Developing tools for precision physics

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Hamburg, 18/11/2024

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DESY.

Starting of my journey :

Starting of my journey :

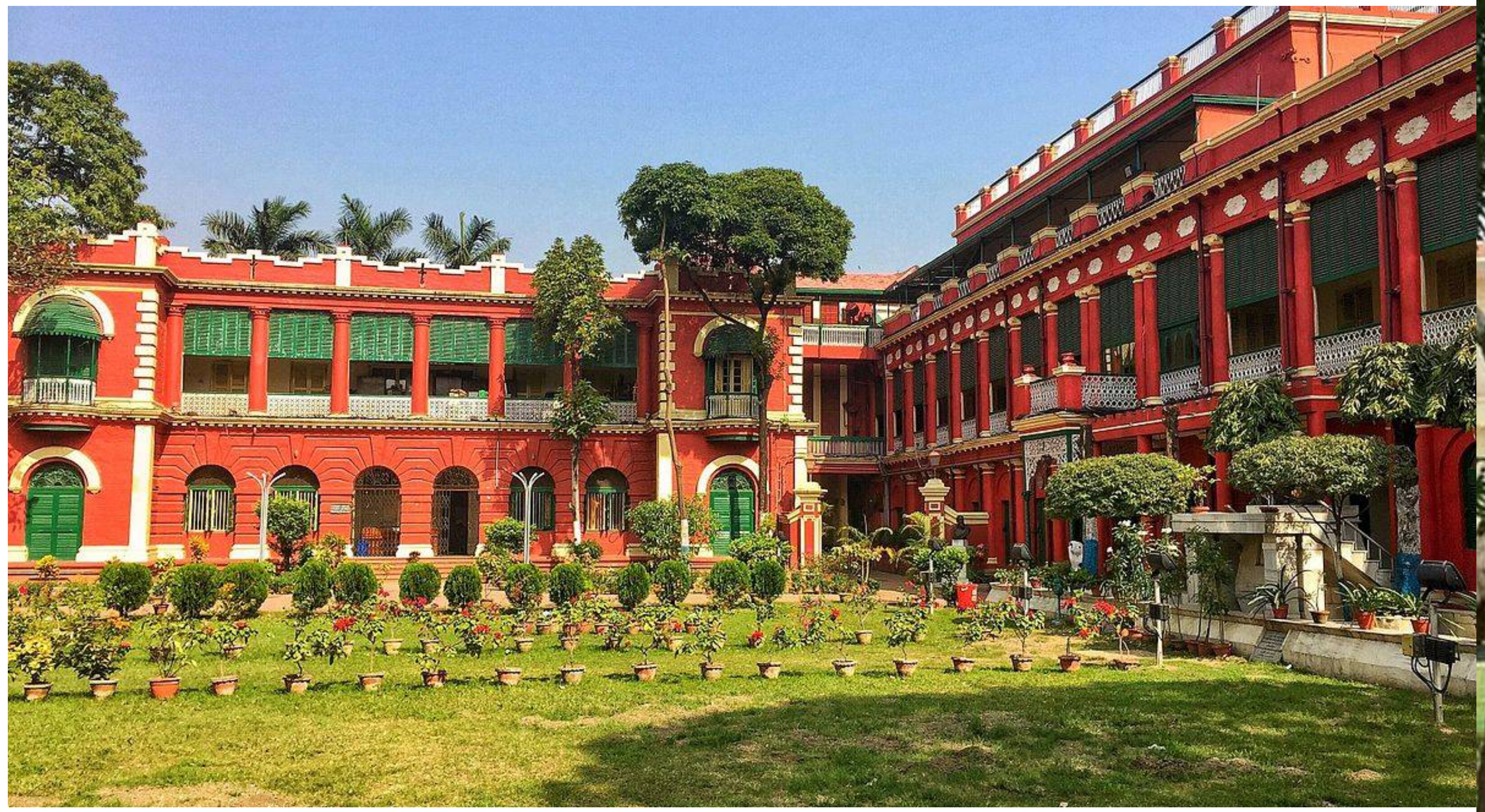
Starting of my journey :

Born in India

Starting of my journey :

