Evidence for the discovery of an excess in the invariant mass distribution of pairs of opposite-sign minimum-ionizing charged particles in the HPS detector

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HPS Collaboration Meeting

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V0 Analysis

- We reconstruct V0s from pairs of oppositely-signed charged ReconstructedParticles
- By default, we assign a pdg ID of either 11 (electron) or -11 (positron) to negatively and positively signed tracks, respectively.
  - This is being addressed…
- However, as I have shown quite some time ago, HPS is also capable of identifying minimum-ionizing particles.
- We are above the muon threshold, so should expect to see MIPs

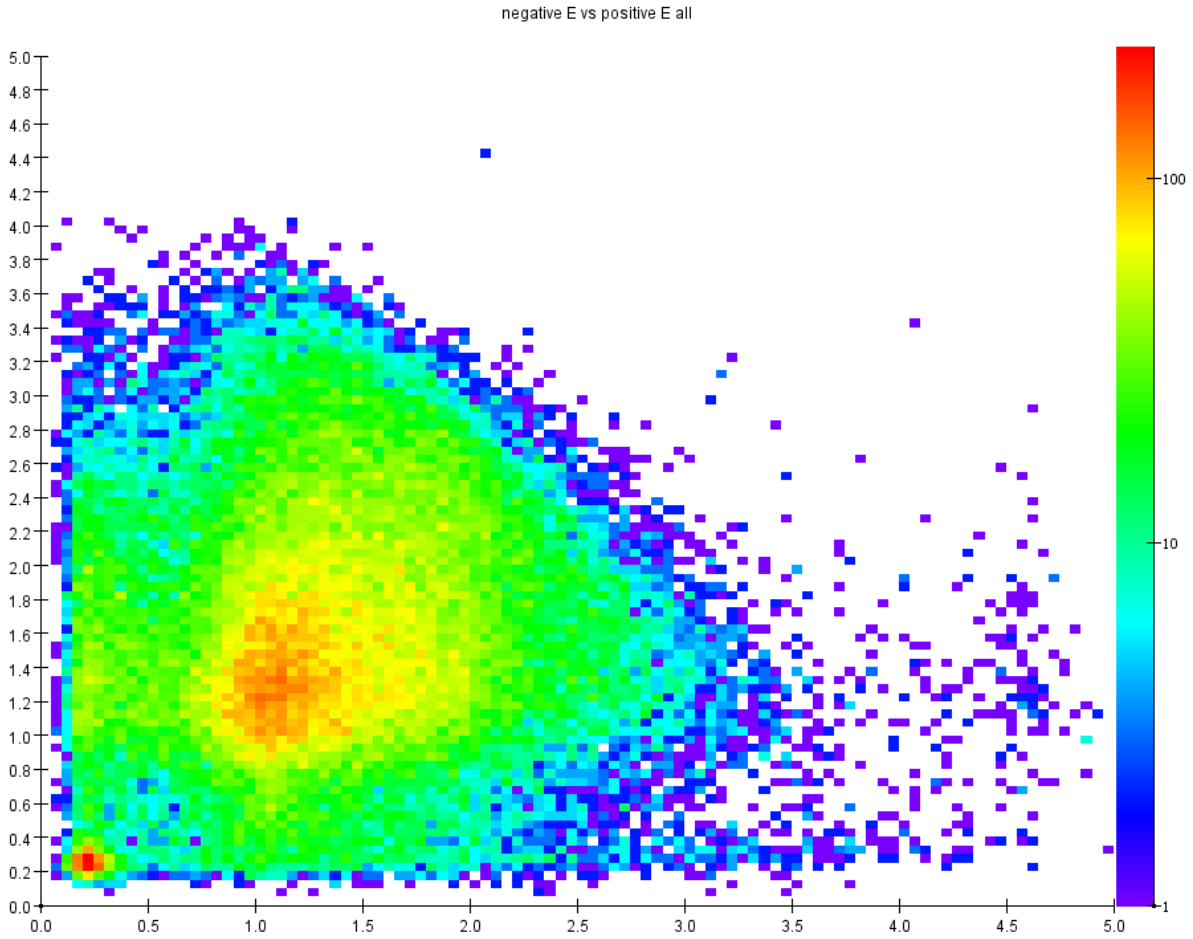
HPS ECal

- Each module is made of a 160mm long tapered $PbWO_4$ crystal
- Radiation Length: 8.9mm ~18 X_0
- Nuclear Interaction Length: 202.7mm ~0.8λ_I

- So in addition to muons, we should also expect a large number of charged hadrons passing through the calorimeter without showering.
  - Was the basis for my first search for $\phi \rightarrow K^+K^-$ to use for momentum calibration of the SVT.

V0 Ecal Cluster Energies

- For V0s having calorimeter clusters associated with both tracks, plot energy of one versus the other.



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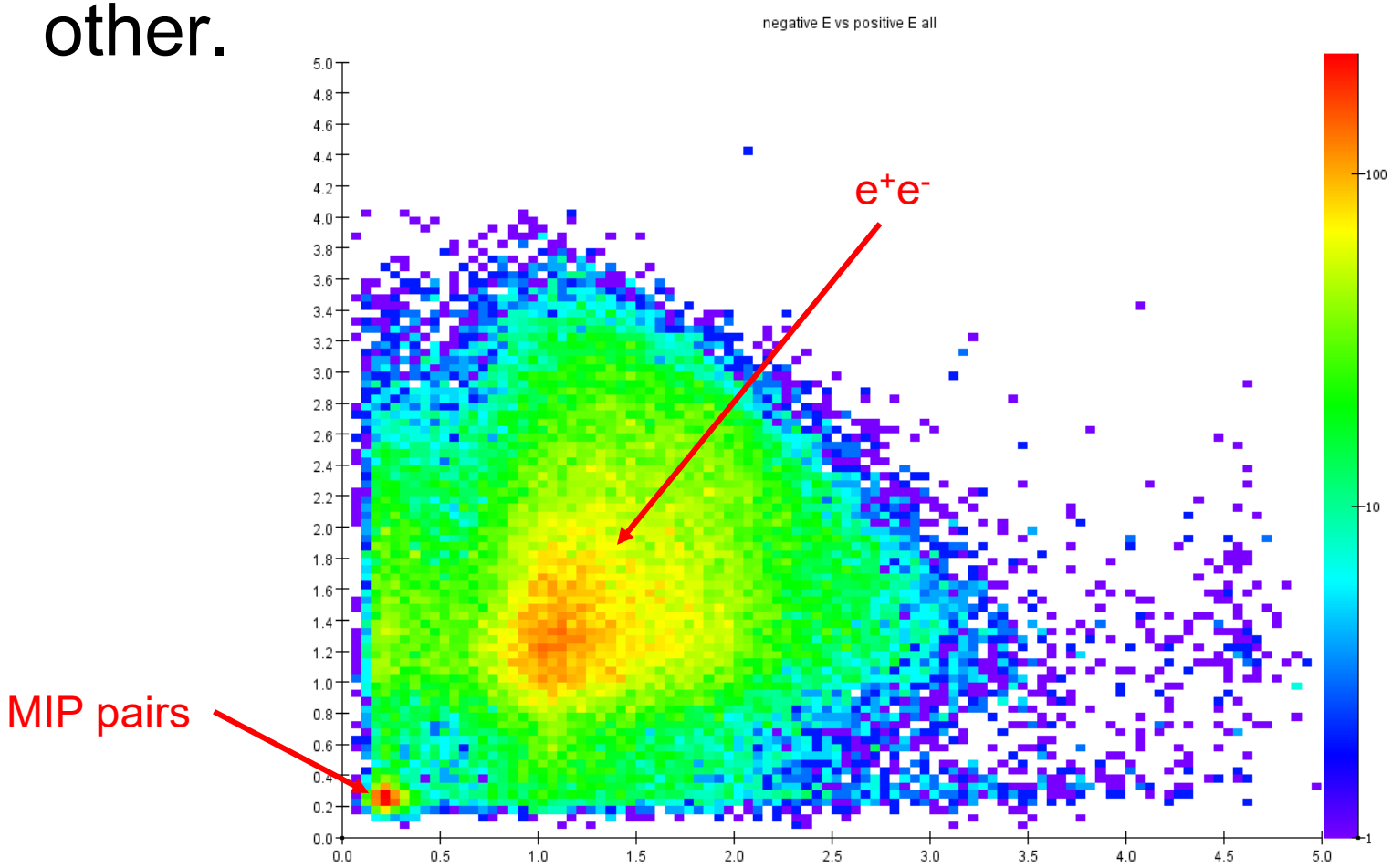
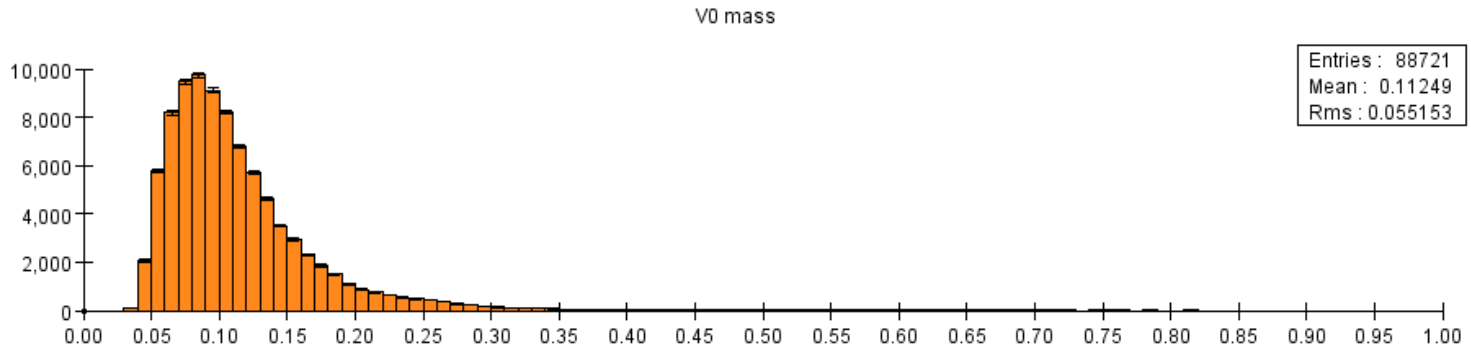
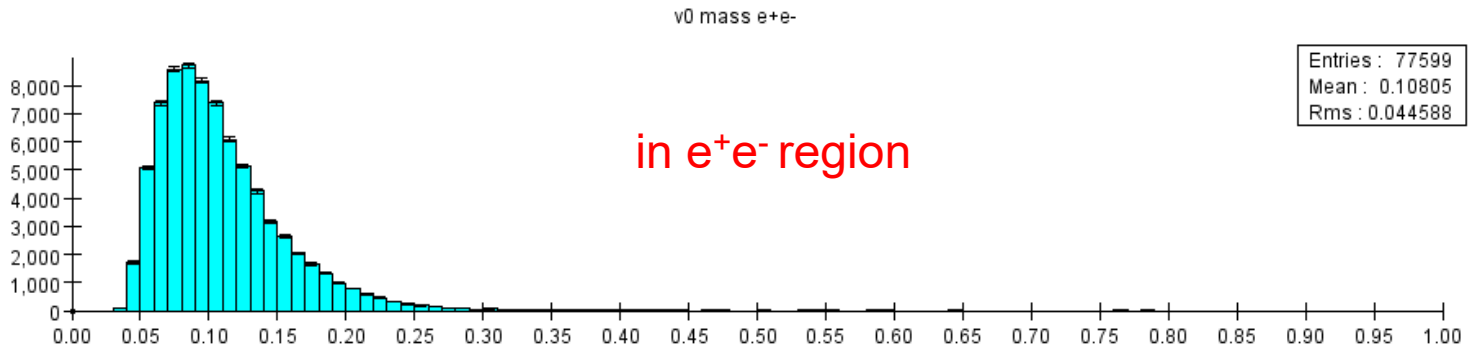


