HASPECT Analysis Framework

Data Analysis chain for CLAS and CLAS12 Hadron Spectroscopy analysis

Hadron Spectroscopy Working Group
CLAS Collaboration Meeting 25/2/2016

HASPECT

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Experimental Analysis:
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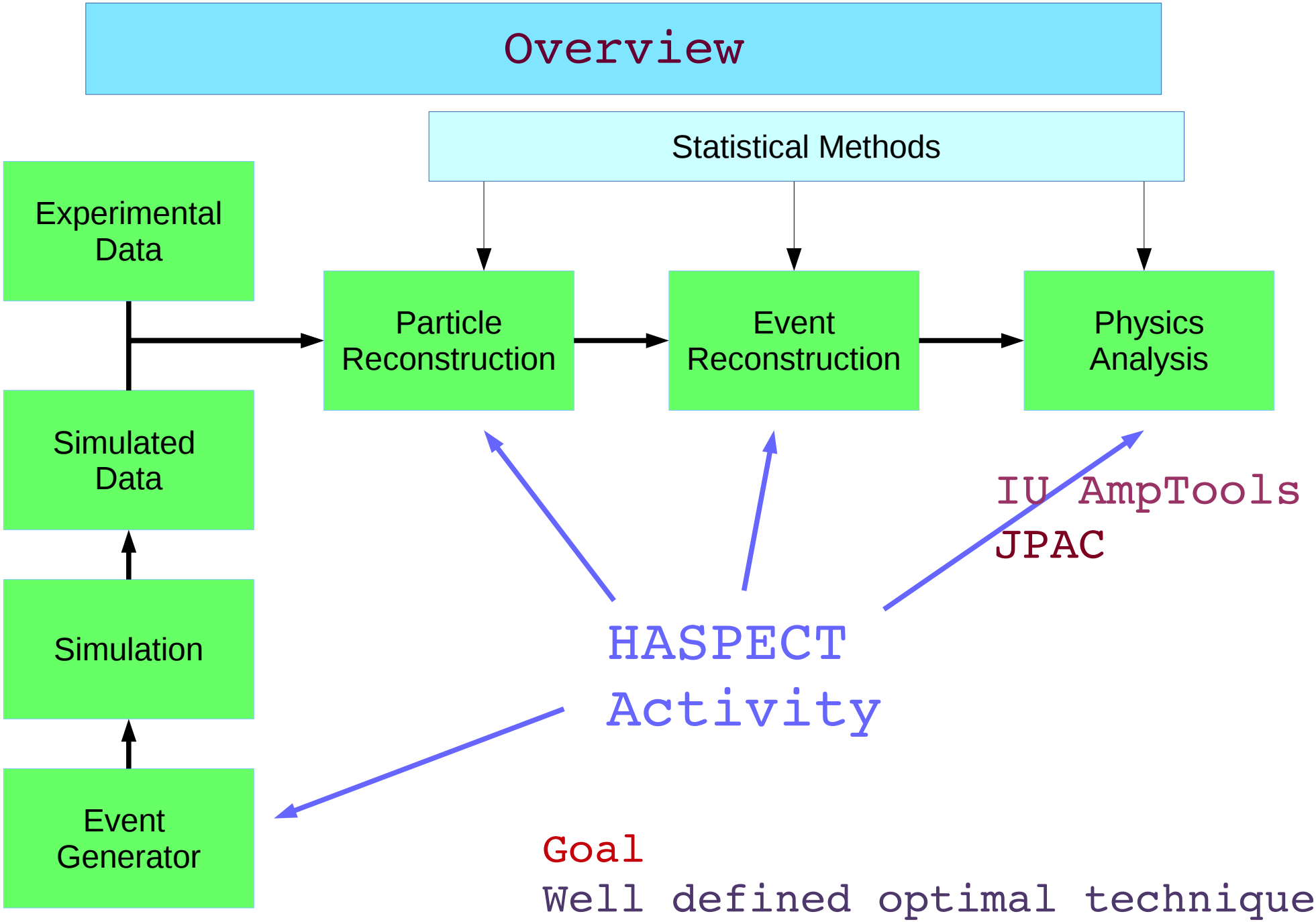
Overview



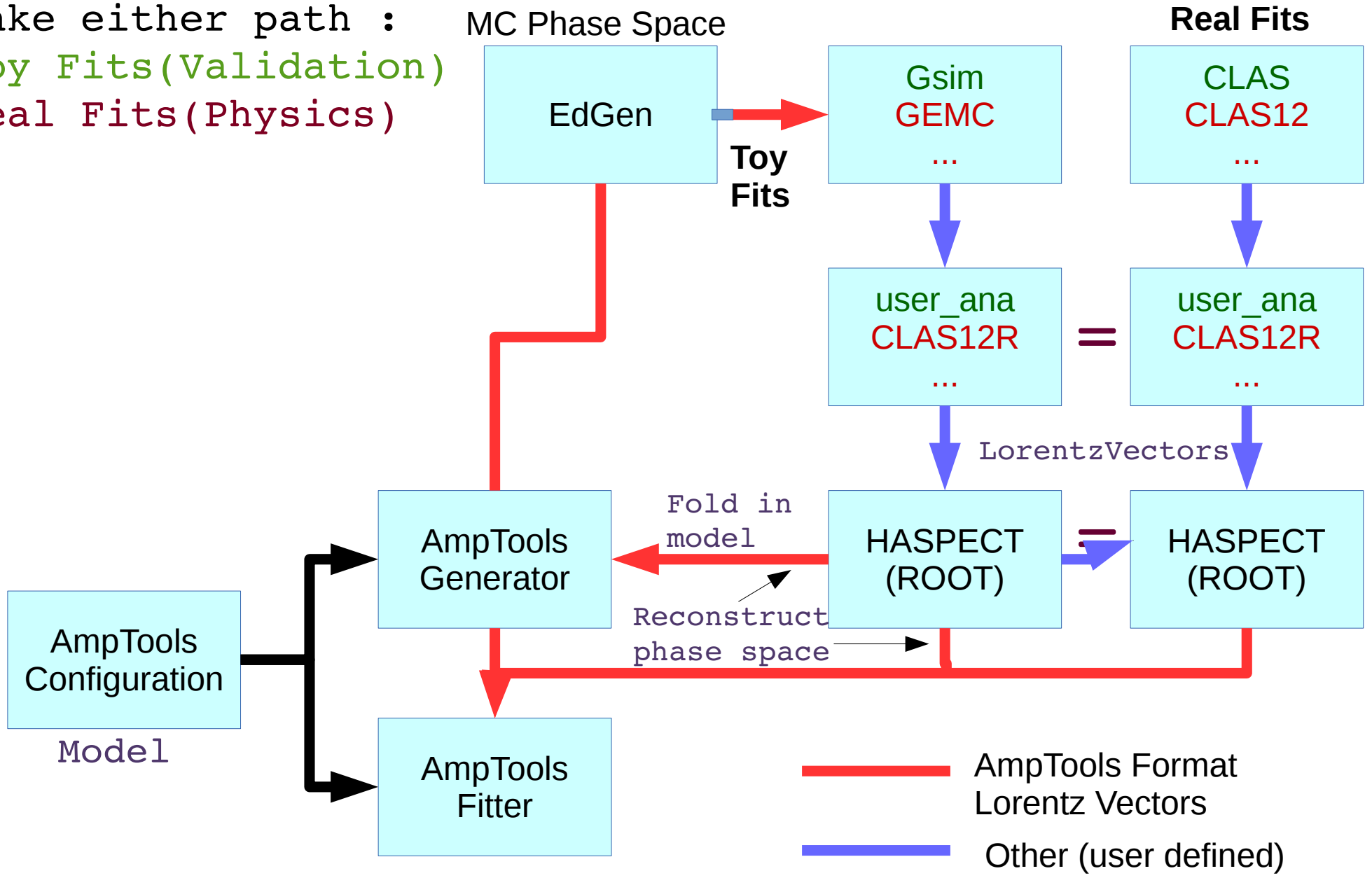
Goal

Well defined optimal techniques

Not ad-hoc solutions

Data Paths

Take either path :
Toy Fits(Validation)
Real Fits(Physics)

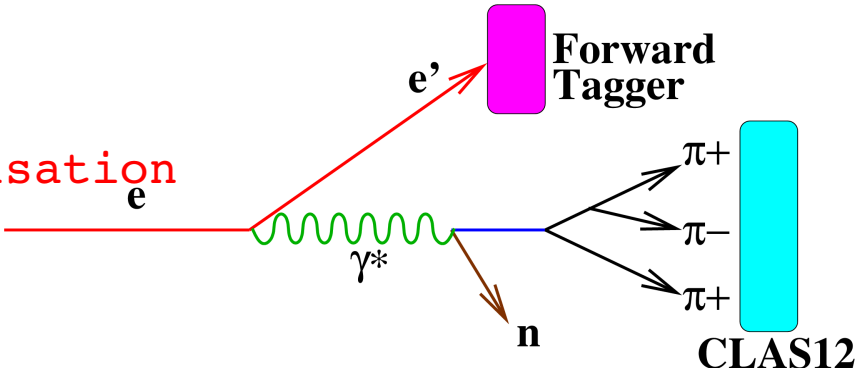


CLAS12 MesonEx fastmc validation

11 GeV e- scattering in 5cm lH_2 target

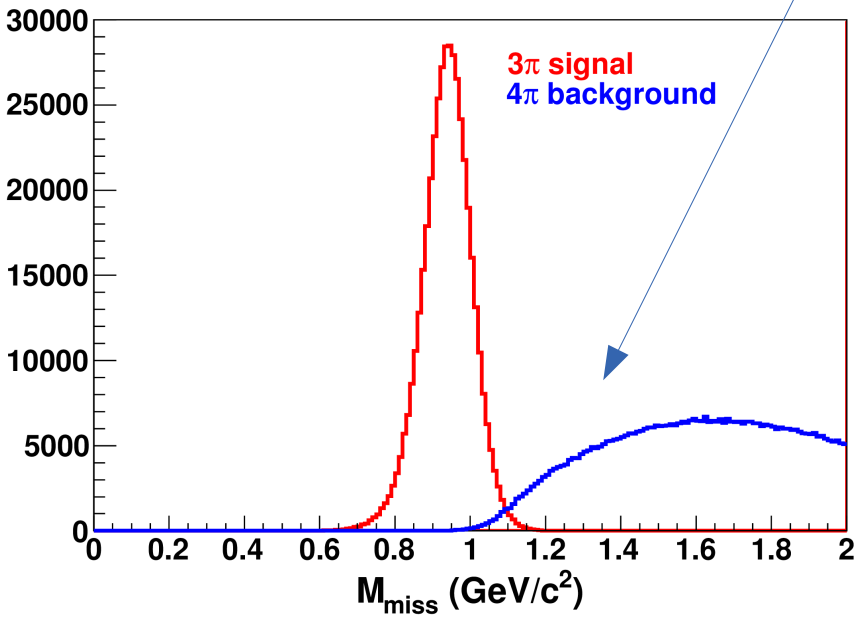
Luminosity ~ $10^{35}cm^{-2}s^{-1}$

e' detected in forward tagger
→γ energy (7-10.5 GeV) and polarisation
- σ_E = 0.02-0.07 GeV



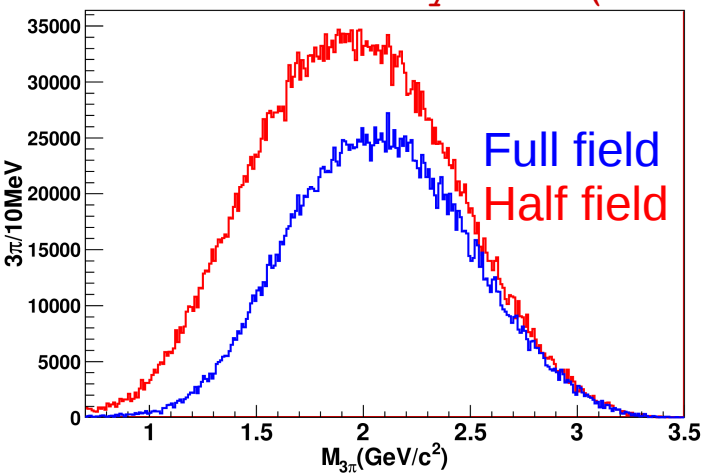
3π detected in CLAS12
- σ_p=0.5 %, σ_θ=1 mrad , σ_φ=3 mrad

Resolution allows good discrimination from other final states (simulation)



Neutron reconstructed by missing mass

Expected number of reconstructed events from initial low luminosity data (20 days)



80 day experiment with full luminosity
80 X more events or 10^6/10MeV

CLAS12 MesonEx fastmc validation

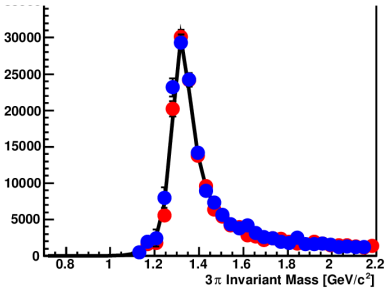
Search for $\pi_1(1600)$ exotic in 3π final state

Detector response capable of reconstructing signals <1%

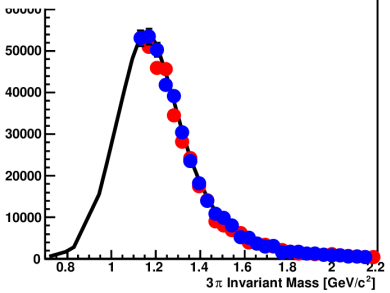
Currently preparing to extend study using gemc and CLAS12 reconstruction

...but also simpler reactions first.

