BGC – SKIMMER 3 PROPOSITIONS LHC 2024-2025 YETS

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This document outlines four proposed 3rd skimmers that are intended as options to be manufactured and installed within the 2024-2025 YETS. They are all compared to the current BGC system (Version 3) installed in the LHC, using a 0.3 x 9 mm 3rd skimmer.

In an attempt to minimise changes to the working system and mitigate risk by realignment or changing the entire injection system, skimmers 1 and 2 will be fixed to their current values and distances of 400 um at 4.5mm, and 2.0mm at 33.1 mm respectively. This allows for an easy change between 3rd & 4th skimmers both in the YETS and other technical stops mid-year if a change is required. This does however, limit the maximum jet sizes and maximum performance for some designs.

The values presented here are approximate estimates to provide more details before a full optimisation study is performed. The optimisation study will attempt to achieve the best conditions (density, length, and width) whilst keeping the background pressure within the beamline as close to identical to Version 3 as possible.

1.1 Thin Curtain

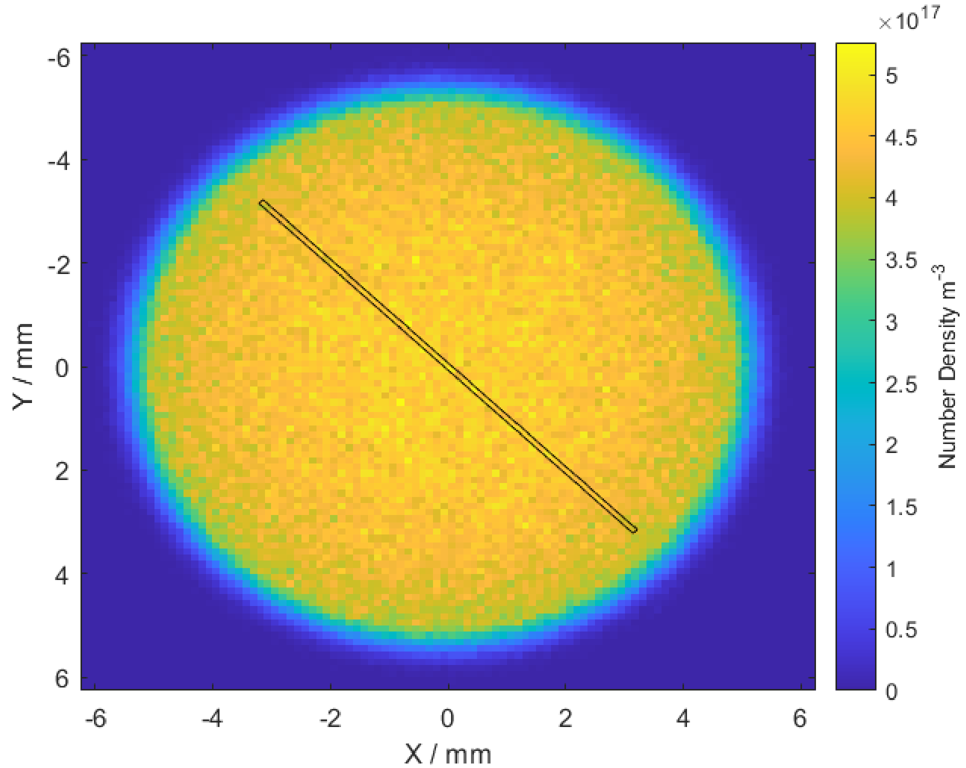

Figure 1. Jet distribution at the 3rd skimmer, with black rectangles as skimmer aperture region.

