Single Composite Particle Studies of L vs S

Work in Progress

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Introduction

- Looking at various single particle samples
- ilcsoft v01-19-05 samples. Thanks MC prod team.
- Compare large vs small detector models with option o1.
- Using MassConstraintFitter developed by Justin that I have now put in MarlinKinfitProcessors - (HEAD version).
- See talk at LCWS17 for more details.
- (Note events are only plotted if they pass the fit with 0.5% fit probability cut and the standard cuts and error estimates - no tuning for S nor for different energies)
- Each sample has 10,000 events

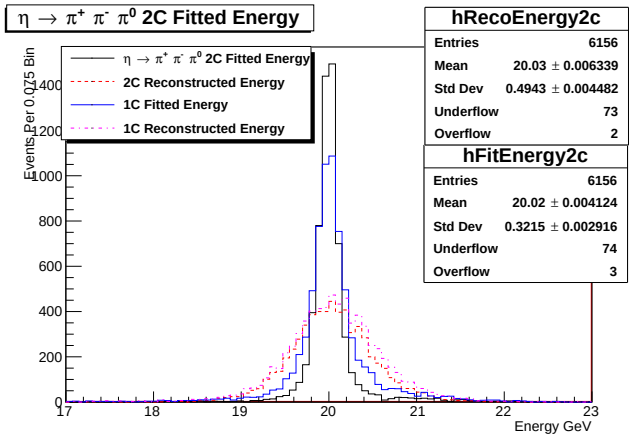
Aside: Slide from Justin

Constrained Fitting

- Improve energy resolution by applying constraints
- Apply multiple constraints to multi-generational sets of reconstructed particles that follow a decay hypothesis
- Example

$$\eta \rightarrow \pi^+ \pi^- \pi^0$$
$$\hookrightarrow \gamma\gamma$$

Can apply 2 mass constraints m_η and m_{π^0}



Testing framework with more single particle decays
$J/\psi \rightarrow \mu^+\mu^- \quad \pi^0 \rightarrow \gamma\gamma \quad \eta \rightarrow \pi^+\pi^-\gamma$

$$J/\psi \rightarrow \quad \phi \quad \eta$$
$$\downarrow \quad \hookrightarrow \pi^+ \pi^- \pi^0$$
$$K^+K^- \qquad \hookrightarrow \gamma\ \gamma$$

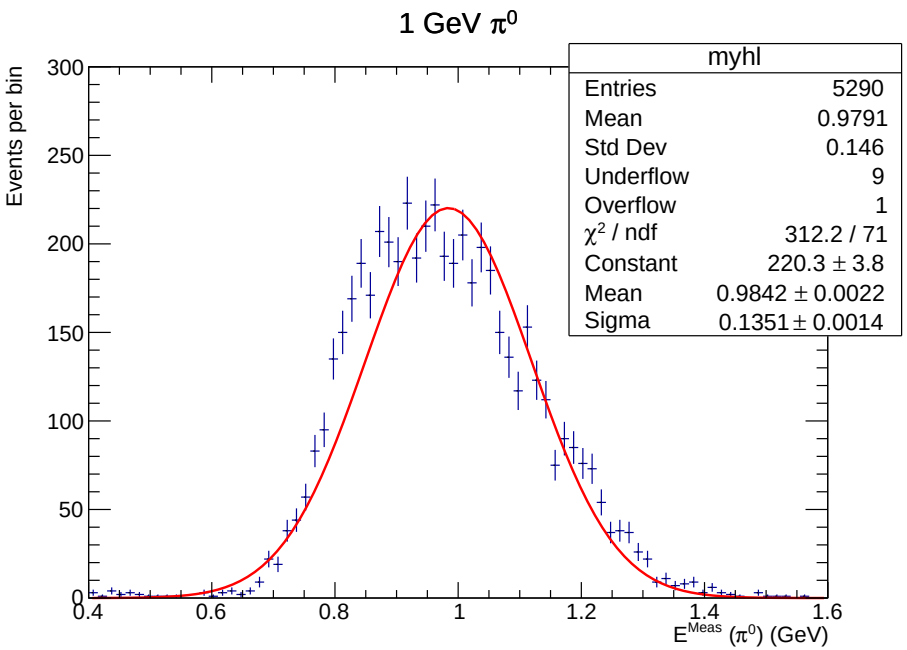
$$\omega \rightarrow \gamma\ \eta$$
$$\hookrightarrow \pi^0\ \pi^0\ \pi^0$$
$$\downarrow\ \downarrow\ \downarrow$$
$$\gamma\gamma\ \gamma\gamma\ \gamma\gamma$$

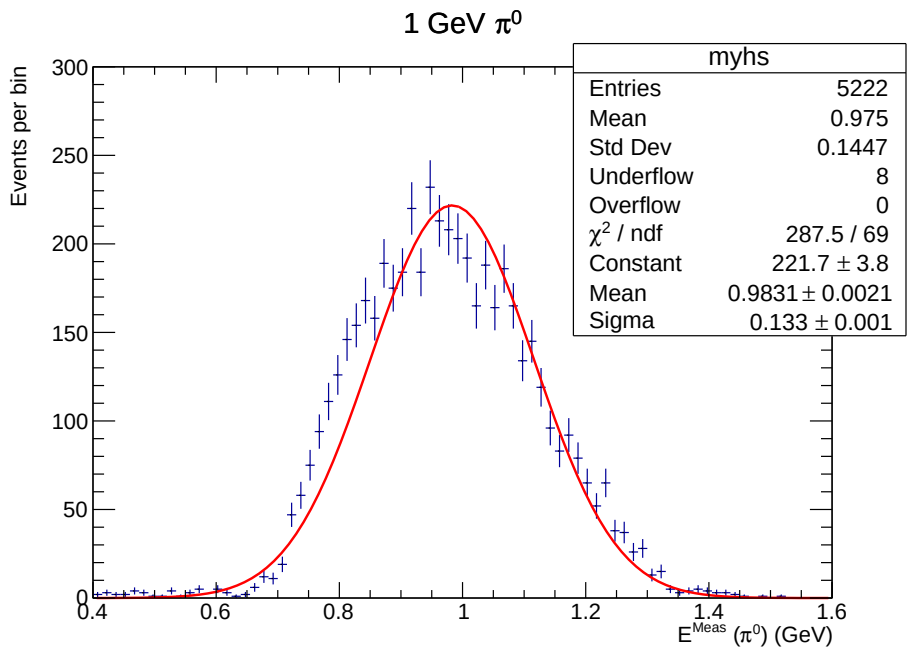
- First version now available on GitHub
  https://github.com/iLCSoft/MarlinKinfitProcessors
- Next version to exploit a general tree structure to optimally generate the minimum reconstructed particle combinations for decays with many potential constraints.
- Also have intended the tool's expansion to arbitrary parameterizations and vertex constraints.

π^0 Samples

- Pi0 Energies of 1, 2, 5, 10, 20 GeV
- Standard Cut: Require measured mass in range (95, 175) MeV.
- Note overall efficiency for π^0 reconstruction vs energy depends on several things:
- Many are best studied directly with single photons (see Daniel's studies)
- photon efficiency (especially at low energy)
- di-photon separability - issue for high energy π^0
- photon energy resolution
- photon angular resolution

