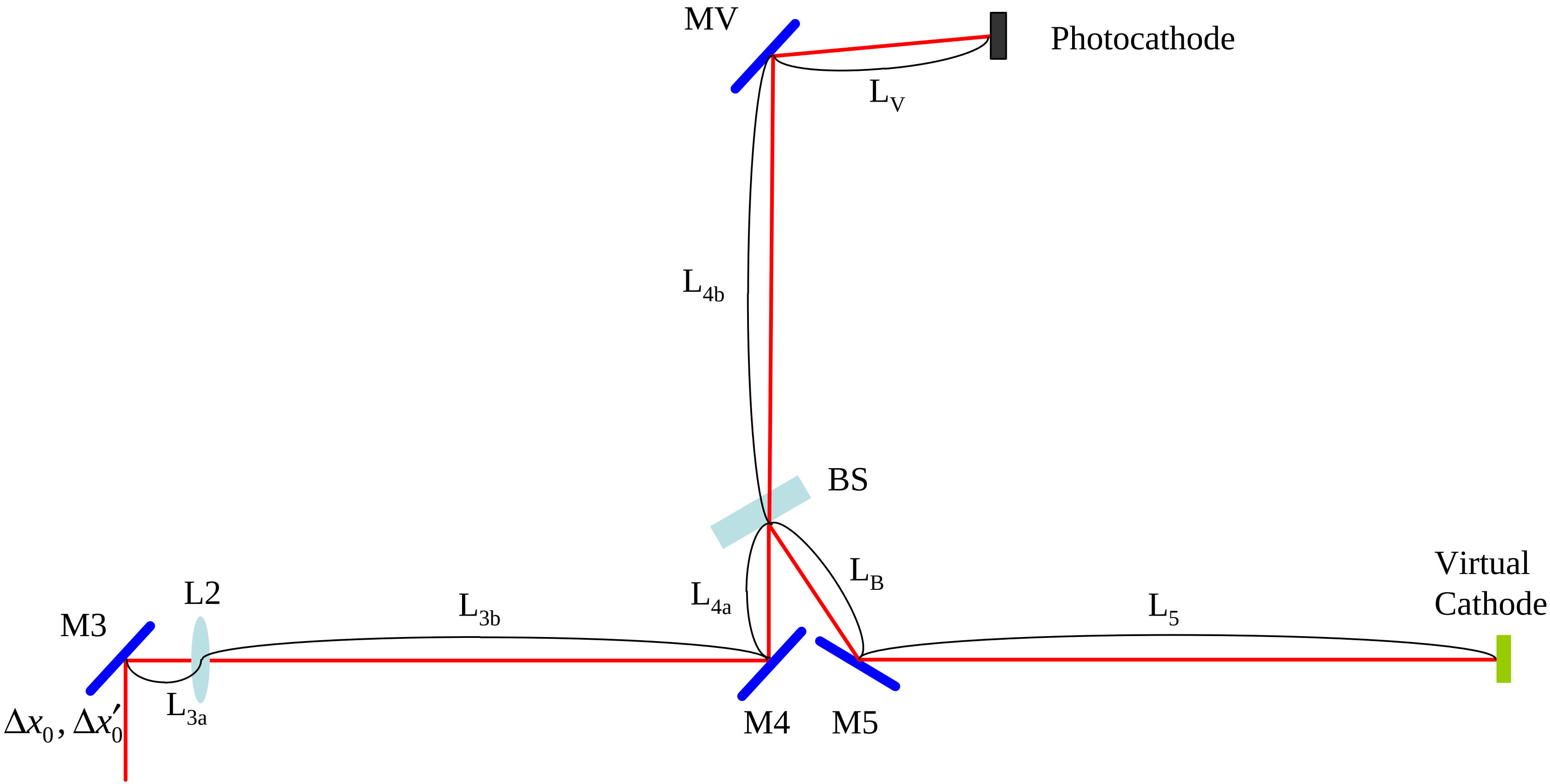
Layout of Optical Components in the Tunnel of PITZ



