NERSC's 6,656-processor IBM RS/6000 SP has 416 16-CPU POWER3+ SMP nodes with a peak performance of 10 teraflop/s.

NCSX Edge Modeling Calculations with VMEC/MFBE

Stellarator Theory Teleconference

8 July 2004

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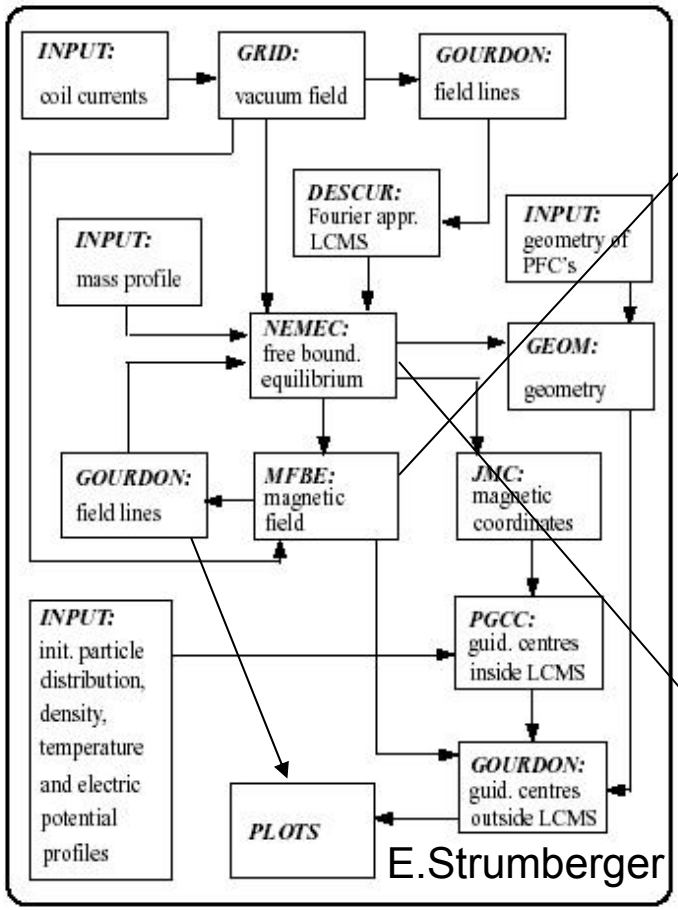
UCSD

Adaptation of W7-X Codes For Scrape-off Layer and Divertor Study



GOURDON modified for interface with MFBE_2001

- MFBE (Magnetic Field Solver for Finite Beta Equilibria-[assumes stellarator symmetry]) parallelized for T3E replaced by MFBE_2001[no symmetry assumed] parallelized for IBM. Both were adapted for net toroidal current via Shafranov "virtual casing".
- NEMEC replaced by VMEC2000 version 6.8

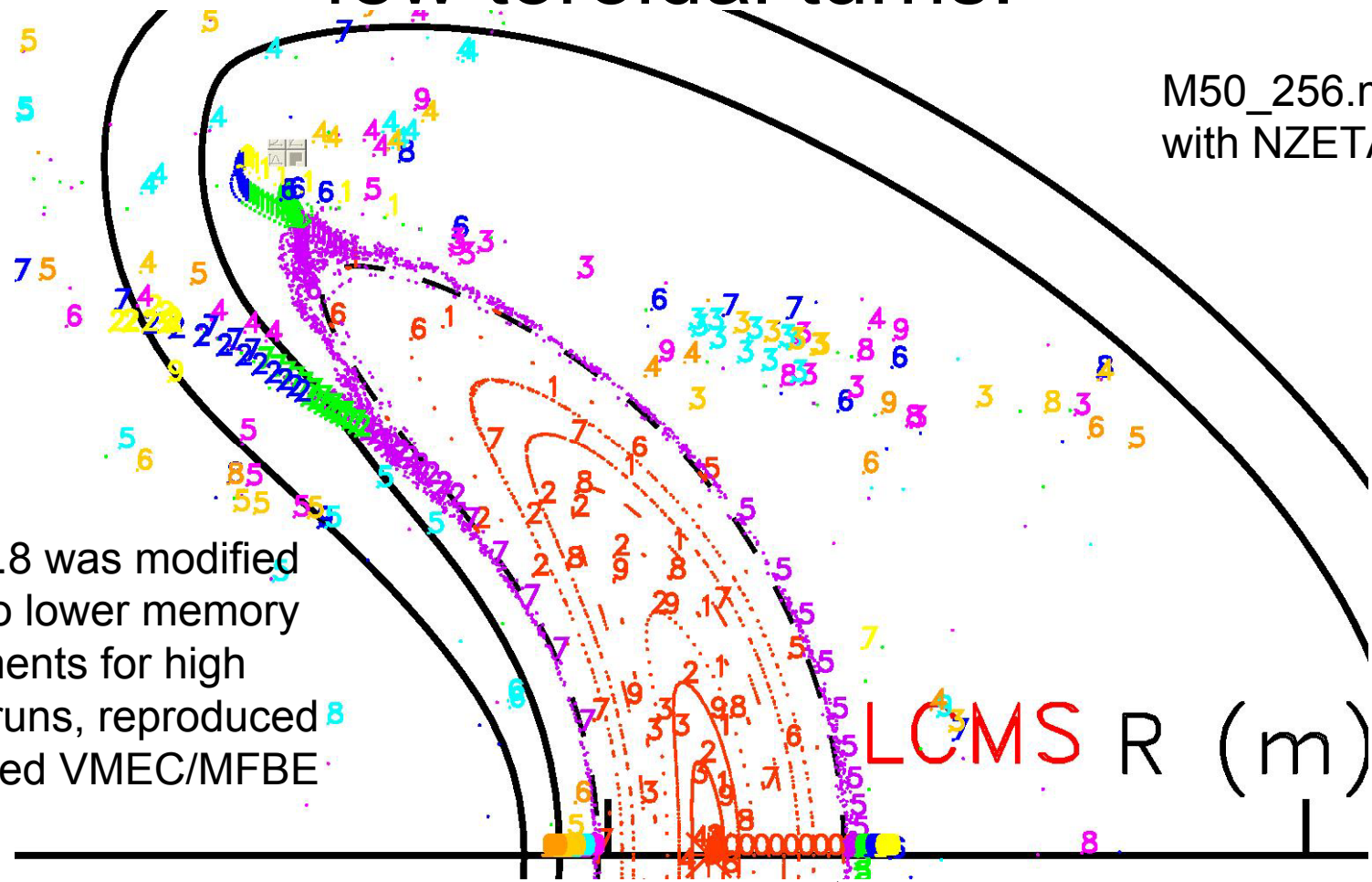
Geometric and Magnetic Quantities

	W7-X	NCSX	Aries-CS
Aspect Ratio	10.0	4.466	4.478
Minor Radius [m]	0.55	0.3225	1.846
Major Radius [m]	5.5	1.440	8.270
Surface Area [m^2]	120.0	23.93	782.1
Plasma Volume [m^3]	30.0	2.959	556.8
Volume Average B [T]	2.5	1.574	6.692

Toroidal Planes (# of processors) and accuracy of field line tracing

Device	R(m)	Toroidal Surfaces per half period (NZETA) (# of processors)	# of periods	Vacuum toroidal grid spacing (m)= 2piR/(2*nfp*ngrid)	comments
W7-X	5.5	100	5	0.03454	Less toroidal shaping than NCSX
NCSX	1.44	30	3	0.05024	More toroidal shaping than W7-X so this is marginal
NCSX	1.44	126	3	0.01136	Required modification to VMEC to reduce memory usage
Aries	8.27	30	3	0.28853	Using prior NCSX processor numbers
Aries	8.27	126	3	0.0686	Requires modified VMEC for reduced memory usage.
Aries	8.27	6656	3	0.0013	Best possible assuming all 6656 processors used.
NCSX	1.44	6656	3	0.000226	Best possible assuming all 6656 processors used.

