Tandem’08

Test Detector Response using the Carbon Beam

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Detectors & FrontEnd & DAQ

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E (Back PD, 300um) detector response

MZ^2 spectra

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E (Back, 300um) detector response

MZ^2 Spectra

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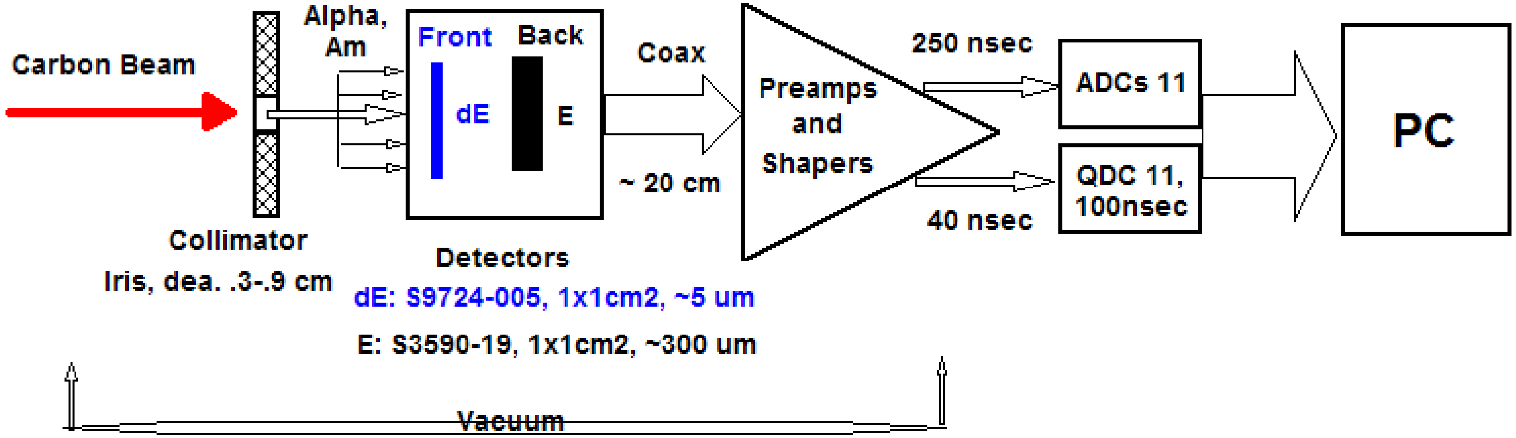
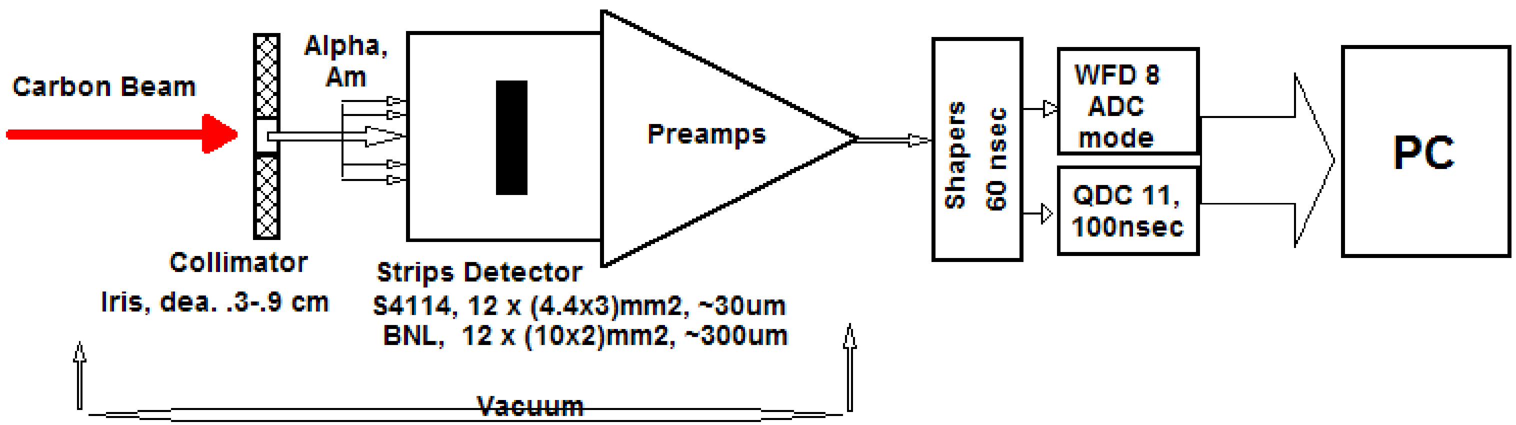
2009 setup

TANDEM Setup

Detectors & FrontEnd & DAQ

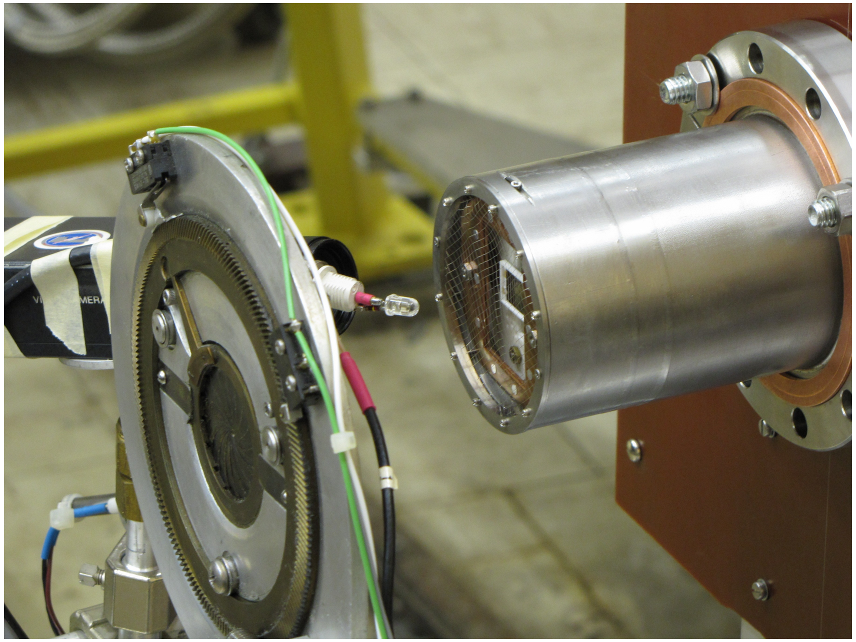


dE|E Setup



E Setup

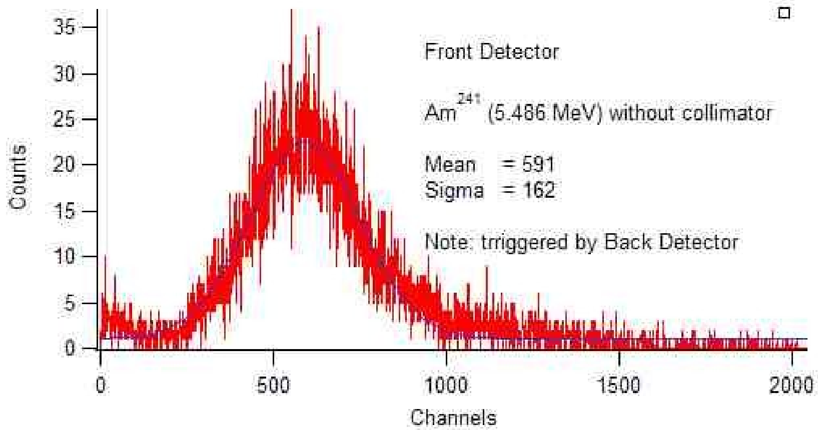
Tandem Setup overview

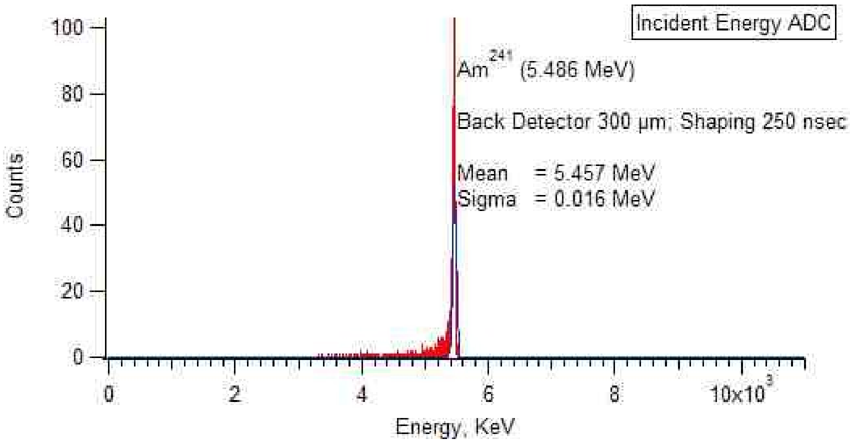


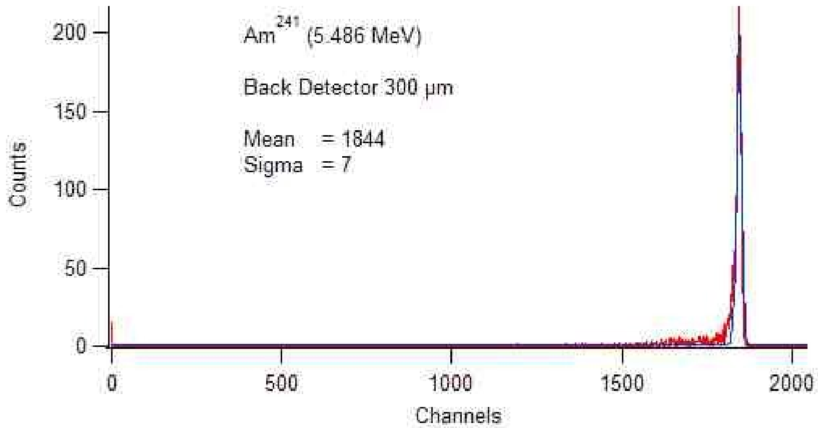
Alpha (Am241, 5.486 MeV) Calibration

dE (Front PD, ~5um) detector response

E (Back PD, 300um) detector response







dE detector (5um), DL = 35ug/cm²

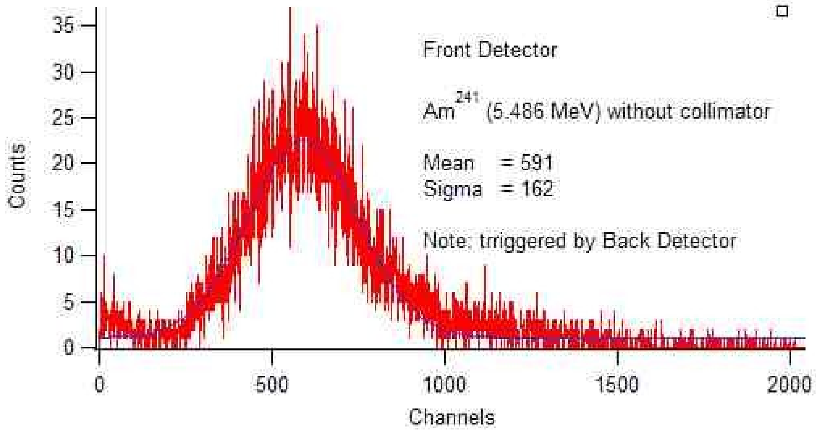
- using SRIM-2003 calculation for electronic stopping power for Alpha in Silicon:

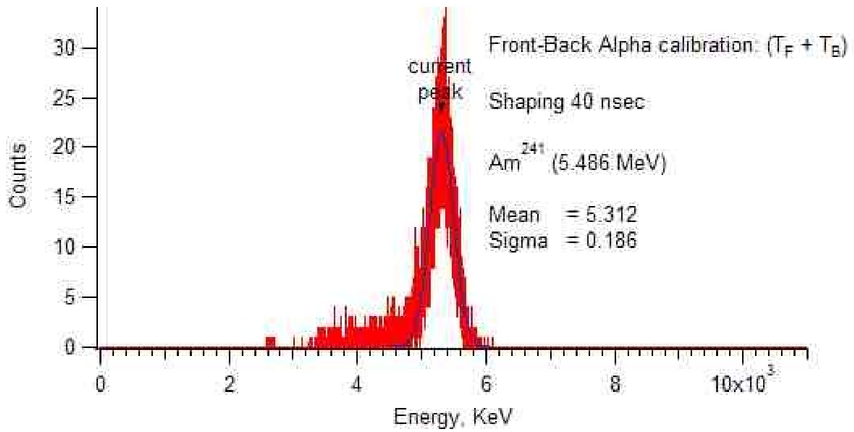
Mean – 677 keV

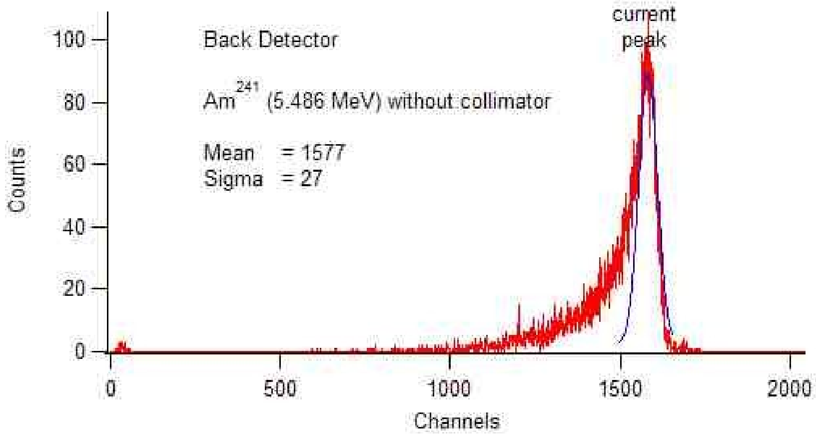
E detector (300um), DL = 54 ug/cm²

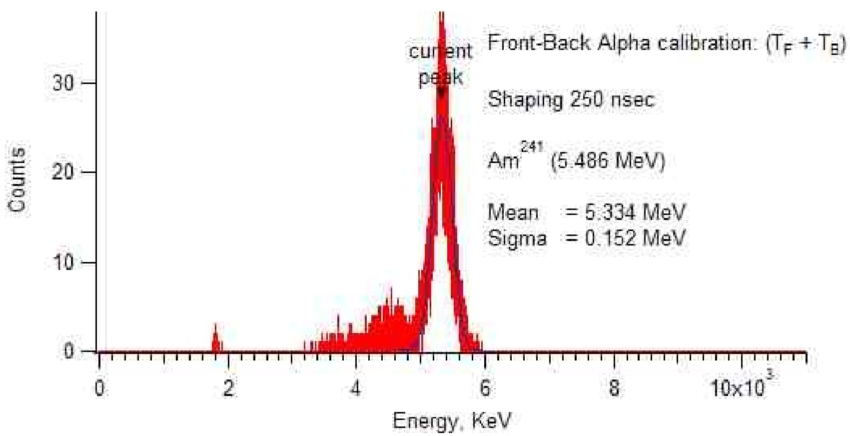
Note: E detector calibrated without dE detector.

dE|E Alpha Calibration

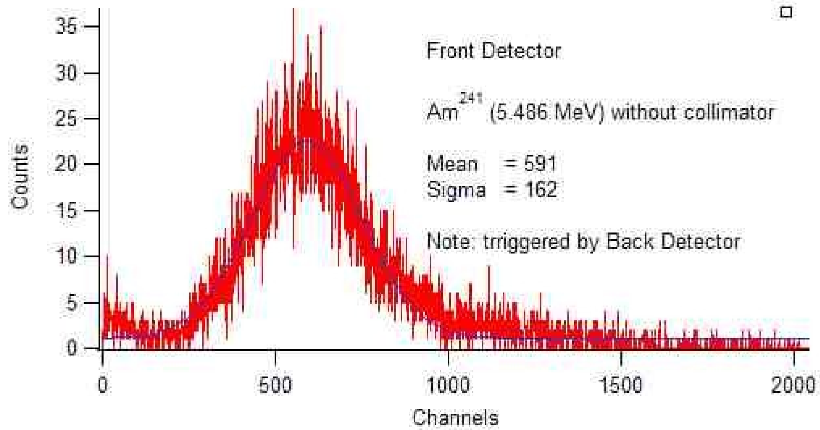


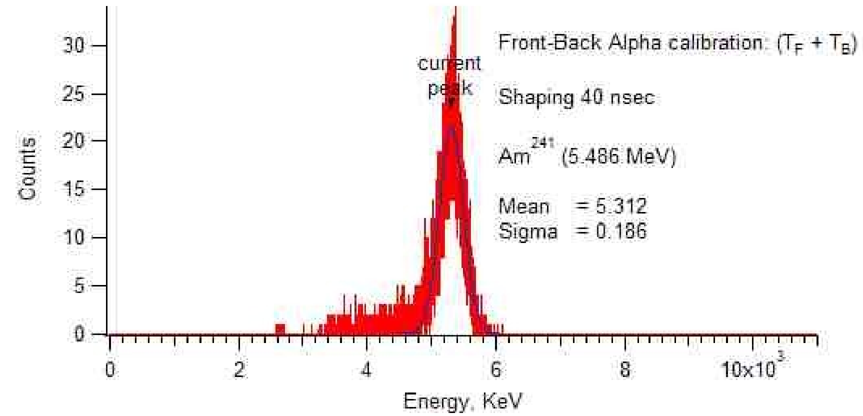


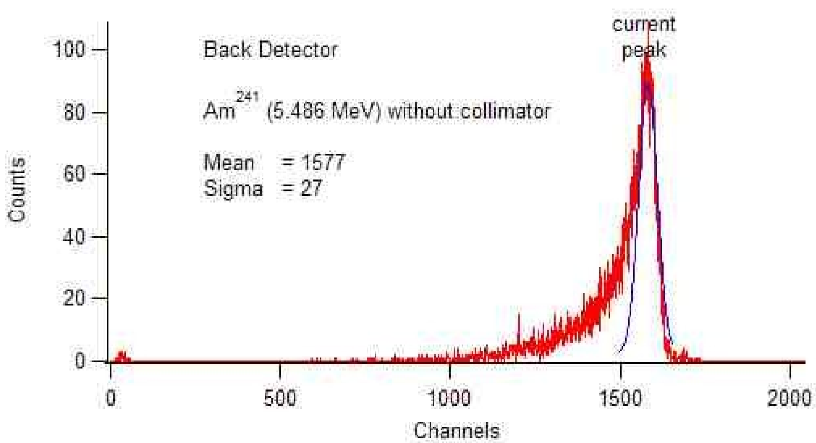


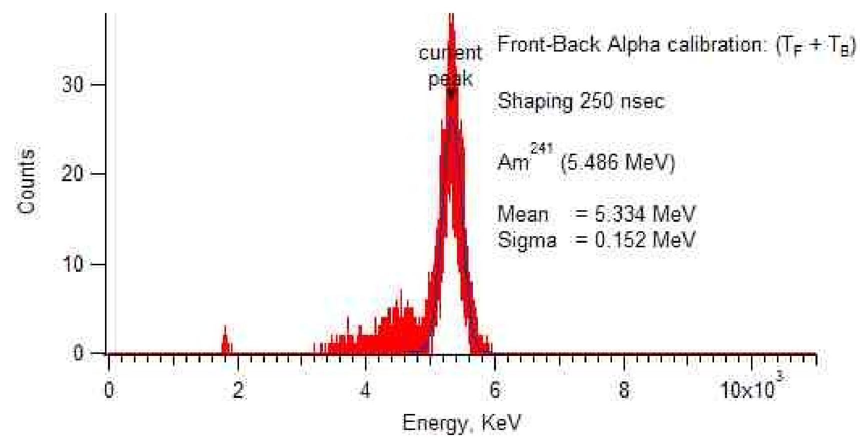


dE|E Alpha Calibration

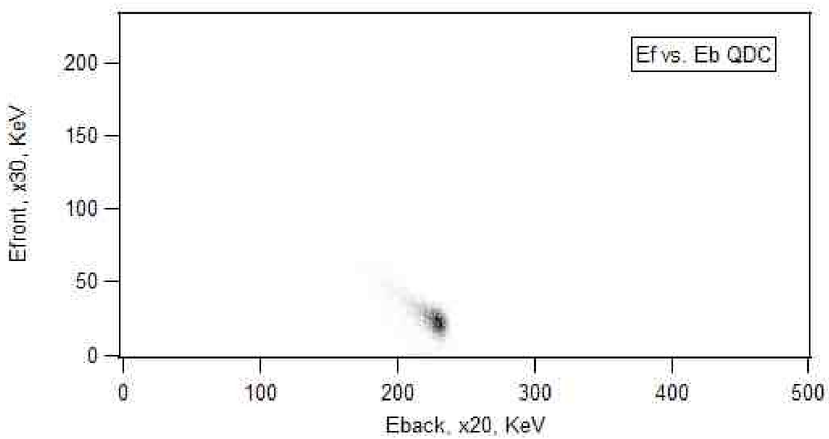


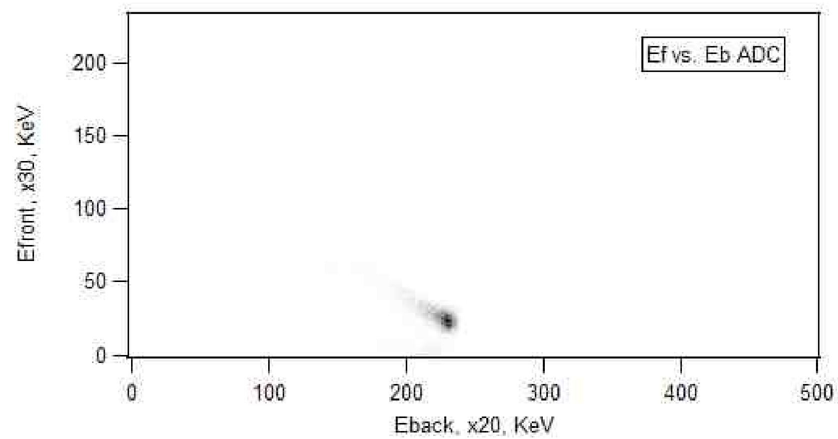


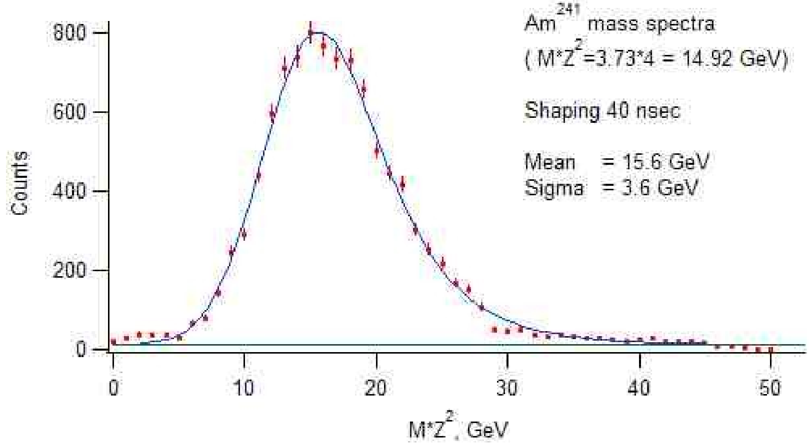




dE|E – Alpha Mass







$$M * Z^2 = m_p * \left[\frac{\alpha}{d_F} * \left| \left(T_F + T_B\right)^{\beta} - T_B^{\ \beta} \right| \right]^{\frac{1}{(\beta - 1)}}$$