V0 Mass Analysis of two MIP tracks

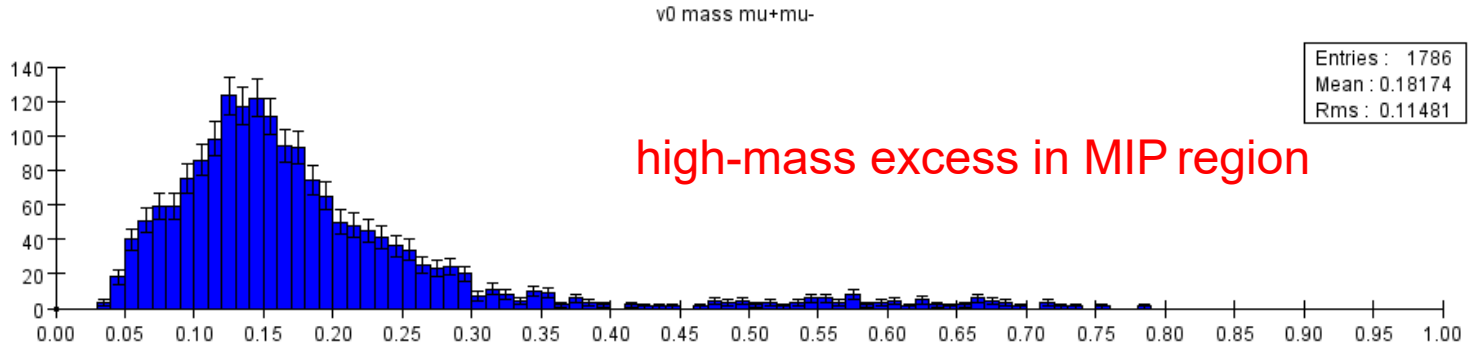
- Perform standard V0 selection, but require both ReconstructedParticles to have an associated Ecal cluster.
- Require both clusters to have less than 450MeV
- Require both clusters to be within 5ns

V0 Mass for e+e- and MIP regions



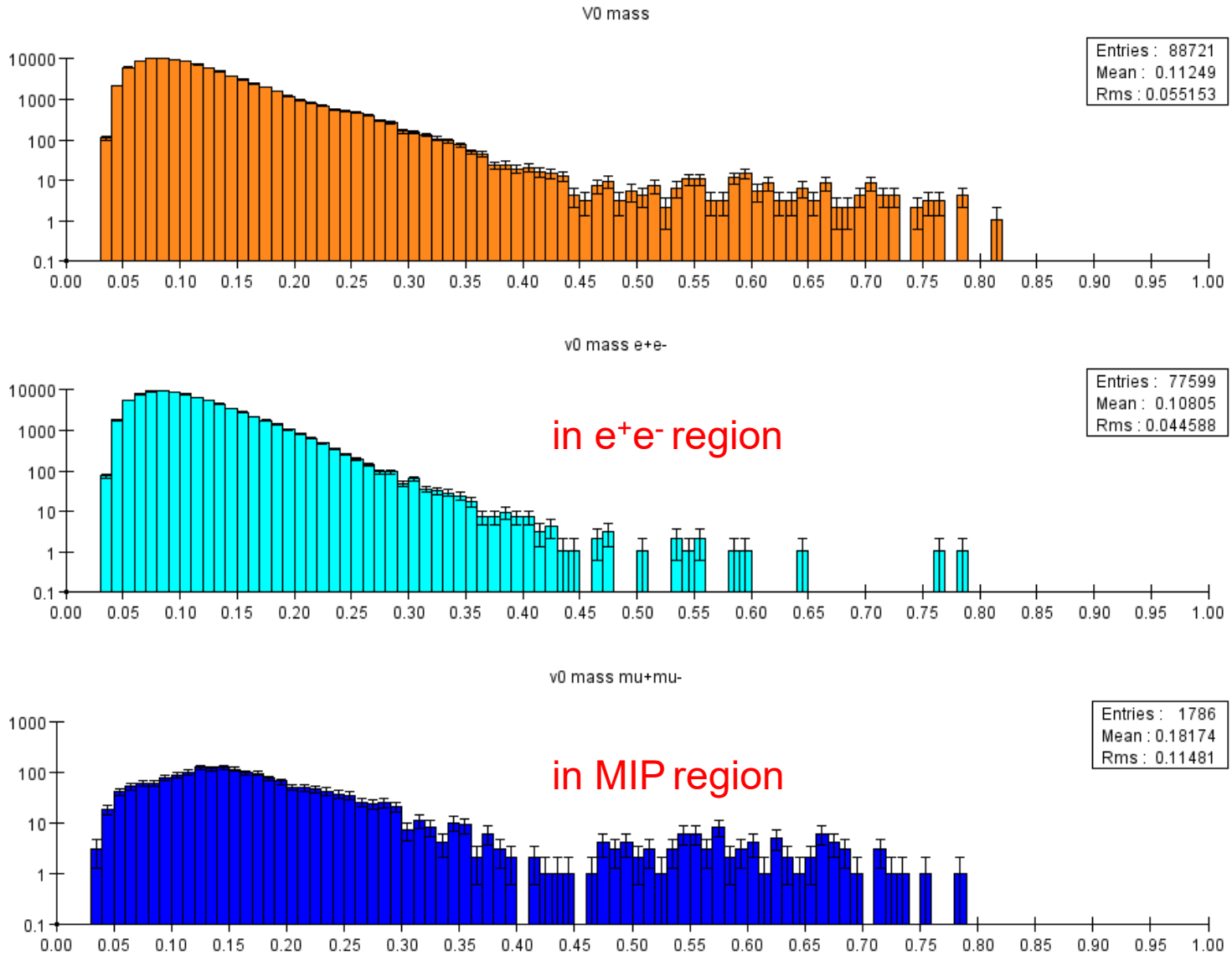


in e^+e^- region



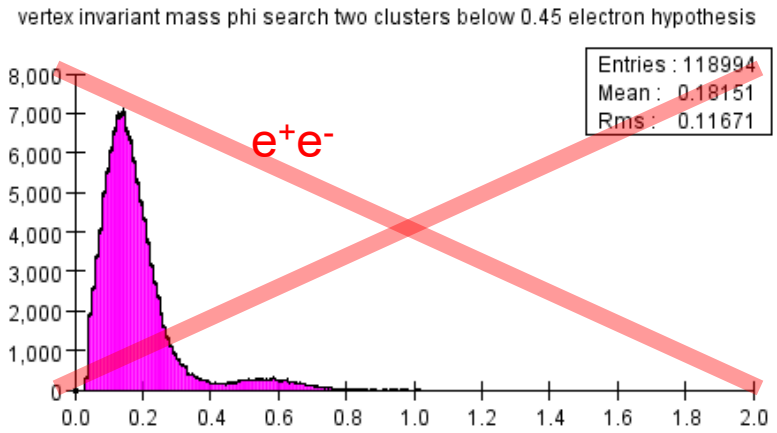
high-mass excess in MIP region

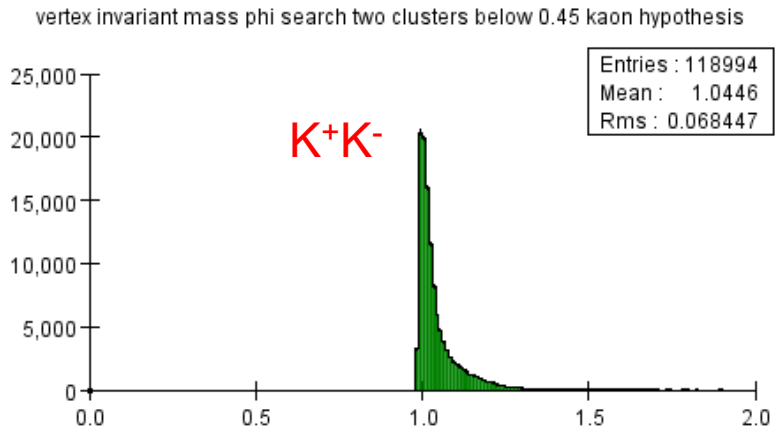
V0 Mass for e+e- and MIP regions

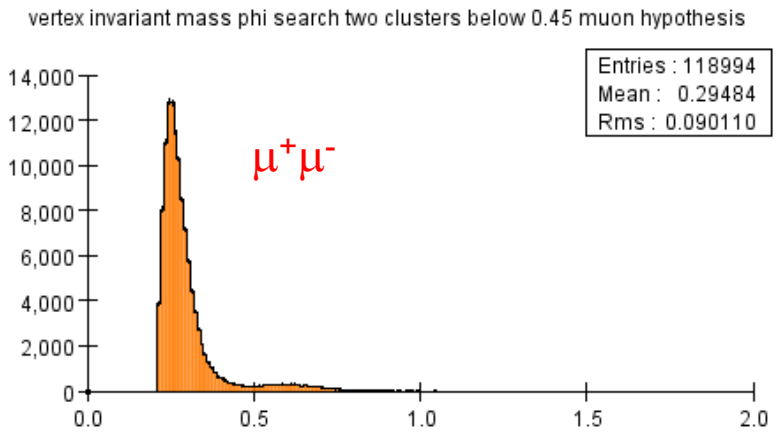


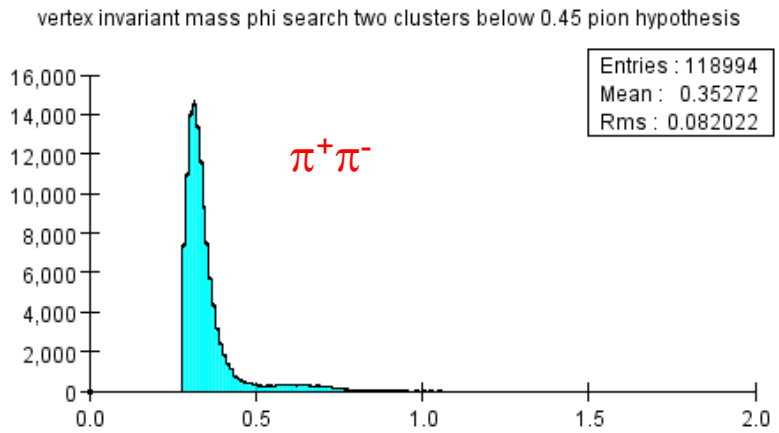
V0 Mass Different Particle Hypotheses

- Particles can't be electrons, as they don't shower
- Recalculate with different particle hypotheses.

