NPS RG1a: Validating Luminosity and HMS Acceptance via Analysis of DIS Yield

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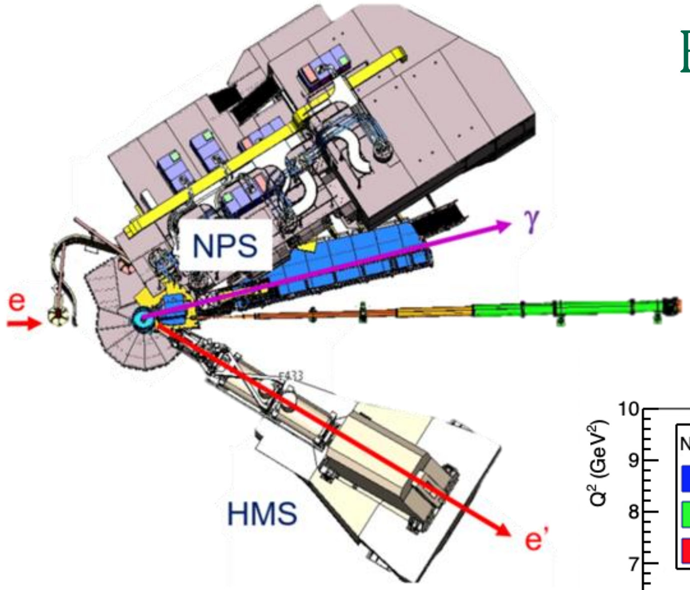
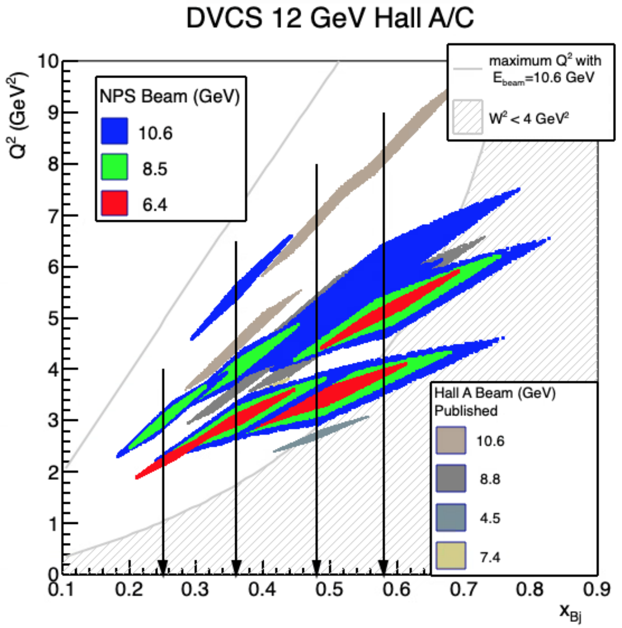
The Neutral Particle Spectrometer (NPS) Experiments

- Normal DVCS runs triggered on recoil electron in HMS and photon in NPS
- Took DIS runs (HMS-only trigger) approximately every 12 hours throughout the experiment
- Analyzing DIS runs: Compare yields from data and MC simulation for 17 HMS settings



Run Group 1a

E12-13-010
E12-13-007
E12-22-006
E12-23-014



DIS Data Comparison to MC Simulation

- Data:
  - Runs with HMS-only trigger
  - Data cuts:
    - Cerenkov: npeSum > 2
    - Calorimeter: etracknorm > 0.6
    - Delta between ± 8%
    - Beam current > 2uA
  - Normalize by charge
  - Corrections for LT, detector efficiencies, prescaling, HMS acceptance
  - Target cell wall and charge-symmetric background contributions subtracted
- Simulation:
  - Generate events at vertex over a large phase space
  - Incorporate radiative corrections
  - Weight according to cross section model (F1F221)
  - Compute reconstructed event variables

