CCFE CULHAM CENTRE FOR FUSION ENERGY

United Kingdom Atomic Energy Authority

The HRTS Density Discrepancies

Causal Analysis for JPN 80800 (c28b) – 87944 (c34)

18/10/2011 – 09/10/2014

and 87944 (c35) – 89485 (c36)

09/10/2014 –11/01/2016

H. Damm, J. Flanagan - 28/02/2022

EUROfusion

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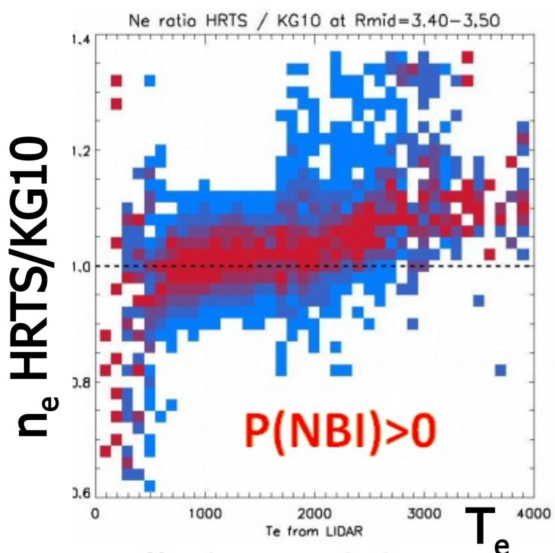
Motivation

80800 (c28b) – 87944 (c34)

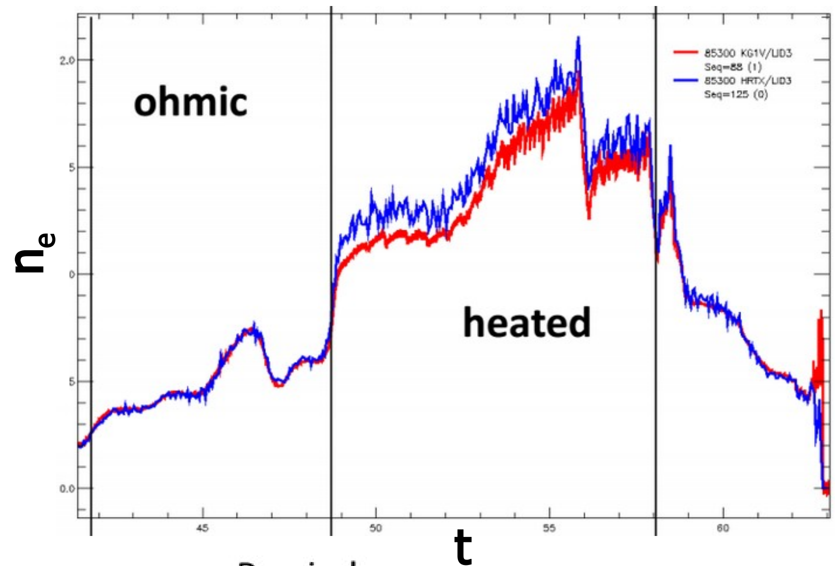
Consistency of T_e and n_e measurements in C31 presented by M. Maslov at DVCM 19.03.2014:

n_e(HRTS)/n_e(KG10) ?? with T_e



Difficult to conclude:
Less validated data points
(M. Maslov 1050 pulses = c31)

Now 8300 pulses analysed



Reminder:
HRTS is cross-calibrated to KG10 at the edge and to LIDAR in the core

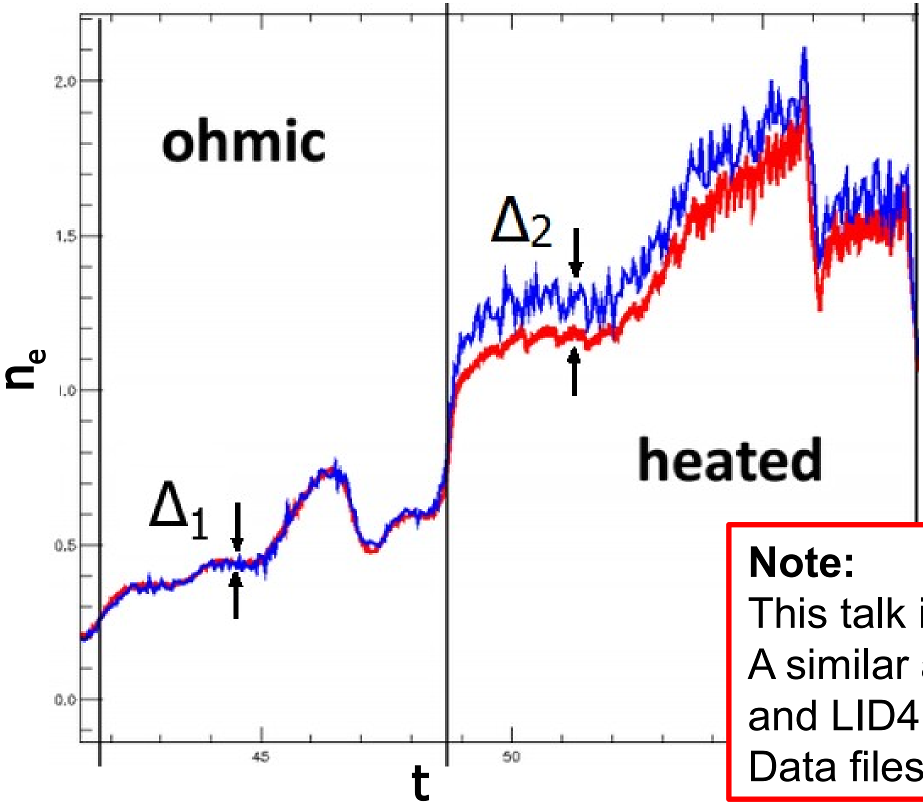
Absolute values adjusted to KG1V/LID3 per pulse, <u>outside heating phase</u>

The Density Discrepancy Δ

80800 (c28b) – 87944 (c34)

$= \langle \quad \rangle_t$

$= \langle \quad \rangle_t$



Density Discrepancy:

$$\Delta = \Delta_2 - \Delta_1$$

Note:
This talk is narrowed down to HRTS LID3 results.
A similar analysis was done for LID4 and LIDAR LID3 and LID4. Results might be shown at a later date.
Data files available at: hdamm\home\PycharmProjects\...

Analysed Physical Parameters

For NBI on and NBI off

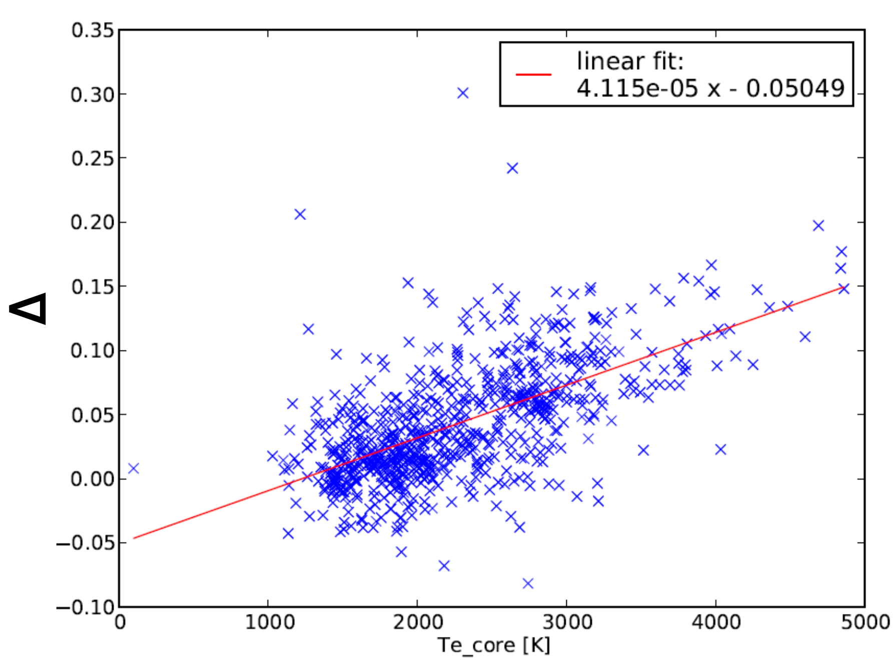
n

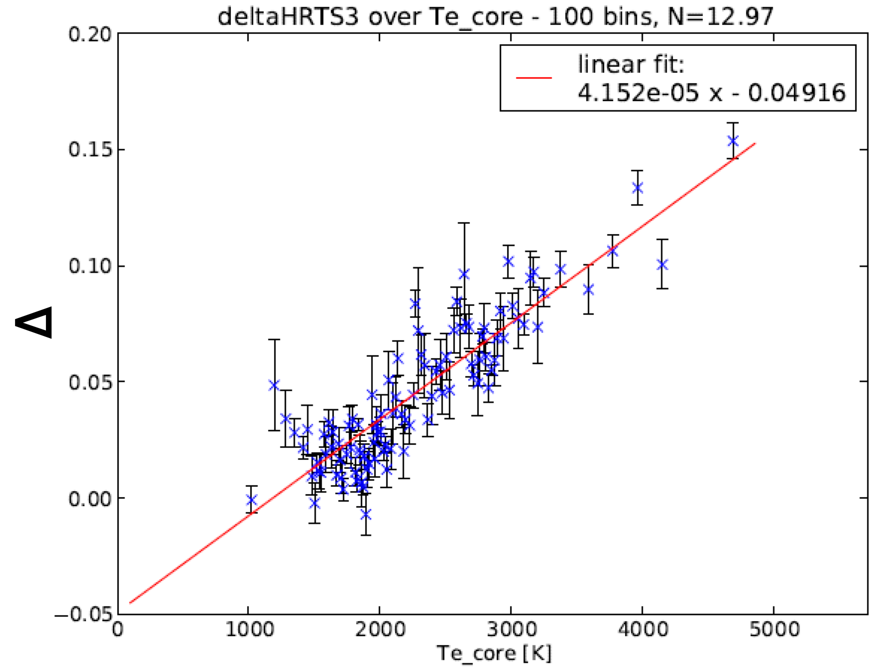
→ P,ß,T(n,p) because people expecting some dependency in H-Mode
→ ROG out of curiosity

Electron Core Temperature T_0

80800 (c28b) – 87944 (c34)

We found a relation between Δ and T_0 (Te_core in the plots)





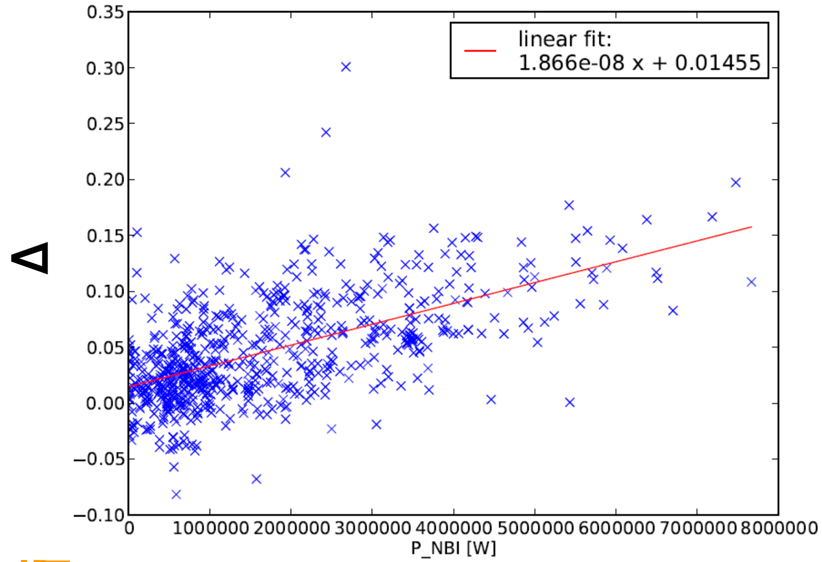
...which seems to be consistent.

