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Impurity Behavior in DIII-D Discharges with Counter Beam Injection[1] N.H. BROOKS, W.P. WEST, General Atomics, M.R. WADE, Oak Ridge National Laboratory, D.G. WHITE, University of California, San Diego, A. RAMSEY, Princeton Plasma Physics Laboratory, R. JAKUMAR, Lawrence Livermore National Laboratory — Accumulation and axial peaking of intrinsic and injected impurities has been studied in DIII–D discharges with neutral beams injected counter to the direction of I_{p}. Evolution of the Z_{eff} profiles has been deduced by cross comparison of data from the Visible Bremsstrahlung (VB) diagnostic, from profile measurements of carbon and neon impurity densities with the Charge Exchange Recombination diagnostic, and from near axial measurements with the Core SPRED diagnostic of XUV charge exchange lines. A recent upgrade in the DIII–D Thomson Scattering System has extended radial coverage in measured n_{e} and T_{e} profiles to the magnetic axis, allowing straightforward analysis of the VB data. Systematic errors in the VB diagnostic have been identified and corrrected in software; hardware changes to eliminate these errors are planned.

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☐ Prefer Oral Session
☒ Prefer Poster Session

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Special instructions: DIII-D Poster Session 1, immediately following TC Jernigan

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ABSTRACT

The emphasis of this poster has been shifted from impurity behavior in counter injection discharges to a discussion of the sources of systematic error in the Bremsstrahlung diagnostic and the measures taken to eliminate them. Application of a fast analysis code has

I. Enabled continuous cross comparison over the duration of a discharge of Z_{eff} profiles from Bremsstrahlung data with those deduced from CER measurements of carbon and neon impurities

II. Revealed consistent departures of the measured Bremsstrahlung intensities from profiles expected from measured plasma parameters assuming a flat Z_{eff} profile

OUTLINE

- Positive impact of Thomson upgrade on Visible Bremsstrahlung analysis
- Cross comparison with other Z_{eff} diagnostics, primarily Charge Exchange Recombination (CER)
- Sources of systematic error in Bremsstrahlung analysis
- Hardware changes to eliminate measurement errors

RECENT UPGRADE TO THOMSON SCATTERING DIAGNOSTIC HAS LED TO INCREASED CONFIDENCE IN CORE Z_{eff} FROM VISIBLE BREMSSTRAHLUNG

- Addition of tangential Thomson system extends measurements of n_e and T_e to magnetic axis
- All measured profiles are mapped to the midplane using EFIT-determined flux surface geometry
- Core Z_{eff} values deduced from Bremsstrahlung and charge exchange emission (CER) agree reasonably well (± 25%)
- Edge Z_{eff} values can be quite different

FAST ANALYSIS CODE GIVES $Z_{eff}(r)$ TIME HISTORY THROUGHOUT DISCHARGE

- Code assumes a constant Z_{eff} along each viewchord in calculating intensity from product of local plasma parameters
- Self consistency of $Z_{eff}(r)$ over time, as n_e and T_e evolve or confinement mode changes, serves as a check on analysis method
- Methods which constrain VB intensity or Z_{eff} profile to some analytic function mask the systematic errors which dominate in DIII–D
- When neon is present, contamination of the VB signal by charge exchange light is avoided by time averaging its signal over just the OFF phases of the modulated beams
- Fast code runs automatically between shots to generate time histories of Z_{eff} along four chords

SOURCES OF SYSTEMATIC ERROR IN EDGE AND CORE Z_{eff} HAVE BEEN IDENTIFIED

- On edge channels, radiative mantle is usually the largest source of error
  - Mantle is measured on outermost viewchord
  - Last chord of core array gives a systematically high value of Z_{eff} possible due to mantle variation with elevation (Z chords 1-4 = –19 cm, whereas Z chords 5–16 = +3 cm)
- Light scattered off graphite tile targets also contaminates edge signals
  - Near specular reflection of light from ρ = 0.3–0.6
  - Diffuse scattering of light from centerpost
  - Ad hoc correction in software gives improved agreement for $Z_{eff}(r)$ in most cases
- In core array, intensities are systematically low on chords 10–15 compared with expected profile
  - Delamination of filter is prime suspect for this long term, secular change in measured data

HARDWARE CHANGES HAVE BEEN MADE TO CORRECT SYSTEMATIC ERRORS

- **Baffled razor blade viewing dumps installed on edge channels**

- **Eight new tangential channels added to study profile of radiative mantle outside $\rho = 1$**

- **Filter assembly modified to permit backlighting fibers for a more precise measurement of tangency radii**