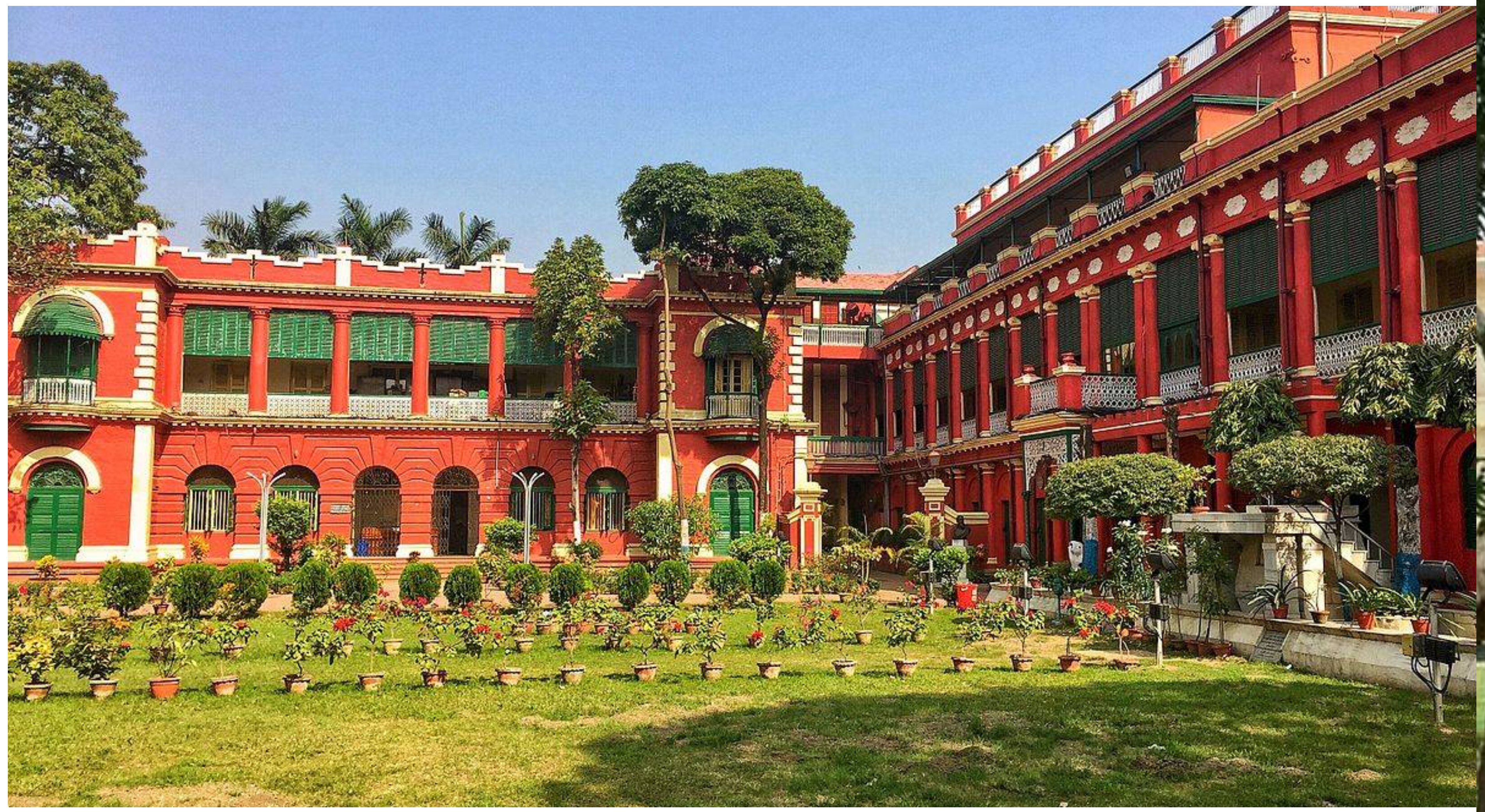
Masters at IIT

Born in India



Starting of my journey :

Born in India



Masters at IIT

Doctoral in IMSc

P.C. Google

Post doctoral journey :

P.C. Google

Post doctoral journey :

P.C. Google

Post doctoral journey :

Postdoctoral in Bonn

P.C. Google

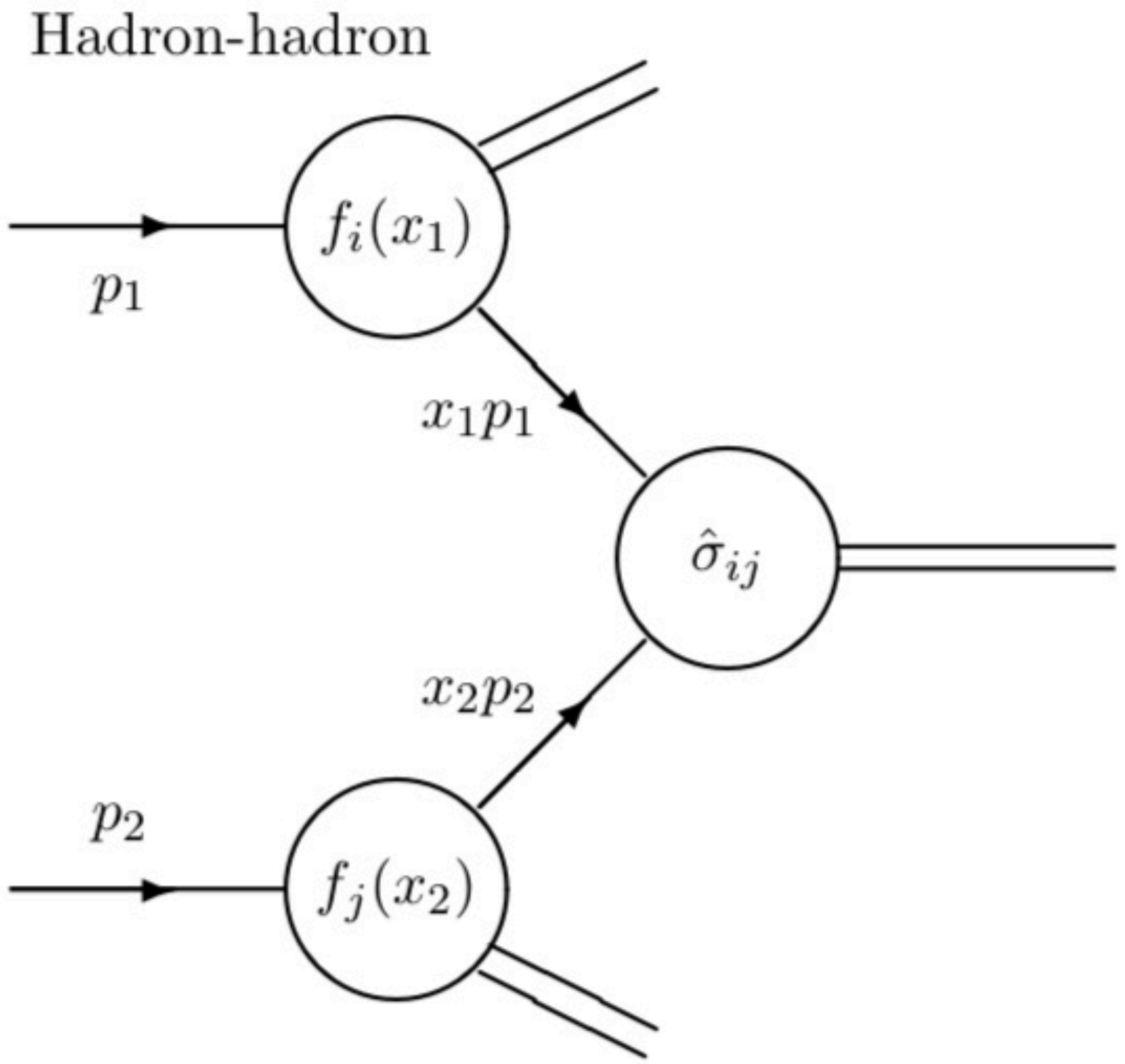
Post doctoral journey :

