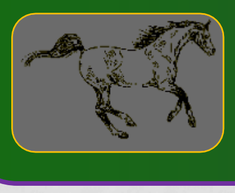
BTR code Recent Modifications for Multi-Run Operation



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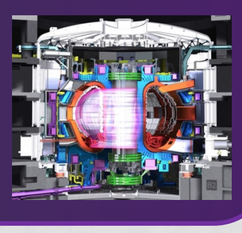


NBI TASKS

- ❑ Particles fueling for fusion
- ❑ Plasma heating
- ❑ Current drive
- ❑ Radial profiles control
- ❑ Plasma toroidal rotation

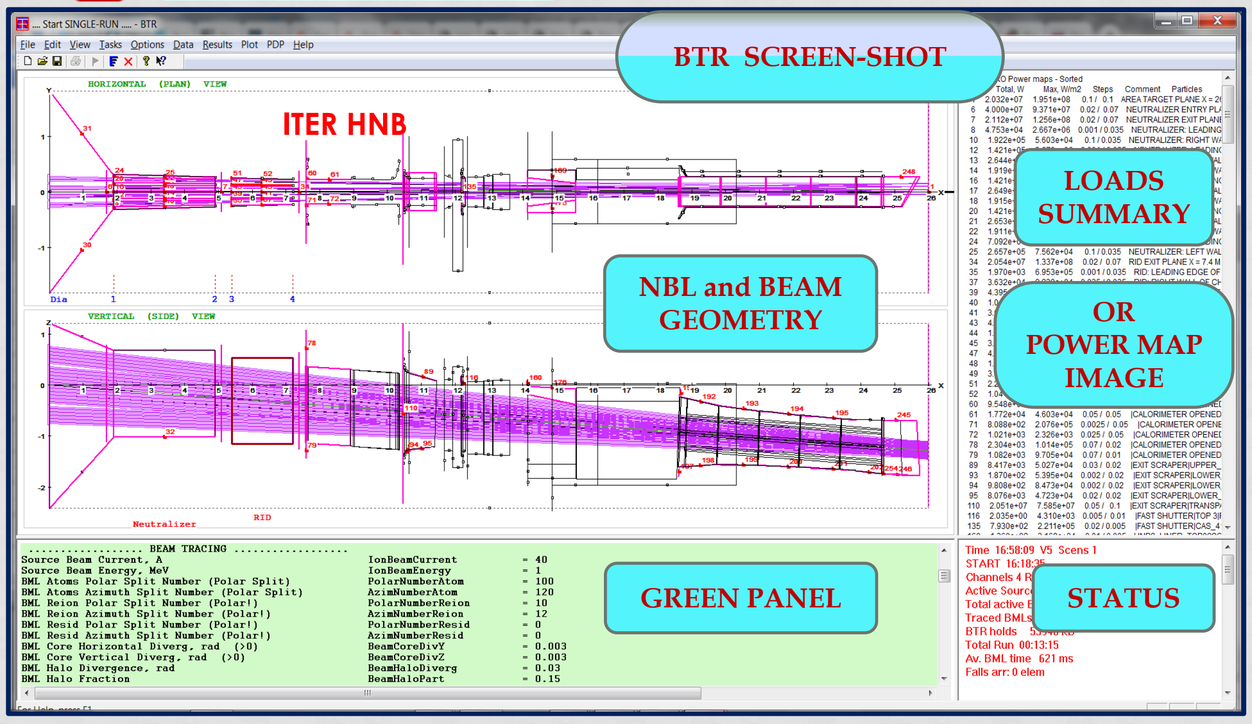
BTR code OVERVIEW

- ➢ *Born To Run (released for public usage)* - in 2005, MS Visual C++
- ➢ Purpose: NBI design and studies
- ➢ Fully Interactive NBI simulator, User-friendly, intuitive GUI (Windows standard)
- ➢ 3D NB geometry, Surfaces number not limited
- ➢ Multi-beamlet source beam (6D), BS GG optics
- ➢ Beamlet (BML): core + halo fractions (bi-gauss)
- ➢ 10^2–10^5 macro-particles (MP) per beamlet, 10^5 – 10^9 MP in total
- ➢ Regular angular splitting of BML current (bi-gauss), each MP << individual weight
- ➢ Direct tracing, MP conversions/collisions << cross-sections
- ➢ Fields, gas, plasma input
- ➢ Neutral particles >> *Light Neutral Beam* (LNB) tracking model
- ➢ No randoms >> results determinism
- ➢ Parallel : multi-thread approach
- ➢ Easily verified on analytical models (PDP)
- ➢ Manually tuned for any standard NBI Config
- ➢ Unlimited statistics >> refined resolution
- ➢ Output: beam normal Foots, power Maps, peak power Profiles
- ➢ CAD compatible input (TXT)
- ➢ Permanent Development and Construction
- ➢ Open-Source https://github.com/EDlougach/BTR
- ➢ Full lifespan Support https://sites.google.com/site/btrcode

BTR Single-Run Usage for any Task: A long and complex routine, a sequence of massive runs with multiple parameters scan

BTR USER INTERFACE

BTR SCREEN-SHOT



LOADS SUMMARY

NBL and BEAM GEOMETRY

OR POWER MAP IMAGE

GREEN PANEL

STATUS

Green Panel – is the **Main Interface Engine** of the code, its Input processor and Input Data Container, used for Interactive Data control and revision. When the User modifies any data field, they can invoke an Immediate Model Update with Image redraw. Next all the changes which can be stored in output Config-file