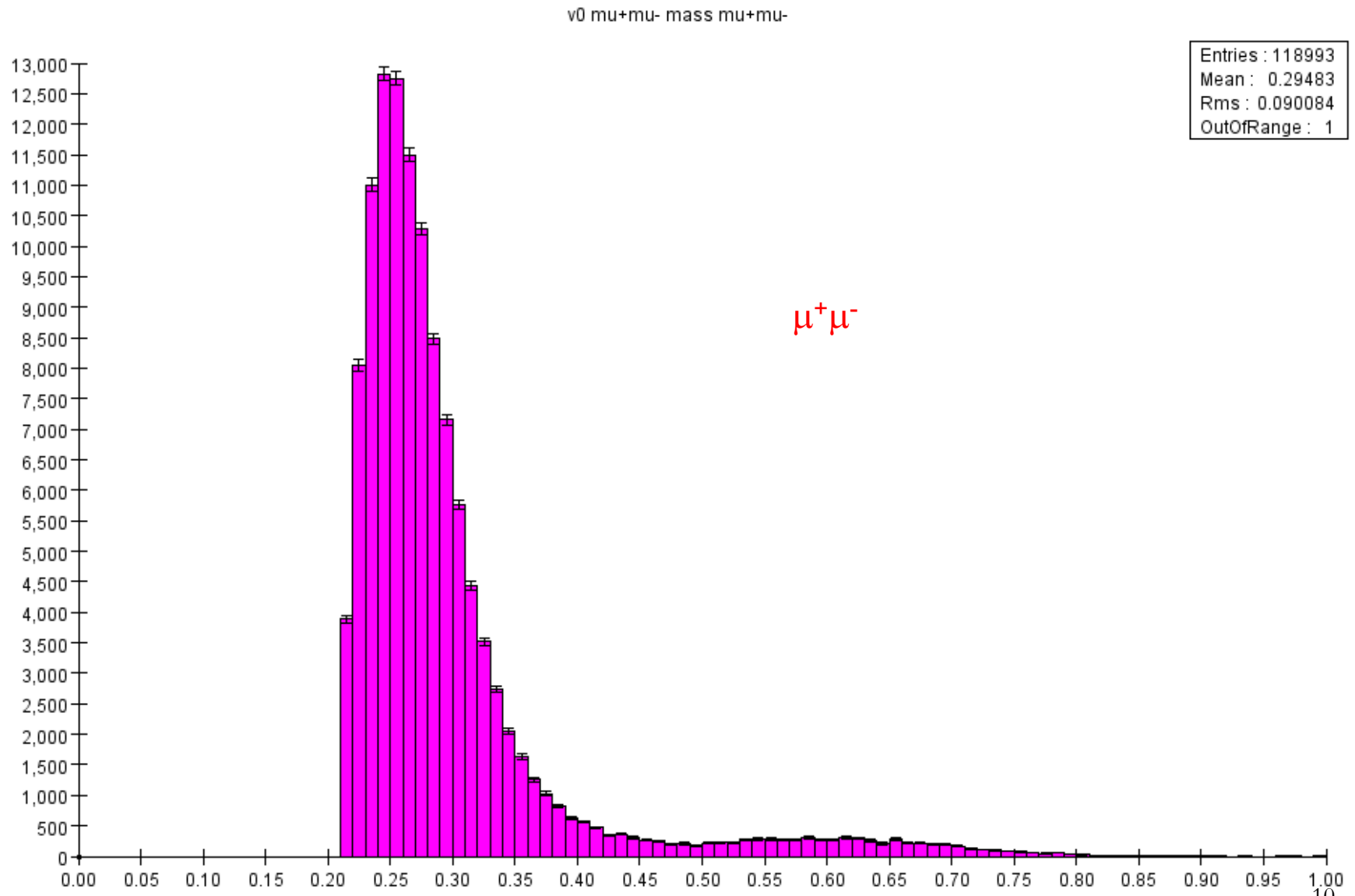








V0 Mass muon hypothesis



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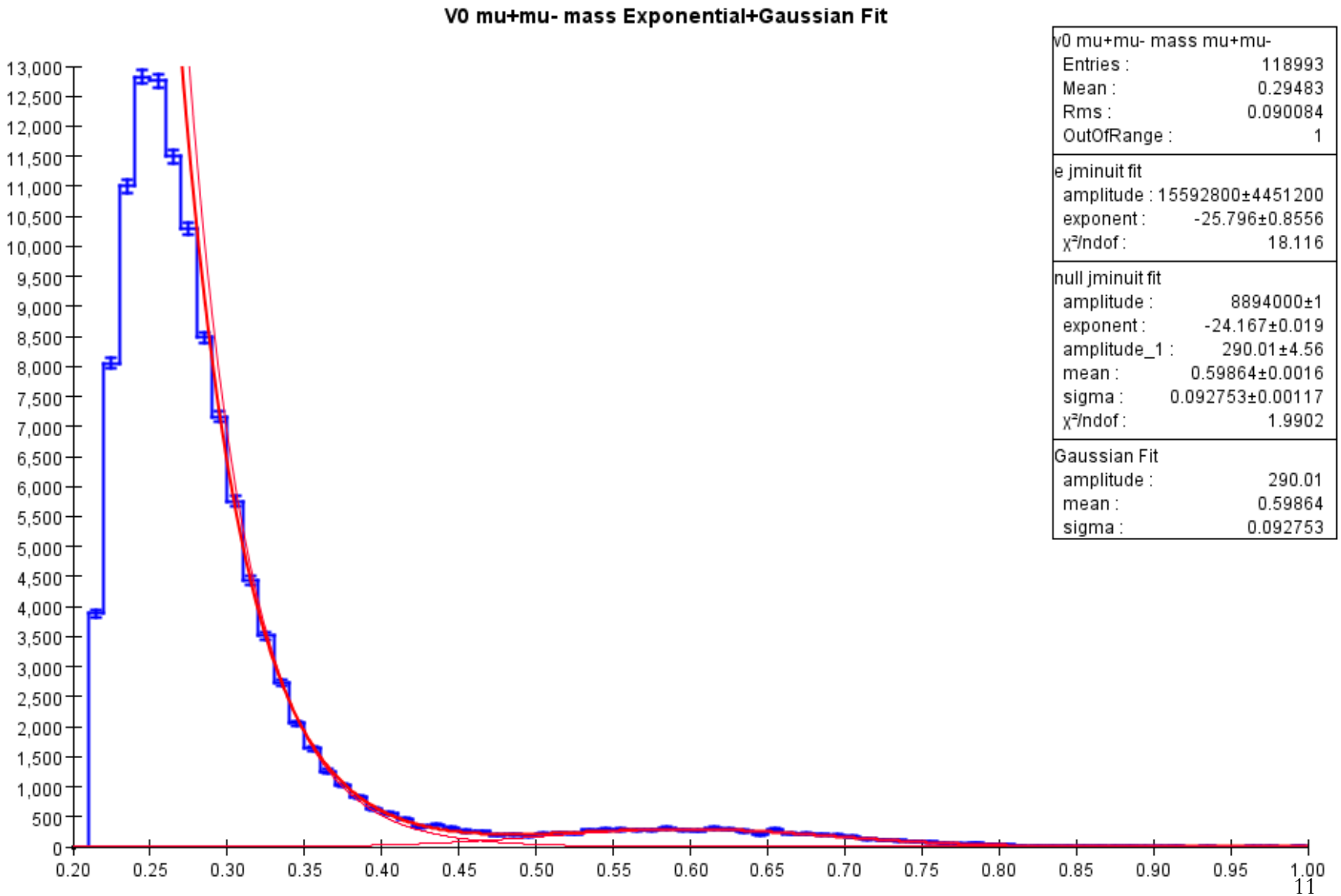

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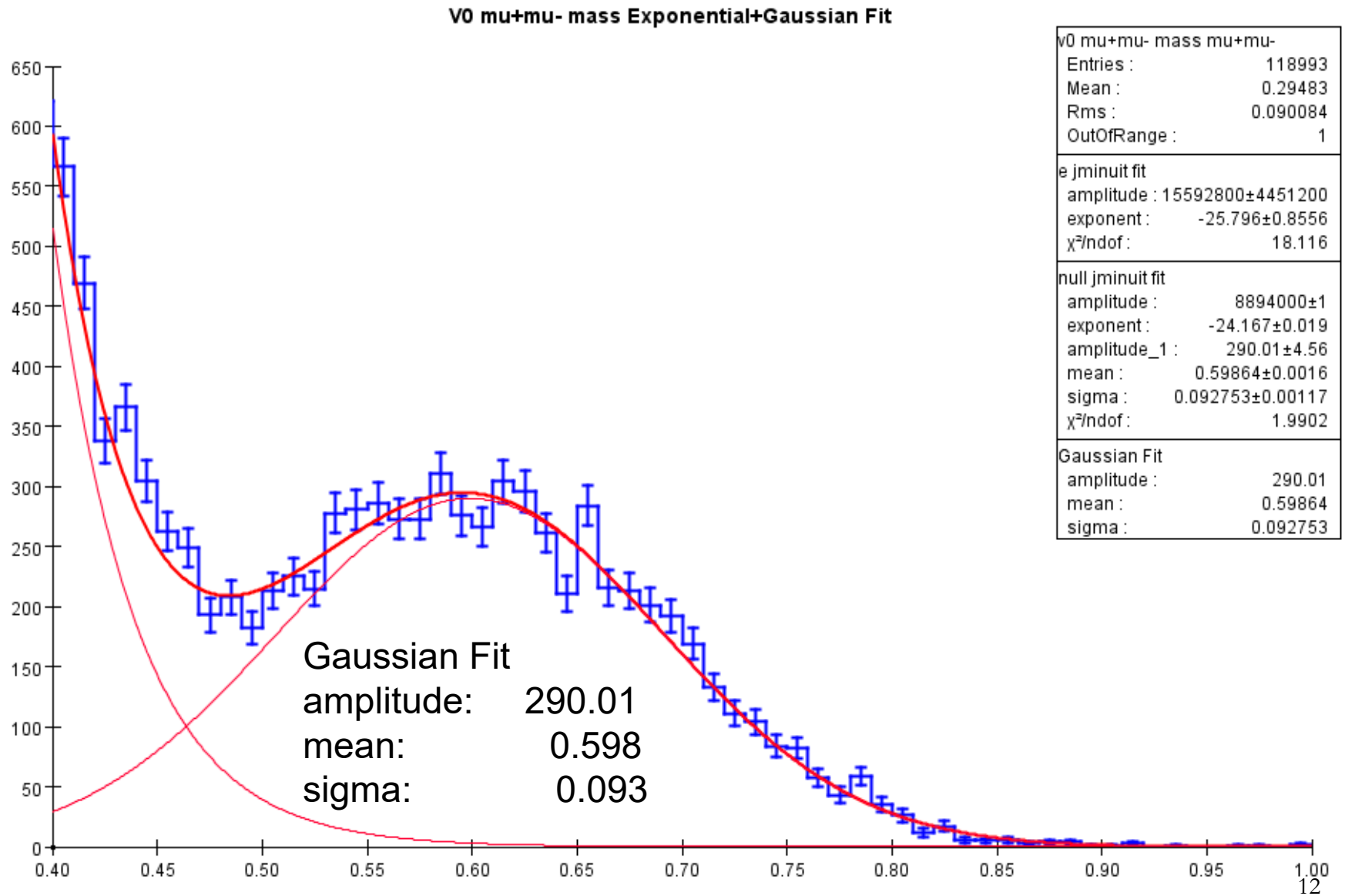

