Dependence of divertor baffle heating during QH mode in DIII-D*

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Abstract

We found previously that the upper outer baffle of DIII-D was receiving an amount of heat comparable to the outer strike point during QH mode in upper-single-null discharges[1]. Here we investigate the dependence of this heat flux on variations in plasma current, distance between the separatrix and outer wall or floor, up-down magnetic balance in double-null, injected neutral beam power, and ratio of more tangential to less-tangential beams. We use these results to test the hypothesis that the baffle heating is due to ions on large banana orbits.

[1] J. Nucl. Mater. 313-316, 904 (2003)

Introduction to QH mode

Definitions

QH-mode: Quiescent H-mode

- An ELM-free H-mode with density and radiated power control and extended duration
- Achieved with strong pumping, counter neutral beams, large outer gap (~10 cm)

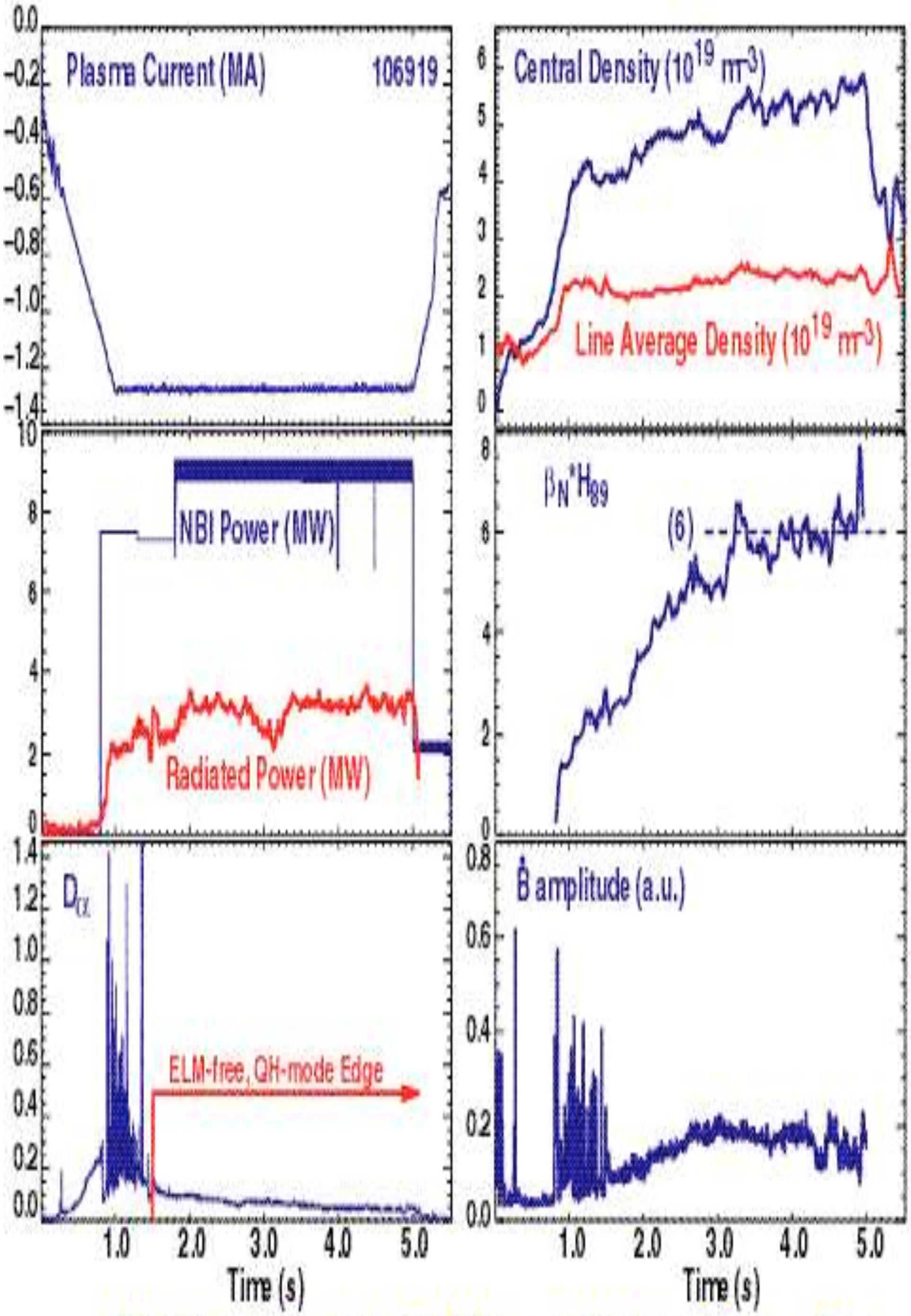
QDB: Quiescent Double Barrier

- An internal transport barrier (ITB) and a QH-mode edge

EHO: edge harmonic oscillation

- A continuous MHD mode usually associated with QH-mode operation

Sustained ELM-free H-mode operating regime obtained with density and radiated power control

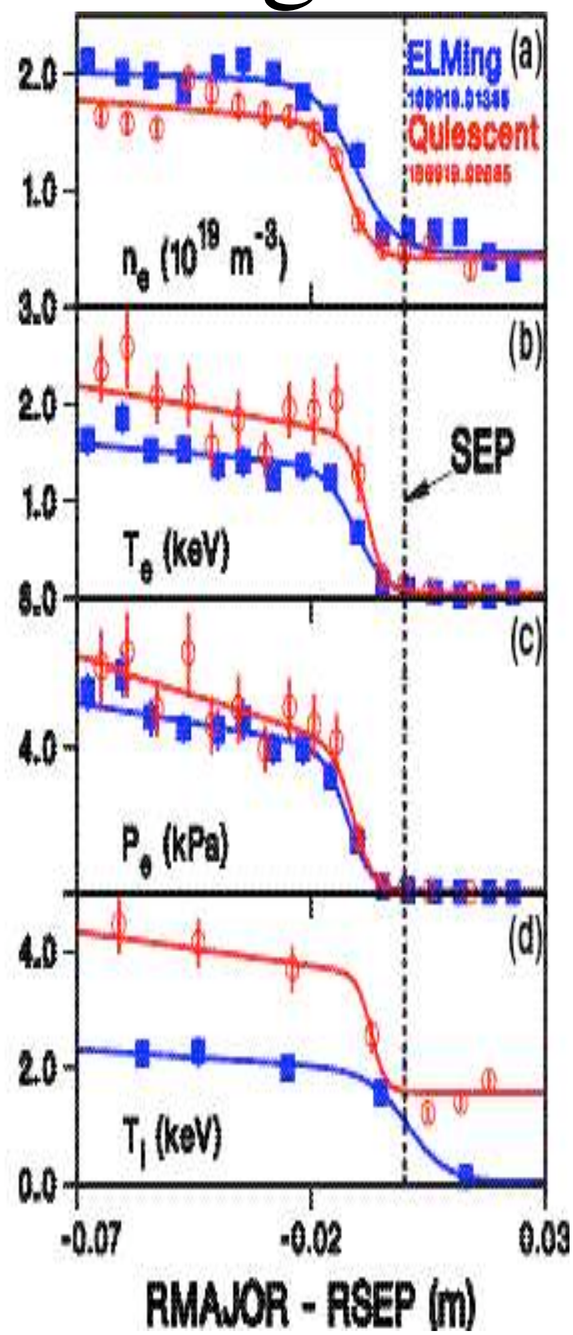


B_T = 2.0 T
q_{95} = 4.45

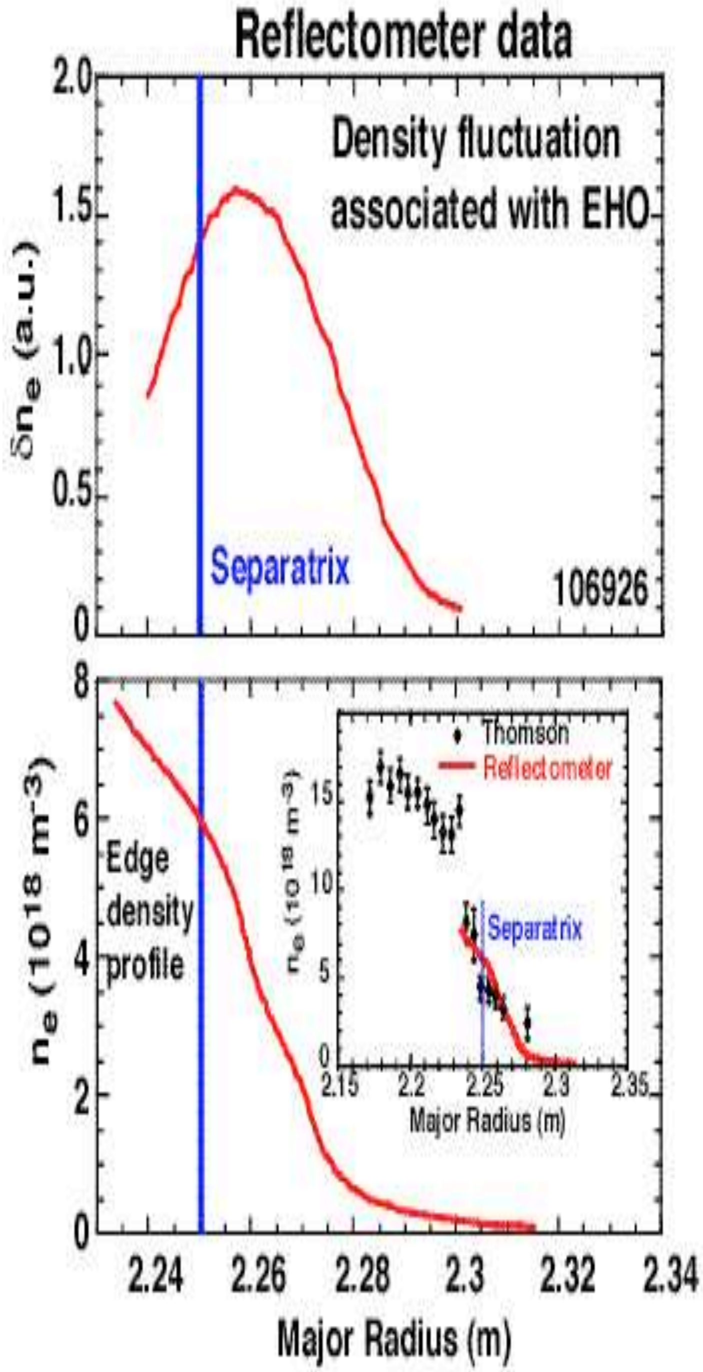
- Maintains quiescent ELM-free edge for >3.5 s, ~25 τ_E

The plasma edge during the quiescent phase is an H-mode edge

- Edge gradientsin quiescent phase are comparableto those in ELMing phase
  - Note high T_i pedestal
- QH-mode edge also has other standard H-mode signatures
  - Edge E_R well
  - Reduced turbulence



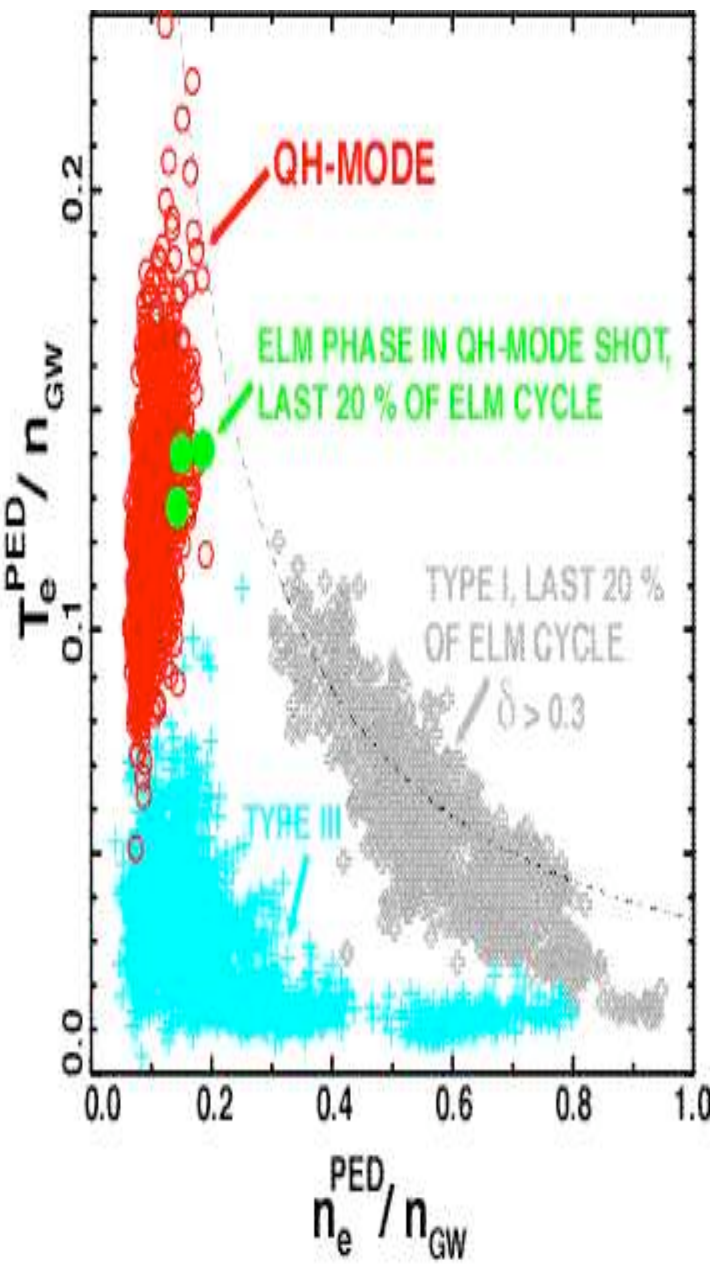
The EHO is located at the base of the edge pedestal



- High resolution measurements with profile reflectometer systems indicate that the EHO is located at the base of the edge profile pedestal, at or slightly outside the separatrix.

