NUBEAM Atomic Physics: *status & wishes*

Princeton Plasma Physics Laboratory
CPPG
presented by
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A. Pankin et al. / Computer Physics Communications 159 (2004) 157–184 159

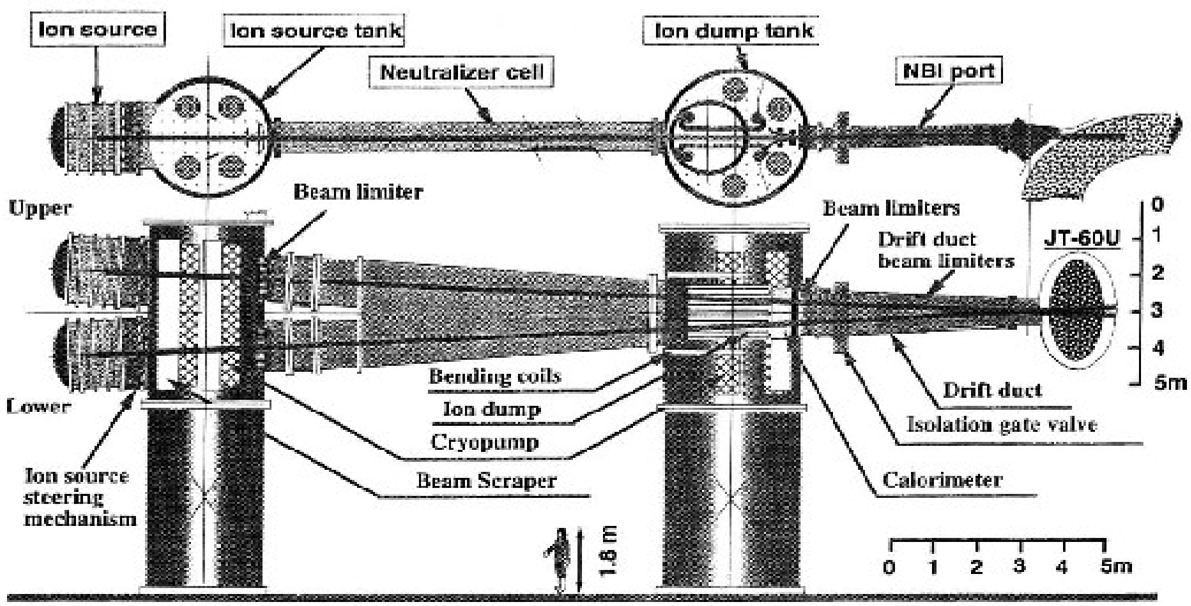
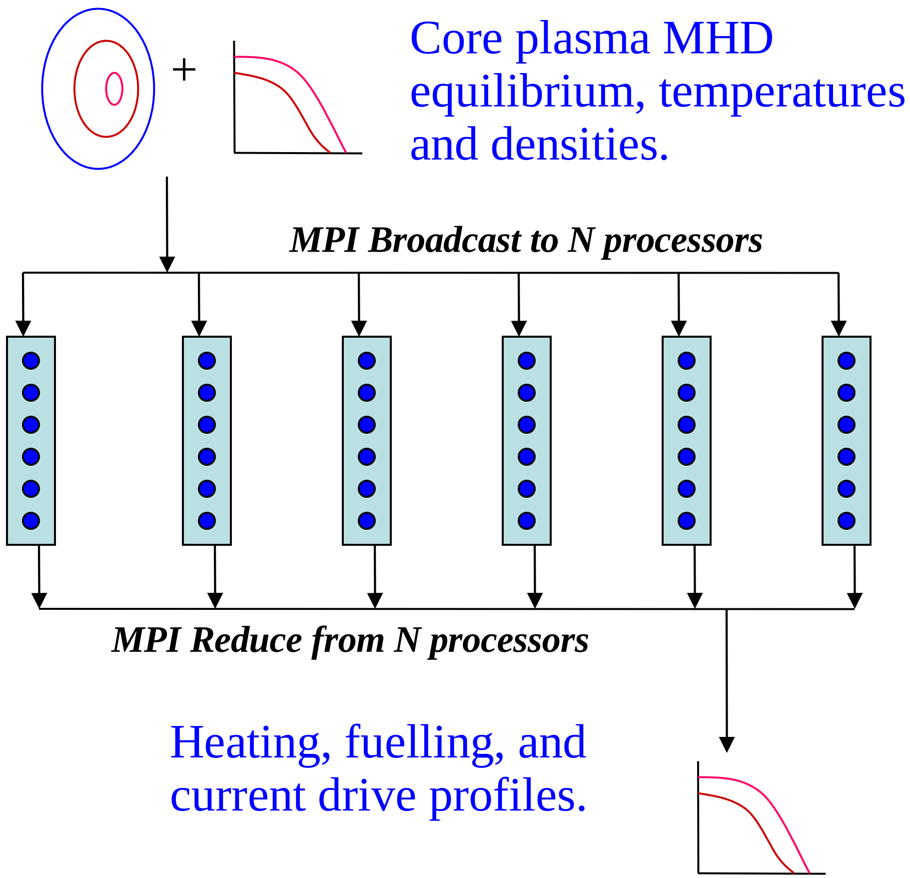


