A Compact and High Current Accelerator for Radioisotope Production

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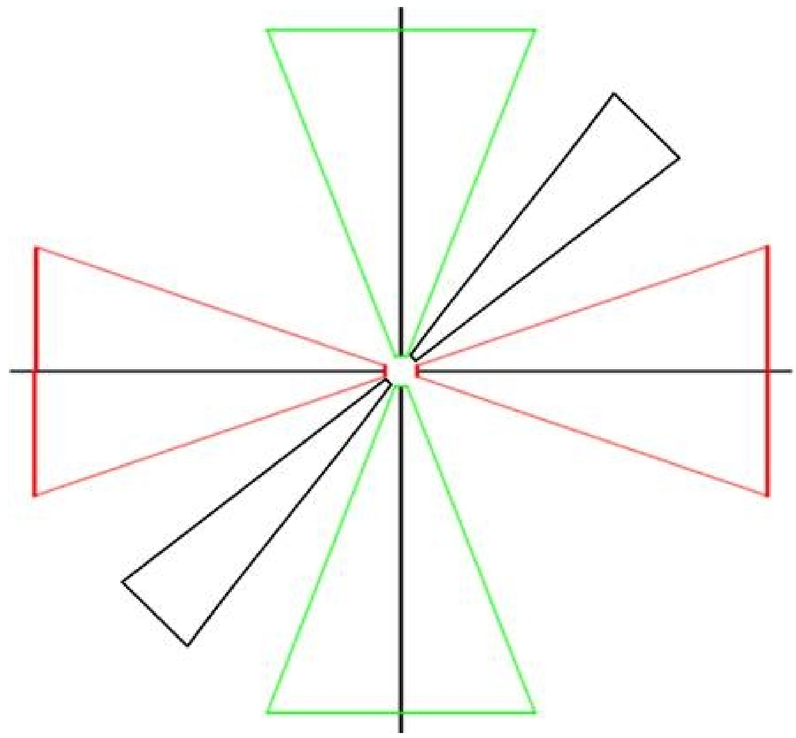
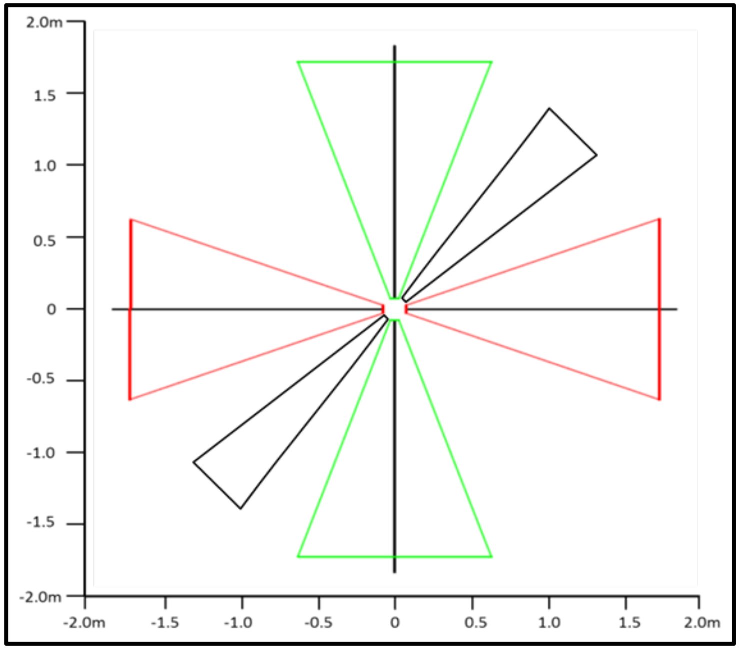


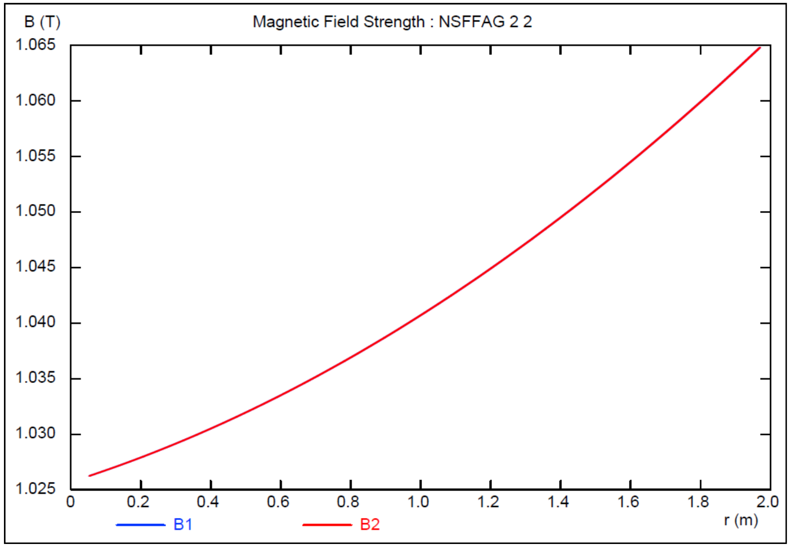
Contents

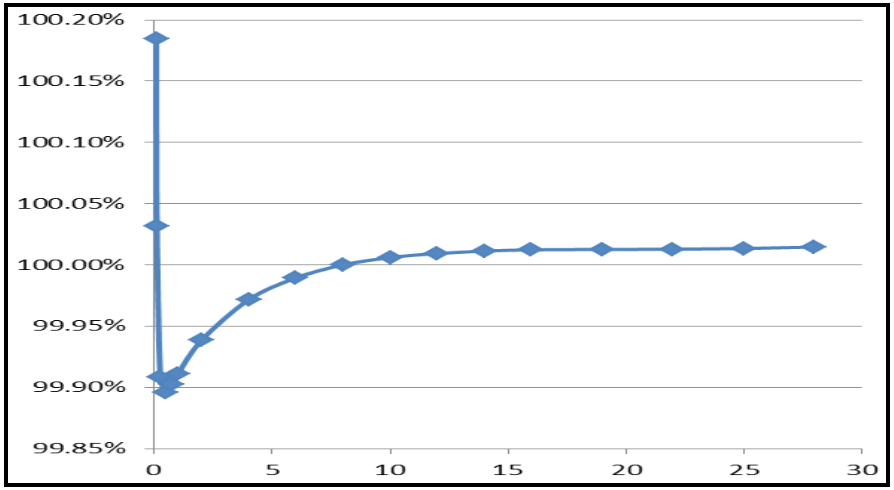
- Overview of design
- Machine characterisation
- Space charge studies
- Target option

- Small cyclotron type FFAG
- Non-Scaling
- Possible isotopes:
  - 18F(10MeV),
  - 99mTc(14MeV),
  - 211At(28MeV).

