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Recent Analysis of Fast Time Series GPI Data on NSTX

K. M. Williams[1], R. Maqueda[2], S. J. Zweben[1], C. E. Bush[3], and NSTX Team

[1]Princeton Plasma Physics Laboratory

[2]Nova Photonics

[3]Oak Ridge National Laboratory

Abstract

The gas puff imaging diagnostic (GPI) is used to study edge turbulence near the outer midplane of NSTX. The detectors include an ultra-fast camera and also an independent array of 13 discrete phototubes, each of which views a 2 cm diameter region of the edge. These discrete detectors produce time series data with a 500 kHz digitization speed over 64 msec during a shot. Edge turbulence measurements were made with these discrete detectors under conditions of varying q-profiles, divertor configurations, NBI or RF heating conditions, plasma densities, and plasma currents. This poster will describe this data set and attempt to identify characteristic turbulence features in each of these conditions.

Motivation

- Turbulence in the plasma edge is known to affect the plasma wall interaction and global confinement .

- The physics behind turbulent motion at the edge is not well understood.

- More experimental data is needed to validate theories and models on plasma edge turbulence in tokamaks and ST's and to further the understanding of L-H transitions

Gas Puff Imaging Diagnostic

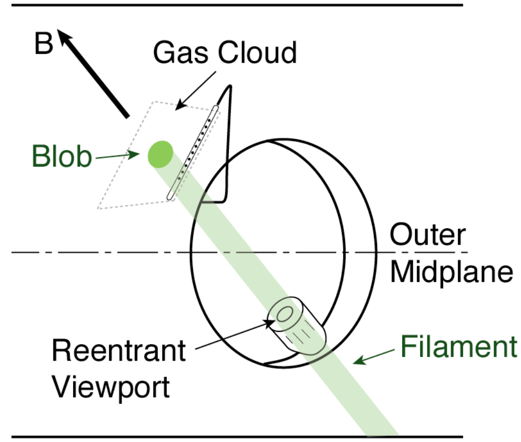
- Long correlation lengths >50m have been observed along the magnetic field with probes in JET revealing a nearly two-dimensional behavior of the turbulence*

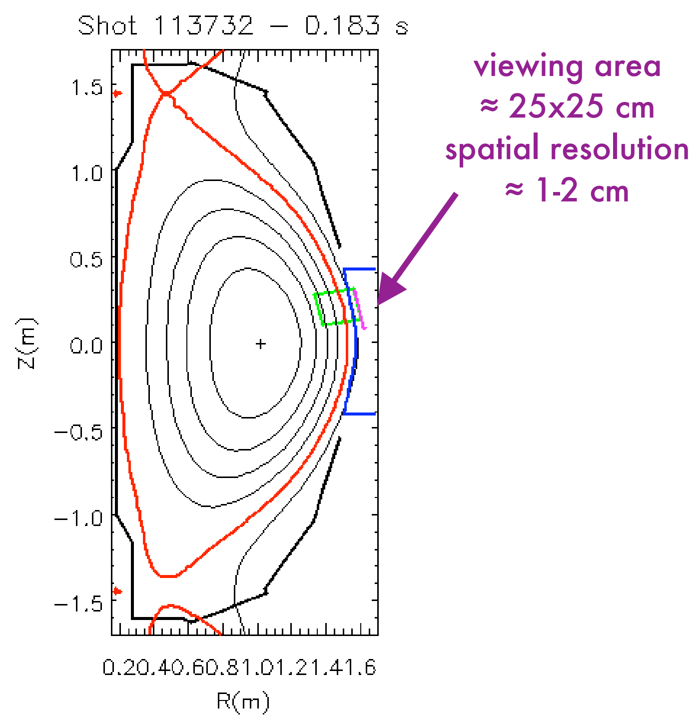
- The GPI diagnostic is designed to observe excited neutral Deuterium or Helium which is injected at the plasma edge.

- The diagnostic does not perturb the plasma or introduce fluctuations in the neutral density.

- The injected gas is viewed along a field line ~42° with respect to horizontal in order to view the radial vs poloidal structure.

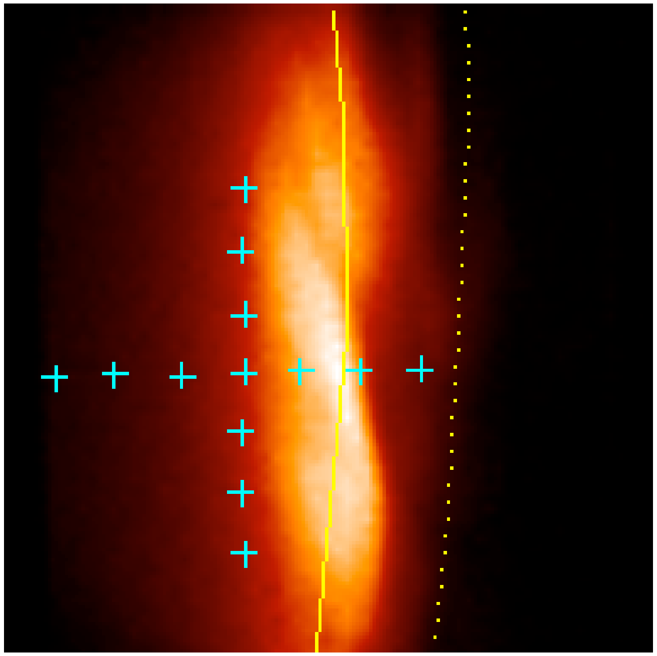
*H. Thomsen,M.Endler et al, Physics of Plasmas, Vol. 9, 4,(2002) 1233-1240





GPI Diagnostic & Measurements

Radial



Poloidal

Shot#117939 @532ms

H1
H2
H3
T7 T6 T5 C T3 T2 T1
H5
H6
H7

Chord Labels

•The chords are arranged to detect light emitted poloidally and radially at the plasma edge.

•The spatial resolution is 1-2cm

•The 23cm x 23cm viewing area is imaged into a 800pixel x 1000 pixel coherent fiber bundle.

•The other end of the fiber bundle is imaged with a beam splitter into the Phantom 7 high speed camera and an array of 13 1mm optical fibers arranged in a cross pattern radially and poloidally.