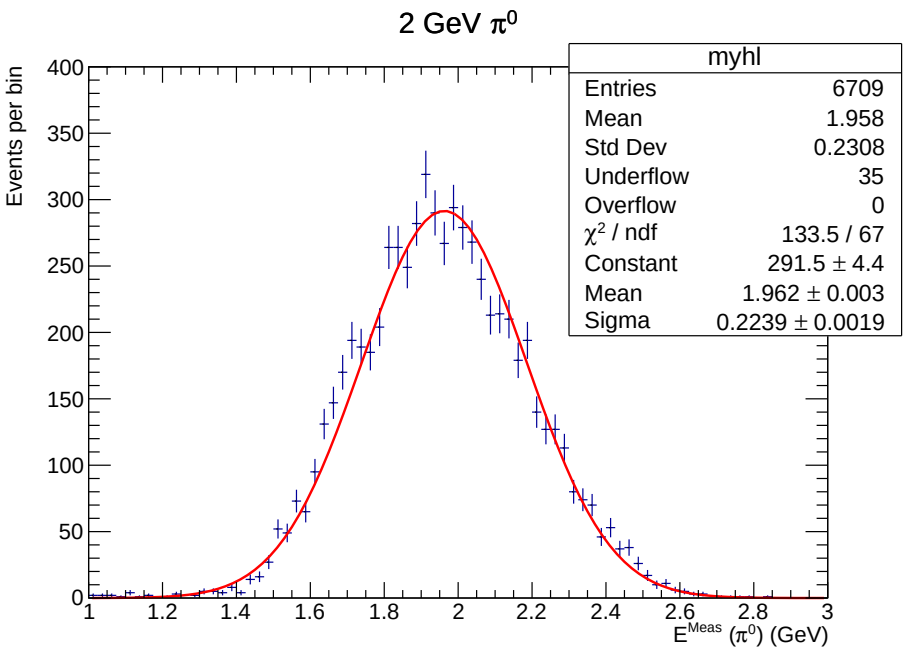
Measured Energy of 1 GeV π^0

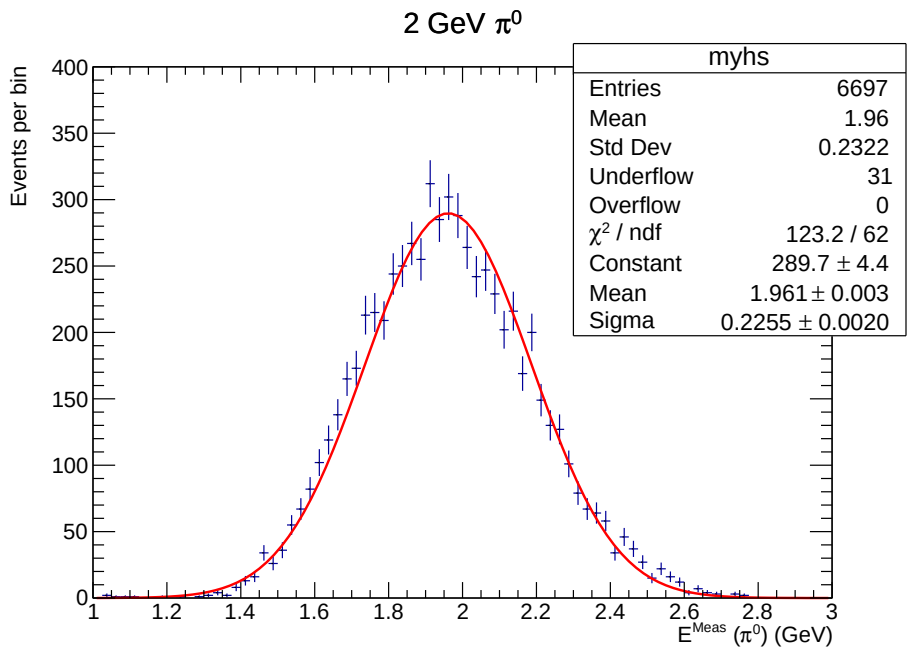




Efficiencies: $52.9 \pm 0.5\%$, $52.2 \pm 0.5\%$

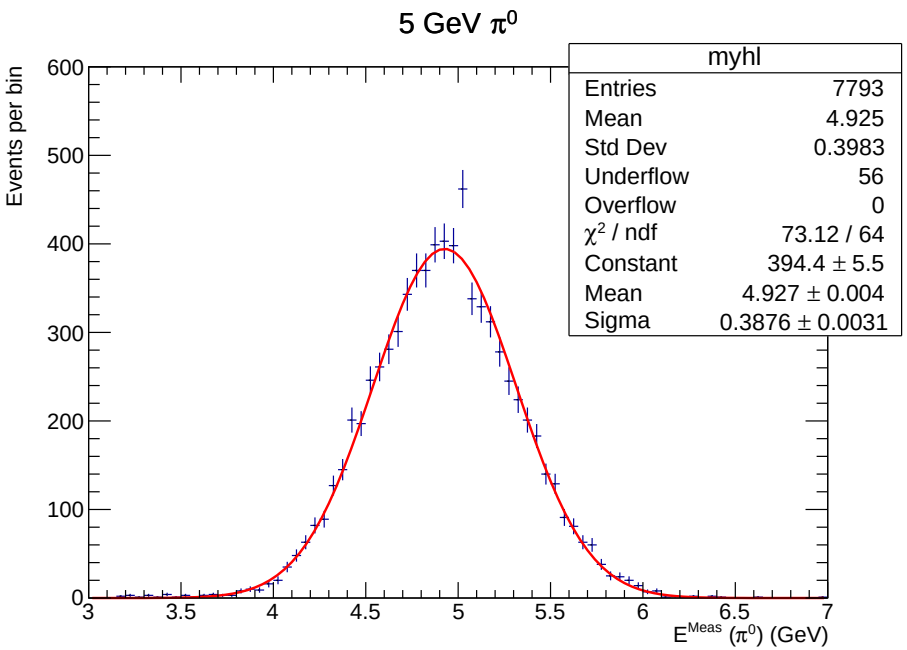
Measured Energy of 2 GeV π^0

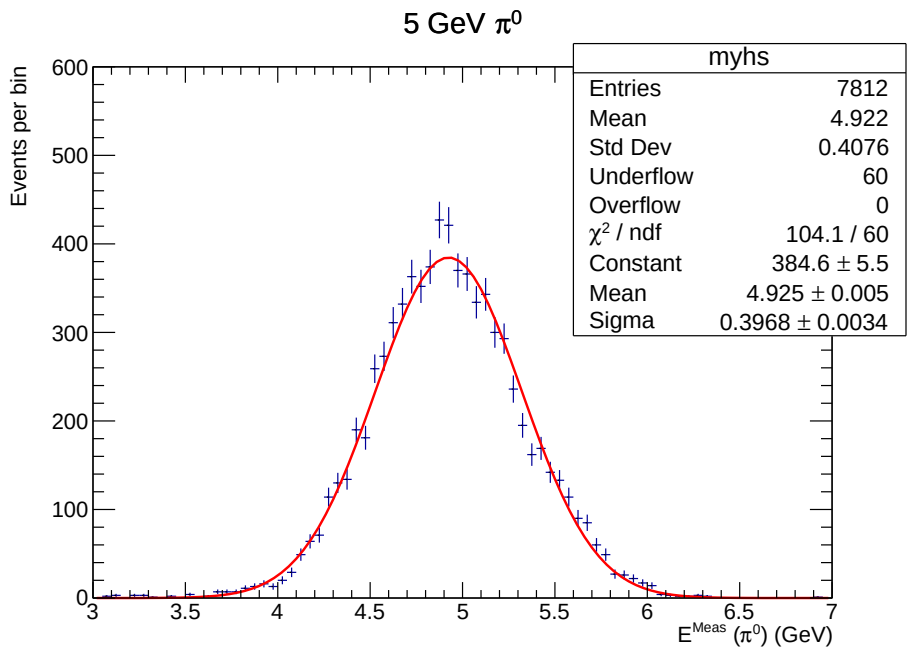




Efficiencies: $67.1 \pm 0.5\%$, $67.0 \pm 0.5\%$

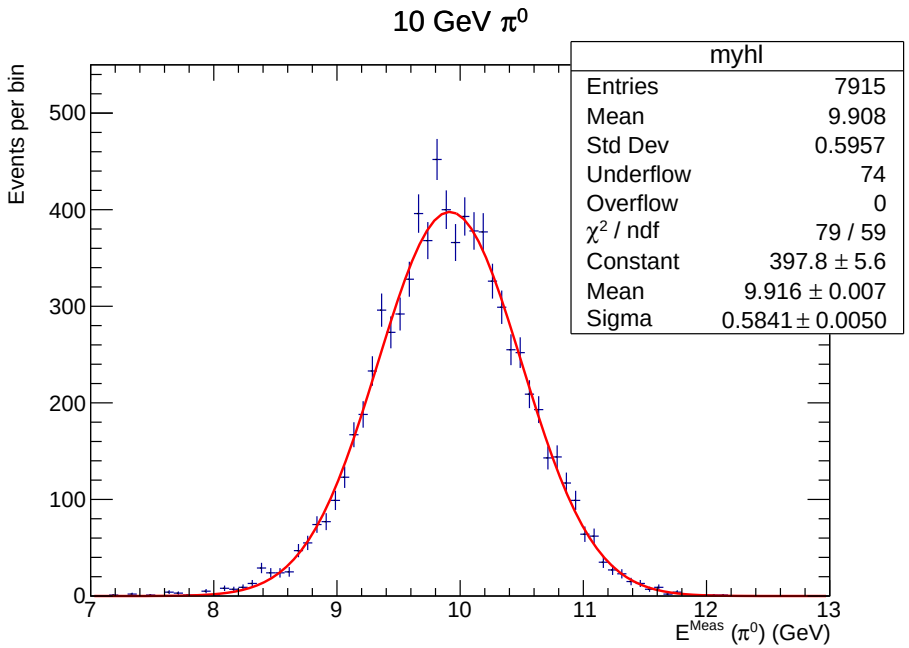
Measured Energy of 5 GeV π^0

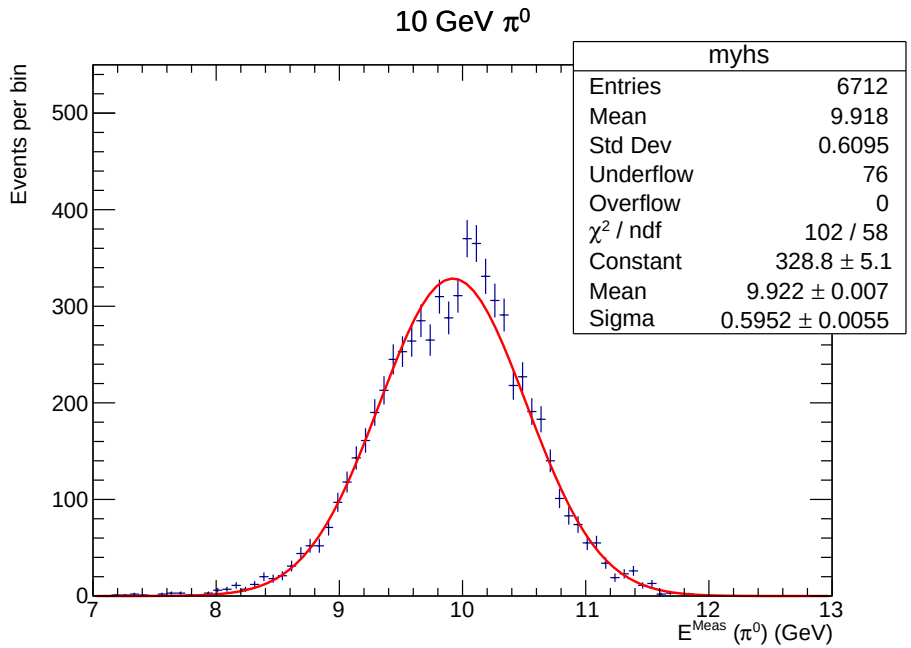




Efficiencies: $77.9 \pm 0.4\%$, $78.1 \pm 0.4\%$

