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Status of BIT1 Porting to GPU and Progress on X-tork

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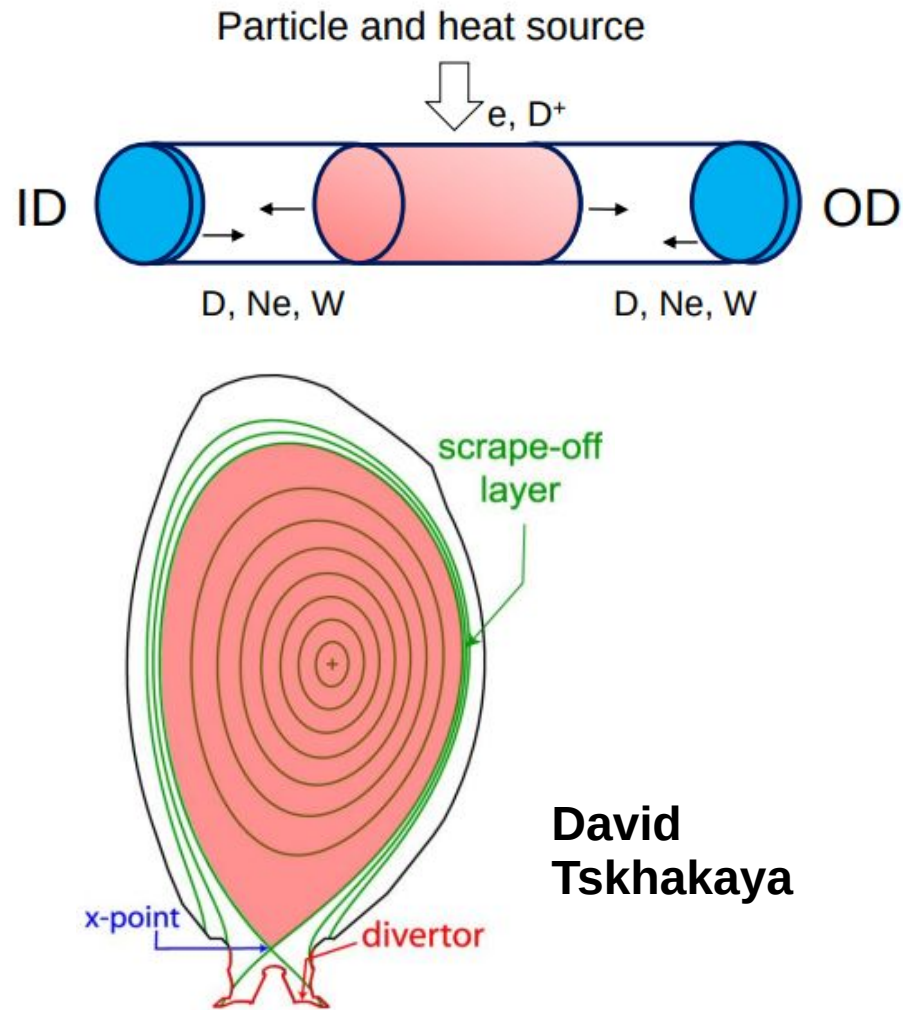


BIT1

Xavier Sáez



BIT1: Introduction

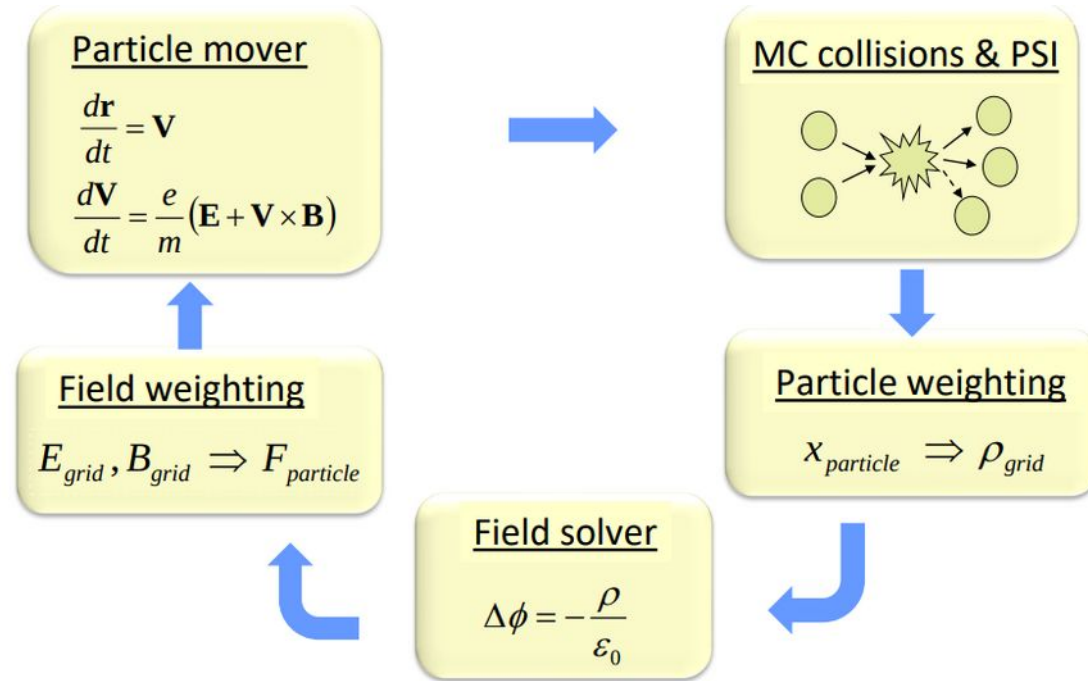


David
Tskhakaya

- BIT1 is an electrostatic 1D3V PIC + 2D3V direct Monte Carlo code for plasma simulations.
- **Input:** Particle, heat sources, geometry and divertor material
- **Simulated particle species:** El, D (H, T), Li, He, Be, O, ...
- Highly accurate → 5×10^6 cells → capability to simulate whole SOL
- **Language:** C
- **Libraries:** No external libs
- **Parallelization:** MPI using domain decomposition



BIT1: Algorithm



- BIT1 is a **Particle-in-cell (PIC)** code



BIT1: Project Goal

- **Main objective:** port BIT1 to GPUs using OpenACC.
 - Ensure maintainability and readability of the codebase.
 - Achieve acceleration by offloading costly routines to GPUs.
- **Sub-objectives:**
 - Introduce OpenACC directives minimally invasively.
 - Preserve usability for non-GPU experts.
 - Measure performance vs MPI-only CPU version.
 - Document issues and propose next steps.

