MCNP/CAD Activities and Preliminary 3-D Results

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ARIES-CS Project Meeting
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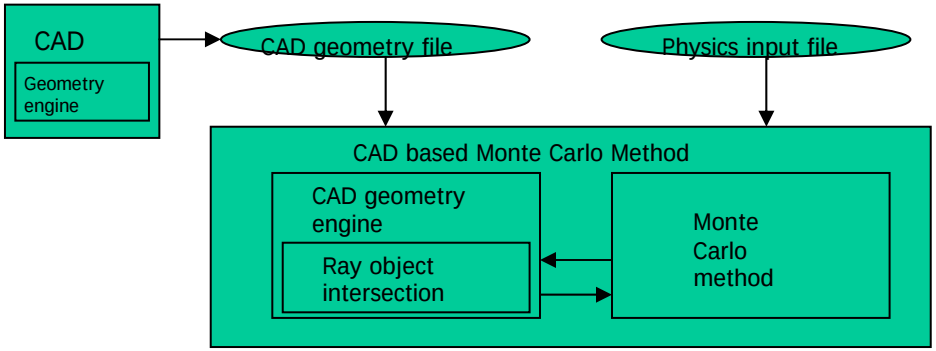
UW – Madison

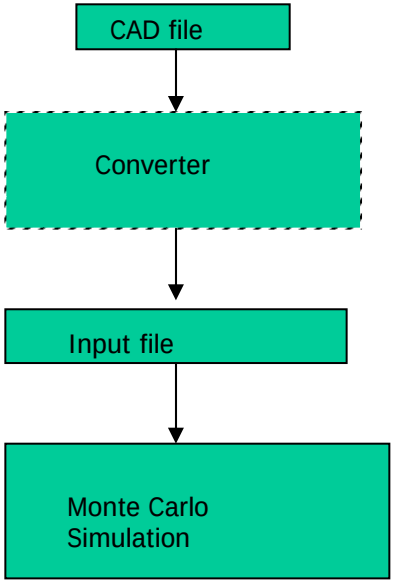
Outline

Introduction	Tim
3-D results	Mengkuo
1-D / 3-D comparison	Laila
Future plan	Laila
Discussion	all

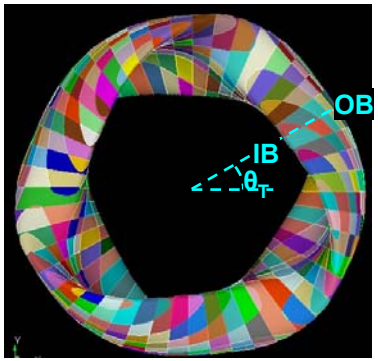
Introduction

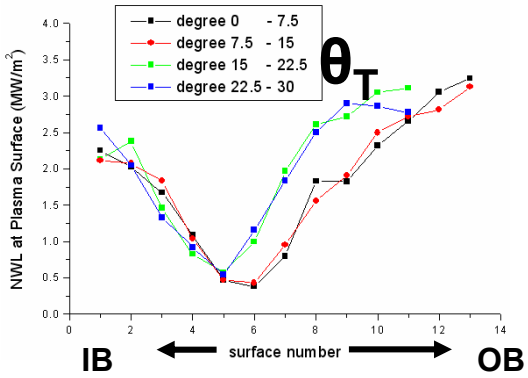
- Direct vs. translation-based Monte Carlo





- Last time:
  - *Plasma surface* loading
  - CAD geometry from Pro/Engineer
  - CPU time 5 days, 10% statistical error

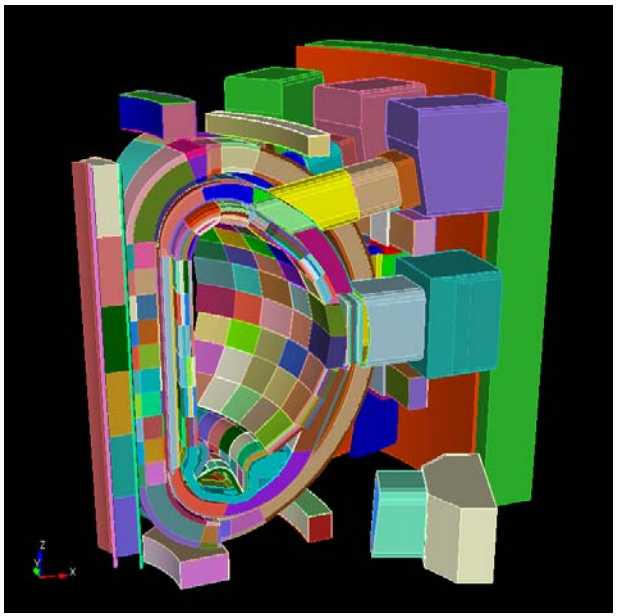




- LOTS of technical progress since then (MengKuo)
- UW/SNL support from DOE for ITER applications
- Others working on different approaches for similar problems

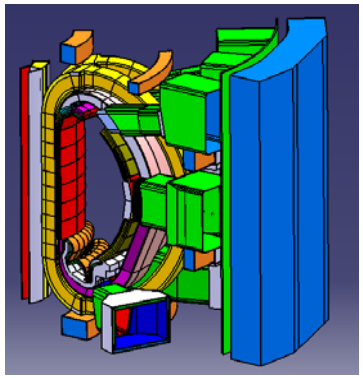
Other (DOE) Support: MCNPX/CGM Application to ITER

