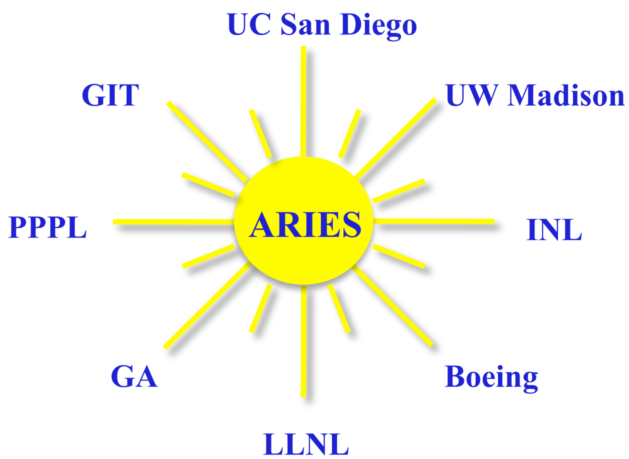

ACT2 Physics Progress

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ARIES Project Meeting, Germantown, MD, Sept 18, 2013

ACT2 Design Point

Filters to produce this operating point

P_{elec} = 1000 MW_e

$\beta_N^{tot} \leq 0.026$

$q_{div}^{peak} \leq 10$ MW/m^2

$H_{98} \leq 1.3$

$n/n_{Gr} \leq 1.3$

Lowest R to meet conditions

These constraints drove R up from 8.75-9.25 to 9.75

	ACT1	ACT2
R, m	6.25 ←→	9.75
a, m	1.56	2.44
κ_x	2.2	2.2
δ_x	0.63	0.63
Ip, MA	10.95 ←→	13.98
B_T, T (B_{Tcoil})	6.0 (10.6) ←→	8.75 (14.4)
β_N^{th}, β_N^{fast}	4.75, 0.85 ←→	2.25, 0.35
β^{th}, β_p^{th}	5.54, 2.76	1.48, 2.32
q_{95}	4.5 ←→	8.0
n/n_{Gr}	1.0 ←→	1.3
H_{98}	1.65 ←→	1.22
$\langle T_{e,i} \rangle$, keV	20.6	17.8
$\langle n \rangle$, /m^3 x 10^{20}	1.3	0.86
$T(0)/\langle T \rangle$	2.15	2.15
$n(0)/\langle n \rangle$	1.27	1.41
$\langle N_w \rangle$, MW/m^2 (at plasma)	2.45 ←→	1.46
Z_{eff}	2.11	2.12
W_{th}, MJ	691	1486
V_{plasma}, m^3	582	2209
f_{BS}	0.91	0.77
P_{brem}, MW	56.3	96.5
P_{cycl}, MW	35.0	150.4
P_{line}, MW	24.2	42.9
$P_{aux(CD)}$, MW	42.7	105.5
P_{alpha}, MW	363	528
P_{fusion}, MW	1813	2637

Ideal MHD stability of ACT2, with no stabilizing shell for low-n kink modes

Use prescribed profiles for pressure and parallel current density to understand the landscape for stability with no stabilizing shell

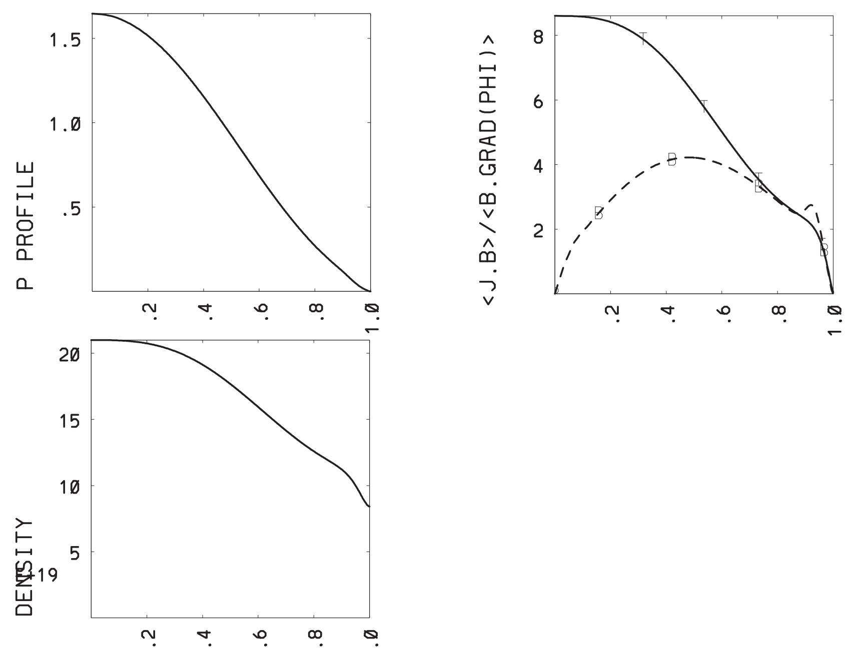
$p = p_o\ [\ (1-f_p)(1-x^{bp})^{ap} + f_p \tanh(\rho_{ped},\Delta_{ped})\ ]$

