Fusion in the GRID (na4-egeeII)

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As coordinator of Fusion-GRID in NA4:
SW-Federation (CIEMAT, BIFI, UCM, INTA -Spain-),
Russian Federation (Kurchatov Institute -Russia-),
CEA (France), ENEA (Italy), EFDA (EU), Korea (KISTI)

NA4-Catania, 2006

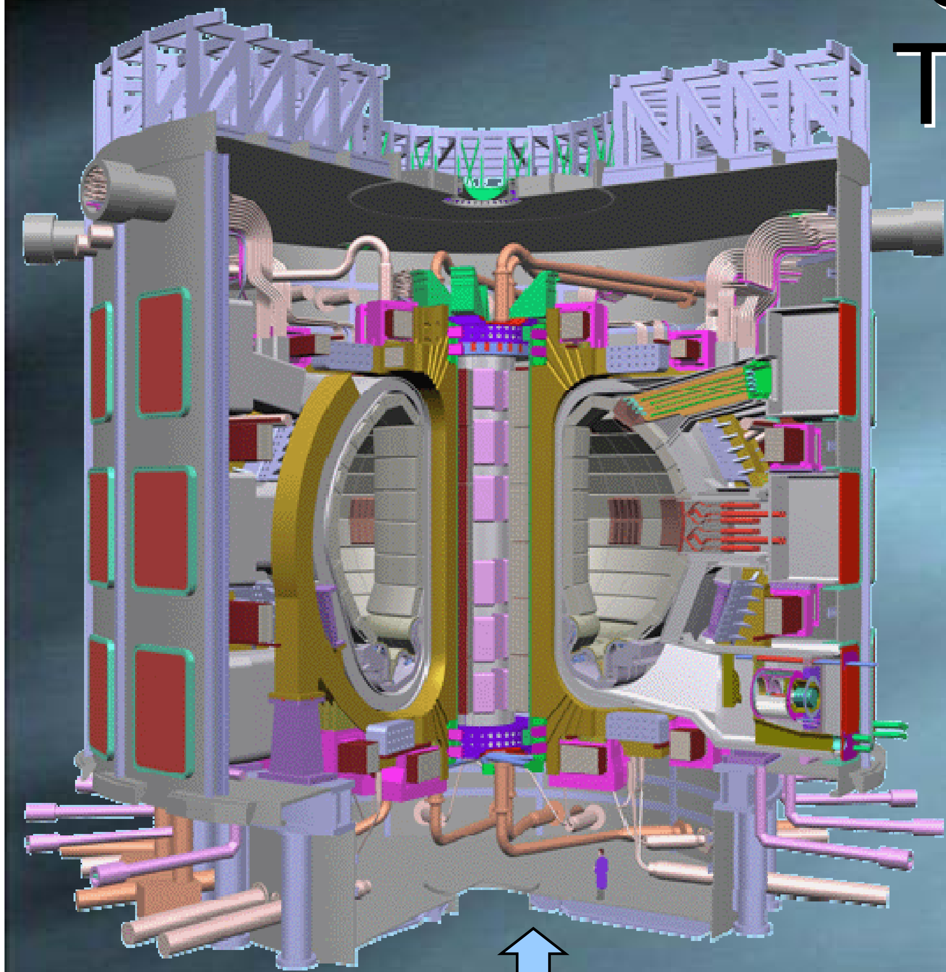
Outline

- Motivation: Fusion on the GRID.
- Strategy.
- Applications: Computing in Plasma Physics.
- Future Applications on the grid.
  - Data storage and handling.
- Partners.
- Final Remarks.

Motivation

- Large Nuclear Fusion installations: International Cooperation among a lot of Institutes.
- Generate ~ 1-10 GB/sec. Less than 30% of data goes into processing.
- Distributed data storage and handling needed.
- Massive Distributed Calculation: A new way of solving problems. (Problems still without solution).
- Fusion community (Science and Technology) needs new IT approaches to increase research productivity.

ITER: Making decisions in real Time !!



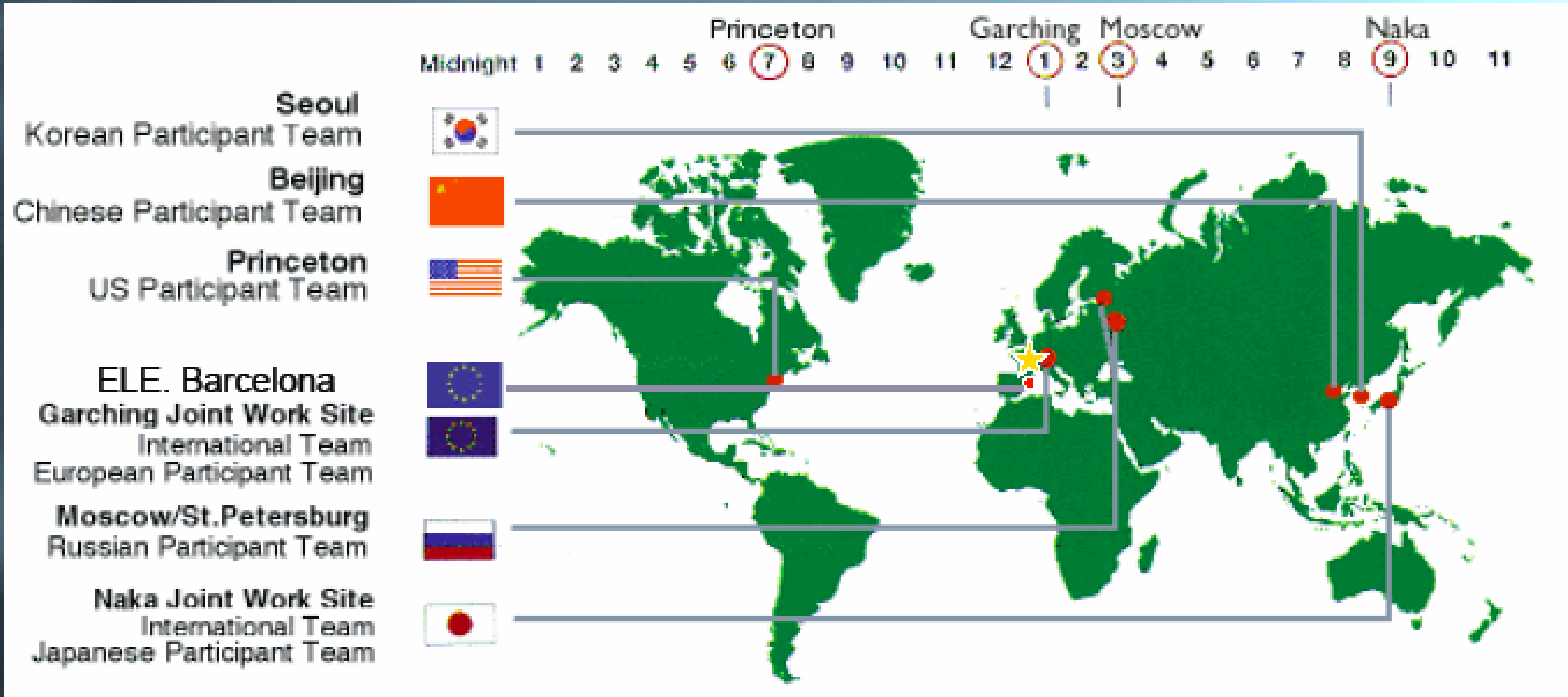
Data Acquisition and Storage (GRID)

Data Analysis and Reduction:
Artificial Intelligence, Neural Network, Pattern Recognition

Simulation: Large codes in different platforms (Grid, Supercomputers)

Decision for present/next shot

ITER Partners



Distributed Participation.

Data access. Remote Control Rooms?

International Tokamak (ITPA) and Stellarator (SIA) collaborations.

Russia:

T-10 (Kurchatov)

Globus (Ioffe)

T-11M (TRINITI)

L-2 (Gen. Inst. Phys.)

EGEE Project

USA:

Alcator C-Mod (MIT)

DIII-D (San Diego)

NSTX (Princeton)

NCSX (Princeton)

HSX (Wisconsin)

QPS (Oak-Ridge)

USA Fusion Grid (GLOBUS, MSPLUS)

EU:

JET (EFDA)

ASDEX (Ger.)

TORE SUPRA (Fran.)

MAST (UK)

TEXTOR (Ger.)

TCV (Switz.)

FTU (Italy)

W7-X (Ger.)

TJ-II (Spain)

EGEE Project

Japan:

JT-60 (Naka)

LHD (Toki)

CHS (Nagoya)

H-J (Kyoto)

GRID Project ?

China, Brazil, Korea, India:

KSTAR (Korea)

TCBRA (Bra.)

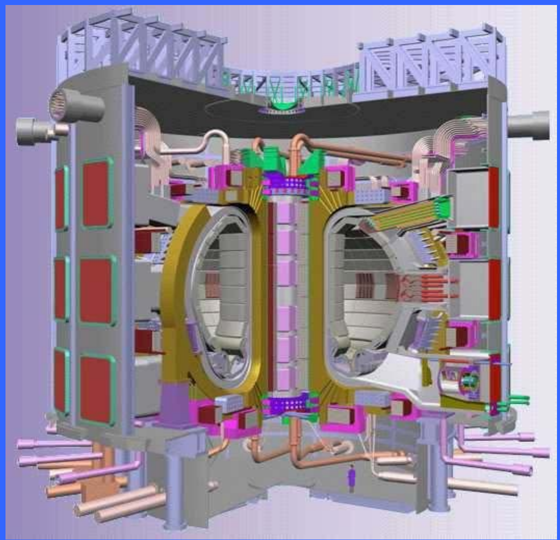
H-7 (China)

U2A (China)

SST1 (India)

EGEE Project

International Experimental Thermonuclear Reactor (ITER) project



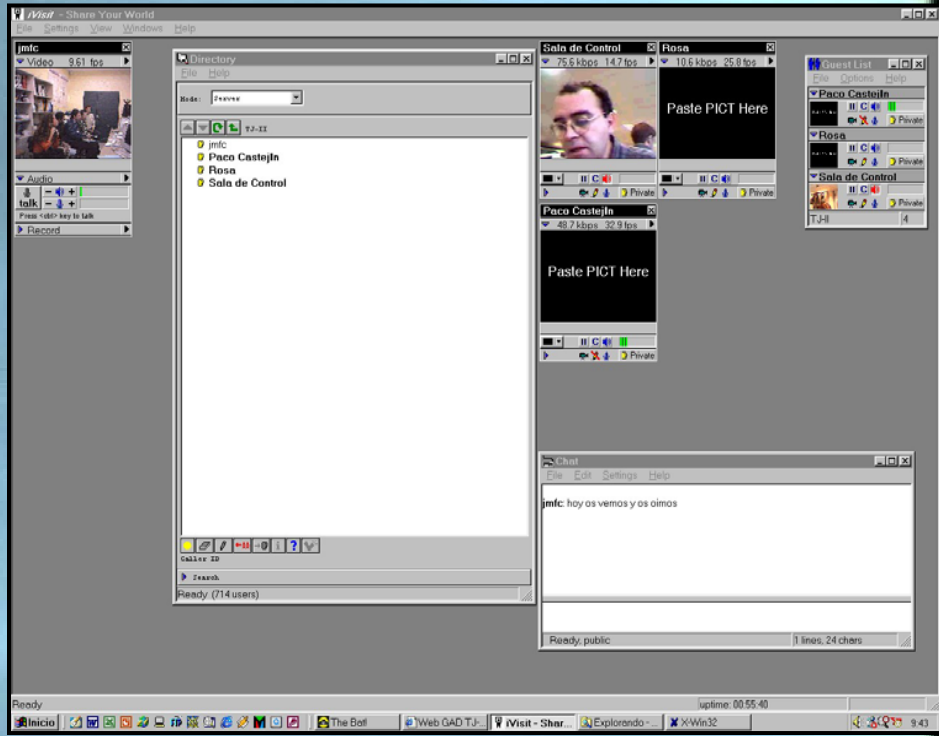
- High speed networks
- Data bases
- Grid and Supercomputers
- Access centers
- New Soft

FUSION GRID as a prototype of ITER GRID

Joint collaboration requires COMPATIBILITY

- Identical representation of data bases.
- Identical graphical interfaces.
- Identical standards of codes for data processing and simulations.
- Identical programming languages.
- Identical Tool kit for codes development.