Large Initial Flux Expansion with Ordering Maintained only over the first few toroidal turns.

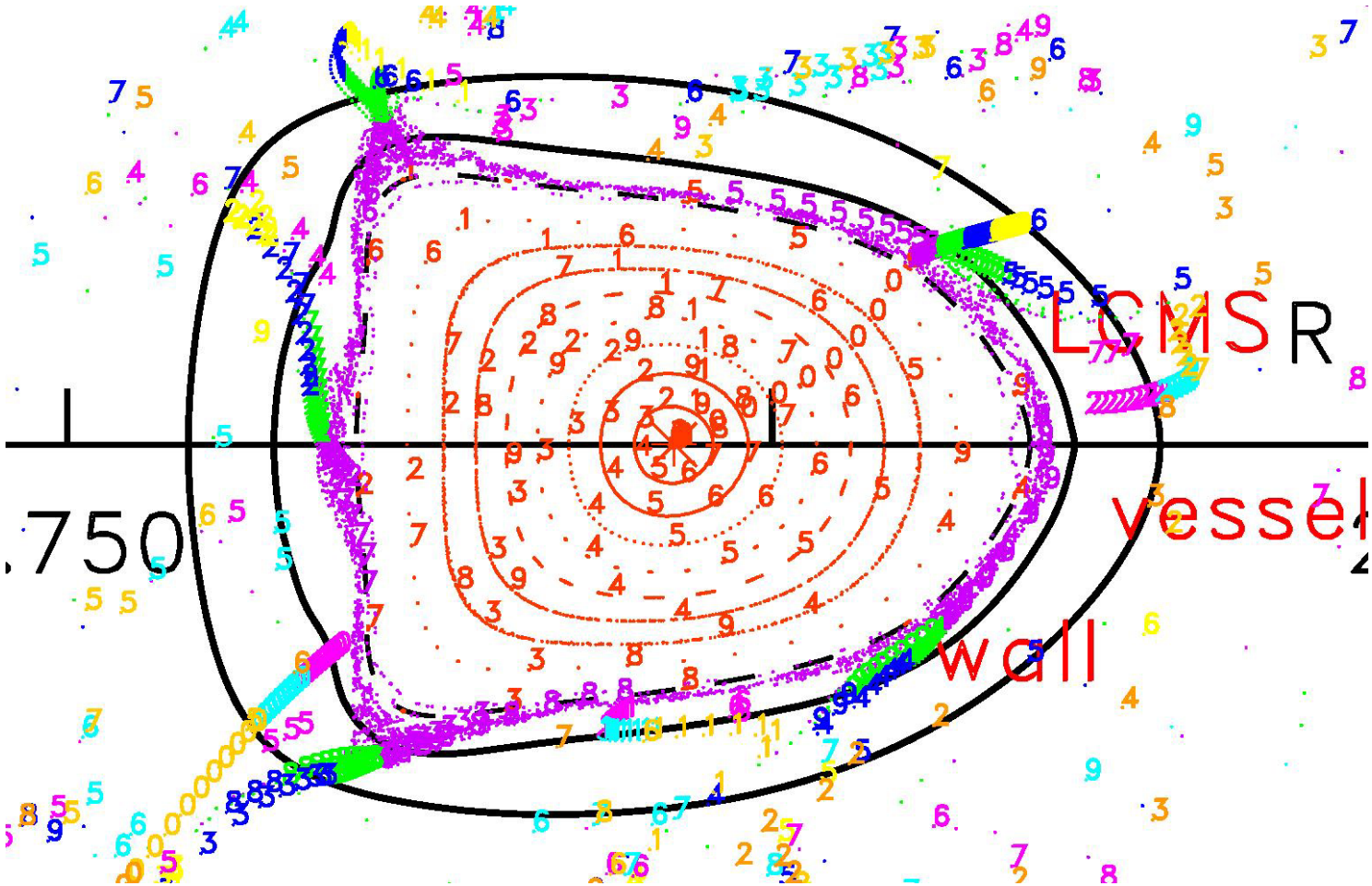


M50_256.multi
with NZETA=30

VMEC 6.8 was modified (L.Ku) to lower memory requirements for high NZETA runs, reproduced unmodified VMEC/MFBE result.

Starting points on midplane 10 per cm with same color over 1 cm intervals.

Limiter Cross-section

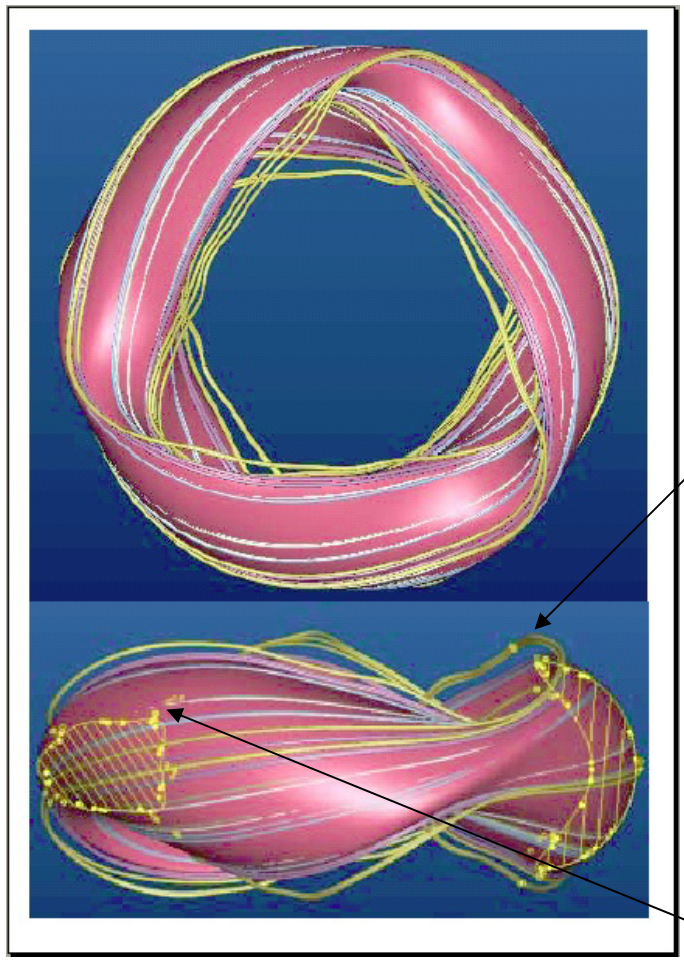


m50_256.multi is a multi-filament coil set derived directly from the PIES healing algorithm – provides best agreement between VMEC LCMS and MFBE LCMS.

