RFQ Simulations

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Goals

- See the effect of warped rods
- Understand why the manufacturer keeps saying energy is correct because of mechanical design.

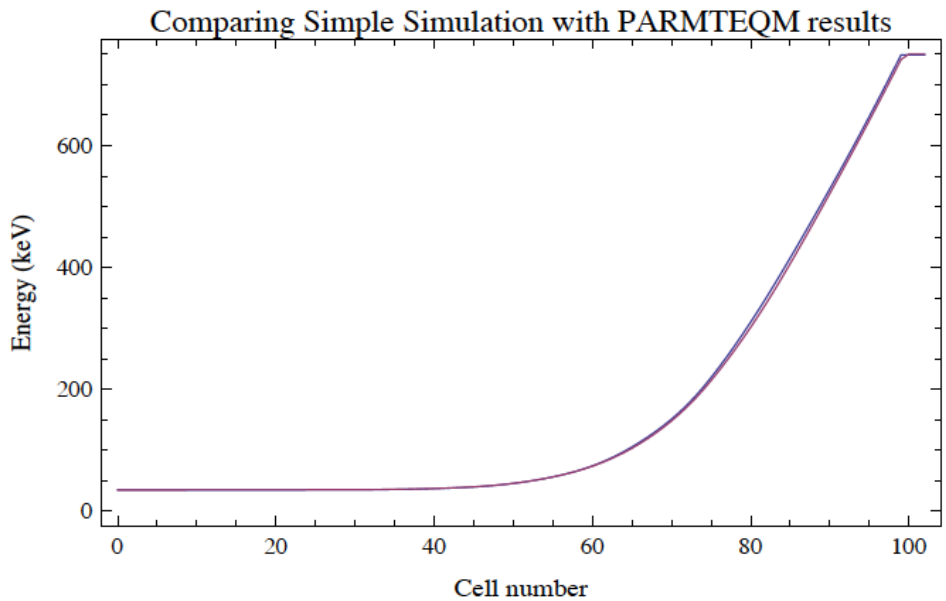
Es vs <E>

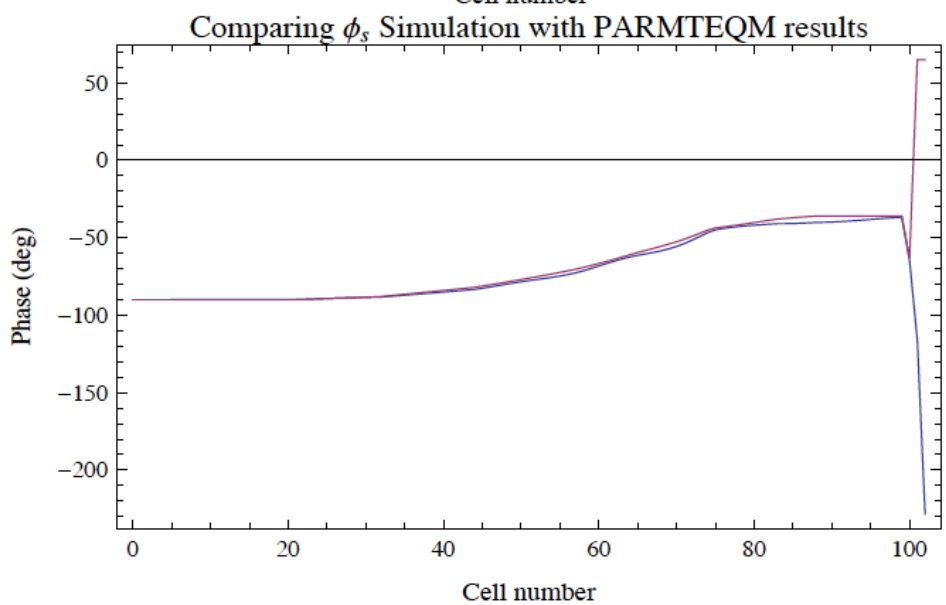
- Were we comparing apples to oranges?
  - Es **is** fixed. Determined by cell length and RF wavelength
    - β_s = 2 cell length/λ
  - <E> is what we measure in TOF and spectrometer magnet.
    - Es != <E>
- Example: rods infinitely far apart. E_z is zero and so <E> = input E, but E_s stays the same!