Numbers from the Draw & Rough Measurement

Numbers in Draw (mm)

$L_3 = 3162$

$L_4 = 3040$

$L_V = 655$

$f = 7000$

Assumed Number (mm)

$L_B + L_5 = L_{4b} + L_V = 3075$

Measured Numbers (mm)

$L_{3a} = 130$

$L_{3b} = (L_3 - L_{3a}) = 3032$

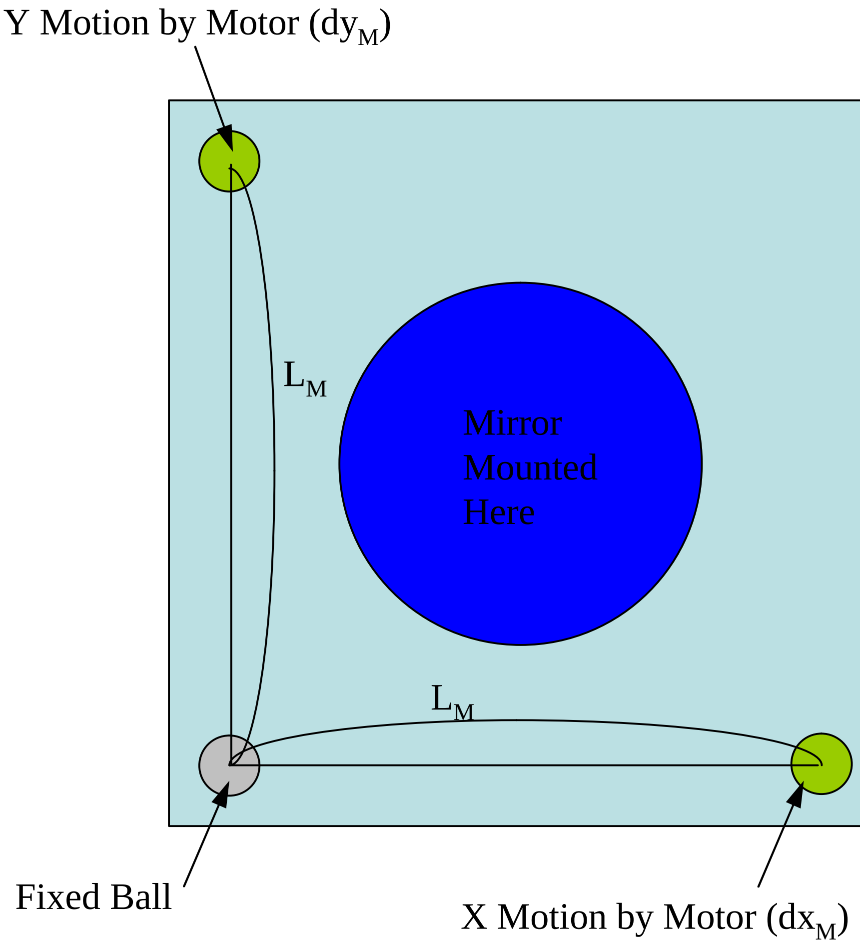
$L_{4a} = 620$

$L_{4b} = (L_4 - L_{4a}) = 2420$

$L_{M3} = 100$

$L_{M4} = 160$

Mechanism of Mirror Movement



Distance between Movable Points

L_{M3}=100
L_{M4}=160

Mirror Diameter

M3=50
M4=75

Position & Angle at M4

$$\Delta x_{M4} = -\left[1-\frac{L_{3b}}{f}\right]\Delta x_0 - \left[(L_{3a}+L_{3b})-\frac{L_{3a}L_{3b}}{f}\right]\Delta x_0' + \left[\frac{1}{\sqrt{2}}+\frac{2(L_{3a}+L_{3b})}{L_{M3}}-\frac{L_{3b}}{\sqrt{2}f}-\frac{2L_{3a}L_{3b}}{f\ L_{M3}}\right]dx_{M3} + \left[\frac{1}{2}-\frac{L_{3b}}{2f}\right]dy_{M3}$$