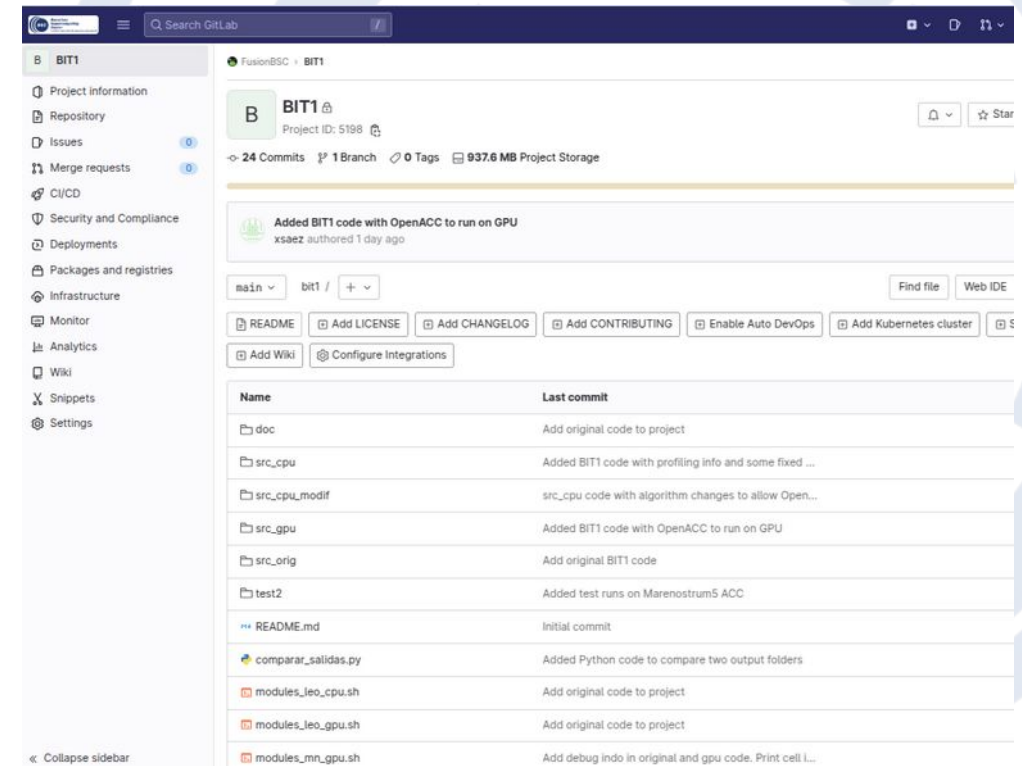




BIT1: Execution Environment

- **Platforms used:**
 - Leonardo (A100 GPUs, HDR IB)
 - MareNostrum 5 (H100 GPUs, NDR IB)
 - Pitagora (incomplete GPU ecosystem)
- **Test case: DCSM_0_e21_c8.inp**
 - 1D bounded plasma with electrons, D^+ ions, and neutrals.
 - Domain: 0.1 m, 100,000 cells.
 - Time step: $4e-14$ s, 1,000 iterations.
 - Each job used 4 MPI ranks (one per GPU), and Each MPI task is explicitly bound to a dedicated GPU.
- **Profiling tools:**
 - NVTX for instrumentation.
 - Nsight Systems for GPU/CPU trace analysis.

- **GitLab Repository: FusionBSC/BIT1**
 - All codes, tests, results and traces are available.





BIT1: Preliminary Work

- **Environment setup:**
 - Creation of module-loading scripts per platform.
- **Cleanup of unused variables to remove warnings.**

```
picc -c -O2 -noacc bincc.c
"bincc.c", line 13: warning: variable "iisp" was declared but never referenced
[declared_but_not_referenced]
    int      isp, iisp, i, s, p1, p2, nnp, k, sid, sod;
                ^
```

- **Fixing segmentation fault caused by long file paths.**

```
Can't find input file /gpfs/projects/bsc21/bsc021331/BIT1/bit1-feature-GPU-OpenACC/tests/../../BIT1_c8/at0N
Can't find input file /gpfs/projects/bsc21/bsc021331/BIT1/bit1-feature-GPU-OpenACC/tests/../../BIT1_c8/at00eH
```

- **Preparation for GPU port:**
 - Ensuring build consistency across supercomputers.



BIT1: CPU Version

- Reference baseline performance:
 - **Original BIT1 CPU:** runtime ~244.5 s.
 - **Instrumented CPU version:** runtime ~249 s (minimal overhead).
step time ~260 ms
- Modifications for GPU preparation:
 - Inlining routines for GPU compatibility.

```
void chist_N()
{
    int isp;

    for (isp=0; isp<nsp; isp++)
    {
        np_hist[isp][hist_hi2] = fnp(isp);
    } /* end of for (isp=0...*/
} /* END of chist_N() */
```

→

```
void chist_N()
{
    int isp;
    int s, j;

    for (isp=0; isp<nsp; isp++)
    {
        // np_hist[isp][hist_hi2] = fnp(isp);
        int j= 0;
        for (s=0; s<nc; s++)
            j += np[isp][s];
        np_hist[isp][hist_hi2] = j;
    } /* end of for (isp=0...*/
} /* END of chist N() */
```

- Replacing complex array accesses with local vars.

```
if (np[iisp][j])
{
    Tx[iisp][j] *= Tscale[iisp]/np[iisp][j];
    T_dif[iisp][j] *= Escale[iisp]/np[iisp][j];
}
```

