Detector Acceptance Calculation for Drell-Yan Process

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1 Introduction

In experimental particle physics, detector acceptance is a crucial correction factor that quantifies the probability of a physics event being successfully detected and reconstructed by the experimental apparatus. Due to geometrical constraints, detector inefficiencies, and the kinematic requirements of event reconstruction algorithms, not all events produced in a collision are recorded. The acceptance, A, is therefore defined as the ratio of the number of events that are detected and pass all selection criteria (N_{acc}) to the total number of events generated within a specific kinematic phase space (N_{gen}).

$$\text{Acceptance (A)} = \frac{N_{acc}}{N_{gen}} \tag{1}$$

This document outlines the step-by-step procedure for calculating the detector acceptance for the Drell-Yan process using Monte Carlo (MC) simulations. The acceptance is evaluated as a function of the dimuon invariant mass and Feynman-x (x_F) for both Liquid Hydrogen (LH2) and Liquid Deuterium (LD2) targets. The calculation is based on the analysis performed by the ROOT C++ script `run_all_plots.C`.

2 Monte Carlo Files Used

The calculation relies on pre-generated Monte Carlo simulation files. For each target, two distinct sets of data are used:

- **Thrown Files:** These files contain the generated four-vector information for Drell-Yan events, simulated over a 4π solid angle. They represent the theoretical population of events (N_{gen}) before any detector effects are considered.
  - `mc_drellyan_LH2_M027_S001_4pi_pTxFweight_v2.root`
  - `mc_drellyan_LD2_M027_S001_4pi_pTxFweight_v2.root`
- **Accepted Files:** These files contain events from the thrown sample that have been processed through a full detector simulation (e.g., Geant4) and reconstructed using the same algorithms applied to real experimental data. These events represent the detected population (N_{acc}).
  - `mc_drellyan_LH2_M027_S001_clean_occ_pTxFweight_v2.root`
  - `mc_drellyan_LD2_M027_S001_clean_occ_pTxFweight_v2.root`

Each event in these files includes a `ReWeight` factor, which is used to adjust the MC simulation to better match the transverse momentum (p_T) distribution observed in experimental data. All calculated histograms are weighted by this factor.

3 Event Selection

To ensure a valid comparison, specific event selection criteria (cuts) are applied to both the thrown and accepted datasets.

- **Thrown Sample Cut (`MCcut`):** A minimal cut is applied to the generated events to define the kinematic phase space of interest. In the provided script, this is set to `"1"`, indicating all generated events are considered.
- **Accepted Sample Cut (`allCut`):** A comprehensive set of cuts is applied to the reconstructed data. These cuts are designed to select high-quality dimuon events and mimic the selection criteria used in the final physics analysis. They are defined in external files (`chuckcuts.h`, `otherCuts.c`) and combined into a single `TCut` object.

4 Kinematic Binning for Acceptance Study

The acceptance is studied differentially across the invariant mass and x_F variables. The binning schemes are defined in the header file `abs_cs.h`.

4.1 Feynman-x (x_F) Bins

The analysis is performed in 16 discrete bins of x_F. The bin edges are defined as:

```
xFEdge[] = {0, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.35,
            0.4, 0.45, 0.5, 0.55, 0.6, 0.65, 0.7, 0.75, 0.8};
```

4.2 Mass Bins

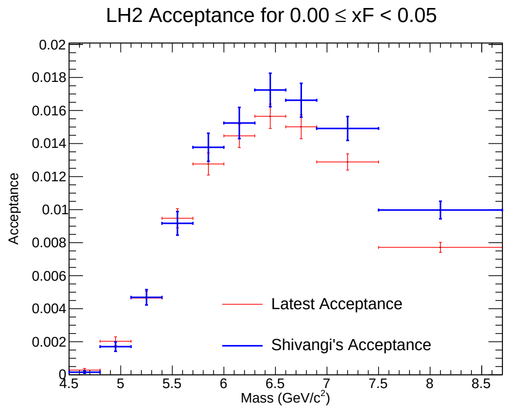
Within each x_F bin, the acceptance is calculated as a function of the dimuon invariant mass. The histograms are created with 10 mass bins defined by the following edges (in GeV/c^2):

```
massEdge[] = {4.5, 4.8, 5.1, 5.4, 5.7, 6, 6.3, 6.6,
              6.9, 7.5, 8.7};
```

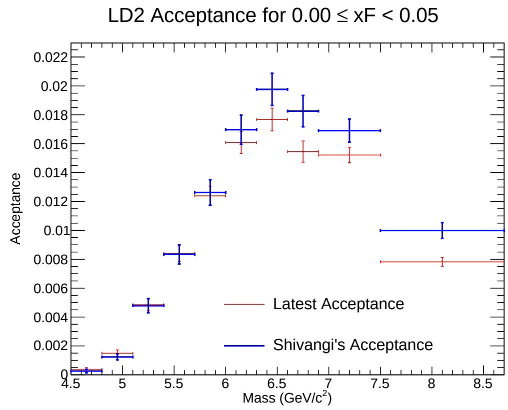
5 Acceptance Plots for each x_F Bin

The following subsections show the resulting acceptance plots as a function of mass for each of the 16 x_F bins. Each figure is arranged in a 2x2 grid displaying four plots:

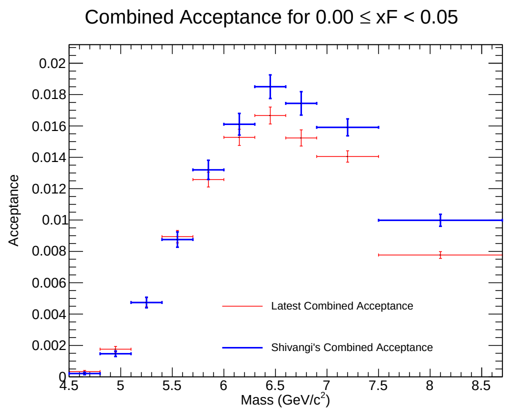
- **Top Left:** The detector acceptance for the LH2 target.
- **Top Right:** The detector acceptance for the LD2 target.
- **Bottom Left:** The combined average acceptance for both targets.
- **Bottom Right:** The ratio of the LH2 acceptance to the LD2 acceptance, used to check for target-dependent effects.