Simple Model

- Just use 2-term potential
  - $$U(r,\theta,z;t) = \frac{V_0}{2}\left(X\left[\frac{r}{a}\right]^2 \cos 2\theta + AI_0(k_s r)\cos kz\right)\sin(\omega t + \phi)$$
  - Consider pencil beam, zero transverse emittance and r=0
    - $$U(z;t) = \frac{AV_0}{2}\cos k_s z \sin(\omega t + \phi)$$
  - Ez field is
    - $$E_z = -\nabla U(z;t) = \frac{k_s V_0 A}{2}\sin k_s z \sin(\omega t + \phi)$$
  - Therefore energy gain in that cell is
    - $$\begin{aligned}\Delta W &= q\int_0^\ell E_z\, dz \\ &= \frac{qk_sV_0A}{2}\int_0^\ell dz\ \sin k_s z \sin(\omega t+\phi) \quad \text{because } z \text{ is a function of } t \\ &= \frac{(qk_s\beta c)V_0A}{2}\int_0^{\ell/\beta c} dt\ \sin(k_s\beta c t)\sin(\omega t+\phi)\end{aligned}$$

Check E_s with PARMTEQM

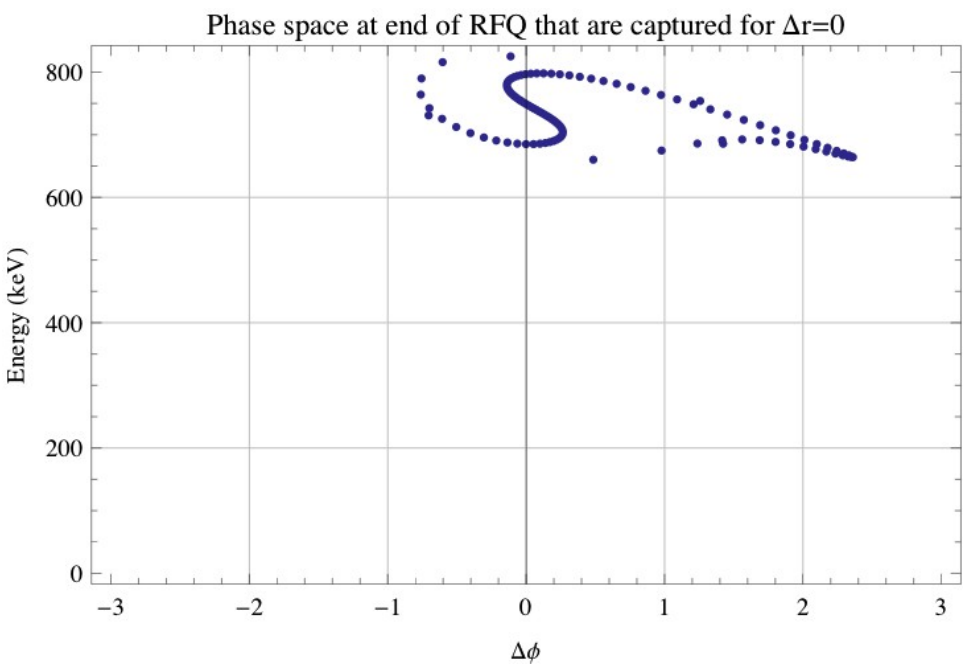


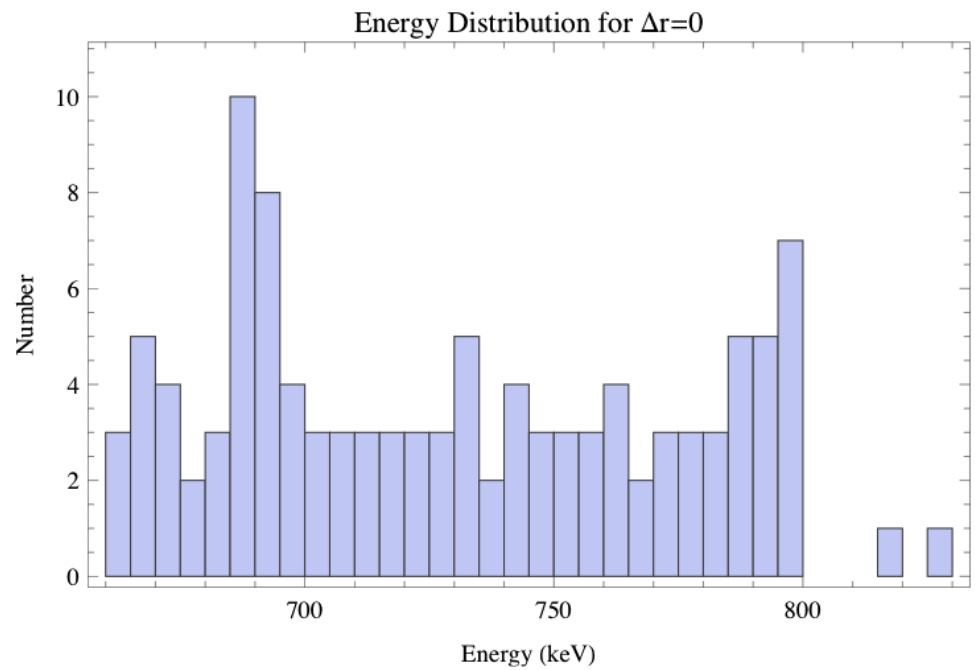


E_s PARMTEQM=750.25 keV,

My sim = 748.45

Energy at end of RFQ (ref)

