HDice Technical note TN23
Empty cell subtractions for g14

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Abstract

Empty target data taken during g14 with cell 21a can be used to subtract the contributions from the Aluminum wires and the Kel-F beam entrance and exit windows. Such subtractions must be flux normalized. In addition, different cells have different amounts of Aluminum in the form of cooling wires, which also need to be taken into account. The cell subtraction follows a 4 step procedure which is discussed in this note. The example of target 19b is detailed in an Appendix.

The ***Empty*** cell subtraction follows 4 steps.

I. Finding and verifying the flux normalization

The process of loading and extracting target cells, in a vertical IBC, and then rolling the IBC into CLAS (with the IBC horizontal) does not guarantee that the IBC returns always to the same position with respect to the CLAS center. As a result, there can be shifts in the z-position of the IBC between runs with different cells. We will refer to these as ***global shifts***. These can be checked by shifting the entire z-vertex reconstruction so as to align fixed features associated with the IBC, namely the Kel-F foil and the Aluminum windows. The areas of the fixed foils (-2 < Z < +30 cm) determine the scaling ratio for subtraction.

II. Verifying the thickness of Kel-F material in full and empty cells

There are also differences in the dimensions of the different cells, so that relative to fixed points within the IBC, such as the downstream foils, the target cell entrance and exit windows appear shifted. We refer to these as ***local shifts***.

III. Scale the empty yield down by the ratio of Aluminum in full and empty cells

Different cells used in g14 had different numbers of Aluminum wires and different thicknesses of wire. The net amounts of Aluminum are known and used for this correction, assuming an approximately uniform wire distribution. Scaling down the ***empty*** in this way results in an under-subtraction of Kel-F.

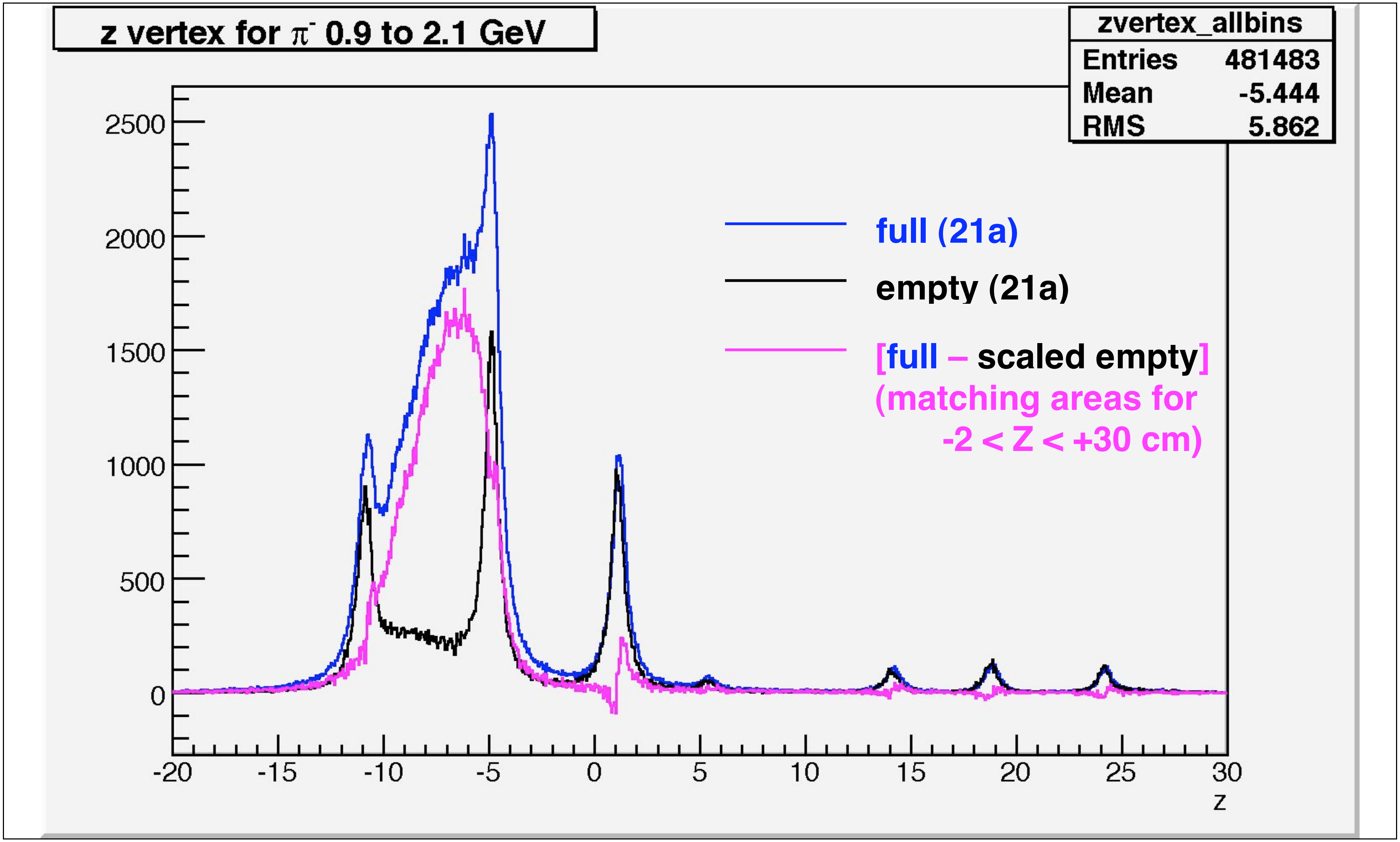
IV. Use the yield in the IBC Kel-F foil to correct for the under-subtraction of Kel-F

The reduction in the ***empty*** subtraction to match the aluminum contribution in the previous step results in an under-subtraction of the Kel-F in the target cell. This is corrected by subtracting a fraction of events from the IBC Kel-F foil (Z ~ +1 cm). This assumes a very similar detection efficiency for the target and this Kel-F foil.