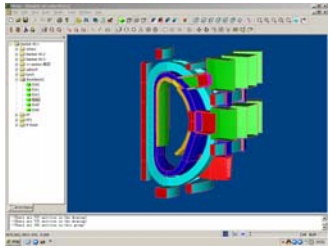
- DOE funded UW/SNL to apply MCNPX/CGM to ITER modeling
- Initial effort will be on benchmarking direct CAD-based approach against other approaches for “simplified” ITER benchmark model
- Significant issues cleaning up CAD models
  - Removing gaps/overlaps
  - ITER IT helping with cleanup, interested in improving design processes
- Will fund distributable version of MCNPX/CGM
  - ARIES participants will have access (w/ license detail caveat)

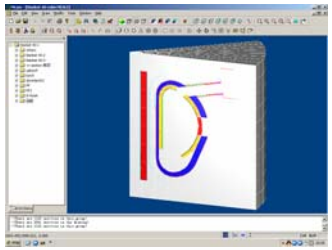


Others' Work in CAD-Based MC

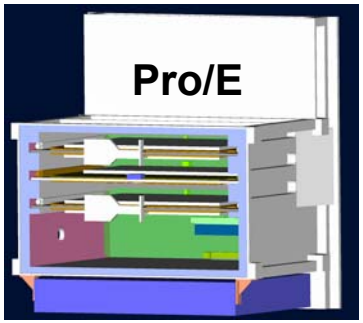
- Wu et. al (Hefei U, China)
  - Current MCAM version 4
  - Most sophisticated of translation-based approaches
  - 12+ student-person effort (started '98)
  - Will get direct comparison late fall

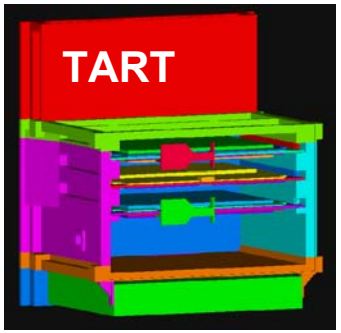




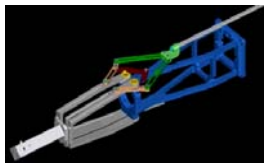


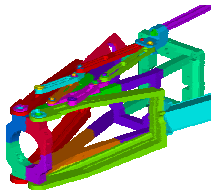
- LLNL/Raytheon
  - Raytheon's TOPACT code: translation from CAD to MC (TART or MCNP, other CG codes possible)
  - Most recent of translation-based efforts (2-3 yrs old)
  - Still determining the "utility (and readiness) of TOPACT"





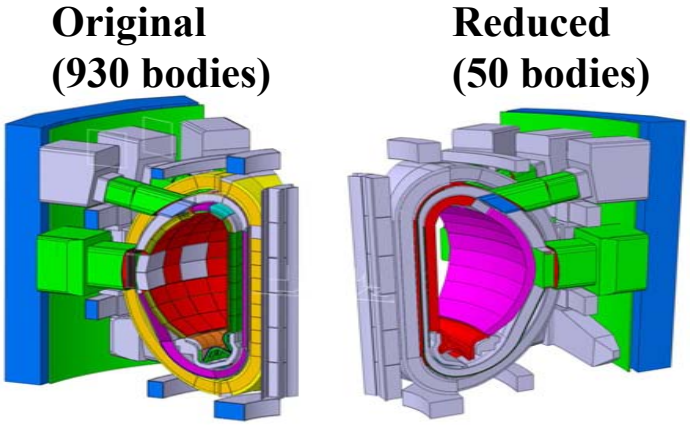
Example images courtesy of Steve Manson, Raytheon





Others' Work in CAD-Based MC (cont)

- Fischer et. al (FZK)
  - Tim visited 4/05
  - Most recently working on automatic complement generation for CAD models
  - Potential collaboration porting CGM to Open-Cascade
- Attila benchmark (Loughlin, UKAEA)
  - Discrete Ordinates-FE approach, but most similar to ours in CAD requirements
  - Took "simplified" ITER benchmark model & further reduced from 930 to 50 bodies
  - Est. 60-90 days to build MCNP input for 50-body model

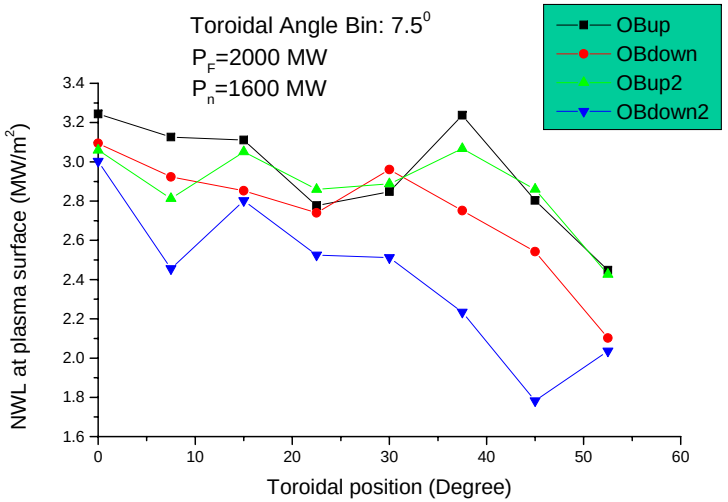


Others' Work in CAD-Based MC (cont)

