Development of Synthetic Diagnostics for ITER

4^{th} IAEA Technical Meeting on Fusion Data Processing, Validation and Analysis

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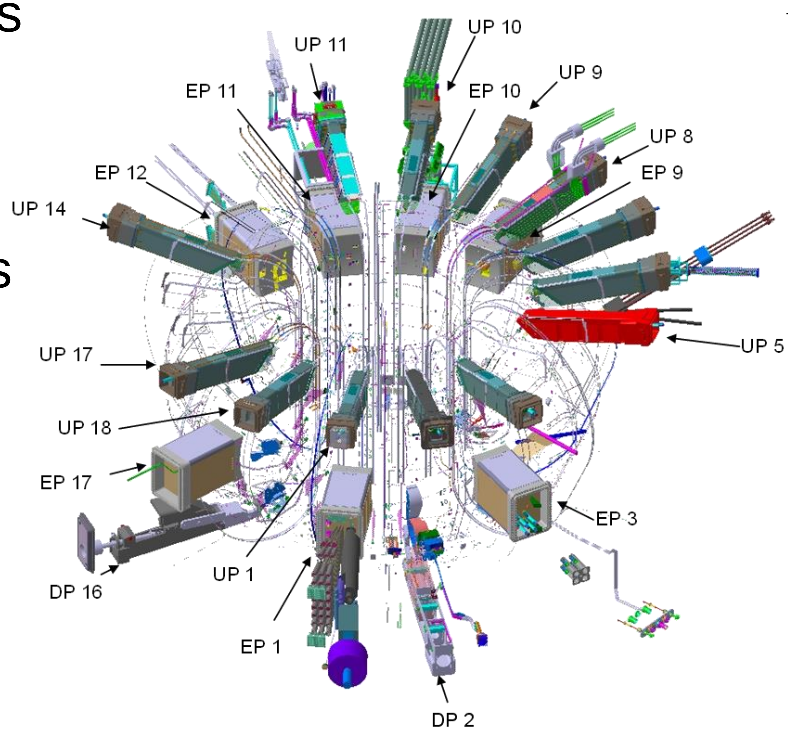
Outline

- Diagnostics in the ITER Research Plan (IRP)
- Synthetic Diagnostics (SD) in IMAS
- Scenario and Machine Description databases
- Examples of Synthetic Diagnostics in IMAS
- Workflows and Bayesian technique platforms
- Summary



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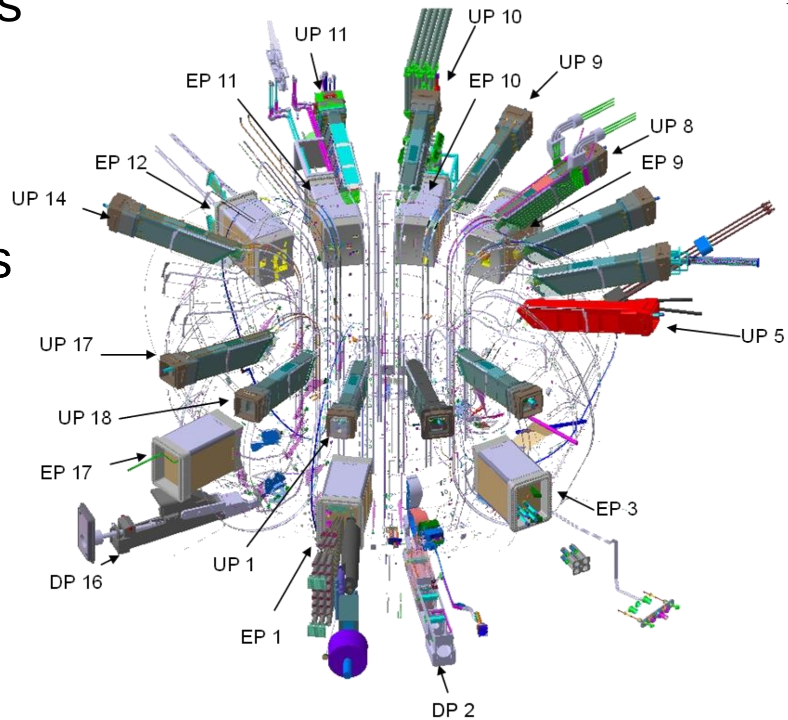


Diagnostics in the ITER Research Plan

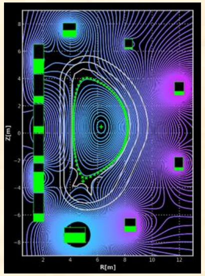
- The ITER Research Plan will unfold in four stages:

First Plasma	Pre-Fusion Power Operation 1 and 2		Fusion Power Operation
18 months **FP**	*18 months* **PFPO-1**	*21 months* **PFPO-2**	*16m periods* **FPO**
H plasmas	**H, ^{4}He plasmas**	**H, ^{4}He plasmas**	**D, DT plasmas**
ECH - 6.7 MW	ECH - 20 (+10) MW	ECH, ICRH, NBI 73 (+10) MW	ECH, ICRH, NBI + fusion 73 (+10) MW + 100 MW
Integrated commissioning of tokamak core components	• Main plant systems commissioning • P_{L-H} determination	• Raise current and power • Increase pulse duration	• Q=10 • Long pulse operation • Burning plasmas
Basic set (magnetics, breakdown, investment protection, density)	Subset for measure-ments of plasma parameters & control	Nearly complete set	Complete set including DT fusion products

ITER (Synthetic) Diagnostics

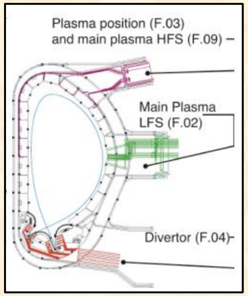
Magnetic Diagnostics

Determination of plasma equilibrium, current and stored energy, control of plasma shape and position



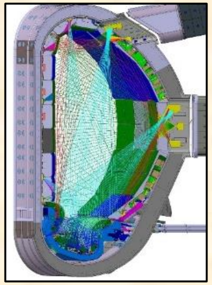
Microwave Diagnostics

Determination of the plasma position, through measurements in the main plasma and divertor **DIP, ECRad, REFI, refractometer**



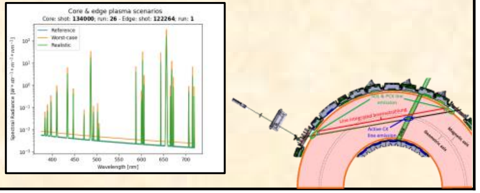
Bolometric Systems

Determination of the spatial distribution of the radiated power in the plasma and divertor using tomographic reconstruction **TOFU_bolo**



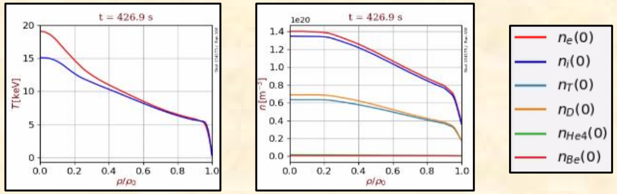
Spectroscopic Instruments and NPA Systems

Determination of plasma composition, density, particle fluxes, ion temperature, fuelling ratio, plasma rotation, current density; **CASPER, CXRS, XICSRT**



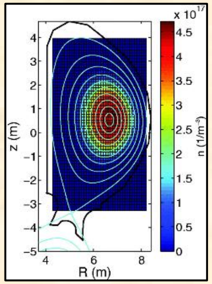
Optical Systems / IR Systems

Measurement of core and edge temperature and density profiles; **TIP, POP**



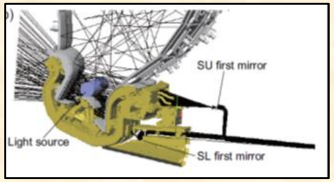
Neutron and Fusion Products Diagnostics

Measurement of fusion power, fusion products and fast ion losses **DNFM, NFM**



Plasma-Facing and Operational Diagnostics

Assist the machine protection and operation, especially the main chamber and divertor state (temperature, pressure, erosion, dust and tritium monitoring)



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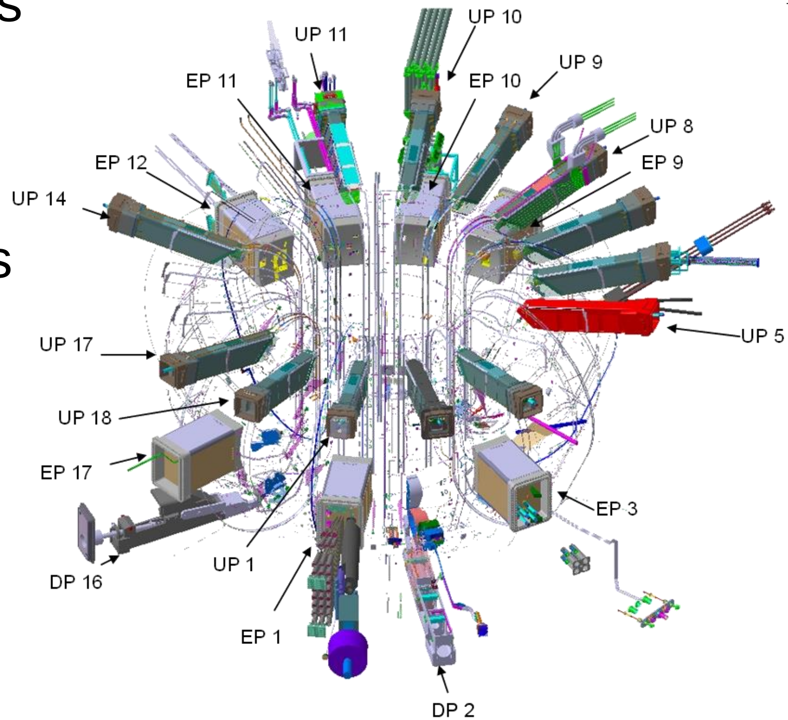
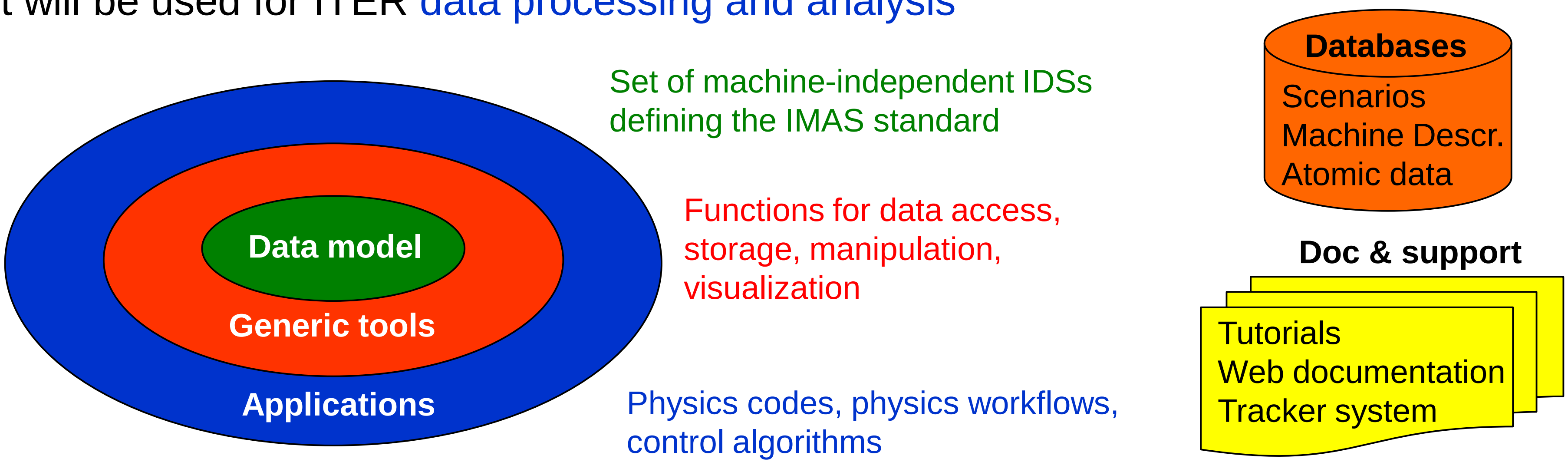


