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Resolution of the NSTX Neutron Conundrum - *Circa 2005*

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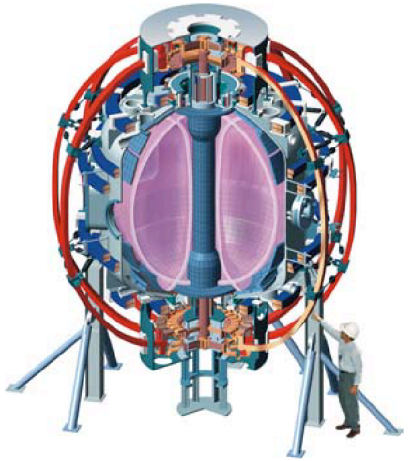
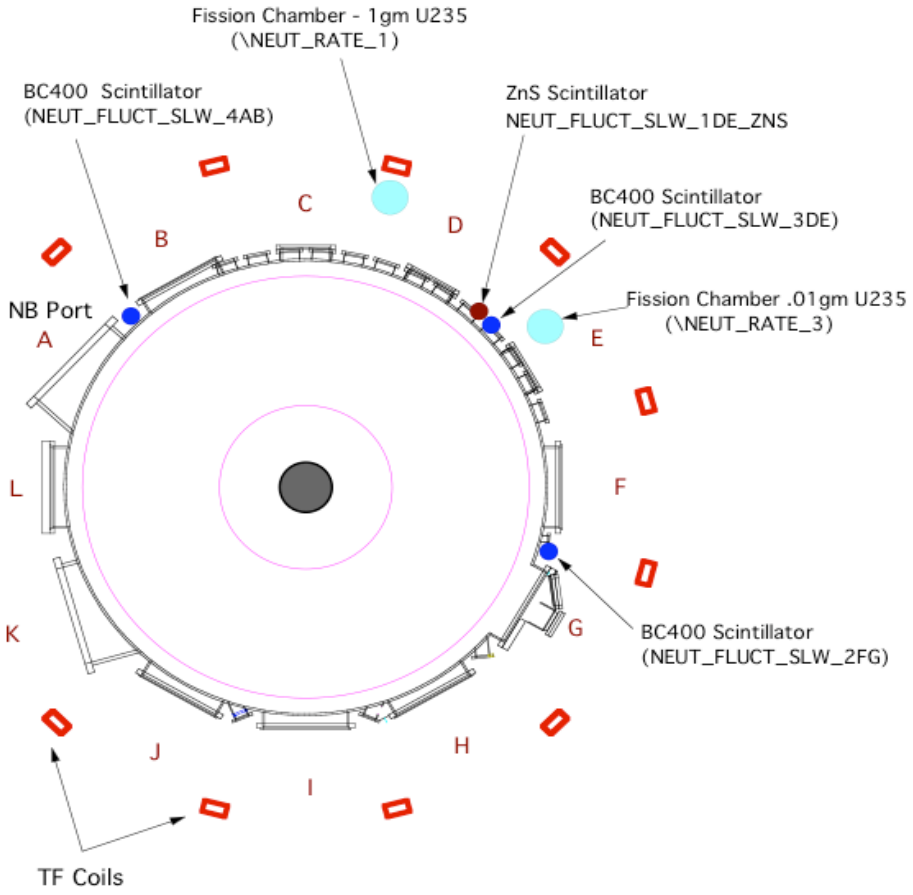


NSTX Physics Meeting
July 11, 2005

NSTX Neutron Diagnostic Suite

Neutron Detector Locations



- **Neutron diagnostic suite consists of:**
  - **2 fission chambers, absolutely calibrated in-vessel with a ^{252}CF neutron source**
  - **4 plastic scintillators cross calibrated to the fission chambers**

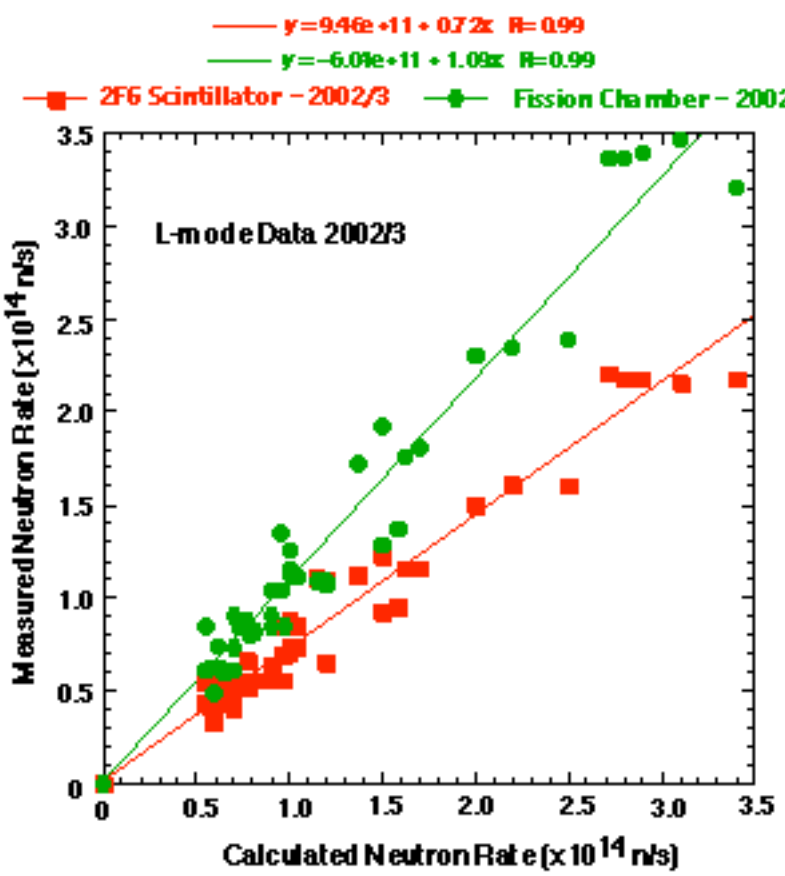
- **Plastic scintillation detector (2FG):**
  - **control room standard**
  - **fast time response**
  - **externally biased**
  - **does not saturate**
  - **calibration shifts have occurred**

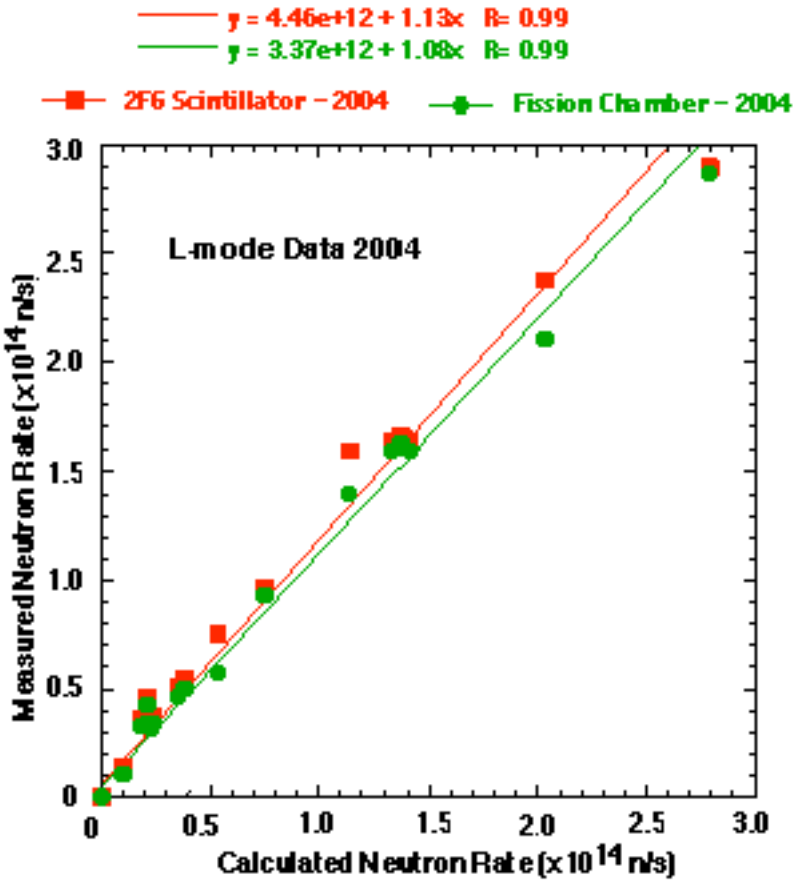
- **Fission chamber detector (FC):**
  - **slower time response**
  - **internally biased**
  - **does not saturate**
  - **most stable calibration**

The NSTX Neutron Conundrum

- The plastic scintillator neutron measurements have changed over time, occasionally inexplicably.
- Neutron measurements amongst the detectors in the suite do not agree.
- Neutron measurements do not agree with TRANSP-calculated neutron rates.