$j = j_o\ [\ c_1(1-x^{bj1})^{aj1} + (1-c_1)(1-x^{bj2})^{aj2}\ ]$

Ip = 14 MA (constrains q_{95})

Vary pressure and current density independently at first

Vary the c_1 coefficient to place more current in the center or the edge



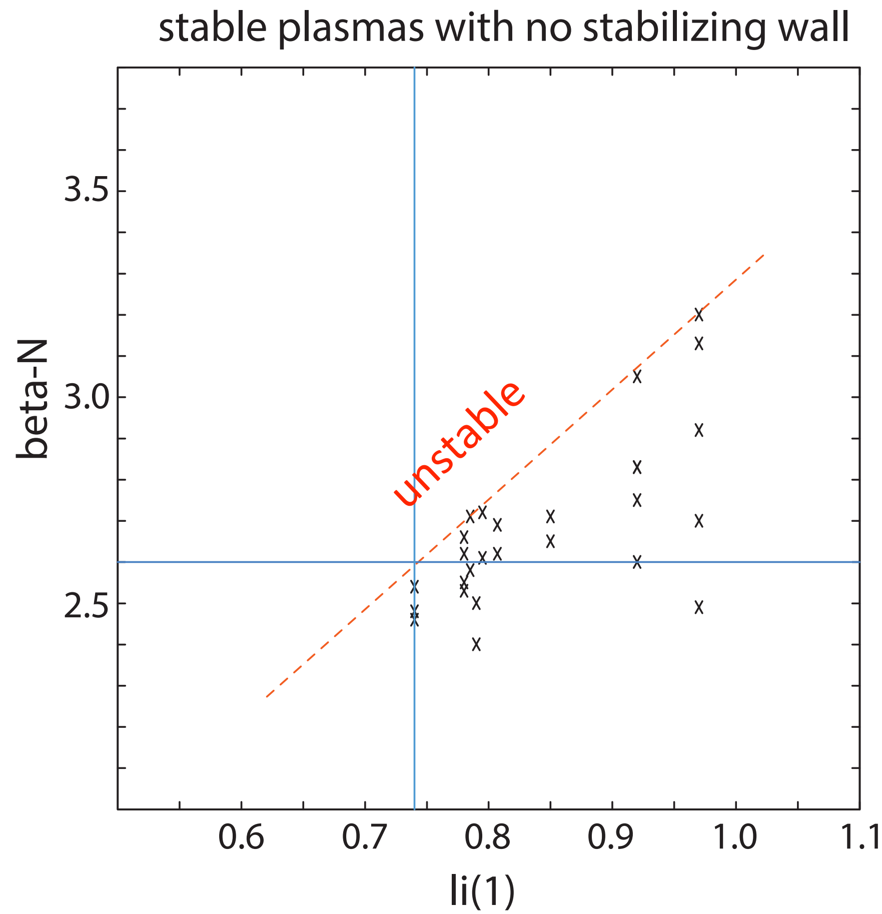
Parametric j and p Profiles Scan of Low-n Kink modes

The plasma stability is sensitive to the current profile, particularly current near the plasma edge

Low li means broad current, high li means peaked current

The higher β_N is obtained with higher li, BUT these are inconsistent with a pedestal at the plasma edge

The pedestal at the plasma edge, from the H-mode transport regime, drives bootstrap current and will stop us from accessing the high li values