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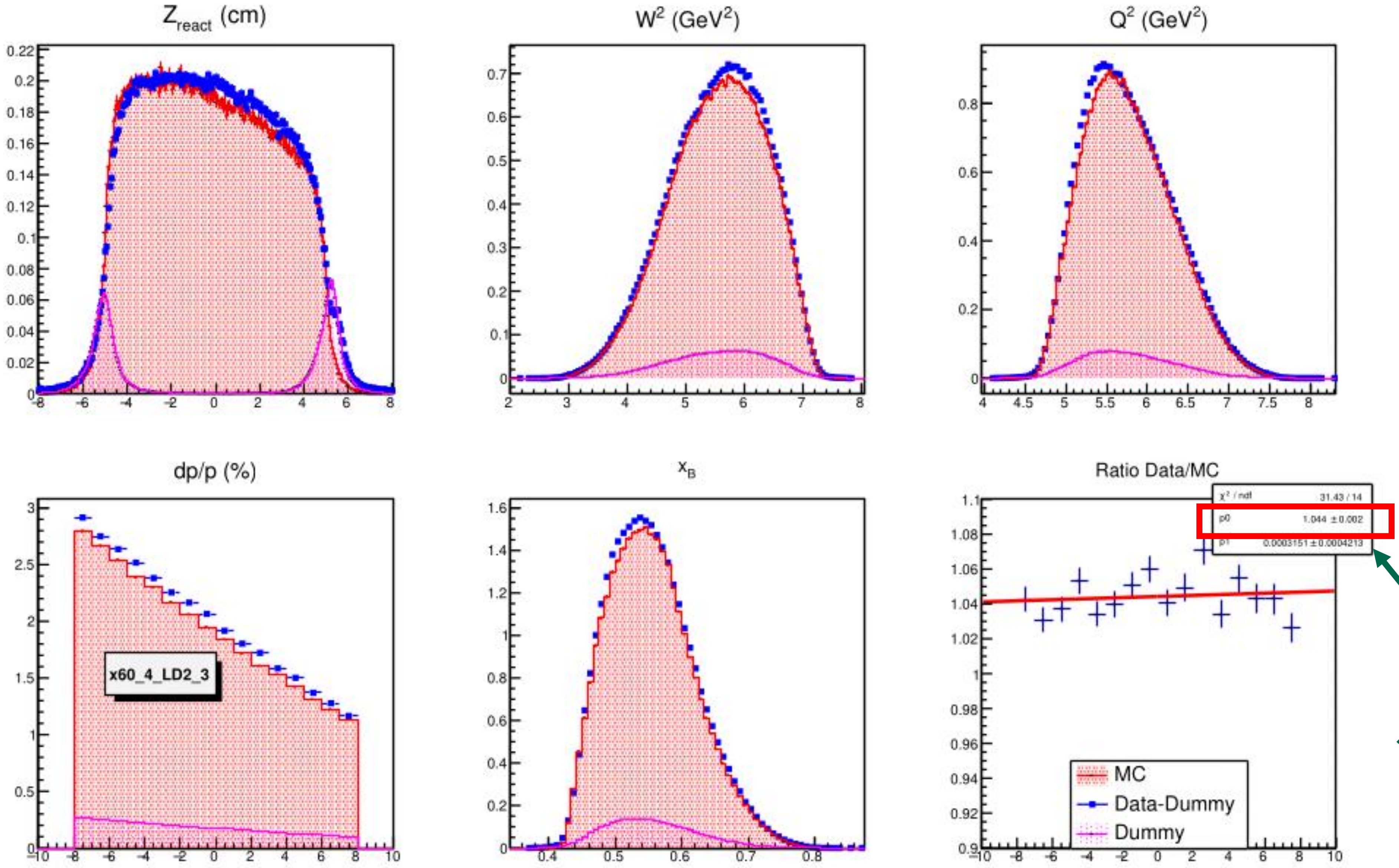
LD2
(loop 1)

