NSTX-U

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Comparison of 3D Halo Neutral Calculation in TRANSP and FIDAsim Codes

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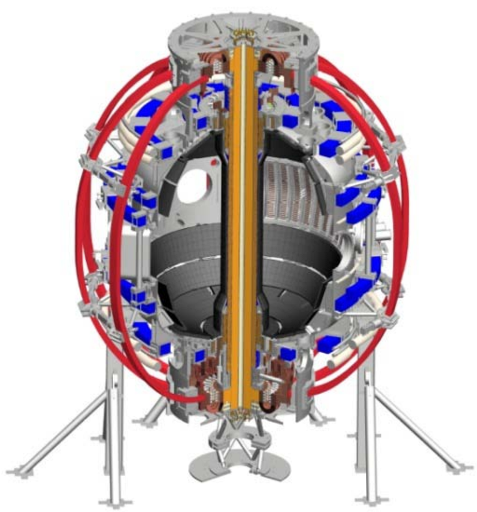
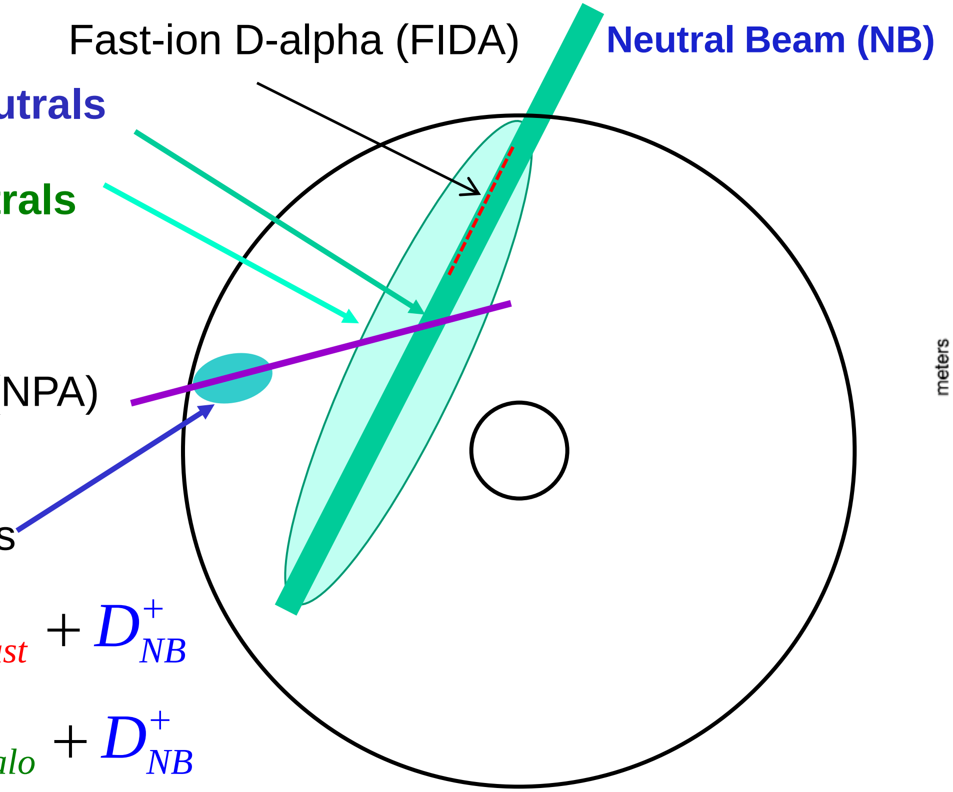
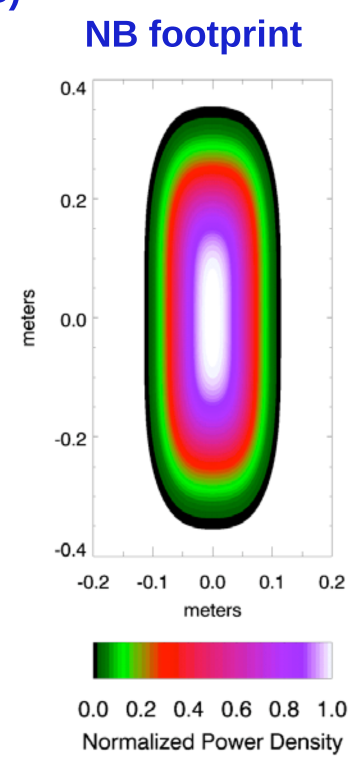
56th Annual Meeting of APS Division of Plasma Physics
October 27-31, 2014
New Orleans, Louisiana



Halo Neutrals are Created in the Vicinity of Neutral Beam through Charge-Exchange Reactions





$$D^+_{fast} + D^0_{NB} \rightarrow D^0_{fast} + D^+_{NB}$$

$$D^+_{bulk} + D^0_{NB} \rightarrow D^0_{halo} + D^+_{NB}$$

$$D^+_{fast} + D^0_{halo} \rightarrow D^0_{fast} + D^+_{bulk}$$

$$D^+_{bulk} + D^0_{halo} \rightarrow D^0_{halo\_high\_generation} + D^+$$

Both NPA and FIDA diagnostics rely on charge-exchange reactions between fast ions and beam and neutrals from neutral beam injection.

Halo Neutral Density is Important for Proper Interpretation of Fast Ion Diagnostic Signals

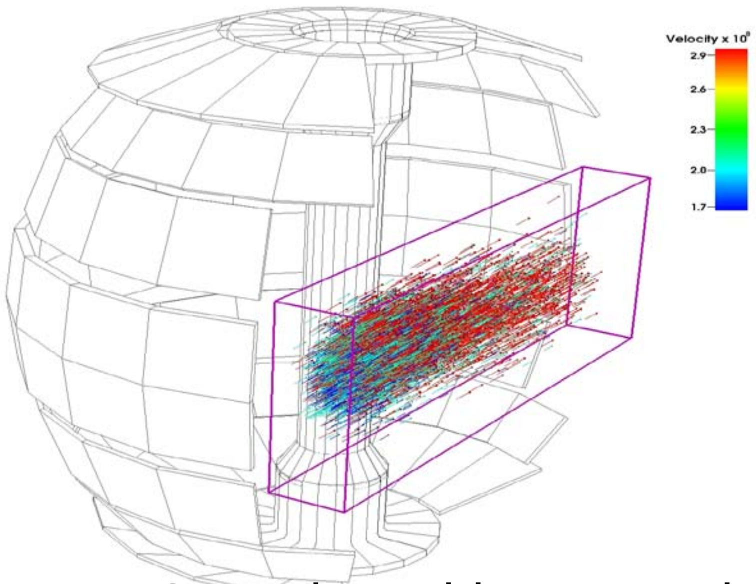
- **Halo density is comparable with beam neutral density. $n_{halo} \sim n_{beam}$**
  →increase NPA/FIDA signal, critical for synthetic diagnostics
  →affect fast ion CX loss, thus impact basic TRANSP calculations, e.g. NB driven current, neutron yield, power balance

