Recent Results of Configuration Studies

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ARIES-CS Project Meeting, November 17, 2005
UCSD, San Diego, CA

Topics

- **Feedback and comments from town meeting.**
- **Recent development and results.**
  - **Aspect ratio variation of the new NCSX-class of configuration.**
  - **Alpha loss scaling with B and collisionality.**
- **15th ISW, some info relevant to configuration development.**

Our work plan outlined in the last project meeting is consistent with the feedback/comments from the town meeting.

Plans presented at September project meeting

- Incorporate feedbacks/ideas of community review into overall configuration development.
- Continue the recent efforts of using biased magnetic spectrum to improve configurations.
- Optimize internal transforms for the families of configurations already developed.
- Revisit coils and try to lower further the aspect ratio for MHH2.
- Examine the reference point(s) of the systems analyses and find consistent and optimized solutions.

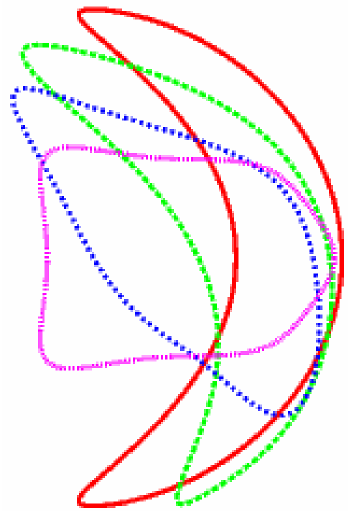
Feedbacks from September town meeting

- Reconsider bootstrap current--make self-consistent with systems code profiles.
- Alpha loss fraction. Acceptable level and power loss distribution.
- Aspect ratio: low A version of NCSX.
- Flat-iota family. Flexibility.
- Fixed versus free boundary calculations. Levels of details in analysis. Resource limitation.
- Metrics of coil complexity and engineering constraints.

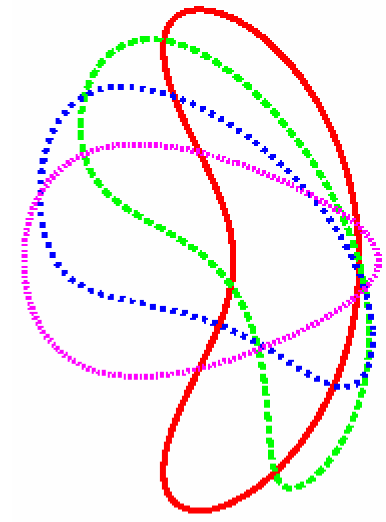
A Re-Cap:

We have found interesting and potentially attractive reactor configurations in a broader rotational transform and aspect ratio space. These configurations should be useful for the systems and engineering studies to understand the respective strengths and shortcomings.

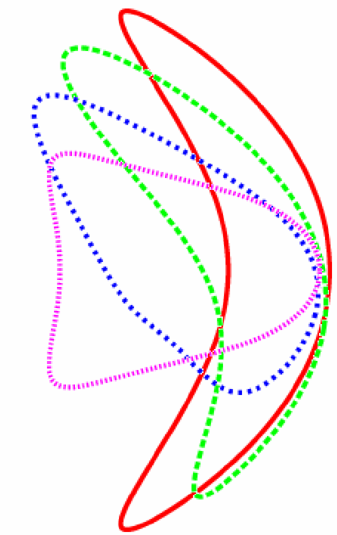
- **Three families of configurations emerged with distinctive characteristics.**
  - **NCSX : scale-up, α-loss improved, surface quality improved**
  - **MHH2 : low A and Ac**
  - **SNS : low magnetic shear, larger A**



NCSX



MHH2



SNS

QA, ε-eff<1%:	✓	✓	✓
α loss <10%:	✓	✓	✓
MHD Stability, 4%β	✓	?	?
Surface Quality:	?H	?H	✓
Coils (Δ_{min}<6,…):	?P	✓	?P
Diverter/Edge:	?	?	?

