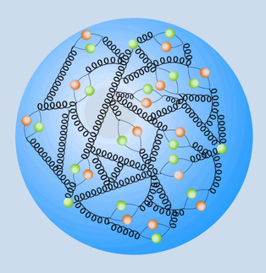


Within the ***NNLOJET*** collaboration we are working on including this contribution into our predictions for **photon** and **hadron production** cross sections at NNLO accuracy. To this end, we have to be able to **identify** the final-state particle when it becomes collinear to other particles.

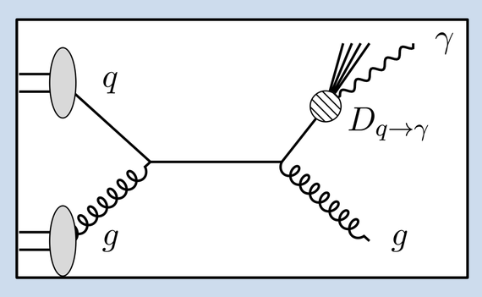


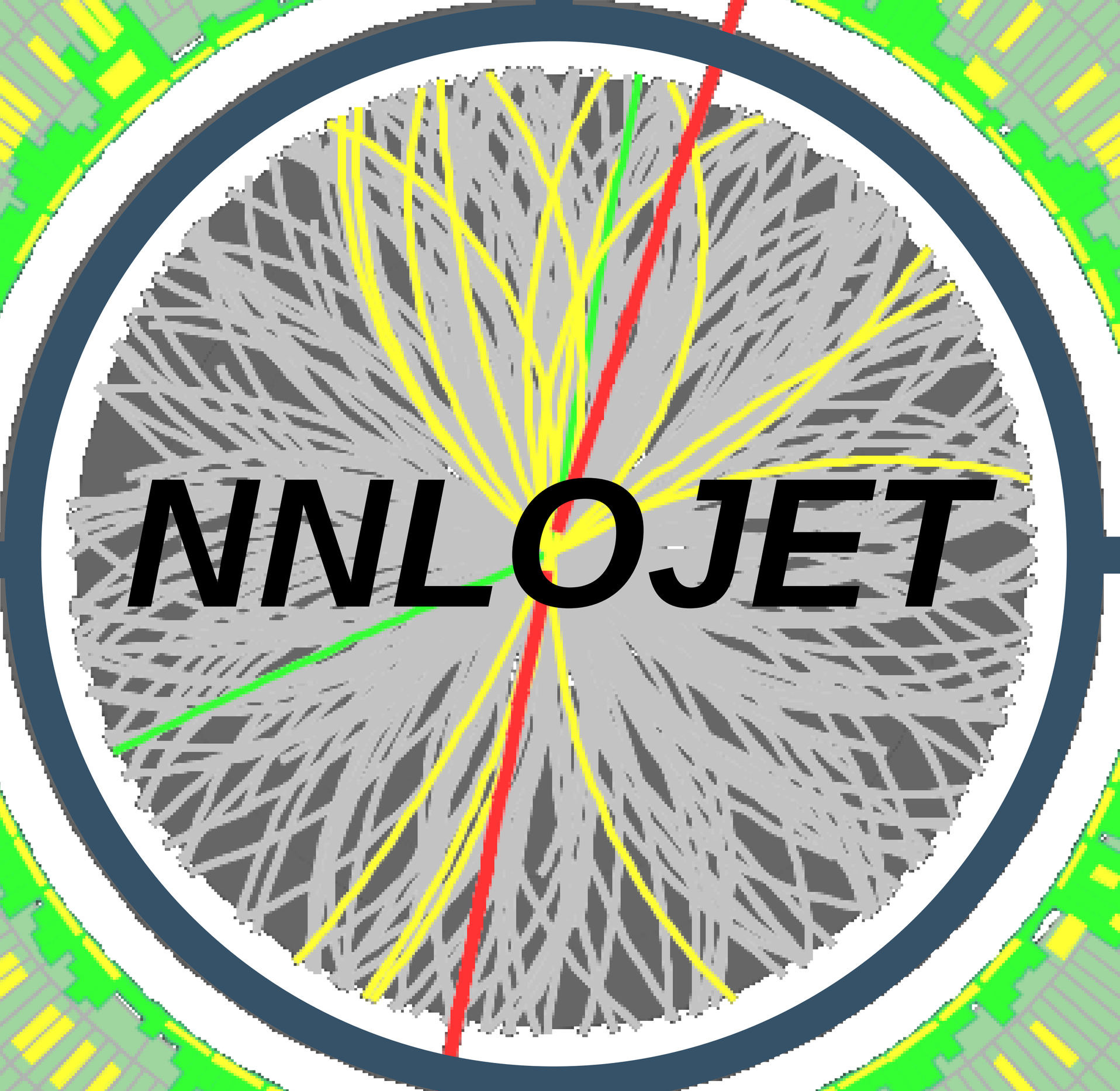
Photon Production @ the LHC

The comparison between measurements and predictions for the photon production cross section enables us