m_p - *proton mass* = 938.27 *MeV*

$\alpha = 13.3$

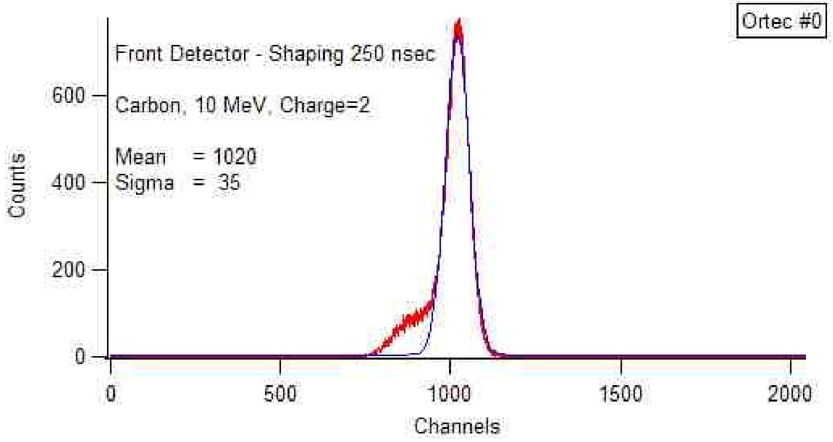
$\beta = 1.73$

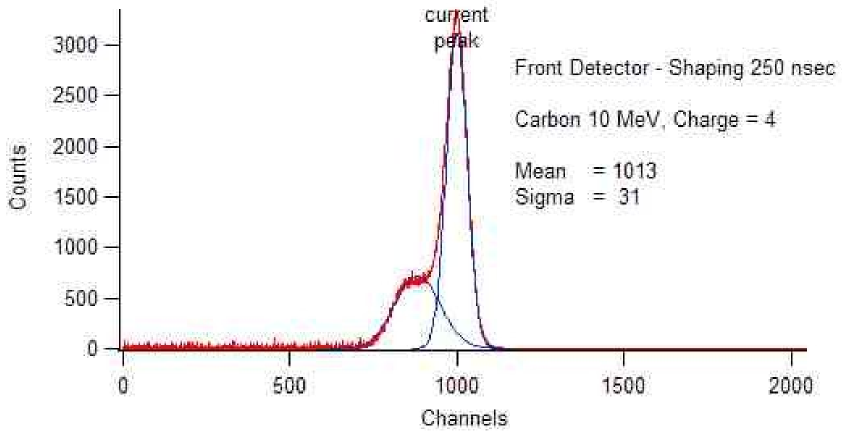
$d_F[\mu m]$ - *Front Detector Thickness*

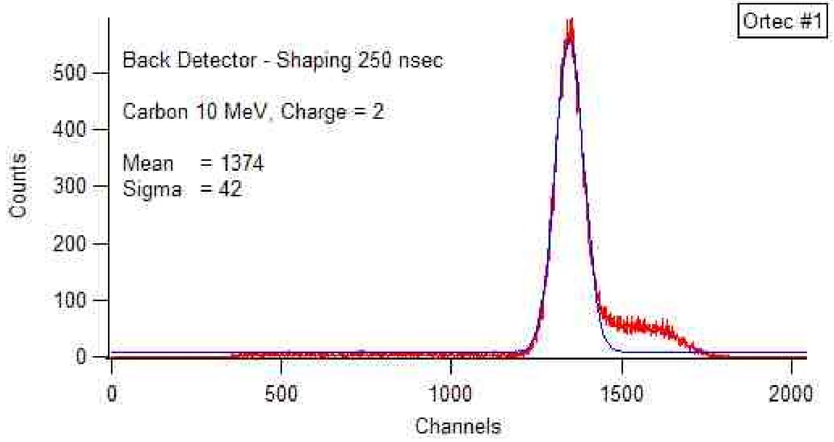
$T_F(T_B)$ - *Front(Back) energy in MeV*

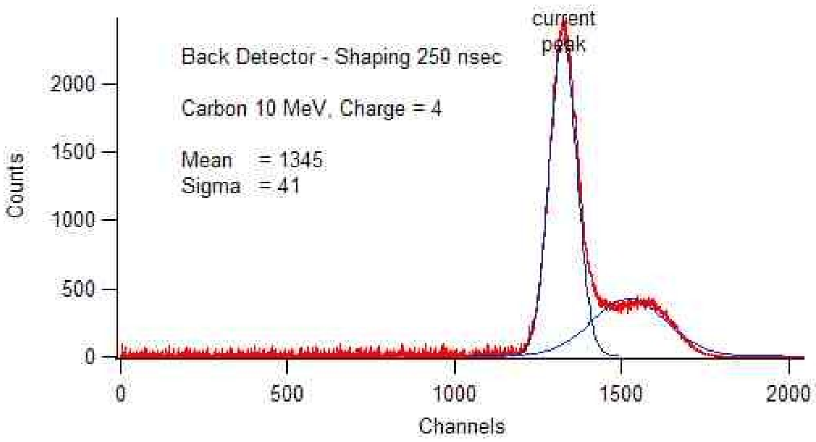
Carbon 10 MeV charge 2 and 4 (dE|E (Front|Back) Configuration)

dE (Front, ~5um) detector response
E (Back, 300um) detector response
Iris diameter 6 mm



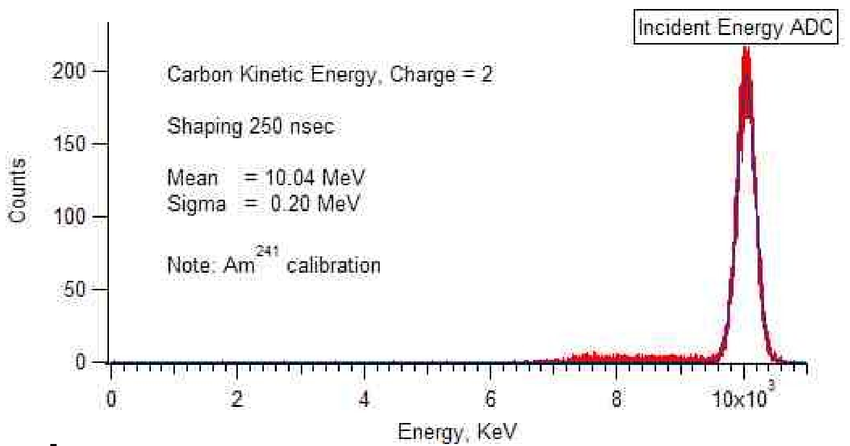


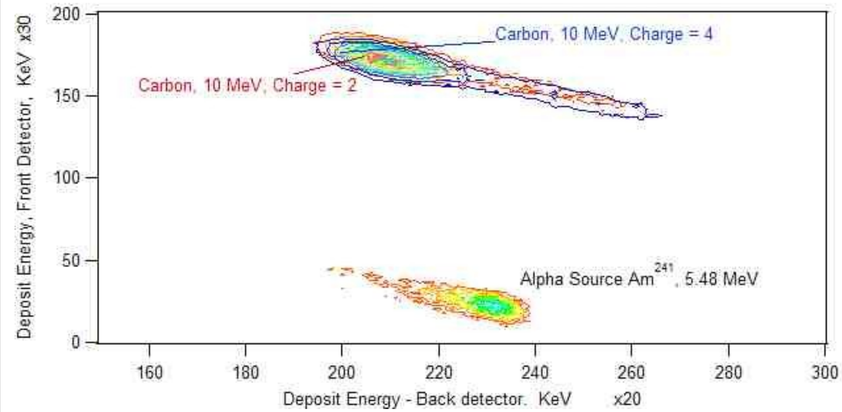


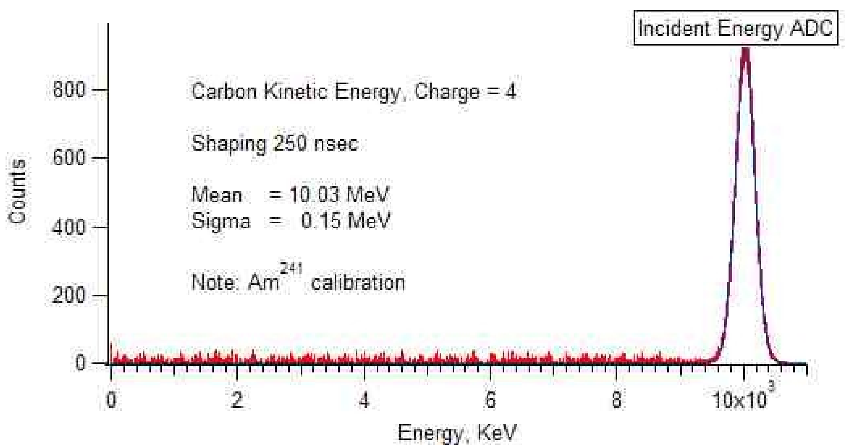


10 MeV Carbon dE|E setup

($T_F + T_B$), T_F vs. T_B energy spectra







- *Incident Carbon energy obtained by Alpha calibration matches well with TANDEM beam.*
- *no dependence was seen from the initial beam charge.*

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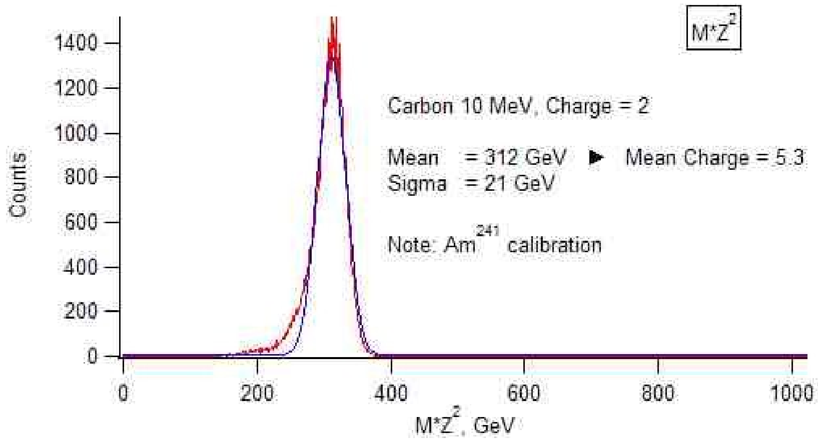
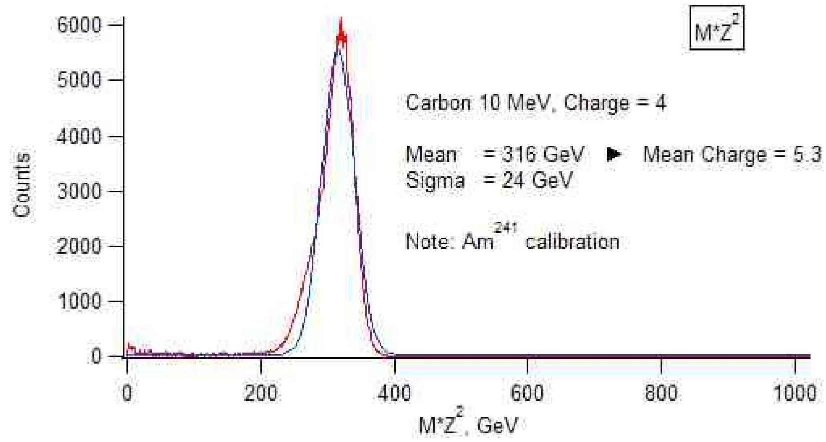
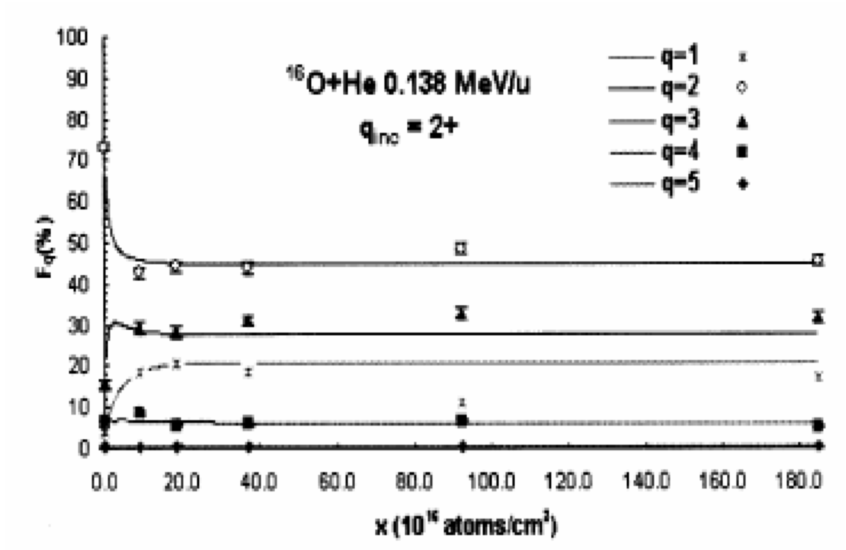
10 MeV Carbon beam dE|E setup M*Z² spectra