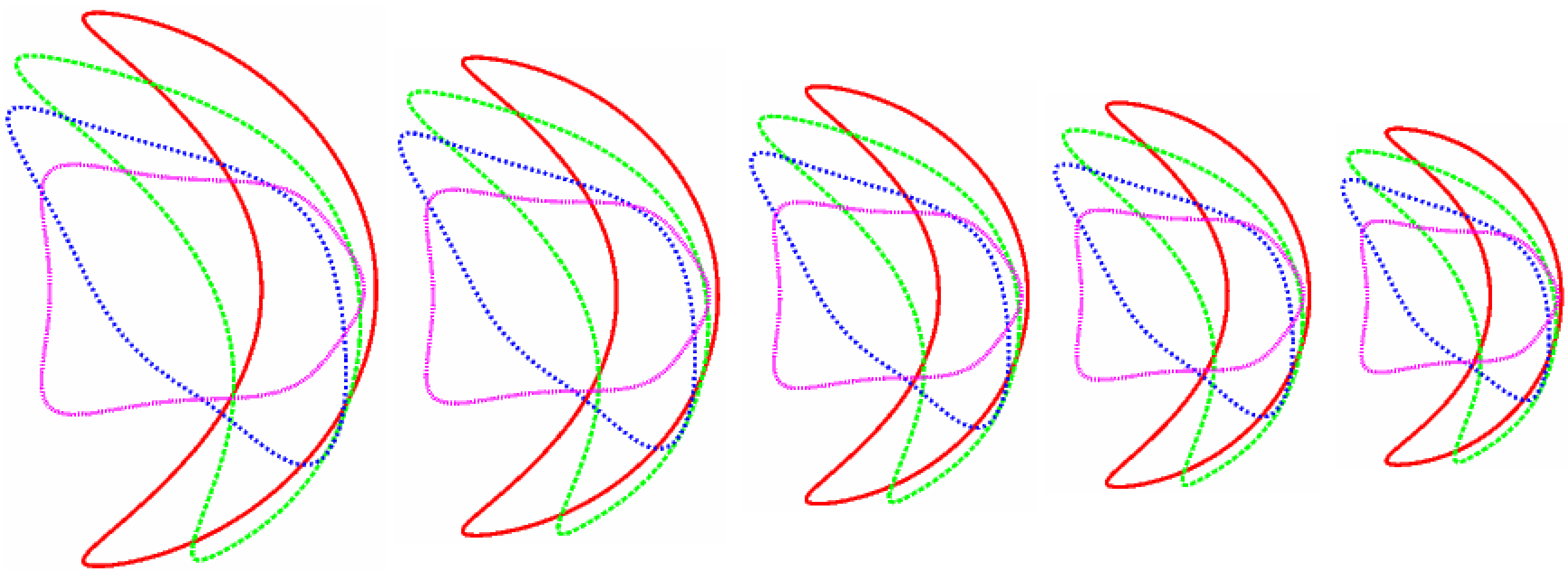
The recent discovery of possible use of biased components in the magnetic spectrum to improve certain aspects of a configuration may open a new window of opportunity for finding better configurations.

- **Need to understand better the role of various dominant components.**

- **Need to understand the implication of component biasing.**
  - **Effects on configuration aspect ratio**
  - **Effects on external and internal transforms**

- **Need to devise methods to take advantage of such an approach in configuration optimization.**
  - **can we also make the integrity of magnetic surfaces more robust?**

Systematic study of plasma aspect ratio for the NCSX class of configuration with the enhanced mirror



