# Longitudinal Phasespace Analysis

A technique to apply kinematic cuts
to enhance different reaction mechanisms

Derek Glazier
University of Glasgow

8.A.8 Nuclear Physics B9 (1969) 331-348. North-Holland Publ. Comp., Amsterdam

# LONGITUDINAL PHASE-SPACE PLOTS OF MULTIPARTICLE HADRON COLLISIONS AT HIGH ENERGY

L. VAN HOVE
*CERN - Geneva*

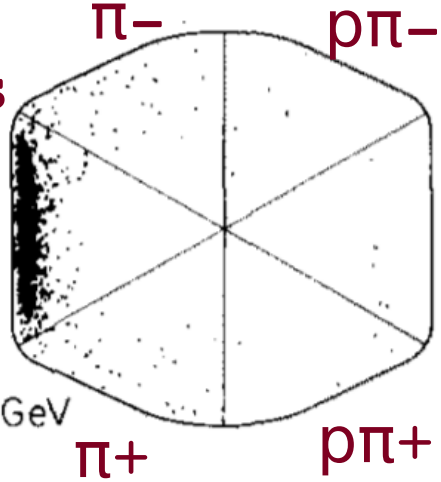
Received 9 January 1969

At high Energy (>8GeV) transverse momenta small

Reduce dimensionality of reaction to N-2

8.B.2 Nuclear Physics B47 (1972) 1–18. North-Holland Publishing Company

1000 events




# ANALYSIS OF γp REACTIONS IN THE LPS FRAMEWORK AT $E_\gamma$ = 6–18 GeV *

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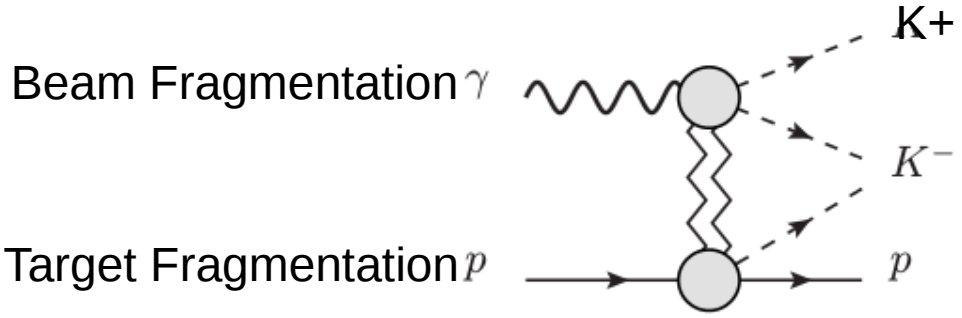
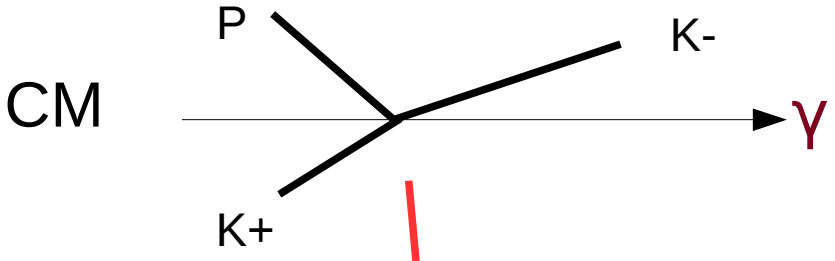
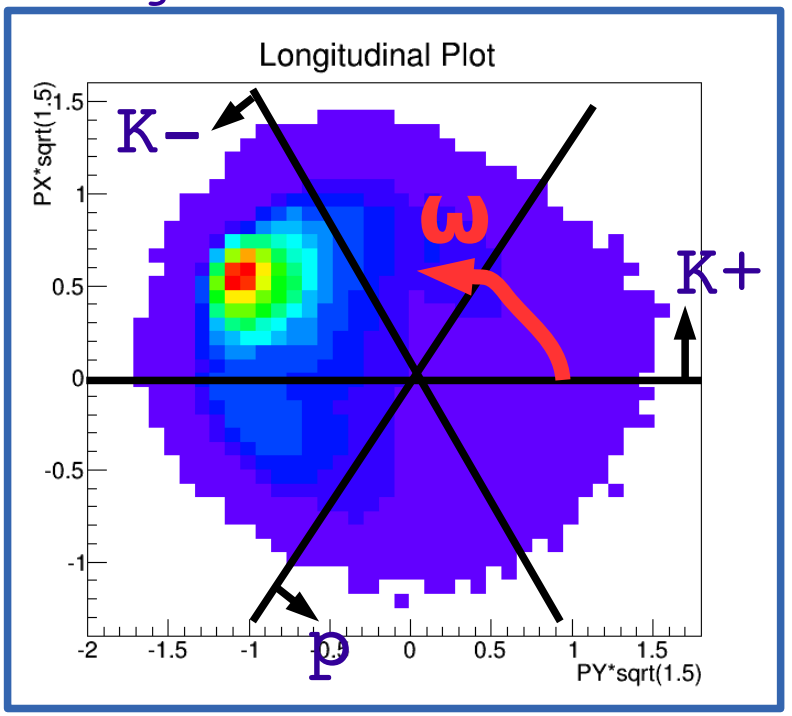
Received 19 June 1972

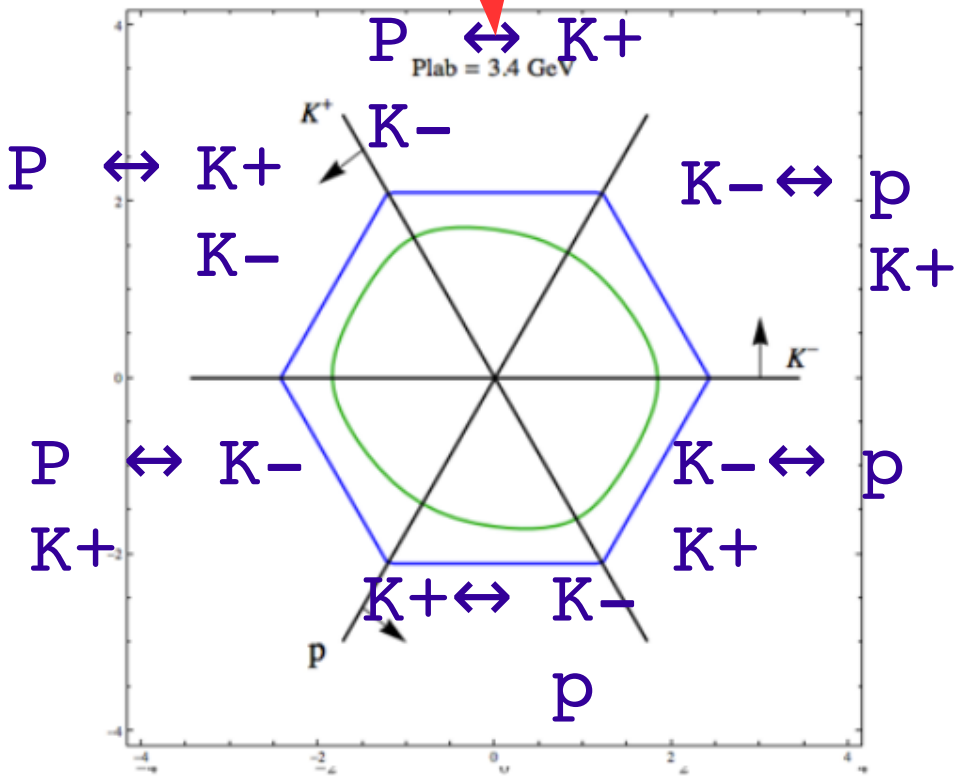
# Van Hove Plots (Longitudinal)