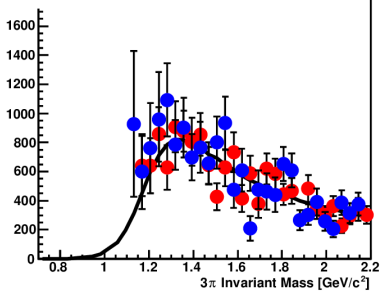
a_2 to ρπ S wave



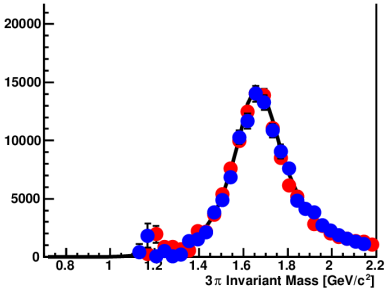
a_1 to ρπ S wave



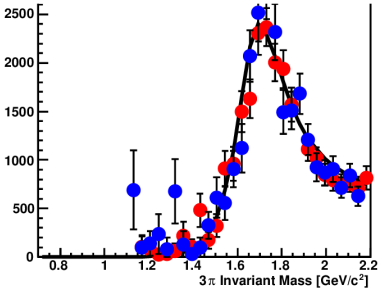
a_1 to ρπ D wave



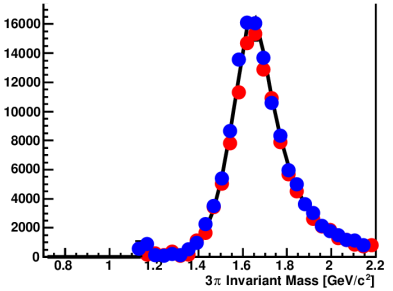
π_2 to ρπ P wave



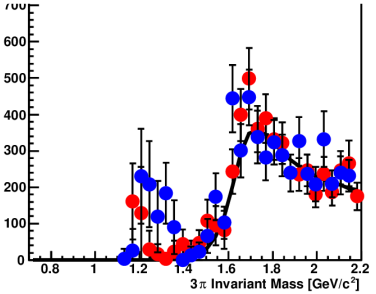
π_2 to ρπ F wave



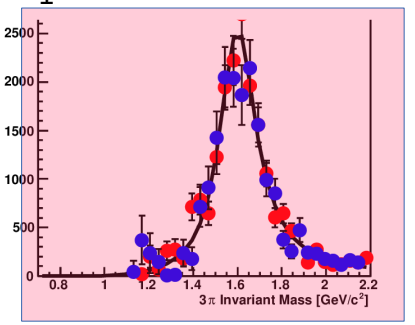
π_2 to $f_2\pi$ S wave



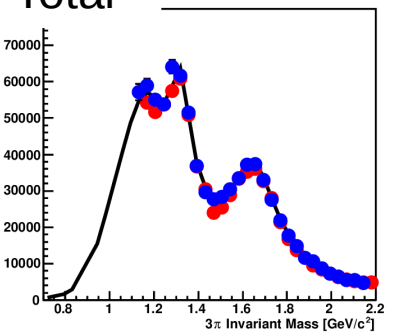
π_2 to $f_2\pi$ D wave



π_1 to ρπ P wave



Total



HASPECT Event Reconstruction

Provide code to handle routine tasks
allowing procedures to become standardised
- Input/Output/Interfacing
- Histogramming
- Particle/reaction identification
- Event weighting

Maintain normal ROOT flexability for users

Users shift to physics and systematic studies

Promote full potential of ROOT
- Based on TSelector Tree analysis class
- Use of TEntryList class to prevent duplicating data
- ROOT system takes care of compilation and configuration
- Parallel ROOT Facility (PROOF)
- Statistical Analysis Packages (RooFit/Stats)

https://github.com/HASPECT/Event

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

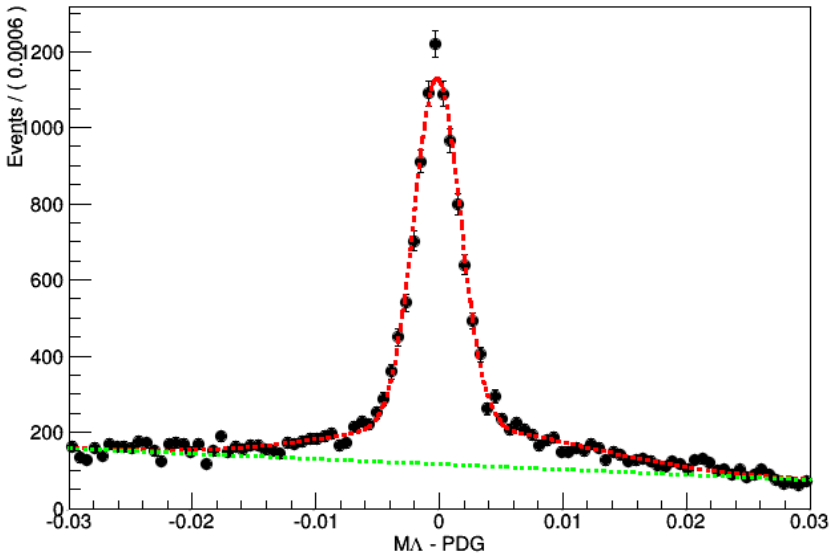
N_k = Yield for species k

V = covariance matrix

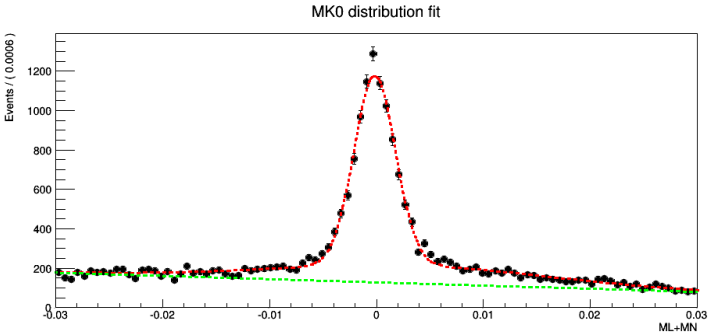
Part of RooStats(used here)

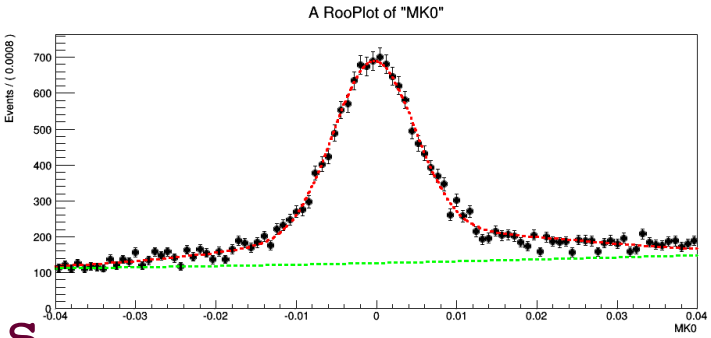
Can include multiple signal and background species

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

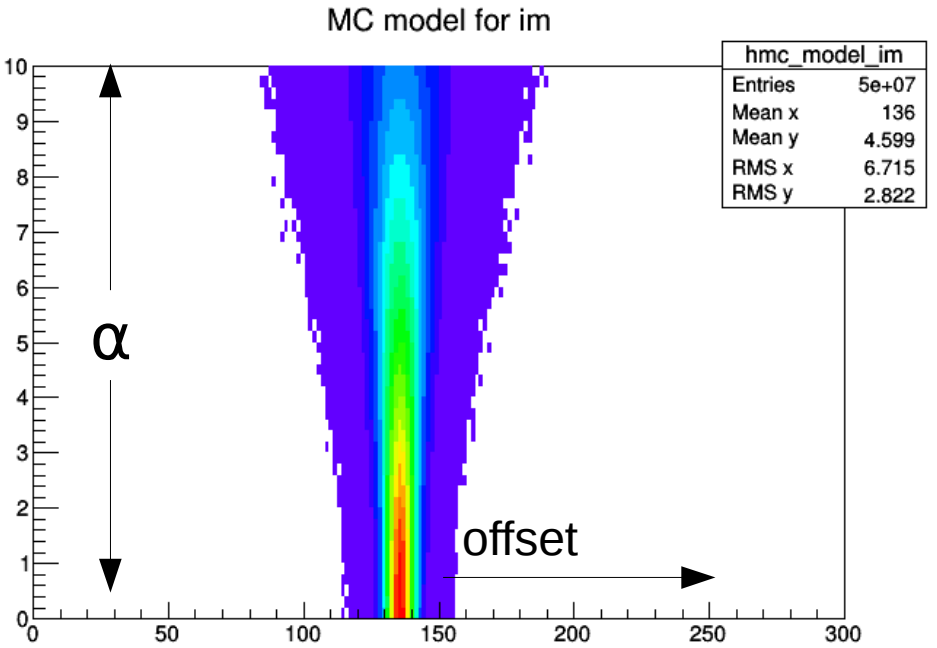
Sequential 1D histograms

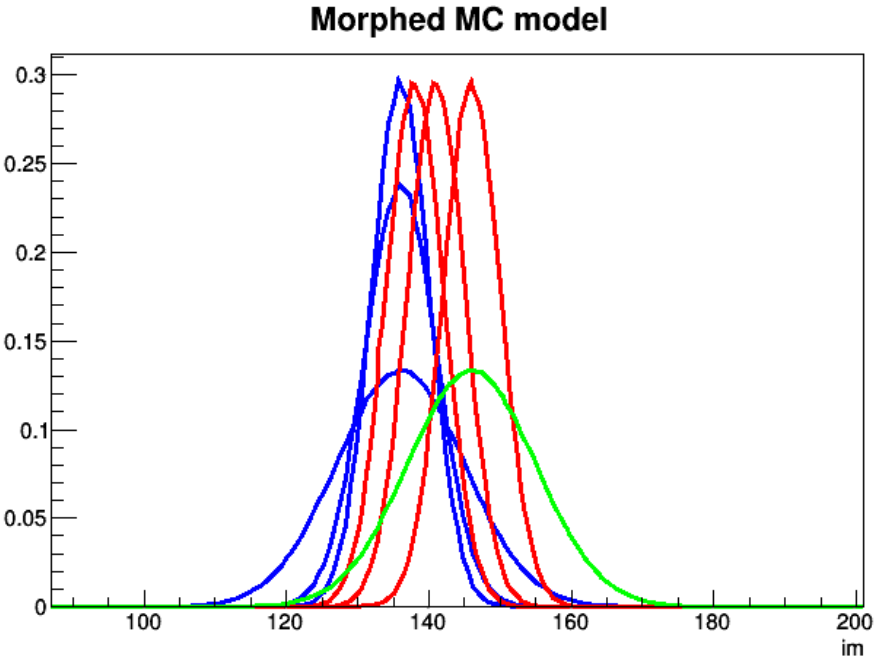
Smoothed and interpolated

Adding greater additional smearing with morphing parameter α

Additional offset parameter

(Also RooFit HistFactory...)





