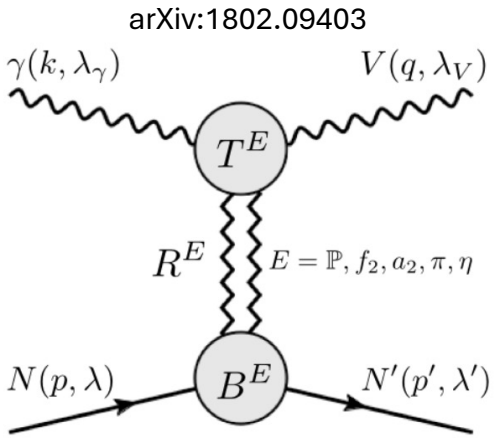
Studies for 2pi quasi-real photoproduction at MesonEX

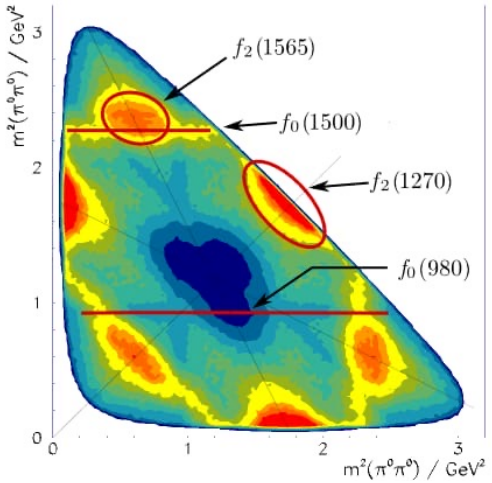
Marco Filippini
University of Messina & INFN Catania

Hadron Spectroscopy

Necessary for understanding:

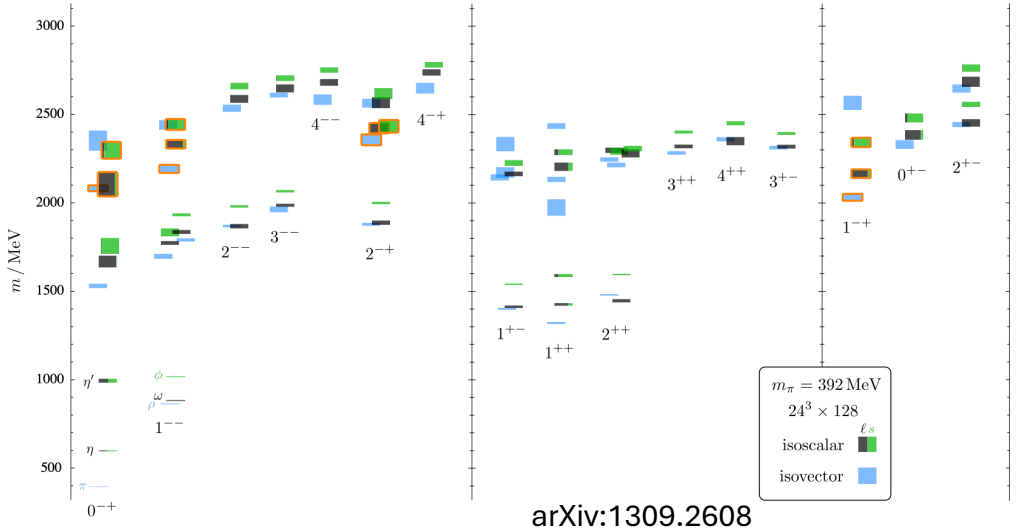
- QCD
- Quark confinement
- Looking for new particles (exotics)
- Nature of mass





The better way is using electromagnetic interactions:

- Photoproduction
- Electroproduction



arXiv:1309.2608

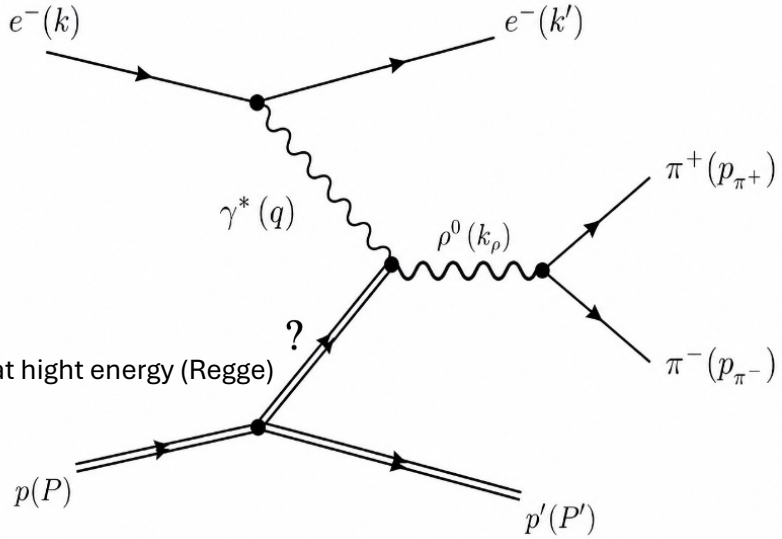
Meson Spectroscopy

Why focus on meson production:

- Look for known ordinary resonances
- Determine production mechanism
  - old results from CLAS g11 for 3-3.8 GeV

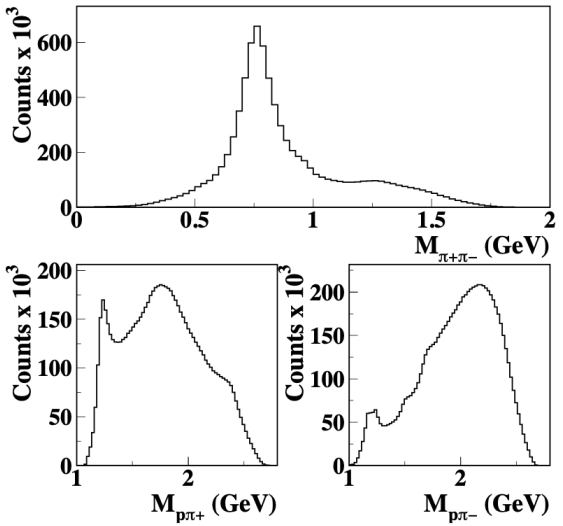
Analysis of channel $\gamma^*p \rightarrow p\,\pi+\,\pi-$

Possible goal is extracting production cross section and SDMEs for f_2

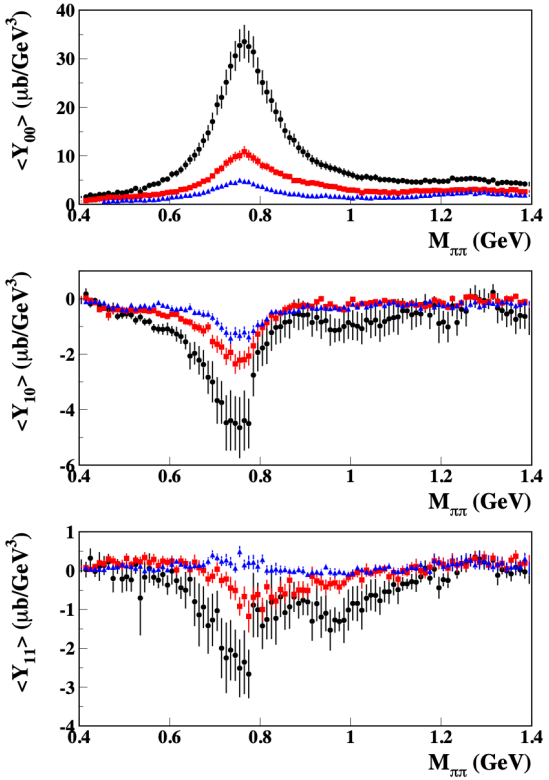


Dominant production at hight energy (Regge)

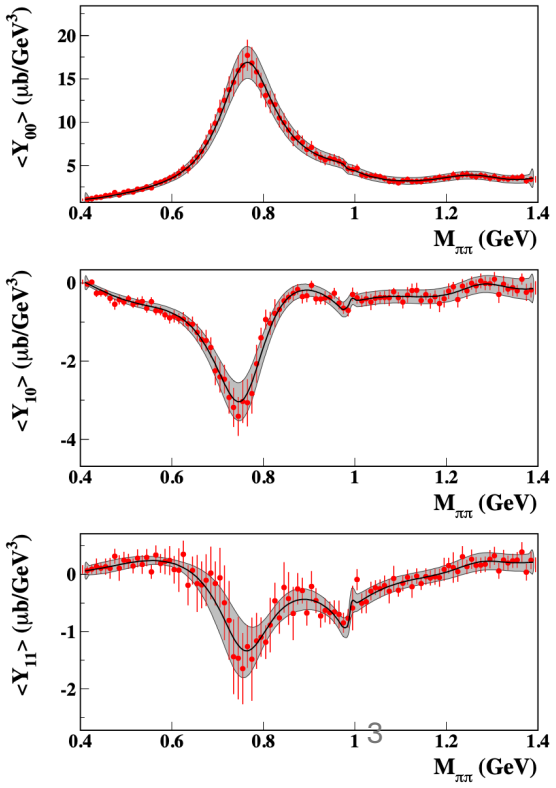
arXiv:0907.1021 CLAS g11



arXiv:0907.1021 CLAS g11



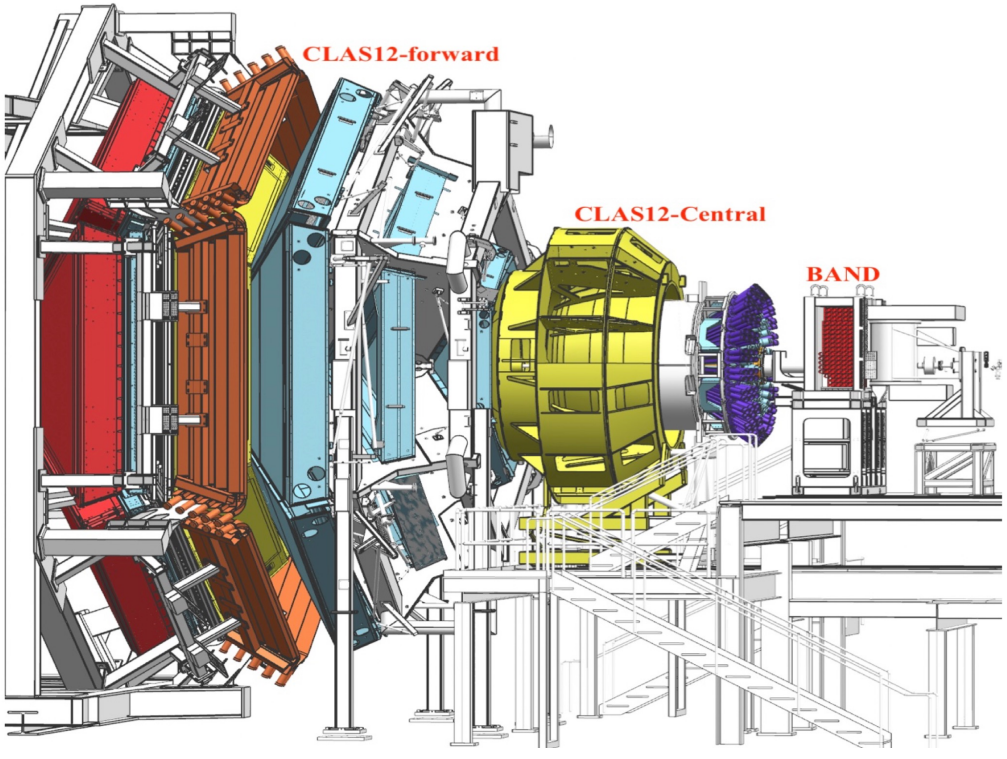
arXiv:0907.1021 CLAS g11

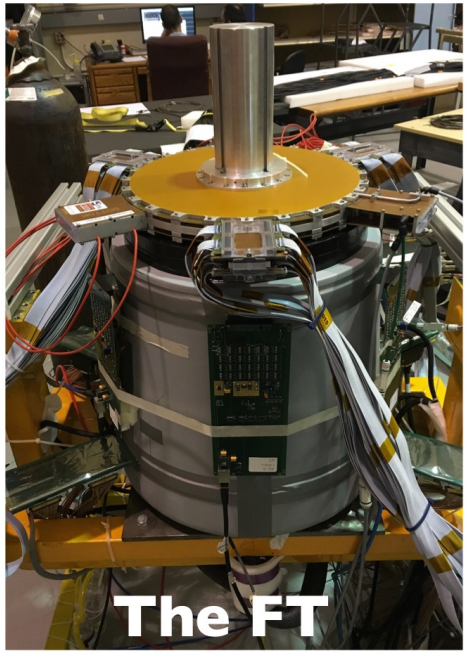


CLAS12 Particles Detection

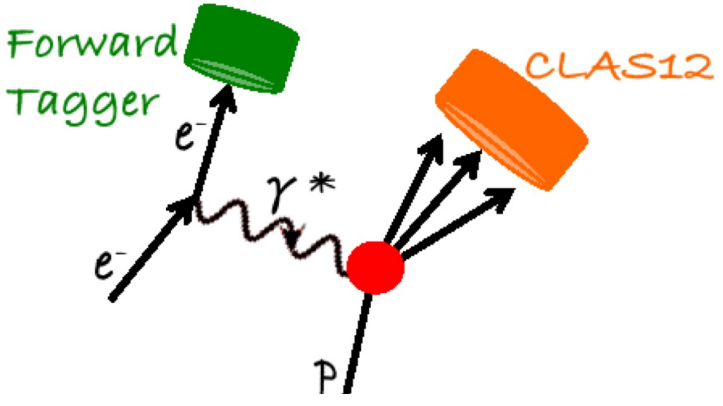
Trigger requirement →

- Electron up to 5 GeV in the FT (low Q^2)
- Two tracks (no specifics ID particles) in at least two sectors of the FD





