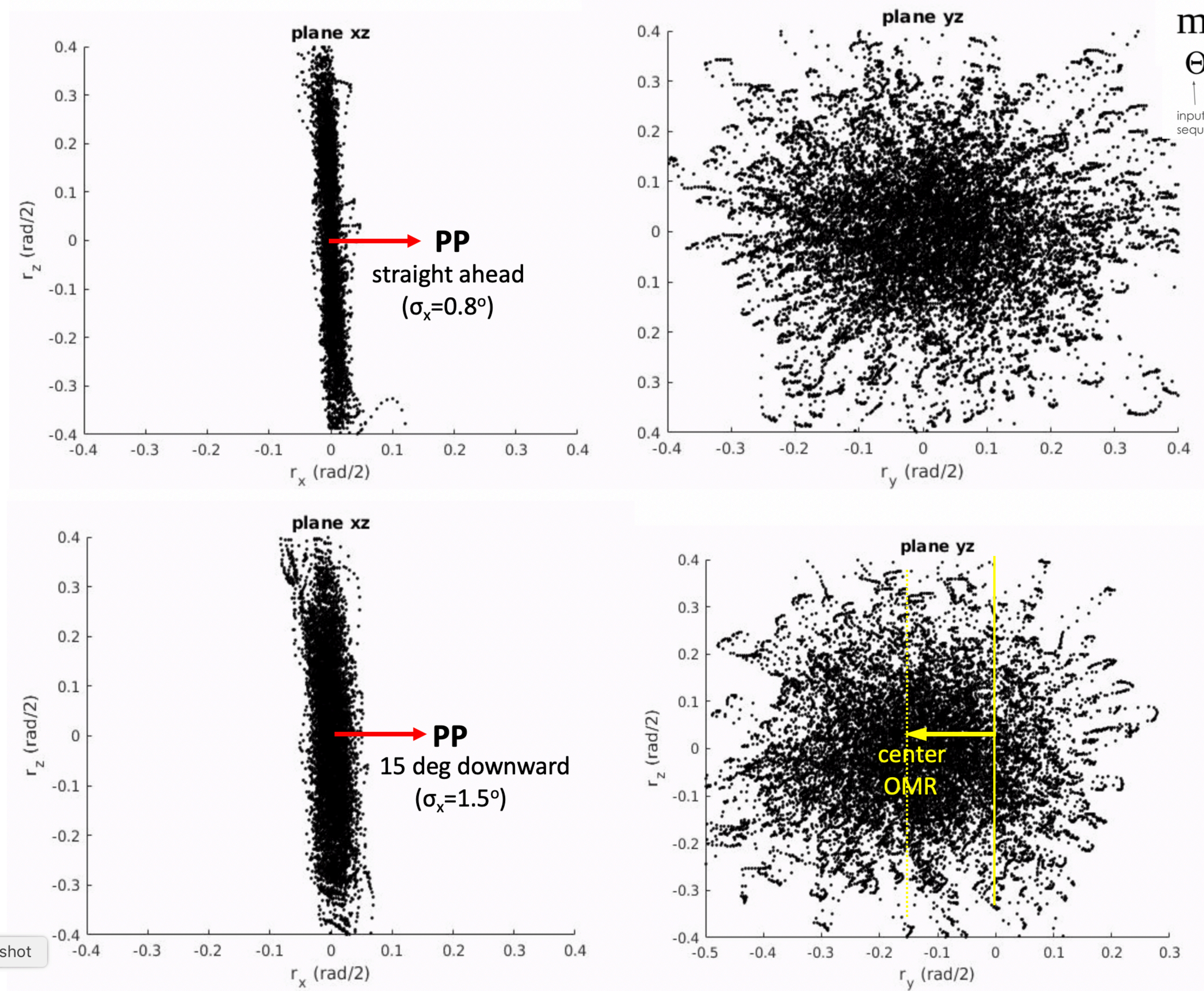

$$\min_{\Theta, p} \quad J(\Theta, p) = \sum_i \lambda_i J_i(\Theta, p)$$

Θ: input sequence; p: saccade duration

Optimal control

$$\Theta = \begin{bmatrix} \mathbf{u_0} \\ \mathbf{u_1} \\ \vdots \\ \mathbf{u_p} \end{bmatrix}$$

$$J_{ene}(\Theta, p) = ||M\Theta||^2$$

$$J_{acc}(\mathbf{\Theta}, \mathbf{p}) = ||\mathbf{y_p} - \mathbf{\hat{y}_p}||^2 \qquad \hat{\mathbf{y}}_p = \begin{bmatrix} \hat{r}_x \\ \hat{r}_y \\ \hat{r}_z \end{bmatrix}$$

$$J_{dur}(\Theta, p) = \left(1 - \frac{1}{1+\beta p}\right) = J_{dur}(p)$$

Listing's law for saccades: I

- minimal duration (single-axis rotation)
- minimal total energy (∝ (control vel.)^2)
- accuracy cost (r_x=0 at end)

$$J_{acc}(\mathbf{\Theta}, \mathbf{p}) = ||\mathbf{y_p} - \mathbf{\hat{y}_p}||^2 \qquad \hat{\mathbf{y}}_p = \begin{bmatrix} \hat{r}_y \\ \hat{r}_z \end{bmatrix}$$

$J_{dur}(\Theta, p)$ and $J_{ene}(\Theta, p)$

$$J_{eff}(\Theta, p) = \mathbf{y_p^T Q_f \; y_p}$$

Q_f = force exerted

Listing's law for saccades: II

- minimal duration and energy
- accuracy cost (no constraint on r_x!)
- minimal effort (total summed forces)