

Near-threshold Cross-section Determination for Coherent J/ψ Meson Photoproduction Off Deuteron

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Project Overview

Project: Experimental near-threshold cross-section determination for coherent J/ψ meson photoproduction off deuteron.

Motivation: Learn about transverse gluon distribution in deuteron.

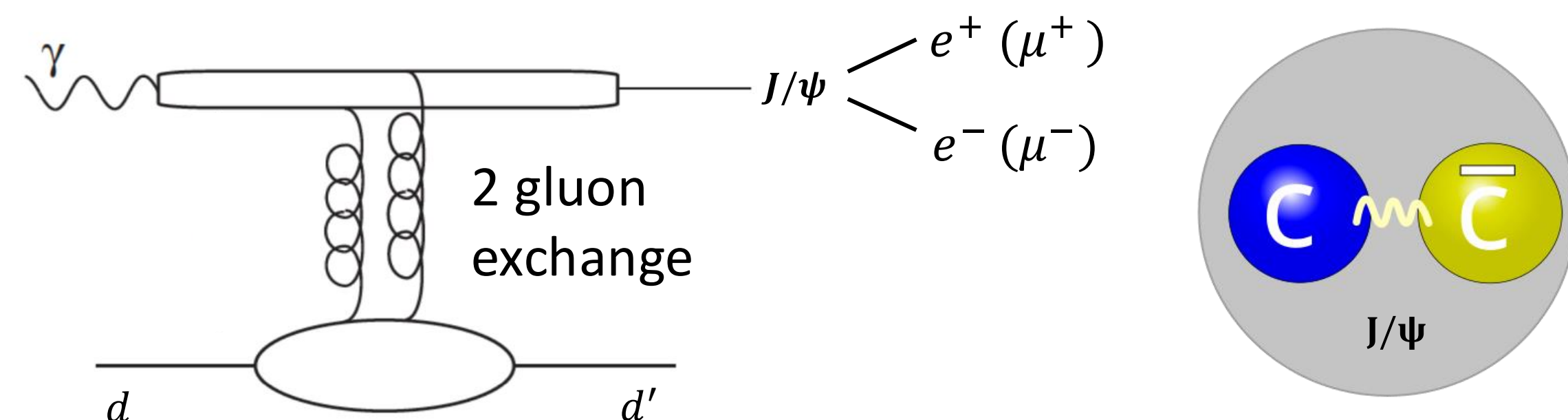
Reaction of Interest: $\gamma d \rightarrow J/\psi d'$.

Technique: $\gamma d \rightarrow J/\psi d'$ is measured in untagged quasi-real (virtual photon with very small virtuality) photoproduction.

Means: Data from Jefferson Lab E12-11-003B.