built in Genoa



electrons in FT

pions mostly in FD

protons mostly in CD

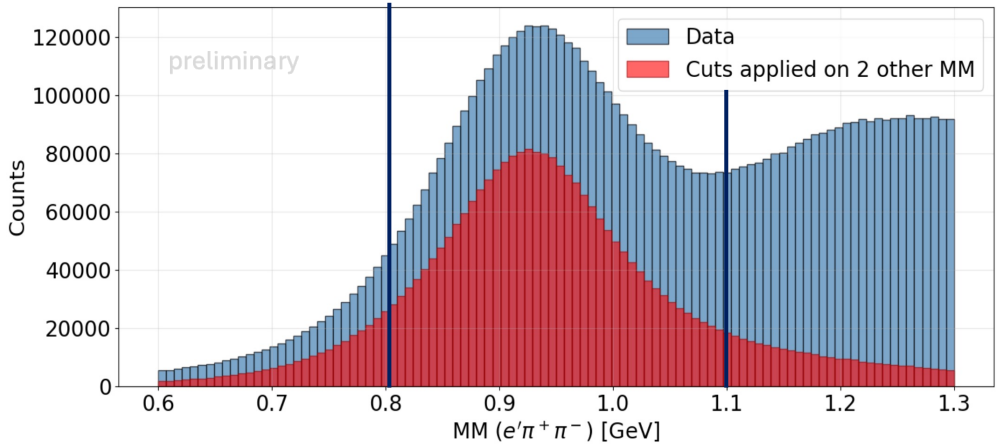
Data Analysis

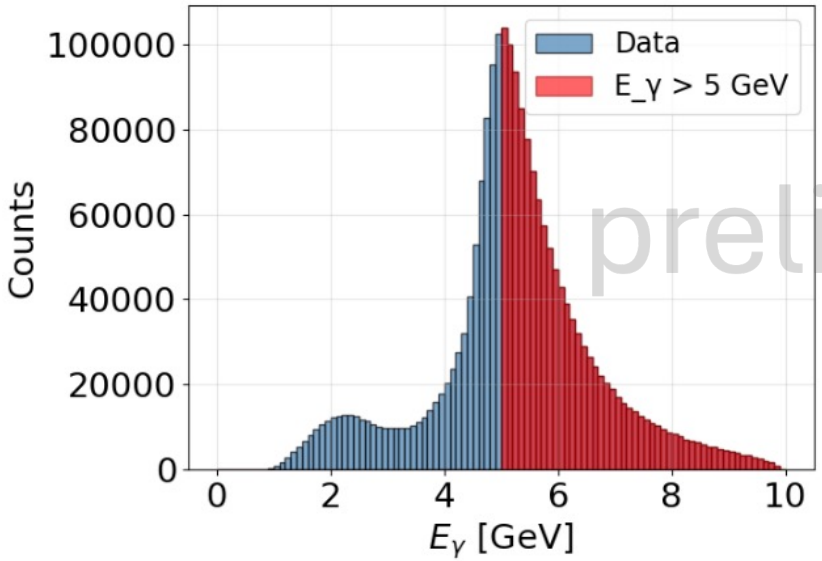
Dataset:

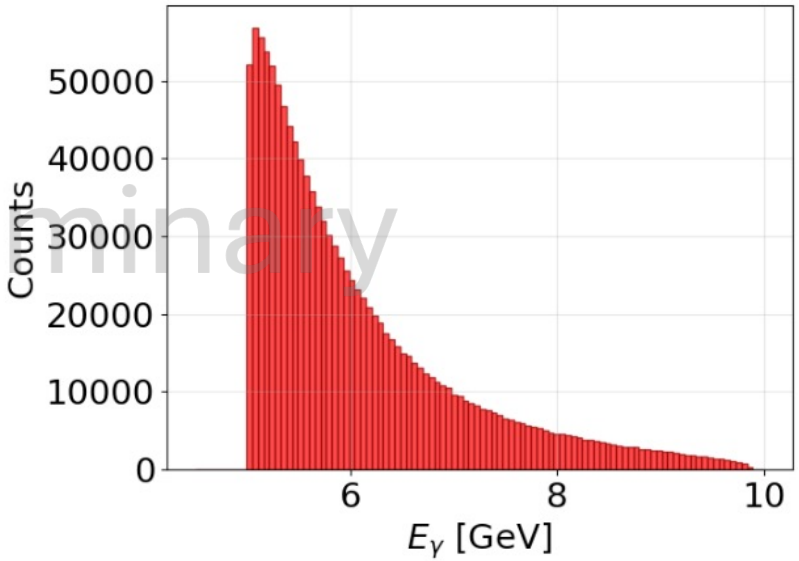
- RG-A pass2
- Spring 2019

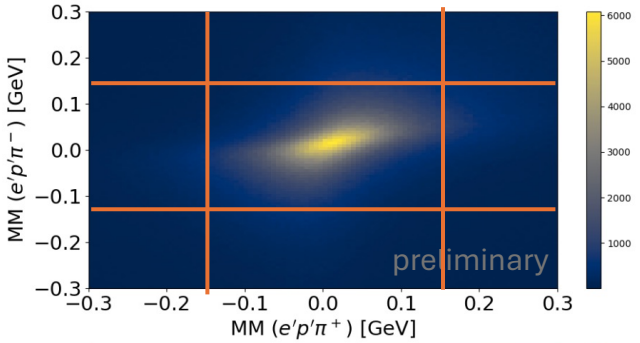
Analysis selection:

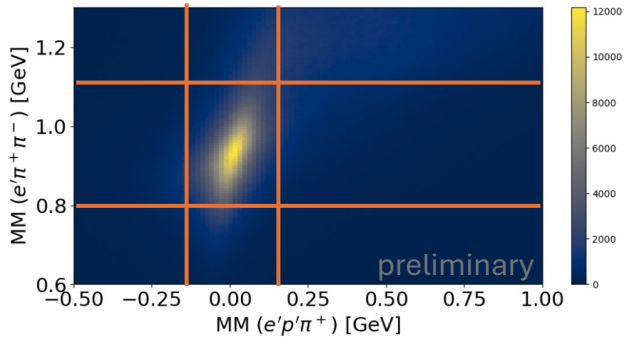
- 0.8 < MM (e' pi+ pi-)< 1.1
- -0.15 < MM (e' p' pi+)< 0.15
- -0.12 < MM (e' p' pi-)< 0.14
- E_γ > 5 GeV