Example 3-3.8GeV γp→K+K-p
CLAS g11 dataset



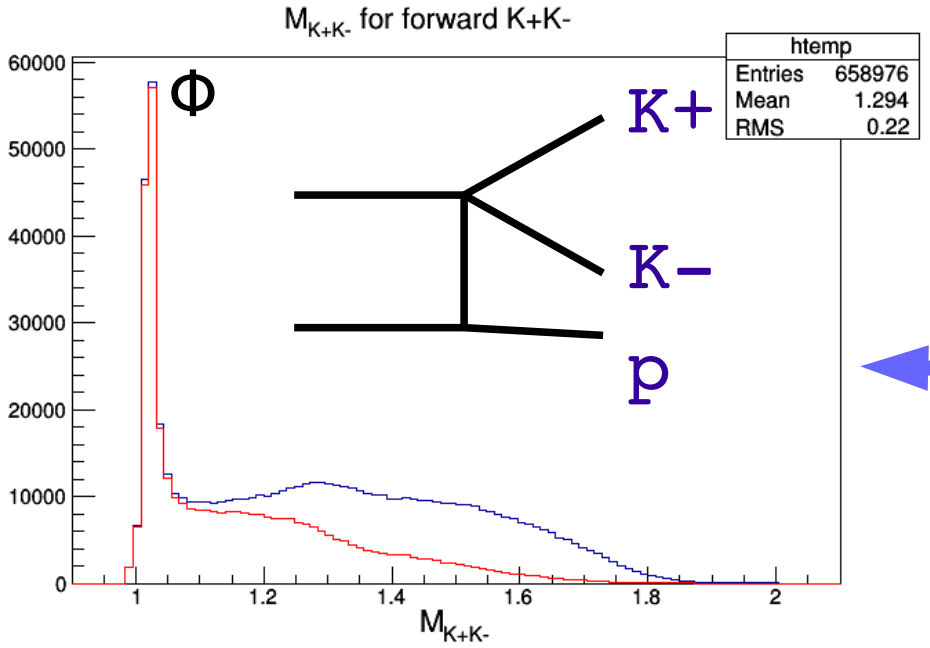



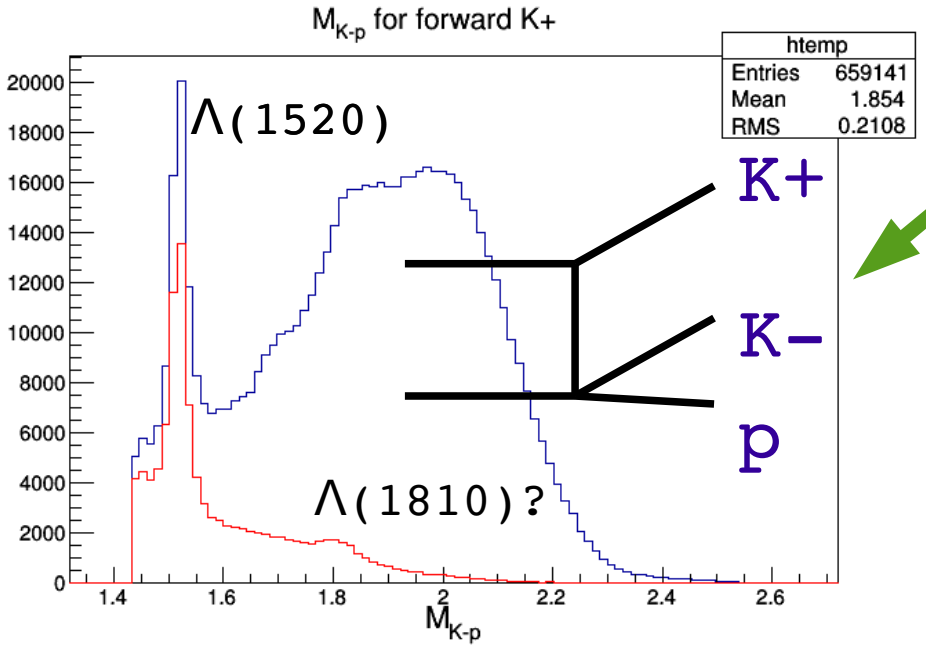

$$p_{K^+L} = \sqrt{\frac{2}{3}} q \sin\omega,$$

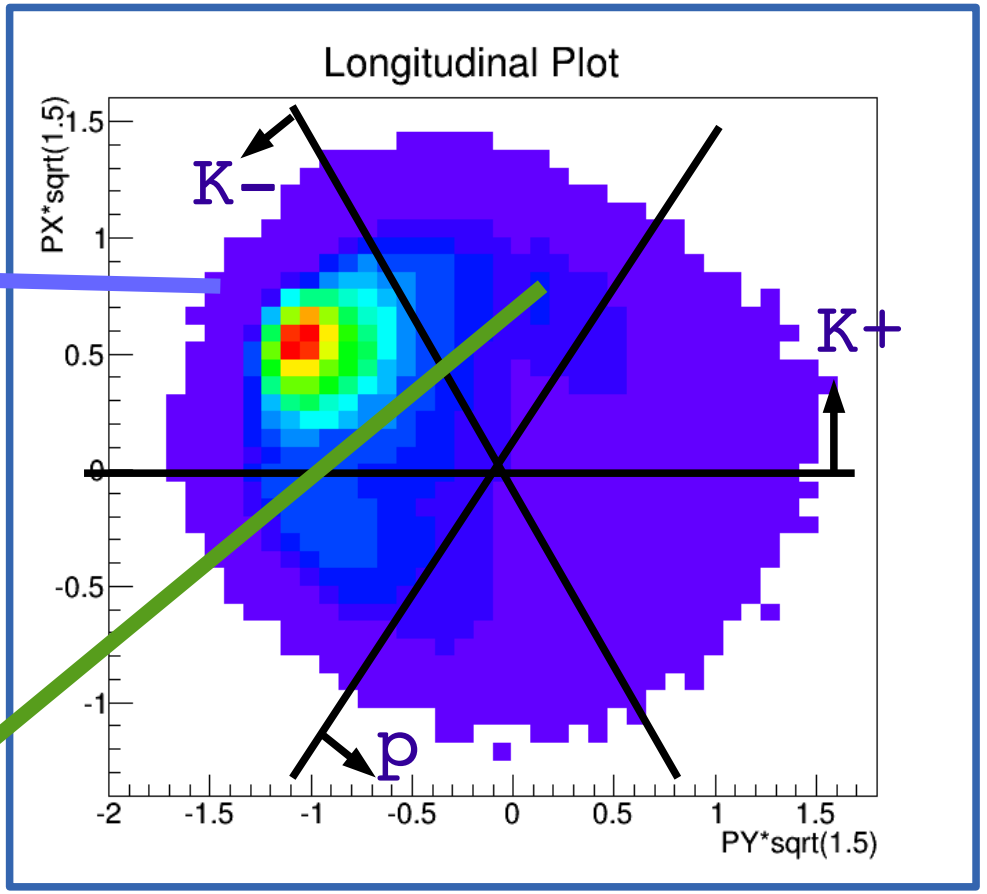
$$p_{K^-L} = \sqrt{\frac{2}{3}} q \sin\left(\frac{2}{3}\pi + \omega\right),$$