- Other assorted efforts
  - French code "Chavir" for walk-through, robotics
  - Japanese possibly thinking about CAD-based Monte Carlo
- Conclusions
  - Our approach (ray tracing/geometry in CAD, transport physics in MCNPX) still unique
  - For ARIES-CS, still only viable approach
    - Complex plasma surface definition (high-order NURBS in CAD)
    - Production-level Monte Carlo code

Last September Meeting

1. Plasma surface overlap with First Wall surface (Use plasma surface for wall loading calculation)
2. Low computation speed (5 days computation, statistical error 10%)

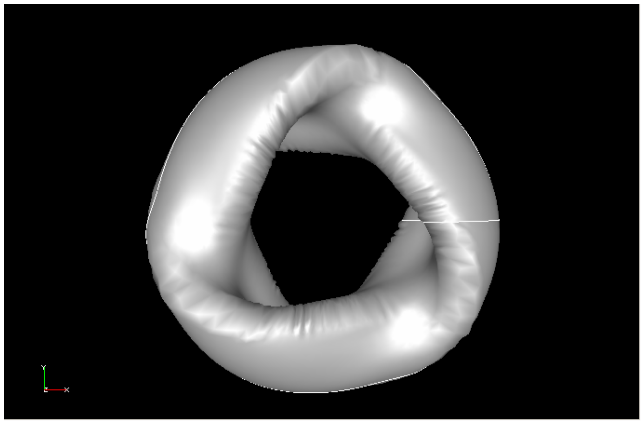


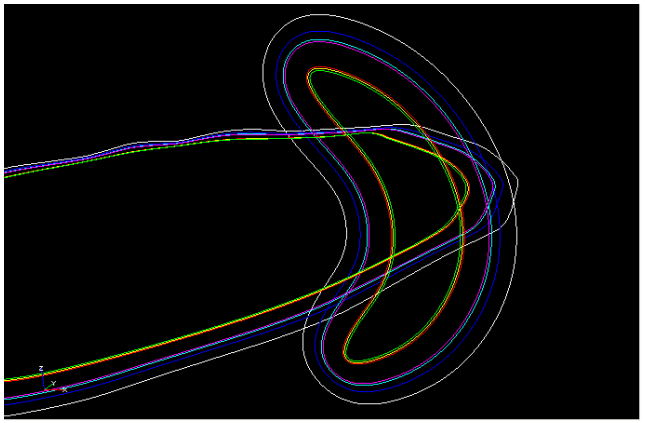
Latest Achievements

1. Successfully constructed the Stellerator surfaces, from First Wall to Manifolds

2. High performance computational algorithm using facet based model for wall loading (Γ)

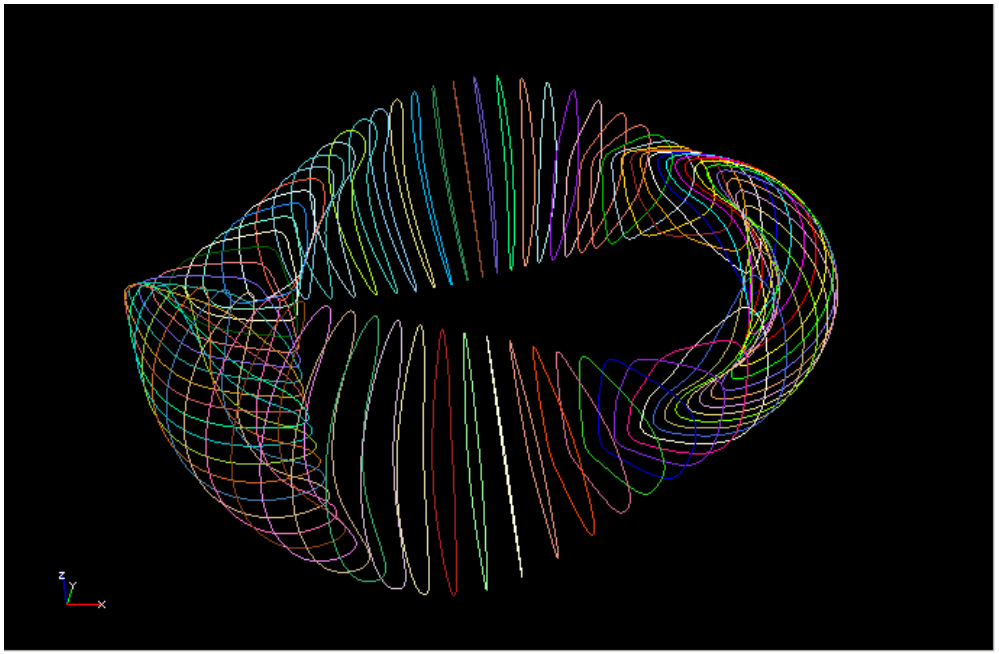
3. 1 hour computation with 1% statistical error