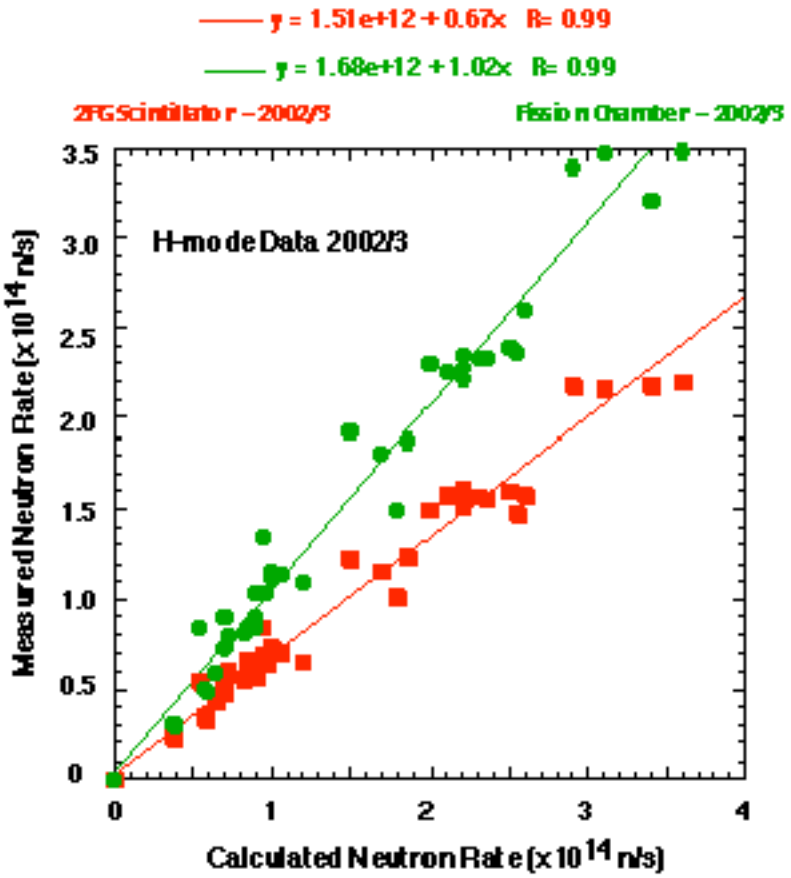
Comparison of Measured and Calculated Neutron Rates in L-mode Discharges

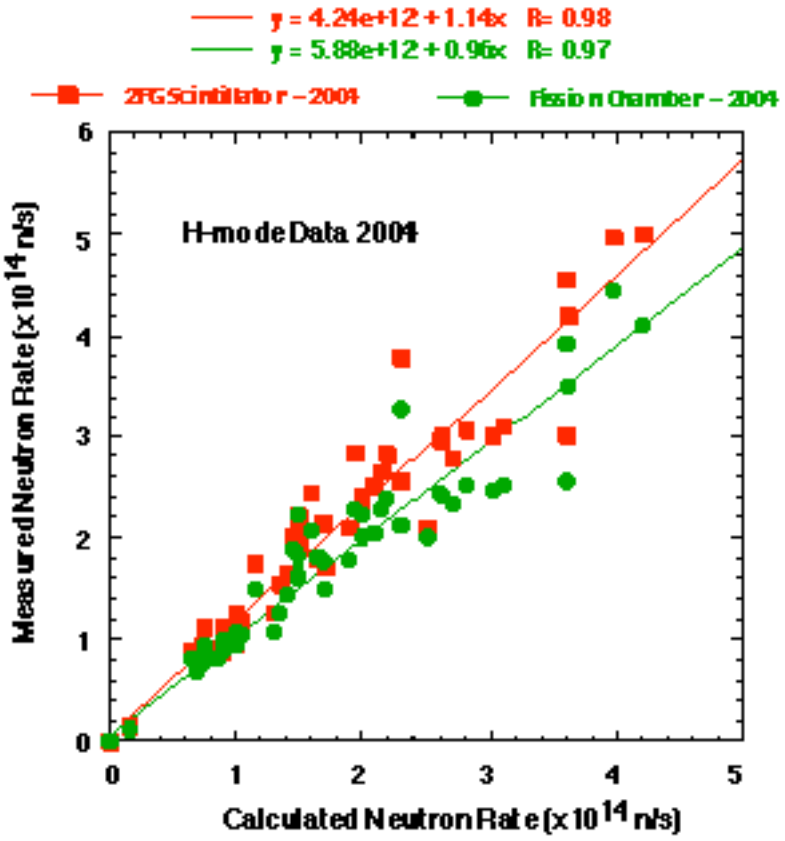




- Fission chamber measurements modestly (~ 8.5%) exceed TRANSP calculations.
- 2FG scintillator measurements changed drastically over time.