Communications



Remote Participation tools:

Data Access.

Local Visualization.

Video Conferences and Chats.

Remote Control.

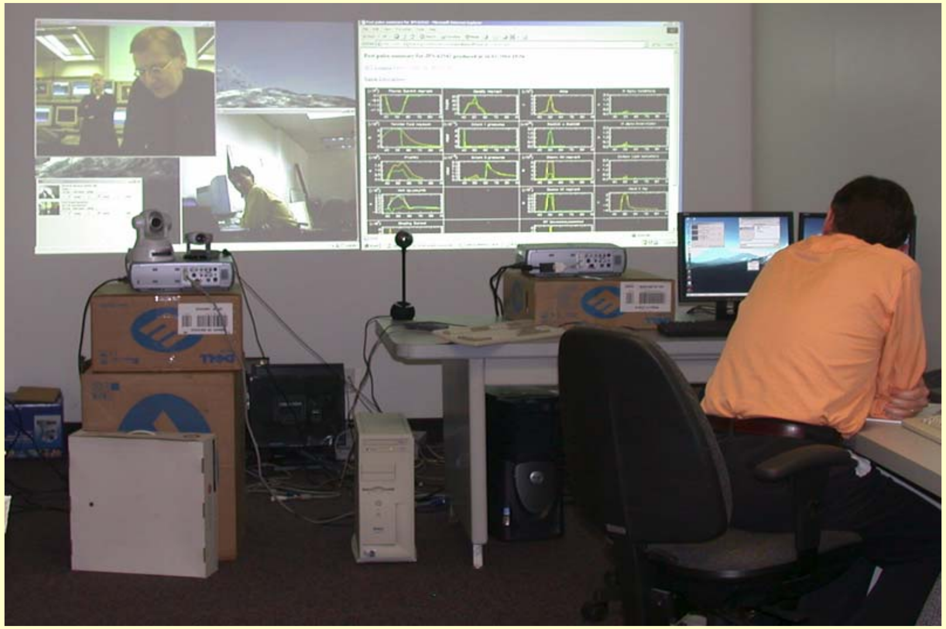
Programming via web.

SECURITY & ROBUSTNESS

➢AccessGRID for Videoconferencing

- ➢ VRVS is also used

Scientific Coordination of JET from DIID



Remote Participation from JET to DIII–D

Strategy

- Enabling mail list and web page.

- Computing:
  - Identify common Codes suitable for GRID. (Ongoing)
  - Adapt codes to the GRID. (Ongoing)
  - Set up VO
  - Production phase.

Data handling:

Define strategies for data storage.

& database organization.

Protocol for data Access.

Standard SCADA (Improve MSPLUS?)

COMPUTING in the GRID: Present Applications

- **Transport and Kinetic Theory: Monte Carlo Codes.**
- **Multiple Ray Tracing: e. g. TRUBA.**
- **Stellarator Optimization: VMEC**

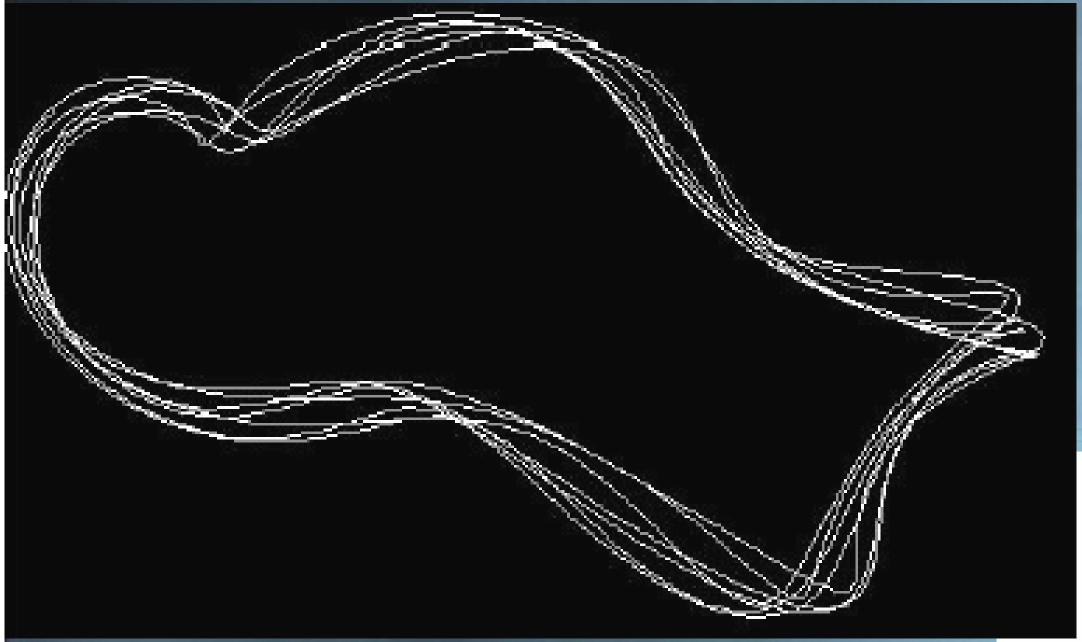
Kinetic Transport

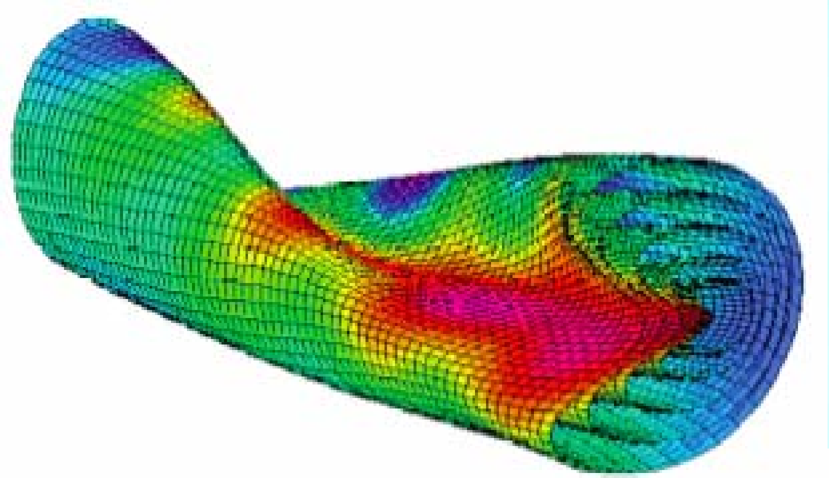
- Following independent particle orbits in the plasma:

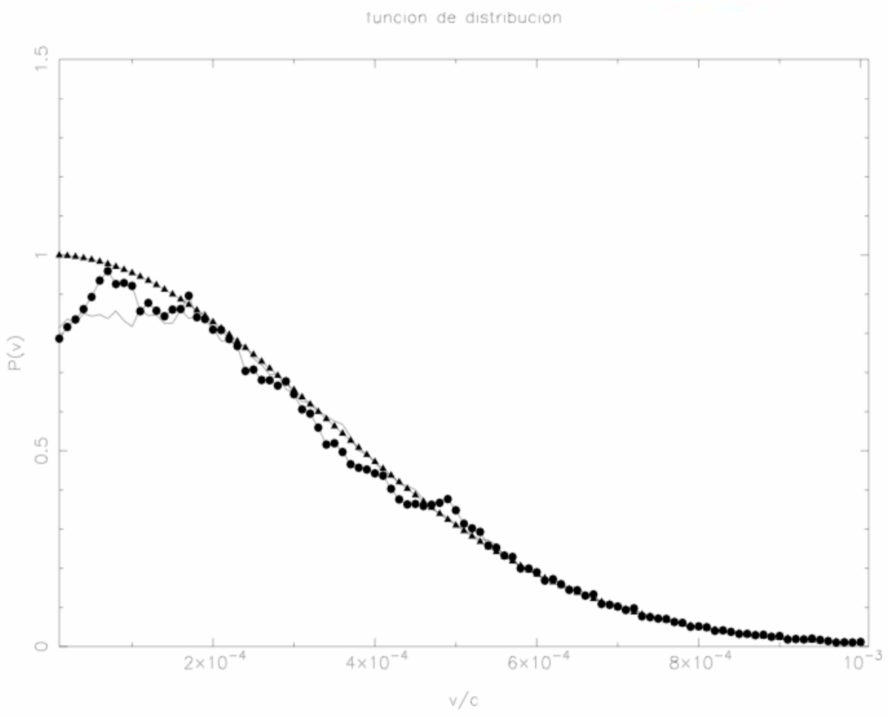
$$\vec{V}_D = \frac{\vec{E} \times \vec{B}}{B^2} + \frac{m}{2q}\left(2v^2 - v_\perp^2\right)\frac{\vec{B} \times \nabla\left|\vec{B}\right|}{B^3}$$

- Typically 30 x 10^6 ions followed.
- Montecarlo techniques: Particles distributed according to experimental density and ion temperature profiles (Maxwellian distribution function)
- SUITABLE PROBLEM FOR CLUSTER AND GRID TECHNOLOGIES

Kinetic Transport







Example of orbit in the real 3D TJ-II Geometry (single PE).

~1 GBy data, 24 h x 512 PE

Distribution function of parallel velocity at a given position (Data Analysis).