Lei Zeng, UCLA

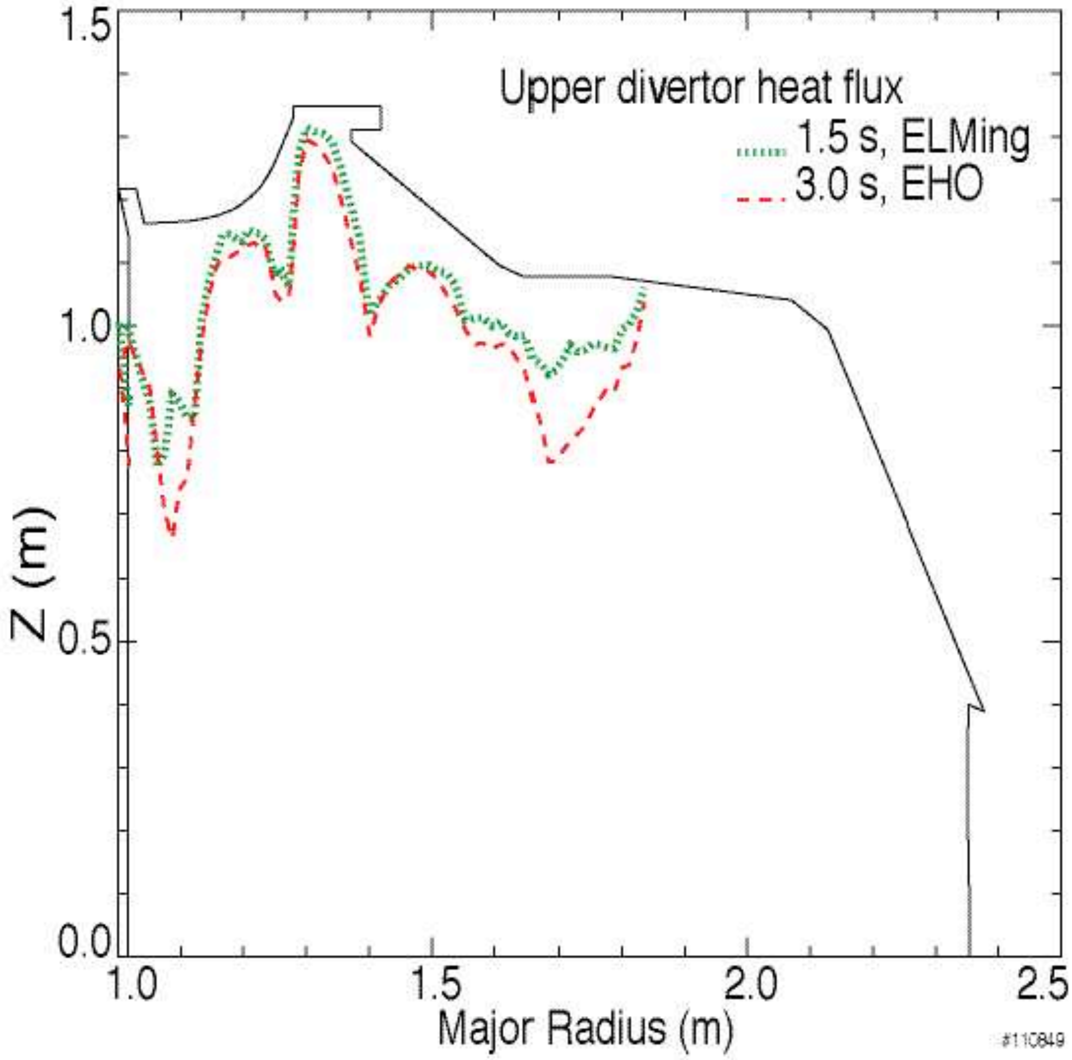
QH-mode edge has a lower density and higher temperature than conventional ELMing H-mode



