GenEx: A simple generator structure for exclusive processes in high energy collisions

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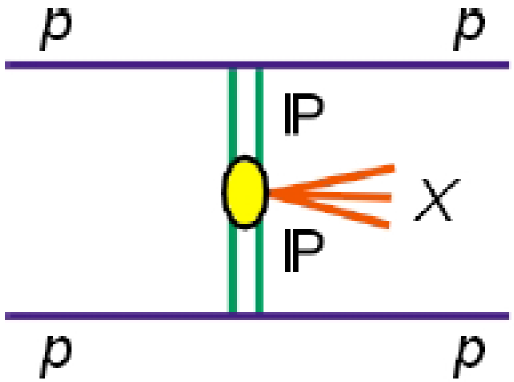
- R.Kycia, J.Chwastowski, R.Staszewski, J.Turnau (arXiv:1411.6035 [hep-ph])
- What it is for
- What are its distinctive features
- How it works
- Summary

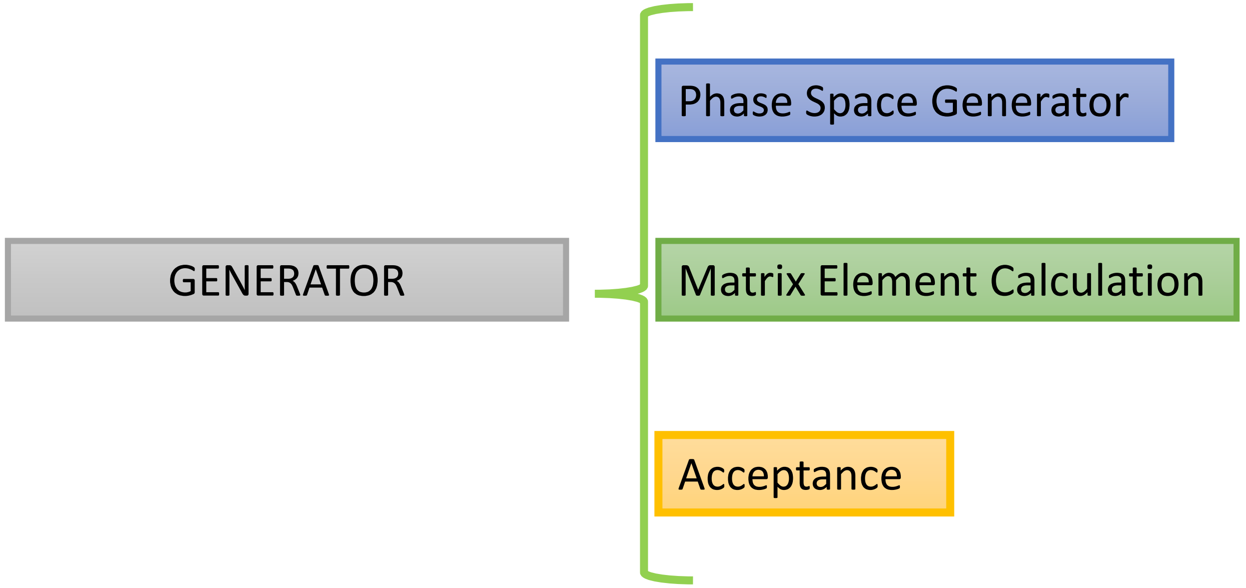
What GenEx has been designed for



- STAR physics program with forward protons taggers : study of central low mass (M < 3 GeV) production in DPE
- Generator implementing Regge models of resonance production and non-resonant background
- Sharply peaked matrix element, very restrictive acceptance cuts→low efficiency of standard event generator
- GenEx: efficient generation of the exclusive processes modelled by sharply peaked matrix elements in presence of very restrictive acceptance cuts

What are its distinctive features

- GenEx has conceptually very simple modular structure, which provides separate moduls for each method of the phase space generation,each matrix element and acceptance cuts

