LPPG – Monte-Carlo event generator for experiments at colliders

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LPPG

- is generator for different processes at hadron and lepton colliders
- with one-loop electroweak corrections
- with exact hard QED Bremsstrahlung contribution
- with shower matching
- Les Houches Accord (LHA) event format
- LHAPDF interface for parton density functions

ADAPTIVE (BLACK BOX) APPROACH

Adaptive MC able to sample from arbitrary function

GENERAL ALGORITHM

split phase space (PS) onto smaller regions

NO A-PRIORI KNOWLEDGE

have to build huge grids

EXAMPLE: FOR DY+J

$d = 6$ dimensional phase space

for 30 splits over each axis

$\texttt{sizeof(grid)} = 30^6 \times \texttt{sizeof(double)} \approx 2.7\text{GB}$

MULTI-CHANNEL APPROACH

APPROXIMATE BY "MASTER" DISTRIBUTIONS

$$|A(x)|^2 \approx \sum_i c_i G_i(x) \;\Rightarrow\; w = \frac{|A(x)|^2}{\sum_i c_i G_i(x)} \approx 1$$

ITERATIVE ALGORITHM

[Kleiss, Pittau] coefficients c_i updated to minimize variance

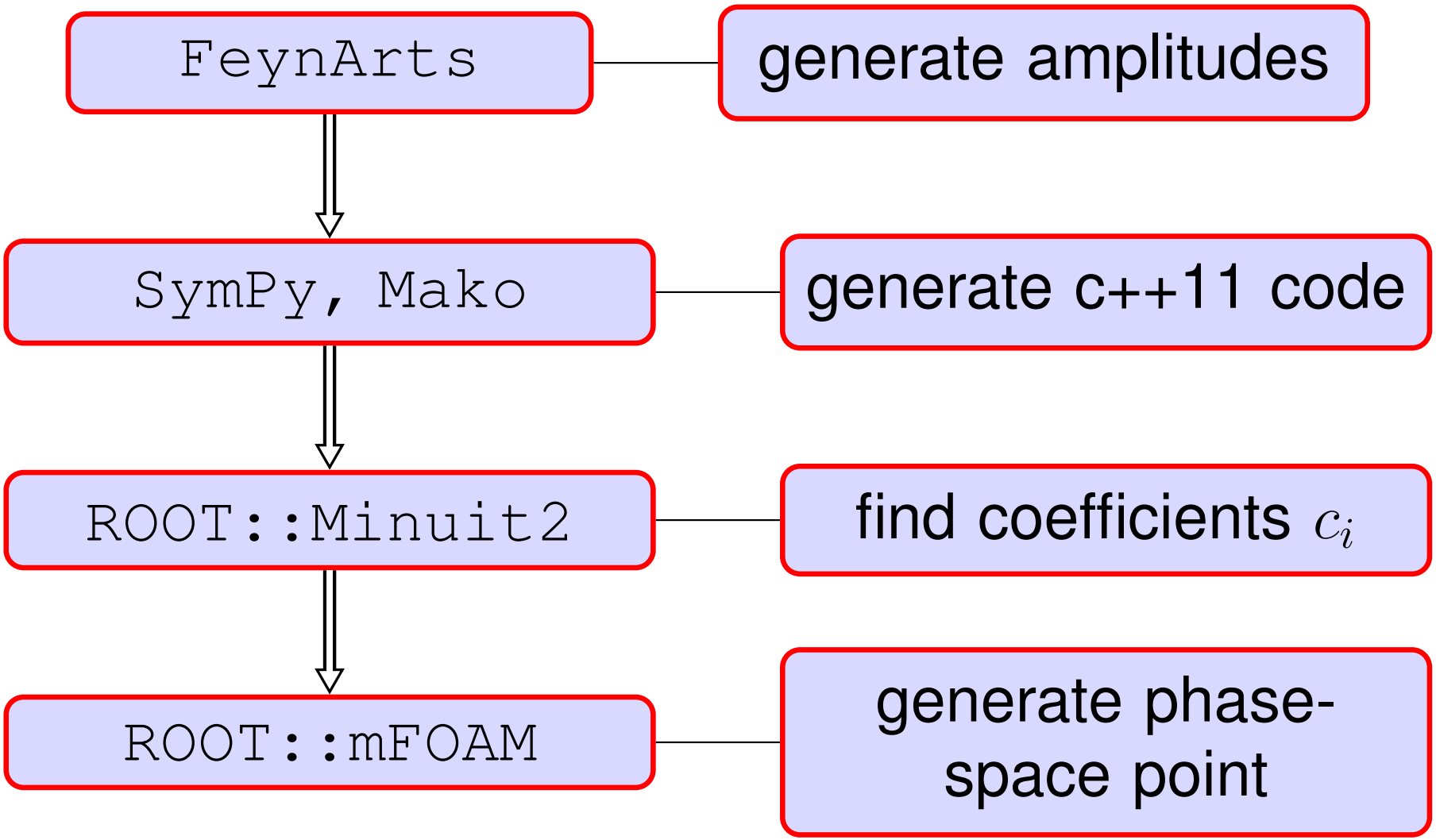
ADAPTATOR ALGORITHM

we choose set of PS points $\{x_k\}$, and find $c_i > 0$ which minimize

$\sum_k K\left(\sum_i c_i G_i(x_k) - |A(x_k)|^2\right)$

$K(x) = x^2 + r x^{10}\theta(x < 0)$, $r > 0$. We obtain $w \lessapprox 1$

GENERATION PROCEDURE



"MASTER" GENERATORS

The wider space of functions $G_i(x)$ the better adaptation

But non-wise **choice of variables** $x = \{x_1, x_2, \ldots, x_d\}$ can strongly complicate the job

In tree-level amplitude all peaks are due to **propagators**

Can we parametrize phase-space by **invariant** variables, which appear in **propagators**?

COMMON APPROACH: PS RECURSIVE BUILDING

Express PS as chain of decays and 2×2 scatterings
[E. Byckling and K. Kajantie, Particle Kinematics]

LPPG'S GENERALIZATION

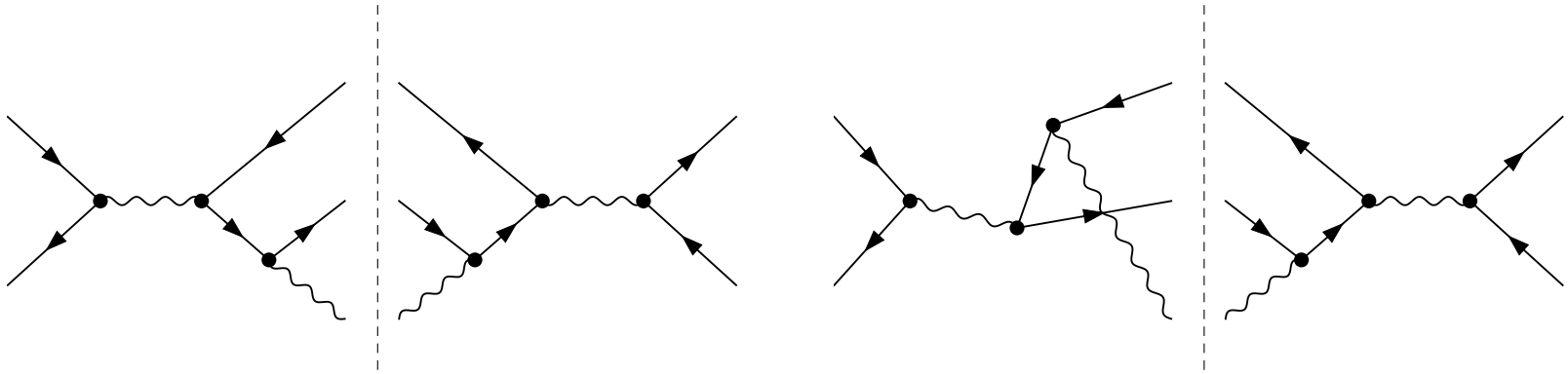
- changing of variables is as simple, as taking integrals with δ-functions:

$$\int dR_n \left(\frac{1}{p^2 - m^2} \ldots \right) = \int ds' \frac{1}{s' - m^2} \left[\int dR_n \delta(p^2 - s') \ldots \right]$$

