First Deuteron Production Measurements in Proton-Proton Interactions at SPS energies by NA61/SHINE

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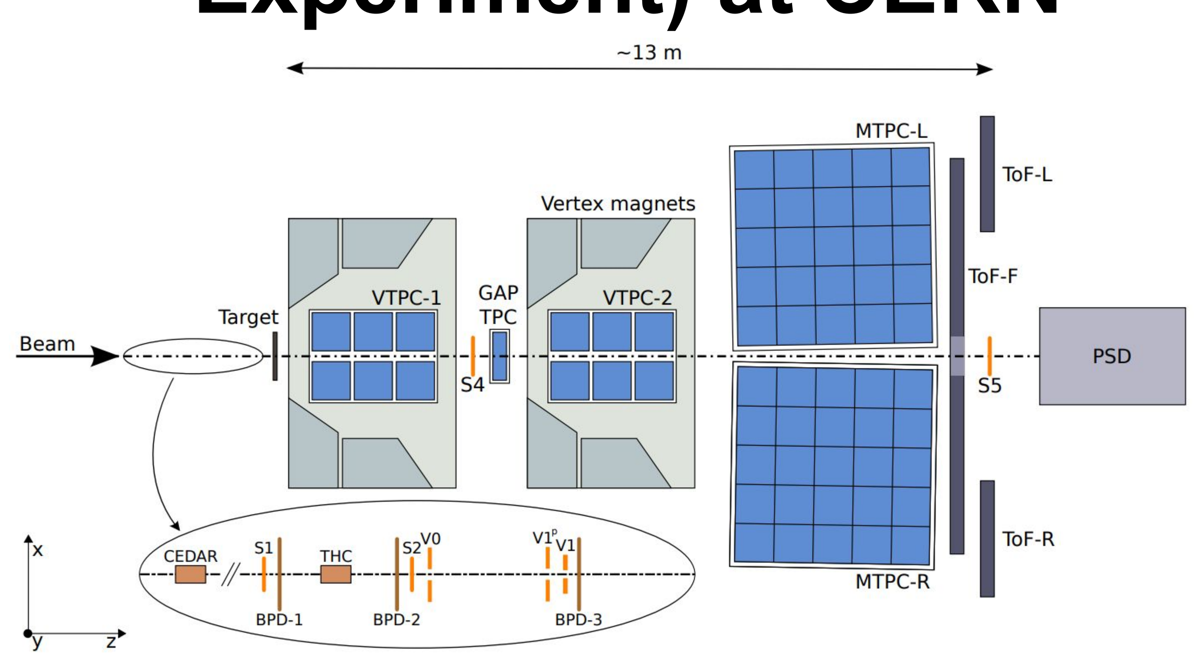
Motivation

NA61/SHINE at CERN-SPS has observed the first deuteron production in proton-proton interactions at 158 GeV/c ($\sqrt{s}$ = 17.3 GeV). This poster presents the analysis of these initial measurements, as well as comparisons with different nuclear formation models. The two most prevalent formation models, the thermal and coalescence models are based on different underlying physics. A better understanding of (anti)nuclei production mechanisms is needed, which drives the effort to analyze high-statistics data sets from fixed-target experiments.

Deuteron production measurements are important to understand cosmic-ray antinuclei. The detection of cosmic antinuclei holds the potential to be a breakthrough approach for identifying dark matter. The main source of cosmic antinuclei background are interactions between cosmic-ray protons and interstellar hydrogen gas. Gaining a deeper insight into deuteron production in p+p interactions is an essential first step in modelling these astrophysical processes.

Furthermore, modeling of light antinuclei production typically requires antiproton production cross sections as input. Precise antiproton measurements are crucial. This poster presents the preliminary measurements of antiproton spectra using the high-statistics p+p data sets. These data sets drastically reduce the statistical uncertainties, and significantly extend the phasespace coverage in rapidity and transverse momentum, as compared to previous results from NA61/SHINE. Moreover, updated proton, $\pi^{\pm}$ and $K^{\pm}$ spectra were also obtained as a by product of this analysis. These advancements can be employed to refine our understanding of proton-proton interactions.

