ProtoDUNE-SP Beamline Calibration

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ProtoDUNE-SP Beamline Calibration

Motivation

- Improve the momentum and TOF calibration – fine tune
- Obtain the momentum scale and systematic uncertainty
- Needed by cross section analyses and perhaps for TPC calibration
- Examine beamline performance

  - found some puzzling bands in phase space

ProtoDUNE-SP Beamline Calibration Procedure

- Exploit the proton and kaon mass scales to simultaneously obtain calibration for TOF and p.

$m = \frac{\mathrm{p}}{\mathrm{c}}\sqrt{\frac{t^2}{t_l^2} - 1}$, where t is the TOF, t_l is the time light travels between the TOF beam monitors (d = 28.575 m) and p is the momentum.

- Assume additive correction for TOF-> $t - \Delta t$, and multiplicative for the momentum p-> αp. Good model for small corrections.

- For two protons with reconstructed TOF and momenta $(t_1, p_1), (t_2, p_2)$

$\frac{m^2}{m^2} = \frac{\alpha^2 p_1^2}{\alpha^2 p_2^2}\frac{\left((t_1-\Delta t)^2 - t_l^2\right)}{\left((t_2-\Delta t)^2 - t_l^2\right)} = 1$, where α cancels allowing to determine Δt.

- Similarly, for proton and kaon with the same momentum p with t_p, t_K

$\frac{m_p^2}{m_K^2} = \frac{\alpha^2 p_p^2}{\alpha^2 p_K^2}\frac{\left((t_p-\Delta t)^2 - t_l^2\right)}{\left((t_K-\Delta t)^2 - t_l^2\right)}$, and α cancels again.

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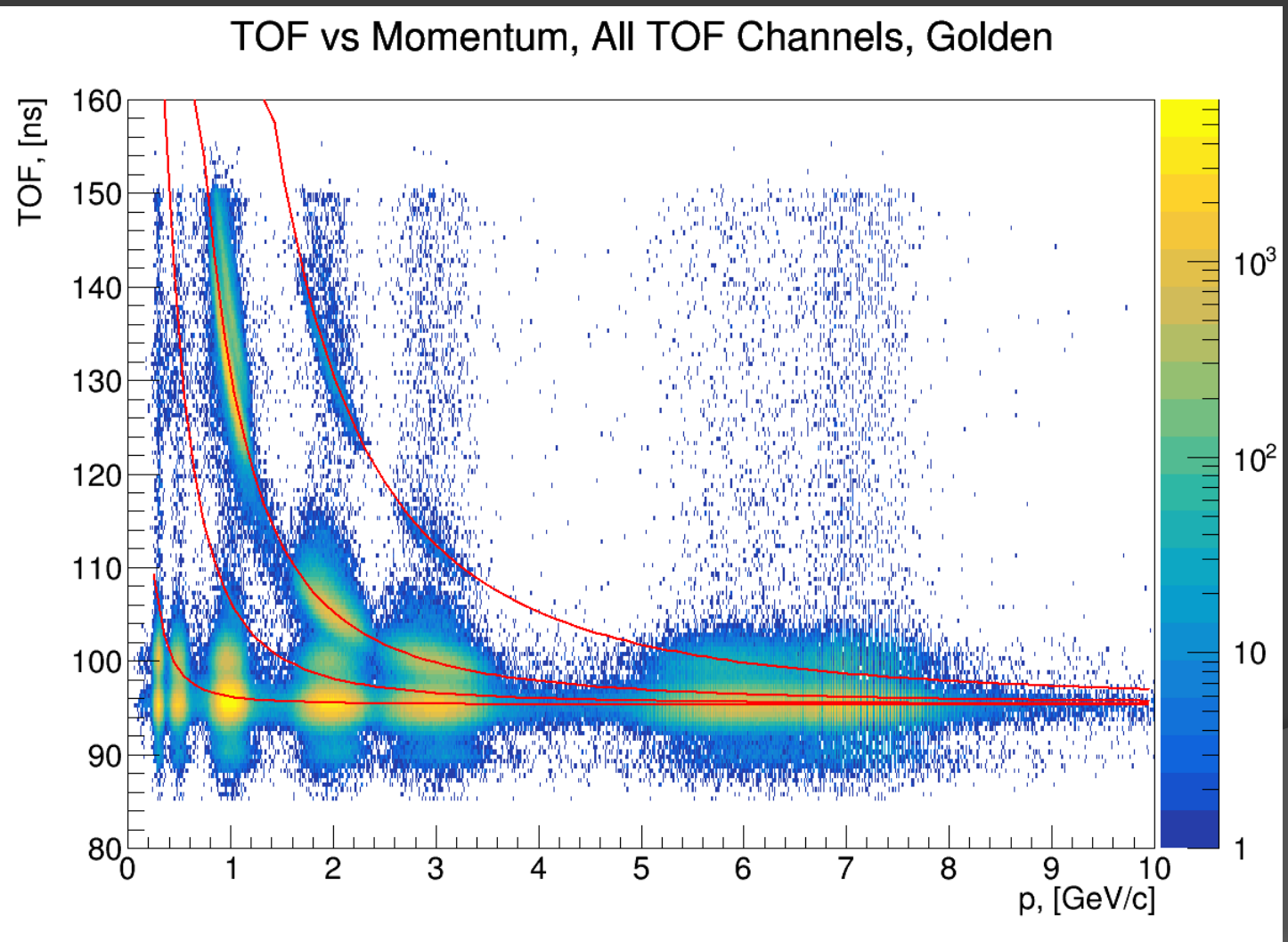
- Assume additive correction for TOF-> $t - \Delta t$, and multiplicative for the momentum p-> αp. Good model for small corrections.

- In this analysis perform a binned 2-parameter fit $(\alpha, \Delta t)$ where the proton sample is binned in momentum and TOF is obtained for each momentum bin.

- Using 1,2,3,6 GeV runs – EventTree provided by the BI group
- Only GOLDEN events with eventRank = 1.

ProtoDUNE-SP Beamline Data

- Log scale of the color axis – look at the tails



- All TOF Channels

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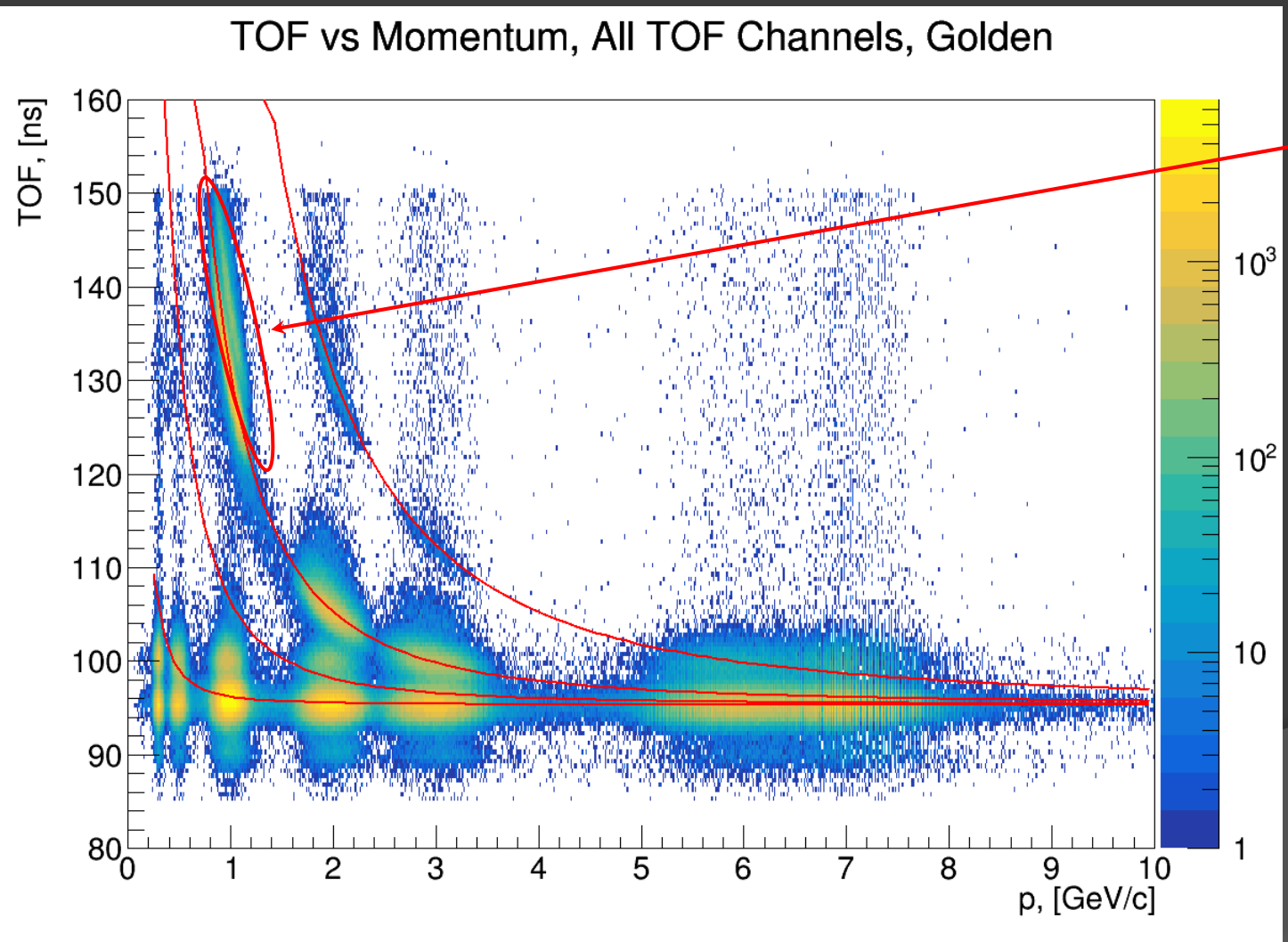

- All TOF Channels
- Extra proton band

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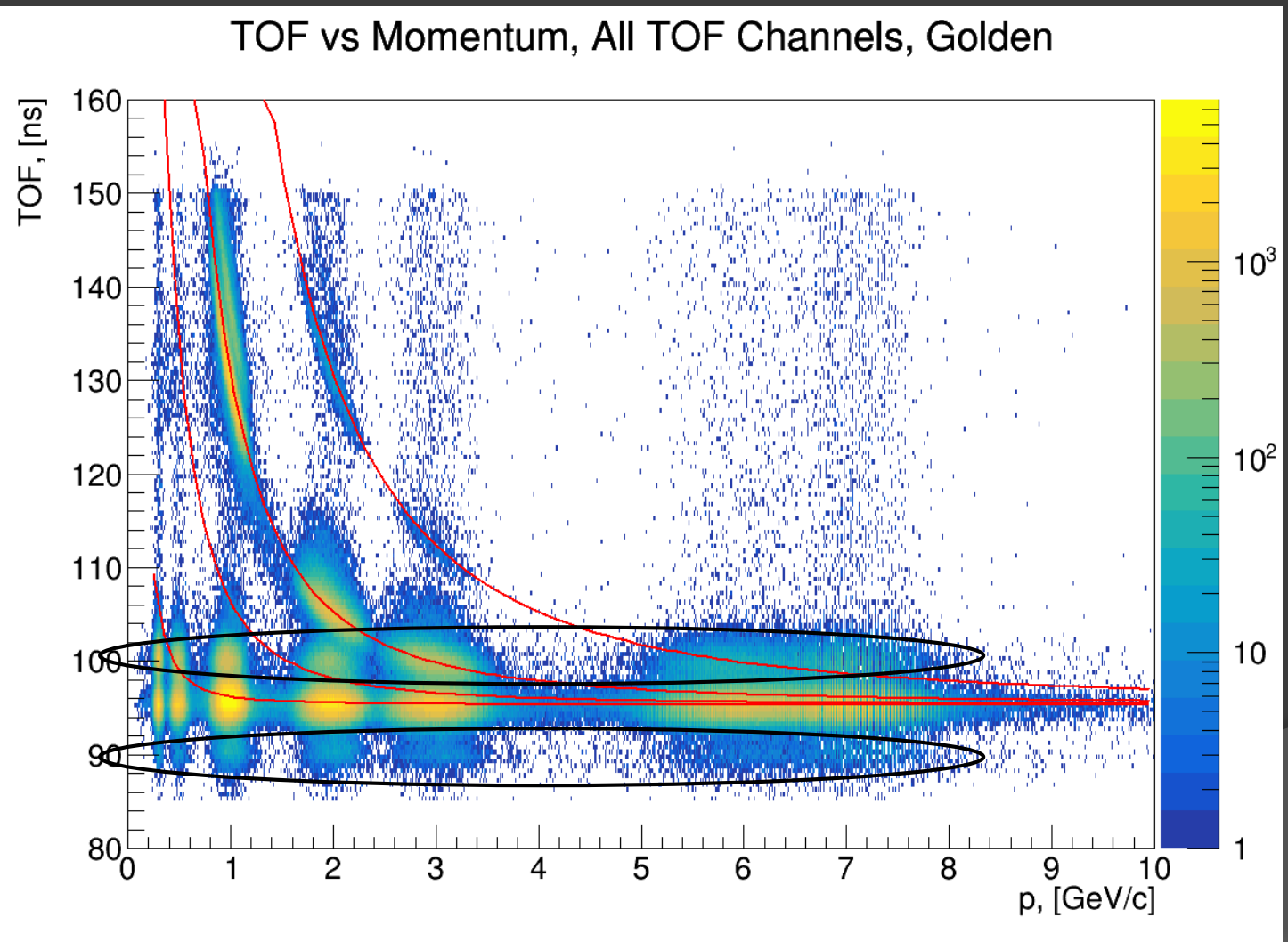

- All TOF Channels
- Extra proton band
- Multiple bands with TOF offset

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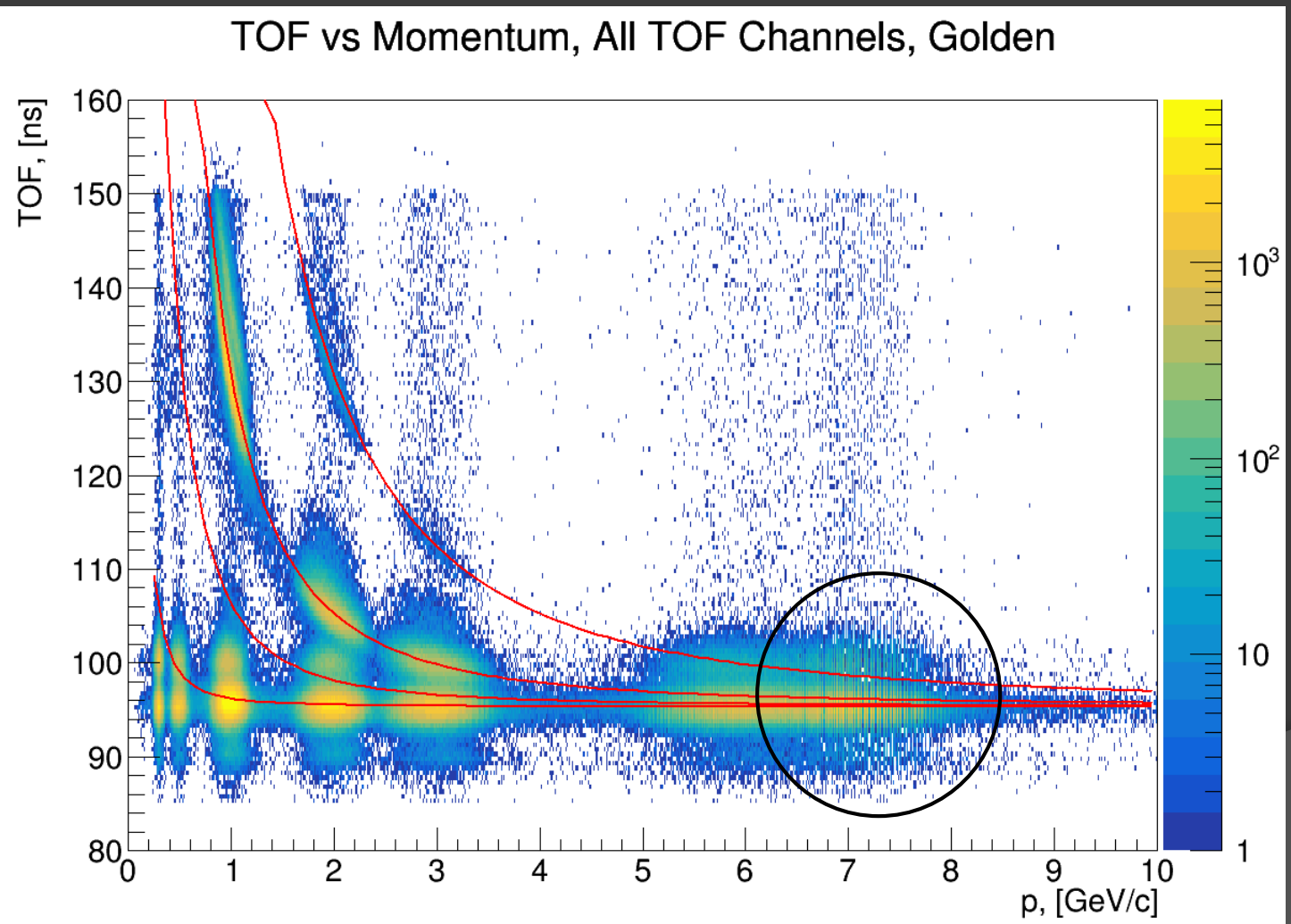

- All TOF Channels
- Extra proton band
- Multiple bands with TOF offset

- Stripes for fine binning.

