Ripple-induced alpha loss calculations by ASCOT and SPIRAL

INFUSE Workshop 2020

A.J. Creely, S.D. Scott (CFS)
G.J. Kramer (PPPL)

Program overview

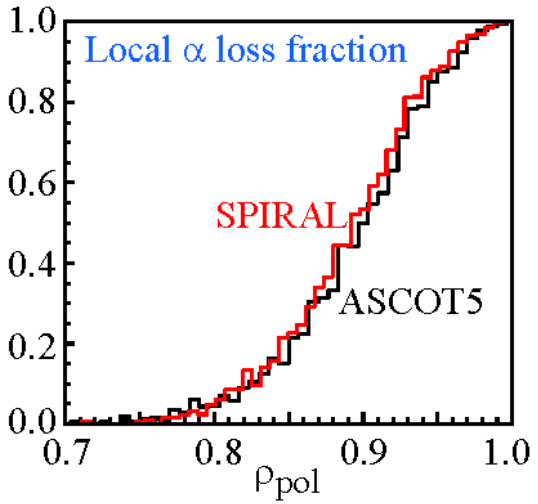
Goal: Calculate alpha particle losses in SPARC due to TF field ripple, instabilities

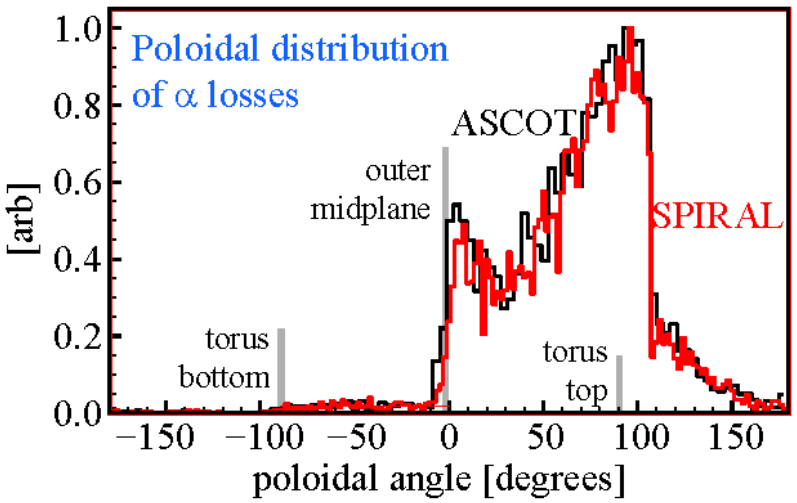
Tasks	2020				2021
	Q1	Q2	Q3	Q4	Q1
Adapt SPIRAL to produce 2D map of SPARC first wall					
Adapt SPIRAL birth distribution weights to improve statistics					
Adapt TRANSP to implement kick model for SPARC and TF ripple in ORBIT					
Train CFS staff to run ORBIT and kick models standalone and as part of TRANSP					
Run TRANSP and kick model to evaluate interaction between ripple-induced and MHD-induced fast ion transport					
Develop workflow to optimize limiter placement and shaping (reach goal)					

- Program is on schedule to meet core milestones and may achieve additional reach goals
- Successful benchmarking of ASCOT and SPIRAL for fusion alpha particle distribution
- Results published in S.D. Scott et al, *J. Plasma Phys.* 86 (2020).

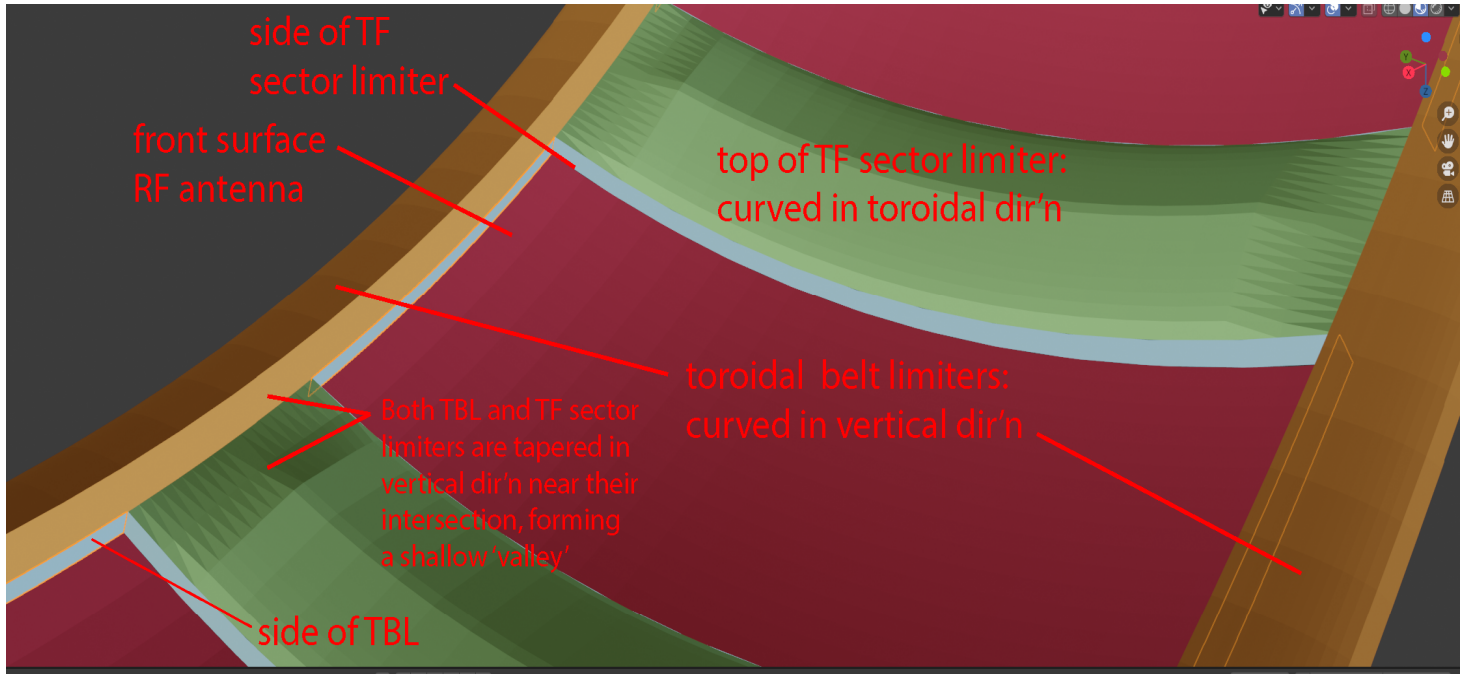
ASCOT and SPIRAL benchmarking resulted in improvements to both codes

