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Low Energy FFAGs for isotope production

### **Original Citation**

Bruton, David, Barlow, Roger, Edgecock, Robert, Toader, Adina and Gonsalves, Basil (2010) Low Energy FFAGs for isotope production. In: 2014 International Workshop on FFAG Accelerators FFAG 14, 22nd-26th September 2014, Upton, New York, USA.

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# Low Energy FFAGs for Isotope Production

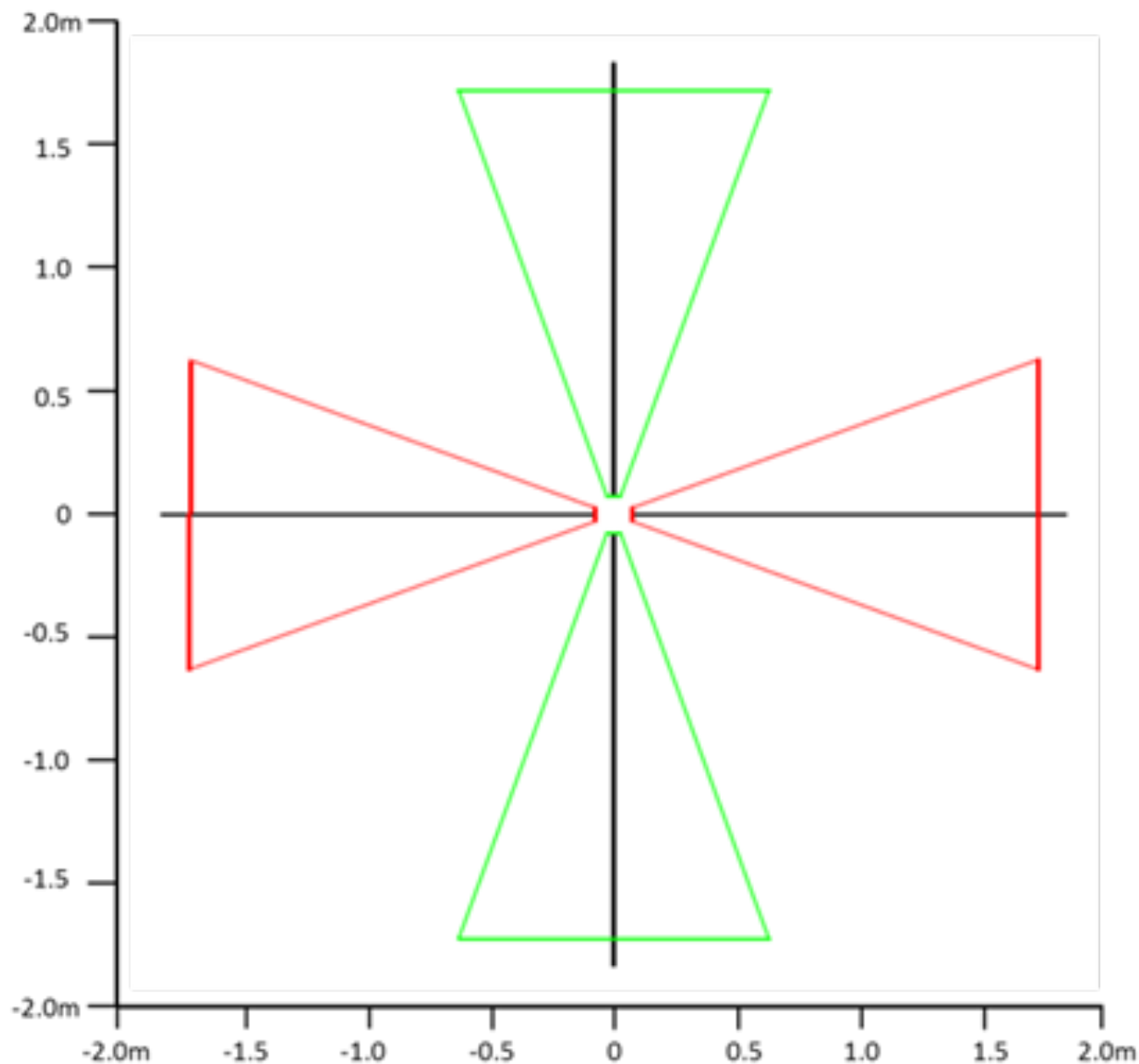
David Bruton, Roger Barlow, Rob  
Edgecock, Carol Johnstone, Adina  
Toader, Basil Gonsalves

- Radioisotopes
- The Design
- Simulations using in house code
- Simulations in OPAL
- Target Studies



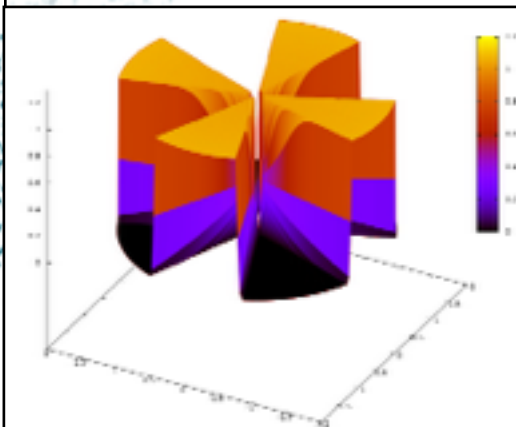
# Medical Isotope Production Options

- Reactors  
Stop  
– NRU, Canada (40% of Tc) 2016  
– HFR, Netherlands (30% of Tc) 2022
- Accelerators  
– Current production small scale  
– 10-100MeV  
– High Beam Currents