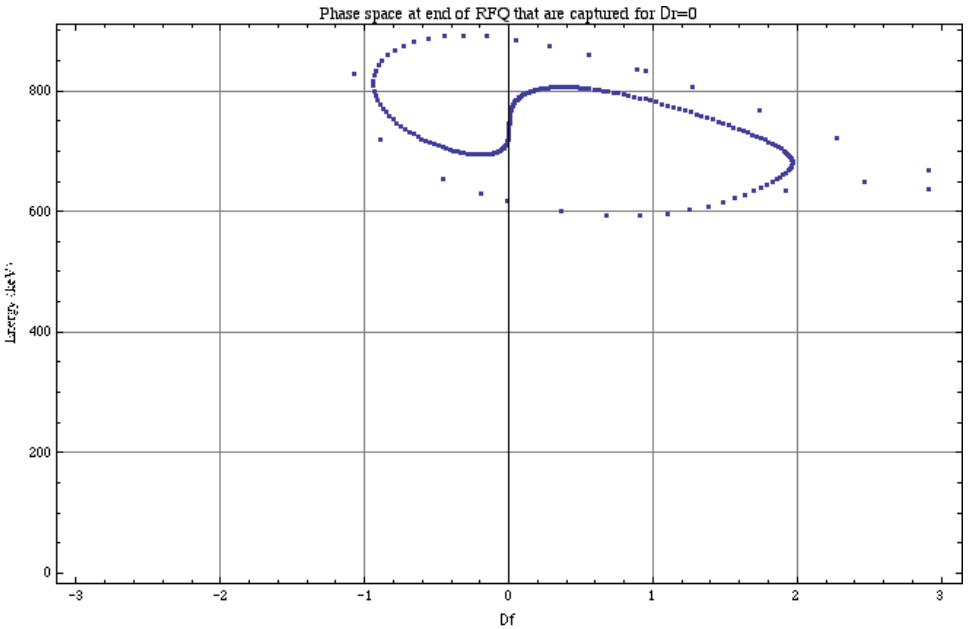


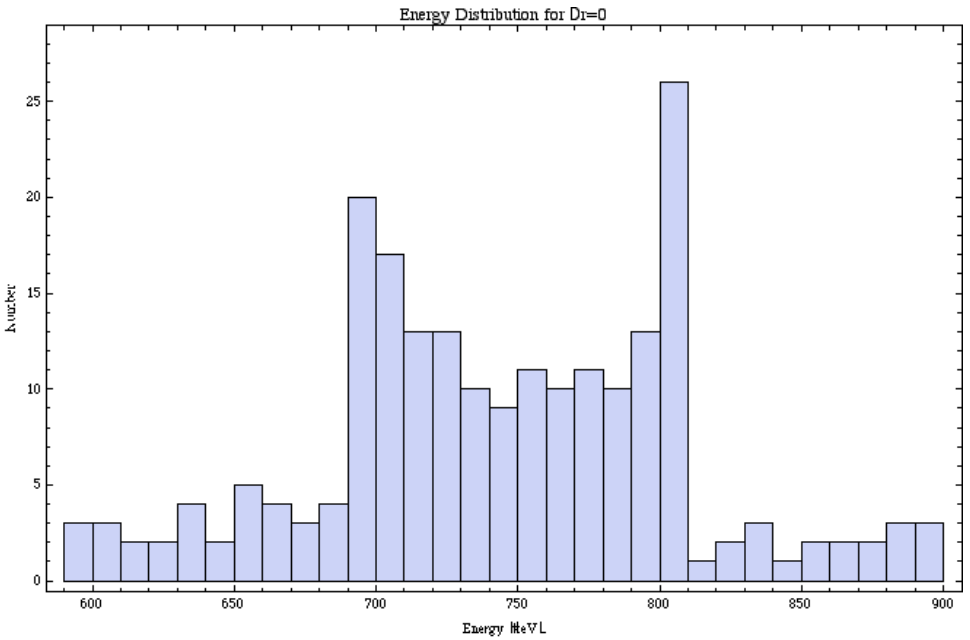


Es != <E>= 730 keV.

Clearly depends on beam distribution!

