A Study of Acceptance for the Stage 1 Hall D Detector

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1 Introduction

In order to better understand the effects of finite acceptance of the proposed stage 1 detector configuration, a simple study of the acceptance as a function of total meson effective mass for various final states has been performed. In doing the Monte Carlo acceptance studies we considered the following reactions:

1. $\gamma p \rightarrow X^+ n$
   - $X^+ \rightarrow \pi^+\pi^+\pi^-$
2. $\gamma p \rightarrow X^+ n$
   - $X^+ \rightarrow \eta\pi^+\pi^+\pi^-$
     - $\eta \rightarrow \gamma\gamma$
3. $\gamma p \rightarrow X^+ n$
   - $X^+ \rightarrow \omega\pi^\circ\pi^+$
     - $\omega \rightarrow \pi^+\pi^-\pi^\circ$
     - $\pi^\circ \rightarrow \gamma\gamma$
4. $\gamma p \rightarrow X^\circ p$
   - $X^\circ \rightarrow \pi^+\pi^-\pi^\circ$
     - $\pi^\circ \rightarrow \gamma\gamma$
5. $\gamma p \rightarrow X^\circ p$
   - $X^\circ \rightarrow \eta\pi^\circ\pi^\circ$
     - $\eta \rightarrow \gamma\gamma$
     - $\pi^\circ \rightarrow \gamma\gamma$

The acceptance studies were performed with a total effective meson masses ($Mass(X)$) of 1.4, 1.7, and 2.0 GeV. At each $Mass(X)$, events were distributed according to a Breit-Wigner of width $\Gamma = 0.250$ GeV. In generating the Monte Carlo events, the following assumptions were made:

- peripheral production where $\frac{d\sigma}{dt} \propto e^{-b|t|}$ and $b = 5.0$ GeV^2;
- events distributed according to phase-space; and
- isotropic decay angles.

For each reaction, 30000 events (10000 for each $Mass(X)$) were generated for different photon beam energies of: 5, 6, 8, 10, and 12 GeV.

2 Detector Geometry

The generated events were processed through *HDFast* –the Hall D Monte Carlo Framework. *HDFast* is a fast and flexible simulation program which is designed to perform parameterized tracking. It assembles a covariance matrix for each track taking into account detector materials, efficiencies, and resolutions for all measurement planes, and it uses this matrix to smear the track

