MEASUREMENTS OF X-RAY SPECTRA ON ECR-II*

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ECRIS08

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Abstract

- FAR-TECH, Inc. is developing an inexpensive and robust X-ray spectral diagnostic for monitoring electron cyclotron resonance ion sources (ECRIS). To this end, FAR-TECH, Inc. has recently performed extensive measurements of X-ray emission from the ECR-II device in the ATLAS facility at Argonne National Laboratory. We find that both the intensity and the shape of the observed spectra are highly correlated with the charge state distribution (CSD) of ions extracted from the ECR-II plasma as measured by a Faraday cup

- Experiments were performed in Feb. 2008

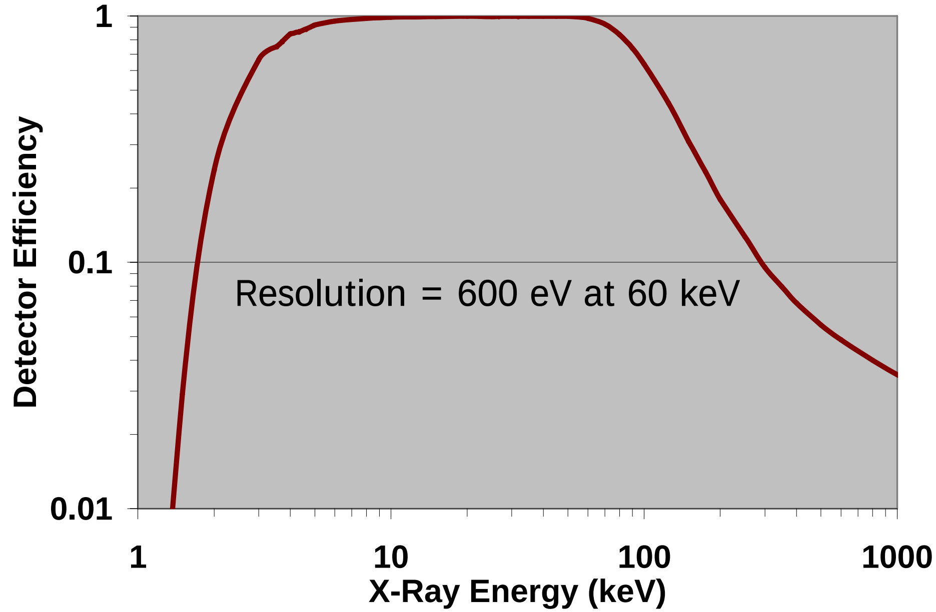
Summary

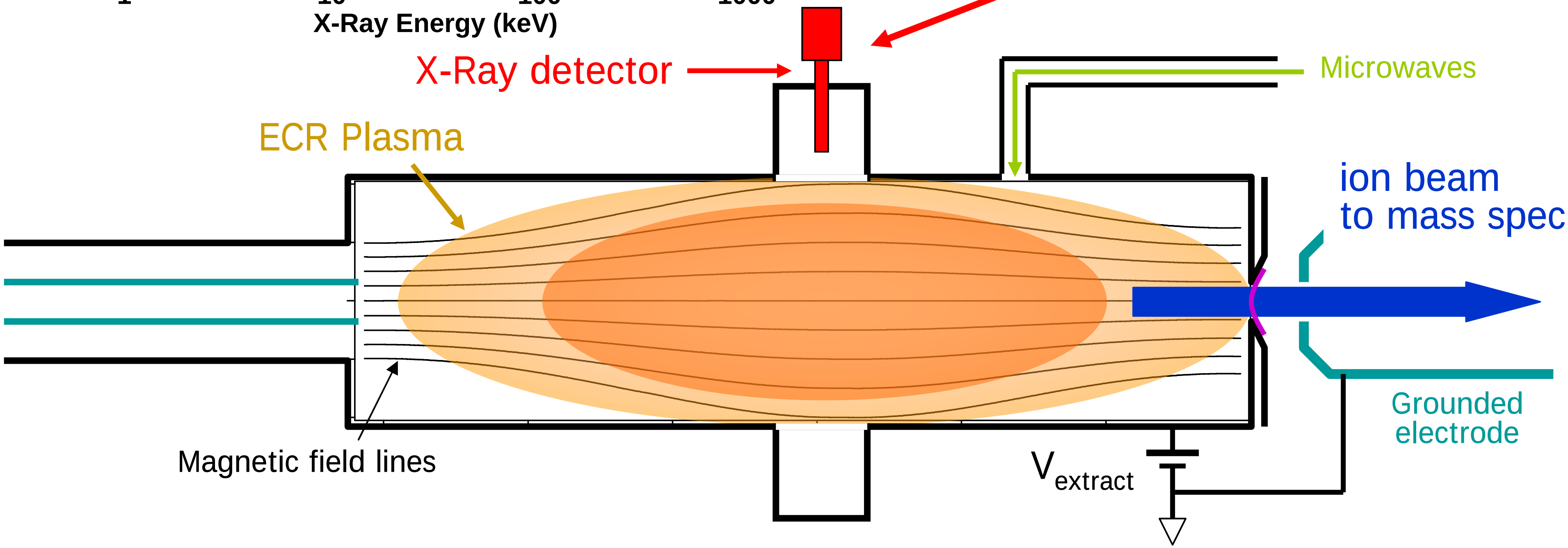
- Inexpensive, robust diode X-ray detectors can provide much useful information about the plasma conditions
- X-ray emission from is strongly dependent on plasma parameters

- Bremsstrahlung intensity increases strongly with RF power
- Bremsstrahlung intensity and effective temperature decreases strongly with gas pressure – opposite $K_{\alpha/\beta}$ line
- Lower frequency heating produces fewer X-rays, lower effective temperature
- X-ray intensity, effective temperature, and charge states all strongly increase with magnetic field