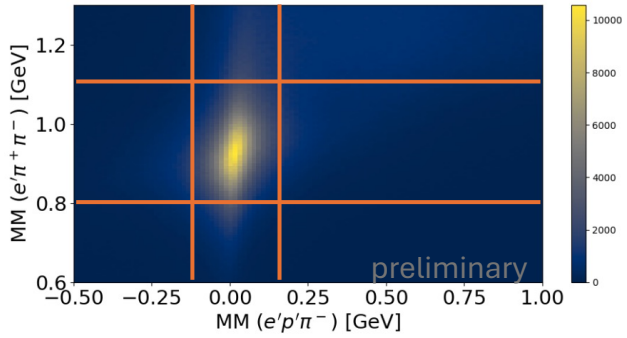






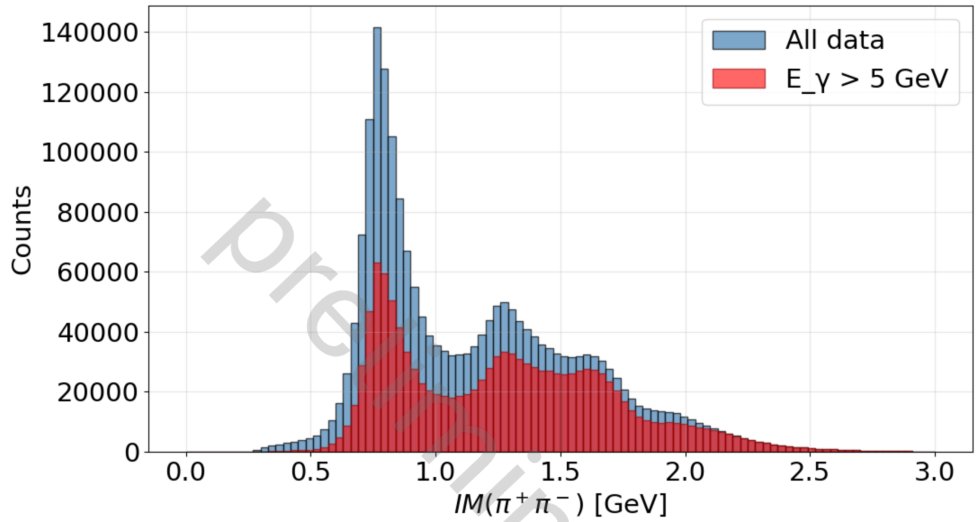


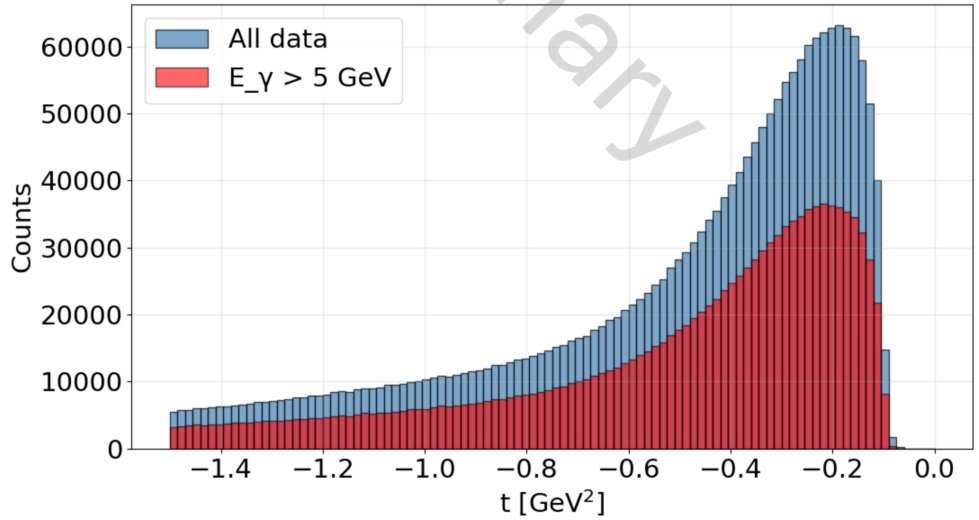


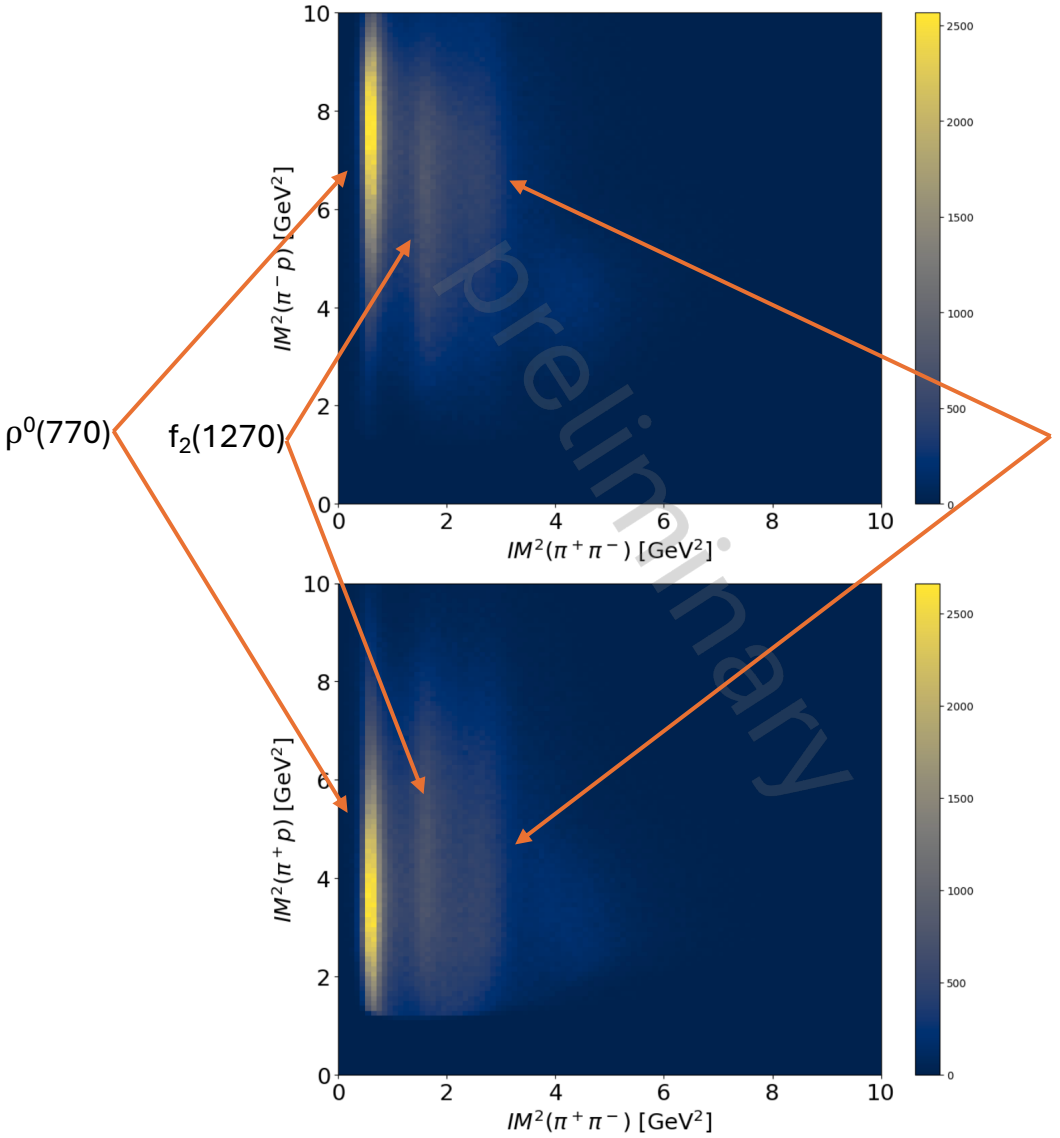


Data Analysis

Looking for resonances



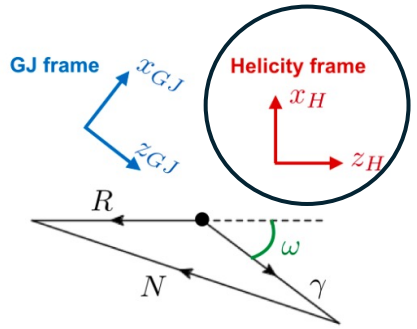




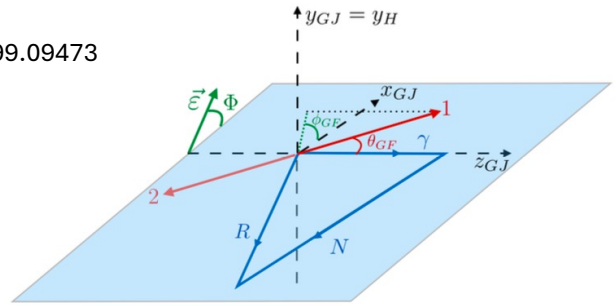
Fitting Moments

First Step to extract Partial Waves

Extracting moments by fitting HEL angles using a PhaseSpace MC for ACCEPTANCE



arXiv:199.09473



arXiv:1909.09473

$$H^0(LM) = \frac{1}{2\pi}\int_0^{2\pi}\int_0^{2\pi}\int_{-1}^{1} I(\Omega,\Phi)\, d^L_{M0}(\theta)\cos M\phi \; \mathrm{d}(\cos\theta)\mathrm{d}\phi\mathrm{d}\Phi,$$

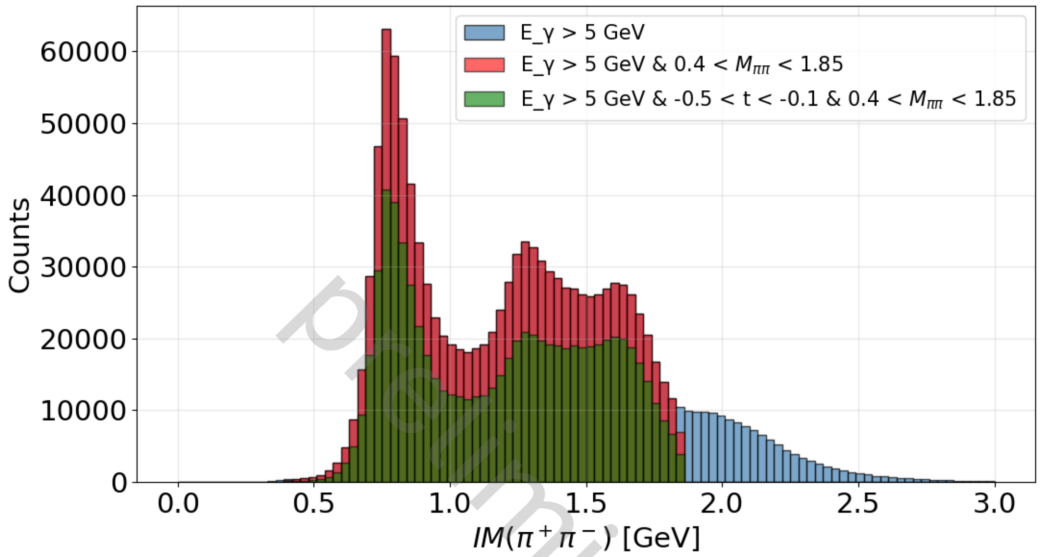
$$H^1(LM) = \frac{1}{P_\gamma \pi}\int_0^{2\pi}\int_0^{2\pi}\int_{-1}^{1} I(\Omega,\Phi)\, d^L_{M0}(\theta)\cos M\phi \cos 2\Phi \; \mathrm{d}(\cos\theta)\mathrm{d}\phi\mathrm{d}\Phi,$$

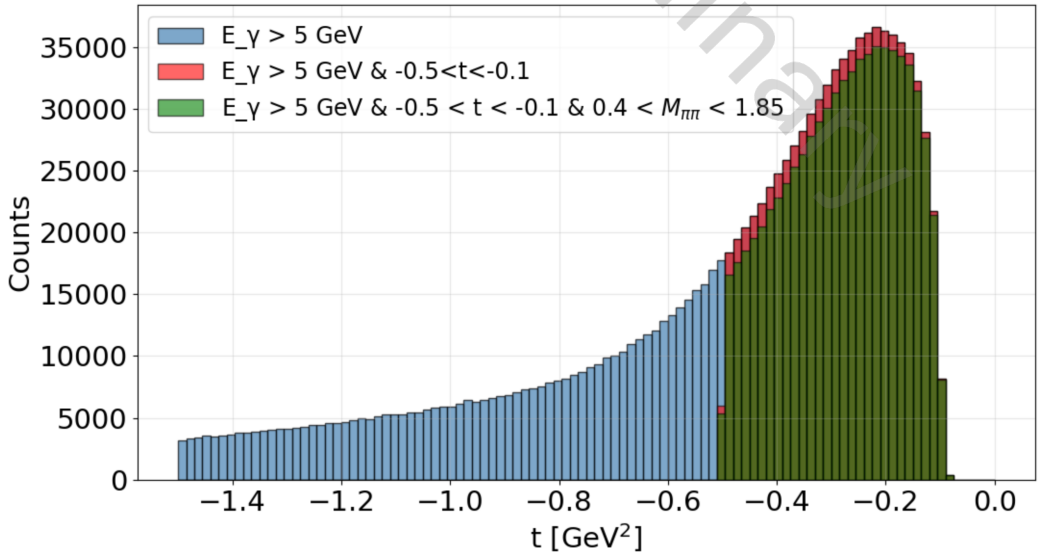
$$\mathrm{Im}H^2(LM) = \frac{-1}{P_\gamma \pi}\int_0^{2\pi}\int_0^{2\pi}\int_{-1}^{1} I(\Omega,\Phi)\, d^L_{M0}(\theta)\sin M\phi \sin 2\Phi \; \mathrm{d}(\cos\theta)\mathrm{d}\phi\mathrm{d}\Phi.$$

In practical we have to use this acceptance term

$$\frac{dN}{d\Omega} = \sum_{LM} H^0_{LM}(m_{\pi^+\pi^-}, t) d^L_{M0}(\theta)\cos M\phi \times \alpha(m_{\pi^+\pi^-}, t, \theta, \phi)$$

d->Y(θ,ϕ)





Likelihood Fitting

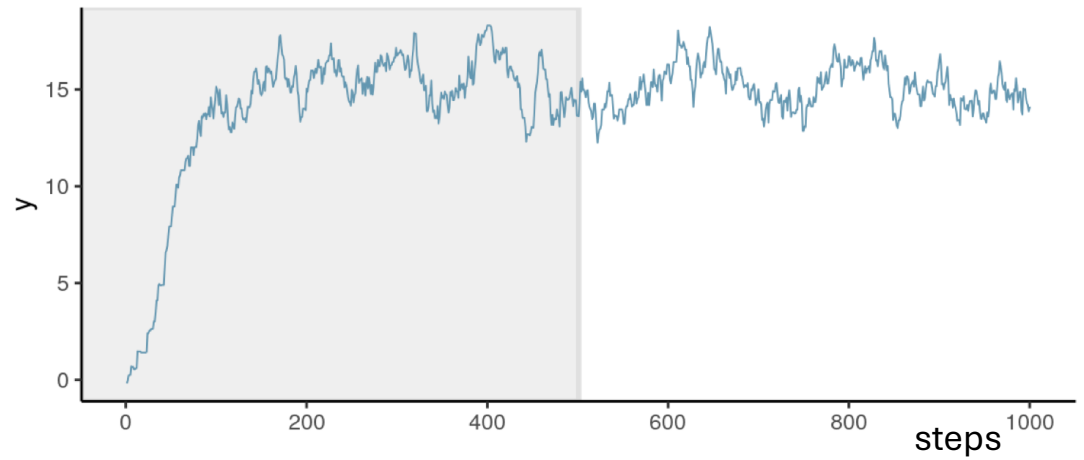
Markov Chain MC is a computational technique used to sample from a probability distribution

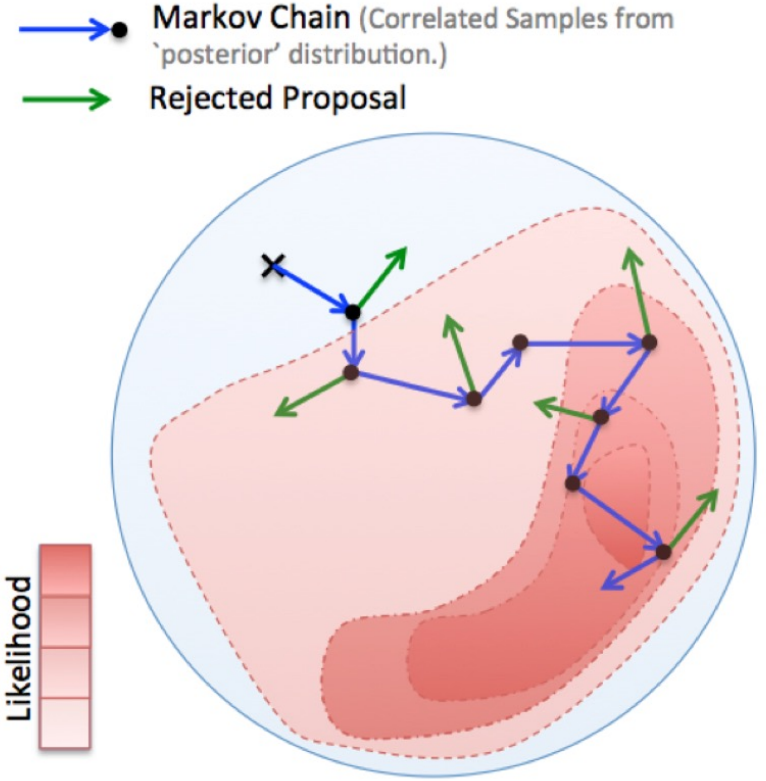
Likelihood

$$\mathscr{L}(x;\theta) = \prod_{n=1}^{p} f(x_n;\theta)$$

$$ln(\mathscr{L}(x;\theta)) \propto \sum_{n=1}^{p} ln[F(x_n;\theta)] - \mathscr{N}$$

burn in

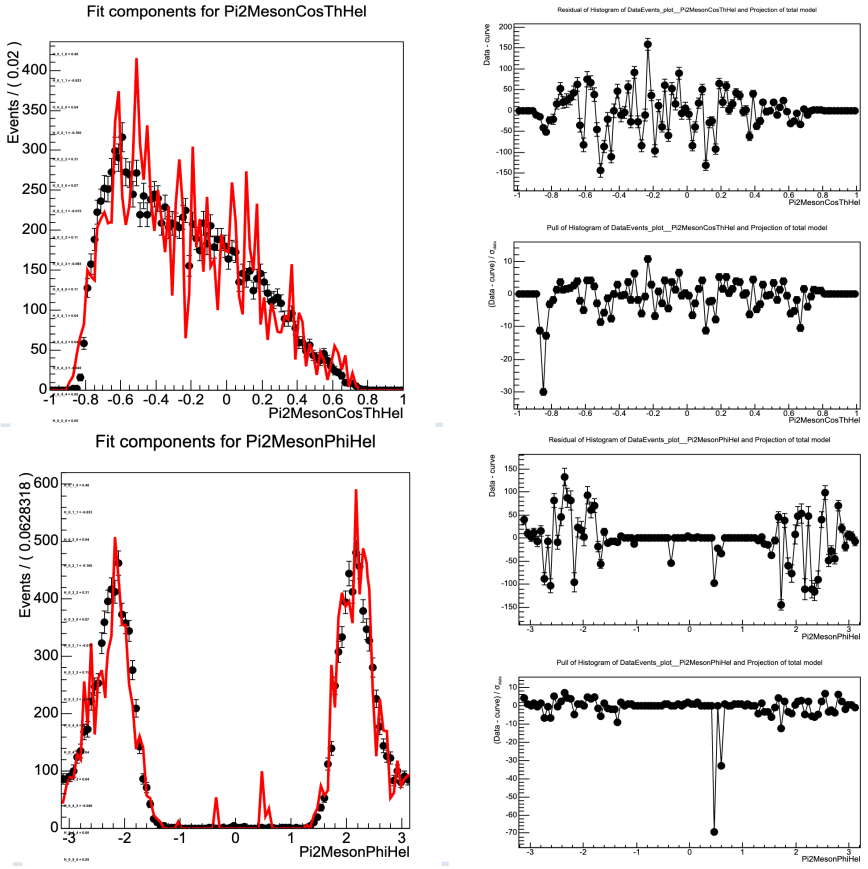




Wishart, Robert (2023) *Analysis of three body decays in quasi-real photoproduction.* PhD thesis.

