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A Double Parallel-Plate Electrostatic Analyzer for Tara Endloss Studies

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ABSTRACT:

An endloss spectrograph has been designed and is being fabricated for the Tara Tandem Mirror. This spectrograph is a double parallel-plate electrostatic analyzer about 60 cm in length with a 30° entrance angle; the high voltage plate is a transparent wire cloth grid which allows higher energy particles to pass through for detection on a symmetric ground plane. The analyzer has three detection planes: first, the normal focal plane for low energy detection at high resolution (100eV to 4keV); second, the entrance grounded plate for mid energies (4 to 6keV); and third, the symmetric ground plane for coarse resolution at higher energies (8 to 20keV). The analyzer is defocusing on the symmetric plane. This spectrograph will be able to measure simultaneously the endloss potential cutoff and ions from the neutral beams; in conjunction with a loss cone neutral beam source the resolution is sufficient (60eV) to measure the plasma potential.

INTRODUCTION:

The Tara experiment at the M.I.T. Plasma Fusion Center is a tandem mirror with outboard anchors, axisymmetric plugs, ICRH center cell heating, and ECH (gyrotron) plug and barrier electron heating[1]. The open ended configuration of the magnetic field means that ions and electrons will escape the plasma regions by streaming out along the field lines. Measurements of the escaping ions can provide information about the plasma and its space potentials. This information is essential for understanding the formation and characteristics of the plasma.

Various detectors have been used to measure the endloss including net current and biased gridded detectors[2]. Recently, a more complex diagnostic[3], the ELIS, has been used succesfully on TMX-U at LLNL. This instrument uses an $E \parallel B$ analyzer to measure simultaneously the rigidity and charge-to-mass ratio of the ion stream. Because two parameters are measured, H^+ and D^+ ions are resolved and their energy spectra measured over a broad energy band. As there is no sweep involved in the energy scan and as current and not individual particles are measured, energy spectra may be taken with fast time resolution.

The double parallel-plate electrostatic analyzer (ion spectrometer), DPPIS, discussed here for Tara is much simpler than the ELIS. This simplification is possible because the Tara plasma contains only a single species, H^+, and consequently only one parameter need be measured; impurity ions such as Ti^+ and Ar^+ are neglected. The DPPIS separates ions and electrons while maintaining fast time resolution and broad energy coverage for the ions.

APPARATUS:

The present diagnostic set on Tara is depicted in Figure 1 with the planned location of the DPPIS indicated at the south end of the machine alongside the other endloss diagnostics. The instrument is located in a magnetic field free region generated by its placement inside a soft iron vacuum chamber placed $\approx$1 m from the machine to minimize field perturbations; a soft iron collar is available if necessary to symmetrize the field disturbance. The divergence of the field lines beyond the fan tank will necessitate careful alignment for efficient plasma transport to the analyzer. The plasma ion stream passes between two collimators with $\approx$1 mm apertures; the collimators are separated by 10 cm and mounted immediately outside the main chamber. A conical field taper may need to be added around the collimator assembly in order to give a smooth transition into the magnetic field free region of the chamber.

The DPPIS is shown schematically, but nearly to scale, in Figure 2. Basically, the analyzer is a conventional double focussing (30°) parallel plate electrostatic analyzer about 60 cm in length[4]. However, the high voltage plane is transparent in order to add a second symmetric detection plane for high energies. A DC high voltage, V, is applied to the middle, high voltage, plane so that ions with energies below

$$T_m = 4QV \quad ,$$

where Q is the charge on the ion, +1 for hydrogen, will be reflected. These reflected ions are double focussed on the normal "focal" plane which is tilted relative to the parallel ground plane[5]. The physical size of the analyzer (along with V) limits the peak energy detected in the focal plane. Actually the "ground" plane, symmetric "ground" plane, and focal plane are held at ≈ -100V in order to suppress secondary electrons; the detector plane is at ground and mounted close behind the focal plane on standoffs. All three planes use high transmission wire cloth (97%) in order to have a high transmission coefficient. A detector array is also mounted off the partially focused ground plane to measure energies up to

$\approx T_m$. The symmetric ground plane is slightly defocussing but still has some energy resolution and is used to measure ions with energies above T_m; there is coarse resolution for energies up to $\approx 3T_m$. The geometric energy resolution may be seen in Figure 3 wherein extremal rays from the collimator are traced to the various detection planes. It should also be noted that there is a straight path through the analyzer in order to avoid scattered light problems.

