Neutralization Effects in 13 keV Region

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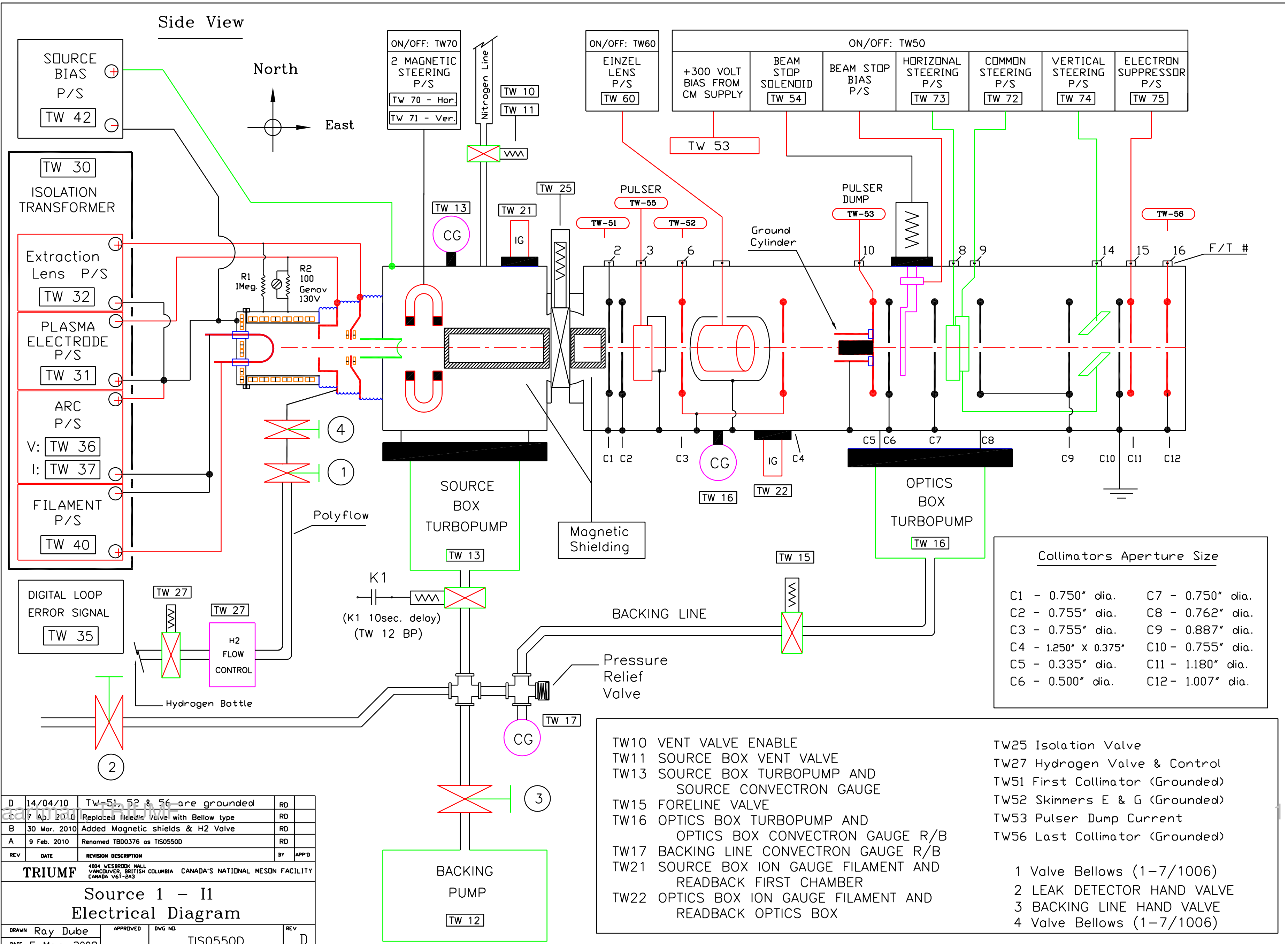

Collimators Aperture Size

C1 – 0.750″ dia.	C7 – 0.750″ dia.
C2 – 0.755″ dia.	C8 – 0.762″ dia.
C3 – 0.755″ dia.	C9 – 0.887″ dia.
C4 – 1.250″ X 0.375″	C10 – 0.755″ dia.
C5 – 0.335″ dia.	C11 – 1.180″ dia.
C6 – 0.500″ dia.	C12 – 1.007″ dia.