$$\Delta x_{M4}' = \frac{\Delta x_0}{f} - \left(1-\frac{L_{3a}}{f}\right)\Delta x_0' + \left(-\frac{1}{\sqrt{2}f}+\frac{2}{L_{M3}}-\frac{2L_{3a}}{fL_{M3}}\right)dx_{M3} - \frac{dy_{M3}}{f}$$

$$\Delta y_{M4} = \left[1 - \frac{L_{3b}}{f}\right]\Delta y_0 + \left[(L_{3a} + L_{3b}) - \frac{L_{3a}L_{3b}}{f}\right]\Delta y_0' - \left[\frac{\sqrt{2}(L_{3a} + L_{3b})}{L_{M3}} - \frac{\sqrt{2}L_{3a}L_{3b}}{f\ L_{M3}}\right]dy_{M3}$$

$$\Delta y_{M4}' = -\frac{\Delta y_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta y_0' - \left(\frac{\sqrt{2}}{L_{M3}} - \frac{\sqrt{2}L_{3a}}{fL_{M3}}\right)dy_{M3}$$

Position & Angle at MV

$$\Delta x_{MV} = \left[1 - \frac{(L_{3b} + L_{4a} + L_{4b})}{f}\right]\Delta x_0$$

$$+\left[(L_{3a} + L_{3b} + L_{4a} + L_{4b}) - \frac{L_{3a}(L_{3b} + L_{4a} + L_{4b})}{f}\right]\Delta x_0'$$

$$-\left[\frac{1}{\sqrt{2}} + \frac{2(L_{3a} + L_{3b} + L_{4a} + L_{4b})}{L_{M3}} - \frac{(L_{3b} + L_{4a} + L_{4b})}{\sqrt{2}f} - \frac{2L_{3a}(L_{3b} + L_{4a} + L_{4b})}{f\ L_{M3}}\right]dx_{M3}$$

$$-\left[\frac{1}{2} - \frac{(L_{3b} + L_{4a} + L_{4b})}{2f}\right]dy_{M3}$$

$$-\left[\frac{1}{\sqrt{2}} - \frac{2(L_{4a} + L_{4b})}{L_{M4}}\right]dx_{M4}$$

$$-\frac{1}{2}dy_{M4}$$

$$\Delta x_{MV}' = -\frac{\Delta x_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta x_0' - \left(-\frac{1}{\sqrt{2}f} + \frac{2}{L_{M3}} - \frac{2L_{3a}}{fL_{M3}}\right)dx_{M3} + \frac{dy_{M3}}{f} + \frac{dx_{M4}}{L_{M4}}$$

$$\Delta y_{MV} = \left[1 - \frac{(L_{3b} + L_{4a} + L_{4b} + L_V)}{f}\right]\Delta y_0 + \left[(L_{3a} + L_{3b} + L_{4a} + L_{4b}) - \frac{L_{3a}(L_{3b} + L_{4a} + L_{4b})}{f}\right]\Delta y_0' - \left[\frac{\sqrt{2}(L_{3a} + L_{3b} + L_{4a} + L_{4b})}{L_{M3}} - \frac{\sqrt{2}L_{3a}(L_{3b} + L_{4a} + L_{4b})}{f\ L_{M3}}\right]dy_{M3} - \frac{\sqrt{2}(L_{4a} + L_{4b})}{L_{M4}}dy_{M4}$$

$$\Delta y_{MV}' = -\frac{\Delta y_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta y_0' - \left(\frac{\sqrt{2}}{L_{M3}} - \frac{\sqrt{2}L_{3a}}{fL_{M3}}\right)dy_{M3} - \frac{\sqrt{2}}{L_{M4}}dy_{M4}$$