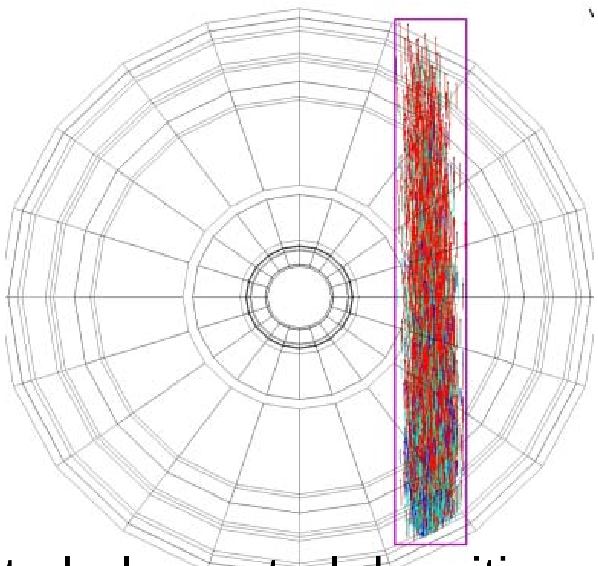
- **Halo neutrals spread wider than beam neutrals**
  →affect spatial localization of NPA and FIDA diagnostics
  →affect relative contribution from beam and halo neutrals

- **A 3D Halo model was recently developed in TRANSP.**

In this poster, comparison of 3D halo neutral calculation in NUBEAM & FIDAsim.

3D Halo Model was Recently Developed in TRANSP/NUBEAM





3d boxes, Cartesian grids are used to calculate halo neutral densities

1. Determine track start point based on the survival probability $\{P_{j,k}\}$ of the parent neutral

- Strongly depends on atomic physics data (ADAS310)

2. Sample velocity vector from ion distribution function

- Maxwellian for a thermal species

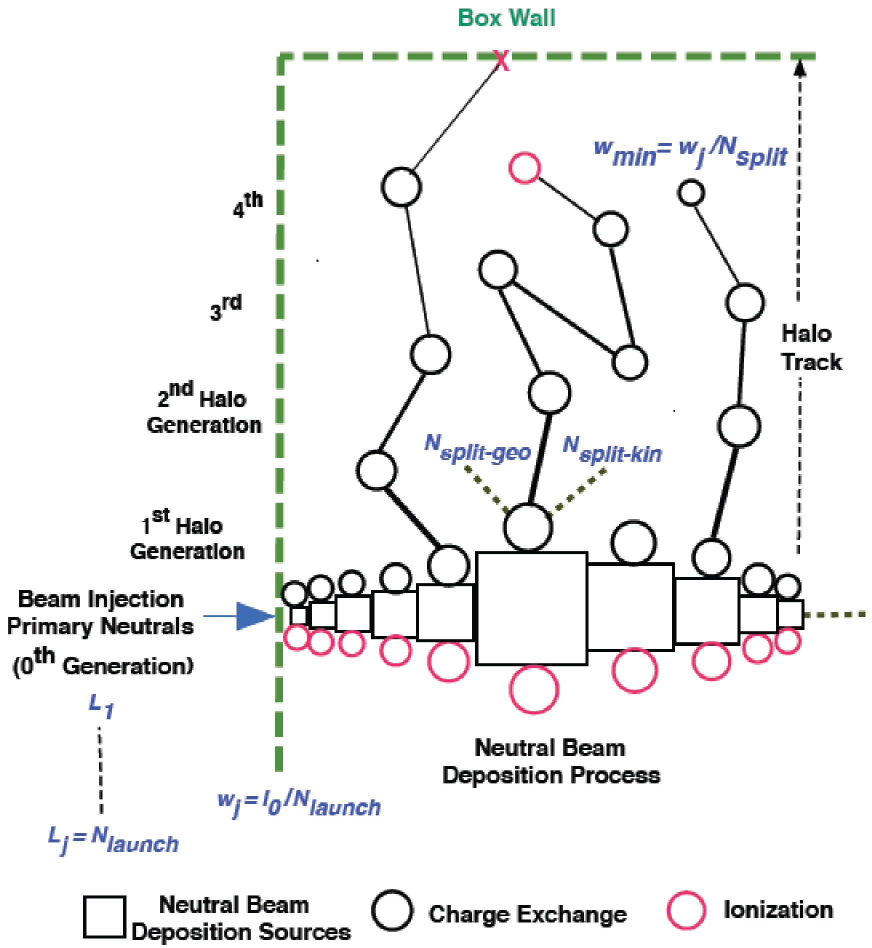
- Non-Maxwellian for fast ions

3. Calculate CX rate

4. Adjust weight of new track $\sigma_{cx} |v_i - v_n| / < \sigma v >_{cx}$

More details about 3D halo model in NUBEAM, see M. N. Gorelenkova's poster PP8.00075