- **Bandpass filter replaced after fifteen years of service**

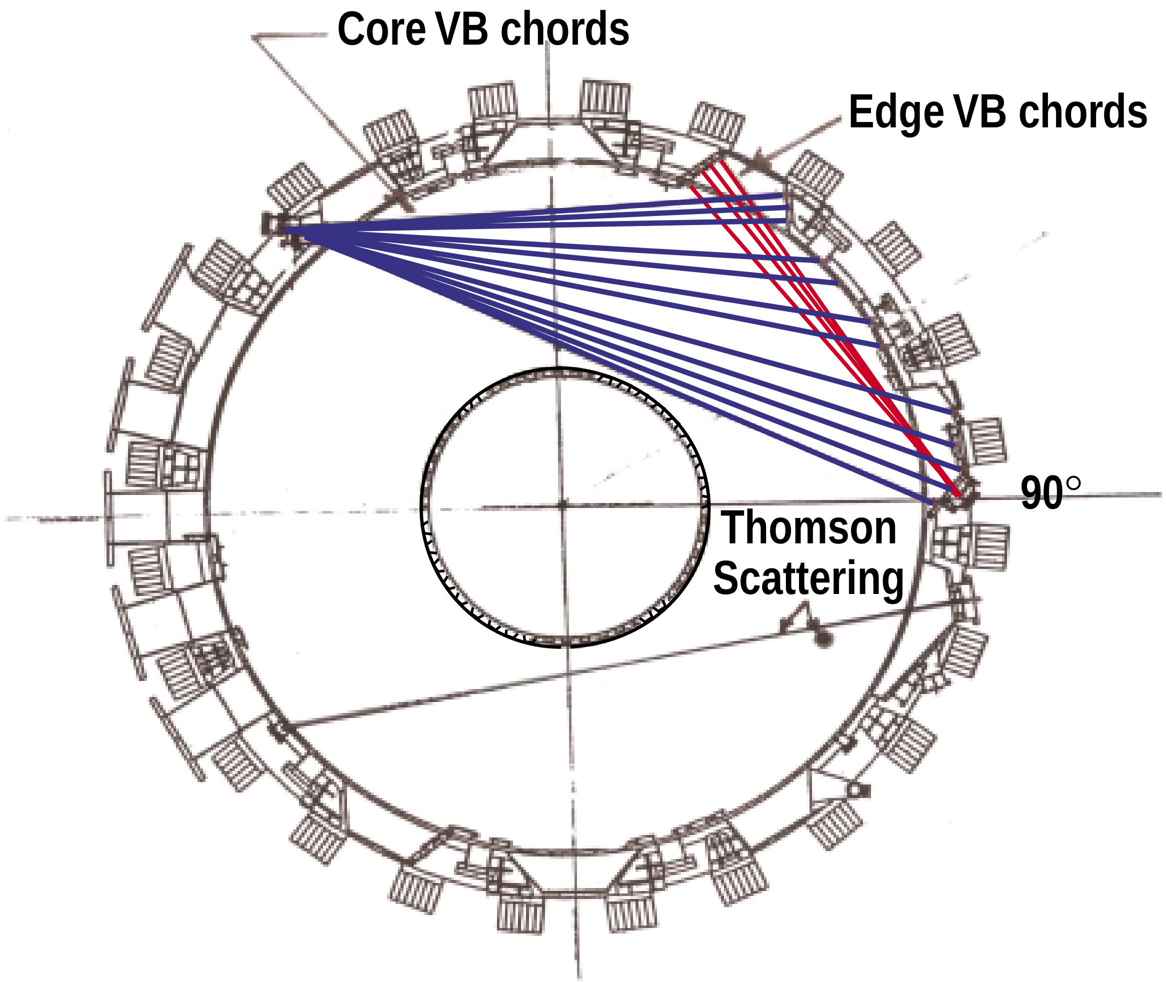
SUMMARY

- Using full measured profiles for n_e and T_e,Bremsstrahlung analysis on DIII–D now gives a better measure of Z_{eff} in core

- Comparison of measured intensity profiles with expected ones and of Z_{eff} profiles with CER-deduced ones has revealed measurement problems

- Hardware changes have been implemented to eliminate systematic errors in measured VB intensities on edge channels

