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Adapting NUBEAM to IMAS

M.V Gorelenkova

PPPL TRANSP User's Group Meeting

May 4-5, 2017

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Why adapting your physics code to IMAS?

(from Mireille Schneider presentation)

- IMAS provides a standardized platform for coupling physics simulation codes.
- It includes modular transport simulator(s) where any adapted physics code can be plugged in, to model the complete dynamics of a plasma discharge.
- IMAS offers a high level of modularity, via standard input/output data structures (IDSs), allowing to choose between multiple combinations of models.
- Each adapted physics code can be added to any analysis or benchmark activity undertaken in IMAS.
- Adapting a physics code to IMAS is straightforward.

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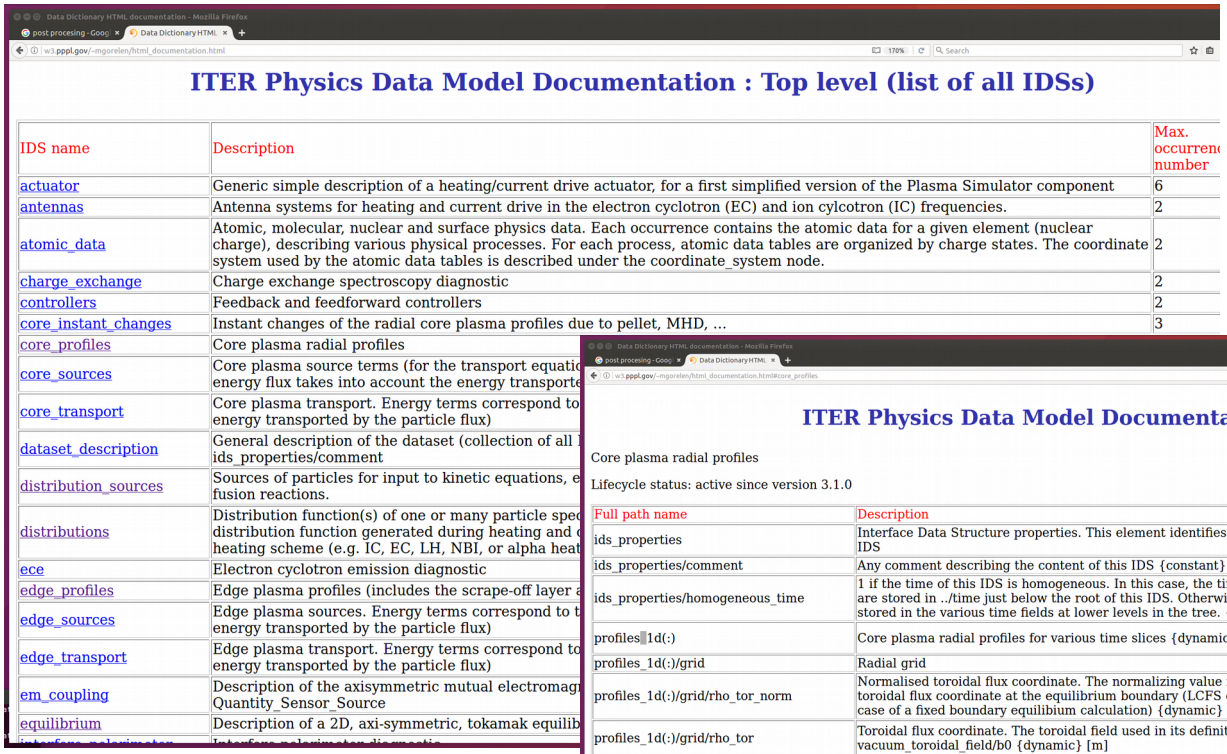
Description of IMAS standard data structures



ITER Physics Data Model Documentation : Top level (list of all IDSs)