TW10	VENT VALVE ENABLE
TW11	SOURCE BOX VENT VALVE
TW13	SOURCE BOX TURBOPUMP AND SOURCE CONVECTRON GAUGE
TW15	FORELINE VALVE
TW16	OPTICS BOX TURBOPUMP AND OPTICS BOX CONVECTRON GAUGE R/B
TW17	BACKING LINE CONVECTRON GAUGE R/B
TW21	SOURCE BOX ION GAUGE FILAMENT AND READBACK FIRST CHAMBER
TW22	OPTICS BOX ION GAUGE FILAMENT AND READBACK OPTICS BOX
TW25	Isolation Valve
TW27	Hydrogen Valve & Control
TW51	First Collimator (Grounded)
TW52	Skimmers E & G (Grounded)
TW53	Pulser Dump Current
TW56	Last Collimator (Grounded)

1 Valve Bellows (1-7/1006)
2 LEAK DETECTOR HAND VALVE
3 BACKING LINE HAND VALVE
4 Valve Bellows (1-7/1006)

REV	DATE	REVISION DESCRIPTION	BY	APP'D
D	14/04/10	TW-51, 52 & 56 are grounded	RD	
C	7 Ap. 2010	Replaced Needle Valve with Bellow type	RD	
B	30 Mar. 2010	Added Magnetic shields & H2 Valve	RD	
A	9 Feb. 2010	Renamed TBD0376 as TIS0550D	RD	

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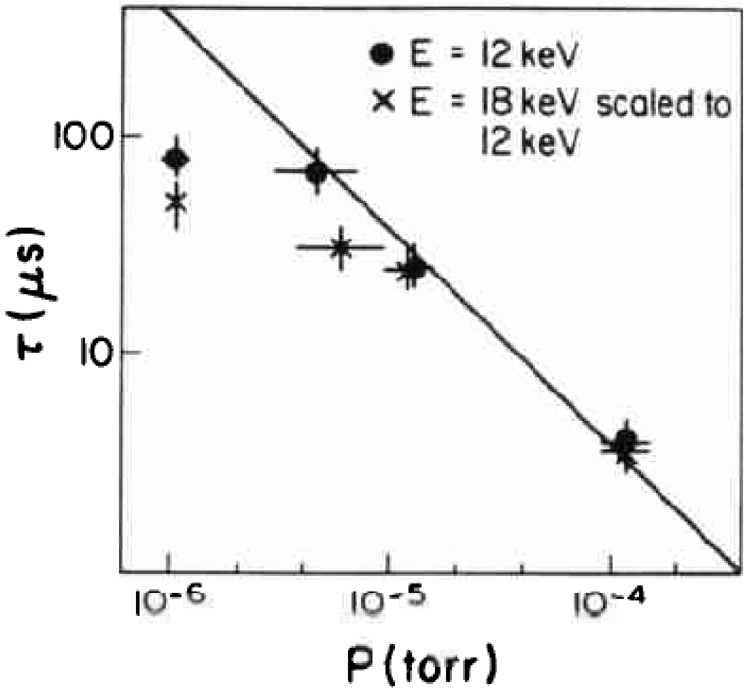
Source 1 – I1
Electrical Diagram

DRAWN Ray Dube
APPROVED
DWG NO. TIS0550D
REV D

Neutralization

Measured in 1988,



Conclude that in optics box where $P = 8 \times 10^{-6}$ Torr, $\tau = 30\,\mu$s. In source box, $P = 8 \times 10^{-5}$ Torr, $\tau = 3\,\mu$s.

In the source box, the rate of generation of positive ions is simply total charge of beam particles divided by neutralization time:

$$I^+ = \frac{I_{\rm beam}}{\beta c}\,\frac{L}{\tau} = 89\,\mu\text{A}$$

I am using 1 mA for beam and $L = 42$ cm.

