SAND2011-5661C

Overview of PMI at SNL-CA

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

- Hydrogen trapping and diffusion in materials
- Hydrogen binding / adsorption / exchange on surfaces
- Surface morphology changes due to PMI
- In situ edge plasma characterization
- PMI in compact toroid accelerators

PSI Science Center

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

UCDAVIS
COLLEGE OF ENGINEERING
Center for Advanced Laboratory Fusion Science and Engineering (CALFUSE)
COMPACT TORUS INJECTION EXPERIMENT (CTIX)

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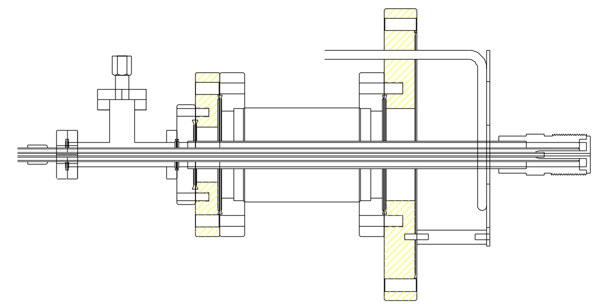
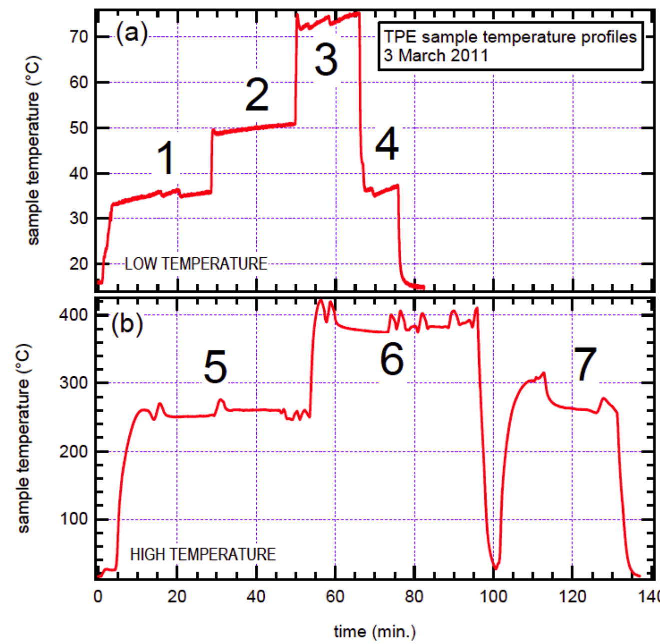
H in materials (Tritium Plasma Experiment - TPE)

- Startup and shutdown thermal transients were problematic
- Testing of prototype sample holder showed much improved temperature regulation with gas cooling
- High temperature sample holder just completed and will be tested in September
- Testing results will be used in permeation stage design





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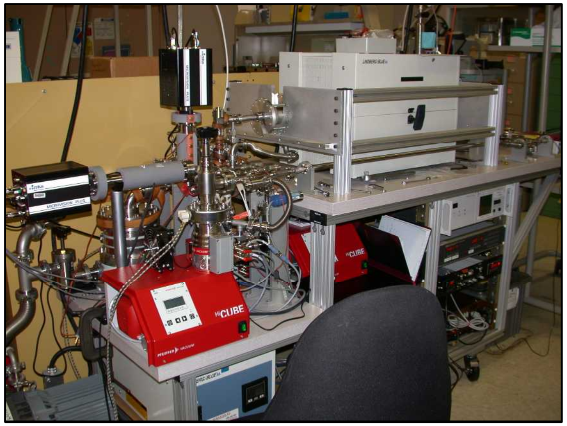
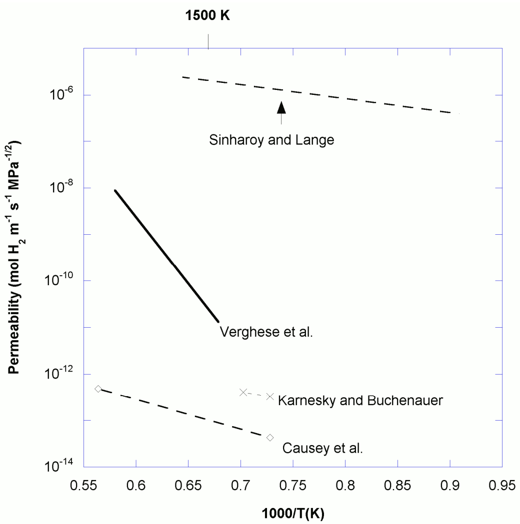
H in materials (Gas driven permeation)

