Ratios 4He(e,e'pn/e,e'pp)

The absolute neutron detection efficiency of HAND is known from exclusive e,e'pn calibration measurement done with Ld2 target. We use this information to estimate the number of e,e'pn events during the production. For the relevant range of the neutron momentum 400 – 800 MeV/c, the efficiency is constant ~ 40 ± 2 %.
The proton detection efficiency of BigBite spectrometer need also to be determined.
During the previous SRC experiment, the overall efficiency of BigBite was ~ 85% (Ran's Thesis, page 63). In that experiment the efficiency was mainly defined by the auxiliary plane. In our experiment we don't have auxiliary plane but the MWDC also reduce the BigBite efficiency to about 75%. This is because we require at least 6 (?) different planes to fire in order to reconstruct an event. The efficiency of each plane is ~ 96%. Additional inefficiency arises from the gaps between the paddles in the E plane. The real efficiency of the E plane (including the gaps) can be estimated with the elastic e,e'p from LH2 target.
As stated above, we loose ~ 25% of e,e'pp events due to the tracking in the MWDC.
The information from MWDC (for the counting the e,e'pp events) is used to narrow the e,e'pp signal in order to achieve better signal to noise ratio. During the previous SRC experiment the signal – noise ration is shown in fig 1:

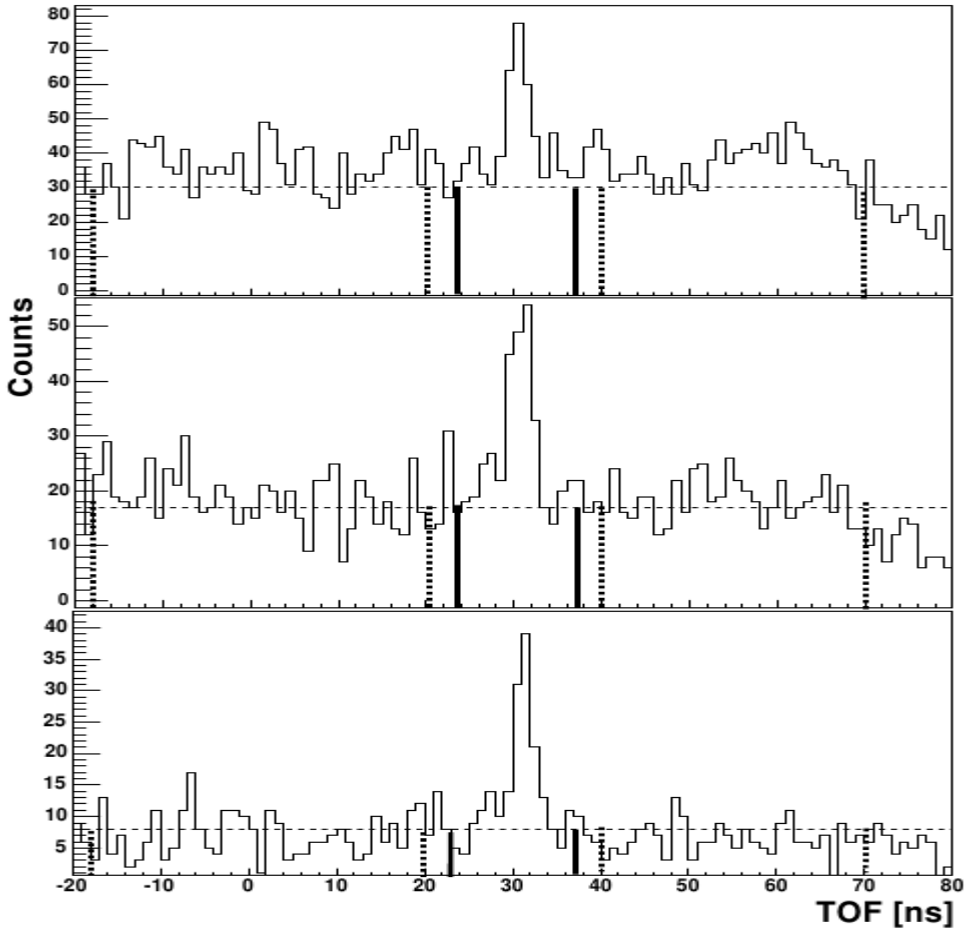

fig 1: Corrected TOF spectra for different Pmiss. The bottom is for Pmiss ~ 500 MeV/c.
Results of E01-015 (Ran's thesis)