BREMSSTRAHLUNG DIAGNOSTIC IS COMPRISED OF CORE AND EDGE VIEWCHORD ARRAYS



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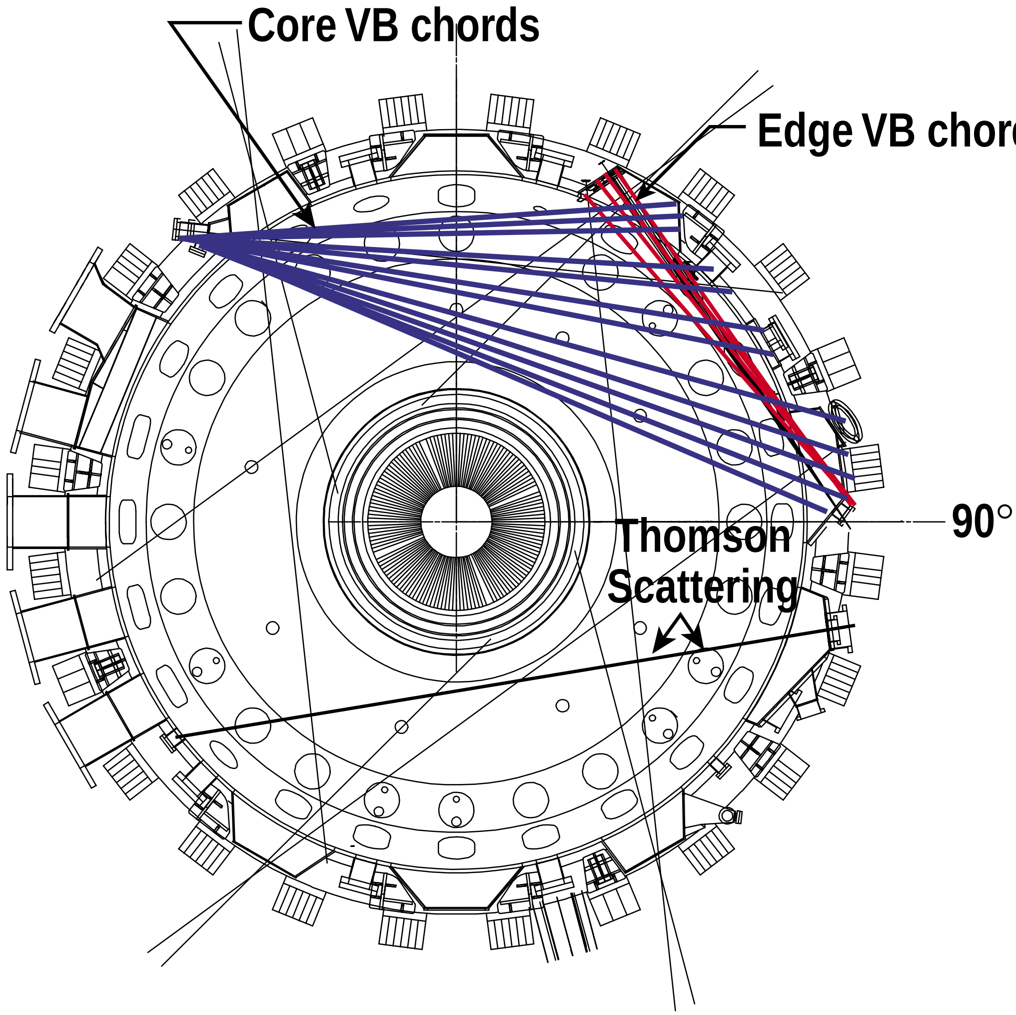
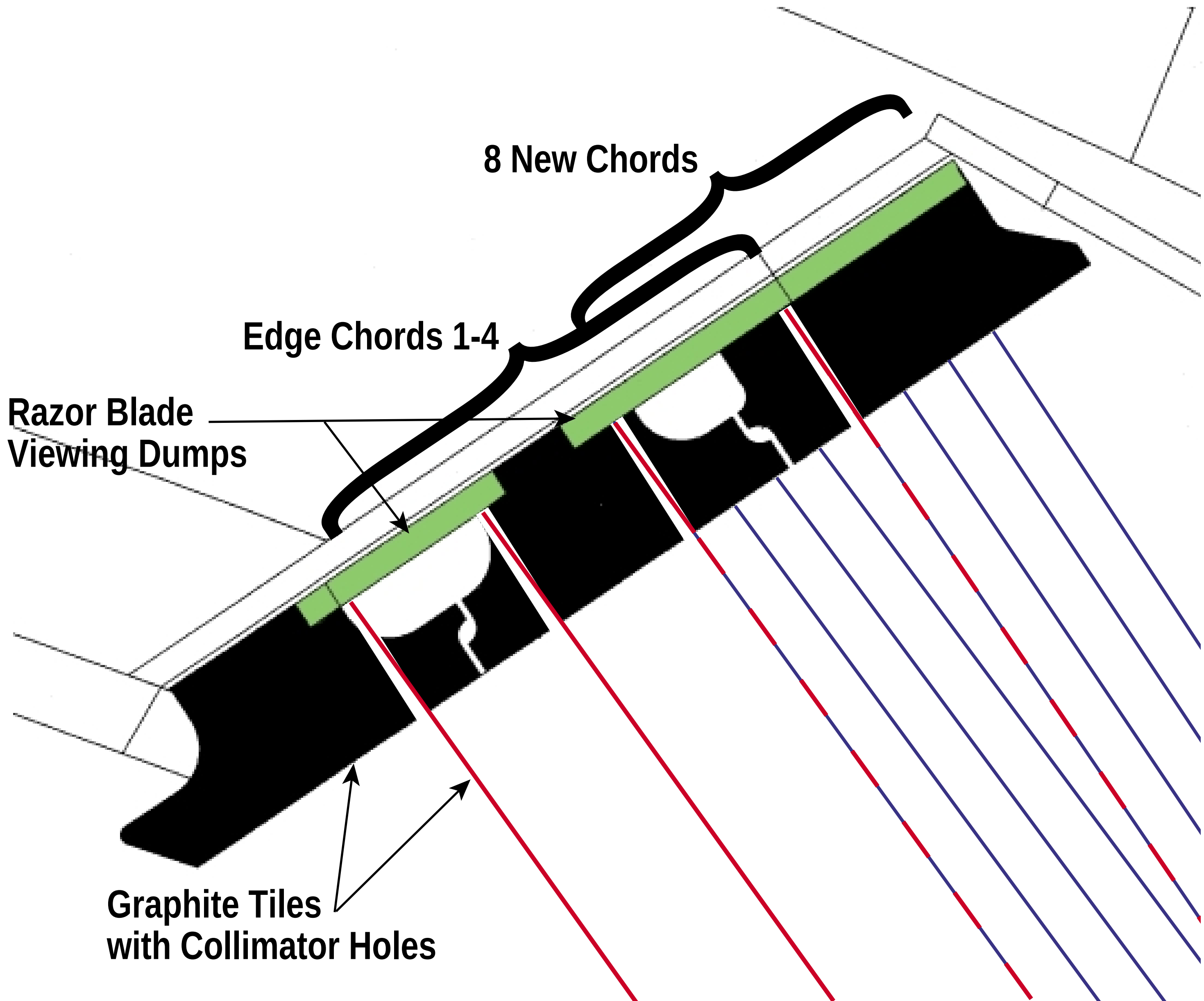
TWO VIEWCHORD ARRAYS COMPRISE THE VISIBLE BREMSSTRAHLUNG DIAGNOSTIC