Comparison of Measured and Calculated Neutron Rates in H-mode Discharges

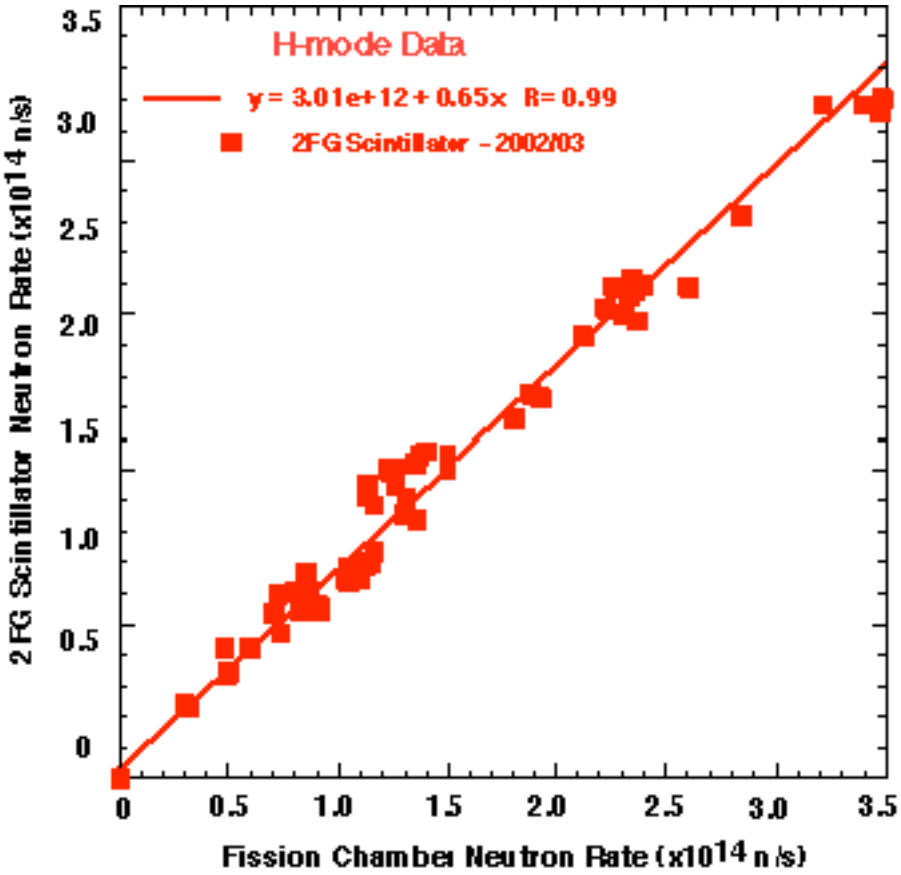


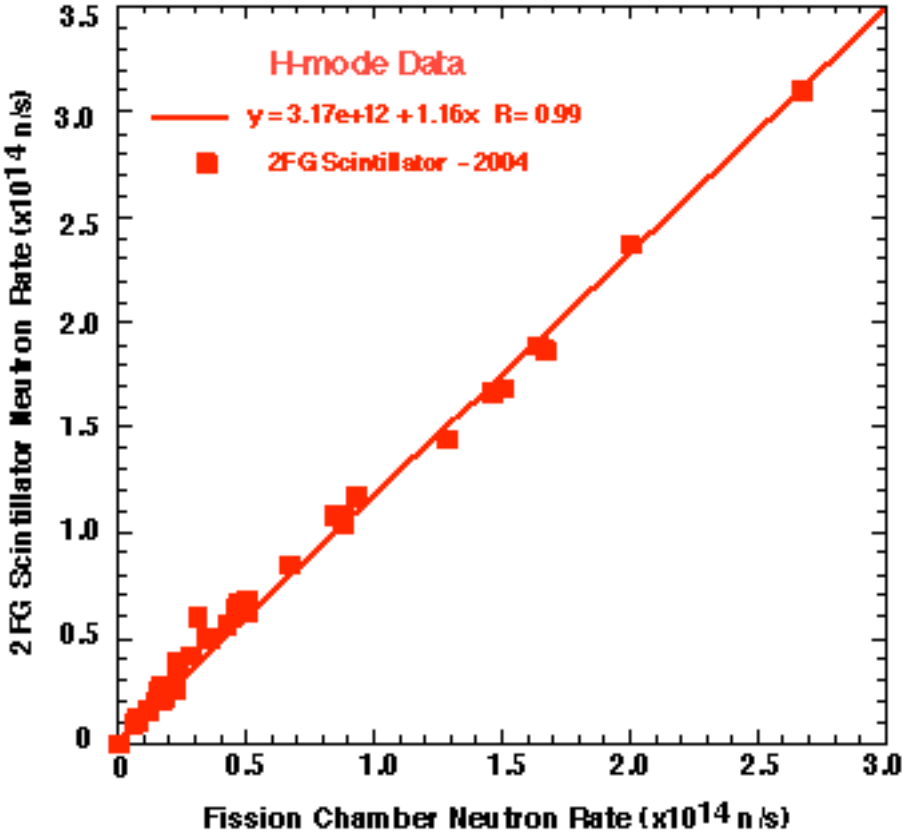


- Fission chamber data are close to TRANSP calculations, in contradiction with NPA energetic ion loss observations.

- 2FG scintillator measurements changed drastically over time.

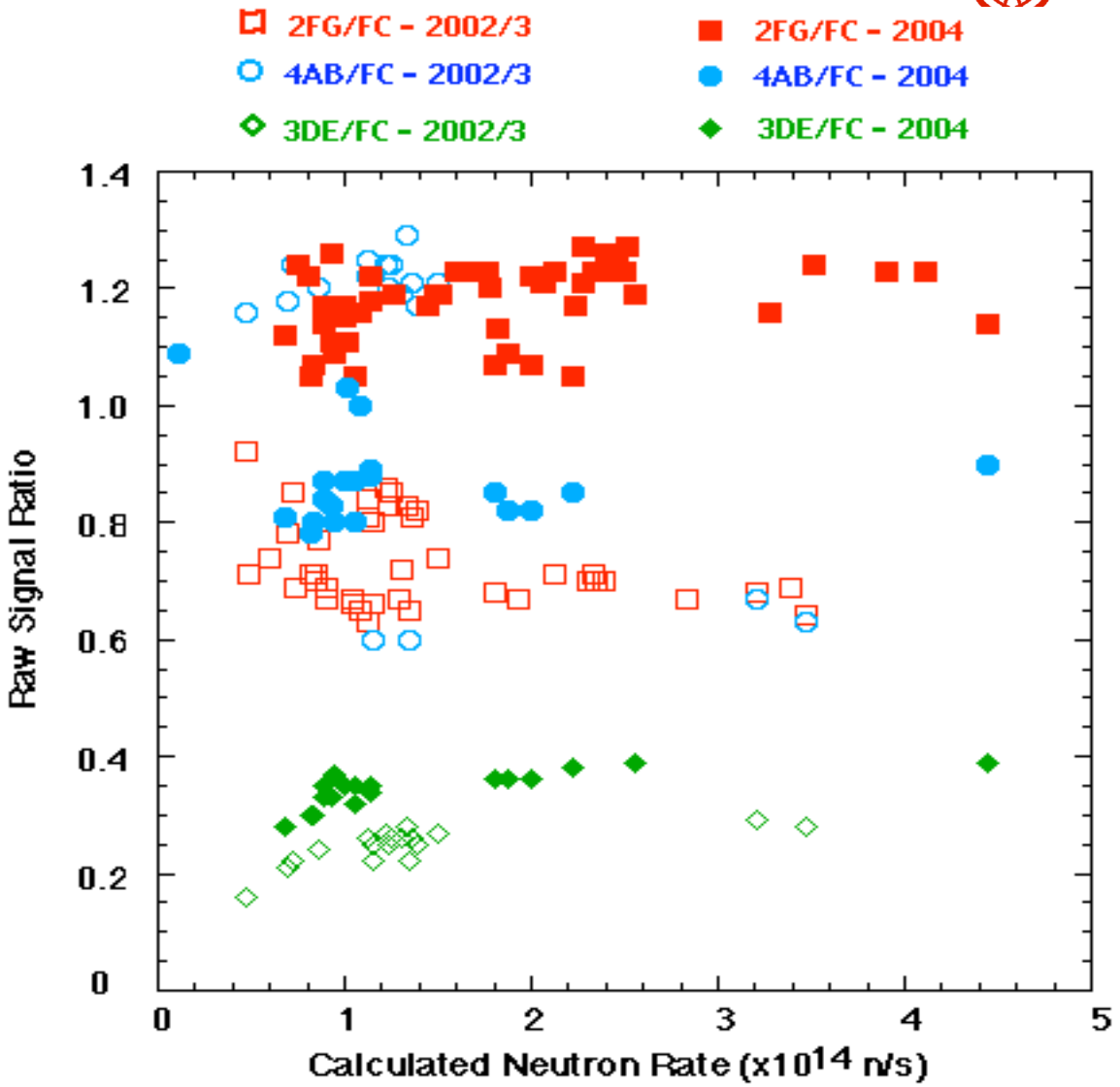
Comparison of Fission Chamber and 2FG Scintillator Measurements in H-mode Discharges