Maximum Excursion at “Helical Edge”

Tokamaks- iota nearly 0 near helical edge at divertor and field lines pass this region slowly.

Stellarators- iota finite near helical edge (eg 0.6) field lines pass helical edge more than once during a toroidal turn- excursions from LCMS can build up quickly.



Location of Strongest curvature of flux surface sections

Connects bottom of banana cross-section to top of banana cross-section one period apart, passing through other cross-sections with less curvature.

New MFBE_2001 runs with NZETA=126 VMEC2000 modified to run on IBM without exceeding its memory limits

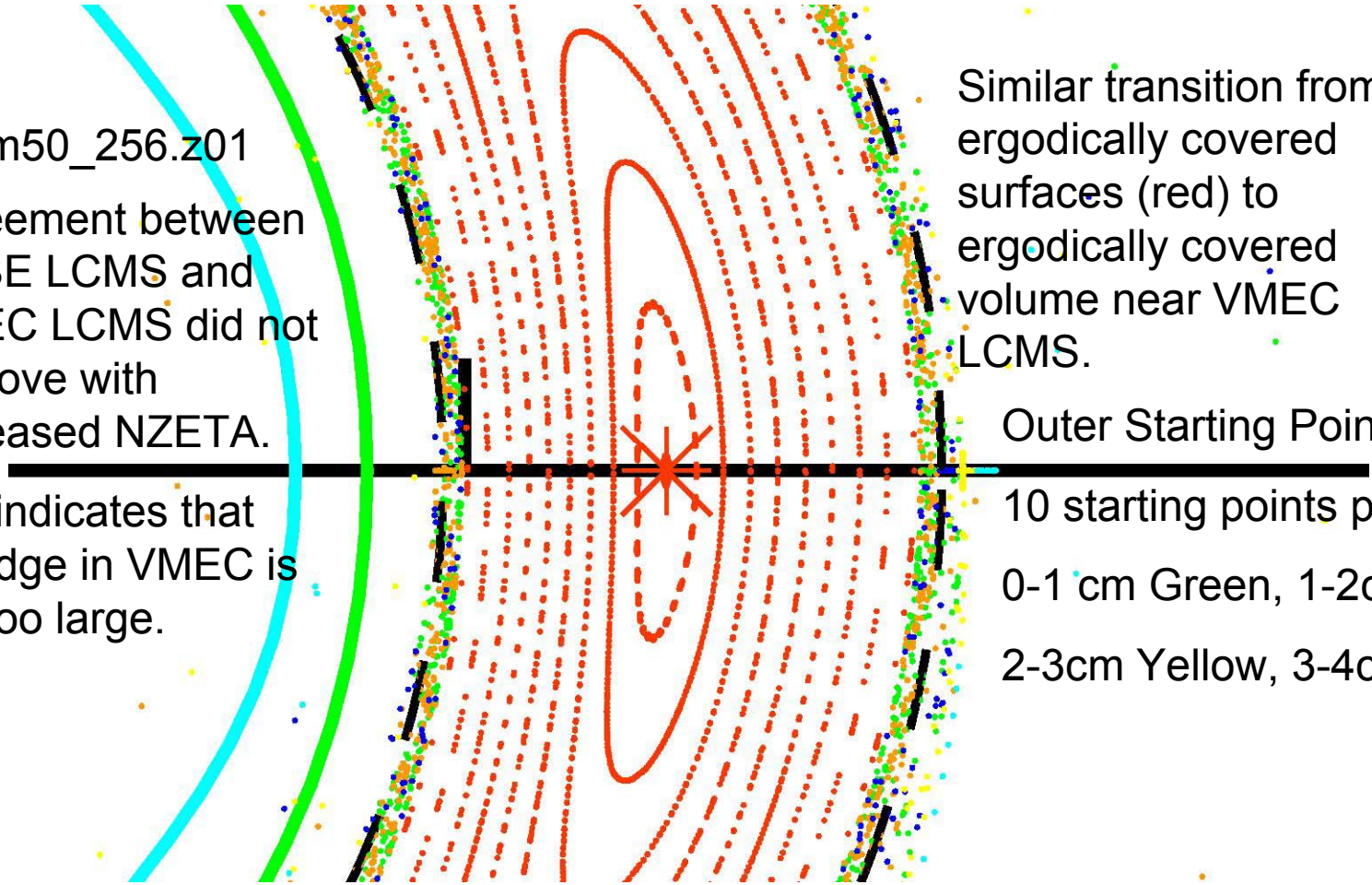
- NCSX:
  - m50_256.z01 (_72)
  - m50_e04 (_68)
  - c08r00_s3.b.min (_71)
  - c08r00_b2.0.min (_70)
  - c08r00_b0.0.min (_69)
- Aries-CS:
  - m50kzd_r8.25b6.5 (_73) and (_66-PHIEDGE sequence)

MFBE Results With NZETA=126 are Similar to NZETA=30 Results

72: m50_256.z01

Agreement between MFBE LCMS and VMEC LCMS did not improve with increased NZETA.

Still indicates that phiedge in VMEC is set too large.



Similar transition from ergodically covered surfaces (red) to ergodically covered volume near VMEC LCMS.

