$\Lambda(1405)$ Photoproduction Using CLAS6 g12 Data (Jefferson Lab)

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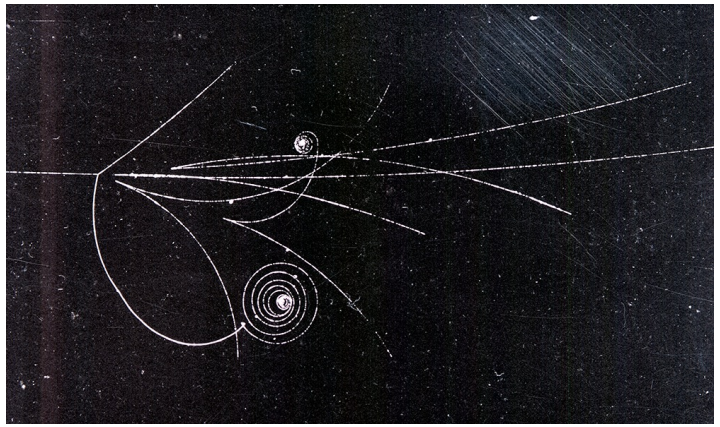
The $\Lambda(1405)$ State

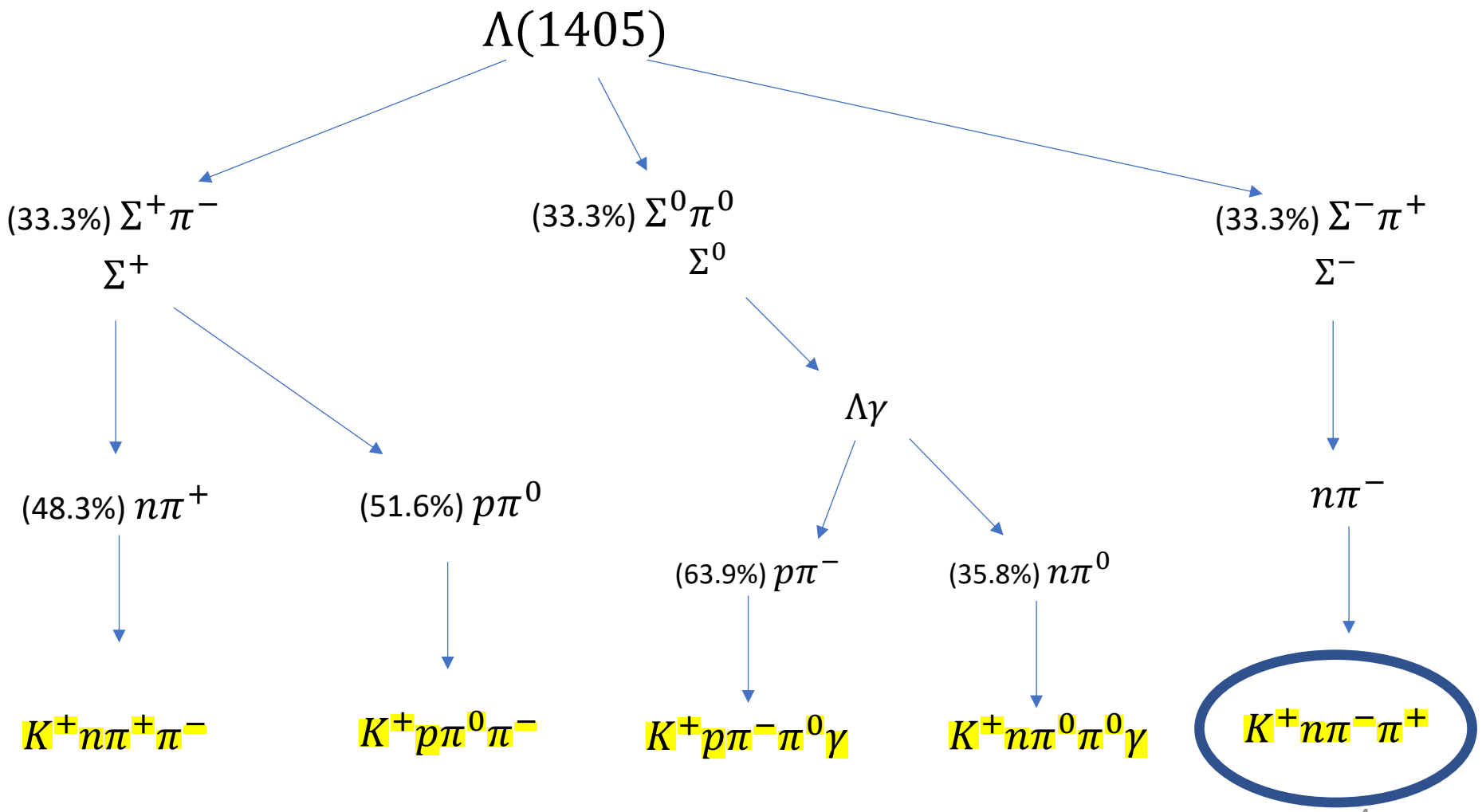
- Predicted in 1959 (Dalitz and Tuan)
- Experimentally discovered in 1961 (Alston et. al.)
  - Data from Lawrence Berkeley Lab liquid H bubble chamber
- Spin and Parity: $J^P = \frac{1}{2}^-$
- Isospin $I = 0$
- Strangeness $s = -1$
- Constituent quark model treats as uds state
  - Measured mass significantly lower than that predicted by quark model