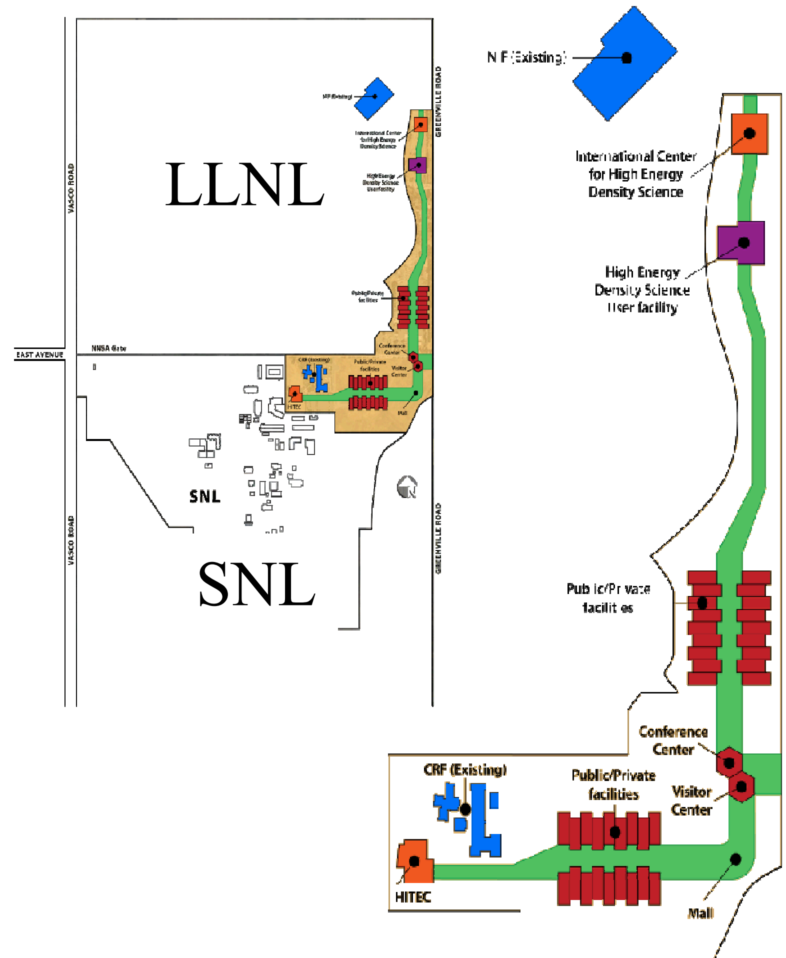
- Synergistic benefit to high pressure H storage
- High temperature D_2 system (< 1200 °C) was an SBIR project with Ultramet
- NW funding is being used to improve sensitivity of high temperature system
- Available in FY12 for further barrier material studies

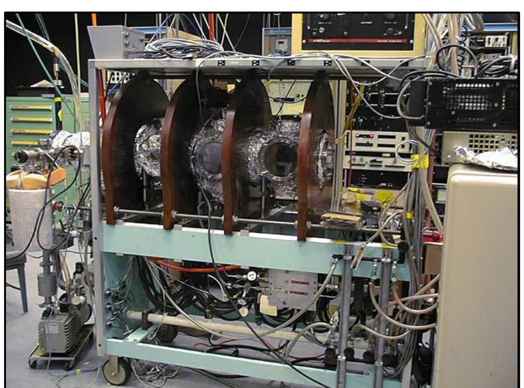




H in materials (Deuterium Plasma Experiment)

- **Expansion of Livermore Valley Open Campus is planned in FY12**
- **DPE will move to B916**
- **Upgrade of experiment being considered (arc reflex source similar to TPE and PISCES-A)**