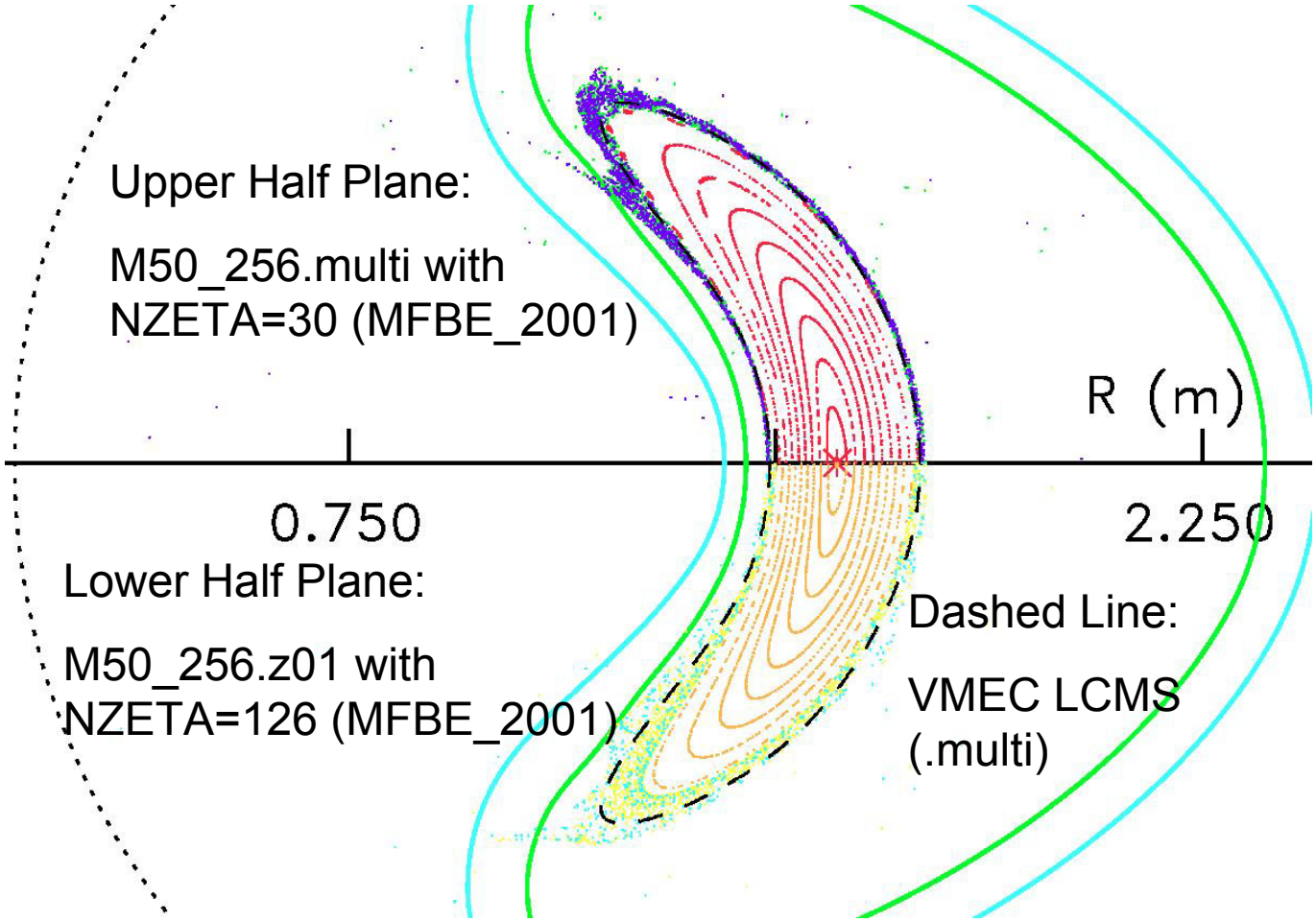
Outer Starting Points:

10 starting points per cm

0-1 cm Green, 1-2cm Blue

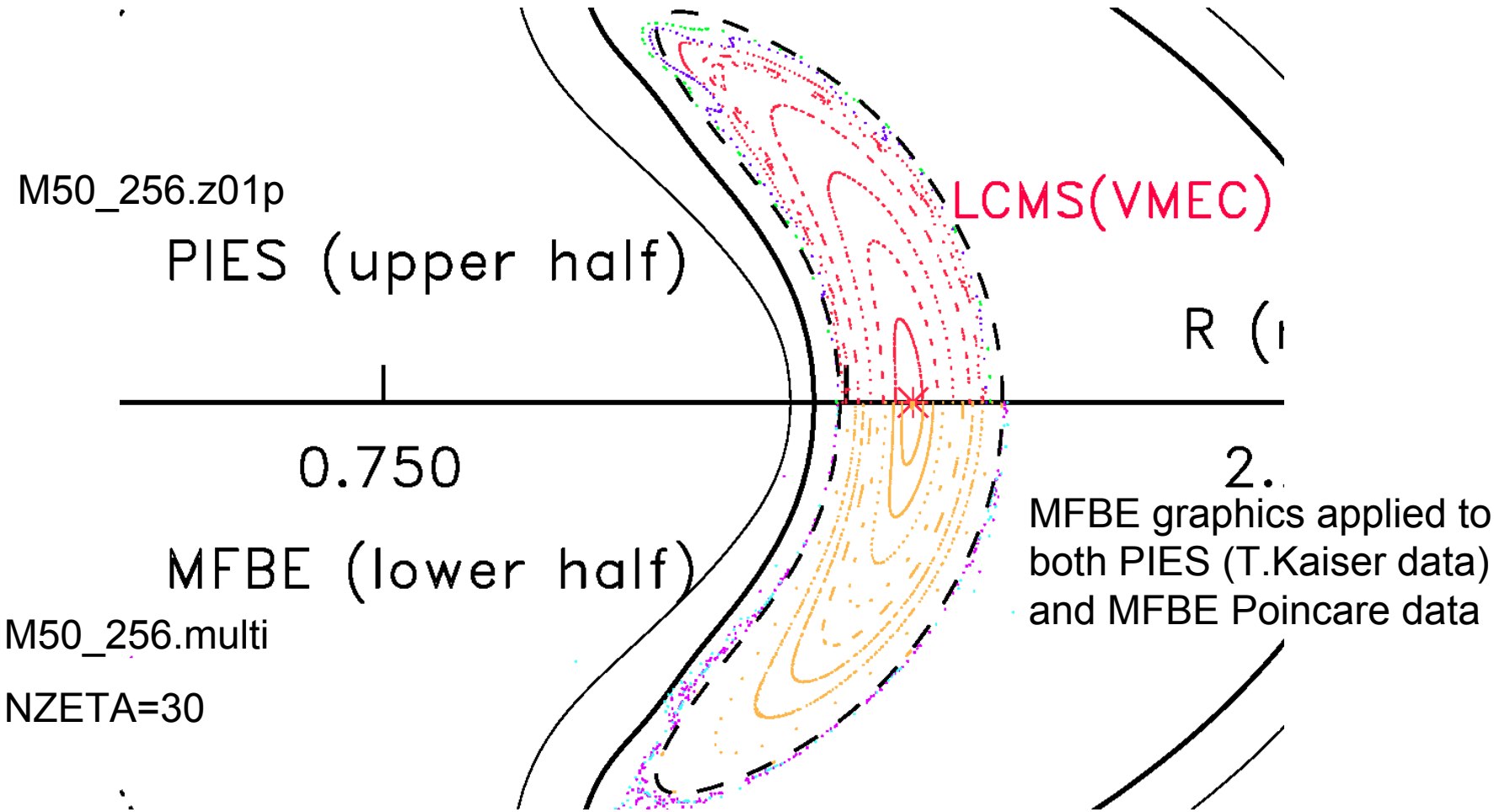
2-3cm Yellow, 3-4cm Cyan

NZETA=30 Multifilament vs. NZETA=126 Single Filament



Agreement between VMEC LCMS and MFBE LCMS better at NZETA=30, multi.

