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BONuS: "Barely Off-Shell Neutron Structure"

Introduction



Projected 12 GeV d/u Extractions



BONuS12 RTPC:

A Gas Electron Multiplier(GEM) based detector was built to measure spectator protons e- clas detector



Peuterium target @7 atm ground foil RTPC with 3 Layers of GEM amplification

3 mm dead zone

Spectator protons ionizes drift gases

- Electrons liberated accelerated due to EM field
- Electrons amplify through GEMs
- 3 layers of amplification for 3 GEM layers
- · Readout the signal through readout pads

FEU Electronics -> Signal height vs Time bin Pad position + time + drift path - >hit position => 3D track reconstruction + momentum + vz

Integrated signal + pad $gains(G_i)$:

$$\left(\frac{dE}{dx}\right) = \frac{\sum_{i} \frac{ADC_{i}}{G_{i}}}{vtl}$$

BONuS12 RTPC in CLAS12

CLAS12 Forward Detector:

- Superconducting Torus magnet (<u>+</u> polarity).
- 6 independent sectors:
- HTCC
- 3 regions of DCs
- LTCC /RICH
- FTOF Counters
- PCAL and ECs
- FT (not used)

Central:

- BONuS12 RTPC
- FMT (3 layers)
- Solenoid (3.8 T)
- CTOF, and CND

Run Conditions

$$\begin{split} E_b &= 10.4 \text{ GeV}, 2.1 \text{ GeV} \text{ (calibrations)} \\ \text{Target} &= D_2 / \text{He-4} / H_2 / \text{Empty} \\ \text{Target Pressure} : 5.6 \text{ atm}, 293 \text{ K} \\ L &= 2 \cdot 10^{-34} \text{ cm}^{-2} \text{s}^{-1} \end{split}$$



Pass1V2 review has been completed. Since then, all Summer-2020 data has been decoded and cooked. All results are based on this

Tdiff cuts : timing difference between expected on time tracks and measured timing of tracks

The observable tdiff:

- · was not stable and varied file by file
- So cut will be file by file for each reconstructed DST files



Run: 12736 D2 Target



Good Run/File Selection:

- Select good run/file for final analysis.
- Extracted the electron yield normalized to beamcharge
- Expect this quantity to be stable and consistent for runs with similar run conditions

Missing FC information for some group of runs:

- FC was not working during some runs
- Used:

DAQgated clock [HEL::Scaler bank] beam current [RAW::epics] Beamcharge = Clock. Current [I_{2c21}]

- Extract relation using the runs that has FC information already available
- Fit the relation
- Extract the fit parameters
- Apply to runs that do not have this information





Accidental Backgrounds in BONuS12

To get better statistics on accidental backgrounds we matched ep pair from different events within our coincident cuts and subtract it from signal.

For every 10 consecutive events with electrons satisfying all electron cuts:

- Form ep pairs
- 10 e^{-} and 10 p corresponds 10 * 10 = 100 ep pairs
- 10 pairs [Red in fig.] will be ones with same ep events
- 90 pairs [Green in fig.] will be ones from different ep events
- Now we define a histogram of :

Diagonal Events : Where electron and proton come from same events [includes true coincidences]

Off-Diagonal Events: Where electron from each event is paired with 9 protons from different events.

Coincidence cuts VIP angle cut, Dv_z cut, and T_{diff} cut except on the quantity which we are plotting.

In principle we expect 9 times as many events in Off-Diagonal sample events.

Hence, we Scale Off Diagonal Sample by 9.



Background Subtraction Illustration





BONuS12 Expected Uncertainties



Deuterium Target Contamination

We need an estimate of fraction of the highermass background in RTPC





- ³H/³He counts measured in all Targets
- Normalized to beamcharge for the run
- Further Cross-Normalized them to those measurements in He Runs

³He counts in each D₂ Runs further cross normalized to He Runs



The vertical red lines represents runs where we did target flush. Hence, Minimum at those runs.