→

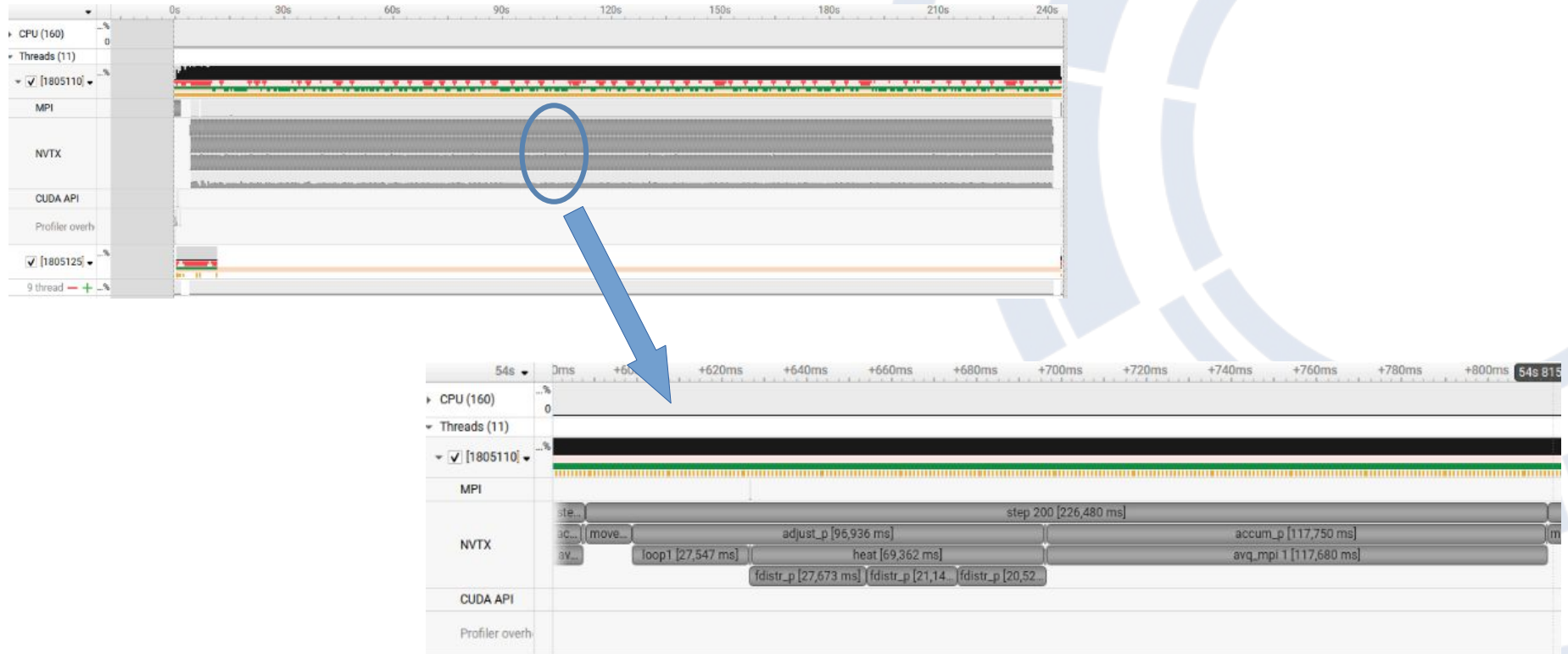
```
np_tmp = np[iisp][j];
if (np_tmp)
{
    Tx[iisp][j] *= Tscale[iisp]/np_tmp;
    T_dif[iisp][j] *= Escale[iisp]/np_tmp;
}
```

- Splitting large loops for better parallel analysis.



BIT1: CPU Version (2)

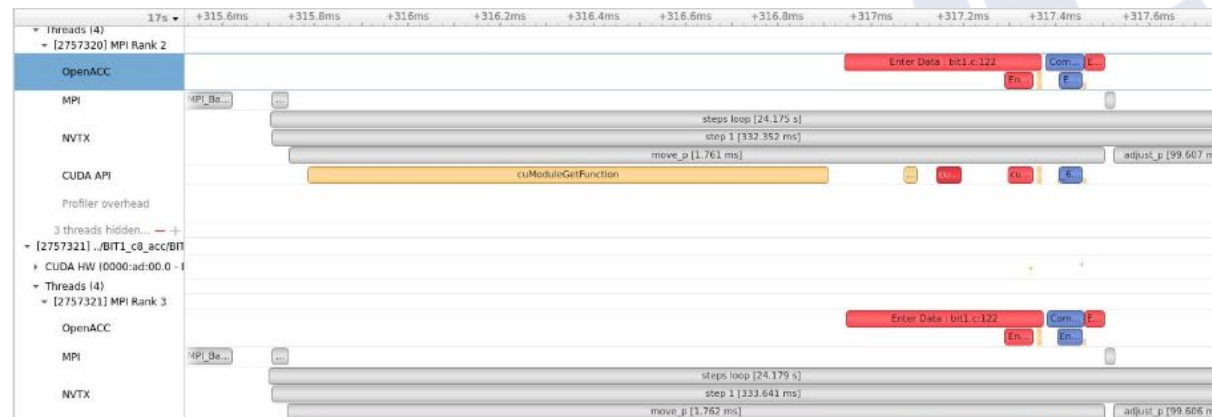
- **Trace:**
 - Execution flow of main PIC loop.
 - Time spent in particle mover and field solver.
 - Profiling used to identify GPU porting targets.





BIT1: First GPU Approach

- **Initial GPU-enabled routines:**
 - move0 (particle mover).
 - arrj (particle-to-cell assignment).
- **Results:**
 - move0 accelerated from 43.6s → 2.16s (20×).
 - Overall runtime worsened (0.87× speedup).
- **Reason: excessive CPU-GPU transfers.**
 - Led to strategy of porting all routines in test case.