Examine stability with artificial CD source profiles

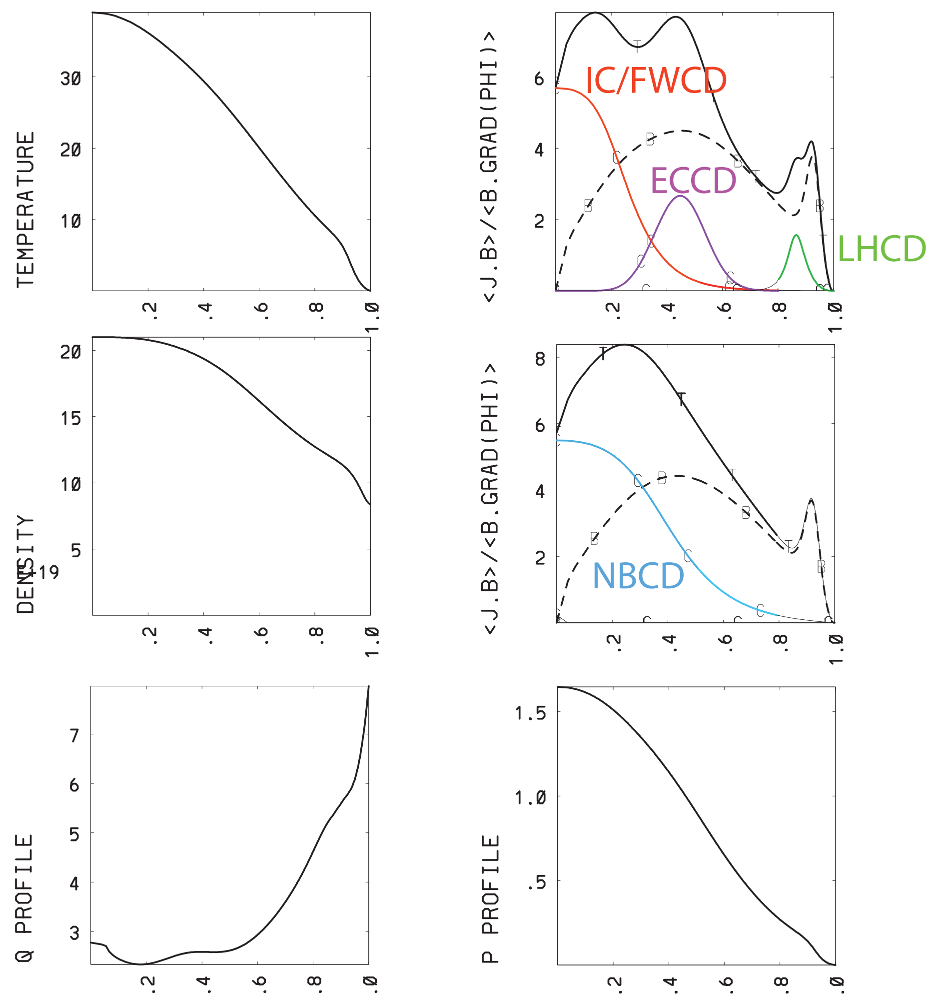
Simulate the CD profiles by typical deposition locations

LHCD tends to lower the maximum β_N since it lowers li, no LHCD is best

NBCD appears to provide a current that is centrally deposited and broad, maintains higher β_N by driving current near the center

The good NBCD feature can be reproduced approximately with IC/FW and EC

Pedestal prediction of 220 kPa, indicates for $n_{ped} \sim 0.9 \times 10^{20}$ /m^3, $T_{ped} \sim 7.5$ keV