Position & Angle at Photocathode

$$\Delta x_{cathode} =$$

$$-\left[1-\frac{(L_{3b}+L_{4a}+L_{4b}+L_V)}{f}\right]\Delta x_0$$

$$-\left[(L_{3a}+L_{3b}+L_{4a}+L_{4b}+L_V)-\frac{L_{3a}(L_{3b}+L_{4a}+L_{4b}+L_V)}{f}\right]\Delta x_0'$$

$$+\left[\frac{1}{\sqrt{2}}+\frac{2(L_{3a}+L_{3b}+L_{4a}+L_{4b}+L_V)}{L_{M3}}-\frac{(L_{3b}+L_{4a}+L_{4b}+L_V)}{\sqrt{2}\,f}-\frac{2L_{3a}(L_{3b}+L_{4a}+L_{4b}+L_V)}{f\ L_{M3}}\right]dx_{M3}$$

$$+\left[\frac{1}{2}-\frac{(L_{3b}+L_{4a}+L_{4b}+L_V)}{2\,f}\right]dy_{M3}$$

$$+\left[\frac{1}{\sqrt{2}}-\frac{2(L_{4a}+L_{4b}+L_V)}{L_{M4}}\right]dx_{M4}$$

$$+\frac{1}{2}dy_{M4}$$

$$\Delta y_{cathode} =$$

$$\left[1 - \frac{(L_{3b} + L_{4a} + L_{4b} + L_V)}{f}\right]\Delta y_0$$

$$+\left[(L_{3a} + L_{3b} + L_{4a} + L_{4b} + L_V) - \frac{L_{3a}(L_{3b} + L_{4a} + L_{4b} + L_V)}{f}\right]\Delta y_0'$$

$$-\left[\frac{\sqrt{2}(L_{3a} + L_{3b} + L_{4a} + L_{4b} + L_V)}{L_{M3}} - \frac{\sqrt{2}L_{3a}(L_{3b} + L_{4a} + L_{4b} + L_V)}{f\ L_{M3}}\right]dy_{M3}$$

$$-\frac{\sqrt{2}(L_{4a} + L_{4b} + L_V)}{L_{M4}}dy_{M4}$$

$$\Delta x'_{cathode} = \frac{\Delta x_0}{f} - \left(1 - \frac{L_{3a}}{f}\right)\Delta x_0' + \left(-\frac{1}{\sqrt{2}f} + \frac{2}{L_{M3}} - \frac{2L_{3a}}{fL_{M3}}\right)dx_{M3} - \frac{dy_{M3}}{f} - \frac{dx_{M4}}{L_{M4}}$$

$$\Delta y'_{cathode} = -\frac{\Delta y_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta y_0' - \left(\frac{\sqrt{2}}{L_{M3}} - \frac{\sqrt{2}L_{3a}}{fL_{M3}}\right)dy_{M3} - \frac{\sqrt{2}}{L_{M4}}dy_{M4}$$

Position & Angle at Virtual Cathode

$$\Delta x_{virtual} =$$

$$\left[1-\frac{(L_{3b}+L_{4a}+L_B+L_5)}{f}\right]\Delta x_0$$

$$+\left[(L_{3a}+L_{3b}+L_{4a}+L_B+L_5)-\frac{L_{3a}(L_{3b}+L_{4a}+L_B+L_5)}{f}\right]\Delta x_0'$$

$$-\left[\frac{1}{\sqrt{2}}+\frac{2(L_{3a}+L_{3b}+L_{4a}+L_B+L_5)}{L_{M3}}-\frac{(L_{3b}+L_{4a}+L_B+L_5)}{\sqrt{2}\,f}-\frac{2L_{3a}(L_{3b}+L_{4a}+L_B+L_5)}{f\;L_{M3}}\right]dx_{M3}$$

$$-\left[\frac{1}{2}-\frac{(L_{3b}+L_{4a}+L_B+L_5)}{2\,f}\right]dy_{M3}$$

$$-\left[\frac{1}{\sqrt{2}}-\frac{2(L_{4a}+L_B+L_5)}{L_{M4}}\right]dx_{M4}$$

$$-\frac{1}{2}dy_{M4}$$

$$\Delta y_{virtual} =$$

$$\left[1 - \frac{(L_{3b} + L_{4a} + L_B + L_5)}{f}\right]\Delta y_0$$

$$+\left[(L_{3a} + L_{3b} + L_{4a} + L_B + L_5) - \frac{L_{3a}(L_{3b} + L_{4a} + L_B + L_5)}{f}\right]\Delta y_0'$$

