Effects seen in the MEGHA telescopes.

R.L.Cowin, September 25, 1996

1 Introduction

The central MEGHA module and four telescopes in the left module were used in the first experiment in the new chamber to probe the low excitation region of the $^{24}Mg \rightarrow ^{12}C + ^{12}C$ reaction.

The existing data acquisition system was set up as in **figure 1**.

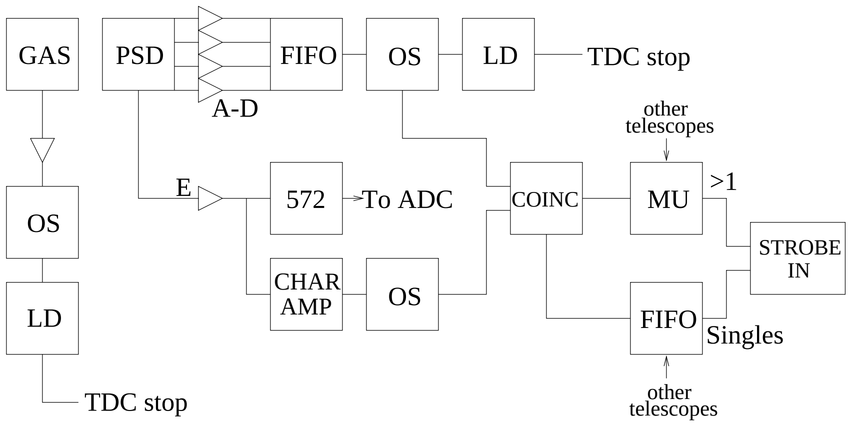

Figure 1: Logic set-up

ORTEC 571/572 spectroscopy amplifiers were used to shape the PSD E signals for $6\mu s$ to curtail the anticipated ballistic deficit. The E trigger was derived by furnishing a copy of the pre-amplifier output to a CHARISSA amplifier; the fast NIM threshold pulse was then shaped to use as the trigger.

A preliminary analysis of the data has revealed a number of problems with the detector response, which are detailed in this report. In addition to the known ballistic deficit in the PSD response, it appears that there is a time dependent 'droop' in both the energy and position signals during the period of the run. Furthermore there appears to be a change in the timing response of the detectors which has repercussions for the way in which coincidence overlaps are generated for event triggers. Finally, there is evidence for feedthrough between the scintillator and gas signals.

2 Energy effects

The charge collection time for the Hamamatsu Position Sensitive Detector varies as a function of position. Analysis of the pre-amplifier output signals shows that at a corner the 10-90% rise time is $\approx$200ns, whereas towards the centre the rise time is $>3\mu$s. If the main amplifier shaping time does not fully encompass the elongated rise times for these central events then a reduced, position dependent pulse height is measured.

Figure 2 shows the elastics pulse height for 60MeV ^{12}C ions scattered from a ^{197}Au target as a function of position for a central slice of data across the PSD face. The data has been calibrated such that the pulse height at the centre of the detector is $\approx$60MeV. A shaping time of 6μs was used to produce this plot. The ballistic deficit, defined here as,

$$BD = \left(1 - \left(\frac{E_{measured}}{E_{true}}\right)\right) \times 100\% \tag{1}$$

is 1.6% at the PSD centre, leading to a spread of 1.2MeV in the energy distribution.

This deficit can be corrected for using the position information provided by the PSD. A spline fit of the data to the expected kinematic distribution results in a full face resolution of 369keV for 85MeV ^{12}C ions, see **figure 3**. The intrinsic resolution for ions passing through the central hole of the calibration grid was 255keV. This fit worked well over the range of the two calibration beam energies used (60 and 85MeV), and the reaction beam energy (170MeV), suggesting that **the ballistic deficit is independent of energy**.

An attempt was made to simplify this correction and fit the ballistic deficit in a polar co-ordinate system, centred on the PSD centre, where,

$$r = \sqrt{X^2 + Y^2} \tag{2}$$

$$\theta = tan^{-1}\left(\frac{Y}{X}\right) \tag{3}$$

It was hoped that the deficit was a unique function of r; however it also depends on θ, with greater deficit towards the corners.

Analysis of the central module PSD performance throughout the reaction data set revealed a gradual drop in height of the ^{24}Mg elastics peak. This drop is position dependent, and seems to be an effect of a worsening ballistic deficit. At the PSD centre the total drop in the *raw* pulse height from start to finish is $\approx$8%, whereas at the edges the pulse height drops by only 1.2%, see **figure 4**. The ballistic deficit at the PSD centre increases from 2.0% in **figure 4(a)** to 14.2% in **figure 4(b)**.

