OLD DOMINION UNIVERSITY
IDEA FUSION

Old Dominion University 2016

Comparing proton and neutron momentum distributions in ^{3}He using the Large Angle Calorimeter (LAC)

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Measure momentum distribution in A=3 (e,e'N)

Scatter electrons from 3He and detect knocked out n or p

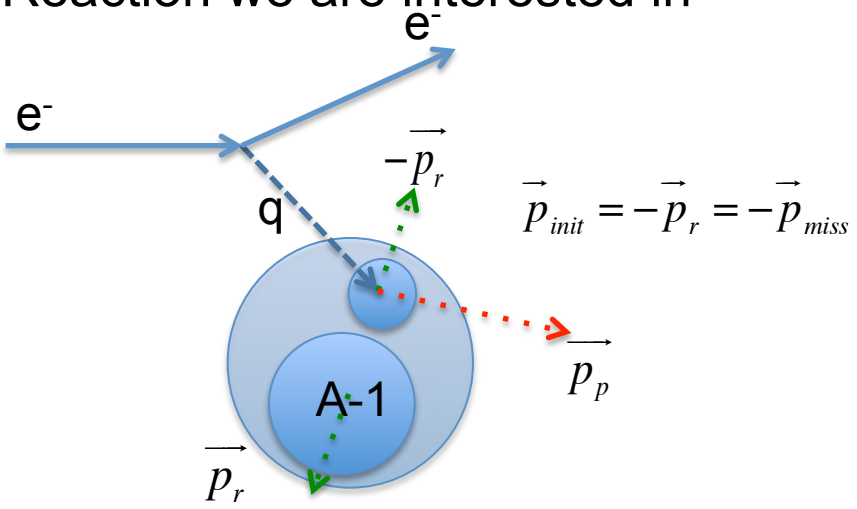
$$\frac{d\sigma}{dE_{e'}d\Omega_e dE_N d\Omega_N} = K\sigma_{eN}S(E_m, p_m)$$

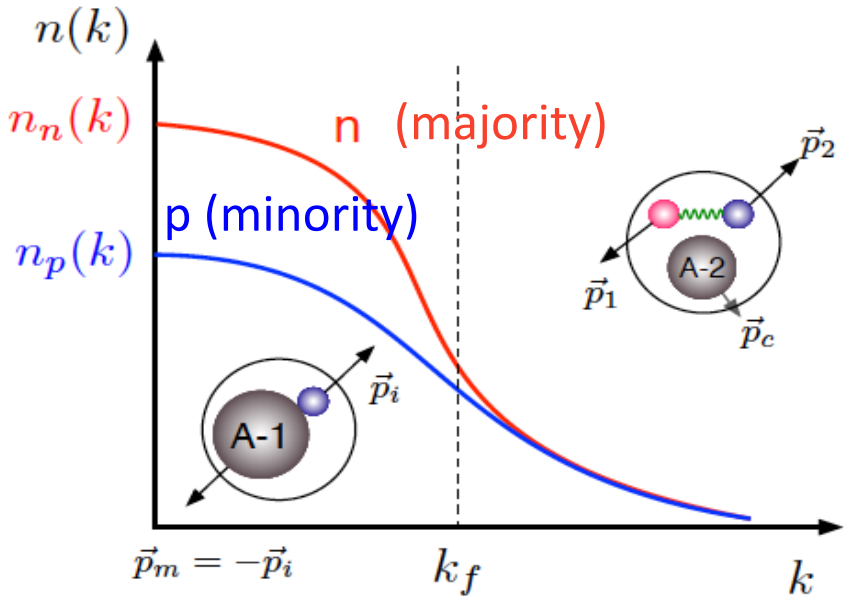
$$K = \frac{E_N p_N}{(2\pi)^3}$$

$$E_{miss} = \omega - T_N - T_{A-1}$$

$$\vec{p}_{miss} = \vec{q} - \vec{p}_N$$

Reaction we are interested in





The momentum distribution of protons and neutrons in ^{3}H.

From isospin symmetry the momentum distribution of p in ^{3}H should be equal to that of n in ^{3}He.

Majority	Minority
p in ^{3}He	n in ^{3}He
n in ^{3}H	p in ^{3}H

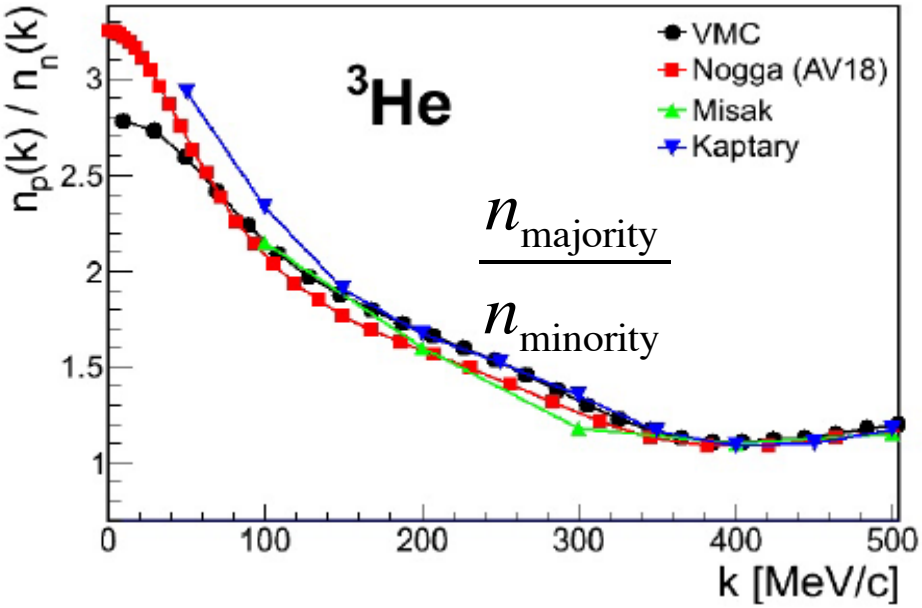
The power of ratios

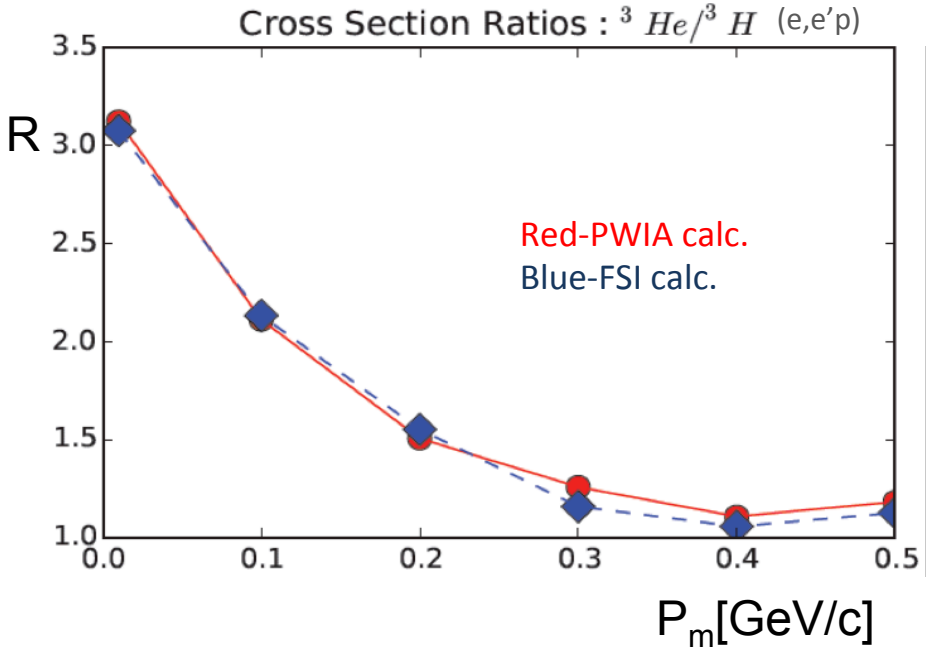
^{3}He(e,e'p)/^{3}He(e,e'n) cross section ratios and $n_p(k)/n_n(k)$ provide:

- Information about majority and minority momentum distributions

$$\frac{n_{maj}(k)}{n_{\min}(k)} \approx \frac{\sigma[^3\mathrm{He}(e,e'p)]}{\sigma[^3\mathrm{He}(e,e'n)]}$$

- Transition to SRC dominance





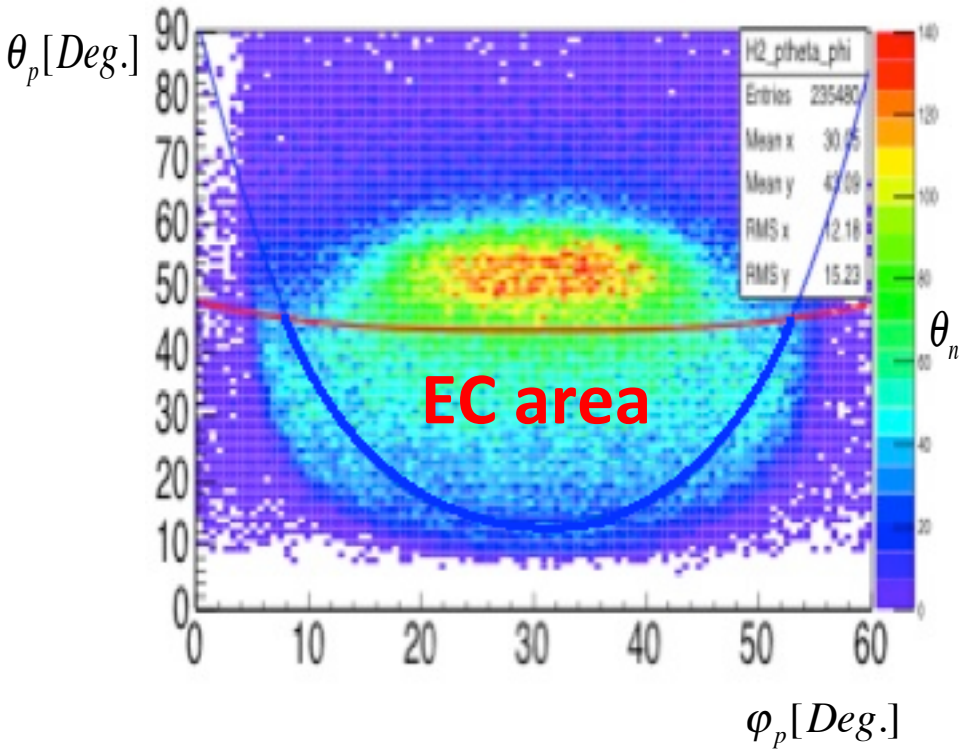
Hall A: $^3\mathrm{He}(e,e'p) / {}^3\mathrm{H}(e,e'p)$

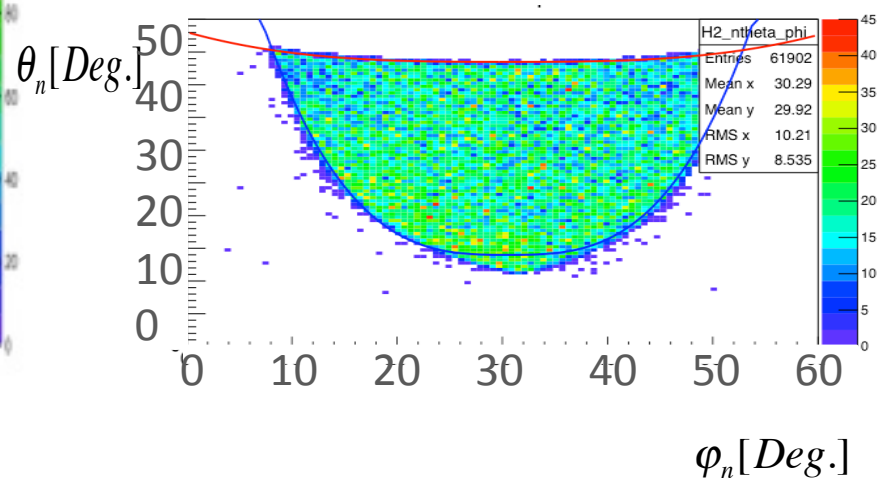
CLAS : $\dfrac{^3\mathrm{He}(e,e'p) / {}^3\mathrm{He}(e,e'n)}{^4\mathrm{He}(e,e'p) / {}^4\mathrm{He}(e,e'n)}$

Expect ^{4}He(e,e'n)/(e,e'p)=1.
Difference from 1 show detector effects.
Use to correct for this effects

E2b 4.7Gev ^3He

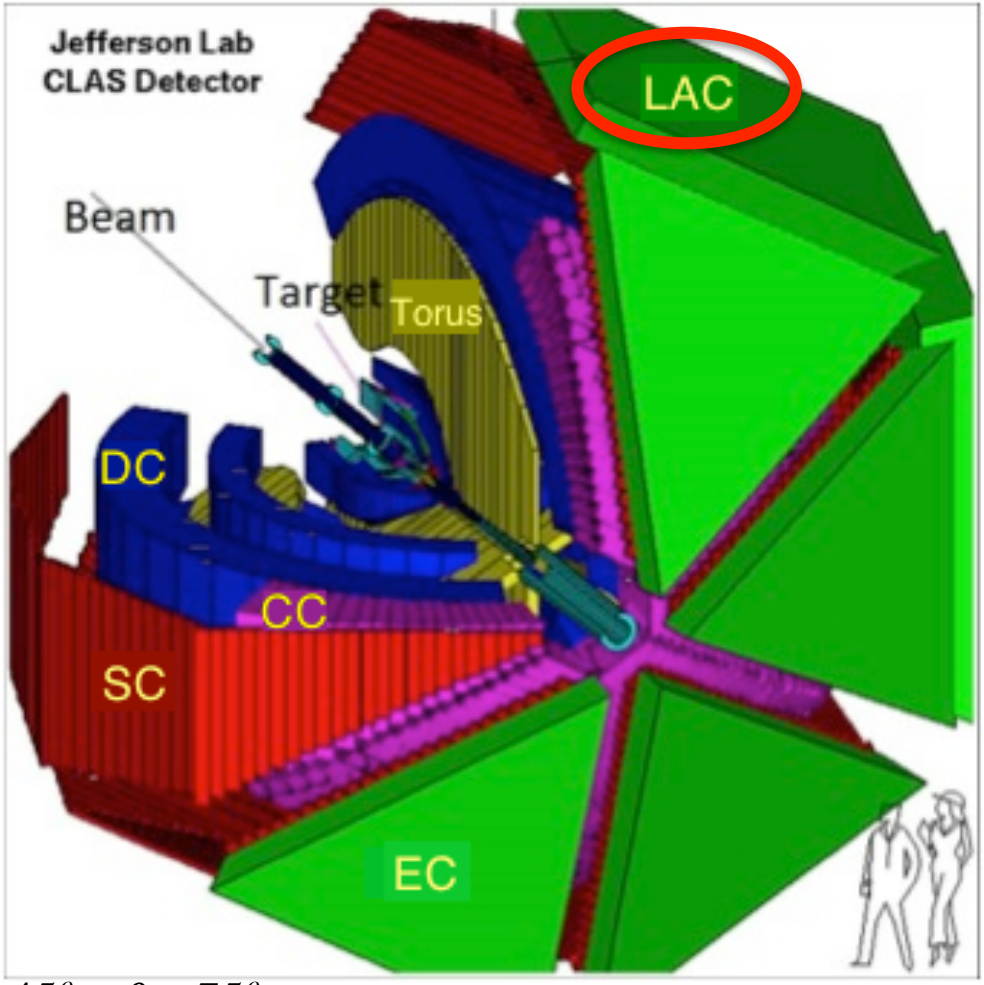
$^3He(e,e'p)$	$^3He(e,e'n)$
protons	neutrons





Quasielastic events are at $\theta_p > 45^0$ ➡ Need LAC!

HALL B neutron detection with LAC

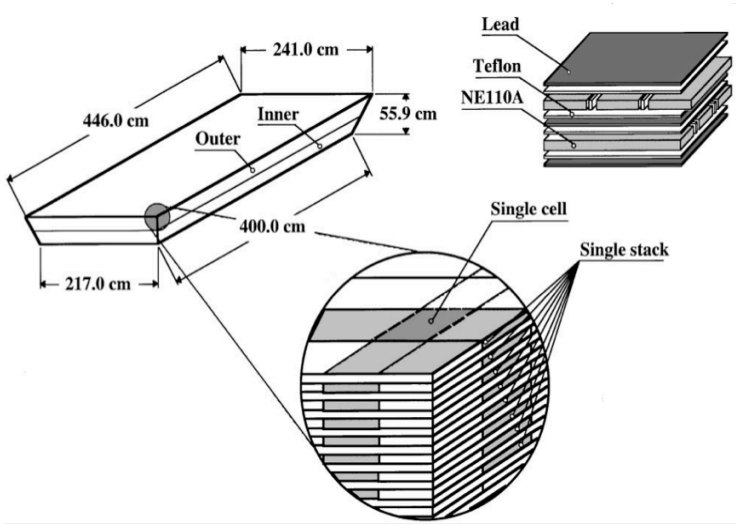


$45^o < \theta < 75^o$

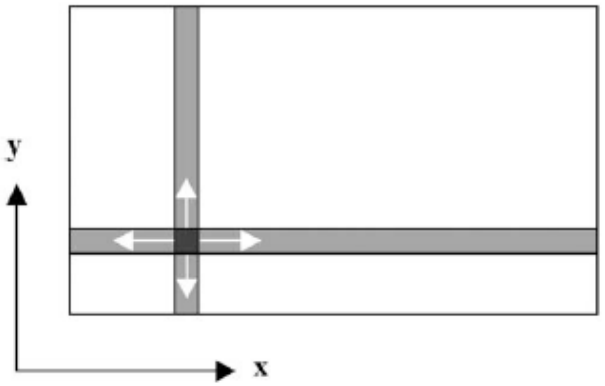
$-30^o < \varphi < 90^o$

Sectors 1,2

Rarely used



The detailed view of one of the LAC modules.