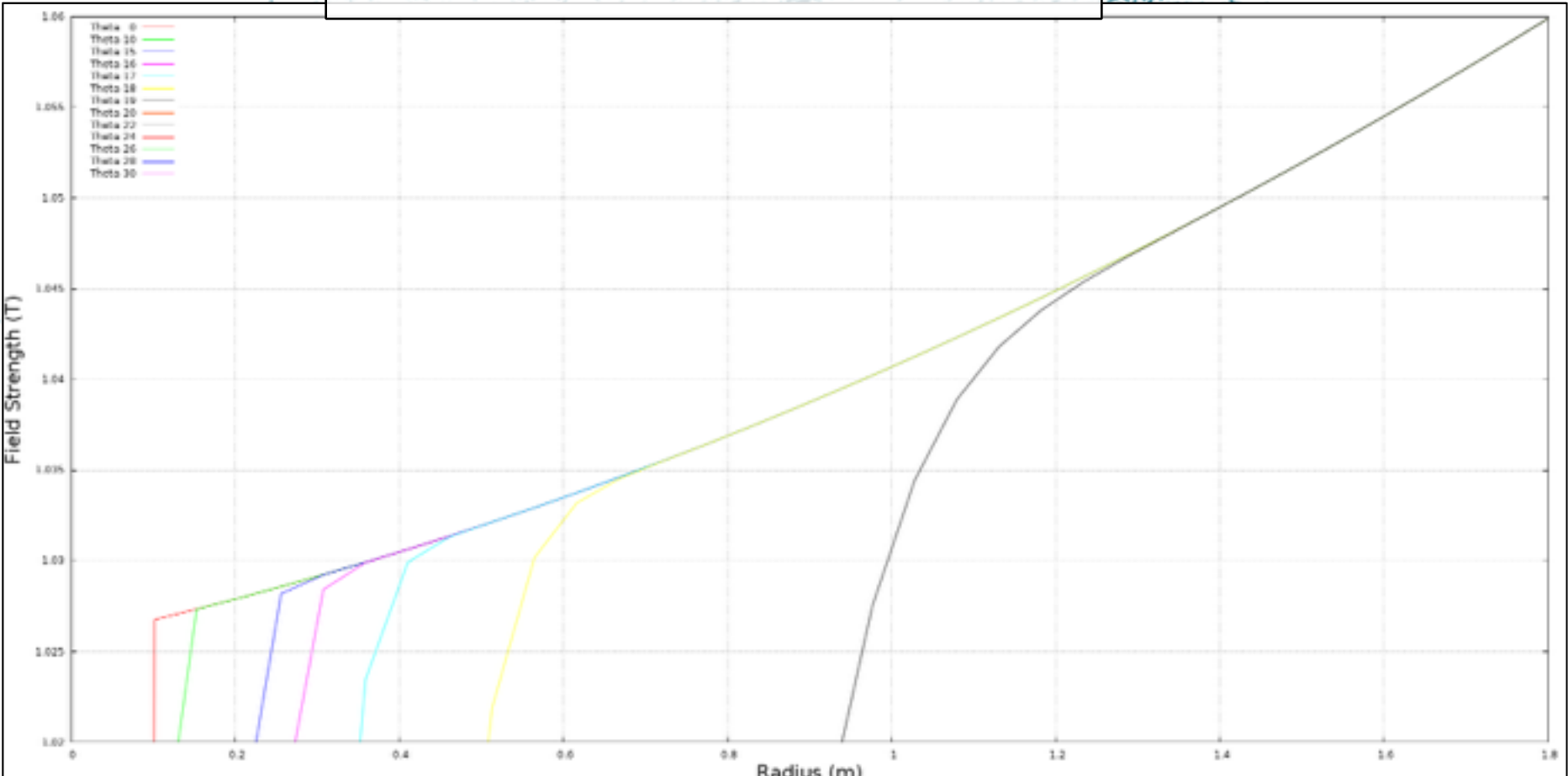


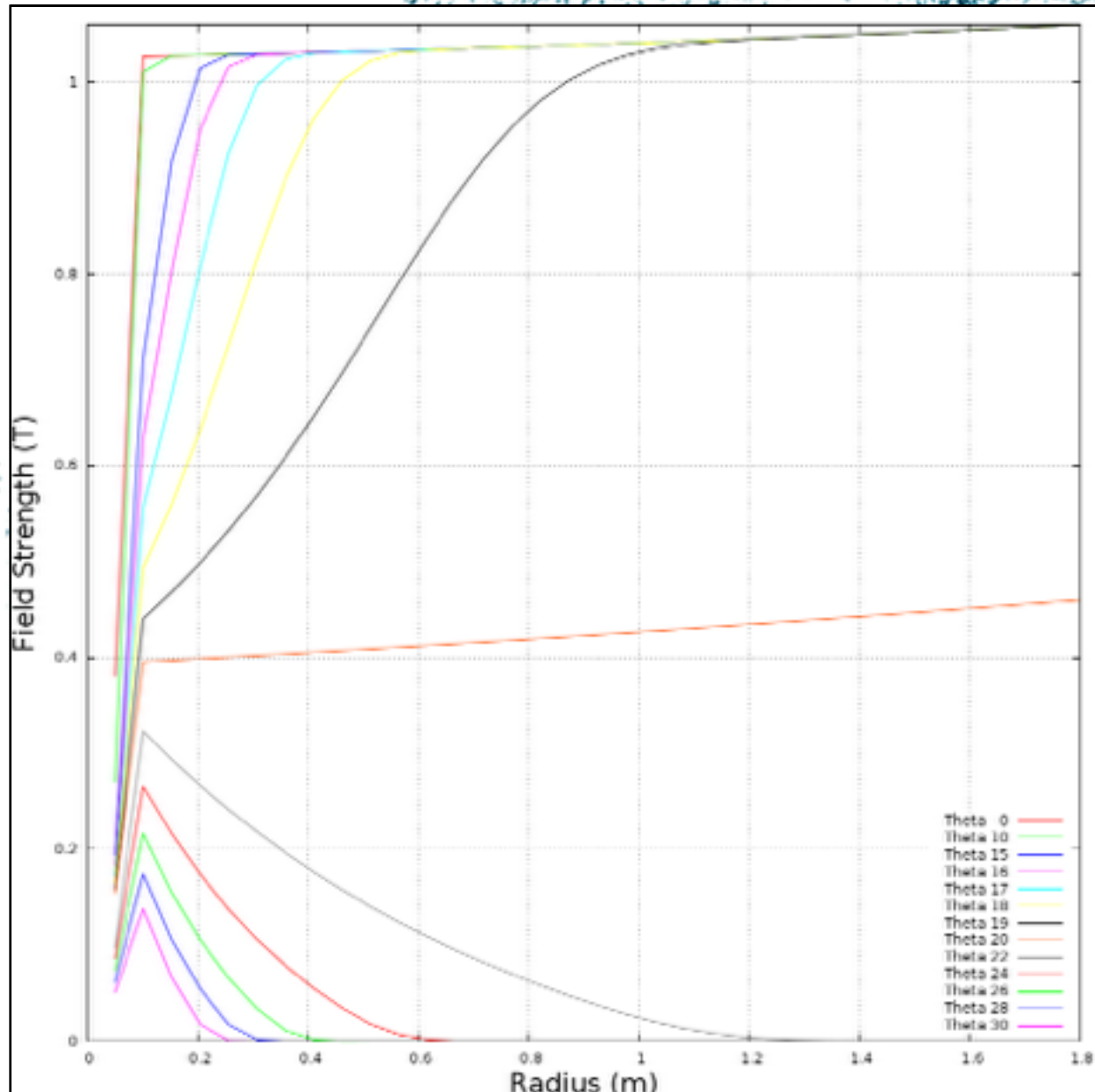
## The machine

- 4 Separate Sector Magnets
- Radially varying field
- Edge Fields provide Focusing



## Radial Field variation





## Edge Profile

- Field drop off at edge varies with radius
- Provides focusing/defocusing effects



## PIP (Proton Isotope Producer)

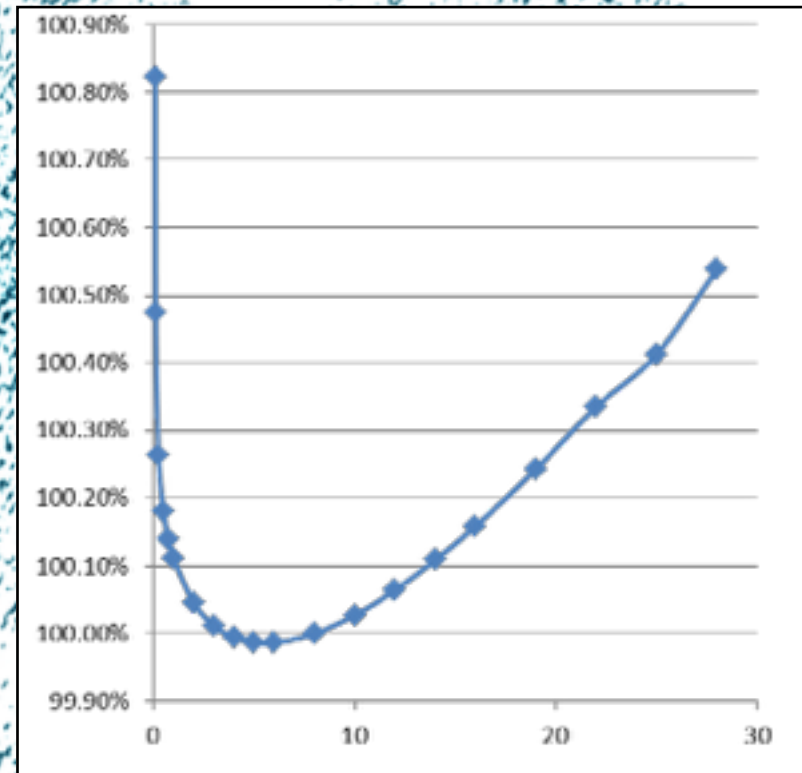
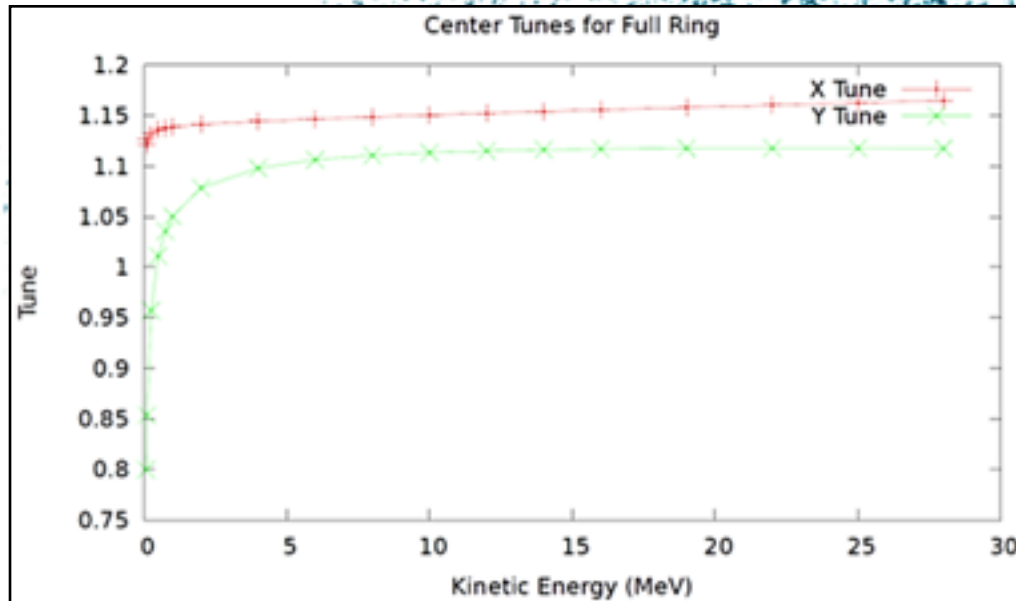
### 4 Possible versions:

- 4 MeV - Neutron production for security applications
- 10 MeV - For production of ( $^{18}\text{F}$ ,  $^{11}\text{C}$ ,  $^{113\text{m}}\text{In}$ ,  $^{87\text{m}}\text{Sr}$  and  $^{121}\text{I}$ )
- 14 MeV - For production of ( $^{99\text{m}}\text{Tc}$ )
- 28 MeV - For production of ( $^{211}\text{At}$ )