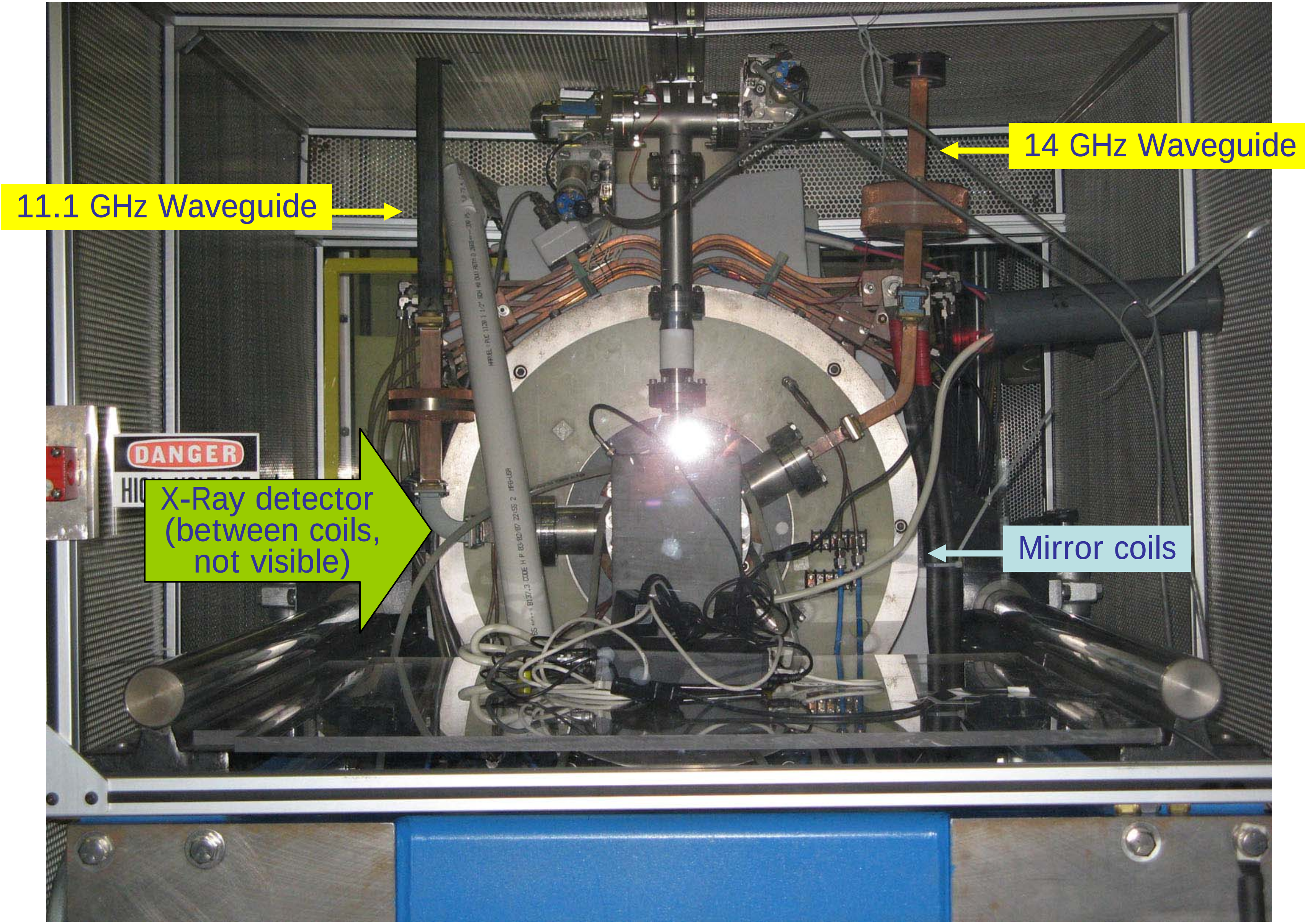
- Future work: Refine shielding to reduce Compton scattering signal

