The EpIC event generator – Update

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June 14, 2021

mFOAM

- EpIC uses mini FOAM (mFOAM, a compact version of FOAM) to generate events randomly
- mini FOAM is a general-purpose Monte Carlo event simulator

  [Jadach and Sawicki, Comput.Phys.Commun. 177 (2007)]
- fully integrated with ROOT
- mFOAM can deal with integrable singularities
- works for dimensions ≤ 20

EpIC: MC event generator

- Input file: model, model parameters, number of events, kinematic limits, beam and target type, beam helicity, target polarization, beam and target energy, mFOAM parameters
- Output file: 4-vectors of all particles

EpIC – Input

```
<?xml version="1.0" encoding="UTF-8" standalone="yes" ?>

<!-- Scenario starts here -->
<!-- For your convenience and for bookkeeping provide creation date and unique description -->
<scenario date="2017-07-18" description="Select specific GPD types">

   <!-- First task: evaluate GPD model for a single kinematics -->
   <!-- Indicate service and its methods to be used and indicate if the result should be stored in the database -->
   <task service="DVCSGeneratorService" method="generate">

      <!-- General configuration -->
      <general_configuration>
         <param name="number_of_events" value="100000" />
      </general_configuration>

      <!-- Kinematic limits -->
      <kinematic_range>
         <param name="range_xB" value="0.0|1.0" />
         <param name="range_t" value="-1.0|-0.0" />
         <param name="range_Q2" value="1.|10." />
         <param name="range_phi" value="0.0|6.2831853" />
      </kinematic_range>

      <!-- Experimental conditions -->
      <experimental_conditions>
         <param name="lepton_energy" value="5.0" />
         <param name="lepton_type" value="e-" />
         <param name="lepton_helicity" value="1" />
         <param name="hadron_energy" value="41.0" />
         <param name="hadron_type" value="p" />
         <param name="hadron_polarisation" value="0.|0.|0." />
      </experimental_conditions>
```

EpIC – Input

```
<!-- Computation scenario -->
<computation_configuration>

   <module type="DVCSProcessModule" name="DVCSProcessGV08">

          <module type="DVCSScalesModule" name="DVCSScalesQ2Multiplier">
                  <param name="lambda" value="1." />
          </module>

          <module type="DVCSXiConverterModule" name="DVCSXiConverterXBToXi">
          </module>

          <module type="DVCSConvolCoeffFunctionModule" name="DVCSCFFConstant">

                  <param name="qcd_order_type" value="LO" />

                  <param name="cff_value_H_Re" value="1.0" />
                  <param name="cff_value_H_Im" value="2.0" />
                  <param name="cff_value_E_Re" value="3.0" />
                  <param name="cff_value_E_Im" value="5.0" />
                  <param name="cff_value_Ht_Re" value="8.0" />
                  <param name="cff_value_Ht_Im" value="13.0" />
                  <param name="cff_value_Et_Re" value="21.0" />
                  <param name="cff_value_Et_Im" value="34.0" />

          </module>
   </module>
</computation_configuration>

<!-- Generator module configuration -->
<generator_configuration>
   <module type="EventGeneratorModule" name="EventGeneratorFOAM">
          <param name="nCells" value="2000" />
          <param name="nSamples" value="400" />
          <param name="nBins" value="400" />
   </module>
</generator_configuration>
```

