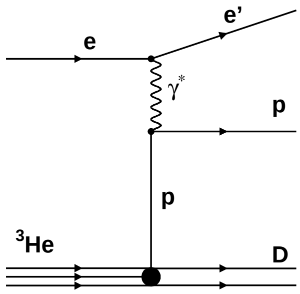
N.Pivnyuk, ITEP.
Trento, Italy. July–2005.

Fast deuteron formation in electron scattering off ^{3}He $e\ ^3He \to e'dp$ at high momentum transfer

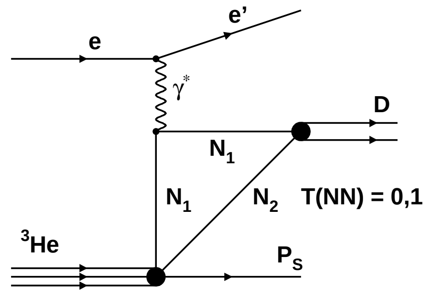
for CLAS collaboration

Fast deuteron formation is studied at initial energies E_0 = 1.16, 2.26 GeV and in the range of momentum transfer $p_{\gamma^\star} \sim$ 0.4 – 1.5 GeV/c. Momenta spectra and angular distributions are studied in kinematical region where the deuteron absorbs the major part of virtual photon momentum $p_{\gamma^\star}$, and plays the role of leading particle with momentum $p_d \sim$ 0.4 – 1.5 GeV/c. Like–uniform proton emission angular distributions and like–uniform Treiman–Yang angle distributions in the reaction $e^3He \to e'dp$ at $p_p <$ 0.2 GeV/c , could be the strongest indication that protons are mostly of a spectator nature. This could mean that we observe quasi–free electron scattering off very close short range nucleon correlation where the mutual distance between nucleons is of the order of $\sim 0.2\ f$. Detailed theoretical calculations are badly needed in this field.

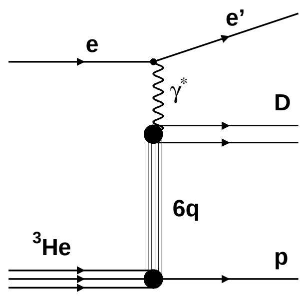
“REGULAR” , “EXOTIC” and



a)

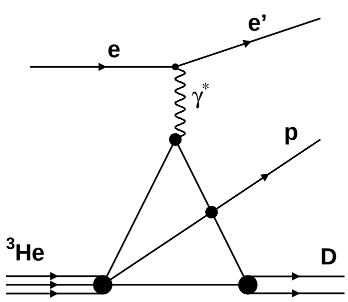


b)

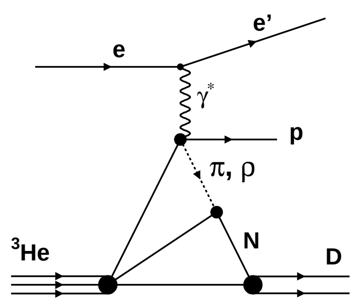


c)

“SIMPLEST FSI” channels



a)



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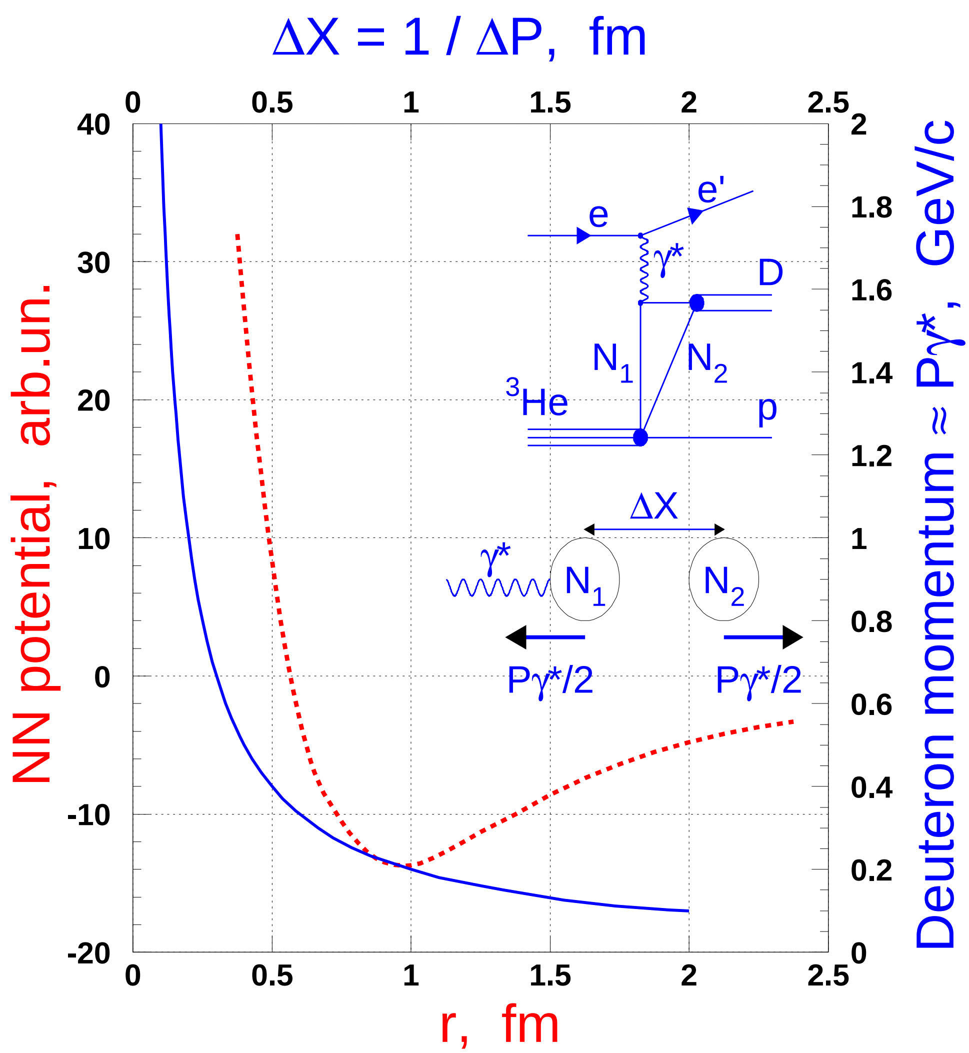
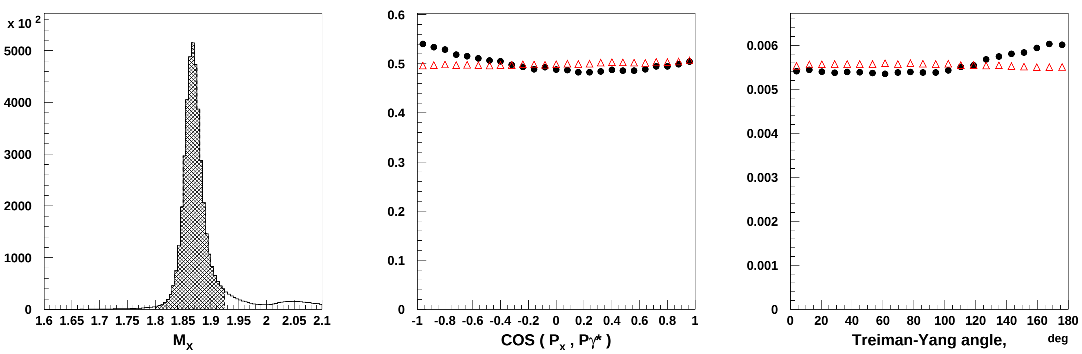


$$p_d \sim \mathbf{1\ GeV/c} \quad \rightarrow \quad r_{NN} \sim \mathbf{0.2\ f}$$