Event Reconstruction : $\pi^+\pi^-p$

Just Phase Space

g11 dataset, detect π^+ and p

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

Signal BG

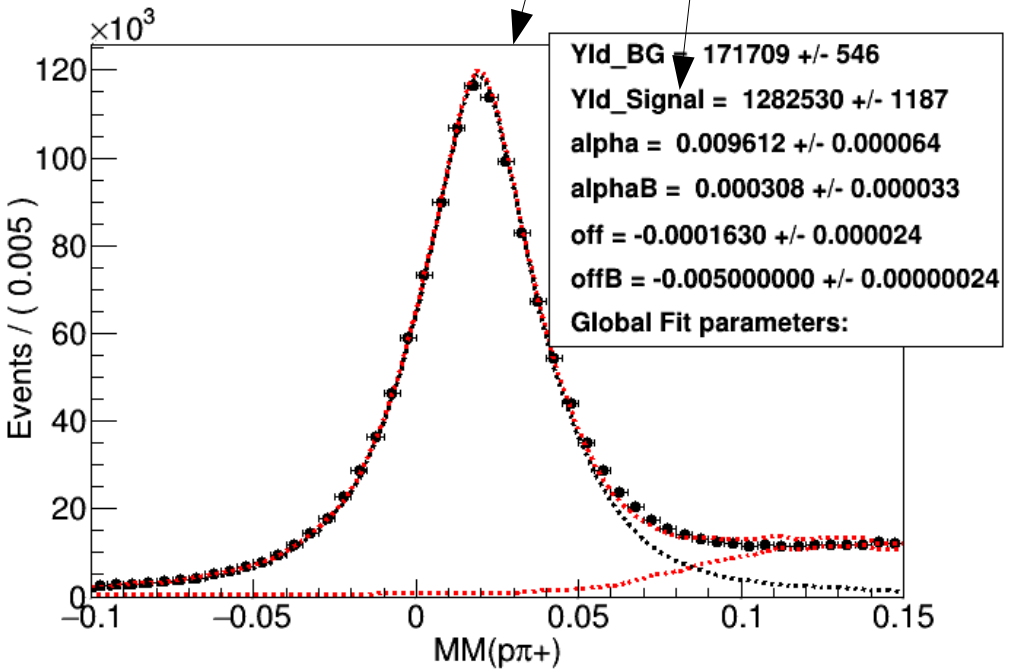
RooFit Extended Maximum likelihood fit

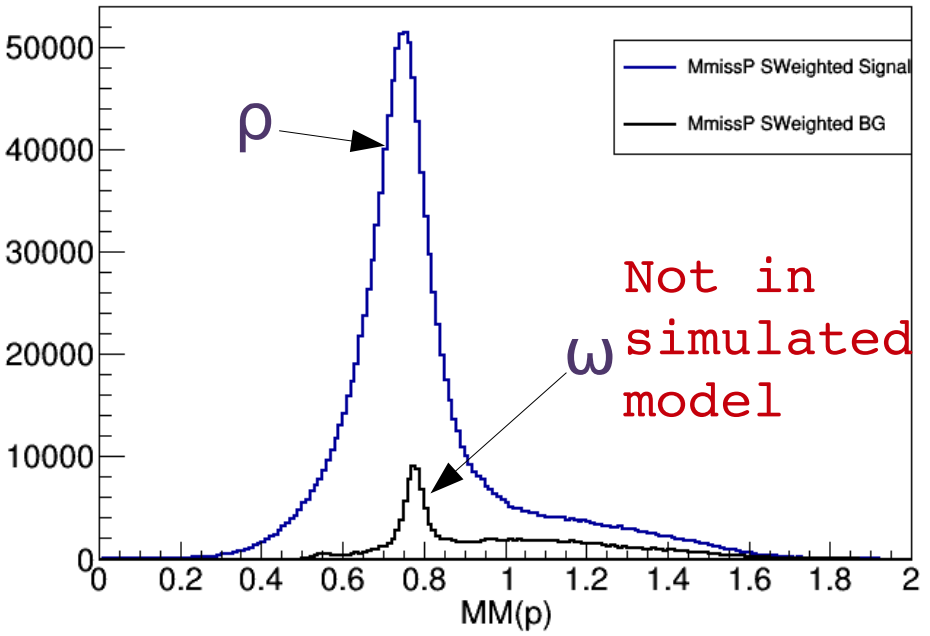
RooStats sWeight calculation

⇒Disentangle distributions

For Cross section

For amp analysis





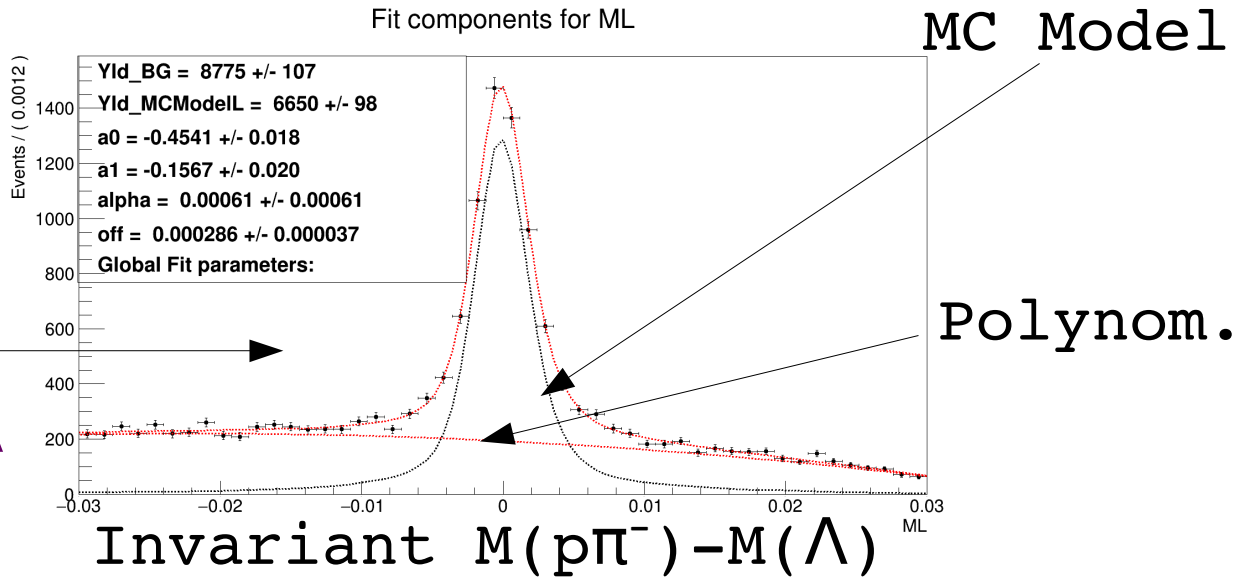
```
THSRooFit* RF=new THSRooFit();  //Manager class
RF->LoadVariable("Mmiss[-0.1,0.15]");//should be same name as variable in tree
RF->LoadAuxVars("Eg[3,4]");//should be same name as variable in tree
RF->LoadAuxVars("fgID[0,1E12]");//should be same name as variable in tree
RF->LoadAuxVars("t[0,0.4]");//should be same name as variable in tree

////////////////////////////Make Model Signal
RF->Factory("THSMorphPDF::Signal(Mmiss,alpha[0.02,0,0.04],off[0,-0.005,0.005],10)");
TChain chainmcL("HSParticles","mcsignal");
chainmcL.AddFile("mc_ppip_cor.root");
//add mc data to make model
((THSMorphPDF*)RF->GetWorkSpace()->pdf("Signal"))\\
                    ->AddSmearedModel(&chainmcL,RF->GetAuxVars());
////////////////////////////Make BG model (same code again)
...
RF->LoadSpeciesPDF("Signal");
RF->LoadSpeciesPDF("BG");
RF->TotalPDF();//Total PDF
////////////////////////Load Data
TChain chain("HSParticles");
chain.AddFile("twopi_ppip_pmiss.root");
RF->LoadDataSet(&chain);//import to RooFit
////////////////////////Fit Model to data
RF->Fit();
RF->PlotDataModel();
////////////////////////Make sWeights
RF->sPlot();
RF->ExportWeightsToFile("MorphW.root");
RF->DrawTreeVar("MPipm",200,0,2);
RF->DrawTreeVar("MmissP",200,0,2);
RF->SavePlots("plots.root");
```

Only really need to configure variable and file names

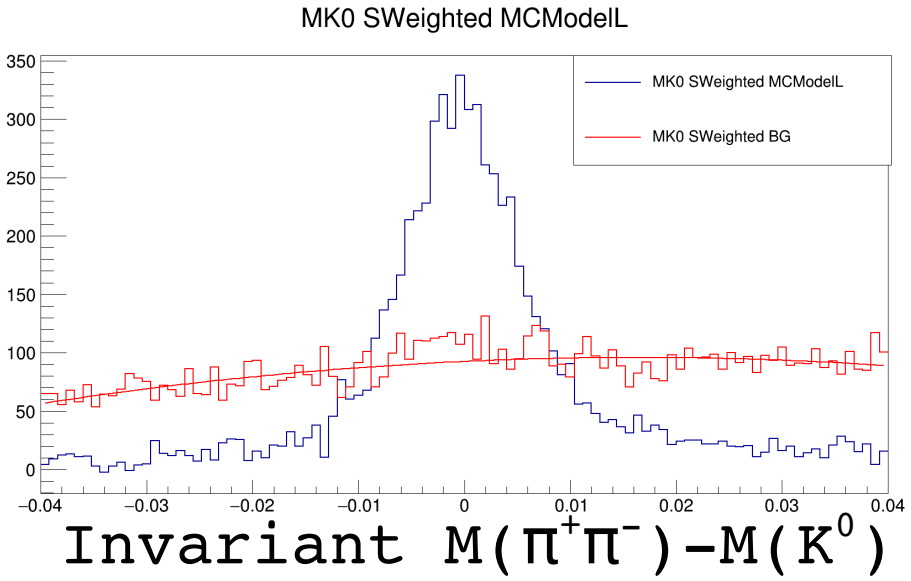
*Developed with Dominik Werthmueller(Glasgow)

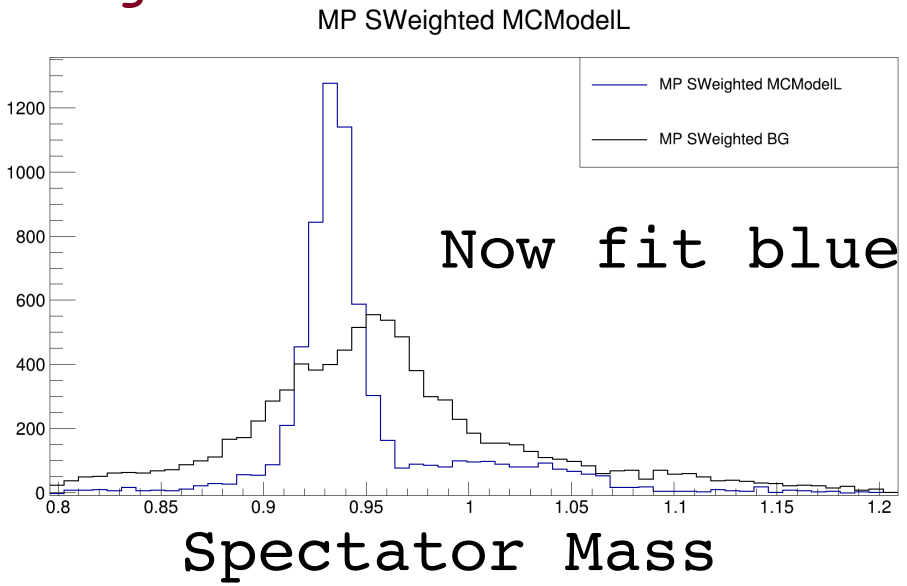
Event Reconstruction : K0Lambda

G13b linear polarised
Deuterium target
Select $\pi^+\pi^-\pi^-p$ events
Fit invariant $M(\pi^-p)$
Tag strangeness from Λ

