NEUTRINO FACTORY
/
MUON STORAGE RING

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INO STUDENT

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What is Neutrino Factory?

- Artificial neutrino sources are

1. Reactor neutrino
2. Short baseline neutrino source
3. Long baseline neutrino source.

- Neutrino Factory is a Long baseline neutrino source
- It is an intense high energy neutrino source based on the muon beam. Energy of the muon beam is 20 GeV.

- $\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$

- $\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$

Why we need Neutrino Factory

- Usual oscillation experiment gives

a) Value of mass squared difference

b) Mixing angles.

- There is no information about all these

a) Sign of the mass squared difference

- No information about mass ordering

b) CP violation effects.

c) Magnitude of $\sin^2 2\theta_{13}$, or the value of θ_{13} .

- To measure CP violation and mass hierarchy
- Long base line Experiment

1. Super beam or Conventional beam

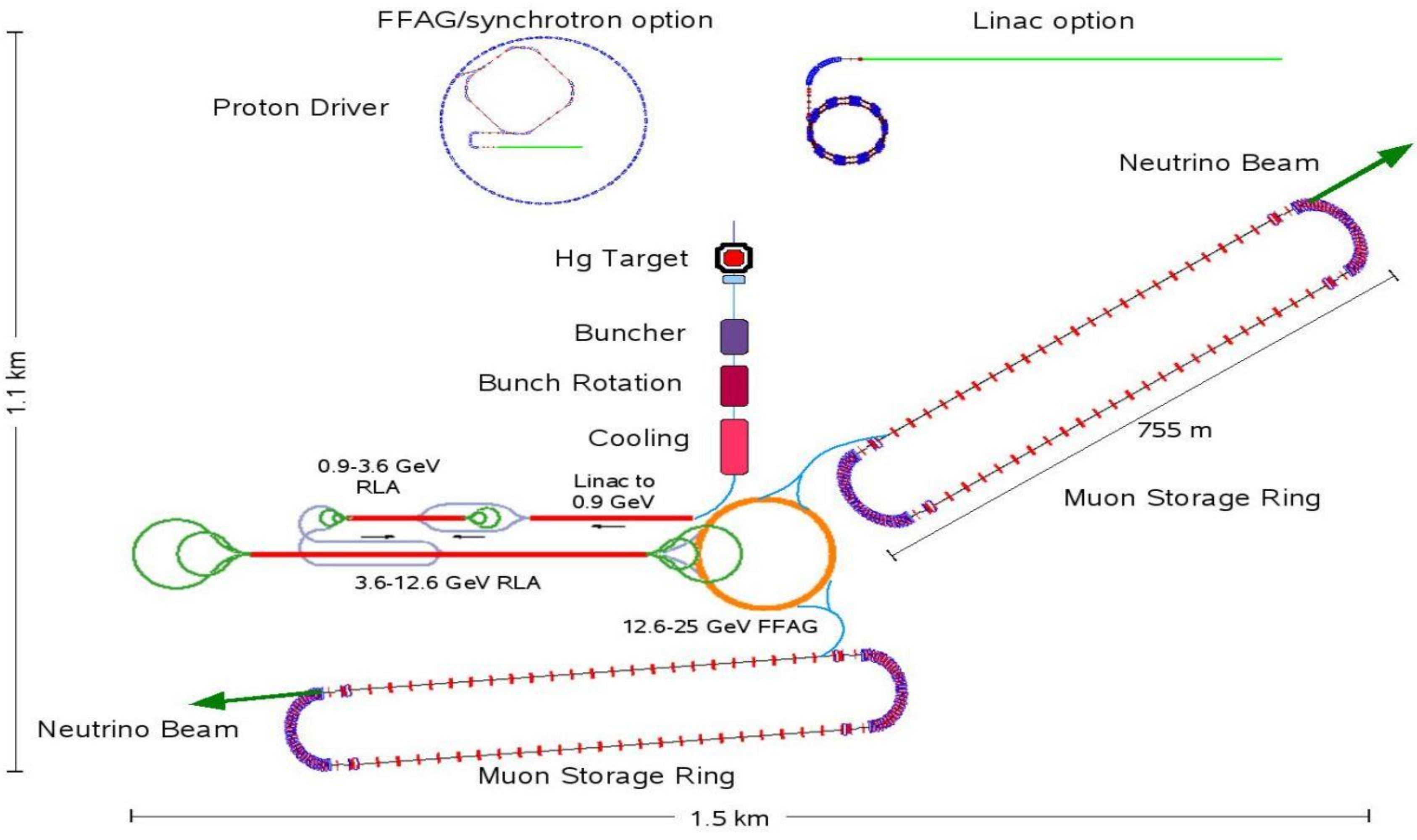
- ➢ K2K ,J2K, MINOS,OPERA etc

2. Beta beam

- ➢ Radioactive ions stored ,decayed to electron-neutrino

3.Neutrino Factory

Details of Neutrino Factory



Generation of neutrinos

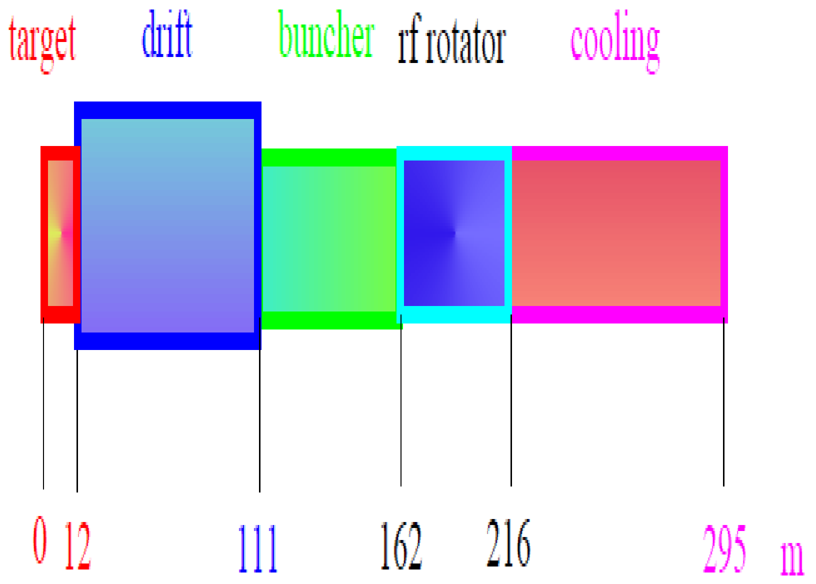
- High intensity proton beam(few GeV) impinges on high Z target, produces pion beam.
- pion beam decays into muon beam(2.2μs).
- muon beams are accelerated up to few tens of GeV and stored into a long straight section of decay ring
- Decay to neutrinos, which will hit detector located at thousands of kilometers from the source.

Main Components of Neutrino Factory

- Proton Driver:-provides

1-4 MW of protons on target
From an upgraded AGS.

- Booster is replaced by 1.2 GeV Superconducting proton linac.
- Average beam power is 1MW.
- Beam energy is 24 GeV.
- Target and Capture:-