e ^{3}He → e' p X – no problems anticipated with acceptance in CLAS

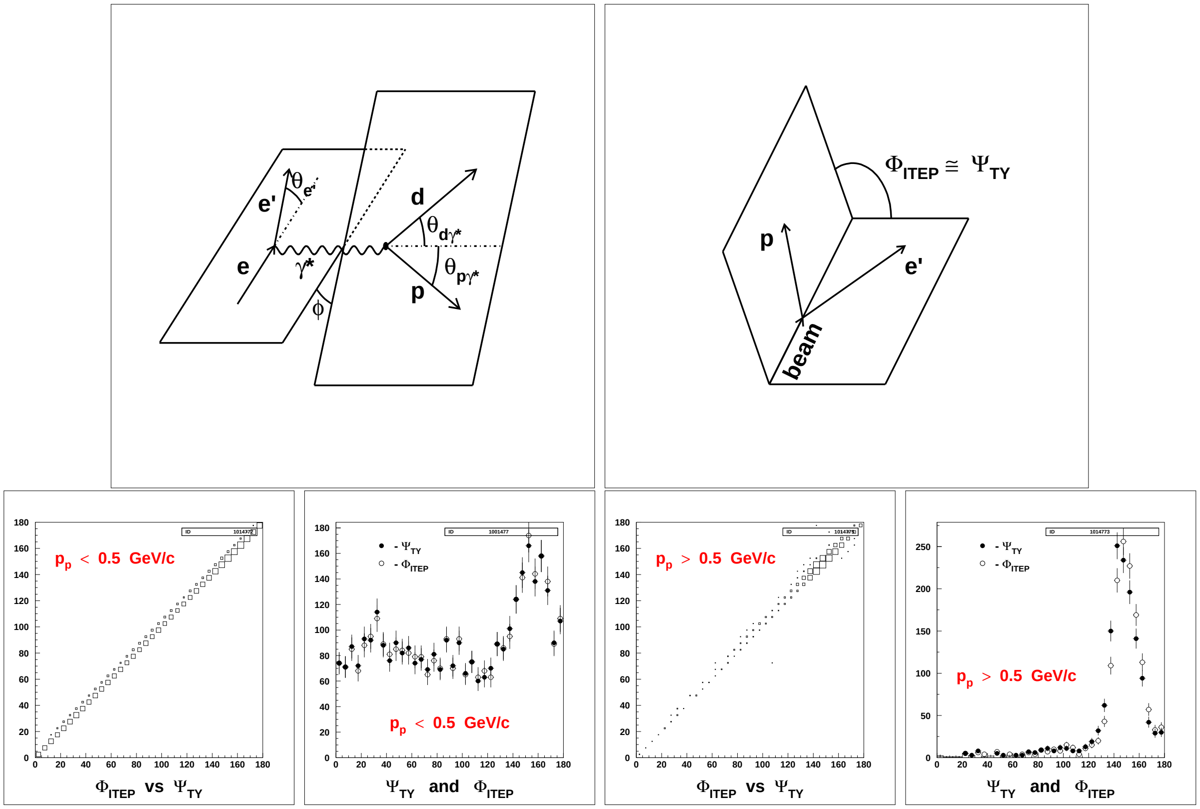
In ITEP in late 1960s I.Shapiro, V.Kolybasov et al. (theory) and G.Leksin et al. (experiment) :

The cross section of the quasi–free nuclear reaction doesn't depend on $cos\theta_{p\gamma^\star}$ and Ψ_{TY} .



Proton–knockout from ^3He in the reaction e ^{3}He→e'pX. Cut on M_X selected events when in quasi–elastic electron–proton scattering the spectators are deuterons or close pn–pairs – see left picture with experimental missing mass distribution. The missing momentum was limited by cut $P_X < 0.2$ GeV/c. Angular distributions for the missing system and distributions of the Treiman–Yang angle look pretty much flat. No acceptance corrections were applied. Open triangles represent calculations at $Q^2 \sim 1GeV^2$ using J.M. Laget code. Distributions were normalized to 1 square.

$cos\theta_{p\gamma^\star}$, Treiman–Yang angle Ψ_{TY} and ITEP "spectator asimuthal angle" Φ_{ITEP}



The Treiman–Yang angle Ψ_{TY} is defined in the anti–laboratory frame where the incoming particle is at rest. It is the angle between two planes: the first plane is defined by momenta of scattered particle (e' in our case) and one of the secondaries, the fast knocked–out system for example, – deuteron, d, in present analysis unless otherwise stated. The second plane is defined by the momenta of the target particle (^{3}He in our case) and another secondary system (spectator system for example), – proton, p, in present analysis unless otherwise stated. It was shown in ITEP [ref] that for the wide class of high energy nuclear quasi–free reactions when outgoing scatterd particle is fast (relativistic e' in our case) and spectator system is moderately slow (a few hundred MeV/c proton in our case), the very good approximation for Treiman–Yang angle Ψ_{TY} in laboratory system is the so called "spectator asimuthal angle", Φ_{ITEP}.

Low panel – comparison of the exactly calculated value of the Treiman–Yang angle ,Ψ_{TY} , acoording to its strict definition, to the "approximate" value calculated as the "spectator asimuthal angle", Φ_{ITEP}. "Slow" – left panels, and "Fast" protons – right panels.

S U M M A R Y

a. We study deuteron formation ^{3}He$(e, e'd)X$ for different values of the momentum transfer $p_{\gamma^\star}$, from the moderate to the highest achieved in our experiment.

1. We study deuteron momentum dN/dp_d and proton momentum distribution dN/dp_p for different regions of momentum transfer $p_{\gamma^\star}$.
2. We study proton angular distribution $dN/dcos\theta_{p\gamma^\star}$, and Treiman–Yang angle distribution $dN/d\Psi_{TY}$ for different regions of proton momentum p_p and for different regions of momentum transfer $p_{\gamma^\star}$.

b. We want to observe the transition from

"deuteron formation" regime (^{3}He = p + n + p)

to the

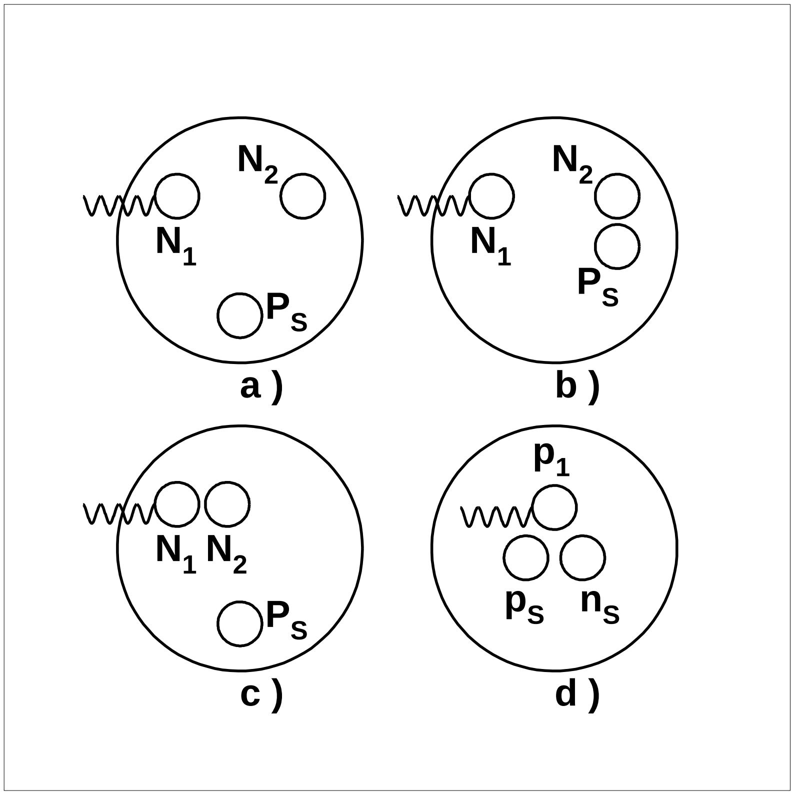
"6q knock–out" regime (^{3}He = (pn)$_{6q(SRC)}$ + p).

c. OUR EXPECTATION : In case when distributions on proton emission angle and Treiman–Yang angle are close to uniform shape (stop distinguishing between "forward" and "backward" directions) – it could be a direct indication on the electron scattering off (pn)$_{SRC}$, or off 6q–bag.

d. We badly need theory input.

e. "b" is impossible in elastic e d $\rightarrow$ e' d.

Possible space–time scenario.