Fig. 1. Schematic view of the NBI system for the JT-60U tokamak described in Ref. [6].

MPI NUBEAM at PPPL



<u>Recent Progress:</u>
- MPI NUBEAM running on small Linux Clusters at PPPL.
- Standalone version– drive with Plasma State from any TRANSP archived time slice.
- Tested to 128pe at NERSC.
- Distributed state capture & restart.
- Dynamically expandable particle lists.

Fast ion deposition, orbiting, and losses computed over N processing elements. Each PE handles (1/N) of the Monte Carlo ions.

NUBEAM: *deposition processes (ADAS)*

Deposition probability profile based on atomic interaction w/target.

$A + B^{+} \text{--->} A^{+} + B$ **CX**

$A + B^{Z+} \text{--->} A^{+} + B^{(Z-1)+}$, $Z>1$ **I I**

$A + B^{Z+} \text{--->} A^{+} + B^{Z+} + e$ **I I**

$A + e \text{--->} A^{+} + 2e$ **EI**

<u>Supports</u>

ground | excited

H-like beam

$H^{+} – F^{+9}$ | $H^{+} – Ne^{+10}$

He beam

$H^{+} – F^{+9}$ | available only at n=0

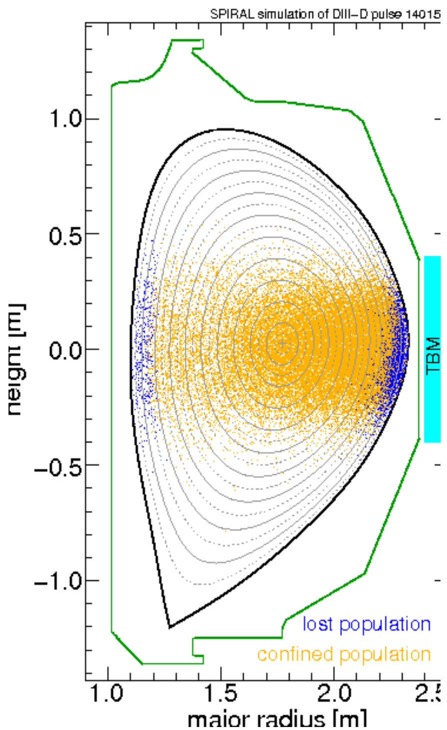
Stopping rate (CX + II) for $\{H\}$ on fully stripped impurities

For impurities with $Z>$avail. stopping rate is scaled

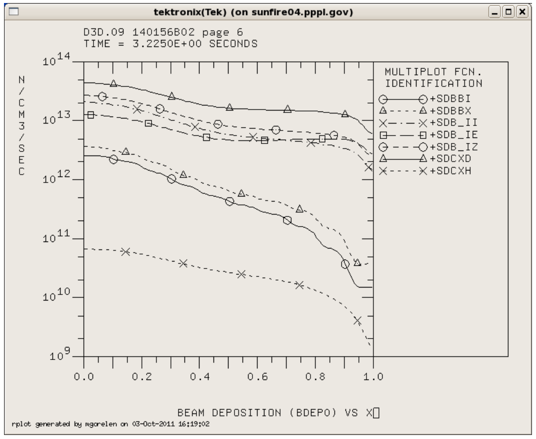
He data are incomplete

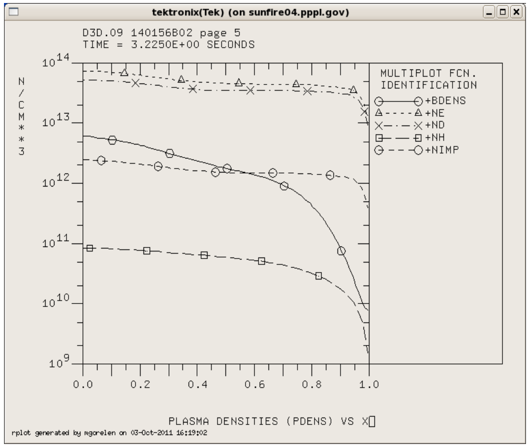
NUBEAM: *deposition (cont.)*

DIIID beam deposition shot #140156, t=3.225sec.