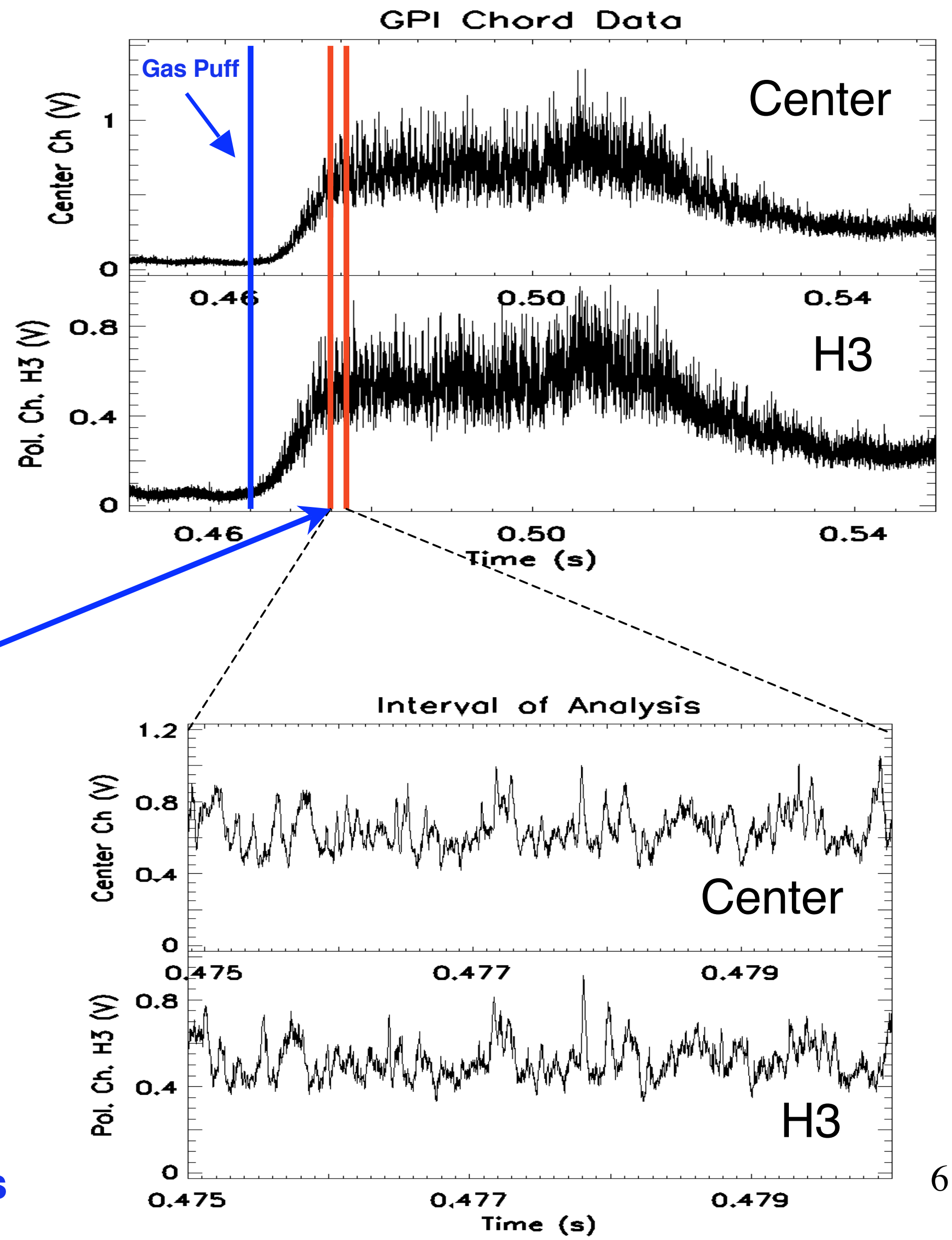
•Each fiber images a 2cm diameter area of the plasma

•The signals from the fiber optical cables are then digitized at 500kHz

Sample PMT Data

•The center channel and poloidal channel 3 are chosen because of their proximity to peak of the GPI light signal.

•The time interval for analysis lies just after the peak in the GPI signal.



Time Interval of Analysis

PMT Data Characteristics

- **Sample rate=500 kHz**
- **Number of samples n=64,000**
- **Measurement time=128ms**
- **Analysis time interval=5ms**
- **D-Alpha=656.2nm**
- **Time scale of turbulence=60-70μs**

Goals of Poster

•The goal of this poster is to find evidence of possible scaling of edge turbulence characteristics with:

- β
- q(a)
- I_p
- location of separatrix
- Neutral Beam Power
- Density

Methods of Calculations

The relative fluctuation level , $\Delta I/I$, for each channel of chord data is calculated using the mean value of the GPI signal over the first 5ms time interval after the peak in the GPI signal.

$$\frac{\Delta I}{I} = \frac{\sqrt{\frac{1}{n-1}\sum_{i=0}^{n-1}\left(x_i - \bar{x}\right)^2}}{\frac{1}{n}\sum_{i=0}^{n-1} x_i}$$

The cross correlation coefficient, $C_{xy}(L)$, for the center channel and poloidal channel 3 is calculated for zero lag.

$$C_{xy}(L) = \frac{\sum_{k=0}^{n-L-1}\left(x_{k+L} - \bar{x}\right)\left(y_k - \bar{y}\right)}{\sqrt{\sum_{k=0}^{n-L-1}\left(x_k - \bar{x}\right)^2 \sum_{k=0}^{n-L-1}\left(y_k - \bar{y}\right)^2}}$$

The auto correlation time, τ, is determined by calculating the FWHM of the auto correlation function, $A_x(L)$, for each channel.

Turbulence structure size is ≈4cm and spatial resolution of optics is ≈ 1-2 cm*.
Since the length scales of the turbulence are larger than the optical spatial resolution local turbulence properties can be studied.

