# *Status of $\eta$ Rare Decay Background Simulation*

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# Background Overview

Channel under study $\gamma p \rightarrow \eta p$ ( $\eta \rightarrow \pi^0 \gamma \gamma$ )

- require 4 clusters in the forward calorimeter

➢ Background from $\gamma p \rightarrow \eta p$ , $\eta \rightarrow \pi^0 \pi^0 \pi^0$

- three orders of magnitude larger branching fration

$Br(\eta \rightarrow \pi^0 \pi^0 \pi^0) = 32.57 \pm 0.23\ \%$

$Br(\eta \rightarrow \pi^0 \gamma \gamma) = (2.7 \pm 0.5) \cdot 10^{-4}$

- missing photons, outside calorimeter acceptance

photon clusters overlapping

➢ $\gamma p \rightarrow 2 \pi^0 p$ background

- has to be measured (Crystal Ball studied $\pi^- p \rightarrow \pi^0 \pi^0 n$ production, Phys. Rev. C 69,045202 (2004)
- use Pythia to estimate background

➢ Electromagnetic background (pile up of EM events in ~60 ns time window)

Define background discriminating variables and form them into a likelihood function

# $\eta \rightarrow \pi^0 \pi^0 \pi^0$ Background

Possible background discriminating variables:

- M ($4\gamma$) invariant mass
- Radial energy spread $(E_{cluster} - E_{max}) / E_{cluster}$
  reduce events with overlapping clusters

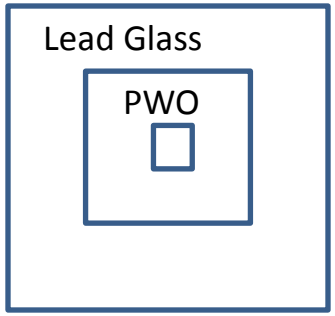
⟸ Need detailed simulation of PWO calorimeter

- Use kinematic fit (missing mass ) for events with reconstructed recoil proton

Simulation inputs:

Calorimeter geometry:

- beam hole size 12 x 12 $cm^2$
- PWO size 120 x 120 $cm^2$
- Lead Glas 212 x 212 $cm^2$



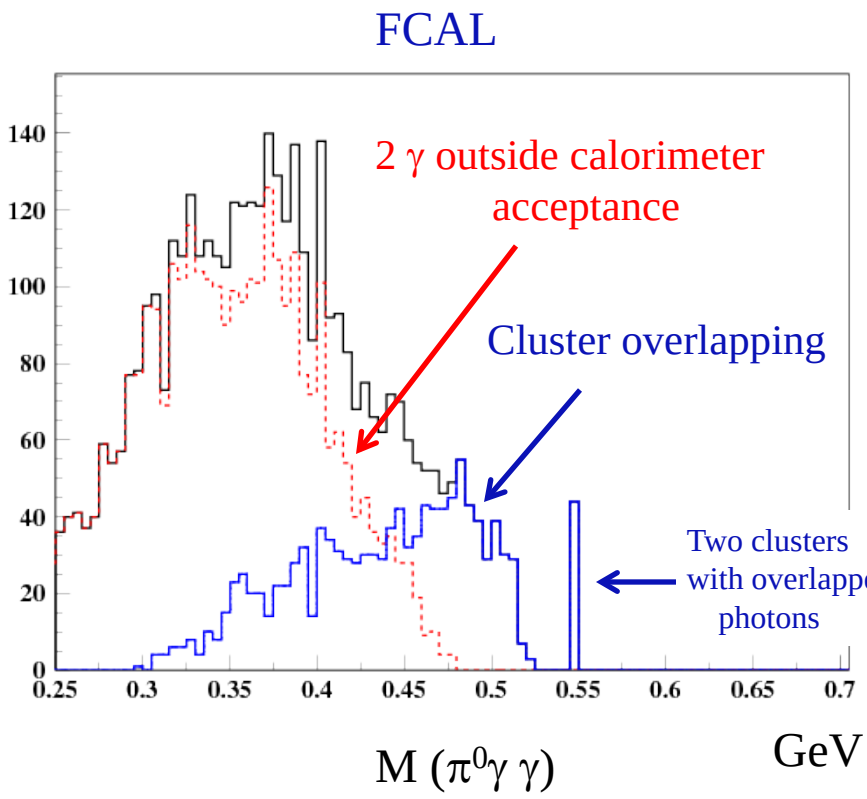

Two cluster separation (Iliya Larin studies )