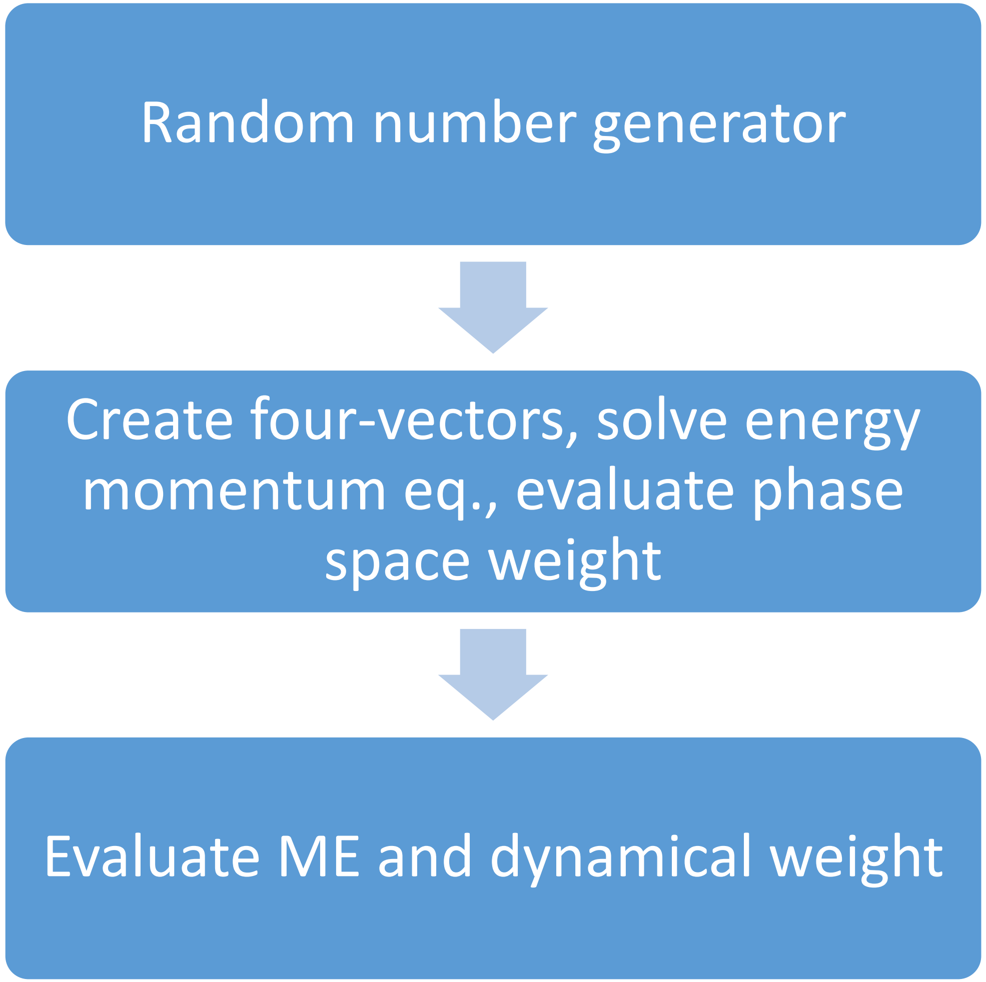


- **GenEx employs self-adapting MC integrator/simulator FOAM (S.Jadach) implemented in ROOT, which ensures very efficient generation of events even for sharply peaked ME**

Foam: A general purpose cellular Monte Carlo event generator
S. Jadach Comput.Phys.Commun. 152 (2003) 55-100