Postdoctoral in Bonn

Postdoctoral in Hamburg

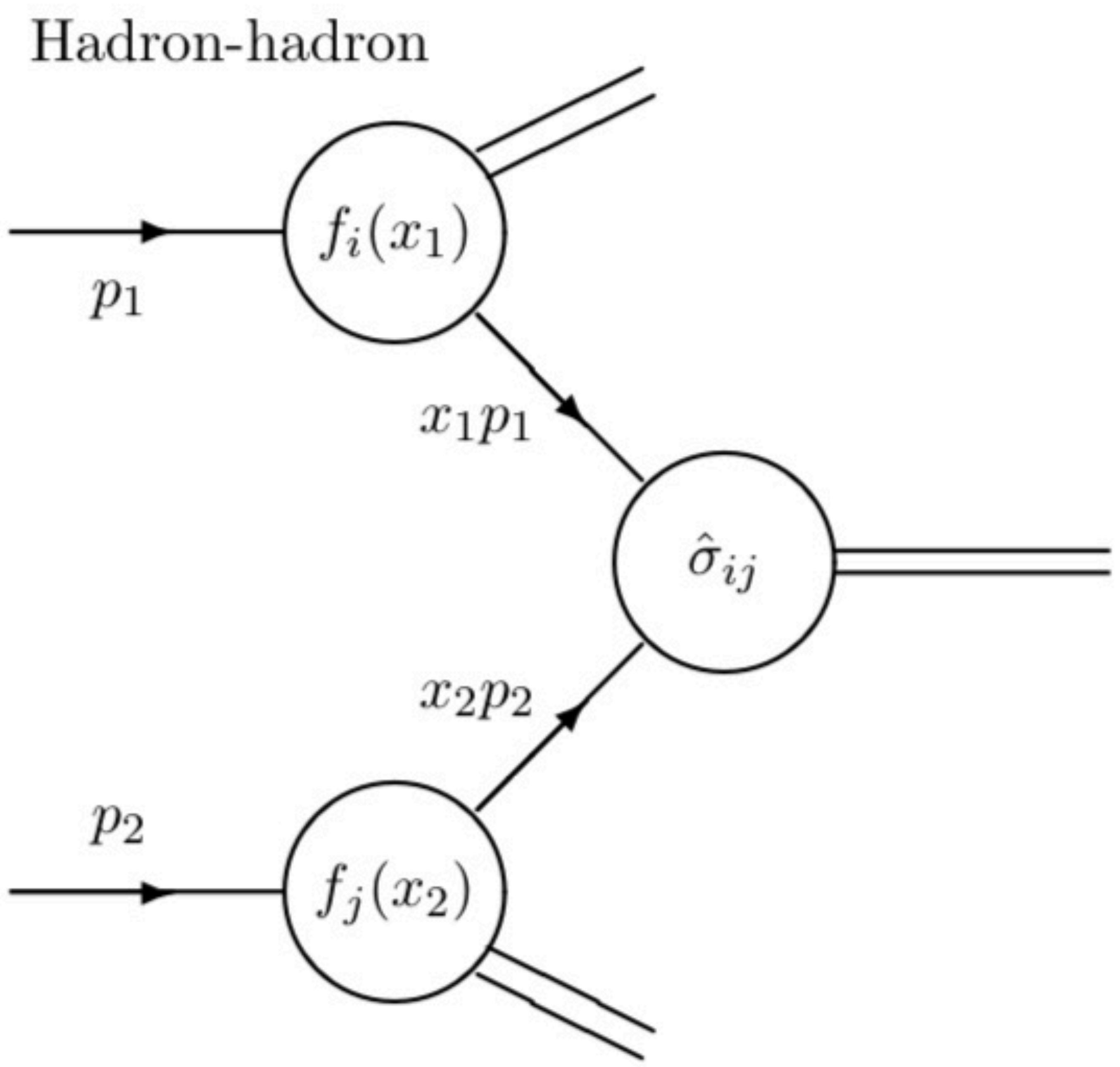
P.C. Google

Ongoing projects:



Observables ~ parton density $\otimes$ Matrix element $\otimes$ parton density

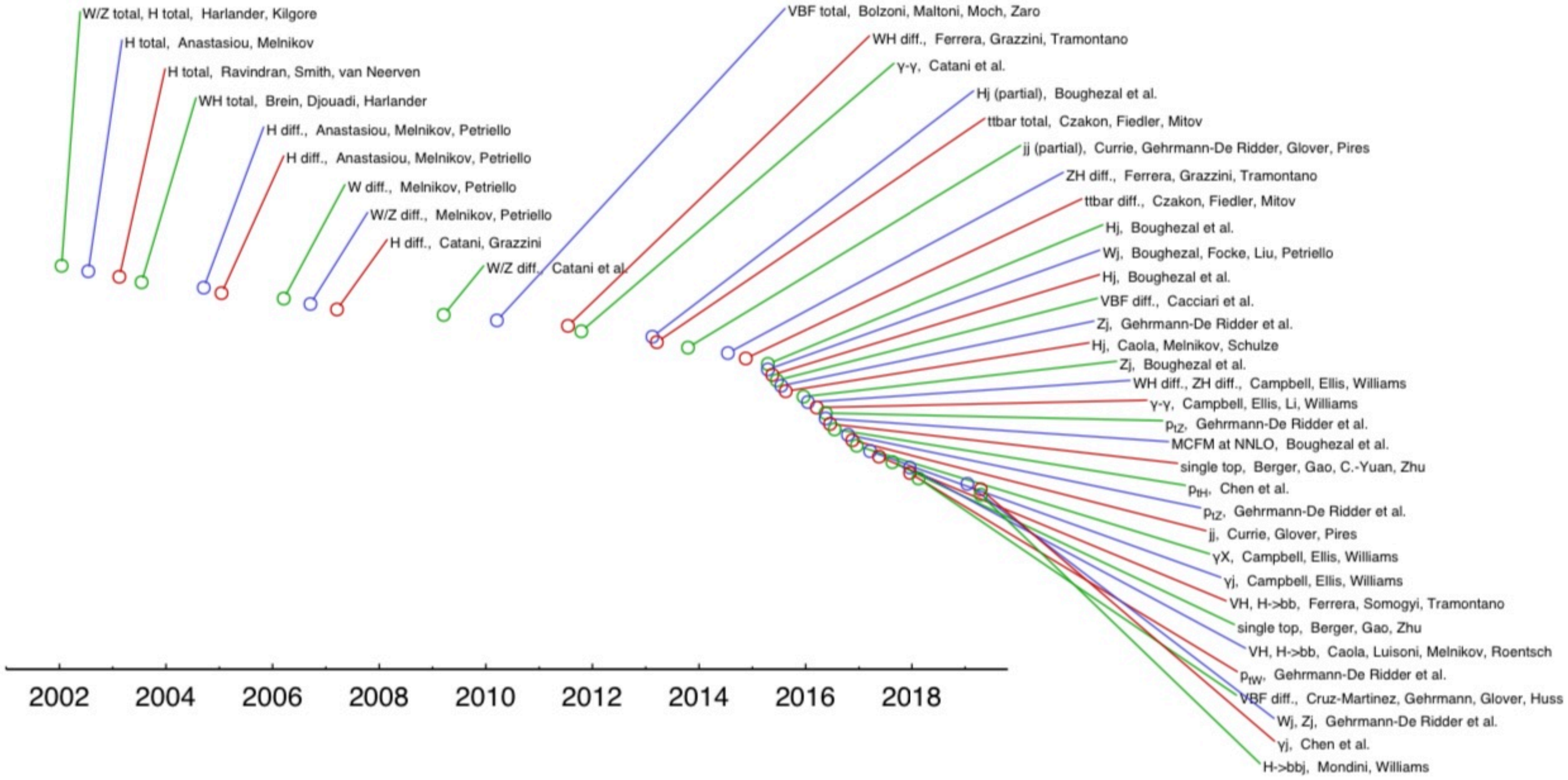
Ongoing projects:



$$\sigma(p_A, p_B) = \sum_{a,b} \int_0^1 dx_a f_{a/A}(x_a, \mu_F^2) \int_0^1 dx_b f_{b/B}(x_b, \mu_F^2) \Big[\sigma_{ab}^{LO}(p_a, p_b; \mu_R^2, \mu_F^2) + \sigma_{ab}^{NLO}(p_a, p_b; \mu_R^2, \mu_F^2) + \sigma_{ab}^{NNLO}(p_a, p_b; \mu_R^2, \mu_F^2) + \ldots \Big]$$