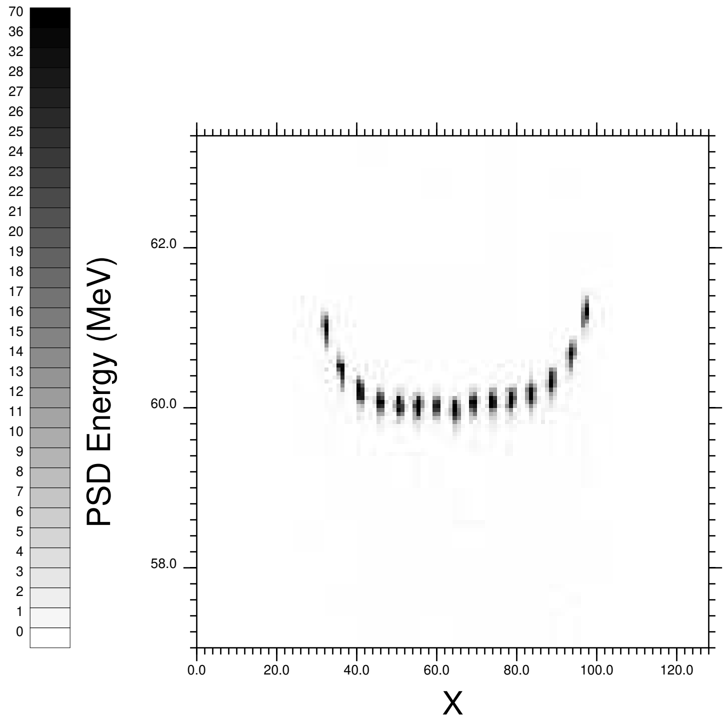

Figure 2: Energy distribution of elastically scattered 60MeV ^{12}C ions as a function of X co-ordinate for a central slice of data across the PSD face.

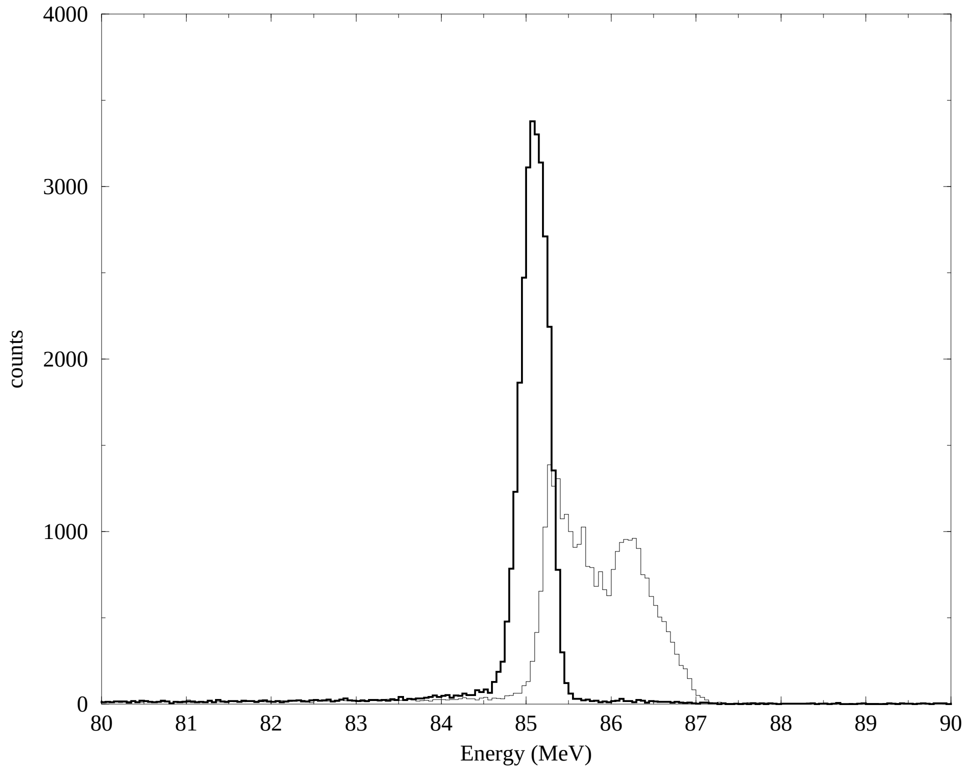

Figure 3: Comparison of corrected (bold) and uncorrected energy distributions for elastically scattered 85MeV ^{12}C ions.

Modifying the ballistic deficit correction by a simple scaling factor to cope with the increasing deficit can correct the energy profile to the expected distribution, see **figure 5**. This suggests that the extra deficit arises from a similar mechanism to the ballistic deficit. The correction applied to the data in **figure 5(a)** was derived from the calibration data, whereas the correction applied to the data in **figure 5(b)** is modified so as to re-fit the data to the profile in **(a)**.

There is a strong correlation between the fall in elastics peak height with an increase in the PSD leakage current, see **figure 6**. Also, the intrinsic energy resolution for the elastically scattered ^{24}Mg ions increases from 1.45MeV (0.85%) during the first reaction run to 3.65MeV (2.14%) during the last; these measurements of *intrinsic* energy resolution are independent of the position dependent correction. The elastic scattering cross-section for the left module PSD's was too small to gauge whether their pulse height was dropping.

The effect of this degradation in performance is obvious in a comparison of the total energy spectra (incremented for the central module telescopes only) for the start and end of the experiment (**figures 7 (a) and (b)**). Clearly, the resolution has worsened and the position of the peaks has shifted down in energy.