Illustration of Halo Neutral Generation and the TRANSP Simulation Approach

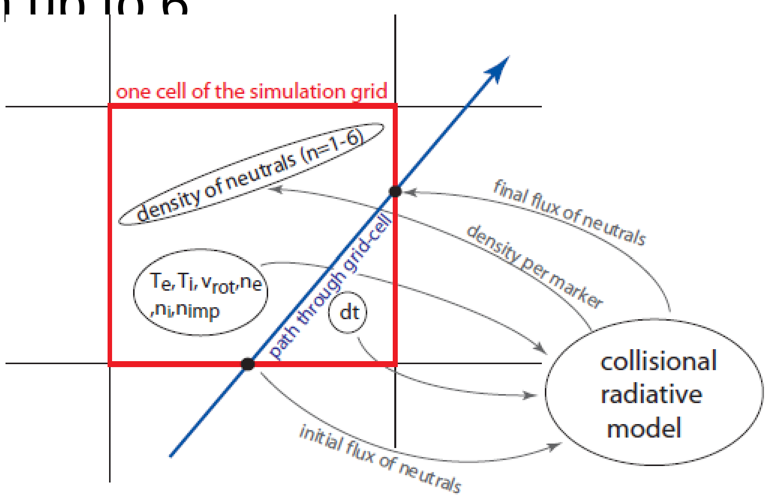


S. S. Medley, M. N. Gorelenkova

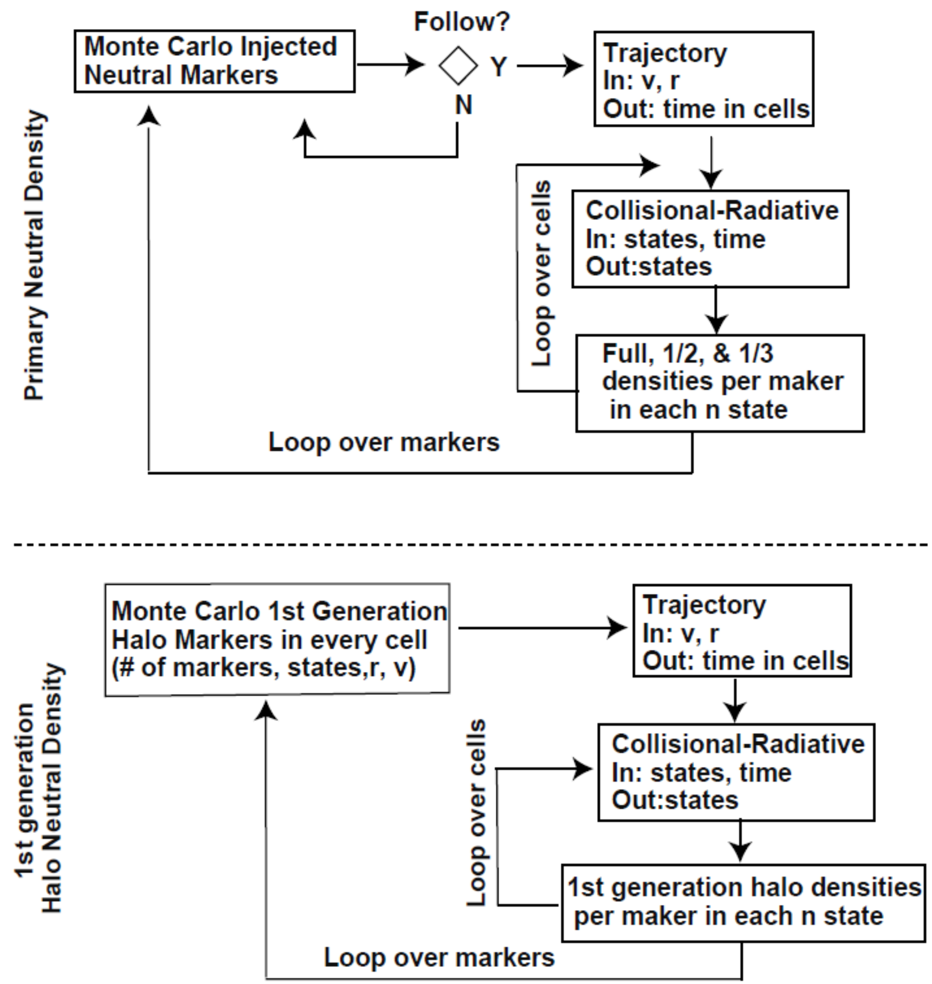
Beam and Halo Neutrals are Calculated Self-consistently with Monte-Carlo Method in FIDAsim

FIDAsim: a synthetic diagnostic code that uses forward modeling to calculate Doppler shifted D_α spectrum, and NPA particle flux at a particular time slice.

The core of the code is collisional-radiative equation with energy level n up to 6



B. Geiger 2012 PhD Thesis



i-th Generation Halos: similar to 1st generation except the number of marks is proportional to (i-1)th generation halos

*More details about FIDAsim code, visit, https://github.com/D3DEnergetic/FIDASIM/

Halo Neutral Models in TRANSP and FIDAsim Differ in Atomics Physics

- **Similarities**

3D Cartesian coordinates; Monte-Carlo approach; effects of toroidal rotation included;

- **Differences**

- New 3D halo model in NUBEAM

(i) time dependent

(ii) ignore quantum energy levels; cross section tables include the effects of excited states, e.g. ADAS excited state model (ADAS310)

(iii) Include both thermal halos and fast halos

- Halo model in FIDAsim

(i) time independent (halo neutrals formed in ion-ion collision time scale ~10μs)

(ii) neutrals in different quantum energy levels (n=1 up to 6); charge-exchange, ionization, and excitation cross sections are calculated separately for different n; cross section tables mainly come from ADAS and Janev's 2004 report

(iii) Include thermal halos only

Comparison of Simulation Results from TRANSP and FIDAsim

A Simplified Test Case for Code Verification

- **Simplifications:**

(1) Atomic physics: ignore all excitation processes; use the same cross sections tables (ground state only) in both TRANSP and FIDAsim, turn off fast neutrals in TRANSP

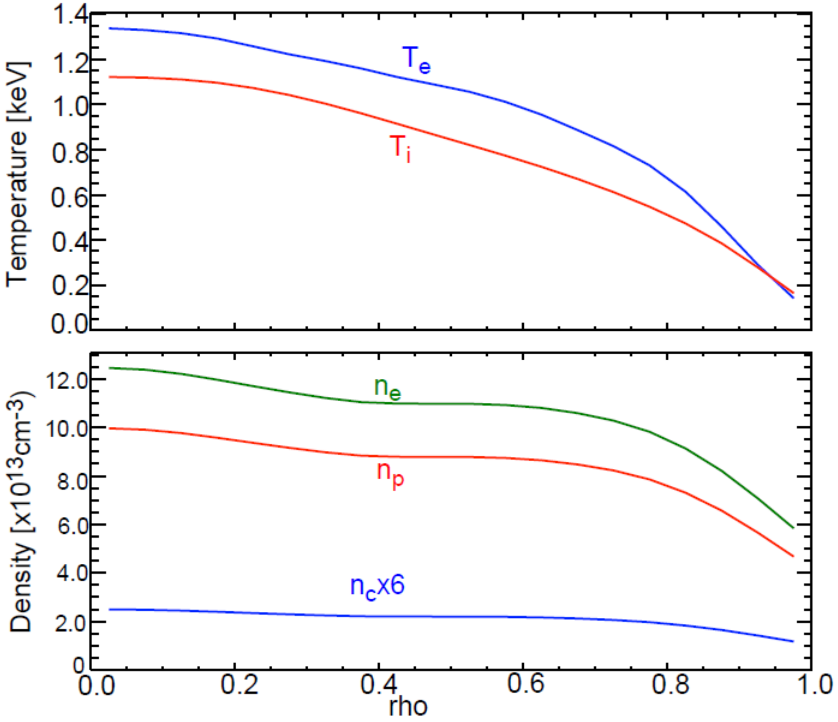
→remove atomic physics differences between FIDAsim and TRANSP

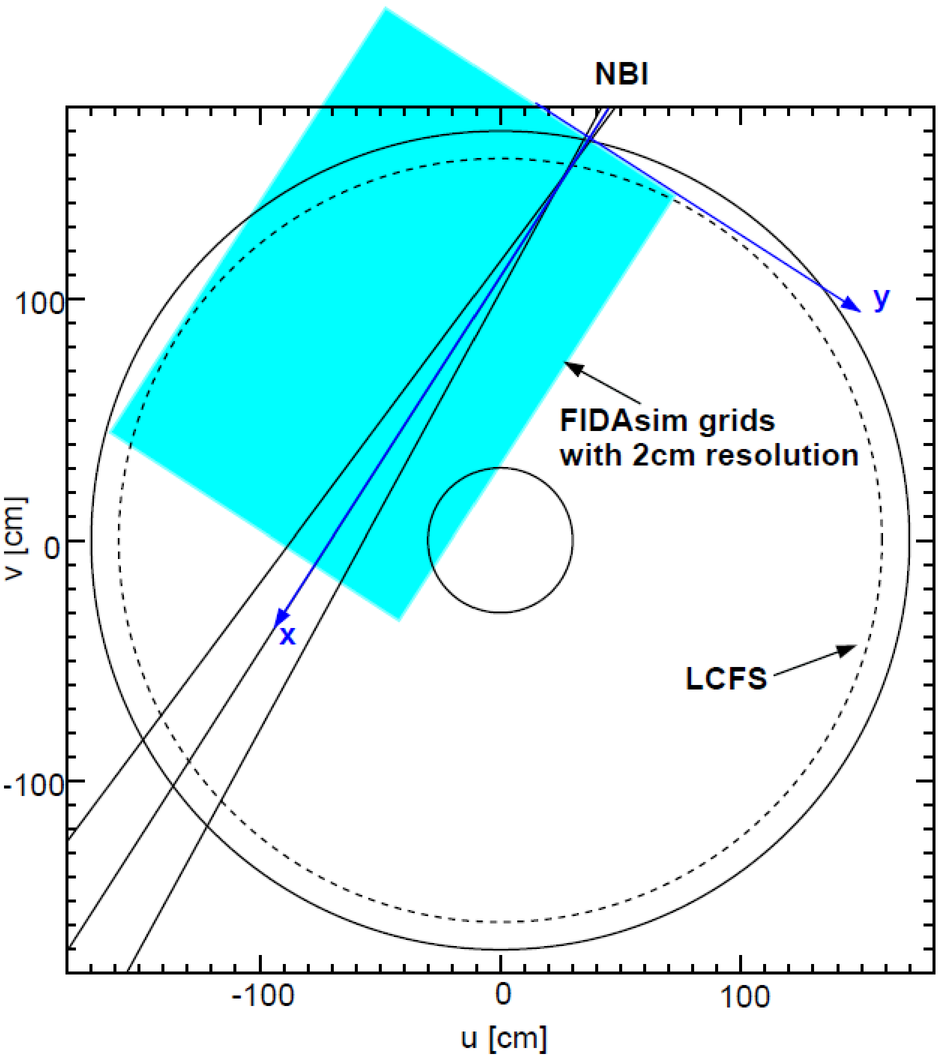
(2) Suppress rotation effects by setting v_{rot}=0