x60_4

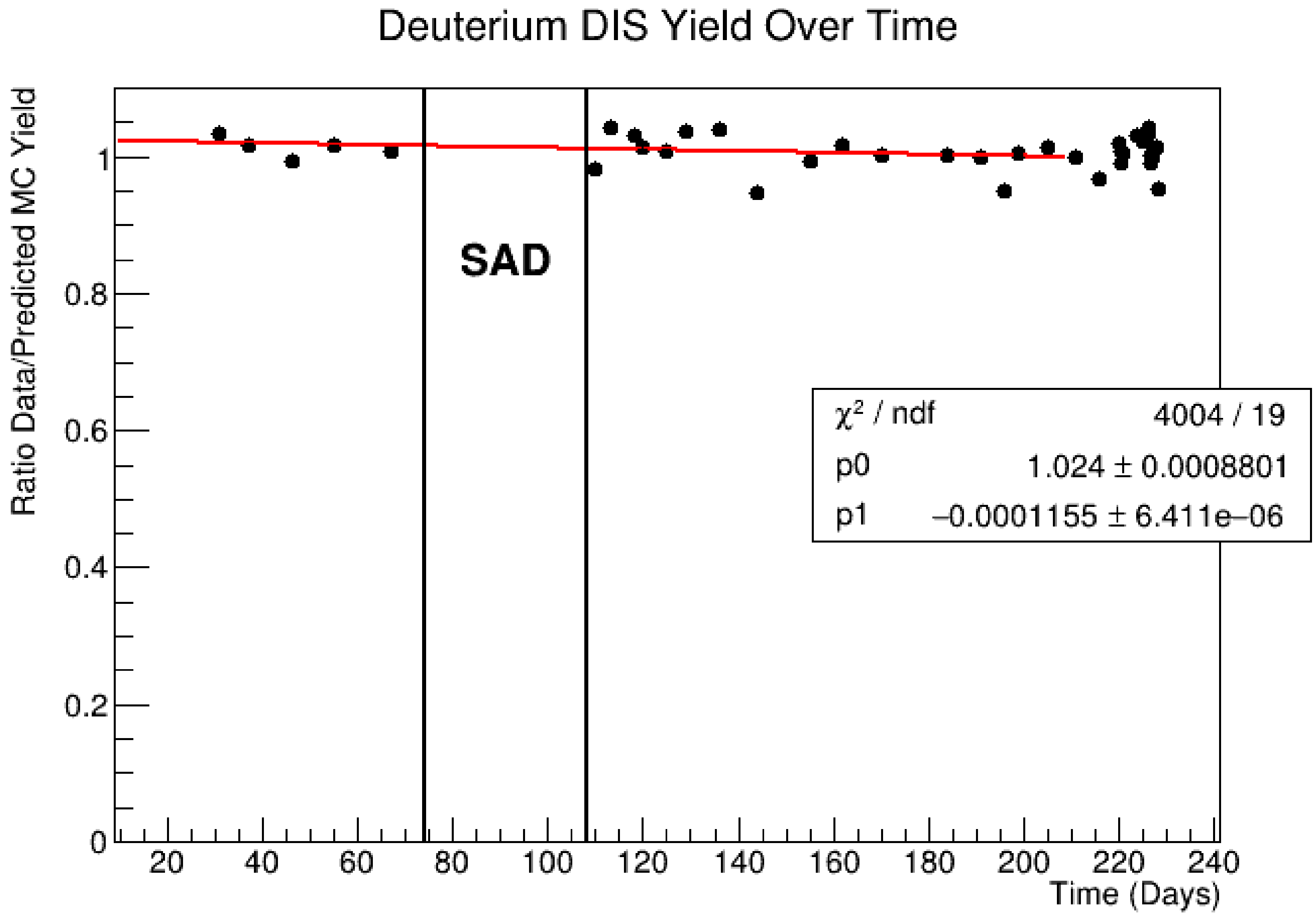
5/16/24
(day 216)