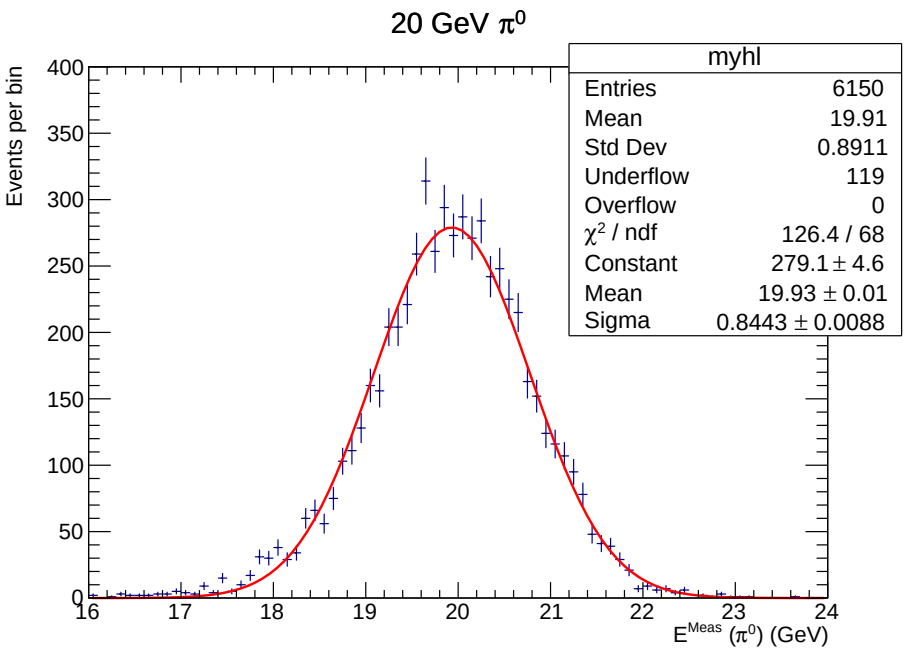
Measured Energy of 10 GeV π^0

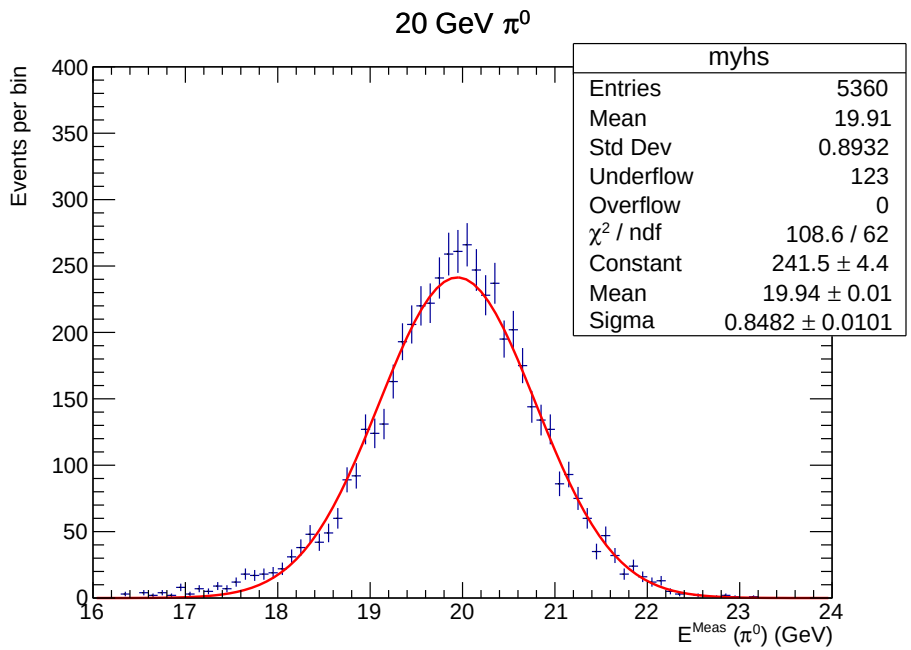




Efficiencies: $79.1 \pm 0.4\%$, $67.1 \pm 0.5\%$

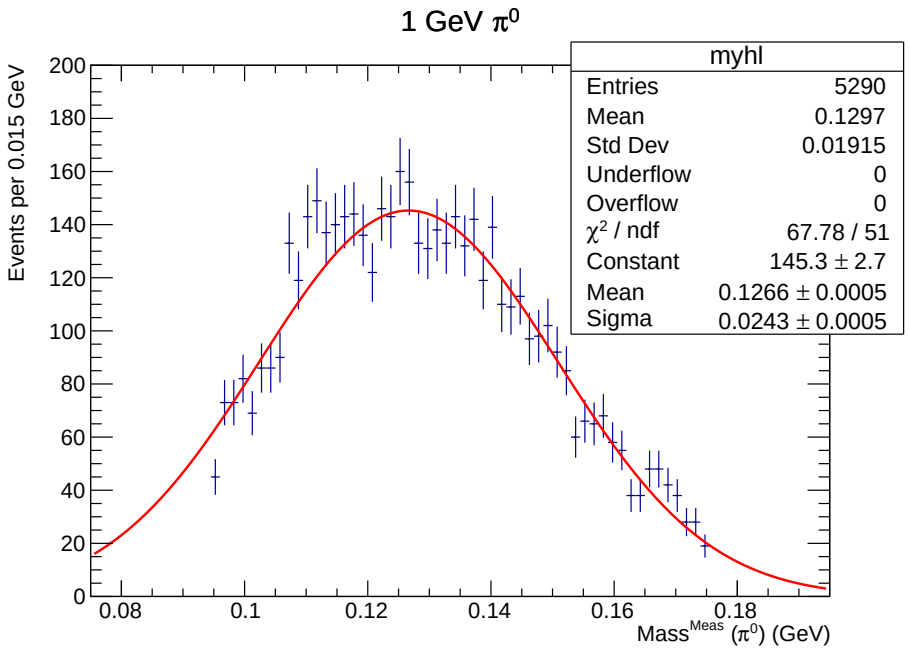
Measured Energy of 20 GeV π^0

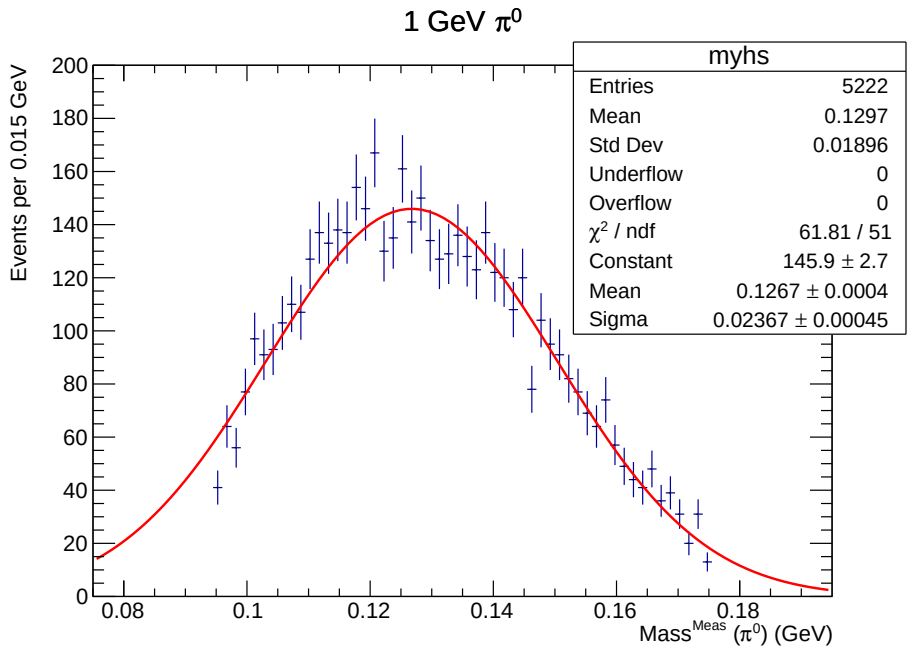




Efficiencies: $61.5 \pm 0.5\%$, $53.6 \pm 0.5\%$

Measured Mass of 1 GeV π^0

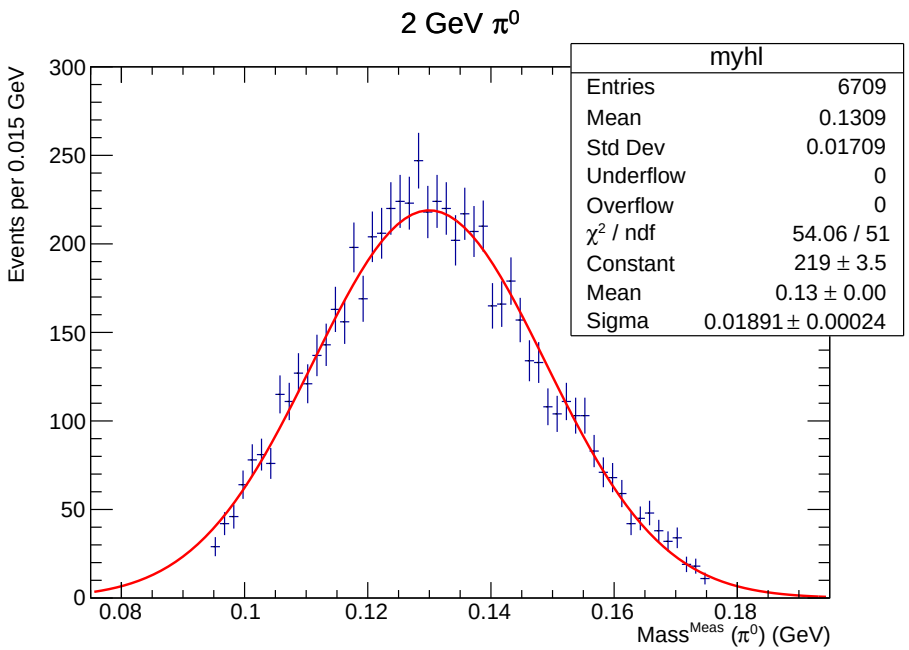


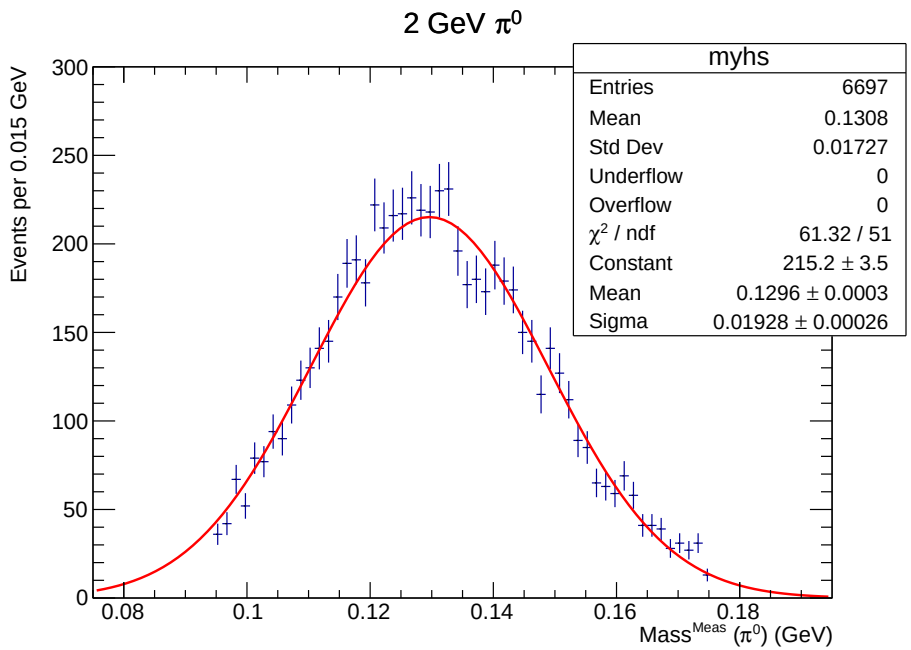


Very inefficient. Also poor mass resolution at low energy.