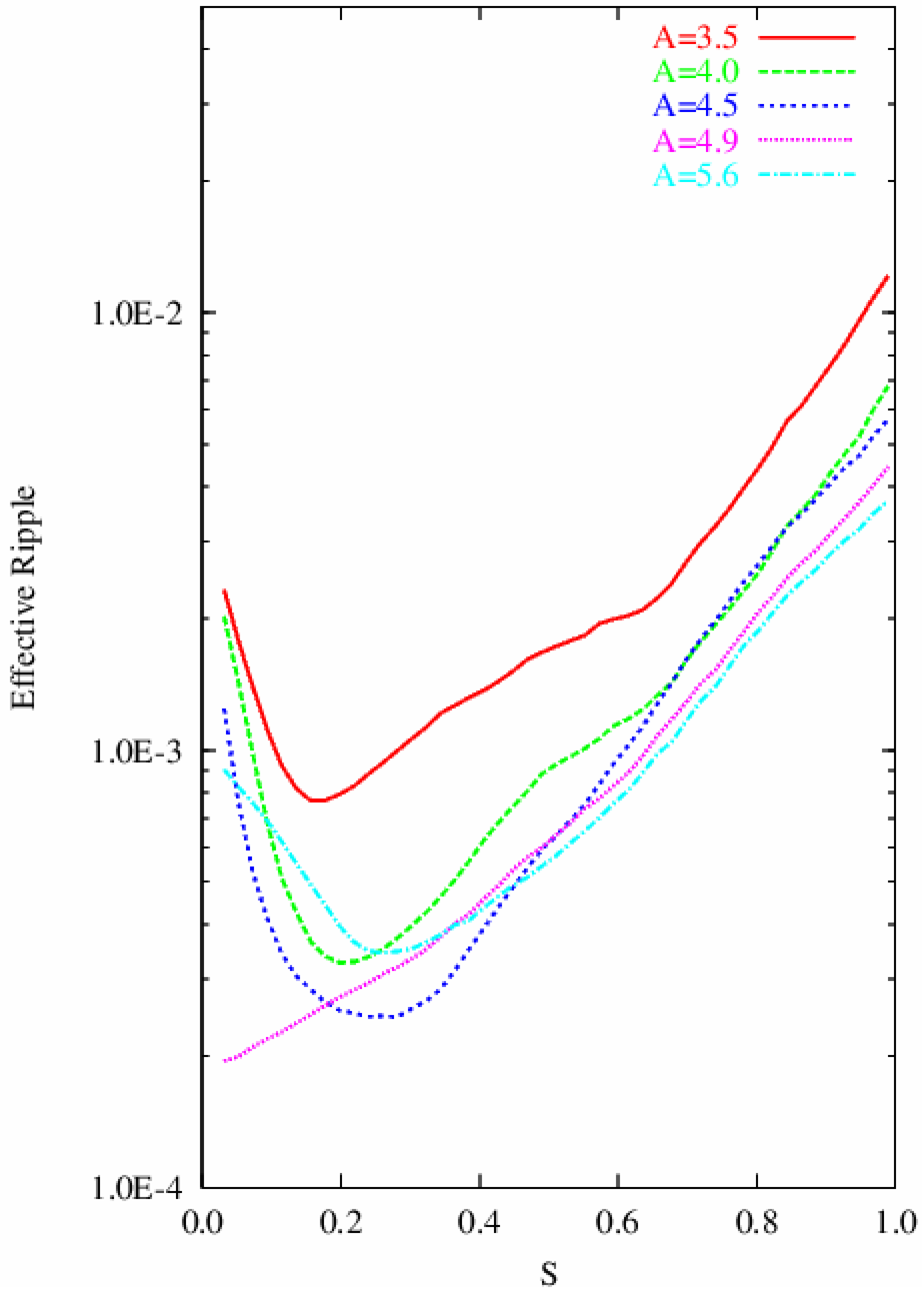
A=3.5 A=4.0 A=4.5 A=5.0 A=5.6

← kink stability

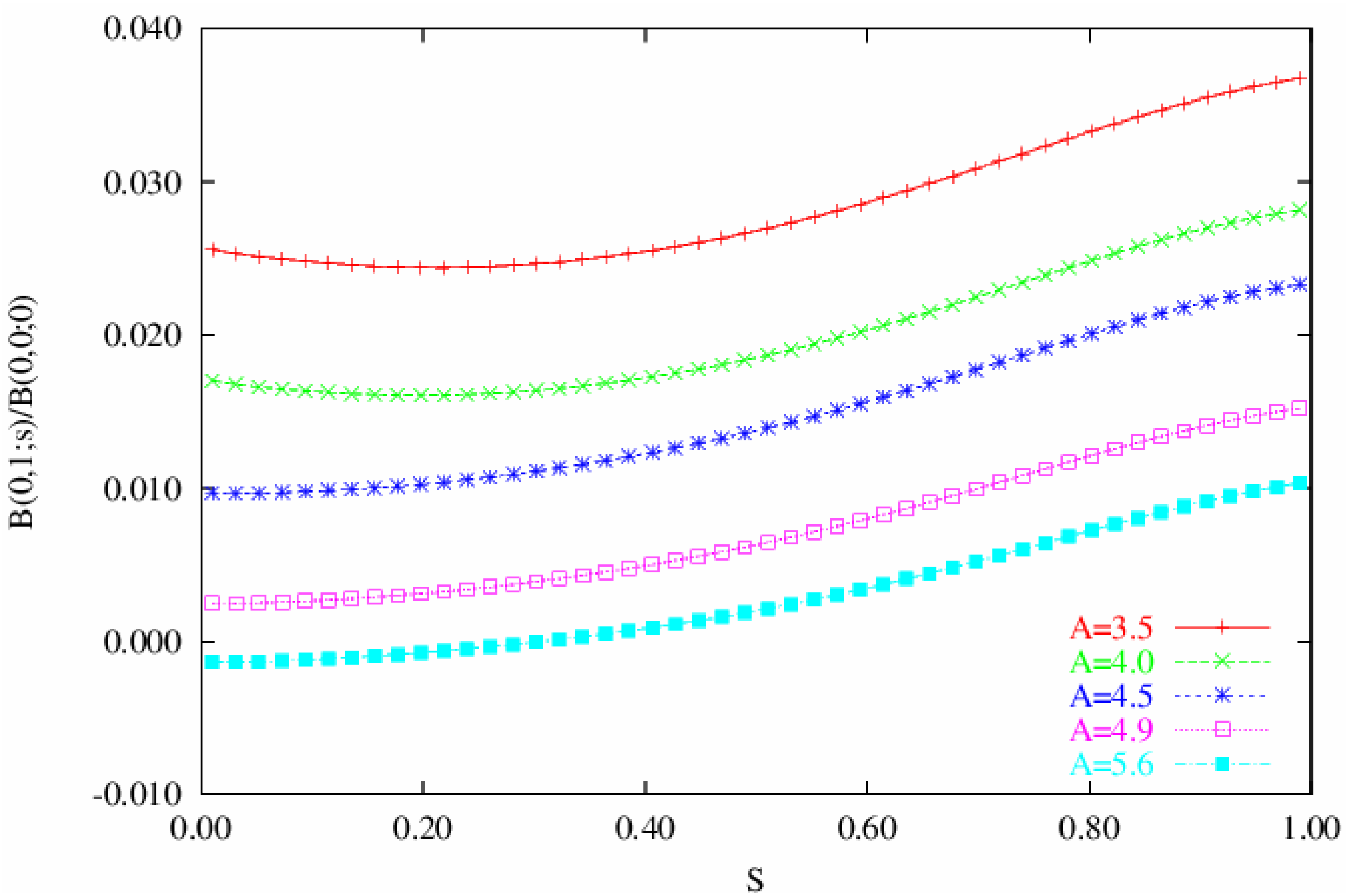
← QA

ballooning stability →

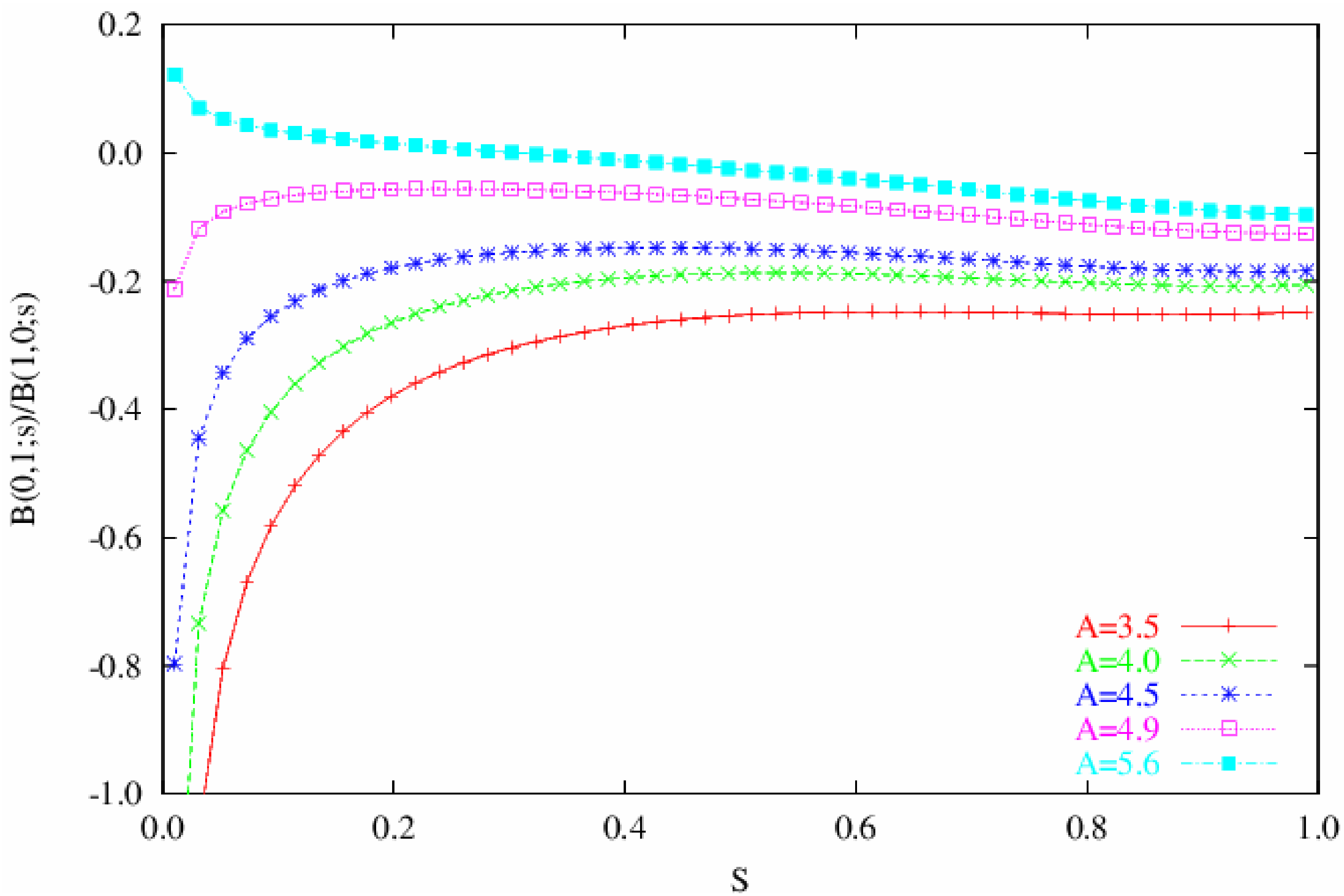
- **All constrained to have favorable MHD stability properties (external kinks, ballooning and interchanges).**
- **All constrained to have good QA with low ε–eff.**
- **QA became harder to attain as A decreases. To compensate, B(0,1) increases.**