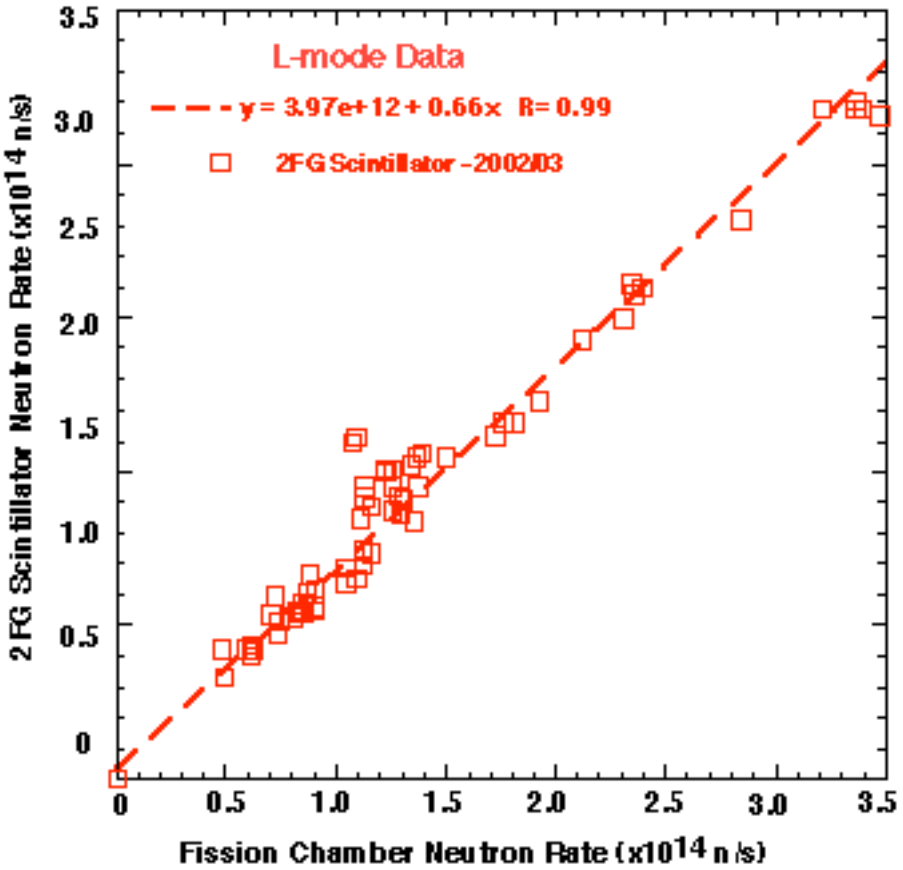


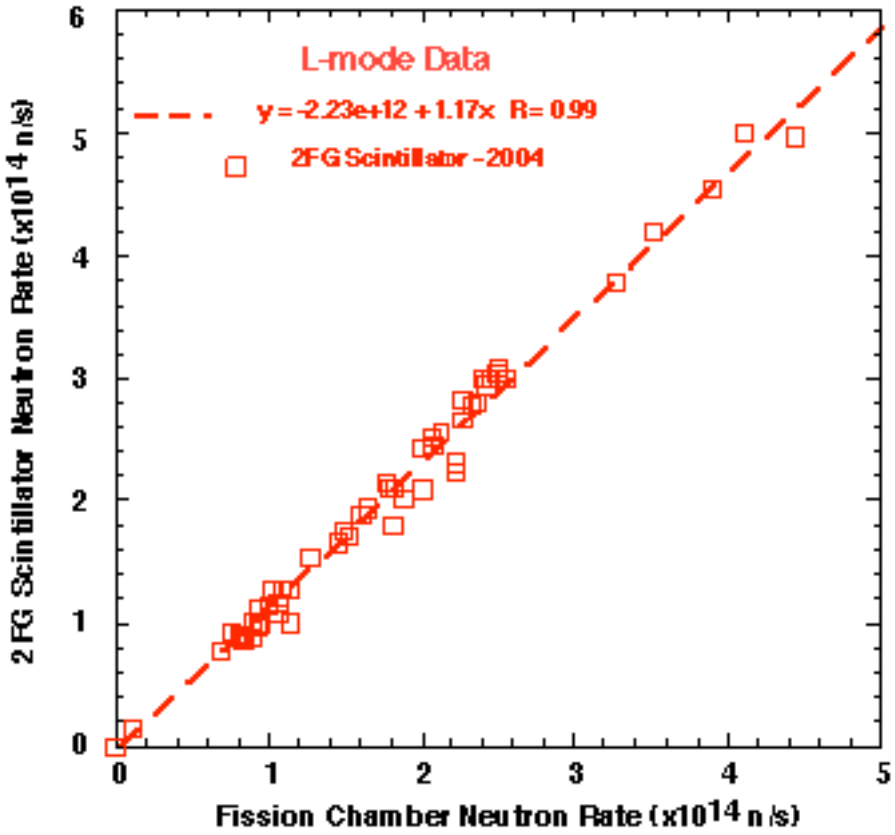
- The fission chamber and 2FG scintillator measurements have never agreed.
- The 2FG scintillator measurements are stable within selected time periods, but increased by ~ 80% in 2004 relative to pre-2004.

The Scintillator/Fission Chamber Raw Signal Ratios are Independent of Neutron Yield



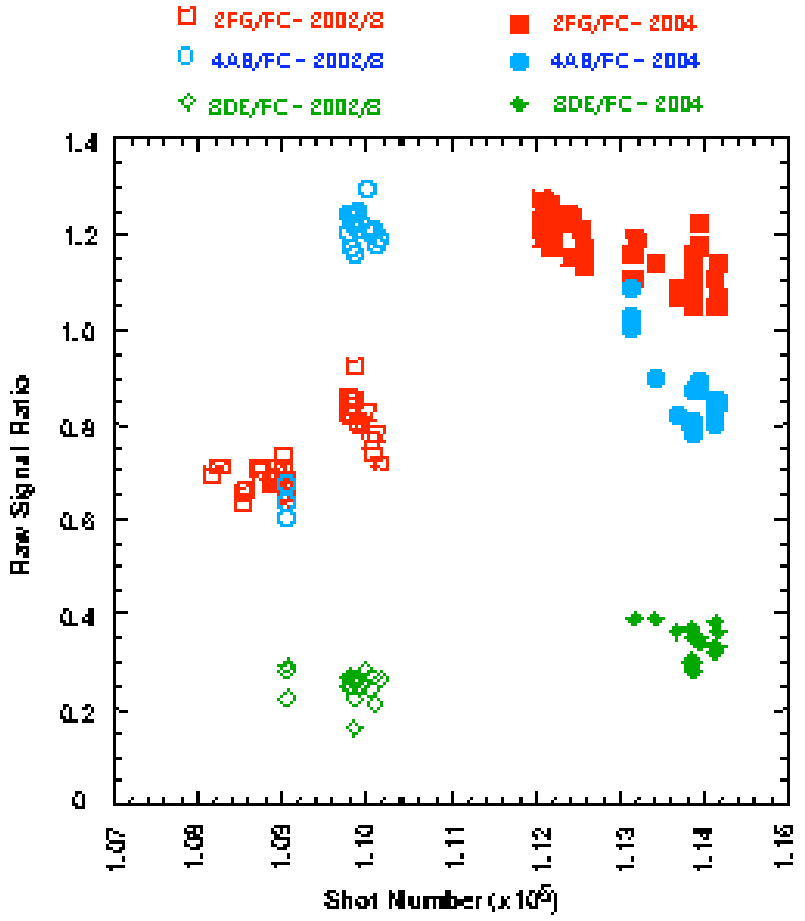
Comparison of Fission Chamber and 2FG Scintillator Measurements in L-mode Discharges

