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GANANAM (गणनम्)

HIGH PERFORMANCE *COMPUTING* NEWSLETTER

INSTITUTE FOR PLASMA RESEARCH, INDIA

INSIDE THIS ISSUE

(3 Pages)

Computational investigation on plasma transport in Negative Ion source using 2D-3V PIC MCC model

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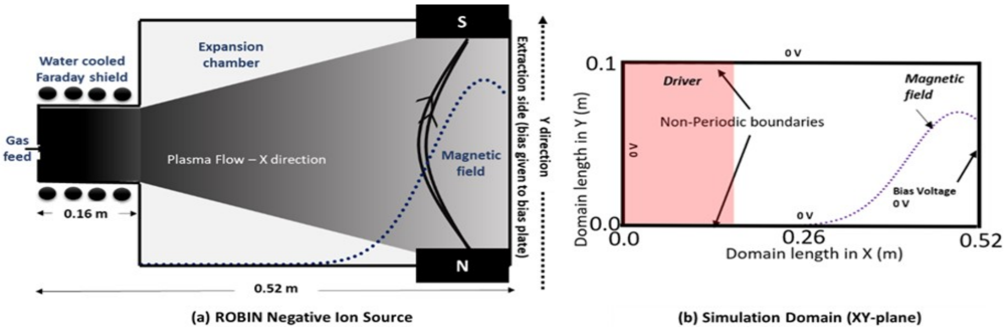


Figure 1 (a) Schematic of ROBIN negative ion source. Red shaded area is driver region. (b) Simulation domain is 2D XY plane with simplified geometry. The magnetic field is in Gaussian shape and perpendicular to the 2D plane. Purple dotted line shows magnetic field and it is in - Z direction.

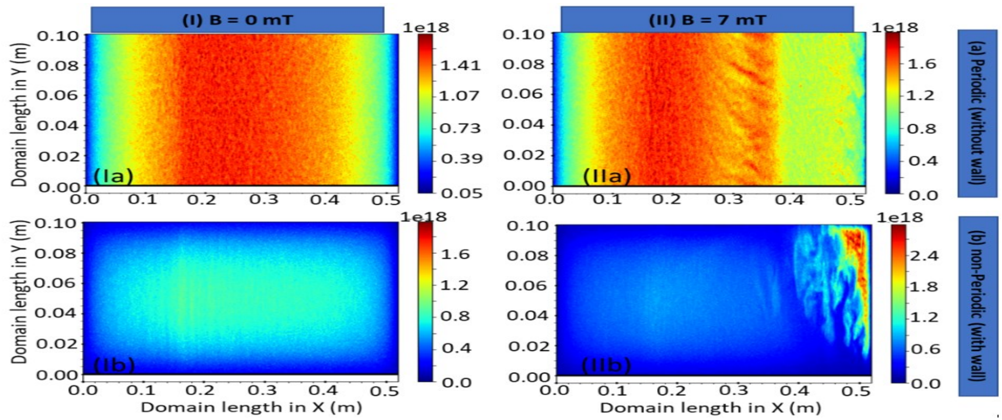


Figure 2 2D snapshots of Plasma density (m^{-3}) (a) Periodic (without wall) condition and (b) non-Periodic (with wall) condition using 2D-3V PIC MCC simulations at 24 μs for two different magnetic field ((I) 0 mT and (II) 7 mT).

Low-temperature plasma, operating in weak magnetic fields and low-pressure environments, has diverse applications, including negative ion sources, Hall thrusters, and more. In negative ion sources, a transverse magnetic filter field manages hot electron flow, reducing the impact on negative ions. However, the combination of non-uniform electric and magnetic fields leads to E x B drifts and introduces asymmetries, causing turbulence and instabilities in plasma parameters. These all are observed in ROBIN ((Rf Operated Beam source in India for Negative ion research) setup [1].