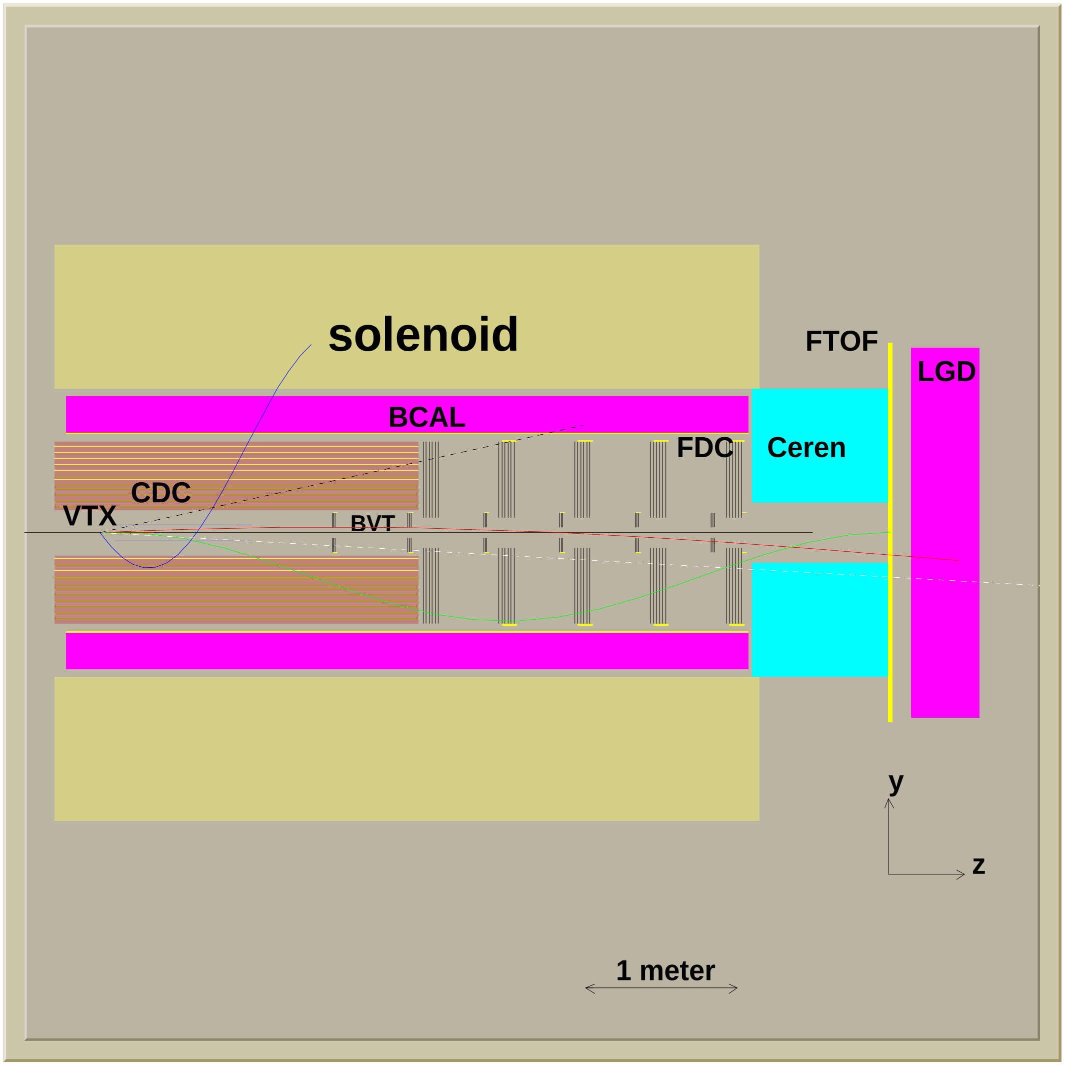

Figure 1: The Hall D Stage I detector. The event shown contains both charged particles (line) and photons (dashed line).

parameters randomly. The covariance matrix is first diagonalized so as to properly account for effects due to correlations. A more detailed description of the Hall D Monte Carlo Framework is given in chapter 9 of the Hall D Preliminary Design Report.

A plan view of the assumed detector geometry is displayed in Figure 1. This configuration is comprised of the following assumptions:

- 2.24 Tesla solenoid magnet –LASS magnet,
- 5-layer Vertex Chamber (VTX),
- 22-layer Central Drift Chamber (CDC),
- 6 3-layer Forward Small Angle Chambers (BVT),
- 5 6-layer Forward Drift Chambers (FDC),
- Barrel Calorimeter which also acts as central TOF (BCAL),
- Cerenkov Detector,
- Forward time-of-flight (FTOF),
- Forward Lead Glass Detector (LGD) 172x172cm with 8x8cm beam hole,
- target-beam vertex distribution at $r = 0.0$cm, $z = 50$cm with $\sigma_r = 0.3$cm, $\sigma_z = 15.0$cm.

3 Acceptance Studies

In the simulation, an event was accepted if the following minimum conditions were met:

- all charged tracks were found with a minimum of four hits per track, and
- all gammas were detected in either the BCAL and/or LGD.

The acceptance as a function of total effective meson mass is shown in Figure 2. It is important to note that at higher beam energies the charged track momentum resolution degrades due to the forward increase of the track momentum, so even though the mass acceptance is seemingly good, the resolution of the tracks for this geometry at these higher energies is rather poor.

See note 7[1] for a more detailed discussion on tracking resolutions and the need to augment the detector with a forward tracker.

In Figure 3 through Figure 7, we show the acceptance for the Gottfried-Jackson decay angles. It is clear that the Gottfried-Jackson angular acceptance is quite good. The acceptance for gammas is also quite well, but it suffers more from holes in the forward and backward regions. The hole in the backward region results from backward going gammas which is the dominant factor at lower beam energies. The forward hole, due to gammas hitting the beam hole in the LGD, becomes a factor (and effectively gets larger) for higher beam energies. Figure 8a displays a lost event for $\gamma p \to p\eta\pi^\circ\pi^\circ$ at $Mass(X) = 2.0$ GeV and beam of 5 GeV. For this channel 75% of the lost events were of this type whereas about 50% of the lost events are due to the beam hole (See Figure 8b) for the same final state but with the beam at 12 GeV. While the beam hole is a necessity, the hole in the backward region suggests the need at the lower beam energies for a backward gamma veto. More importantly, the acceptance for the Gottfried-Jackson decay angles is flat and not strongly dependent on $Mass(X)$ or the beam energy. Even though the method of partial wave analysis can account for effects of finite detector acceptance, a small misunderstanding of the detector acceptance can be greatly amplified by the need for large acceptance corrections and thus produce false or misleading results. Work on acceptance studies for other more complicated final states and background channels, such as the affects of misidentified Δ's and $N^\star$'s, is in progress.