(3) NBI: one NB source at 90 keV

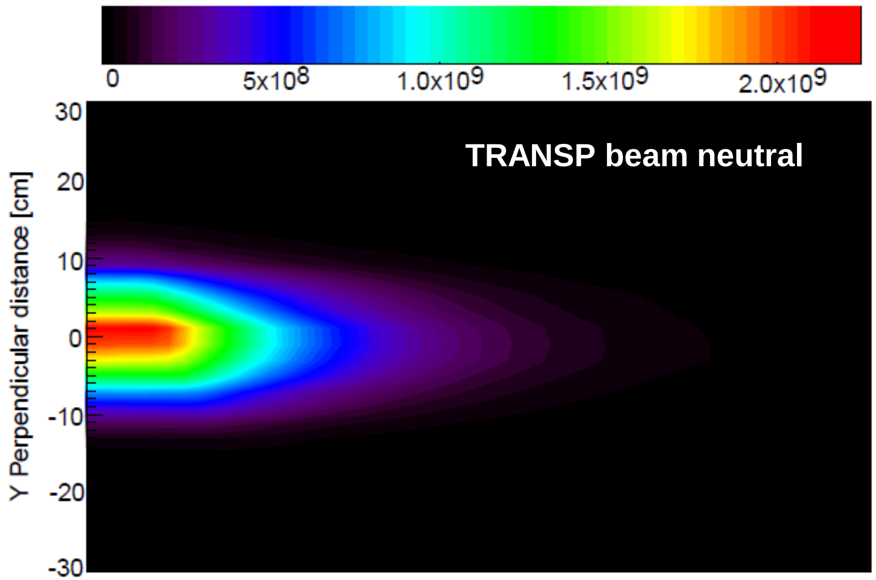
Input Plasma Profiles and FIDAsim Coordinates

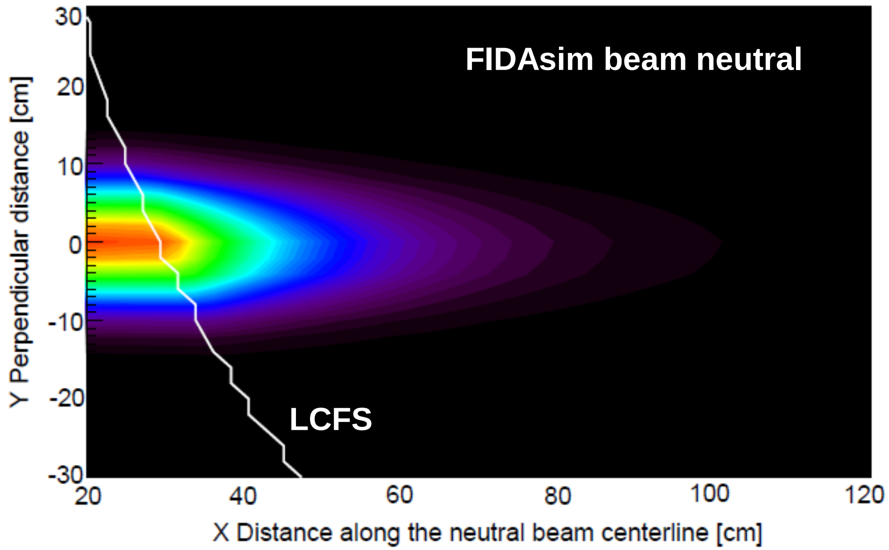
- **FIDAsim inputs:**
- Kinetic profiles (n_e, n_p, n_c, T_e, T_i),
- Magnetic equilibrium (geqdsk file)
- Fast ion distribution f(R, Z, E, v||/v)