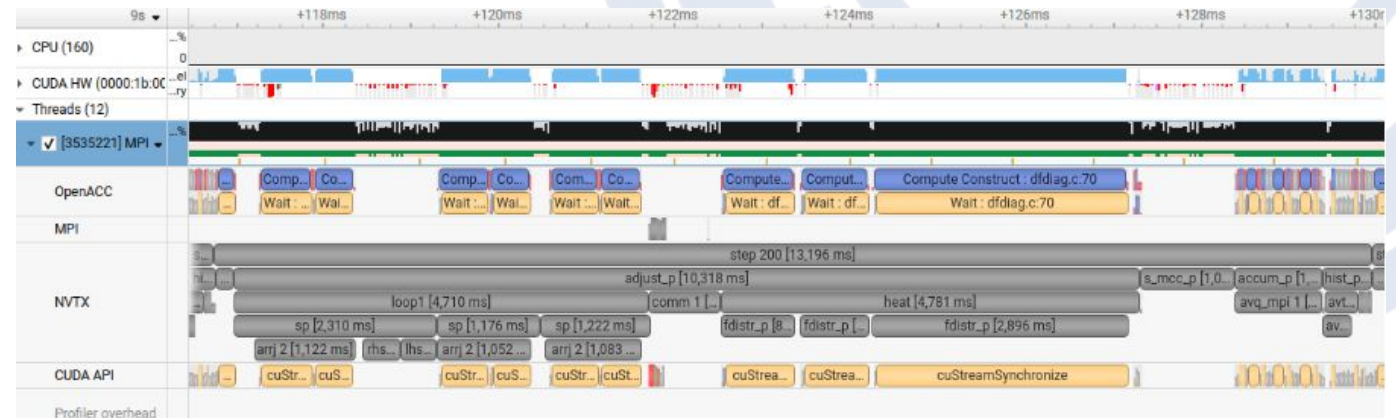
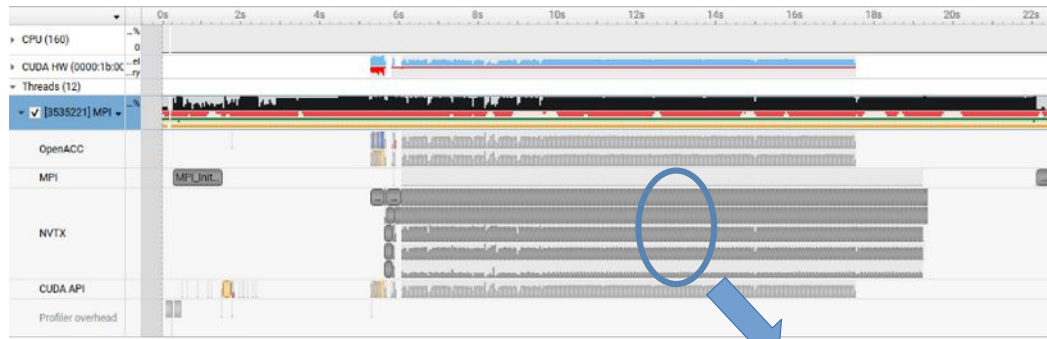
BIT1: GPU Version

- **GPU-enabled routines:**
 - 16 routines across 10 source files.
- **Substantial redesign of arrj for parallel execution.**
- **Performance:**
 - Total runtime improved from 249 s to 35.8 s (~7× faster).
 - Step time improved from 260 ms to 13 ms (~20× faster).
- **Most runtime now spent on GPU kernels.**



BIT1: GPU Version (2)

- Trace:
 - Dominance of GPU kernels over CPU execution.
 - Greatly reduced host-device transfers.
 - Balanced overlap of MPI communication.





BIT1: Floating-Point Differences

- GPU results differ slightly from CPU outputs:
 - Due to different operation ordering in parallel execution.
 - Floating-point arithmetic differences between CPU/GPU.
- All outputs provided for validation in the repository.