[1]C. Meyer *Tracking Resolution Requirements in the Meson Spectroscopy Facility at Jefferson Lab* , 20 Oct 1998,(*http://www.phys.cmu.edu/halld/notes_main.html*)

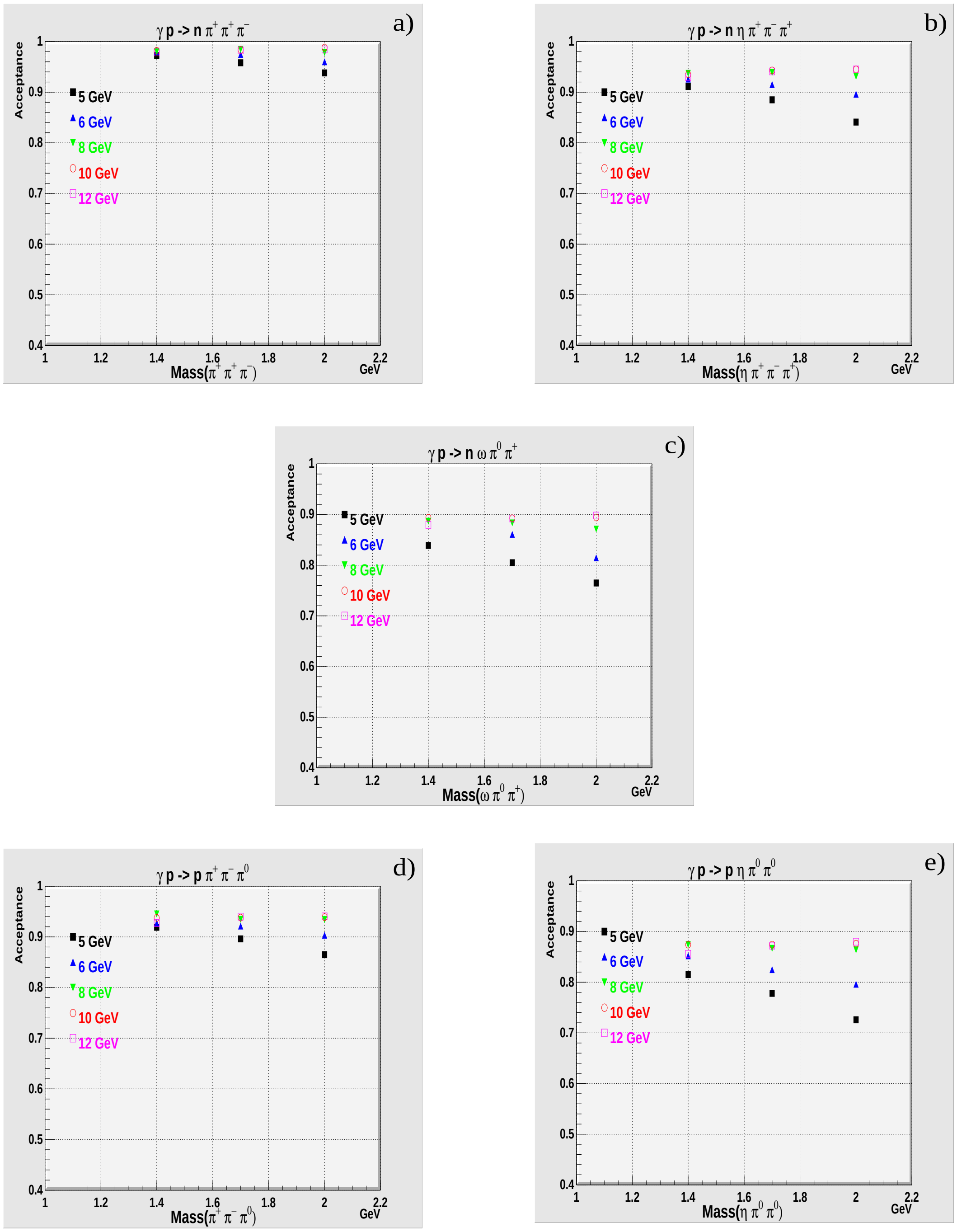

Figure 2: The acceptance as a function of total effective meson mass: a) $X^+ \to \pi^+\pi^+\pi^-$, b) $X^+ \to \eta\pi^+\pi^-\pi^+$, c) $X^+ \to \omega\pi^\circ\pi^+$, d) $X^\circ \to \pi^+\pi^-\pi^\circ$, e) $X^\circ \to \eta\pi^\circ\pi^\circ$.