IDS name	Description	Max. occurren number
actuator	Generic simple description of a heating/current drive actuator, for a first simplified version of the Plasma Simulator component	6
antennas	Antenna systems for heating and current drive in the electron cyclotron (EC) and ion cylcotron (IC) frequencies.	2
atomic_data	Atomic, molecular, nuclear and surface physics data. Each occurrence contains the atomic data for a given element (nuclear charge), describing various physical processes. For each process, atomic data tables are organized by charge states. The coordinate system used by the atomic data tables is described under the coordinate_system node.	2
charge_exchange	Charge exchange spectroscopy diagnostic	2
controllers	Feedback and feedforward controllers	2
core_instant_changes	Instant changes of the radial core plasma profiles due to pellet, MHD, ...	3
core_profiles	Core plasma radial profiles	
core_sources	Core plasma source terms (for the transport equatic energy flux takes into account the energy transporte	
core_transport	Core plasma transport. Energy terms correspond to energy transported by the particle flux)	
dataset_description	General description of the dataset (collection of all ids_properties/comment	
distribution_sources	Sources of particles for input to kinetic equations, e fusion reactions.	
distributions	Distribution function(s) of one or many particle spec distribution function generated during heating and heating scheme (e.g. IC, EC, LH, NBI, or alpha heat	
ece	Electron cyclotron emission diagnostic	
edge_profiles	Edge plasma profiles (includes the scrape-off layer a	
edge_sources	Edge plasma sources. Energy terms correspond to t energy transported by the particle flux)	
edge_transport	Edge plasma transport. Energy terms correspond to energy transported by the particle flux)	
em_coupling	Description of the axisymmetric mutual electromagn Quantity_Sensor_Source	
equilibrium	Description of a 2D, axi-symmetric, tokamak equilib	

ITER Physics Data Model Documentation for core_profiles

Core plasma radial profiles

Lifecycle status: active since version 3.1.0

Full path name	Description	Data Type	Coordinates
ids_properties	Interface Data Structure properties. This element identifies the node above as an IDS	structure	
ids_properties/comment	Any comment describing the content of this IDS {constant}	STR_0D	
ids_properties/homogeneous_time	1 if the time of this IDS is homogeneous. In this case, the time values for this IDS are stored in ../time just below the root of this IDS. Otherwise, the time values are stored in the various time fields at lower levels in the tree. {constant}	INT_0D	
profiles_1d(:)	Core plasma radial profiles for various time slices {dynamic}	struct_array [max_size=unbounded]	1- profiles_1d(:
profiles_1d(:)/grid	Radial grid	structure	
profiles_1d(:)/grid/rho_tor_norm	Normalised toroidal flux coordinate. The normalizing value for rho_tor_norm, is the toroidal flux coordinate at the equilibrium boundary (LCFS or 99.x % of the LCFS in case of a fixed boundary equilibrium calculation) {dynamic} [-]	FLT_1D	1- 1...N
profiles_1d(:)/grid/rho_tor	Toroidal flux coordinate. The toroidal field used in its definition is indicated under vacuum_toroidal_field/b0 {dynamic} [m]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/grid/psi	Poloidal magnetic flux {dynamic} [Wb]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/grid/volume	Volume enclosed inside the magnetic surface {dynamic} [m^3]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/grid/area	Cross-sectional area of the flux surface {dynamic} [m^2]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/electrons	Quantities related to the electrons	structure	
profiles_1d(:)/electrons/temperature	Temperature {dynamic} [eV]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/electrons/density	Density (thermal+non-thermal) {dynamic} [m^-3]	FLT_1D	1- profiles_1d(: /rho_tor_norm
profiles_1d(:)/electrons/density_fast	Density of fast (non-thermal) particles {dynamic} [m^-3]	FLT_1D	1- profiles_1d(:

TRANSP outputs to IMAS standard data structures (IDSs)

Post-processing wrapper to write time dependent data to IDSs (Johan Carlsson)

```
program transp2ids
        use ids_schemas          ! Fortran type definitions for the Physics Data Model
        use ids_routines         ! Access Layer routines + management of IDS structures
        implicit none
        type(ids_equilibrium)   :: eq
        type(ids_core_profiles):: cp
        type (ids_nbi)          :: bms
            ! read data from 38530B10.CDF file and NAMELIST
            ! interpolate  profiles √norm.toroidal flux to norm.toroidal flux
          …
        call imas_create( 'ids' ,385,30,0,0,idx)
        call ids_put(idx, 'equilibrium' ,eq )
        call ids_put(idx, 'core_profiles' ,cp)
        call ids_put(idx, 'nbi' ,bms)
        call imas_close(idx)
        ...
    end program transp2ids
```