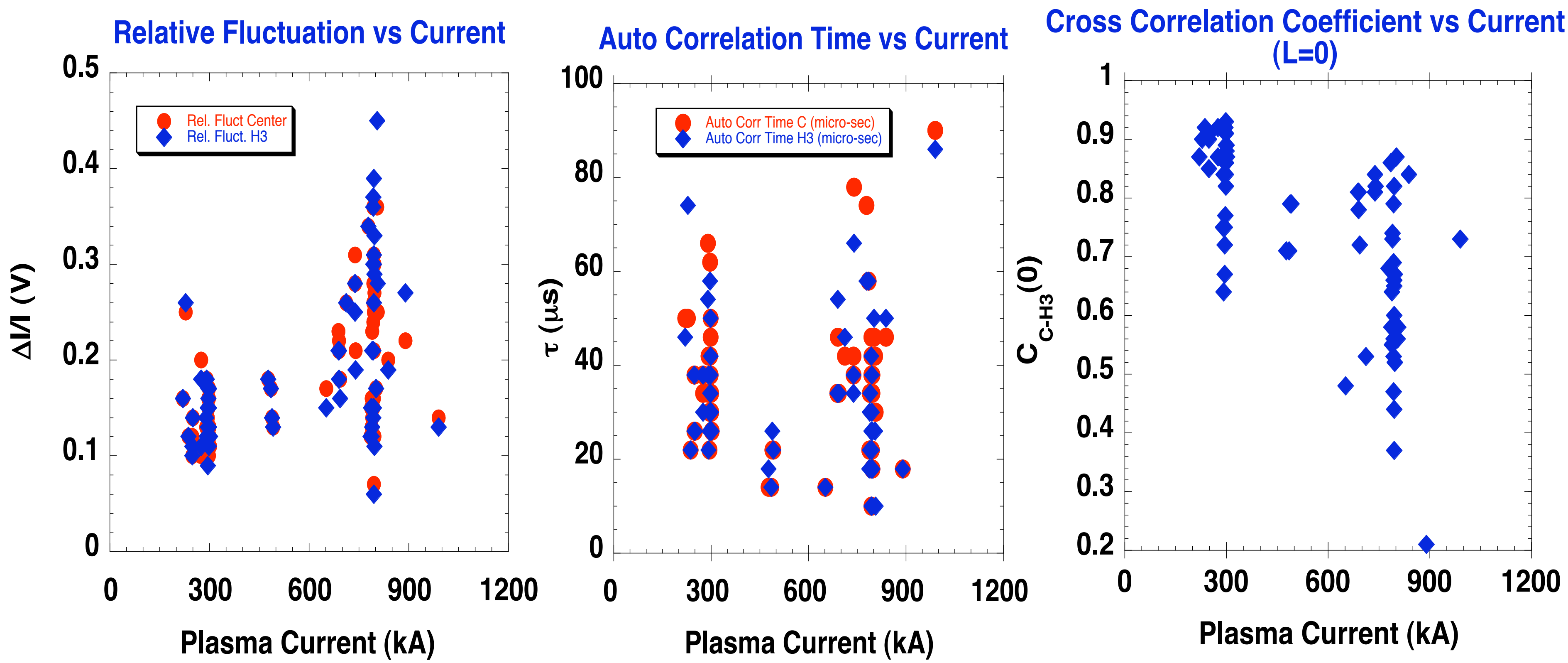
$$A_x(L) = \frac{\sum_{i=0}^{n-L-1}\left(t_i - \bar{t}\right)\left(t_{i+L} - \bar{t}\right)}{\sum_{i=0}^{n-1}\left(t_i - \bar{t}\right)^2}$$

*S.J. Zweben, R.J. Maqueda, *et al*, Nucl.Fus. **44** (2004) 134-153

Data Set

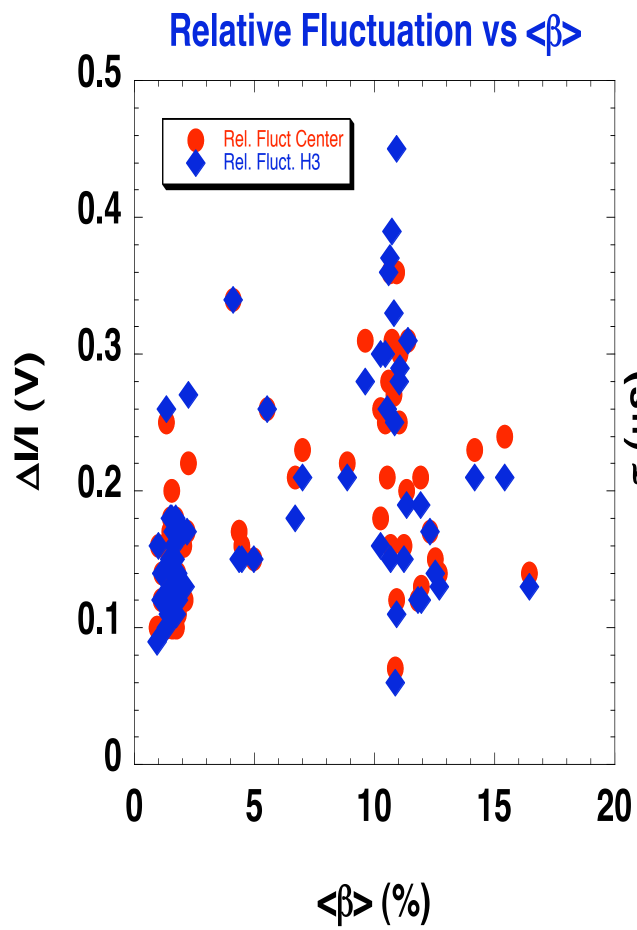
- Number of shots=73
- B_{Tor}=4.44 kG
- I_p=0.220-1.2 MA
- N=1.05×10^{13}-6.0×10^{13}
- Shots=117258-117979
- Dates =7/20/05-8/24/05