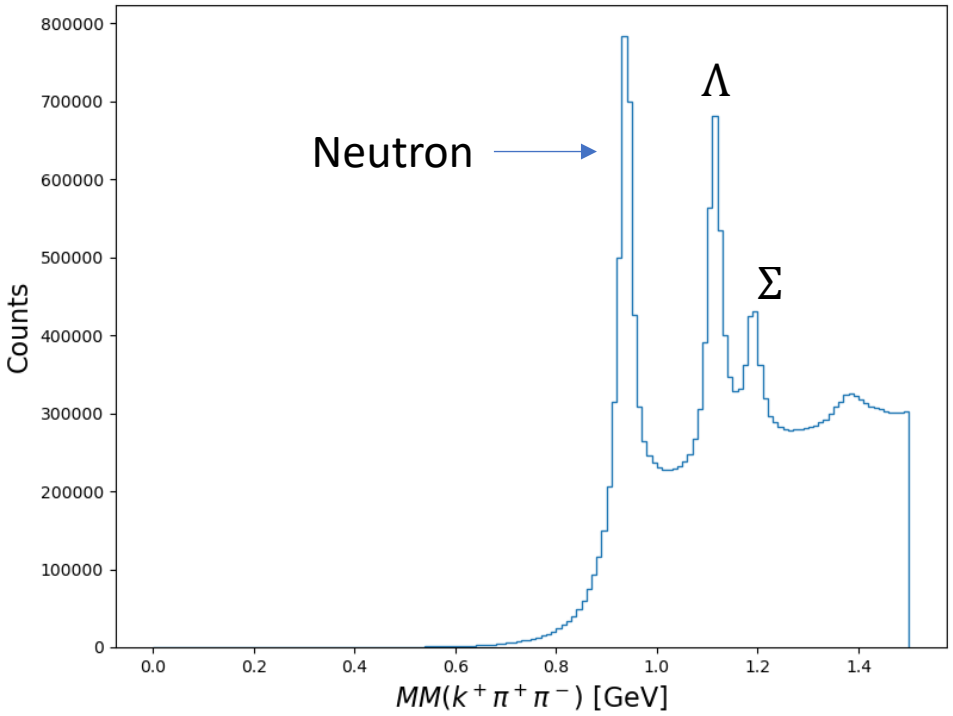
Motivation

- Structure of $\Lambda(1405)$ still not well understood
  - Atypical line shape
    - Deviates from usual Breit-Wigner Resonance
  - What is it?
    - Three-quark baryon (uds), baryon-meson molecule ($\overline{K}N$), multiple-pole resonance,…
  - Differential cross-sections can be useful in providing constraints for theoretical models
- Extend $\Lambda(1405)$ cross-sections to higher energy range
  - g11:
    - E_γ: $1.56 - 3.86$ GeV (W: $1.95 - 2.85$ GeV)
  - g12:
    - E_γ: $1.46 - 5.44$ GeV (W: $1.90 - 3.33$ GeV)

$\Lambda(1405)$ Photoproduction: $\gamma + p \rightarrow K^+ + \Lambda(1405)$

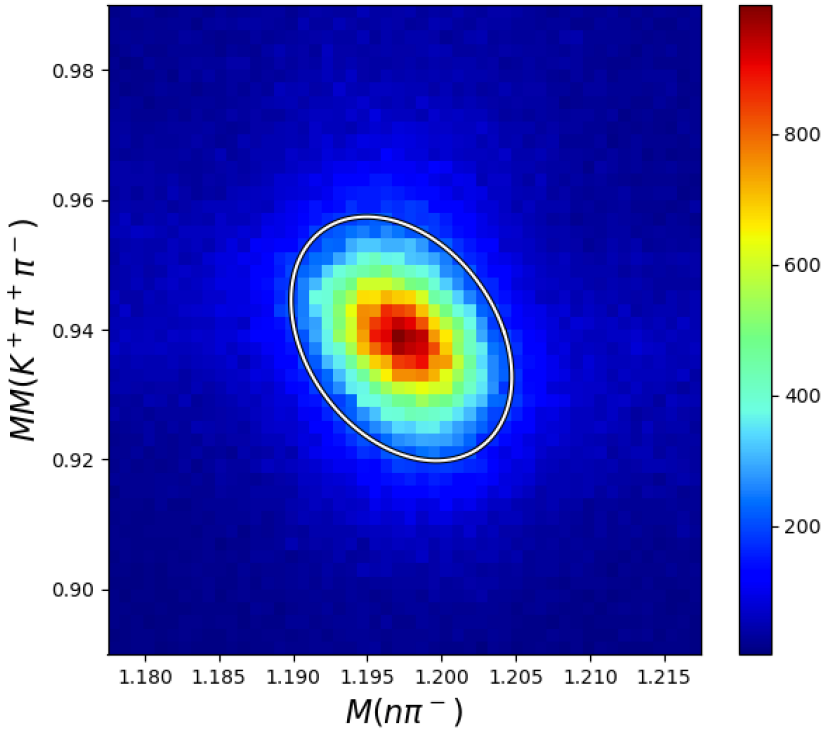


CLAS6 g12 Data: Particle Selection



- Requiring exactly one of: K^+, π^+, and π^-
- Let the neutron go undetected
- Already applied fiducial cuts, TOF knock-out cuts, and π^+ mis-ID cut