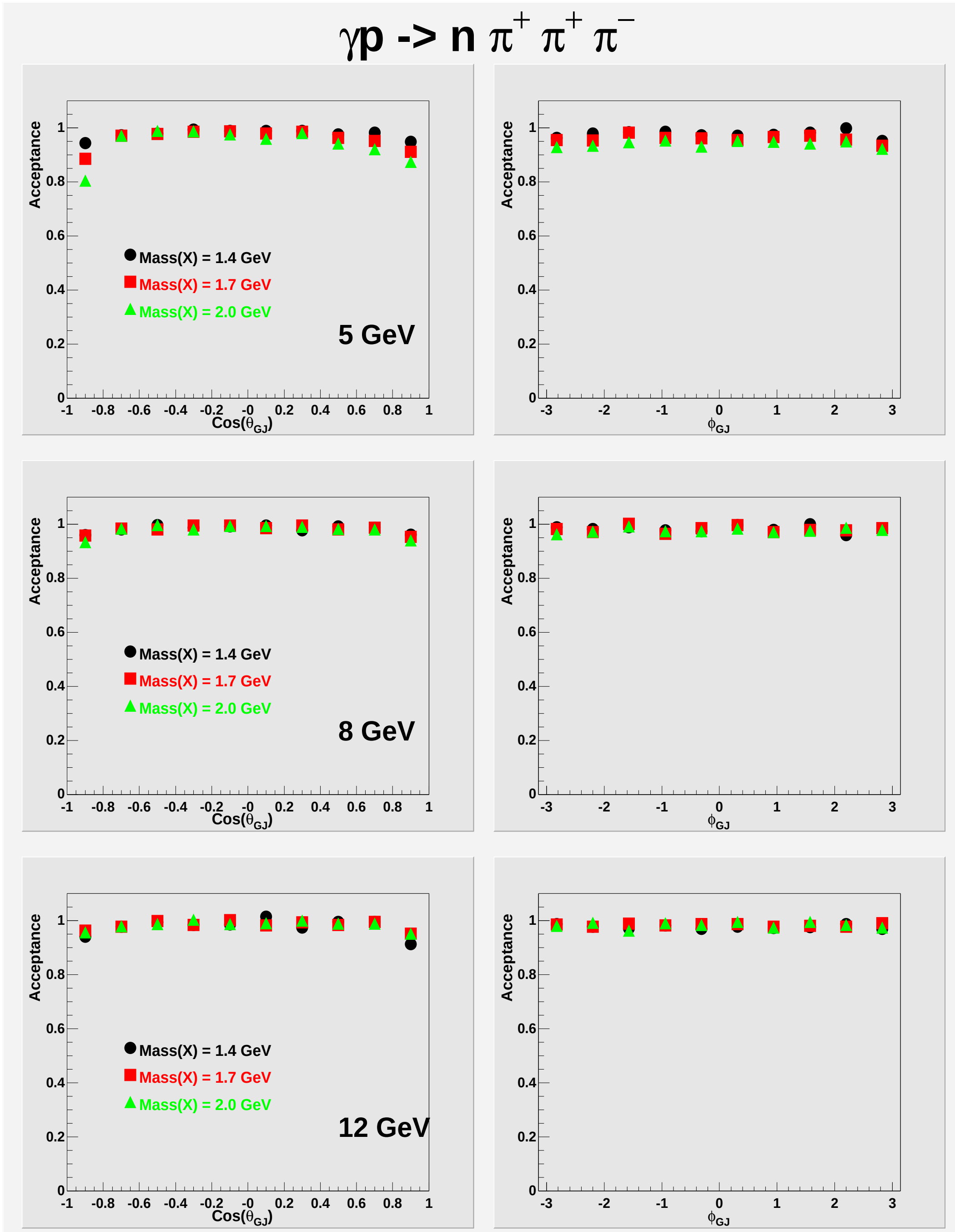

Figure 3: The acceptance in $cos(\theta_{GJ})$ and ϕ_{GJ} for $X^+ \to \pi^+\pi^+\pi^-$.