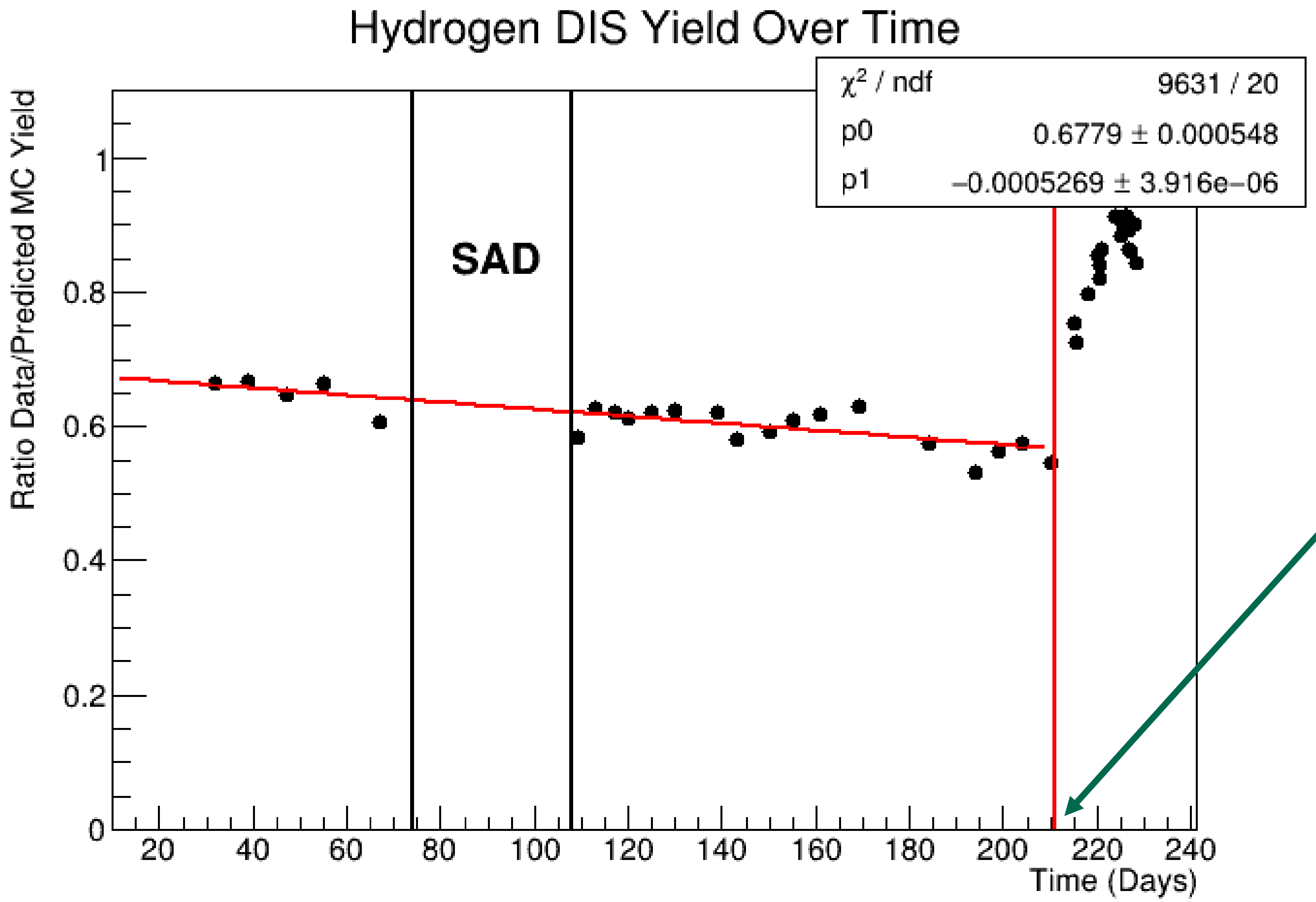
Data has 104.4% of MC yield

DIS Yield Over Time

- Repeat analysis approximately once per week from beginning of run period until LH2 target adjustment period
- Post-LH2 target adjustment, took DIS runs at every kinematic
- Each kinematic has at least 2 data points
- Plot ratios of yield to MC prediction over time
  - Set October 3, 2023 as "Day 0"
  - LH2 target adjustment begins day 211



Simulation works well for all kinematics throughout the experiment


Hydrogen DIS Yield Over Time
χ^2 / ndf 9631 / 20
p0 0.6779 ± 0.000548
p1 −0.0005269 ± 3.916e−06
SAD
Ratio Data/Predicted MC Yield
0
0.2
0.4
0.6
0.8
1
20 40 60 80 100 120 140 160 180 200 220 240
Time (Days)
5/1/24 (day 211): Begin adjusting LH2 target conditions

