FFA and Magnet Design

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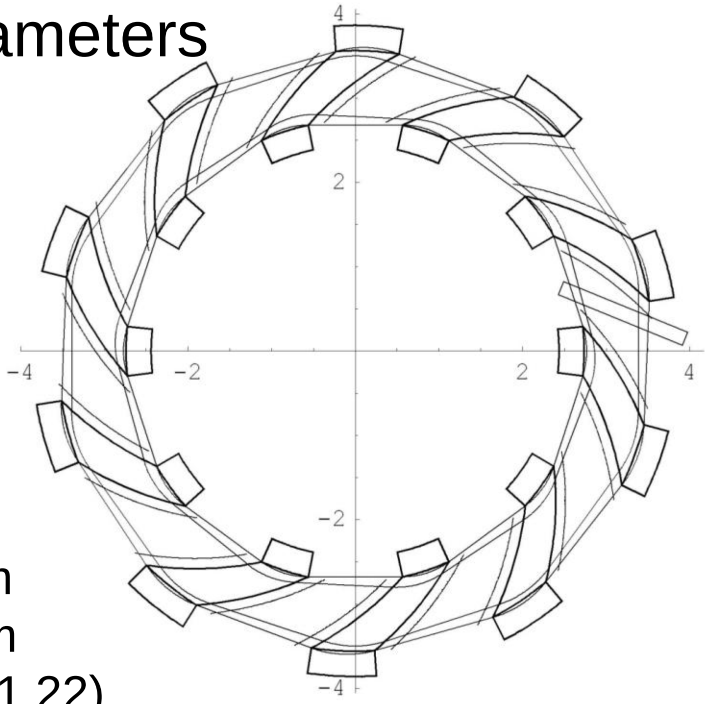
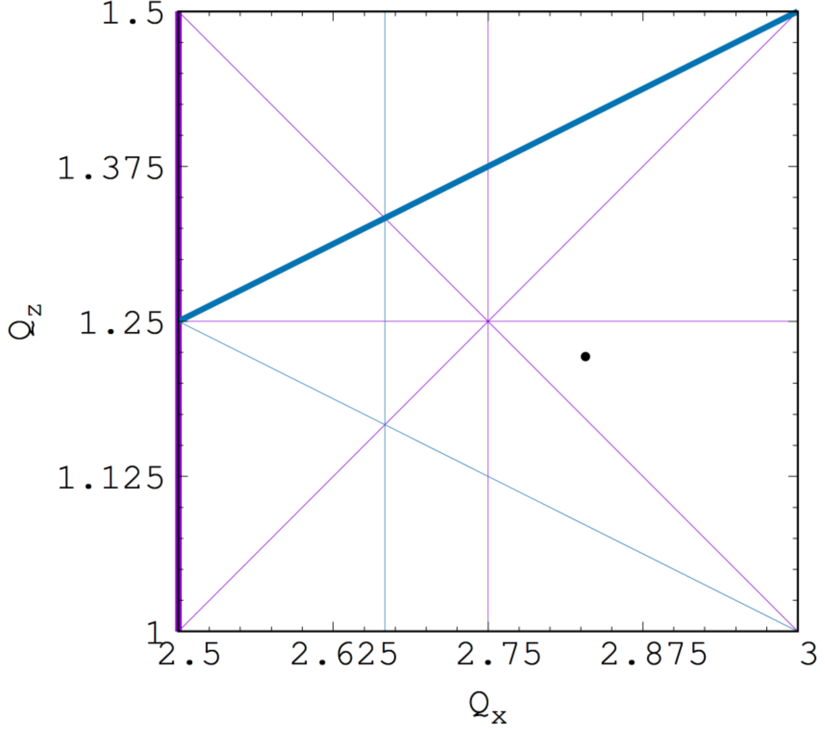
Outline