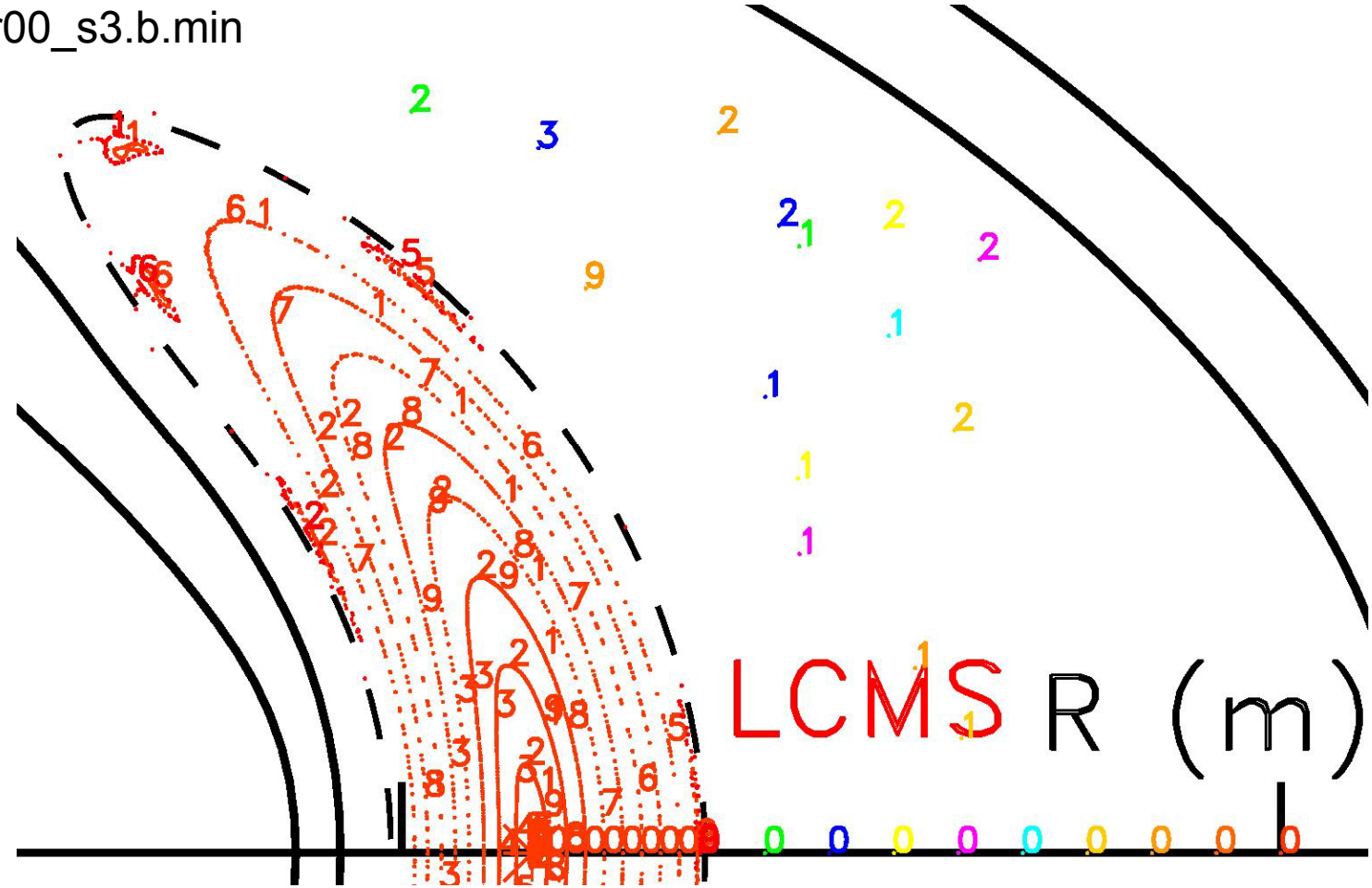
PIES vs MFBE_2001+VMEC (v6.8)



Large excursions from VMEC LCMS at the tips from both PIES and MFBE.

Small Island Chain Resolved in S3 with NZETA=126

C08_r00_s3.b.min



Starting Points Widely Separated. Far from LCMS punctures leave computational box in 1 turn.

Determination of iota-values

3/4 = 0.75
9/13 = 0.692
6/9 = 0.6667
9/14 = 0.6428
21/33 = 0.636
12/19 = 0.6315

3/5 = 0.6
6/11 = 0.545
15/28 = 0.5357
9/17 = 0.5294
12/23 = 0.5217
15/29 = 0.5172

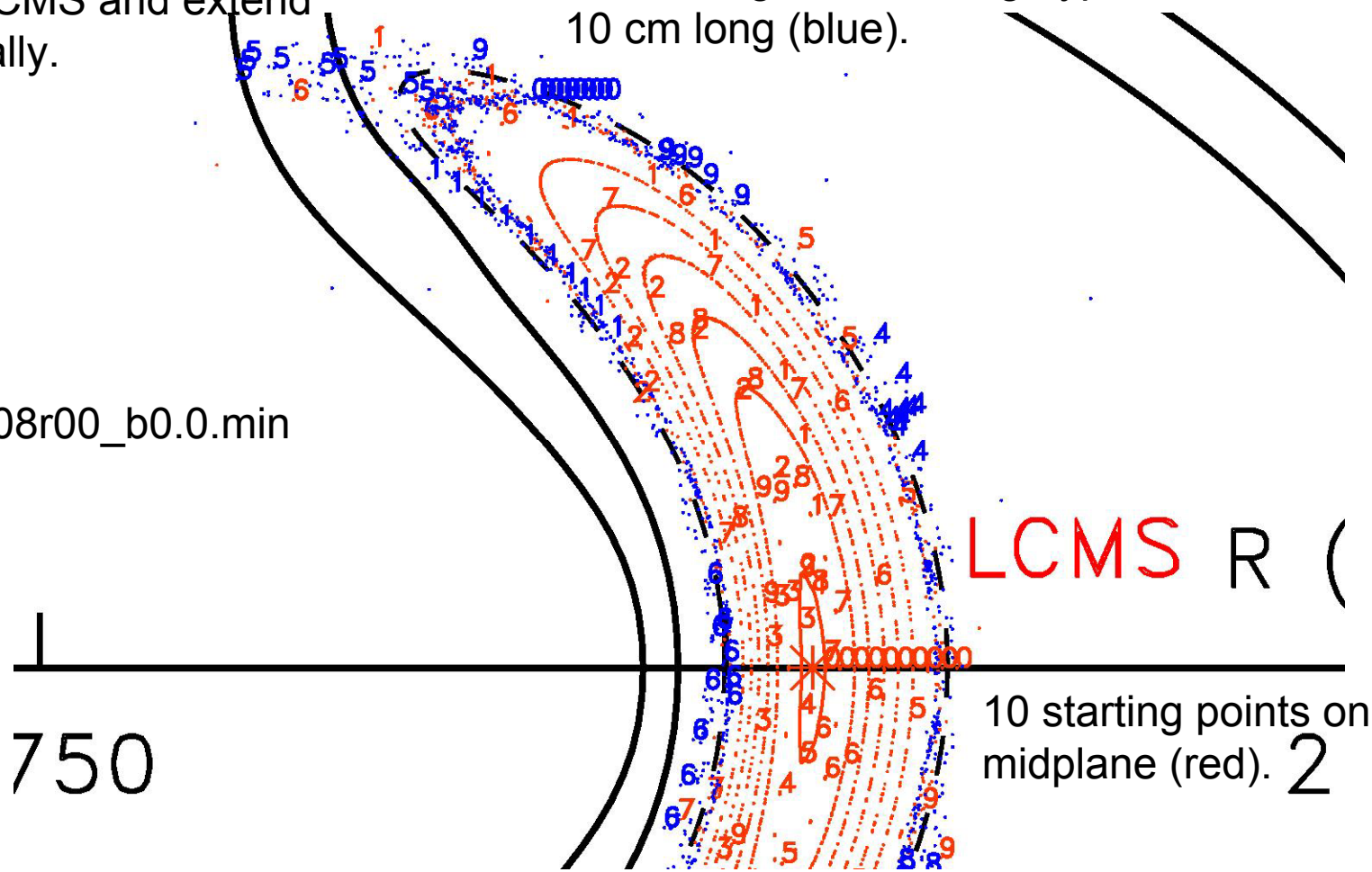
3/6 = 0.5
6/13 = 0.461
3/7 = 0.428
6/15 = 0.4
3/8 = 0.375
you get more and more values by adding numerator and denominator of two neighbouring iota values (example: 3/7 + 3/8 => 6/15)