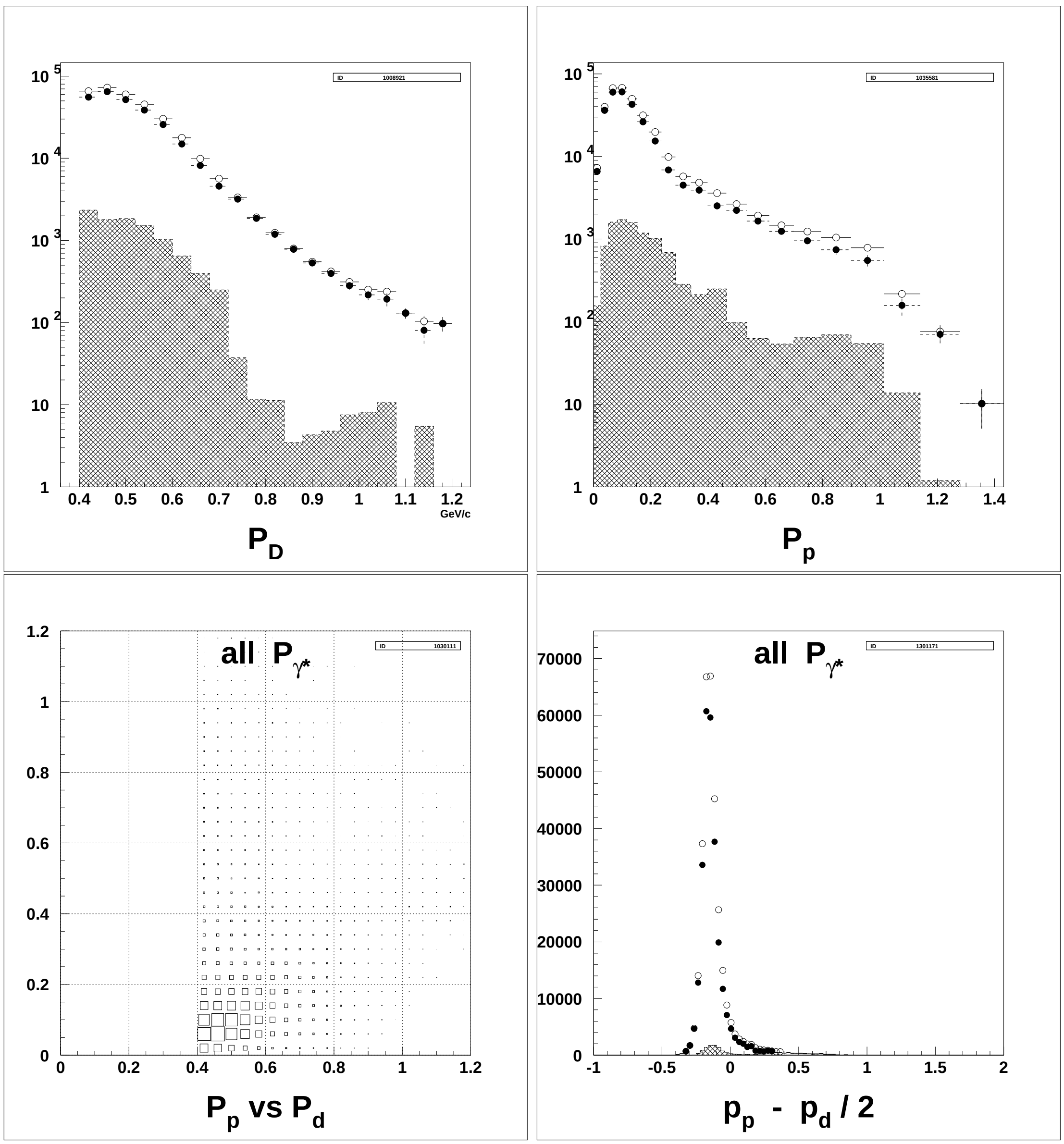


Four possible in principal initial states for fast deuteron emission off ^{3}He. "Regular" configuration where all three nucleons are at relatively large distances – a). Two of three nucleons form "close correlation" – b) and c), and finally all three nucleons form 3N correlation – d). First three configurations a),b),c) could contribute in the pick–up mechanism where N_1 is "initial" nucleon and N_2 is the "picked up" one; P_S – spectator proton. The fourth configuration, d), could provide fast deuteron as a spectator.

N.Pivnyuk, ITEP.   Trento, Italy.   July-2005.

e ^{3}He $\rightarrow$ e$'$dp . Momentum spectra. $E_0 = 1.161$ GeV.

ALL MOMENTUM TRANSFER .



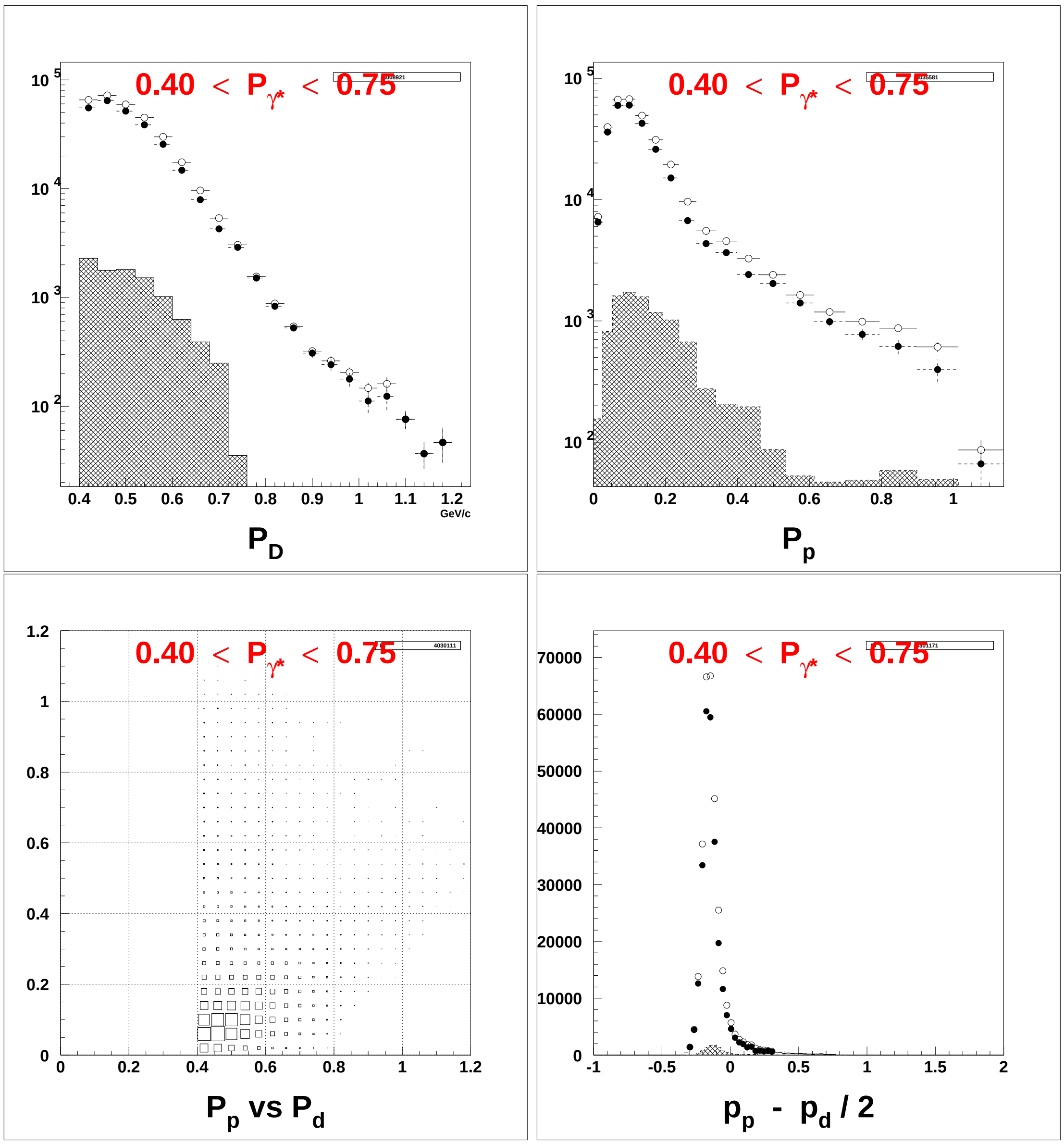
CLAS PRELIMINARY

N.Pivnyuk, ITEP. Trento, Italy. July-2005.

e ^{3}He $\to$ e$'$dp . Momentum spectra. $E_0 = 1.161$ GeV.

