A Thought on the 1st BCM Location in MEBT – In Perspective of Dynamics of Unaccelerated Particles from RFQ –

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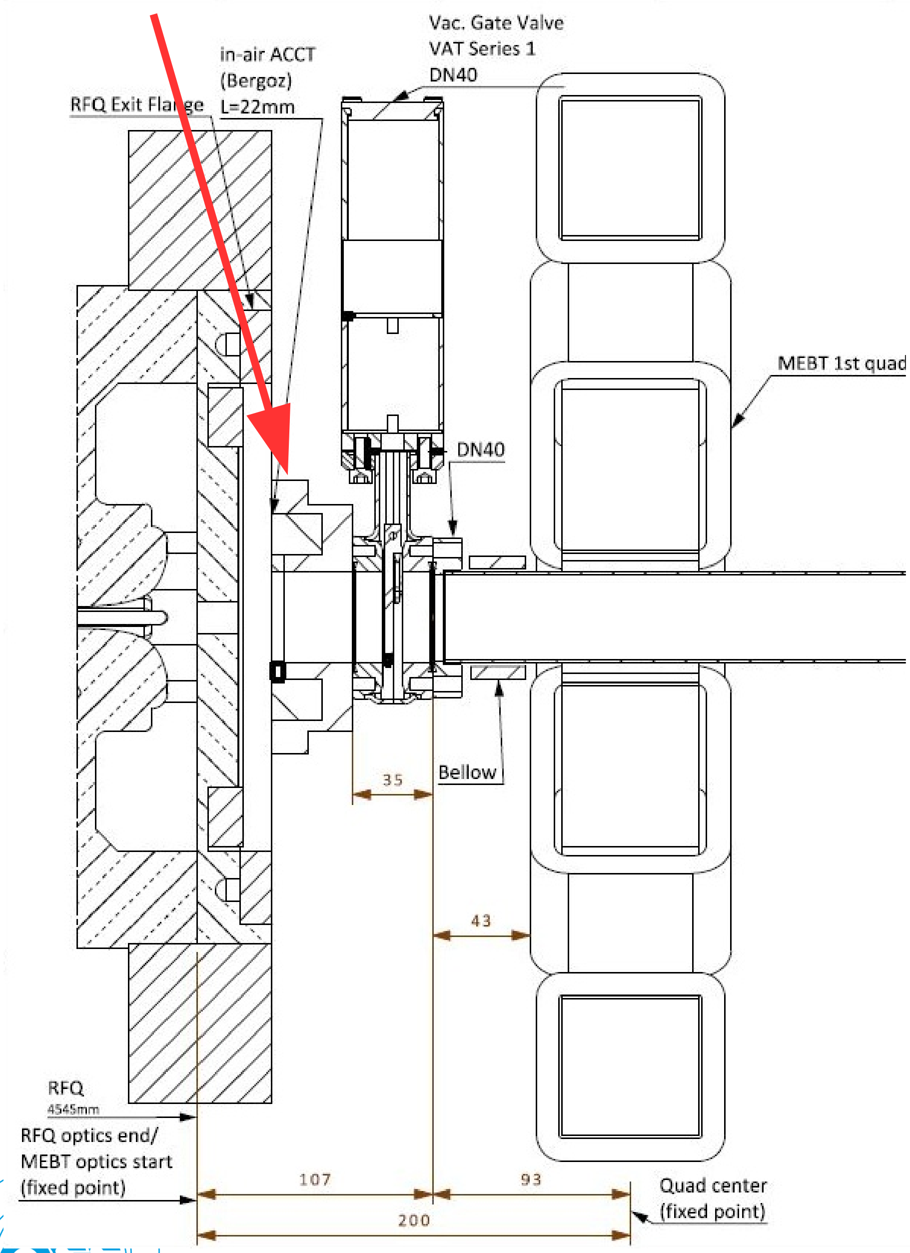
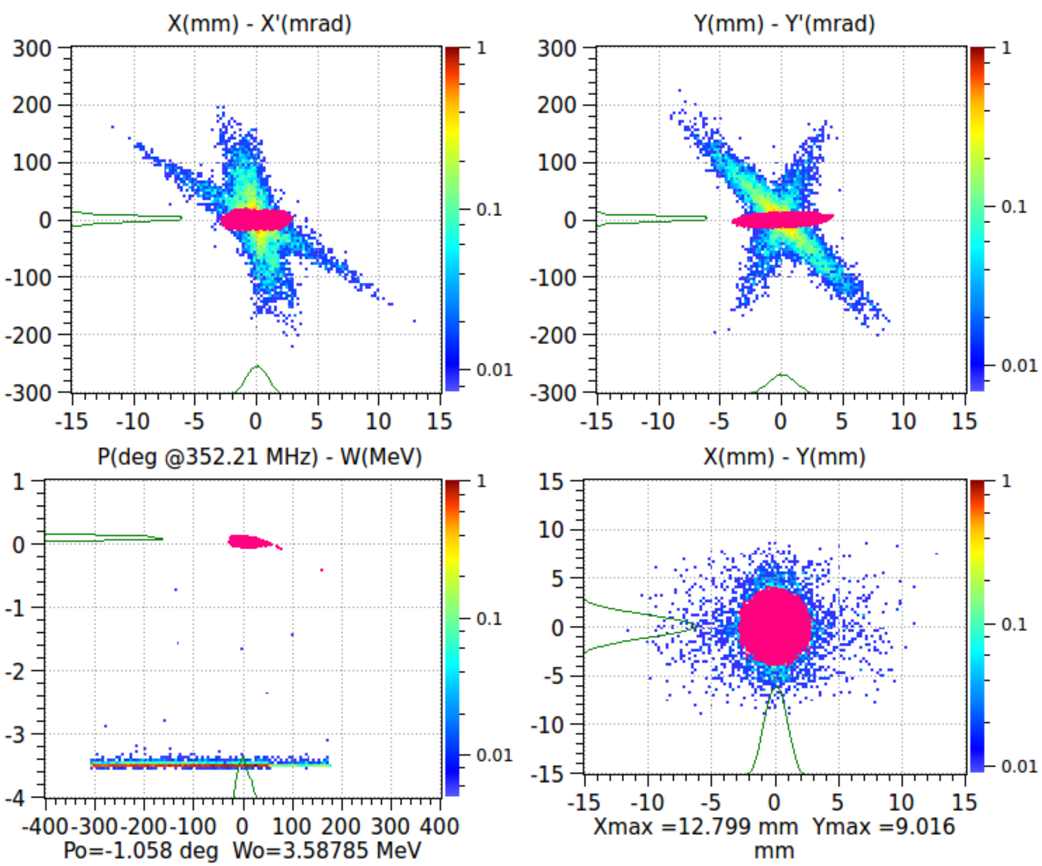
Introduction