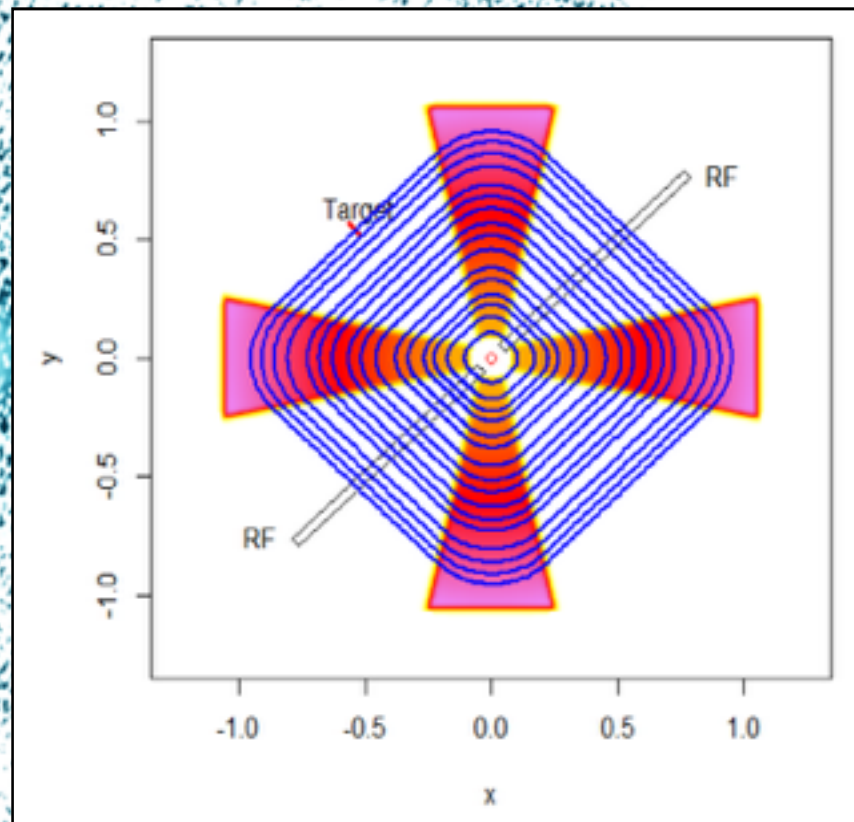
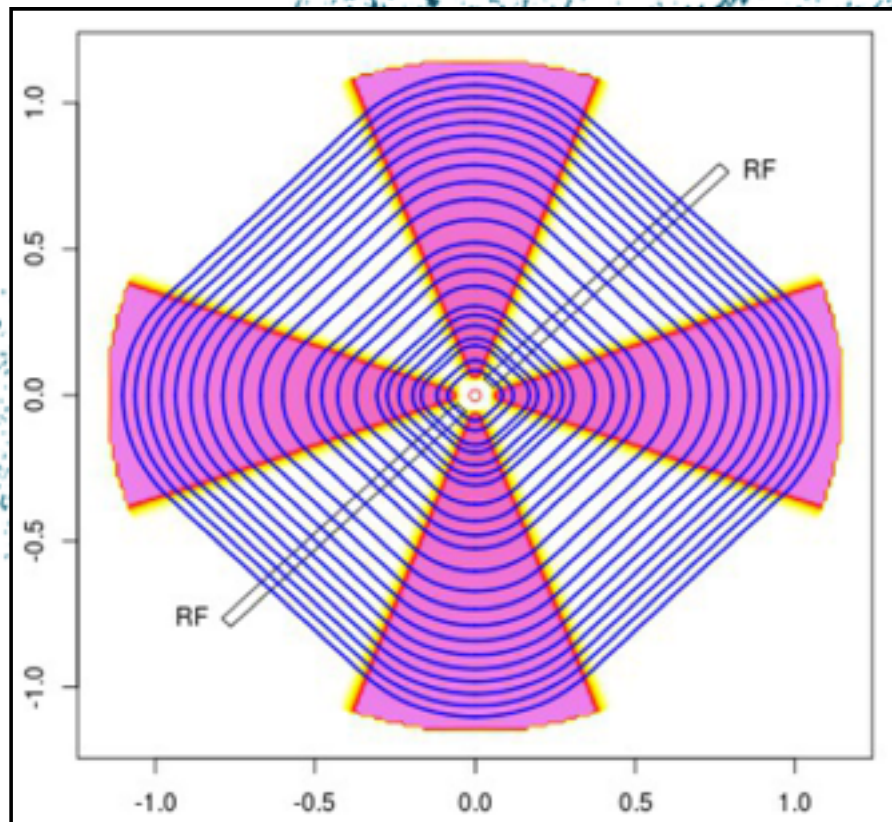


# Tune and Time of Flight

- Vertical Tune passes through an integer resonance
- Machine is Isochronous to within 1%