Efficiencies: $52.9 \pm 0.5\%$, $52.2 \pm 0.5\%$

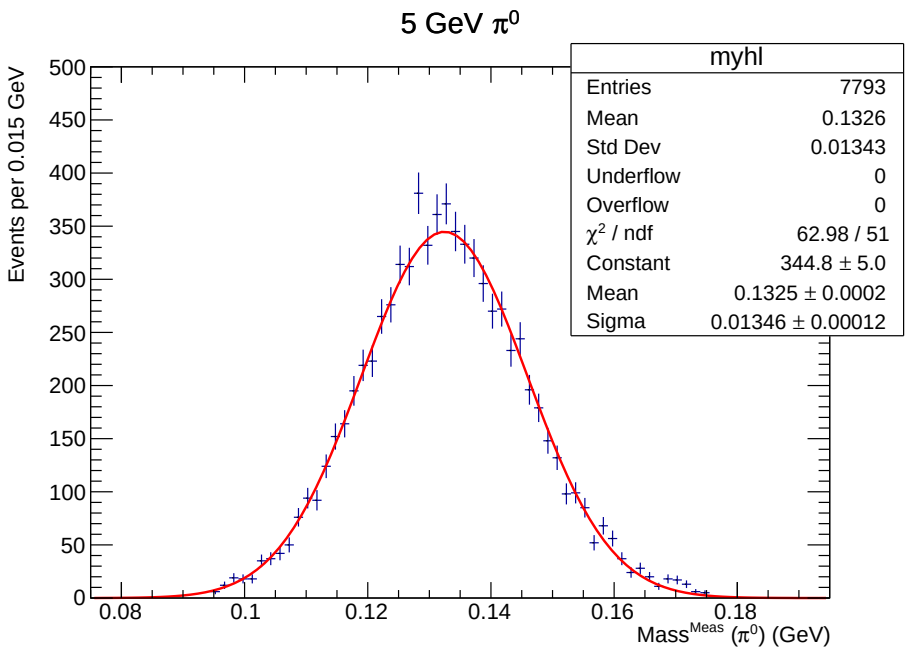
Measured Mass of 2 GeV π^0

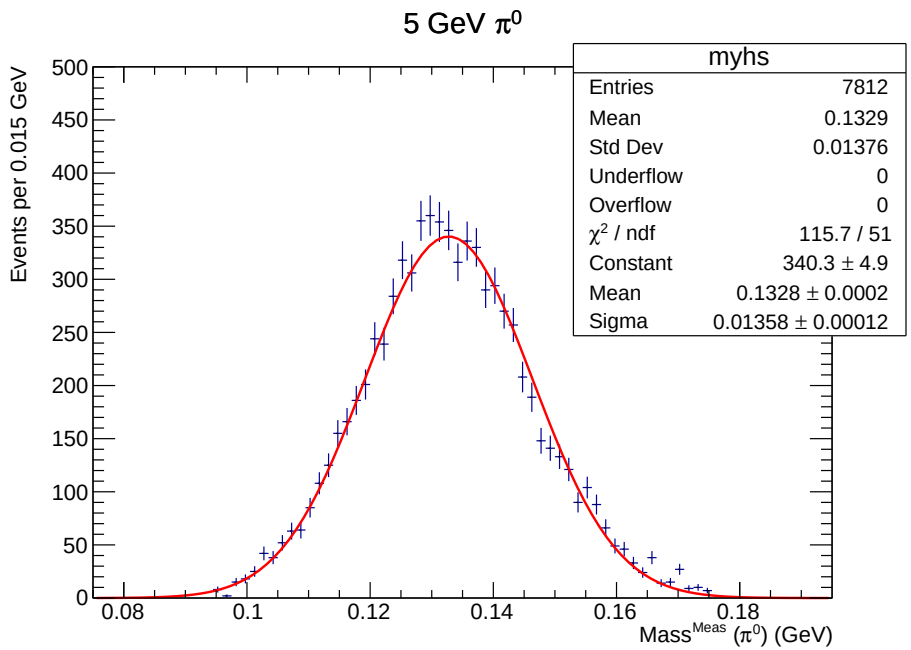




Efficiencies: $67.1 \pm 0.5\%$, $67.0 \pm 0.5\%$

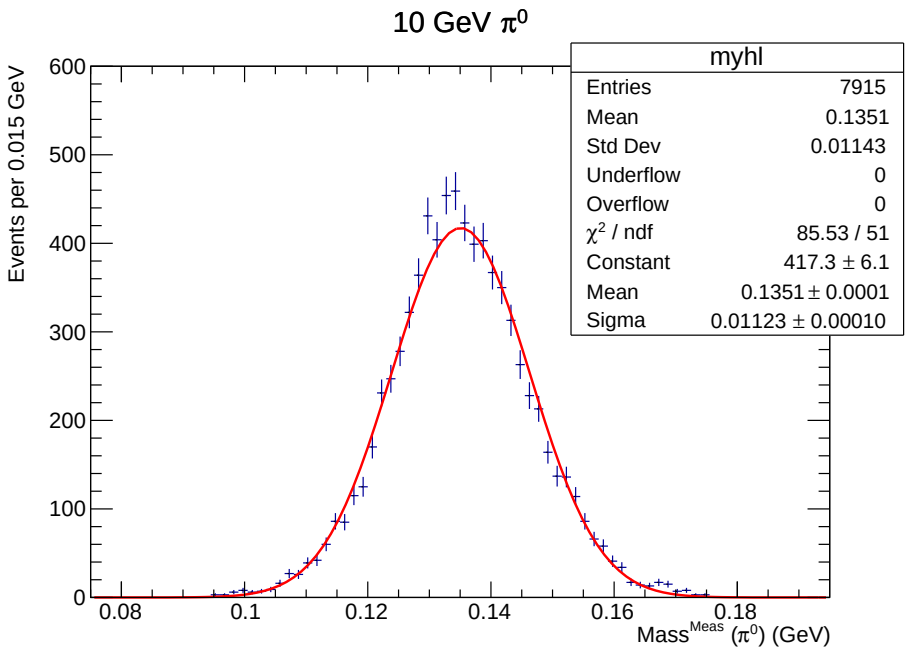
Measured Mass of 5 GeV π^0

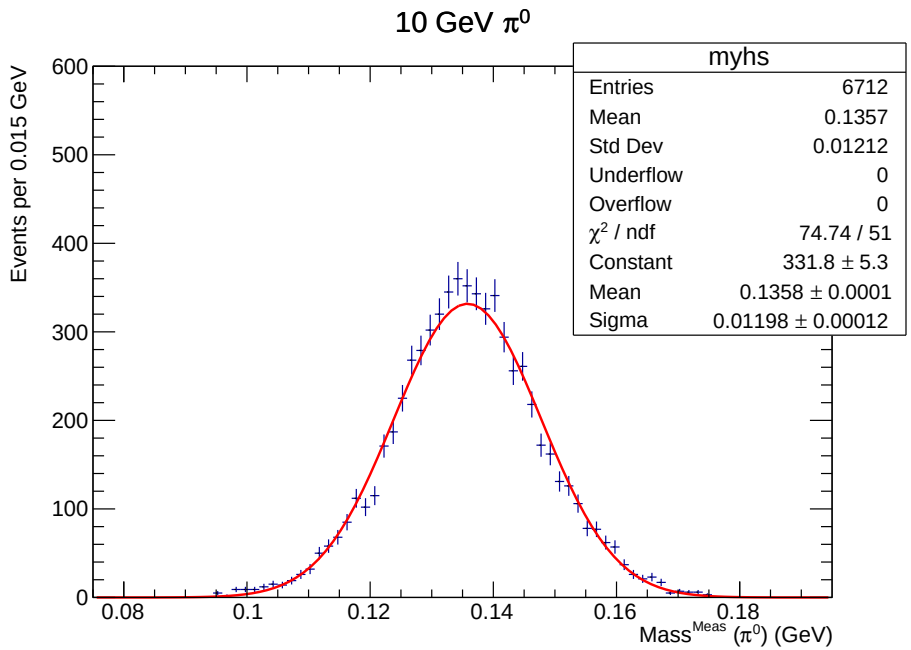




Efficiencies: $77.9 \pm 0.4\%$, $78.1 \pm 0.4\%$

Measured Mass of 10 GeV π^0

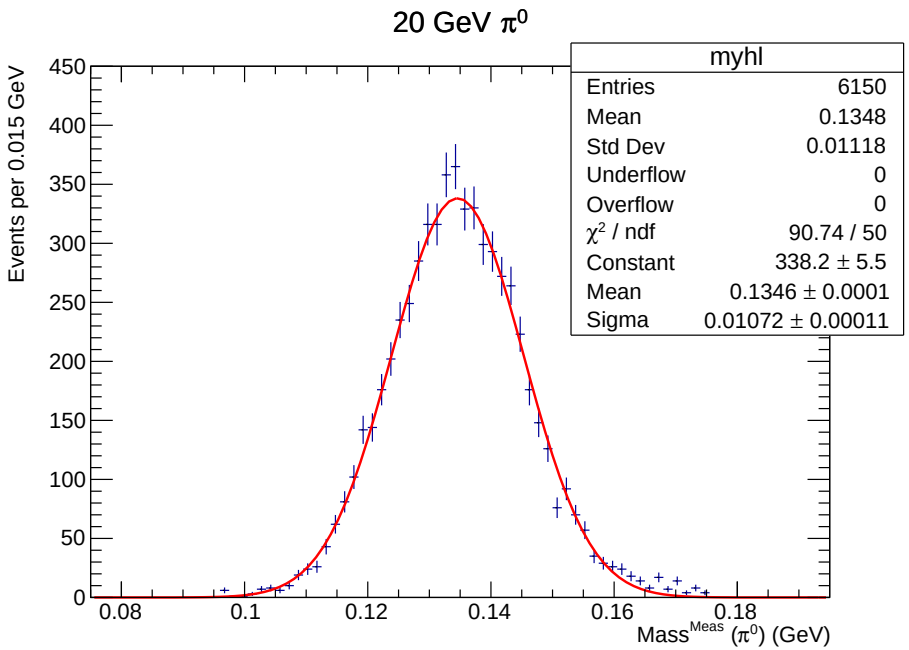


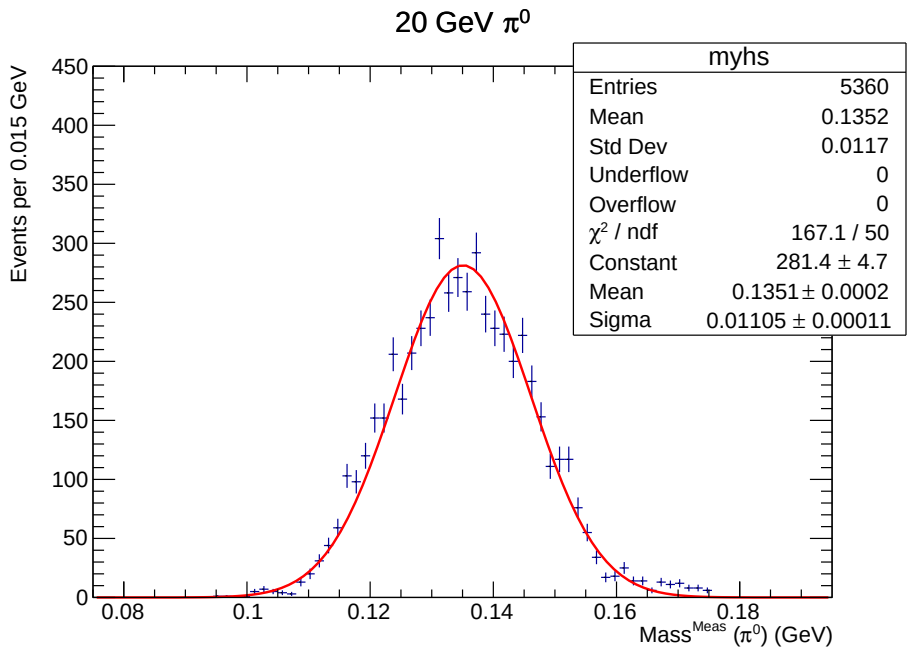


Efficiencies: $79.1 \pm 0.4\%$, $67.1 \pm 0.5\%$

Start seeing S detector di-photon resolvability issues.

