NCSX Heating

Neutral Beam Injection

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NCSX Physics Validation Review

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NCSX NBI Physics Requirements

Requirement	Baseline	Upgrade	Long Term
H^0 Power	3 MW	6 MW	6 MW
Pulse Length	300 msec	500 msec	1.2 sec
Voltage	50 kV	50 kV	50 kV
Orientation	1-Co,1-Cntr	2-Co,2-Cntr	TBD
Focusing	3 MW to Plasma	6 MW to Plasma	6 MW to Plasma

The PDX, PBX, and PBX-M Projects Used a High Performance Neutral Beam Injection System

- **Some PBX-M Highlights Achieved With the NBI System (88-93)**
  - **High Beta (6.8% Beta total)**
  - **High confinement (3-3.5 x "ITER-P")**
  - **High stability (Beta normal of 4.5)**
  - **MHD instability control with close-fitting, conducting shell..**
  - **H-mode power threshold reduction with "m=1" edge biasing..**
  - **New core high-confinement ("CH")mode**
    - **Peaked density & high bootstrap fraction with IBW**

- **NBI Specifications**
  - 6 MW H^0, 50kV, 100A
  - 300-500 msec pulse
  - 4 Beamlines
  - 30 cm Circular Grids
  - 440 cm Focal Length
  - Power Density HWHM~1.2°
  - $P^0(E):P^0(E/2):P^0(E/3)$ = 80:13:7
  - Total Computer Control for conditioning & operation -reliable economical operation

- **The NCSX Neutral Beam Heating Design Adopts the Available PBX-M NBI Systems**

The NCSX NBI Design Has the Required Heating Power

- **PBX-M Injected Power Capability**
  - ORNL Qualification of Individual Ion Sources (Without Fringe Fields)

    NBI (H^0) = 6 MW (4 x 1.5 MW), NBI (D^0) = 8 MW (4 x 2.0 MW)
  - PDX Simultaneous Testing of 4 NBI (Without Fringe Fields)

    NBI (D^0) = 8.3 MW (4 NBI @ > 52 kV)
  - Neutral Power Reionization Loss Fractions in PBX-M Due to Duct Neutral Gas (~1-4x10^{-4} T) Due to No Front End Cryopumping

    Perp ducts = 0.88 P_0 (12% loss), Tangential ducts = 0.83P_0 (17% loss)

- **NSCX NBI Design Will Reinstall NBI Front End Cryopumping for Maximum Power Injection and <u>Enhanced Torus Pumping</u>**

  NBI (H^0) = 6 MW (4 x 1.5 MW), NBI (D^0) = 8 MW (4 x 2.0 MW)

The NCSX NBI Design Has the Required Pulse Length

• The NB power handling surfaces are engineered to operate to 500 msec pulse lengths at the full power, peak power density of 3 kW/cm^2.

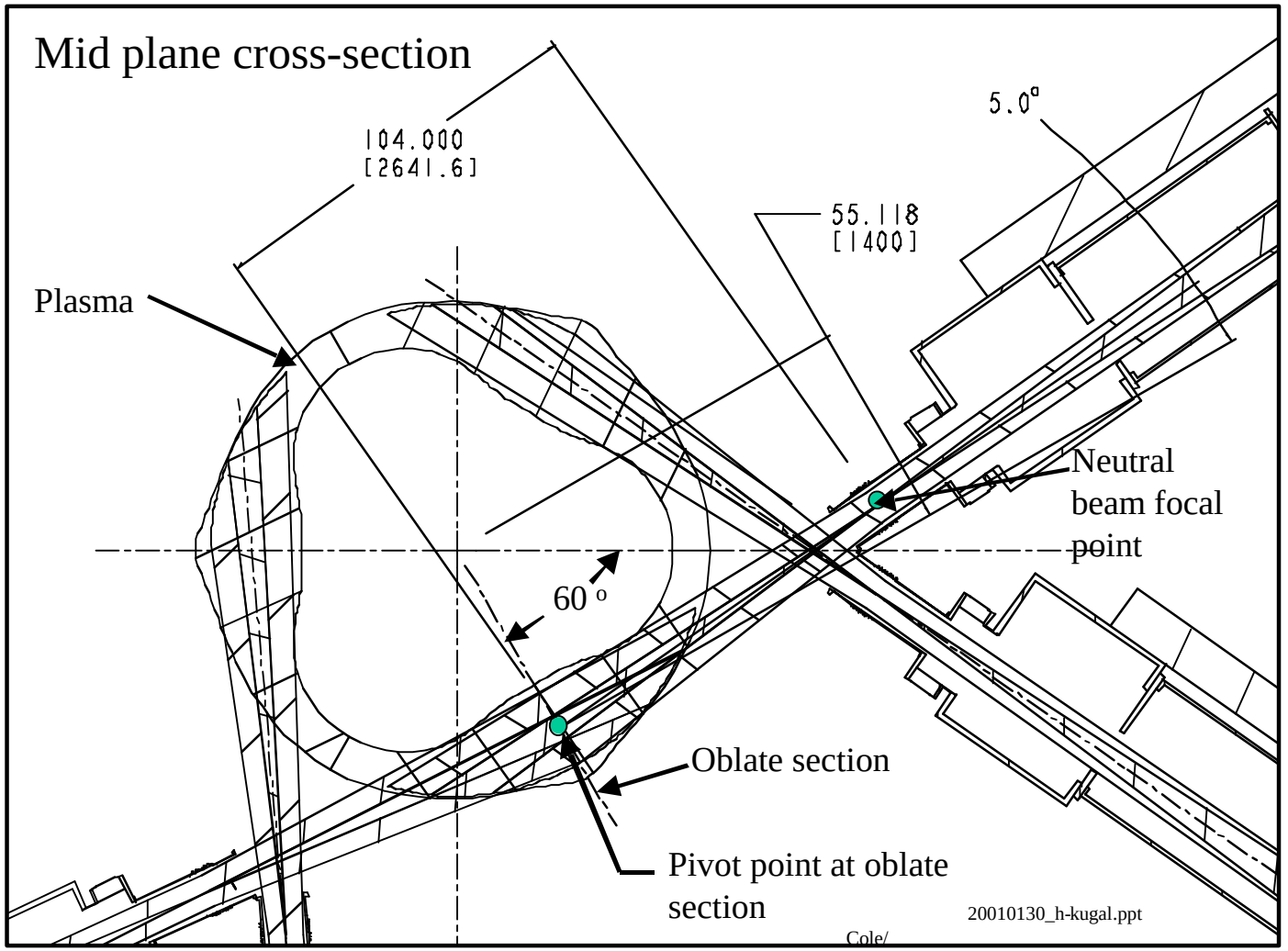
• PBX-M NBI systems pulse lengths were typically ~300 ms
  - testing to 500 msec did not start until toward the end of PBX-M.