COLLIMATOR HOLES PREVENT INTENSE CORE EMISSION FROM SCATTERING INTO VIEWCONES OF EDGE CHANNELS



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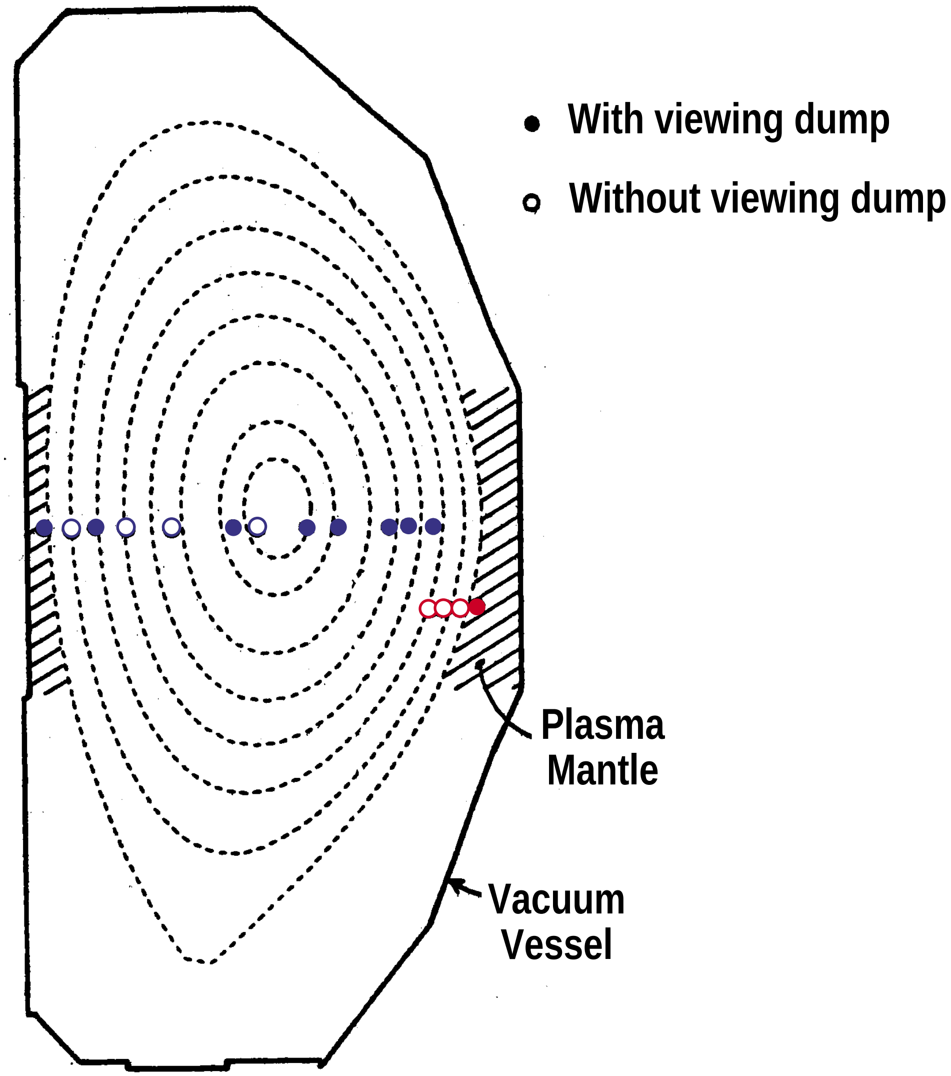