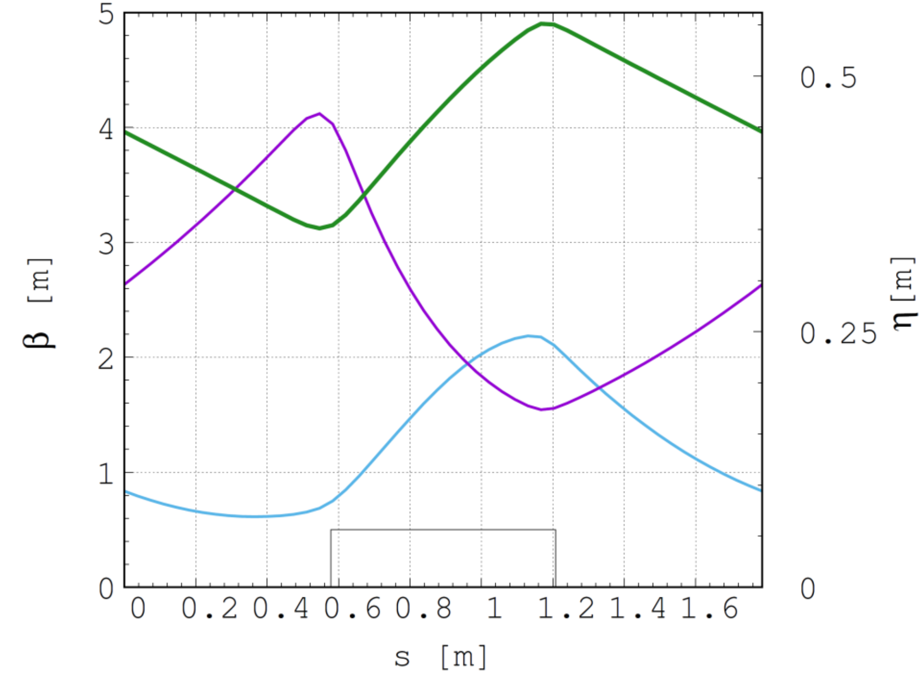
- LhARA FFA baseline
- Variable energy FFA
- LhARA double spiral FFA candidate
- Magnet design
- Conclusions

LhARA FFA baseline ring parameters





- Lattice type: single spiral scaling FFA
- N: 10
- k: 5.33
- Spiral angle: 48.7°
- R_{max}: 3.48 m
- R_{min}: 2.92 m
- (Qx, Qy): (2.83, 1.22)
- B_{max}: 1.4 T
- p_f: 0.34
- Max Proton injection energy: 15 MeV
- Max Proton extraction energy: 127.4 MeV
- h: 1
- RF frequency
  for proton acceleration (15-127.4MeV) 2.89 – 6.48 MHz
  (range compatible with MA RF cavities and ferrite loaded ones)
- Bunch intensity: few×10^8 protons
- Range of other extraction energies possible
- Other ions also possible



