Addendum

Release note for IoP: Joint APP, HEPP and NP Conference 2021:

Hard Exclusive π_0-Production off neutrons using a deuteron target at CLAS12

Paul Naidoo

09/04/21

Abstract

When presenting a dry run of my IoP talk to the Glasgow group, it was suggested to me that in the interest of clarity, and in to save time in explaining what is meant by "Truth-Matched" in the MC plots, it would be more appropriate to show the distributions on the single plot. Having produced these plots, I am inclined to agree with them, and so provide this addendum to the previous note to seek approval for release such that I can use these in place of the previous. All cuts, data and MC sources remain the same. I include all information such that this document can be fully understood without reference to the previous note.

Data:

- RG-B Spring '19 Pass1
- Liquid deuterium target
- 10.6 (and 10.2) GeV polarized electron beam
- Torus: inbending
- Beam current: 50nA
- Event selection:
    - At least 1 electron, 1 neutron, >1 photon (and anything else)
    - Full combinatorial (all particles)

MC:

- GENEPI event generator
  – Produces proton/neutron DVπ_0P proportional to x-sects
  – Proton:neutron 10:1
- Reconstructed with COATJAVA 6.5.8 (same as RGB Spring '19)
- No background-merging

Cuts:

- Event Builder PID
- 3σ π_0 mass cut — *on $\gamma\gamma$ invariant mass*
- $\theta_{e\gamma} > 8°$ — *opening angle between scattered electron and each photon, to remove radiated photons.*
- $\delta\Phi_{Trento} < 2°$ — *coplanarity between hadronic planes, defined using n'γ* or $\pi_0\gamma$*, where Φ_{Trento} is defined as the angle between the leptonic and hadronic plane.*
- $MP_{eD->e'n'\gamma\gamma X} < 0.7$GeV — *should correspond to Fermi-momentum of spectator.*
- $|MM^2_{e'n'\gamma\gamma X}| < 0.02$ GeV2 — *should be zero*
- DIS cuts
    - $Q^2 > 1$ GeV^2
    - $-t < 1$ GeV^2
    - $W > 2$ GeV

Analysis status:

We know that in order to measure the BSA, we need good exclusive selection of our final state. I will explain this in the introduction/motivation section of my presentation. Hence, when focusing on the status of my analysis, I will show the progress in achieving exclusive final state selection by comparing MC studies with data.

All distributions below, are integrated across all detectors (eg, neutrons in the CD and the FD, etc.).

I note, that for the sake of comparison, the distributions in the overlaid plots are normalised such that the area under each distribution is equal to one.

Exclusivity variables:

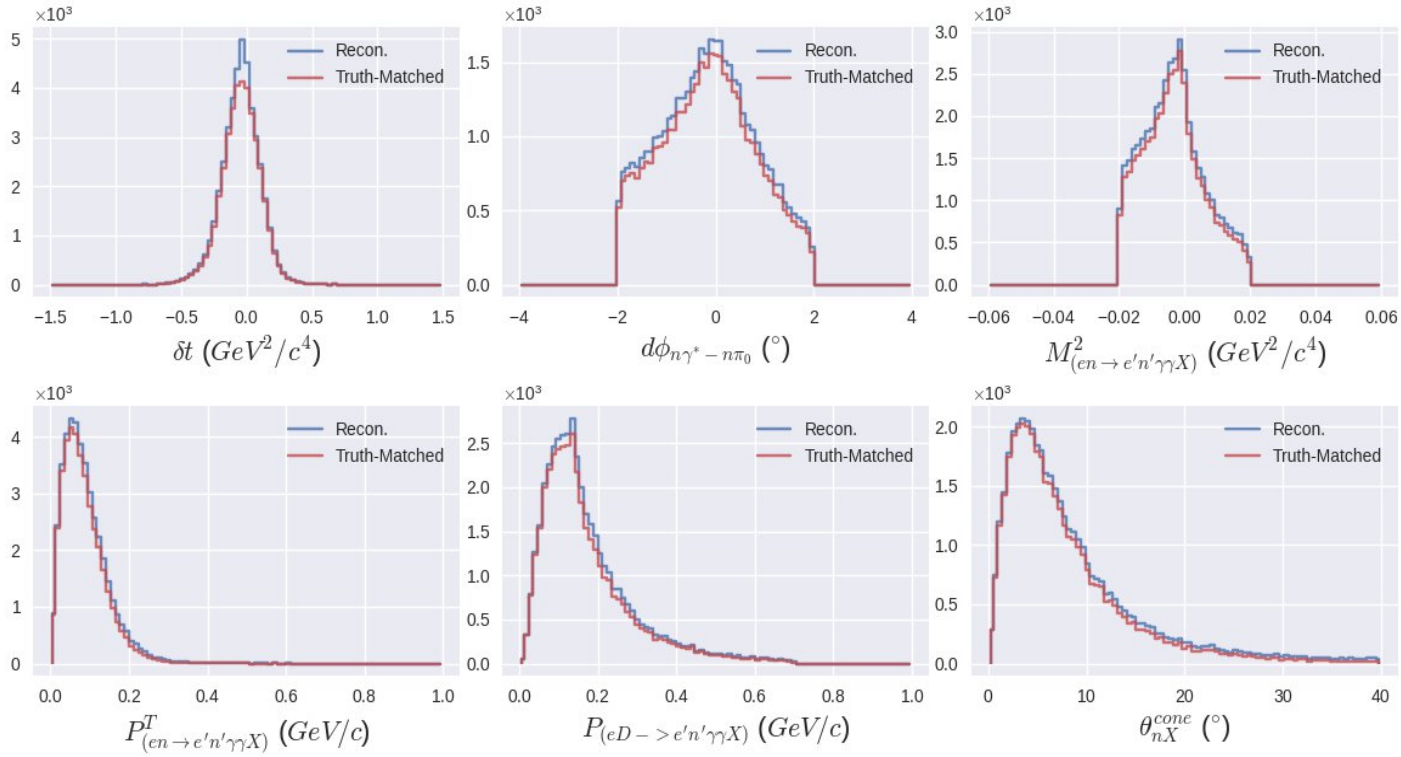
TOP (left/right):

- δt
  The difference between Manselstam t calculated using (recoil-target), or the (γ* - π_0)
- $\delta\Phi_{Trento}$
  Coplanarity between hadronic planes, defined using n'γ* or $\pi_0\gamma$*
- $MM^2_{e'n'\gamma\gamma X}$

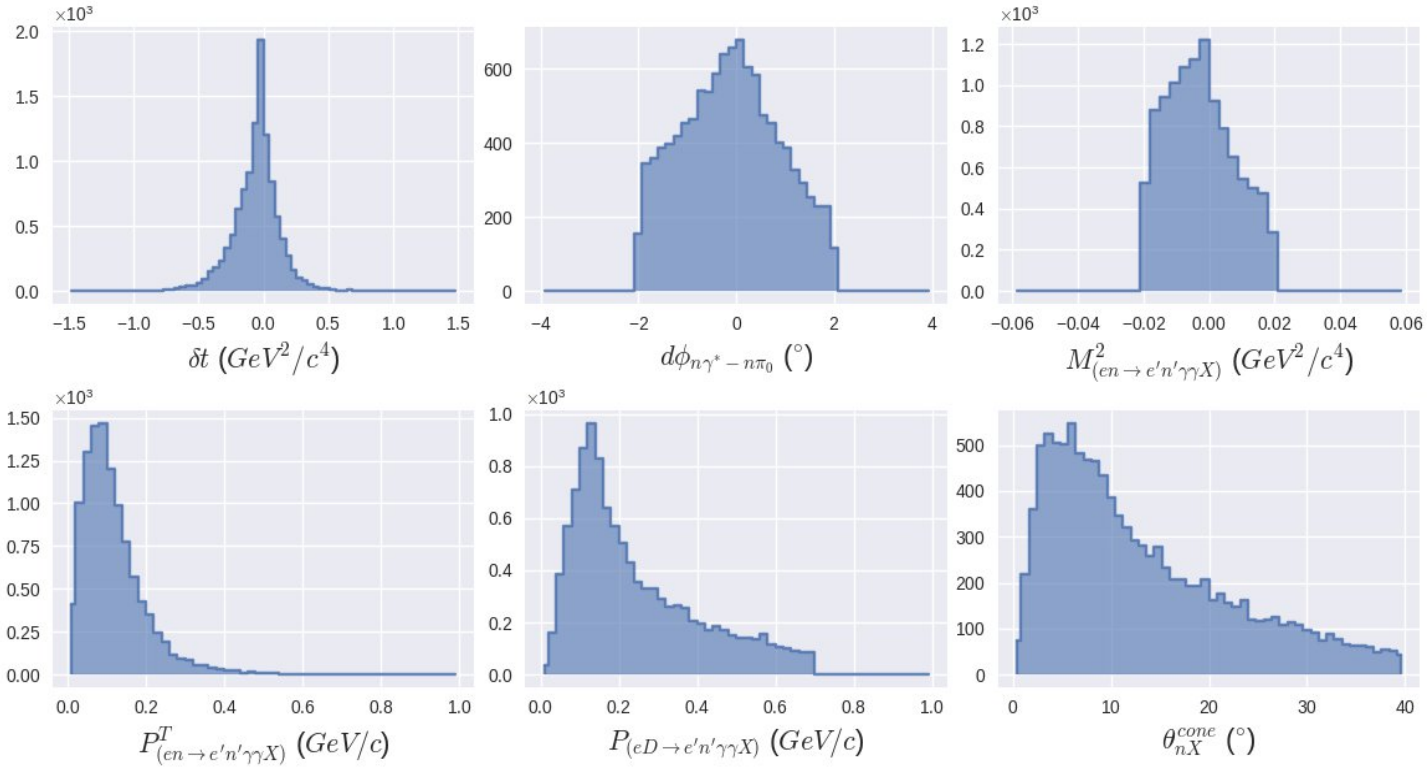
BOTTOM (left/right)

