Simulation of a Collimator System For the GlueX Experiment

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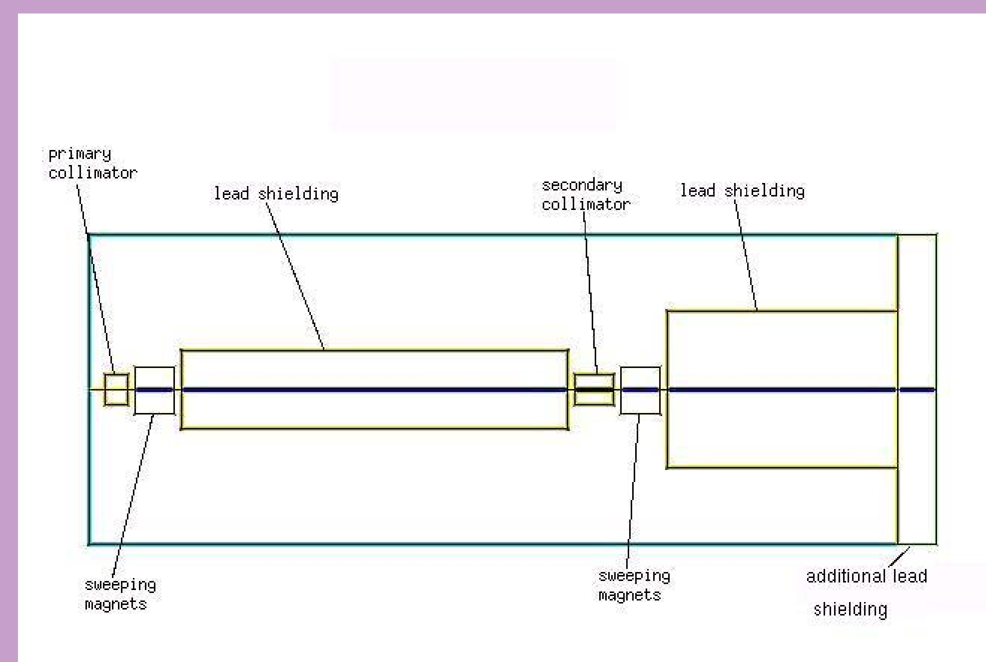
The GlueX Experiment

The GlueX project is an experiment that hopes to confirm our present theory on the nature of quark confinement by making detailed measurements of the meson spectrum.

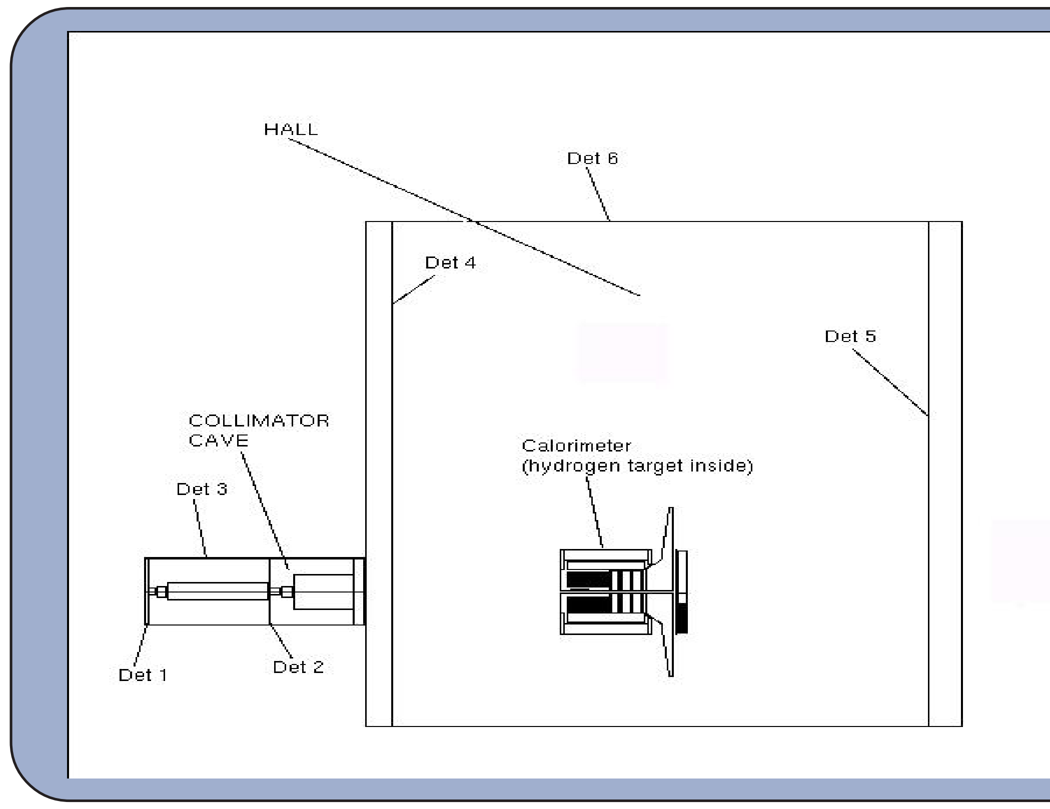
Because mesons are composed of only a quark and an antiquark this makes them the ideal system in which to study the complicated dynamics of the gluon field.

