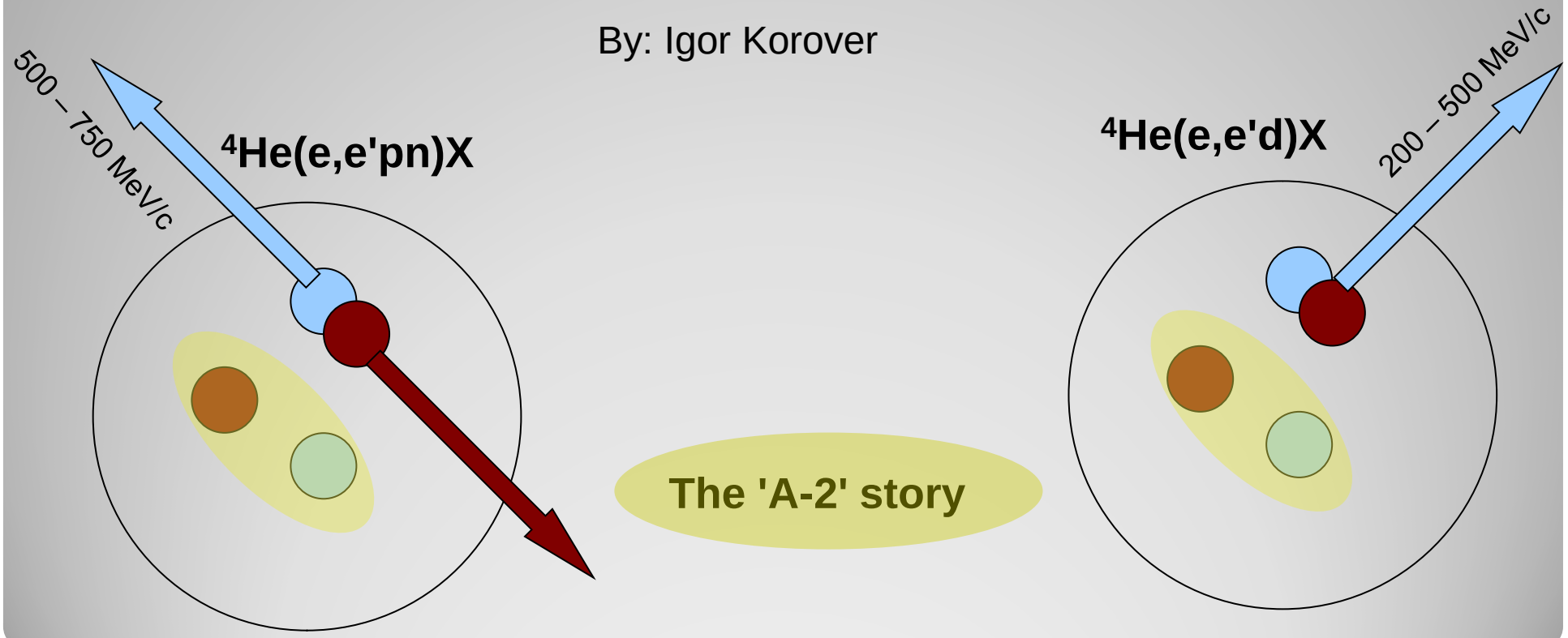
Multi – nucleon excitation of ^{4}He following a violent 2N emission
A report on (e,e'd) and (e,e'pn) analysis of Hall A EXP 07-006

A work in progress

Tel Aviv University – Israel

By: Igor Korover



INT workshop **Feb 2013**

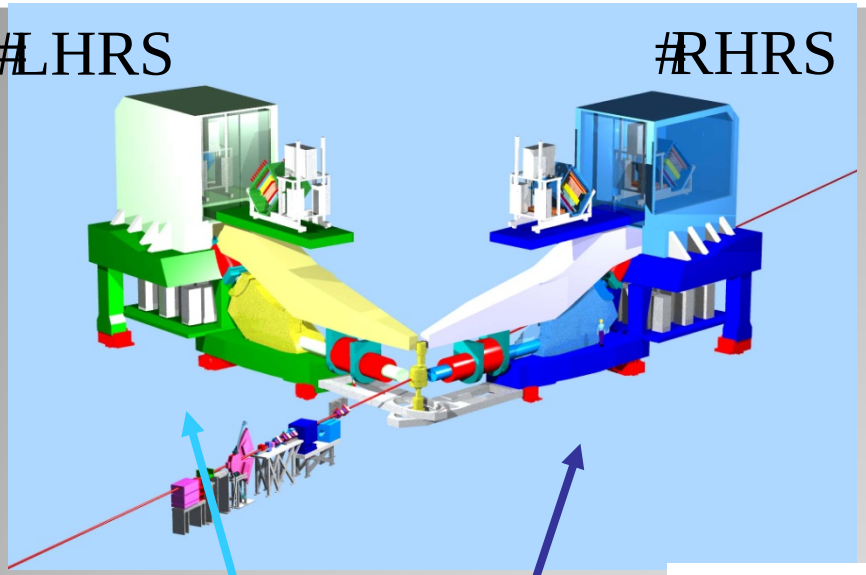
Motivation and Outlook

In light nuclei we can investigate the remained system after a violent extracting of two nucleons