Increase intervane PD

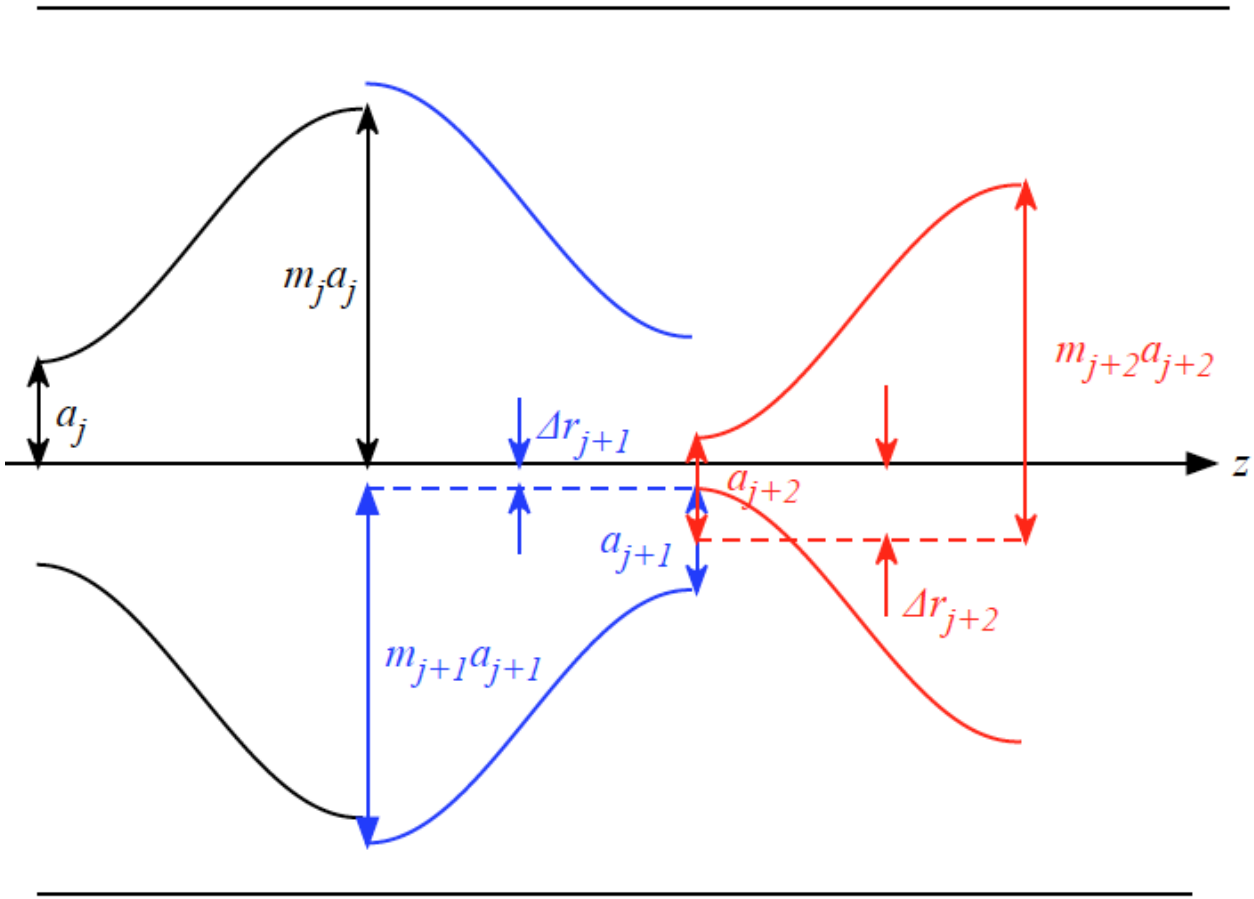




Increase intervane voltage to 95 kV (c.f. 72 kV). Bunching gets better and <E>=746 keV Es=752 kV (c.f. 72 kV 748.45 kV)

Note: 4000 particles here. All other sims use 1000 particles.

