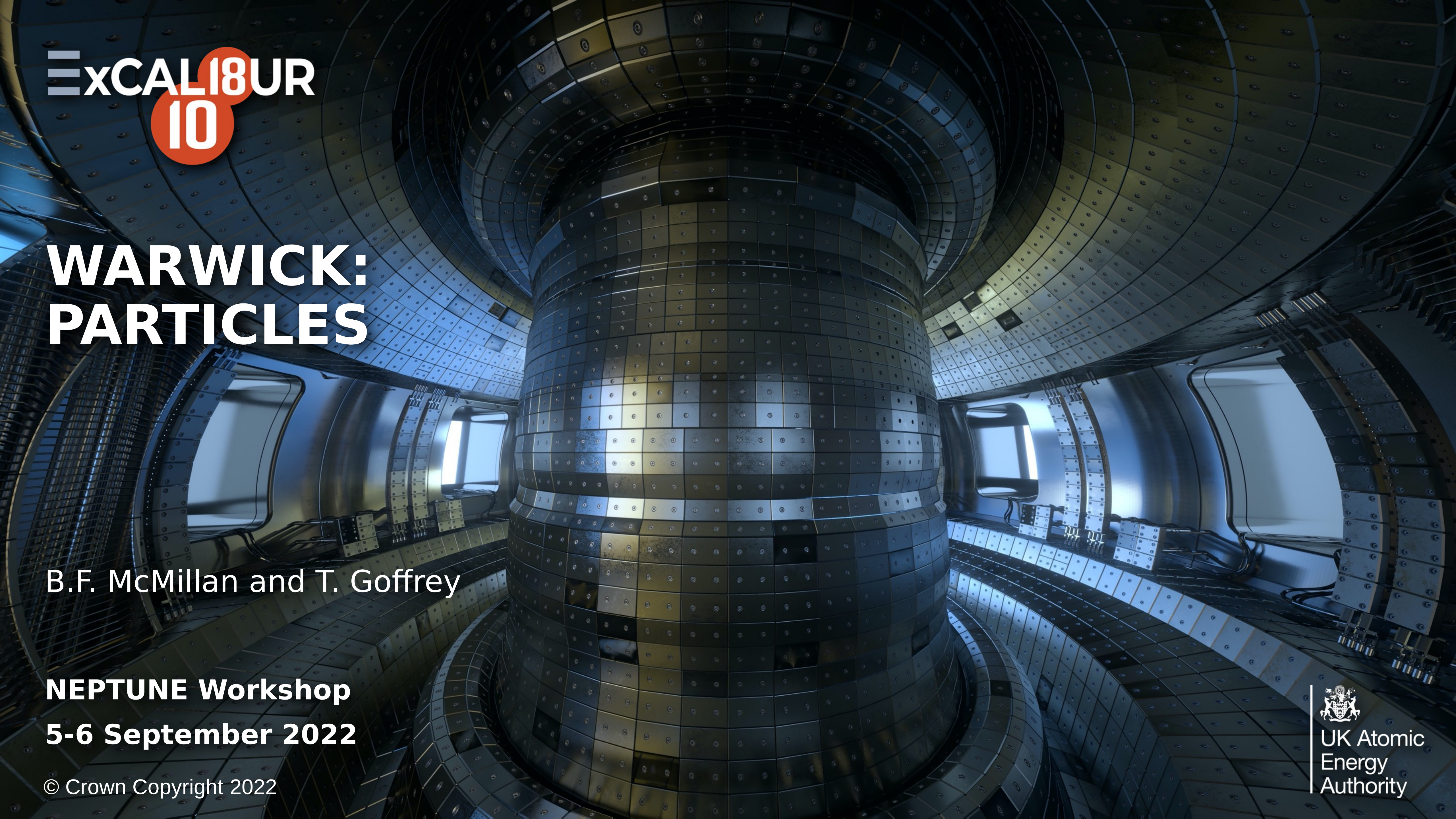


# WARWICK: PARTICLES

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.

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

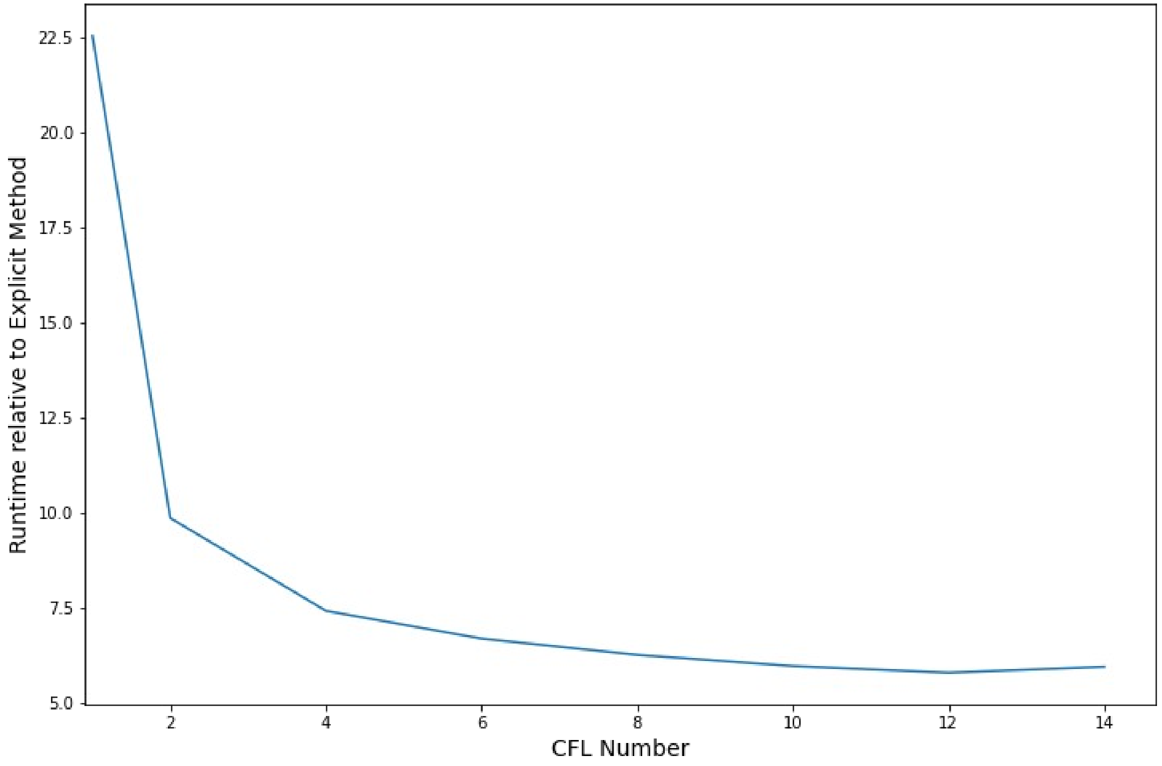
$$\frac{\partial nv}{\partial t} + \nabla.[n\mathbf{v}^2 + 3nkT] - \mathbf{F} = \int d\mathbf{v} v S,$$