X-ray detector installed on ECR-II at ANL ATLAS facility





ECR-II at the Argonne ATLAS facility



Lead Shielding and Alignment System blocks wall X-rays

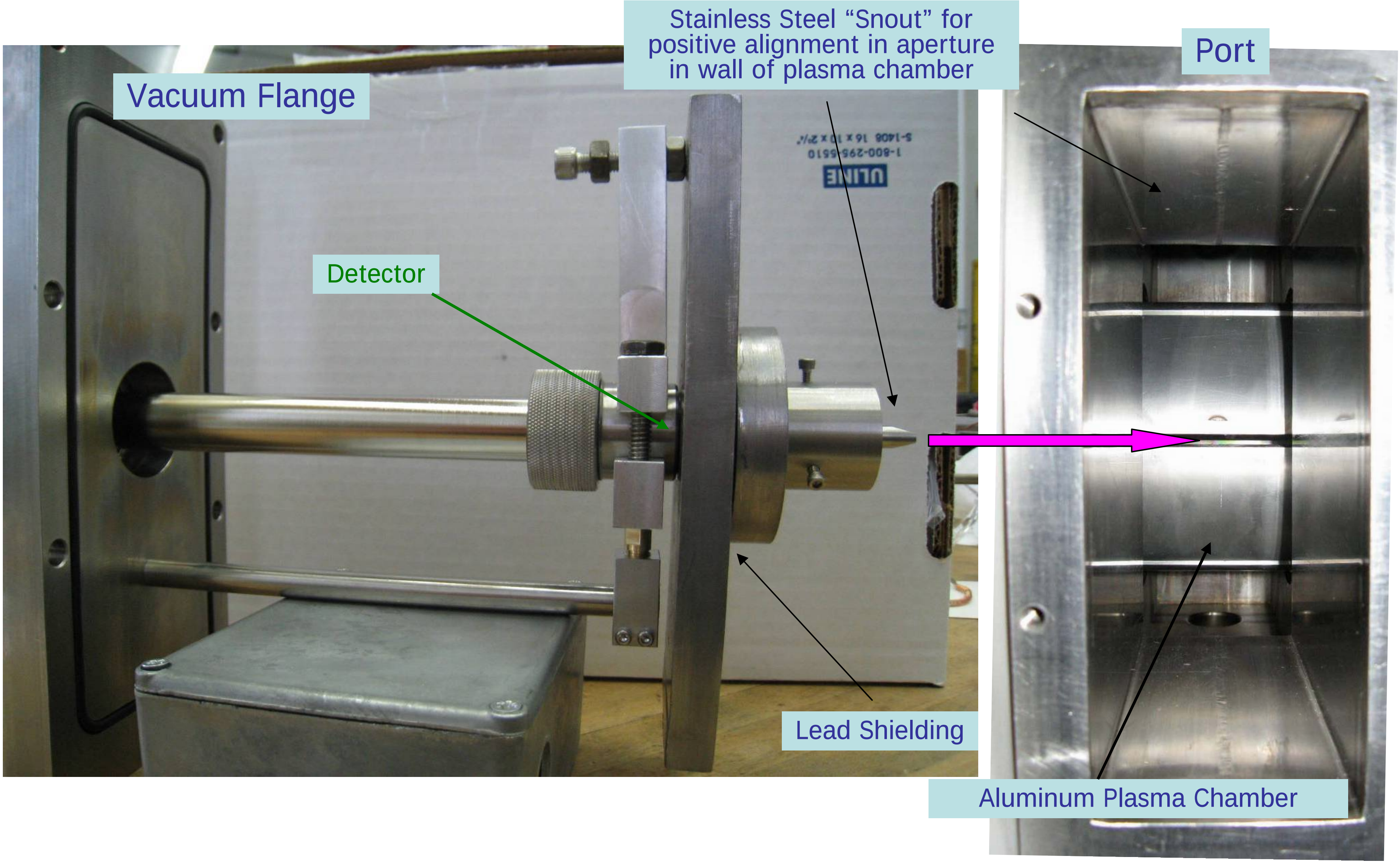
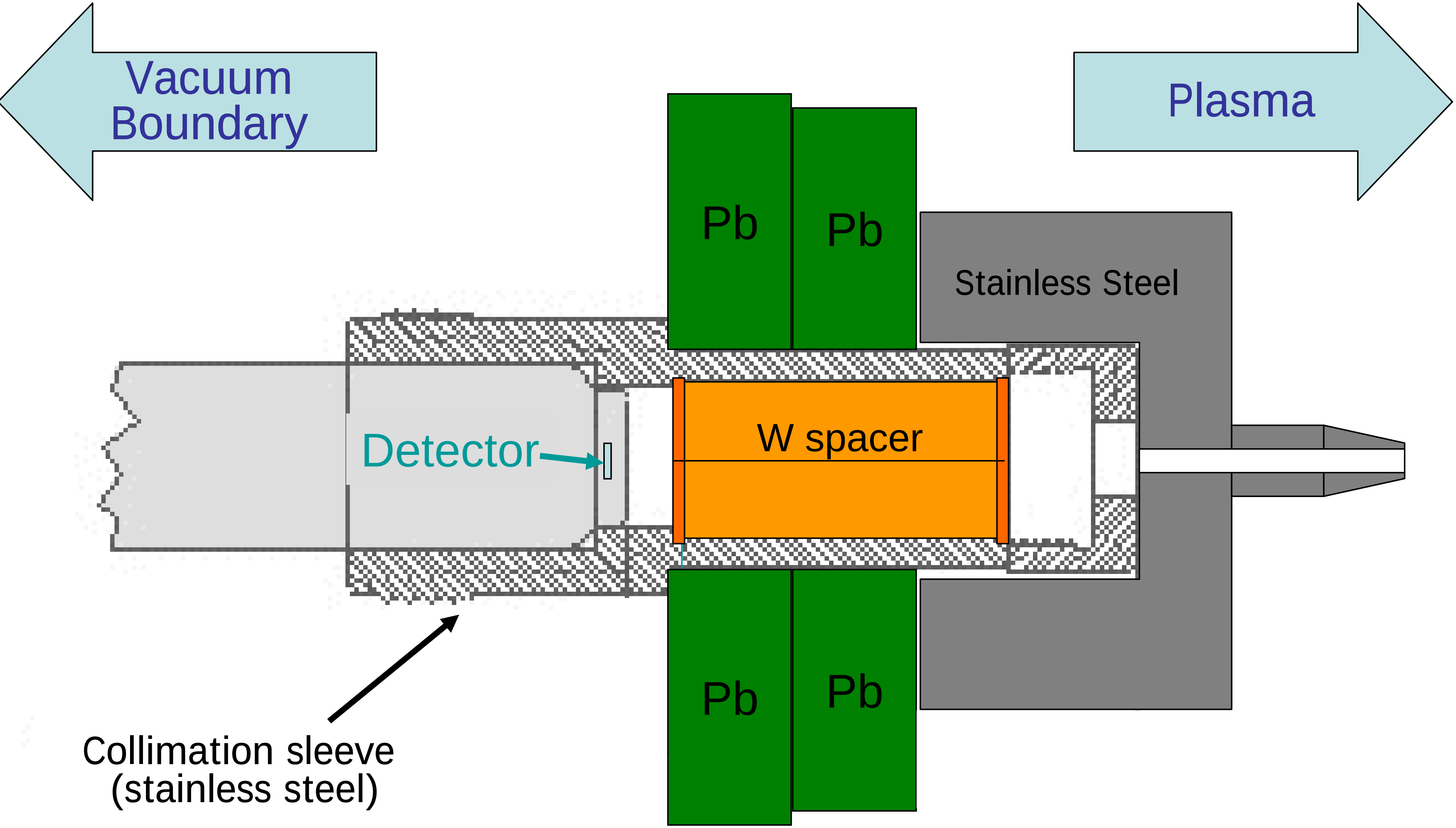
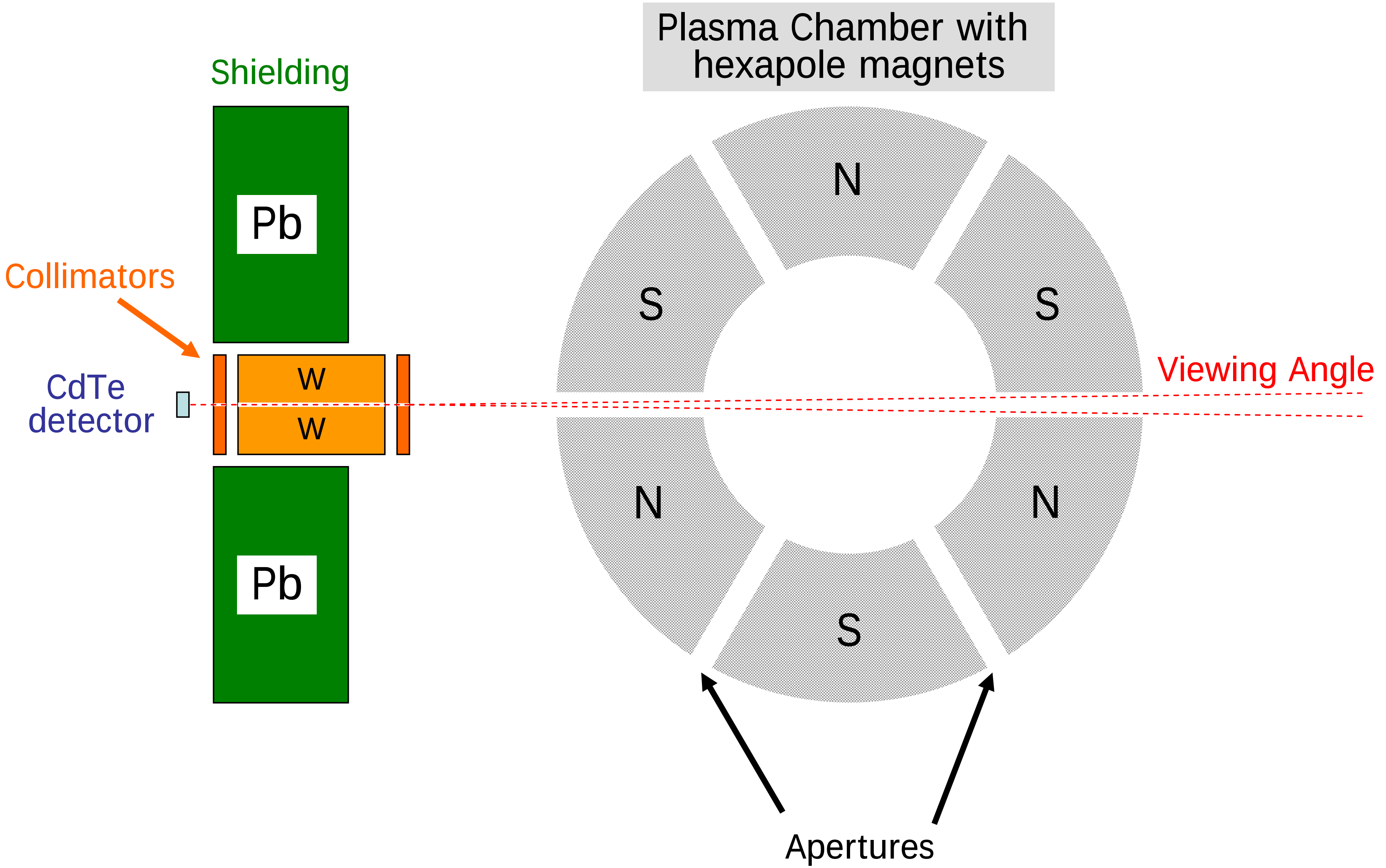