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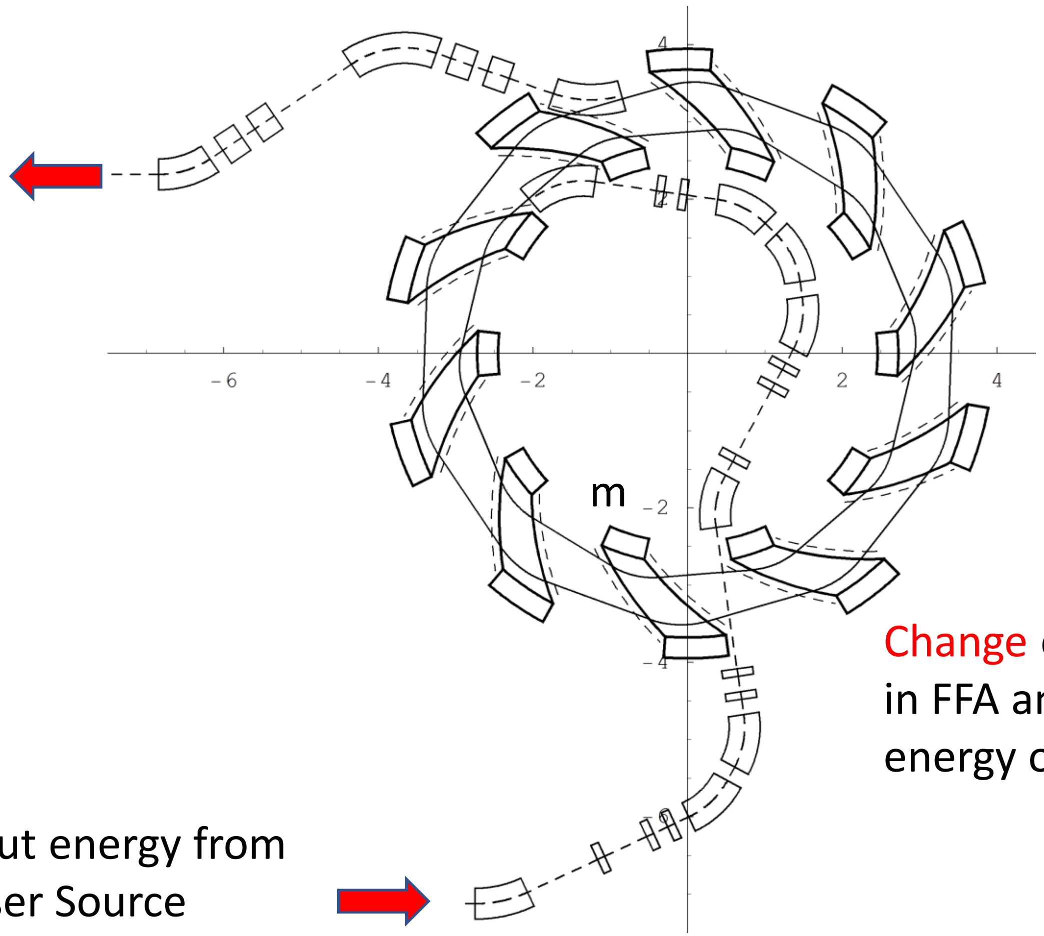
Energy Variability using Laser Accelerated Ions

Variable extraction energy from FFA within 1 s (20-127.4 MeV) at fixed geometry

+

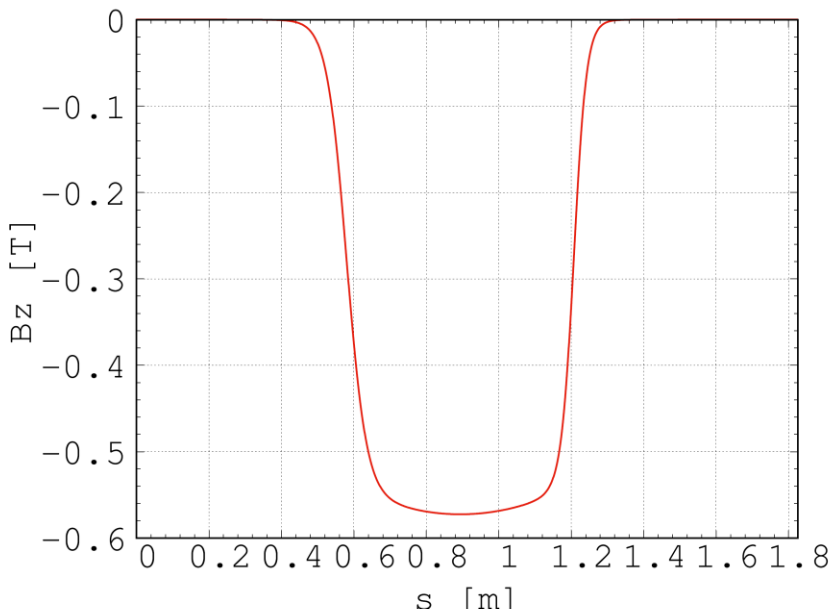
pulse by pulse variation with kicker could be implemented