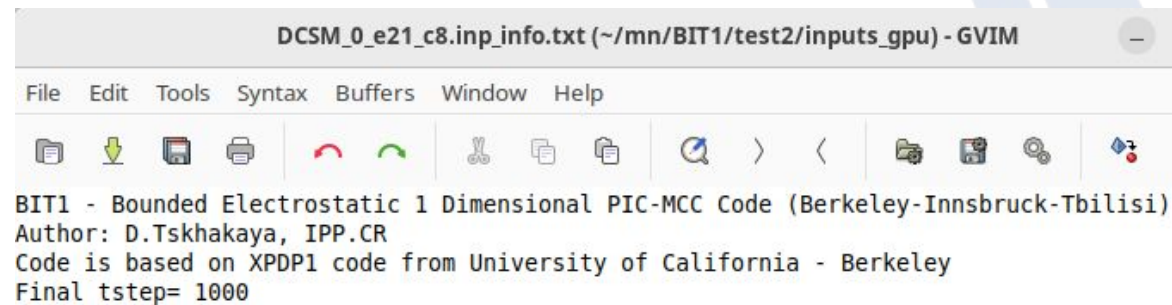
1	-1.305733e+03	4.383658e+04	5.085077e+20	1.979633e+01	1.693475e+08	1.719642e+08	-9.626951e-02	0	-1.305740e+03	4.383658e+04	5.085077e+20	1.979633e+01	1.693475e+08	1.719642e+08	-9.626951e-02	0	-1.305740e+03	4.383658e+04	5.085077e+20	1.979633e+01	1.693475e+08	1.719642e+08	-9.626951e-02								
2	1.765481e+03	5.362079e+04	9.972641e+20	1.968144e+01	1.967254e+08	1.803522e+08	3.194767e-01	1	1.765481e+03	5.362079e+04	9.972641e+20	1.968144e+01	1.967254e+08	1.803522e+08	3.194767e-01	1	1.765481e+03	5.362079e+04	9.972641e+20	1.968144e+01	1.967254e+08	1.803522e+08	3.194767e-01								
3	-1.409178e+03	4.765828e+04	1.000071e+21	1.962440e+01	1.537368e+08	1.469803e+08	4.722936e-01	2	2.574044e+02	1.058991e+04	1.000566e+21	1.903135e+08	-6.107078e-02	1.903135e+08	1.045079e+08	-6.107078e-02	2	2.574044e+02	1.058991e+04	1.000566e+21	1.903135e+08	-6.107078e-02	1.903135e+08	1.045079e+08	-6.107078e-02						
4	1.265987e+03	7.708656e+04	9.963090e+20	1.998557e+01	1.753537e+08	1.587920e+08	-2.055935e-01	3	-1.409178e+03	4.765828e+04	1.000071e+21	1.962440e+01	1.537368e+08	1.469803e+08	4.722936e-01	3	-1.409178e+03	4.765828e+04	1.000071e+21	1.962440e+01	1.537368e+08	1.469803e+08	4.722936e-01	3	-1.409178e+03	4.765828e+04	1.000071e+21	1.962440e+01	1.537368e+08	1.469803e+08	4.722936e-01
5	-1.361334e+03	1.258777e+05	1.007177e+21	1.960387e+01	1.385910e+08	1.420734e+08	3.723428e-01	4	1.265987e+03	7.708656e+04	9.963090e+20	1.998557e+01	1.753537e+08	1.587920e+08	-2.055935e-01	4	1.265987e+03	7.708656e+04	9.963090e+20	1.998557e+01	1.753537e+08	1.587920e+08	-2.055935e-01	4	1.265987e+03	7.708656e+04	9.963090e+20	1.998557e+01	1.753537e+08	1.587920e+08	-2.055935e-01
6	-5.081111e-02	9.009522e-04	9.930929e+20	1.956407e+01	1.461550e+08	1.304046e+08	4.352144e-01	5	-1.361334e+03	1.258777e+05	1.007177e+21	1.960387e+01	1.385910e+08	1.420734e+08	3.723428e-01	5	-1.361334e+03	1.258777e+05	1.007177e+21	1.960387e+01	1.385910e+08	1.420734e+08	3.723428e-01	5	-1.361334e+03	1.258777e+05	1.007177e+21	1.960387e+01	1.385910e+08	1.420734e+08	3.723428e-01
7	1.722018e+02	9.750659e+04	1.002049e+21	1.954863e+01	1.493295e+08	1.321224e+08	2.643016e-01	6	-5.081111e-02	9.009522e-04	9.930929e+20	1.956407e+01	1.461550e+08	1.304046e+08	4.352144e-01	6	-5.081111e-02	9.009522e-04	9.930929e+20	1.956407e+01	1.461550e+08	1.304046e+08	4.352144e-01	6	-5.081111e-02	9.009522e-04	9.930929e+20	1.956407e+01	1.461550e+08	1.304046e+08	4.352144e-01
8	-3.459532e+02	8.298938e+04	1.002107e+21	1.946534e+01	1.310772e+08	1.388425e+08	5.994001e-01	7	1.722018e+02	9.750659e+04	1.002049e+21	1.954863e+01	1.493295e+08	1.321224e+08	2.643016e-01	7	1.722018e+02	9.750659e+04	1.002049e+21	1.954863e+01	1.493295e+08	1.321224e+08	2.643016e-01	7	1.722018e+02	9.750659e+04	1.002049e+21	1.954863e+01	1.493295e+08	1.321224e+08	2.643016e-01
9	2.653474e+03	5.424571e+04	9.934892e+20	1.967532e+01	1.389679e+08	1.127970e+08	5.608725e-01	8	-3.459532e+02	8.298938e+04	1.002107e+21	1.946534e+01	1.310772e+08	1.388425e+08	5.994001e-01	8	-3.459532e+02	8.298938e+04	1.002107e+21	1.946534e+01	1.310772e+08	1.388425e+08	5.994001e-01	8	-3.459532e+02	8.298938e+04	1.002107e+21	1.946534e+01	1.310772e+08	1.388425e+08	5.994001e-01
10	-2.282975e+03	2.082189e+04	1.007957e+21	1.957580e+01	1.064252e+08	1.127443e+08	6.000707e-02	9	2.653474e+03	5.424571e+04	9.934892e+20	1.967532e+01	1.389679e+08	1.127970e+08	5.608725e-01	9	2.653474e+03	5.424571e+04	9.934892e+20	1.967532e+01	1.389679e+08	1.127970e+08	5.608725e-01	9	2.653474e+03	5.424571e+04	9.934892e+20	1.967532e+01	1.389679e+08	1.127970e+08	5.608725e-01
11	3.683810e-02	3.718746e+04	9.954905e+20	1.972097e+01	1.321273e+08	1.224449e+08	3.469109e-01	10	-2.282975e+03	2.082189e+04	1.007957e+21	1.957580e+01	1.064252e+08	1.127443e+08	6.000707e-02	10	-2.282975e+03	2.082189e+04	1.007957e+21	1.957580e+01	1.064252e+08	1.127443e+08	6.000707e-02	10	-2.282975e+03	2.082189e+04	1.007957e+21	1.957580e+01	1.064252e+08	1.127443e+08	6.000707e-02
12	-5.678264e+02	7.767774e+04	9.992440e+20	1.964396e+01	1.267608e+08	1.207299e+08	1.020732e-01	11	3.683810e-02	3.718746e+04	9.954905e+20	1.972097e+01	1.321273e+08	1.224449e+08	3.469109e-01	11	3.683810e-02	3.718746e+04	9.954905e+20	1.972097e+01	1.321273e+08	1.224449e+08	3.469109e-01	11	3.683810e-02	3.718746e+04	9.954905e+20	1.972097e+01	1.321273e+08	1.224449e+08	3.469109e-01
13	-7.473935e+02	5.241955e+04	1.004227e+21	1.949756e+01	1.134558e+08	1.096655e+08	4.708157e-01	12	-5.678264e+02	7.767774e+04	9.992440e+20	1.964396e+01	1.267608e+08	1.207299e+08	1.020732e-01	12	-5.678264e+02	7.767774e+04	9.992440e+20	1.964396e+01	1.267608e+08	1.207299e+08	1.020732e-01	12	-5.678264e+02	7.767774e+04	9.992440e+20	1.964396e+01	1.267608e+08	1.207299e+08	1.020732e-01