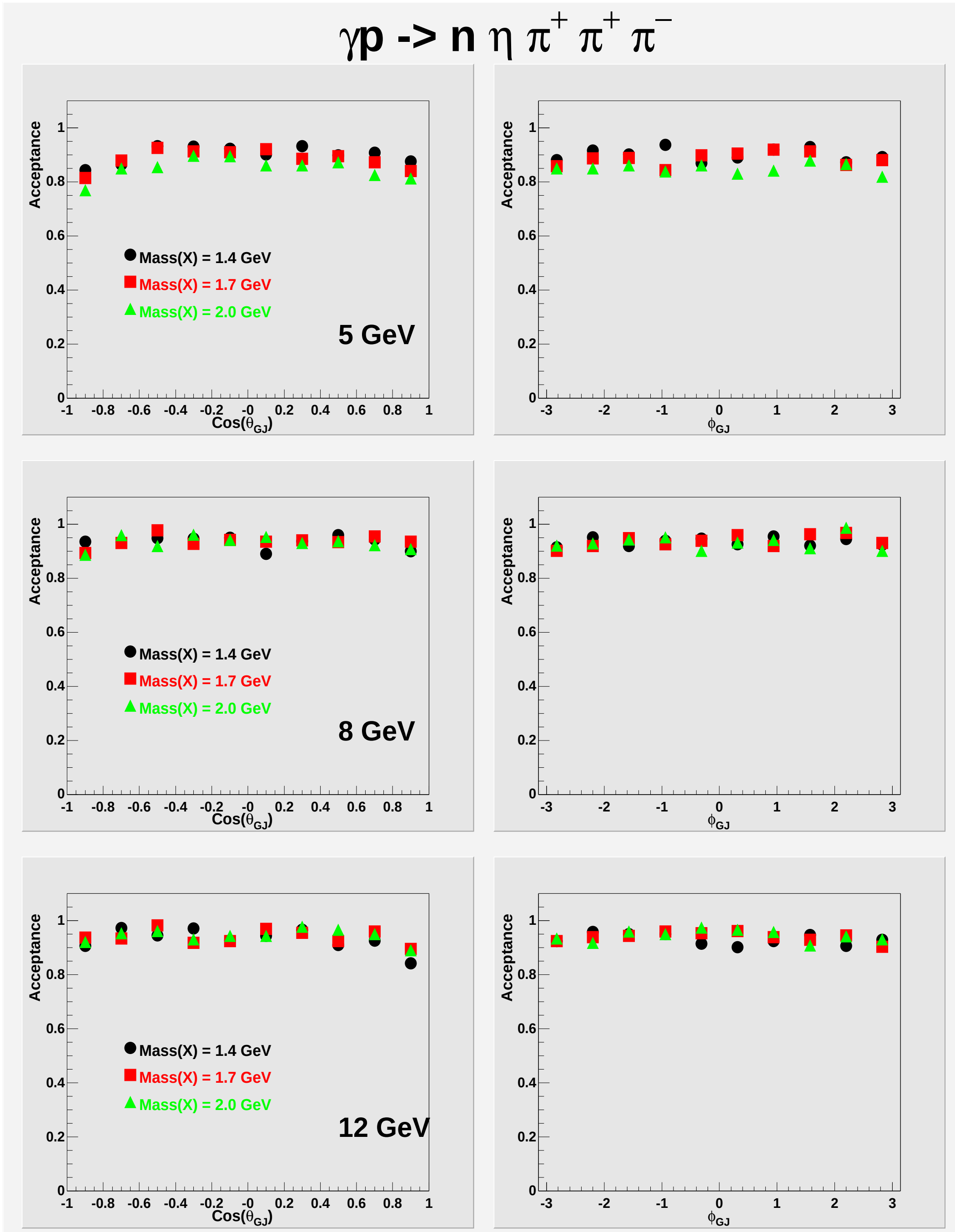

Figure 4: The acceptance in $cos(\theta_{GJ})$ and ϕ_{GJ} for $X^+ \to \eta\pi^+\pi^+\pi^-$.