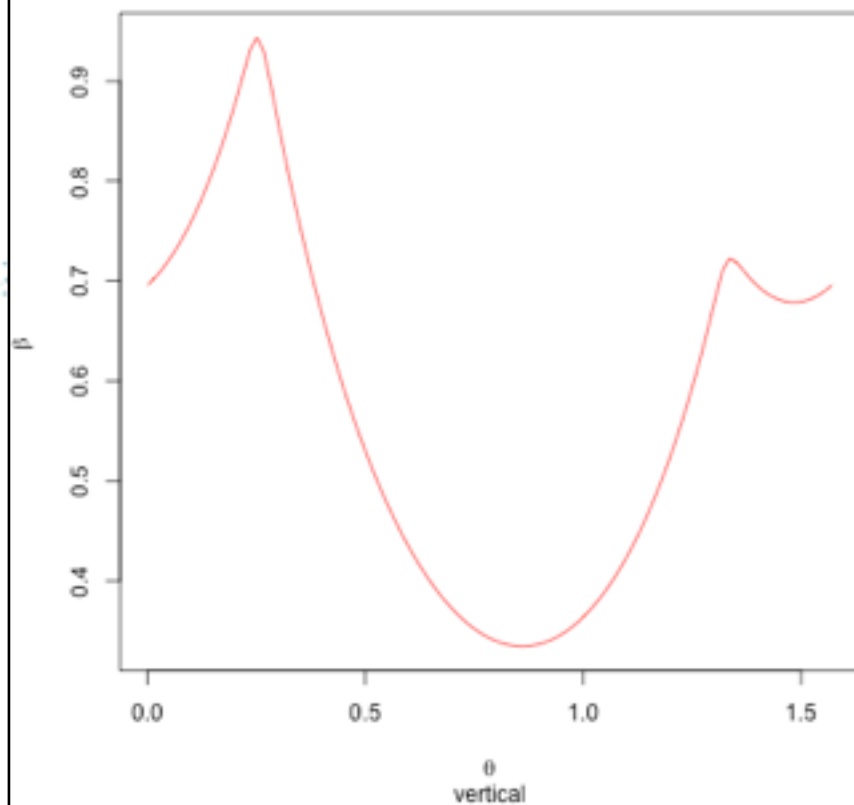


# PIP(14 and 4) using internal code

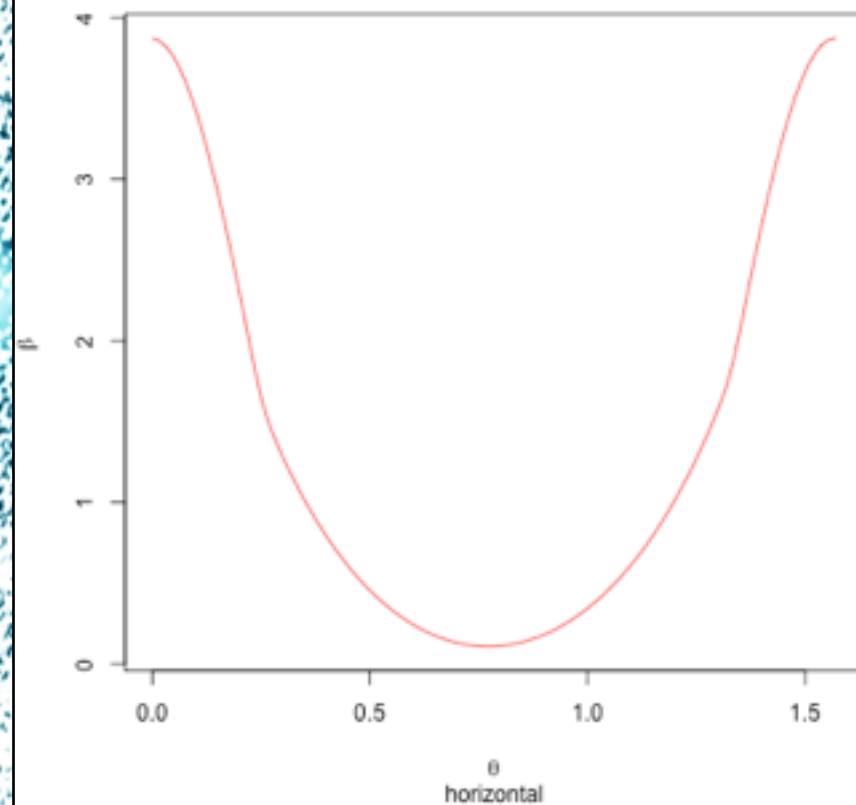


# Beta Function

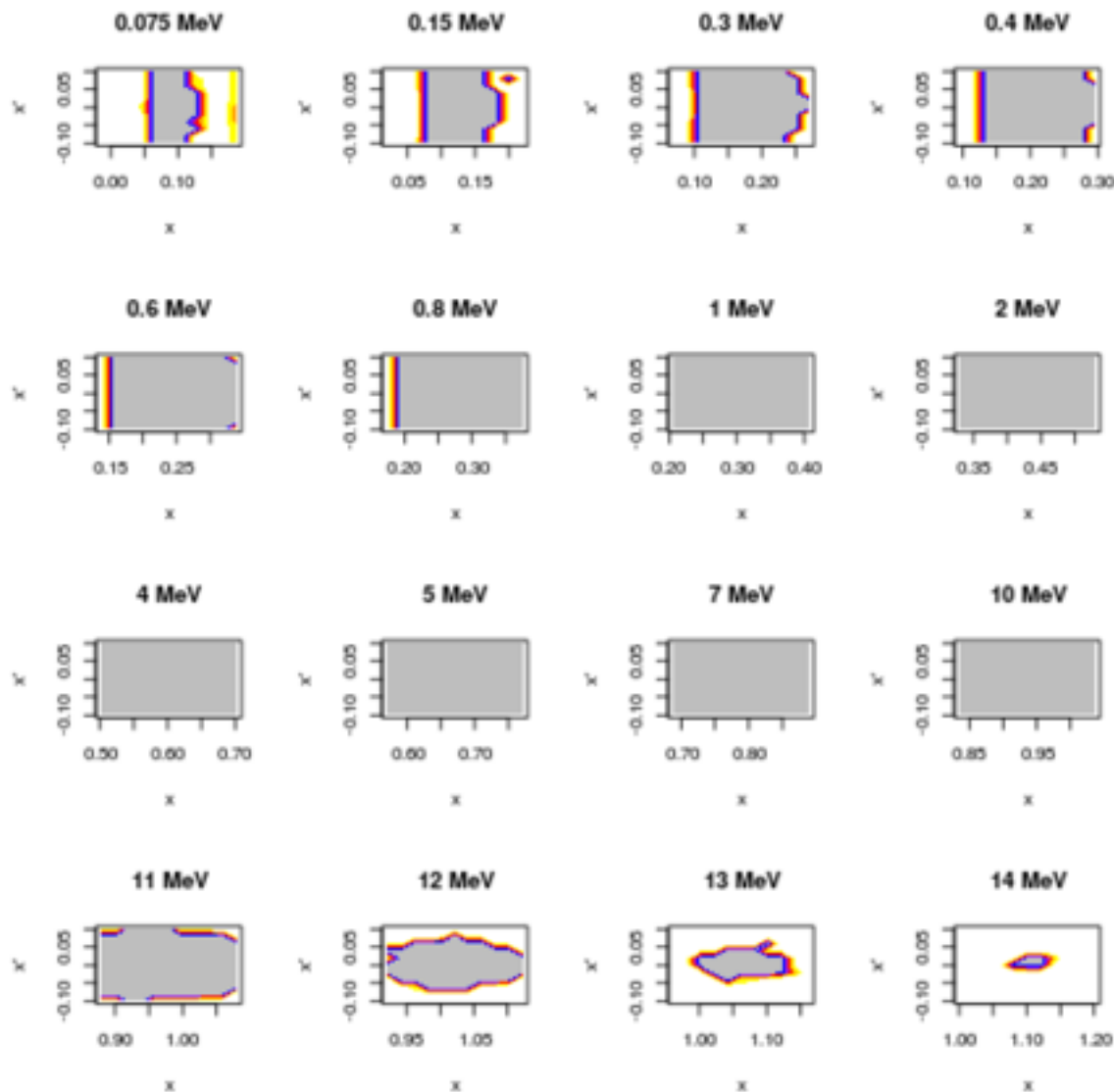
Twiss Parameters



Twiss Parameters



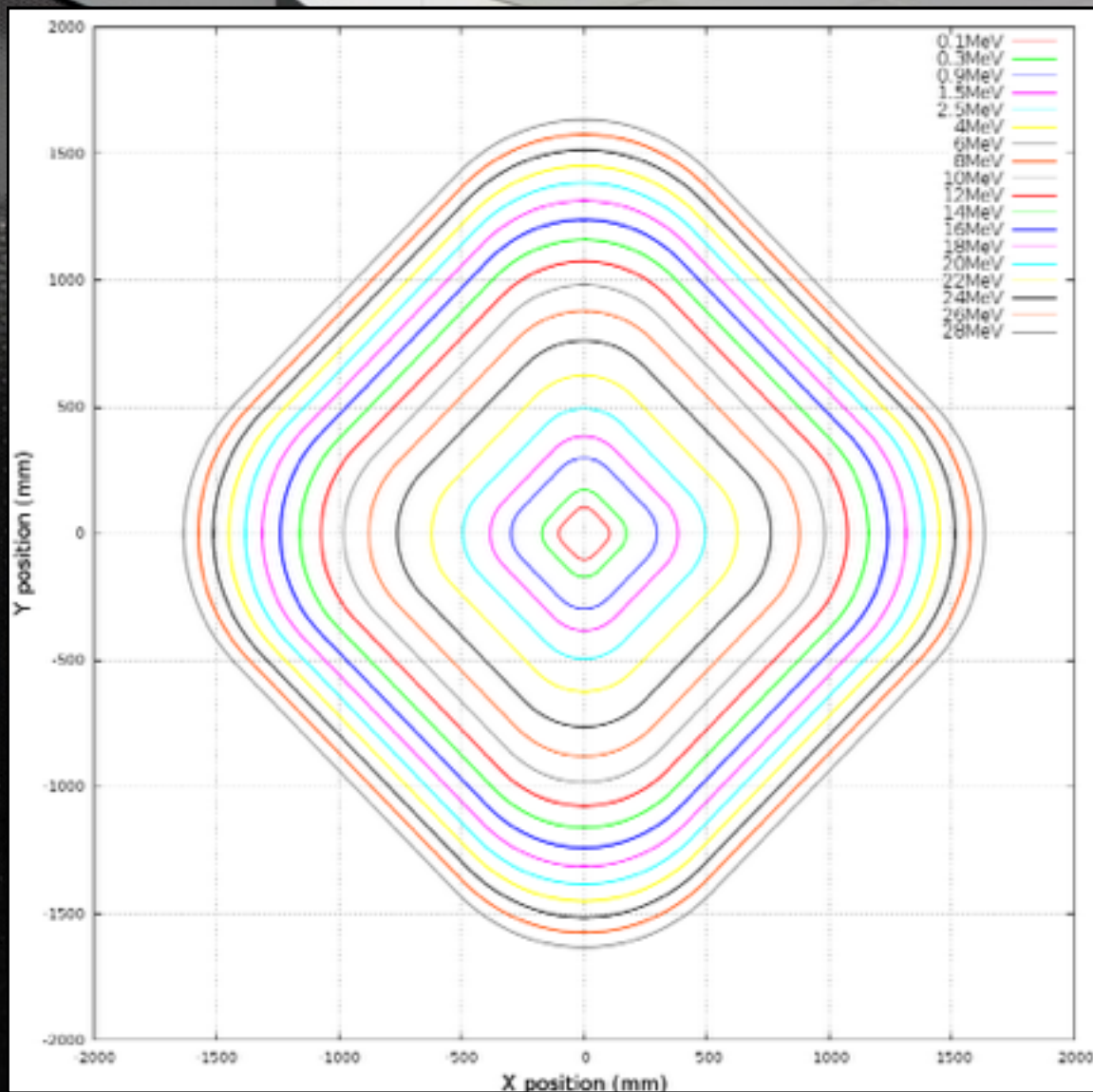
# Acceptance



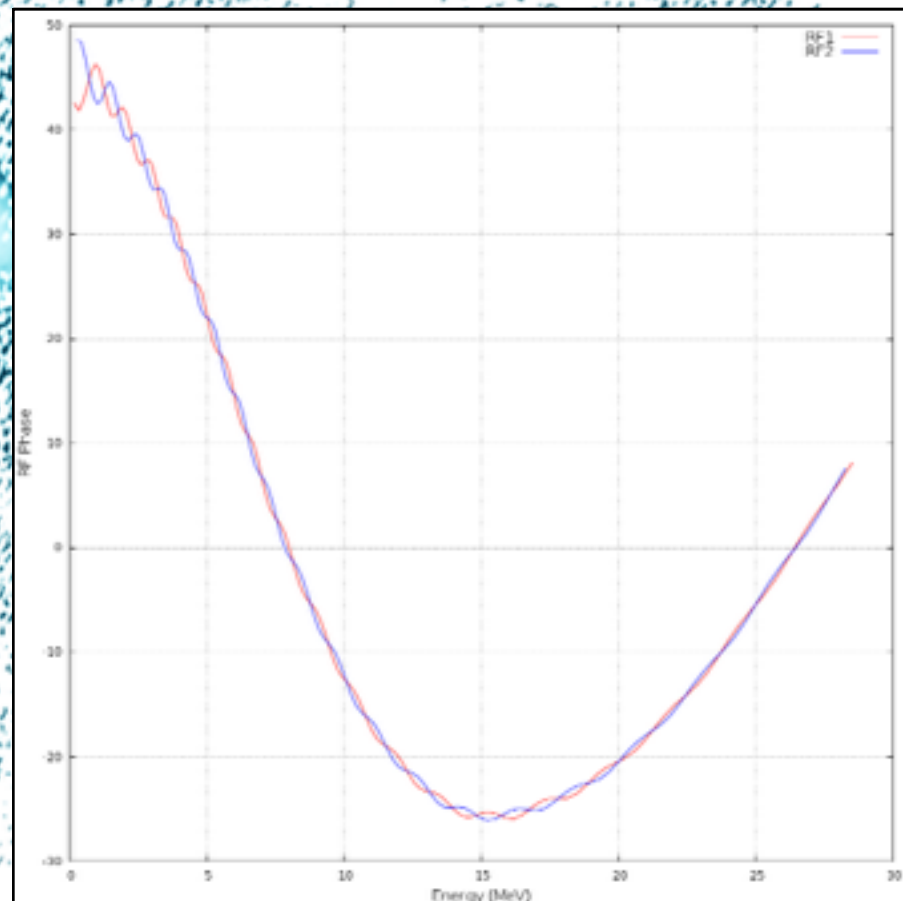
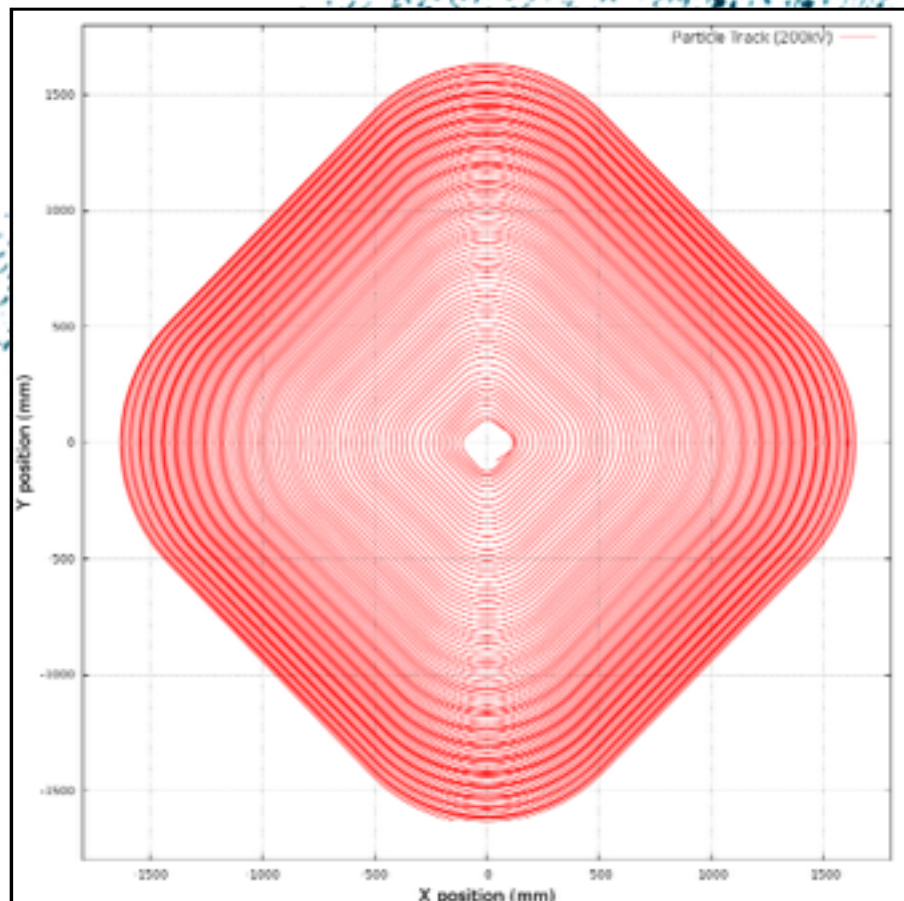
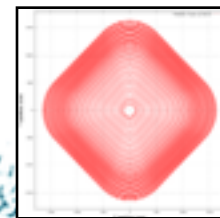
