Introduction
Progress and Impact

Brussels

30 March 2011

Delegation

- Pär Strand, Chalmers, Sweden, Coordinator
- David Coster, IPP, Germany, Deputy
- Adrian Jackson, UEDIN, United Kingdom, NA2, JRA2, SA2, SA3
- Miguel Cardenas, CIEMAT, Spain, NA3
- Marcus Hardt, KIT, Germany, SA1
- Francisco Castejon, CIEMAT,
- Marcin Plociennik, PSNC, Poland, JRA3, SA3
- Bernard Guillerminet, CEA, France, JRA3
- Olivier Hoenen, UDS, France, JRA4
- David Tskhakaya, University of Innsbruck, Austria, User
- Antonio Gomez, CIEMAT, Spain, user
- Christian Konz, IPP, Germany, user

Thanks

- Chalmers University of Technology (Coordinator) from Sweden
- Max Plank Institute for Plasma Physics (IPP) from Germany
- Centro Superior de Investigaciones Científicas (CSIC) from Spain
- Centro de Investigaciones Energéticas, Medio Ambientales y Tecnológicas (CIEMAT) from Spain
- Forschungszentrum Karlsruhe (FZK) from Germany
- Finnish IT Center for Science (CSC) from Finland
- Abo Akademi University (ABO) from Finland
- University of Edinburgh (UEDIN) from United Kingdom
- Barcelona Supercomputing Center (BSC) from Spain
- French Atomic Energy Commission (CEA) from France
- University of Strasbourg from France
- University of Ljubljana (UOL) from Slovenia

Poznan Supercomputing and Networking Center PSNC from Poland

Italian National Agency for New Technologies, Energy and the Environment (ENEA) from Italy

EUFORIA FP7-INFRASTRUCTURES-2007-1 Grant 211804

EUFORIA

14 member Institutes

522pms covering

- **Management (NA1)**
- **Training (NA2)**
- **Dissemination (NA3)**
- **Grid and HPC infra-structure & support (SA1, SA2, SA3)**
- **Code adaptation & Optimization (grid-JRA1, HPC-JRA2)**
- **Workflows (JRA3)**
- **Visualization (JRA4)**

Supporting fusion users

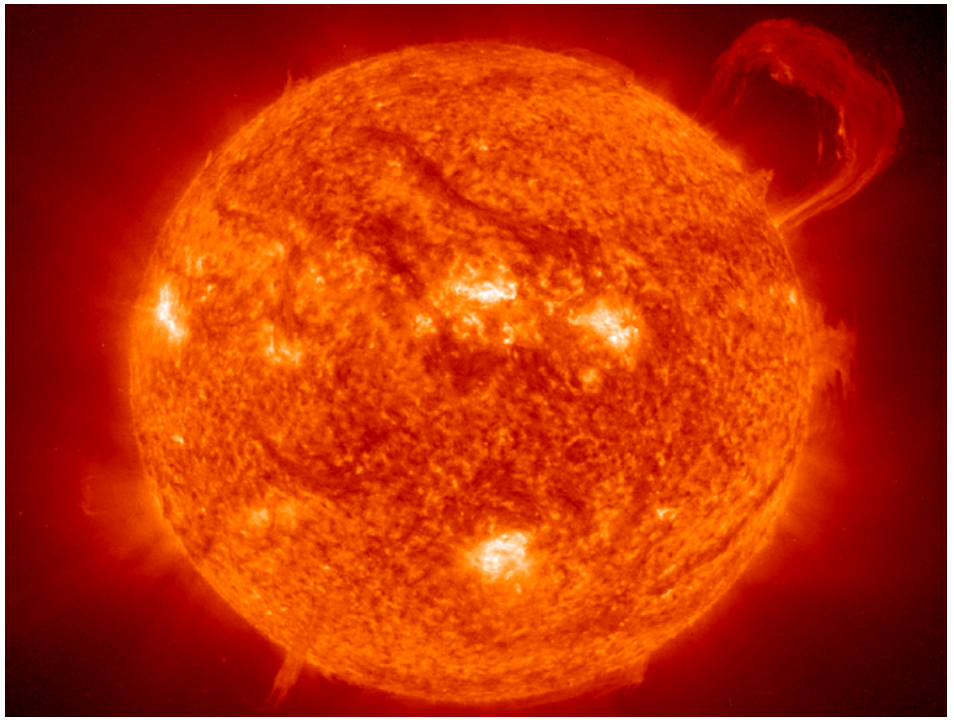
- Providing infrastructure
  - Grid (parallel and serial) and HPC infrastructures and support
    - EUFORIA Grid infrastructure
    - HPC infrastructure available for application development and proof of principle runs (BSC, CSC, .EPCC)
- Provide Application porting for select codes to both Grid and HPC
  - EFDA proposal: Focus on Edge and Core Turbulence and Transport
- Provide Training
  - Use of and adaptation for grid and HPC technologies
  - Direct Code adaptation for select codes and tools
  - Help to “self-help”. EUFORIA has provided much of the training to the fusion community. (Target communities: ITM-TF and GOTiT)
- Provide extended toolkits for existing infrastructure
  - Visualization , Workflow extensions Middleware developments

EU Fusion for ITER Applications - EUFORIA

A few words on Fusion and ITER

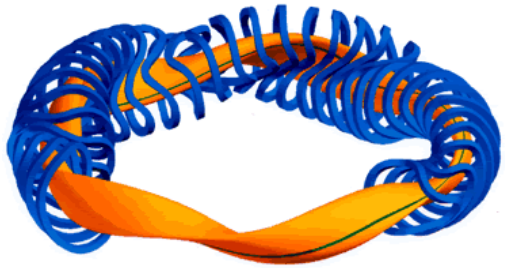
Fusion

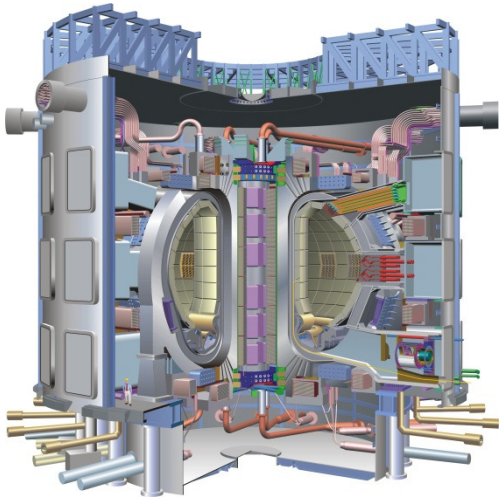
- Energy source for the sun and other stars
- Provides a potential source of base load energy production
- Been working on this for more than 50 years
- Has turned out to be a very difficult problem



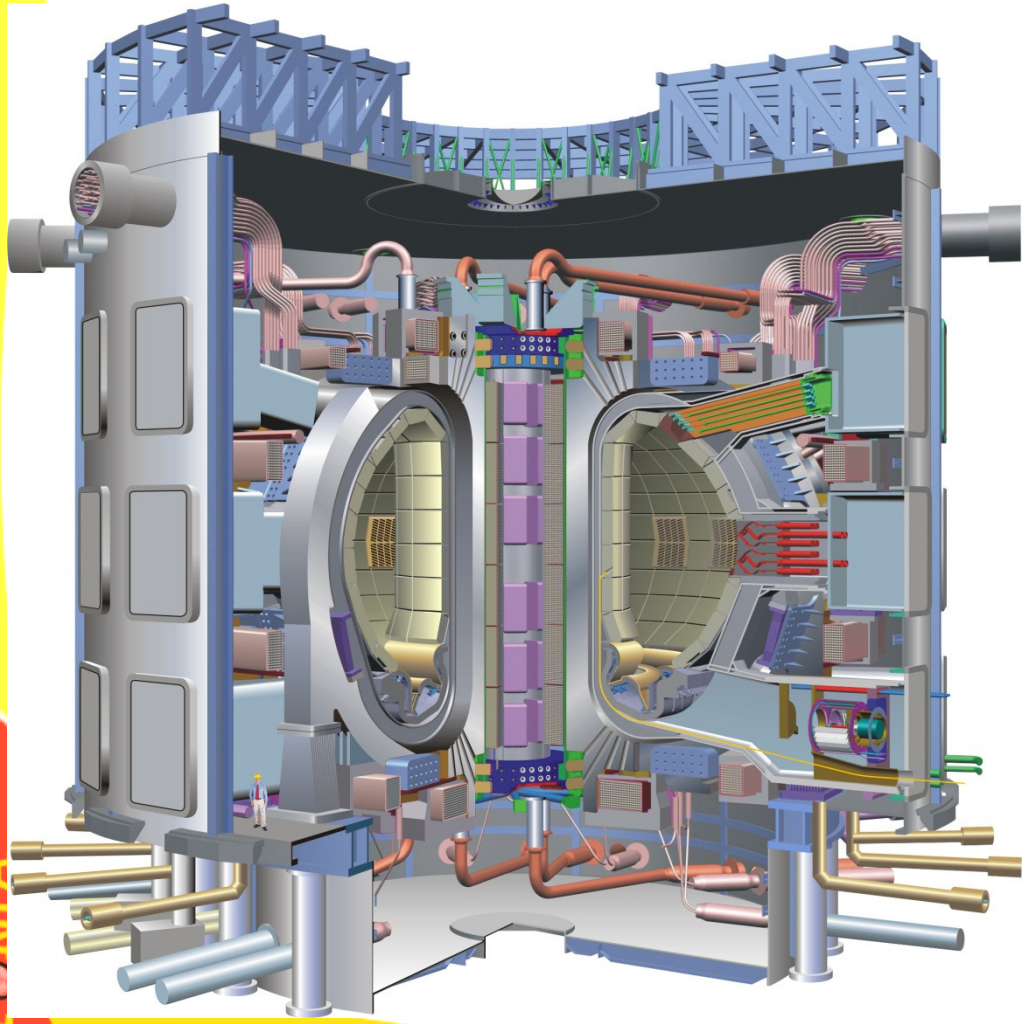
Fusion

- Two main lines of research
  - Inertial confinement
    - Implosion of small pellets
    - NIF at LLNL
  - Magnetic confinement
    - Two main lines of research at the moment
      - Stellarator – W7X
        - » Currently under construction in Greifswald in Germany
      - Tokamak – ITER
        - » To be constructed in Cadarache in France