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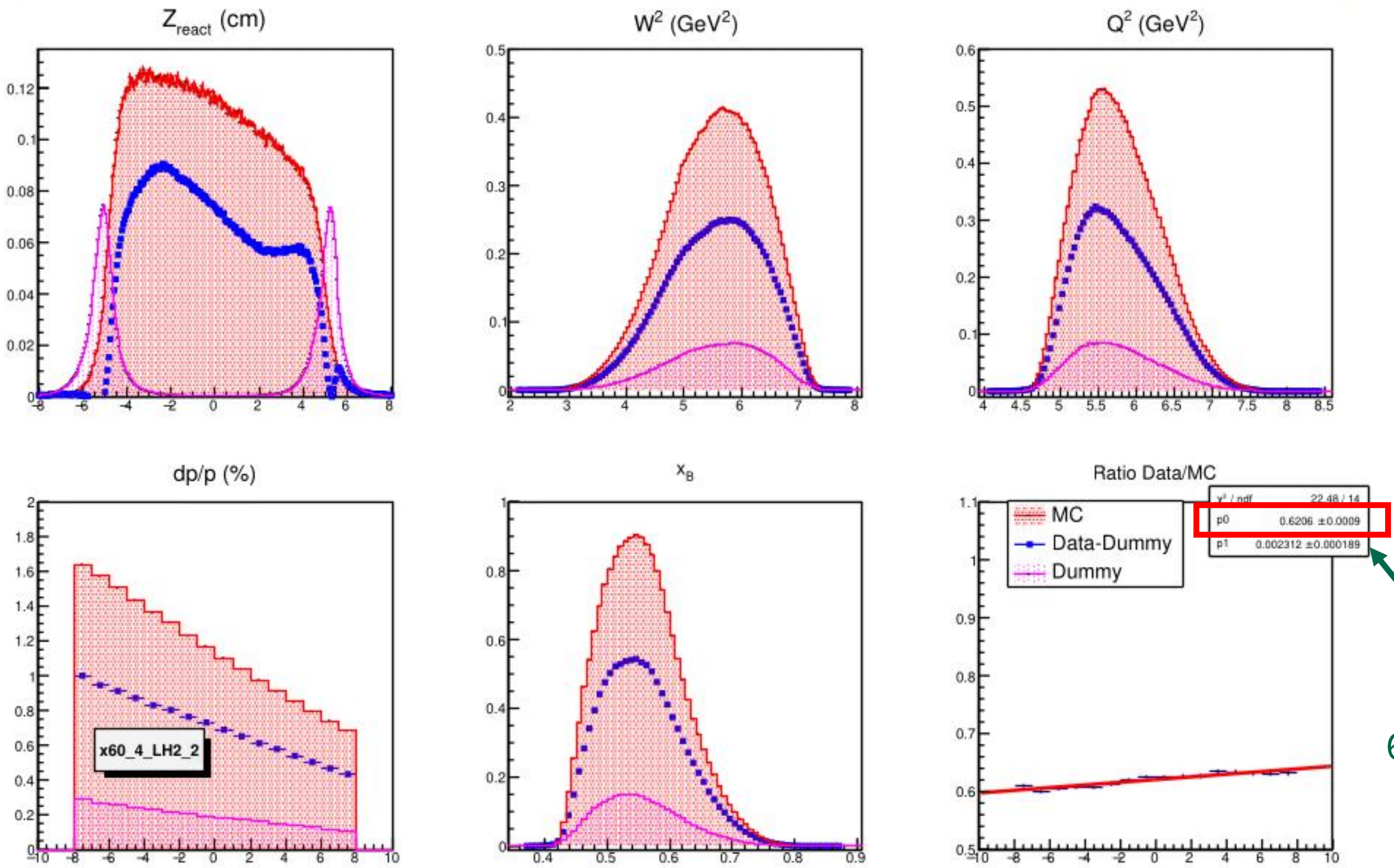
LH2 (loop 2)

x60_4

2/19/24 (day 139)



Data has 62.06% of MC yield

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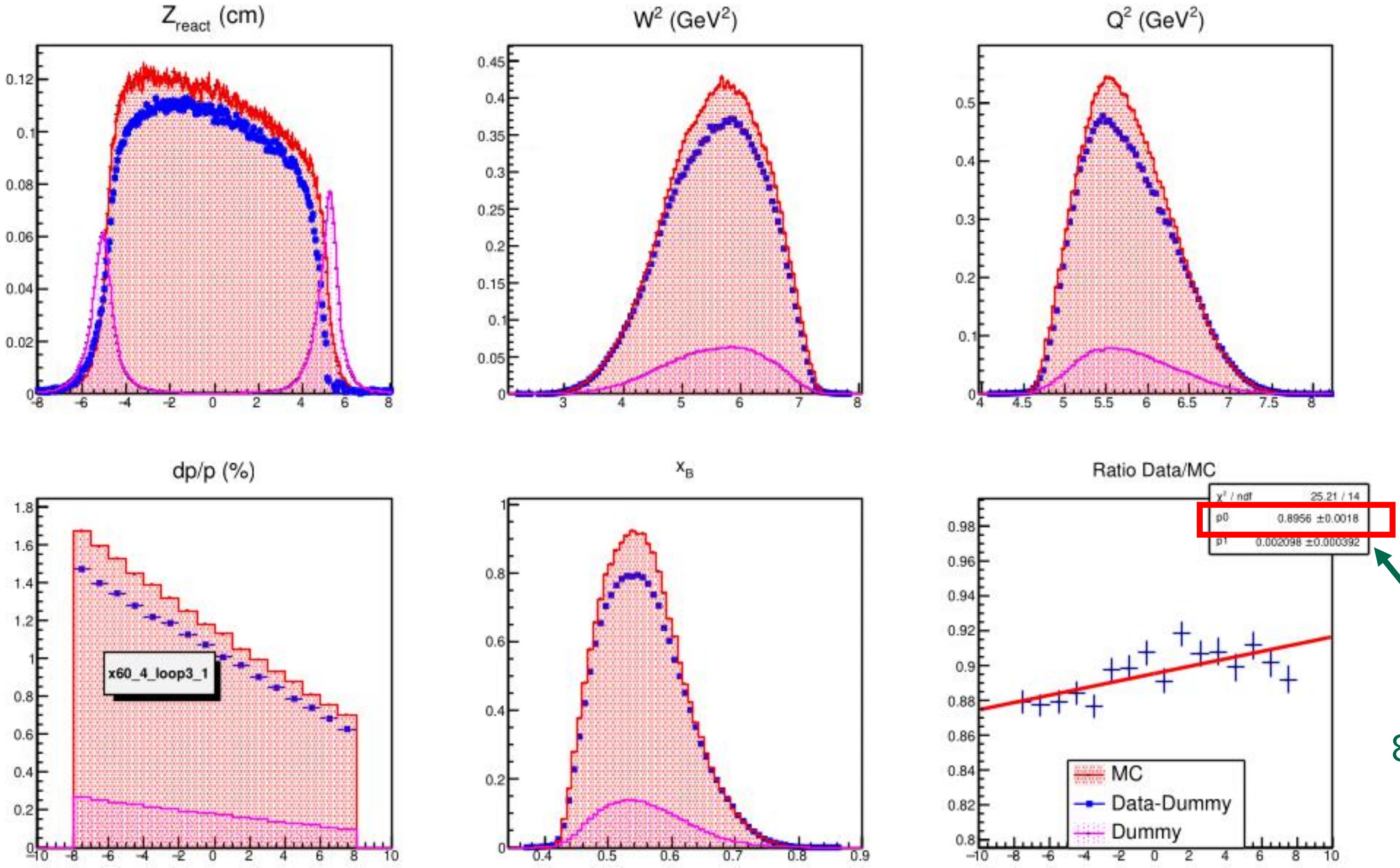
LH2
(loop 3)