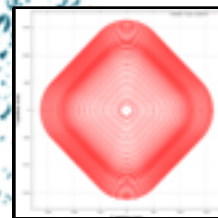
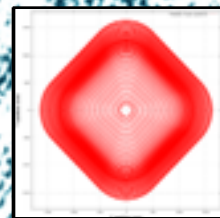
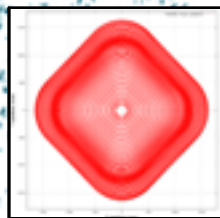
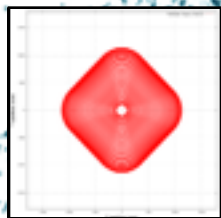
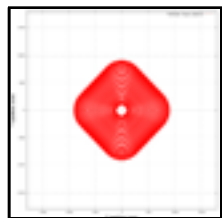
- Acceptance Very large
- Important for recirculation



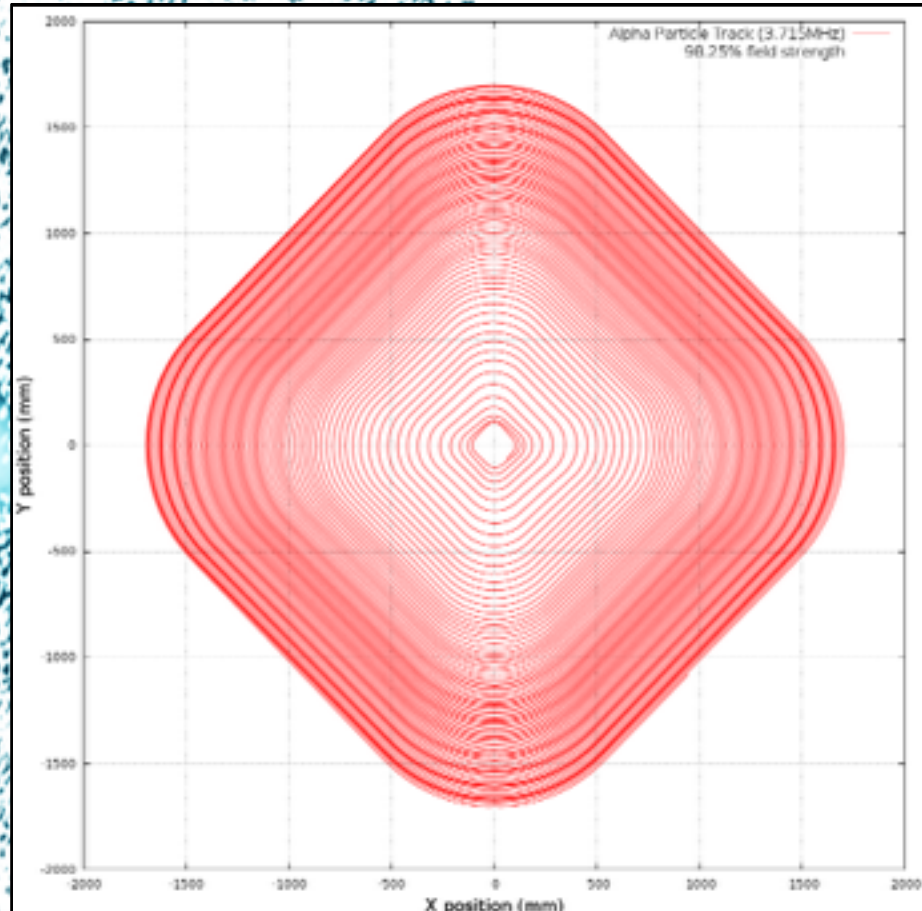
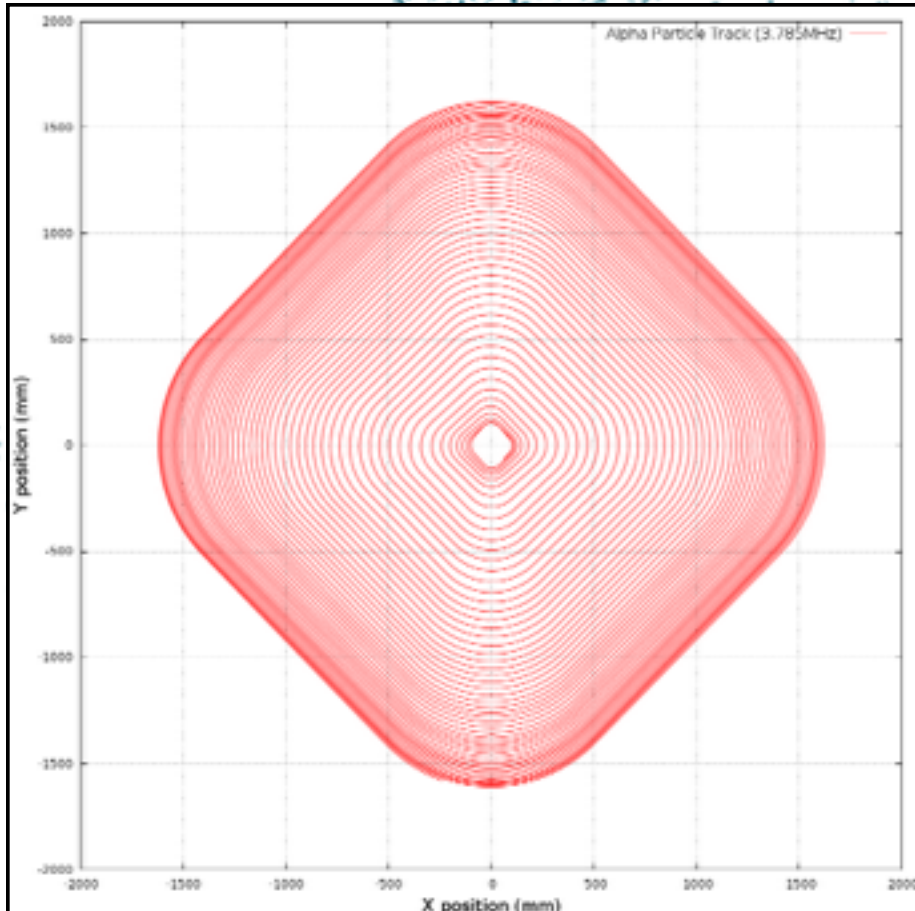
# Studies with OPAL