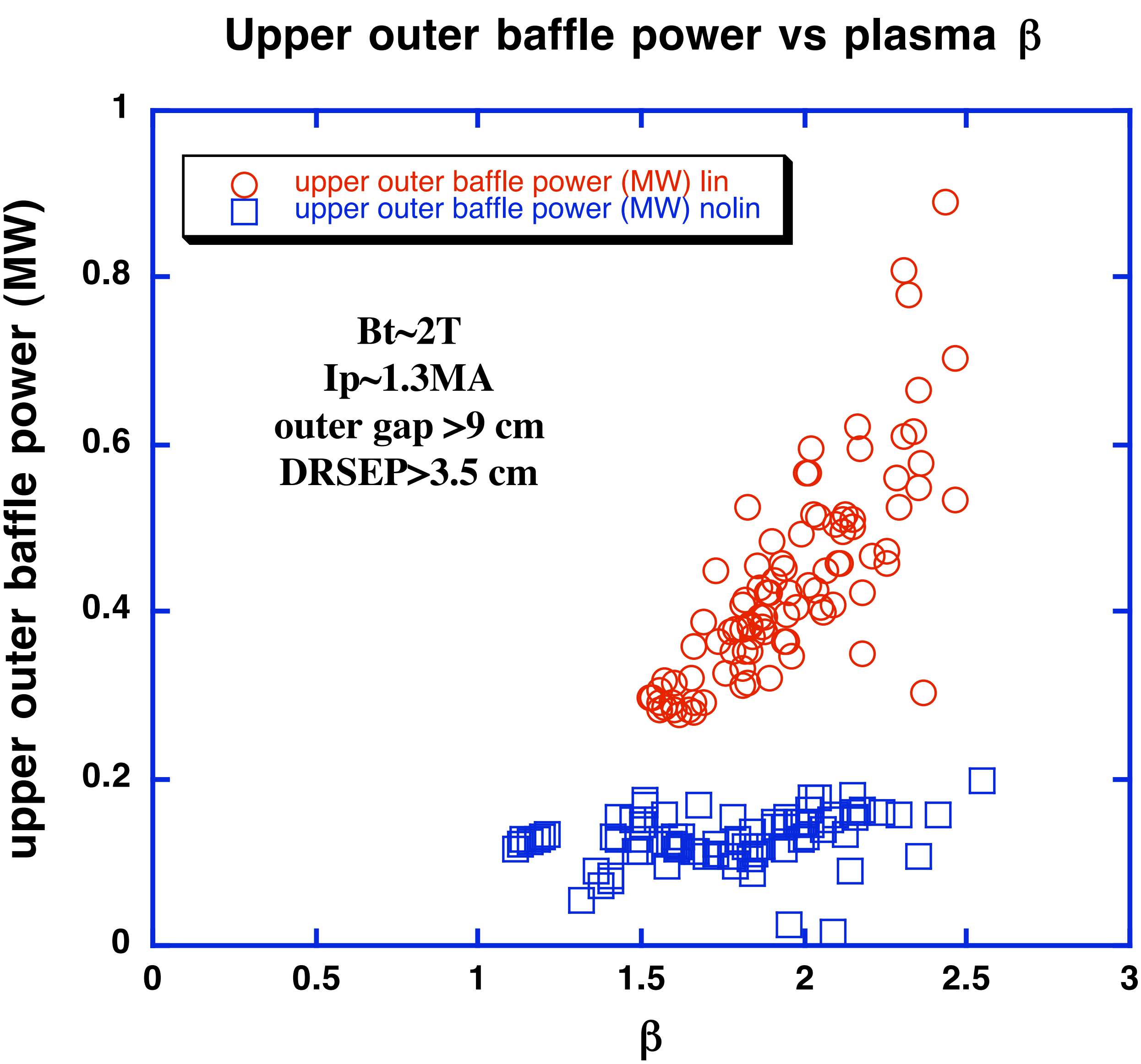
T.H. Osborne, General Atomics

Scaling of Upper Outer Baffle (UOB) heat

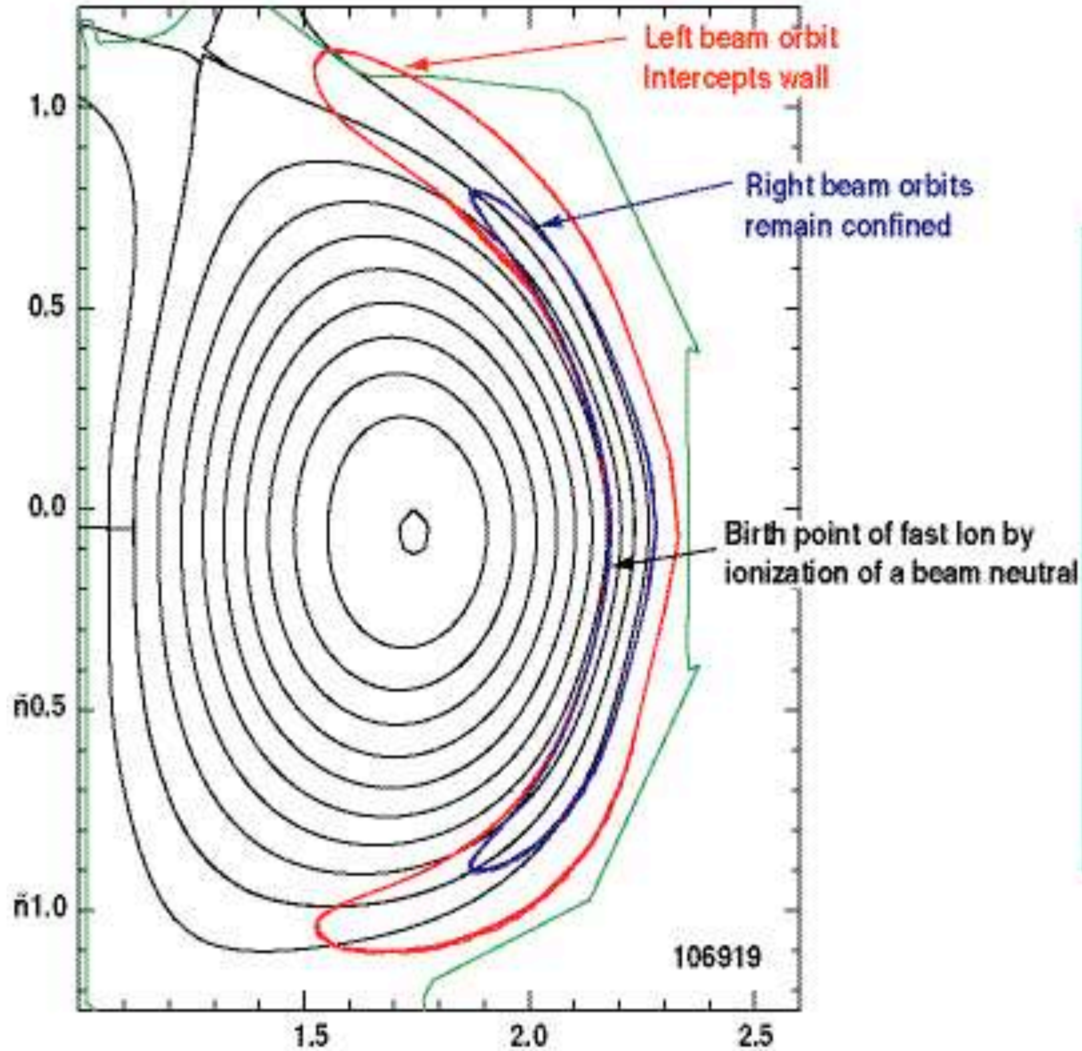
Divertor heat flux on tile geometry

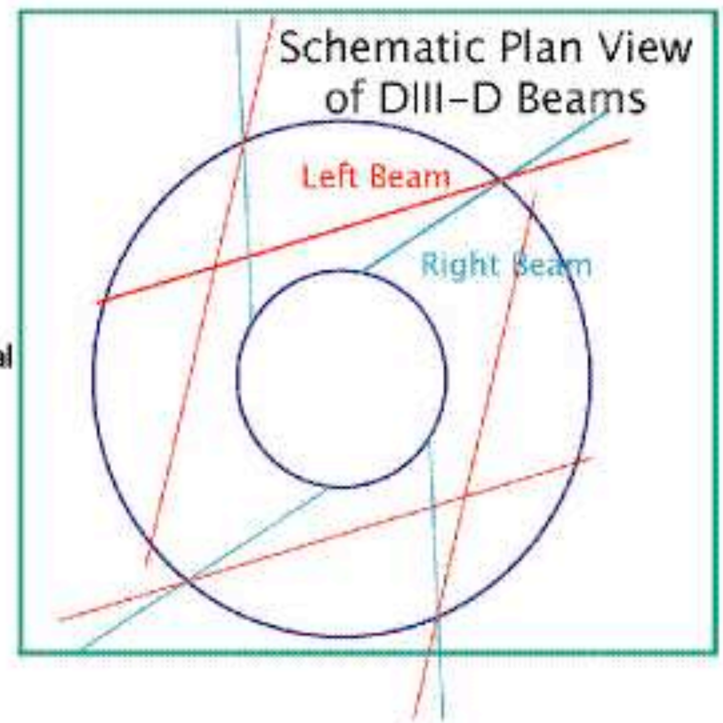


One set of UOB powers scales with β

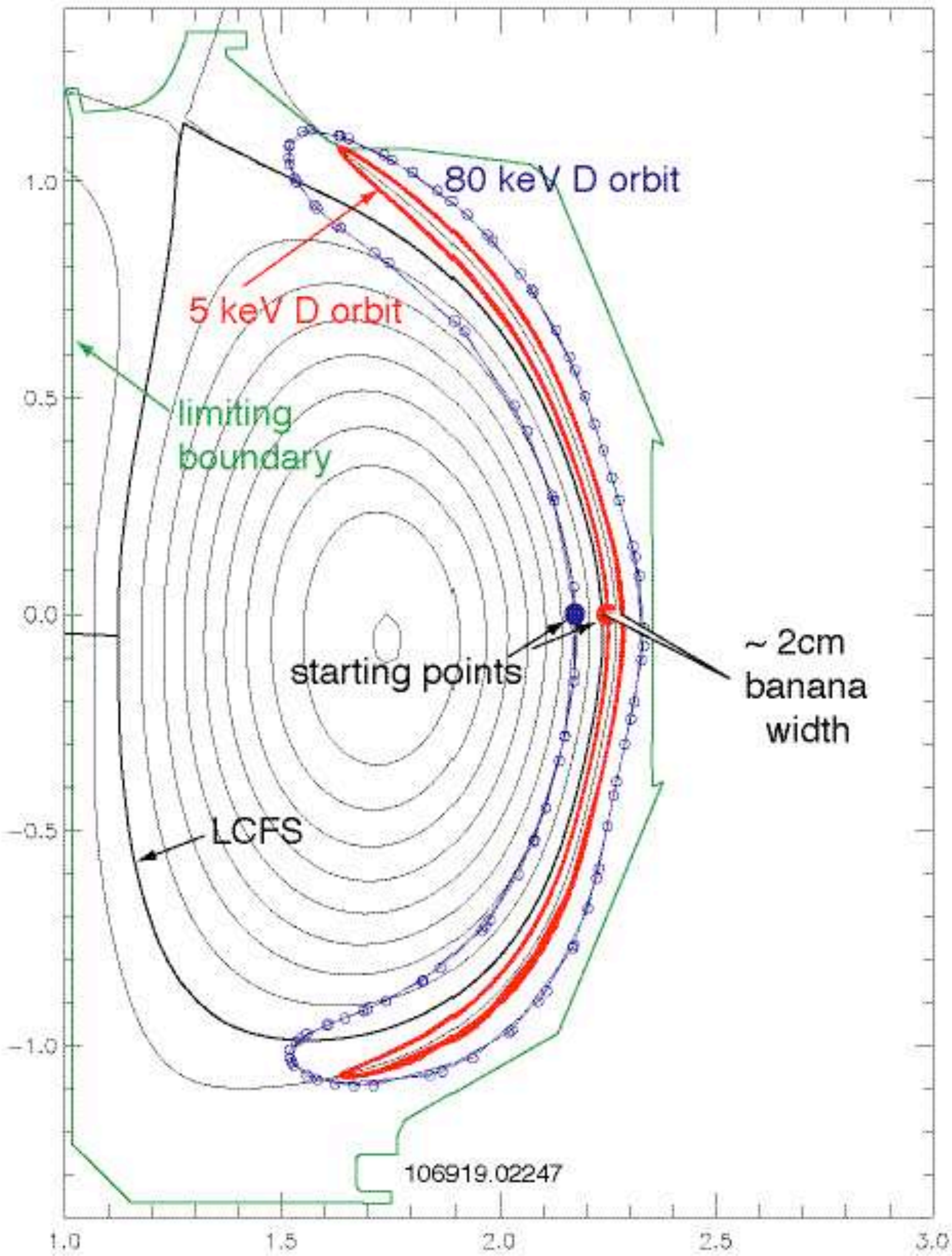


IONIZATION OF LEFT BEAM NEUTRALS IN THE EDGE LEADS TO PROMPT LOSS TO THE OUTER WALL





Banana orbits can intersect the baffle



deGrassie orbit3.eps

Upper divertor images

Linear dependence

118745.2000 upper diveror IR

Normal view

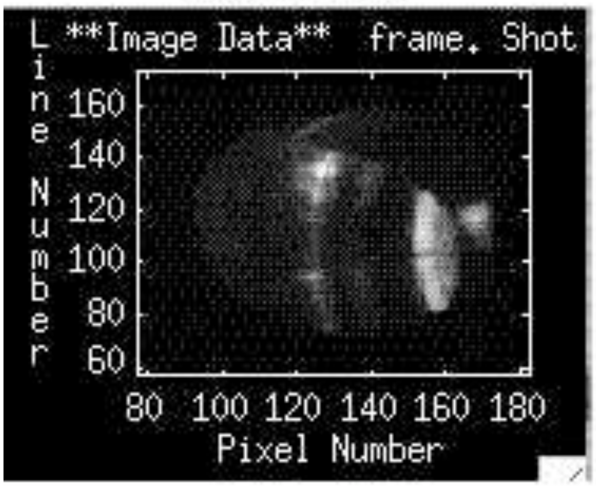
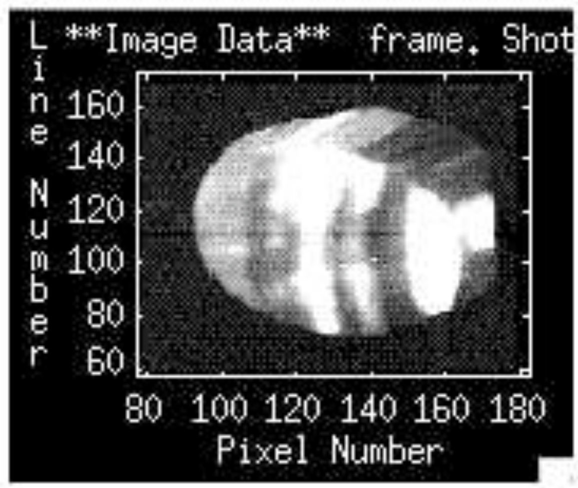
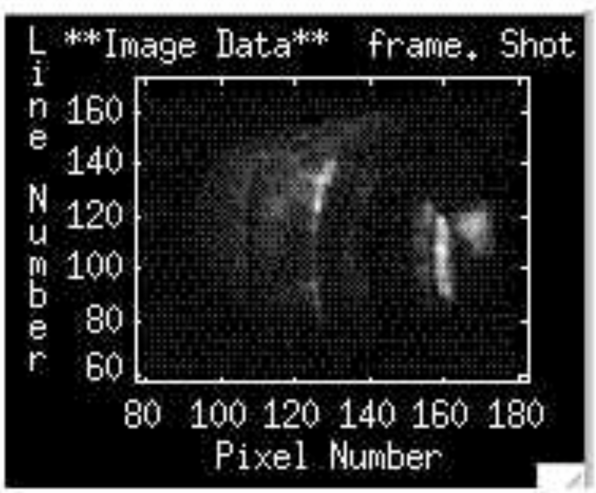


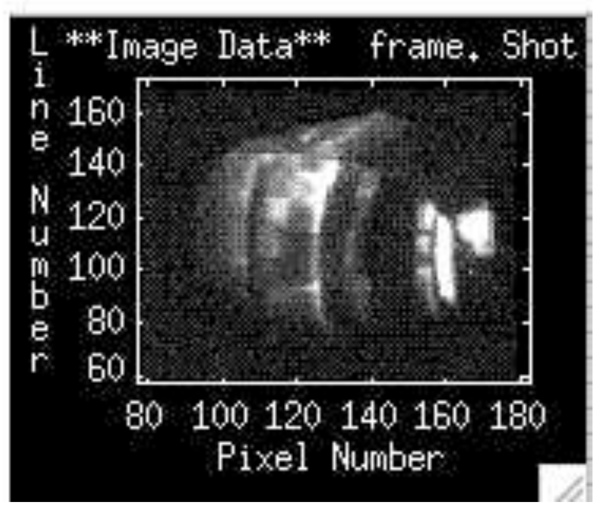
Image Enhanced



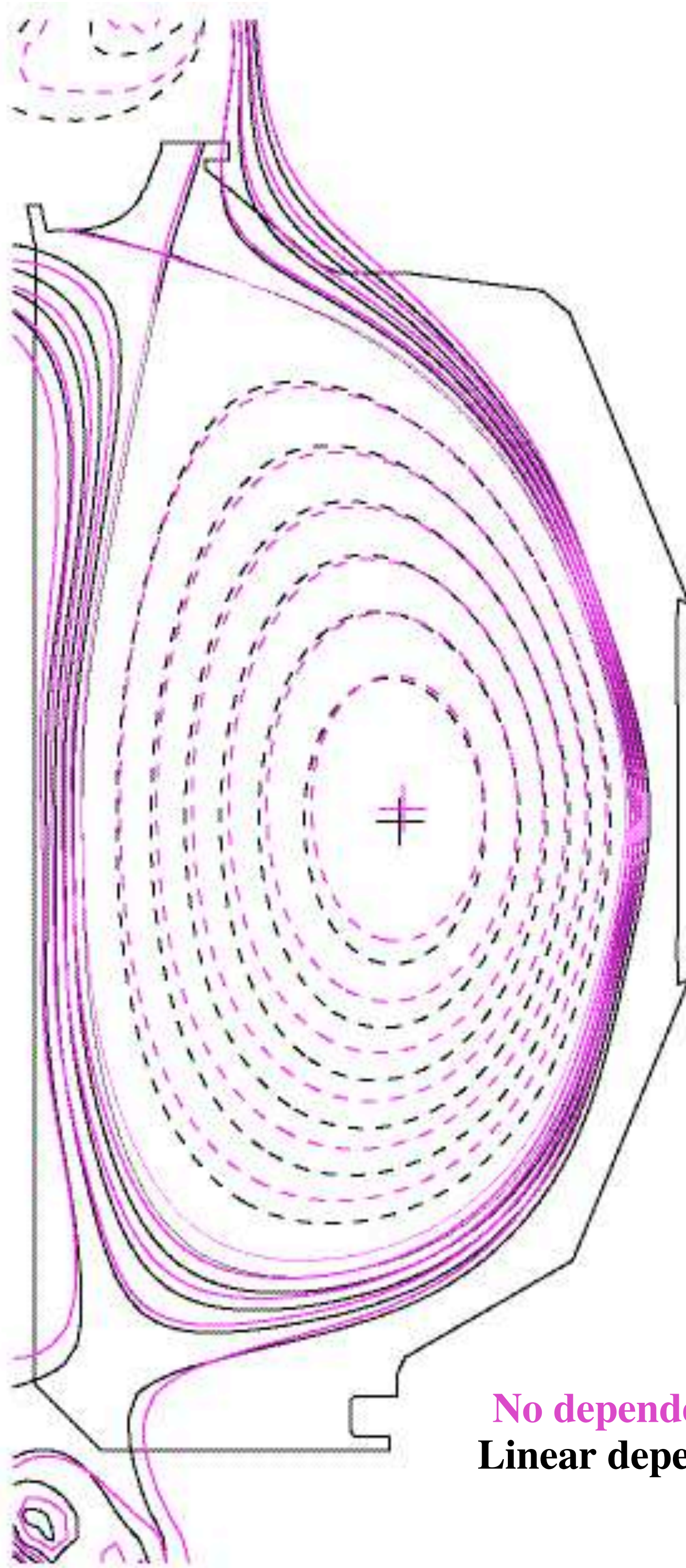
No dependence

118774.2666 upper diveror IR image





shot	118774
time	2675.00
chi**2	36.783
Rout(m)	1.679
Zout(m)	0.071
a(m)	0.565
elong	1.848
utri	0.697
ltri	0.168
indent	0.000
V (m**3)	18.486
A (m**2)	1.798
W(MJ)	0.719
betaT(%)	1.594
betaP	1.186
betaN	1.868
In	0.853
Li	0.989
error(e-4)	60.887
q1	11.121
q95	5.474
dsep(m)	0.098
Rm(m)	1.782
Zm(m)	-0.035
Rc(m)	1.741
Zc(m)	-0.018
betaPd	1.188
betaTd	1.595
Wdia(MJ)	0.720
Ipmeas(MA)	-0.980
BT(0)(T)	-2.002
Ipfit(MA)	-0.975
Rmidin(m)	1.114
Rmidout(m)	2.243
gapin(m)	0.098
gapout(m)	0.110
gaptop(m)	0.115
gapbot(m)	0.262
Zts(m)	0.756
Rvsin(m)	1.081
Zvsin(m)	1.165
Rvsout(m)	1.360
Zvsout(m)	1.348
Rsep1(m)	1.161
Zsep1(m)	-1.212
Rsep2(m)	1.285
Zsep2(m)	1.116
psib(Vs/R)	0.000
elongm	1.520
qm	1.403
nev1(e19)	1.316
nev2(e19)	1.497
nev3(e19)	1.273
ner0(e19)	2.265
n/nc	-0.948
dRsep	0.037
qmin	1.403
rhoqmin	0.000