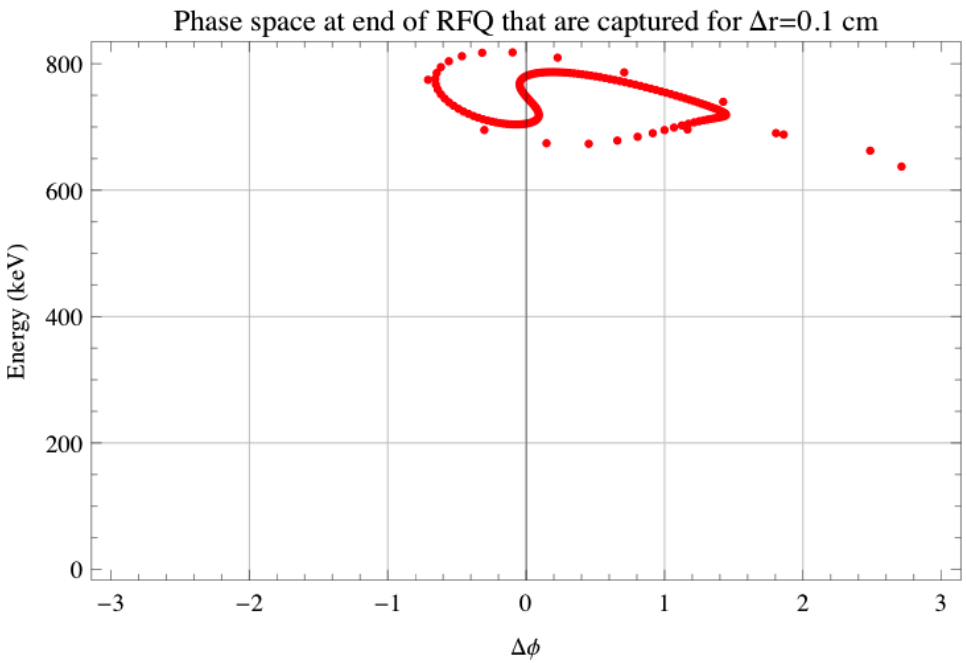
Rod Mounting Error

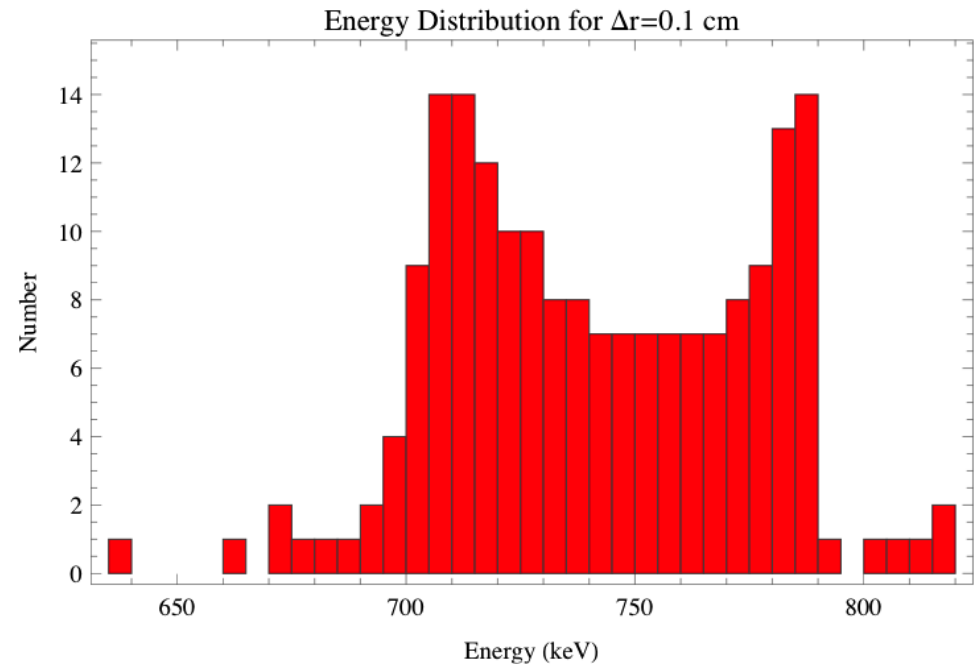


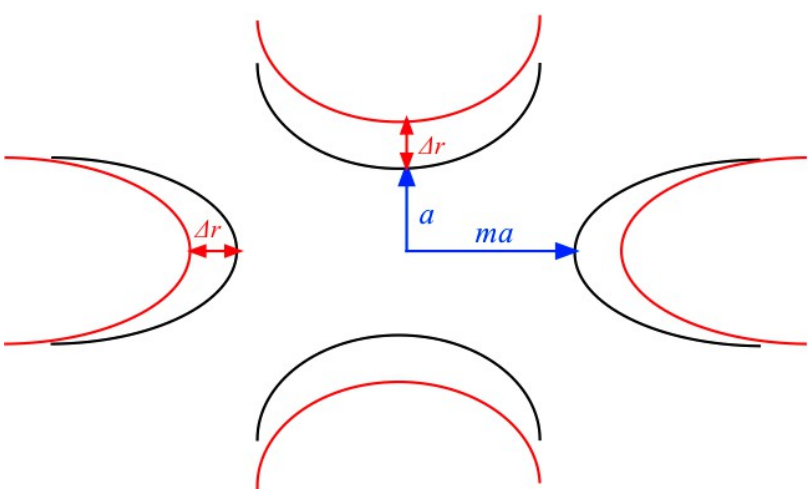
Each cell can have a mounting error Δr_j.