G.J Kramer, Nuclear Fusion 51 (2011) 103029





Ground state model

NUBEAM computes contribution from II_{th} , CX_{th} , II_{fast} , CX_{fast}

Beam atoms are 100% in ground state

Thermal component

$<\sigma v>^{II}$ (E_b/amu, T_i) , $<\sigma v>^{cx}$ (E_b/amu, T_i) adf01, adf02

Fast component

step (N-1):

$\sigma^{II}(E_{rel})v_{rel}$, $\sigma^{CX}(E_{rel})v_{rel}$ MC integral from particle orbiting

step N:

use $\sigma(E_{rel})v_{rel}$ from (N-1) for the beam–beam deposition

Excited state model "appropriate applicable"

Beam atoms in excited state:

BMS for the mixed species plasma is constructed as linear superposition of pure impurity solutions $S_{cr}^{(i)}$ (H. Anderson, Plasma Phys, **42** (2000) 781-806)

$$\sum_{i=1}^{I}[z_{0_i}^{(imp)} f_i^{(imp)} S_{cr}^{(i)}(E_b, N_e^{(i),equiv}, T_I)]$$

This approximation is made in assumption that all impurities have same temperature T_I.

What to do with fast component of plasma?

Fast ion population

Fast ions population:

On step N data from step N-1 are used for fast ion population

Differs by:

- CO and COUNTER injected neutral beam particles
- by energy fractions of beam

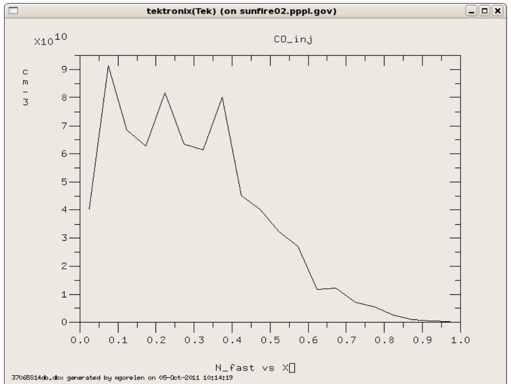
Data for N_{fast}, E_{rel} are saved from MC orbiting.

Temperature for fast population:

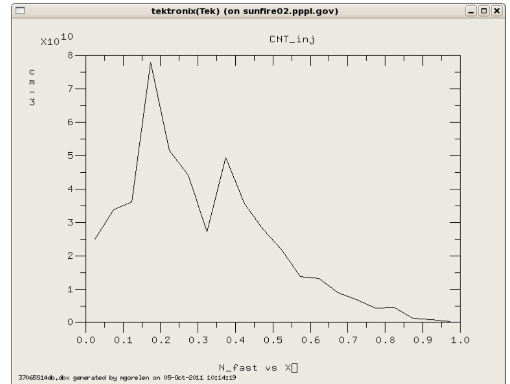
$$T_{fast} = \left(\langle E_{rel}^2 \rangle - \langle E_{rel} \rangle^2 \right)^{1/2}$$