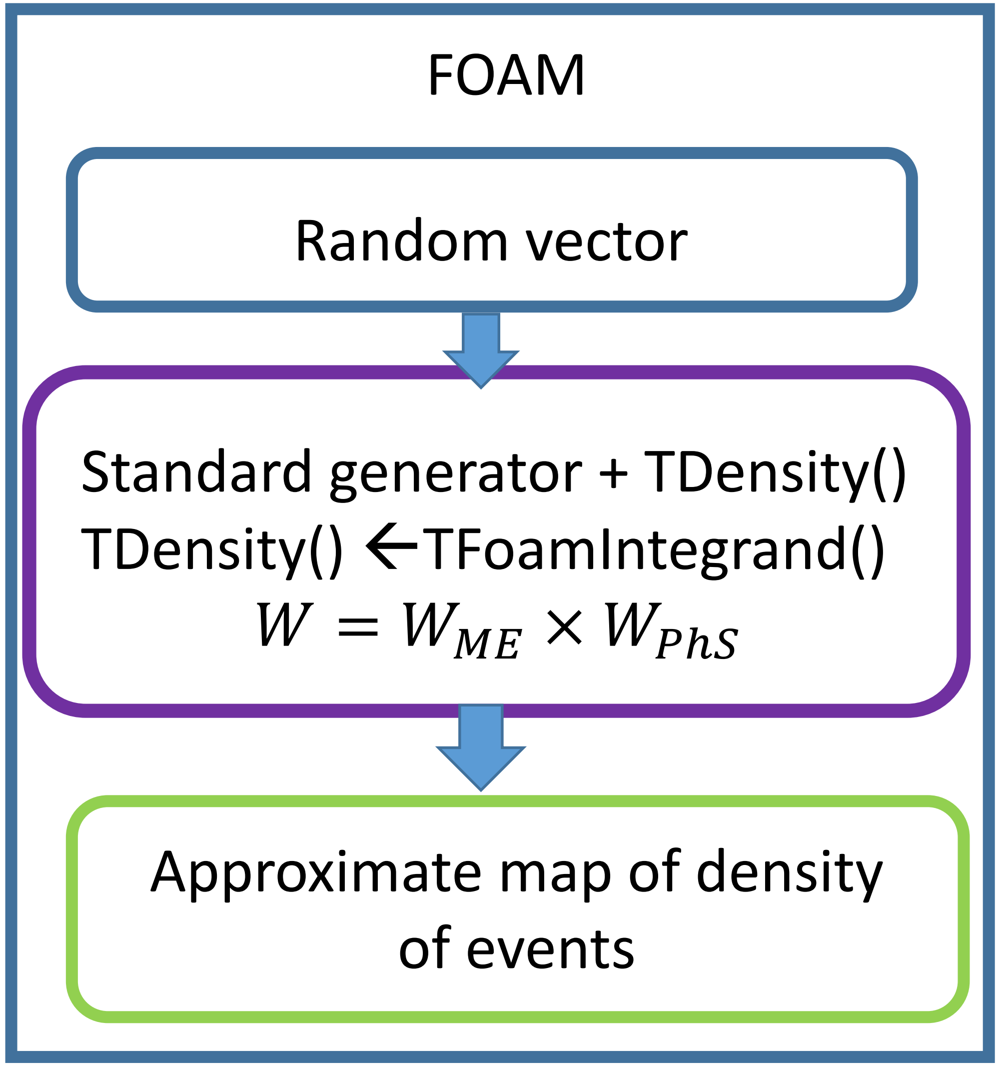
- A general purpose, self-adapting, Monte Carlo (MC) event generator (simulator)
- The high efficiency of the MC, that is small variance of the MC weight, is achieved by means of dividing the integration domain into small cells. The cells can be n-dimensional simplices or hypecubes
- The grid of cells, called "foam", is produced in the process of the binary split of the cells
- „The algorithm is able to deal, in principle, with an arbitrary pattern of the singularities in the distribution" (a bit exaggeretad statement)
- Foam has been implemented in CERN ROOT : class TFoam: public TObject