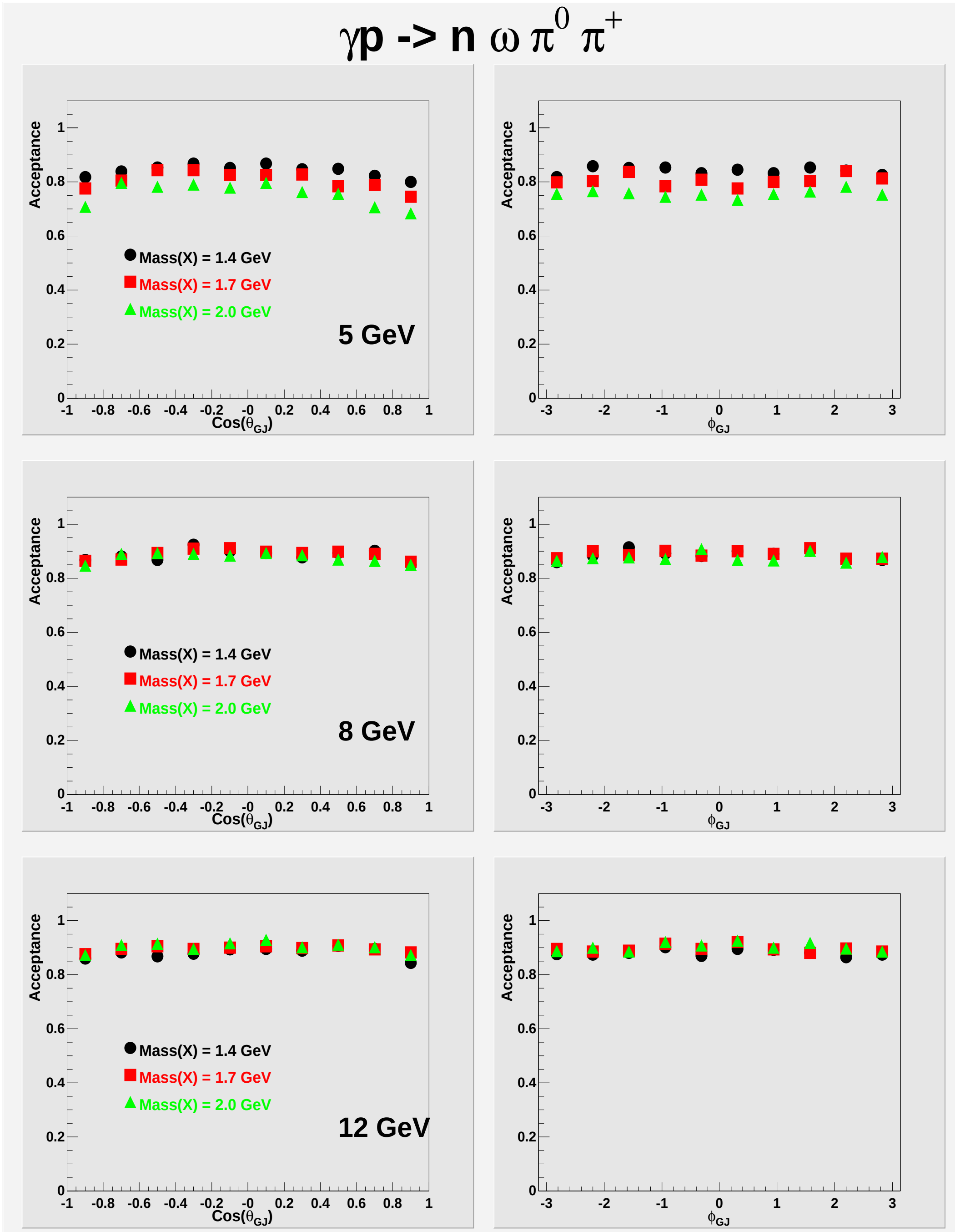

Figure 5: The acceptance in $cos(\theta_{GJ})$ and ϕ_{GJ} for $X^{\circ} \rightarrow \omega\pi^{\circ}\pi^{+}$.