^{4}He(e,e'd)X Pmisss (e,e'd) = 200 – 500 MeV/c

^{4}He(e,e'pn)X Pmiss (e,e'p) ~ Precoil = 500 -750 MeV/c

Experimental setup E07 -006 JLab

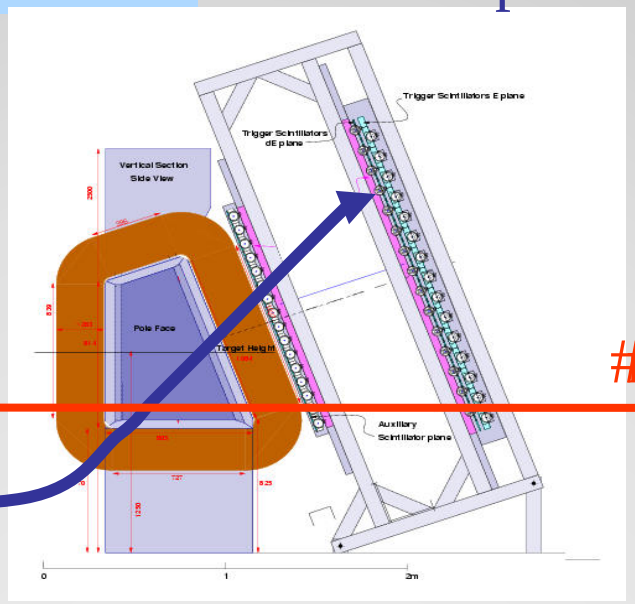


#n array

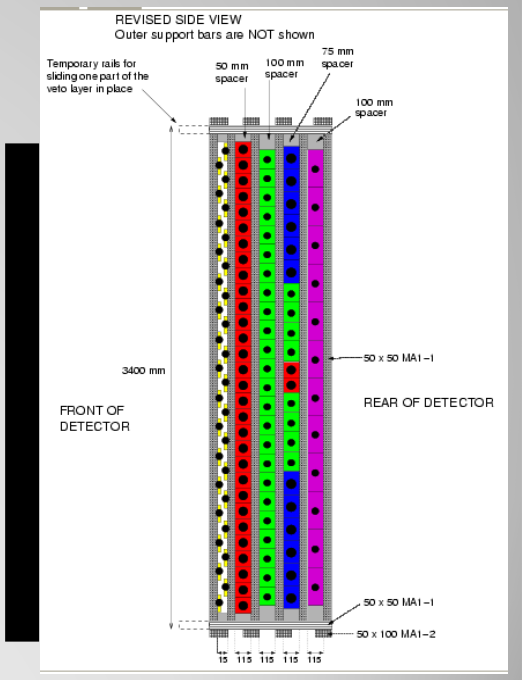
#p

#p/d

#e



#n



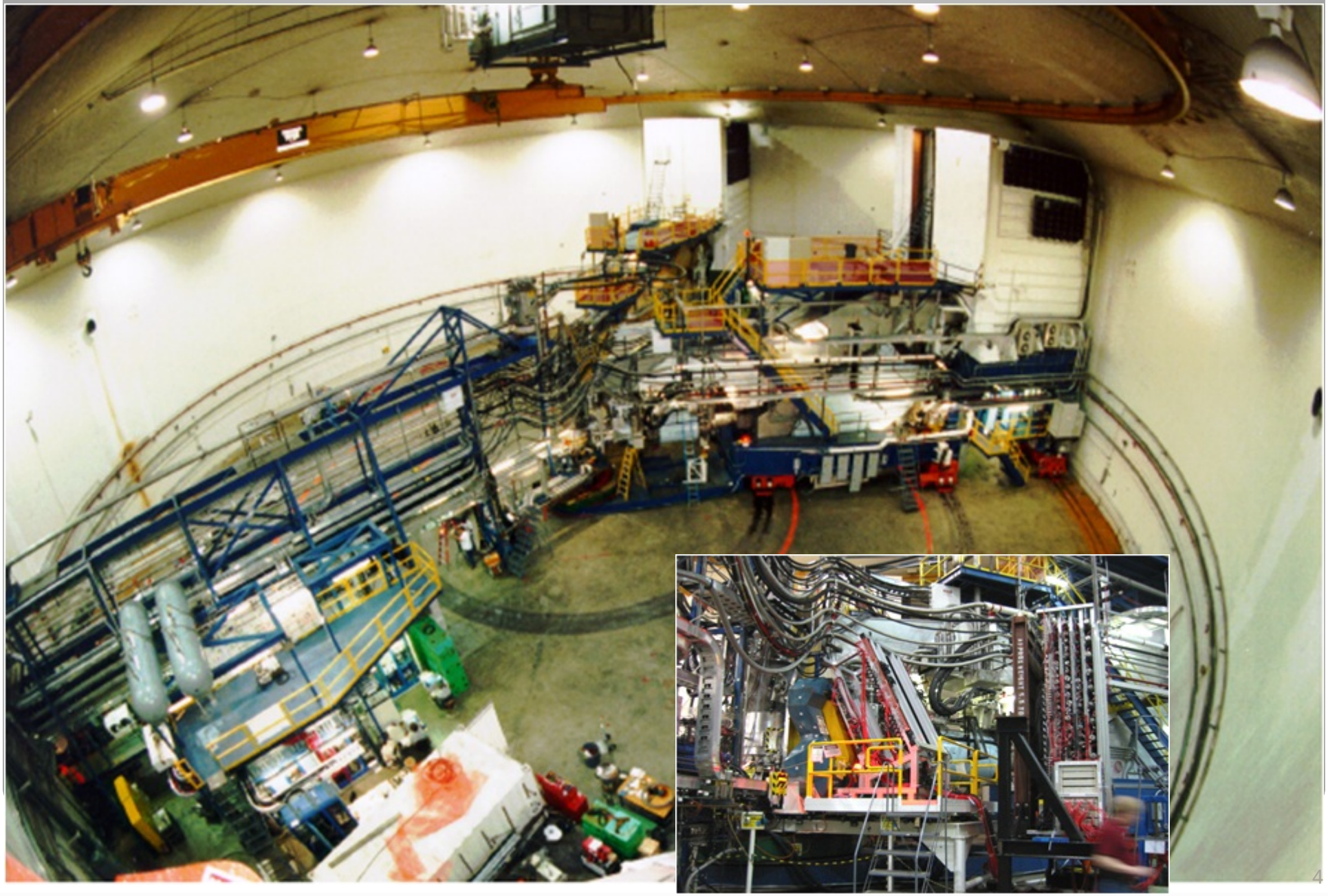
Target
^{4}He

#e

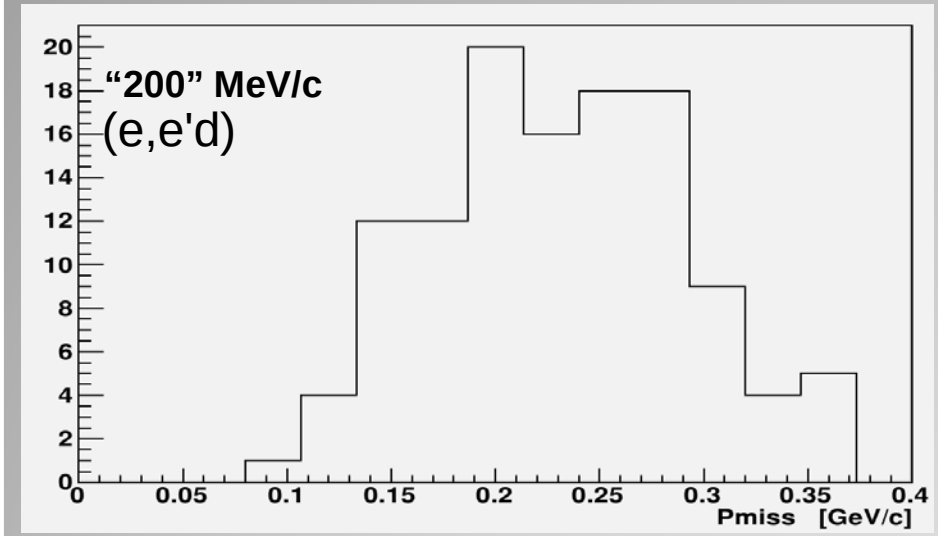
#Big Bite

#Lead wall

JLab E07 - 006: Experimental Setup



^{4}He(e,e'd) Kinematics



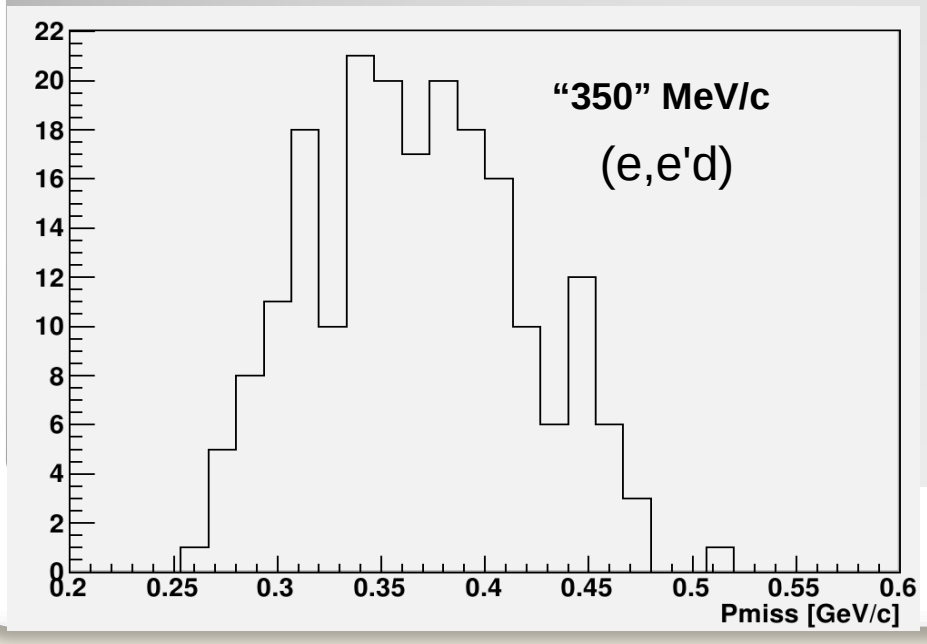
We had 5 different Pmiss settings

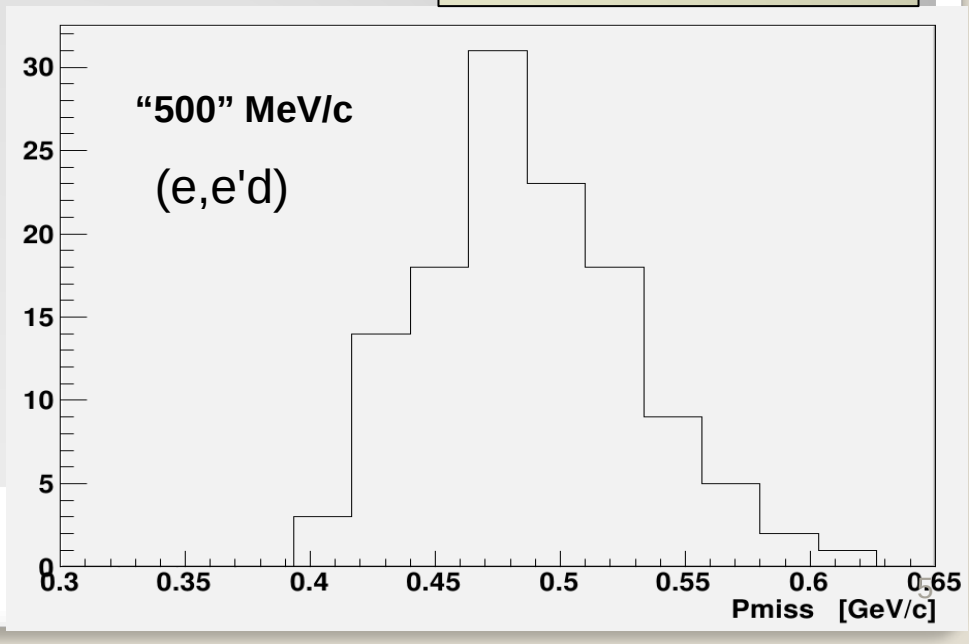
- "**200**" MeV/c
- "**350**" MeV/c
- "**500**" MeV/c
- "**625**" MeV/c **(e,e'p) only**
- "**750**" MeV/c **(e,e'p) only**

For last two settings the e,e'd was out of coincidence time

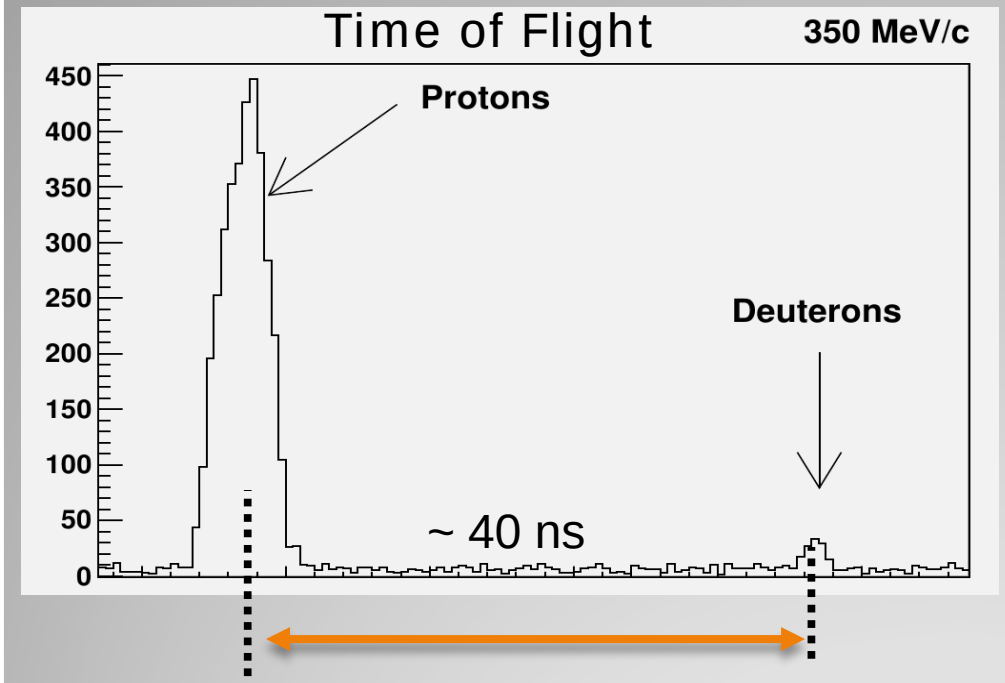
Electrons: **3.605 GeV 20.3 deg**

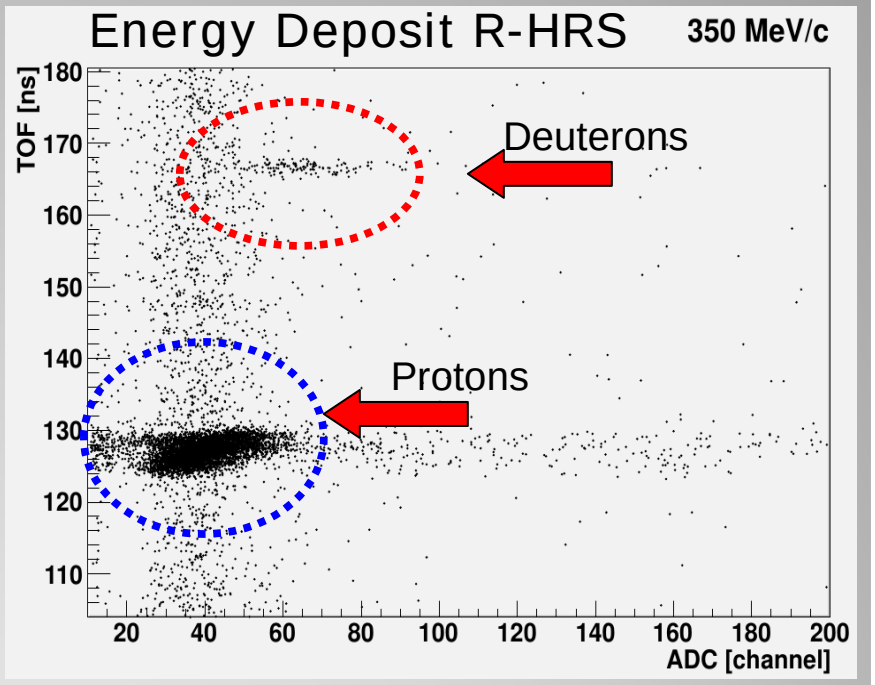
Protons / Deuterons: **1.2 – 1.5 GeV/c**
24.5 – 47 deg



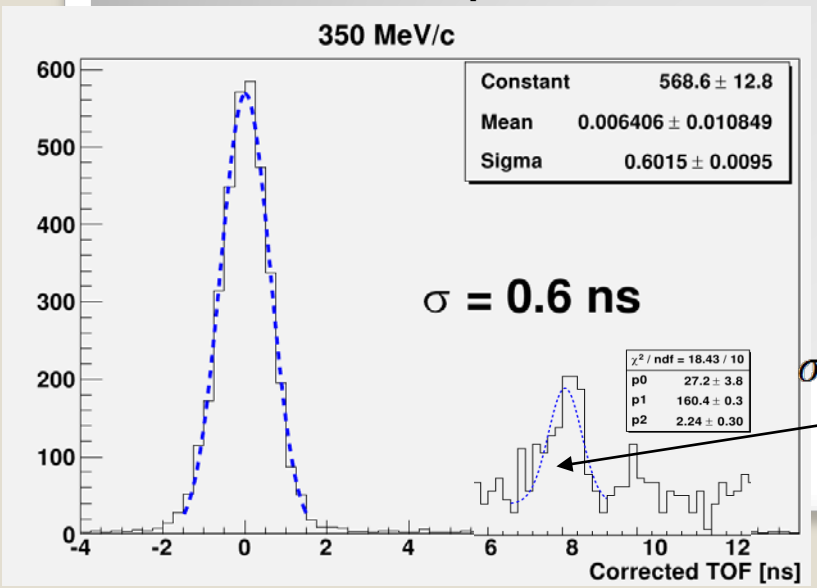


$^4He(e,e'd)X$ - PID





TOF calculated with proton mass

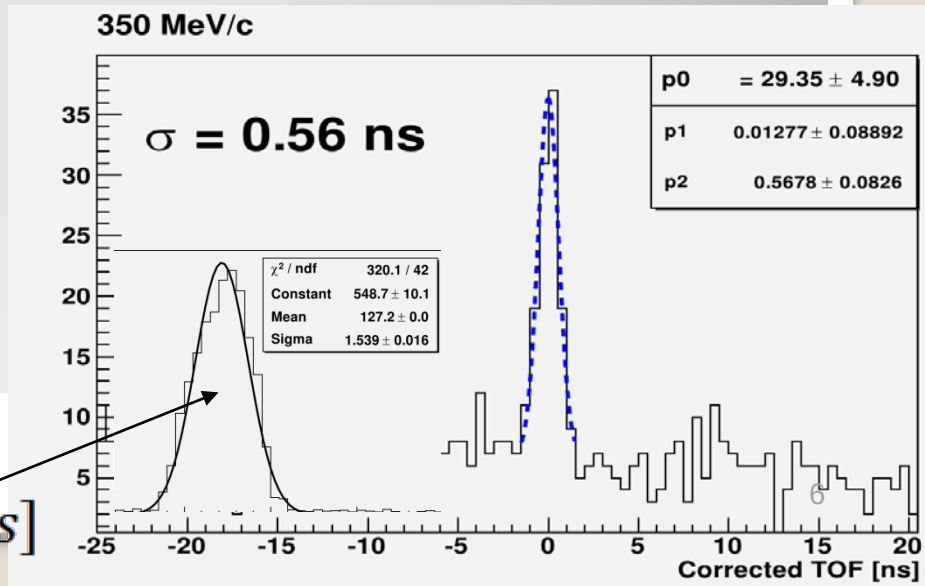


For p and d Similar resolution (after the correct mass in the TOF calculation)