Typical MC event generator



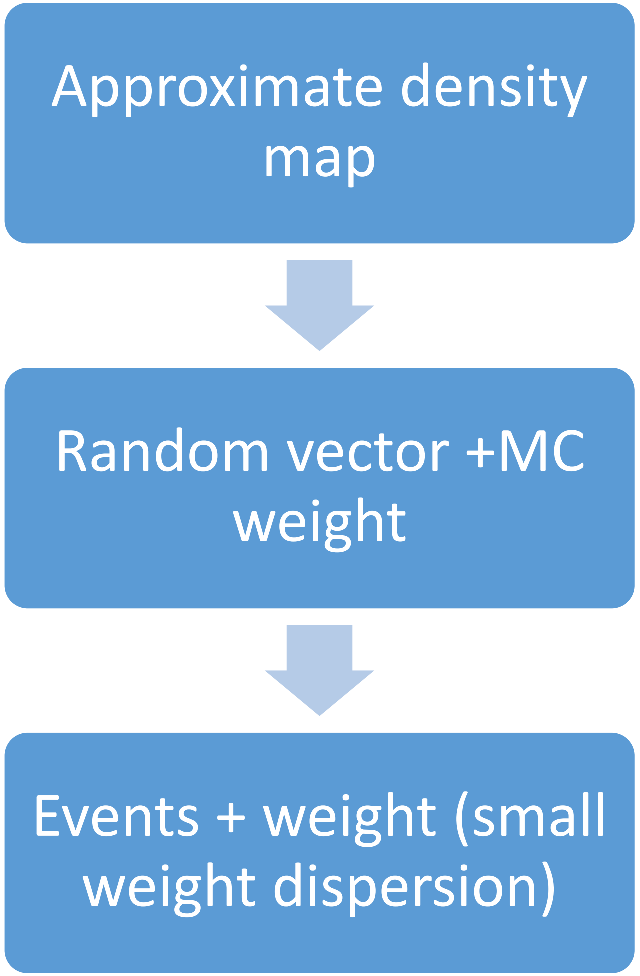
- Create vector of random numbers R
- transform R into a set of final state particles four-momenta P which fulfil the energy-momentum conservation
- evaluate the matrix element square and the event total weight
- use the rejection method to generate events with unit weight.

GenEx exploration phase



- Foam generates a vector of random variables $\mathcal{R}$ and feeds it to a few-body generator $\mathcal{G}$, chosen as the most appropriate for the considered problem,
- $\mathcal{G}$ produces events which fulfil the energy-momentum conservation and corresponding phase space weight $\mathcal{W}_{PhS}$,
- matrix element square is evaluated, providing the weight $\mathcal{W}_{ME}$ inside detector acceptance and set to zero outside,
- product of weights $\mathcal{W} = \mathcal{W}_{PhS} \cdot \mathcal{W}_{ME}$ provides measure of the event density for self-adapting MC (Foam) in exploration phase.