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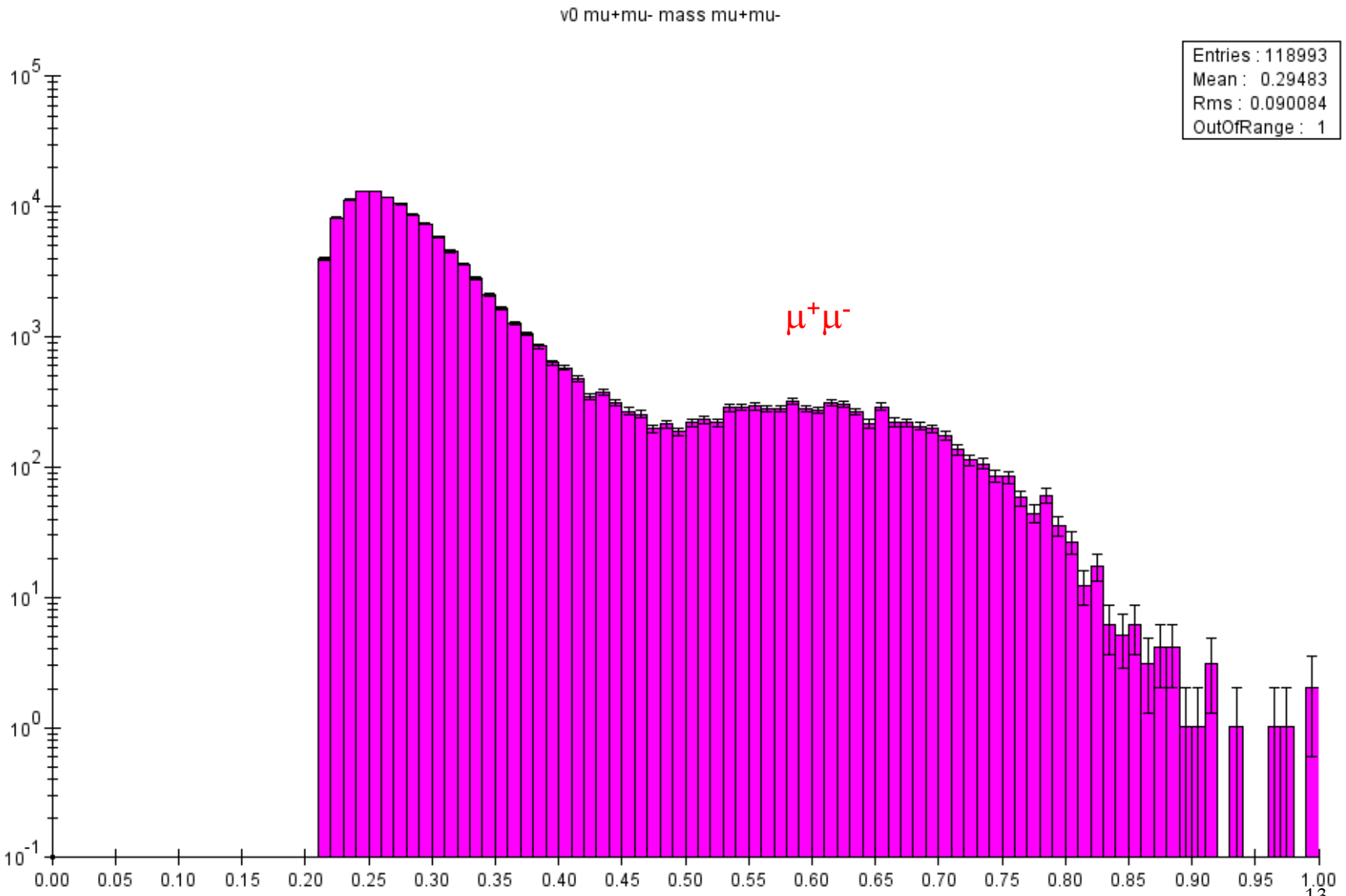
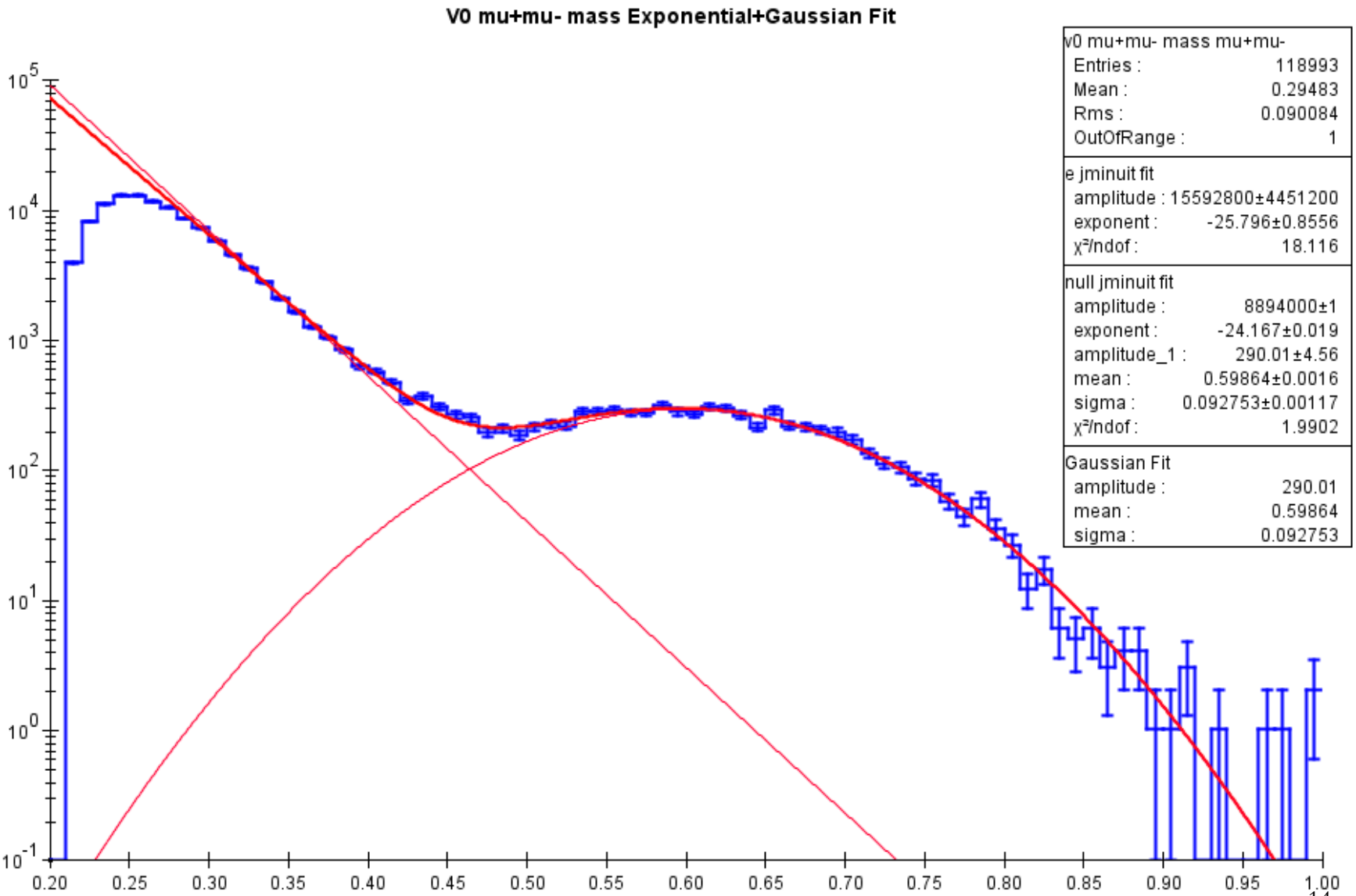


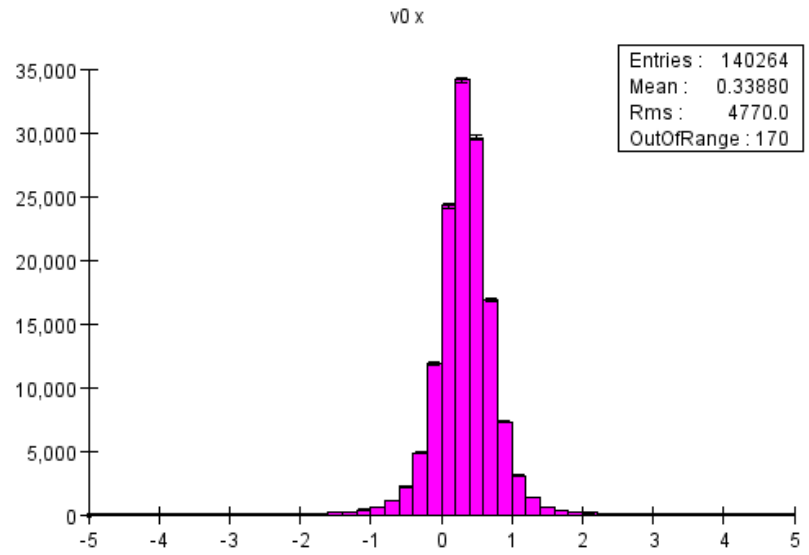
V0 Mass muon hypothesis

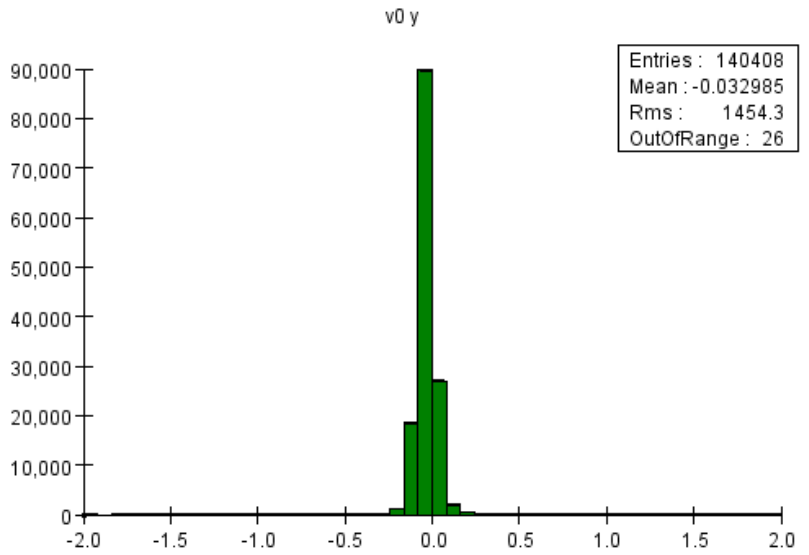


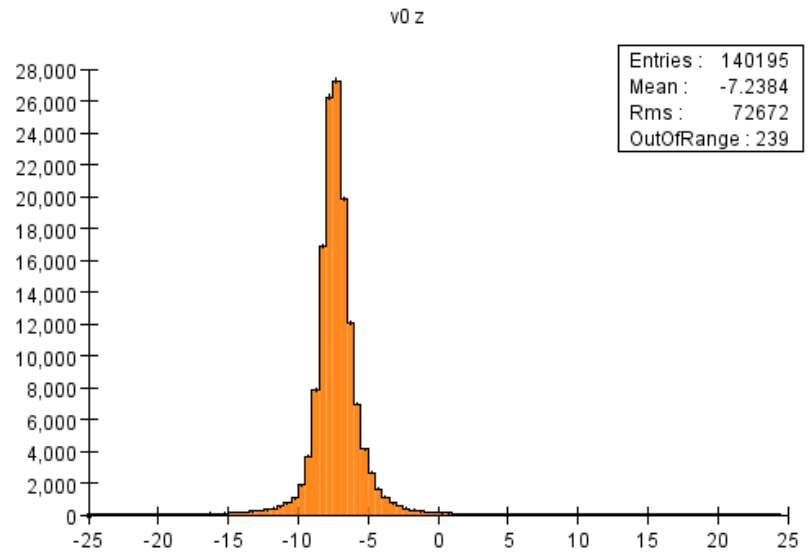
Event Characteristics

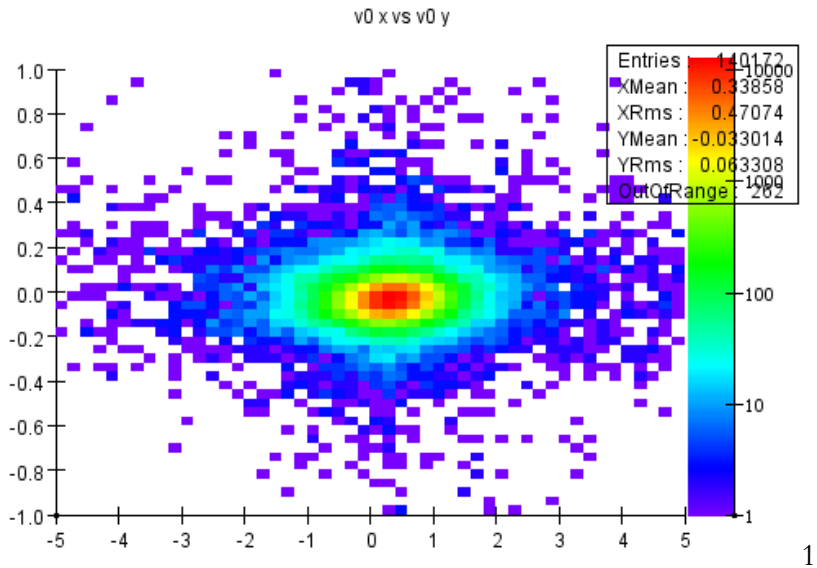
- Split sample to study event characteristics
- low-mass “background”, mass <450MeV
- high-mass “signal”, mass > 450MeV