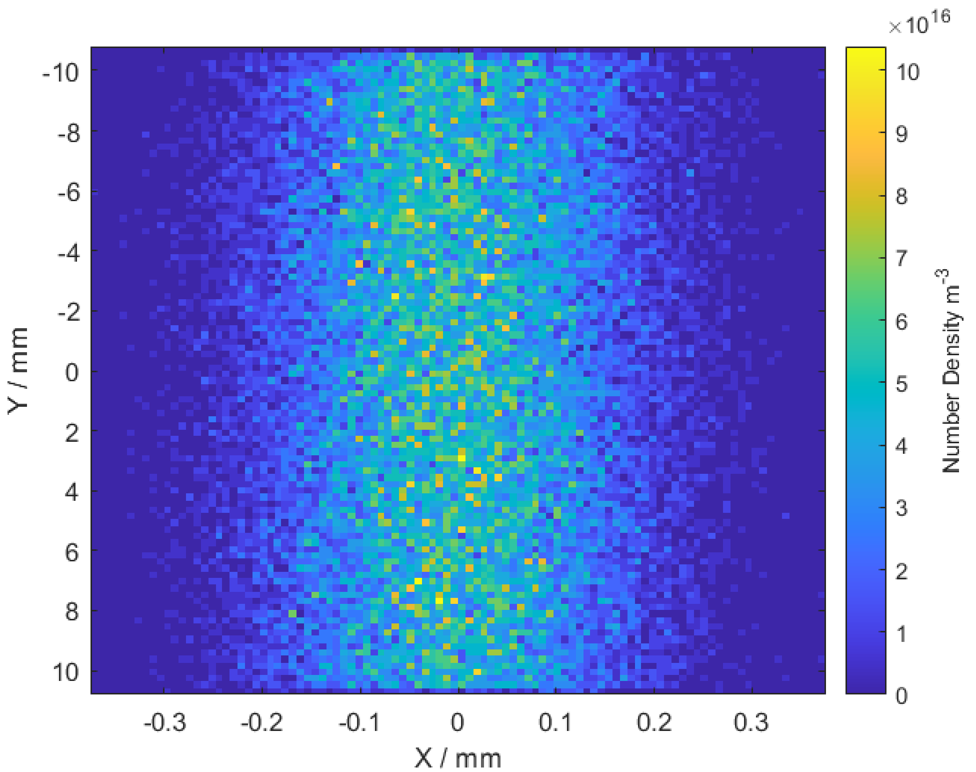

Figure 2. 2D Jet distribution at the IP

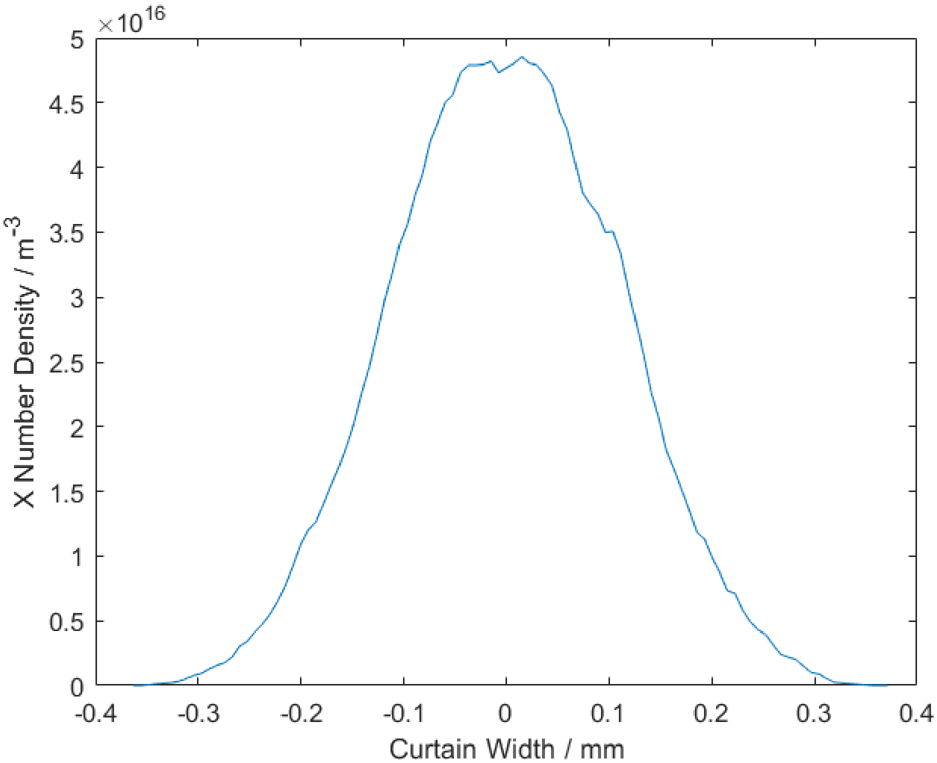

Figure 3. Jet density distribution along beam axis

3rd Skimmer = 0.1 x 9 mm (initial estimate)

Description

The "Thin curtain" option is intended to be at 45 degrees, to generate a profile measurement with more accuracy on the beam's X sigma by reducing the thickness smearing effects of the current installed system (V3). This improved accuracy comes at the cost of a reduced signal due to the width-density relationship demonstrated in Figure 15 at the end of the document.

Design	Density / m^{-3}	Length / mm	Width / mm
V3	6.3×10^{16}	20.6	0.68
Thin Curtain	4.8×10^{16}	20.6	0.27
Delta	-29.4%	0%	-60.3%

$$Relative\ Signal = \frac{Density_{Thin\ Curtain} Thickness_{Thin\ Curtain}}{Density_{V3} Thickness_{V3}}$$

$$RS = \frac{(4.8 \times 10^{16})(\sqrt{2} \times 0.27)}{(6.3 \times 10^{16})(\sqrt{2} \times 0.68)} = 0.30$$

It is expected to receive 30% of the signal from Version 3 and take ~3 times as long for a measurement. Standard imaging time would be approximately 6 minutes per detailed profile.

Pro's

- Improved accuracy for vertical profile measurements
- Reduced gas load for potential N2 injection
- Extremely low risk
- BLM-Jet calibration possible (scaling for halo with different design can be calculated)

Con's

- Reduced signal by 70%
- No full experimental validation for halo diagnostic

1.2 Halo – Single-slit

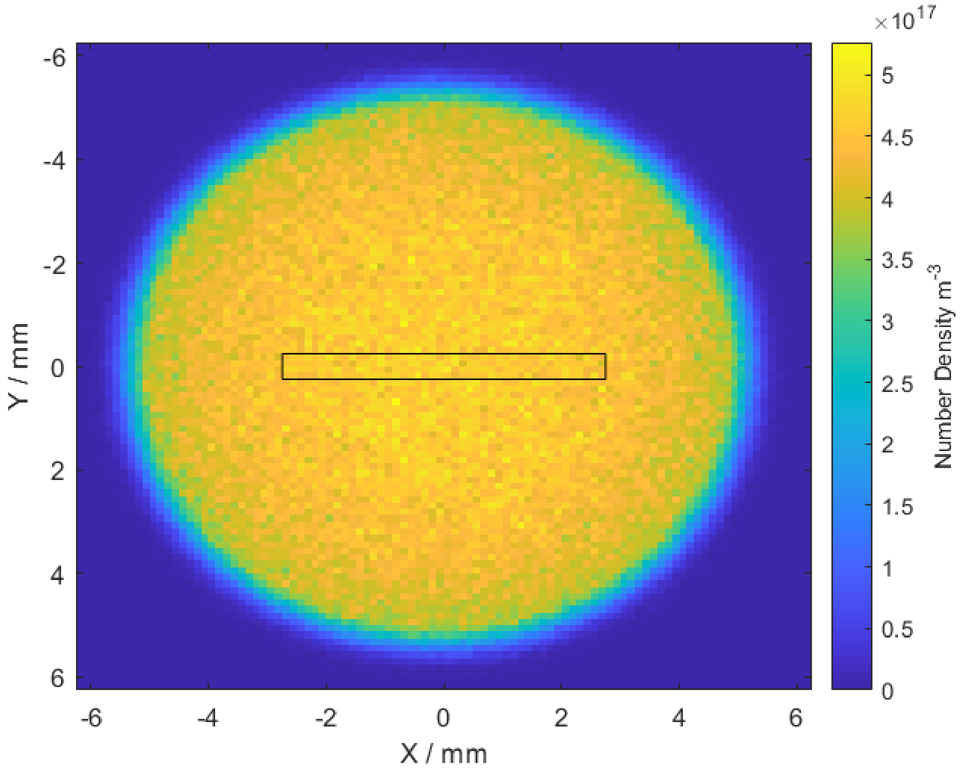

Figure 4. Jet distribution at the 3rd skimmer, with black rectangles as skimmer aperture region.