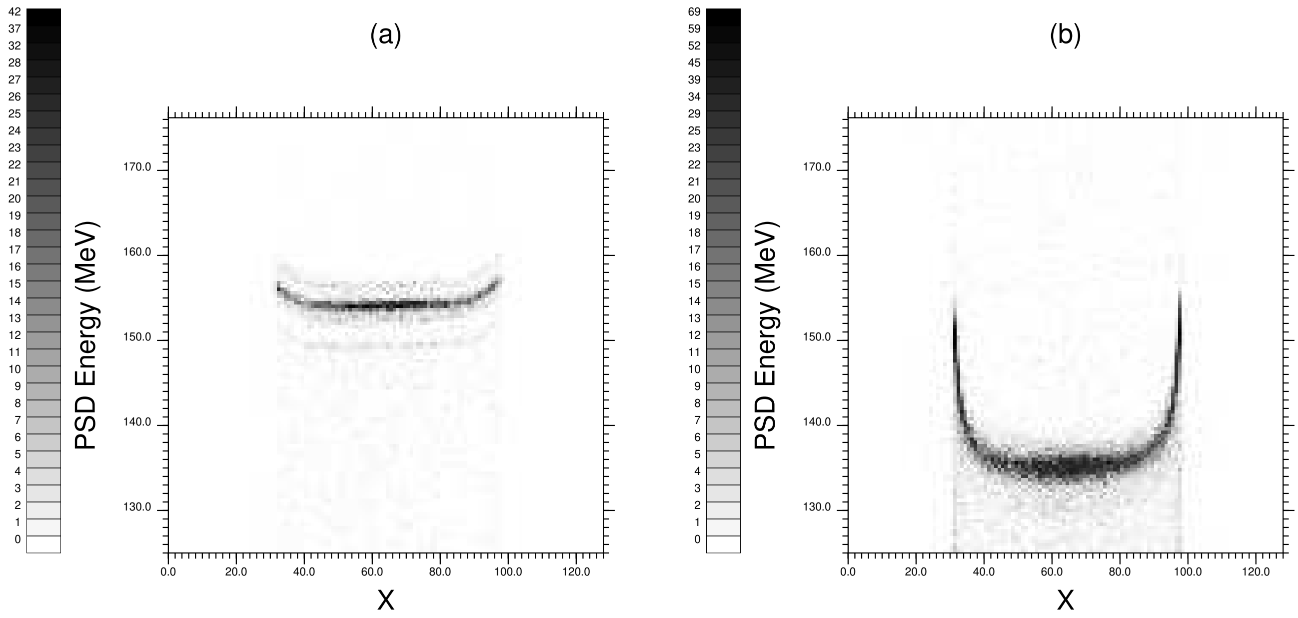

Figure 4: Energy distribution of 170MeV ^{24}Mg ions scattered from a ^{12}C target as a function of X co-ordinate for a central slice of data across the PSD face, for (a) the start of the reaction data, and (b) the end of the reaction data. **No correction for ballistic deficit has been applied to the above data.**

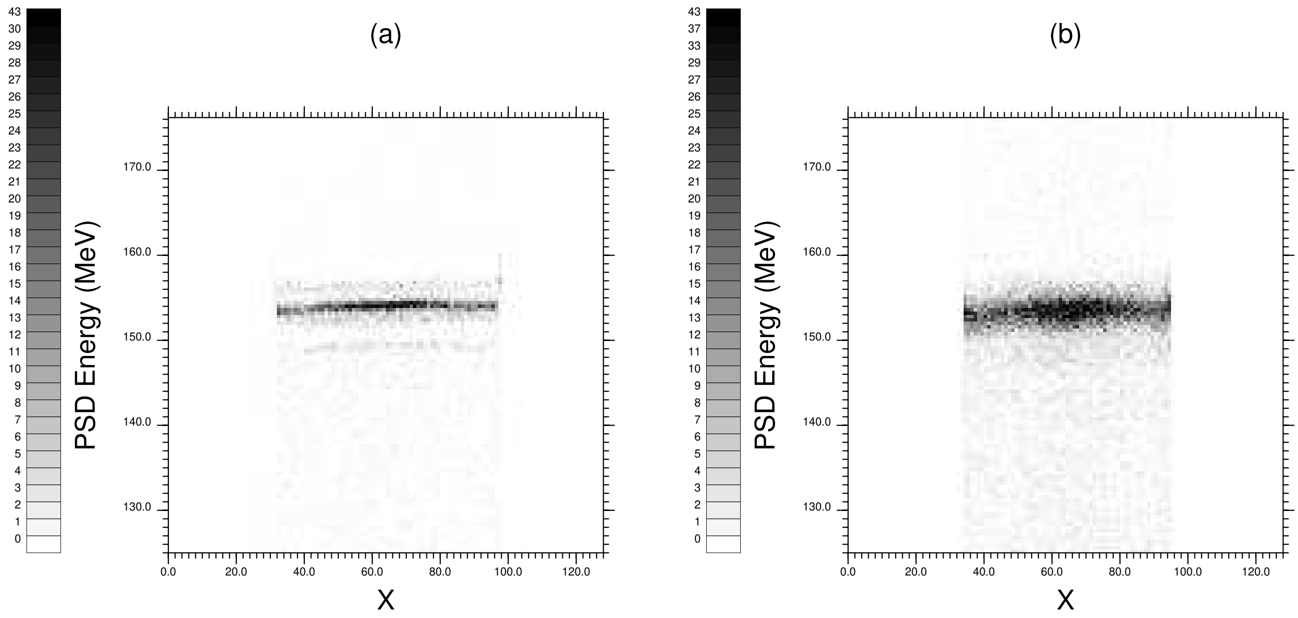

Figure 5: **Corrected** energy distribution of 170MeV ^{24}Mg ions scattered from a ^{12}C target as a function of X co-ordinate for a central slice of data across the PSD face, for (a) the start of the reaction data, and (b) the end of the reaction data.