GenEx generation phase



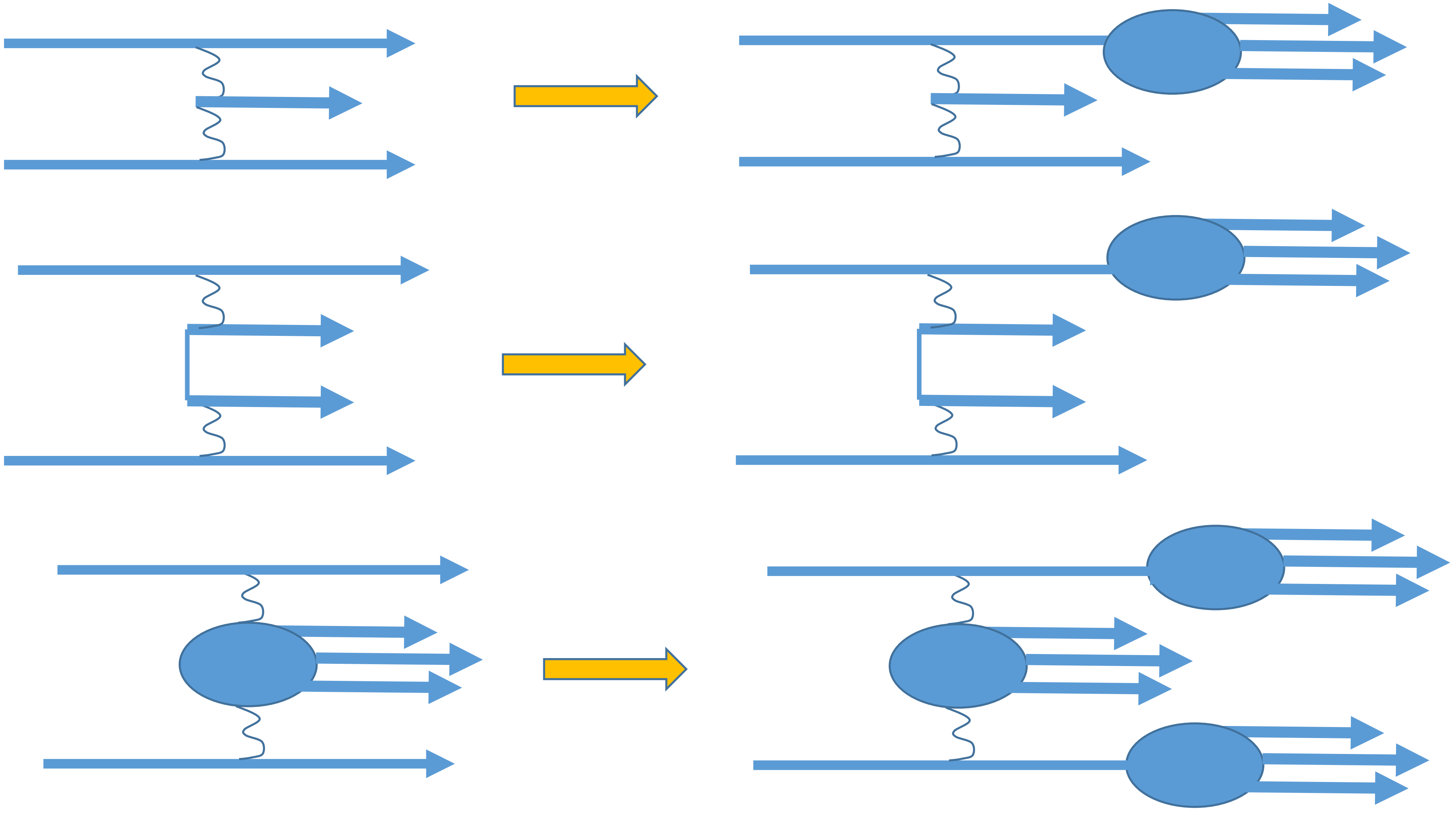
- Foam using the weight distribution found in the exploration phase provides random vectors R’
- R’ are transformed into the final state particles four-momenta i.e. events corresponding to the assumed matrix element and the detector acceptance cuts,
- if required, the events can be produced with a unit weight by use of rejection method.

Phase space generation

- Currently few types of phase space generation modules implemented
- Common feature: two particles in the final state are peripherally scattered i.e. $p_{beam} * p_{z1/2} > 0$ and their $p_{T1/2}$ are restricted
- Modules differ by choice of the integration variables → same functionality but different possibilities to restrict phase space on the generation level (i.e. before applying acceptance cuts):