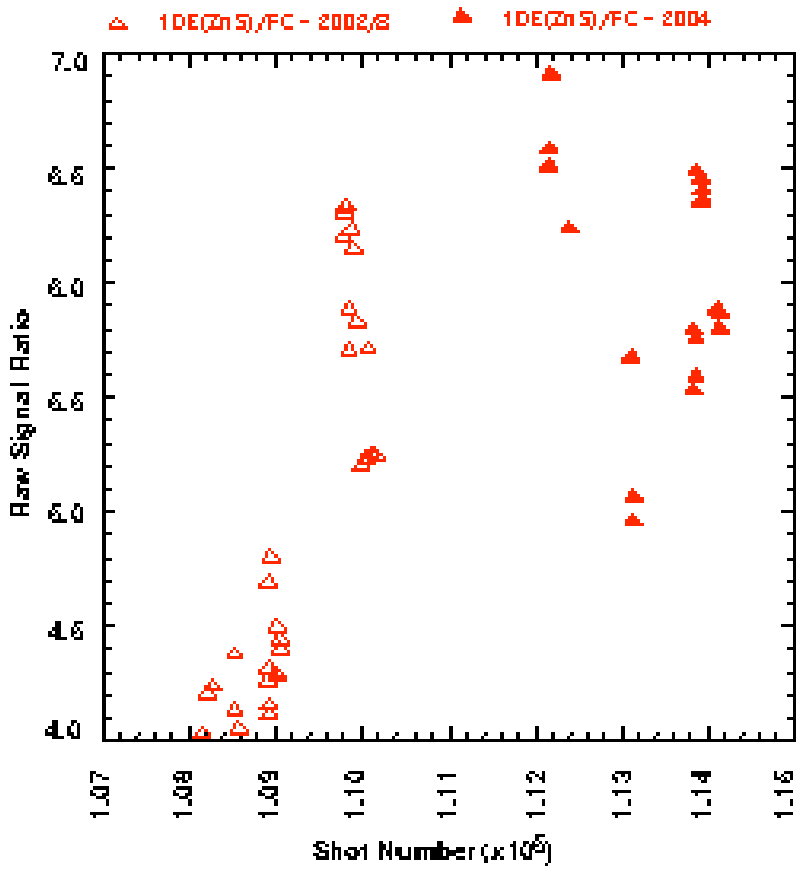




- The fission chamber and 2FG scintillator measurements have never agreed.
- The 2FG scintillator measurements are stable within selected time periods, but increased by ~ 77% in 2004 relative to pre-2004.

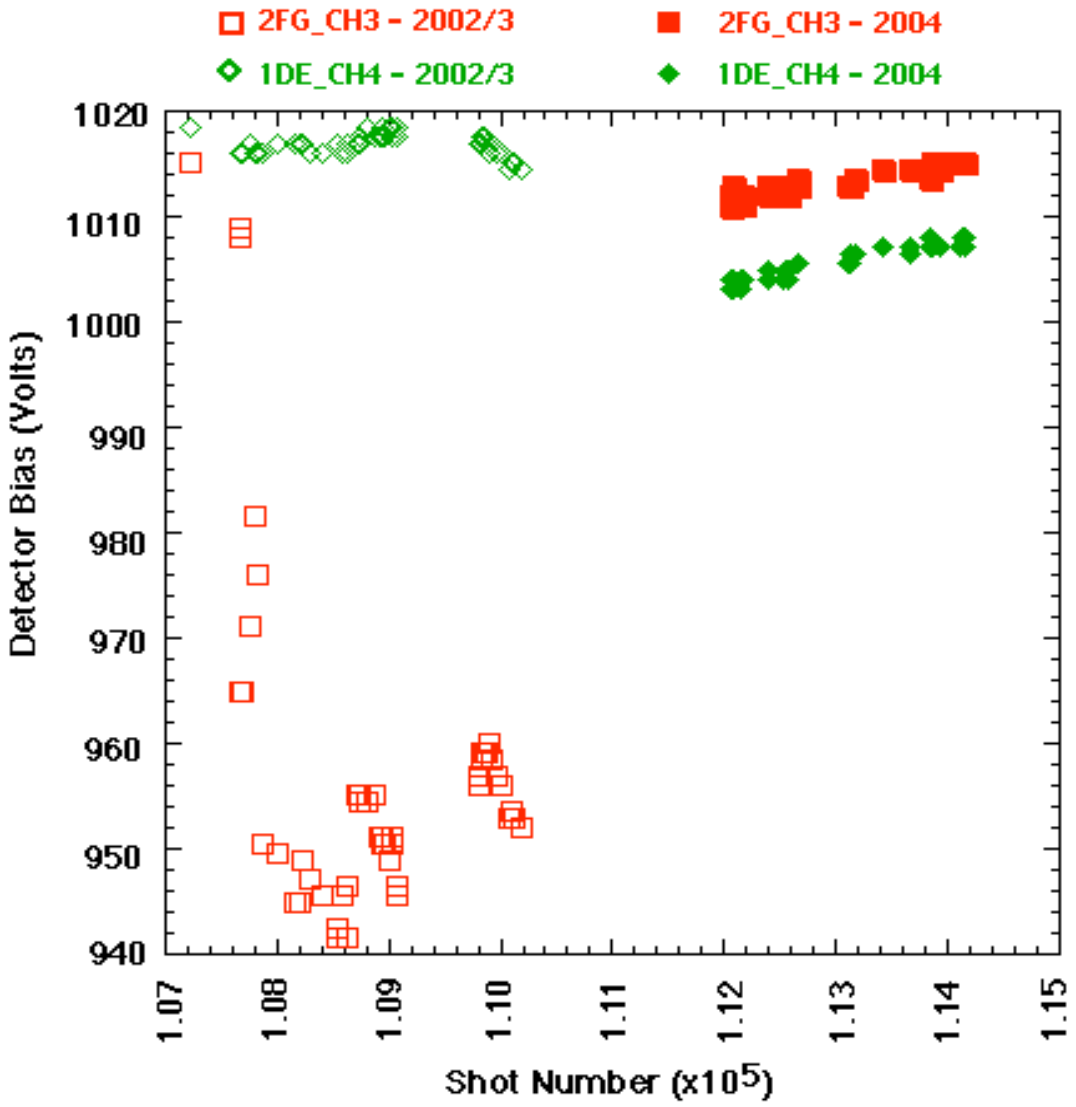
Comparison of Scintillator/Fission Chamber Raw Signal Ratios Over 2002-2004





- Large variations in the scintillator/fission chamber signal ratios occurred in time.
- The fission chamber is stable, so the scintillator response must have changed.