"SMALL" MOMENTUM TRANSFER

$0.40 < p_{\gamma^\star} < 0.75\ GeV/c.$



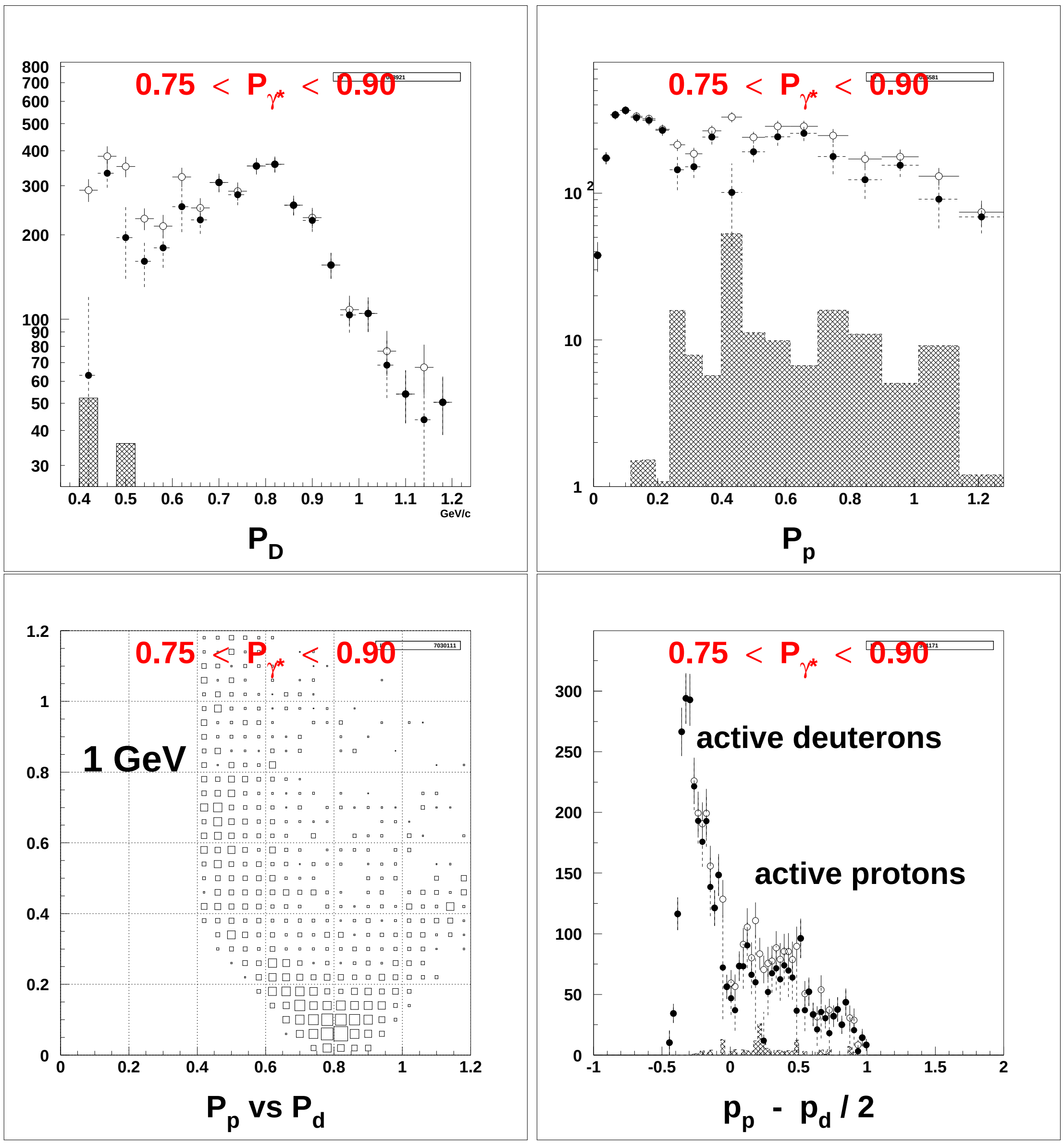
CLAS PRELIMINARY

N.Pivnyuk, ITEP. Trento, Italy. July-2005.

e ^{3}He $\rightarrow$ e$'$dp . Momentum spectra. $E_0 = 1.161$ GeV.

“MEDIUM” MOMENTUM TRANSFER

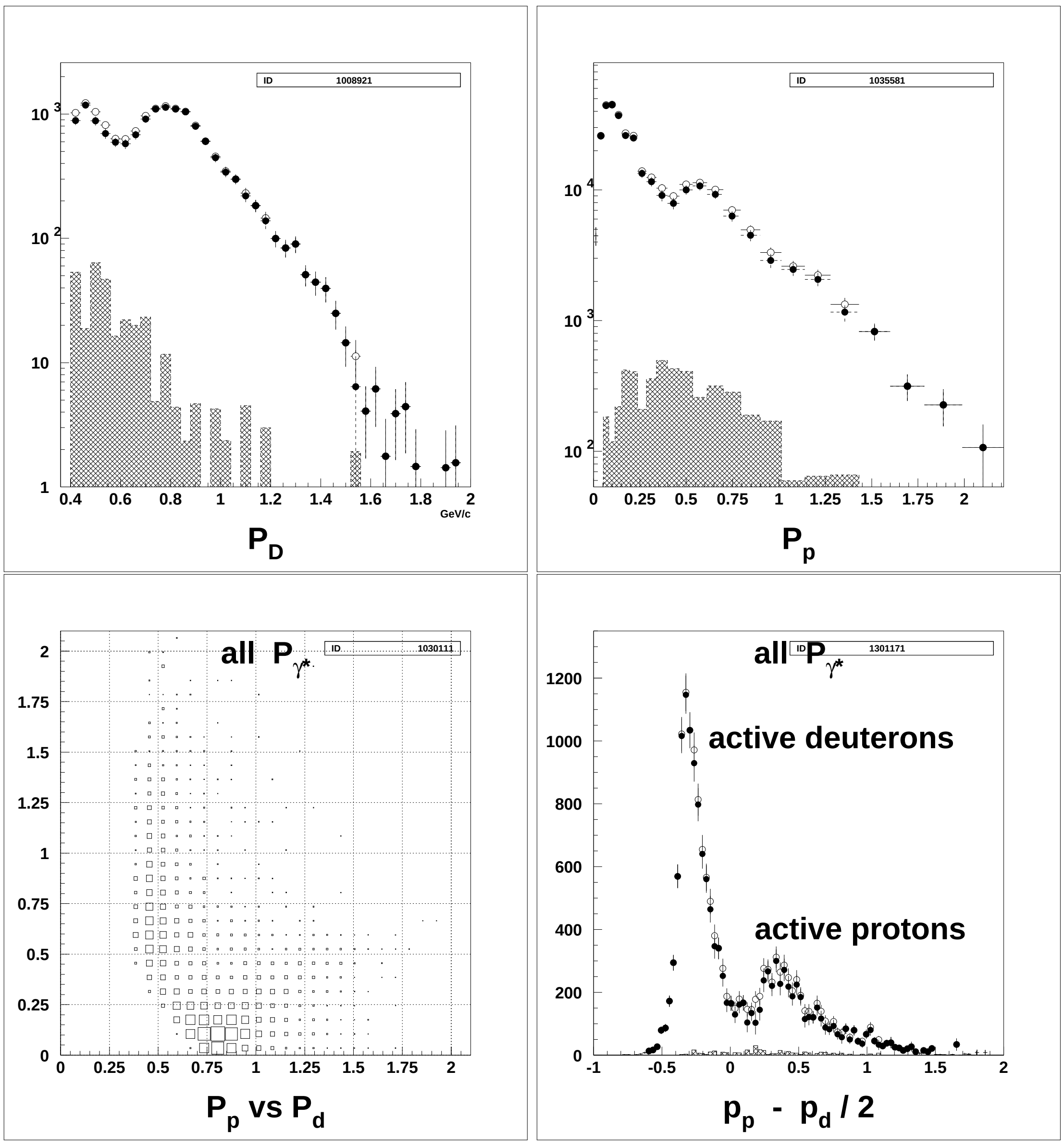
$0.75 < p_{\gamma^\star} < 0.90\ GeV/c$.



CLAS PRELIMINARY

e ^{3}He $\rightarrow$ e$'$dp . Momentum spectra. $E_0 = 2.261$ GeV.

ALL MOMENTUM TRANSFER.

