Absolute Calibration of the NSTX neutron Monitoring System

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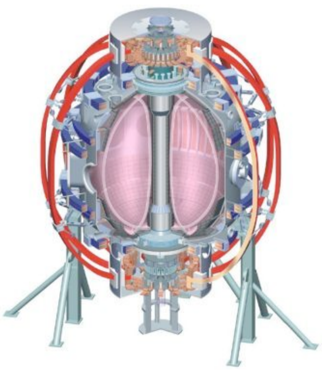

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Abstract

- NSTX has a complement of six neutron detectors consisting of two fission chambers, one NE-451 ZnS scintillator and 3 plastic BC-400 scintillators. The primary purpose of the fission chambers is to provide an absolute calibration of the neutron emission rate, while the scintillator detectors monitor fast excursions in the neutron yield, due for instance to MHD events. Initially, a point-wise calibration was performed by introducing a ^{252}Cf source on the midplane of NSTX at 10 toroidal locations. The more recent calibrations employed a commercial G-gauge model train and three different diameter circular tracks as a source transport. This method provided the most accurate calibration to date, as well as information on detector sensitivity with changes in plasma position. The results of the four *insitu* calibrations are presented and the technique of cross-calibration from pulse counting to current mode using low-yield plasma discharges will be discussed.

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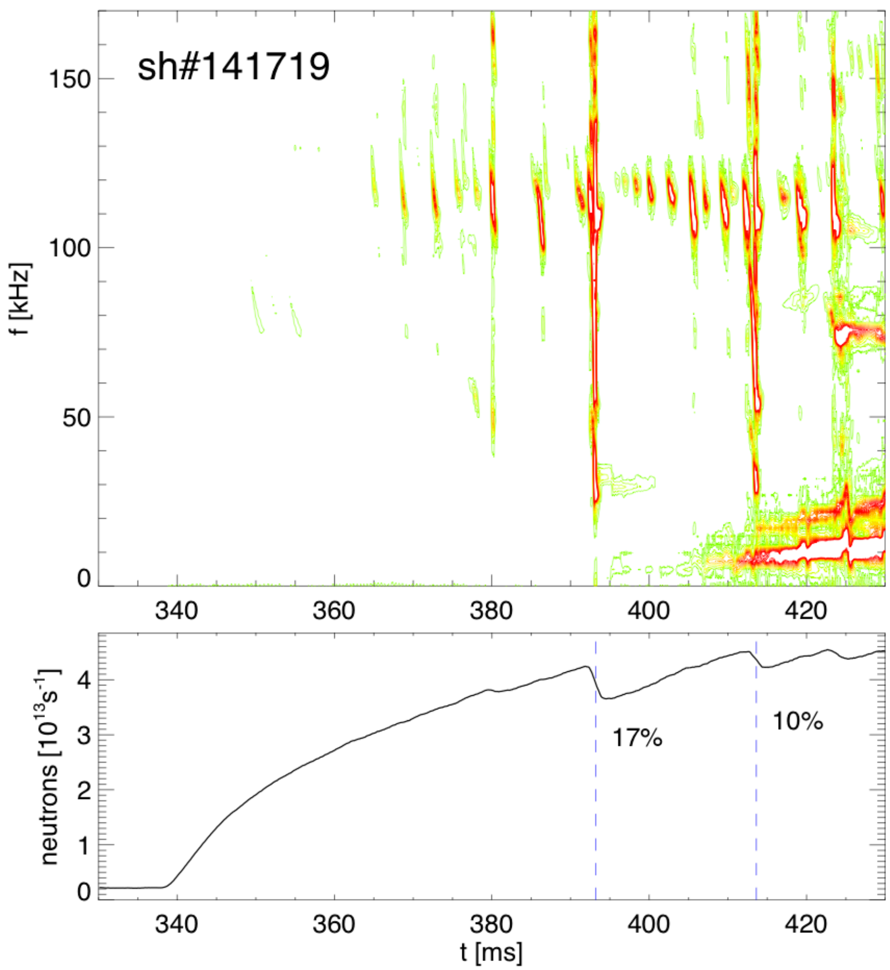
Motivation

Avalanche with beam ion loss



Darrow PP9.00053 This session

- Neutron yield is a benchmark for TRANSP
- Sensitive measure of fast ion behavior
- Measure of impurity concentration in the core