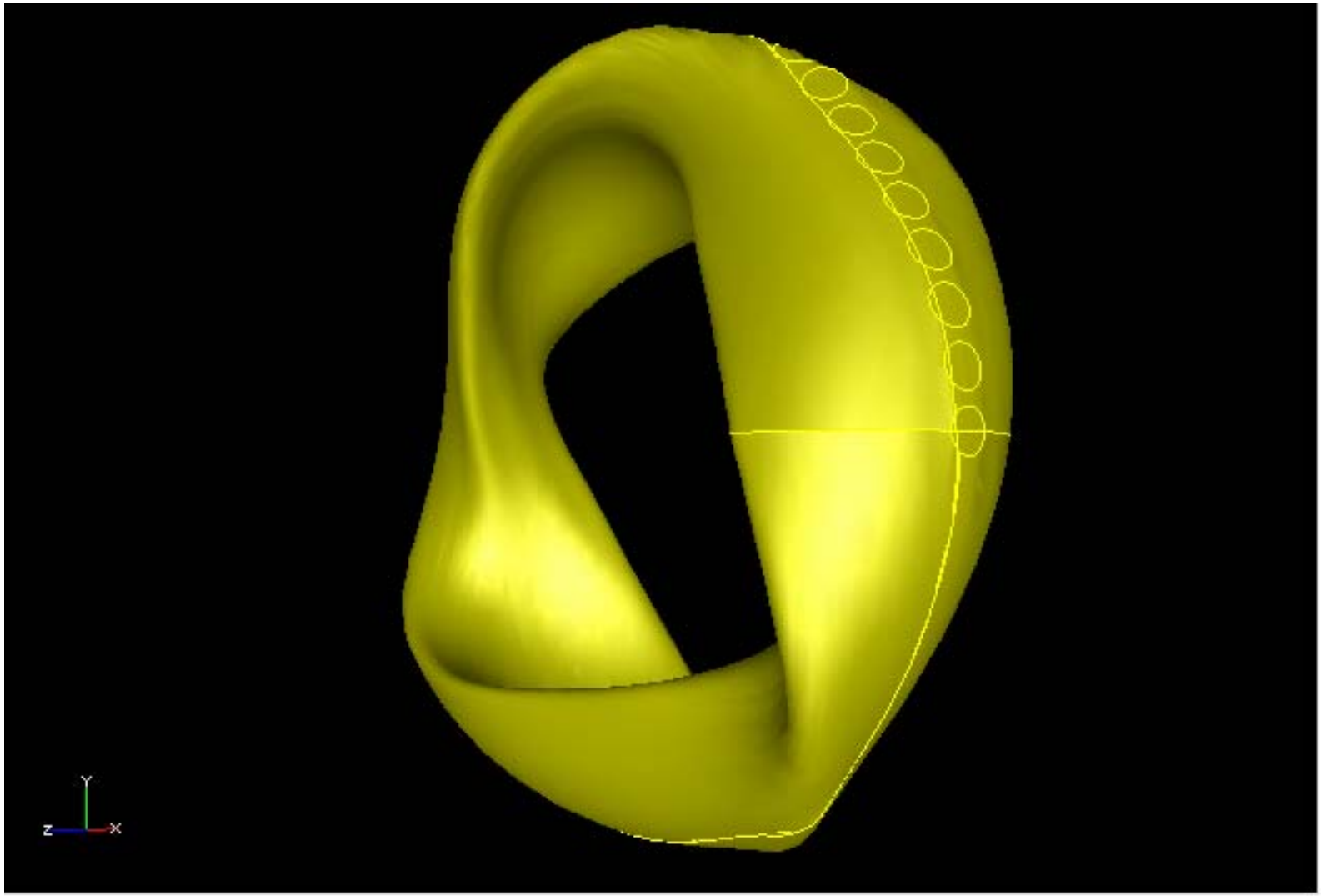
Stellerator Model

1. High precision profile: 1e-15 precision
2. Offset each profile curve
3. Used 72 profile curves to generate each Stellerator surface



