Particle Physics Simulation MG/PYTHIA/DELPHES

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Physics at colliders

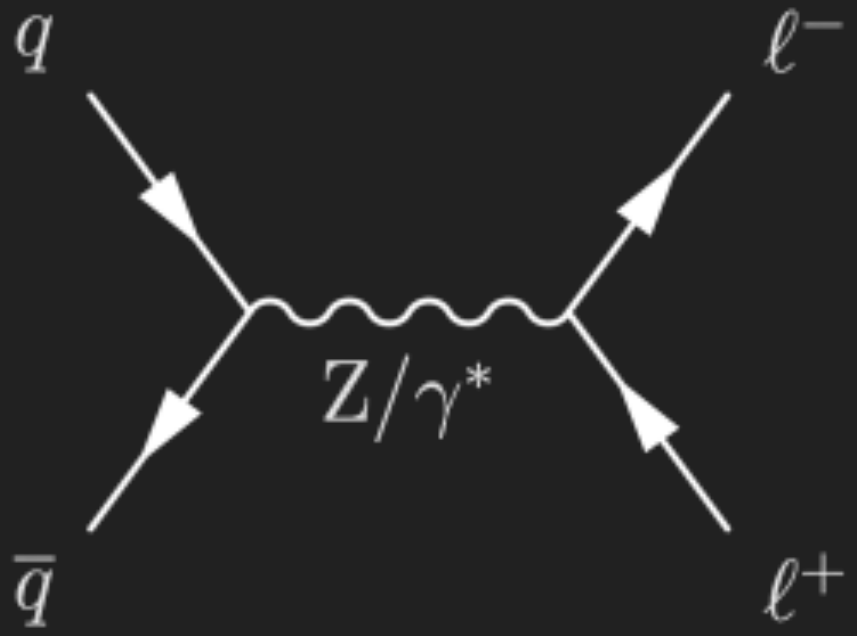
Experiment (as the LHC):

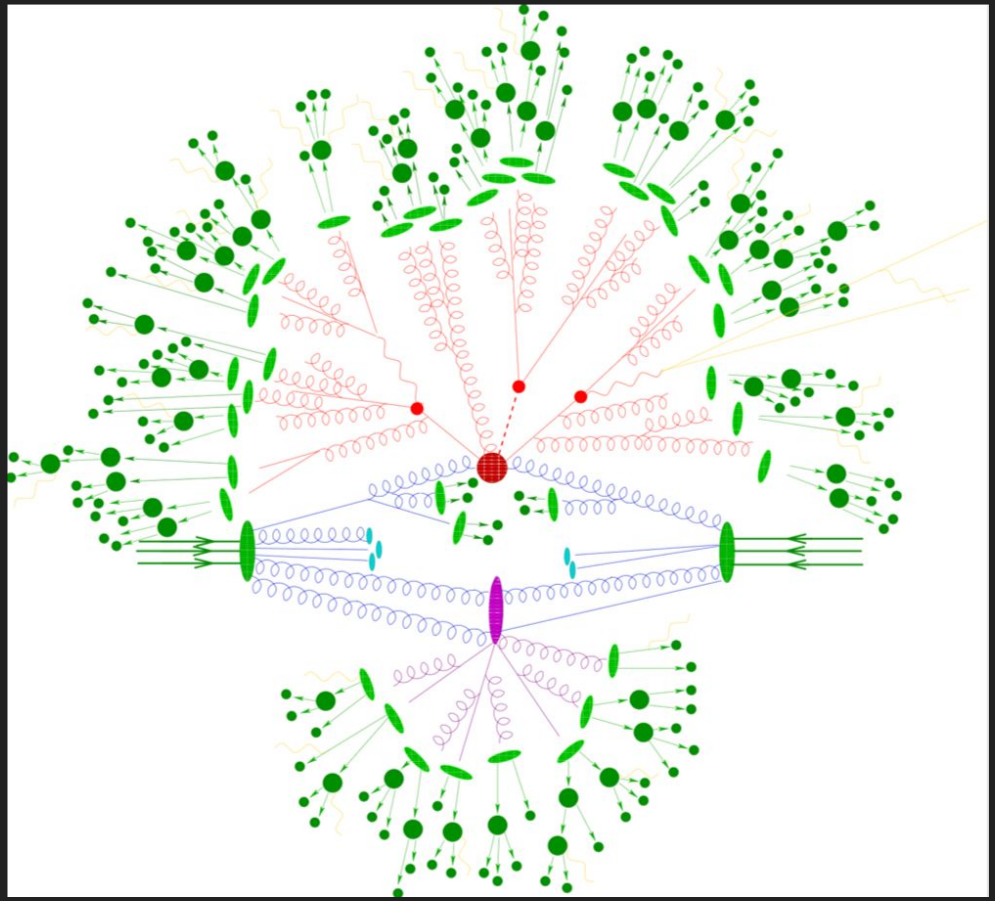
1. Accelerate and collide particles (protons at 13 TeV).
2. Detect the product of the collisions at experiments (as CMS or ATLAS).
3. Reconstruct and identify produced particles from collisions.
4. Study the produced events for the underlying physics (data analysis).

Theory (SM and beyond):