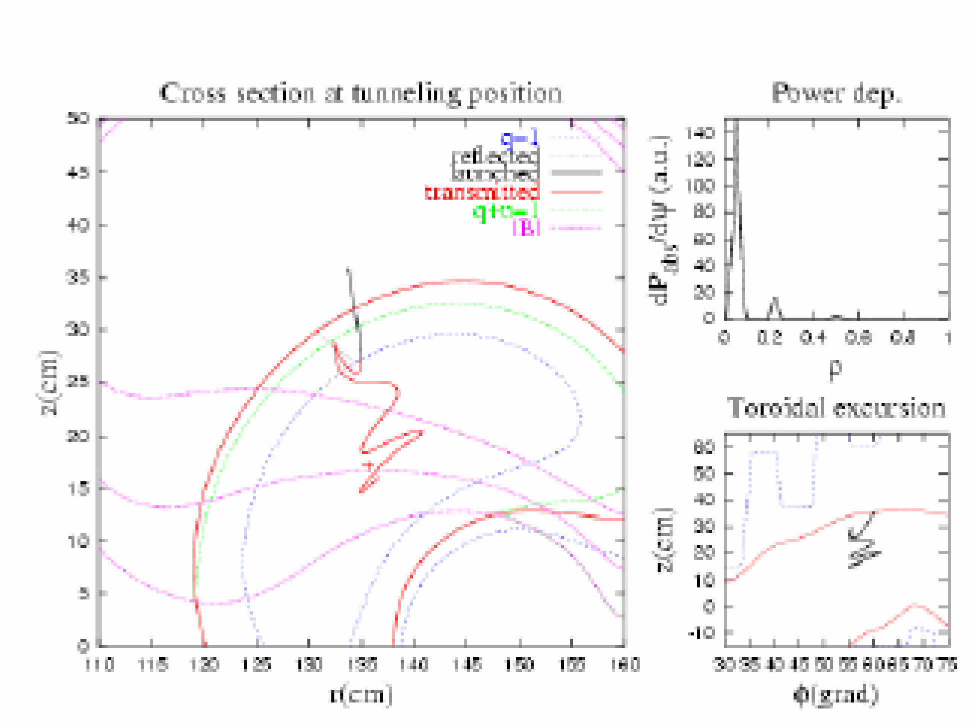
Kinetic transport

No collisions: 0.5 ms of trajectory takes 1 sec. CPU..

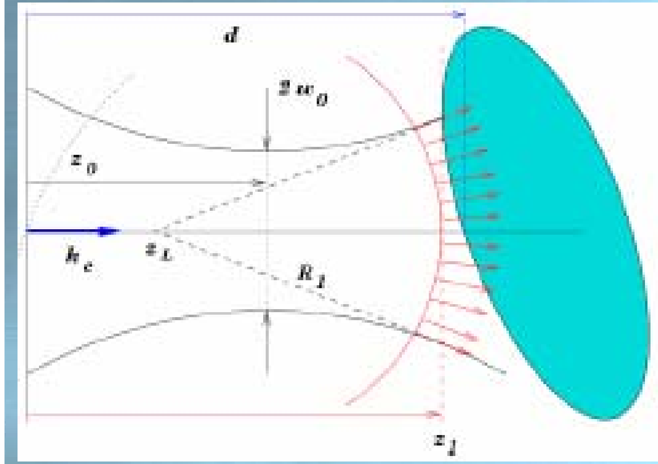
Collisions: 1 ms of trajectory takes 4 sec CPU.
Particle life: 150 - 200 ms. Single particle ~ 10 min.

Necessary statistics for TJ-II 10^7 particles.

Multiple Ray Tracing: TRUBA

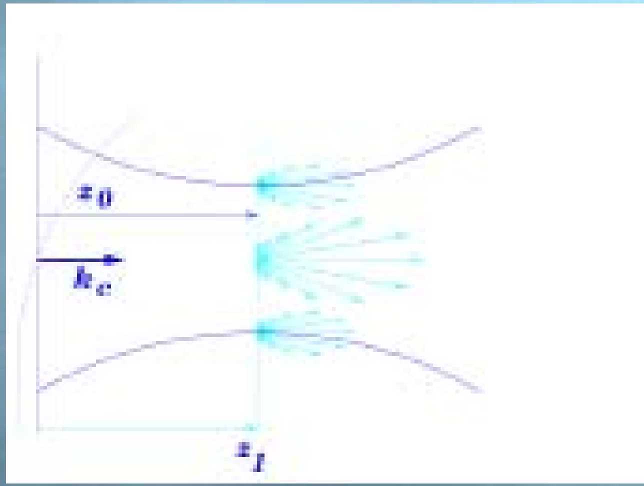


Single Ray (1 PE):
Hamiltonian
Ray Tracing Equations.



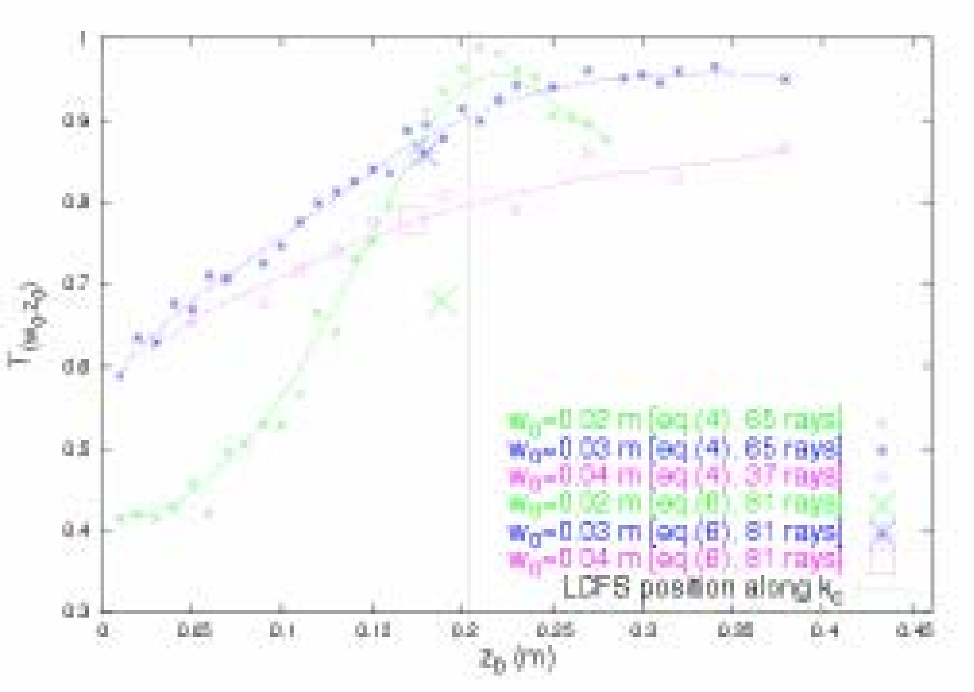
Beam Simulation:

Bunch of rays with beam waist far from the critical layer (100-200 rays)



Bunch of rays with beam waist close to the critical layer (100-200 rays) x (100-200 wave numbers) ~10^5
GRID PROBLEM

TRUBA: Multiple Ray Tracing



Different results with the two approximations.

(Also useful tool for looking for Optimum Launching Position in complex devices)

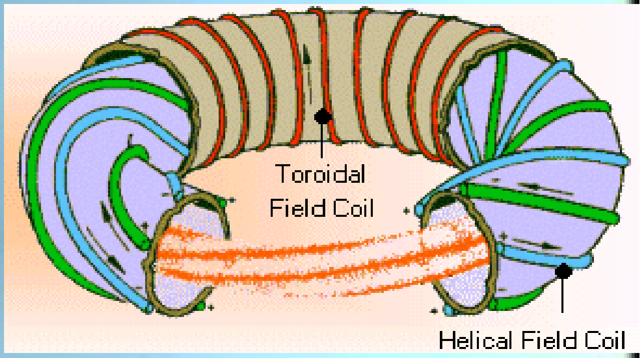
TRUBA for EBW:
Collaboration between IOFAN and CIEMAT.
Useful for all Institutes with EBW heating (Culham, Princeton, Greifswald, CIEMAT,…)

TRUBA: Multiple Ray Tracing

TRUBA for EBW:

- Cylinder geometry: A single Non-relativistic ray (tens of sec.)
-Real geometry in TJ-II:Coming from a supercomputer (VMEC).
    - A single Non-relativistic ray (about 18').
    - A single relativistic ray (about 40').
- Some problems with Geometry libraries.

Stellarator optimization



Coils producing field confining the plasma may be optimised numerically by variation of the field parameters.

-*A lot of different Magnetic Configurations operating nowadays.*

OPTIMIZATION NECESITY BASED ON KNOWLEDGE OF STELLARATOR PHYSICS.

Every variant computed on a separate processor (~10')

VMEC (Variational Momentum Equilibrium Code)

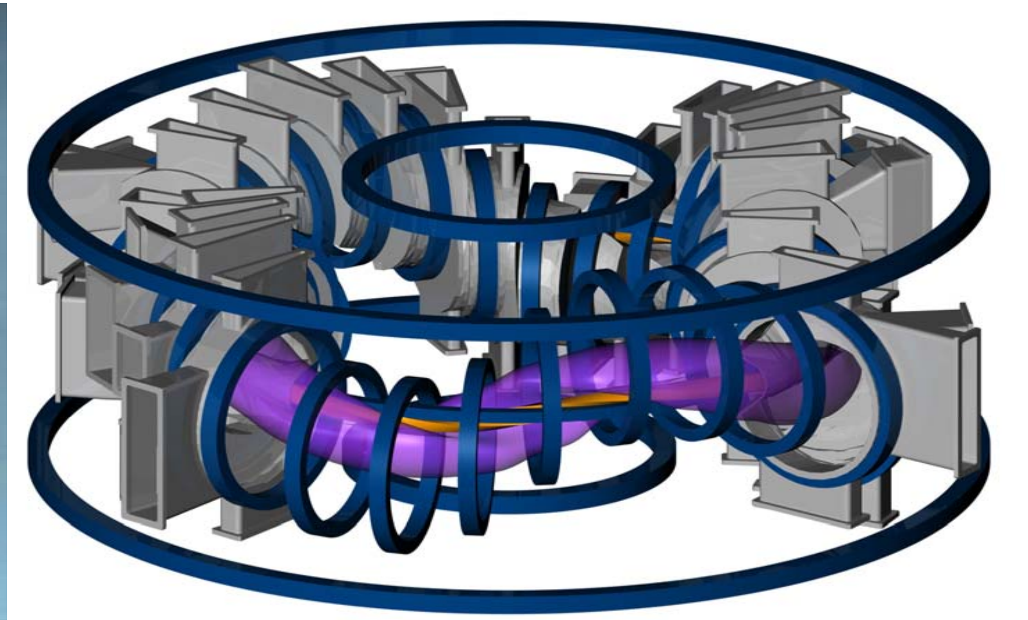
120 Fourier parameters are varied.

