Power transmission from the ITER model negative ion source on MANTIS

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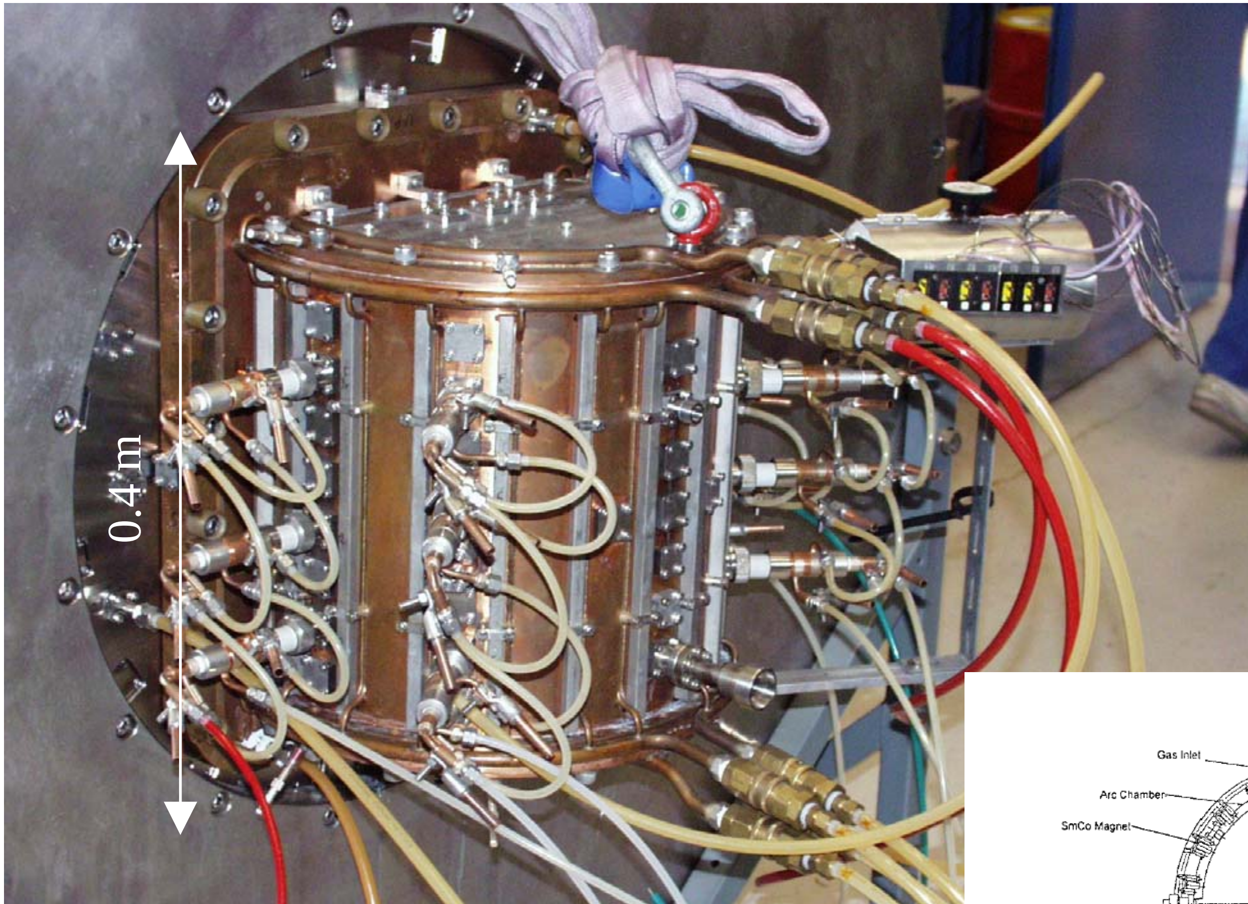
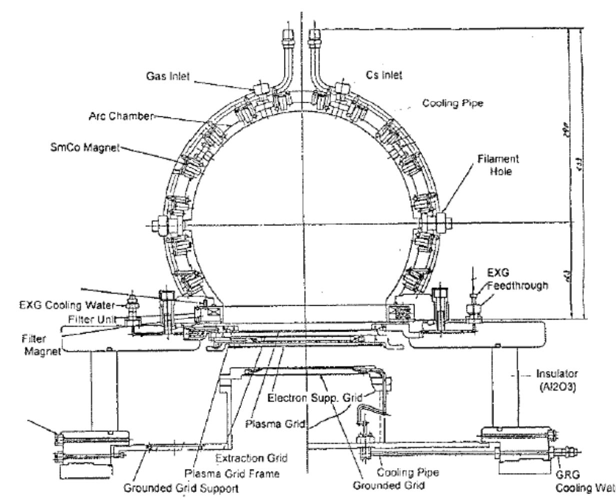
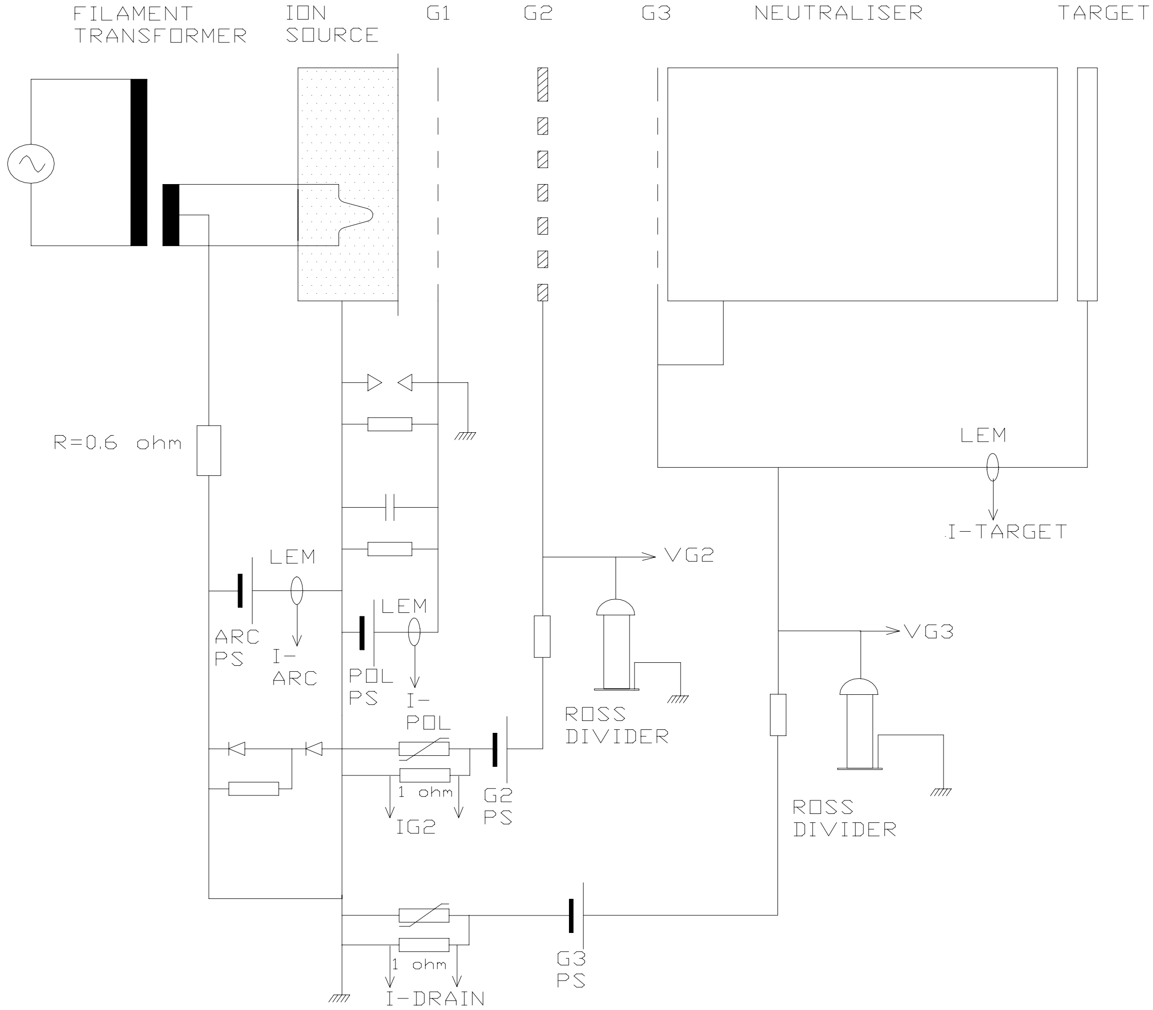




