NCSX
Physics Requirements

M. Zarnstorff
Princeton Plasma Physics Laboratory

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Outline

- Physics Requirements Document (PRD)
- Issues $\rightarrow$ Plans $\rightarrow$ PVR

Physics Requirements Document

- Document the range of requirements for engineering

- Communicate within the group

⇒ Working document
  – state of our knowledge and *lack*
  – goals and *prejudices*

- Requirements need to be justified and substantiated ⇒ series of memos documenting analysis and choices
  likely hypertext linked on web pages

- Initial draft available now for comments

- Goal is to publicly release at PVR
  Many issues need further study and development

  1) Target Configuration Studies
  2) Plasma Evolution Studies
  3) Plasma / Wall Studies
  4) Reactor Projection Studies

Experiment Goals

Develop, demonstrate, test understanding of attractive compact stellarator configurations

– establish basis for whether they can be an attractive fusion reactor (~ Aries-RS)

– with bootstrap consistent equilibria

- Ability to operate at $<\beta>$ ~ 4 - 5% without disruptions
  what ι_{ext} is required to avoid disruptions at high β ?

- Determine β-limit, limiting mechanisms, and scaling

- Test adequacy of neoclassical transport optimization
  and projection to reactor-scale

- Test ability to control transport; obtain enhanced confinement; measure confinement scaling.

- Test bootstrap current stabilization of equilib. islands & neoclassical tearing

- Start exploration of edge designs for power and particle exhaust control in compact stellarators

Establish basis for decisions on next scale experiments

Proof-of-Performance

Expected Research Campaigns

1	~ 2 m	Initial plasma operation and shakedown
2	~ 4 m	Field-line mapping
3	~ 1 y	Plasma Heating(NBI, short pulse) & Diag. Commissioning • Study density limits & disruptions, neocl. optimization, velocity damping, • initial boundary control, initial RF coupling studies • at end: beta push, can we challenge beta limit with initial power?
		Add diagnostics, *possible plasma edge design modification*
4	~ 6 m	Confinement optimization • explore methods for enhancing confinement: sheared v_φ, edge conditioning and coatings, pellet injection
		Add diagnostics, *possible heating power upgrade*
5	~ 1 y	High beta studies (short pulse) • can we get to beta-limit? Study limiting mechanisms • disruption boundaries • continue confinement improvement studies (current profile equilibration via evolution control)
		Extend heating pulse length, plasma edge design upgrade, *possible heating power upgrade*
6	~ 1 y	Long pulse operation at high-beta • heating system and edge recommisioning • test j(r) equilibration • disruption boundaries in long pulse • transport stationarity

Target Configuration Studies

1.1 Required poloidal flux $\Rightarrow \langle\iota\rangle$ for NBI

- analytic and axisymmetric studies:
  ~0.28 W, $\langle\iota\rangle \sim 0.45$
- non-axisymmetric underway
- 3D assessment of candidate configurations

