Extension of Quasi-Elastic dd Simulation to Different Energies

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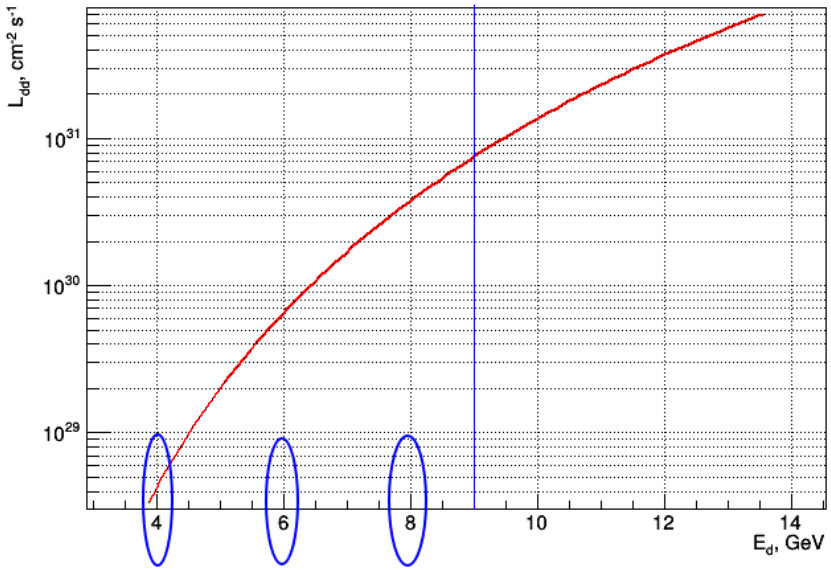
Custom Quasi-Elastic Generator Strategy

- Start from 4-momenta of two colliding deuterons
- Generate spectator n in the rest frame of fractured deuteron ($p_z > 0$ for convenience) based on S-wave function - boost n to lab frame
- Accept events for neutrons reaching ZDC (polar angle cuts)
- Remaining p and d undergoes elatsic scattering
- Boost to COM frame of $p + d$, generate events according to Glauber unpolarized elastic cross-section
- Boost scattered p,d back to lab frame - accept events when p,d tracks reach MVD (polar angle cut)

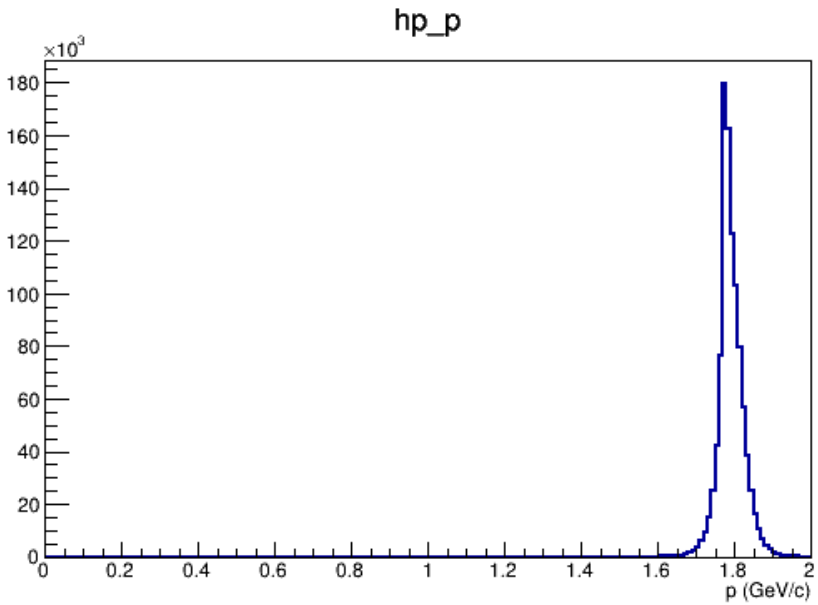
Custom Generator and SpdRoot

- This method is efficient - standalone root macro can generate 1 Million events within a few minutes
- To reconstruct events in SpdRoot - use a dummy generator class that reads 4-momenta of n,p,d and feeds to the SpdPrimaryGenerator