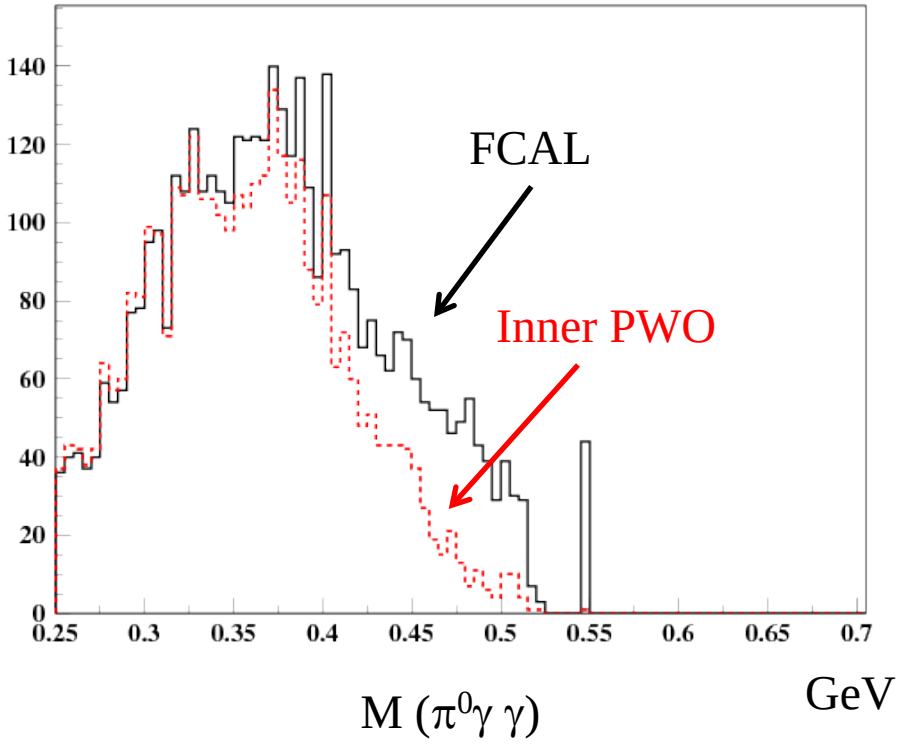
$d_{min}$ = 2.5 cm - PWO

$d_{min}$ = 5.0 cm - Lead Glass

# $\eta \rightarrow \pi^0 \pi^0 \pi^0$ Background

MC sample for 11 GeV beam photons




*No energy position smearing on these plots

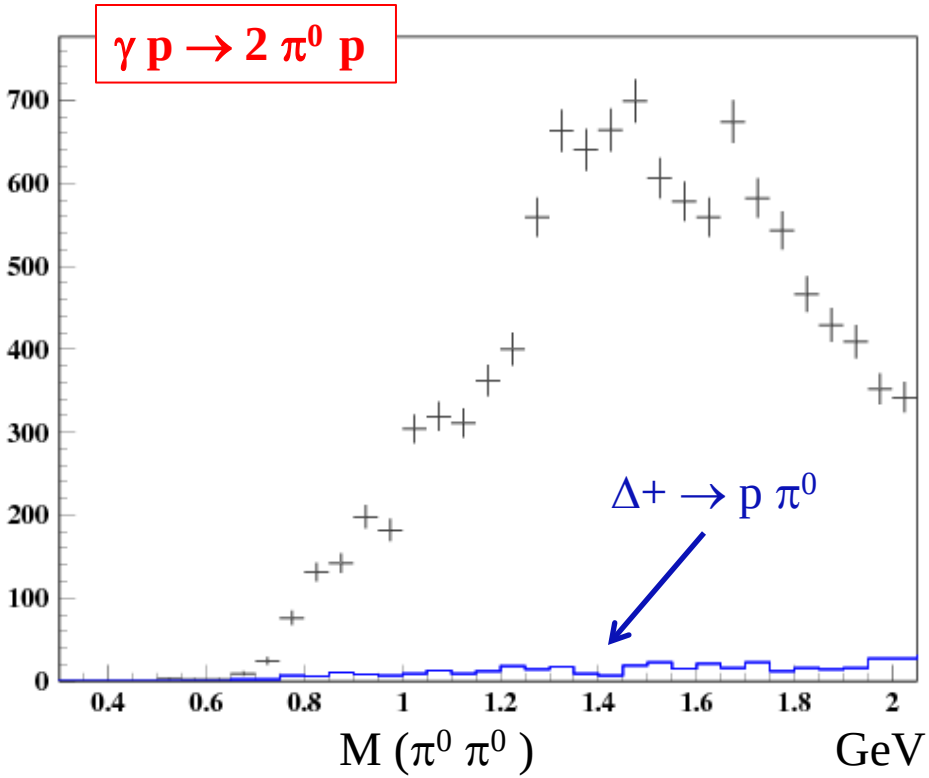
# $\gamma p \rightarrow 2\ \pi^0\ p$ Background

Possible background discriminating variables:

- M ($4\gamma$) invariant mass
- two pion mass difference $\Sigma|\ M\ (\gamma\ \gamma) - M(\pi^0)|\ /\ M(\pi^0)$

Pythia generator (4 M events)

9 GeV < $E_\gamma$ < 12 GeV

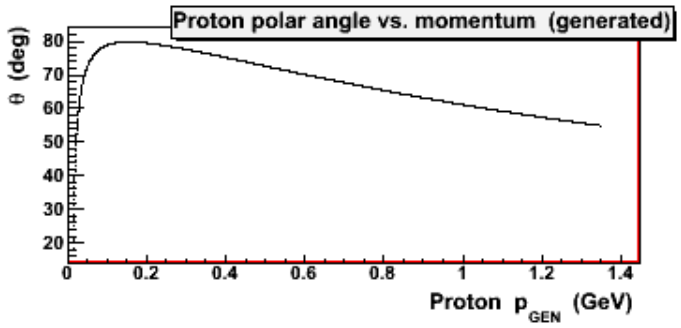


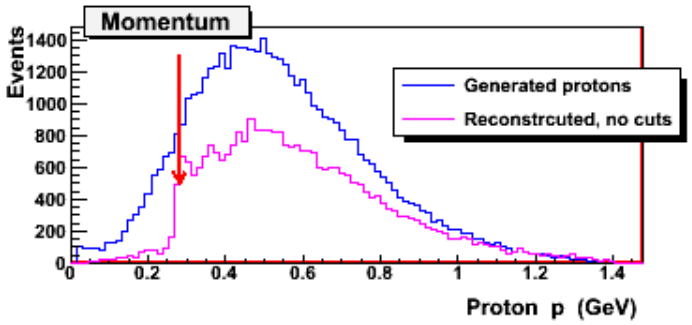

Pyhia processes:

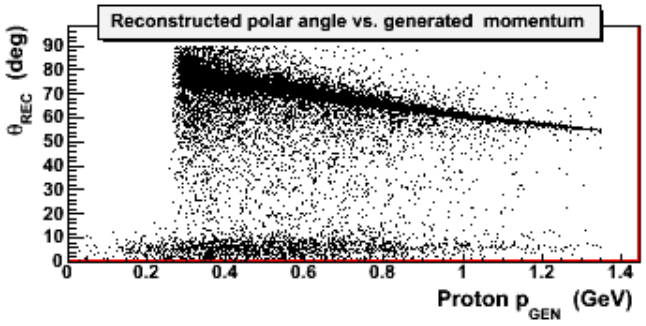
Parton system in cluster/string fragmentation