1.2 NB aiming angles to optimize heating

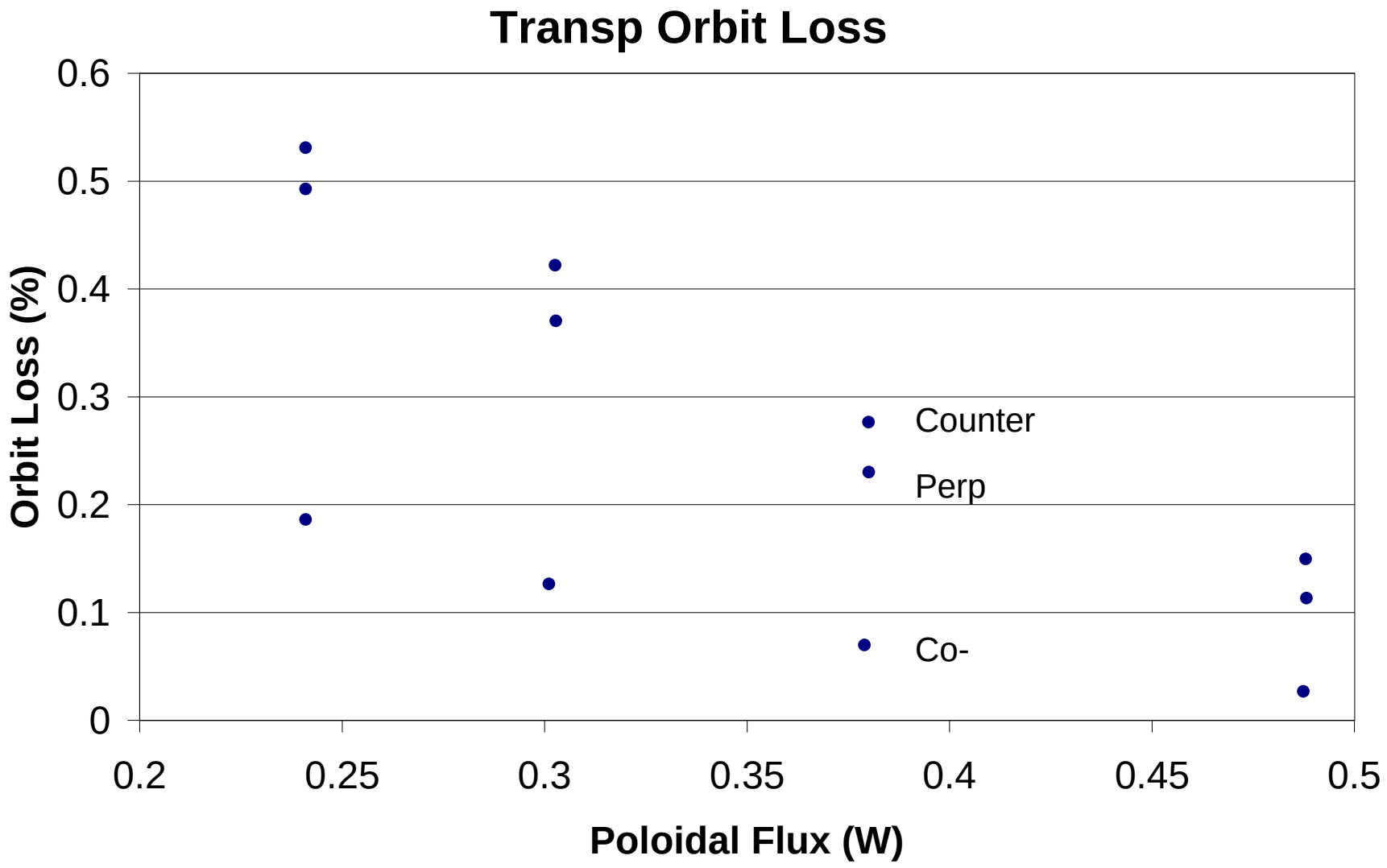
- axisymmetric studies: counter- or $\perp$ requires substantially more poloidal flux
  $\Rightarrow$ probably co-only at B = 1T
- 3D assessment of candidate configurations

