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Introduction to Phenomenology and Experiments in Particle Physics, PBL:An experiment from start to end.

A gang of enthusiastic Marie Curie PhD students had seen that when a fixed target experiment at the SPS was dismanteled, a large number of fancy crystals from the electromagnetic calorimeter had been taken out. The crystals were 1000 blocks of BGO ($3*3*30cm^3$) and they were equipped with photodiode readout. BGO is extremely expensive (~10€ per cm^3 if bought in Russia) and they started to think about how to use the equipment.

They went to the spokesman of their big collider experiment and proposed to install them. One would have to let the owners of the crystals join the collaboration but that was a fair price to get the hands on 3M€ worth of high resolution calorimetry.

In terms of electronics it seemed feasible since one was anyway reading out a lot of photodiodes from the low resolution calorimeter which covered 4π steradians around the vertex region in the experiment and 1000 additional channels was much less than the number of spares they had. It even seemed to fit into the high energy triggering capability of their calorimeter readout.

The spokesman wanted to encourage their enthusiasm and said. So you ask us to replace a square meter of our lead-scintillator sampling calorimeter with BGO. That may be a good idea but you have to convince me about the performance and how we could improve our experiment by adding high resolution calorimetry in a small solid angle like this, inside our big solenoid magnet.

Literature list:

Geant4 web site. http://geant4.web.cern.ch/geant4/
Geant lecture by Sverker Almhed

Teachers instructions:

The students should analyse what physics observables could be addressed better with a calorimeter of this kind, in spite of the small coverage. An expected answer could be to trigger and measure neutral pions at larger transverse momenta than what is possible with moderate resolution calorimetry.

In order to demonstrate the performance, the students have to perform a GEANT simulation. A lecture is probably needed together with the GEANT manual to get a quick enough start. An example from which the student can build the simulation can also be provided.

The students need to generate a realistic spectrum of neutral pions. Instead of running a full blown event generator they should construct a simple particle generator based on empirical spectra. This is more instructive than running a full blown event generator, as it forces the student to decide what is important and what is not. And in real life, quick, simplified tests are often very useful.

It is likely that the work is too much for one week if each student should go through all steps. Instead they should specialize, and in groups of 2-3 students solve part of the problem. They have to define clear interfaces where the result of one group forms input to the next. A group of 8 students could divide the work in 4 parts:

- generate particles
- geometrical description of the experiment
- digitize the detector response to a measured event
- read the simulated data, reconstruct the PT-spectrum and compare with input.

Detailed learning goals in key words.

Generate particles at random
-pions, kaons, protons,
-PT-distribution
-rapidity distribution
-production ratios
-multiplicity distribution

Geometry
-BGO crystals
- Sampling calorimeter
- magnetic field
- charged particle veto

Sample signal
-energy resolution
-energy linearity
-position resolution
-hadron resolution
-digitize detector signal
-calibrate detector signal
-write calibrated raw data events

Reconstruct invariant mass.
- obtain PT spectra for neutral pions
- correct for efficiency and acceptance.