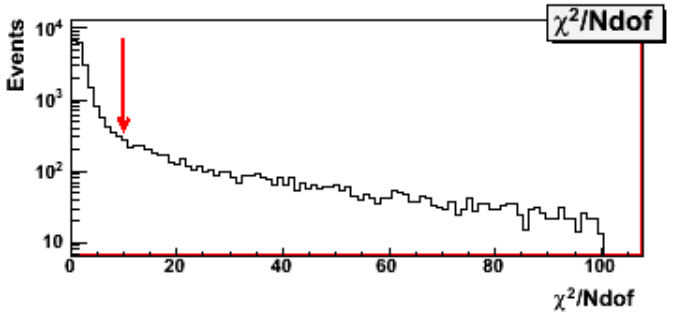
$\Delta+ \rightarrow p\ \pi^0$

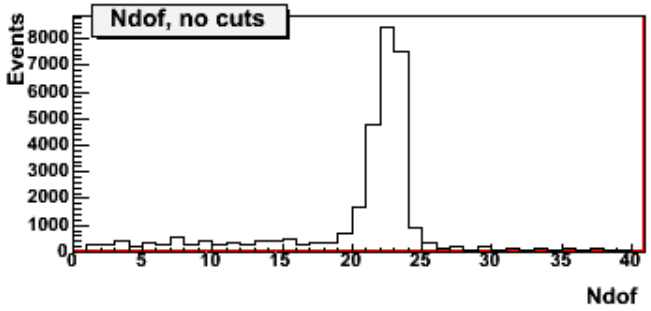
# Recoil Proton Reconstruction: Kinematics