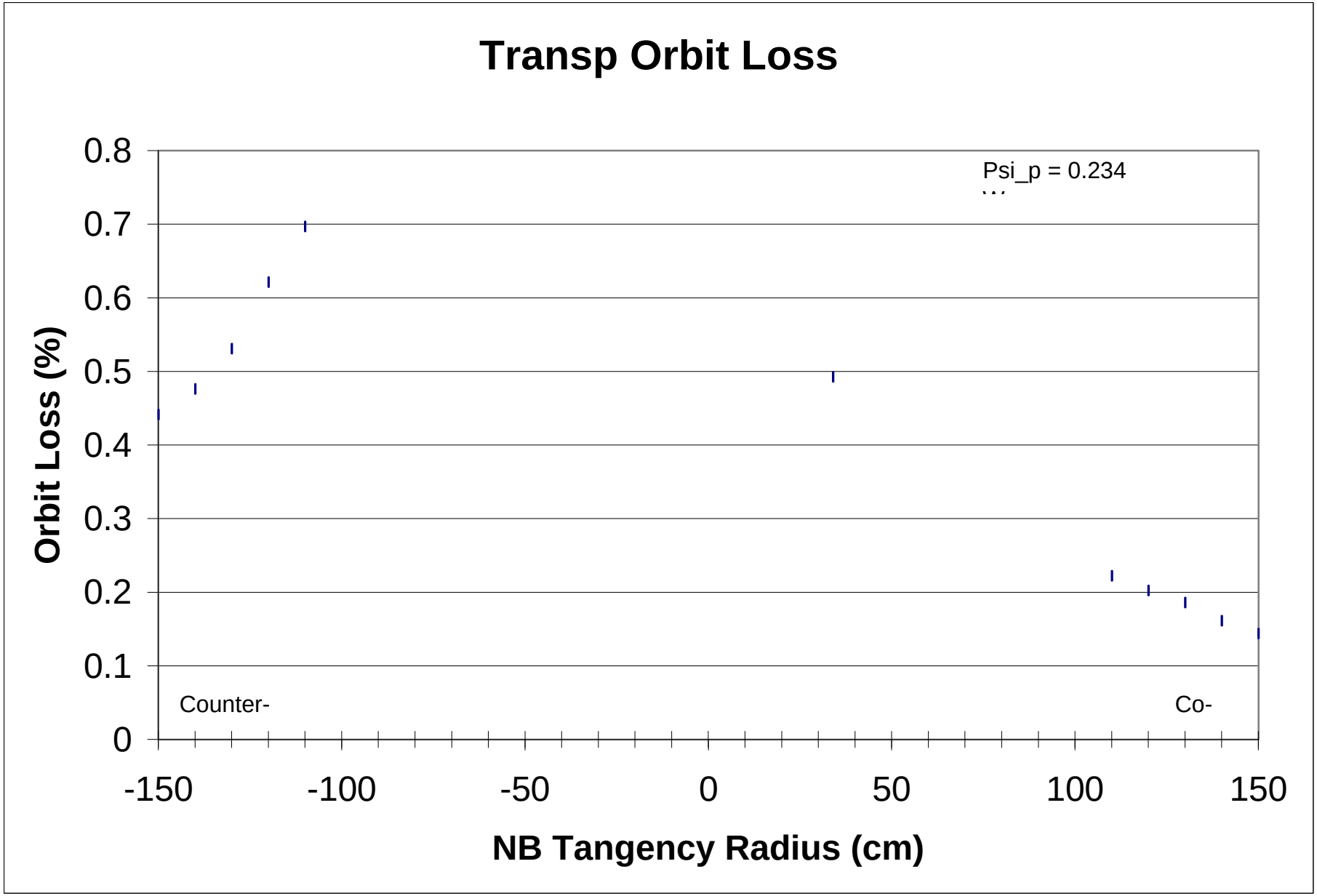
1.3 Required $\langle a\rangle$ due to CX losses (NB & thermal)