14	-2.408444e+03	4.324254e+04	9.945964e+20	1.958141e+01	1.049239e+08	1.279735e+08	7.083207e-01	13	-7.473935e+02	5.241955e+04	1.004227e+21	1.949756e+01	1.134558e+08	1.096655e+08	4.708157e-01	13	-7.473935e+02	5.241955e+04	1.004227e+21	1.949756e+01	1.134558e+08	1.096655e+08	4.708157e-01	13	-7.473935e+02	5.241955e+04	1.004227e+21	1.949756e+01	1.134558e+08	1.096655e+08	4.708157e-01
15	-2.127246e+02	8.744150e+04	1.003497e+21	1.955347e+01	1.091700e+08	1.091211e+08	9.493763e-01	14	-2.408444e+03	4.324254e+04	9.945964e+20	1.958141e+01	1.049239e+08	1.279735e+08	7.083207e-01	14	-2.408444e+03	4.324254e+04	9.945964e+20	1.958141e+01	1.049239e+08	1.279735e+08	7.083207e-01	14	-2.408444e+03	4.324254e+04	9.945964e+20	1.958141e+01	1.049239e+08	1.279735e+08	7.083207e-01
16	-2.300737e+03	6.510937e+04	9.992722e+20	1.946500e+01	1.096139e+08	1.160008e+08	7.140012e-01	15	-2.127246e+02	8.744150e+04	1.003497e+21	1.955347e+01	1.091700e+08	1.091211e+08	9.493763e-01	15	-2.127246e+02	8.744150e+04	1.003497e+21	1.955347e+01	1.091700e+08	1.091211e+08	9.493763e-01	15	-2.127246e+02	8.744150e+04	1.003497e+21	1.955347e+01	1.091700e+08	1.091211e+08	9.493763e-01
17	-2.676803e+02	1.102518e+05	9.978595e+20	1.949590e+01	1.118024e+08	1.113776e+08	4.658093e-01	16	-2.300737e+03	6.510937e+04	9.992722e+20	1.946500e+01	1.096139e+08	1.160008e+08	7.140012e-01	16	-2.300737e+03	6.510937e+04	9.992722e+20	1.946500e+01	1.096139e+08	1.160008e+08	7.140012e-01	16	-2.300737e+03	6.510937e+04	9.992722e+20	1.946500e+01	1.096139e+08	1.160008e+08	7.140012e-01
18	5.534511e+02	5.078928e+04	1.003277e+21	1.975926e+01	1.308958e+08	1.322671e+08	1.695052e-01	17	-2.676803e+02	1.102518e+05	9.978595e+20	1.949590e+01	1.118024e+08	1.113776e+08	4.658093e-01	17	-2.676803e+02	1.102518e+05	9.978595e+20	1.949590e+01	1.118024e+08	1.113776e+08	4.658093e-01	17	-2.676803e+02	1.102518e+05	9.978595e+20	1.949590e+01	1.118024e+08	1.113776e+08	4.658093e-01
19	2.299354e+03	4.192657e+04	9.975122e+20	1.945600e+01	1.337467e+08	1.347877e+08	8.308054e-01	18	5.534511e+02	5.078928e+04	1.003277e+21	1.975926e+01	1.308958e+08	1.322671e+08	1.695052e-01	18	5.534511e+02	5.078928e+04	1.003277e+21	1.975926e+01	1.308958e+08	1.322671e+08	1.695052e-01	18	5.534511e+02	5.078928e+04	1.003277e+21	1.975926e+01	1.308958e+08	1.322671e+08	1.695052e-01
20	-1.398375e+03	4.894574e+04	1.001469e+21	1.962839e+01	1.163111e+08	1.200725e+08	-3.997979e-02	19	2.299354e+03	4.192657e+04	9.975122e+20	1.945600e+01	1.337467e+08	1.347877e+08	8.308054e-01	19	2.299354e+03	4.192657e+04	9.975122e+20	1.945600e+01	1.337467e+08	1.347877e+08	8.308054e-01	19	2.299354e+03	4.192657e+04	9.975122e+20	1.945600e+01	1.337467e+08	1.347877e+08	8.308054e-01
21	-6.553039e-01	1.750897e+03	9.999903e+20	1.998504e+01	1.236330e+08	1.257647e+08	1.025778e-01	20	-1.398375e+03	4.894574e+04	1.001469e+21	1.962839e+01	1.163111e+08	1.200725e+08	-3.997979e-02	20	-1.398375e+03	4.894574e+04	1.001469e+21	1.962839e+01	1.163111e+08	1.200725e+08	-3.997979e-02	20	-1.398375e+03	4.894574e+04	1.001469e+21	1.962839e+01	1.163111e+08	1.200725e+08	-3.997979e-02
22	-6.794828e+02	-1.703654e+04	9.980189e+20	1.903110e+01	1.180380e+08	1.205807e+08	3.800070e-01	21	-6.553039e-01	1.750897e+03	9.999903e+20	1.998504e+01	1.236330e+08	1.257647e+08	1.025778e-01	21	-6.553039e-01	1.750897e+03	9.999903e+20	1.998504e+01	1.236330e+08	1.257647e+08	1.025778e-01	21	-6.553039e-01	1.750897e+03	9.999903e+20	1.998504e+01	1.236330e+08	1.257647e+08	1.025778e-01
23	-1.777024e+03	-5.043761e+04	1.003659e+21	1.988010e+01	9.372087e+07	1.010969e+08	-3.755415e-01	22	-6.794828e+02	-1.703654e+04	9.980189e+20	1.903110e+01	1.180380e+08	1.205807e+08	3.800070e-01	22	-6.794828e+02	-1.703654e+04	9.980189e+20	1.903110e+01	1.180380e+08	1.205807e+08	3.800070e-01	22	-6.794828e+02	-1.703654e+04	9.980189e+20	1.903110e+01	1.180380e+08	1.205807e+08	3.800070e-01
24	1.644731e+02	1.147254e+04	9.971010e+20	1.993910e+01	6.899812e+07	6.293504e+07	1.304312e-01	23	-1.777024e+03	-5.043761e+04	1.003659e+21	1.988010e+01	9.372087e+07	1.010969e+08	-3.755415e-01	23	-1.777024e+03	-5.043761e+04	1.003659e+21	1.988010e+01	9.372087e+07	1.010969e+08	-3.755415e-01	23	-1.777024e+03	-5.043761e+04	1.003659e+21	1.988010e+01	9.372087e+07	1.010969e+08	-3.755415e-01
25	-1.198177e+03	-5.639258e+02	1.000596e+21	1.949802e+01	7.144772e+07	9.490472e+07	2.032746e-01	24	1.644731e+02	1.147254e+04	9.971010e+20	1.993910e+01	6.899812e+07	6.293504e+07	1.304312e-01	24	1.644731e+02	1.147254e+04	9.971010e												