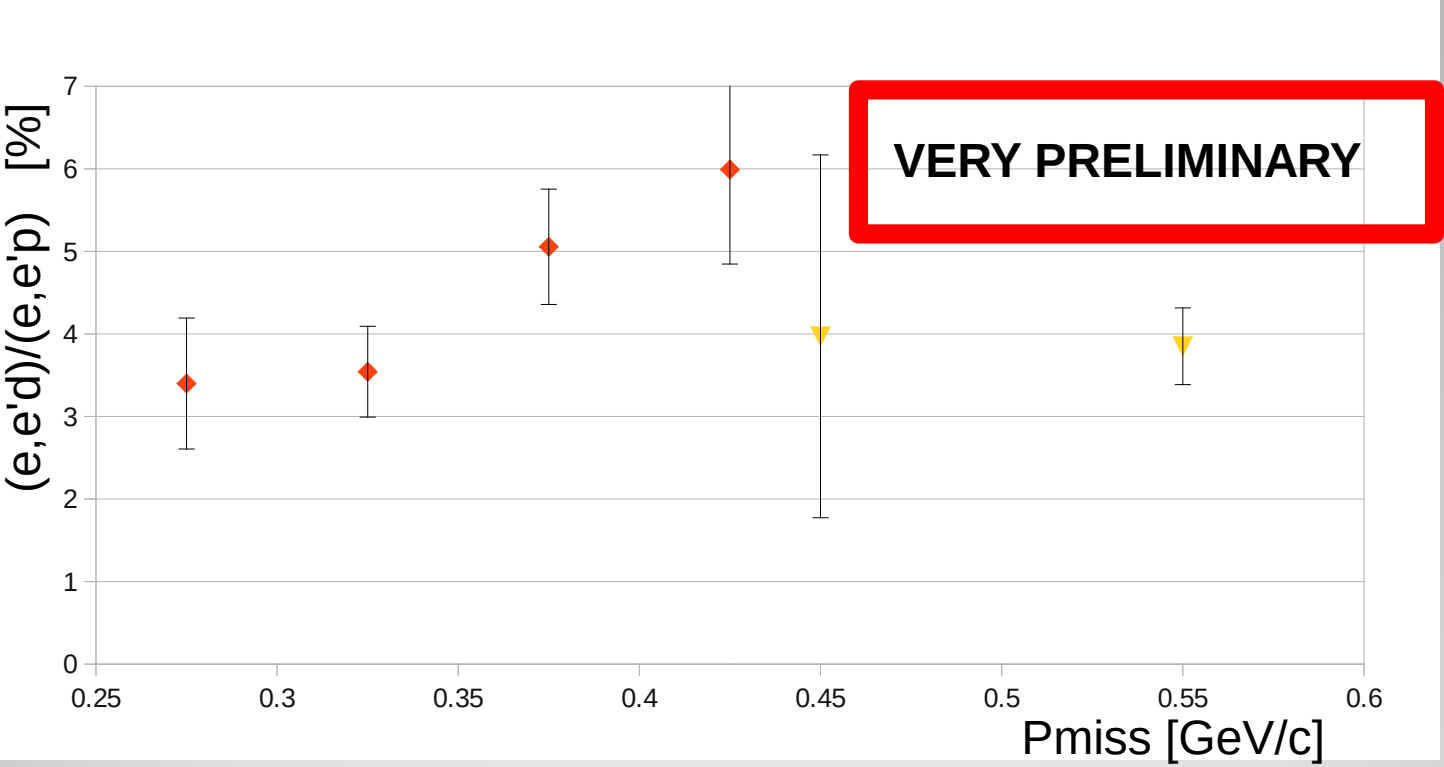
$\sigma \approx 2.2\ [ns]$

$\sigma \approx 1.6\ [ns]$

TOF calculated with Deuteron mass



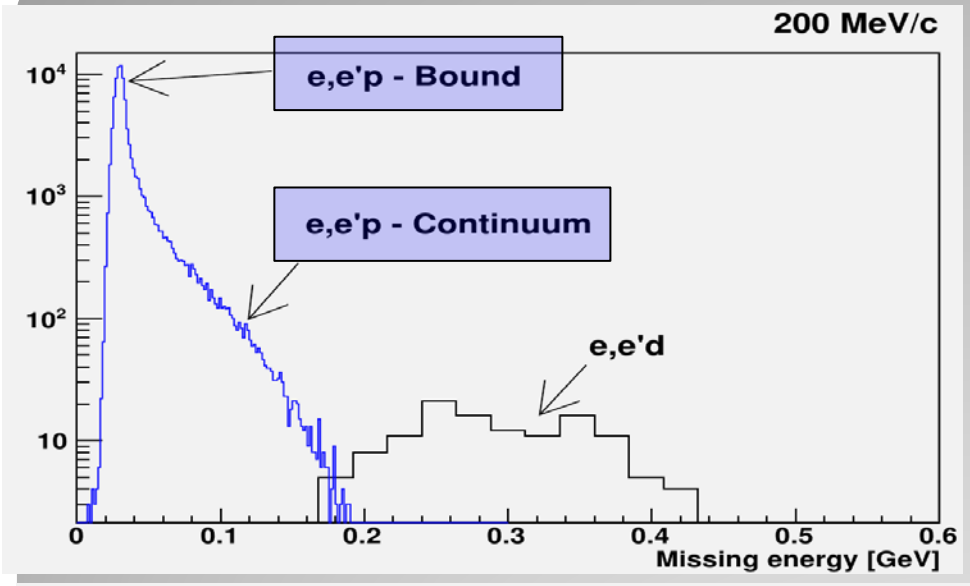
$^4He(e,e'd)X$ / $^4He(e,e'p)X$ - Ratio



(e,e'd) / (e,e'p) ~ 4 ± 1.5%

Acceptance correction can vary this results by (10 - 15)%

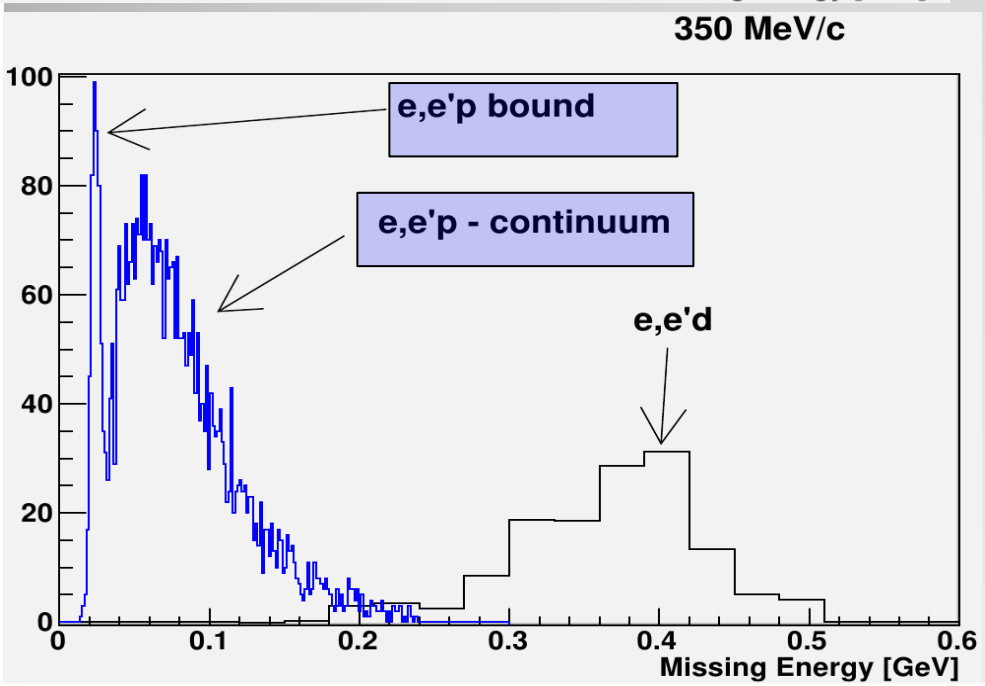
$^4He(e,e'p)X$ and $^4He(e,e'd)X$ ' - Missing Energy

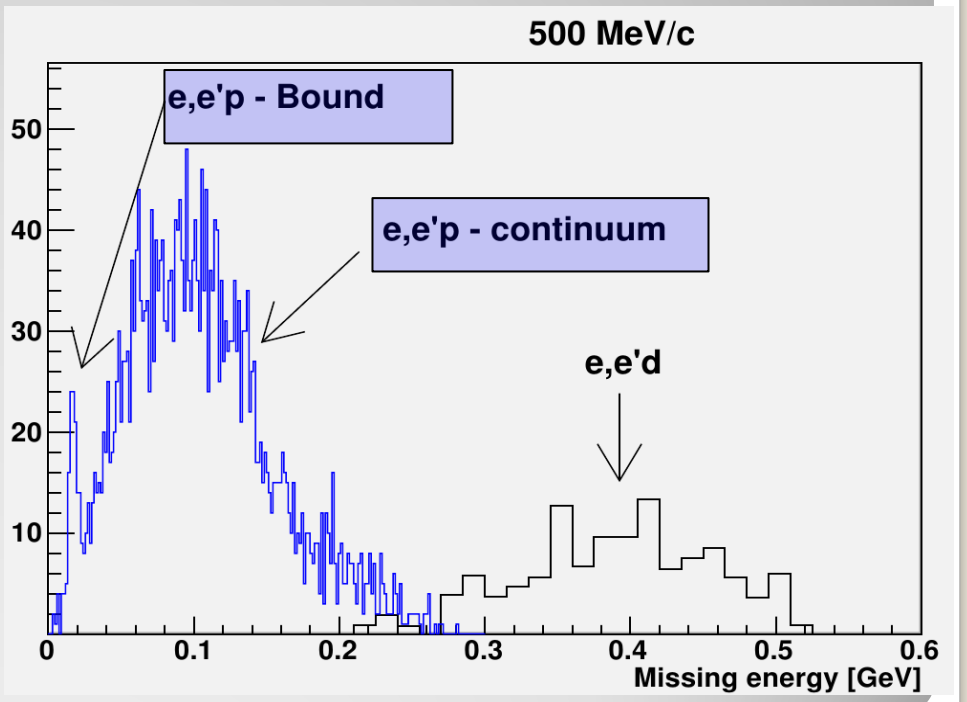


$$E_{miss} = É - T_f - T_B$$

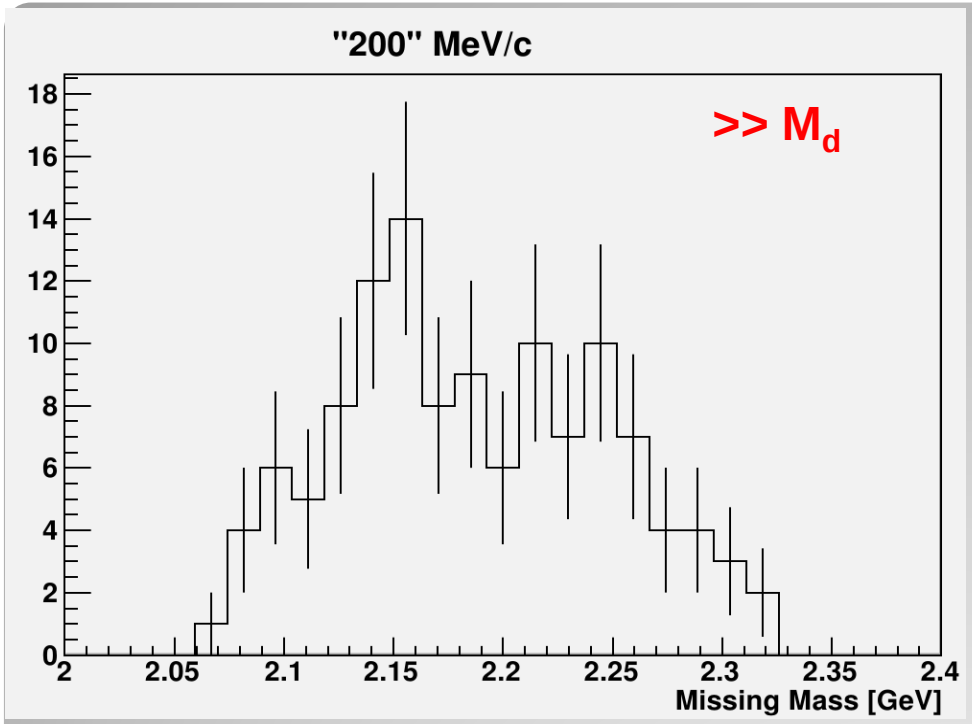
T_f Kinetic energy of detected proton / deuterium

T_B Kinetic energy of the residual system



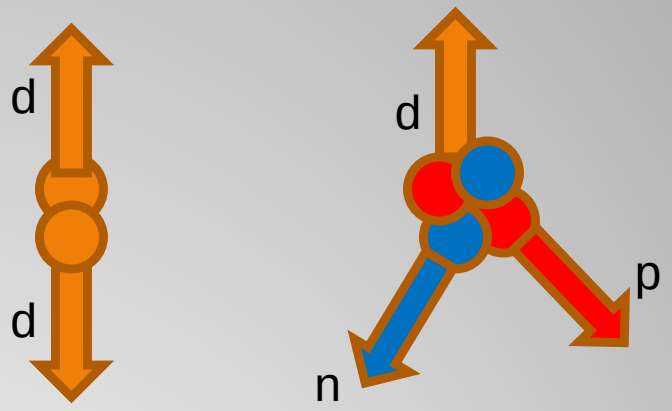


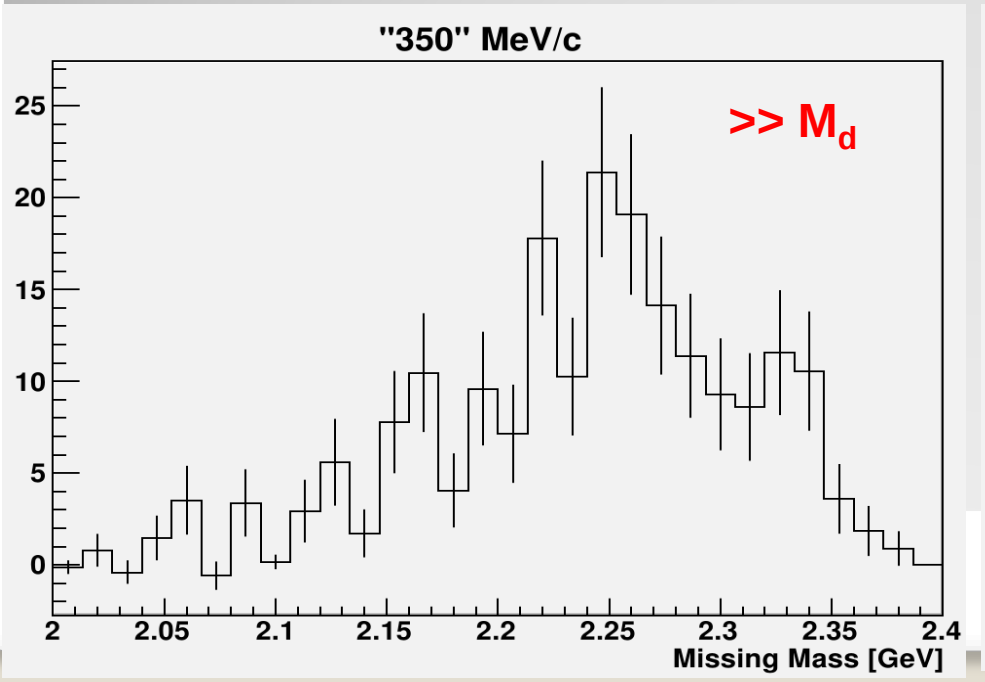
Large Emiss Notice: $E_{miss} \gg \sqrt{(m_d^2 + p_{miss}^2)} - m_d \approx 60\ MeV$ For 200 – 500 MeV/c