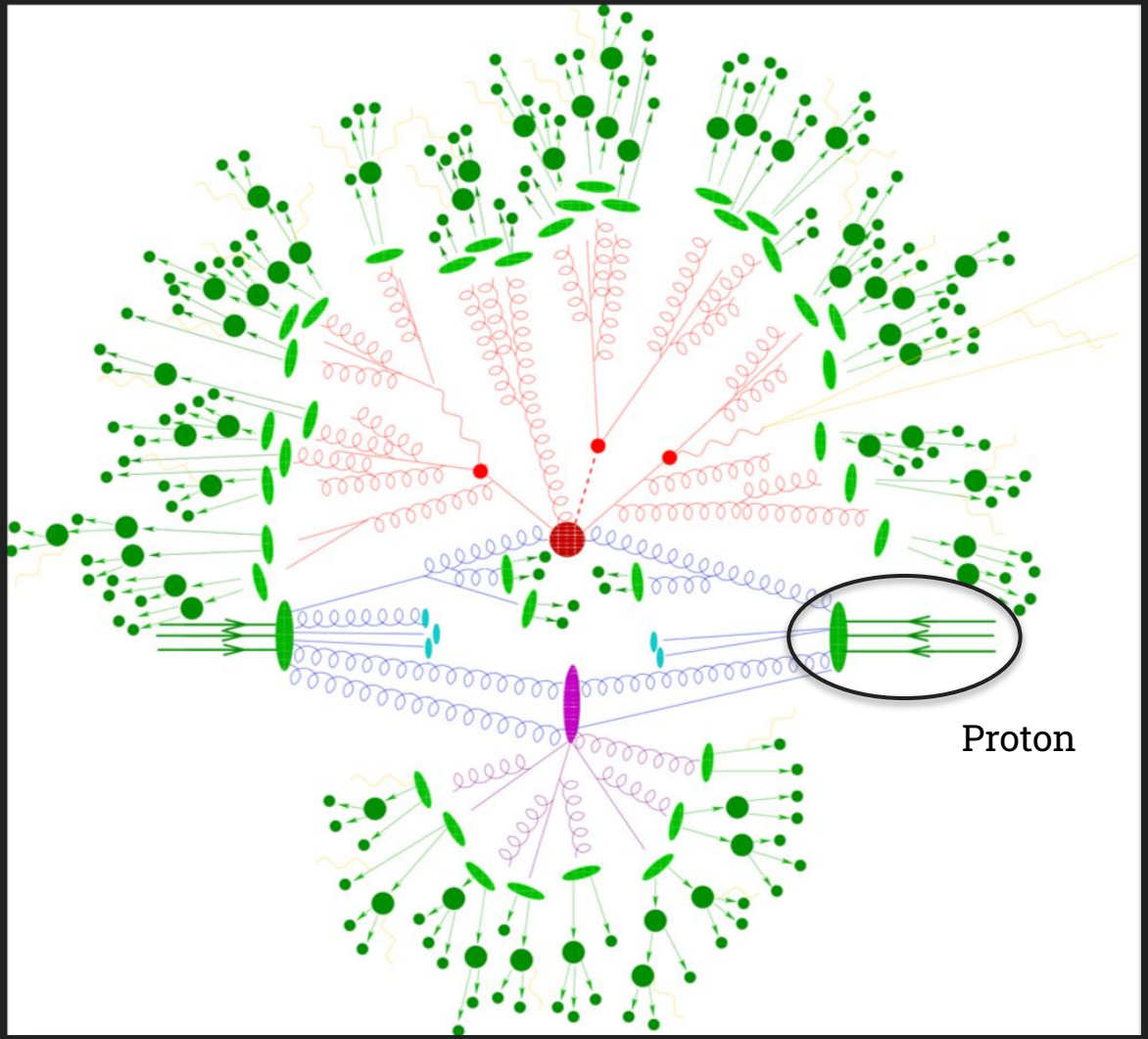
1. Underlying theory with interactions among the colliding particles.
2. Model hadron dynamics.
3. Model detector-particle interactions.
4. Model reconstruction and identification performance by the experiments.
5. Predicts rates and distributions accordingly to the luminosity.

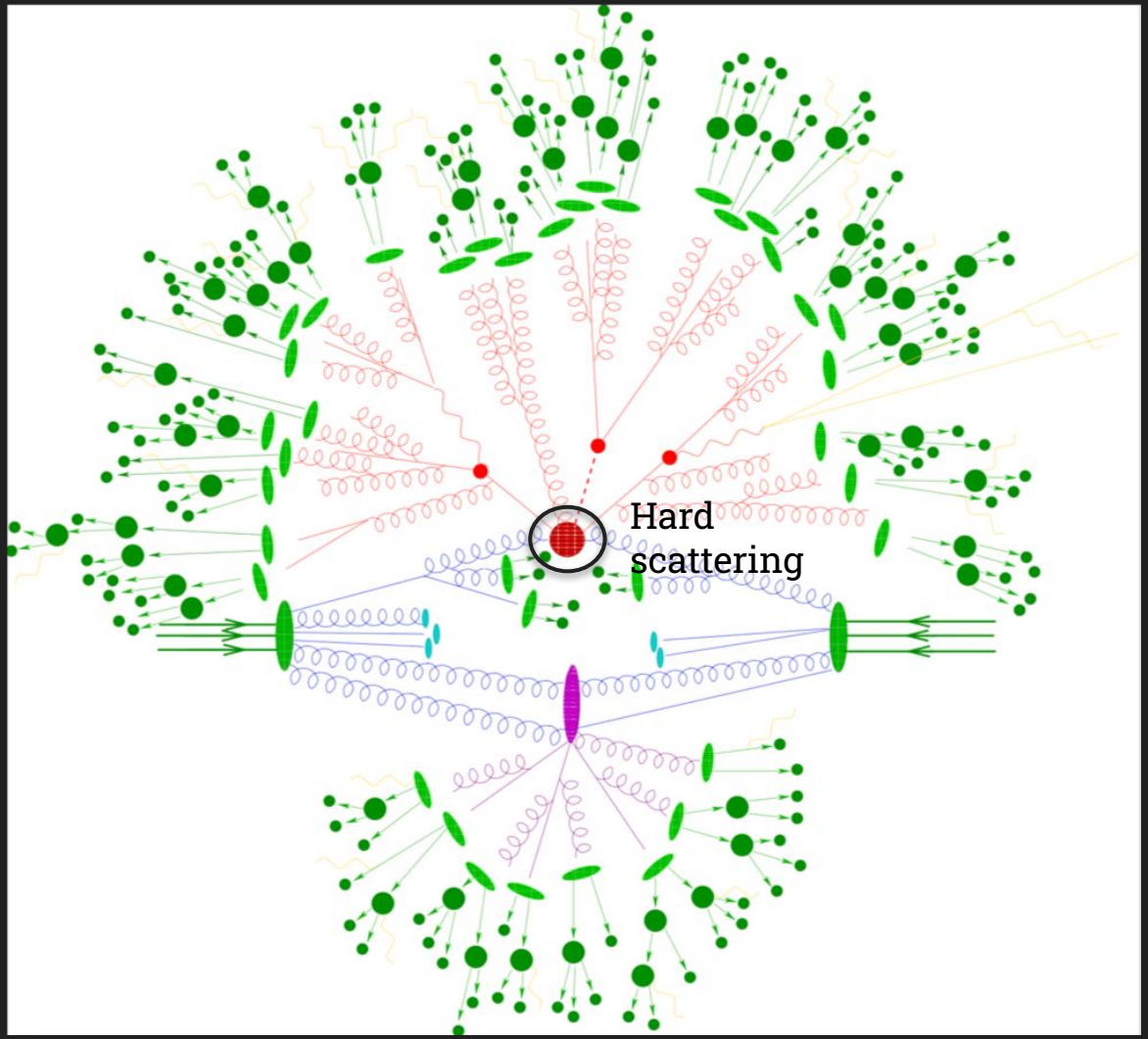
From the simplicity of theory...