EpIC – Output

```
HepMC::Version 3.02.03
HepMC::Asciiv3-START_EVENT_LISTING
E 0 2 6
U GEV MM
A 0 GenCrossSection 1.00000000e+00 0.00000000e+00 -1 -1
P 1 0 11 0.0000000000000000e+00 0.0000000000000000e+00 -9.9999999869440064e+00 1.0000000000000000e+01 5.1099888971089147e-04 1
P 2 1 11 -9.4597000370743234e-01 0.0000000000000000e+00 -8.2149584505868916e+00 8.2692443339100254e+00 5.1099886190093845e-04 21
P 3 1 22 9.4597000370743234e-01 0.0000000000000000e+00 -1.7850415363571144e+00 1.7307556660899719e+00 -1.0419776191127450e+00 21
P 4 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 3.4589829375255371e-01 1.0000000000000000e+00 9.3827201299999996e-01 1
V -2 0 [3,4]
P 5 -2 22 1.2050257554984007e+00 2.5074954833574503e-01 -1.1508881236315567e+00 1.6850833452744216e+00 -4.2146848510894035e-08 21
P 6 -2 2212 -2.5905575179096896e-01 -2.5074954833574503e-01 -2.8825511897300382e-01 1.0456723208155490e+00 9.3827201299999974e-01 21
E 1 2 6
U GEV MM
A 0 GenCrossSection 1.00000000e+00 0.00000000e+00 -1 -1
P 1 0 11 0.0000000000000000e+00 0.0000000000000000e+00 -9.9999999869440064e+00 1.0000000000000000e+01 5.1099888971089147e-04 1
P 2 1 11 -1.2182260574739716e+00 0.0000000000000000e+00 -4.0194575590996422e+00 4.2000135782675407e+00 5.1099890709211131e-04 21
P 3 1 22 1.2182260574739716e+00 0.0000000000000000e+00 -5.9805424278443624e+00 5.7999864217324575e+00 -1.9002947050587289e+00 21
P 4 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 3.4589829375255371e-01 1.0000000000000000e+00 9.3827201299999996e-01 1
V -2 0 [3,4]
P 5 -2 22 9.7181996115325742e-01 -5.1880033904910705e-01 -5.5915543746086378e+00 5.6990409853674810e+00 -1.6858739404357614e-07 21
P 6 -2 2212 2.4640609632071450e-01 5.1880033904910716e-01 -4.3089759483173062e-02 1.1009454363649775e+00 9.3827201299999963e-01 21
E 2 2 6
U GEV MM
A 0 GenCrossSection 1.00000000e+00 0.00000000e+00 -1 -1
P 1 0 11 0.0000000000000000e+00 0.0000000000000000e+00 -9.9999999869440064e+00 1.0000000000000000e+01 5.1099888971089147e-04 1
P 2 1 11 -1.1195124280790041e+00 0.0000000000000000e+00 -8.0885372407303073e+00 8.1656440672138206e+00 5.1099888971089147e-04 21
P 3 1 22 1.1195124280790041e+00 0.0000000000000000e+00 -1.9114627462136977e+00 1.8343559327861769e+00 -1.2418277733398912e+00 21
P 4 0 2212 0.0000000000000000e+00 0.0000000000000000e+00 3.4589829375255371e-01 1.0000000000000000e+00 9.3827201299999996e-01 1
V -2 0 [3,4]
P 5 -2 22 5.9373736443280545e-01 -5.0230833407787345e-01 -1.4452517630346717e+00 1.6412161280472863e+00 -5.5755039852469285e-08 21
P 6 -2 2212 5.2577506364619864e-01 5.0230833407787345e-01 -1.2031268942647227e-01 1.1931398047388897e+00 9.3827201300000007e-01 21
```

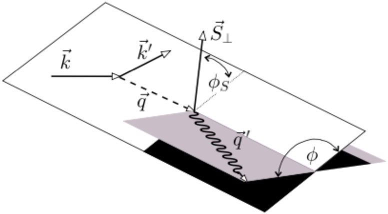
Leptoproduction of a real photon

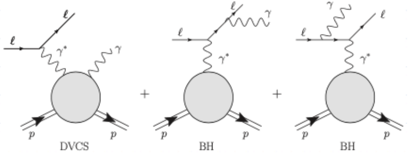
- Differential cross section for the leptoproduction of a real photon