The detector arrays are quite similar to those used on the ELIS[6] and consist of circuit boards with collector strips separated by etching; these will be plugged into edge connectors allowing changes to be made easily to the collection geometry. We plan on $\approx$0.25 cm strip segments in the focal plane with 36 quasi-logarithmically spaced groups; for the symmetric "ground" plane 8 linearly spaced groups of $\approx$1cm segments; and for the "ground" plane only 4 groups. Again as on the ELIS the collected currents will be readout directly into CAMAC modules which take a direct current input thus eliminating the need for signal amplifiers before the digitization.

PLANNED MEASUREMENTS:

For the plasma parameters of Tara, we plan on initially operating the DPPIS with 1.5 kV on the central plane. This will allow us to measure with high resolution ($\approx$40eV) H^+ ions between 100eV and 4kV on the focal plane, with medium resolution between 4kV and 6kV on the "ground" plane, and with coarse resolution between 6kV and 20kV on the symmetric "ground" plane. Under these operating conditions, we can measure simultaneously the endloss potential cutoff of the plasma, the thermal spread above that cutoff, other potential knees if present, and ions from the full, half, and third energy components of the neutral beams. If the beams are directly injected into the loss cone then by changing the high voltage the resolution is sufficient to measure the local plasma potential at the beam footprint.

SUMMARY:

In conclusion, the status of the Tara double parallel-plate electrostatic analyzer can be summarized as follows:

1) The instrument has a simple design and is inexpensive.

2) The instrument is currently being fabricated for installation in early summer 1986.

3) This new diagnostic instrument should provide energy spectral measurements with fast time resolution.

ACKNOWLEDGEMENTS:

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Figure Captions:

1) A schematic of the Tara diagnostic set indicating the planned addition of the DPPIS on the south fan tank.

2) A schematic of the DPPIS in its vacuum vessel showing the major components of the analyzer. The three detection planes are a unique feature of this instrument. Values corresponding to nominal operating conditions are indicated. The guard rings are used with a voltage divider to give a uniform field between the planes.

3) Bundles of ion trajectories from a ray tracing code. The different focal properties of the various detector planes is evident.