$$R(\psi) = \sum_{m,n} R_{m,n}(\psi)\cos(m\theta - n\varphi)$$

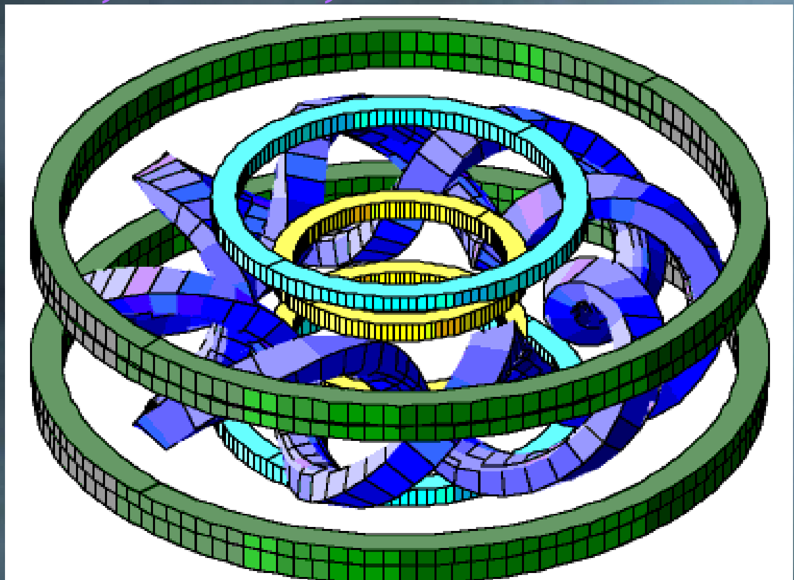
$$\vec{B}(\psi,\theta,\varphi) = \sum_{m,n} B_{m,n}(\psi) e^{i(m\theta - n\varphi)}$$

$$Z(\psi) = \sum_{m,n} Z_{m,n}(\psi)\sin(m\theta - n\varphi)$$

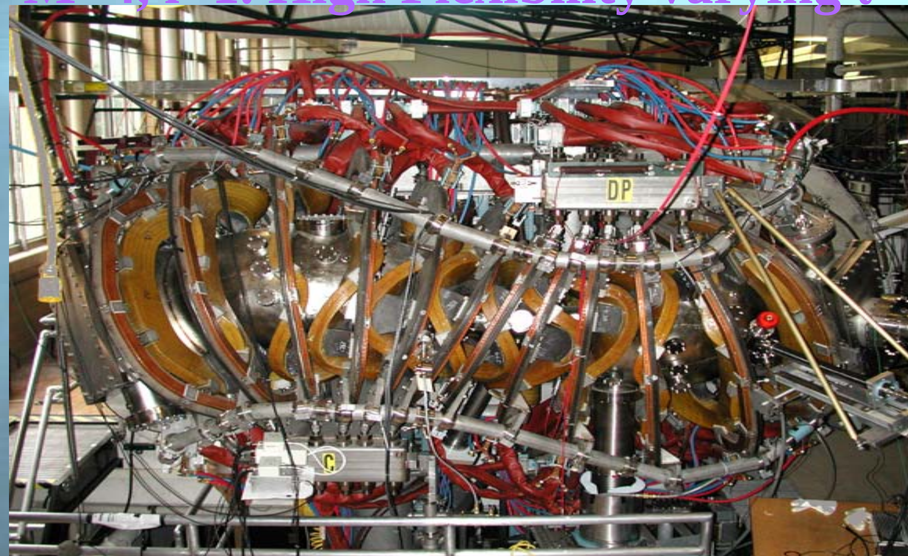
LHD: R= 3.6,3.75,3.9 m; a= 0.6-0.65 m
M=10, l=2. n=1, m=1 island in the edge.



TJ-II: R= 1.5 m; a= 0.2 m
M=4, l=1. High Flexibility varying ι



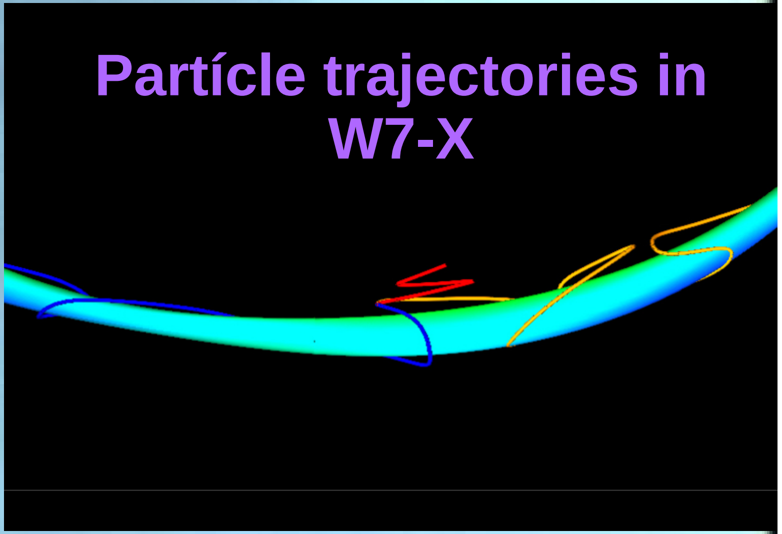
CHS: R= 1 m; a= 0.2 m; M=8; l=2.



HSX: R=1.2 m; a=0.15 m
QHS and Mirror Configurations

Optimization Criteria: Target Functions

-Neoclassical Transport.
- Bootstrap current.
- Equilibrium vs. plasma pressure.
- Stability (Balloning, Mercier,…)



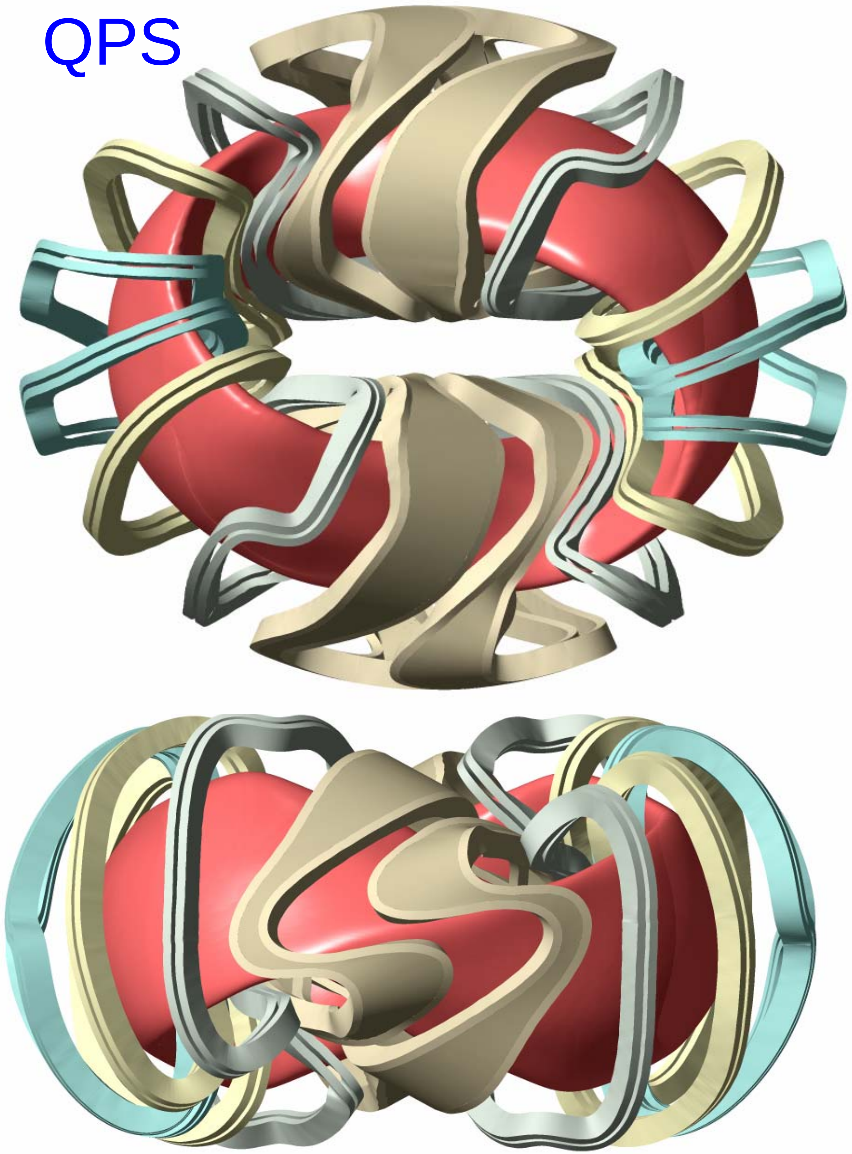
-Genetic Algorithm to detect the optimum configuration for given criteria.
 Target Functions can be modified.

VMEC on Kurchatov GRID

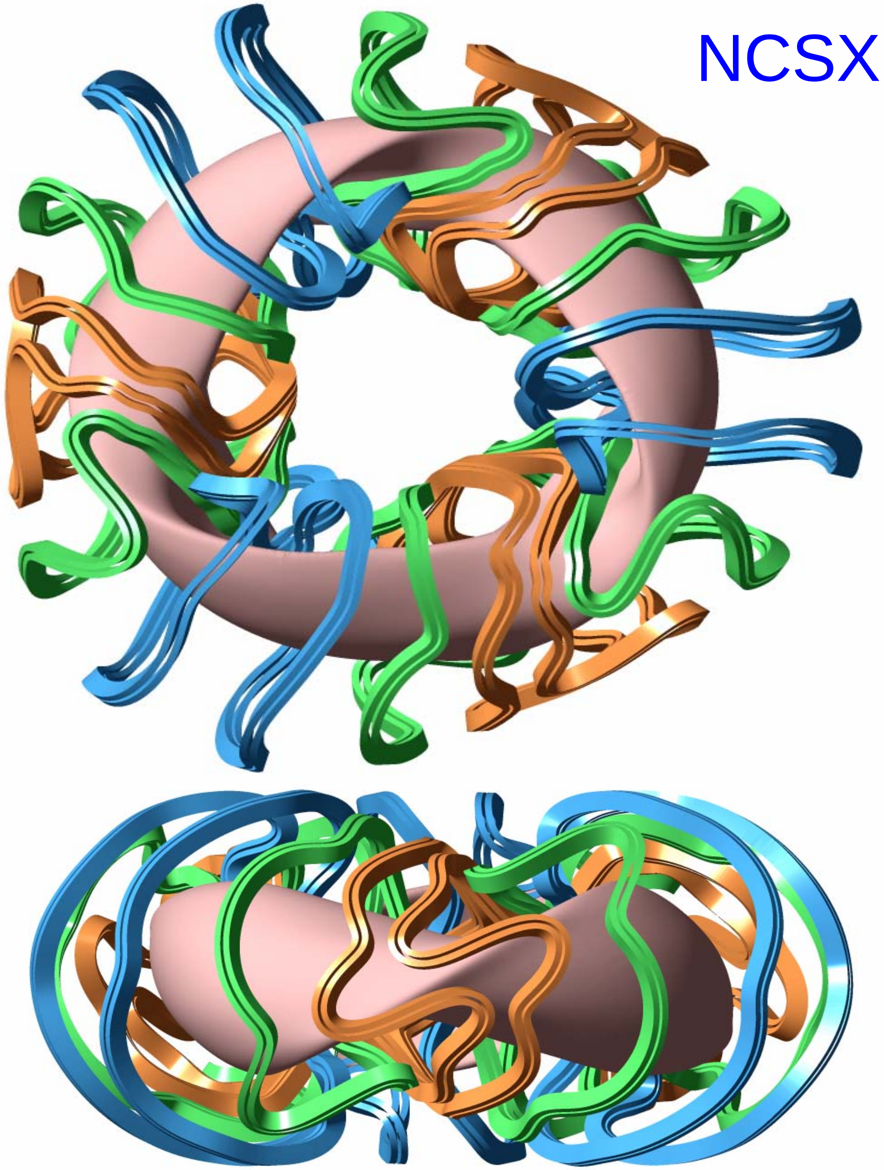
- LCG-2 - based Russian Data Intensive Grid consortium resources.
- About 7.500 cases computed (about 1.500 was not VMEC-computable, i.e. no equilibrium).
- Each case took about 20 minutes.
- Up to 70 simultaneous jobs running on the grid.