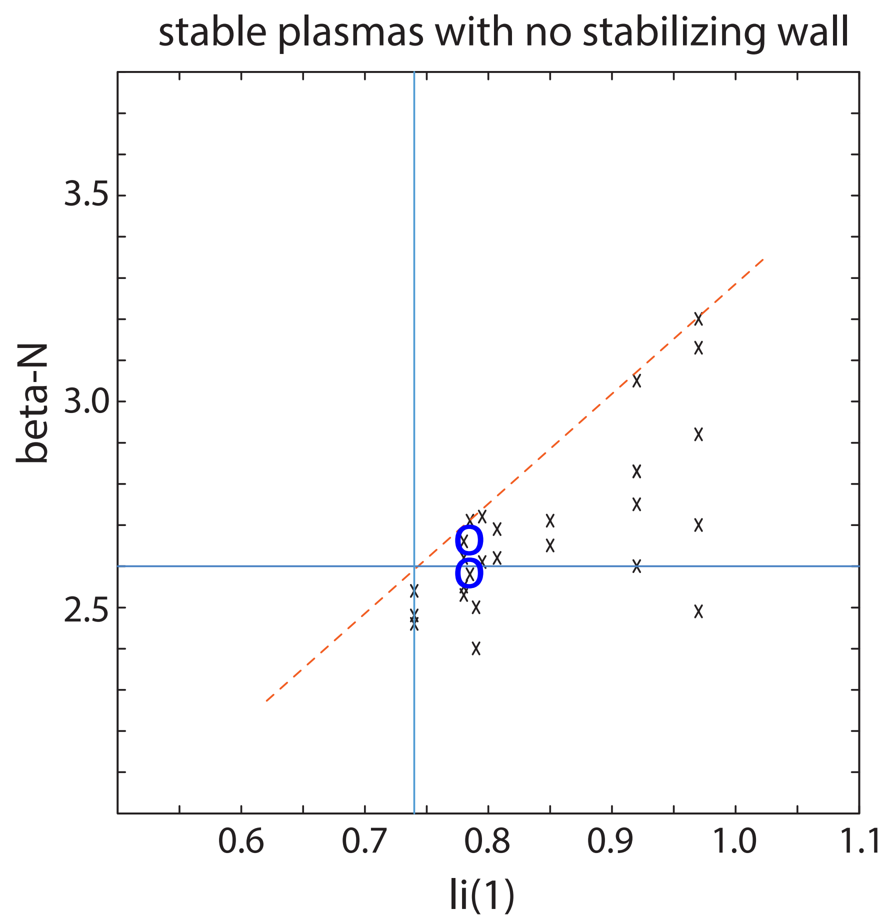
Using CD profiles confirms the range of stable configurations

β_N values of 2.56-2.65 were found stable using approx CD profiles

What if we have a stabilizing shell far away from the plasma, does it allow us to get to higher β_N

b/a = 0.675 , can access β_N = 2.85
→ 1.65 m from plasma on outboard side

b/a = 0.45, can access β_N = 3.18
→ 1.09 m from plasma on outboard side



Pedestal height in ACT2

$$p_{ped} = 2410\left(\frac{M}{n_{ped,20}}\right)^{0.33}\frac{R^{1.33}}{a^4}\frac{I_p^2}{\left(\frac{1+\kappa^2}{2}\right)^{2.33}}(1+\delta)^{3.2}\kappa^{3.62}A^{-2.94}\left(\frac{P_{tot}}{P_{L-H}}\right)^{0.06}$$

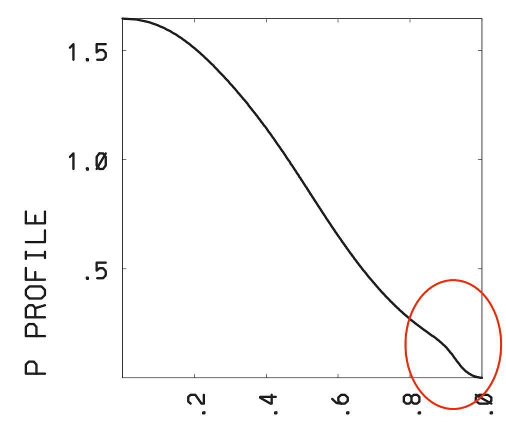
Sugihara 2003 formula does not agree with EPED1 provided by P. Snyder for ACT2

M=2.5
n_{ped} ~ 0.8 x 10^{20} /m^3
R = 9.75
a = 2.4375
Ip = 14.0 MA
κ = 2.2
δ = 0.63
A = 4
P_{tot} = 634 MW
P_{LH} = 300 MW

