MesonEx: Two Pion Production

Adam Thornton
PhD Student

CLAS Collaboration Meeting
12/11/2020

University of Glasgow

MesonEx: Two Pion Production

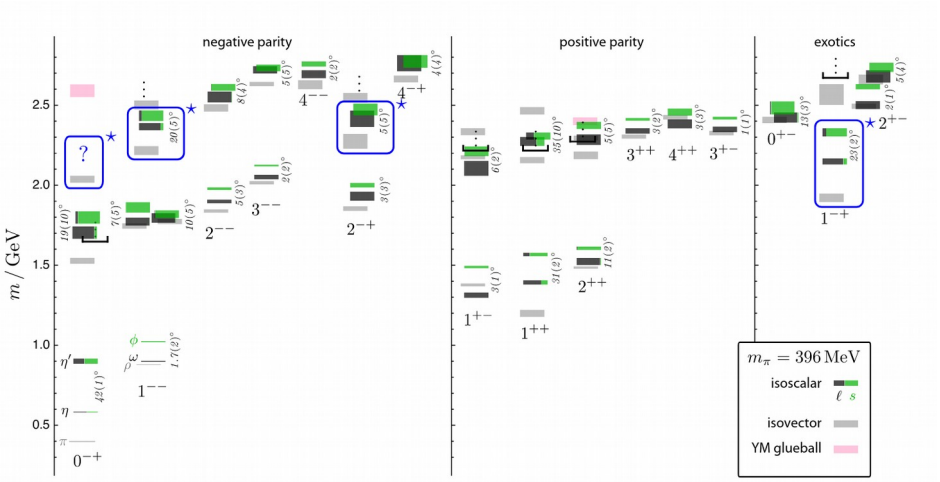
Introduction

- PhD thesis project: 2π photo-production
- Motivation
- First look at data analysis
- Future steps and plans

Introduction

Motivation

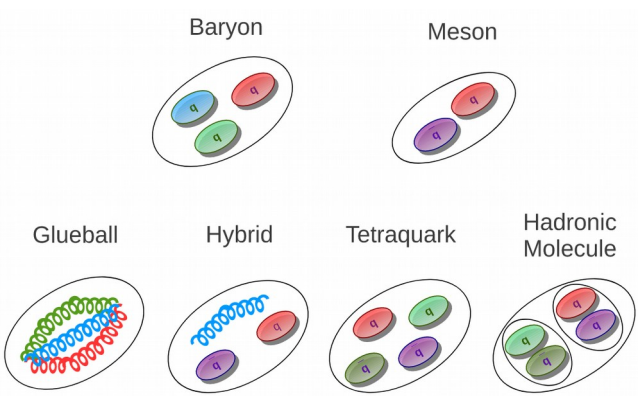
- Search for mesons at CLAS12
  > Regular, hybrid, exotic?



Blue boxes representing the lightest hybrid mesons as calculated with LQCD (m_π~400MeV), exotic quantum numbers on right

QCD allows only colour neutral states (hadrons)

- No restrictions on how to form them however
- Usual combinations: J^{PC}
  - + baryons, mesons
- Exotic combinations:
  - + **glueballs**
  - + hybrid mesons
  - + **tetra-quark**
  - + hadronic molecule