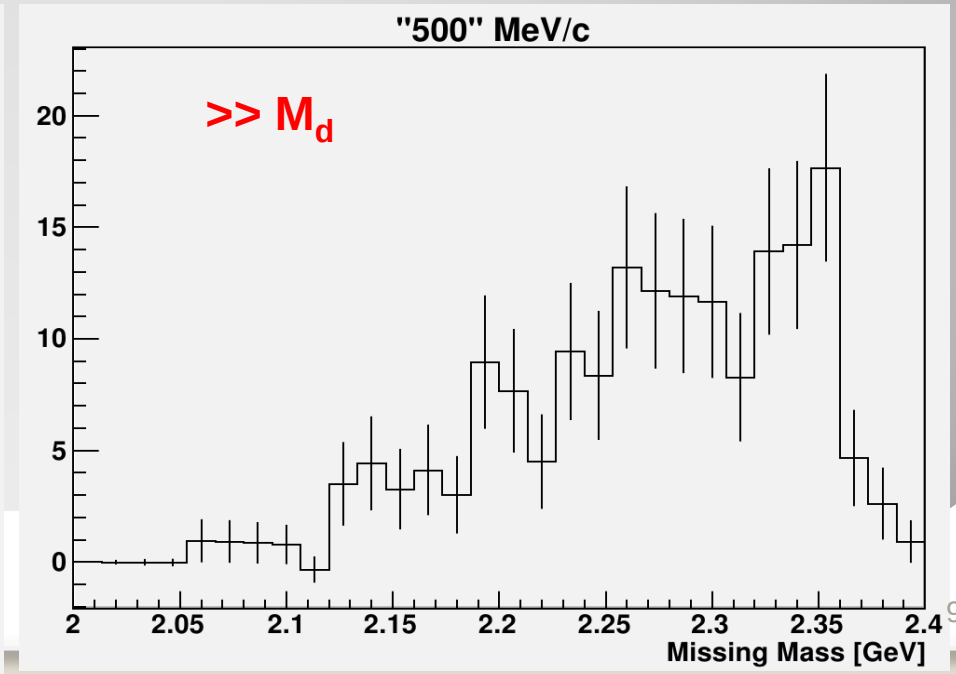


$^4He(e,e'd)X$ - Missing Mass

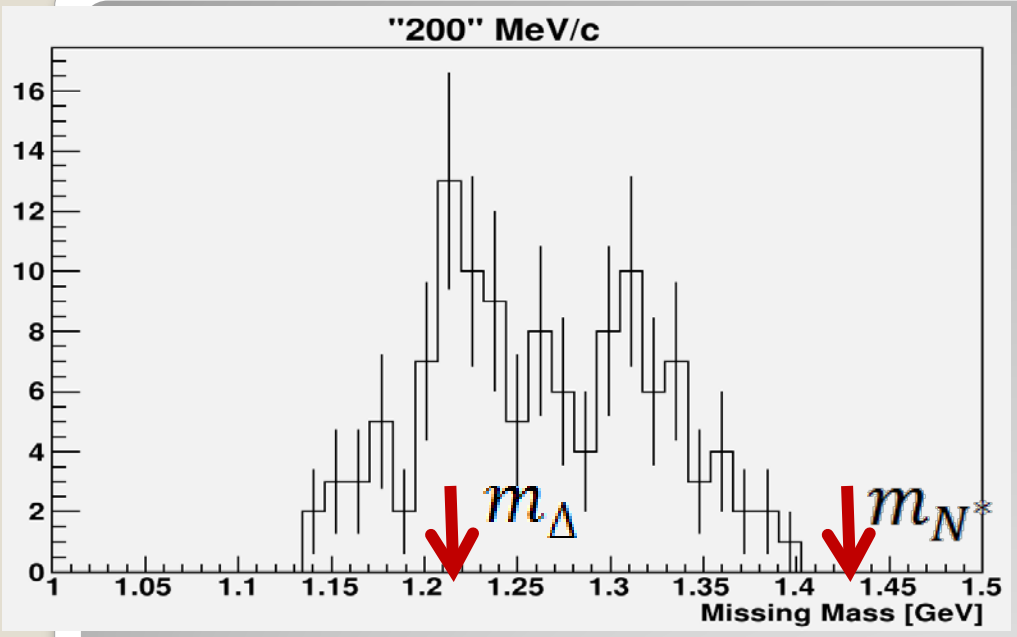
$$M = \sqrt{(q + m_A - p_f)^2}$$





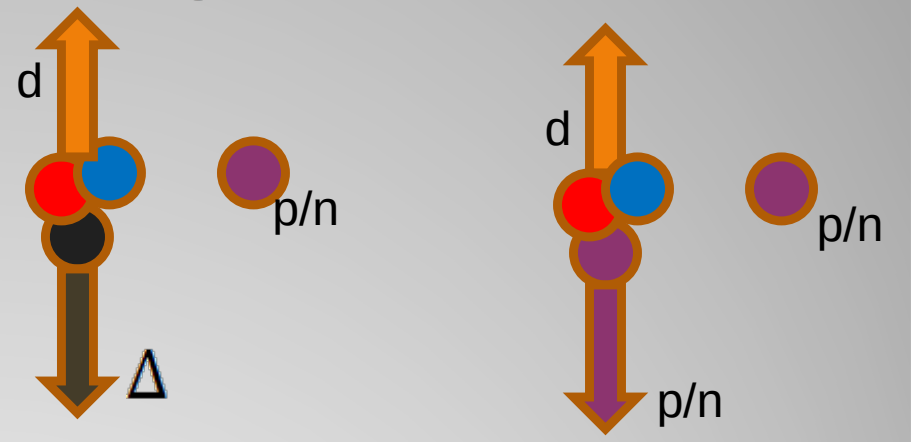


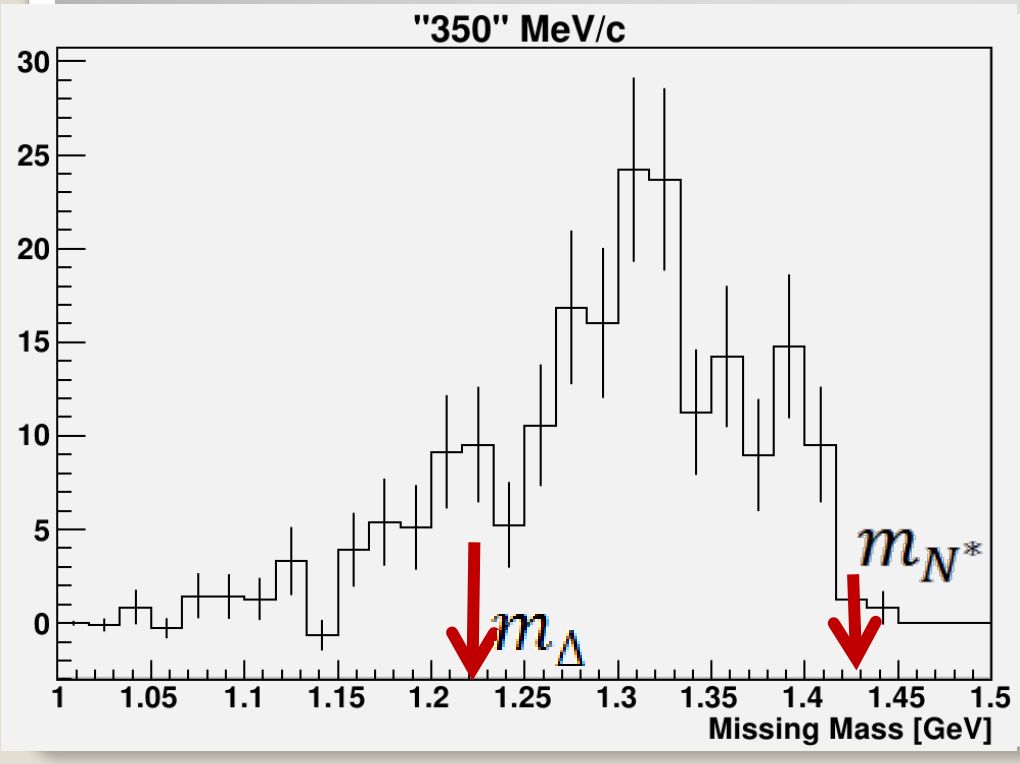
$^3He(e,e'd)X$ - Missing Mass

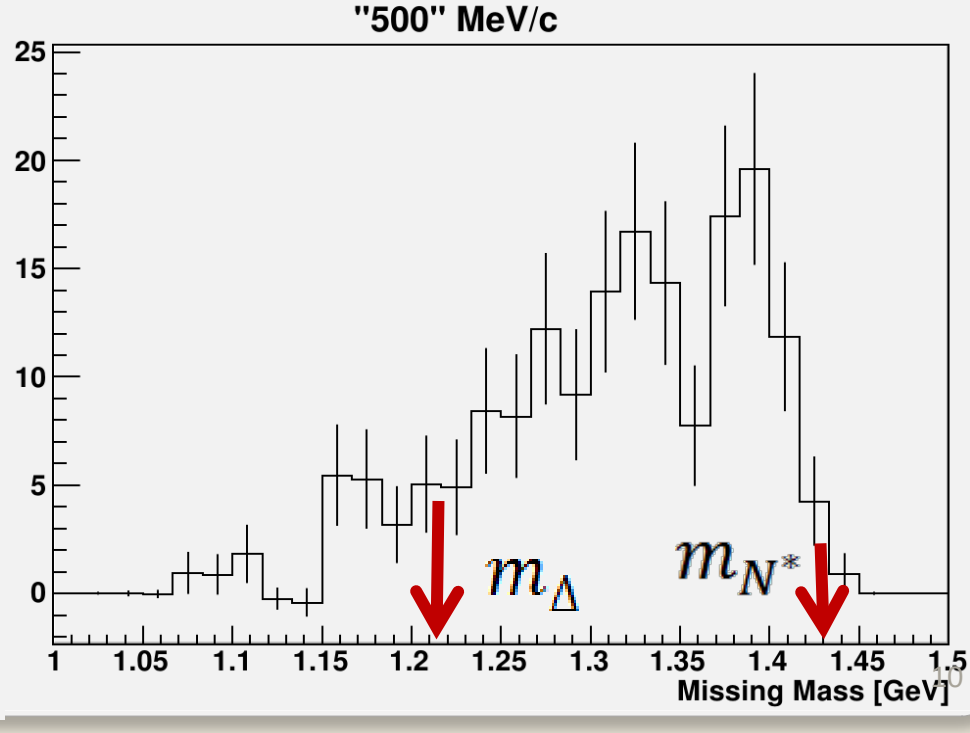


(assuming a spectator nucleon)

$$M = \sqrt{(q + m_{^3He} - p_f)^2}$$







Final State after deuteron removal ?

Can't be:

- A deuteron (or np pair with low relative momentum) that balance the missing momentum
- A single nucleon that balance the missing momentum (and a spectator nucleon)

Possible FS:

- Large momentum resonance (~1.2 – 1.3 GeV) and a spectator nucleon
- Two nucleon excitations with large momentum
- NN + xÀ

What are the dominant processes following a deuteron removal with high Pmiss ? Why?

Triple coincidence $^4He(e,e'pn)X$

JLab / Hall A E07 – 006 : Kinematics

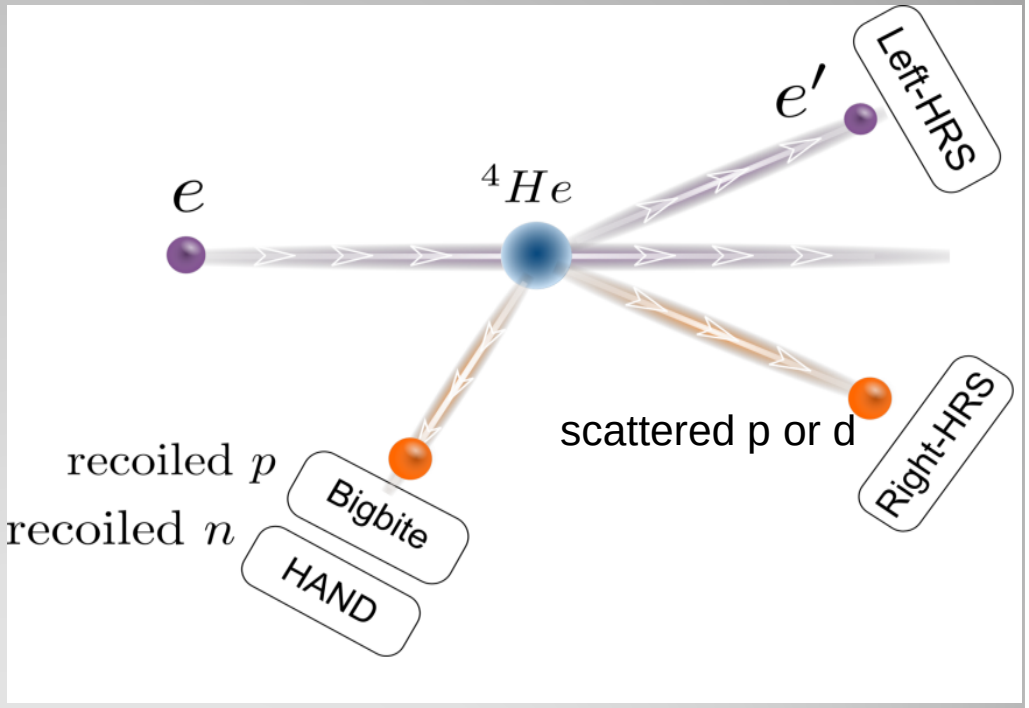
$$E_{beam} = 4.457\ GeV$$

$$Q^2 = 2\left(\frac{GeV}{c}\right)^2$$

$$x_B = \frac{Q^2}{2m\omega} > 1$$

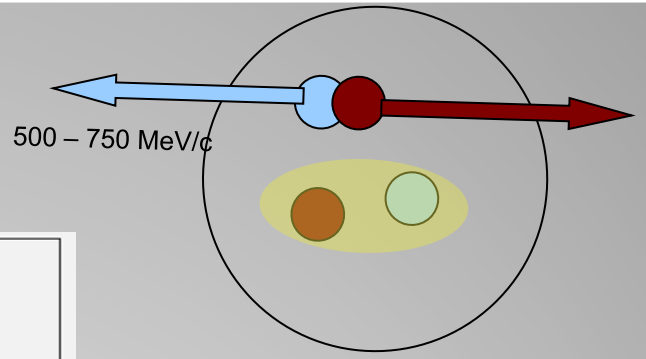
$$P_{miss} = 500 - 800\ MeV/c$$

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



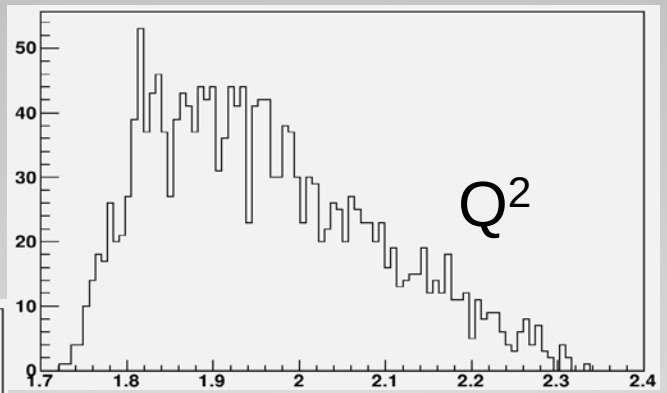
BigBite and HAND were at 97^0 and 92^0

Triple coincidence ^{4}He(e,e'pn)X

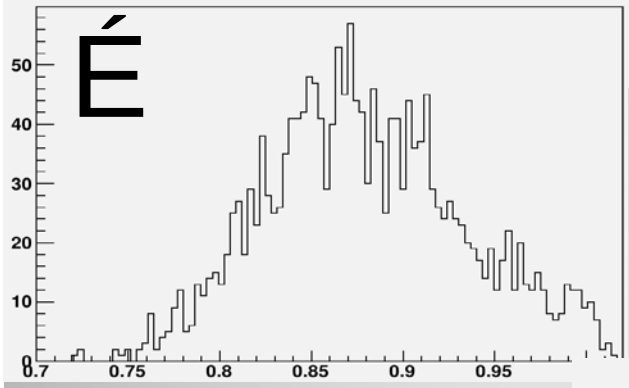


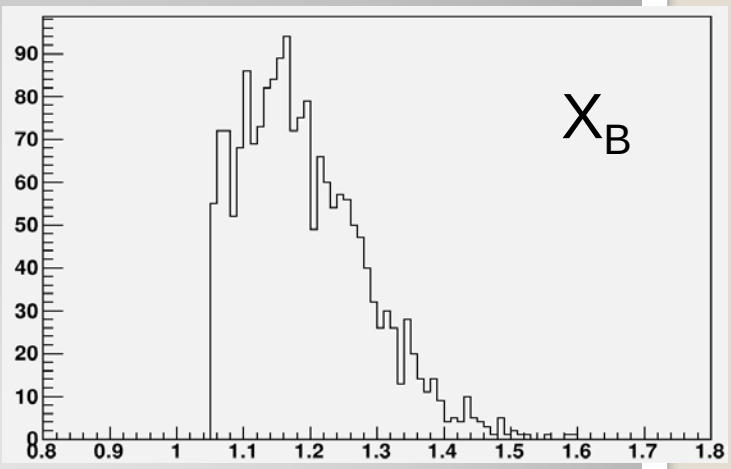
3 kinematical settings:

"500" MeV/c
"625" MeV/c
"750" MeV/c



$Q^2 = 1.96$ [GeV]^2 (mean)