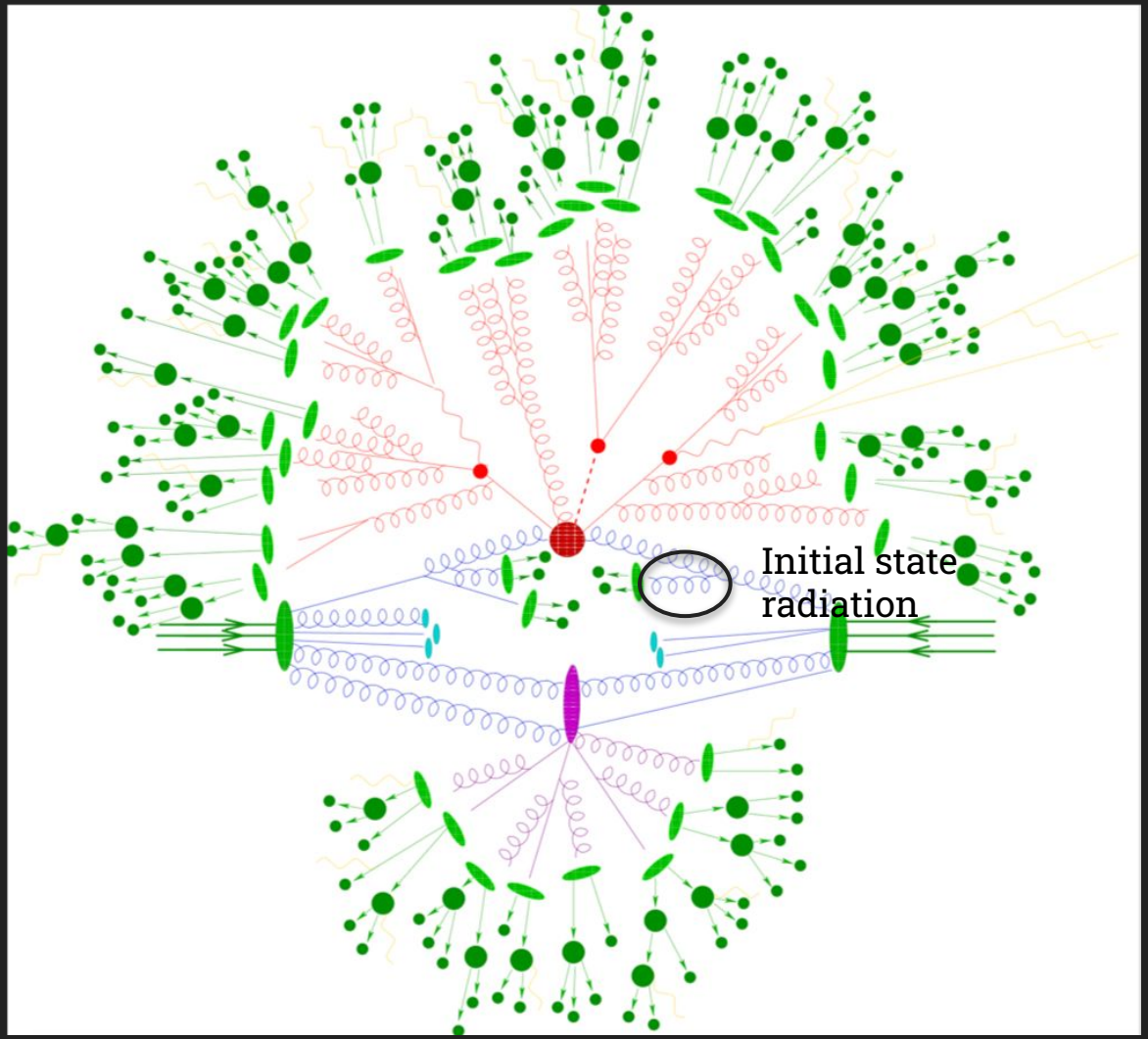


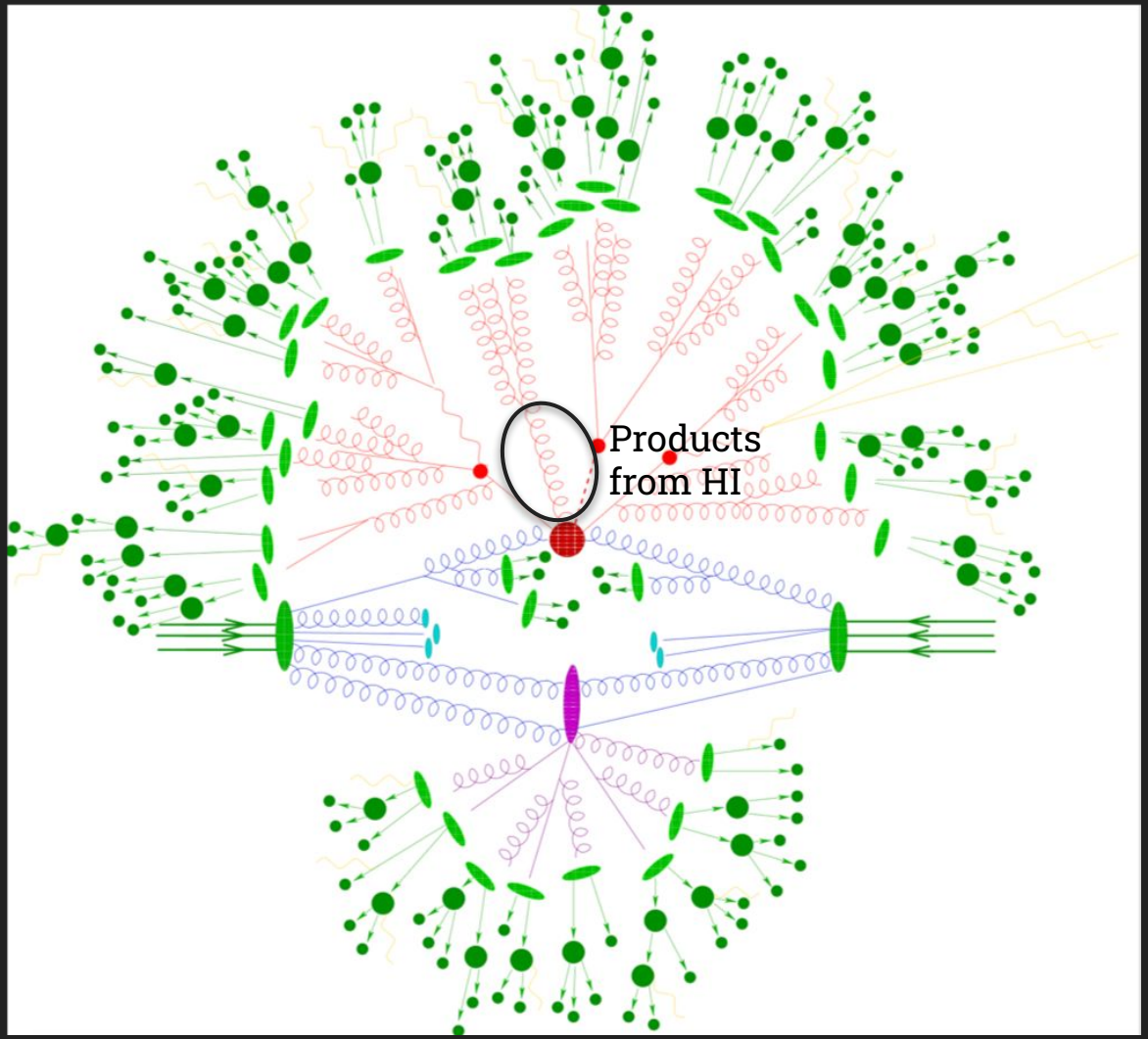