10^{16} cm^{-2}s^{-1} → 10^{18} cm^{-2}s^{-1}

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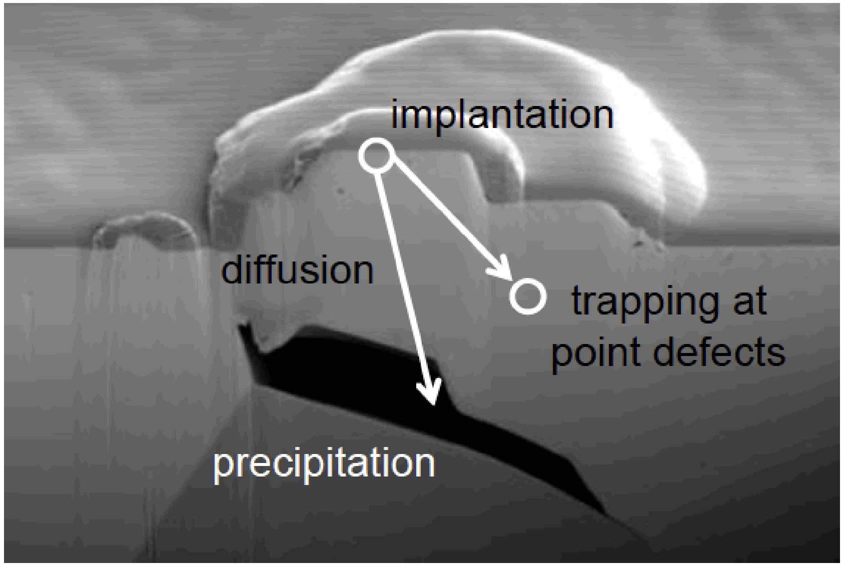
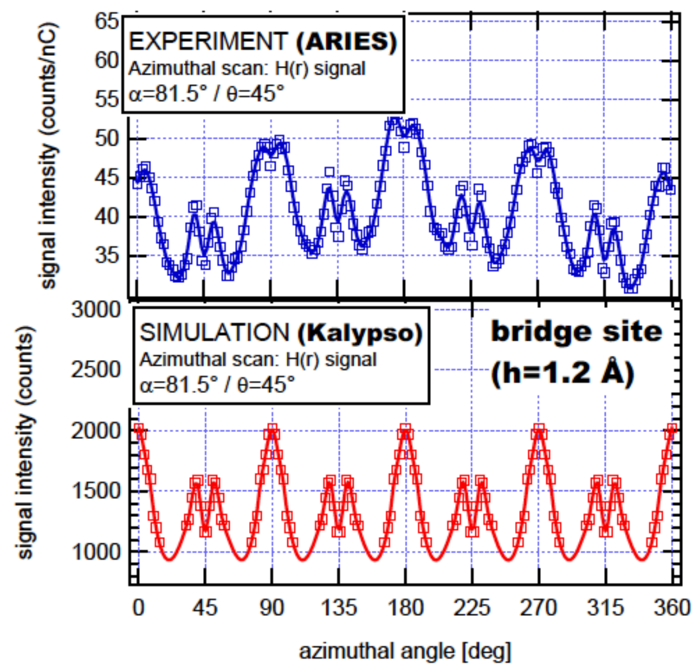
H in materials (Bubble model)

- **Precipitation of H from solution can be modeled using a continuum description**
  - **^{3}He bubble growth model developed by Cowgill**
  - **Precipitation model from Wampler**
- **Bubbles grow from**
  - **Crack propagation**
  - **Dislocation loop punching**
  - **Vacancy clustering**
- **Compare model results with microscopy and TDS**



H on surfaces (ARIES+simulations)

- AIRES upgraded to include
  - Collection of neutral recoils for improved sensitivity
  - In-situ Auger spectroscopy
- Bridge site identification of H confirmed using DFT and MD simulations
- Experiments on Be surfaces underway and will be focus for FY12