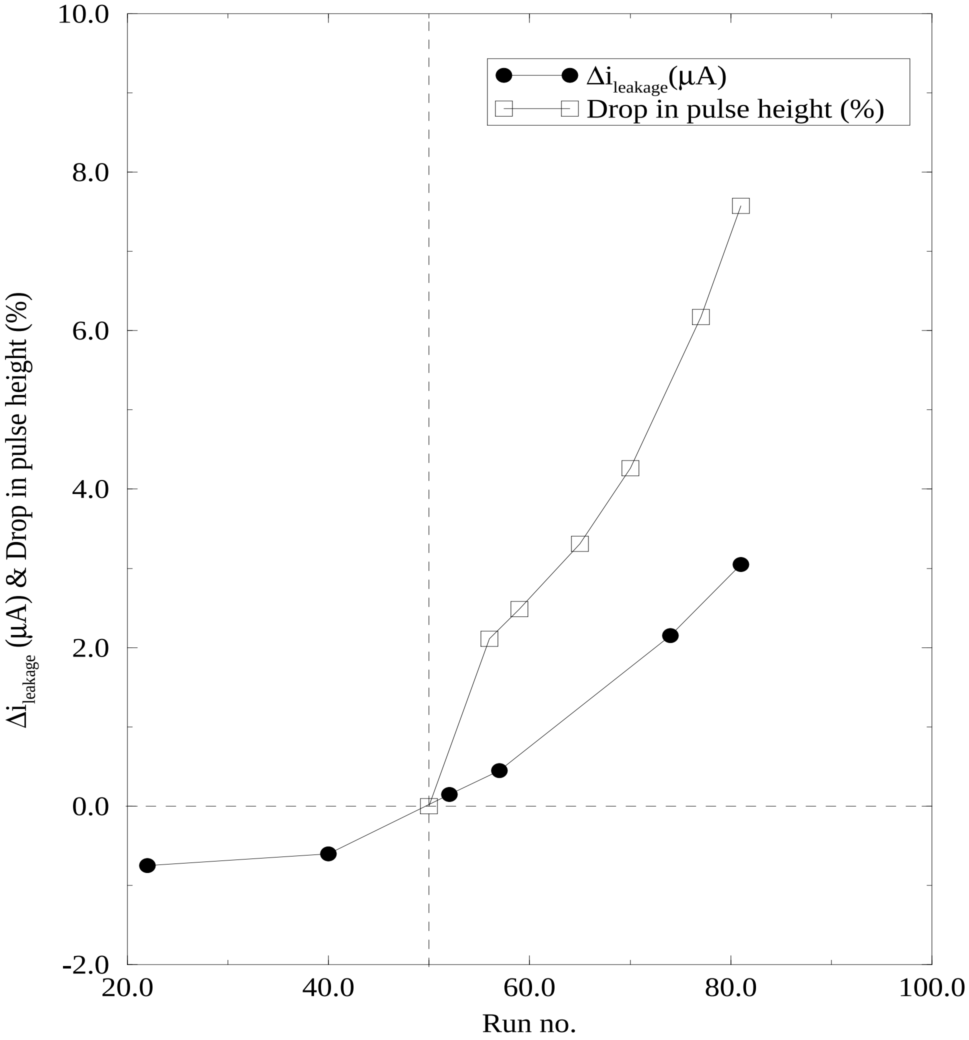

Figure 6: Correlation of PSD leakage current with percentage drop in ^{24}Mg elastics pulse height at the PSD centre (both normalized to run 50).

