PROPOSAL FOR BES-CPO

Authors: Ö. Asztalos[1], G.I. Pokol[1], M. Aradi[1] and B. Szondy[1]

[1]BME NTI, Budapest, Hungary

Purpose of the proposal:

The RENATE synthetic diangnostic, designed for arbitrary BES diagnostic system modelling is to be integrated into EU-IM. Communication of various actors responsable for executing code is only possible through **C**oherent **P**hysical **O**bjects (CPO). The current proposal outlines the design of the BES – CPO, responsable for handling all data relevant for a BES sysnthetic diagnostic within the EU-IM mainframe.

Highest level summary layout of the BES-CPO:

time [tag]:

- Parameters that tags each timeslice with the corresponding values of the CPO, it presents the time instances chartacteristic of turbulence timescales.

beam [tag]:

- Handles all data pertinent to 3D beam modelling: beam dimensions, positions, current and energy distributions.

profiles [tag]:

- Stores density and temperature for all points along the beamlets for every atomic species present in the plasma.

equilibrium [tag]:

- Stores the flux surface values for all the points along the beamlets.

observation [tag]:

- Stores all pertinent data regarding observation geometries, such as: lens radius, observation point, transmission matrices, pinhole observation data.

output [tag]:

- Contains the light profile along each beamlet, the detected photon current on each detector, the expected spatial resolution for each detector and a fluctuation response matrix for given time interval.

measurement [tag]:

- Contains the registered signal from the existing shot modelled, if it is available.

Detailed layout and design of BES – CPO tags:

A. time (:)

1. **slice** [s] [integer]: Contains the number of the time slice in question.
2. **fluctuation** [s] [1D array]: Contains the time instances on a turbulence timescale.

B. beams (:) Vector of different beams; each beam having following structure [n_beams]

1. **parameters** (:) Contains the numerical resolutions of the 3D modelled beam
   a. **size** (:) Contains the size of the beam in SI coordinates
      i. <u>along</u> [m] [float]: length of the modelled beam
      ii. <u>width</u> [m] [float]: width of the modelled beam
      iii. <u>height</u> [m] [float]: height of the modelled beam
   b. **resolution** (:) Contains the numerical resolution of the modelled beam
      i. <u>along</u> [-] [integer]: number of points along each beamlet
      ii. <u>width</u> [-] [integer]: number of beamlets in beam width
      iii. <u>height</u> [-] [integer]: number of beamlets in beam height
   c. **divergence** [rad] [float]: the divergence angle of the beam
   d. **shape** [-] [string]: describes the shape of the beam (elliptical or rectangular)
   e. **type** [-] [string]: Sets the type of atoms in the beam (H,D,Li,Na)
2. **geometry** (:) Contains all data precluding to the spatial location of beam
   a. **position** [-] [1D array]: Contains an index of the possible beam positions, for all available timesteps, characteristic of the turbulence timescale.
   b. **init** [m,m,m] [3D array] [position_index, 2, 3]: Contains the start and waypoint coordinates for each beam position
   c. **coordinates** [m,m,m] [4D array] [position_index, nr_beamlets, nr_points_along, 3]: Contains the coordinates of points within the beam, pertinent to beam evolution calculation.
3. **energy** [eV] [-]: Energy of the beam.
4. **current** [A] [1D array]: Contains the beam current values corresponding to each beamlet

C. profiles (:)

1. **components** [-] [string list]: Contains all the plasma components: (e, H, D, C, O, etc)
2. **density** [m^-3] [5D array] [n_beams, time_steps, components, n_beamlets, n_points_along]: Contains density values for all beamlets of various plasma components for all turbulent timesteps.

3. **temperature** [eV] [5D array] [n_beams, time_steps, plasma_comp, n_beamlets, n_points_along]: Contains density values for all beamlets of various plasma components for all turbulent timesteps.

D. equilibrium (:)

1. **norm_toroidal_flux** [psi] [3D array] [n_beams, n_beamlet, n_point_along] Contains a 3D array with the flux surface values of all the points along the beamlets.
2. **magnetic_vector** [-] [4D array] [n_beams, n_beamlet, n_point_along, 3] Contains array with the unit vectors of magnetic field at all the points along the beamlets.

