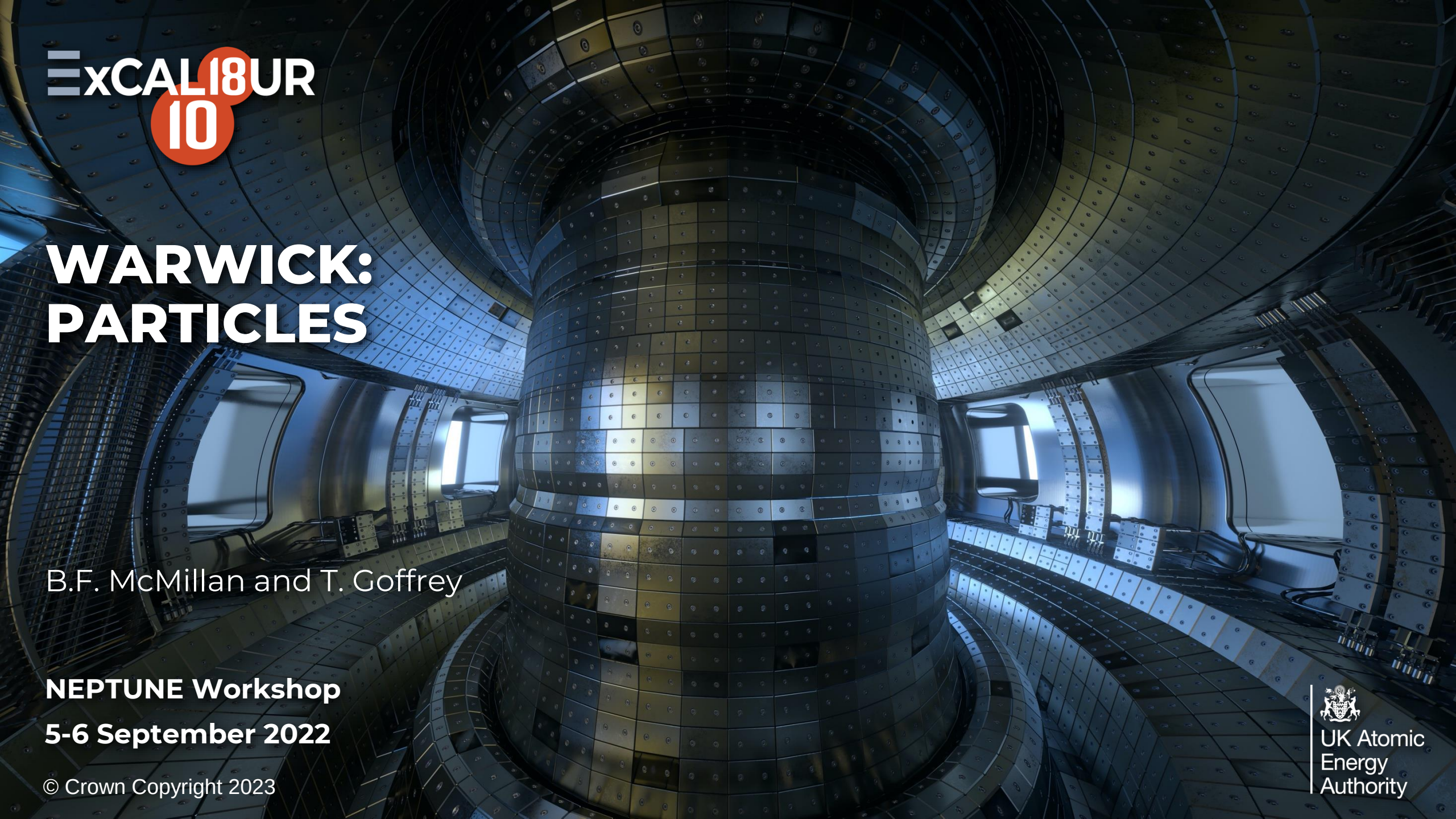


WARWICK: PARTICLES

B.F. McMillan and T. Goffrey

NEPTUNE Workshop

5-6 September 2022

UK Atomic Energy Authority

Low Noise PIC

Moment Based Scheme

- Density distribution f(**Z**) where **Z** is a physical space + velocity space

$$\frac{\partial f}{\partial t} + \nabla_{\mathbf{Z}} . \left[\dot{\mathbf{Z}} f \right] = S(f)$$