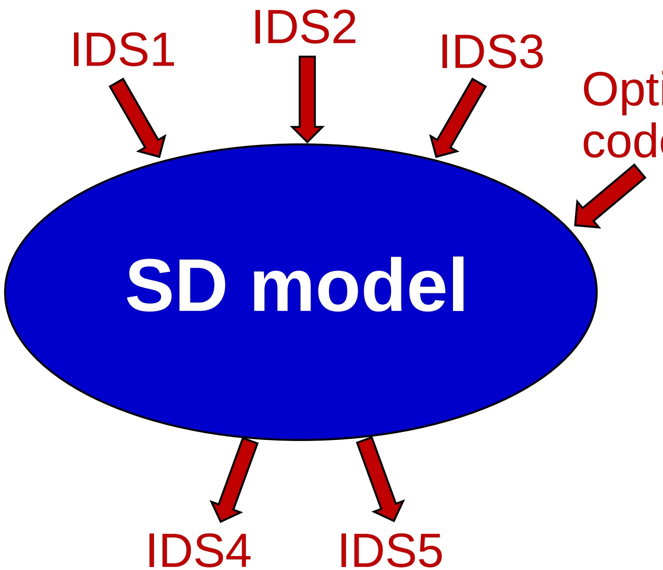
The ITER Integrated Modelling & Analysis Suite (IMAS)

- IMAS is the collection of physics software that will be used to support ITER operations and research as defined in the ITER Integrated Modelling Programme
- It uses standard Interface Data Structures (IDS) for access to experimental and simulated data that are defined in collaboration with the ITER Members
- It is suitable for any fusion device
- It will be capable of high physics-fidelity predictive simulations of ITER plasmas
- It will be used for ITER data processing and analysis



Criteria for SD models in IMAS

- An IMAS model exchanges IDSs exclusively + an optional xml code parameter file:



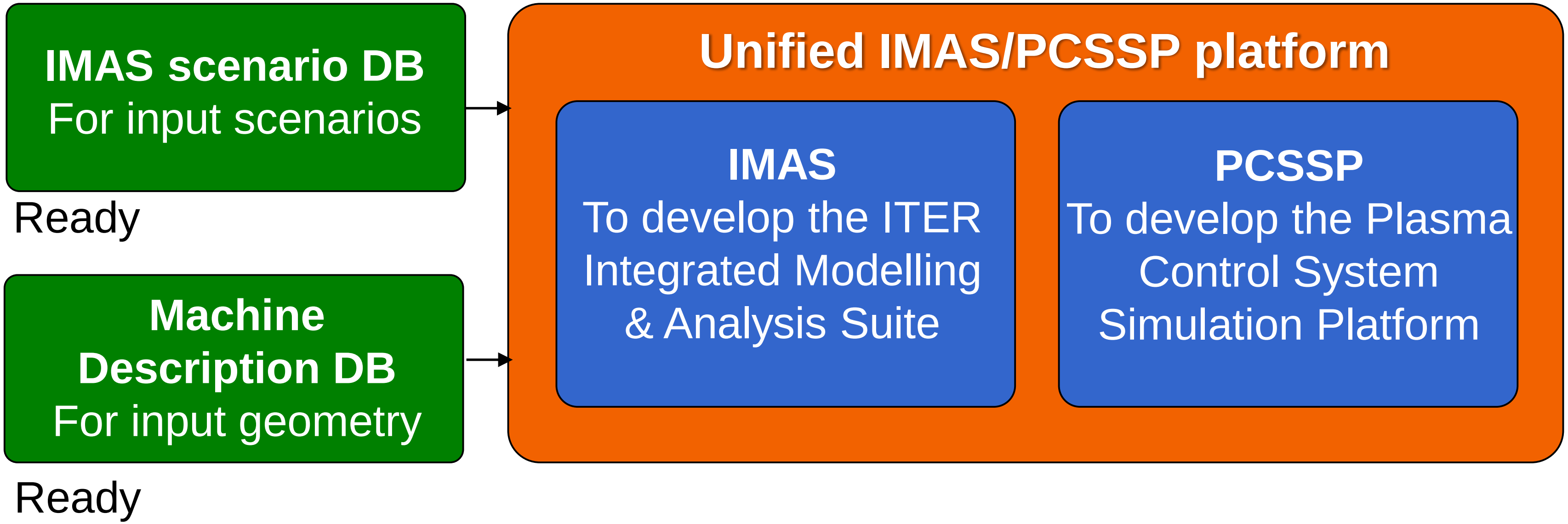
→ Single component that can be integrated into the IMAS framework.

!!! The model should not depend on any other external file (for now we use centralised CAD files to be later included in the Machine Description database)

```
ids4,ids5 = sd_model(ids1,ids2,ids3,xml_codeparam)
```

- Associated development:
  - Extension of the IMAS Data Dictionary (some IDSs are too basic or not existing)
  - Population of the Machine Description DB with the geometry of ITER diagnostics

SD models in IMAS



- Working in the IMAS environment enables better portability and traceability of data
- What will SD models in IMAS be used for?
  - Diagnostic performance assessments (for design & optimisation)
  - Analysis and interpretation software (not specific to ITER)
  - Simulations in which actuators are controlled in response to measurements

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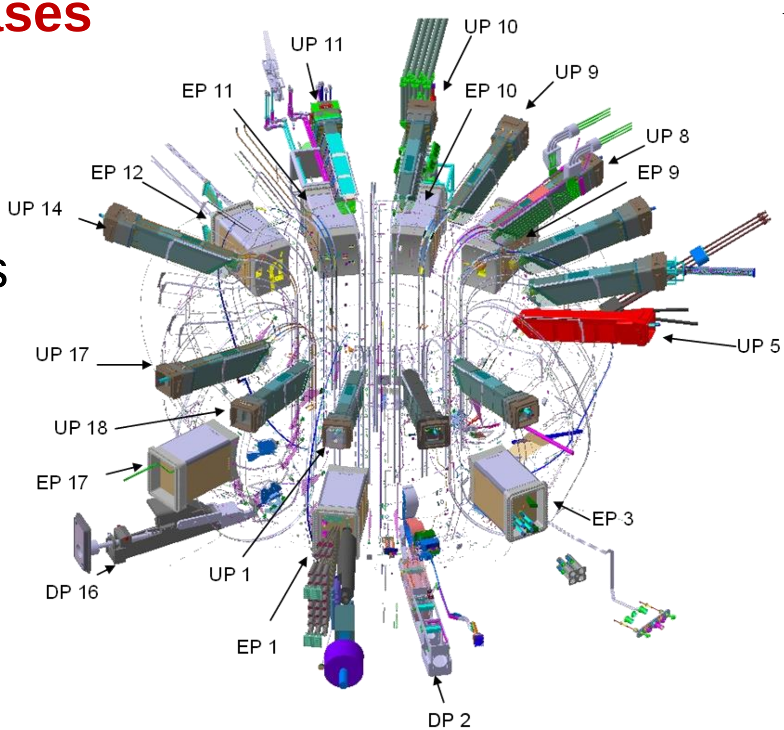
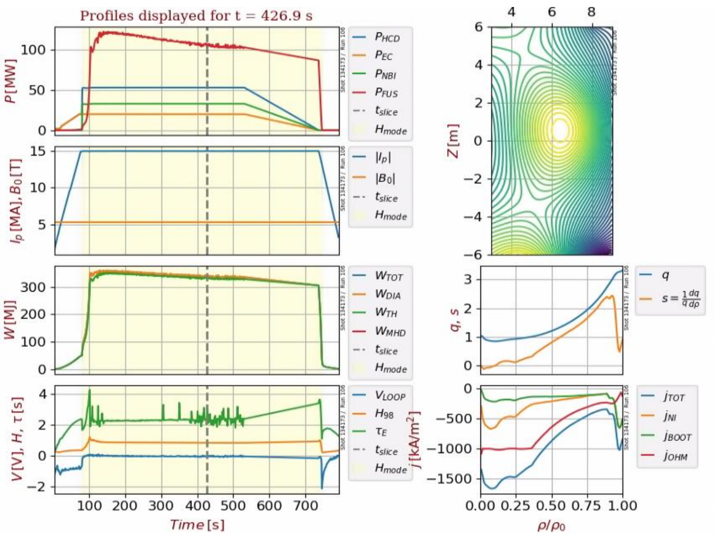


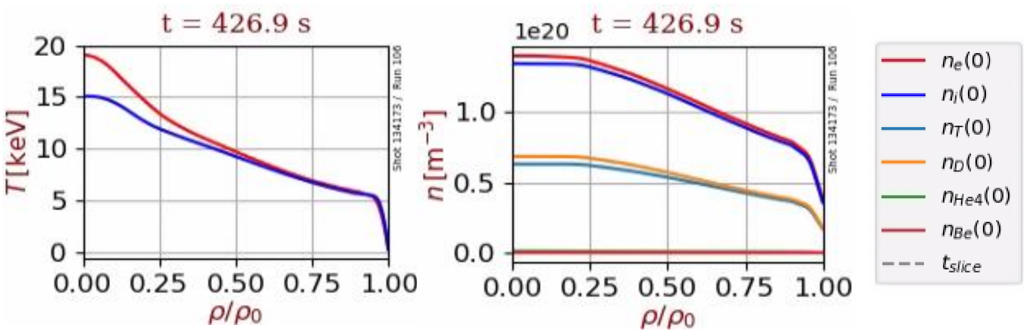
IMAS scenario database

- ~1800 simulations for core and/or edge scenarios, among which 680 are active

```
----> Default call equivalent to:
      scenario_summary -c shot,run,database,ref_name,ip,b0,fuelling,confinement,workflow
------------------------------------------------------------------------------------------------------------------------------
Pulse    Run  Database  Reference                                         Ip[MA]  B0[T]  Fuelling  Confinement      Workflow
------------------------------------------------------------------------------------------------------------------------------
100001  2    ITER      ITER-full-field-H                                  -15.0   -5.3    H         L-mode           METIS
100002  1    ITER      ITER-half-field-H                                  -7.5    -2.65   H         L-mode           METIS
100003  1    ITER      ITER-third-field-H                                 -5.0    -1.8    H         L-H-L            METIS
100007  1    ITER      ITER-intermediate-3T-H                             -8.5    -3.0    H         L-H-L            METIS
100008  1    ITER      ITER-intermediate-3.3T-H                           -9.5    -3.3    H         L-H-L            METIS
100009  1    ITER      ITER-intermediate-4.5T-H                           -12.5   -4.5    H         L-mode           METIS
100013  1    ITER      ITER-PFPO1-1.8T-H                                  -5.0    -1.8    H         L-H-L            METIS
100014  2    ITER      ITER-PFPO2-1.8T-H-0.5*n_GW-NBI_530keV_9.4MW        -5.0    -1.8    H         L-H-L            METIS
100015  1    ITER      ITER-PFPO2-1.8T-H-0.9*n_GW-NBI_745keV_22.3MW       -5.0    -1.8    H         L-H-L            METIS
100501  3    ITER      ITER-nonactive-H                                   -7.5    -2.65   H         L-H-L            CORSICA
100502  3    ITER      ITER-nonactive-H                                   -7.5    -2.65   H         L-H dithering    CORSICA
100503  3    ITER      ITER-nonactive-H                                   -7.5    -2.65   H         L                CORSICA
100504  3    ITER      ITER-nonactive-H                                   -9.6    -3.25   H         L                CORSICA
100505  3    ITER      ITER-nonactive-H                                   -12.7   -4.7    H         L                CORSICA
100506  3    ITER      ITER-nonactive-H                                   -15.0   -5.3    H         L                CORSICA
100507  3    ITER      ITER-nonactive-H                                   -5.0    -1.77   H         L-H-L            CORSICA
101000  50   ITER      PFPO-2 tf=tE,2NBI,highTped,postST                  -7.5    -2.65   H         H-mode           ASTRA
101001  50   ITER      PFPO-2 tf=tE,2NBI,highTped,preST                   -7.5    -2.65   H         H-mode           ASTRA
101002  50   ITER      PFPO-2 tf=tE,2NBI,lowTped,postST                   -7.5    -2.65   H         H-mode           ASTRA
101003  50   ITER      PFPO-2 tf=tE,2NBI,lowTped,preST                    -7.5    -2.65   H         H-mode           ASTRA
101004  60   ITER      PFPO-2 tf=2tE,2NBI                                 -7.5    -2.65   H         H-mode           ASTRA
101005  60   ITER      PFPO-2 tf=tE,2NBI                                  -7.5    -2.65   H         H-mode           ASTRA
101006  60   ITER      PFPO-2 tf=0.5tE,2NBI                               -7.5    -2.65   H         H-mode           ASTRA
101007  40   ITER      PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=2)            -5.0    -1.8    H         H-mode           ASTRA
101007  41   ITER      PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=1)            -5.0    -1.8    H         H-mode           ASTRA
101007  42   ITER      PFPO-2 H-5MA-20EC-10NBI Pr=0.3(tF/tE=0.65)         -5.0    -1.8    H         H-mode           ASTRA
```

DINA-JINTRAC free boundary core-edge ITER DT scenario 15 MA / 5.3 T



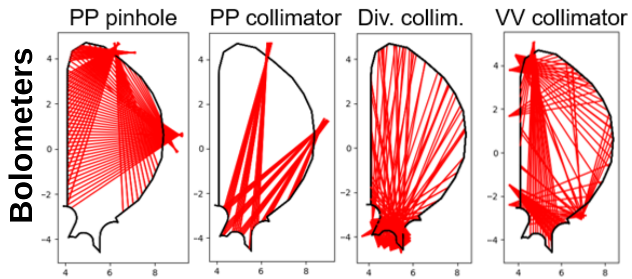


Tools are available to list (`scenario_summary`) and visualise (`scenplot`, `kinplot`, etc.) all available simulations in the scenario database.