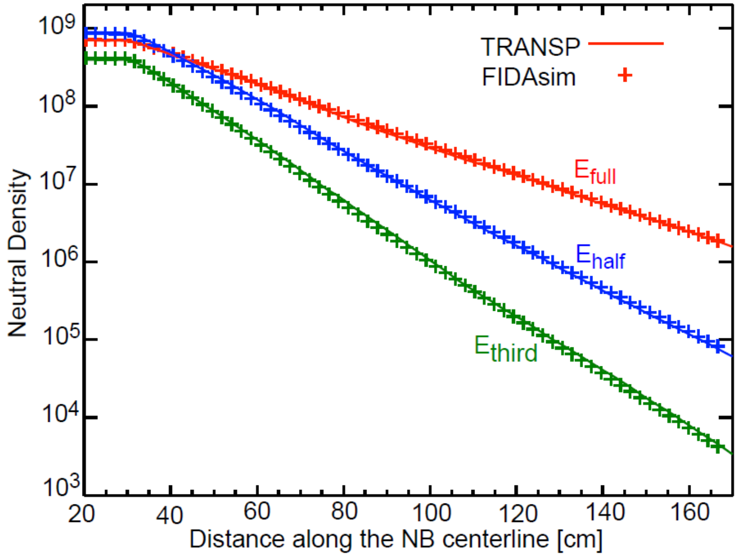


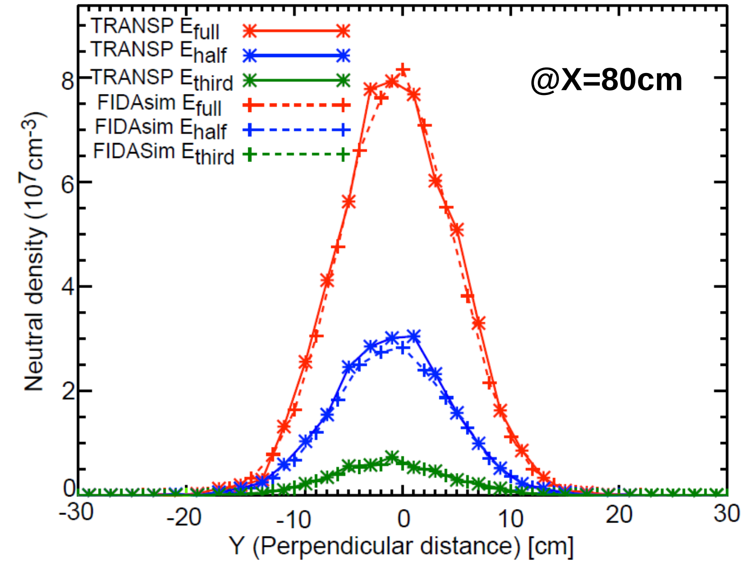


Excellent Agreement in Beam Neutral Density between TRANSP and FIDAsim

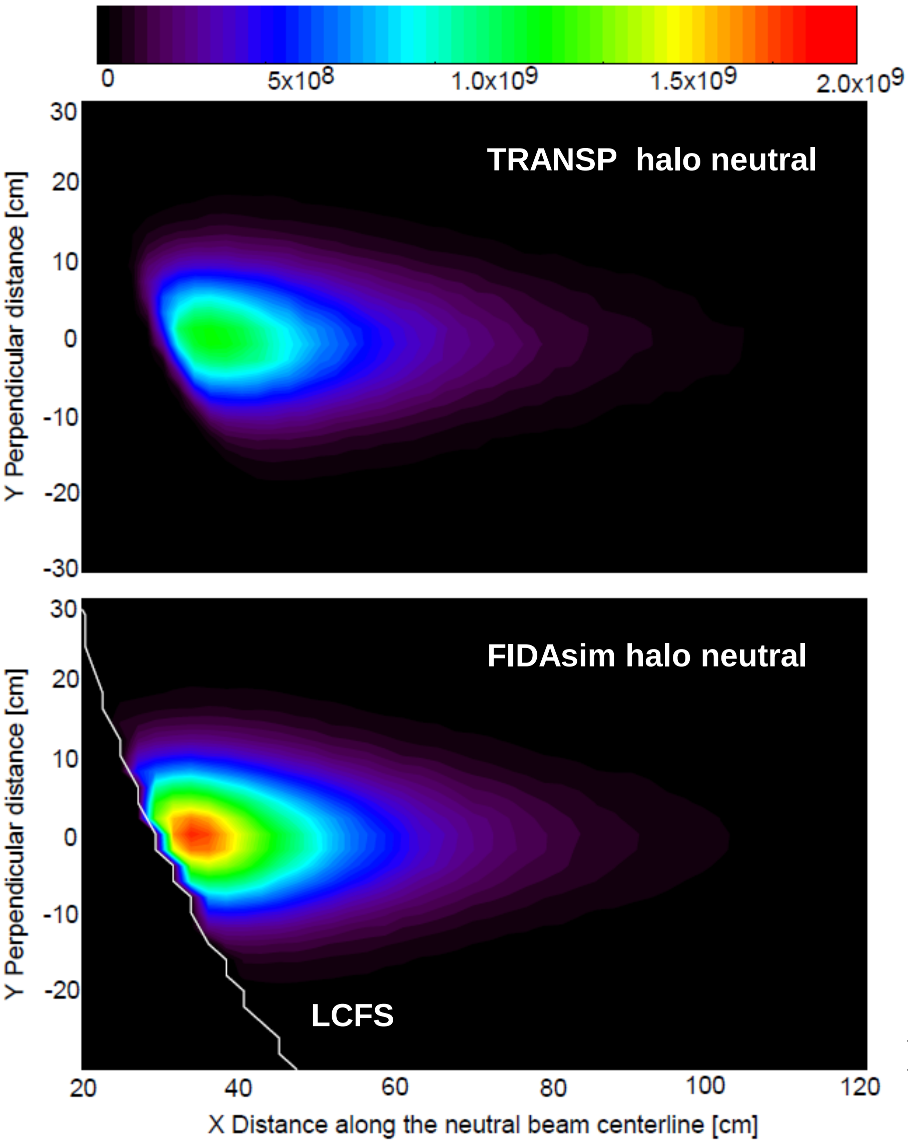


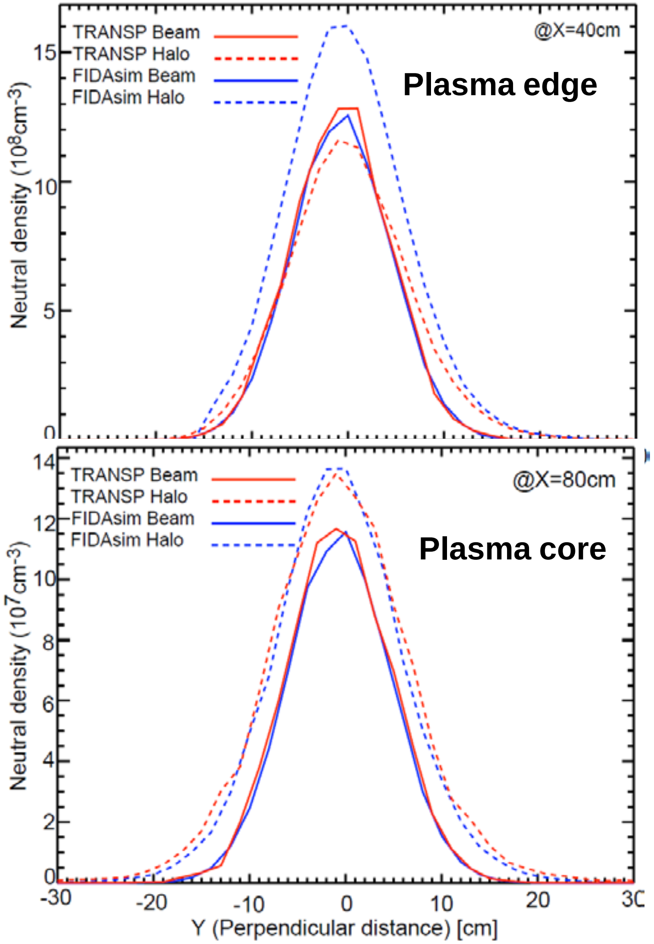






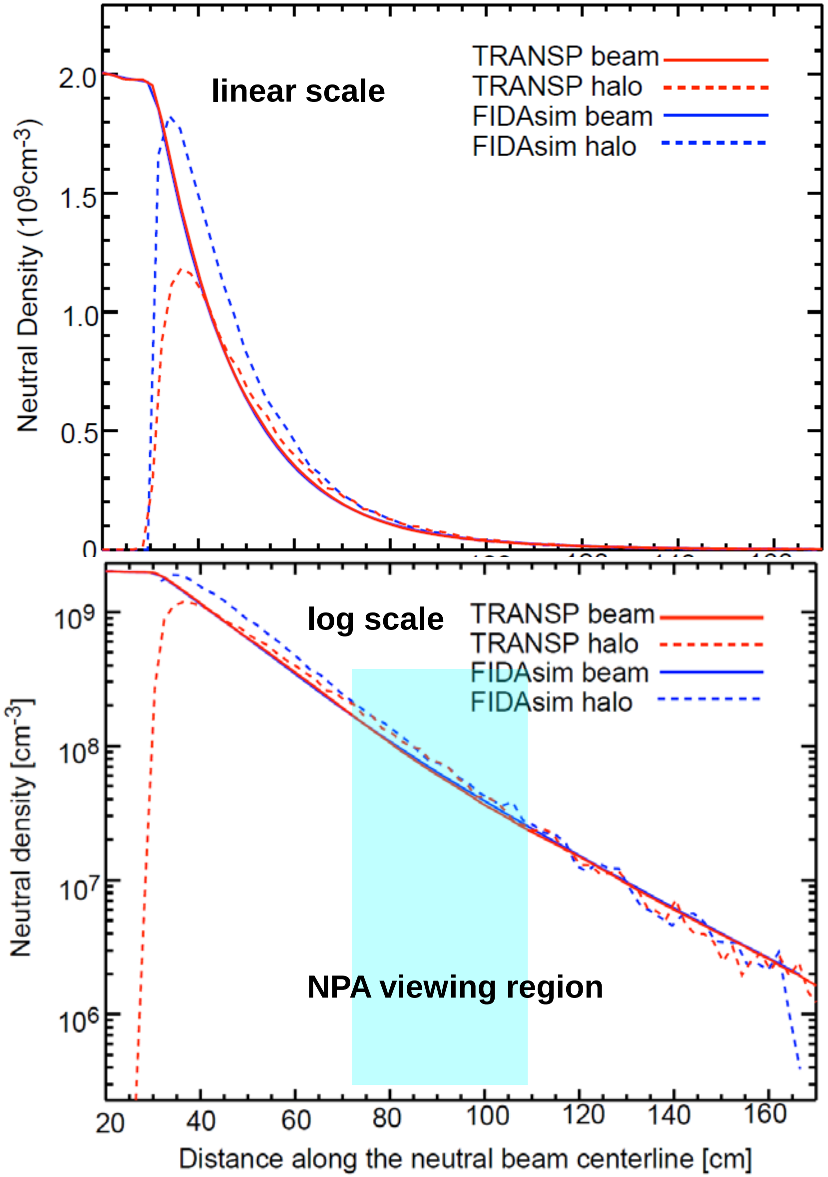
Halo Neutrals from TRANSP and FIDAsim Simulations have Similar Spatial Profile Shape





- Halo neutral density is comparable with primary beam neutral density, and spread wide in space

Halo Neutral Density from TRANSP 3D Halo Model is Less than FIDAsim Prediction



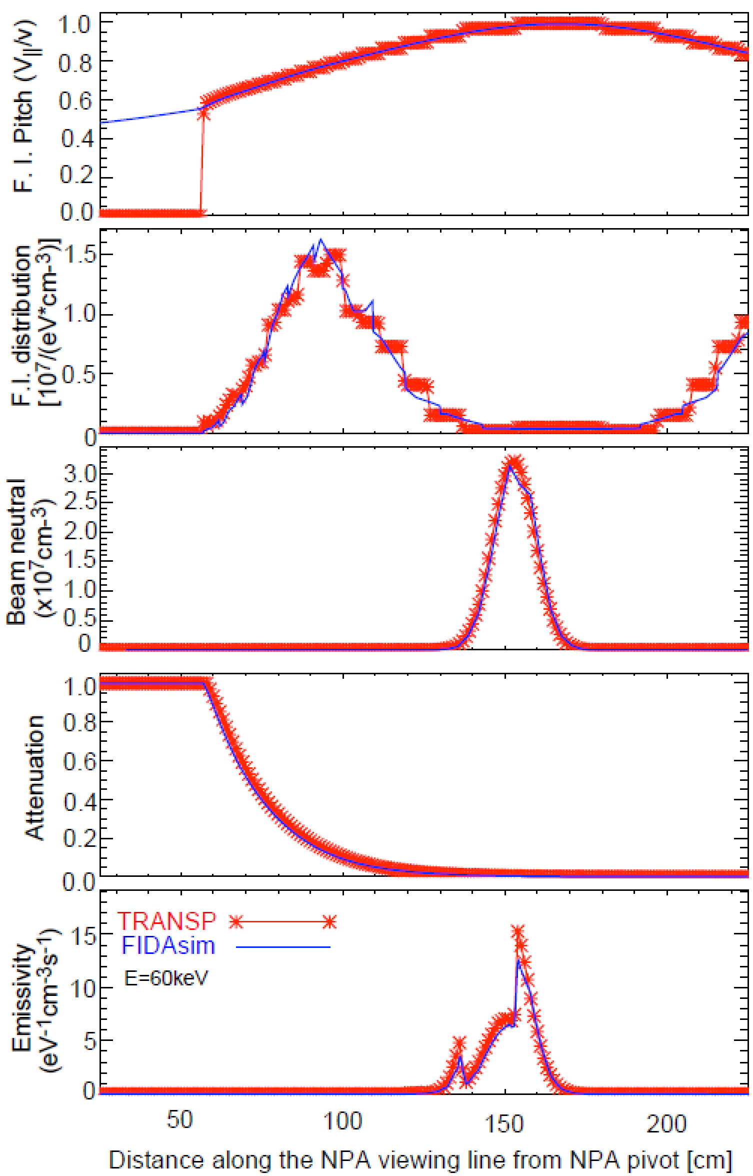