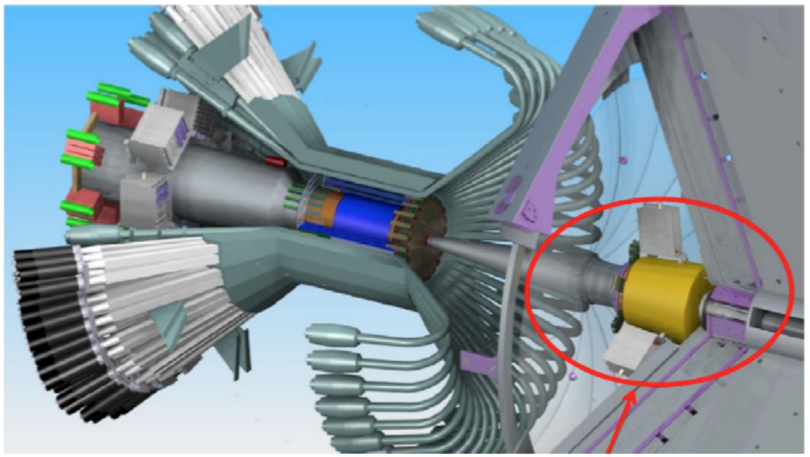


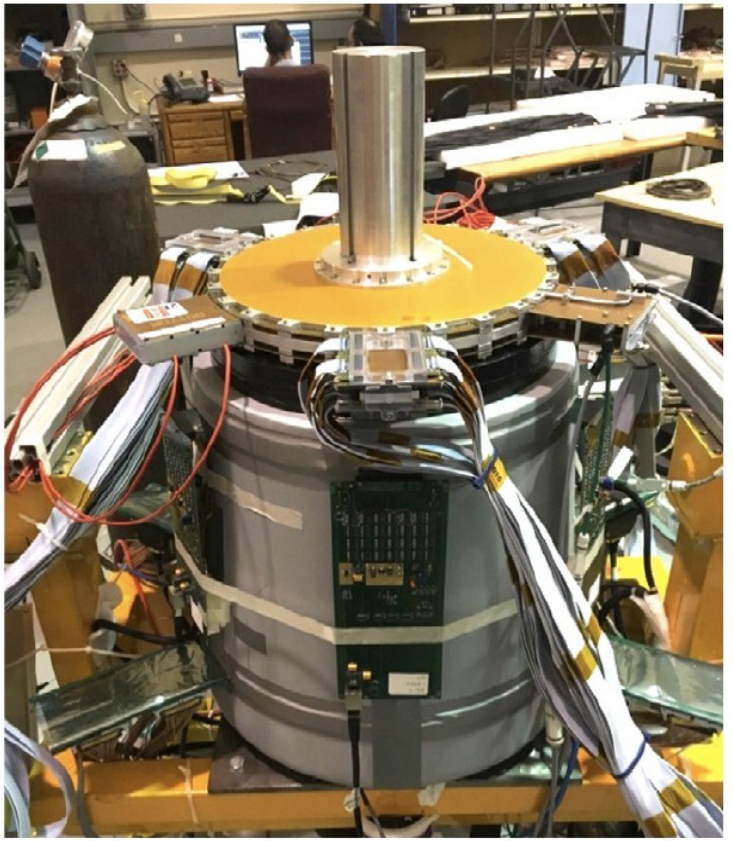
https://arxiv.org/abs/1106.5515
https://arxiv.org/abs/1405.4195

Introduction

Mesonex Experiment (run group A)

- Quasi-real photon scattering at very low Q^2 (10^{-2} to 10^{-1} GeV^2, high flux and linear polarisation)
- 5cm LH_2 target
- Using forward tagger (scattered electron θ=2.5 to 4.5^o)
  - Hodoscope and calorimeter
- Use tagger for trigger → electron in FT + 2 tracks in FD (skim3)
- Study meson spectrum around 1.5 to 2.5 GeV





https://www.jlab.org/exp_prog/proposals/11/PR12-11-005.pdf

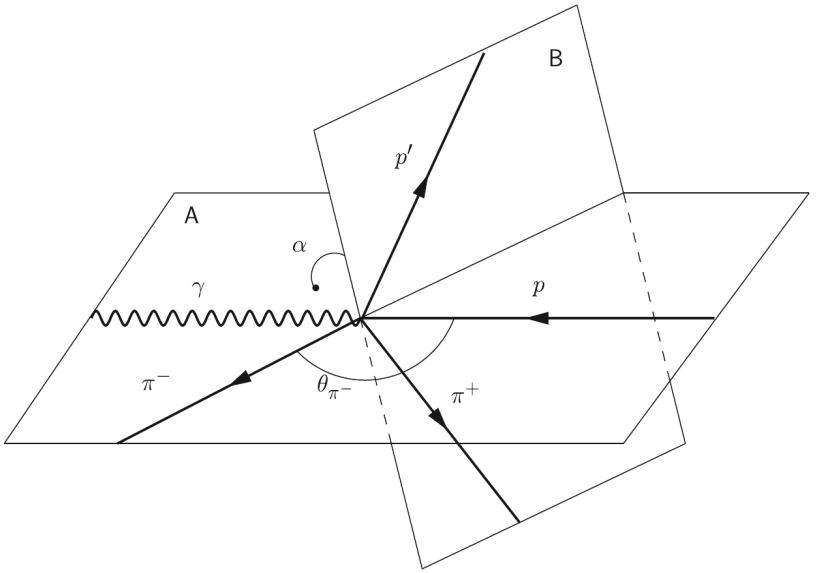
Introduction

Data Analysis

Since many of the mesons of interest decay to 2π, use final-state: **electron + proton + π^+ + π^-**