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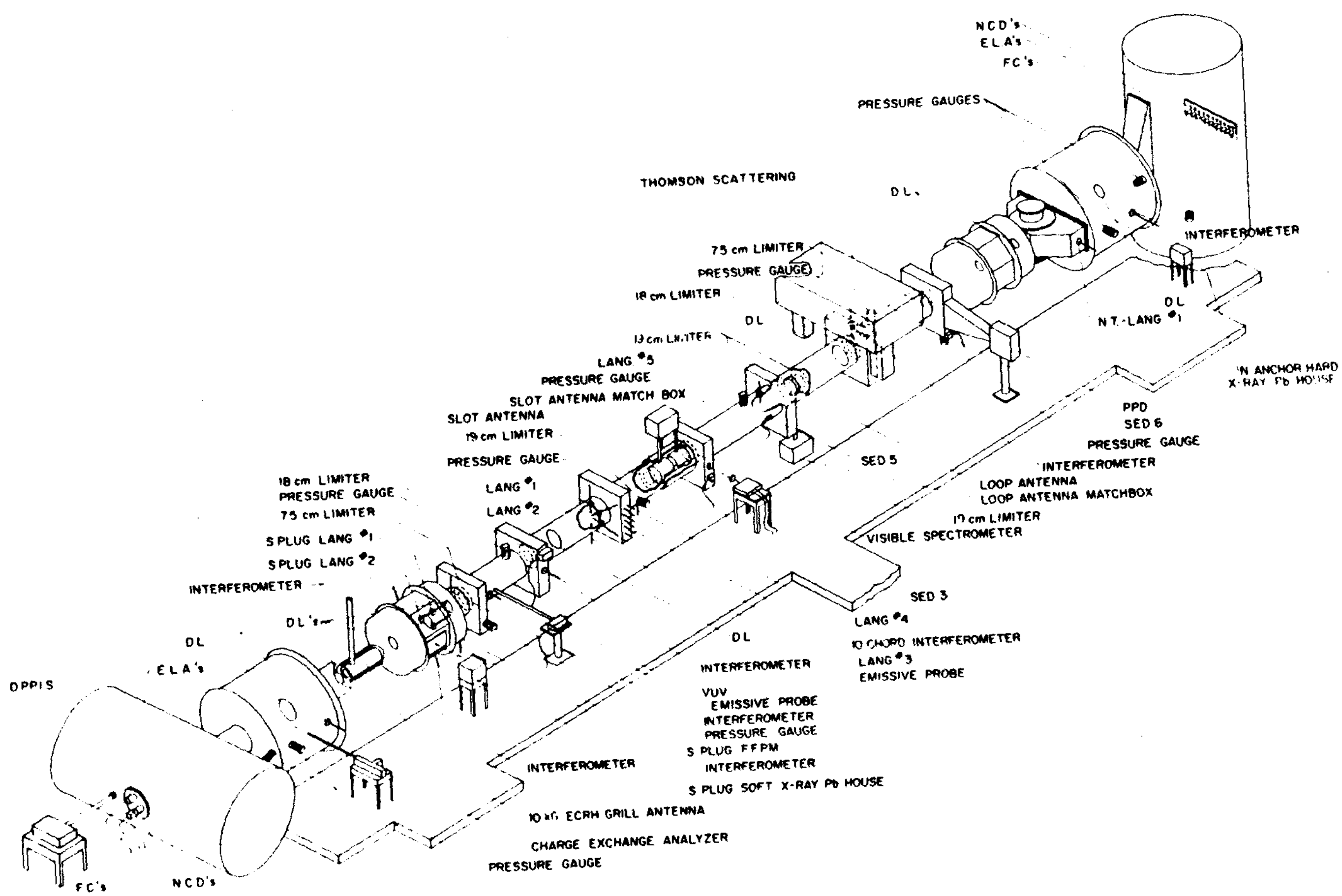
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NT-LANG #1
13 cm LIMITER
LANG #5
PRESSURE GAUGE
SLOT ANTENNA MATCH BOX
SLOT ANTENNA
19 cm LIMITER
PRESSURE GAUGE
PPD
SED 6
PRESSURE GAUGE
INTERFEROMETER
LOOP ANTENNA
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VISIBLE SPECTROMETER
SED 5