0% Beta with NZETA=126

Begin blue starting points at VMEC LCMS and extend horizontally.

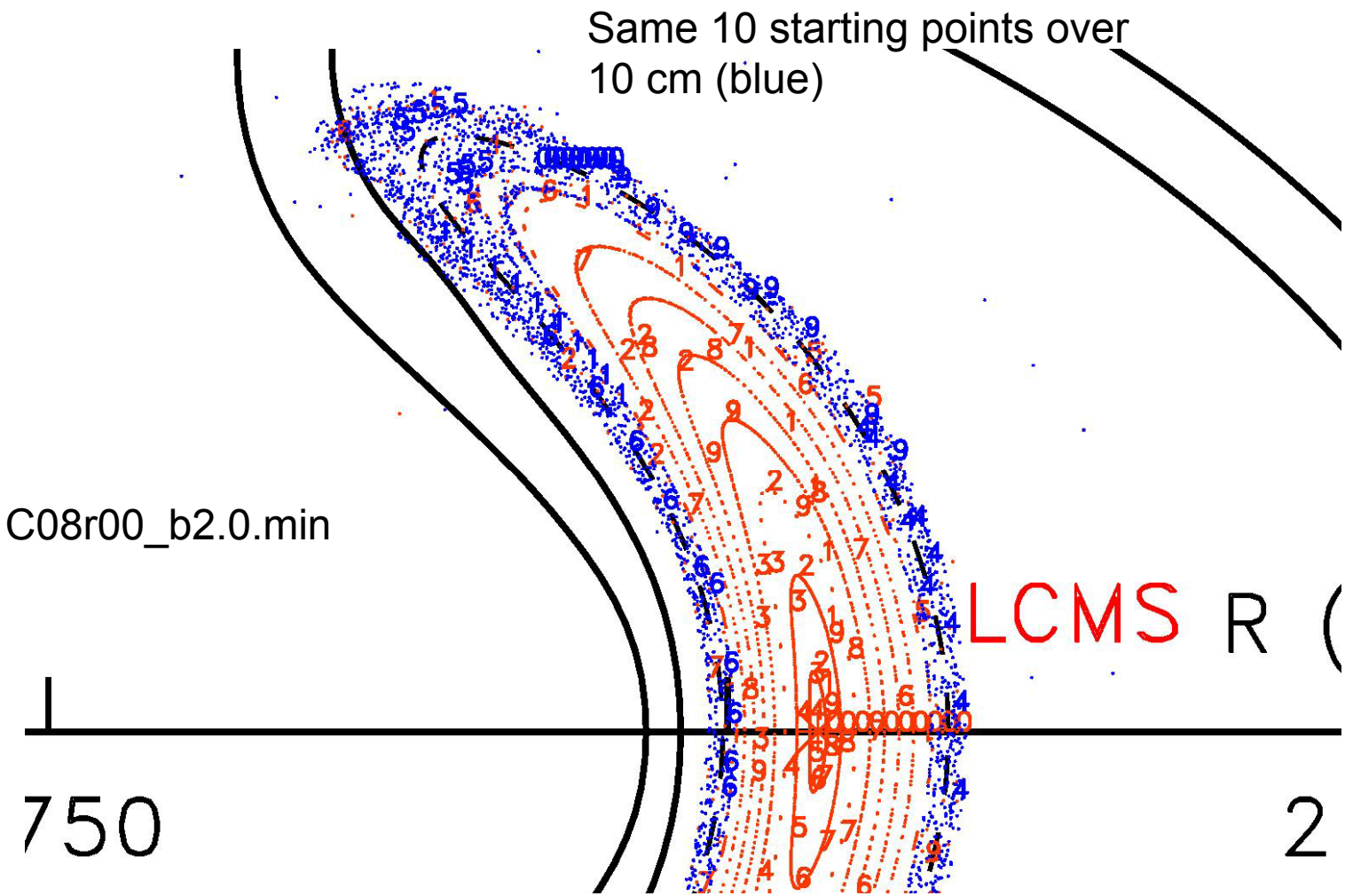
10 Starting Points along hypothetical baffle plate 10 cm long (blue).

C08r00_b0.0.min



10 starting points on midplane (red).