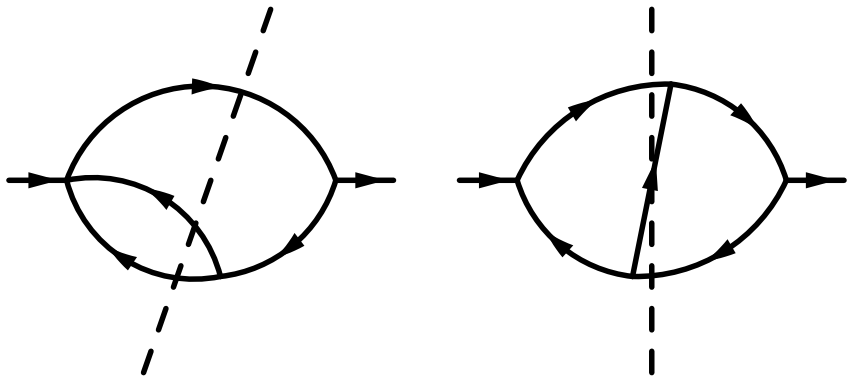
- problem now reduces to **generalized unitarity** integrals
- now formally all (intermediate and final) particles are **on-shell**

LOOP CONTRACTION

FSR

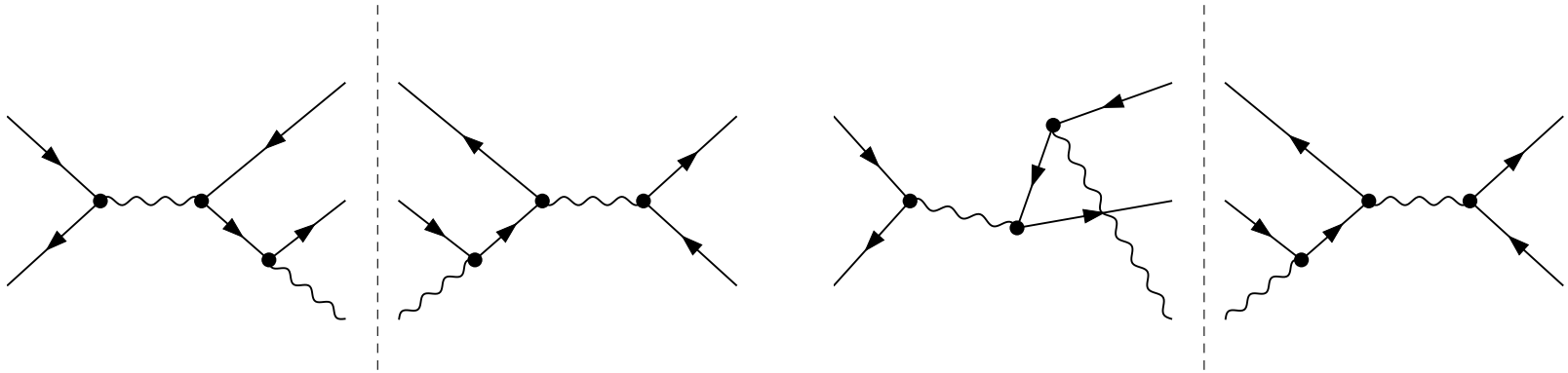


"MASTER" GENERATORS



LOOP CONTRACTION

FSR



