J/ψ Polarisation Observables with RG-A and RG-C data

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VIA VERITAS VITA

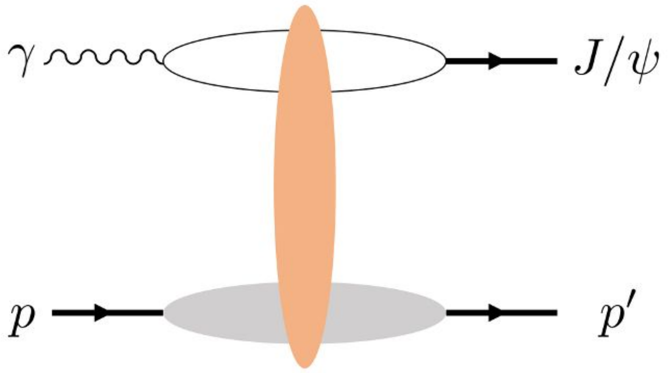
clas

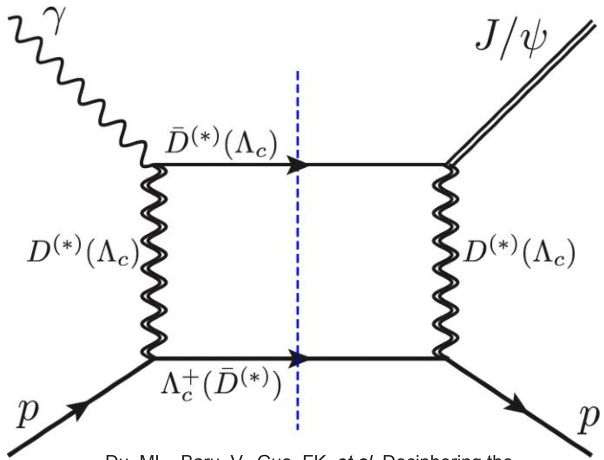
CEBAF Large Acceptance Spectrometer

Motivation

The J/ψ near-threshold production mechanism is still a point of contention:

- A **two-gluon exchange** would give access to the **gluonic mechanical properties** of the target
- The 2015 and 2019 LHCb **Pentaquarks** have not been observed in photoproduction experiments
- Suggested **intermediate open-charm states**, pomeron exchange, meson exchange…



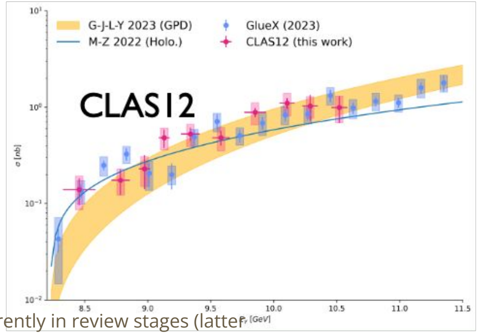


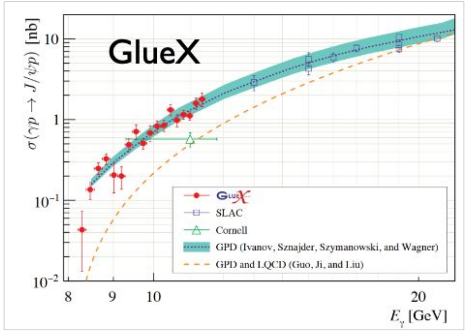
Du, ML., Baru, V., Guo, FK. *et al.* Deciphering the mechanism of near-threshold photoproduction. *Eur. Phys. J. C* 80, 1053 (2020). https://doi.org/10.1140/epjc/s10052-020-08620-5

Previous Measurements

J/ψ photo-production on free proton @Hall C @GlueX @CLAS12

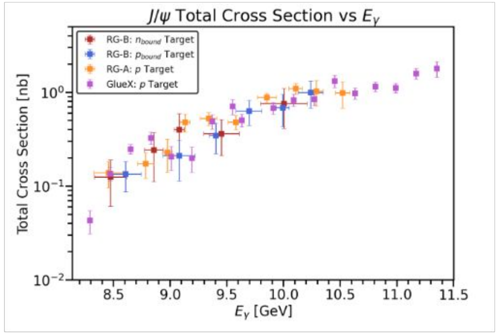
S. Adhikari et al., Phys. Rev. C 108, 025201 (2023), arXiv:2304.03845 [nucl-ex].



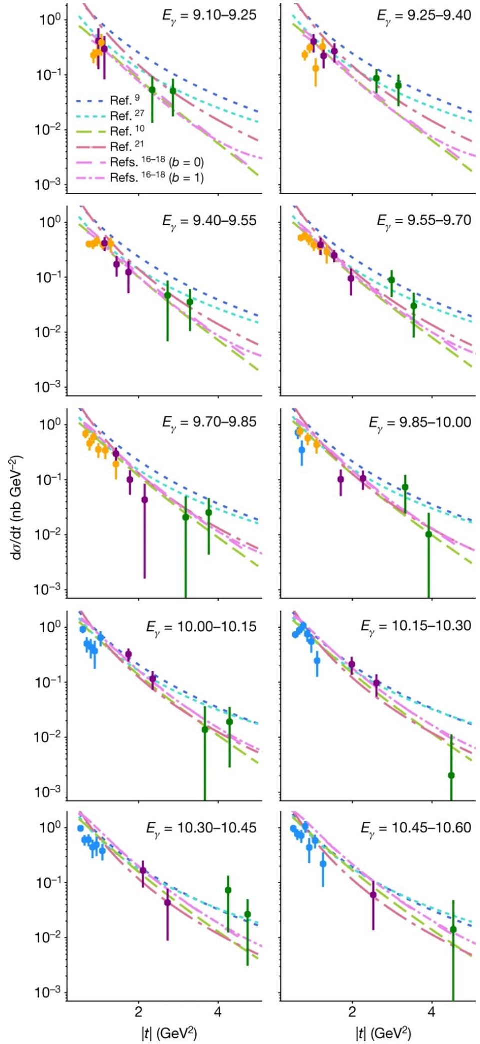


Currently in review stages (latter stages)

J/ψ photo-production on bound proton/neutron in LD2 @CLAS12



Currently in review stages (2nd round)



Hall C

Duran, B., et al. "Determining the gluonic gravitational form factors of the proton." *Nature* 615.7954 (2023): 813-816.