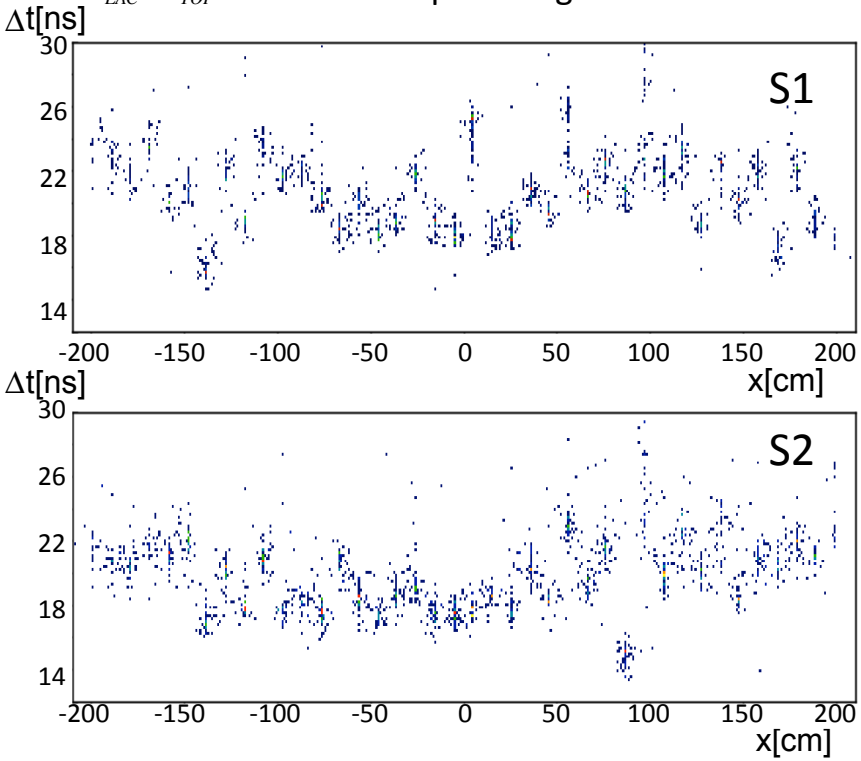


LAC local x and y views

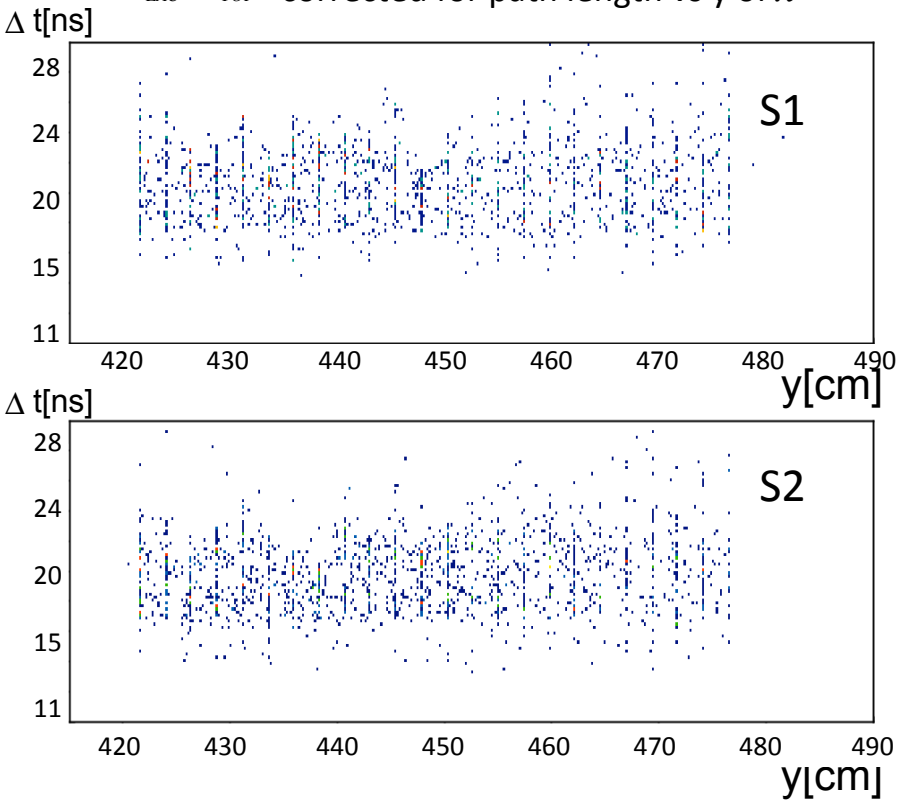
LAC timing with calibration constants from "calib.RunIndex"

E2a 2.26Gev He4

$t_{LAC} - t_{TOF}$ corrected for path length vs x of π^+

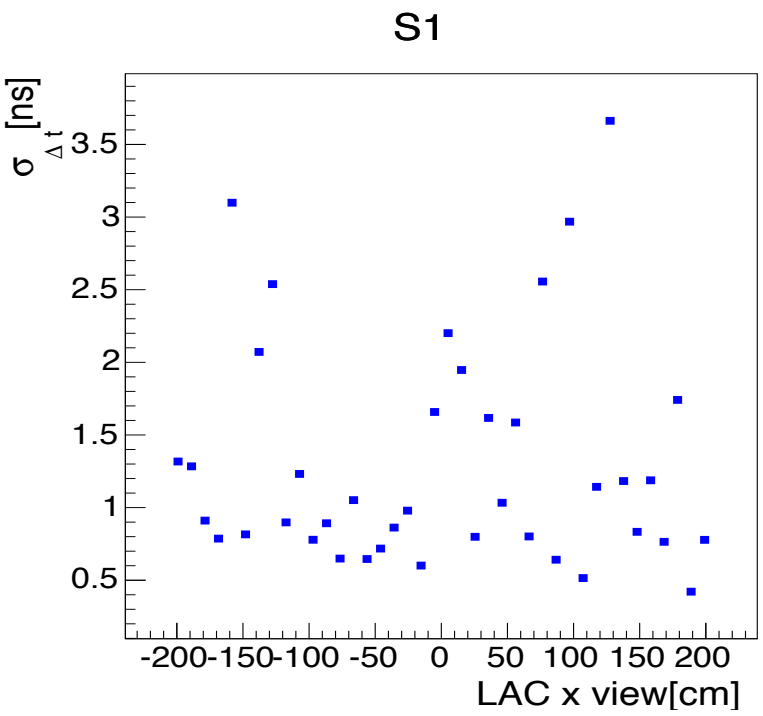


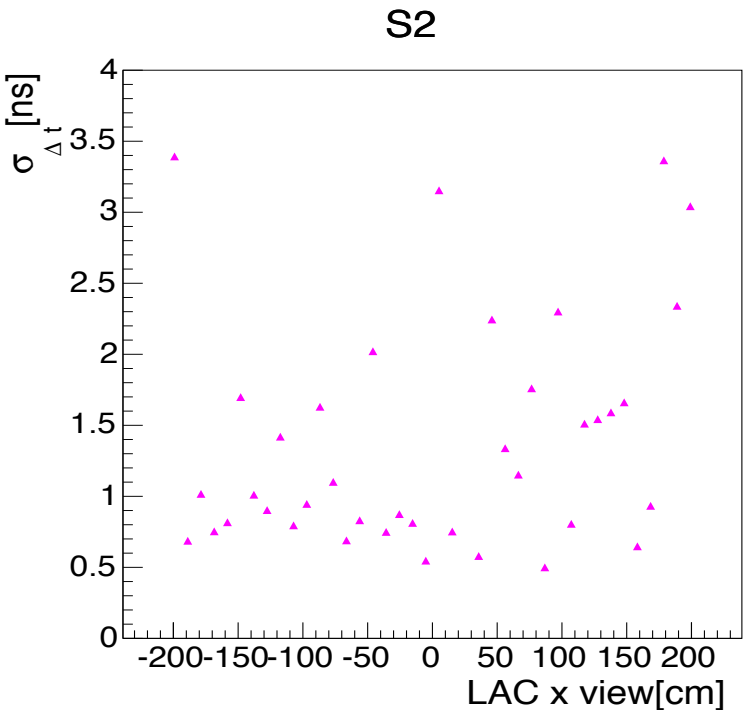
$t_{LAC} - t_{TOF}$ corrected for path length vs y of π^+



Timing depends on x not y

LAC timing resolution



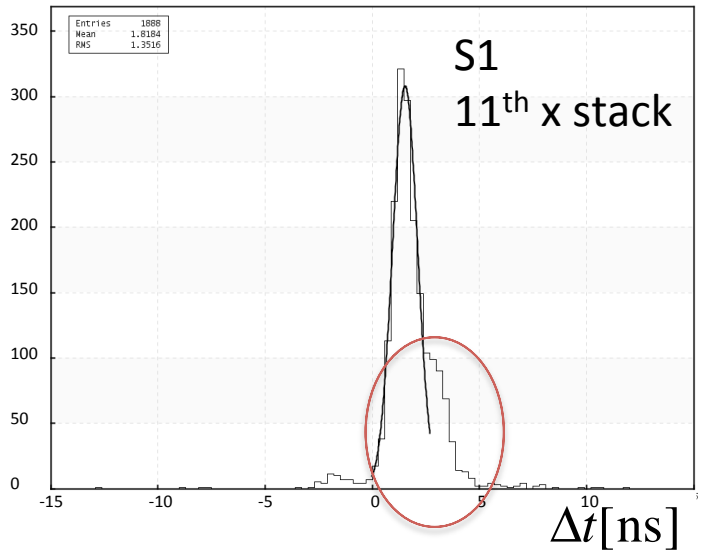


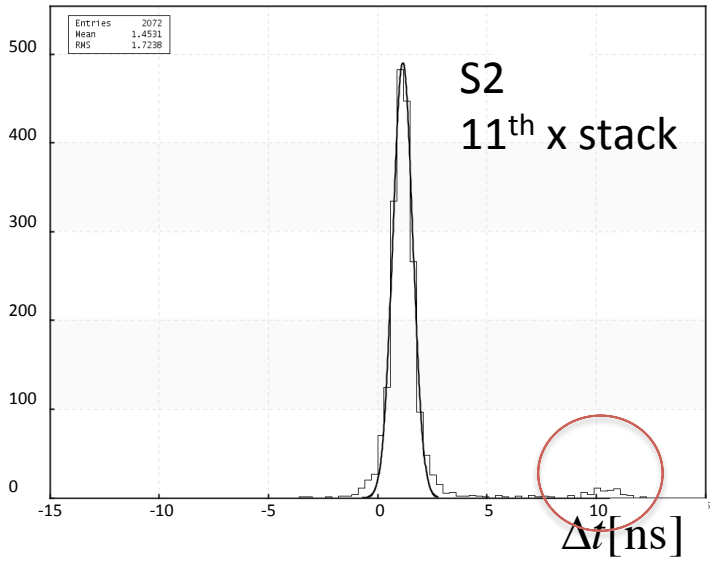
Need more precise time calibration of LAC!

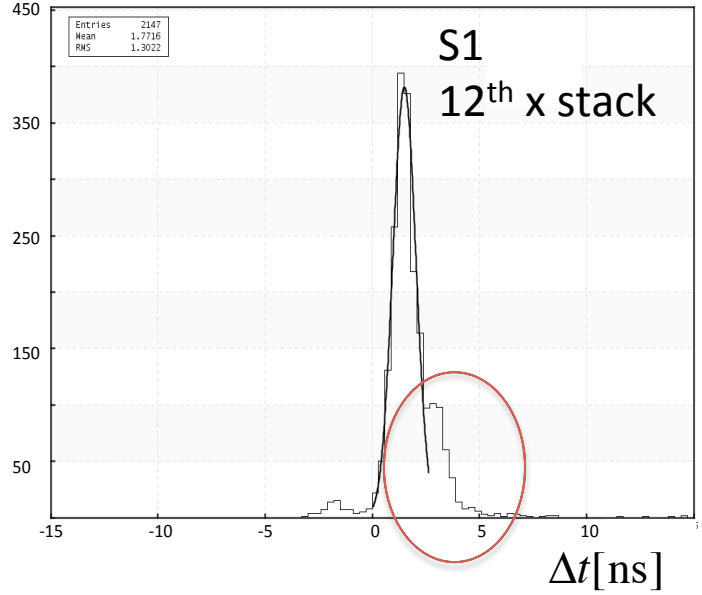
Need to recook the data to include individual TDC information for all PMTs

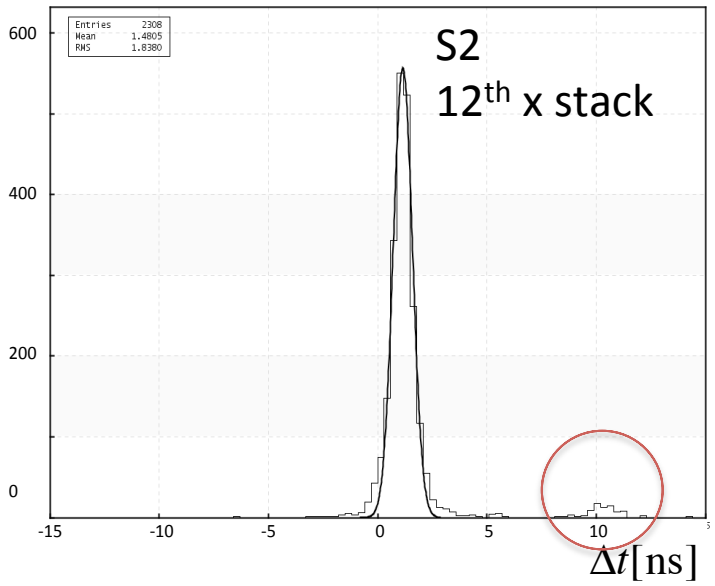
LAC timing with calibration constants from e1c (run 17748)

E2a 4.46Gev He4









LAC timing with calibration constants from e1c (run 17748)

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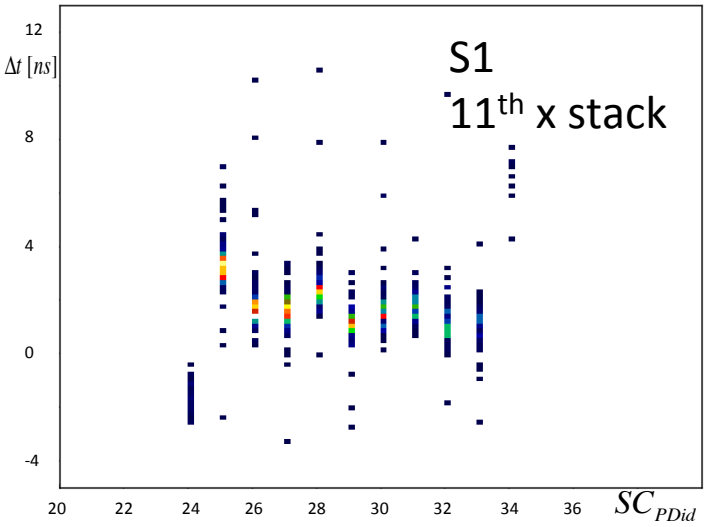
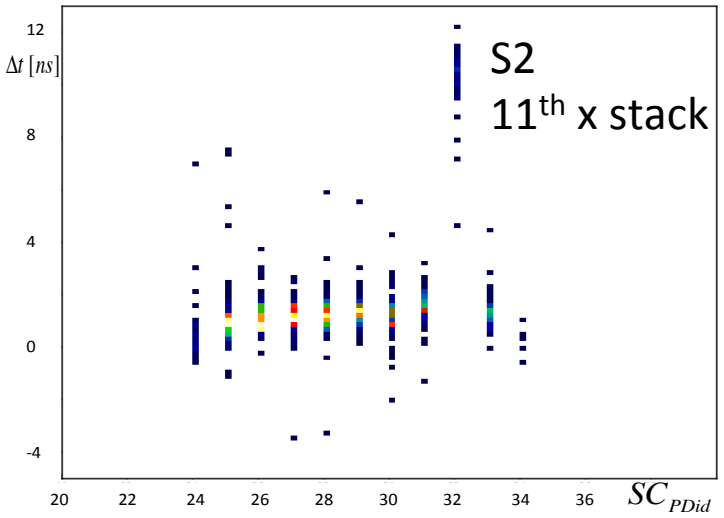
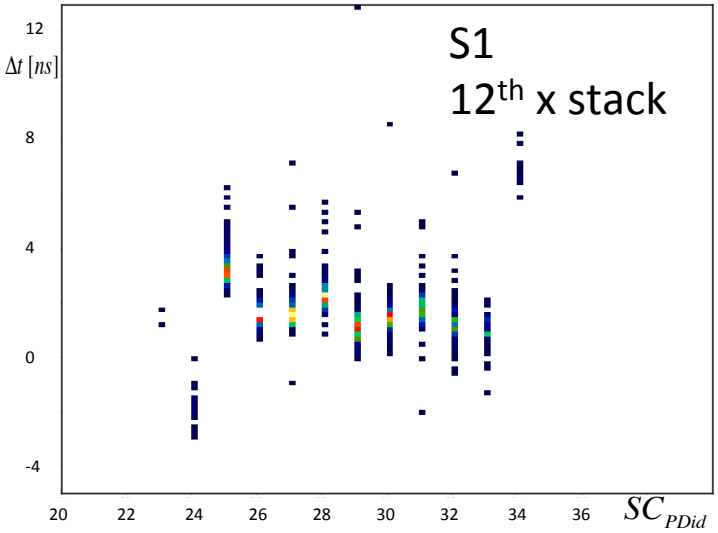
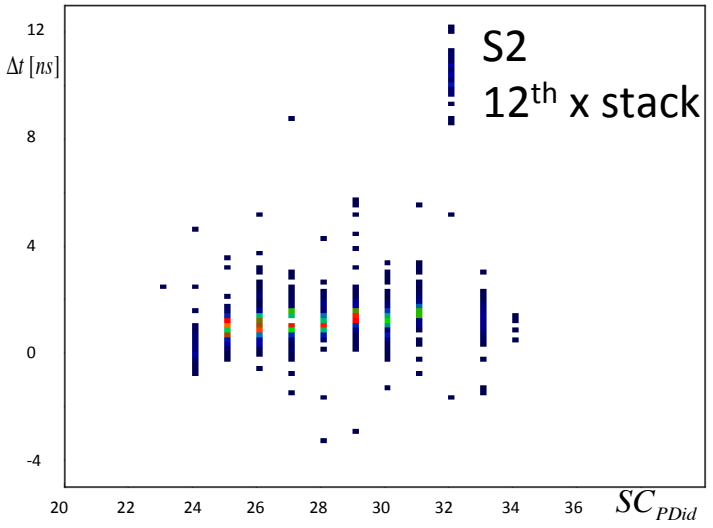