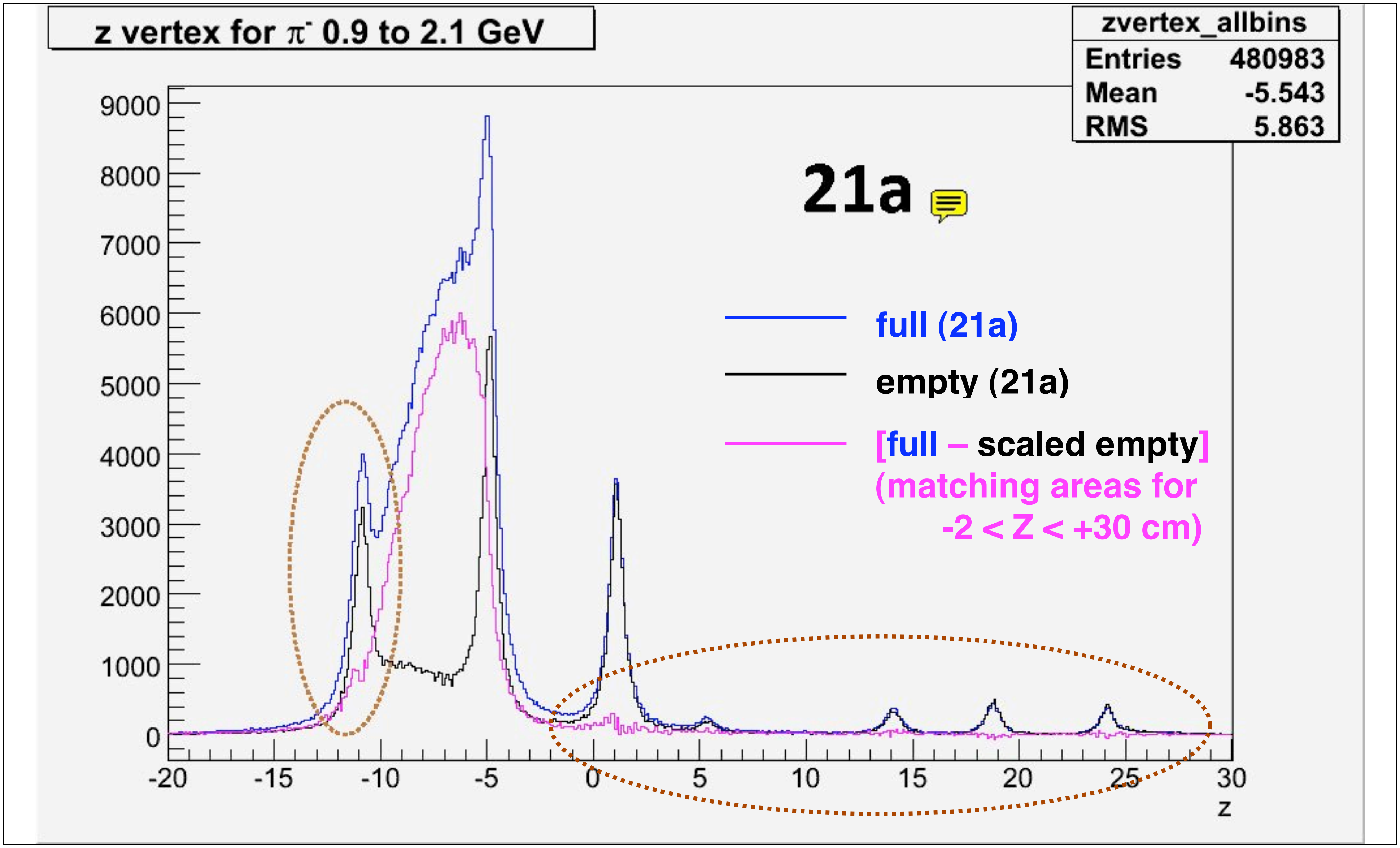
Silver (21a) target

Since empty and 21a full data used the same cell, only step (I) is needed.

- **no shifts** between full and empty.



- **Global** shift of 21a-full by +1.00 mm to the left, wrt 21a-empty.