Californium source issues

Calibration Date	Years since assay	Cf-252 n/s	Cf-250 n/s	Tot neut/sec	ratio 252/250	250/252	neut/count
30-May-00	7.411	3.371E+07	4.065E+06	3.778E+07	8.29	0.12	
19-Nov-01	8.8849	2.291E+07	3.760E+06	2.667E+07	6.09	0.16	2.54E+08
22-Oct-03	10.808	1.385E+07	3.390E+06	1.724E+07	4.09	0.24	
13-Aug-04	11.616	1.120E+07	3.253E+06	1.445E+07	3.44	0.29	
3-Dec-09	16.926	2.780E+06	2.455E+06	5.235E+06	1.13	0.88	2.41E+08
19-Feb-11	18.137	2.028E+06	2.303E+06	4.331E+06	0.88	1.14	2.25E+08

Original assay of Cf source was in 1992
Source strength ^{252}Cf = 2.35 E 8 n/sec   Half life =2. 645 years
Source strength ^{250}Cf = 6.02 6 n/s   Half life =13.06 years.

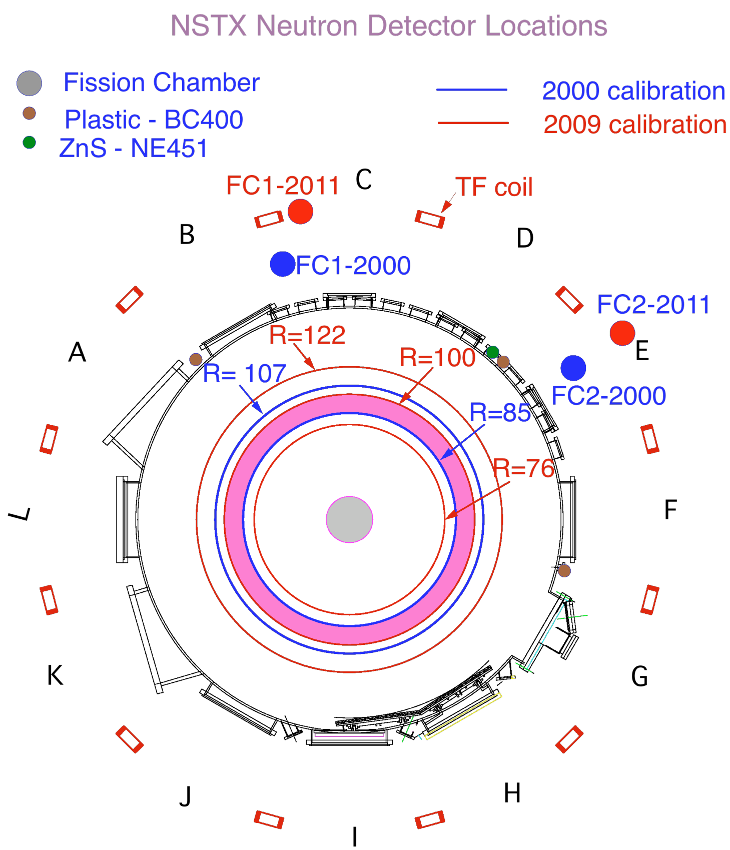
^{250}Cf component was initially ignored.

After 7 half-lives, the ^{250}Cf became the dominant source component.

When the detectors were relocated, the calibration was repeated and did not match expectations since only the 252 component was considered. Darrow found original assay results and discovered the importance of the ^{250}Cf component.
Calibration now agrees with that of 2001.

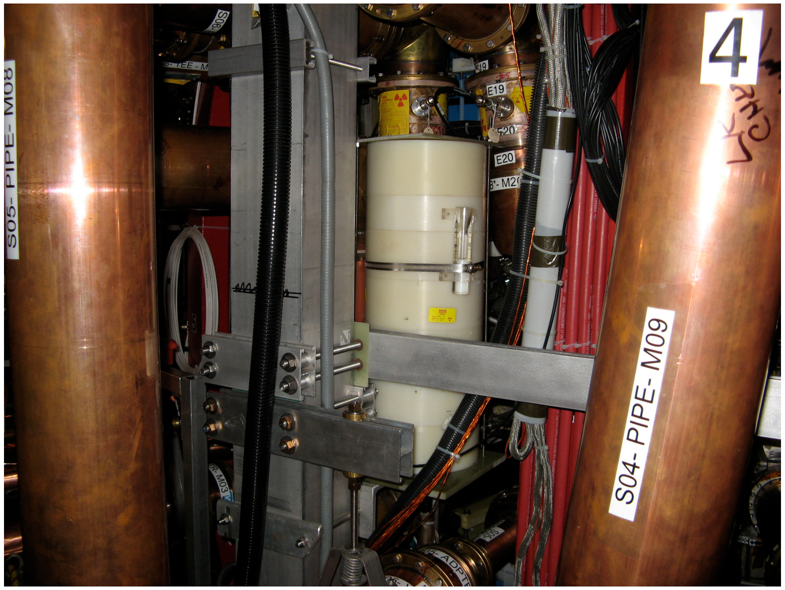
2001 data was recalculated and found to be off by ~10%