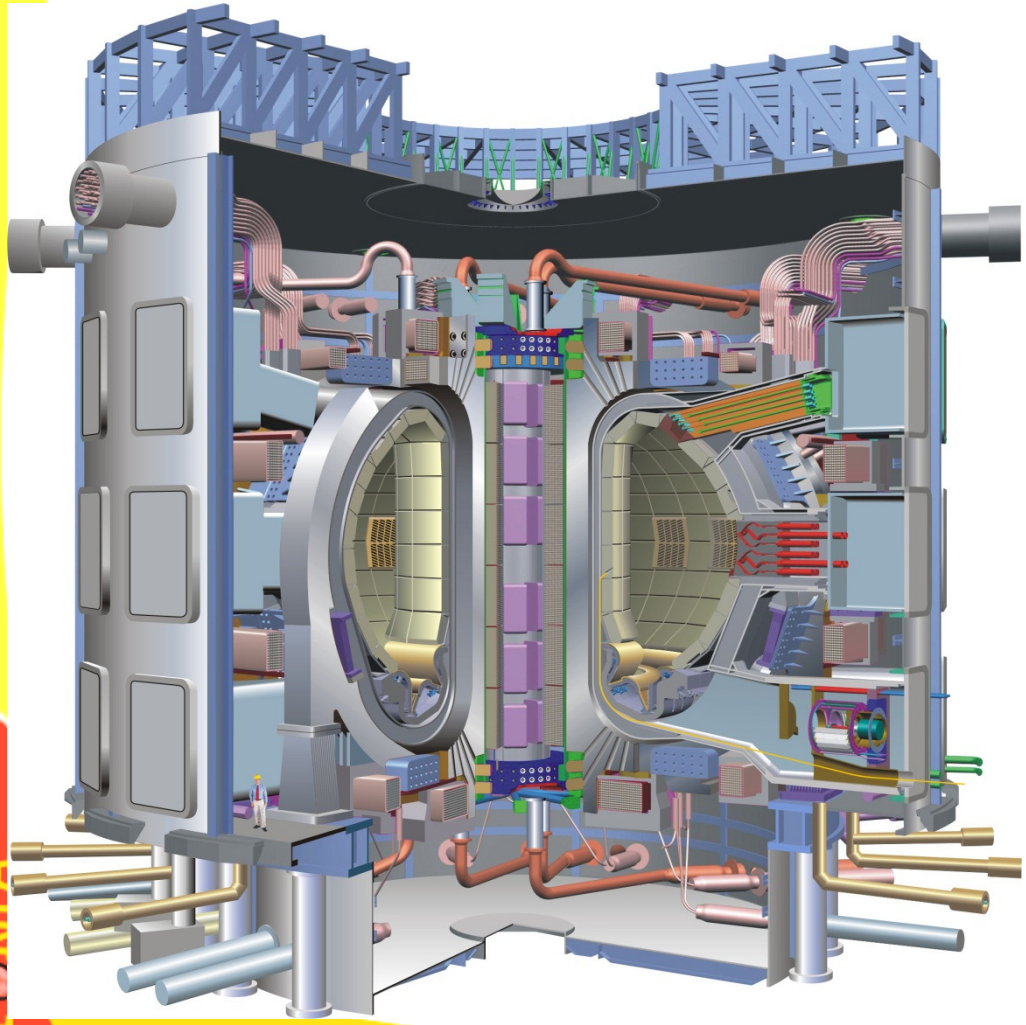


ITER



Involves 7 partners representing more than 50% world population
Costs > 10 G$
Under construction in Cadarache, France
Key element on the path to fusion energy production

ITER



		Units
Plasma Major Radius	6.2	m
Plasma Minor Radius	2.0	m
Plasma Volume	840	m3
Plasma Current	15.0	MA
Toroidal Field on Axis	5.3	T
Fusion Power	500	MW
Burn Flat Top	>400	s
Power Amplification	>10	

Motivation – Background for EUFORIA

Impact through modelling

- Safe and optimal ITER operation will rely on a high degree on physics modelling and simulation
  - Not funded directly by ITER - modelling capacity derived from partner programmes (EU, US, JP, CHINA, RU, INDIA, S. Korea)
  - ITER modelling very challenging from computational point of view
- EUFORIA physics focus (Edge and core transport and turbulence modelling) critical component for ITER – hence the choice

Competitiveness

- ITER Experimental time allocated through competitive proposals
  - Modelling integral and essential component in proposal process!
  - Pan-European structure needed to compete with national programme structures in US and JP in particular

ITER shorter term needs (during construction)

- Physics design studies – modelling of critical design issues
- Modelling for diagnostics development
- Physics Scenario assessments

We will demonstrate:

- Significant progress:
  - In technical achievements (RTD)
    - Code Porting, optimization and workflow developments including visualization
  - In providing a robust infrastructure for end users
    - HPC access is significant and beyond DoW planning
    - Grid access is robustly implemented and transparently available
  - In establishing EUFORIA as a vehicle for promoting science & technology
    - An increasing number of presentations and publications in conferences and peer-reviewed journals
    - Impact on ITER infrastructure planning

We will demonstrate (cont'd):

- Significant progress:
  - In establishing EUFORIA's impact in and on the fusion and Computer Science community
    - On the agenda and (directly or indirectly) advising ITER, EFDA and other entities.
    - Extending collaboration to US projects (outside of DoW)
  - In supporting and training the fusion Theory and modelling community
    - EUFORIA and GOTiT together with the collaborative umbrella of ITM-TF is the major provider in the fusion community.