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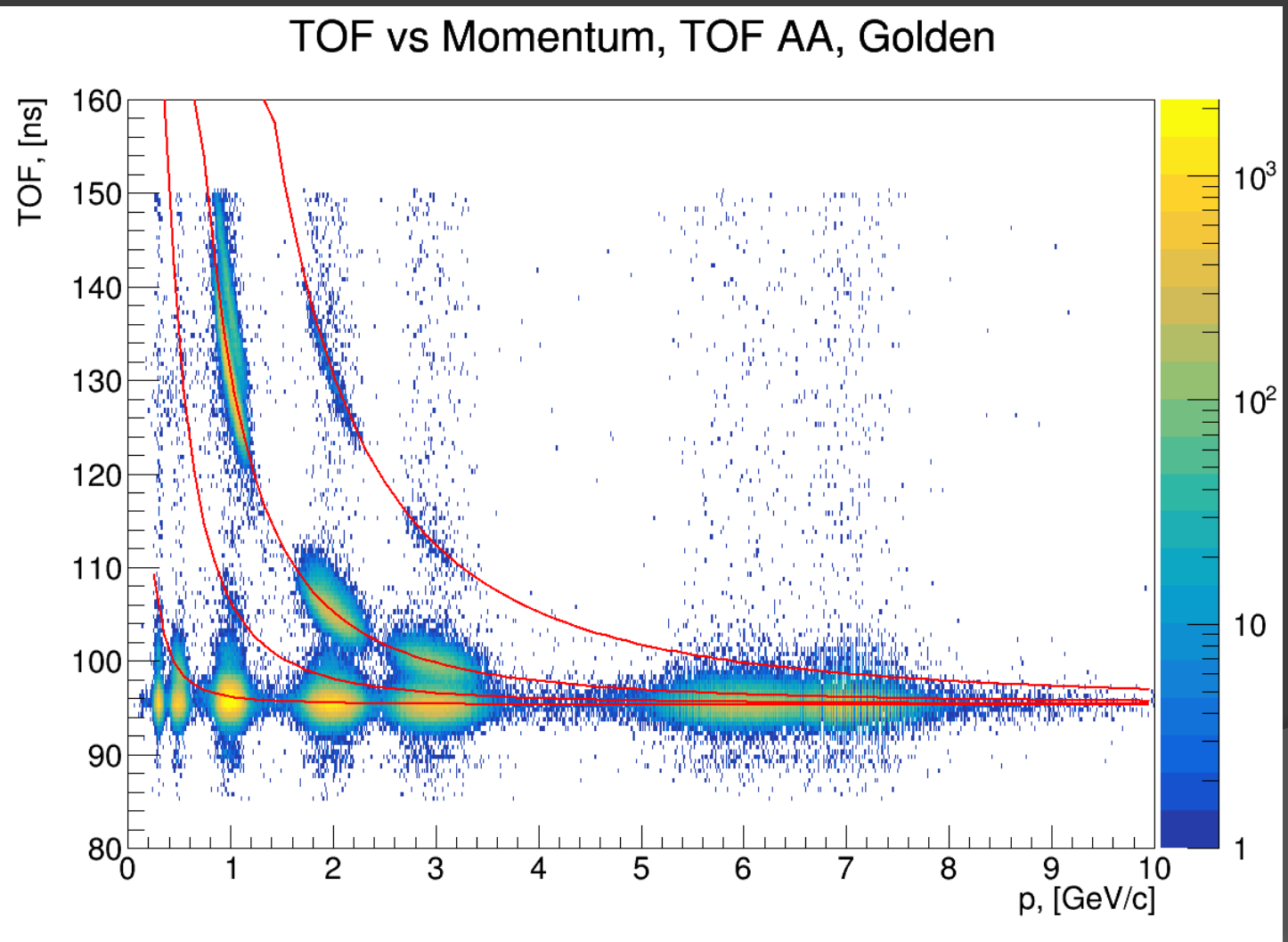

- AA TOF Channels
- Cleanest
- Extra proton band is there.

ProtoDUNE-SP Beamline Data

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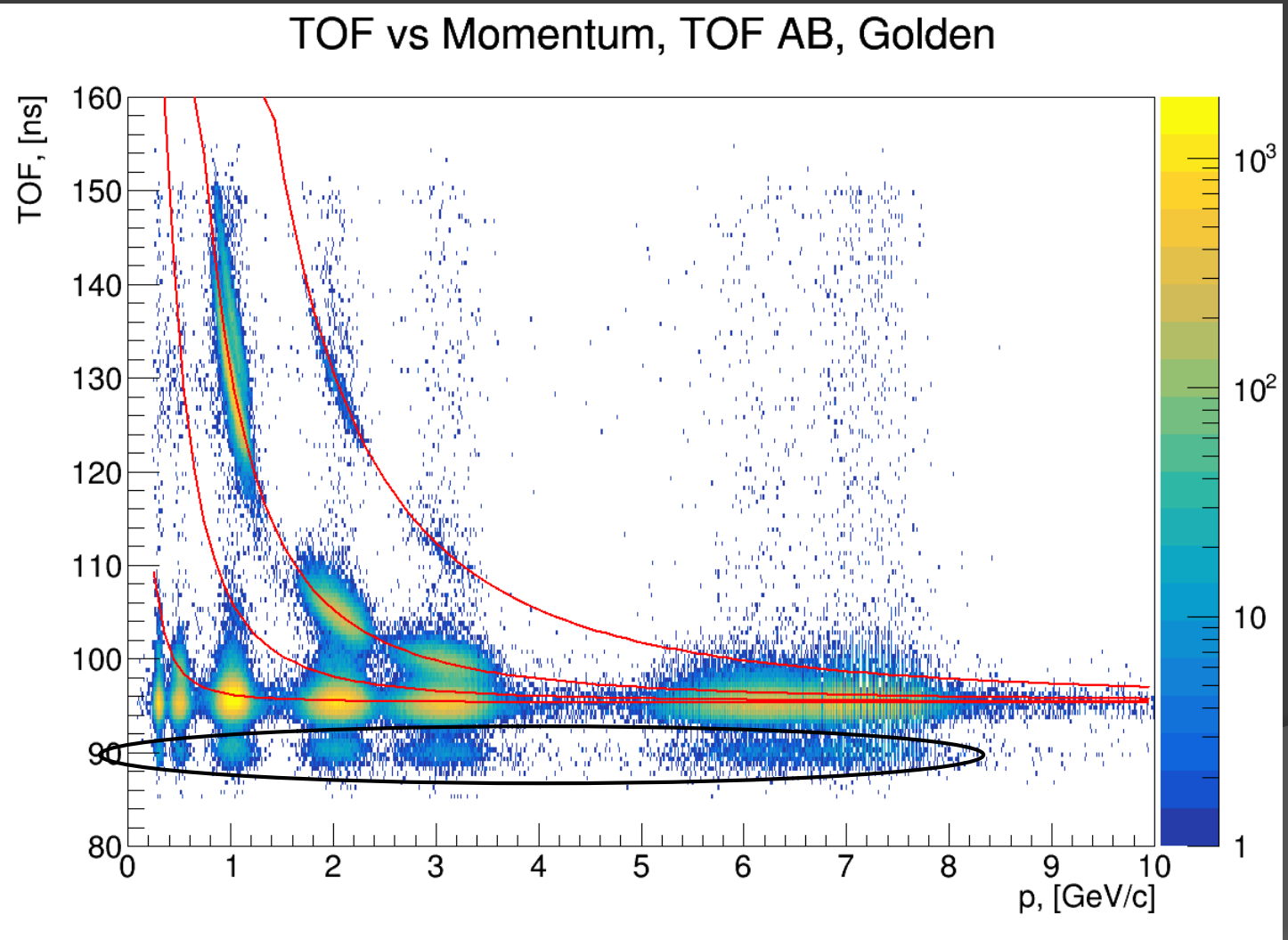

- AB TOF Channels
- Some TOF offset not a problem.
- Extra proton band is there.

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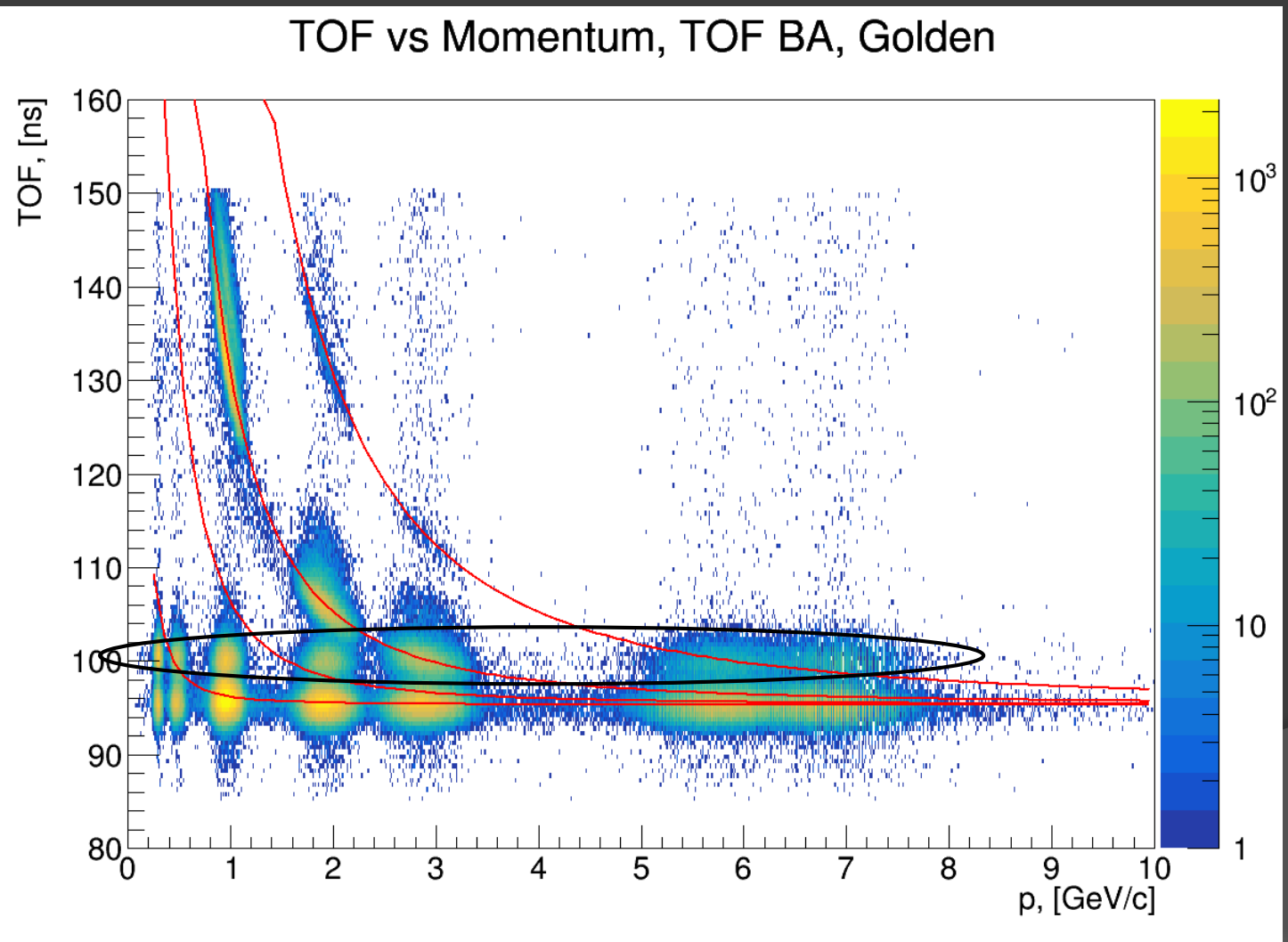

- BA TOF Channels
- TOF offset sample
- Extra proton band is there.

ProtoDUNE-SP Beamline Data

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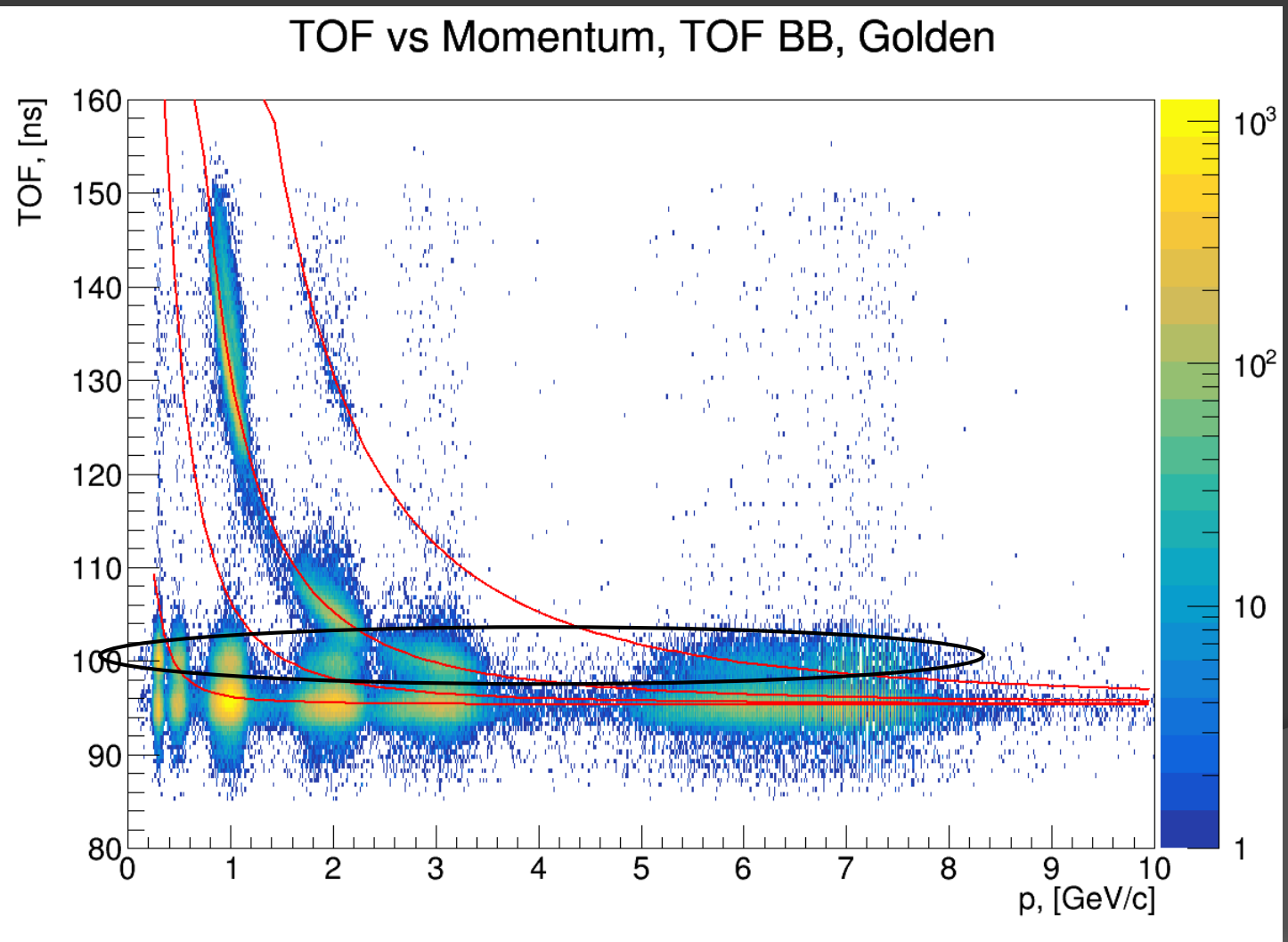