From the figure 1, we clearly see that for higher missing momentum the signal – noise ratio is improving. In our experiment, the lowest momentum is 500 MeV/c, this means that signal – noise ratio in our case is better. In fig 2, the corrected TOF for 750 MeV/c is shown:

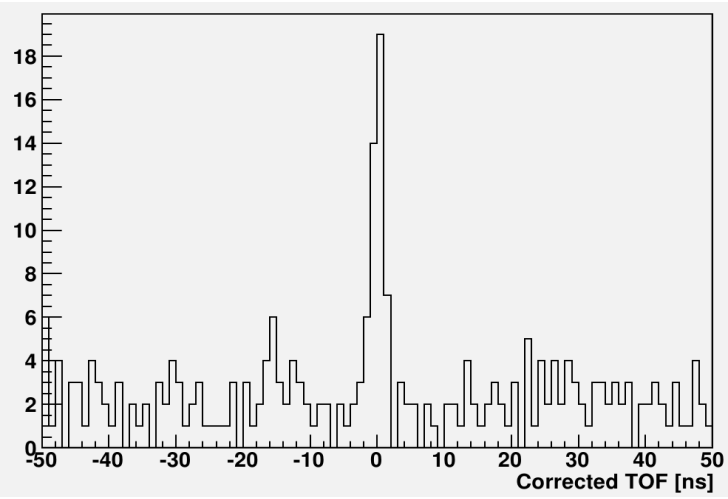

fig 2. Corrected TOF for 750 MeV/c

From this we have 35.5 ± 6.8 e,e'pp events.

If we ignore the tracking from the MWDC and look on the events in the E plane. We can count the number of events in two cases: 1) all possible hits (with position consistency check) fig 3.
2) count only the events when we had only one hit in each PMT that fire, fig 4.

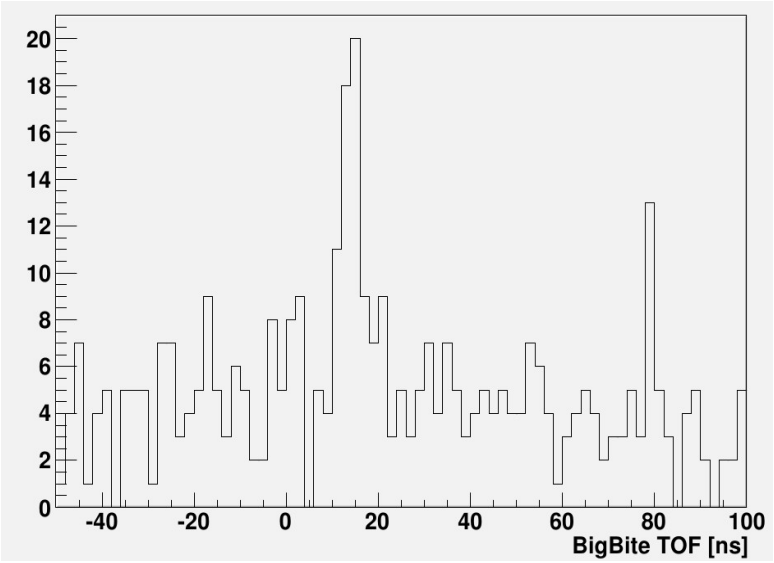

fig 3: TOF for all possible combinations

number of e,e'pp events in this case: 47.3 ± 9.5 (notice: 35.5/47.3 ~ 0.75)

