MPP PLD port plunger design review

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MPP feedback

- Plungers insert from the aisle side
- The electron beam injection is on the wall slide of the p+ bunch trajectory
- The input aperture of the vapor source has a 3mm half-moon, 8mm rectangle, 3mm half-moon
- The aperture is such that the center of the p+ bunch is aligned onto the center of left-hand side half-moon, i.e., the racetrack extends towards the wall
- That means that the laser beam (regardless of its diameter) is clipped on the aisle side to a radius of 3mm
- There are YAG screens only over the first five or six plungers, diffraction of the laser beam may make the beam larger transversely, but last plungers only have laser screens
- in the most retracted position, the tip of the plunger is some 5.94mm away from the beam axis (all being aligned)
- If the laser beam became misaligned towards the aisle and the plungers, the aperture would clip the beam and 'protect' the first five/six YAG screens
- Plungers' tip should be roughened, not be shinny
- The plasma radius is smaller than 6mm, even with wakefields, and plasma is low temperature, and no current is drawn

MPP feedback

- For the minimum clearance, the maximum is the best. As mentioned in the notes I sent, I believe that some 6mm clearance is tight, but should clear the laser pulse, thanks to the geometry (plungers on the aisle side and racetrack aperture in the US expansion volume limiting the laser pulse to a 3mm radius on that side). That means there should be no direct hit from the laser pulse on the screen. Of course, clipping a laser beam creates diffraction that bends some energy away from the beam axis ...

- There is only one (minor) contradiction I see: to spare the screens from that possible laser pulse energy we should start measurements with the four shims that leads to the plungers retracted the most. However, in order to measure large incident angles for the e-beam, we would like the YAG screen to be in as much as possible (i.e., no shims).

- So, if what is proposed is the maximum possible for the retracted position, we move forward like that ...

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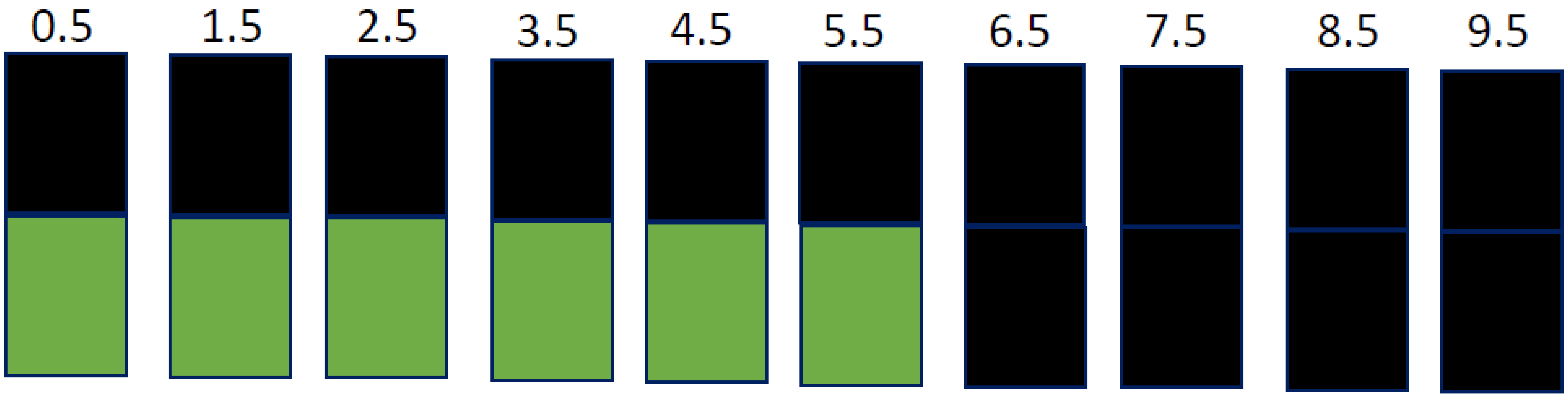
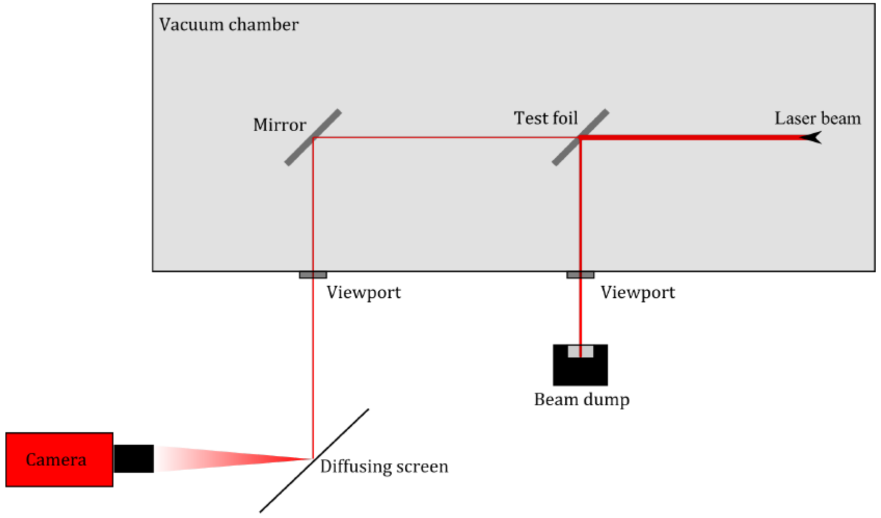
Screen holder - Variants