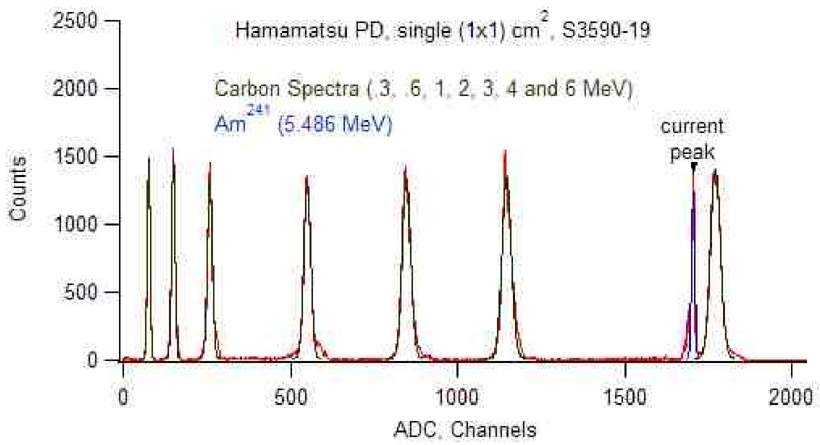


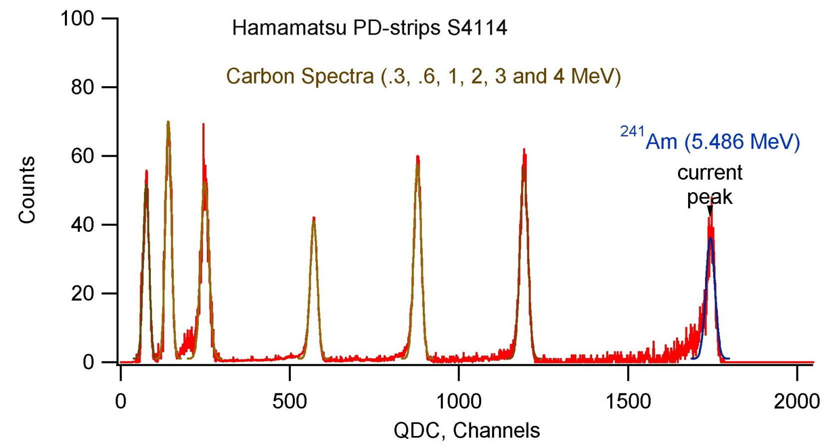


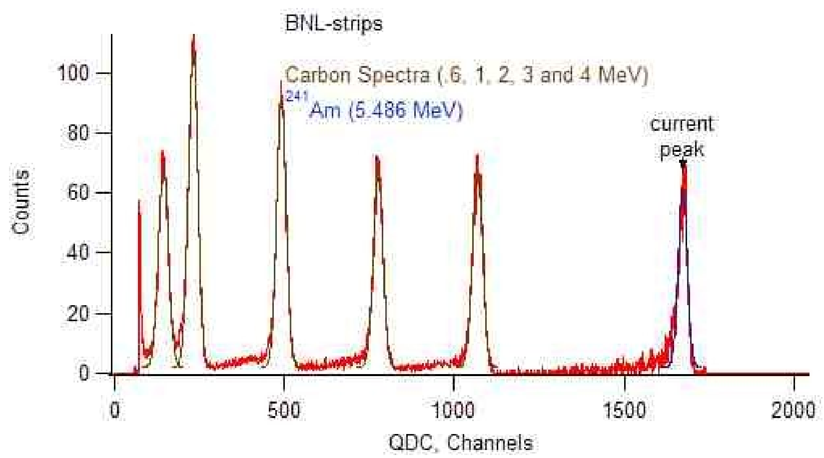
- *Mean charge is the same for both initial Carbon Beams.*
- *There are some indications that charge distr. has lower tail, but our resolution does not allow to give quantative estimation.*
- *There are no reasons to assume that equilibrium charge state for the 10 MeV Carbon does not have place.*

Carbon Calibration
Carbon 0.3, 0.6, 1.0, 2.0, 3.0, 4.0, and 6.0 MeV

Single Hamamtsu PD, 300um response
Hamamatsu array PD response
BNL array response

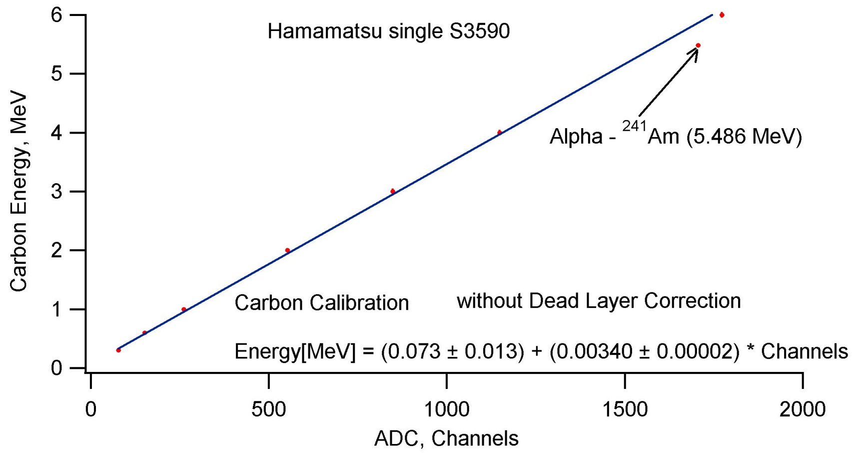


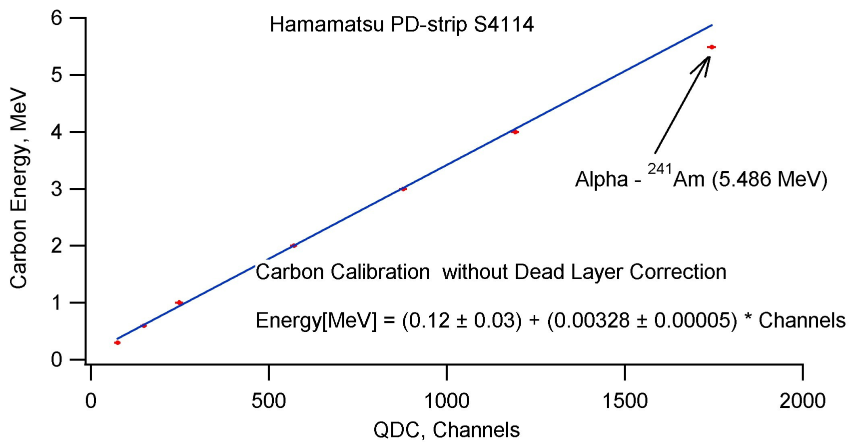


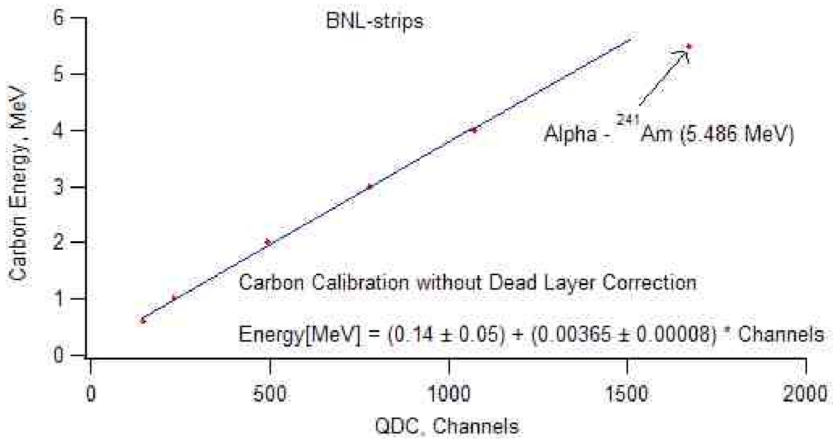


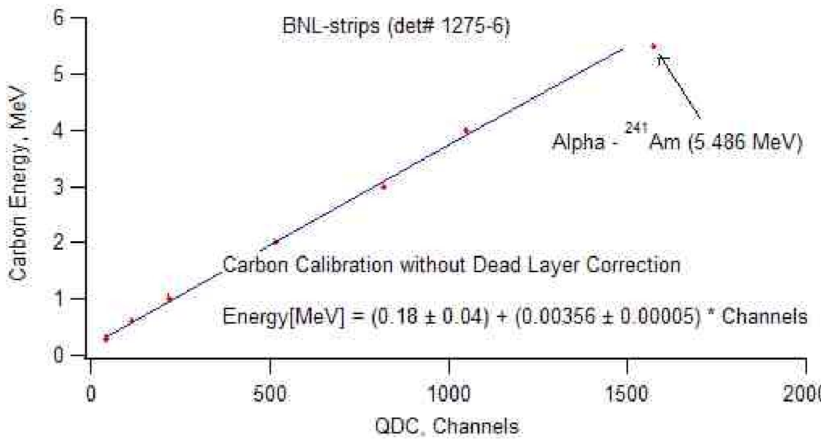
- *- best response is given by the Ham. single*
- *- Hamamatsu strips & BNL strips are similar except for the BNL-strips of 0.3 MeV which are out of the range (dead layer ?)*