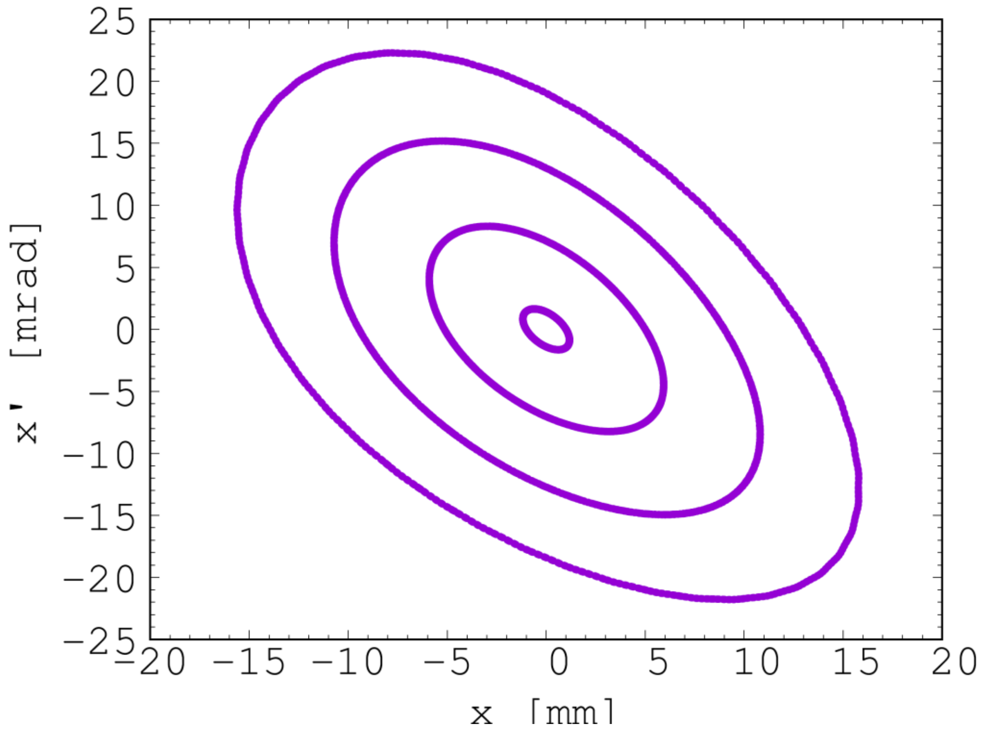
Change of the value of magnetic field in FFA and transfer lines for a specific energy operation (laminated magnets)

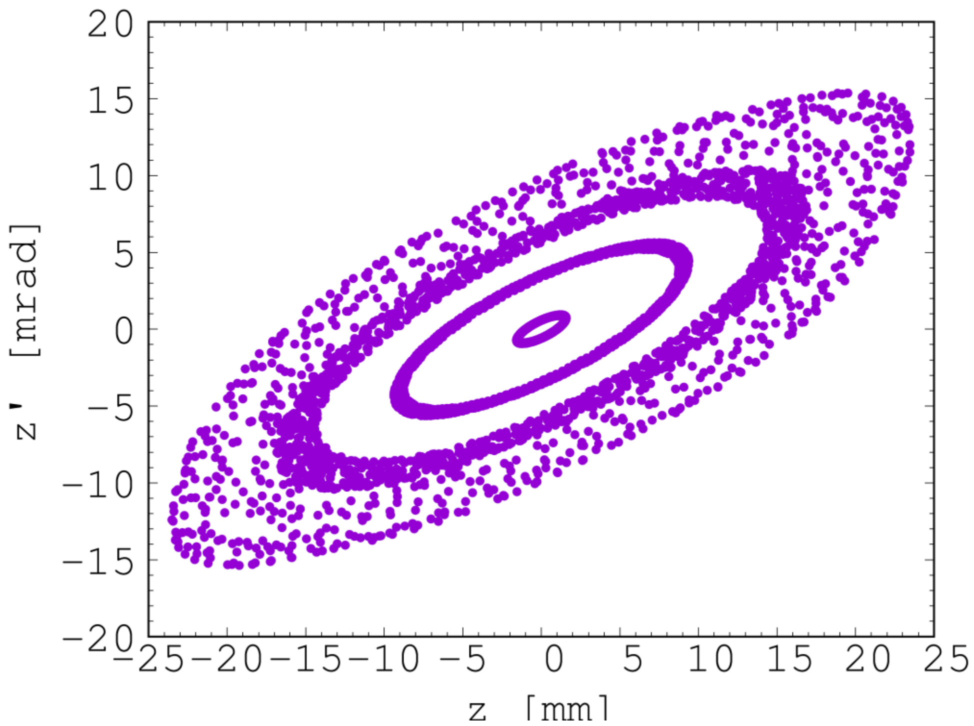
Variable input energy from the Laser Source (multiple ions are possible)