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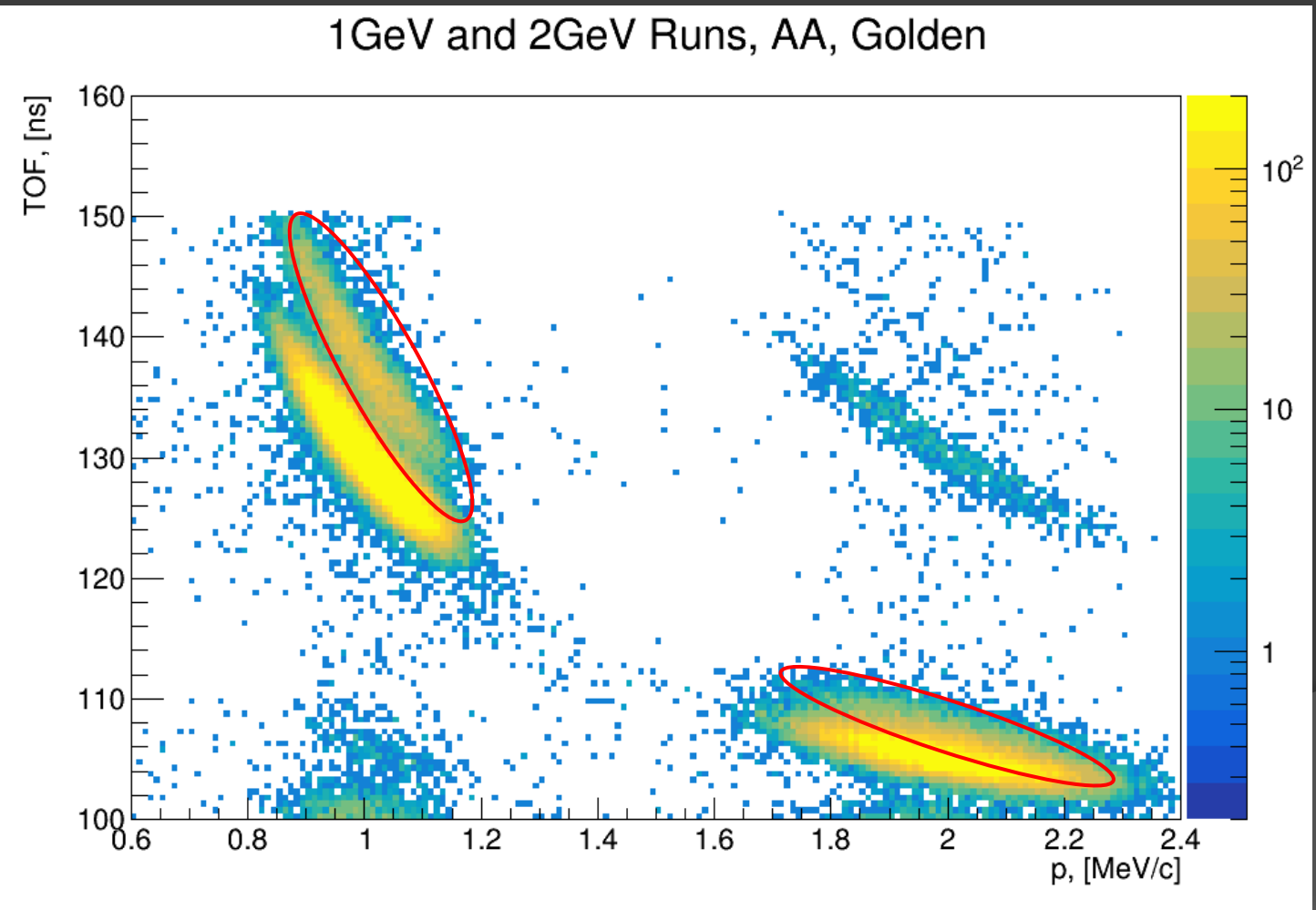

- AA TOF Channels
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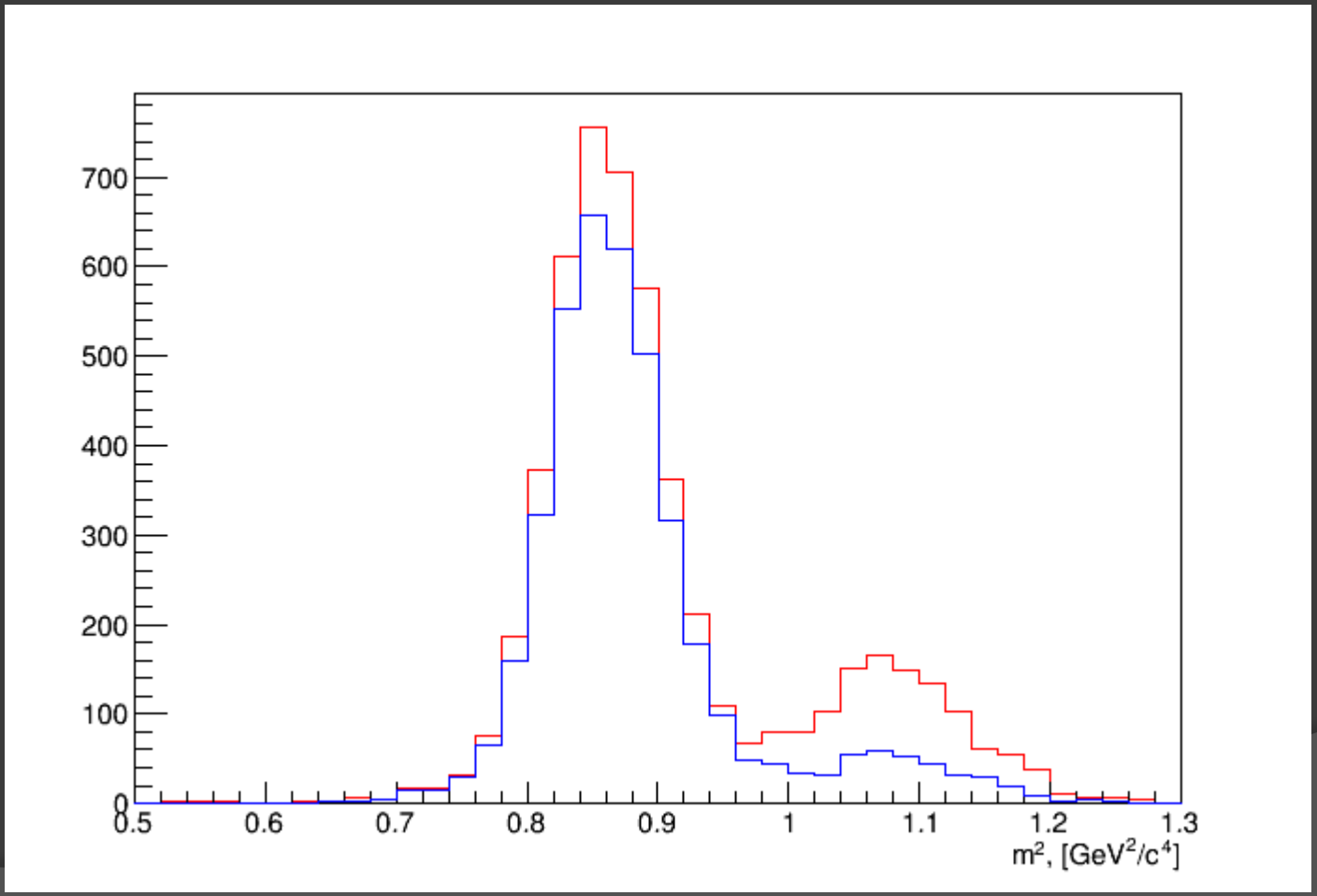
- Extra proton band is there.
- Zoom in for 1GeV and 2GeV runs.

ProtoDUNE-SP Beamline Data

- 1 GeV run proton kinematic region.



- AA TOF Channels
- Cleanest
- Extra proton band is there.
- Zoom in for 1GeV.
- Red multiple reconstructed TOF
- Blue single reconstructed TOF

ProtoDUNE-SP Beamline Data

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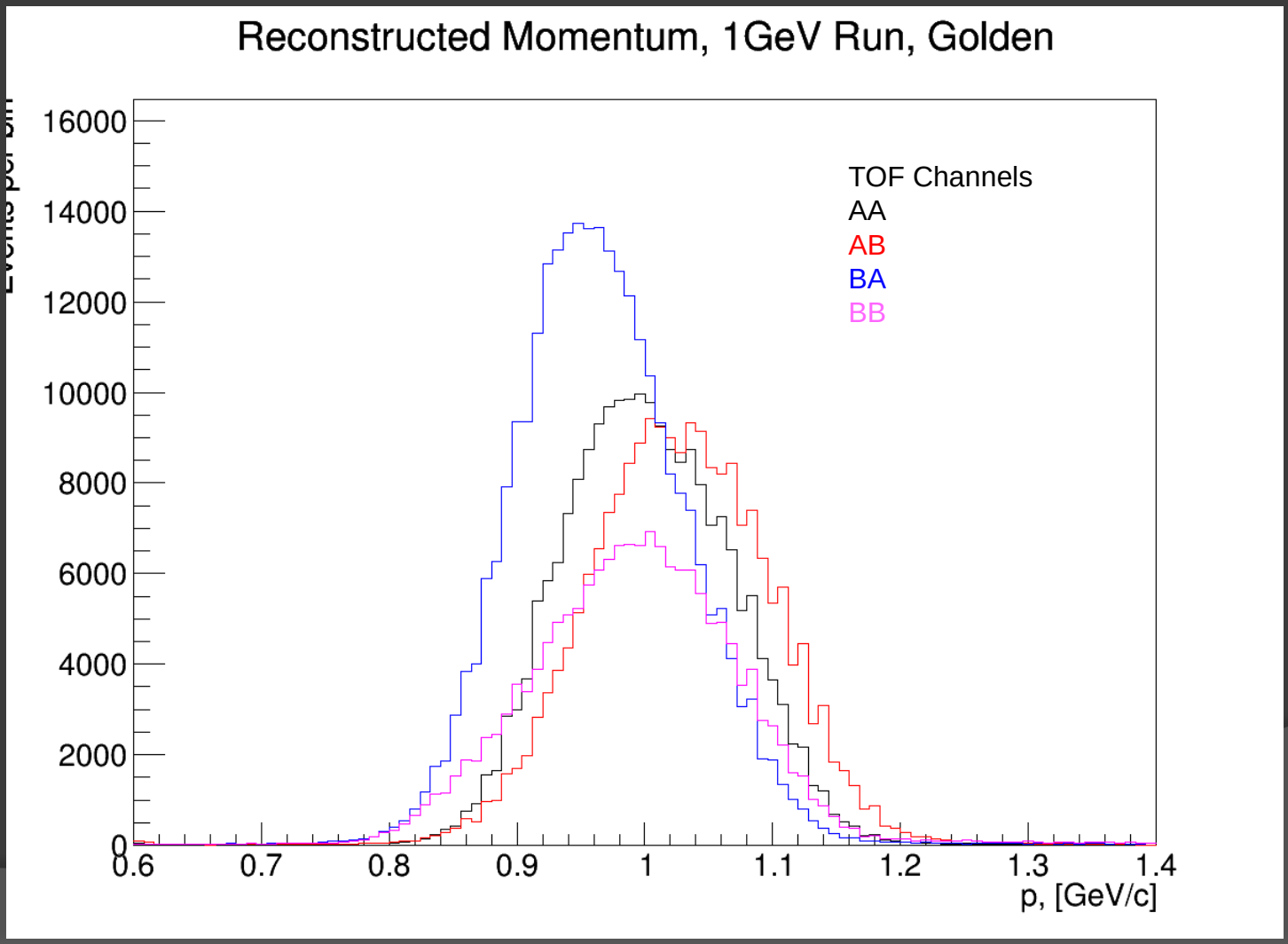

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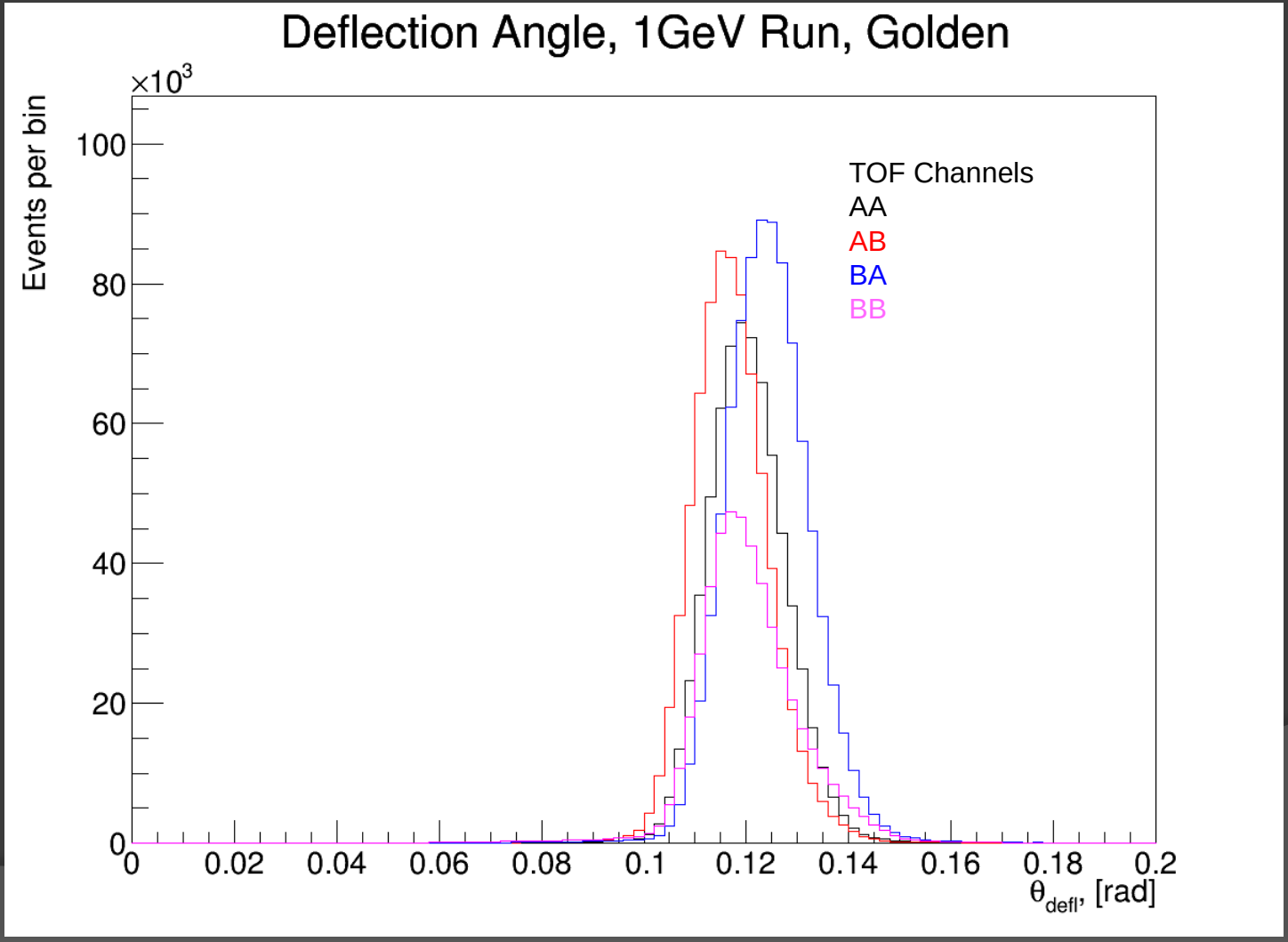

- Different TOF channels sample different deflection angles. Results in different momentum distributions.