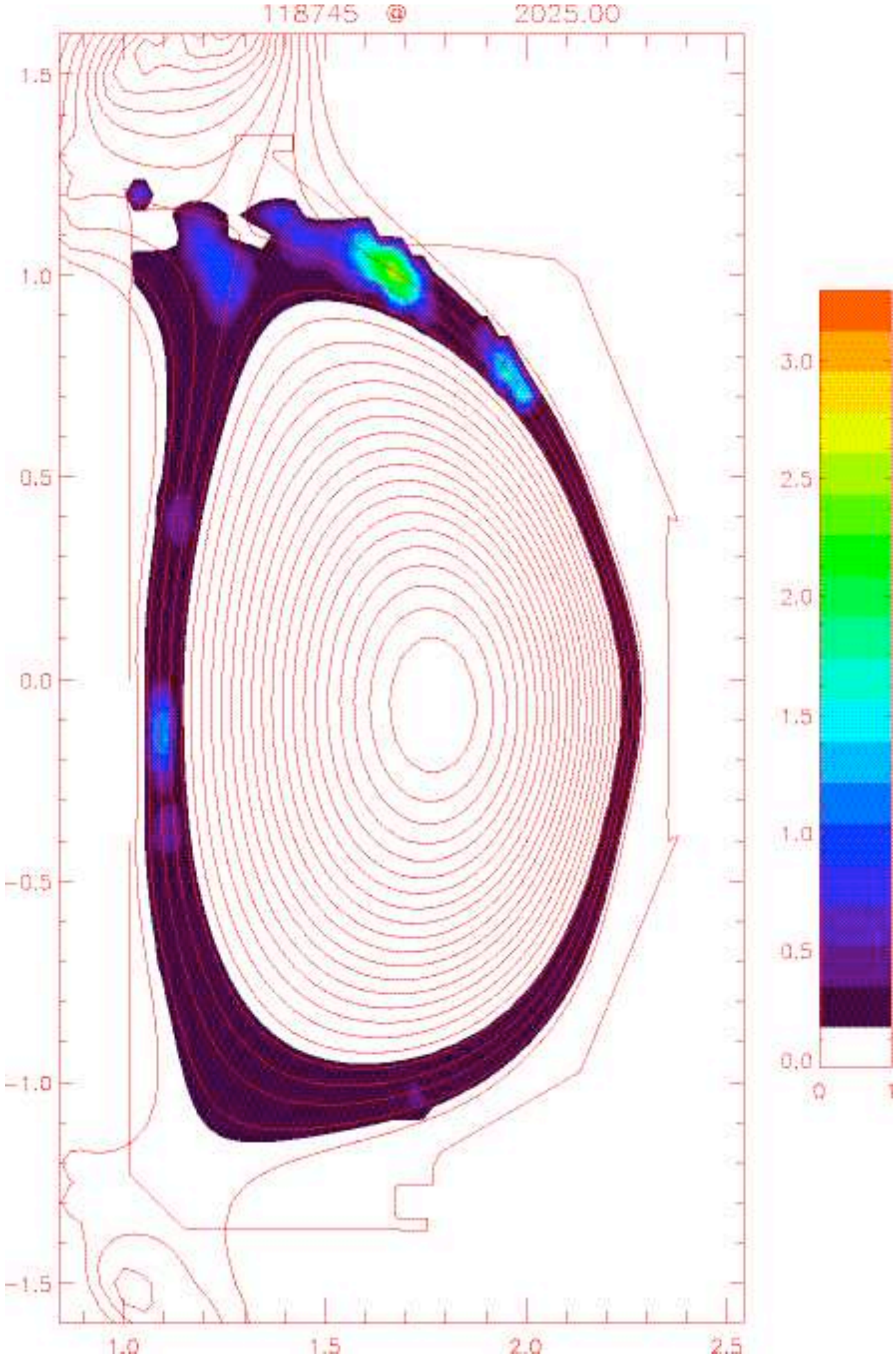


No dependence

Linear depedence

118774 2675.00

118745 2000.00



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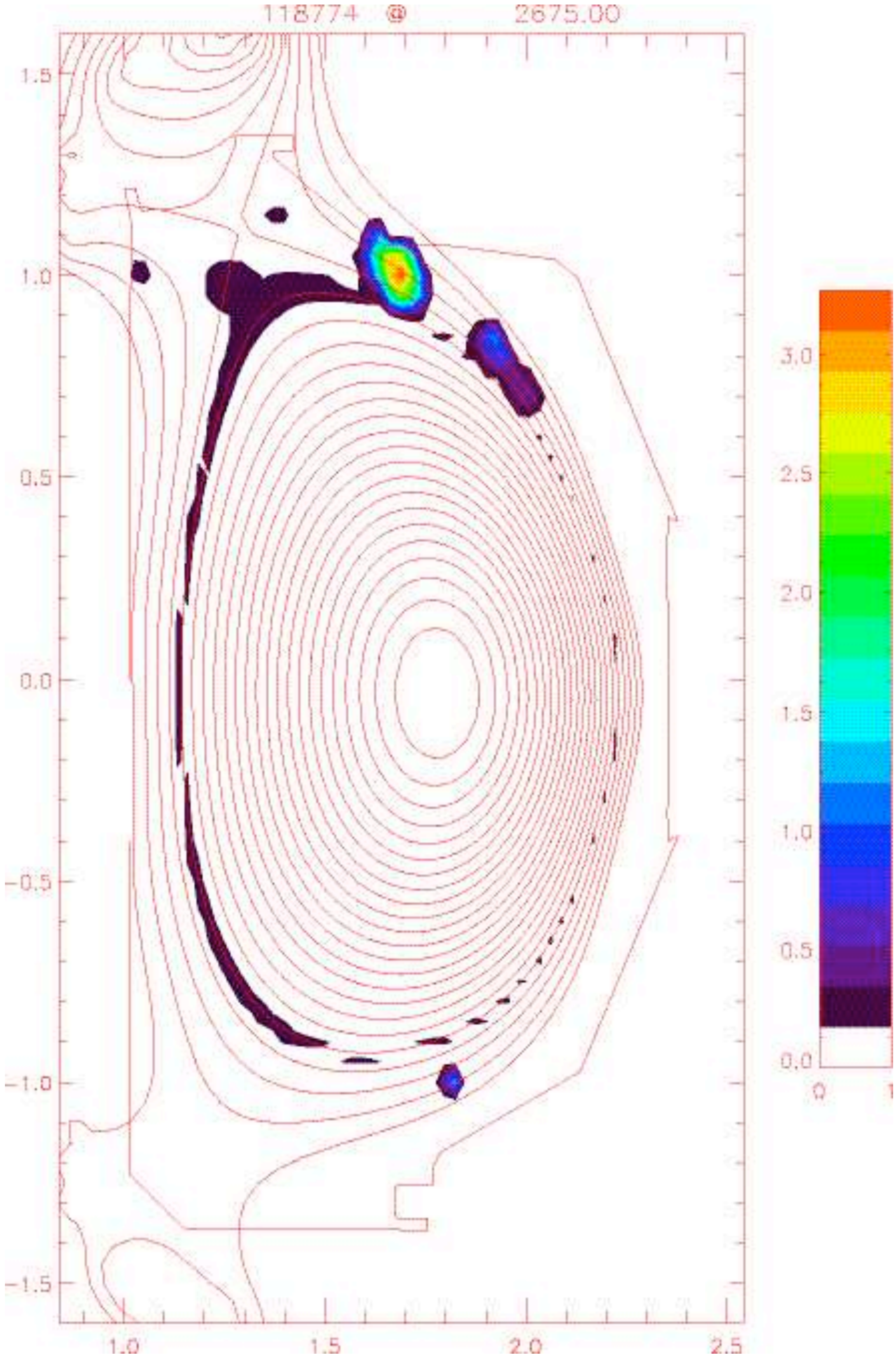
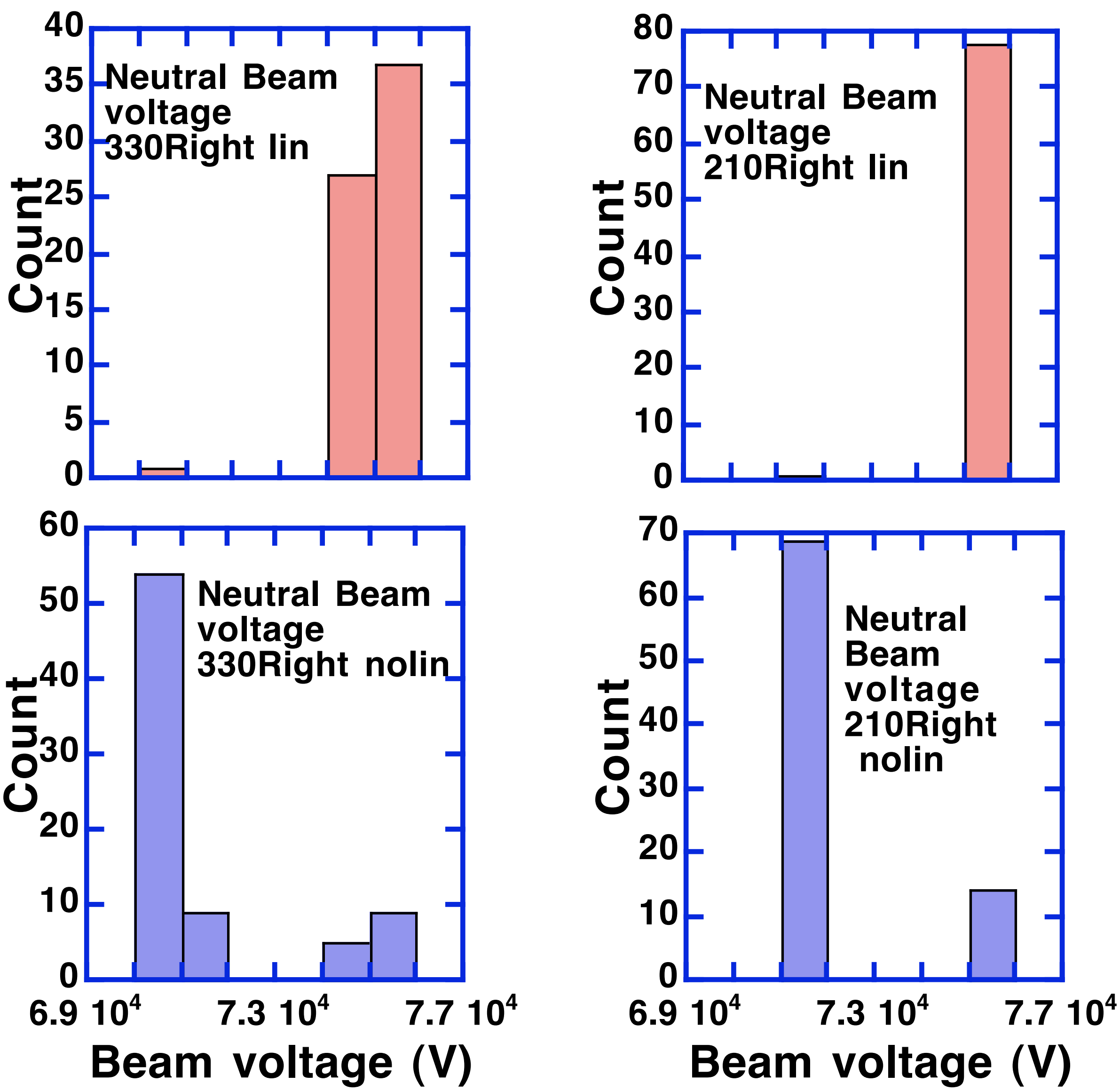
Linear dependence