BIT1: Segmentation Fault After Completion

- **Observed crash after simulation ends:**
 - Occurs after all files are written.
 - Likely related to memory deallocation.
- **Does not affect correctness.**
 - Requires future debugging for clean execution.

```
=== Execute gpu version ===  
time mpirun -n 4 ./wrap_nsys.sh ../src_gpu/BIT1 inputs_gpu/DCSM_0_e21_c8.inp  
Max. number of particles per cell per species: 0 2000 1 2000 2 2000  
[as03r5b31:3535221:0:3535221] Caught signal 11 (Segmentation fault: address not mapped to object at address 0x42058058)  
Generating '/scratch/tmp/31995526/nsys-report-9ded.qdstrm'
```





BIT1: Conclusion

- **The main objective of porting BIT1 to GPUs using OpenACC was achieved**, with a maintainable and readable codebase preserved and GPU execution successfully demonstrated on a test case.
- **Next steps:**
 - **Fix finalization segmentation fault.**
 - **Extend GPU port with OpenACC:**
 - Continue adding OpenACC directives to the remaining code paths → decide new test cases.
 - Improve host-device data management:
 - Use manual control of data regions instead auto-managed memory.
 - Overlap communication and computation where possible.
 - **Perform a deep GPU redesign**



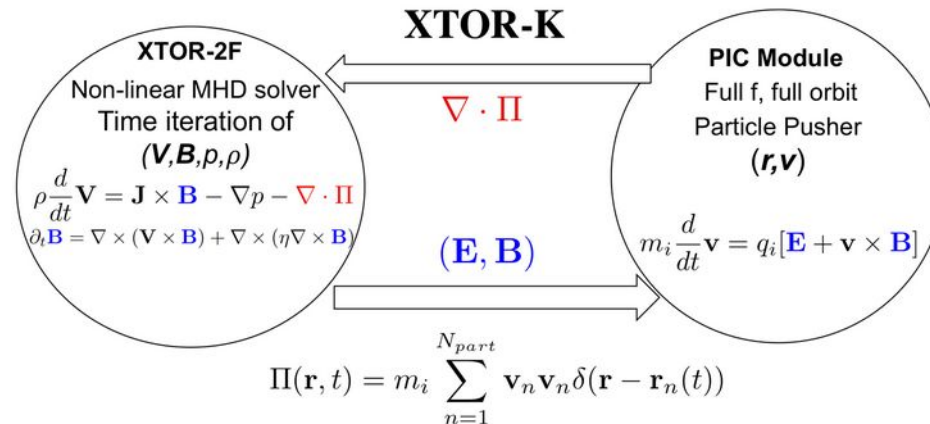
XTOR-K

Eduardo Cabrera



XTOR-K: Introduction

- XTOR-K is a fully implicit, HPC-oriented hybrid fluid-kinetic model that incorporates a Particle-in-Cell (PIC) Boris-Buneman particle pusher applied to one or more populations of kinetic ions. This enables the simulation of couplings between the Alfvénic spectrum and ion kinetic effects.
- It couples in a self-consistent manner the time advance of a complete set of bi-fluid equations in full tokamak geometry (thermalized plasma electron and ions background) with a 6D PIC method accurately integrating the trajectories of selected ion populations, making accessible new families of instabilities which are not allowed in a simplified framework such as magnetohydrodynamics.



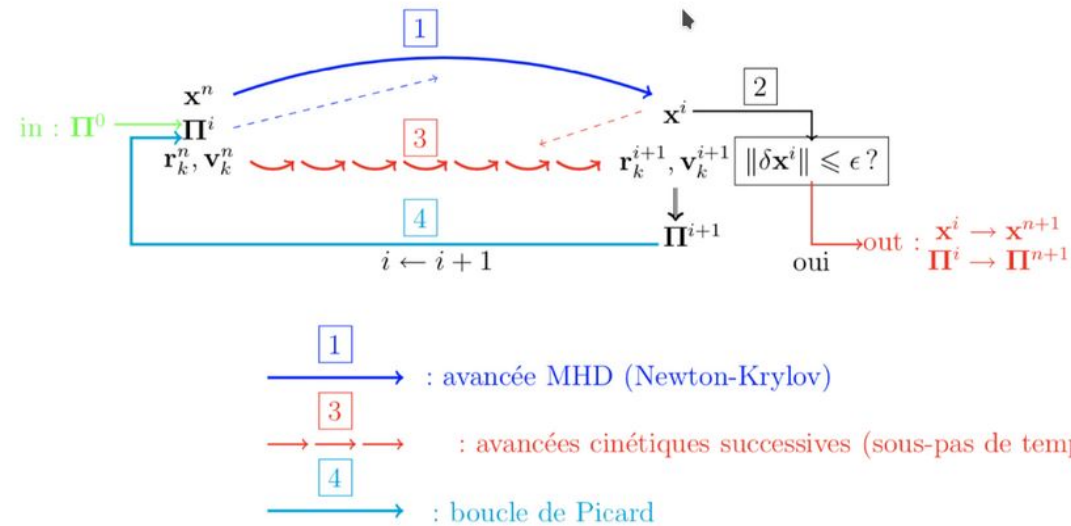
Hinrich Lütjens

- It is implemented in Fortran2008, parallelised with MPI and OpenMP already.



XTOR-K: Project Goal

- **Motivation:**
 - The kinetic component dominates the overall computational cost.
 - It relies on a PIC time-advance scheme.
- **Goal: Porting the kinetic components to GPU**
 - Reduce time spent in kinetic routines → Improve overall scaling.
 - Significantly increase the number of markers per simulation → Reduce the numerical noise inherent to the PIC method.