Carbon Calibration
without dead layer correction





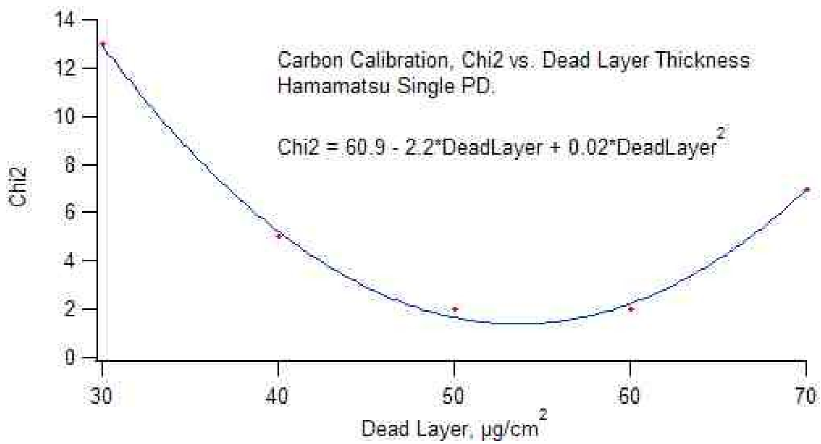


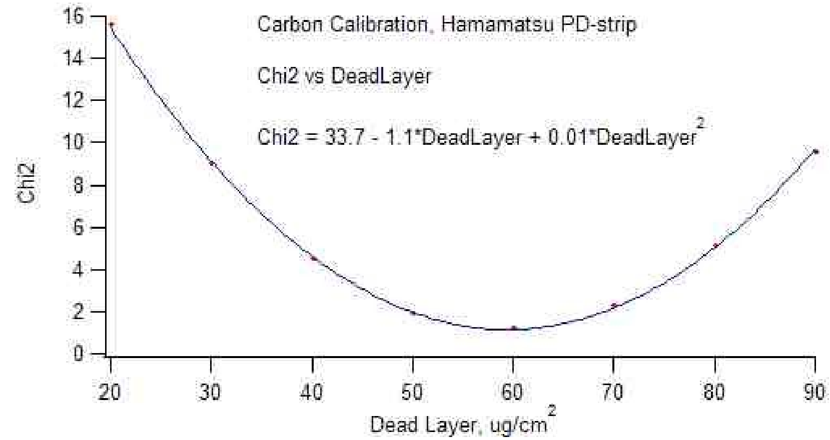


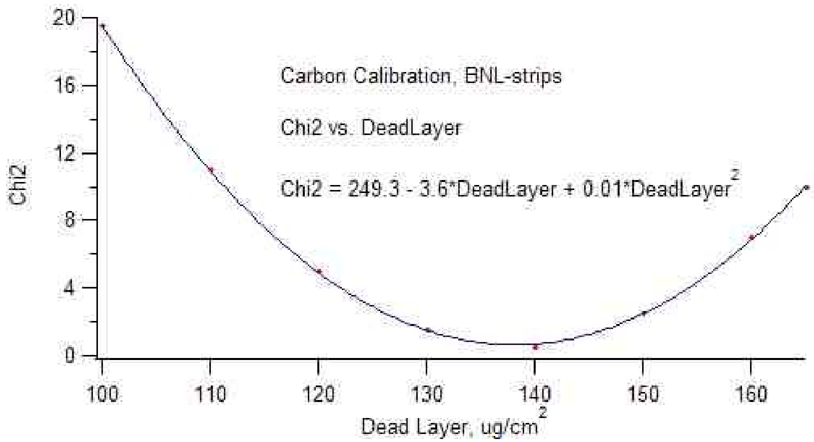
Carbon Calibration

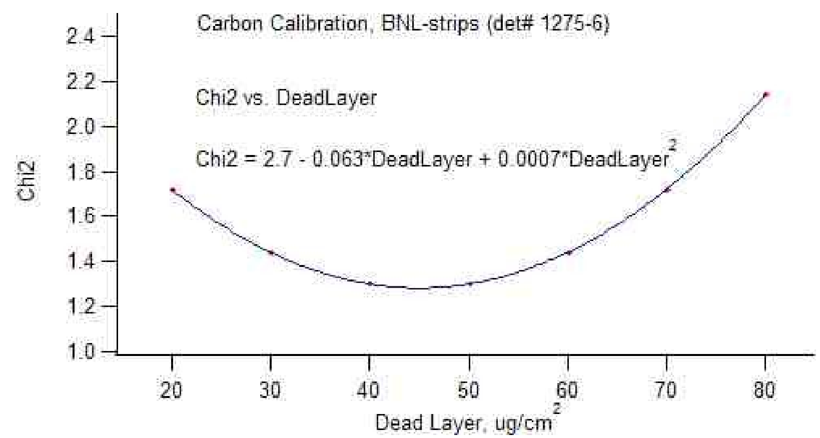
Dead Layer Estimation

Method: Use of deposit energy for Carbon initial beams and Alphas from ^{241}Am source.
Search minimum Ch2 from the linear fits with the application of stopping power for different dead layer thicknesses.





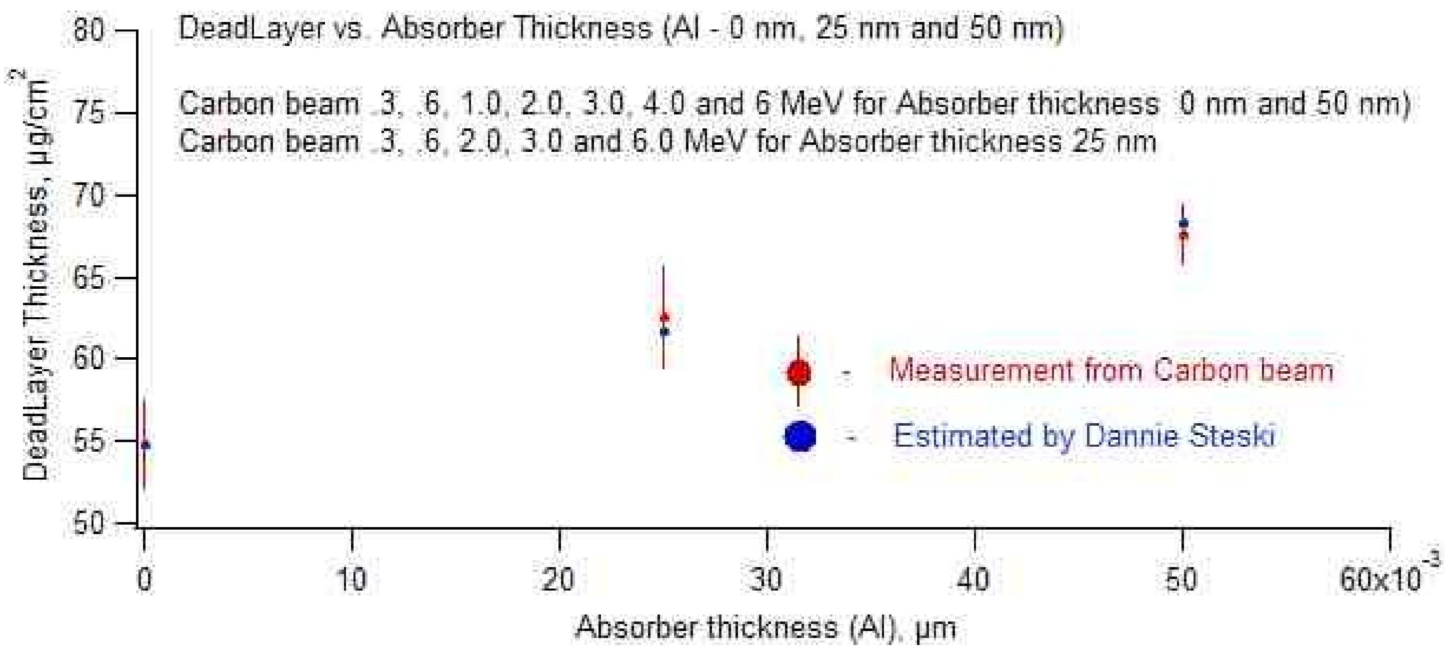




Carbon Calibration

Dead Layer estimation method: verification

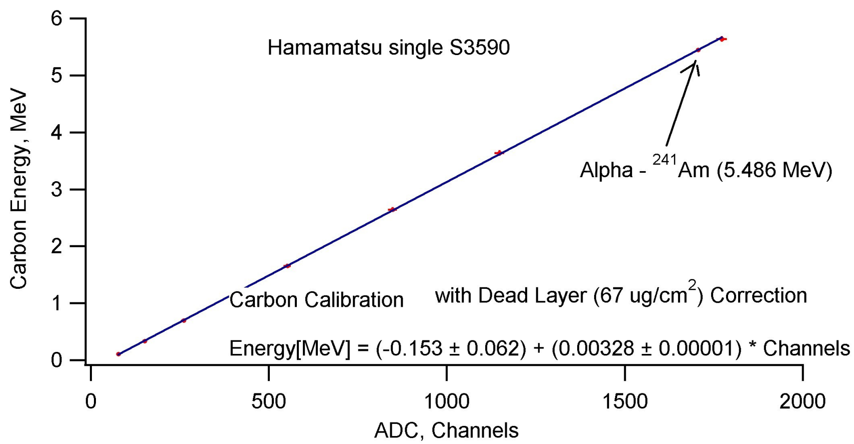
- evaporation of 20nm and 50nm AL on Hamamatsu Single detector;
- estimation of the dead layers.

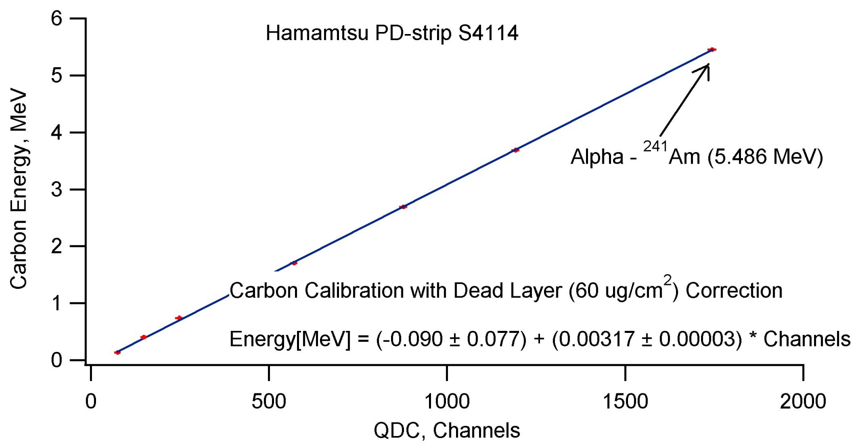


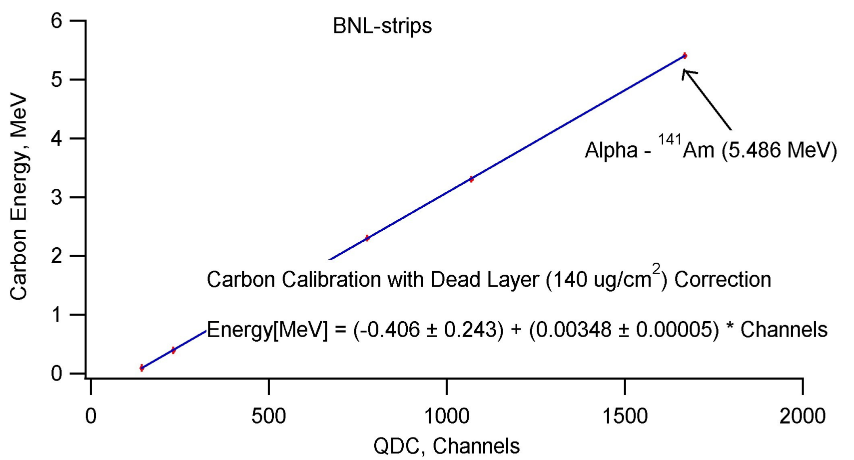
Carbon Calibration.

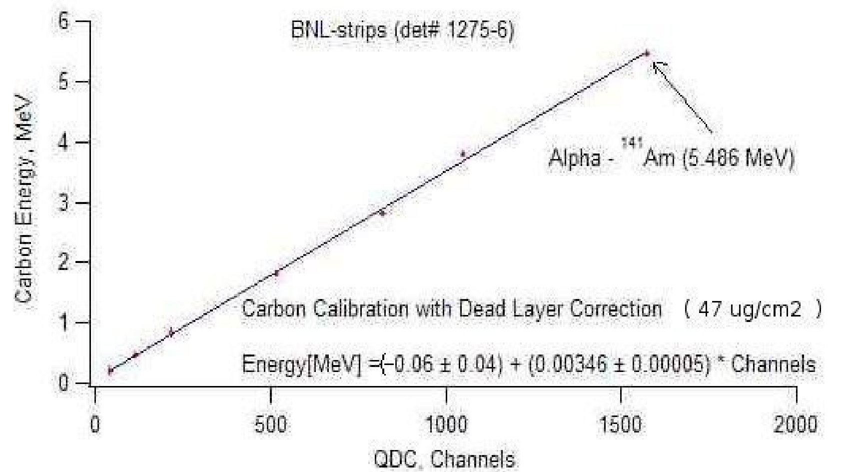
With dead layer correction

Resume: after applying dead layer correction one can use the Alpha calibration and linear dependence on the energy.