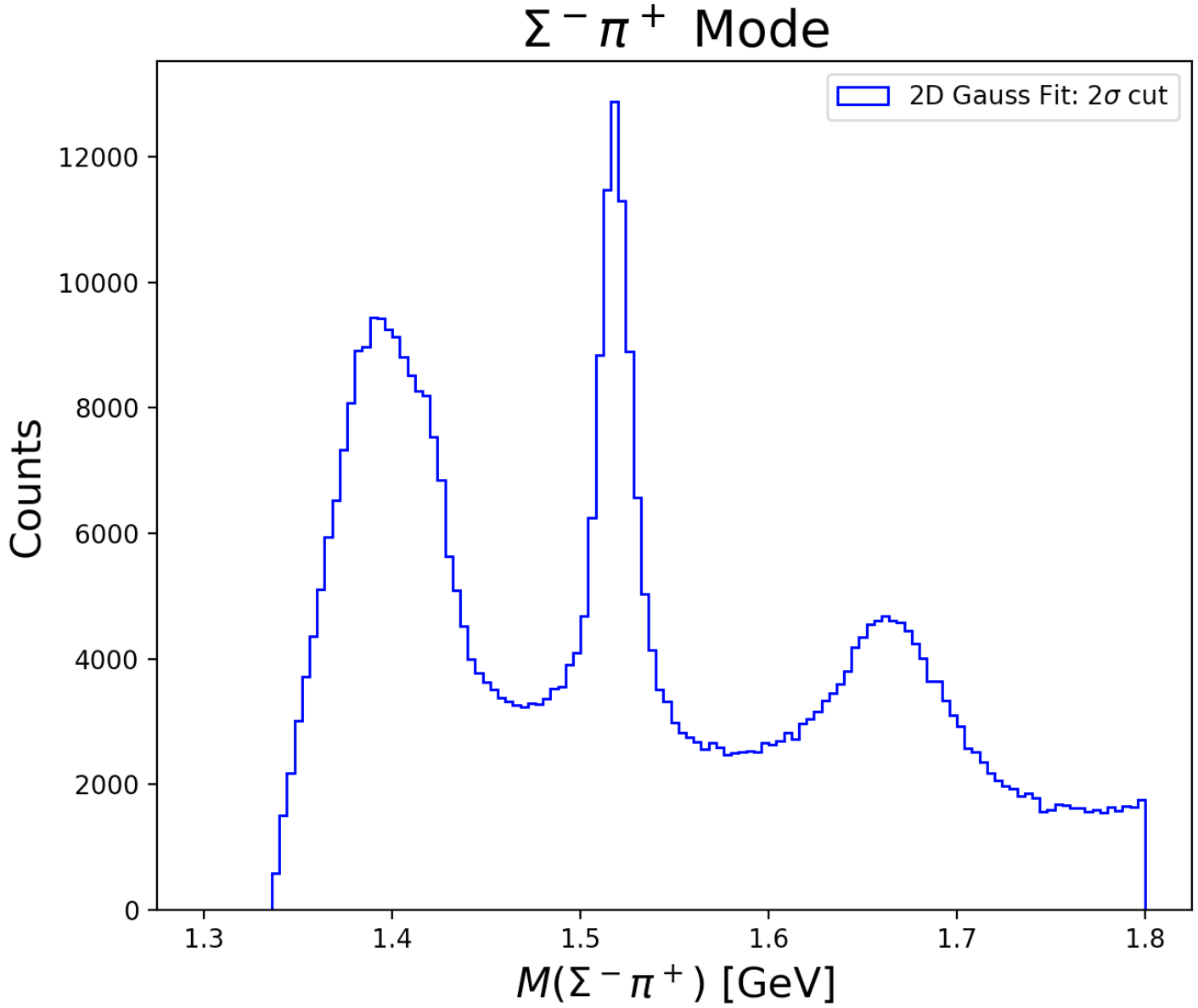
Define Neutron and Σ^- Cut



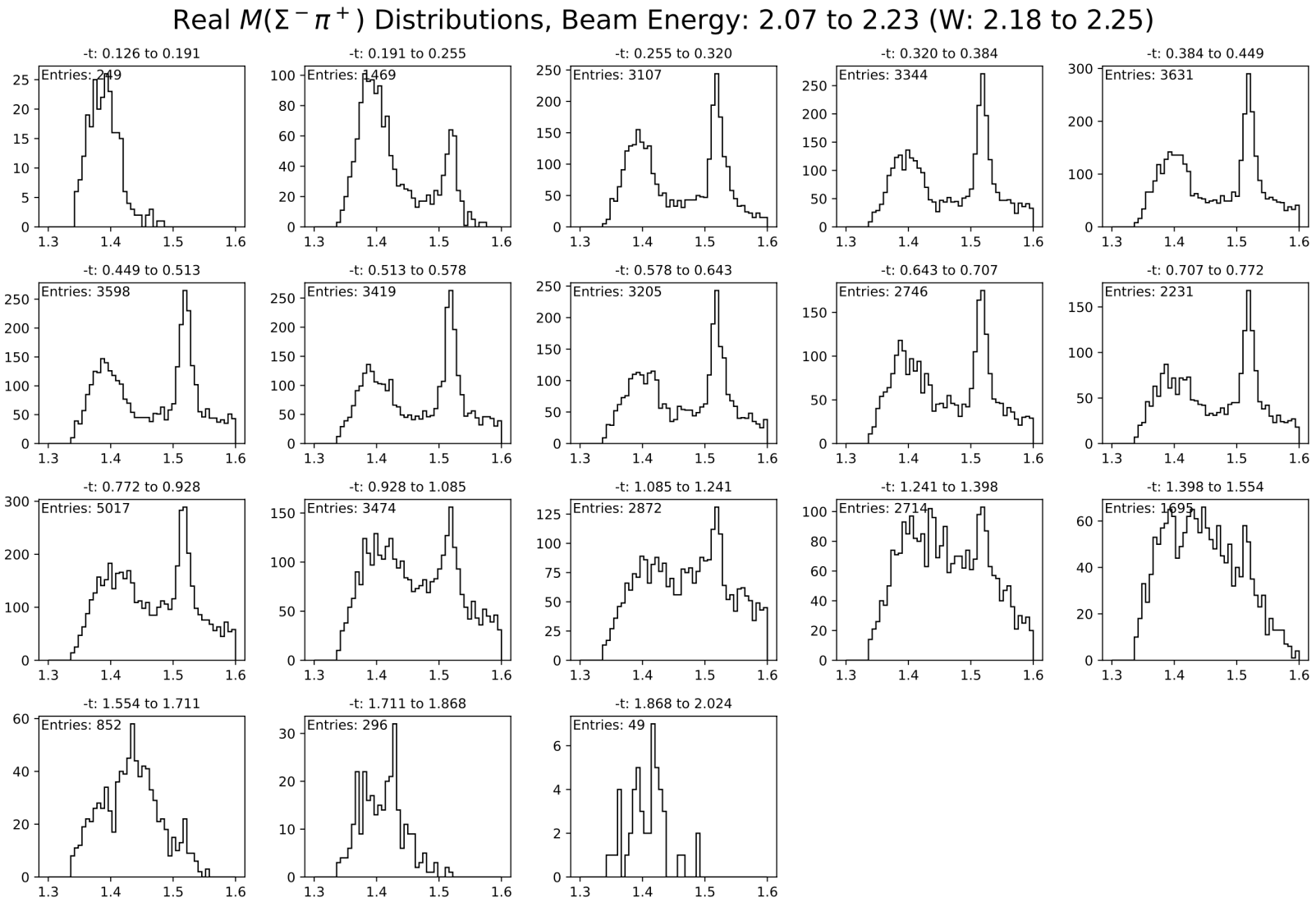
- Ellipse represents a 2σ cut using a 2-dimensional gaussian fit with a 2-dimensional quadratic background
- *neutron* 4-momentum constrained using nominal *neutron* mass