Optimised Stellarators QPS and NCSX Supercomputer Optimization

QPS



NCSX



COMPUTING in the GRID: Future applications

- **EDGE2D   Application for tokamaks**

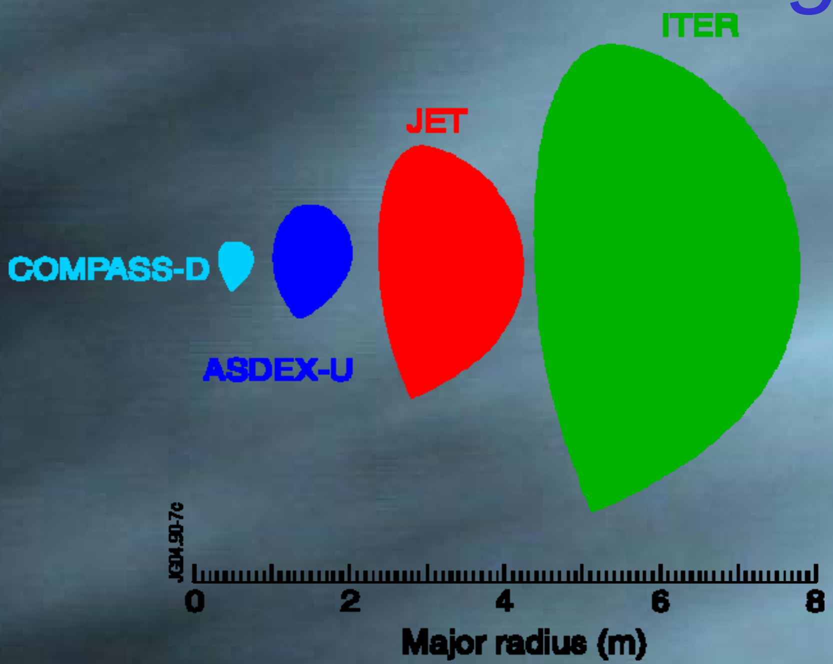
- **Transport Analysis of multiple shots (typically 10^4 shots) or Predictive Transport with multiple models: e. g. ASTRA. CIEMAT(Spa) + IPP(Ger) + Kurchatov(Rus) + EFDA(UE) + …**

- **Neutral Particle Dynamics: EIRENE:**

CIEMAT(Spa) + IPP(Ger)

JET – Flagship of Worldwide Fusion: EDGE2D Equilibrium code.

EDGE2D: Determine plasma shape from Measurements: Plasma current, Pressure, Magnetic field…



Cross section of present EU D-shaped tokamaks compared to the ITER project

$$\vec{j} \times \vec{B} = \vec{\nabla} p$$

-EDGE2D code solves the 2 D fluid equations for the conservation of energy, momentum and particles in the plasma edge region.

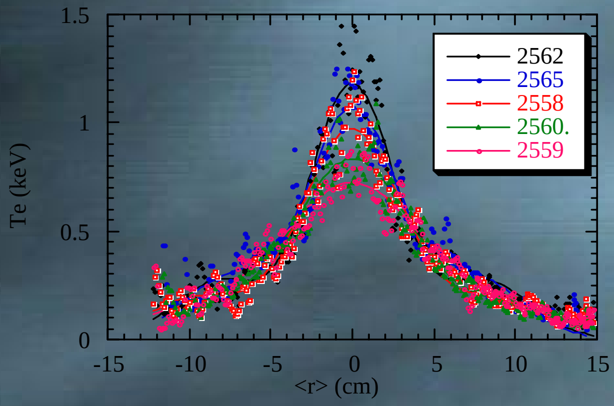
-Ions, electrons and all ionisation stages of multiple species are considered.

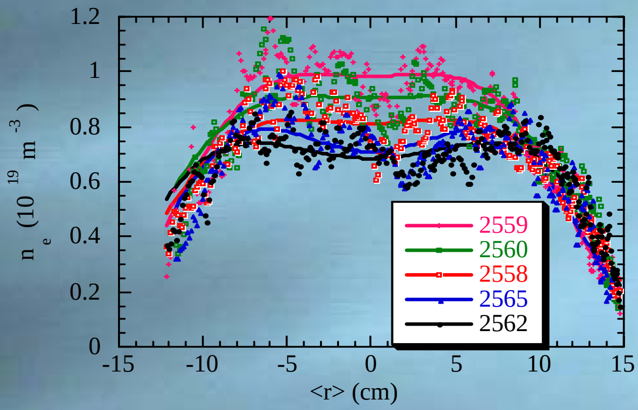
-Interaction with the vessel walls is simulated by coupling to Monte-Carlo codes, to provide the neutral ion and impurity sources.

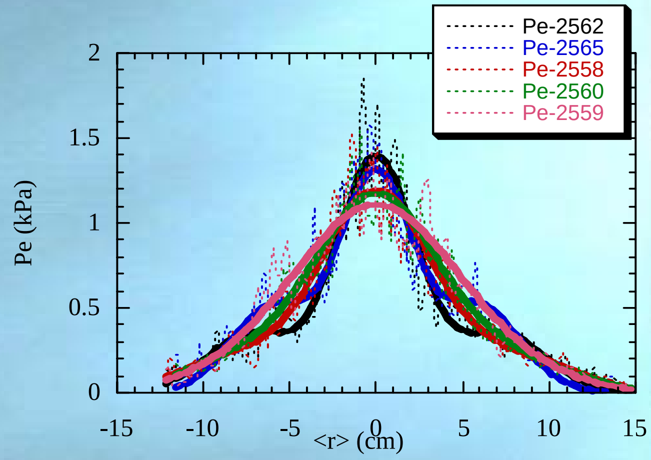
Massive Transport Calculations

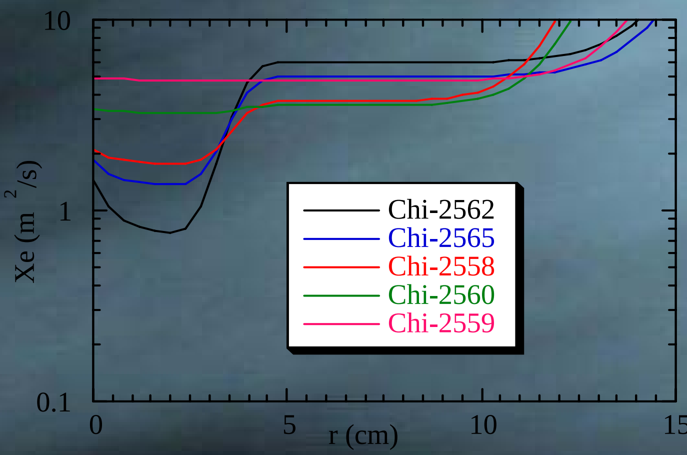
For Instance: Enhanced heat Confinement in TJ-II. Lower heat diffusivity for low electron density and high absorbed power density.

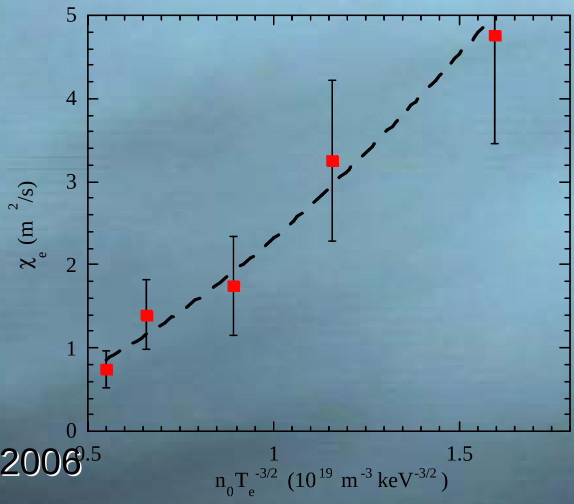
A different case on every PE.