• ORNL operated one ion source with H^0 to 500 msec at ~1.5 MW .
(Ion source I_{decel} rose beyond 400 ms and a control technique was applied)

• **PBX-M demonstrated 500 msec at reduced power (4MW total)**
  - Each NBI demonstrated to operate with D^0 at ~40 KV, 1 MW, to 500 msec. Operation to higher powers at 500 msec feasible for both H^0 and D^0.

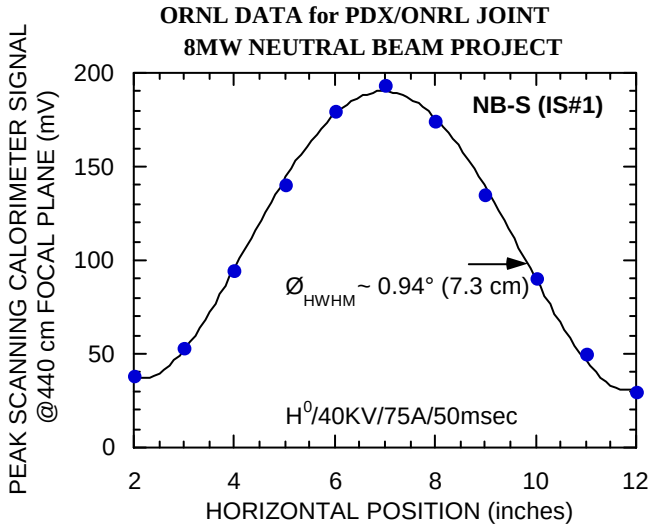
• MAST using similar ORNL NBI plans to upgrade to 1.5-3 pulse lengths.
  - NCSX will adopt this technology for long pulse NBI.

The NCSX NBI Design Has Co- and Cntr- Injection for Beam Balance Studies and Control of Beam Driven Currents



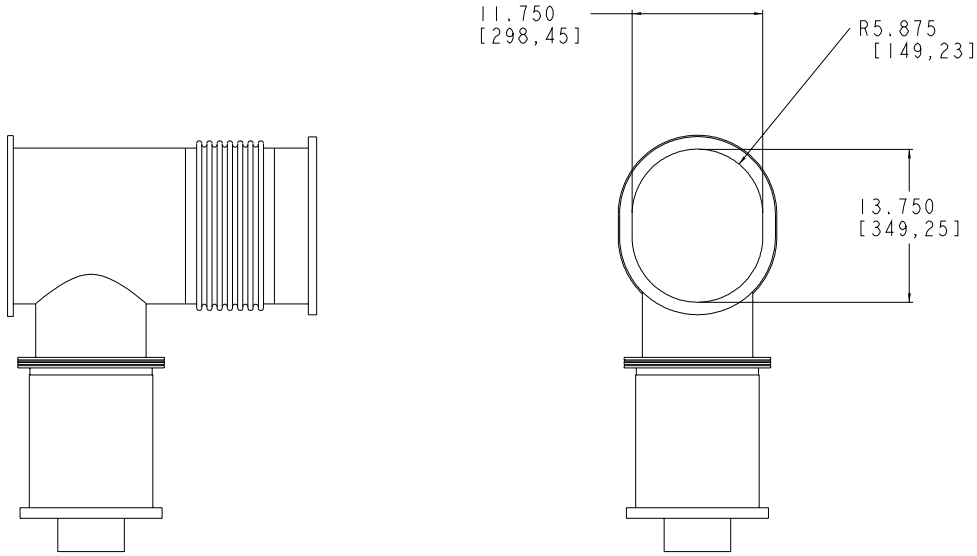
The NCSX NBI Design Has Power Density Profiles to Transit the Available Ports and Heat the Oblate Target Plasma