Invariant Mass of $(\Sigma^-\pi^+)$

- Σ^- 4-momentum constrained using nominal Σ^- mass



Binning by E_γ and t

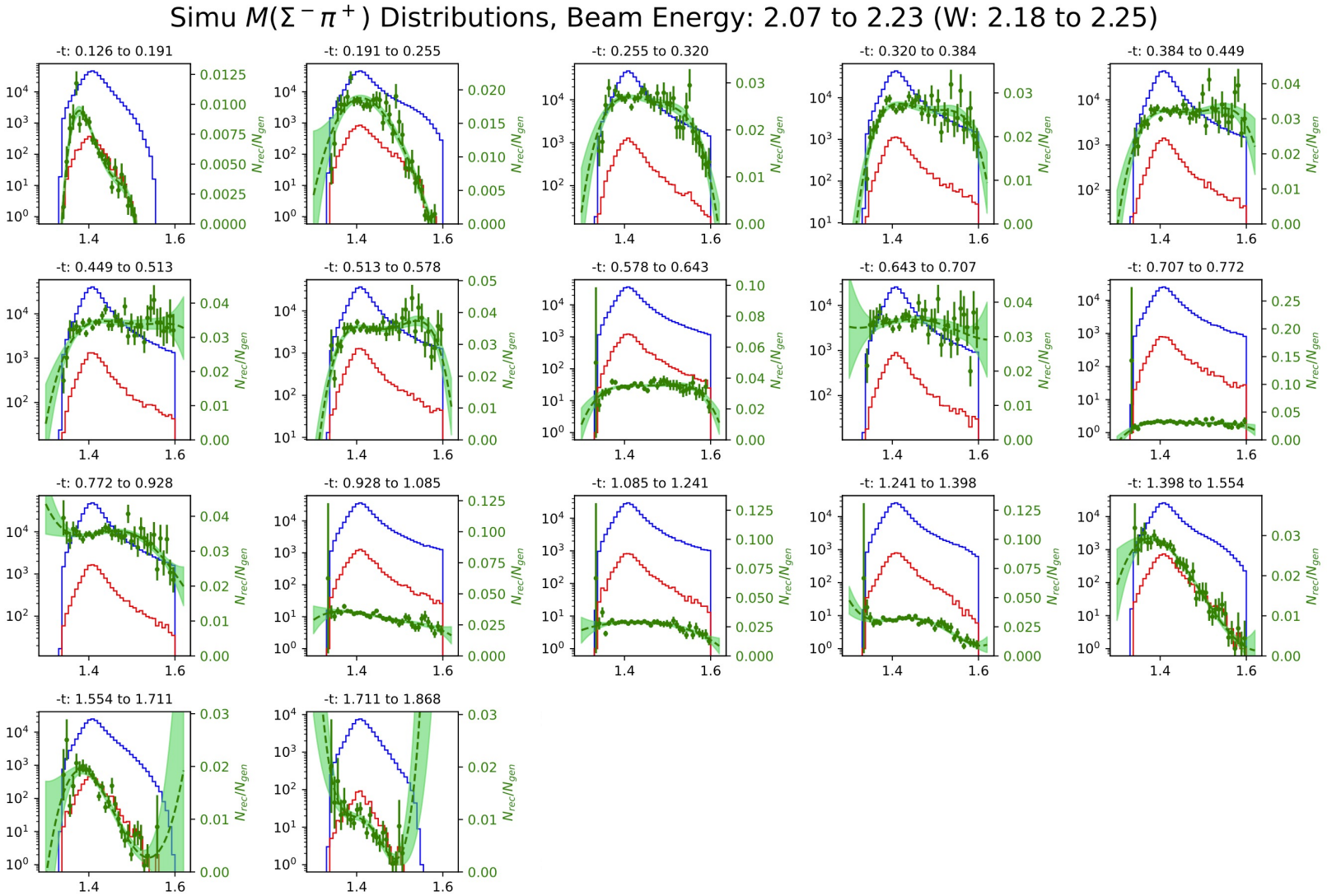


- 16 energy bins
  - E_γ: 1.46 – 5.44 [GeV]
  - W: 1.90 – 3.33 [GeV]
- 12 – 18 *t* bins (depending on energy)
- Plots to left are before acceptance corrections

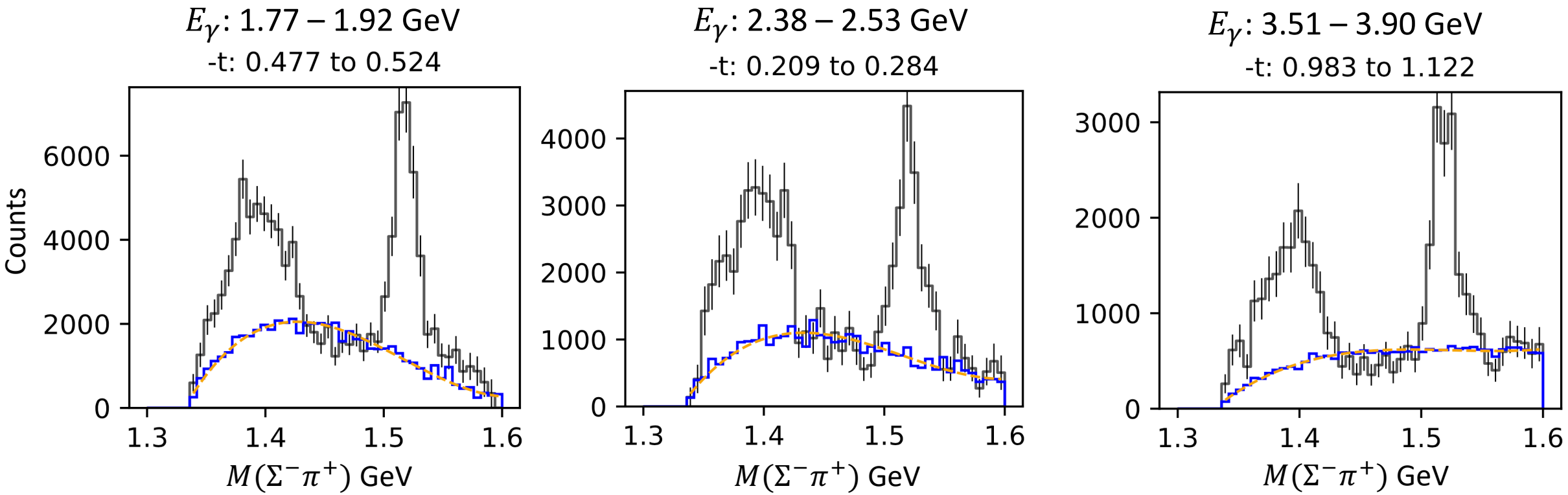
Acceptance

- Generated 80 million events
  - Generator weighted by beam energy and t

- Blue histogram: raw MC
- Red histogram: reconstructed MC
- Green points: acceptance
  - $a = \frac{N_{rec}}{N_{gen}}$
- Green dashed curve: 4th order polynomial fit to acceptance points
  - Shaded green area represents uncertainty of fit