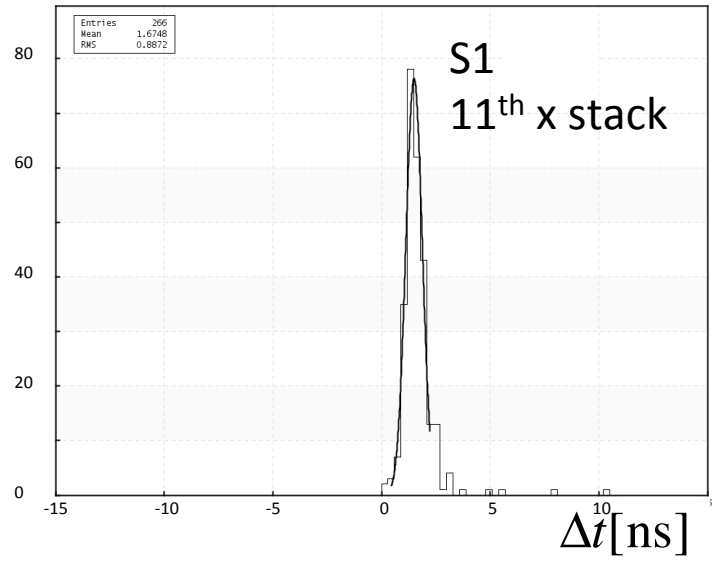


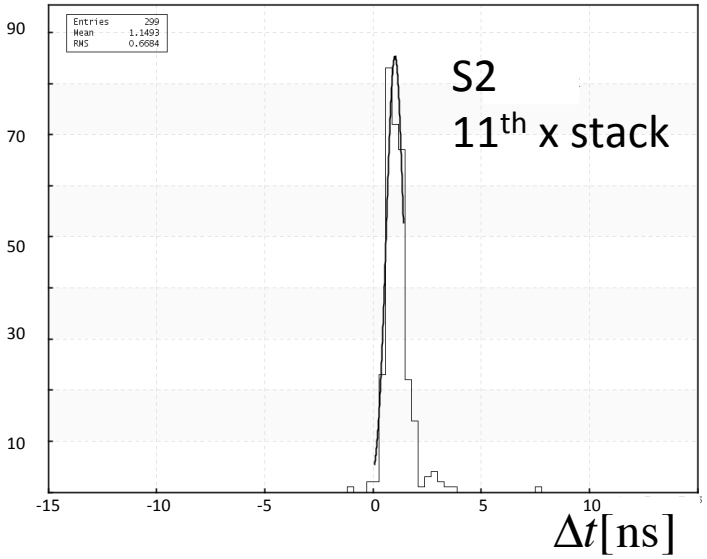
Δt as a function of the TOF paddle number where the pions have been detected for the 11th and 12th x stacks of LAC S2 module

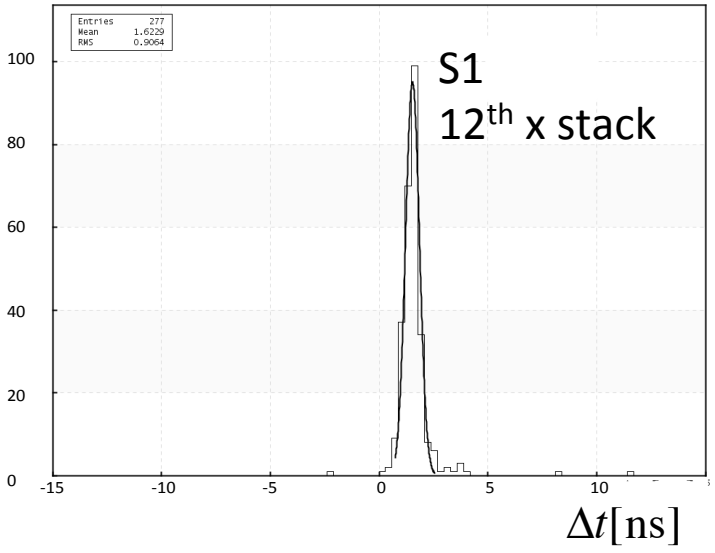
LAC timing with calibration constants from e1c (run 17748)

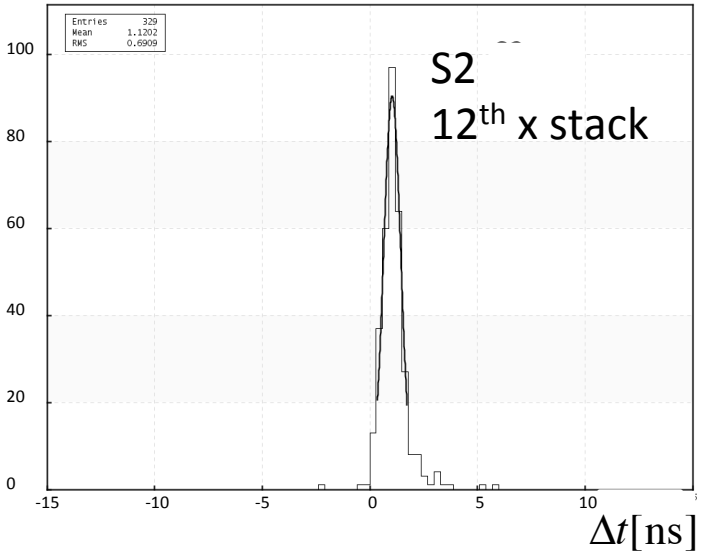
E2a 4.46Gev He4

Cut on single TOF



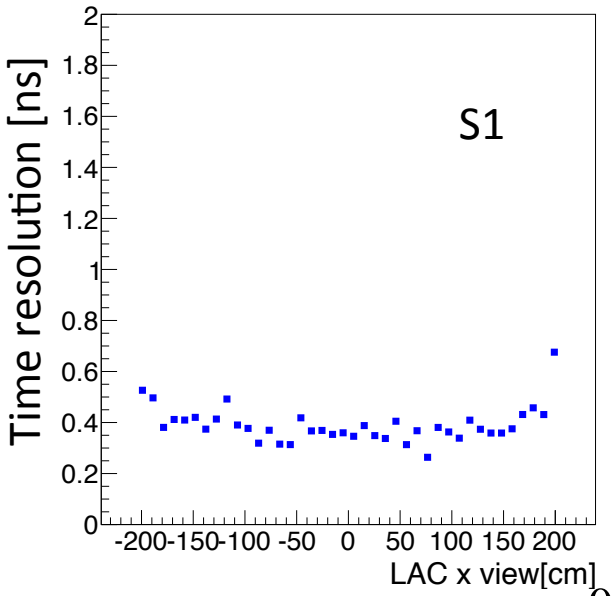


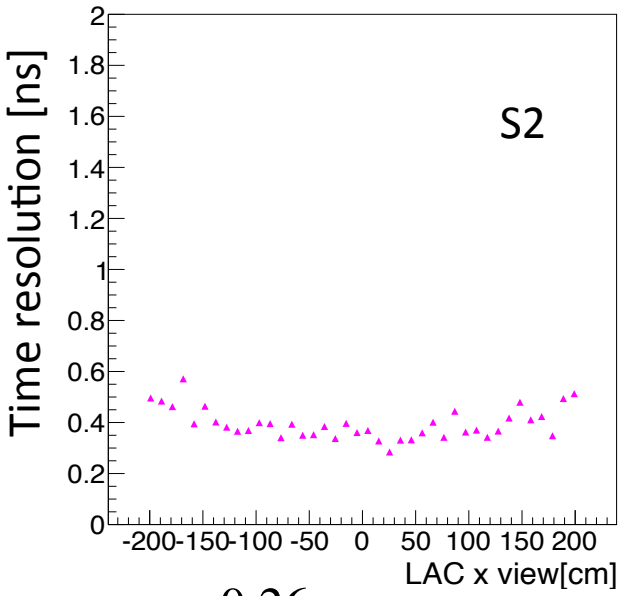




LAC timing with calibration constants from e1c (run 17748)

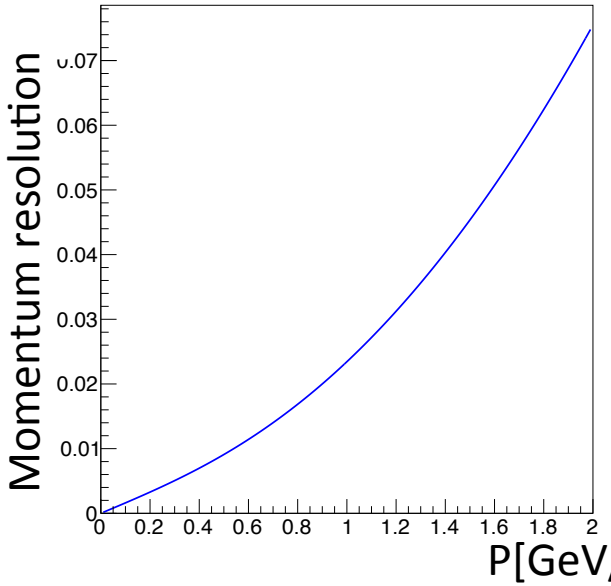
E2a 4.46Gev He4





LAC resolution is satisfying, no additional time calibration is needed.

$$\sigma_{TOF} = 0.3ns \quad \Rightarrow \quad \sigma_{LAC} = 0.26ns$$



The blue line corresponds to momentum resolution corresponding to time resolution.

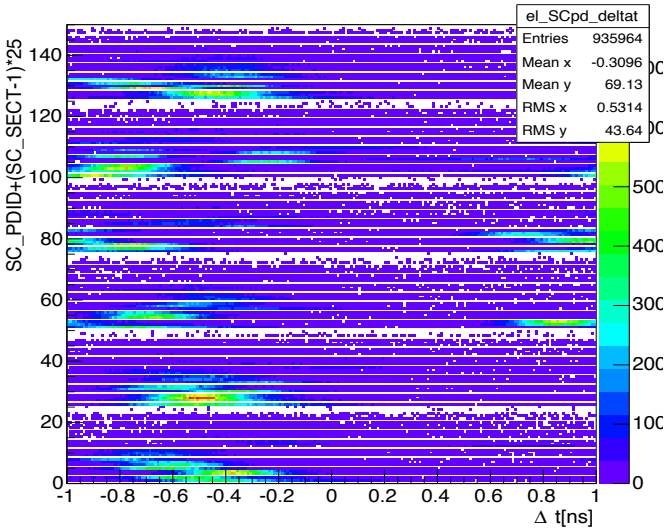
$\sigma_{\Delta p}/p$ corresponding to $\sigma_{\Delta t} = 0.26$ns as a function of neutron momentum

Time calibration of Time Of Flight detectors (TOF)

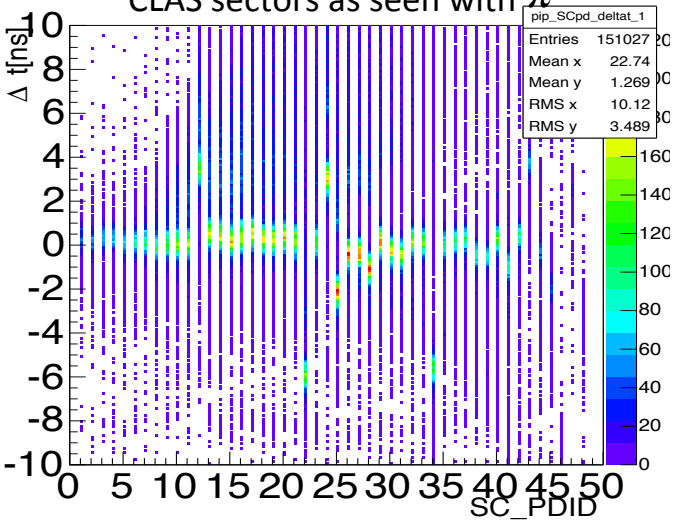
Run 17920 ^{4}HE 4.46 GeV

Before time calibration

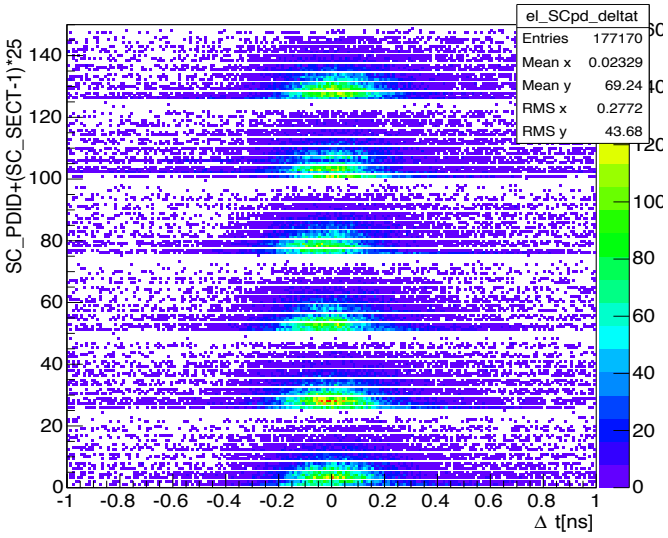
The timing of first 24 TOF paddles of 6 CLAS sectors as seen with e^-

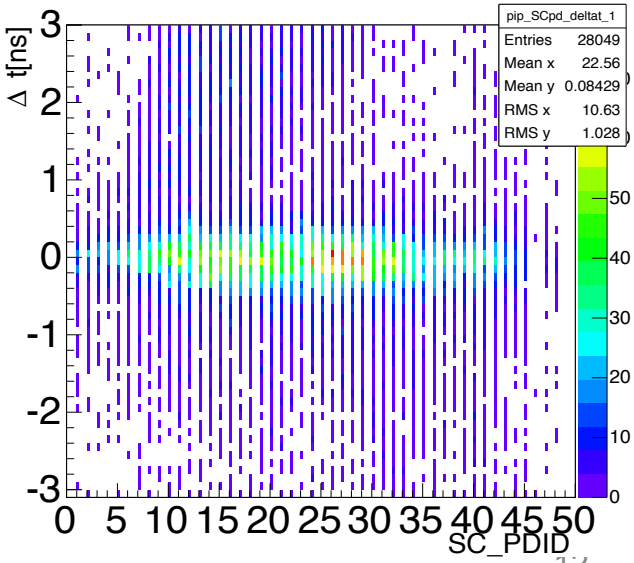


The timing of all TOF paddles of 1st CLAS sectors as seen with $\pi^{\pm}$



After time calibration





First look at the data

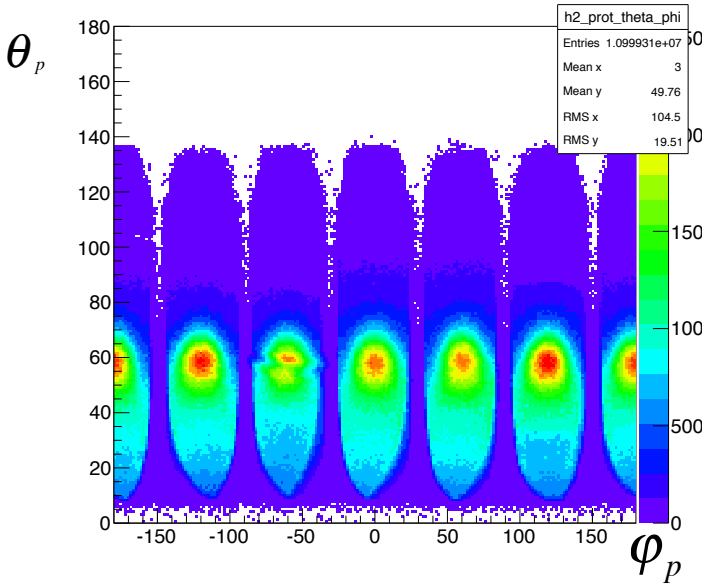
Use e2a ^{3}He(e,e'p) and ^{3}He(e,e'n) to compare n(p_n) and n(p_p)

To compare these:

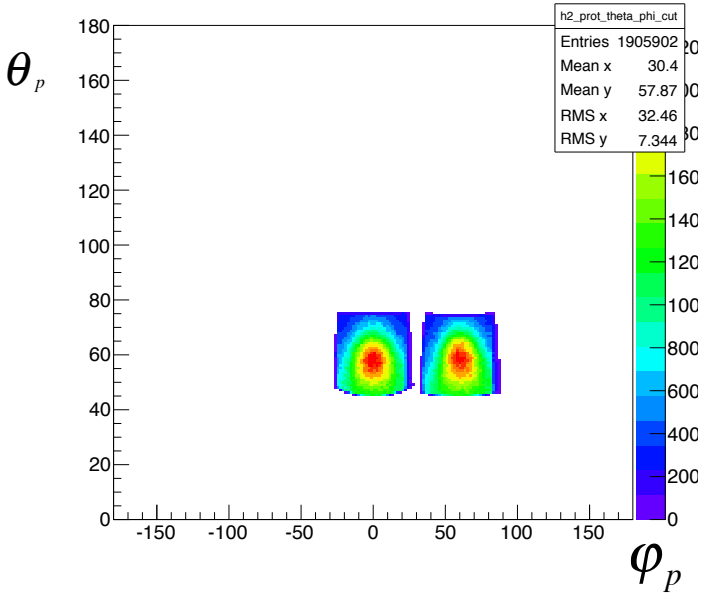
- Correct (e,e'n) for detection efficiency (not done)
- Smear (e,e'p) with n resolution (not done)
- Apply standard cuts and corrections (not done)
- Require $45^0 < \theta_p < 75^0$

$^3He(e,e'p)$

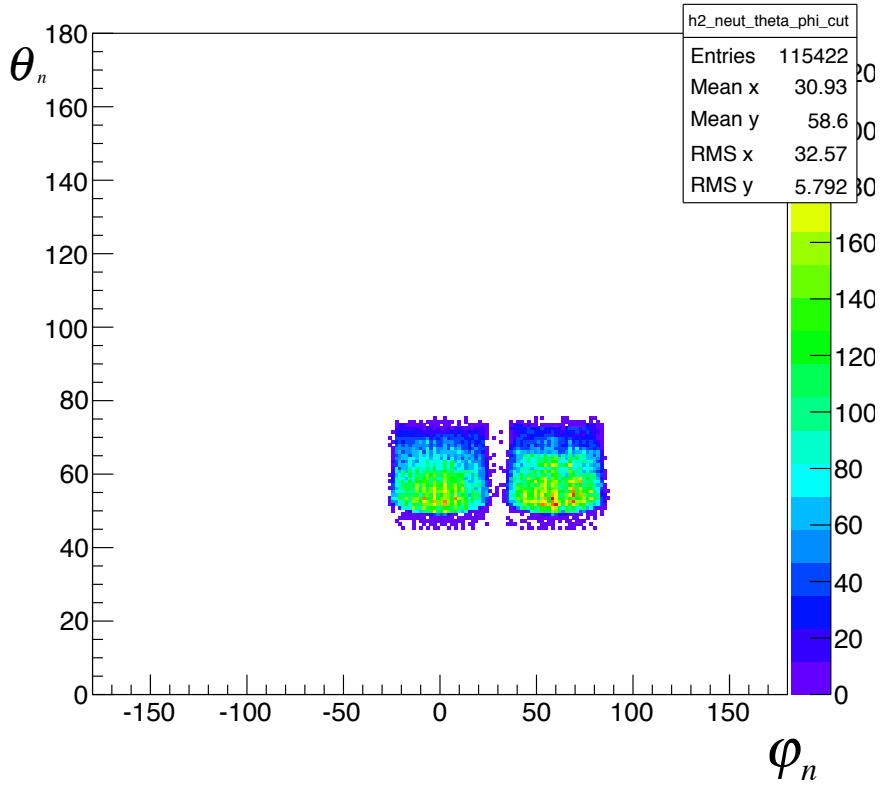
E2a 2.26Gev He3



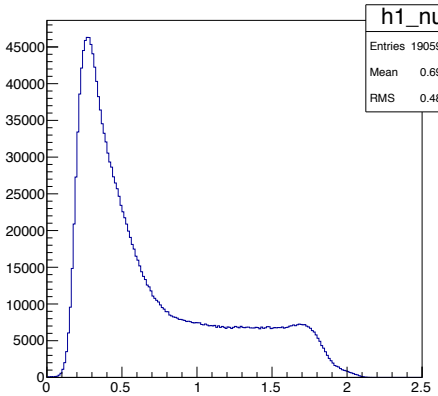
Cut on θ_p,φ_p to match LAC detection area

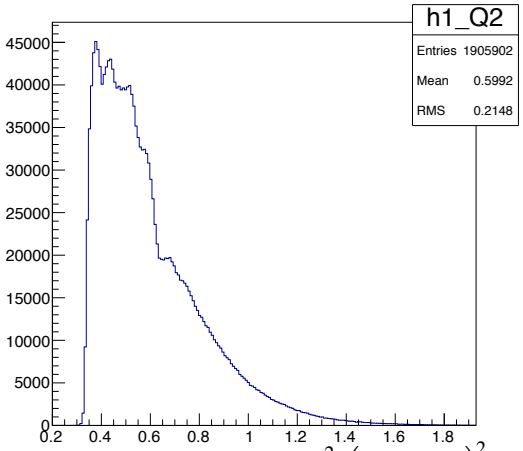


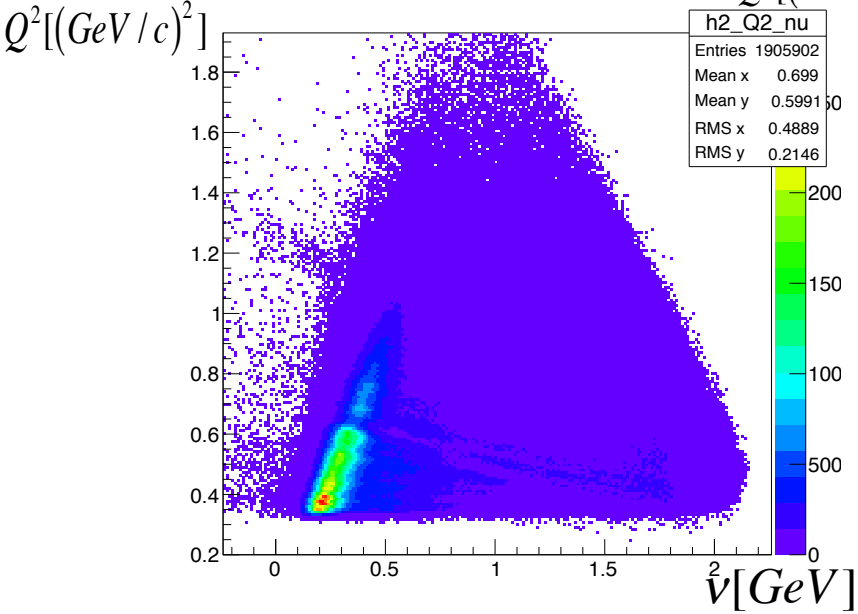
$^3He(e,e'n)$



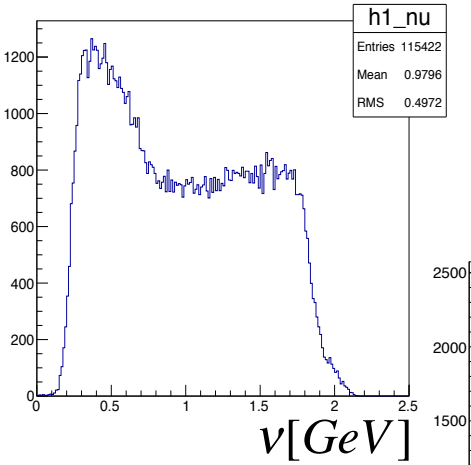
$^3He(e,e'p)$

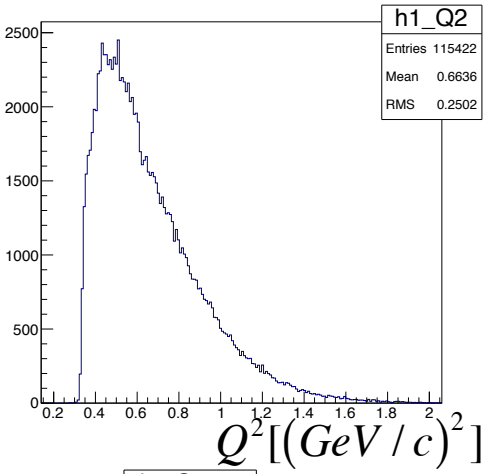


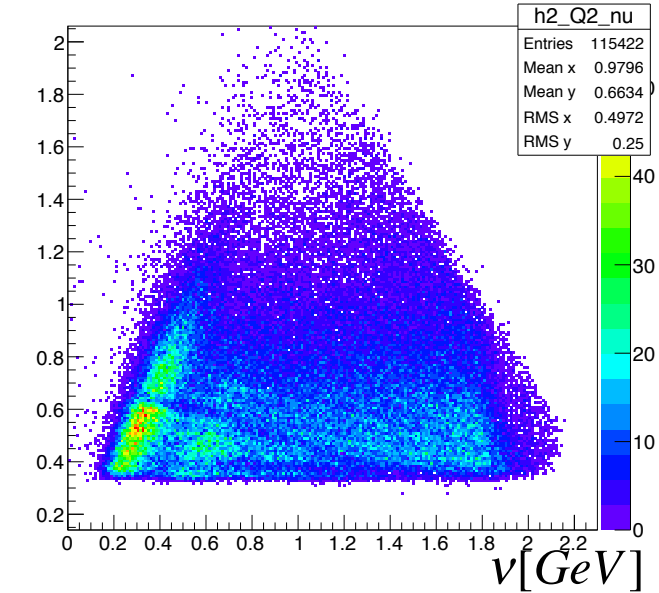




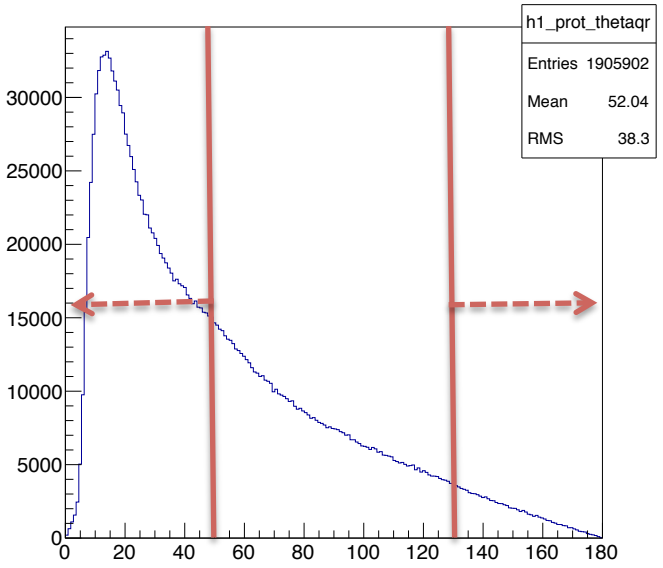
$^3He(e,e'n)$



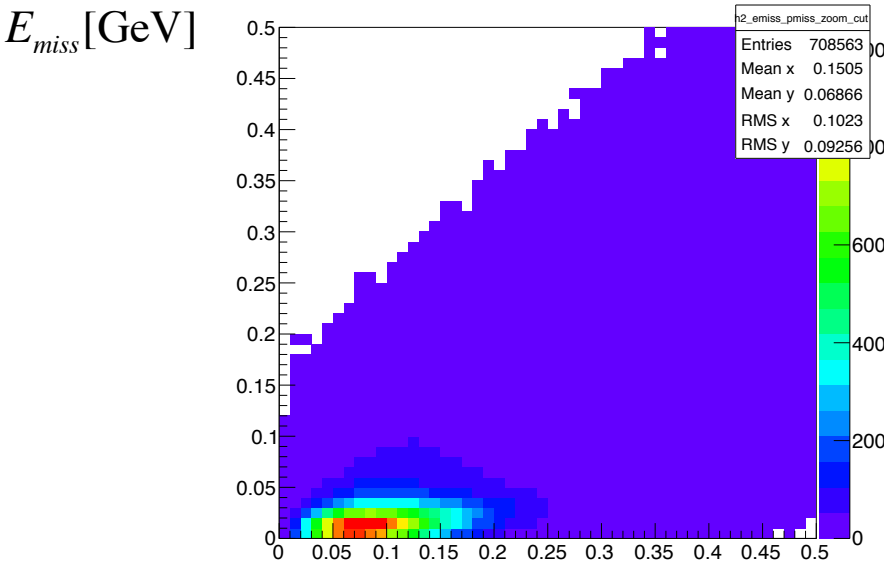




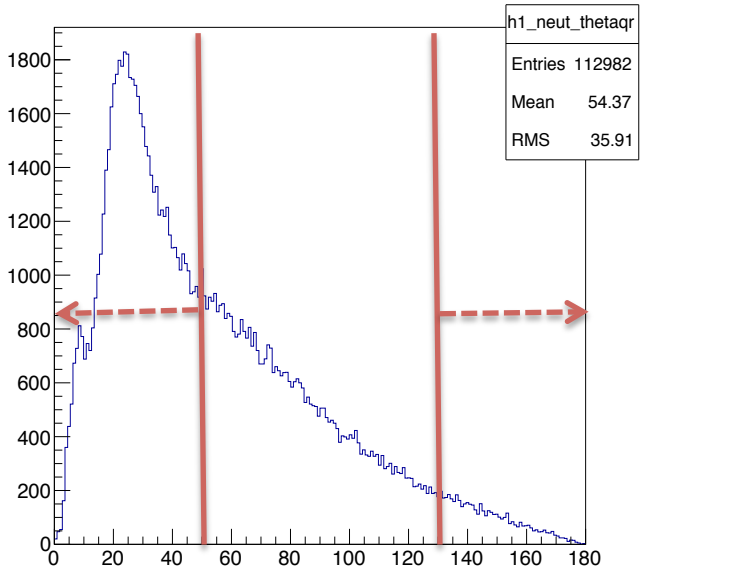
$^3He(e,e'p)$



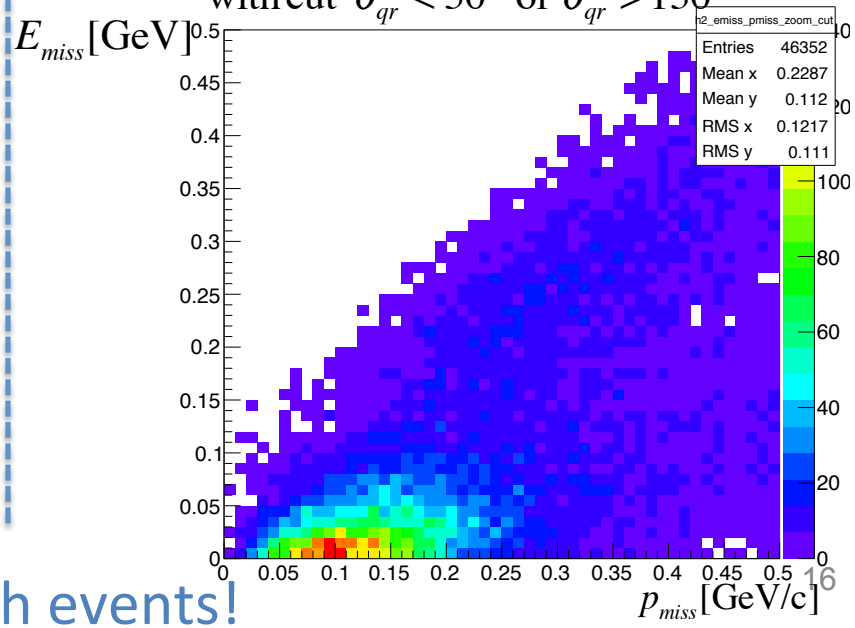
with cut $\theta_{qr} < 50^0$ or $\theta_{qr} > 130^0$



$^3He(e,e'n)$

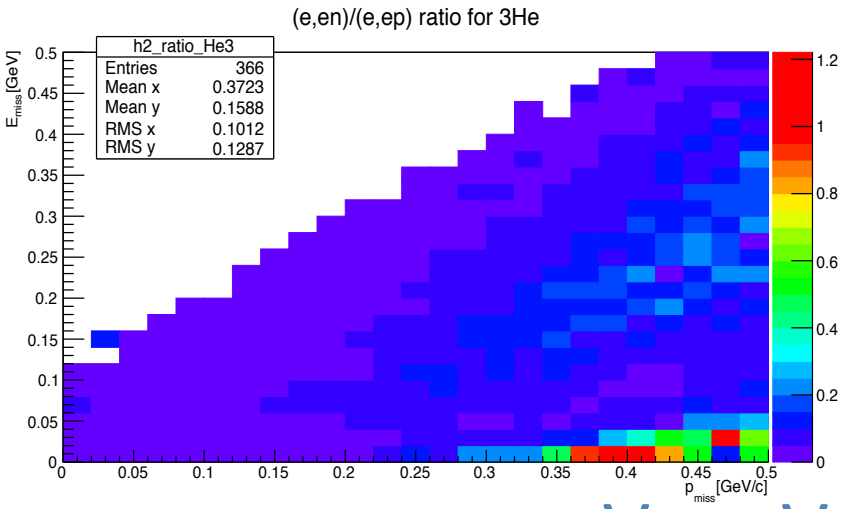


with cut $\theta_{qr} < 50^0$ or $\theta_{qr} > 130^0$

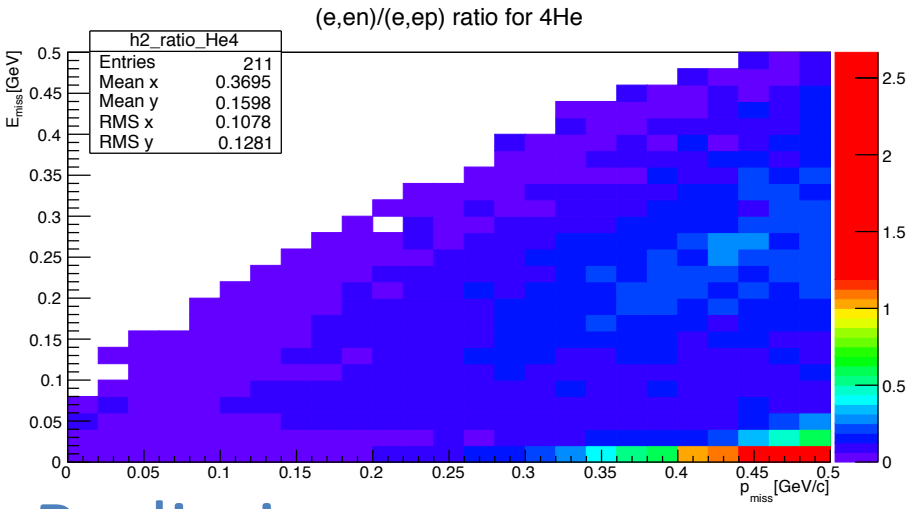


Enough events!