- **Dataset:** pass1 inbending/outbending skim3
  - Mesonex trigger: e FT, >=2 tracks in FD
- → Transfer to local computing system at Glasgow
- → Analyse events with **Chanser*** (C++/ROOT analysis framework)
  - Select my finalstate of interest (electron + proton + π^+ + π^-)
  - Using either event builder or charge + “delta-time” for PID
  - Calculate quantities of interest (4 vectors → masses, angles, etc)
  - Apply cuts (exclusivity, fiducal, region, PID, other)
  - Output as ROOT trees
  - Plots and post-processing in Python (uproot, numpy and matplotlib)

- Next steps
  - Fitting decay angles with **Brufit*** (C++/ROOT analysis framework)
  - Simulations needed for fit, using **clas12software** singularity



CM frame kinematic variables for $\gamma p \rightarrow p' \pi^+ \pi^-$ (baryon example)

https://www.sciencedirect.com/science/article/pii/S0146641019300870

https://github.com/dglazier/chanser
https://github.com/dglazier/brufit

Data Analysis

Dataset: pass1 inbending and outbending skim 3 ALL files (2.8TB and 2.5TB respectively)

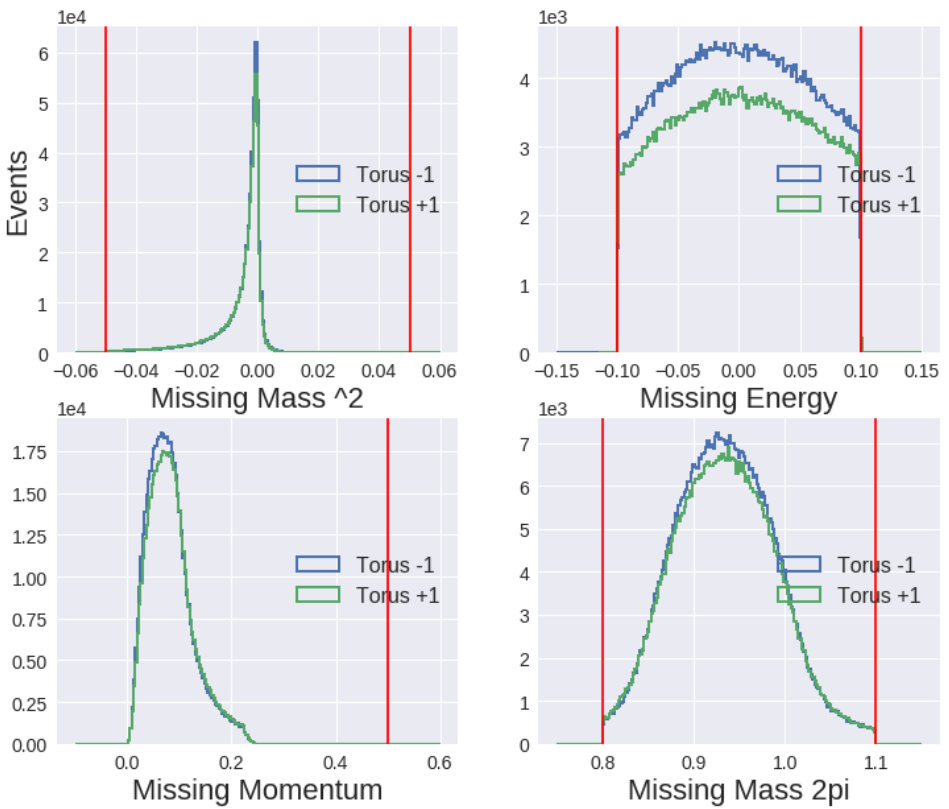
Finalstate: electron + proton + π^+ + π^-

Event selection:

Variable	Value	Unit
Electron Δt	±1.0	ns
Proton and π(±)	±0.5	ns
Missing mass^2	±0.05	$(GeV/c^2)^2$
Missing energy	±0.1	GeV
Missing momentum	<0.5	GeV/c
Missing mass (e π^+ π^-)	0.8<m<1.1	GeV/c^2
Trigger bit 25 (mesonex)	1	-
Electron region	1000 (FT)	
π(±) region	2000 (FD)	