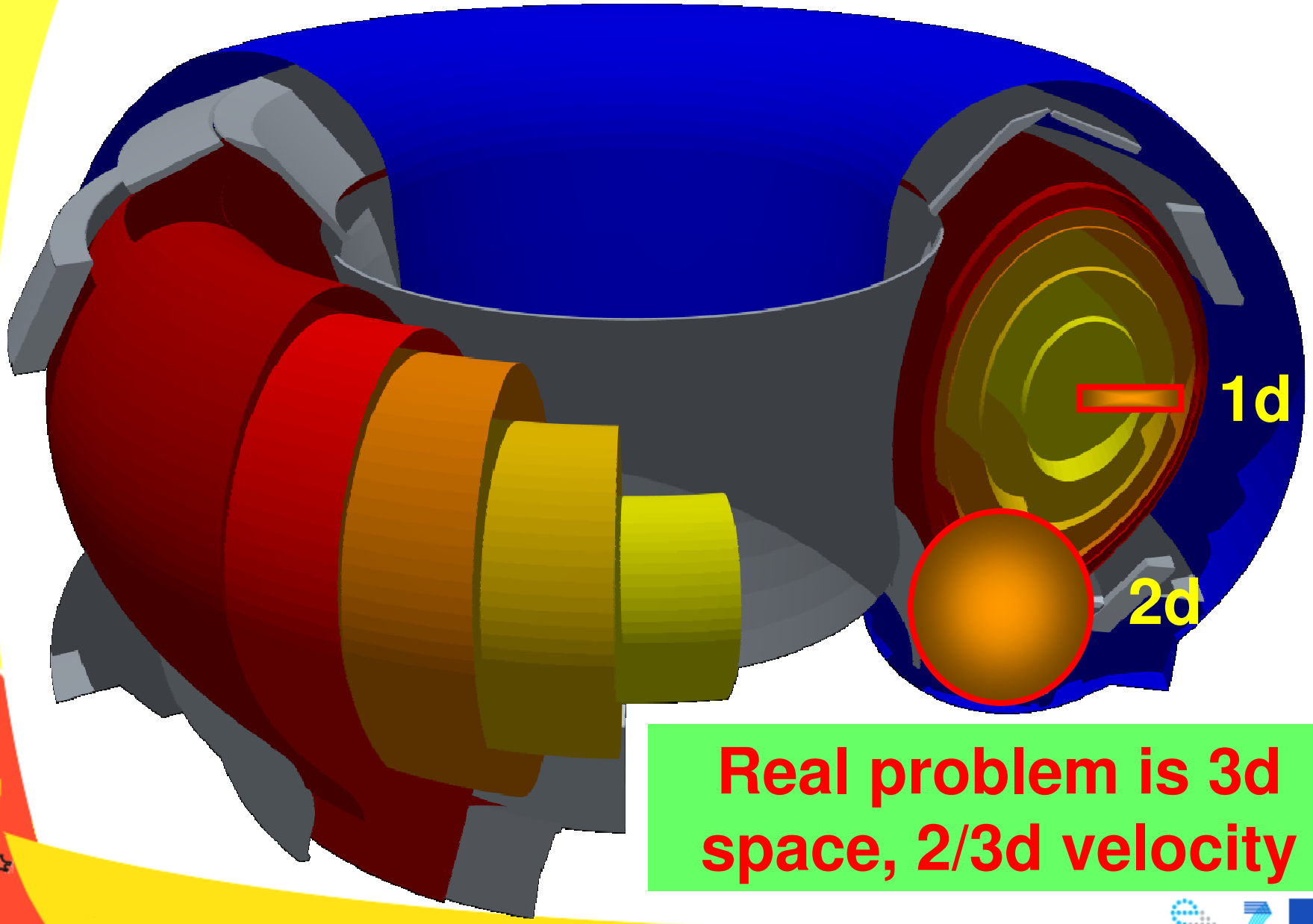
Meeting general objectives

- ✓ Active use of a EUFORIA compliant grid service – supported by NGI's
- ✓ Active use of a EUFORIA compliant HPC infrastructure - supported by DEISA/PRACE/HPC-FF/IFERC
- ✓ Easy Access for general user - Migrating desktop, Kepler, community portals and support
- ✓ Adaptation of a standard ontology for edge-core simulations - well underway with edge code providers - Need to promote the ontology on the global scale with full range of physics
- ✓ Empowered users with a range of high quality codes and fusion simulation tools targeting
  - Serial grid applications
  - Parallel grid applications
  - High Performance Computing
  - A standard for code coupling and structured interfaces
- ✓ An advanced framework or code platform tool with
  - Dynamic workflow orchestration - Kepler
  - High quality Visualization - Python, Matplotlib, Visit and actors
  - Data mining capabilities - python, workflow tools
  - Direct links to experiments and simulation databases

EU Fusion for ITER Applications - EUFORIA

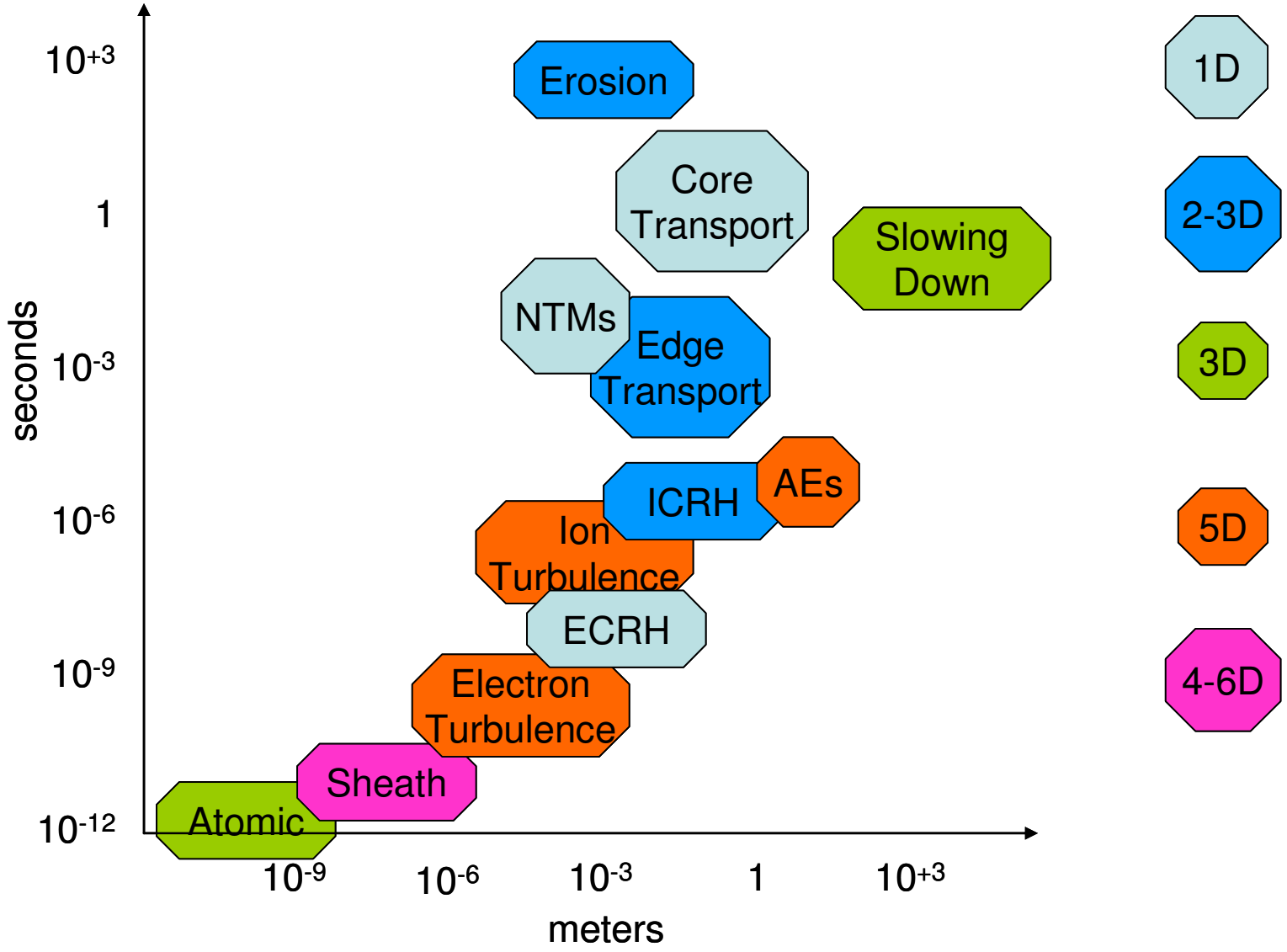
A few words on Fusion Applications

Simulations



Real problem is 3d space, 2/3d velocity

Models describing the plasma vary in complexity



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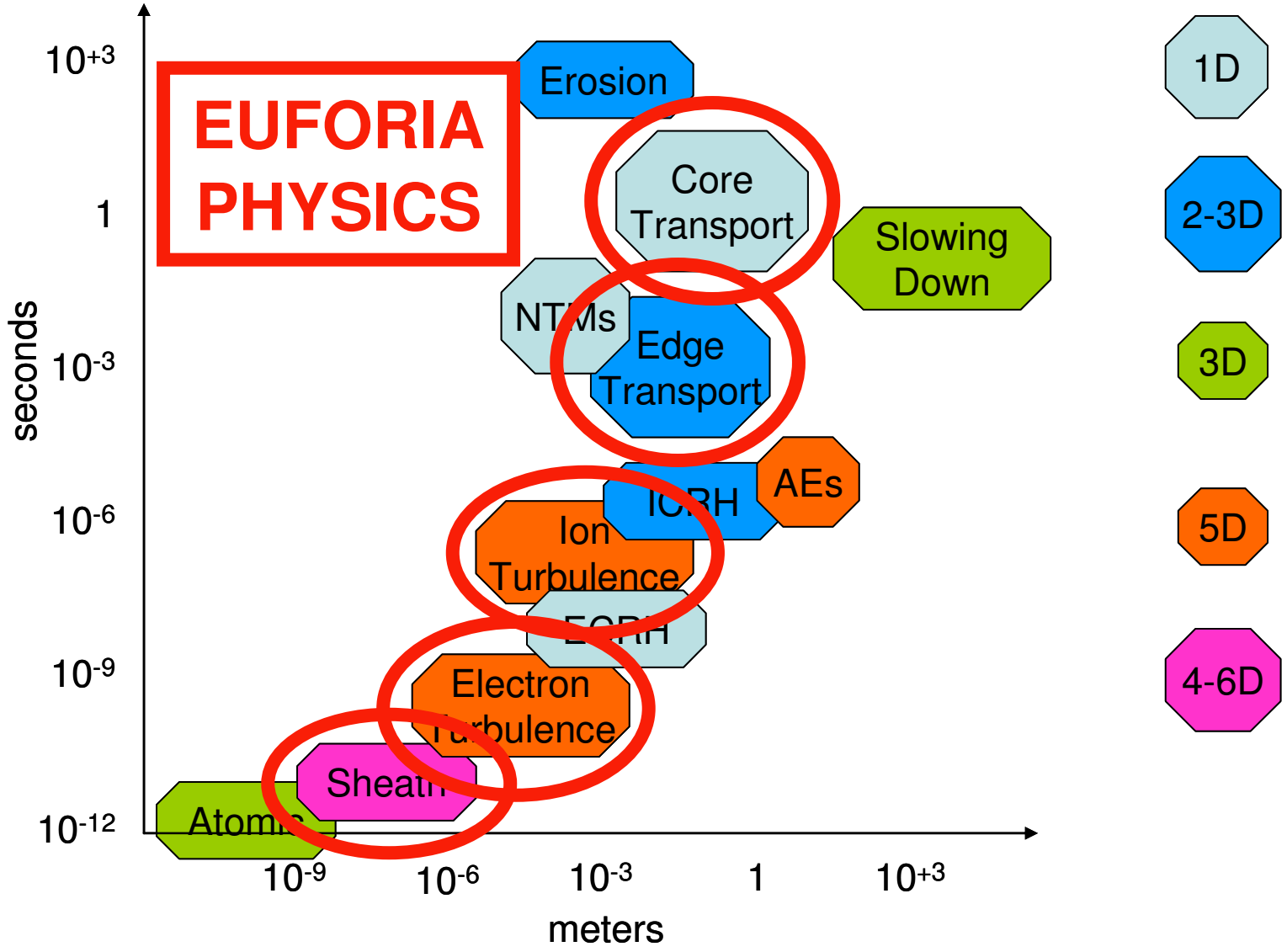

