Laser Transport Optics and Alignment

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PIP2 Laserwire Final Design Review

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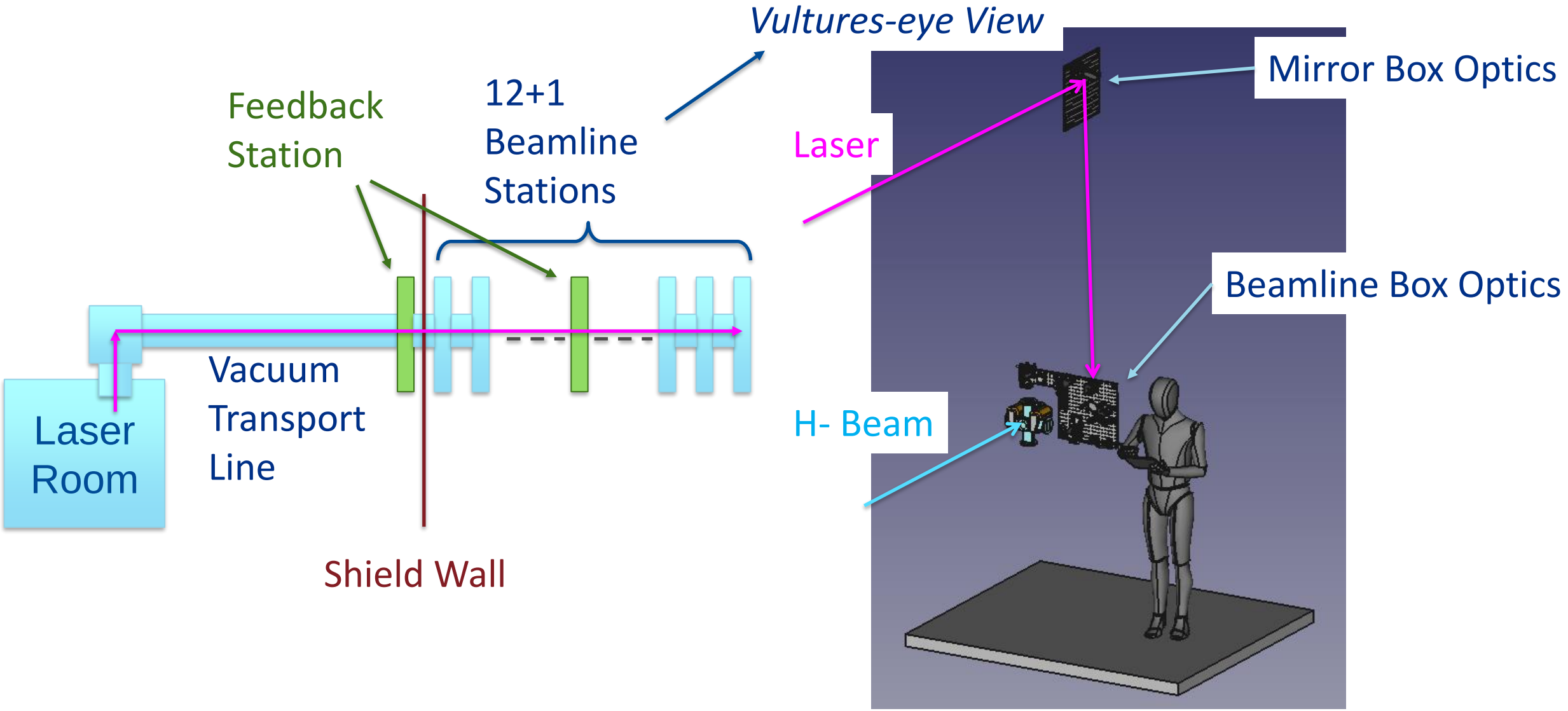
PIP-II

A Partnership of:

US/DOE
India/DAE
Italy/INFN
UK/STFC-UKRI
France/CEA, CNRS/IN2P3
Poland/WUST

Laserwire Beamline



Feedback Box Optics

- ≥ 2-inch cube beamsplitter

1064 nm Laser

Alignment/Feedback Laser

Not at focal point

Optical BPM

– *Alternatively* –

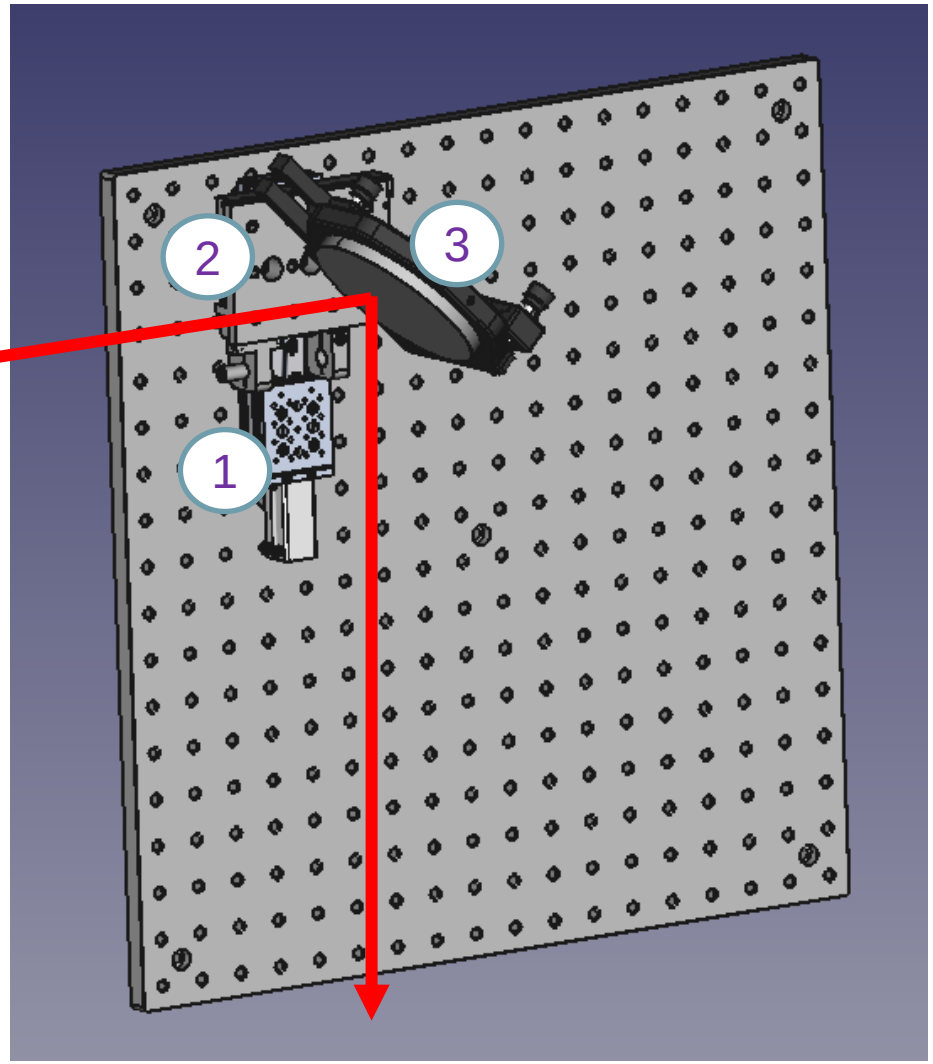
- Pair of ≥ 3-inch mirrors

Not 90 degrees to maximize mirror acceptance

Optical BPM

Thorlabs Lateral Effect Position Sensor

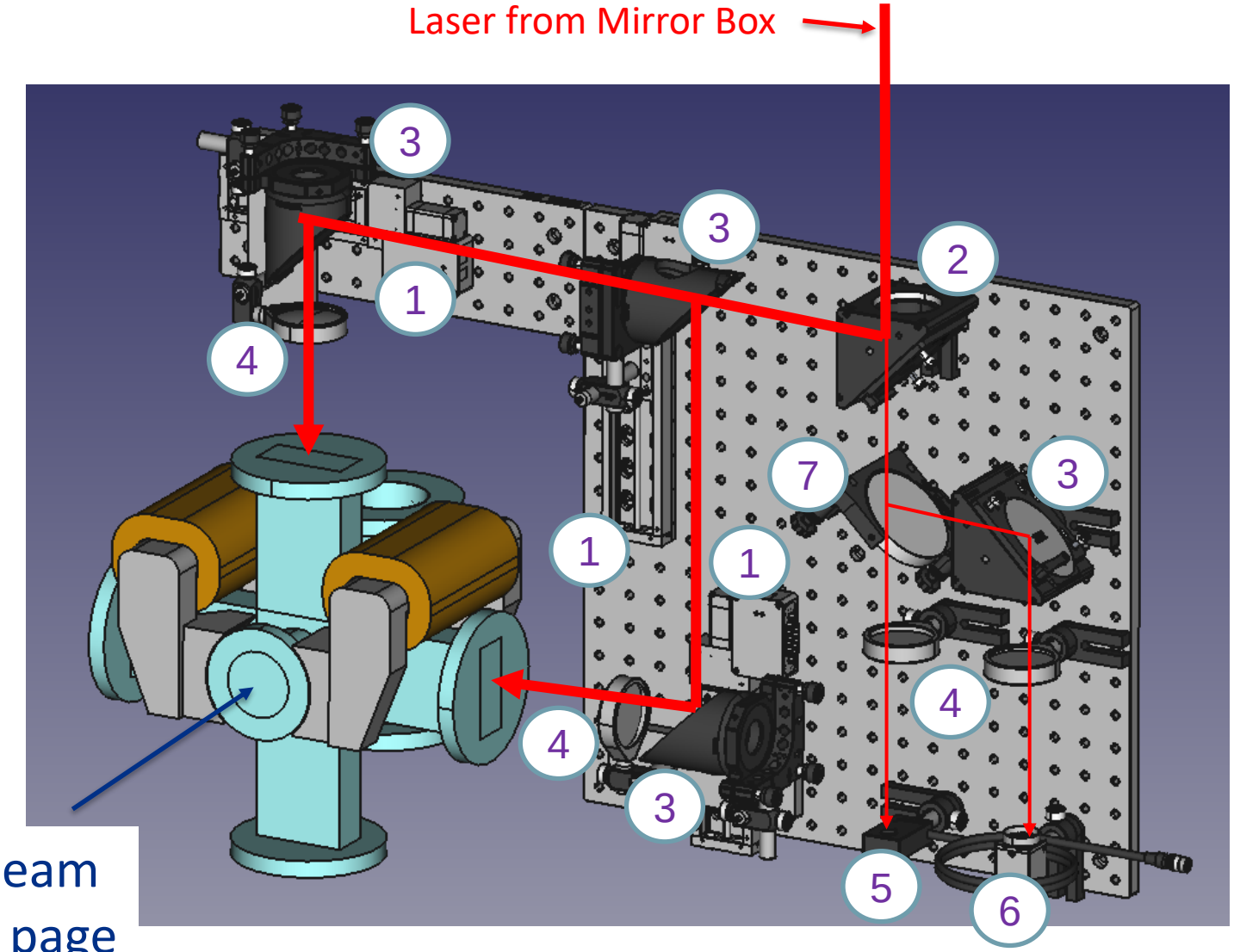
Mirror Box Optics



1. Motorized stage
2. Manual Stage
3. Pickoff Mirror

- Motorized stage to insert pickoff mirror
- Manual stage to adjust longitudinal position of downward laser trajectory during alignment
- Extra space for potential feedback or monitoring devices