Read inputs from IDSs and write plasma-state file

```
program ids2nubeam
     use ids_schemas                    ! IMAS module
     use ids_routines                   ! IMAS module
     implicit none
     type(ids_equilibrium):: eq
     ...
          ! read data from $MDSPLUS_TREE_BASE_0

          ! [mgorelen@sunfire05 0]$ ls ids_3850030*
          ! ids_3850030.characteristics  ids_3850030.datafile      ids_3850030.tree
          …
     call imas_open( 'ids' ,3850,30,idx)
     call ids_get(idx, 'equilibrium' ,eq )
     call ids_get(idx,"core_profiles",cp)
     call ids_get(idx,"nbi",bms)
     call imas_close(idx)….
     ! interpolate profiles norm.toroidal flux  to √norm.toroidal flux
     ! and write plasma-state
     ….
end program ids2nubeam
```

NUBEAM_COMP_EXEC outputs to IDS

```
program ids2nubeam

        use ids_schemas                    ! IMAS module
        use ids_routines                   ! IMAS module
        implicit none
        type (ids_distributions)   :: dis       ! distributions
        ...
        call imas_create( 'ids' ,385,35,385,30,idx)
              ! read data from  xplasma.cdf file
              ! interpolate  profiles √norm.toroidal flux to norm.toroidal flux
           …
        call ids_put(idx, 'distributions' ,dis)
        call imas_close(idx)

end program ids2nubeam
! [mgorelen@sunfire05 0]$ ls ids_3850030*
! ids_3850030.characteristics  ids_3850030.datafile      ids_3850030.tree
```

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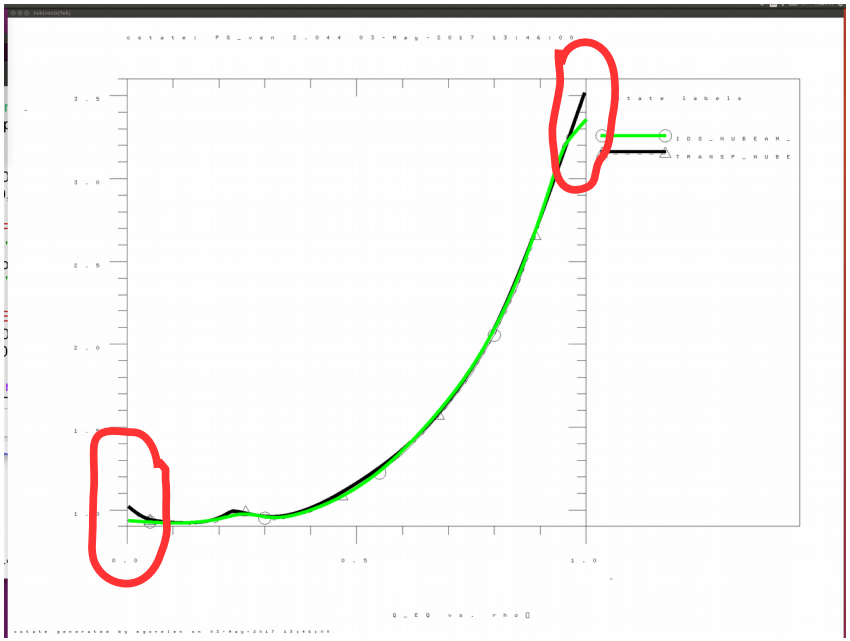
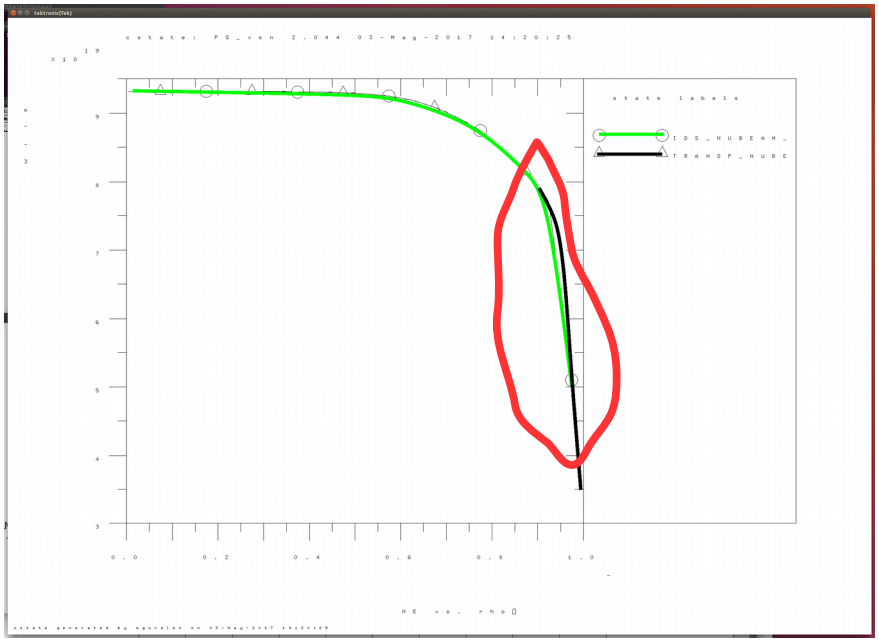
NUBEAM inputs: IDS2NUBEAM vs TRANSP/NUBEAM