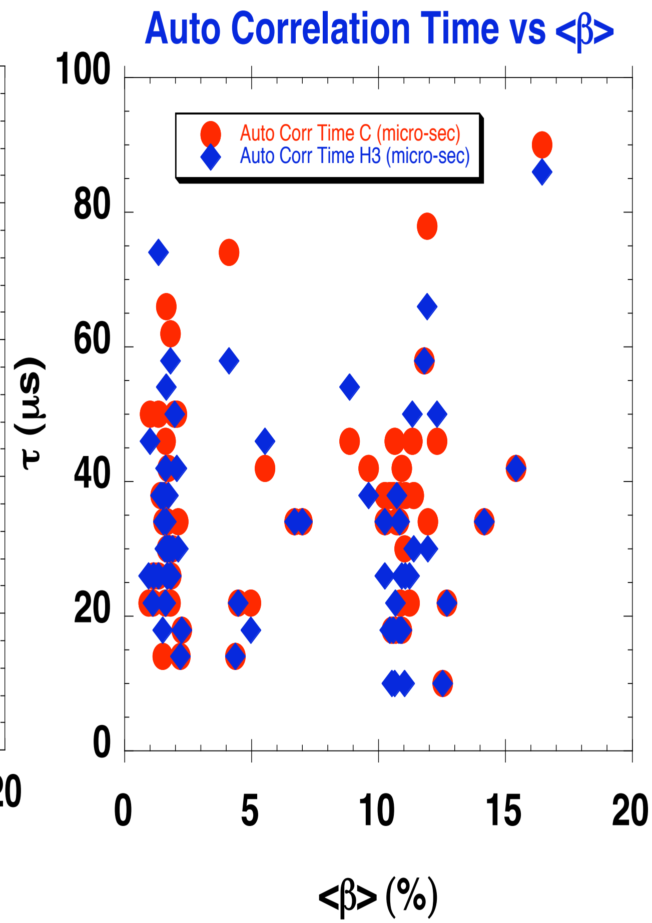
Plasma Current Scaling

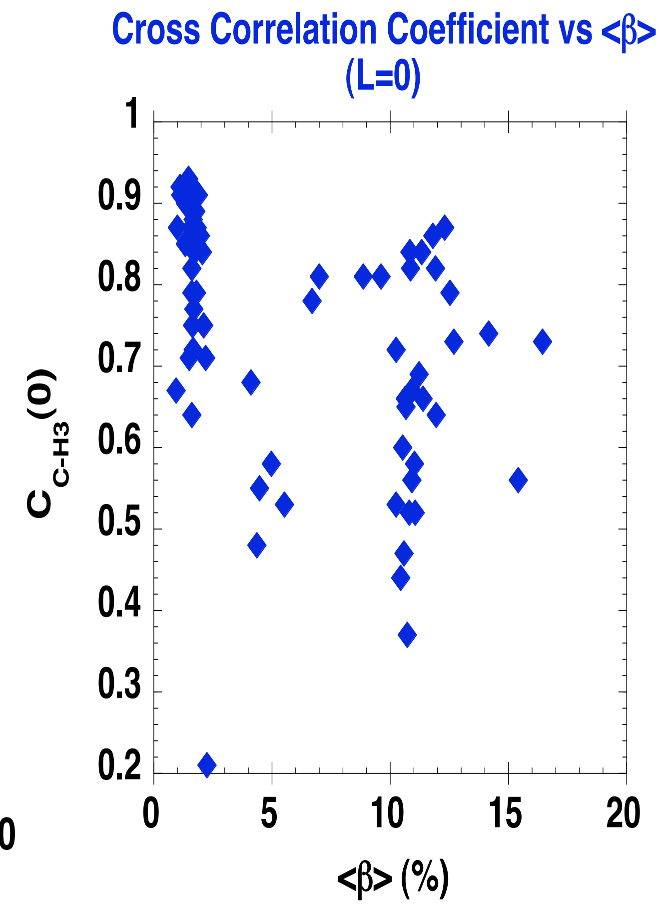


None of the statistical quantities show any evidence of current scaling from 0.220-1.2 MA (constant toroidal field of ~4.44kG)