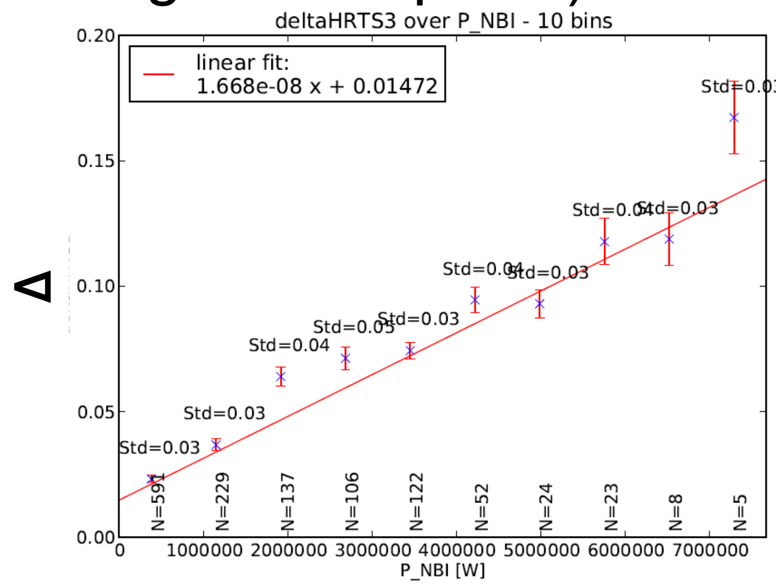
→ consistency supports the theory of a calibration error

NBI Heating Power P_{NBI}

80800 (c28b) – 87944 (c34)

similar behaviour for Δ and P_{NBI} (averaged over pulse)

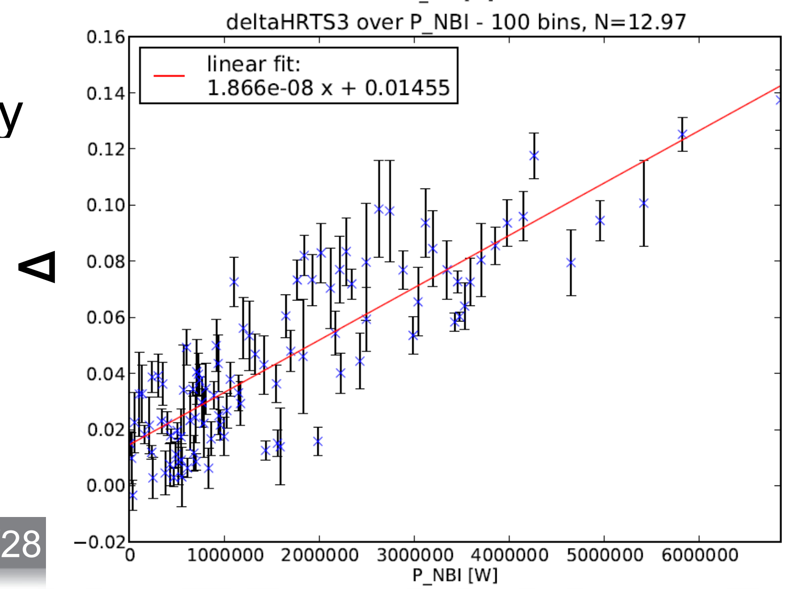




BUT:

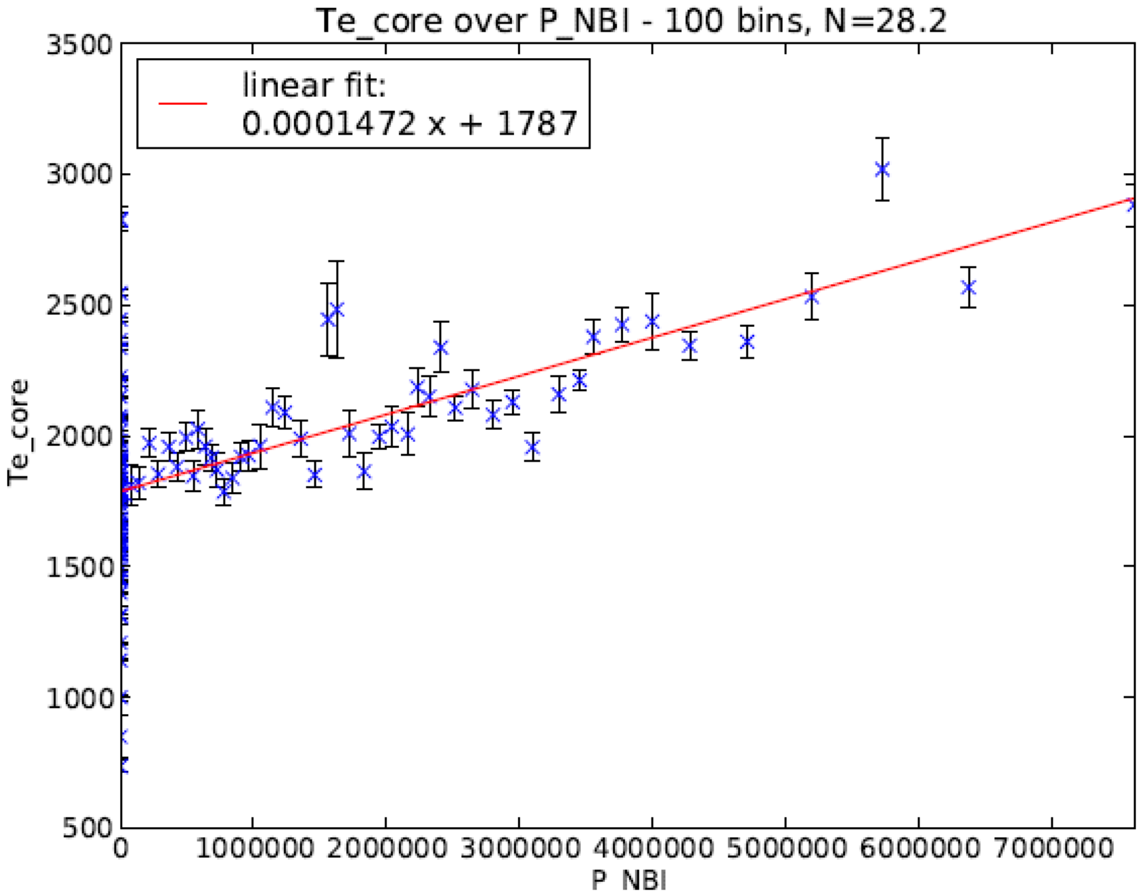
- T_0 and heating power P obviously (non-linear/linear?) related
- not just NBI-heating heats up the plasma!

→ **analyse of other heating sources on later slides**



T_0 and P_{NBI}

- slope Δ - P_{NBI} Plot / Δ-T_0 Plot slope ≈ 10^{-4}:



→ Relations between Δ, P_{NBI} and T_0 seem to be linear

T_0 and P_{NBI} & Evolution of Δ over JPN

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80800 (c28b) – 87944 (c34)

Linear relation between Δ, P_{NBI} and T_0:

- continue with analysis of P because „direct controllable“ variable

→T is not direct controllable, but depends direct on P

- additionally, effect first seen when $P_{NBI}>0$

→P_{NBI} for analysis of 80800 (c28b) – 87944 (c34)

Evolution of Δ over JPN:

- more recent pulses (87944) seemed to have less Δ but in general Δ increased over JPN

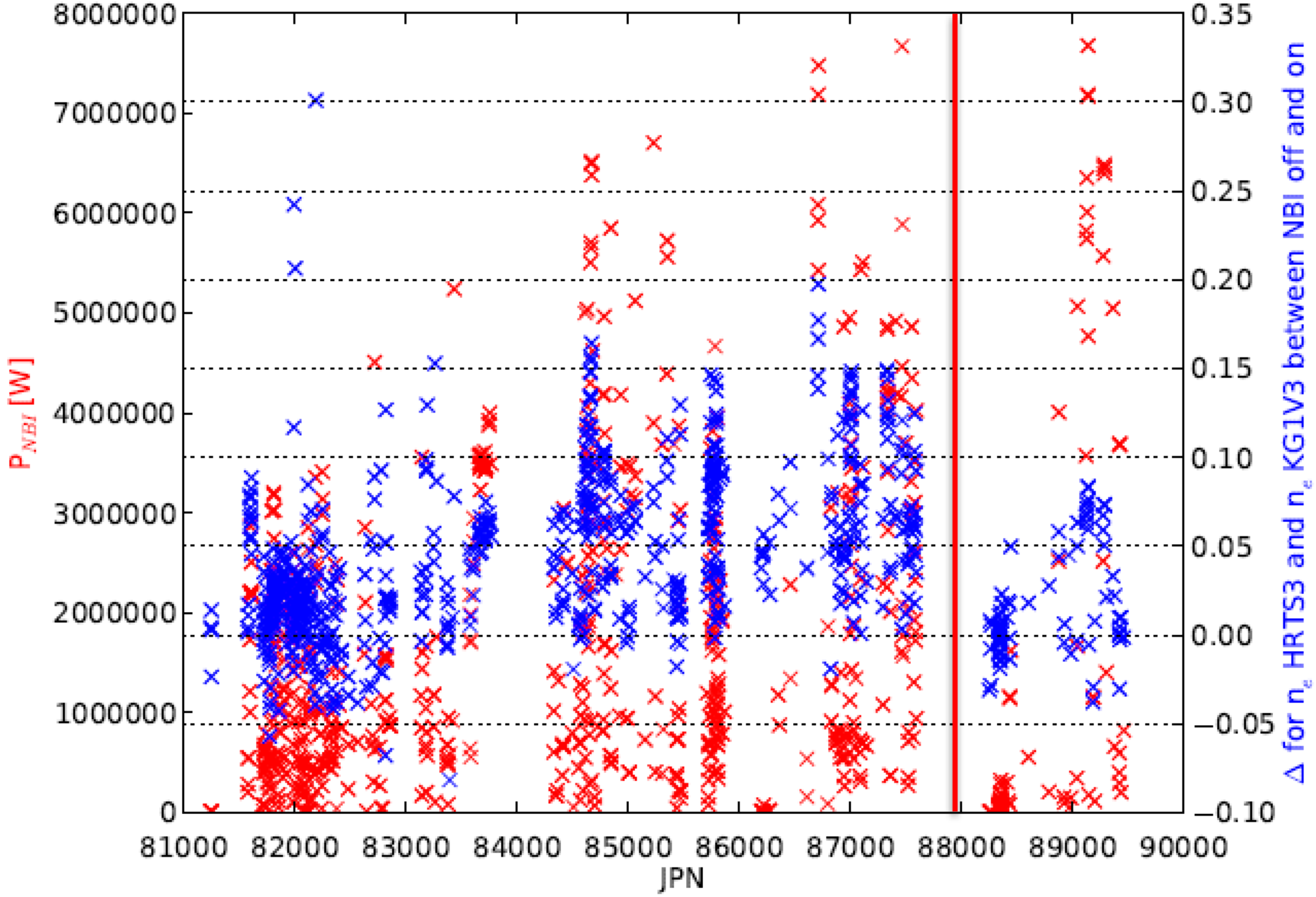
→ plot Δ over JPN

(dataset begins at 2010 Torus Hall Optics calibration)