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

# 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)

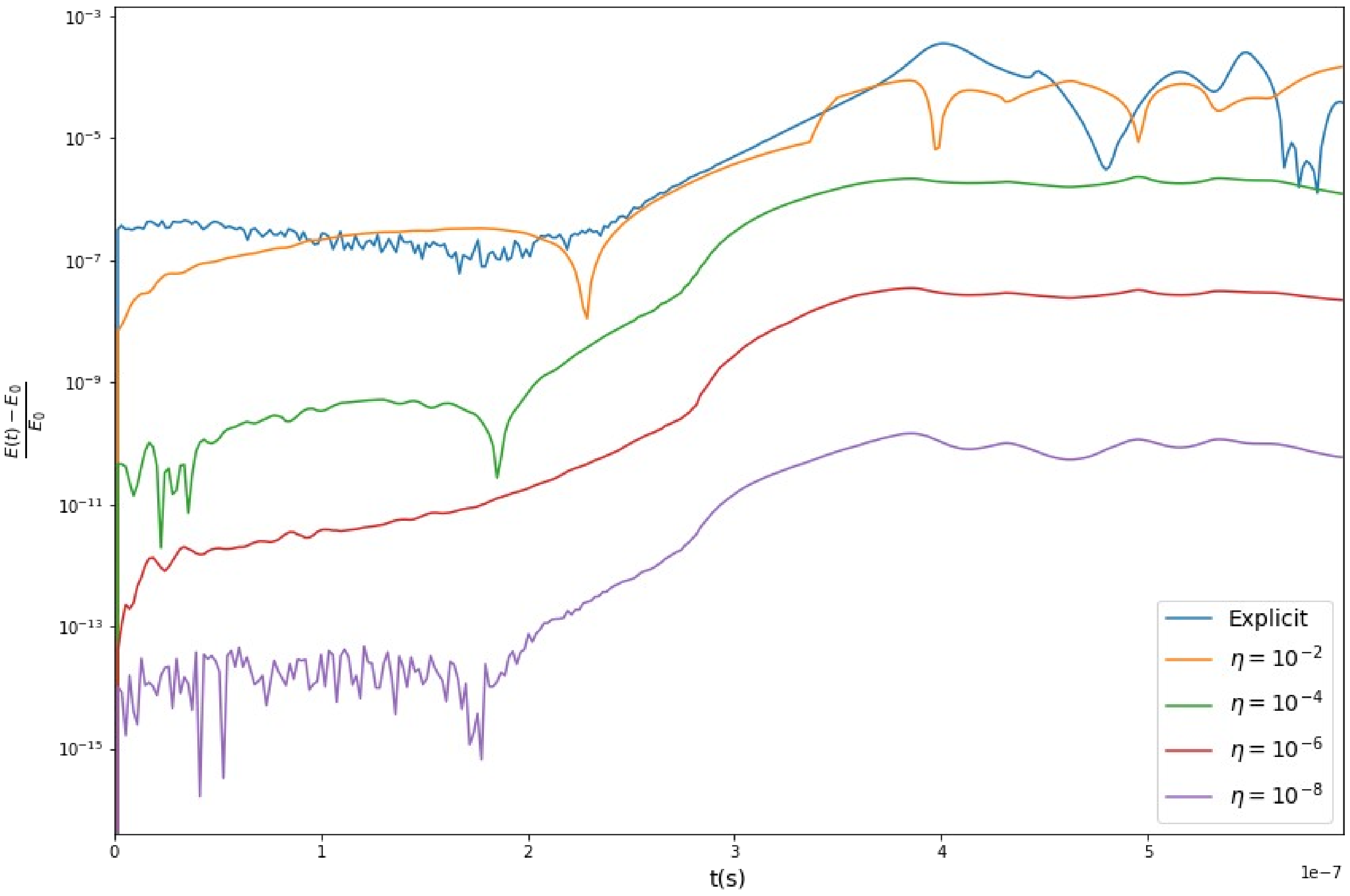
Runtime against CFL number – two stream instability



# 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