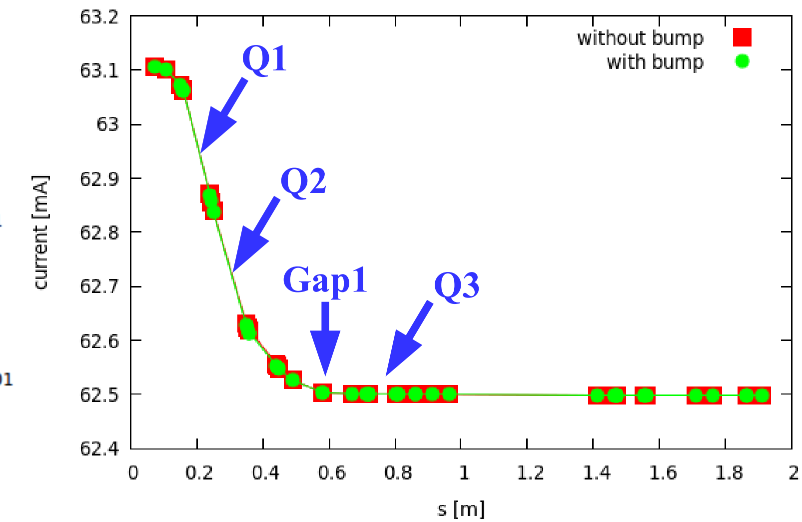
BCM on RFQ

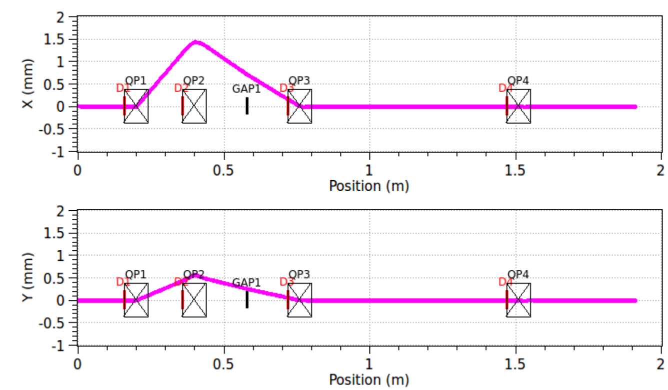


- The 1st BCM in MEBT is used to be in the Q1-Q2 drift but now is in the first drift, attached to the RFQ flange (see the left Fig). At this location, however, the BCM signal includes the unaccelerated part of the RFQ output beam.
- The transmission of **the bunched part of the beam** is an important figure of merit of IS+LEBT+RFQ. On the other hand, the BCM attached to the RFQ flange provides us information of beam loss in the RFQ together with the other BCM at the RFQ entrance via the differential current measurement.
- Given these two conditions, if possible, it is ideal to keep the one on the RFQ flange and add another in the initial part of the MEBT.
- This presentation sees where in the MEBT the unaccelerated part of the beam is (almost) completely lost and discusses potential locations for an additional BCM.

Where in the MEBT the unaccelerated particles are lost?