$$p_{PL} = \sqrt{\frac{2}{3}} q \sin\left(\frac{4}{3}\pi + \omega\right).$$

# Example γp→K+K-p at around 3-3.8GeV

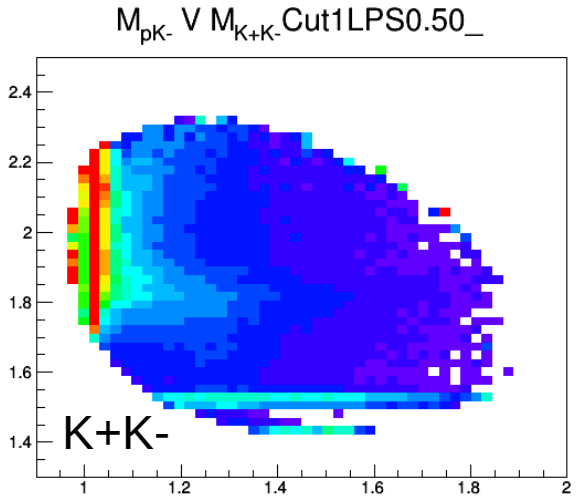


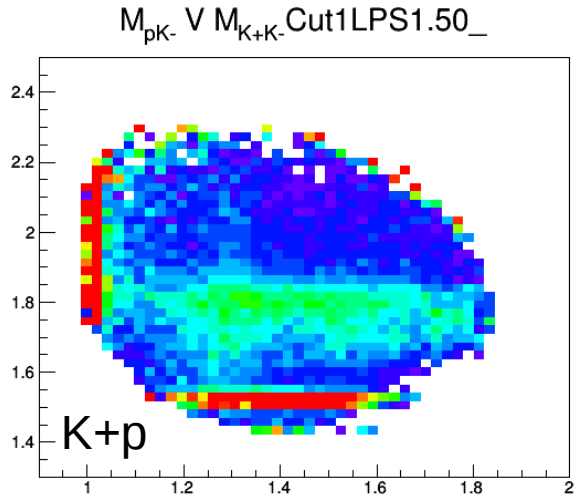



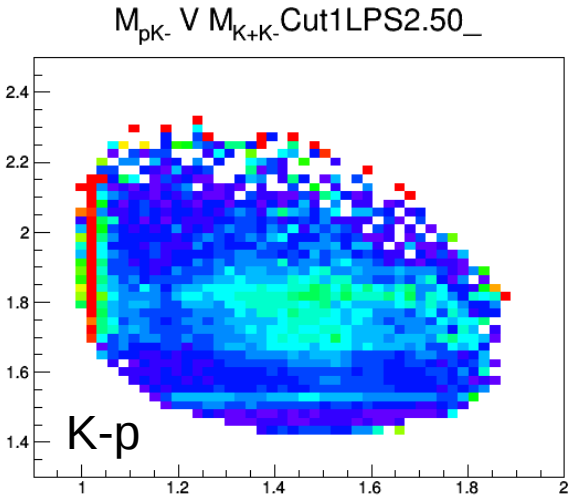



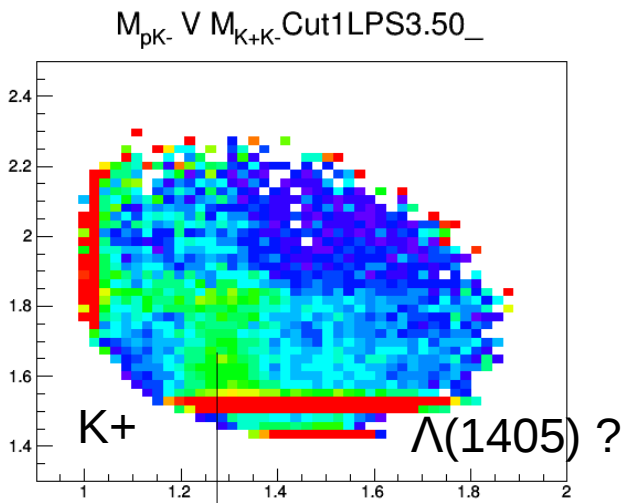

All Events

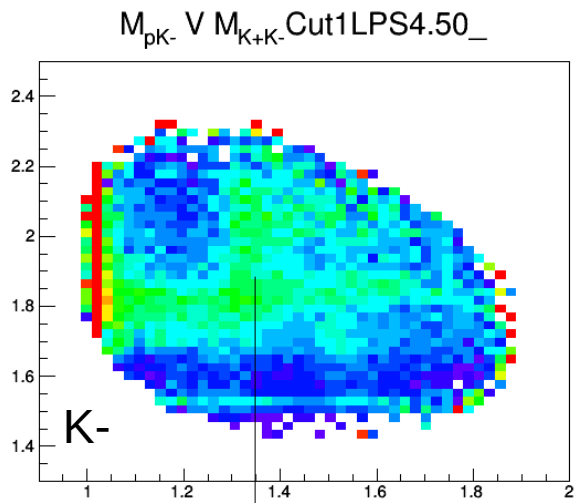
Cut on Longitudinal Plot sector

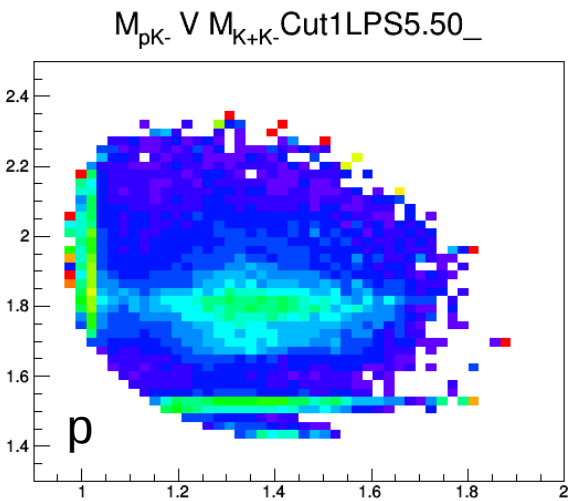


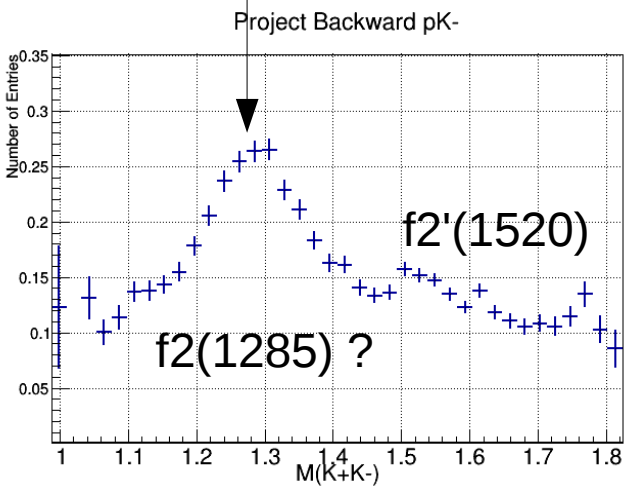



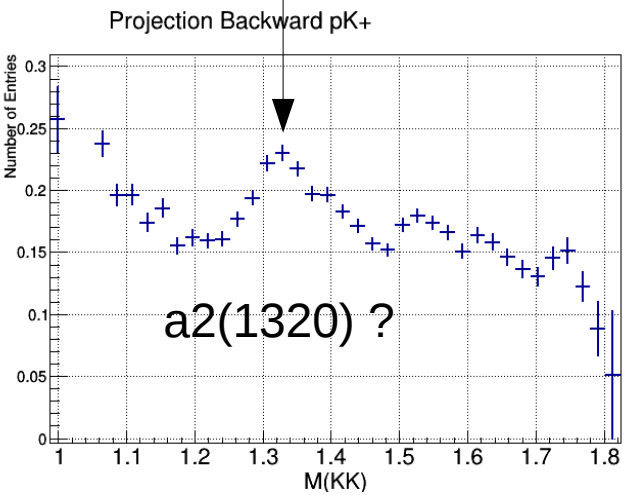



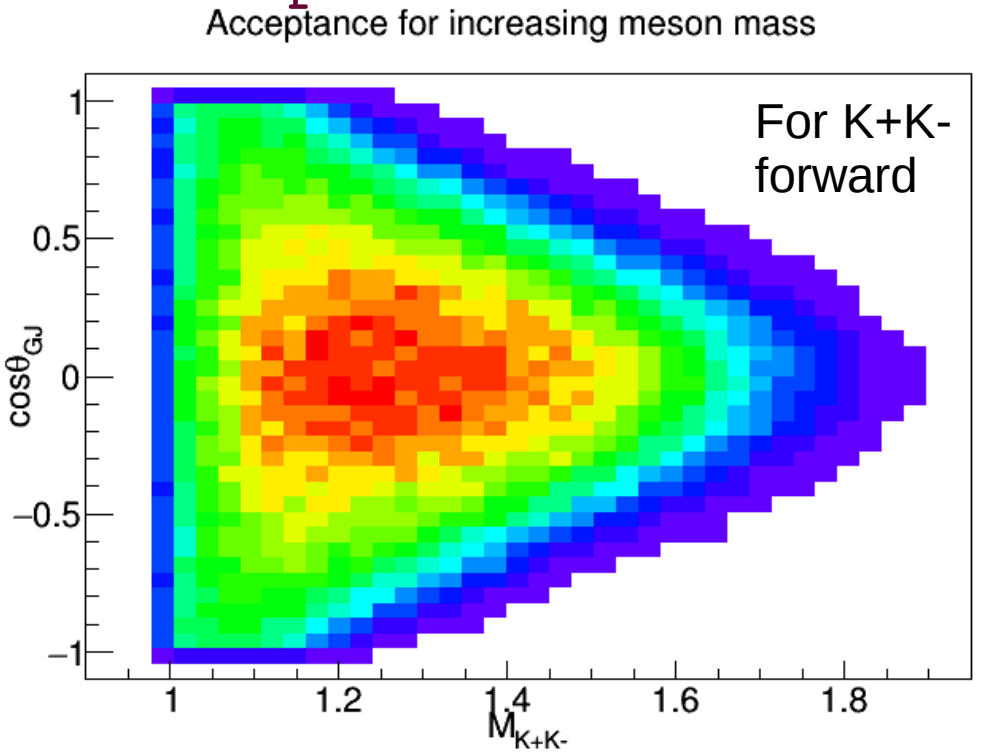



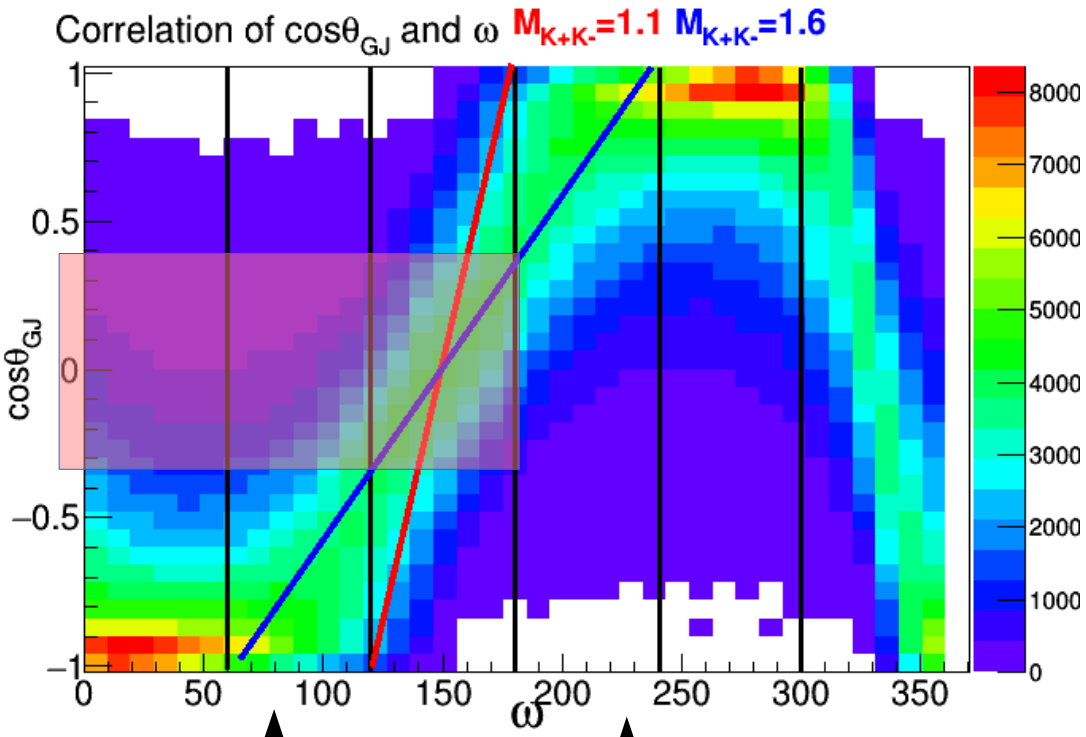




Now acceptance corrected

Divide out phase space distribution

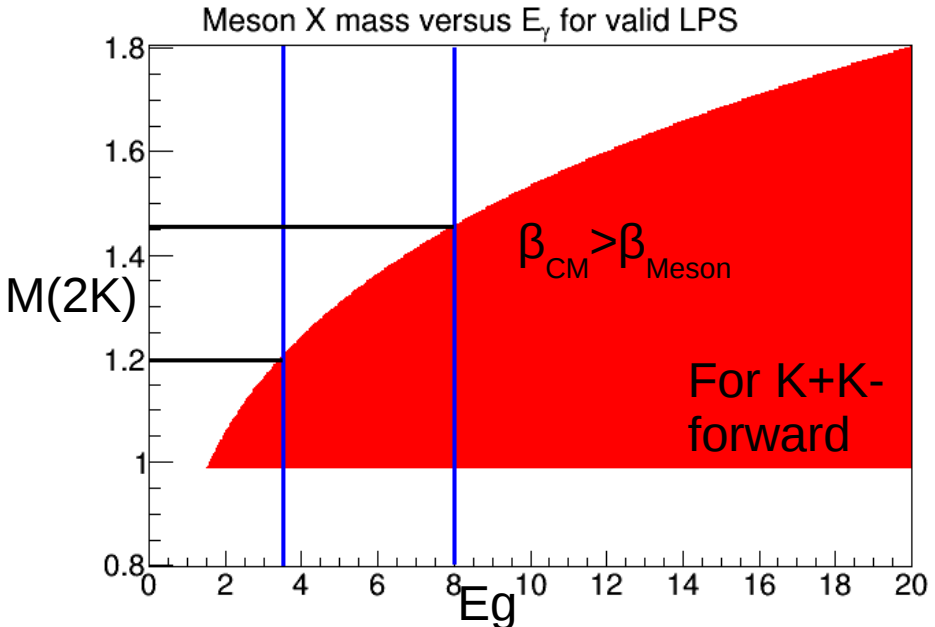
# Larger Mass 2K mesons will have lower CM momenta
# Decay products can decay back into different sector
# Phase Space Plots :



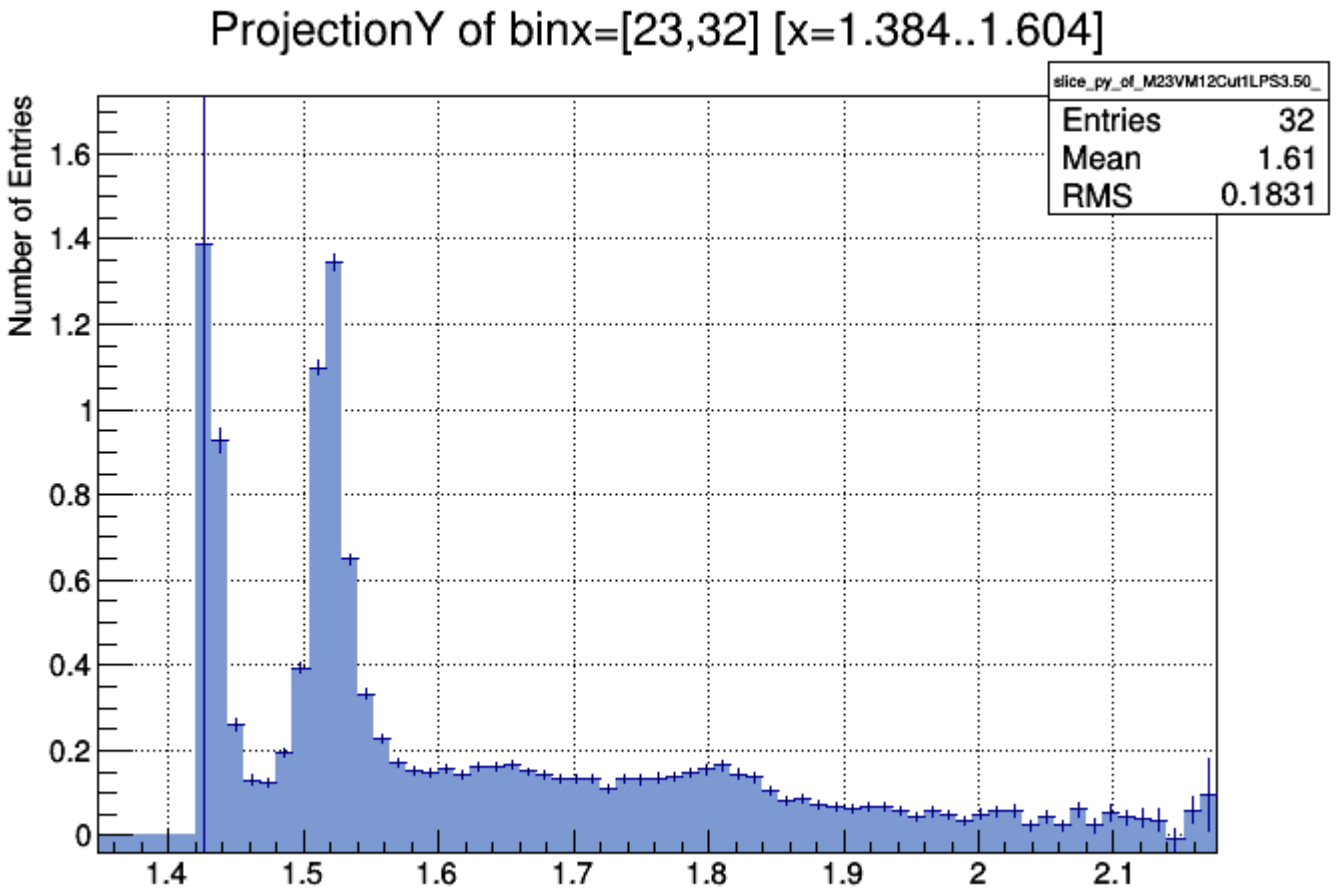

K- back
From decay

K+ back
from decay
of meson



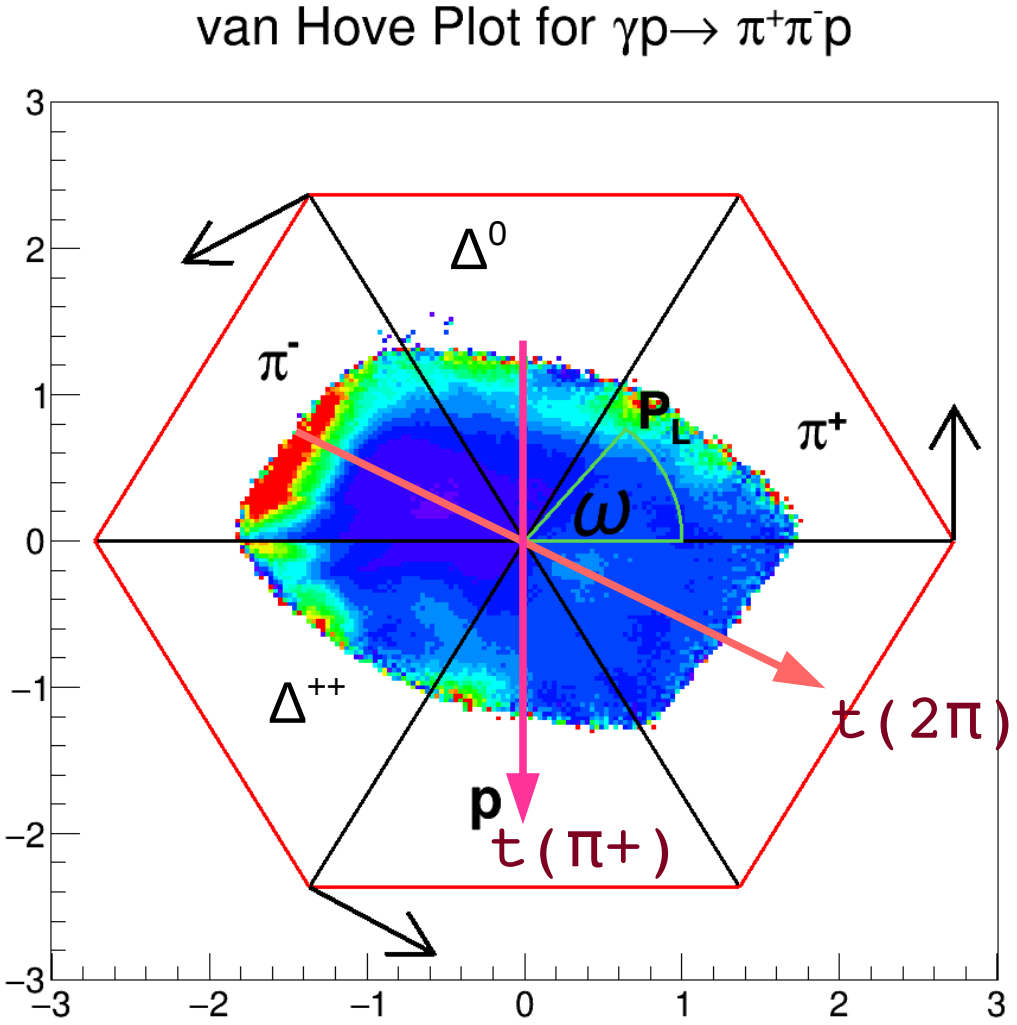

M(2K) = 1-1.2 OK, but...
M(2K) > 1.2 has limited $\theta_{hel}$
Also if -t>0 can decay
in different sector

# Threshold enhancement in pK-, phase space corrected

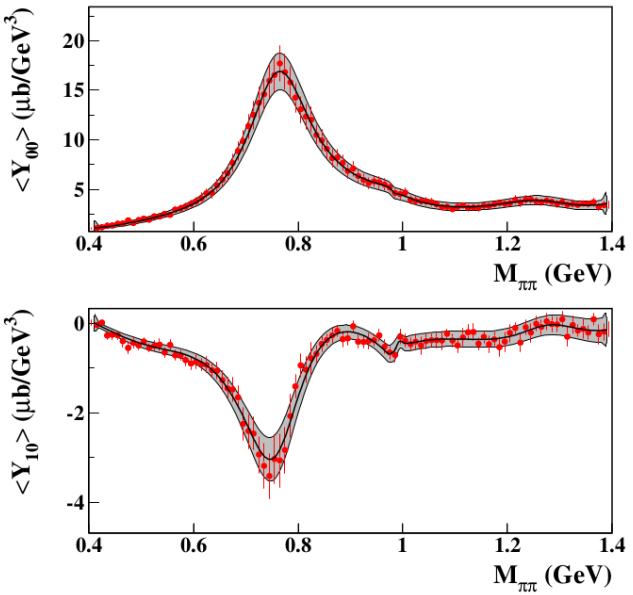



Sensitive to pK- scattering length

# Longitudinal Plots π+π-p




CLAS g11 dataset
Select all 4 topologies for π+π-p final state
These results are Background subtracted and acceptance corrected