  [Belitsky, Mueller, and Kirchner Nucl.Phys.B 629 (2002)]

$$\frac{d^5\sigma}{dx_B dQ^2 d|t| d\phi d\varphi} = \frac{\alpha^3 x_B y}{16\pi^2 Q^2 \sqrt{1+\epsilon^2}} |\mathcal{T}|^2$$

where $|\mathcal{T}|^2 = |\mathcal{T}_{\text{DVCS}}|^2 + |\mathcal{T}_{\text{BH}}|^2 + \mathcal{I}$





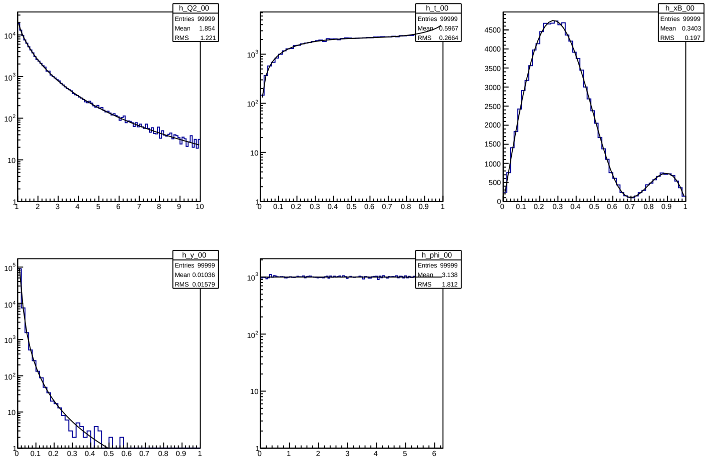
Leptoproduction of a real photon

- Compare generated events with theory expectation curves

$$\int_{\text{bin}} \frac{d\sigma}{dx_B}\, dx_B = \int_{\text{bin}} dx_B \int dQ^2 \int d|t| \int d\phi \int d\varphi \frac{d^5\sigma}{dx_B dQ^2 d|t| d\phi d\varphi}$$

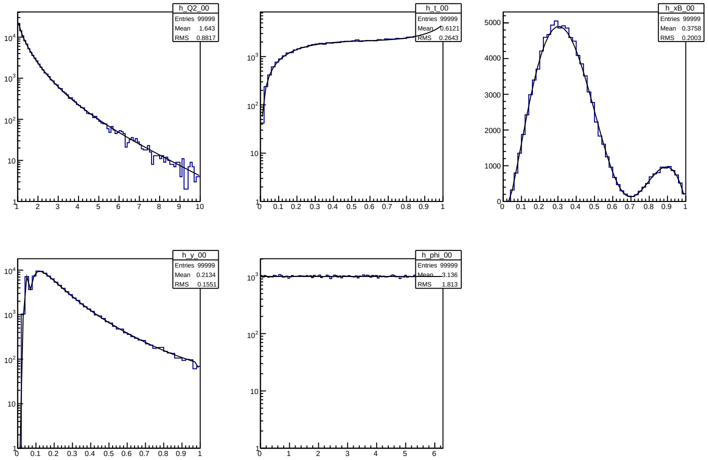
EpIC – DVCS

Unpolarized target, $E_e = 5\,\text{GeV}$, $E_p = 41\,\text{GeV}$ (DVCSProcessGV08)