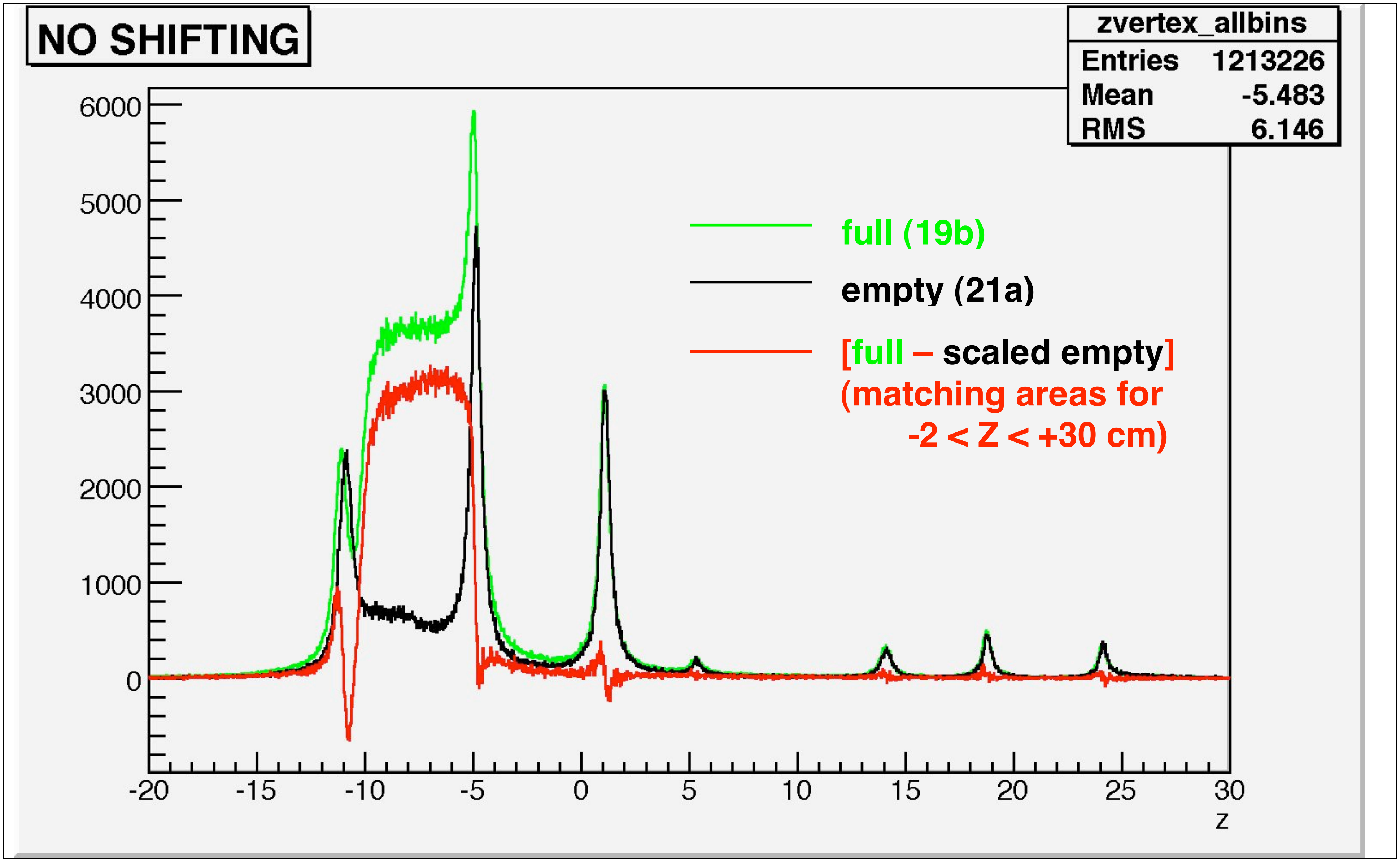


⇒ smooth subtraction

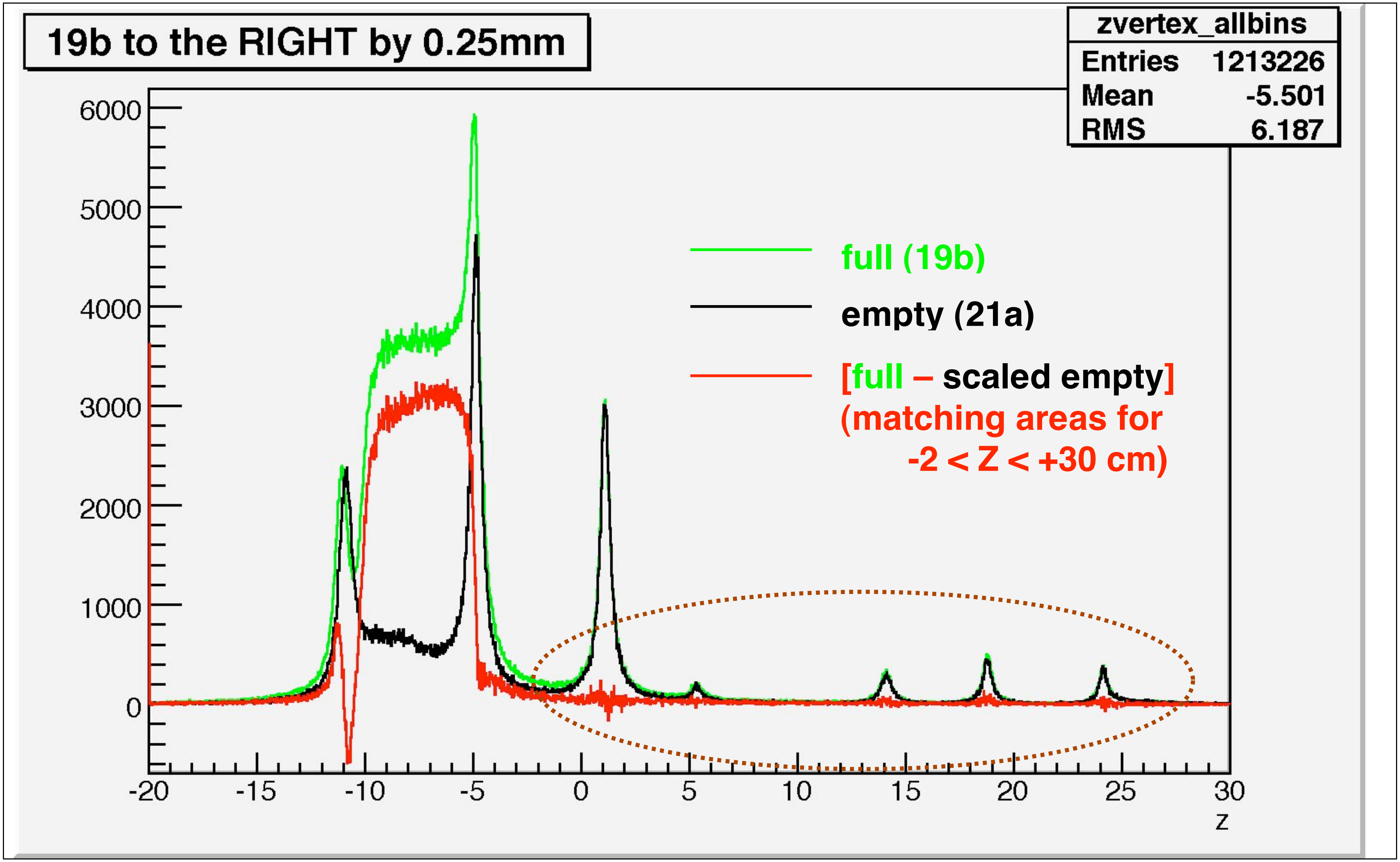
target (19b)

I. global shifts to align IBC

- initial z-vertex, before any shifts:



- global shift of 19b-full by 0.25 mm to the right (downstream) wrt 21a-empty:



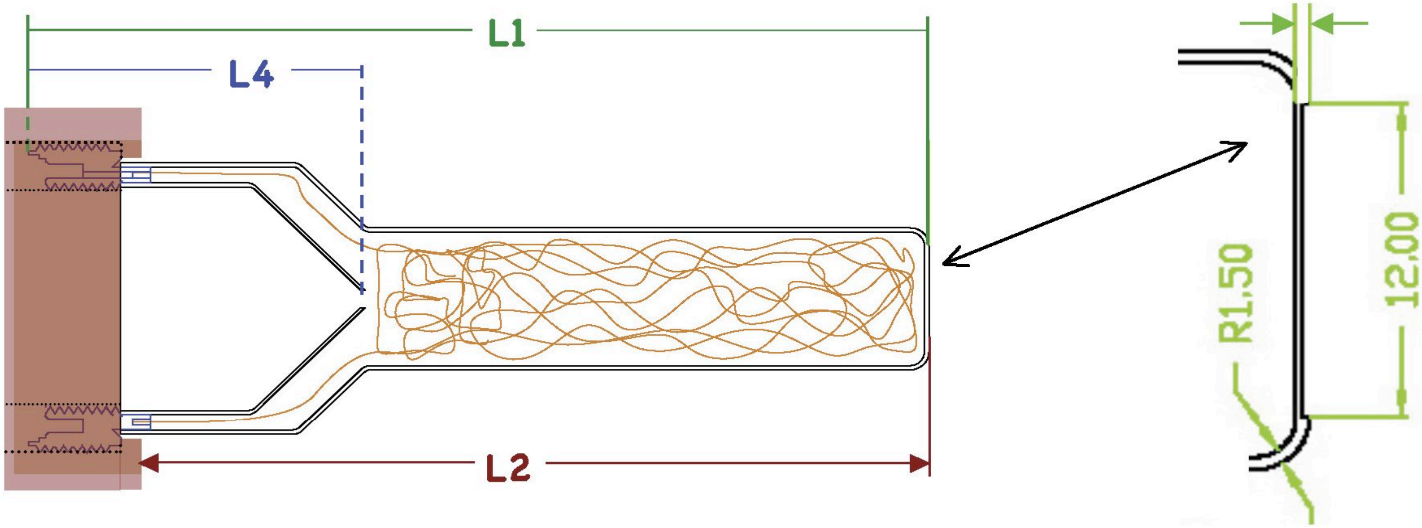
⇒ smooth subtraction of IBC foils

II. Verify Kel-F material in full and empty

This requires local shifts to compensate for differences in cell dimensions.

Lengths of target cells used in g14 (ref. tgt cell Log 2, p 86)

tgt threaded into IBC MIX :



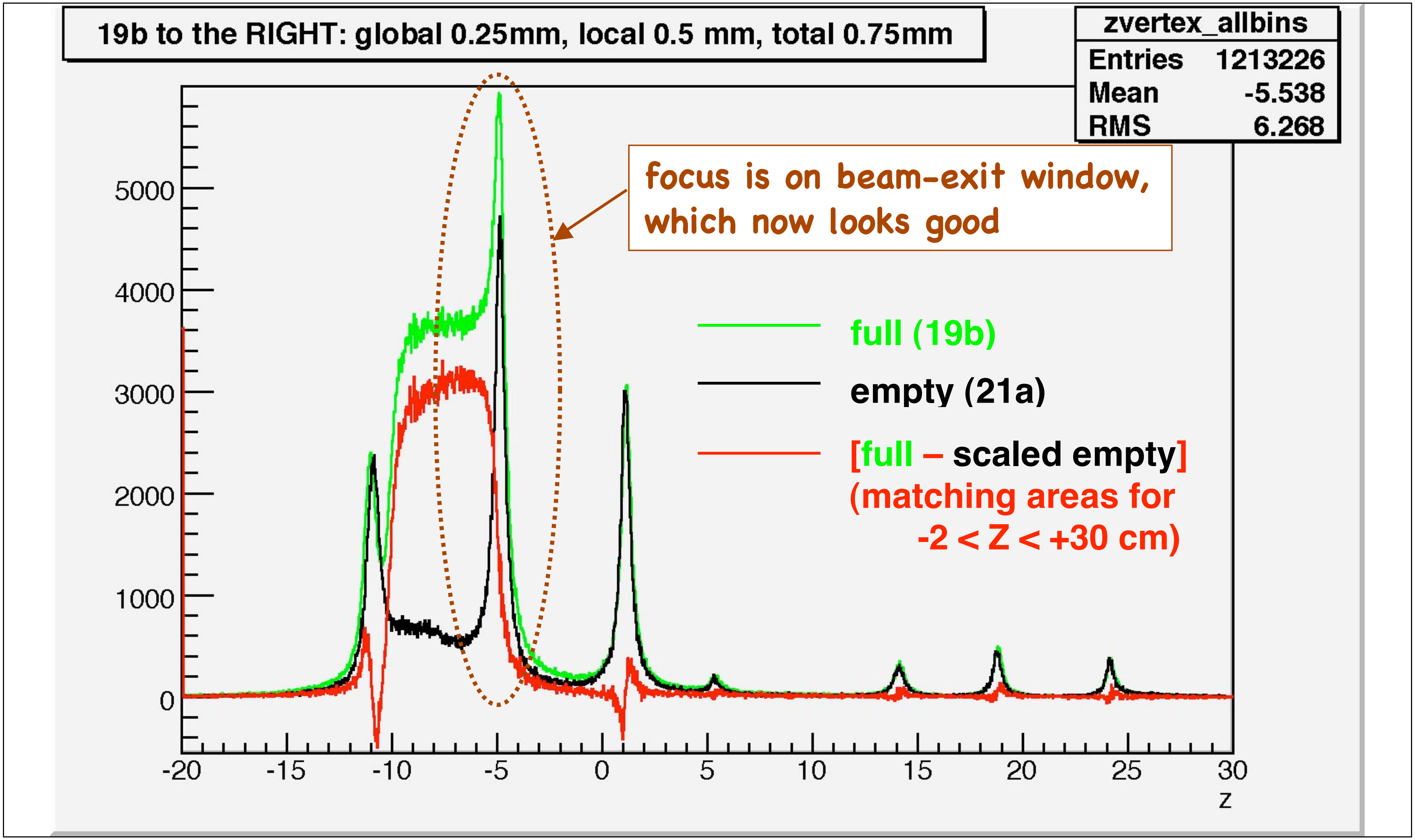
Tgt #	L1 (mm)	L2 (mm)	L3 (mm)	L4 (mm)	L2-L3 (mm)	KelF beam exit Z-offset* (mm) relative to 21a	L1-L3-L4 (mm)	KelF beam entrance Z-offset* (mm) relative to 21a
21a	96.21	82.24	0.11	36.90	82.13	0.00	59.20	0.00
19b	95.75	81.65	0.02	34.10	81.63	-0.50	61.63	-2.43
22b	95.54	81.87	0.25	35.65	81.62	-0.51	59.64	-0.44