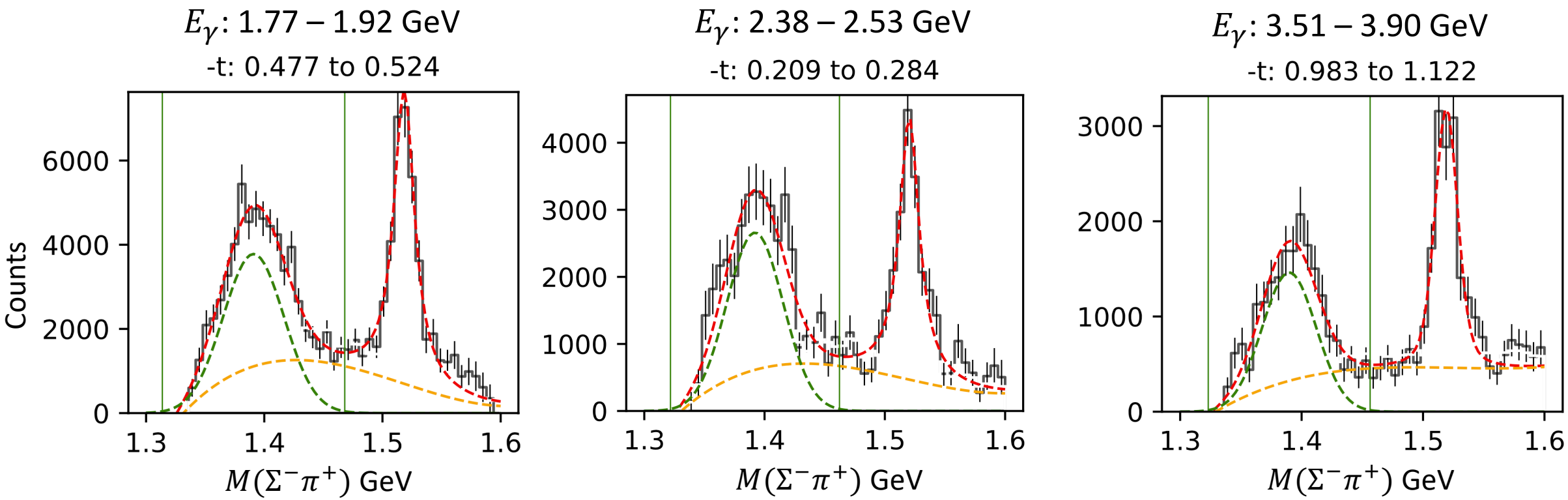


Correcting for Acceptance and Determining Background Shape



- Mixed-events (blue): combine K^+, π^+, and π^- from different events
- Mixed events fit with 3rd order polynomial (orange)
- Fix resultant polynomial parameters for each $E_\gamma - t$ bin and use as background in total fit