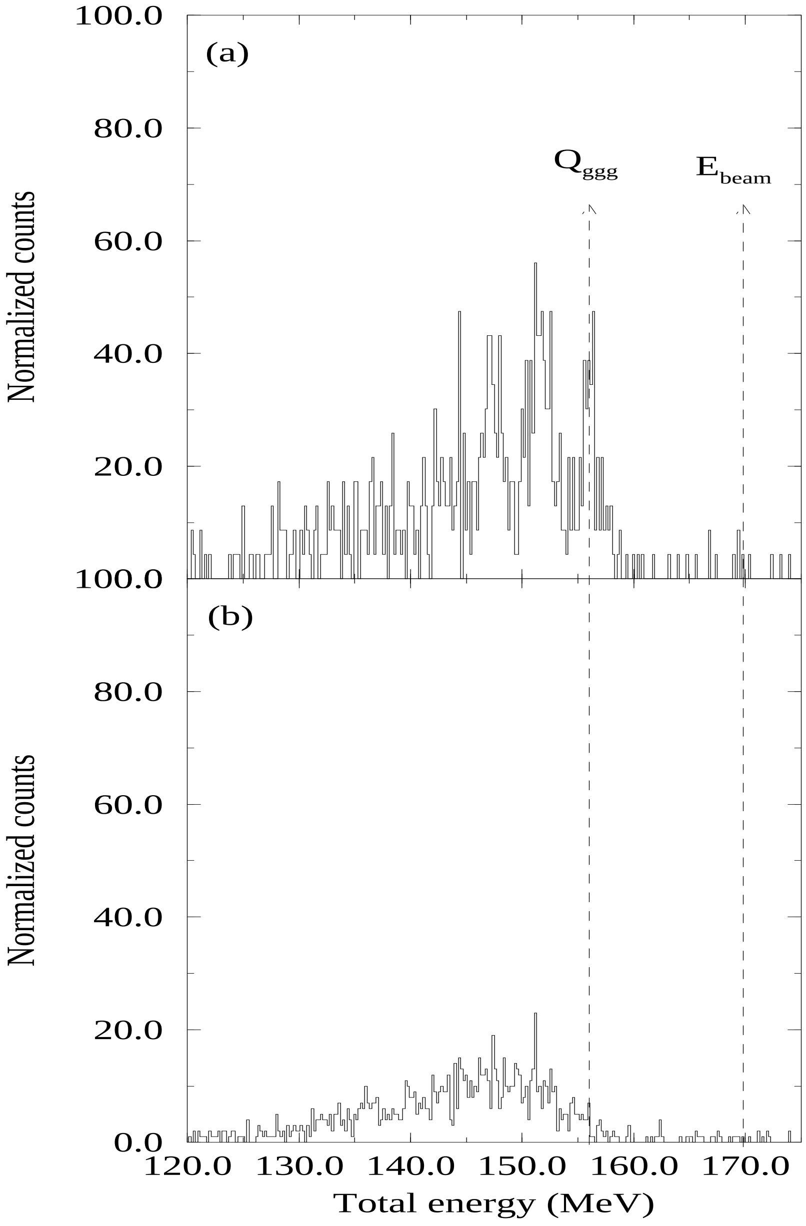

Figure 7: Total energy spectra for the reaction $^{12}C(^{24}Mg,^{12}C^{12}C)^{12}C$, E_{beam}=170MeV, at the start (a) and end (b) of the experiment.

3 Timing effects

An E-position coincidence requirement was made to ensure that a valid event contained at least a PSD E signal with the fastest of the four position signals. The falling edges of the octal shaper output generated by the E and position signal threshold pulses had to fall within a $\pm$550ns coincidence window, the width of which was set by the octal shaper widths, see **figure 8**. Timing information was collected for the Gas and PSD position signals, but not for the PSD E signals. No coincidence requirement was made for the Gas or CsI detectors.

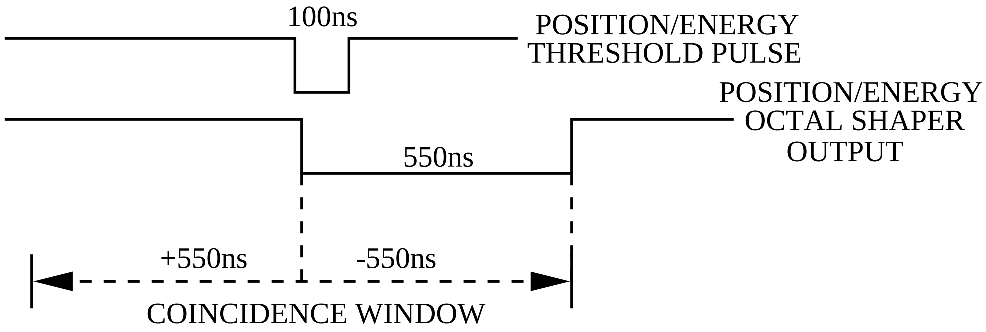

Figure 8: The falling edge of the E trigger shaper output must fall within $\pm$550ns of the position trigger shaper output or vice-versa, depending on which signal is first.

It was noticed that appearing in the centre of each PSD was a region with significantly less counts. Eventually this region virtually engulfs the entire PSD face, see **figures 9 and 10**. The semi-circular cut-out from the top edge of the PSD is due to a circular shield place around the beam axis. **Figure 10** shows evidence that the XY pattern has become distorted also; the cut-out does not retain its shape throughout the experiment. There was evidence for a small dead region in each of the left module PSD centres, present, and unchanging, throughout the entire data set. The dead regions have caused a drop in the data acquisition efficiency, as can be seen in **figure 7**.

I believe that these effects are related to a timing problem between the PSD energy and position triggers. The problem being that the E signal is slipping outside the coincidence window for events near the centre of the PSD. To test this idea I plotted a variable t_{gp}=TDC$_{Gas}$-TDC$_{position}$ against the X co-ordinate for a slice of data across the PSD face. The gas timing signal varies by only 50ns[1] for the full range of gas energy sampled during the experiment ($\approx$1-20MeV), and, I assume, is independent of position, and so can be used as a reliable timing reference point to investigate PSD

[1] This value was obtained by plotting the variable t_{gp} as a function of gas energy for a small gated region of the PSD face in order to eliminate any position dependencies in TDC$_{position}$, so that it could be used as a reliable reference.

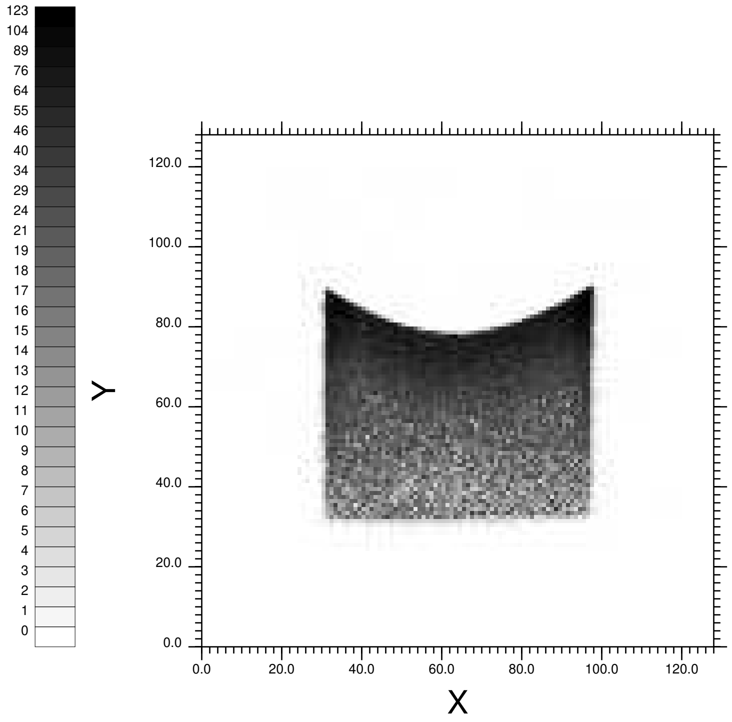

Figure 9: XY pattern incremented during the first reaction run.