Evolution of Δ over JPN

80800 (c28b) – 89485 (c36)

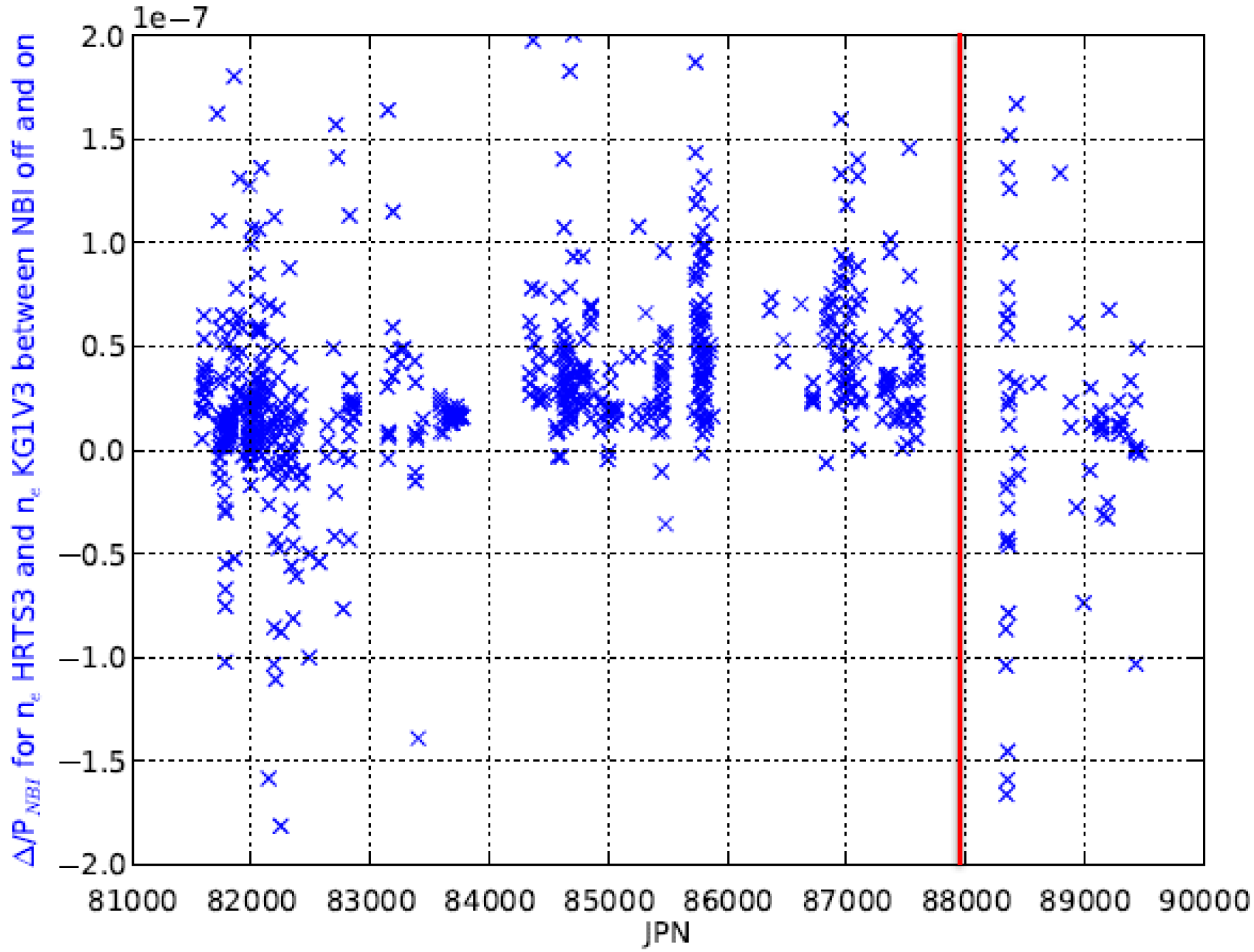
- decalibration (dirt?) over time → Δ increases
- much better since 2015 calibration after JPN 87944 (red line)



Power normalised Δ

80800 (c28b) – 89485 (c36)

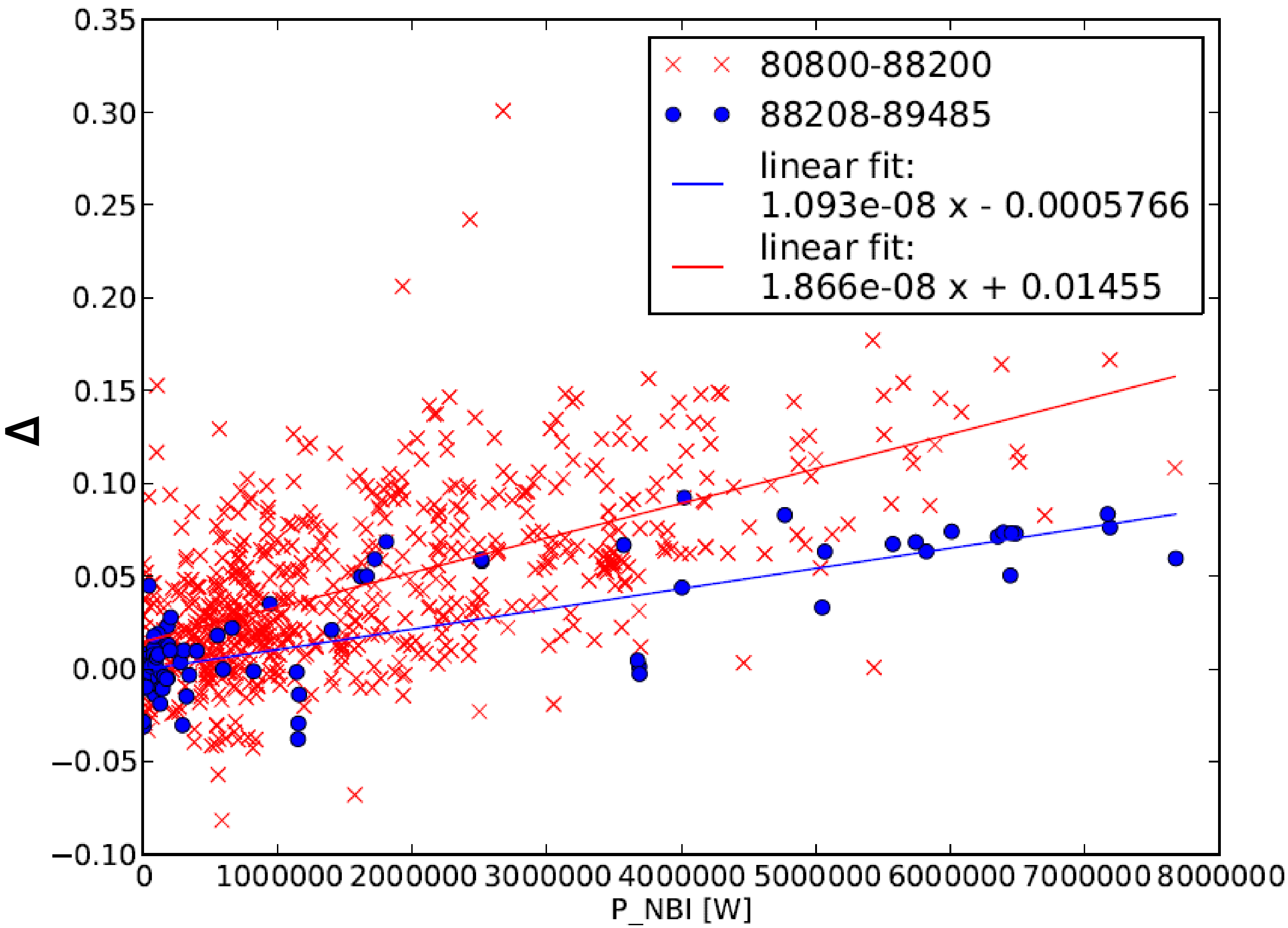
- Δ/P_{NBI} much smaller after 2015 Torus Hall optics calibration



Old and New Data Discrepancy NBI

80800 (c28b) – 89485 (c36)

- (pre-87944 slope) = 1.7 x (post-87944 slope):

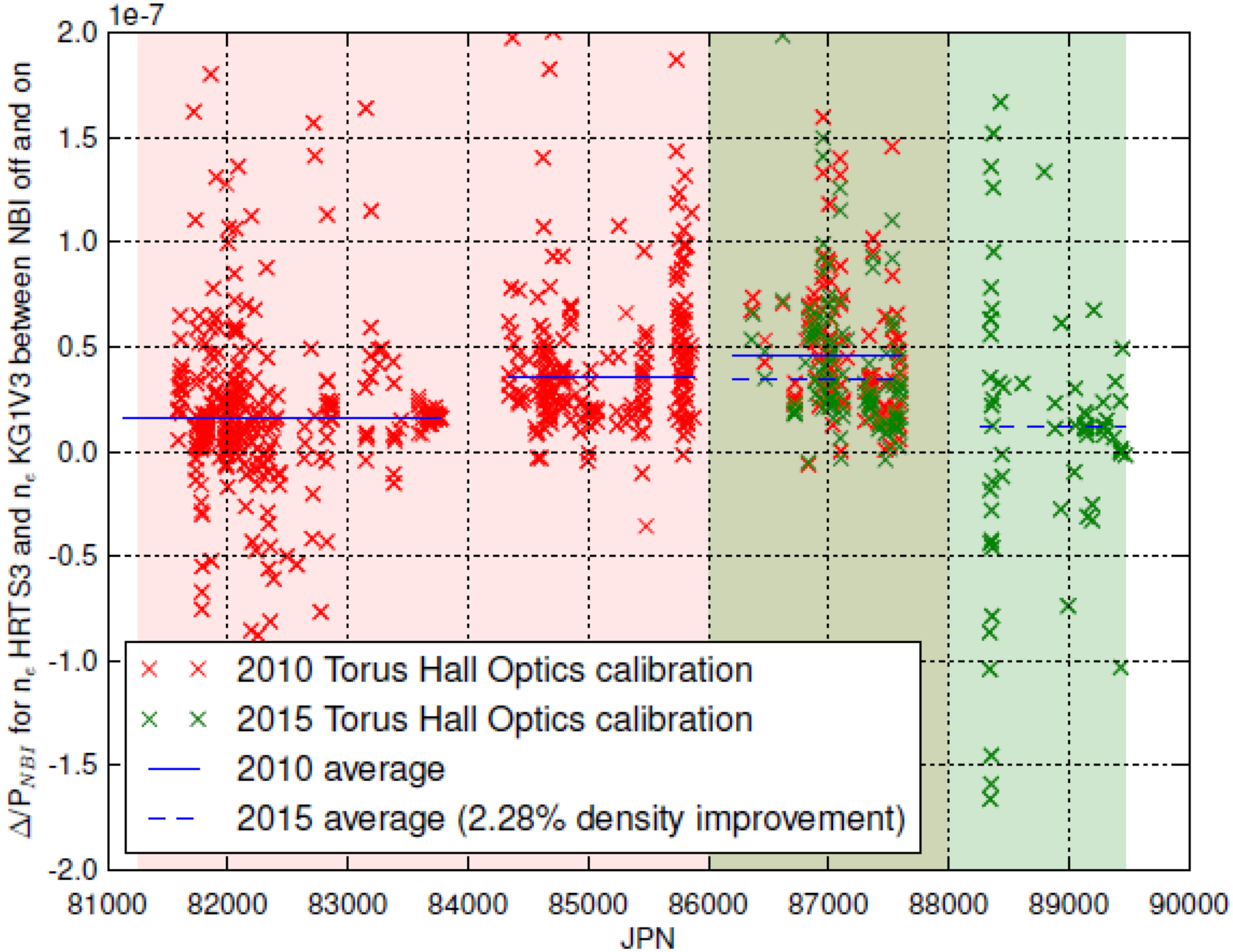


Suggested Recalibration NBI

80800 (c28b) – 89485 (c36)