- One major result is successful benchmarking of ASCOT and SPIRAL SPIRAL for fusion alpha particle distribution.
- Corrected errors in the alpha weighting pre-processors of both codes.
- Results to date recently published in:
  Fast-ion physics in SPARC, S.D. Scott et al, J. Plasma Phys. 86 (5), 865860508 (2020). https://doi.org/10.1017/S0022377820001087 .
- Along with first wall work, directly led to specifications for SPARC design (see later).
- This work has reiterated the importance of detailed benchmarking of codes against one another in order to produce accurate results.





Current work focuses on extending early results to more detailed physics and engineering considerations



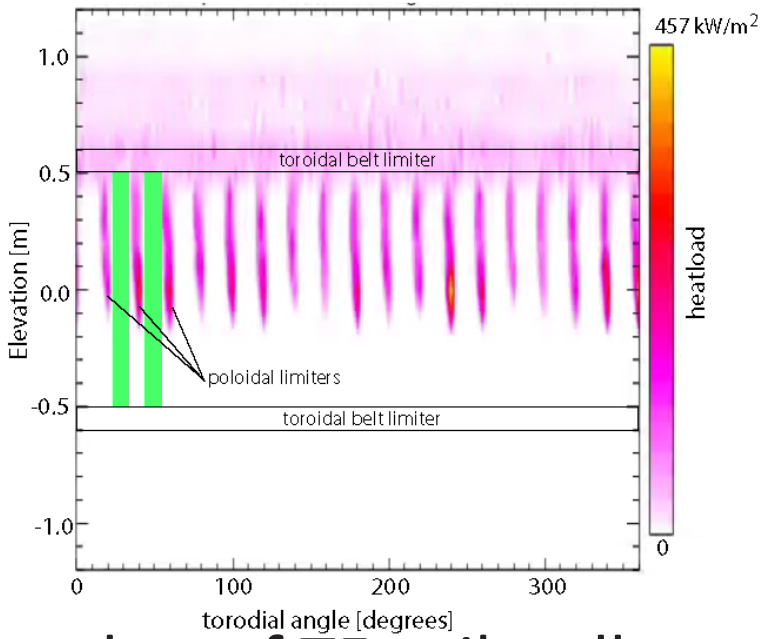
- This work has laid the foundations for more detailed physics investigations of the interactions between ripple, MHD, and alpha transport, which are now in progress.
- TRANSP and ORBIT are being added to the full workflow for this evaluation
- Fully 3D models of the SPARC first wall are being implemented in ASCOT and SPIRAL to optimize the shape to minimize alpha heating (in addition to other considerations), as seen in the figure above.

CFS plans to build long-term proficiency in the area of fast-particle modeling to mitigate long-term risk

- To mitigate the risk of personnel turnover, CFS plans to train a new generation of modelers in the area of fast ion physics to ensure the expertise remains available for subsequent SPARC and ARC modeling
- This will be done in collaboration with MIT and other academic partners
- Alpha physics will be a key part of SPARC's contribution to plasma physics knowledge so this will be a core capability of the project going forward

The work of this INFUSE project has directly impacted SPARC design

Displacement	Ensemble misalignment		
wall heating	500 kW/m2	750 kW/m2	1000 kW/m2
in/out	5.6 mm	9.3 mm	11.8 mm
toroidal	10.1 mm	15.0 mm	20.5 mm
up/down	24.5 mm	(big)	(big)



- In additional to intrinsic ripple due to a finite number of TF coils, all machines will have additional ripple caused by coil misalignments
- ASCOT and SPIRAL calculations determined allowable misalignments in SPARC TF Coils
- In addition, both 2D and 3D calculations of alpha heating of walls have led to specifications on RF antennas and plasma limiters.

2019 INFUSE Programs on the SPARC Timeline

Divertor Component Testing

OAK RIDGE National Laboratory

Divertor Plasma Simulations

Lawrence Livermore National Laboratory

Divertor CDR

Materials Downselect

Plasma Facing Components PDR

2020 (Q4) | **2021 (Q1)** | **2021 (Q2)** | ... | **2025**

Toroidal Field CDR

Central Solenoid CDR

Limiter CDR

Central Solenoid Model Coil PDR

SPARC commissioned

Alpha Particle Diagnostics

PPPL PRINCETON PLASMA PHYSICS LABORATORY

Superconducting Cable AC Loss and Quench Detection

BROOKHAVEN NATIONAL LABORATORY