Vertex Position ("background")

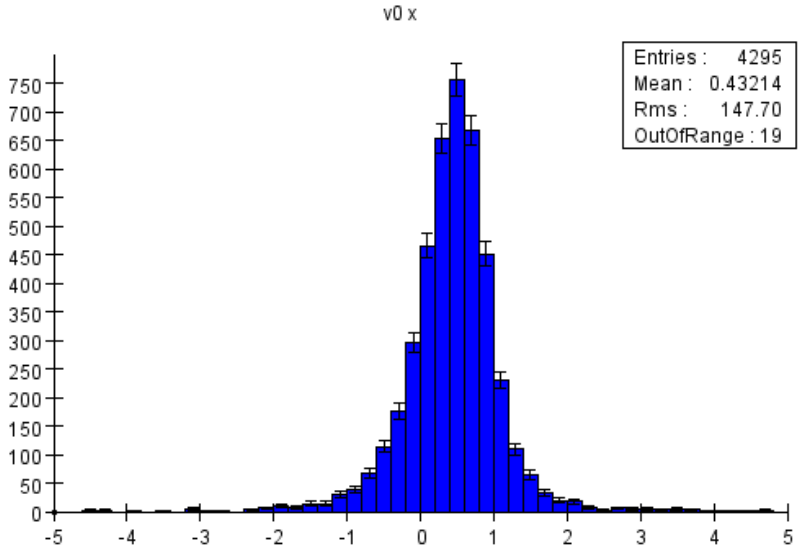


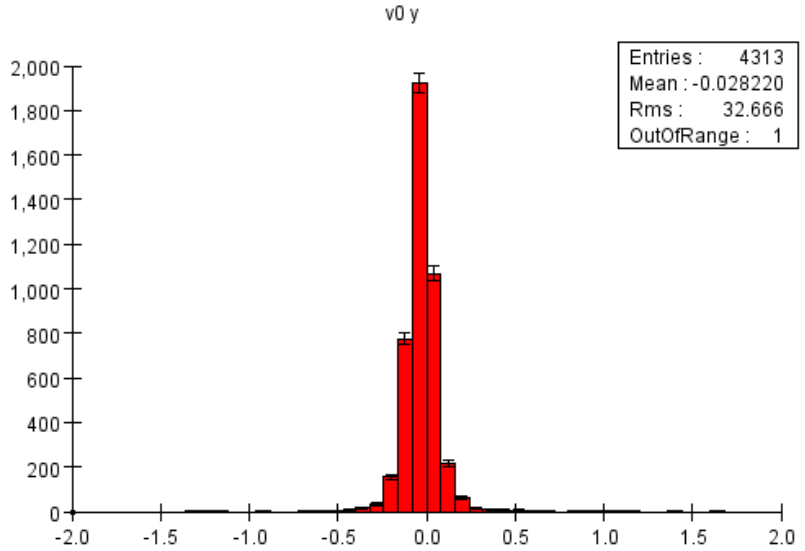


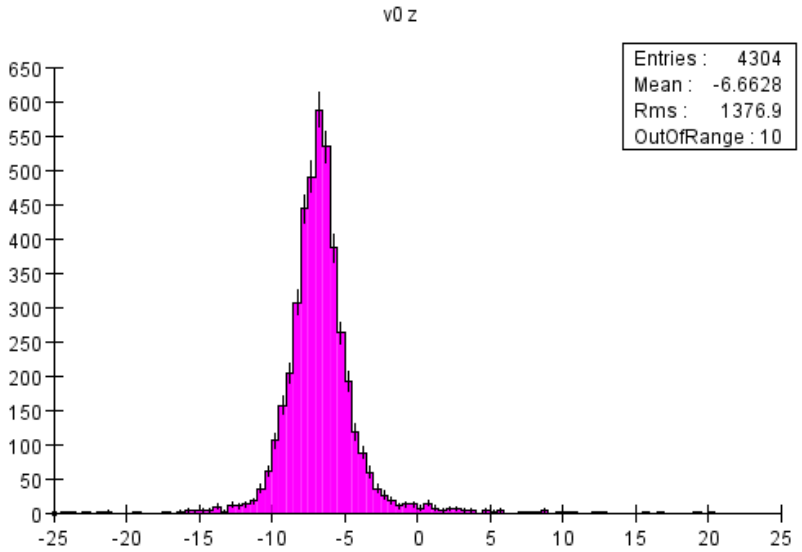


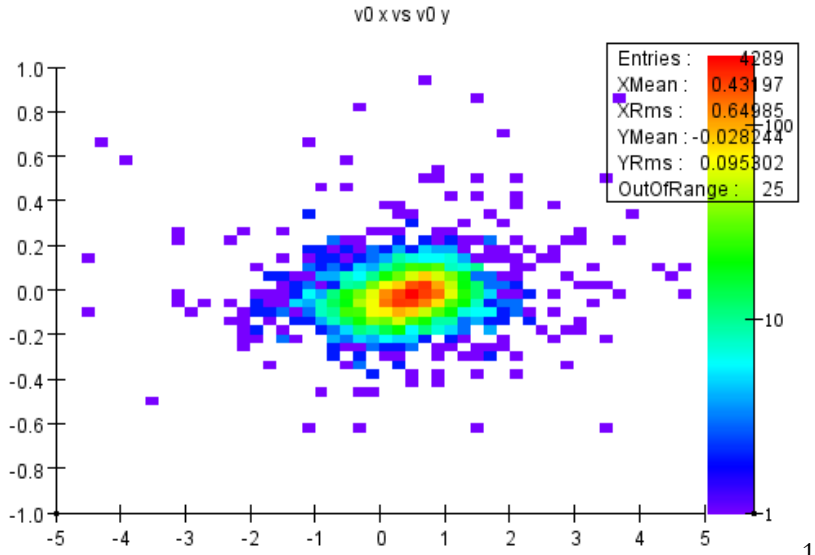


Vertex Position (“signal”)

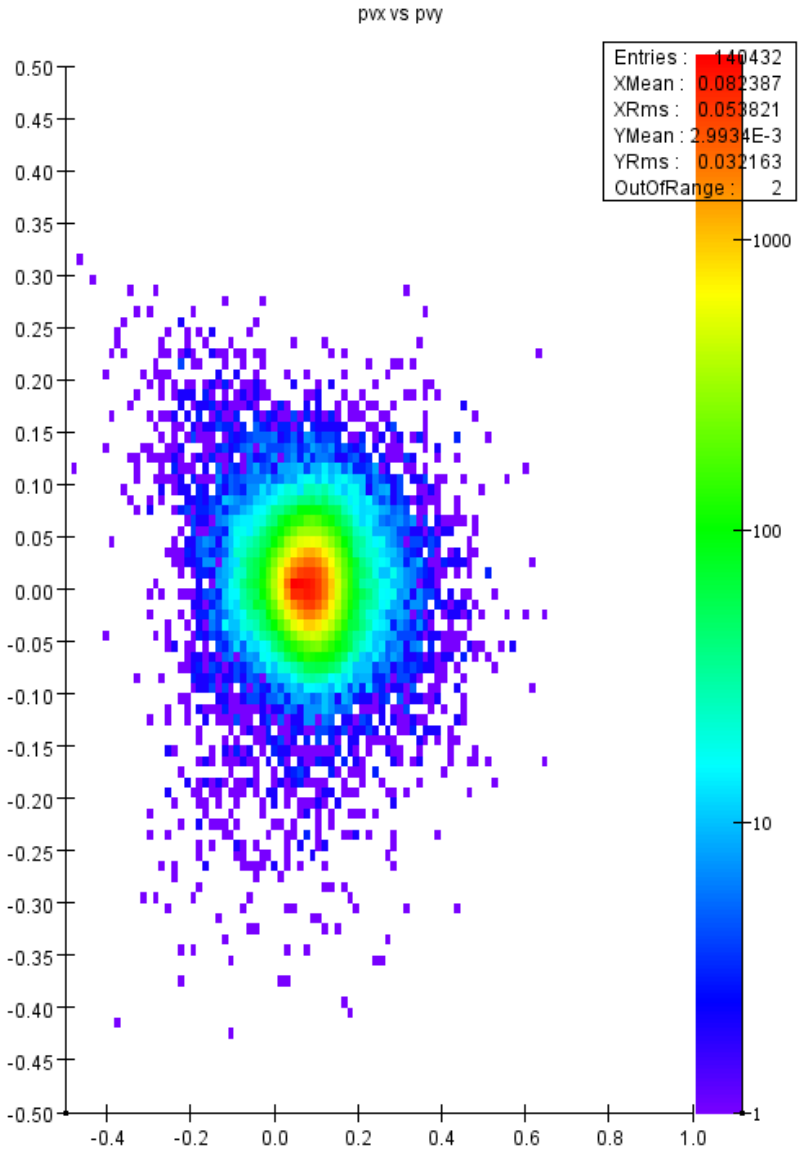


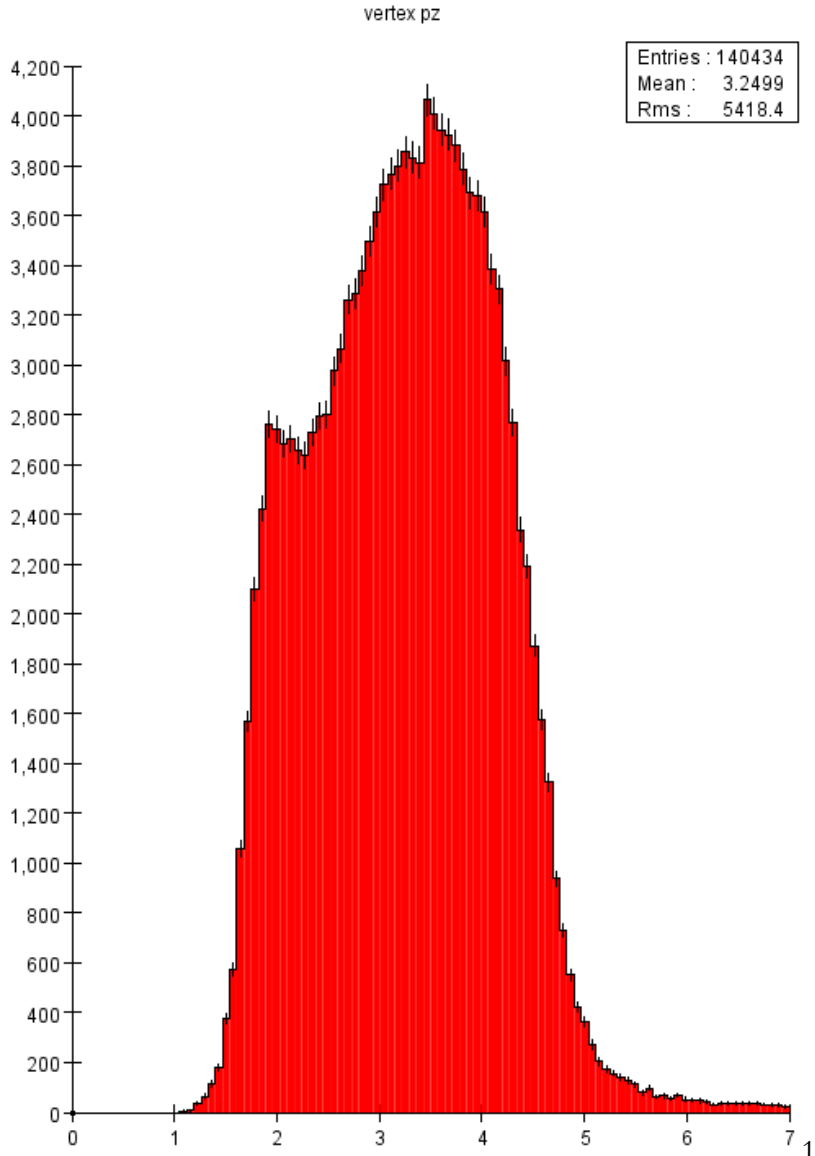






Vertex Momentum ("background")