Beamline Box Optics

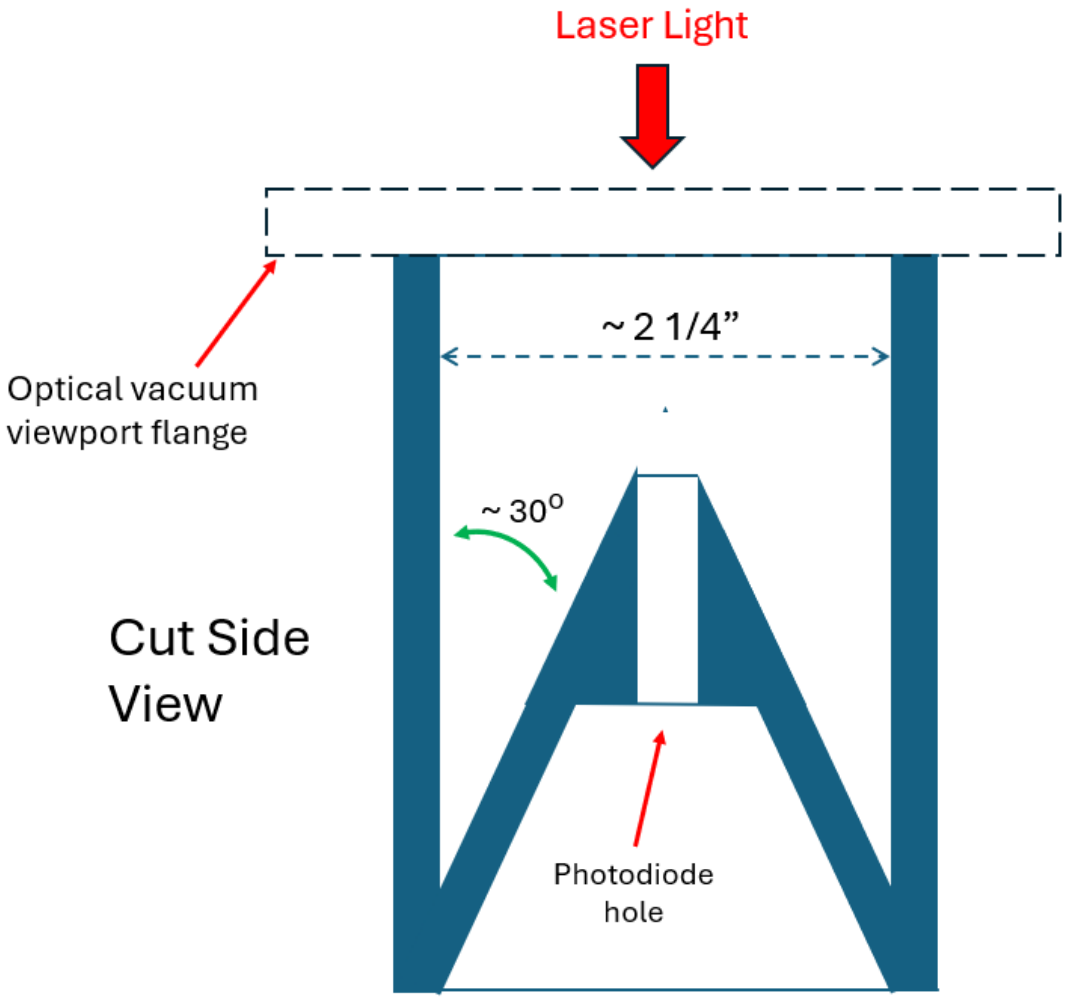


1. Motorized stage
2. Sampler (dielectric mirror)
3. Mirror
4. Focus Lens
5. Photodiode/BPM
6. Camera
7. Beamsplitter

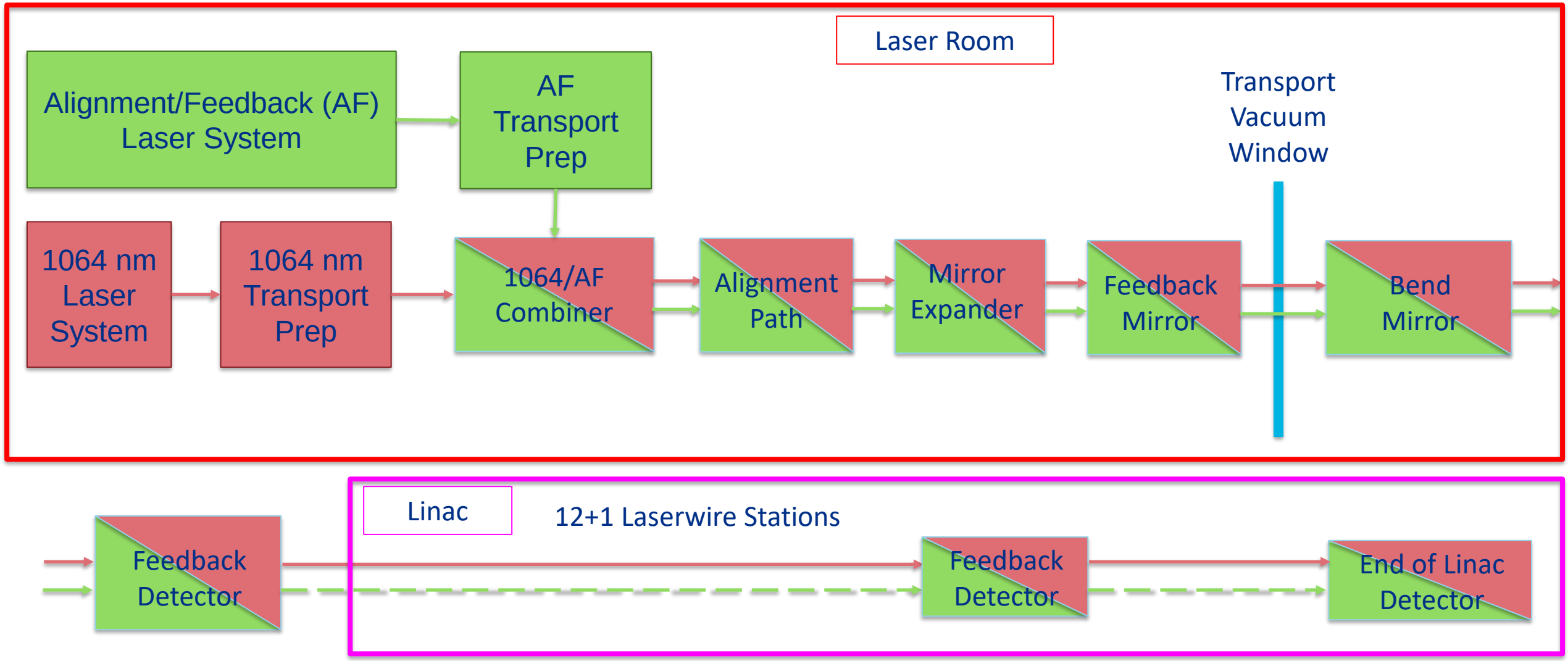
- Detectors may only be there for commissioning

Dump Box

- Two located on horizontal and vertical exit windows
- Absorber with hole for photodiode
- Dump aperture to be same as optical vacuum viewport
- Dump interior painted black or black anodized
- Interior angle ~ 30 degrees to minimize back reflections
- Seal between dump box and optical viewport flange will be light-tight