Q-profile



electron density

Need improvement at mag. axis and plasma boundary

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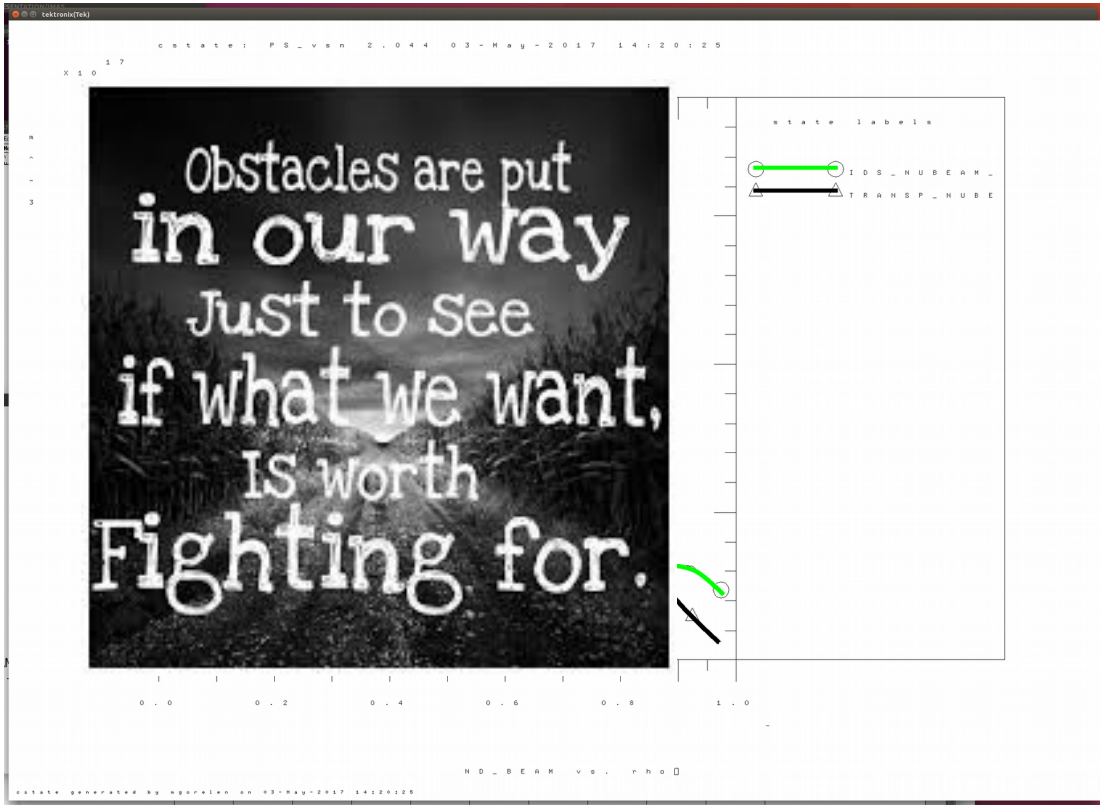
NUBEAM_COMP_EXEC outputs: IDS2NUBEAM vs TRANSP/NUBEAM inputs