Measured Mass of 20 GeV π^0

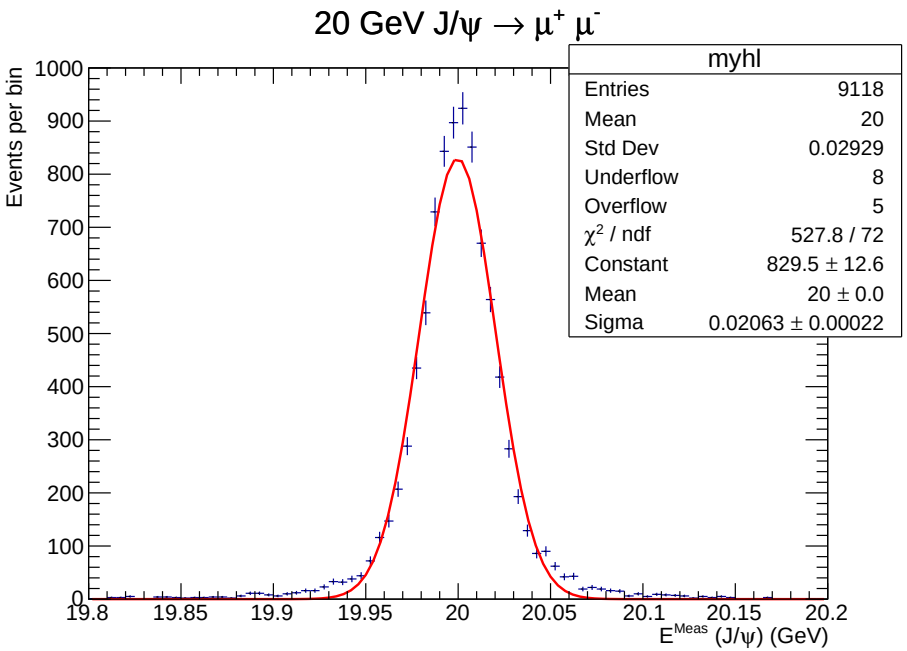


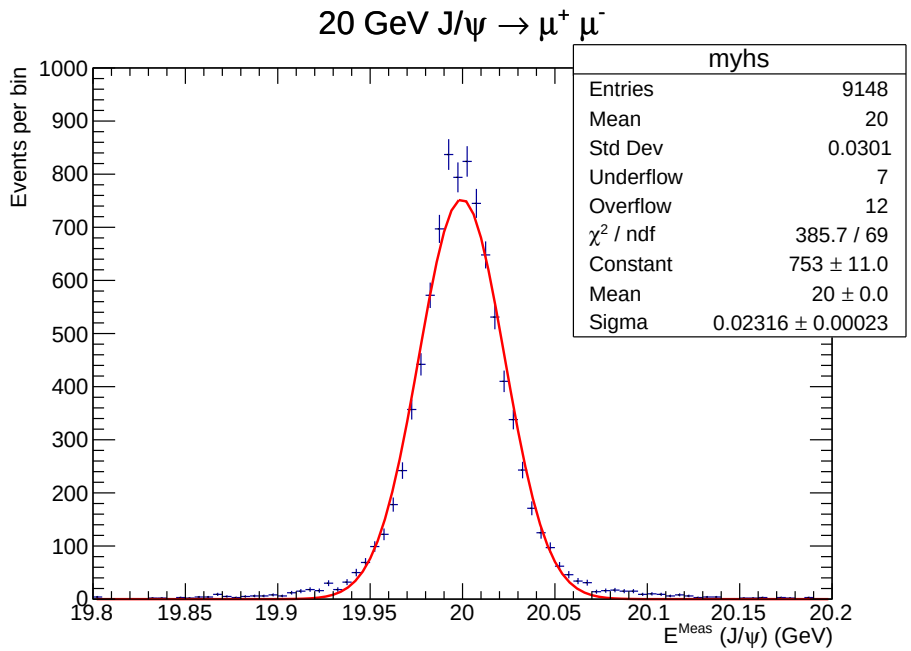


Efficiencies: $61.5 \pm 0.5\%$, $53.6 \pm 0.5\%$

Both L and S have lost efficiency. S more so.

Measured Energy of 20 GeV $J/\psi \to \mu^+\mu^-$

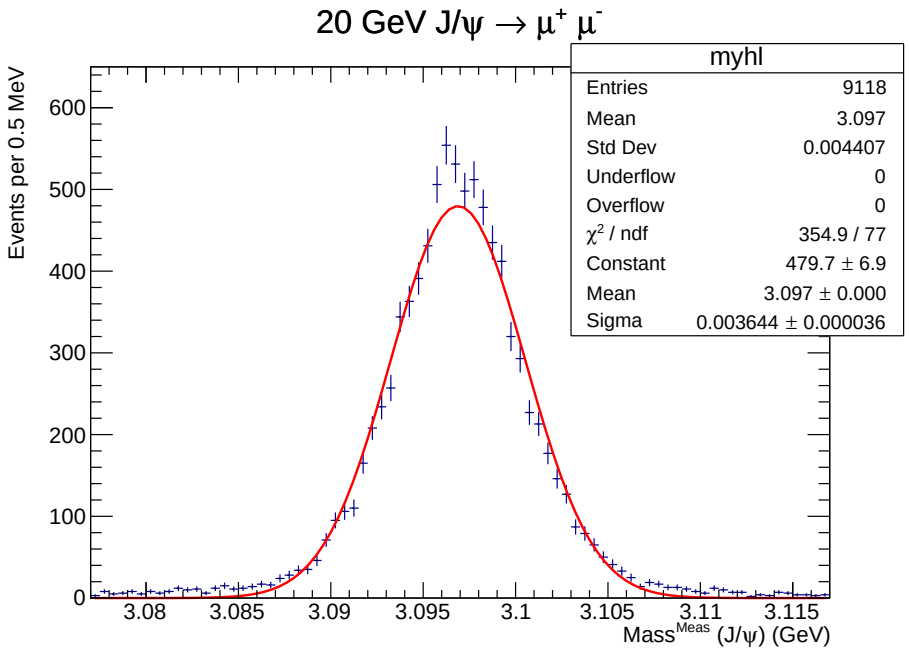


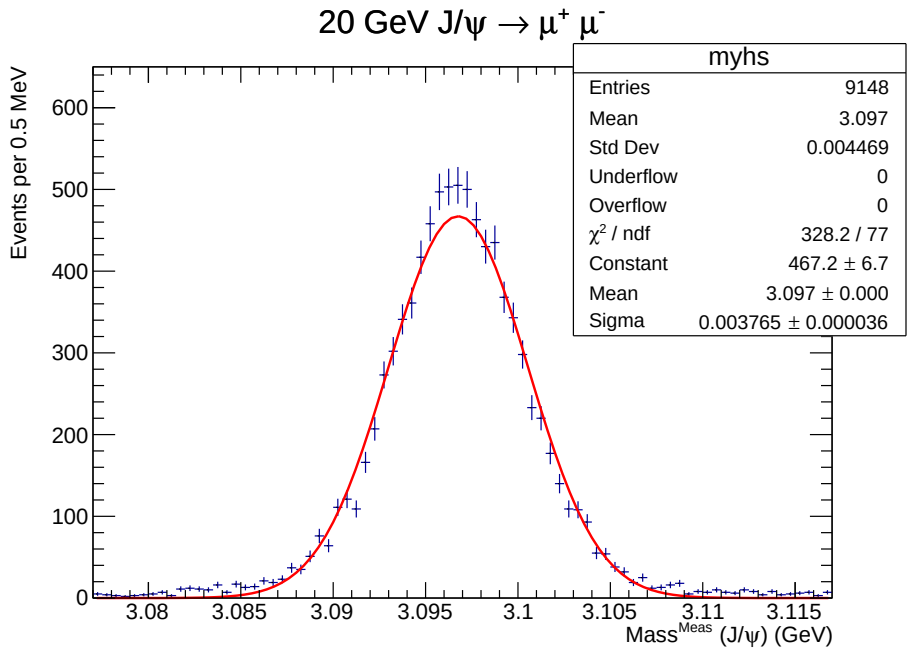


Efficiencies: $91.18 \pm 0.28\%$, $91.48 \pm 0.28\%$

Momentum resolution better for L.

Measured Mass of 20 GeV $J/\psi \to \mu^+\mu^-$





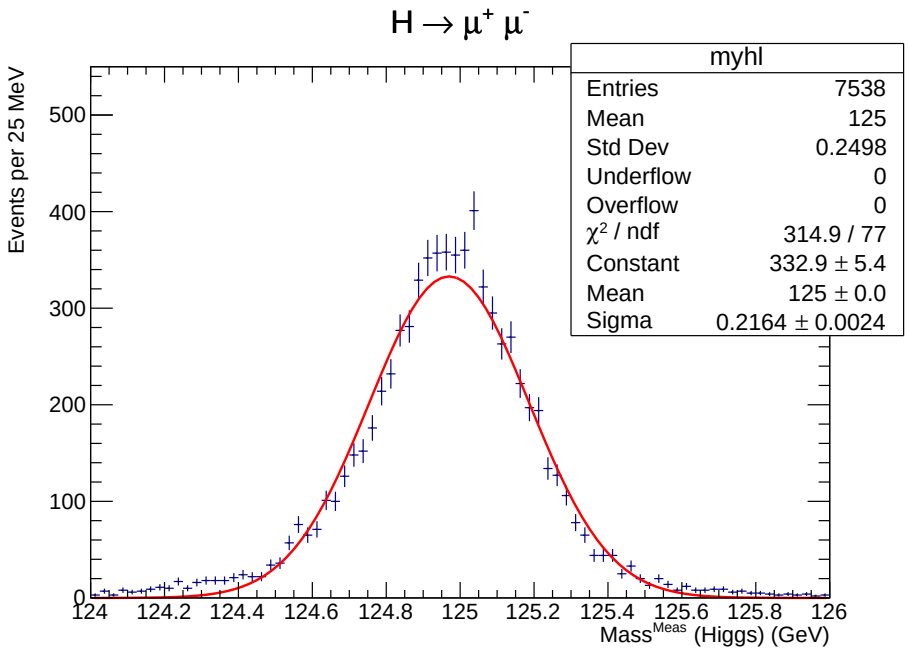
Efficiencies: $91.18 \pm 0.28\%$, $91.48 \pm 0.28\%$