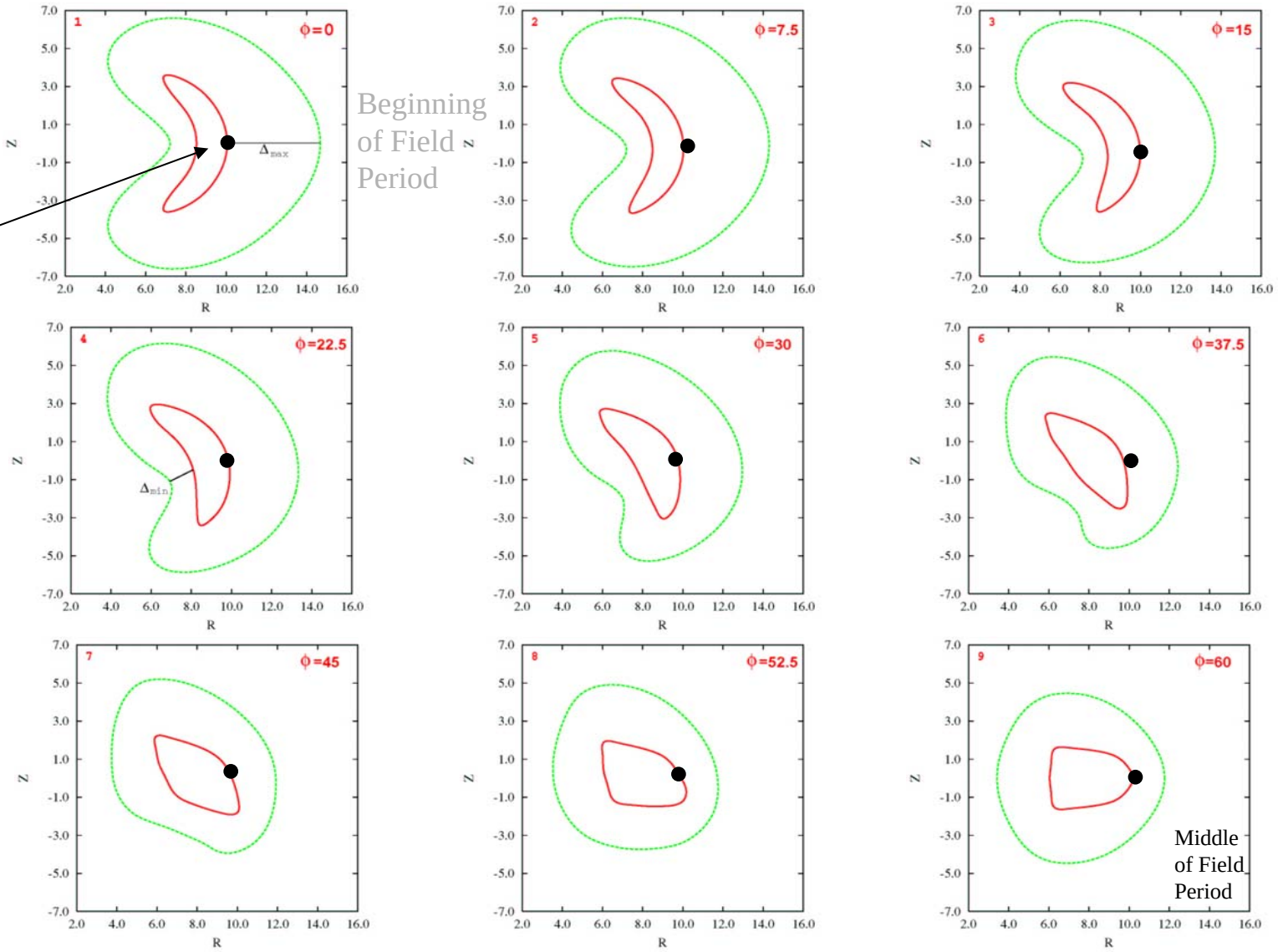
Computation: Wall Loading

Tally surfaces at first wall surface



9 Xns of Plasma Boundary (red) and WP Center (green) Covering 1/2 Field Period (~9 m)

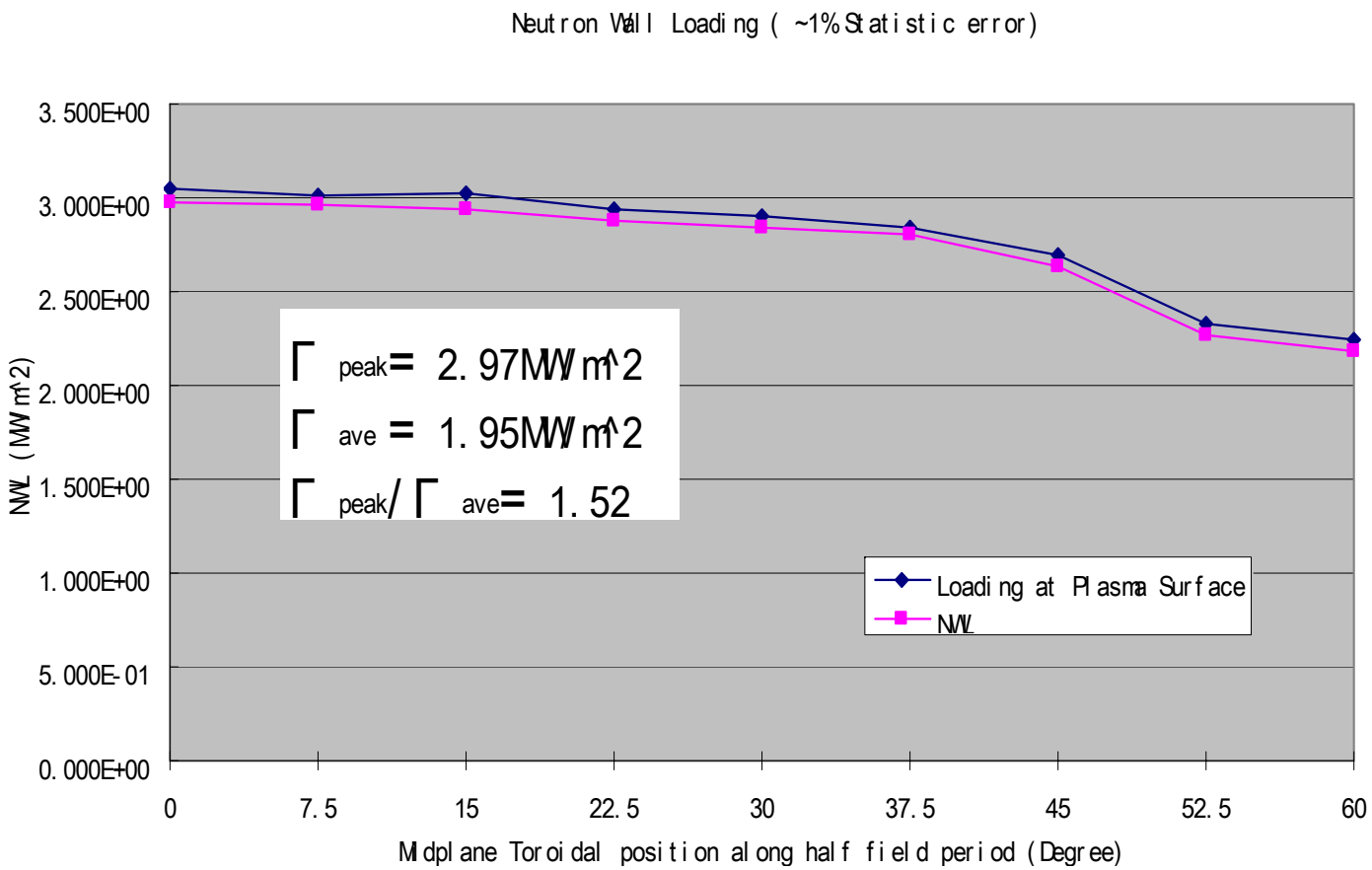
Peak Γ



Beginning of Field Period

Middle of Field Period