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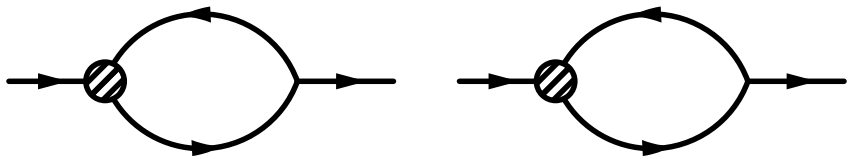
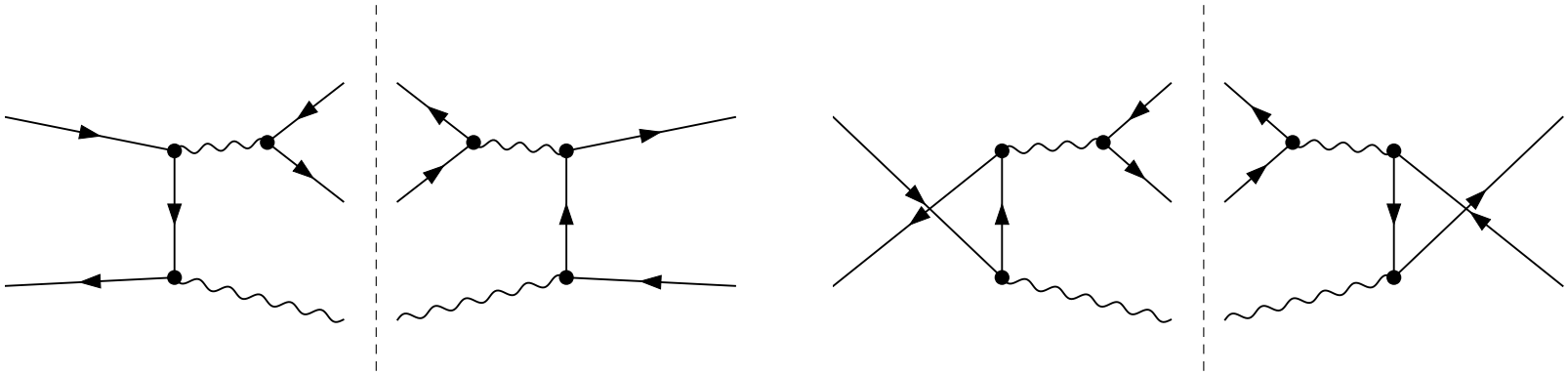
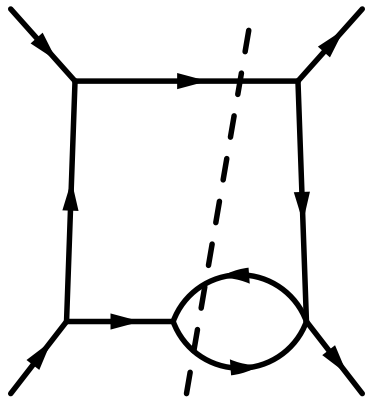


LOOP CONTRACTION

ISR



"MASTER" GENERATOR



LOOP CONTRACTION

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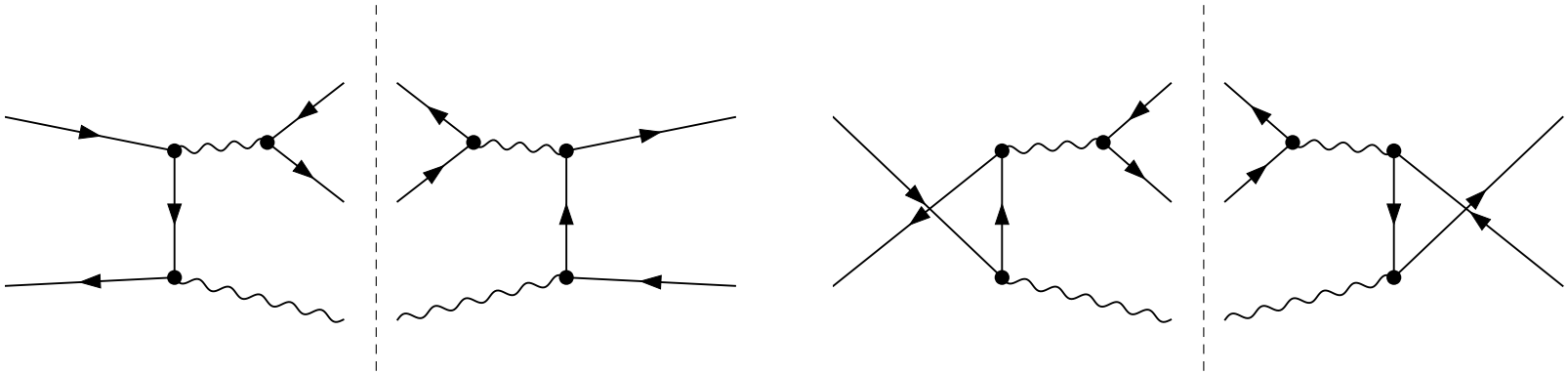