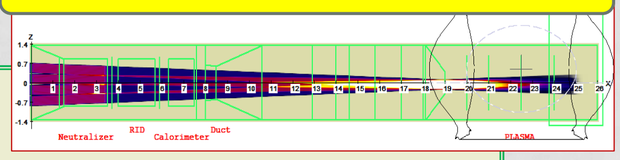
BTR USAGE

- → For NBI Training
- → NBI scheme choice, geometry optimization
- → For ready (frozen) NBI design - thermal loads study, sensitivity analysis, operational constraints

The NEED for UPGRADE

BTR Moves towards MULTI-RUN

BTR version 5 - MULTI



Each single run in a conventional Single-Run BTR session is started by the input manual tuning procedure for a specific scenario, which is next followed by the code restart. This input routine requires the User's extensive efforts and time to obtain and comprehend the results for multiple operation scenarios, with several input parameters scanned independently. Recent modifications in the code engine and input-output concept have formed a new BTR version 5 (or *Multi-Run*), which made possible to run automatically multi-parametric scans of different scenarios by a single click, with a preset list of scenarios input records. The main purpose was to implement the Multi-Scenarios / Multi-Task running modes in BTR sessions, with keeping intact the *customary* Single-run mode for all dedicated BTR users. In other words, the transition to the new version should be seamless and intuitive, compatible with the global BTR concept.

PURPOSE: multi-scenarios, multi-tasks

NEW FEATURES

- Model: multi-task settings, run options (diff steps, splits through runs)
- Model: plasma module, beam ionization maps, shine-through refined maps
- Model: Static surfaces (including transparent) – no limit
- Input: Automatic Surfaces download, Hidden Surfaces
- Input: Scenario file with parameters and Macro-Commands
- Output: Requested Maps resolution up to 1000x1000 cells
- Output: Folders tree, Reports (TXT, CSV format), All Scenarios Summary
- Output: Additional Format for Loads
- Output: Falls Statistics (option)
- Safety and Control: Surfaces clones, invalid corners
- Safety and Control: Terminal screen, Log file