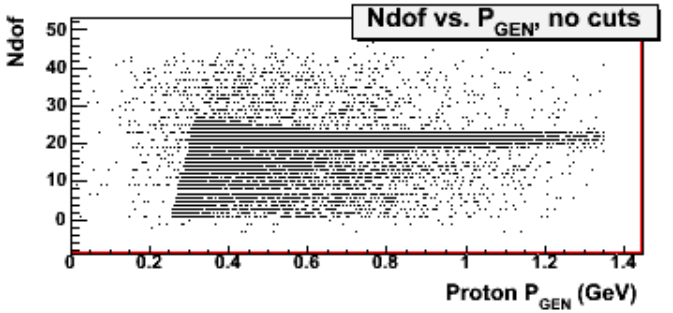


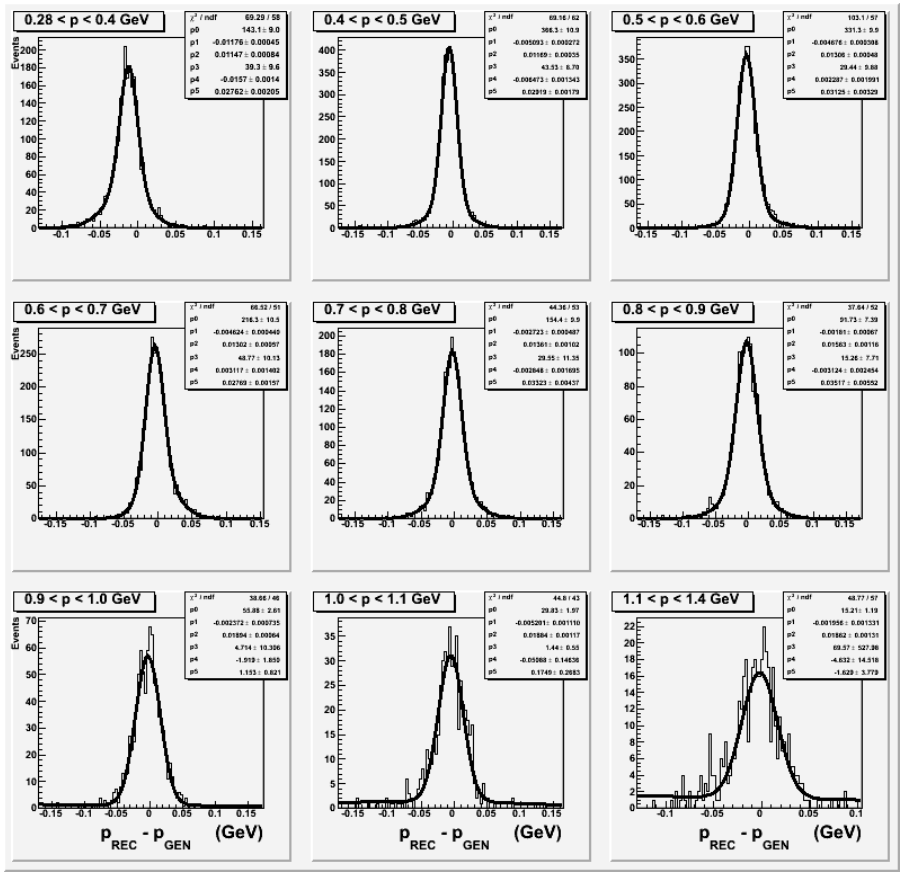



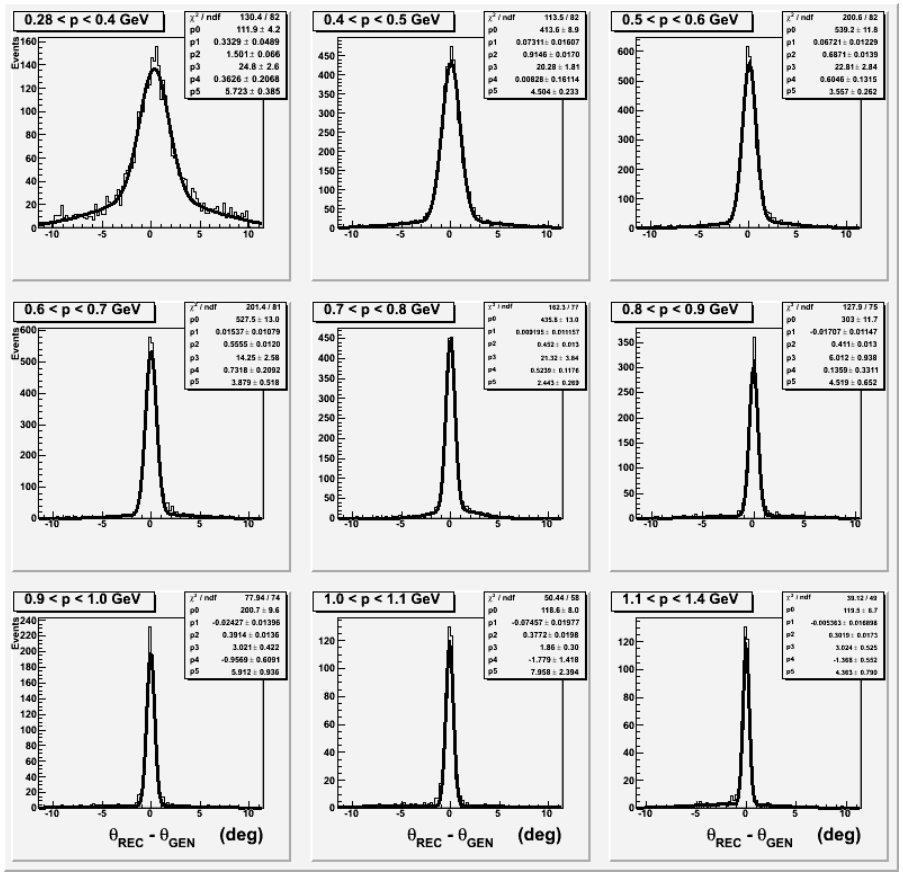



# Proton Momentum and Polar Angle Reconstruction

## Momentum residuals

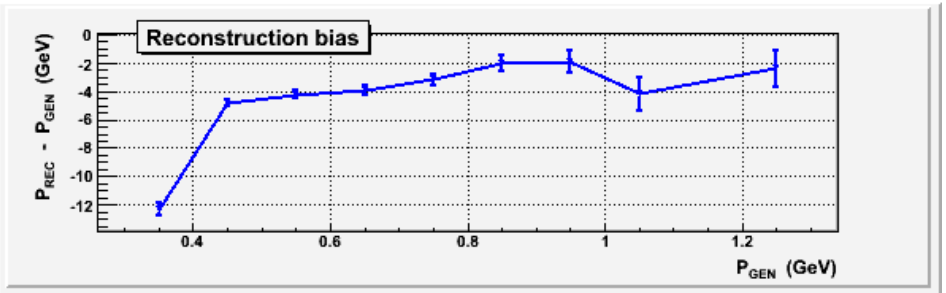