Polarisation Observables

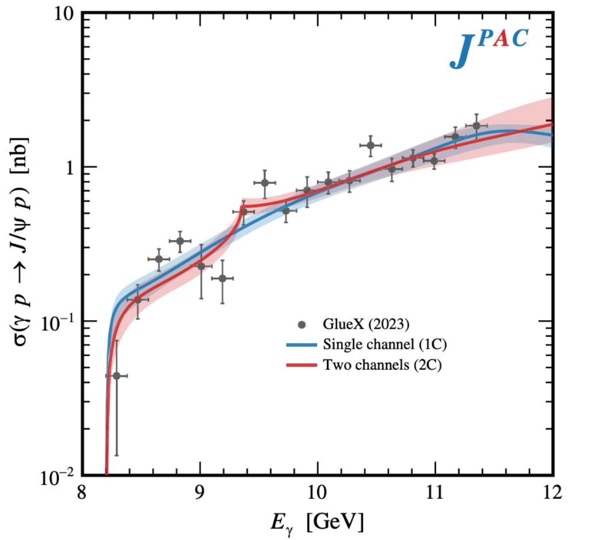
Existing cross section measurements do not have the statistical precision to distinguish production mechanisms.

Polarisation observables would help **disentangle production mechanisms**:

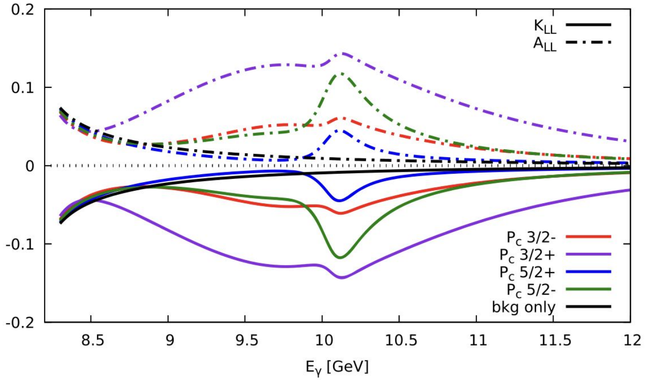
- BSA and unpolarised SDMEs in RG-A
- TSA, DSA in RG-C

JPAC Collaborators are currently **producing model predictions for polarisation asymmetries**, for various production mechanisms

- Expect 2-Gluon exchange to be flat



Winney, Daniel, et al. "Dynamics in near-threshold J/ψ photoproduction." *Physical Review D* 108.5 (2023): 054018.



Winney, Daniel, et al. "Double polarization observables in pentaquark photoproduction." *Physical Review D* 100.3 (2019): 034019.

Datasets

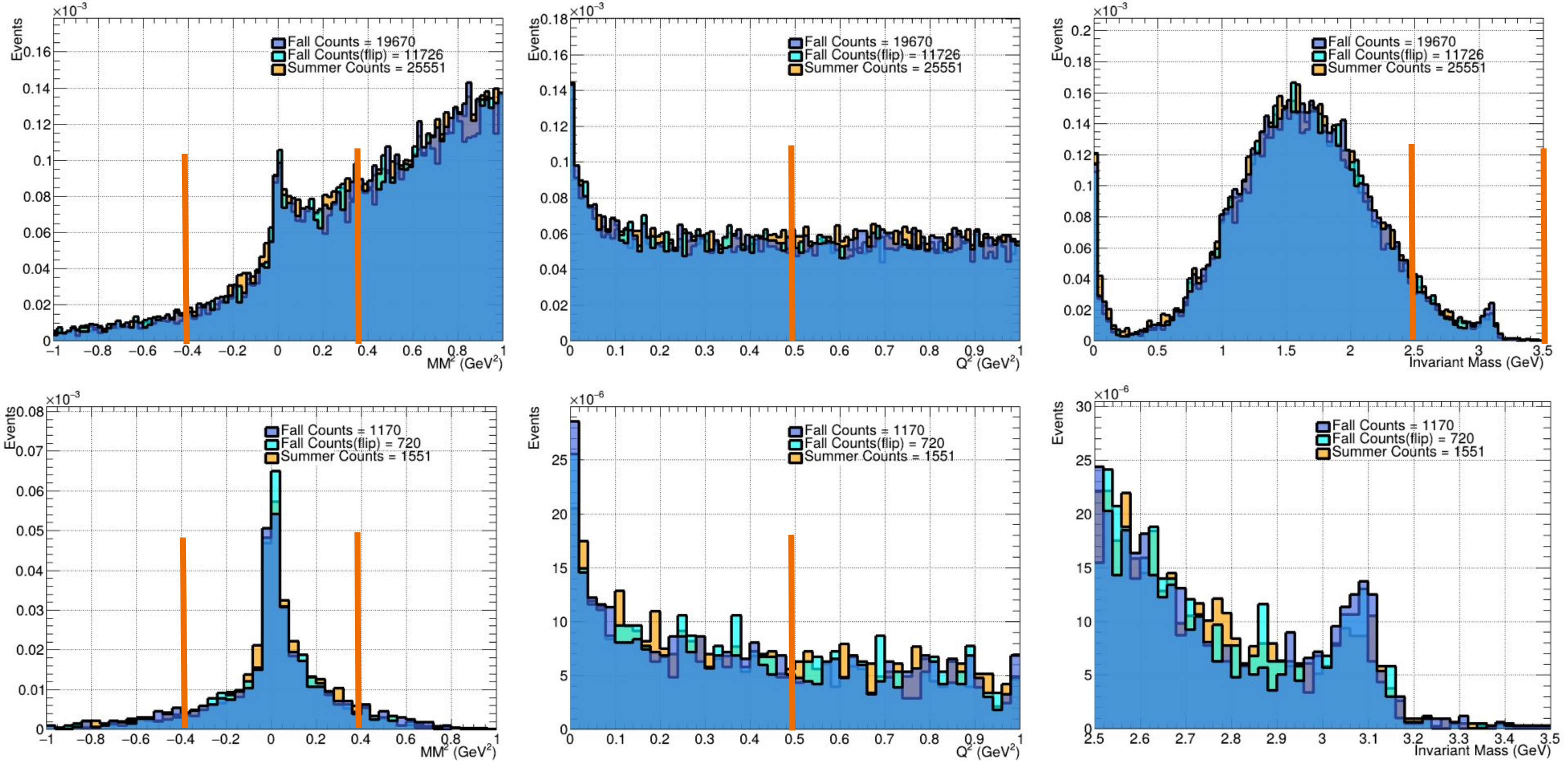
RG-A

- **Liquid hydrogen target**
- Three run periods - Spring 2018, Fall 2018 and Spring 2019
  - 536 runs in Spring18 (388 inbending)
  - 353 runs in Fall18 (169 inbending)
  - 121 runs in Spring19 (all inbending)
- Total accumulated charge for all three run periods approx **285mC**