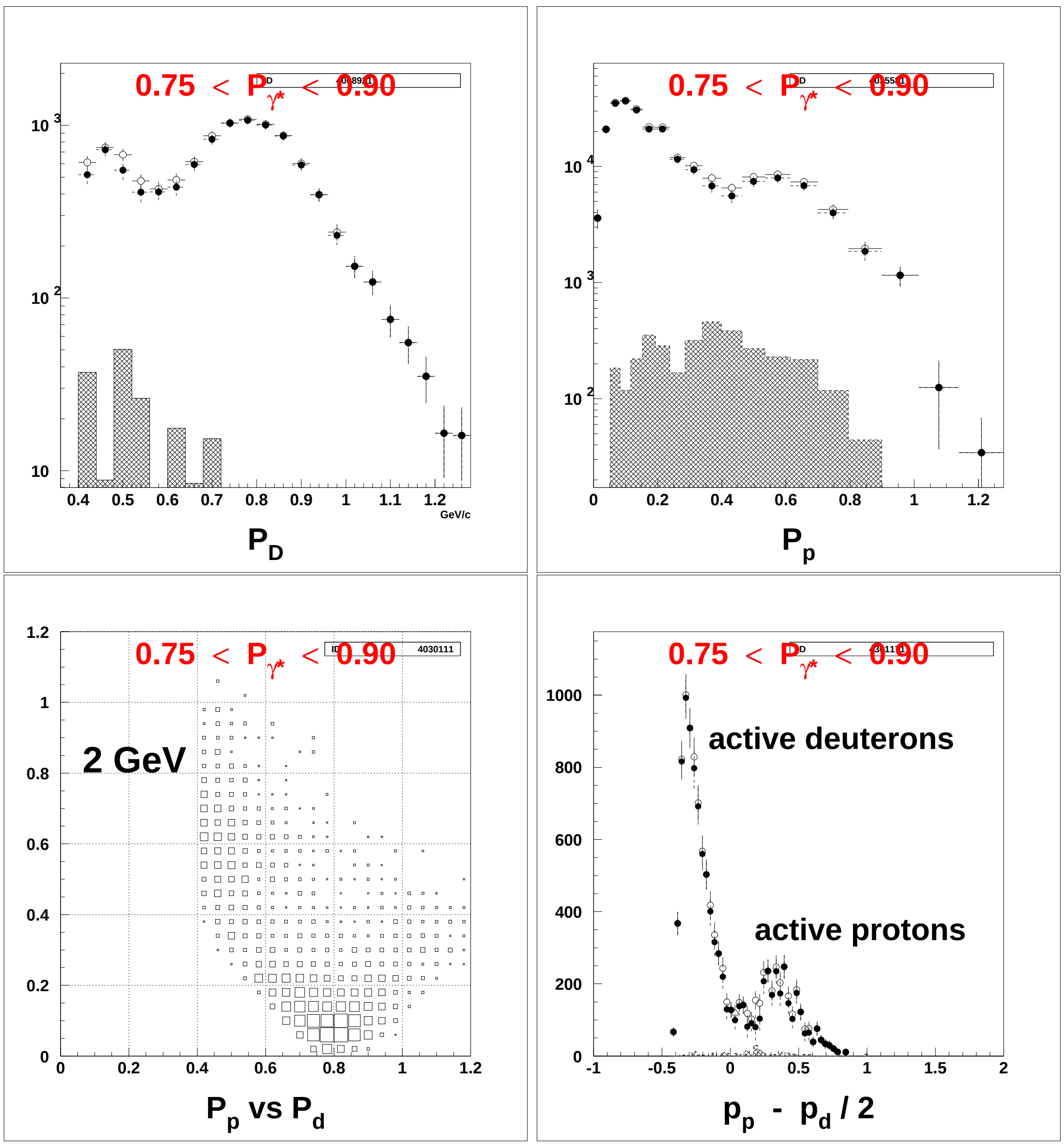


CLAS PRELIMINARY

e ^{3}He $\to$ e$'$dp . Momentum spectra. $E_0 = 2.261$ GeV.

"MEDIUM" MOMENTUM TRANSFER

$0.75 < p_{\gamma^\star} < 0.90\ GeV/c.$

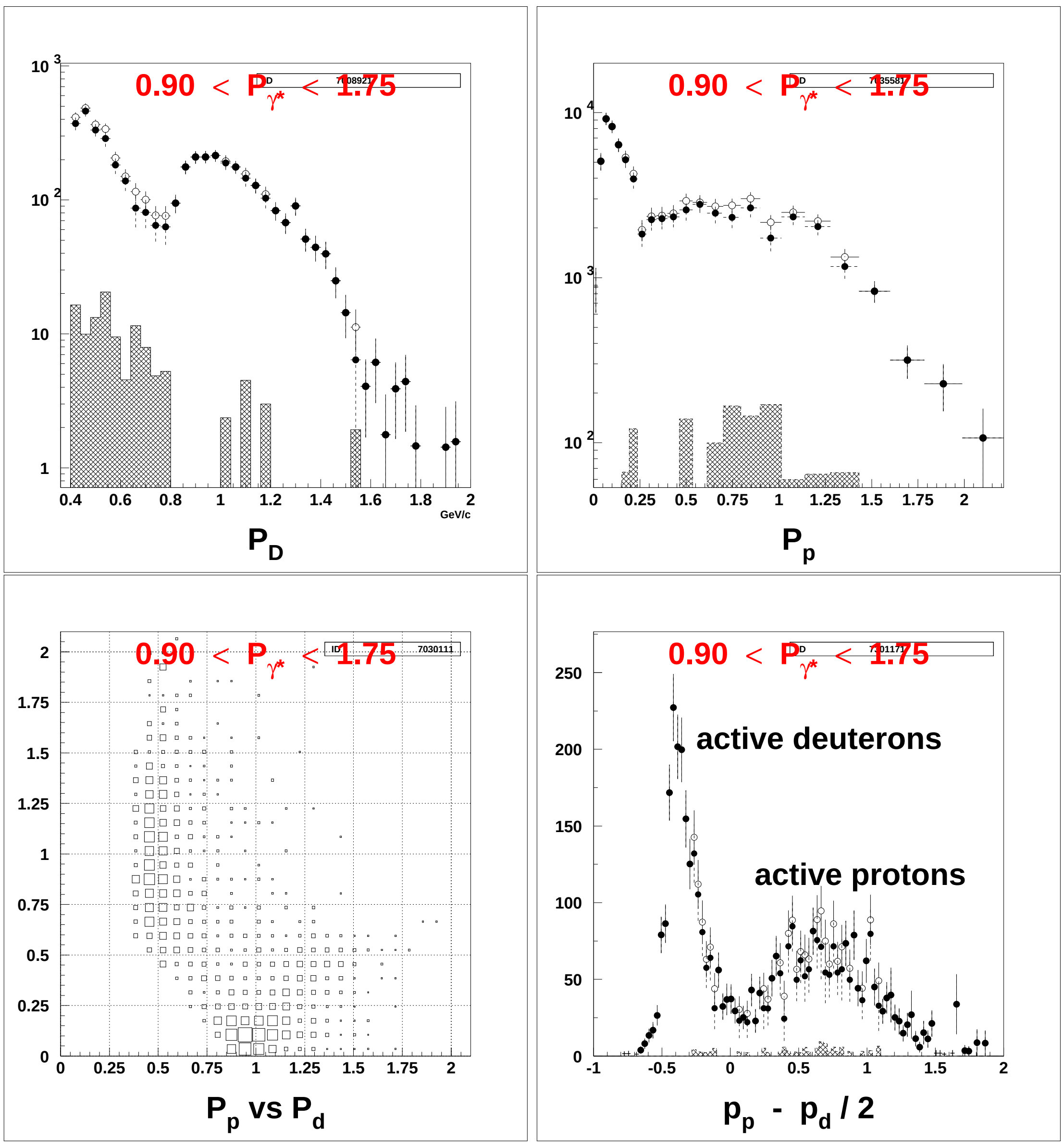


CLAS PRELIMINARY

e ^{3}He $\rightarrow$ e$'$dp . Momentum spectra. $E_0 = 2.261$ GeV.