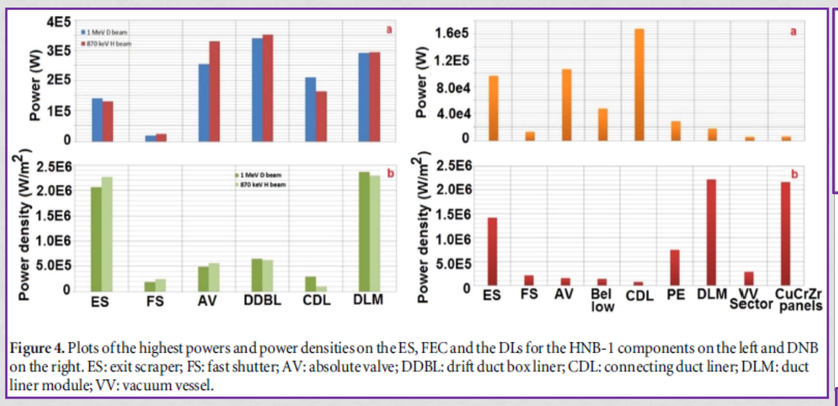
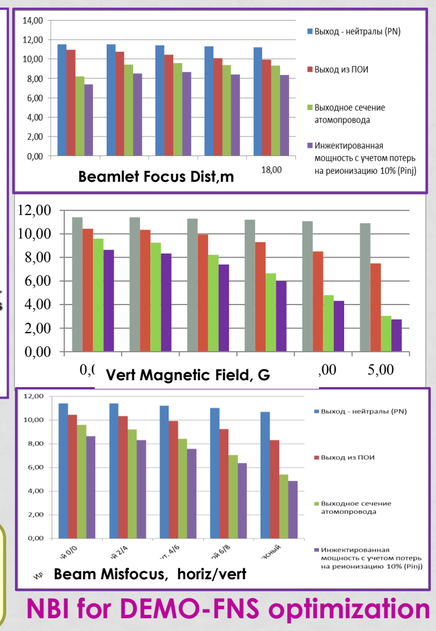


Figure 4. Plots of the highest powers and power densities on the ES, FEC and the DLs for the HNB-1 components on the left and DNB on the right. ES: exit scraper; FS: fast shutter; AV: absolute valve; DDBL: drift duct box liner; CDL: connecting duct liner; DLM: duct liner module; VV: vacuum vessel.

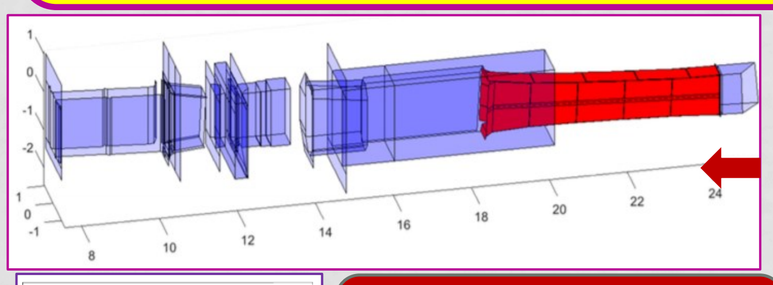
Heating neutral beams for ITER: negative ion sources to tune fusion plasmas M J Singh *et al* 2017 *New J. Phys.* 19 055004



NBI for DEMO-FNS optimization

These are some examples of BTR analysis, which included many BTR restarts for multiple operation scenarios - to obtain results for parameters scan

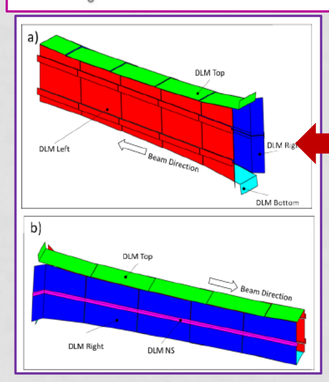
BTR-MULTI APPLICATION



NBI Surfaces are imported by BTR from CAD generated (TXT) format

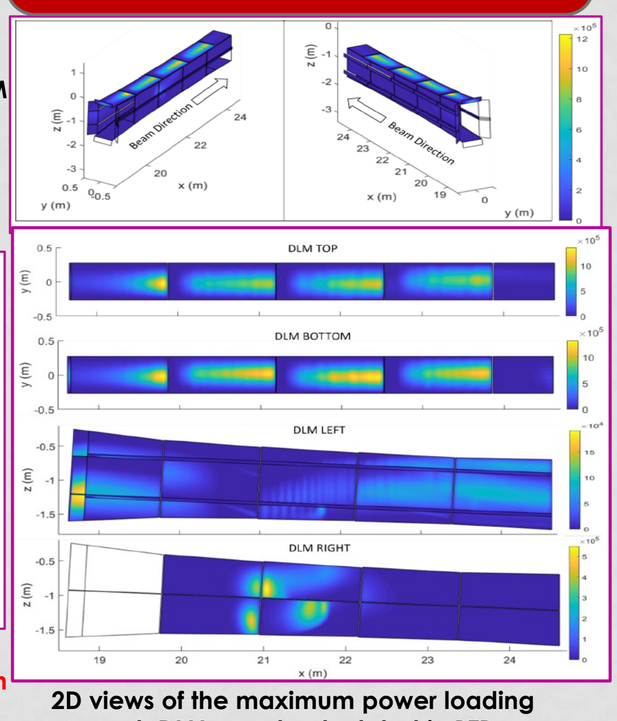
MATLAB view of NBI surfaces. From left to right: Calorimeter, Exit Scraper, Fast Shutter, Absolute Valve, Drift duct liner, connecting duct, and the Duct Liner DLM (in red)