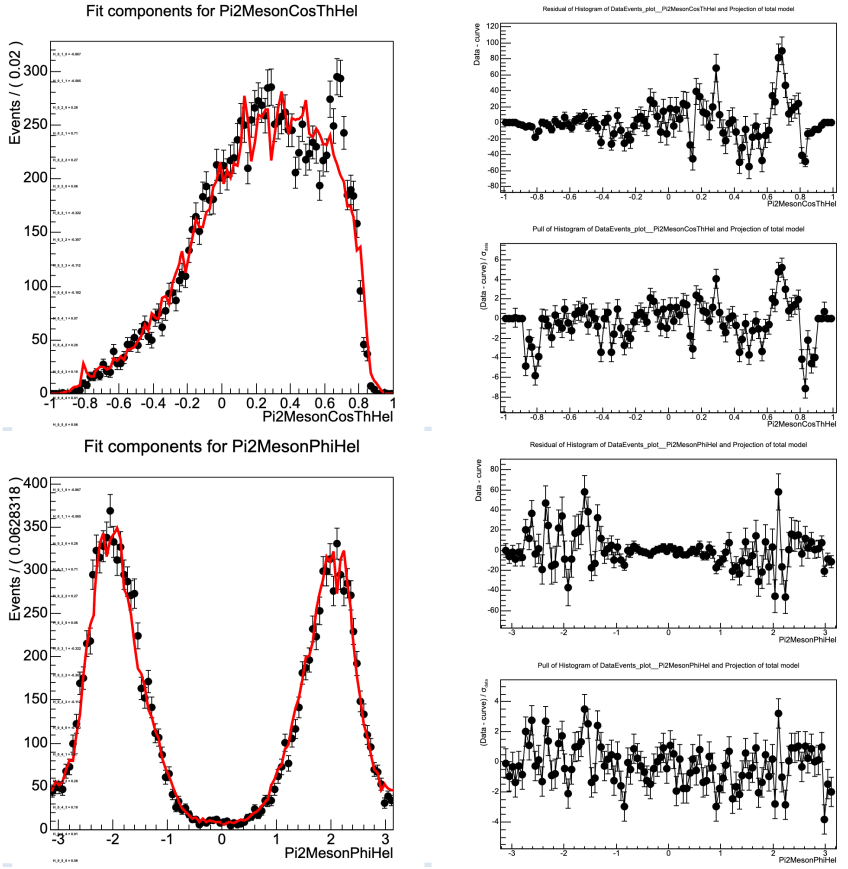
Fitting Moments

IM region of the ρ^0 resonance



Low acceptance

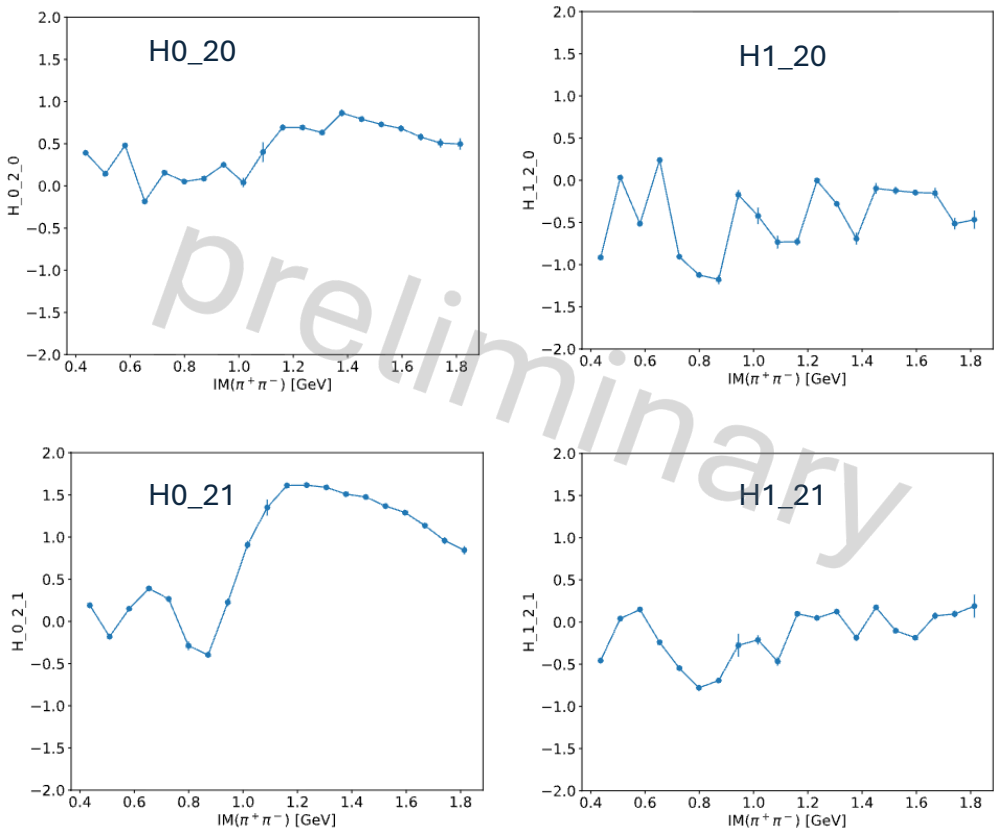
IM region of the f_2 resonance



High acceptance

Extracting Moments

From moments we can see the partial waves contributions of resonances

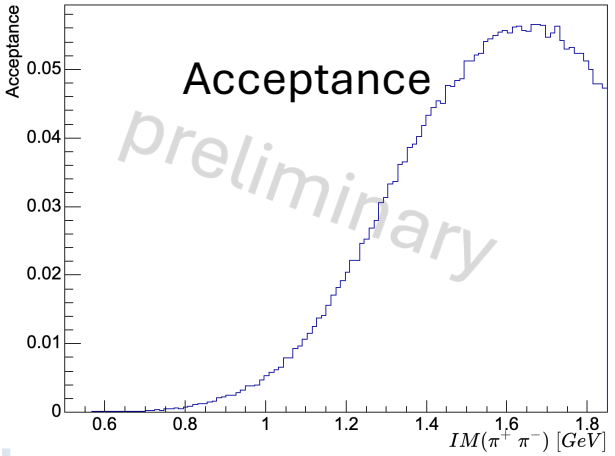


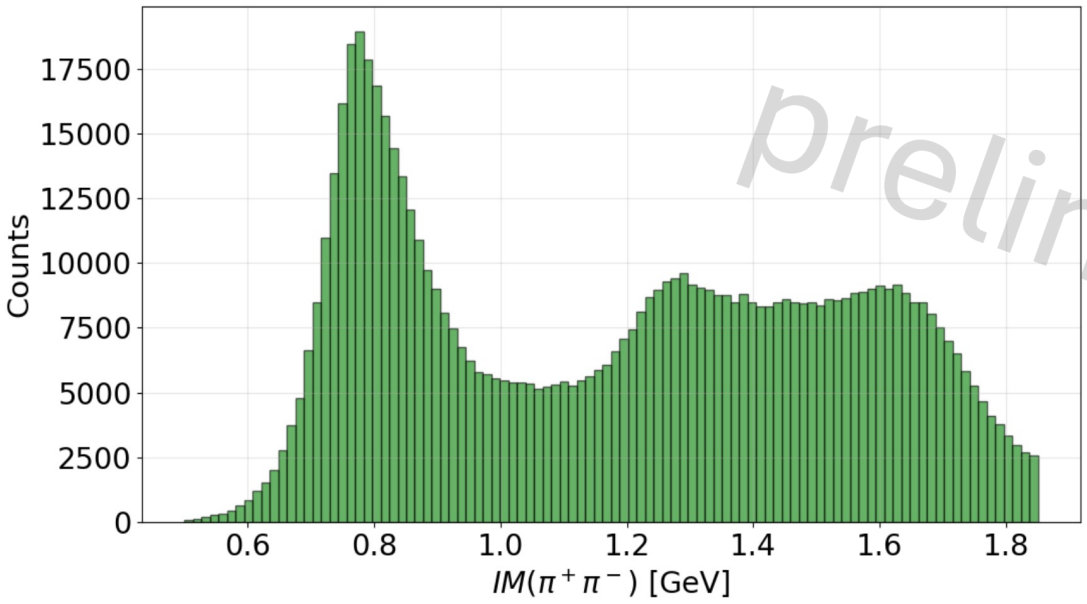
$$
\begin{aligned}
{}^{(+)}H^0(20) &= \frac{4}{5}|P_0^{(+)}|^2 - \frac{2}{5}\left(|P_1^{(+)}|^2 + |P_{-1}^{(+)}|^2\right) + \frac{4}{7}|D_0^{(+)}|^2 + \frac{2}{7}\left(|D_1^{(+)}|^2 + |D_{-1}^{(+)}|^2\right) \\
&\quad - \frac{4}{7}\left(|D_2^{(+)}|^2 + |D_{-2}^{(+)}|^2\right) + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^1(20) &= \frac{4}{5}|P_0^{(+)}|^2 + \frac{4}{5}\mathrm{Re}\left(P_1^{(+)}P_{-1}^{(+)*}\right) + \frac{4}{7}|D_0^{(+)}|^2 - \frac{4}{7}\mathrm{Re}\left(D_1^{(+)}D_{-1}^{(+)*}\right) - \frac{8}{7}\mathrm{Re}\left(D_2^{(+)}D_{-2}^{(+)*}\right) \\
&\quad + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^0(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_2^{(+)*} - D_{-1}^{(+)}D_{-2}^{(+)*}\right] \\
{}^{(+)}H^1(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_{-2}^{(+)*} + D_{-1}^{(+)}D_2^{(+)*}\right]
\end{aligned}
$$

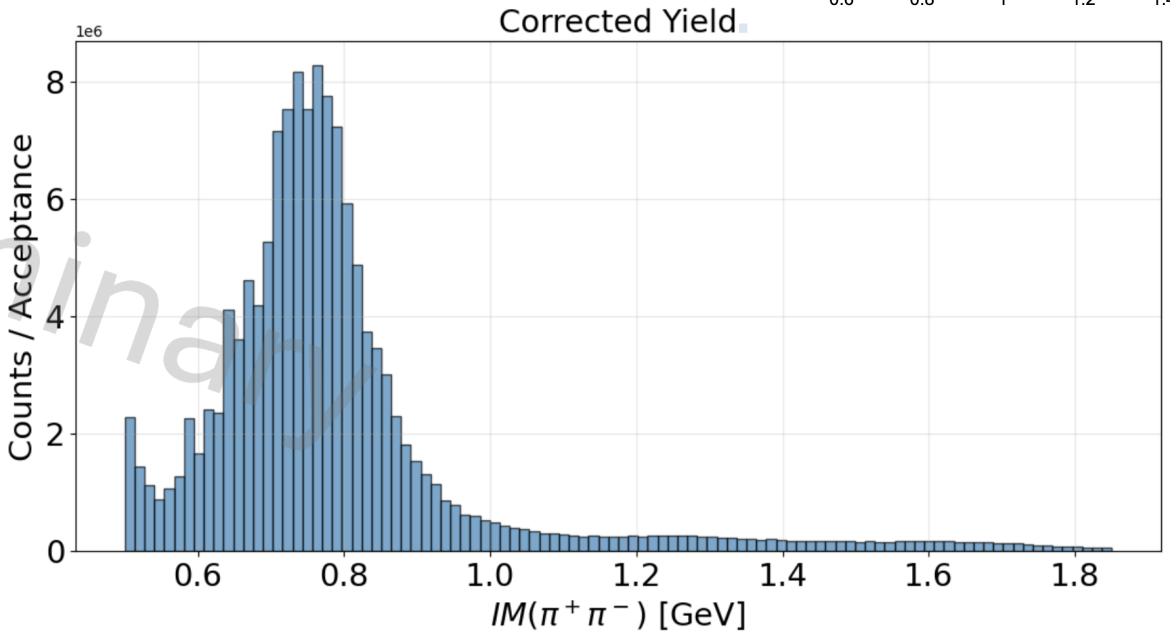
arXiv:1909.09473

Acceptance Correction

We approximated the acceptance correction with a 1-D distribution to study the yield

