NEUTRAL PARTICLE CALORIMETER: SIMULATIONS

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Overview

Neutral Particle Calorimeter

→ Concepts and options
→ Features used in the simulations

GEMC/GEANT4 simulations

→ Set up of the detector
→ Signal and background consideration
→ Sensitivity to parameters:
  • Size of integration time window
  • Beam current
Detector design

Neutral Particle Calorimeter
Here, we will consider a neutral particle spectrometer with the following characteristics:

- \( \text{PbWO}_4 \) or \( \text{PbF}_2 \) crystals
- Temperature controlled frame
- Essentially deadtime-less digitizing electronics (flash ADC)
- A sweeping magnet
- HV bases with built-in amplifiers

These concepts were considered to take advantage of existing detector (components) from, e.g., PrimEx or DVCS.
Studies using option: PbWO$_4$ crystals

Detector dimensions:

31 x 36 matrix of PbWO$_4$ crystals
2.05 x 2.05 x 18 cm$^3$ each crystal

Assuming we will have crystals from PrimEx experiment:

Energy resolution

$\sigma = 2.45\%$ @ 1. GeV

Spatial resolution

$\sigma = 5.6$ mm @ 1. GeV

More details of the crystals in talk:
H. Mkrtchyan, “Neutral Particle Detector: Crystal Properties”
**Sweeping magnet**

- Resistive magnet based on Hall C horizontal bend (HB) design for SHMS
  - Normal-conducting copper coil magnet
  - Aperture: 35x36cm$^2$
  - Magnetic field strength: 0.3 T-m

- Designed to work with existing JLab power supplies [*P. Brindza, 2012]*

Treated in the simulation as:

- Magnetic field for background charged particles bending
Usage of flash ADCs

- Continuous sampling of the signal – 4ns window
- Internal buffer for pre-trigger sampling
- FPGA for sampling and bufferizing signal. Also possible to create advanced online processing for trigger system, e.g. cluster finding, ...
- FPGA $\rightarrow$ real parallel processing $\rightarrow$ “no” electronic deadtime

Treated in the simulation as:

Different time window for signal integration
Simulated Detector Features

Neutral Particle Calorimeter
Calorimeter design

Detector features:

- 34 x 34 matrix of PbWO₄ crystals
- 2.05 x 2.05 x 18 cm³ each crystal
- No PMT/detector efficiency simulated

✓ GEMC / GEANT4 framework
✓ Studies based on the option of using PbWO₄ crystals.
✓ Studies with lead fluoride are on the way.
Shower profile

3 GeV photon hitting the center of the crystal

Front view

3D view

Side view
\( \pi^0 \) decay simulation

- Includes photons from \( \pi^0 \) decay
  - Simulate \( \pi^0 \) signal normalized to rate.
  - For each event decay \( \pi^0 \) into 2 \( \gamma \)

- Simulated background consists of realistic fluxes of neutral and charged particles, the latter suppressed by sweeper magnet [P. Degtiarenko, 11+]

- Photon pair is selected from other processes in the calorimeter using a cluster finding algorithm

- \( \pi^0 \) invariant mass reconstructed for each hit in the calorimeter

Combinatorial background is small (<1%)
Total energy deposited in each crystal. The shadow blue peaks show the cluster analysis for finding the two greatest peaks on the detector. In this case, it was used a cluster size of 2x2 crystals.
Studies on the $\pi^0$ detector

Each event contains 2 photons from $\pi^0$ decay and background.

One typical analysis (almost no background)

Fitting peaks close to the edges of the detector

Fitting two peaks close to each other
Distance of the simulated peak to the original peak (input photon position)

Sub-crystal resolution!

Crystal dimension
Simulations including background

- Events with two photons from $\pi^0$ decay and background
Simulations including background

10 ns

40 ns

80 ns

200 ns
Simulations with higher currents

1 uA

2 uA

5 uA

8 uA
Next steps

Neutral Particle Calorimeter
Next steps...

On the detector concept

→ Simulate same situation with PbF$_2$ crystals (from DVCS)

On the parameters of the simulation

→ Simulation for different angles of SHMS (changing signal to background ratio)
Simulations including a pre-showers

Possibility of working with pre-showers:

- Particle identification (e, p, gamma)
- A problem for two photons too close in a $\pi^0$ decay

First simple pre-showers:

10mm thick PbWO$_4$ crystal

1 GeV gamma

1 GeV proton

1 GeV e$^-$

“No” interaction

Absorbed

Pre-shower created