Computation Result: Wall Loading



Computation Model

7 Layers:

1 Plasma

2 Sol

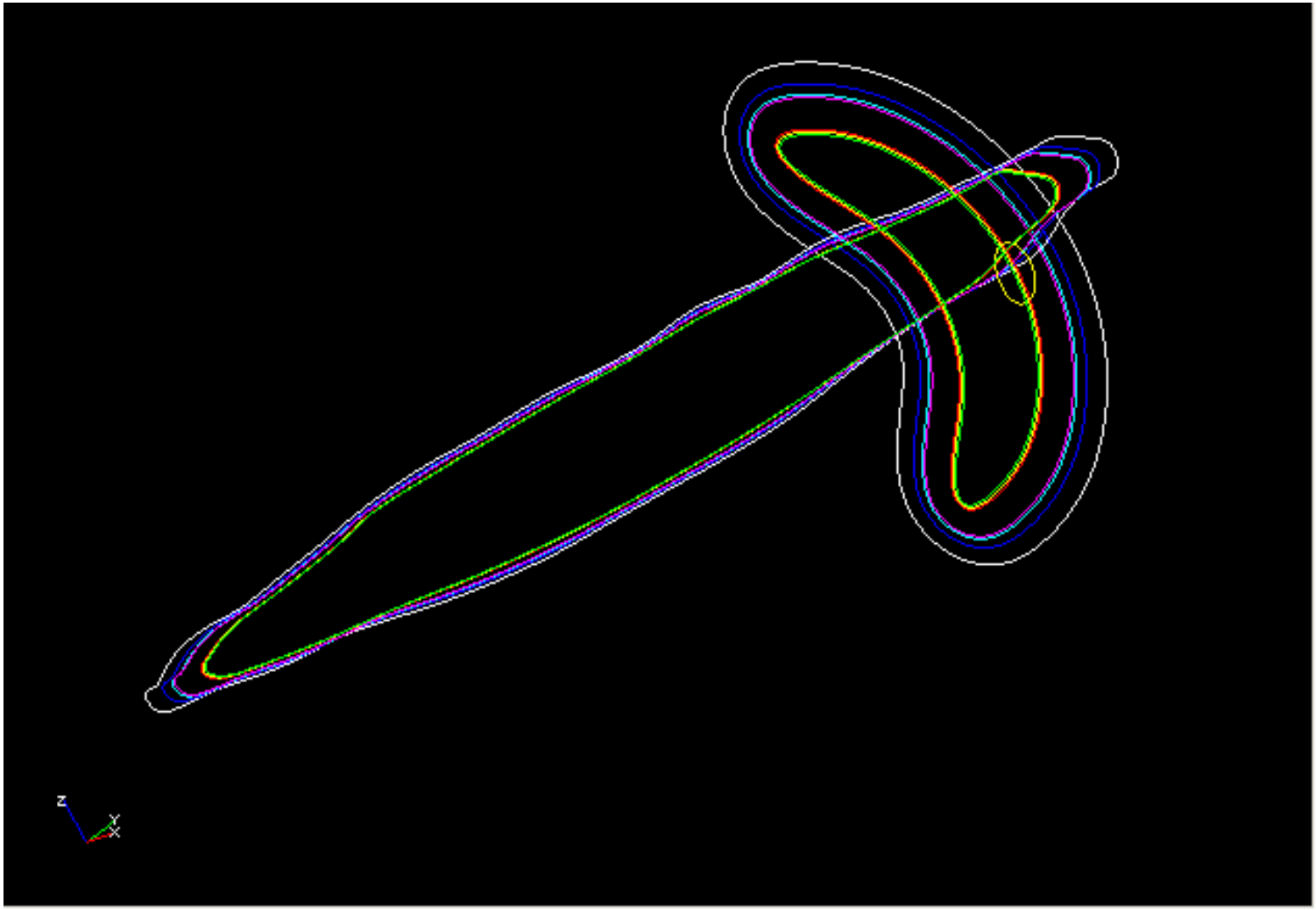
3 FW

4 Blanket

5 Back Wall

6 FS Shield

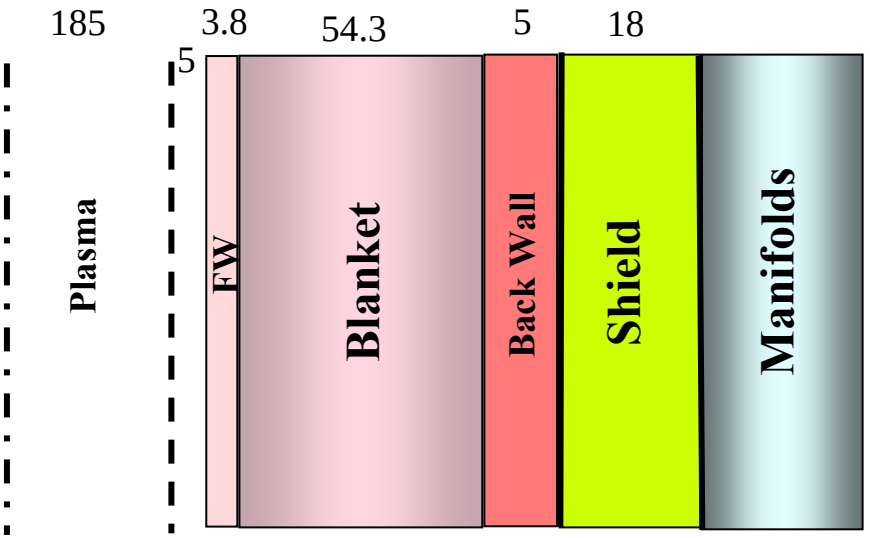
7 Manifolds

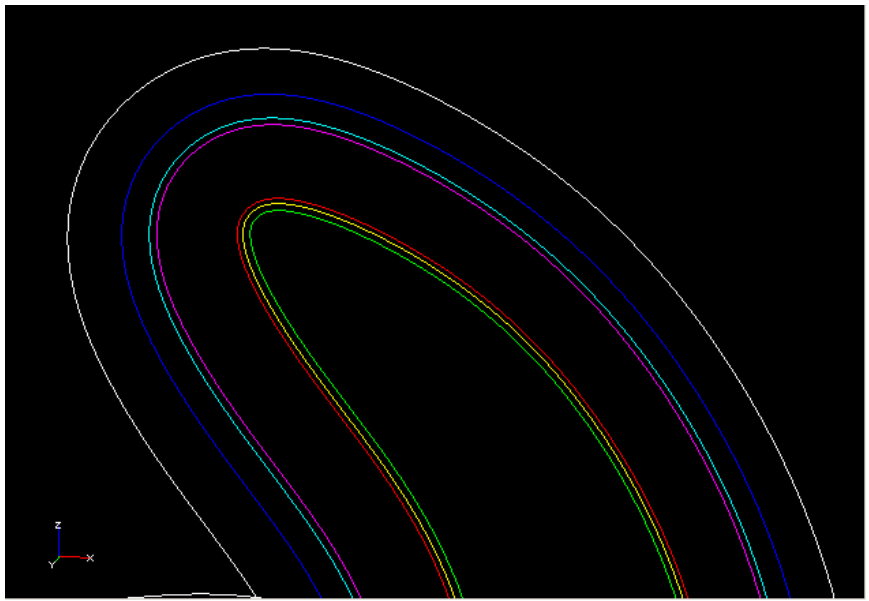


Materials for Reference Radial Build

Homogeneous composition:

FW	34% FS Structure 66% He Coolant
Blanket	79% LiPb (90% enriched Li) 7% SiC Inserts (95% d.f.) 6% FS Structure 8% He Coolant
Back Wall	80% FS Structure 20% He Coolant
FS Shield	15% FS Structure 10% He Coolant 75% Borated Steel Filler
Manifolds	52% FS Structure 24% LiPb (90% enriched Li) 24% He Coolant