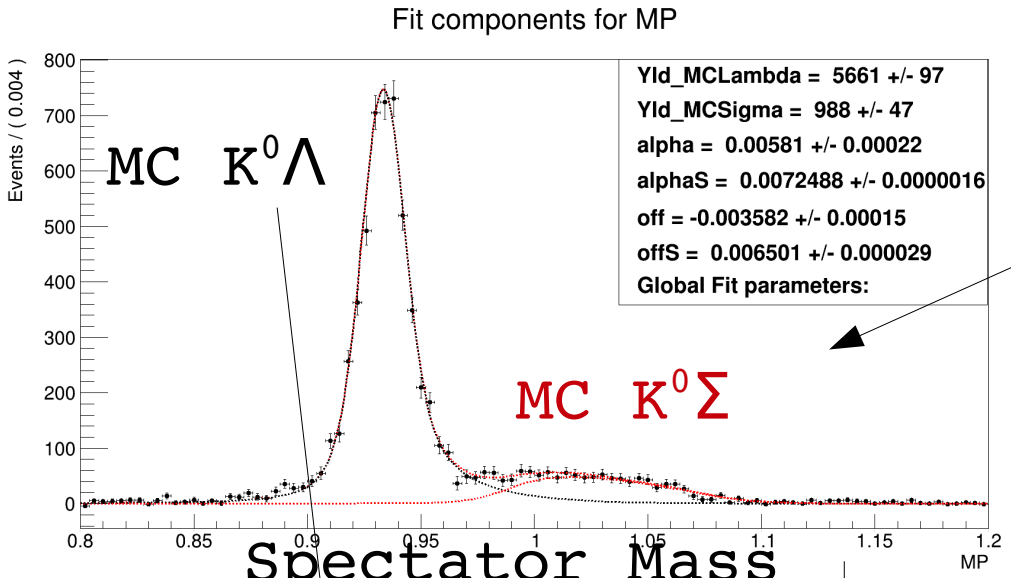


Use weights



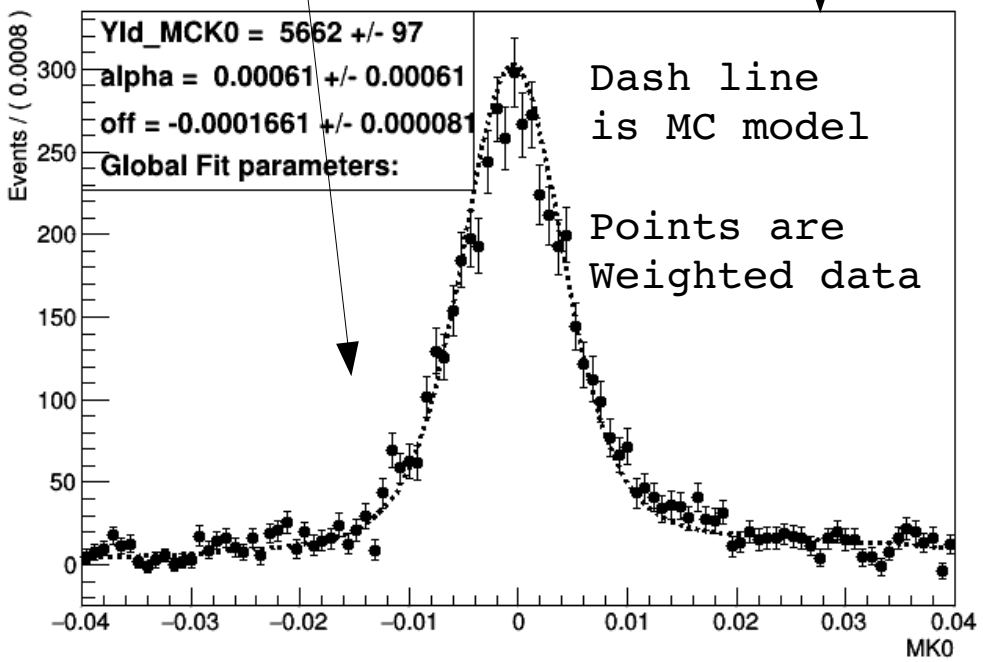


Event Reconstruction : K0Lambda



Spectator Mass

Use weights



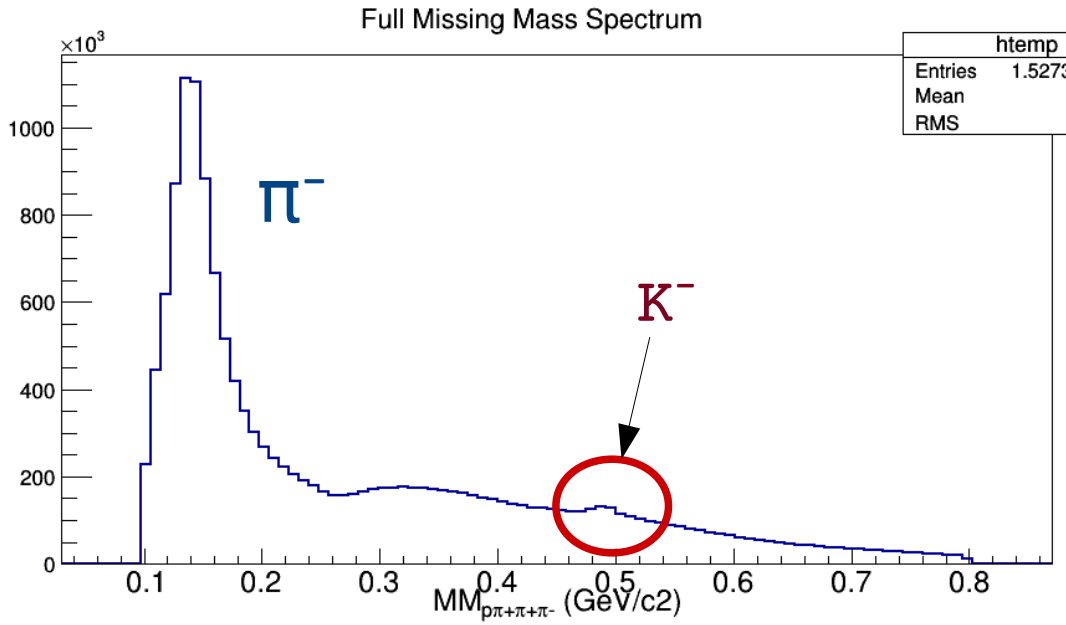
Use sWeights for Λ
Fit Spectator Mass
= Missing Mass(ΛK^0)

With K0Λ and K0Σ
Simulated models

Fits factorise
Avoid modelling
Non-strange background

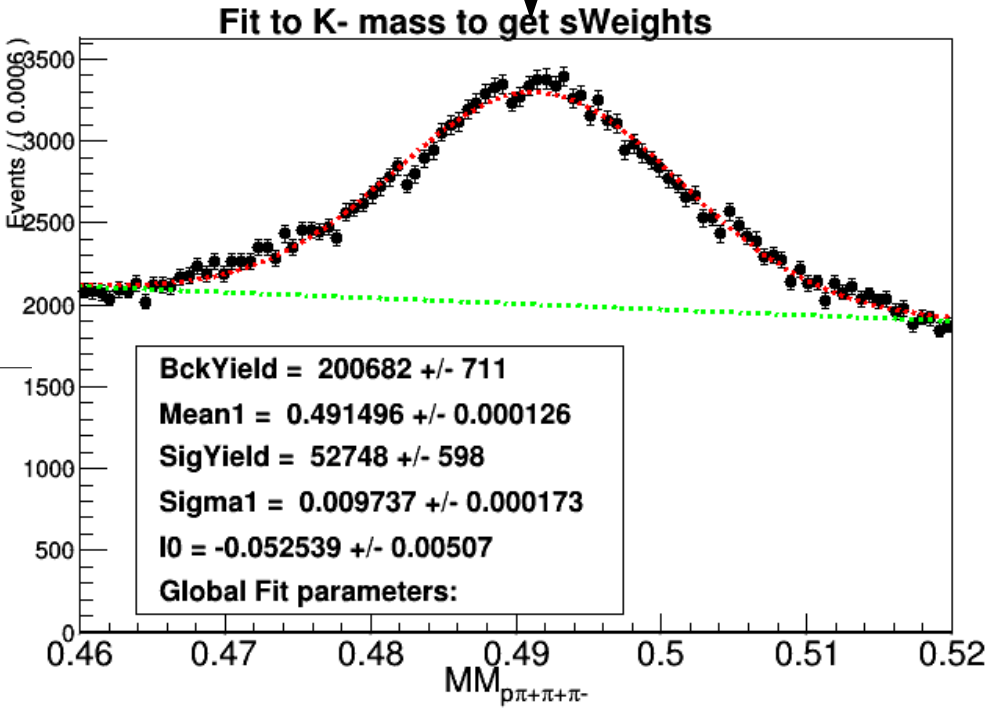
Can now used combined
sWeights in further
Analysis
Polarisation observables
for K0Λ

Event Reconstruction : g11 skim p, $2\pi^+$, π^-



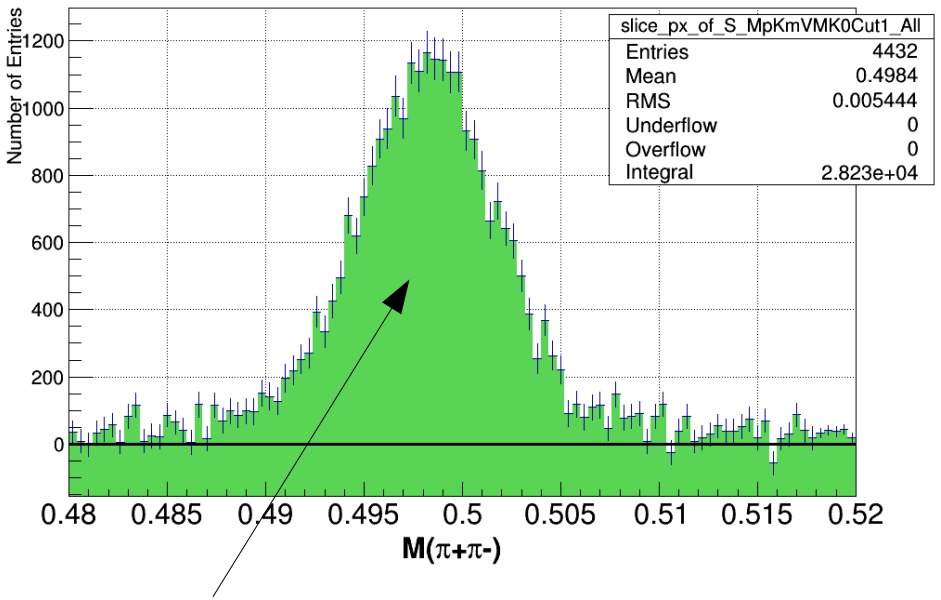
$|M(\pi^+\pi^-) - M(K0)| < 0.02$ with both combinations of π^+

And fit Gaussian +Linear



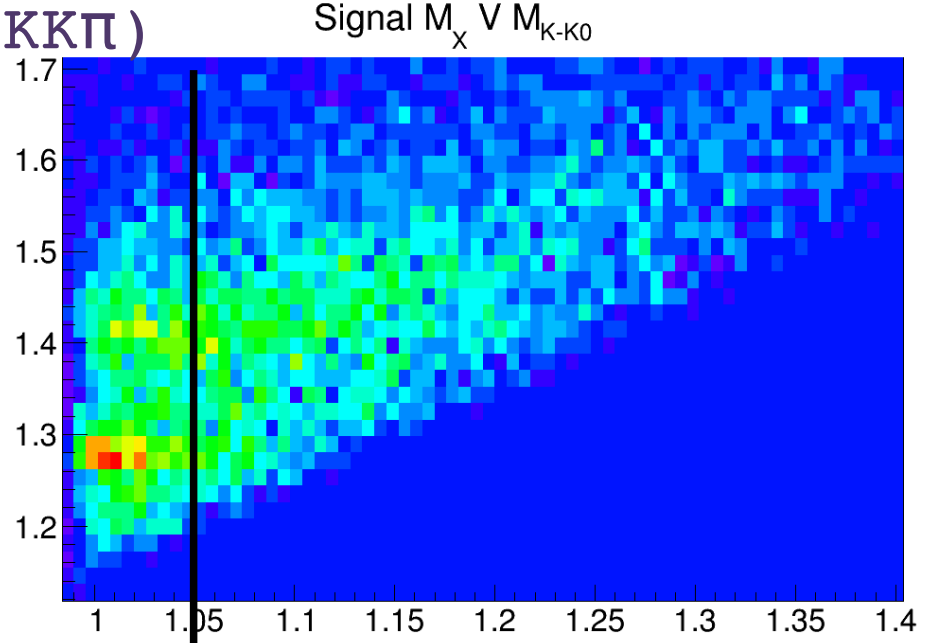
Using these weights Imply clean $p\pi^+\pi^+\pi^-K^-$ events

Event Reconstruction : pK-K0π+

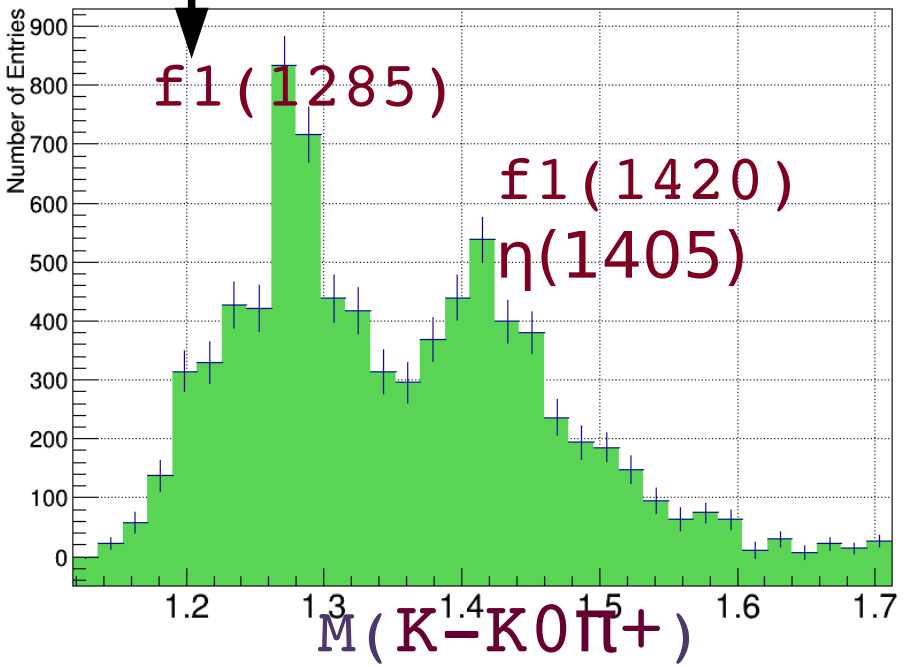


Using K- weights get a Clean K0 in M(π+π-)

M(KKπ)