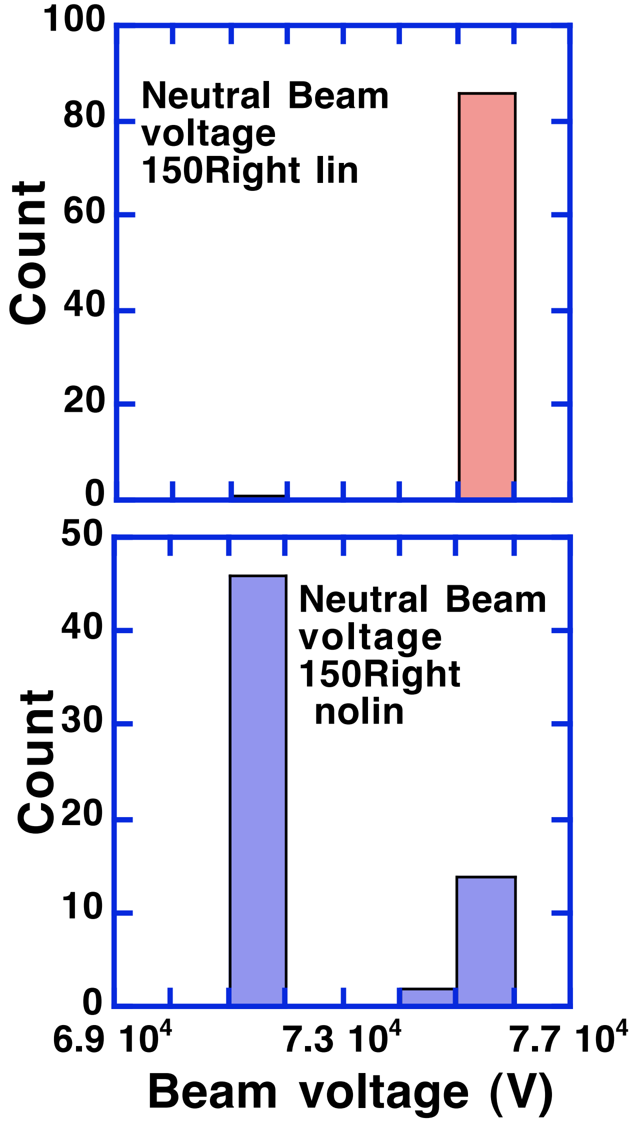


No dependence

UOB power dependence correlates with 330Right, 210Right beam voltage



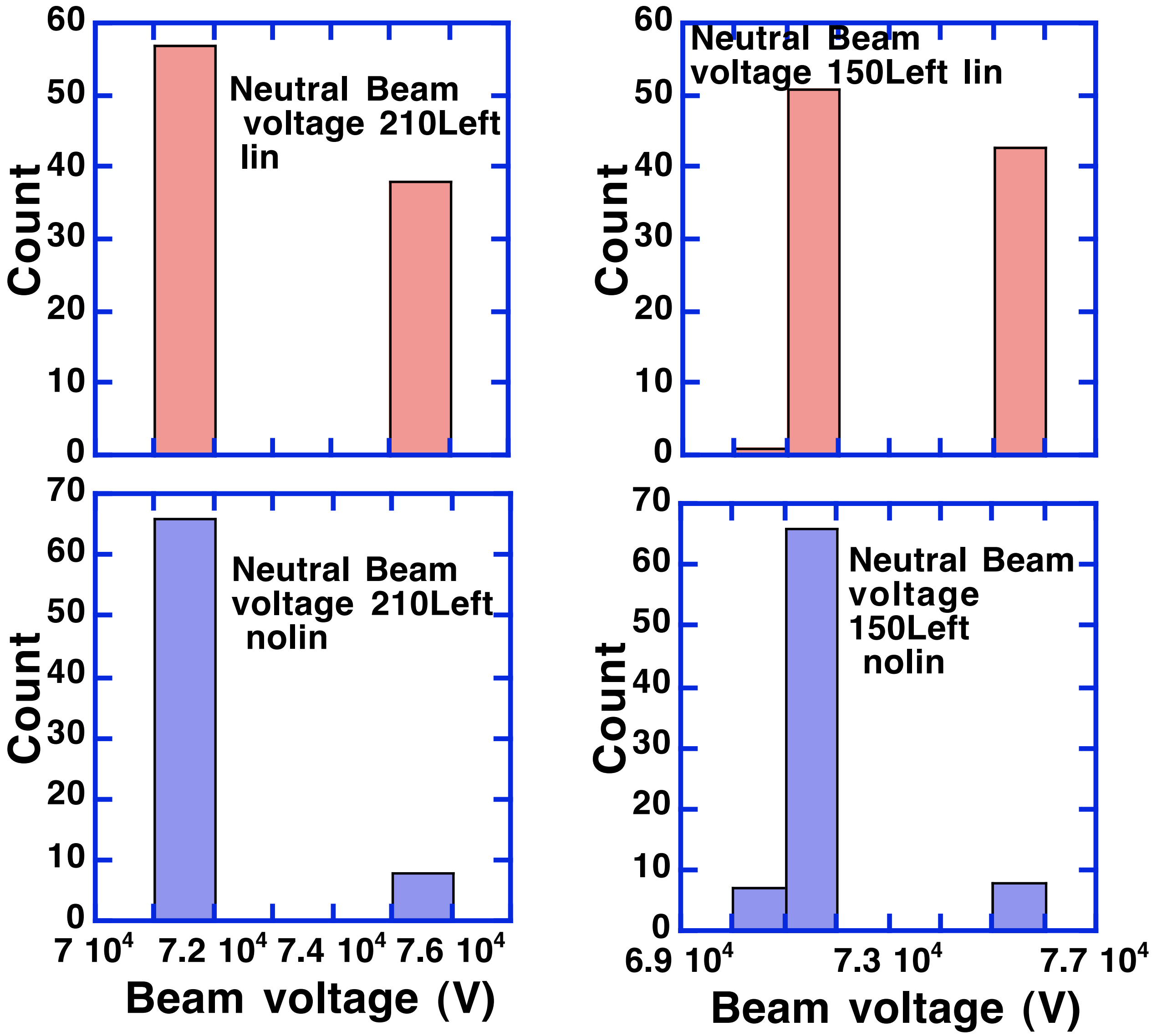
UOB power dependence correlates with 150Right beam voltage



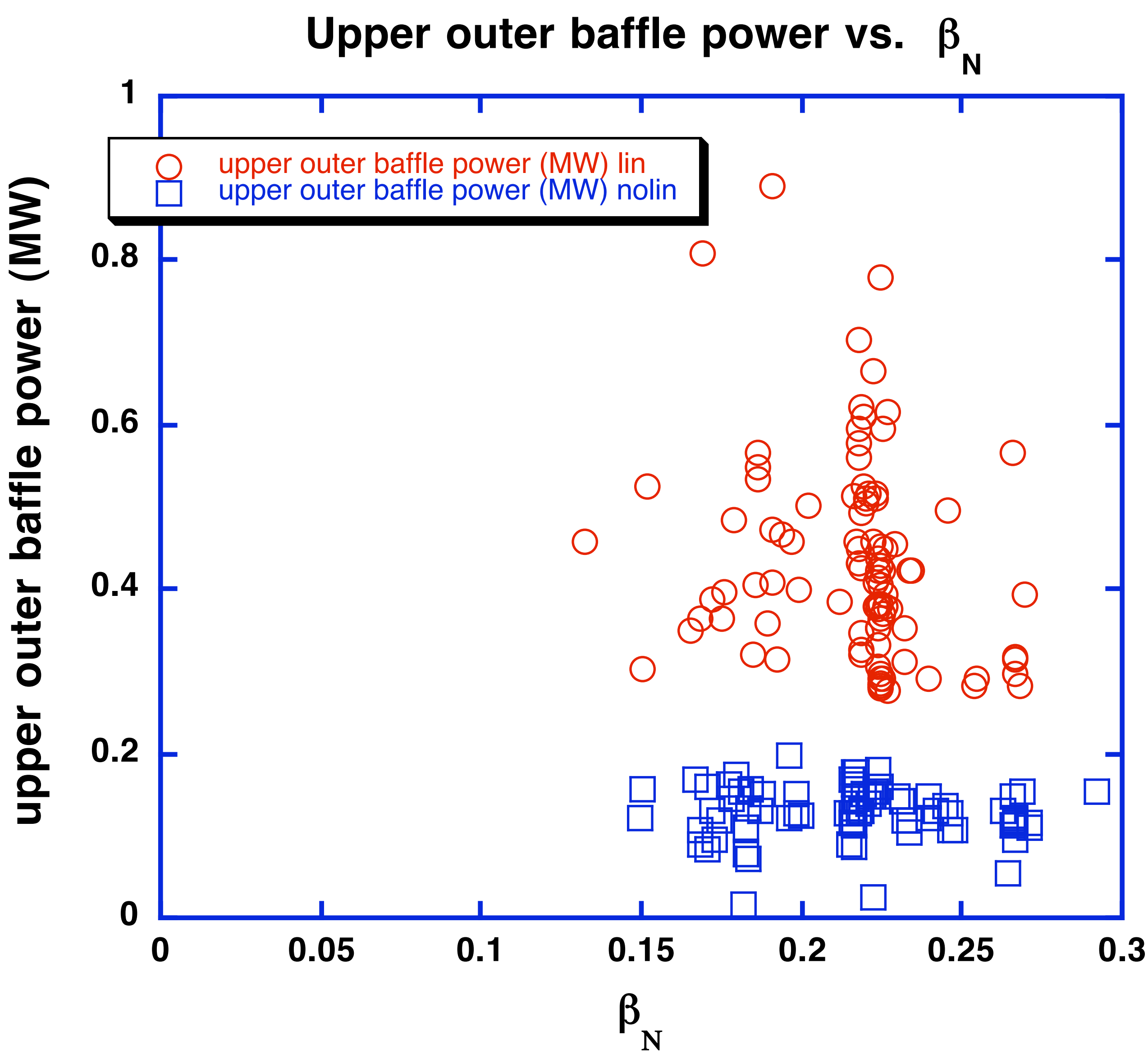
No voltage variation 330Left, 30L 30R not used

UOB heat does not correlate with these

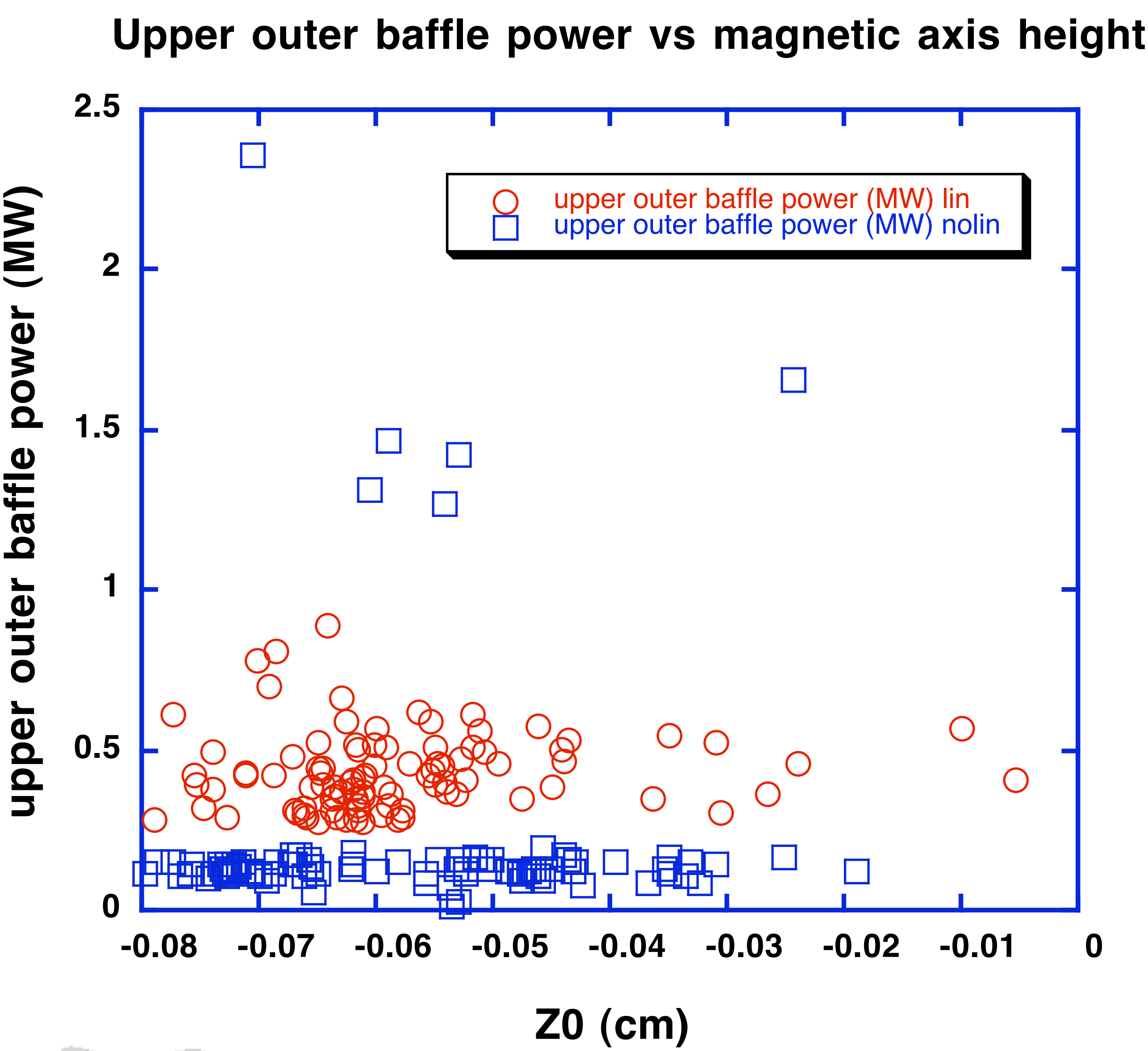
NB voltage 210Left, 150Left



Normalized β



Magnetic axis height



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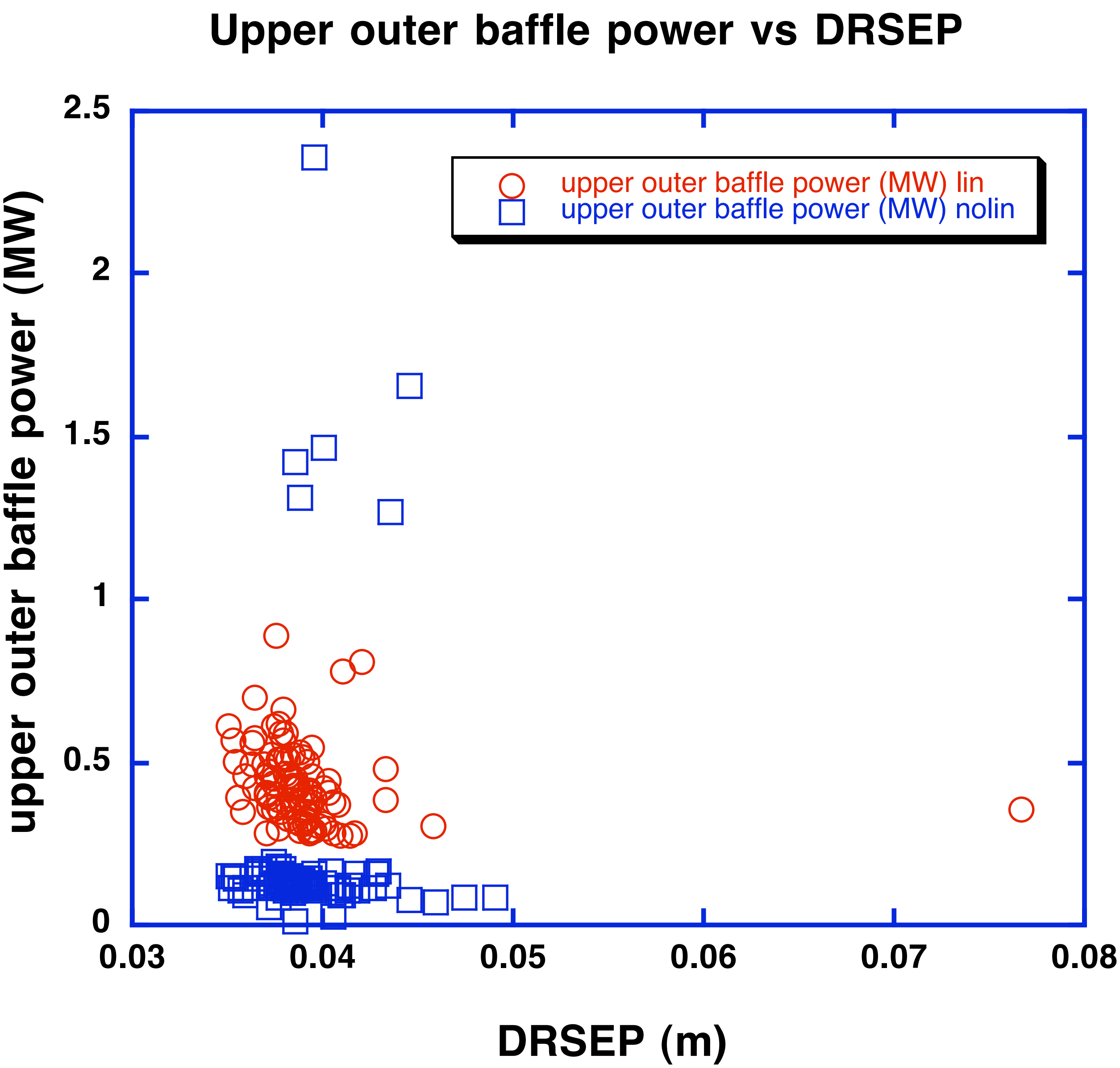
DRSEP