Detector Locations before/after Relocation

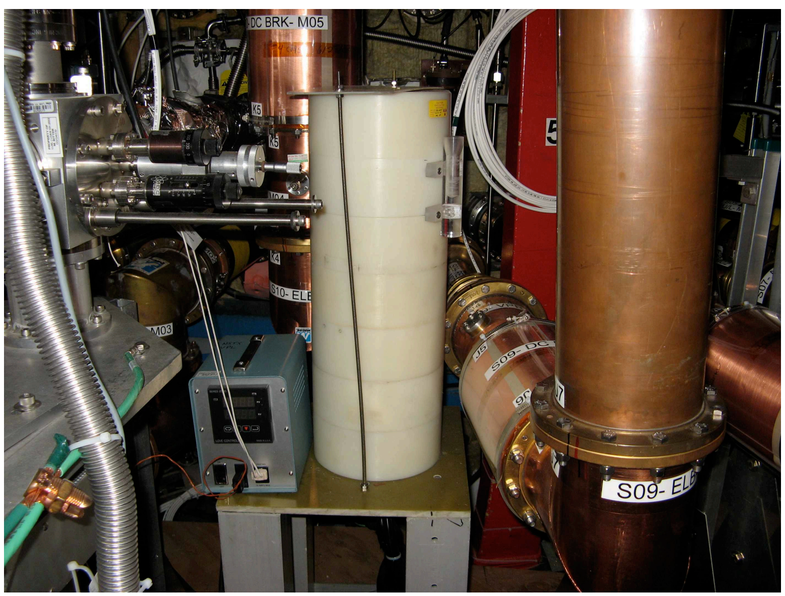


Detectors were relocated outboard by ~ 45 cm to make room for the RF waveguides.

Fission Chambers

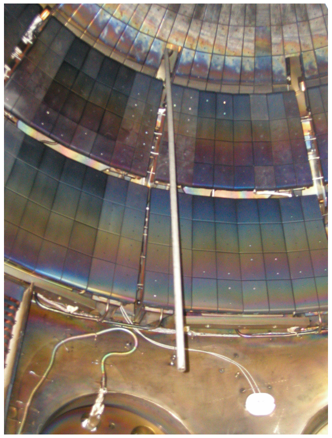


NE1 (after relocation)
Both Detector encased
in 7cm thick polyethylene



NE2 (after relocation)
Note the TF coil in front
of the detector accounting for
most of the drop in sensitivity.

Discrete Calibration Points in Dec 2001

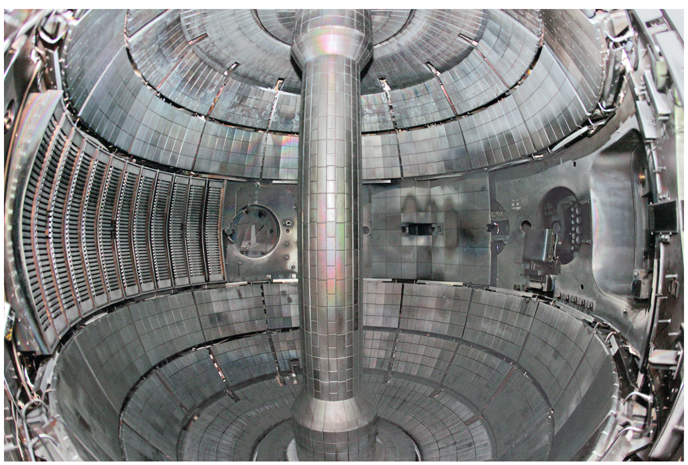


•Thin–walled tube lowered straight down at R=107cm. Similar angled tube inserted for R=85cm.