**Photoproduction of $\pi^+\pi^-$ meson pairs on the proton**

M. Battaglieri,[1] R. De Vita,[1] A. P. Szczepaniak,[2] K. P. Adhikari,[35] M.J. Amaryan,[35] M. Anghinolfi,[1] H. Baghdasaryan,[45] I. Bedlinskiy,[22] M. Bellis,[7] L. Bibrzycki,[29] A.S. Biselli,[13,36] C. Bookwalter,[15]

# Event Reconstruction : sWeights

**M. Pivk,F.R. Le Diberder,Nucl.Inst.Meth.A 555, 356-369, 2005**

Given discriminatory PDF for signal and background calculates weight :

$$ {}_s\mathcal{P}_n(y_e) = \frac{\sum_{j=1}^{N_s} \mathbf{V}_{nj} f_j(y_e)}{\sum_{k=1}^{N_s} N_k f_k(y_e)} $$

$N_s$ = Number of species

$f_k$ = PDF for species k

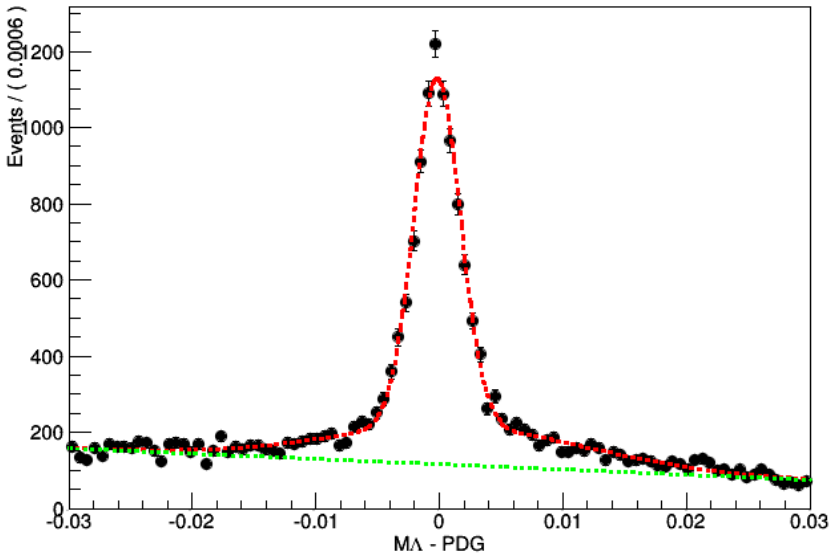
$N_k$ = Yield for species k

V = covariance matrix

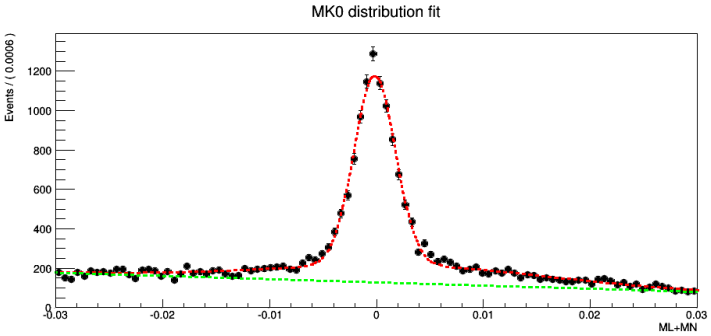
Part of RooStats(used here)

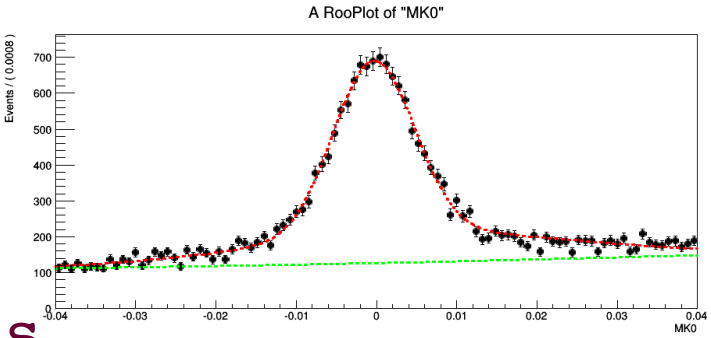
Can include multiple signal and background species

Can fit multidimensional discriminatory PDF




Only as good as fit model...




Can use directly in likelihood fits

# Event Reconstruction : Simulated Models

Signal shapes are not always well described by parameteric functions

⇒Simulated PDFs

systematic uncertainty in shape accounted for via morphing with additional nuisance parameters

i.e Profile Likelihood

Construct new RooFit PDF

Supply simulated events

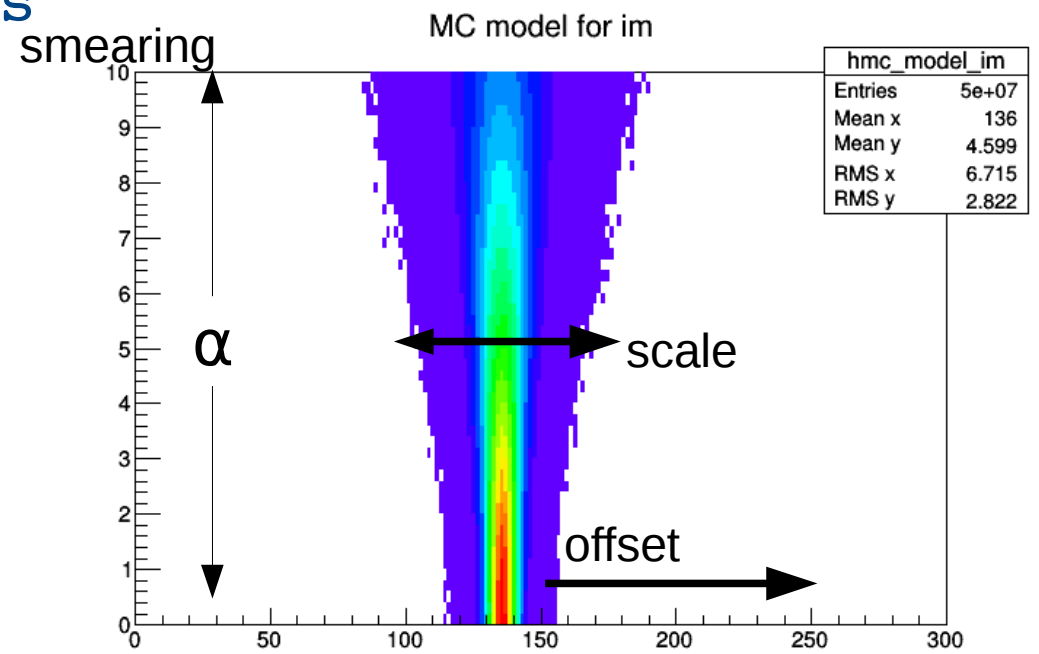
Sequential 1D histograms

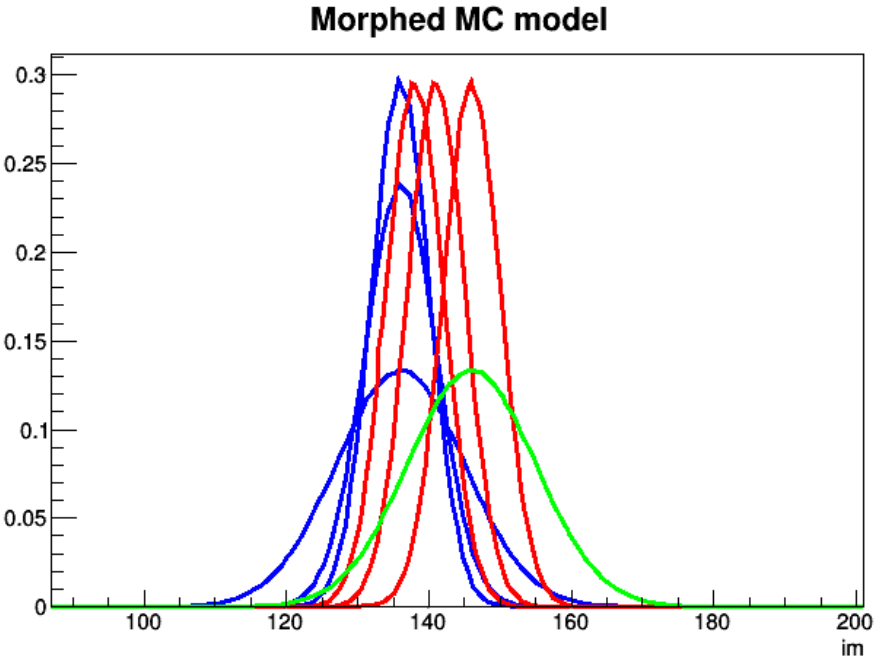
Smoothed and interpolated

Adding greater additional smearing with morphing parameter α

Additional offset parameter

(Also RooFit HistFactory...)