Scintillator Operating Biases Varied Drastically Over 2002-2004

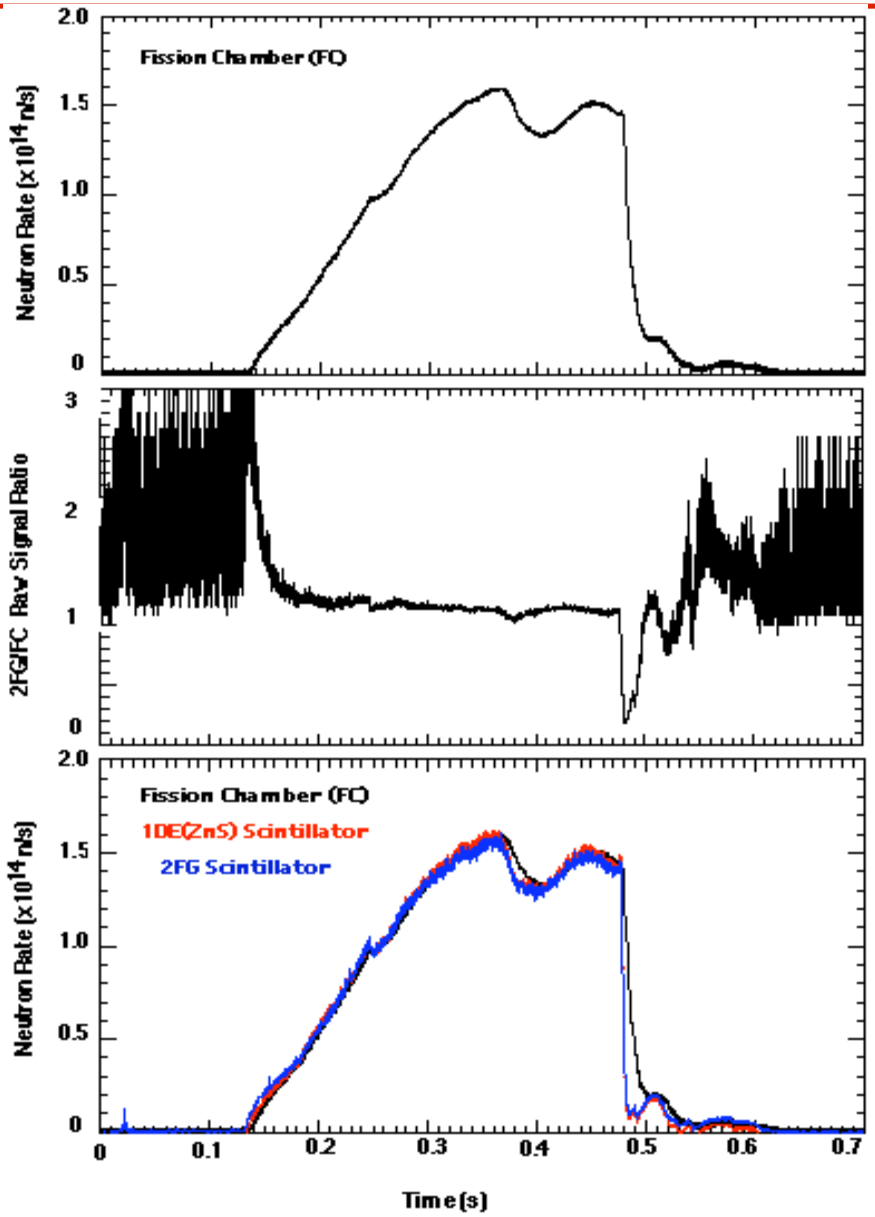


- The externally applied scintillator bias voltages have been archived since 2002.
- An inexplicable decrease in the 2FG scintillator bias occurred in early 2002.
- The 2FG scintillator bias was increased (intentionally) from ~ 960 volts in 2003 to ~ 1012 volts in 2004.
- This implies that the 2FG scintillator photomultiplier gain increased by $(1012/960)^7 \sim 1.52$, but the calibration factor was not updated.

The NSTX Neutron Conundrum

- The plastic scintillator neutron measurements have changed over time, occasionally inexplicably.
  - due to changes in the bias voltages
- Neutron measurements amongst the detectors in the suite do not agree.
- Neutron measurements do not agree with TRANSP-calculated neutron rates.

A New Procedure was devloped to Cross Calibrate the Scintillators with the Fission Chamber

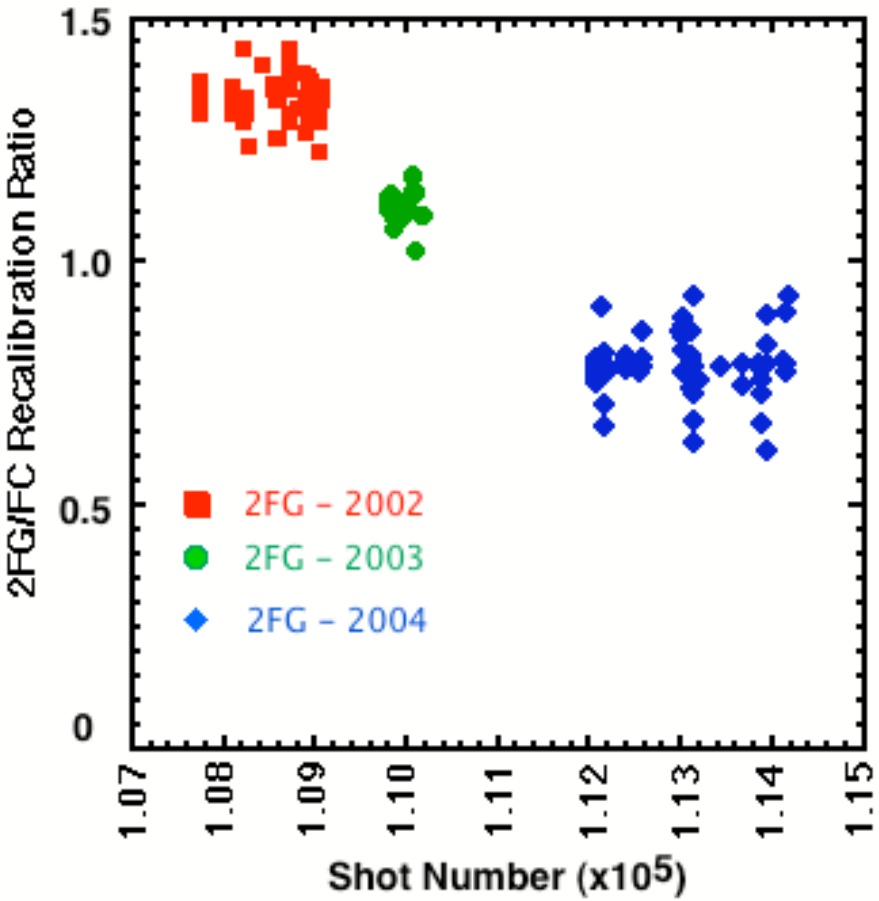


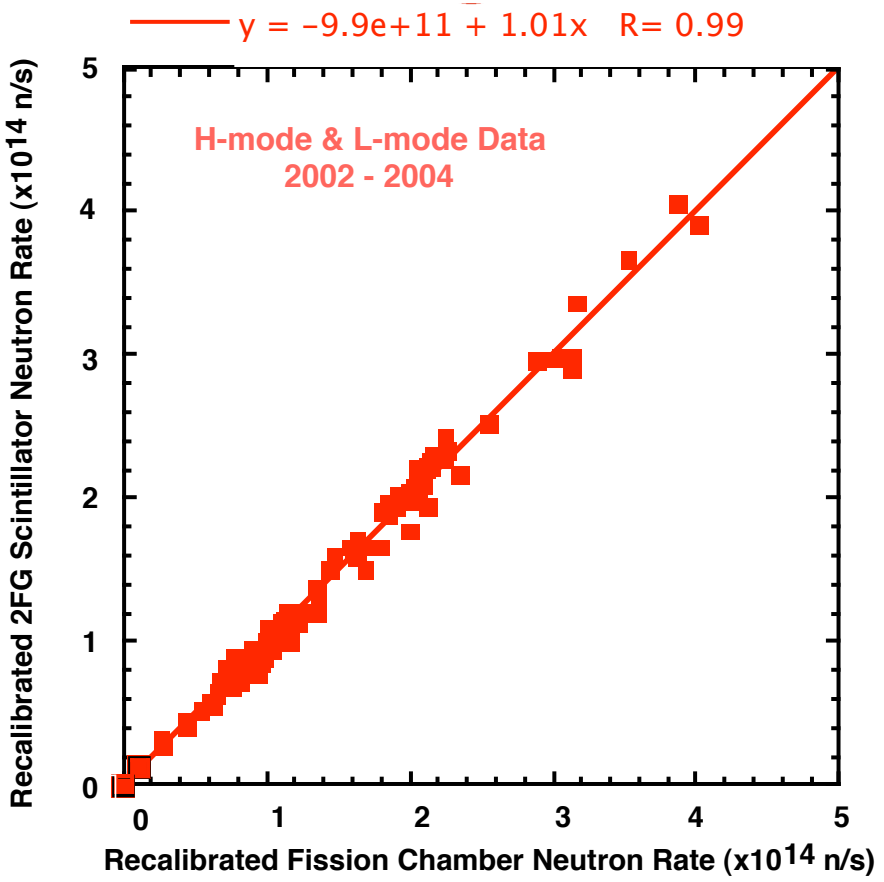
- Previously, the scintillators were cross calibrated against the fission chambers operated in *pulse-counting* mode. This was faulty because of premature saturation of the pulse-counting mode.

- In the new procedure, cross calibration was performed with the FC1 fission chamber in the *current mode*.

- An additional (perhaps controversial) step was taken by normalizing the fission chamber neutron rate to the TRANSP-calculated rate for MHD-quiescent L-mode discharges (where perfect agreement could be expected).

Neutron Re-calibration Details





- The 2FG and ZnS scintillators and the fission chamber now agree for both L-mode and H-mode discharge conditions over the entire 2002-2004 period.