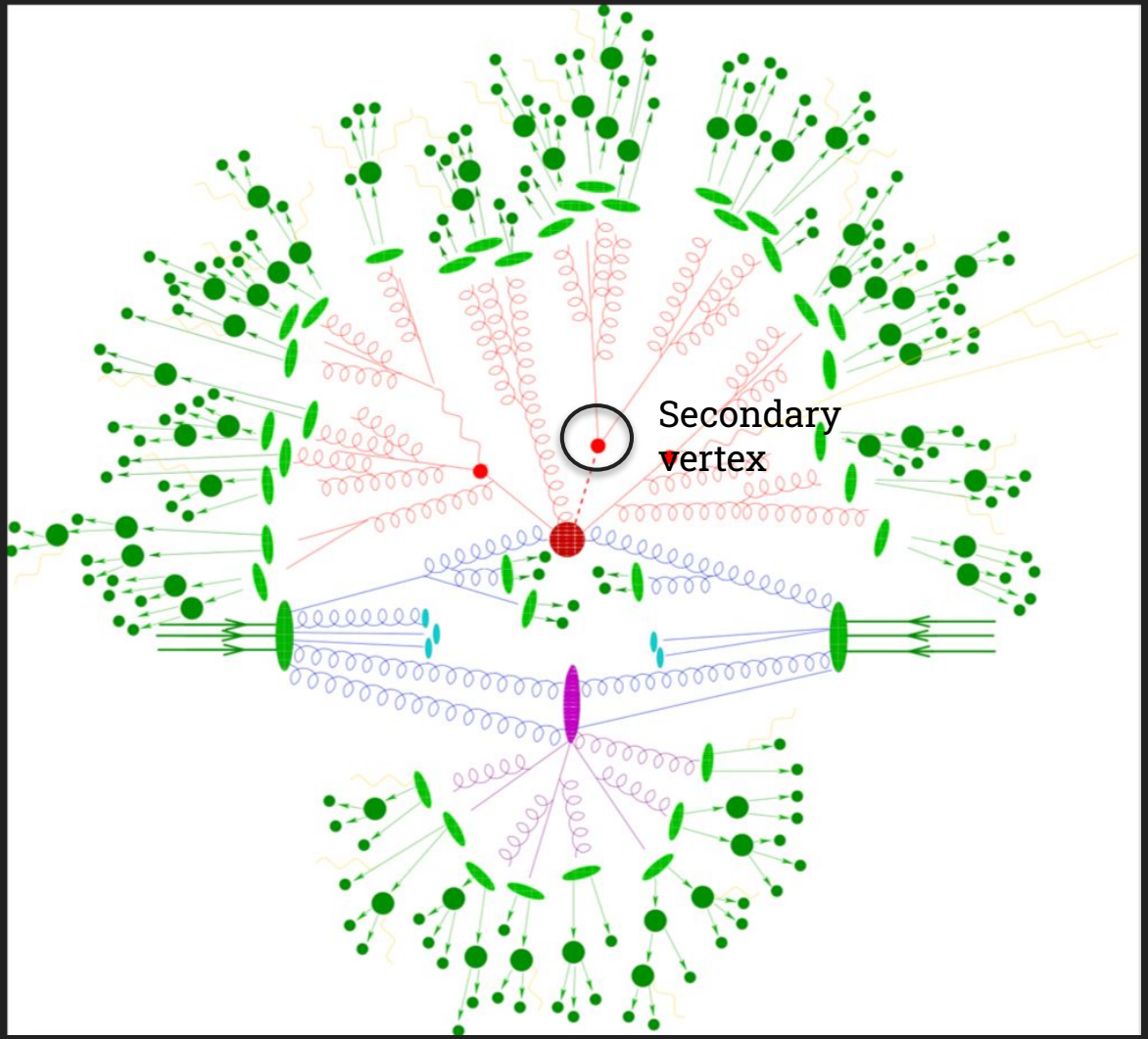
… to the complexity of reality.