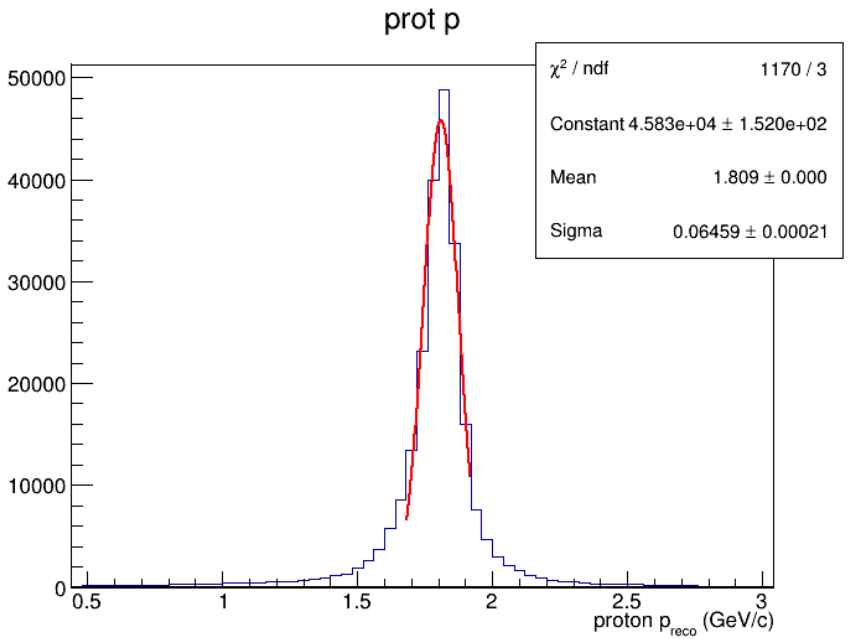


Study extended to three different energies : $\sqrt{s_{dd}} = 8, 12, 16$ GeV

Generated and Reconstructed Protons for $\sqrt{s_{dd}} = 8$ GeV

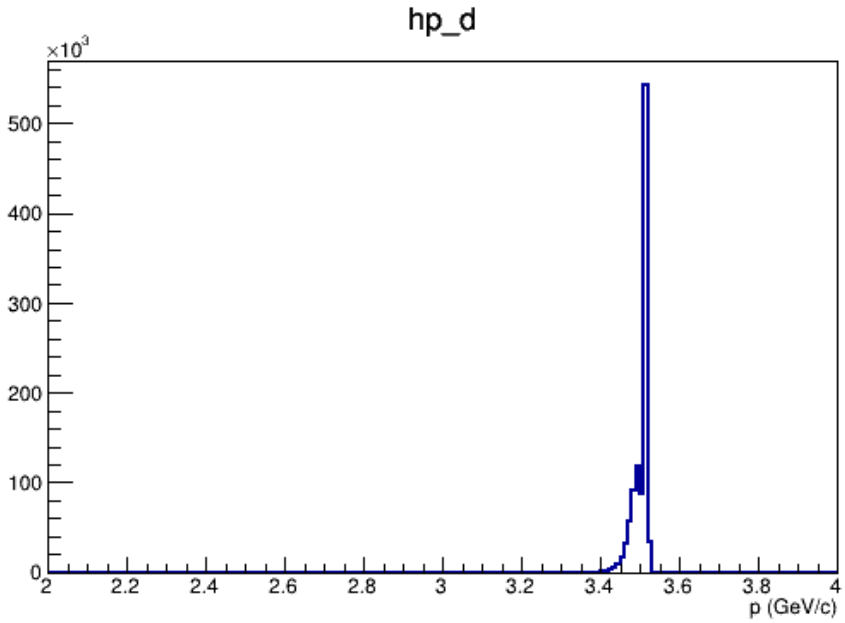


Generated protons

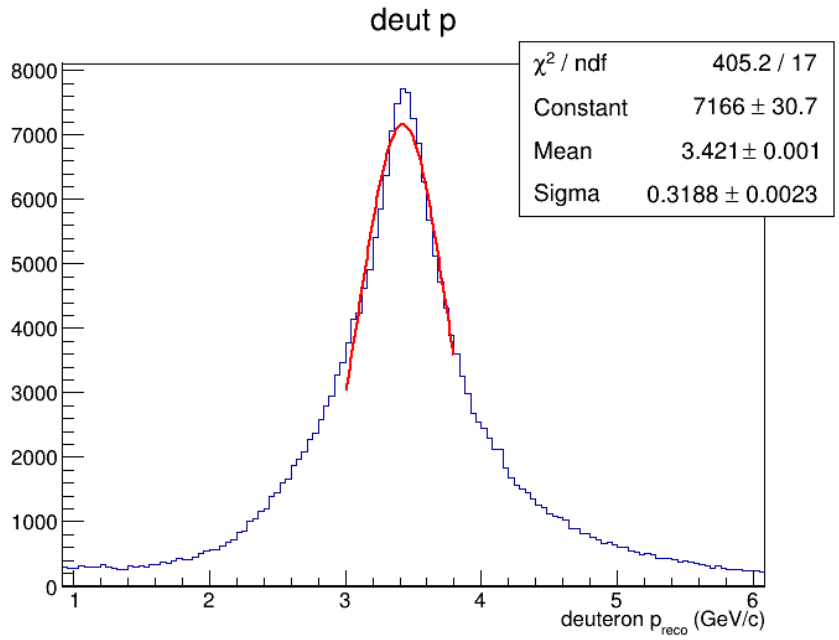


