



# Solenoid Focusing in an Ion Linac

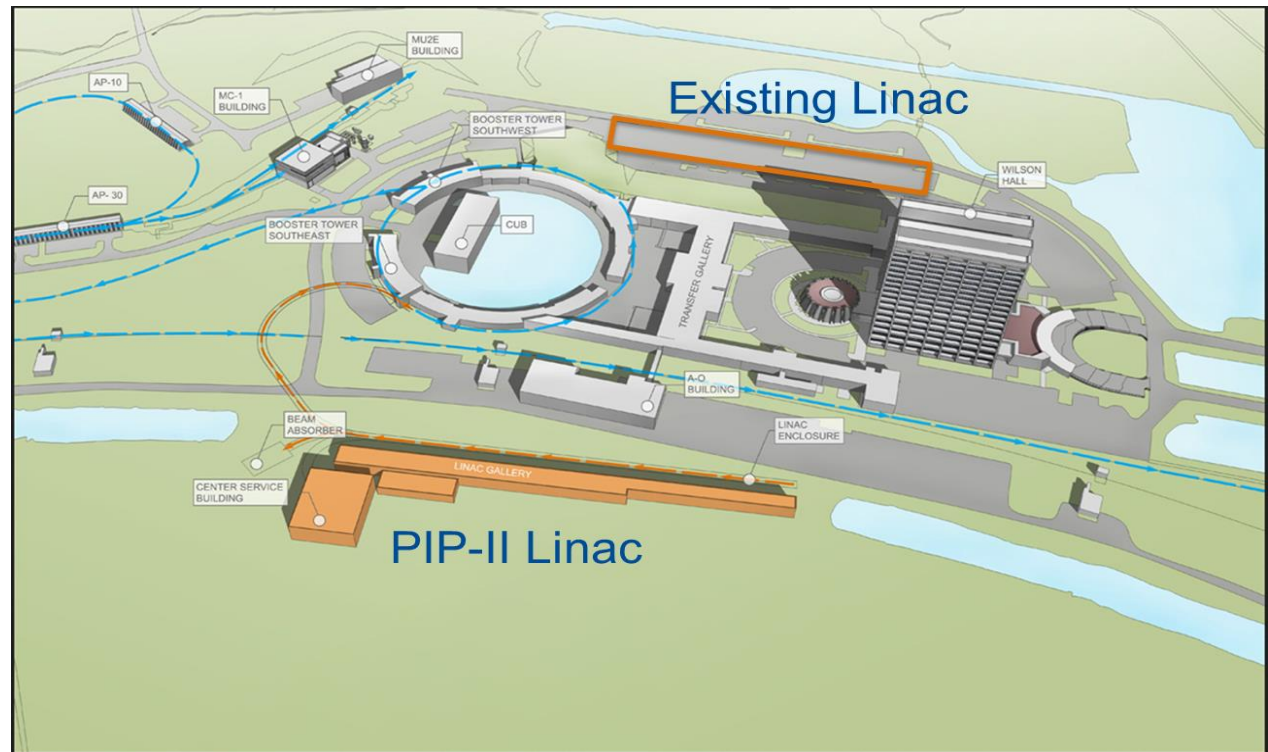
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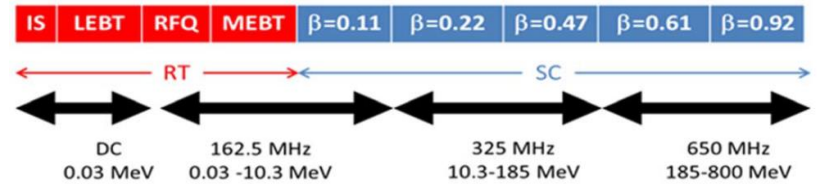
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# Outline