* negative Z-offsets require a shift to the right (downstream) to align with EMPTY(21a).

target cell lengths used in g14

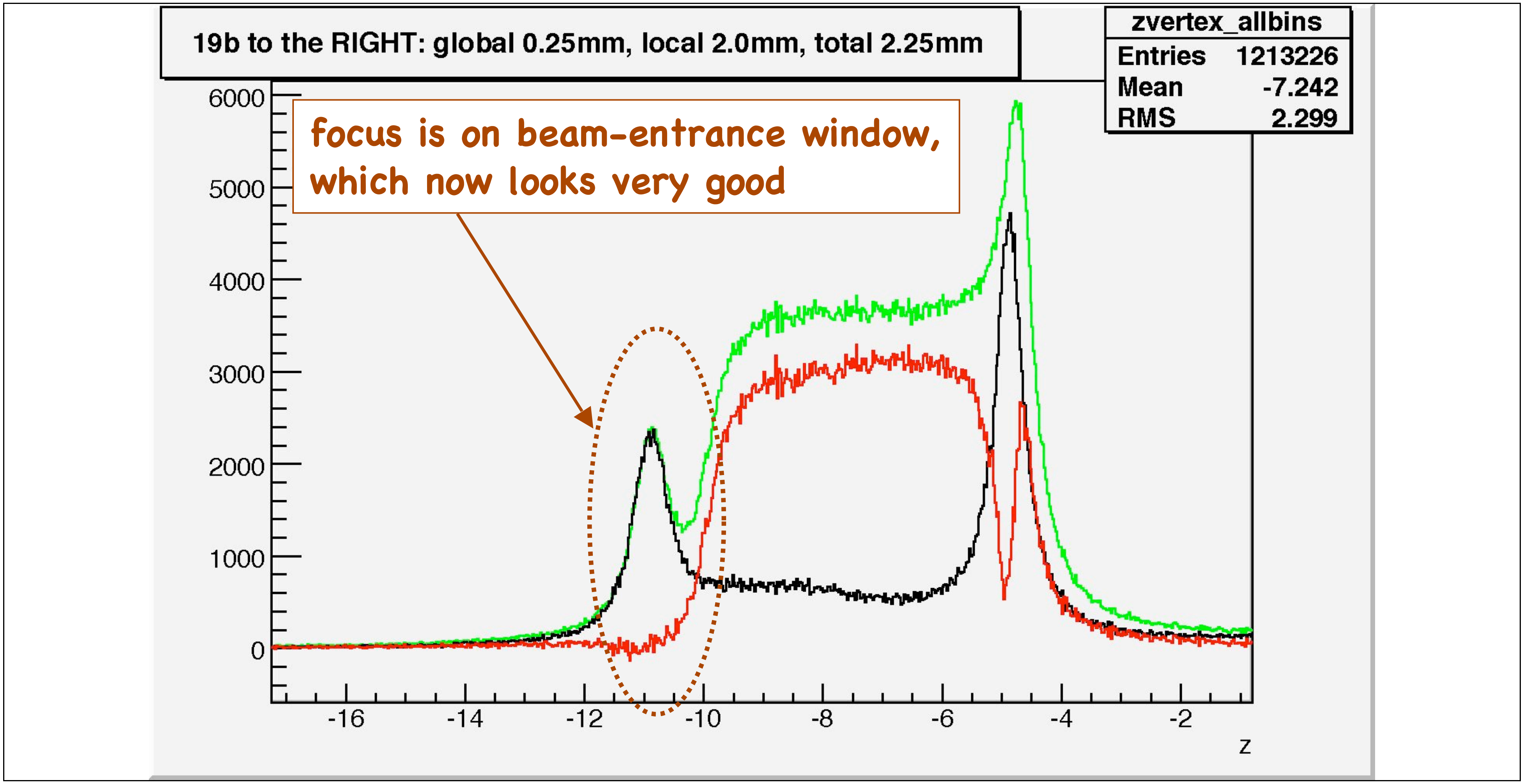
- In the above Target-cell table, the length L2-L3 is the distance from the IBC Mixing Chamber to the downstream Kel-F beam-exit window. This is longer for the empty-cell 21a than for 19b. So the 19b full spectrum must be shifted by 0.50 mm to the right (downstream) in order to compare with the empty.

- Global IBC shift + "local" 0.50 mm shift



- In the above Target-cell table, the length L1-L3-L4 is the separation between beam-entrance and beam-exit windows. Relative to empty cell 21a, the beam-entrance window of 19b is 2.4 mm further upstream. So, to align the upstream beam-entrance windows, we expect to have to shift the 19b full histogram another 2.4 mm to the right.

- Best looking shift is less. But position of conical beam-entrance Kel-F is difficult to measure:



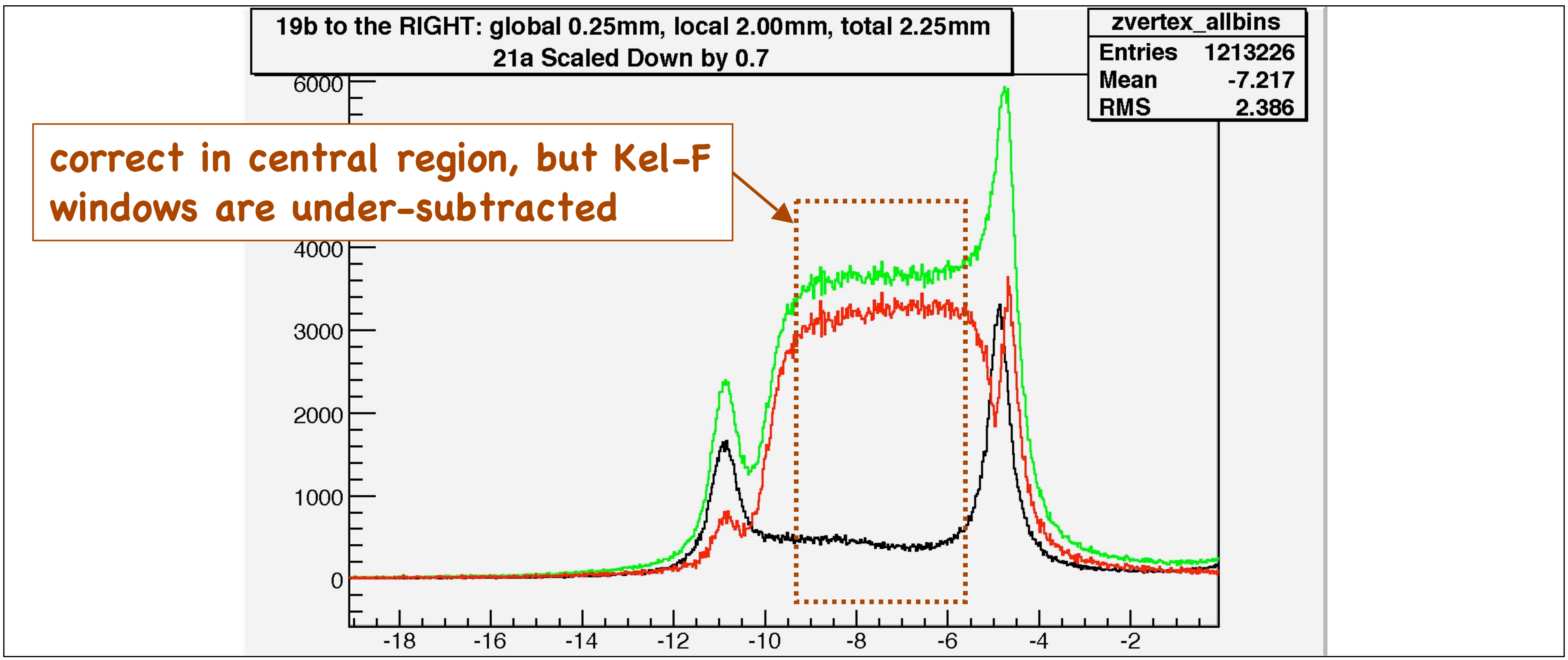
⇒ **Kel-F in 19b and 21a look the same !**

III. Scale the empty yield down by the ratio of Aluminum in full and empty cells

The amount of aluminum the the g14 cells is taken from HDice-TN22, section **A.1.1** :

Cell #	< ρ(HD) > (gm/cc)	< HD length > (cm)	< ρ(Al) > (gm/cc)	< ρ(Al) > (relative to cell 21a)
21a	0.1470	4	0.0280	1
19b	0.1470	5	0.0196	0.700
22b	0.1470	5	0.0268	0.957

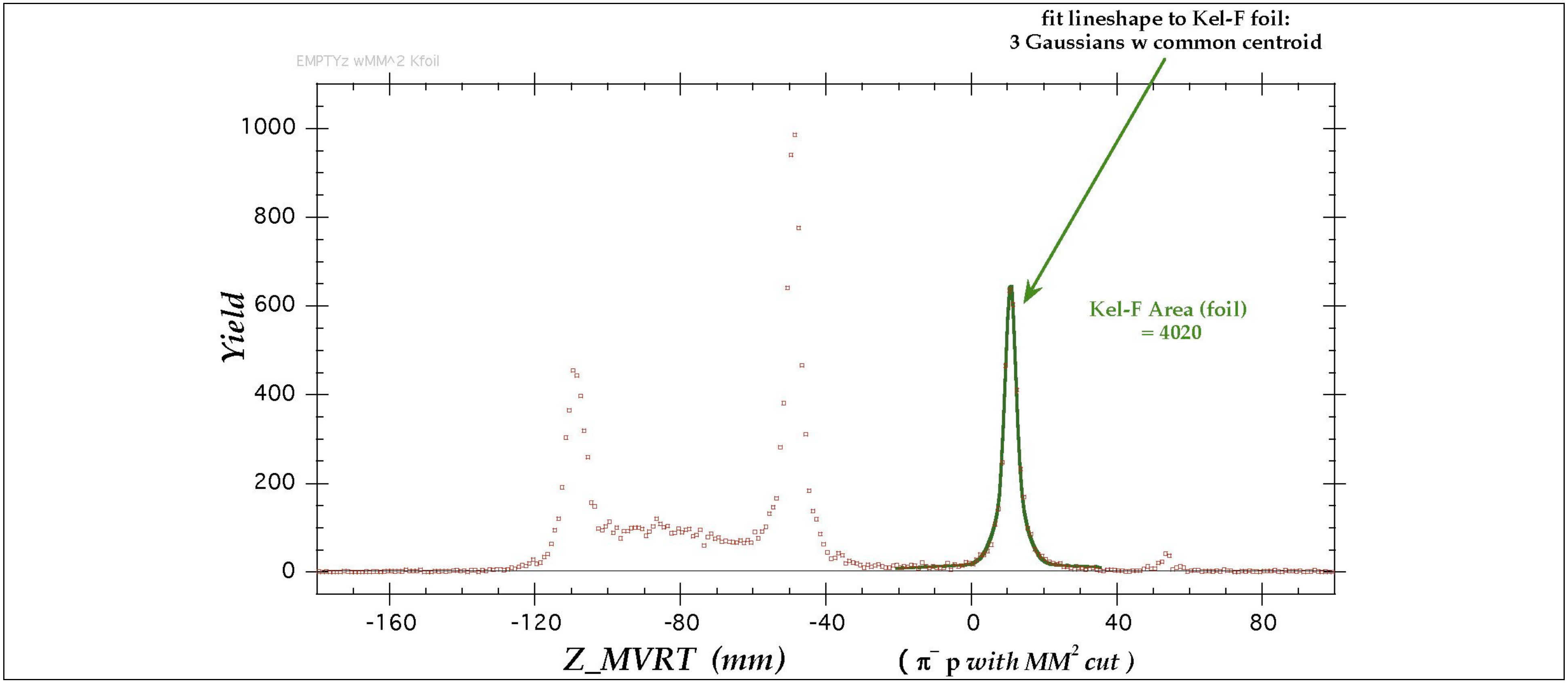
- **to match Aluminum in 19b and 21a, the empty yield must scaled down by 0.7**