Laser Transport Optics



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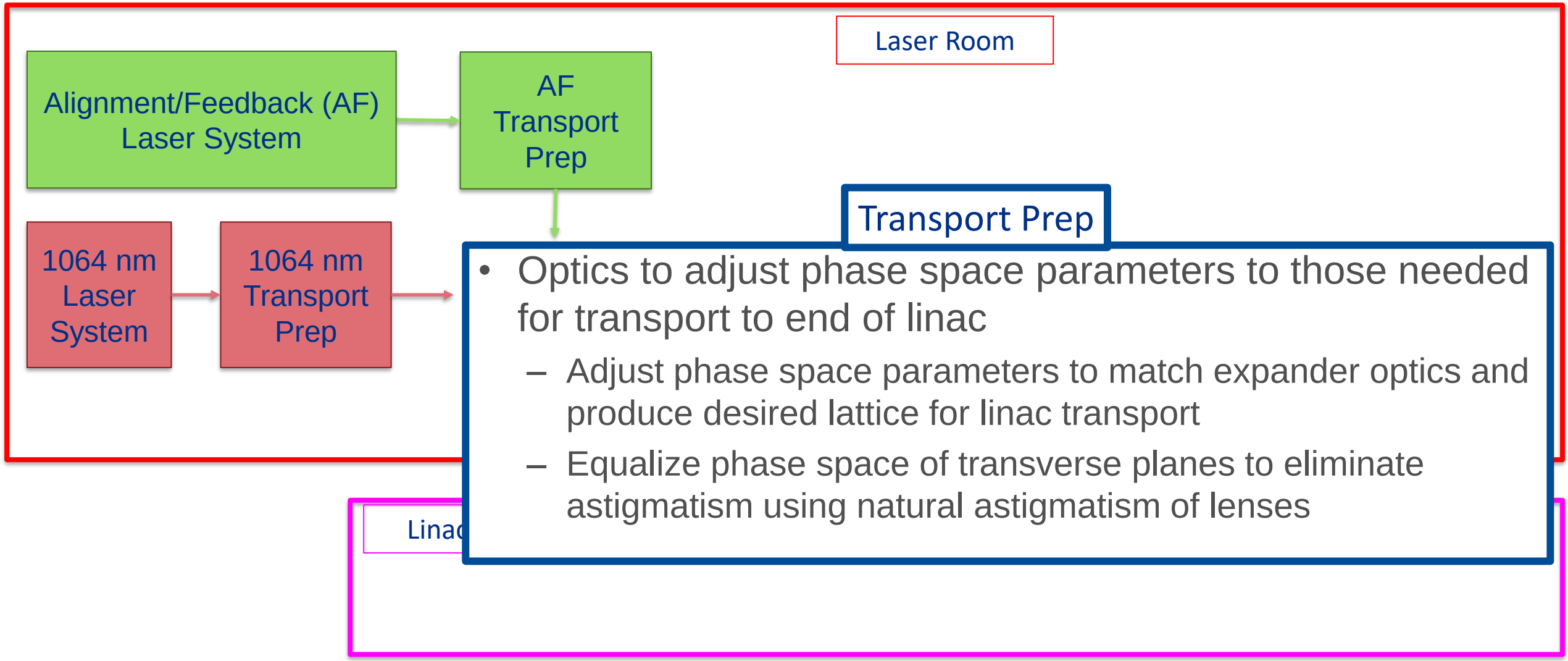
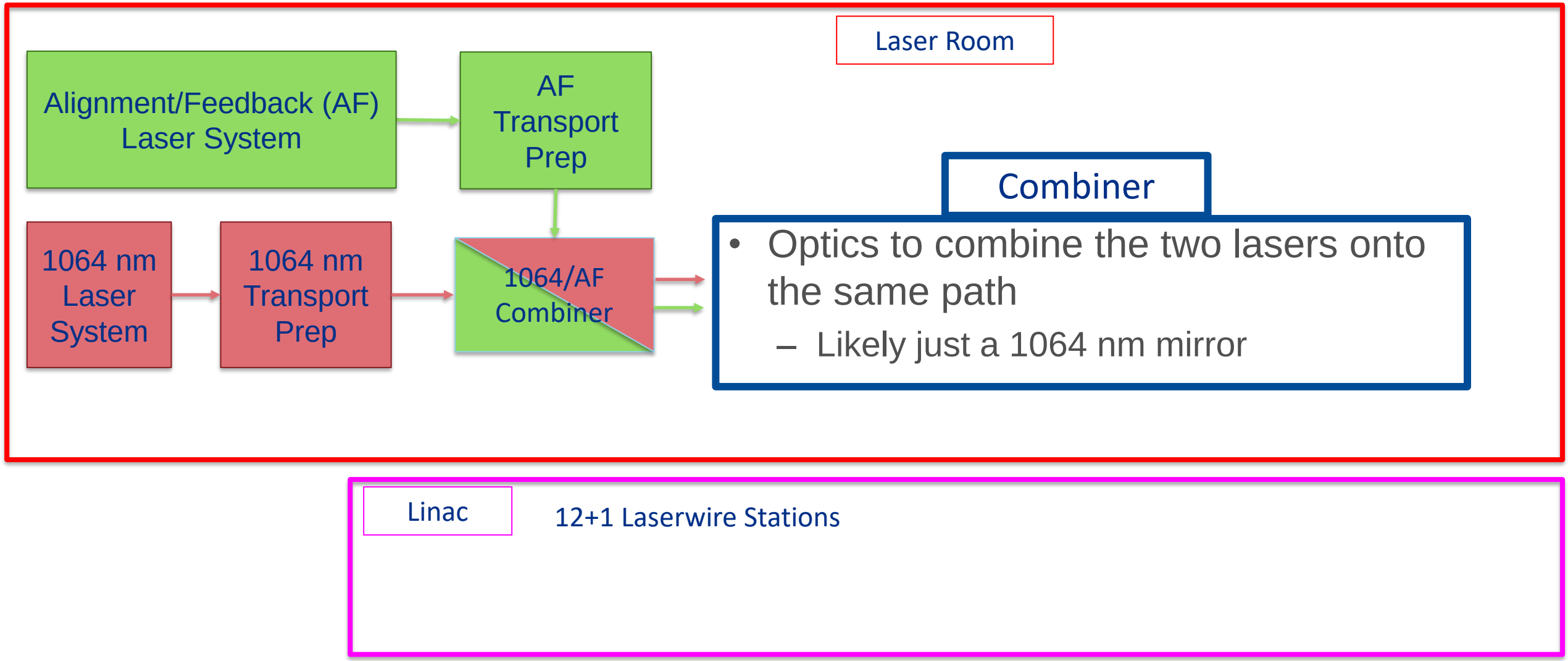
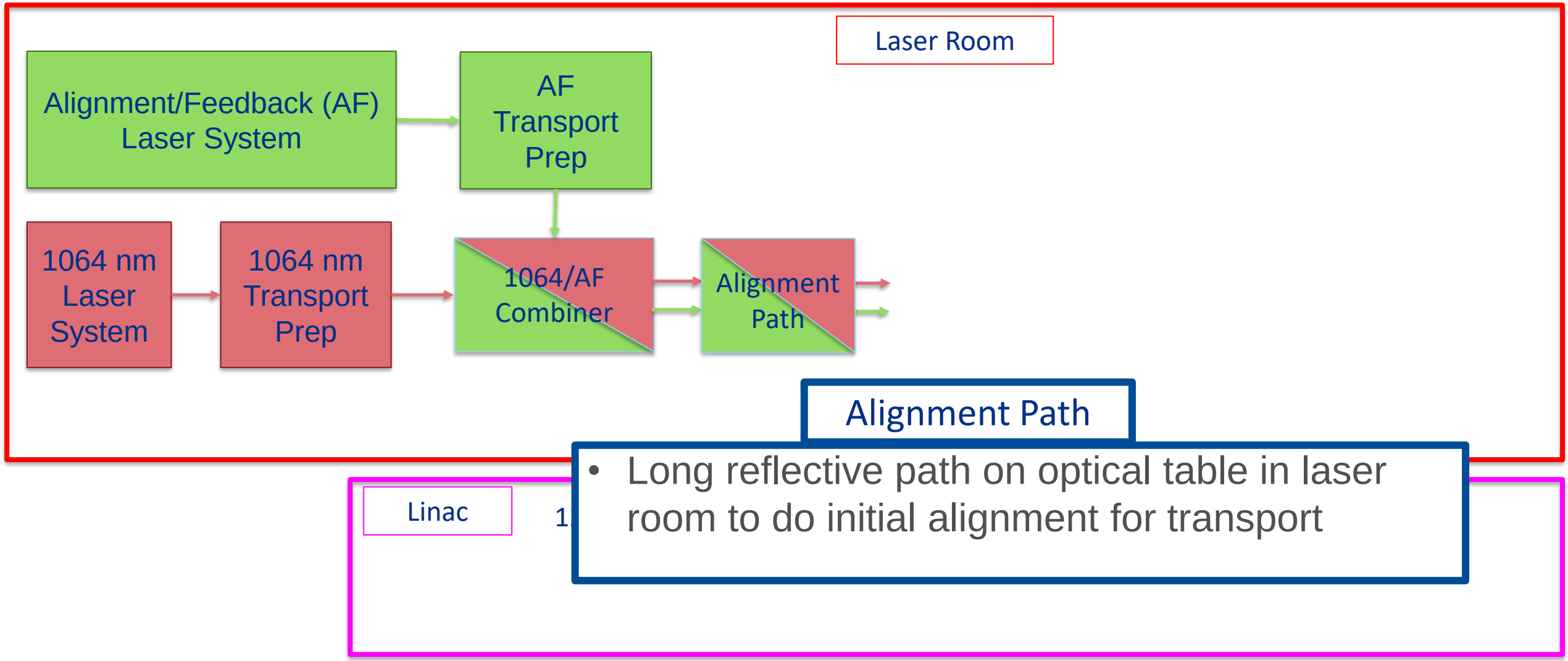