- $MP^T_{e'n'\gamma\gamma X}$
  Total transverse missing-momentum
- $MP_{eD->e'n'\gamma\gamma}$
  Missing momentum of reconstructed spectator proton
- θ_{nX}
  Cone angle between reconstructed and expected neutron momentum.

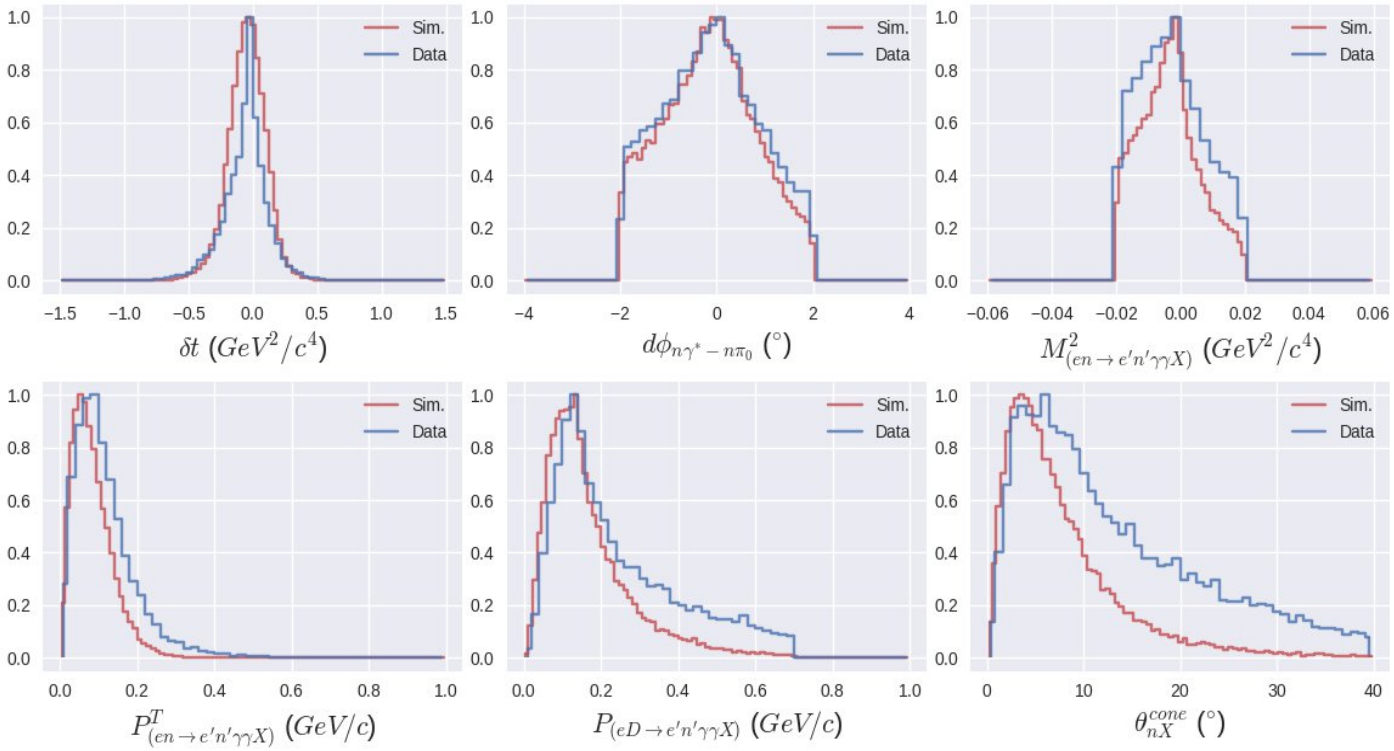
MC Distributions [Released]