NA61/SHINE (SPS Heavy Ion and Neutrino Experiment) at CERN



- Fixed-target, large acceptance hadron spectrometer, with coverage of the full forward hemisphere, down to p_T = 0.
- TPCs are main tracking detectors. ToF also placed downstream.
- Momentum resolution: ~1%, dE/dx energy resolution: ~4%.
- Particle identification using energy deposition (dE/dx) in the TPCs.

Proton-proton data sets

- More than 60 million recorded collisions over multiple years.
  - 30 million events after selection.
  - 750 million particle tracks → 65 million after event & track selection cuts.

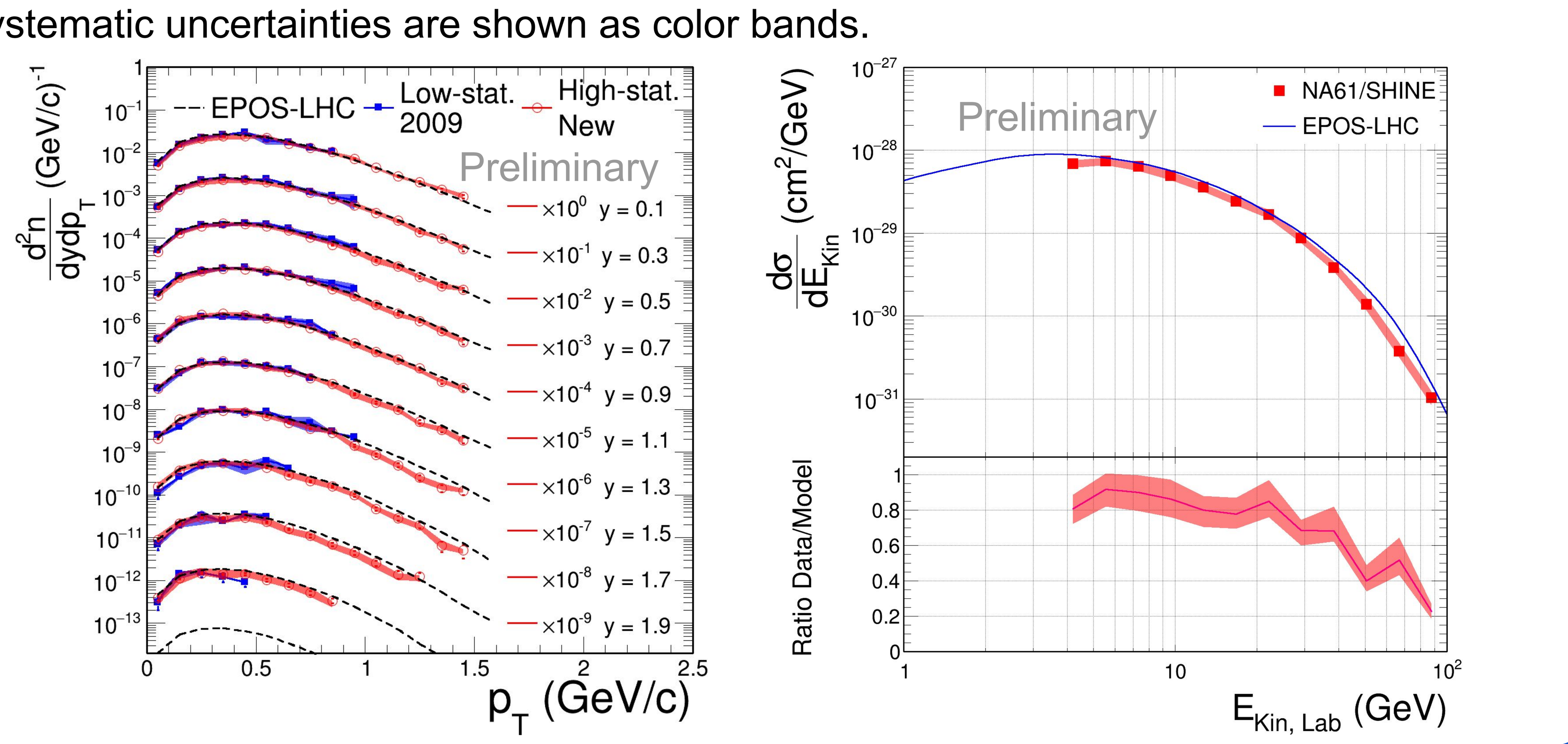
Run	Total p+p events (millions)	After event selection (millions)
2009	4	1
2010	44	16
2011	14	4