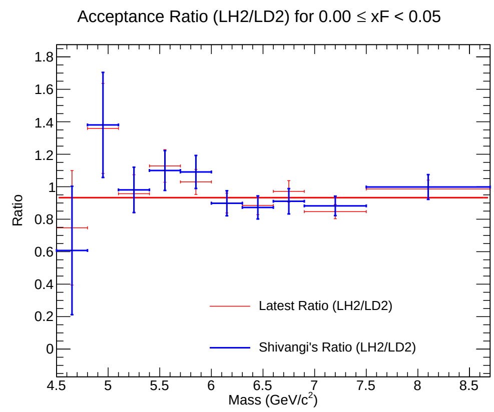
(a) Acceptance for LH2



(b) Acceptance for LD2

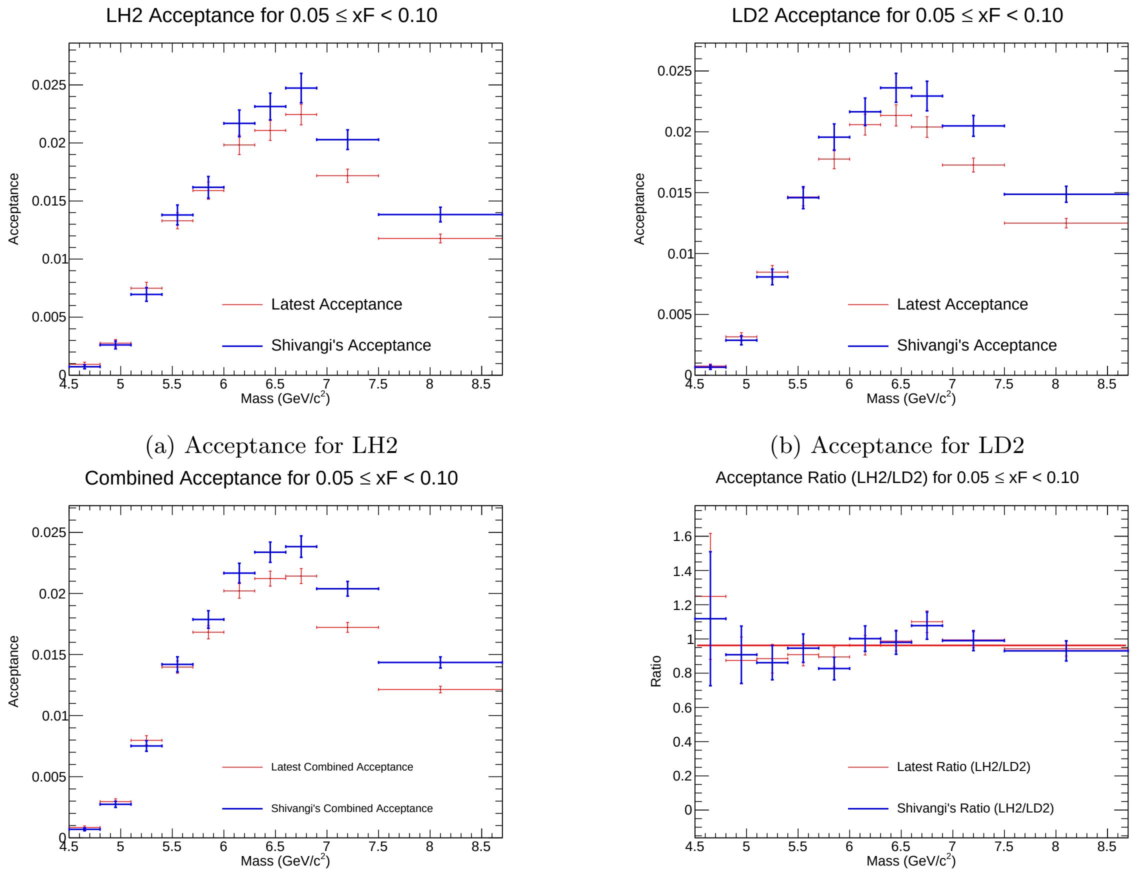


(c) Combined Acceptance



(d) Acceptance Ratio (LH2/LD2)

Figure 1: Acceptance plots for $0.00 \leq x_F < 0.05$.



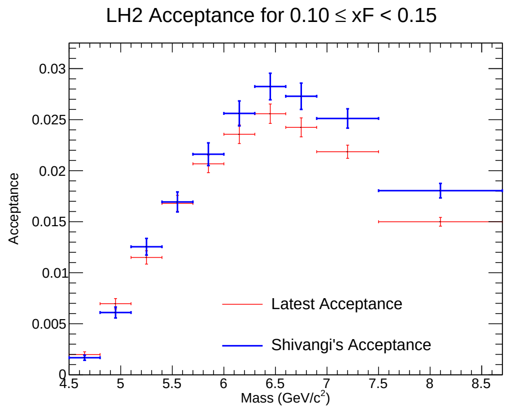
(a) Acceptance for LH2

(b) Acceptance for LD2

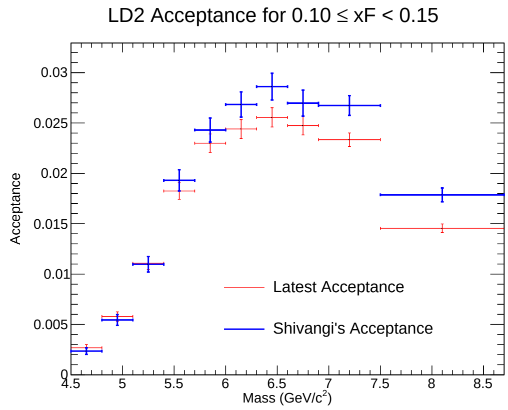
(c) Combined Acceptance

(d) Acceptance Ratio (LH2/LD2)

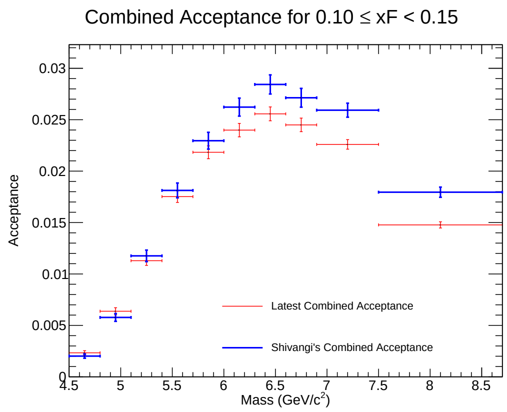
Figure 2: Acceptance plots for $0.05 \leq x_F < 0.10$.