RG-C

- **Longitudinally polarised target**
- Three run periods - Summer 2022, Fall 2022, Winter/Spring 2023
- Total of 334 good NH3 runs
- Runs taken on Carbon, CH2, Empty and Foils, across all three periods for dilution factor studies.
- Total accumulated charge on NH3 approx **13mC**

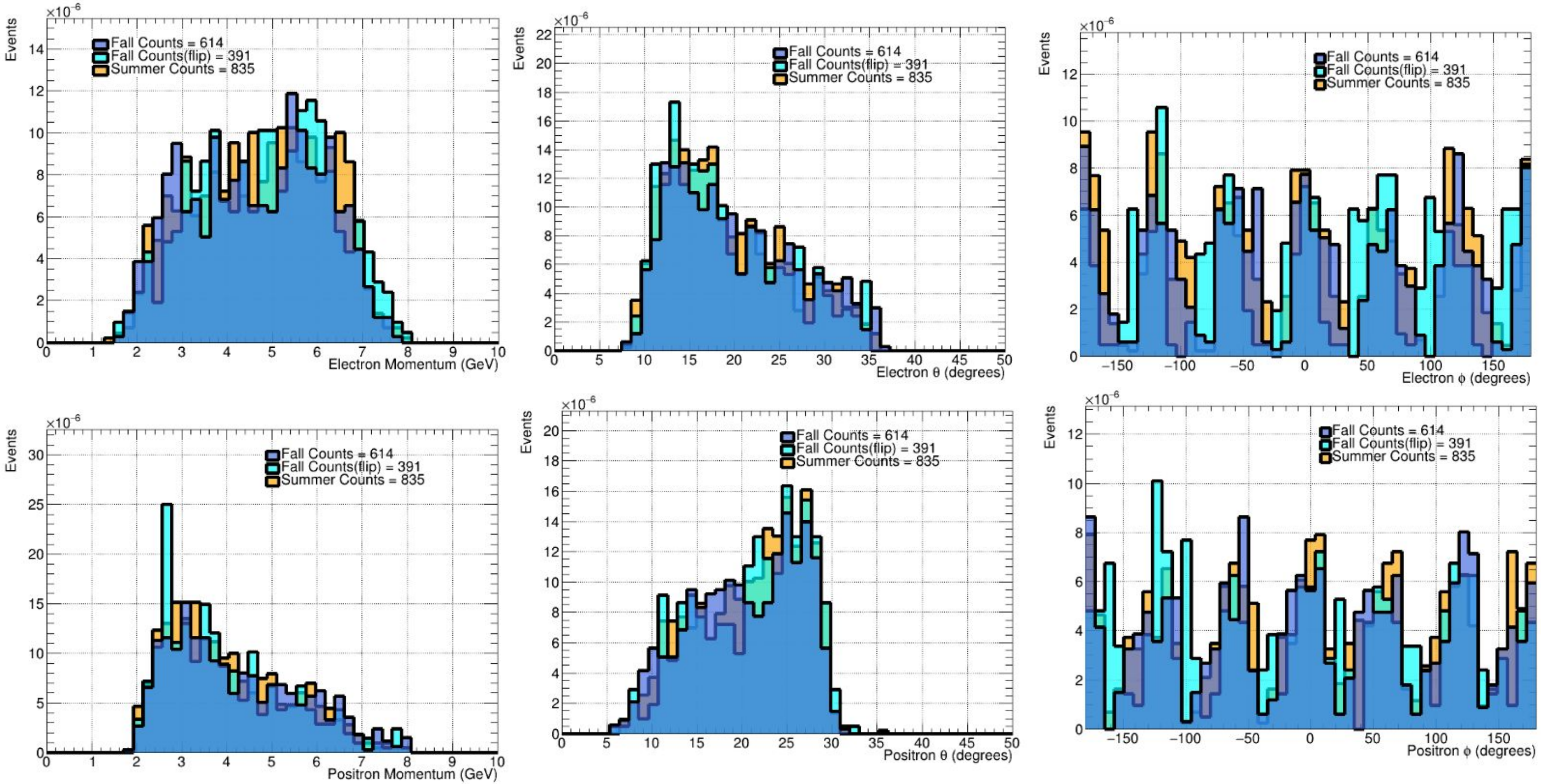
Exclusivity cuts



Pre cuts on M_{e+e-} invariant mass

Post cuts on M_{e+e-} invariant mass;