A and B channels are physically next to each other.

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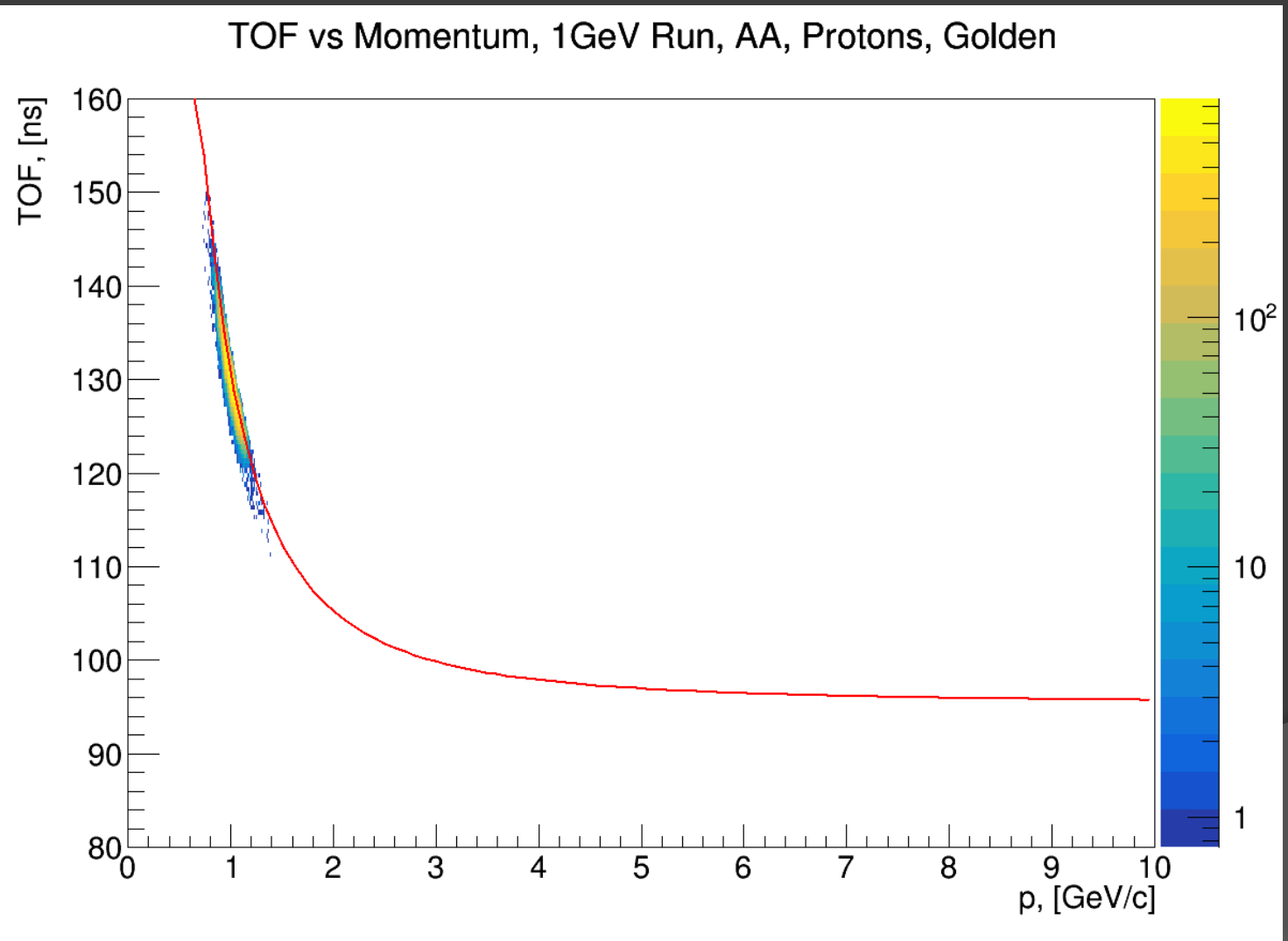
- Using 1,2,3,6 GeV runs – EventTree provided by the BI group
- Only GOLDEN events with eventRank = 1.
- Use only AA channel for this study. Check results for all.

Events Selection

- Select protons and kaons based on mass and Cherenkov – remove the extra band for 1GeV and 2GeV runs



- 50MeV mom Bins for 1GeV and 2GeV runs.
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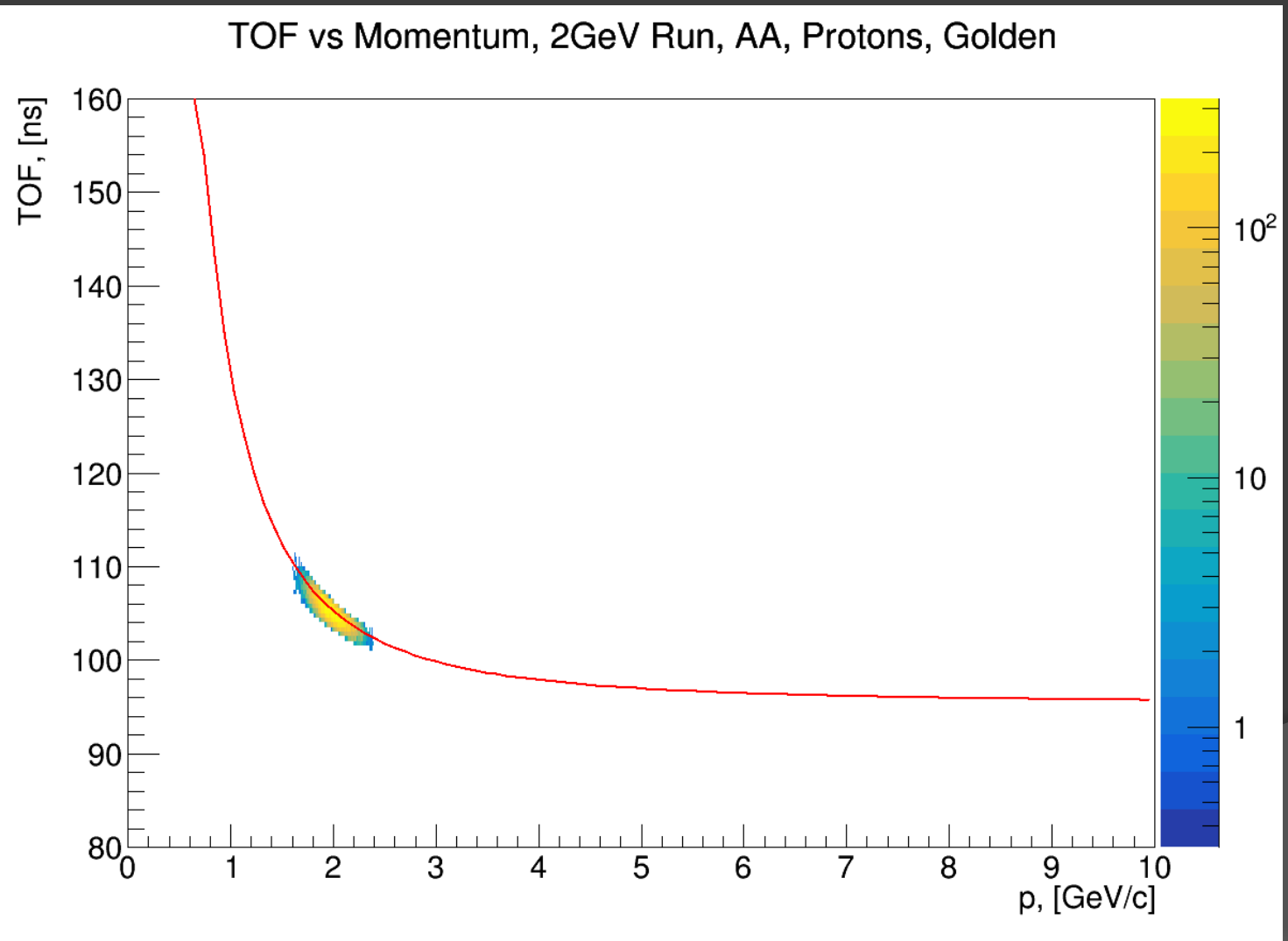

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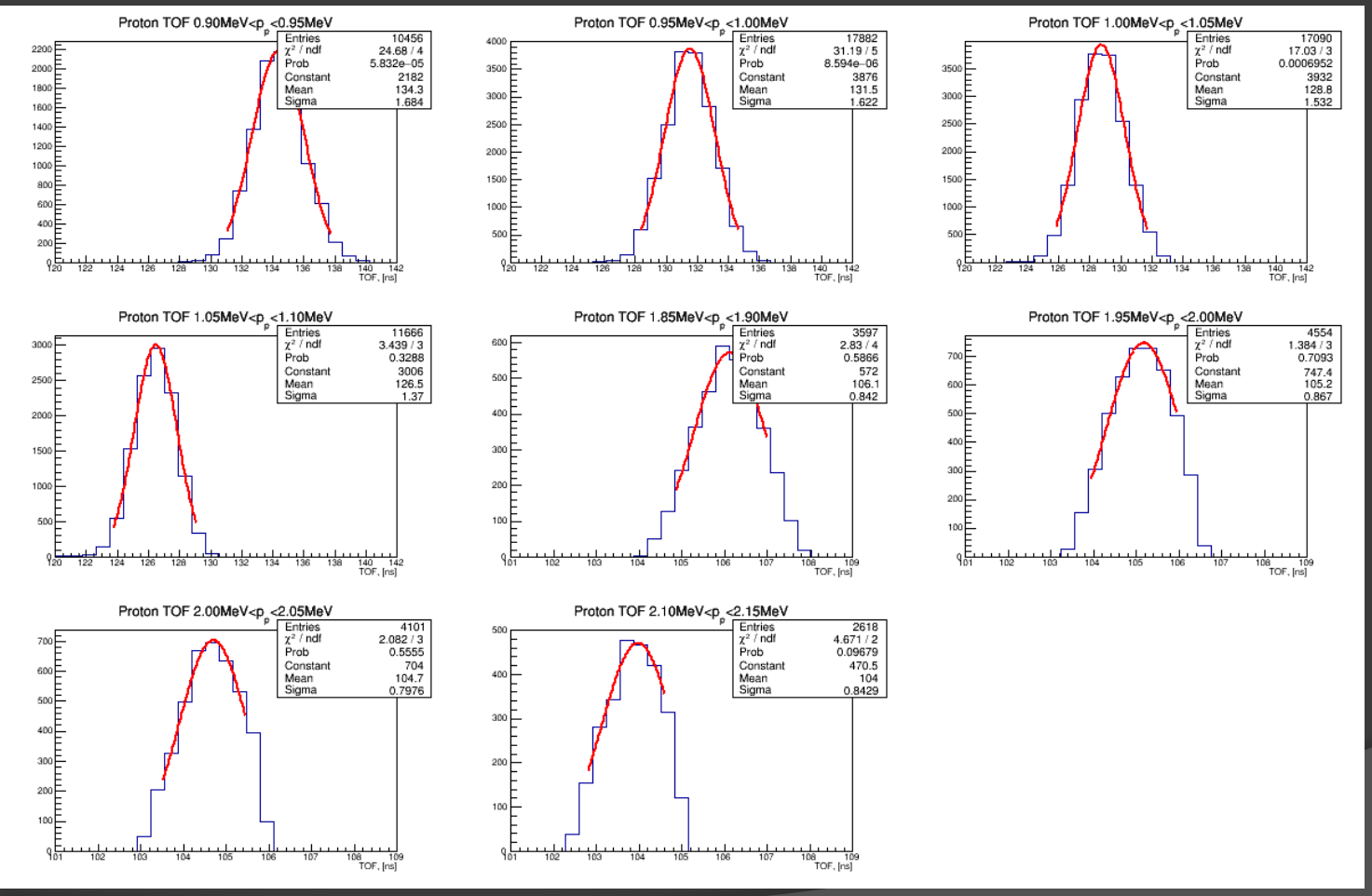
TOF Fits

- Truncated fits to the mass TOF peaks.