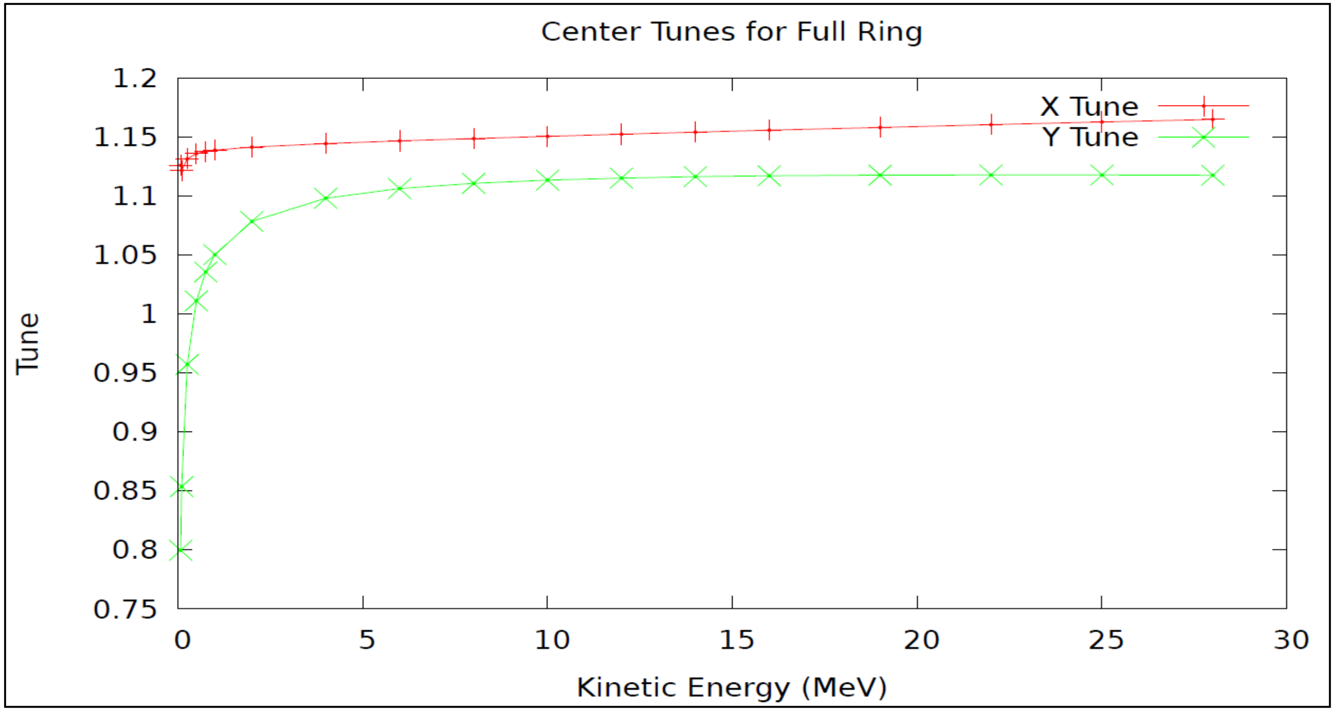


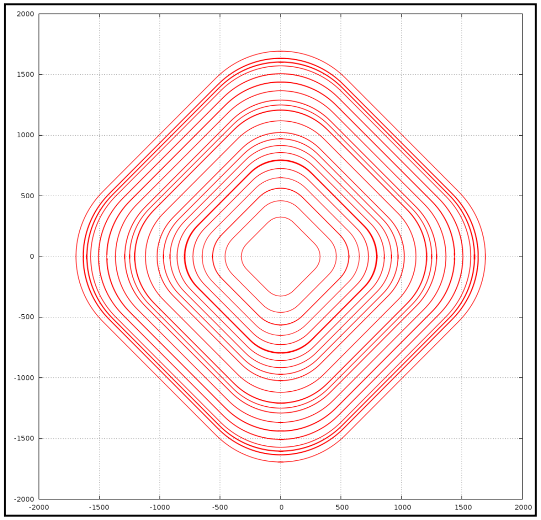
- 4 Sectors
- Radially varying magnetic field
- Focusing from Gradient, Edge and Weak focusing.
- 2 RF cavity's
- Isochronous to within ±0.5%





- Injection at 75keV, r=100mm
- Extraction at 28MeV, r=1700mm
- Vertical Tune passes through integer resonance