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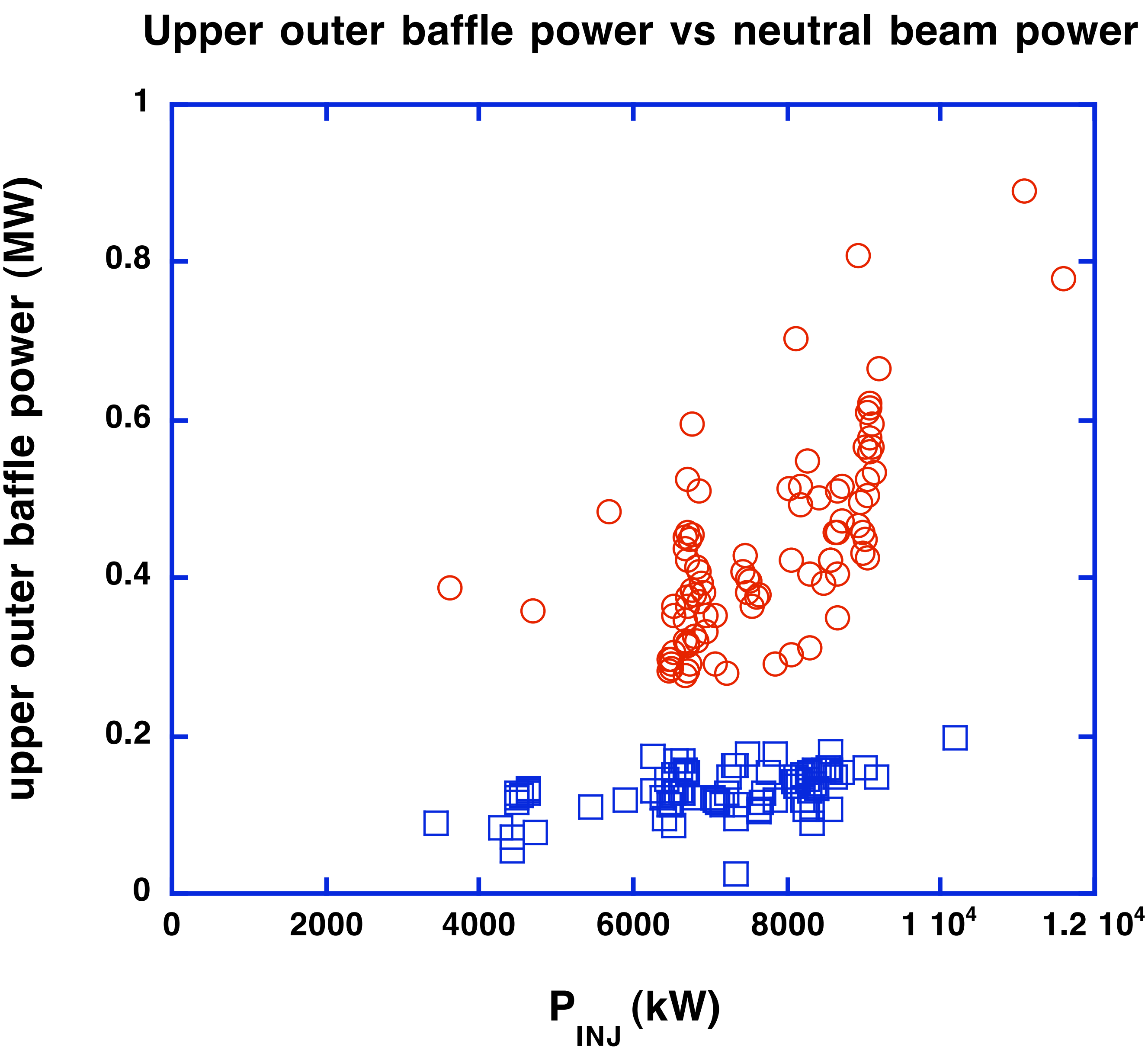
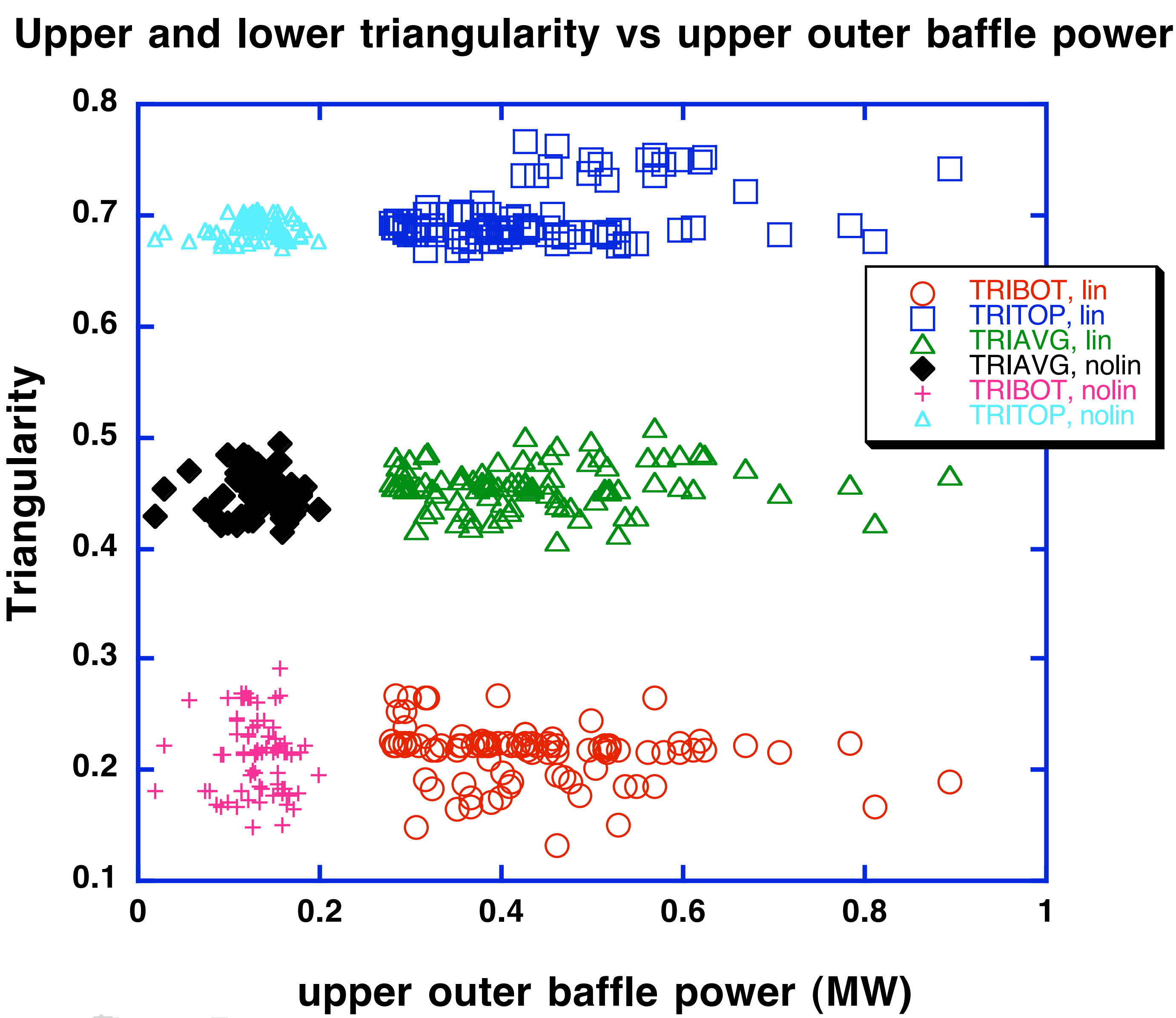
Neutral beam power



DIII-D NATIONAL FUSION FACILITY SAN DIEGO

Triangularity



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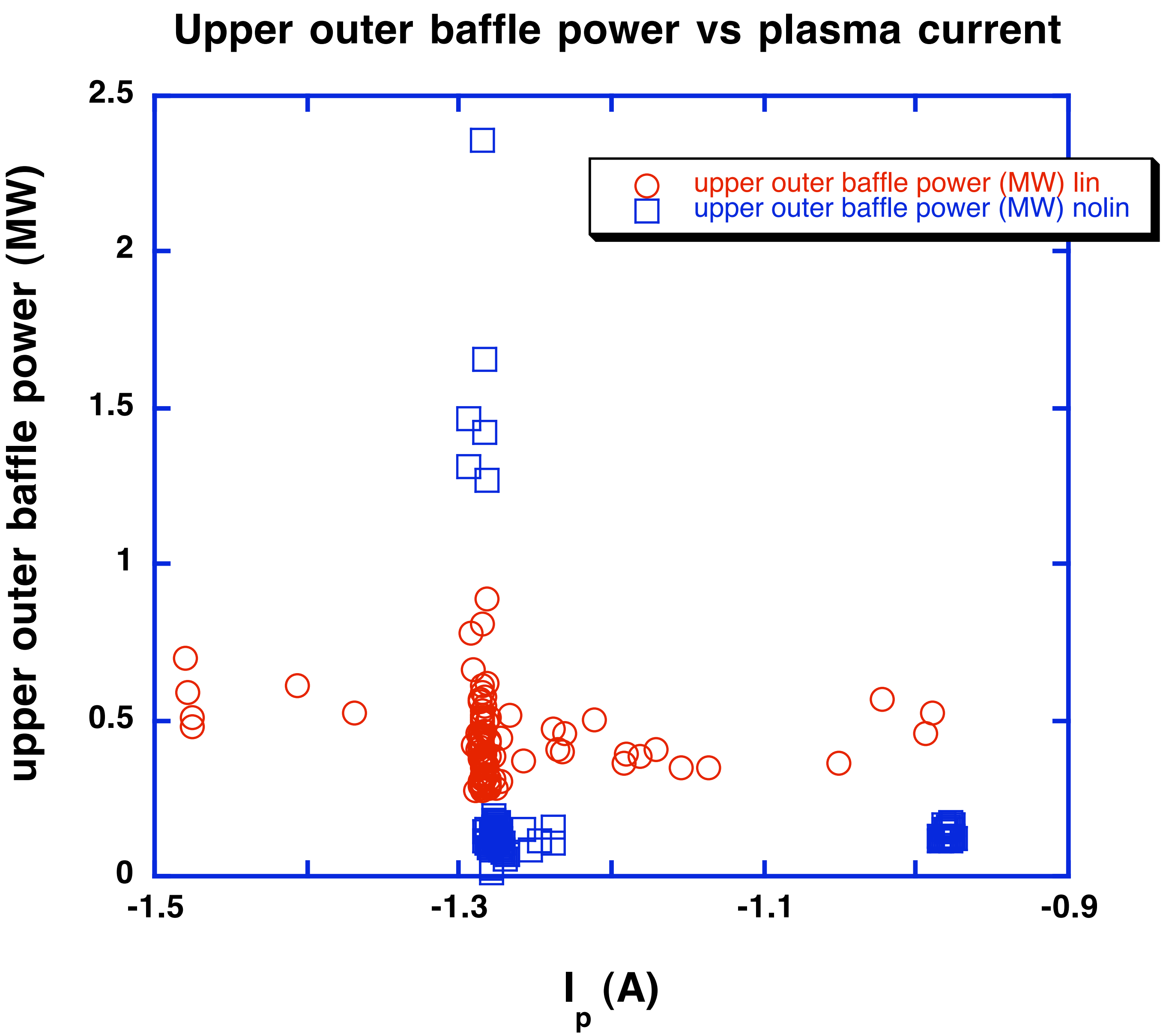
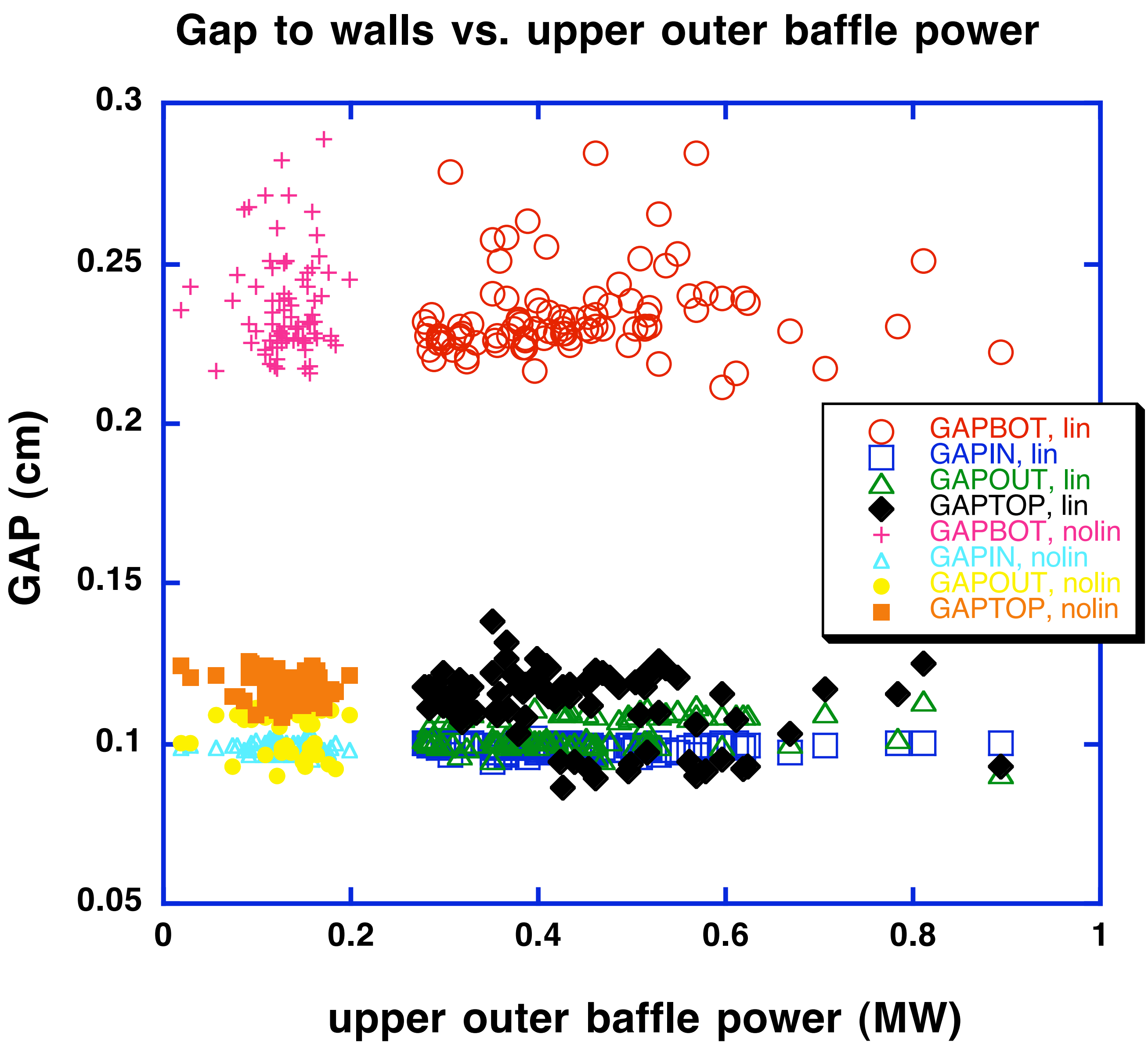
I_p