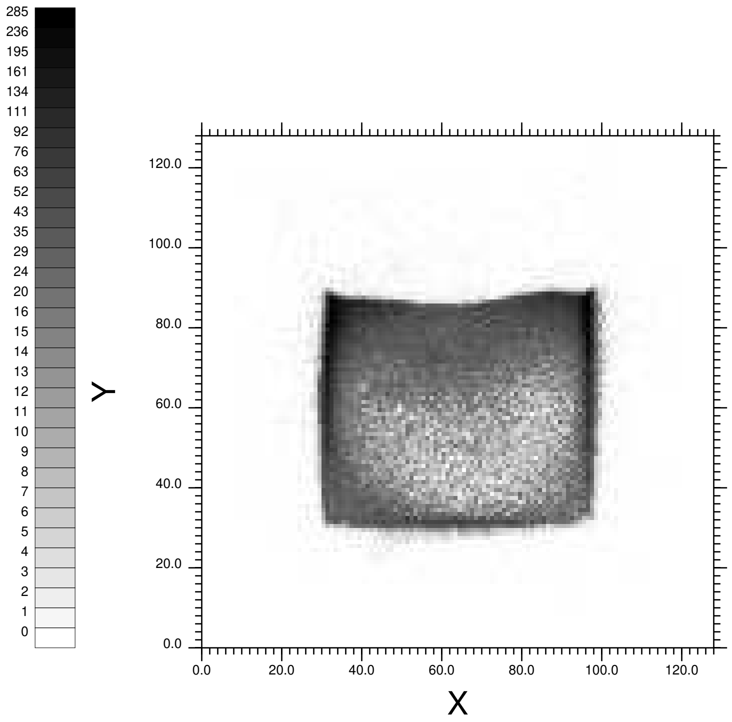

Figure 10: XY pattern showing the 'hole' formed during the reaction runs, incremented during the last reaction run.

timing characteristics. t_{gp} was found to be roughly independent of the PSD E signal, in-line with observations that these effects are roughly independent of energy.

As can be seen in **figure 11**, incremented during the first reaction run, the position dependency is extensive. The position trigger is up to 400ns slower than the gas. **Figure 12** shows that at the end of the runs this time deficit is much greater than 550ns for a central region of the PSD. Although this tells us nothing of the E-position coincidences, it does indicate that one of the trigger signals is slowing down in a position dependent way.

We also know that the E signal is intrinsically slower than the position signal, hence the difference in shaping time constants used (1μs for the position signals and 6μs for the E signal). This is a consequence of the slower rise time of the PSD E current pulse and associated pre-amplifier voltage pulse; and therefore I think it is safe to assume that the E trigger (threshold pulse) will be slower than the position trigger for the same event for the same position co-ordinate, and will be more sensitive to any signal timing changes.

The likely causes of these changes in detector current pulses are: (a) the build up of charge trapping centres in the silicon due to radiation damage; this would also explain why the effects are unchanging in the left module PSD's[2], and/or (b) because of a change in the signal propogation across the face of the detector to the contacts; this is influenced by the capacitance across the detector junction, C, and the resistance of the implanted layer, R. If the RC time constant changes, the signal propogation will be delayed; this could arise from a change in C as the the leakage current increases and the bias voltage decreases, or a rise in the resistance of the implanted layer resulting from ion bombardment.

If the difference between the E and position triggers is greater than 550ns then there will be no coincidence overlap. This effect will be greatest in the centre of the PSD where the pre-amp output rise-time (10-90%) has been measured to be $\approx 3\mu$s slower than at the corners (for an unused PSD), not necessarily where the radiation damage is greatest. The ballistic deficit of the pulse height would be accentuated for these central events, hence we see a gradual position dependent fall off in recorded elastics energy, as described in **section 2**. There will always be some E-position coincidences at the edges/corners of the detector as the difference between E and position timing here tends to zero.

This effect makes it dangerous to demand E-position(-gas) coincidences for events in telescopes. Similarly, we can assume that the change in delay will differ between

[2]The evidence from the left module PSD's suggesting that there were dead regions prior to the main experiment may be explained in part by the different E trigger used; the pre-amplifier outputs were furnished to timing filter amplifier - quad discriminator combinations to provide the E trigger as opposed to a CHARISSA amplifier, possibly resulting in discrepant timing.