Beta Scaling

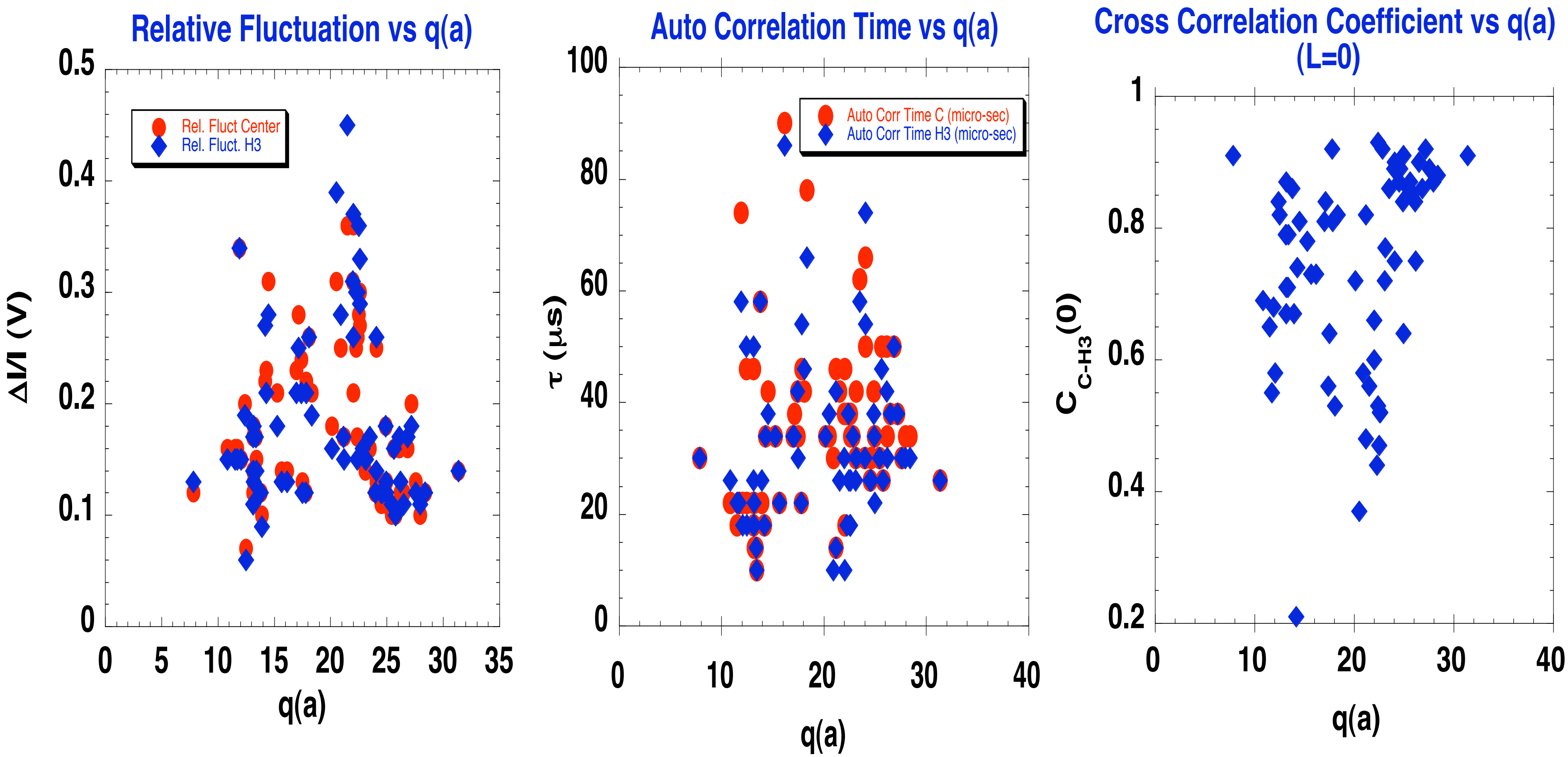






None of the statistical quantities show any evidence of <β> scaling from ≈ 1-15%

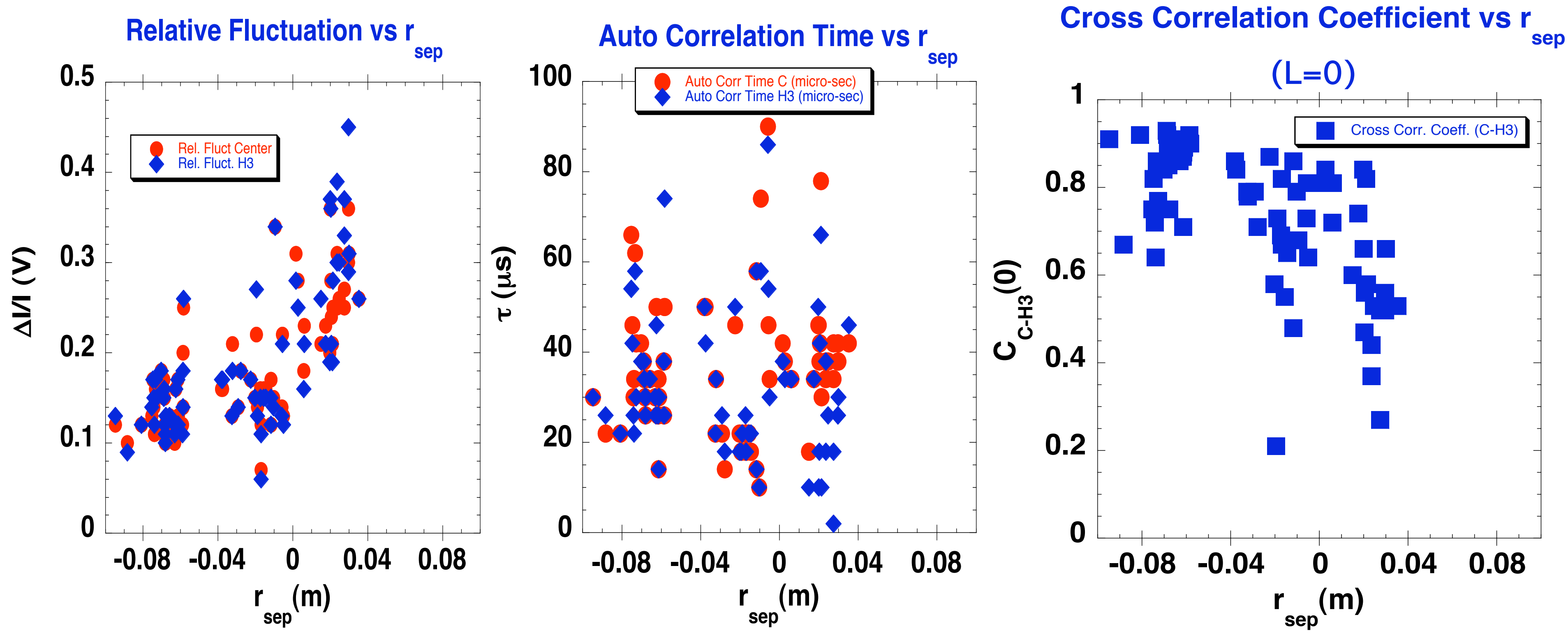
q(a) Scaling



None of the statistical quantities show any evidence of q(a) scaling from ≈ 8-32

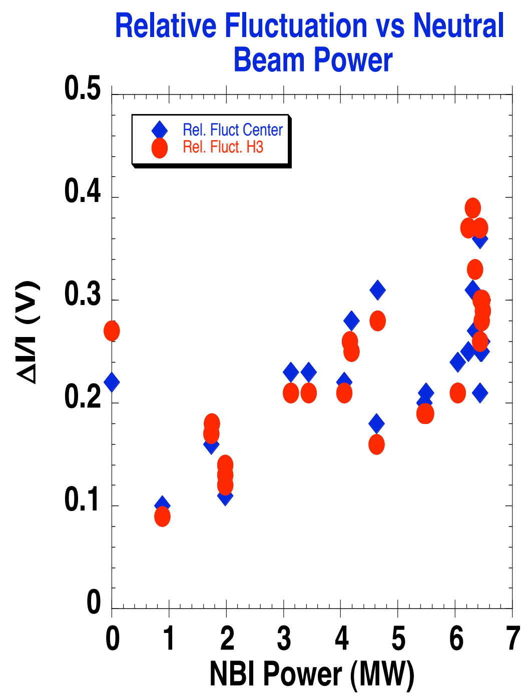
Scaling with r_{sep}

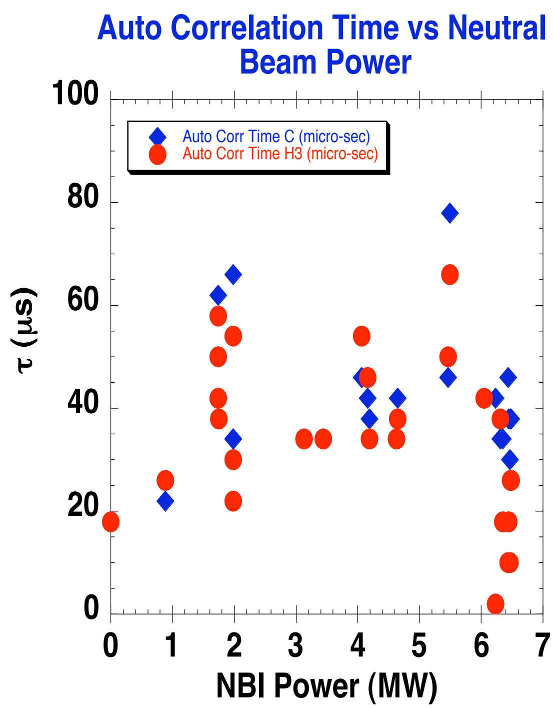
r_{sep}= Distance between center channel and separatrix

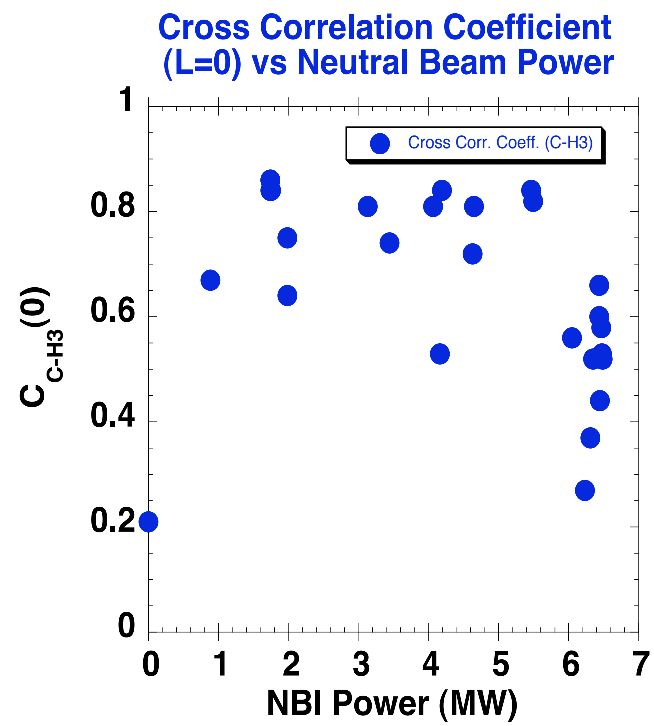


Relative fluctuations increase directly with r_{sep}. For auto correlation time and cross correlation coefficient there is no evidence of r_{sep} scaling.