Reco Protons : $\sigma_p \sim 65$ MeV/c

Generated and Reconstructed Deuterons for $\sqrt{s_{dd}} = 8$ GeV



Generated deuterons

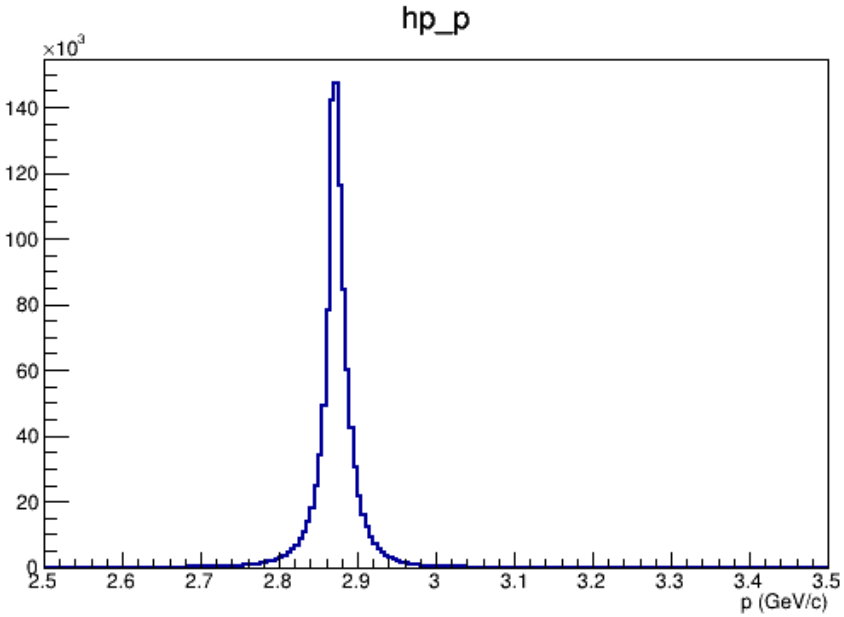


Reco Deuterons : $\sigma_p > 320$ MeV/c

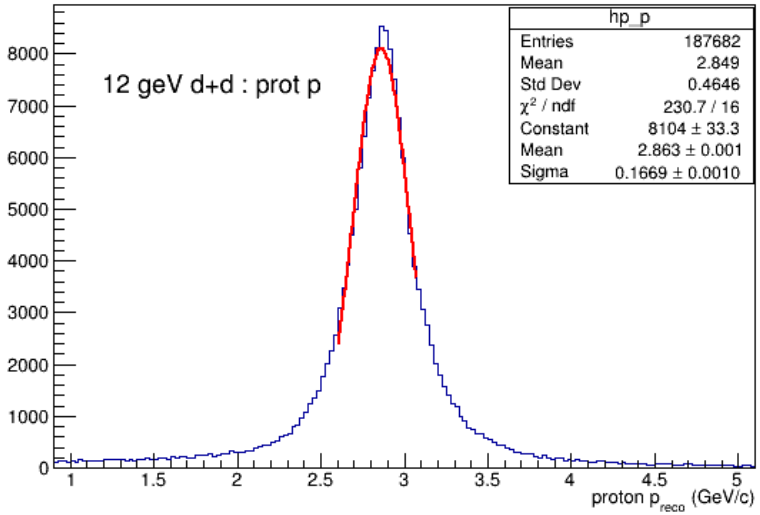
Notice the terrible momentum resolution for deuterons