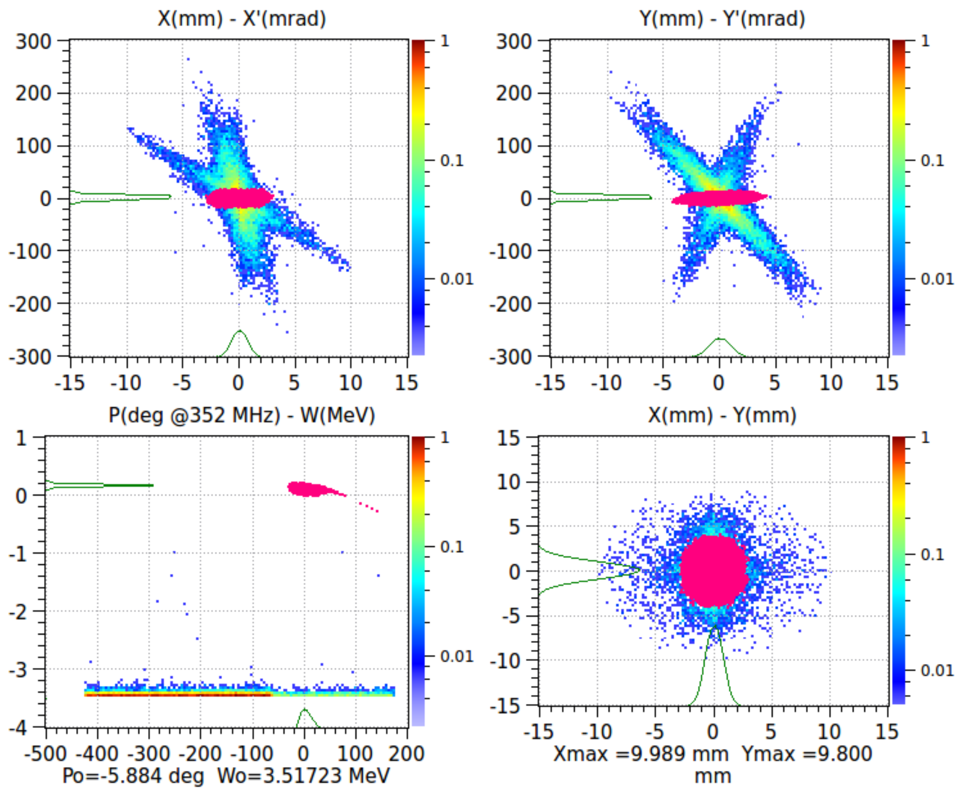




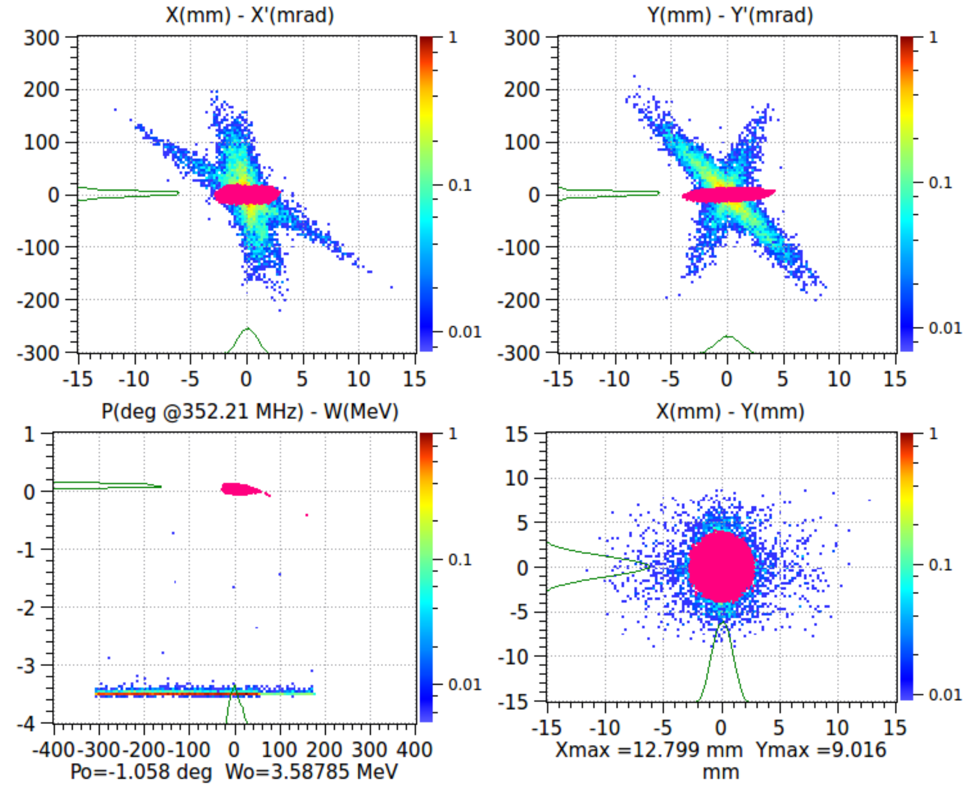
- The RFQ output distribution **likely** looks like the left Fig. This is the nominal distribution from the RFQ of 2013, assuming a Gaussian distribution with 0.25 pi mm mrad emittances at the RFQ entrance. In the figure, the magenta part is the bunched part and the rest is the unaccelerated part.
- The top right Fig shows the current vs *s* (in the MEBT lattice ver 2015.v0c). The unaccelerated part is ~0.6 mA (63.1 – 62.5) in this particular example and takes until the first gap or Q3 until it gets (almost) completely lost. This indicates that the original plan of having the BCM in the Q1-Q2 drift has the same problem of seeing the unaccelerated part.
- "An" ideal of removing the unaccelerated part faster is to use steerers. The right bottom Fig shows closed 3-bumps in *x* and *y* planes formed with steerers in Q1-3 with the maximum steerer strength (250 G or 20 G m). The green markers and lines in the right top Fig show the current vs *s* with these bumps. Unfortunately, the bumps made practically no difference. We can also think of changing strengths of quads but this can't be done during the operation. As of now, I have no solution to lose most of the unaccelerated particles by the end of Q1.