This experiment will produce mesons by using gamma rays to excite a deuterium nucleus. For our proposes it would be advantageous to use a highly polarized beam of gamma rays, possible through the use of precise collimation.

The Collimator (fig 1.)



GlueX (fig. 2)



Simulating the Collimator

Using Geant, a physics simulation program, I created a system for collecting and utilizing data using spread sheets from a simulated GlueX experiment. A particle that enters any one of six “virtual” detectors (see fig. 2) is added to the spread sheet, and with it, all vital information about that particle.

Geant itself had to be updated since it did not account for photo-hadronic interactions or Bethe-Heitler muon pair production. Under most circumstances these effects are small and can be neglected, however, for our purposes they must be accounted for.

How Good Is Our Model?

The first question we need answered about our “virtual” collimator, is how good is it at stopping unwanted secondary particles from leaving the collimator housing.

In our simulated GlueX experiment we found the flux of secondary particles such as neutrons and pions leaving the collimator were well below that of photons.

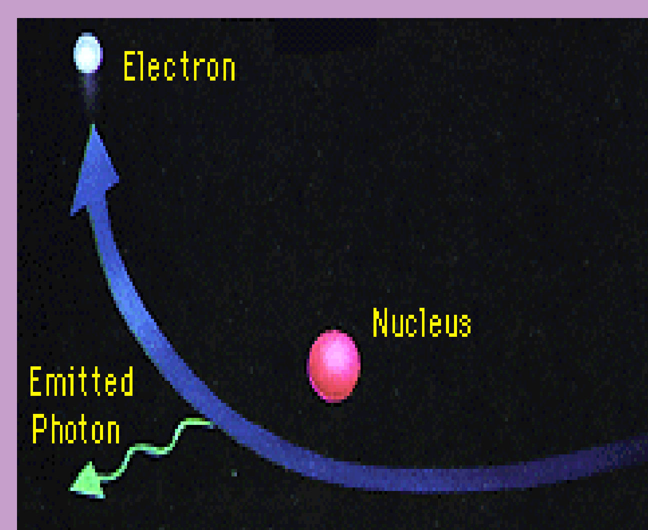
After examining the amount of flux in other areas in our simulated model, we found an anomaly at detector 4. As shown in figure 4, the flux reaches a minimum at -200 and 200 on the x-axis. After further inspection we found that this was due to the extra shielding at the end of the collimator box (see fig. 2). Still, The flux was not expected to increase after it reaches a minimum. The reason for this increase is that our model of GlueX disregards the earth that surrounds the hall and the collimator cave, allowing neutrons to escape the collimator housing, and enter the hall without any resistance.

Coherent Bremsstrahlung

In a typical bremsstrahlung process, lite, ultra-relativistic particles hit a radiator, releasing radiation. While this process does provide the neccessary flux needed for the GlueX experiment it is impossible to make a coherent, polarized beam of photons in this way.

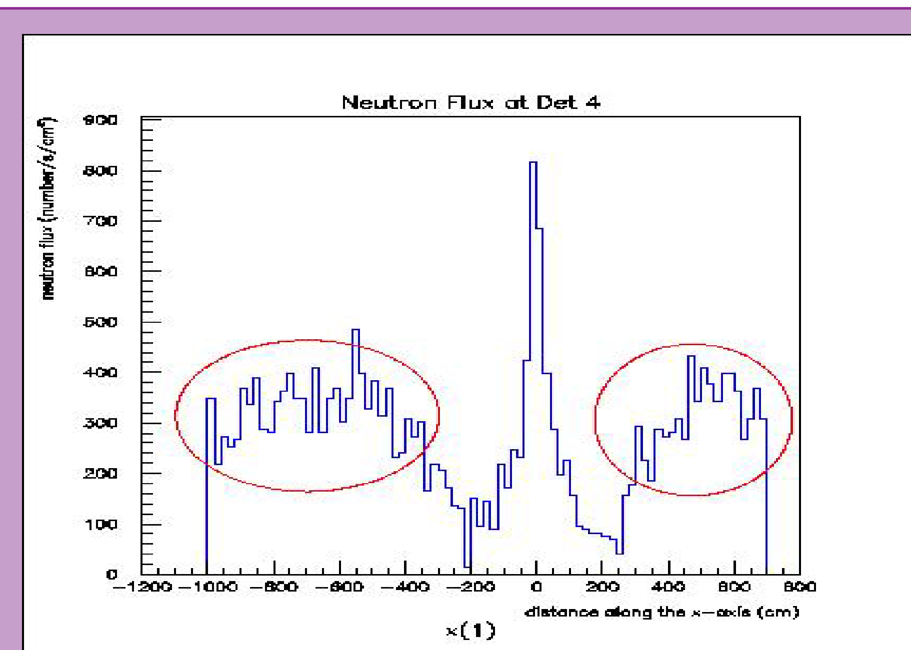
Coherent bremsstrahlung uses as a radiator a highly ordered crystal such as diamond. This retains the sufficient flux we need plus another attractive feature, coherence.