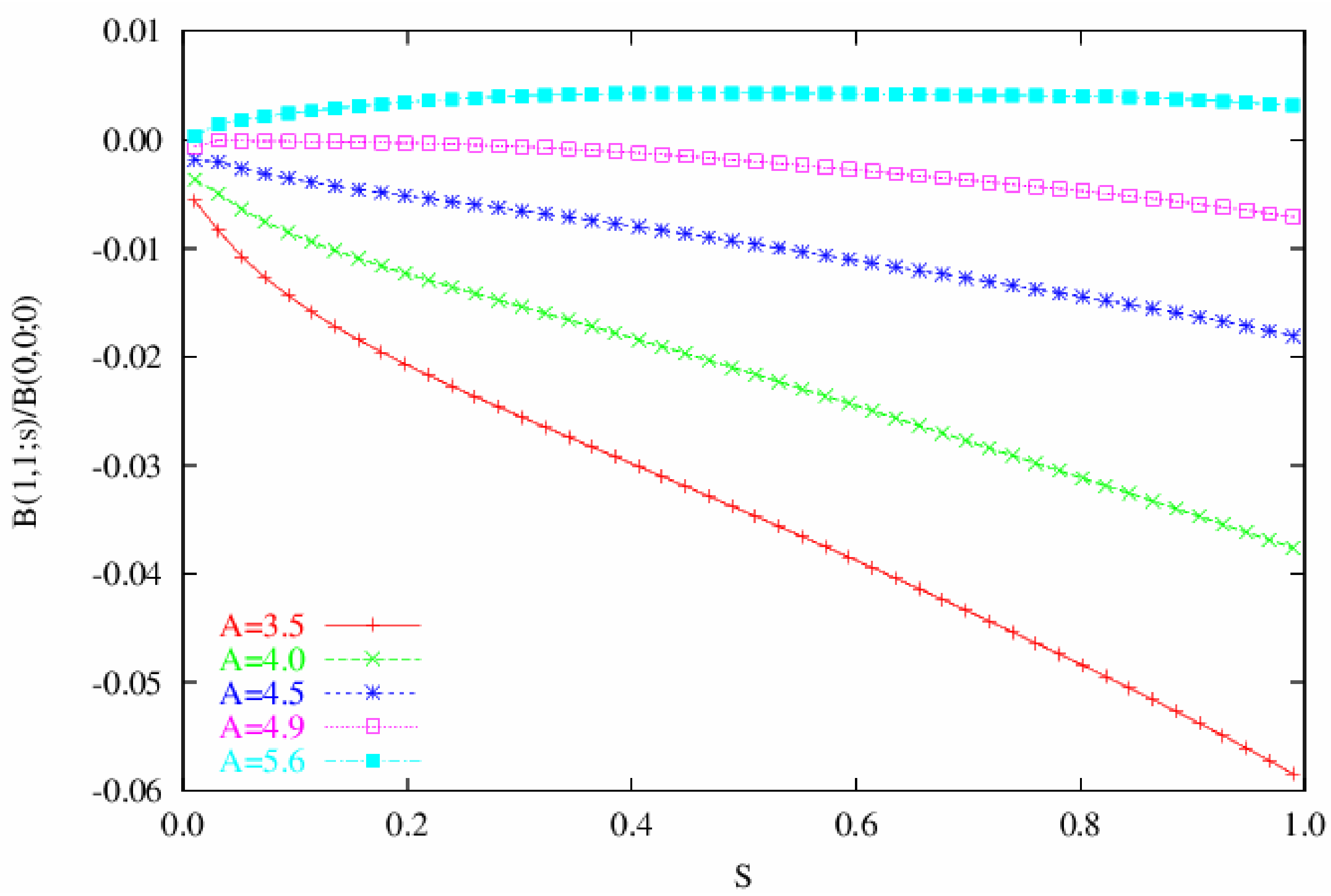
To satisfy the external kink and infinite-n ballooning stability constraint, low ε-eff and low α loss, the magnitude of mirror increases consistently as the plasma aspect ratio decreases. The role of $B_{0,1}$ appears to diminish for A>6 as QA becomes easier to attain.



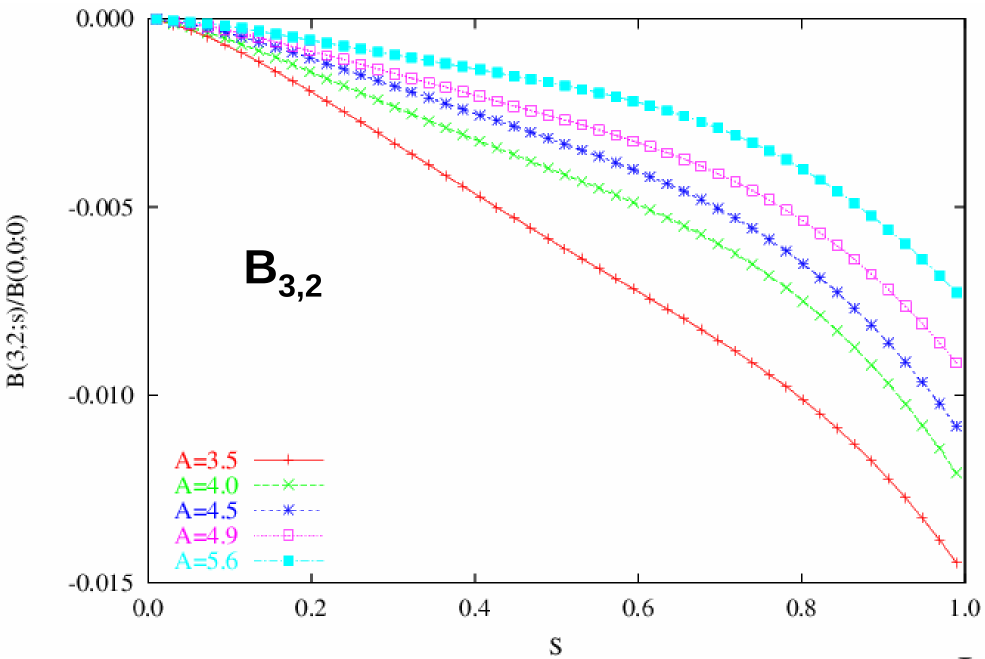
Despite the increased magnitude of the mirror, it is still small compared to the main toroidal term, $B_{1,0}$, in the magnetic spectrum. In typical quasi-isodynamic configurations, $B_{1,0}$ is very small so that $B_{0,1}/B_{1,0}$>>1.