- 50MeV mom Bins for 1GeV and 2GeV runs.
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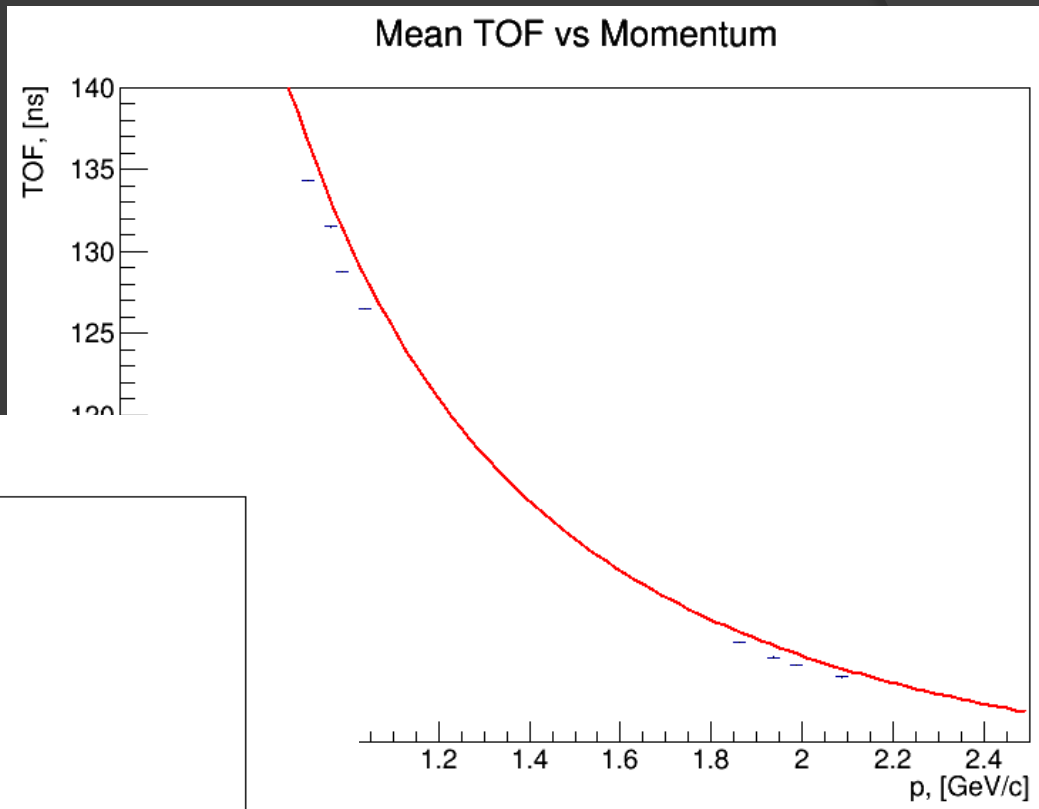
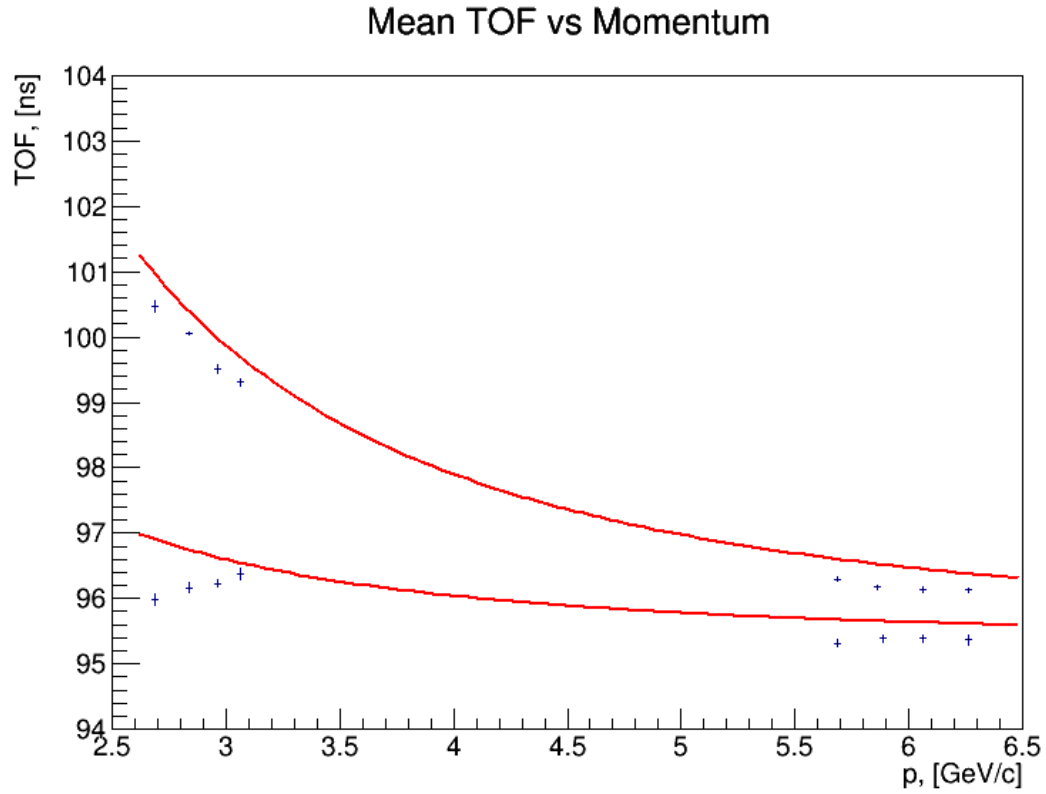
Before Mass Fit

- Red line is the $t = t(p)$ for p, K travelling the distance between the two TOF.





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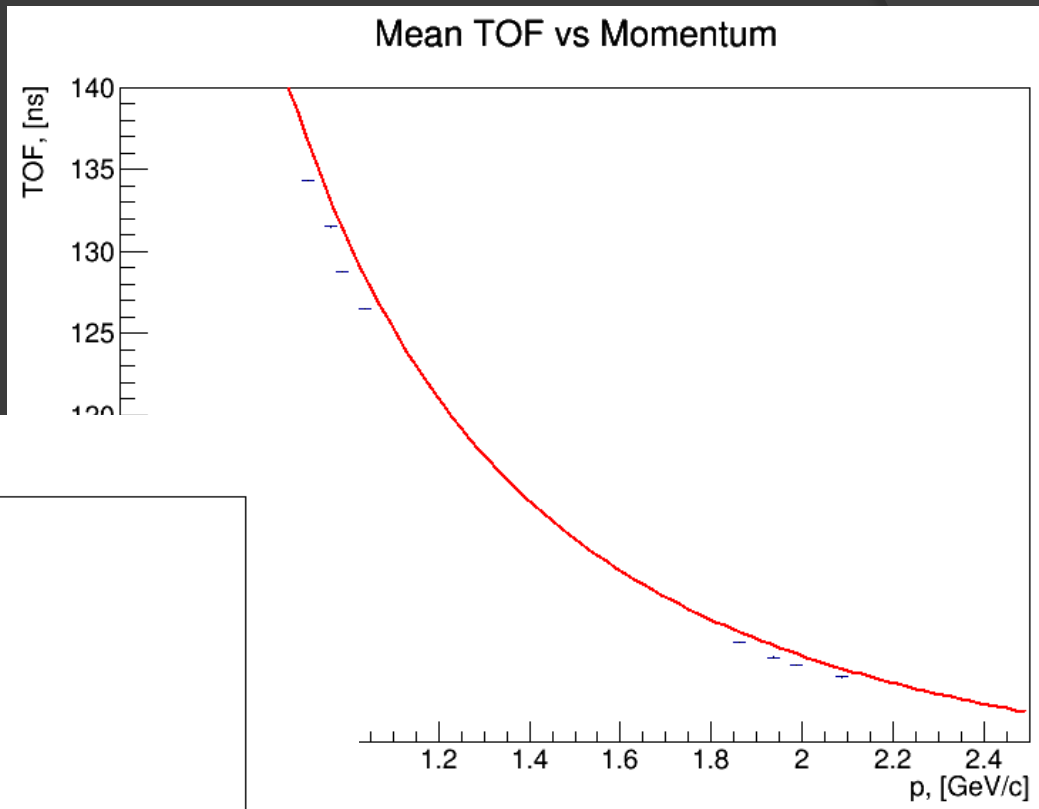
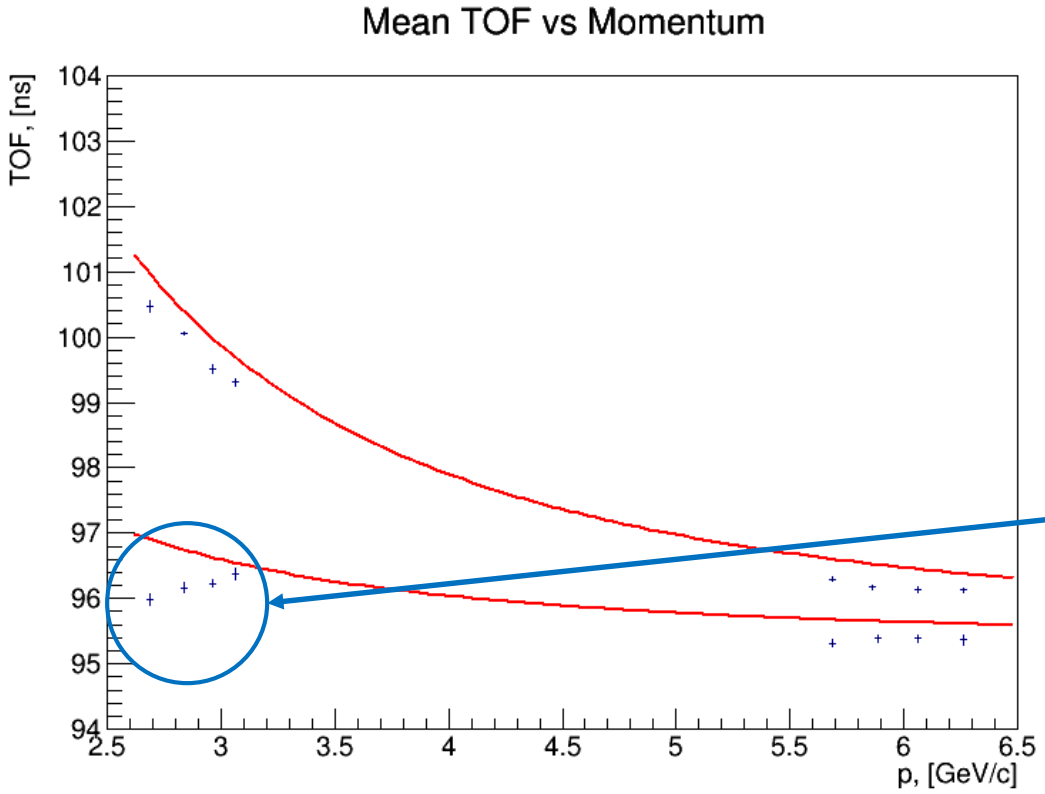


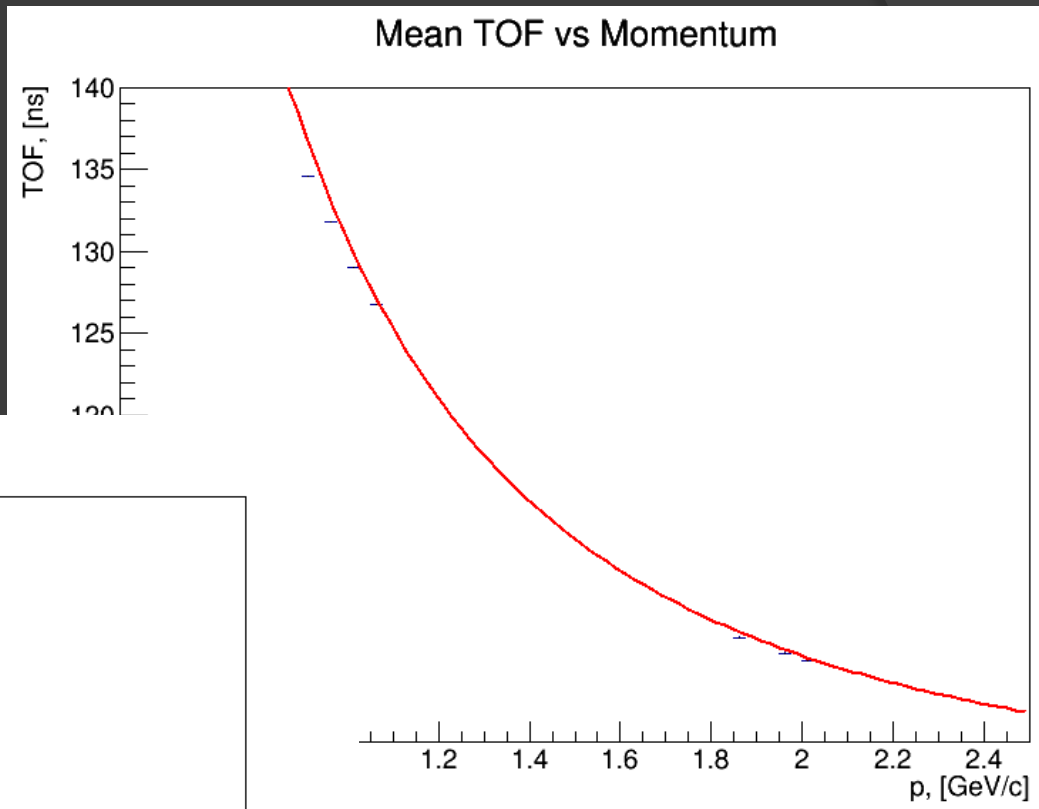


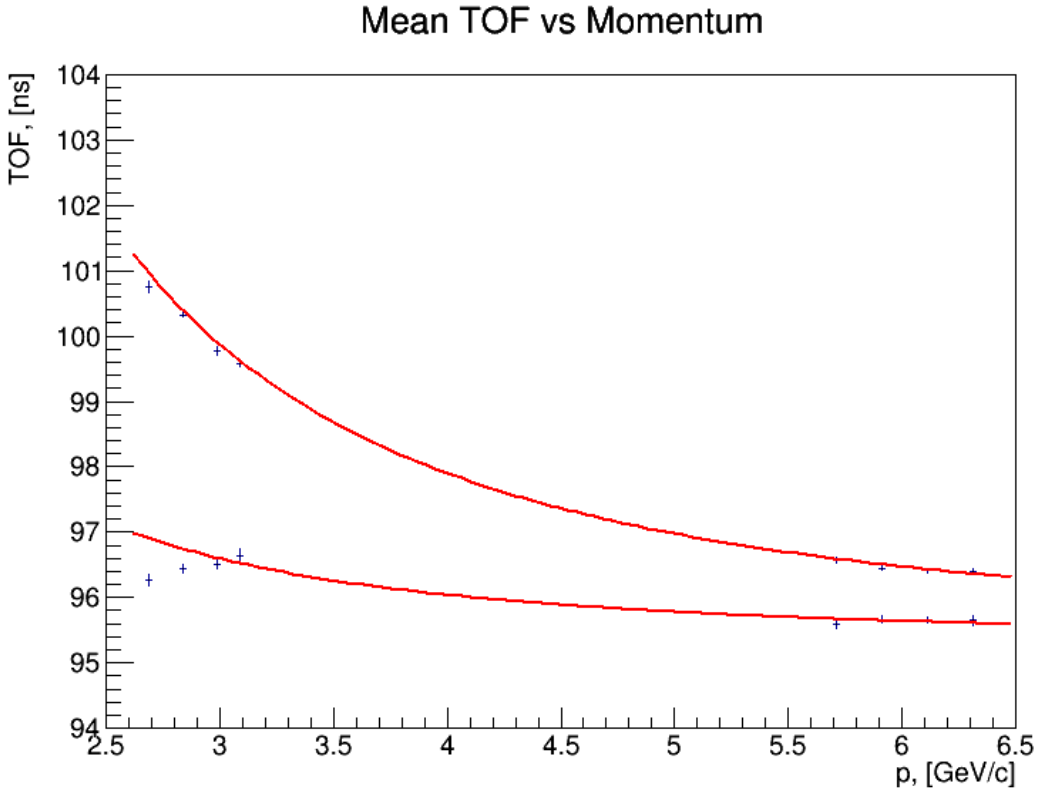
A number of 3GeV kaons likely decay after the DS Cherenkov.

Not used in the mass fit.

After Mass Fit

- Red line is the $t = t(p)$ for p, K travelling the distance between the two TOF.