It is time to decide on the plunger foil/screen installation, including:

- Where to put screens (and what size)
- Where to put laser beam dumps (material, thickness, angle)



Fluence calculations recap



Quick review of Mattias pre-experiment testing:

- Set up tested foil at 45°
- 200µm foil @ 45° can take 600 shots (with 2x safety margin*)

- Shot reduction if angle is changed:
  - $Shots\ (\theta) = 600\ shots\ \times \frac{cos45}{cos\theta}$

Reducing foil angle on screen holder

Foil angle (degs)	**Shots**
45	600
40	**554**
35	**518**
30	**490**
25	**468**
20	**451**

** Option to go to 1000 laser shots but less margin*

Summary of Results:

foil	thickness	runs	$\overline{N} \pm \Delta N$	AAR [nm/pulse]
Al 99% hard	200 µm	9	1283 ± 139	157 ± 19

Conclusion

- pure Al seems to have slightly lower ablation rates than alloys
- "hard" seems to be best temper

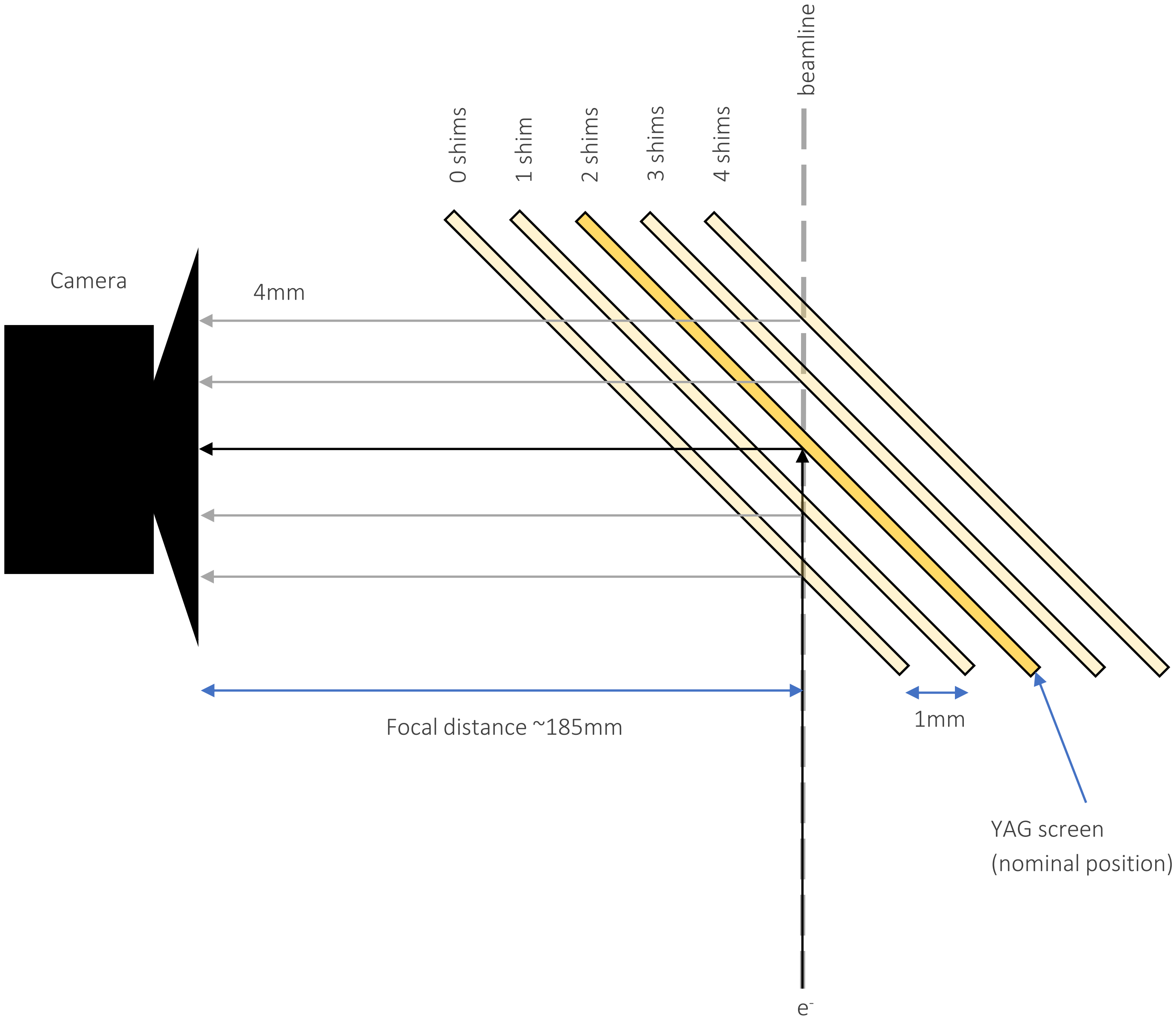
suggestion for a reasonable foil selection:

→ Al 99% hard
→ 200 µm thickness
→ limitaion to 600 shots (50% safety margin)

Dual holder – YAG geometry

YAG screen assumptions:

- 10mm square; 200µm thick
- Mounted at 45° to beamline
- 7.1mm of screen ⊥ to beamline
- Beam incident on central ⊥ 4mm of YAG screen with shim adjustment
- Top & bottom edge 1mm will be occluded by screen holder



Design geometry looks good

One issue to check:

Does the number of shims fitted affect the measurable e- beam incident angle such that experimental operation is compromised?