To aid the experimental investigations, a 2D-3V Particle in Cell Monte Carlo Collision model is used. We have used an in-house developed 2D-3V PIC MCC model with double precision. The computational framework of this model is detailed in references [2][3][4]. The implementation of the 2D-3V PIC-MCC algorithm involves the computational solution of Vlasov-Poisson equations, which provides the spatial and temporal evolution of charged-particle velocity distribution functions in plasmas under the effect of self-consistent electromagnetic fields and collisions [2][3]. Stringent numerical constraints on the total number of particles, number of grid points, and simulation time-scale associated with PIC codes make it computationally prohibitive on CPUs (serial code) in case of large problem sizes. We have a parallelized model on hybrid (OpenMP + MPI) parallel architecture for accelerated simulations [3], which can be used to perform such expensive simulations on an ANTYA HPC cluster with several nodes. A Monte Carlo collision scheme is applied to account for sixteen types of collisional phenomena, encompassing hydrogen chemistry, including ionization, elastic, and inelastic collisions [5]. Furthermore, self-consistent electron heating is applied within the "driver" region of the domain. Randomly selected electrons are continuously heated at an RF heating frequency, contributing to energy transfer through collisions and sustaining the plasma.

"Unlocking the Power of Parallelization: Accelerate Expensive Simulations on ANTYA HPC Cluster with Hybrid 2D-3V PIC-MCC Model!"

The investigation initially explores plasma behavior without a wall (periodic case in top and bottom boundaries) (Fig. 2-a). In the absence of a magnetic field, revealed a sequence where plasma density first increased, reached uniformity, and then decreased near the extraction boundary (Fig. 2-Ia). The presence of a magnetic field without a wall led to the emergence of strip-like structures (Fig. 2-IIa), indicating instability. This magnetic field generated electron pressure gradients, driving a drift, while the potential gradient induced a drift, both propagating along the Y-axis

Subsequently, the study examined scenarios with walls (Fig. 2-b), revealing significant asymmetries in plasma profiles within the magnetic filter region [3][6]. These asymmetries are attributed to drifts and instabilities, resulting in heightened plasma density at the upper extraction side (Fig. 2-IIb). Comparing the results indicate that the strip structures observed in periodic conditions transformed when interacting with walls, causing non-uniformities in plasma density and potential. These findings provide valuable insights into the intricate dynamics of ion sources, offering potential avenues for optimizing their performance.

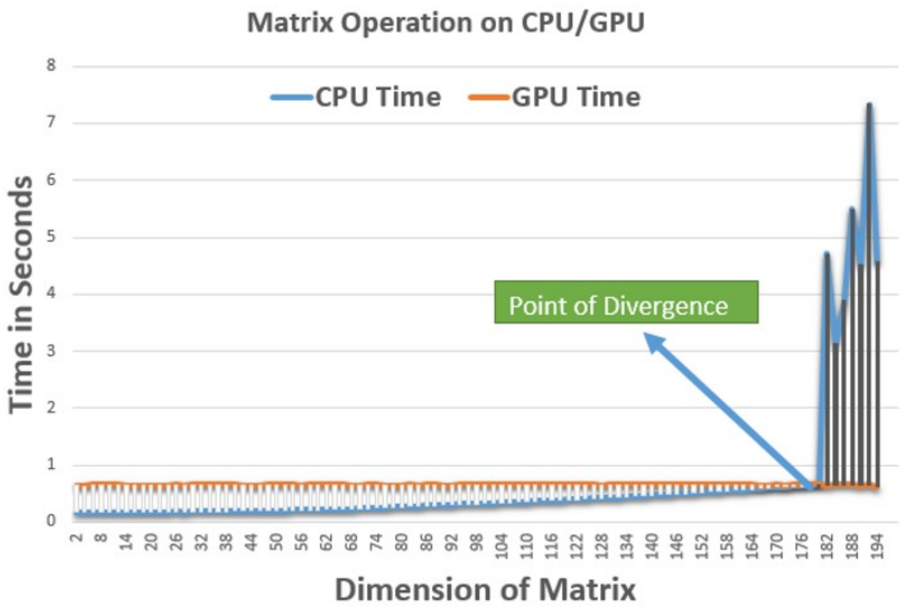
In summary, wall effects significantly impact plasma behavior, creating asymmetries and increased density at the magnetic filter's top. The walls introduce distinct E x B drifts and density gradients, amplifying asymmetries. FFT analysis uncovers additional instabilities. These insights are crucial for understanding plasma dynamics in practical applications

References:

1. *M. Bandyopadhyay, Rev. Sci. Instrum. 93, 023504 (2022).*
2. *K Shah et al., SuperComputing Conference17 (2017).*
3. *M. Shah et al., Fusion Eng. Design 151, 111402 (2020).*
4. *B. Chaudhury et al., Communication in Computer and Information Sciences (2018).*
5. *M. Shah et al., Mathematics and Computing, Advances in Intelligent Systems(2020).*
6. *M.Shah et al., Phys. Plasma 30, 010701 (2023)*

Is GPU Always Faster than CPU?