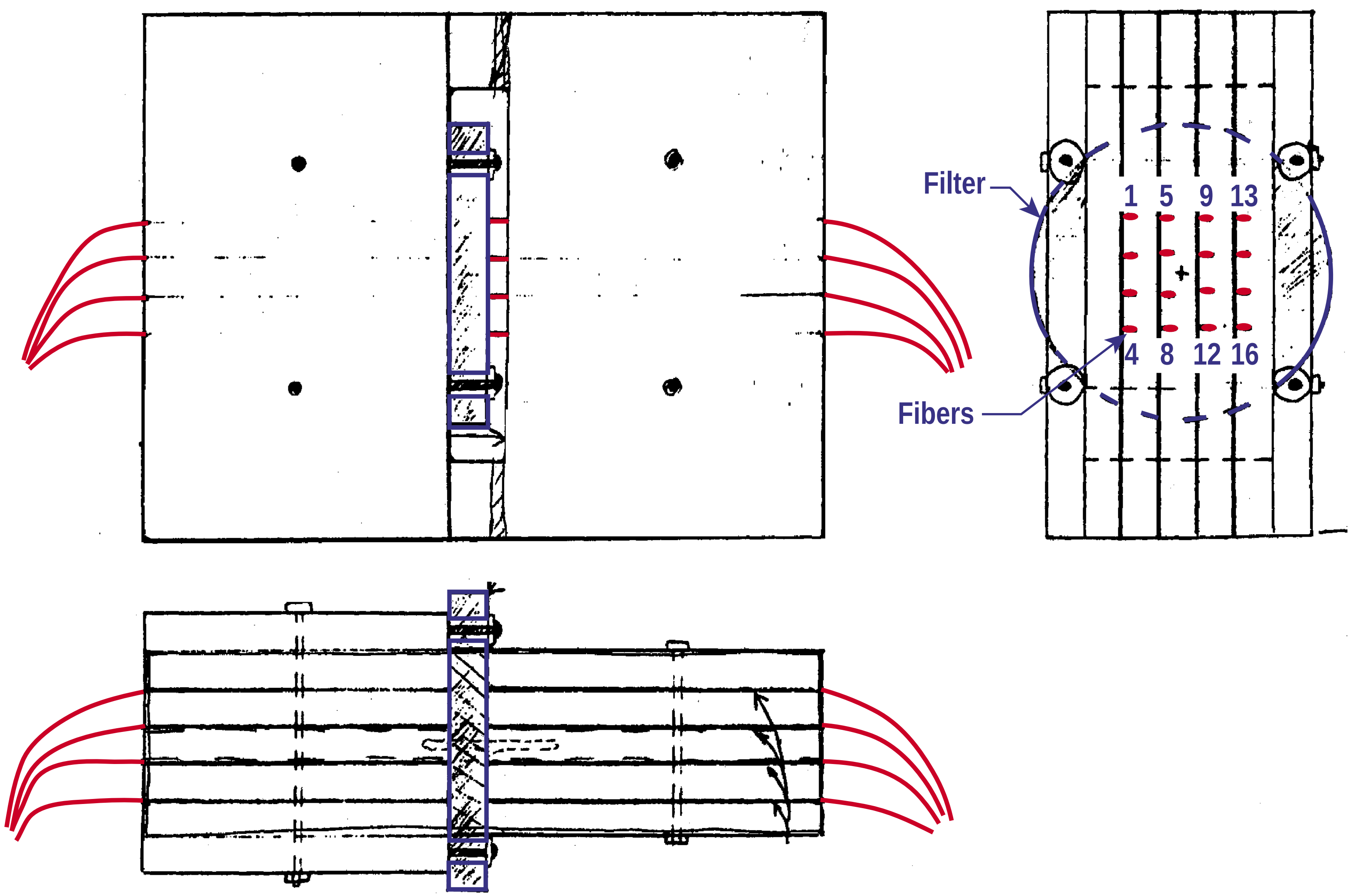
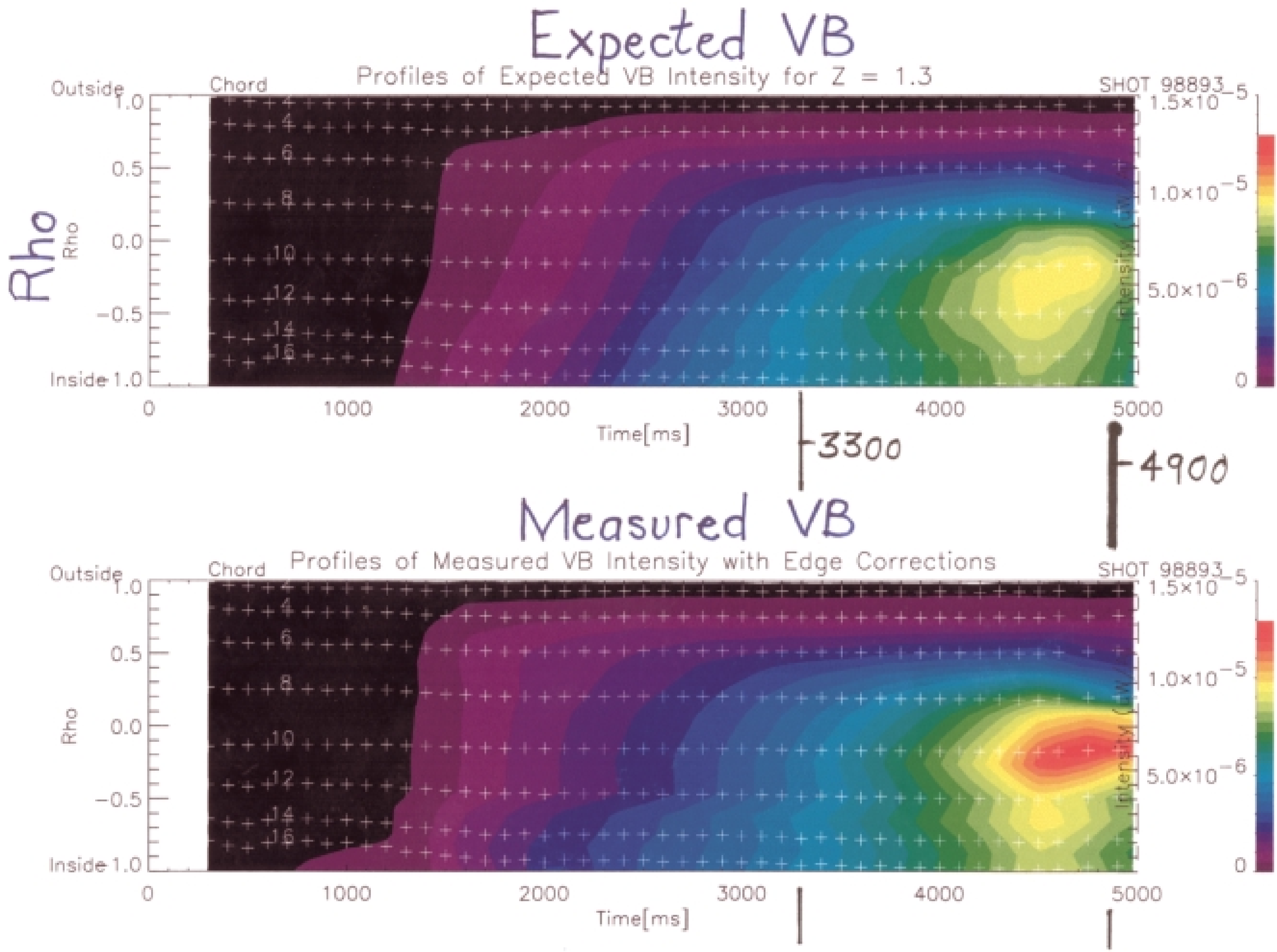
TANGENCY RADII OF VB CHORDS EXTEND FROM CENTERPOST TO OUTER WALL