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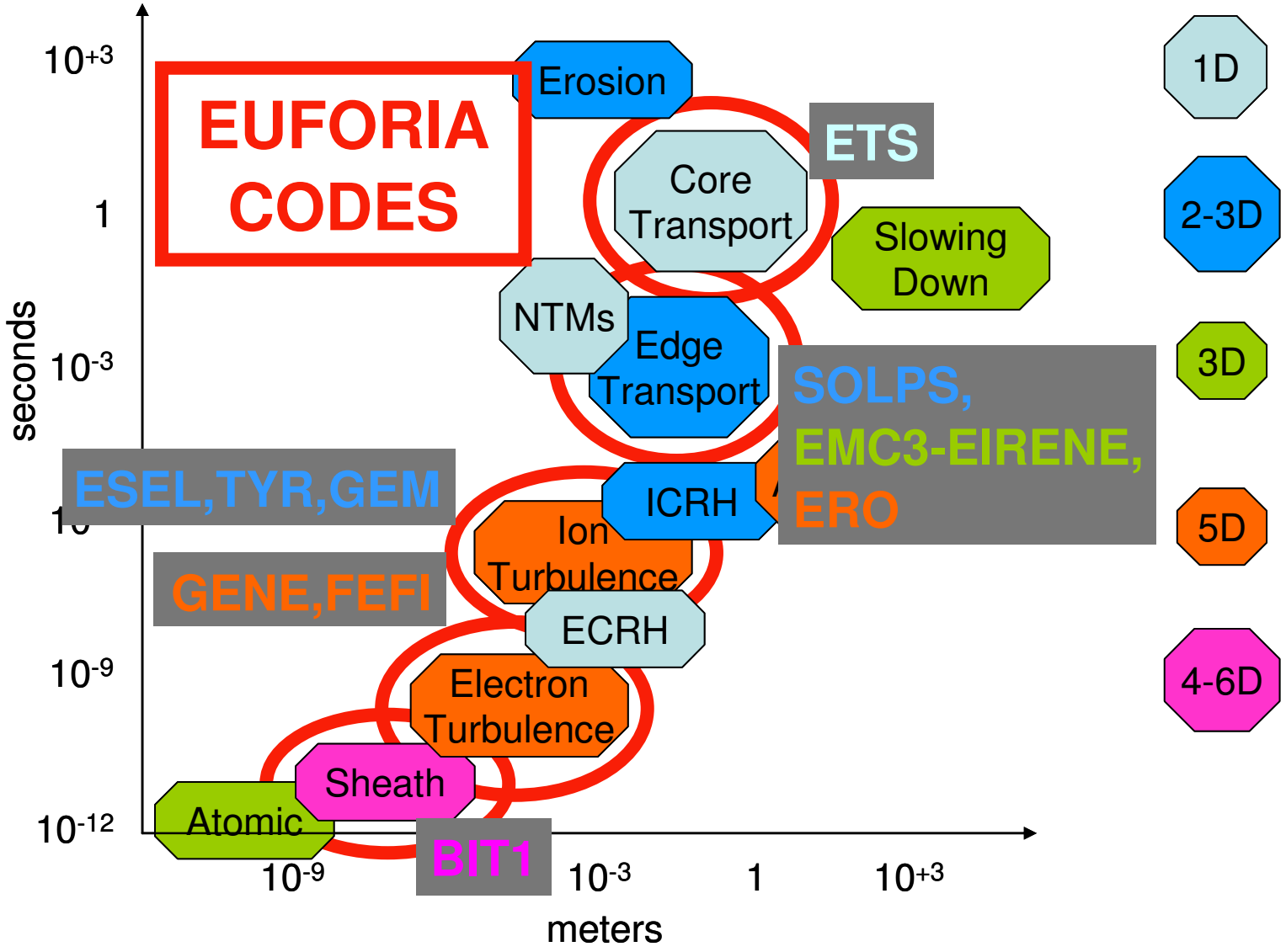
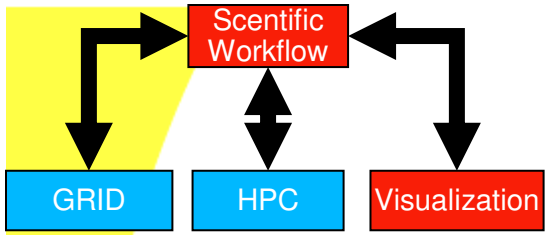
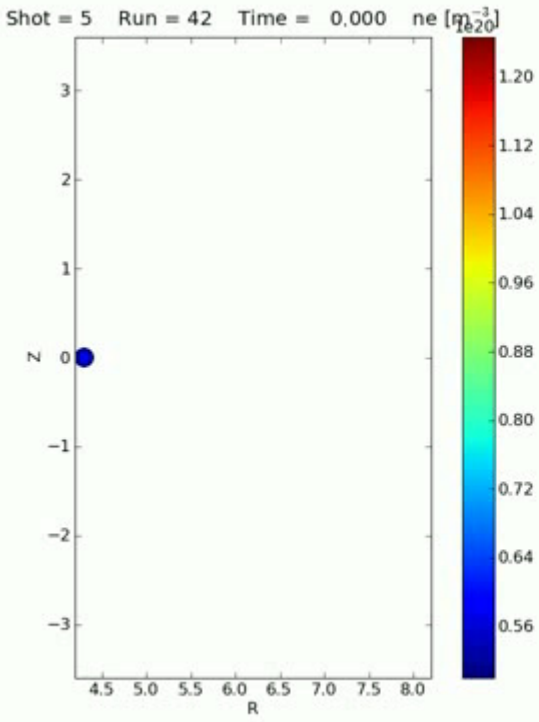
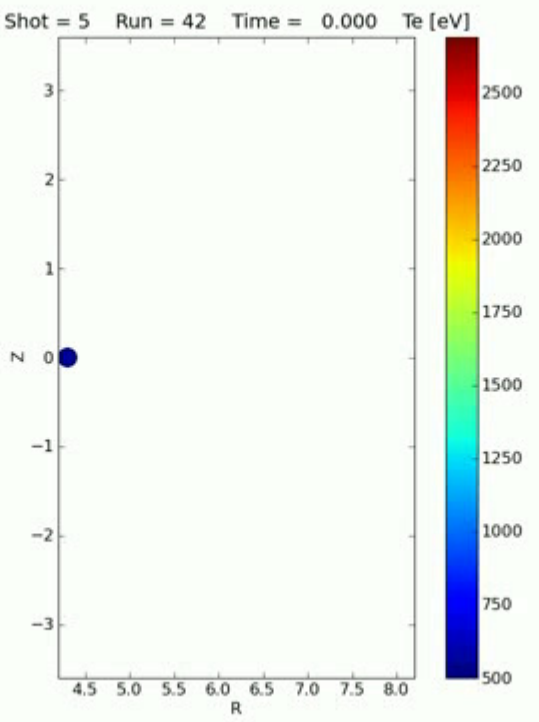