In coherent bremsstrahlung, there is a well defined relationship between the energy of the emitted photon and it’s emission angle, which we can exploit to further increase the level of coherence.



(fig.3) A picture representing the Bremsstrahlung process. An electron is slowed down by it’s attraction to a nucleus and emits a photon in the process

What’s Wrong With the Neutrons?



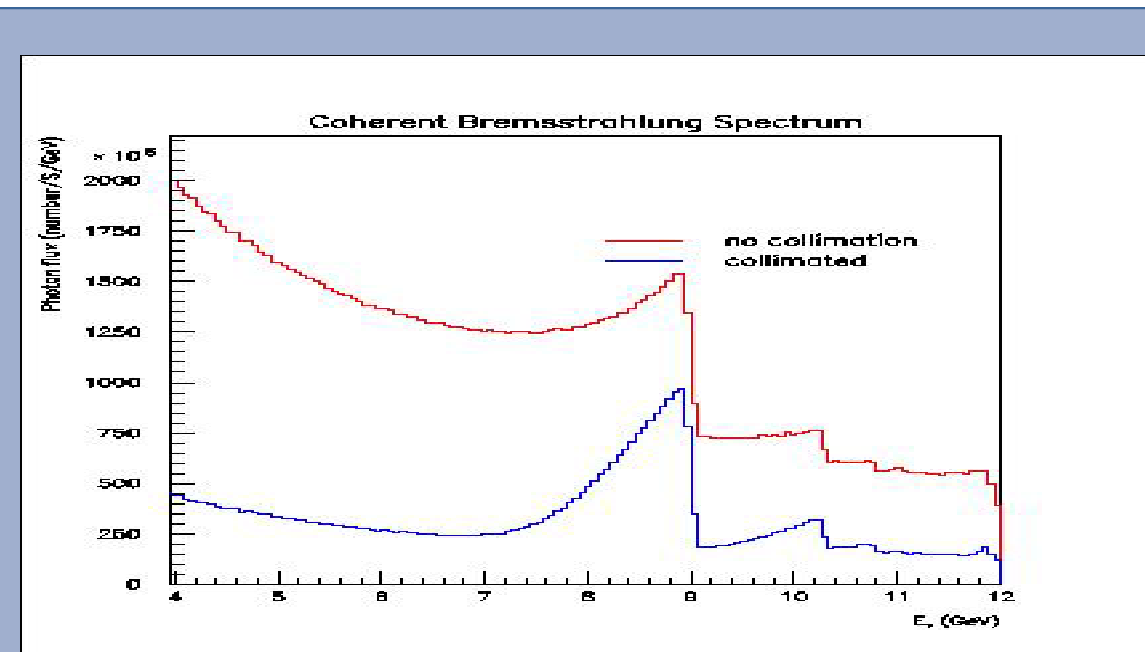
(fig. 4) The neutron flux at det 4. The red circles point out the unusually large flux of neutrons due to the lack of shielding in our model.

Why Collimation?

In coherent bremsstrahlung, the higher the emission angle the lower the energy of the emitted photons. Since the lower energy photons reside in the outer halo of the gamma ray beam, a collimator can further increase the level of coherence by absorbing these “noisy” low energy photons.

Also, as the emission angle increases, the degree of linear polarization decreases, so in the process of “shaving” off this outer halo of photons we also increase the polarization of the gamma ray beam.

The Effect of Collimation



(fig. 5) This figure shows the effect that collimation has on the coherent bremsstrahlung spectrum. notice the relative increase in the number of photons with energies between 8 and 9 GeV compared with the number of those with energies less than 8 GeV.;

So How Does Our Simulation Stack Up?

The numbers of neutrons and muons seen in our simulation is encouraging and suggests that we have successfully incorporated photo-hadronic and muon pair production effects into the Geant simulation

The levels of flux leaving the collimator are within reasonable levels so no further shielding will be needed in that part of our GlueX model. However, observation of an anomalous neutron flux at detector 4 indicates that our model will need to include the earth surrounding the hall.

This change will have to be incorporated in to our simulation in future GlueX models.