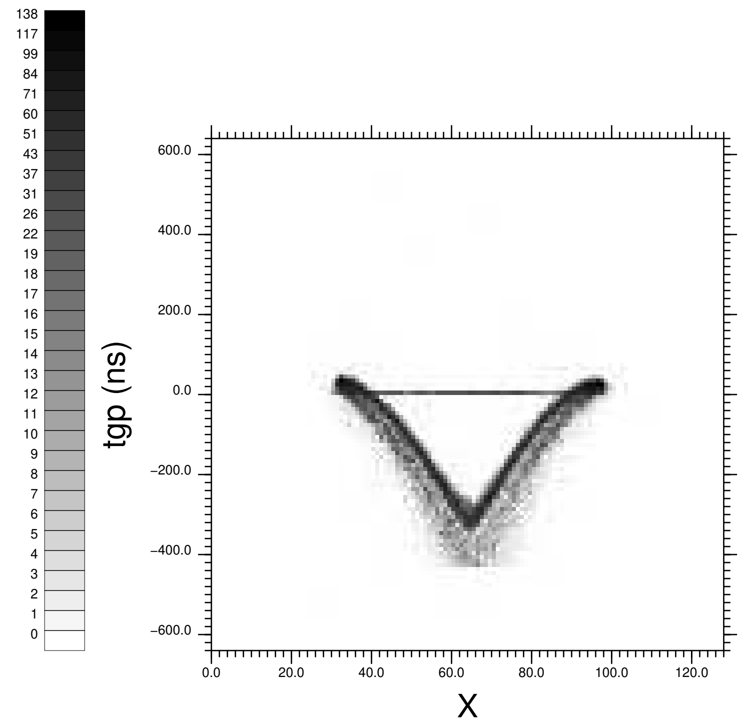

Figure 11: Relative timing between Gas and position signals plotted as a function of X for a central slice of data across the PSD face for the first reaction data run.

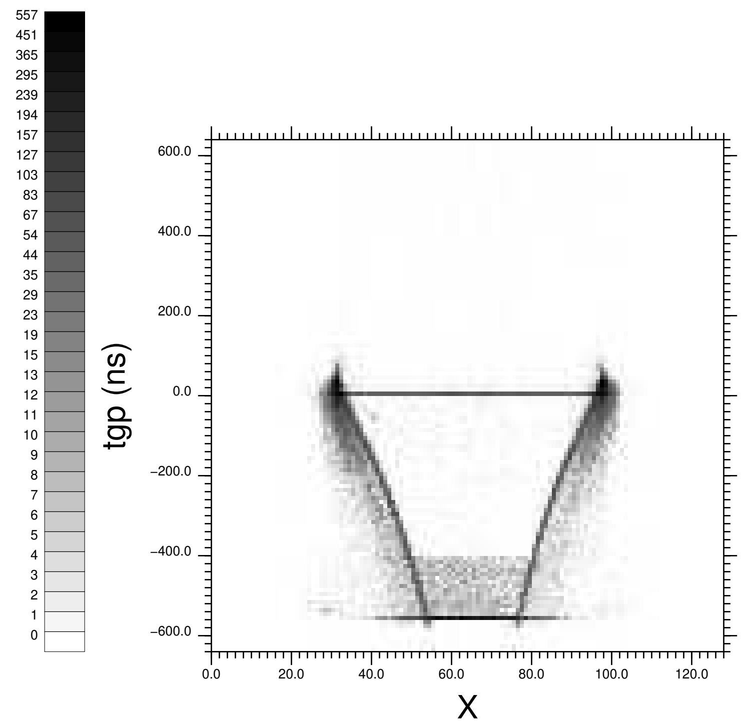

Figure 12: Relative timing between Gas and position signals plotted as a function of X for a central slice of data across the PSD face for the last reaction data run.

detectors if they experience different particle fluxes, and this makes it dangerous to demand E-E coincidences to identify coincident events between telescopes. We could get round the first of these problems by dropping the check for internal coincidences within a telescope. This would just mean that there may be an increased rate to tape of incomplete events (ie, too few signals to ensure that the 'hit' can be reconstructed). For the second problem we could use gas-gas coincidences to identify events, since the gas signals are not affected. Then, providing the walk is not so extreme as to take the peak detect outside the ADC gate signal (many μs), all the signals would be recorded. *However*, we may then have problems recording high energy, light ions where the signal in the gas is below threshold. The only way round this is would be to use position-position coincidences or a mixture of position and CsI detector coincidences, ensuring the timing gates are long enough to cover the extremes of any changes. Also, by overbiasing the PSD (for this experiment we applied a +100V bias), the signals can be forced to emerge quicker, reducing the timing and pulse height deficit.

A future test to confirm these ideas would obviously be to measure the timing of the E signal relative to the position and gas signals as a function of bias. A comparison of the pre-amplifier output rise times from the damaged PSD's with a new one should indicate the extent of the damage. An investigation of the distortion XY pattern for the damaged PSD's also needs to be made.

4 Saturation in the Caesium Iodide scintillators

During the experiment the CHARISSA amplifiers associated with the CsI detectors were set to read positive input pulses, similar to the inputs of both the PSD and gas energy signals. This was done because, with the beam on, all the pulses were of this polarity except for a few curious negative pulses with very small amplitude $\approx$-30mV compared to the $<$850mV real events. So I expected to see a normal bipolar amplifier output with sending a negative pulser to the pre-amplifier. Instead the positive lobe saturates around 3.5V and increasing the amplitude of the pulse any further simply causes the negative lobe to be delayed from the positive part .The pre-amplifier output signal itself follows what looks like a capacitor charging curve before turning over quickly and resuming the normal feedback capacitor discharge tail. This has been suggested to be the result of insufficient drive current on one of the power rails. Sending a positive pulser to the pre-amplifier gives a normal bipolar output without saturation. This to me suggests that the pre-amplifier only amplifies positive inputs properly, whereas we require it to amplify negative real signals from the photodiode.