➢**Near the plasma edge, TRANSP predicted halo neutral density is ~30% less than that from FIDAsim estimation**

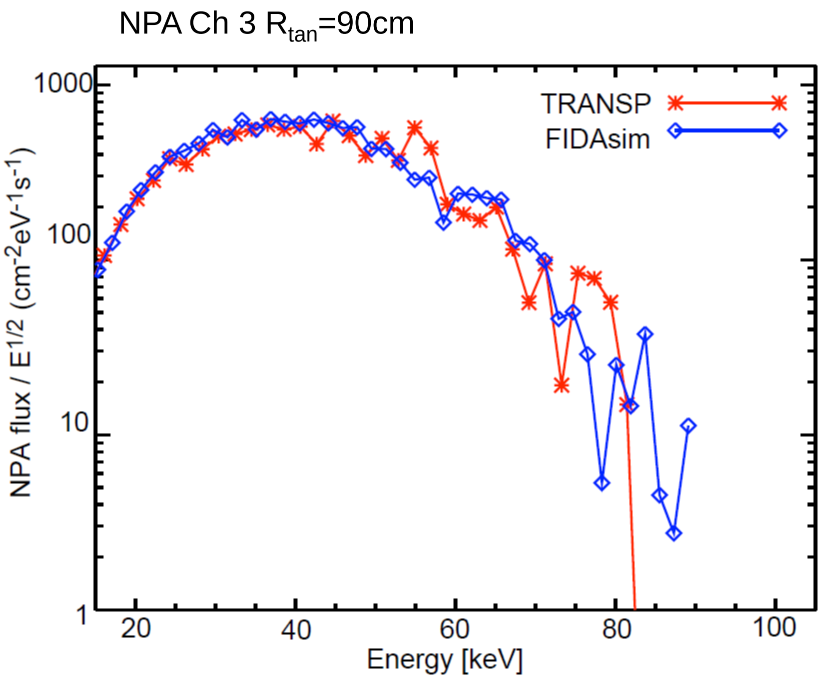
➢**In the plasma core (x=80cm ~ R=100cm), halo neutral density from both codes are similar**

➢**Discrepancy in halo neutral magnitude needs to be resolved**

- not due to cross section tables in this simplified test case since exactly the same cross sections tables were used.
- Correction of a few bugs slightly reduce the discrepancy. Are there still some bugs?
- Not enough statistics near plasma edge