IV. Use the yield in the IBC Kel-F foil to correct for the under-subtraction of Kel-F

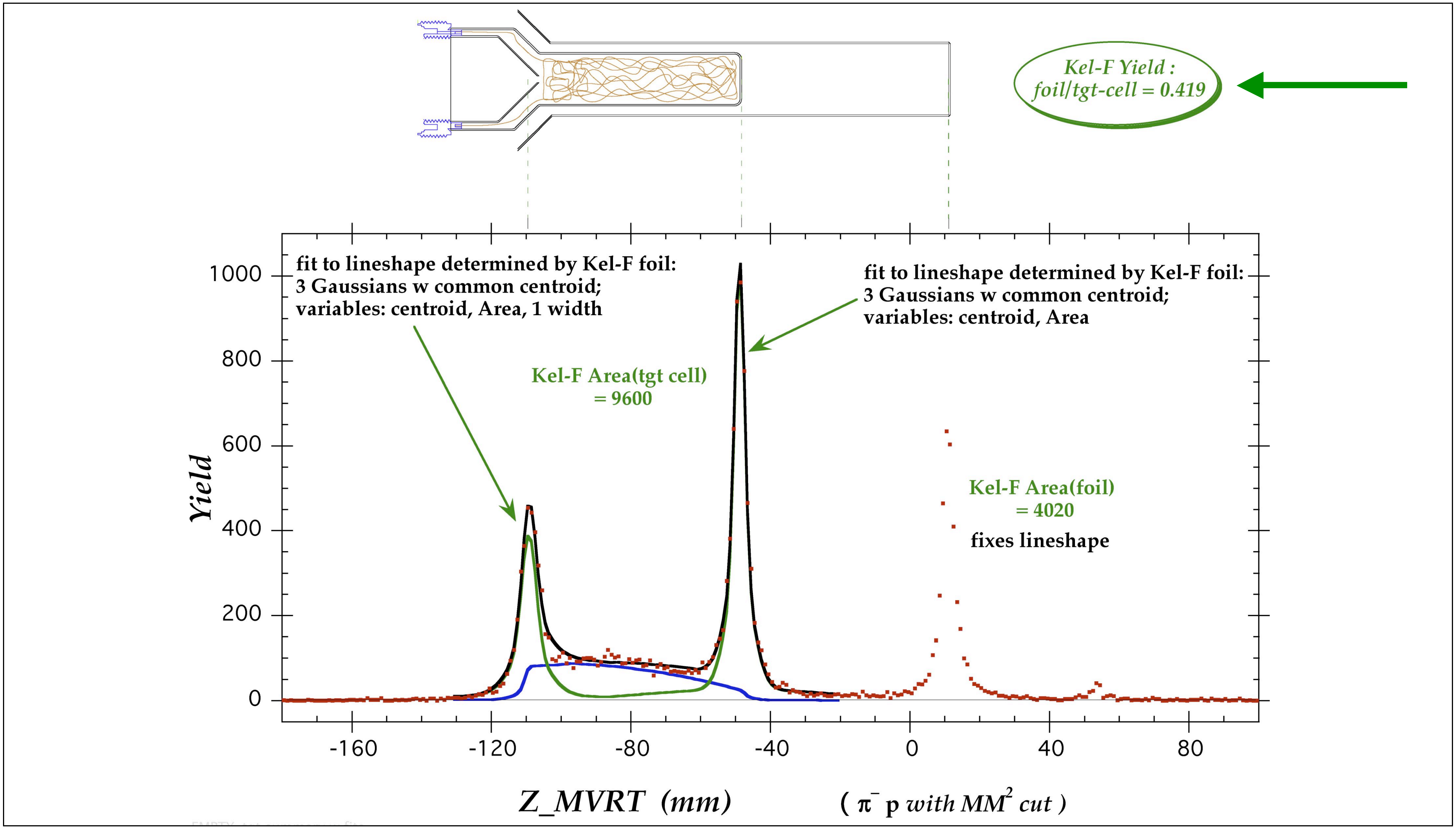
We take the ratio of Kel-F in the IBC foil to that in the target cell from the empty

- first we use the IBC Kel-F foil to fix the line shape:



- ratio of Kel-F peaks should be independent of cuts;
- MM^2 cut around 2-body π^-p peak helps narrow line shape;
- IBC Kel-F foil (z ~ +10 mm) fitted to triple-Gaussian with common centroid

- then we use the lineshape of the IBC Kel-F foil to fit the target cell peaks:



- beam exit window (z ~ −50 mm) fitted to foil line-shape, varying only centroid and area;
- fit to beam entrance window (z ~ −110 mm) holds ratios of the 3 Gaussian widths and amplitudes fixed by foil fit, but varies 1 Area and 1 overall width to account for spread from conical shape
- Aluminum fit to quadratic, with edges at Kel-F windows, smeared with line shape determined by foil

$\Rightarrow$ Kel-F(target cell) = (1/0.419) X Kel-F(IBC foil)

- due to Aluminum scaling in III, 30% of the Kel-F in the target cell still needs to be subtracted

$\Rightarrow$ need to subtract additional (0.30) X Kel-F(target cell) = (0.30/0.419) X Kel-F(IBC foil)
= (0.716) X Kel-F(IBC foil)

Summary of procedure for empty-cell subtraction of 19b data

- **replay both 19b (full) and 21a-empty files with the same Torus polarity, using your favorite cuts (MM^2, coplanarity, etc, BUT NOT Z-vertex)**
- **scale 21a-empty to match the Z-vertex yield from the IBC (-2 cm < Z < +30 cm)**
- **multiply this scaled 21a-empty by 0.70 to match the Aluminum and subtract from 19b, keeping events from the entire target region, -13 cm < Z < -3 cm**
- **finally, subtract off (0.716) X the yield from the foil region (-1 cm < Z < +3 cm) in the 19b (full) data.**

Appendix: An example with a little detail

Let's consider as an example, a beam-target asymmetry formed from two initial spin states. For the circular running, the spins of the beam and target are either parallel (P) or anti-parallel (A). Let's start with the parallel P-state. We go through the steps summarized on the previous page.