- Introduction
- Project Description
- Initial Preparation
- Next Steps

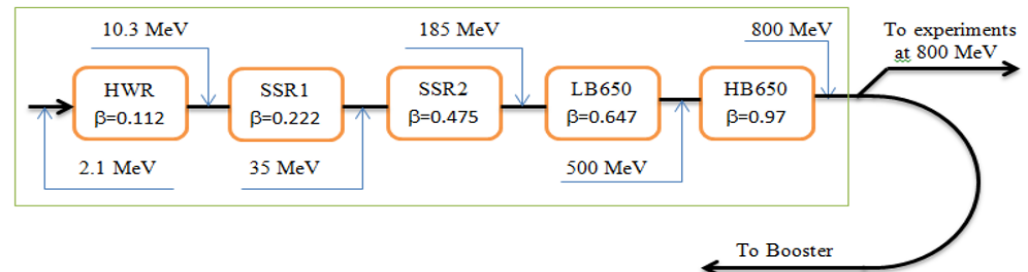


# Introduction: PIP-II SC Linac



## • Description of the PIP-II

- It encompasses a set of upgrades and improvements to Fermilab accelerator complex.
- The central element of PIP-II is a new 800 MeV superconducting Linac accelerating  $H^-$  ions and located in close proximity to the existing Booster
- Linac is segmented in two parts, the room temperature front-end and the superconducting (SC) Linac
- The SC Linac starts immediately downstream of the MEBT. It accelerates the beam from 2.1 MeV to 800 MeV and includes five types of SC cavities to cover the entire velocity range required for acceleration of  $H^-$  (or protons).
- In the first three sections, HWR, SSR1 and SSR2, superconducting solenoids were chosen to provide transverse focusing. In the last two sections, LB650 and HB650, quadrupoles were selected.
- A choice of solenoidal focusing for low energy is desirable as it facilitates a large transverse aperture and a compact axial-symmetric focusing.

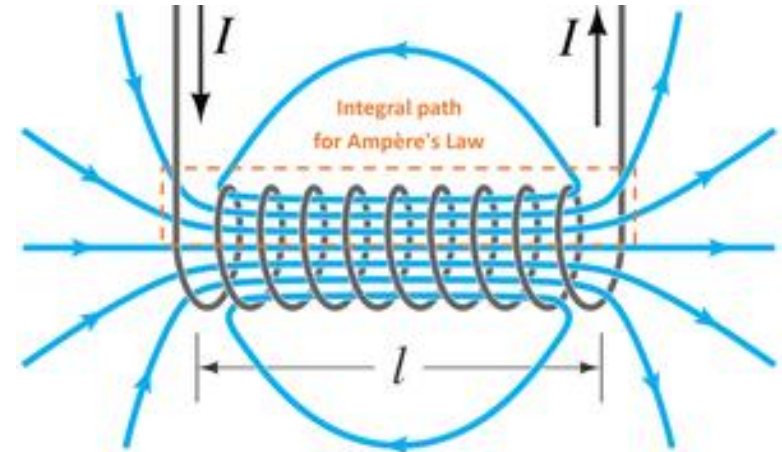


# Problem Description

- Solenoids nature of focusing :
  - A solenoid provides axial symmetric focusing.
  - Solenoids are compact relative to quadrupole.
- A quadrupole focuses beam in one plane and defocuses in another
- However, solenoids could provide a weak asymmetric focusing, like a quadrupole
- My project for the summer is to help my advisor develop a theory:
  - Explaining weak quadrupole focusing from solenoids
- This can allocate for further research on applications of solenoid focusing

# Initial Preparation: First three weeks as SIST (1)

- Solenoids
  - A long straight coil of wire that can be used to generate a nearly uniform magnetic field
  - The magnetic field is concentrated in the center of a long solenoid
  - Produce longitudinal fields
  - They can be used to contain and transport low momentum particles in helical trajectories along the field lines
  - Utilize to focus low energy beam
  - Able to find equation of motion and graph it using Matlab