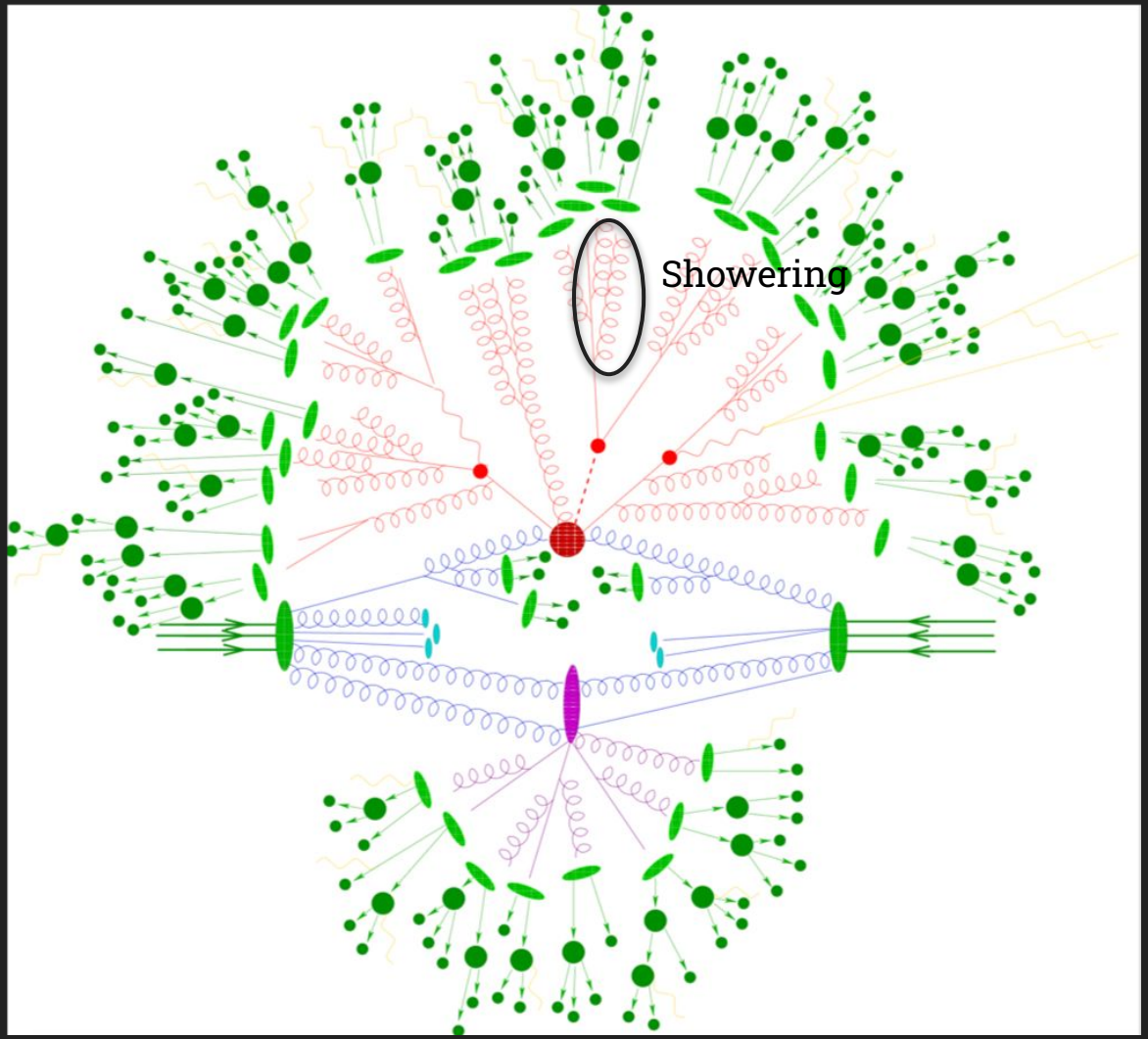

Proton

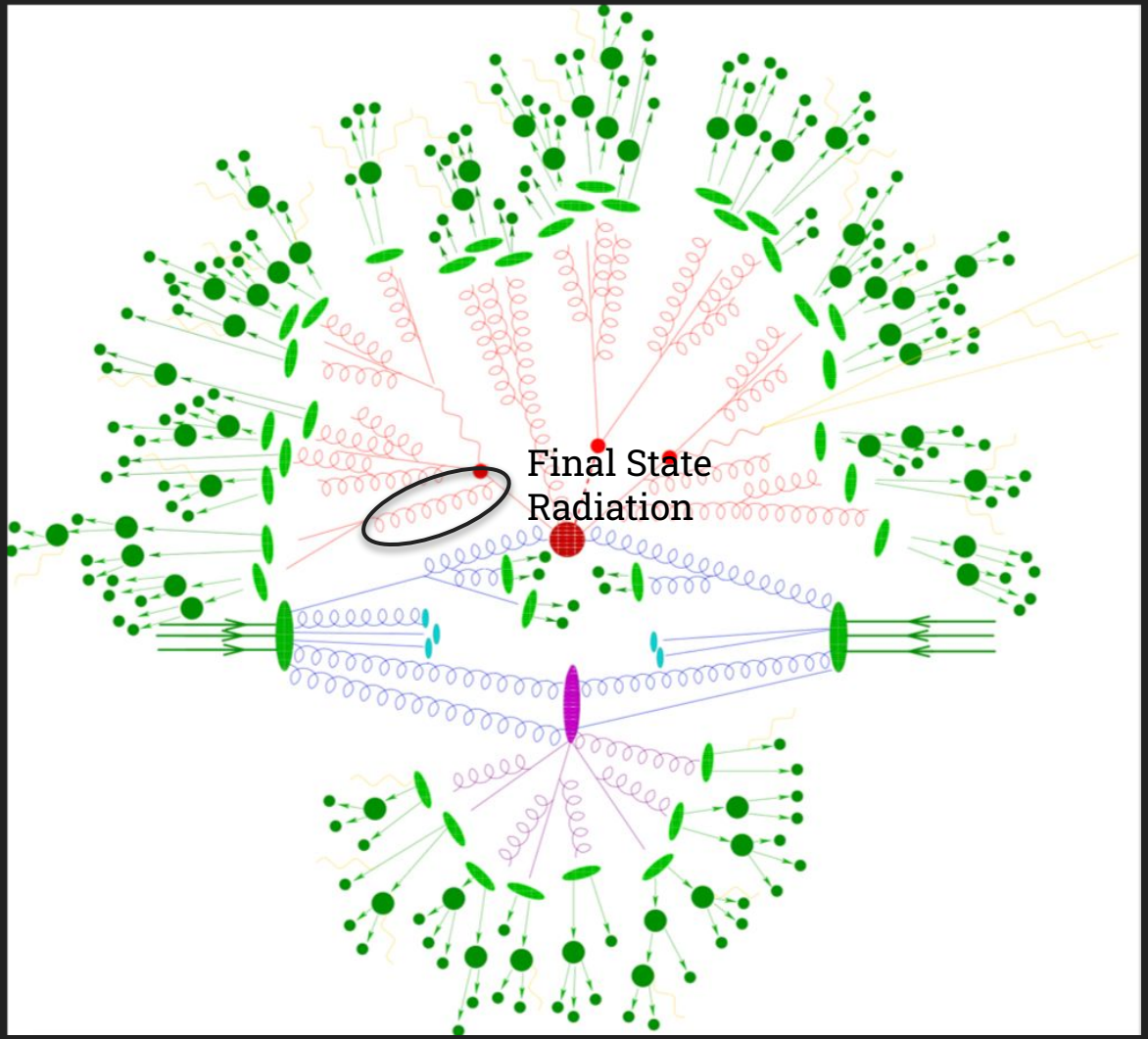

Hard
scattering

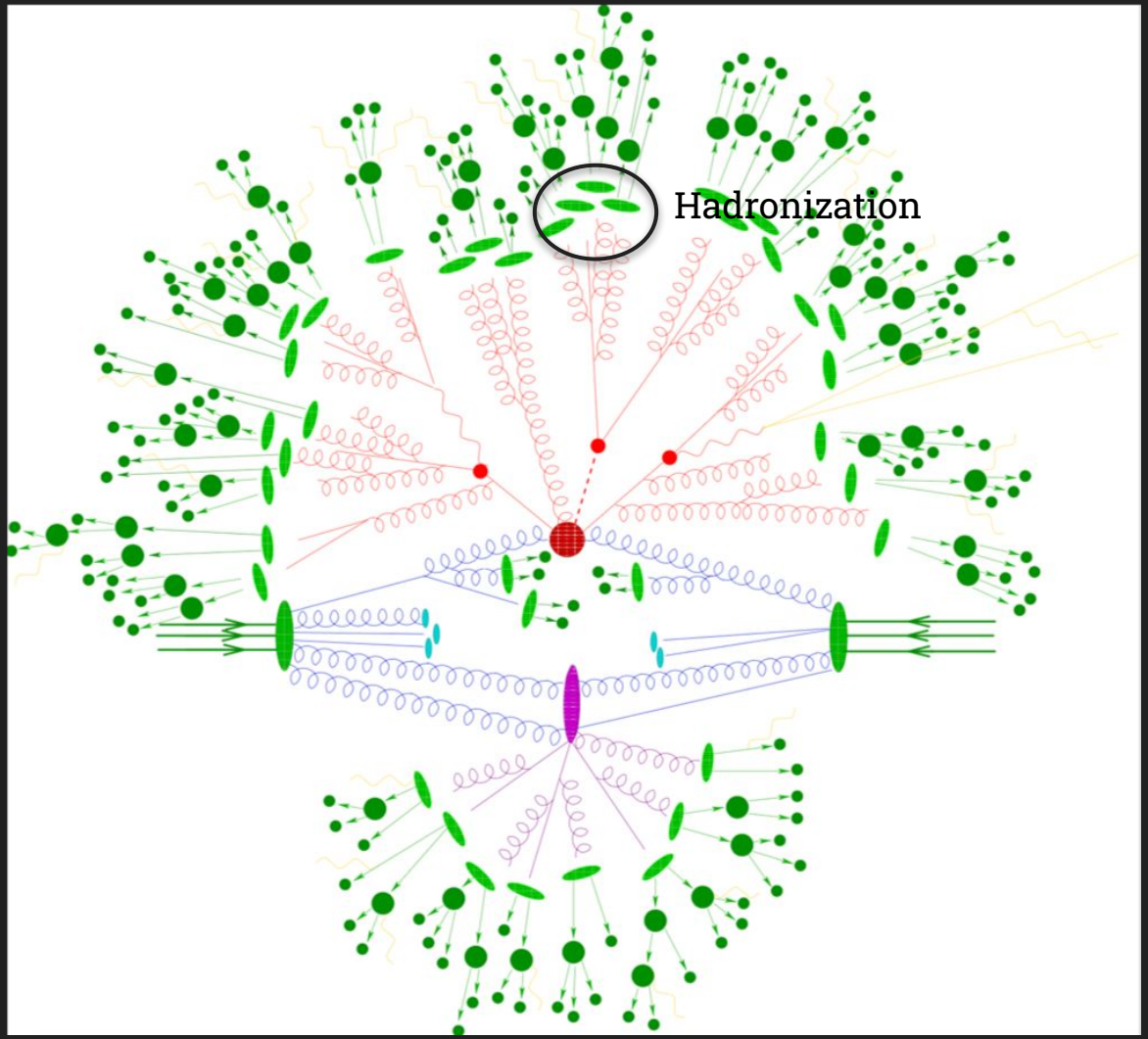

Initial state