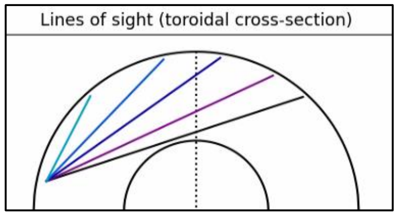
IMAS Machine Description database

- Machine Description available for H&CD systems, many diagnostics, wall, magnetics and coils:

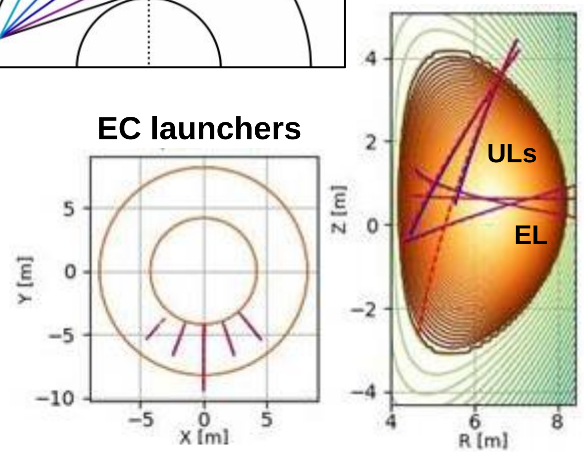
```
----> Default call equivalent to:
      md_summary -c pbs,ids,description
-----------------------------------------------------------------------------------------------------------------------------
PBS            IDS                           DESCRIPTION                                                           SHOT/RUN
-----------------------------------------------------------------------------------------------------------------------------
PBS-55.E5      spectrometer_x_ray_crystal    Core X-Ray Spectrometer (XRCS)                                        150505/1
PBS-11         pf_active                     PF/CS Coil System                                                     111001/1
PBS-11         tf                            TF Coil System                                                        111002/1
PBS-11         coils_non_axisymmetric        Ex-Vessel Coils (EVC) Systems (CC)                                    111003/1
PBS-15         coils_non_axisymmetric        In-Vessel Coils (IVC) Systems (ELM)                                   115001/1
PBS-15         coils_non_axisymmetric        In-Vessel Coils (IVC) Systems (ELM periodic)                          115002/1
PBS-15         coils_non_axisymmetric        In-Vessel Coils (IVC) Systems (VS)                                    115003/1
PBS-55.D1      bolometer                     PP pinholes and collim., Div. collim., VV collim. (550 channels)      150401/2
PBS-55.EC      spectrometer_visible          Charge Exchange Recombination Spectroscopy (CXRS) Edge                150512/2
PBS-55.E1      spectrometer_visible          Charge Exchange Recombination Spectroscopy (CXRS) Core                150501/2
PBS-55.EF      spectrometer_visible          Charge Exchange Recombination Spectroscopy (CXRS) Pedestal            150515/2
PBS-52         ec_launchers                  Electron Cyclotron (EC) launchers                                     120000/1
PBS-55.F1      ece                           Electron Cyclotron Emission (ECE) - Radial O-mode                     150601/1
PBS-55.F1      ece                           Electron Cyclotron Emission (ECE) - Radial X-mode                     150601/2
PBS-55.F1      ece                           Electron Cyclotron Emission (ECE) - Oblique O-mode                    150601/3
PBS-55.F1      ece                           Electron Cyclotron Emission (ECE) - Oblique X-mode                    150601/4
PBS-51         ic_antennas                   Ion Cyclotron (IC) antennas                                           110000/1
PBS-55.C5      interferometer                Toroidal Interfero-Polarimeter (TIP)                                  150305/1
PBS-55.FA      interferometer                Density Interfero-Polarimeter (DIP)                                   150610/1
PBS-55.A*      magnetics                     AD,AE,AF,AH,AI,A3,A4,A5,A6,AA,AB,AJ,AL,A9,AC,AG,AP magnetic systems   150100/3
PBS-53         nbi                           Heating Neutral Beams (HNB) - H beams 870 keV - off-off               130000/1201
PBS-53         nbi                           Heating Neutral Beams (HNB) - H beams 870 keV - off-on                130000/1301
PBS-53         nbi                           Heating Neutral Beams (HNB) - H beams 870 keV - on-on                 130000/1501
PBS-53         nbi                           Heating Neutral Beams (HNB) - D beams 1 MeV - off-off                 130000/2201
PBS-53         nbi                           Heating Neutral Beams (HNB) - D beams 1 MeV - off-on                  130000/2301
PBS-53         nbi                           Heating Neutral Beams (HNB) - D beams 1 MeV - on-on                   130000/2501
PBS-53         nbi                           Diagnostic Neutral Beam (DNB) - on-axis                               130000/3201
PBS-53         nbi                           Diagnostic Neutral Beam (DNB) - off-axis                              130000/3101
PBS-55.C6      polarimeter                   Poloidal Polarimeter (POP)                                            150306/1
PBS-55.F9.40   refractometer                 Sub-system refractometer of HFS reflectometer                         150609/401
PBS-55.E6      spectrometer_visible          Visible Spectroscopy Reference System (VSRS)                          150506/2
PBS-16         wall                          First wall and divertor geometry for PFPO and FPO phases              116000/2
PBS-16.FC      wall                          First Plasma Protection Components (FPPC)                             116612/1
-----------------------------------------------------------------------------------------------------------------------------
```



Toroidal Interfero-Polarimeter



EC launchers



- The MD database provides the geometry of the plant systems to be used as input of simulation codes.

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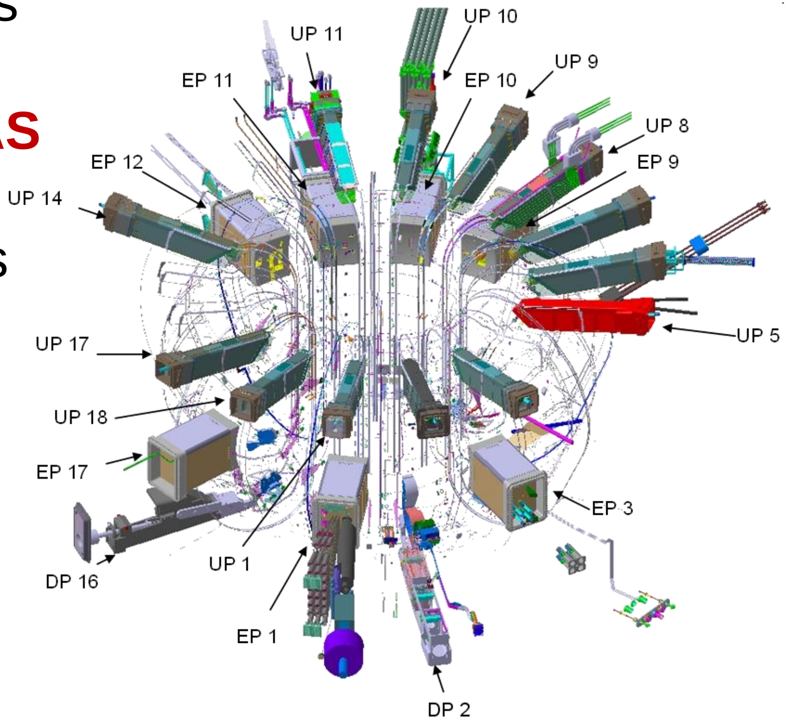
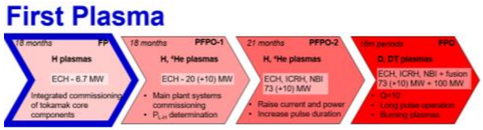
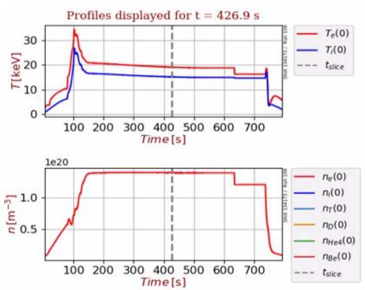


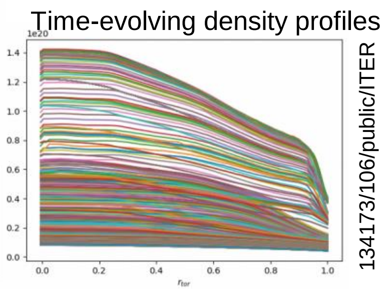
Examples of IMAS-adapted Synthetic Diagnostics for ITER

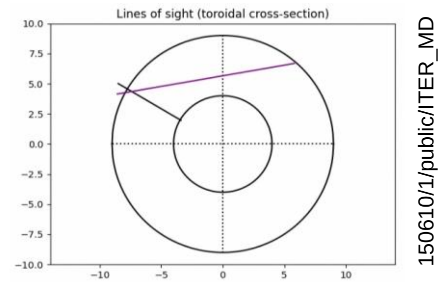
Model	Modelled diagnostic or signal	Input IDSs from scenario	Input IDSs from Machine Description or upstream code	Output IDSs
CASPER	Generic light spectrum for visible spectrometry	equilibrium core_profiles edge_profiles	spectrometer_visible nbi	spectrometer_visible
CXRS	Fit to create synthetic CXRS signal from spectrum	-	spectrometer_visible	charge_exchange
DIP_TIP_POP	Toroidal Interfero-Polarimeter Density Interfero-Polarimeter	equilibrium core_profiles	interferometer	interferometer
	Poloidal Polarimeter		polarimeter	polarimeter
ECRad	Electron Cyclotron Emission	equilibrium core_profiles	ece	ece
REFI	LFS and HFS reflectrometers	equilibrium core_profiles	reflectometer_profile	reflectometer_profile
Refractometer	Refractometry channel of the HFS reflectometer	equilibrium core_profiles	refractometer	refractometer
TOFU_bolo	Bolometers	edge_sources wall	bolometer	bolometer
DNFM	Divertor Neutron Flux Monitor	equilibrium distribution_sources	neutron_diagnostic	neutron_diagnostic
NFM	Neutron Flux Monitor	equilibrium distribution_sources	neutron_diagnostic	neutron_diagnostic
XICSRT	X-ray Core diagnostic	equilibrium core_profiles	spectrometer_x_ray_crystal	spectrometer_x_ray_crystal

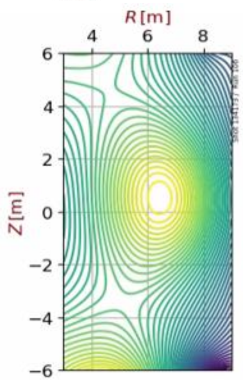
- 55.FA Density Interfero-Polarimeter (DIP), measures $\int n_e dl$
- Python model by A. Medvedeva → see her talk later in this session