# Studies with OPAL



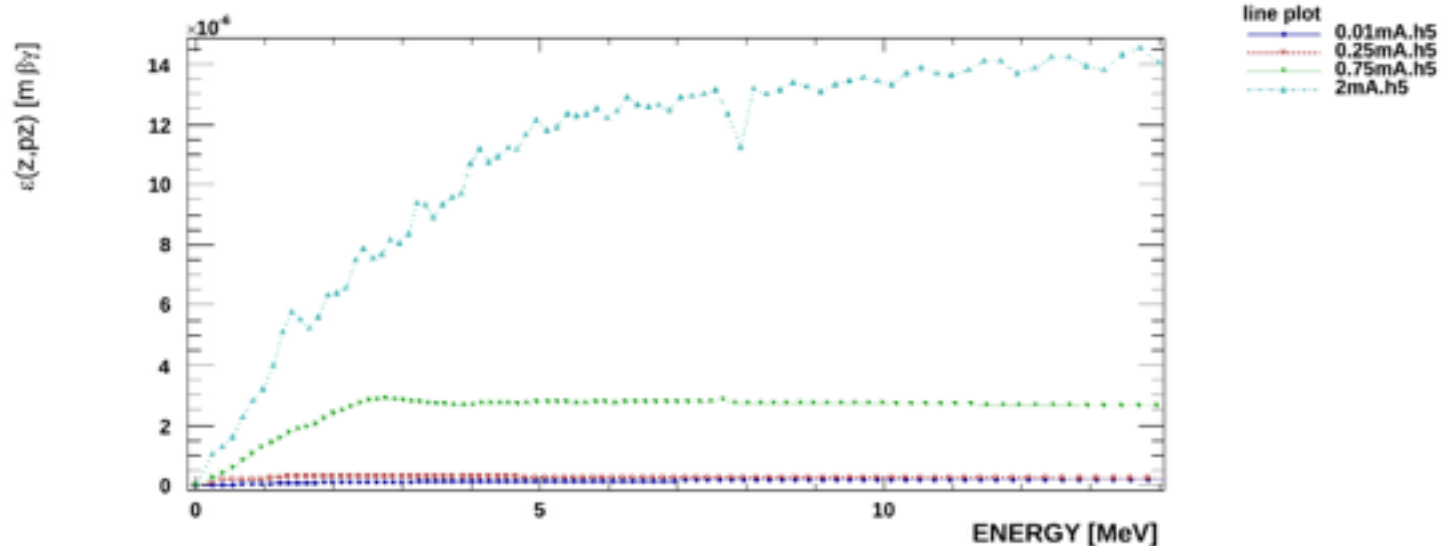
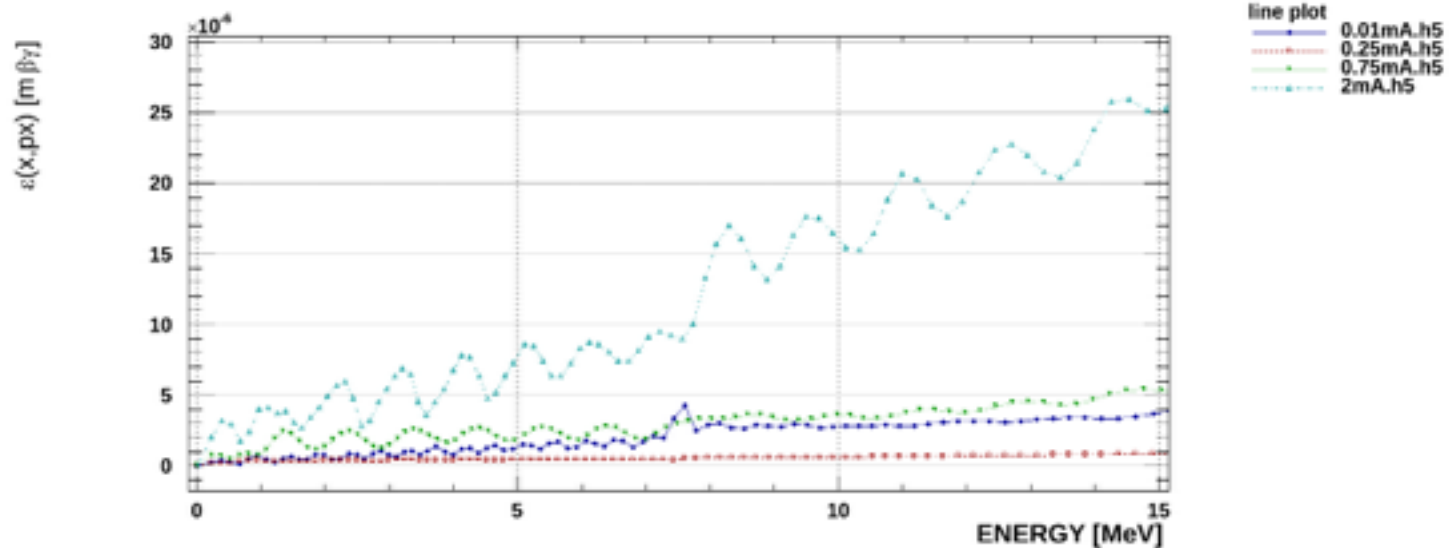
# Accelerating Alphas



Requires a frequency of 3.765 - 3.795 MHz  
1.35 - 2.15 % higher than half the proton RF

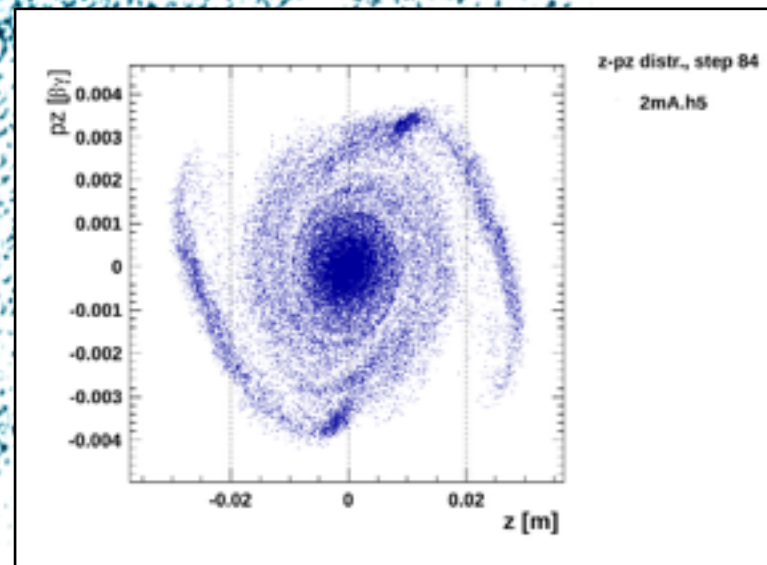
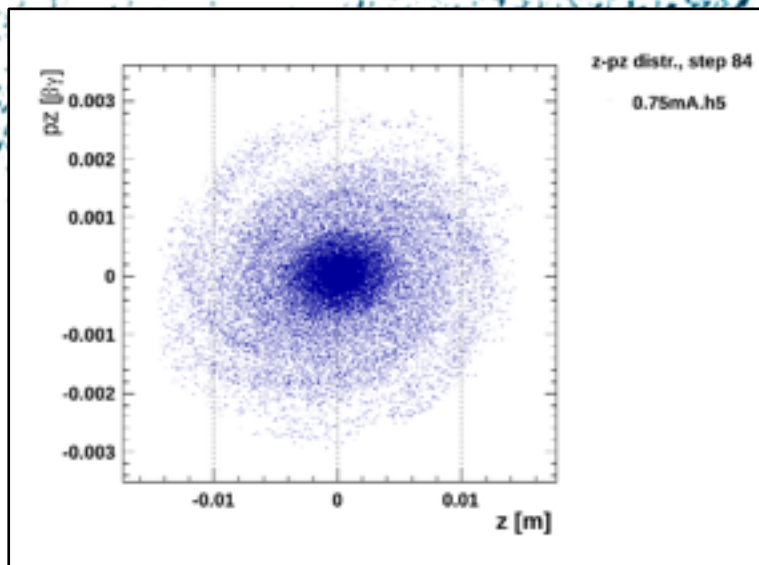
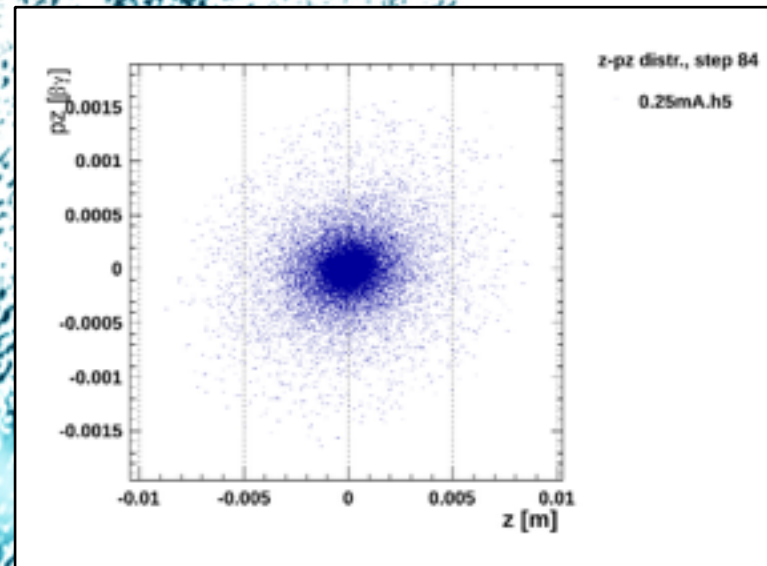
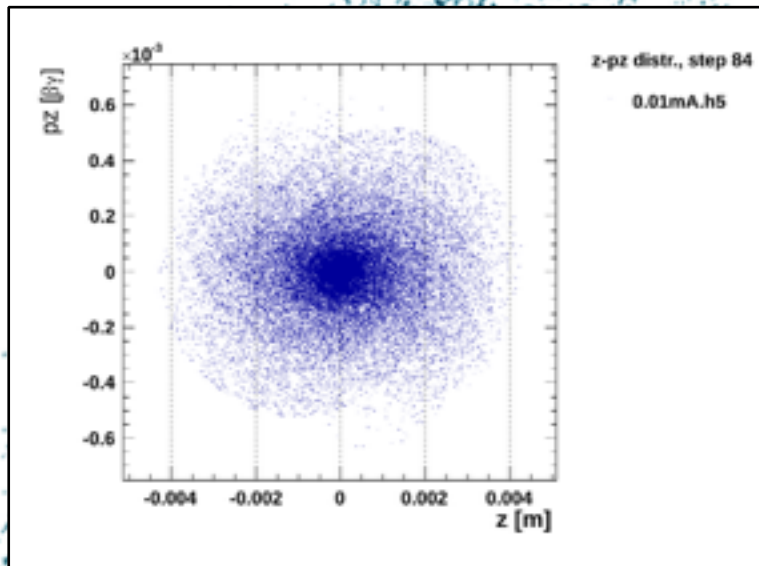
RF Frequency of 3.715 (Half the proton RF)  
Requires scaling the fields to 98.25%