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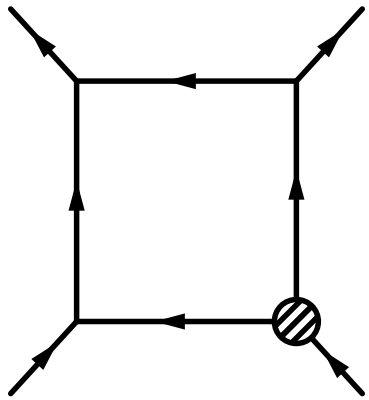
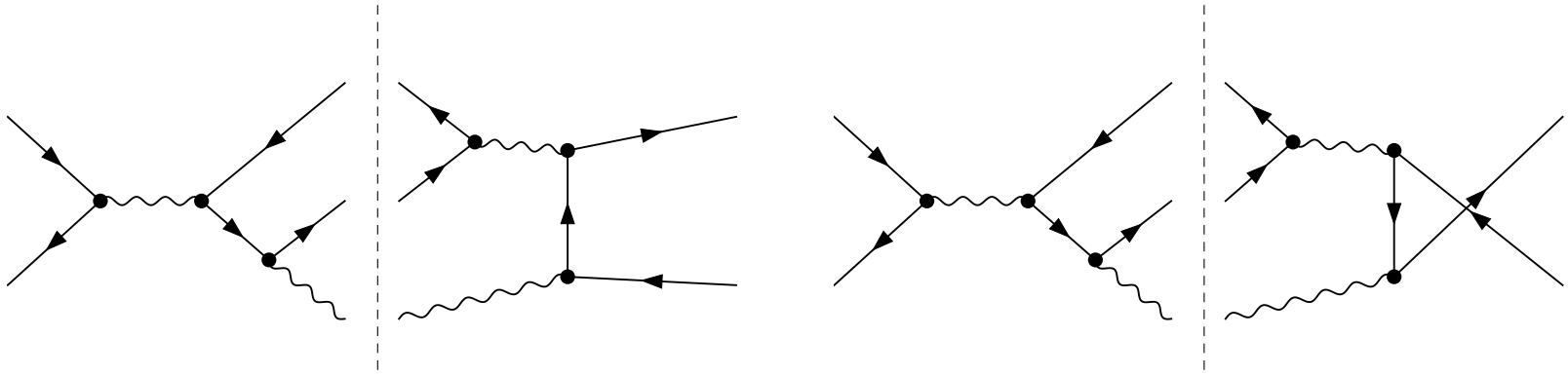


LOOP CONTRACTION

ISR-FSR INTERFERENCE



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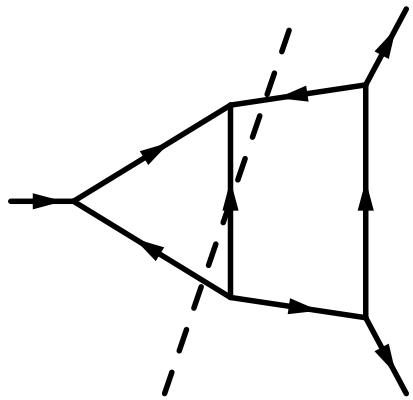

LOOP CONTRACTION

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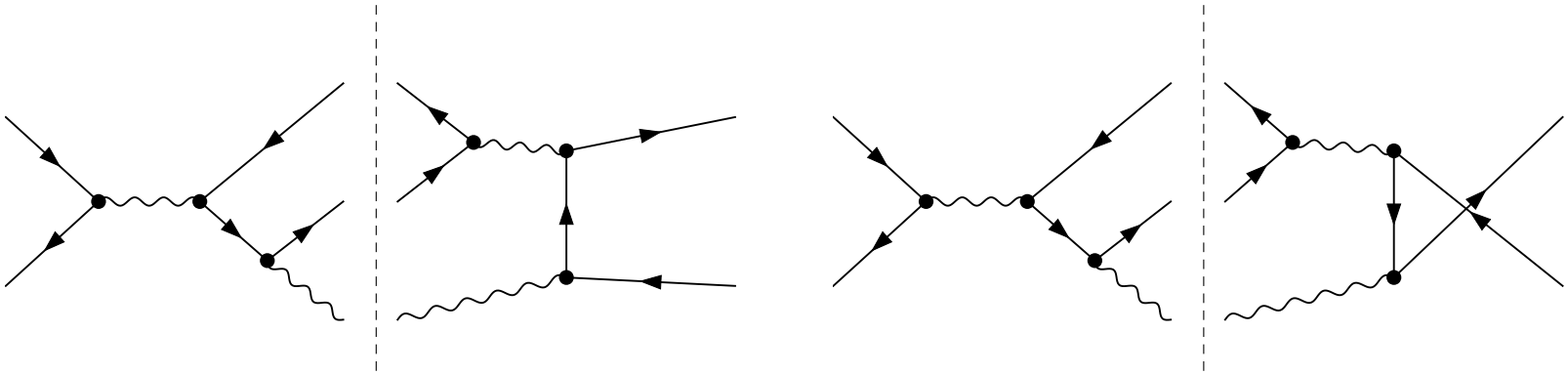