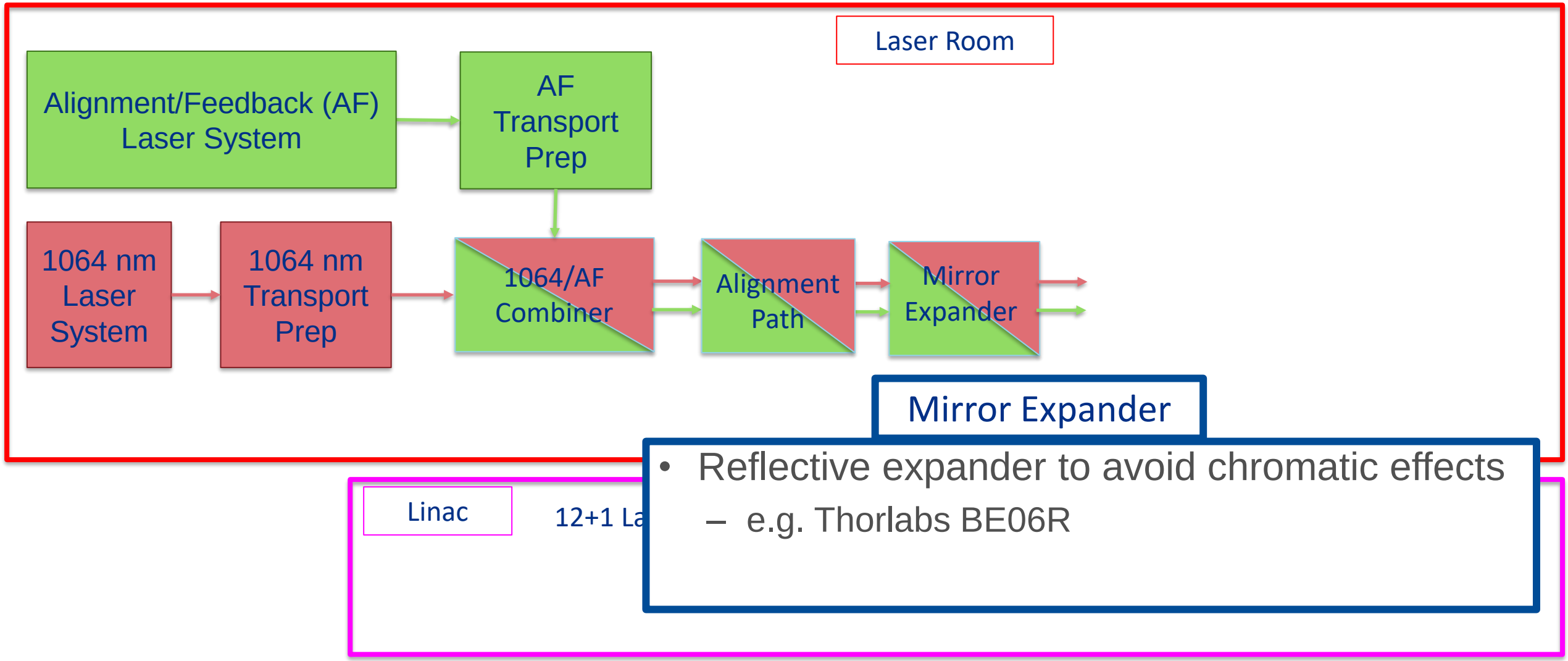
Laser Transport Optics



Laser Transport Optics



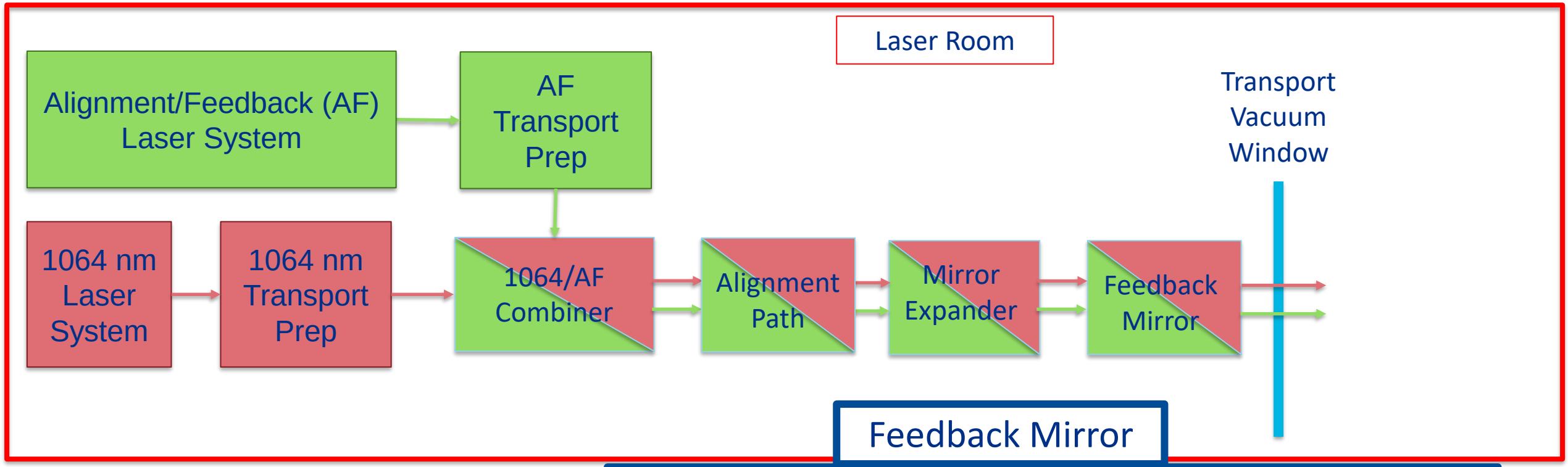
Laser Transport Optics



Mirror Expander

- Reflective expander to avoid chromatic effects
  - e.g. Thorlabs BE06R

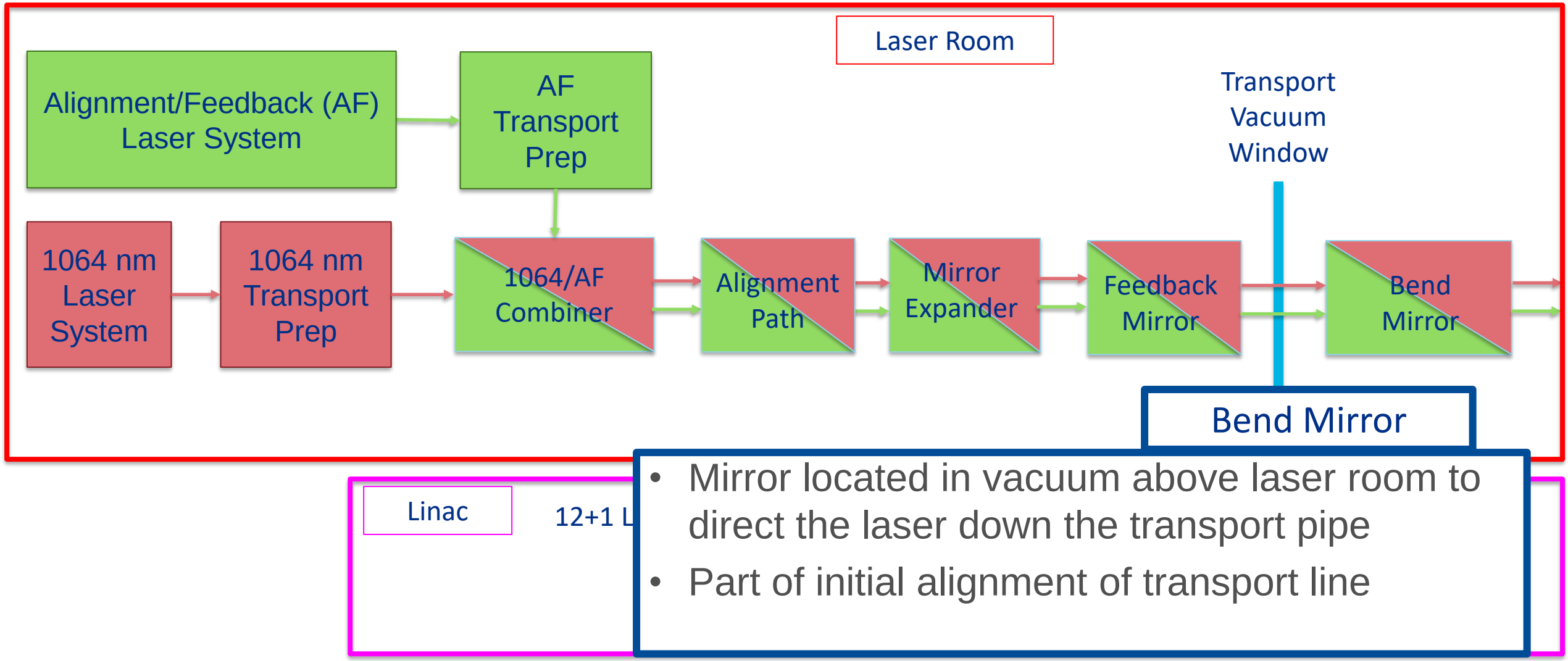
Laser Transport Optics



Feedback Mirror

- Piezo mirror to control alignment with feedback from downstream detectors
  - e.g. Thorlabs : PDP90A plus KPA101 plus POLARIS-K2S2P

Laser Transport Optics



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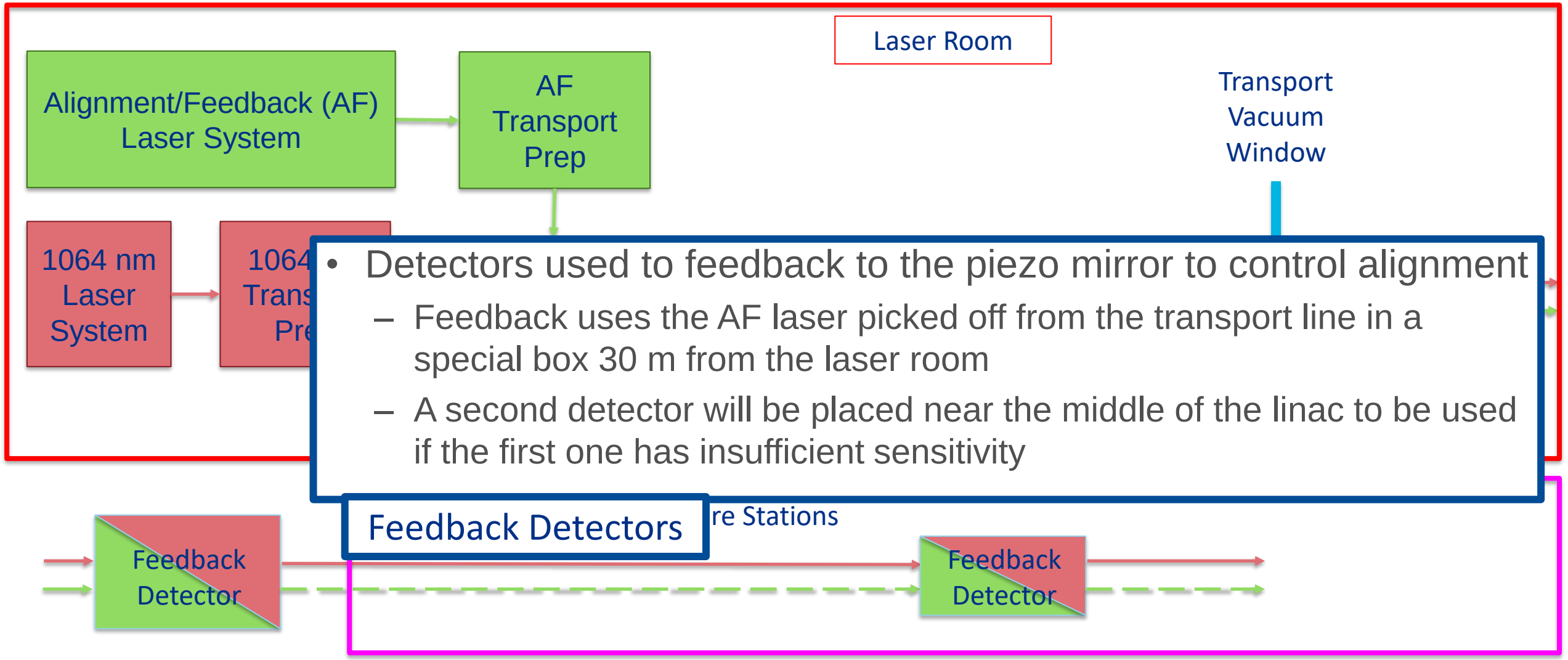

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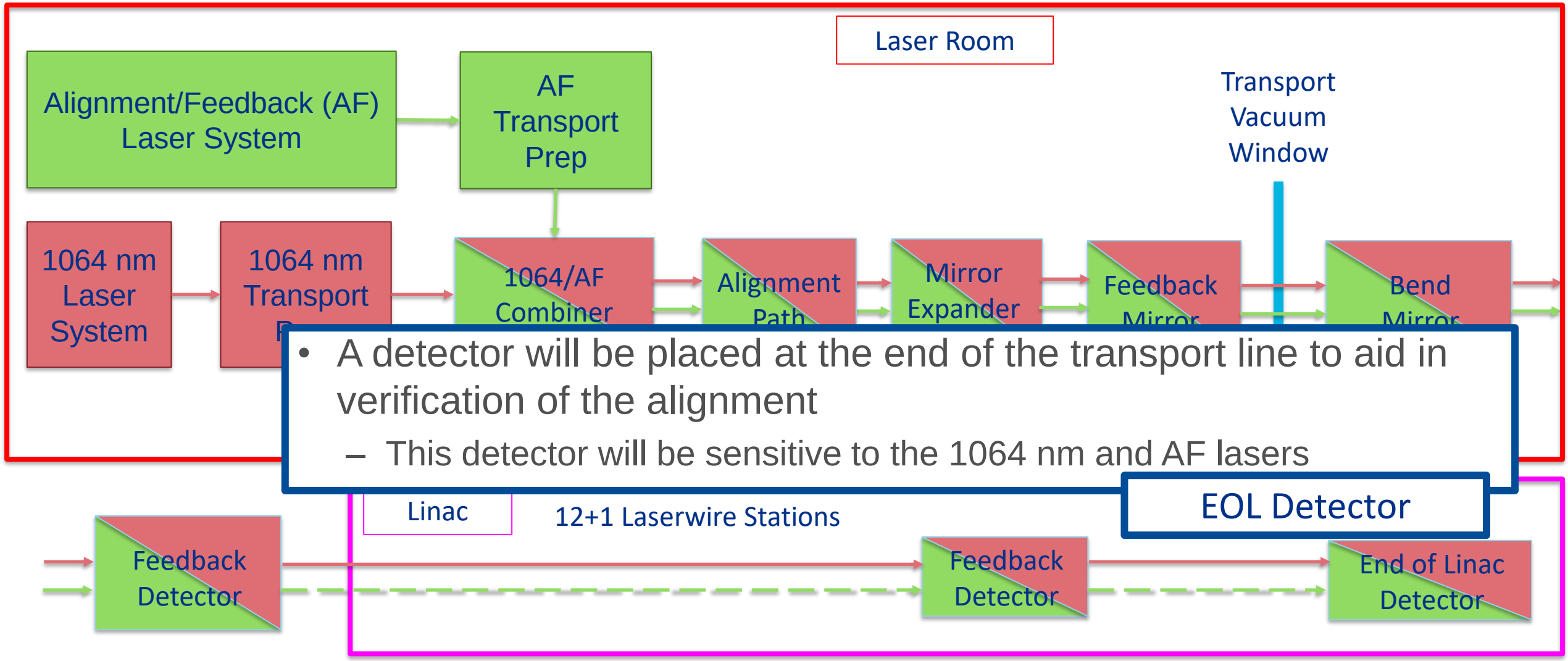
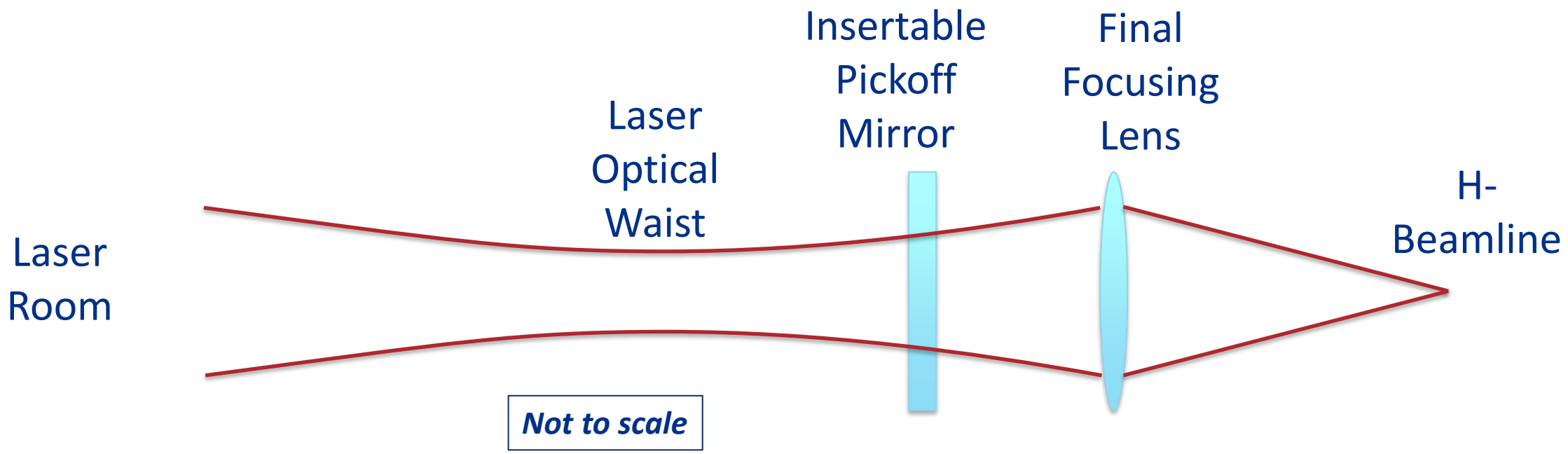