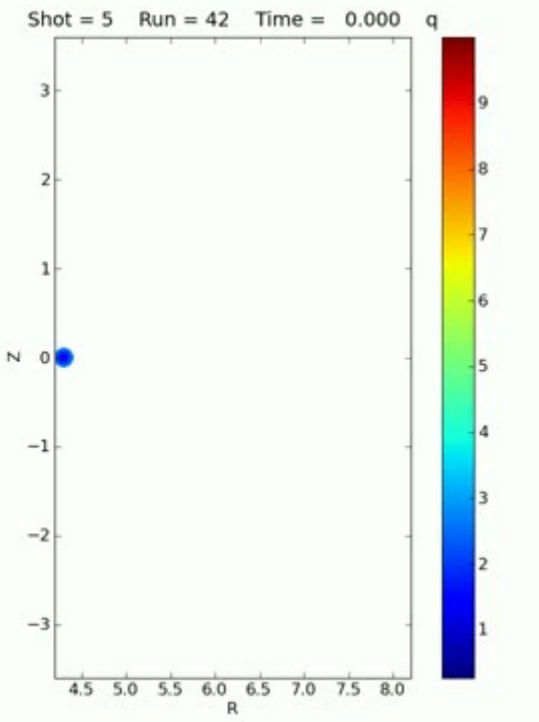


Experimental version of the ETS

n_e T_e q







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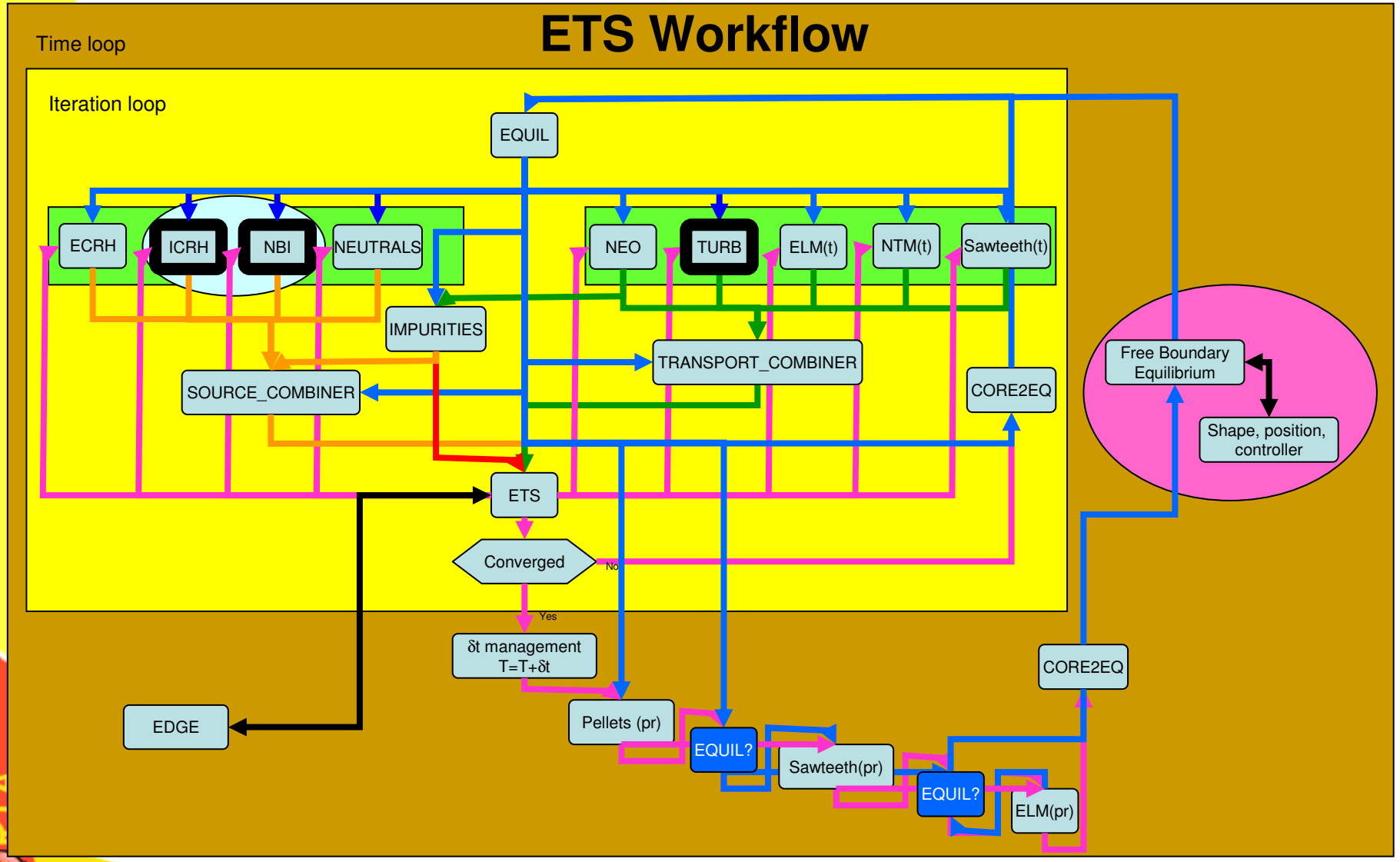
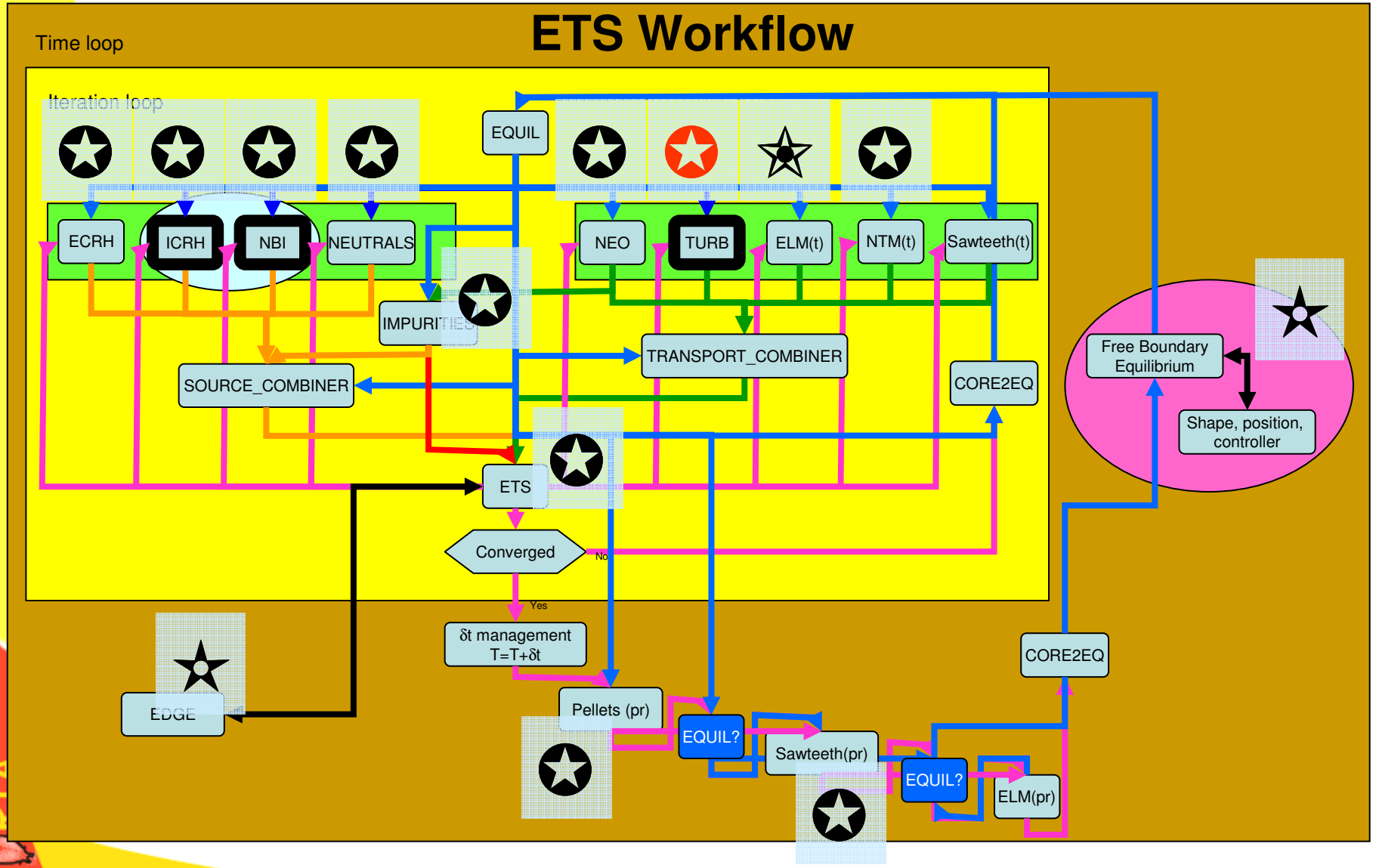

ETS Workflow
Time loop
Iteration loop
EQUIL
ECRH
ICRH
NBI
NEUTRALS
NEO
TURB
ELM(t)
NTM(t)
Sawteeth(t)
IMPURITIES
TRANSPORT_COMBINER
SOURCE_COMBINER
CORE2EQ
Free Boundary Equilibrium
Shape, position, controller
ETS
Converged
No
Yes
δt management T=T+δt
EDGE
Pellets (pr)
EQUIL?
Sawteeth(pr)
EQUIL?
ELM(pr)
CORE2EQ

ETS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Sustainability

- JRA1:
  - Euforia VO → fusion VO
  - increasing number of codes running on the GRID
  - expertise of users, uptake in EFDA ITM-TF
- JRA2:
  - improved codes and knowledge transfer
  - HLST under EFDA
- JRA3:
  - Workflows and tools → EFDA-ITM
  - Kepler developments back to Kepler team
- JRA4:
  - Visualization picked up by HLST and ITM