$$-\left[\frac{\sqrt{2}(L_{3a} + L_{3b} + L_{4a} + L_B + L_5)}{L_{M3}} - \frac{\sqrt{2}L_{3a}(L_{3b} + L_{4a} + L_B + L_5)}{f\ L_{M3}}\right]dy_{M3}$$

$$-\frac{\sqrt{2}(L_{4a} + L_B + L_5)}{L_{M4}}dy_{M4}$$

$$\Delta x'_{virtual} = -\frac{\Delta x_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta x_0' - \left(-\frac{1}{\sqrt{2}\,f} + \frac{2}{L_{M3}} - \frac{2L_{3a}}{fL_{M3}}\right)dx_{M3} + \frac{dy_{M3}}{f} + \frac{dx_{M4}}{L_{M4}}$$

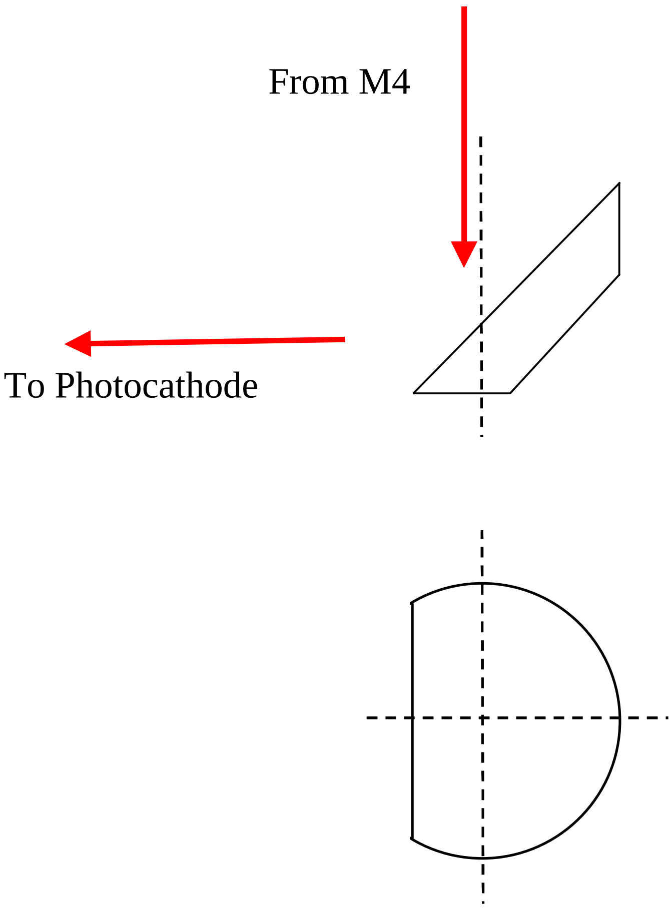
$$\Delta y'_{virtual} = -\frac{\Delta y_0}{f} + \left(1 - \frac{L_{3a}}{f}\right)\Delta y_0' - \left(\frac{\sqrt{2}}{L_{M3}} - \frac{\sqrt{2}L_{3a}}{fL_{M3}}\right)dy_{M3} - \frac{\sqrt{2}}{L_{M4}}dy_{M4}$$

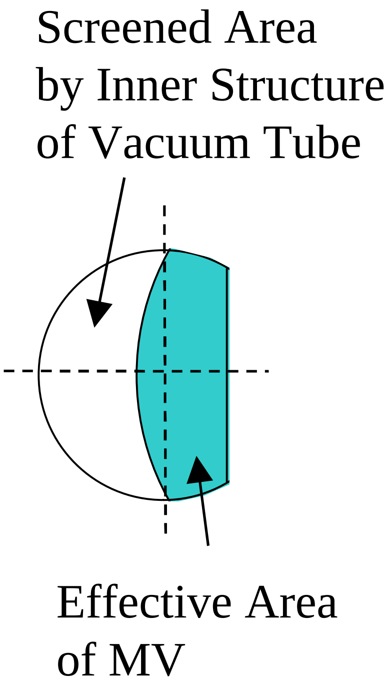
Position Variations Resulted from Initial Position & Angle Offset of the Laser Beam and the Movement of Mirrors