Scenario DB

equilibrium

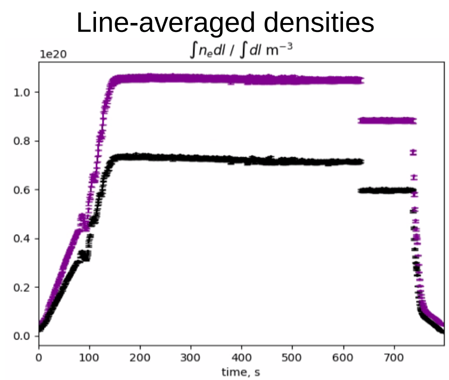
core_profiles

Machine Descr. DB

interferometer

DIP model

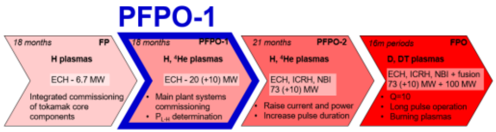
interferometer

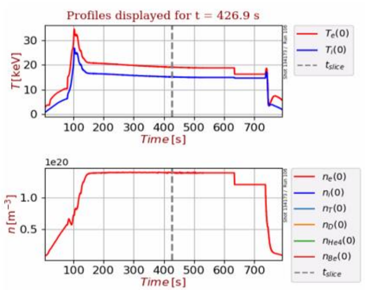


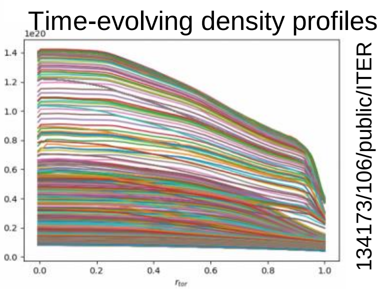

```
out_interferometer = dip_tip_pop(equilibrium,core_profiles,interferometer_md)
```

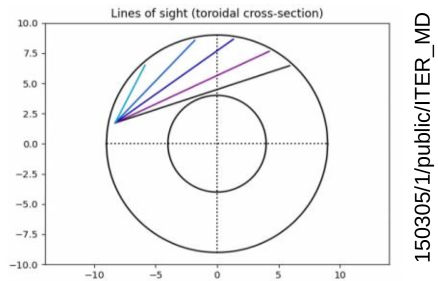
Toroidal Interfero-Polarimeter

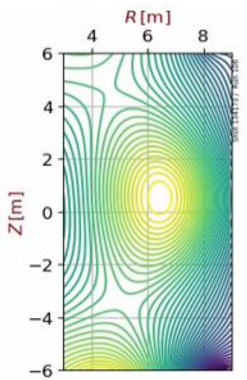
- 55.C5 Toroid. Interfer. Polarim. (TIP), measures $\int n_e dl,\ \delta n_e/n_e,\ \delta T_e/T_e$
- Python model by A. Medvedeva → see her talk later in this session









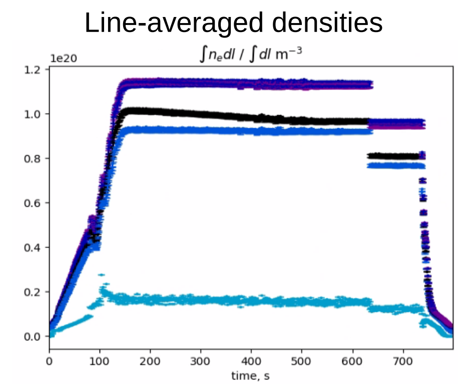


Scenario DB
- core_profiles
- equilibrium

Machine Descr. DB
- interferometer

TIP model

interferometer




```
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```
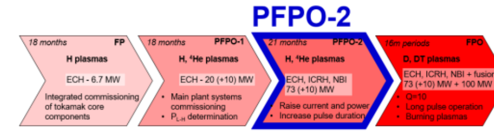
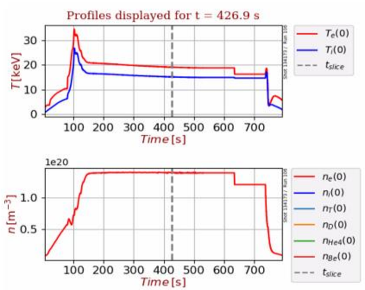
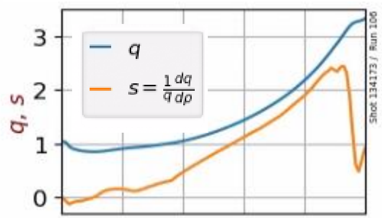
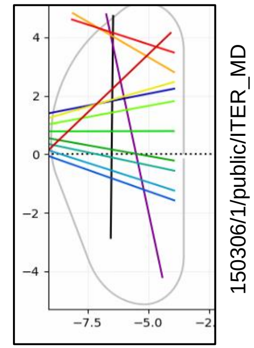

Poloidal Polarimeter

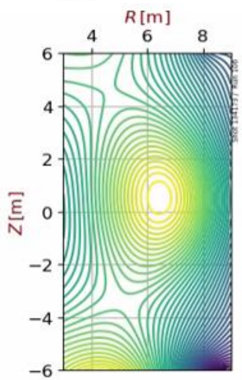
- 55.C6 Poloid. Polarim. (POP), measures q profile
- Python model by A. Medvedeva → see her talk later in this session

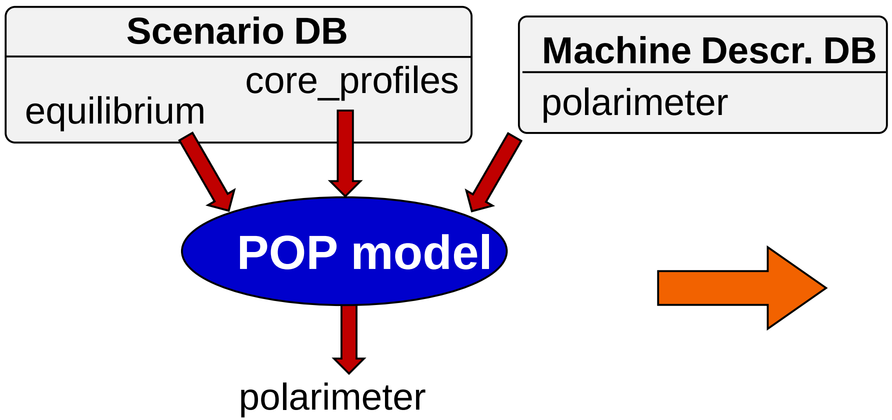


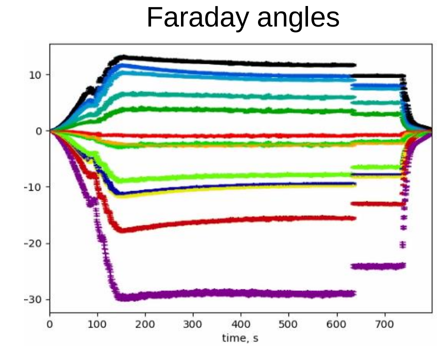








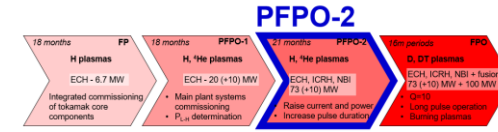


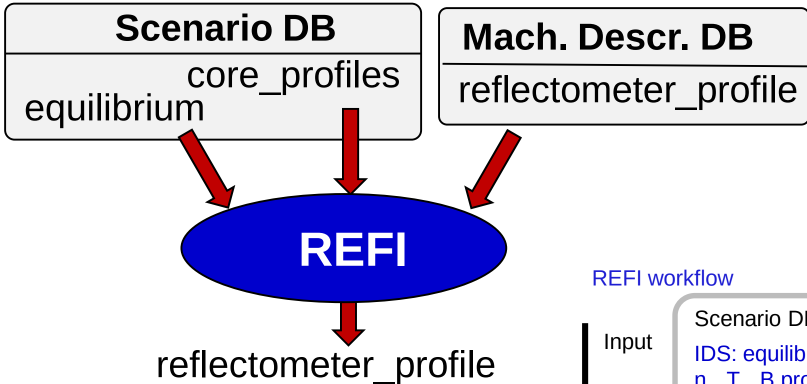