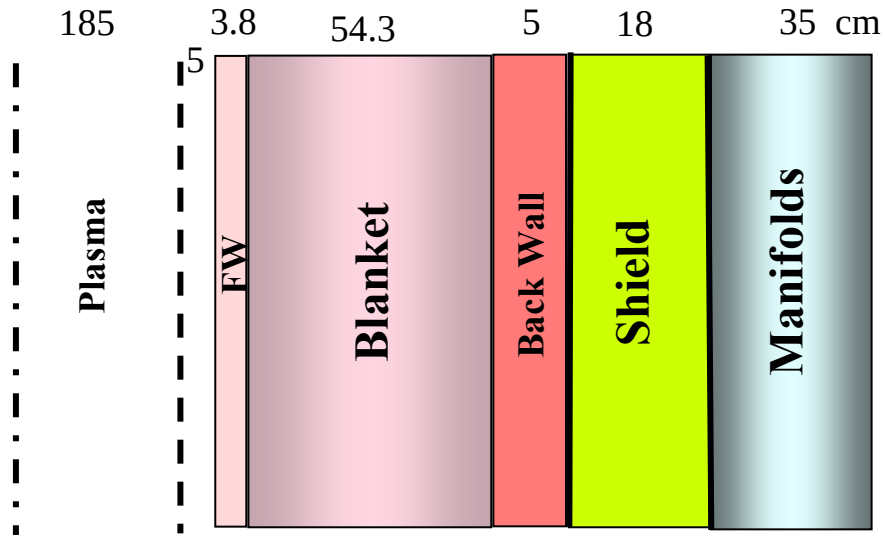
3D Result

Local TBR	1.316	± 0.61%
Energy multiplication (Mn)	1.143	± 0.49%
Average dpa rate (dpa/FPY)	29.5	± 0.66%
Peak dpa rate (dpa/FPY)	39.4	± 4.58%
FW/B lifetime (FPY)	5.08	± 4.58%
Nuclear heating (MW):		
• FW	145.03	± 1.33%
• Blanket	1585.03	± 0.52%
• Back wall	9.75	± 6.45%
• Shield	62.94	± 2.73%
• Manifolds	19.16	± 5.49%
• Total	1821.9	± 0.49%

1-D Cylindrical Model (nominal blanket/shield region)

Homogeneous composition:

FW	34% FS Structure 66% He Coolant
Blanket	79% LiPb (90% enriched Li) 7% SiC Inserts (95% d.f.) 6% FS Structure 8% He Coolant
Back Wall	80% FS Structure 20% He Coolant
FS Shield	15% FS Structure 10% He Coolant 75% Borated Steel Filler
Manifolds	52% FS Structure 24% LiPb (90% enriched Li) 24% He Coolant



3 MW/m^2 for peak dpa
2 MW/m^2 for total nuclear heating
Uniform blanket/shield, 100% coverage
(no divertor, no penetrations, no gaps)

1-D / 3-D Comparison

	1-D	3-D	
Local TBR	1.285	1.316 ± 0.61%	
Energy multiplication (M_n)	1.14	1.143 ± 0.49%	
Average dpa rate (dpa/FPY)	26	29.5 ±0.66%	
Peak dpa rate (dpa/FPY)	40	39.4 ± 4.58%	
FW/B lifetime (FPY)	5	5.08 ± 4.58%	
Nuclear heating (MW):			
FW	156	145.03	±1.33%
Blanket	1572	1585.03	±1.52%
Back wall	13	9.75	± 6.45%
Shield	71	62.94	± 2.73%
Manifolds	18	19.16	± 5.49%
Total	1830	1821.9	± 0.49%

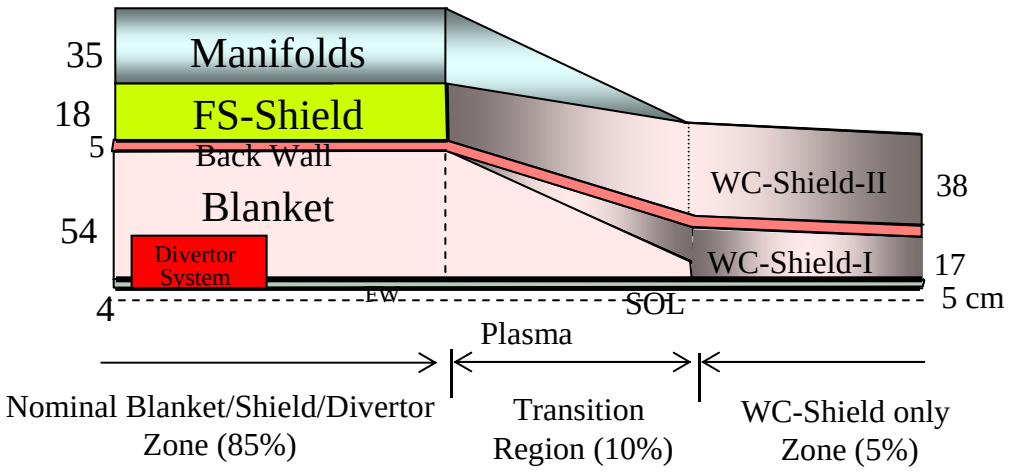
Remarks

- Slight disagreement between 1-D and 3-D results attributed to differences in analyses:

	1-D	3-D
Plasma shape	cylindrical	actual
n source distribution	uniform over 1/2 plasma	actual
NWL distribution	uniform ⇒ more reflection from off peak	non-uniform ⇒ less reflection
Cross section data	multi-group	pointwise
• Library	FENDL-2.0	FENDL-2.1

Future Plan

- To estimate overall TBR & M_n, include in 3-D model:
  - Shield-only zone
  - Transition region
  - Divertor system
  - Penetrations.



- Need better CAD exchange method
  - Double-precision input to generate cross-sections, fitted plasma surface
  - Mengkuo Wang's work based on ACIS engine using equations from L-P Ku
  - Collaborative addition of engineering features to Mengkuo's model(e.g. divertor system, shield-only and transition zones, penetrations)
- Publications?