to better understand the **inner structure of the proton** and might help us to discover **new physics** at the LHC.



The experimental setup at the LHC can only be accurately reproduced in our predictions if we include the fragmentation contibution.

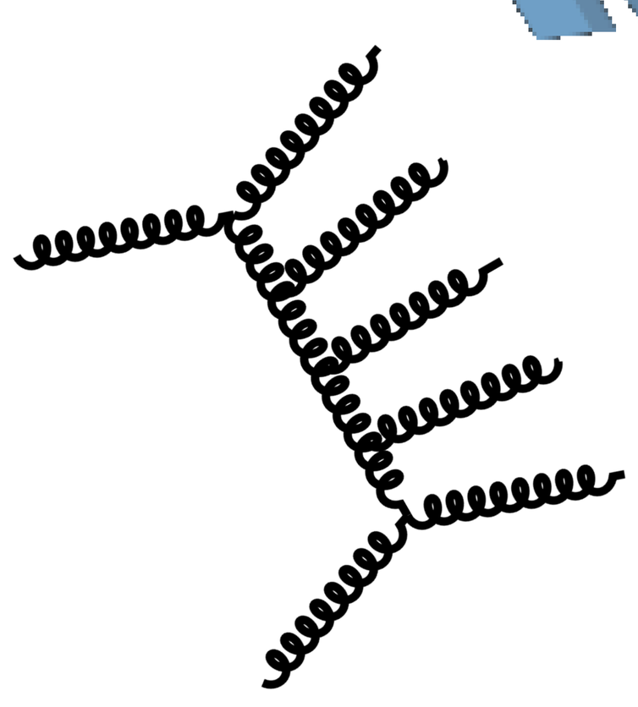


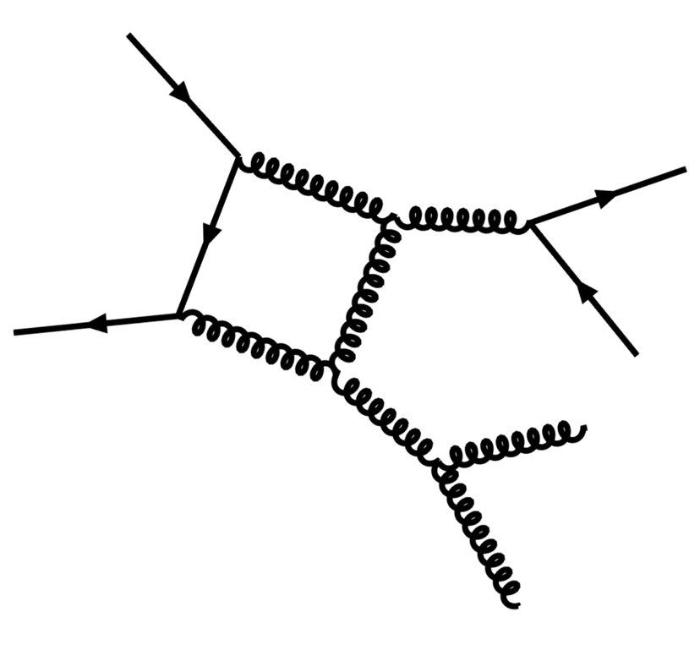


High Multiplicity Processes

Thanks to the increasing luminosity at the LHC (and in future at HL-LHC), we expect precise measurements to become available for rare events, in particular for **high-multiplicity events**.