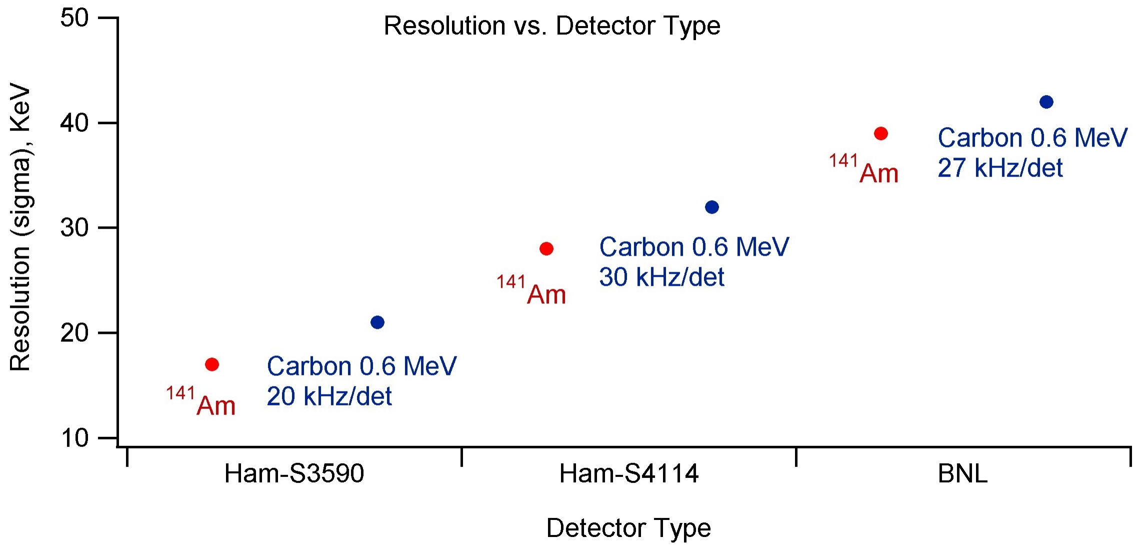




Carbon 0.6 MeV

Resolution

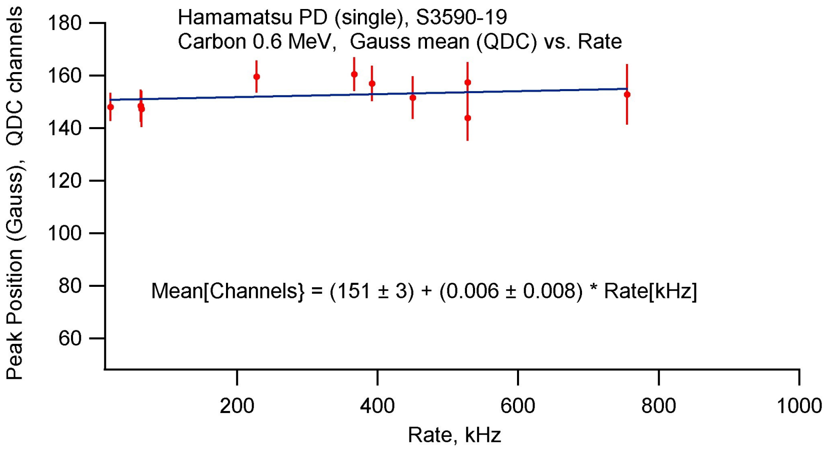
Iris Ø6mm, Carbon Beam 0.6 MeV

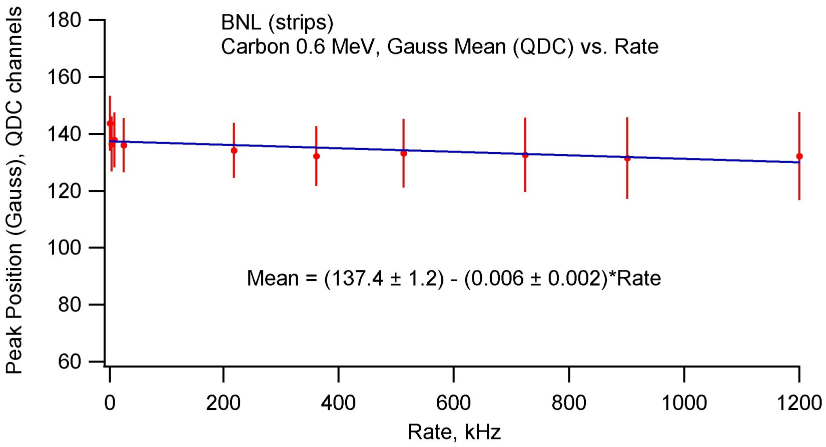


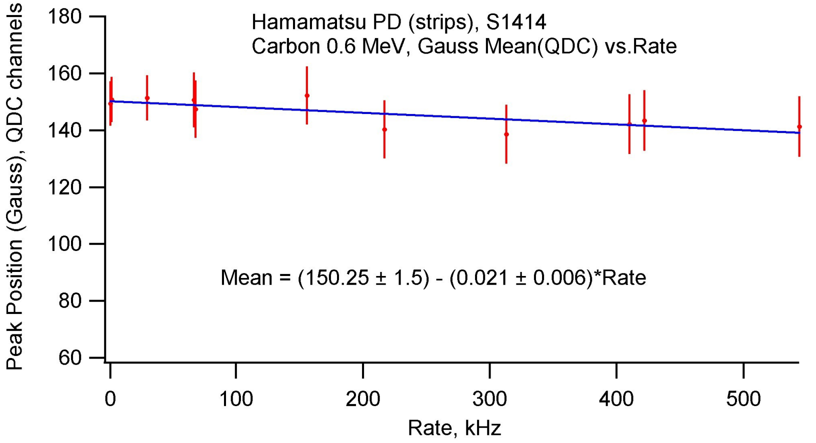
The Hamamatsu-single (S3590) has best resolution (as was expected).

Note: since the Hamamatsu-strips (S4114) had thickness about 10 times less than BNL-strips, we expected that Hamamatsu-strips should have worse resolution than BNL, but it seems not the case.

Carbon 0.6 MeV
Peak Rate dependence

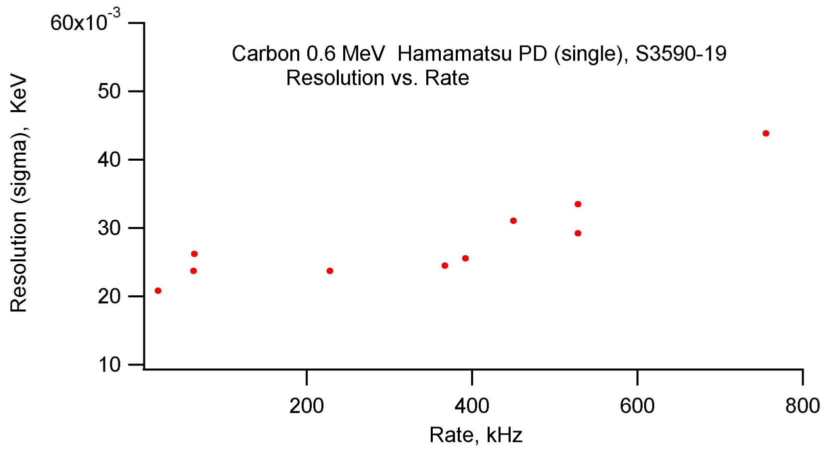


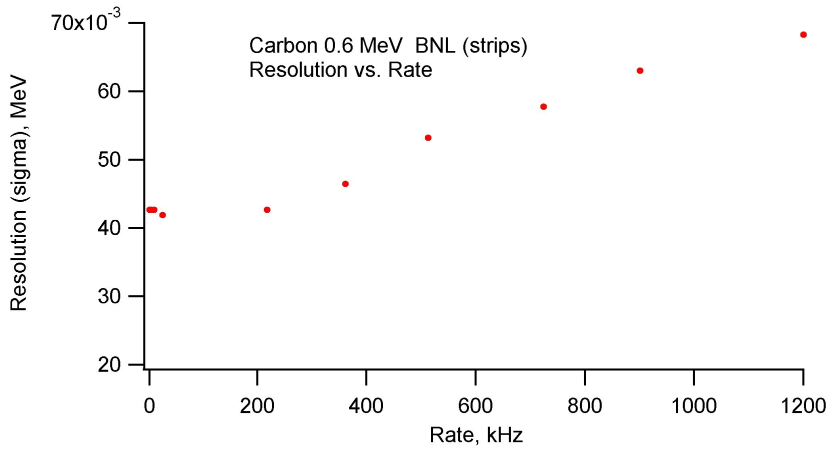


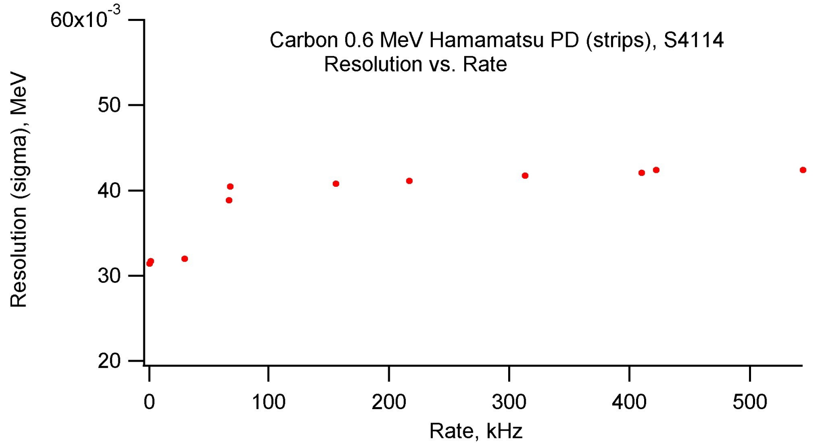


Iris Ø6mm
- weak rate dependence

Carbon 0.6 MeV
Resolution vs Rate



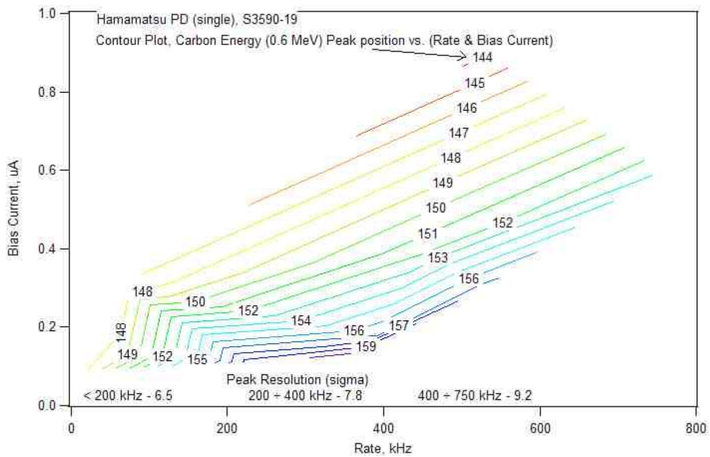


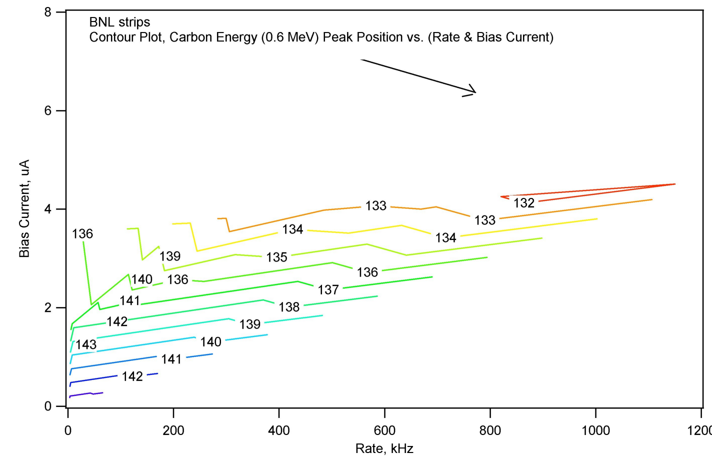


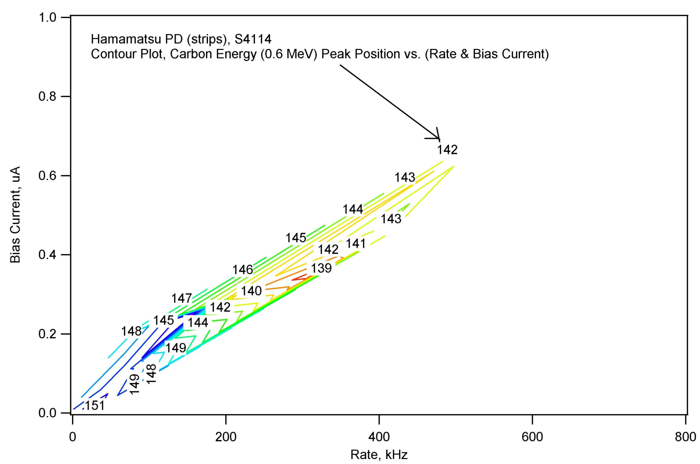
- There is weak dependence for Hamamtsu detector for the rates up to ~500 kHz
- BNL detectors show linear dependence (~0.02*Rate[kHz])