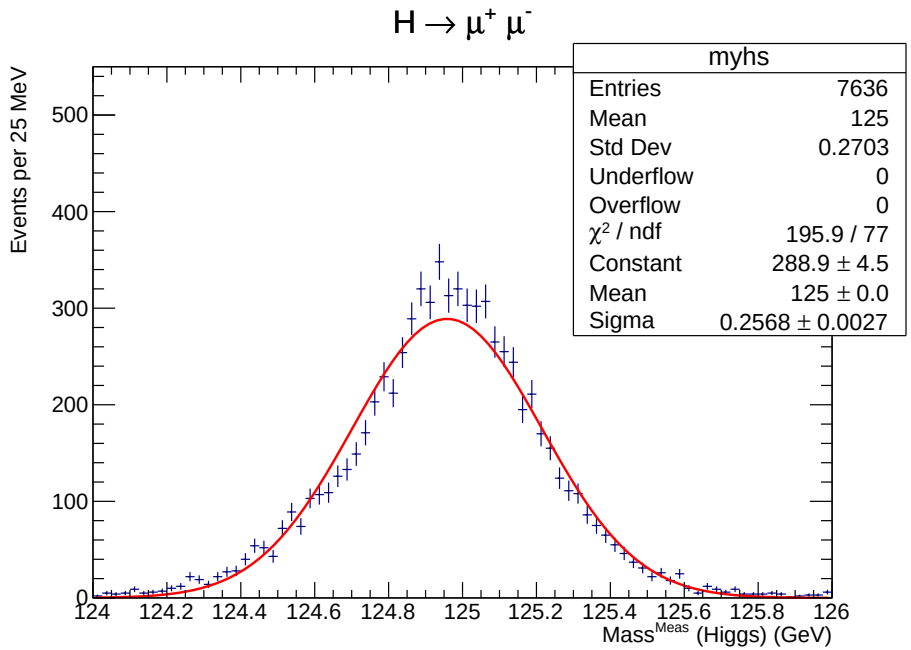
Somewhat worse mass resolution with S compared to L - but not that different.

Very important channel for momentum-scale calibration.

θ dependence? S with higher B does best in forward region?

Measured Mass of $H \to \mu^+\mu^-$ (ZH at $\sqrt{s} = 250$ GeV)



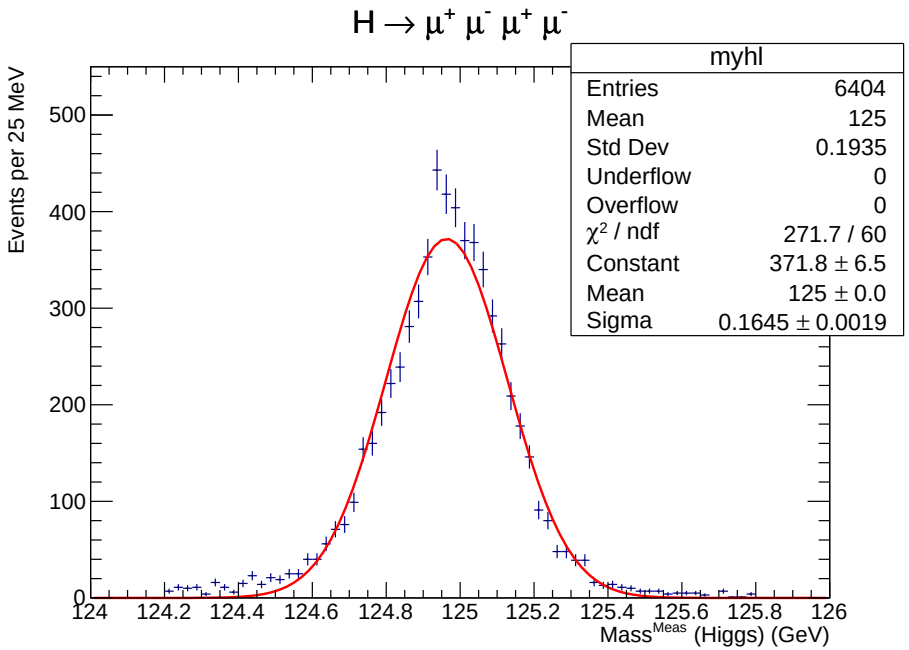


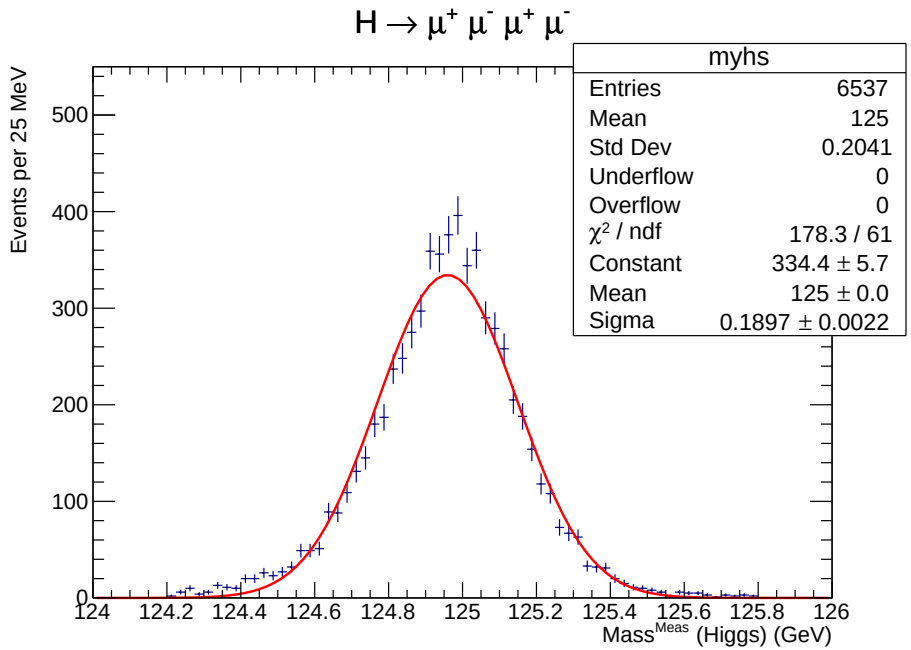
Efficiencies: $75.38 \pm 0.43\%$, $76.36 \pm 0.42\%$

Worse mass resolution with S compared to L?

Note events with significant FSR will fail the fit - and are a major part of the inefficiency.

Measured Mass of H $\rightarrow \mu^+\mu^-\mu^+\mu^-$ ($\nu_e\overline{\nu_e}H$ at 250 GeV)



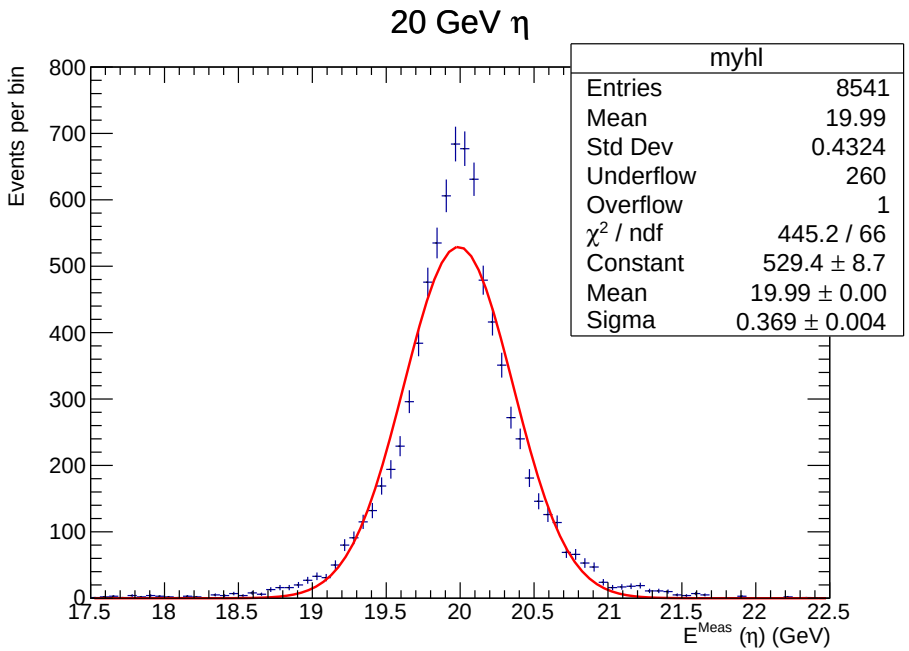


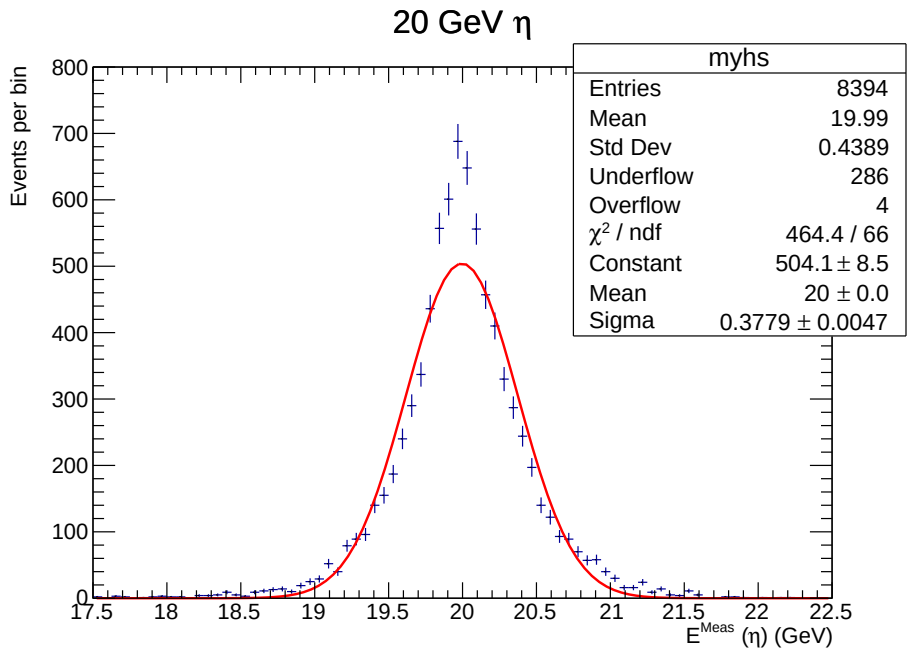
Efficiencies: $64.04 \pm 0.48\%$, $65.37 \pm 0.48\%$

Worse mass resolution with S compared to L

Note events with significant FSR will fail the fit - and are a major part of the inefficiency.