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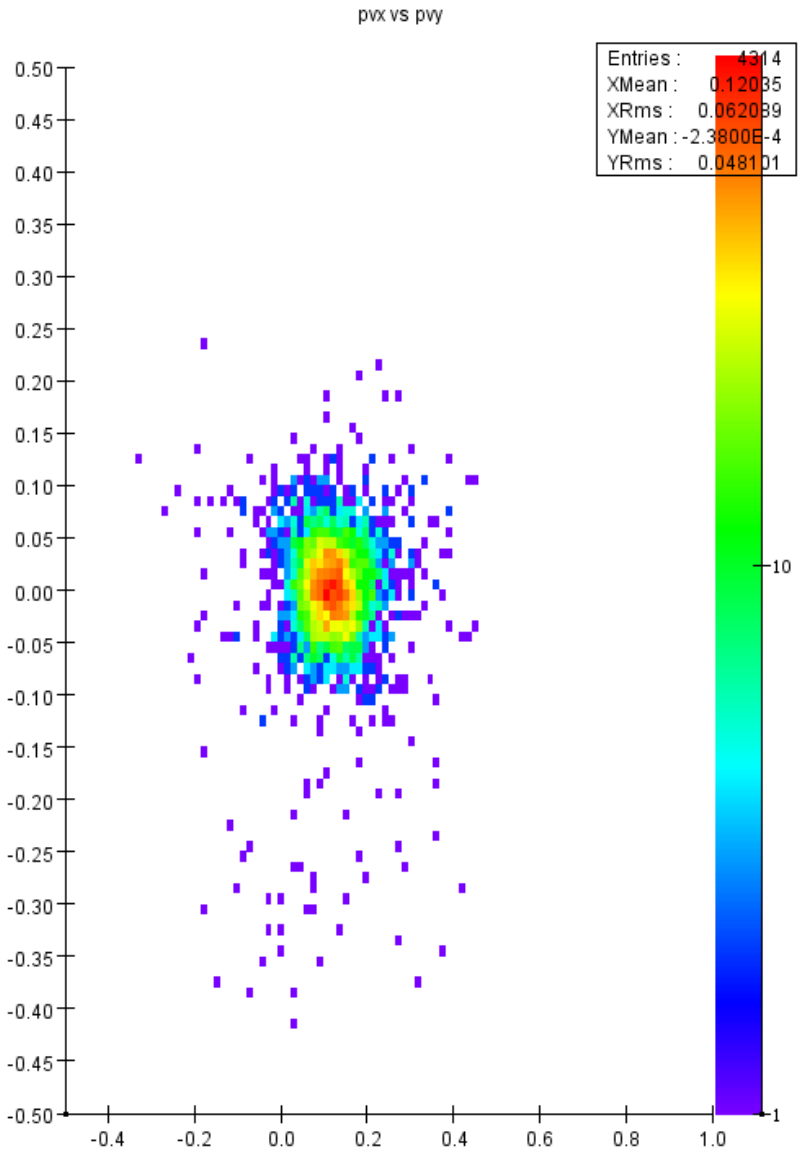
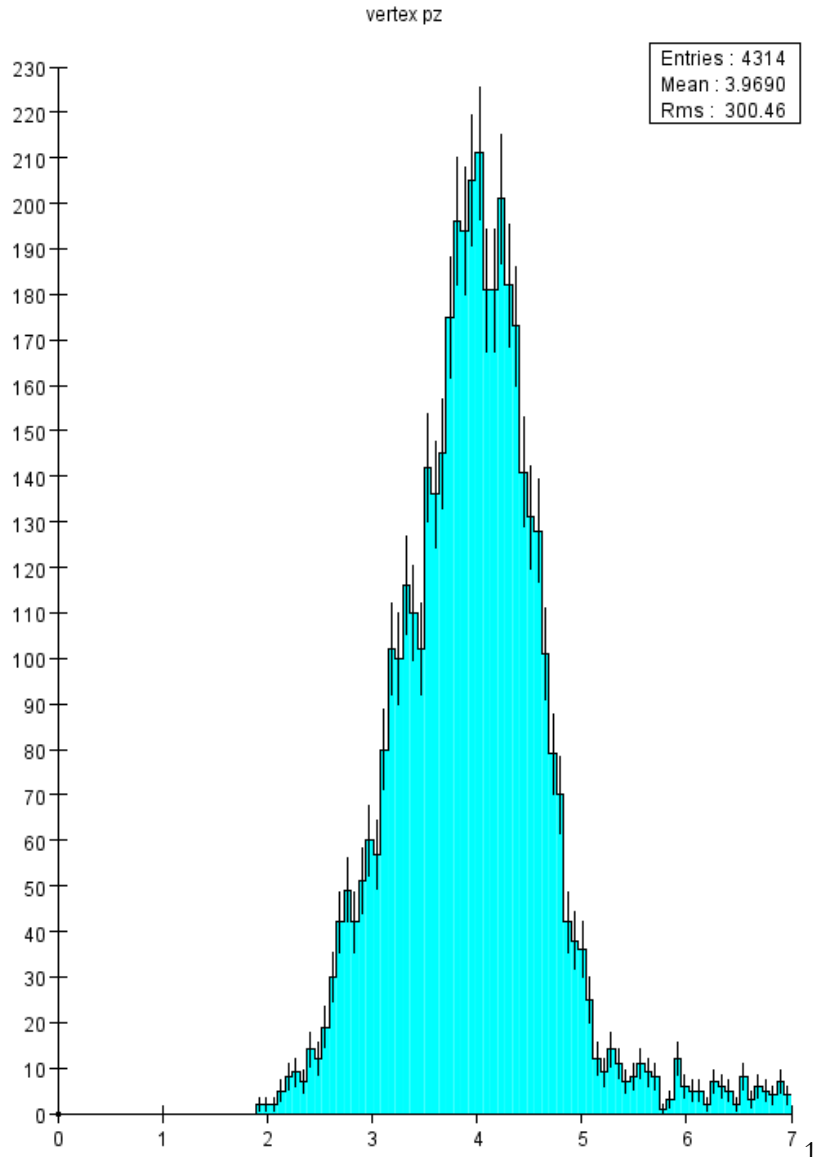
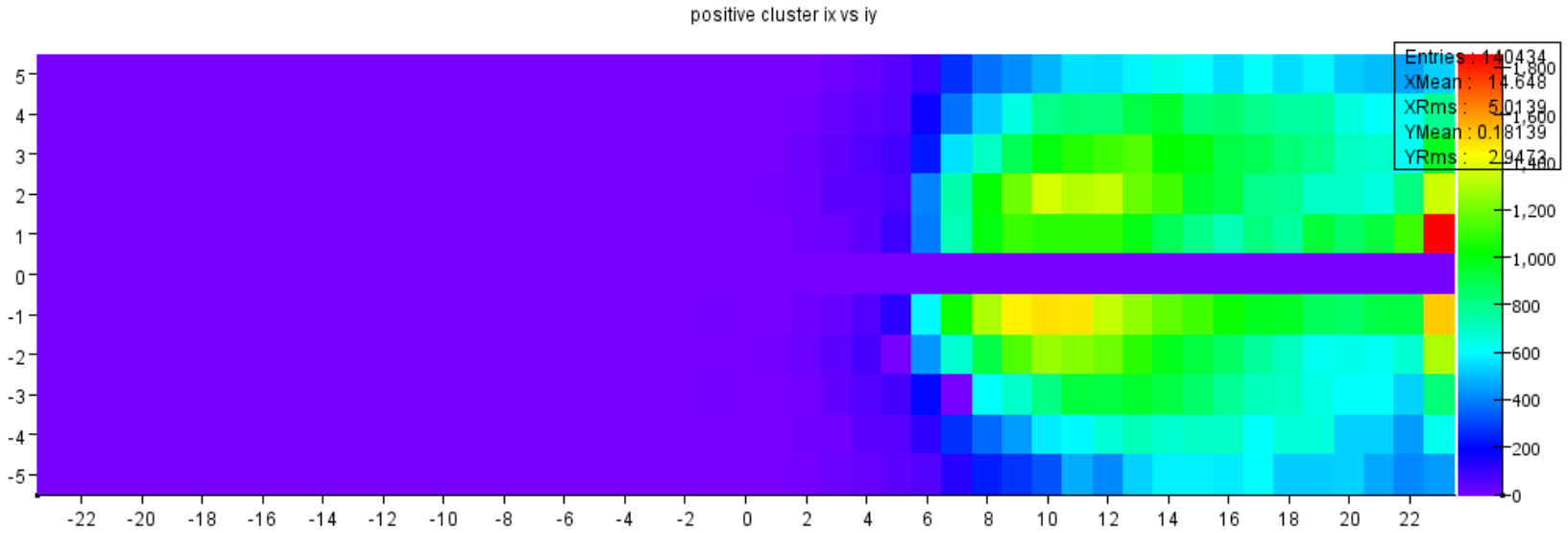
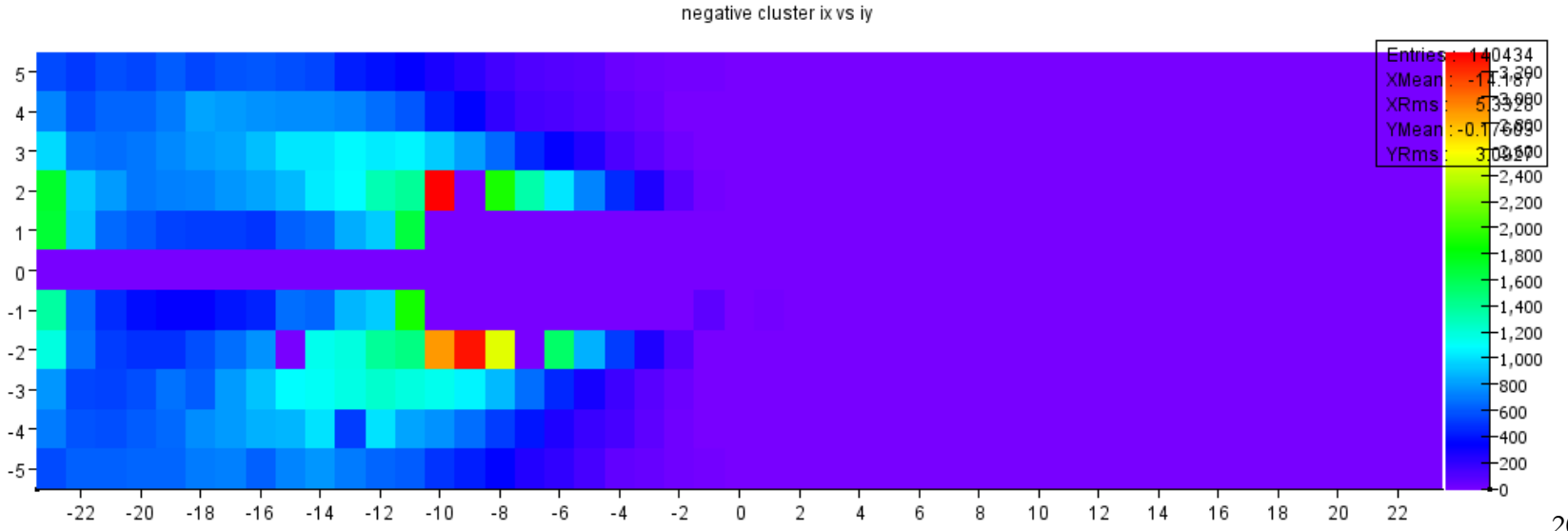