$\sigma_p/p \sim 9\%$, offset (gen-reco) ~ 0.08 GeV/c

Generated and Reconstructed Protons for $\sqrt{s_{dd}} = 12$ GeV

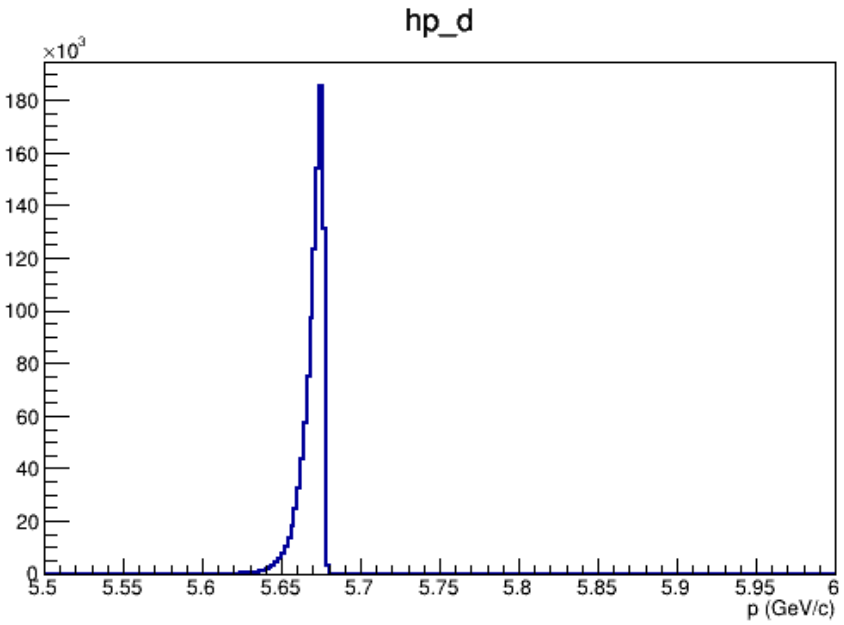


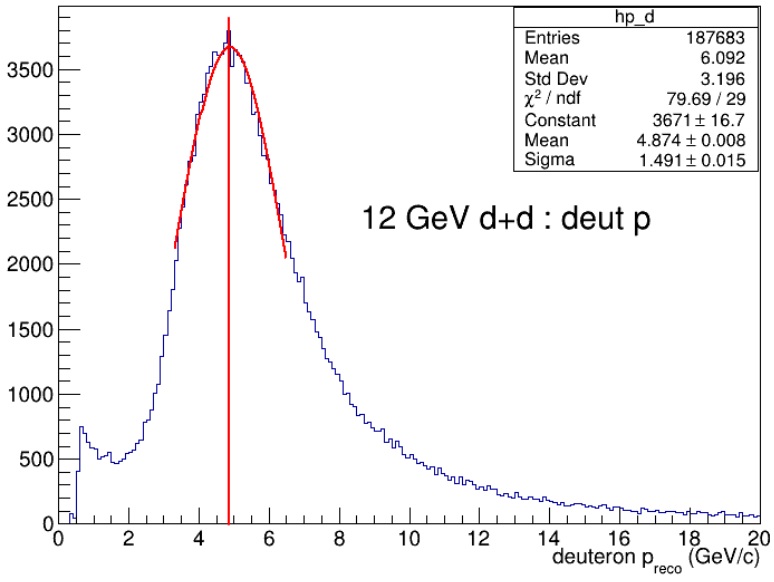
Generated protons



Reco Protons : $\sigma_p \sim 170$ MeV/c

Generated and Reconstructed Deuterons for $\sqrt{s_{dd}} = 12$ GeV



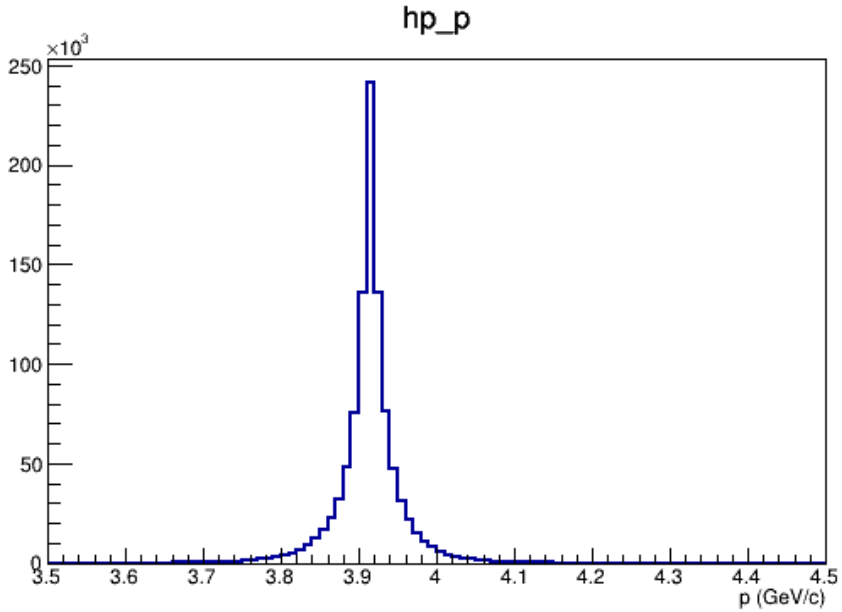


Generated deuterons

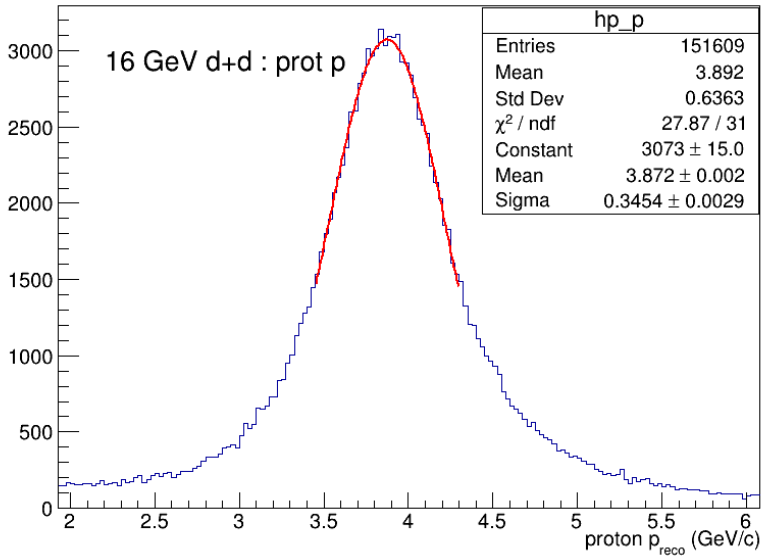