- A mercury jet target is chosen to give a high yield of pions per MW of incident proton power.



Main components of NF

- pions emerging from the target are captured and focused down the decay channel by a solenoid field of 20 T at the

  target center.

- Bunching and Phase Rotation :-

  Bunching is done to reduce energy spread

  and is rotated along the longitudinal phase space.

  1st Bunching is done by rf cavities of modest gradient then

  rotated with higher gradient rf cavities to reduce energy spread.

  Benefit of rf cavity is that it can transport both sign of muon.

- Cooling :

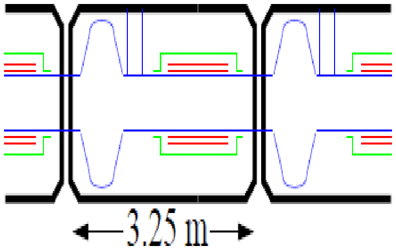
  Transverse emittance cooling by lowering

  beam energy by LiH.

Main components of NF

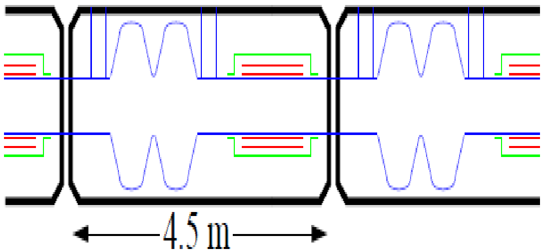
- Acceleration :

Super conducting linac →1.5 GeV



RLA → 5 GeV muon beam

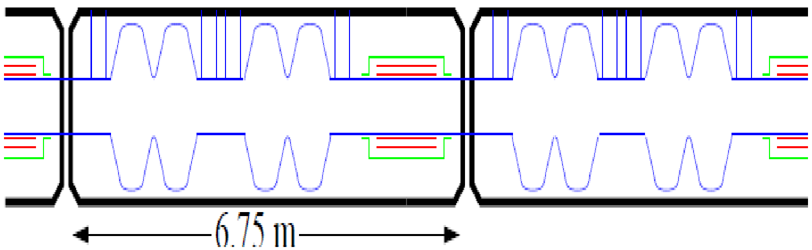
Pair of Cascated FFAG →20 GeV



Storage Ring :

Compact racetrack superconducting Storage ring

35% of stored muons decay



Detector for different channel

- Three detectors of different technologies for different channel

1. Magnetized iron detector(MID):

- It is for $\nu_e \rightarrow \nu_\mu$ "Golden channel"
- Wrong sing muon signal is detected
- 50 KTon magnetized iron calorimeter optimized for the study of $\nu_e \rightarrow \nu_\mu$
- Threshold $\approx$10 GeV ,to reduce dominant source of background
- But we lost signal due to 1st oscillation peak for L$\approx$ 3000 Km

Detector for different Channel

2) Emulsion Cloud Chamber(ECC):

- $\nu_e \rightarrow \nu_\tau$ (Silver Channel)
- Unique feature with high neutrino energy to produce τ CC events.
- Signal is tagged for wrong sign muon in coincidence with τ decay vertex, to distinguish from Golden channel

3) Liquid Argon Detector- (Platinum Channel)

- $\nu_\mu \rightarrow \nu_e$
- CP conjugate of Golden Channel
- Upper threshold 7.5 GeV.