Multi-jet production rates are crucial to probe **QCD**, measure the **strong coupling constant α_s** and search for physics beyond the Standard Model .

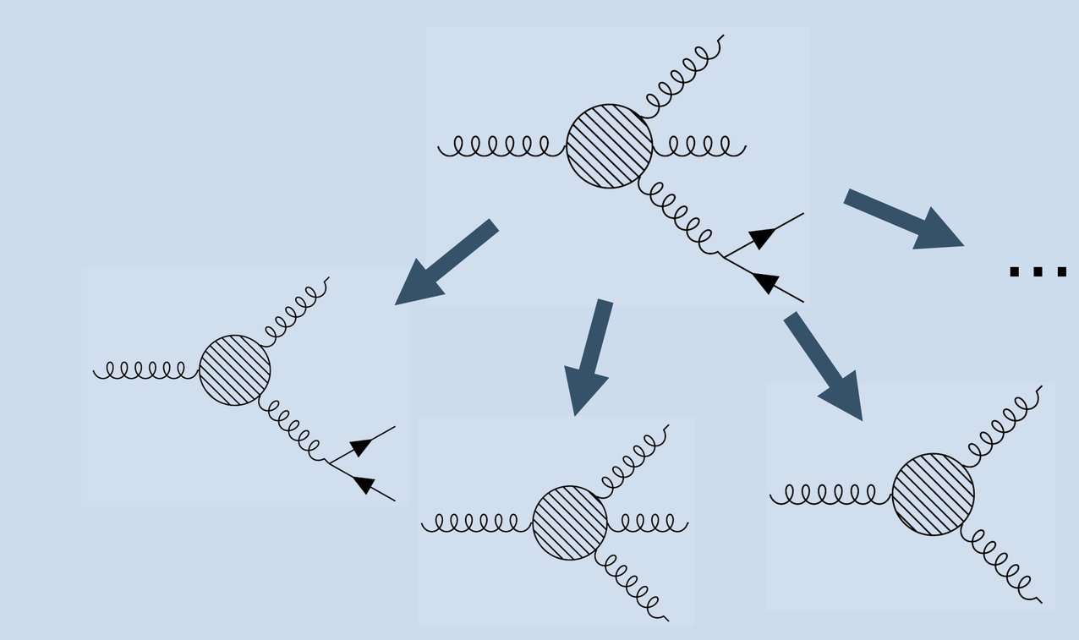




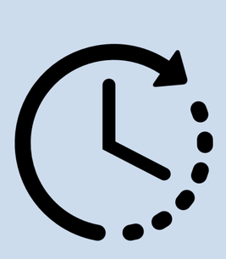
The complexity of precision calculations dramatically increases with the number of particles involved.

The next frontier of NNLO calculations is represented by **2→3 processes**, which pose some very challenging obstacles:

- several unresolved limits;