Extracting Acceptance Corrected Yield

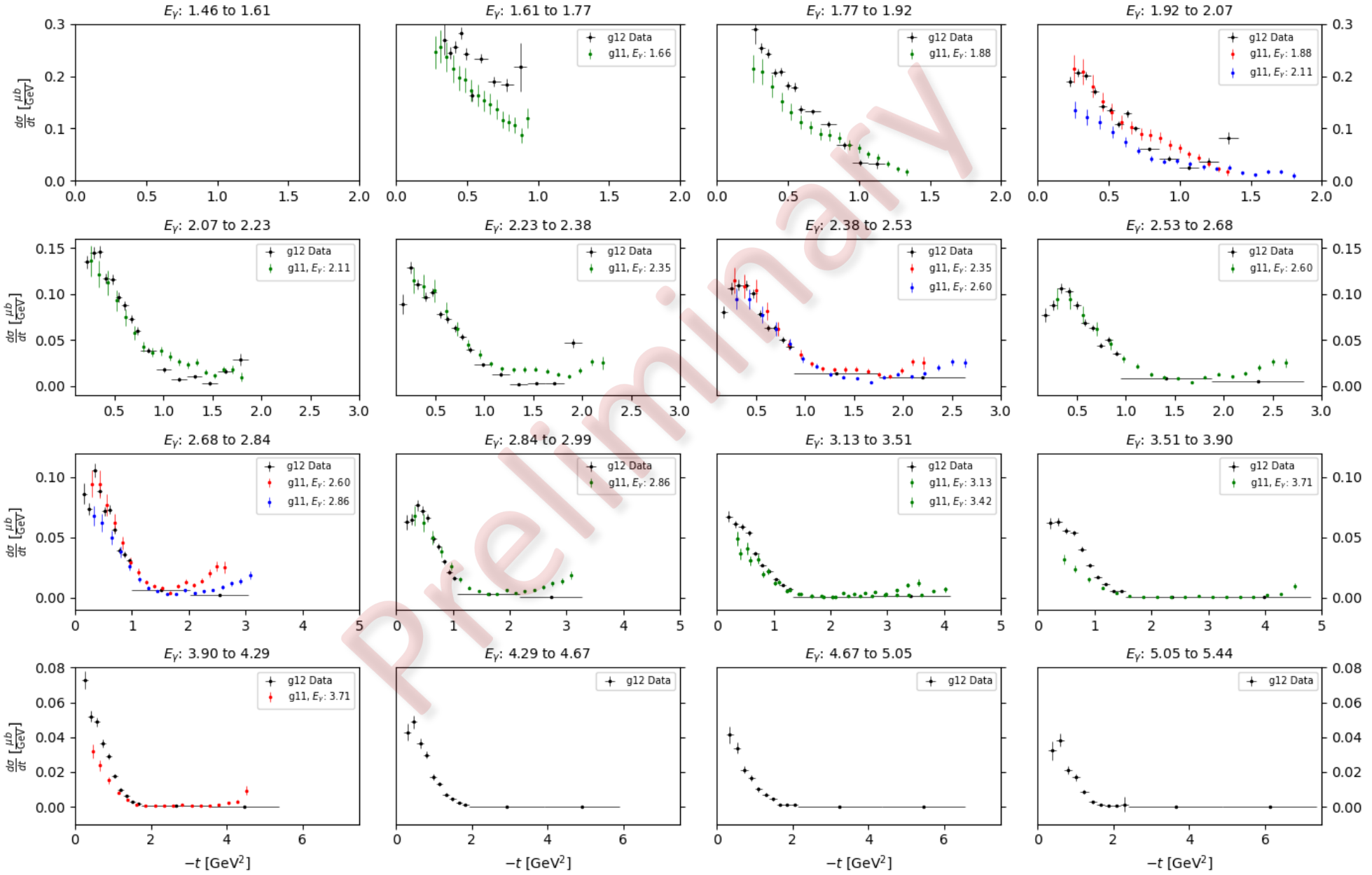


- Total fit function (red): (Gaussian on $\Lambda(1405)$) + (Voigt on $\Lambda(1520)$) + $C * bg$
  - bg is 3rd order polynomial with fixed parameters from fits to mixed events
  - C is a scaling factor ($C * bg$ shown in orange)
- Gaussian portion of total fit (green): Acceptance corrected yield
  - Green vertical lines drawn at $\mu \pm 3\sigma$

$\Lambda(1405)$ Photoproduction Differential Cross-Sections , $\frac{d\sigma}{dt}$, as function of $-t$

Comparing to Published g11 Results

- Results after accounting for 33% branching ratio of $\Lambda(1405) \rightarrow \Sigma^{-}\pi^{+}$
- **g12 data**: Black
- **g11 data**:
  - **Green**: g11 E_γ bin falls within current E_γ bin
  - **Red**: g11 E_γ bin just below current E_γ bin
  - **Blue**: g11 E_γ bin just above current E_γ bin
- Does not consider contribution to signal from $\Sigma(1385)$