Try an alternative RFQ output

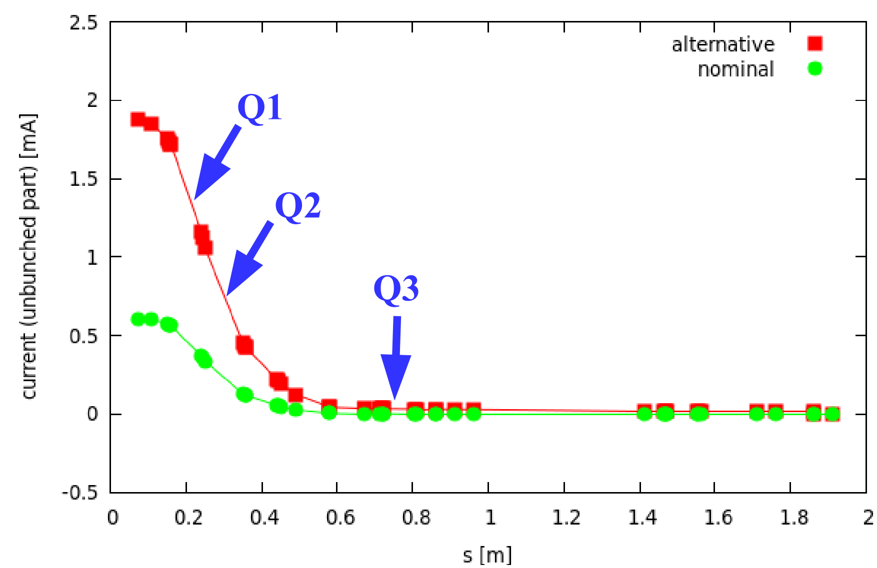
Alternative



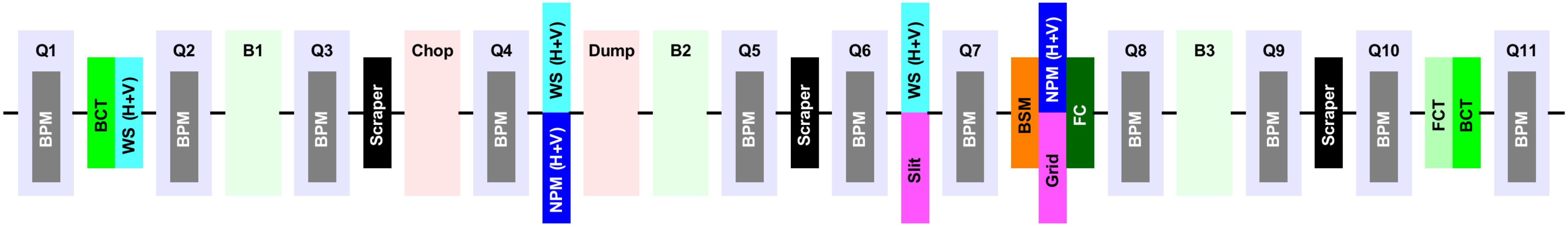
Nominal



- The structure of the unaccelerated part depends on the input to the RFQ so I repeated the same calculation with another distribution. The left Fig shows an RFQ output distribution, generated by starting from an ion source distribution (courtesy of Y. Levinsen).
- The bottom right Fig compares the currents of the unaccelerated parts for this case and the nominal case (in the previous page). The alternative case includes more unaccelerated particles but **the situation of the most being lost by Q3 remains**.
- Note, the lattice 2015.v0c is adjusted for the alternative distribution.



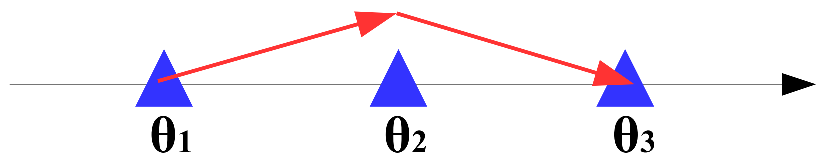
Discussions



- The above diagram shows the MEBT diagnostics layout, **before the first BCM is moved to the flange of the RFQ**. In this presentation we saw the unaccelerated particles survive until around the first buncher or Q3. Given this condition, I can think of two options for an additional BCM.
  - The space between Q4 and the dump is 150 mm. Maybe we can squeeze a BCM here. Or, we may want to replace the NPM with a BCM.
  - The first scraper can be placed in the Q1-Q2 drift. So, maybe, we have the 1st scraper there and WS+BCM in the space between Q4 and the chopper.
- **Inputs and recommendations from BI are certainly needed.**

Appendices

A note on the 3-bump



Suppose we have three steerers at locations 1, 2, and 3, the transfer matrix from 1 to 3 is M_{13} and that from 2 to 3 is M_{23} with elements:

$$M_{13} = \begin{pmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{pmatrix} \quad , \quad M_{23} = \begin{pmatrix} n_{11} & n_{12} \\ n_{21} & n_{22} \end{pmatrix}$$

The equation to solve for a closed 3-bump is obviously

$$\begin{pmatrix} 0 \\ 0 \end{pmatrix} = \begin{pmatrix} 0 \\ \theta_3 \end{pmatrix} + M_{23} \begin{pmatrix} 0 \\ \theta_2 \end{pmatrix} + M_{13} \begin{pmatrix} 0 \\ \theta_1 \end{pmatrix}$$