•Special angled tube was lowered in each port to provide R=85 cm calibration point.

•Bay A and L were blocked off and not available.

•Total of 10 locations were used



Model train as source transport

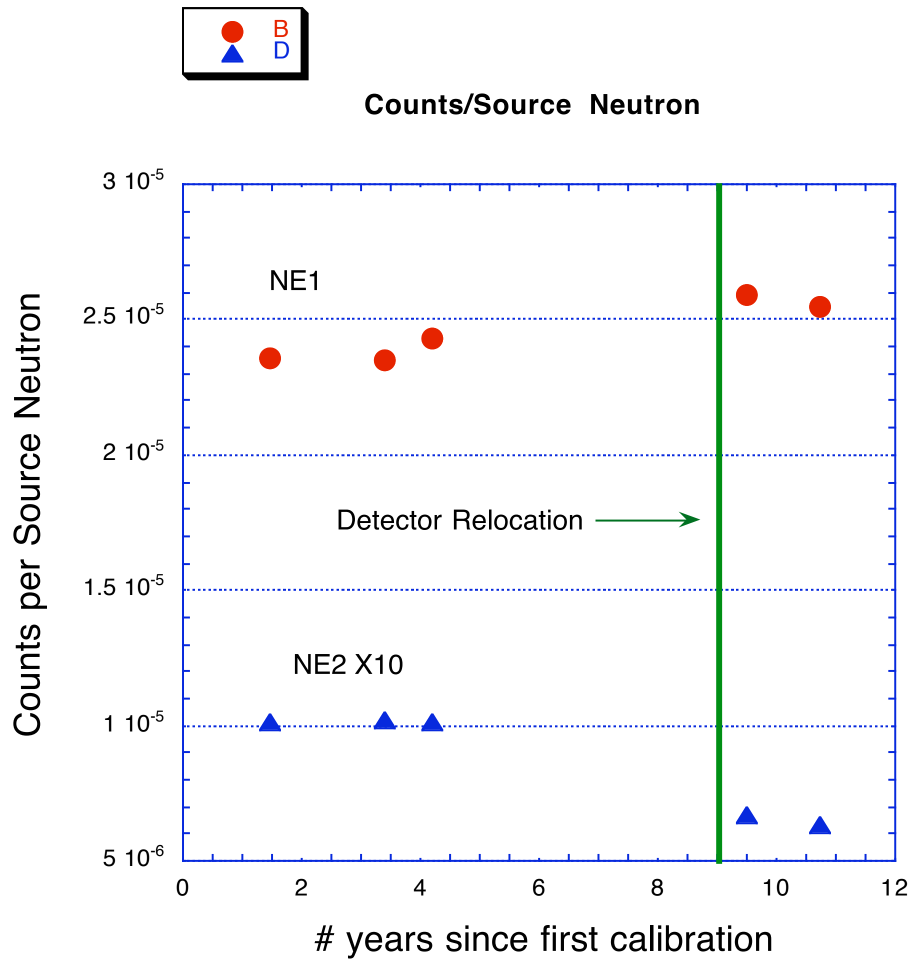
Model train employed as source mechanism transport. G-guage

•Three different track diameters were utilized, 152 cm, 200 cm, and 244 cm. 200 cm track was raised and lowered about midplane by ± 30 cm.

•Train was operated up to 58 hours continuously at a speed of 1 mph.

•Each revolution took 14 seconds, No change in time/revolution noted after 58 hours.
Model train closely mimics a ring source and makes it unnecessary to do the integral of counts.