Scaling with Neutral Beam Power

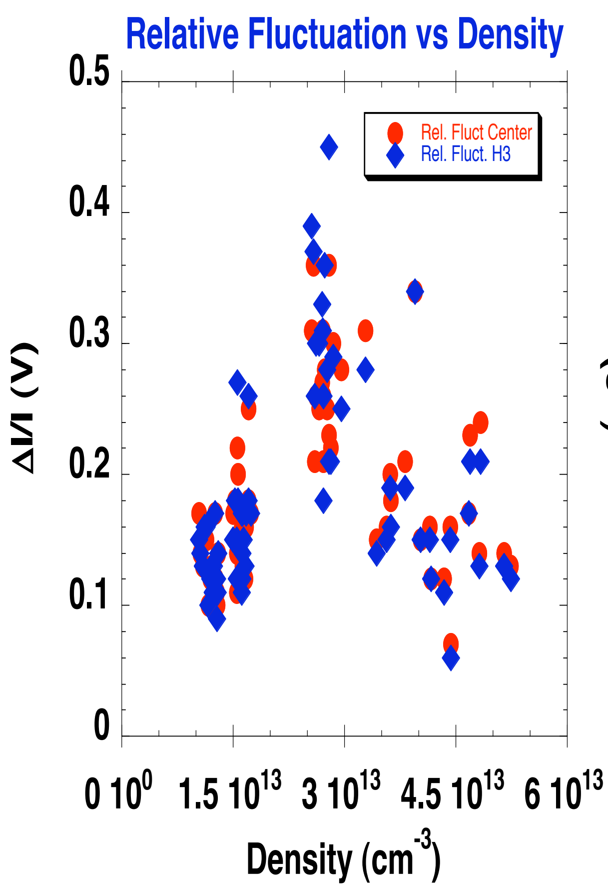


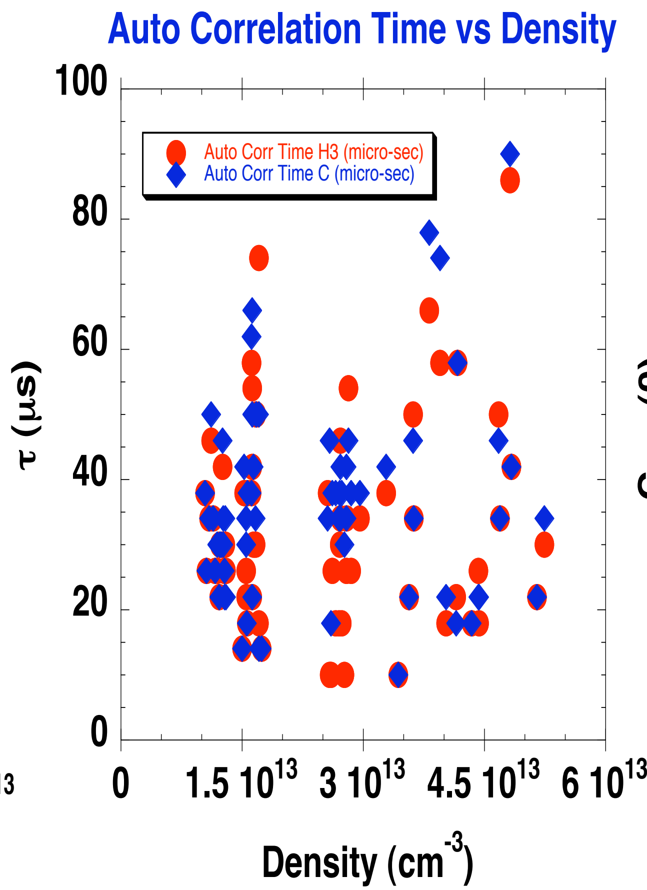


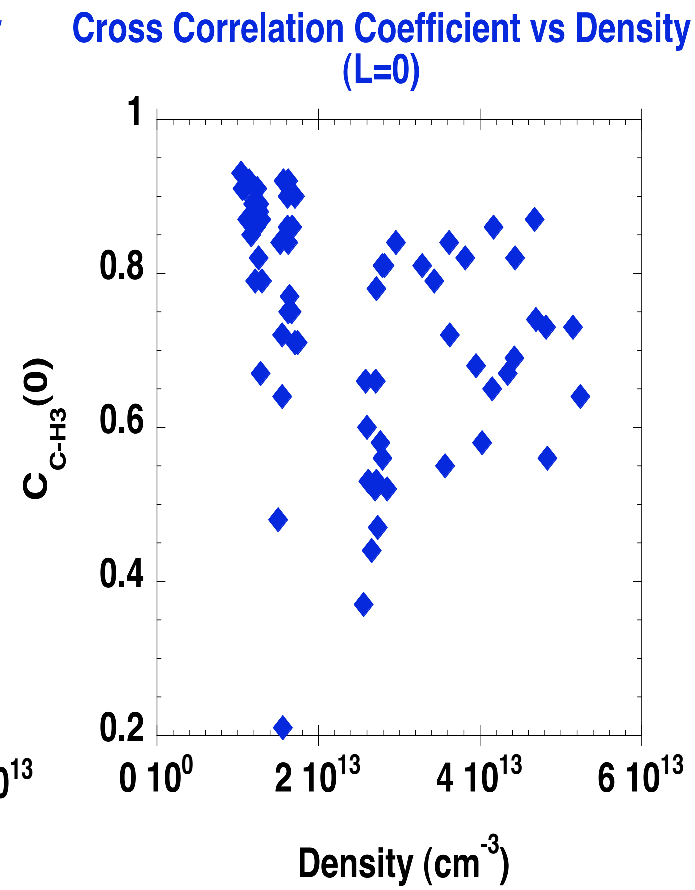


Relative fluctuations increase as NBI power increases. For auto correlation time and cross correlation coefficient there is no trend is observed.