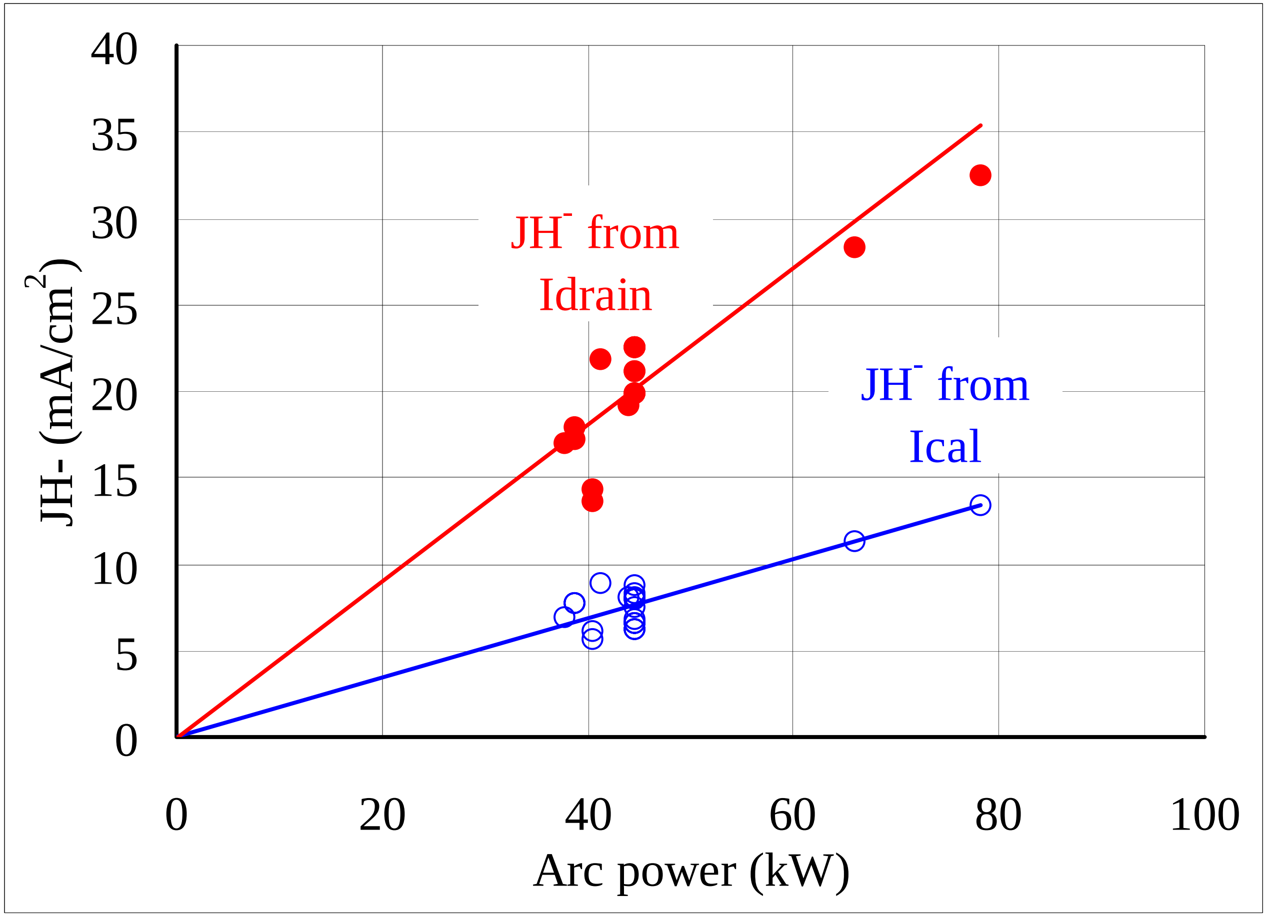
Cross-sectional view of the high confinement (KAMABOKO) source

- <u>KAMABOKO ion source</u>


FILAMENT TRANSFORMER
ION SOURCE
G1
G2
G3
NEUTRALISER
TARGET
R=0.6 ohm
LEM
I-TARGET
VG2
LEM
LEM
ARC PS
I-ARC
POL PS
I-POL
ROSS DIVIDER
VG3
1 ohm
IG2
G2 PS
ROSS DIVIDER
1 ohm
I-DRAIN
G3 PS

1 Low negative ion current to the calorimeter:

Poor Beam Transmission



How do we account for this lost power?