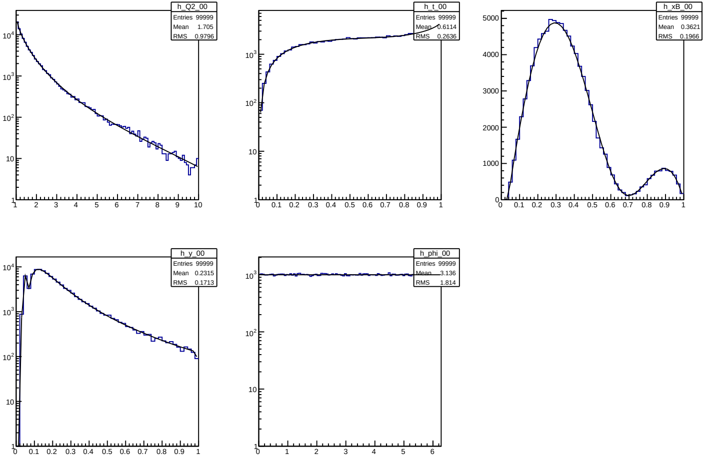
EpIC – DVCS

Longitudinally polarized target, $E_e = 10\,\text{GeV}$, $E_p = 1\,\text{GeV}$



EpIC – DVCS

Transversely polarized target, $E_e = 10\,\text{GeV}$, $E_p = 1\,\text{GeV}$



EpIC – Bethe-Heitler

- Bethe-Heitler amplitude includes singularities

$$|\mathcal{T}_{\mathrm{BH}}|^2 = \frac{1}{x_B y^2 (1+\epsilon^2) t \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{\mathrm{BH}} + \sum_{n=1}^{2} c_n^{\mathrm{BH}} cos(n\phi) + s_1^{\mathrm{BH}} sin(\phi) \right\}$$

with

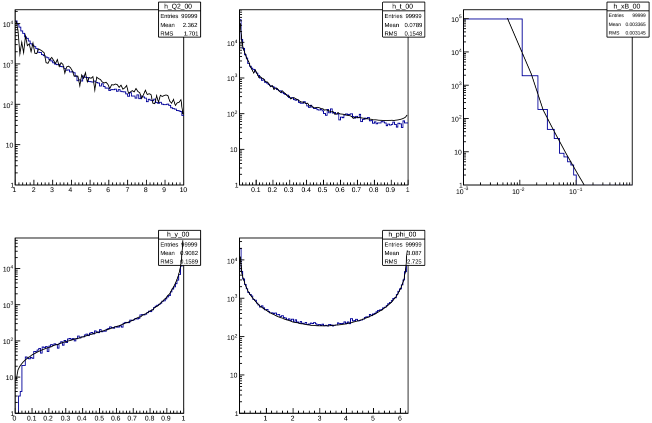
$$\mathcal{P}_1(\phi) = 1 + \frac{2k\cdot\Delta}{Q^2} \qquad \mathcal{P}_2(\phi) = \frac{t - 2k\cdot\Delta}{Q^2}, \quad \text{where}$$

$$k\cdot\Delta = -\frac{Q^2}{2y(1+\epsilon^2)}\left\{1 + 2Kcos\phi - \frac{t}{Q^2}\left(1 - x_B(2-y) + \frac{y\epsilon^2}{2}\right) + \frac{y\epsilon^2}{2}\right\}$$

$$K^2 = -\frac{t}{Q^2}(1-x_B)\left(1 - y - \frac{y^2\epsilon^2}{4}\right)\left(1 - \frac{t_{\mathrm{min}}}{t^2}\right)\left\{\sqrt{1+\epsilon^2} + \frac{4x_B(1-x_B)+\epsilon^2}{4(1-x_B)}\frac{t - t_{\mathrm{min}}}{Q^2}\right\}$$

EpIC – Bethe-Heitler

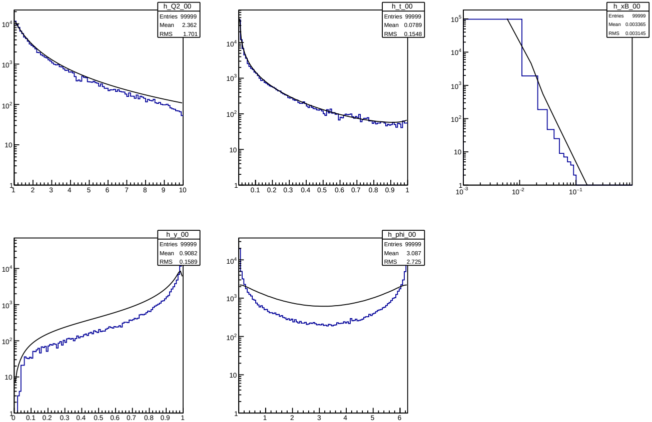
Unpolarized target, $E_e = 5\,\text{GeV}$, $E_p = 41\,\text{GeV}$ (DVCSProcessBMJ12, $\epsilon = 0.0$)