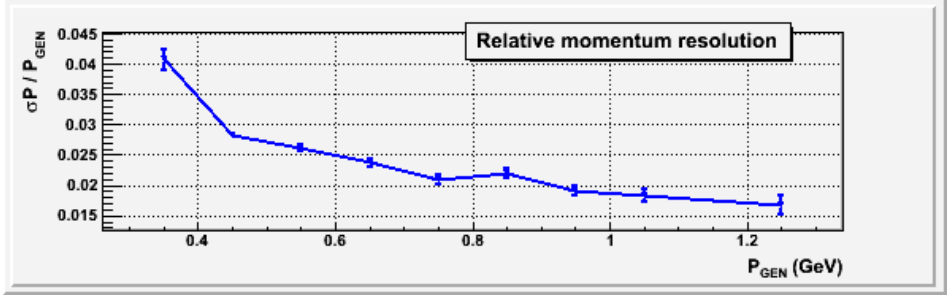

## Polar angle residuals



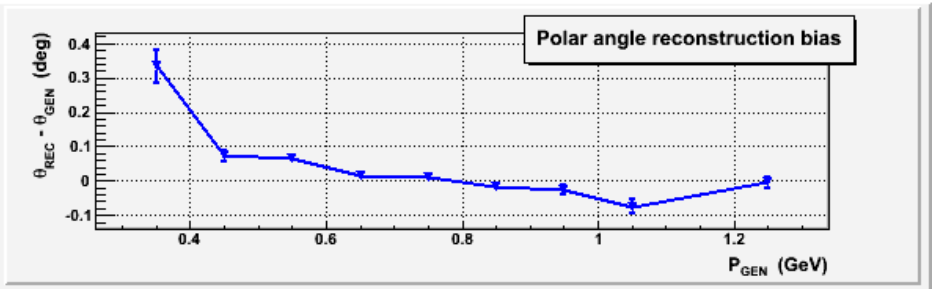
# Momentum and Polar Angle Resolutions

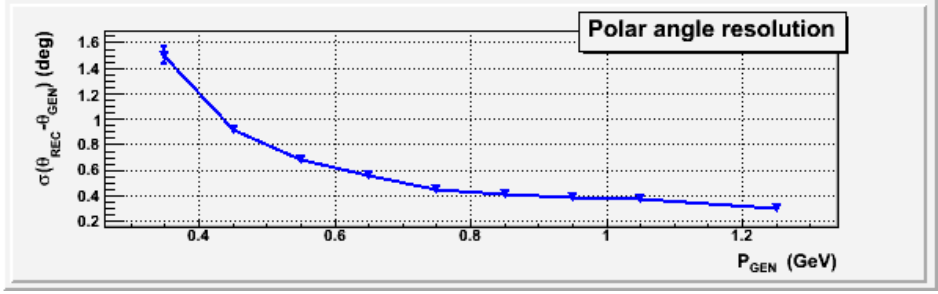