Data Distributions [Released]



Overlaid Distributions **[FOR RELEASE]**



The red line is simulated data. These distributions correspond to the red “Truth-Matched” distributions of the released plots above. “Truth-Matched” means that the events out of the combinatorial events, whose final state particles best match those in the LUND have been chosen. As as can be seen from the released plots above, there is very close agreement between Truth-Matched and the “naively” reconstructed distributions, meaning that the exclusivity cuts we are using have the combinatorial background sufficiently under control. The Truth-Matched distribution is chosen in the plot above as it represents the “best-case” for each distribution.

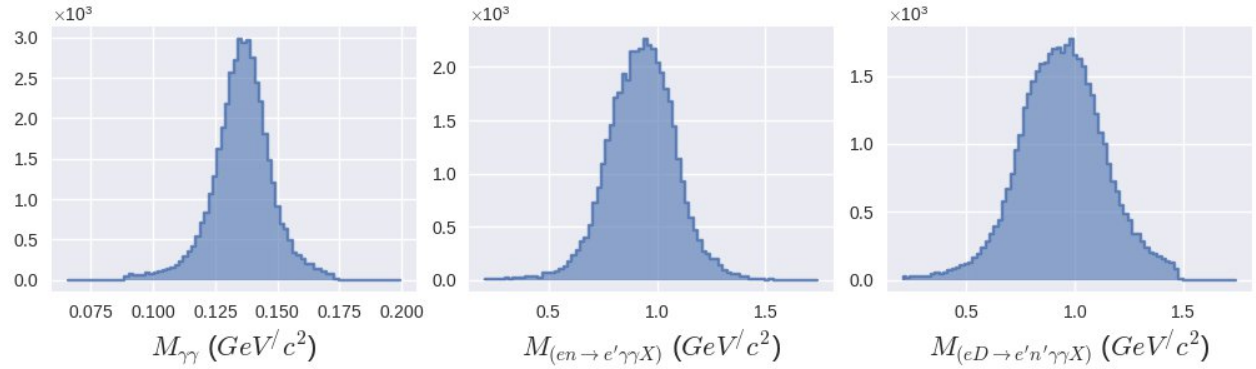
The blue line is real data. For all six distributions above, we have good agreement between data and simulation, with a bit of extra smearing from background, and the true resolutions of our detectors in real data.

Overall, these distributions look as expected. We expect the top row variable to be centred on zero. On the bottom row, we expect no missing transverse momentum and a Fermi-momentum peak at around 60MeV for the missing spectator momentum. Within the limits of our resolutions, both these distributions look good. Finally for cone angle we expect a peak at low value with a long tail; arising from the fact we rely on nuclear knock-out to detect neutrons.