5 Signal coupling problems

An E(PSD)-ΔE(Gas) particle identification plot for the reaction ^{12}C(^{24}Mg at E_{beam}=170MeV, see **figure 13** shows the Lithium traces crossing that of the Carbons. Furthermore the gas signals for the light ions (α's and Lithiums) are far higher than those predicted by the DEDX code. Even more puzzling is that these events have an associated CsI signal despite the fact that the particles shouldn't have enough energy to punch through to the PSD. This CsI signal increases as the Gas signal increases, which is clearly unphysical. If the light ions did leave some energy in the gas above detection threshold then you would expect that it would decrease as the CsI signal increased.

A plot of CsI energy vs gas energy clearly shows the relationship of the two signals, see **figure 14**. The difference between the different telescopes is in the gradient of this correlation.

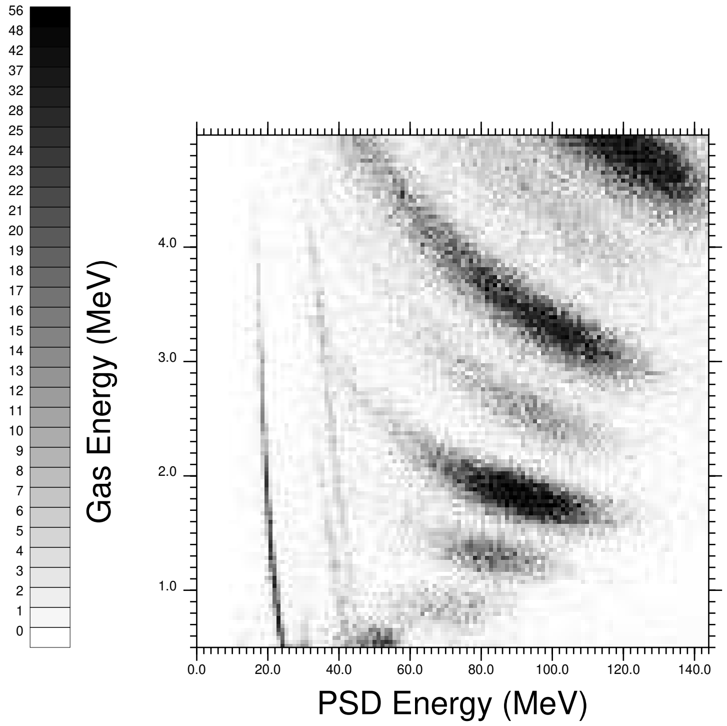

Figure 13: E(PSD)-ΔE(Gas) particle identification plot for the reaction ^{12}C(^{24}Mg at E_{beam}=170MeV. Identification of particle species from top right to bottom left is as follows; Ne, F, O, N, C, B, Be, (^{7}Li, ^{6}Li, and He).

It seems that one of the two signals is somehow feeding through to the create the other. It is most likely that the gas signal is false and just represents a copy of the CsI signal since it is too large to be physical (an α cant leave as much energy in the gas at the same PSD energy as a carbon).

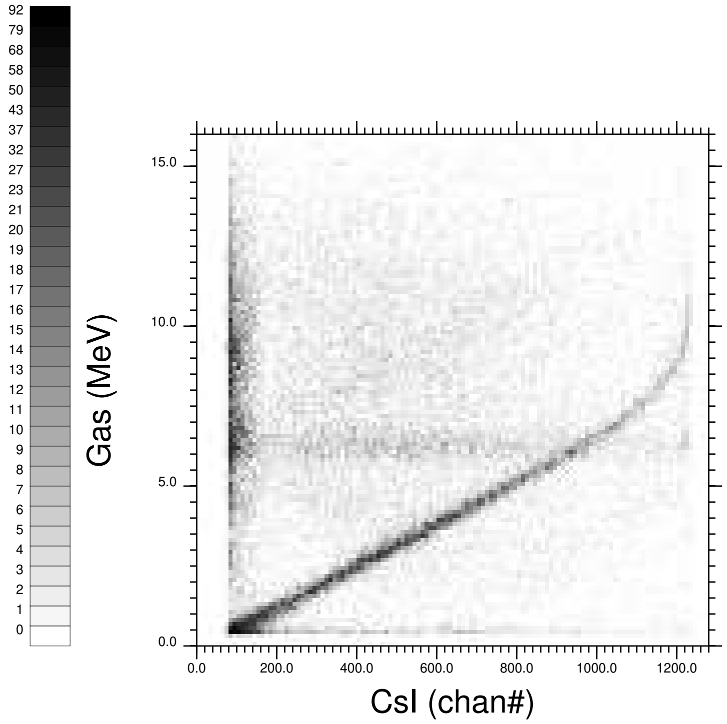

Figure 14: Plot of gas energy vs CsI energy showing the correlation between the two signals as a diagonal stripe. The faint horizontal band is due to random coincidences between Mg elastics events and any CsI signal.

I presume that the feedthrough must be happening somewhere before the CsI signal reaches its pre-amplifier, because as the CsI signal saturates (another problem) the corresponding false gas signals don't (see the upturn in the correlation in **figure 14**), indicating that the feedthrough is pre-saturation.