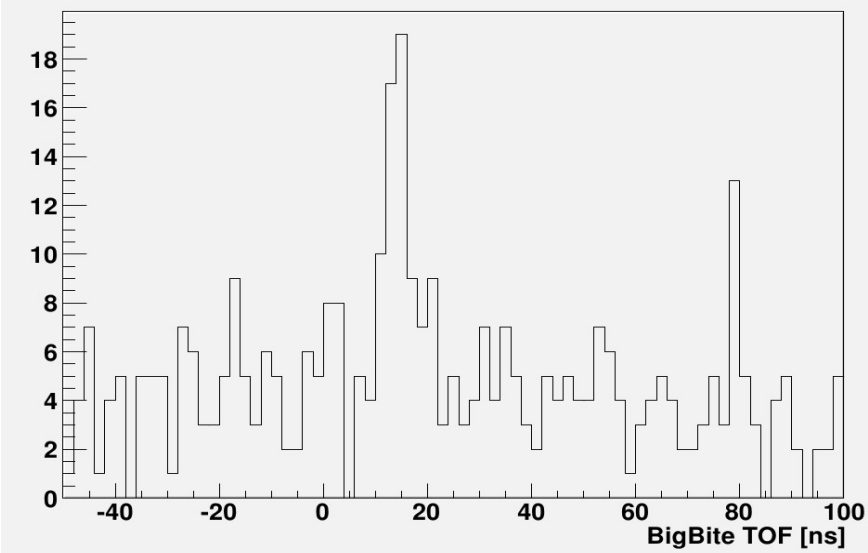

fig 4: BigBite TOF only for the cases when we take the first hit in PMT.

Number of e,e'pp events: 46 ± 9.1

The number of e,e'pp events with MWDC information already include the requirement of proton PID in BigBite. For the last two cases we need to verify that we count only protons. This can be done by looking on the dE/E or look on the energy deposit in E plane. In fig 5 energy deposit in E plane vs momentum reconstructed by MWDC is shown.

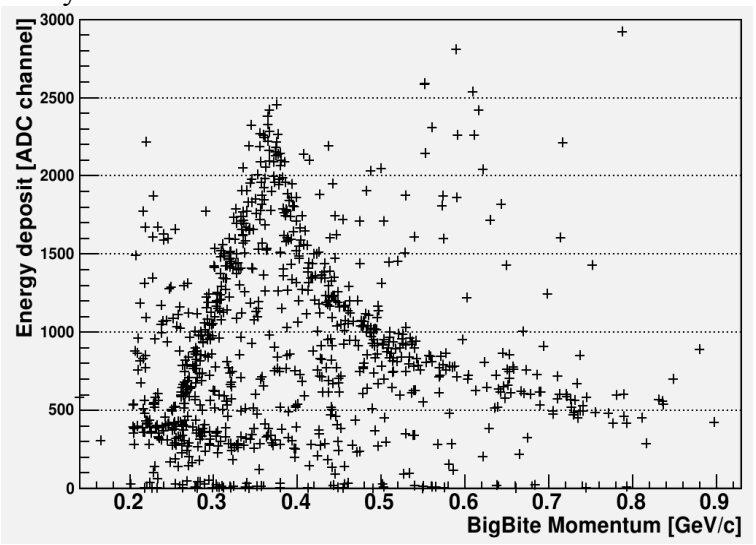

Fig 5: Energy deposit vs momentum

From figure 5 we see that in order to reduce the contribution from minimum ionizing particles, we need to cut above channel ~450.

However, we should look back and verify that valid data was recorded in the ADC (we used retiming circuit).
Up to now, we required cut on the retiming window, fig 6-7.