Already published in [Aduszkiewicz et al. Eur. Phys. J. C (2017) 77: 671]

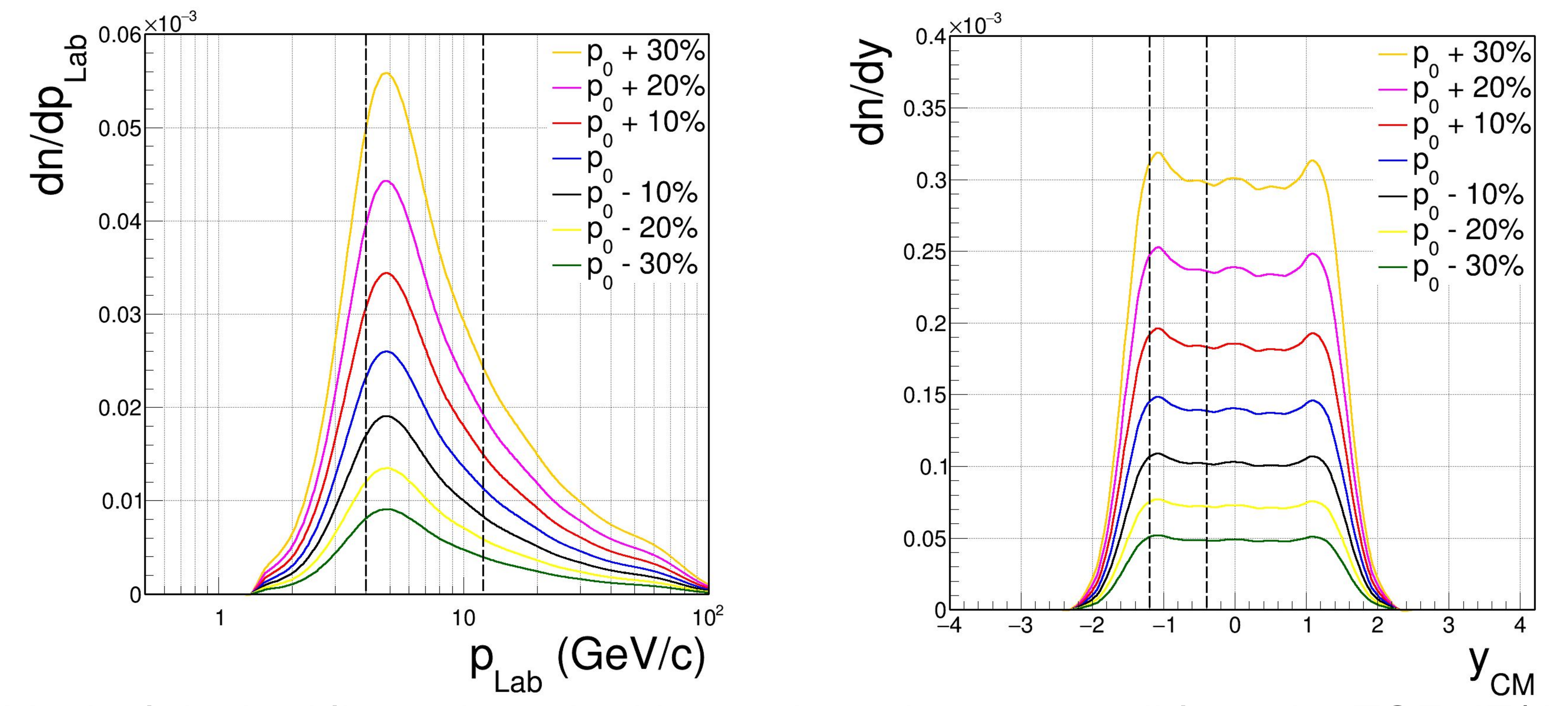
New results for antiprotons

Antiproton produced by strong interaction processes and in electromagnetic decays of produced hadrons in inelastic p+p interactions at 158 GeV/c ($\sqrt{s}$ = 17.3 GeV).