1) replay all 21a-EMPTY runs with the same torus setting, and separate all events that had (a) a P initial state from those with (b) an A initial state. Use exactly the same cuts you intend to use on the full target.

2) with these two groups, select those events coming from the target region, -13 cm < Z < +3 cm, and form an asymmetry, (a)-(b) / (a)+(b). We expect such beam-target asymmetries to be always zero within statistics.

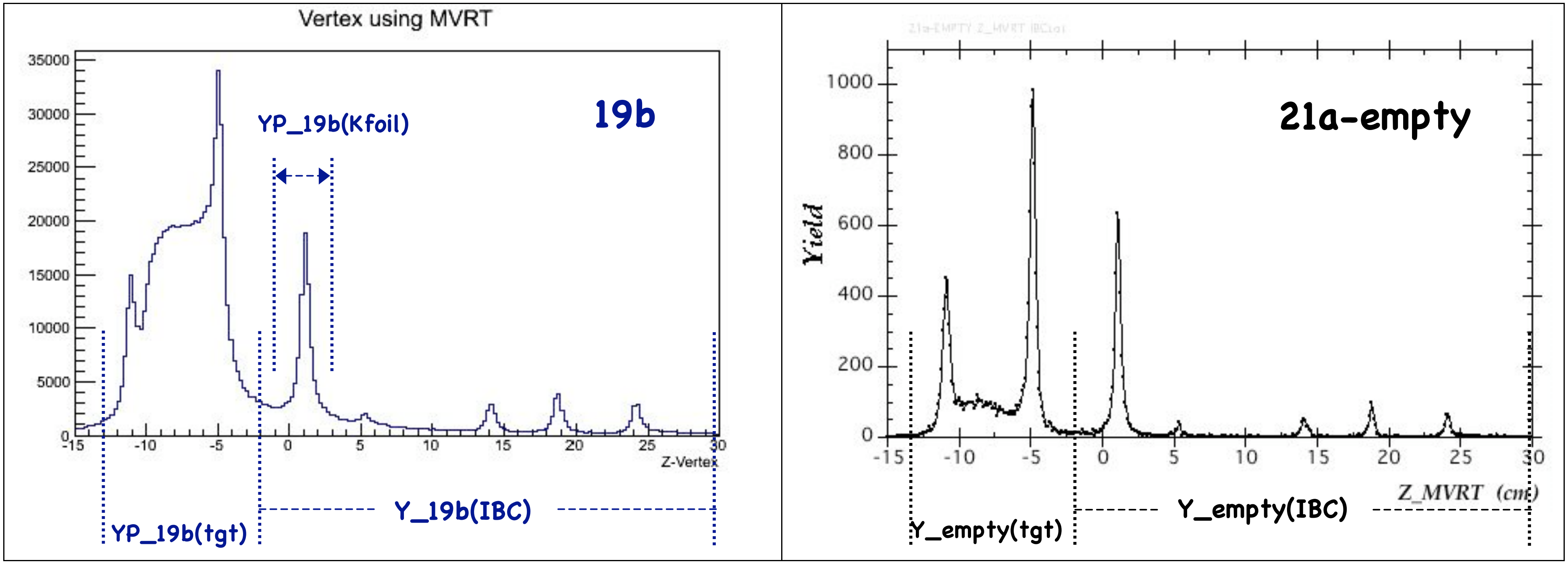
3) repeat this exercise with events that come from the IBC Kel-F foil, -1 < Z < +3 cm and check the asymmetry. This too should be zero within statistics. Once we have verified that events coming only from the target cell and the downstream Kel-F have no asymmetry, we will be able to combine the two spin states for empty subtractions, which will reduce the propagated statistical error.

4) Now, replay 19b runs, collecting all events with a P initial state.

5) Next replay all 21b-EMPTY runs, no longer separating P and A Empty yields, because we have shown that they have no spin-dependence.

6) Compare the z-vertex histograms for the results of steps (4) and (5) and for each, evaluate the yields coming from the IBC foils, -2 < Z < +30 cm. Let's call these Y_19b(IBC) and Y_empty(IBC). These are proportional to the gamma-ray flux through the target.

7) Next, for both the state P of 19b and all (P+A) of the empty, count the number of events coming from the target region, -13 < Z < -3 cm. Lets call these YP_19b(tgt) and Y_empty(tgt).



8) Next (or during the same analysis pass used for the previous step), count the number of events coming from IBC Kel-F foil, -1 < Z < +3 cm, from all the 19b runs with an initial P state. Let's call this YP_19b(Kfoil).

9) Finally, the number of events coming only from pure HD during the part of the 19b runs with an initial P state is given by:

YP_19b(HD) = YP_19b(tgt) - Y_empty(tgt)*[Y_19b(IBC)/Y_empty(IBC)]*(0.700) - YP_19b(Kfoil)*(0.716)

10) repeat steps (4) through (9) for events coming from the initial A state to form YA_19b(HD).

11) the desired asymmetry from HD is

[YA_19b(HD) - YP_19b(HD)] / [YA_19b(HD) + YP_19b(HD)].

A few comments:

(I) In step (8) above we kept only the yield from the Kel-F foil from those events with an initial P state. This was just for simplification. Since we will hopefully have shown that there is no spin dependence to events coming from the Kel-F, one could combine yields from both A and P states, but with different factors (which can be worked out in detail).

(II) This example is for a beam-target asymmetry, NOT involving recoil polarization. When we get to hyperon final states, the empty yields from the two states will have to be kept separate, since there can be a recoil asymmetry even when there is no target polarization (or beam polarization).

(III) The reconstructed Z-vertex resolution, and even the aluminum contribution evident in the empty, depends on the kinematic requirements imposed. For example, stringent 2-body requirements would include cuts on MM^2, on coplanarity and on missing momentum. All of these are more difficult to satisfy for an event originating in a nucleus than for events from H or D. But the analysis on page 12 that determined the relative amount of Kel-F in the foil vs the target cell can be done with any set of cuts. (In fact, this has been verified with two different sets of cuts and yielded the same ratio.)