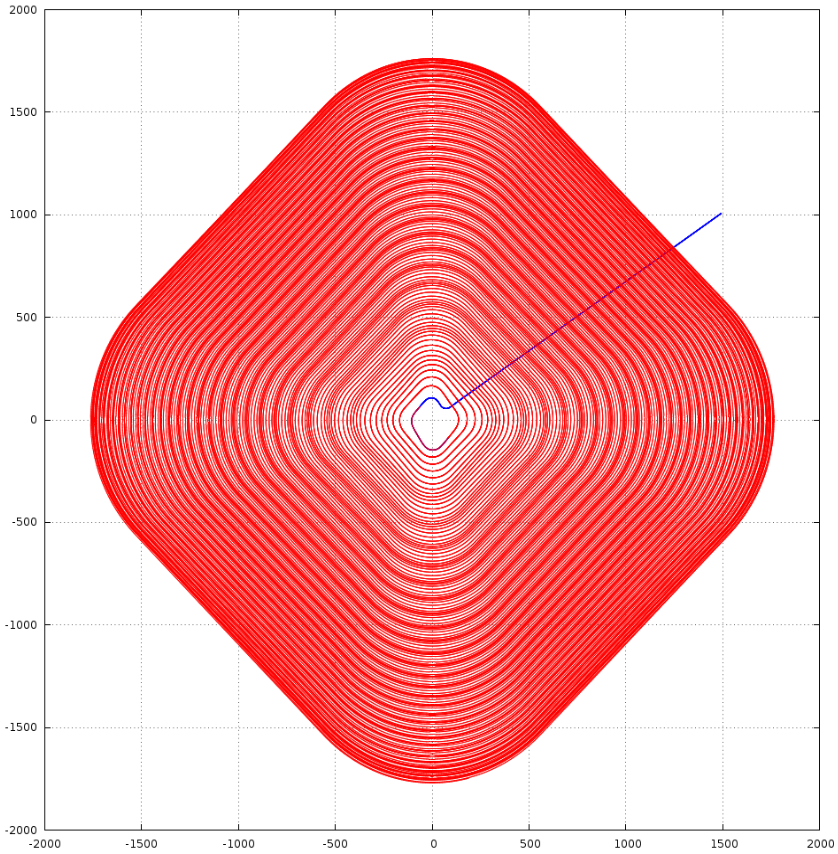


- 144 turns to reach 28MeV with 200kV per turn

- Injection by spiral inflector, Or perhaps radially?

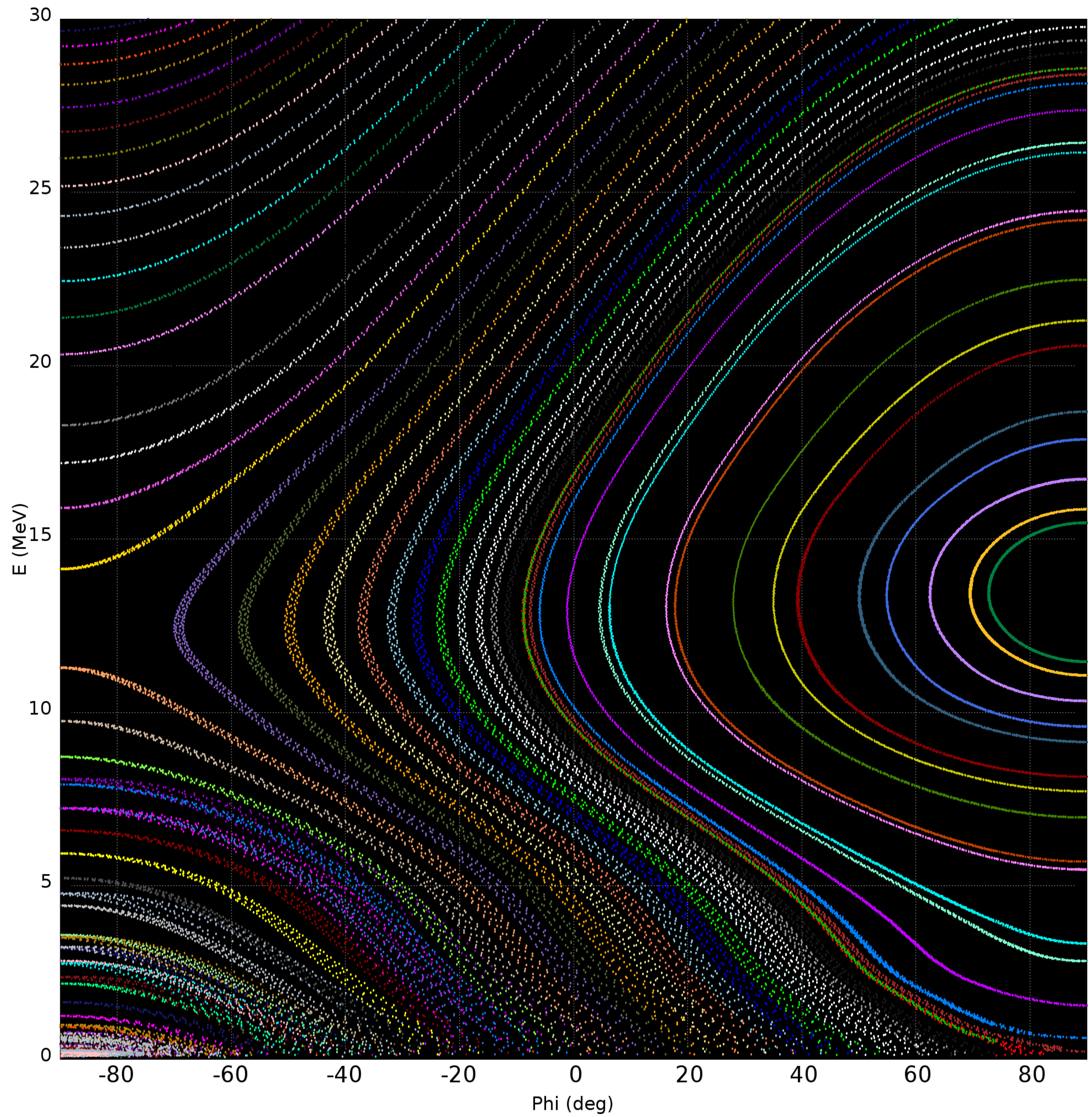
- Smaller versions for lower energy isotopes