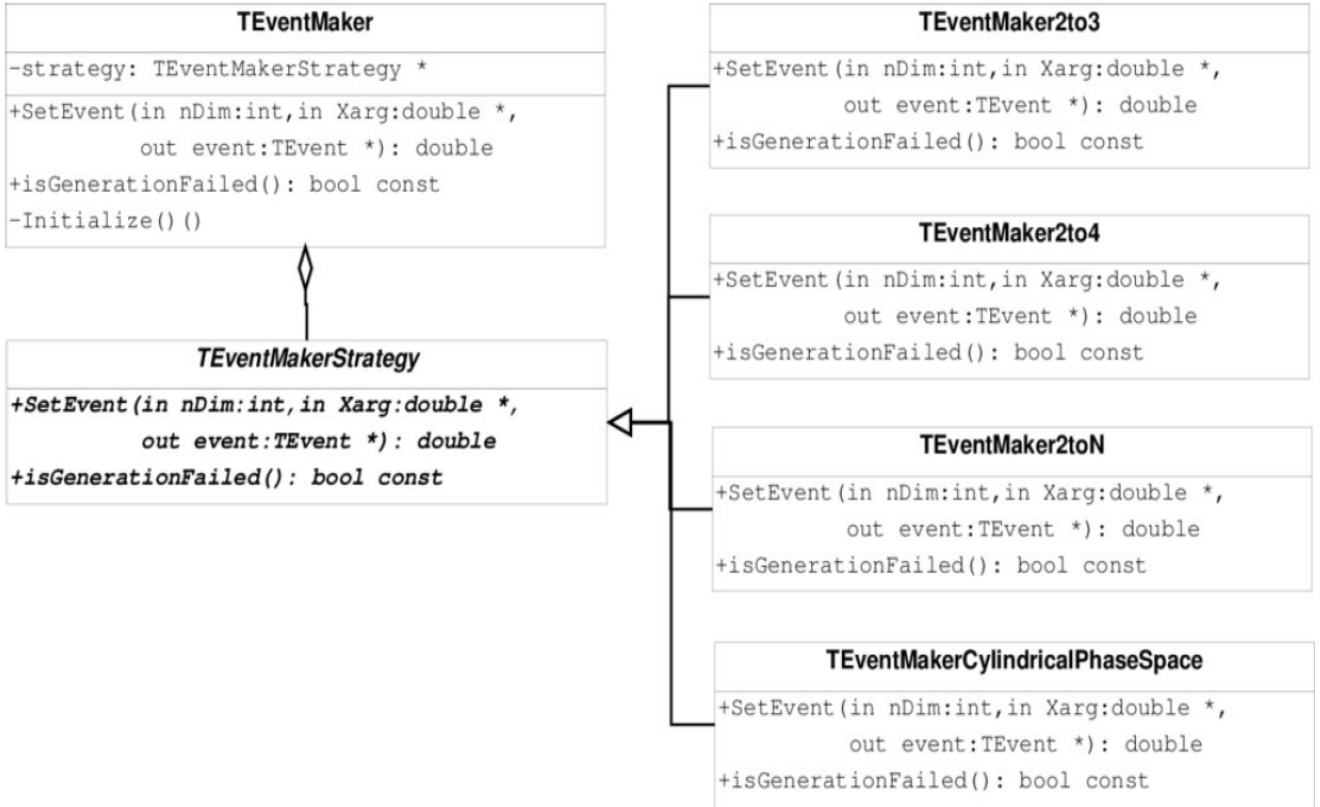
  - Cylindrical phase space (importance sampling for transverse momenta, uniform distribution in rapidity)
  - 3-body (transverse momenta of the peripherally scattered, rapidity of the third)
  - 4-body (transverse momenta of the peripherally scattered, rapidities and difference of transverse momenta of the other two
  - N-body (transverse momenta of the peripherally scattered, invariant mass and rapidity of centrally produced object, decay of the object according to phase space)