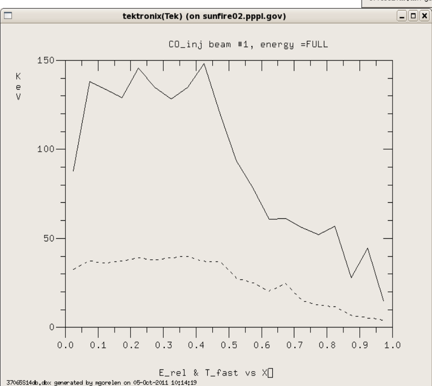
Fast ion populations: data

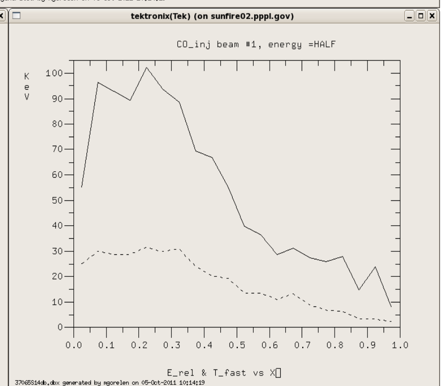
CO-inj

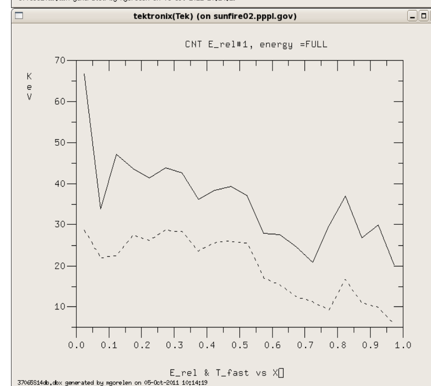


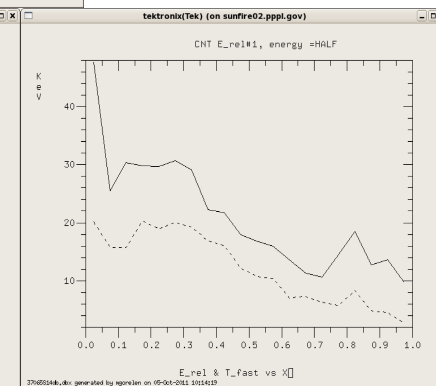
CNT-inj

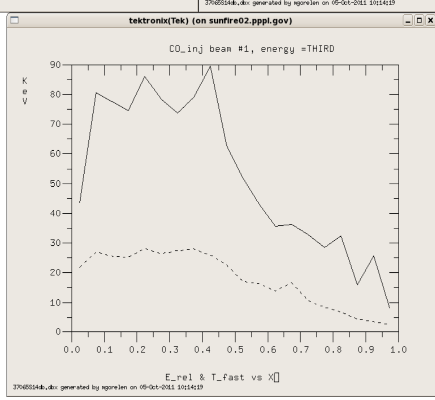


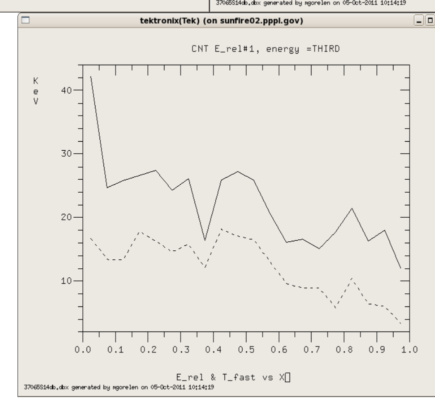












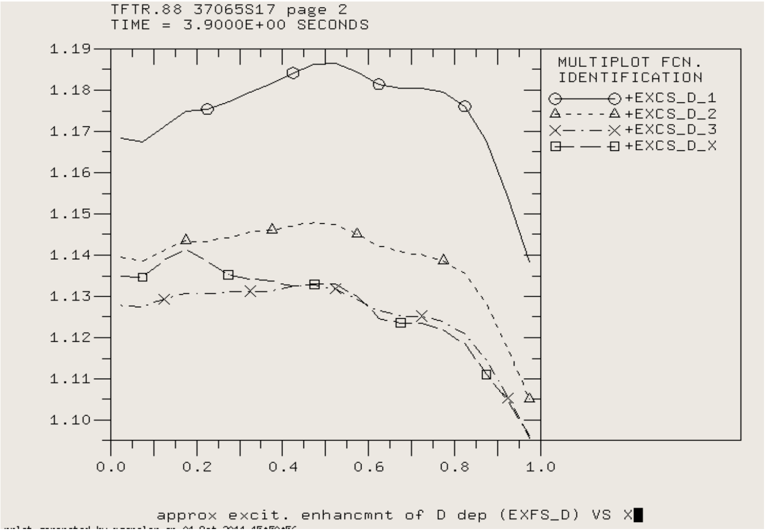
"appropriate applicable" excited state model