- Statistical uncertainties are smaller than the symbol sizes.
- Systematic uncertainties are shown as color bands.



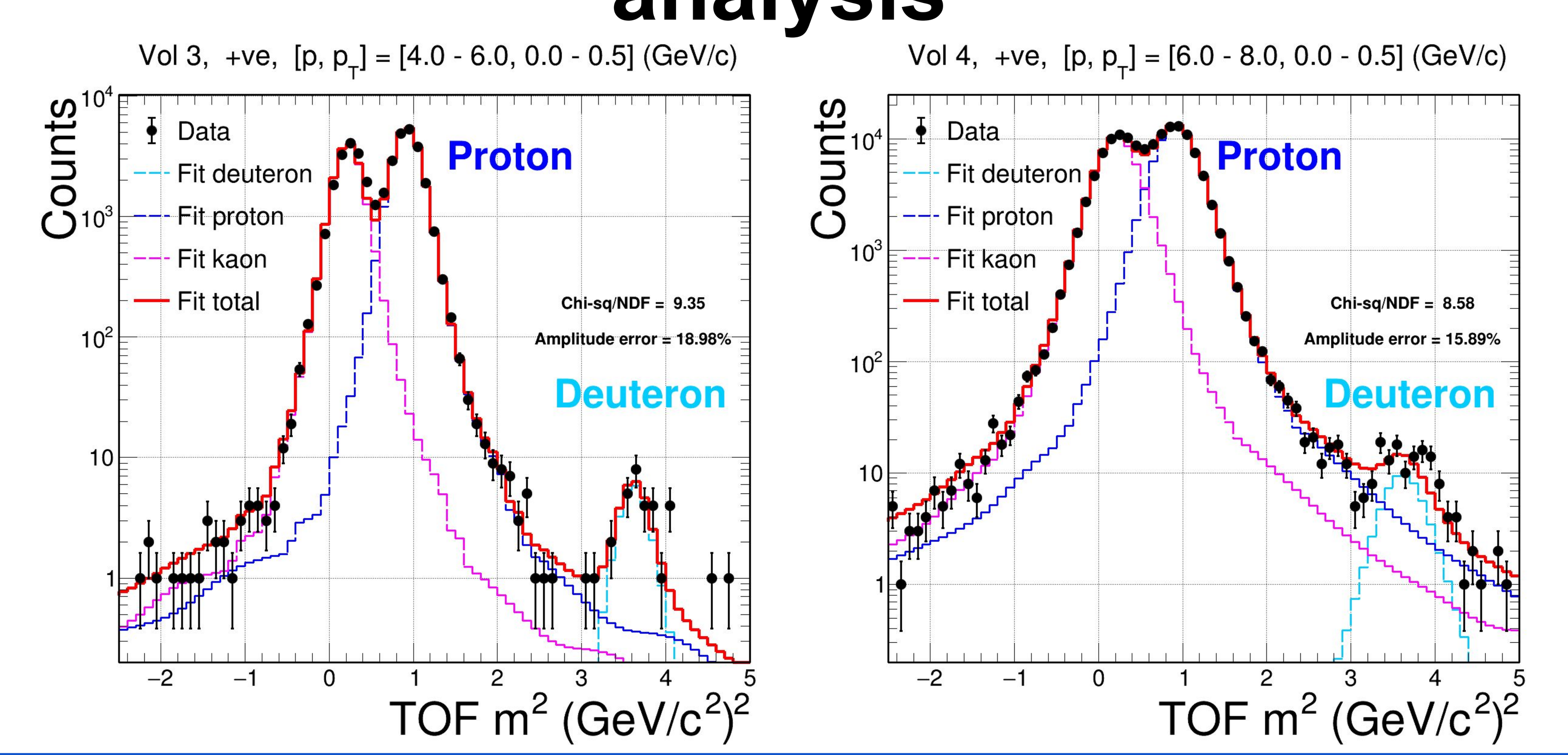
Predicted deuterons from the Coalescence model