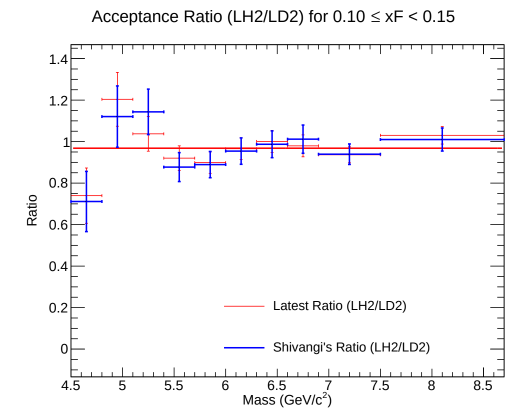
(a) Acceptance for LH2



(b) Acceptance for LD2

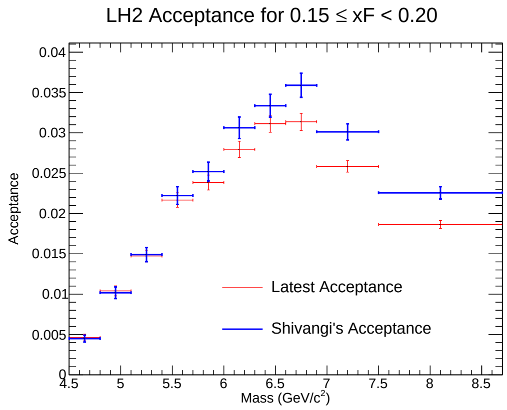


(c) Combined Acceptance

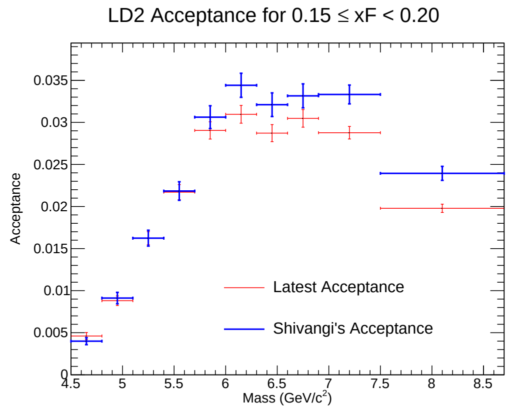


(d) Acceptance Ratio (LH2/LD2)

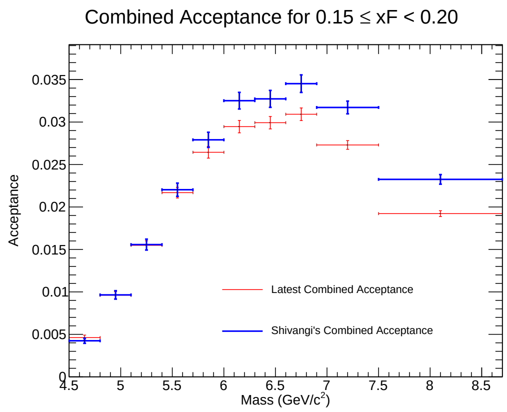
Figure 3: Acceptance plots for $0.10 \leq x_F < 0.15$.



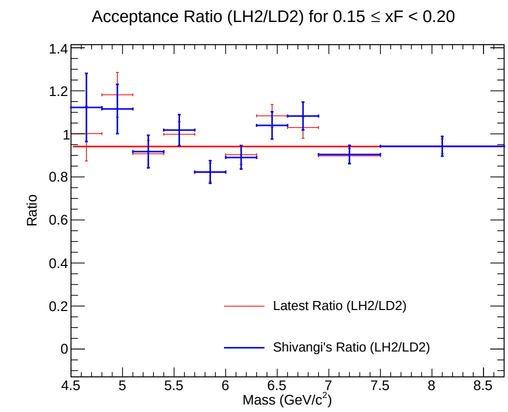
(a) Acceptance for LH2



(b) Acceptance for LD2

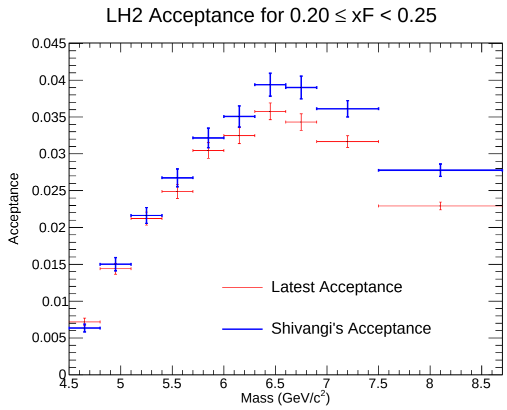


(c) Combined Acceptance

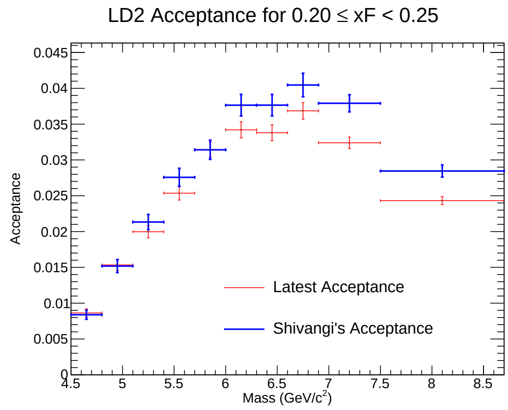


(d) Acceptance Ratio (LH2/LD2)

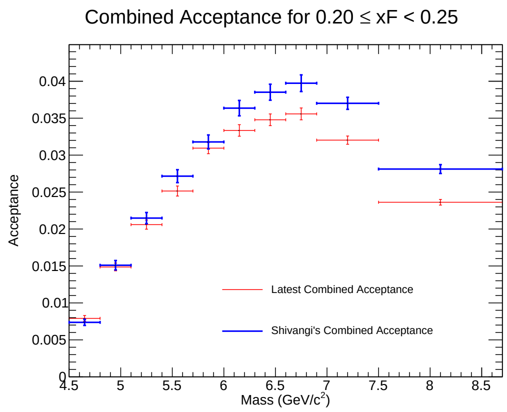
Figure 4: Acceptance plots for $0.15 \leq x_F < 0.20$.