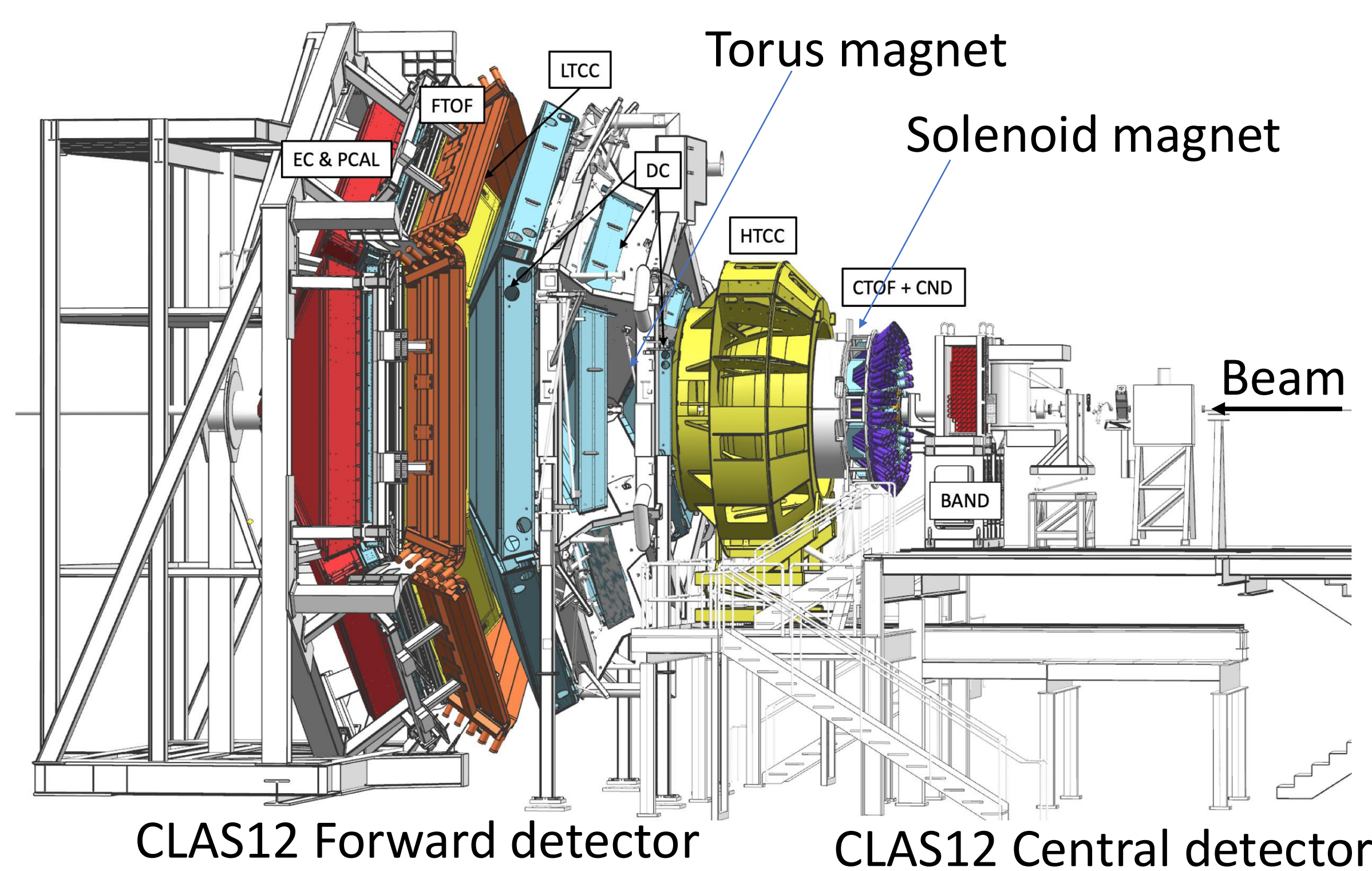
Project Goal: Estimate differential and/or total cross section.

Technique: J/ψ is reconstructed by means of its decay to an electron-positron pair and all final state particles are charged and are detected.



- The four-vector of the quasi-real photon is reconstructed by means of four-momentum conservation of all the detected final state particles.
- The four-vector of J/ψ is reconstructed by means of four-momentum conservation of lepton pair.