# Sweight Event Selection : $\pi^+\pi^-p$

Just Phase Space

g11 dataset, detect $\pi^+$ and p

Model from simulated $\pi^+\pi^-p$ and $\pi^+\pi^-\pi^0p$ events

Signal BG

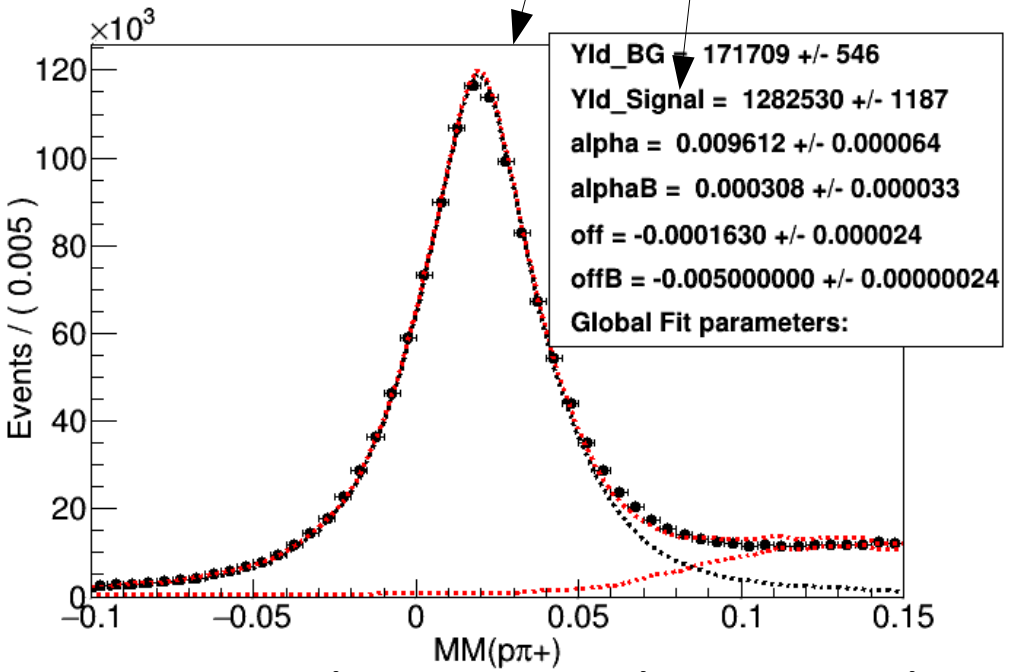
RooFit Extended Maximum likelihood fit

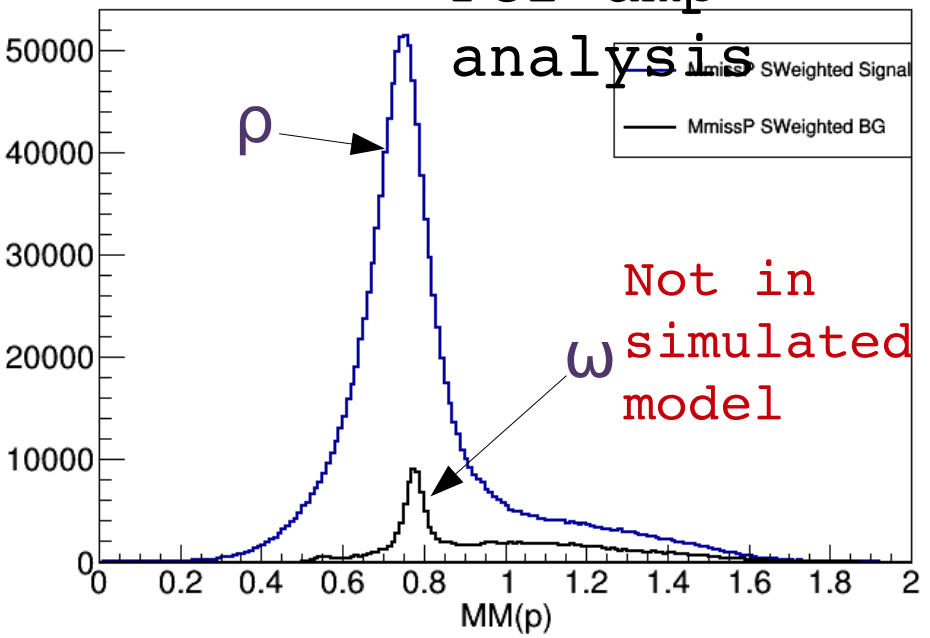
RooStats sWeight calculation

⇒Disentangle distributions

For Cross section

For amp analysis



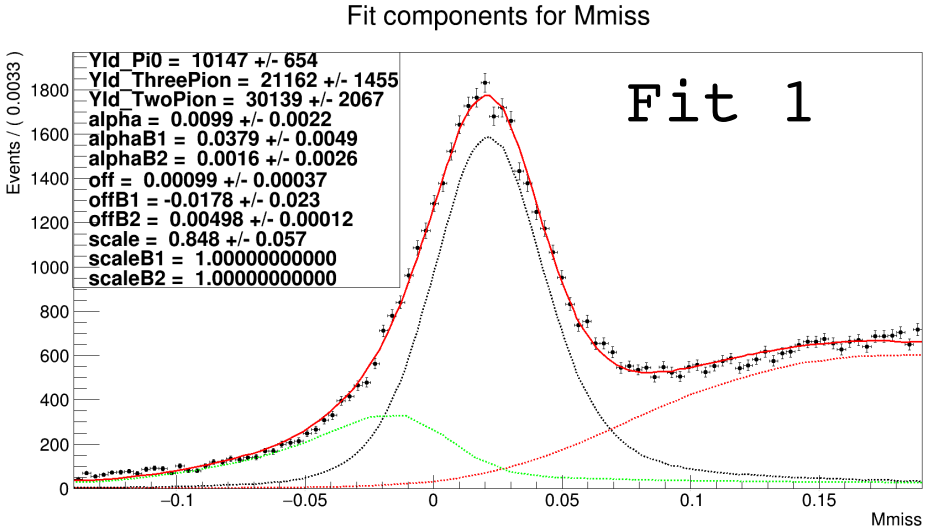



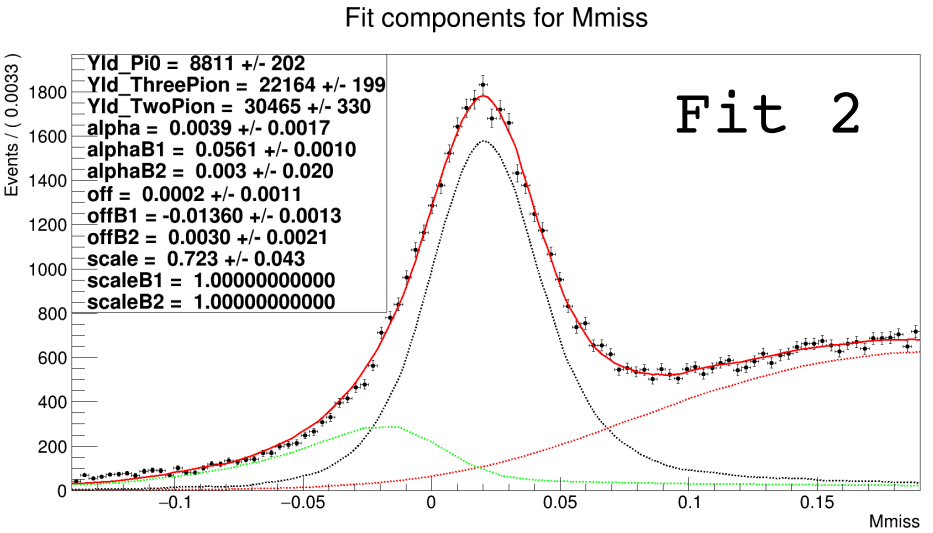

Note 2 fits required. First fixes alpha and off.

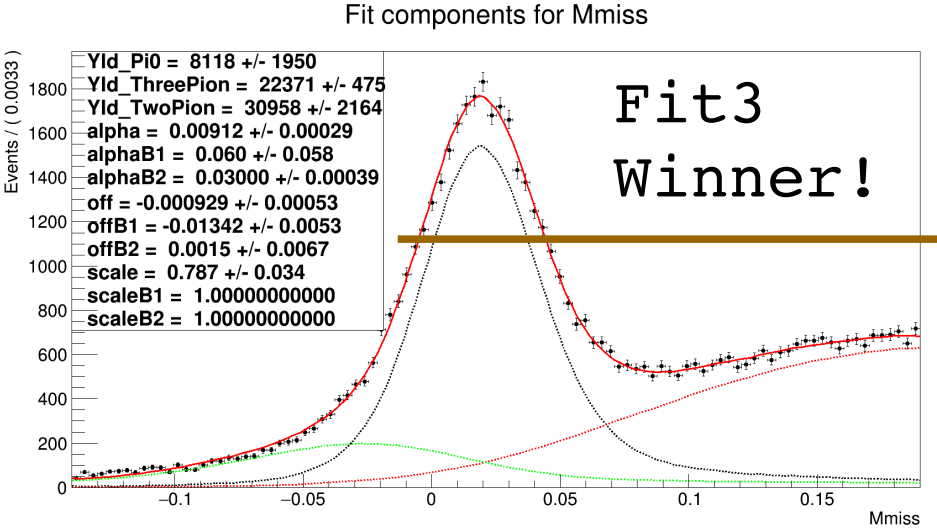
Second, only Yields free => Covariance matrix

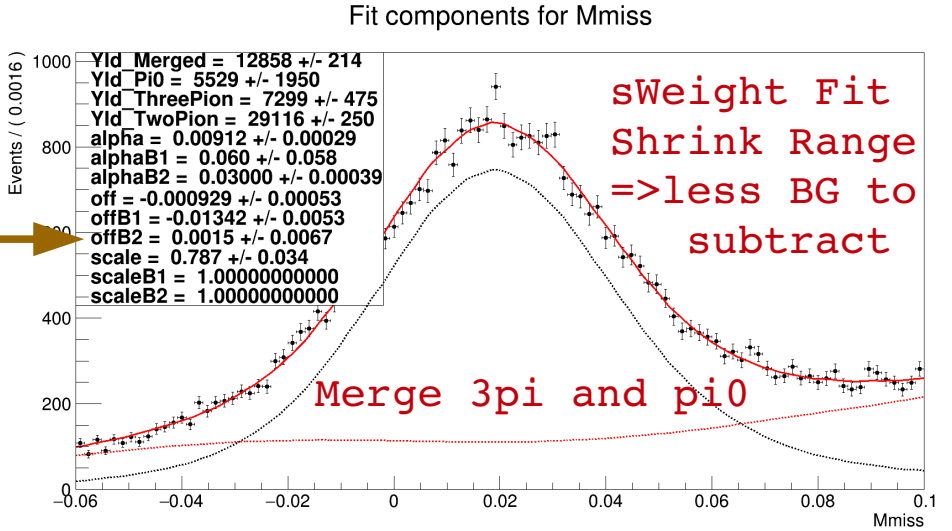
# More sWeights

Perform multiple fits to find best parameters
Can do binned chi2 for speed
Can limit range and merge background for sWeight Fit



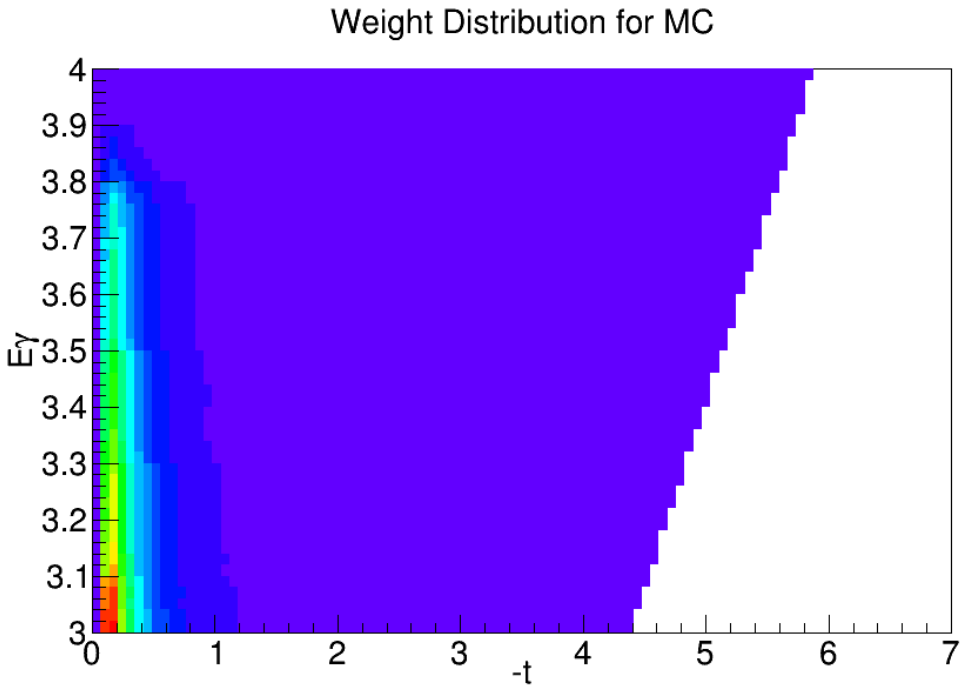
# Some Analysis details

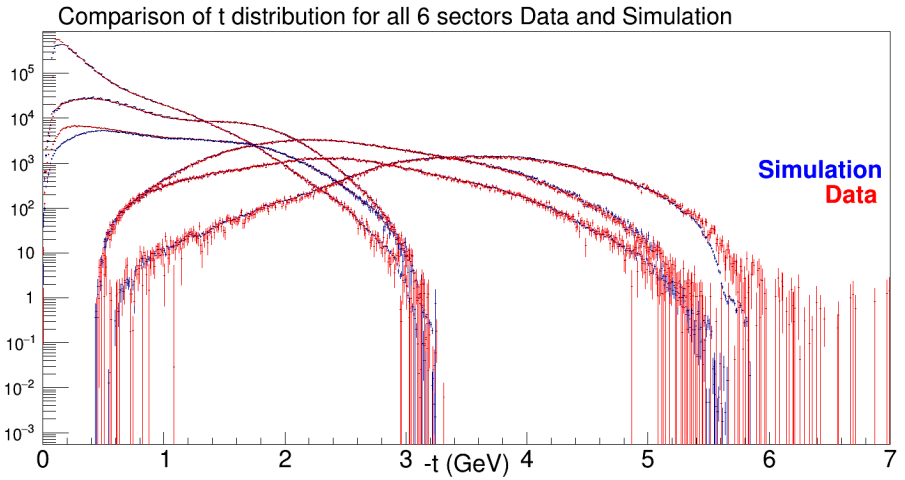
Fiducial Cut as analysis note (more or less)

Background Subtraction Done
- -Shown previously
- -Sweights Method

Acceptance Correction Done for p pi+

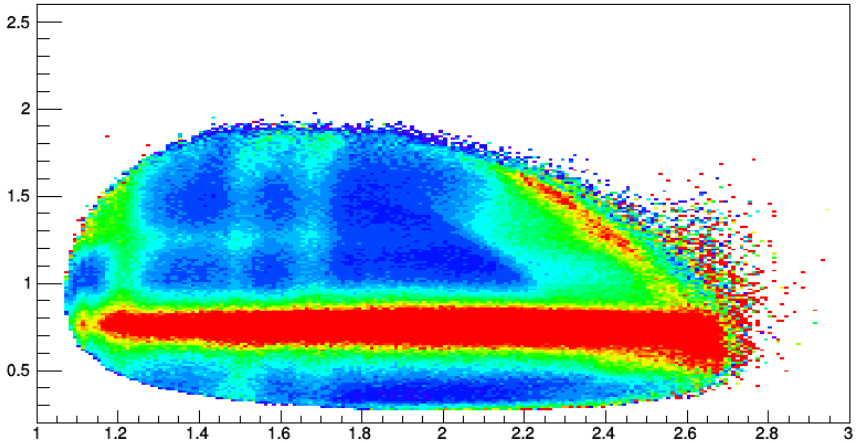
Weighted MC function of Eg, t and Omega (Van Hove)