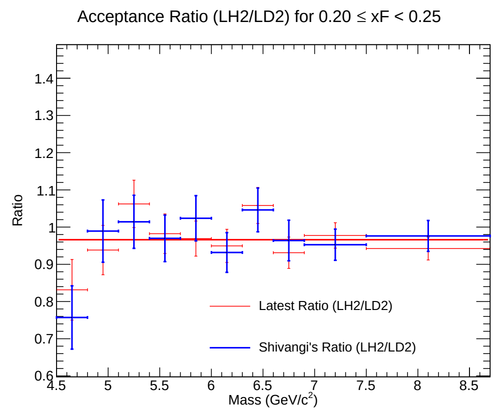
(a) Acceptance for LH2



(b) Acceptance for LD2

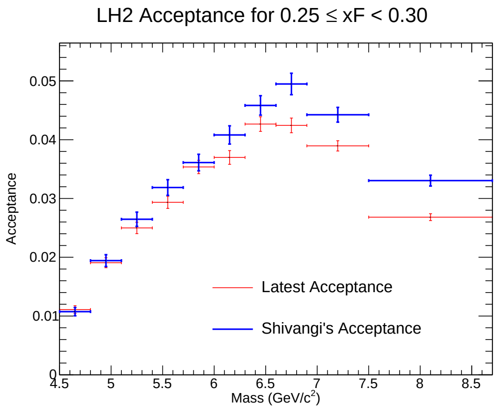


(c) Combined Acceptance

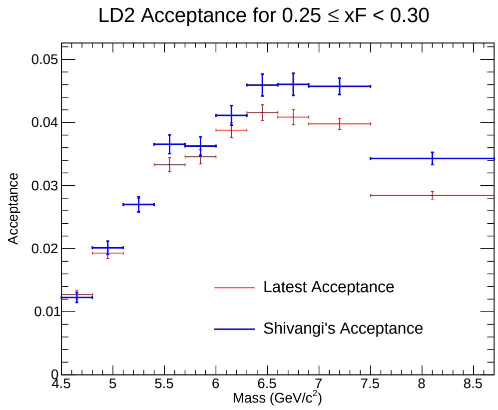


(d) Acceptance Ratio (LH2/LD2)

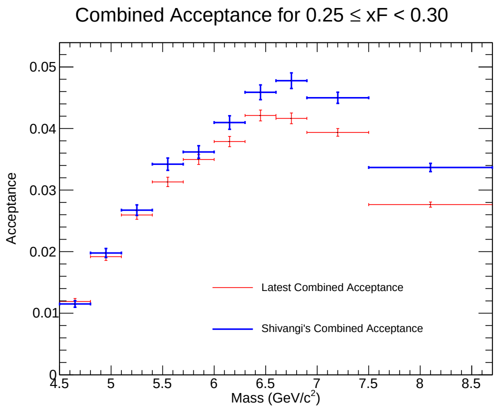
Figure 5: Acceptance plots for $0.20 \leq x_F < 0.25$.



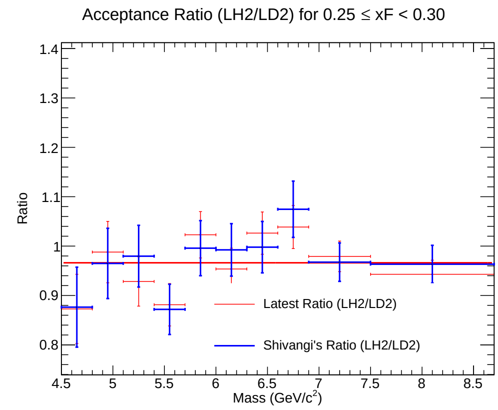
(a) Acceptance for LH2



(b) Acceptance for LD2

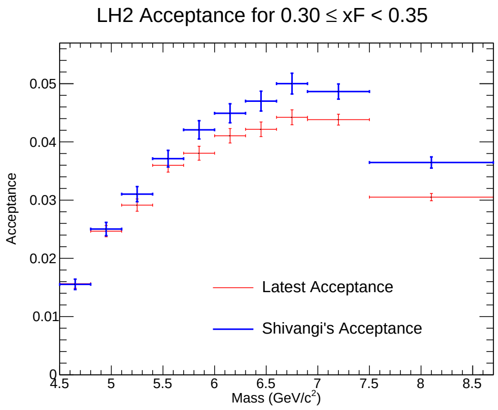


(c) Combined Acceptance

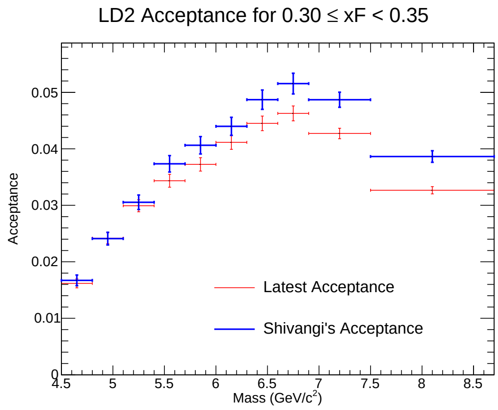


(d) Acceptance Ratio (LH2/LD2)

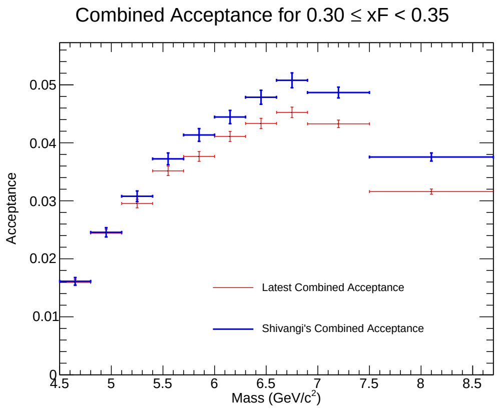
Figure 6: Acceptance plots for $0.25 \leq x_F < 0.30$.