CLAS12 Detector



The CLAS12 Spectrometer at Jefferson Laboratory by V. D. Burkert

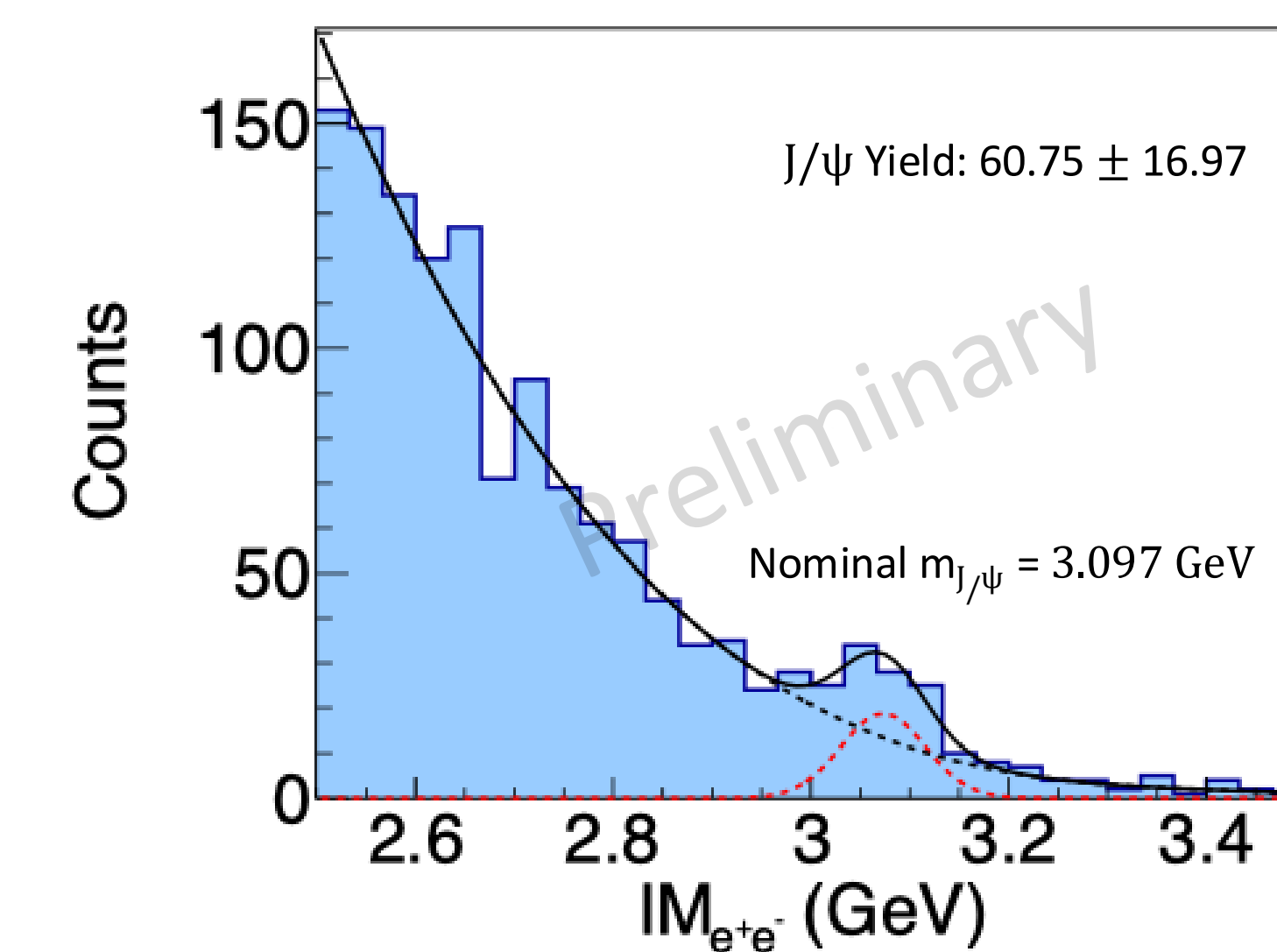
- Forward Detector (FD)**
 - Angle coverage: $5^\circ \leq \theta \leq 35^\circ$
 - High Threshold Cherenkov Counter (HTCC)
 - Torus magnet
 - Drift Chambers (DC)
 - Low Threshold Cherenkov Counters (LTCC)
 - Time-of-Flight (FTOF)
 - Electromagnetic Calorimeters (EC + PCAL)
- Central Detector (CD)**
 - Angle coverage: $35^\circ \leq \theta \leq 125^\circ$
 - Back Angle Neutron Detector (BAND)
 - Silicon Vertex Tracker (hidden)
 - Barrel Micromesh Tracker (hidden)
 - Central Time-of-Flight (CTOF)
 - Central Neutron Detector (CND)
 - Superconducting Solenoid Magnet

The E12-11-003B Experiment (2019-2020)

- This experiment studies quasi-real photoproduction of the J/ψ meson using a liquid deuterium (LD₂).
- The experiment is conducted using the CLAS12 detector with a 10.6 GeV electron beam incident on a 5 cm long liquid deuterium target.
- The analysis focuses on quasi-real photon interactions, where the scattered electron is not detected, corresponding to a virtual photon with very low momentum transfer ($Q^2 \approx 0$).

