Flexible Fueling System for NSTX Transport Studies

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Pellet Fueling System will Extend NSTX Capabilities

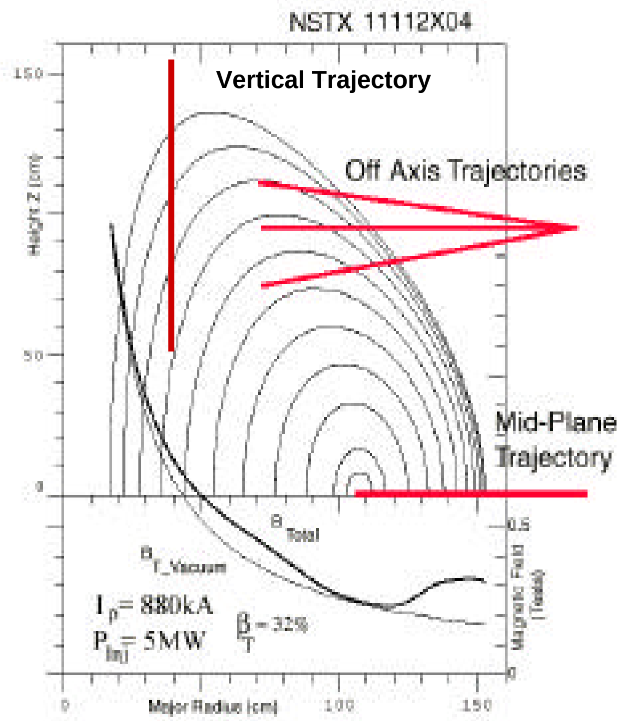
- Pellet injection will extend NSTX operating regime
  - START achieved $n_e(0)$ of $5x10^{20}$ m^{-3}, n_{GW} of 1.6 with vertical pellet injection
- Pellets will provide a potential advanced confinement regime trigger
  - Pellet induced H-mode (DIII-D), PEP-mode
- Pellet fueling system will provide a tool for core particle transport studies

Advanced NSTX pellet fueling system can be obtained at low-cost using existing designs and components

- NSTX machine size and target plasmas well matched to simplified pellet injection system
  - 1.8 mm diameter (1e20 atoms), 200 - 1500 m/sec speed
- Simplified advanced design utilizes self contained LHe refrigerator – external LHe supply not required for initial simplified pellet fuelling system
- Curved guide tubes for different injection locations

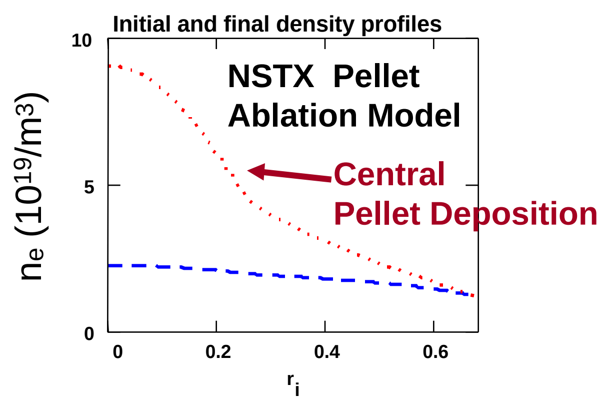
Proposed Injection Geometry

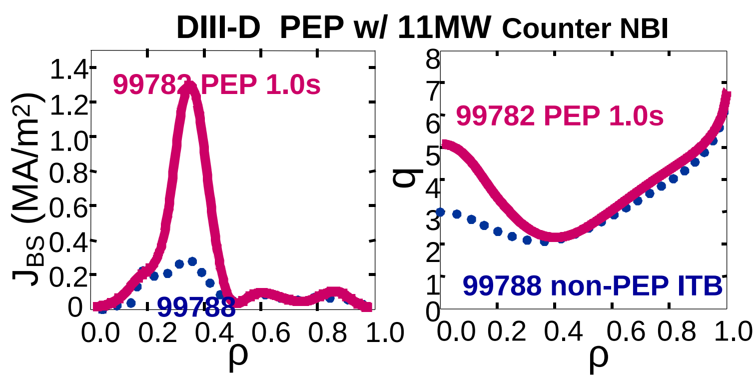
- Several injection trajectories can be used to investigate different NSTX physics objectives:
  - Outside midplane - ITB formation, density limit, transport, B drift
  - Off axis - ITB formation with off axis shear in rotation
  - Vertical - HFS fueling, transport
- For NSTX, B is inward on LFS in high beta cases, which may yield inward drift of pellet ablatant instead of outward drift seen in tokamaks.