The optics box is different because there are only short regions of potential less than the space charge potential, which is $(30\,\Omega/\beta)I_{\rm beam} = 5$ Volts. Coupled with 10 times better vacuum, it probably does not contribute very much.

In any case, these $89\,\mu$A have to show up somewhere. If there is no potential barrier, they will be accelerated backward into the source, possibly doing damage or upsetting the plasma.

A region that needs specail consideration is the 1cm diameter by 8cm long differential pumping aperture, since the pressure inside it is probably much higher than 8×10^{-5} Torr. If we assume it is twice this value, then the neutraliztion time is 1.5 μs. A relevant question is how far do neutralizing ions travel in one neutralization time. Assume temperature is 400 K. Then the ions travel 1300 m/s, and in one neutraliztion time travel only 2 mm. This is good as it means the ions stay in the beam long enough to neutralize it. But we must also ensure that the electrons leave the region. Their speed is $\sqrt{938/0.511}$ times faster, so they travel 88 mm in one neutralization time. This is marginal: more pumping is desirable.

Stripping

As well, stripping loss is 50% per metre at $P = 1.2 \times 10^{-4}$ Torr, so is $33\%/$m in source box, or about 14% total. This is huge: $140\,\mu$A lost, and appearing here and there as a broad background for the roughly 1 mA beam.

This emphasizes that we need better vacuum. Moreover, the mild steel tubes installed for shielding out the magnetic field is restricting the pumping on the beam axis and likely making the pressure much worse than at the gauge. I favour removing them.

Emittance

19 June, 2012, we measured emittance as 6.3μm 4rms; 6.0 at 86%contour. The beam at 030 is about 53μA at 10%, would be 530μA at 100

Under these conditions and using the periodic section quad voltage 3.05kV, I find the matched 2rms size of the beam is 0.114” at the locations of the slits.

We set the slits to 200 thou, but I do not know what their resulting widths are, since the pot readbacks read anything from 0.164” to 0.202”. I have to conclude that they are only approximately at 0.2”.

Anyway, if slits are +/-0.114”, then each of the 4 slits pass 95%, for a total of 81% for the 4 dimensions. (This is larger than the 86% times 86% = 74%, since that 86% applies to a selected ellipse, and we are selecting the square.)

This would be 43μA. In fact, we measured 41.8μA throughput. Turning this around, $41.8/53 = 79\% = 0.94^4$; our slits should have each transmitted 0.94, which for a gaussian is about 1.88σ or 0.214” slit size, which is believable.

In any case, this is useful to keep in mind: 0.200” slit sizes will transmit about 80% of the beam if the emittance is 6μm (or 6 πmm-mrad, if you find the μm notation confusing).

Translating the emittance to the 13 keV region, we must multiply by 5. So in this region, $\epsilon \sim 30\,\mu$m. Ultimately, we want more, so should allow for about $50\,\mu$m.

In the region between the source and the first collimator, there is virtually 100% space charge neutralization, so we can treat this as a pure drift with no space charge. With a 4 mm source aperture, we thus need only ± 25 mrad divergence; the rest is not useful for the cyclotron. For $L = 42$ cm between source and collimator, the collimator diameter must be 21 mm. Other combinations in the table.

Source waist dia./mm	Collimator dia./mm
5	17
4	21
3	27
2	42

Currently, the source aperture dia. is 8 mm. According to simulations performed by Suresh, the source waist is 6cm downstream of the source aperture and has a size of only 2mm diameter and divergence of ± 40mrad. If this is so, and the divergence is gaussian, then its

2rms size at C1 is 16mm. Since C1 radius is only 9.5mm, this would mean roughly 30% of the beam is lost on C1, trimming the 4rms emittance to $24\,\mu$m. This is believable, and may explain why when the source is putting out more than 1 mA, only $700\,\mu$A appears at the Faraday cup. The beam envelope for this case is below.

But another implication is that pulser dump aperture C5 can be very small: 5 mm is easily sufficient, currently it is 8.5 mm.

Beam Envelope