Carbon 0.6 MeV

Amplitude vs. Rate/BiasCurrent





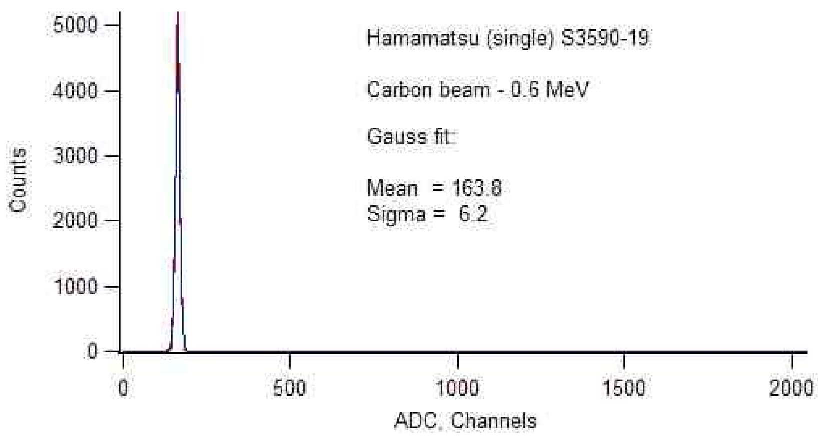


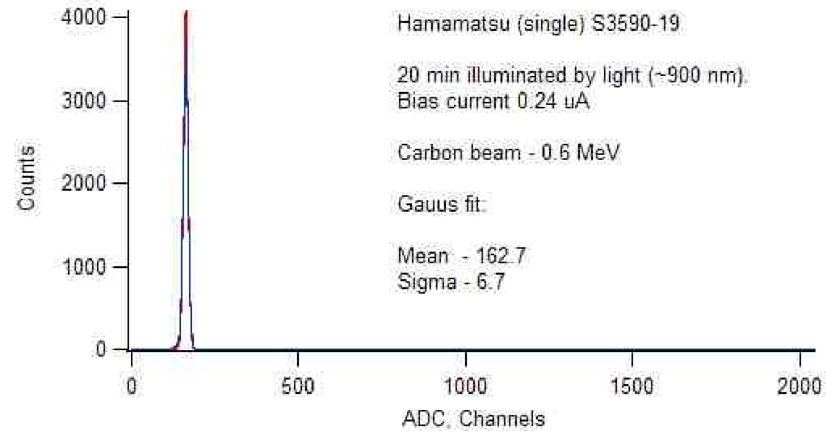
- *Iris – ø6mm*
- *Shaping: 40nsec for S3590*
  65nsec for S4114&BNL

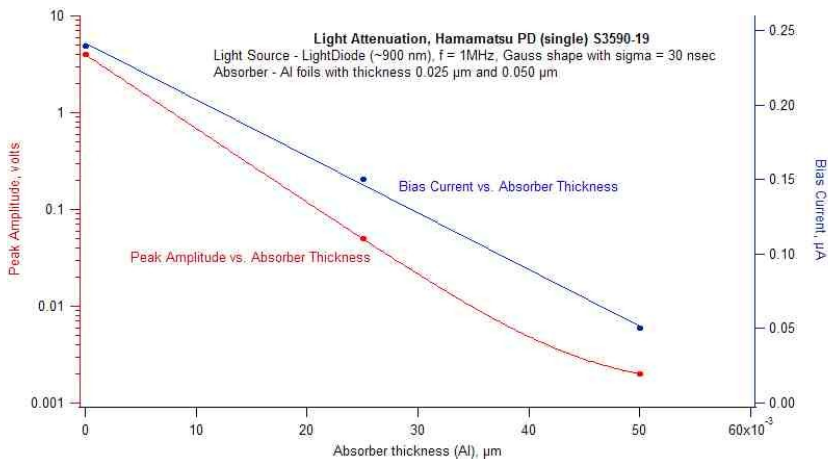
On the whole, performance is surprisingly good even at the high bias current

S3590 (Hamamatsu-single) shows the best.

Light sensitivity
Single Hamamatsu PD, 300um

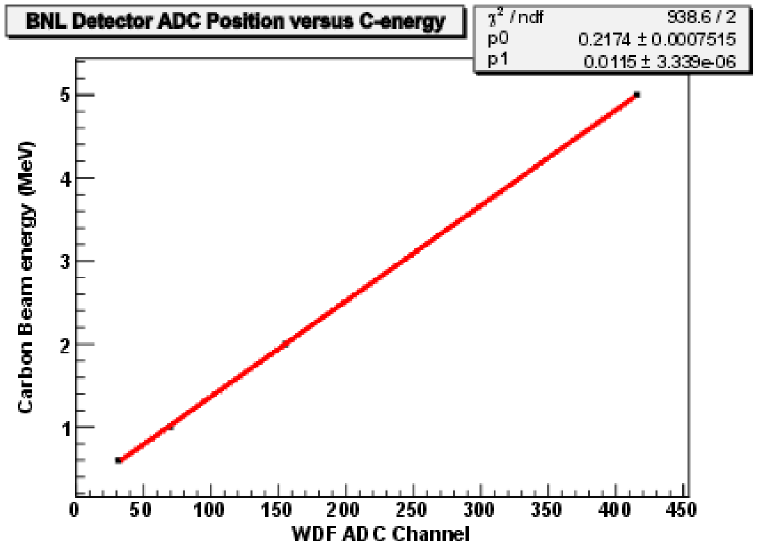


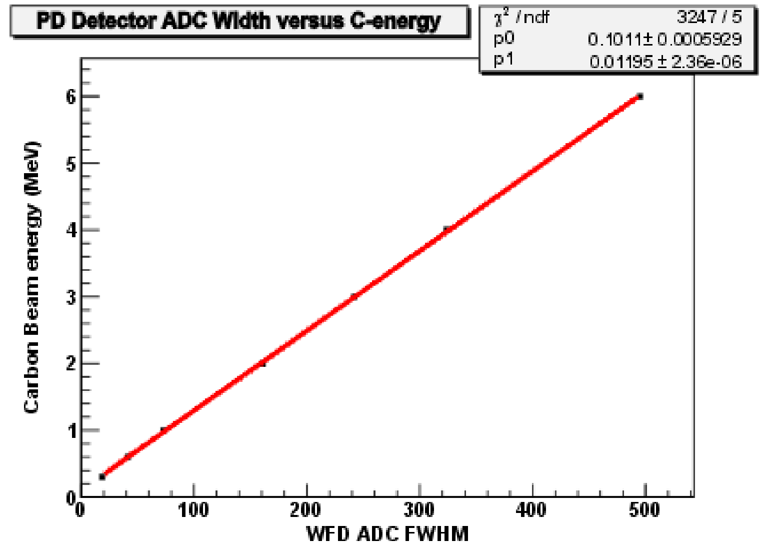


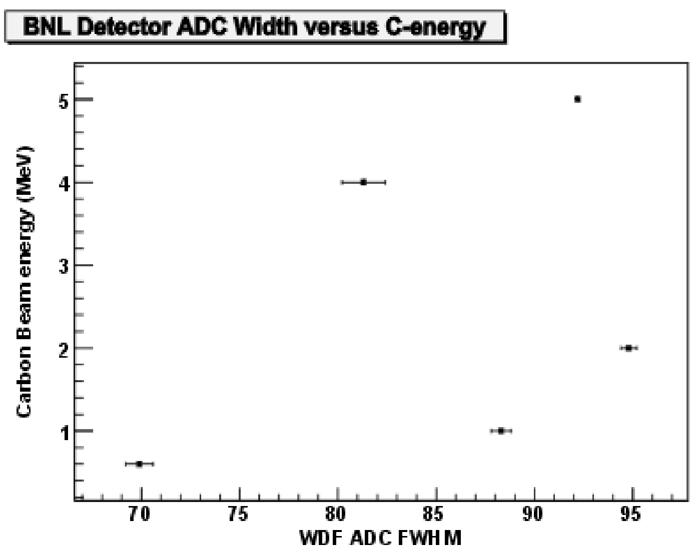


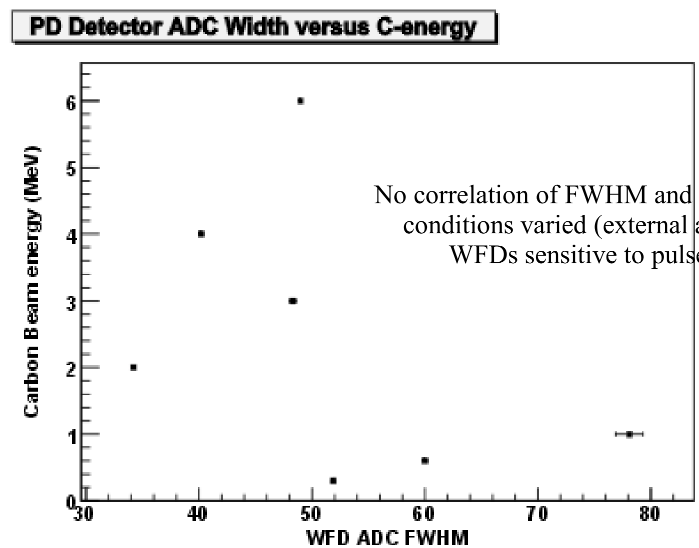
- There is no degradation on the Carbon spectra after illumination.
- The ~ 900nm Light Peak amplitude about three orders lower with the 50nm Al absorber.

BNL and Photodiode using the WFD-based DAQ



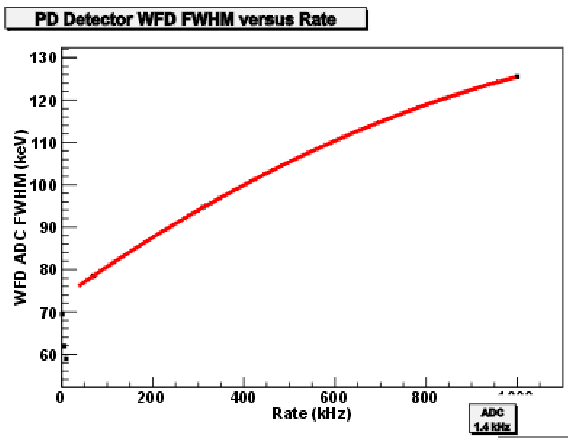




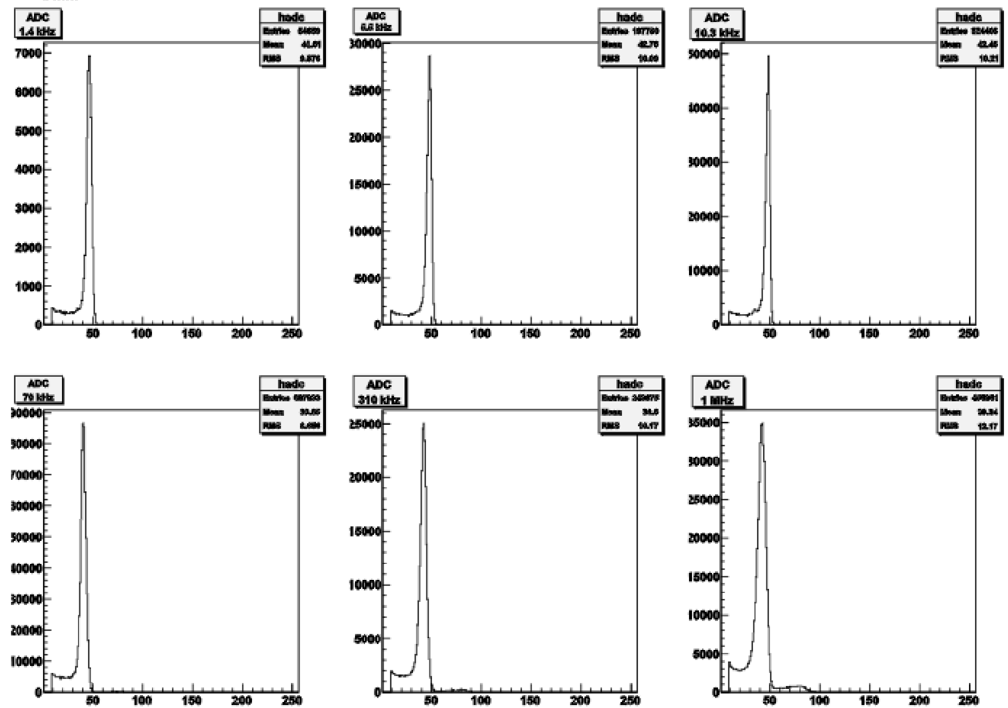


No correlation of FWHM and C-energy. But conditions varied (external attenuators) WFDs sensitive to pulse shape

WFD DAQ



WFD DAQ (ADC mode) gives a similar performance as "conventional" DAQ. In fact, it matches well with the "conventional" DAQ concerning Carbon response (Amplitude & resolution) at the low rate. At the high rate WFD DAQ shows the same behavior for Amplitude response, but it gives about twice worse resolution compared to the "conventional" DAQ.