Central penetration gives steep density gradients for advanced performance

- Example when pellet “expires” on axis :
  - 1.8mm, 1 km/s, $T_e(0)$ = 1.5keV
  - Shafranov shift reduces distance to axis
  - model uses self limiting ablation (finite heat reservoir of flux surfaces)
- Expected to produce strong off axis peaking of the bootstrap current and shear reversal as observed on DIII-D.





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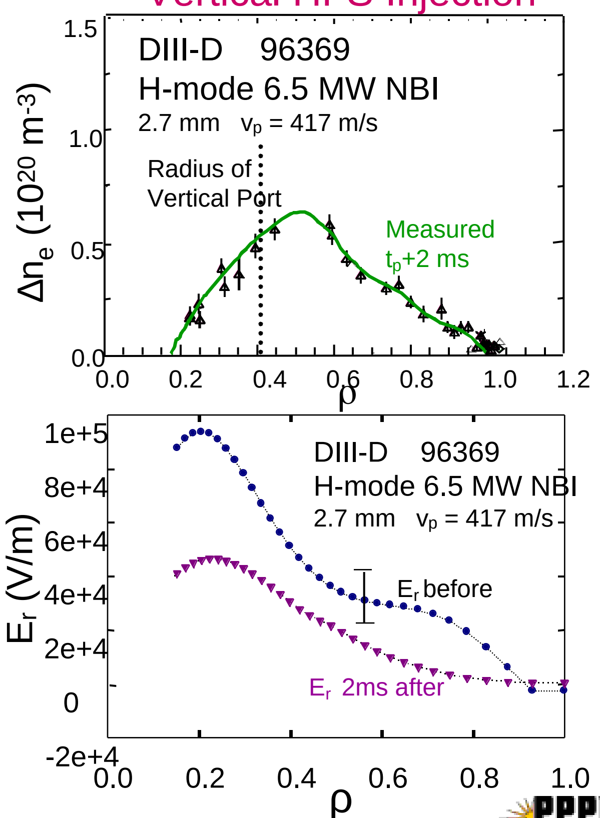
Radial Electric Field Modification by Pellet Injection - Vertical HFS Pellet

- The radial electric field can be modified by a pellet primarily due to the reduction in v_ϕ where there is strong mass deposition from the pellet. E_r from the radial force balance:

$$E_r = P/Zen + v_\phi B_\theta - v_\theta B_\phi$$

- Example from DIII-D shows strong change in Er induced by deep deposition of vertical HFS injected pellet.
- Partial penetration can lead to strong gradient in Er for barrier formation.

Vertical HFS Injection



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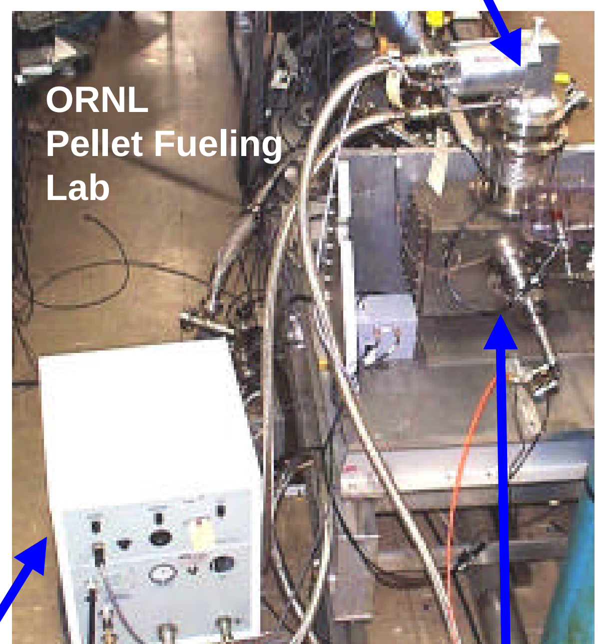
Proposed Pellet Injection System for NSTX