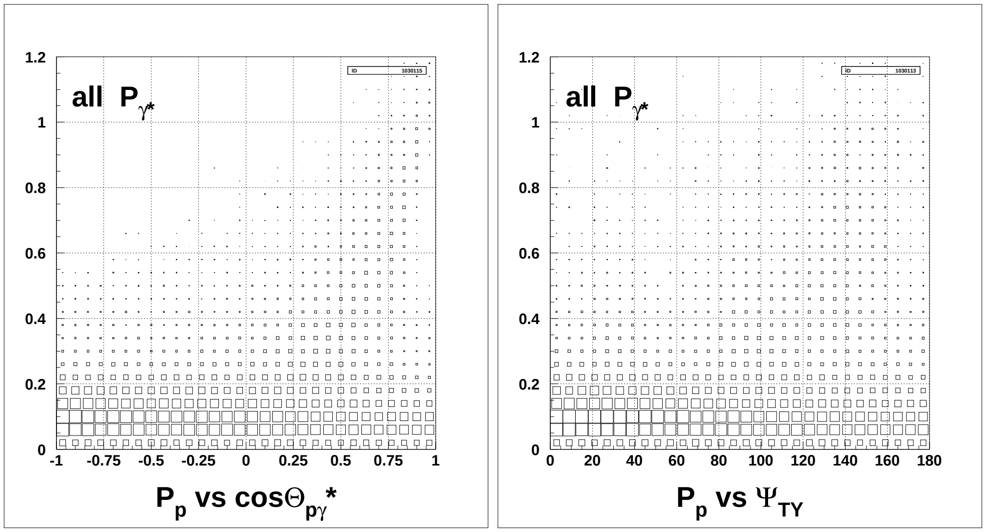
"LARGE" MOMENTUM TRANSFER

$0.90 < p_{\gamma^\star} < 1.75\ GeV/c.$

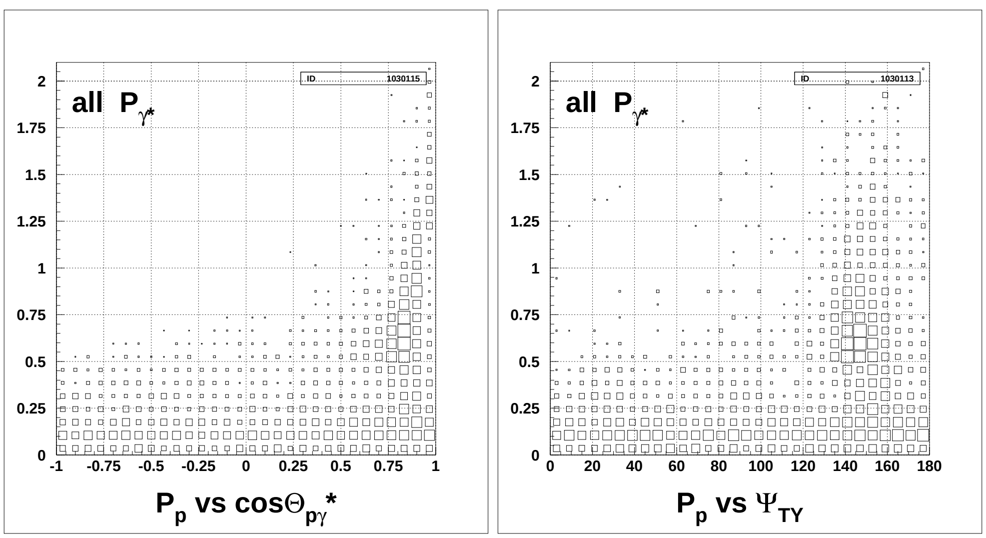


CLAS PRELIMINARY

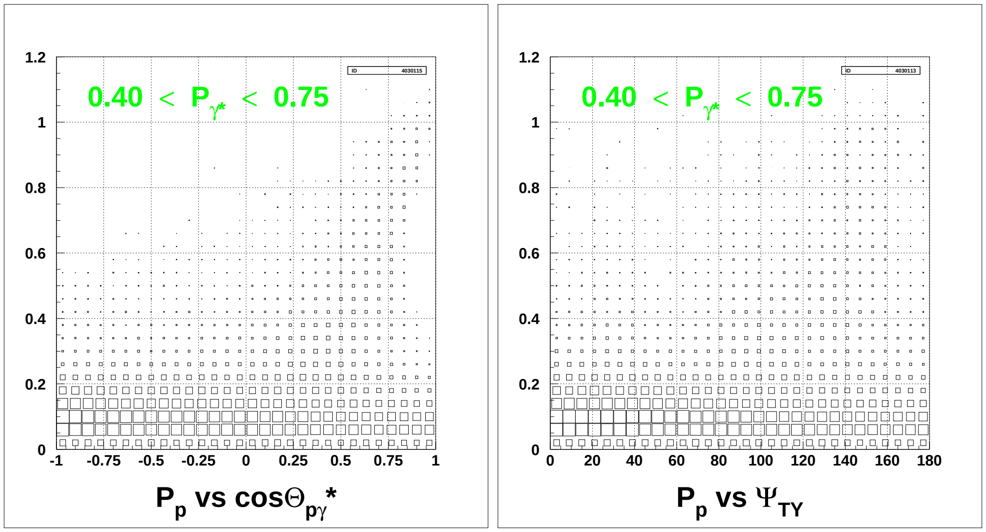
e ^{3}He $\rightarrow$ e$'$dp . Proton angular distributions $dN/dcos\theta_{p\gamma^\star}$ and distributions on Treiman–Yang angle $dN/d\Psi_{TY}$ for different ranges of momentum transfer and for different ranges of proton momentum.



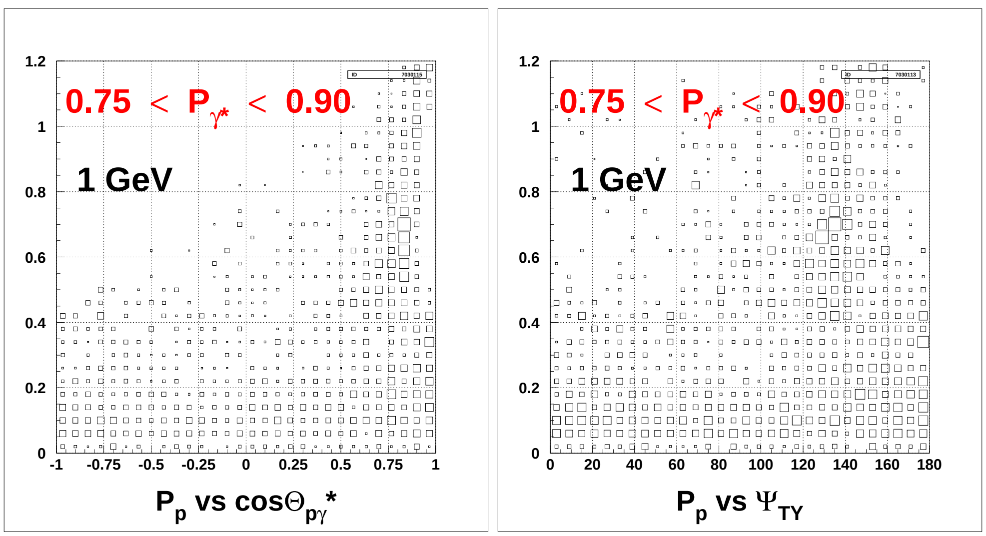
E$_0$ = 1.161 GeV. Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY} . All events, no specific cut on momentum trasfer, only general restriction $0.40 < p_{\gamma^\star} < 0.90\ GeV/c$.



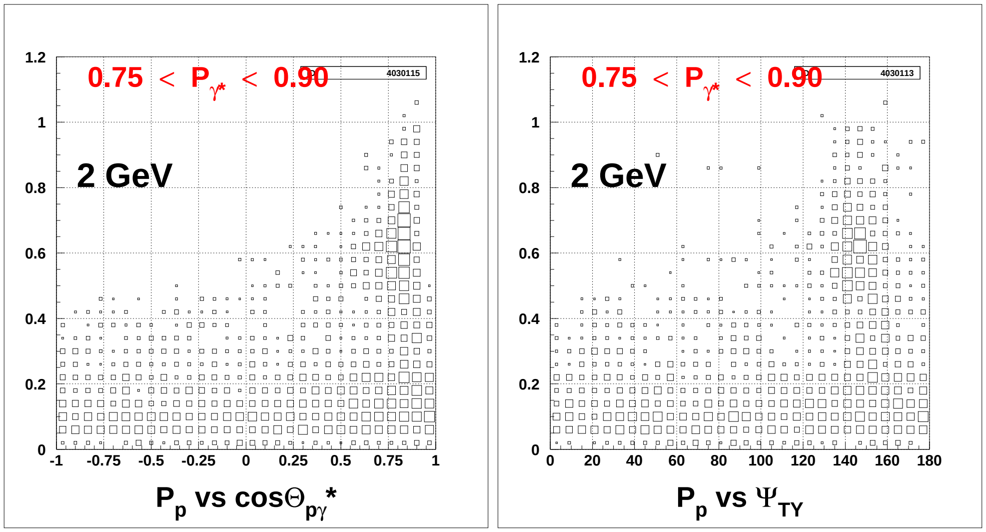
E$_0$ = 2.261 GeV.Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY} . All events, no specific cut on momentum trasfer, only general restriction $0.75 < p_{\gamma^\star} < 1.75\ GeV/c$.



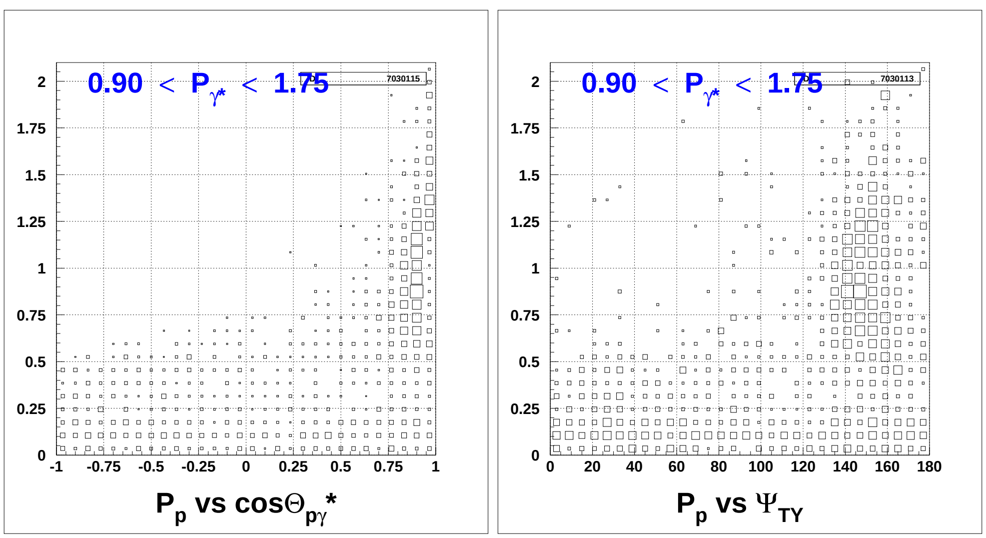
$E_0 = 1.161$ GeV. Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY} . "Small" momentum transfer $0.40 < p_{\gamma^\star} < 0.75\ GeV/c$.



$E_0 = 1.161$ GeV. Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY} . "Medium" momentum transfer $0.75 < p_{\gamma^\star} < 0.90\ GeV/c$.