•Possibilities are as follows:

(a) I_{drain} is made up of extracted electrons, stripped electrons or secondary electrons.

(b) bad beam optics and/or presence of large beam halos

(c) presence of back streaming ions

All of these effects are investigated here.

a) The "lost" beam is electrons.

Extracted electrons:

Operation of the source in pure Ar:

- **No negative ions are produced in the discharge**
- **A high electron current of 2.8 A was extracted and collected on G2**
- **No power was recorded on the calorimeter**
- **The accelerated current, was 50 mA, i.e.<2% of the extracted current**
- **The current to the acceleration grid was equal to the current drain from the high voltage power supply**

Conclusion: The extracted electron current during H_2 operation is typically <20% of the accelerated current, therefore accelerated extracted electrons cannot explain the lost beam.

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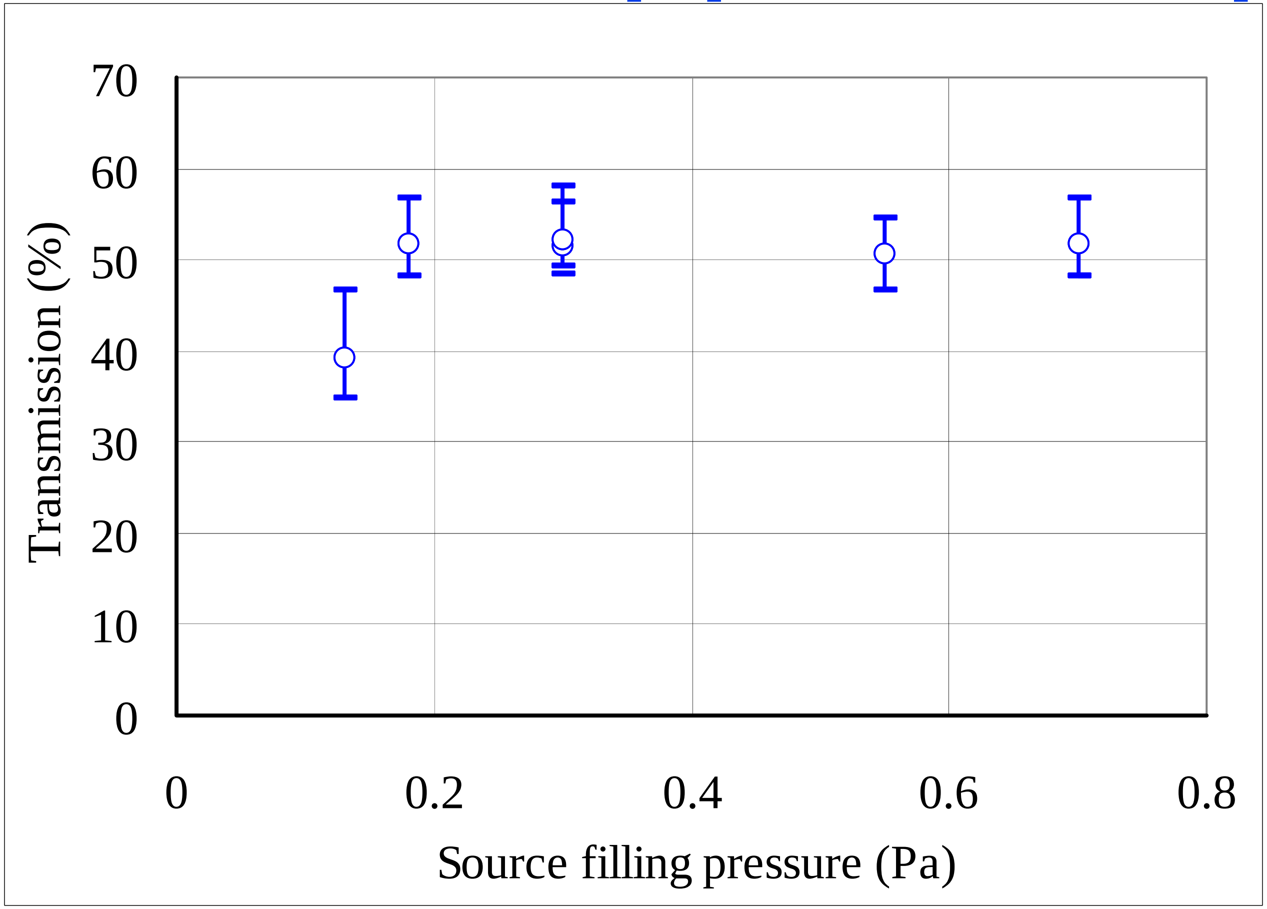
Electrons from stripping. In this case the number of stripped electrons hence the transmission, should be proportional to the source pressure.