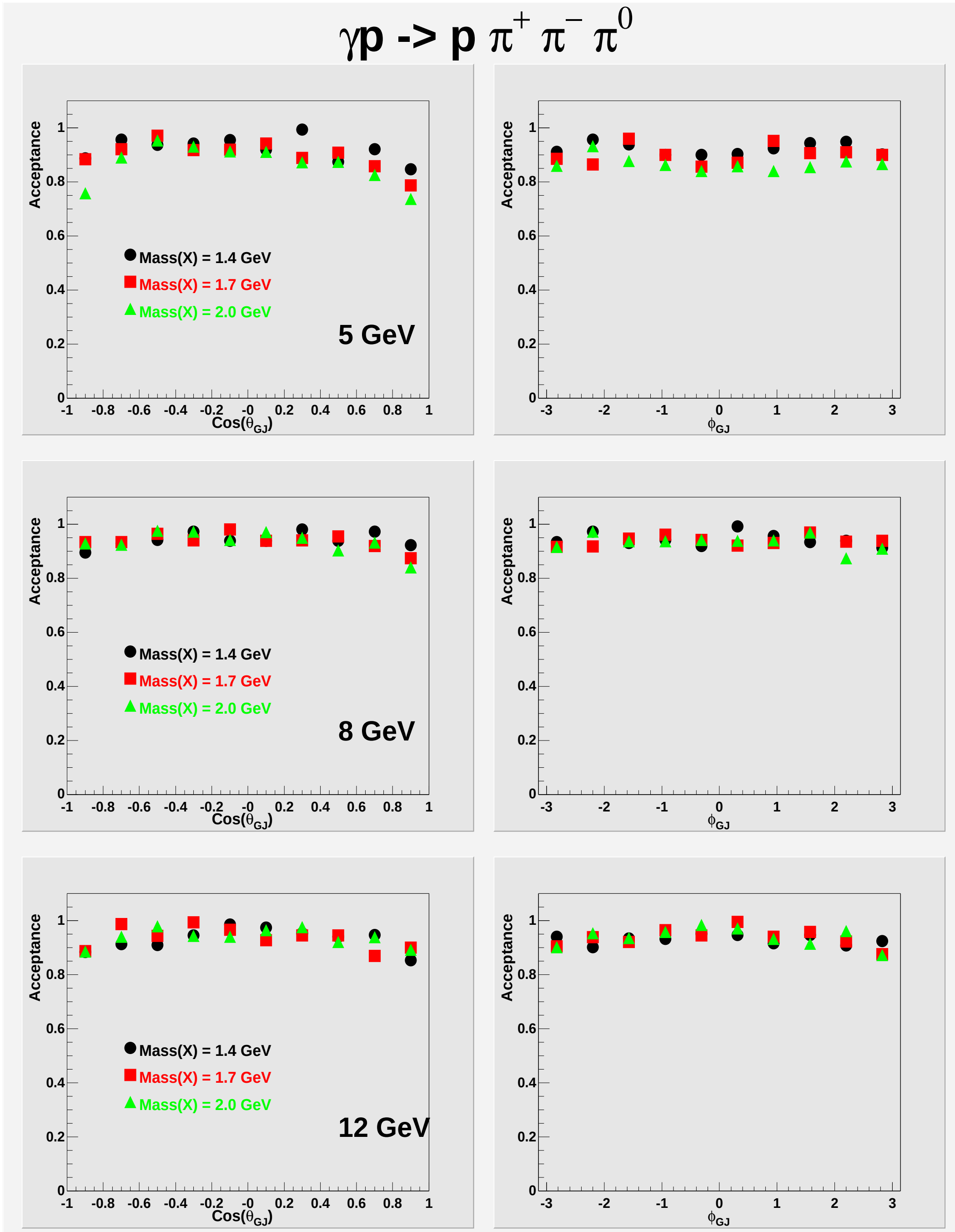

Figure 6: The acceptance in $cos(\theta_{GJ})$ and ϕ_{GJ} for $X^{\circ} \rightarrow \pi^{+}\pi^{-}\pi^{\circ}$.