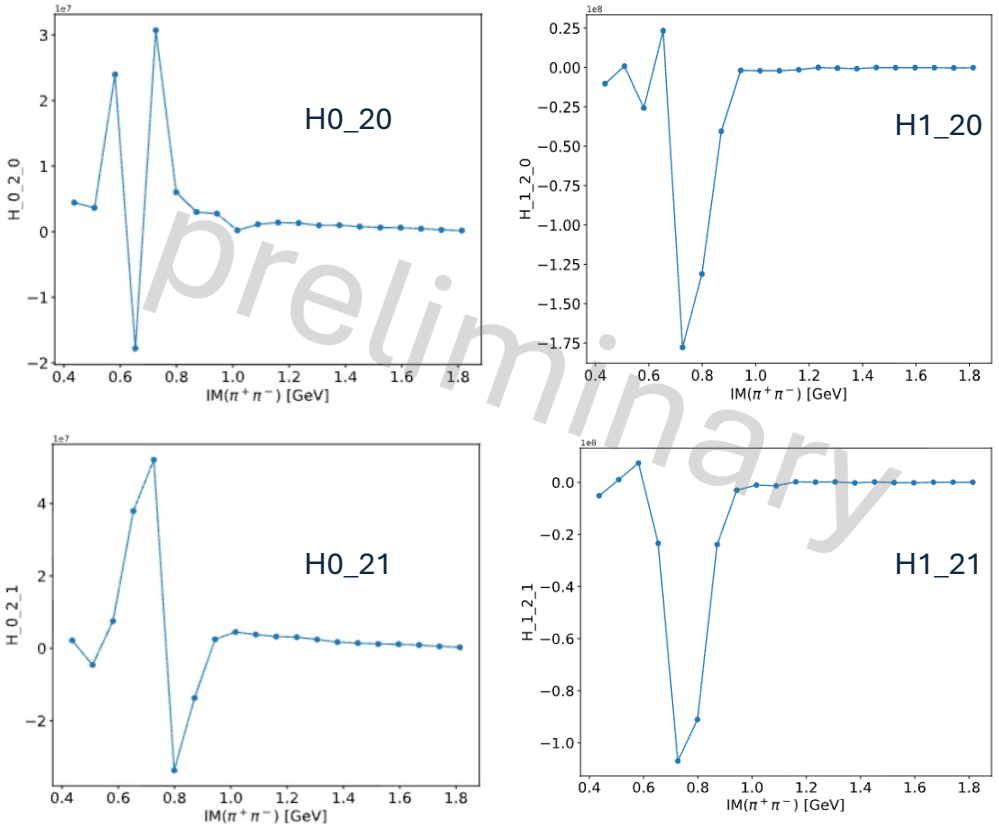






Extracting Moments

From moments we can see the partial waves contributions of resonances



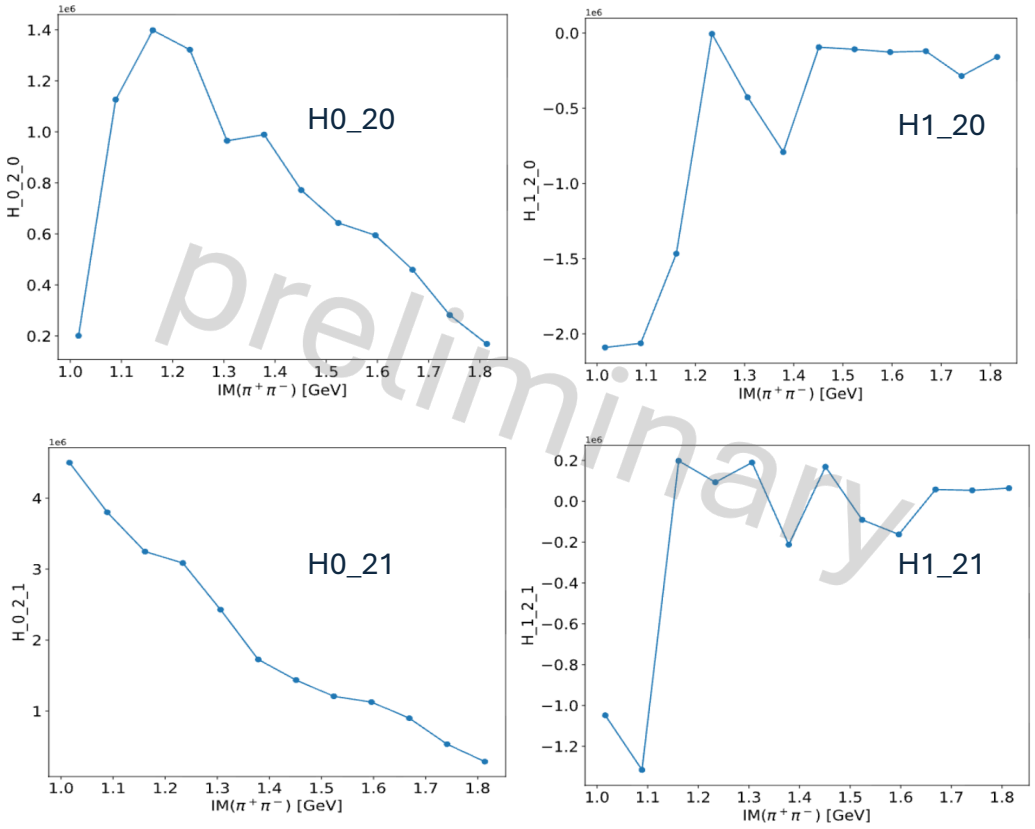
$$
\begin{aligned}
{}^{(+)}H^0(20) &= \frac{4}{5}|P_0^{(+)}|^2 - \frac{2}{5}\left(|P_1^{(+)}|^2 + |P_{-1}^{(+)}|^2\right) + \frac{4}{7}|D_0^{(+)}|^2 + \frac{2}{7}\left(|D_1^{(+)}|^2 + |D_{-1}^{(+)}|^2\right) \\
&\quad - \frac{4}{7}\left(|D_2^{(+)}|^2 + |D_{-2}^{(+)}|^2\right) + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^1(20) &= \frac{4}{5}|P_0^{(+)}|^2 + \frac{4}{5}\mathrm{Re}\left(P_1^{(+)}P_{-1}^{(+)*}\right) + \frac{4}{7}|D_0^{(+)}|^2 - \frac{4}{7}\mathrm{Re}\left(D_1^{(+)}D_{-1}^{(+)*}\right) - \frac{8}{7}\mathrm{Re}\left(D_2^{(+)}D_{-2}^{(+)*}\right) \\
&\quad + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^0(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_2^{(+)*} - D_{-1}^{(+)}D_{-2}^{(+)*}\right] \\
{}^{(+)}H^1(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_{-2}^{(+)*} + D_{-1}^{(+)}D_2^{(+)*}\right]
\end{aligned}
$$

arXiv:1909.09473

Rescaling moments with yields

Extracting Moments

From moments we can see the partial waves contributions of resonances



$$
\begin{aligned}
{}^{(+)}H^0(20) &= \frac{4}{5}|P_0^{(+)}|^2 - \frac{2}{5}\left(|P_1^{(+)}|^2 + |P_{-1}^{(+)}|^2\right) + \frac{4}{7}|D_0^{(+)}|^2 + \frac{2}{7}\left(|D_1^{(+)}|^2 + |D_{-1}^{(+)}|^2\right) \\
&\quad - \frac{4}{7}\left(|D_2^{(+)}|^2 + |D_{-2}^{(+)}|^2\right) + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^1(20) &= \frac{4}{5}|P_0^{(+)}|^2 + \frac{4}{5}\mathrm{Re}\left(P_1^{(+)}P_{-1}^{(+)*}\right) + \frac{4}{7}|D_0^{(+)}|^2 - \frac{4}{7}\mathrm{Re}\left(D_1^{(+)}D_{-1}^{(+)*}\right) - \frac{8}{7}\mathrm{Re}\left(D_2^{(+)}D_{-2}^{(+)*}\right) \\
&\quad + \frac{4}{\sqrt{5}}\mathrm{Re}\left(S_0^{(+)}D_0^{(+)*}\right) \\
{}^{(+)}H^0(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_2^{(+)*} - D_{-1}^{(+)}D_{-2}^{(+)*}\right] \\
{}^{(+)}H^1(21) &= 2\mathrm{Re}\left[\left(\frac{S_0^{(+)}}{\sqrt{5}} + \frac{D_0^{(+)}}{7}\right)\left(D_1^{(+)*} - D_{-1}^{(+)*}\right)\right] + 2\frac{\sqrt{3}}{5}\mathrm{Re}\left[P_0^{(+)}\left(P_1^{(+)*} - P_{-1}^{(+)*}\right)\right] \\
&\quad + 2\frac{\sqrt{6}}{7}\mathrm{Re}\left[D_1^{(+)}D_{-2}^{(+)*} + D_{-1}^{(+)}D_2^{(+)*}\right]
\end{aligned}
$$

arXiv:1909.09473

Rescaling moments with yields

Summary

CLAS12 analysis on $\gamma^* p \rightarrow p \pi^+ \pi^-$

- Extract of Moments and PWA
- Optimizing cuts and data selection
- Possible goal: f_2 SDMEs

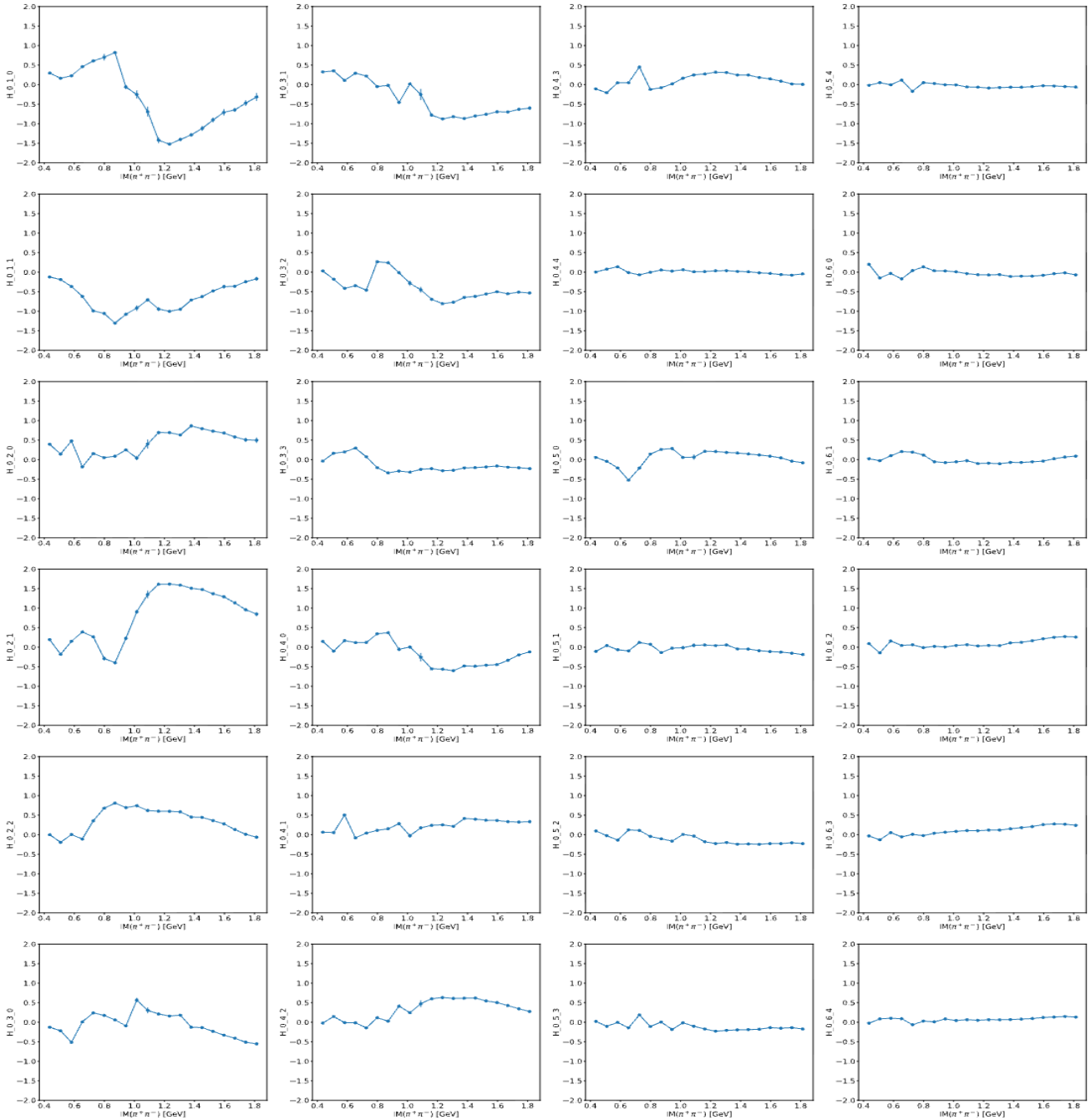
Future directions:

- Considering different topologies
- Extending to finite Q^2
- Mass dependent fits
- Cross sections of f_2