XTOR-K: Profiling & Bottlenecks

- **Profiling tool:**
 - Application Performance Snapshot (APS) from Intel VTune.
 - Runs performed on MareNostrum 5 (H100 GPUs, NDR InfiniBand)
- **Profiling results:**
 - Slightly low vectorization → addressed using appropriate compiler flags
 - Main hotspots identified:
 - interpolate_eb_fields (most time-consuming routine).
 - moveRZ (calls interpolate_eb_fields multiple times).
 - OpenMP barrier synchronization overhead.
- **Conclusion:**
 - GPU porting targets these bottlenecks.



XTOR-K: CPU code

- **Ensuring a stable bug-free CPU version**
- **Identified and fixed issues when compiling with newer Intel compiler version**
 - PETSc type mismatches (e.g. ierr must be PetscErrorCode, not PetscInt).
 - Incorrect use of REAL for array indices → Replaced with proper INTEGER indices.
 - Division-by-zero errors when accessing ghost-point indices at domain boundaries.
 - Makefile compilation order issues → Reordered modules so dependencies are compiled first.
 - Mismatch between routine definitions and their implementations (argument list).
- **Outcome**
 - Stable and validated hybrid MPI/OpenMP CPU version ready.



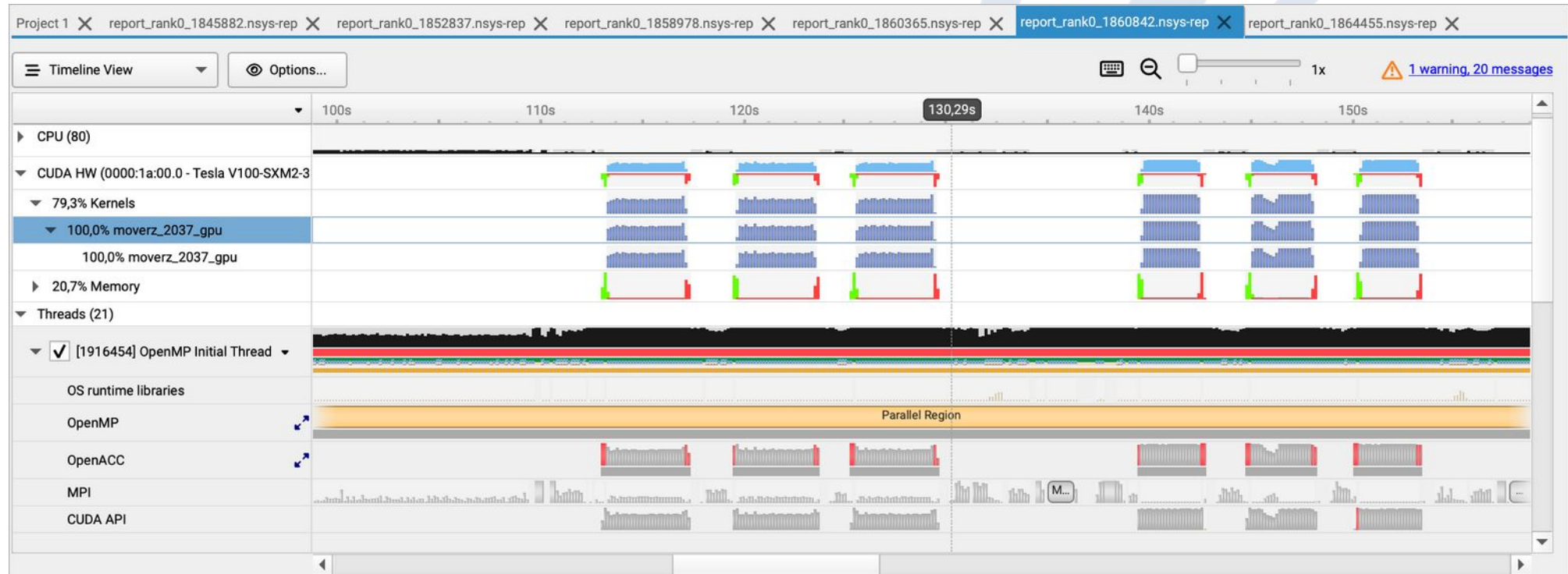
XTOR-K: GPU Porting

- **Initial Approach:**
 - Tested OpenMP offloading option → more than 3x slower than CPU.
- **Final Approach**
 - Adoption of OpenACC.
 - Porting of 6 kinetic subroutines: particlepositioninfo, interpolate_eb_fields, particleshaperz, depositmoments, inirun and **moveRZ**.
 - **Issue:** Loops often too small (≤ 64 iterations) for efficient GPU parallelism.
 - **Revised Strategy:**
 - Parallelize only the outermost loop in moveRZ (# particles).
 - Execute the routines it calls serially on the GPU.
 - Transfer all required data (CPU -> GPU) prior to executing moveRZ routine.
- **Work completed:**
 - Full moveRZ routine successfully ported to GPU.
 - Additional routines (fullebeparmappingrz and fullparticleadvance) from non-kinetic part were ported.
 - Data transfer between CPU and GPU streamlined.
 - Redundant MPI barrier calls removed.



XTOR-K: Performance Results

- The GPU version outperforms the CPU version.
- Achieved simulations with up to 100 million particles per GPU → Not feasible on CPU nodes.
- GPU porting now enables large-scale simulations that were not feasible on CPU-only systems.





XTOR-K: Future work

- **Ongoing Work:**
 - Porting projectedmomentsmappingrtheta subroutine using cuFFT and cuBLAS.
 - **Issues:** ~30 missed deallocations detected with compute-sanitizer tool.
 - **Critical issue:**
 - Argument-passing inconsistency: 3D array passed as 4D.
 - Fortran requires exact matching of array dimensions.
 - This inconsistency currently blocks completion of the GPU port.
- **Next steps:**
 - Clarification has been requested from developers regarding whether this array mismatch is intentional to evaluate alternatives.
 - Complete GPU port of the remaining routines.
 - Further optimization needed for data transfers.



Thanks for your attention !