- Could also accelerate He^{2+}



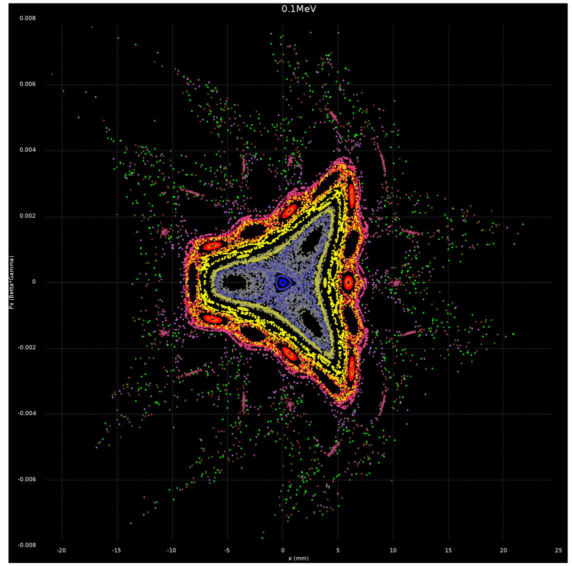
Longitudinal Phase Space

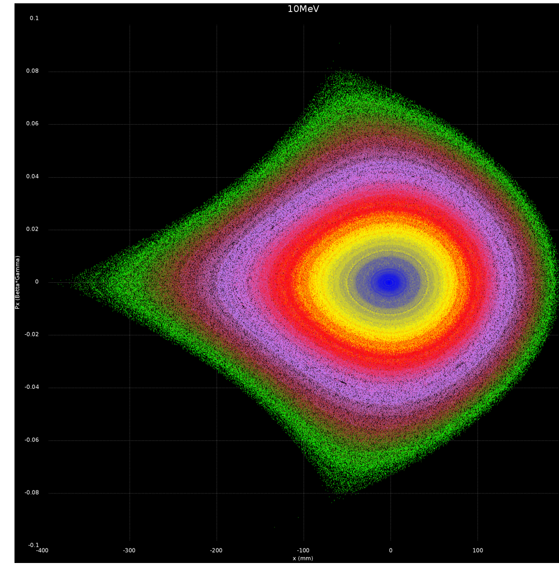
- Cross crest acceleration
- $\Delta\Phi_{acc}$=40°

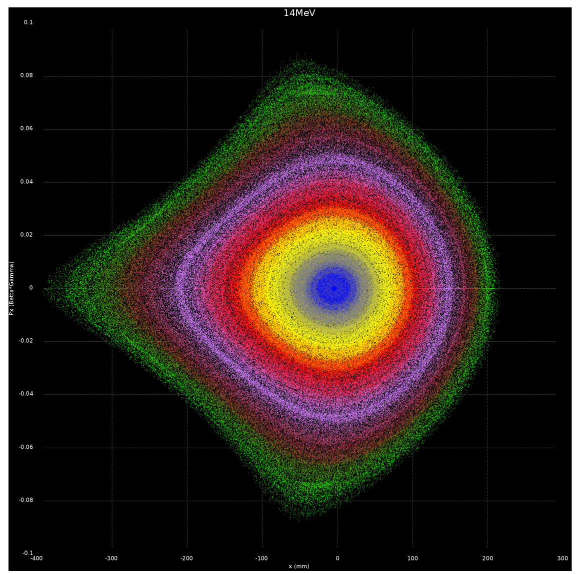


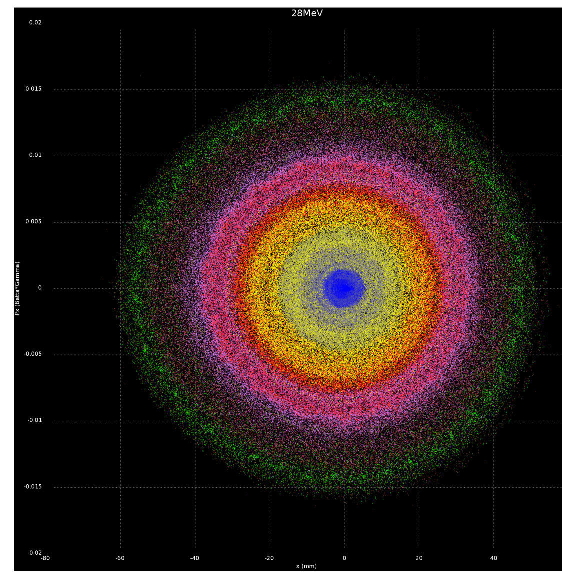
Acceptances

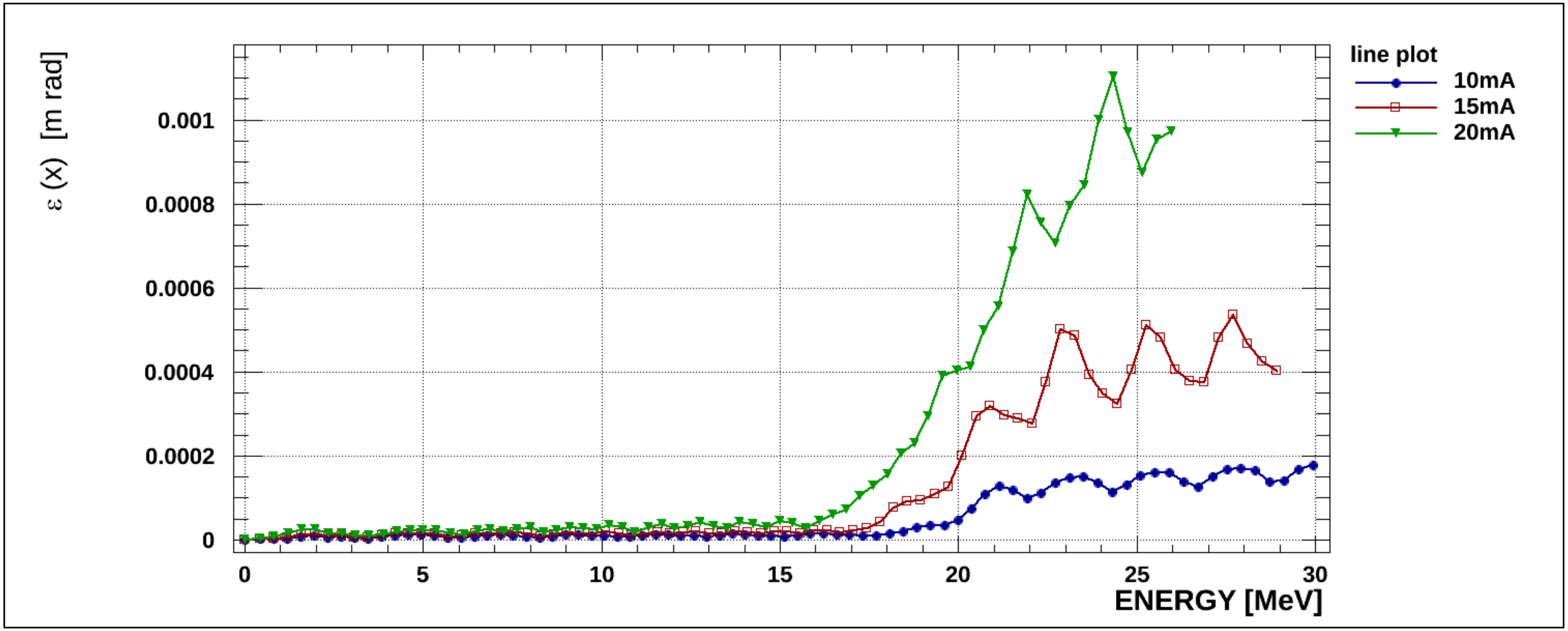
Energy (MeV)	Acceptance (π*m*mrad)
0.1	24.5
10	29.9
14	23.8
28	22.1