DUCT LINER MODEL



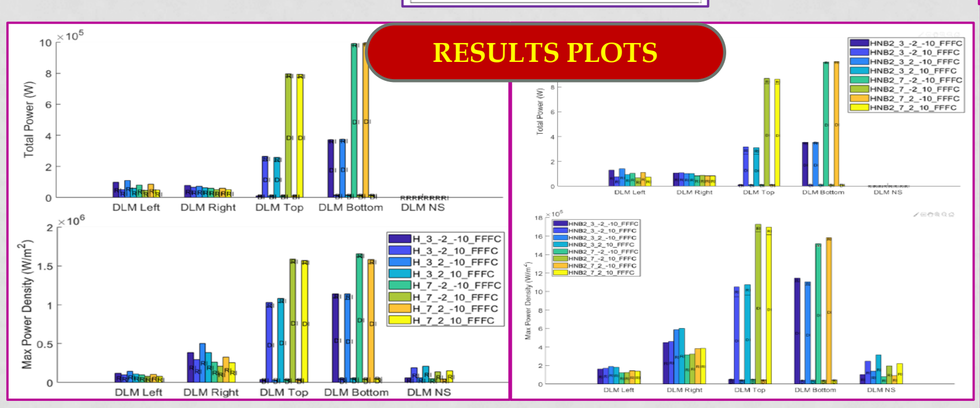
DLM model: 54 surfaces, including two surfaces mimicking the DLM opening towards the neutron shield (DLM-NS) area behind Duct Liner

RESULTS of POWER CALCULATIONS



2D views of the maximum power loading on each DLM panel calculated in BTR run of all the scenarios (Multi-Scenarios option)

RESULTS PLOTS



Total Power and Peak Power Density on the different components of the DLM – for different scenarios (shown in legend). Left - Hydrogen beam, right - Deuterium

BTR-MULTI USAGE SUMMARY

BTR version 5 (MULTI) is more adapted for Massive Calculations and can be used for Complex Thermal Load Studies in NB lines and beam Ducts.

BTR-5 modifications provide:

- ✓ Parameters scanning with no restart
- ✓ Flexibility in NBI Geometry Input
- ✓ Input Control and Diagnostics
- ✓ Unlimited Particles Statistics, Surfaces Number, Power Maps and Beam Foot Maps Resolution
- ✓ Results Load-Summary and Reports

The Multi-Scen running option can be used also for NBI Geometry Optimization – during the 1st stages of NBI Design, when all NBI components and the Beam (*or NBI Config*) need to be carefully tuned

ANALYSIS CONCLUSIONS

Directly Intercepted atoms (DI) mainly load the Top (for vert. tilting UP) or bottom (for vert. tilting DOWN) panels of the DLM;
Maximum Total Power and Peak PD are caused by DI particles;
Re-ionized particles (RI) are deflected Left or Right (depending on local MF)
RI deposition >> onto Left and Right DLM panels;
Horizontal Misalignment >> small effect on the RI power distribution;
Both Total Power and Peak PD are mainly defined by high beam Div (7mrad)
Max Peak PD << for beam vert. tilt ±10 mrad; >> on the top/bottom panel

[1] BTR webpage https://sites.google.com/site/btrcode/
[2] BTR Source https://github.com/EDlougach/BTR
[3] Hemsworth R S et al 2017 Overview of the design of the ITER heating neutral beam injectors New J. Phys. 19 025005
[4] M. Singh et. , AIP Conf. Proceeding of NIBS Conference, 2014