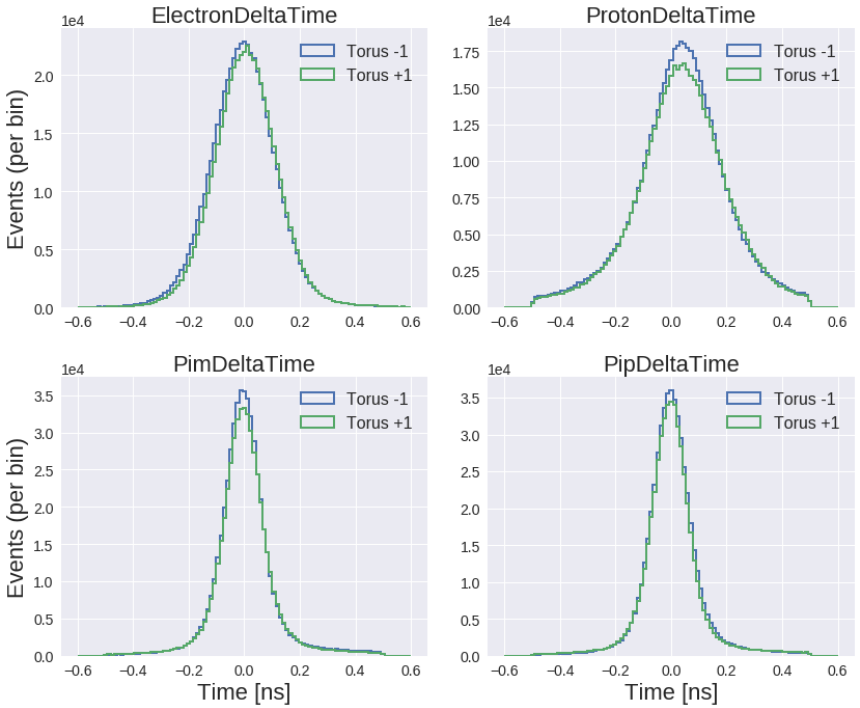
Notes:

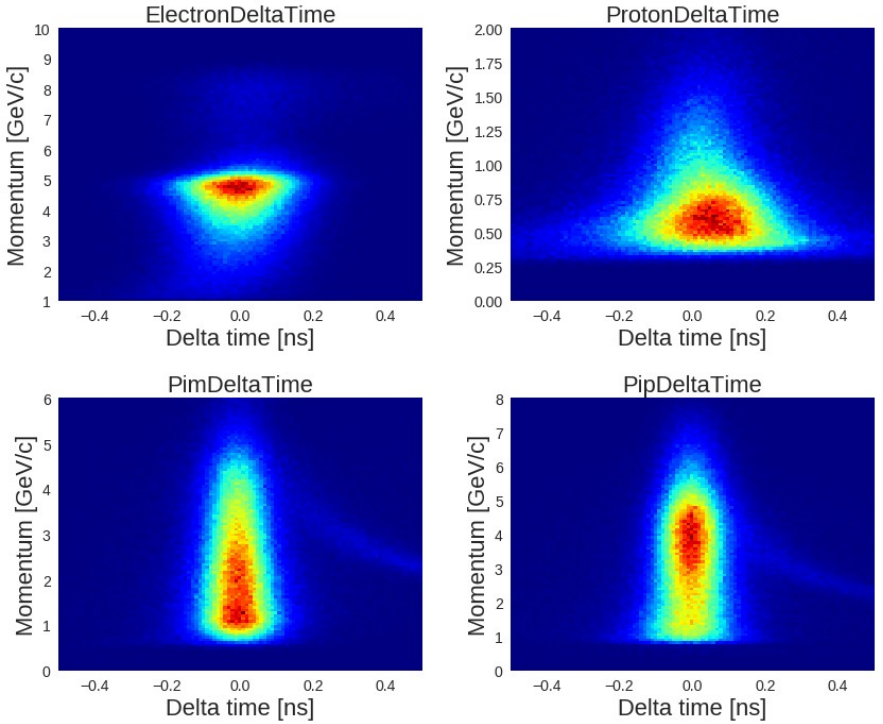
- events after finalstate processing:
  - Inbending 531727
  - Outbending 508944



Exclusivity cuts for both datasets

Data Analysis

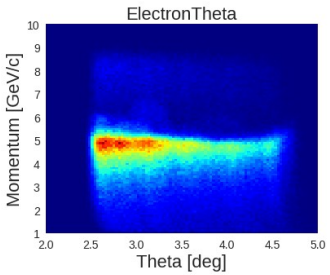


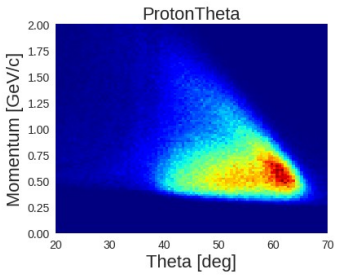


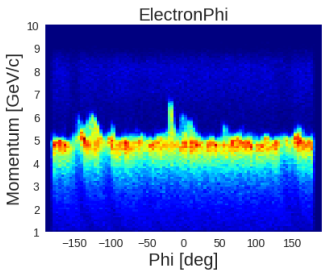
Plots of the electron, proton, π^+ π^-

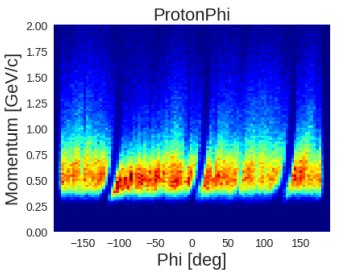
- Chanser particle “delta-time” used for PID:
  - Use the charge to guess PID, compare the hypothesised momentum against time of flight
  - Expect a value centred at zero if correctly identified
- Values well within timing cuts (1ns electron, 0.5ns otherwise)