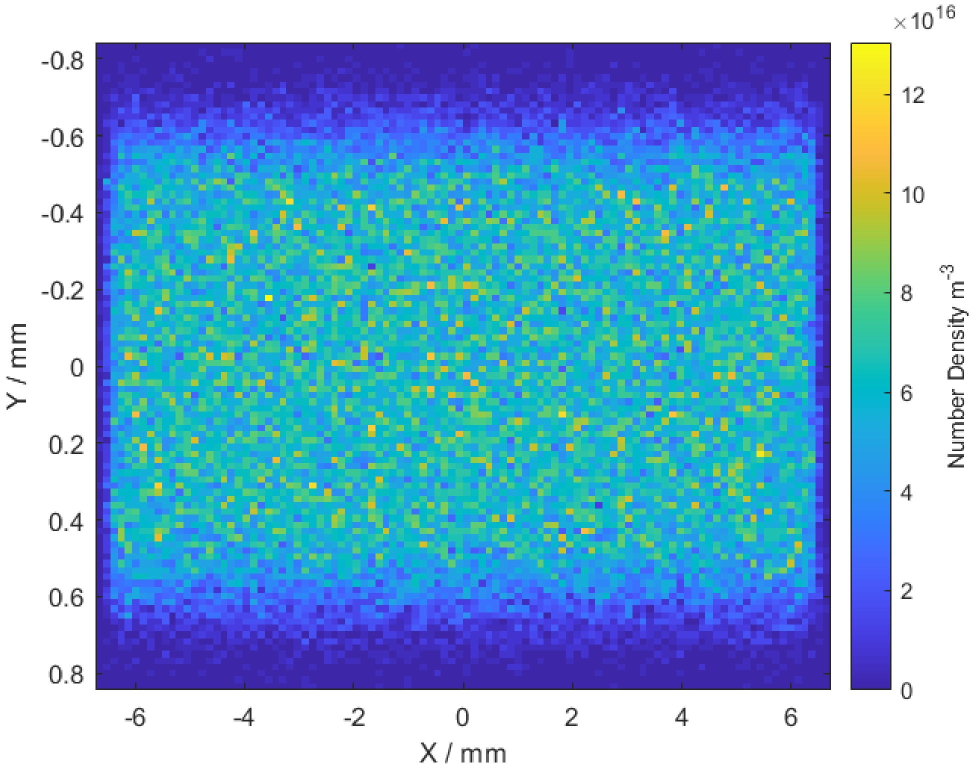

Figure 5. 2D Jet distribution at IP.

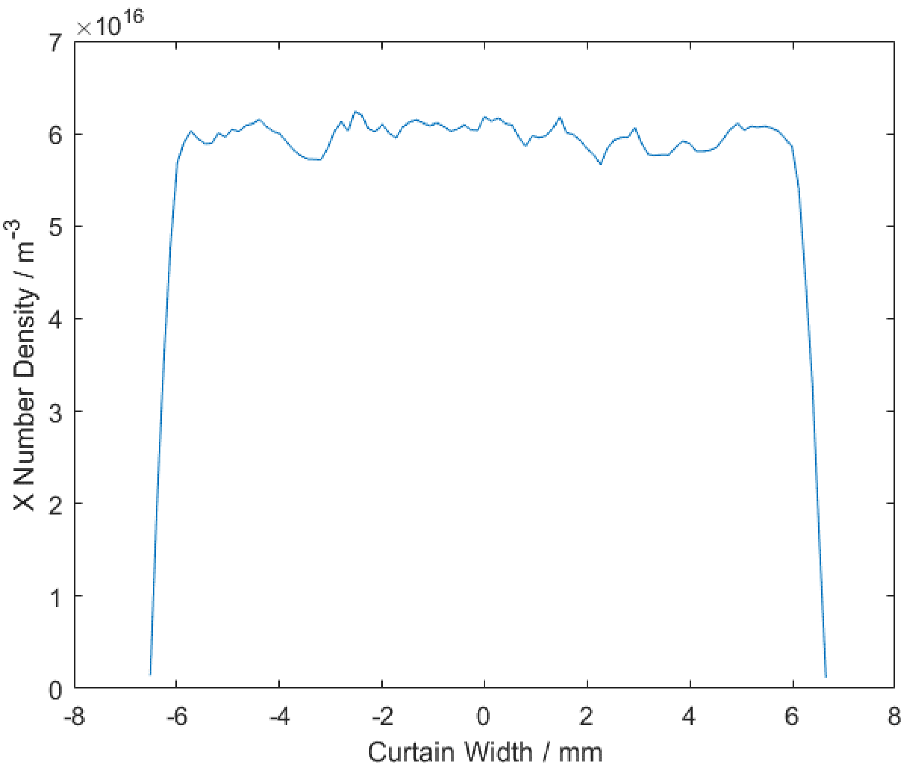

Figure 6. Jet density distribution along beam axis.