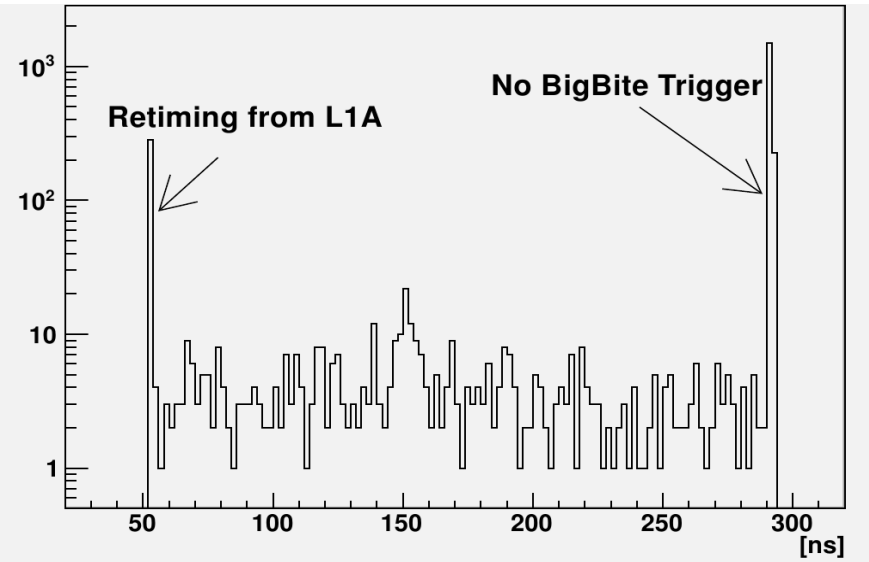

Fig 6: Time distribution of L1A signal in respect to Re-timed L1A

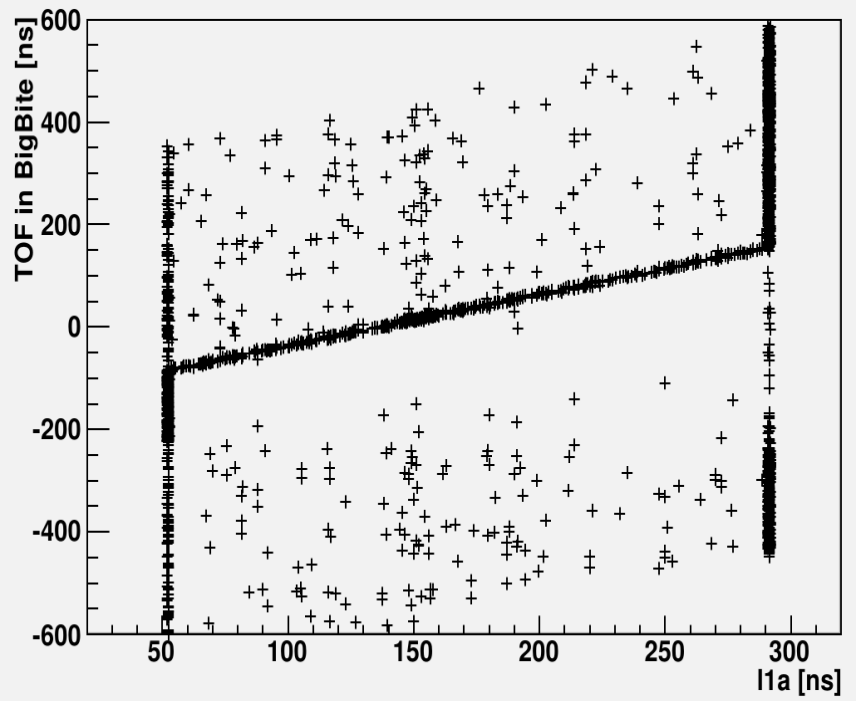

Fig 7: TOF in BigBite vs L1A (Important notice! The stop for TOF and L1A are different! If they had same stop, than th TOF line were horizontal)

In order to verify that the signal was inside the ADC gate we can look on ADC vs TOF, fig 8:

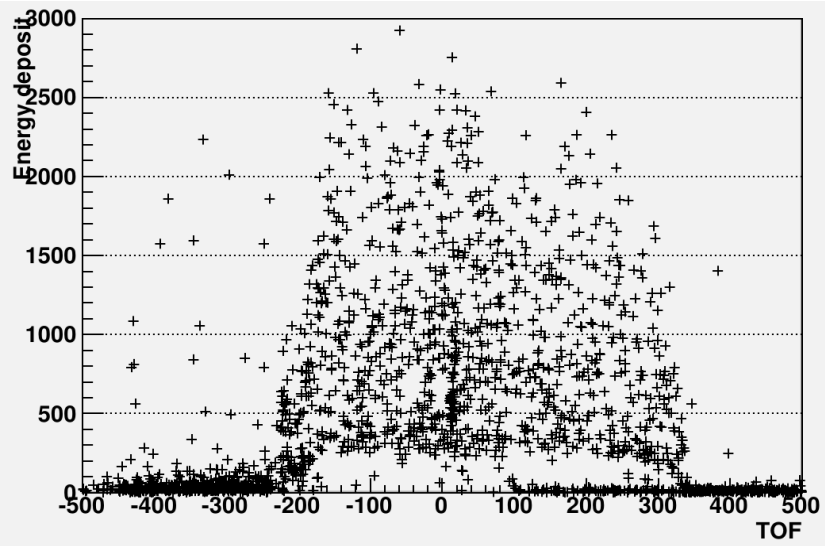

fig 8: Energy deposit (adc channels) in E plane vs TOF in [ns] (no cut on the retiming)

In figure 8 we see number of important features:

1) We identify the real signal in the random noise at the expected position ~15 ns.
2) We see the ADC gate
3) Part of the ADC gate have zero (!) values.