The solution is

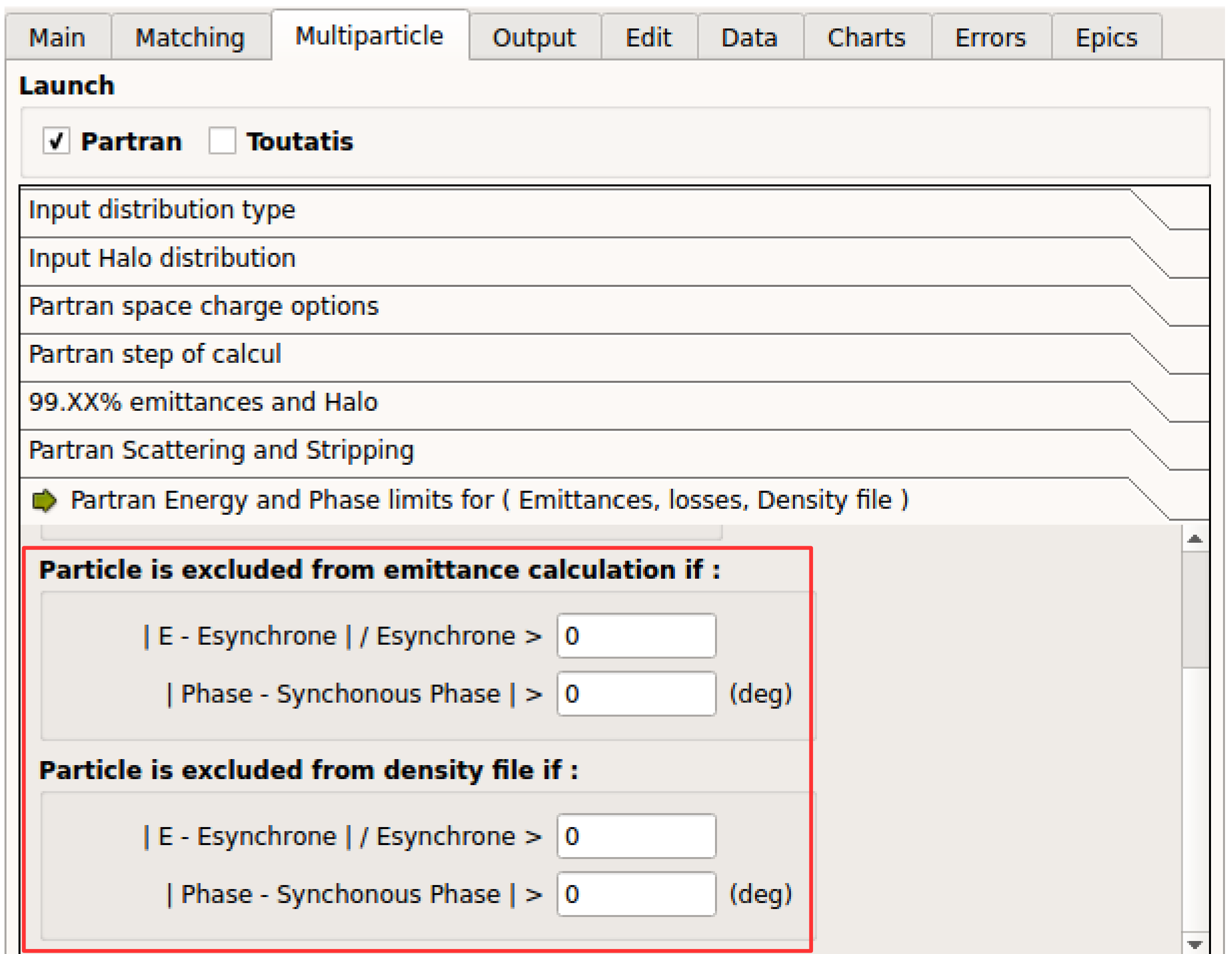
$$\theta_2 = -\frac{m_{12}}{n_{12}} \theta_1 \quad , \quad \theta_3 = \frac{m_{12} n_{22} - m_{22} n_{12}}{n_{12}} \theta_1$$

For the first 3 steerers in MEBT (ver 2015.v0c), the solutions are given by

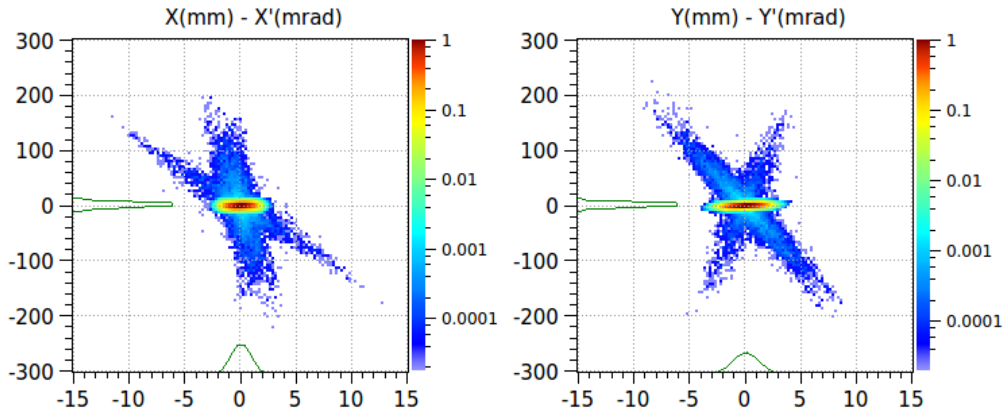
$$\theta_{x2} = -0.5932\,\theta_{x1} \quad , \quad \theta_{x3} = 0.5231\,\theta_{x1}$$
$$\theta_{y2} = -2.5324\,\theta_{y1} \quad , \quad \theta_{y3} = 0.5113\,\theta_{y1}$$