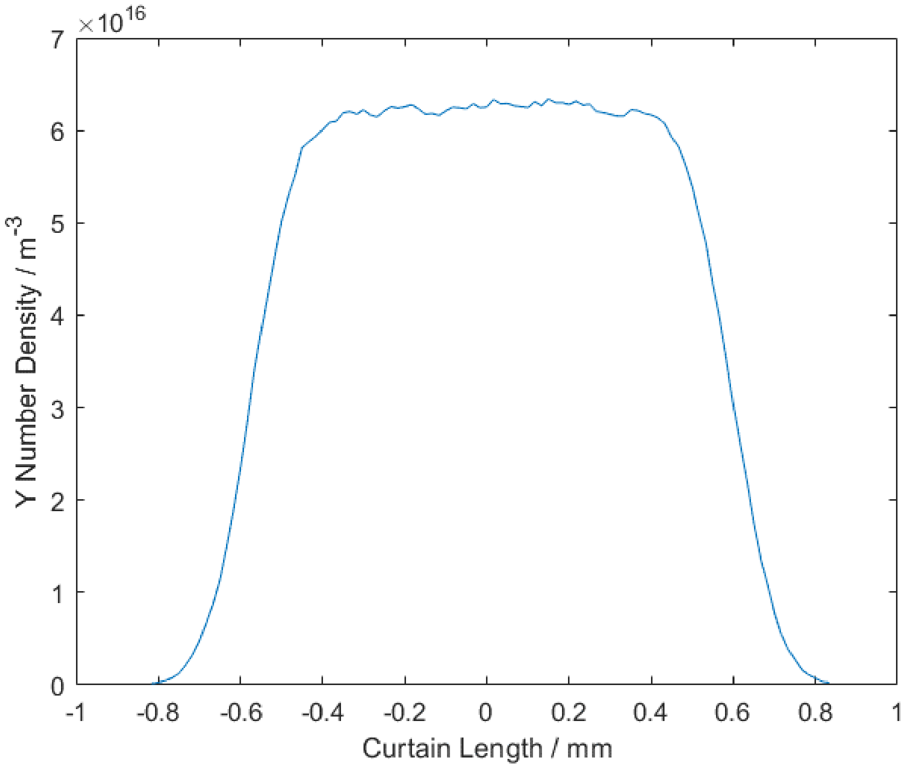

Figure 7. Jet density distribution vertical to the beam axis, showing the acceptance range for beam-jet interaction

3rd Skimmer = 5.5 x 0.5 mm (initial estimate)

<u>Description</u>

The "Halo -Single Slit" design is intended to be mounted horizontally as shown and is intended to maximise losses to be generated for halo detection. It is wider and shorter than the current Version 3 skimmer to ensure imaging capabilities at stable beams. It could still provide a 1D beam profile in addition to losses for halo, assuming the alignment to the beam is successful. With the compounding errors of flanges, perfect alignment to the beam core is unlikely, and thus has a potential to be completely un-usable. Even with perfect alignment, this setup would also likely lose the ability to image the beam during injection and ramp before the squeeze, due to the beam size limitation from the flat top density region of Figure 7 (~0.8mm). This size can be improved at a reduction to the halo signal for a final design if desired.

Design	Density / m^{-3}	Length / mm	Width / mm
V3	6.3×10^{16}	20.6	0.68
Halo – Single Slit	6.3×10^{16}	1.15	12.6
Delta	0%	-94.4%	1753%

$$Relative\ Signal = \frac{Density_{Halo\ Multi-slit} Thickness_{Halo\ Multi-slit}}{Density_{V3} Thickness_{V3}}$$

$$RS = \frac{(6.3 \times 10^{16})(12.6)}{(6.3 \times 10^{16})(\sqrt{2} \times 0.68)} = 13.1$$

The halo signal would be expected to increase by approximately 13.1 times that of the current V3 configuration.

Pro's

- Full experimental validation for halo diagnostic possible if good alignment
- Maximum integrated relative signal for halo jet
- Can retain 1D profile imaging capabilities

Con's

- Ideal length to not miss beam unknown – tough decision.
- Potential to miss beam all together and be useless
- High risk, high reward

1.3 Halo – Multi-slit

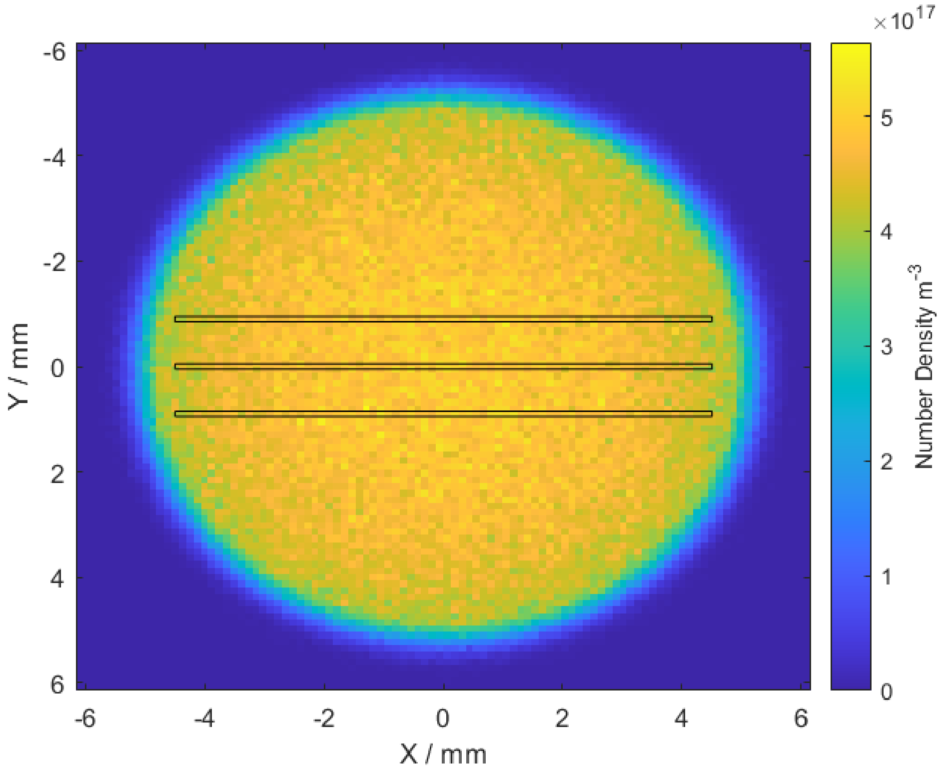

Figure 8. Jet distribution at the 3rd skimmer, with black rectangles as skimmer aperture regions.