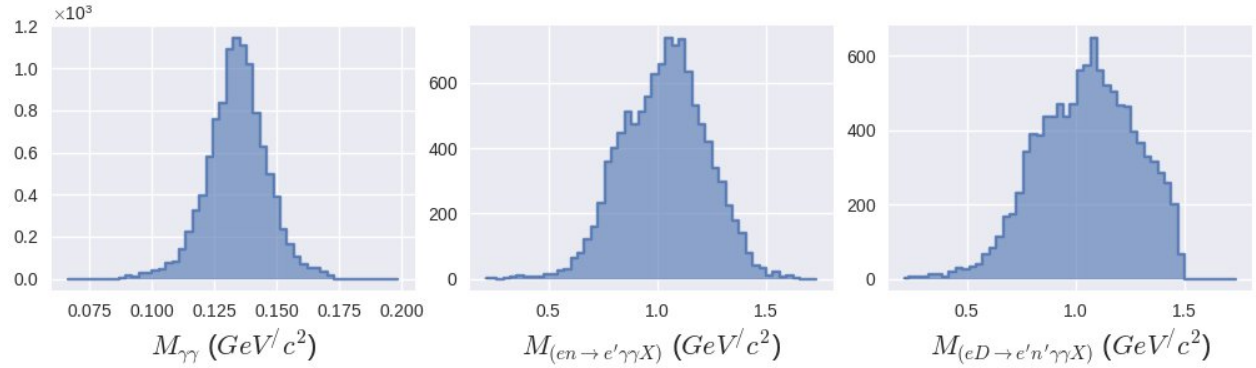
Mass spectra (π_0, recoil-neutron and spectator-proton):

MC and Data separately [Released]

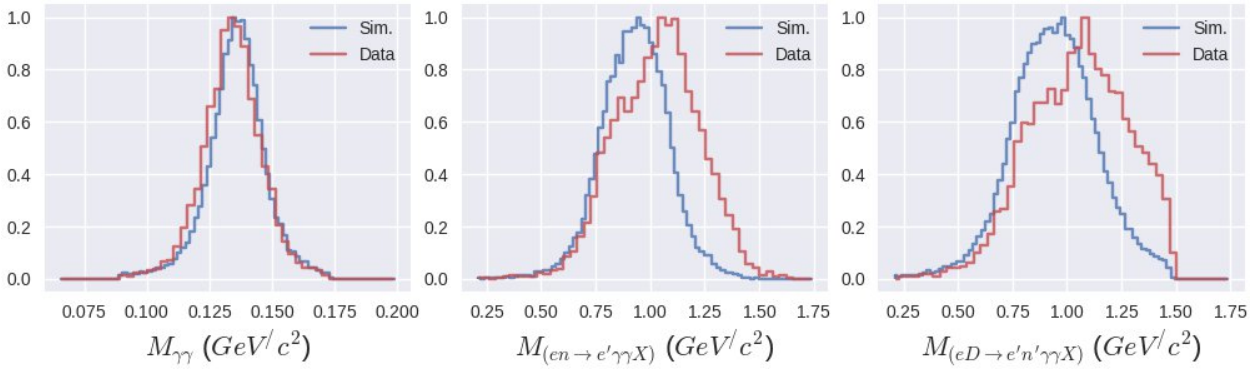
MC:



Data:



Overlaid Distributions **[FOR RELEASE]**



Remaining background is most apparent in the reconstructed recoil/spectator masses. The good agreement in π_0-mass distributions, in contrast with the recoil and spectator mass distributions tell us that the main background appears to be within the neutron signal. This is perhaps expected, given that we know there are challenges to overcome for neutrons in the CD and the FD.

Conclusions:

Sources of background are largely now largely understood, with ideas on how to proceed:

- Proton Pollution in CD:
  - Fiducial cut on φ to remove “hotspots” arising from gaps in BMT acceptance should radically reduce number of protons.
  - “Chi-Sq parametrisation” of multiple exclusivity variables proposed by Adam Hobart.
  - Neural-Net to separate protons from neutrons.
- Clustering for neutrals in FD:
  - Work ongoing by various individuals to address this.

- Potential to open up cuts in both cases once background is under control.
- Plan to develop detector specific exclusivity cuts.
- Ongoing kinematic corrections.

In all cases, I believe overlaid plots make for a clearer comparison, and highlight the message of the presentation, which is that we are converging on exclusive selection of the final-state, see and understand the background, and have a plan on how to progress.