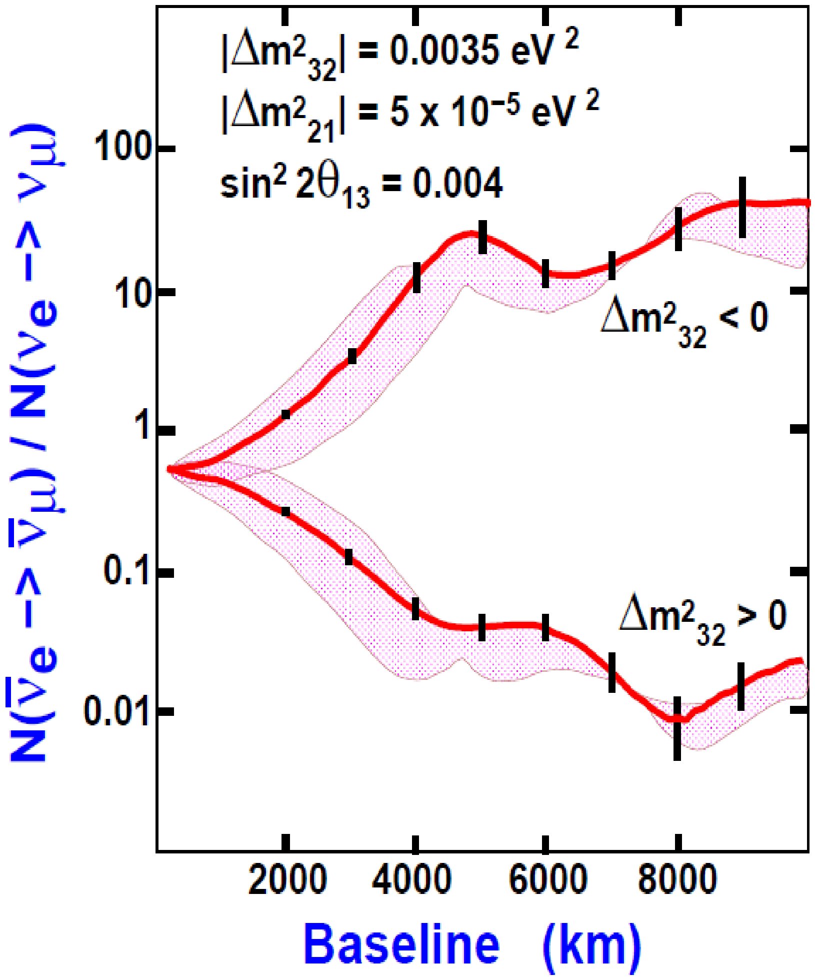
Neutrino Factory Sensitivity

Wrong sign muon :-

- Ratio of wrong sign muon event rates as a function of baseline.
- Within the band CP violating phase δ is varying.
- Sign of Δm^2_{32}

- Sensitivity to Θ_{13}

Maximum sensitivity is



$1.4*10^{-5}$

- Baseline from 1000 to 4000 km with as much muon energy as possible give the best sensitivity.
- At the magic baseline there is dependence on

δ ,thus improving Θ_{13} .

- ➢ Sensitivity to the mass hierarchy-

$\nu_e \rightarrow \nu_\mu$

- Oscillation probability in matter depends on the sign

of $\Delta m^2{}_{32}$.

- Change of this sign is equivalent to a CP transformation.
- Maximum sensitivity to the sign of $\Delta m^2{}_{32}$ is expected at baseline 7000 km.

Challenges of Neutrino Factory

- Proton driver-
- Production of intense short proton bunches with Space charge compensation and high gradient.
- Target, Capture and decay section-
- Optimization of target material and form.
- Design and performance of high field solenoid.
- Bunching and phase rotation section-
- Design of efficient and cost-effective bunching system
- Cooling section-

Development and testing of high gradient normal conducting rf cavities at a frequency near 200 MHz.

- Acceleration section-
  - Optimization of acceleration to increase energy from few GeV to few tens of GeV.
  - Design and testing of components that will operate in the muon decay radiation environment.
- Storage ring-
  - Design of large-aperture, well-shielded SP magnet that will operate in muon decay radiation.

Conclusion

- Neutrino Factory can produce muon of energy 20-50 GeV
- It can store both sign of muon.
- CP violation, mass ordering and value of mixing angle
- Technology is difficult to design.

References

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