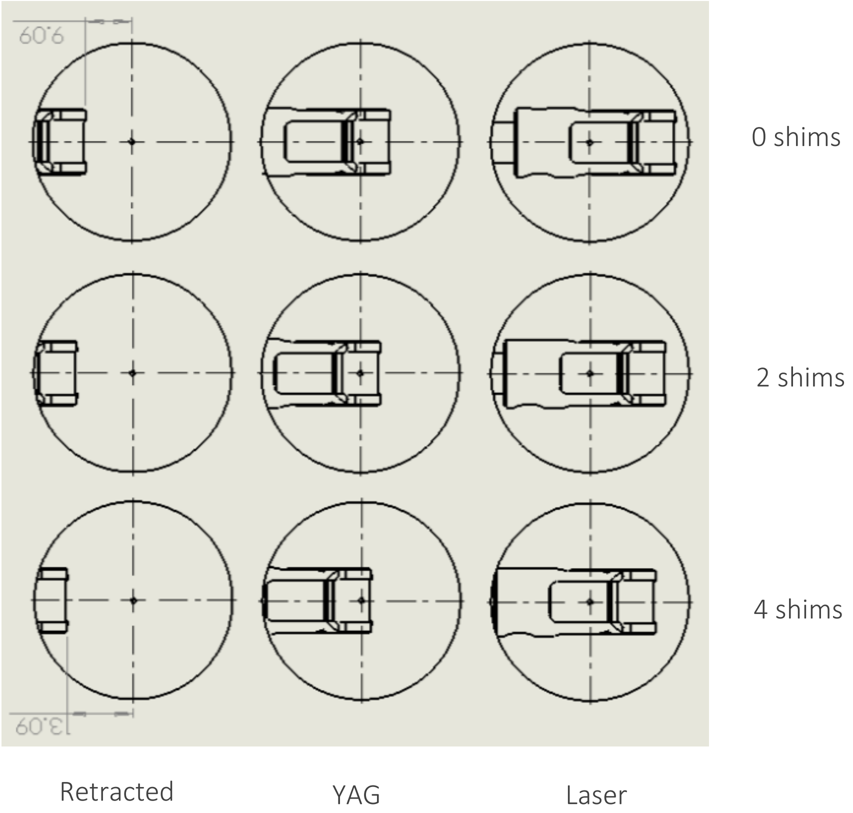
Dual holder – YAG & Electron incident angle calculation

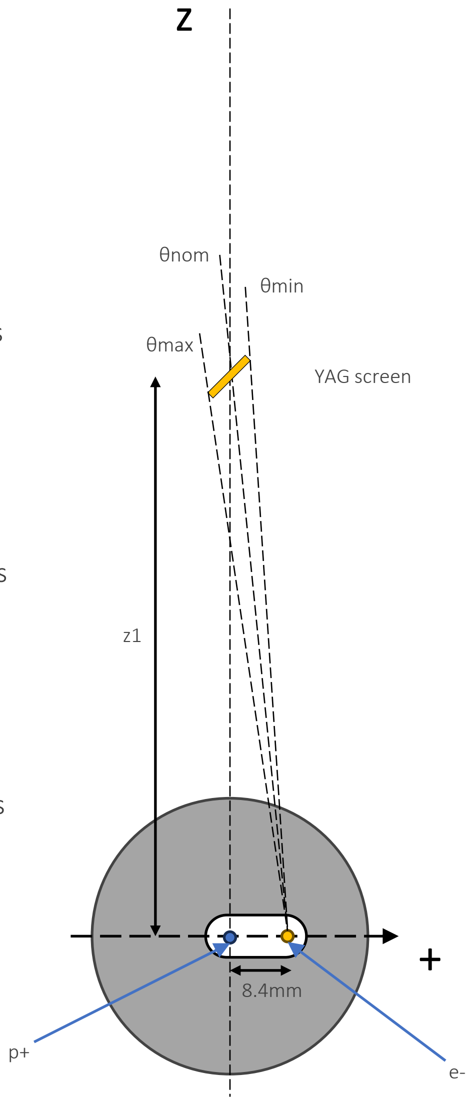
The visibility of the electron beam on any given screen due to its incident angle depends on:

- Plunger location (z1)
- Number of shims fitted to plunger
- E beam entry point (assumed 8.4mm off axis for following analysis)

Calculation completed for:

- The nominal incident angle at each screen
- The min and max angles where the edges of the YAG screen will just be clipped
- How many screens will show the e beam for a given incident angle





Upstream aperture plate
(looking downstream)

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Dual holder – YAG & Electron incident angle summary

- Table shows min, max & nominal injection angle for each plunger with 2 shims fitted and 4 shims fitted
- Observations:
  - The nominal angle is constant (as it should be!)
  - The angular range is the same and is independent of the number of shims
  - The range is biased around the nominal depending on the number of shims
  - There are gaps in the incident angle that cannot be investigated but this is shim dependent (e.g. with 2 shims an e beam incident at 8.0 for 9.7mrad isn't seen on any screens) – **I think this is OK but can MPP confirm**