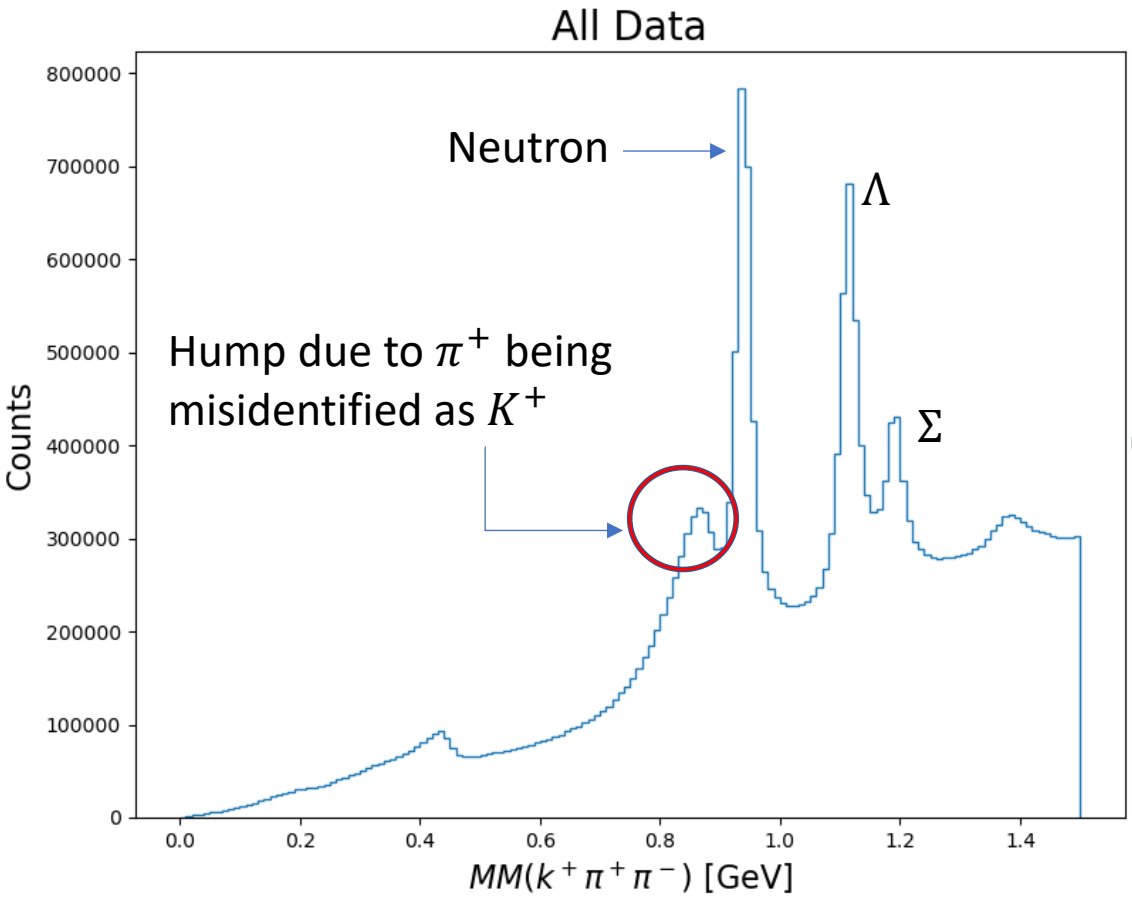
Conclusions

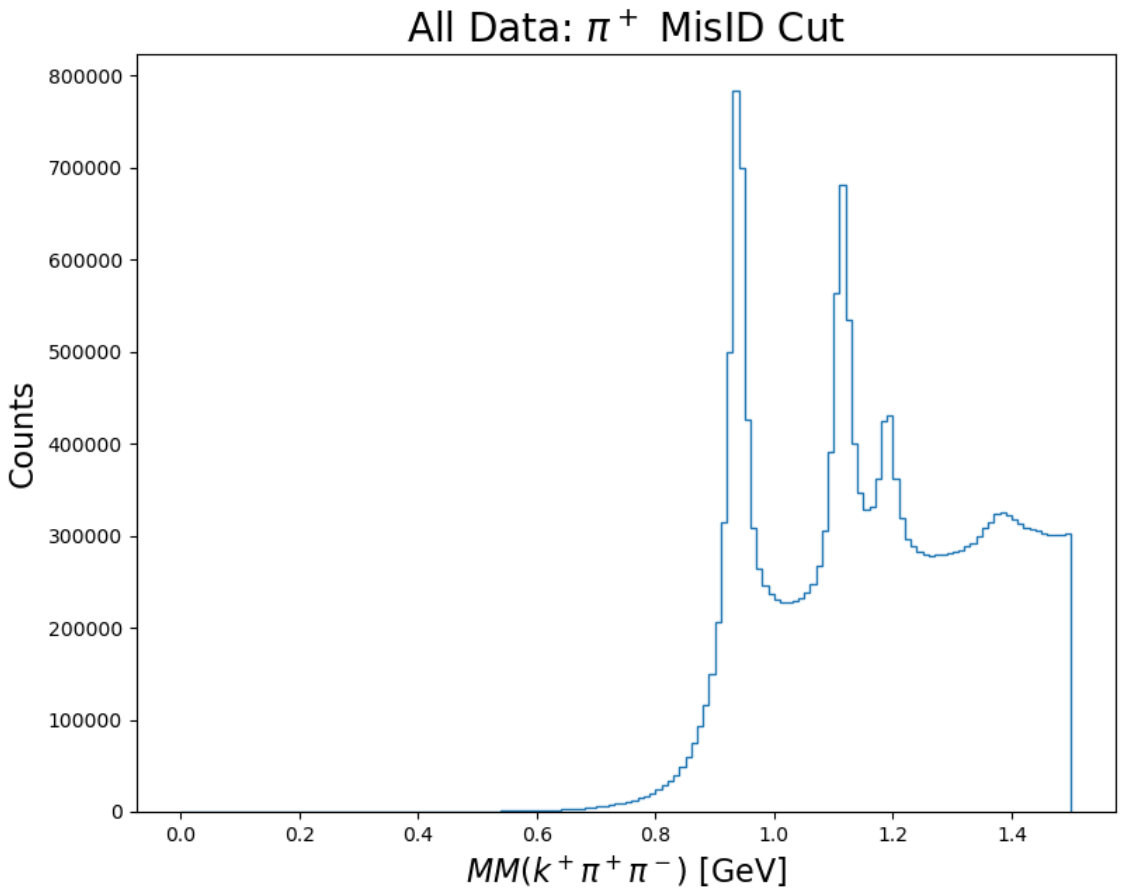
- Strong agreement between newly measured g12 differential cross-sections of $\Lambda(1405)$ photoproduction and published g11 results over beam energy range 2.07 to 2.99 GeV
- Deviations of g12 from g11 results are most extreme at lowest and highest several energy bins
- Additional corrections and work still need to be done
  - Account for contamination of $\Sigma(1385)$ in signal, calculate cross-sections from other decay mode(s), kinematic fitting,…
- Preliminary results are promising for extending $\gamma + p \rightarrow K^+ + \Lambda(1405)$ cross-sections to higher energy range

Thank You!

Backup Slides

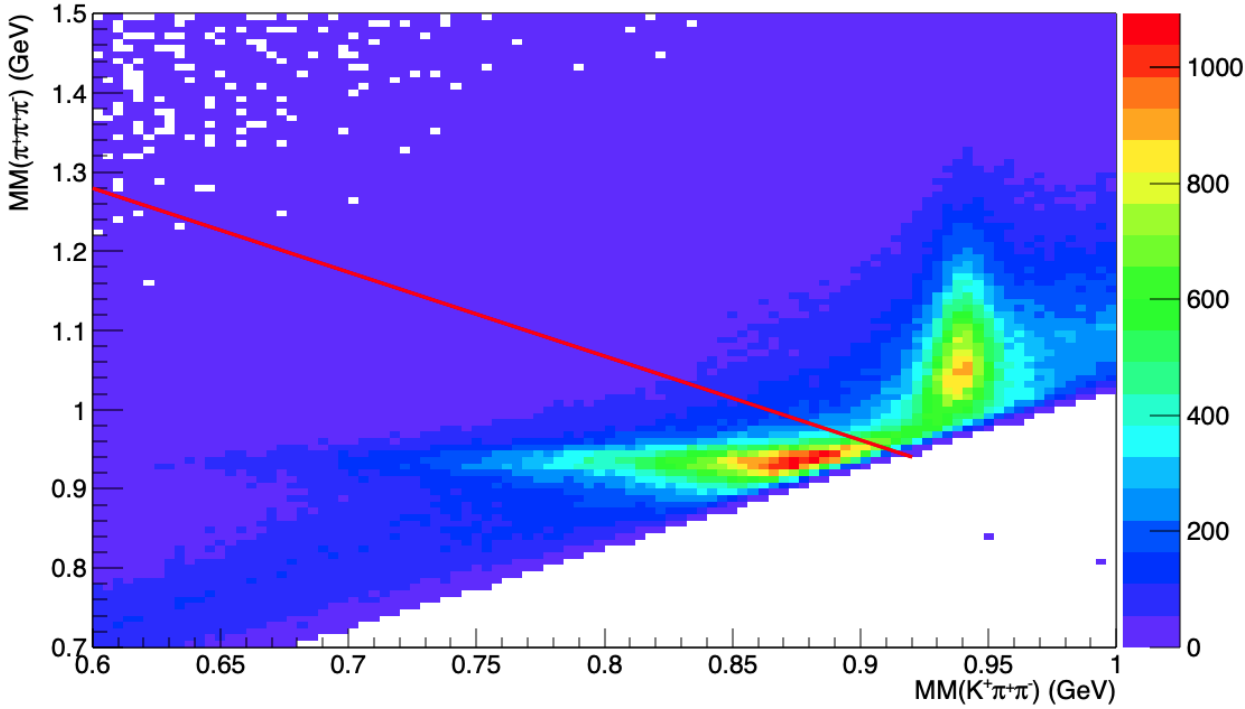
Applying Cut to Remove Events with Misidentified π^+