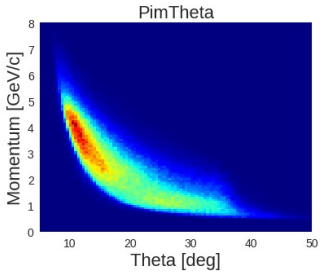
Data Analysis

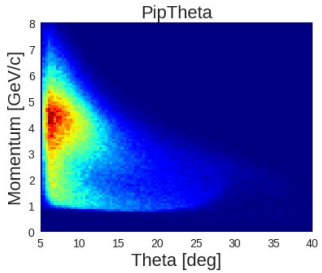


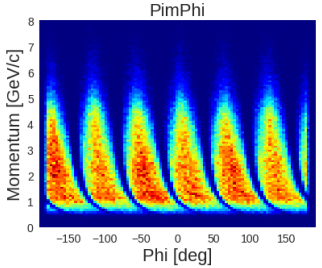


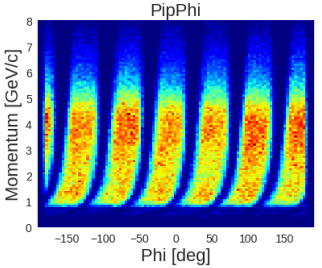


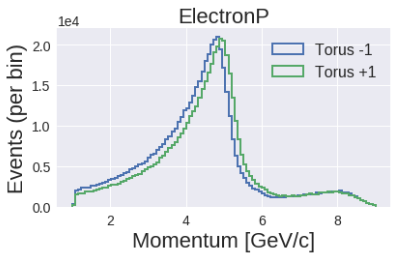


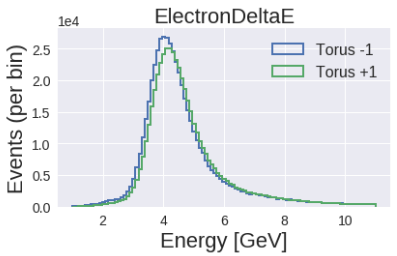


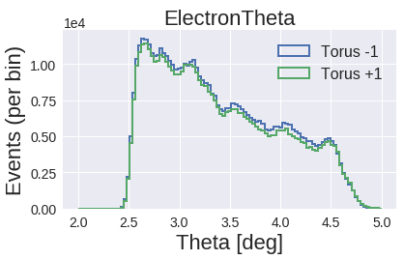


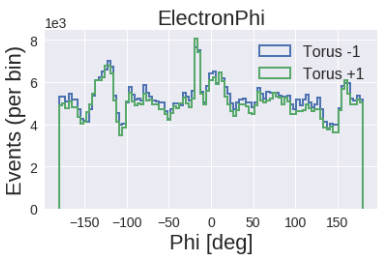








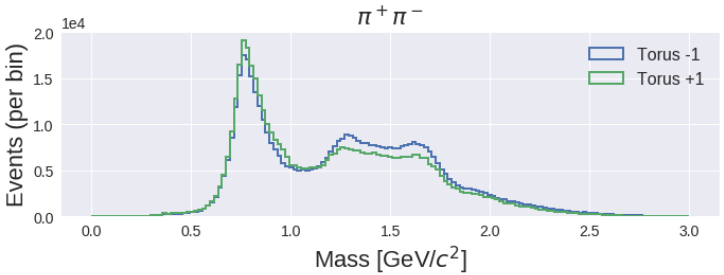


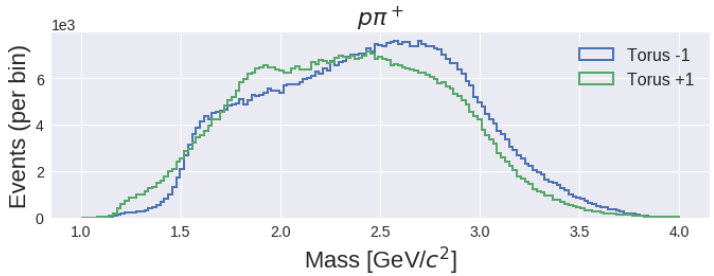


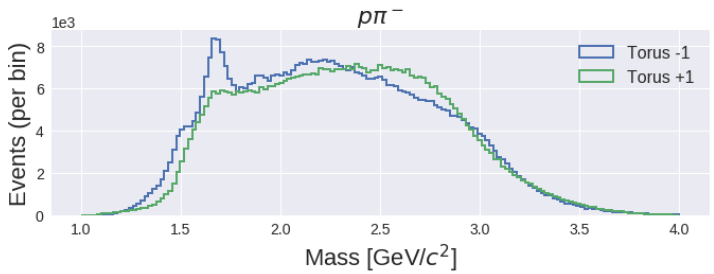
For the inbending dataset, theta and phi angles

- Moment and angles for the electron, comparing both datasets
- Similar stats and shape between torus settings