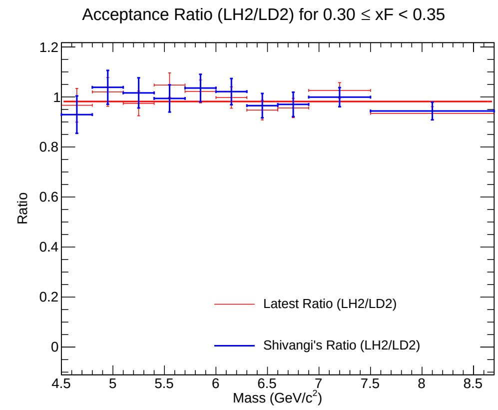
(a) Acceptance for LH2



(b) Acceptance for LD2

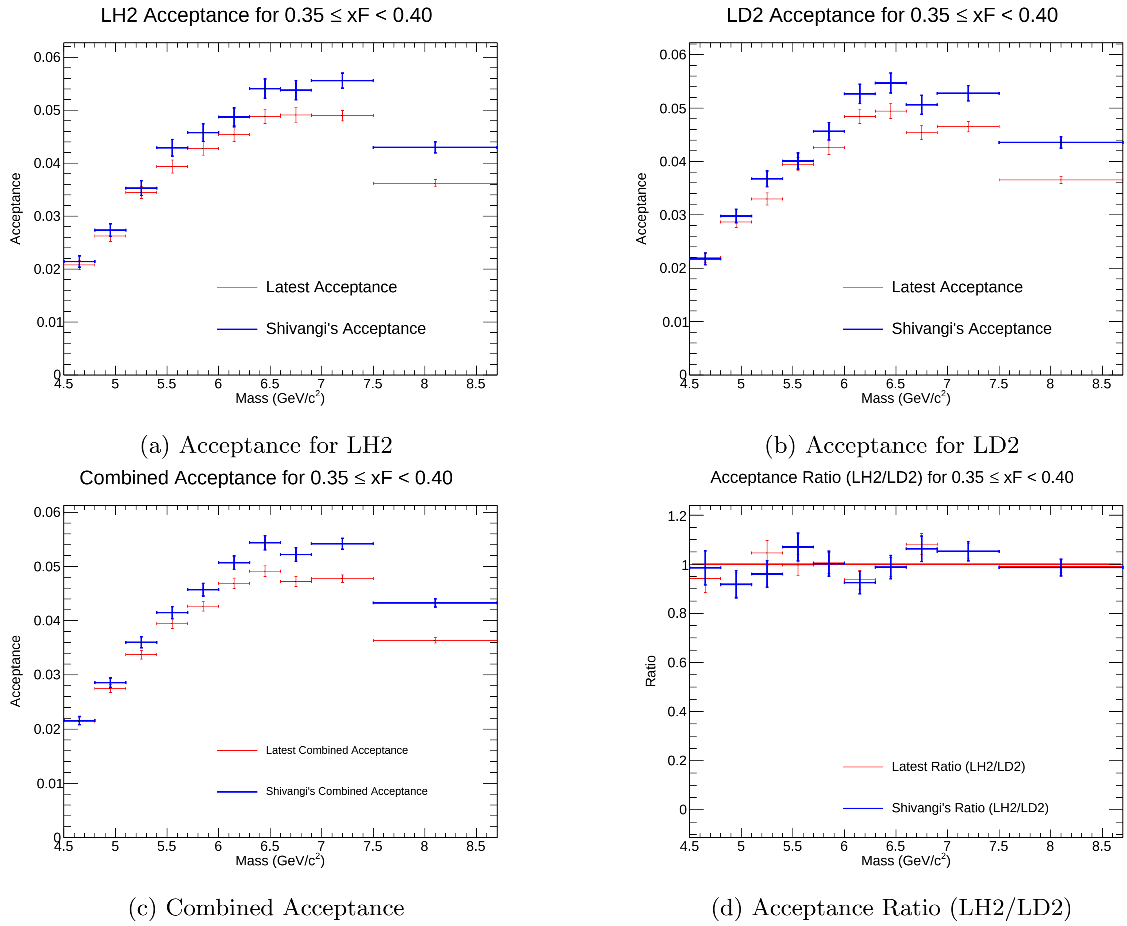


(c) Combined Acceptance



(d) Acceptance Ratio (LH2/LD2)

Figure 7: Acceptance plots for $0.30 \leq x_F < 0.35$.



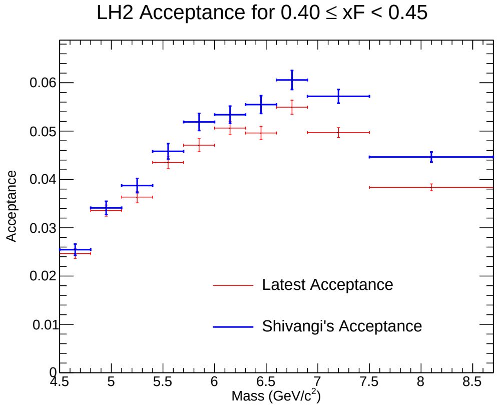
(a) Acceptance for LH2

(b) Acceptance for LD2

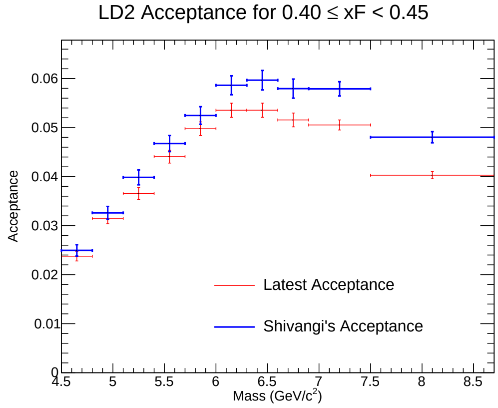
(c) Combined Acceptance

(d) Acceptance Ratio (LH2/LD2)

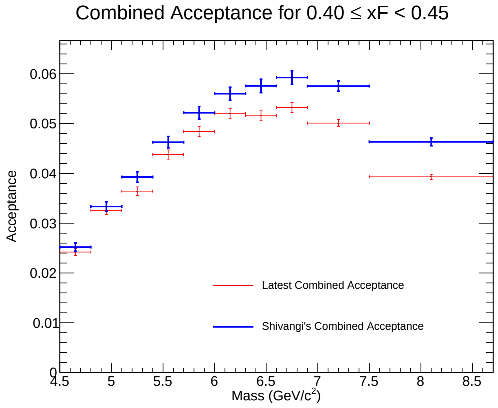
Figure 8: Acceptance plots for $0.35 \leq x_F < 0.40$.



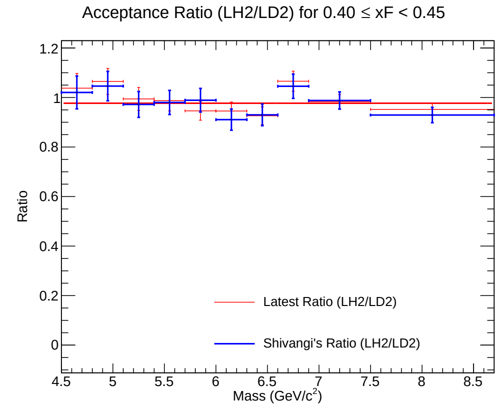
(a) Acceptance for LH2



(b) Acceptance for LD2

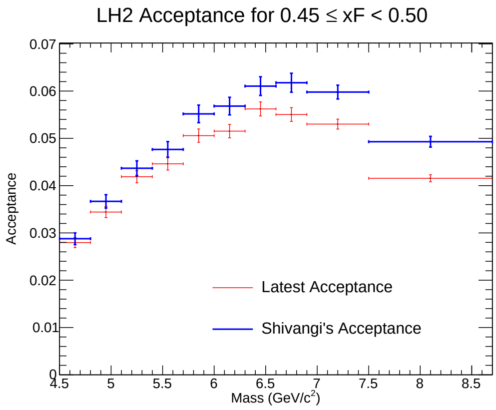


(c) Combined Acceptance

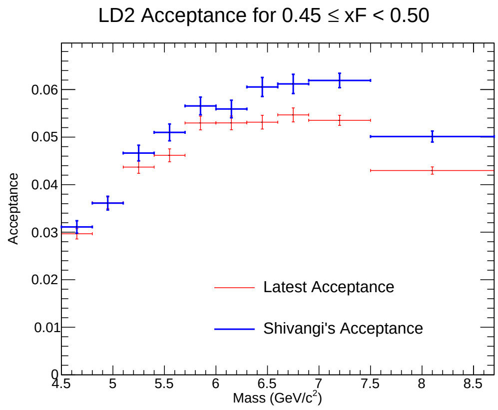


(d) Acceptance Ratio (LH2/LD2)

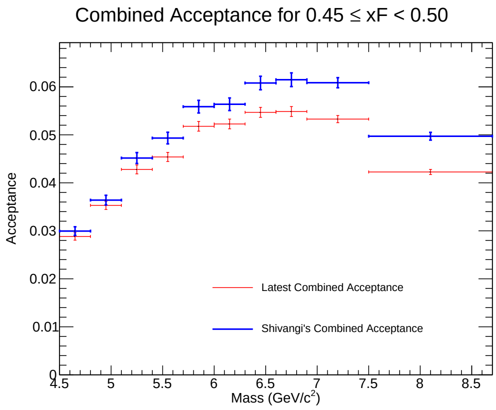
Figure 9: Acceptance plots for $0.40 \leq x_F < 0.45$.