x60_4

5/16/24
(day 216)



Data has 89.56% of MC yield

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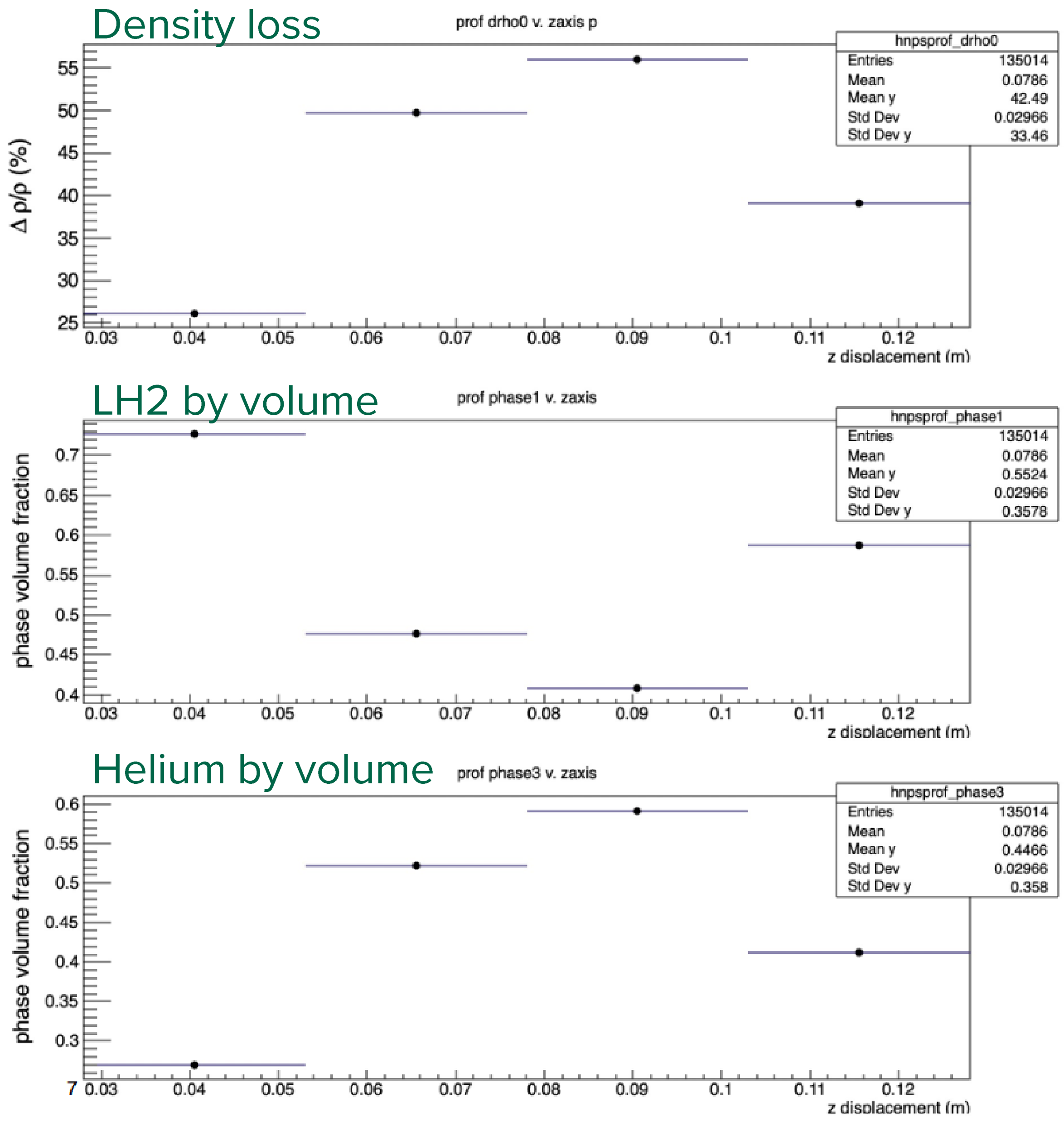
Modifications to LH2 Target