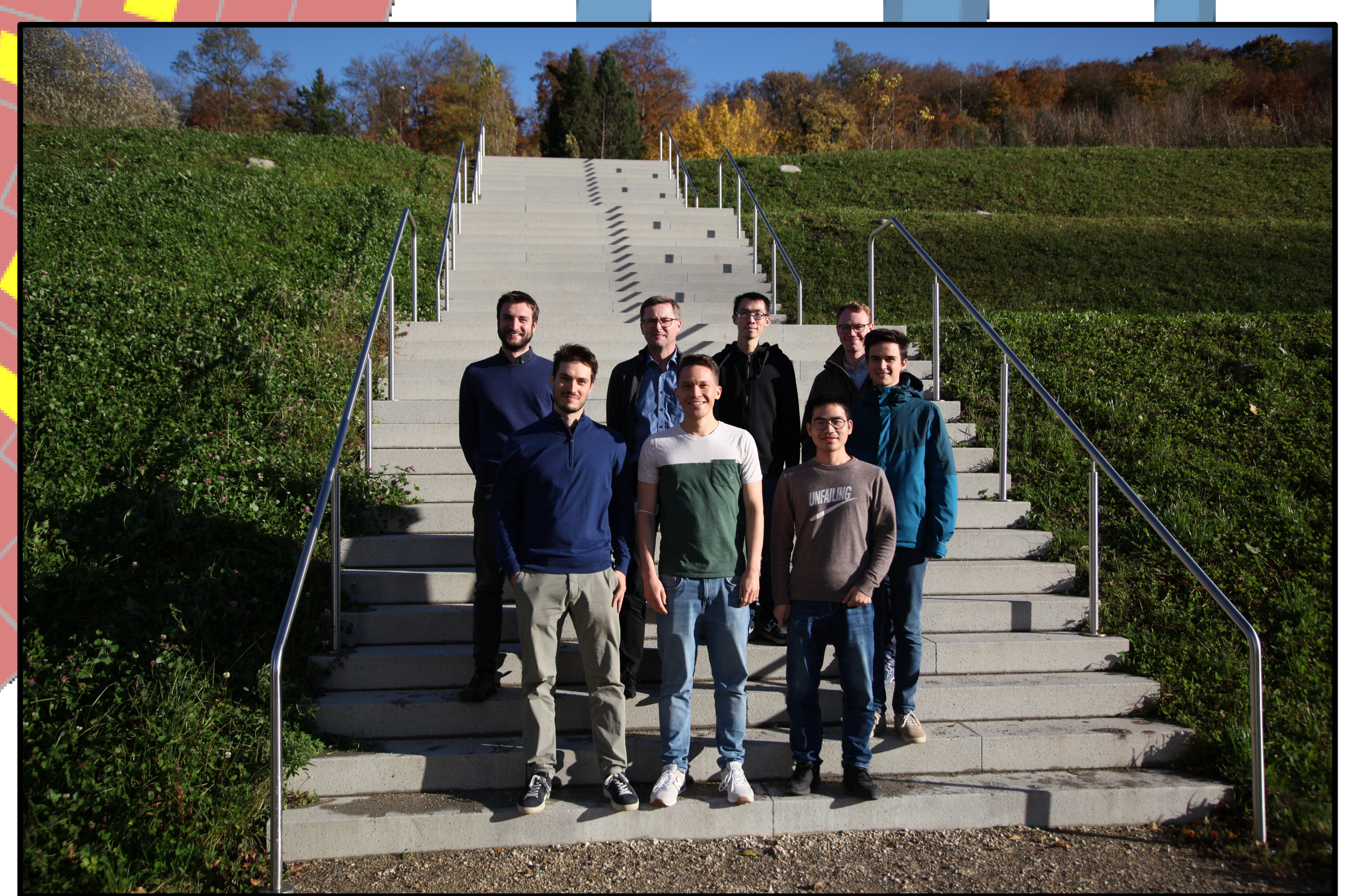


- heavy computational cost;



10^5-10^6 hours!

Theoretical Particle Physics Group
Prof. Thomas Gehrmann



We are a collaboration of 20 scientists working in different universities. Local members are:

- Thomas Gehrmann
- Giovanni Stagnitto
- Tong-Zhi Yang
- Jonathan Mo
- Markus Löchner
- Petr Jakubcik
- Robin Schürmann
- Matteo Marcoli

Universität Zürich[UZH] · ETH zürich · LMU Ludwig-Maximilians-Universität München · Nikhef · CERN · IP3 · KIT Karlsruher Institut für Technologie

Check out Tong-Zhi's poster about **splitting functions**!

Website

Video