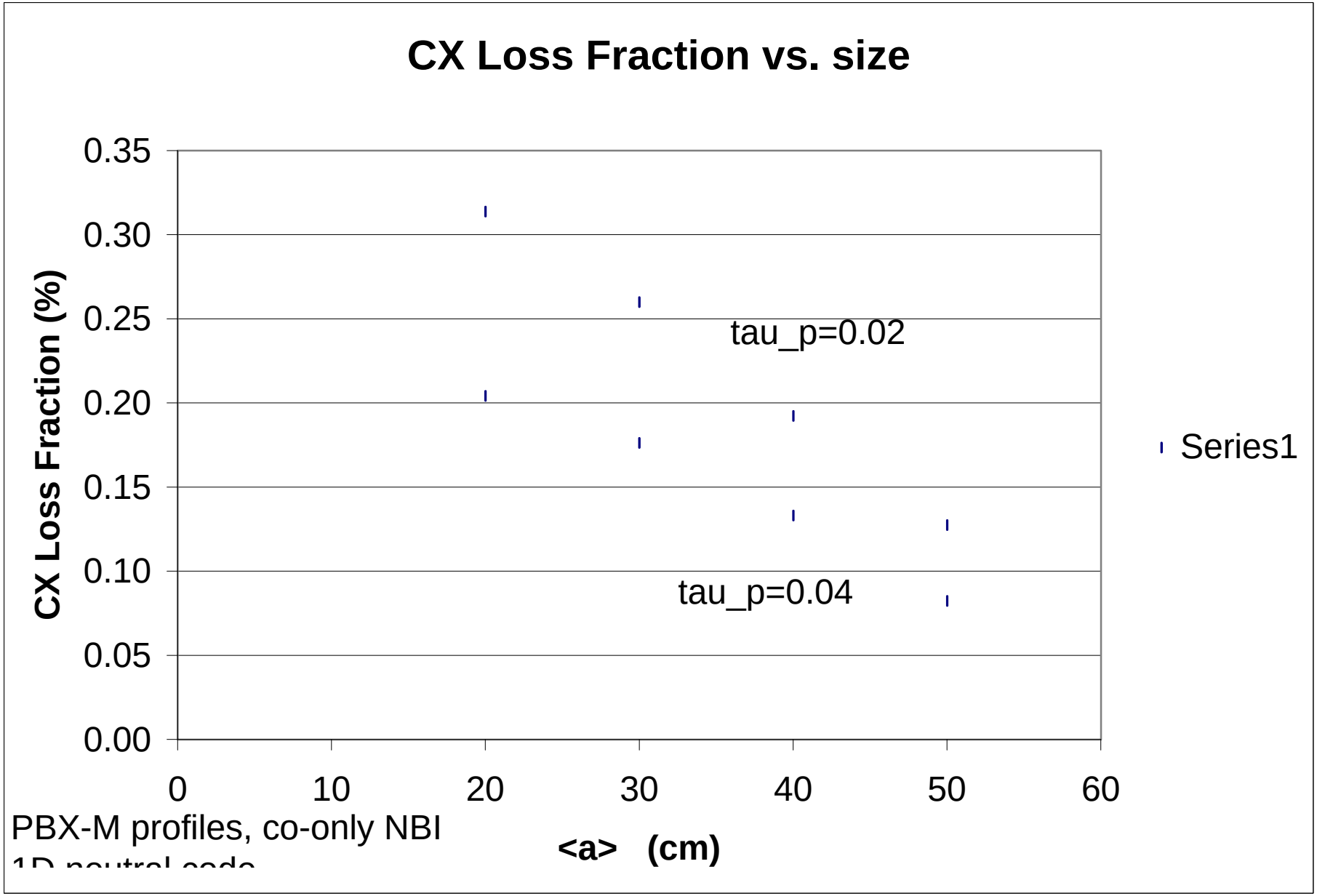
- axisymmetric study underway
- 3D neutral penetration comparison
- 3D assessment of candidate configurations

1.4 Required $\langle a\rangle$ from other factors

- global scaling?
- power handling?