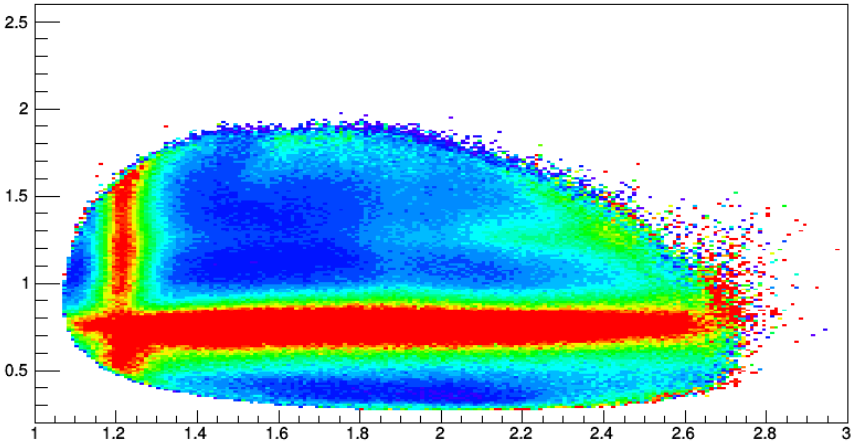



# Two Pion Masses

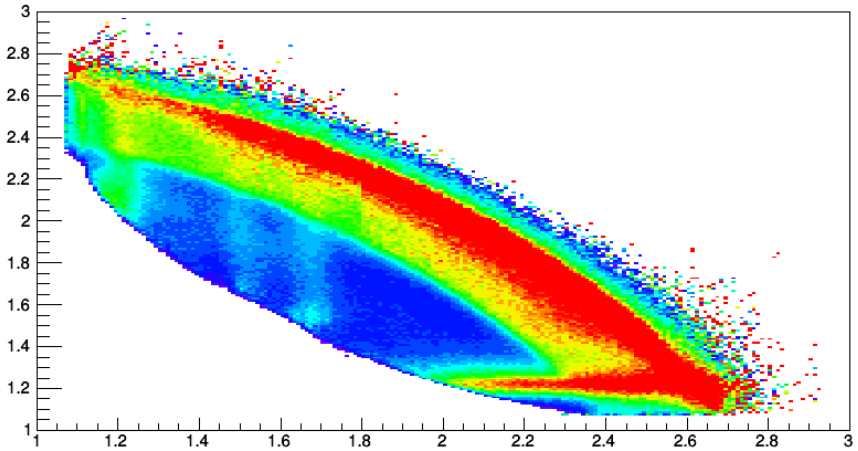
M(π+π-) V M(pπ-)TwoPion_All




M(π+π-) V M(pπ+)TwoPion_All




M(pπ+) V M(pπ-)TwoPion_All




All Events.
Background Subtracted
Acceptance Corrected
Phase Space divided out

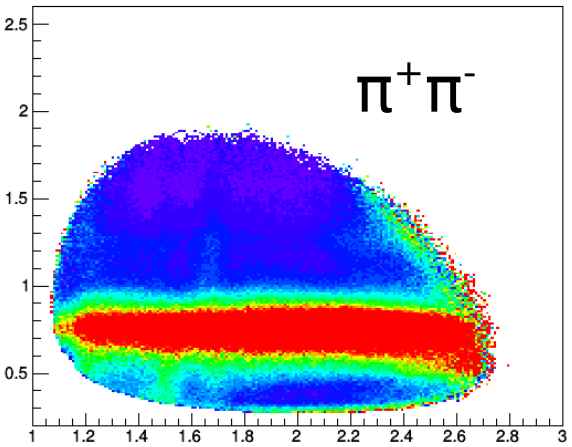
# Two Pion Masses in LPS Sectors

Split into LP Sector

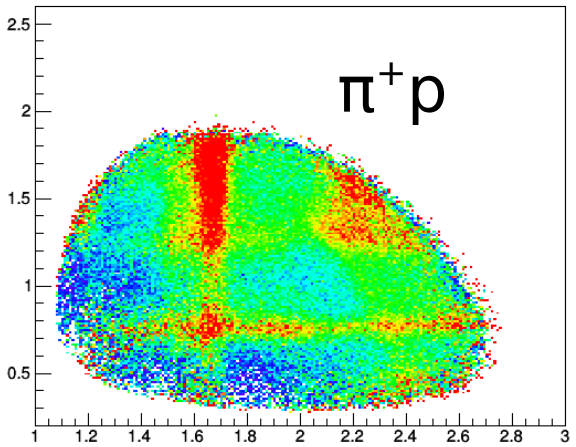
Baryon/Meson Masses : $M(\pi^+\pi^-)$ v $M(\pi^-p)$

Named particles are travelling forward

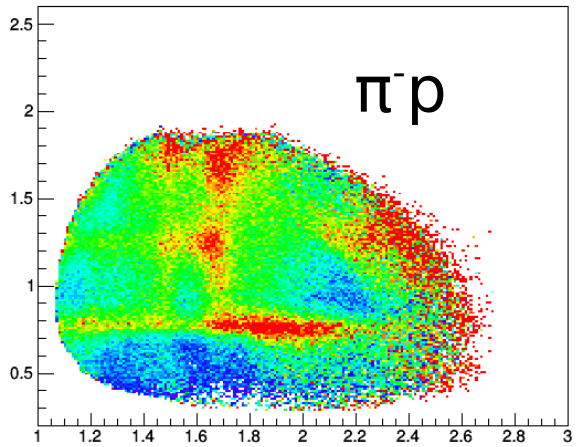
M(π+π-) V M(pπ-)TwoPionLPS0.50_



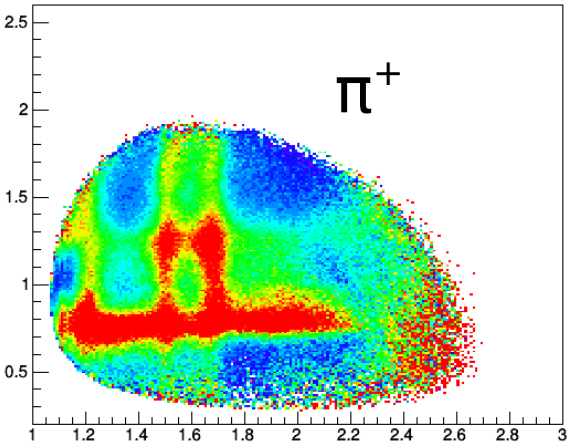

M(π+π-) V M(pπ-)TwoPionLPS1.50_



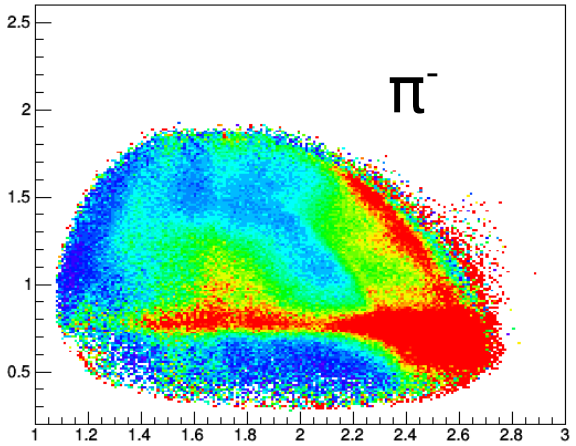

M(π+π-) V M(pπ-)TwoPionLPS2.50_



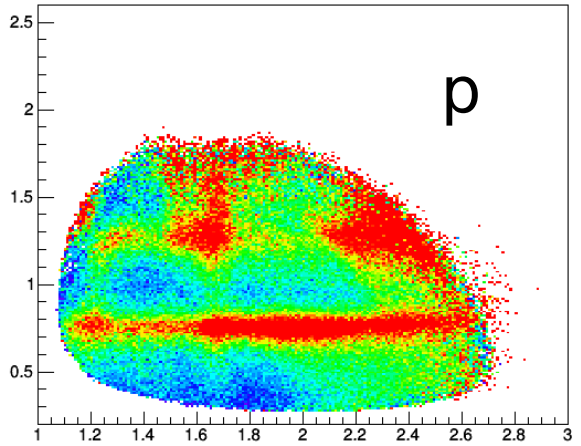

M(π+π-) V M(pπ-)TwoPionLPS3.50_




M(π+π-) V M(pπ-)TwoPionLPS4.50_




M(π+π-) V M(pπ-)TwoPionLPS5.50_

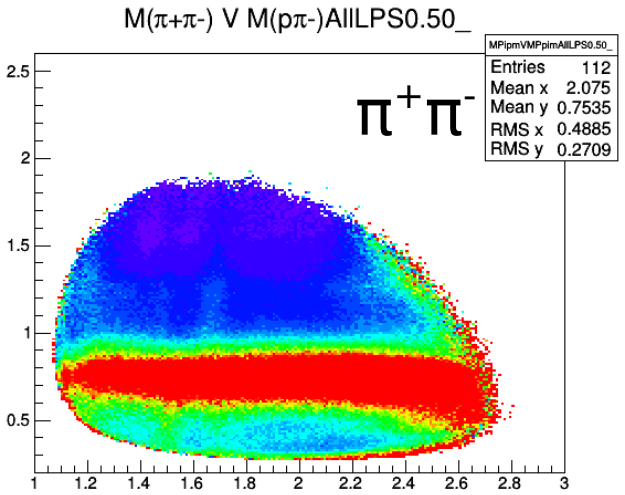


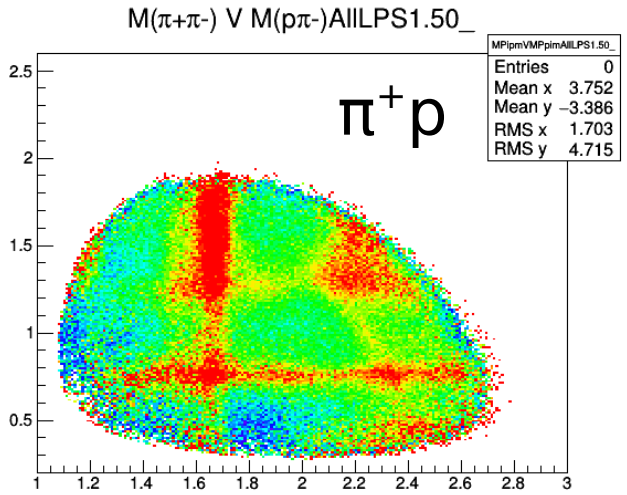
# No Background Subtraction

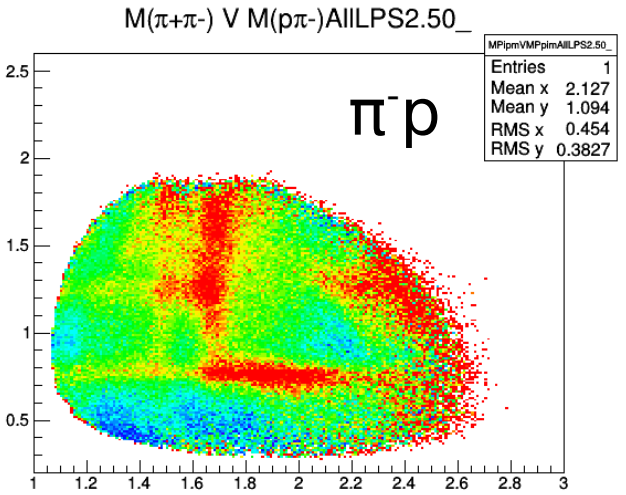
Split into LP Sector

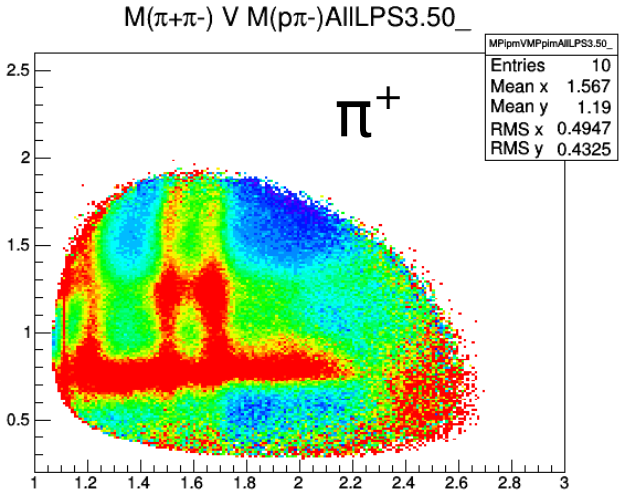
Baryon/Meson Masses : $M(\pi^+\pi^-)$ v $M(\pi^-p)$