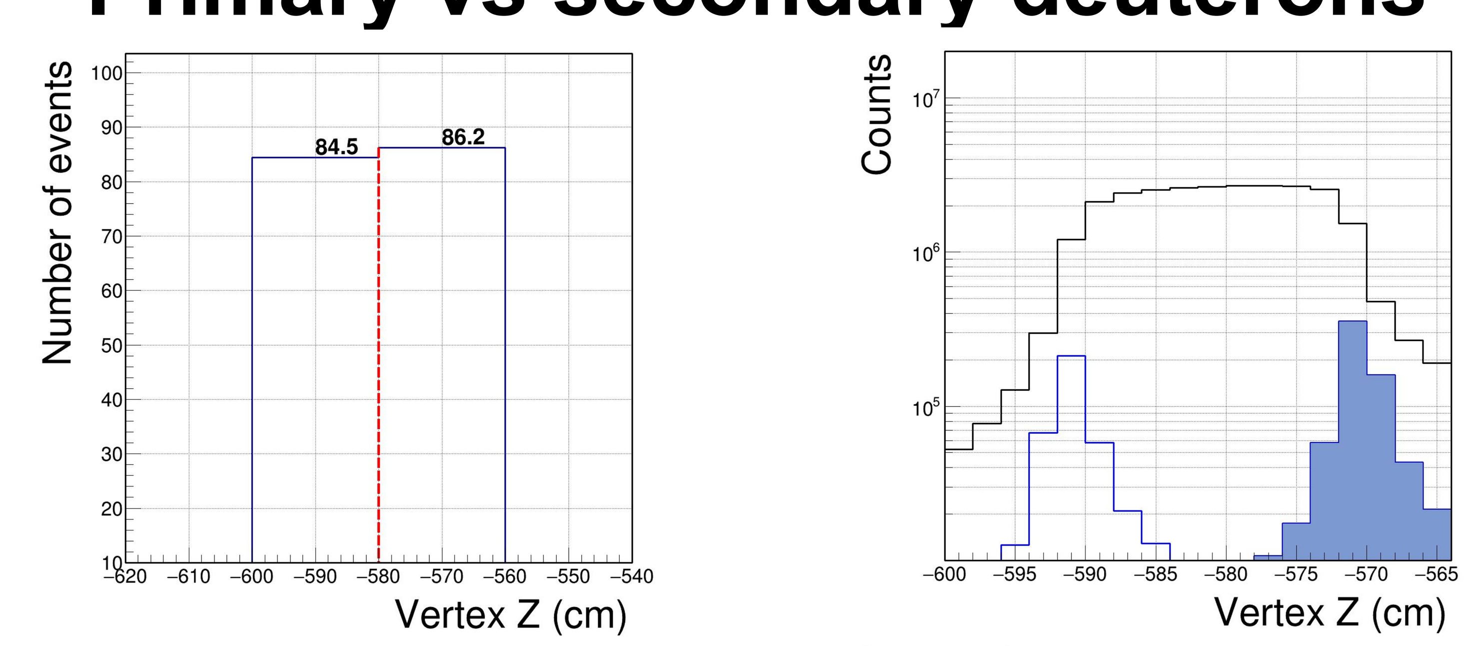
Vertical dashed lines show the kinematic regions accessible to the TOF-dE/dx analysis in NA61/SHINE

(Phys. Rev. D 98, 023012 2018, Phys. Rev. D 102, 063004 2020, CERN-THESIS-2023-051)