Density Scaling







None of the statistical quantities show any evidence of density scaling from ≈ 1.5×10^{13}-6.0×10^{13} cm^{-3}

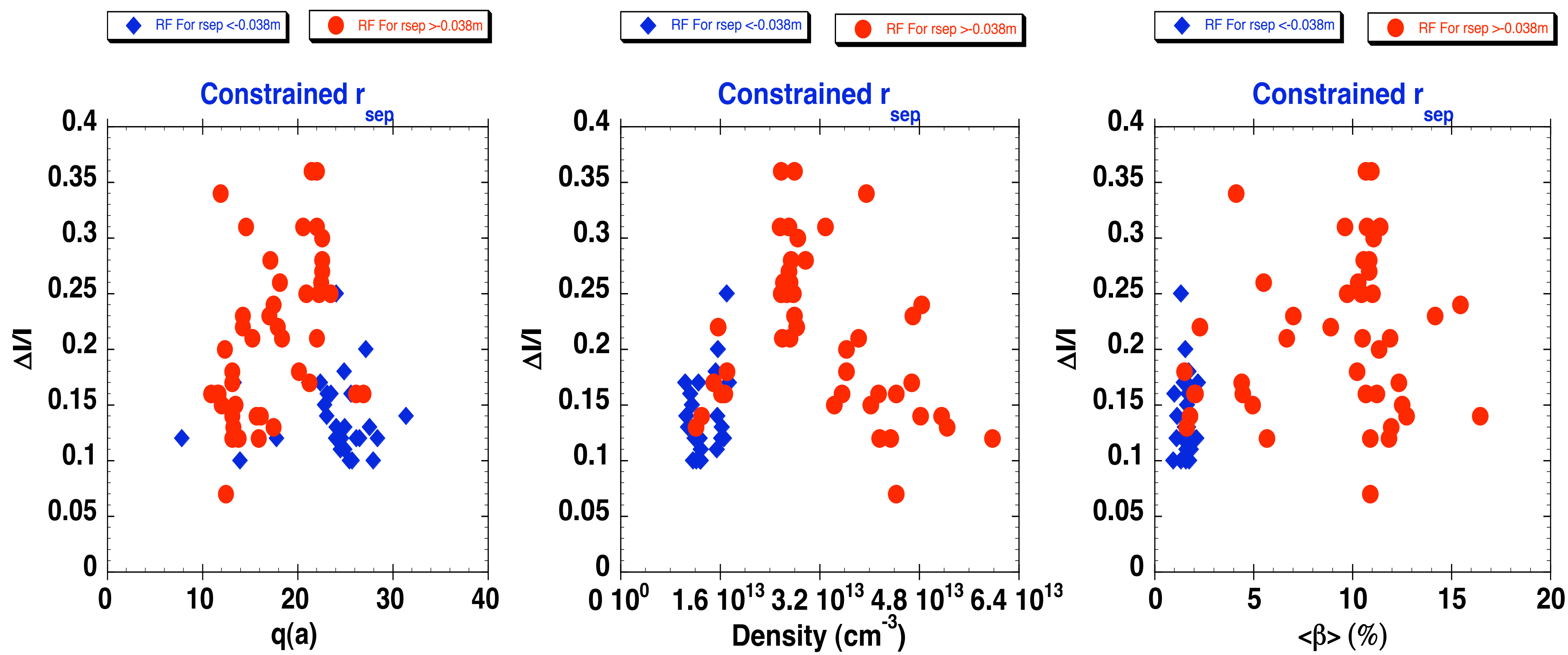
Interpretation of Scaling Results

•The data collected and results presents were limited by narrow range of $B_{Toroidal}$.

•The only trend observed shows increasing relative fluctuations with increasing r_{sep} which is consistent with previous experimental data that shows increasing fluctuations as the plasma enters the scrape off layer where the flux surfaces are open and the plasma nears the wall

Relative Fluctuations for Constrained r_{sep}

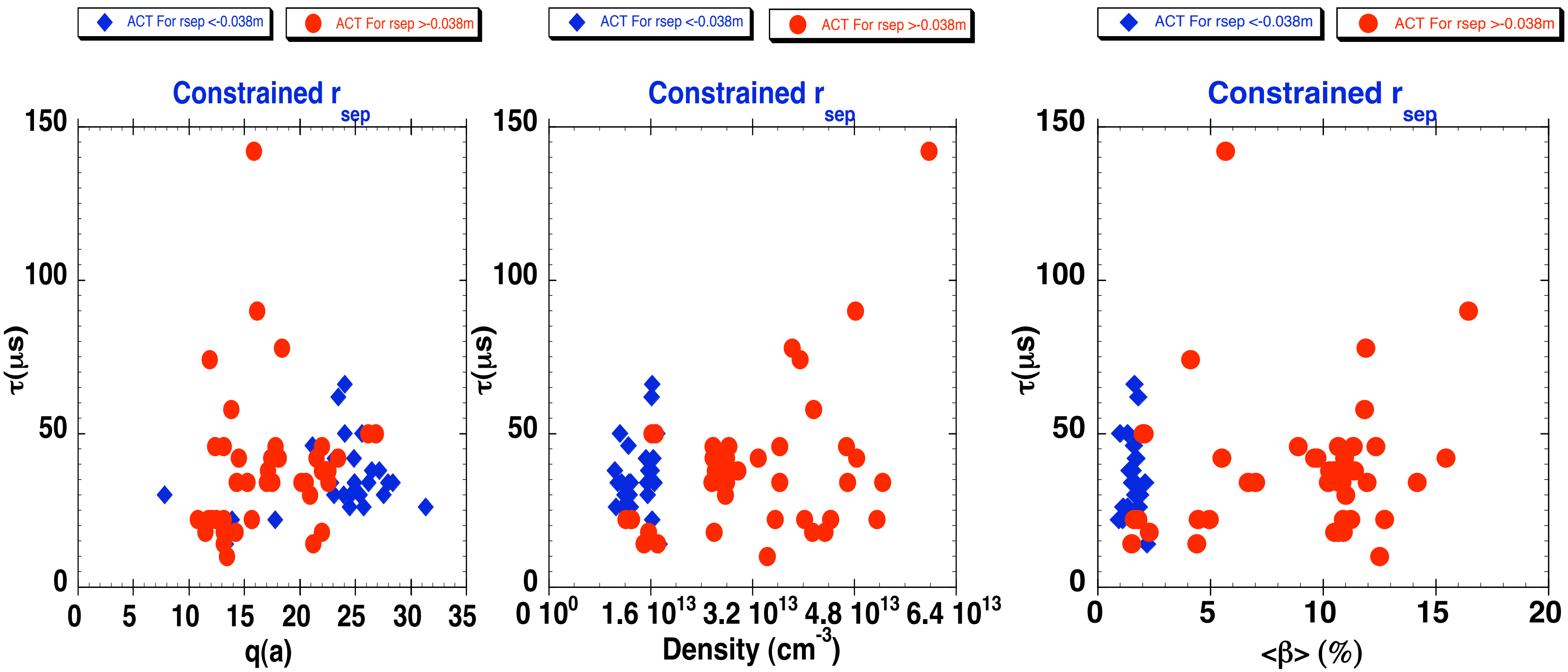
r_{sep}= Distance between center channel and separatrix



Even when the range of the r_{sep} is restricted, no apparent trends result from the analysis.