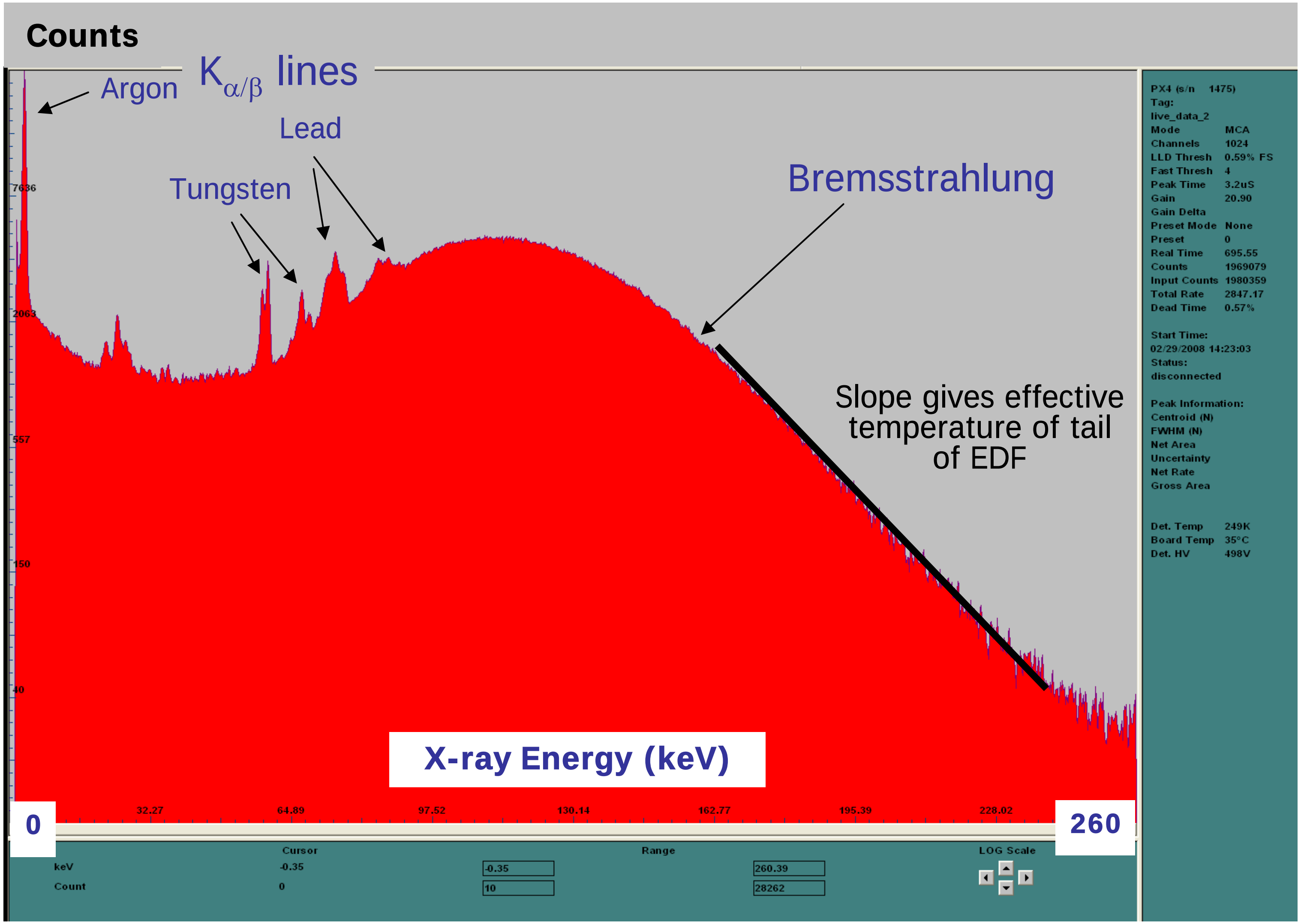
Diagram of Shielding/Collimation



Collimation ensures that detector looks only at plasma



Spectrum provides much useful information about plasma



Argon Plasma Operating Parameters for the experiments

ECRH Power (14 GHz)	300 W
Argon Gas pressure	1.e-7 torr
Plasma radius	3.8 cm
Plasma length	27 cm
Current in Injection solenoid	530 A → 9200 G
Current in Extraction solenoid	484 A → 8400 G

- Two frequency heating experiment used 11.1 GHz ECRH as well as 14 GHz
- Argon was default working gas, but helium sometimes used
- Oxygen present at low level due to desorption and dissociation of H_2O.
- Mass spectrometer ion currents measured with a Faraday Cup (FC)