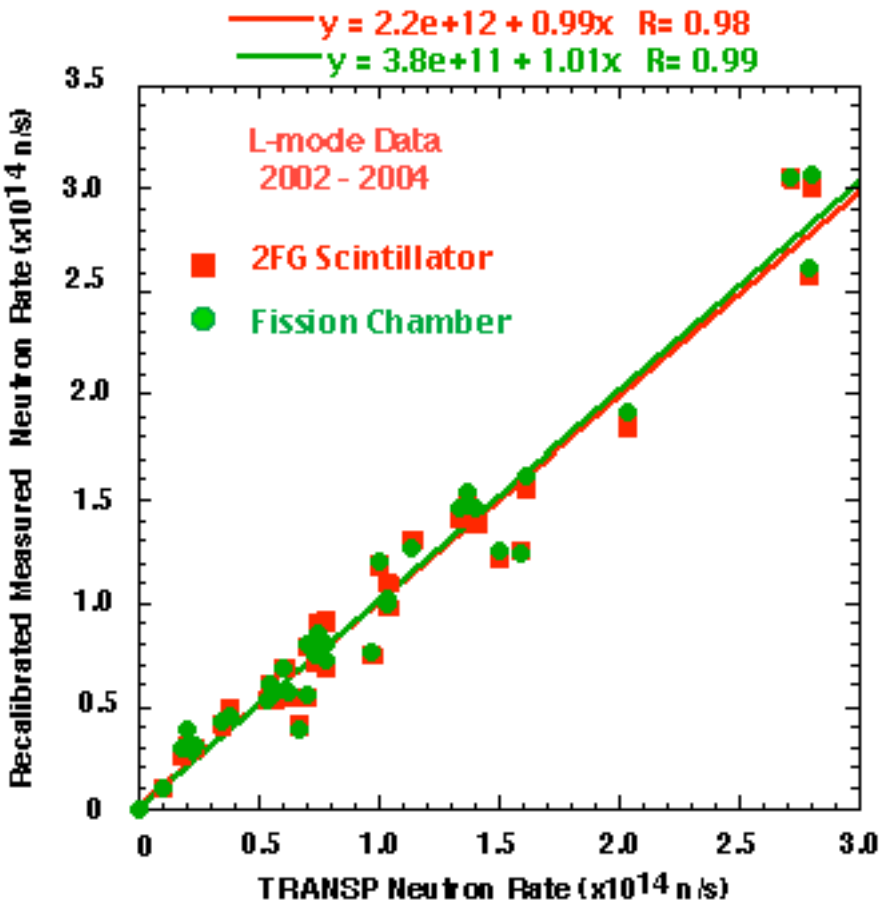
The NSTX Neutron Conundrum

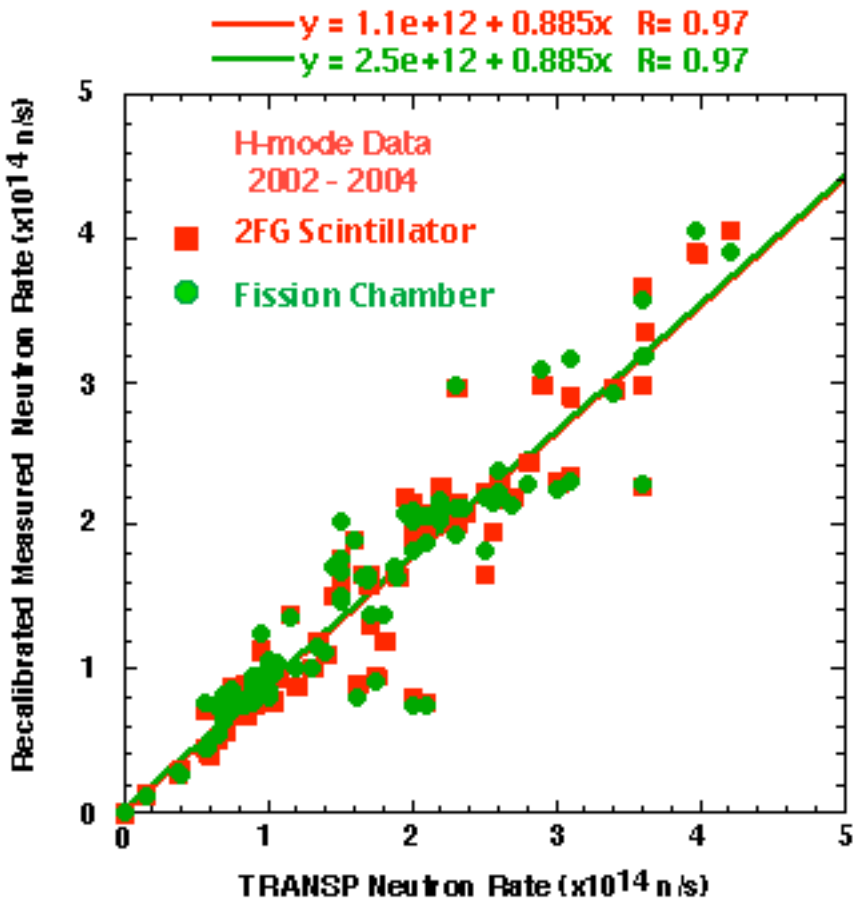
- The plastic scintillator neutron measurements have changed over time, occasionally inexplicably.
  - due to changes in the bias voltages

- Neutron measurements amongst the detectors in the suite do not agree.
  - resolved by new cross calibration procedure

- Neutron measurements do not agree with TRANSP-calculated neutron rates.

Neutron Re-calibration Results





- The 2FG scintillator and the fission chamber agree with TRANSP calculations to within ± 1% for L-mode discharges over the entire 2002-2004 period.
- For H-mode discharges, measurements agree and show a neutron deficit of 11.5%