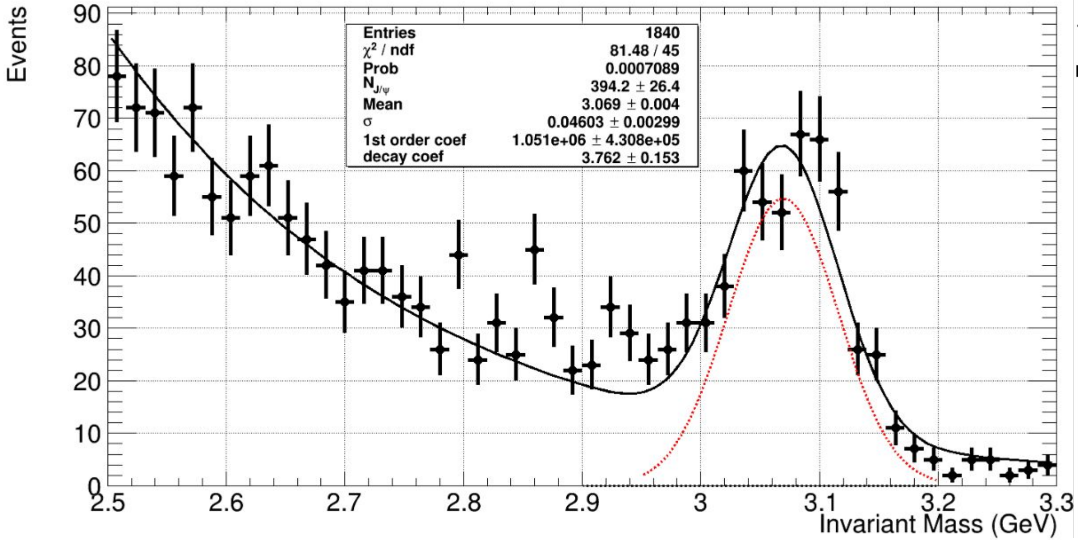
2.5 GeV< M_{e+e-}
M_{e+e-} < 3.5 GeV



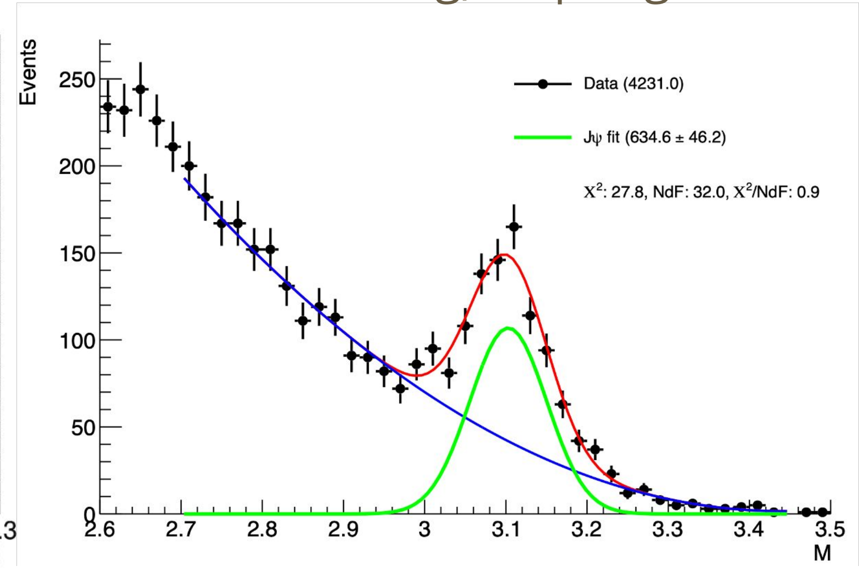
- **$|MM^2| < 0.4\ GeV^2$ and $Q^2 < 0.5\ GeV^2$**
- **e+,e-, p' all in FD**
- Fiducial cuts & PID refinements from RG-A analysis (adapted to RG-C)

Final state invariant mass

RGC Summer + Fall



RGA Fall18 (inbending & outbending) + Spring19

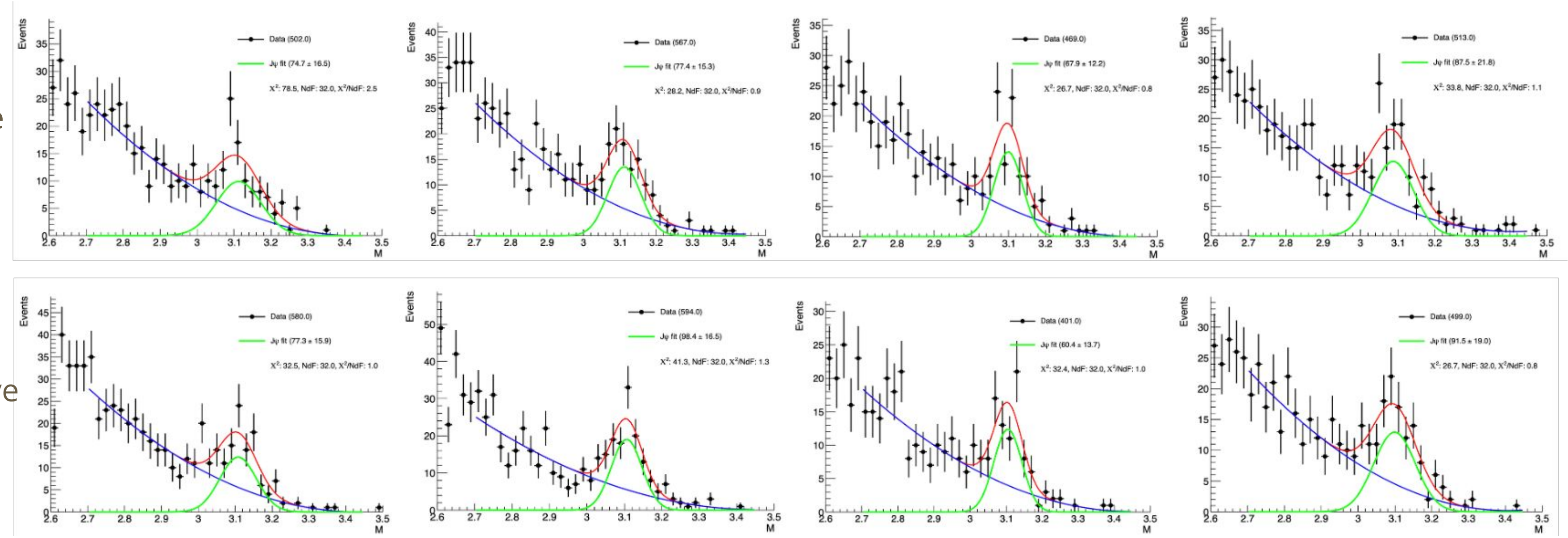


RGA

	-180° to -90°	-90° to 0°	0° to 90°	90° to 180°

Positive helicity

Negative helicity



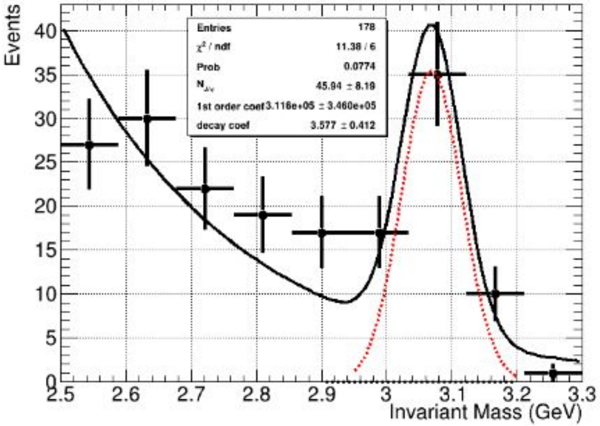
Asymmetry Equations - Polarised target

BSA; $$A_{LU} = \frac{P_t^-(N^{++} - N^{-+}) + P_t^+(N^{+-} - N^{--})}{Pb \times (P_t^-(N^{++} + N^{-+}) + P_t^+(N^{+-} + N^{--}))}$$