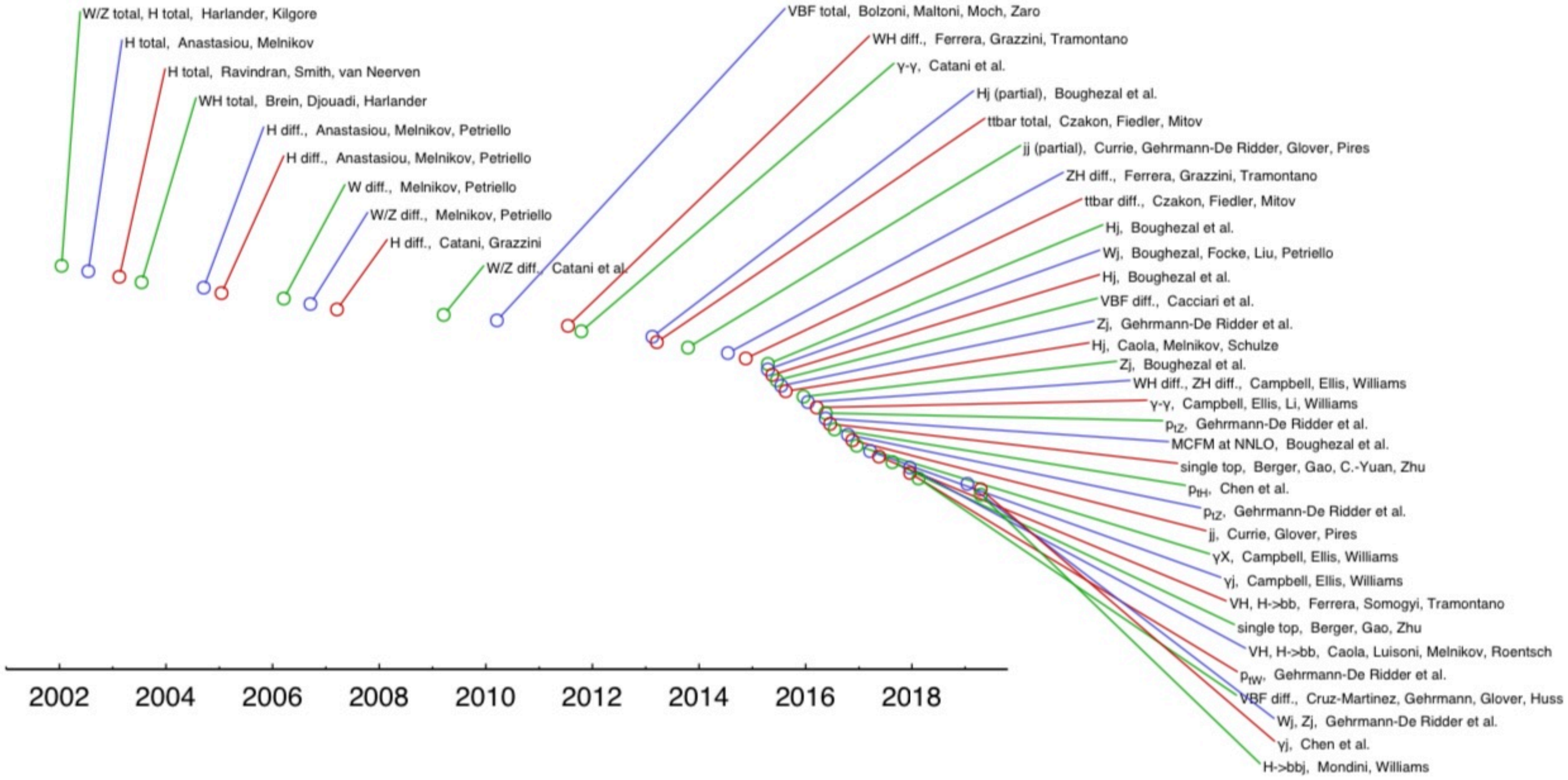
So far :

Plot by G. Salam



So far :

Plot by G. Salam



Further progress requires improvement in two-loop computations

CoLoRFul NNLO **Subtraction Scheme**

Aim: To construct a fully general local subtraction scheme for differential NNLO cross-section.

- **To do so**: Phase space (PS) integrals must be performed numerically
- **Problem**: IR singularities at intermediate stages
- **Solution**: Treat them using a subtraction method

The Scheme: Consider the NNLO correction to a generic m-jet observable

$$\sigma^{\mathrm{NNLO}} = \sigma^{\mathrm{RR}}_{m+2} + \sigma^{\mathrm{RV}}_{m+1} + \sigma^{\mathrm{VV}}_{m} = \int_{m+2} \mathrm{d}\sigma^{\mathrm{RR}}_{m+2} J_{m+2} + \int_{m+1} \mathrm{d}\sigma^{\mathrm{RV}}_{m+1} J_{m+1} + \int_{m} \mathrm{d}\sigma^{\mathrm{VV}}_{m} J_{m}$$

- J_m is infrared (IR) and collinear safe m final-state parton jet function.
- Matrix element for $\sigma^{\mathrm{RR}}_{m+2}$ (tree) and $\sigma^{\mathrm{RV}}_{m+1}$ for many processes.
- σ^{VV}_{m} (2-loop) know for 4 parton, V+3 parton processes, higher multiplicities are on the horizon.
- The three contributions are separately infrared divergent in $d = 4$ dimensions.

Double Real: σ^{RR}_{m+2}

- Kinematic singularities as one or two partons unresolved: up to $\mathcal{O}(\epsilon^{-4})$ poles from PS integration.
- No explicit ϵ pole

Real Virtual : σ^{RV}_{m+1}

- Kinematic singularities as one partons unresolved: up to $\mathcal{O}(\epsilon^{-2})$ poles from PS integration.
- Explicit ϵ pole up to $\mathcal{O}(\epsilon^{-2})$.