$^3He(e,e'n)/^3He(e,e'p)$

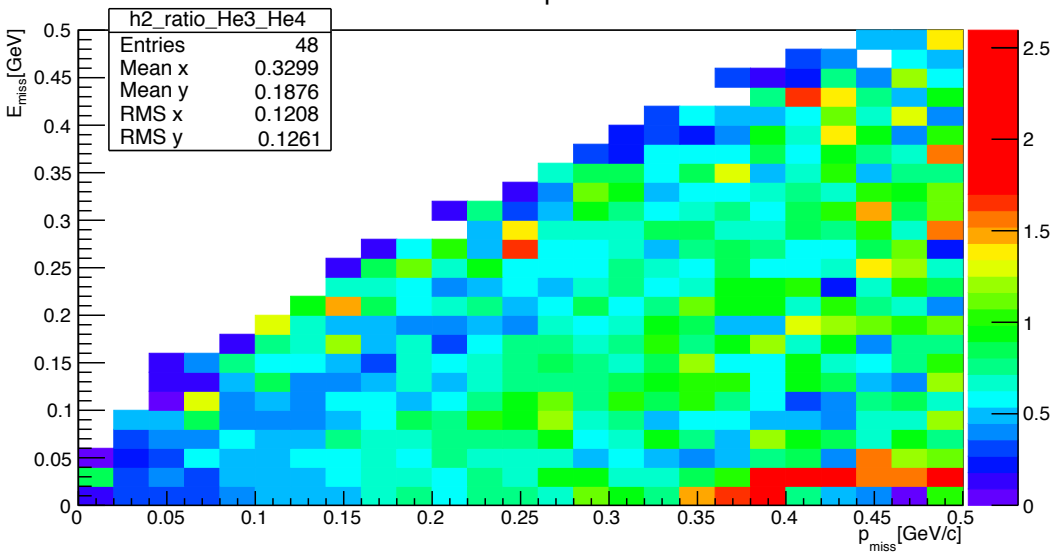


$^4He(e,e'n)/^4He(e,e'p)$



Very Very Preliminary

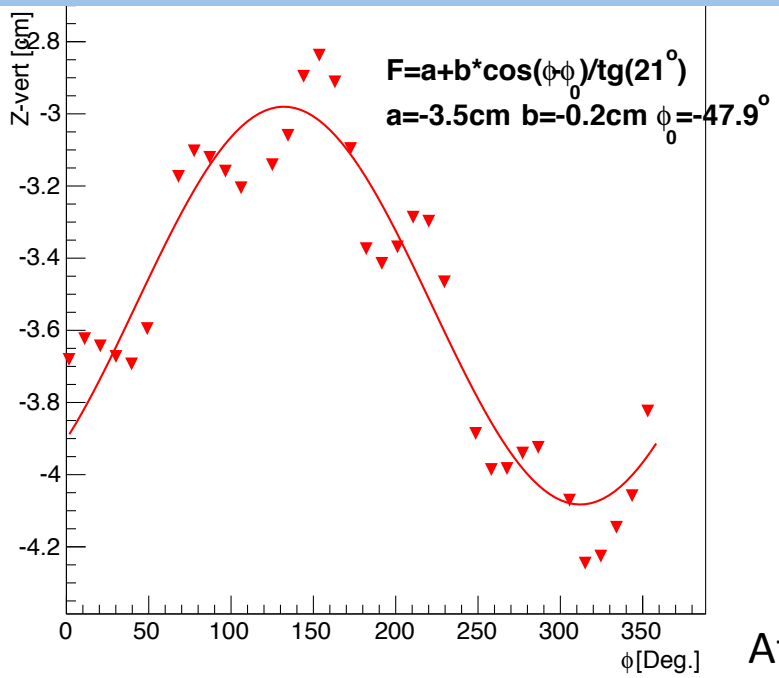
$$\left\{^3He(e,e'n)/^3He(e,e'p)\right\}/\left\{^4He(e,e'n)/^4He(e,e'p)\right\}$$



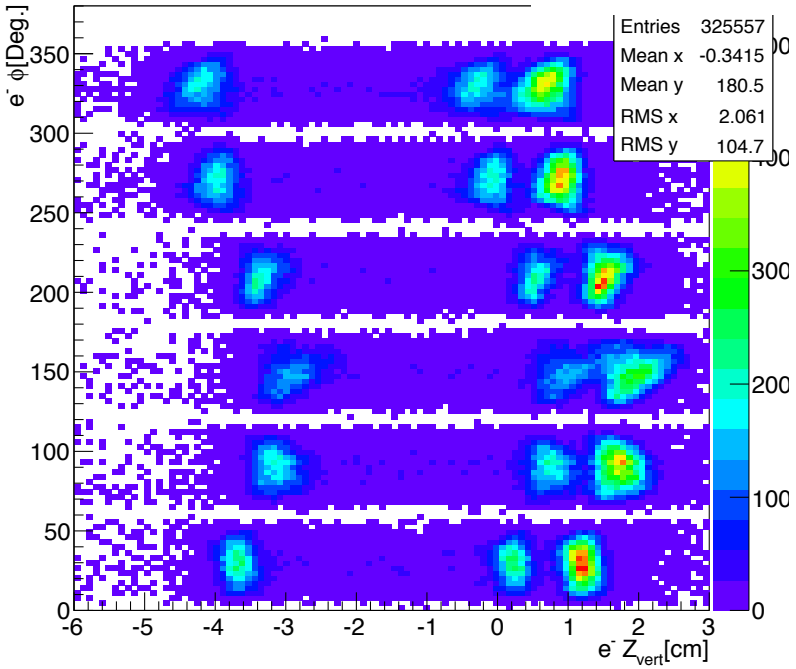
Cuts and corrections

1. e^- momentum corrections
2. e^- fiducial cuts
3. Vertex corrections
4. n detection efficiency
5. e^-,p particle ID
6. p energy loss correction

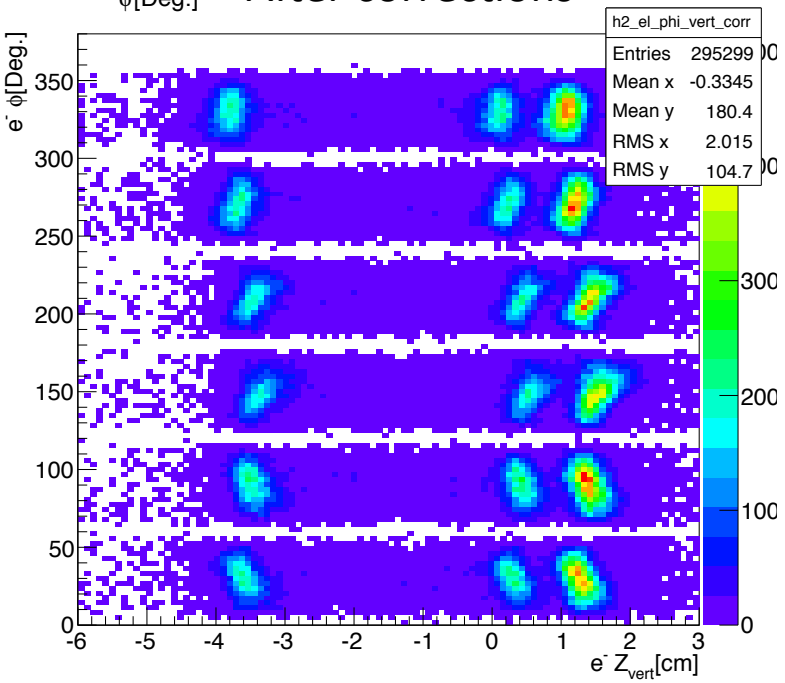
Vertex corrections



Before corrections

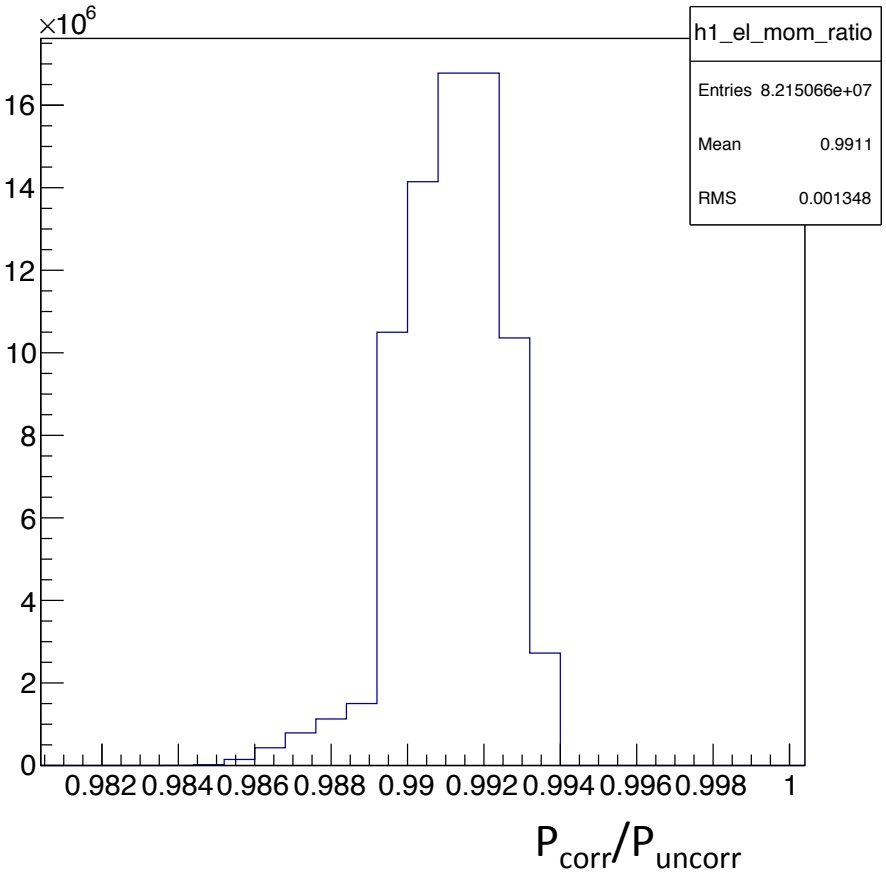


After corrections



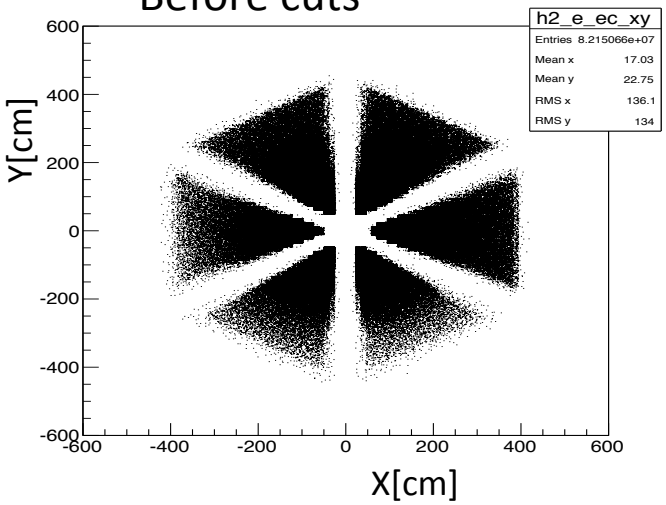
e- fiducial cuts and momentum correction

The ratio of the corrected e- momentum over the uncorrected e- momentum (~1% change)

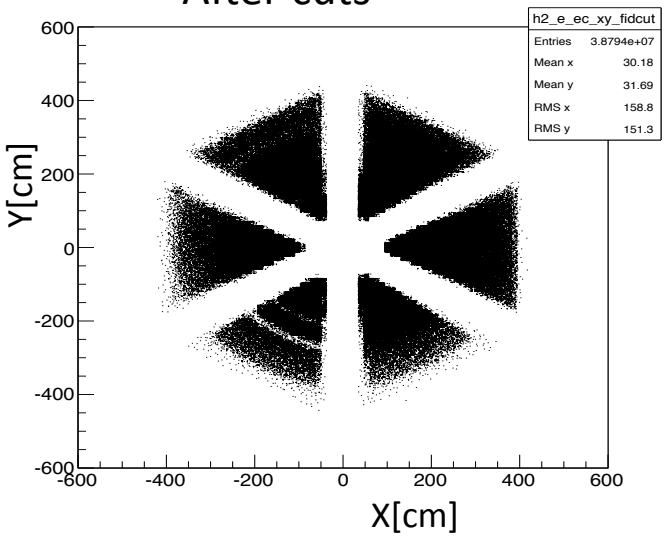


Due to lack of precise knowledge of magnetic field and some other factors e- momentum needs to be corrected

Before cuts



After cuts



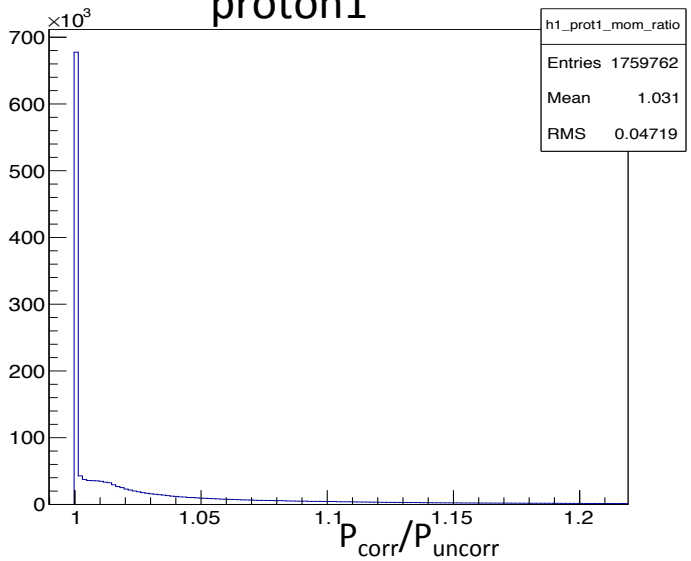
Fiducia cuts include

- ✧ EC edge cut
- ✧ Theta vs outline cut (phi cut)
- ✧ Bad channel knockout (theta phi cut)