```
out_polarimeter = dip_tip_pop(equilibrium,core_profiles,polarimeter_md)
```

Reflectometry

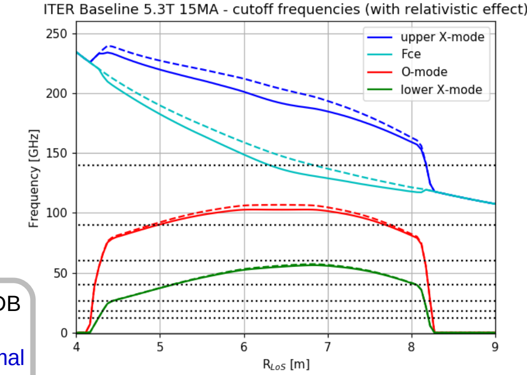
- 55.F9 (HFS) and 55.F2 (LFS)
- Measure core/edge n_e profiles, $\delta n_e/n_e$, $\delta T_e/T_e$
- REFI model developed by V. Nikolaeva



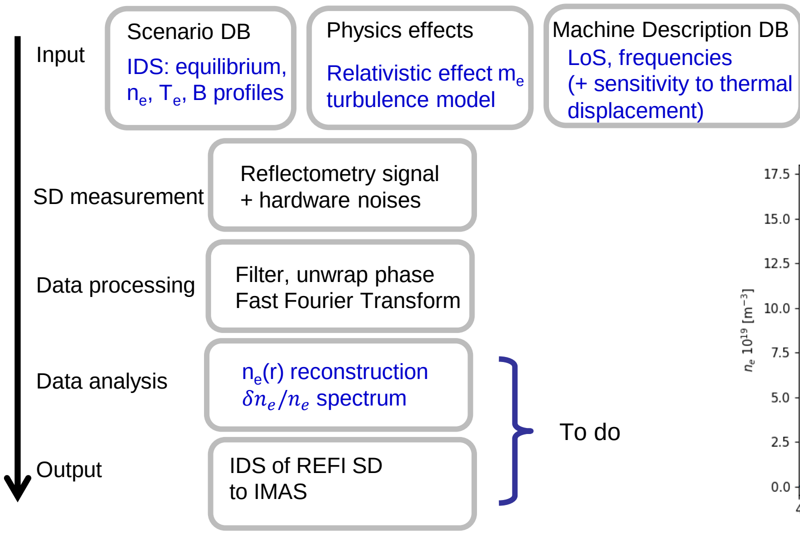


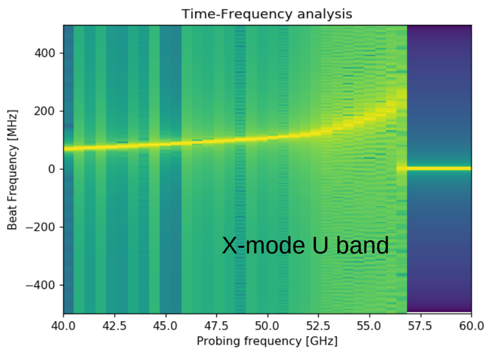
GHz O-mode
F: 90 - 140
E: 60 - 90
U: 40 - 60
Ka: 26.5 - 40
K: 18 - 26.5
Ku: 12 - 18
X-mode

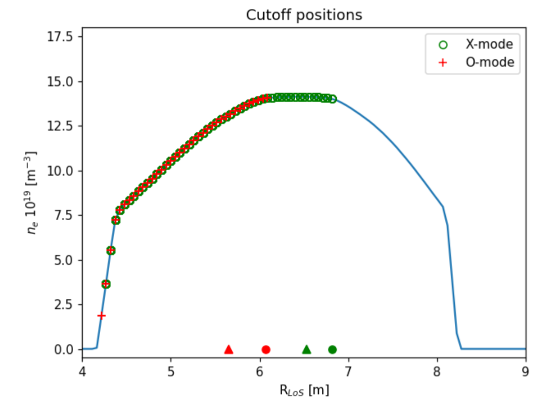
Input: shot 134173, run 106, time slice 296.9 s



REFI workflow





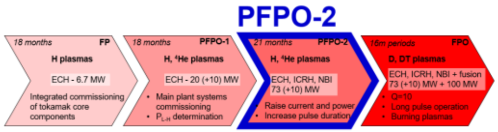


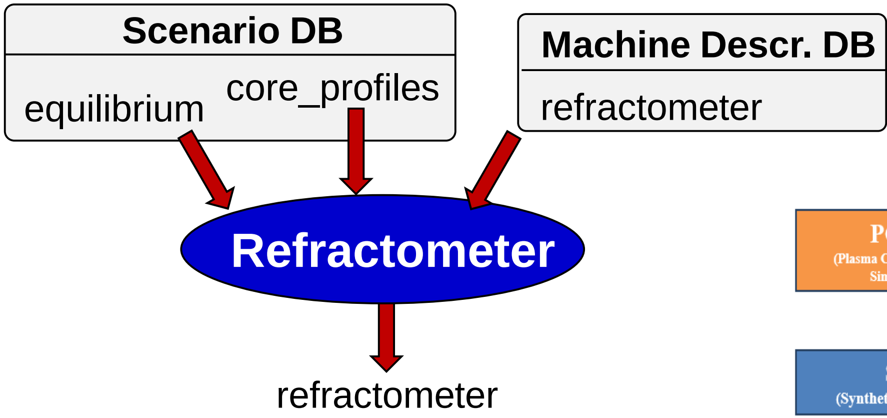
- Beat frequency → tof delay → radial locations
- Probing frequency → density

Refractometer

- 55.F9.40: refractometry channel of HFS reflectometer
- Measures $\int n_e dl$ (supplementary)

→ Python model developed by K. Afonin





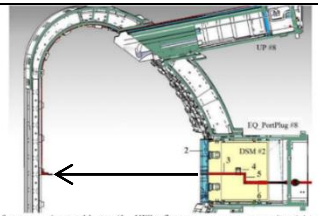
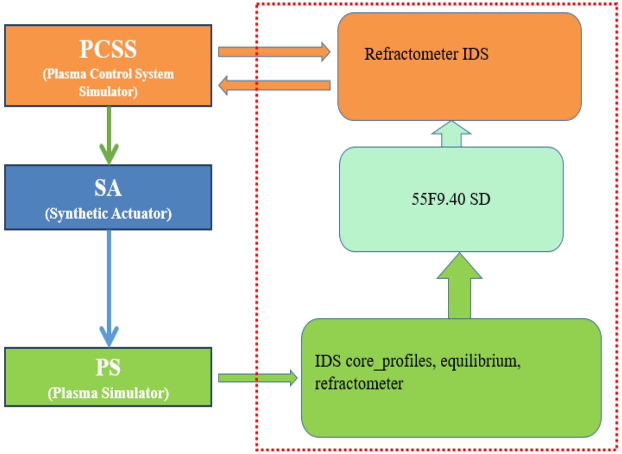
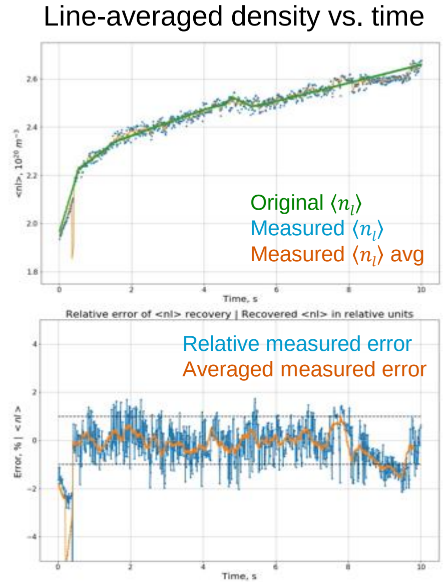


Fig. 6.6. Refractometer in-vessel layout (1 – HFS reflectometer antenna system (receiving antenna for refractometer); 2 – DFW (Diagnostic First Wall); 3 – Transmitting antenna; 4 – Support; 5 – Dog leg; 6 – Horns).





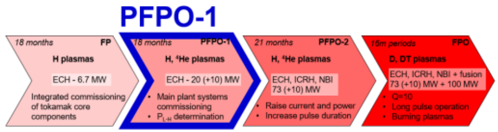
- Model used for basic machine control
- Integrated into DINA PCS workflow

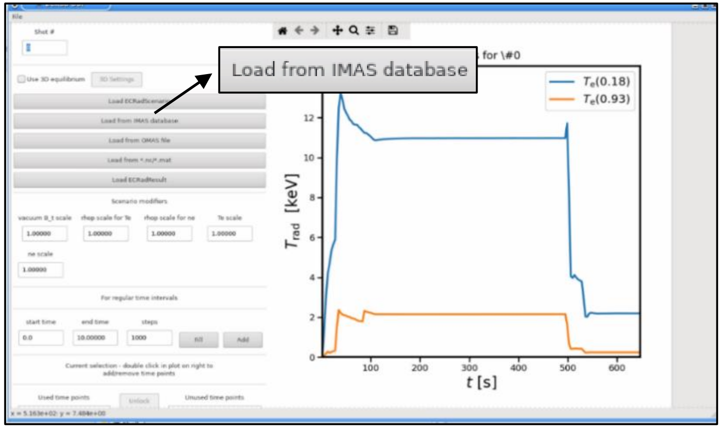
```
refractometer = sd.slice_xml_wrapper(equilibrium,core_profiles,refractometer,xml_filename)
```

ECE synthetic diagnostic for ITER with ECRad

- 55.F1 Electron Cyclotron Emission (ECE)
- Measures T_e profile and $\delta T_e / T_e$
- ECRad model developed by S. Denk, adapted to IMAS with A. Medvedeva

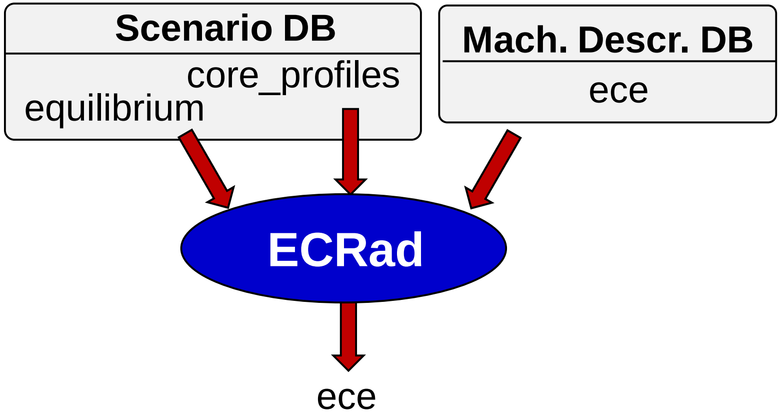
  → Cf. talk by S. Denk, this session.
- First tests for 1.8 T and 2.65 T PFPO scenarios done to predict the ECE system operation and radial resolution



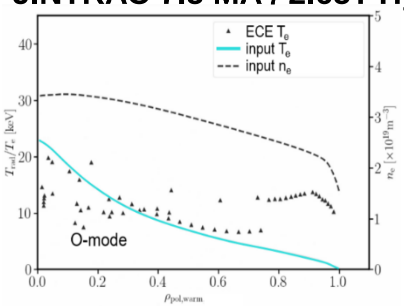


[S.S. Denk, CPC 2020]

(radial and oblique ECE channels 123-353 GHz, O- and X-mode)



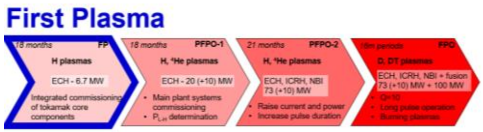
JINTRAC 7.5 MA / 2.65T Hydrogen

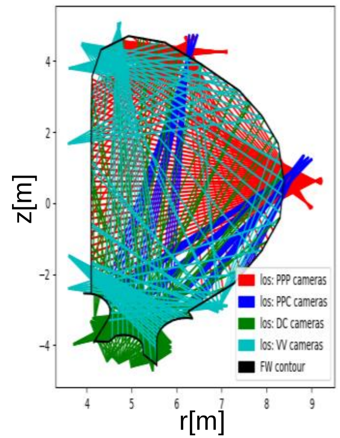


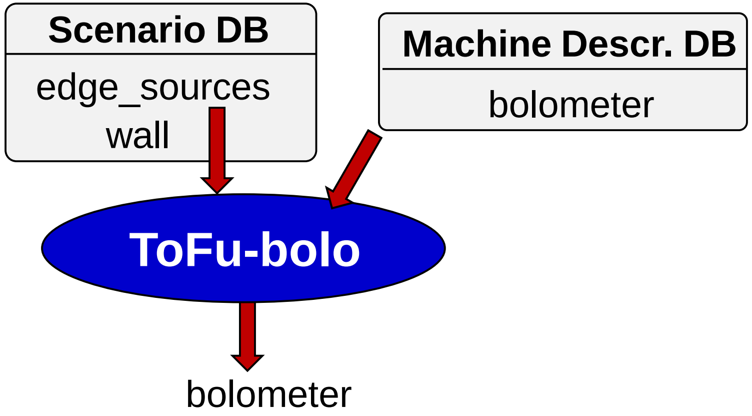
[A. Medvedeva et al., AAPPS-DPP2021]

Bolometers

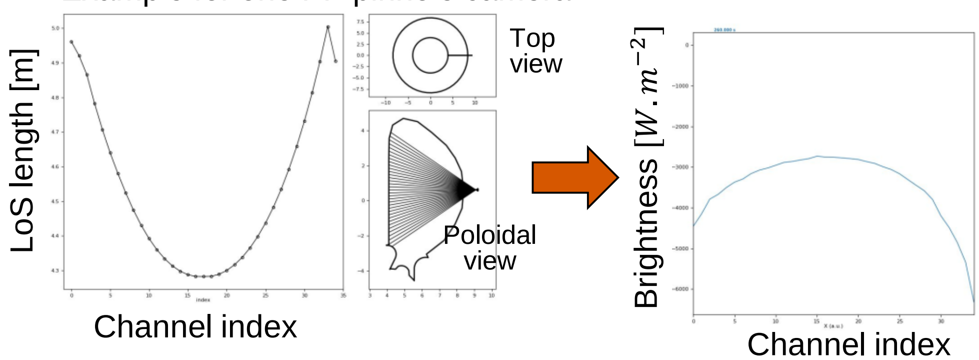
- 55.D1: bolometers, measure radiated power (total + profiles)
- Model using ToFu developed by D. Vezinet: Open Source Python library natively IMAS-compatible, made for SDs and tomography for Fusion
- Forward model and tomographic reconstruction of bolometers using CHERAB, TOFU and TOMOTOK, by M. Brank







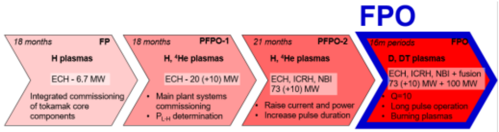
Example for one PP pinhole camera

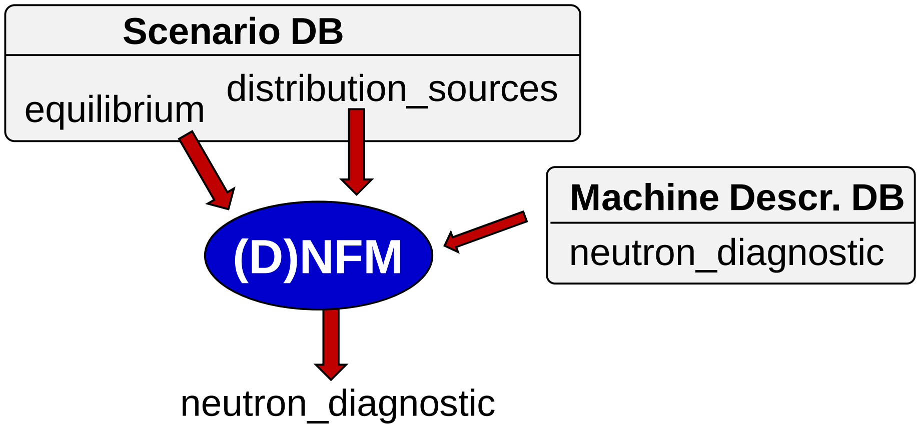


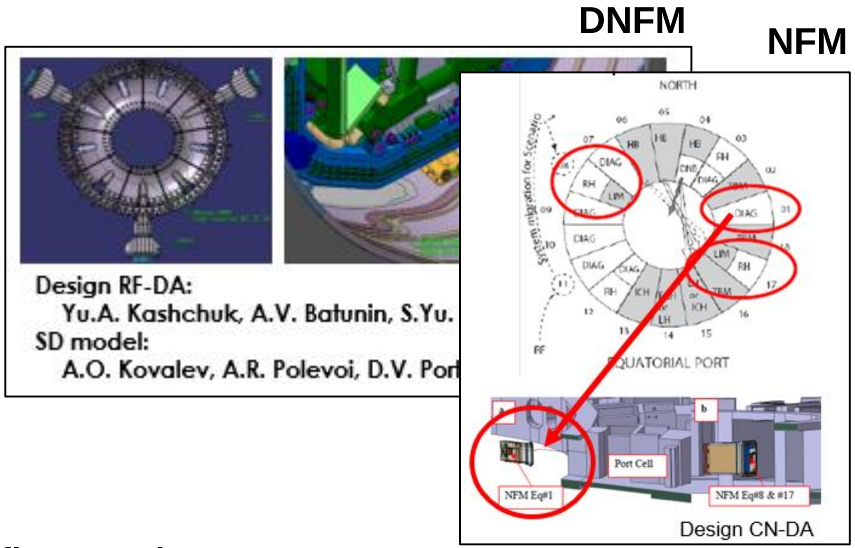