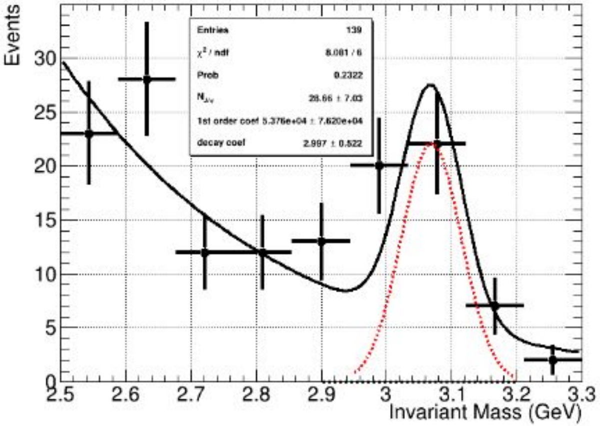
TSA; $$A_{UL} = \frac{N^{++} + N^{-+} - N^{+-} - N^{--}}{Df \times (P_t^-(N^{++} + N^{-+}) + P_t^+(N^{+-} + N^{--}))}$$

DSA; $$A_{LL} = \frac{N^{++} + N^{--} - N^{+-} - N^{-+}}{P_B \cdot D_f(P_T^-(N^{++} + N^{-+}) + P_T^+(N^{+-} + N^{--}))}$$