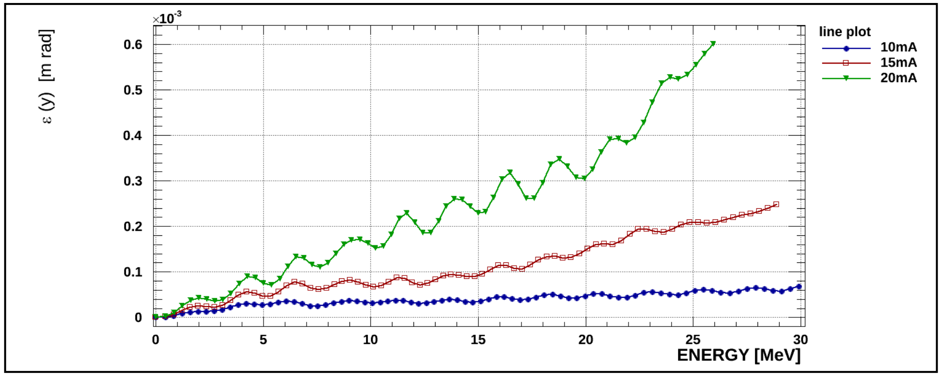


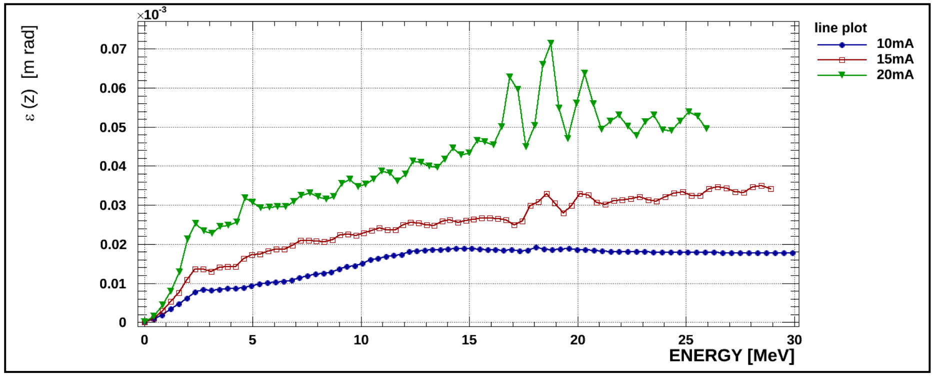




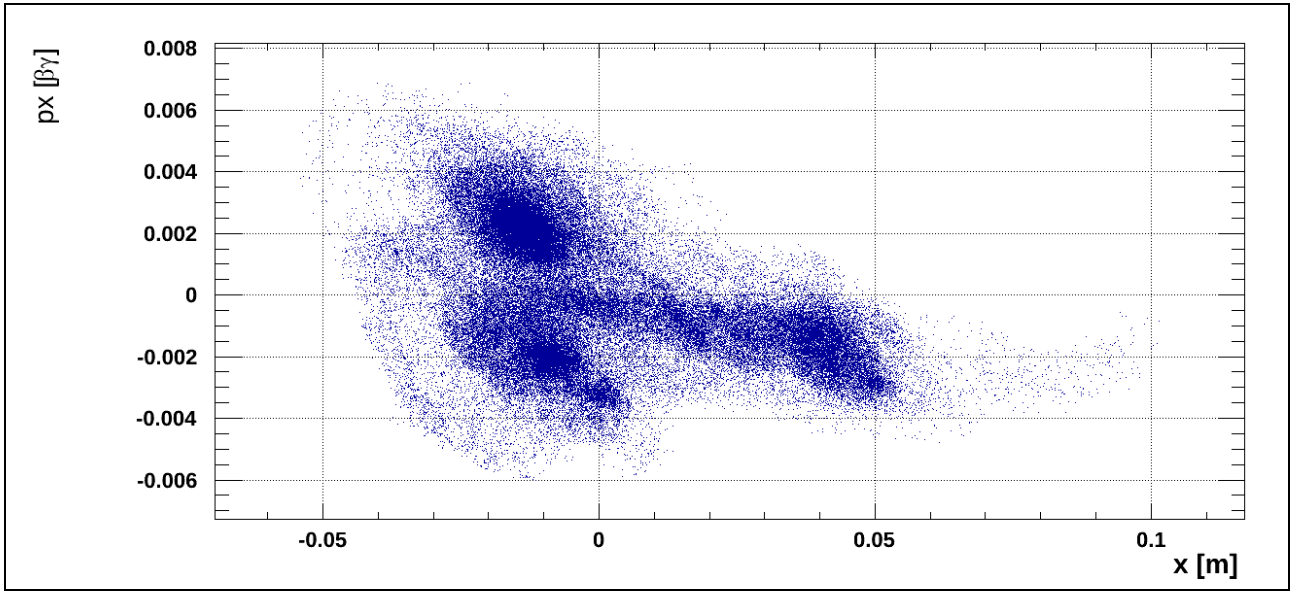



ε (x) [m rad]
0.001
0.0008
0.0006
0.0004
0.0002
0
0
5
10
15
20
25
30
ENERGY [MeV]
line plot
10mA
15mA
20mA