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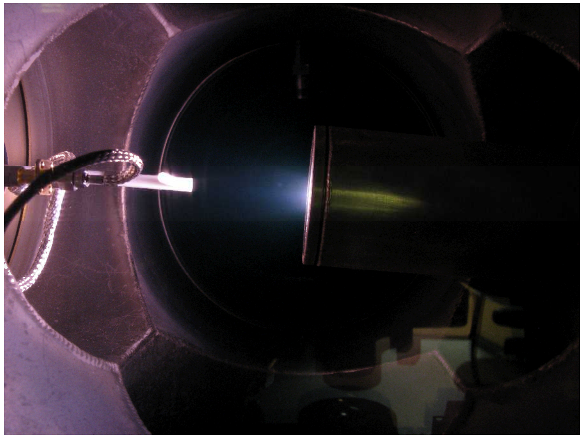
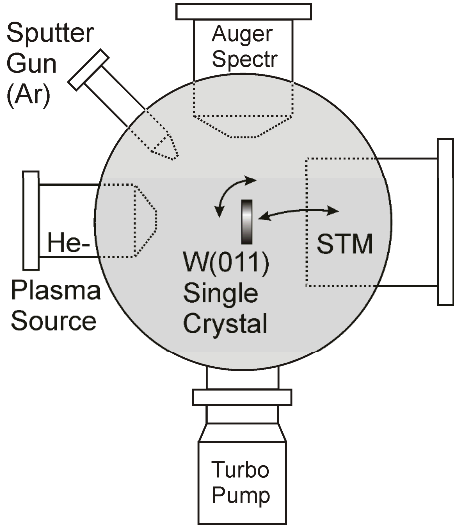
Surface morphology

- **Continue to support erosion / redeposition experiments on DiMES**
- **Low energy He-induced W morphology changes**
  - **Use SAXS to examine crystalline structure of W fuzz**
  - **Study initial stages of fuzz growth by Scanning Tunneling Microscopy (STM)**



Compact ECR plasma source testing



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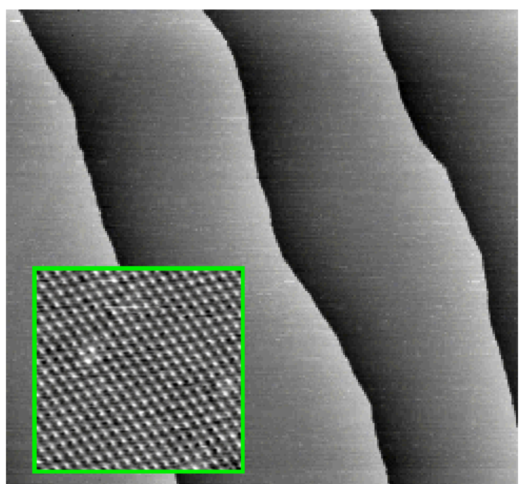
Surface morphology (W fuzz growth study)

- **Approach:**
  - **Prepare clean atomically flat W surface in UHV**
  - **Expose W surface to low-energy He plasma**
  - **Track early stages of fuzz evolution with STM**
  - **Compare with MD simulations of Wirth, et.al.**

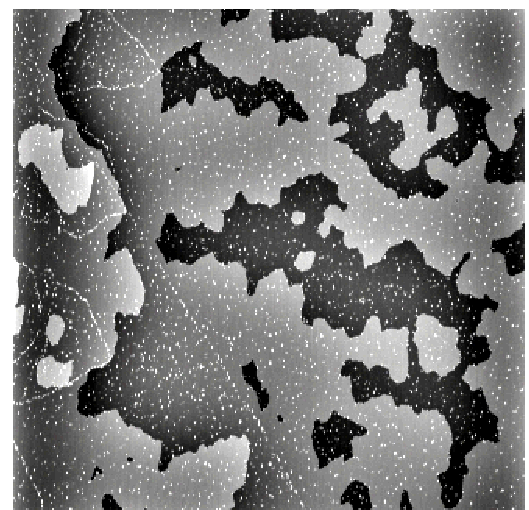
Example STM study:

Initial stage of hydrogen etching of Al

Clean Al(111) surface



Etching by atomic H



E.P. Go, K. Thürmer, J. Reutt-Robey, Surface Science ***437****, 377 (1999).*

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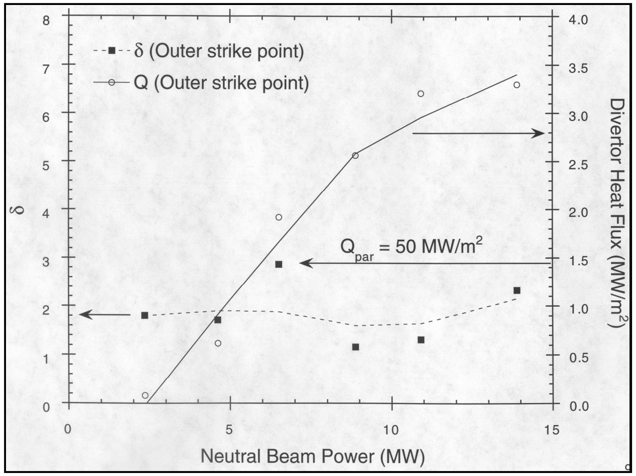
Edge diagnostics (Sheath Studies)

- **Use edge Langmuir probes and heat flux diagnostics to investigate power transmission through the divertor sheath**
- **Utilize DiMES capability for active measurements**

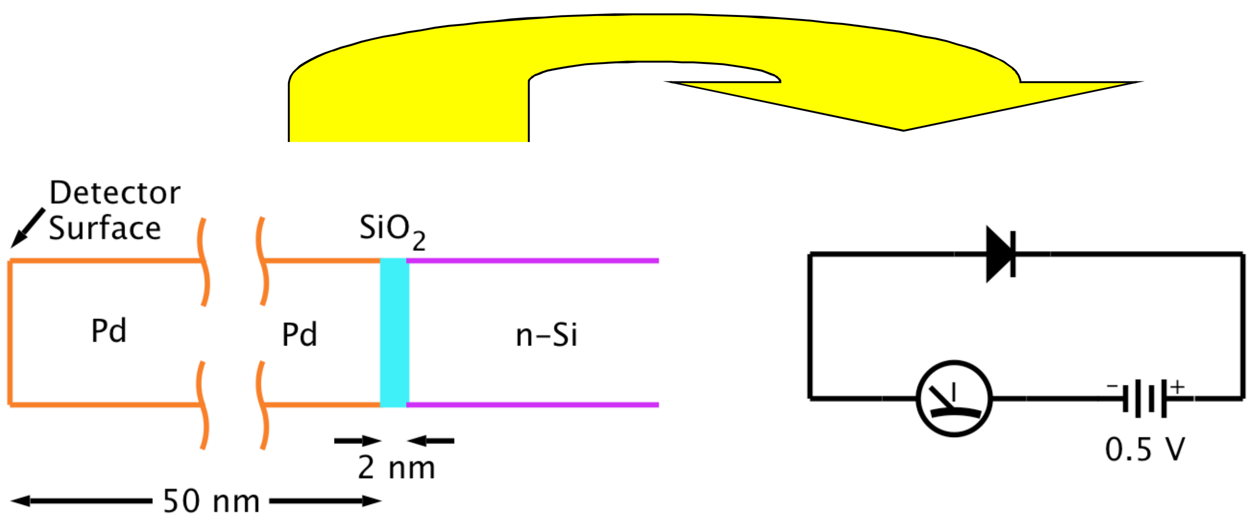


$$\gamma \approx \frac{2.5 \cdot T_i}{T_e} + \frac{2}{1-\delta_e} - 0.5 \cdot \ln\left[(2\pi \cdot \frac{m_e}{m_i})(1+\frac{T_i}{T_e})(1-\delta_e)^{-2}\right] \approx 7$$

D. Donovan, Session 11

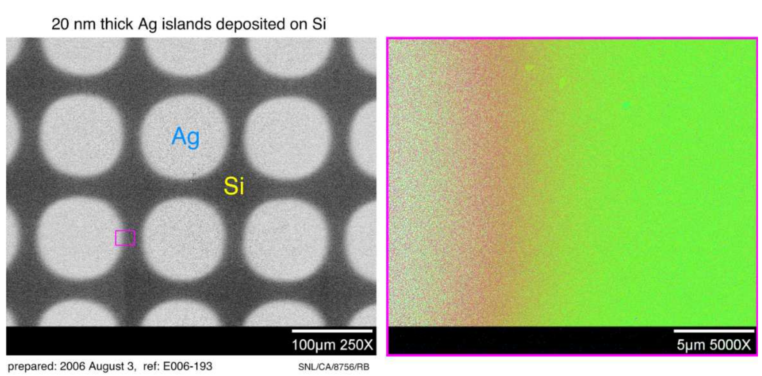
Edge diagnostics (H-sensors)