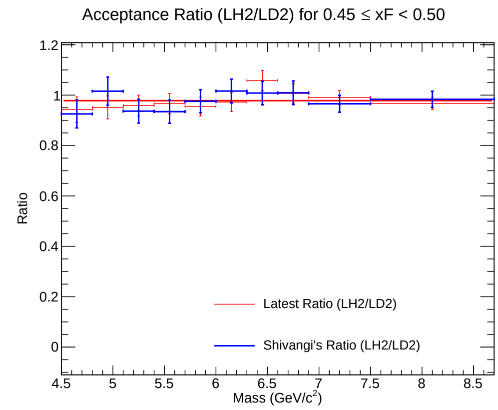
(a) Acceptance for LH2



(b) Acceptance for LD2

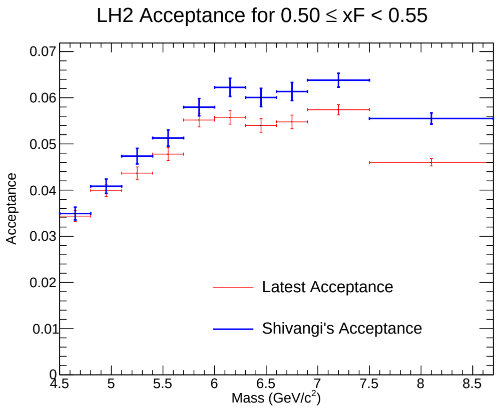


(c) Combined Acceptance

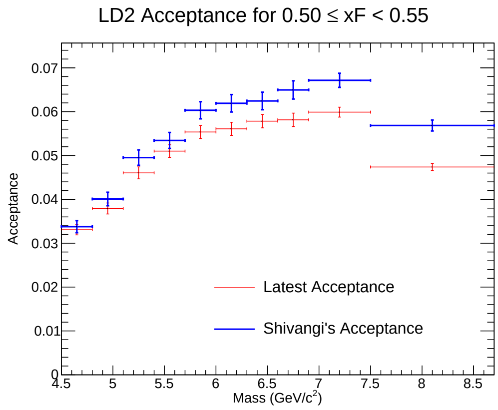


(d) Acceptance Ratio (LH2/LD2)

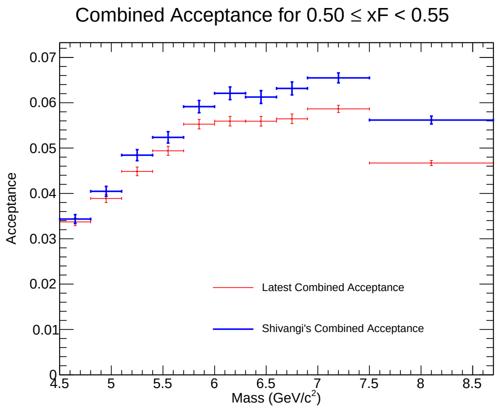
Figure 10: Acceptance plots for $0.45 \leq x_F < 0.50$.



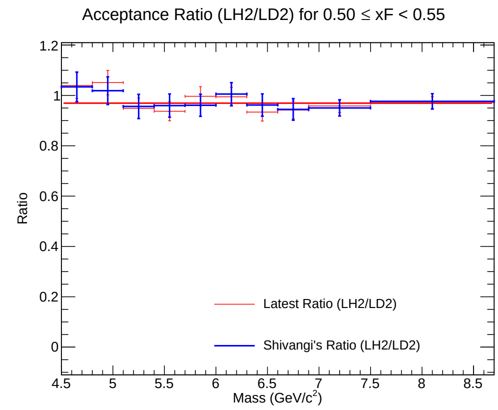
(a) Acceptance for LH2



(b) Acceptance for LD2

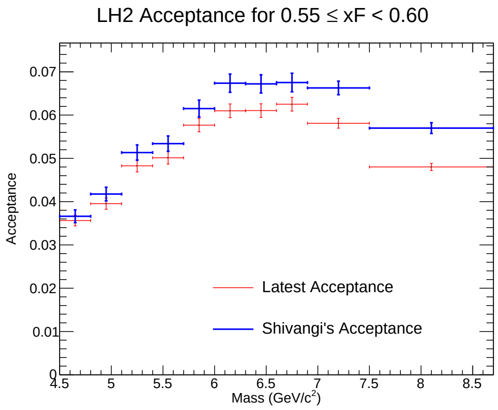


(c) Combined Acceptance

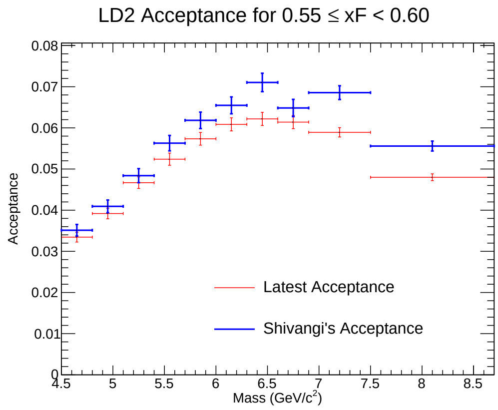


(d) Acceptance Ratio (LH2/LD2)

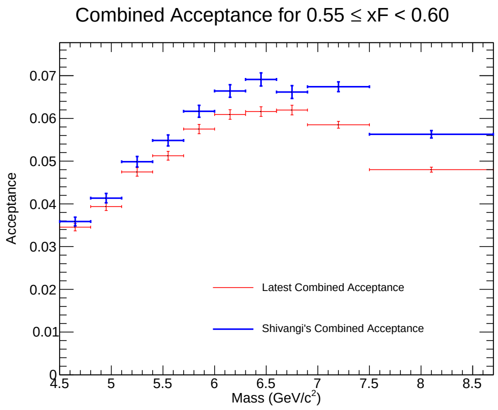
Figure 11: Acceptance plots for $0.50 \leq x_F < 0.55$.