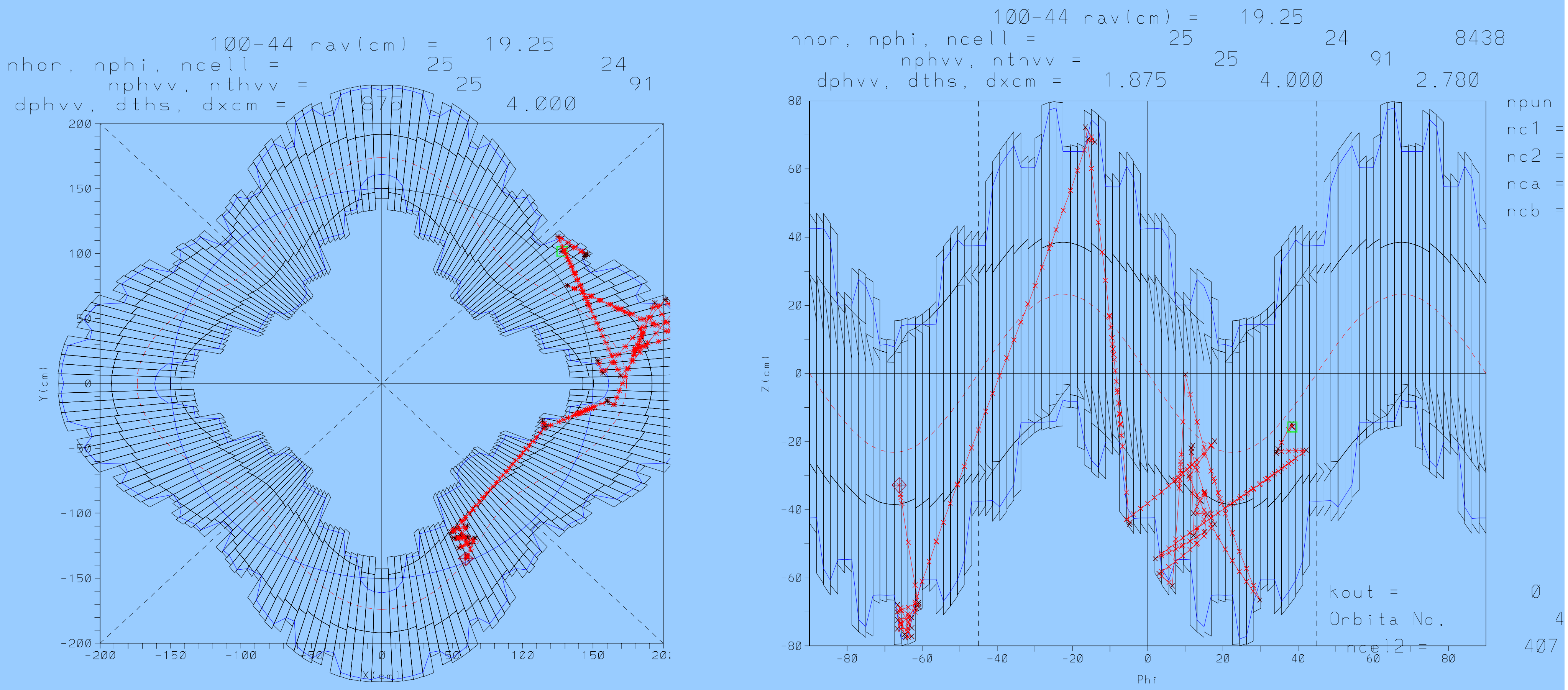








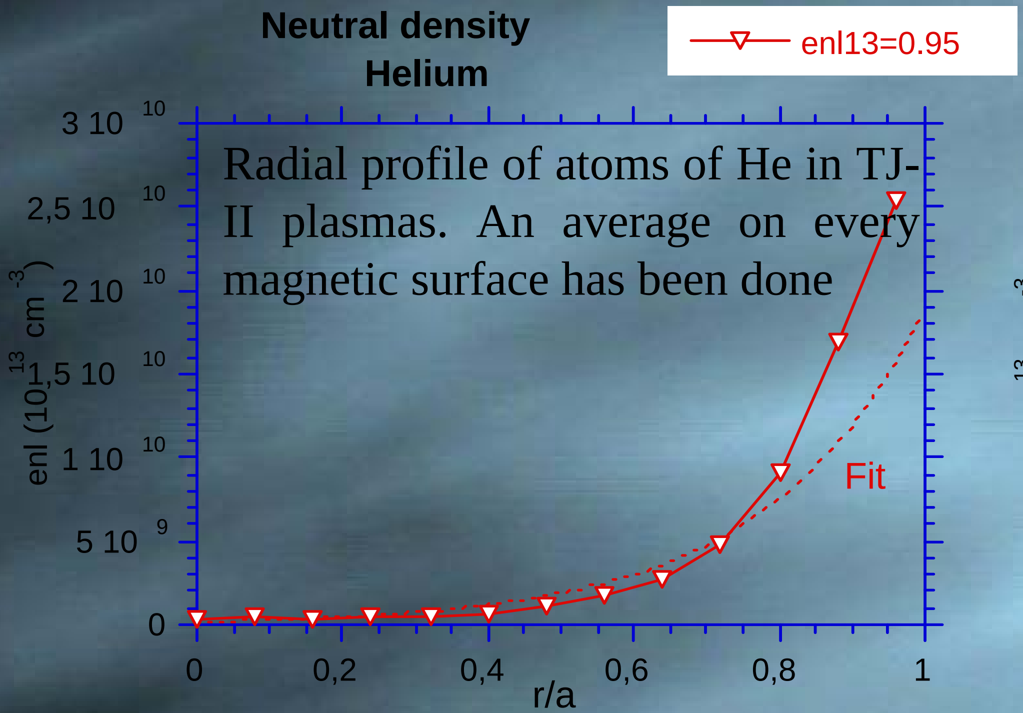
EIRENE Code

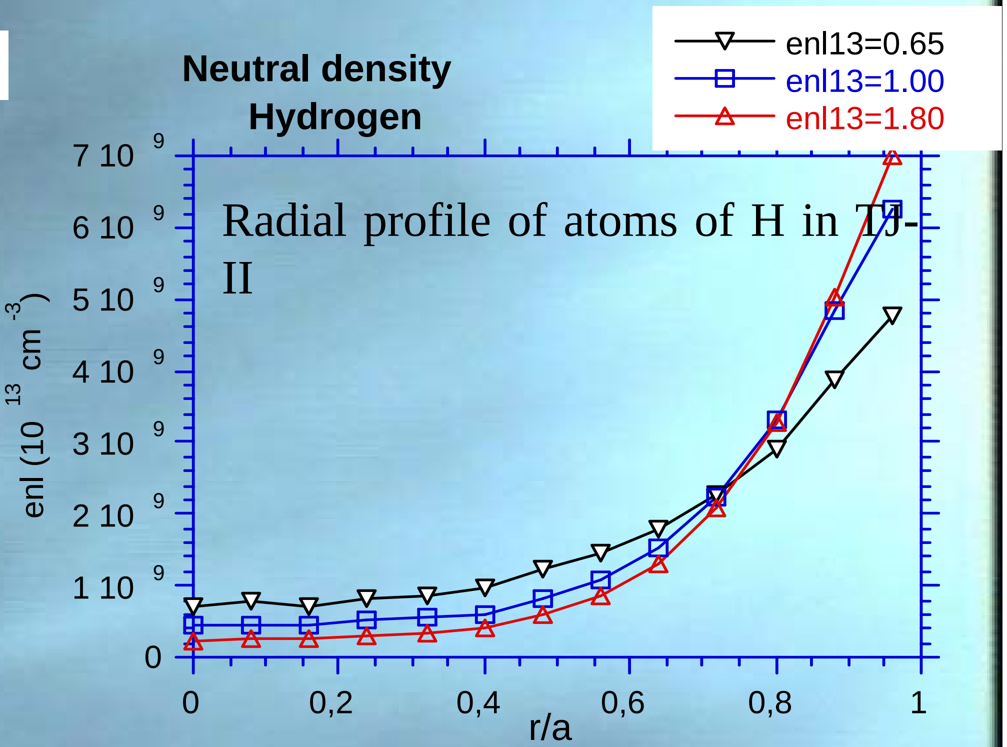


Trayectory of a He atom in TJ-II. Vertical and horizontal proyections. It starts in the green point and is absorbed in the plasma by an ionization process.

The real 3D geometry of TJ-II vacuum chamber is considerd.

EIRENE Code

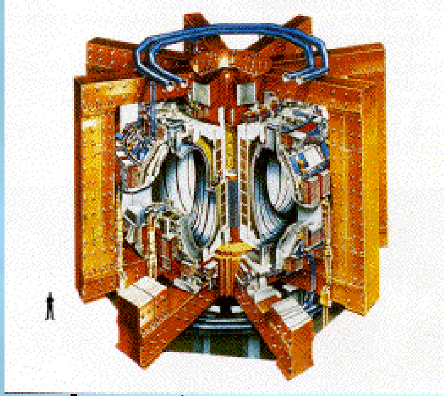




Two parts:
1) Following trajectories (Totally distributed) --> GRID
2) Reduction to put all together.

EIRENE Code comes from IPP (Jülich, Germany) and is extensively used by Fusion community.

DATA HANDLING



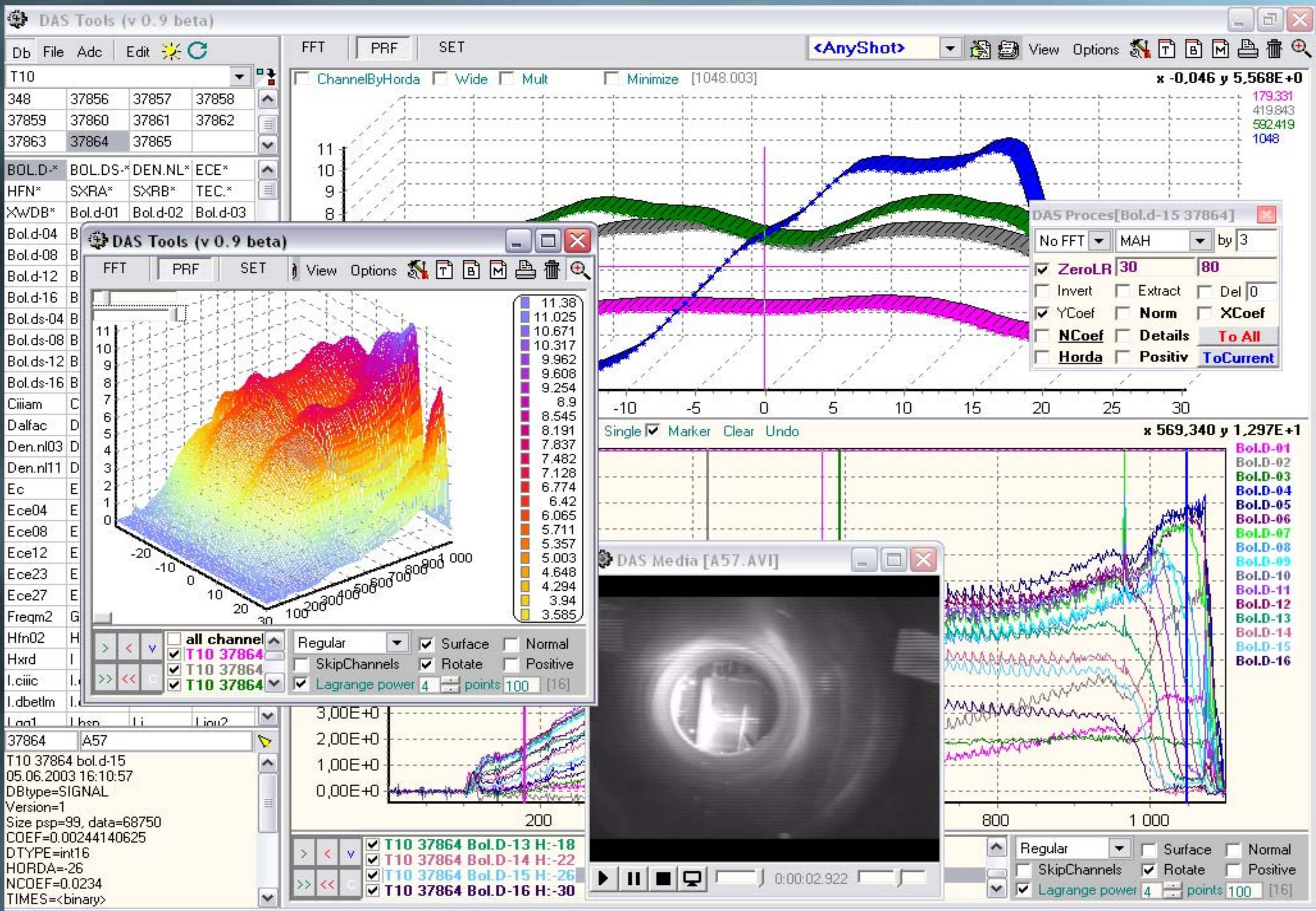
Storage:

Large data flux: 10^4 sensors x 20-50 kHz sampling=
1-10 GBy per second raw data
x 0.5 h= 3 TBy per shot in ITER every 1,5 h

Supercomputing and Grid Computing -->
Data Storage: Scratch and permanent.