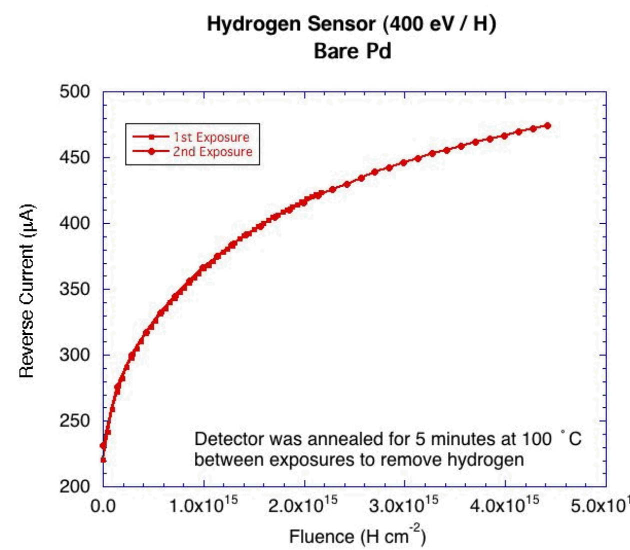
- **Pd-MOS detectors can be used to sense atomic hydrogen fluxes**
  - **Small size, low voltage, and high sensitivity (10^{12} – 10^{15} cm^{-2})**
  - **Dosemetric devices that can provide energy resolution**



Edge diagnostics (H-sensors)

- **Trapping of x-ray induced charges can cause polarization (also by high energy particles)**
  - **Need thick Pd film (> 100 nm) with thin tunnel oxide (2 nm)**
- **First set of detectors were characterized by D^+ ion beam**
  - **Detectors fabricated in standard configuration and with 20 nm Ti post grids (200 nm Pd)**
  - **Use MESAfab for next set**





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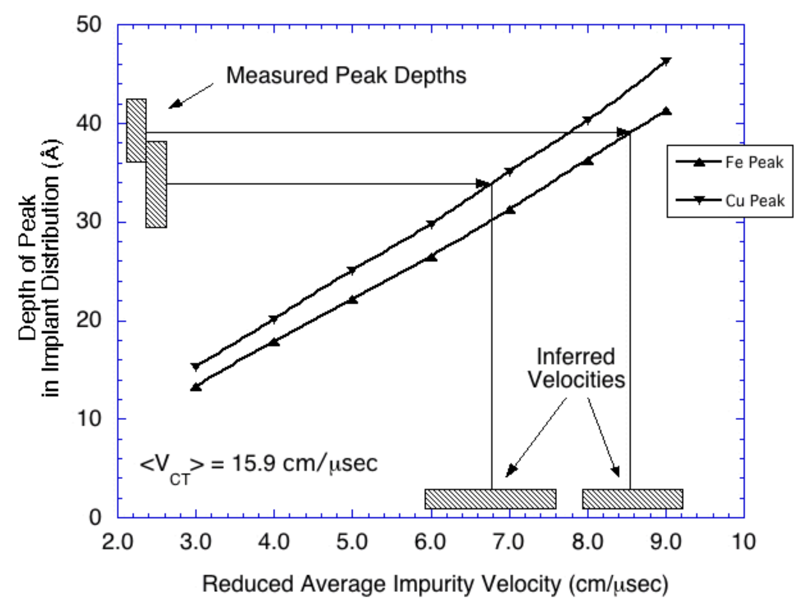
CT accelerators (ICC program)

- **New program in FY11 to**
  - **Examine PMI in the UC Davis accelerator (CTIX)**
  - **Design improved PFCs for CTIX**
  - **Investigate the potential of CTs for disruption mitigation**

Earlier informal collaboration examined metallic impurities at the injector exit

Result:

Impurities were not accelerated at the full CT velocity



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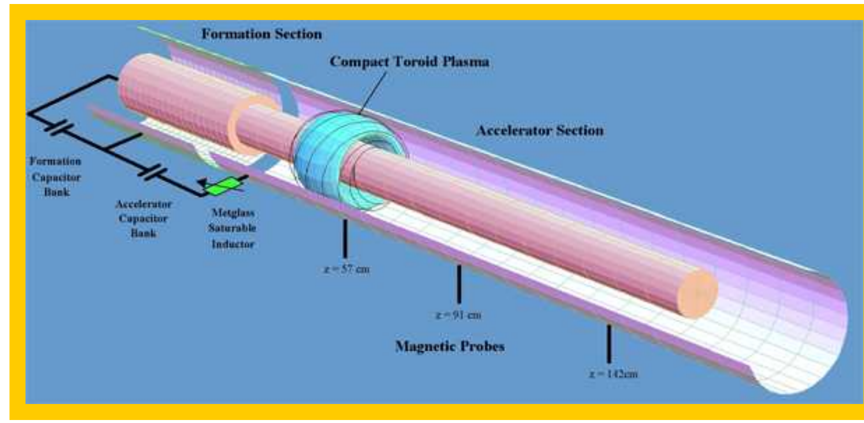
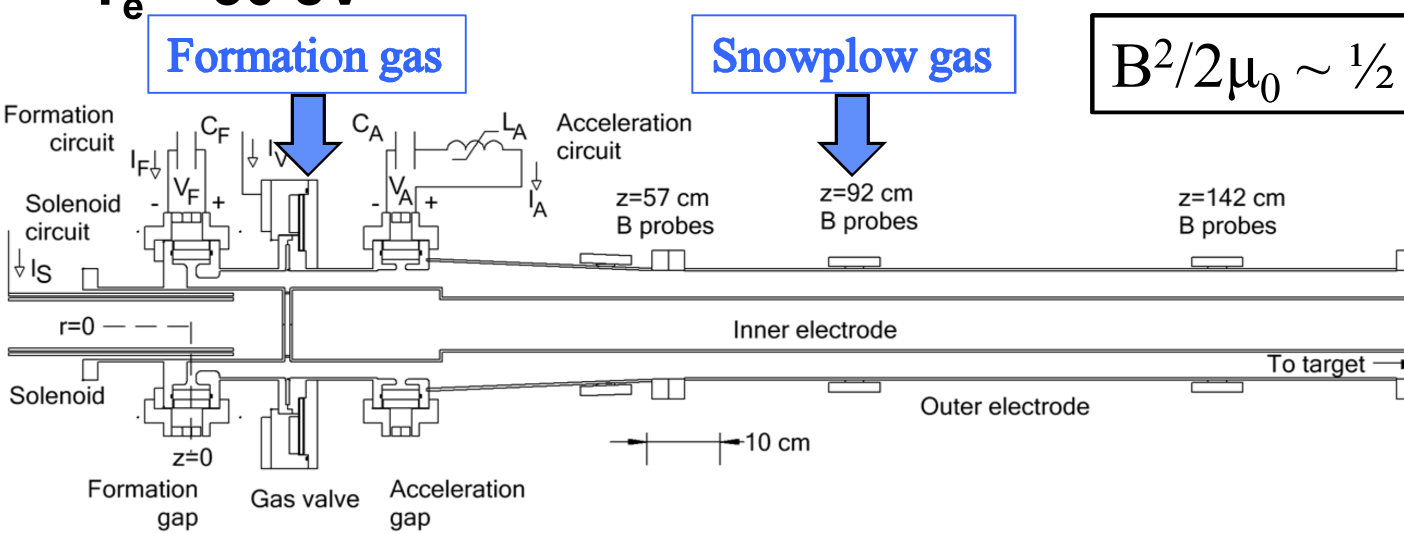
CT accelerators (CTIX)

- CITX parameters
  - Length ~ 2 m
  - Diameter 15 cm
  - V_{CT} ~ 200 km/s (200 eV H)
  - $N_{pl} > 10^{14}$ cm^{-3}
  - T_e ~ 30 eV