```
bolometer_sd = tofu_bolo(edge_sources, wall, bolometer_md, xml_codeparam)
```

(Divertor) Neutron Flux Monitors

- 55.BC: DNFM developed by A. Kovalev
- Fortran and Python versions, all in IMAS

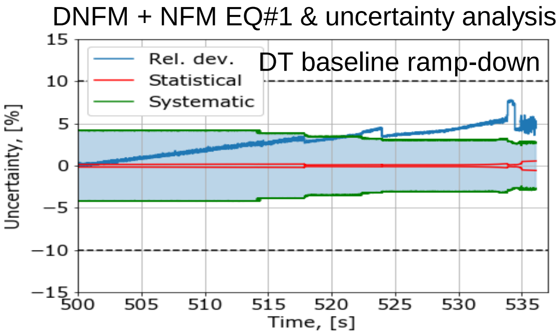




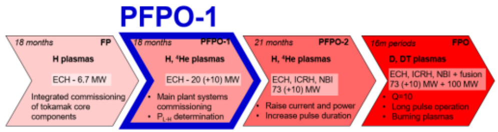


- 55.B4: NFM developed by A. Kovalev
- DNFM and NFM measure the total neutron flux and fusion power:
  - DNFM more sensitive to vertical plasma shift
  - NFM more sensitive to horizontal plasma shift

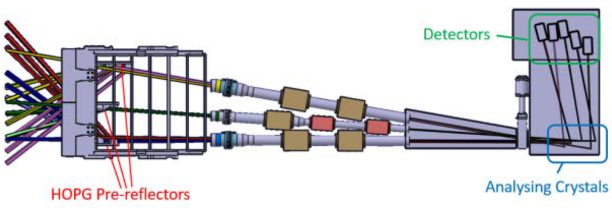
→ To be combined to deliver a measurement with less systematic error.

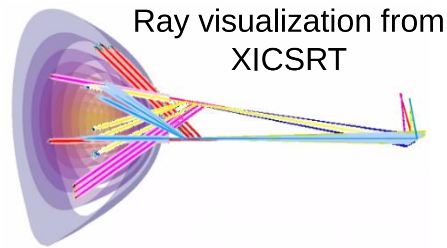


X-Ray Crystal Spectrometer Core



- 55.E5 X-Ray Crystal Spectrometer Core, measures T_i and v_{tor}
- XICSRT python code developed by N. Pablant, IMAS-adapted by E. Bourcart and Z. Cheng





Ray visualization from XICSRT

Spectrometer_x_ray_crystal IDS

Geometry | Instrument function | Output signal

XRSA
XICSRT

SpectraSim
x_ray_matrix_signal
Minerva XICS

Scenario DB

equilibrium | core_profiles

Machine Description DB

spectrometer_x_ray_crystal

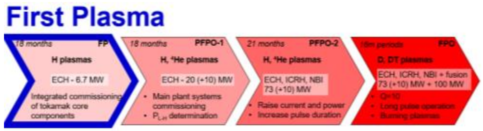
XICSRT

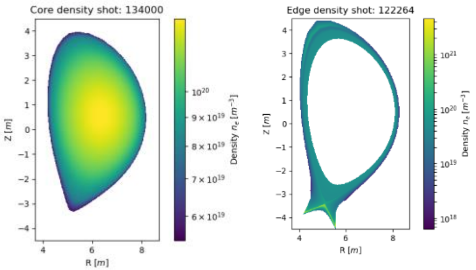
spectrometer_x_ray_crystal

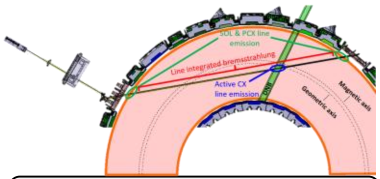
- Ray-tracing codes (on-going comparison):
  - XICSRT (Python, N. Pablant)
  - XRSA (Matlab, Z. Cheng)
- Output signal computed from RTM:
  - SpectraSim (Matlab, Z. Cheng)
  - x_ray_matrix_signal (Python, E. Bourcart)
  - Minerva XICS (Java, A. Langenberg)

Visible Light Spectrum

- CAmera & SPectroscopy Emission Ray-tracer: generates the light spectrum for visible spectroscopy and cameras synthetic diagnostics







Scenario DB
- core_profiles
- equilibrium
- edge_profiles

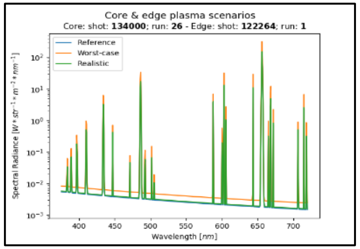
Mach. Descr. DB
- spectrometer_visible
- nbi

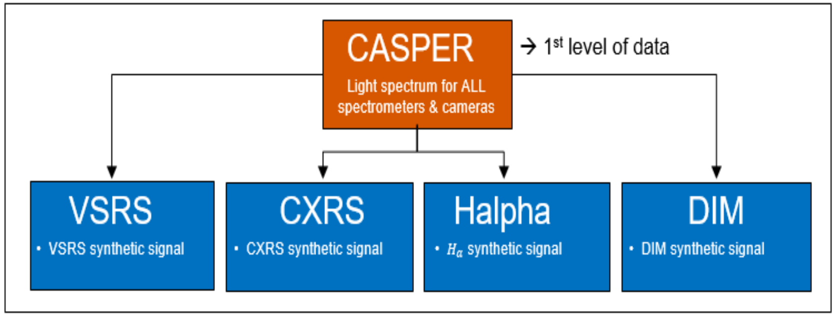
↓ ↓ ↓

CASPER

↓

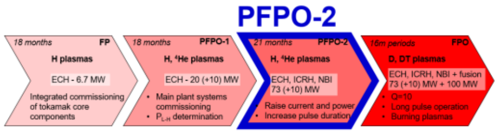
spectrometer_visible



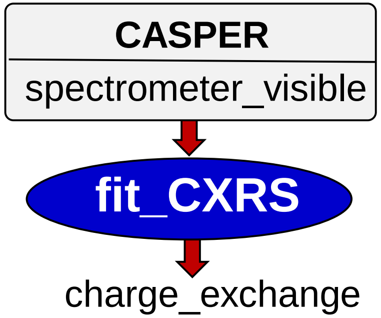


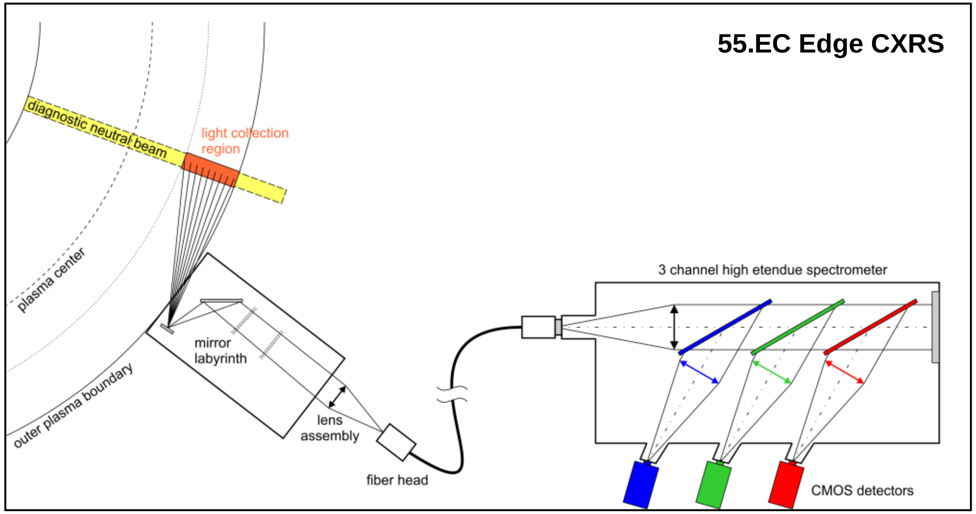
- Current status:
  - CASPER provides light spectrum for VSRS and CXRS
  - H-alpha and Divertor Impurity Monitor to be added (with RTM calculation)

Charge Exchange Recombination Spectroscopy

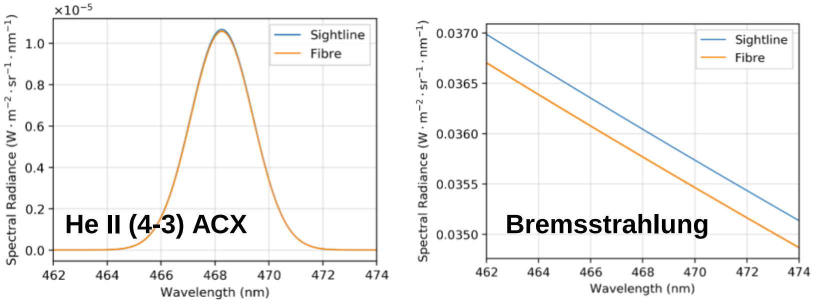


- 55.E1 / 55.EC / 55.EF Core / Edge / Pedestal Charge Exchange Recombination Spectroscopy
- Measure T_i, Z_{eff}, He, impurity profiles, toroidal and poloidal rotation
