A Phase Space Tomography Diagnostic for PITZ

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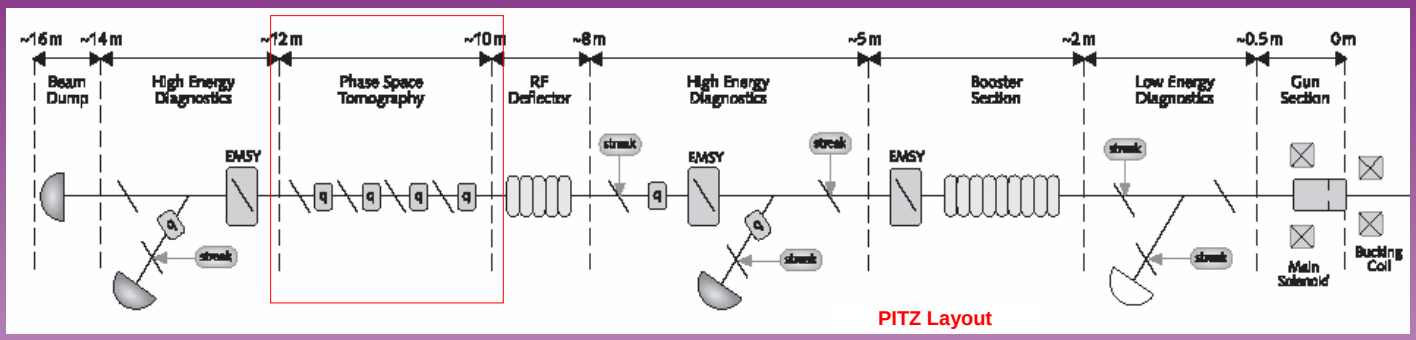


PITZ Layout

PITZ Constraints:

-Cover energy range of 13-40 MeV (to include upgrade options);

-Total length <5 m;

-Diagnostic positioned at 9 m from the cathode;

-ASTRA simulates beam properties for various injector settings;

-Four-screen emittance measurement method.

Designing the FODO lattice

The FODO cell must be periodic in beta and have a phase advance of 45 degrees. For arbitrarily chosen sensible quadrupole parameters, length (l) = 0.2 m and strength k = 10 m^{-1} the periodic solution can first be estimated using the thin lens solution.

Thin Lens Approximation of a FODO Cell

$$\begin{pmatrix} 1 & L/2 \\ 0 & 1 \end{pmatrix}\cdot\begin{pmatrix} 1 & 0 \\ 1/f & 1 \end{pmatrix}\cdot\begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix}\cdot\begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix}\cdot\begin{pmatrix} 1 & L/2 \\ 0 & 1 \end{pmatrix}$$

Point to Point Transfer Matrix

$$\begin{pmatrix} \cos(\mu)+\alpha\sin(\mu) & \beta\sin(\mu) \\ -\gamma\sin(\mu) & \cos(\mu)-\alpha\sin(\mu) \end{pmatrix}$$

The two can be equated with the constraint that cos(μ)=√2/2.

The solution is (q=kl):

$$L = \frac{\sqrt{2-\sqrt{2}}}{q}$$

$$\alpha = -\sqrt{2\left(2-\sqrt{2}\right)}$$

$$\beta = \frac{1}{2}\left(\frac{\sqrt{2-\sqrt{2}}}{q} + \frac{3\sqrt{2\left(2-\sqrt{2}\right)}}{q}\right)$$

$$\gamma = \sqrt{2\left(2-\sqrt{2}\right)}\,q$$

Tomography Diagnostic Layout

The diagnostic consists of a four-quadrupole matching section followed by 3 FODO cells. A screen is placed around each FODO cell. The field strength in the FODO quadrupoles remains constant.

When the beam is matched into the FODO lattice the alpha and beta function are well defined. The emittance measurement can be inferred from the area constructed in phase space.

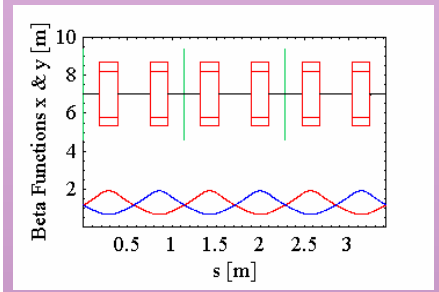
The phase advance between FODO cells is defined to give results in phase space at different orientations. The optimum screen to screen phase advance is π/N, where N is the number of screens.