Revised Neutron Calibration Factors

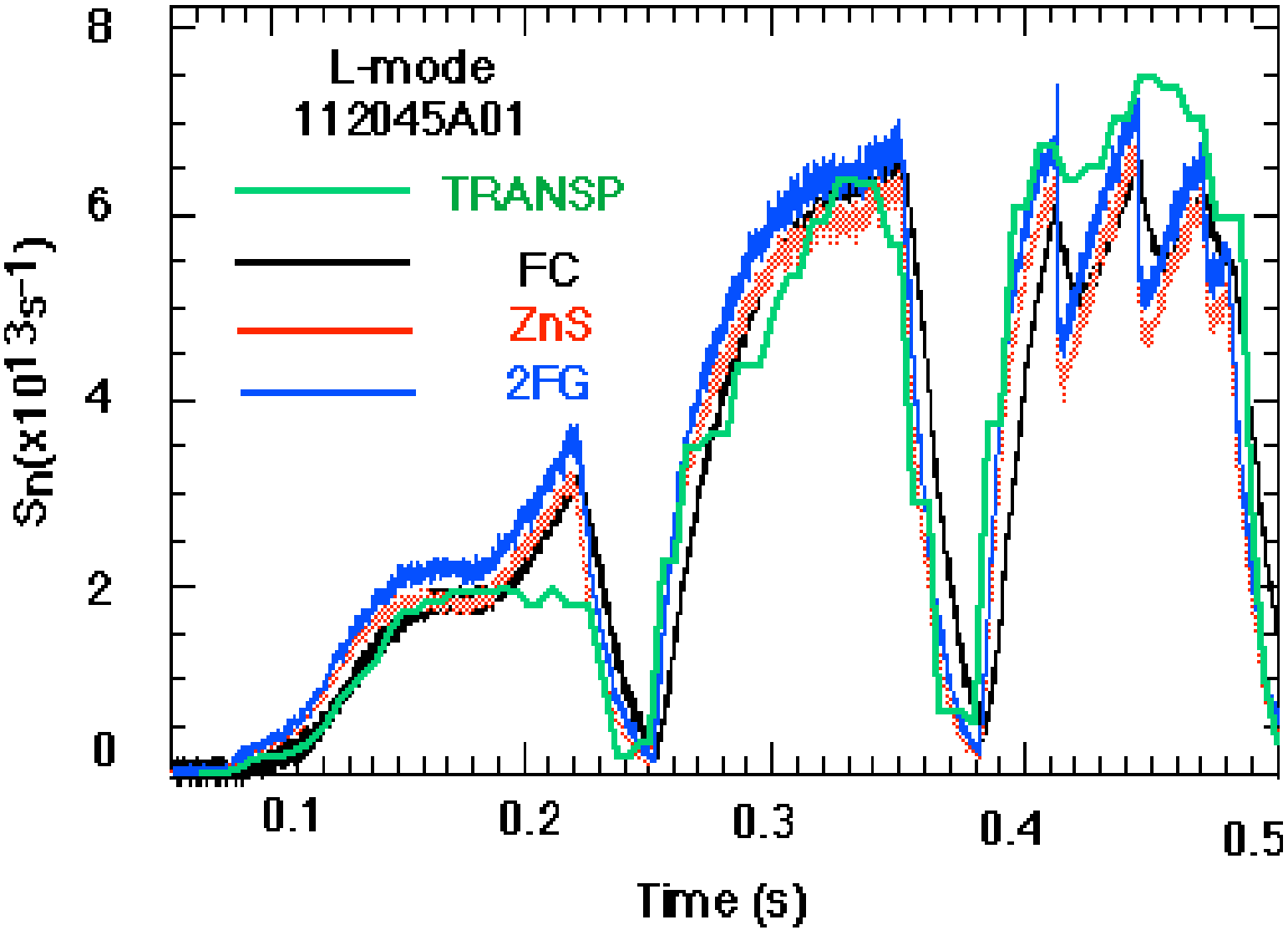
Parameter	Year (Shot Range)	FC1 - Fission Chamber	2FG Scintillator	1DE (ZnS) Scintillator
Detector Bias (V)	Early 2002 (107213-107670)	NA	(1008-960)	(1016)
	2002 (107671-109077)	NA	(945 ± 10)	(1017 ±1)
	2003 (109772-110186)	NA	(954 ± 4)	(1016 ± 2)
	2004 (111060-114475)	NA	(1013 ± 2)	(1005 ± 2)
	2005 (115674 -)	NA	1060 (1008)	850 (804)
Calibration Factor (n/s/Volt)	Early 2002 (107213-107670)	(7.6×10^{13})	($5.4\pm1.4\times10^{13}$)	
	2002 (107671-109077)	(9.0×10^{13}) $8.2\pm0.1\times10^{13}$ Offset=0.040v	($8.8\pm0.5\times10^{13}$) $12.2\pm0.70\times10^{13}$ Offset=0.082v	($1.2\pm0.2\times10^{13}$) $1.78\pm0.09\times10^{13}$ Offset=0.147v
	2003 (109772-110186)	$8.2\pm0.1\times10^{13}$ Offset=0.040v	$10.2\pm0.90\times10^{13}$ Offset=0.087v	$1.24\pm0.14\times10^{13}$ Offset=0.180v
	2004 (111060-114475)	$8.2\pm0.1\times10^{13}$ Offset=0.040v	$6.95\pm0.72\times10^{13}$ Offset=0.069v	$1.18\pm0.72\times10^{13}$ Offset=0.063v
	2005 (115674 -)	$8.2\pm0.1\times10^{13}$ Offset=0.040v	$7.23\pm0.36\times10^{13}$ Offset=0.063v	$7.61\pm0.07\times10^{13}$ Offset=0.095v

- **Bracketed quantities are old values.**
- **The new procedure for correcting the raw neutron waveforms subtracts the voltage offset first: e.g.**

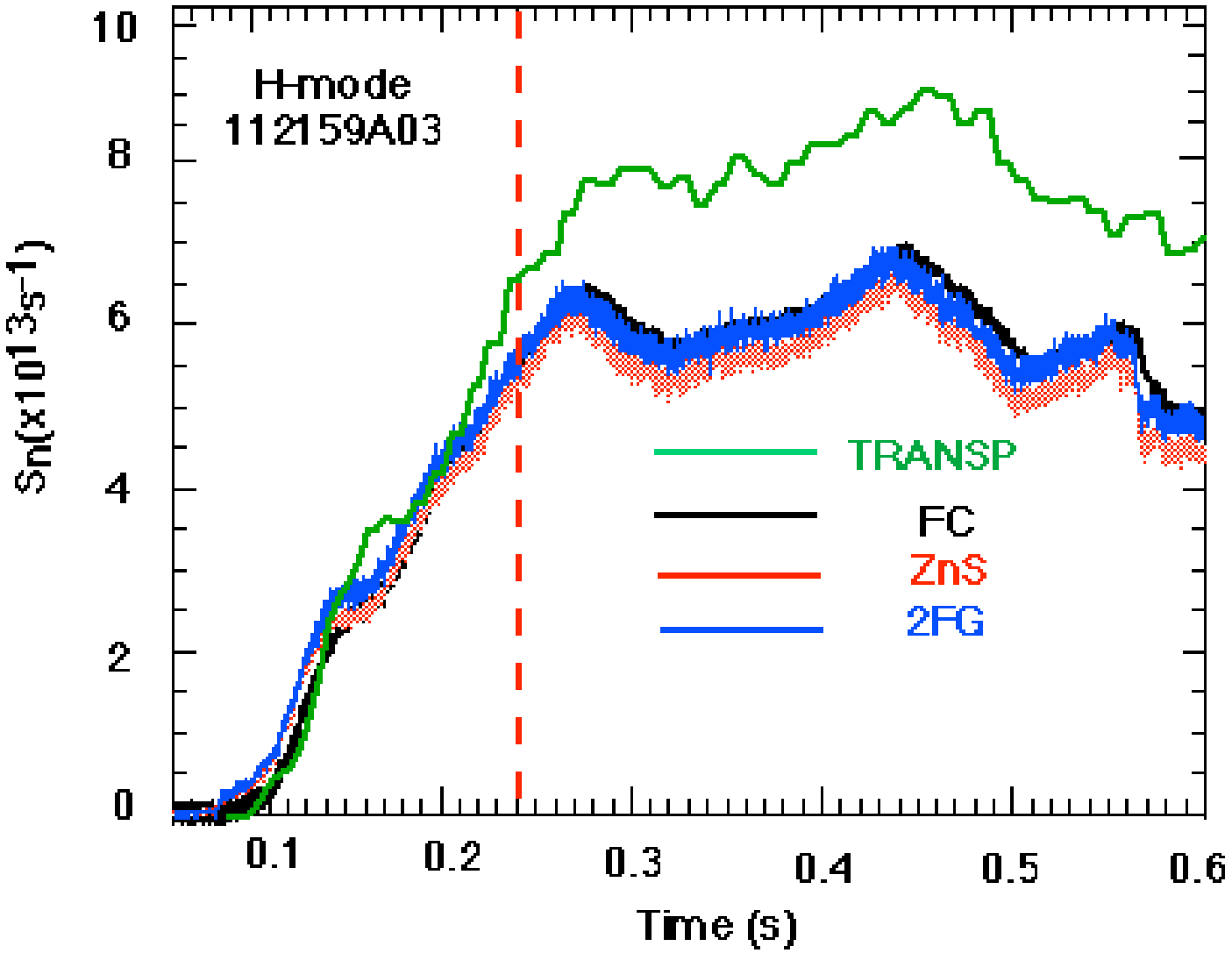
(\NEUT_FLUCT_SLW_2FG-0.063)*7.23e13

- **Calibrations errors are maximum variations in the data set. RMS errors are ~ 1/3 of these values.**
- **Measured/calculated neutron rates for 2005 data with corrected CHERS Z_{eff} will be studied to assess the L-mode normalization step.**

Measured/Calculated Neutron Rates for a 2004 L-mode Discharge



Measured/Calculated Neutron Rates for a 2004 H-mode Discharge



Conclusions

- The plastic scintillator neutron measurements have changed over time, occasionally inexplicably.
  - due to changes in the bias voltages

- Neutron measurements amongst the detectors in the suite do not agree.
  - resolved by new cross calibration procedure

- Neutron measurements do not agree with TRANSP-calculated neutron rates.
  - agreement enforced in L-mode by normalization
  - will be further examined for 2005 L-mode plasmas

S. S. Medley, D. S. Darrow and A. L. Roquemore, "Reconciliation of Measured and TRANSP-calculated Neutron Emission Rates in the National Spherical Torus Experiment," PPPL-4080 (June, 2005)