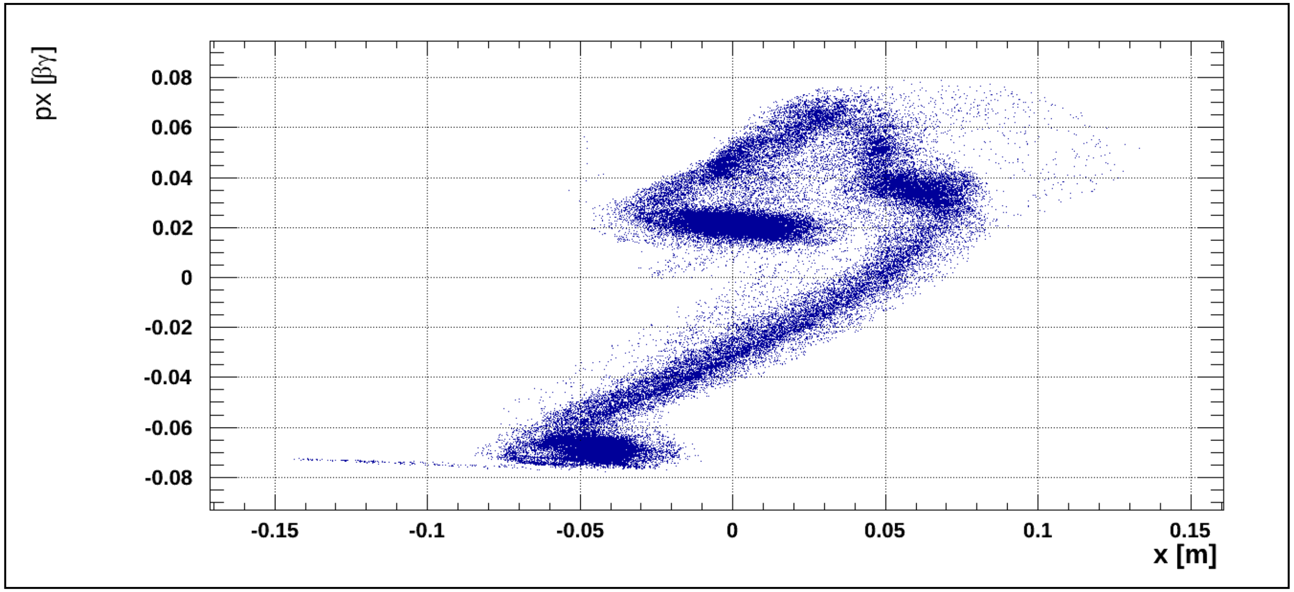

ε (y) [m rad]
×10⁻³
0.6
0.5
0.4
0.3
0.2
0.1
0
0
5
10
15
20
25
30
ENERGY [MeV]
line plot
10mA
15mA
20mA


ε (z) [m rad]
×10⁻³
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
5
10
15
20
25
30
ENERGY [MeV]
line plot
10mA
15mA
20mA

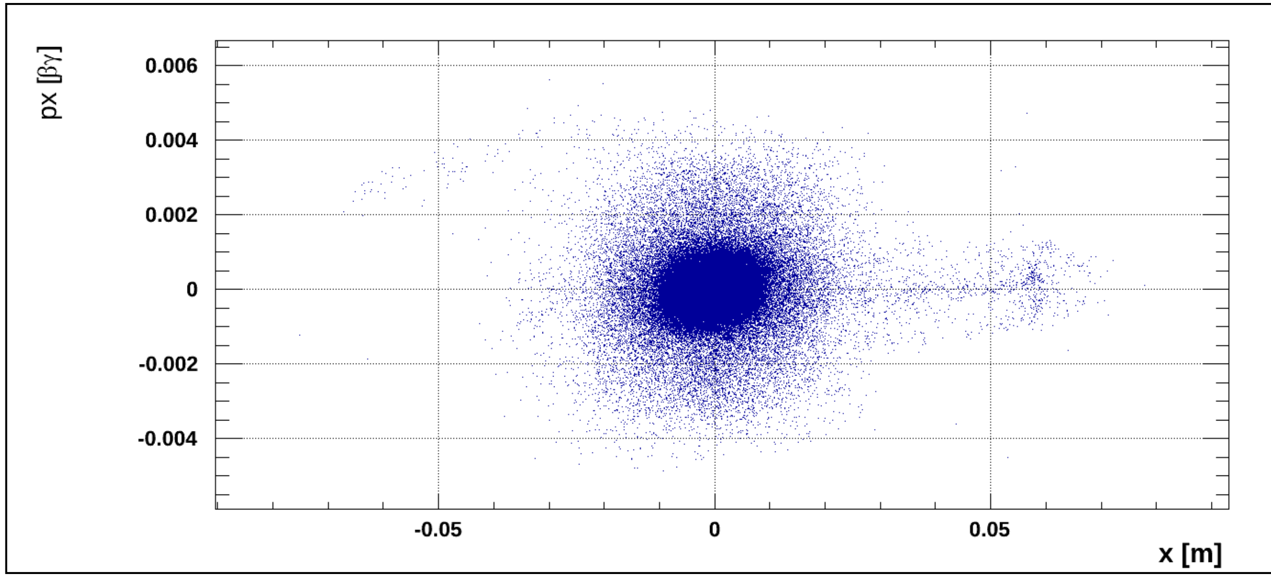
14MeV


px [βγ]
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.05
0
0.05
0.1
x [m]