Double Virtual: σ^{VV}_{m}

- Kinematic singularities screened by jet function: PS integration finite
- Explicit ϵ pole up to $\mathcal{O}(\epsilon^{-4})$.

Rewrite the NNLO correction as a sum of three terms

$$\sigma^{\mathrm{NNLO}} = \sigma^{\mathrm{RR}}_{m+2} + \sigma^{\mathrm{RV}}_{m+1} + \sigma^{\mathrm{VV}}_{m} = \sigma^{\mathrm{NNLO}}_{m+2} + \sigma^{\mathrm{NNLO}}_{m+1} + \sigma^{\mathrm{NNLO}}_{m}$$

each integrable in four dimensions

$$\sigma^{\mathrm{NNLO}}_{m+2} = \int_{m+2} \left\{ \mathrm{d}\sigma^{\mathrm{RR}}_{m+2} J_{m+2} - \mathrm{d}\sigma^{\mathrm{RR,A_2}}_{m+2} J_m - \left[\mathrm{d}\sigma^{\mathrm{RR,A_1}}_{m+2} J_{m+1} - \mathrm{d}\sigma^{\mathrm{RR,A_{12}}}_{m+2} J_m \right] \right\}$$

$$\sigma^{\mathrm{NNLO}}_{m+1} = \int_{m+1} \left\{ \left[\mathrm{d}\sigma^{\mathrm{RV}}_{m+1} + \int_1 \mathrm{d}\sigma^{\mathrm{RR,A_1}}_{m+2} \right] J_{m+1} - \left[\mathrm{d}\sigma^{\mathrm{RV,A_1}}_{m+1} + \left(\int_1 \mathrm{d}\sigma^{\mathrm{RR,A_1}}_{m+2} \right)^{\mathrm{A_1}} \right] J_m \right\}$$

$$\sigma^{\mathrm{NNLO}}_{m} = \int_{m} \left\{ \mathrm{d}\sigma^{\mathrm{VV}}_{m} + \int_2 \left[\mathrm{d}\sigma^{\mathrm{RR,A_2}}_{m+2} - \mathrm{d}\sigma^{\mathrm{RR,A_{12}}}_{m+2} \right] + \int_1 \left[\mathrm{d}\sigma^{\mathrm{RV,A_1}}_{m+1} + \left(\int_1 \mathrm{d}\sigma^{\mathrm{RR,A_1}}_{m+2} \right)^{\mathrm{A_1}} \right] \right\} J_m$$

The **counterterms** are constructed as:

- $\mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_2}$ regularizes the doubly-unresolved limits of $\mathrm{d}\sigma_{m+2}^{\mathrm{RR}}$.

- $\mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_1}$ regularizes the singly-unresolved limits of $\mathrm{d}\sigma_{m+2}^{\mathrm{RR}}$.

- $\mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_{12}}$ accounts for the overlap of $\mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_1}$ and $\mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_2}$.

- $\mathrm{d}\sigma_{m+1}^{\mathrm{RR},A_1}$ regularizes the singly-unresolved limits of $\mathrm{d}\sigma_{m+1}^{\mathrm{RV}}$.

- $\left(\int_1 \mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_1}\right)^{A_1}$ regularizes the singly-unresolved limits of $\displaystyle\int_1 \mathrm{d}\sigma_{m+2}^{\mathrm{RR},A_1}$.

The **Phase space integrals** are then solved as :

- choose explicit parametrization of phase space.
- write the parametric integral representation in chosen variables.
- resolve the ϵ poles by sector decomposition.
- pole coefficients are finite parametric integrals.
- evaluate the parametric integrals in terms of multiple polylogs
- simplify the result by converting all polylogarithms in terms of :

$$G[a,b;x] = \mathrm{Li}_2\left[\frac{b-x}{b-a}\right] - \mathrm{Li}_2\left[\frac{b}{b-a}\right] + \log\left(1-\frac{x}{b}\right)\log\left(\frac{x-a}{b-a}\right).$$