Reco Deuterons : $\sigma_p > 1.5$ GeV/c

$\sigma_p/p \sim 26\%$, offset (gen-reco) ~ 0.8 GeV/c

Generated and Reconstructed Protons for $\sqrt{s_{dd}} = 16$ GeV

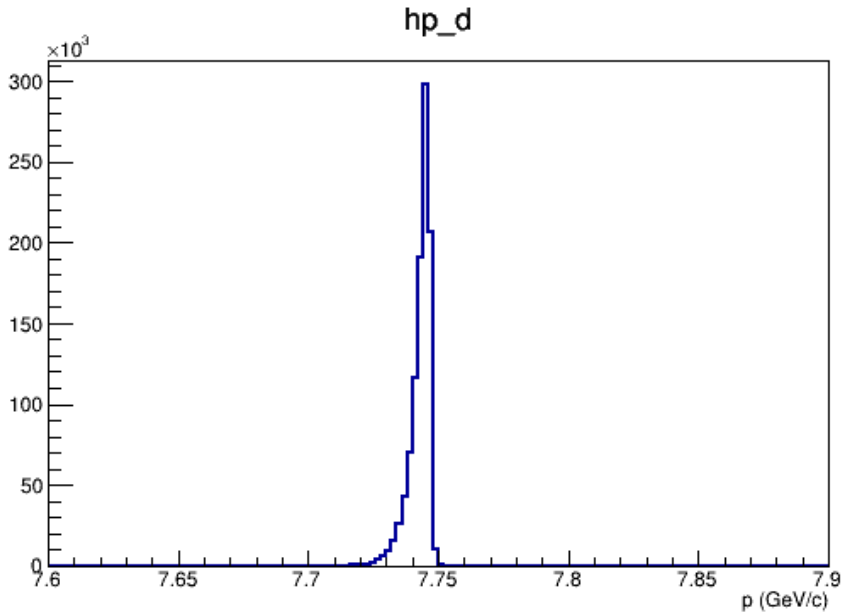


Generated protons

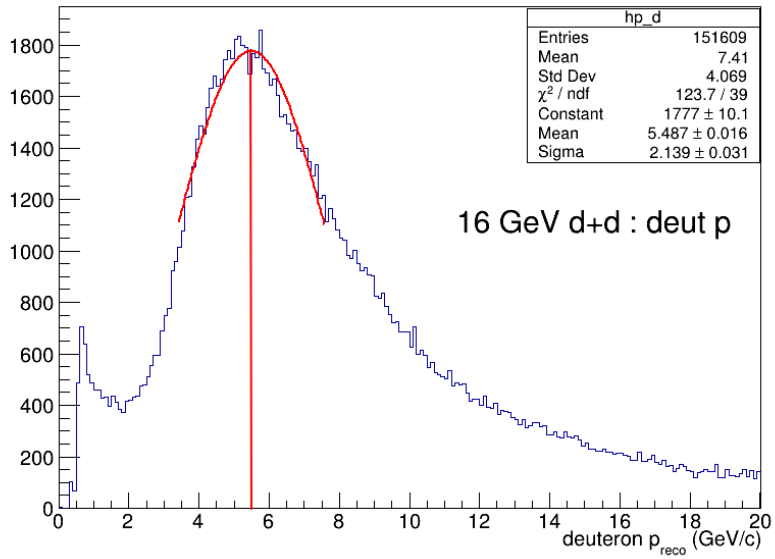


Reco Protons : $\sigma_p \sim 345$ MeV/c

Generated and Reconstructed Deuterons for $\sqrt{s_{dd}} = 16$ GeV



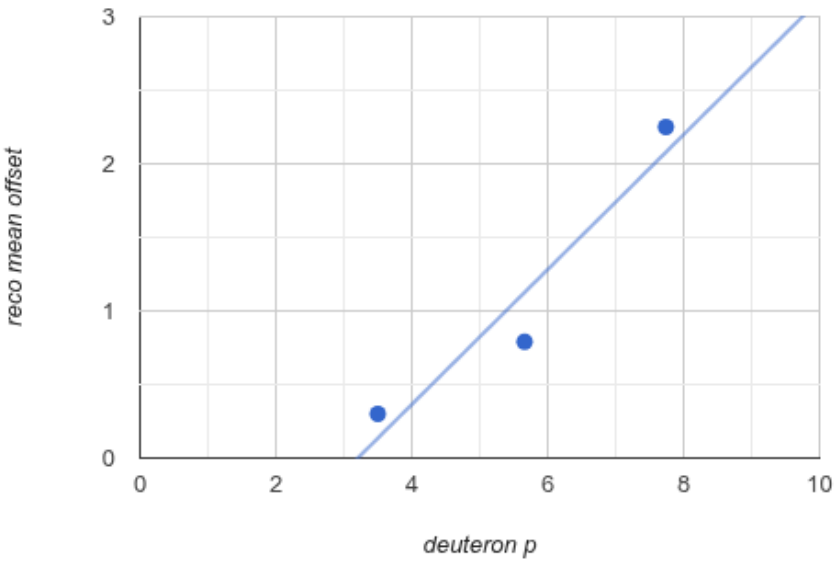
Generated deuterons



Reco Deuterons : $\sigma_p > 2.1$ GeV/c