I get p_{ped} ~ 50 kPa, and T_{ped} ~ 2 keV

EPED1 estimate is p_{ped} ~ 220 kPa at ψ ~ 0.89

n_{ped} ~ 0.8 x 10^{20} /m^3
T_{ped} ~ 8.5 keV



ELM Parameters for ACT2

$W_{ped} = (3/2)p_{ped}V_{plasma}$

$P_{ped} \sim 220$ kPa
$V_{plasma} = 2209.4\ m^3$

$W_{ped} = 729$ MJ
$W_{plasma} = 1486$ MJ

Collisionality
$\langle T \rangle = 17.8$ keV
$\langle n \rangle = 0.86\times10^{20}\ /m^3$
$\nu^* = 0.006$

based on collisionality
$\Delta W_{ELM} = 20\text{-}25\%\ W_{ped}$
$= 146\text{-}182$ MJ

Using prescription for power splits

All ELM energy released to outboard
50% to divertors
65% to each divertor
40% in rise phase → 19-24 MJ on each divertor

Time constant
$C_{s,ped} = 8.0\times10^5$ m/s
$\tau_{||}^{front} = 610\ \mu s$ (not on experimental data plot)

$\lambda_q = 3.8$ mm
$A_{ELM,OB} = 2\pi(R-a/2)\lambda_q f_\psi f_{tilt} \sim 2.04\ m^2$ (assuming $f_\psi f_{tilt} = 10$)

ΔT_{rise} (°K or °C) $= 2/3\ (2\ \alpha^{1/2}\ \Delta W_{ELM}^{div,rise})\ /\ [\pi^{1/2}\ k\ A_{div,ELM}\ (2\ \tau_{||})^{1/2}]$,

$= 2/3\ C_{material}\ \Delta W_{ELM}^{div,rise}\ /\ A_{div,ELM}\ (2\ \tau_{||})^{1/2}$
$= 11{,}000\text{-}14{,}000$ °K

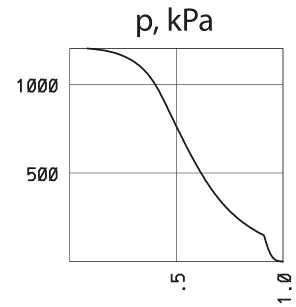
Large FW area, makes $\Delta T \sim 76$ °K for Fe-steel

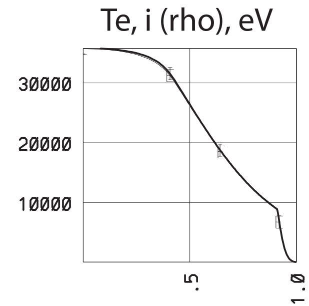
Expansion factors of 4-6 for large ELMs will still not avoid melting

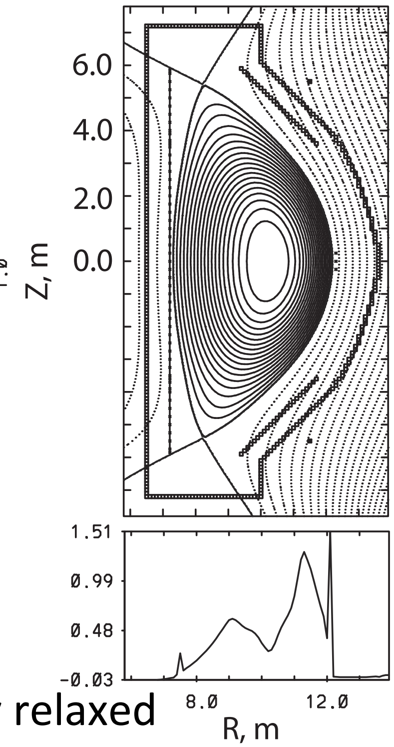
TSC Simulations

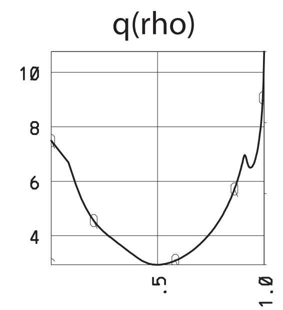
Still trying to get configuration that matches our systems code point as best as possible