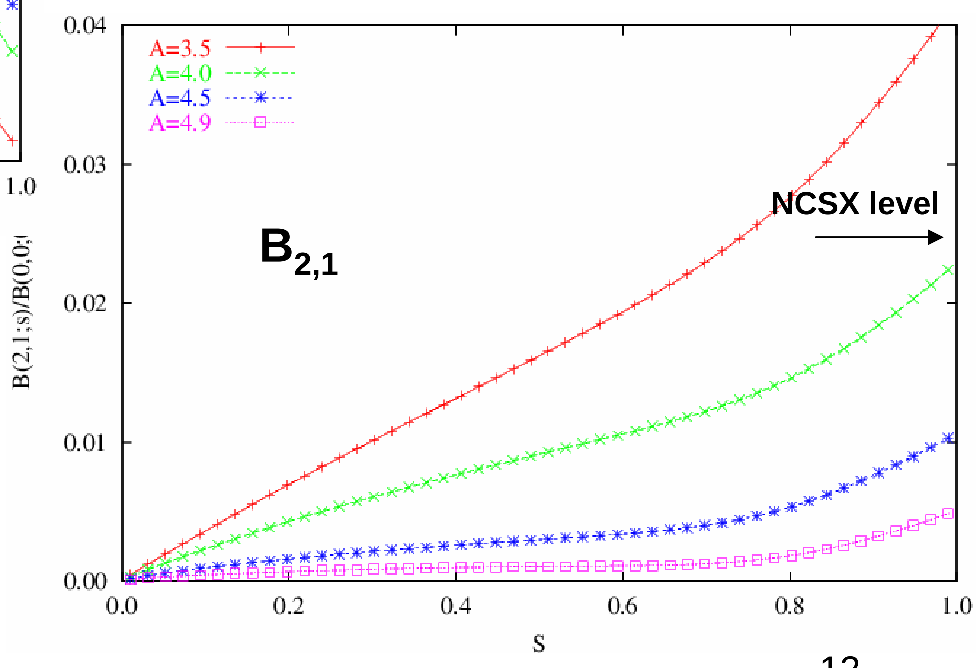


There is a corresponding increase in $B_{1,1}$ as $B_{0,1}$ increases and A decreases. It is approaching 6% for A=3.5 at the plasma boundary!

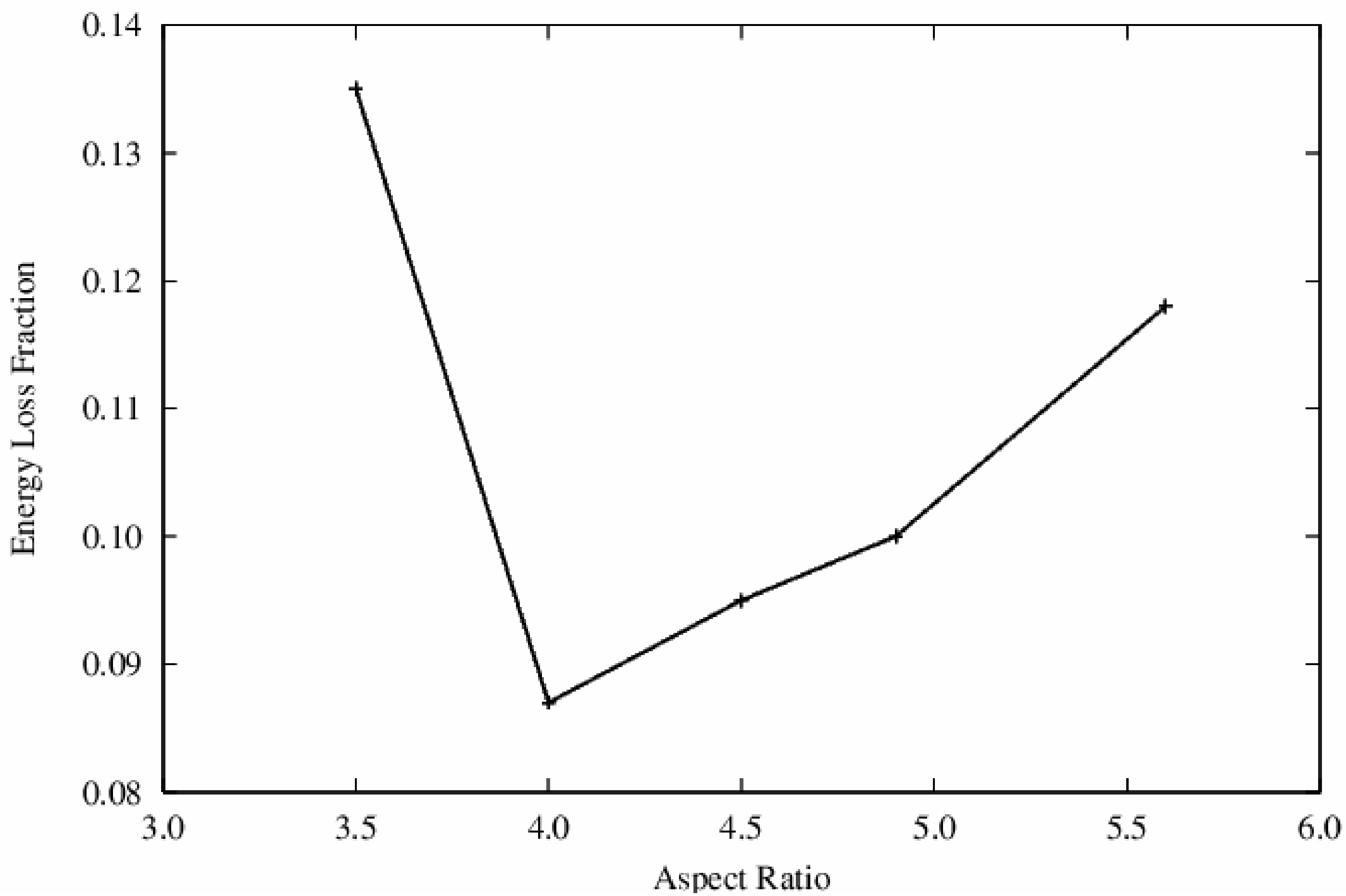


Effects of $B_{2,1}$ and $B_{3,2}$ become more unfavorable for ε-eff and α loss as A decreases even in the presence of a relatively large $B_{0,1}$.