$$B^2/2\mu_0 \sim \tfrac{1}{2}\rho_{CT}V_{CT}^2$$

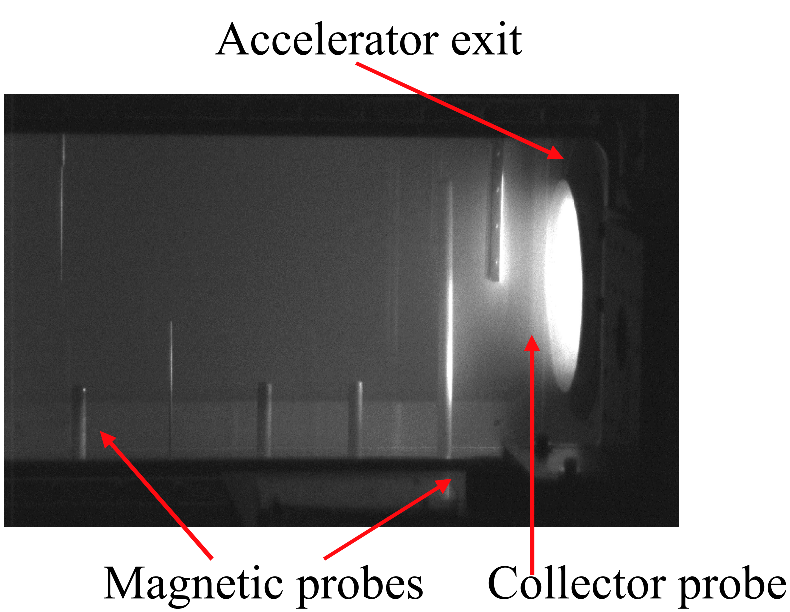


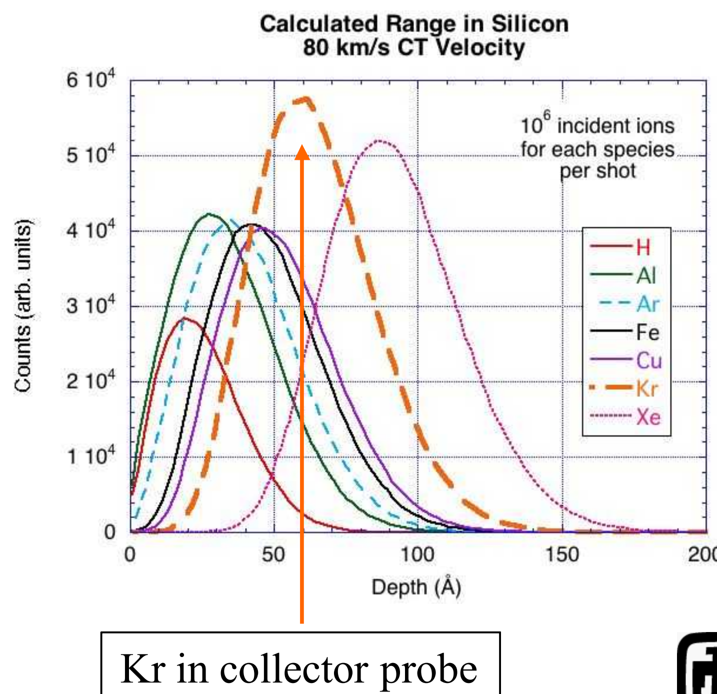
CT accelerators (PMI studies)

- CTIX is changing from passive to active switching
  - Requires synchronization of low inductance plasma switches (4 Trigatrons to switch 7-15 kV / 50 kA each)
- Active switching will
  - Improve gas utilization in the formation region (plasma fueling)
  - Provide improved timing for snowplow density increase
- PMI studies will extend to injector surfaces

CT accelerators (Disruption mitigation)

- CTs can be formed to travel ~ meter in just a few μsecs
  - MARAUDER formed mg Ar CTs with V_{CT} ~ 120 km/s
  - Initial experiments are underway on CTIX to incorporate Kr by snowplow with passive switching
    - RBS for detection of Kr





Summary

- Hydrogen trapping and diffusion in materials
  - T retention / permeation in TPE, bubble model, D_2 permeation
- Hydrogen binding / adsorption / exchange on surfaces
  - AIRES experiments with MD simulations
- Surface morphology changes due to PMI
  - Tungsten fuzz
- In situ edge plasma characterization
  - Langmuir probes, heat flux, and H-sensors
- PMI in compact toroid accelerators
  - PMI studies and disruption mitigation

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  - Second level 22 pt
    - Third level 20 pt
      - Fourth level 18pt
        - Fifth level 18pt