- The ion sources have a focal length of 440 cm
- Power density profiles were measured in the 440 cm focal plane



NBI System [a]	θ HW@HM [b]	W HW@HM [c]	θ HW@1/e [d]	W HW@1/e [e]
S	1.5°	11.58 cm	1.8°	13.9 cm
E	1.13°	8.75 cm	1.36°	10.5 cm
NW	1.2°	9.25 cm	1.44°	11.1 cm
SW	0.94°	7.25 cm	1.13°	8.7 cm

The Width of the Candidate NB Transition Duct is Comparable to the PBX-M Tangential Duct Diameter

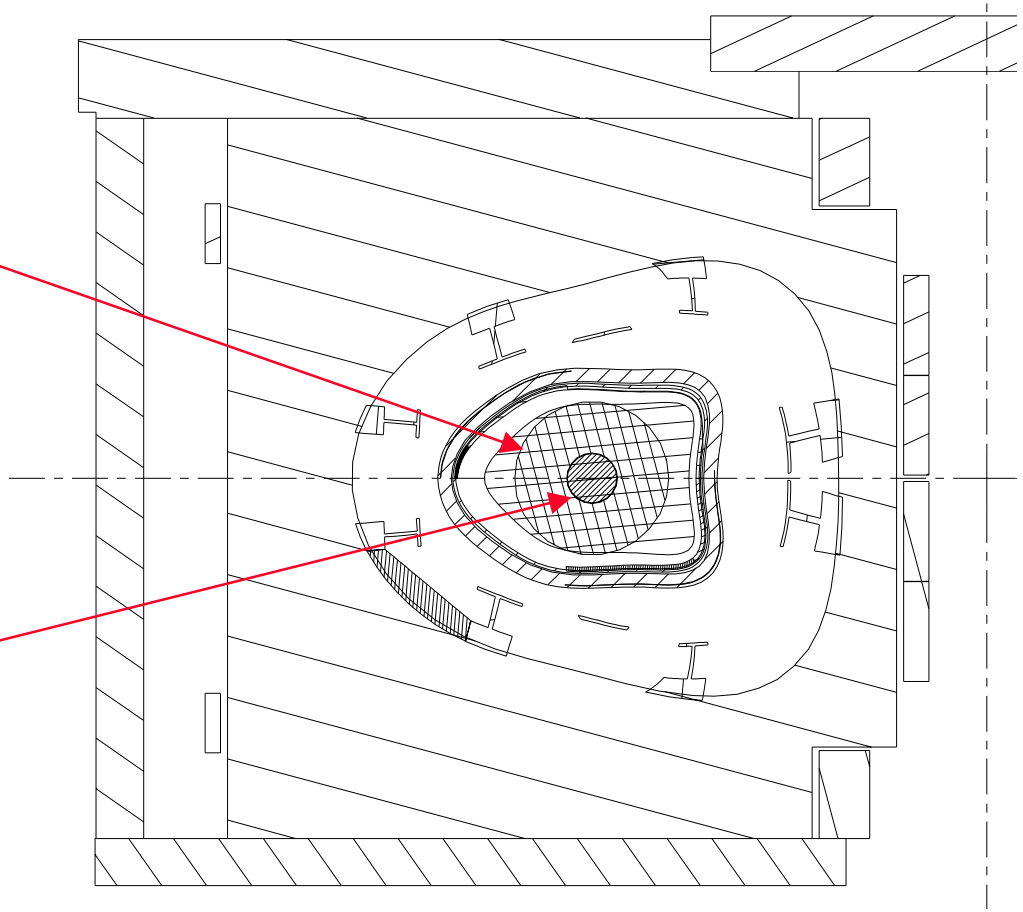


- During the Conceptual Design Phase it appears possible to increase the duct height for greater conductance

The Envelope of the Oblate Target Plasma Encloses More than 90% of Injected Power from Most Poorly Focused NB

- Circle Enclosing ~96% of the Injected Power from NB-S (IS#1) (HWHM =1.5°) Superimposed on the Oblate Target Plasma

- Encloses ~47% of Injected Power



Summary and Conclusions

- **The NCSX Neutral Beam design adopts the high performance NBI system of the PDX, PBX, and PBX-M projects**
  - **provided automated, reliable, economical operation.**

- **The design has the required heating power and pulse Length.**

- **The design has power density profiles that can transit the available ports and heat the oblate target plasma.**

- **The design has co- and cntr- NBI for beam balance studies, and control of beam driven currents.**

- **The NCSX NBI design will support the NCSX Physics Program.**