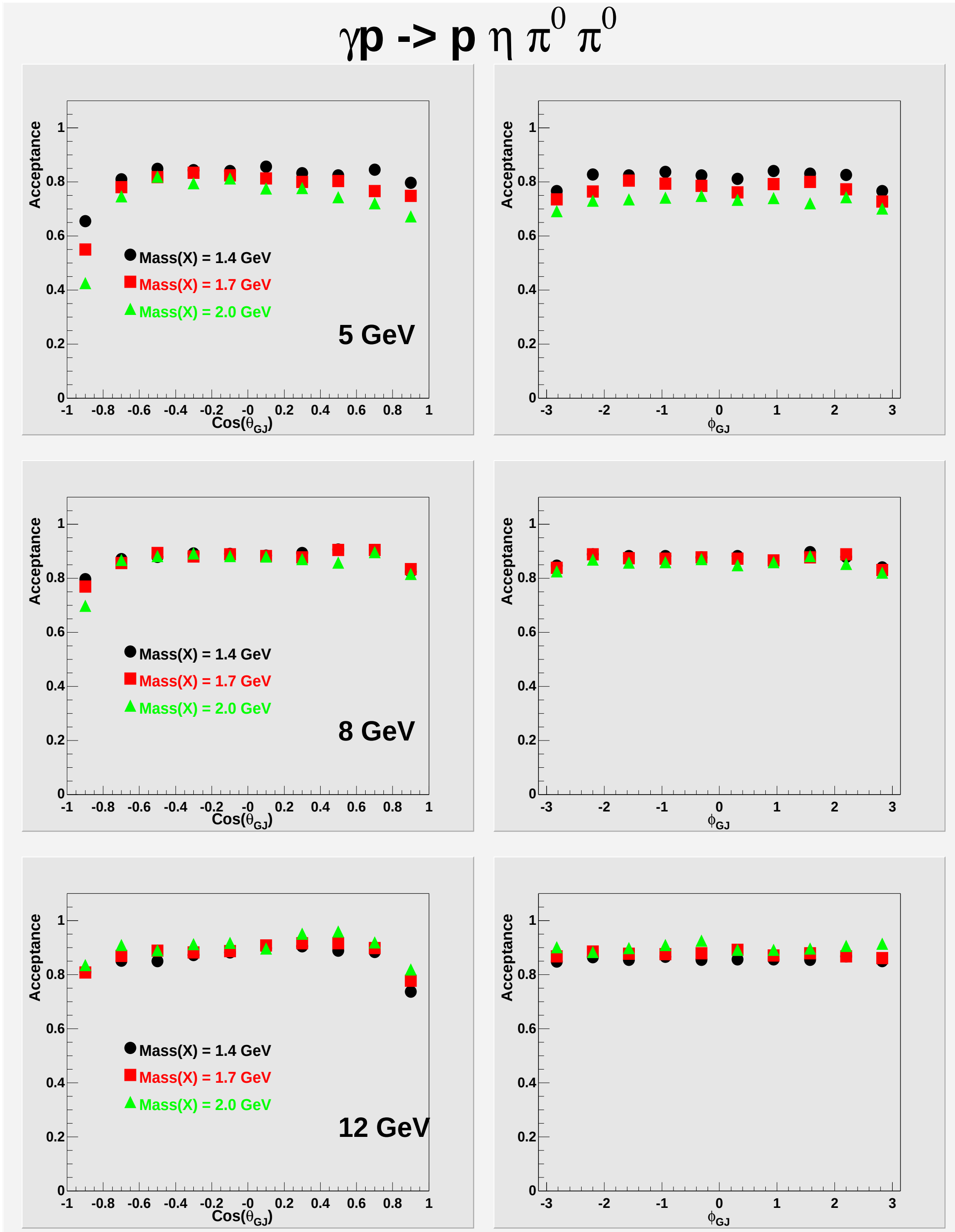

Figure 7: The acceptance in $cos(\theta_{GJ})$ and ϕ_{GJ} for $X^\circ \rightarrow \eta\pi^\circ\pi^\circ$.

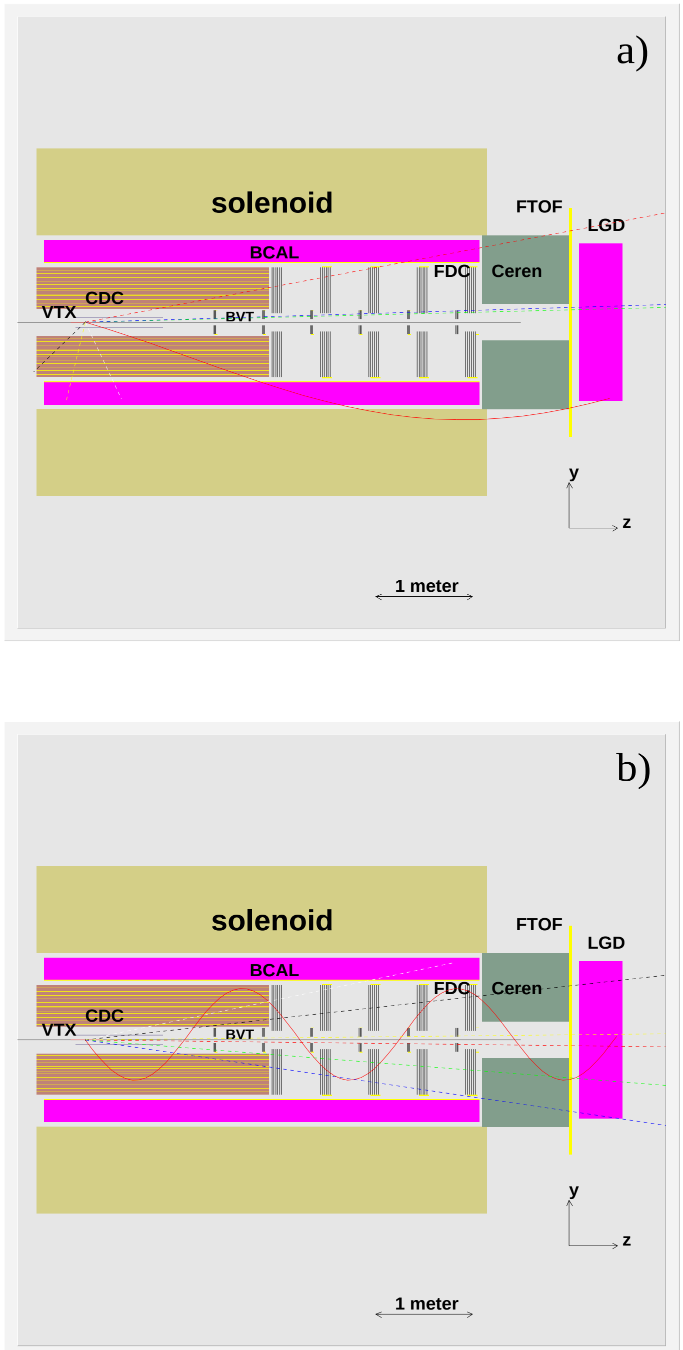

Figure 8: Event displays of lost events for $\gamma p \rightarrow p\eta\pi^{\circ}\pi^{\circ}$ for $Mass(X) = 2.0$ GeV: a) backward missed gamma at beam= 5 GeV, and b) forward missed beam hole gamma at beam= 12 GeV.