Transp Orbit Loss
Orbit Loss (%)
0.6
0.5
0.4
0.3
0.2
0.1
0
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Poloidal Flux (W)
Counter
Perp
Co-


Transp Orbit Loss
Psi_p = 0.234
Counter-
Co-
Orbit Loss (%)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-150
-100
-50
0
50
100
150
NB Tangency Radius (cm)


CX Loss Fraction vs. size
CX Loss Fraction (%)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
tau_p=0.02
tau_p=0.04
Series1
<a> (cm)
PBX-M profiles, co-only NBI
1D neutral code

Target Configuration Studies

Cont'd

1.5 Flexibility required by Physics Goals

- what range of n_e, $\langle\iota\rangle$, I_P ?
- what range of $\langle\kappa\rangle$, $\langle\delta\rangle$, 3D shaping?
- expected range of pressure and current profile shapes
- what are required heating characteristics? (e.g. NB aiming)

some aspects are clear:

- need ability to make kink stable & unstable
- need factor of ~2 range in B for transport scaling studies
- need momentum source for damping studies

Need to sketch experimental plan for each of the major experimental goals, determine required capabilities series of "proto-XPs"

1.6 Diagnostics requirements and plan

Plasma Evolution Studies

2.1 OH-CD target plasma scenario

- use OH current to achieve needed $\langle\iota\rangle$ and n_e to start NBI
- evaluate V-s consumption and requirements
- evaluate ability to meet flexibility requirements

develop control and coil flexibility requirements

Likely plan: modify 3D-Whist for current evolution

2.2 Non-CD target plasma scenario

- evaluate shaping evolution to achieve needed $\langle\iota\rangle$ to start NBI
- heating and densification requirements

e.g. ECH/ICRF scenario like CHS

- evaluate ability to meet flexibility requirements

develop control and coil flexibility requirements

2.3 Evolution during heating

- evolution of $\iota(s)$, equilibrium
- low and high-β
- short and long pulse

develop control and coil flexibility requirements

Plasma Evolution Studies

Cont'd

2.4 Evaluation of candidate coil designs

- flexibility for Physics Goals
- ability to control plasma evolution
- robustness vs. range of pressure & current profiles

2.5 Disruption Requirements

- Current decay rate in NCSX size machines
- are vertical displacements expected during disruptions?

Need: something like 3D-TSC

Plasma/Wall Studies

3.1 Vacuum baking requirements

- past experience based
- PFC conditioning to achieve high plasma performance.

3.2 Wall coating requirements

- for vacuum cleanliness
- for improved confinement & recycling control

3.3 Limiter requirements and characteristics
(for each exp. Phase)

- number, size, likely locations
- moveable?

3.4 Foreseeable divertor requirements

- likely locations
- space envelope required

3.5 Localized power handling

- field line tracing for localized particle loss
- NB protective plates

3.6 Foreseeable ergodic edge requirements

- space envelope required
- characteristics

Reactor Projections

Needed for FESAC and SEAB

4.1 Candidate Reactor Configurations building on NCSX

- Plasma design without PBX-M constraint
- Coils designed for a reactor

4.2 Update of SPPS projections

- Najmabadi interested, applied for funding?

	Issues / Studies Needed	PRD Sections	Req'd By	
	Target Plasma Configuration			
1.1	Required poloidal flux		PVR	Axisymm
1.2	NB aiming angles		PVR	
1.3	Required <a> from CX losses		PVR	Axisymm
1.4	Other <a> requirements?		PVR	
1.5	Flexibility required by Physics Goals		PVR	
1.6	Diagnostics requirements		PVR	
	Plasma Evolution Studies			
2.1	OH-CD target plasma scenario		PVR	
2.2	Non-CD target plasma scenario		PVR	
2.3	Evolution during Heating		PVR	
2.4	Evaluationof candidate coil designs		PVR	
2.5	Disruption requirements		post PVR	
	Plasma / Boundary Studies			
3.1	Vacuum baking requirements		PVR	Kugel Memo
3.2	Wall coating requirements		PVR	
3.3	Limiter requirements and characteristics		PVR	
3.4	Forseeable divertor requirements		PVR	
3.5	Localized power handling requirements		PVR	
3.6	Forseeable ergodic edge req'ts		PVR	
	Reactor Projections			
4.1	Candidate Reactor Configurations		SEAB	
4.2	Update of SPPS Projections		SEAB	