Phase space generation

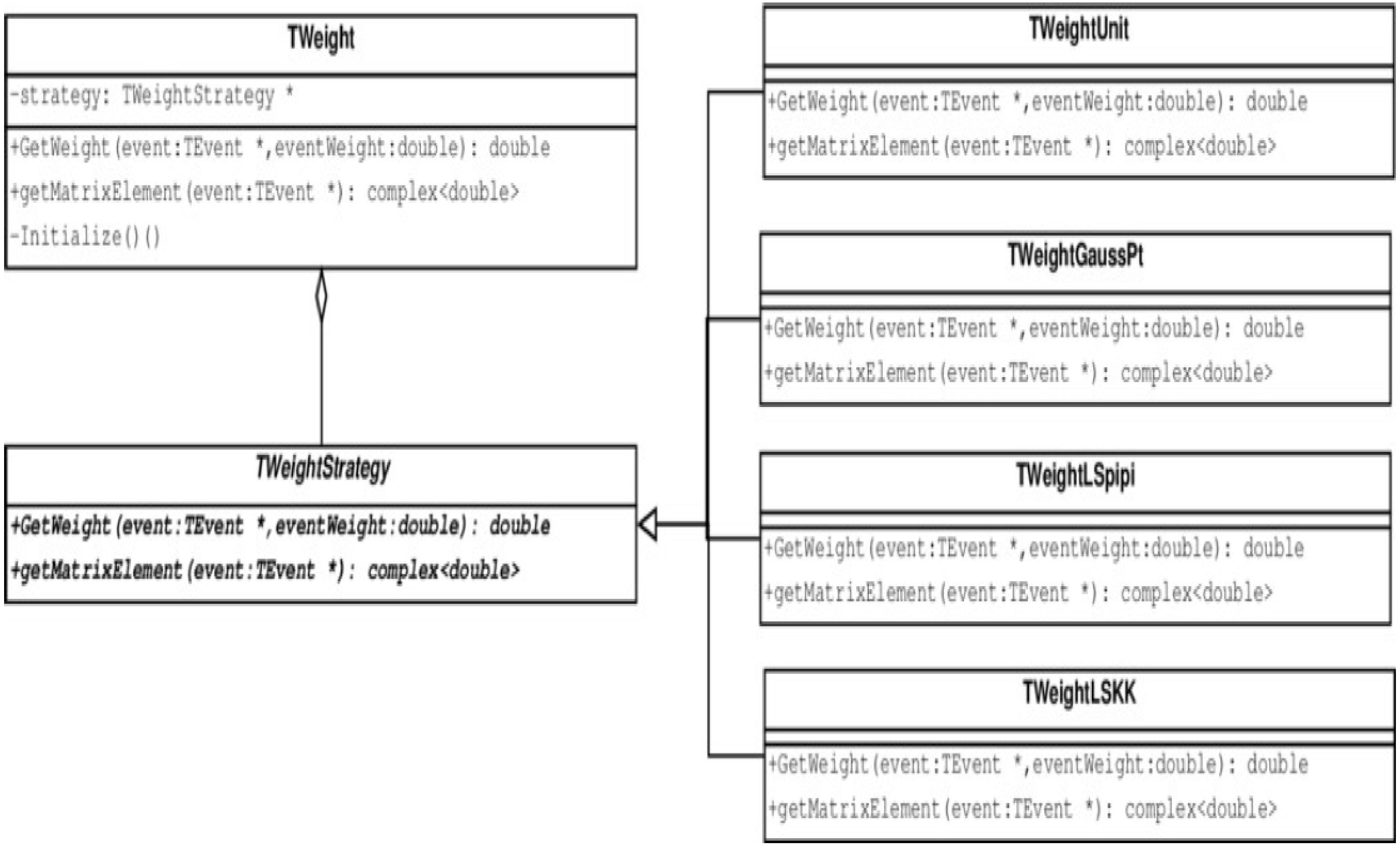


Phase space generation

The choice of the method is done in the framework of strategy pattern: **general interface/abstract class TEventMakerStrategy**. Owing the interface definition, the users can extend the generator by defining their own strategies.



Models: matrix element, dynamical weight



Additional features

- Histograms:
  - Few types of histograms for different reactions; adjustable;
- Event bookkeeping:
  - Root tuples;
  - Les Houches Accord (text/Fortran format; XML format);
- Logging:
  - Recording configuration for next runs in single file (concise format);
- Python script for automatic running selected configurations/tests.

SUMMARY

- A simple structure for generating events and Monte Carlo integration in particle physics was presented.
- The generator is specially designed for simulation of central exclusive particle production in peripheral processes e.g. double pomeron exchange.
- It employs the self-adaptive Monte Carlo algorithm Foam implemented in ROOT - a very powerful tool which makes it possible to generate effectively processes described by sharply peaked matrix elements and to impose restrictive cuts on the phase space.
- The program is characterized by a modular structure and can be easily extended by adding new strategies for generating phase space events and calculating the matrix elements.
- The generator can be treated as a scheme for creating small, effective generators for various purposes.

The code of the GenEx generator in a form of a compact file *GENERATOR.tar.gz* can be obtained from the authors on request.

R.Kycia et al.. arXiv:1411.6035 [hep-ph]) contains full description (manual) of GenEx