Definition of Measured quantities

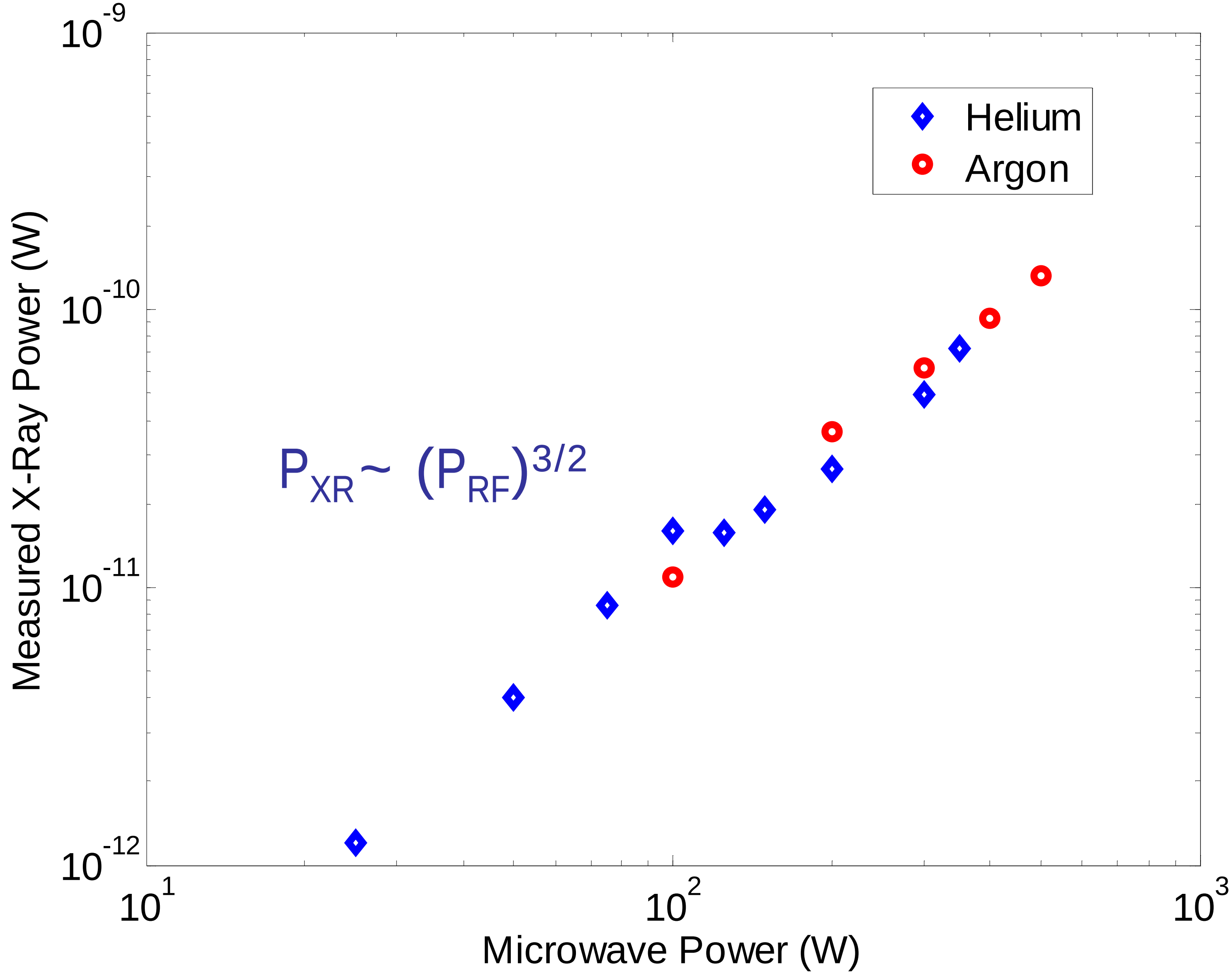
- Measured X-Ray Power $$P_{XR} = \frac{1}{\tau_{acq}} \int dE \frac{C(E)E}{\varepsilon(E)}$$
  - *E* = X-ray energy
  - *C(E)* = Counts at energy *E*
  - $\varepsilon(E)$ = Detection efficiency
  - τ_{acq} = acquisition time

- Effective (spectral) temperature is slope of high energy tail:

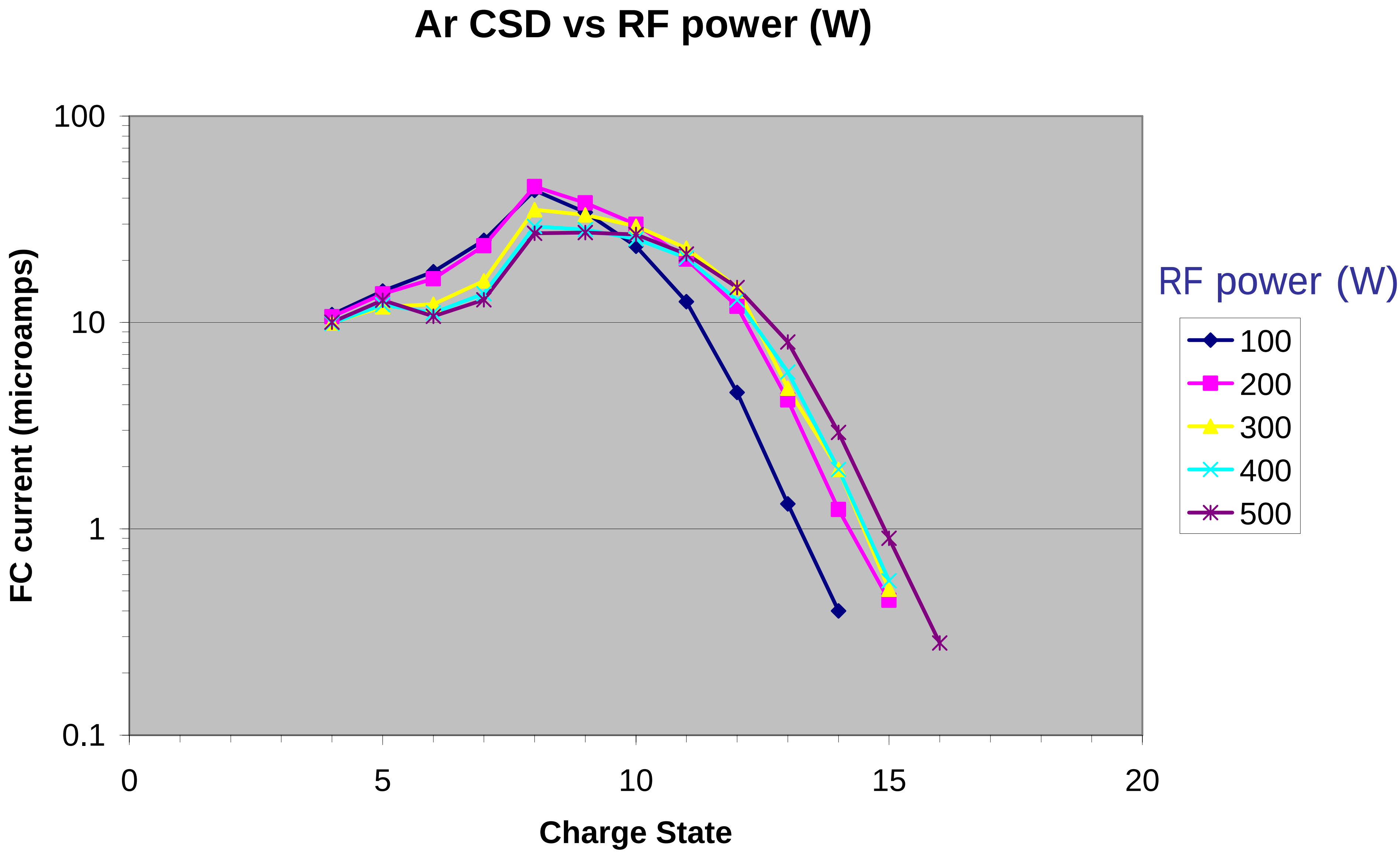
$$\frac{C(E)}{\varepsilon(E)} \sim \exp\left(-\frac{E}{T_{eff}}\right)$$

