Conceptual LBNE Lattice Optics Design

[opus #2]

JOHN A. JOHNSTONE

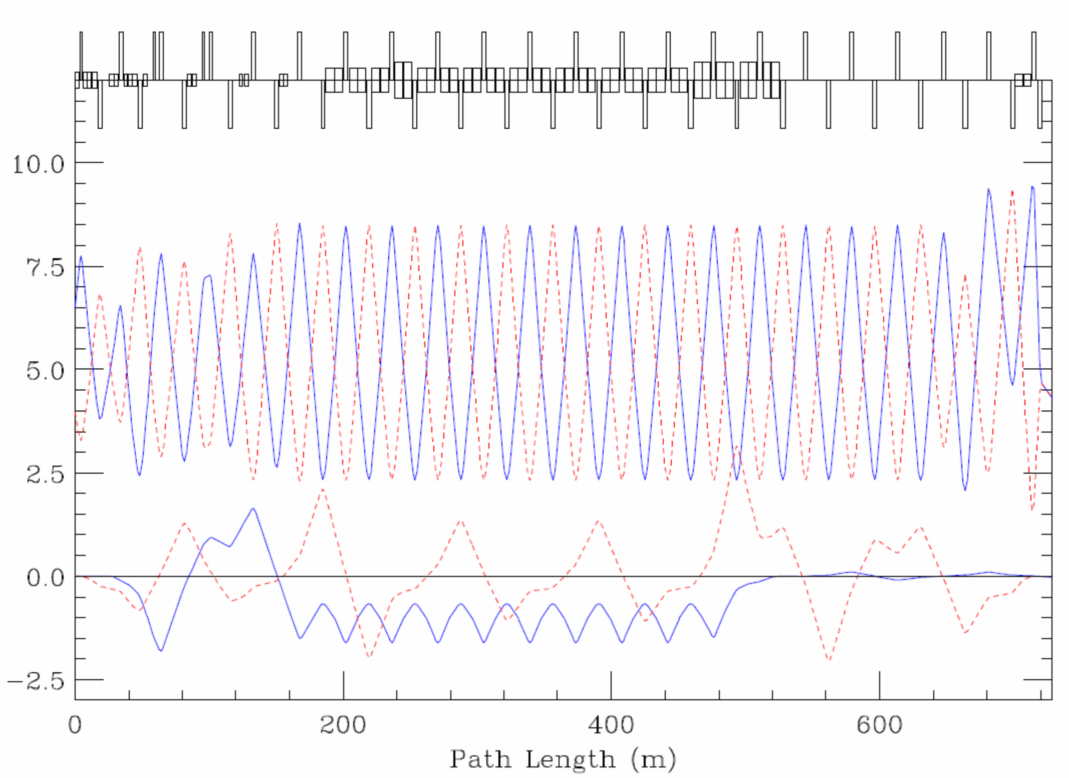
Fermilab / APC

0.1.20.2010

Outline

- Flashback – the 120° FODO lattice.
- Opus #2 – a 90° FODO cell conceptual design:
  - overview;
  - NuMI → LBNE matching + 'up-flat-down-flat' vertical bends;
  - horizontal dispersion suppression + steep achromatic vertical bend insertion;
  - achromatic vertical up bend using a triplet;
  - dispersion-free final focus with triplet.
- The future …..