EFDA

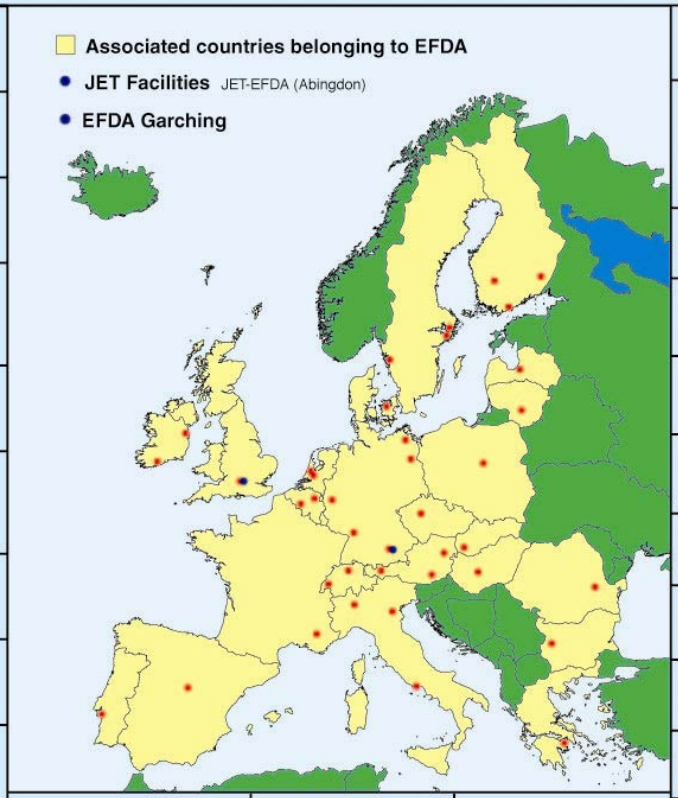
European Fusion Development Agreement

All EU Laboratories / Institutions working on Fusion are parties to EFDA

Defined under EURATOM under "Contract of Associations"

EURATOM : KEY ACTION FUSION Associated Laboratories, parties to EFDA

- **Euratom - Belgian State** (Brussels) - (Mol)
- **Euratom - CEA** TORE SUPRA (Cadarache)
- **Euratom - CIEMAT** TJ-II (Madrid)
- **Euratom - Conf. Suisse** TCV - SULTAN (Lausanne) - (Villigen)
- **Euratom - DCU** (Dublin) - (Cork)
- **Euratom - ENEA** FTU - RFX (Frascati) - (Milan) - (Padua)
- **Euratom - FOM** (Petten) - (Nieuwegein)
- **Euratom - FZJ** TEXTOR (Julich)
- **Euratom - FZK** TOSKA (Karlsruhe)
- **Euratom - Greece** (Athens) - (Heraklion) - (Ioannina)

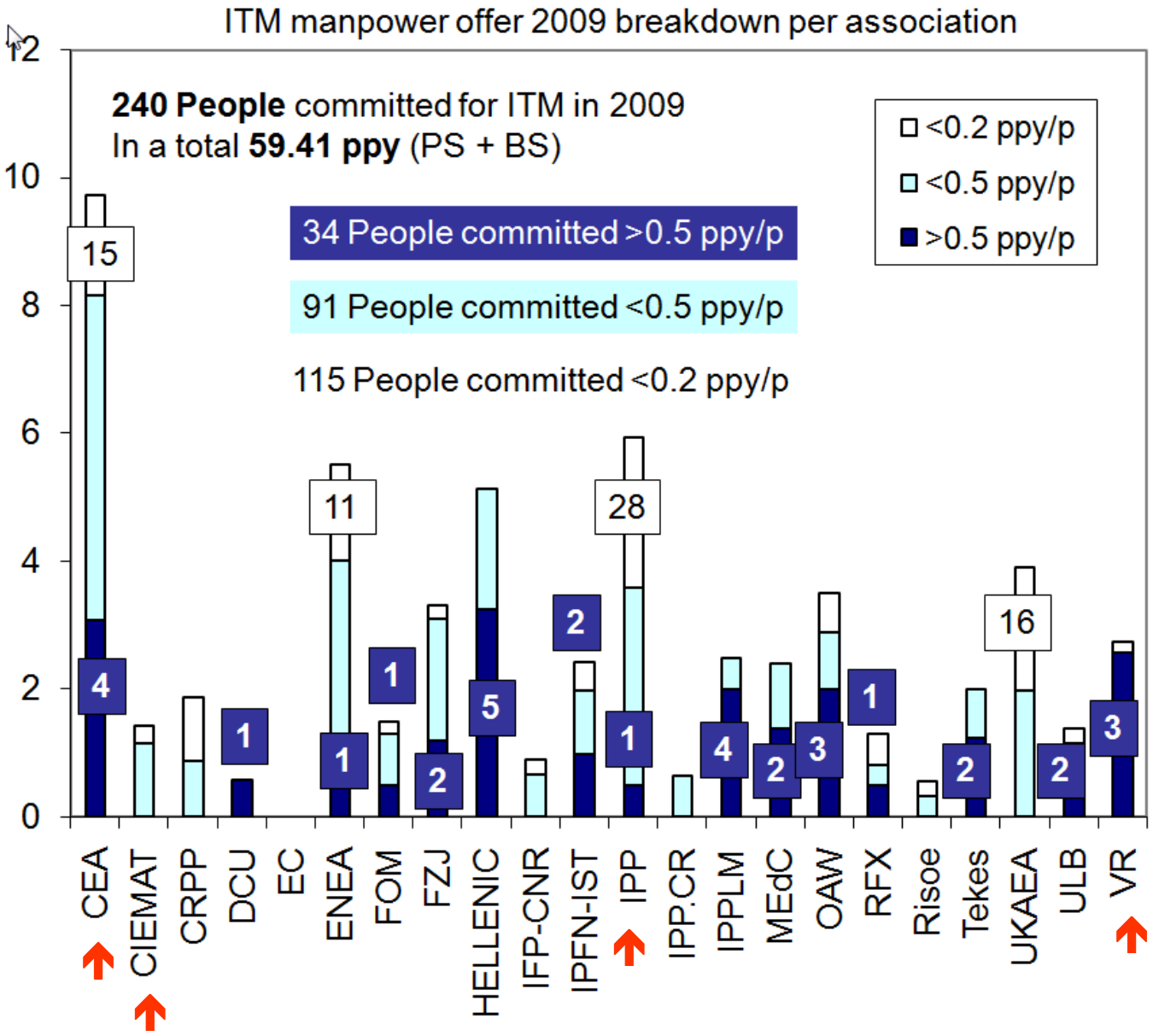


- **Euratom - INRNE** (Sofia)
- **Euratom - LEI** (Kaunas)
- **Euratom - CU** TOSKA (Bratislava)

- **Euratom - HAS** (Budapest)
- **Euratom - IPP** Asdex Upgrade - Wendelstein 7-AS Wendelstein 7-X (Garching) - (Greifswald) - (Berlin)
- **Euratom - IPP.CR** CASTOR (Prague)
- **Euratom - IST** ISTTOK (Lisbon)
- **Euratom - Latvia** (Riga)
- **Euratom - MEC** (Bucharest)
- **Euratom - ÖAW** (Vienna) - (Graz) - (Innsbruck)
- **Euratom - RISØ** (Roskilde)
- **Euratom - TEKES** (Helsinki) - (Tampere) - (Lappeenranta)
- **Euratom - UKAEA** MAST - JET (Culham)
- **Euratom - VR** EXTRAP T2R (Stockholm) - (Lund) (Gothenburg) - (Studsvik) - (Uppsala)