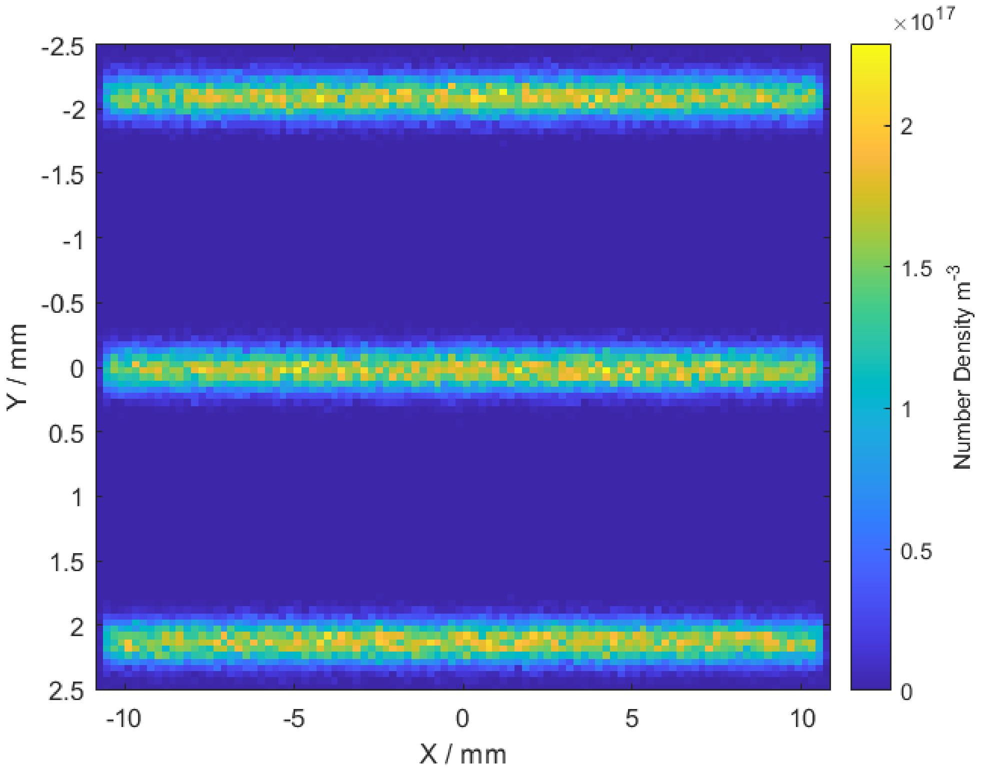

Figure 9. Jet distribution at IP.

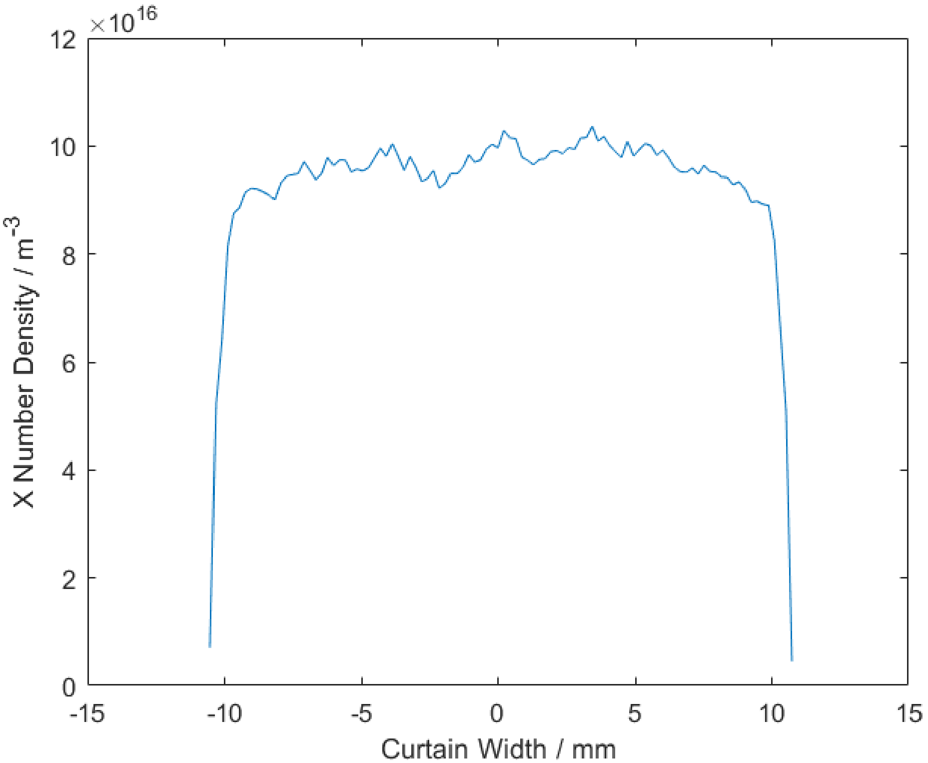

Figure 10. Jet density distribution along beam axis (for one slit).