Verification of NPA Simulators in TRANSP and FIDAsim

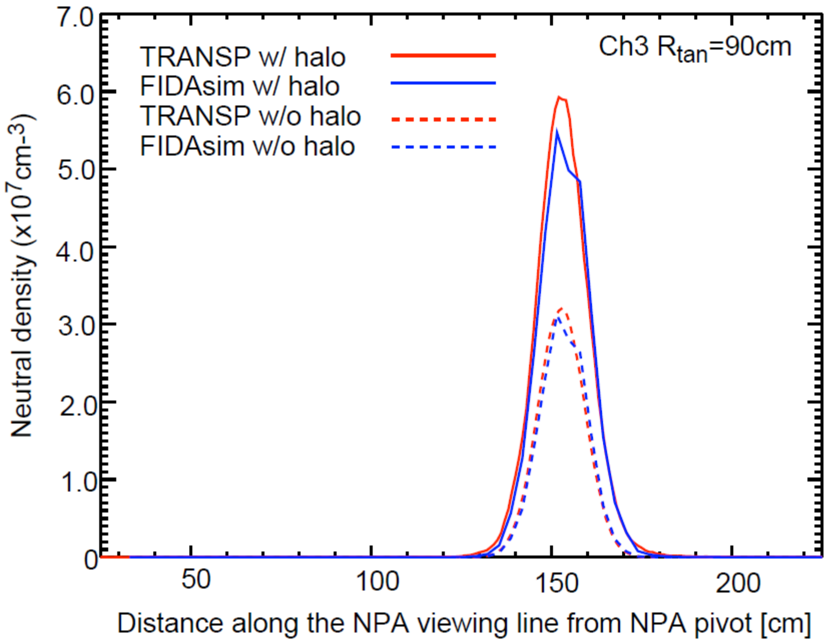


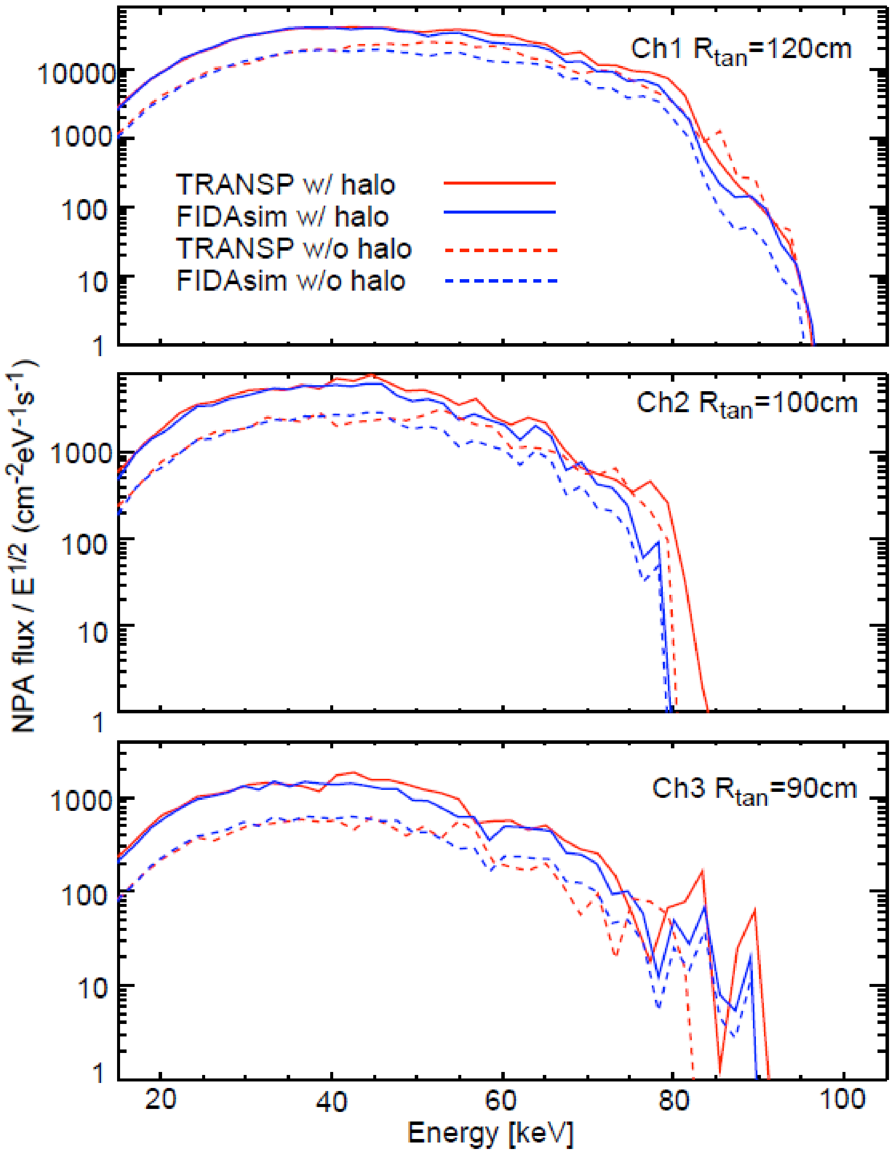


- Only primary beam neutrals are considered;
- NPA energy spectra from both NPA simulators agree with each other.