Conclusion

- Equilibrium charge state

The value of Carbon Mean Charge is independent on the initial Carbon charge at 10MeV. The equilibrium charge state is reached faster for the solid media compare with gaseous material when Carbon ions penetrate the media. As it was pointed out by Peter Thieberger, there is no ground to believe that we are working in non equilibrium charge state at the Carbon energy range (0.1 – 4 MeV) and ≥20 ug/cm^2 dead layer thicknesses. Practically, it means that it is safe enough to use stopping power values, provided for example by Zeigler (or ESTAR, SRIM-2003), which take into account the mean charge of the Caron ions.

- Thin detector performance

Since the Carbon range in Si at our energies less than 5μm, it is possible to use such very thin detector in the CNI setup. It will minimize response for fast prompt particles ("prompt free" detector). Unfortunately, our result shows bad resolution (~185 KeV for Alpha). To improve the resolution the additional studies (e.g. instead of Charge sensitive Preamps use Current Preamps) are required. Also, we got some "bad" news from Hamamatsu: this device is out of production. So, consideration of using the ultra thin detector is unpractical, at least for now.

Conclusion

Detectors + Preamps/Shaper performance

Three detectors had been tested:

1. Hamamatsu (single) S3590

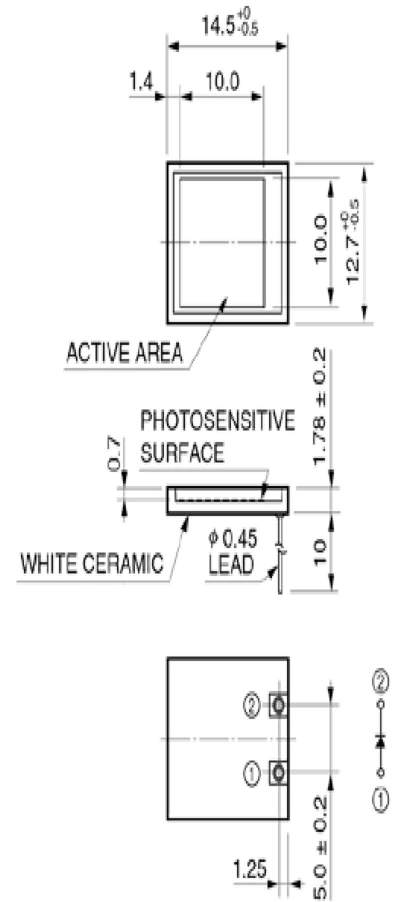
this detector gives best performance in term of:

- good resolution (17 KeV for Alphas, 21 KeV for 0.6 MeV Carbon);
- inverse bias current versus rate (~0.02μA at "zero" rate, ~0.7μA at 755 kHz);
- Carbon response versus rate (~4% amplitude shift at 0-755 kHz rate range);
- Carbon resolution versus rate (~20 KeV at "zero" rate, 44 KeV at 755 kHz). Can be use for Carbon detection for energy as low as ~150 KeV!!!;
- easy way to make light shield;
- robustness (ten years old device gives almost the same performance that the new one);
- modern cost (~$220 per detector).

Some improvements for our needs can be done by Hamamatsu:

- to decrease Si thickness from 300μm to 100μm;
- to decrease Dead Layer (from 55 μm to ~30 μg/cm^2 without removing the passivation layer;
- mounting it to "window" ceramic base.

Unfortunately, it is impossible to decrease sensitive area without changing mask.



Conclusion
Detectors + Preamps/Shaper performance

2. Hamamatsu (strips) S4114

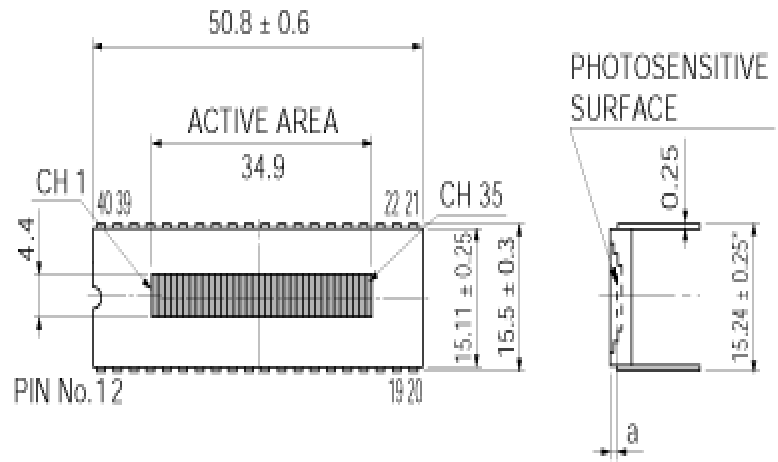
This 35 strip device has more complicated structure than another, but… it has the lowest cost (~$140 per detector).

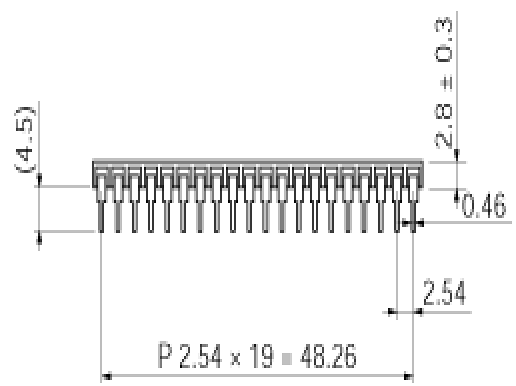
Although it gives almost twice worse performance (except for amplitude versus rate) than S3590, there are the main two advantages of use them into CNI setup:

- it has ~30 μm depletion layer thickness (compared to 300 μm) that will minimize the prompt response;
- it has small effective strip area (3.96 mm^2) that can be useful for the high rate application.

In our setup we grouped three strips together.

Unfortunately, nothing can be improved straightforward about Hamamatsu. So, we have to use them like they are.





Type No.	a
S4111-35Q	1.45
S4114-35Q	1.35

Conclusion

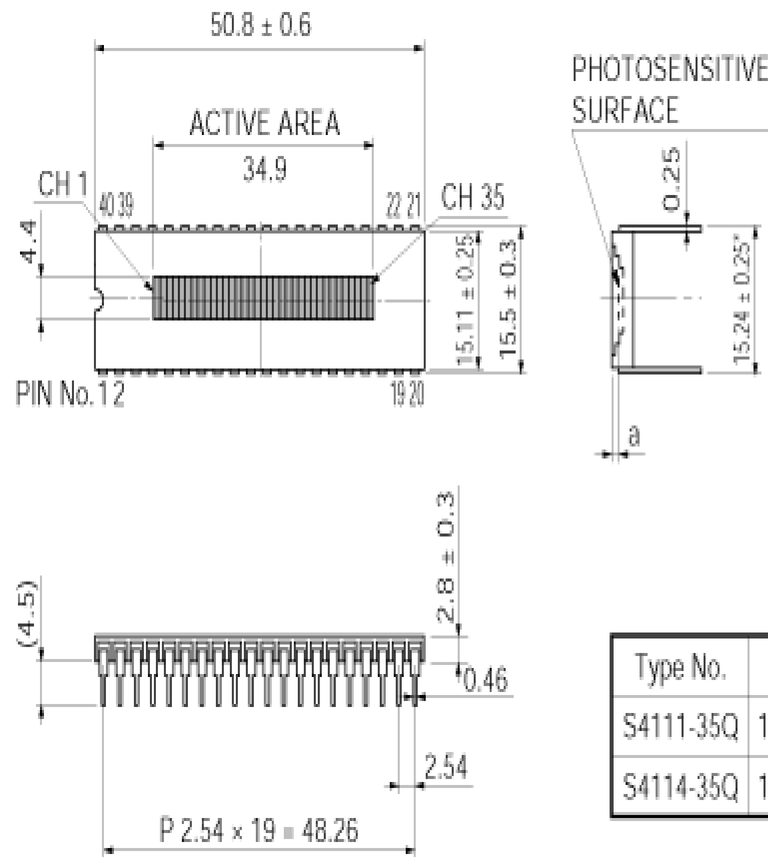
Detectors + Preamps/Shaper performance

3. BNL strip detector

This12 (10 x 2) mm strip device was manufactured by the Instrumentation Division. Compared to Hamamtsu detectors this detector does not have a passivation layer. It has 300 µm thickness (the same as S3590).
We tested detector that is made for 2009 run.
In fact, we use first detector which was mounted to the new ceramic board.

The main difference of the 2009 detector to previous years Is that it had the high 40kV implantation voltage. Compare Of the old BNL detector to the present one gives the twice low slope bias current vs.rate.
There are no Alpha and Carbon spectra degradation at ~3µA bias current like it was for the old one.
It has about twice better resolution for Alpha as well as for Carbon. Although the Carbon response is worse that for the Hamamatsu detectors, the main performances (resolution and rate) are compatible with S4114.
One of the main surprise is that we've got the high Dead Layer thickness (~138µg/cm²). The value was about 1.6 times higher as predicted. In fact, we were not able to detect the 0.3 MeV Carbon due to this.
This is a subject for further investigation.
Possible future improvements:

- decrease thickness to 100µm;
- make ~5nm AL "safe" layer (needs mask modification)

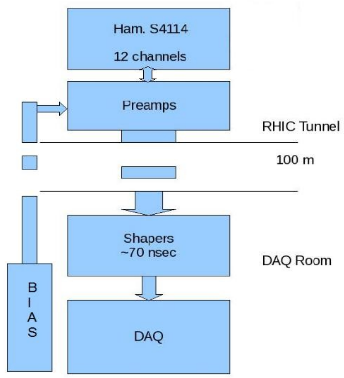


Type No.	a
S4111-35Q	1.45
S4114-35Q	1.35

2009 setup

To test PD detectors (S3590&S4114) at "real" condition. It would be good to include these detectors in the present polarimeter setup:

1. Blue ports:
- equip the two ports with the Hamamatsu-strip (S4114) PD detectors;
- use 12 channels configuration (the same as in Tandem setup): 4.4x2.9mm = 12.76 mm^2 - st **2009 setup** rip effect area is about twice less than for the BNL-strips;
- use the same front-end as for the BNL strip detectors (~70nsec Shaper).



2. Yellow ports:
- equip the two ports with light shielded (50nm Al) Hamamatsu-single (S3590) PD detectors;
- use 2 channels configuration for each port;
- use 8x4mm collimator for each detector (32mm^2 effective area is 1.45 times more than for BNL-strips);
- connect detector to the new ChargePreamps &40nsec Shapers with the 0.5m low-capacitance coax cables.

The signals from these 4 ports are to be connected to the present DAQ (based on the WFD digitizer). The reverse voltage for these detectors is provided by separate Bias power supply.