Numerical Implementation

```
************************** version  beta  **************************
*                                                                  *
* ##    ## ##    ## ##        #######   ######     ###    ##       *
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*                                                                  *
*********************** September 10th, 2024 ***********************
*                                                                  *
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*                                                                  *
* https://github.com/nnlocal/nnlocal.git                           *
*                                                                  *
********************************************************************
* Using input file named input.DAT

* [General options to specify the process and execution]
```
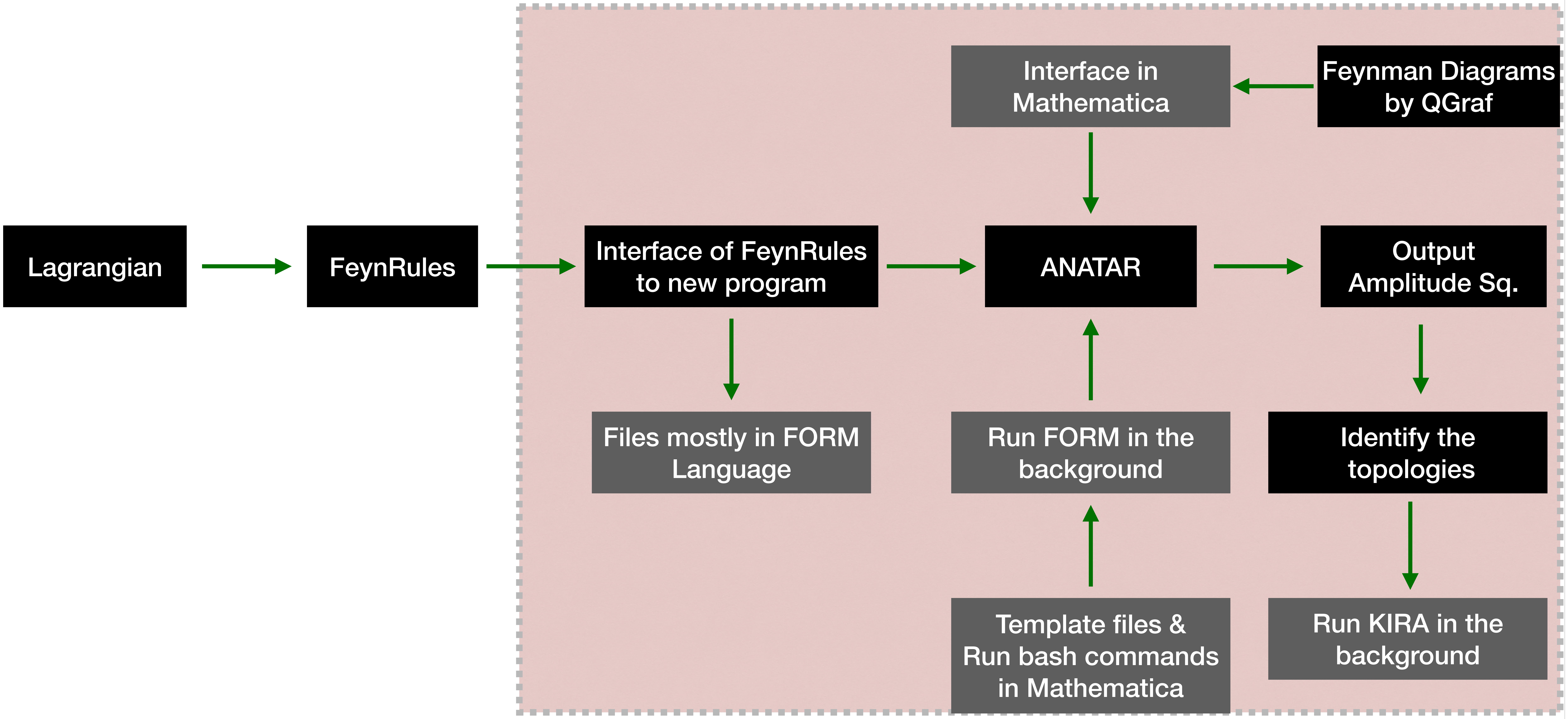
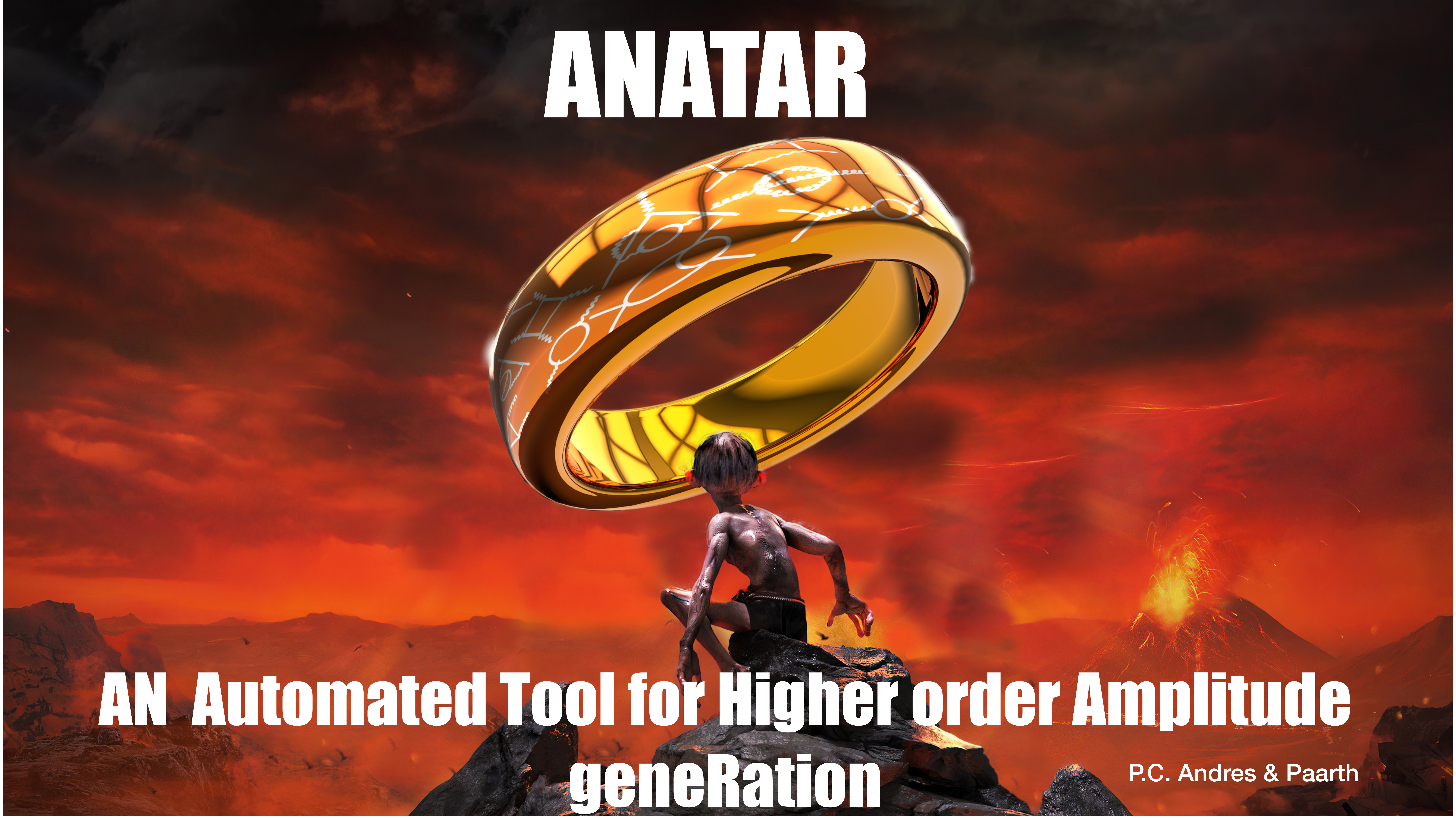
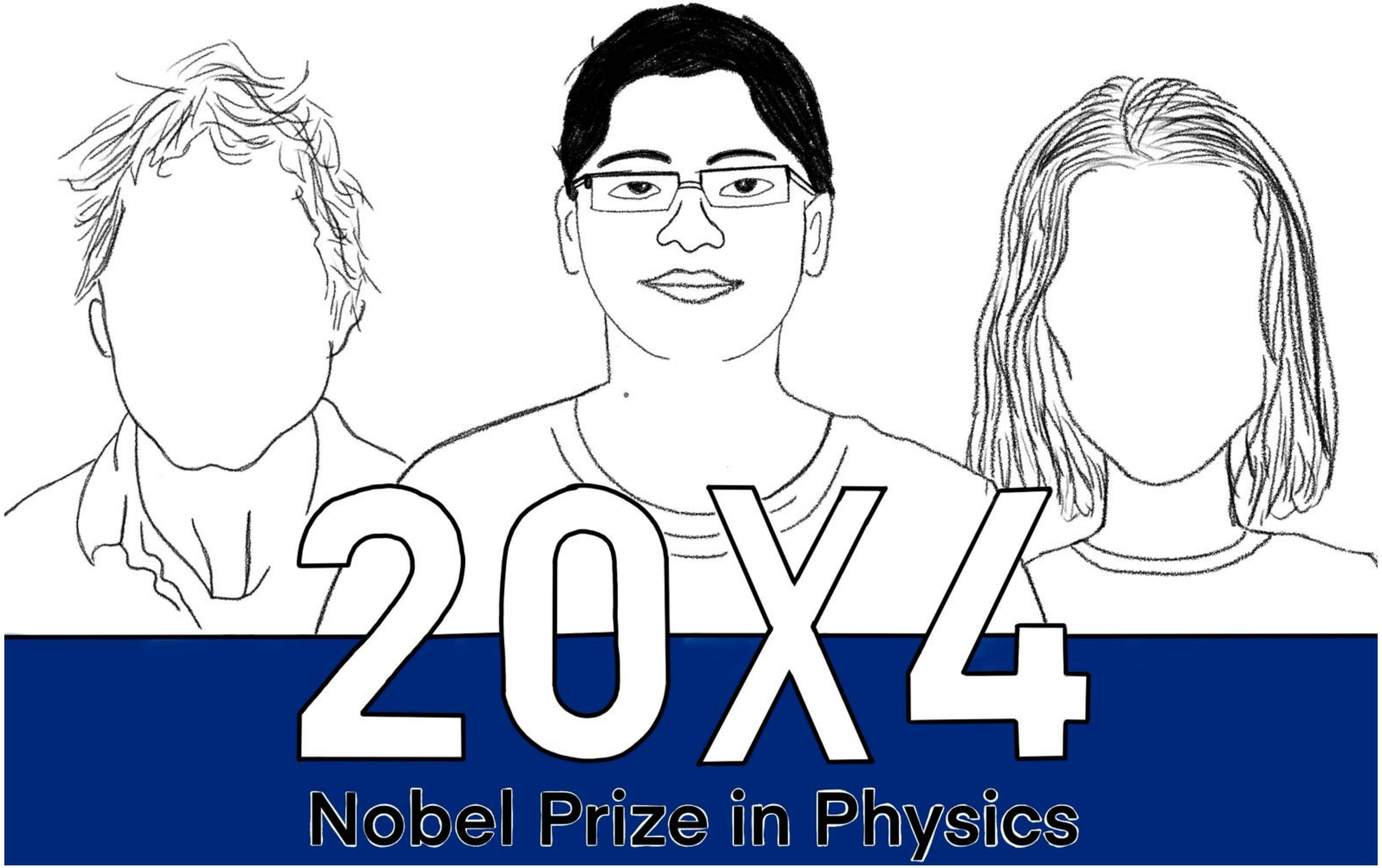

Package for automatizing steps of loop computation




ANATAR
AN Automated Tool for Higher order Amplitude geneRation
P.C. Andres & Paarth

End of my journey :

P.C. Yashasvee Goel



End of my journey :

Thank you for your attention !