Effects of Halo Neutrals on NPA and FIDA Diagnostics

Halo Neutrals nearly Double NPA Flux

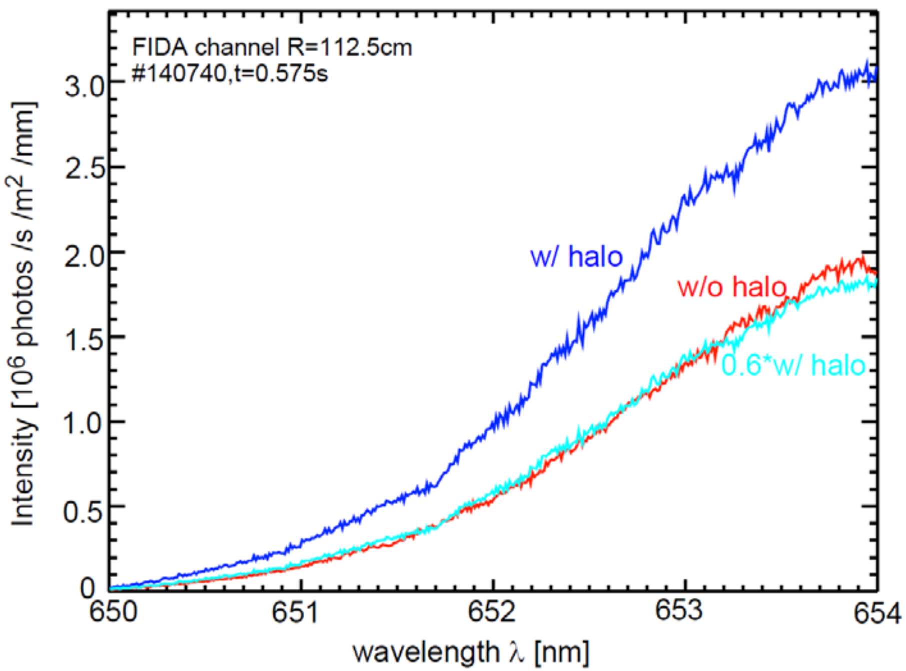


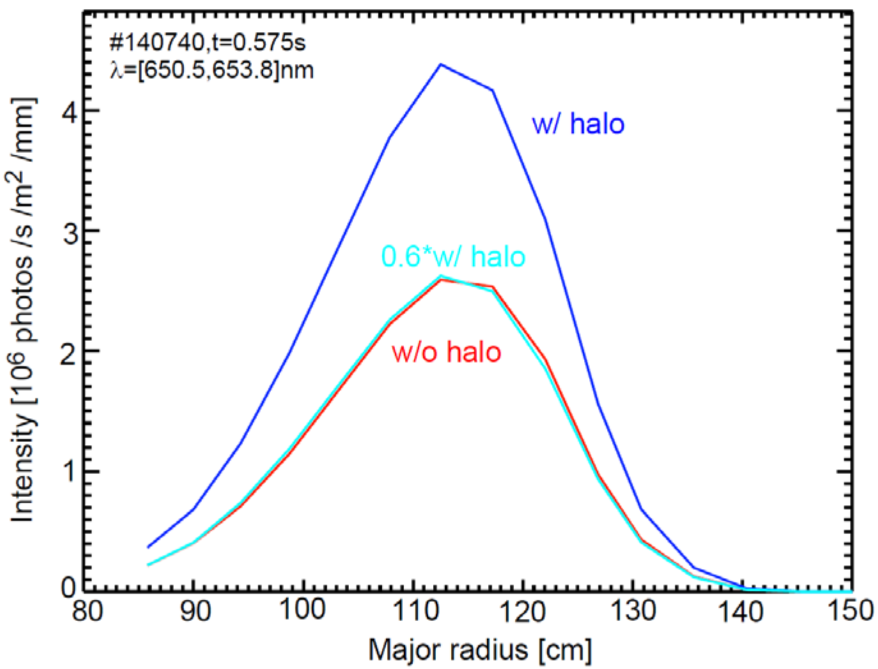


- Due to large halo neutral density, NPA flux in all channels nearly double, but the shape of energy spectrum is weakly affected.

- Since the ratio of halo neutrals to beam neutrals depends on plasma parameters, halo neutrals can affect the evolution of NPA signals

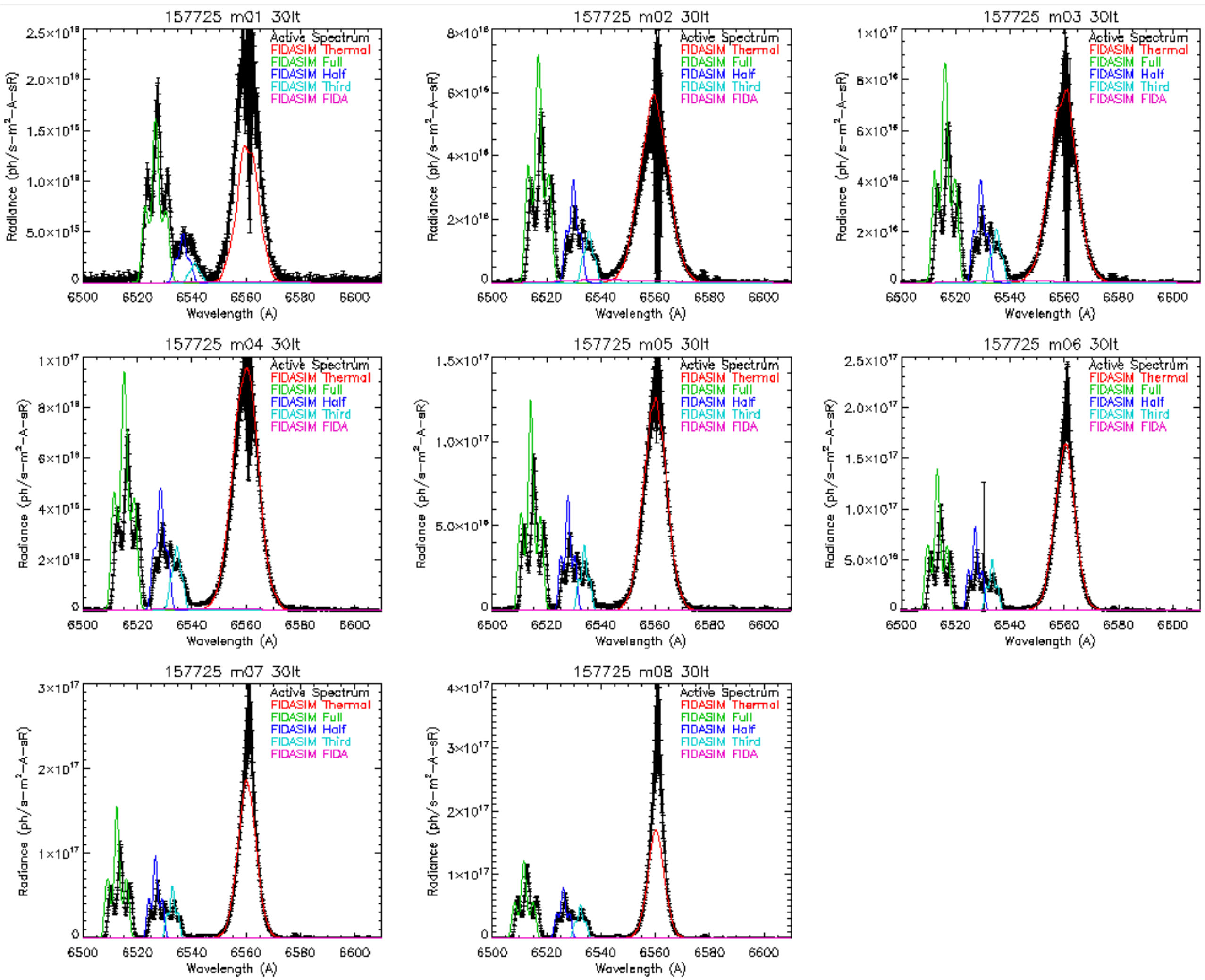
Halo Neutrals Significantly increase FIDA Signal





- FIDA signal is significantly increased due to large population of halo neutrals.
- The shape of FIDA spectra and FIDA spatial profile is slightly modified.

Both beam and thermal Emission from FIDAsim Simulations Agree with Experimental Measurements



B. Grierson

- ➢**FIDAsim predicted thermal emission agrees well with experimental measurements**
- →**Halo neutral density and profile from FIDAsim are reasonable.**

Summary

- Excellent agreement between TRANSP and FIDAsim calculated beam neutral density profile and magnitude.

- Good agreement on halo neutral density profile shape, but differ in magnitude (~30%) especially near the plasma edge. The reasons for magnitude discrepancy are currently under investigation.

- Halo neutral density is comparable with primary beam neutrals, and halo neutrals spread wider than beam neutrals.

→ Significantly increase the NPA flux, weakly affect the shape of NPA energy spectra.

→ Significantly increase the FIDA signal, slightly modify the shape of FIDA spectra and FIDA spatial profile.

- Reasonable agreement between FIDAsim calculated and experimentally measured beam and thermal emission.

Backup Slides

$$\frac{n_{1gen\_halo}}{n_{beam}} \propto n_i < \sigma v >_{CX} \frac{1}{\sqrt{T_i}}$$

Halo neutrals from TRANSP and FIDAsim calcuation have Similar Spatial Profile Shape, but slightly diff in Magnitude