Pushing the boundaries of leadership computer and fusion science in CPES

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As more powerful leadership class computer is becoming available at OLCF, fusion particles codes are entering the physics domain which has never been possible before. The XGC1 global multiphysics particle code scales all the way up to the maximal number of available Jaguarpf processor cores (223,488) (see Figure 1). This allows us to perform multiscale simulation of the small scale ion temperature gradient (ITG) driven micro-turbulence dynamics together with the large scale background neoclassical dynamics in 3D ITER mesh. Microinstabilities that are driven by spatial gradients in the equilibrium temperature profiles of the ions are known to produce the most robust turbulence, and the associated ion transport, observed in tokamaks. Together with "neoclassical" physics (the collisional relaxation of the spatial gradients in a magnetically-confined plasma), the ITG dynamics set the baseline behavior in such systems. New scientific discoveries enabled by the leadership class computer Jaguarpf are numerous: the nonlocal core-edge plasma interaction through turbulence spreading and heat flux, the residual ITG turbulence in the quiescent H-mode pedestal layer, the global circulation of turbulence energy, the non-Fickian heat transport, the ExB staircase, the spontaneous plasma rotation, and others. All of these large scale simulations on the existing large tokamak device DIII-D can be obtained in less than 24 hours on Jaguarpf, which have not been possible before. As the leadership class computers enhance their capability toward exascale speeds, global fusion particle codes will be able to add more detailed and complete turbulence physics (such as electron scale turbulences), heating physics (such as rf and neutral beam heating) and fusion alpha particle physics, in the pursuit toward "virtual" or "numerical" tokamak experiments in support of the ITER operation and the fusion reactor design. Strong collaboration with the enabling technologies from SciDAC institutes and centers has been, and will be, an essential element behind these achievements. Next level of algorithm and computer science developments is being discussed as the fusion particle codes are getting ready for the future exascale computing.

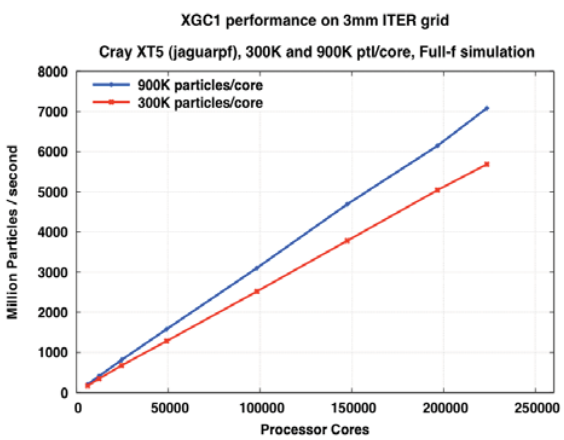

Figure 1. XGC1 on global ITER grid scales all the way up to the maximal number of available cores on Jaguar, making the global multiphysics gyrokinetic simulation of ITER possible.