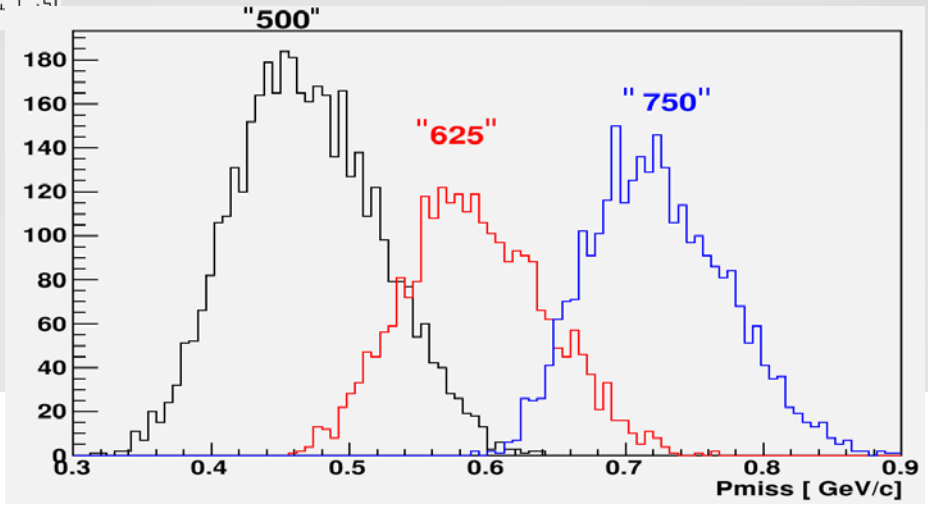




$X_B = 1.2$ (mean)

$$\omega = 0.879\ GeV$$

mean

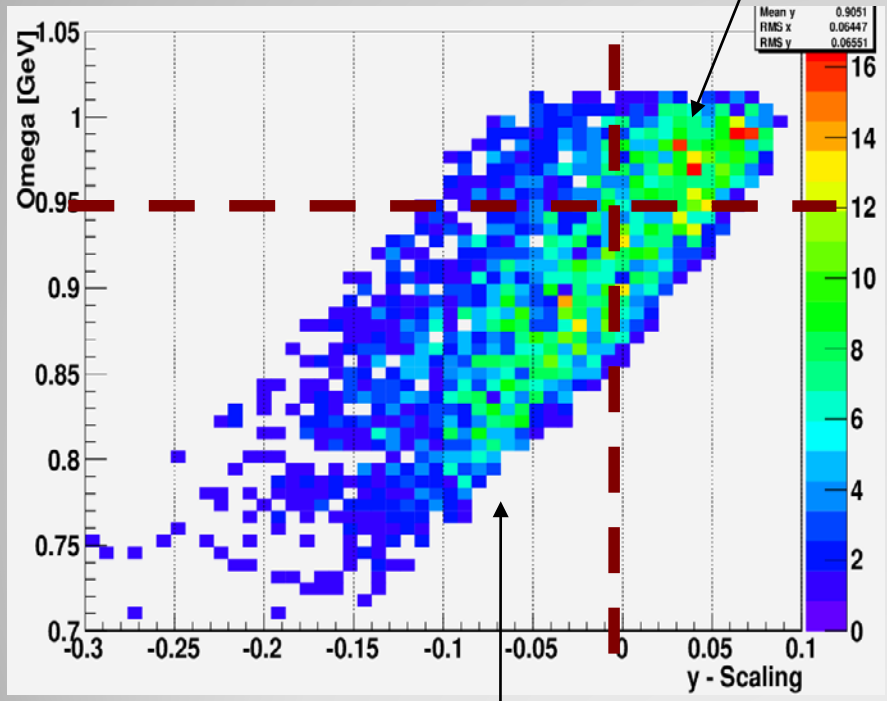


(e,e'p) / (e,e'Δ) separation cuts

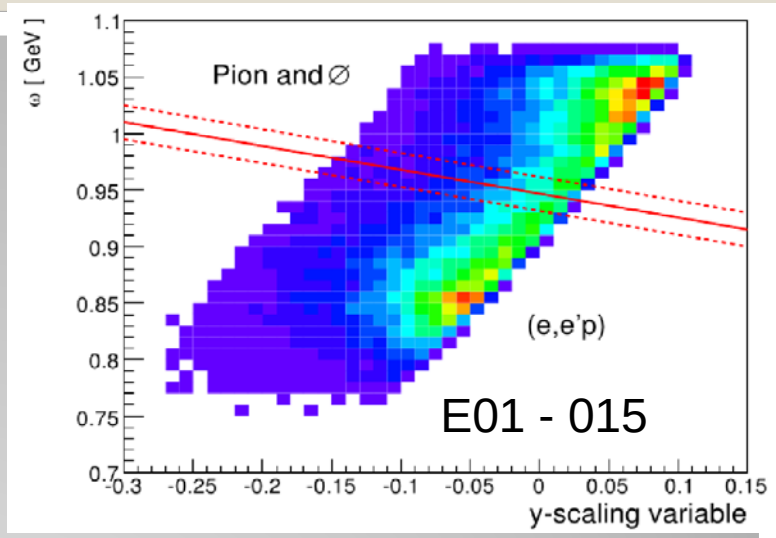
Used remove ” 's and À's production at the hard vertex

(e,e''')

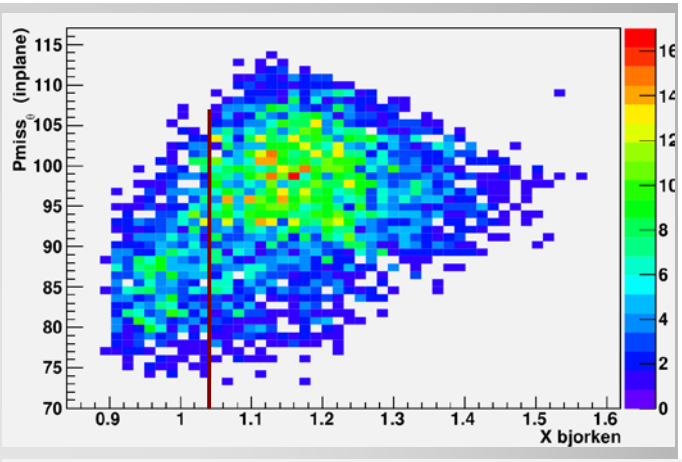
E07 – 006 Data



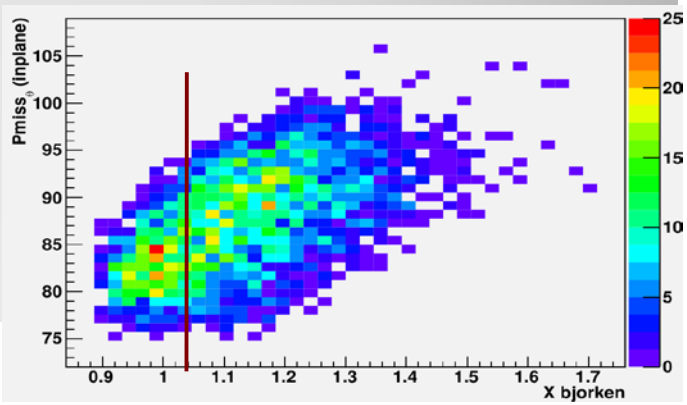
(e,e'p)



