Fast Simulation of a HERA–like Detector

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Abstract

A set of FORTRAN routines to perform a fast simulation of a HERA–like detector including the smearing of the z coordinate of the interaction vertex, the simulation of a tracker system, of an electromagnetic and of a hadronic calorimeter is presented.

1 Introduction

One of the main goals of this workshop has been to study the measurability, under realistic experimental conditions, of the different observables from spin asymmetries proposed in [1]. To this end a fast simulation of a HERA–like detector has been implemented and will be described here. It consist of one function and four subroutines, written in standard FORTRAN, which can be called directly by the user: `z_vtx, ele_det, had_det, track_det`. It also includes two private functions: `thvtx, gauss_vec`. The sources can be found in [2].

The package covers the simulation of the smearing in the z–coordinate of the interaction vertex[1], the simulation of an electromagnetic and a hadronic calorimeter, and that of a tracker system.

The effects taken into account were the following. The acceptance of the detectors in the polar direction[2] (It was assumed that the coverage in the azimuthal direction amounts to 2π). An effective distribution of dead material between the interaction vertex and the trackers and/or the calorimeters. Smearing of the energy (the transverse momentum for the tracks) and angles of the generated particles. The possibility to alter the absolute energy scale to perform systematic studies.

The efficiency to trigger and select a given event have not been simulated and must be taken from somewhere else. All parameters used in these routines have realistic values, and are quite similar to the equivalent values used by the H1 [3] and ZEUS [4] collaborations at HERA.

2 The interaction vertex and the auxiliary routines

At HERA the bunches have a big size in the z direction compared to their transverse size. Thus the z coordinate of the interaction vertex is distributed over several centimetres around the nominal interaction point [5]. The function

[1] The positive z axis is defined by the direction of the incoming proton beam

[2] angle with respect to the positive z axis

```
real function z_vtx(z_0, z_sigma)
real z_0, z_sigma
```

returns a random value for the z coordinate of the interaction vertex assuming a Gaussian distribution of mean value `z_0` and variance `z_sigma`, where the units are in centimetres. If `z_sigma = 0` then `z_sigma=10.0` is assumed. This function has to be called first and only once per event.

To obtain the needed random numbers used by the simulations routines a generator of a vector of Gaussian numbers have been implemented

```
subroutine gauss_vec(g,n)
real g(*)
integer n
```

It takes as input an even integer value `n` and returns the vector of `n` Gaussian numbers in `g`.

The dead material correction factors are stored as a function of the polar angle θ assuming an interaction vertex at $z = 0$. Therefore, given the smearing of the vertex, it is necessary to perform a transformation to to find the appropriate correction factor. This occurs internally via the function `thvtx` which is automatically called when needed and the user does not have to worry about the details.

3 The tracker system

The simulated tracker system consist of a central part covering the polar range $20° < \theta < 160°$ and a forward part with acceptance $7° < \theta < 25°$. The trackers simulate only particles with a transverse momentum bigger than 200 MeV and have a reconstruction efficiency of 95% and 70% percent respectively. Each section has its own sets of parameters to smear the transverse momentum of the particles as well as their polar angle. All the values used for the different parameters are in accordance with those quoted in [6, 7].

This routine has to be call inside of a loop of all the charged hadrons generated in the event and has following syntax

```
subroutine track_det(z_vtx,vin,vout)
real z_vtx, vin(4), vout(4)
```

where the input is the z coordinate of the interaction vertex for the current event `z_vtx`, and the four momentum (p_x, p_y, p_z, E) of the charged particle `vin`. The output is the simulated four momentum `vout`.

4 The calorimeter

The calorimeter consist of an electromagnetic part to simulate the measurement of the scattered electron in DIS and a hadronic part to simulate the measurement of the hadronic final state.