	x_0	x'_0	dx_{M3}	dy_{M3}	dx_{M4}	dy_{M4}
x_{M4}	-0.57	-3106	62.5	0.28		
x_{MV}	0.13	6089	-122	-0.07	37.3	-0.5
$x_{cathode}$	-0.04	-6732	135	0.02	-45	0.5
$x_{virtual}$	0.04	6732	-135	-0.02	45	-0.5

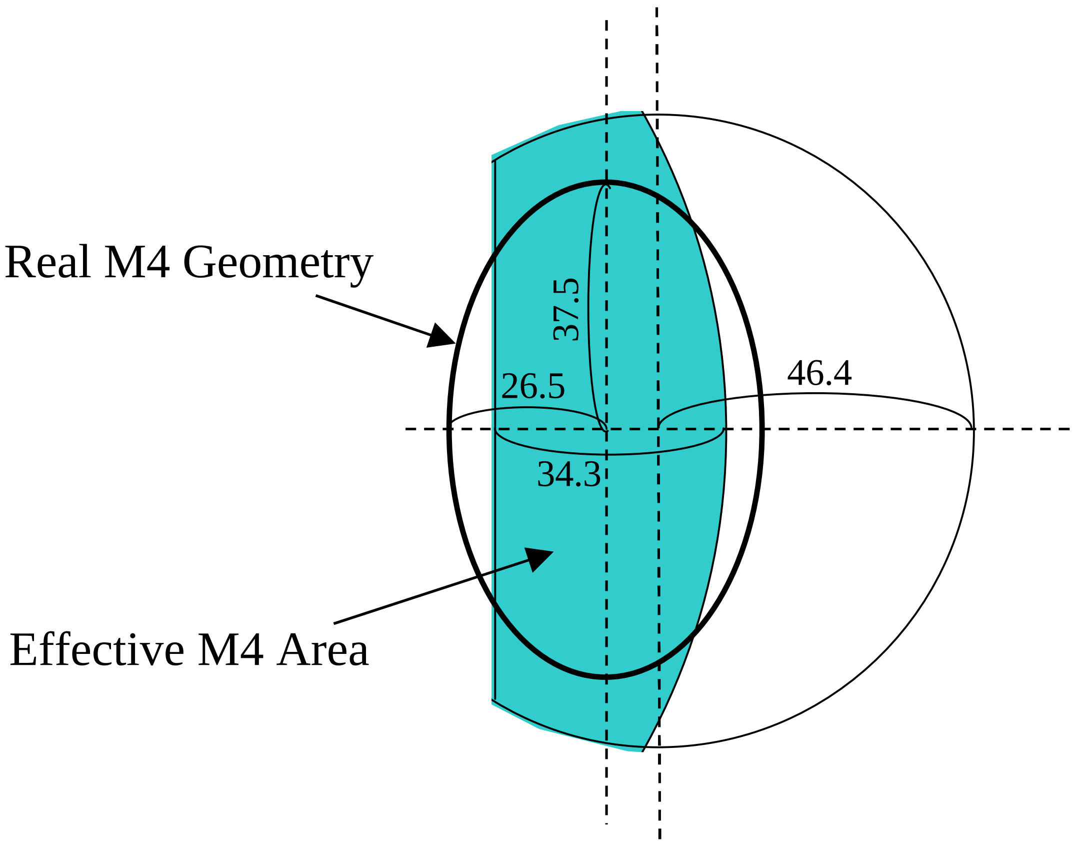
	y_0	y'_0	dx_{M3}	dy_{M3}	dx_{M4}	dy_{M4}
y_{M4}	0.57	3106	0	-43.9		
y_{MV}	0.13	6089	0	-84.7	0	-26.9
$y_{cathode}$	0.04	6732	0	-98	0	-32.5
$y_{virtual}$	0.04	6732	0	-98	0	-32.5