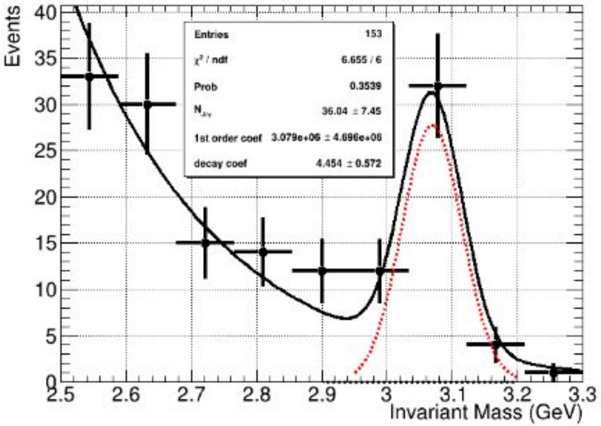
RGC



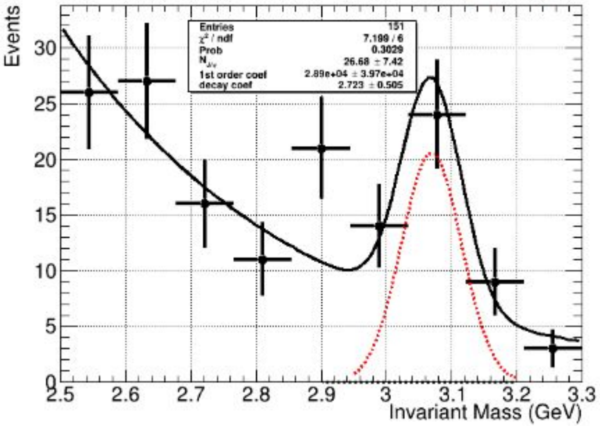
(a) Bin 1 ϕ -180° to -50° $P_b^+ P_T^+$



(b) Bin 1 ϕ -180° to -50° $P_b^+ P_T^-$

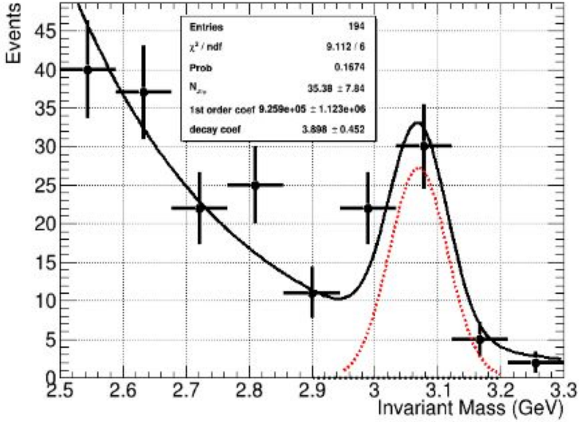


(c) Bin 1 ϕ -180° to -50° $P_b^- P_T^+$

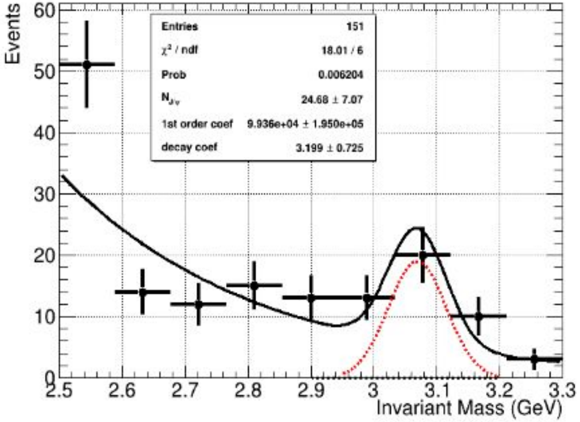


(d) Bin 1 ϕ -180° to -50° $P_b^- P_T^-$

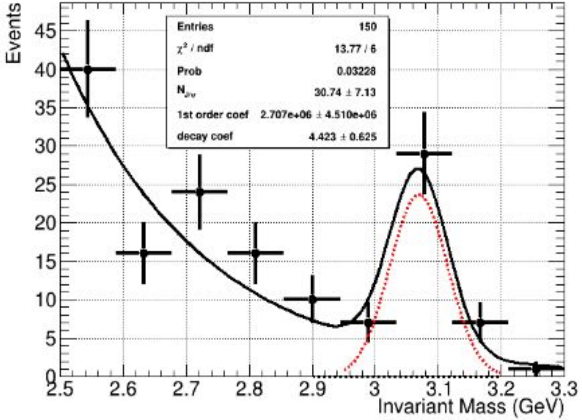
RGC



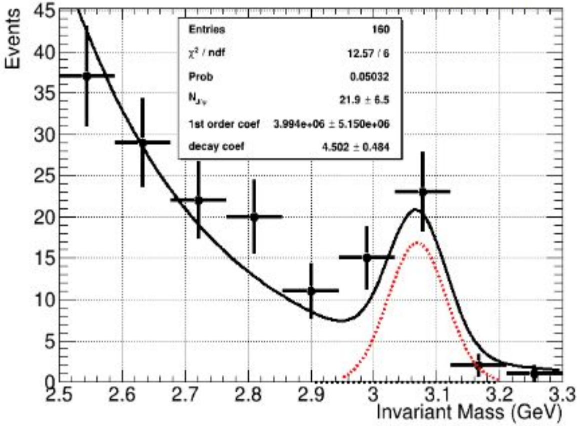
(a) Bin 1 ϕ -50° to 50° $P_b^+ P_T^+$



(b) Bin 1 ϕ -50° to 50° $P_b^+ P_T^-$

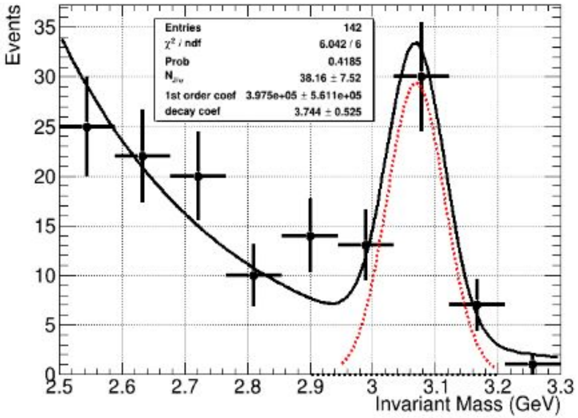


(c) Bin 1 ϕ -50° to 50° $P_b^- P_T^+$

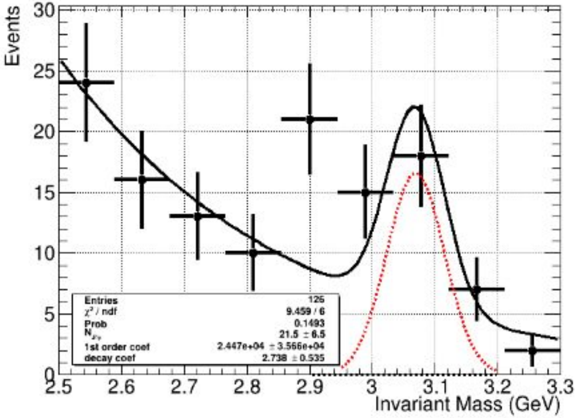


(d) Bin 1 ϕ -50° to 50° $P_b^- P_T^-$

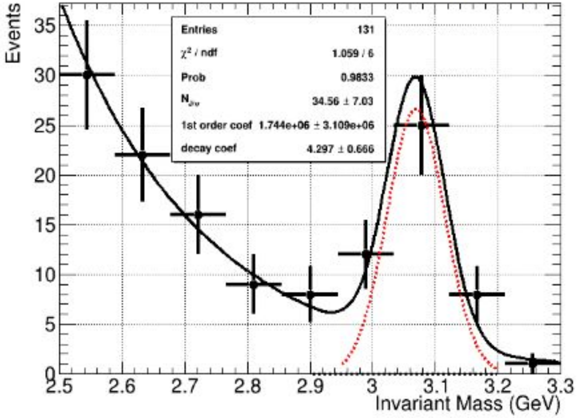
RGC



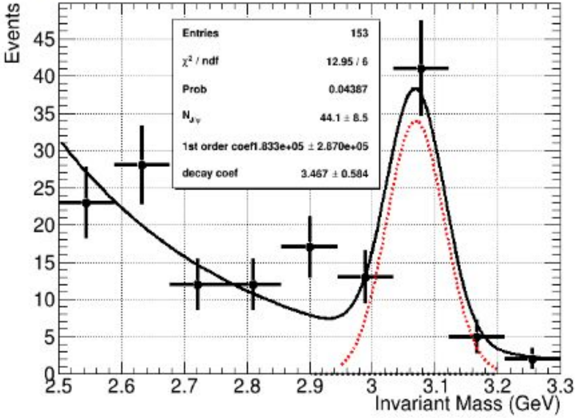
(a) Bin 1 ϕ 50° to 180° $P_b^+ P_T^+$



(b) Bin 1 ϕ 50° to 180° $P_b^+ P_T^-$



(c) Bin 1 ϕ 50° to 180° $P_b^- P_T^+$



(d) Bin 1 ϕ 50° to 180° $P_b^- P_T^-$

Summary

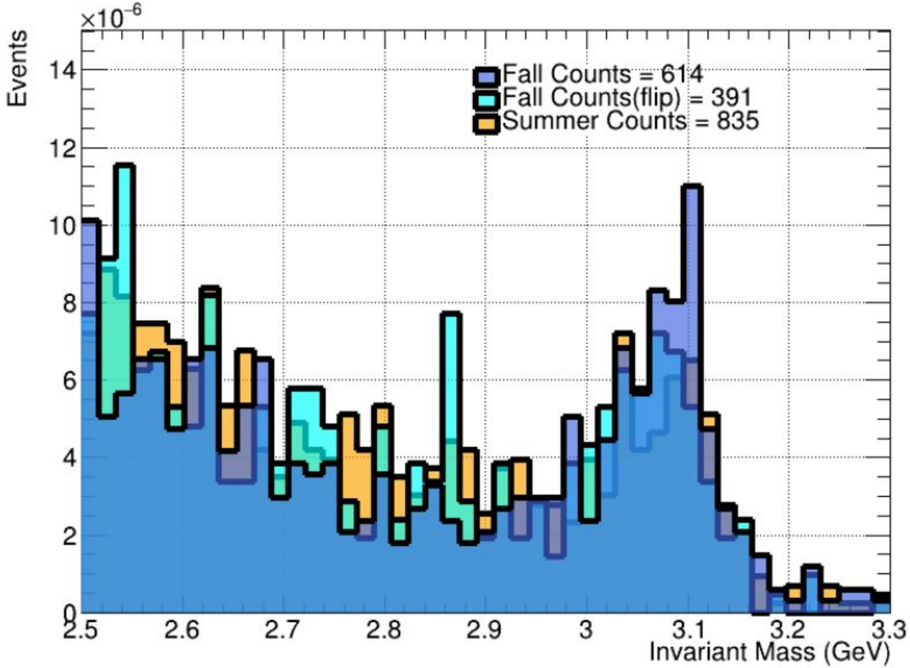
- **Polarisation observables** would help **disentangle production mechanisms**
- Ability to extract BSA and unpolarised SDMEs using RG-A data
- Potential for extraction of both a TSA and DSA in RG-C
- Clear peak at J/ψ invariant mass present for both datasets
- Potential for asymmetry in multiple bins looks promising
- **CAA document in progress**
  - **We will send round the document in time and welcome everyone to sign it!**

Thank you for your attention!
Questions?