- 2 primary hypotheses for the cause of target issues:
    - Atypical fan speed created bubbles
    - Helium contamination in LH2
- Measures taken:
    - Adjusted target fan speed (58Hz to 42Hz)
    - Replaced fan controller
    - Moved LH2 from loop 2 to loop 3
    - Increased pressure in target loop (25psia to 40psia)
- Each measure made small improvements

Characterization of LH2 Target

- Silviu Covrig Dusa conducted computational fluid dynamics (CFD) simulations of target cell
  - See Silviu's slides, NPS Collaboration Meeting, July 2024: https://indico.jlab.org/event/866/contributions/14977/subcontributions/255/attachments/11507/17809/nps_cdusa_targetcfd_17jul2024.pdf
  - If LH2 pump efficiency >80%, loss of target thickness not explained with only LH2
  - LH2-He mixture shows concentration of He in downstream half ➔ He "bubble"
  - Overall thickness loss of about 35-40%
- Beam tests showed high power heater only sensed ~70% of LH2 target thickness

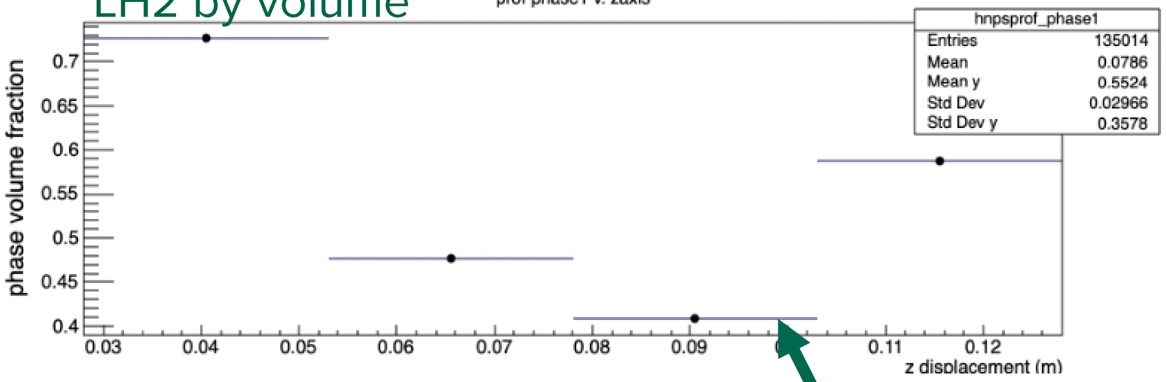


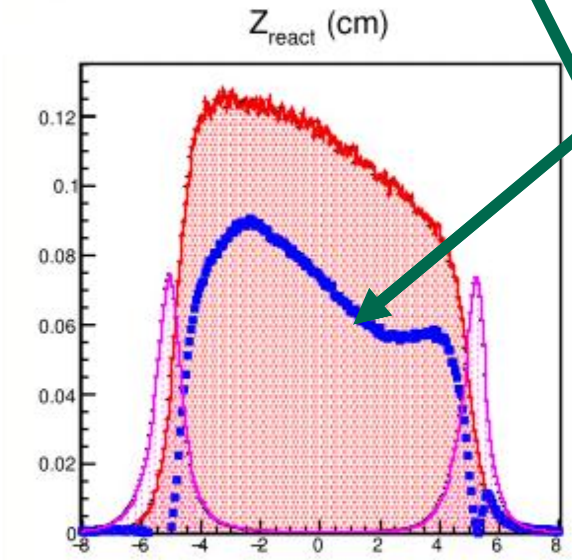
Plots: Silviu Covrig Dusa

Characterization of LH2 Target

- DIS analysis consistent with Silviu’s results
  - Target density loss concentrated in middle of target, skewed downstream
  - Typically 60-65% expected target thickness overall
- Helium contamination report from Dave Meekins:
  - Both samples 0.5% He by volume in H2 tank
  - Much higher levels than expected
  - https://logbooks.jlab.org/entry/4324739