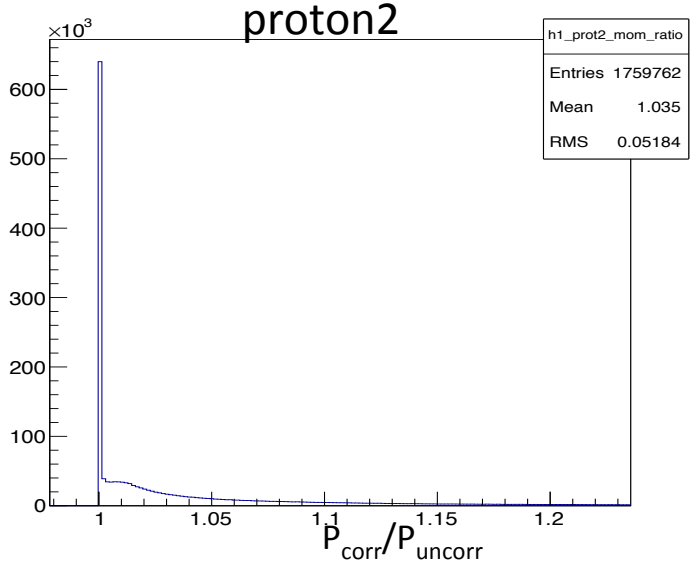
Used from Zehang thesis

p momentum energy loss correction

proton1

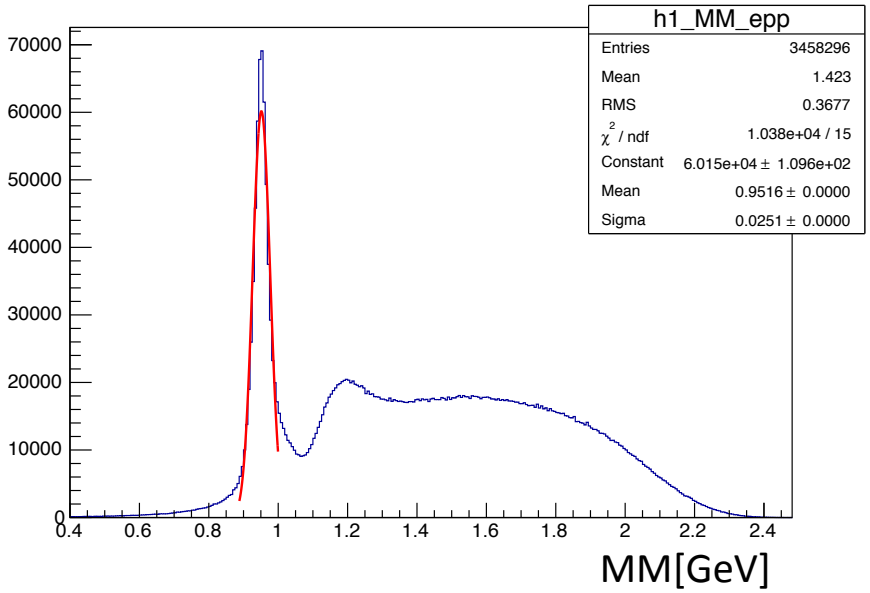


proton2

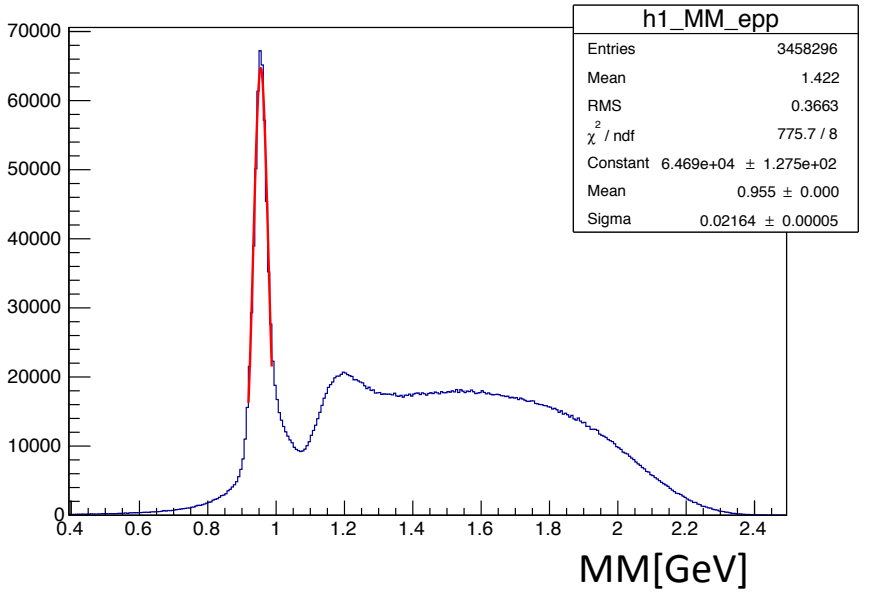


MM(e,e'pp)n

Before e⁻,p momentum corrections

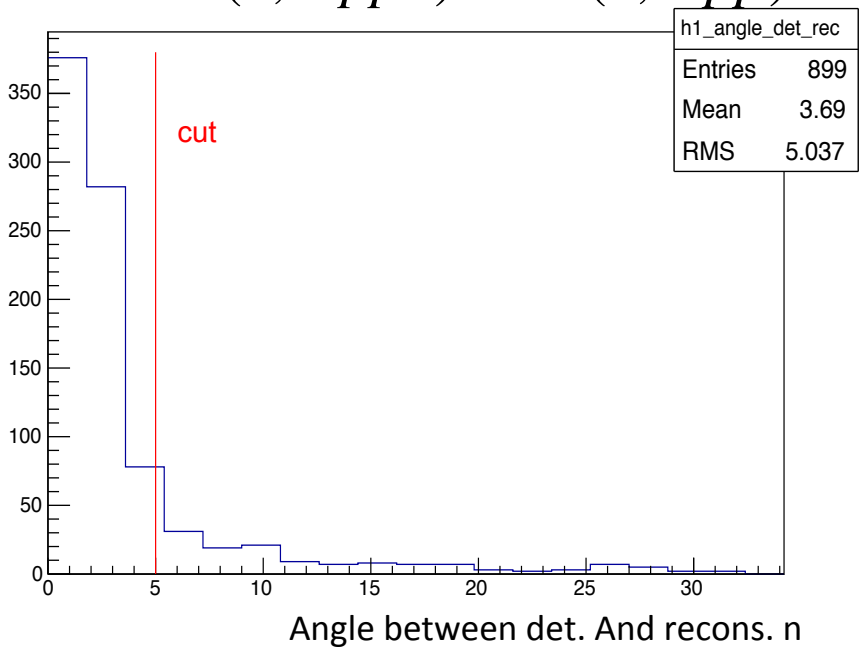


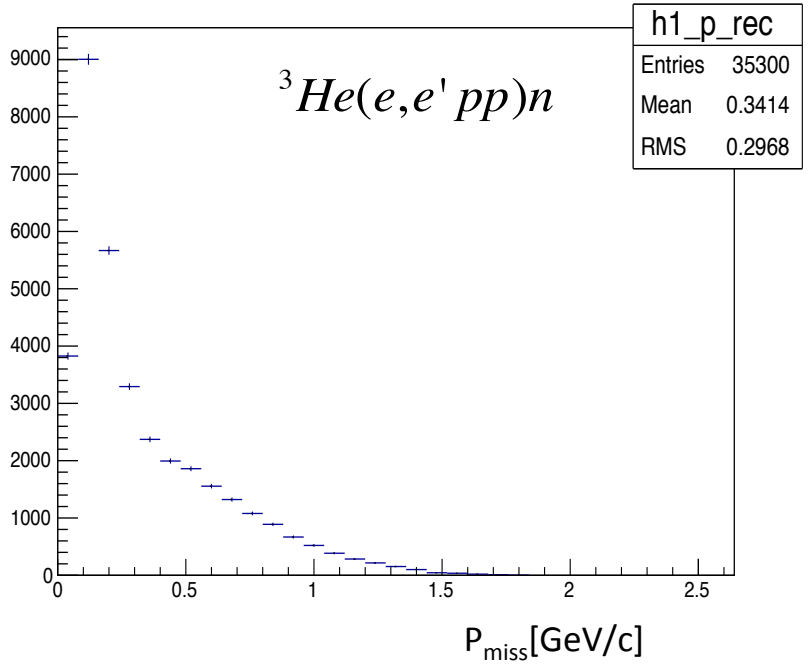
After e⁻,p momentum corrections

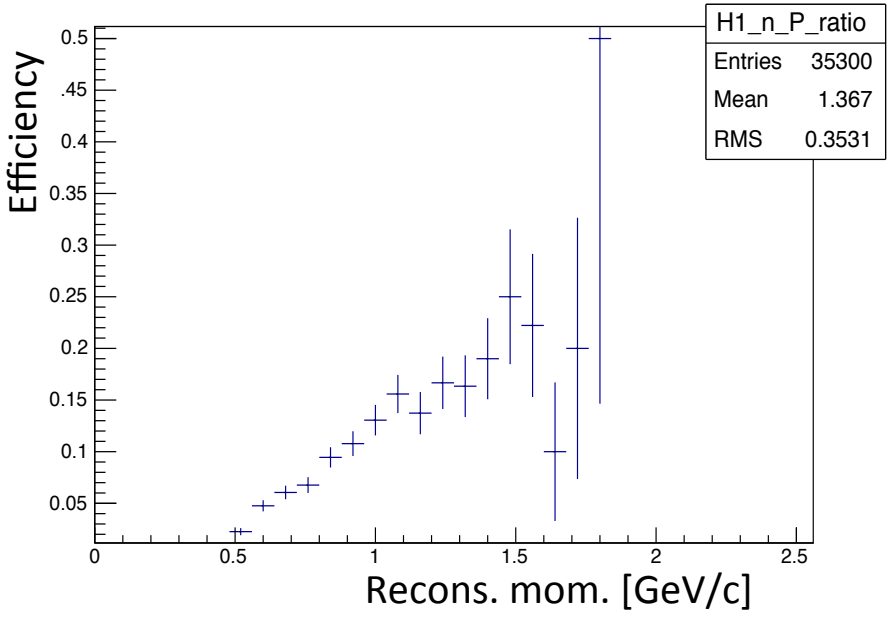


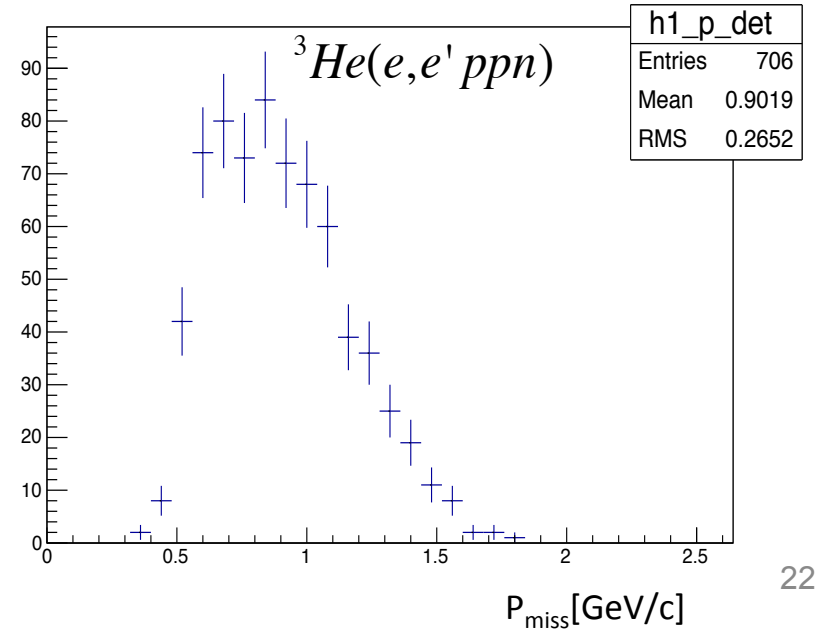
n detection efficiency after p and e- momentum corrections

e2a $^3He(e,e'ppn)/^3He(e,e'pp)n$









Cuts on reconstructed neutron are

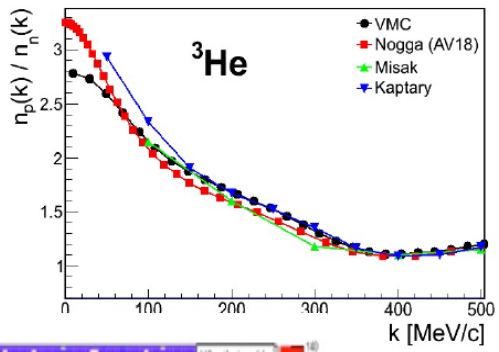
1. $0.9 \leq$ Missing Mass ≤ 1
2. $\varphi_{recons}, \theta_{recons.}$ cuts
3. Vertex cuts

Cuts on detected neutron are

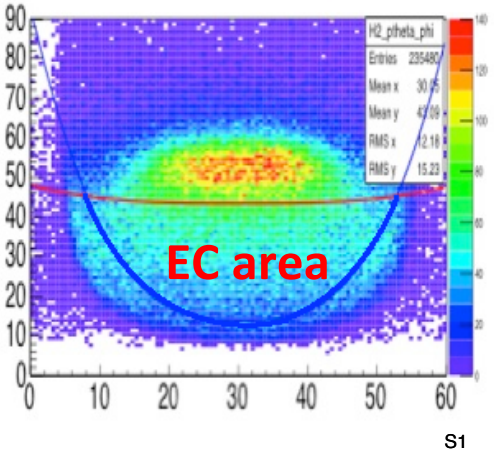
1. n_beta_det ≤ 0.95
2. φ, θ cuts
3. -0.3 GeV/c$\leq$ p-pmiss $\leq$0.3 GeV/c
4. Angle between recons. and det. neutrons <5^{o}

Conclusions

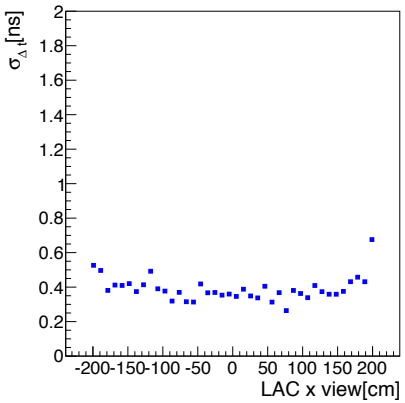
- Want to measure $\frac{^3He(e,e'n)/^3He(e,e'p)}{^4He(e,e'n)/^4He(e,e'p)}$ using e2a and e2b



- Calibrated EC for e2b
  - Quasielastic neutrons at 2.2 and 4.7 Gev miss the EC



- Have studied LAC timing.
  - LAC timing is satisfying with calibration constants from e1c
  - Tof timing was poor calibrated, thus it was recalibrated.



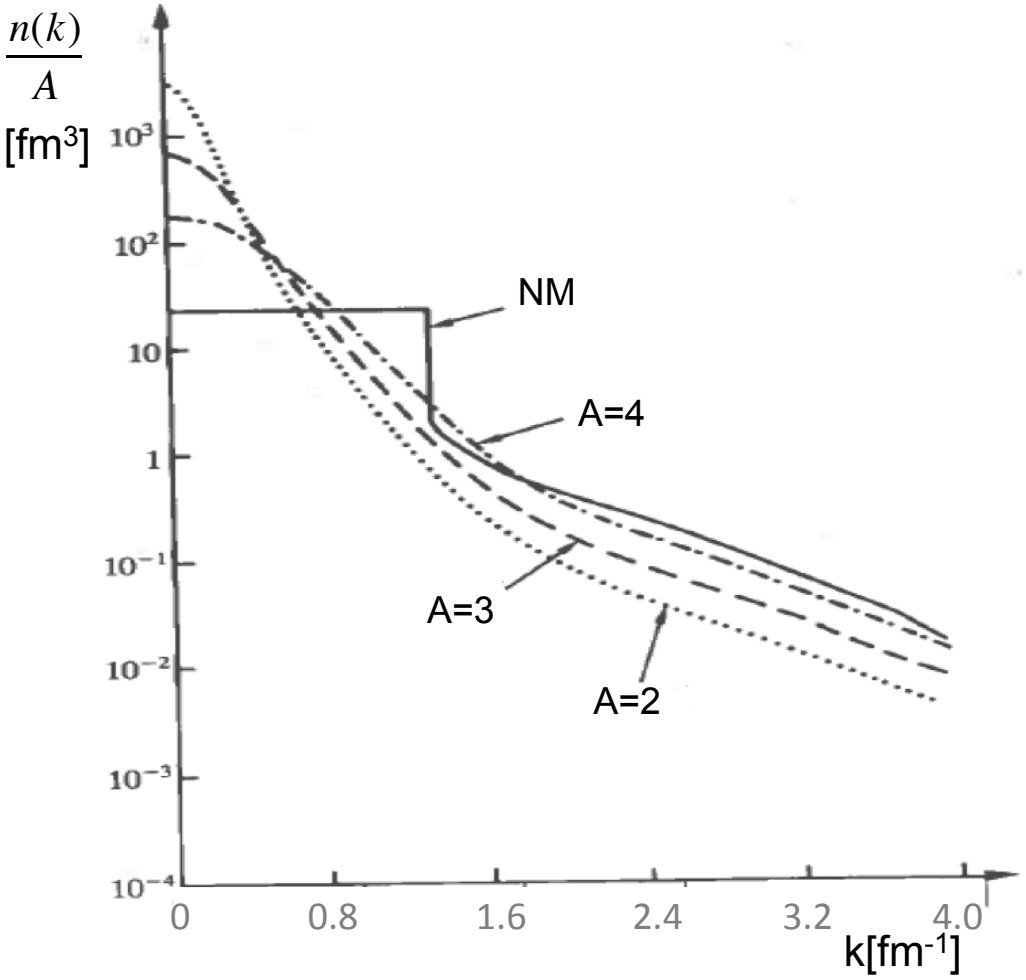
- Have recooked e2a experiment data

- e2a $\frac{^3He(e,e'n)/^3He(e,e'p)}{^4He(e,e'n)/^4He(e,e'p)}$ (2.26 GeV)
  - First glance looks good
  - Analysis ongoing [e2b to come]

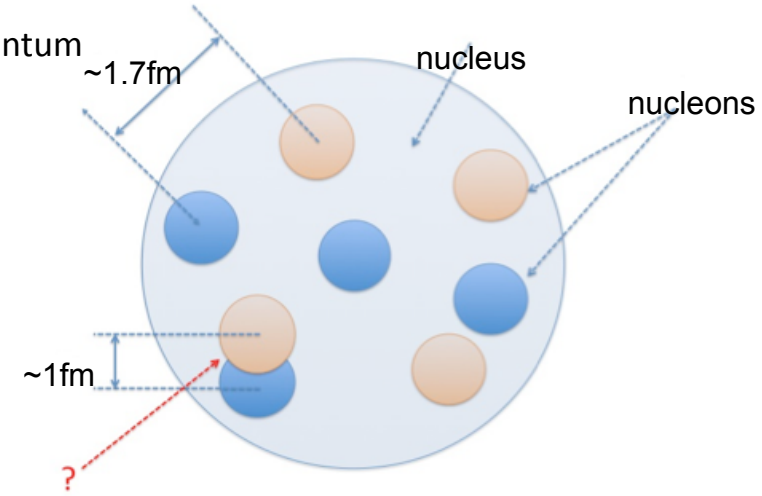
What are SRC?

2N-SRC are pairs of nucleons with;

- with small distance between each other(~10^{-15}m)
- High relative momentum and small center of mass momentum with respect to Fermi momentum(250-270 MeV/c)



N(k)/A calculated by Schiavilla et al.(1986) in A=2,3 and 4 nuclei and nuclear matter (NM).



n-p pairs dominate over p-p,n-n pairs.

- n-p(90%)
- p-p(5%)
- n-n(5%)

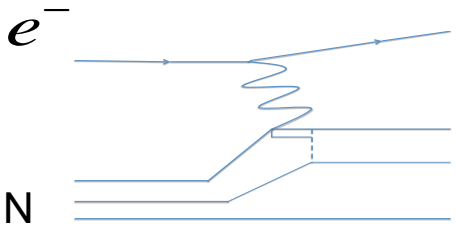
- Almost all high momentum nucleons belong to SRC pairs
- Not described by I.P.M. (the motion of the nucleon is not affected by the other individual nucleons)

Hall A experiment

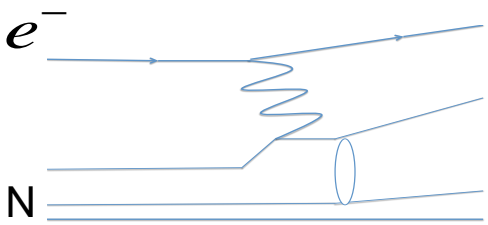
Will study majority and minority nucleon (p in ^{3}He and p in ^{3}H) momentum distributions in A=3 asymmetric nuclei.