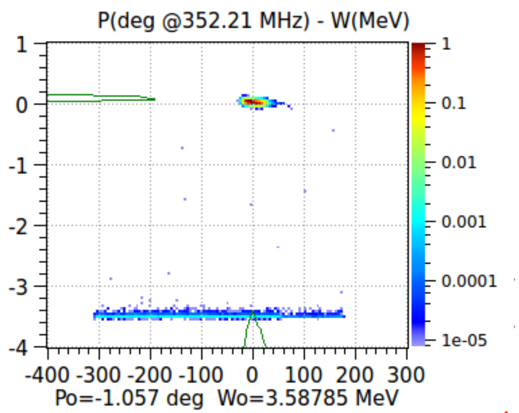
How to include unaccelerated particles in TraceWin (1): disable the filters for phase and energy

- In the following, I presents the procedure to include unaccelerated particles in TraceWin's Partran tracking.
- When we **load** the dst file including unaccelerated particles, we shouldn't use the filter in the longitudinal plane. Otherwise, setting of the initial conditions, discussed in the following pages, won't be correct.

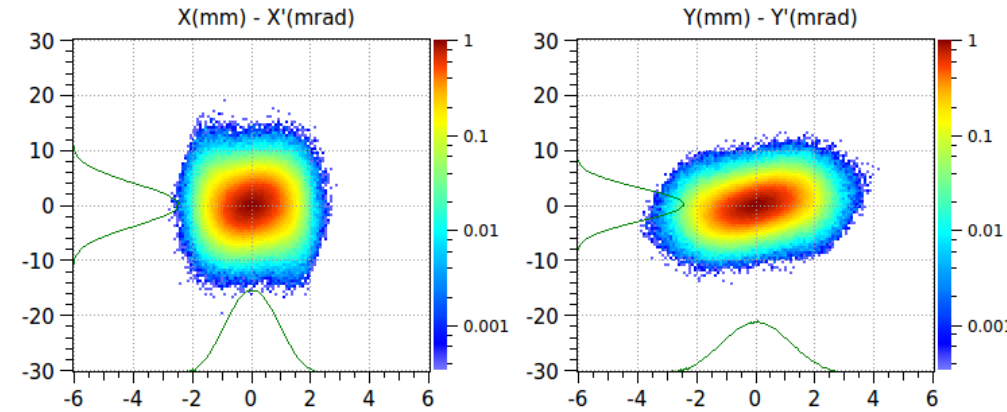


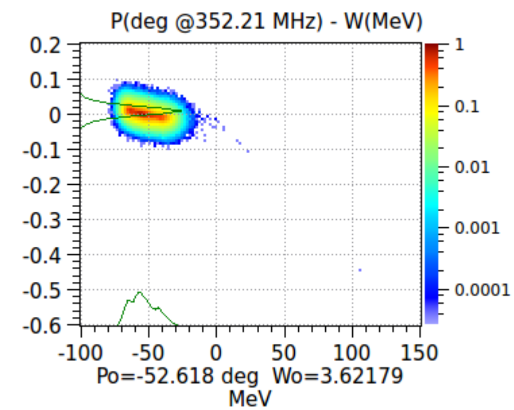
How to include unaccelerated particles in TraceWin (2): shift the center of the distribution





Dx	0.00058493417	mm
Dx'	-0.019320284	mrad
Dy	0.0030146591	mm
Dy'	0.026456675	mrad
Dz	11.066602	mm
Dp	-53.675122	deg