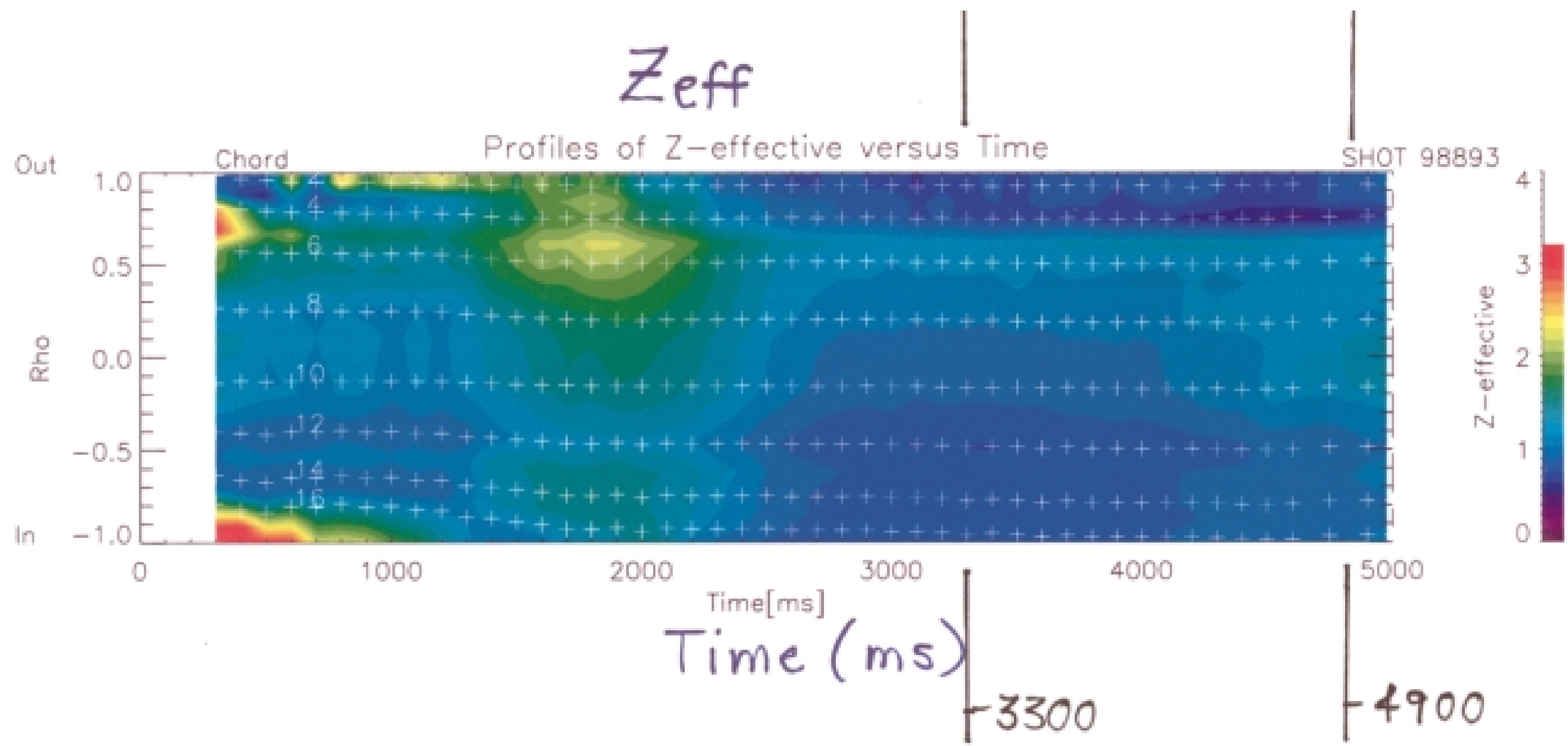


LIGHT FROM 16 VIEWCHORDS PASSES THROUGH A SINGLE FILTER

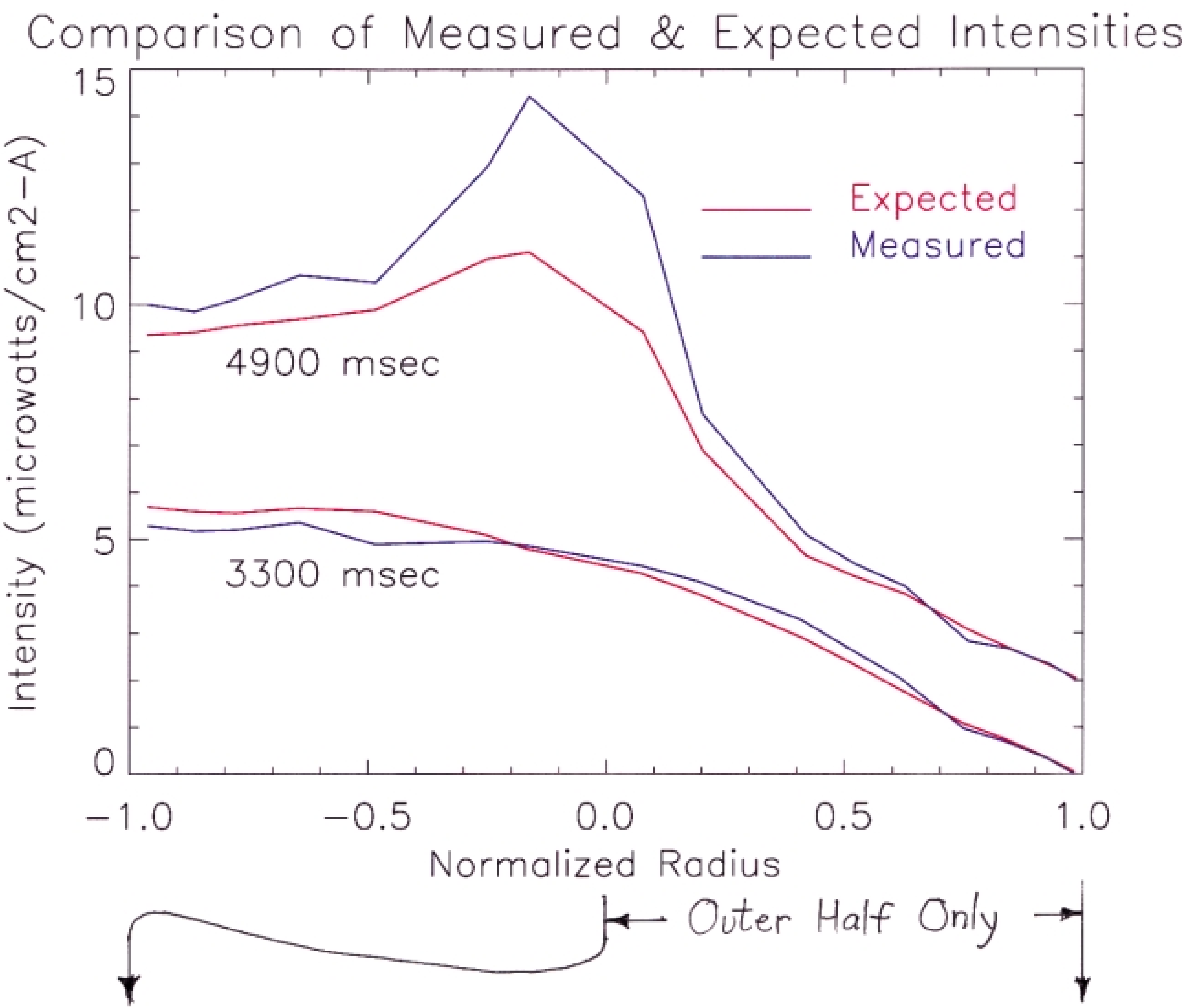