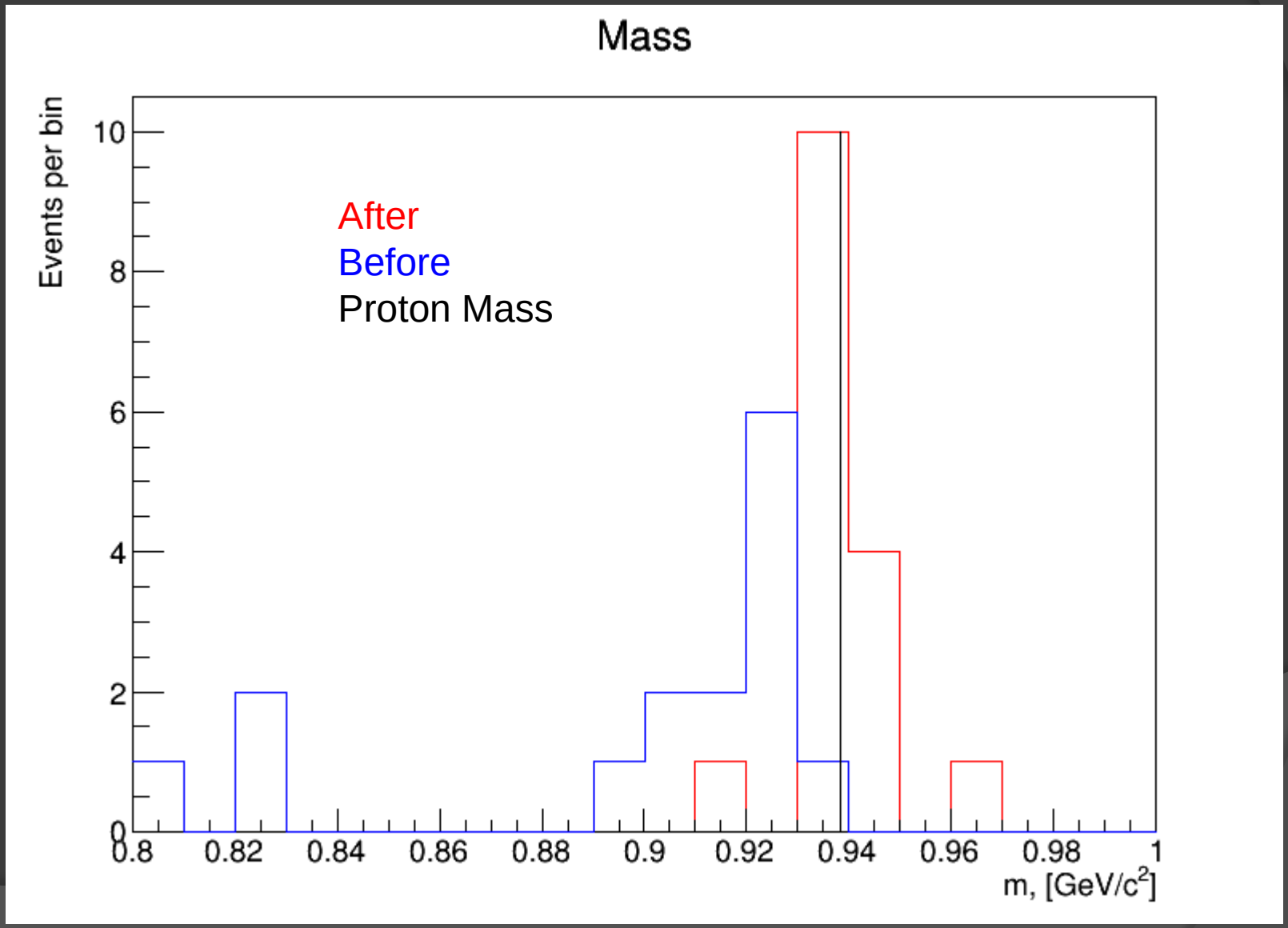




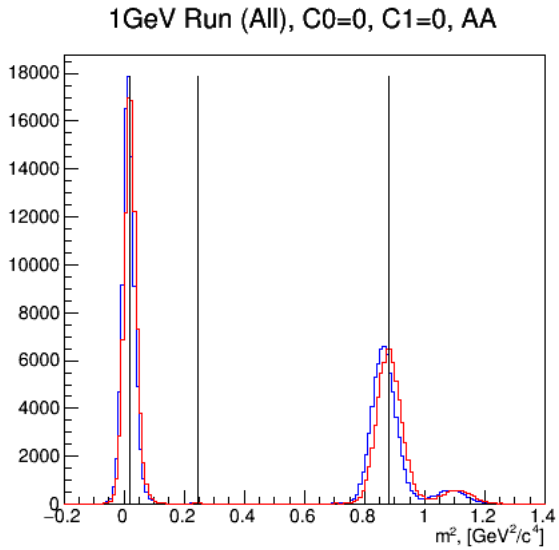
$\Delta t = -272 \pm 13$ ps

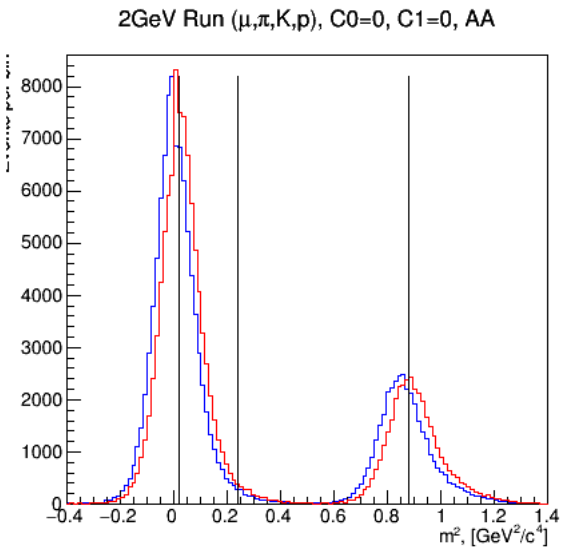
$\alpha = 1.0053 \pm 0.0011$

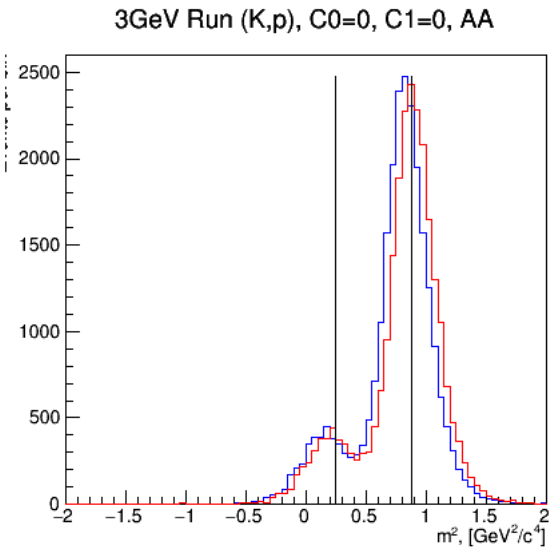
Mass Distribution for Fit Points

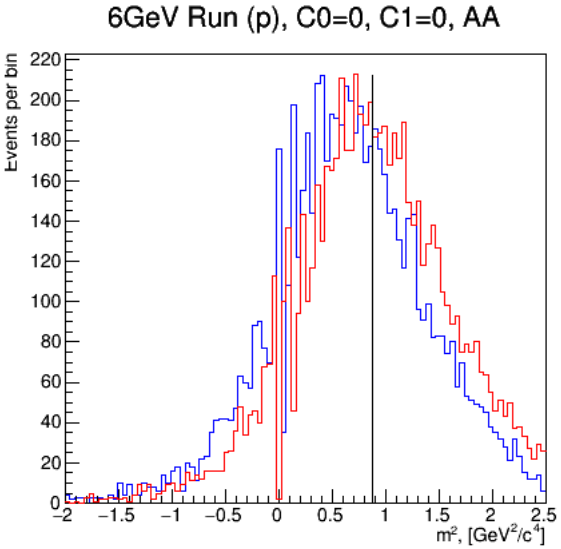


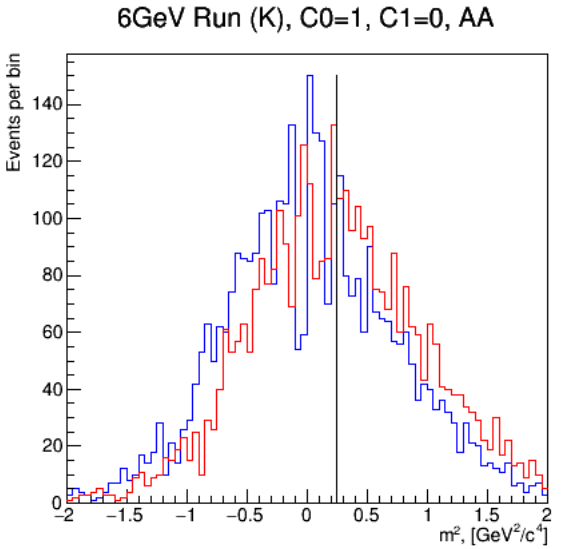
Squared Mass Distribution for Whole AA Sample









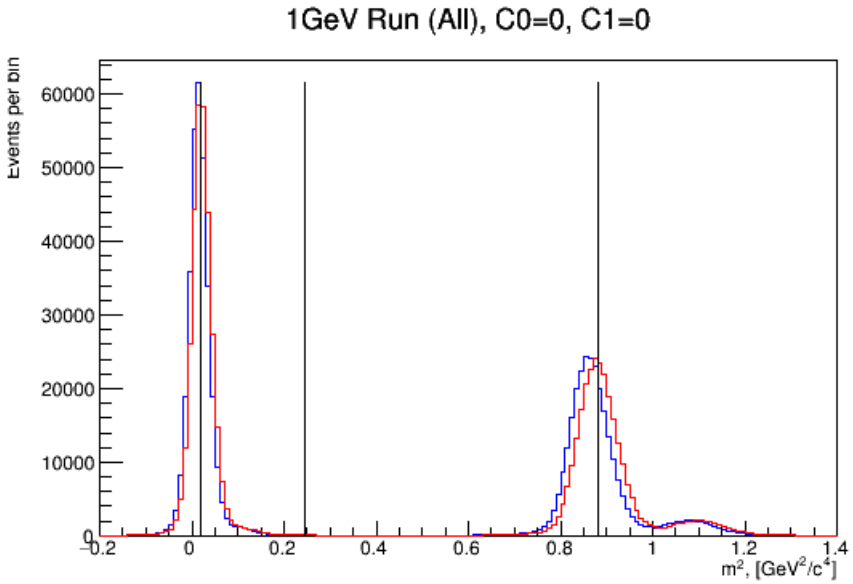


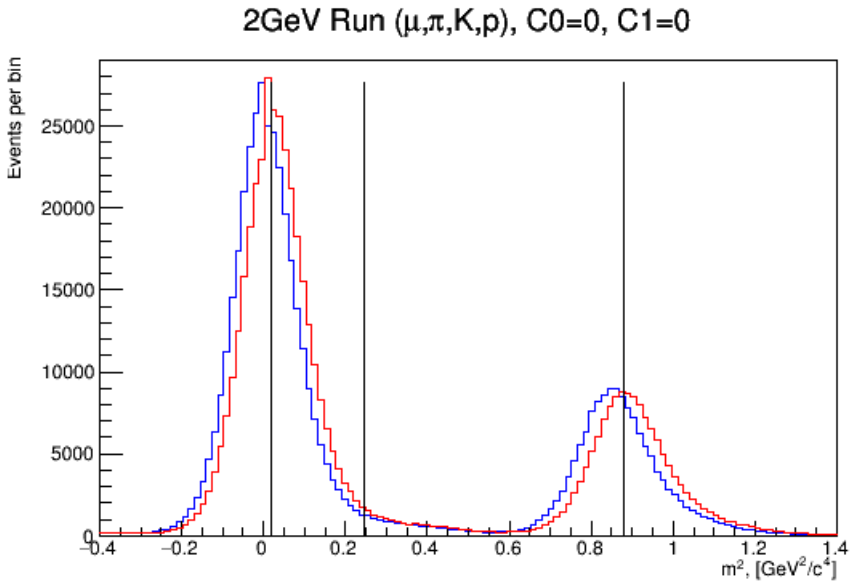
After Fit

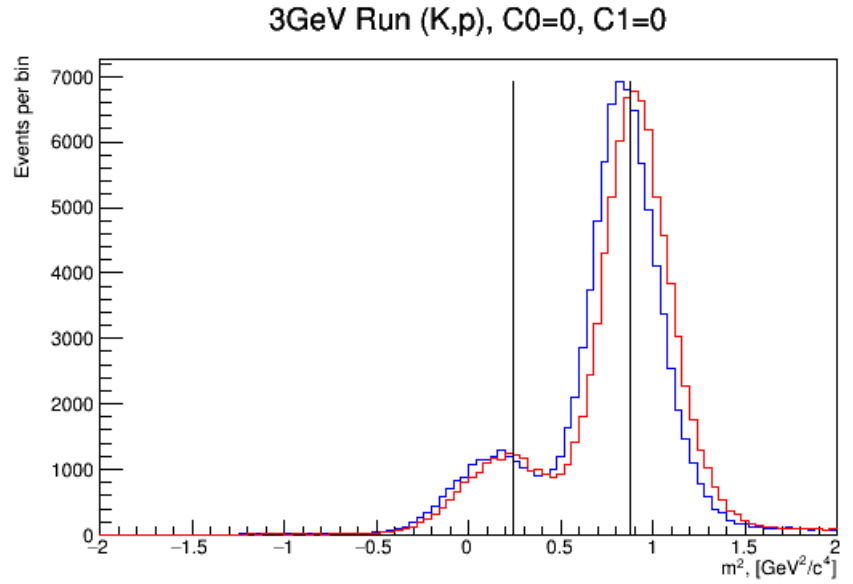
Before

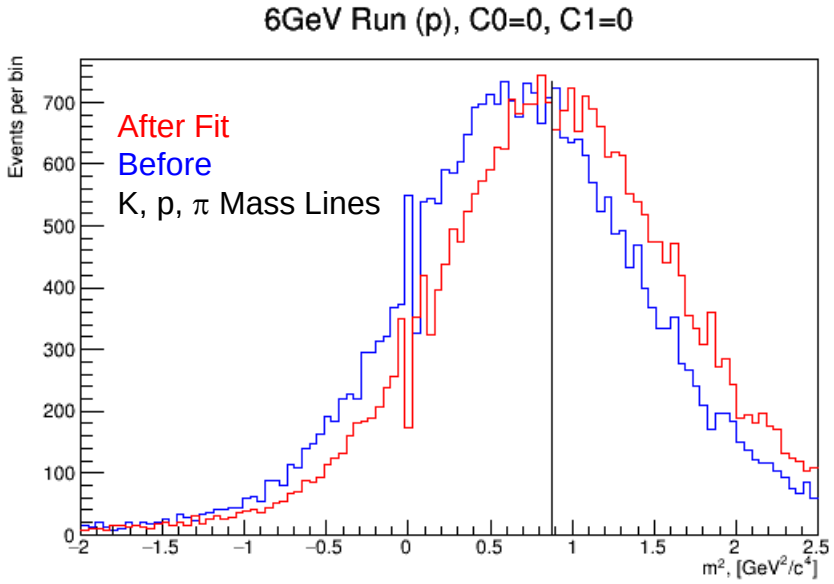
K, p, π Mass Lines

Squared Mass Distribution for All TOF









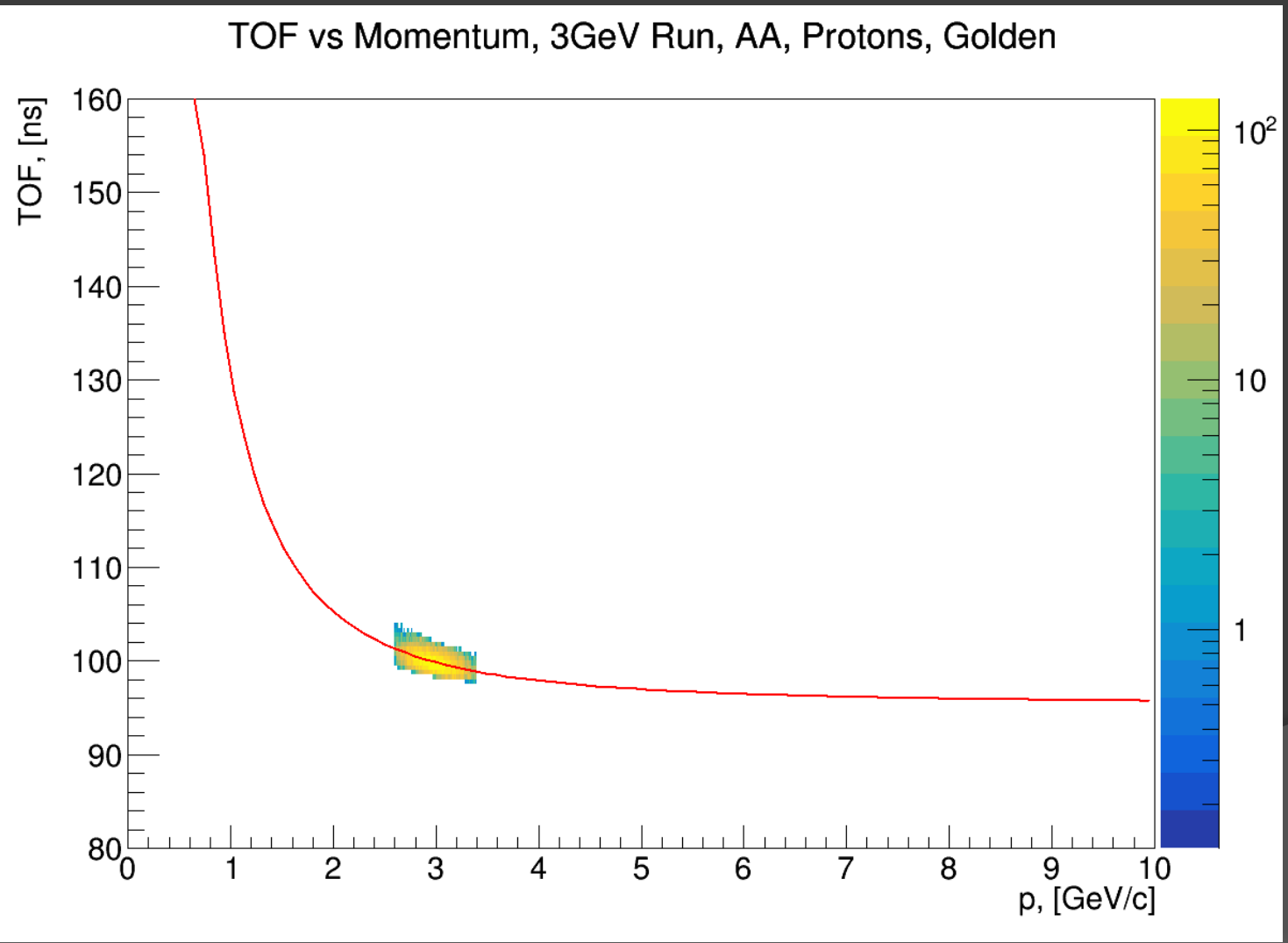
Conclusions

- ProtoDUNE-SP beamline calibration was examined
- BI group has done an excellent job
- Obtained data driven fine tune of the momentum scale with less than 0.5% uncertainty.
- This fine calibration can be applied to all TOFChannels
- Analyzers should be careful with selection to avoid biases.