18 cm LIMITER
PRESSURE GAUGE
75 cm LIMITER
LANG #1
LANG #2
S PLUG LANG #1
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SED 3
LANG #4
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LANG #3
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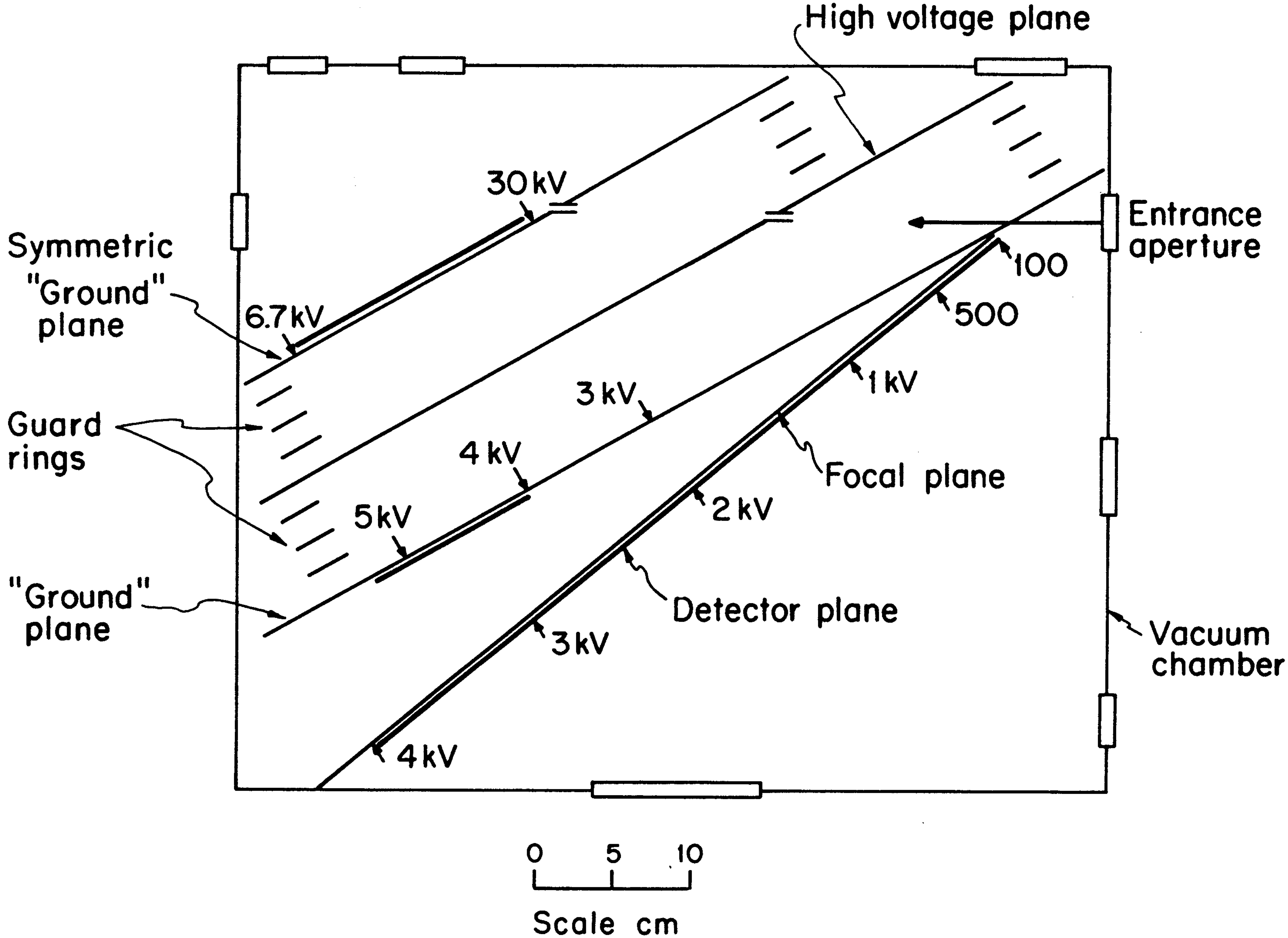
High voltage plane
Entrance aperture
Symmetric "Ground" plane
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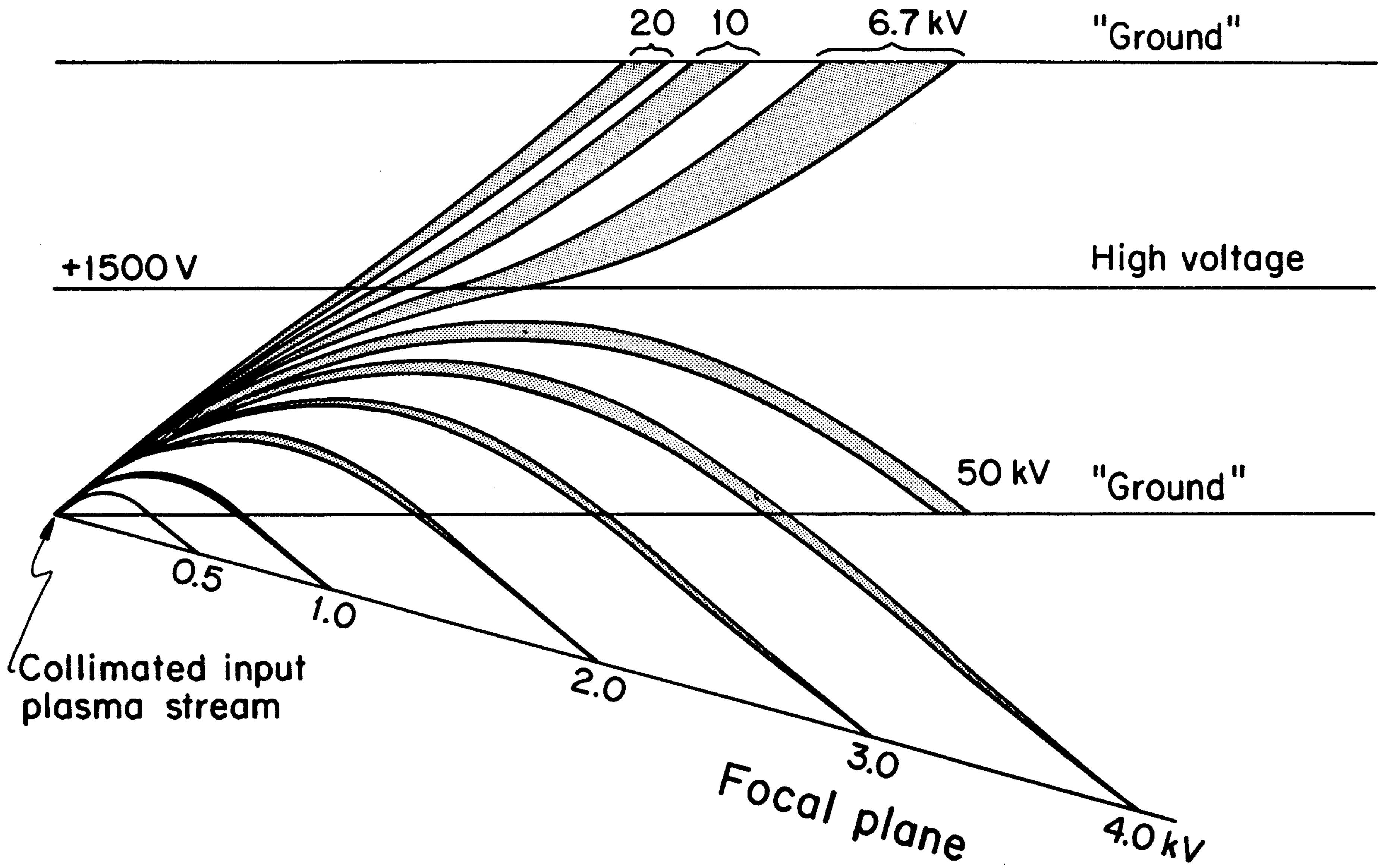
6.7 kV
100
500
1 kV
3 kV
4 kV
5 kV
Guard rings
Focal plane
2 kV
"Ground" plane
Detector plane
3 kV
4 kV
Vacuum chamber
0
5
10
Scale cm


20
10
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"Ground"
+1500 V
High voltage
50 kV
"Ground"
0.5
1.0
2.0
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4.0 kV
Focal plane
Collimated input
plasma stream