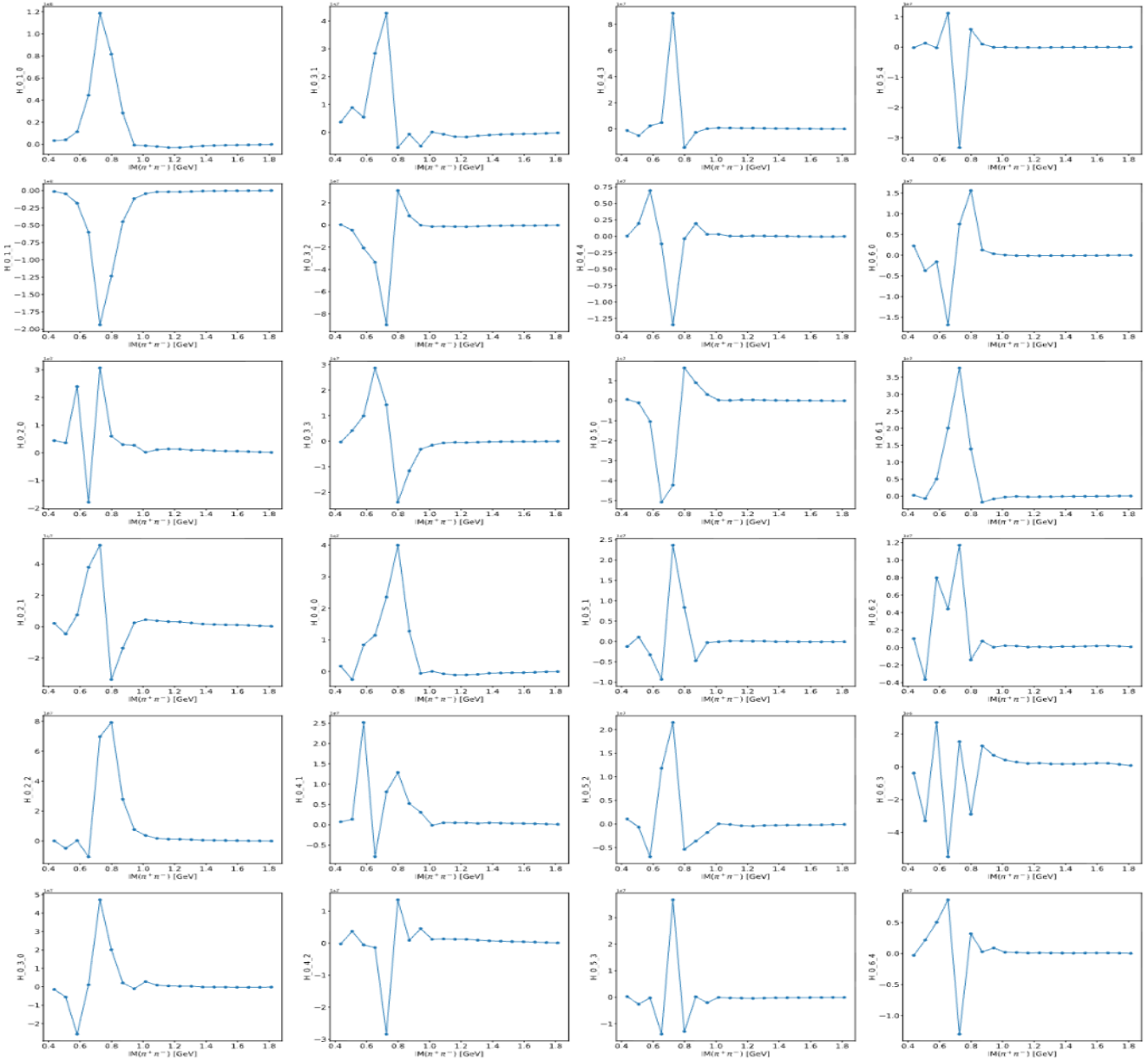
THANKS FOR YOUR ATTENTION

BACKUP

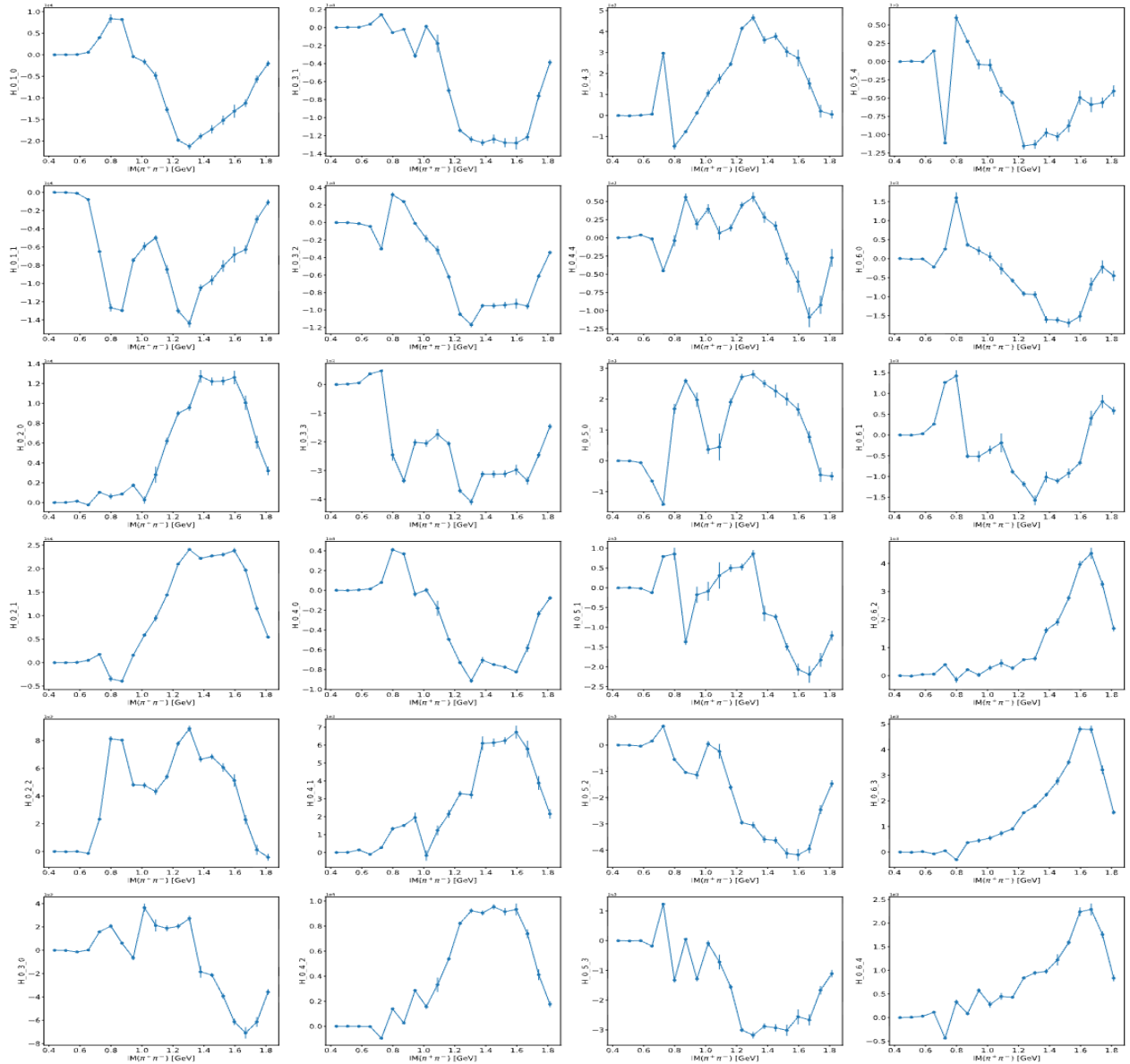
Normalized
H0_LM



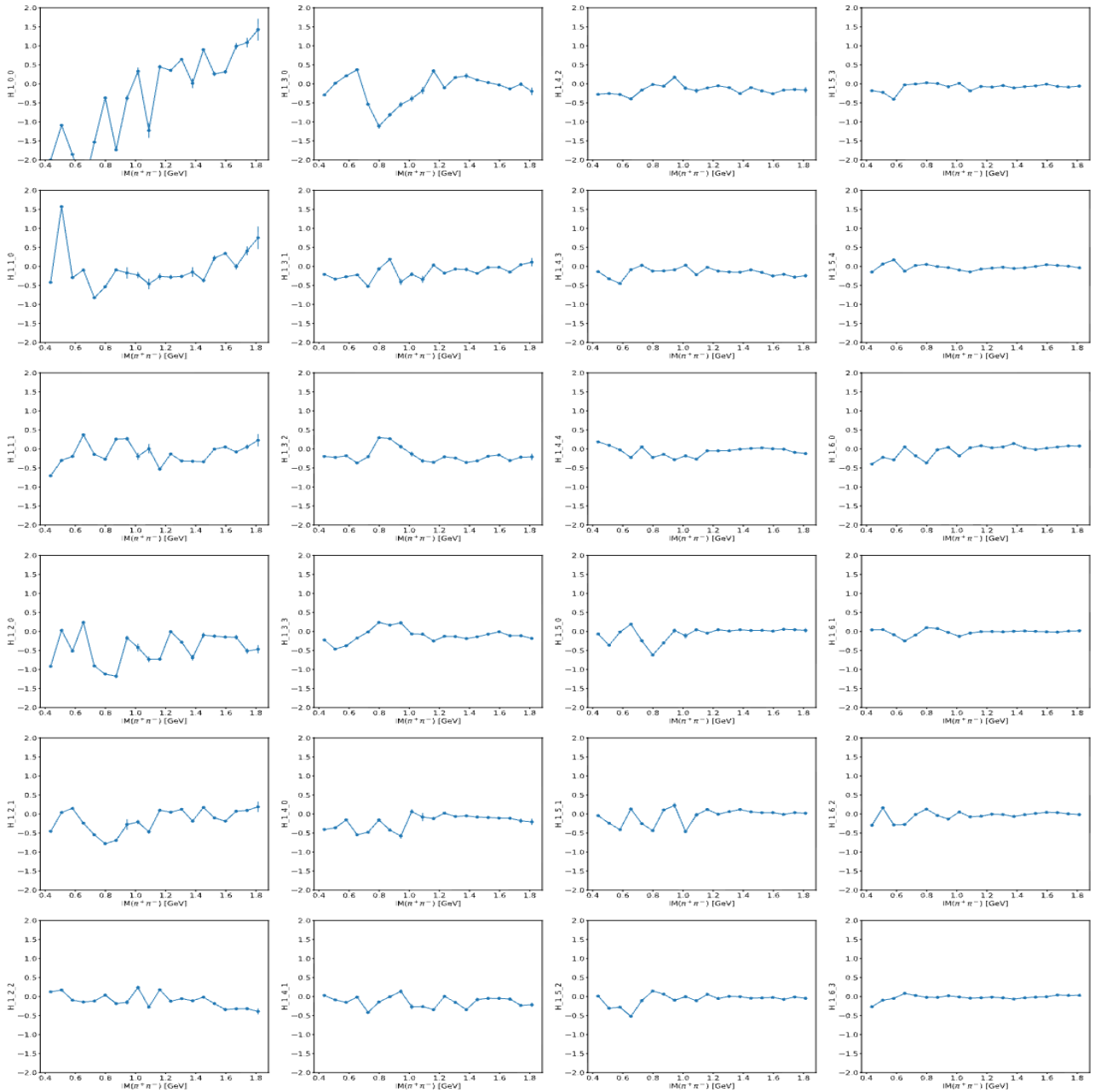
H0_LM
Rescaled
approx
correction
acceptance



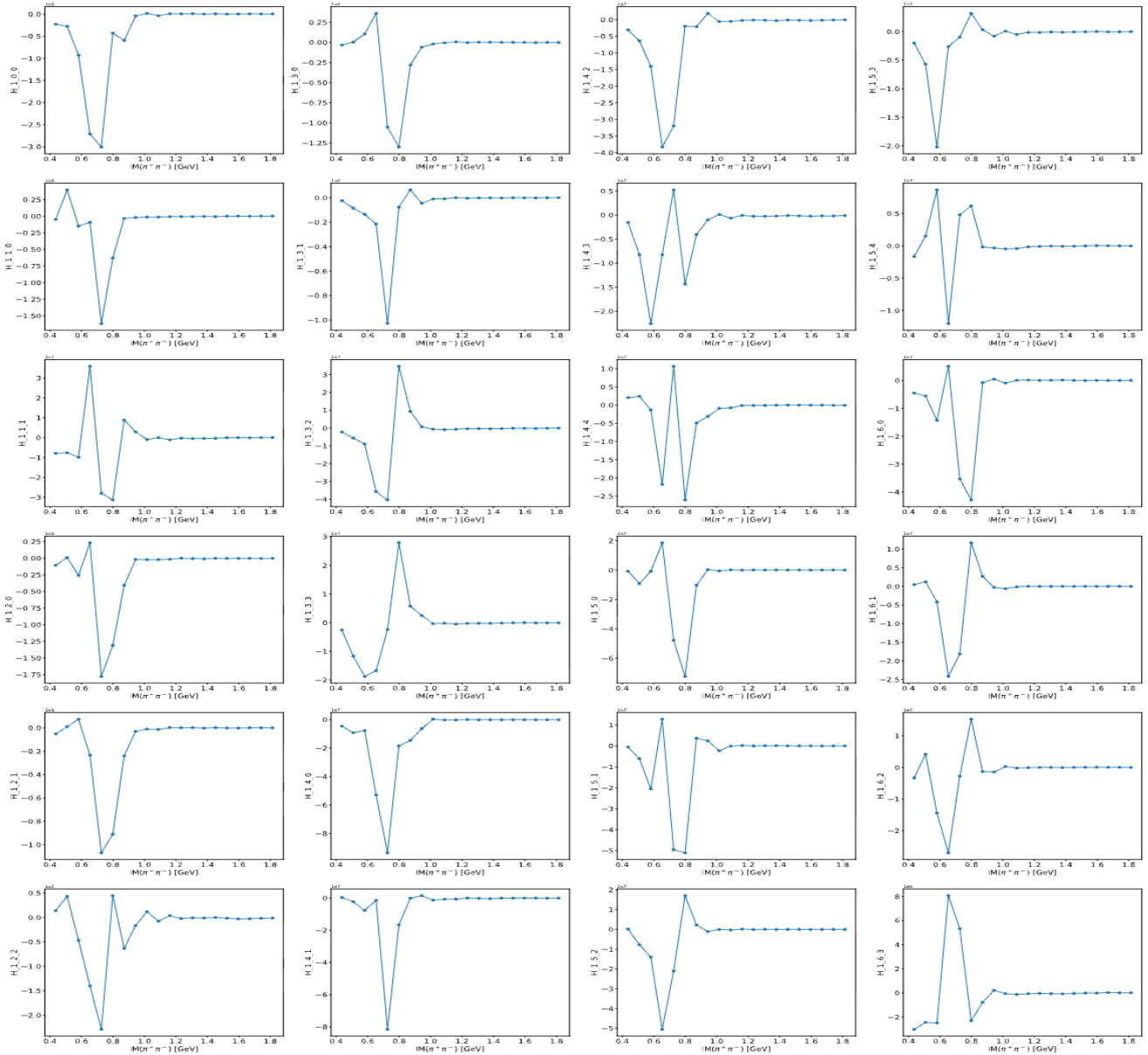
H0_LM Rescaled without approx correction acceptance