BACKUP Slides

Events Selection

- Select protons and kaons based on mass



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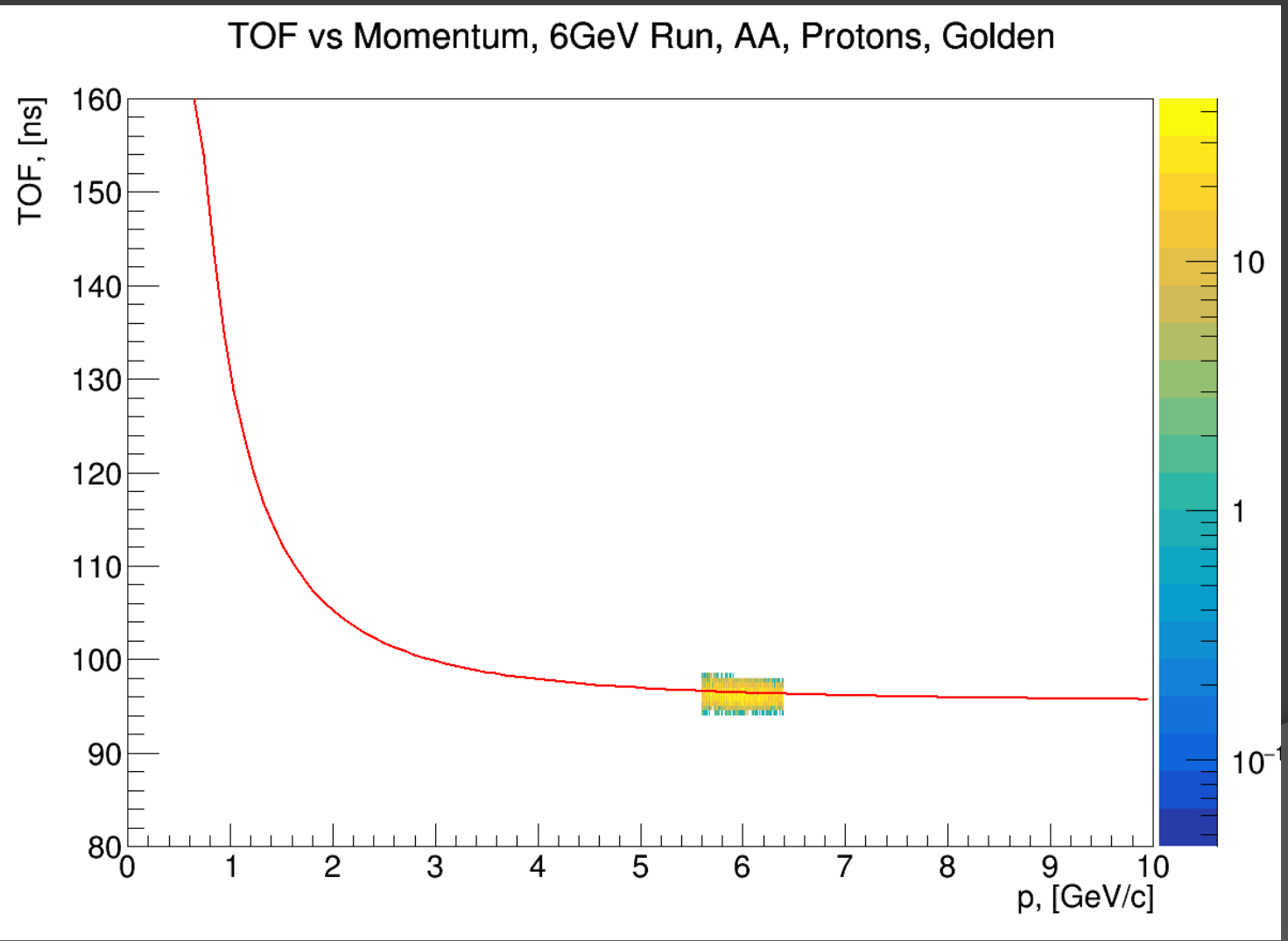

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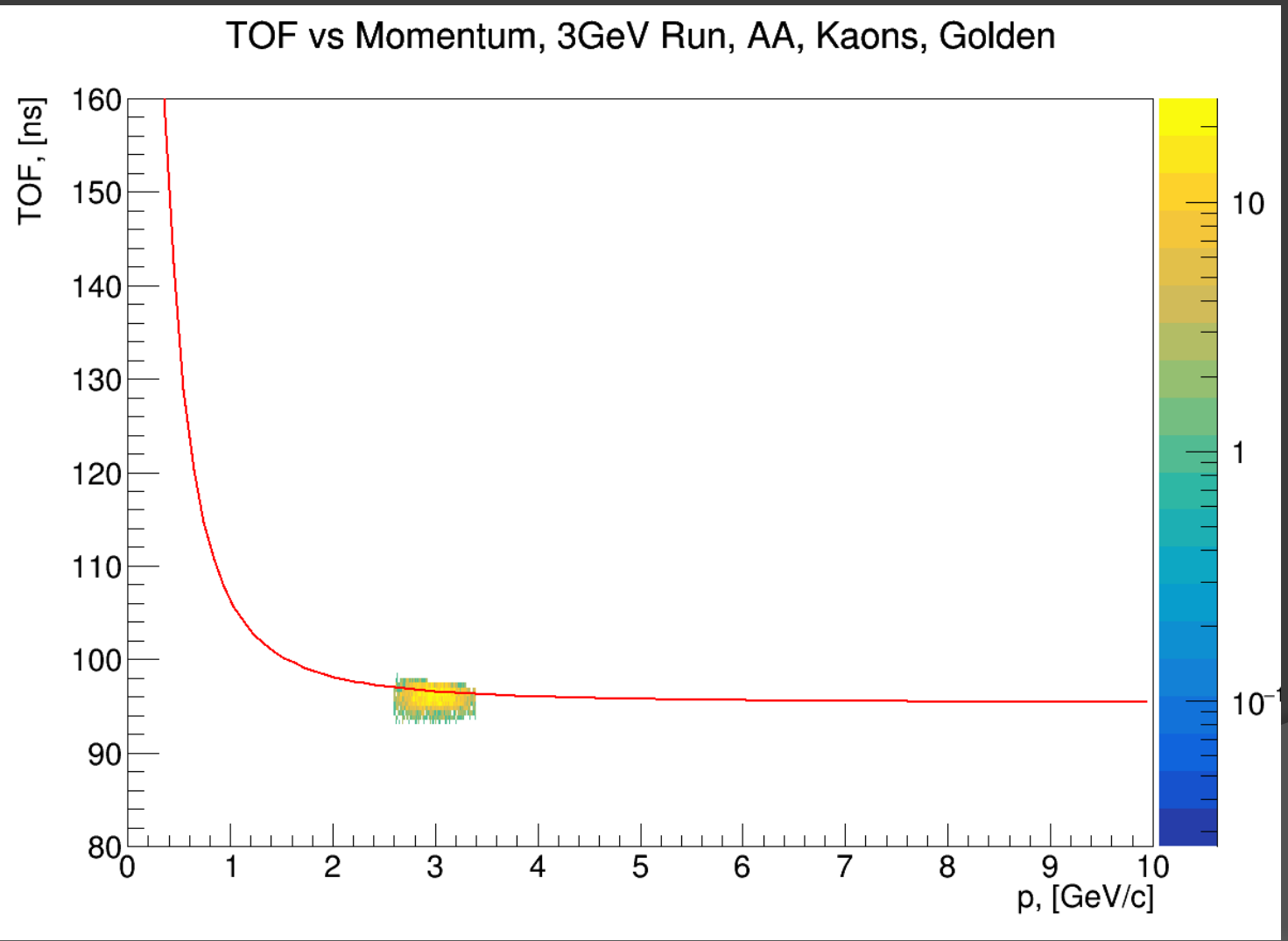

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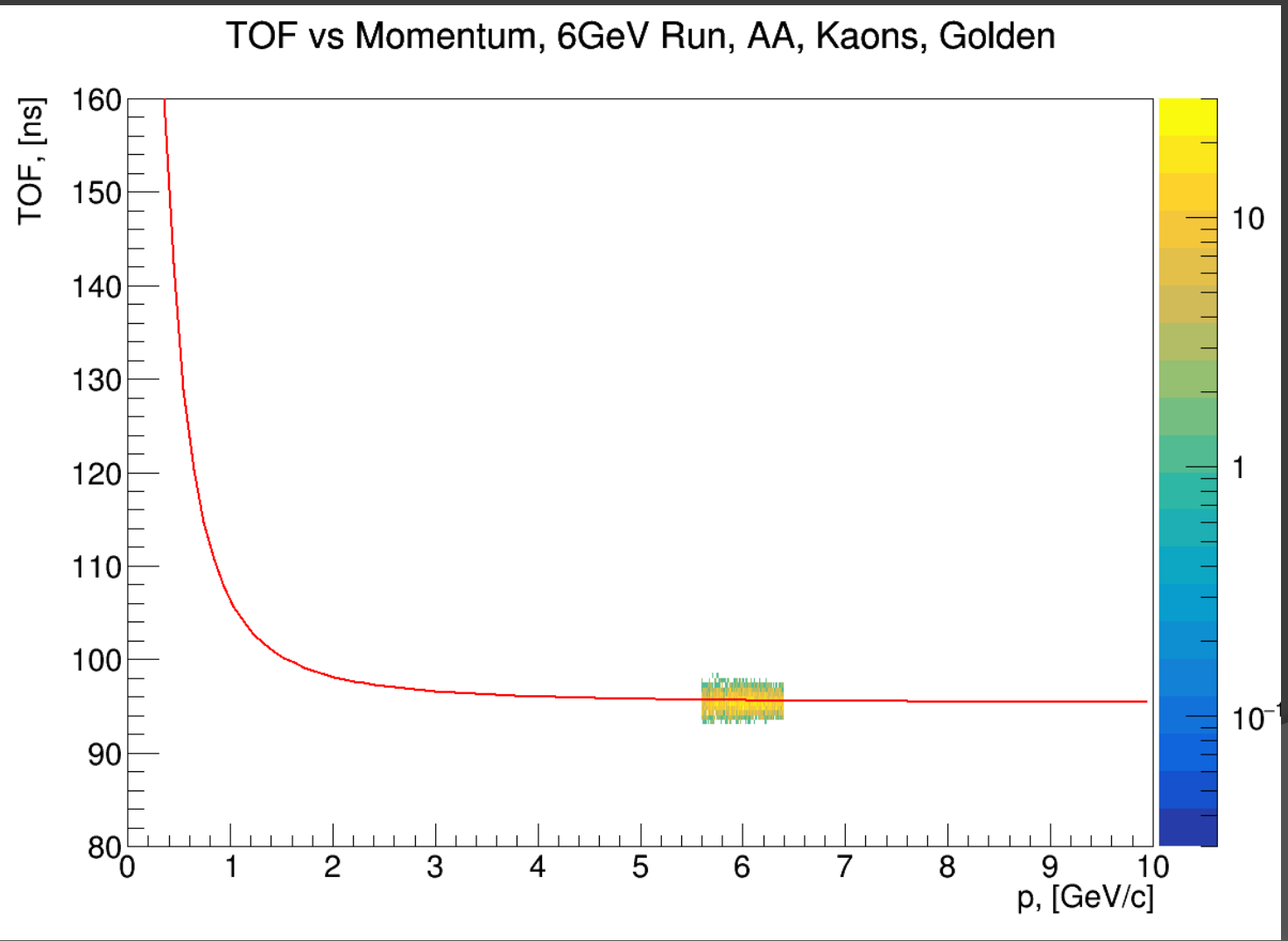

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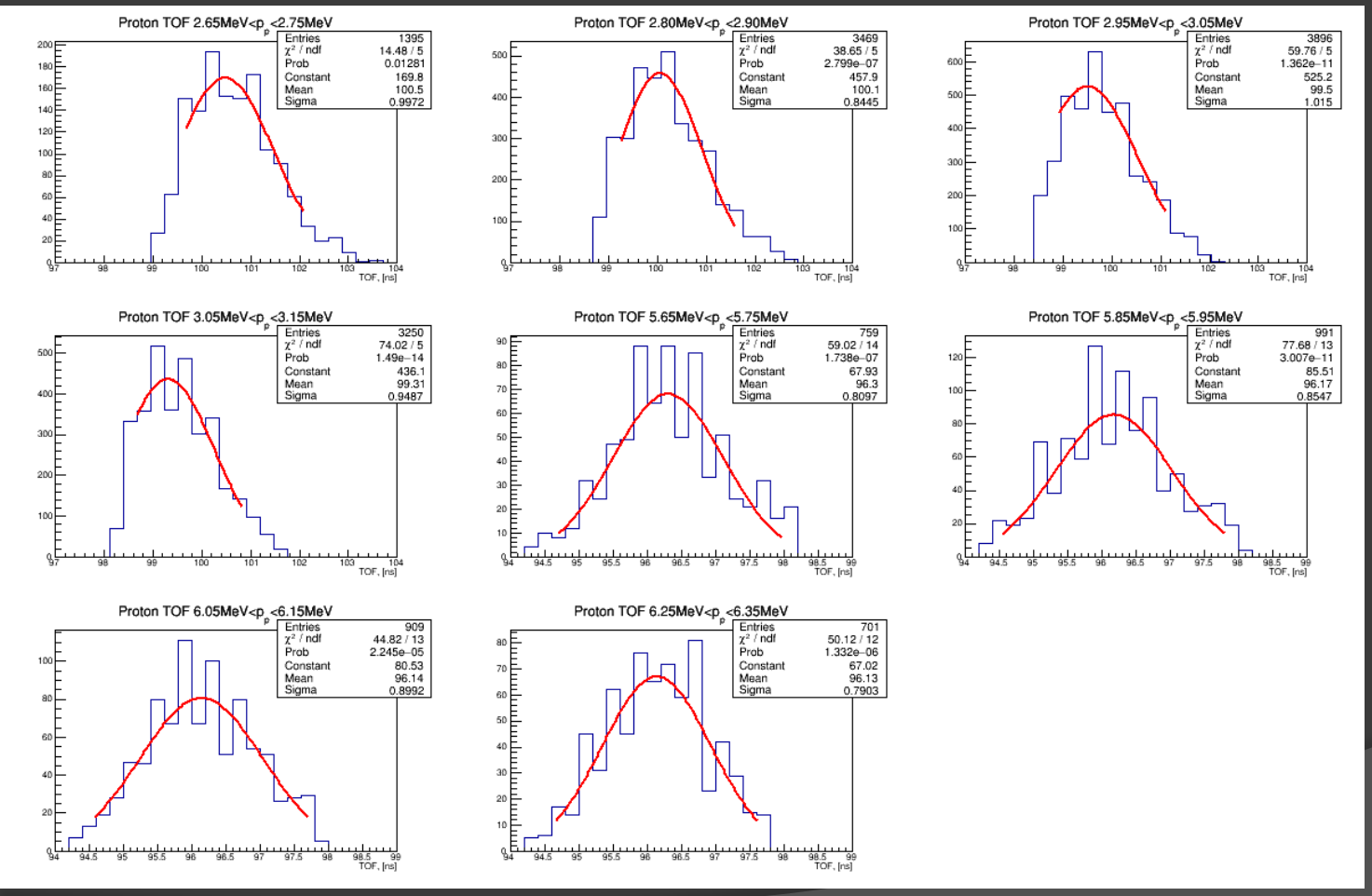