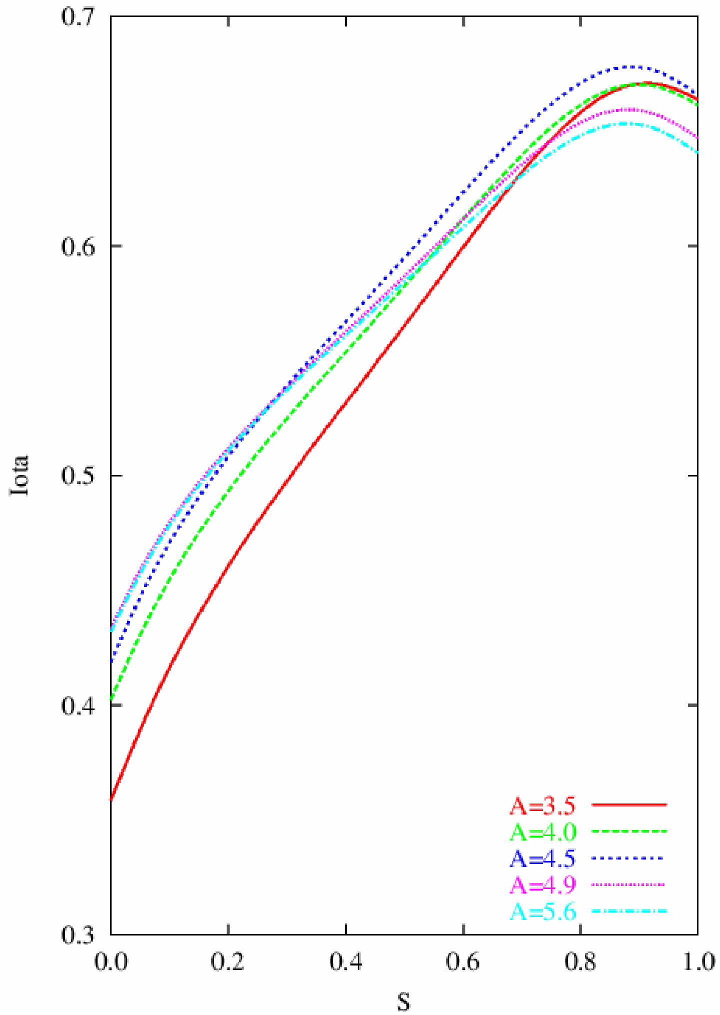


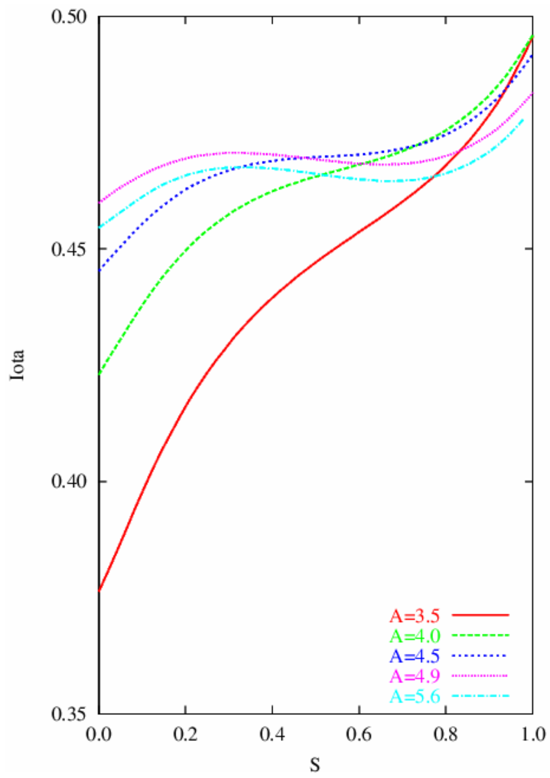


The energy loss fraction of α particles calculated with the same volume (1000 m^3), field (B_0=6.5 T), β (4%) and collisionality parameter (n_0R/T_0^2~0.1) shows a favorable aspect ratio ~4.



The rotational transform profiles of these configurations are similar. The quality of equilibrium flux surfaces is expected to be similar as well.





Question: would further imposing transform profile constraint be possible without hurting other targets?