radiation

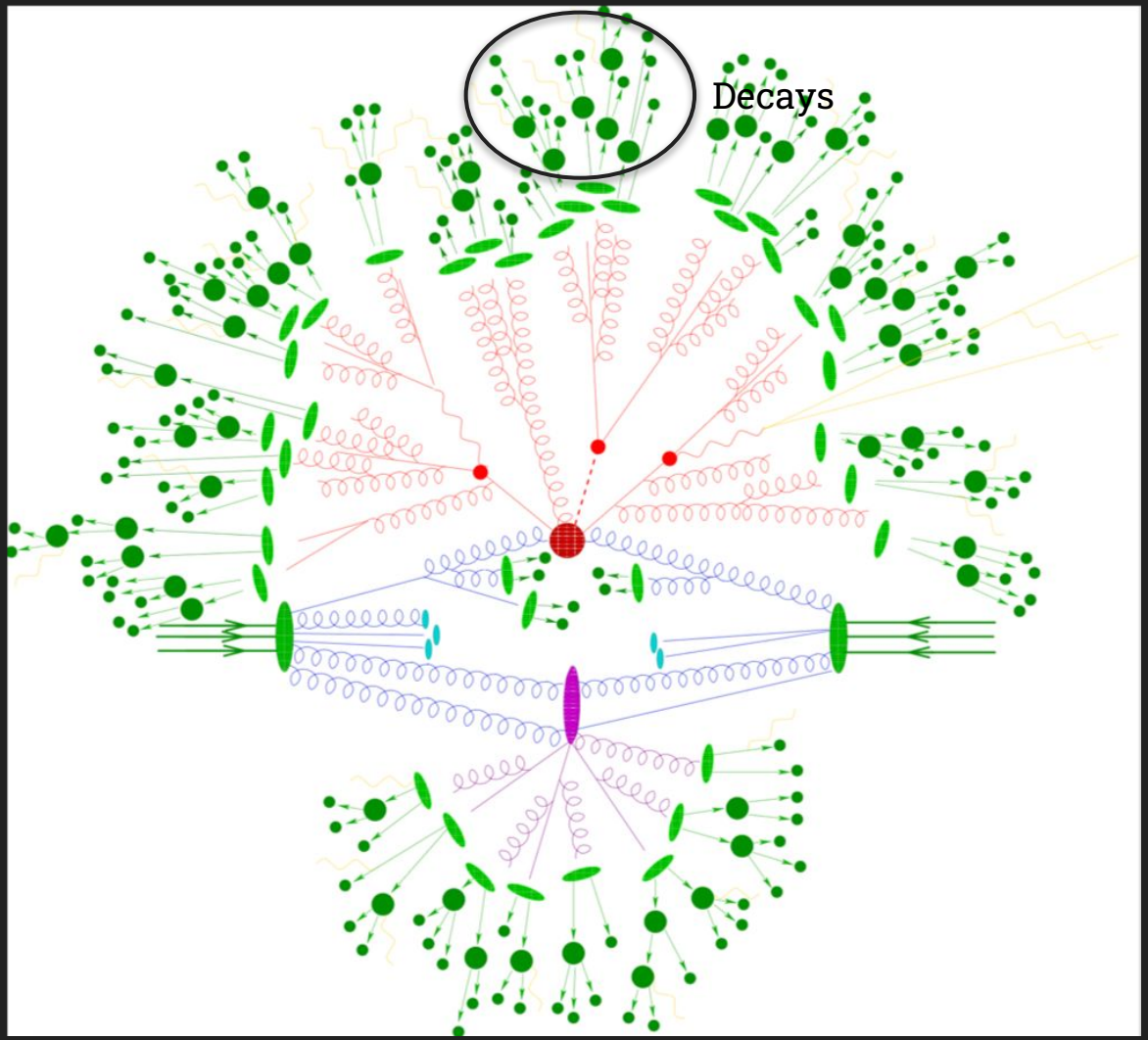

Products
from HI

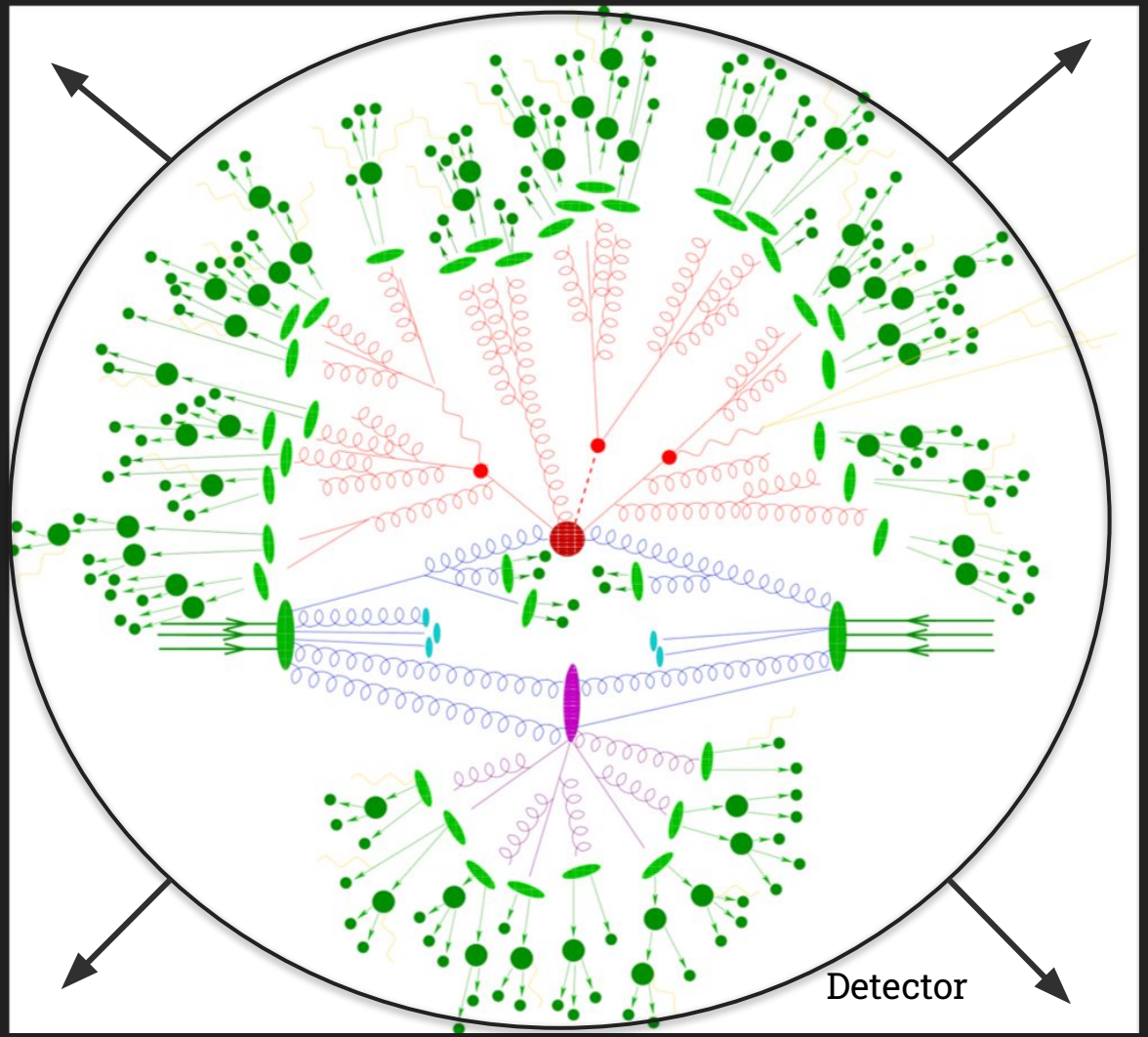

Secondary
vertex


Showering


Final State
Radiation


Hadronization


Decays


Detector

Parton simulation: MadGraph

Provides a full setup for collider studies interfaced with other tools. Python interfaced:

https://launchpad.net/mg5amcnlo

Requires a baseline theory or model, which can be coded with tools as Feynrules. However, many models (SM or SUSY) already come with MadGrpah and many others can be found at:

https://feynrules.irmp.ucl.ac.be/wiki/ModelDatabaseMainPage

Provides a common setup for new physics implementations.

Hadronization simulation: Pythia

Standalone event generator, that can be interfaced with MadGraph:

https://pythia.org/

Extensive documentation and examples:

https://pythia.org/documentation/

For new physics cases it is commonly used interfaced with MadGraph.

Detector emulation: Delphes

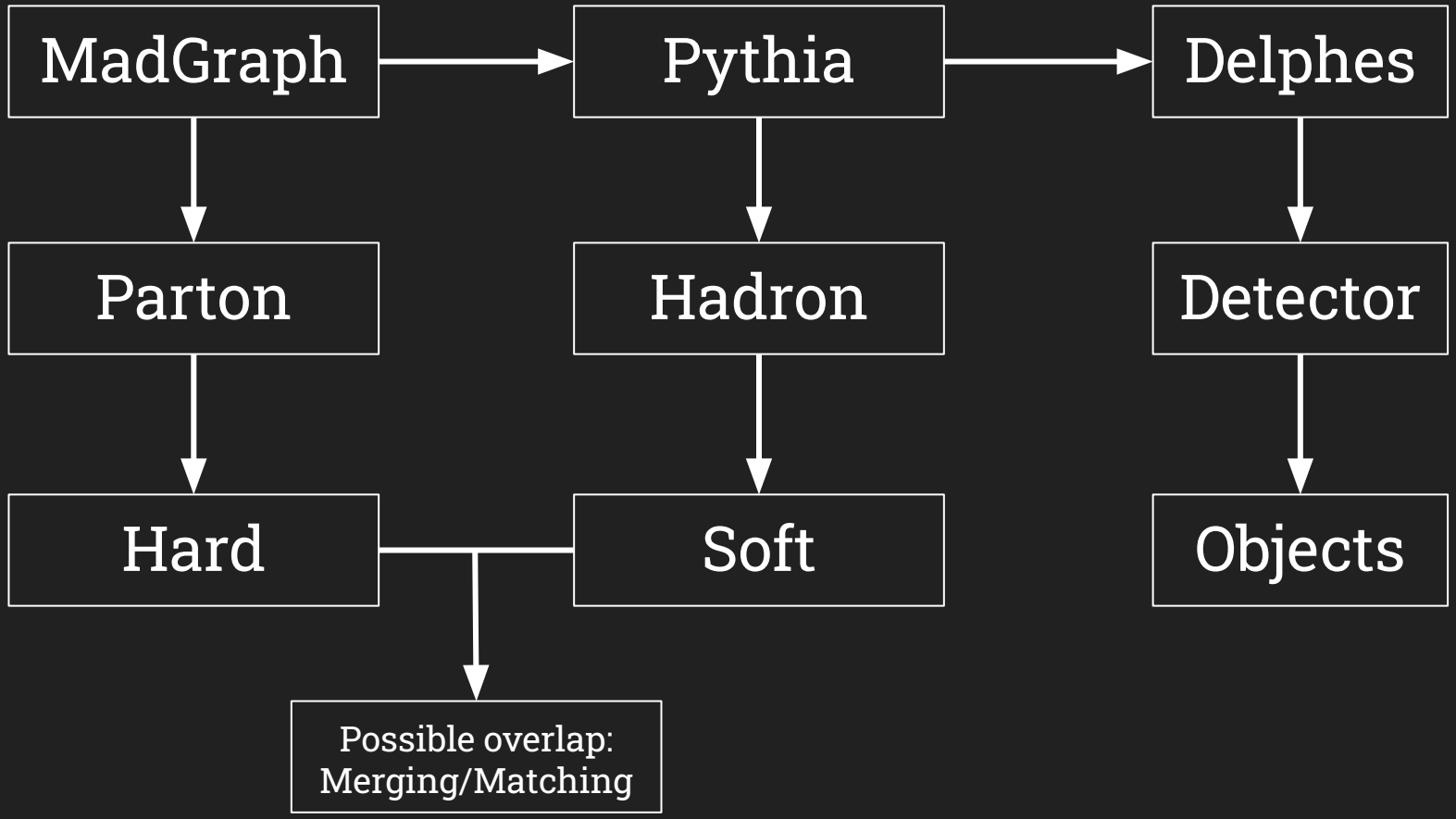
Emulates the detector response to particles:

https://cp3.irmp.ucl.ac.be/projects/delphes

Gives a full set of reconstructed objects with parametric efficiencies.

It is an approximate physics description, usually good enough for phenomenological studies and for projections.

Developed by CMS, used in the collaboration for HL and HE projections, however for actual physics GEANT 4 is used for simulation of the particles interactions with the detector.


MadGraph
Pythia
Delphes
Parton
Hadron
Detector
Hard
Soft
Objects
Possible overlap:
Merging/Matching

Matching/Merging

Needed to be performed when including additional jet production with the central process when using both MadGraph and Pythia.

Grants smooth transition between soft and hard physics simulation, and also grants correct simulation physics wise.

Two steps:

- Restrict MadGraph phase space to only simulate hard processes.
- Restrict Pythia phase space to only simulate soft processes.