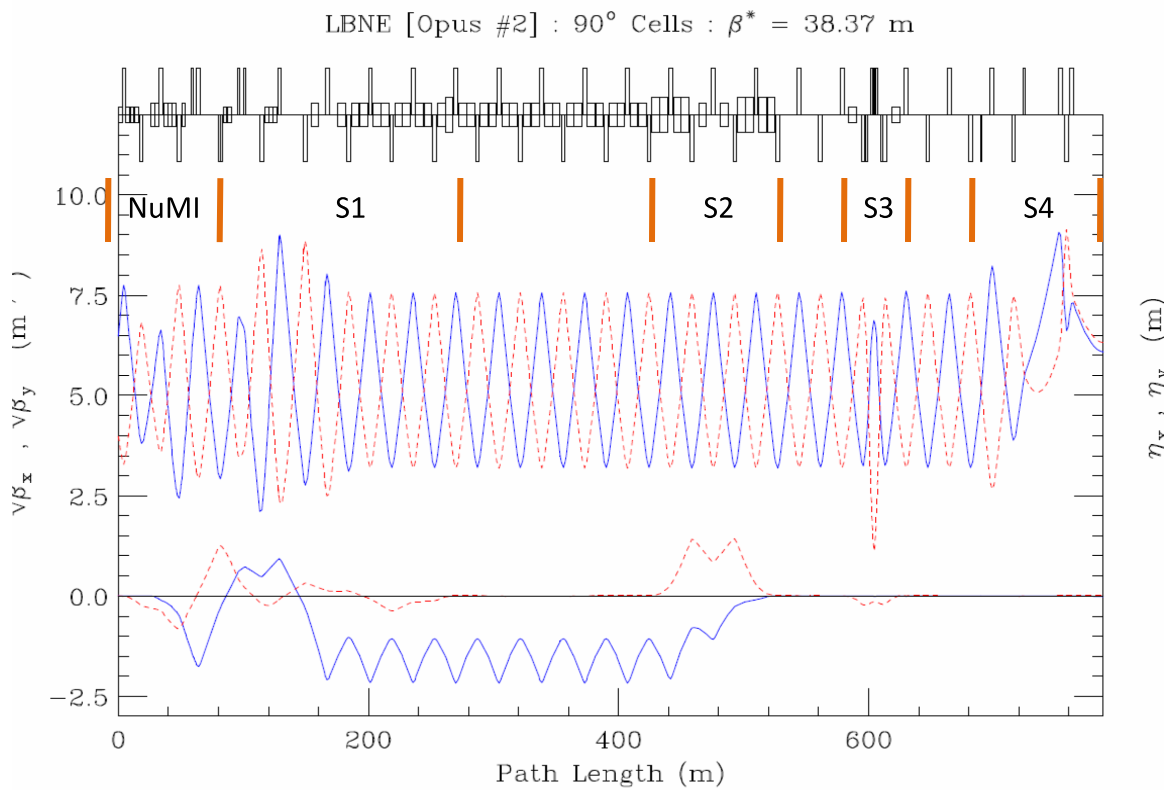
"Recall" – Opus #1 With 120° FODO Cells



- β(max) = 72 m
- η_x(FODO) = 1.67 m

η_y – 3+ m rattling down the entire beamline to final 'up' bend

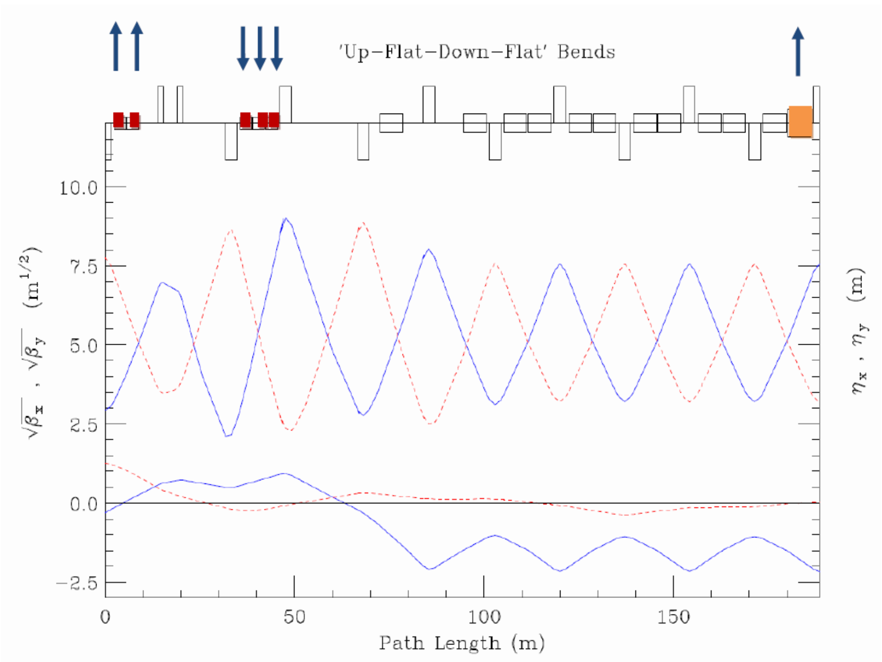
NEW! IMPROVED! LBNE Beamline with 90° Cells