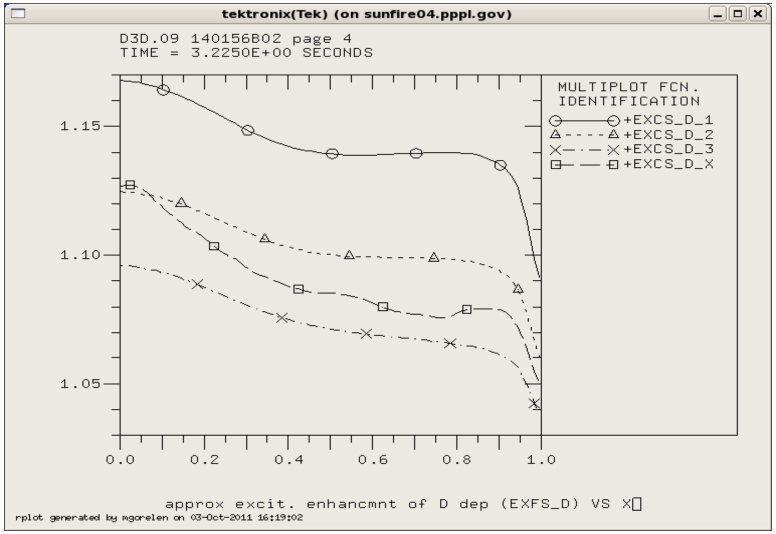
NUBEAM have to know II_{th} , CX_{th} , II_{fast} , CX_{fast}

Assumption: $II_{th}^{exc} = II_{th} * Enh$, $II_{fast}^{exc} = II_{fast} * Enh$

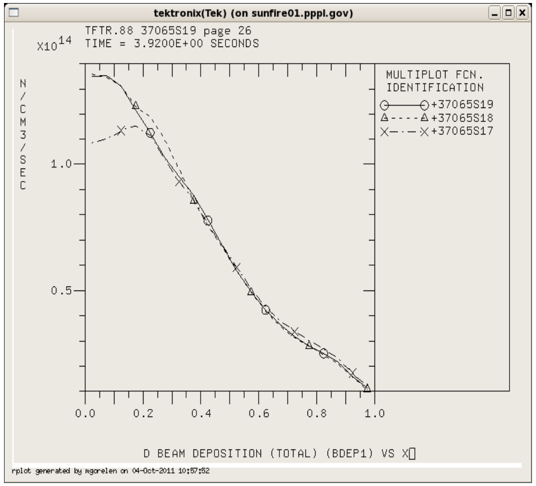
$$Enh = (BMS - CX_{th} - CX_{fast})/(II_{th} + Ii_{fast})$$

Apply enhancement factor (Enh) to ionization components from the ground state model.





BEAM deposition

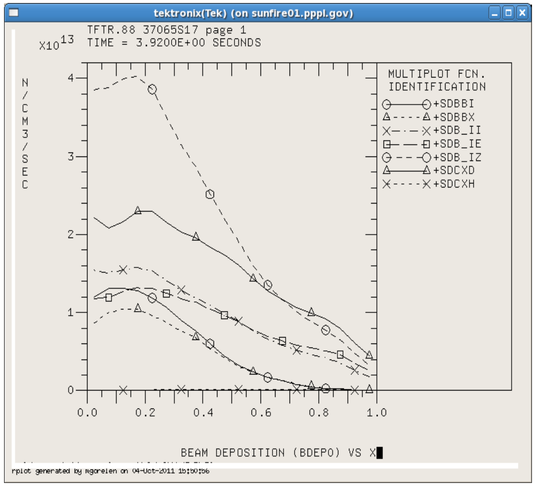


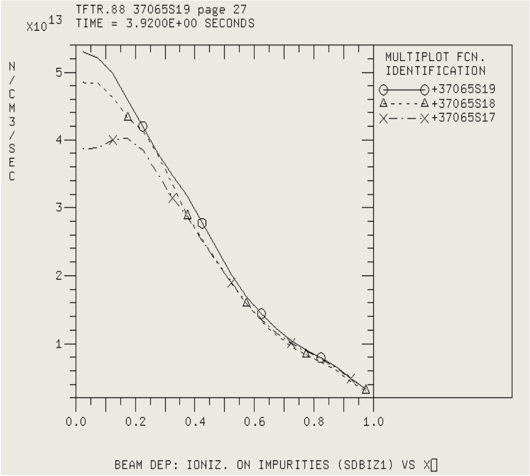
TFTR #30965, t=3.92 sec +

S17 – ADAS (exc.st)

S18 - ADAS (gr.st)

S19 - PREACT(gr.st)





$$BMS_{NUBEAM} = Enh * (II_{th} + II_{fast}) + CX_{th} + CX_{fast}$$

Summary and issues to be addressed

- Excited state model plays important role in neutral beam deposition.

ADAS310 have to be implemented in NUBEAM
with previous validation.

- Beam-beam interaction should be taken into account.

Advise wanted.