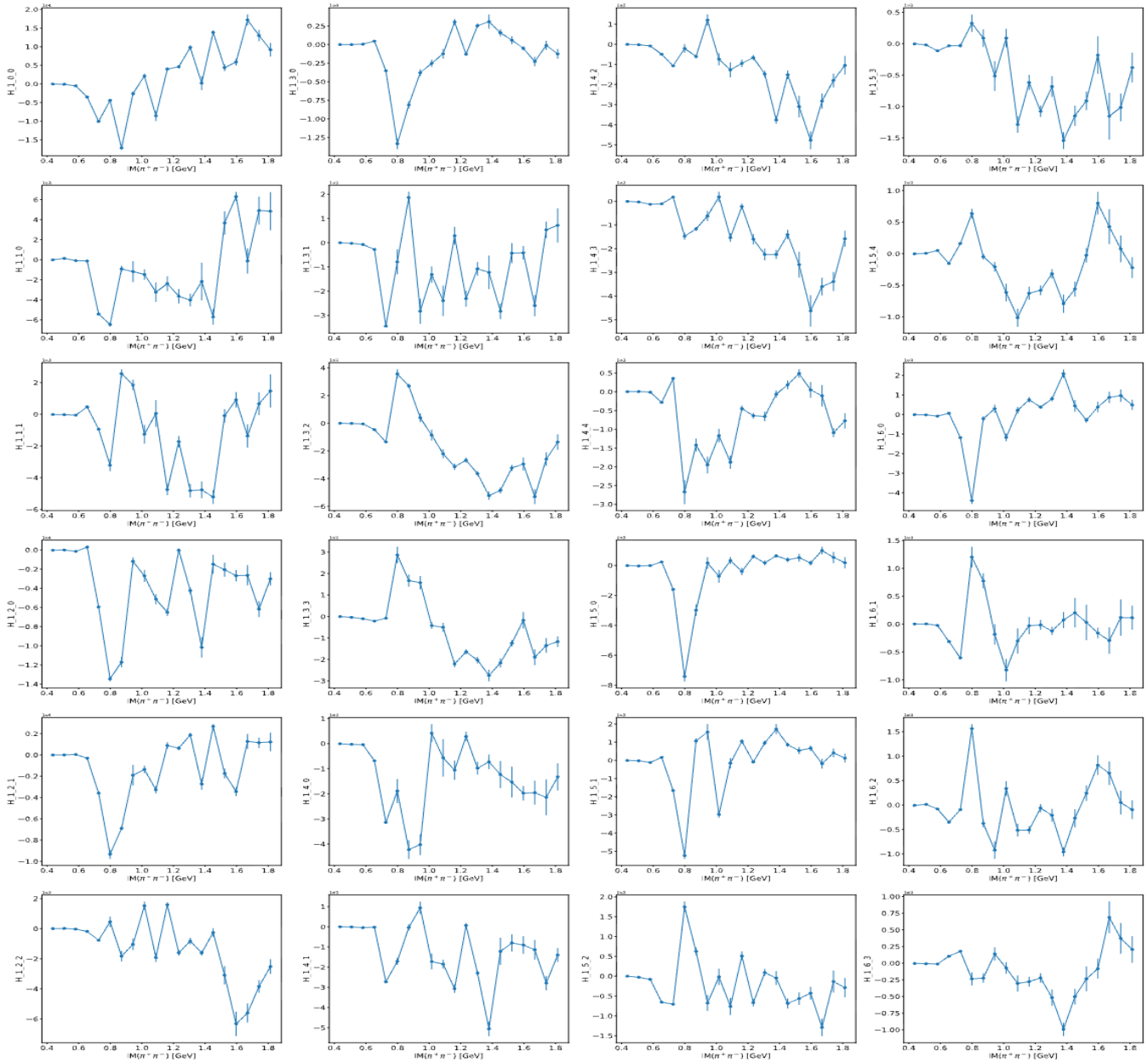
Normalized
H1_LM



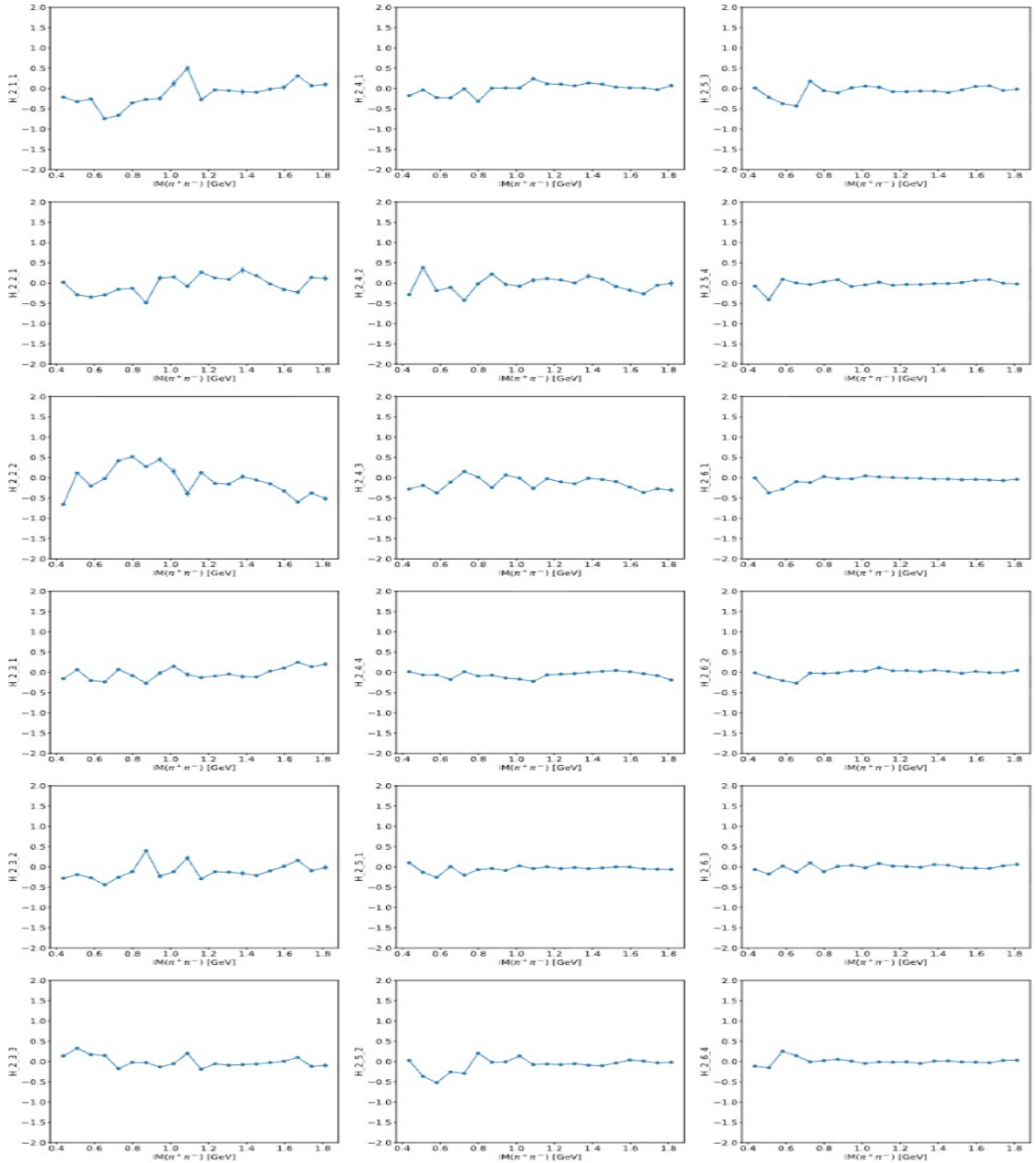
H1_LM
Rescaled
approx
correction
acceptance



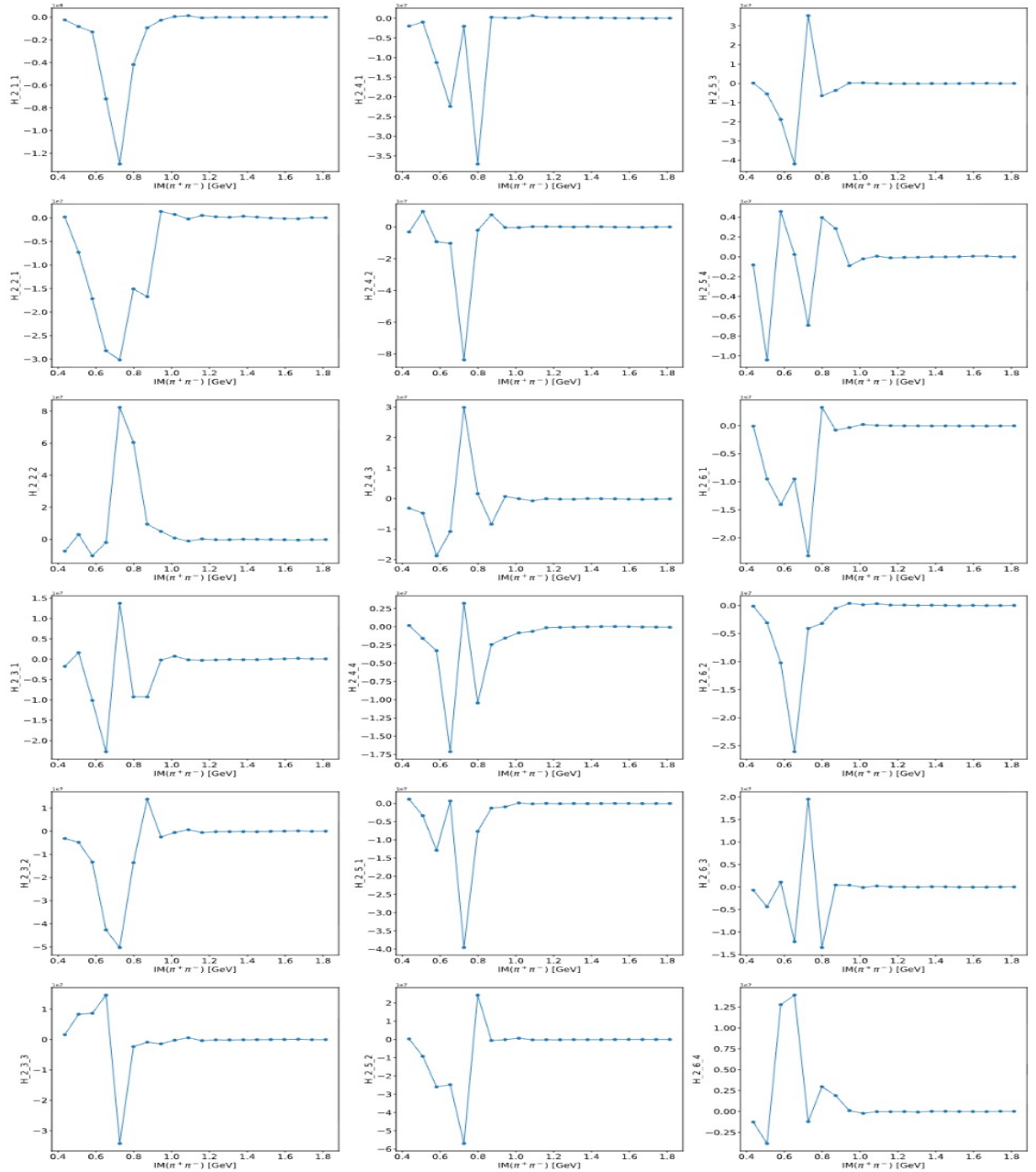
H1_LM Rescaled without approx correction acceptance