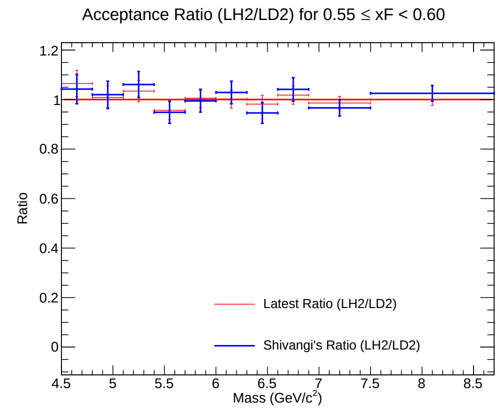
(a) Acceptance for LH2



(b) Acceptance for LD2

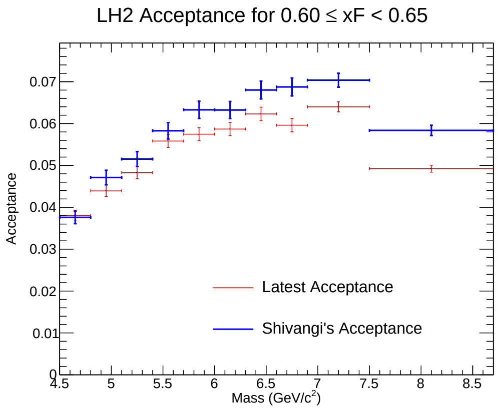


(c) Combined Acceptance

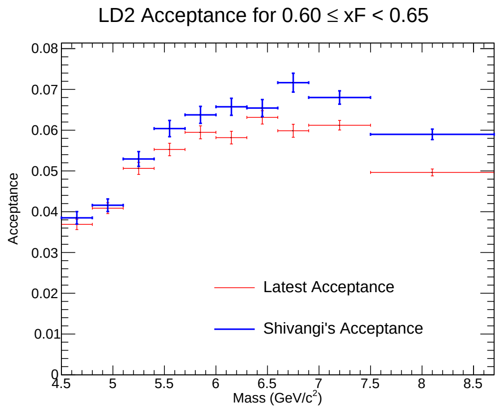


(d) Acceptance Ratio (LH2/LD2)

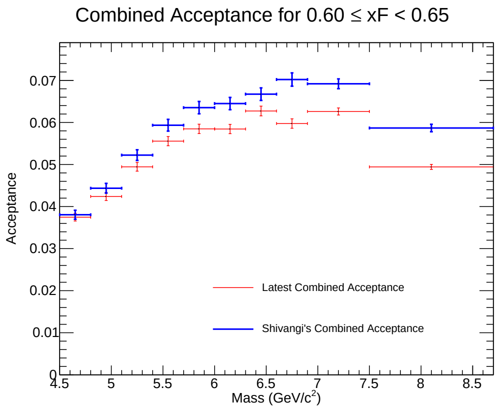
Figure 12: Acceptance plots for $0.55 \leq x_F < 0.60$.



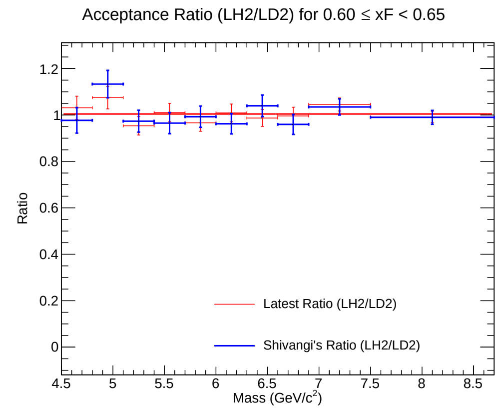
(a) Acceptance for LH2



(b) Acceptance for LD2

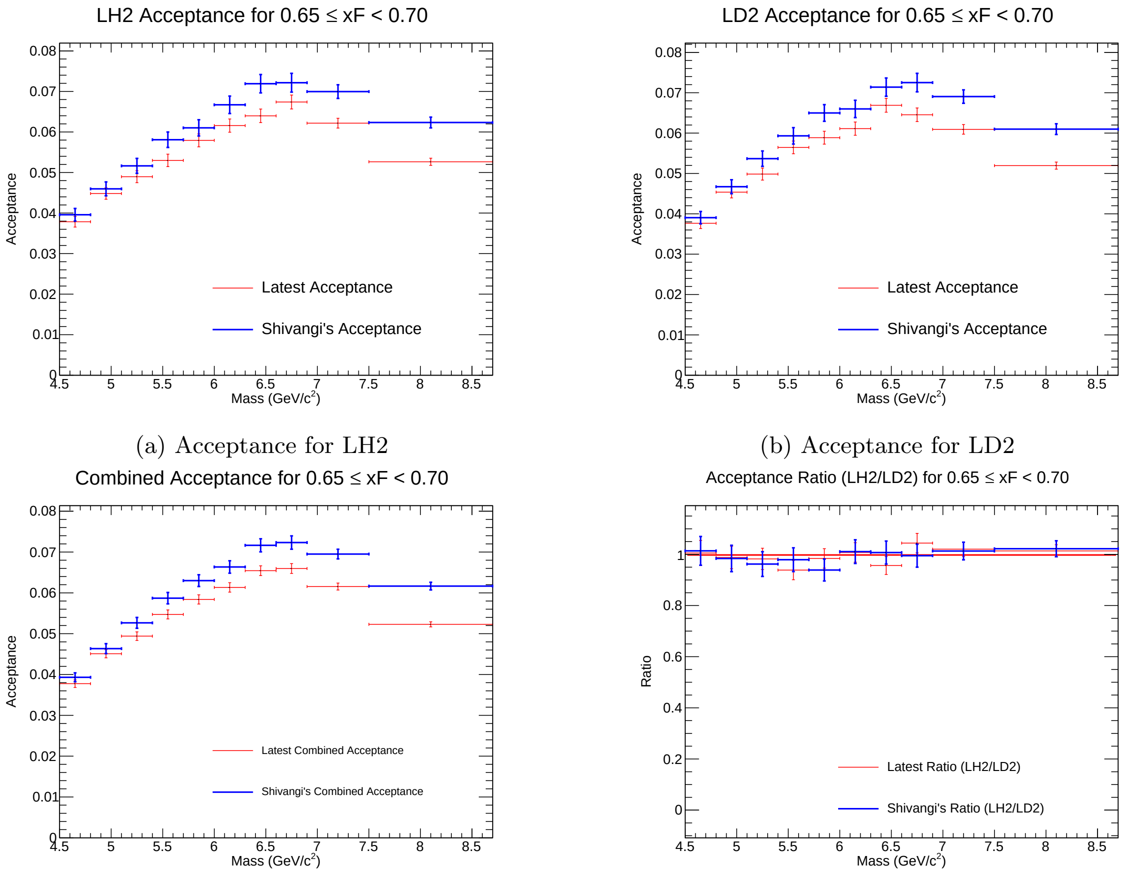


(c) Combined Acceptance



(d) Acceptance Ratio (LH2/LD2)

Figure 13: Acceptance plots for $0.60 \leq x_F < 0.65$.