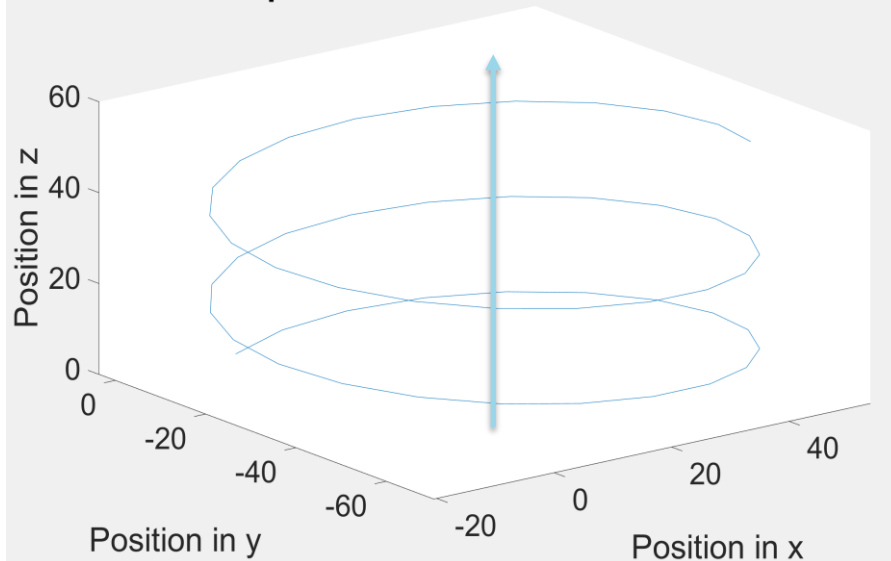
- $B = \mu I N/L$



# Initial Preparation: First three weeks as SIST (2)

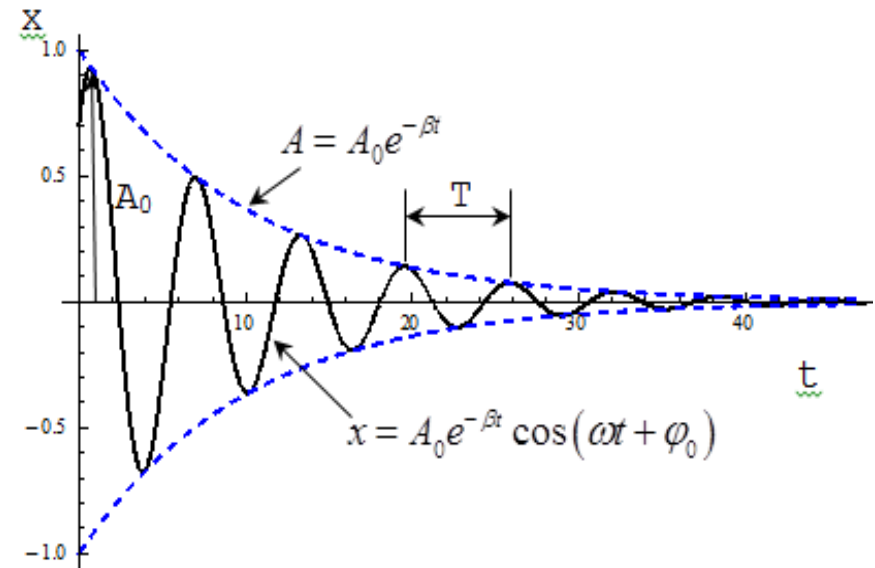
- Solenoids

Equation of motion in a Solenoid



- Chare Particle Trajectory in a solenoid field
- $$x = \frac{v_x \sin(\omega t) - v_y \cos(\omega t) + x_0}{\omega}$$
- $$y = \frac{v_y \sin(\omega t) + v_x \cos(\omega t) + y_0}{\omega}$$

- Oscillation



- Review about Oscillators, more specifically on damping oscillations
- Beam betatron oscillation of beam is like a damped oscillation

# Project Description: Next Steps

- Developing theory of beam propagation in a solenoid
  - Be able to understand how the particles move in linear accelerators (linac) from the basics of solenoids and oscillators
- Applying theory in framework of PIP-II linac and validating model.
  - Use Matlab to help develop the theory
  - Explaining weak quadrupole focusing from solenoids

# References

- [http://www.bog5.in.ua/lection/vibration\\_lect/lect4\\_vibr\\_eng.html](http://www.bog5.in.ua/lection/vibration_lect/lect4_vibr_eng.html)
- <https://en.wikipedia.org/wiki/Solenoid>
- <http://lss.fnal.gov/archive/design/fermilab-design-2017-01.pdf>
- [https://www.google.com/search?q=accelerator+physics&hl=en&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj5sO7H2dLiAhVHPK0KHchdA-gQ\\_AUIESgB&biw=1368&bih=802&dpr=2#imgsrc=voicaiHizwTNBM:](https://www.google.com/search?q=accelerator+physics&hl=en&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj5sO7H2dLiAhVHPK0KHchdA-gQ_AUIESgB&biw=1368&bih=802&dpr=2#imgsrc=voicaiHizwTNBM:)
- The pip-ii preliminary design report