Beam density

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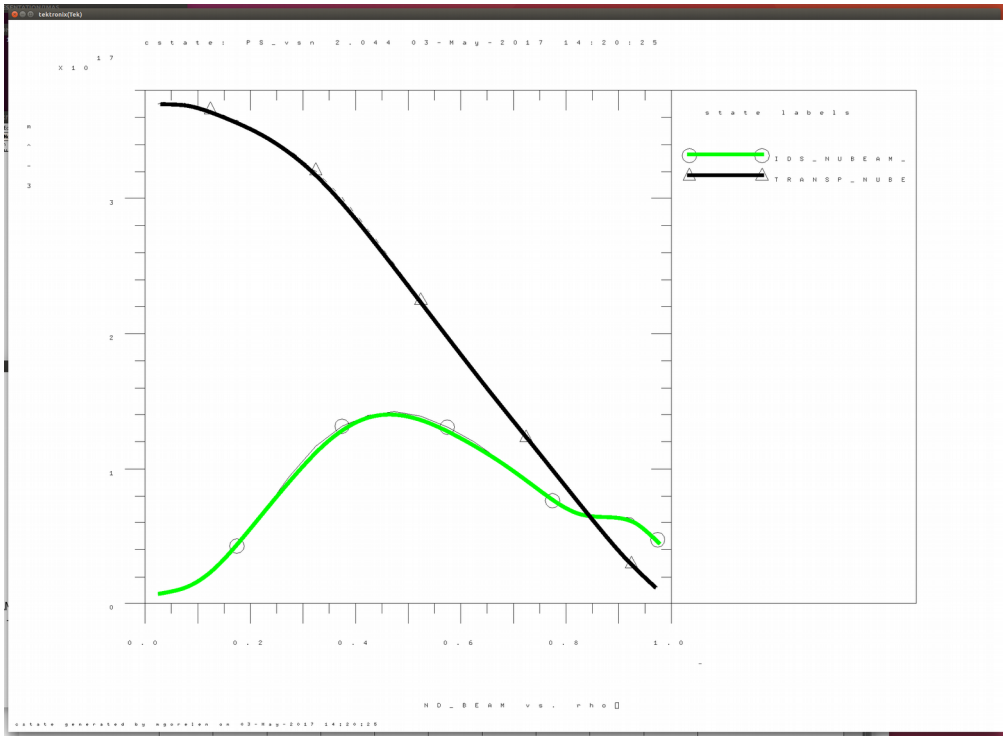
NUBEAM_COMP_EXEC outputs: IDS2NUBEAM vs TRANSP/NUBEAM inputs (cont)



Beam density

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NUBEAM_COMP_EXEC outputs: IDS2NUBEAM vs TRANSP/NUBEAM inputs (cont)

OBSTACLES:

- Different version of IMAS module (3.3.1 vs 3.2.2)

  Radial electric field

  Anomalous diffusivity

  Neutral density outside plasma

- Physic model switches from TRANSP namelist are missing (no storage in IDS)

  LEV_NBIDEP, NSIGEXC -- beam deposition atomic physic model

  NLBBCX -- beam-beam interection

  ...