- recalibration of JPN 86000 – 87944:

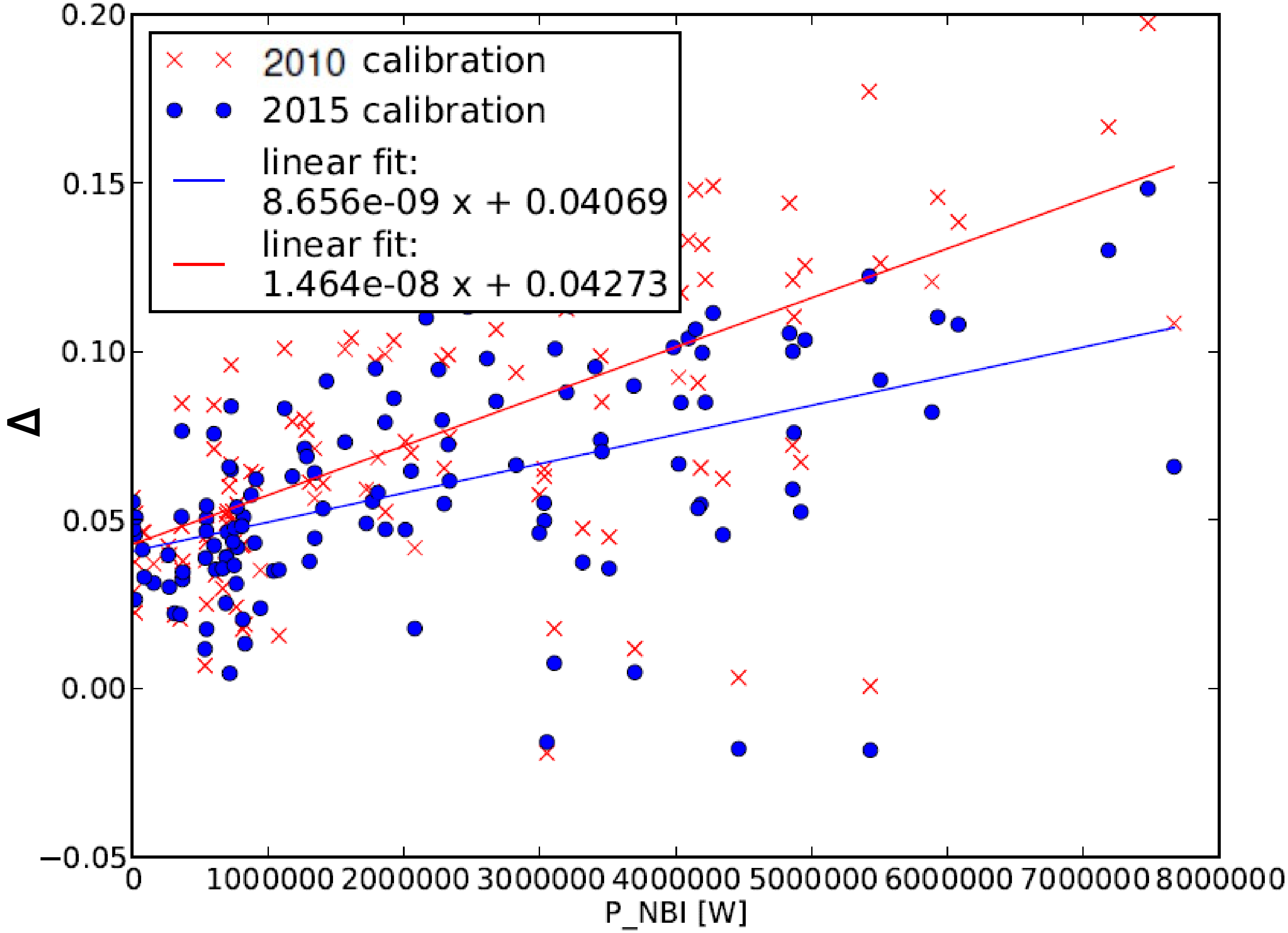
→ from 8.96% to 5.68% n_e HRTS discrepancy from n_e KG1V (no effect for NBI off!)



Suggested Recalibration NBI

80800 (c28b) – 89485 (c36)

- Δ for NBI 86000-87944 with old and new calibration



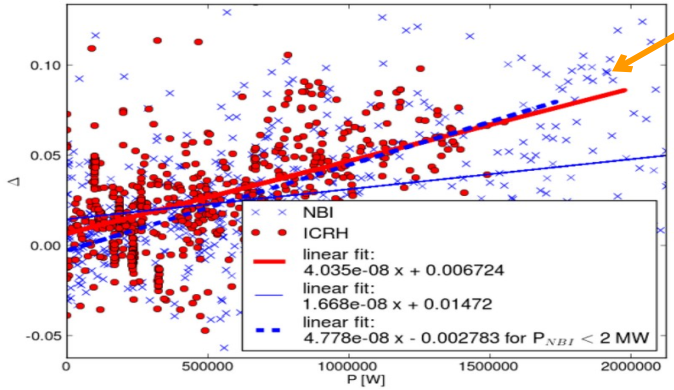
If it was just calibrational…

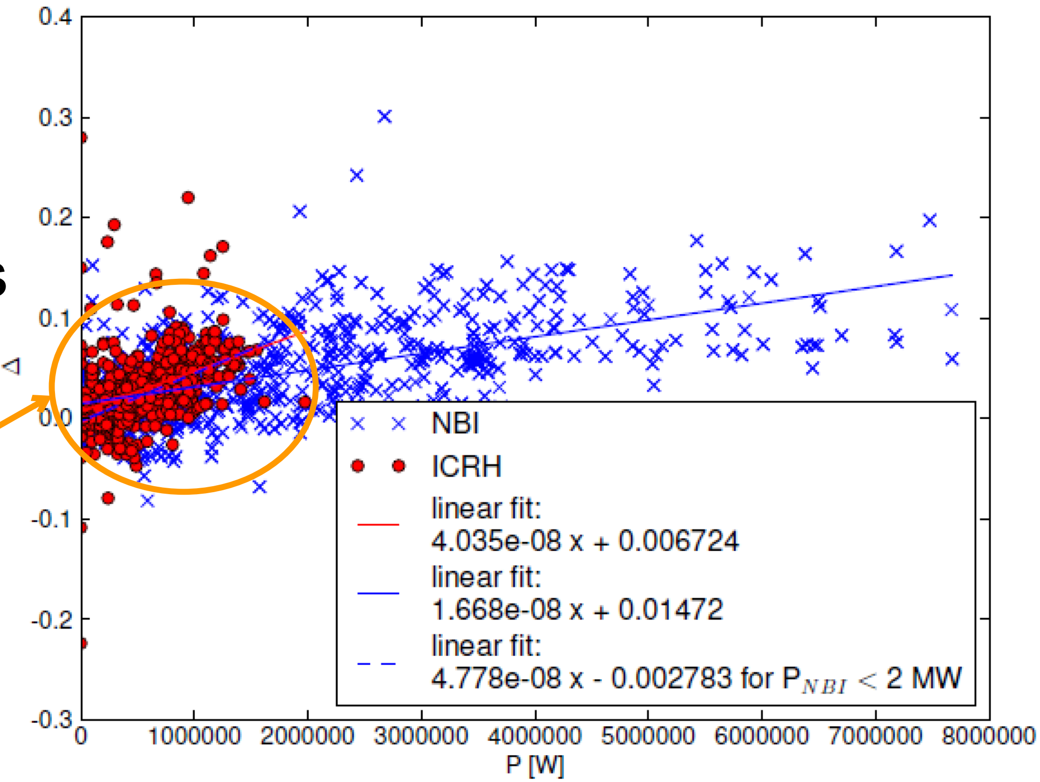
80800 (c28b) – 89485 (c36)

… similar behaviour for all other sources would be expected.

→ analogue findings for ICRH (LHCD, OHM to less data)!

→ slope approx. the same for P_{NBI} < 2MW but minor general effect due to less available heating power



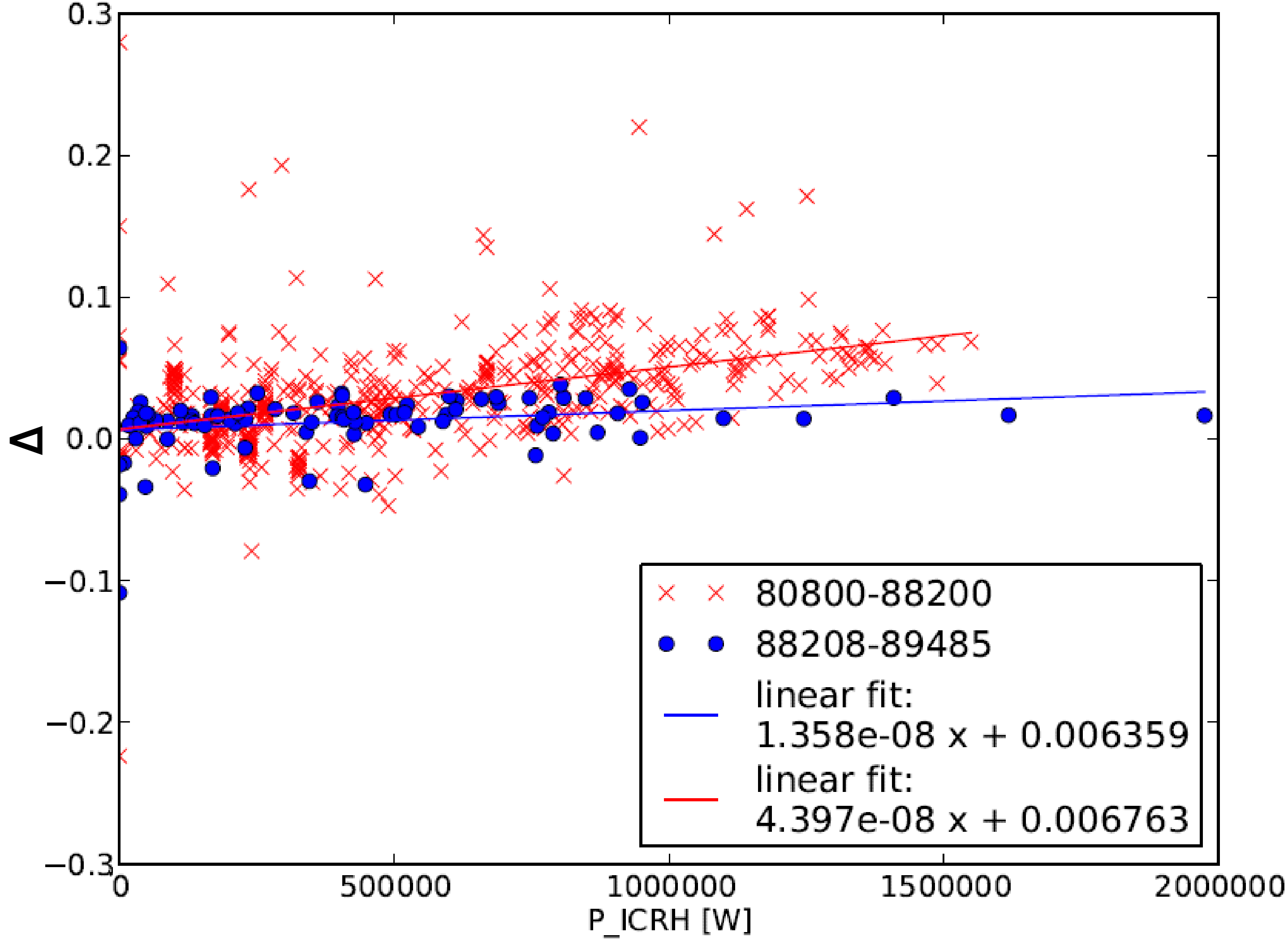


→ very likely the reason why Δ was first seen for NBI and assumed as pure NBI effect