Cluster ix vs iy ("background")





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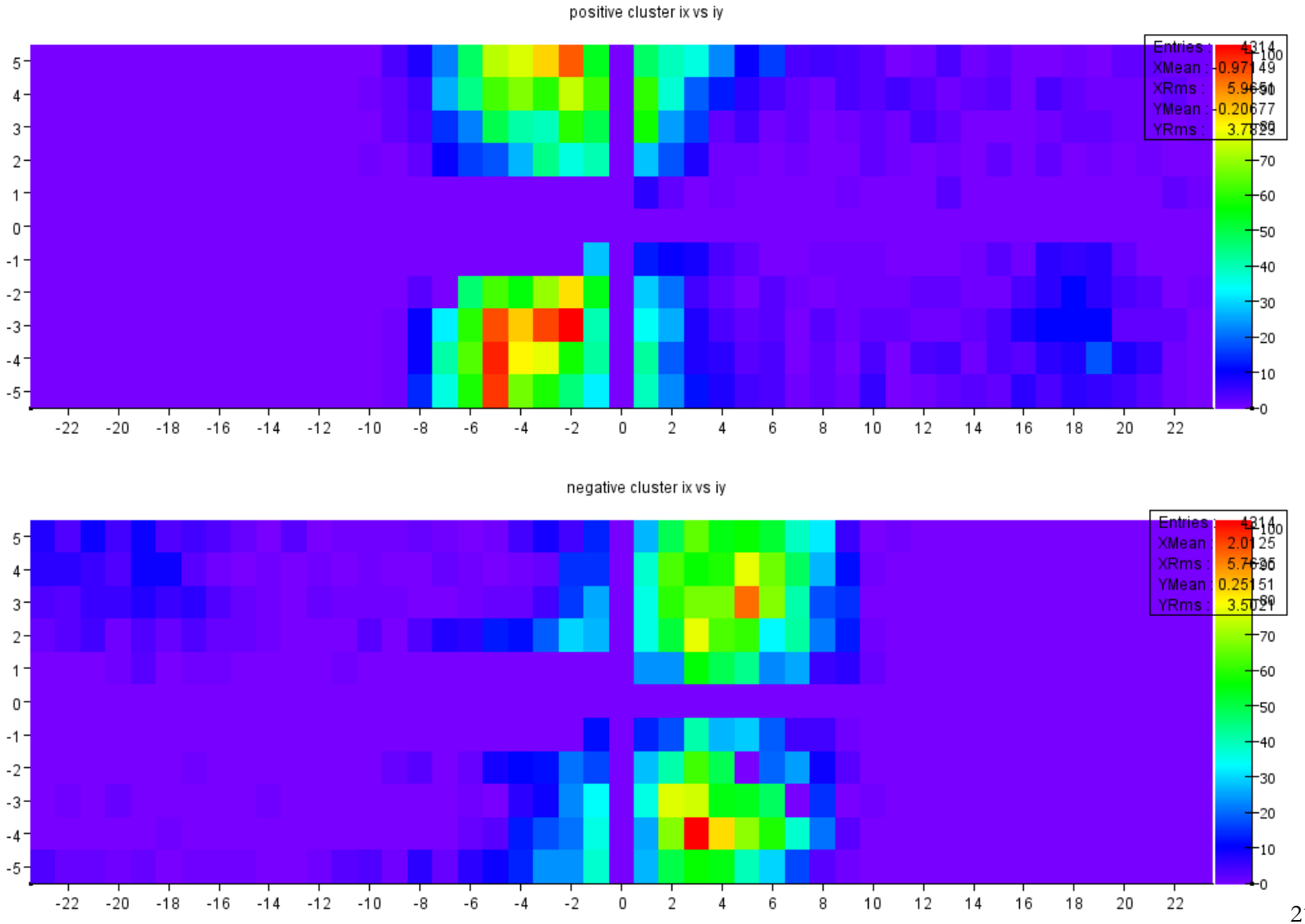
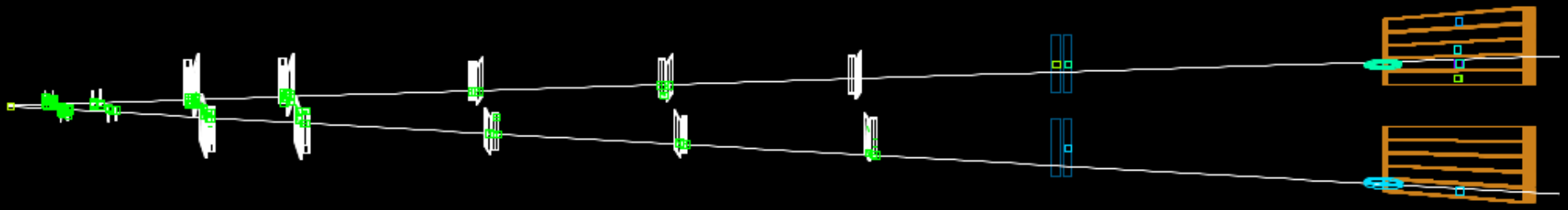
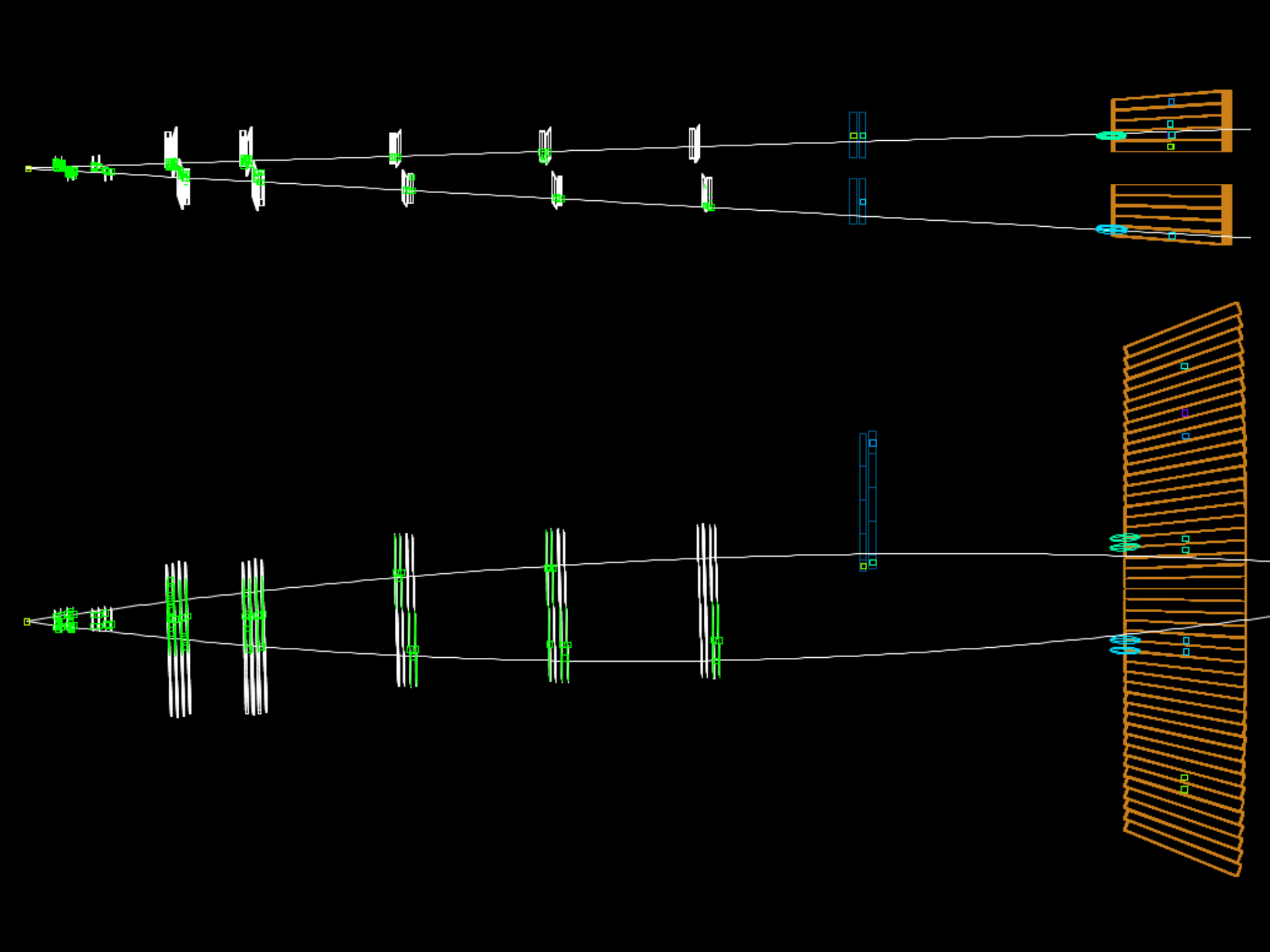
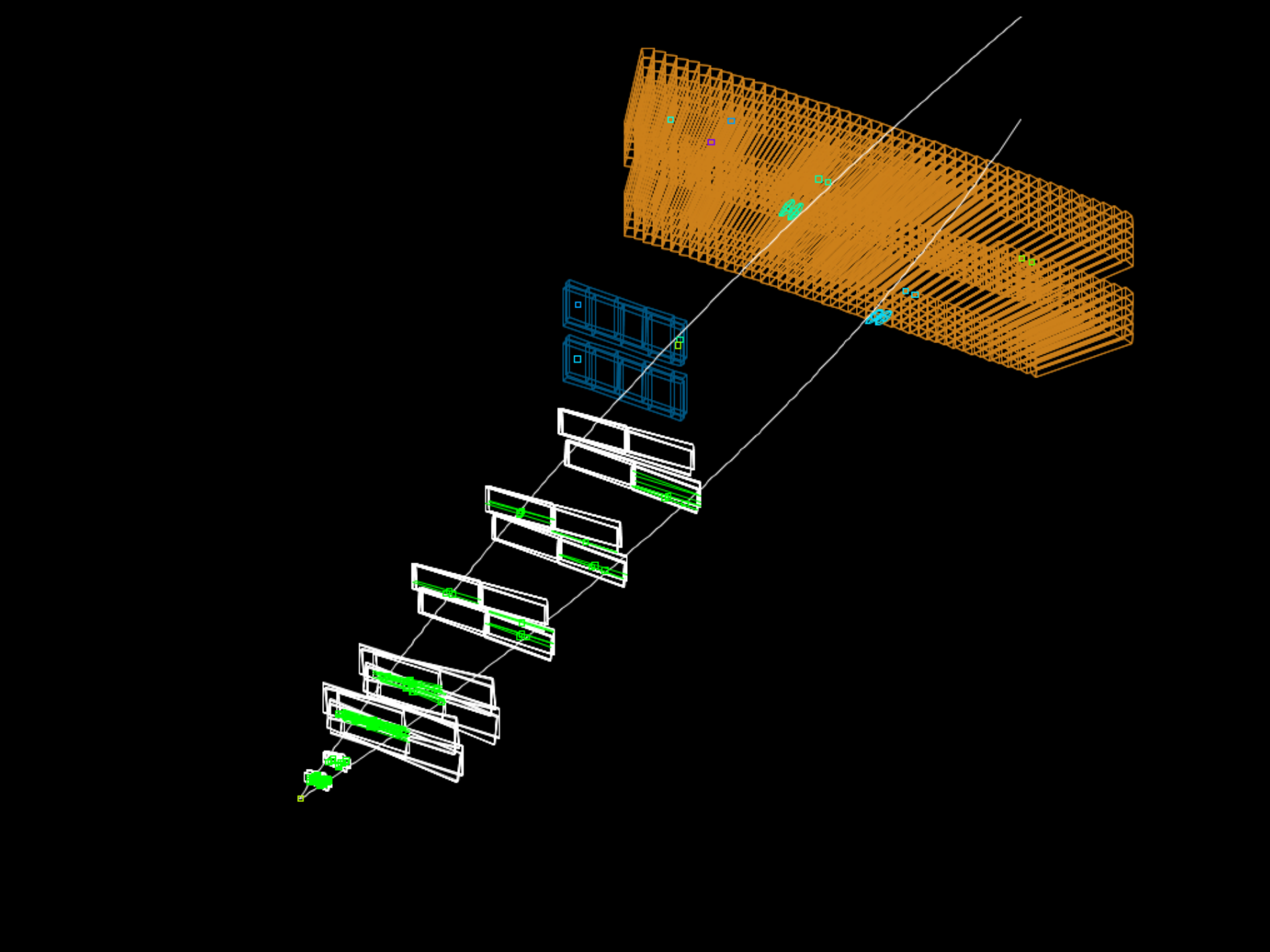