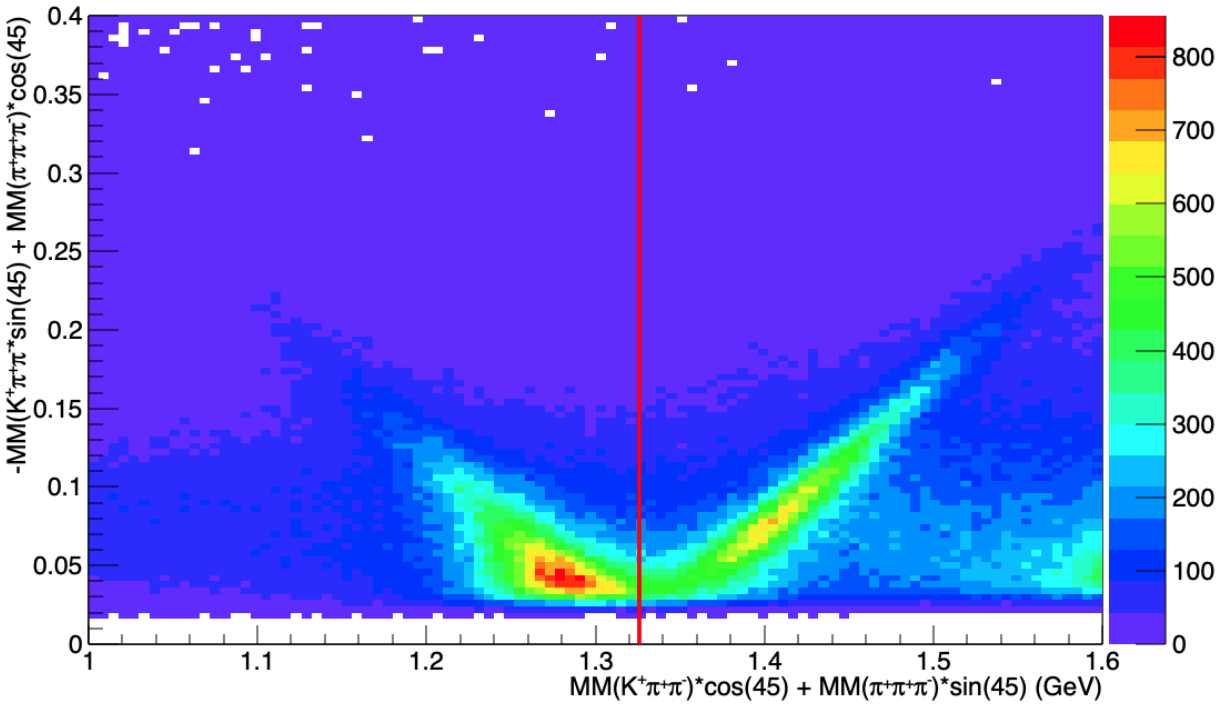


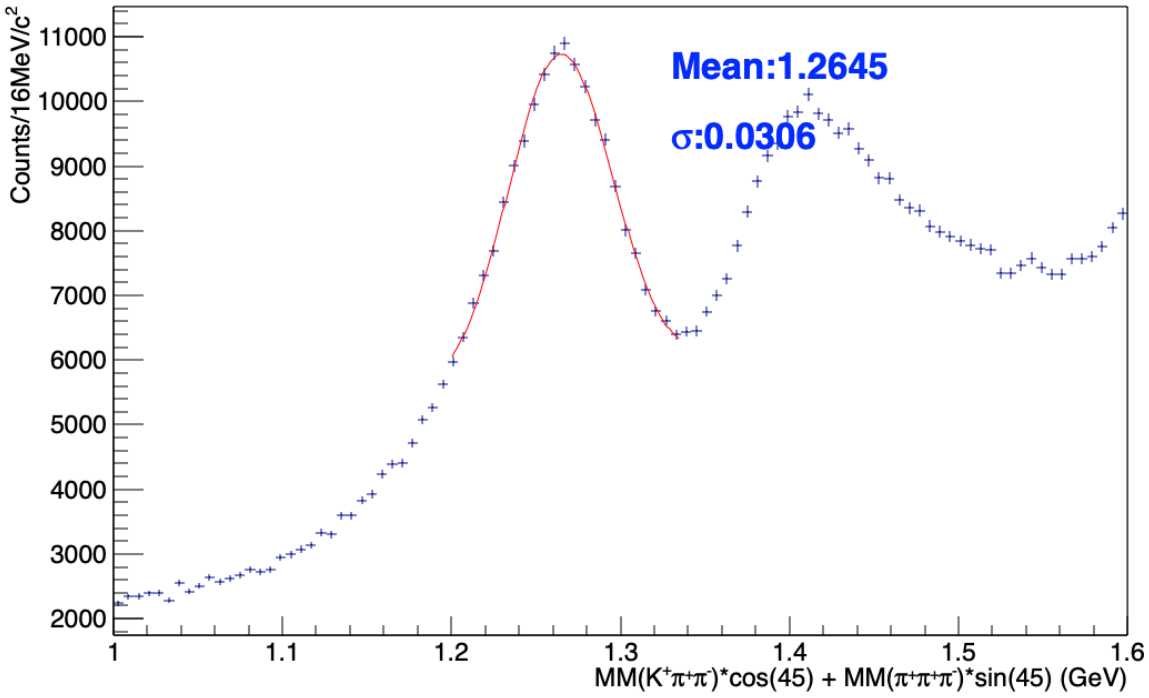
Identifying Events from Hump-Region

- Hump on MM($K^+\pi^+\,\pi^-$) plot due to misidentification of π^+ as K^+
- Redefine K^+ 4-momentum using π^+ nominal mass
- Cut on MM($\pi^+\pi^+\,\pi^-$) and MM($K^+\pi^+\,\pi^-$) shown at right (red line)
- Remove all events to left of red line



MM($\pi^+\pi^+\pi^-$) vs. MM($K^+\pi^+\pi^-$) Rotated by 45°





g11 Cross-Sections

- $\sim 6\%$ branching ratio of $\Sigma(1385) \rightarrow \Sigma^{-}\pi^{+}$

E_γ (GeV)	$\Sigma^0(1385)$		$\Lambda(1405)$	
	σ_{tot}	$\pm$	σ_{tot}	$\pm$
1.662	0.921	0.414	0.489	0.244
1.881	0.818	0.083	0.615	0.008
2.110	0.532	0.043	0.371	0.005
2.350	0.457	0.026	0.309	0.011
2.600	0.339	0.039	0.285	0.008
2.862	0.268	0.027	0.216	0.008
3.133	0.189	0.085	0.176	0.014
3.416	0.151	0.124	0.144	0.014
3.709	0.151	0.041	0.138	0.010

K. Moriya et al., Phys. Rev. C 88, 045201 (2013)