Current Work

J/ψ Signal Observed



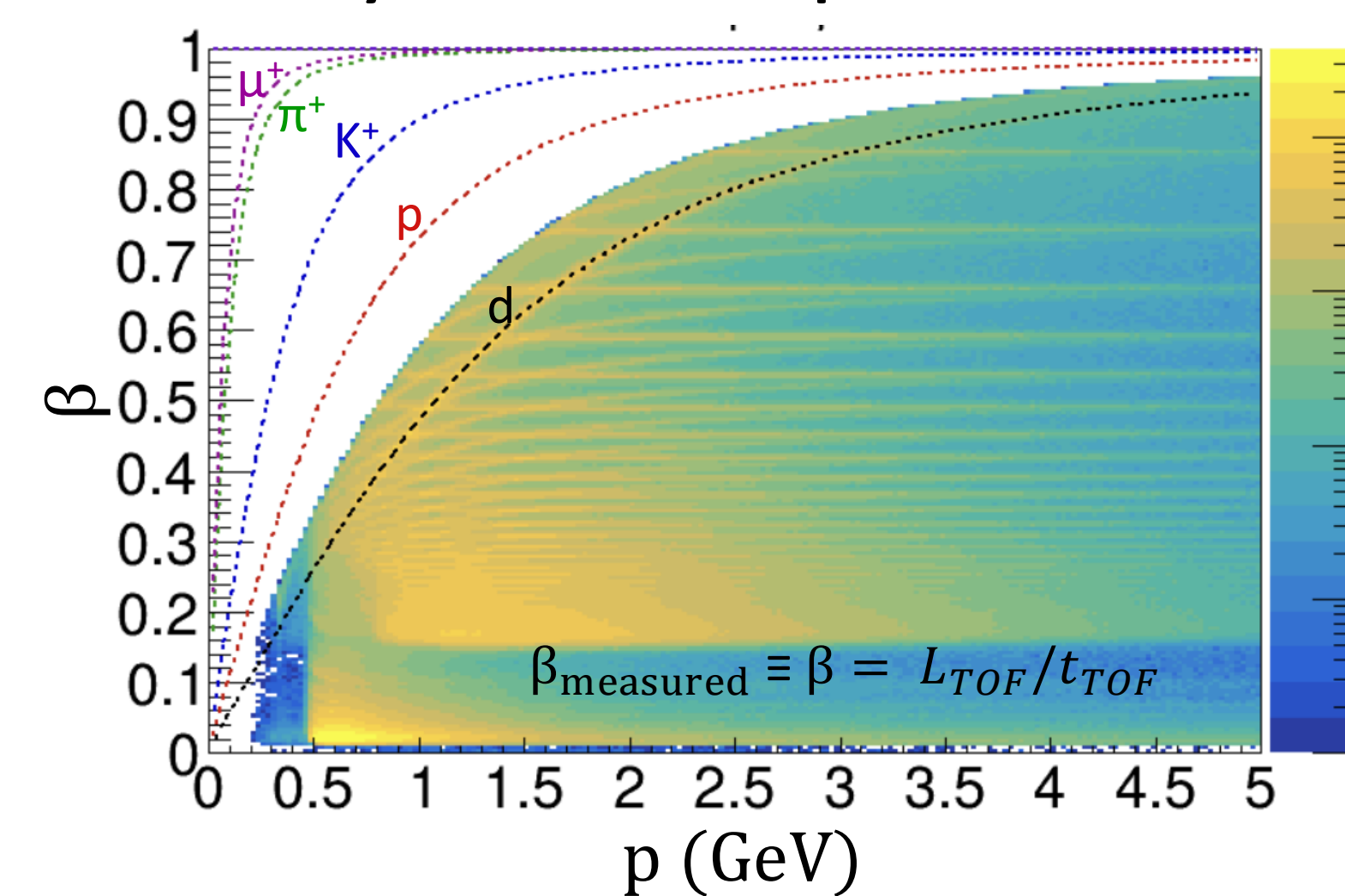
Event Selection:

- At least one e^- , at least one e^+ , and at least one good d
- The leptons are detected in the Forward Detector
- Quasi-real photoproduction: $ed \rightarrow e'd'e^+e^-$ with a forward-going, undetected (missing) e'
- $Q^2 < 5 \text{ GeV}^2$
- $|M_X^2| < 1 \text{ GeV}^2$

$$M_X^2 = (\vec{P}_e + \vec{P}_d - \vec{P}_{e^-} - \vec{P}_{e^+} - \vec{P}_{d'})^2, \text{ where we look for } X \equiv e'$$

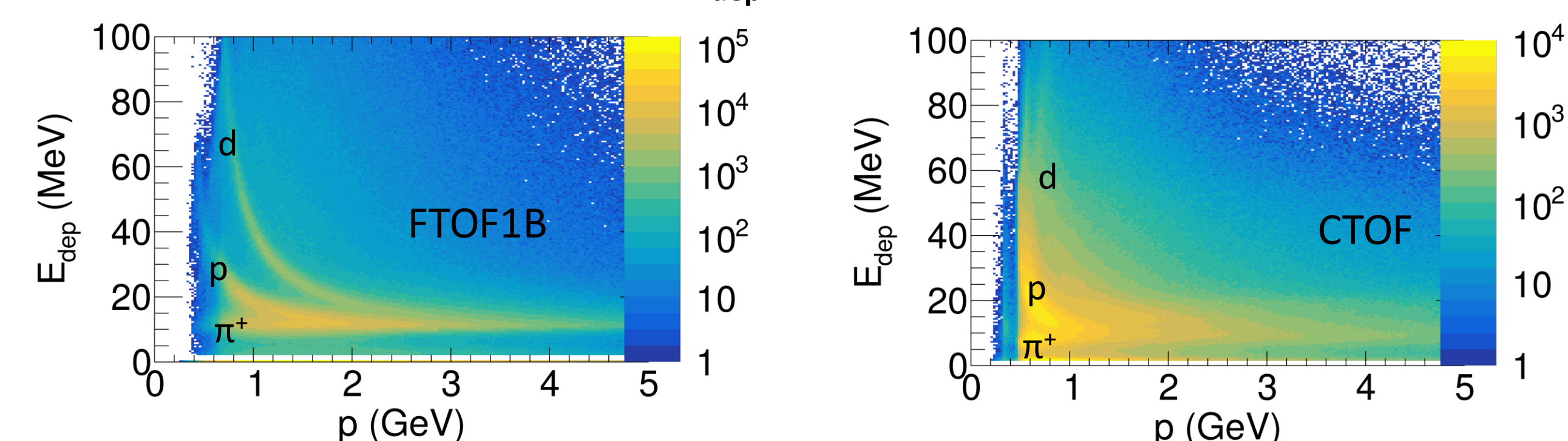
Accidental Background in Deuteron Sample

Primary PID Method: Speed vs Momentum



The TOF technique selects deuterons by applying a cut on $\beta(p)$. Substantial accidental background also passes the cut. The energy deposition in the TOF, $E_{dep}(p)$ can provide independent PID. Due to large energy straggling, a simple cut on $E_{dep}(p)$ is not viable.