Auto Correlation Time for Constrained r_{sep}

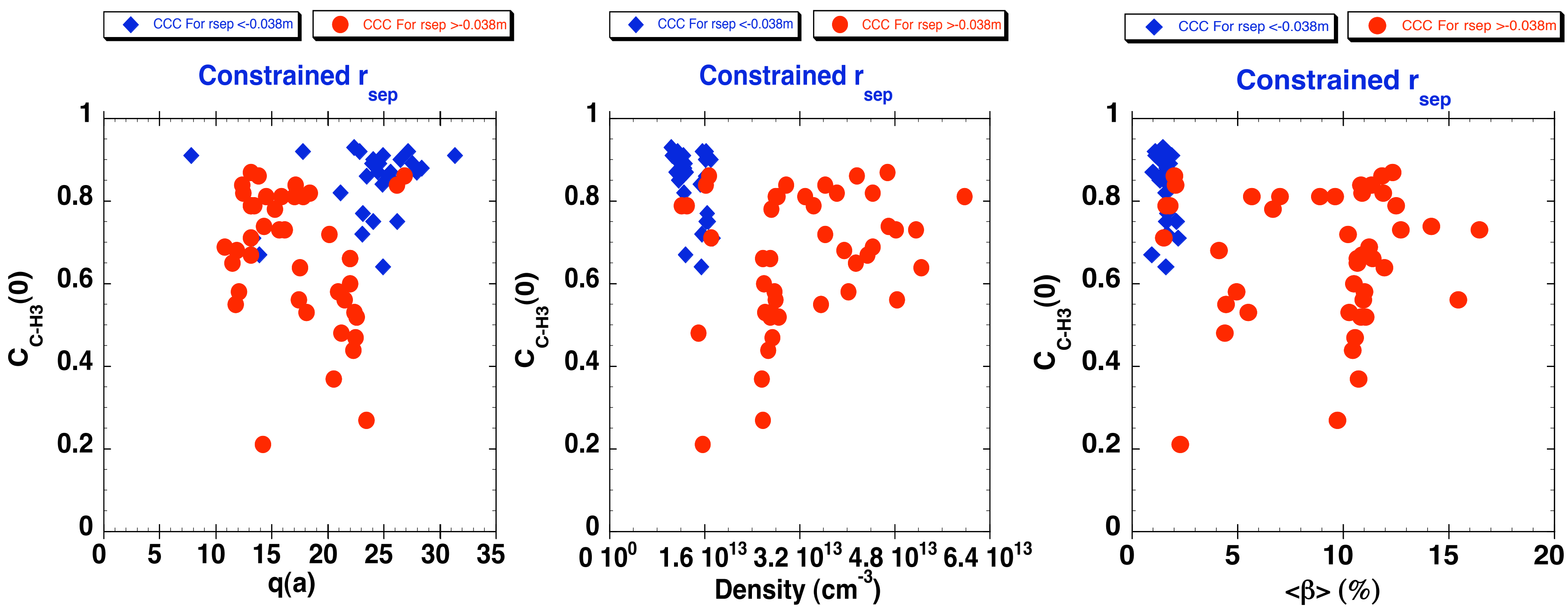
r_{sep}= Distance between center channel and separatrix



Even when the range of the r_{sep} is restricted, no apparent trends result from the analysis.

Cross Correlation Coefficient for Constrained r_{sep}

r_{sep}= Distance between center channel and separatrix



Even when the range of the r_{sep} is restricted, no apparent trends result from the analysis.

Conclusions

•There is no apparent evidence of scaling with respect to Beta, Plasma Current, Density, and q-profile when relative fluctuations, auto correlation times, and cross correlation coefficient are examined.

•The relative fluctuations in both the center channel and poloidal channel 3 increased directly with increasing r_{sep}.

•The sampling of data over a limited toroidal field range is a likely contributor to the inconclusiveness of data analyzed.

Future Work

- Get larger database in a dedicated experiment

- Improve the experimental capability to better track coherent structures at the plasma edge by increasing the number of channels in the PMT array for the GPI diagnostic

Possible PMT Upgrade in GPI Diagnostic

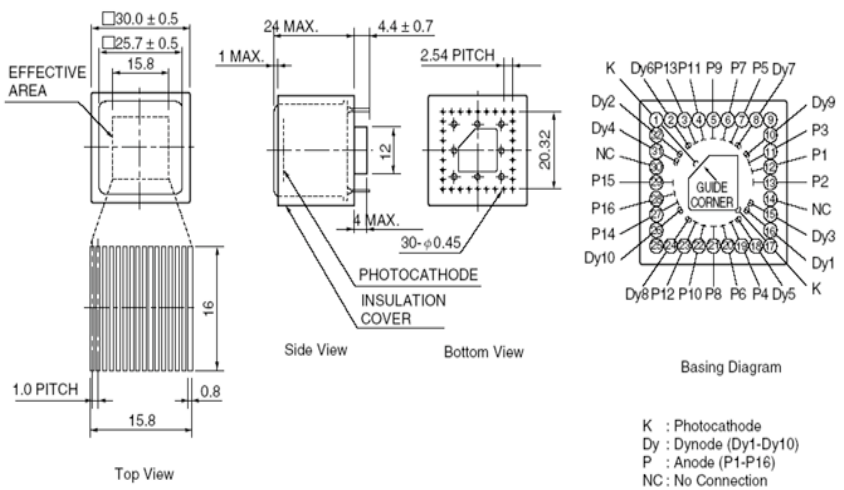


Diagram of Hamamatsu R5900U-20-L16 multianode PMT

- The current detectors used in the GPI diagnostic are Hamamatsu R762 PMTs designed for wavelengths 160-650nm.

- The light observed is D_{α}=656.2nm

•The Hamamatsu R5900U-20-L16 is 16-channel multianode PMT which allows for the addition of more channels in the same operating area

- The Hamamatsu R5900U-20-L16 operates with a higher quantum efficiency in the desired range of wavelengths (500-700nm), greater peak sensitivity wavelength (650nm instead of 420nm for R762), and improved rise time

- The R5900U-20-L16 detector geometry is more compact which adds greater flexibility in placement in the experiment