- Python fit_CXRS model developed by A. Shabashov: → reconstruct plasma parameters from spectrum fit



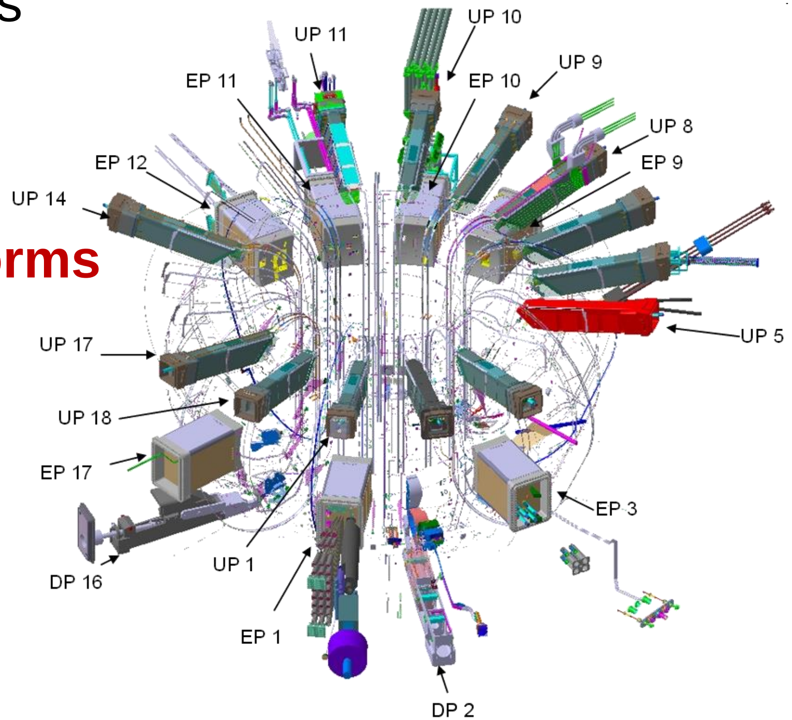


- On-going comparison between sightline and simplified fibre source models

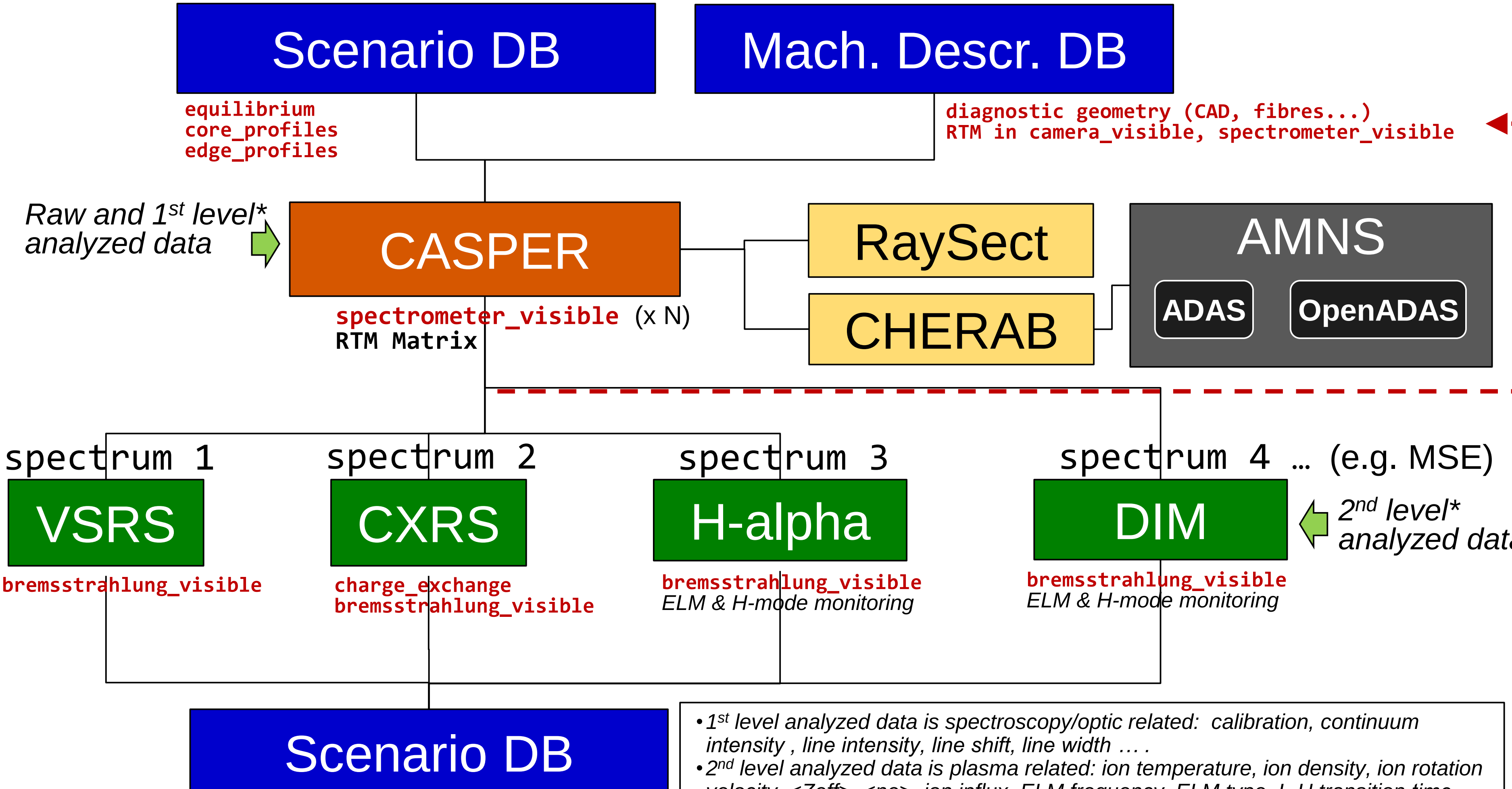


Outline

- Diagnostics in the ITER Research Plan (IRP)
- Synthetic Diagnostics (SD) in IMAS
- Scenario and Machine Description databases
- Examples of Synthetic Diagnostics in IMAS
- **Workflows and Bayesian technique platforms**
- Summary

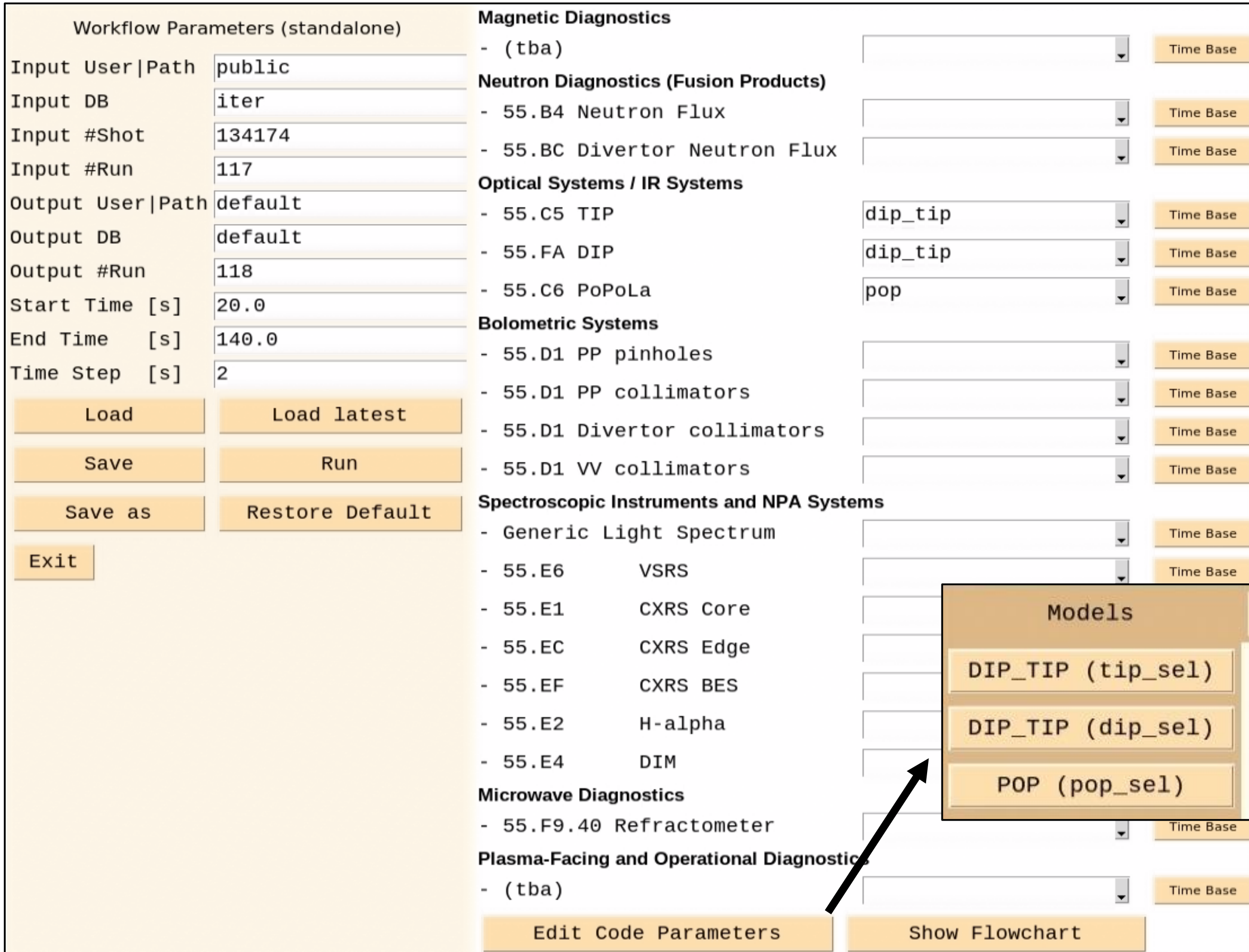


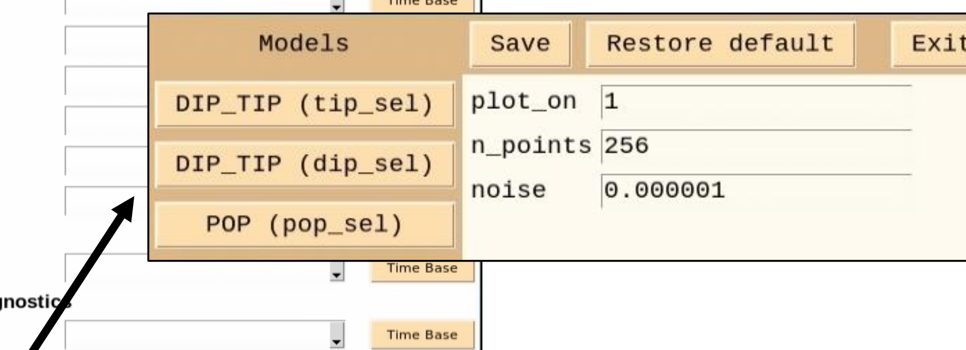
Workflow for Spectrometry Modelling



- *1st level analyzed data is spectroscopy/optic related: calibration, continuum intensity , line intensity, line shift, line width … .*
- *2nd level analyzed data is plasma related: ion temperature, ion density, ion rotation velocity, <Zeff>, <ne>, ion influx, ELM frequency, ELM type, L-H transition time …*

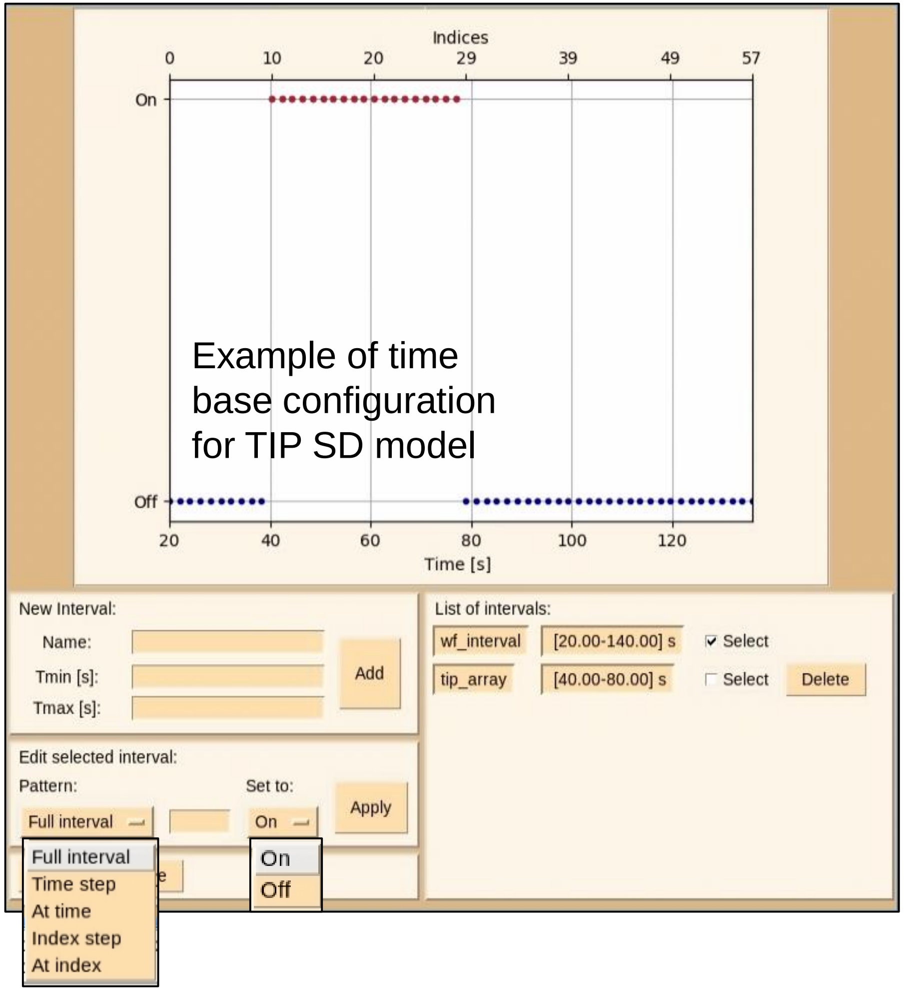
Workflow for Synthetic Diagnostic modelling

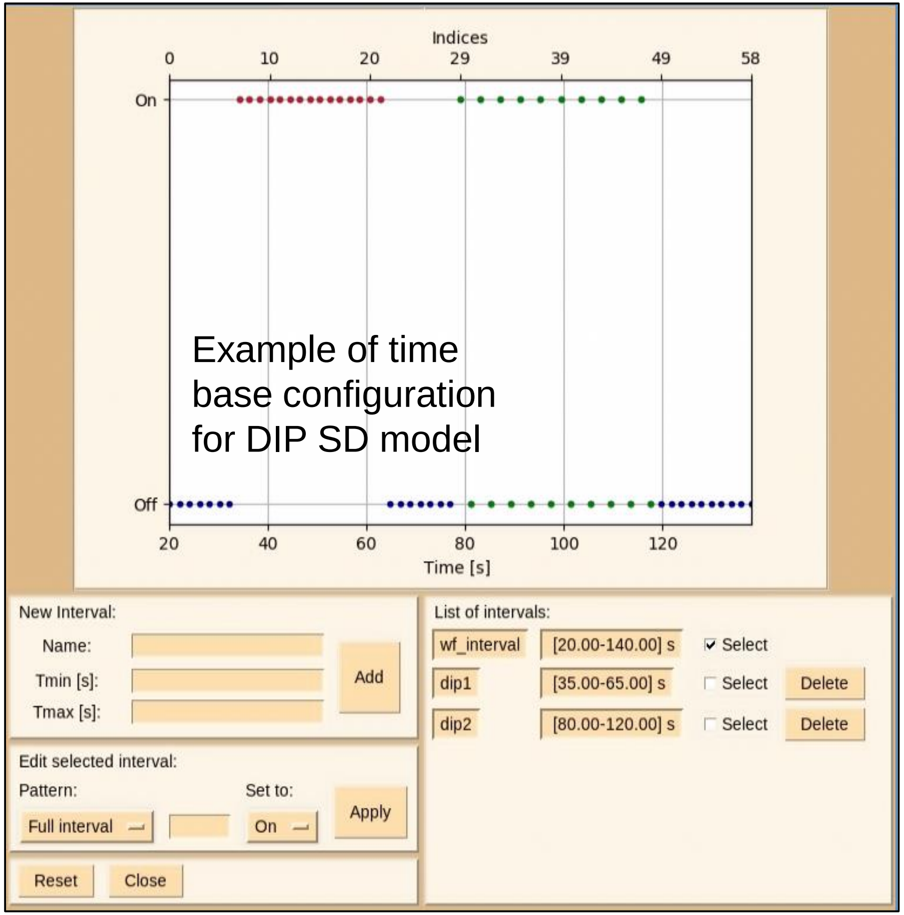




- GUI adapted from H&CD workflow, with extended features
- Workflow still under developement

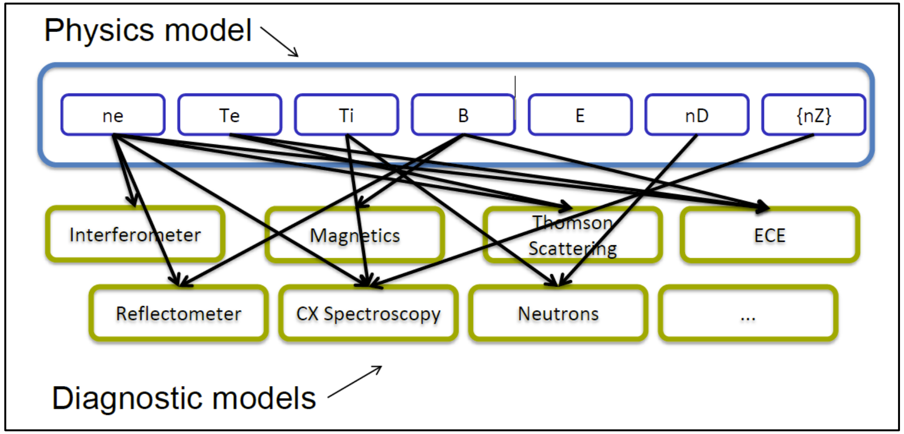
Workflow for Synthetic Diagnostic modelling

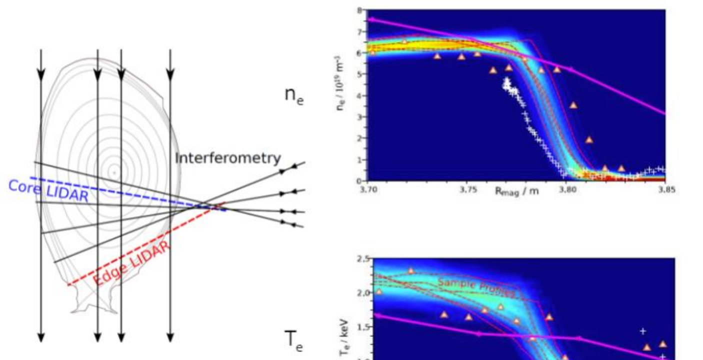




Bayesian inference with the Minerva framework

- Minerva is a platform for building large scale scientific models and performing corresponding inference using those models (→ Cf. talk by A. Langenberg)
  - Modular, traceable, versioned
  - Single of combination of diagnostics without information loss





Combination of JET core LIDAR, edge LIDAR and interferometer channels

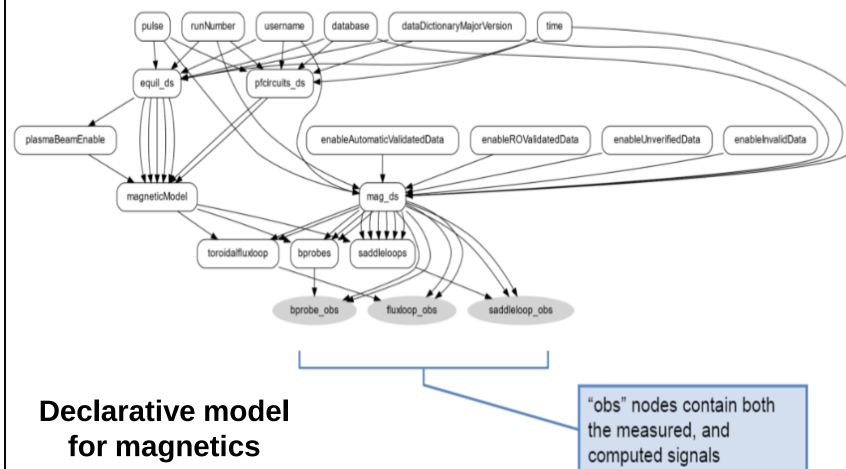
[O. Ford. "*Tokamak Plasma Analysis through Bayesian Diagnostic Modelling*", PhD thesis, University of London, 2010]

  - Accounts for uncertainties from measurement, systematic errors and model
  - Based on Bayesian probability theory: uncertainties = probability distributions
  - Used for forward analysis and experimental design
- Minerva installed in ITER cluster and reads IDSs

Synthetic Diagnostics in Minerva

- First focus on magnetics, VSRS, H-alpha, interferometer, X-ray spectrometer
- Associated Machine Description data (being populated):
  - Coils, flux loops, Rogowski loops:
    - input = `magnetics`, `pf_active`, `pf_passive`, `equilibrium`
    - output = `magnetics`