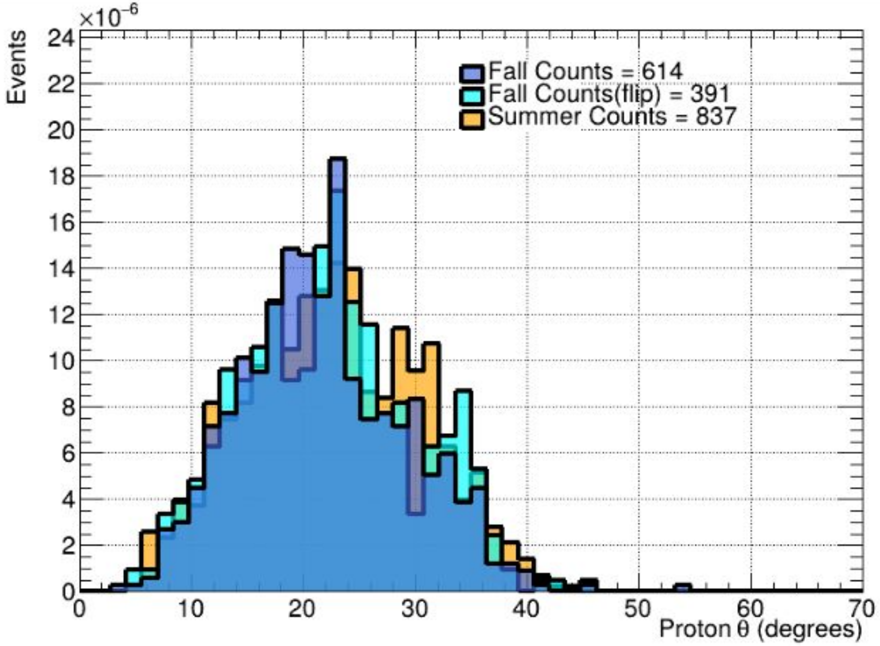
BACKUP

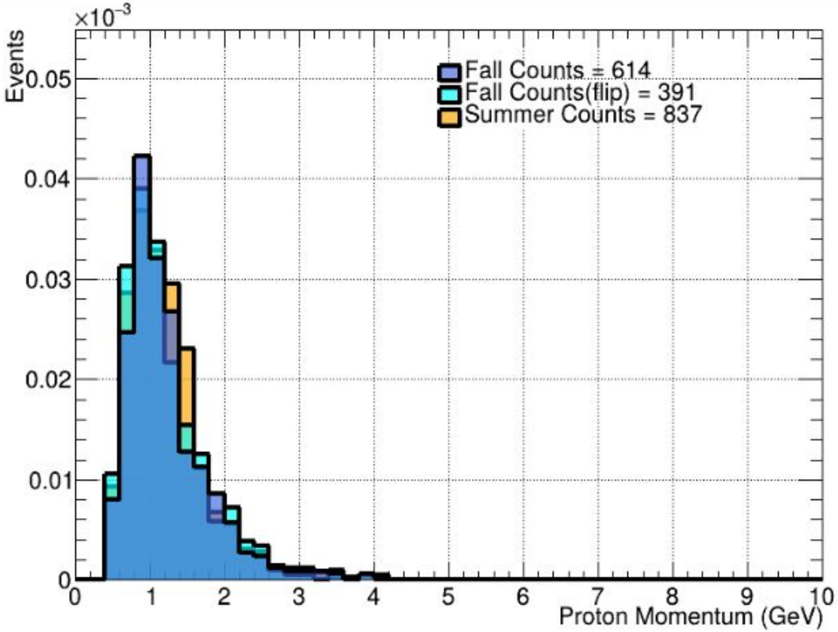
Invariant mass across RGC summer and Fall