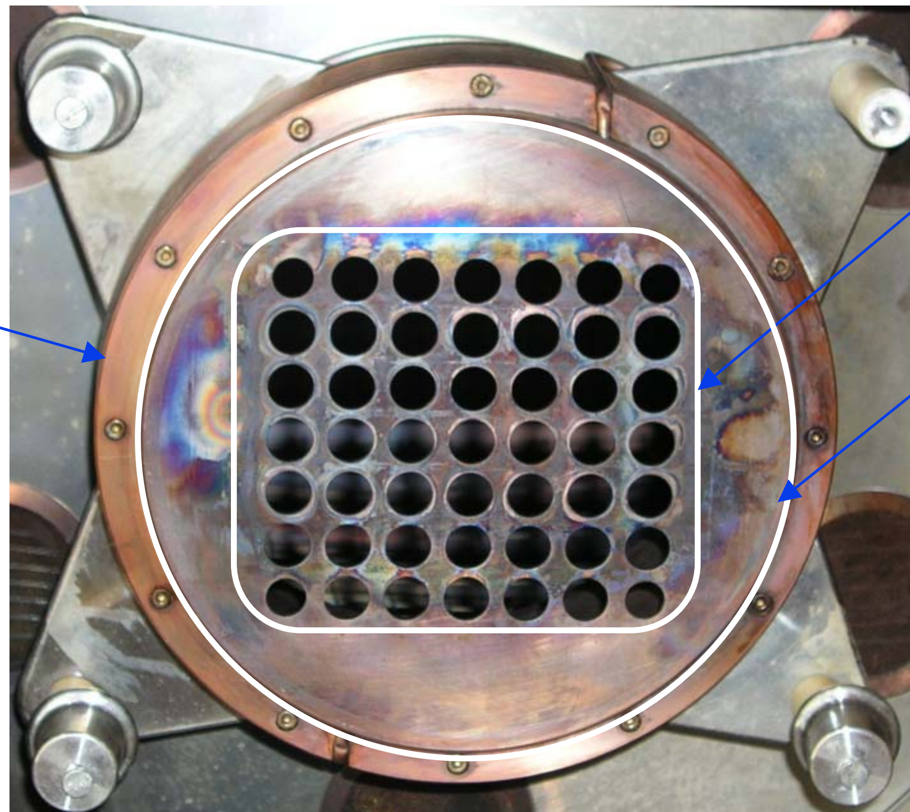
Conclusion: Accelerated stripped electrons cannot explain the lost beam.

b) The beam optics is extremely bad.

1 Simulations with assumed possible variations and errors predict beams with adequate optics to achieve good transmission.