LH2 by volume





Target density loss in same location

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What this Means for Physics Outcomes

- Need to apply time-dependent luminosity correction for hydrogen targets
- Does this correction also need to be z-dependent?
  - Can investigate with DVCS simulations
- Need to minimize error on correction

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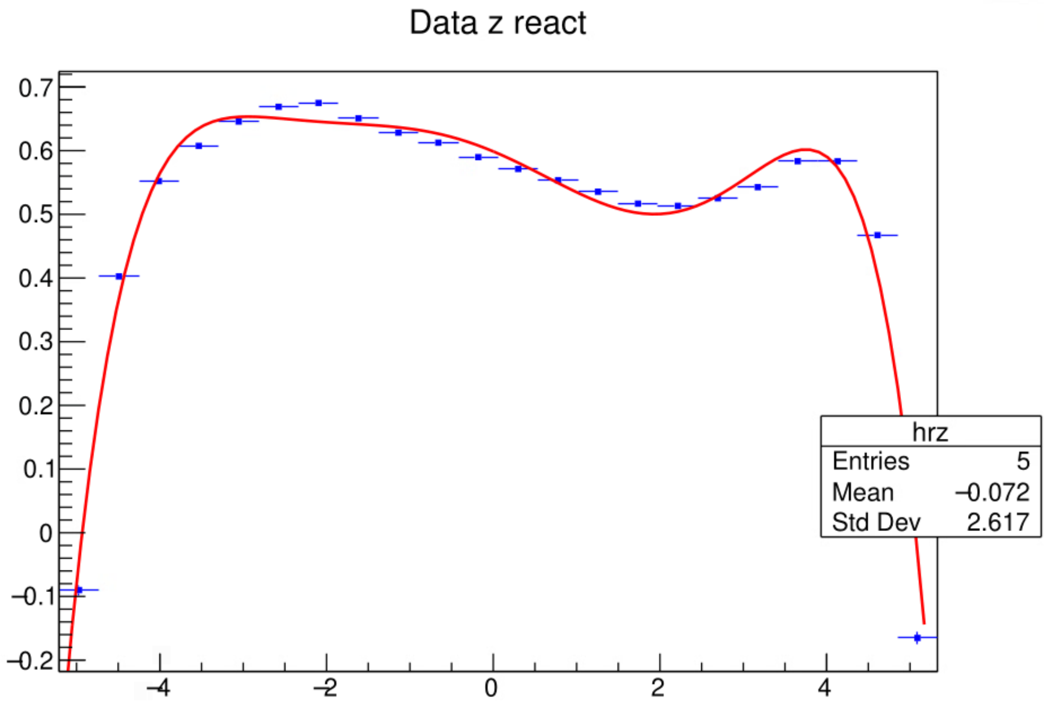
DVCS Simulation

- Developed profiles of LH2 target for use in DVCS simulation
  - Ratio data/MC as a function of z
- Hao and Yaopeng modelled non-uniform z densities in DVCS simulation
  - Simulated cross section as a function of ϕ
  - Preliminary results showed little difference between uniform and non-uniform z densities
- Results imply z-distribution of target material has minimal effect on cross sections as long as overall scale is correct



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Extracting High-Precision Luminosity Corrections

- Initial results indicate z-dependent correction is not necessary, so focus on making overall scale factor is as accurate as possible
- Remaining uncertainties:
  - Dummy target scale factors – contribution from dummy target is slightly different to contribution from aluminum foils in cryo target. Can be investigated with aluminum simulation + radiative corrections
  - Boiling correction
  - Pion contamination
  - HMS acceptance correction
- DIS is not limited by statistics – can repeat analysis on small time scales over experimental run to construct accurate time-dependent profile of correction factor

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Summary and Outlook

- Deuterium DIS studies give reasonable results, so discrepancies in hydrogen seem to be coming from the target
    - Issues with hydrogen target were present from the start of the experiment and seemed to have gotten worse over time
    - Significant improvement with adjustment of hydrogen target conditions
- Initial results from DVCS simulation indicates overall luminosity correction will be sufficient
- Task is now to reduce remaining uncertainties in DIS analysis and extract correction factors

Thank you for your time

Questions?