Smoking Gun?

- This is actually exactly what you would expect if you were trying to maximize the opening angle, and hence the mass, of the two-particle system.
- Maximize $\delta\theta_y$ by pushing clusters to top/bottom of the calorimeter
- Maximize opening angle in X-Z plane by selecting positrons that point to the “electron” side and *vice versa*.
- “Cowboy” vs “Sailor”







Bump? What Bump?

- The excess is not formed by obviously bad events
- Physics?
  - $f_0(600)$ (aka σ)
- Detector acceptance?
  - Trigger and/or geometrical acceptance sculpting the inclusive $\mu^+\mu^-$ / $\pi^+\pi^-$ pair spectra.
- Both?
  - Trigger and/or geometrical acceptance sculpting the $\rho \rightarrow \pi^+\pi^-$ invariant mass spectrum.
- New Physics?

ρ Event Generators

- Takashi pointed me towards DIPSI

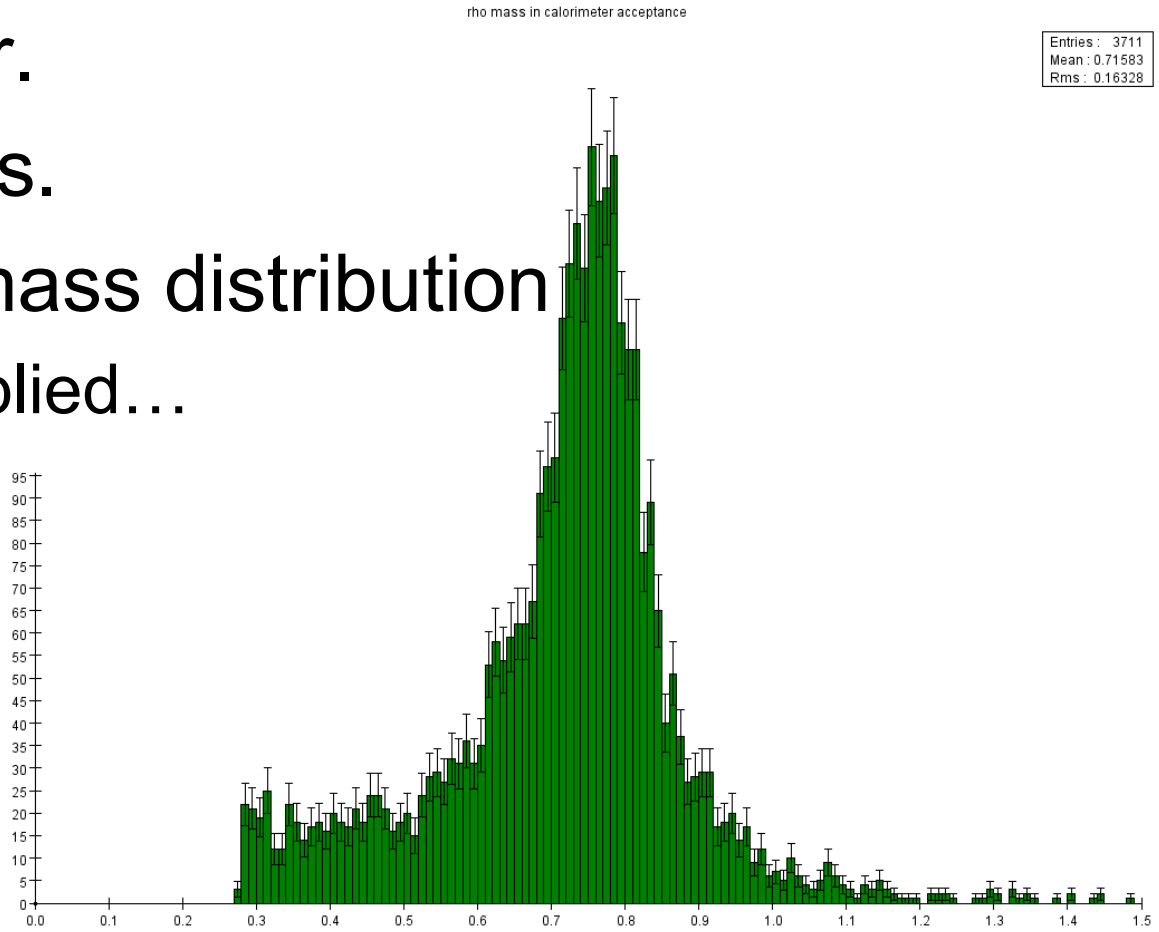
DIPSI: a Monte Carlo generator for elastic vector meson production in charged lepton-proton scattering

M. Arneodo[a], L. Lamberti[b] and M. Ryskin[c]

  - Took quite some time to locate the FORTRAN source from the last millennium.
  - Took even longer to get a working version of cernlib, patchy, etc. compiled and installed.
  - Generated a sample of 10 million $\rho \rightarrow \pi^+\pi^-$ events
- Stepan contacted Derek Glazier at Glasgow
  - Generated 100k events using CLAS12 generator

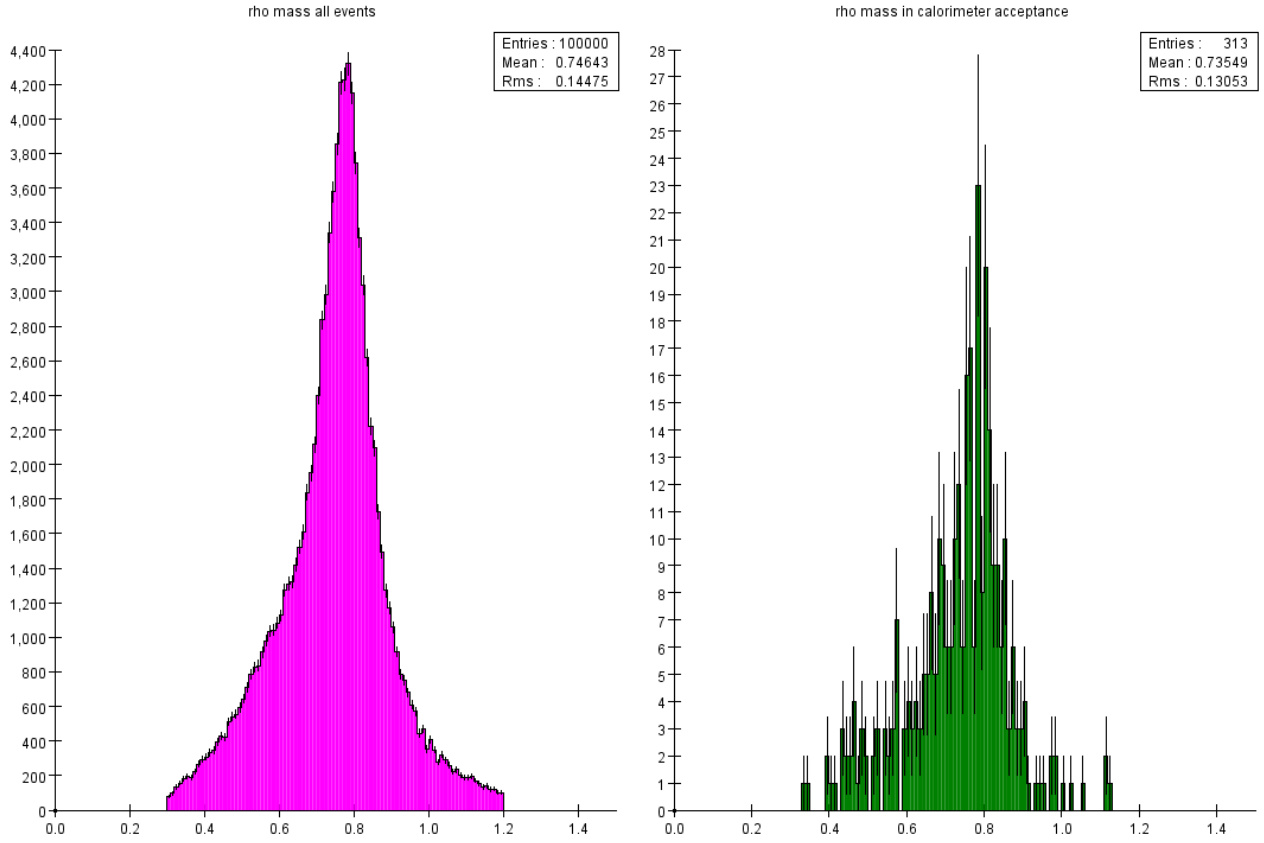
DIPSI Analysis

- Processed events through slic
- Select events where both the π^+ and π^- showered in the calorimeter.
- Plot MC rho mass.
- No sculpting of mass distribution
  - but no trigger applied…



CLAS12 Event Analysis

- Processed 100k events through slic.
- Same simple analysis



Bump? What Bump? Redux

- It appears that we have geometrical acceptance for $\rho \rightarrow \pi^+\pi^-$ events
- "Bump" not obviously caused by sculpting of rho mass.
  - Events need to be processed through the full chain to ensure no trigger bias.
  - Also begs the question why we don't see the rho!

Path Forward

- Excess appears to be real.
- Is it physics?
  - If so, what is it?
  - If not, what is causing it?
- How do we eliminate it?
- How do we use it for analysis?
- 2019 10% Data Reconstruction Pass coming up.
- What minimal set of output collections do you need to perform this analysis?
- Is there any missing information that would clear this up?