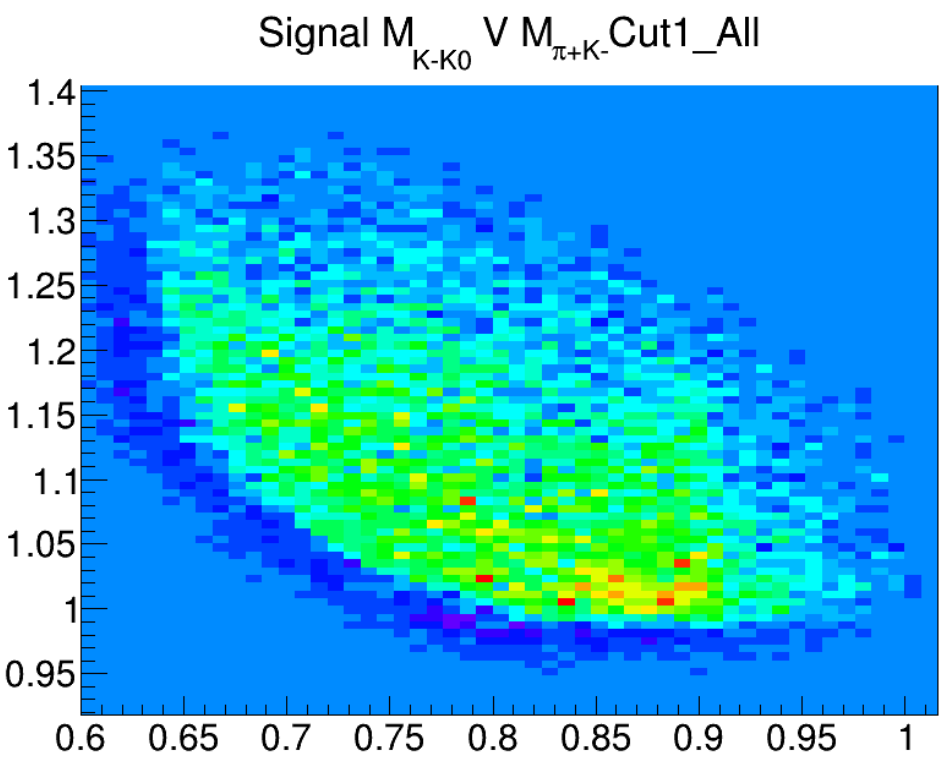


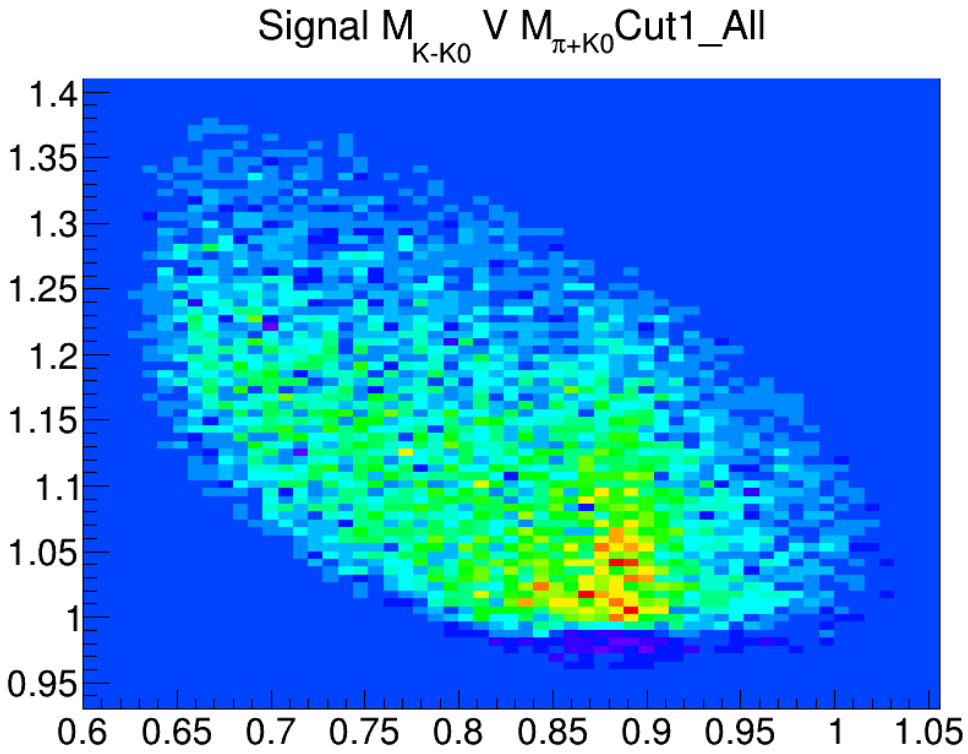
M(X) cut on M(KK)<1.05 (a0 region)

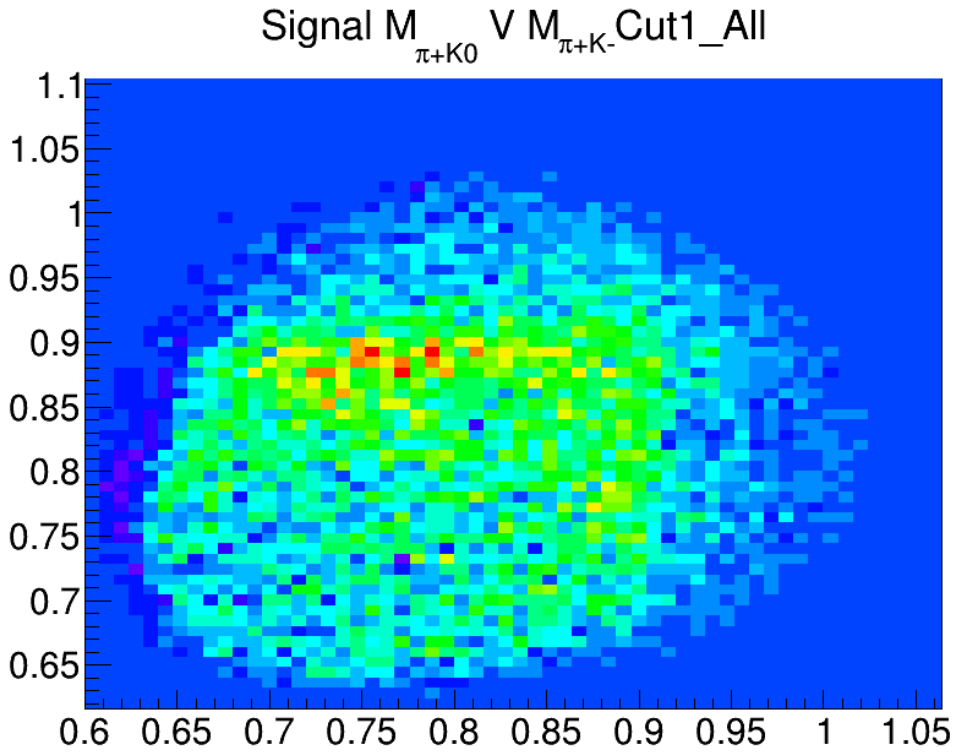


M(X) = 1430 ± 90
Dalitz Plots

Decays : a0- π+
K*+ K-
K*0 K0s
K0s K- π+

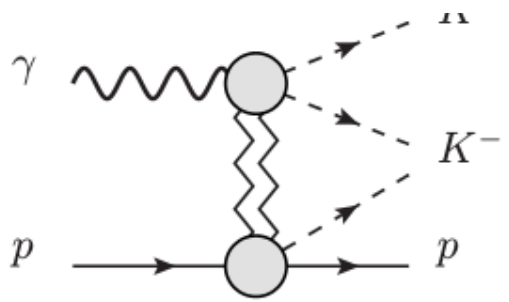


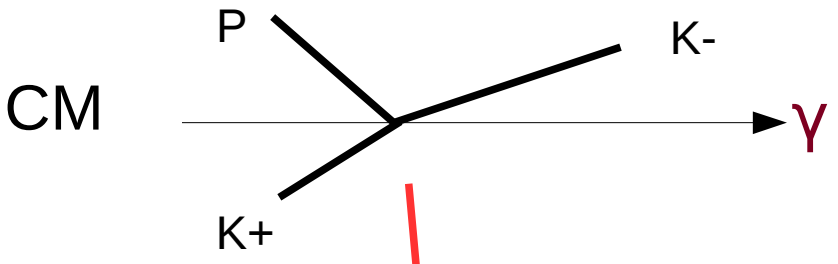


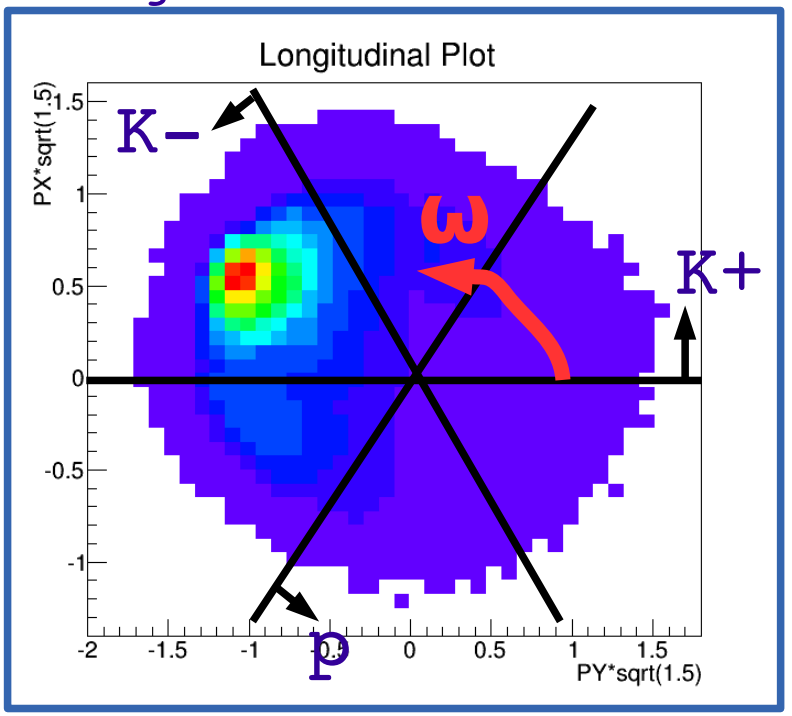


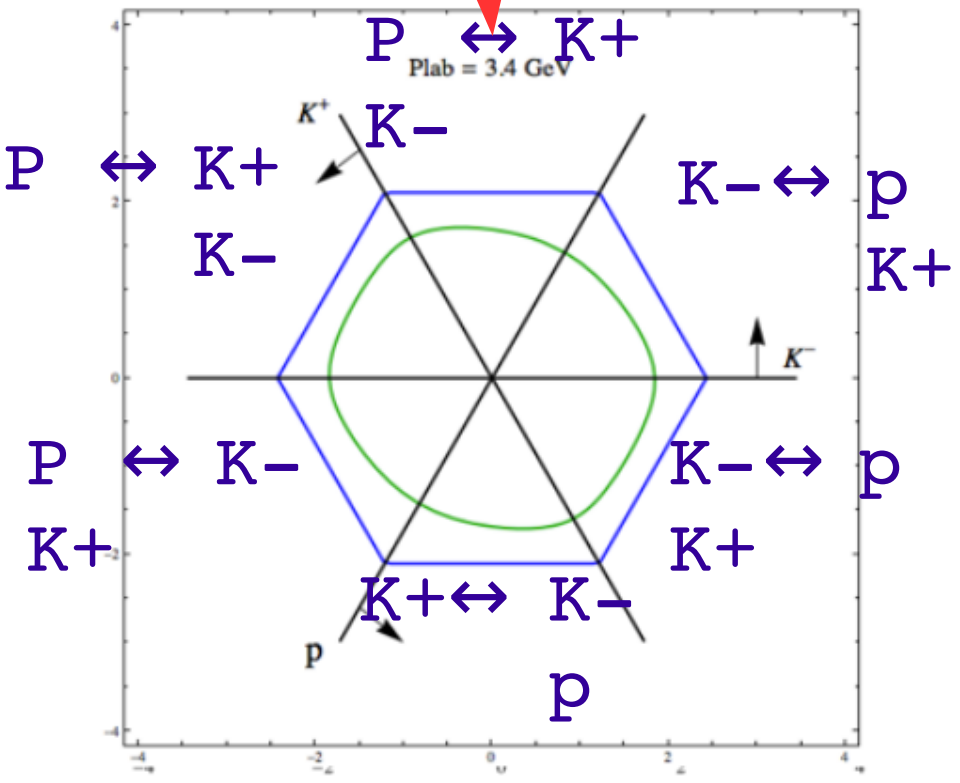
Van Hove Plots (Longitudinal)

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







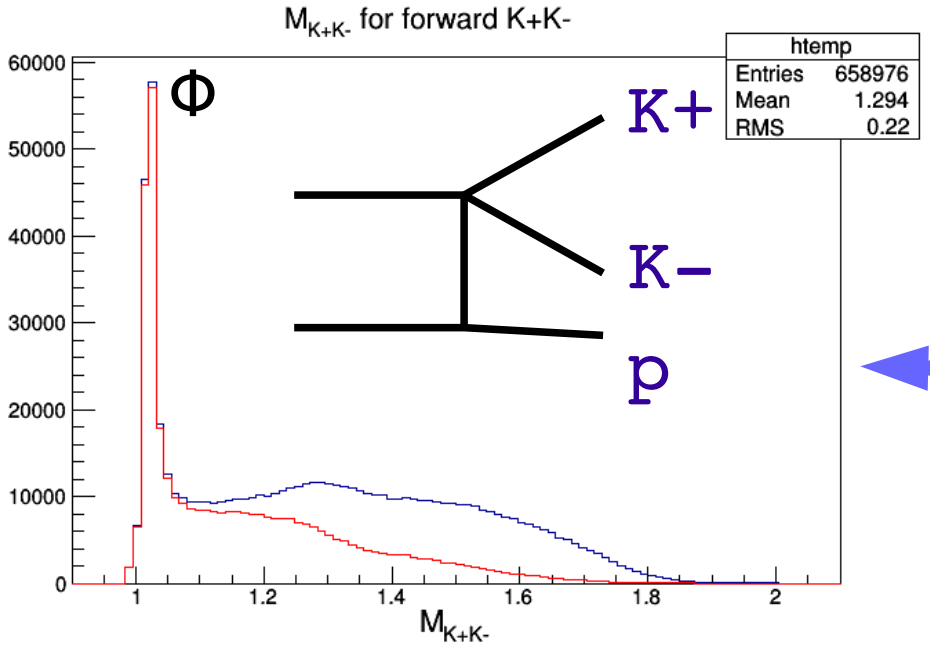


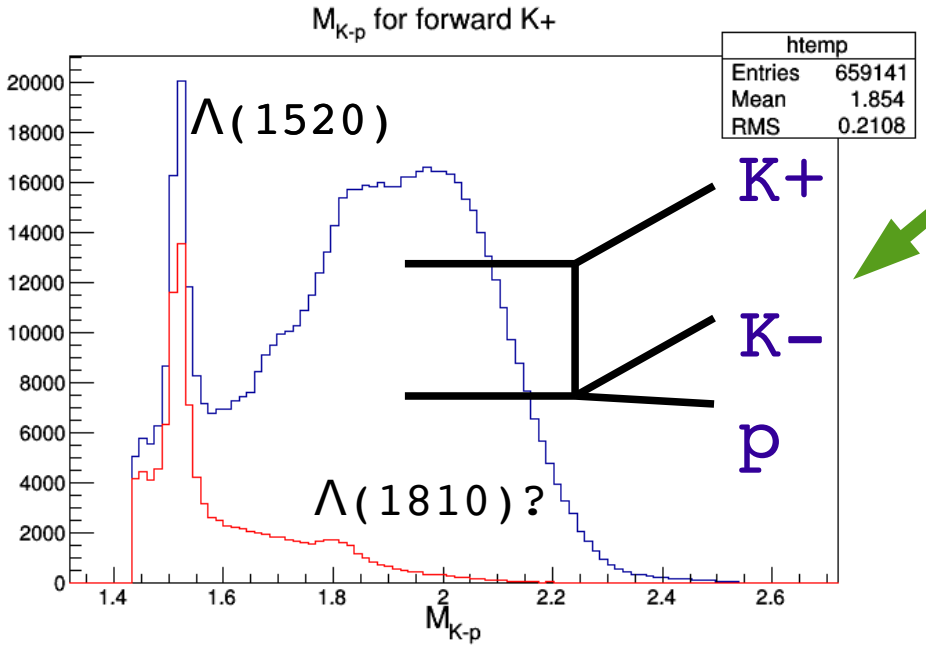
$$p_{K^+L} = \sqrt{\frac{2}{3}} q \sin\omega,$$