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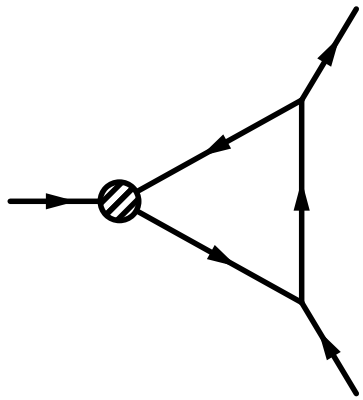
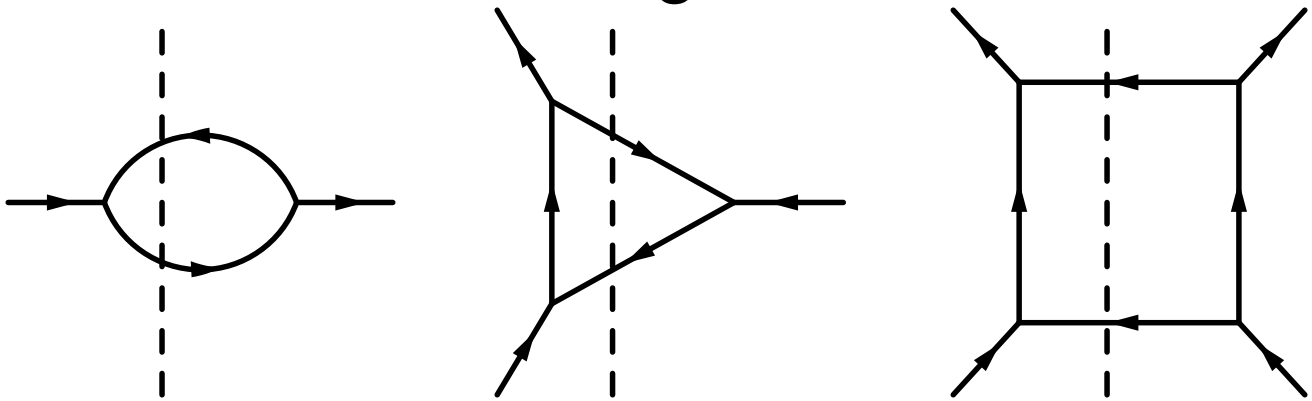


ELEMENTARY LOOPS

In our simple case only ”self-energy”, ”vertex” and ”forward-box” diagrams are needed