- A detector will be placed at the end of the transport line to aid in verification of the alignment
  - This detector will be sensitive to the 1064 nm and AF lasers

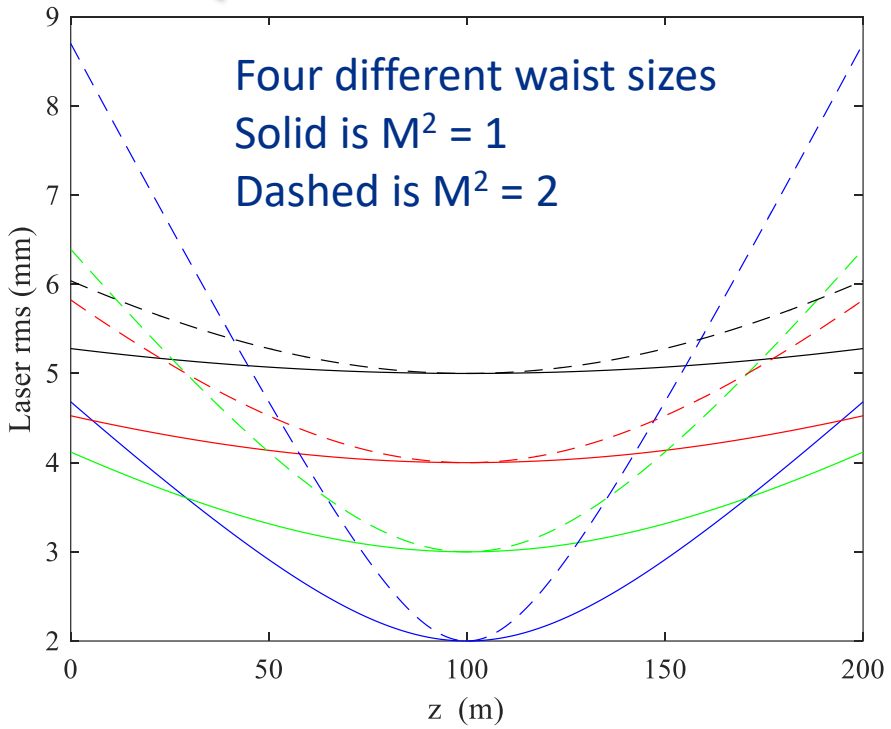
Laser Transport Optics

- Transport line optical arrangement features a single optical waist generated by an initial collimating section in the laser room
- Each laserwire has an insertable pickoff mirror in the mirror box which leads to final focus lenses inside the beamline boxes



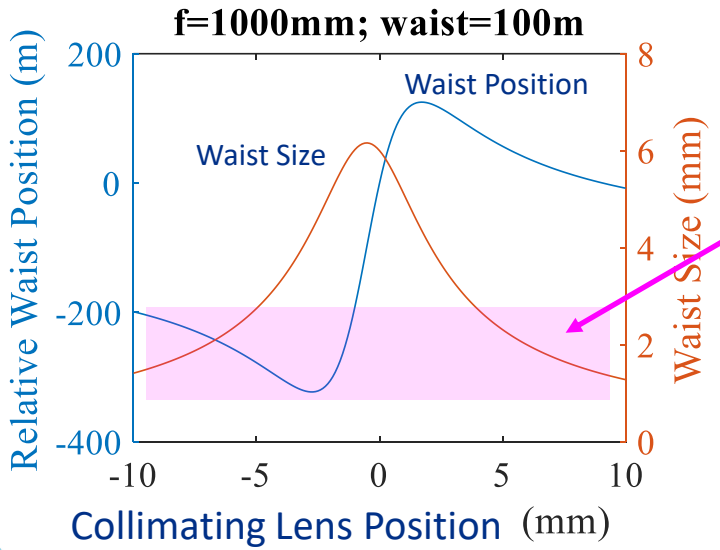
Laser Transport Optics

- A single waist but many pickoff points requires an optical evaluation of each laserwire location to ensure that the laser radius has the proper size at all points of interest
  - Laser size does not become too large (or too small) down the transport
  - Does not become too small on vacuum windows and optical elements
  - Is small enough at the H- intersection
  - **Plan is ~5 mm**

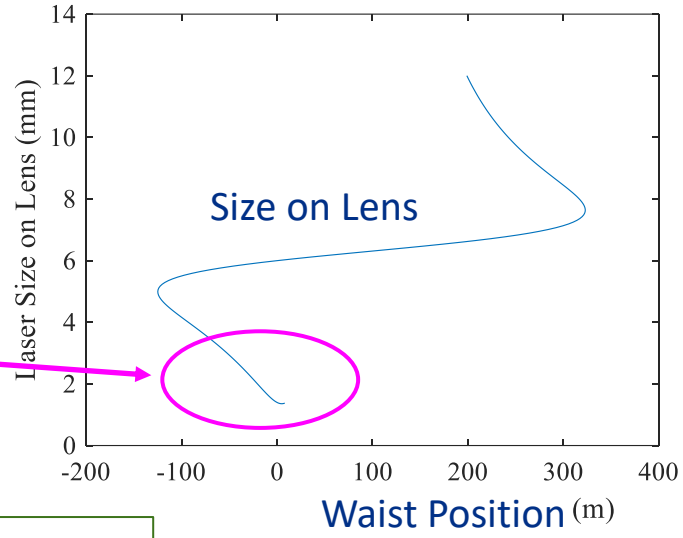


Laser Transport Optics

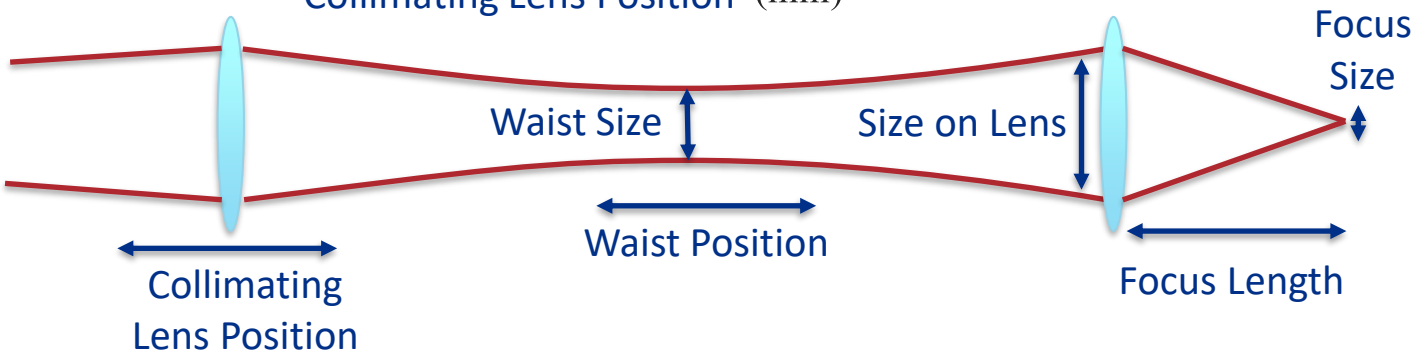
- Test of sensitivity of optics to ideal collimating lens
  - Control of optics via lens position, and stability of optics to small movements in lens position