RG-F CD Neutron Corrections

- Fact: RG-F is using CND and CTOF calibration constants from last RG-B calibration run on Jan-28, 2020
- Obstacle: CND and CTOF are calibrated using vertex-tracked Minimum Ionizing Particles, while BONUS12-RTPC is totally blind to MIPs.
- Solution: Using elastic neutron from channel $ed \rightarrow ep(n)$: compare measured and true kinematics



Recovering Neutrons Outside Measured β[0,0.8]

Fact: Only neutrons in the measured β [0,0.8] are reconstructed.

Goal: As the true β is shifted from the reconstructed one, we miss neutrons at higher true β .

The Goal is to recover these neutrons.

Solution: Using the hit coordinates in the CND and CTOF, we re-calculate the angles for all Neutral particles in CD. β and momentum are corrected using the extracted corrections.



Conclusions:

- In addition to correcting the kinematics of the reconstructed neutrons, our corrections recovered 50% more elastic non-reconstructed neutrons.

- These corrections will be applied to the 10 GeV data for the neutron-DVCS analysis.

Updates on Simulation

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- Improved RTPC and target configurations in GEMC for RG-F.
- Generator: An extension version from previous
 Bonus experiment that accommodates to the 12GeV

Red: data Blue: MC





Conclusions and Future Plans of RG-F

- All Summer-2020 data cooked and ready for Higher Level Analysis
- RTPC cuts developed and ready
- Good Run/File selection for analysis completed
- Accidental Background sampling done, and background subtraction procedure has started
- Simulation Software is ready [Fine tuning the simulation is going on]
- Hopefully, some publishable results by end of Summer or early Fall of 2023

BACK UP SLIDES

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BONuS12 Nuclear Uncertainties



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BONuS12 RTPC:

A Gas Electron Multiplier(GEM) based RTPC will measure protons between 70 MeV/c and 150 MeV/c .

Design

- 400 mm long cylindrical Detector.
- 360° Azithumal coverage
- Target gas is inside a 50 µm Kapton tube placed along axis at center of detector
- Consists a cathode foil at 4.3 kV
- 4 cm drift region
- Uniform E = 500V/cm and B = 3.78T
- 3 GEM's layers
- 17280 readout elements (2.7 mm x 3.9 mm)

Advantages:

- Momentum threshold around 70 MeV/c
- Reduced quantity of material in forward part





BONuS12 Run Summary

- Feb 11 -2020 : Official start of experiment ٠
- March 24 June 08 -2020 Experiment halted due to MEDCON6 [Due to covid outbreak]
 Sep 21 -2020: End of experiment

<u>Beam Energy:</u>		Target Gas :		Target Pressure:
٠	2.18 GeV (1 pass)	•	H ₂	 68 psi
٠	10.4 GeV (5 pass)	•	Hē	-
		•	D_2	
		•	Empty	

Beam Energy	Target	Spring - 2020	Summer - 2020
	H2	81 M	185 M
1 Pass	D2	37 M	45 M
	4He	19 M	44 M
	Empty	1 M	22 M
	H2	151 M	266 M
5 Pass	D2	2275 M	2355 M
	4He	77 M	51 M
	Empty	21 M	45 M

PID cuts for separating proton/deuteron from other particles in dEdx band







For spectator ep events selection we apply several quality cuts on the tracks.

For true coincidences following 2 cuts are further applied

- Δv_z cut: $< \Delta v_z > \pm 1.7 \sigma$
- tdiff cut: <tdiff > $\pm 1.9 \sigma$

Even after these cuts total accidental background is over 72 % of signal

Background sampling

Could be done by extrapolating the side wing outside to inside of the wing. But

- > The Δv_z distributions are not flat because,
- for a given Δv_z contributions can only come from some fraction of target length.
- It makes extrapolation uncertain and lowers statistics.



Momentum Calibration Beam energy 2.18 GeV , Target H_2 gas