LhARA Ring Tracking



- Performed using proven stepwise tracking code (FixField)
- It takes into account fringe fields and non-linear field components
- Results show dynamical acceptances are large
- No space charge effects included yet





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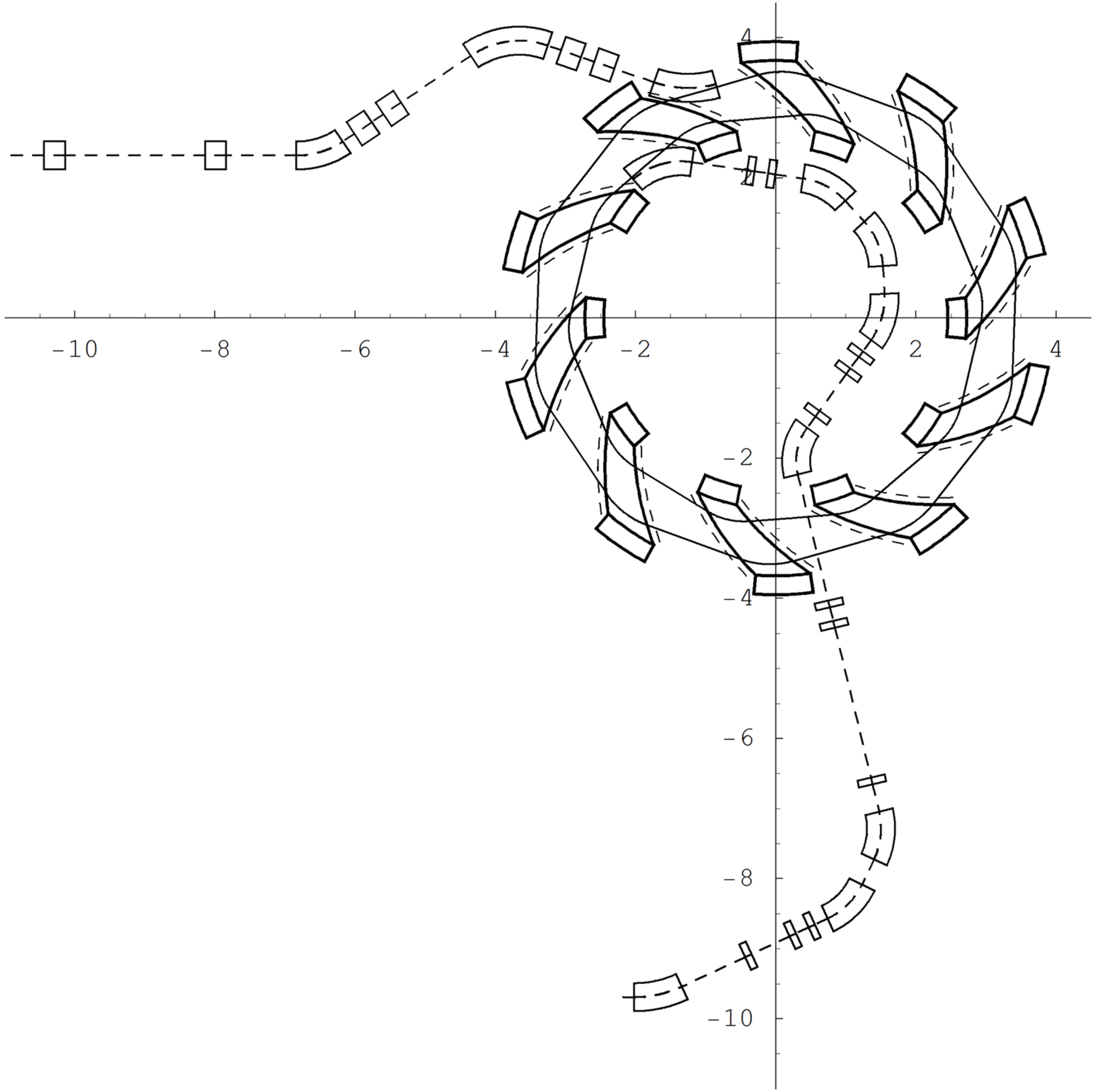
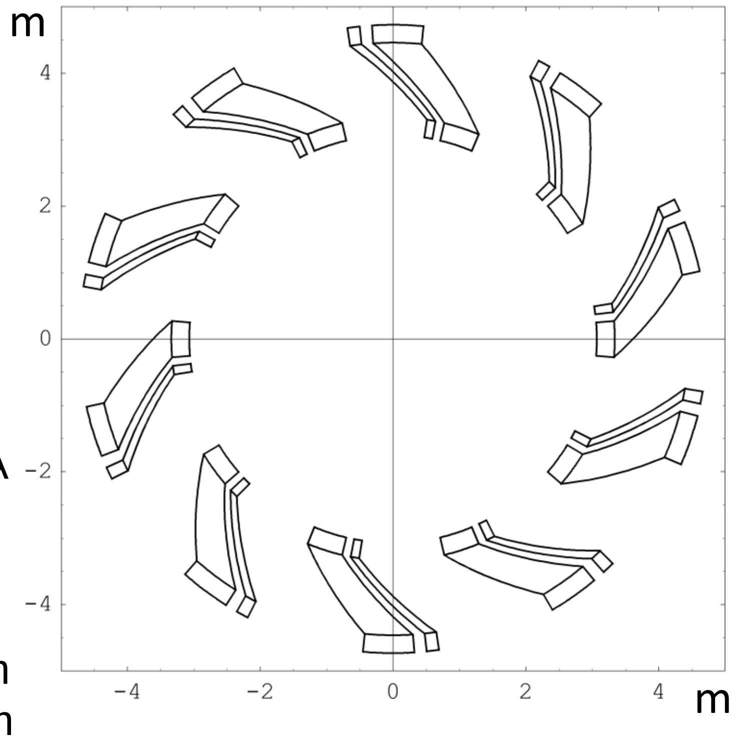
FFA Ring with subsystems