Data Analysis

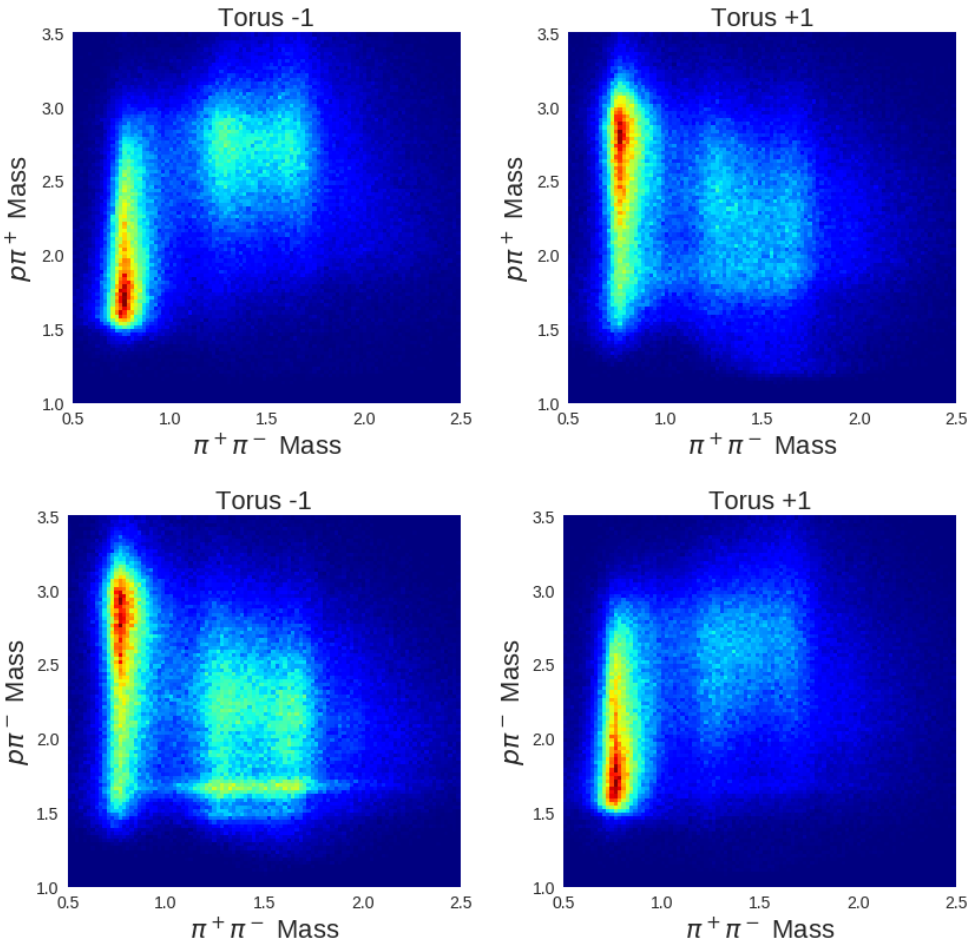






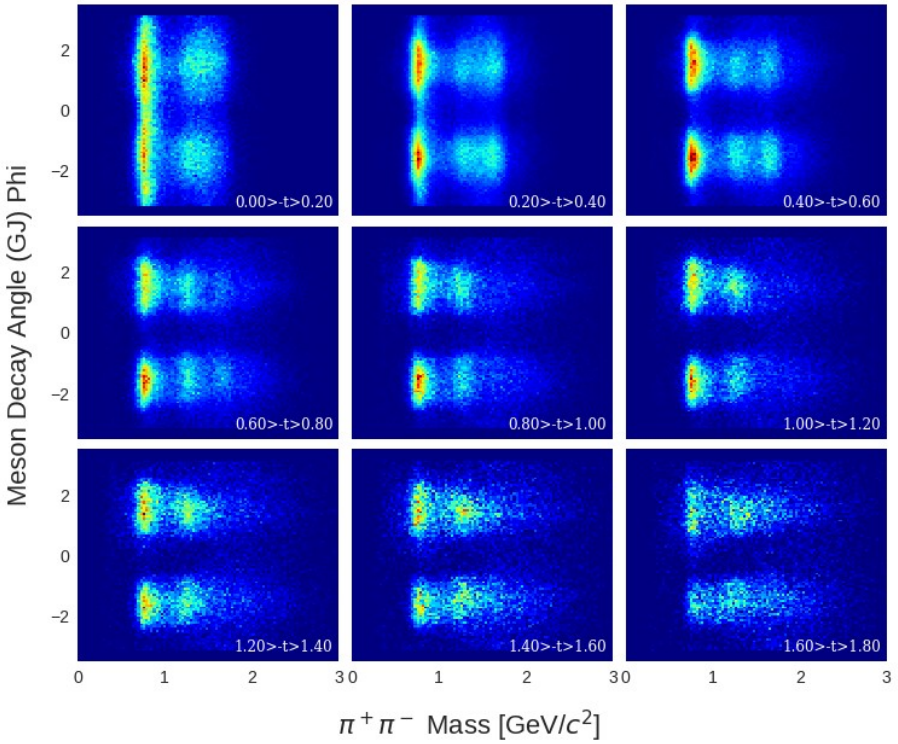
Invariant mass plots

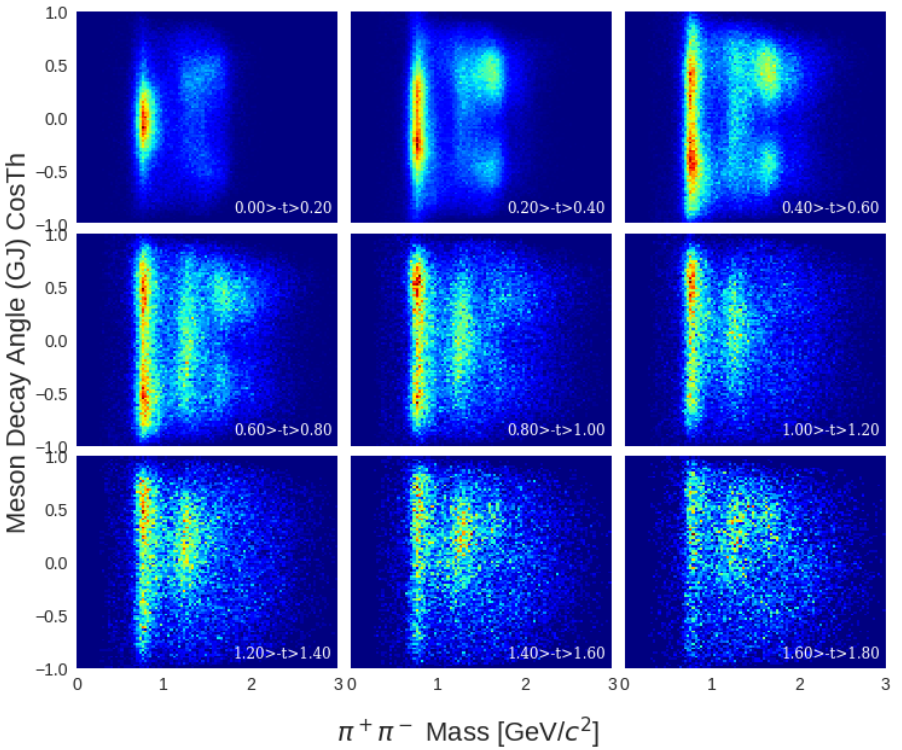
- $\pi^+ + \pi^-$
- proton + π^+ (Δ^{++})
- proton + π^- (Δ^0, N*)



Comparing for different torus settings

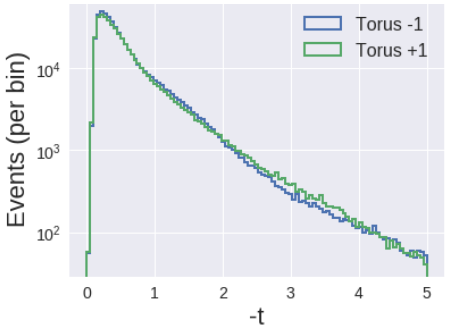
Data Analysis

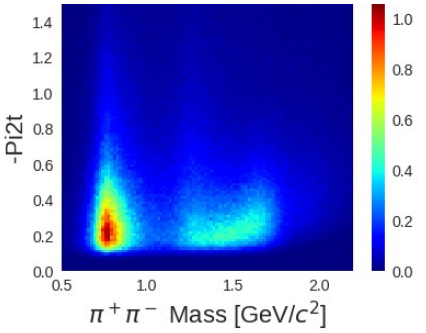




Decay angles of the meson ($\pi^+\pi^-$)
Φ (left) and cos(θ) (right)