Description on MV

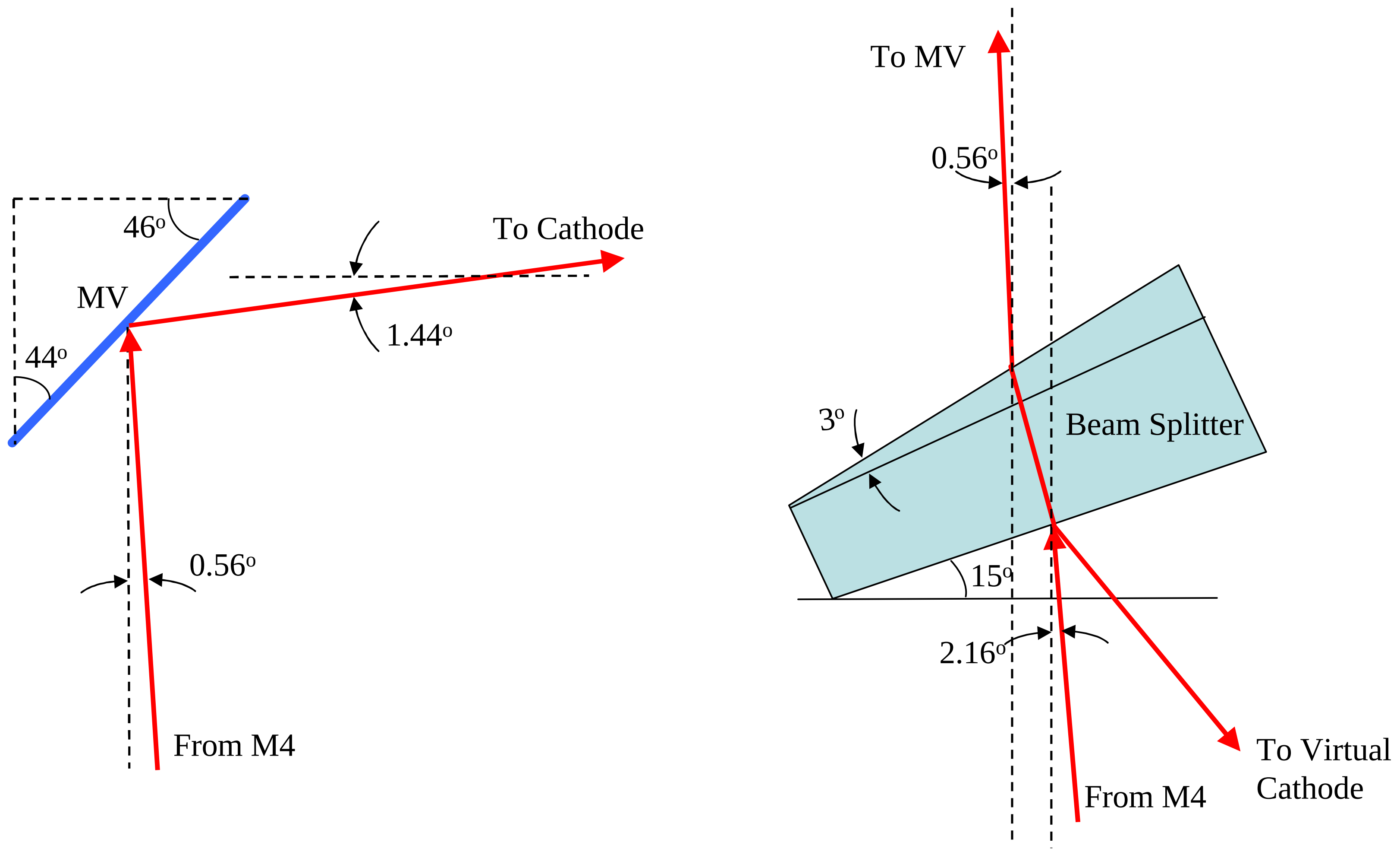




Effective Area of M4



Laser Motion at MV & Beam Splitter



Optimum Position & Angle of M4