- Charge state distributions are uncorrected Faraday cup currents

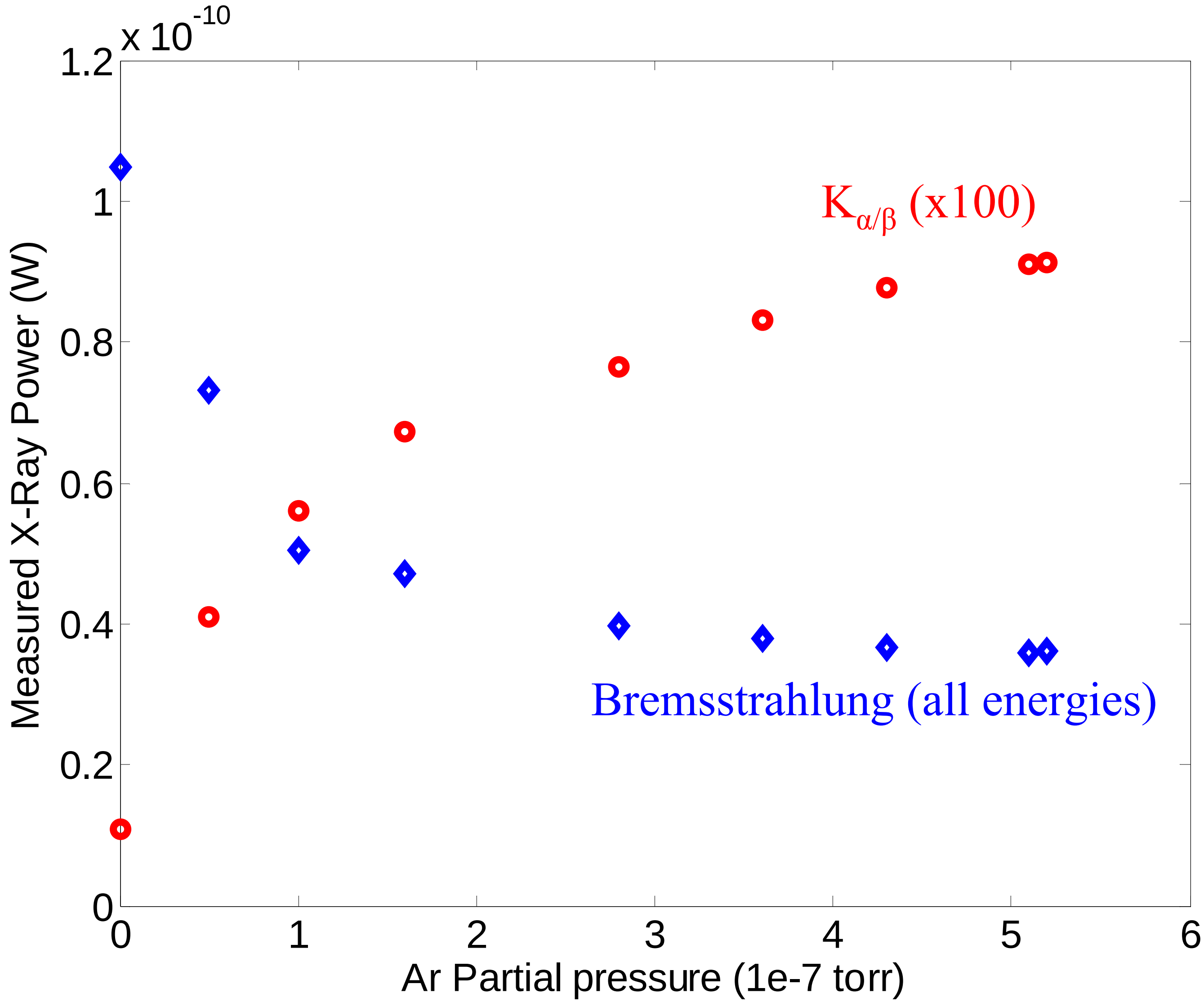
Integrated X-Ray Power increases with RF Power



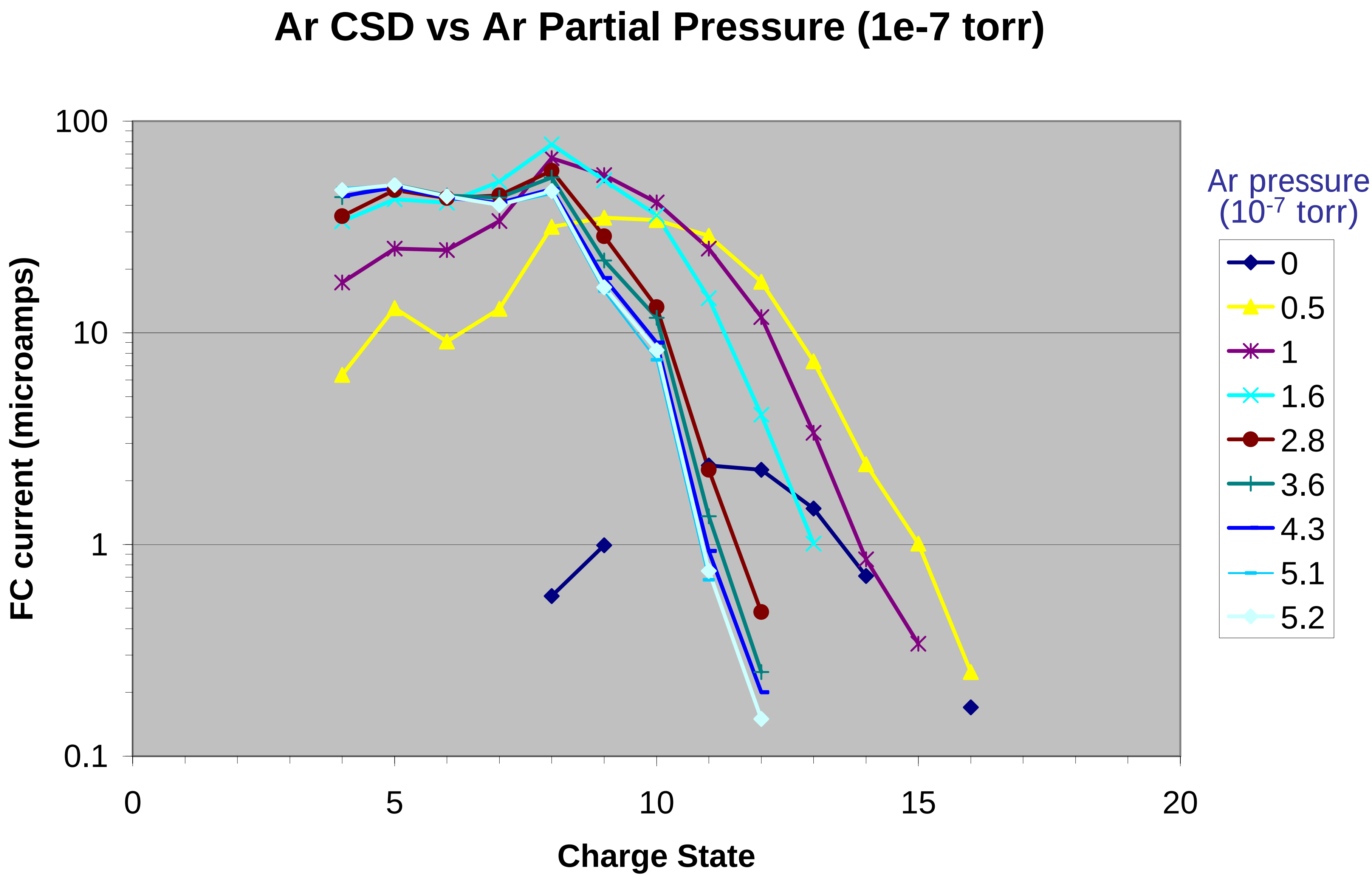
Argon ion charge state increases with RF power