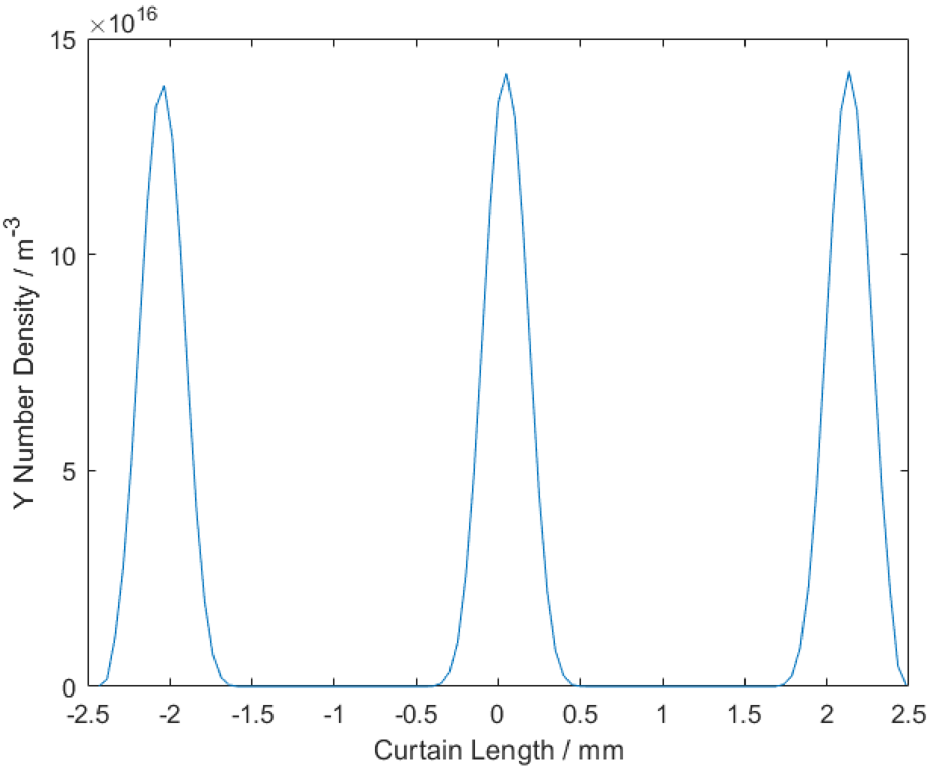

Figure 11. Jet density distribution vertical to the beam axis, showing the acceptance range for beam-jet interaction

3rd Skimmer (Halo) = three, 9.0 x 0.1 mm (initial estimate), with two offset by 0.9mm from centre.

Description

The "Halo – Multi-slit" design is intended to be orientated horizontal to maximise loss interactions for halo detection. The use of multiple thin slits allows a significantly increased misalignment between jet and beam to be detected. As the stable beam can be deflected by +- 1mm, with a gap between two slits 2mm or less, the beam will always be detectable by at least one slit, so long as it is within the total range of the slits. This increases the total jet coverage from 1.2mm in design 1.2, to 5mm. By splitting the jet into multiple slits, it does however remove any continuous 1D profiling capabilities, but could technically still be used as a 1D wire scanner with beam deflections, but this is impractical for continuous use.

Design	Density / m^{-3}	Length / mm	Width / mm
V3	6.3×10^{16}	20.6	0.68
Halo – Multi-slit	4.7×10^{16}	0.27	20.6
Delta	-25.4%	0%	-60.3%

$$Relative\ Signal = \frac{Density_{Halo\ Multi-slit} Thickness_{Halo\ Multi-slit}}{Density_{V3} Thickness_{V3}}$$

$$RS = \frac{(4.7 \times 10^{16})(20.6)}{(6.3 \times 10^{16})(\sqrt{2} \times 0.68)} = 16.0$$

The halo signal would be expected to increase by approximately 16 times that of the current V3 configuration, the greatest signal improvement of these designs. However, this system would be unable to provide 1D profile measurements unless a "jet wire scan" is performed via beam deflection.

Pro's

- Full experimental validation for halo diagnostic possible
- High chance of beam-jet interaction compared to standard horizontal that risks missing via misalignment.
- Maximum integrated relative signal for halo jet
- Low risk

Con's

- Removes profile capabilities (including 1D imaging)

- Separation is optimised for stable beams, during injection and ramp where beam size is much larger, halo diagnostic will potentially not be obtainable.

1.4 Profile & Halo – Double Jet

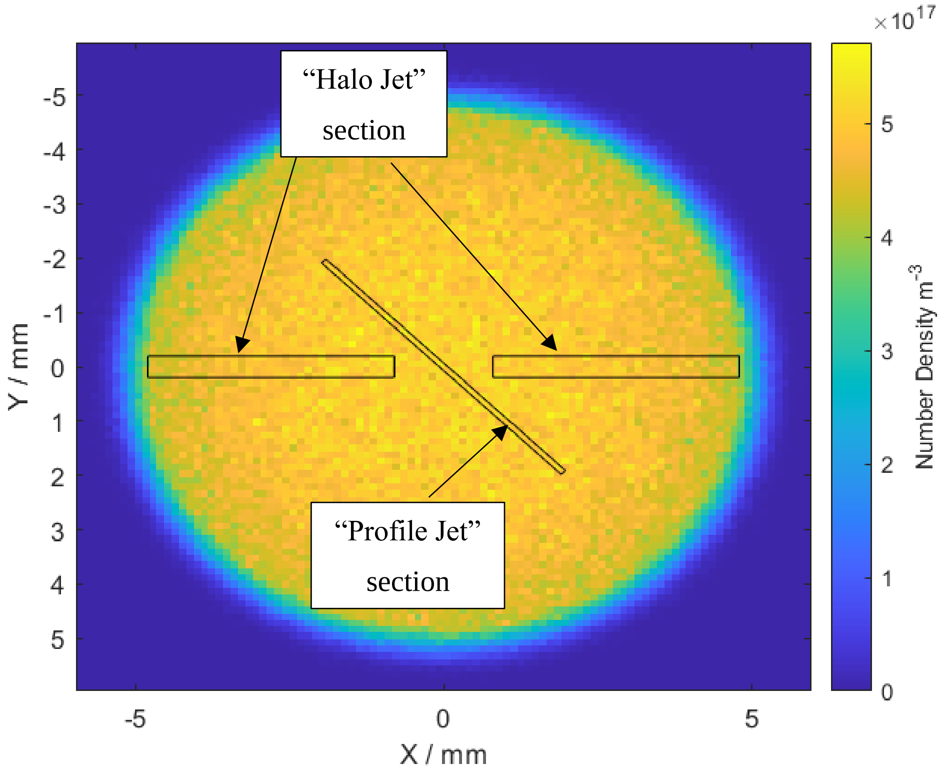

Figure 12. Jet distribution at the 3rd skimmer, with black rectangles as skimmer aperture regions.