E. observation (:)

1. **lens_diameter** [m] [float]: Contains the diameter of the last optical element of the observation system.
2. **pixel_number** [-] [integer]: Gives the number of detector pixels the optical system is modelled with.
3. **spatial_calibration** (:) Contains information with regard to the observation volumes used for the pinhole optics modelling.
    a. **pyramid** (:) Contains the data for pyramid shaped observation volumes.
        i. <u>center</u> [m] [2D array] [n_detectors, 3]: Coordinates of the center of the observation pyramids.
        ii. <u>edges</u> [m] [3D array] [n_detectors, 4, 3]: Coordinates of the edges of the observation pyramids.
    b. **cone** (:) Contains the data for pyramid shaped observation volumes.
        i. <u>center</u> [m] [2D array] [n_detector, 3]: Coordinates of the center of the observation cones.
        ii. <u>radius</u> [m] [1D array]: Contains the radii of the bases of each observation cone.
4. **transmission** (:) Contains the various forms of transmission rates that are applicable for each detector.
    a. **rate** [-] [1D array]: Contains the transmission rates for each detector that arises from the optical system in case of the pin hole optical model.
    b. **matrix** [-] [2D array] [n_detector, points]: Contains the transmission matrix for each detector pixel. Used in case of the Zmax model.
5. **observation_point** [m] [1D array]: Contains the coordinates of the observation system.
6. **focus_point** [m] [1D array]: Contains the coordinates of the focus point of the observation system.
7. **filter (:)** Contains data regarding the filter capabilities modelled.
    a. **transmission** [-] [2D array] [n_beams, n_detector]: Contains the spectral transmission rate for each detector pixel.
    b. **characteristic** [-] [3D array] [n_beams, n_detector, wavelengths]: Contains the filter characteristics for each detector pixel.

F. output (:)

1. **beam_evolution** (:) Contains data resulting from the beam evolution calculation as well as detected photon current profiles. All arrays of the output.beam_evolution tag will have an added temporal dimension to accommodate for turbulence timescale.
    a. **emissivity** [-] [4D array] [n_beams, timestep, n_beamlet, n_point_along]: Contains the emissivity along each individual beamlet, result of the beam evolution calculation.
    b. **photon_current** [1/s] [2D array] [timestep, n_detector]: Contains the detected photon count on each detector for all timesteps in question.
    c. **relative_population** [-] [5D array] [n_beams, timestep, levels, n_beamlet, n_point_along]: Contains the relative populations for all calculated atomic levels along each individual beamlet.
2. **fluctuation_response** [m^2/s] [2D array] [n_perturbation, n_detector]: Contains the responses in the detected photon current of various density perturbations in the beam evolution.
3. **spatial_resolution** (:) Contains values for various calculations for the spatial resolution.
    a. **atomic_smear** (:) Contains the smearing caused by the atomic physics processes on each detector pixel
        i. <u>radial</u> [m] [1D array]: Radial component of spatial resolution from atomic physics processes.
        ii. <u>vertical</u> [m] [1D array]: Vertical component of spatial resolution from atomic physics processes.
    b. **mag_beam_smear** (:) Contains the smearing of emission caused by the beam and magnetic geometry with respect to the LOS, for each detector pixel.
        i. <u>radial</u> [m] [1D array]: Radial component of spatial resolution from smearing caused by the misalignment of the magnetic field lines with LOS within the beam geometry.
        ii. <u>vertical</u> [m] [1D array]: Vertical component of spatial resolution from smearing caused by the misalignment of the magnetic field lines with LOS within the beam geometry.
    c. **pixel_proj** (:) Contains the size of the projections for each detector pixel.
        i. <u>radial</u> [m] [1D array]: Radial component of detector pixel projection.
        ii. <u>vertical</u> [m] [1D array]: Vertical component of detector pixel projection.
    d. **total** (:) Contains the total spatial resolution as a convolution of the atomic smearing, magnetic and beam geometry smearing and detector projection components for each detector pixel.
        i. <u>radial</u> [m] [1D array]: Radial component of the total spatial resolution.
        ii. <u>vertical</u> [m] [1D array]: Vertical component of the total spatial resolution.
    e. **sensitive_area** (:) Contains the spatial resolution calculated from fluctuation response calculation for all detector pixels.
        i. <u>radial</u> [m] [1D array]: Radial component of spatial resolution from fluctuation response calculation.

    ii. vertical [m] [1D array]: Vertical component of spatial resolution from fluctuation response calculation.
    iii. center [m] [2D array] [n_detector, 2]: Radial and vertical coordinates of the center of the sensitive area.

G. measurement (:)

1. **data** [-] [2D array] [n_detectors, data_point]: Contains experimental BES measurements for the shot data in question.
2. **beam_on** [s] [1D array]: Contains the time intervals where the beam was on, used for beam chopping.

Datainfo (:) TO XML not in CPO

1. **atomic_levels** [-] [integer]: sets the number of atomic levels to be used for beam evolution calculation.
2. **field_line_step** [m] [float]: length of field line trace step.
3. **velocity_distribution** [-] [string]: sets the type of velocity distribution used for rate generation
4. **fluctuation** (:) Contains relevant data used for fluctuation response calculation.
    a. **amplitude** [m^-3] [float]: Density amplitude of the induced fluctuations.
    b. **size** [m] [float]: Size of the induced fluctuations.
    c. **spacing** [-] [float]: The ratio of distance between perturbations with regard to its size.
    d. **temperature_ratio** [-] [float]: The temperature perturbation amplitude with regard to the magnitude of the normalized density perturbation.