Old and New Data Discrepancy ICRH

80800 (c28b) – 89485 (c36)

- (pre-88000 slope) = 3.2 x (post-88000 slope)

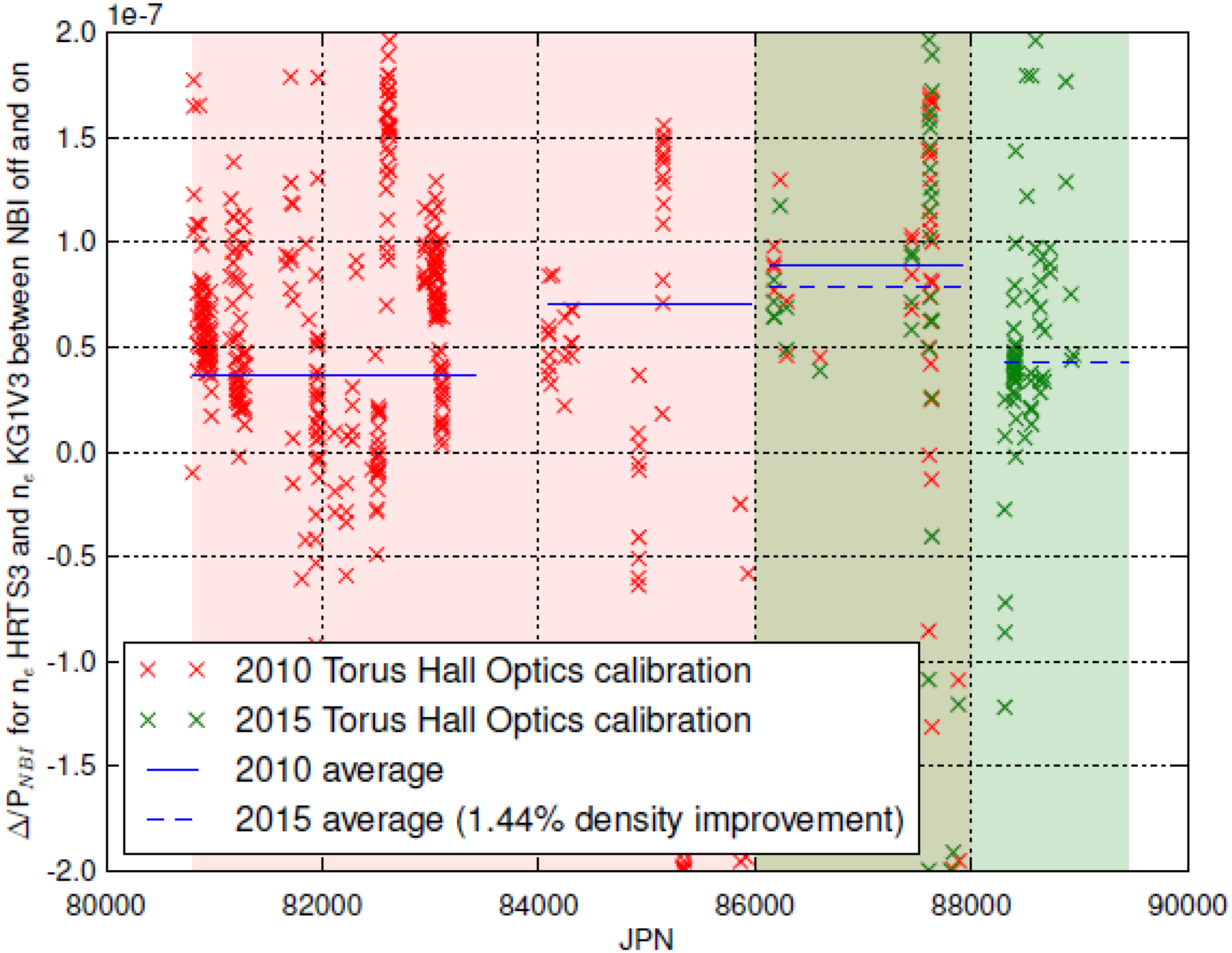


Suggested Recalibration ICRH

80800 (c28b) – 89485 (c36)

- recalibration of JPN 86000 – 88000:

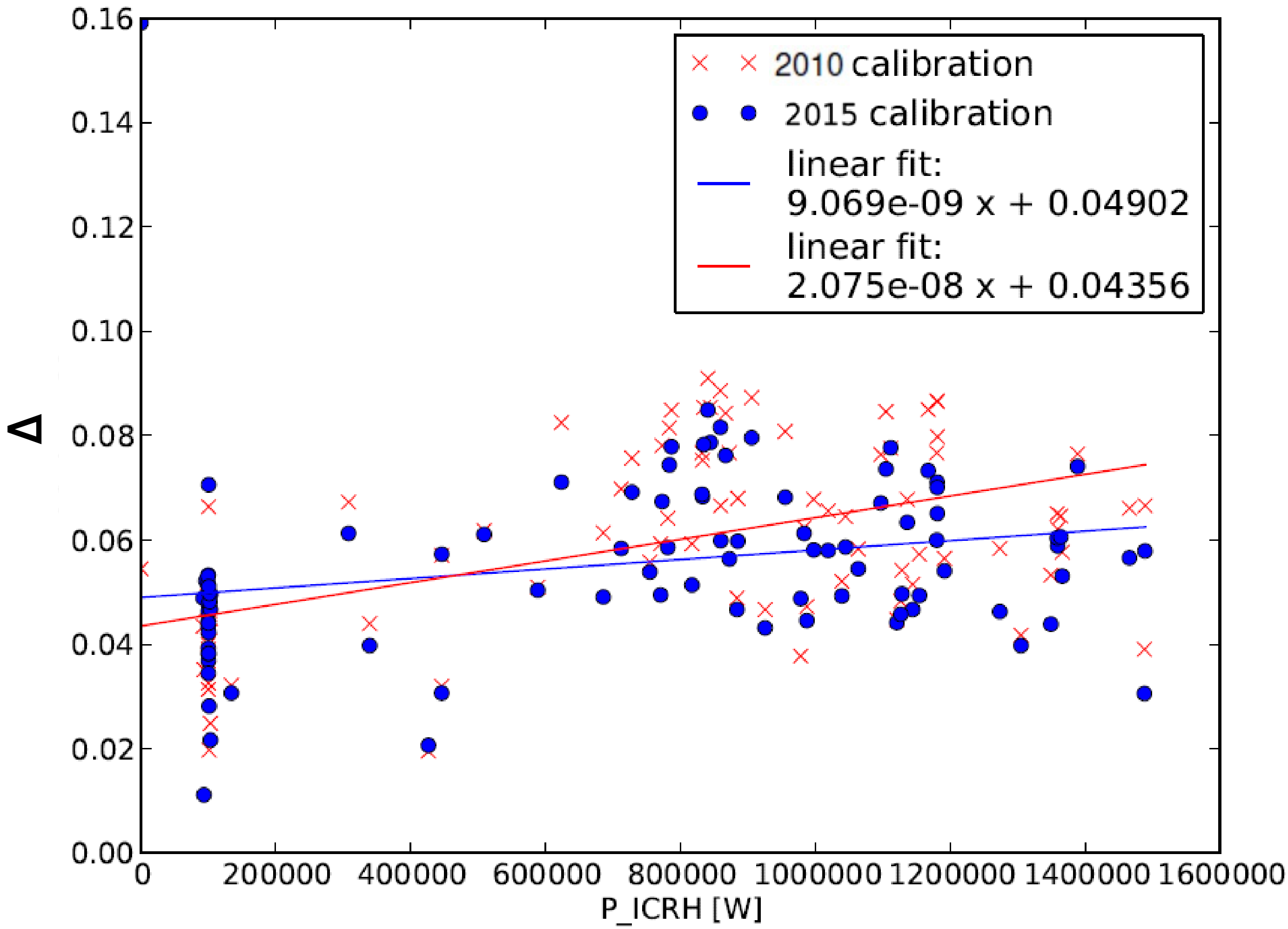
→ after all 1,44% improvement for ICRH



Suggested Recalibration NBI

80800 (c28b) – 89485 (c36)

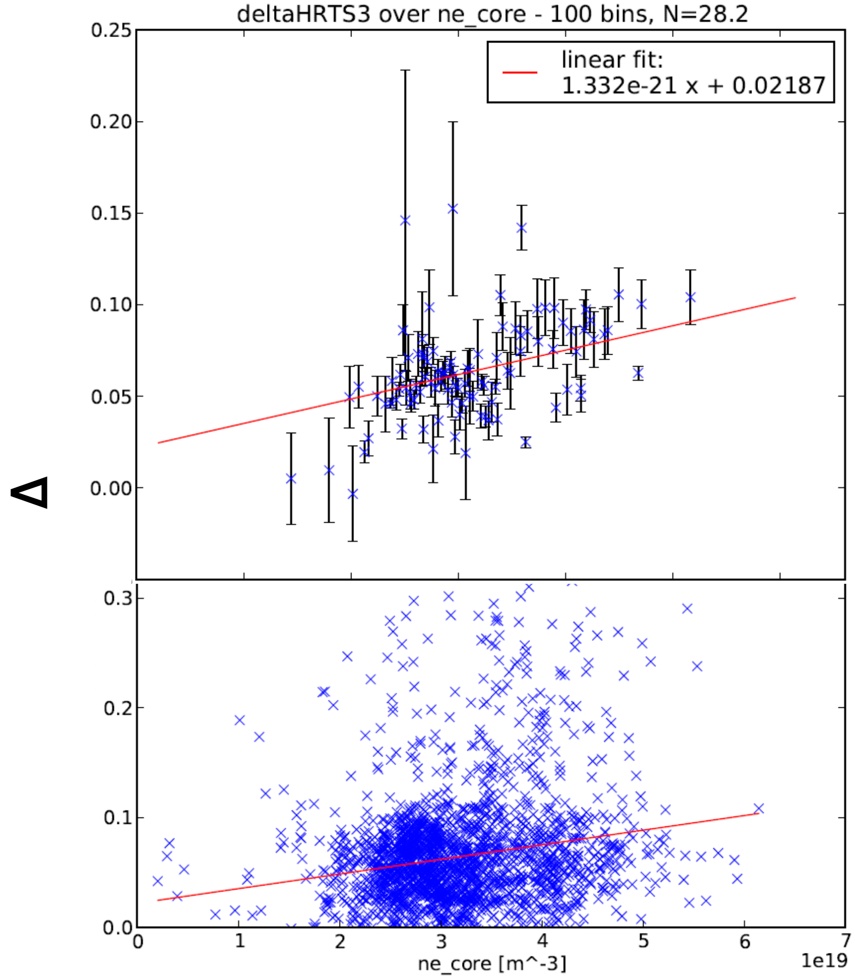
- Δ for ICRH 86000-87944 with old and new calibration



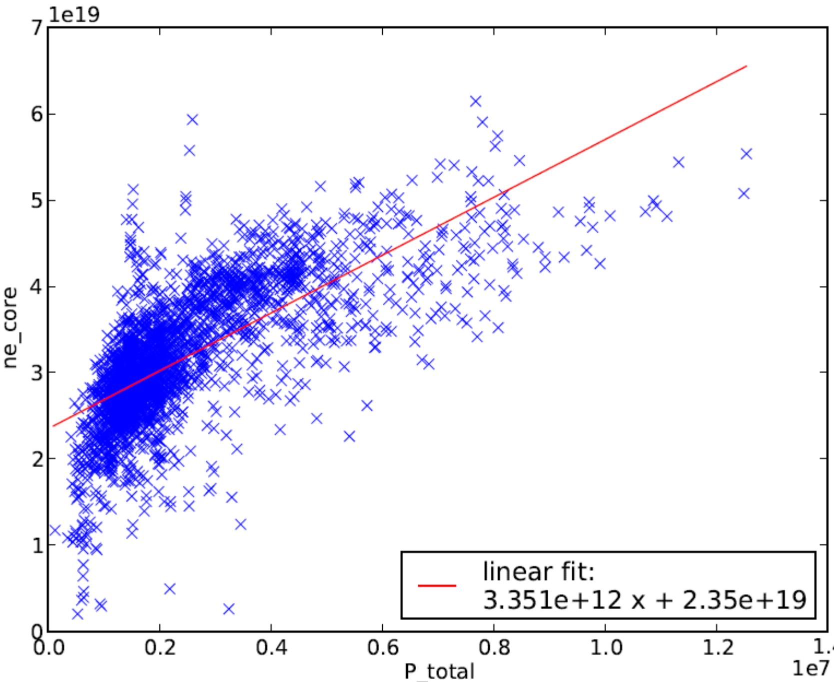
Electron Core Density n_0

80800 (c28b) – 87944 (c34)

- dependency of n_0 on Δ (?)



