Neutrino Factory
front-end:
44-88 MHz (rotation)
progress
44-88 MHz Front-end (1/2)

Pion production: 2 GeV proton beam on a 26 cm long Hg target in 20 T field (SPL+accumulator & compressor ring).

Decay: 30 m long in 1.8 T.

Rotation: particles with 100-300 MeV in kinetic energy rotated by 44 MHz (2 MV/m) RF cavities (energy spread divided by 2).

Cooling I: 44 MHz RF + H$_2$ absorbers reducing the transverse emittance in each plane by a factor 0.6.

Acceleration I: particles accelerated to an average energy of 300 MeV with 44 MHz cavities.
44-88 MHz Front-end (2/2)

Cooling II: 88 MHz (4 MV/m) RF + H₂ absorbers.

Acceleration II: 88 MHz cavities.
Lattice transverse optics (1/3)

Initial beam of 4 particles with (x,px,y,py) coordinates:

\[ \begin{align*}
    x_1 &= (a,0,0,b) \\
    x_2 &= (\cos(30),b/2,a/2,b\cos(30)) \\
    x_3 &= (a/2,b\sin(60),\sin(60),b/2) \\
    x_4 &= (0,a,b,0)
\end{align*} \]

\[ a = 0.01 \text{ m} \quad b = 0.01075 \text{ GeV/c}. \]

(x-y) plane circle of radius a.
(x,px) plane ellipse of semi-axes a,b.
(y,py) plane ellipse of semi-axes a,b.

Need \( x_i \) belonging to the same 4D ellipsoid.
Lattice transverse optics (2/3)

ICOOL gives for each z position & momentum but not the optics parameters (twiss, emittance...).

Transfer map $R$ between plane $i$ & $i+1$ is $X_{i+1} = R.X_i$:

- retrieve from ICOOL $X_I = (x_1, x_2, x_3, x_4)$ plane $i$
- retrieve from ICOOL $X_F = (x_1, x_2, x_3, x_4)$ plane $i+1$

$X_F = R.X_I$ ⇔ $R = X_F.(X_I)^{-1}$

$X_I$ needs to be invertible

Beam ellipsoid $\sigma$ such as $X^T.\sigma^{-1}.X = 1$ for each plane:

$\sigma_{i+1} = R.\sigma_i.R^T$

must stay an ellipsoid after each transformation
Lattice transverse optics (3/3)

Determination of $\sigma_0$ coefficients.

Assume $\sigma_{ij} = \langle x_i . x_j \rangle$ (correct ?)

Use the relations:

$\langle \cos x . \cos x \rangle = \langle \sin x . \sin x \rangle = \frac{1}{2}$

$\langle \cos x . \sin x \rangle = 0$ (can we ?)

Problems:

$\det(\sigma_0) = 0$

2x2 sub-matrices in \((x,px)\) and \((y,py)\) factor $\frac{1}{2}$
Checking the algorithm (1/1)

No RF & no magnetic field: drift, no x-y coupling.

In 2D R is indeed the map of a drift $R_{11} = 0$, $R_{12} = L$, $R_{21} = 0$, $R_{22} = 1$ in (x,px) or (y,py) planes.

Does not work for 4D?

R11 is not 1
R12 is not L
Momentum transformation (1/1)

Need to check if energy spread /2
Sigma matrix (1/2)

5 m periodicity
Sigma matrix (2/2)
To do

Try to understand the problems or change to a “real” optics code (MAD-X, OPTIM, PATH).

- pros: ICOOL not designed for transverse optics
- cons: more code learning/implementation time lost

Implement cooling & acceleration in the lattice.
Look at the longitudinal phase space.
Implement the 20T to 1.8 T drift part.
Test a 5-15 GeV beam on this lattice.