$\sigma_p/p \sim 28\%$, offset (gen-reco) ~ 2.29 GeV/c

Worsening Deuteron Reconstructed Momenta

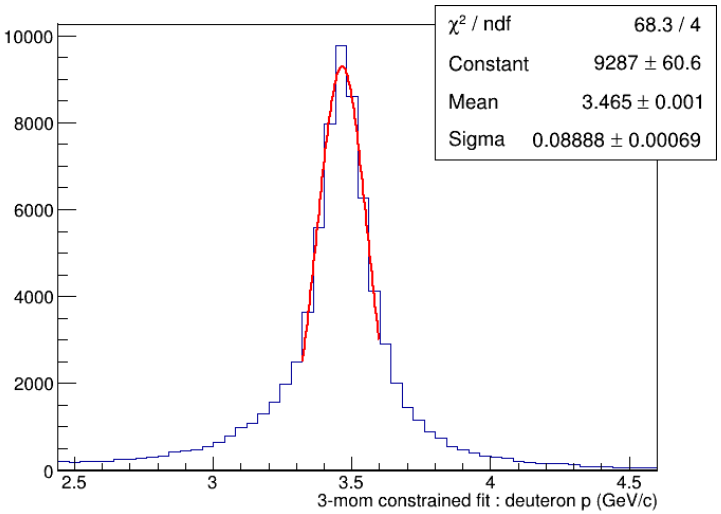


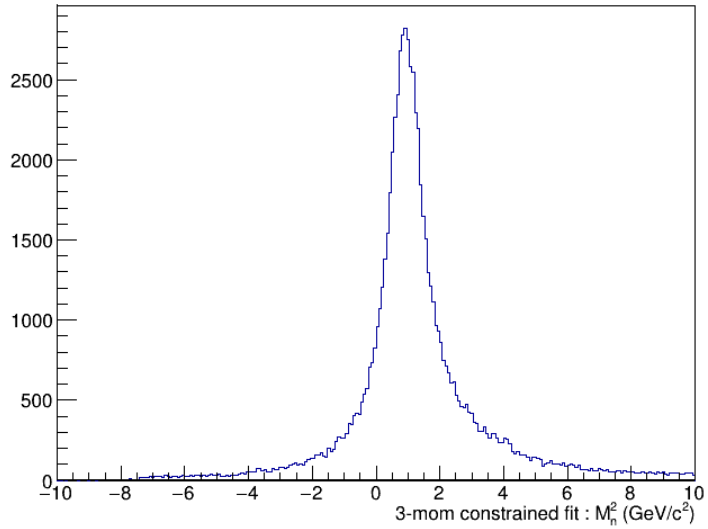
Deuteron momentum offset

- Reconstructed deuteron momentum gets worse
- Not only does the resolution gets worse
- But we also see a (-)ve offset, momentum is underestimated systematically
- Effect increases (almost) linearly
- Remember, these are very low polar angle tracks