Detector Stability

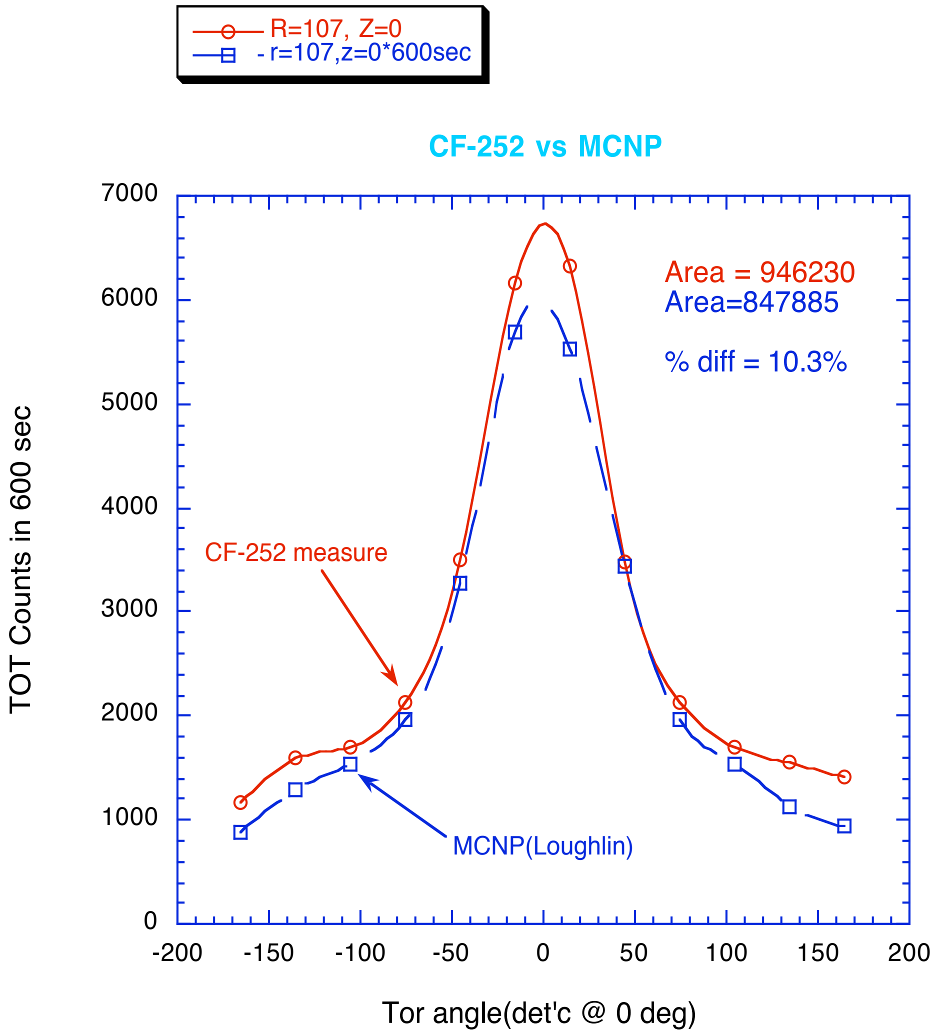


•Frequent Renormalizations measure the fission chamber stability.

•In 2009, both detectors were relocated to make room for new equipment.

•Both chambers are wedged among RF antennas.
The sensitivity changed with relocations.