- Non-Maxwellian over velocity space – kinetic description.
- Write f as a Maxwellian plus a correction (g)

$$f(\mathbf{Z}, t) = f_0(\mathbf{Z}, t) + g(\mathbf{Z}, t)$$

- Integrate first equation to get equations for first 3 moments: density, momentum and energy.

$$\frac{\partial n}{\partial t} + \nabla . [n\mathbf{v}] = \int d\mathbf{v} S,$$

$$\frac{\partial nv}{\partial t} + \nabla . [n\mathbf{v}^2 + 3nkT] - \mathbf{F} = \int d\mathbf{v} v S,$$

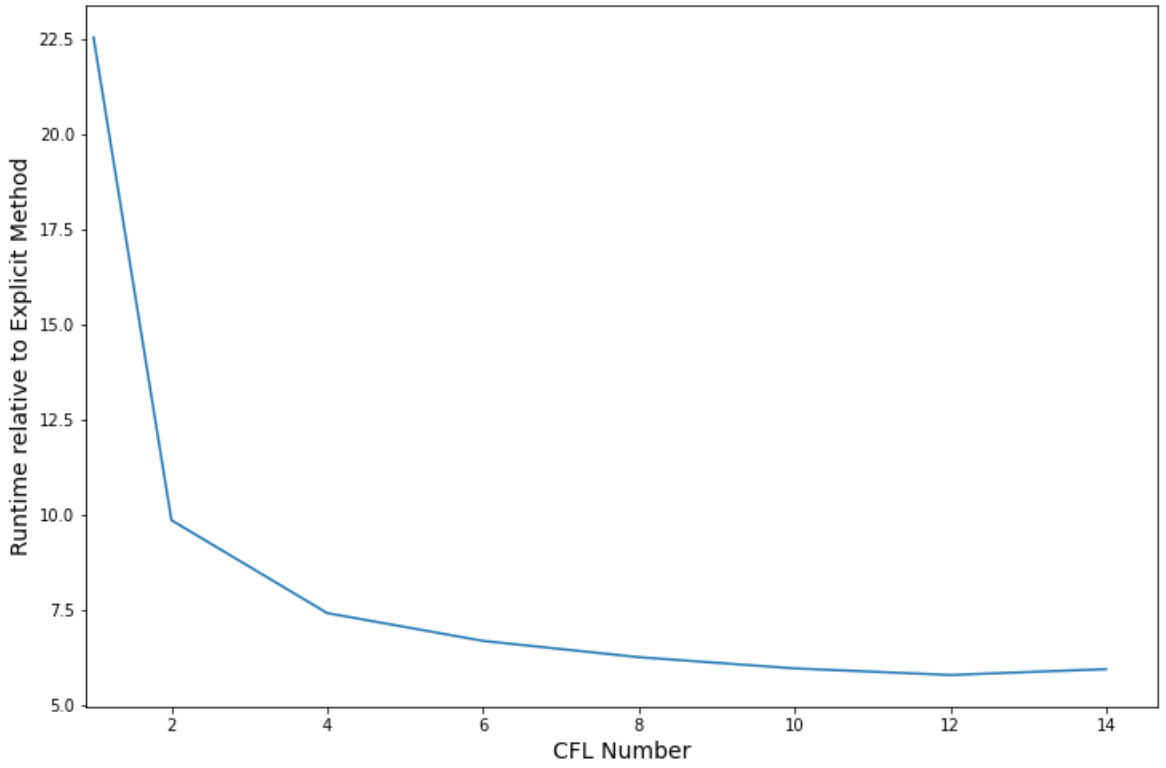
$$\frac{\partial [3nkT + nv_0^2]}{\partial t} + \nabla . \left[\mathbf{v_0} \{3nkT + nv_0^2\} + \int dV (\mathbf{v} - \mathbf{v_0})(v - v_0)^2 g \right] - \mathbf{F} . \mathbf{v_0} = \int d\mathbf{v} v^2 S.$$

ProxyApp

minepoch

- Proxyapp for performance testing.
- Maxwell's equations
- Eulerian mesh (staggered Yee), coupled to Lagrangian particles
- Extensions to allow drift-kinetic particles
- Implicit time stepping (to conserve energy)
    1. Crank-Nicolson method
    2. Jacobian-free Newton-Krylov
    3. Particle Enslavement
    4. Investigations into conserving charge (Gauss Law)
    5. Investigations into sub-stepping
    6. Decreasing time to solution with larger CFL number
    7. Still slower than explicit (5.8x slower at CFL=12)