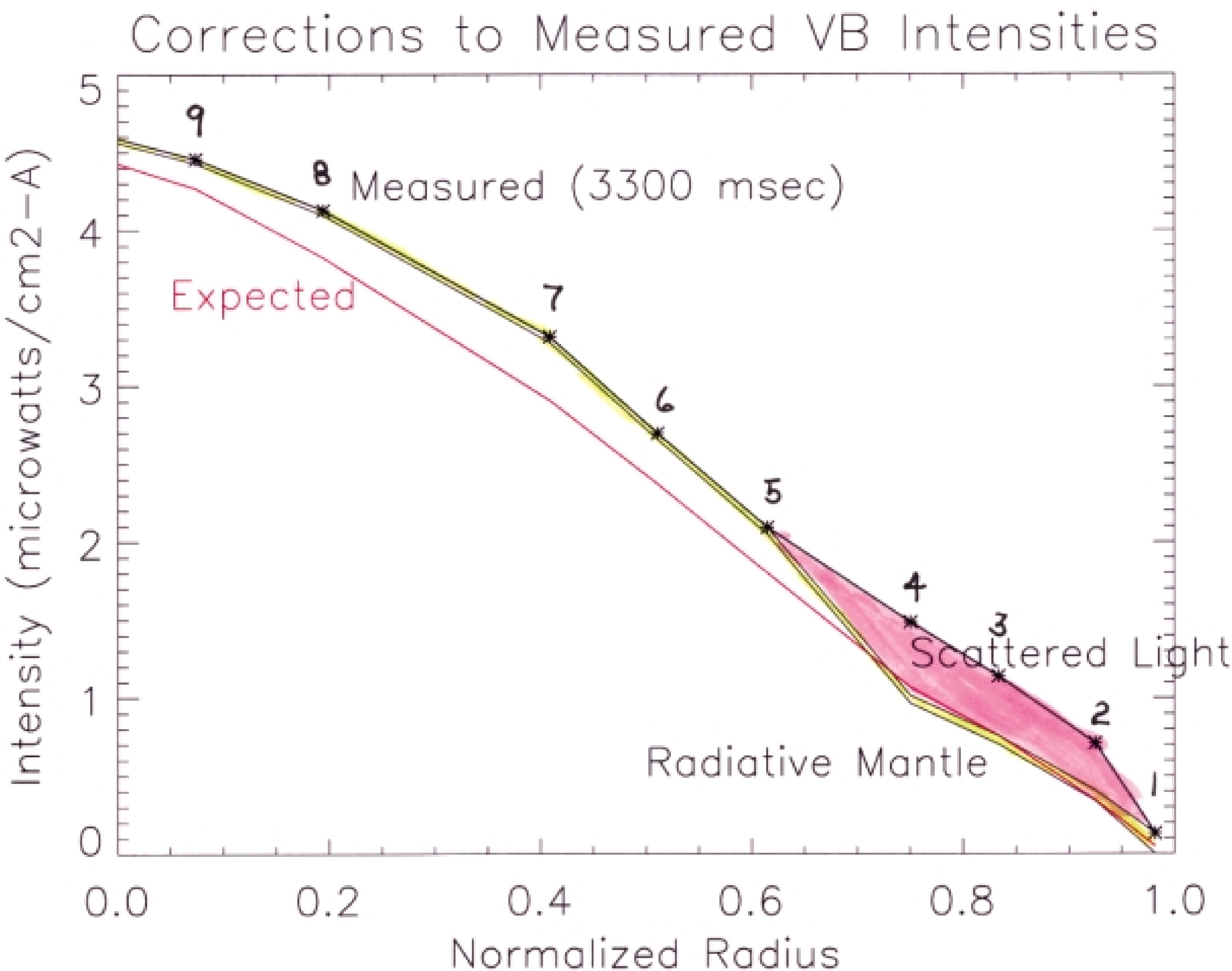
HIGH DENSITY CAMPAIGN (MAHDAVI et. al.) PROVIDES DISCHARGE WITH $Z_{eff}(r)$ CLOSE TO UNIT