500 MeV/c

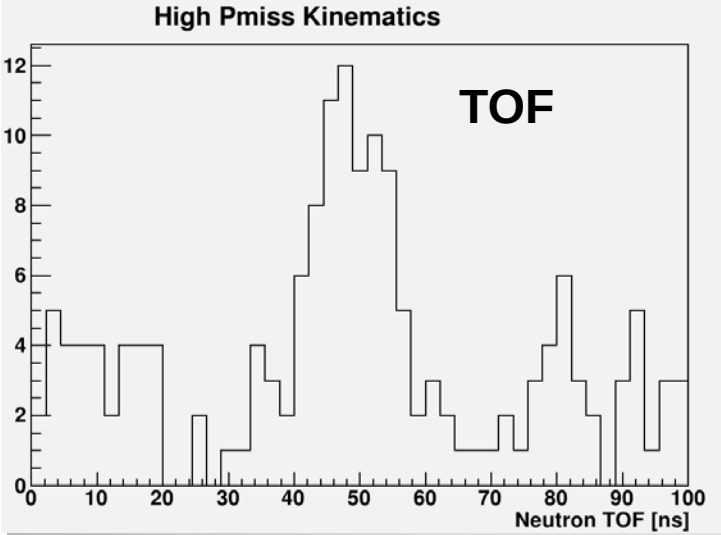


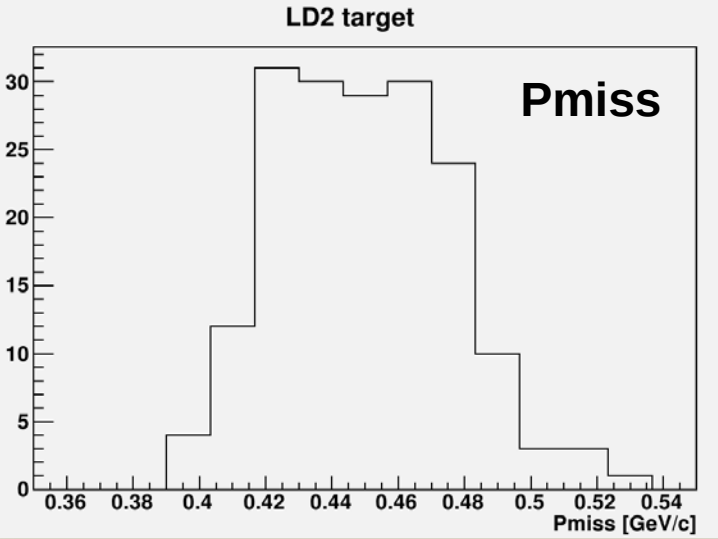
750 MeV/c

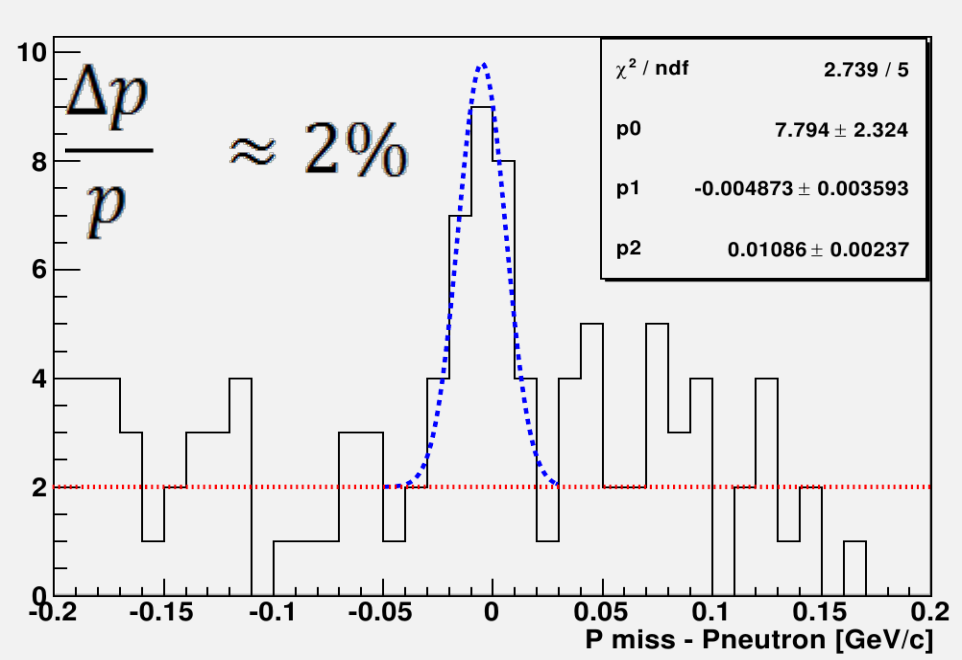


Exclusive measurement (e,e'pn) on LD_2 target

TOF to Momentum conversion

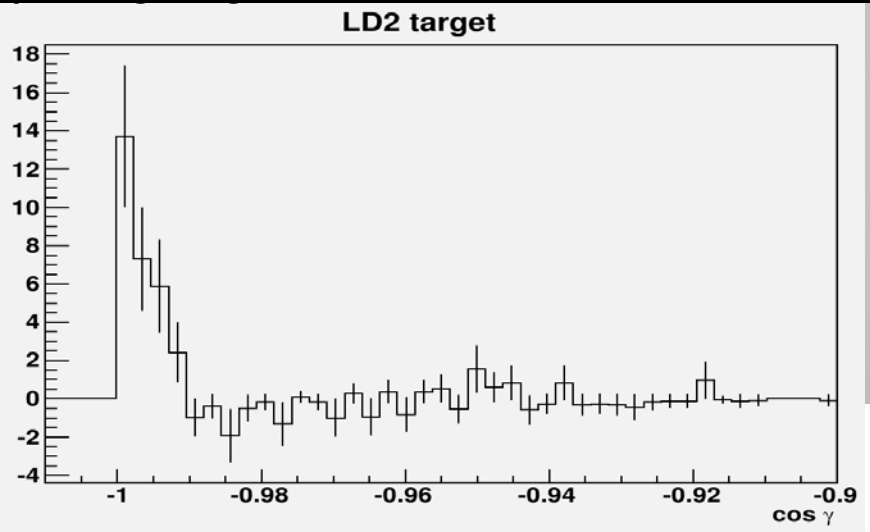




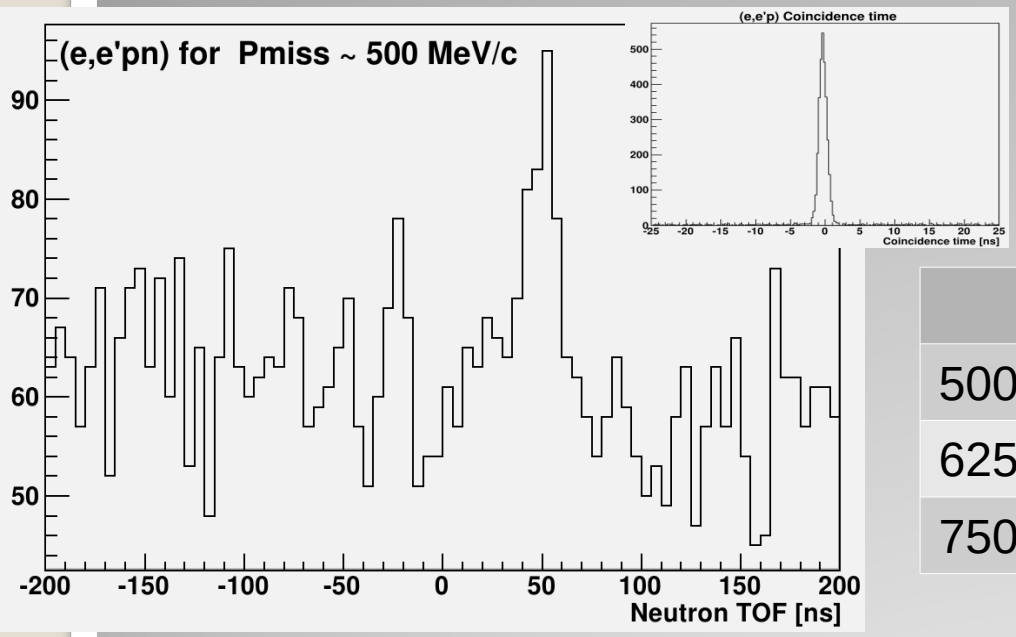


HAND momentum resolution: ~ 2 %

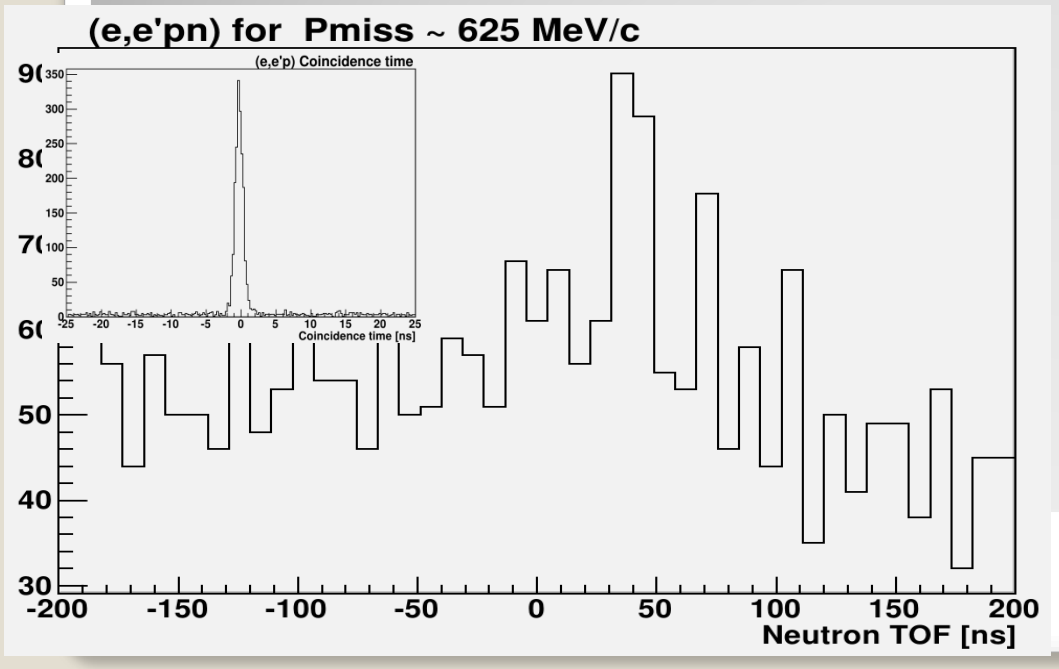
Opening angle between Pmiss and Neutron

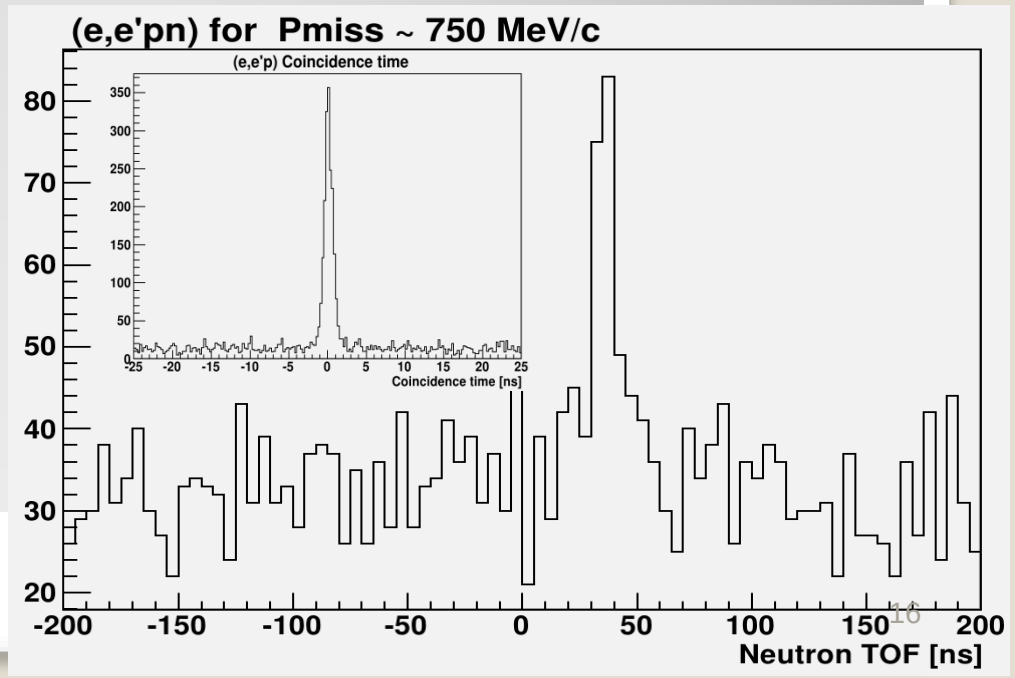


Number of (e,e'pn) events



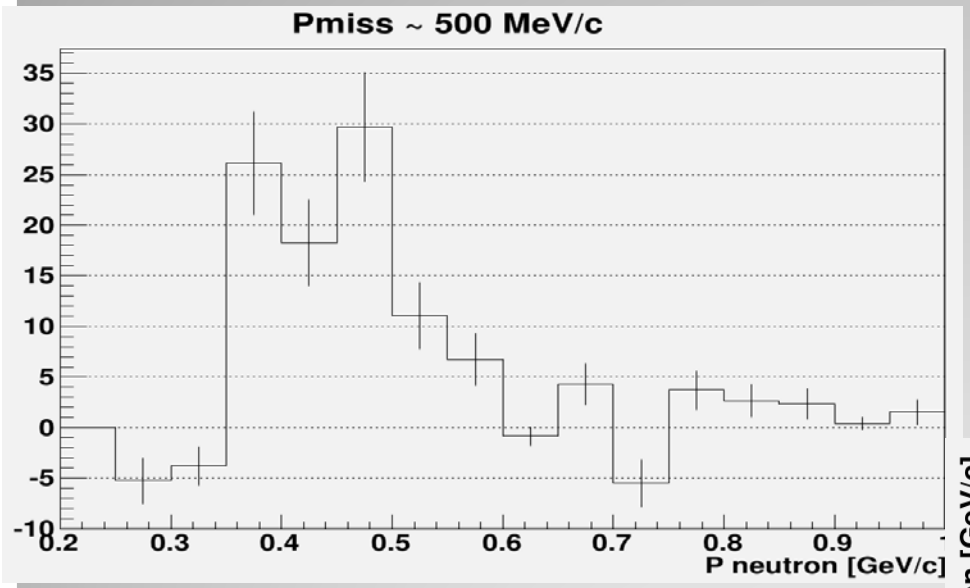
	#e,e'pn	#e,e'p
500 MeV/c	117 ± 29	3000 ± 60
625 MeV/c	88 ± 22	1900 ± 45
750 MeV/c	120 ± 25	2000 ± 45

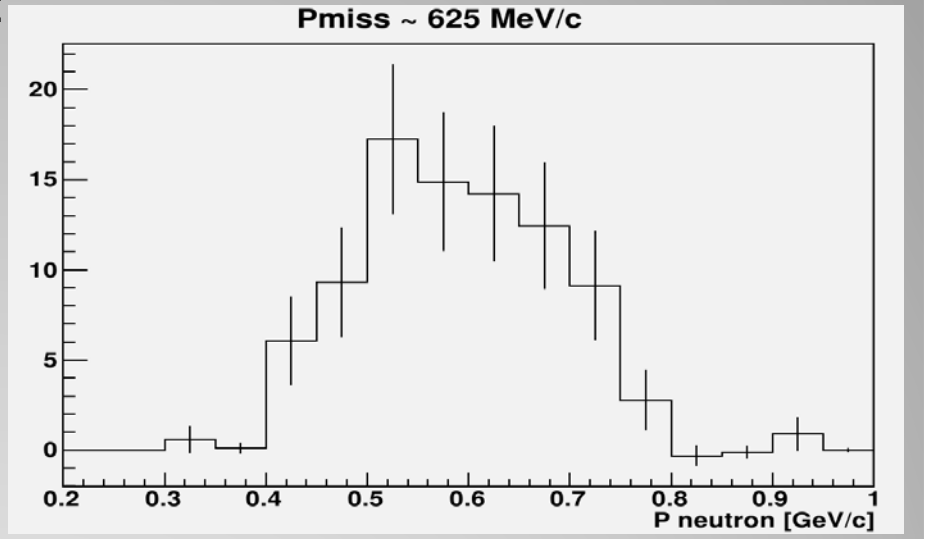


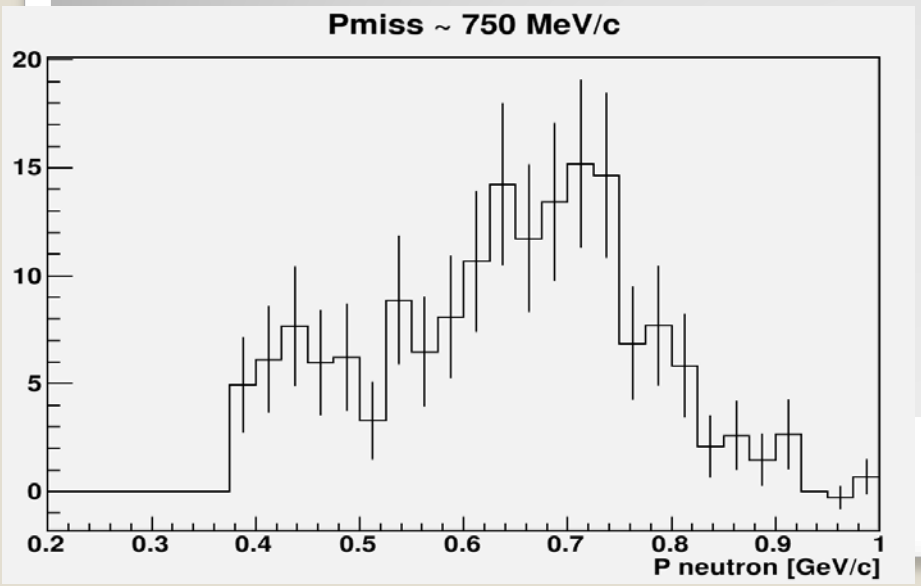


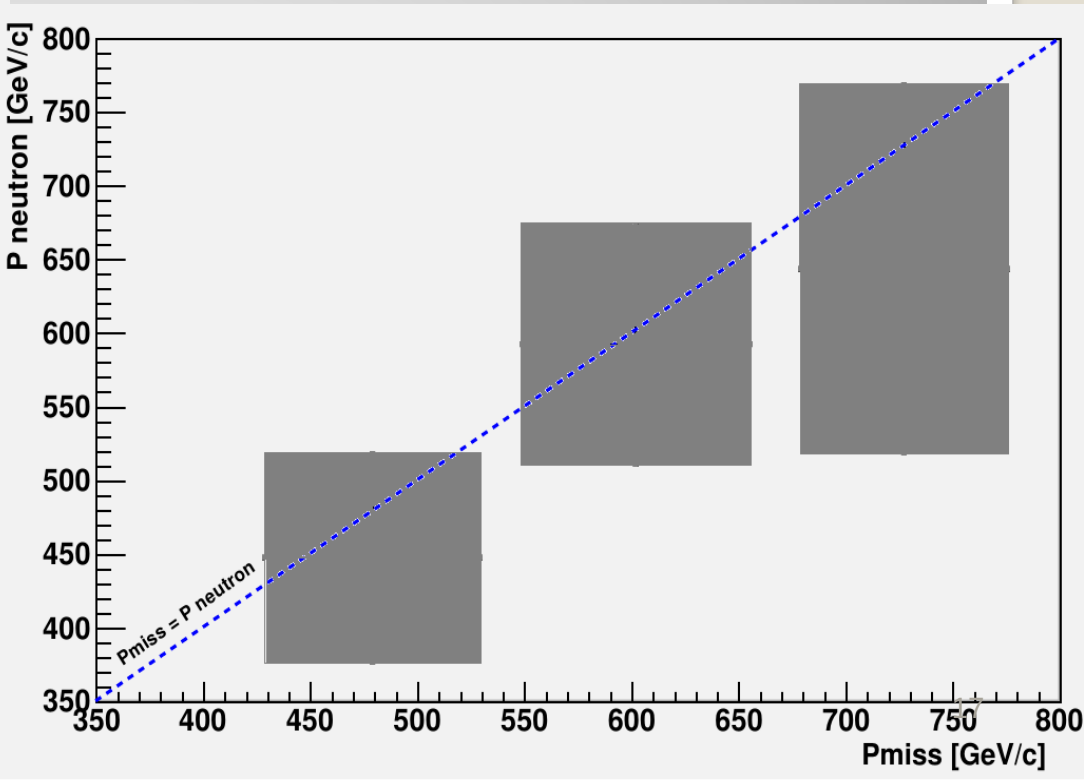
Recoil neutron momentum

From neutron TOF we can extract momentum:





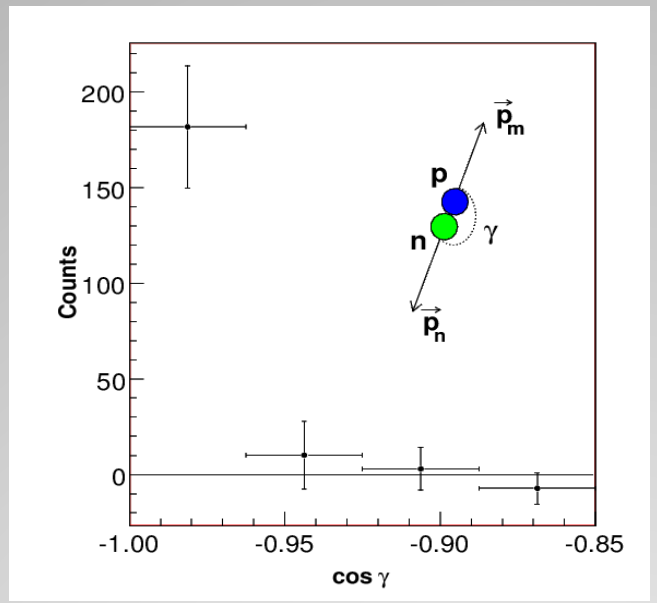




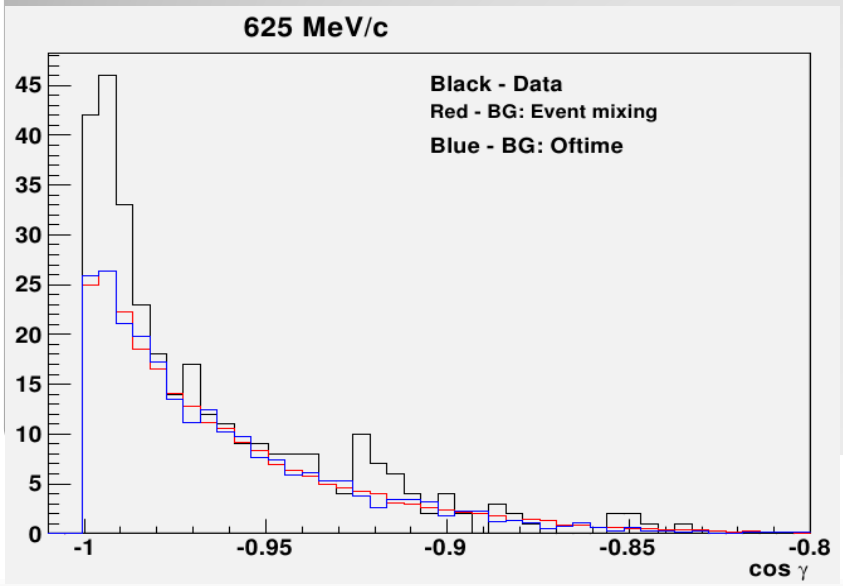
Angular Correlation

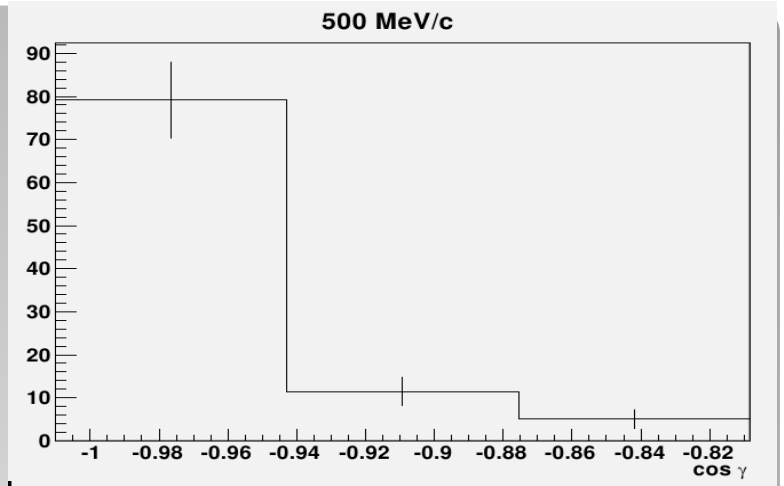
E01-015

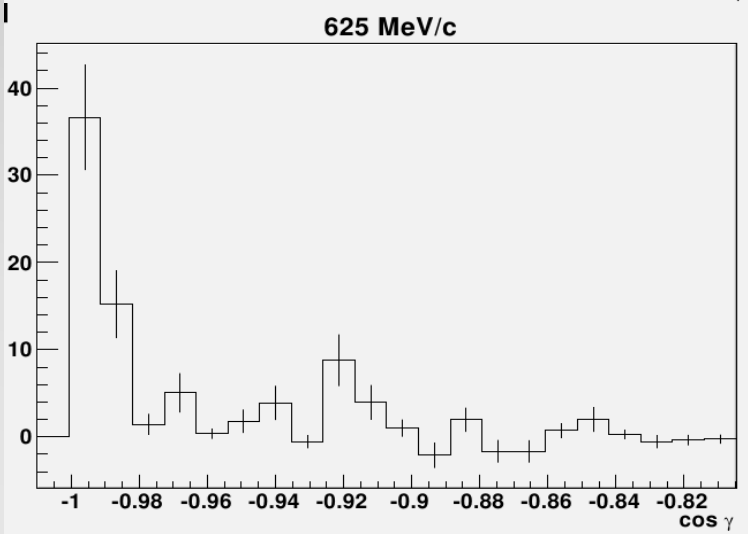
Result from previous SRC experiment on 12C

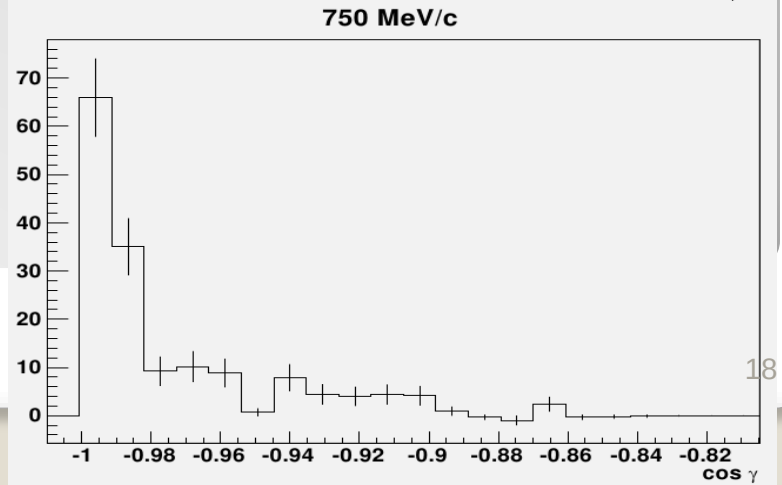


BG subtraction:

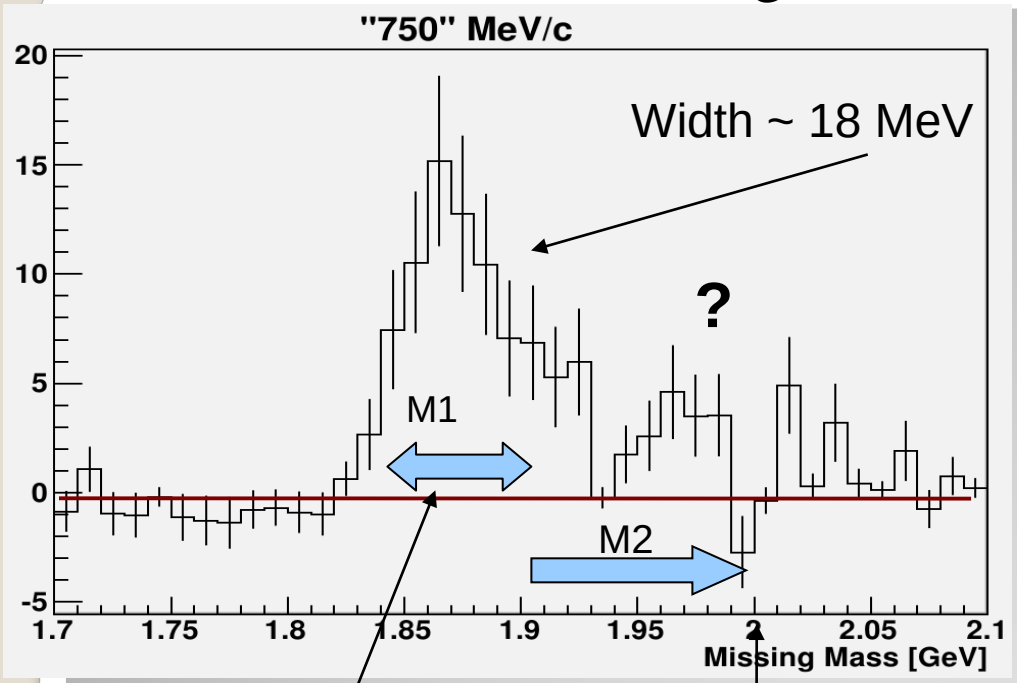


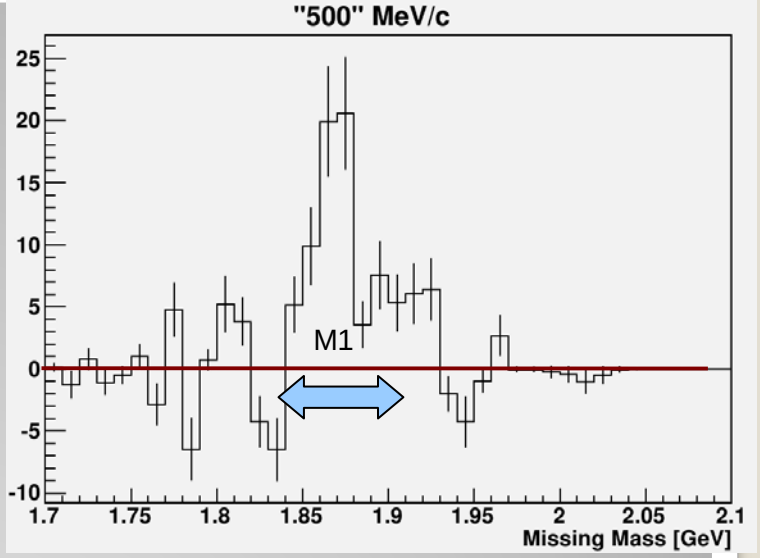


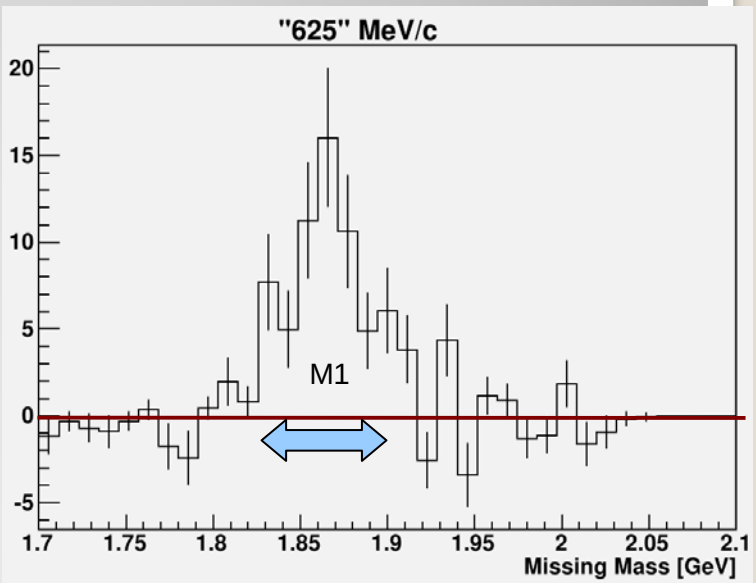




Missing Mass Distribution



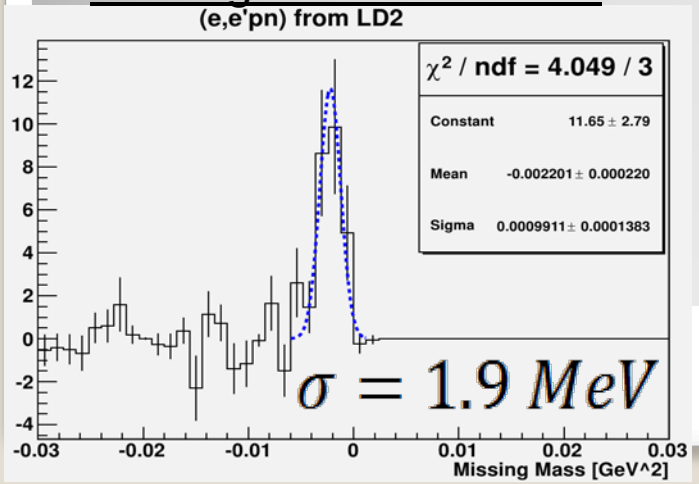




Moving np pairs

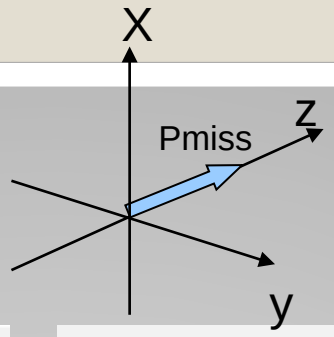
Pion production threshold

Missing mass resolution



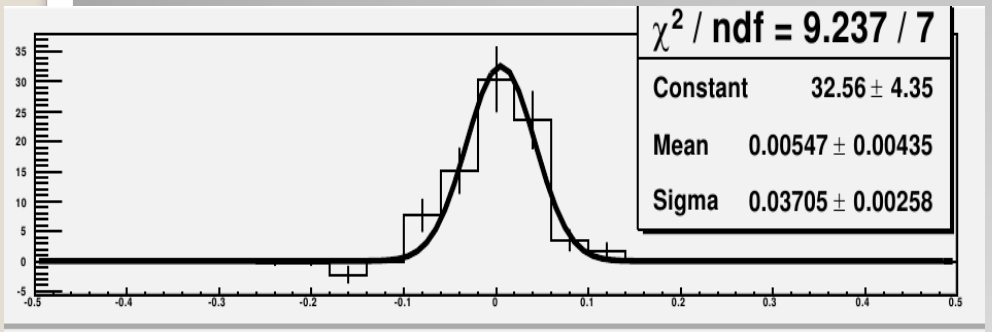
The dominant FS at all energies is np – pair with relatively low CM and relative momenta. M2, tail or peak?

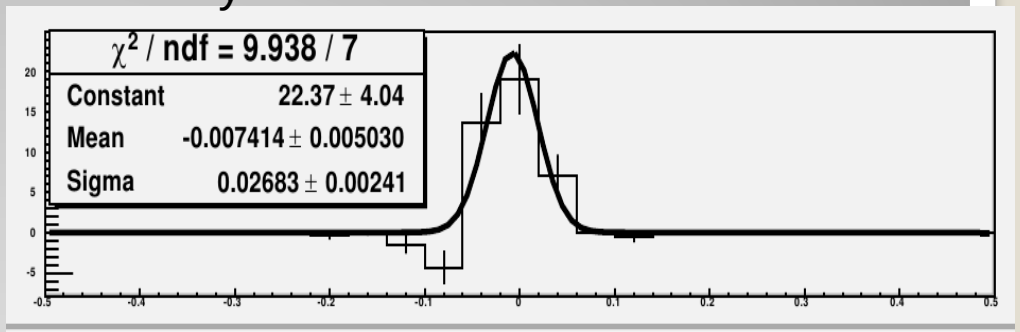
Pcm for ^{4}He(e,e'pn)