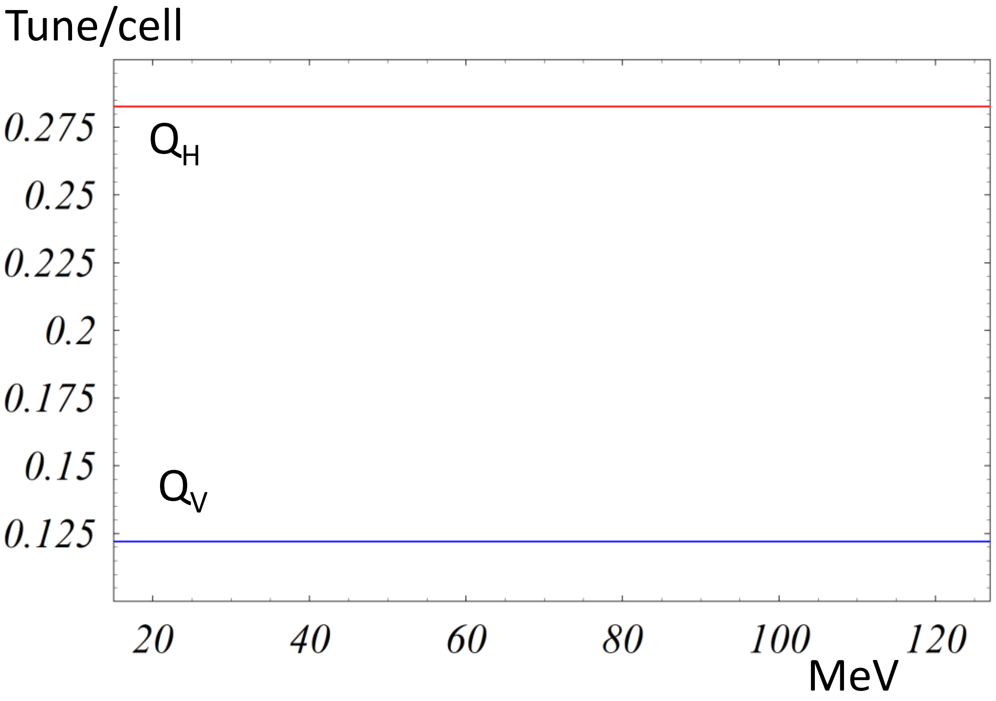
Parameter	unit	value
Injection septum:		
nominal magnetic field	T	0.53
magnetic length	m	0.9
deflection angle	degrees	48.7
thickness	cm	1
full gap	cm	3
pulsing rate	Hz	10
Extraction septum:		
nominal magnetic field	T	1.12
magnetic length	m	0.9
deflection angle	degrees	34.38
thickness	cm	1
full gap	cm	2
pulsing rate	Hz	10
Injection kicker:		
magnetic length	m	0.42
magnetic field at the flat top	T	0.05
deflection angle	mrad	37.4
fall time	ns	320
flat top duration	ns	25
full gap	cm	3
Extraction kicker:		
magnetic length	m	0.65
magnetic field at the flat top	T	0.05
deflection angle	mrad	19.3
rise time	ns	110
flat top duration	ns	40
full gap	cm	2