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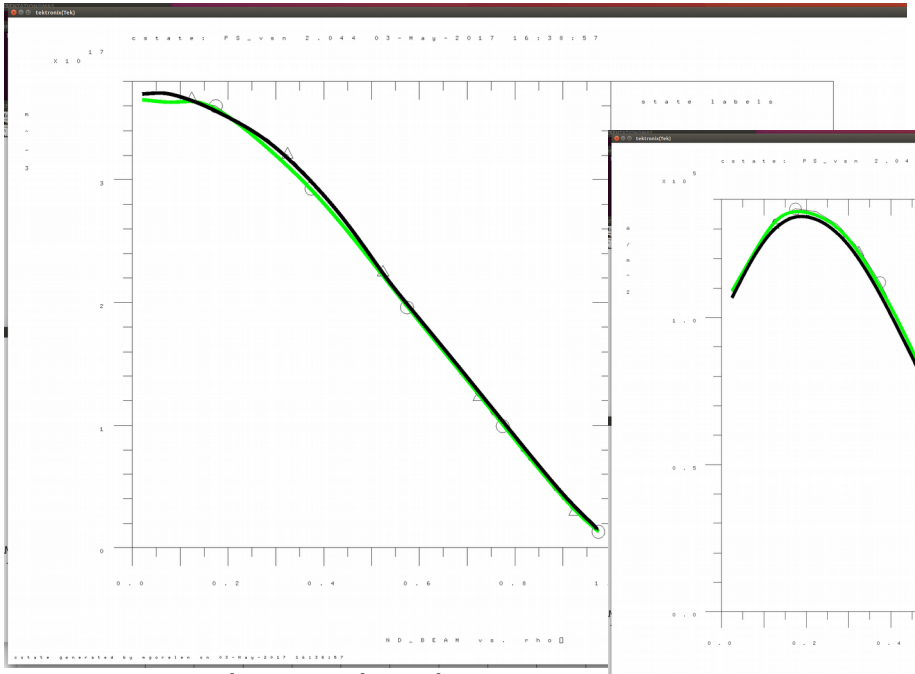
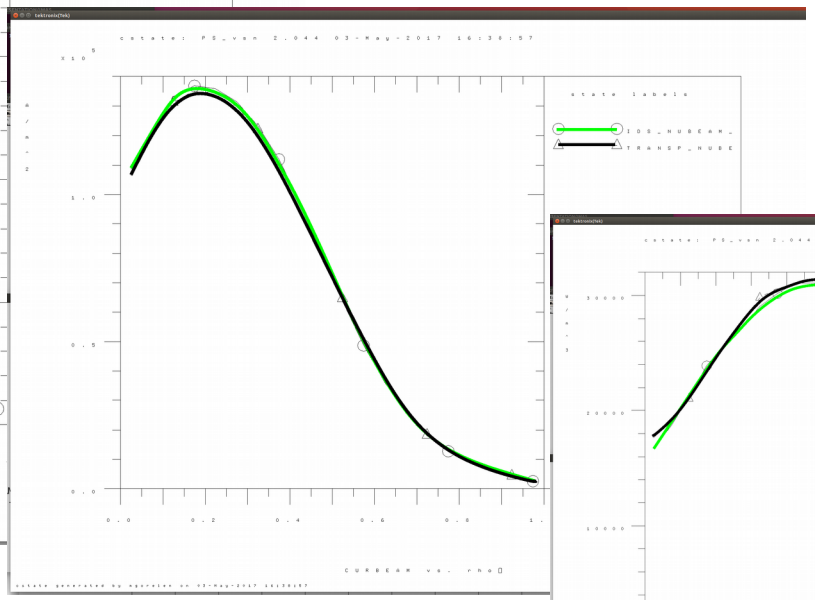
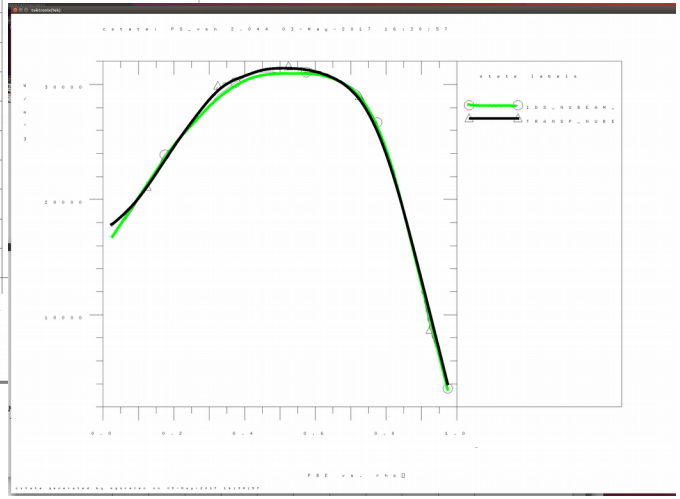
NUBEAM_COMP_EXEC outputs: IDS2NUBEAM vs TRANSP/NUBEAM inputs (cont)