  - EFIT++ reconstruction:
    - input = `pf_active`, `pf_passive`, `wall`, `tf`
    - output = `pf_passive`, `equilibrium`
  - VSRS, H-alpha:
    - `spectrometer_visible`
  - interferometry:
    - `interferometer`
  - X-ray spectrometer (edge/core/survey):
    - `x_ray_crystal_spectrometer`

- Model to compute toroidal flux loops, saddle loops and pickup probes.
  - Both pf currents and plasma current included



Declarative model for magnetics

- Near-term application:
  - Assessment of diagnostic coverage for L-H transition in PFPO (cf talk A. Medvedeva)

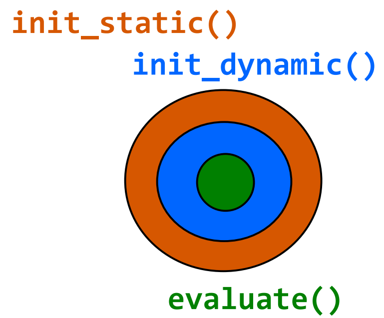
Bayesian techniques with Integrated Data Analysis (IDA)

- Development of a workflow to combine the signals from ECE, TS and interferometry
  → Cf. talk by R. Fischer, this session
- First prototype by R. Fischer using the TIP model from A. Medvedeva
  → Cf. talk by A. Medvedeva, this session
- Adaptation of physics models to be compatible with IDA iteration loops:

  → Separate methods between initialisation steps and evaluation of SD signals

  → Future IMAS development planned for 2022 on “persistent actors” that would facilitate this

Initialisation of static variables	Defines input scenario, generates time loop, initialise all static data	`init_static()`
Initialisation of dynamic variables according to scenario time step	Execution within the time loop: get_slice, put_slice, etc. (e.g. read equilibrium for this time slice)	`init_dynamic()`
Evaluation of SD signal to be iterated in the IDA loop	Execution within the IDA convergence loop (adjustment of core_profiles quantities)	`evaluate()`



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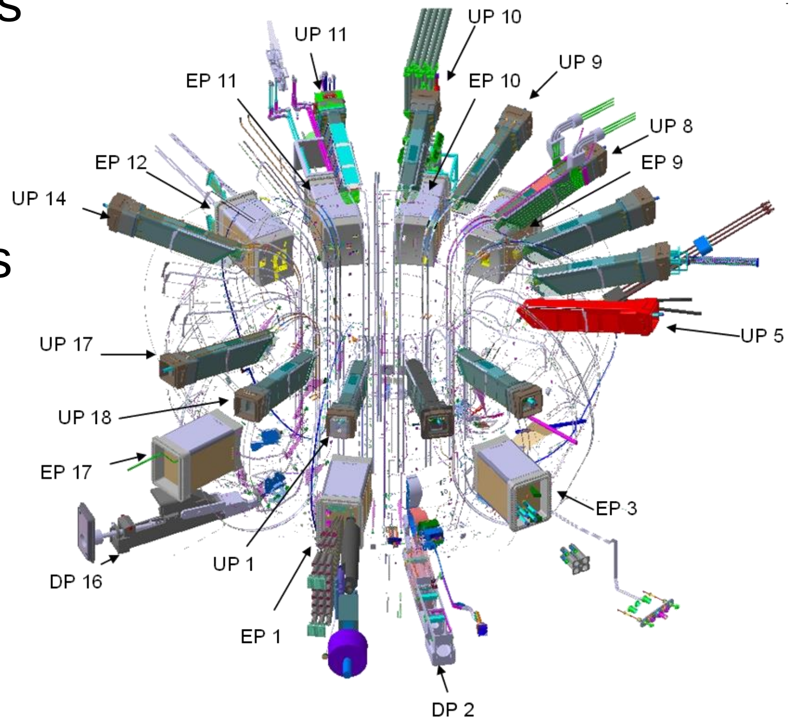

Summary

- Databases for ITER scenarios and Machine Description provide input for synthetic diagnostics:
    - Main scenarios from the ITER Research Plan now covered
    - Machine Description database populated for ITER main plant systems
- Significant progress in development of Synthetic Diagnostics for ITER
- IMAS workflow for generating synthetic data under active development
- Progress in using synthetic diagnostics in frameworks using Bayesian techniques:
    - Minerva: SD models for magnetics, VSRS, H-alpha, interferometry, X-ray
    - IDA: prototype workflow for combining signals from ECE, TS, interferometry
- Collaboration on the development of additional diagnostic models is most welcome and support is available