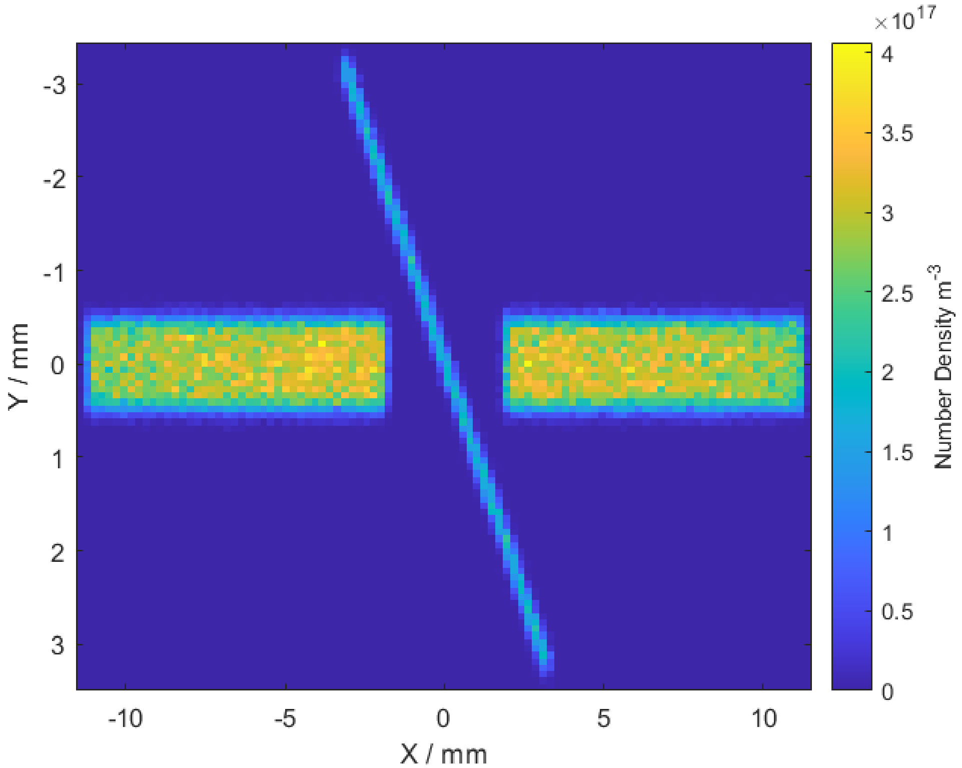

Figure 13. Jet distribution at IP.

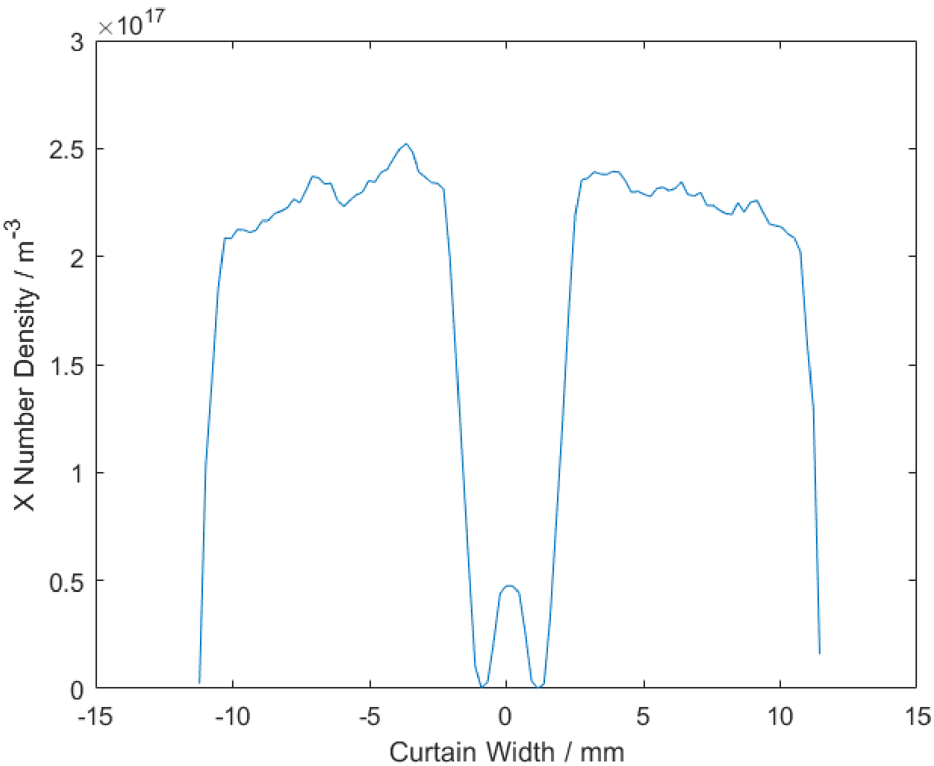

Figure 14. Jet density distribution along beam axis.

3^{rd} Skimmer (Profile) = 0.1 x 5.5 mm (initial estimate)

3^{rd} Skimmer (Halo) = two, 4.0 x 0.4 mm (initial estimate), offset by 2.8mm from centre.

Description

The “Profile & Halo – Double Jet” Design is intended to be installed in the orientation above, to give both a horizontal jet intended for generating losses for halo detection, as well as a 45 degrees thin curtain for accurate profile measurements. Whilst gaining the benefit of potentially allowing both configurations, it also suffers from both drawbacks and more.

For the profile measurement, the improved 2D image, without smearing from the gas curtain thickness would be possible. However, due to the increase in gas loads compared to design 1.1, injection of N2 gas would lead to faster NEG saturation.

For the halo measurement, calibration of the BLM could be possible if the jet is aligned well with the beam, but chance of misalignment is high. Additionally, the detecting losses from halo only may be difficult as the beam core will always interact with the profile curtain which likely dominate the signal.