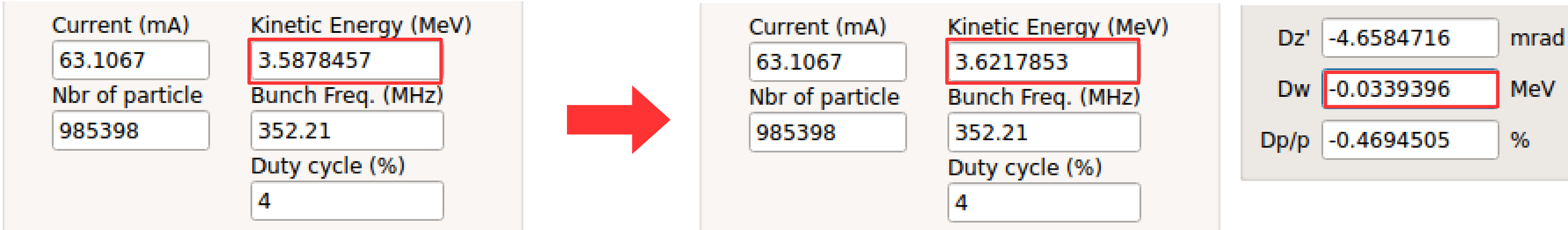


Dx	0.00062946473	mm
Dx'	-0.015519734	mrad
Dy	0.0034523973	mm
Dy'	0.018716504	mrad
Dz	10.899549	mm
Dp	-52.618024	deg

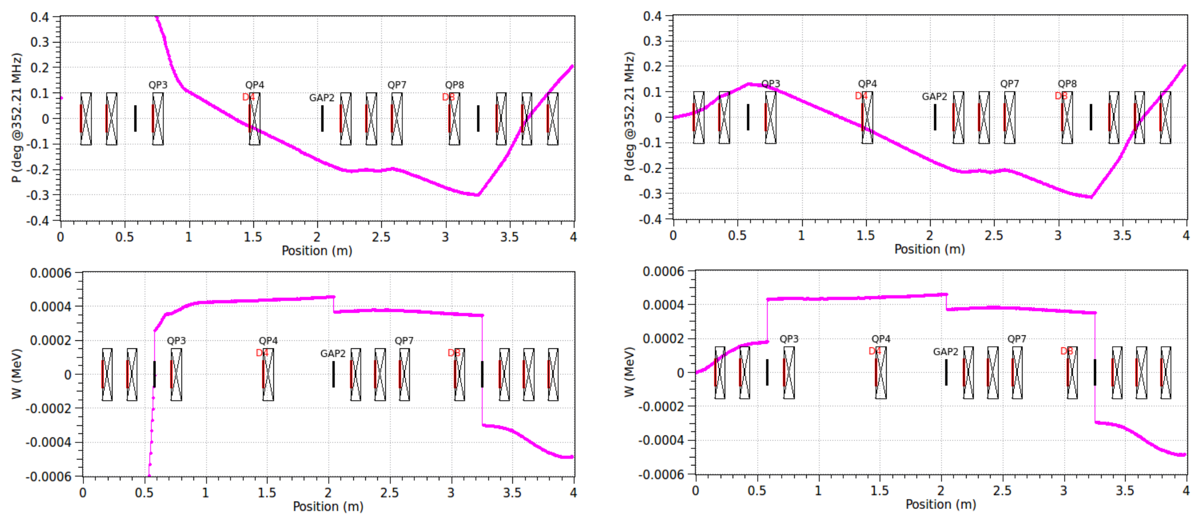
Dx	-4.4531e-05	mm
Dx'	-0.0038006	mrad
Dy	-0.00043774	mm
Dy'	0.0077402	mrad
Dz	0.21795023	mm
Dp	-1.0571	deg

- The left is the original distribution and the right is its bunched part. We want to have the center of the bunched part at the origin of the phase space. So, we subtract the numbers of the left from those of the right and use these numbers in **Twiss Parameters** of **Main** tab. For example for the phase, we subtract ~52.6 deg from ~53.7 deg: 52.6 − 53.7 ~ −1.1 deg.
- Once we do the tracking and save the distribution at the 0th element, this process isn't necessary from the 2nd time.
- Note, for the longitudinal coordinate, the above subtraction should be done for phase and not *z* since *z* depends on the average energy.
- Scaling may be needed for the current to make it ~62.5 mA.

How to include unaccelerated particles in TraceWin (3): shift the energy



- Finally, we have to make adjustments in energies. When we load a dst file including unaccelerated particles, the kinetic energy in **Main** tab is less than ~3.62 MeV (left fig). This energy, however, is used as the energy of the reference particle so we have to change it to the value of the bunched part by hand (middle).
- This means that the mean energy is now less than the reference energy so we have to change **Dw** in **Twiss Parameters** as well by hand (right). In this example, 3.588 – 3.621 ~ –0.033 MeV.



- These two plots show the phase and energy centroids with (left) and without (right) the unaccelerated particles, demonstrating the described scheme is working. In the last half, once most of the unaccelerated particles are lost, the two cases are very close. The small difference towards the end is likely due to that there are still a few unaccelerated particles left at the MEBT exit for the left case.
- Something wrong with TraceWin to output the phase centroid when including the unaccelerated particles.