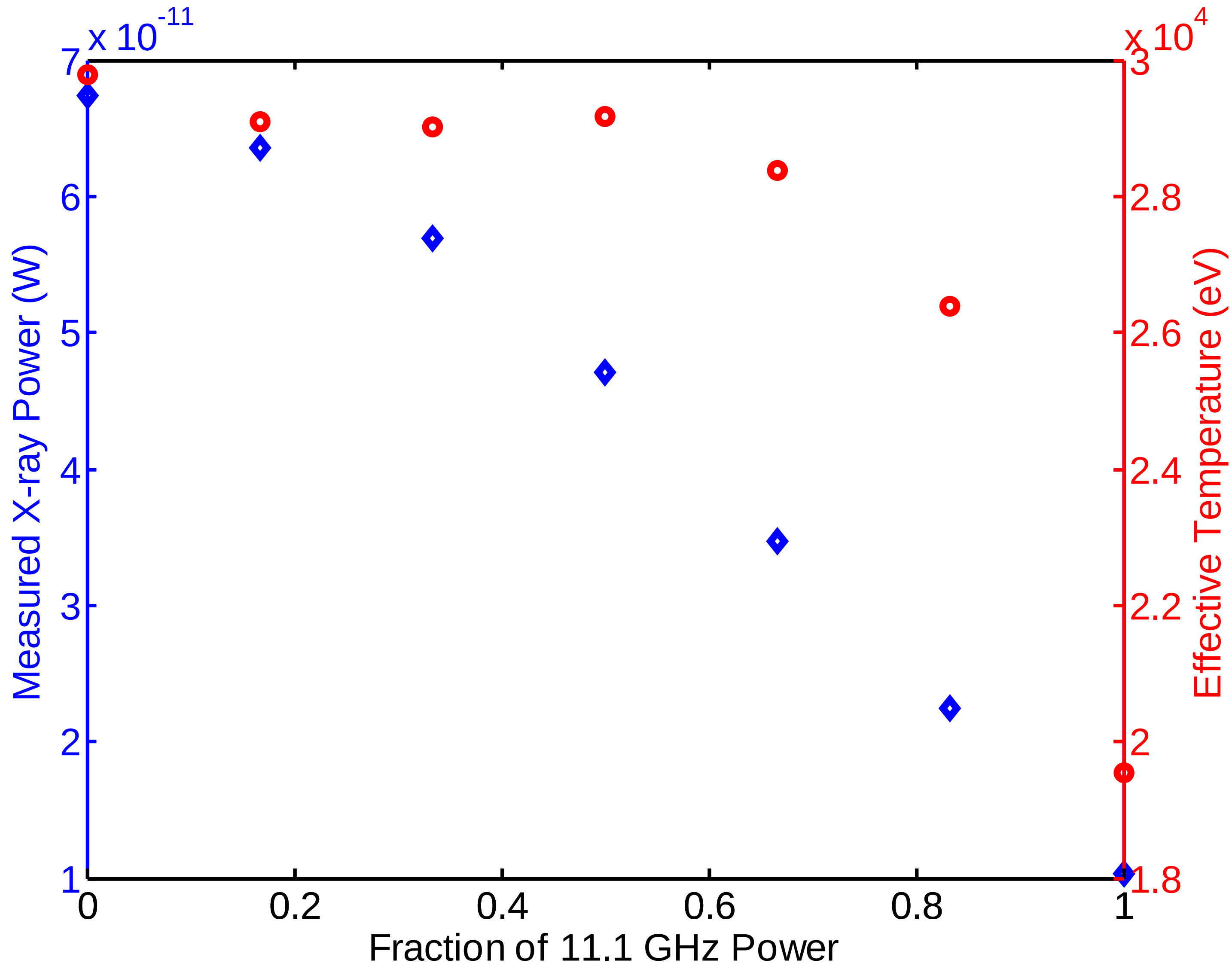
Intensity of X-ray emission also depends on Argon pressure