2 Grid distortion due to thermal expansion of the acceleration grid (G3)

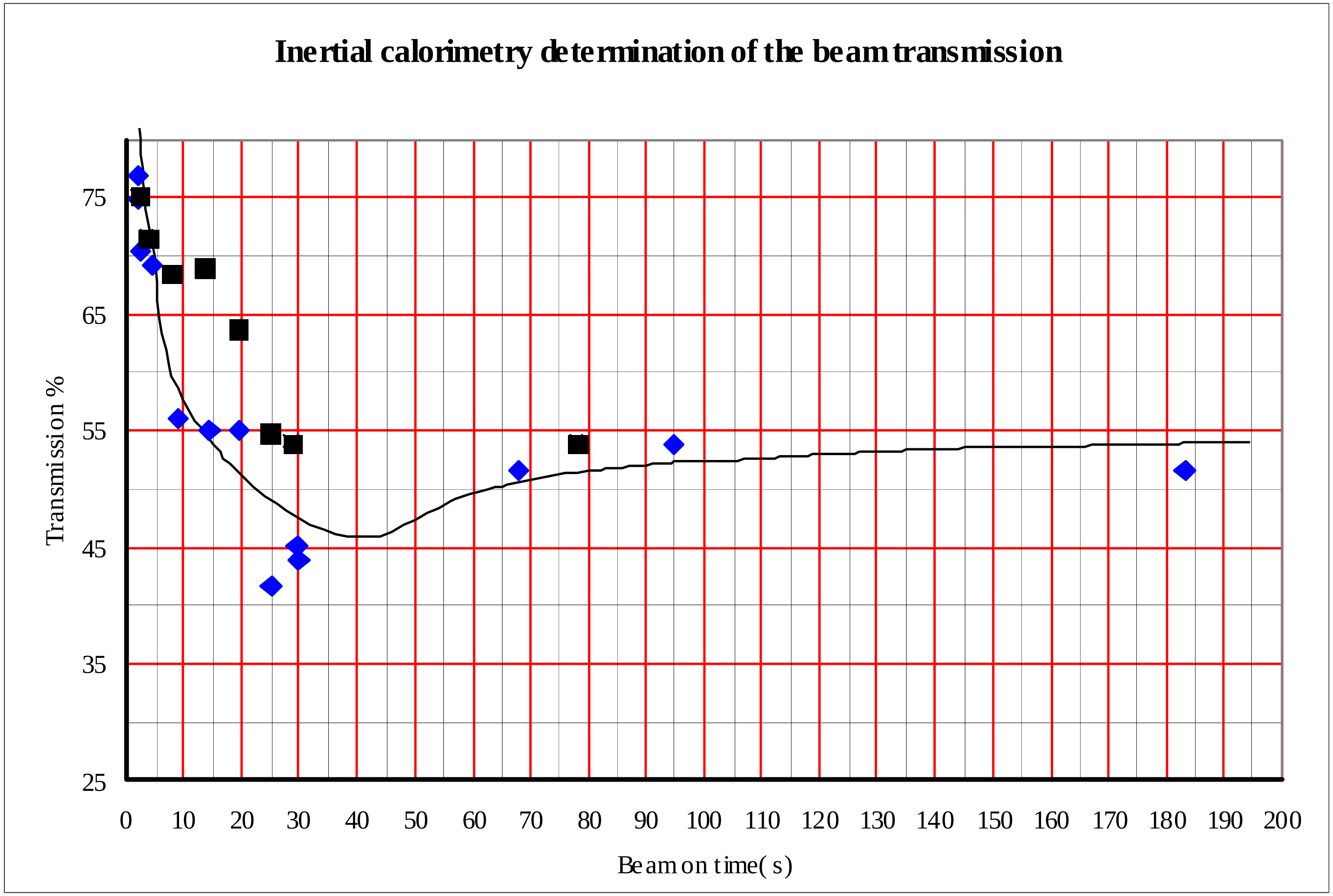
6.5 mm thick rim



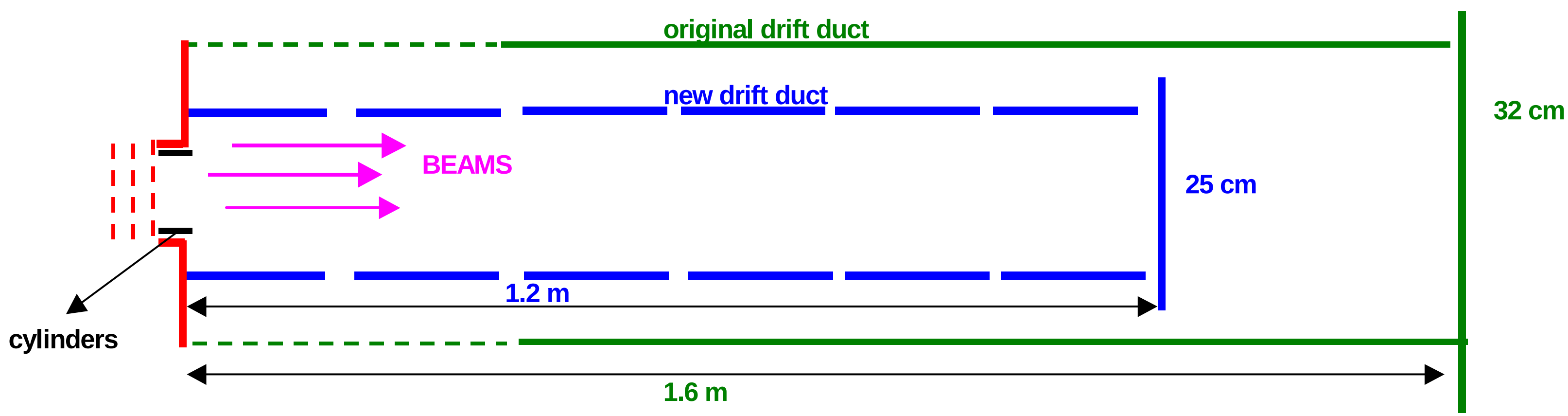
Grid thickness 3 mm within this area

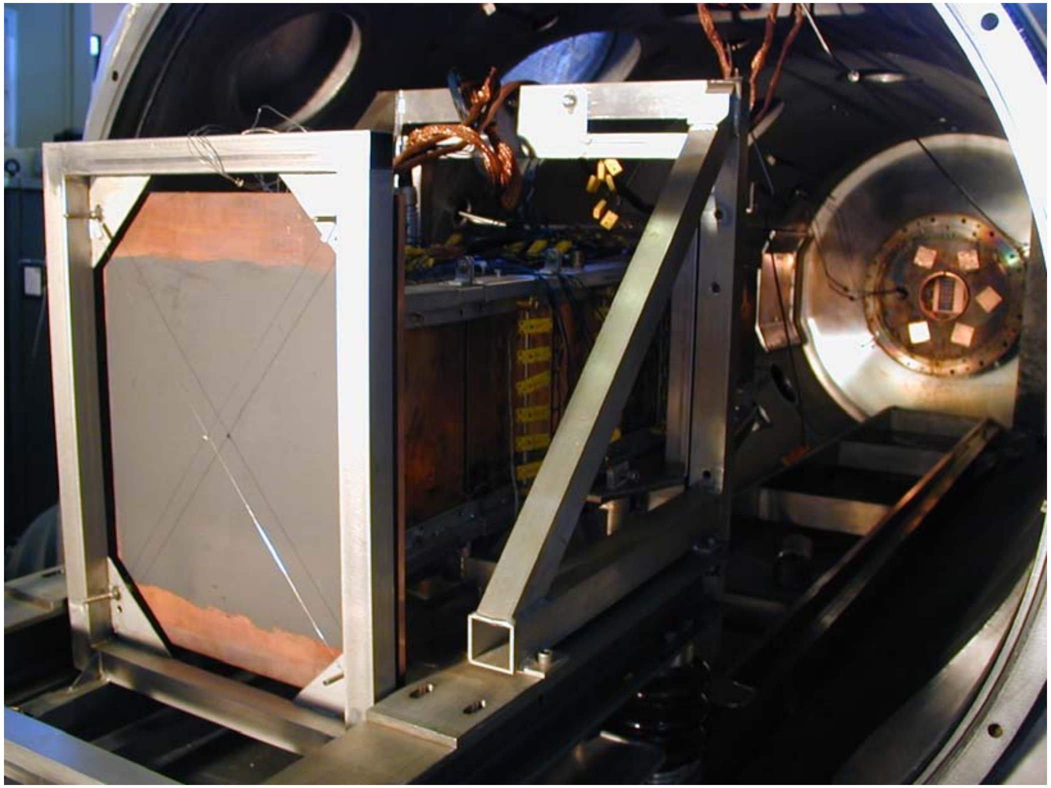
10.5 mm thick within this circle

If G3 is distorting, the transmission should vary with time, therefore pulse length.