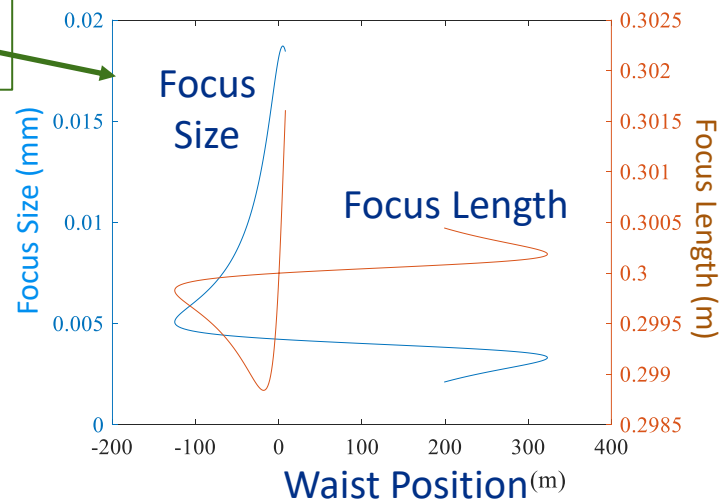


Region to avoid
Small size on focus lens → small size on vacuum window



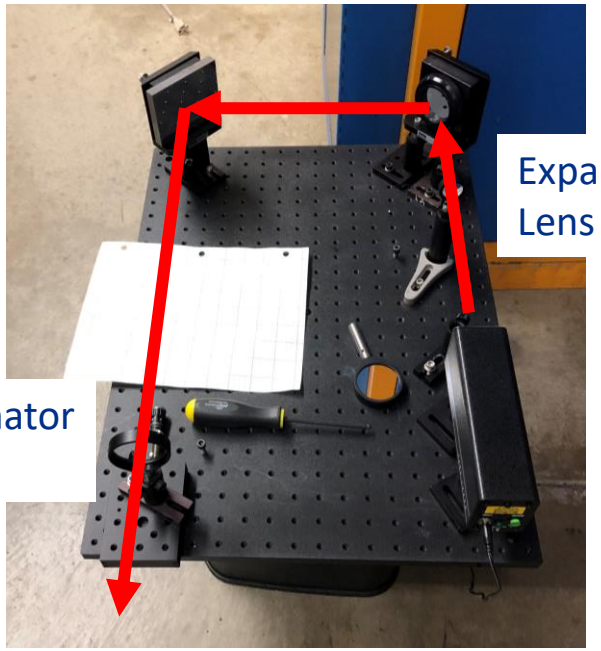
Focus Length ~constant
Focus Size small

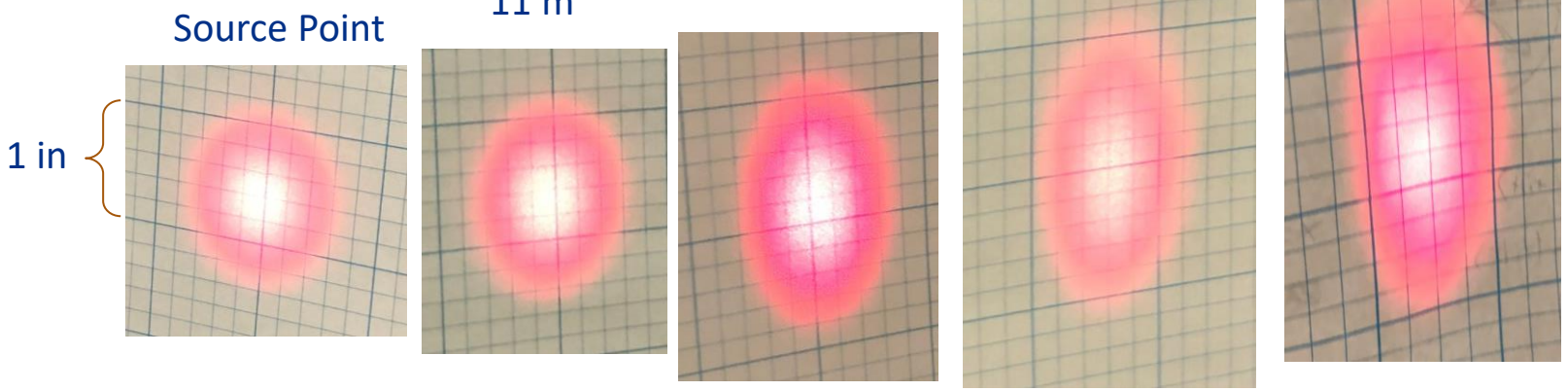


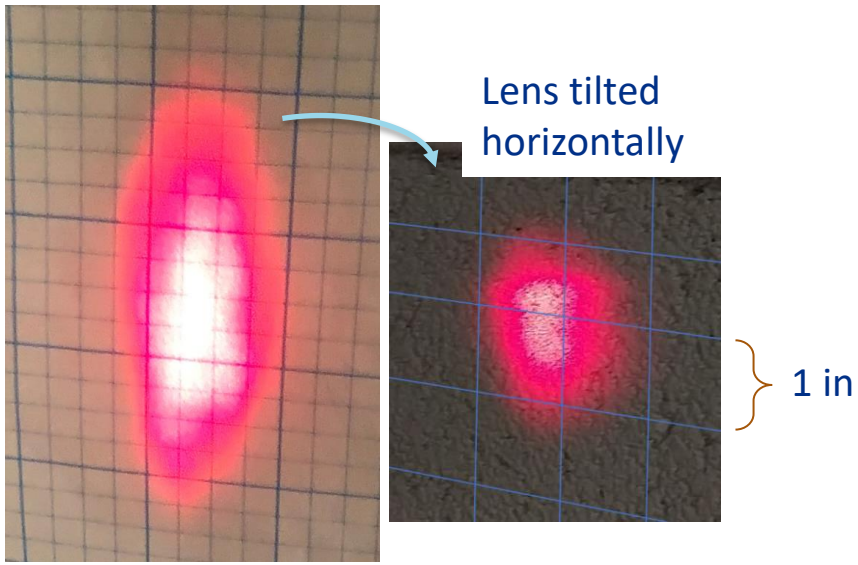


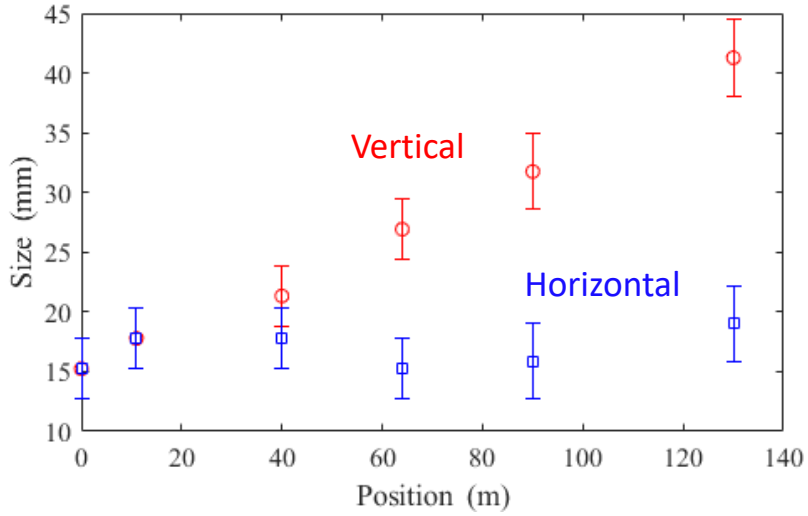
Laser Transport Optics – Test

- Collimated a HeNe laser over 130 m length



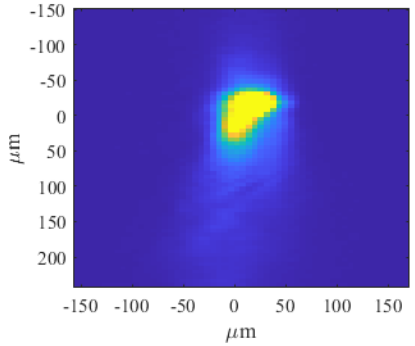






Second test

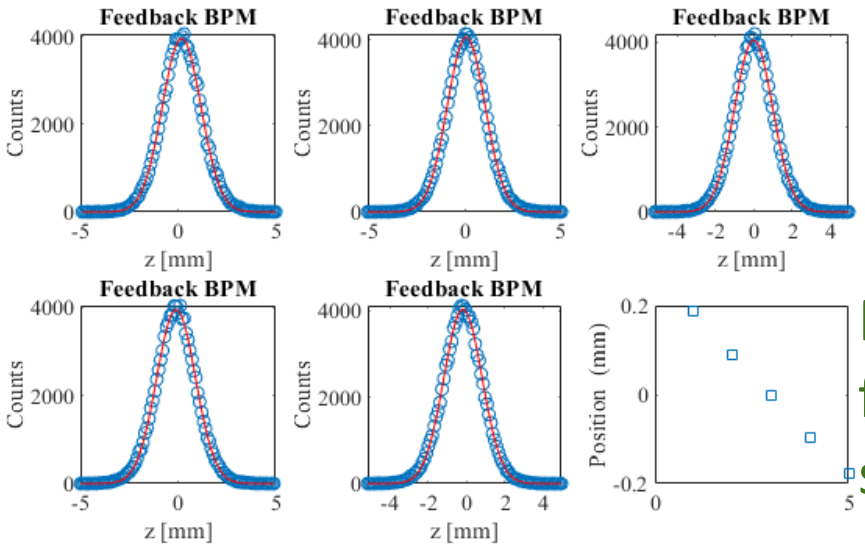
Refocused after 117 m



Laser Transport Optics – Feedback

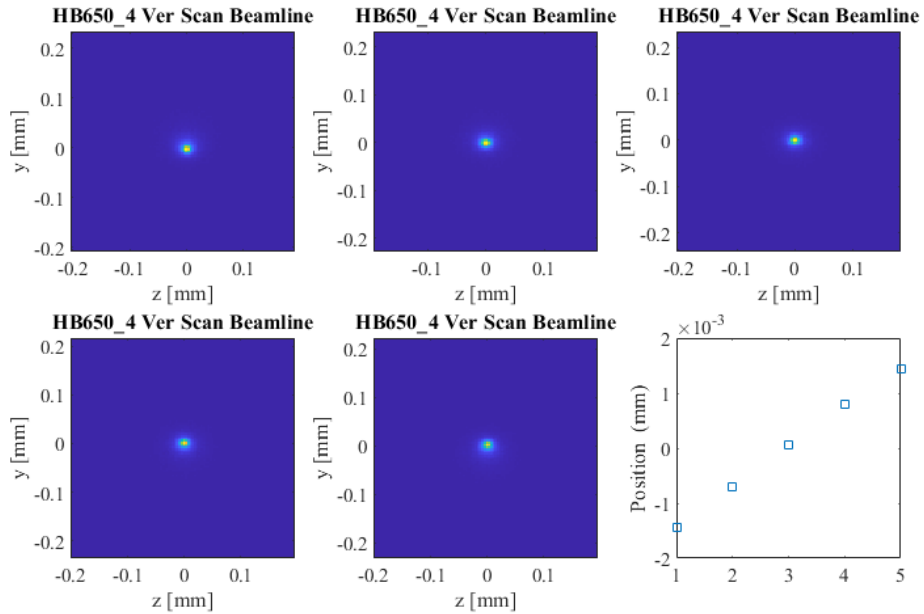
- Feedback will be implemented with a detector before the shield wall
  - 9 mm active area; sub-micron sensitivity
  - Approximately 35 m from laser room
  - Laser partially focused onto detector
- Ray tracing simulations
  - Study steering errors corresponding to deflections between +/- 6 mm at the end of linac