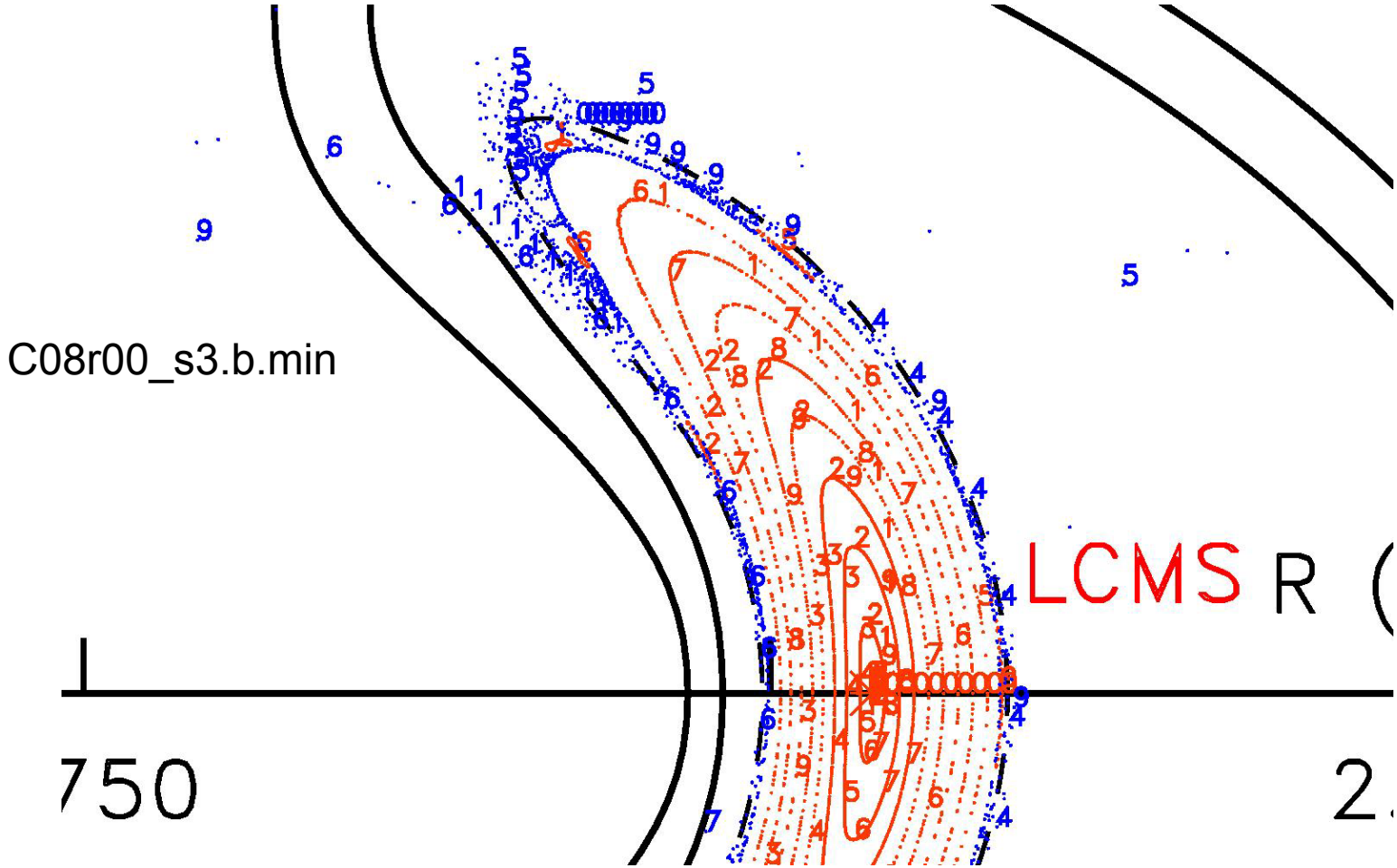
2% beta at NZETA=126



Ergodically covered volume around LCMS is larger at 2% than at 0%

4% beta with NZETA=126

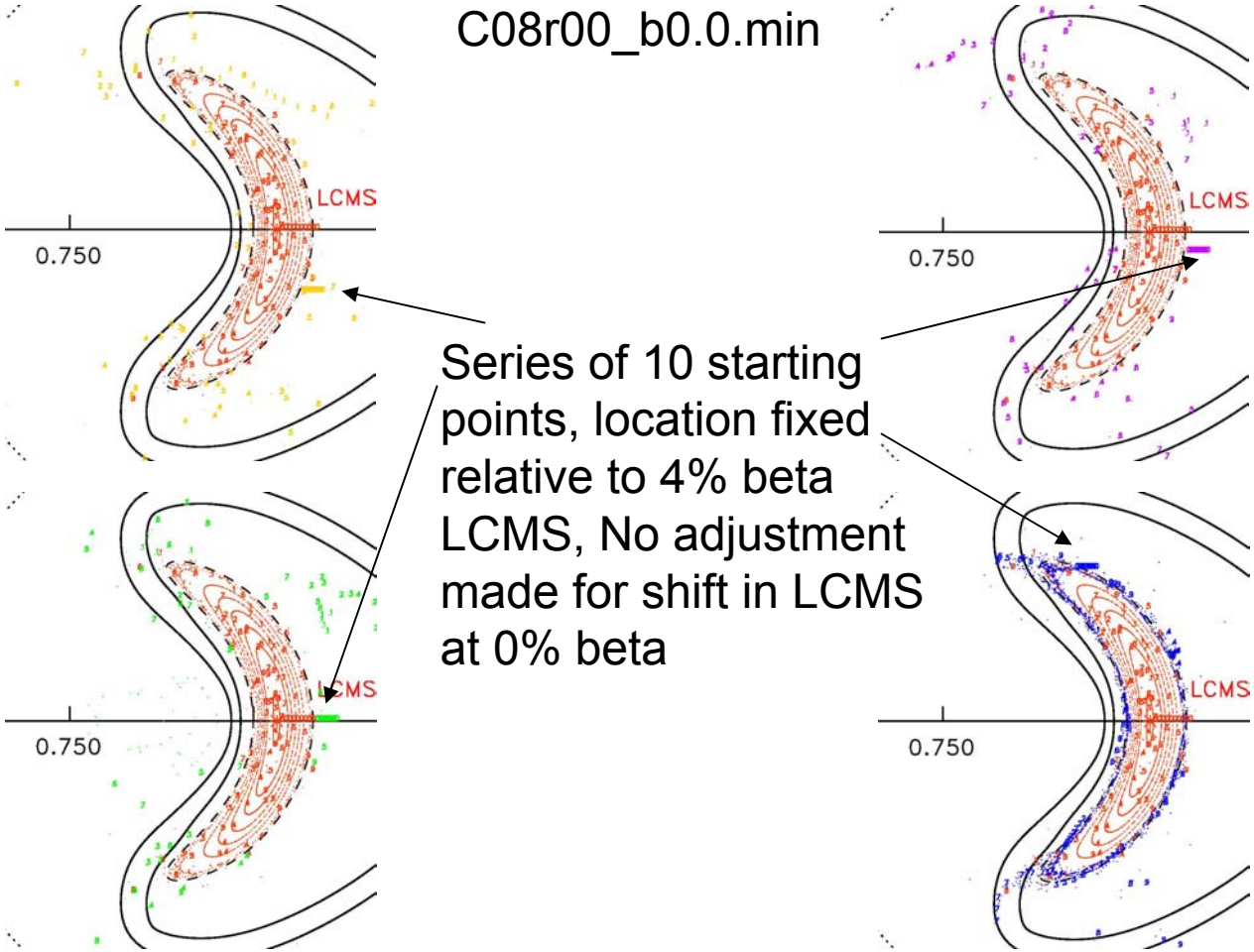
Same 10 starting points over 10 cm (blue)



Ergodically covered volume smaller than 2% comparable to 0% but with less flux expansion at tips.