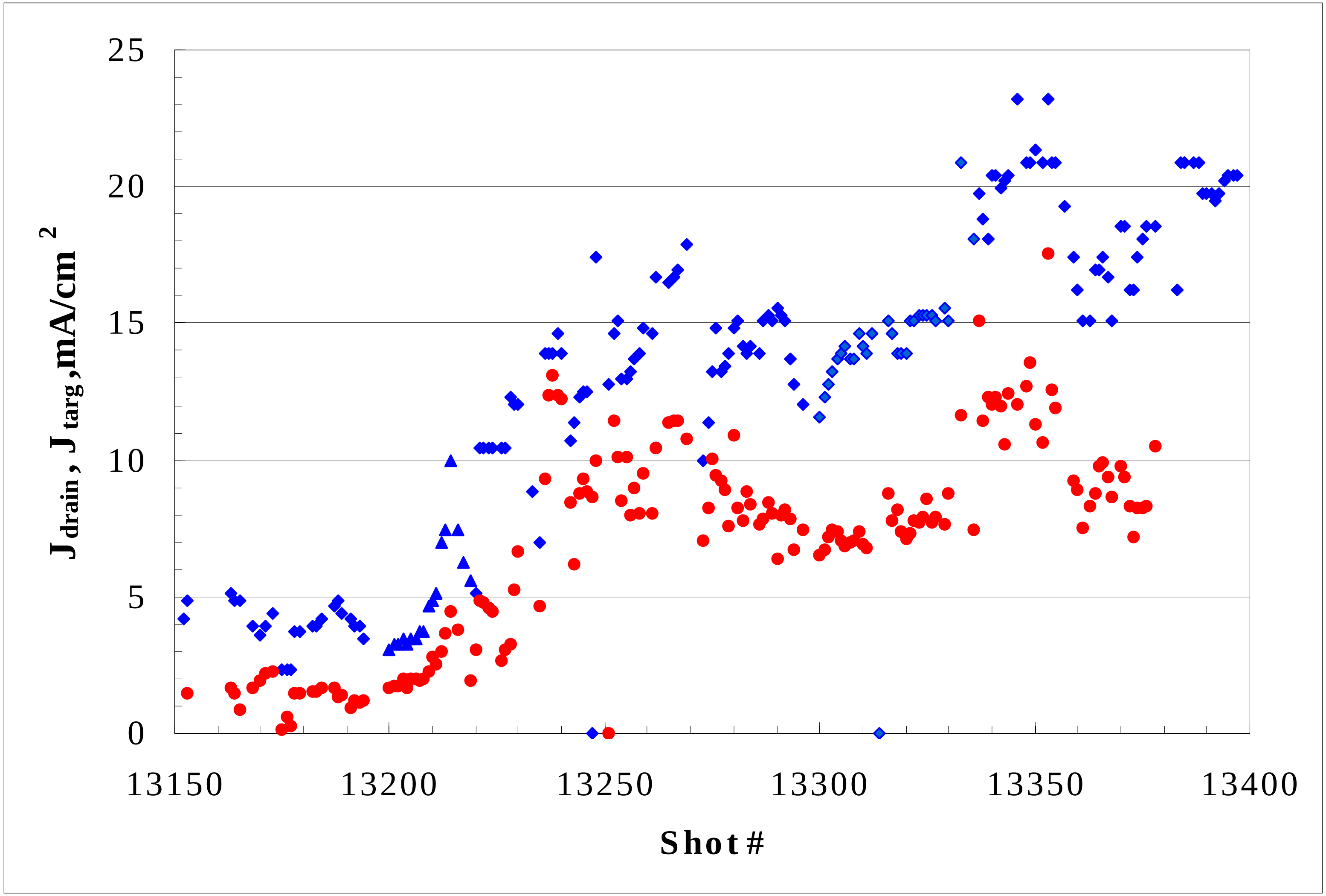
Presence of large beam halos?