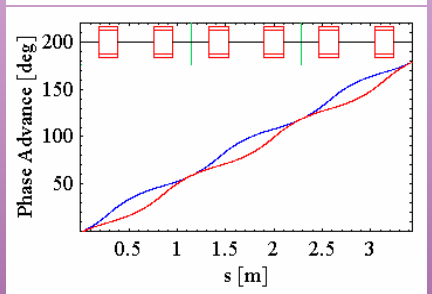
With three parameters to measure (alpha, beta, epsilon) a four screen measurement provides some redundancy.

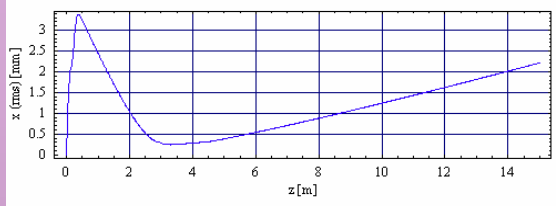
For maximum coverage of phase space, μ_x and μ_y = 45 degrees.

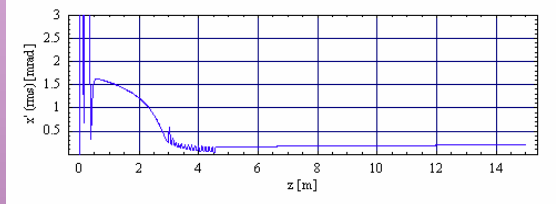
Graphically, the normalised matched phase space is a circle with beam measurements made at π/N phase intervals. Poor fits to the expected circle indicate a mismatch.

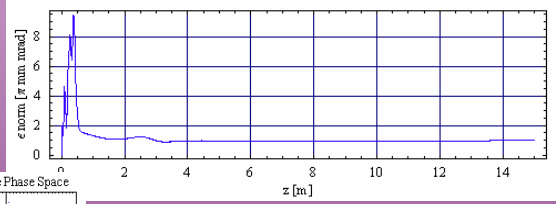
To produce the condition of a matched beam into the FODO lattice, four matching quadrupoles are required upstream of the tomography measurement diagnostic (one for each degree of freedom). They must be designed to operate over the full working range of PITZ.

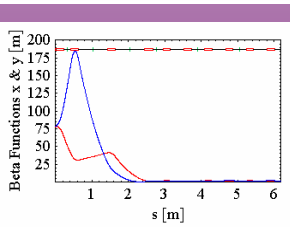


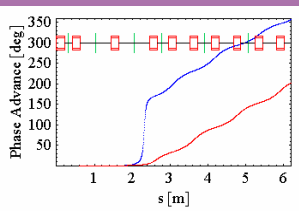


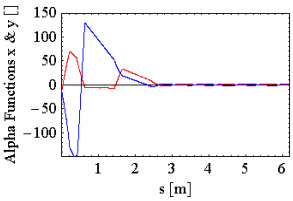












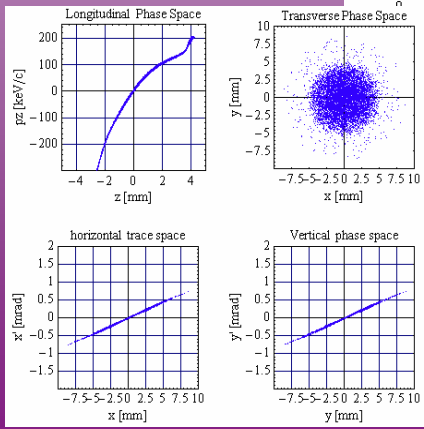
Preliminary Results

Next steps:

-Diagnostic is 6 m long!

-Large alphas and betas – maybe need more quads in matching;

-For low energy case (13 MeV) there is space charge blow up over the length of tomography section.



PITZ Upgrade ASTRA Simulation @32 MeV

1 nC

βx,y at 9 m	78 m
αx,y at 9 m	-13.46