JG03.241-6c

Resources in the ITM



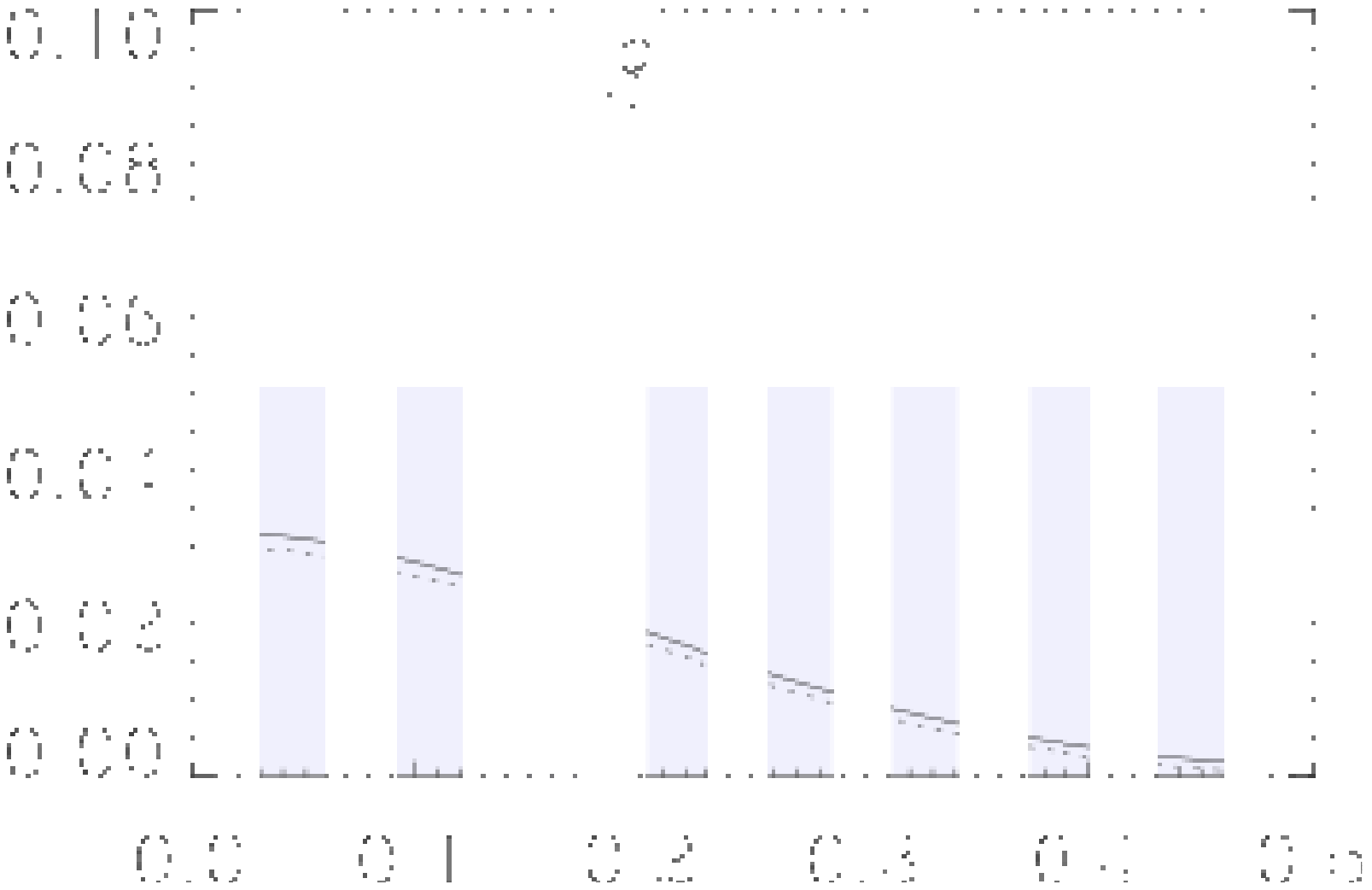
Science

- More than 45 papers have already been published that used inputs from EUFORIA
  - HPC allocations of time
  - GRID computing
    - EUFORIA VO
    - Training of scientists
  - Workflows
- More papers will trickle out over the next few years

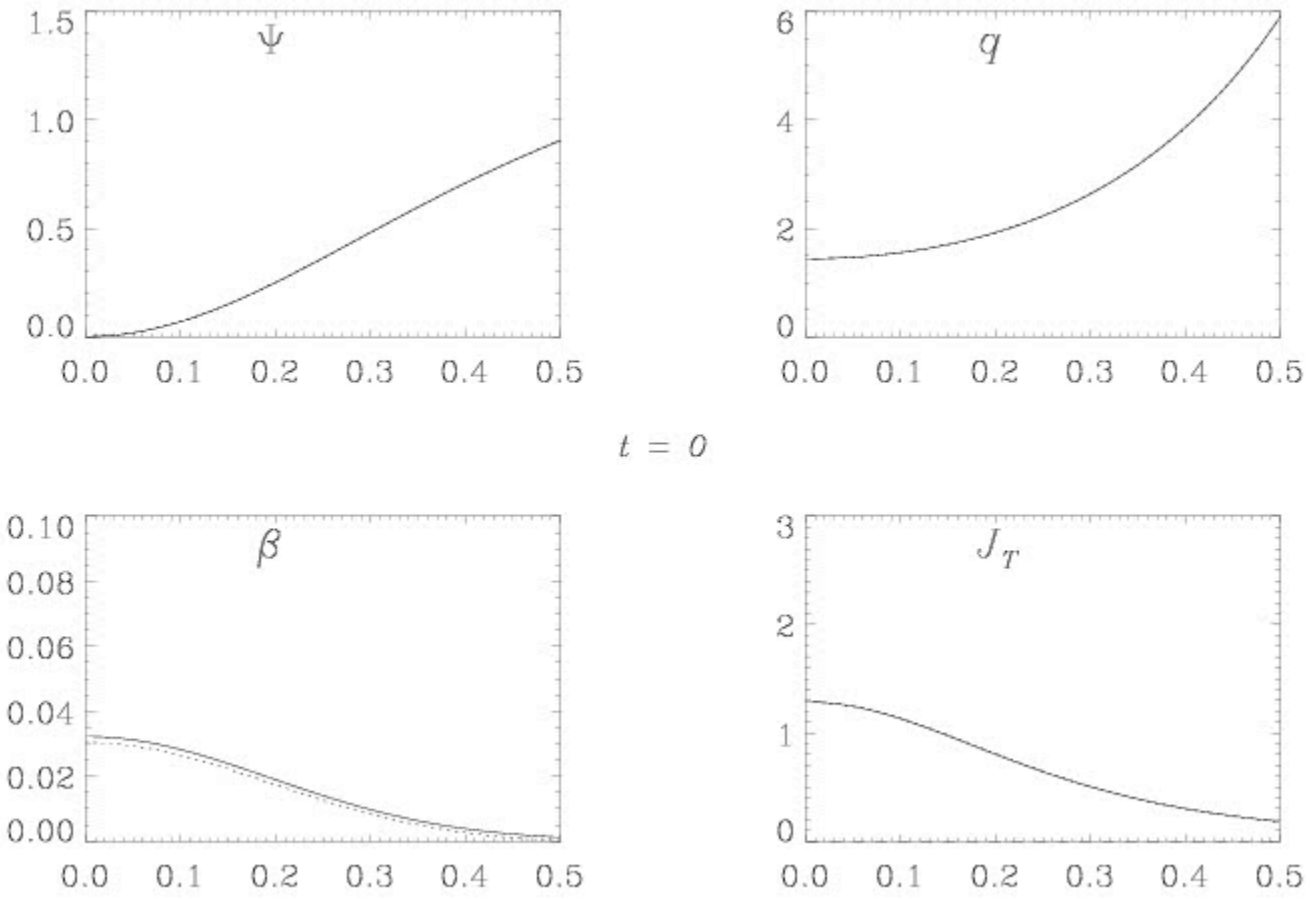
Some examples

- Work on resonant magnetic perturbations
  - Critical issue for ITER
- Work on turbulence
  - Individual codes
  - Incorporation into workflows
    - Expect this to become a hot topic!
- Kinetic treatment of edge plasma
  - Serial code → parallel code
  - Single scientist in Austria with limited resources got access to significant EU expertise and resources

Turbulence-Transport-Equilibrium Workflow



Turbulence-Transport-Equilibrium Workflow



Successes

- 550 training days provided
- More than 50 publications
- 10 million HPC hours provided
- Complex workflows established across range of application scenarios/types (Grid serial, Grid parallel, parameter scan, HPC, …)
- Significant parallel performance improvement in high impact fusion codes
- Workflows providing transparent access to Grid, HPC, and Cloud resources
  - Including EGEE-EUFORIA-DEISA pilot project
- Satisfied user community
- Extensive uptake in fusion community of EUFORIA developed visualisation tools

Impact on Users

- Large scale uptake by user community
  - Simplified, generic, access to computational resources through Kepler
  - Python visualisation tools
  - Significant contributions to European fusion (ITM) workflows
    - Opportunities for new physics!
  - New science already achieved (e.g. see later user presentations)

Broader Impact

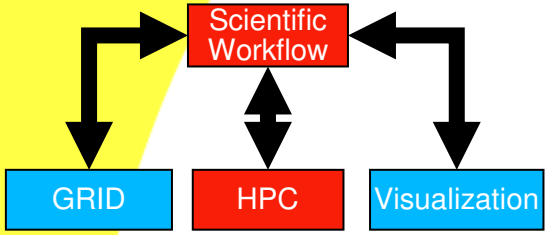
- ITER very interested in EUFORIA technologies
  - Other communities also interested
- Enabled new contacts in European fusion community
  - New labs involved in EFDA-ITM
- Created large scale collaboration between Fusion and computing communities within Europe