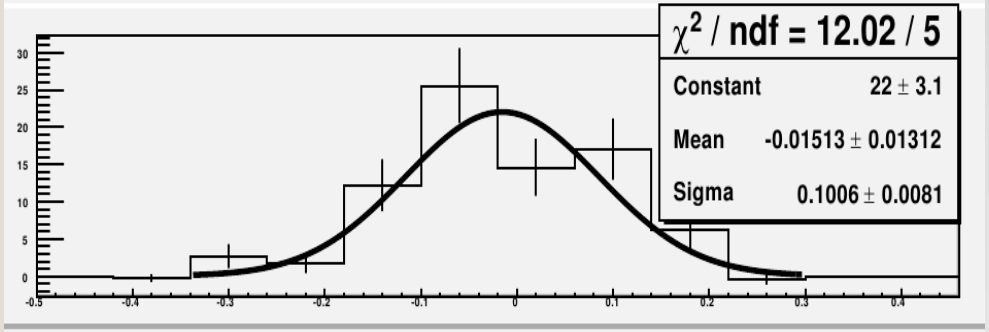


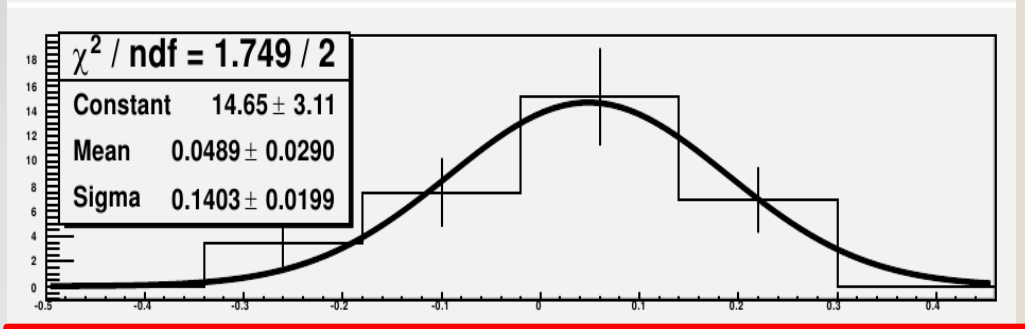
M1 Region

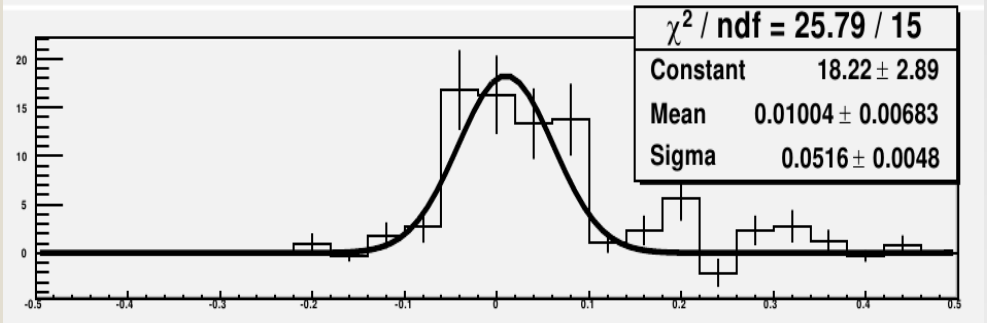
M2 Region

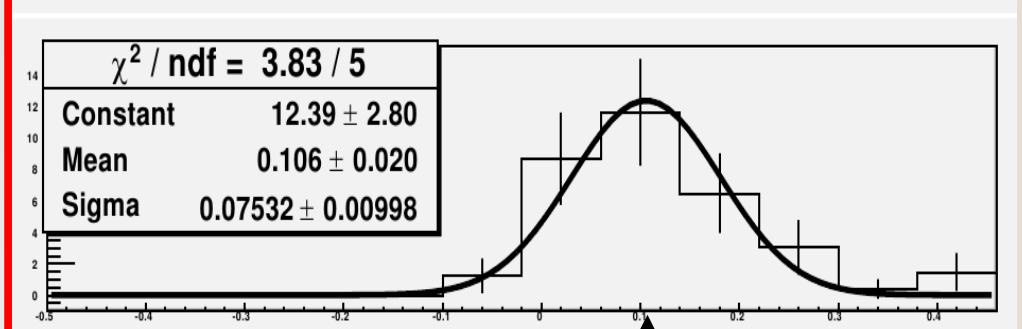












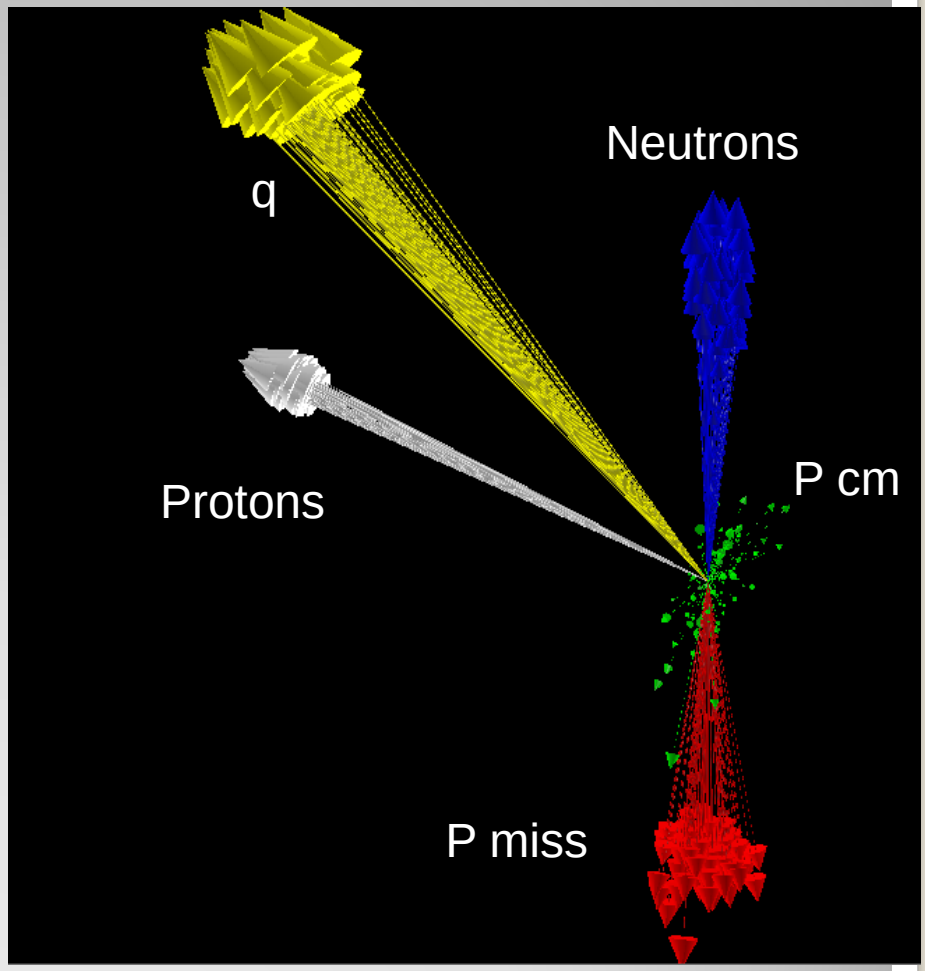
Shift in Pcm is coming from the M2 region!

~ 100 MeV/c

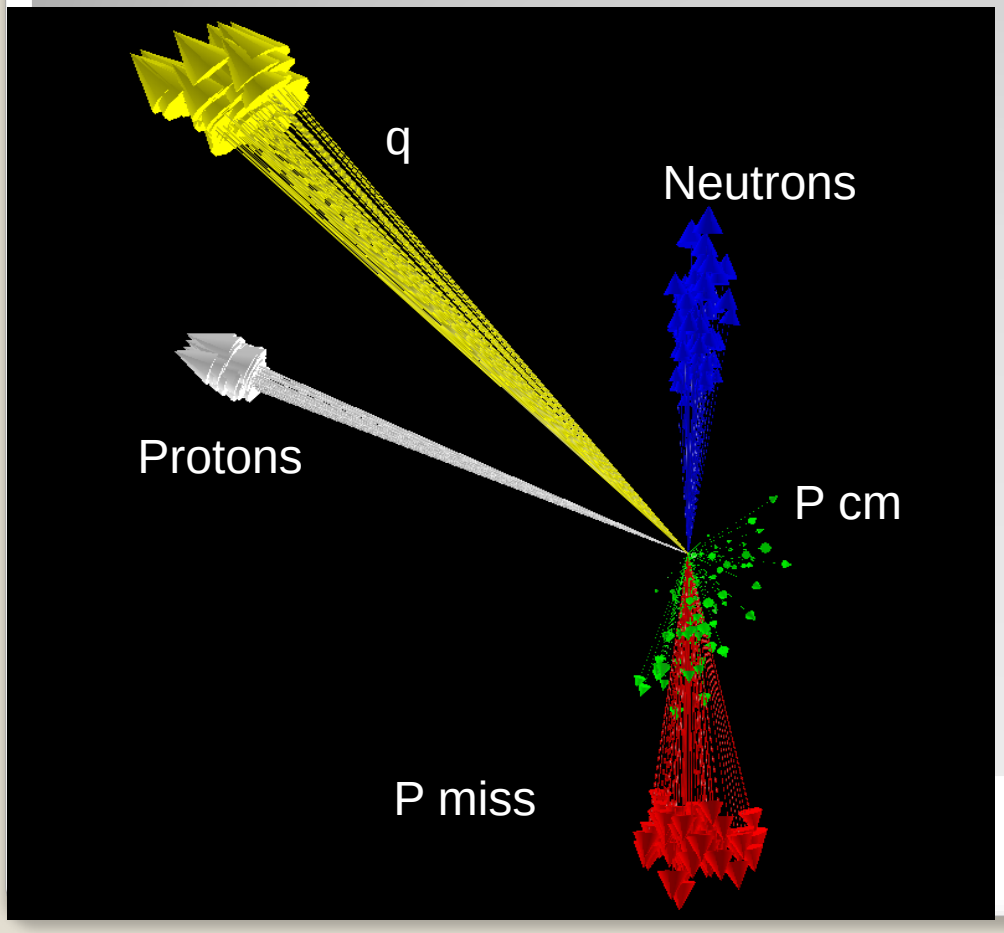
Pcm ^{4}He(e,e'pn)X

How it's looks likes (including the BG events)

M1 Region



M2 Region



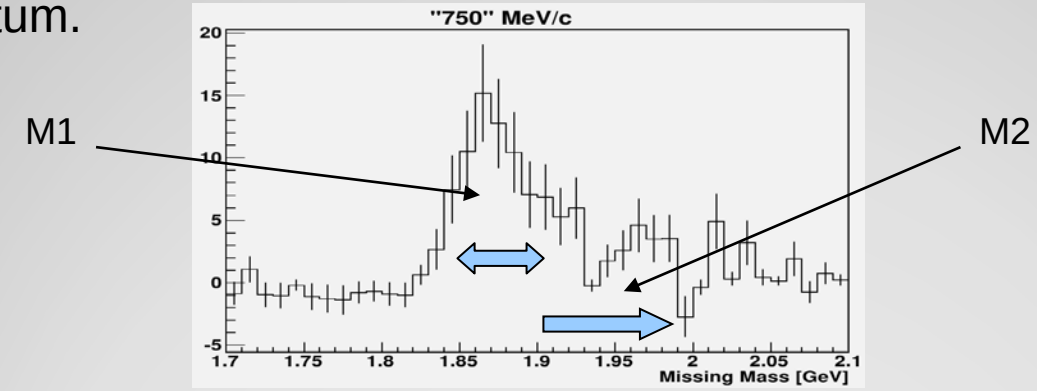
Final State after the two nucleon removal

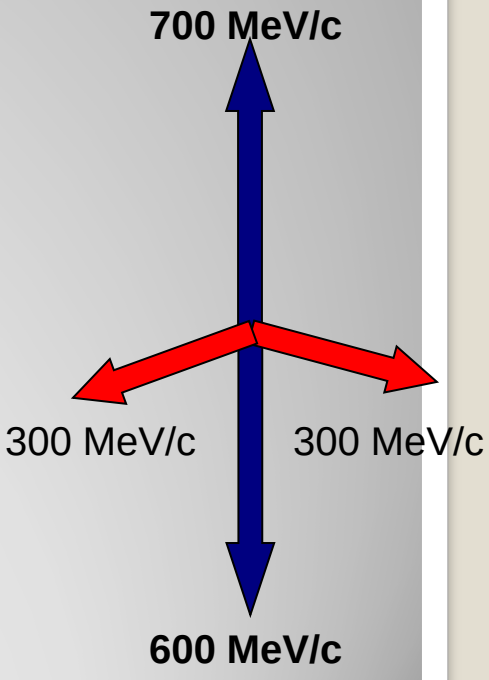
M1: M1 peak correspond to pn system with low cm and relative momenta

M2: Events from M2 region have ~ 100 MeV extra mass and ~ 100 MeV/c CM momentum

It's below the pion production threshold.
It can't be one nucleon moving and second spectator because it's inconsistent with the Pcm motion.

Probably all possible FS have four nucleons with high momentum.





If the 100 MeV is split symmetrically between the remaining nucleons:

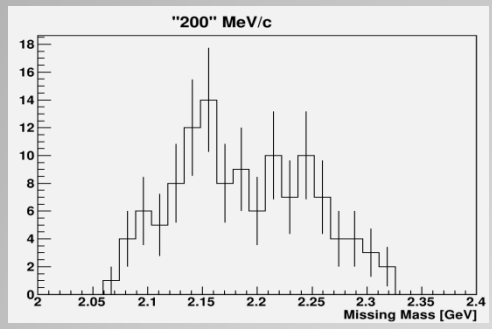
Two back to back nucleons with relative momentum ~ 700 MeV/c
and two 300 MeV/c nucleons with opening ~ 145 deg

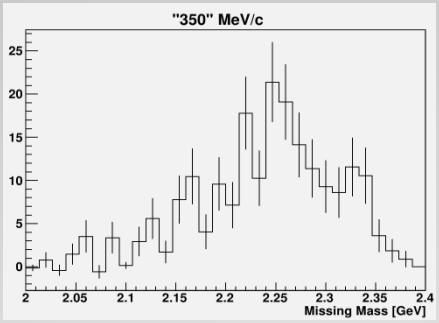
M2 – does it exist? What is it?

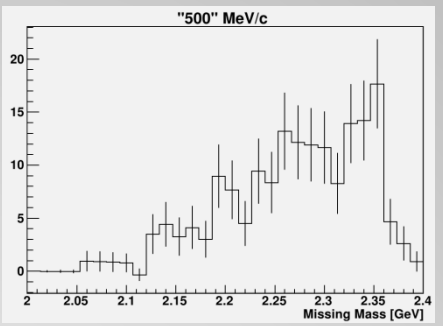
Summary

- We study the residual systems that are left after removal of two nucleons with high CM momentum (e,e'd) or high relative momentum (e,e'pn)

- ^{4}He(e,e'd)X ^{4}He(e,e'd)X / ^{4}He(e,e'p)X ~ 4 +1.5%







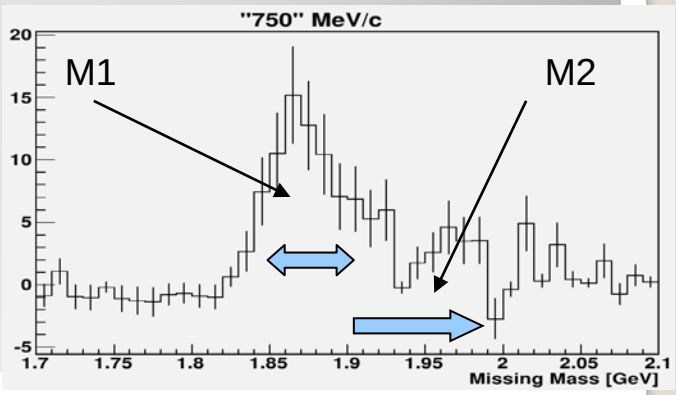
Missing Mass of $X \gg m_n + m_p$

What is the dominant process?

- ^{4}He(e,e'pn)

Major contribution (M1) from a spectator np system with small CM and relative momenta

Excitation below pion production up to about Missing Mass ~ 2 GeV.



What is that?