- Injection line and, fast injection and extraction systems parameters are established
- The slow extraction option is possible – no short-stopper found (Steinberg's and Taylor's work)

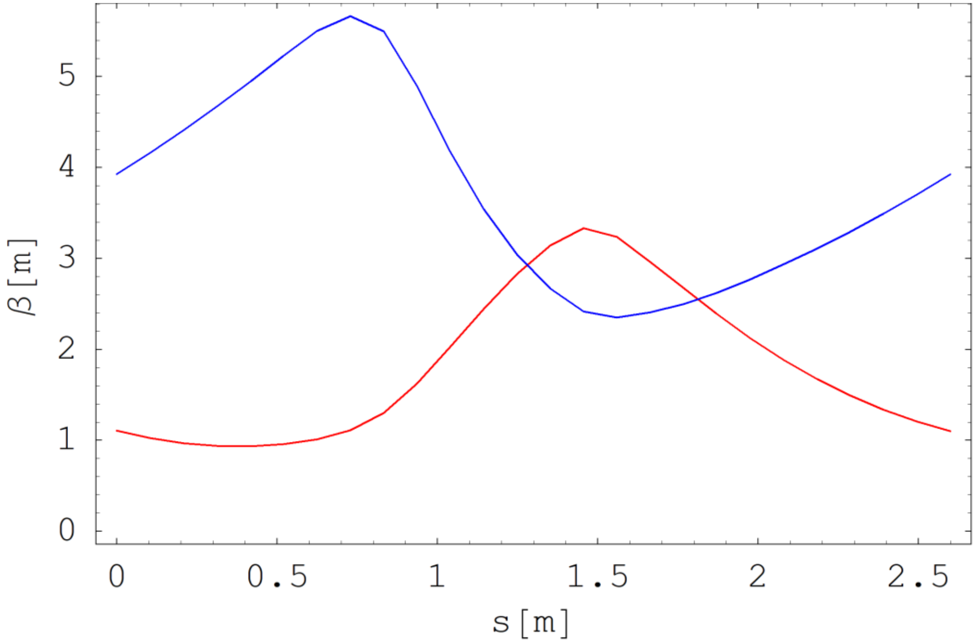


LhARA double spiral baseline alternative, Ff configuration (nominal tune)





- Lattice type double spiral scaling FFA
- N 10
- k 5.26
- Spiral angle 45.87°
- R_{max} 4.14 m
- R_{min} 3.55 m
- (Qx, Qy) (2.83, 1.22)
- B_{max} 1.5 T
- p_f 0.386
- Max Proton injection energy 15 MeV
- Max Proton extraction energy 127.4 MeV
- h 1
- RF frequency
  for proton acceleration (15-127.4MeV) 2.37 – 5.47 MHz
- Bunch intensity few×10^8 protons
- Range of other extraction energies possible
- Other ions also possible
- Lattice allows for flexible tune adjustment