Both calorimeters consist of a central and a backward part. They cover the polar range from 4° to 177°, whereas the central and backward part meet at 152°. An optional acceptance in the range $10° < \theta < 170°$ can be used to take into account an eventual upgrade of the HERA machine [8]. The complete azimuthal angle ϕ is covered for both calorimeters.

The influence of the dead material before the calorimeters and the losses due to geometric acceptance at the edges and in the region between the central and backward parts was modelled with correction factors which depend on the polar angle of the particle to be simulated. For the hadronic calorimeter there are 80 of these factors. For the electromagnetic calorimeter are two sets of 24 factors. Which of the two sets is used depends on the energy of the scattered electron.

Smearing of the energy and angles of the particles measured with the hadronic calorimeter was applied using the following realistic factors [9]. The energy resolution of the backward part is $\sigma/E = 0.56$, and of the central part $\sigma/E = 0.46/\sqrt{E} \oplus 0.73/E \oplus 0.026$, where the energy is given in GeV. For the angular resolutions in mrad $\sigma_\theta = 50$ and $\sigma_\phi = 90$ were used.

For the measurement of the scattered electron following values have been used (see for example [10]). In the backward part $\sigma_{cent}/E = 0.071/\sqrt{E} \oplus 0.01$, $\sigma_\theta = 2$ and $\sigma_\phi = 6$ were applied. In the central part $\sigma_{cent}/E = 0.13/\sqrt{E} \oplus 0.05$, $\sigma_\theta = 9$ and $\sigma_\phi = 30$ were used. Again the energies are given in GeV and the angles in mrad.

The absolute energy scale of the calorimeters, which is one of the main sources of uncertainty for the different measurements, was assumed to be known within 4% and 10% for the central, respectively for the backward, part of the hadronic calorimeter. For the electromagnetic section the values were 3% and 1%.

The routine for the electromagnetic section

```
subroutine ele_det(z_vtx, vin, vout, en_sc )
real z_vtx, vin(4), vout(4)
integer en_sc
```

has to be called once per event. The input is the z coordinate of the interaction vertex `z_vtx`, the four momentum of the generated scattered electron `vin`, and a flag `en_es` to govern the absolute energy scale of the calorimeter: if it is positive (negative) the energy will be up(down)scaled, otherwise it will remain unaltered. The four momentum of the simulated scattered electron is returned in `vout`. The hadronic section

```
subroutine had_det(z_vtx,vin, vout, en_sc)
real z_vtx, vin(4), vout(4)
integer en_sc
```

has to be called inside a loop of all the particles of the event except the scattered electron. The variables act as in the routines already presented.

5 Conclusions

A set of FORTRAN routines to simulate in a time effective way the behaviour of a HERA–like detector to study the measurability of spin asymmetries at HERA has been implemented. They are described here. It includes the smearing of z coordinate of the interation vertex, the simulation of a tracker system as well as that of an electromagnetic and a hadronic calorimeter. Effects included are acceptance of the detector, correction for dead material and smearing of the four momentum of the simulated particle.

References

[1] J. Feltesse, A. Schäfer, Future physics at HERA Workshop, Vol. 2 (DESY, 1996) 760.

[2] http://www.desy.de:8888/ gehrt/heraspin/.

[3] H1 Collaboration, Nucl. Instr. and Meth. **A 386** (1997) 310 and 348.

[4] The Zeus detector, Status Report 1993 DESY (1993).

[5] B. H. Wiik, Physics at HERA Workshop, Vol. 1 (1992) 1.

[6] H1 Collaboration, Nucl. Phys. **B 485** (1997) 3.

[7] Zeus Collaboration, Z. Phys. **C 70** (1996) 1.

[8] W. Bartel et al., Future physics at HERA Workshop, Vol. 2 (DESY, 1996) 1095.

[9] B. Andrieu et al., Nucl. Instr. and Meth. **A 336** (1993) 460.

[10] T. Nicholls et al., Nucl. Instr. and Meth. **A 374** (1996) 149.