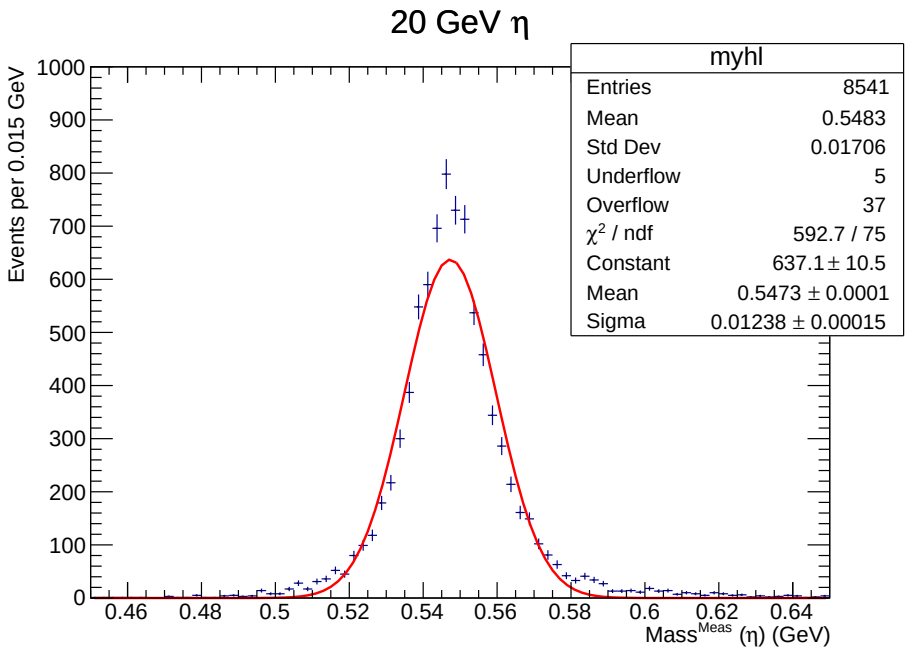
Measured Energy of 20 GeV η decaying to $\pi^+\pi^-\gamma$

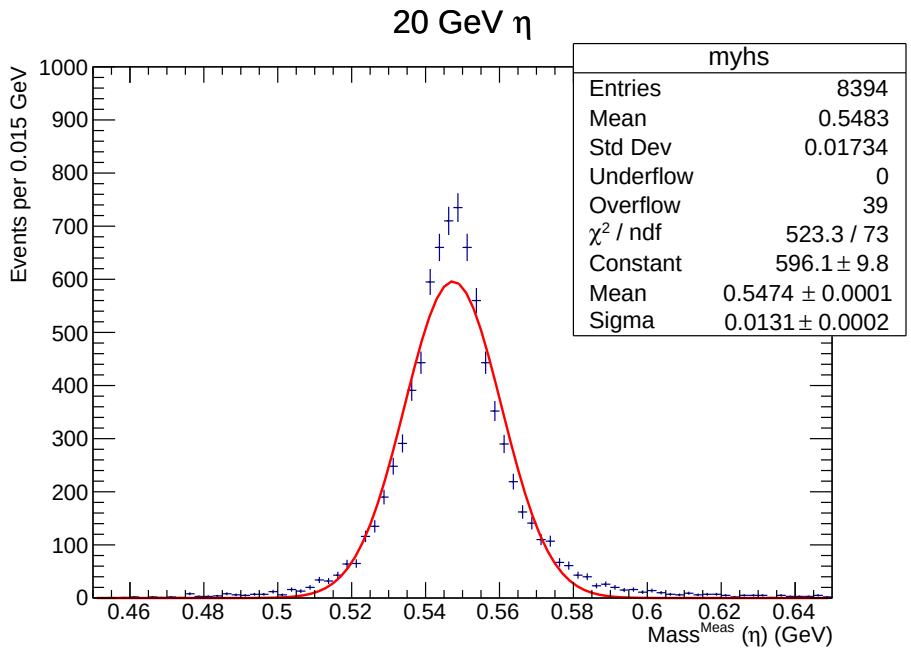




Efficiencies: $85.41 \pm 0.35\%$, $83.94 \pm 0.37\%$ ($\Delta = +1.47 \pm 0.51\%$)
Non-gaussian. Energy resolution depends strongly on photon energy (which varies according to the decay angle).

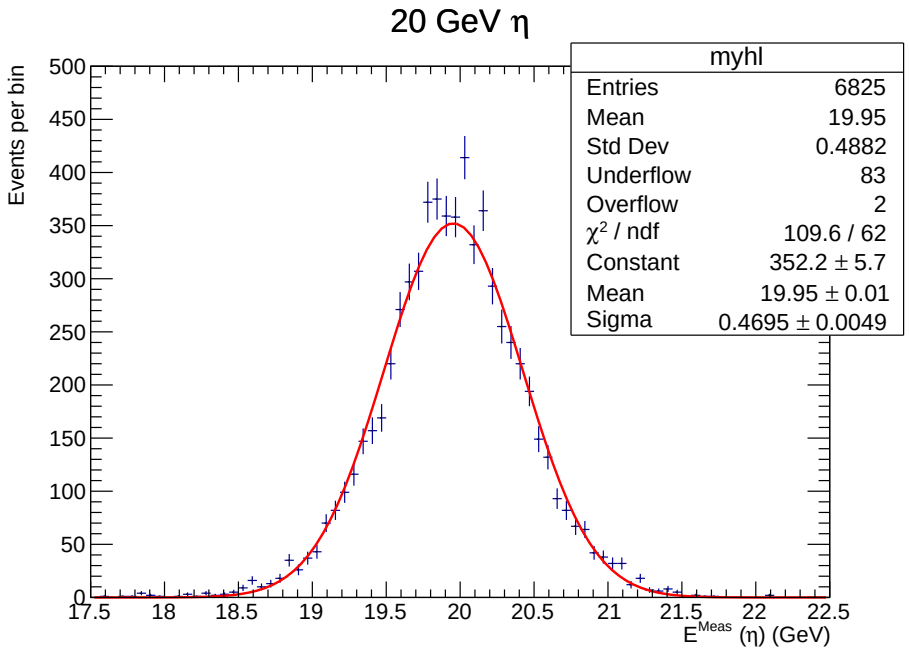
Measured Mass of 20 GeV η decaying to $\pi^+\pi^-\gamma$

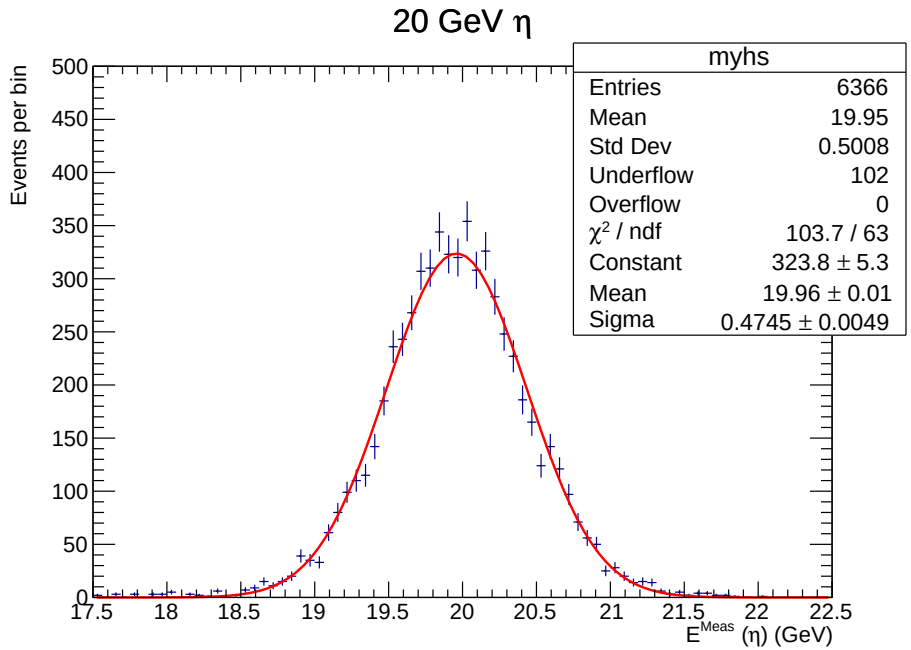




Efficiencies: $85.41 \pm 0.35\%$, $83.94 \pm 0.37\%$

Measured Energy of 20 GeV η decaying to $\pi^+\pi^-\pi^0$ (2C)