We see the ADC gate, but it “double”. The explanation for it comes together with the point 3. If we look on the retiming (fig 6). We know that the ADC gate will have gate even if E plane didn't had any trigger. This gate generated by the retiming of L1A from the delayed copy of L1A. This mean, if I cut out the right peak in the fig 6, this feature should disappear, fig 9:

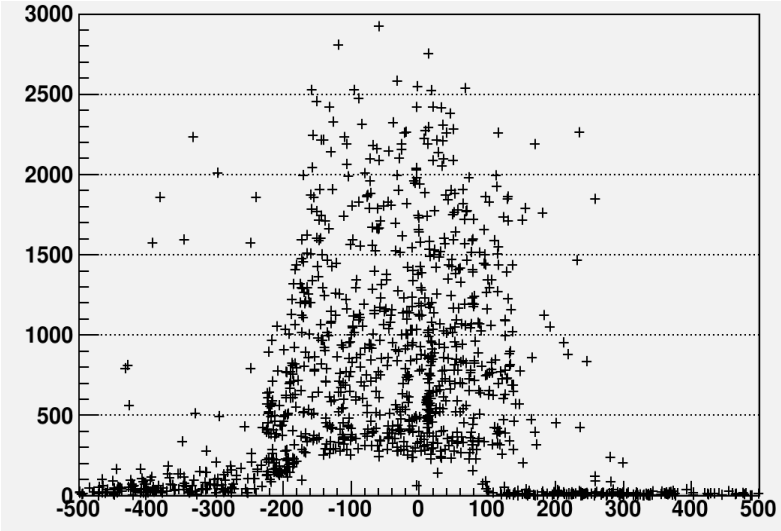

fig 9: ADC vs TOF in BigBite (cutting out the right peak in fig 6)

Until now we used additional cut on the retiming in order to cut out the left peak in fig 6. However, I don't think that it's necessary. If we look on the ADC vs TOF with full cut on the retiming fig 10:

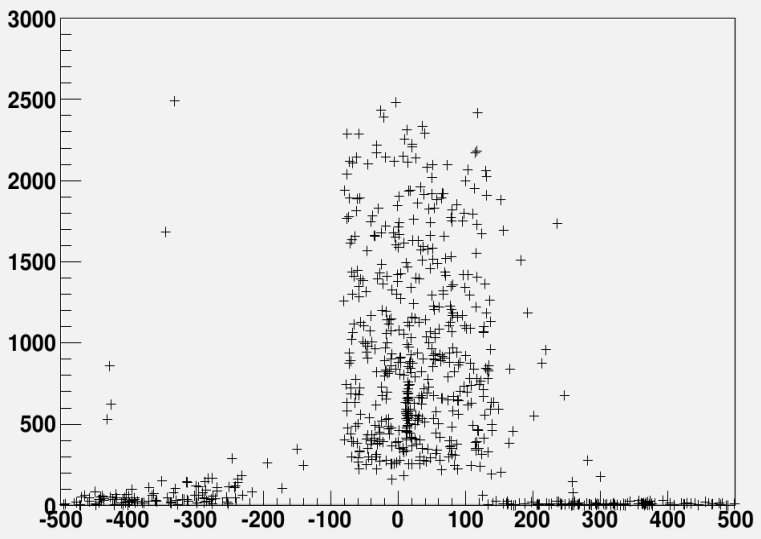

fig 10: ADC vs TOF with cut on Re-Timing

We used to cut out the left peak of the retiming window because of two reasons:

1) We don't know the actual time of the event because the Re-Timing is defined by l1A and not by E plane.
2) Only part of the signal enter the ADC gate.