Starting Point/LCMS Location Shift Effect

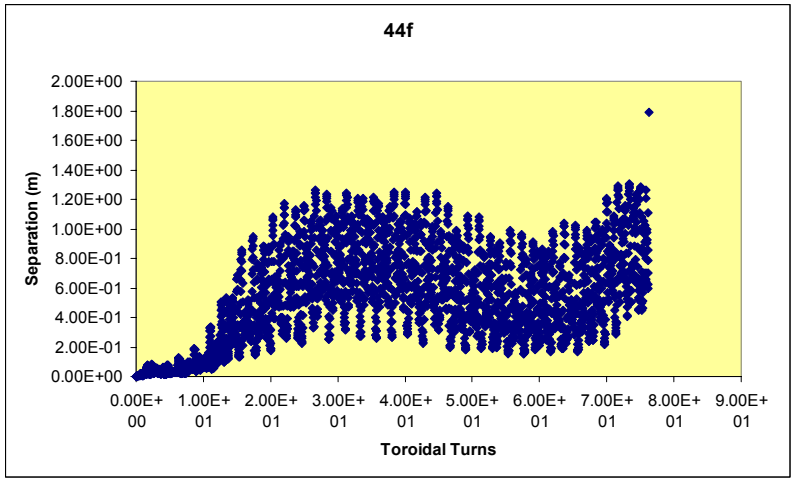
C08r00_b0.0.min

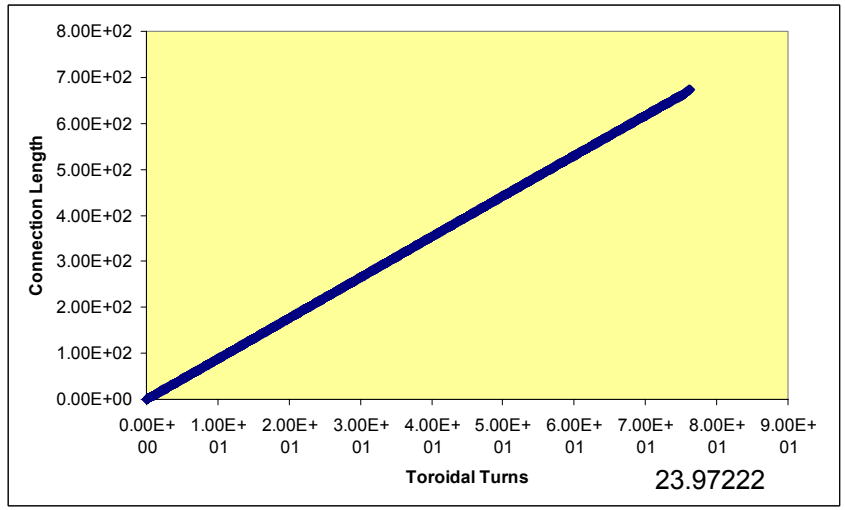


Series of 10 starting points, location fixed relative to 4% beta LCMS, No adjustment made for shift in LCMS at 0% beta

Blue Starting point series is most tangential to LCMS and remained in contact with the 1cm ergodic layer around LCMS

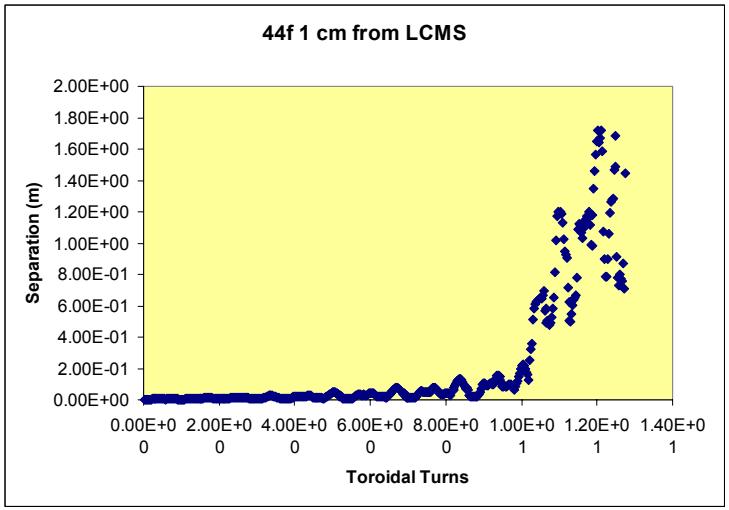
Separation of Magnetic Field Lines Just Outside LCMS

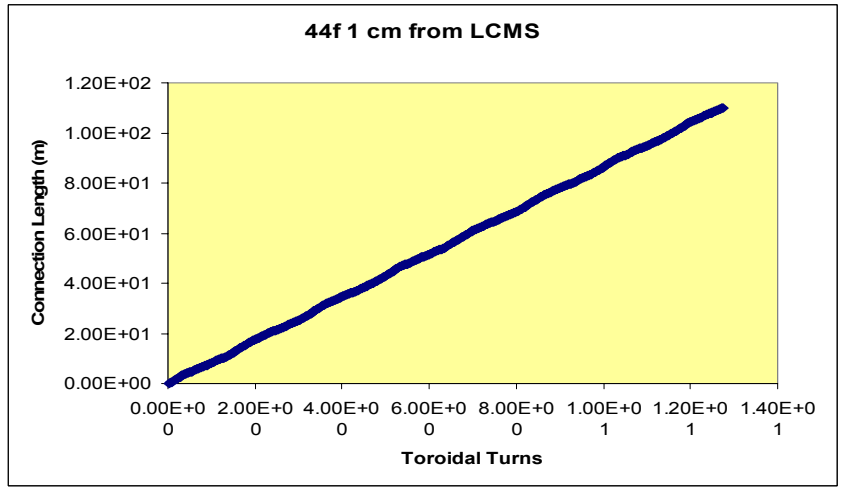




- Initial Starting Points at R1=1.755m and R2=1.756m and Z=0.0 (separation is 1mm).
- Line closest to LCMS intersects wall after 23.9 toroidal turns, Connection Length = 211.6m Leaves domain after 76.2 toroidal turns.

Separation of Magnetic Field Lines with Start 1 cm from LCMS





Starting Points: R=1.766 and 1.767m; Z=0.0

Intersect walls after: 8.5 and 6.1 toroidal turns,

Connection lengths: 70.04 and 55.7 m.

Conclusions

- Increasing the toroidal resolution did not yield major qualitative changes in the MFBE results:
  - Agreement between MFBE and VMEC LCMS did not improve- iterative determination of LCMS via PHIEDGE is still indicated.
  - A small higher order island chain was made resolvable.
  - Subtle changes to beta dependence of MFBE SOL results.

Conclusions

- SOL consists of an ergodically (“densely”) covered volume.
  - Transition from ergodically covered surfaces to ergodically covered volume defines LCMS.
  - Natural ergodic divertor without special divertor coils.
  - Stochasticity increases with distance from LCMS.
  - 3/5 island remnants corresponding to iota=0.6 seem to exist, but an island divertor concept based on them does not appear feasible- they do not seem robust, large enough, and are now cut-off by wall at bullet shaped cross-section.