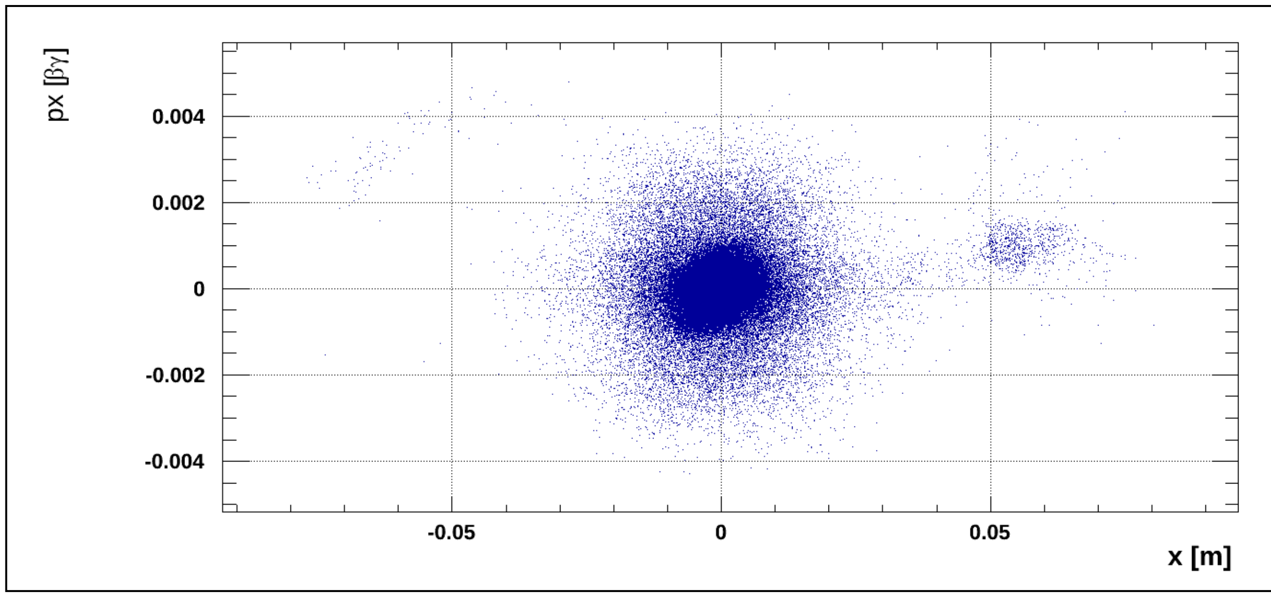
24MeV

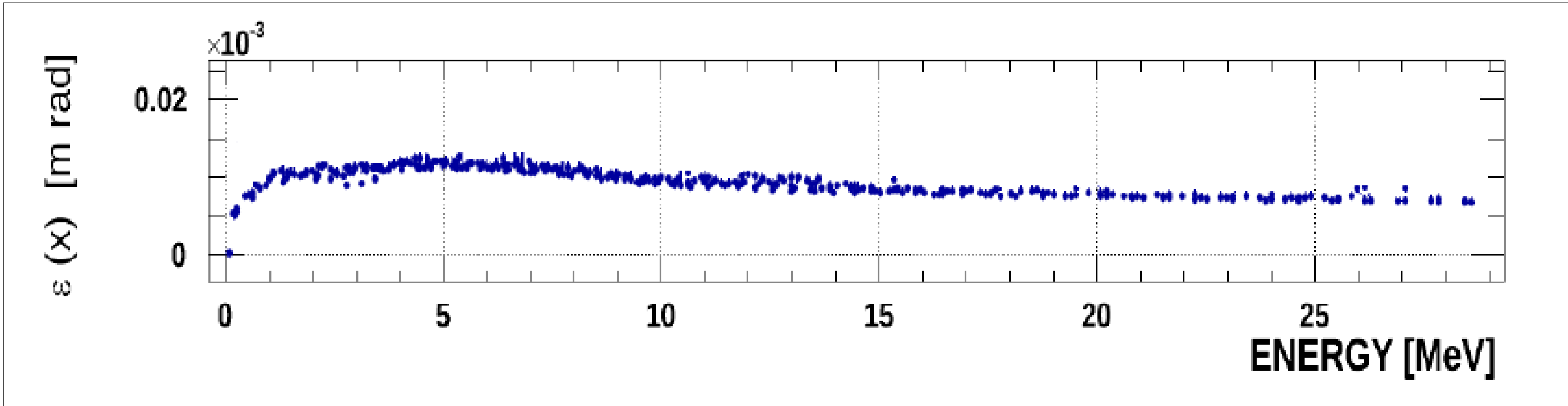

px [βγ]
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
x [m]

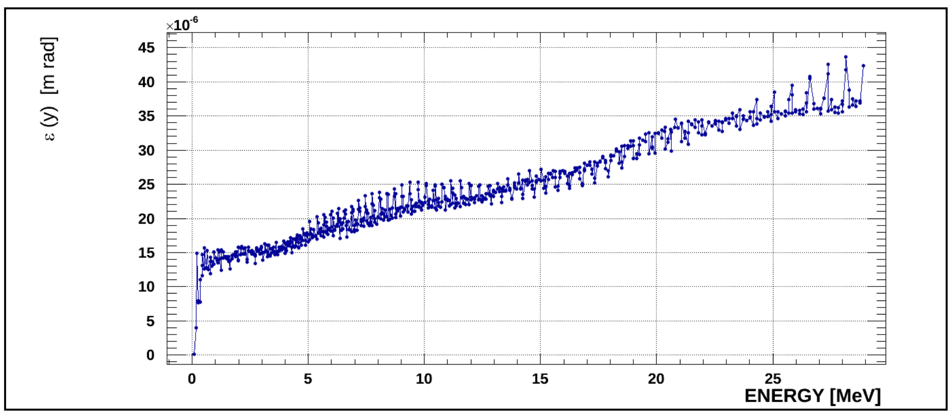
14MeV

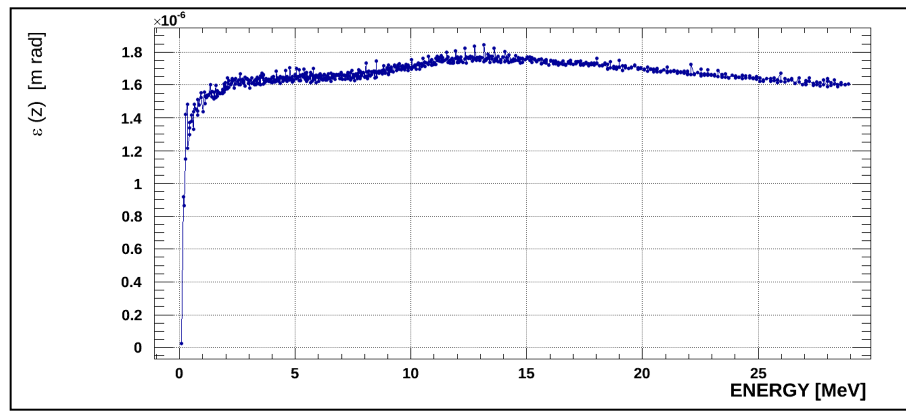

px [βγ]
0.006
0.004
0.002
0
-0.002
-0.004
-0.05
0
0.05
x [m]