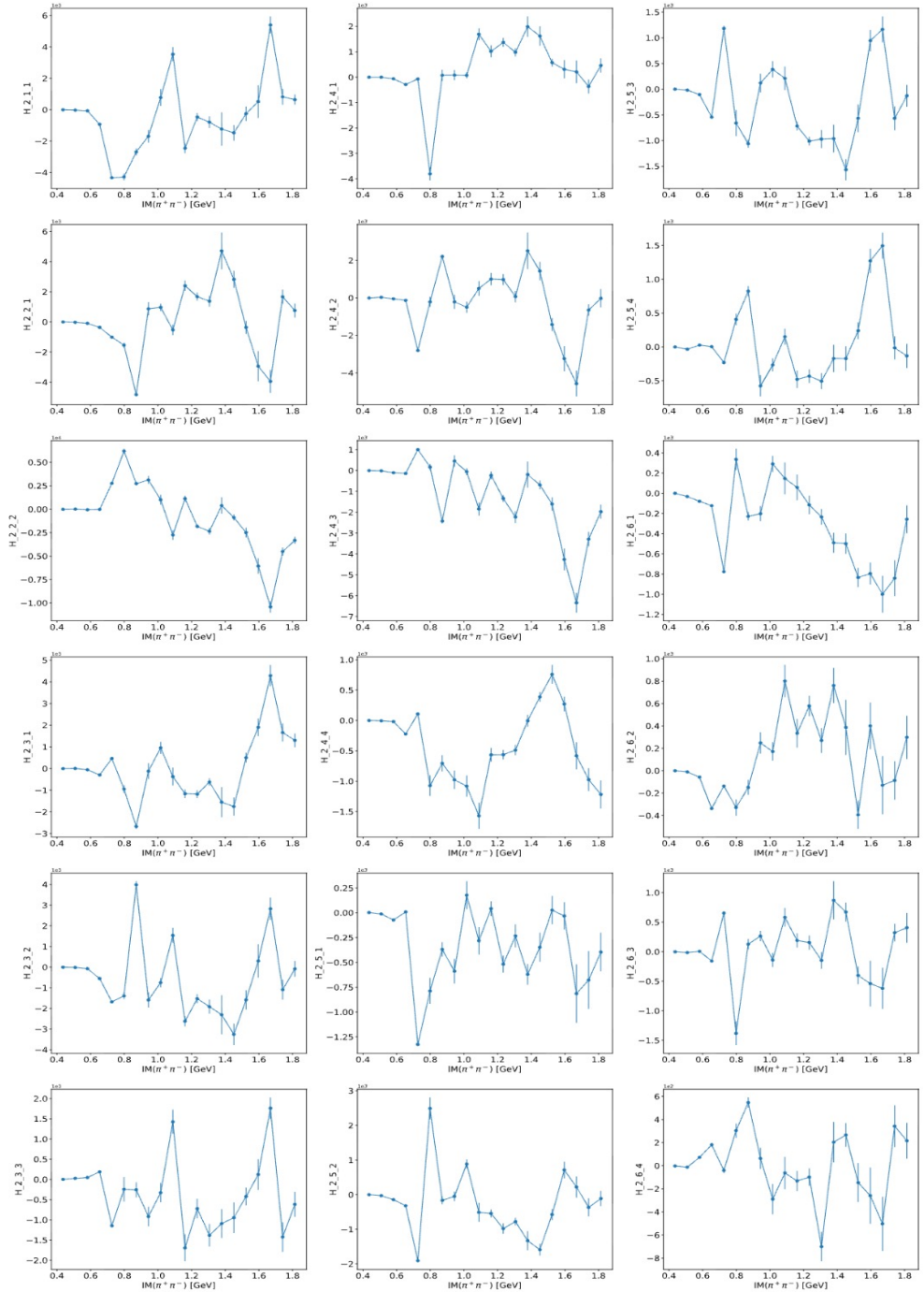
Normalized
H2_LM



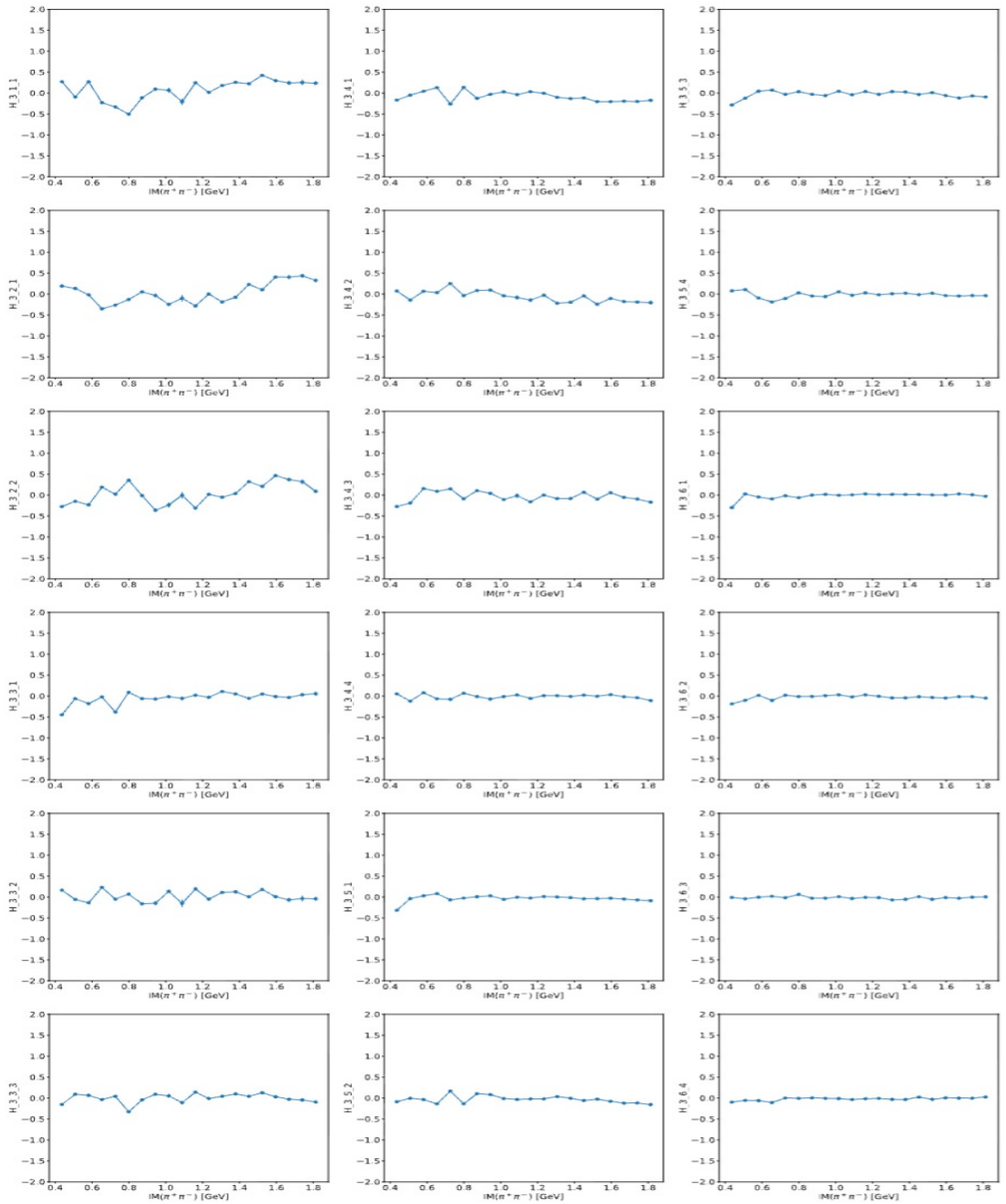
H2_LM
Rescaled
approx
correction
acceptance



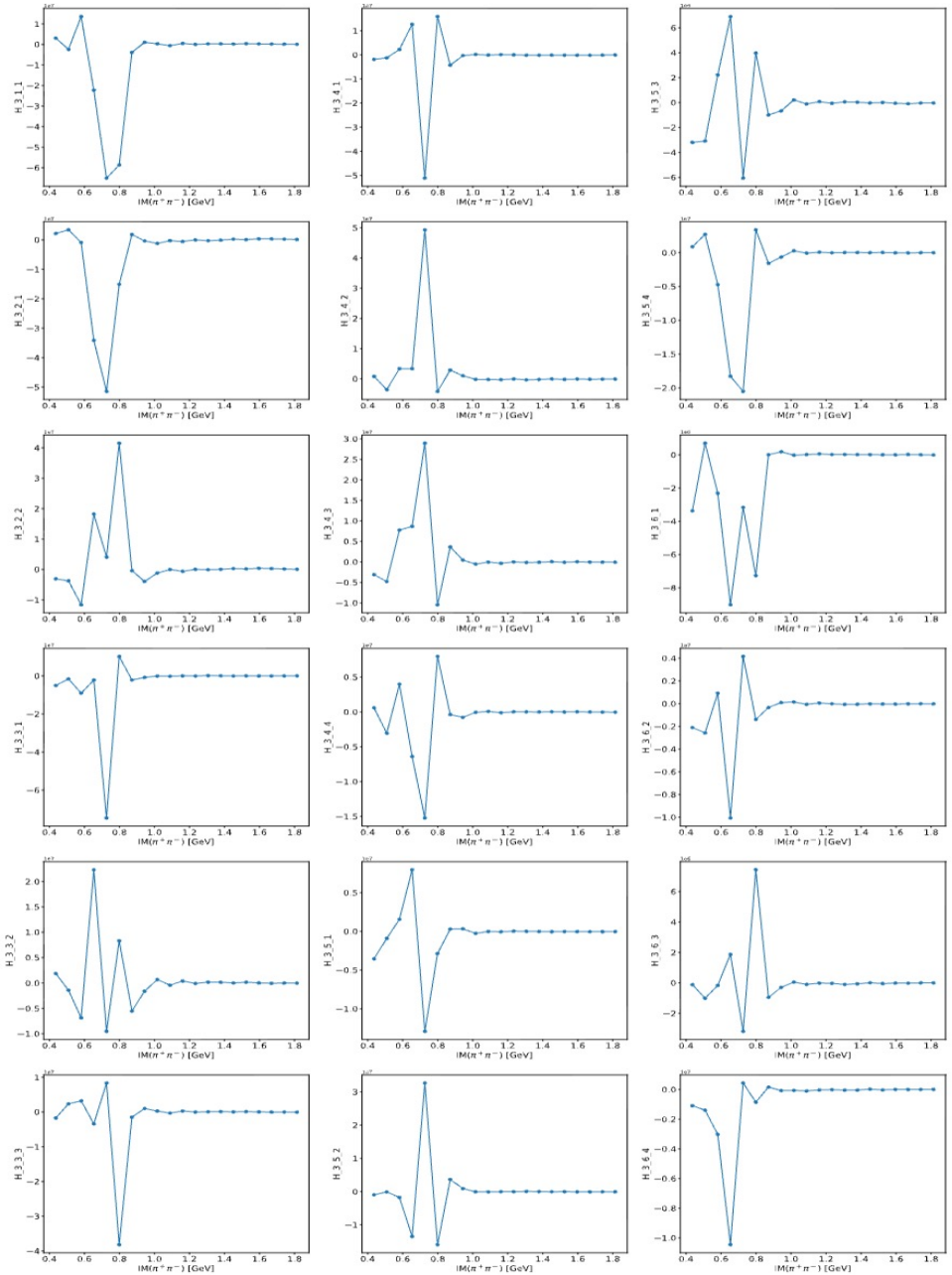
H2_LM
Rescaled
without
approx
correction
acceptance



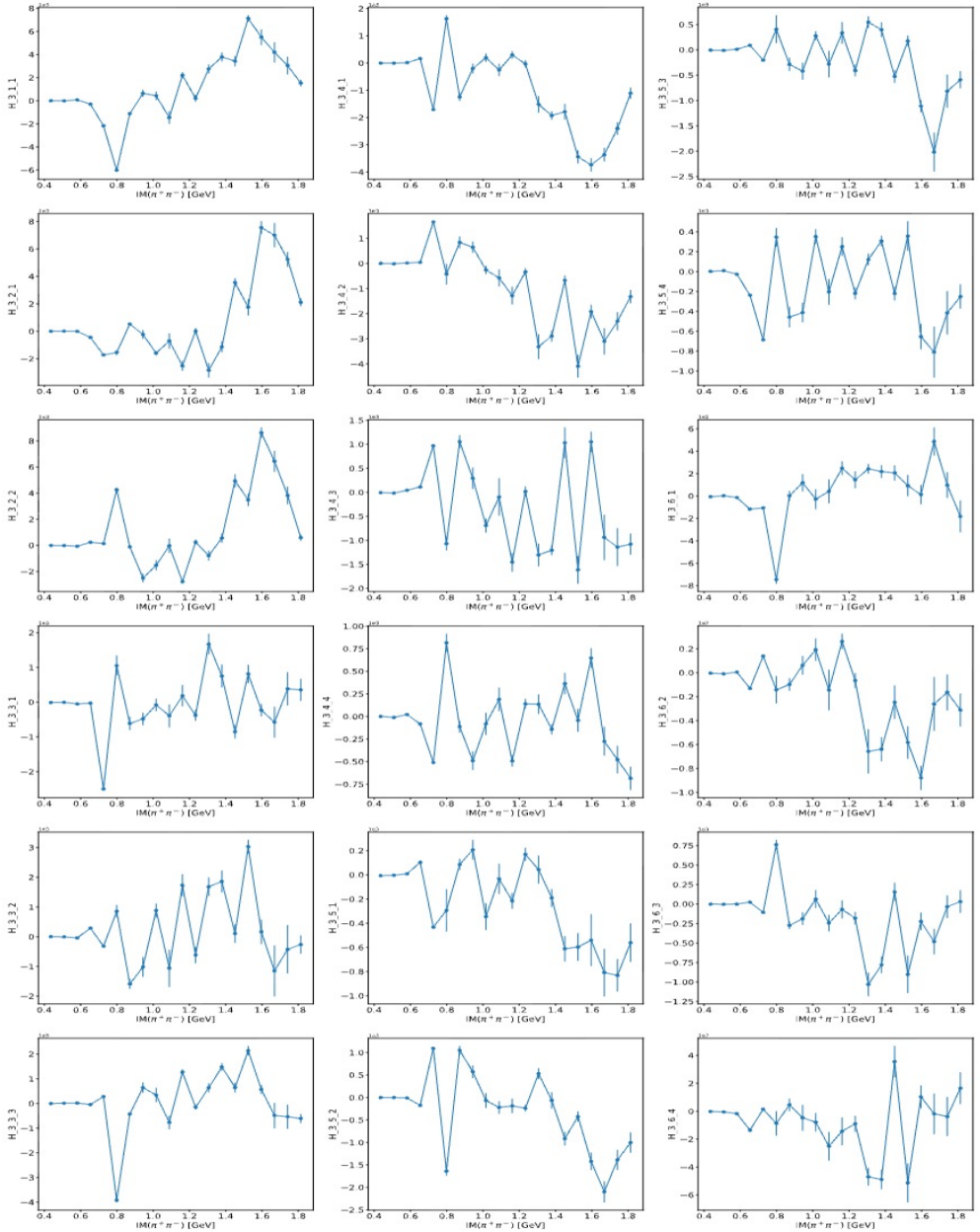
Normalized
H3_LM



H3_LM
Rescaled
approx
correction
acceptance



H3_LM
Rescaled
without
approx
correction
acceptance



Timelines