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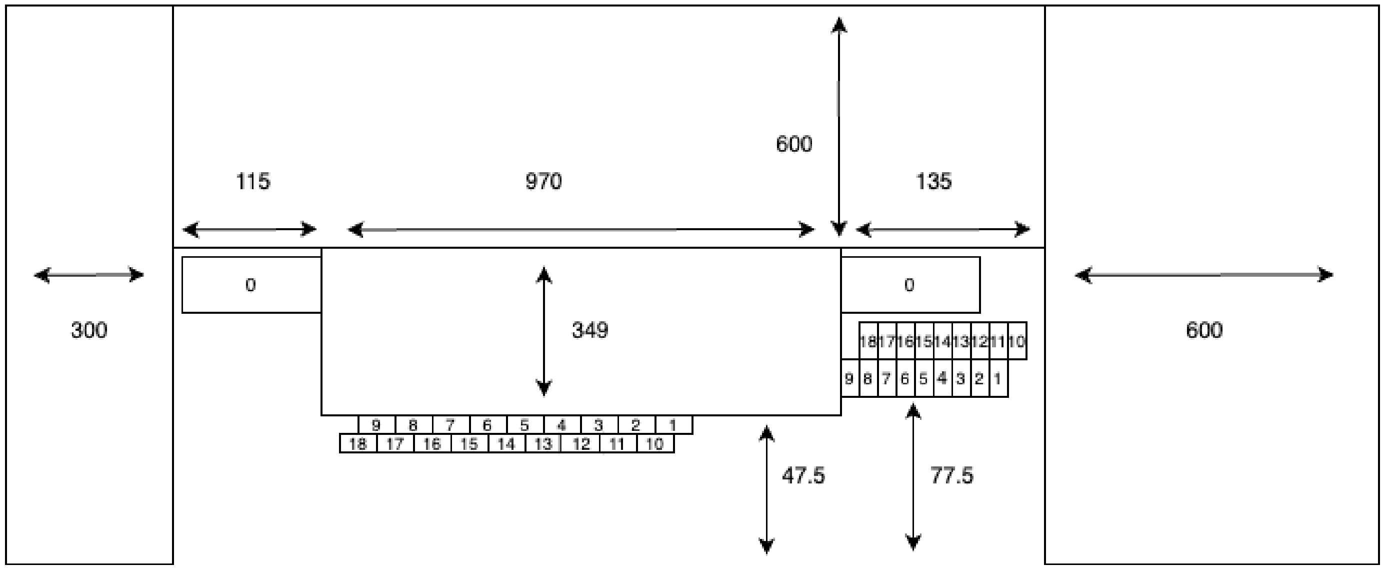
Magnet Design



Half of the magnet with flat pole and distributed trim coils (from Milestone 6 report)

- Magnetic field ~R^k is generated by distributed trim coils with individual currents on the flat pole
  - Conventional room temperature combined function magnet has the gap shaped to generate the wanted field
  - Gap is closing towards the high field region, which makes fringe-field extend to be reduced towards high field region, but in FFA we need the opposite λ~R
    - You can use field clamp, but it is already difficult with the flat pole
- Gap-shaping magnet does not allow to change k, so you cannot adjust optics
  - Variable energy operation requires different B_0
    - Different saturation levels at different B_0 may affect the optics, so you may need to adjust it
  - You may want to change the working point, for example to allow for the slow extraction
- For details of the design see Ta-Jen's talk

Magnet Design (2)

Goals for the magnet design:

- Optimise geometry (including the clamps) and currents to obtain scaling magnet for the baseline energy
  - Zero-chromaticity is important
- Investigate the behaviour (tunes as a function of energy) for different energies
  - Is it still zero-chromatic? Do we cross any resonances?
  - We may need to adjust the currents
- If the vertical tune is NOT flat we need to do something
  - We may need to break the scaling law a bit to recover zero-chromaticity
    - But you need two knobs for two tunes, so we could introduce “superperiod” powering two consecutive magnets a bit different introducing 5-fold symmetry in the ring

Conclusions

- LhARA at Stage 2 requires a variable energy FFA
- The cost effective, single spiral scaling FFA chosen for the baseline shows a good performance in tracking studies
- Preliminary design for the magnet has been created (see Ta-Jen's talk)
  - Key is the zero-chromaticity for different energies
- Alternative double spiral scaling lattice was proposed