$p_{miss}=p_{initial,}$ only if there are no final state interactions or other interactions.

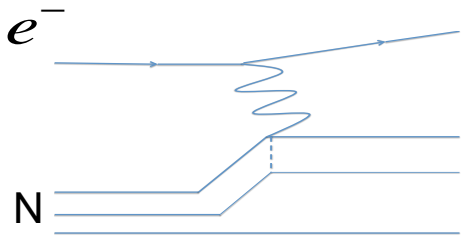
Processes we want to avoid



Excitation of the nucleon into intermediate Delta.



Final State Interactions



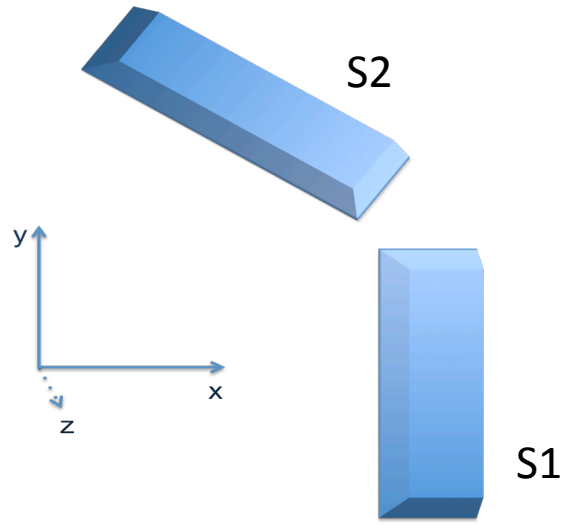
MEC(Meson exchange currents)

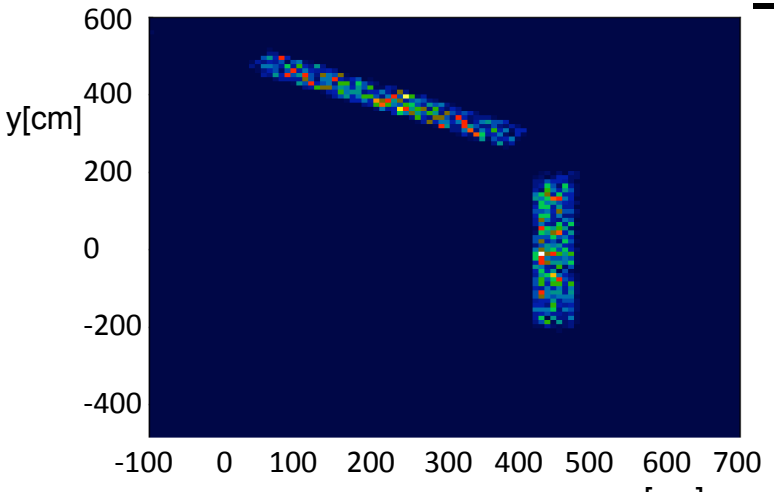
Kinematics:

- $x = \frac{Q^2}{2m\omega} > 1$ to suppress Delta production.
- High Q^2 (Q^2~2(GeV/c)^2) to minimize meson exchange currents (MEC)
- Small $\theta_{rq} < 40^o$ (angle between recoil momentum and momentum transfer) to suppress Final State Interactions

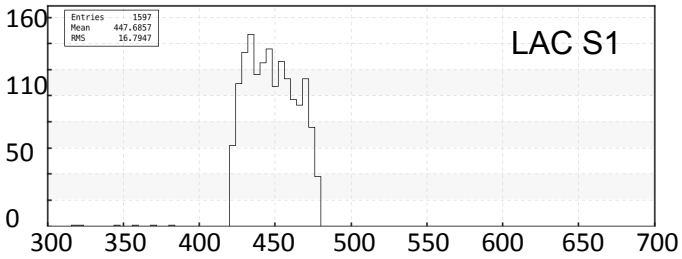
LAC timing with calibration constants from "calib.RunIndex"

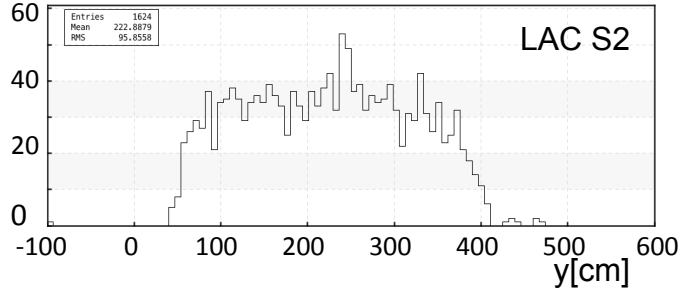
E2a 2.26Gev He4



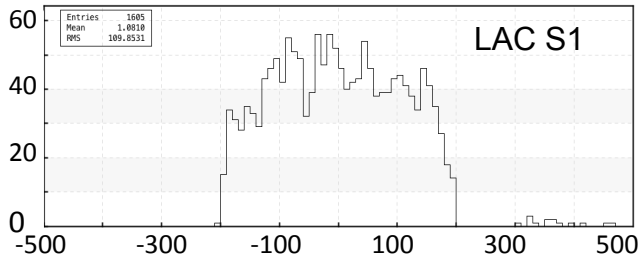


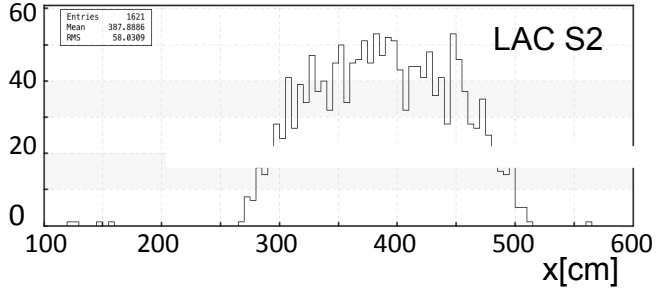
The y vs x global coordinate of π^+ in LAC





y global coordinate of π^+





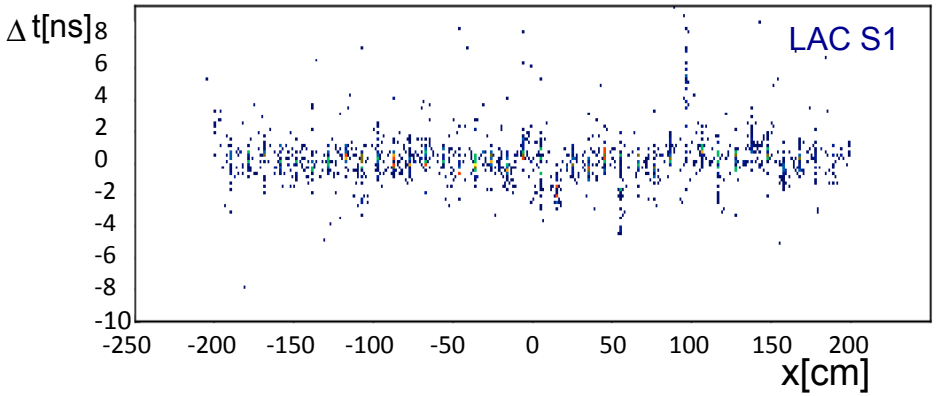
x global coordinate of π^+

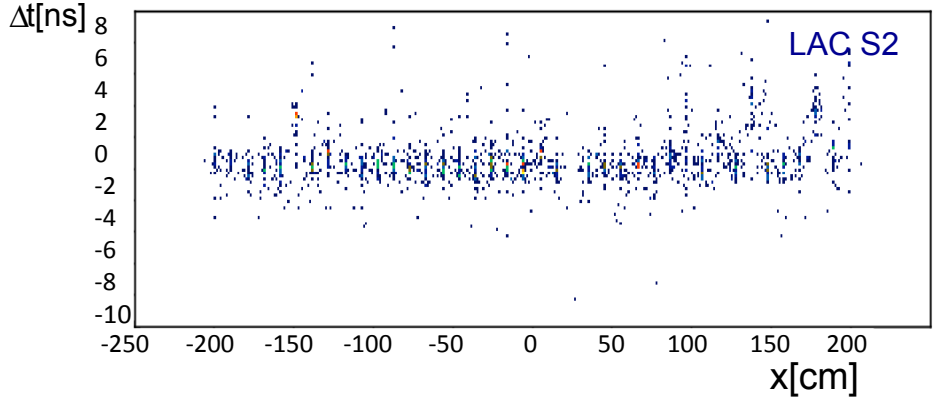
Rotate x,y coordinates to local coordinates

LAC timing after offset correction

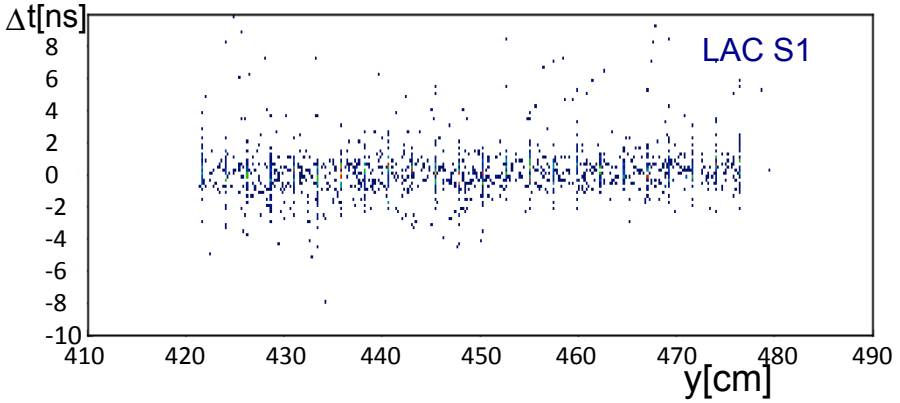
E2a 2.26Gev He4

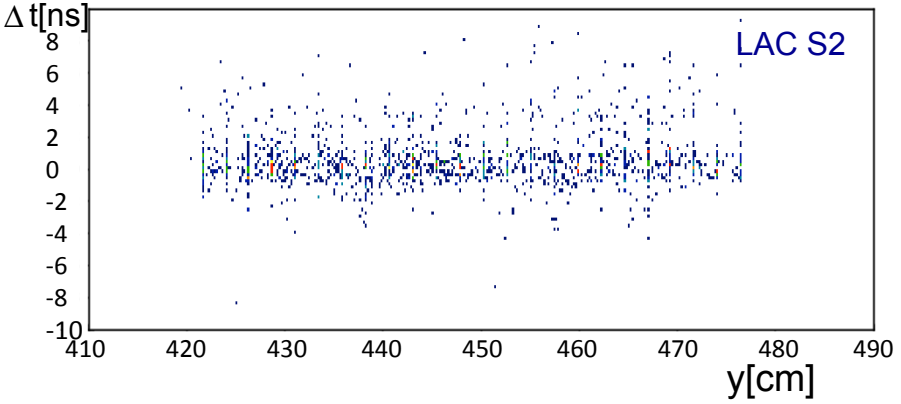
$t_{LAC} - t_{TOF}$ after correction vs x



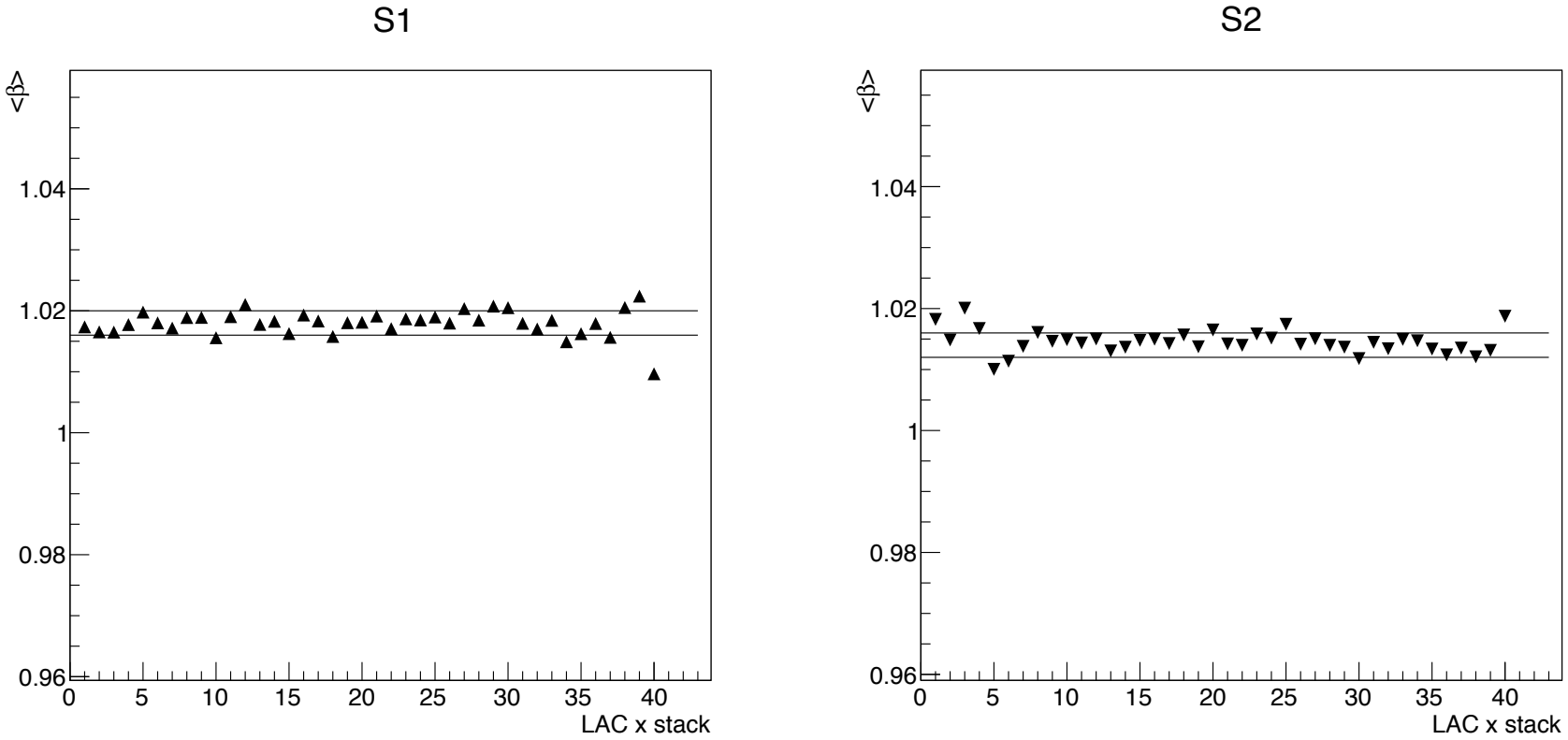


$t_{LAC} - t_{TOF}$ after correction vs y





Photon β in LAC

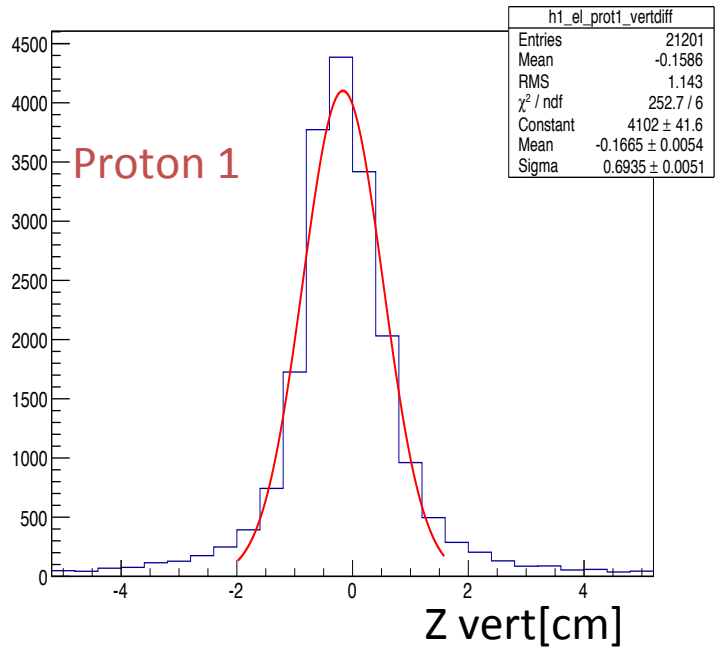


The mean values of photon β distributions as a function of LAC x stacks in S1 and S2

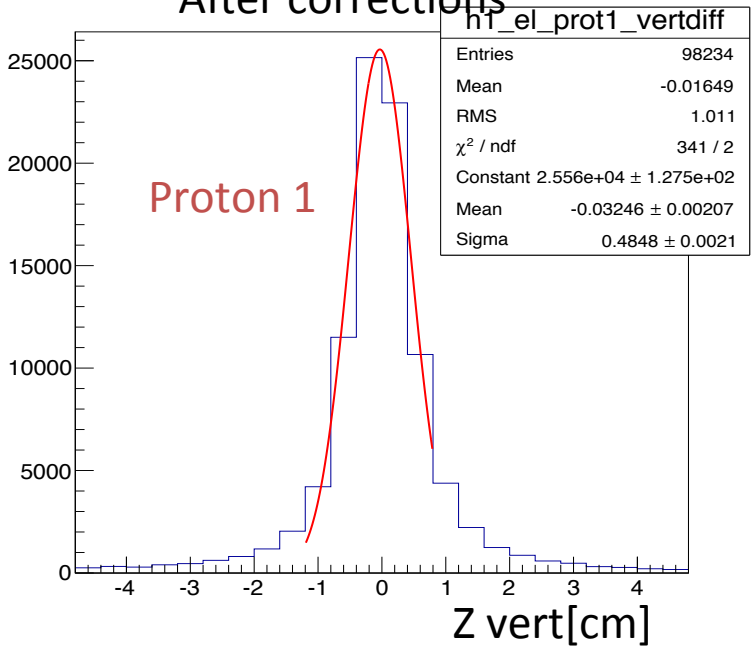
$$\frac{d\beta}{\beta} = -\frac{dt}{t} \Rightarrow \Delta\beta \approx 0.004 \text{ corresponds to } \Delta t \approx 80\text{ps}$$