Cuts: $0.001 < x_B < 0.999$, $0.001\,\text{GeV}^2 < |t| < 1\,\text{GeV}^2$, $1\,\text{GeV}^2 < Q^2 < 10\,\text{GeV}^2$

EpIC – Bethe-Heitler

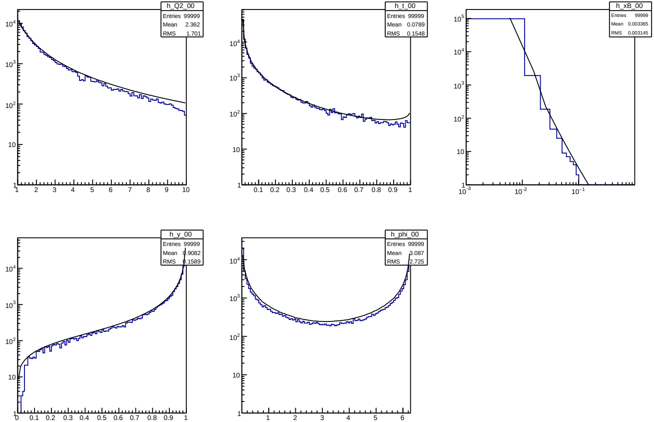
Unpolarized target, $E_e = 5$ GeV, $E_p = 41$ GeV ($\epsilon = 0.01$)



Cuts: $0.001 < x_B < 0.999$, $0.001\,\text{GeV}^2 < |t| < 1\,\text{GeV}^2$, $1\,\text{GeV}^2 < Q^2 < 10\,\text{GeV}^2$

EpIC – Bethe-Heitler

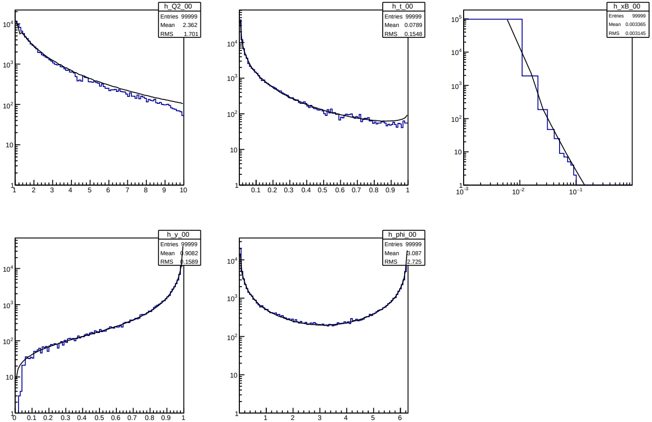
Unpolarized target, $E_e = 5$ GeV, $E_p = 41$ GeV ($\epsilon = 0.00001$)



Cuts: $0.001 < x_B < 0.999$, $0.001\,\mathrm{GeV}^2 < |t| < 1\,\mathrm{GeV}^2$, $1\,\mathrm{GeV}^2 < Q^2 < 10\,\mathrm{GeV}^2$

EpIC – Bethe-Heitler

Unpolarized target, $E_e = 5$ GeV, $E_p = 41$ GeV ($\epsilon = 0.000001$)



Cuts: $0.001 < x_B < 0.999$, $0.001\,\text{GeV}^2 < |t| < 1\,\text{GeV}^2$, $1\,\text{GeV}^2 < Q^2 < 10\,\text{GeV}^2$

Outlook

- Generation of pure DVCS events give consistent results
- Bethe-Heitler process involves singularities. However, EpIC so far gives consistent results in overcoming them
- To do: Implementation of radiative corrections