- Summer, Fall pre solenoid flip, Fall post solenoid flip

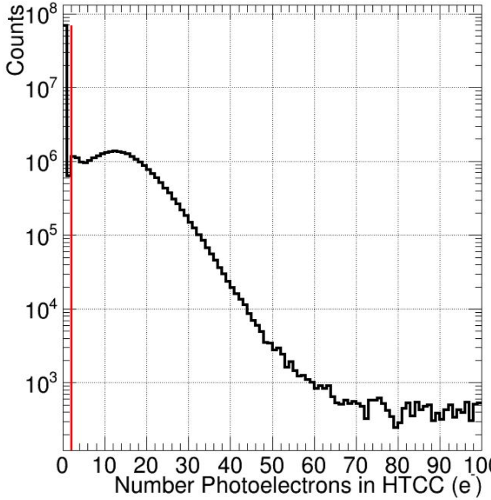


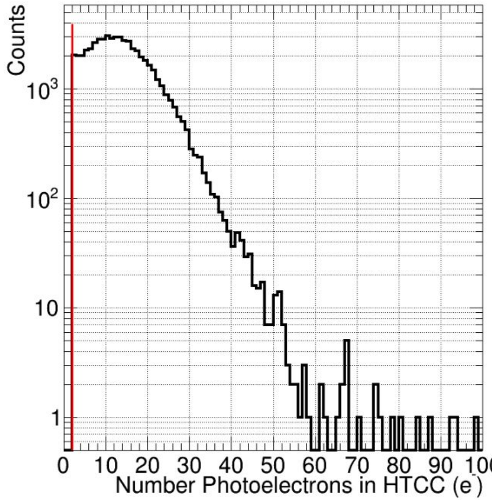
Proton kinematics

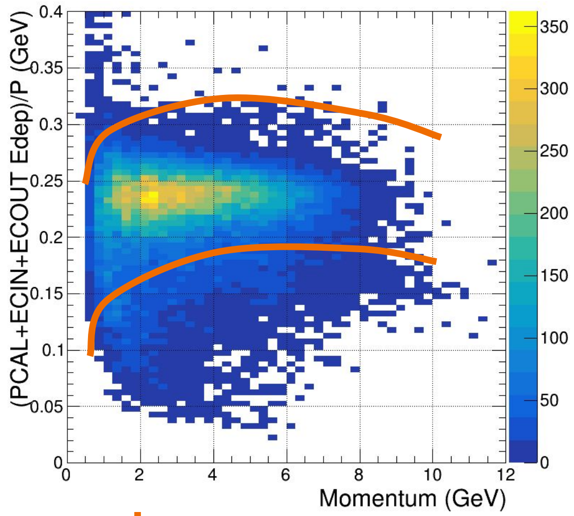


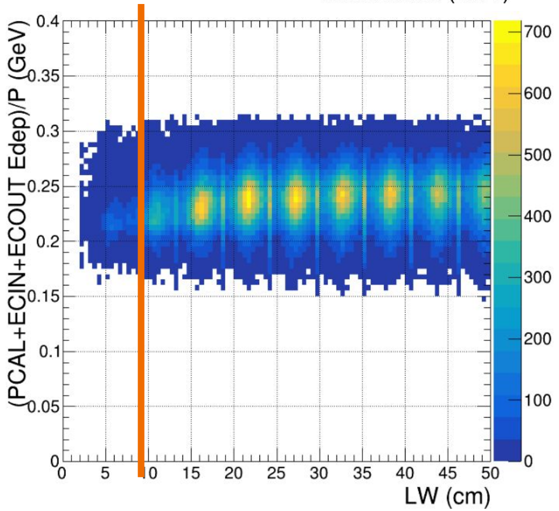


Example of fiducual cuts RGC

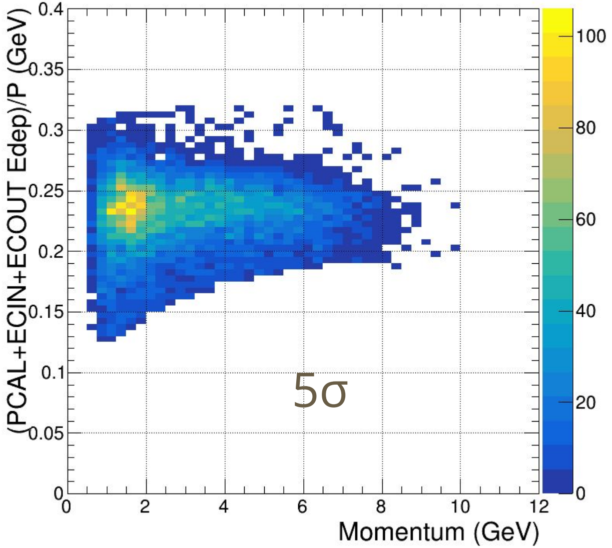


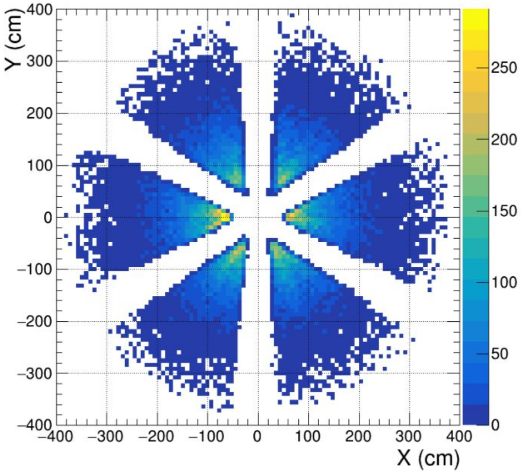


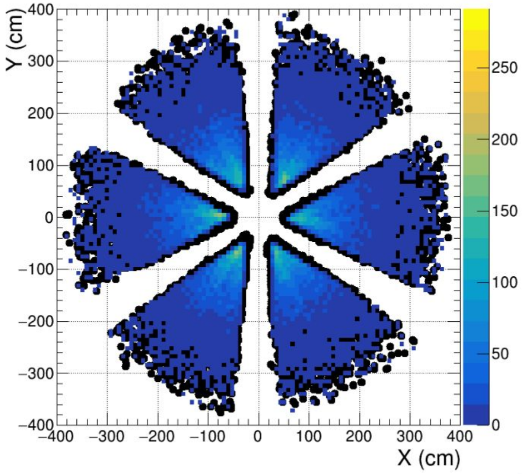


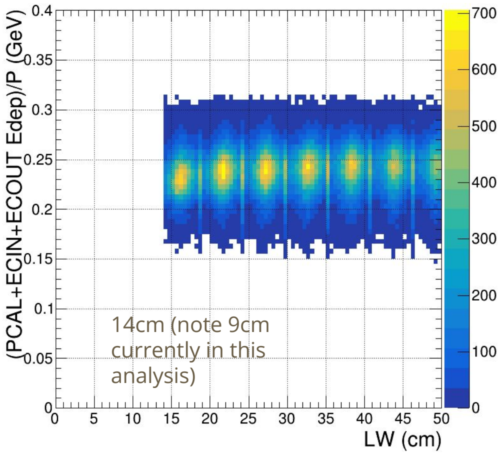


SF, PCAL, after cuts









Dilution Factor updated strategy

334 total ‘good’ NH3 runs across all 10.5GeV runs across all run periods - 69 Carbon, 61 CH2, 9 Foils, 6 Empty.

if statistics allow the following strategy is advised;

- Calculate Packing fraction (PF) once for each **run** epoch (Summer22, Fall22, Winter22/Spring23)
  - PF should be kinematics independent but plotting in different bins is a good cross check
  - This PF is then used for Dilution factor (DF) calculations for the whole run epoch
- Calculate the DF for each kinematic bin, check its dependance on epoch and kinematics

$$DF(PF) = PF\frac{3\rho_A(l_C L\rho_C(n_{CH}-n_{MT}) + l_C l_{CH}(\rho_C-\rho_{CH})(n_{MT}-n_F) - l_{CH}L\rho_{CH}(n_C-n_{MT}))}{2l_C l_{CH} n_A \rho_C \rho_{CH}}$$
$$= \frac{3PF\rho_A}{2n_A\rho_C\rho_{CH}}\left(\frac{L}{l_{CH}}\rho_C(n_{CH}-n_{MT}) + (\rho_C-\rho_{CH})(n_{MT}-n_F) - \frac{L}{l_C}\rho_{CH}(n_C-n_{MT})\right).$$

Subscript A, C, CH, MT, F refer to the ammonia, carbon, CH2, empty and empty with no liquid helium (i.e. foils) respectively.

n = number of events in kinematic bin per target.
ϱ = target density
ℓ = target length
L = length of ammonia cell or full target, depending on the calculation used

Dilution factor for each summer epoch of NH3 - Packing fraction taken as 55% from inclusive studies by RG-C members

Dataset	**Parameter**
Summer NH3 epoch 2	Dilution Factor (cell) = 0.369475+/-0.154308
Summer NH3 epoch 3	Dilution Factor (cell) = 0.309693+/-0.128141
Summer NH3 epoch 4	Dilution Factor (cell) = 0.306159+/-0.126553
Summer NH3 epoch 5	Dilution Factor (cell) =0.433254+/-0.184205
Summer NH3 epoch 6	Dilution Factor (cell) = 0.346592+/-0.144641
Summer NH3 epoch 7	Dilution Factor (cell) = 0.353089+/-0.146498
Summer NH3 epoch 8	Dilution Factor (cell) = 0.376032+/-0.158242
Summer NH3 epoch 9	Dilution Factor (cell) = 0.326271+/-0.13619
Summer NH3 epoch 10	Dilution Factor (cell) = 0.35634+/-0.1509

Summer only, Fall still to be checked for J/ψ final state