MCNP

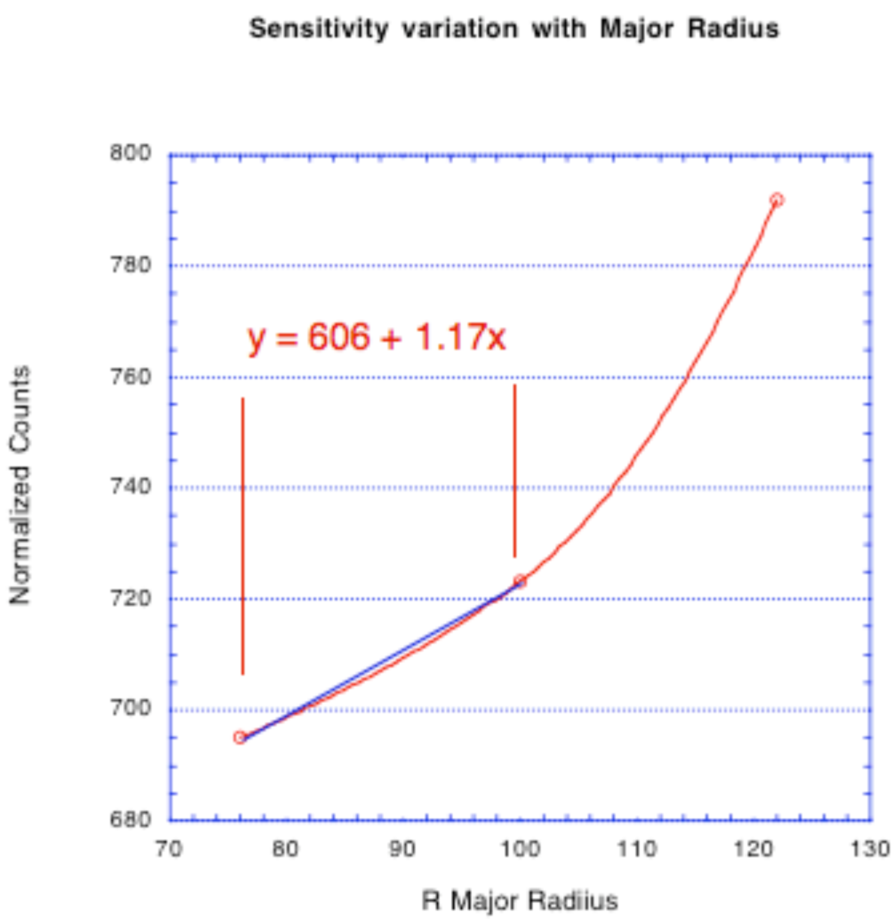


Calibration factor Neut/Count

Tot source neut * duration of calibration/
Integral of counts*360 degrees

Result = 2.54×10^8 source neutrons/count

Sensitivity Variation with Plasma Major Radius



•Some dependence of Sensitivity with major radius.

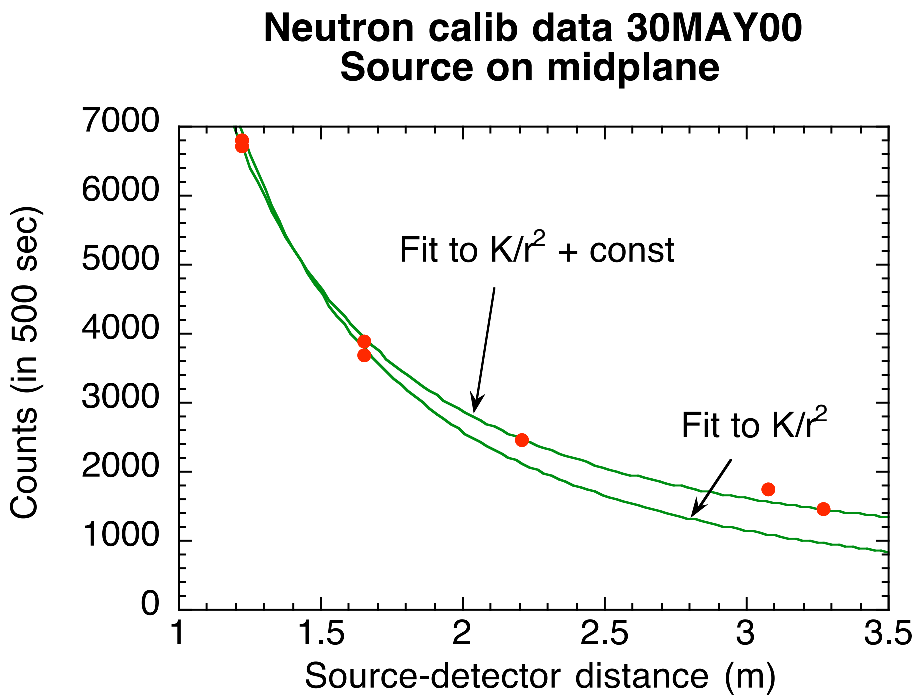
•Most NSTX plasmas have R =85-100 cm

•In this range the sensitivity varies by ~ 4%.

•A linear correction between R=76 -100cm is made to the data.