Thorlabs Lateral Effect Position Sensor



Size on feedback sensor

Position at feedback sensor

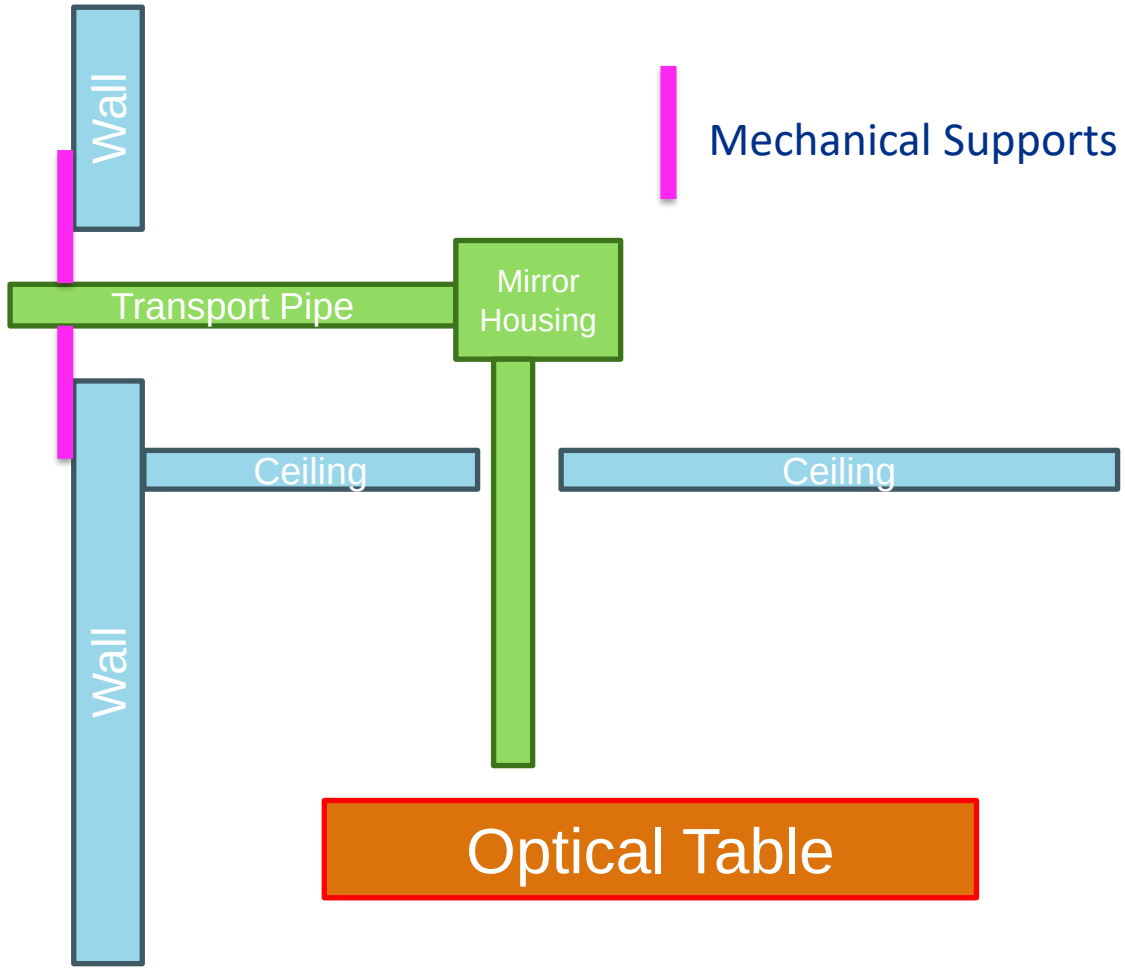


Less than 1% loss of laser beam through components

Position at H- beam: <2 µm variation

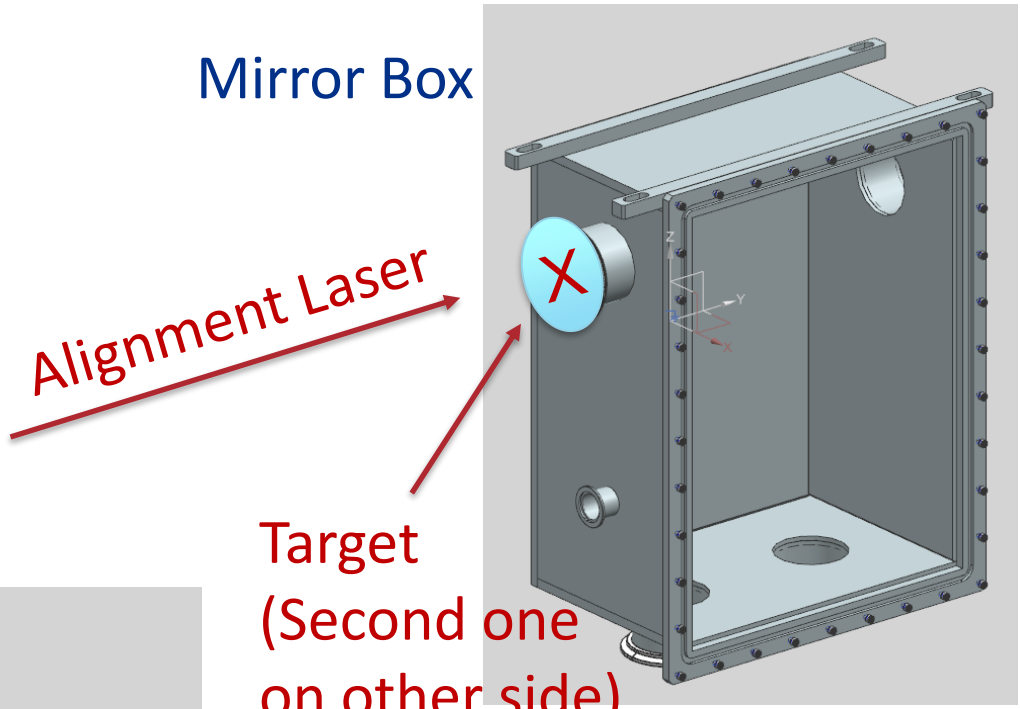
Installation and Alignment – Laser Room

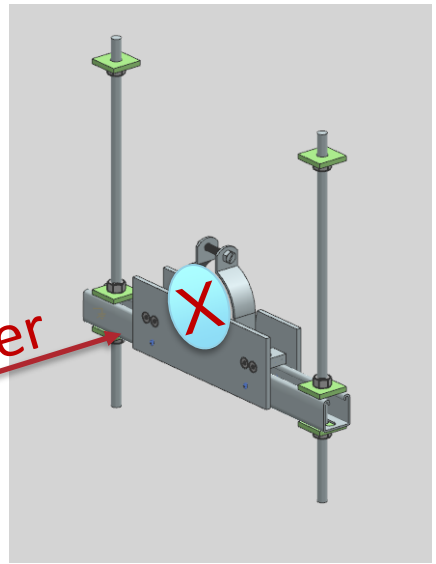
- Install transport pipe and mirror housing in laser room structure
- Align transport pipe to nominal location relative to beam (Alignment Crew)
- Install target at end of linac and align to nominal location relative to beam (Alignment Crew)
- Setup laser systems on optical table
- Align and focus green laser through complete transport line



Installation and Alignment – Transport Line

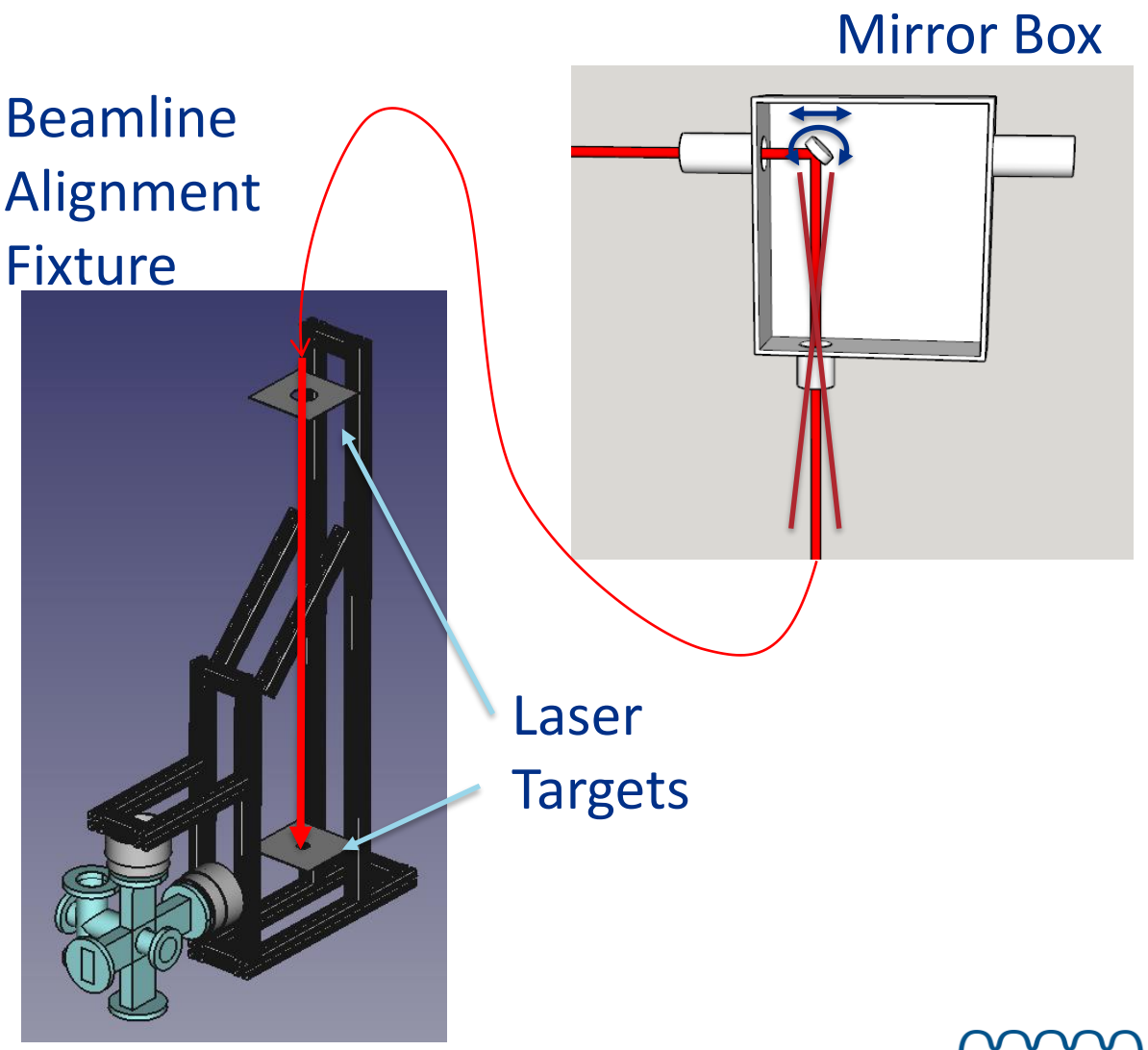
- Install shield wall support and align to green laser
- Install feedback box and align to green laser
- Install mirror boxes
  - Align to nominal location relative to beam (Alignment Crew)
  - Verify transverse alignment with green laser
- Install pipe hangers and align to green laser