Access & Sharing Data :
Large Cooperative Experiments

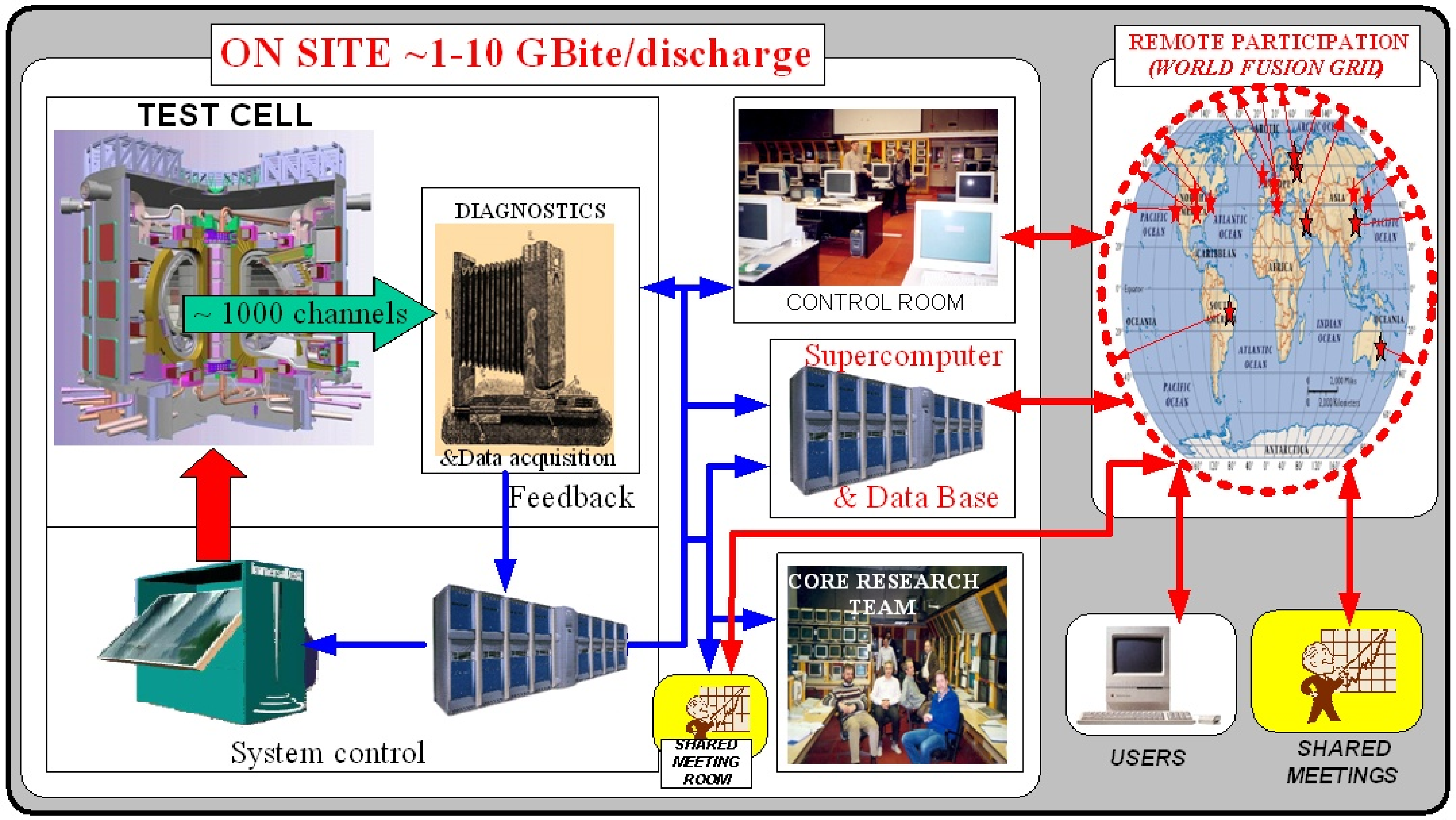
DAS Tools: Visualization, DAQ and processing



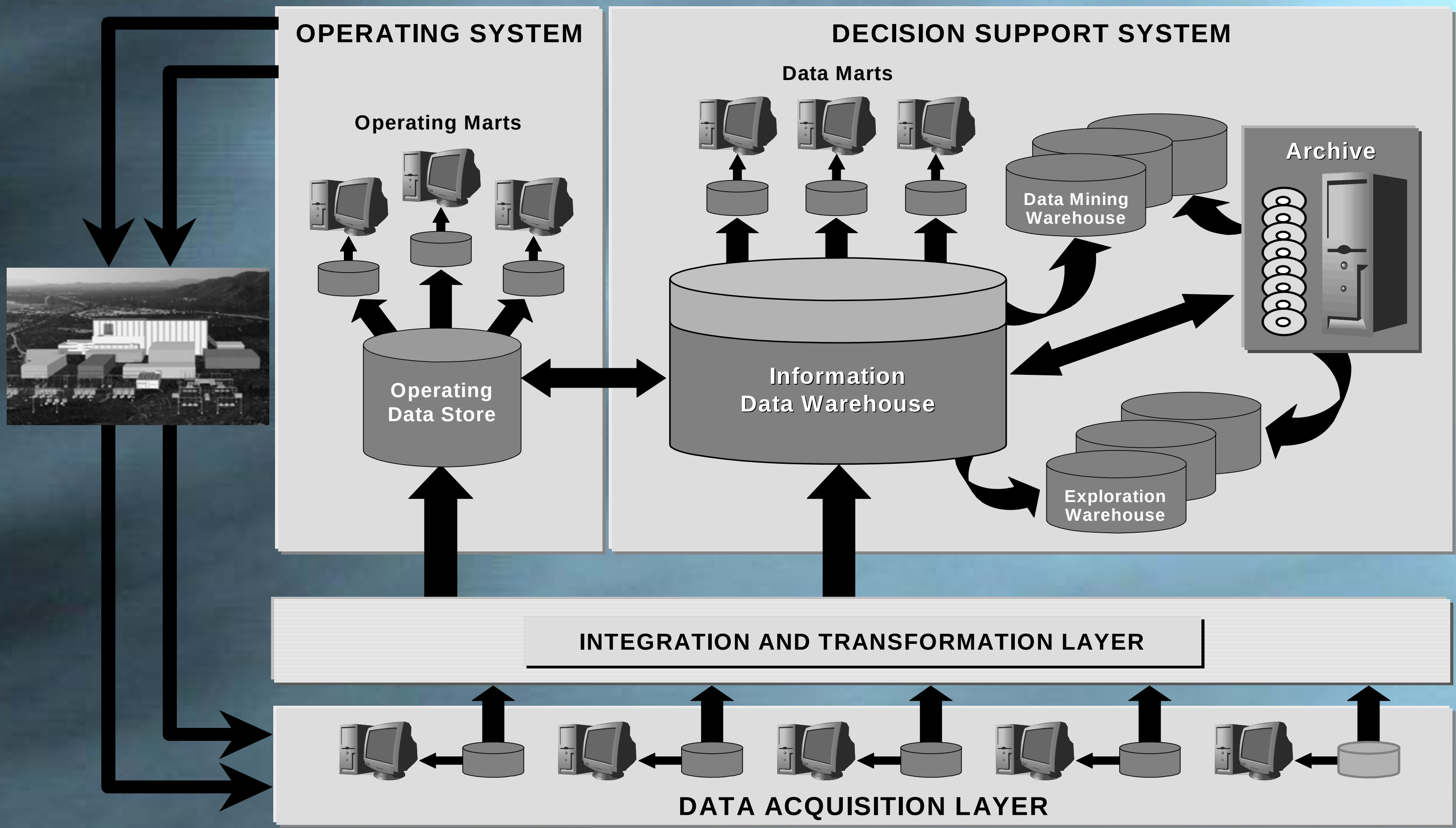
To add grid-aware protocols for:

- **Data navigation and mining**
- **Data exchange**
- **Data search**
- **Event catch**

Schematic data flow in Fusion



A proposal for data storage components of the ITER Information Plant



PARTNERS and Resources for VO

- CIEMAT (Spain) (plus BIFI, UCM, INTA): Kinetic Transpor tand Massive Ray Tracing.
  - 60 + 40 + 30 nodes (Pentium IV with 2,8 Ghz and 512k of Memory)
- Kurchatov (Russia): Stellarator Optimisation.
  - 40 Processors.
- EFDA (European Union) >> International Tokamak Modelling Group (EDGE2D)
  24 processor (12 dual core 64 x 2 Athlon 4600+)1 TB raided disk storage
- KISTI (South Korea). GRID needs foreseen:
  - 1. Internatinal data sharing for KSTAR experiment.
  - 2. Grid computing service for experiment and modelling.
  - 3. Grid-enabled remote control system for remote experiment scheduling, remote experiment monitoring, and remote operation.
- ENEA (Italy).
- CEA (France).

- Possible new Partners: University of Sao Paolo (Brazil)
- Contact with Japan, USA and China Institutes is desirable and possible.

Experience in using and developing Fusion Applications.