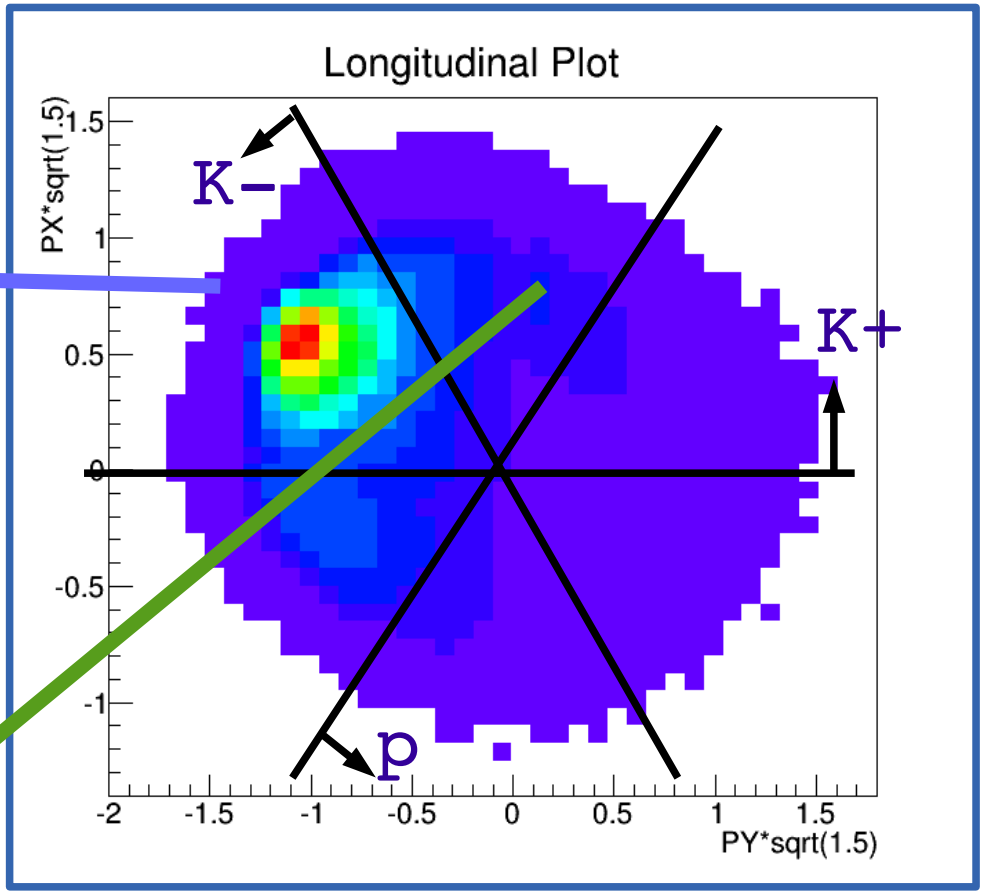
$$p_{K^-L} = \sqrt{\frac{2}{3}} q \sin\left(\frac{2}{3}\pi + \omega\right),$$

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

Example γp→K+K-p at around 3-3.8GeV

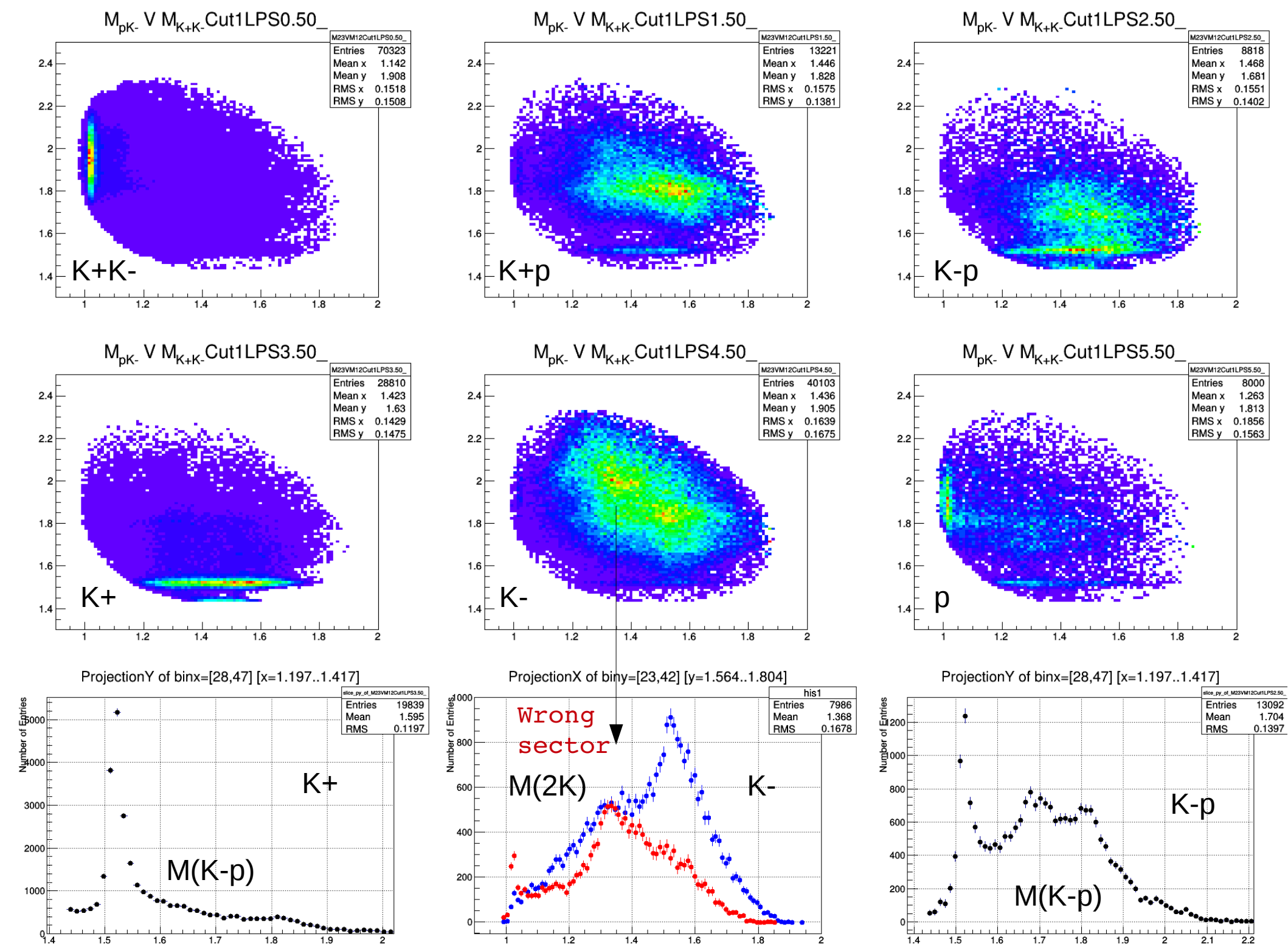




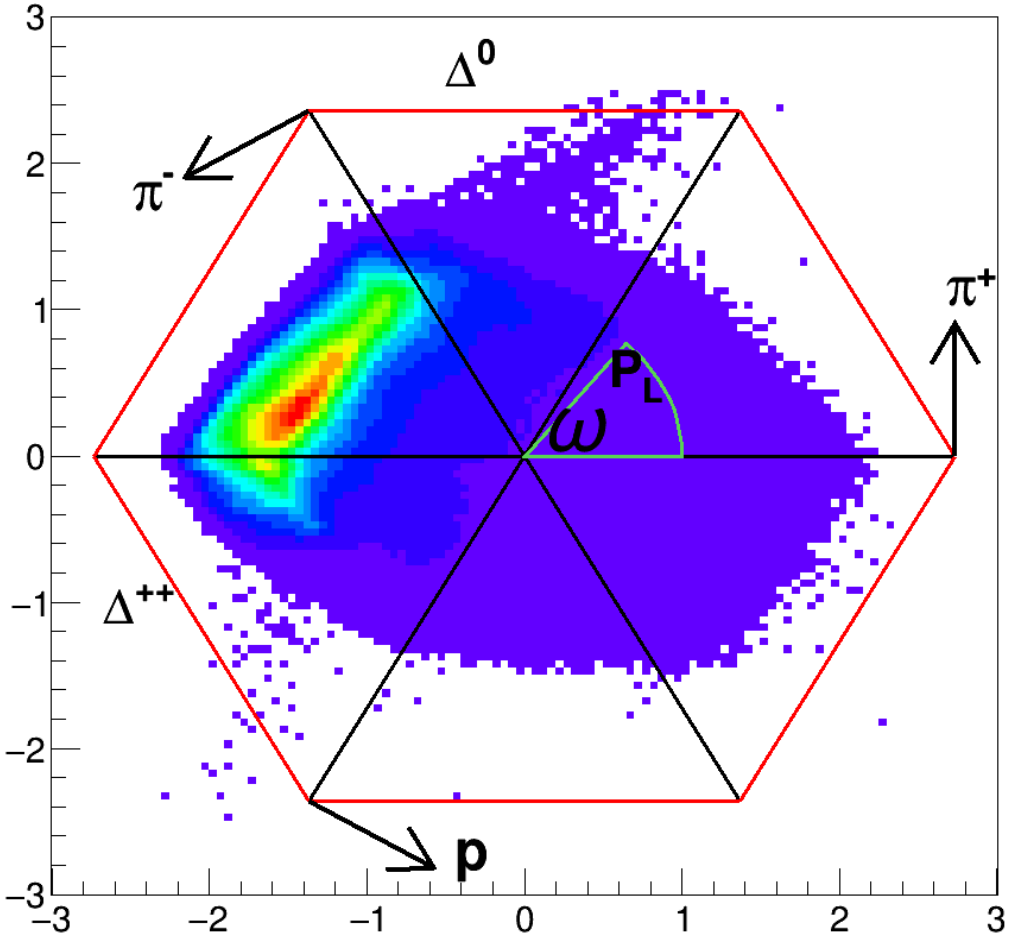


All Events

Cut on Longitudinal Plot sector


M_pK- V M_K+K-Cut1LPS0.50_
M23VM12Cut1LPS0.50_
Entries 70323
Mean x 1.142
Mean y 1.908
RMS x 0.1518
RMS y 0.1508
K+K-
M_pK- V M_K+K-Cut1LPS1.50_
M23VM12Cut1LPS1.50_
Entries 13221
Mean x 1.446
Mean y 1.828
RMS x 0.1575
RMS y 0.1381
K+p
M_pK- V M_K+K-Cut1LPS2.50_
M23VM12Cut1LPS2.50_
Entries 8818
Mean x 1.468
Mean y 1.681
RMS x 0.1551
RMS y 0.1402
K-p
M_pK- V M_K+K-Cut1LPS3.50_
M23VM12Cut1LPS3.50_
Entries 28810
Mean x 1.423
Mean y 1.63
RMS x 0.1429
RMS y 0.1475
K+
M_pK- V M_K+K-Cut1LPS4.50_
M23VM12Cut1LPS4.50_
Entries 40103
Mean x 1.436
Mean y 1.905
RMS x 0.1639
RMS y 0.1675
K-
M_pK- V M_K+K-Cut1LPS5.50_
M23VM12Cut1LPS5.50_
Entries 8000
Mean x 1.263
Mean y 1.813
RMS x 0.1856
RMS y 0.1563
p
ProjectionY of binx=[28,47] [x=1.197..1.417]
slice_py_of_M23VM12Cut1LPS3.50_
Entries 19839
Mean 1.595
RMS 0.1197
Number of Entries
K+
M(K-p)
ProjectionX of biny=[23,42] [y=1.564..1.804]
his1
Entries 7986
Mean 1.368
RMS 0.1678
Number of Entries
Wrong sector
M(2K)
K-
ProjectionY of binx=[28,47] [x=1.197..1.417]
slice_py_of_M23VM12Cut1LPS2.50_
Entries 13092
Mean 1.704
RMS 0.1397
Number of Entries
K-p
M(K-p)