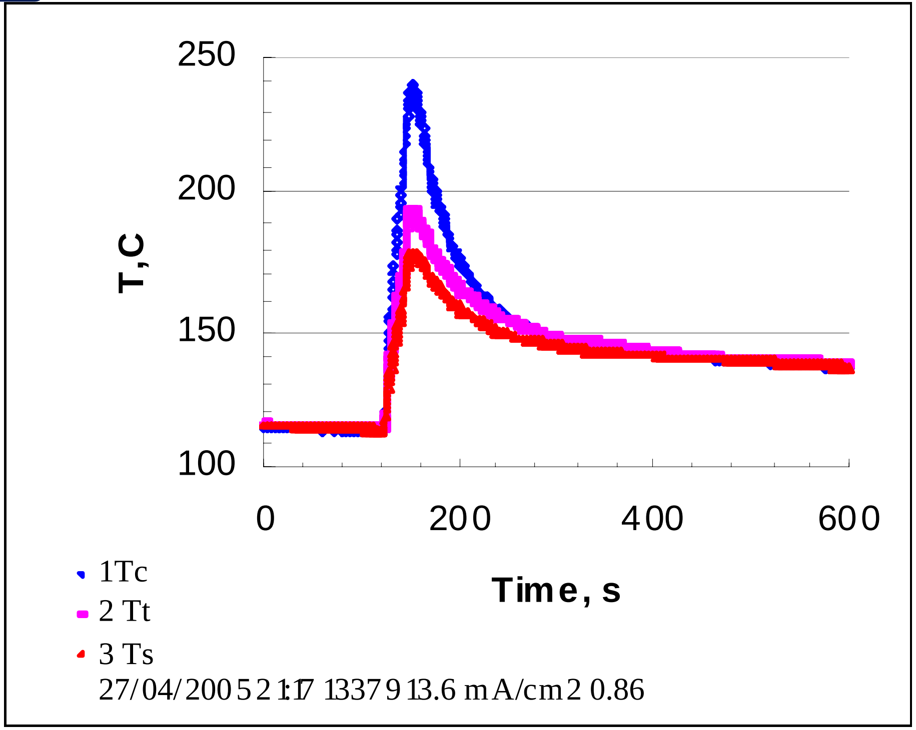


An inertial target closes the end of the drift duct

Extracted e^{-}s should be deflected onto the cylinder

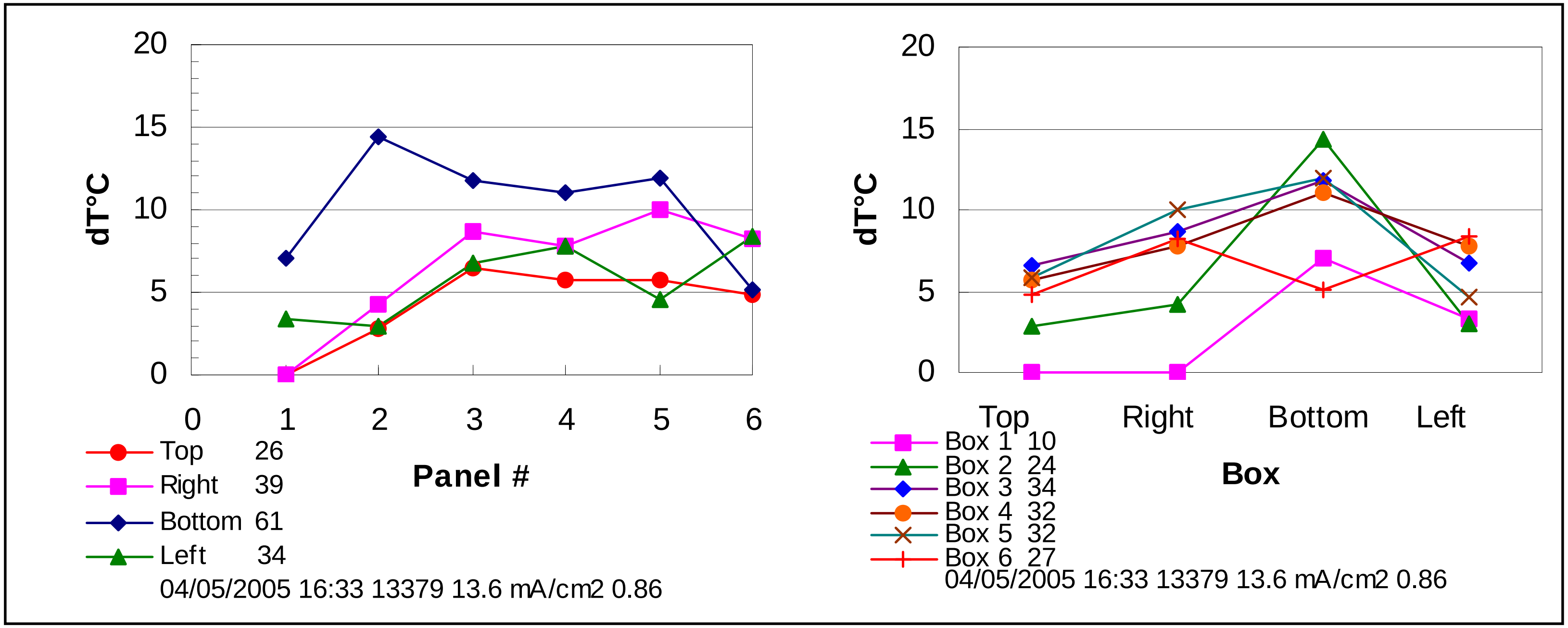


Current density evolution with shot number



Thermal measurements taken from 3 thermocouples embedded into the rear of the copper target give the calorimetric power intercepted by the target.

A transmission of 64 % is seen in this case of the accelerated current to the inertial target. Approx 13.5 mA/cm^2 is intercepted here.



- **Thermal measurements taken from the 24 measurements on the drift duct.**
- **A halo of 30 % of the accelerated power is observed on the walls of the drift duct.**
- **Approx 1 % power is intercepted on the cylinders.**

•Typically 21 mA/cm2 achieved from the accelerated current, resulted in an intercepted current on the target of 13 mA/cm2.

•Giving 64 % transmission

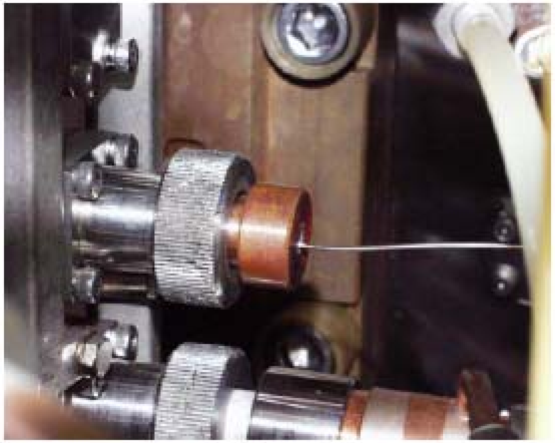
•A halo of 30 % of the accelerated power is intercepted on the drift duct walls.

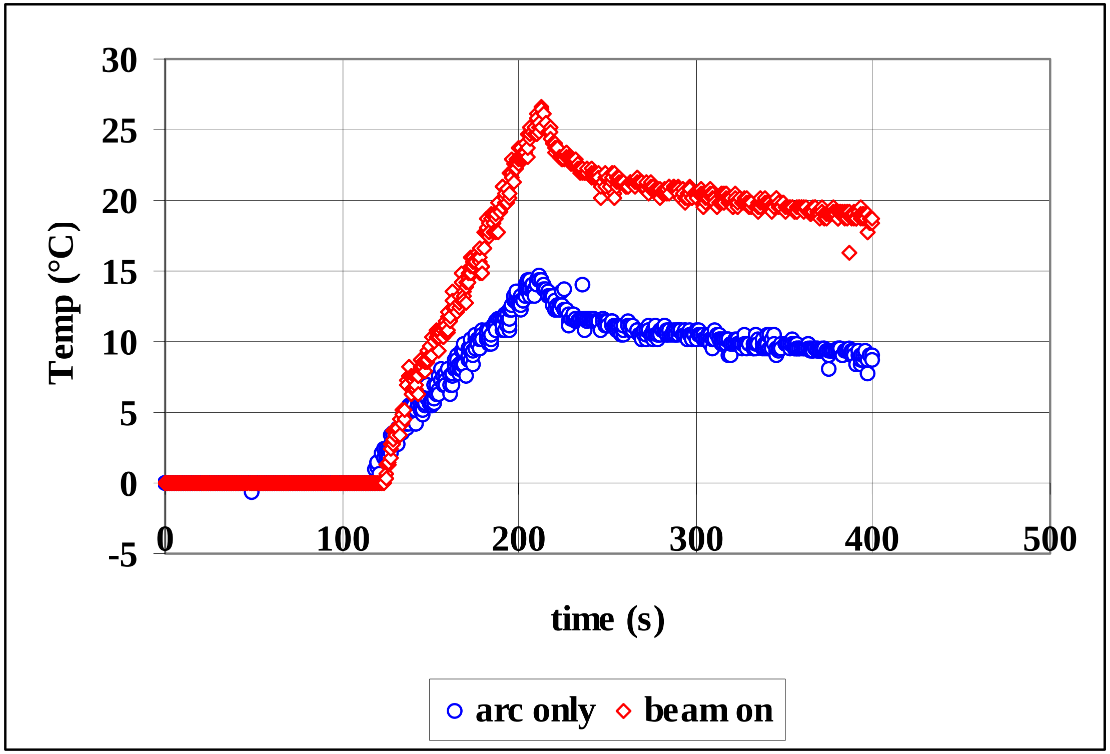
•1% accelerated electrons are deflected to the copper cylinders.

•The total accelerated power from the ion source is approx 20 mA/cm2.

•The acceleration of this negative ion current is another matter.

(c) Presence of positive ions





- Back streaming positive ion measurement, copper stopper on rear of ion source.
- Approx 2 %back streaming positives measured.