Kinematic Fit Example : $\sqrt{s_{dd}} = 8$ GeV

Fitted deuteron momentum

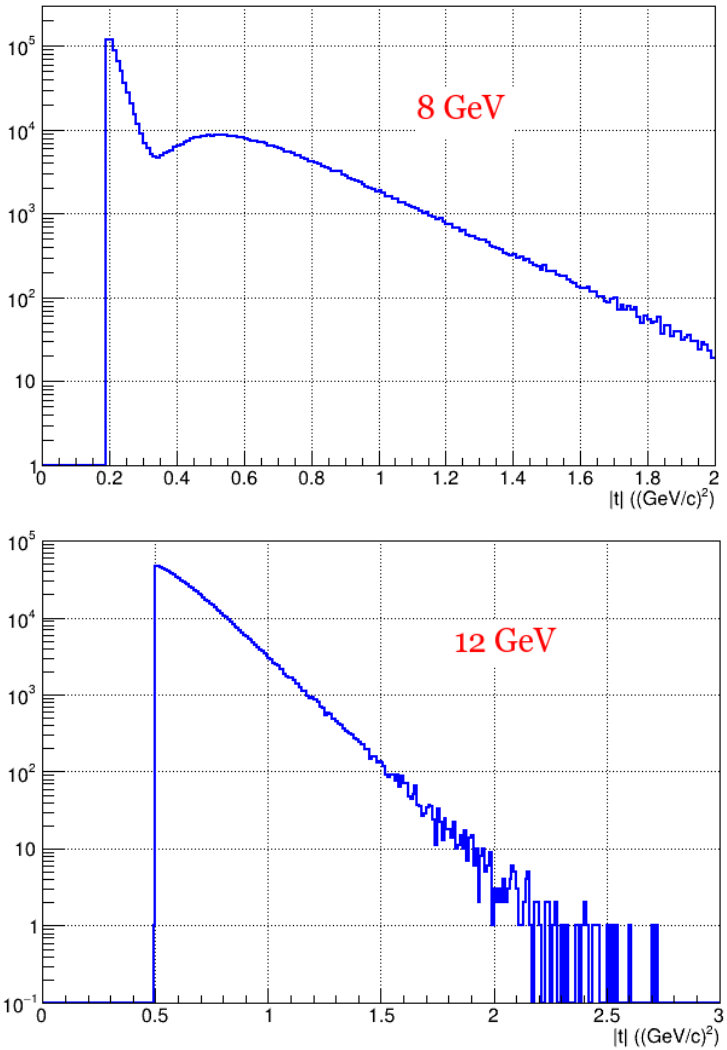


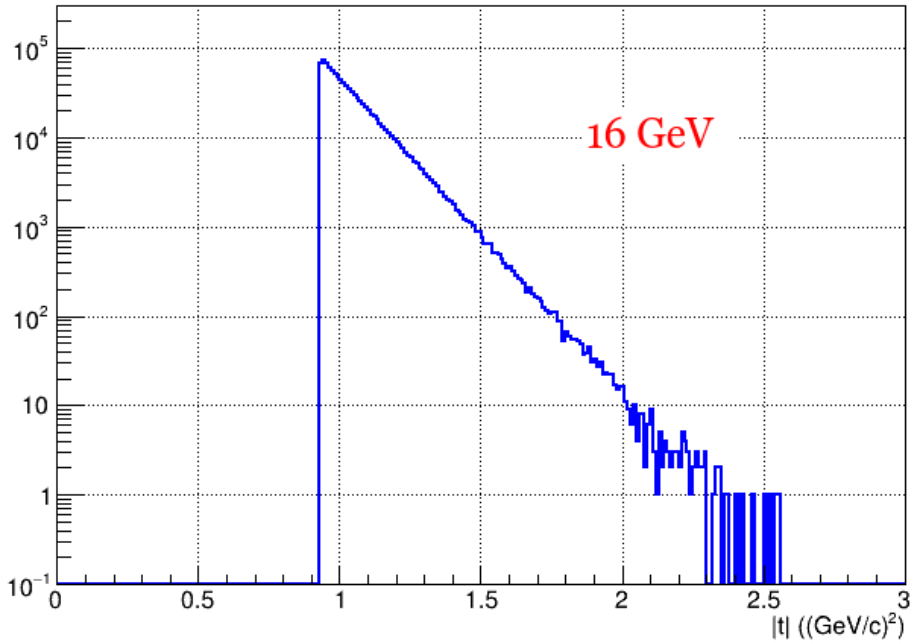


Fitted neutron mass-squared

- Kinematic fit with Lagrange multipliers with 3-momenta constraints(BES-III technique adapted by I. Denisenko)
- Takes into account neutron directions from ZDC
- Distribution of neutron mass - not normalized - can be used for selecting signal from background
- Further fit (i.e. FUMILI) can be applied AFTER selecting signal events with n,p,d final state