- β(FODO) = 58 m
- η_x(FODO) = 2.12 m

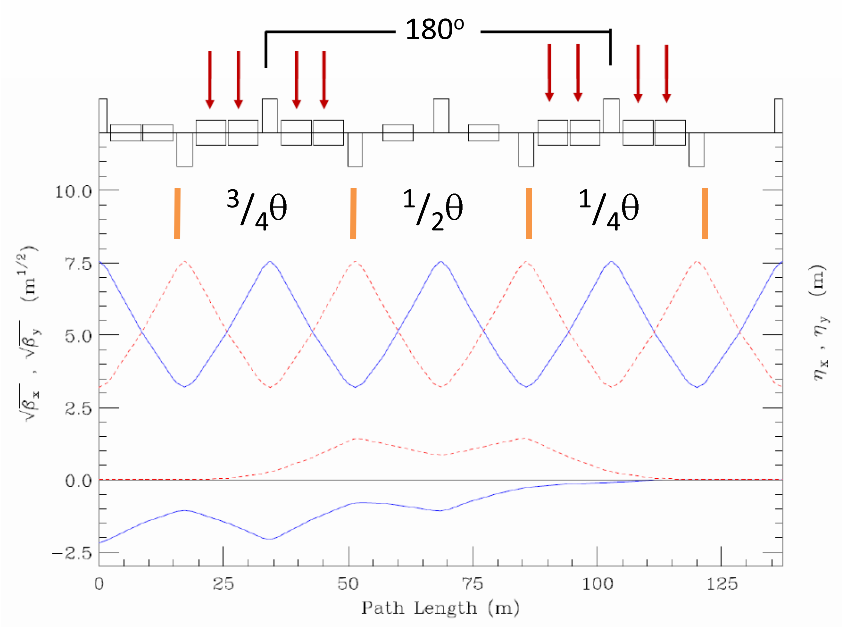
η_y(max) = 1.67 m at 150 mr down bend, but is killed locally via achromatic optics.

NuMI → LBNE Transfer: Match to η_x in 90° Cells, and; Kill Residual η_y from NuMI Line



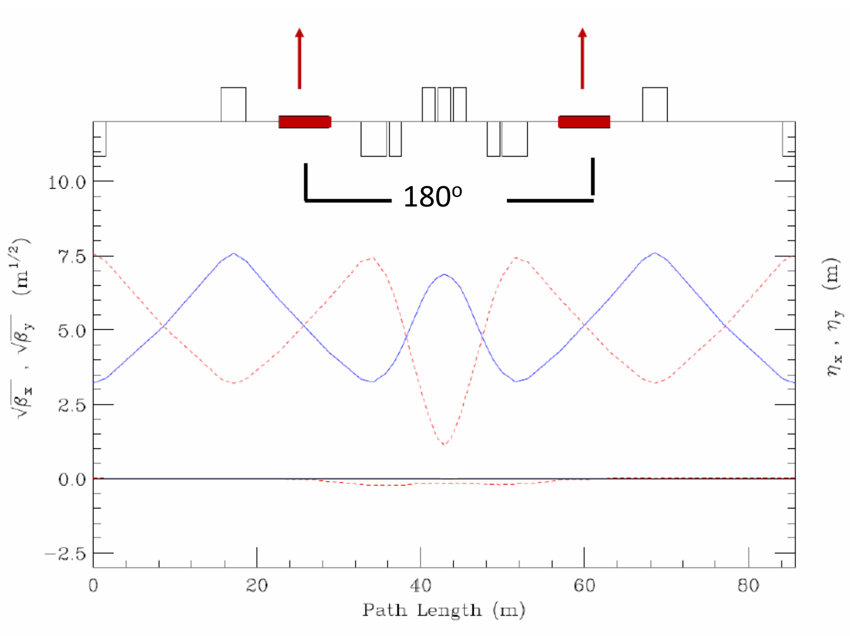
- Following NuMI Q106, 2 EPB's bend the beam up by ~11 mr each to clear the NuMI magnets.
- D/S of Q208, 2 EPB's flatten the beam trajectory, a third pitches the beam down by ~11 mr.
- At the MI elevation an individually powered B2 is rolled such than up bend of 11 mr is created + a horizontal bend equal to that of a standard arc B2.