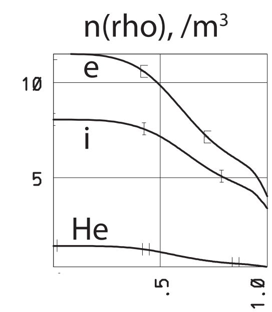
Will examine NB, IC, and EC



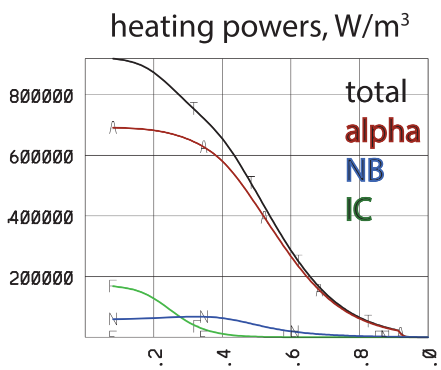


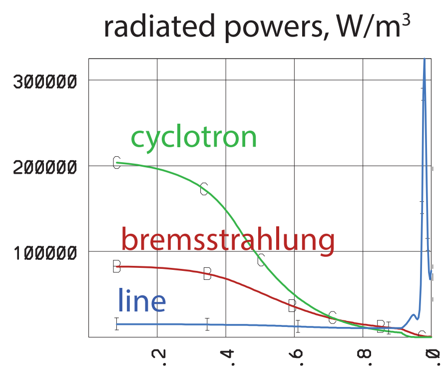


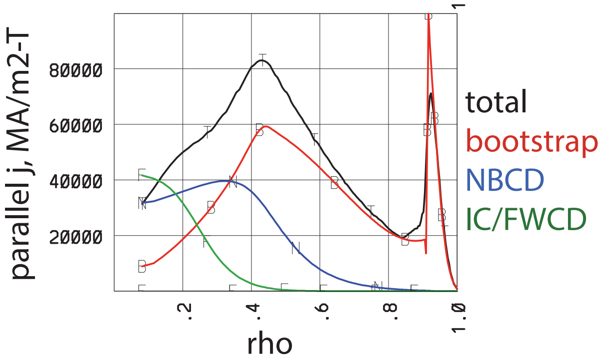


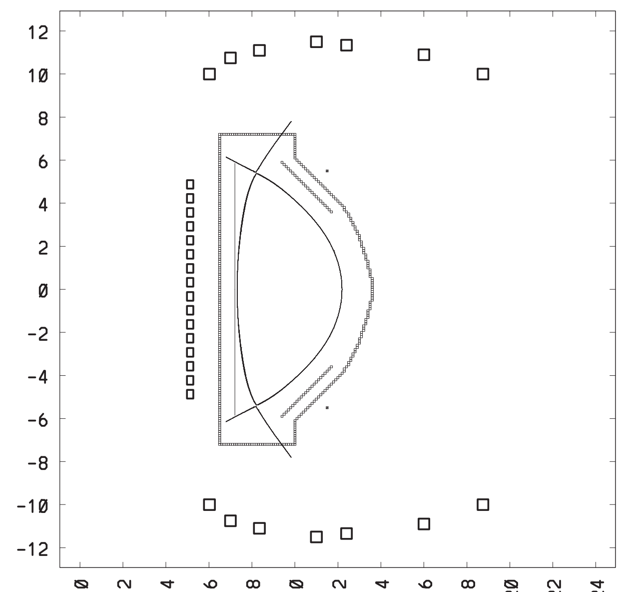


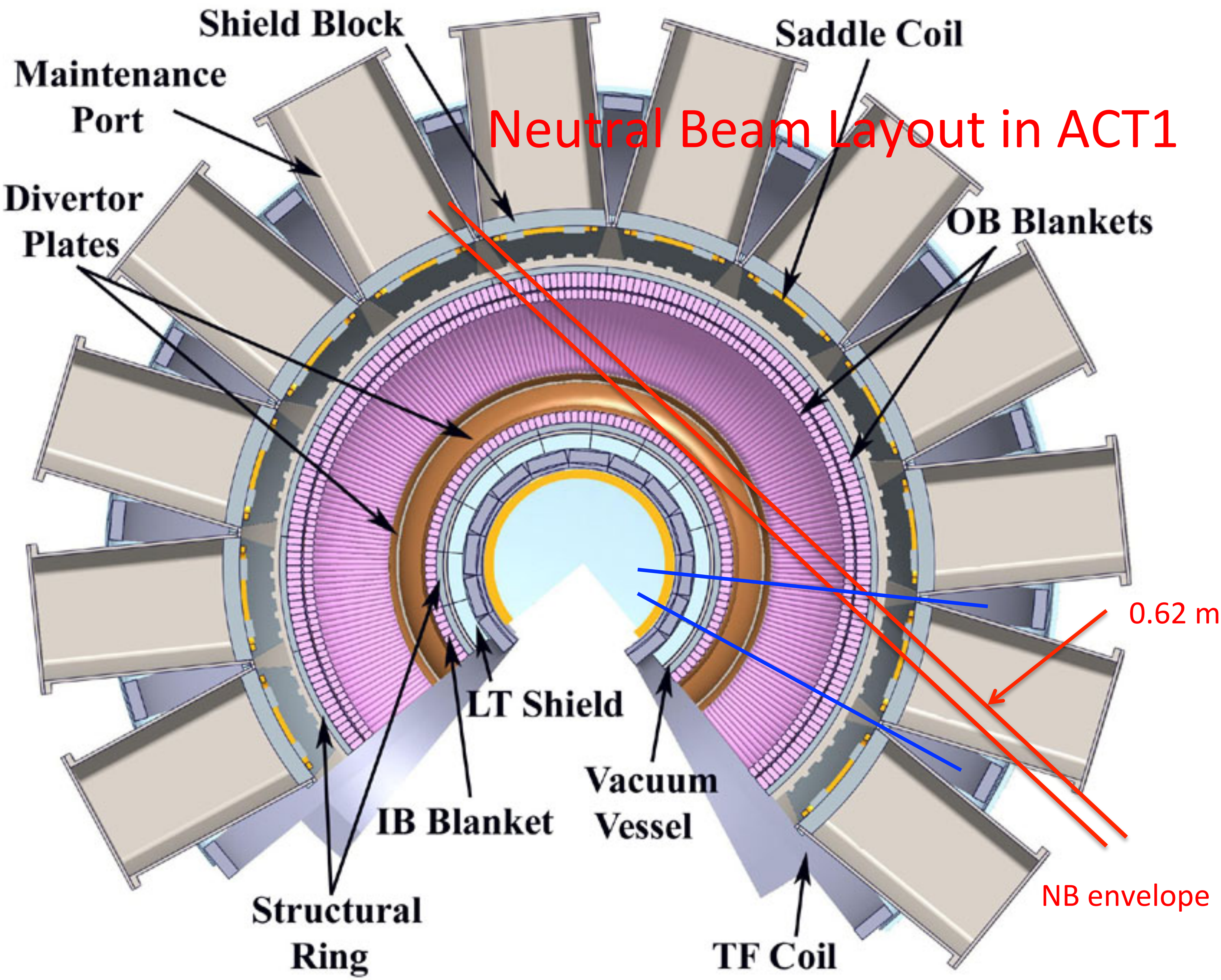
This plasma is not fully relaxed










Neutral Beam Layout in ACT1
Shield Block
Maintenance Port
Divertor Plates
Saddle Coil
OB Blankets
0.62 m
NB envelope
LT Shield
Vacuum Vessel
IB Blanket
Structural Ring
TF Coil

Observations for ACT2

The cyclotron radiation is high, ~ 100-150 MW, due to high B_T and T(0)

P_{cyc} = 150 MW (TSC 140 MW)

P_{brem} = 96 MW (TSC 75 MW)

P_{line} = 43 MW (TSC 48 MW)

→ Core radiation is higher $(P_{cyc}+P_{brem}+P_{line})/(P_{alpha}+P_{aux})$ ~ 45%

The ratio of P_{net} $(P_{alpha}+P_{aux}-P_{rad}-dW/dt)$ to H-mode threshold power is not high, $P_{net}/P_{thr,LH}$ = 1.36

Volt-seconds required in rampup is ~ 290 V-s, which is slightly higher than ITER capability, due to the large size and plasma current for ACT2

High pedestal pressure at relatively low density, gives a high T_{ped}, and with LH cutoff at 10 keV, it will not penetrate

NBCD is likely to be efficient, so that 105 MW of auxiliary power may not be required

IC/FWCD will be efficient since the plasma is similar to ACT1 in T and n

EC will be tried to mockup a NB profile