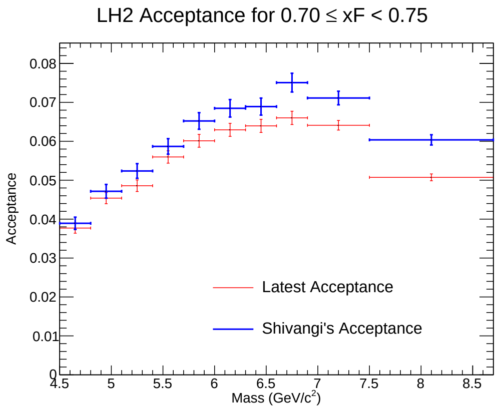
(a) Acceptance for LH2

(b) Acceptance for LD2

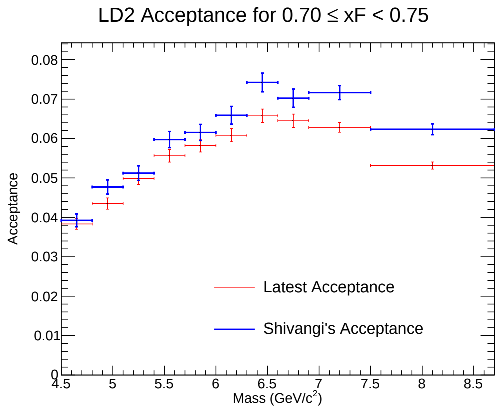
(c) Combined Acceptance

(d) Acceptance Ratio (LH2/LD2)

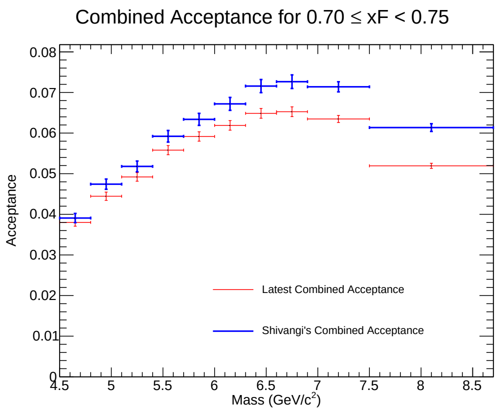
Figure 14: Acceptance plots for $0.65 \leq x_F < 0.70$.



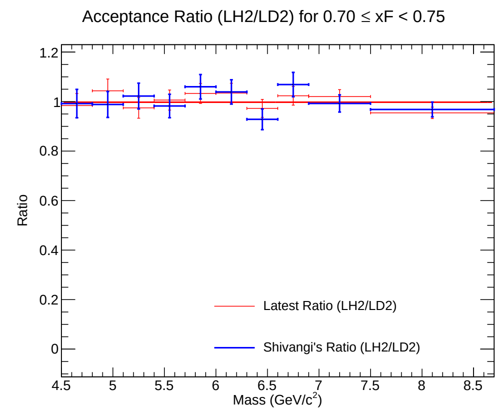
(a) Acceptance for LH2



(b) Acceptance for LD2

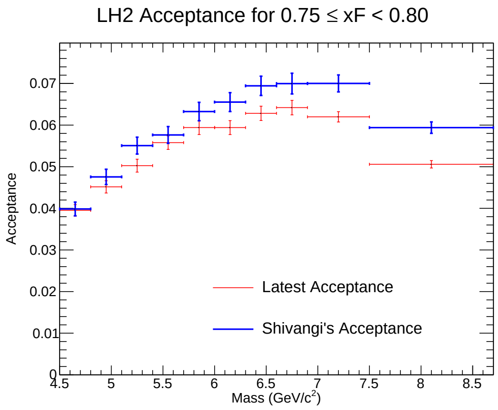


(c) Combined Acceptance

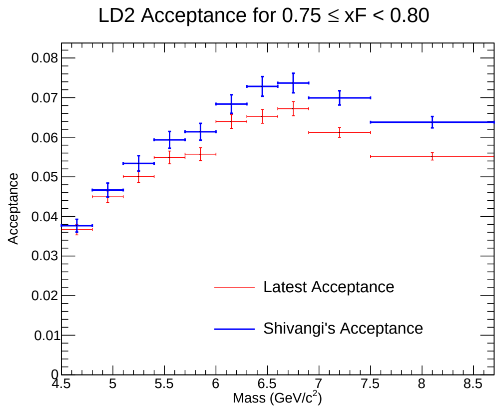


(d) Acceptance Ratio (LH2/LD2)

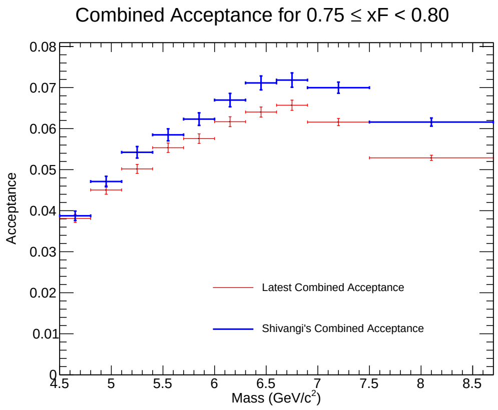
Figure 15: Acceptance plots for $0.70 \leq x_F < 0.75$.



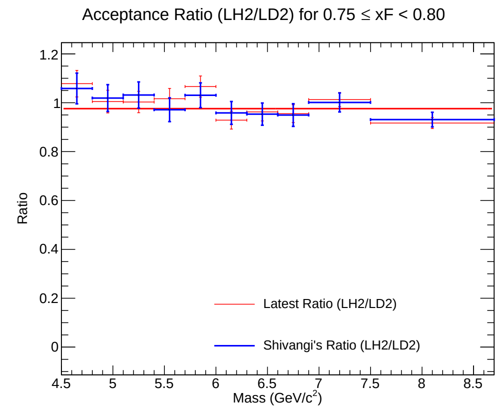
(a) Acceptance for LH2



(b) Acceptance for LD2



(c) Combined Acceptance



(d) Acceptance Ratio (LH2/LD2)

Figure 16: Acceptance plots for $0.75 \leq x_F < 0.80$.