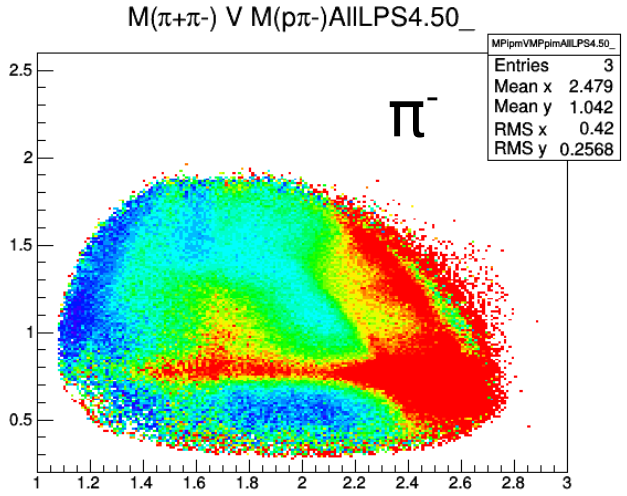
Named particles are travelling forward

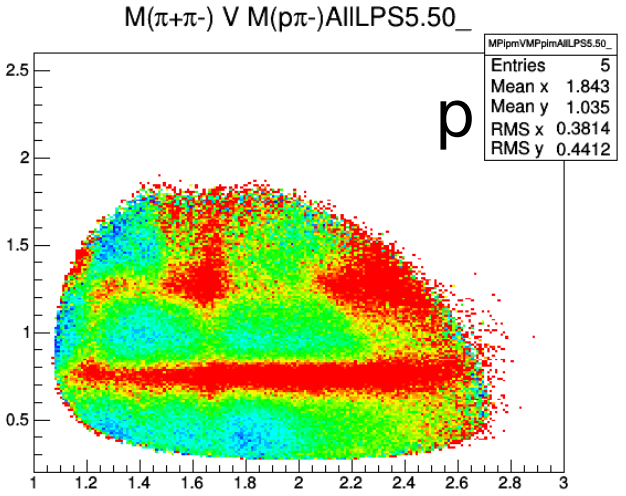


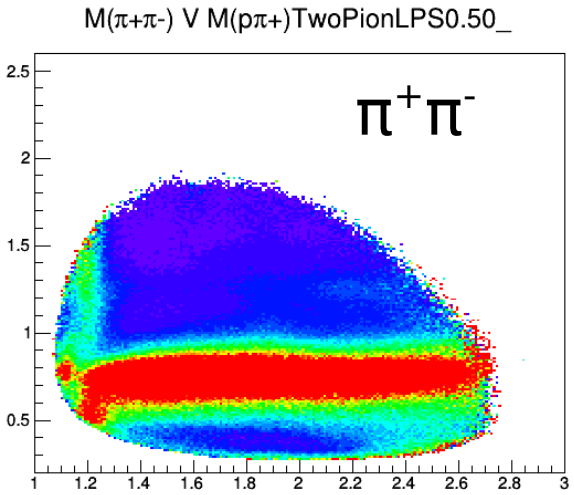



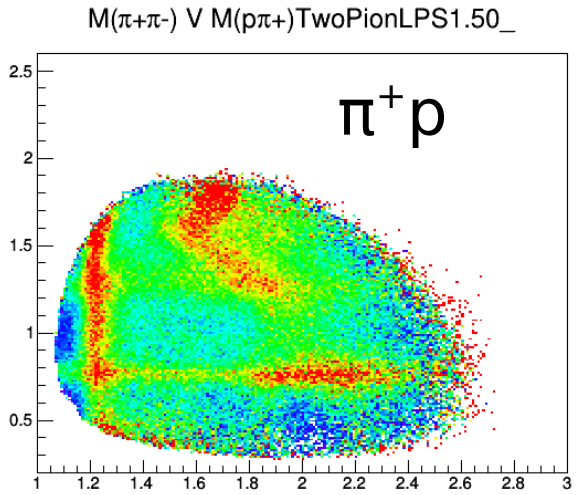
# Two Pion Masses in LPS Sectors

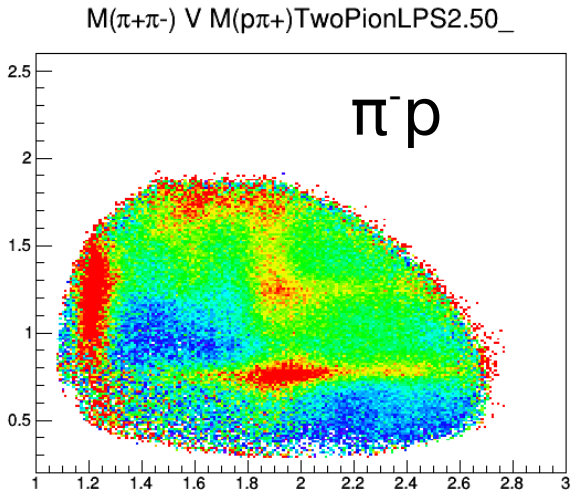
Split into LP Sector

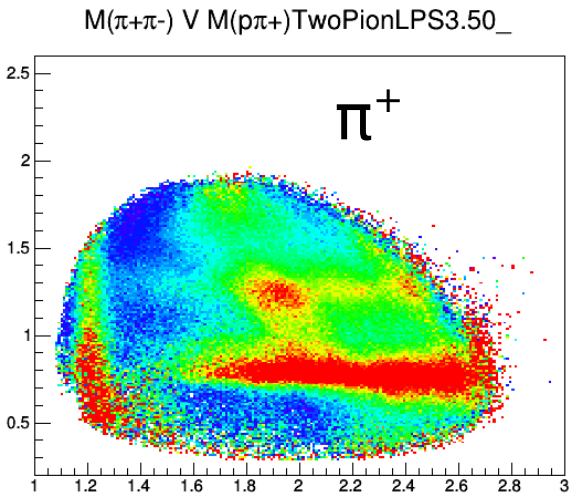
Baryon/Meson Masses : $M(\pi^+\pi^-)$ v $M(\pi^+p)$

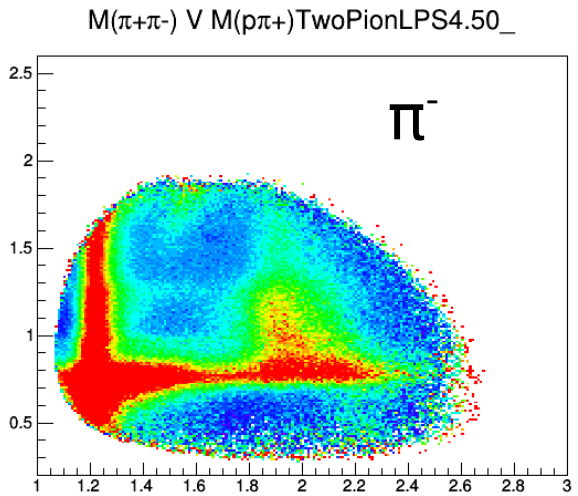
Named particles are travelling forward

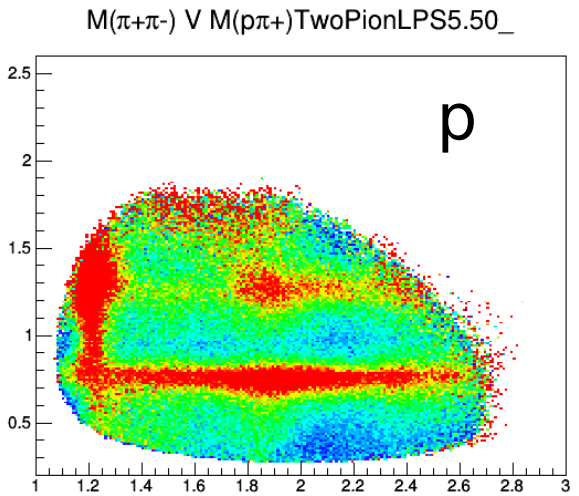


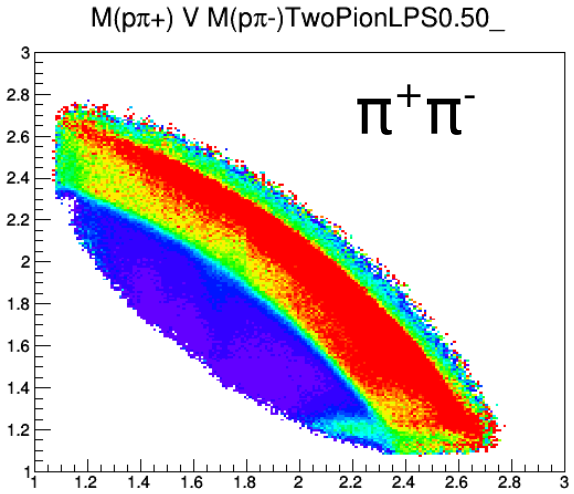



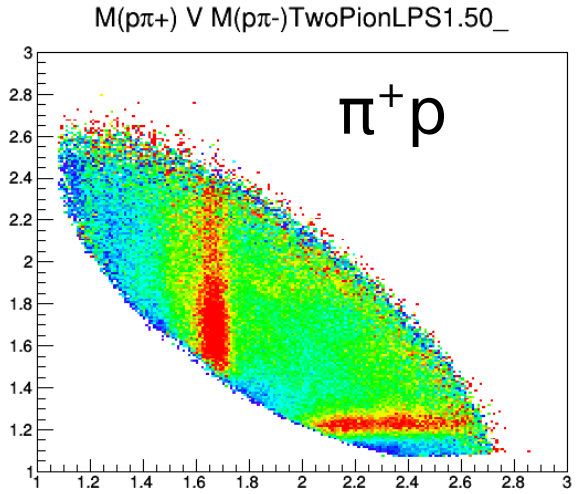
# Two Pion Masses in LPS Sectors

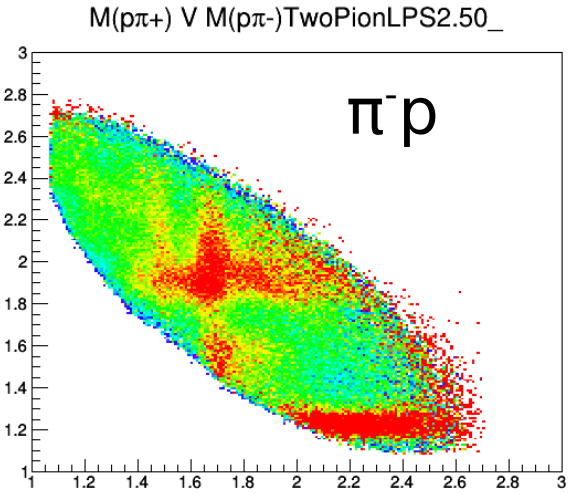
Split into LP Sector

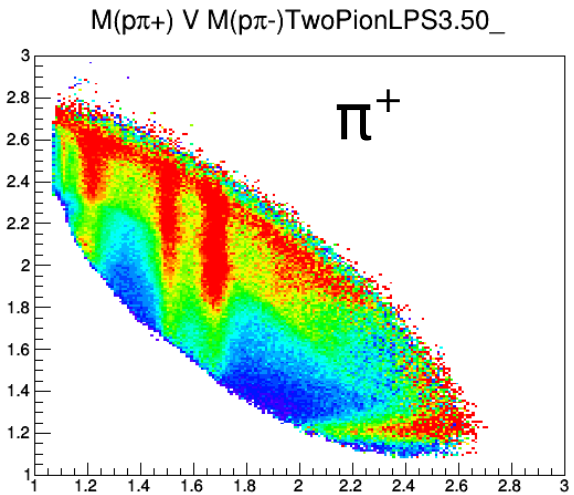
Baryon/Meson Masses : $M(\pi^- p)$ v $M(\pi^+ p)$