→ but n_0 ~ P:



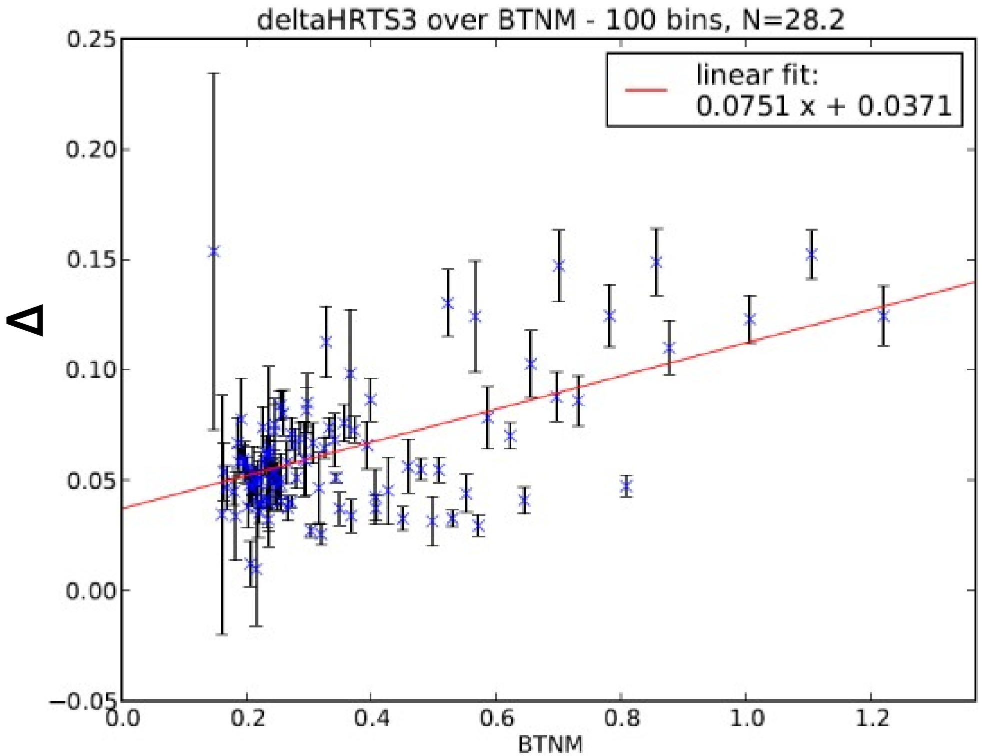
Plasma-Magnetic Pressure Coefficient β_{MHD}

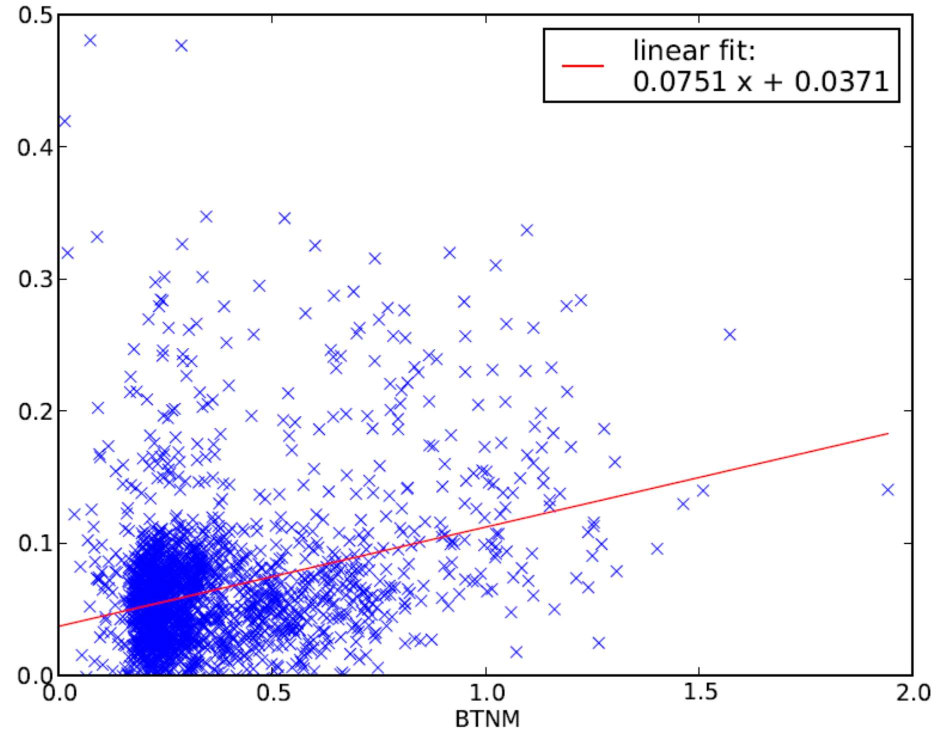
80800 (c28b) – 87944 (c34)

- some β relation between Δ
- BUT if P (and therefore T) increases B needs to increase for stable plasma (stable β <1)!

→ relation non-linear

$$\beta = \frac{p}{p_{mag}} = \frac{nk_BT}{B^2/(2\mu_0)}$$

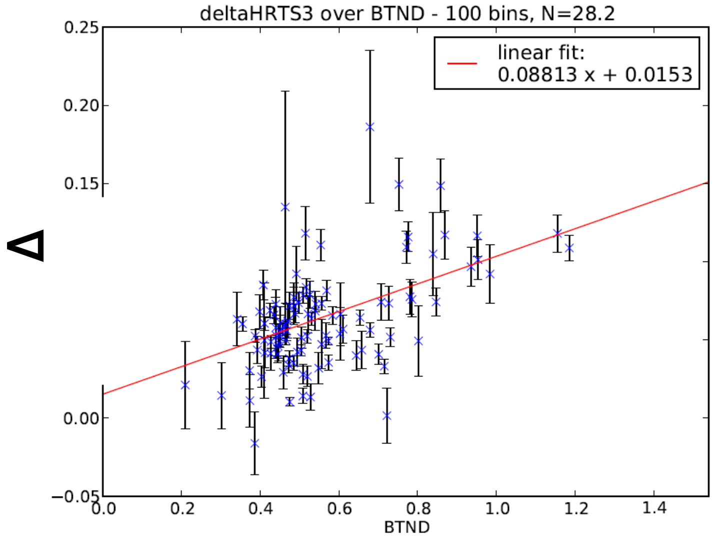


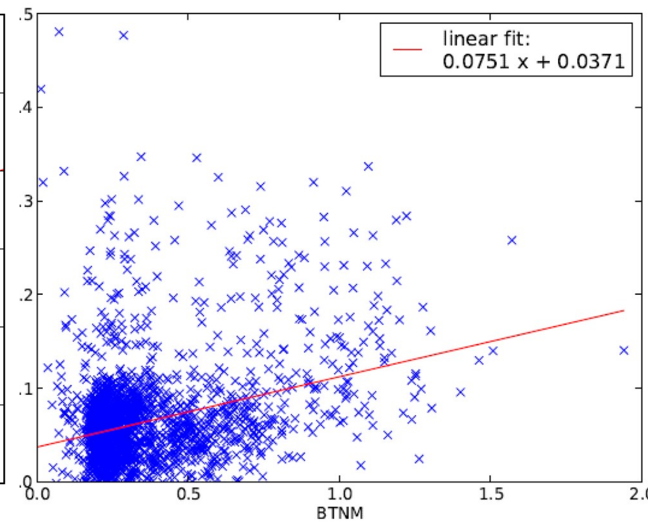


Plasma-Magnetic Pressure Coefficient β_{diamag}

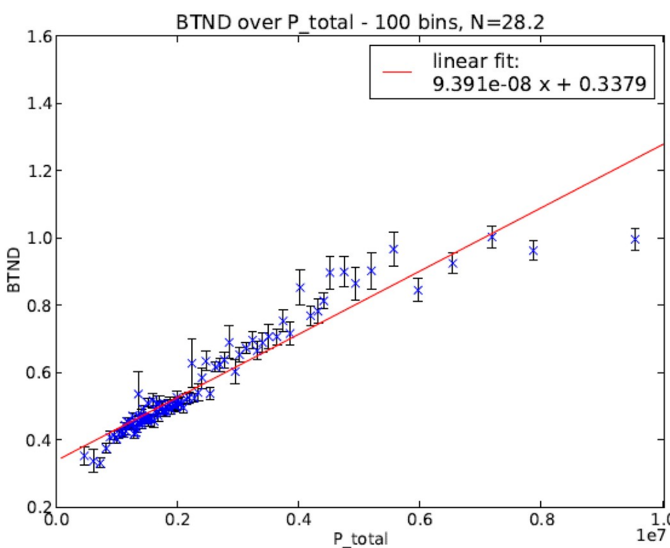
80800 (c28b) – 87944 (c34)

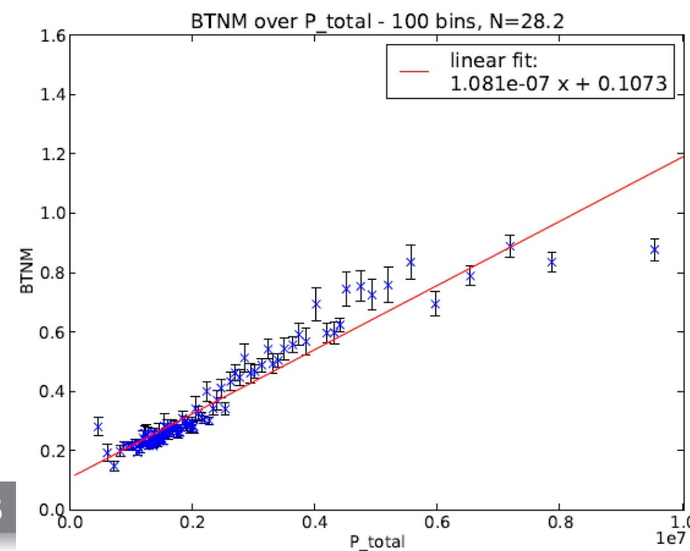
- Same for β_{diamag}





→ BUT again β~P:

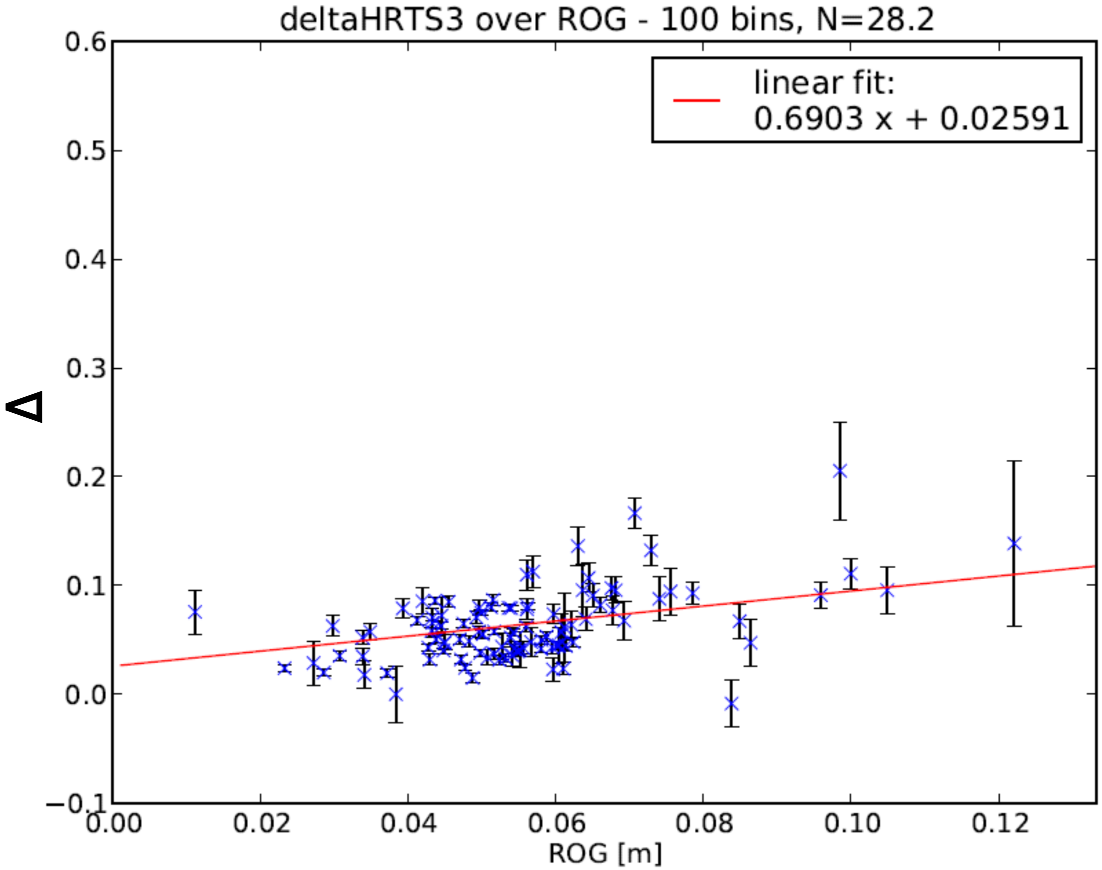


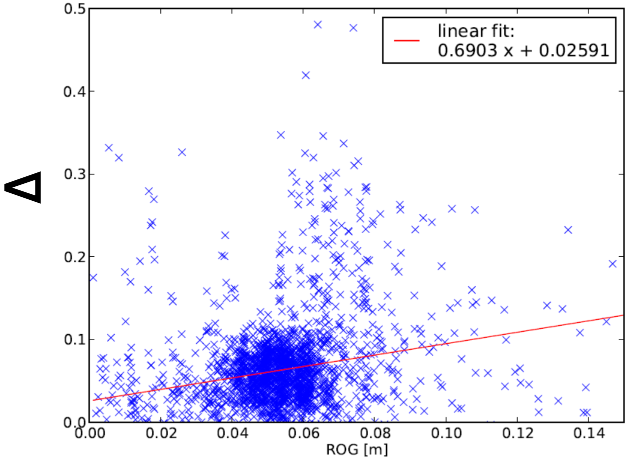


Plasma-Wall Distance ROG

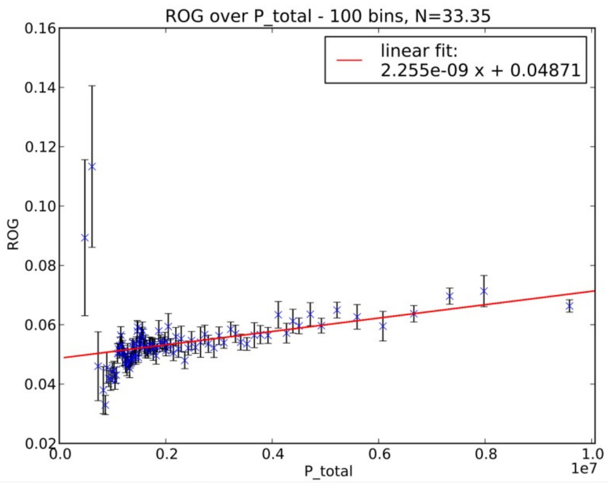
80800 (c28b) – 87944 (c34)

- more cloudish behaviour than clear trend for ROG
- and hotter plasmas should stay away from the wall!





P:



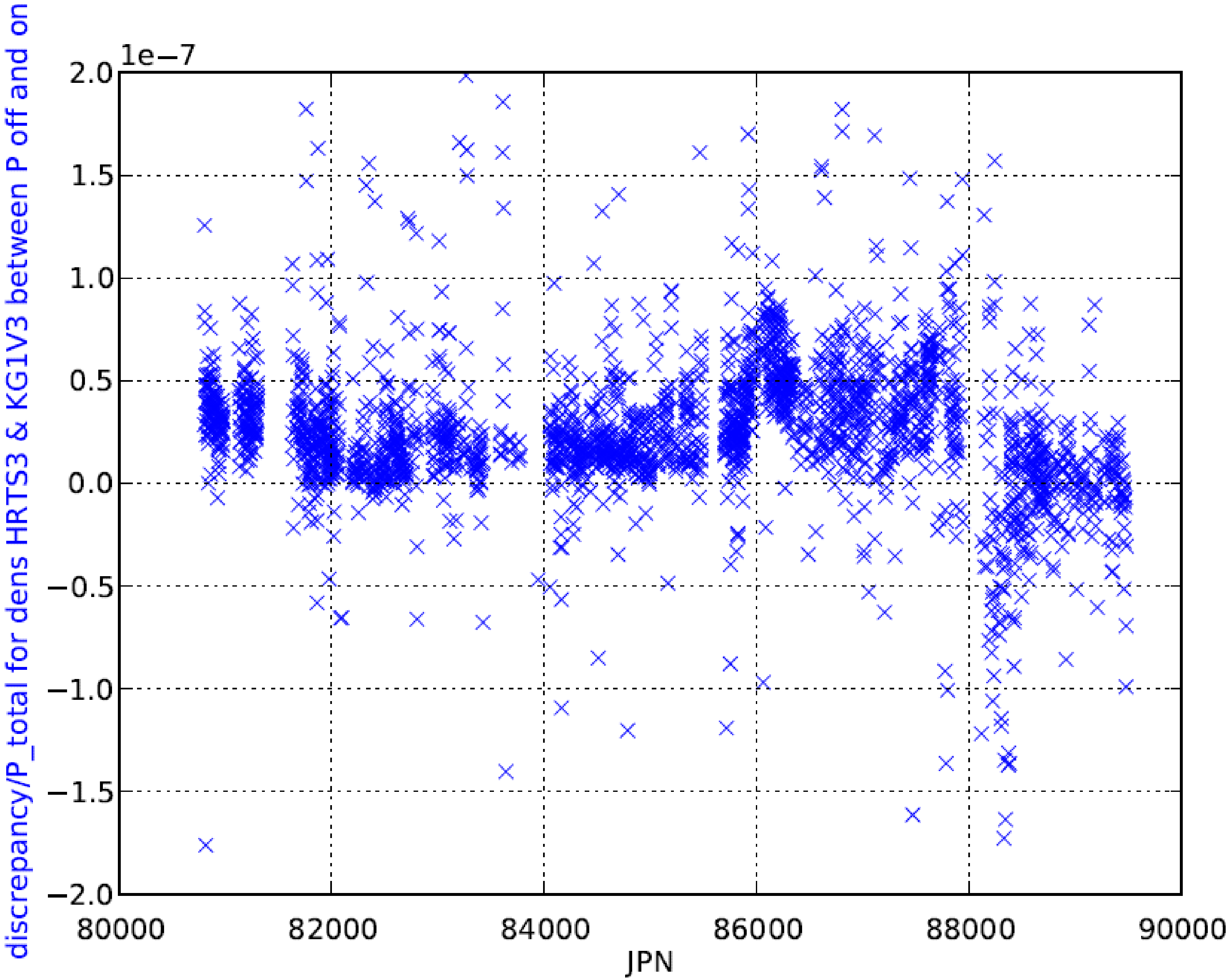
Bibliography

- M. Maslov, "Consistency of T_e and n_e measurements in C31", DVCM, 19.03.2014

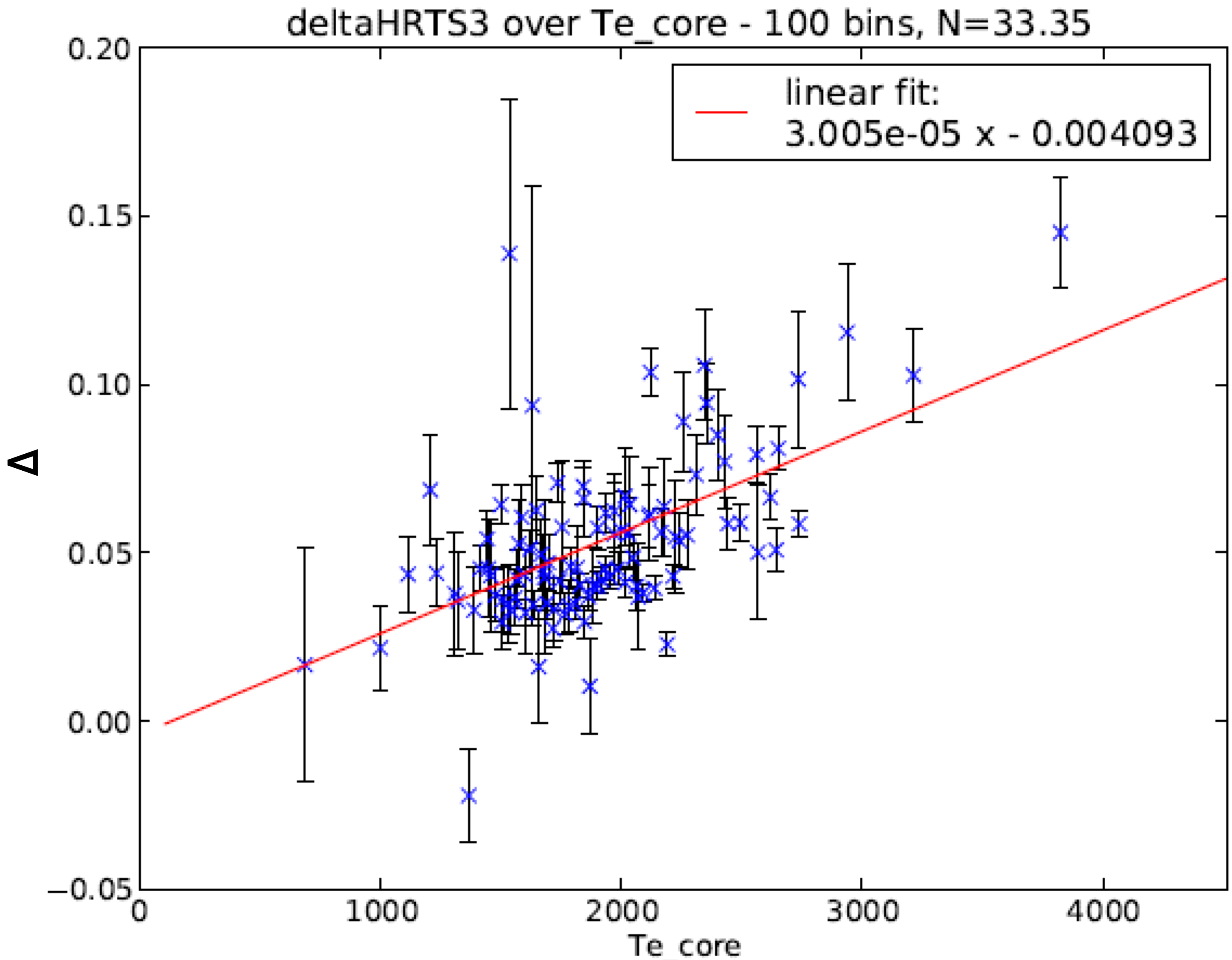
Thank you!