For both datasets, as a function of t
(between 0 and 1.8)

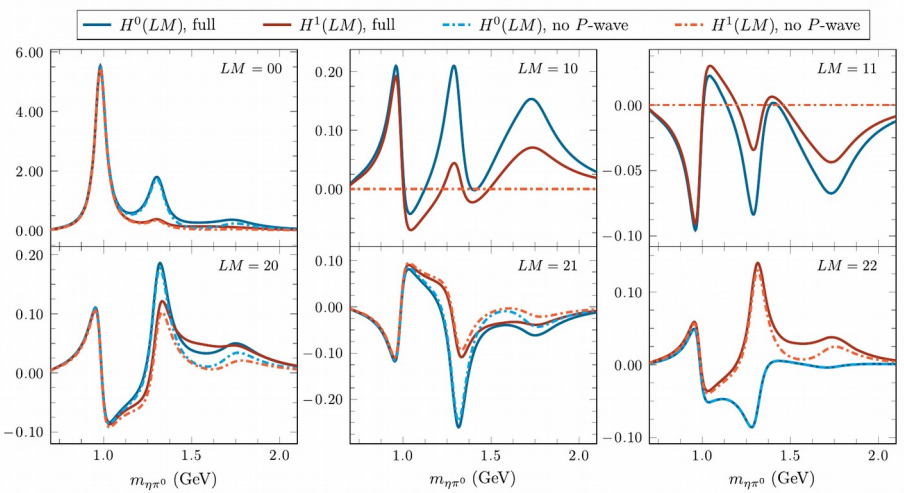




Next Steps: Moments Fitting

Extracting polarised harmonic moments

- Following V. Mathieu's et al ηπ⁰ paper
- Apply the same approach to a 2π final-state
- Using Brufit (extended maximum likelyhood)
- Decay angles → moments → (SDMEs and/or partial waves)
- Formalism in appendix of paper
- Accurate simulations required (work in progress)



Example from paper (fig 2) of unpolarised (blue) and polarised (red), for L = 0, 1, 2, in helicity frame. Solid lines full model, dotted without P wave.

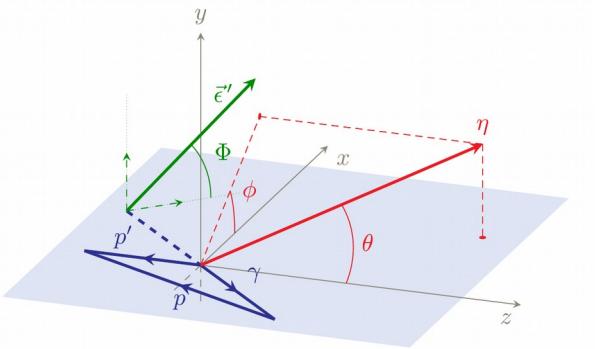


FIG. 7. Definition of the angles in the helicity frame. The reaction plane xz, containing the momenta of the photon beam (γ), the nucleon target (p), and recoiling nucleon (p'), is in blue. θ and ϕ are the polar and azimuthal angles of the η. The polarization vector of the photon forms an angle Φ with the reaction plane.

III. MOMENTS

From the intensities in Eqs. (4), one computes the moments

$$H^0(LM) = \frac{P_\gamma}{2}\int_\circ I(\Omega,\Phi)d^L_{M0}(\theta)\cos M\phi,$$

$$H^1(LM) = \int_\circ I(\Omega,\Phi)d^L_{M0}(\theta)\cos M\phi\cos 2\Phi,$$

$$\mathrm{Im}H^2(LM) = -\int_\circ I(\Omega,\Phi)d^L_{M0}(\theta)\sin M\phi\sin 2\Phi, \qquad (13)$$

https://doi.org/10.1103/PhysRevD.100.054017

MesonEx: Two Pion Production

Conclusions

- Early analysis presented
- Workflow for data analysis
  - Tools are working, pass1 dataset good for now!
- Cuts have been refined, removed sufficient background
- Possible to see mesons, extract values

Next steps

- Produce accurate simulated data (needed for fits)
- Fit the meson decay angles
- Extract the moments (for use with partial waves)

Thanks for your attention! Any questions?