Longitudinal Plots π+π-p



g11 dataset
Select all 4 topologies for
π+π-p final state

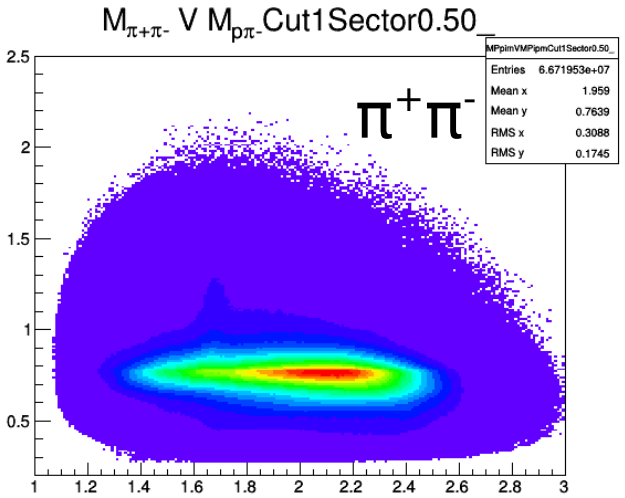
These results are not (yet)
Background subtracted
or acceptance corrected

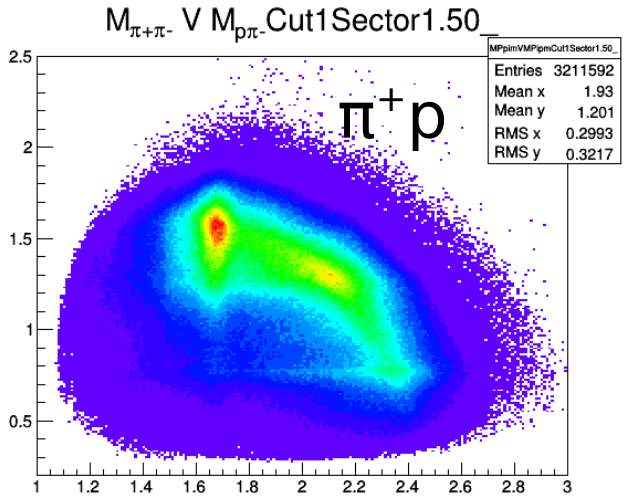
Longitudinal Plots

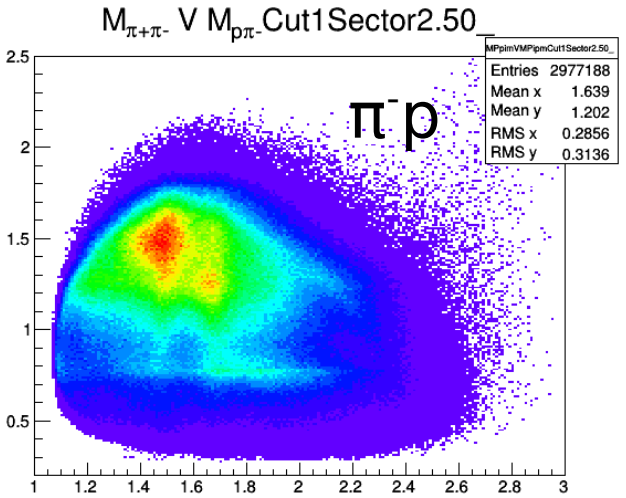
Sum Topologies, Split into LP Sector

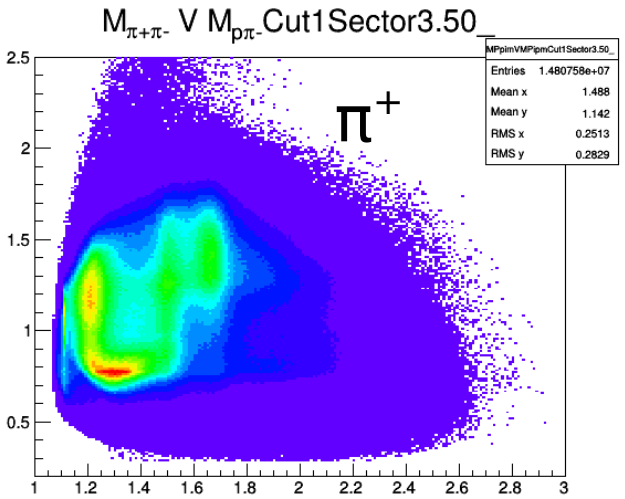
Baryon/Meson Masses : $M(\pi^+\pi^-)$ v $M(\pi^-p)$

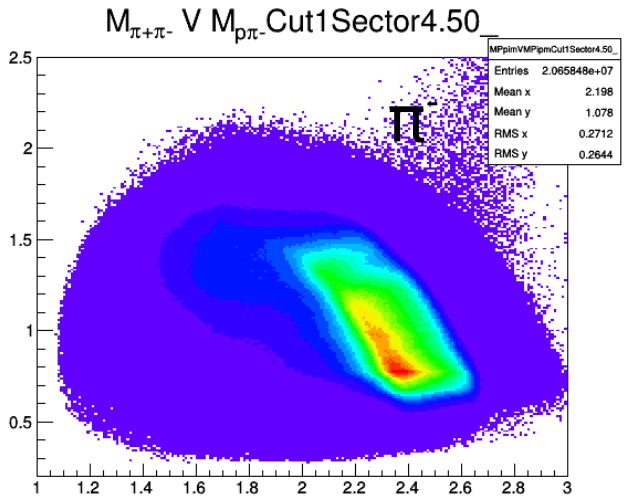
Named particles are travelling forward

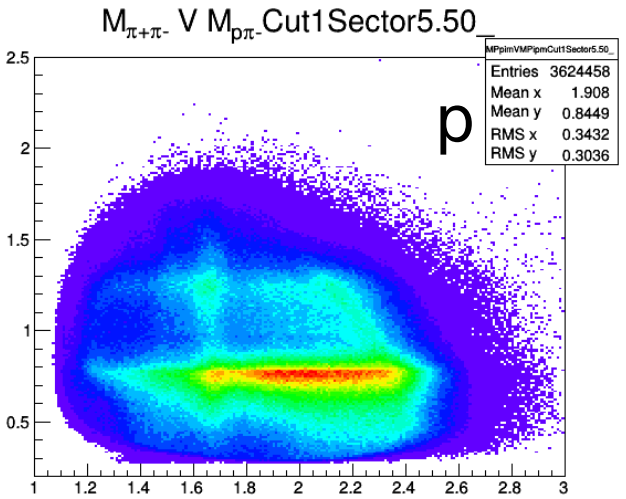












Optimised Meson/Baryon cuts

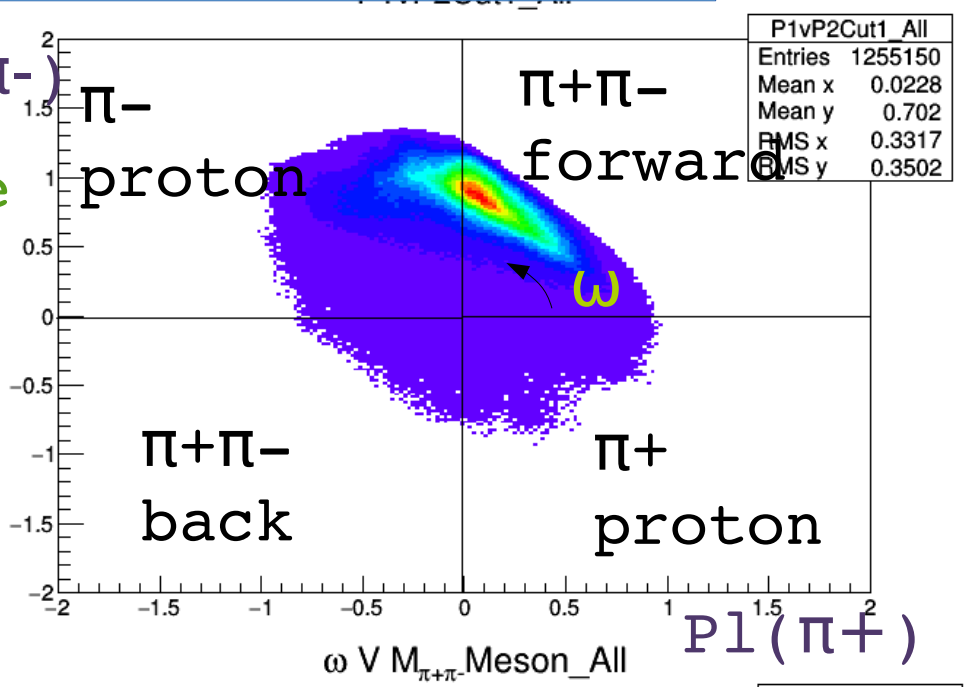
*Speculative

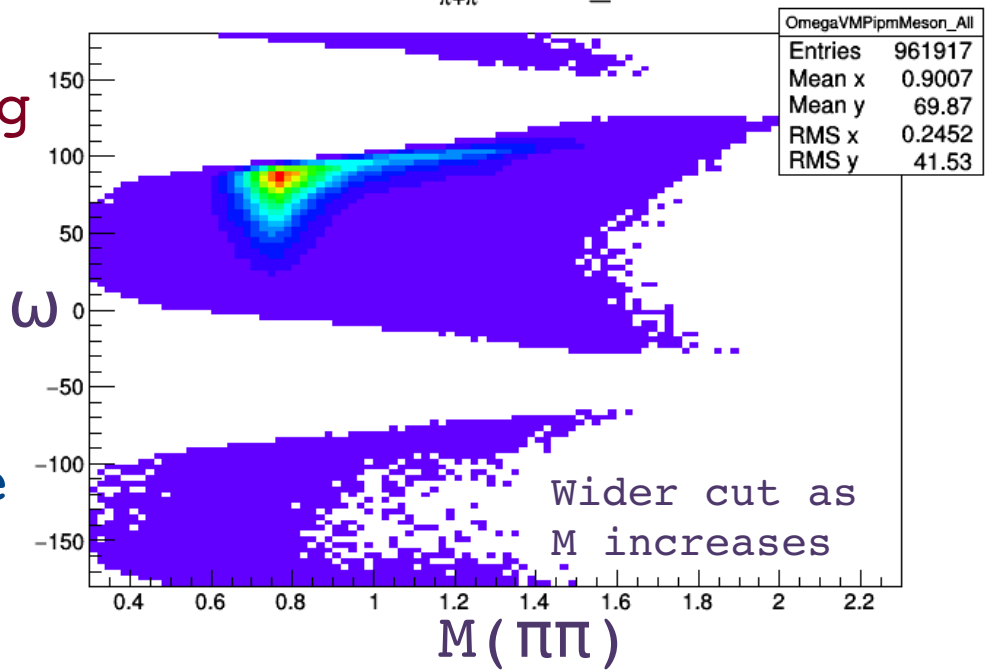
Remove production dependence
-Z-axis along meson CM momentum
-proton momentum along -z (purely longitudinal)

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





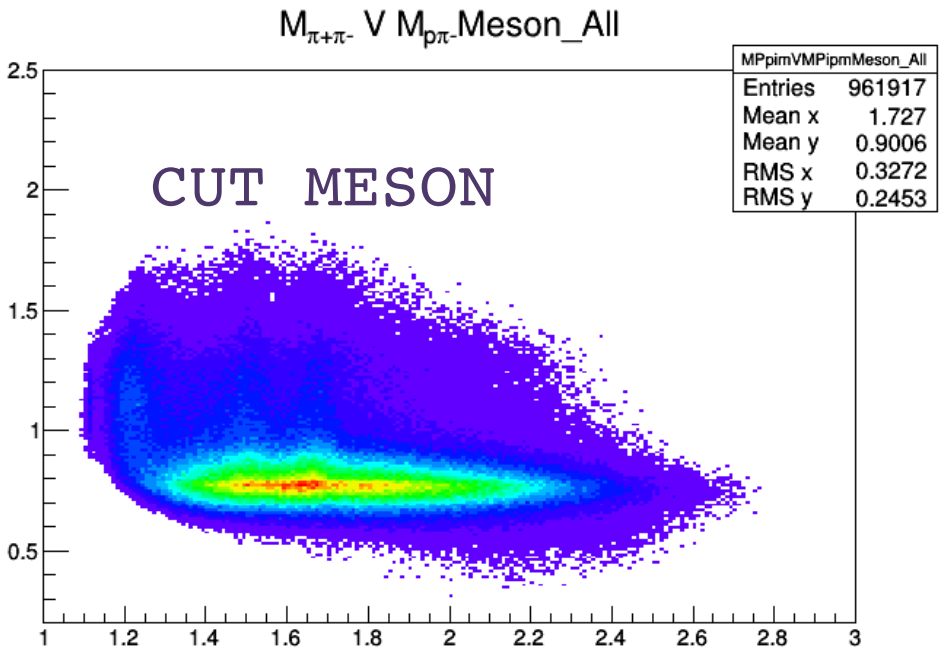
Optimised Meson/Baryon cuts

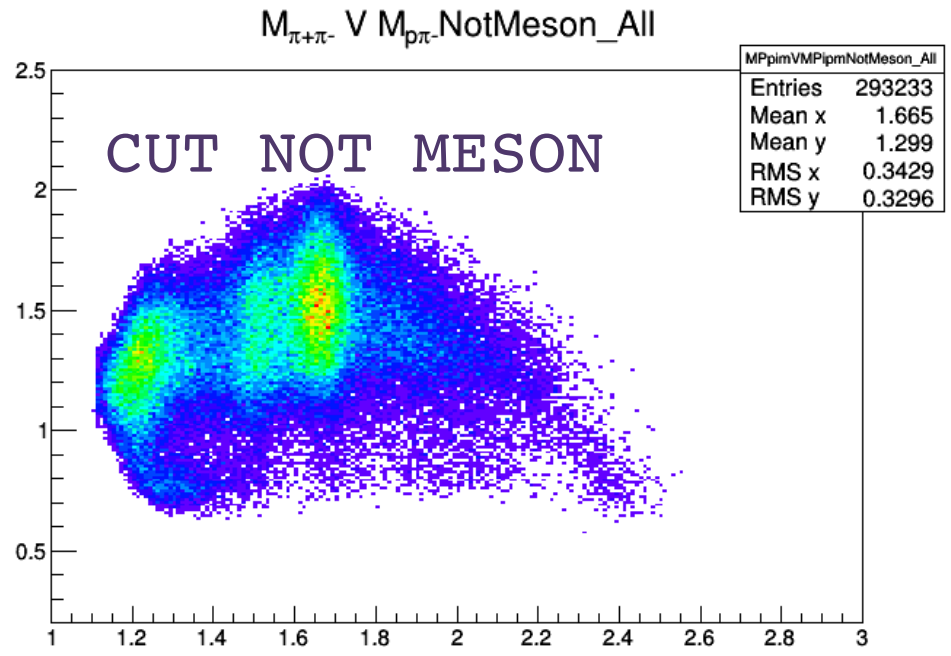
Now our cut is defined as the corresponding value of omega for π-(π+) decaying backwards along z axis in meson rest frame.