Additional PID Information: E_{dep} vs Momentum

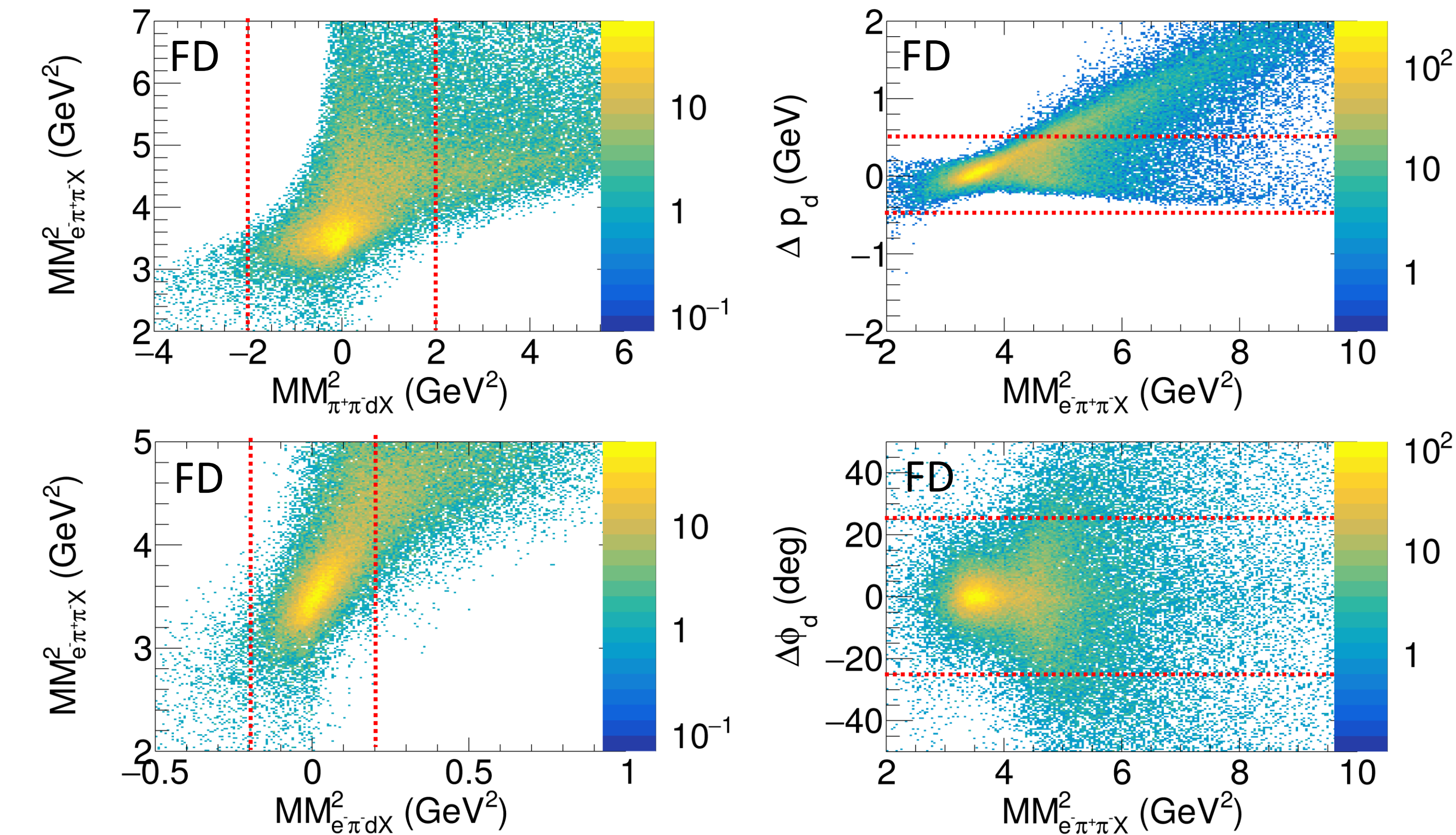


Alternatively, a neural network could be trained on clean deuteron and background samples to use simultaneously all PID variables to identify deuterons.