24MeV


px [βγ]
0.004
0.002
0
-0.002
-0.004
-0.05
0
0.05
x [m]

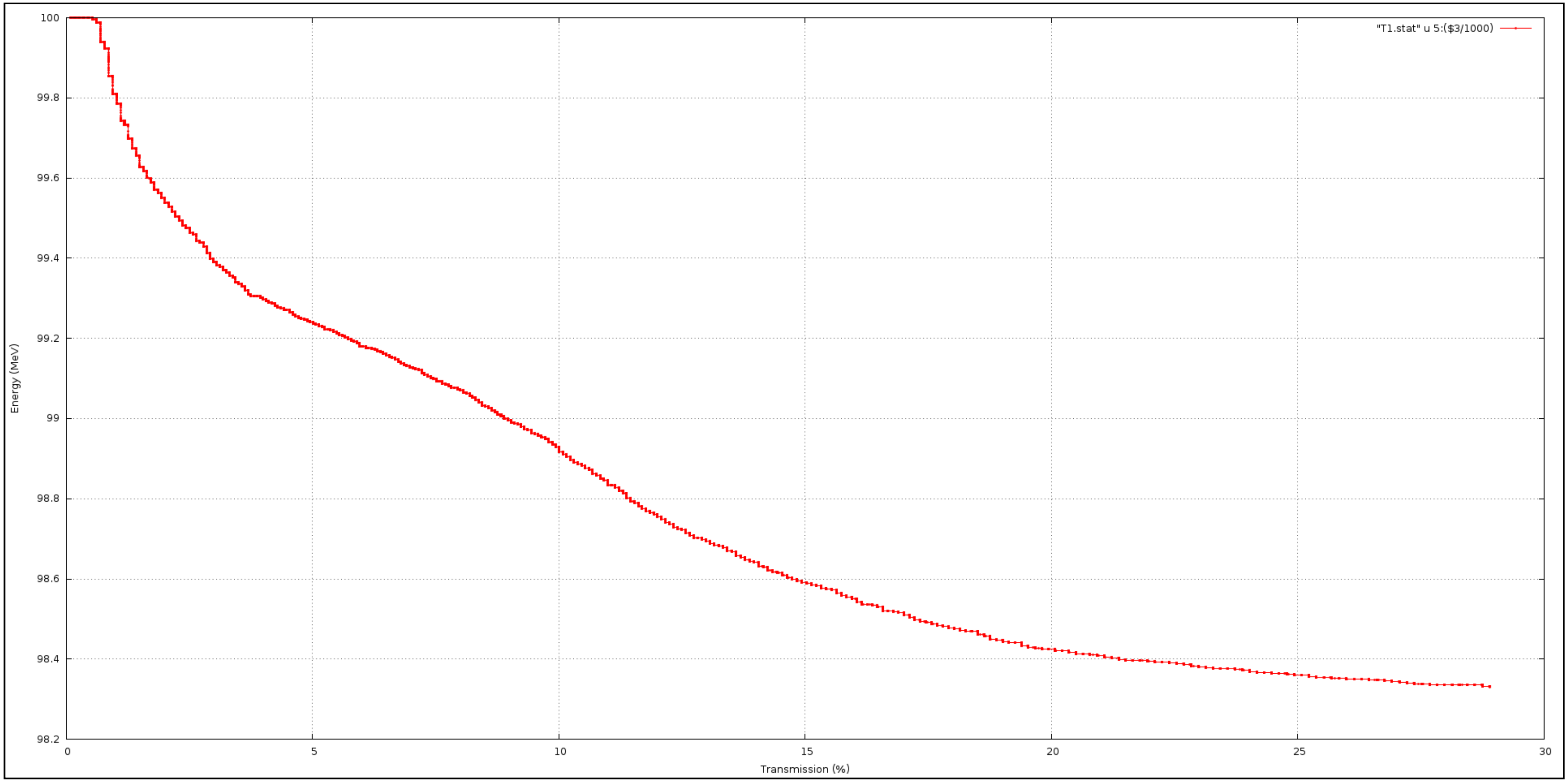

ε (x) [m rad]
×10⁻³
0.02
0
0
5
10
15
20
25
ENERGY [MeV]


ε (y) [m rad]
×10⁻⁶
45
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
ENERGY [MeV]


ε (z) [m rad]
×10⁻⁶
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
ENERGY [MeV]

Transmission

- ± 2cm Vertical aperture applied
- 1.7% losses by 28 MeV



Extraction

Charge Exchange

- Lossy, not possible for α's

Electrostatic deflector and septum

- Need to optimise orbit separation at extraction

Multiple different targets

Internal Target

- Cross-section of production energy dependent
- In thick target many proton wont react before dE/dX moves them away from peak
- To increase efficiency use internal target and recycle the beam
- Large acceptances key!
- Change energy by moving target further into the machine

Yields of various imaging isotopes after 1 hr at 2mA, using Talys

Isotope	Reaction	Beam Energy	Particle	Typical patient doses/hr
^{99m}Tc - SPECT	^{100}Mo (p,2n) ^{99m}Tc	14 MeV	p	2300
^{123}I - SPECT	^{124}Te (p,2n) ^{123}I	28 MeV	p	18000
^{111}In - SPECT	^{109}Ag (α,2n) ^{111}In	28 MeV	α	100
^{18}F - PET	^{18}O (p,n) ^{18}F	10 MeV	p	13000
^{11}C - PET	^{14}N (p,α) ^{11}C	10 MeV	p	16000
^{68}Ga - PET	^{68}Zn (p,n) ^{68}Ga	14 MeV	p	80000

Future work

- Further develop design
  - See how far we can push the current.

- Look at magnet design
  - Varying pole gap
  - Trim coils
  - Hybrid design

- Investigate internal target
  - How long can the beam survive
  - Target configuration

Summery

- Compact FFAG

- It works!
  - Isochronous
  - Flat tunes

- High current: 20mA to 28MeV

- Versatile:
    - Protons or α's
    - Variable energy

- Internal target

- Could produce: ^{99m}Tc, ^{18}F, ^{211}At and others