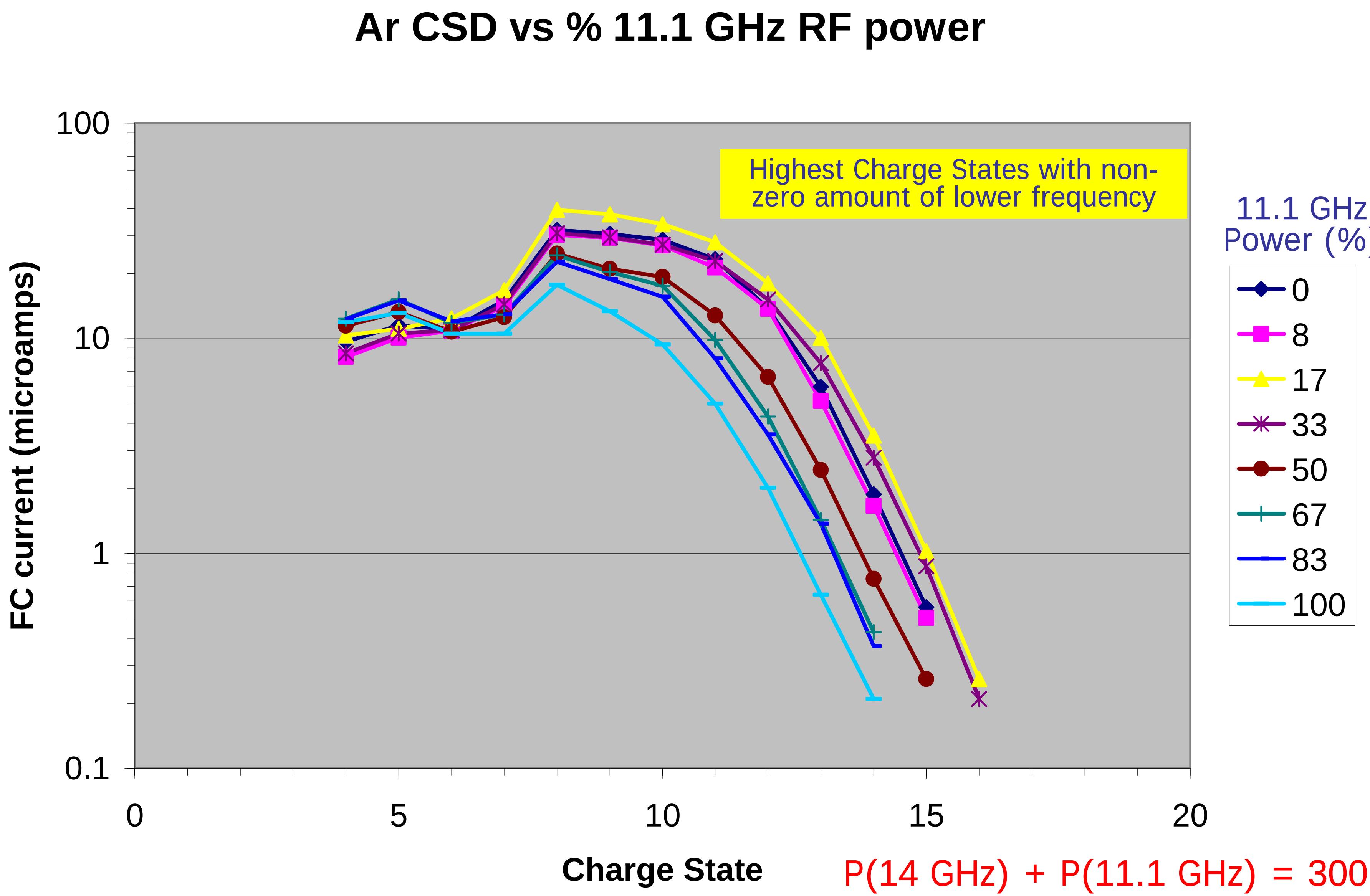
Increasing argon pressure reduces charge state



X-Ray emission varies strongly with two frequency heating

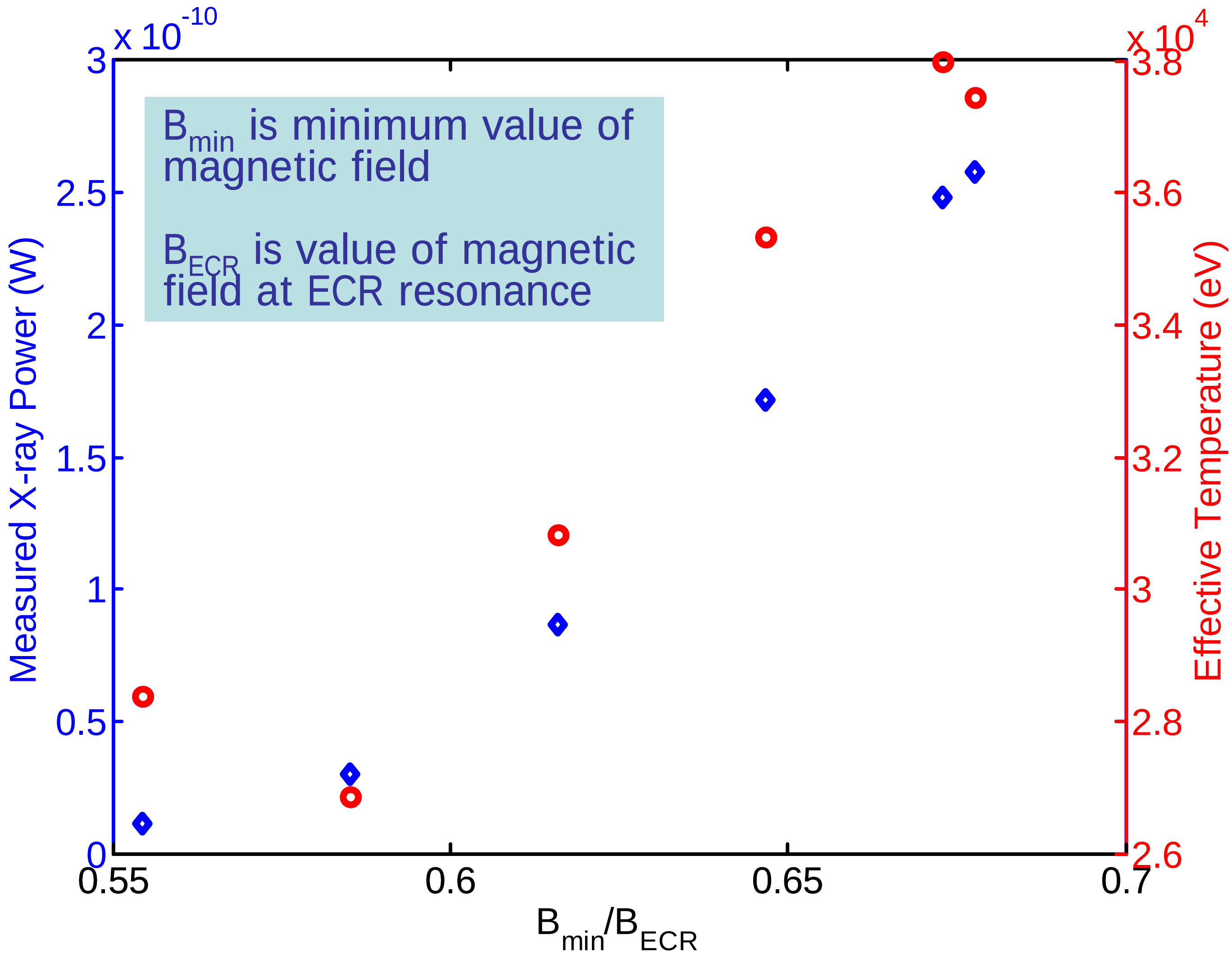


Two frequencies: higher frequency gives higher charge states



P(14 GHz) + P(11.1 GHz) = 300 W

X-Ray emission increases strongly with magnetic field



Note that mirror field profile maintained as constant

Increasing B-field increases charge states