Upper outer baffle power vs plasma current
upper outer baffle power (MW) lin
upper outer baffle power (MW) nolin
upper outer baffle power (MW)
2.5
2
1.5
1
0.5
0
-1.5
-1.3
-1.1
-0.9
I_p (A)

Gap



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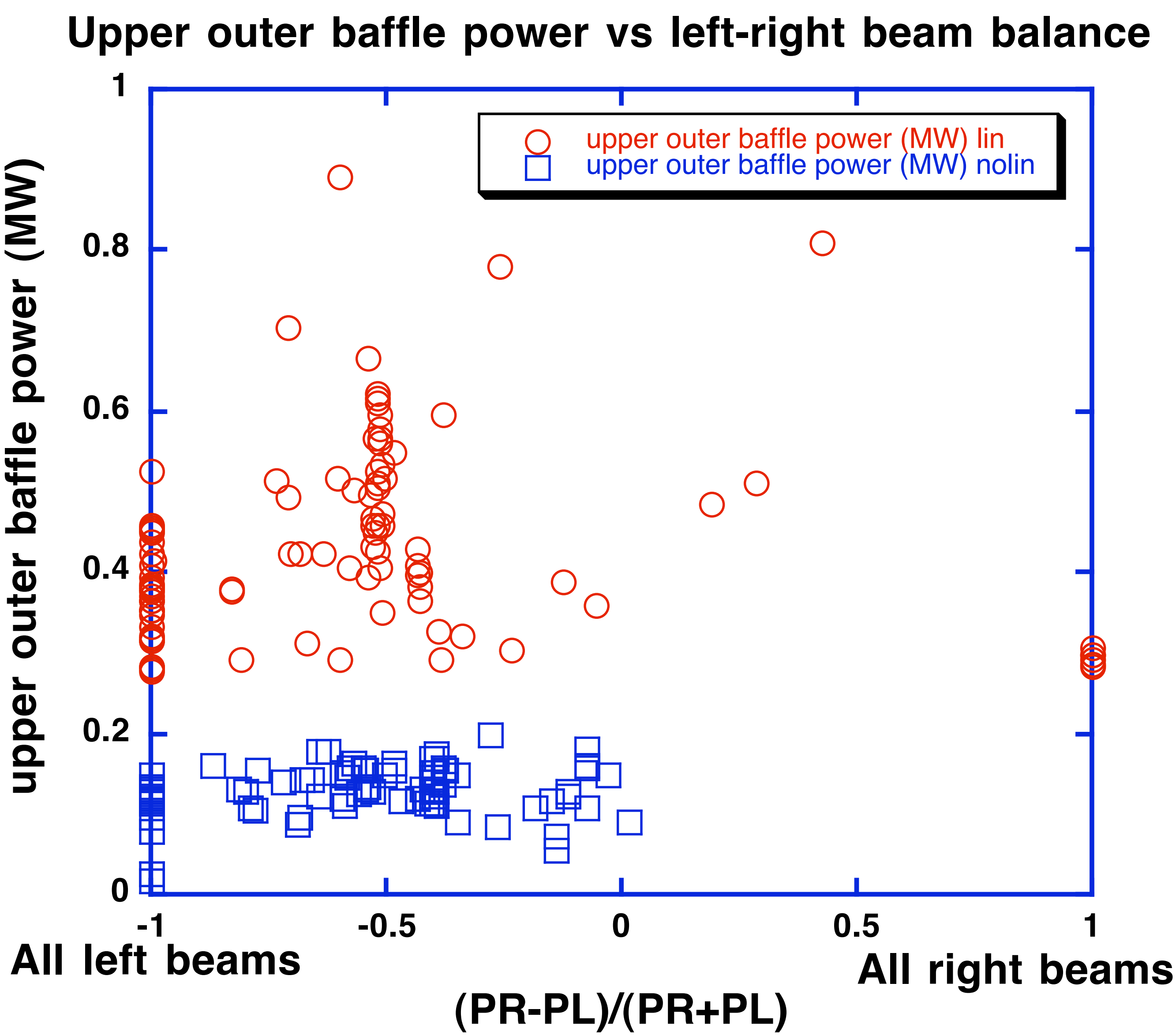
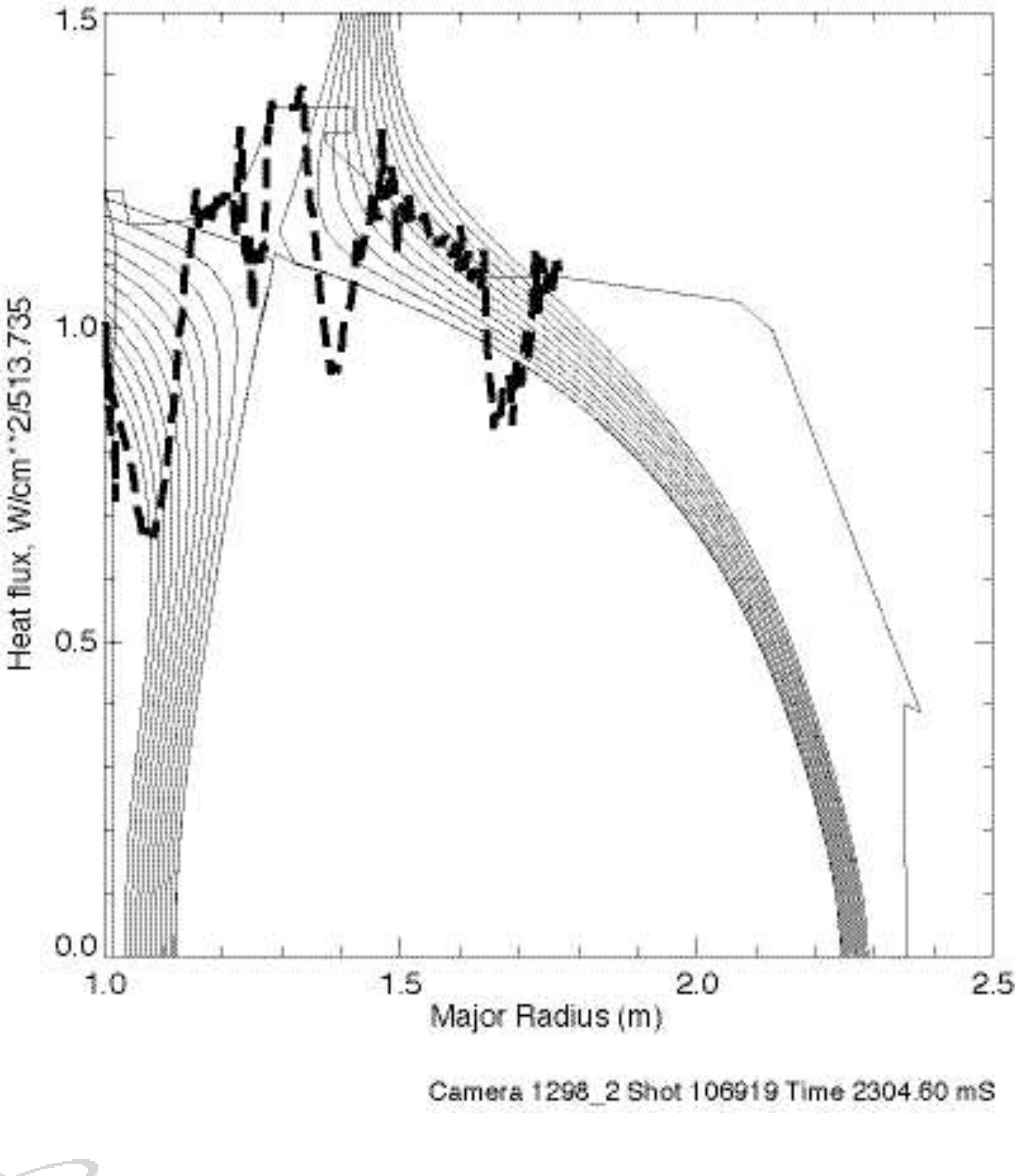
UOBpower vs left-right beam balance