Horizontal Dispersion Suppression + Vertical 150 mr Achromatic Bend



- B2's are rolled to create 8 down bends of 18.75 mr each.
  - Vertical bend centers are separated by 180º of phase → canceling η_y locally.
  - Maximum η_y = 0.25 m.
- The horizontal bends generated in the 3 suppressor cells are in the ratio 0.75 : 0.50 : 0.25 relative to the bend θ in a standard arc cell.

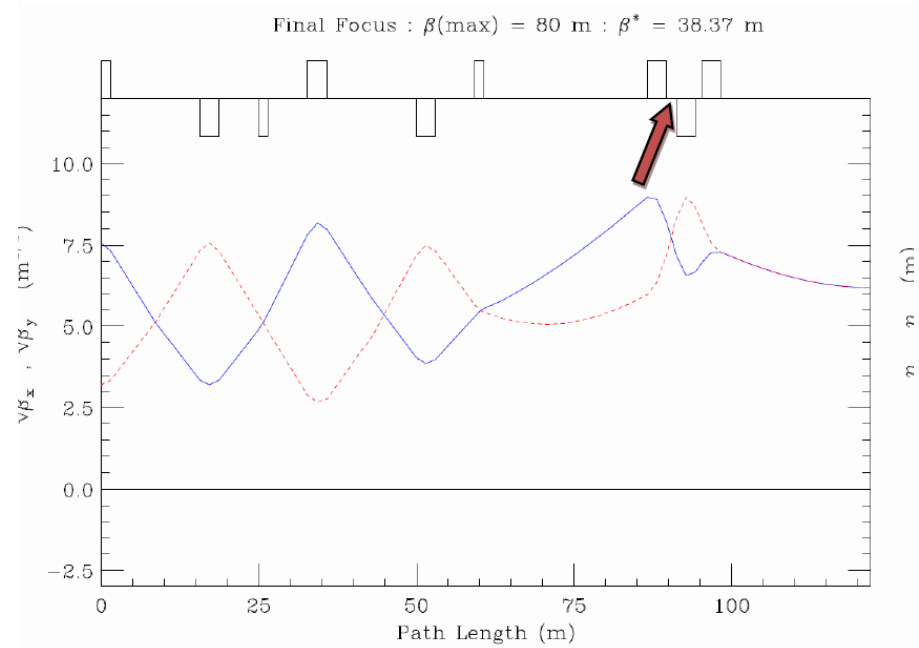
Final Achromatic 50 mr 'UP' Bend with Triplet Matching



Triplet insertion between bend centers provides 180° of phase advance to cancel dispersion + match into the regular 90° FODO lattice.

- 2 3Q120s + 5 3Q60's operating at ~17.6 T/m.
- Total insertion length (mid-QF to mid-QF) is $1^{1}/_{2}$ standard cells.

Final Focus with Triplet



- Target is 23.775 m from triplet.

- β^* = 38.37 m, α^* = 0 gives a spot size σ = 1 mm for 20π emittance (120 GeV/c).

- $\beta_{x,y}$(max) = 80 m in the triplet.

The 1.6 m space between Q2 & Q3 is ideal for beam diagnostics & correction packages:

- $\beta_x = \beta_y$ = 60 m for MW's, BPM's, etc.

- 90° of phase advance to the target for both horizontal & vertical correctors.

$\eta_x = \eta_y \equiv 0$ throughout the FF

So, what now …

- **Geometry** – confirm (i.e: ***Gordan*** confirms) that the line goes where I think it does, and doesn't wander off to … well, say, Kentucky.
    - refine geometry as necessary.
- **Optics** – in the beam direction, sequentially:
    - refit & optimize NuMI $\rightarrow$ LBNE matching section to reduce β(max) from ~78 m;
    - revisit combined η_x suppressor + vertical achromatic insertion to explore other possibilities;
    - the triplet vertical achromatic insertion is already ***beeoooootiful*** and can be lengthened and/or slide up & down the line in units of integral cell lengths if desired.
    - final focus matching quad sites need to be optimized to provide a "wide" range of β^* to accommodate varying beam conditions. [Ideally, the triplet gradients remain constant & only 4 variable quads would be needed to dial up any β^* with $\alpha^* = 0$].
- other ….. ?