•A 12% change occurs from the inner and outer track count rates

Counting Variation with distance

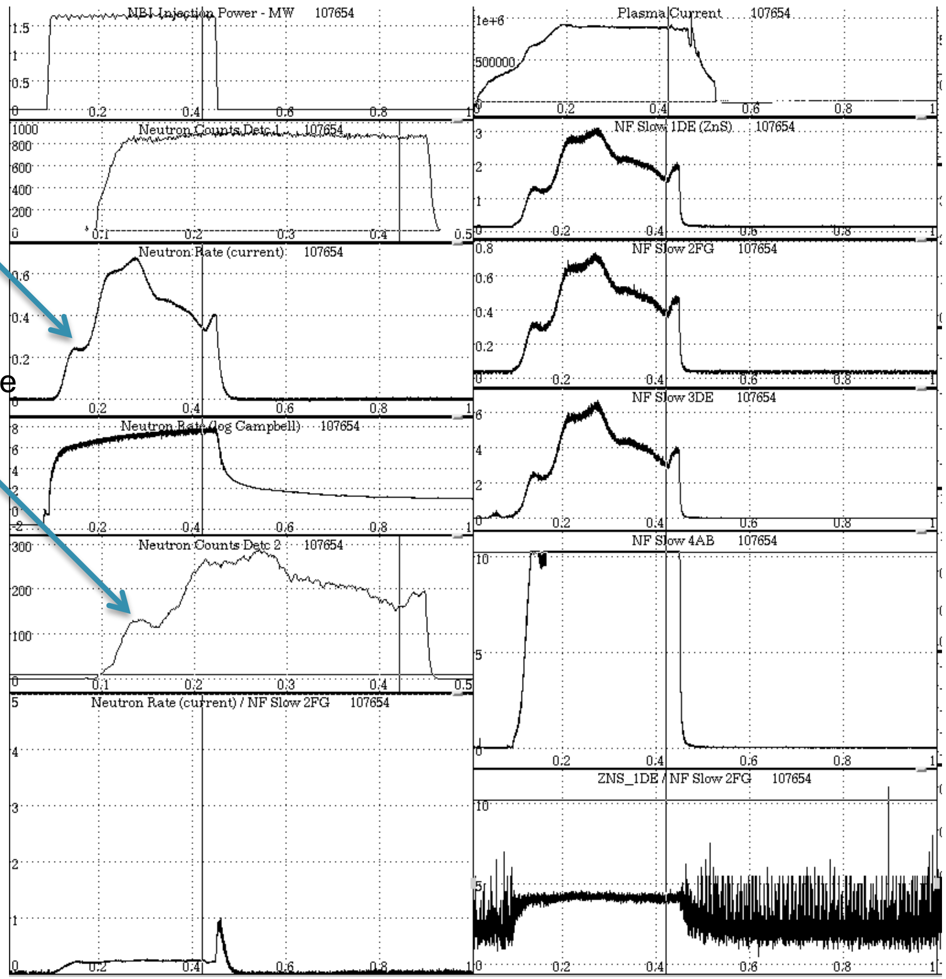


- Lower curve is a simple $1/r^2$ curve for the source to detector distance.
- By adding a constant factor to the $1/r^2$ data the data (red dots) can be reproduced.
- The constant is a measure of the scattered neutron component into the detector.

Calibration of NE1

NE1 Current Mode

NE2 Pulse Counting Mode



Calibration factor
2.25×10^8 neutrons / count
For NE2 detector

NE1 .246 volts

NE2 150 count/millisecond

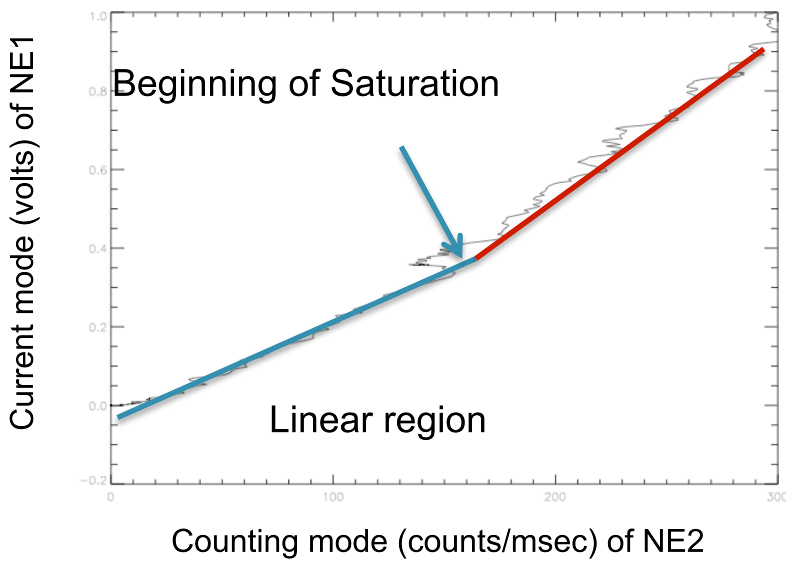
131c/ms*1000 ms/s*2.25 $\times 10^8$/ .246 Volts