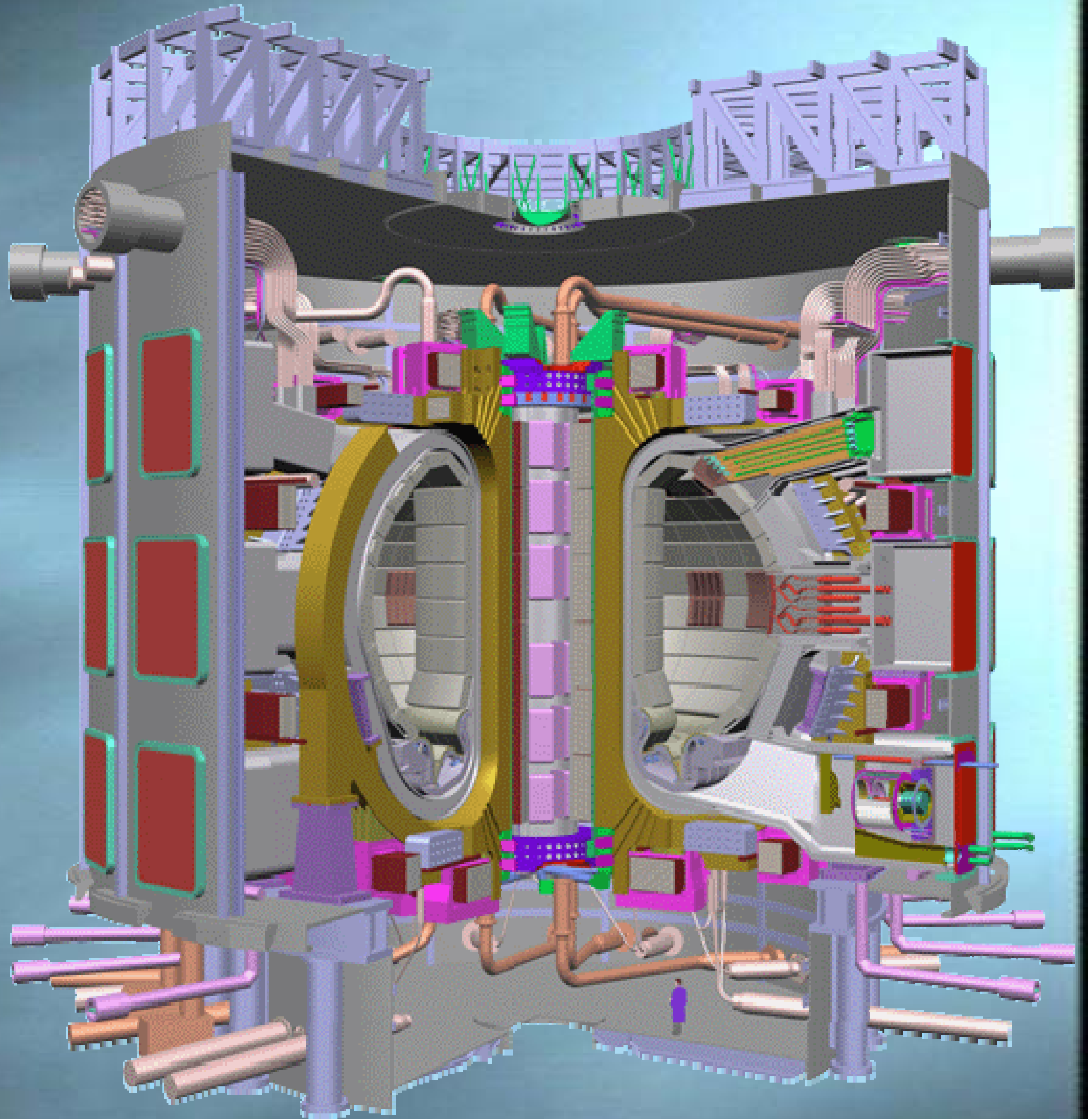
Experience in porting applications and developing Grid Technologies.

Final Remarks

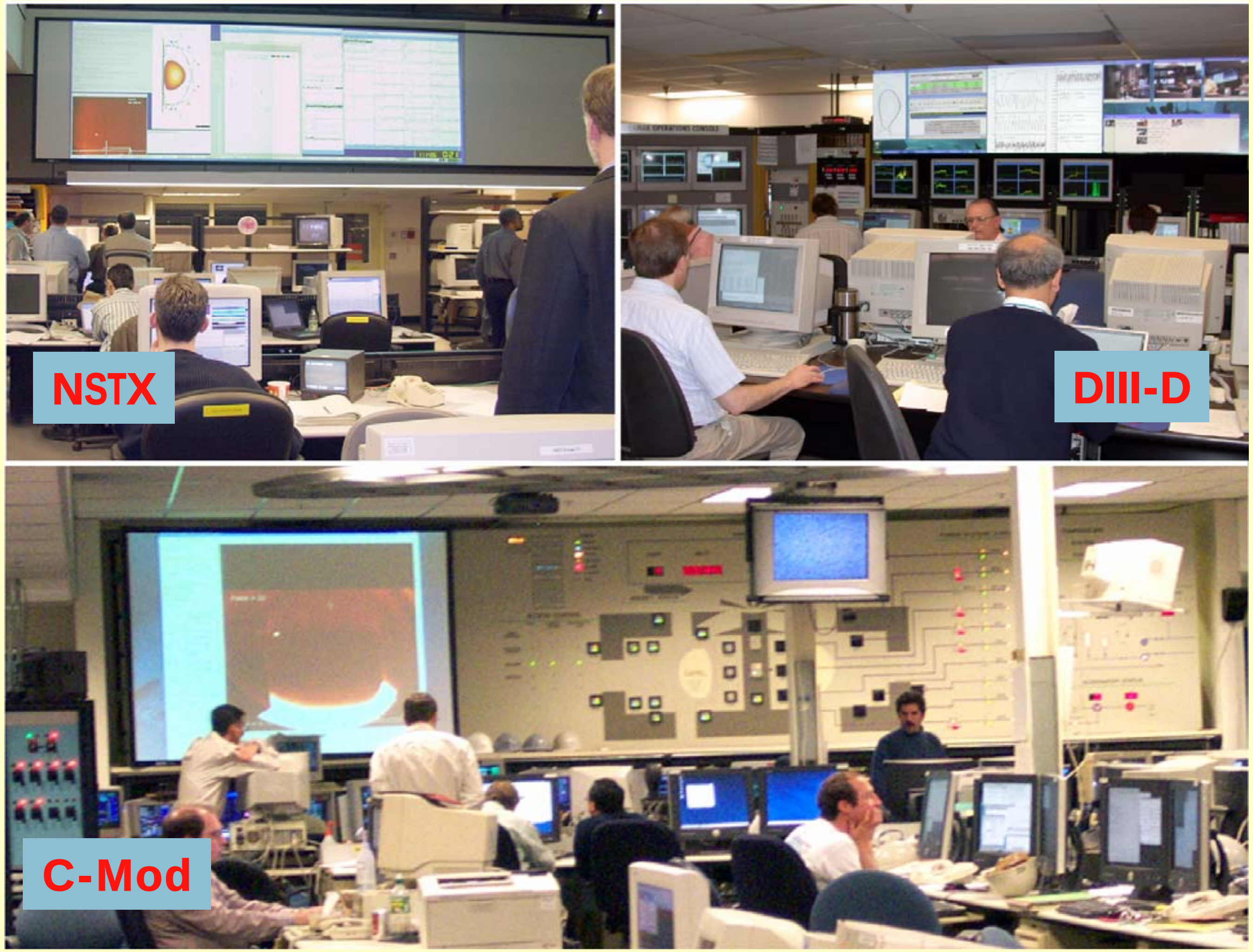
- GRID technologies will enhance Fusion Research: computing and data handling.
- GRID technologies will win visibility when applied to large Fusion Experiments (like ITER).
- Demonstration effect: If Fusion-Grid is succesful, GRID technologies will be extensively used by Fusion Community in the future.

- FIRST APPLICATIONS ARE READY TO RUN IN THE GRID.

Para ver esta película, debe disponer de QuickTime™ y de un descompresor TIFF (LZW).

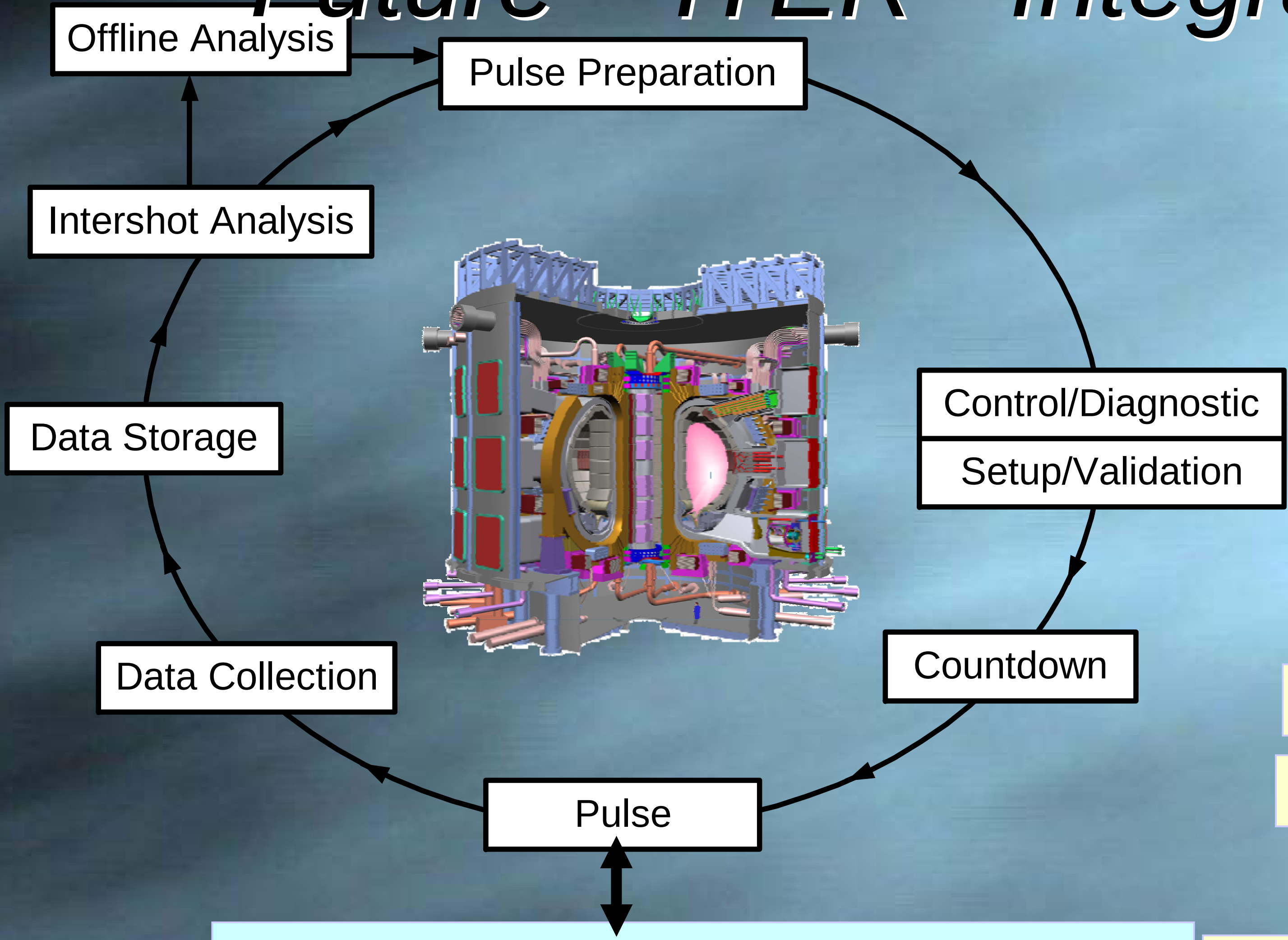


Tiled Wall Displays



- Customized Apps
  - Display Walls
- Sharing to the group
  - Collocated
- Sharing from off-site
  - “See my graph”

Future – ITER - Integration



Off-line analysis: Decisions in real time

- Pulse Preparation
- Simulation
- Modelling
- Data Acquisition
- Real-time control
- Data Analysis
- Data Management
- International Project
- Remote Participation
- IT Security
- Nuclear Registered Site

E-Science and GRID technology