$E_0 = 2.261$ GeV. Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY}. "Medium" momentum transfer $0.75 < p_{\gamma^\star} < 0.90\ GeV/c$.

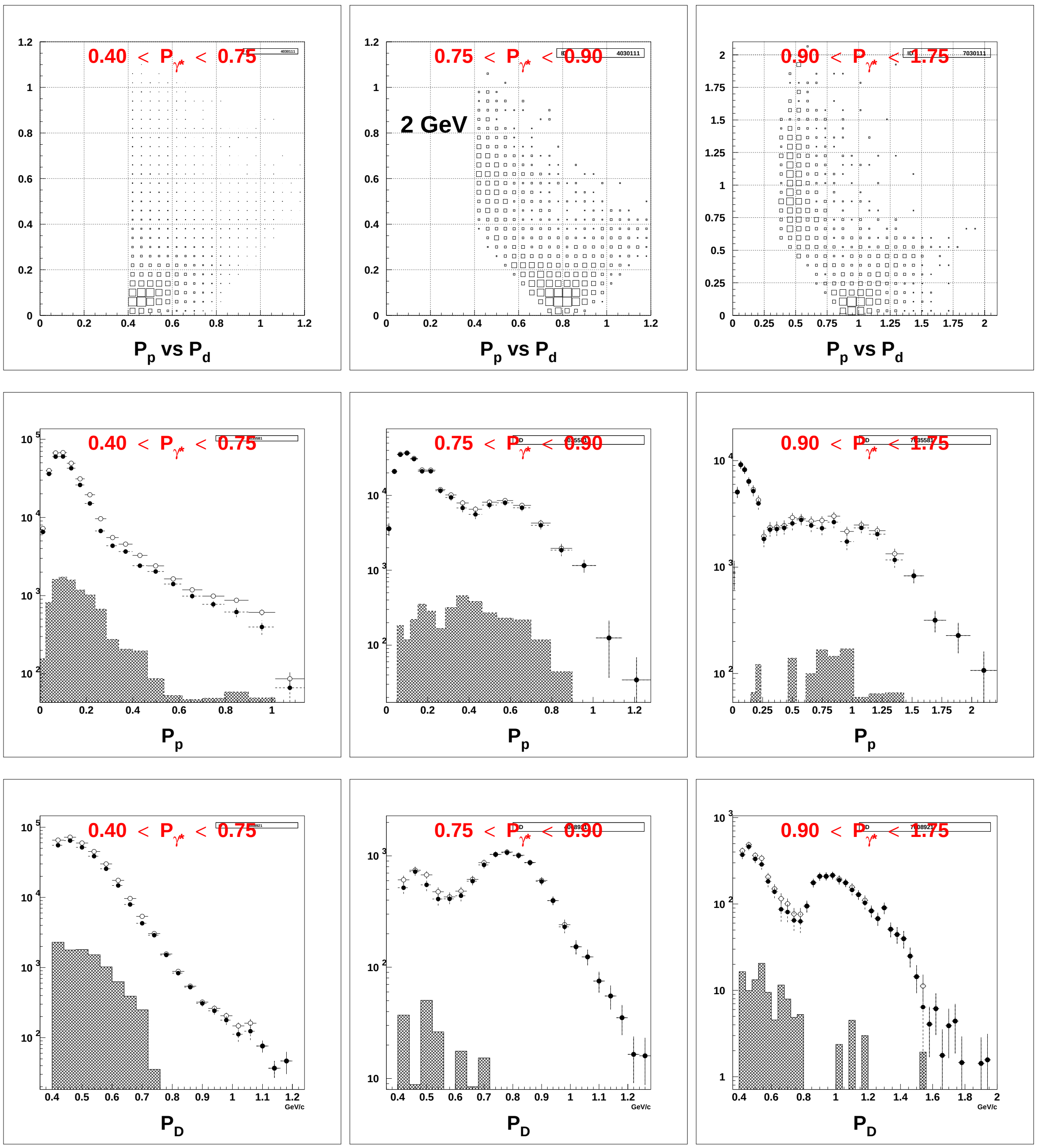


$E_0 = 2.261$ GeV. Proton momentum p_p vs $cos\theta_{p\gamma^\star}$ and p_p vs Ψ_{TY}. "Large" momentum transfer $0.90 < p_{\gamma^\star} < 1.75\ GeV/c$.

e ^{3}He $\to$ e$'$dp . Momentum spectra's evolution.

Momentum transfer :

"SMALL"	"MEDIUM"	"LARGE"

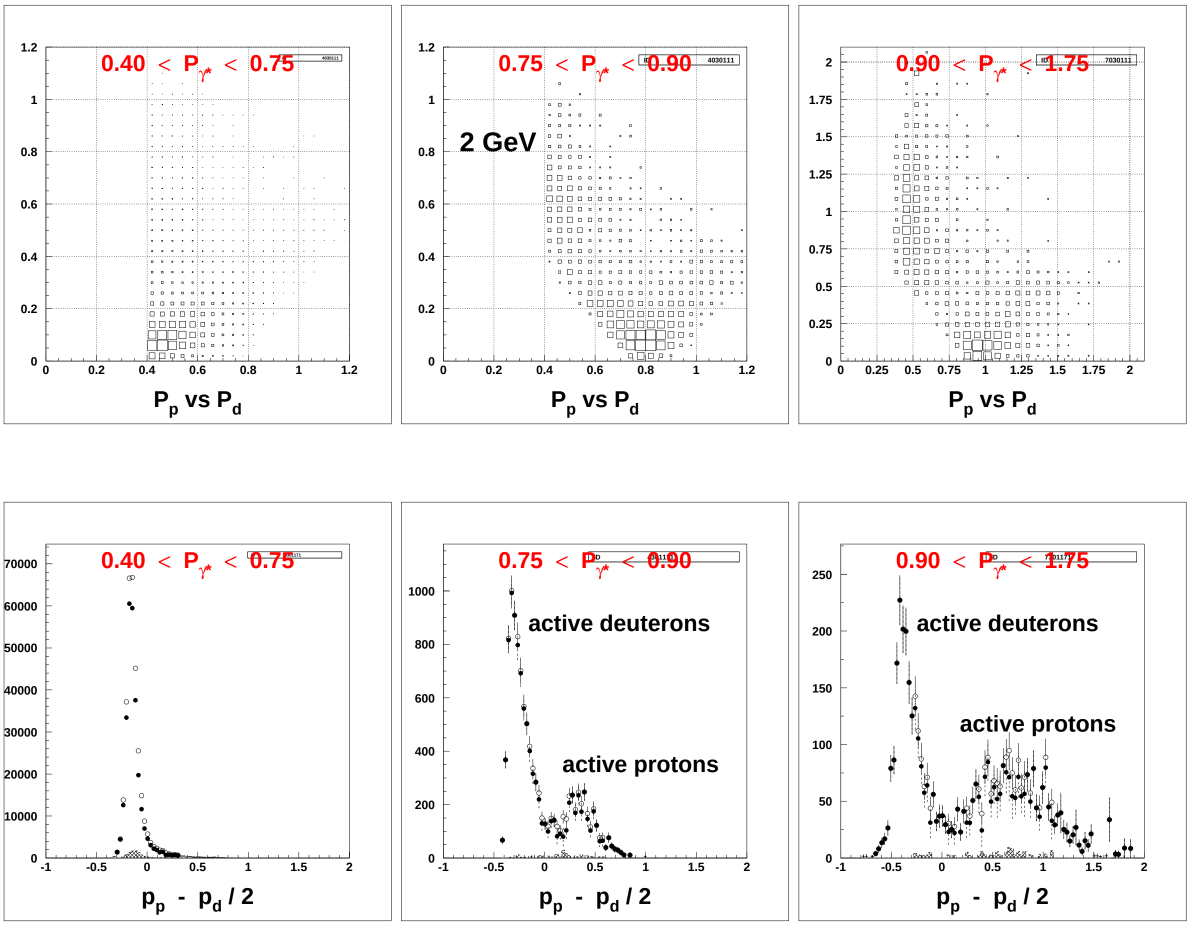


CLAS PRELIMINARY

e ^{3}He $\rightarrow$ e$'$dp . Momentum spectra's evolution.

Momentum transfer :

"SMALL" "MEDIUM" "Large"



CLAS PRELIMINARY

N.Pivnyuk, ITEP. Trento, Italy. July-2005.