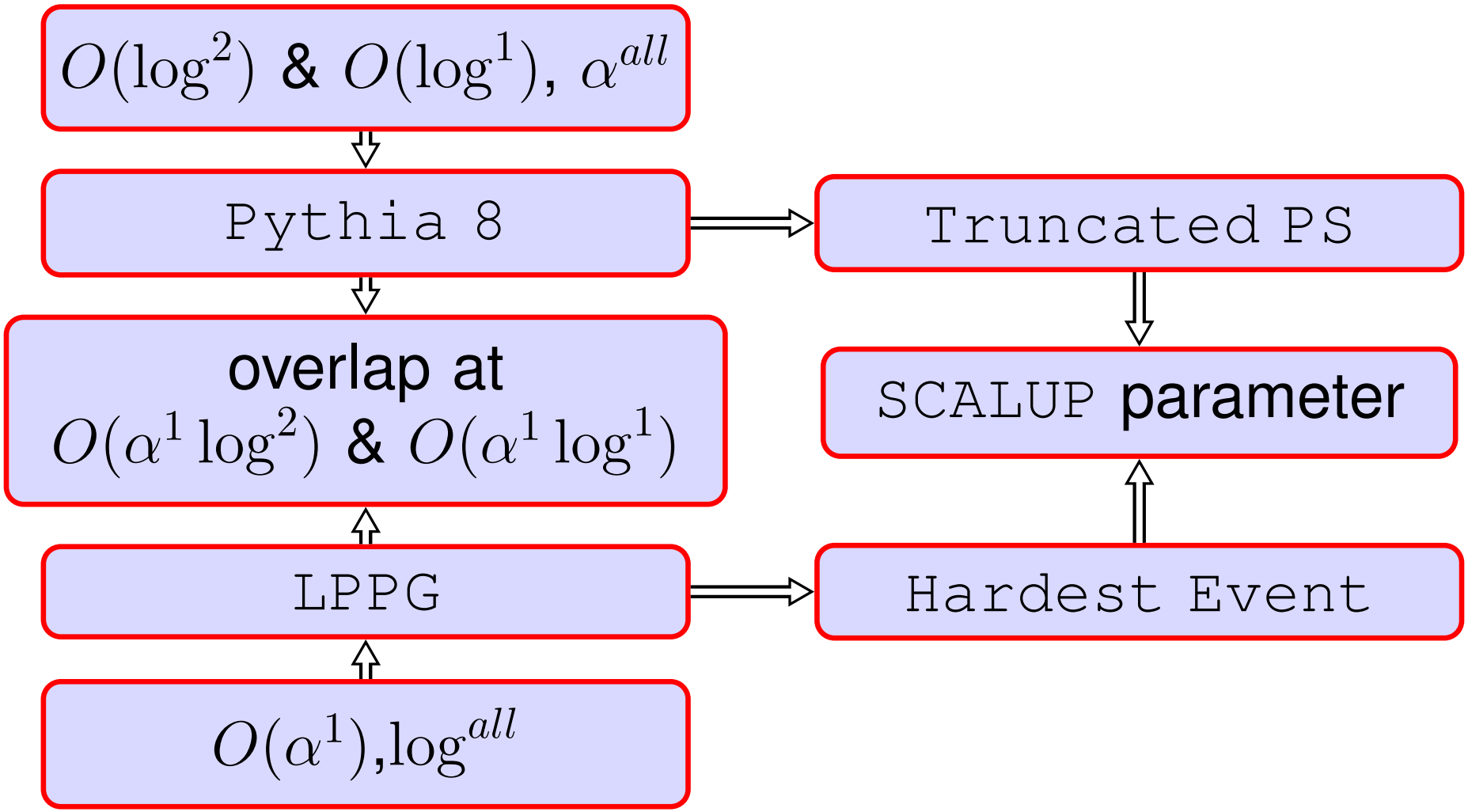


The same diagrams are used by vectorizer to construct particles momenta in desired reference frame