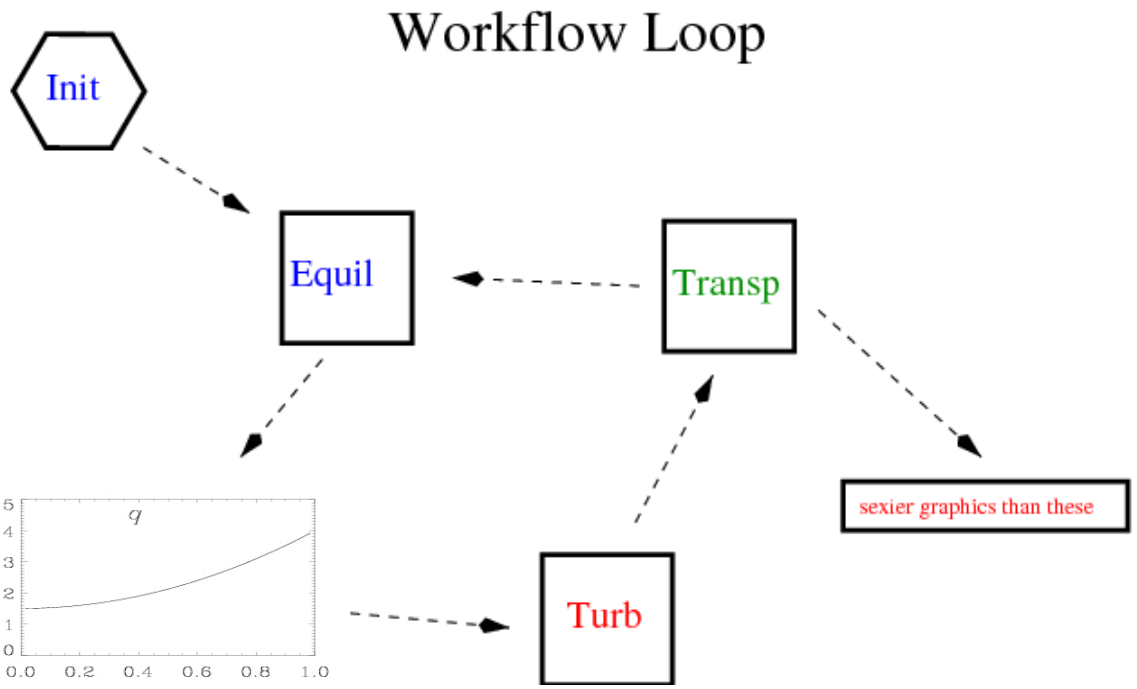
Thank you!

Questions?

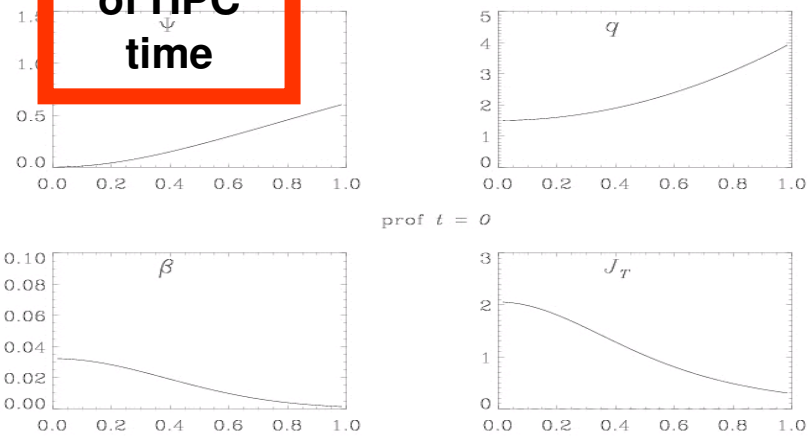
Agenda

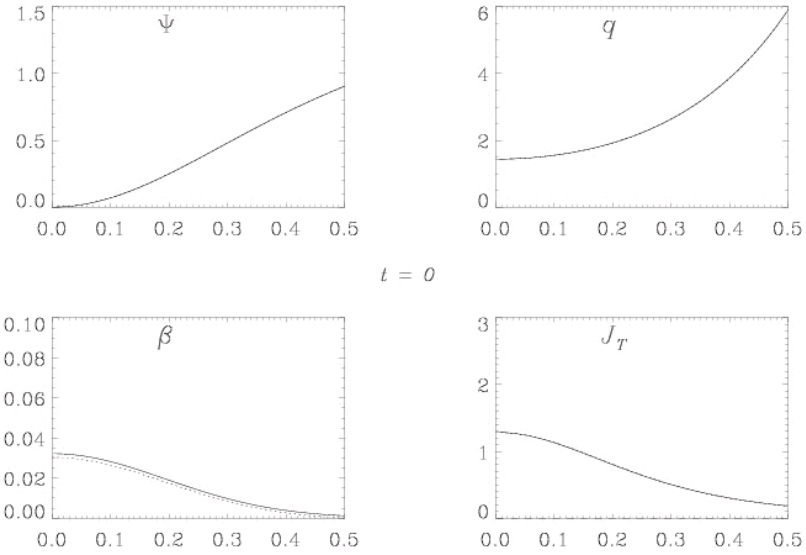
- Introduction – Impact of EUFORIA (Pär, David)
- NA2: Training (Adrian)
- NA3: Dissemination (Miguel)
- Infrastructure:
  - SA1: Grid (Marcus)
  - SA2: HPC (Adrian)
  - SA3: User support (Adrian)
  - Cloud pilot: Cloud demo (Marcin)
- End user support: Codes and code adaptation
  - JRA1 Codea adaptation for grid (Paco)
  - JRA2 Code adaptation for HPC (Adrian)
  - Demonstration/Discussion (Antonio, David T)
- Middleware and tools development
  - JRA3: workflows (Bernard)
  - JRA4: visualization (Olivier)
  - User demo:
    - MHD workflows (Christian)
    - Mixed grid HPC Workflow
-
- Exploitation and sustainability - (Par, David)
- Management: Financial matters (manpower, costs, utilization) (Par)
- Q&A (expected largely in relation to presentations)
- Feedback

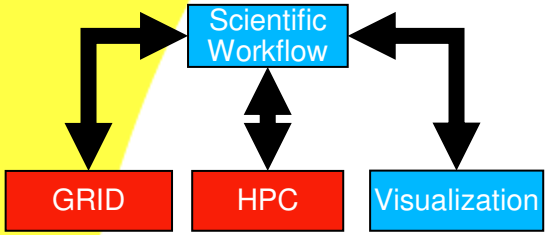




Recipient of HPC time







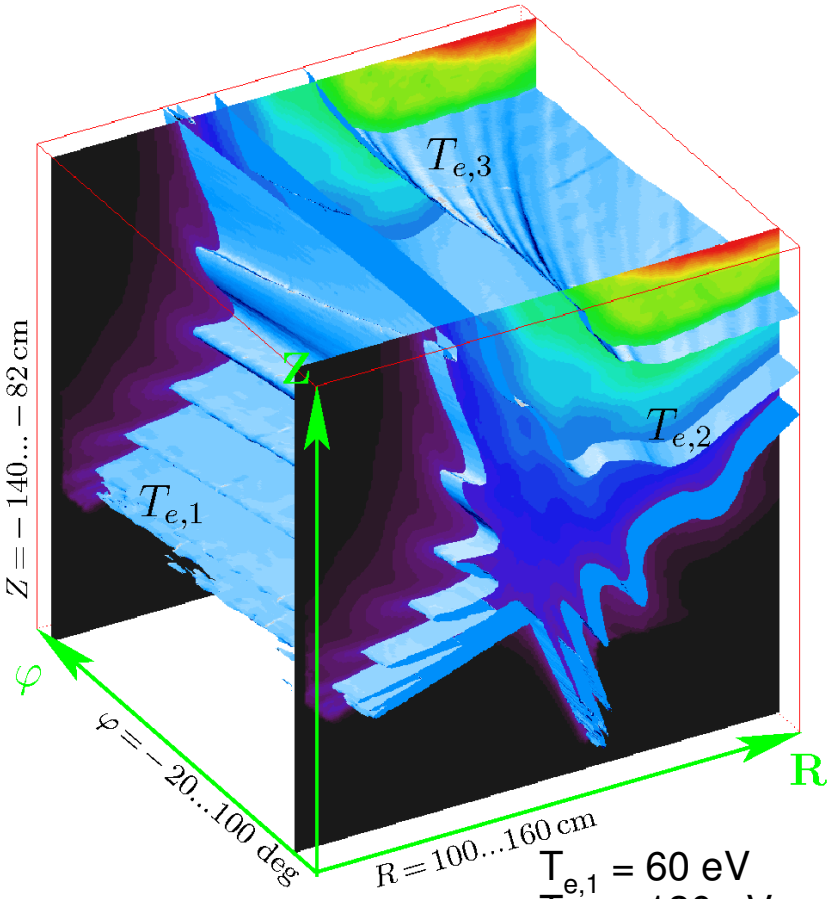
Towards fully 3D CFD: The EMC3-EIRENE code (IPP Greifswald – FZ-Juelich)

Frerichs, H., Reiter, D. *et al.*, Comm. Phys. Commun. (2010) **181** 61-70
and: Nuclear Fusion (2010) **50,** in print

- (initially developed for stellarator applications W7AS, W7X, LHD) was advanced to a more flexible grid structure to allow divertor tokamak + RMP applications.
- first self-consistent 3D plasma and neutral gas transport simulations for poloidal divertor tokamak configurations with RMPs.
- Simulation results for ITER similar shape plasmas at DIII-D show a strong 3D spatial modulation of plasma parameter, e.g. in T_e.
- EMC3-EIRENE code verification (by benchmarks with 2D tokamak edge codes) and validation (TEXTOR, DIII-D, JET, LHD experiments) ongoing

EMC3-EIRENE is currently foreseen for contractual ITER RMP design studies (jointly by FZJ and IPP, 2010…)

Electron Temperature, DIII-D, with RMPs



$T_{e,1}$ = 60 eV
$T_{e,2}$ = 120 eV
$T_{e,3}$ = 200 eV

Recipient of HPC time

EUFORIA FP7-INFRASTRUCTURES-2007-1 Grant 211804

EUFORIA

e-infrastructure