Discussion and Backup slides ;)

BACKUP Δ:P_{total}/JPN



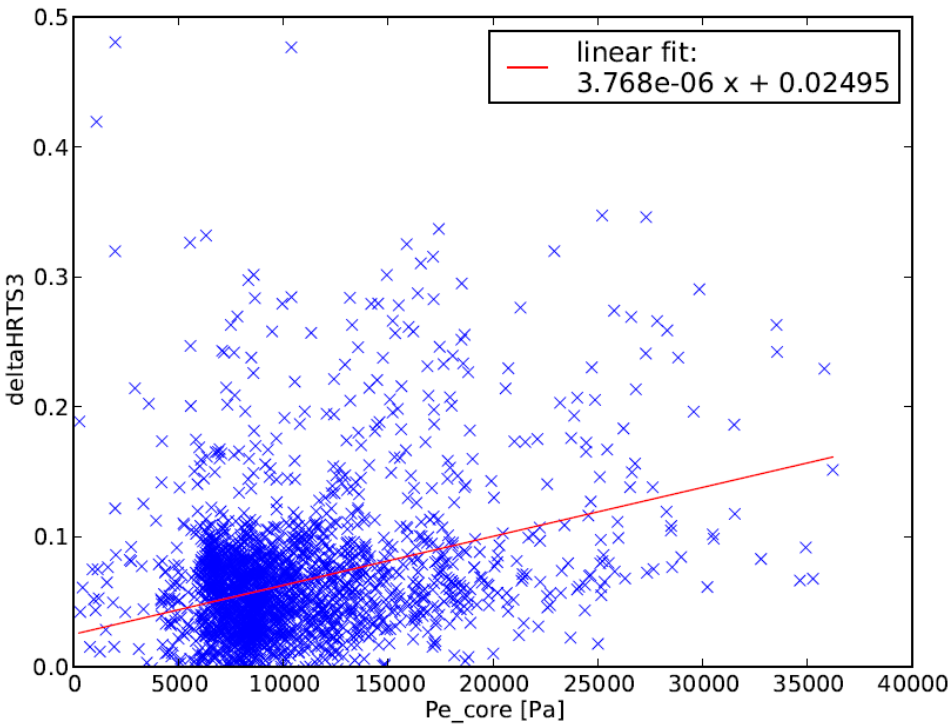
BACKUP Δ/T_0 for JPN 80800 – 89485

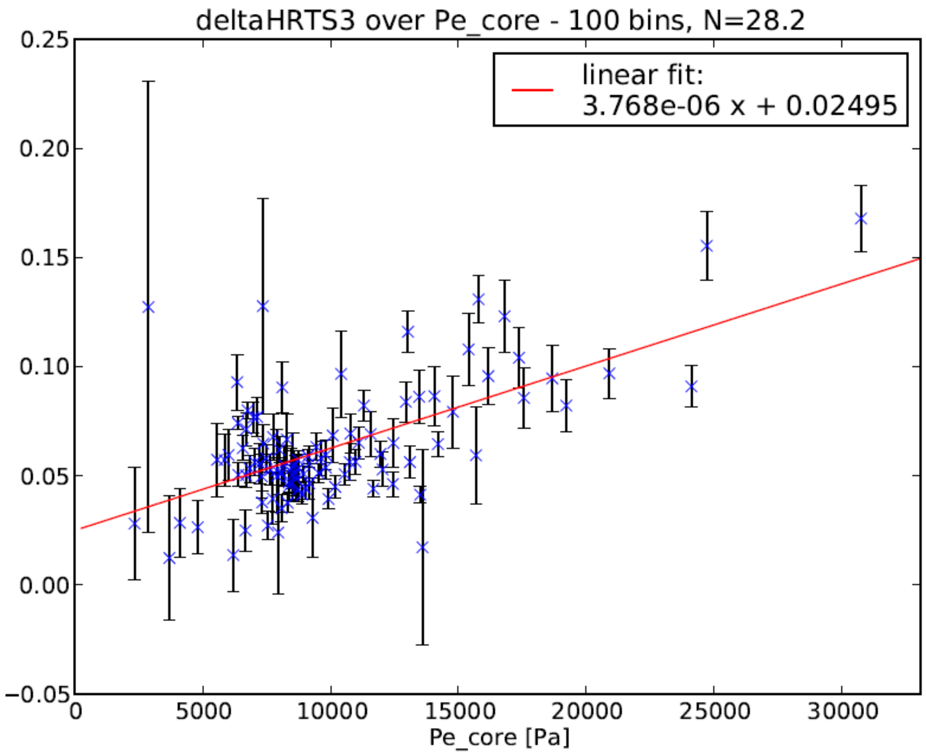


Electron Core Pressure p_0

80800 (c28b) – 87944 (c34)

- some dependency of p_0 on Δ as well



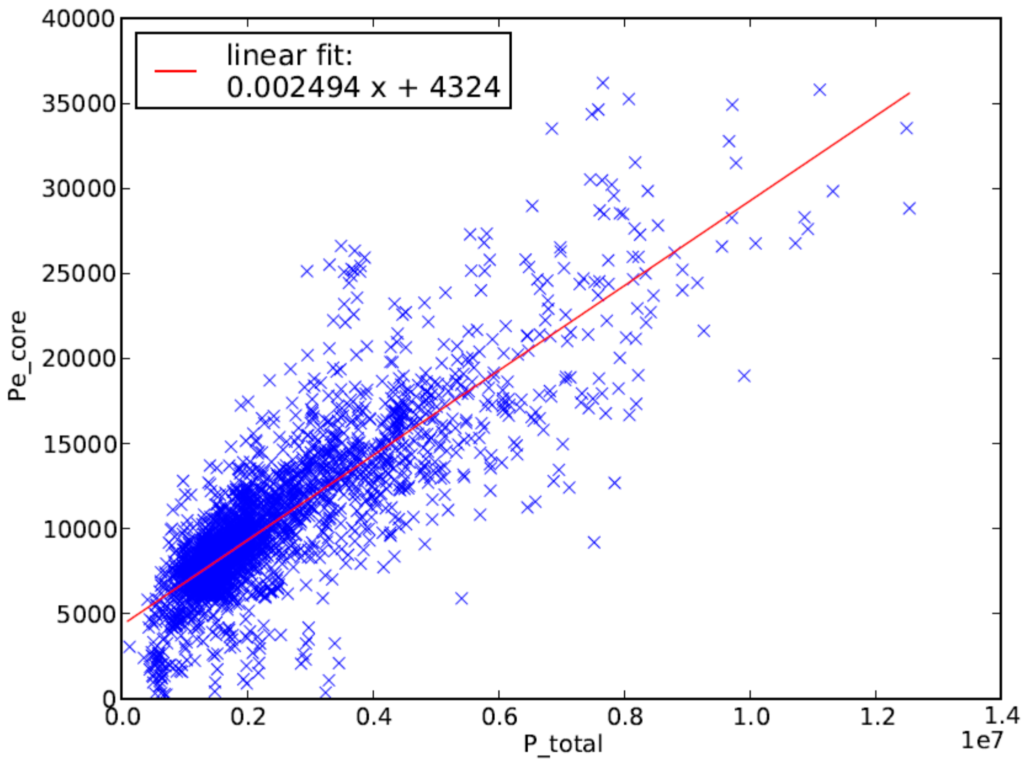


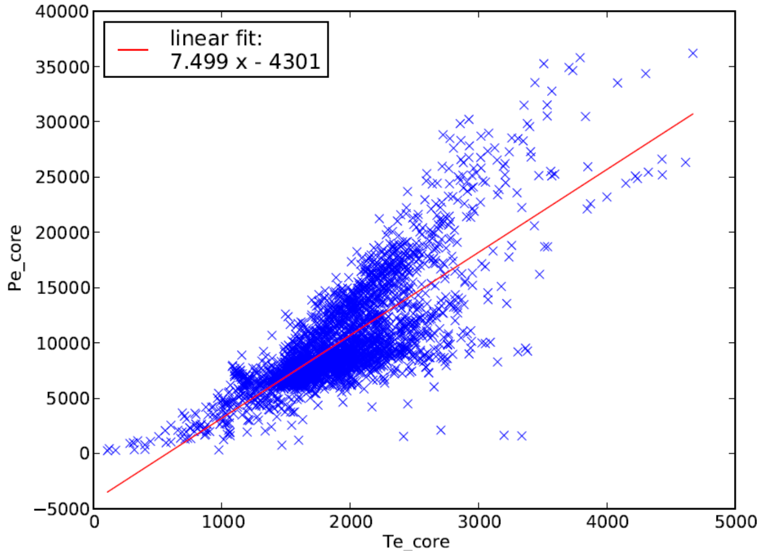
Electron Core Pressure p_0

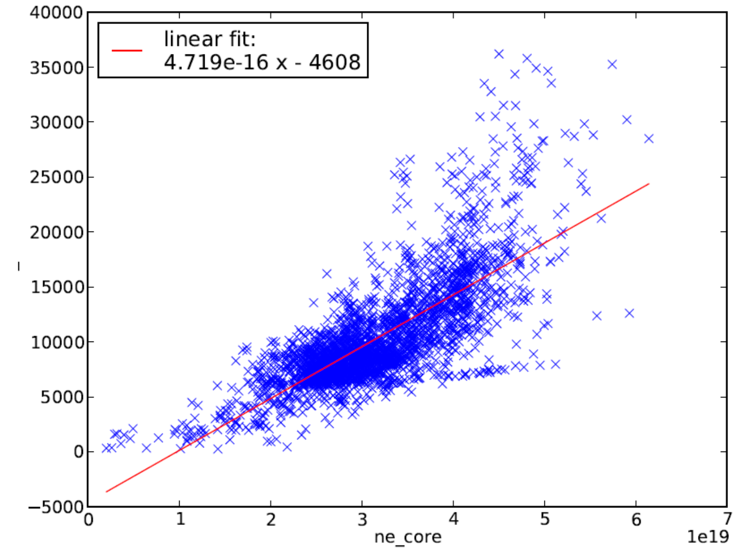
80800 (c28b) – 87944 (c34)

- but related to n_0 and T_0 →

- and p_0 ~ P:







All Parameter P dependencies