Heat flux transient at inner strike point

Large heat flux at ISP during gap ramp



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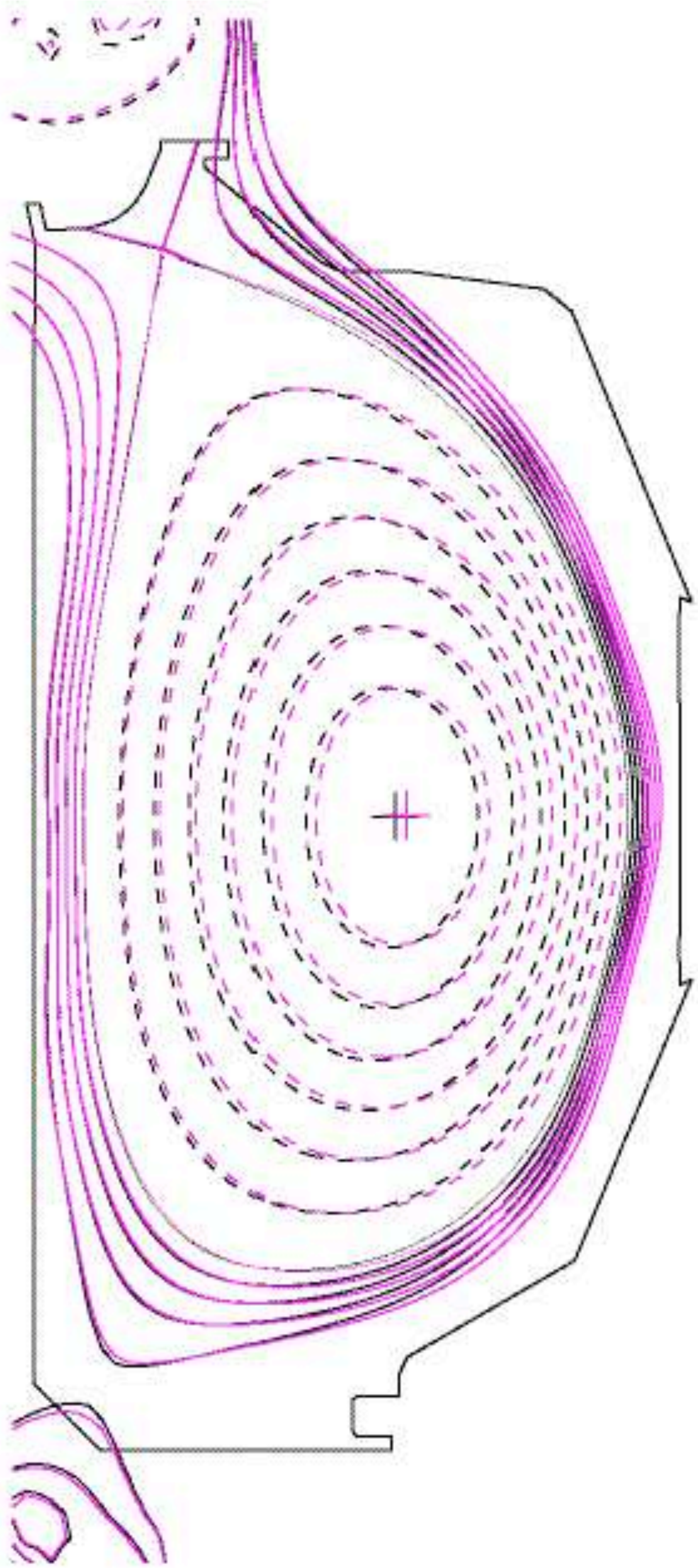
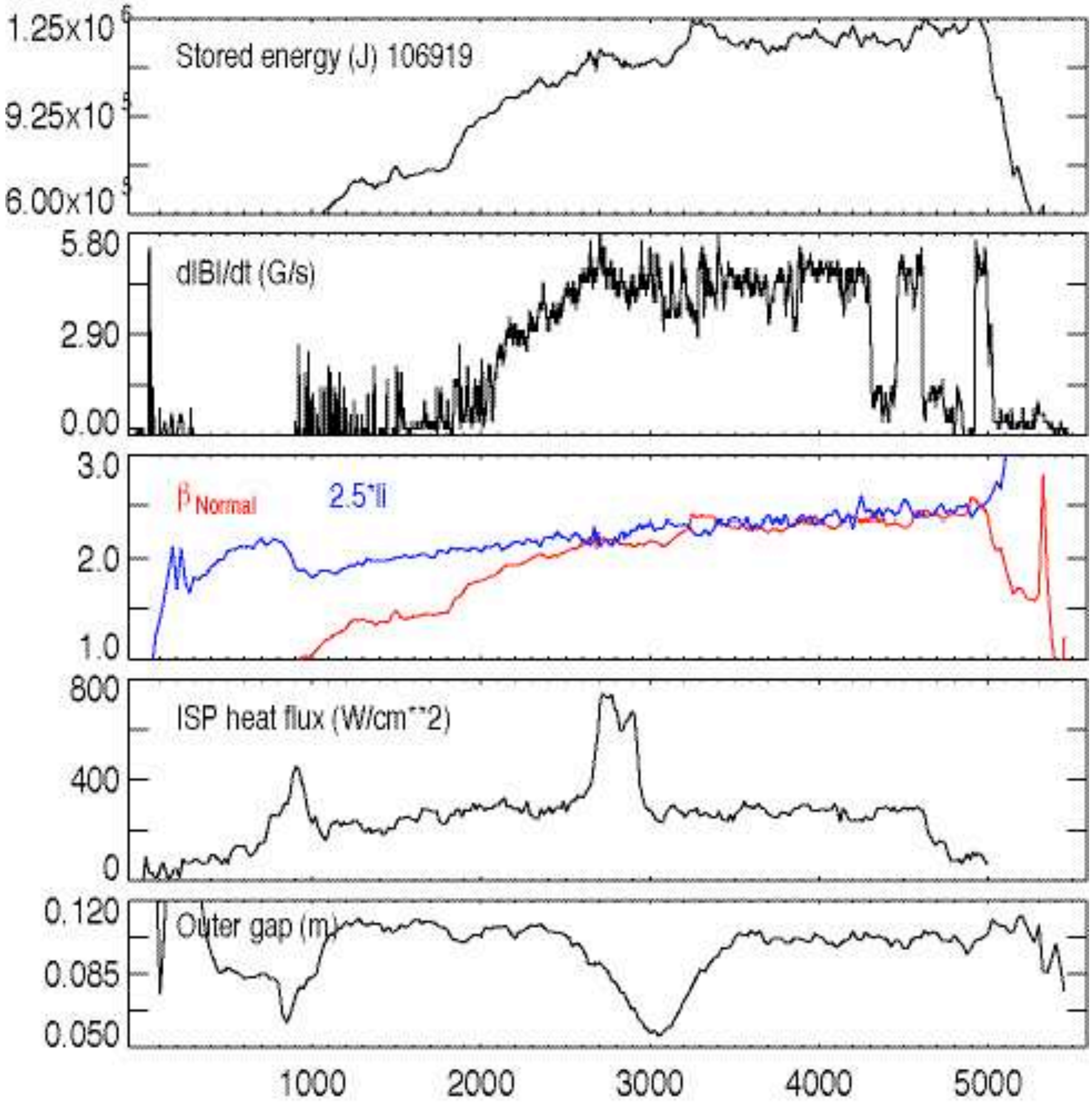
shot	106919
time	2800.00
chi**2	21.522
Rout(m)	1.697
Zout(m)	0.064
a(m)	0.576
elong	1.838
utri	0.716
ltri	0.197
indent	0.000
V (m**3)	19.174
A (m**2)	1.849
W (MJ)	1.093
betaT(%)	2.383
betaP	1.048
betaN	2.151
In	1.108
Li	0.916
error(e-4)	0.494
q1	7.530
q95	4.339
dsep(m)	0.080
Rm(m)	1.784
Zm(m)	-0.054
Rc(m)	1.744
Zc(m)	-0.031
betaPd	1.050
betaTd	2.389
Wdia(MJ)	1.096
Ipmeas(MA)	-1.272
BT(0)(T)	-2.004
Ipfit(MA)	-1.279
Rmidin(m)	1.121
Rmidout(m)	2.271
gapin(m)	0.105
gapout(m)	0.080
gaptop(m)	0.109
gapbot(m)	0.237
Zts(m)	0.759
Rvsin(m)	1.122
Zvsin(m)	1.167
Rvsout(m)	1.355
Zvsout(m)	1.348
Rsep1(m)	1.156
Zsep1(m)	-1.233
Rsep2(m)	1.284
Zsep2(m)	1.124
psib(Vs/R)	-0.082
elongm	1.442
qm	1.031
nev1(e19)	1.678
nev2(e19)	2.274
nev3(e19)	1.400
ner0(e19)	2.597
n/nc	-0.759
dRsep	0.041
qmin	1.031
rhoqmin	0.000



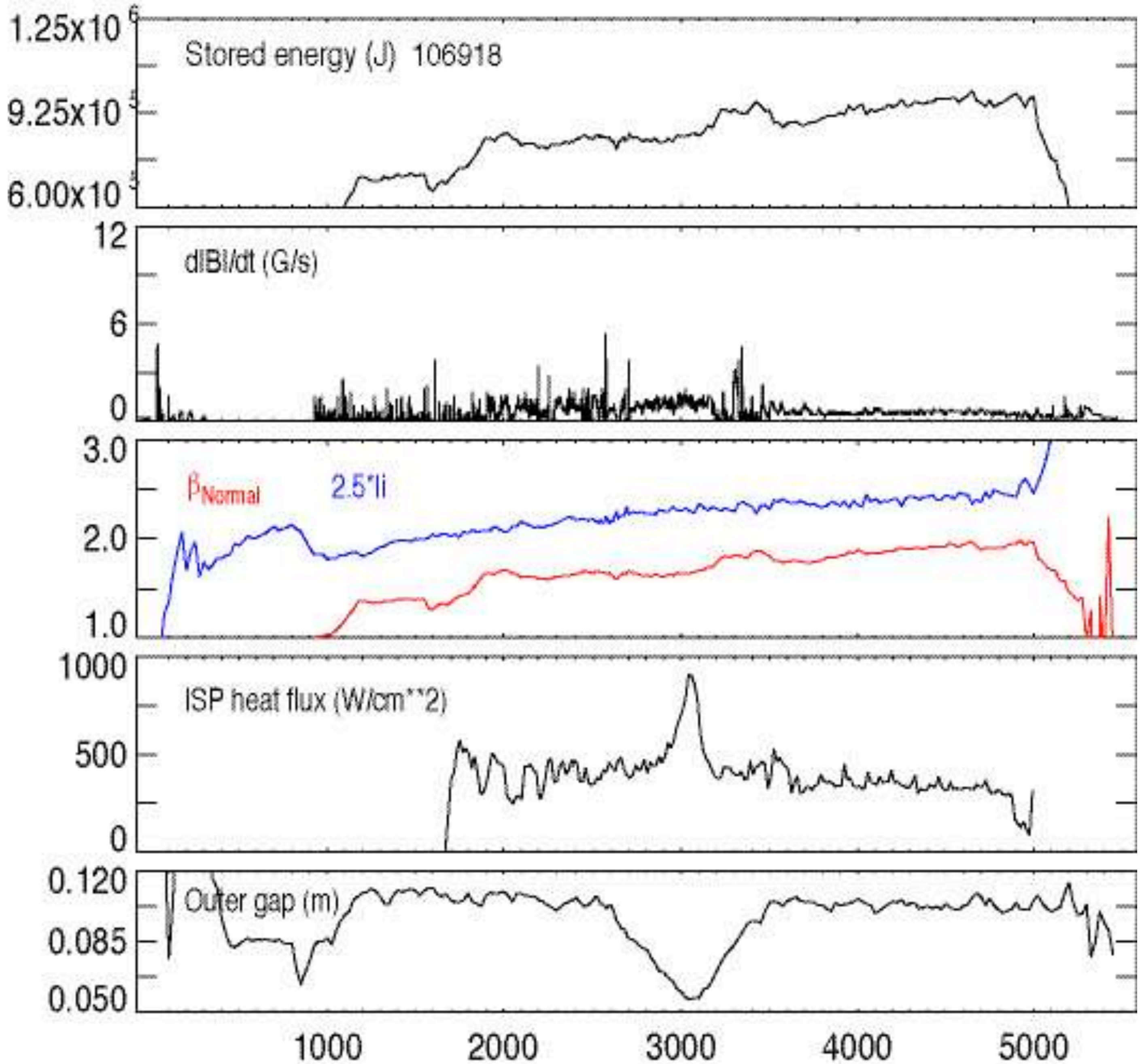
106919 2800.00

106919 2300.00

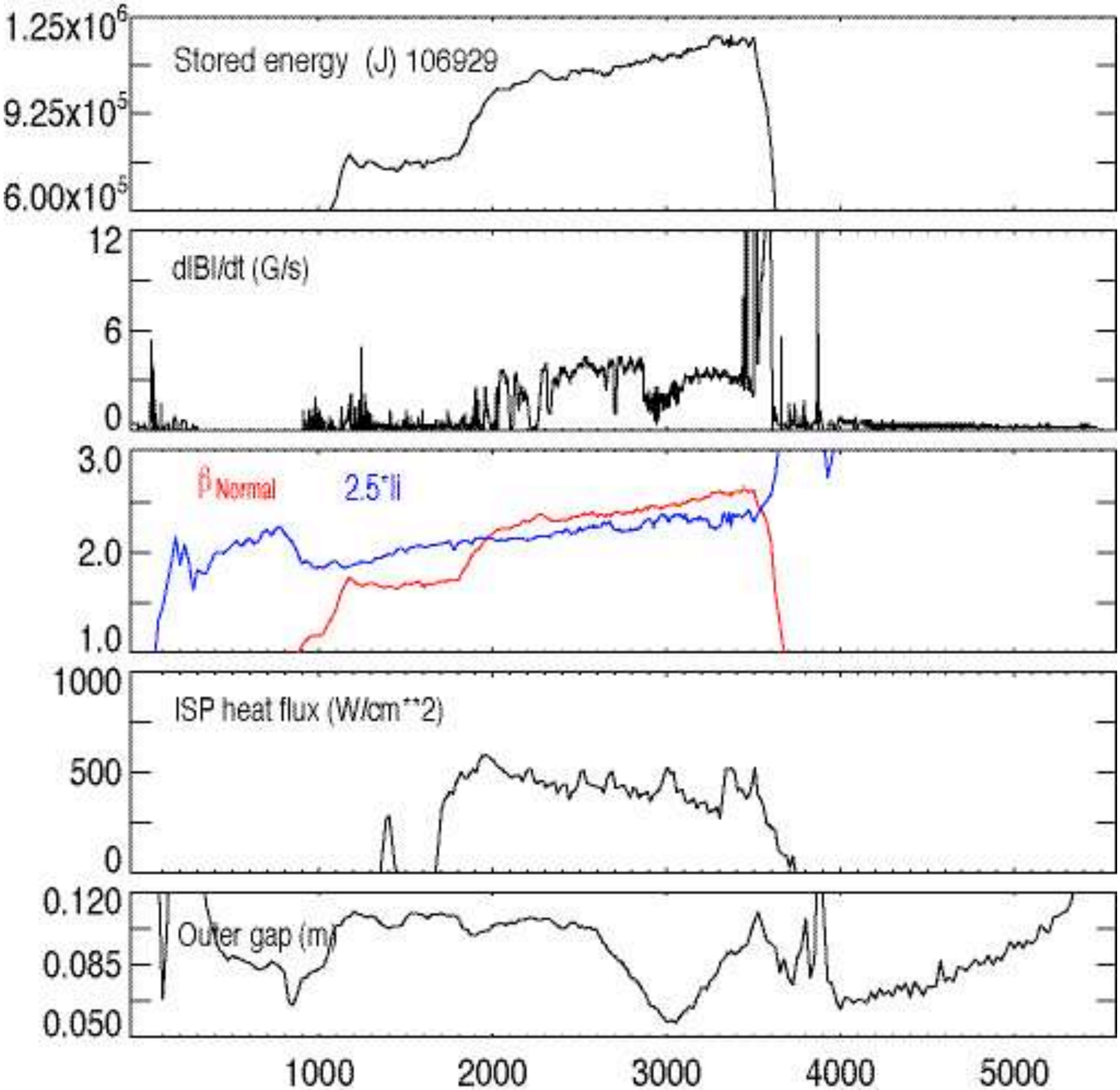
ISP transient due to gap ramp or $\beta_N \sim 2.5 \times L_i$?



Transient but $\beta_N \neq 2.5 \times L_i$



$\beta_N \sim 2.5\times L_i$ but no transient, gap ramp later



Discussion

- There is one class of QH time slices in with UOB power ~linear with β, and another class with no dependence on β.
- The linear UOB power case is strongly favored by the higher of the two NB voltages used- right beams but not left. This is consistent with increased ion loss due to Alfvén eigenmodes, which occur at the higher beam energy.
- No new evidence of banana effects
- At times during a QH outer gap ramp, there is a large transient heat flux at the inner strike point. This happens at various times in the gap ramp, and independent of the phenomenological $\beta_N \sim 2.5\times L_i$ 'limit'. The mechanism of this transient is still under investigation.