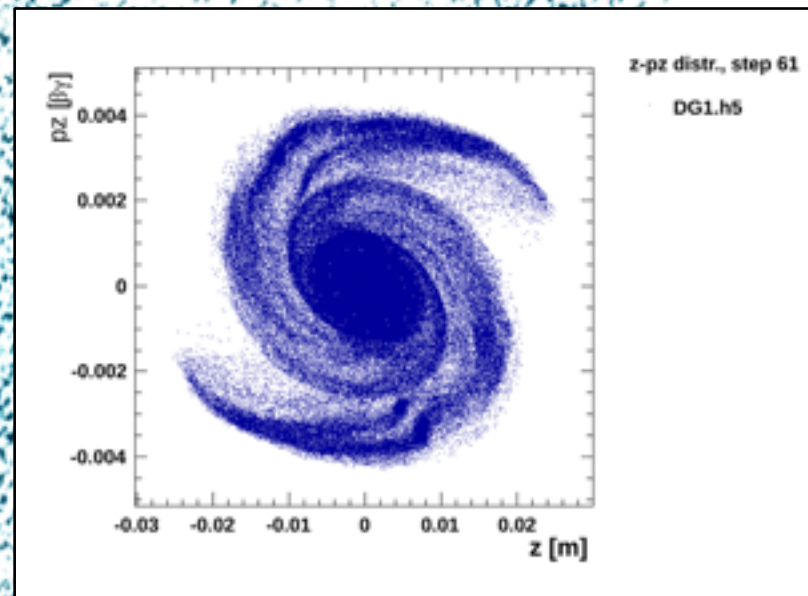
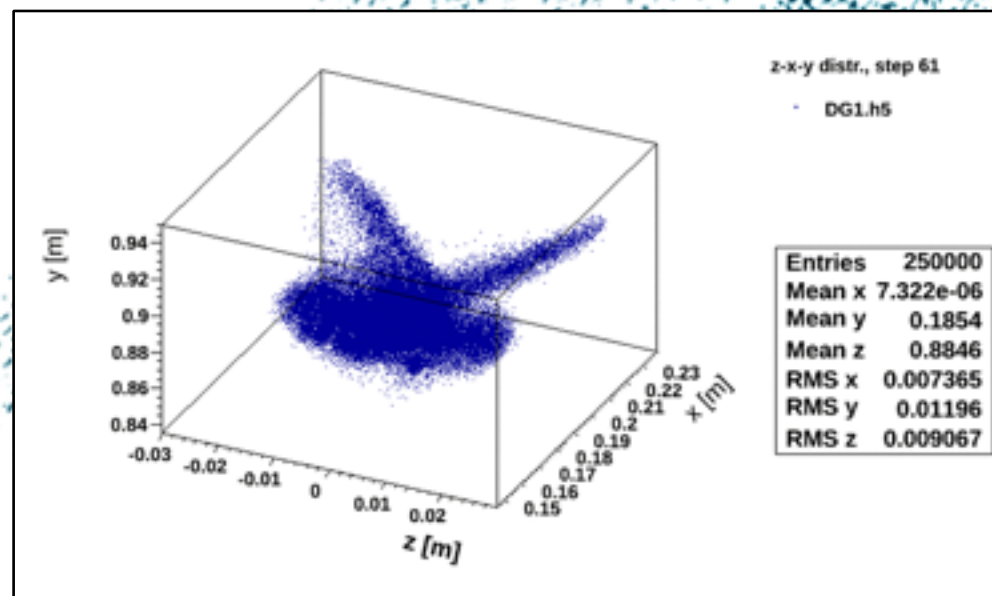






# Vertical Phase Space





# Target: Internal or External

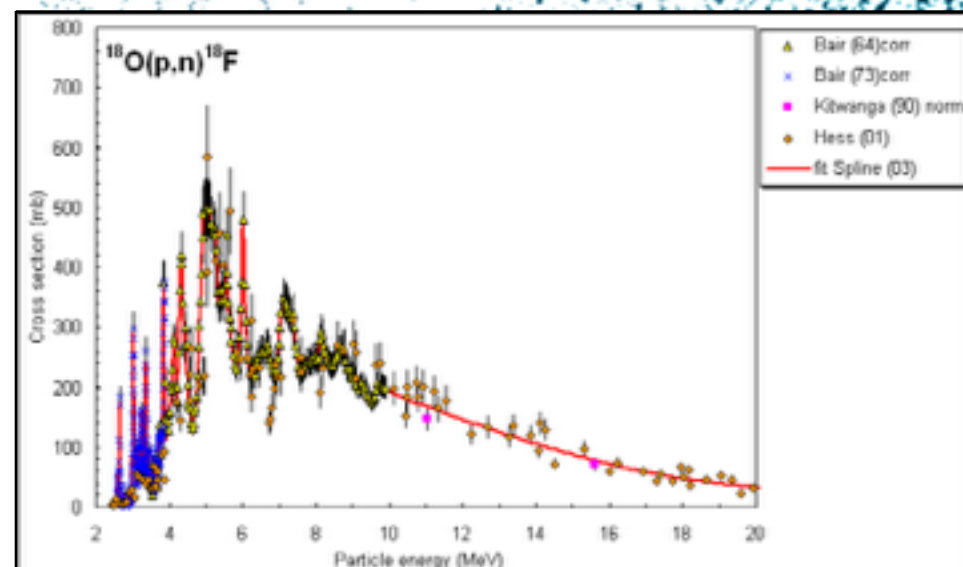
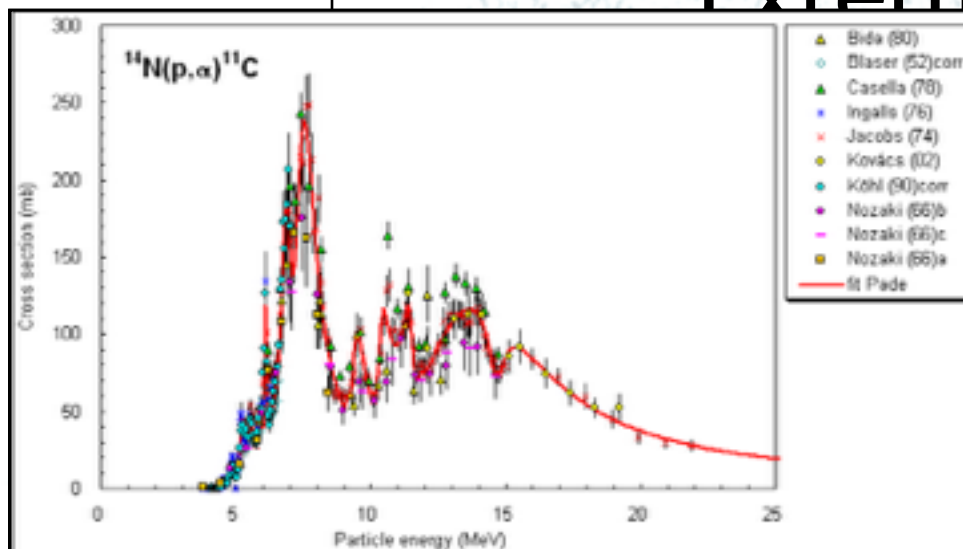
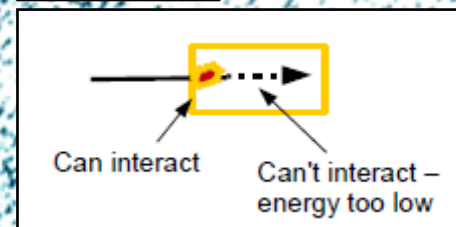
Internal