Comparison of $p + d$ System Momentum Transfer



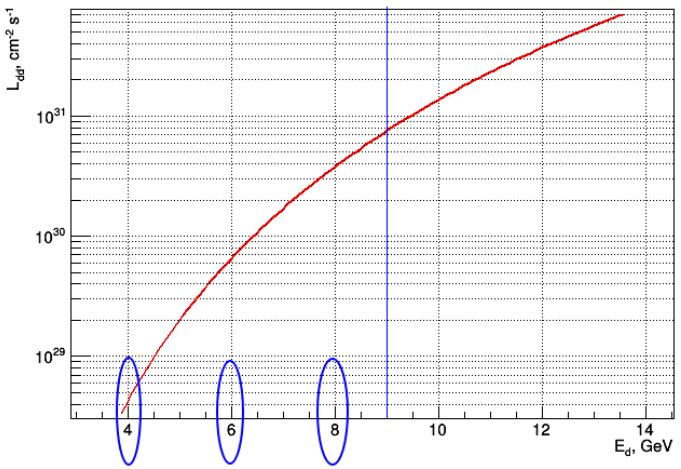


- Detected momentum transfer $|t|$
- Starts from 0.2, 0.5, 0.9 $(\mathrm{GeV}/c)^2$ for 8, 12, 16 GeV collisions respectively

Estimates Details : $\sqrt{s_{dd}} = 8$ GeV

- FTF generator : $\sigma_{dd}^{inel} \sim 250$ mb, Pythia8 : $\sigma^{tot} \sim 160$ mb
- (Custom) generated signal event : $\sigma_{dd}^{sig} \sim 45.6\ \mu$b
- (Custom) generator efficiency ~ 0.2 (geom. acc. of neutron)
- For symmetric spin config., factor of 2 gain
- Assuming $\mathcal{L}_{dd} \sim 4.5 \times 10^{28}$ cm^{-2} s^{-1} for $\sqrt{S_{dd}} = 8$ GeV : for every month of 'data recording' :
  1. 10 billion all d+d events
  2. 300 000 signal events produced
  3. 17k signal events detected (5% detection efficiency)

Estimate of counts for Different Energies



Event count for 1 month of 'data recording' (2σ mass window, one deuteron break up) :

- 8 GeV d+d : $\sigma_{dd}^{sig} \sim 45.6\ \mu$b, $\mathcal{L}_{dd} \sim 4.5 \times 10^{28}$ cm^{-2} s^{-1}, $\epsilon_{det} \sim 5\%$, $\epsilon_{gen} \sim 0.2$
- Estimated detected count (2σ m_n window) : 17100
- 12 GeV d+d : $\sigma_{dd}^{sig} \sim 4.5\ \mu$b, $\mathcal{L}_{dd} \sim 6.5 \times 10^{29}$ cm^{-2} s^{-1}, $\epsilon_{det} \sim 10\%$, $\epsilon_{gen} \sim 0.3$
- Estimated detected count (2σ m_n window) : 72 900
- 16 GeV d+d : $\sigma_{dd}^{sig} \sim 0.94\ \mu$b, $\mathcal{L}_{dd} \sim 3.8 \times 10^{30}$ cm^{-2} s^{-1}, $\epsilon_{det} \sim 10\%$, $\epsilon_{gen} \sim 0.4$
- Estimated detected count (2σ m_n window) : 120 320

Trouble With Background Study

- FTF event generator included in the current SpdRoot does not generate d due to some Geant4 version dependent bug - quick fix generator separately compiled
- Limited $d + d$ at $\sqrt{s_{dd}} = 8$ GeV inelastic data from FTF - does not show any background in the kinematic range of interest - requiring neutron track in ZDC removes most random p-d combinations
- Should check for background in larger data sets with FTF and/or Pythia8

Outlook

- We have an efficient method to generate quasi-elastic $d + d$ events
- We have (rough) estimates of signal events produced and detected
- Need to test for possible background in large $d + d$ minbias data
- Glauber elastic cross-section rises exponentially at low $|t|$, we lose most low $|t|$ tracks due to our limitation of detecting low angle tracks with high accuracy
- MVD end-cap may benefit this study - Artem Vasyukov is trying to implement MVD end-cap in SpdRoot so we can test quantitatively
- With increasing energy, we can get increased statistics but also higher range of observed $|t|$ - what's the best range of measurement for Yuriy Uzikov's proposal?

Thank You