Table summarizing the results of Cs seeded operation on MANTIS

Shot	JH- I drain (mA/cm2)	JH- target (mA/cm2)	Transmission %	% halo	% cylind	% Back streaming positive ions	Total accountability of accelerated power %	JH- from KAMABOKO mA/cm2
13349	20.9	13.5	65	30	1	2	98	20
13338	18.8	11.4	61	32	1		94	17
13339	18.1	12.3	68	28	1		97	17
13340	20.4	12.0	59	30	1		90	18
13341	20.4	12.3	60	28	1		89	18
13342	20.0	12.0	60	30	1		91	18
13343	20.2	10.6	52	32	1		86	17
13344	20.4	12.4	61	33	1		95	19
13346	23.2	12.0	52	30	2		83	19
13348	20.9	12.7	61	34	1		96	20
13350	21.3	11.3	53	33	1		87	18
13552	20.9	10.7	51	35	1		87	18

- 20 mA/cm2 JH- is easily achievable from the ion source.
- The acceleration of this current is proving to be problematic.

Presence of very wide halos- why?

- A caesiated source is thought to operate on the principle of back scattering of positive ions and neutrals from the plasma grid as negative ions.
- Cs neutrals can escape the ions source between pulses and during arc only pulses, they can then reach the extraction grid and cover it.
- Hydrogen atoms leave the discharge during pulses and can be converted to negative ions on grid 2.
- The optics of these ions produced on the extraction grid are not good and are deflected to the drift duct, increasing/influencing the halo.

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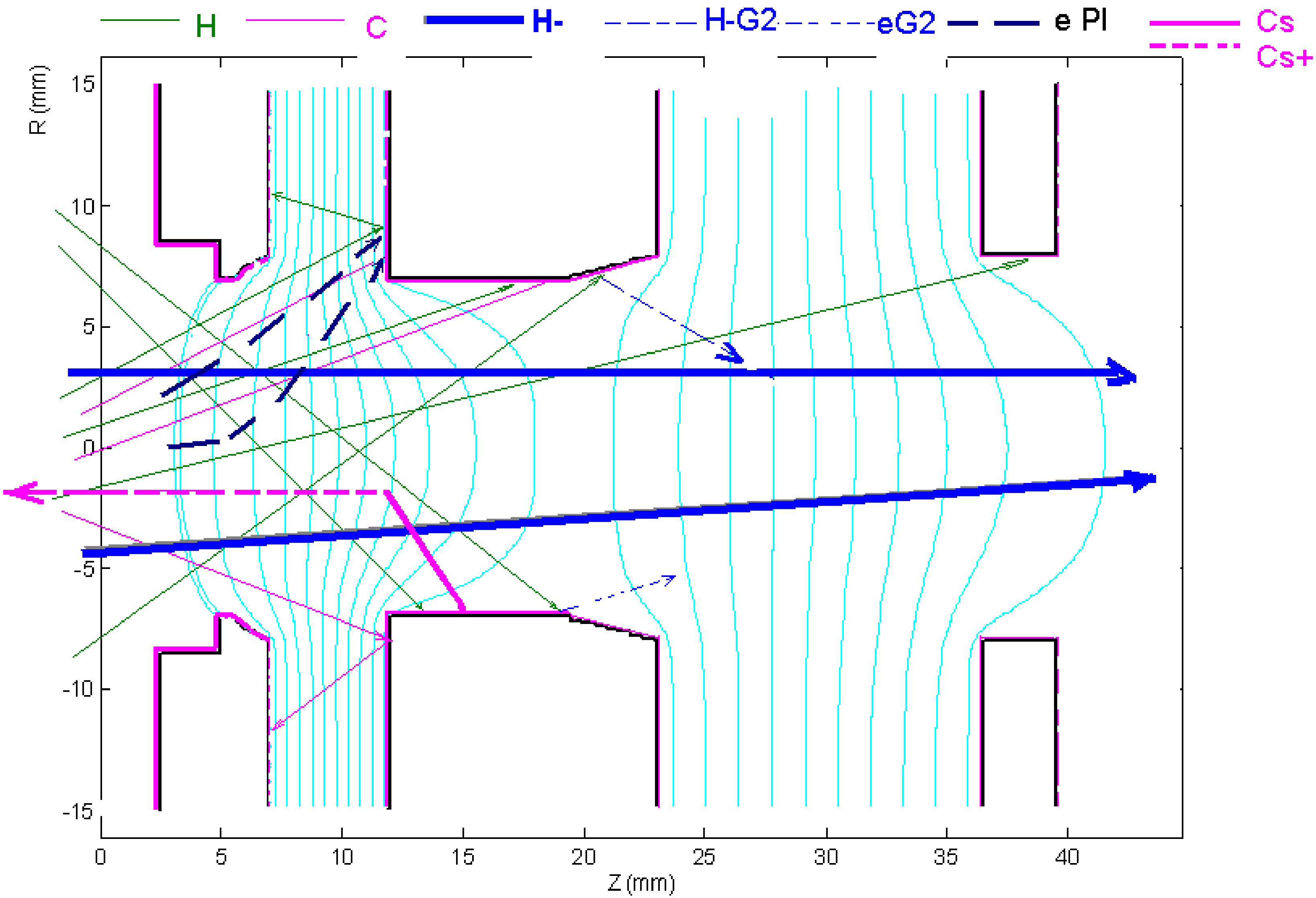

Conclusions

- A new neutraliser has been designed, instrumented and commissioned with the objective of measuring the ~50% of missing power (P_{drain}-P_{cal}) seen on MANTIS during long pulse experiments.
- Transmission of the accelerated current to the target is typically 60- 70 %.
- Measurements with this drift duct have shown 30 % halos in Cs operation.
- It is estimated that a very small percentage of the accelerated power is electrons, as only a small power deposition is measured on the grid 3 support. The magnetic filter will prevent electrons from travelling beyond this point.

- **A measurement of the back streaming ions in Cs discharges indicate they account for approx 2 % of the accelerated power.**
- **Power accountability on MANTIS is now quite high, > 85 % in Cs seeded discharges. Power accountability in volume operation was not successful due to the very small temperature rises from low current densities accelerated.**
- **Results of Cs seeded operation from this campaign indicate that negative ion densities of 20 mA/cm2 are easily achievable at about 45-50 kW and 0.3 Pa filling pressure, but that the beam optics are very bad, producing a very large halo.**
- **Core beam divergences are calculated to be of the order of 4 degrees and the halo of 11 degrees. Further investigation into the reason for these extremely wide beams is required. One hypothesis is that there is surface generation of negative ions on the extraction which could contribute to the halo found.**