Collisionality, B and α loss

- **The energy loss of α tends to be smaller if the field is higher and/or the overall collisionality with the background ions is larger.**

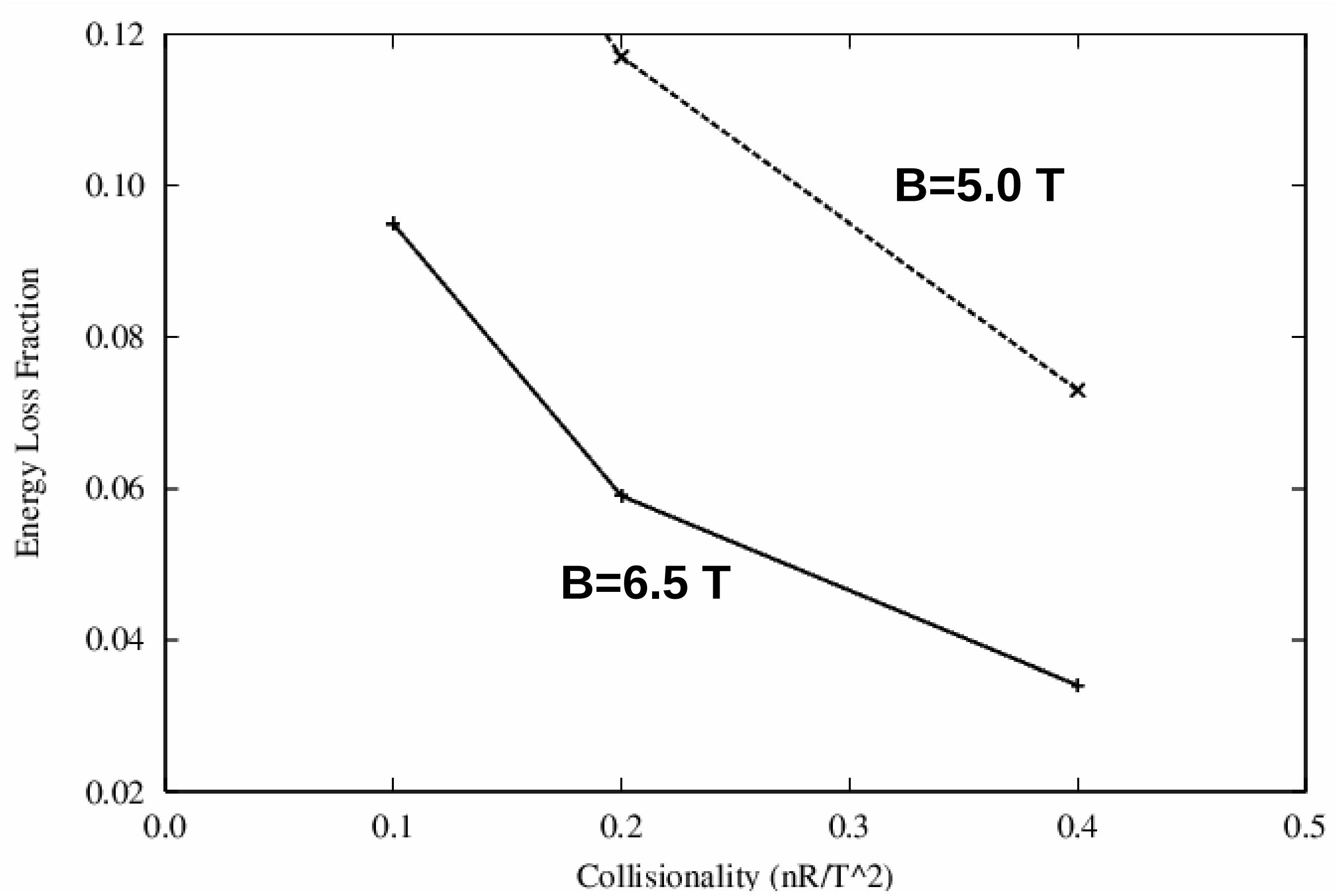
- **At a given β**

  $\beta \sim n \cdot T/B^2$
  $\nu \sim n \cdot R/T^2$
  $n < (P_{in} \cdot B/V)^{0.5;}$ **Sudo limit**
  $V \sim R^3/A^2$

- **The collisionality can be increased with higher n and lower T.**
  - **Need self-consistent solution from systems study**
  - **Also need self-consistent bootstrap current**

Calculations for the “mirror-enhanced” NCSX with A=4.5, β=4% show strong ν and B dependence.

Note: same equilibrium used. vol=1000 m^3, (1-s)^8 birth distribution, parabolic distribution for background ions.



15th ISW, Configurations

- Excellent review talks by J. Nuhrenberg and A. Weller
  - http://www-fusion.ciemat.es/sw2005/talks/
  - J. Nuhrenberg : Critical issues and comparison of different optimized stellarators.
  - A. Weller : Significance of MHD effects in stellarator confinement.

- Development of new configurations
  - QI, N=12, A=35, β=17%

β-limit due to local mode stability increases with N.

- Development of new tools.
  - New Γ_v, Γ_w measure based on bounce-averaged ∇B drift velocity of trapped particles across magnetic surfaces. ←
  - Bootstrap codes and self-consistent approaches.

Initial tests (WK) of some of our cases showed consistent correlation with the fast particle loss.

Work Plans

- **Continue the effort of using biased magnetic spectrum to improve configurations.**
  - **Add iota constraint for surface quality improvement**
  - **Study coil complexity and plasma aspect ratio**
- **Optimize internal transforms by varying p and J profiles.**
- **Examine physics aspects of the reference design point(s) from the systems code.**