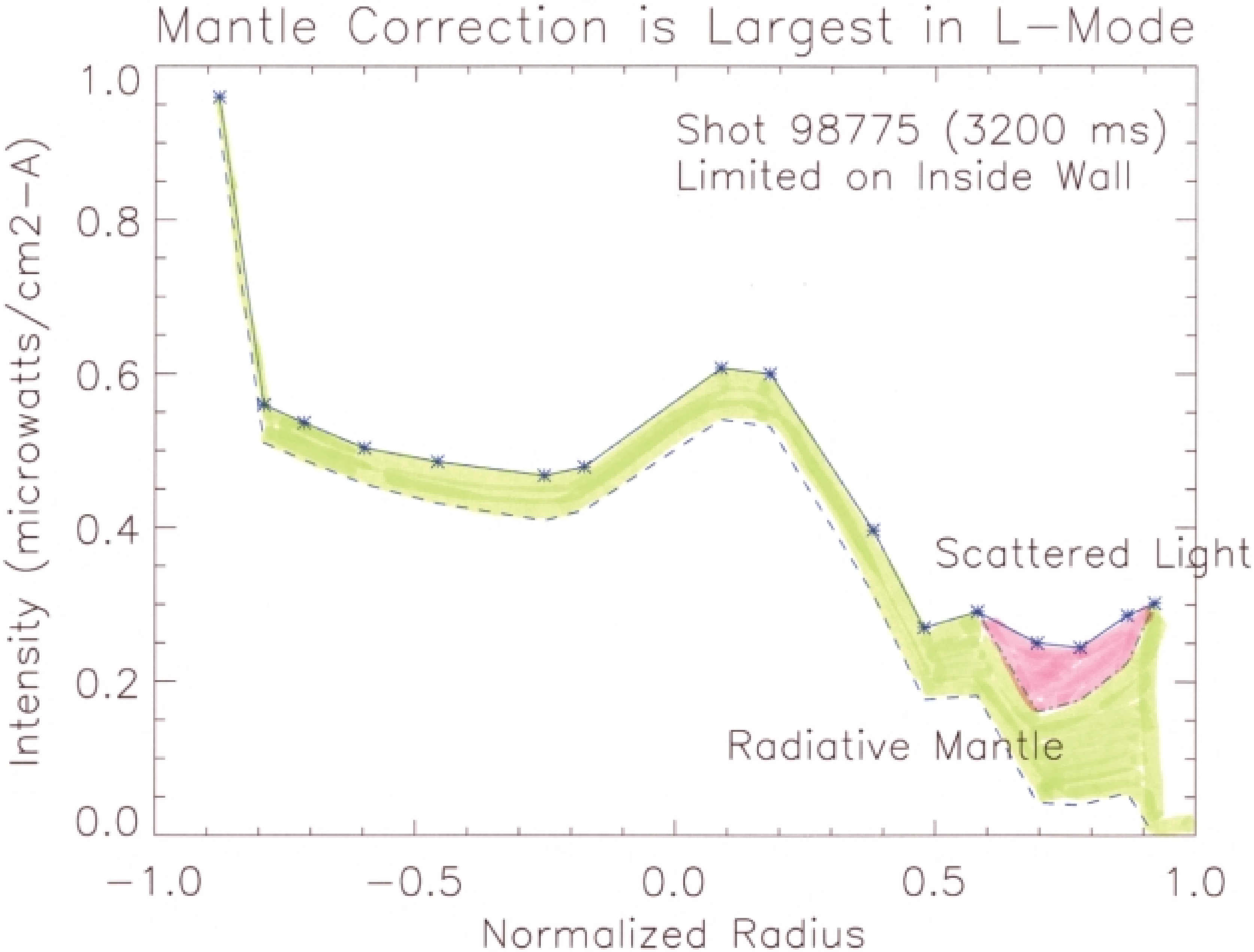


Zeff
Profiles of Z-effective versus Time
SHOT 98893
Out
In
Chord
Rho
1.0
0.5
0.0
−0.5
−1.0
0
1000
2000
3000
4000
5000
Time[ms]
Z-effective
0
1
2
3
4
Time (ms)
3300
4900


Comparison of Measured & Expected Intensities
15
10
5
0
Intensity (microwatts/cm2-A)
Expected
Measured
4900 msec
3300 msec
-1.0
-0.5
0.0
0.5
1.0
Normalized Radius
Outer Half Only



Corrections to Measured VB Intensities
Measured (3300 msec)
Expected
Scattered Light
Radiative Mantle
9
8
7
6
5
4
3
2
1
Intensity (microwatts/cm2-A)
Normalized Radius
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5



Mantle Correction is Largest in L–Mode
Shot 98775 (3200 ms)
Limited on Inside Wall
Scattered Light
Radiative Mantle
Intensity (microwatts/cm2–A)
Normalized Radius
1.0
0.8
0.6
0.4
0.2
0.0
–1.0
–0.5
0.0
0.5
1.0

EARLY DATA (1988) LOOKED MUCH BETTER!

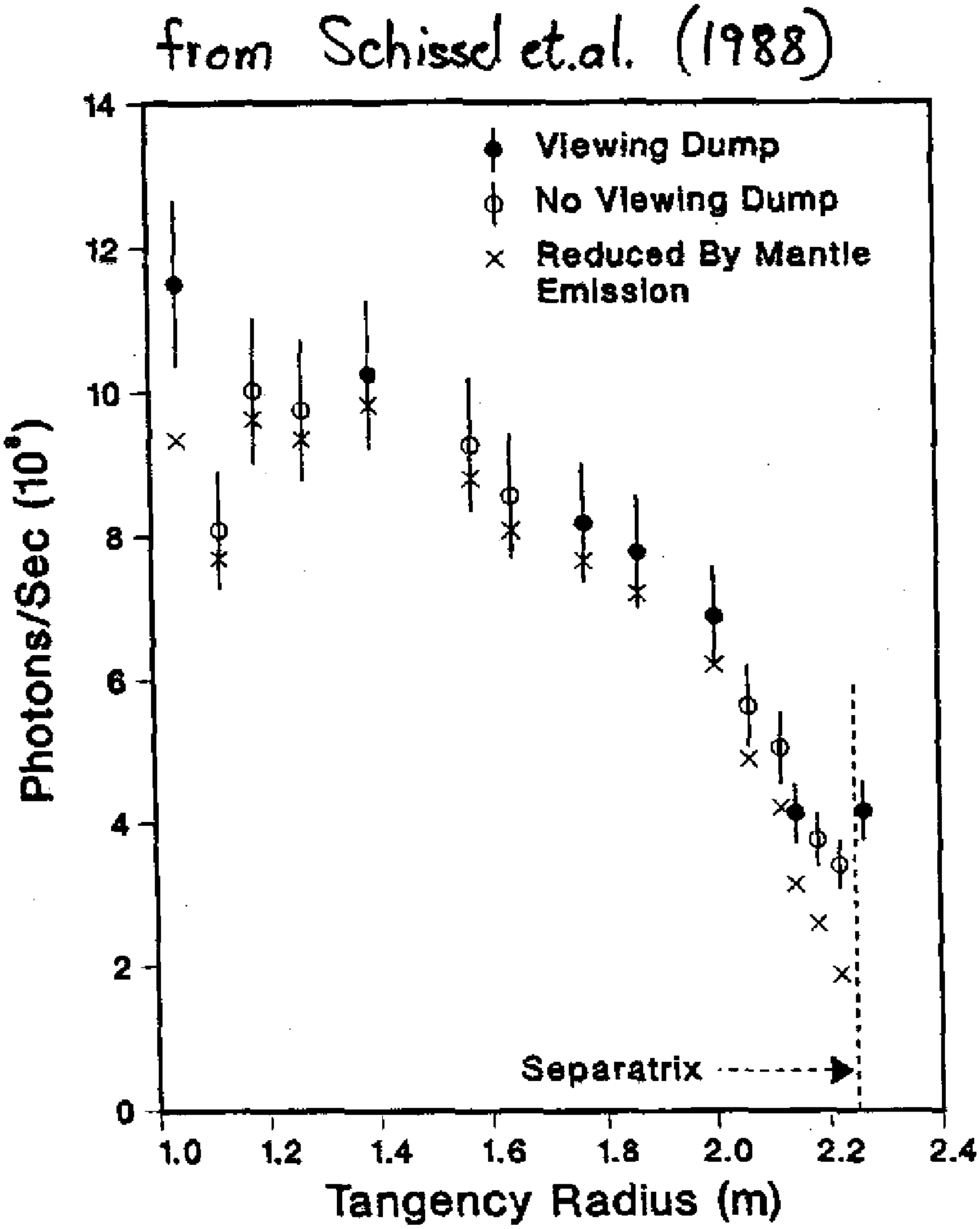


Fig. 3 The measured visible bremsstrahlung profile versus tangency radius for an ohmically-heated divertor discharge (Case I). The lines through the circles are the raw data error bars used for the calculation of the Z_{eff} profile error. The data point at the largest tangency radius does not pass through the main plasma and detects emission only from the plasma mantle. The data point at the smallest tangency radius passes through the inner plasma mantle while the neighboring chord does not. The X's are the raw data corrected for the line integral of emission each receives from the mantle.