From the figure 9, we can say that point 2 is not a problem and the signals are inside the integration gate.
The first point is partially correct, but TOF, as I calculate, is actually the difference between the counter in the BigBite TDC and the counter in the LHRS TDC. There is no dependency on the retiming. All dependencies are eliminated (the exact algebra is shown in the report from 21-3-2013, timing.pdf).

How the ratio changed if we remove the cut on the left peak of fig 6.

	# e,e'pp
With Tracking	37.5 ± 6.9 (correcting for eff: 50.3 ± 9.2)
“All combinations”	55.8 ± 9.8
Only first hit	53.8 ± 9.5

Now we need to summarize the amount of (e,e'pn) events, fig 11:

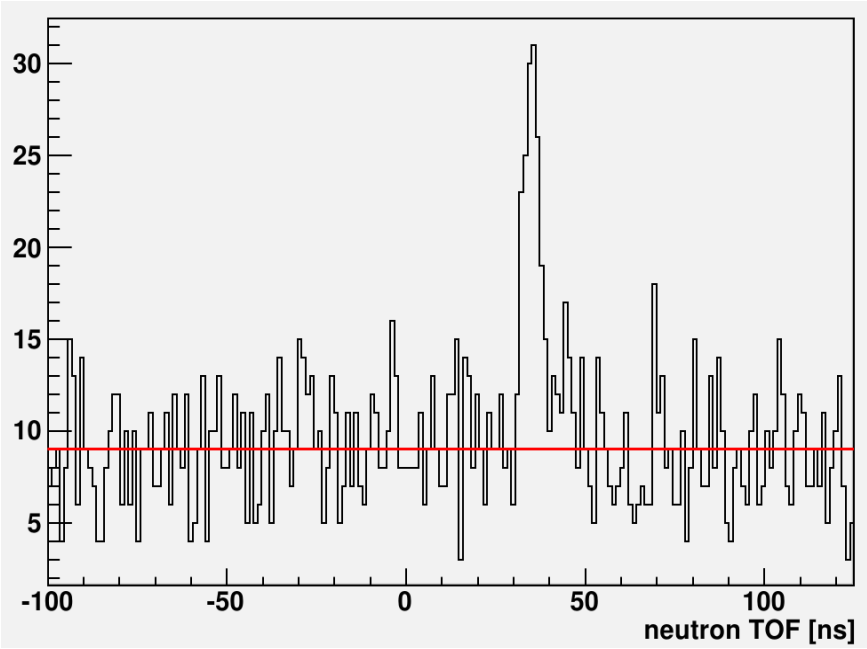

fig 11: HAND TOF

Number of e,e'pn events: 130 ± 20. (40% efficiency)

The ratio's for e,e'pn to e,e'pp (with new cut on retiming) are:

	# e,e'pp	**# e,e'pn**	**ratio**	**comment**
Track	(37.5 ± 6.)/0.75	130 ± 20	8.6 ± 2.5 (6.45 ± 1.59)	Ignoring the efficiency issues in BigBite (including 75% efficiency of BigBite)
All	55.8 ± 9.8	130 ± 20	5.8 ± 1.1	Ignoring the efficiency of E plane and PID
Single	53.8 ± 9.5	130 ± 20	6.0 ± 1.1	Ignoring the efficiency of E plane and PID

Ratio for the 625 MeV/c kinematics:

Corrected TOF spectra fig 12:

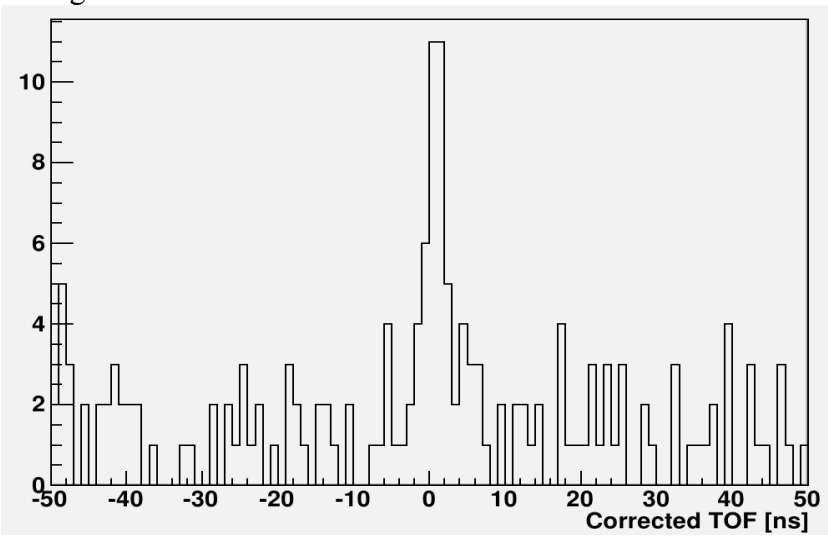

fig 12: Corrected TOF for 625 MeV/c

If we ignore the MWDC, fig 13:

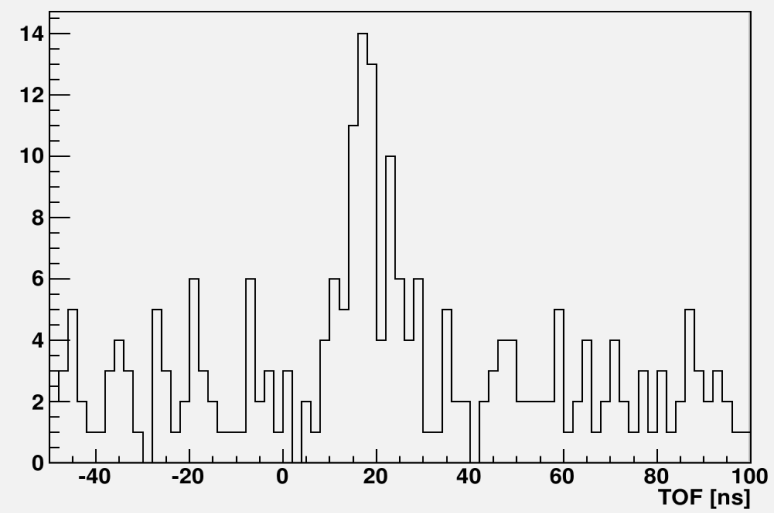

fig 13: TOF in BigBite with no tracking

TOF spectra for e,e'pn, fig 14:

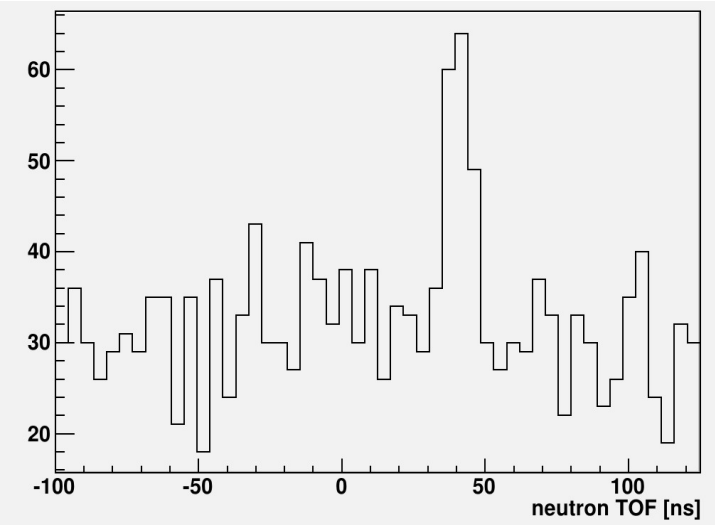

fig 14: HAND TOF

In figure 15 energy deposit vs momentum:

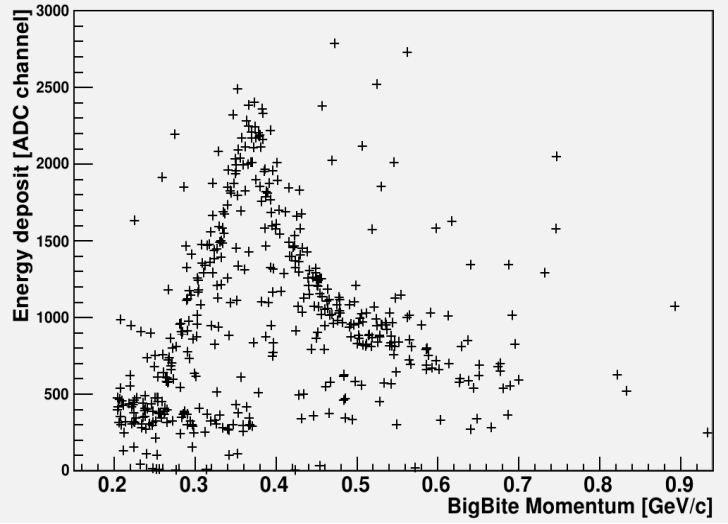

fig 15: Energy deposit in E plane vs Momentum for 625 MeV/c

In the figure 16 we can see the energy deposit vs TOF:

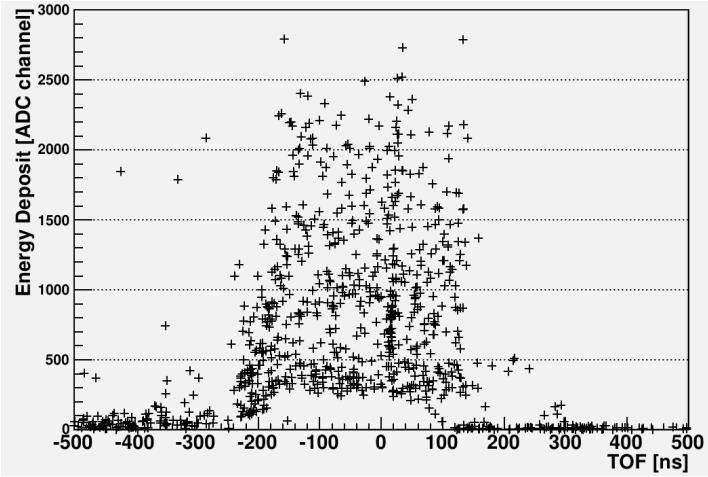

fig 16: Energy deposit vs TOF for 625 MeV/c

	# e,e'pp	# e,e'pn	ratio	comment
Track	29.1 ± 6.3 (38.8 ± 8.4)	86+-18	7.4 ± 2.3 (5.5 ± 1.97)	Ignoring the efficiency issues in BigBite (including 75% efficiency of BigBite)
All	54.3 ± 9.3	86+-18	3.96 ± 1.70	Ignoring the efficiency of E plane and PID
Single	51.4 ± 9.2	86+-18	4.18 ± 1.73	Ignoring the efficiency of E plane and PID

In fig 17 I summarize the ratio for different Pmiss.

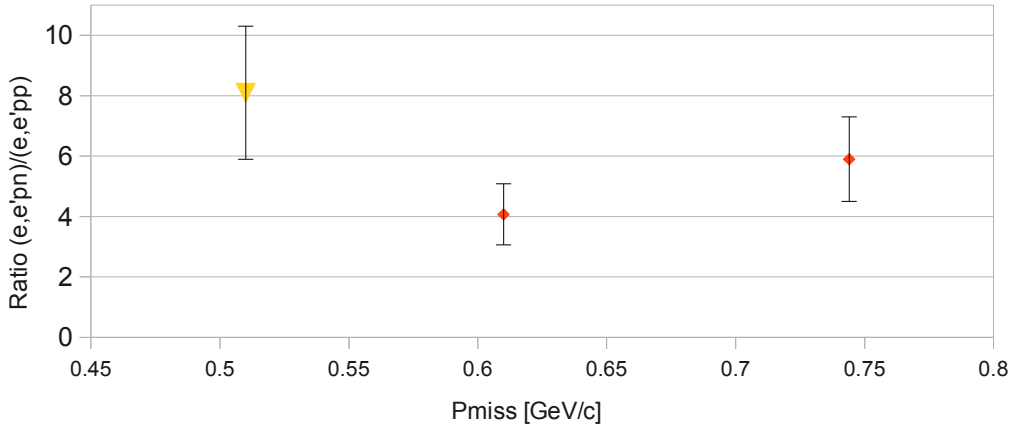

Fig 17: The yellow triangle correspond to the result of E01-015 experiment and the orange points represent the ratio for 625 MeV/c and 750 MeV/c kinematics.