With 2 shims fitted

Plunger Port ID ->	1	2	3	4	5	6
Distance from aperture plate (m)	0.5	1.5	2.5	3.5	4.5	5.5
Max injection angle (mrad)	23.9	8.0	4.8	3.4	2.7	2.2
Nominal injection angle (mrad)	16.8	5.6	3.4	2.4	1.9	1.5
Min injection angle (mrad)	9.7	3.2	1.9	1.4	1.1	0.9
Injection angle range (mrad)	14.2	4.7	2.8	2.0	1.6	1.3

With 4 shims fitted

Plunger Port ID ->	1	2	3	4	5	6
Distance from aperture plate (m)	0.5	1.5	2.5	3.5	4.5	5.5
Max injection angle (mrad)	27.9	9.3	5.6	4.0	3.1	2.5
Nominal injection angle (mrad)	16.8	5.6	3.4	2.4	1.9	1.5
Min injection angle (mrad)	13.7	4.6	2.7	2.0	1.5	1.2
Injection angle range (mrad)	14.2	4.7	2.8	2.0	1.6	1.3

Dual holder – YAG & Electron incident angle ranges

- Table shows e beam visibility on different YAG screens for a given incident angle range
- Observations:
    - Angles in the 1.1 to 4.7mrad range are visible on multiple screens – useful for beam 'finding'?
    - Angles less than ~1mrad and greater than ~5mrad will be harder to 'find' as only visible on a single screen
- I think this is OK but can MPP assess if the incident angle limitations will affect experimental operation
- Excel calculator available which shows which screens 'see' the e beam depending on the screen position, number of shims fitted and e beam incident angle

With 2 shims fitted

Injection angle (mrad)	Electron beam visibility
0 to 0.8	**Not visible on any screens**
0.9 to 1.0	**Only visible on screen 6**
1.1 to 4.7	**Visible on at least 2 screens**
4.8 to 7.9	**Only visible on screen 2**
8.0 to 9.6	**Not visible on any screens**
9.7 to 23.9	**Only visible on screen 1**

Dual holder – Laser foil

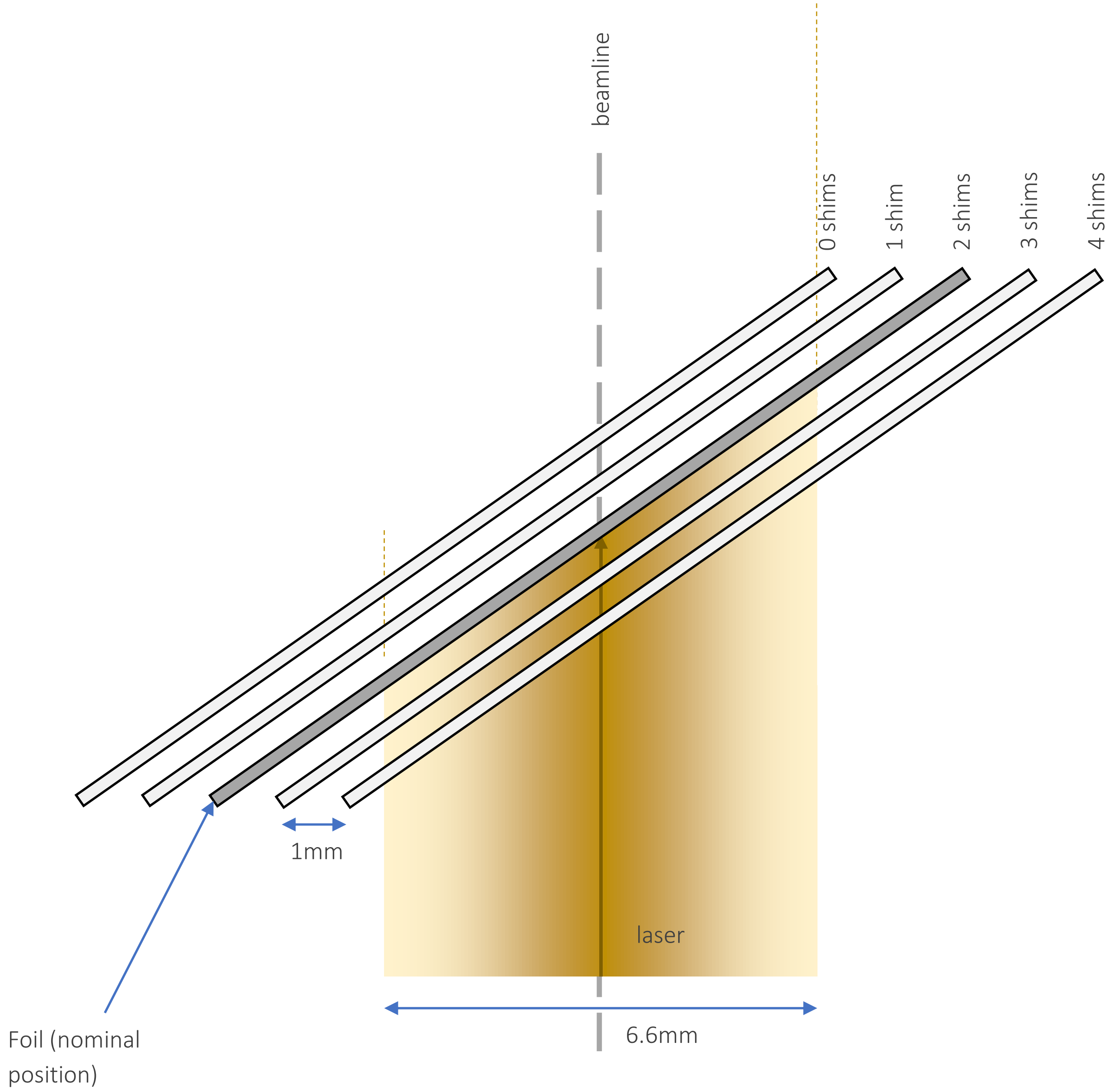
Laser foil screen logic:

- Laser to be dumped is Ø6.6mm (±3 rms)
- Shim positioning allows 4mm of adjustment

⇒ **Need minimum of 10.6mm of foil ⊥ to beamline**

Proposal

- 14mm x 8mm rectangle + 1mm frame
- *Add 3mm rads to corners for clearance - TBC*
- Mounted at 35° to beamline
- 11.5mm of foil ⊥ to beamline
- Covers 3σ laser in all 5 shimmed positions
- 518 laser shots per position
- **2590 total laser shots**

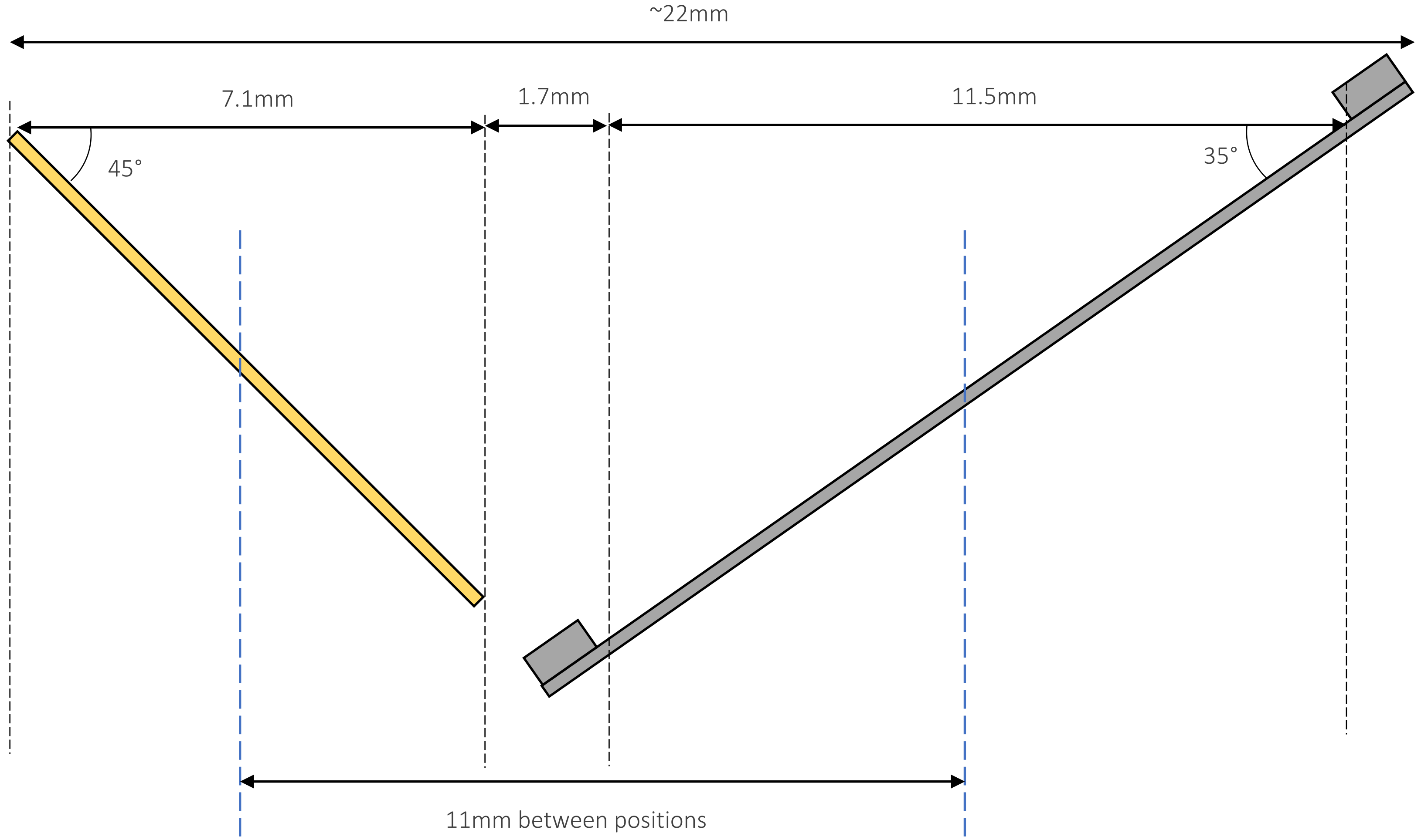


Dual holder – Geometry

Proposed dual screen holder geometry:

YAG = 10mm x 10mm

Foil = 16mm x 10mm (inc frame & 3mm rads)



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Single holder – Laser foil

Trade off for single foil plungers between number of laser shots it can dump, how far it encroaches onto the beamline and complexity of screen holder

Three options presented in following slides

Single holder – Laser foil

Laser foil screen logic - Laser to be dumped is Ø6.6mm (±3 rms)

Option 1 -> Single 20 deg angled foil:

- Shim positioning allows 4mm of adjustment at each position (11mm centres)
- **Need minimum of 21.6mm of foil ⊥ to beamline**

Option 2 -> Two 45 deg foil:

- Actuator positions are 11mm apart
- **Foils can only have a maximum of 11mm ⊥ to beamline otherwise one will shadow the other**
- Allowing for a 1mm frame gives 9mm ⊥ to beamline
- Allows only 3 shim states per actuator position

Option 3 -> One 45 deg foil:

- **Need minimum of 10.6mm of foil ⊥ to beamline to cover 5 shim positions**

Single holder – Laser foil

	Option 1	Option 2	Option 3
Number of foils	1	2	1
Foil size (inc 1mm frame)	26mm x 10mm	15mm x 10mm	18mm x 10mm
Foil corner rads	0mm	5mm	5mm
Angle	20	45	45
Shim positions possible	10 (2 x 5)	6 (2 x 3)	5 (1 x 5)
Shots per position	451	600	600
Total shots	4510	3600	3000
Beamline clearance (min)	6mm	~8mm	>12 mm
Control system integration	Additional work to support 2 laser positions	Additional work to support 2 laser positions	None
Screen holder complexity	Easy	Medium	Easy

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