- Pipe-gun (in situ condensation) developed in technology program using cryorefrigerator and minimal pumping system ("Pellet injector in a suitcase")
  - 1.8 mm diameter (1e20 atoms), 200-1500 m/sec pellet speed
- Steerable guide tube for tangential/poloidal injection for central or off-axis density pertubation

Cryorefrigerator - cold head



Cryorefrigerator compressor

Pipe-gun with mechanical punch

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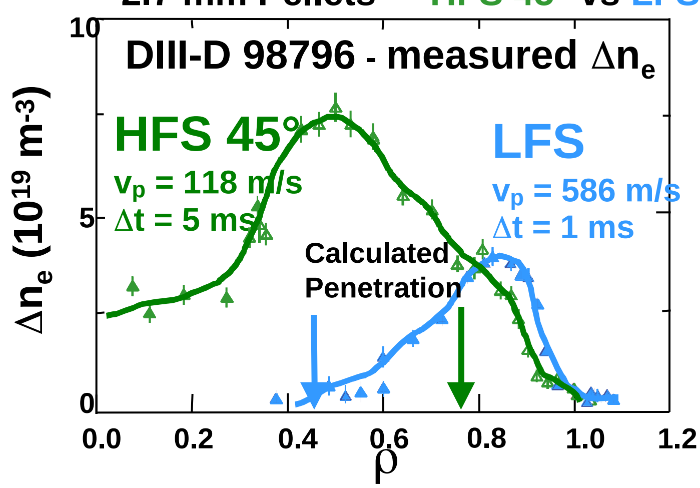
Summary of Proposal

- **Flexible low-cost pipe-gun injector system proposed for installation on NSTX**
  - 1-3, ~1.8mm pellets, 200-1500 m/s, steerable injection line for central or off-axis density perturbation
  - More flexible than MAST system, which will use low speed outside midplane injection

- **Pellet injection tool applications:**
  - Extending operating regime to high density ($n \gg n_{GW}$)
  - Particle confinement and transport studies
  - Peaked density profiles for PEP-mode ITB formation with $T_i \sim T_e$, (unlike other ITB regimes)
  - Off-axis density/rotation perturbation for ITB formation
  - Triggers for L to H-mode transitions for reduced power threshold

High Field Side (HFS 45°) Pellet Injection on DIII-D Yields Deeper Particle Deposition than LFS Injection

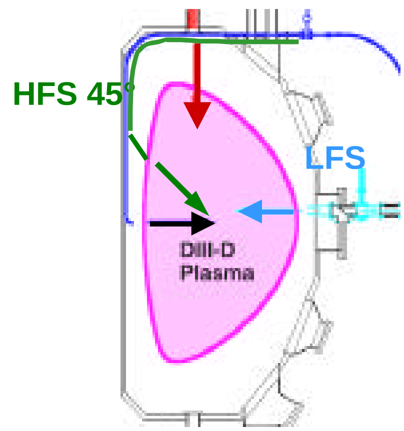
2.7 mm Pellets - HFS 45° vs LFS



Fueling Efficiency:

HFS - 95%

LFS - 55%



- Net deposition is much deeper for HFS pellet in spite of the lower velocity
- Pellets injected into the same discharge and conditions (ELMing H-mode, 4.5 MW NBI, $T_e(0)$ = 3 keV)

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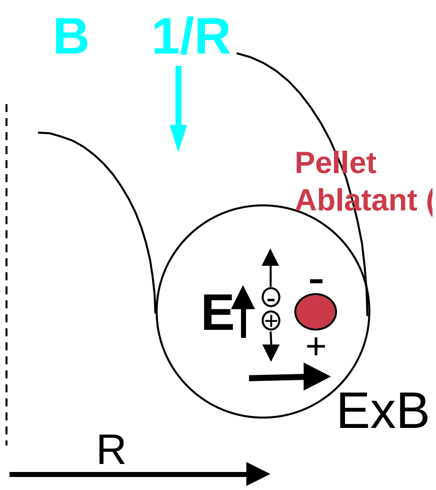
ExB Polarization Drift Model of Pellet Mass Deposition
(Rozhansky, Parks)



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