beam density



beam ion driven current



elect heating by beam ions

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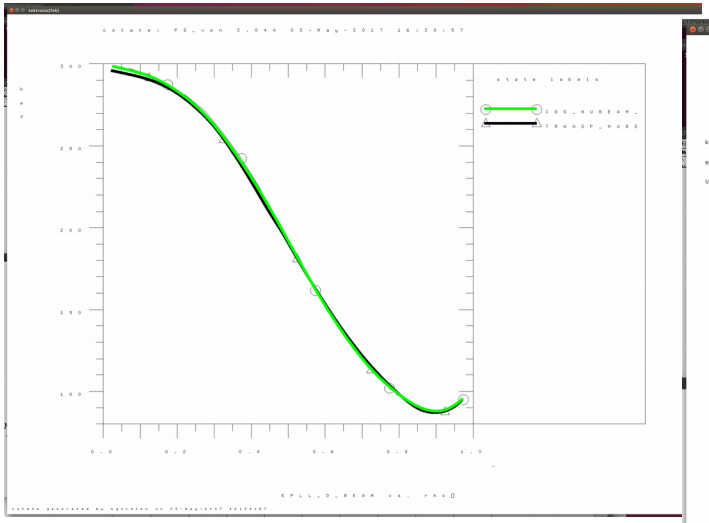
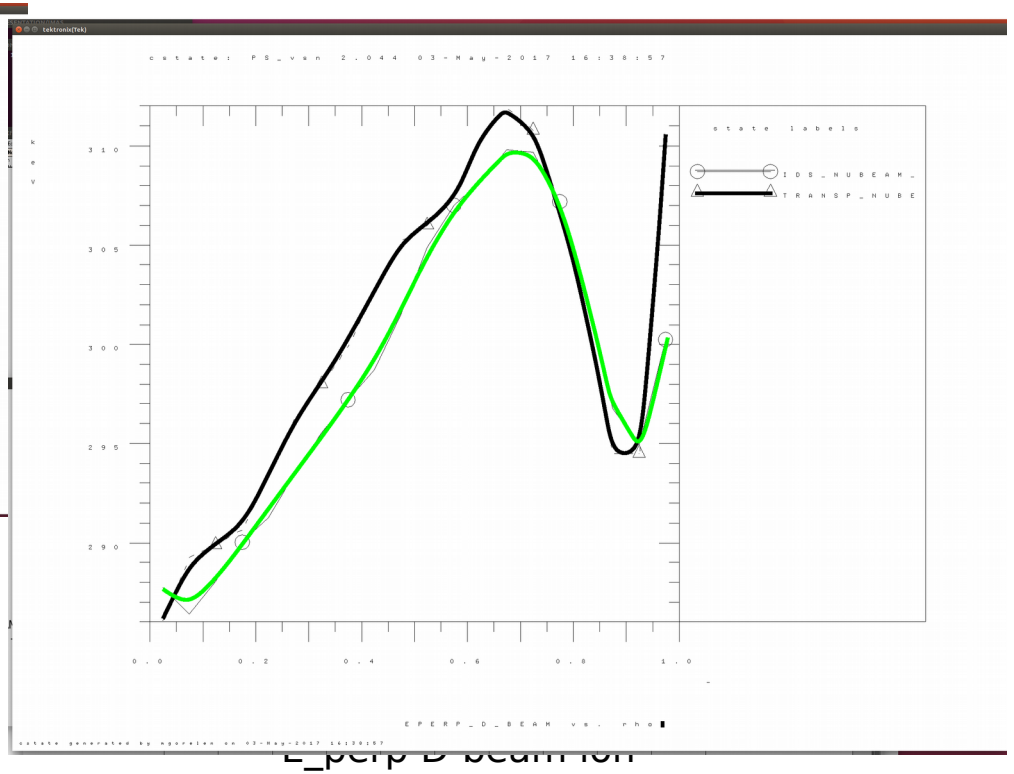
NUBEAM_COMP_EXEC outputs: IDS2NUBEAM vs TRANSP/NUBEAM inputs(cont)



E_II D-beam ion



E_perp D-beam ion

benchmark activity is not over

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CONCLUSION

- Translators:
  TRANSP outputs to IDS,
  IDS input data to NUBEAM
  NUBEAM_COMP_EXEC to IDS

- An accuracy of interpolation for a different translators has to be verify

- TRANSP switches for a physics modeling need a space in IDS

- Additional benchmark has to be done. NUBEAM_COMP_EXEC with inputs from ISD and TRANSP

- Next step – Kepler component