## Momentum



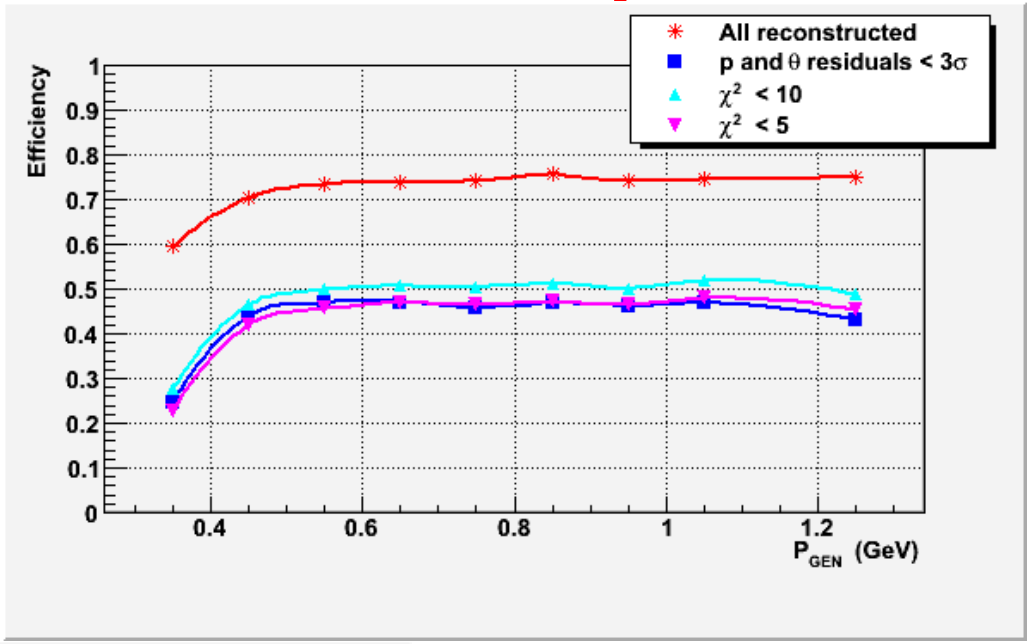

## Polar Angle

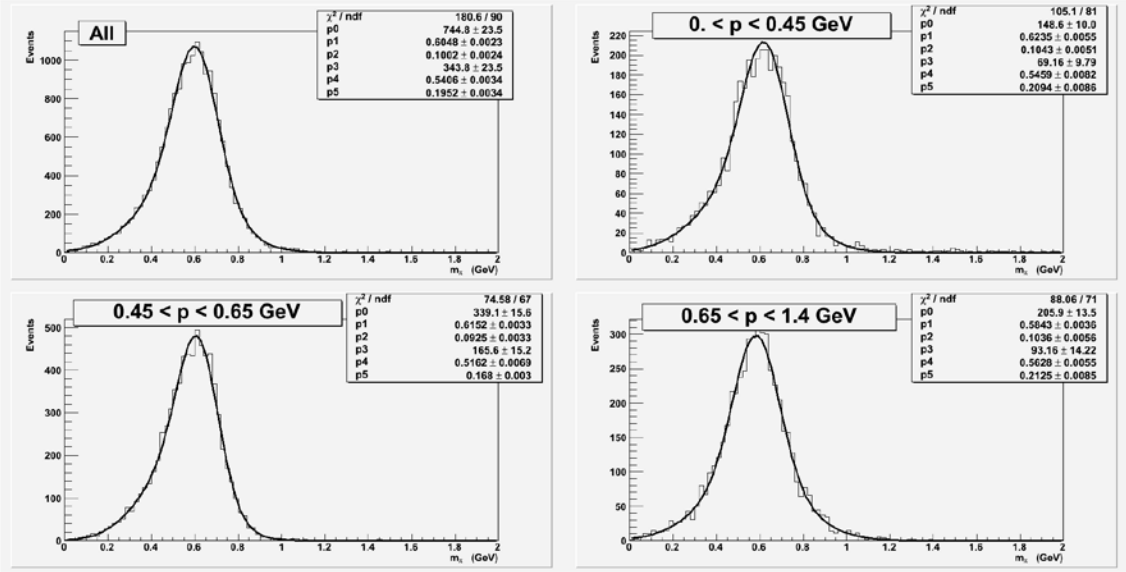


# Proton Reconstruction Efficiency

**Proton Reconstruction Efficiency**




**Eta missing mass**