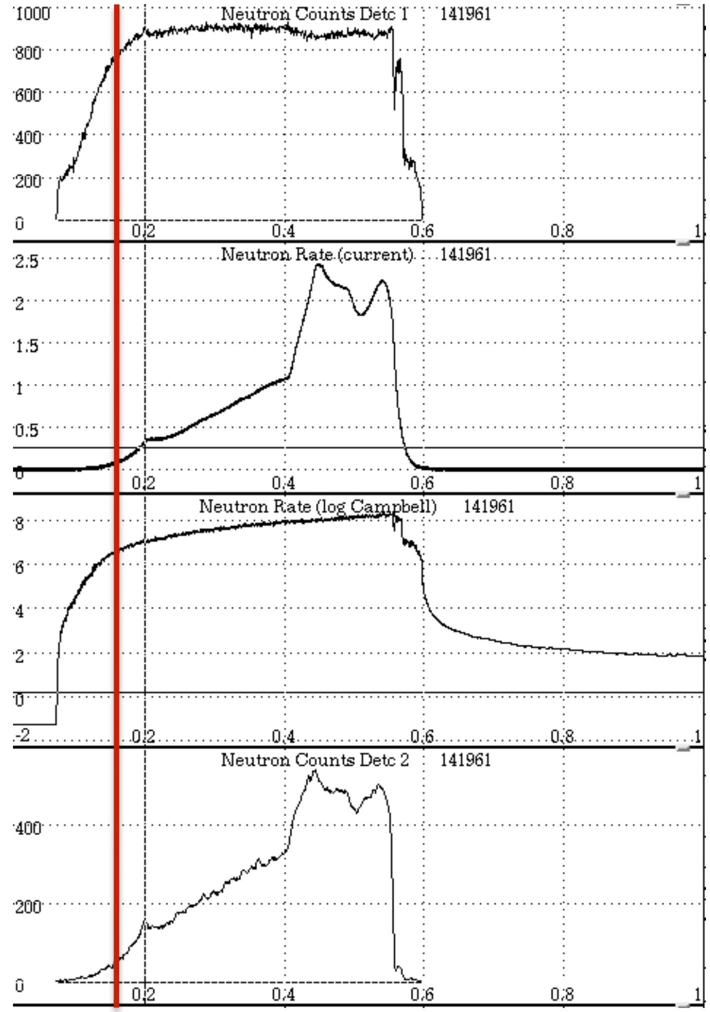
=1.2 $\times 10^{14}$ neutrons/volt.

Error of ± 13%

Pulse counting vs. Current signal

•The blue line is the "best" linear fitting region but still not a good linear match. The red lines shows the start of saturation in pulse counting mode for NE2.
•True linearity does not exist between pulse counting vs. Campbell mode, or current vs. Campbell mode.





Summary of Calibrations (after corrections for CF-250 contribution)

Detector	2000	2001	2009	2011
FC2 $X10^{11}$ (neut/count/s)	1.69	1.56	2.4	2.17
FC1 $X10^{13}$ (neut/V/sec)	8.6	8.9	9.7	8.8
Zns $X10^{13}$ (neut/V/sec)	1.9510	32	7.76	8.01
2FG $X10^{13}$ (neut/V/sec)	1.3	9	3.55	2.7

NOTE: Large changes in scintillator values are due problems with amplifiers.

Error Analysis

- Statistical counting errors 1.6%
- Scattering from transport mechanism 3% (measured)
- Extended vs. line source 3% (Calculated from MCNP)
- Cross-calibration errors NE2 to NE1 ±8%
- Cf source strength 2%
- Stability Errors 5%

- Error = Sqrt (1.6^2 + 3^2 +3^2 + 8^2 +2^2+5^2) = 10.6%

- Note: major error is in non-linearity between pulse counting of FE2 and current mode of current mode of FE1.

Summary

- Absolute neutron calibrations have occurred in NSTX since May 2000.
- Detector sensitivities have varied by as much as 40%, especially after relocation in 2009.
- Calibration values vary by only 10%.
- Accurate half-life calculations for Californium source require accounting for the ^{250}Cf component.
- Error analysis give absolute values with ± 15 %.
- Cross calibration values have count rates on NE2 to be 150 counts/ms to avoid saturation.
- Cross calibration between NE1 and the scintillator detectors requires values to be evaluated where the ratios are not changing rapidly.