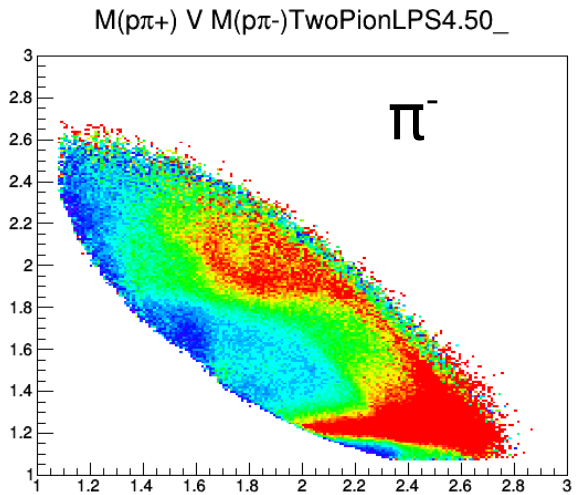
Named particles are travelling forward

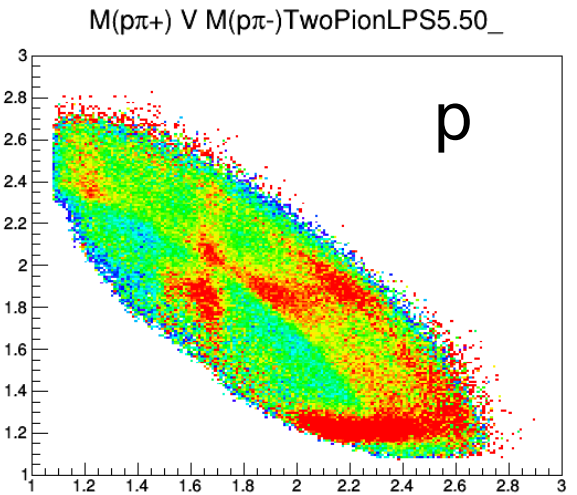


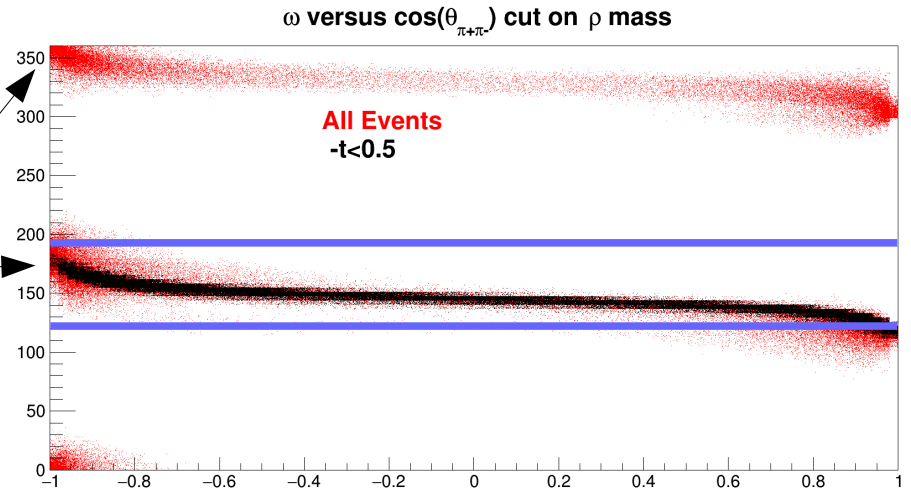



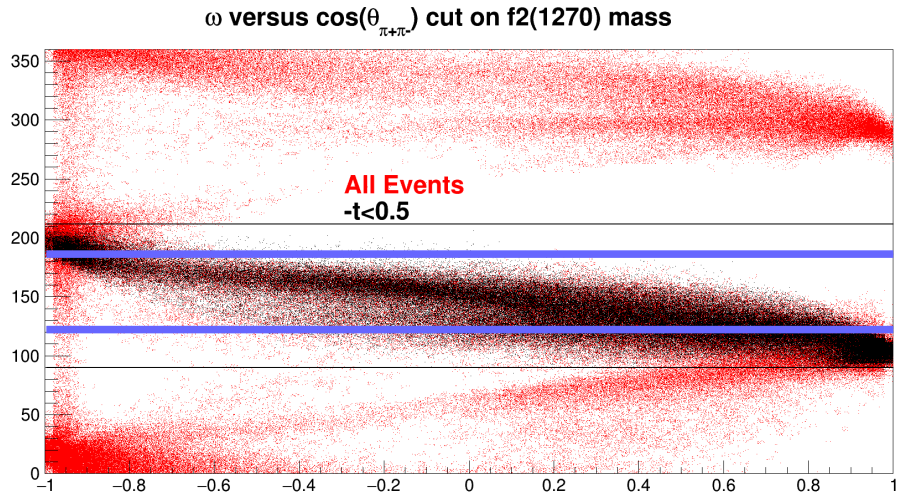
# Restrictions on Longitudinal Phase Space

At low reaction s
Affected by t dependence
And mass dependence

ρ restricted to ω where
both π go forward or back
All ρ contained 100<ω<200
Low t van Hove 120<ω<180

All f2 contained 90<ω<210

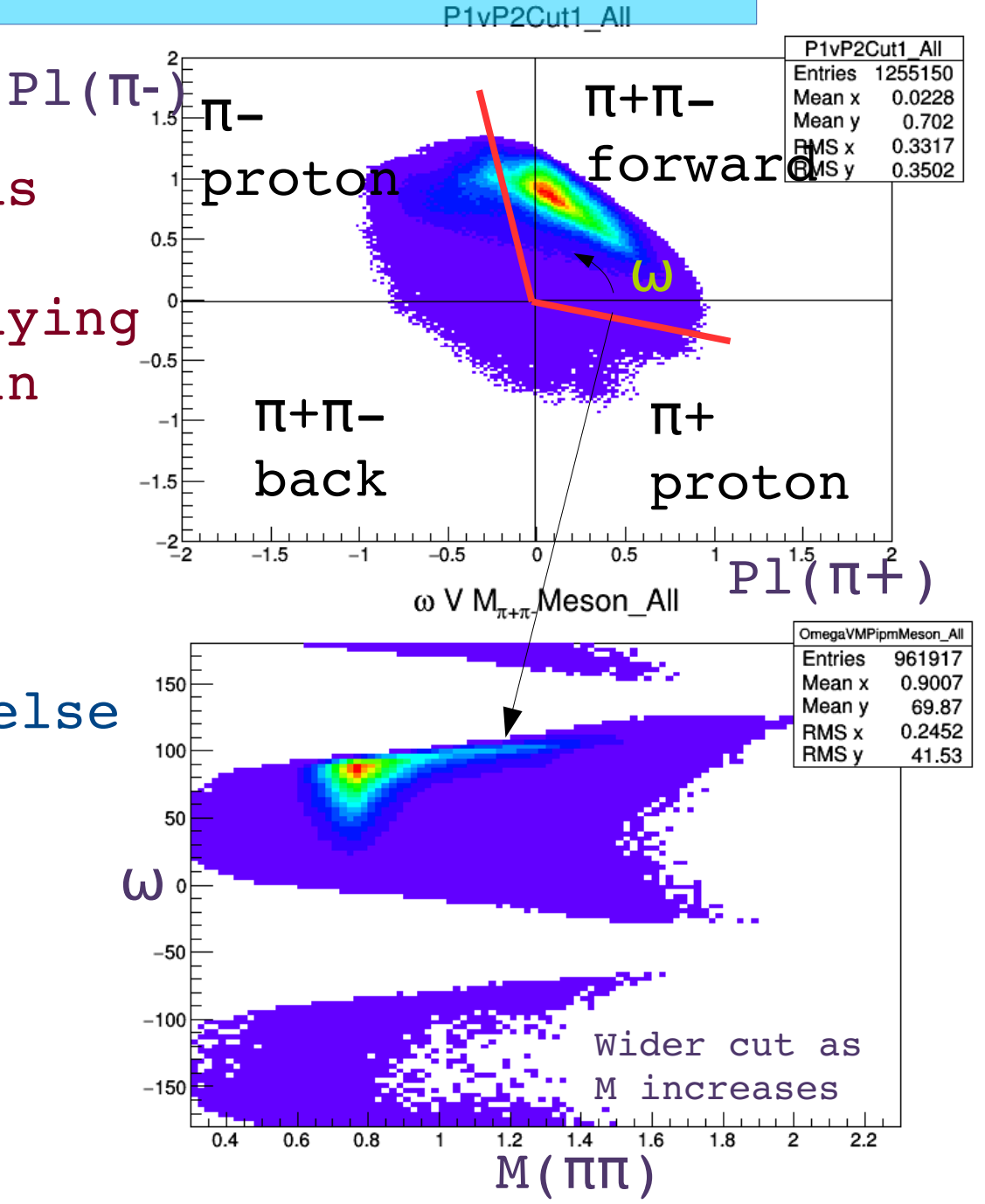


# Optimised Meson/Baryon cuts

Now our cut is defined as the corresponding value of omega for π-(π+) decaying backwards along z axis in meson rest frame.

⇒Do not lose any meson decays (acceptance)
⇒Throw away everything else

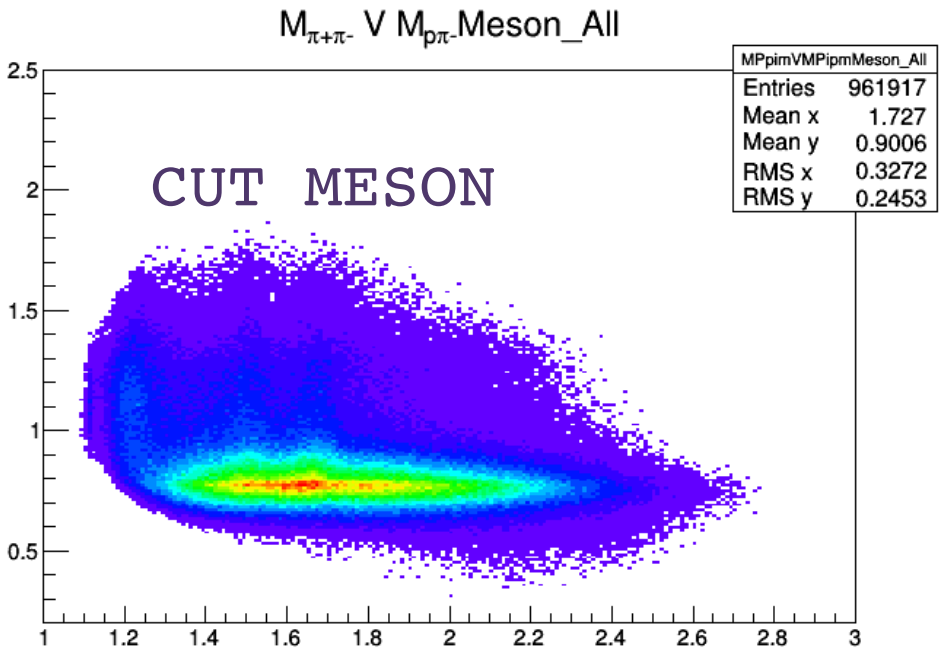


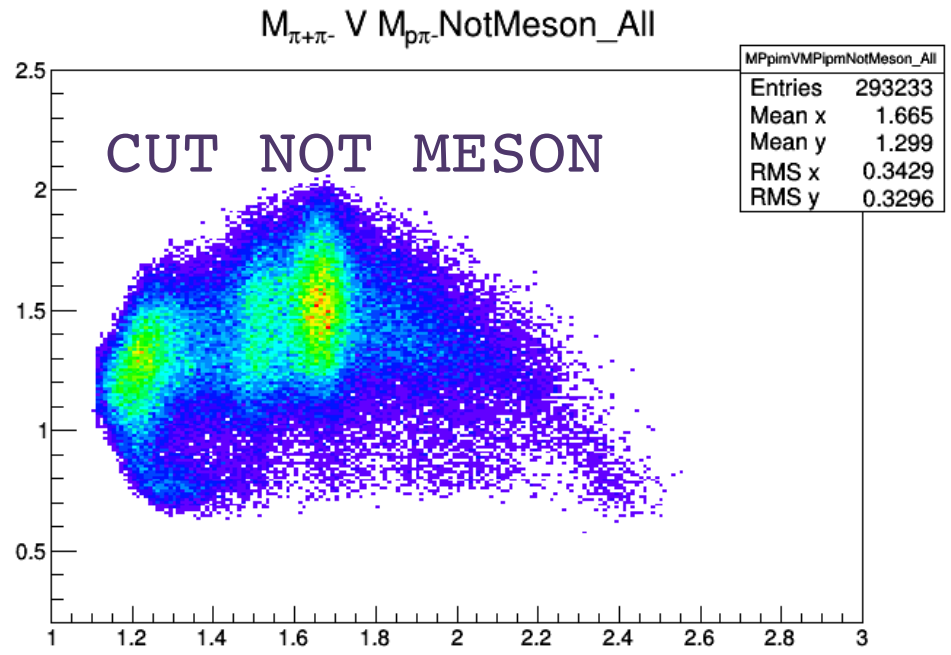
# Optimised Meson/Baryon cuts

Now our cut is defined as the corresponding value of omega for π-(π+) decaying backwards along z axis in meson rest frame.

This is a function of W, M(π-π+), M(π-), M(π+) i.e rest frame breakup momentum.

Problem : resolution effects are an issue, need to widen the cuts to compensate



# Summary

Investigated Longitudinal Phase Space as a means for enhancing different reaction mechanisms

Publication in process

Found to be effective means of seperating meson and baryon production, with some limitations at JLAB energy

Currently investigating more specific method :

Isobar Phase Space

# WORK IN PROGRESS....
# Equivalent to Longitudinal Phase Space plots