External

Can interact

Can't interact –  
energy too low

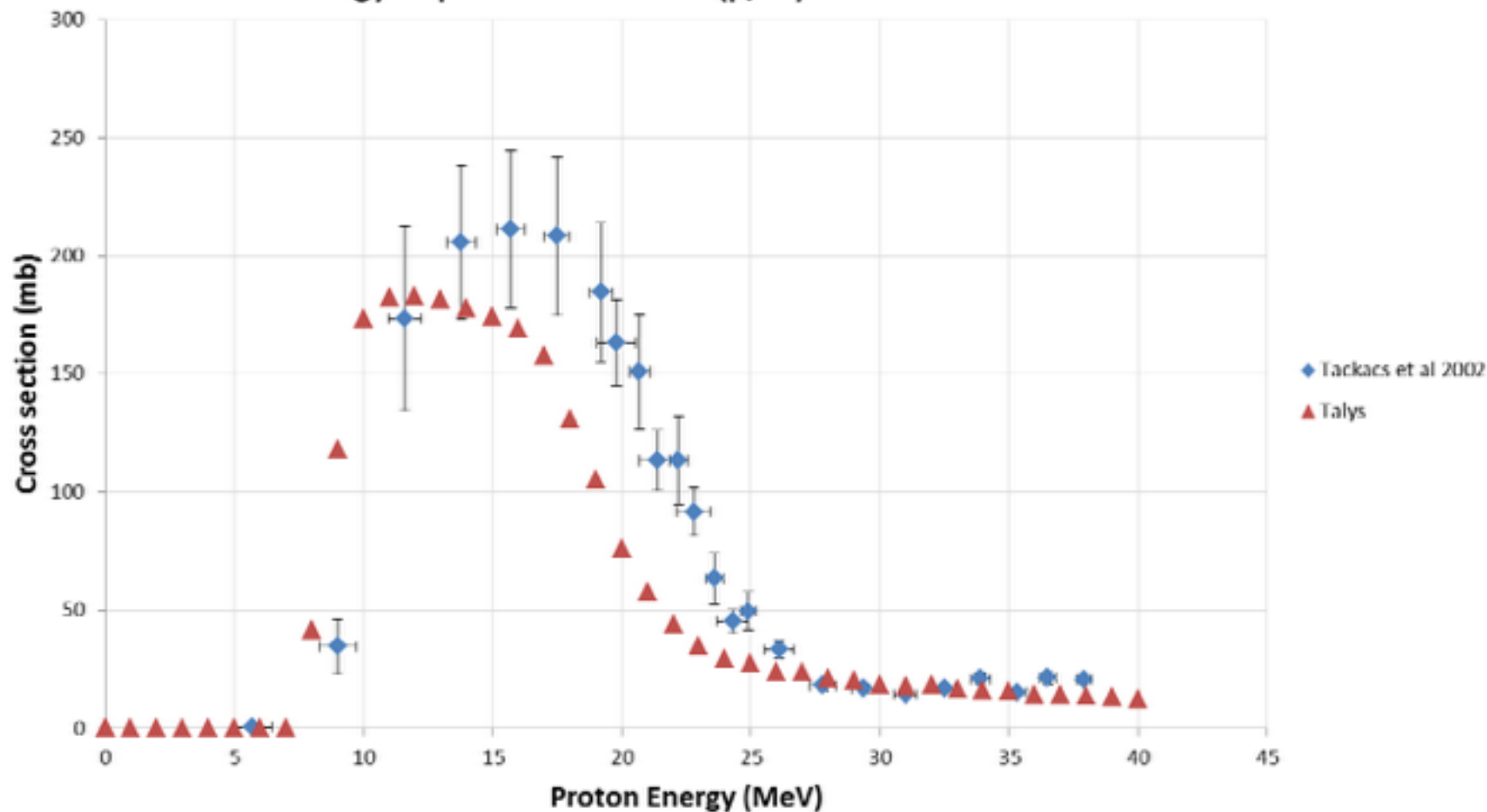
Can interact





# Molybdenum Target

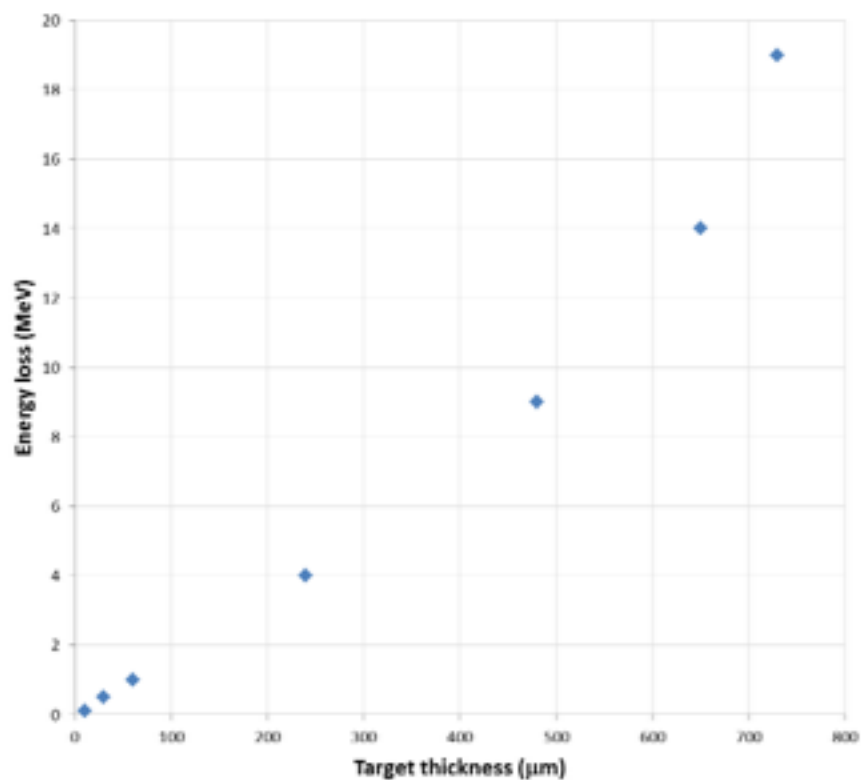
Energy Dependence of  $\text{Mo}^{100}(\text{p},2\text{n})\text{Tc}^{99\text{m}}$  Cross Section



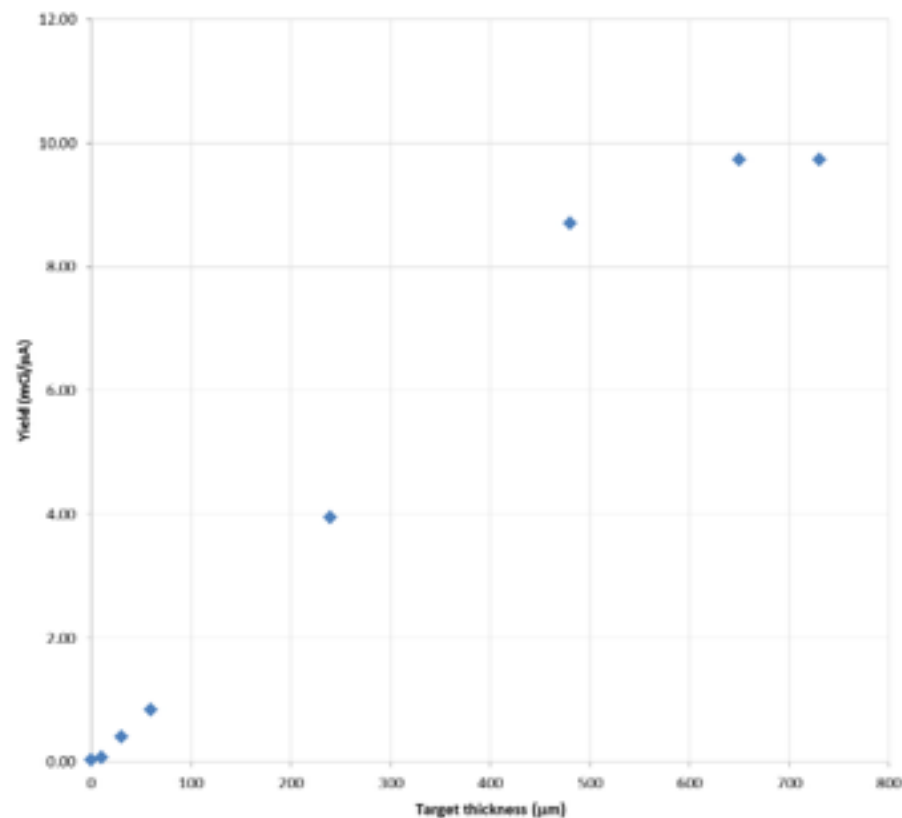


# Target Thickness

Attenuation of 19MeV Proton Beam through a  $\text{Mo}^{100}$  Target



Yields for 2mA beams for 1hr



# Further work

- Tracking Studies: Investigate integer tune crossing, Include real field map, continue studies with new iterations of field map.
- Magnet studies: Design feasibility, Central region and injection
- Target Studies and Extraction: Internal/ External, Charge Exchange/electrostatic deflector