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

Note, currently only π+π- missing p topology





Other HASPECT Stuff

Previously presented :
Alessandro Rizzo, ππη sWeights analysis
  -Implementing Veneziano B4 Amplitude Fit
Andrea Celentano, ω to 3π decay
  -fitted with Veneziano B4 Amplitude

Ongoing g11,
Alessandra Filippi, KKπ final states
Simon Hughes, ωππ partial wave analysis
Ivana Stankovic, K+K- B5 Veneziano Amplitude fit

Bayesian Nested Sampling for Maximum Likelihood
  -Implemented in AmpTools

Associated AmpTools analysis,
Bryce Garillon e'π+π- PWA
Shloka Chandavar, K0sK0s g12 Moments analysis

Summary

Defined full analysis chain for real and MC data
Additional methods required for reaction selection

Investigated methods for cleanly identifying reactions

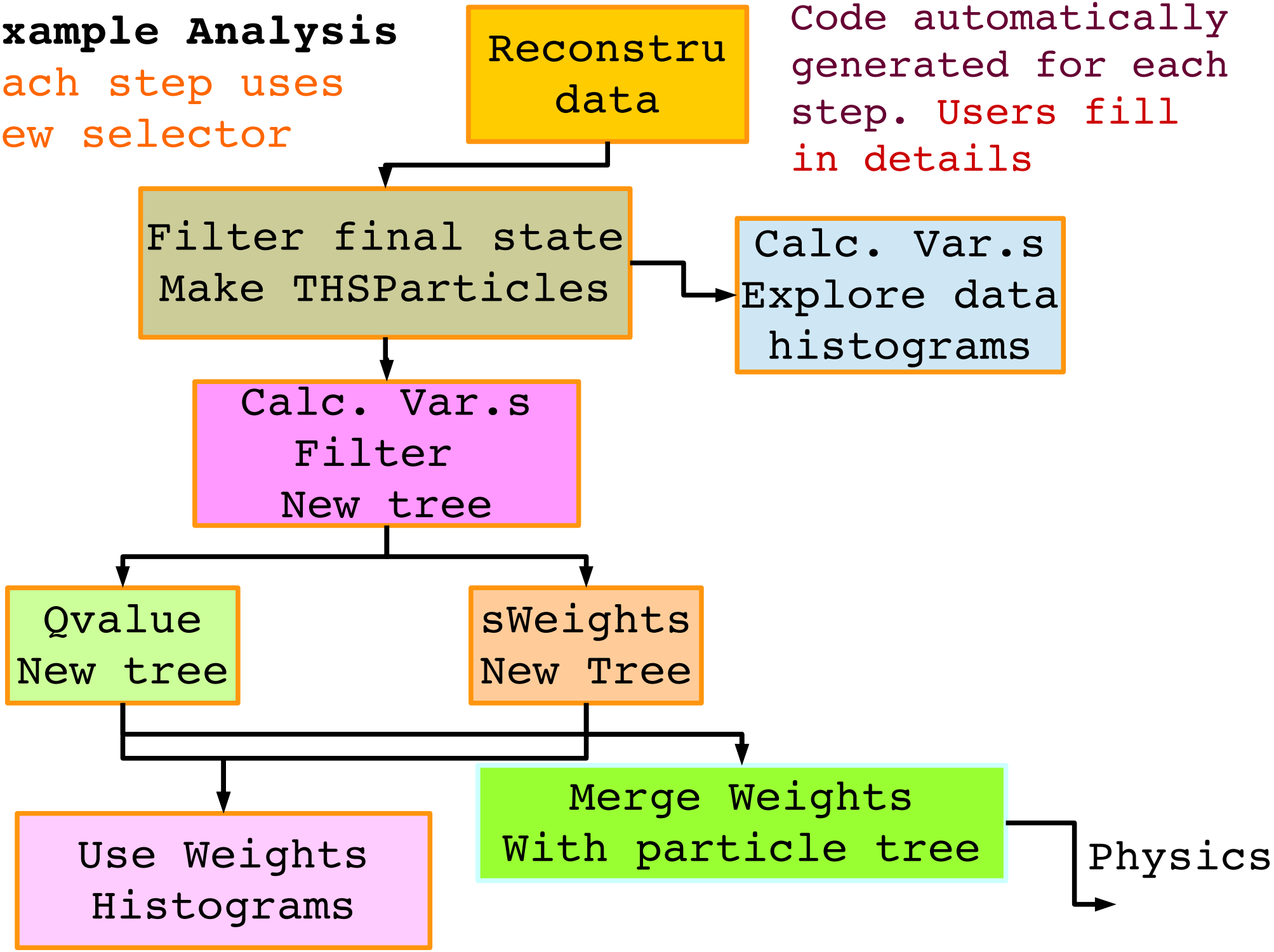
Prefered solution : sWeights with simulated models
and profile likelihood fits

Investigating seperation of reaction mechanisms
- Longitudinal Phase Space Analysis
- Maximum allowed Meson/Baryon cuts

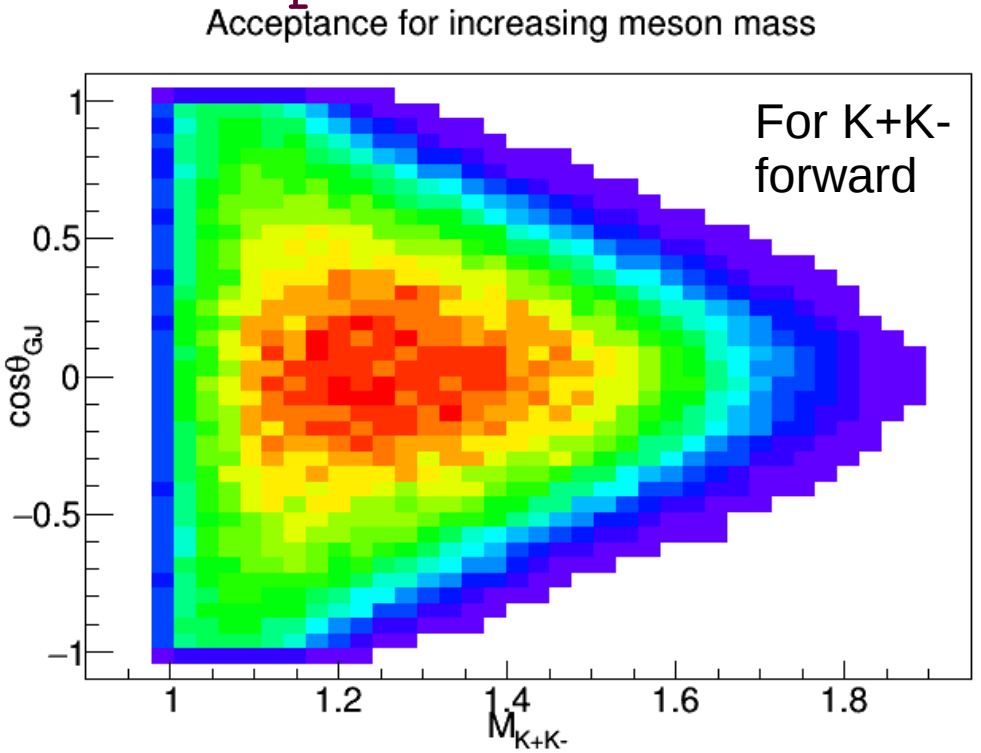
Currently finalising ROOT based software,
developing amplitude models with JPAC/AmpTools

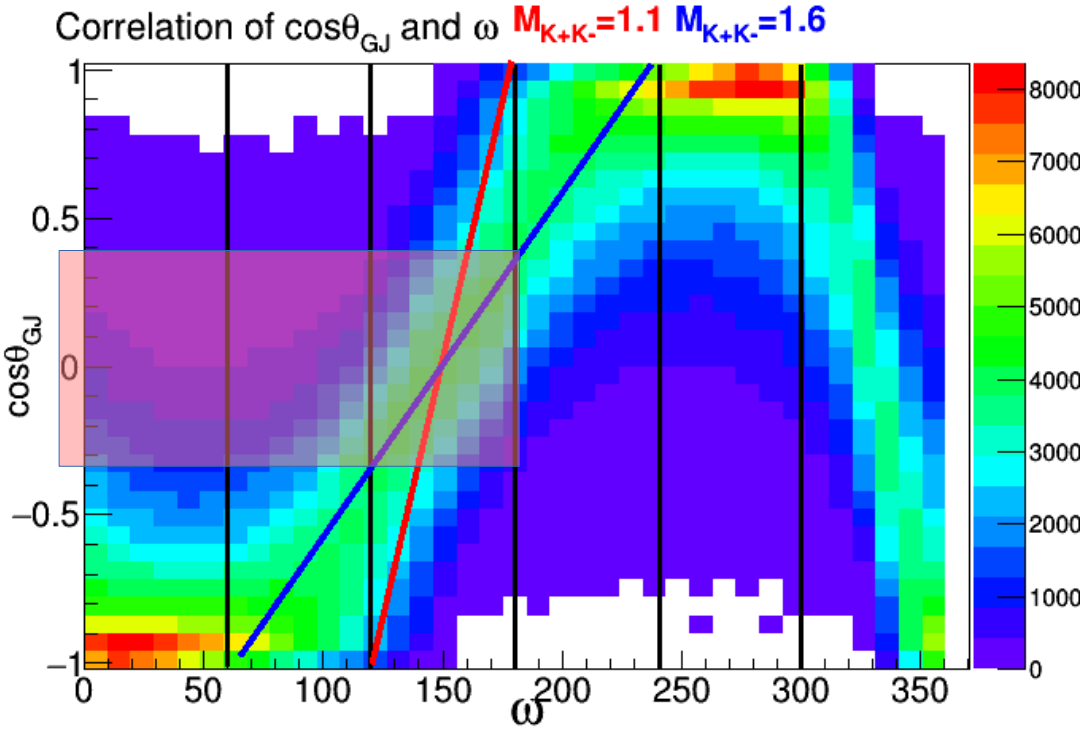
Example Analysis

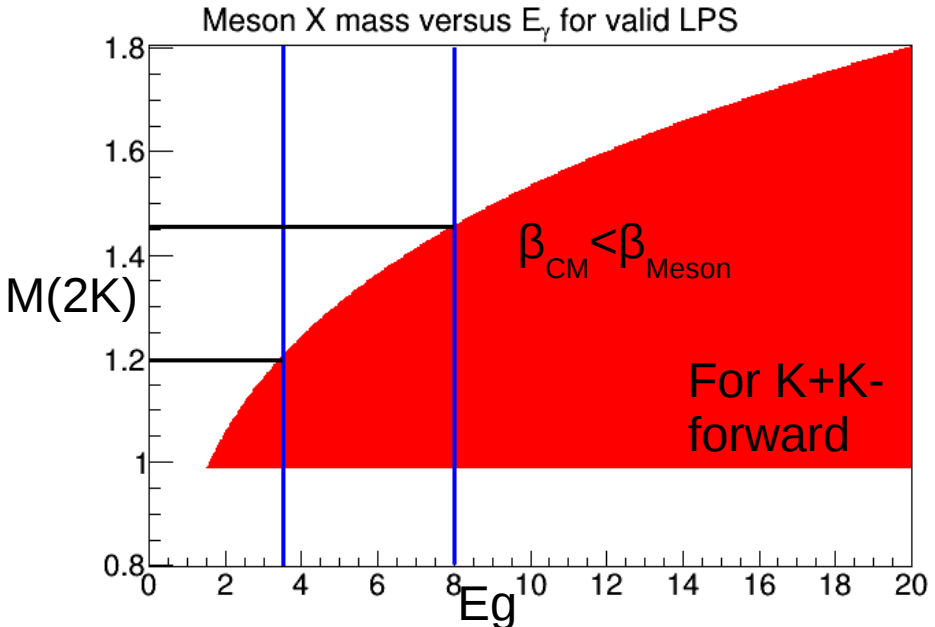
Each step uses new selector



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 θ_{GJ}