Fitted deuteron peaks in the ToF-dE/dx analysis



Primary vs secondary deuterons

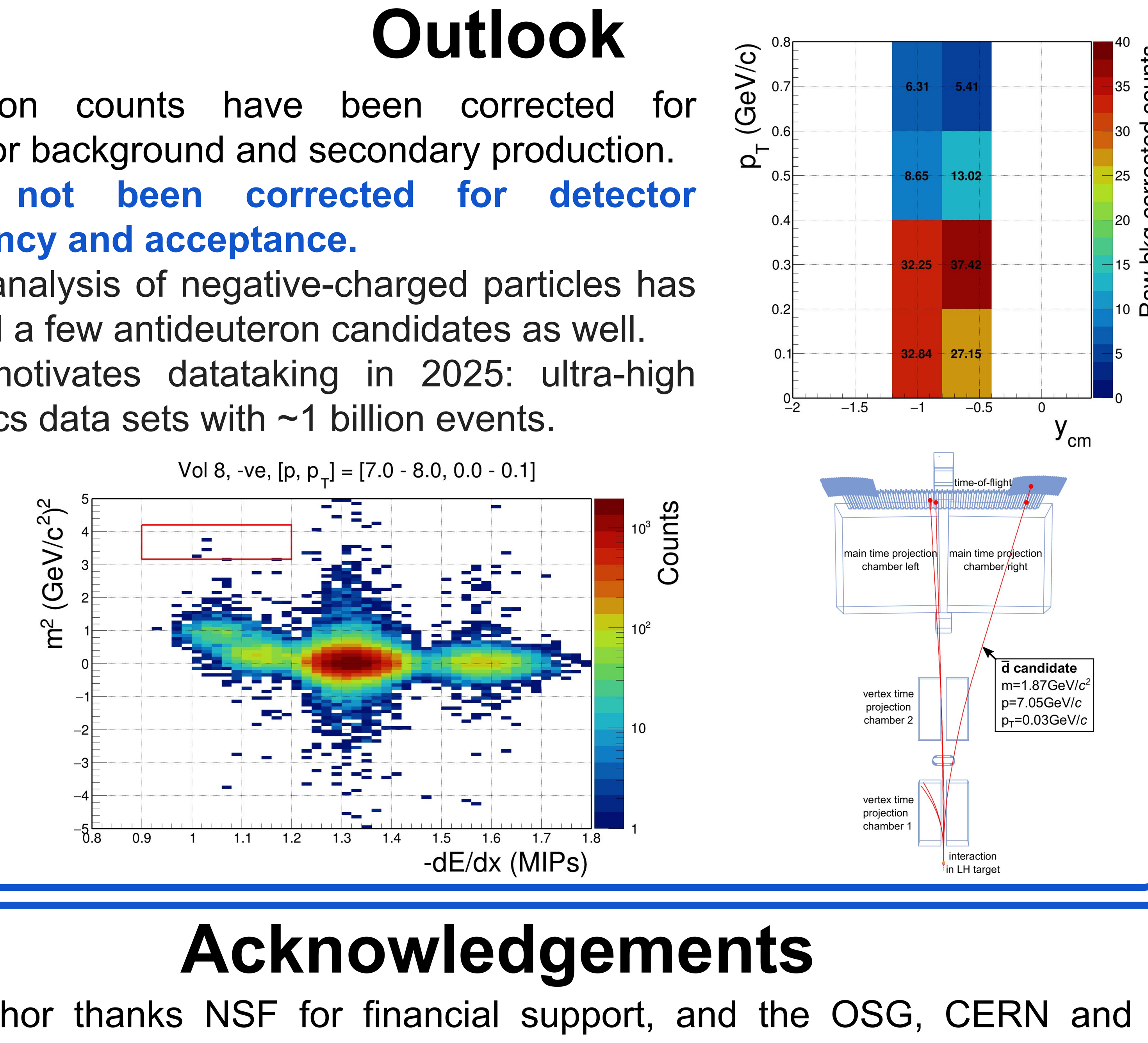


Check for excess deuterons produced downstream of target midpoint.

Check for deuterons produced by secondary particles interacting with the right target window of the LHT.

Outlook

- Deuteron counts have been corrected for detector background and secondary production.
- **Have not been corrected for detector efficiency and acceptance.**
- Initial analysis of negative-charged particles has yielded a few antideuteron candidates as well.
- This motivates datataking in 2025: ultra-high statistics data sets with ~1 billion events.



Acknowledgements

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