Symmetric cell error only

Put in rod mounting error 1 mm



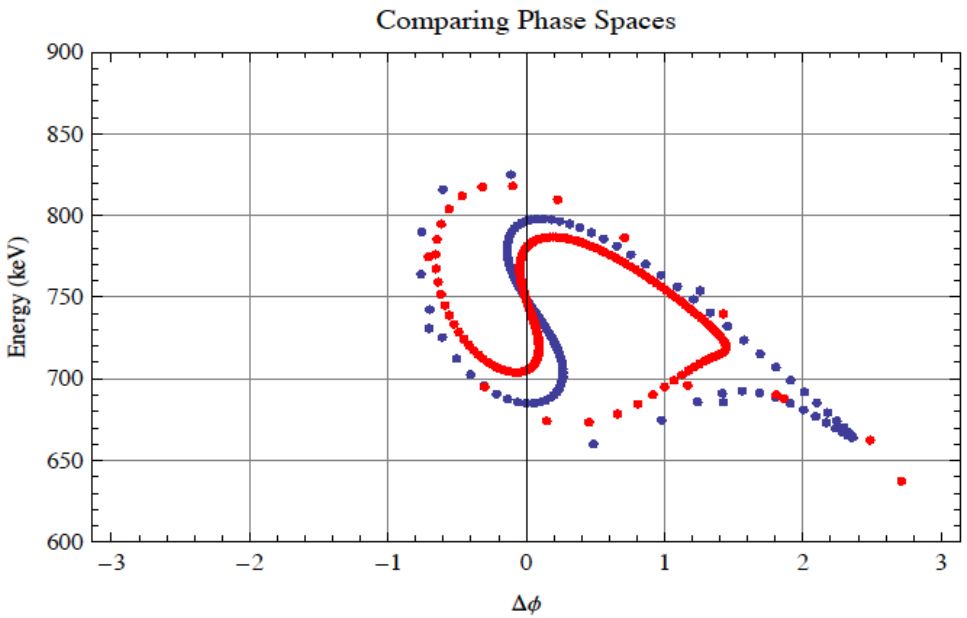


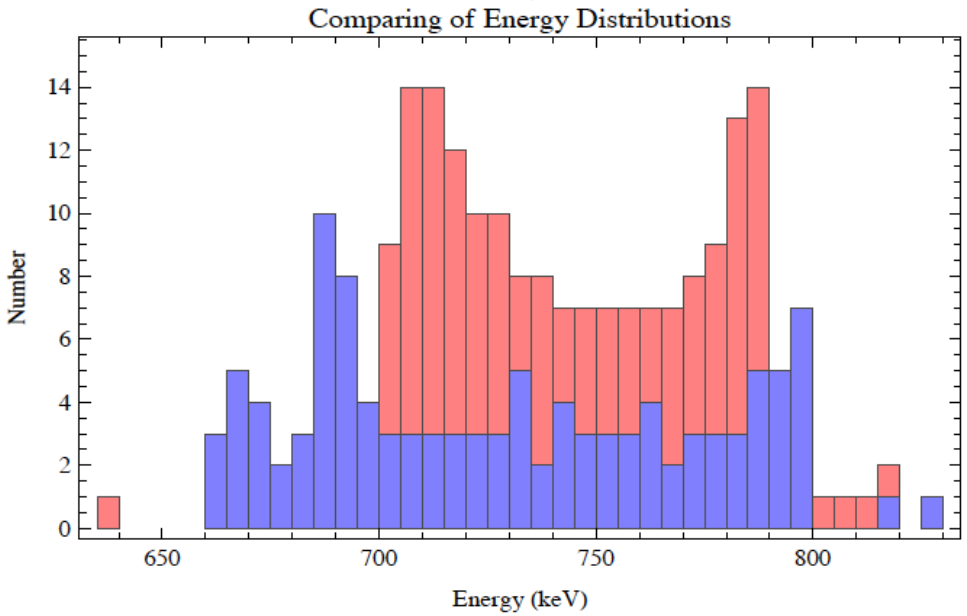


Better bunching!
<E>=742 keV!

Clearly mean energy is dependent on bunch distribution and bunching!