Design	Density / m^{-3}	Length / mm	Width / mm
V3	6.3×10^{16}	20.6	0.68
Profile – Double Jet	4.8×10^{16}	12.7	0.27
Delta	-29.4%	-38.3%	-60.3%
Halo - Double Jet	6.2×10^{16}	1.0	$2 \times (9.0)$
Delta (Halo)	-1.5%	-95.1%	2550%

$$Relative\ Signal_{Profile-Double\ Jet} = \frac{Density_{Profile-Double\ Jet} Thickness_{Profile-Double\ Jet}}{Density_{V3} Thickness_{V3}}$$

$$RS_{Profile-Double\ Jet} = \frac{(4.8 \times 10^{16})(\sqrt{2} \times 0.27)}{(6.3 \times 10^{16})(\sqrt{2} \times 0.68)} = 0.30$$

The profile jet is expected to receive 30% of the signal from Version 3, and take ~3 times as long. Standard imaging time would be approximately 6 minutes per detailed profile.

$$Relative\ Signal_{Halo-Double\ Jet} = \frac{Density_{Halo-Double\ Jet} Thickness_{Halo-Double\ Jet}}{Density_{V3} Thickness_{V3}}$$

$$RS_{Halo-Double\ Jet} = \frac{(6.2 \times 10^{16})(2 \times 9.0)}{(6.3 \times 10^{16})(\sqrt{2} \times 0.68)} = 18.4$$

The halo section of the jet would generate 18.4 times the signal from Version 3. This could be used for a 1D profile in addition to halo losses if the alignment is perfect.

In addition, the relative signal between the halo jet and the profile jet should also be calculated, as this will limit the beam halo resolution, with the beam always interacting with the profile jet.

$$Relative\ Signal_{Halo-Double\ Jet} = \frac{Density_{Halo-Double\ Jet} Thickness_{Halo-Double\ Jet}}{Density_{Halo-Profile\ Jet} Thickness_{Halo-Profile\ Jet}}$$

$$RS_{Halo-Double\ Jet} = \frac{(6.2 \times 10^{16})(2 \times 9.0)}{(4.8 \times 10^{16})(\sqrt{2} \times 0.27)} = 60.9$$

The relative signal between the two jets would produce 60.9 times more signal from the halo jet, than the profile jet. This sets a floor limit of the halo losses, as the beam core will always interact with the profile curtain. Ideally this would be 10^3 to be comparable to core-halo intensity, but this is unobtainable.

Pro's

- Potential for partial experimental validation of halo
- 2D profile obtainable with reduced thickness effects

Con's

- High gas loads compared to 1.1 Thin Curtain, possible problem for extended N2 injection
- Losses signal will be dominated by profile jet for entire halo scan – limited halo losses calibration
- Potential to miss beam with halo jet all together
- Reduced integrated relative signal for halo jet in comparison to designs 1.2 and 1.3
- Ideal height for halo jet unknown – tough decision
- Changes to optics may be needed? (fluorescence image could be dominated by halo jet interacting with beam core?)
- Medium risk, medium reward

The width-density dependence is explained below. Beyond a certain skimmer size, the curtain width is too small to reach the flat top density as a result of the curtain size being smaller than the size of the gaussian tails from thermal velocity components. As such, the centre maximum is now receiving a reduced gas load, with a reduced skimmer size. This specific width value is dependent on the flat top density and the size of the gaussian tails, and a single, one-size-fits-all value cannot be obtained.

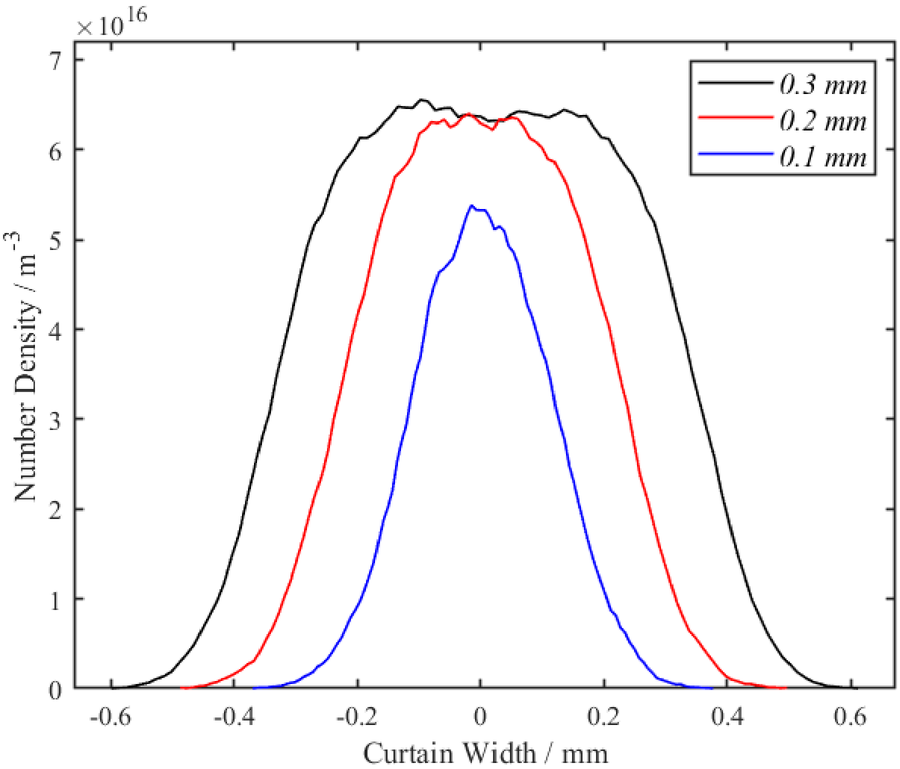

Figure 15. Density distributions of the same jet, with 3rd skimmer widths of 0.3, 0.2 and 0.1mm, demonstrating the width-density dependence.