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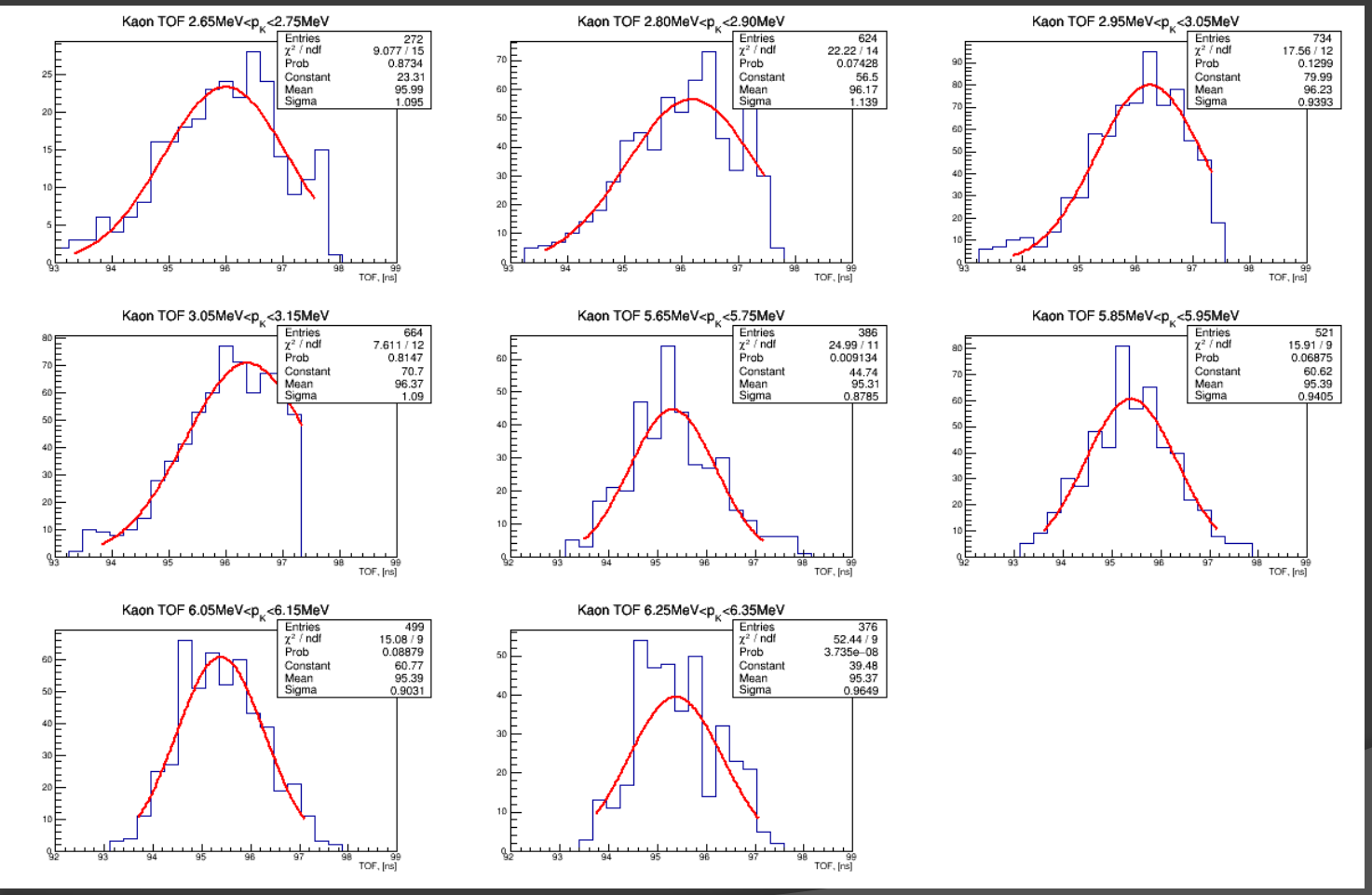

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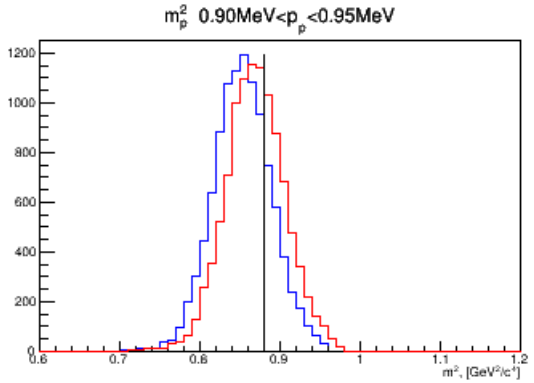
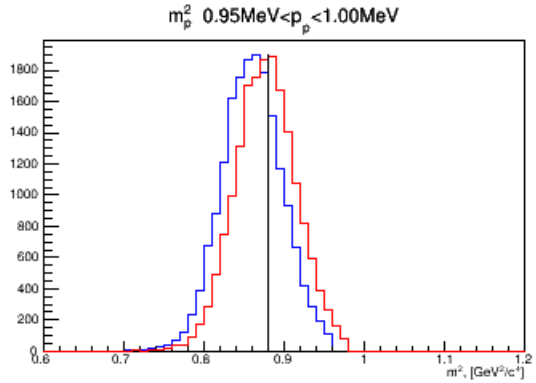
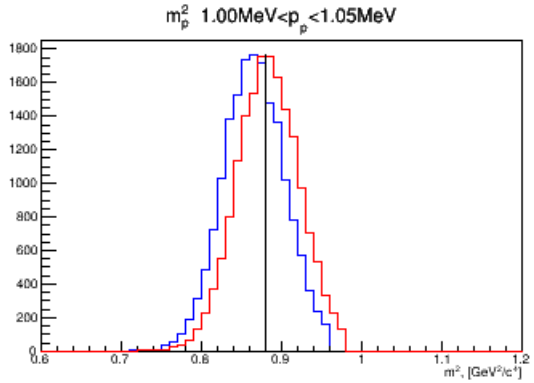
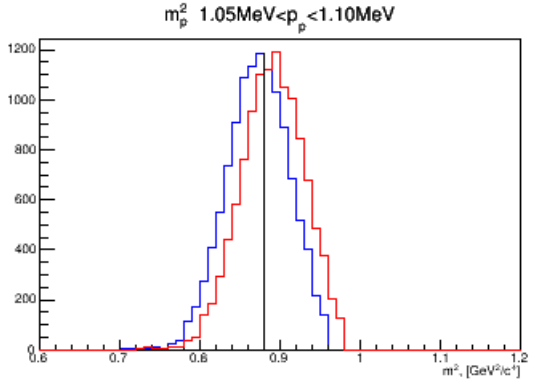
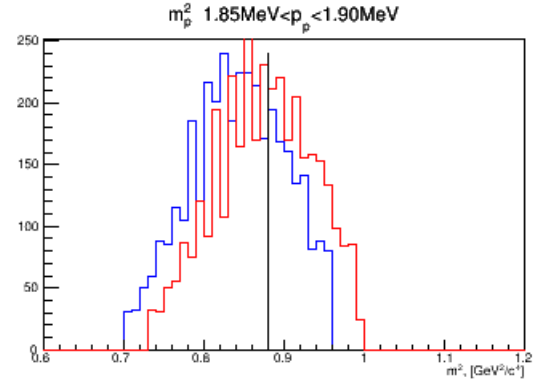
Squared Mass Distribution for Fit Points

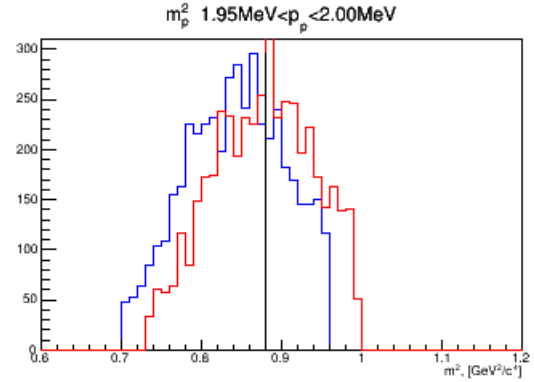


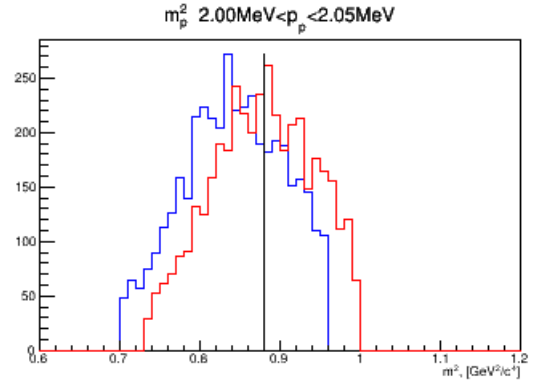


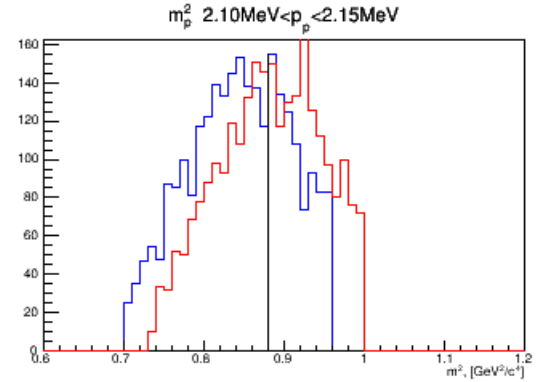






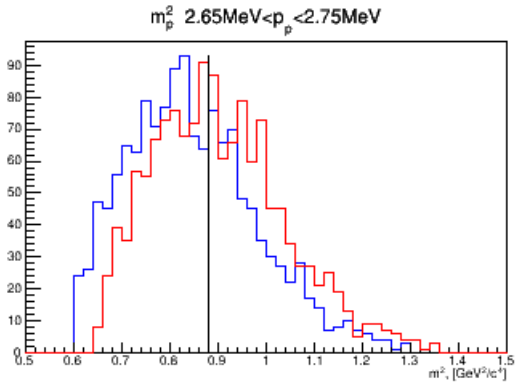


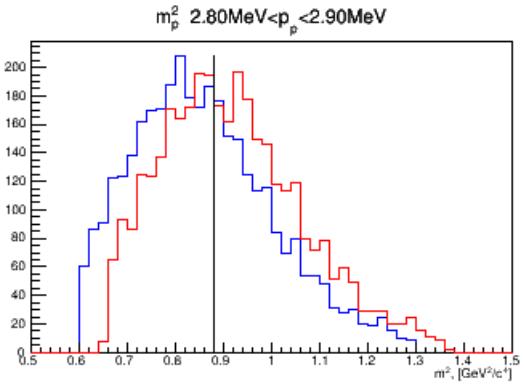


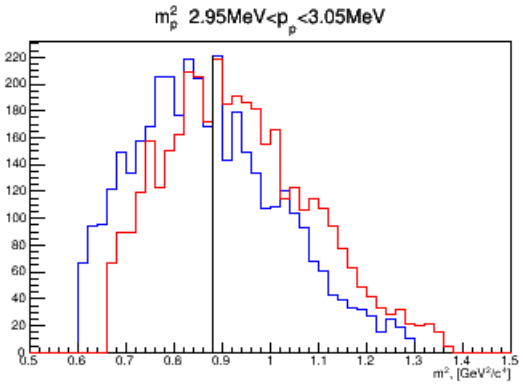


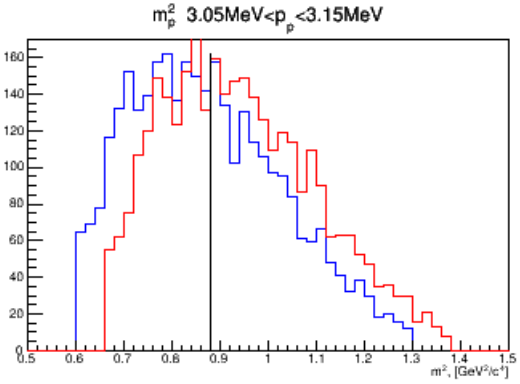
After Fit
Before
Proton Mass

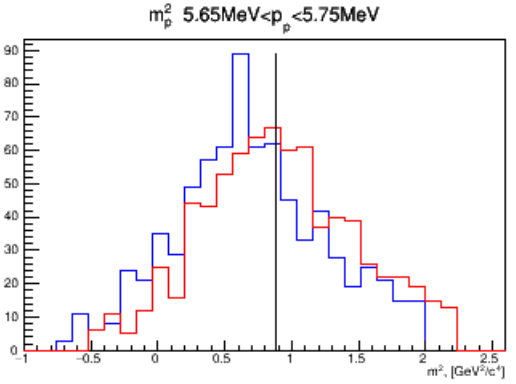
Squared Mass Distribution for Fit Points

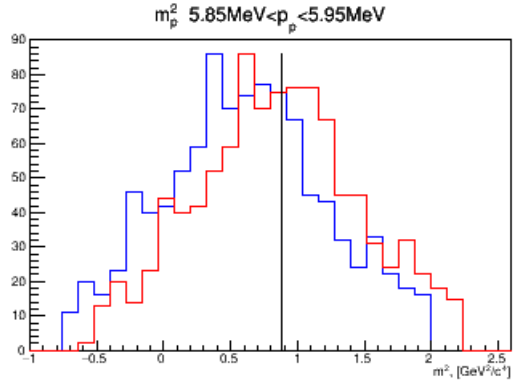


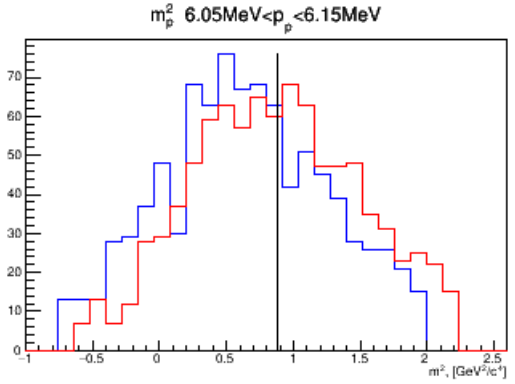


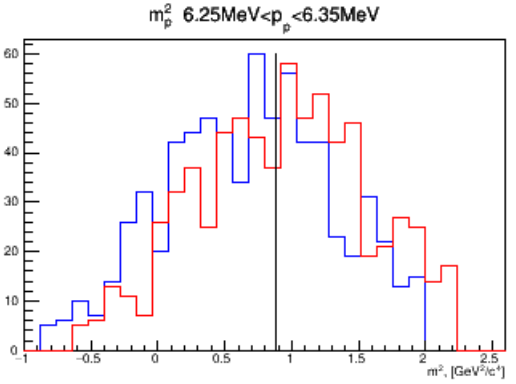












After Fit
Before
Proton Mass