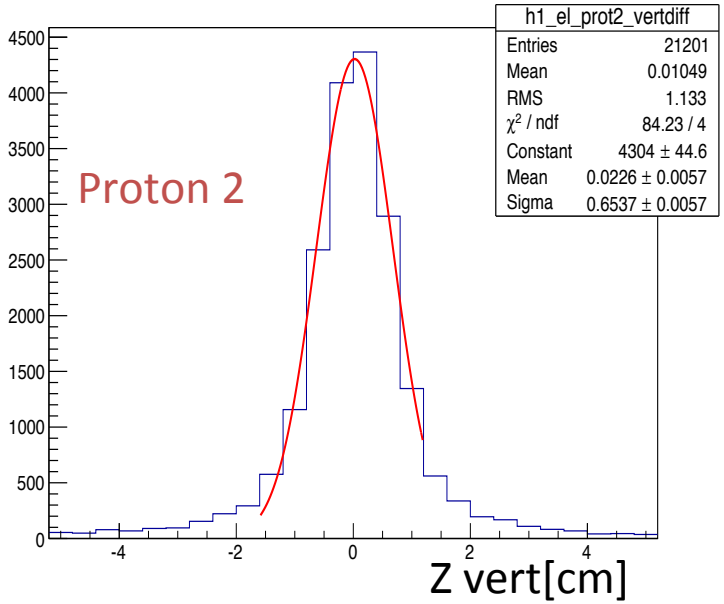
e^- ,proton Z_{vertex} differences

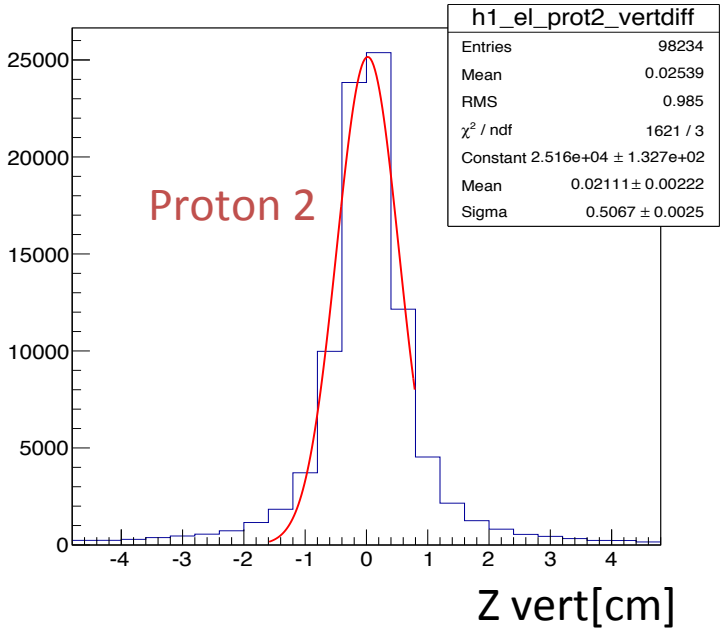
Before corrections



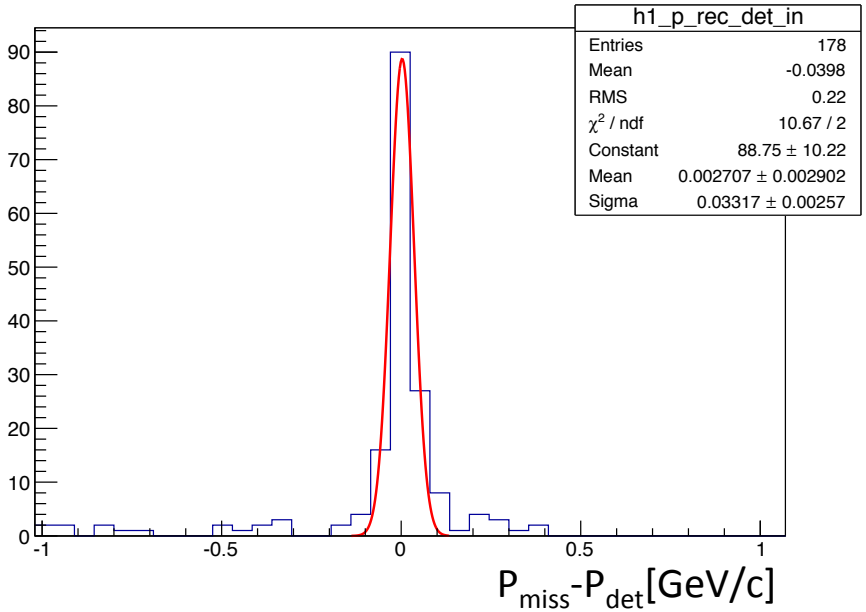
After corrections

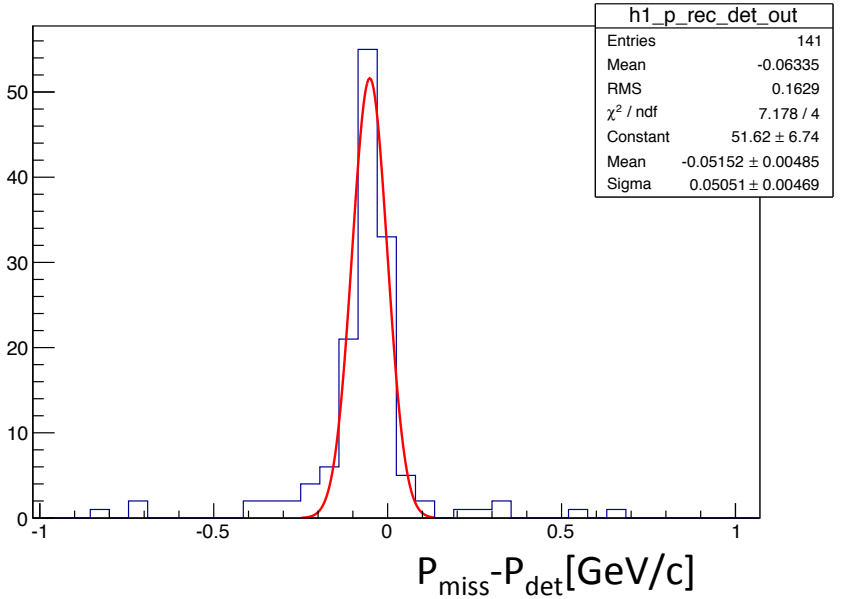


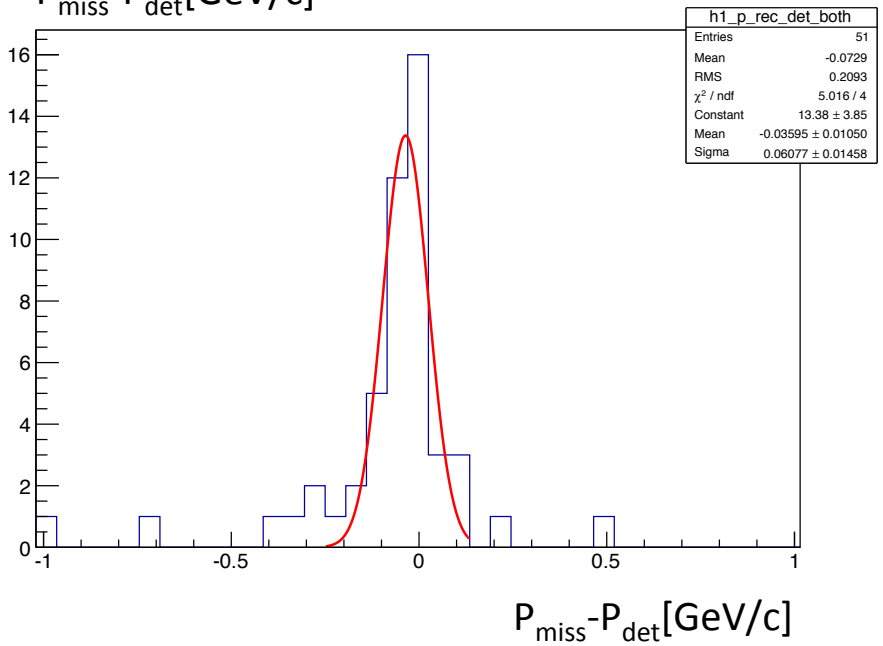




The difference between detected and recons. neutron momenta





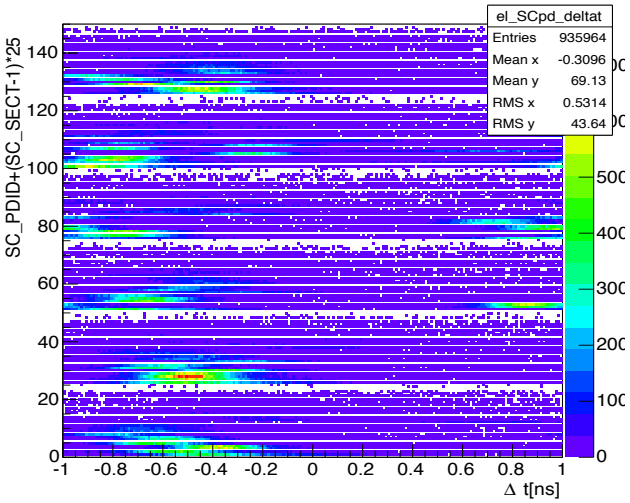


Time calibration of Time Of Flight detectors (TOF)

Run 17920 ^{4}HE 4.46 GeV

Before time calibration

The timing of first 24 TOF paddles of 6 CLAS sectors as seen with e^-



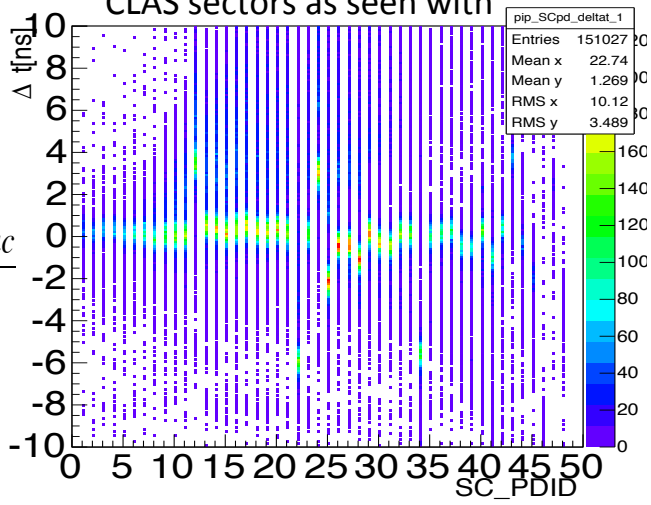
$$\Delta t^{e^-}_{Tof} = t^{e^-}_{Tof} - \frac{d^{e^-}_{Tof}}{c} - \frac{Z^{e^-}_{vert}}{c} - t_{RF}$$

$$RF\_struc = 2.004\,\text{ns}$$

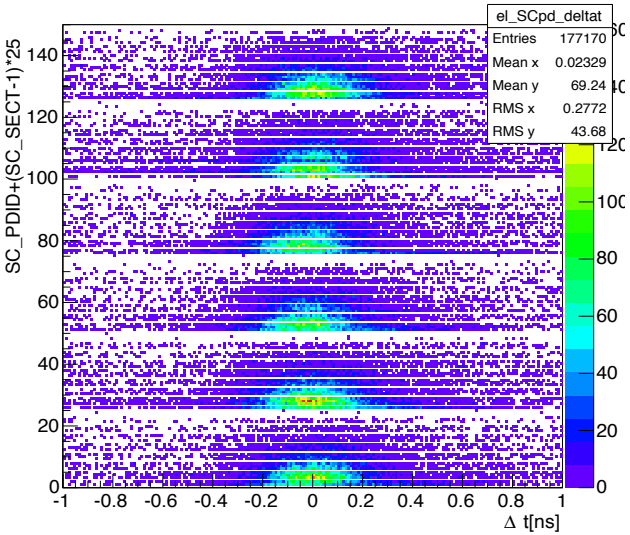
$$\Delta t^{e^-} = AMOD(\Delta t^{e^-}_{Tof}, RF\_struc) - \frac{RF\_struc}{2}$$

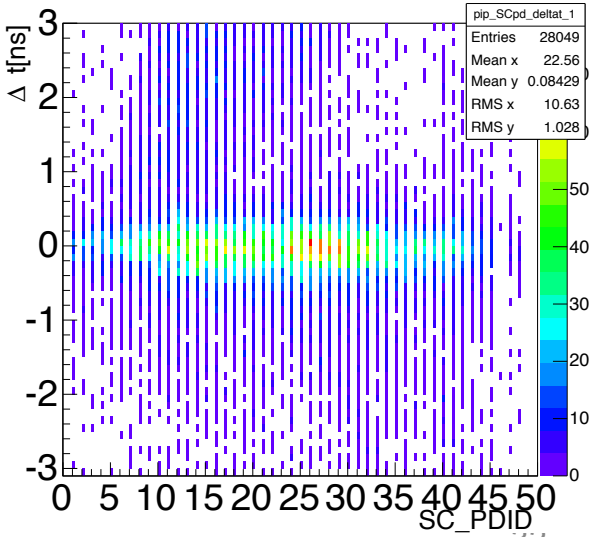
$$\Delta t^{\pi^\pm} = t^{\pi^\pm}_{Tof} - \frac{d^{\pi^\pm}_{Tof}}{c * \beta^{\pi^\pm}} - \left(t^{e^-}_{Tof} - \frac{d^{e^-}_{Tof}}{c} \right)$$

The timing of all TOF paddles of 1st CLAS sectors as seen with π^-

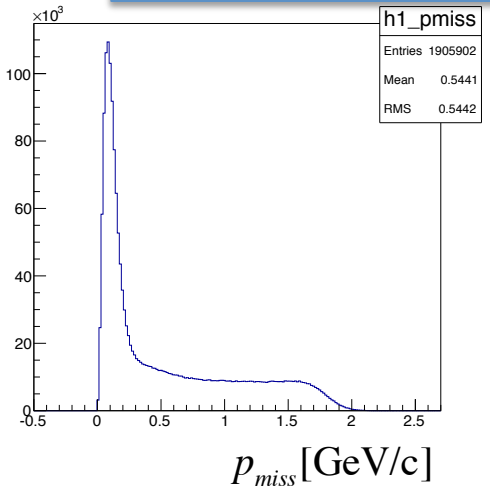


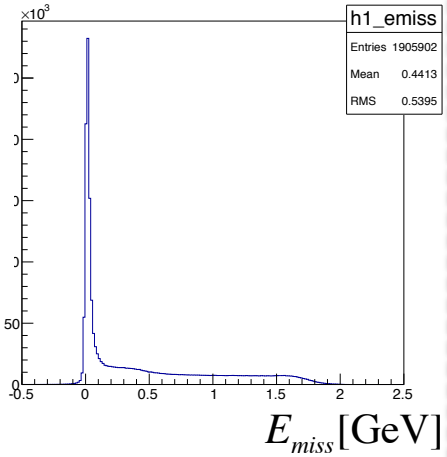
After time calibration

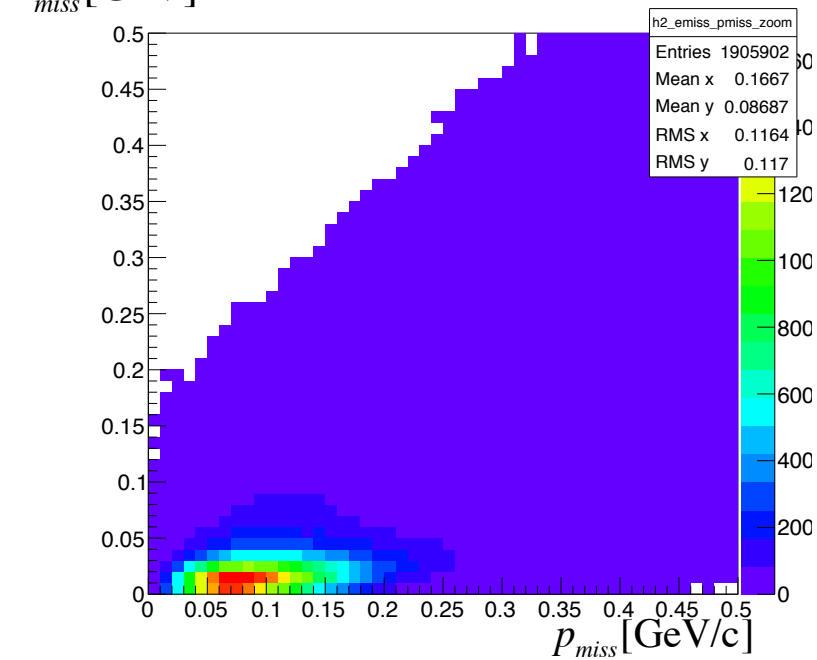




$^3He(e,e'p)$







$^3He(e,e'n)$