Compare

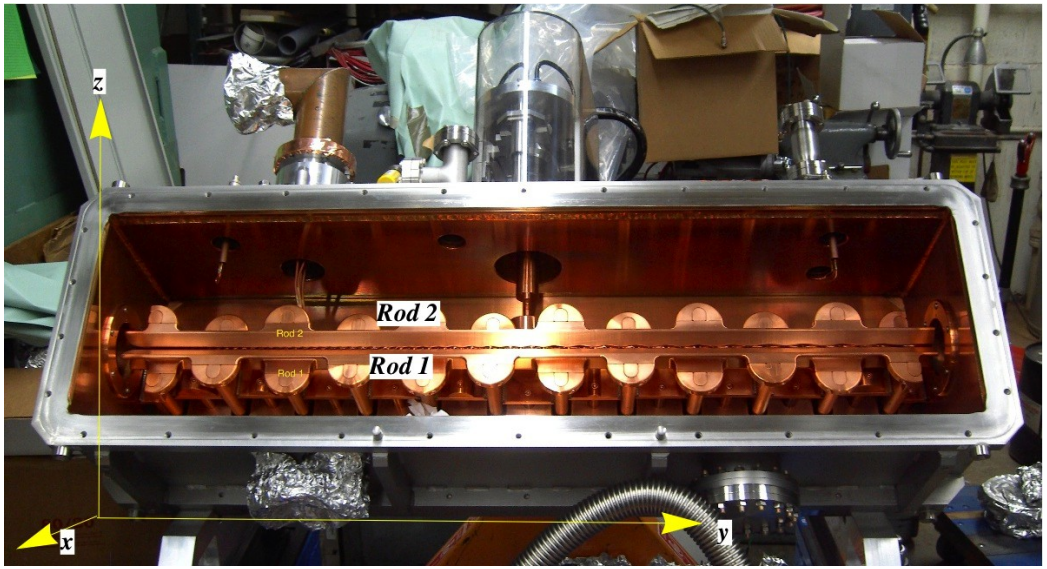


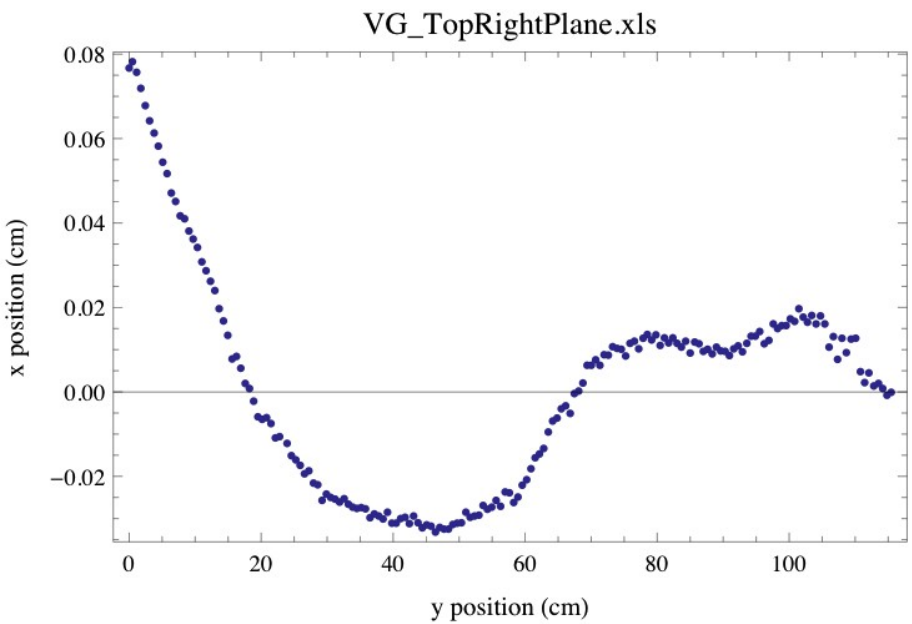


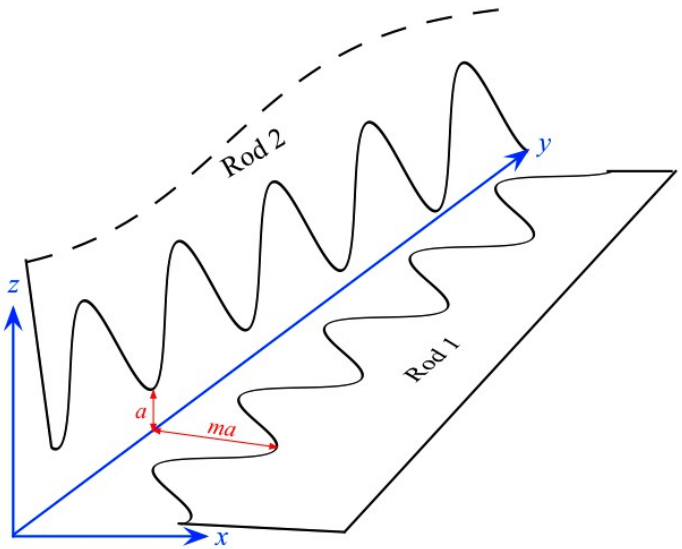
Note Es is the same for both systems BUT <E> is different.