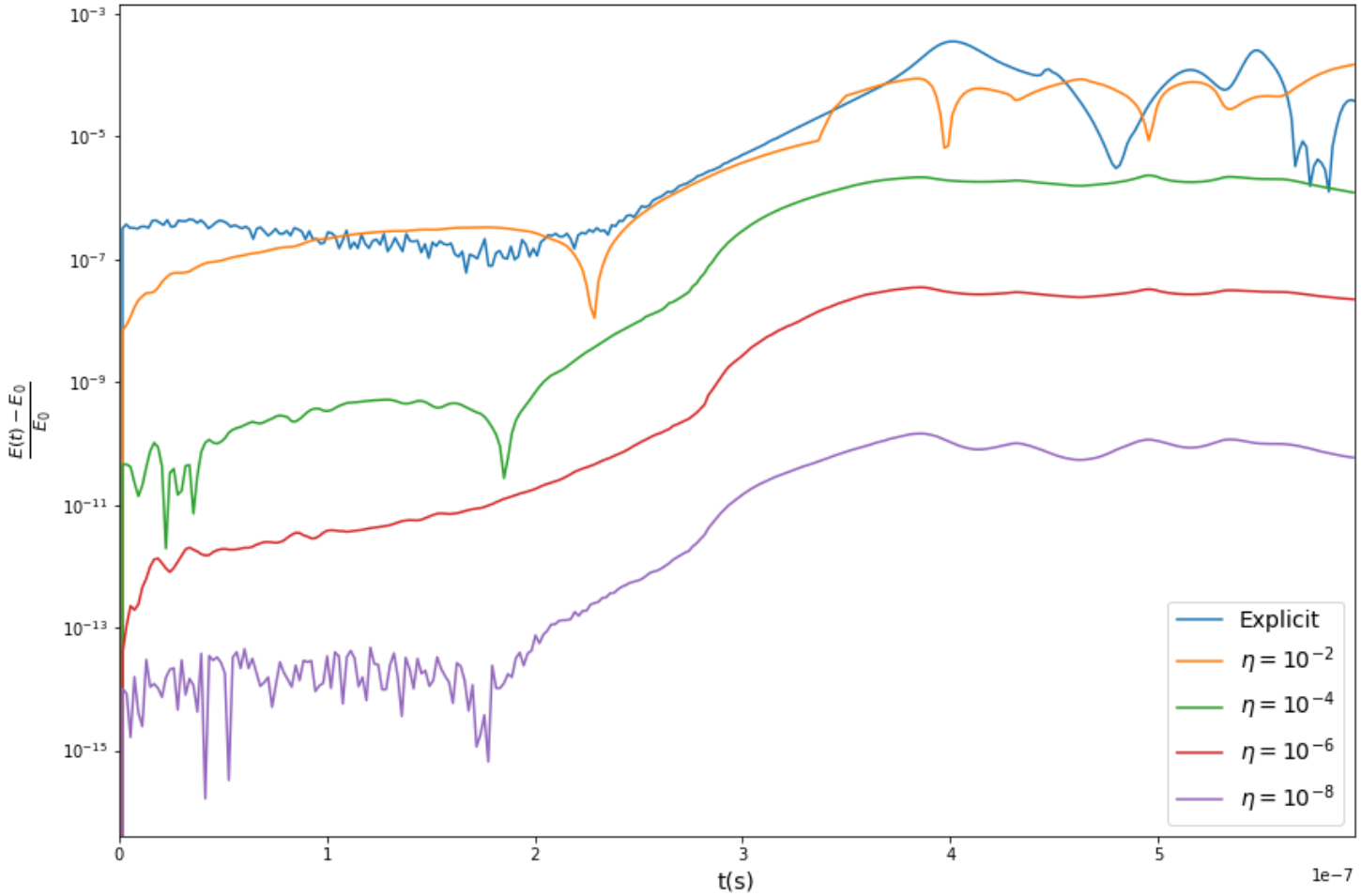
Runtime against CFL number – two stream instability



Minepoch

Energy Conservation (Two-Stream Instability)

Energy conservation error for various non-linear tolerances



Summary

- Low-noise moment based method
- Implicit timestepping
- Proxyapp "minepoch" [1]

[1] https://github.com/ExCALIBUR-NEPTUNE/minepoch

The End