The graph below illustrates that GPUs do not consistently outperform CPUs. For instance, consider an operation involving the addition of a matrix to its own values, ranging from a dimension of (2, 2) to (200, 200). CPUs are computationally efficient for smaller matrix dimensions, but their computation cost increases as the dimension grows. In contrast, GPU devices maintain a similar processing time across the studied range of dimensions. For CPU cores, computation costs increase linearly with growing matrix dimensions and become particularly pronounced near a matrix dimension of approximately (182, 182). Interested users may delve into the reasons behind this sudden increase in cost.




```
import torch
import time

for dimension in range(2,200,2):
    x = torch.randn(dimension,dimension)
    start_time = time.time()
    for i in range(100000):
        x+=x
    elapsed_time_cpu = time.time() - start_time

    x = torch.randn(dimension,dimension,device=torch.device("cuda:1"))
    start_time = time.time()
    for i in range(100000):
        x+=x
    elapsed_time_gpu = time.time() - start_time

    print('Dimension = ', dimension, 'CPU Time = ', elapsed_time_cpu, 'GPU Time = ',elapsed_time_gpu)
```

This above code is a performance benchmarking script that assesses the computational speed of both CPU and GPU (specifically, CUDA) for matrix operations using the PyTorch library. It conducts a series of tests with randomly generated matrices of varying dimensions, ranging from 2 to 198 (in increments of 2). For each dimension, the script first creates a random tensor on the CPU and measures the execution time for a specific operation—doubling the tensor's values—repeated 100,000 times. This benchmark helps determine how quickly the CPU can perform the operation.

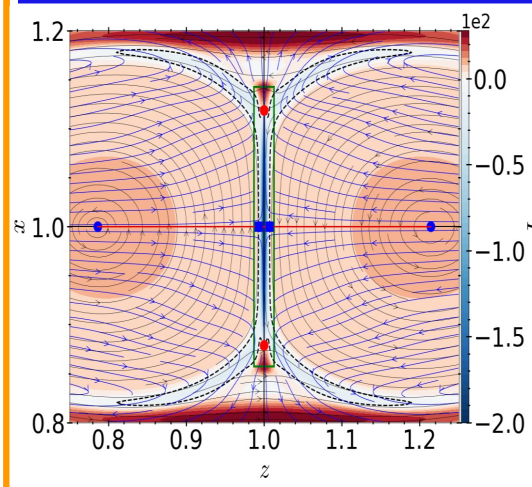
Then, it repeats the process on the GPU, using CUDA device 1. It records the execution time for the same operation to assess GPU performance. The script prints the dimension, CPU execution time, and GPU execution time for each tested dimension, allowing for a direct comparison of CPU and GPU efficiency across different matrix sizes.

ANTYA UPDATES AND NEWS

1. New Packages/Applications Installed

Modules list remains the same for this month. To check the list of available modules:
$ module avail –l

HPC PICTURE OF THE MONTH



Pic Credit: Jagannath Mahapatra

Zoom-in view of a reconnecting current sheet (the central blue color region, site for magnetic reconnection) formed due to two coalescing magnetic islands (whose centers are represented by blue circles). The plot shows the Current density (colormap), magnetic field (black streamline) and flow field (blue streamline) profiles at the time of maximum reconnection rate. The green rectangle and the black dotted contour represents the shape of the current sheet, having thickness measured as the distance between the two blue square dots, and length measured as the distance between the two red circles .