Es = 750 keV

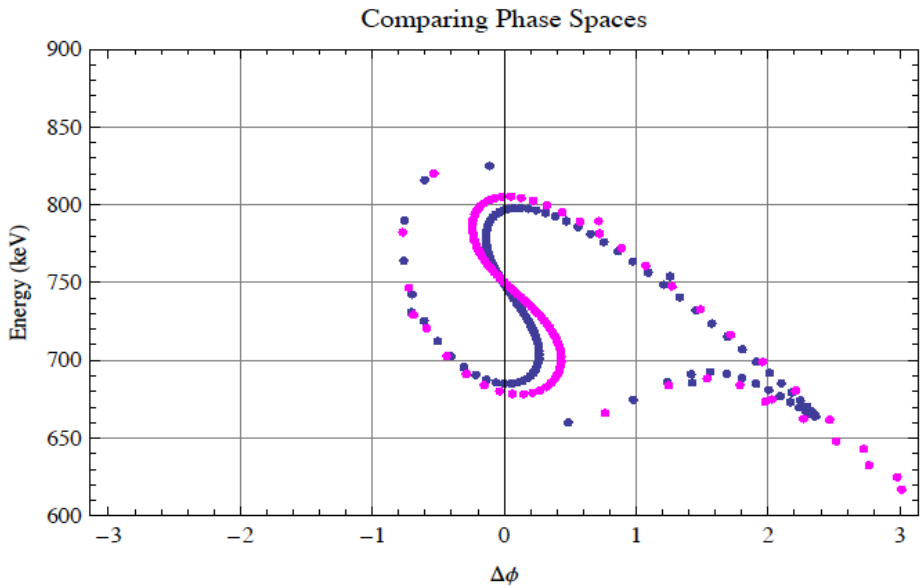
The warp

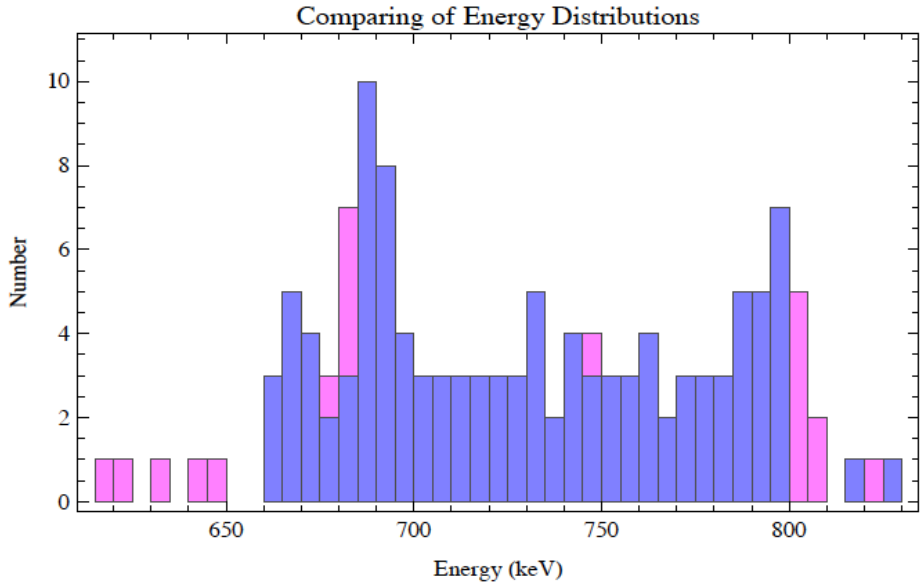

z
Rod 2
Rod 1
x
y


VG_TopRightPlane.xls
0.08
0.06
0.04
0.02
0.00
−0.02
x position (cm)
0
20
40
60
80
100
y position (cm)


Rod 2
y
z
Rod 1
a
ma
x

For Warped Rods





<E> is about the same: 732 keV compared to reference 730 keV.

Again Es = 750 keV

Error in accelerating section is small.

Conclusion

- Rod mounting error can change <E> because beam distribution changes.
  - In simple model, bunching not so good for reference.
- Simple model does not show significant energy change with warped rods.
  - Symmetric change only … clearly not true in RFQ.
  - Is the reason why energy is low is due to bad energy bunching in RFQ?