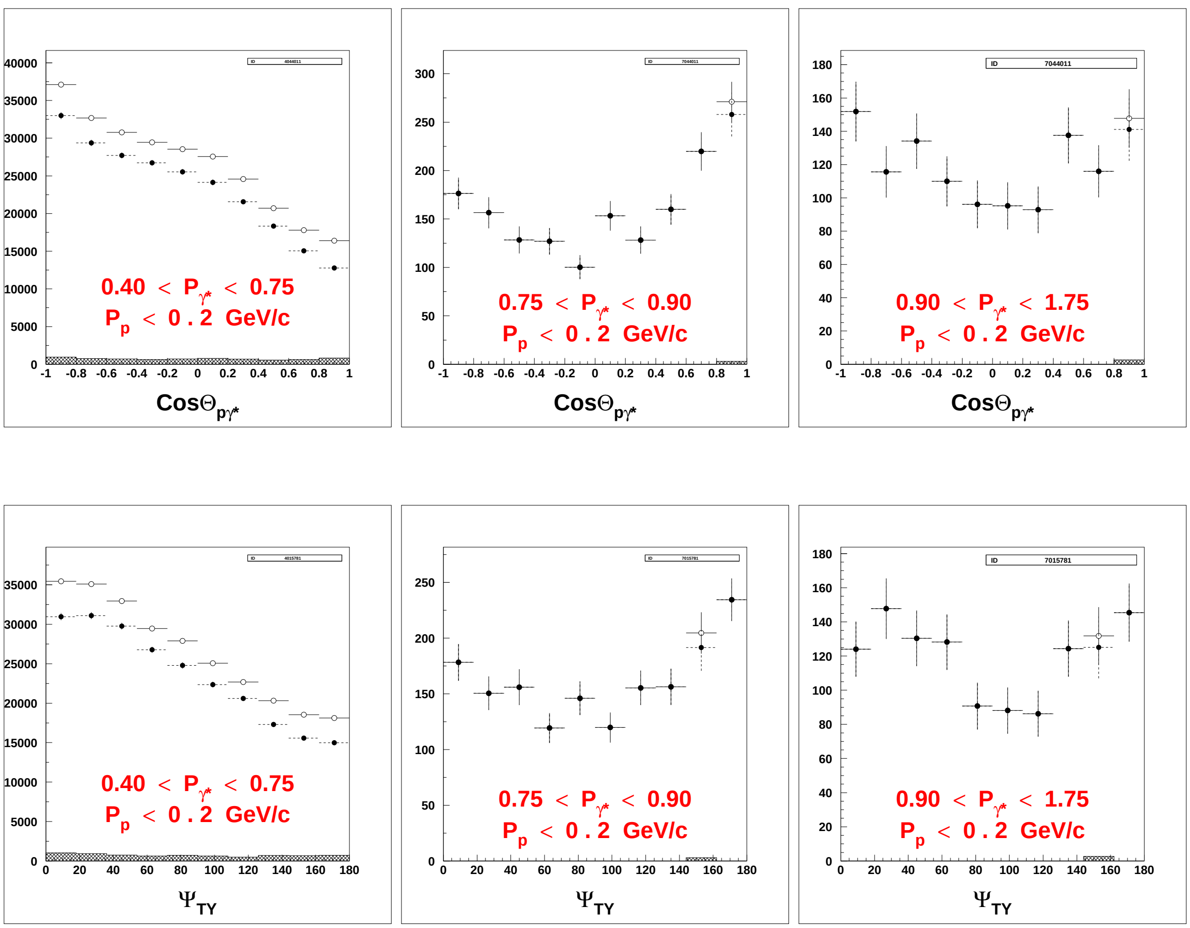
$e\ {}^{3}He \rightarrow e'dp$, $p_p < 0.2$ GeV/c

$dN/dcos\theta_{p\gamma^\star}$ and

$dN/d\Psi_{TY}$ evolution

Momentum transfer :

"SMALL" "MEDIUM" "LARGE"

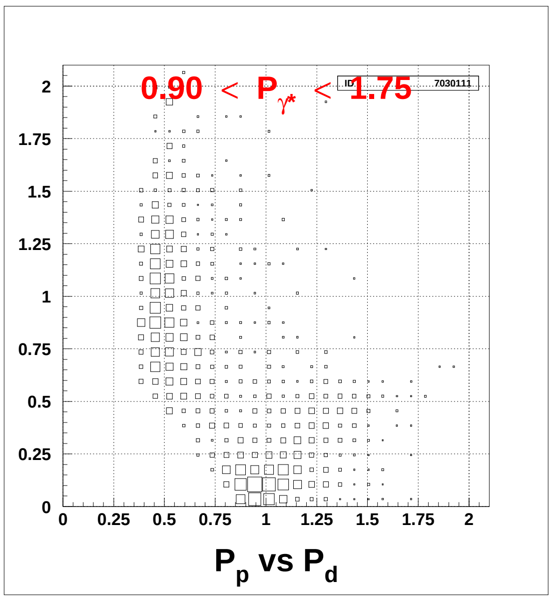


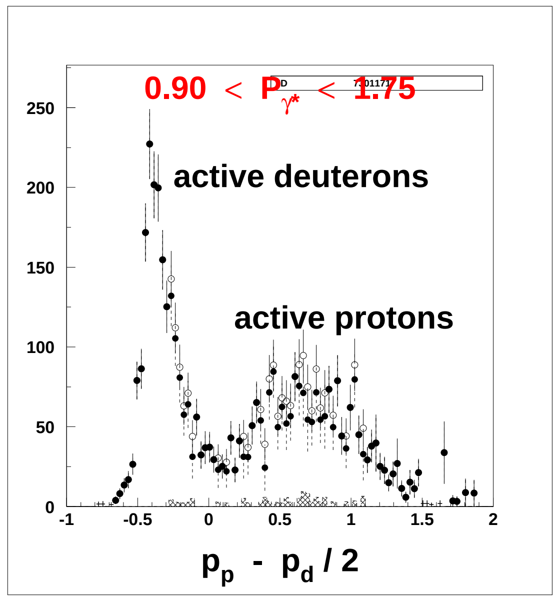
CLAS PRELIMINARY

CONCLUSIONS

Two major channels of the e ^{3}He $\to$ e$'$dp reaction are observed clearly and seperatly if the momentum transfer is large :

- through active proton : $\gamma^\star + p \to p$
- through active deuteron : $\gamma^\star + pn_{SRC} \to d$





CLAS PRELIMINARY

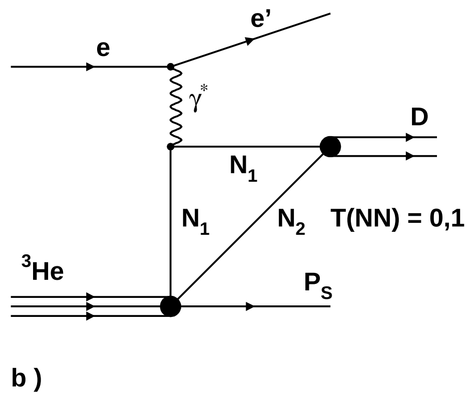
If proton–spectator momentum is small two scenario are possible :

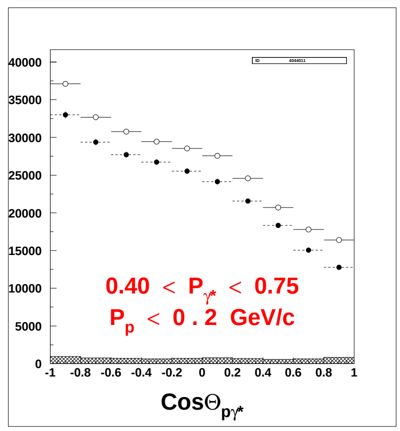
b) $p_{\gamma^\star}$ **S M A L L**

All three nucleons in ^{3}He initial state are in approximately similar conditions :

^{3}He = (p + n + p) = *pnp* wide *3N*–correlation

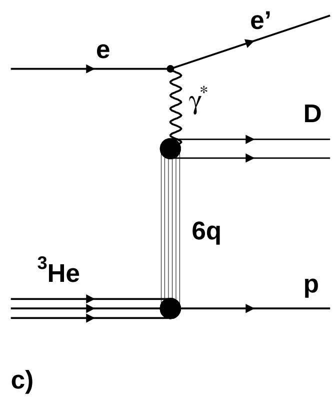
^{3}He = p + (n + p) = p + *np* wide *2N*–correlation

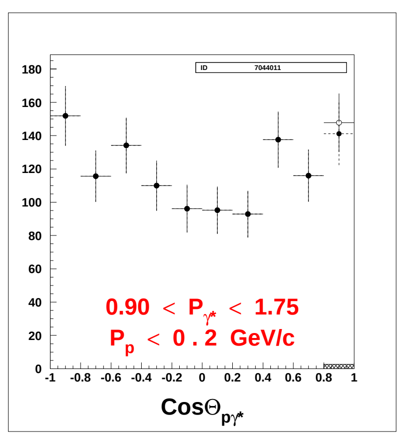




c) $p_{\gamma^\star}$ **L A R G E**

Two nucleons form SRC, and the third one "stands alone" : ^{3}He = (pn)$_{6q,SRC}$ + p





CLAS PRELIMINARY