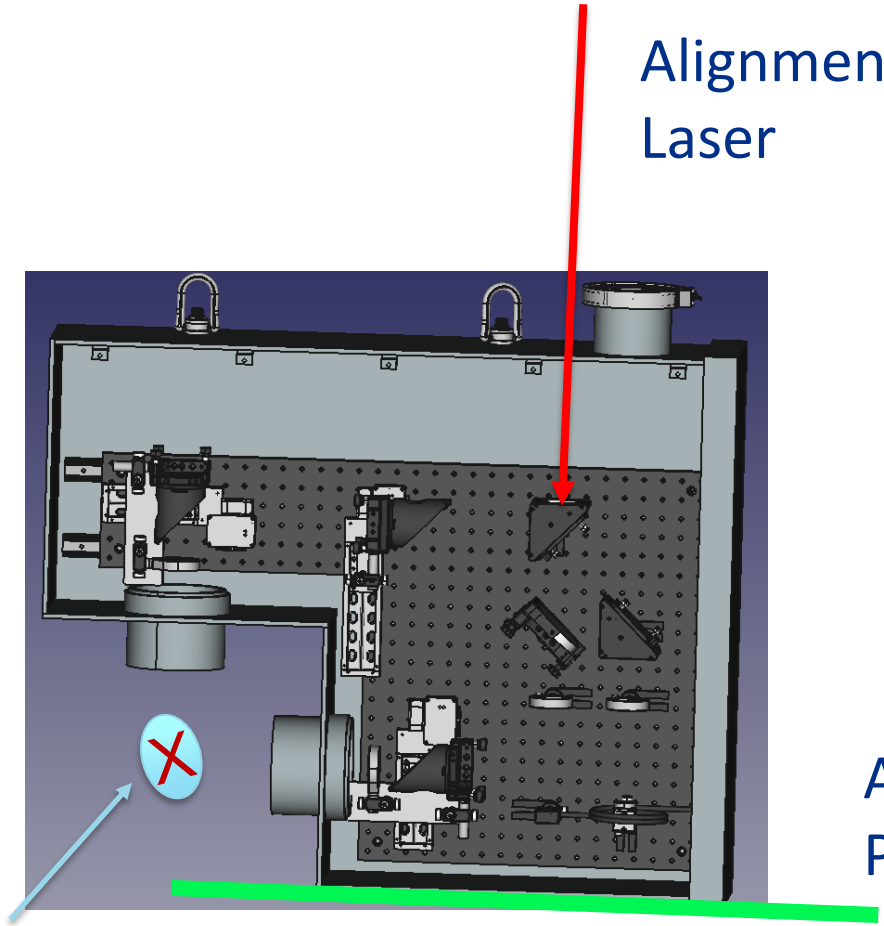
Installation and Alignment – Beamline Box Mount

- Install mirror box mirror with longitudinal position adjustment
  - Align mirror with alignment laser
- Install beamline alignment fixture
  - Designed as a sparse replica of actual beamline box
  - Allows alignment without bulk of actual box
- Adjust mounting to align vacuum flanges
- Adjust downward alignment laser trajectory to intercept both targets



Installation and Alignment – Beamline Box Optics

- Alignment of beamline box optics will happen in the laser lab
- Utilizes three elements
  - An alignment plate that replicates the beamline box mounting plate
  - A laser aligned with the alignment plate to replicate the trajectory from the mirror box
  - A target also aligned with the alignment plate and positioned at the design location of the beamline
- The aligned optics box can then be mounted on the beamline box mount



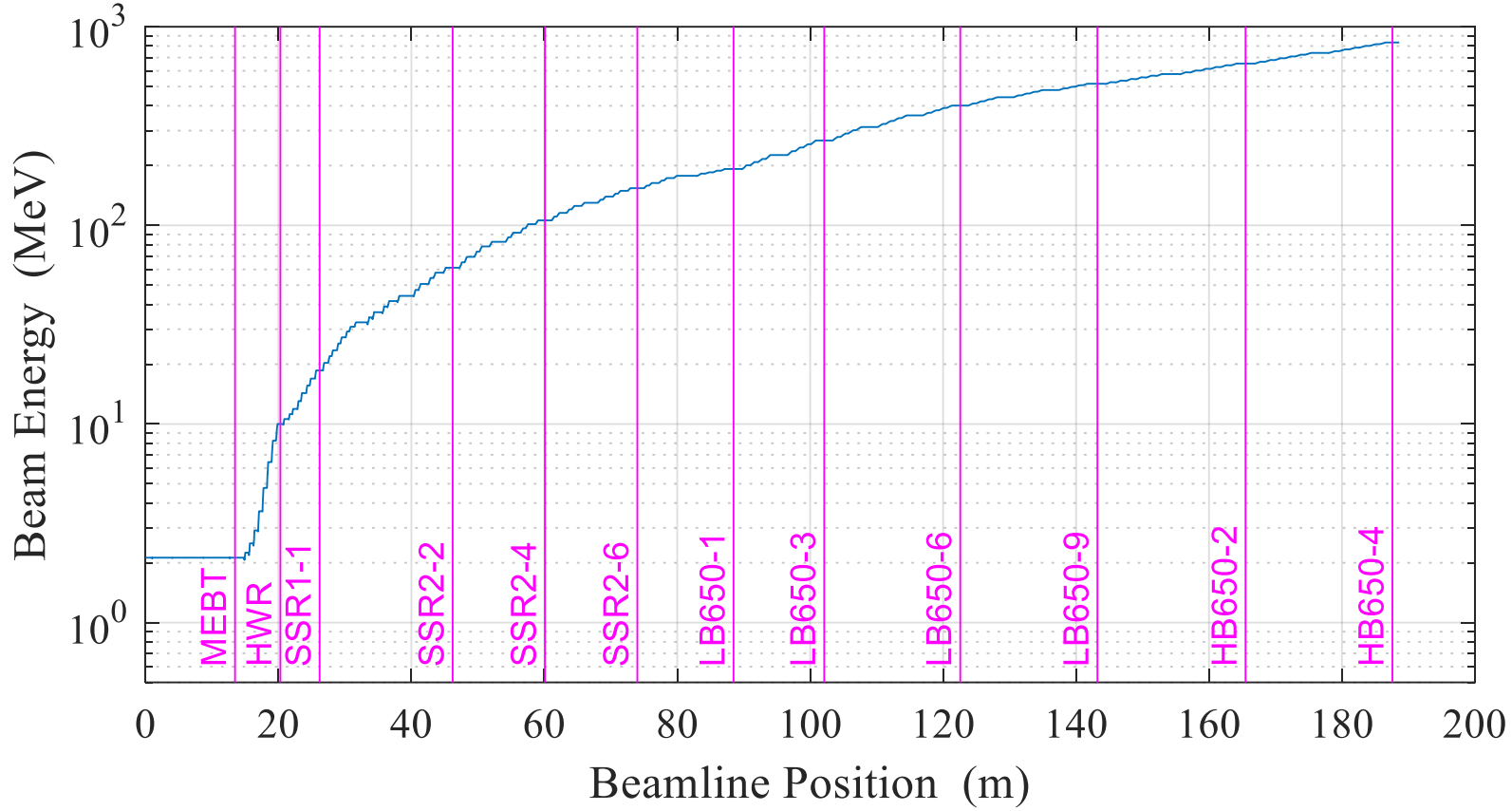
Summary

- Have a design for the transport optics
  - Have considered control of the laser
  - Have tested the transport over 130 m
- Have a procedure for alignment of laser transport and beamline optics
  - Transport alignment is coincident with installation of transport line
  - Beamline box mounting alignment is done after installation of warm units
  - Beamline box optics alignment is done in laser room

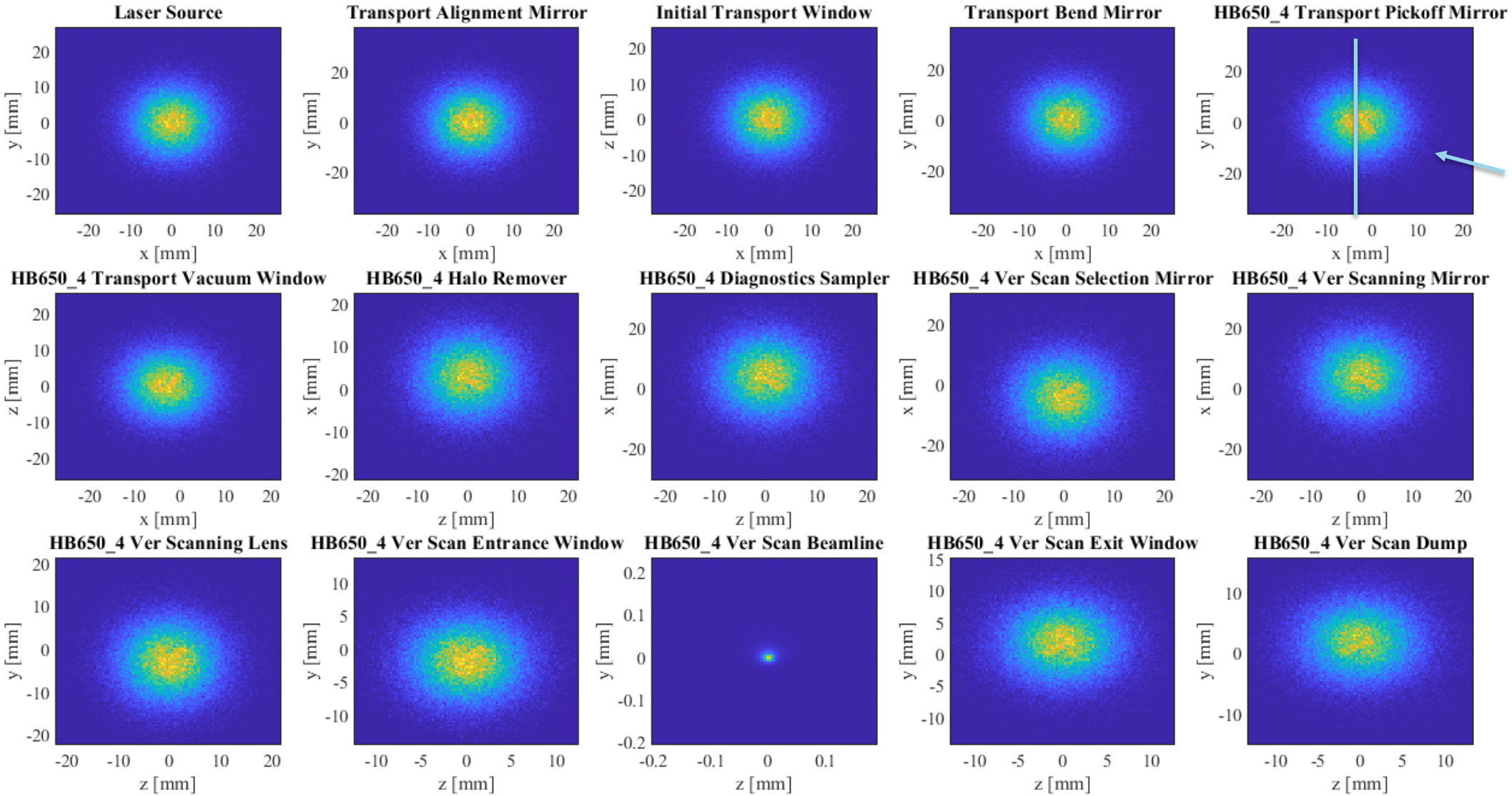
Backup Slides

Laserwire Locations

- Twelve + one laserwire stations in the PIP2 Linac proper (last not shown below)
- The laser room is upstream of the H- source which is at 0 m



Laser Transport Optics – Feedback



Steering error in x

Laser Transport Optics – Feedback

Loss of laser beam from steering errors