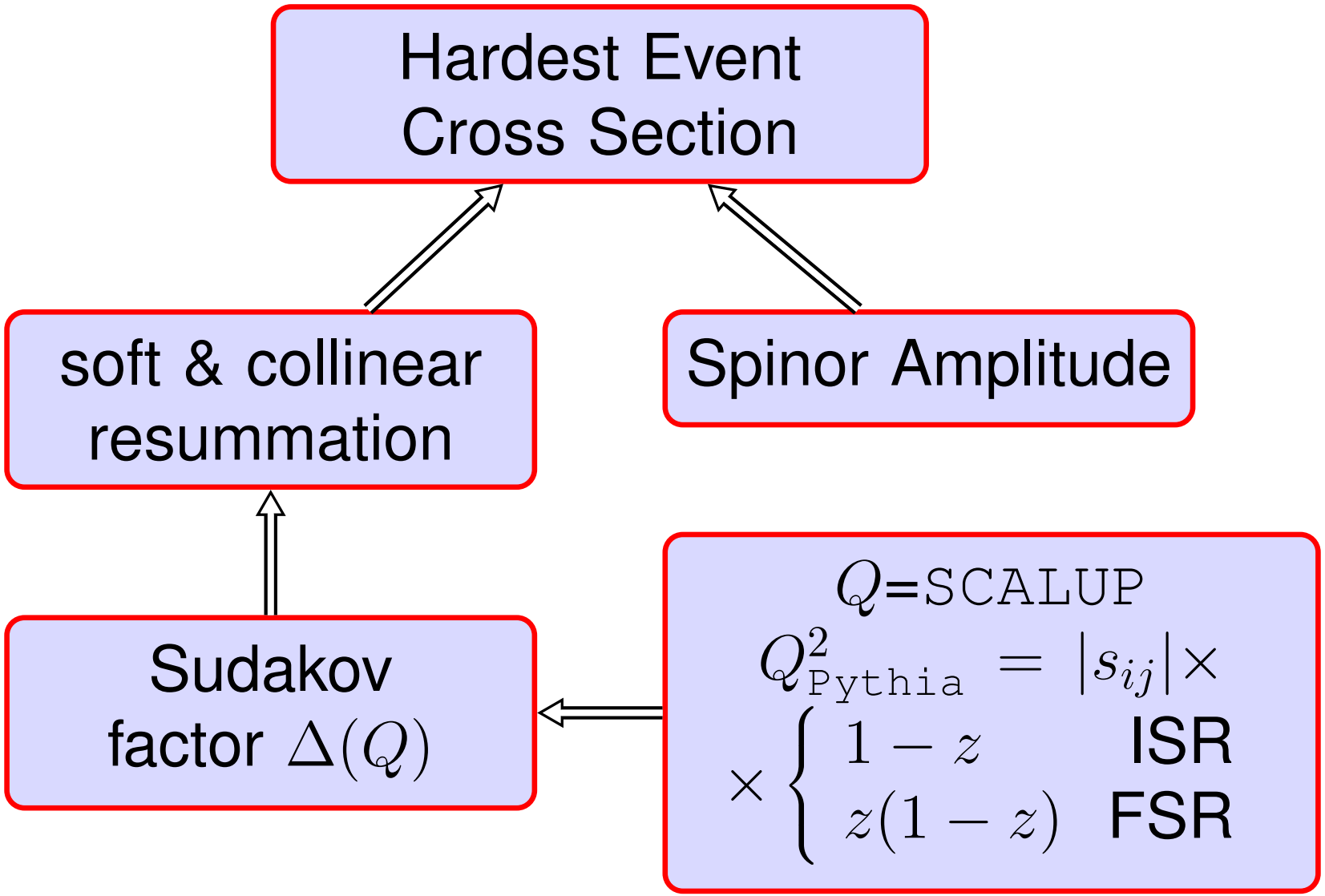
MOMENTA CONSTRUCTION

- one-loop sub-diagrams used for reconstruction of the momentum, running in the loop
- reference frame and axes directions are fixed by external legs
- boosts and rotations can easily be performed by operators from Clifford algebra [Doran, Lasenby Geometric Algebra for Physicists]

HARDEST EVENT PS MATCHING



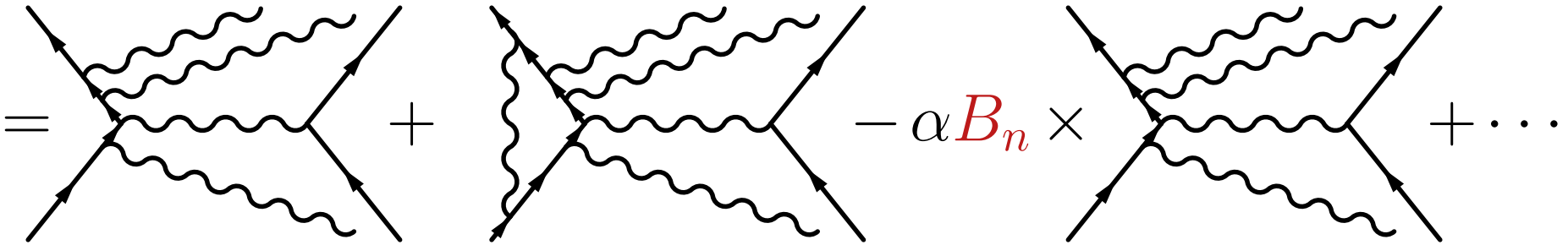
HARDEST CROSS SECTION



HARD CROSS-SECTION

INFRARED FINITE CROSS-SECTION

$$\sigma_n^H = \sigma_n^{H\,0\,\text{loop}} + \sigma_n^{H\,1\,\text{loop}} - \alpha B_n \sigma_n^{H\,0\,\text{loop}} + \cdots =$$



TOTAL CROSS-SECTION

$$\sigma_n = \sigma_n^H \Delta_n(k_{\text{cut}}^T)$$

PROPERTIES

IF CALCULATIONS ARE ORGANIZED IN PROPOSED WAY, THEN

- Infrared singularities are effectively regularized with Sudakov factor;
- Projection to lower phase-space are unnecessary. No off-shell extrapolation also;
- We deal with a positive-defined integrable distribution suitable for Monte-Carlo;
- Generator for multiplicity n effectively generates events for lower multiplicities;

CONCLUSION

- proposed method of generation with multi-channel optimization approach and wise phase space parametrization
- matching with parton shower MCs implemented
- all necessary interfaces for inclusion into analysis infrastructure available

Thank you!