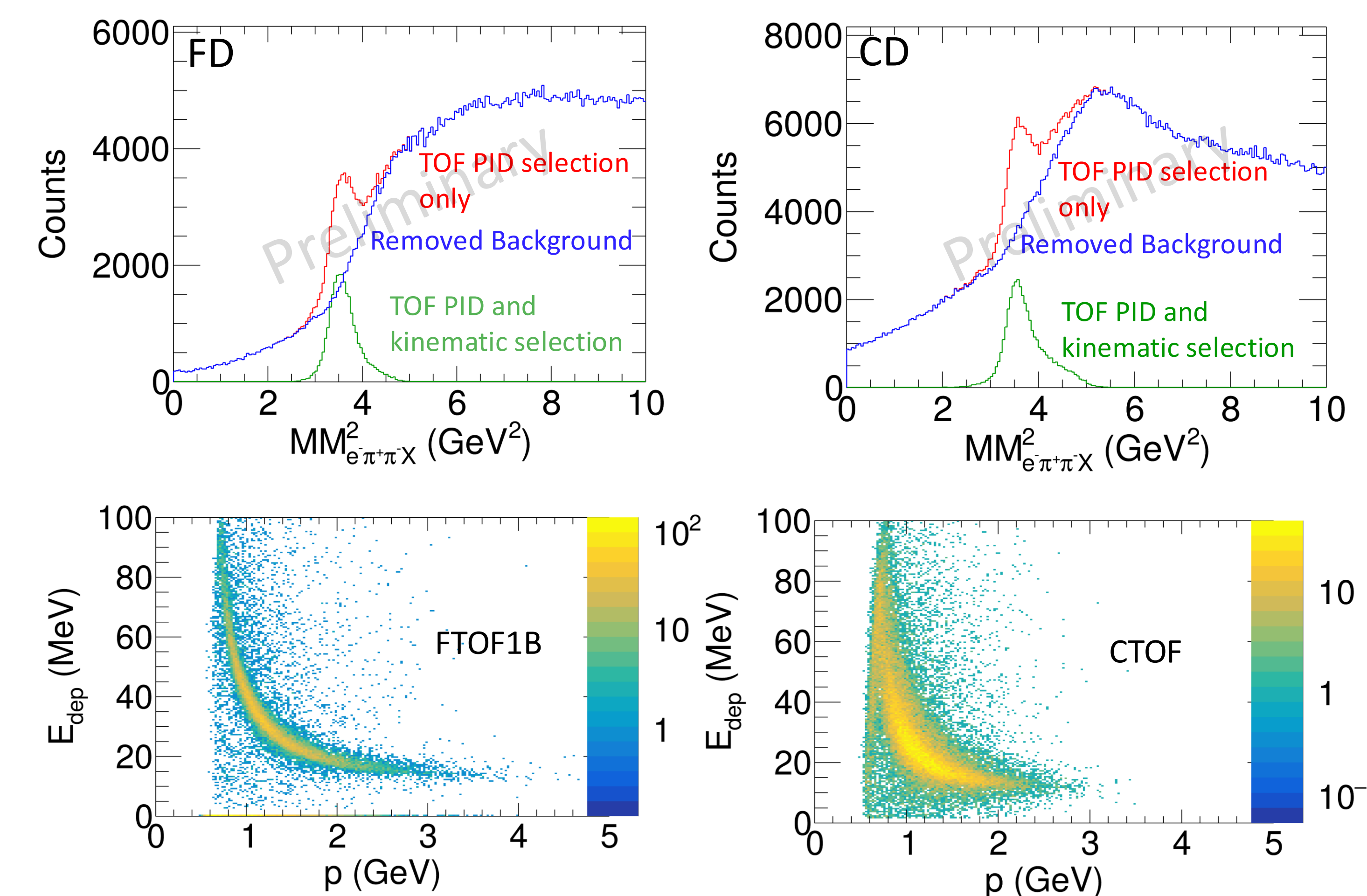
A clean high-statistics deuteron sample is aimed to be obtained from the same data set, from the reaction $ed \rightarrow e'\pi^+\pi^- d'$, where all final state particles are detected. A large set of kinematic cuts can be defined to remove the background.

Obtaining Background-Free Deuterons: Analysis of $ed \rightarrow e'\pi^+\pi^- d'$

Kinematic cuts are identified by treating one of the final-state particles as “missing” and calculating its four-momentum by means of four-momentum conservation. A comparison of the calculated momentum components with the measured ones provides a set of kinematic cuts. Sets of cuts were determined using all final-state particles, for CD as well as FD.



Background-Free Deuteron Sample



In both, FD and CD, the kinematic selection reduces the background to an acceptable level. We thus have a sufficiently clean deuteron sample for training.

Next: to obtain clean background samples from the data; to verify results by means of detector simulation.

Acknowledgement

I acknowledge the guidance from my advisor Prof. Yordanka Ilieva as well as Prof. Steffen Strauch, Prof. Pawel Nadel-Turonski, Dr. Matthew Nicol, and Dr. Krishan Gopal.

This work has been supported in part by NSF PHY-2412777.