(J Mahapatra, Phys. Plasma 29, 112107, (2022), https://dx.doi.org/10.1063/5.0116269)

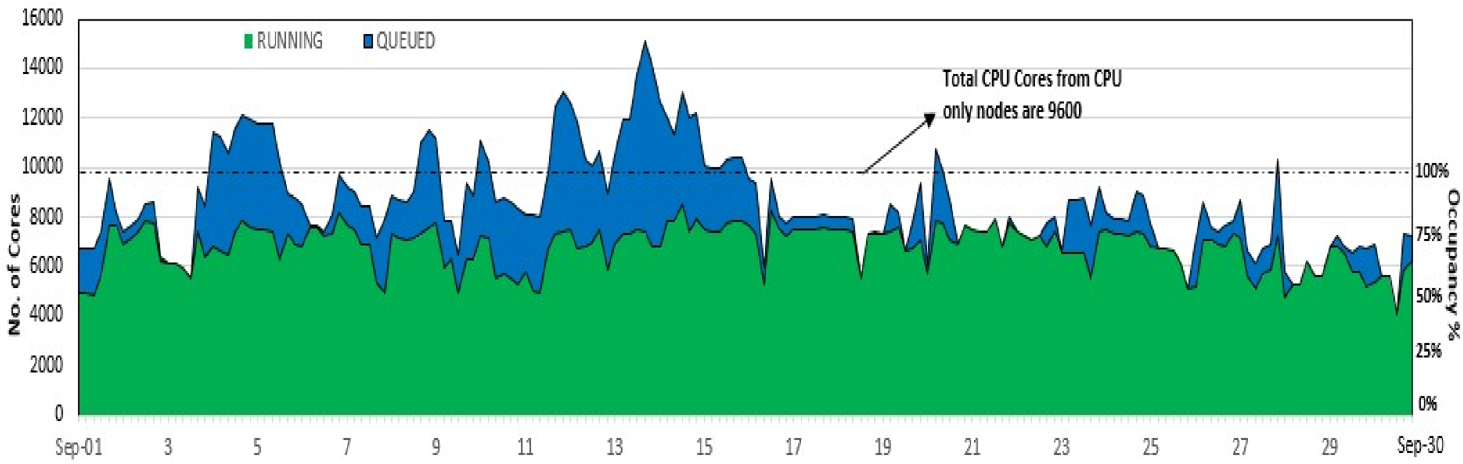
TIP OF THE MONTH

To check the number of jobs in specific queue, there is an option available in qstat command. For e.g.
>> qstat queue <queue_name>

[user@login1 ~]$ qstat queue longq

ANTYA Utilization: SEPTEMBER 2023

ANTYA Daily Observed Workload



Other Recent Work on HPC (Available in IPR Library)

Influence of Wall on Plasma Transport across Magnetic Filter Field in a Negative Ion Source: A 2d-3v Pic Mcc Simulation Study	**Dr. Miral Shah**
Do Embedded columnar Vortices in a 3D plane Couette flow lead to subcritical turbulence in Yukawa Liquids	**Suruj Jyoti Kalita**
Design Development of Drift Duct for Diagnostic Neutral Beam System of ITER	**M. Venkata Nagaraju**
Electromagnetic Vlasov simulations of warm electron magnetized plasma excitations	**Anjan Kumar Paul**
Design and analysis of mixed bed solid breeder blanket with titanium berrylide as neutron multiplier	**Deepak Sharma**
Design and Simulation of High Temperature Thermally Insulated Chamber to Operate Graphite Electrode Based Plasma Arc	**Atikkumar N. Mistry**
Nonlinear propagation of quasi-longitudinal whistler wave in plasma	**Gayatri Bhay-yaji Barsagade**

ANTYA HPC USERS' STATISTICS— SEPTEMBER 2023

- **Total Successful Jobs~ 7952**
- **Top Users** (Cumulative Resources)

- **CPU Cores** — **Amit Singh**
- **GPU Cards** — **Shishir Biswas**
- **Walltime** — **Sapna Mishra**
- **Jobs** — **Sarvesh Kumar**

Acknowledgement

The HPC Team, Computer Division IPR, would like to thank all Contributors for the current issue of *GAṆANAM*.

On Demand Online Tutorial Session on HPC Environment for New Users Available
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