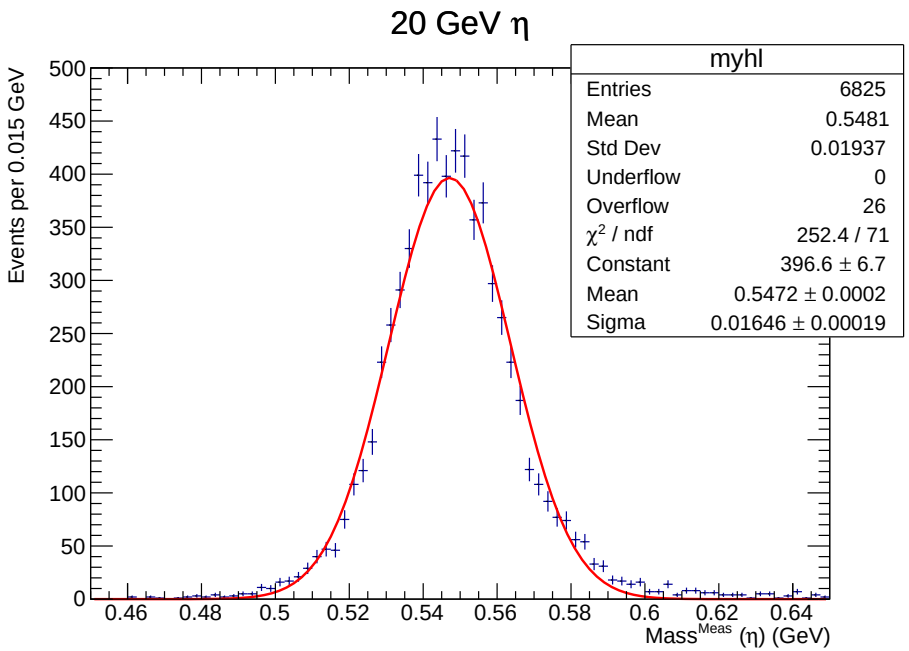


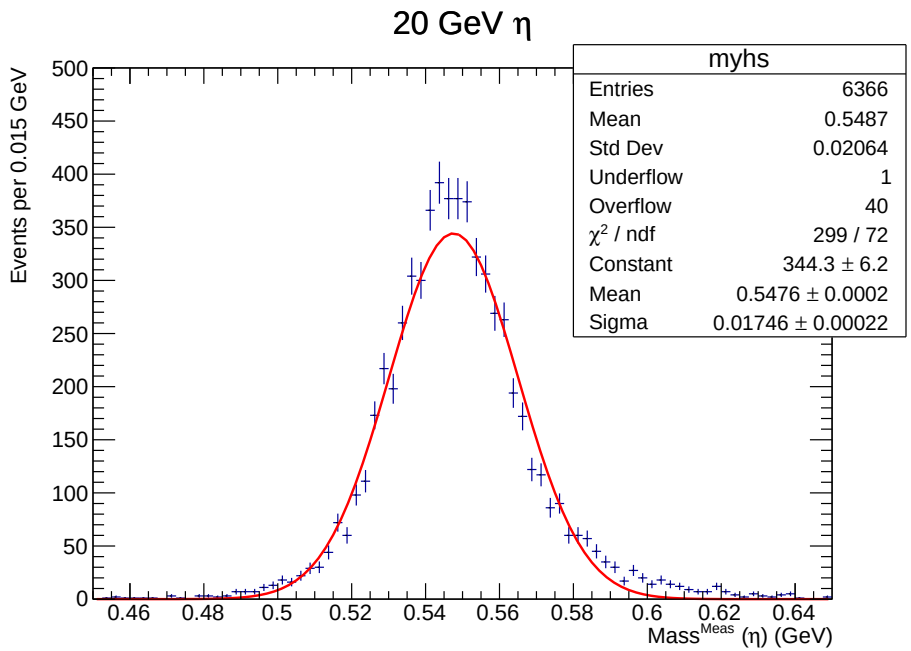


Efficiencies: $68.25 \pm 0.47\%$, $63.66 \pm 0.48\%$

Significant difference: $+4.59 \pm 0.67\%$.

Measured Mass of 20 GeV η decaying to $\pi^+\pi^-\pi^0$ (2C)

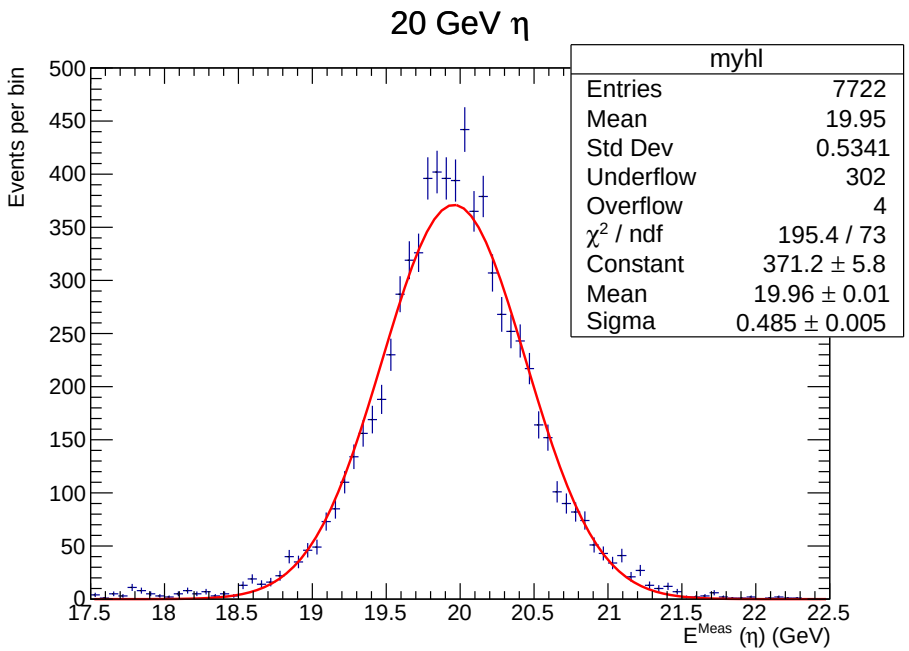


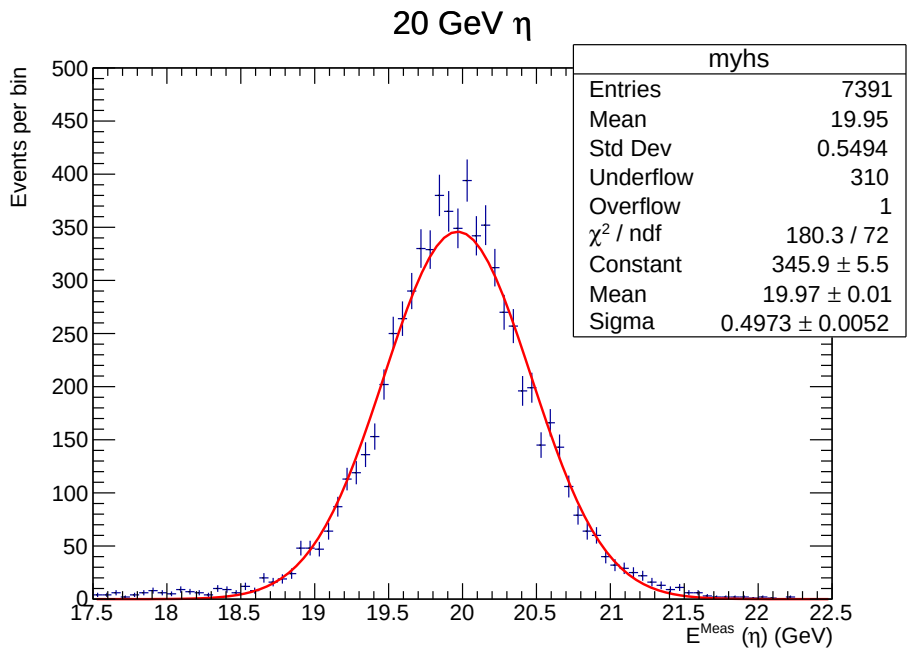


Efficiencies: $68.25 \pm 0.47\%$, $63.66 \pm 0.48\%$

Difference: $+4.59 \pm 0.67\%$

Measured Energy of 20 GeV η decaying to $\pi^+\pi^-\pi^0$ (1C)

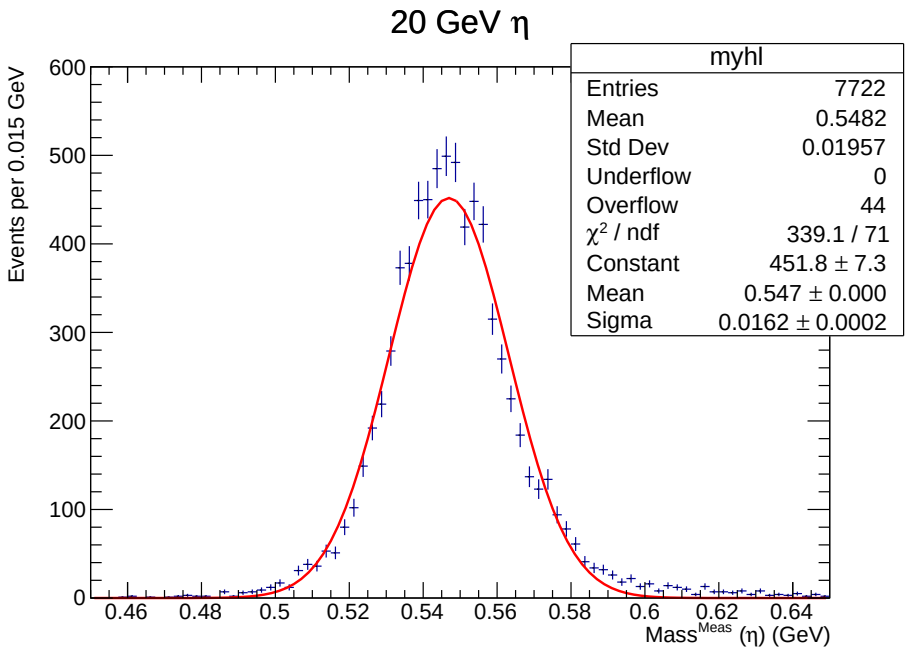


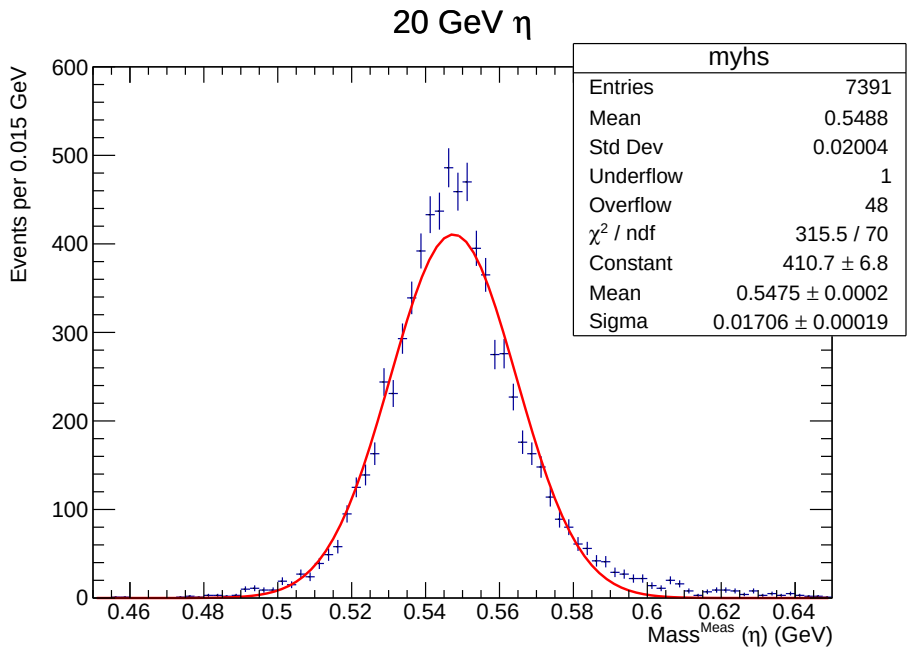


Efficiencies: $77.22 \pm 0.42\%$, $73.91 \pm 0.44\%$

Difference: $+3.31 \pm 0.61\%$

Measured Mass of 20 GeV η decaying to $\pi^+\pi^-\pi^0$ (1C)





Efficiencies: $77.22 \pm 0.42\%$, $73.91 \pm 0.44\%$

Summary

No big surprises.
Need more diagnostics though, and in-depth understanding of significant efficiency losses.
Mass-constrained fits also need good control of biases and error estimates. Fit probability distributions are quite reasonable.
Finding low energy photons likely needs emphasis.