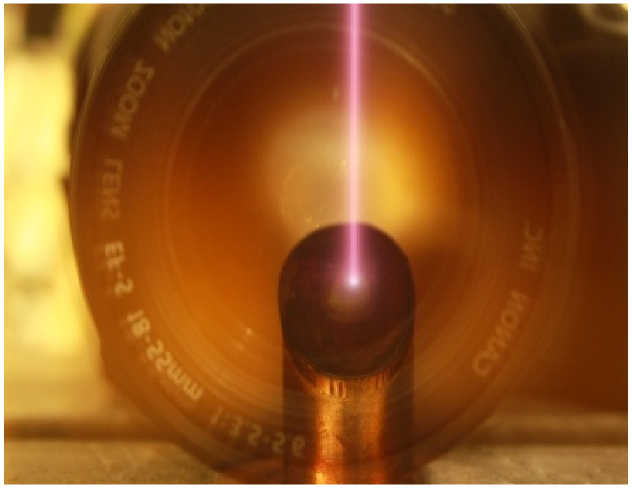
Development of Time-tagged Neutron Source for Imaging with Enhanced Spatial Resolution



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Thomas Schenkel

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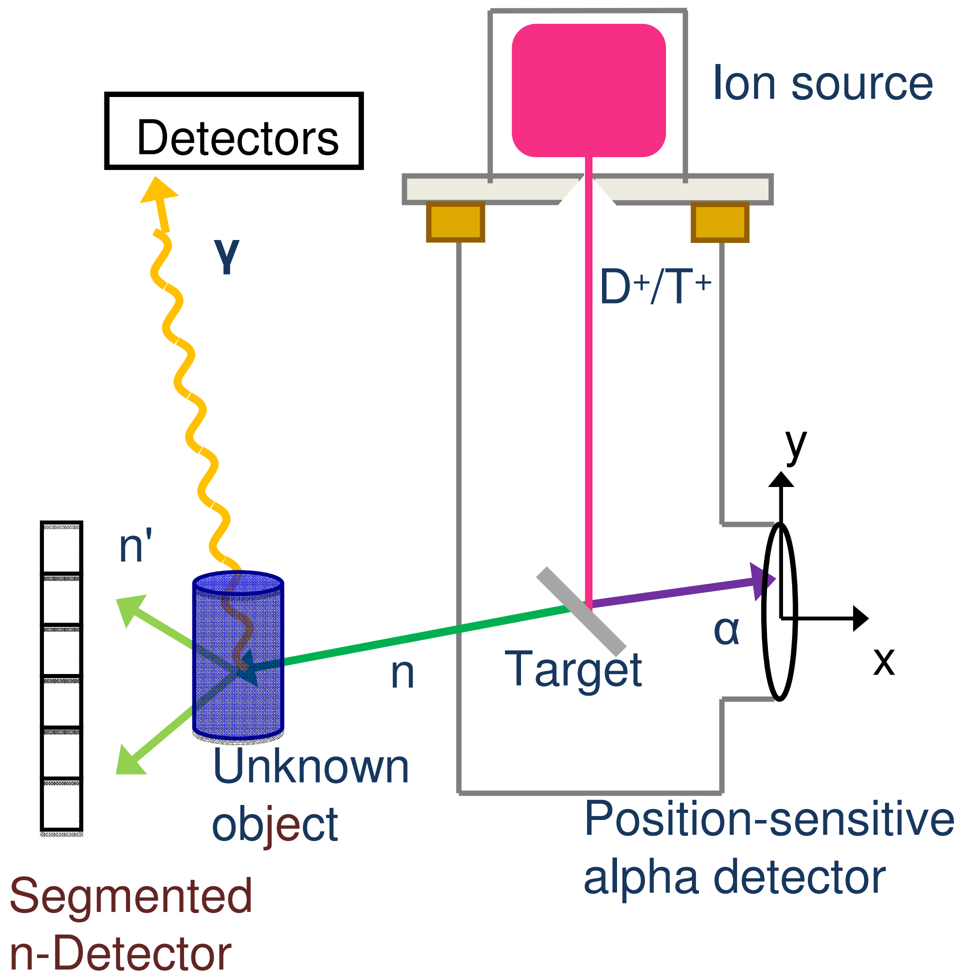
Associated Particle Imaging System

D + T $\rightarrow$ ^{4}He (3.5 MeV) + n (14 MeV)



- Detection of alpha particles allows the neutrons to be tagged
  - Time
  - Direction
- Improvement needed
  - Higher spatial resolution
  - Higher intensity
- Both transmission imaging and induced fission imaging methods will be greatly enhanced.
- Applications
  - Nuclear safeguards
  - Homeland security
  - Treaty verification
  - Other similar applications

Tagged Neutron Source for API Inspection Systems
Proliferation Detection and Nuclear Safeguards Application

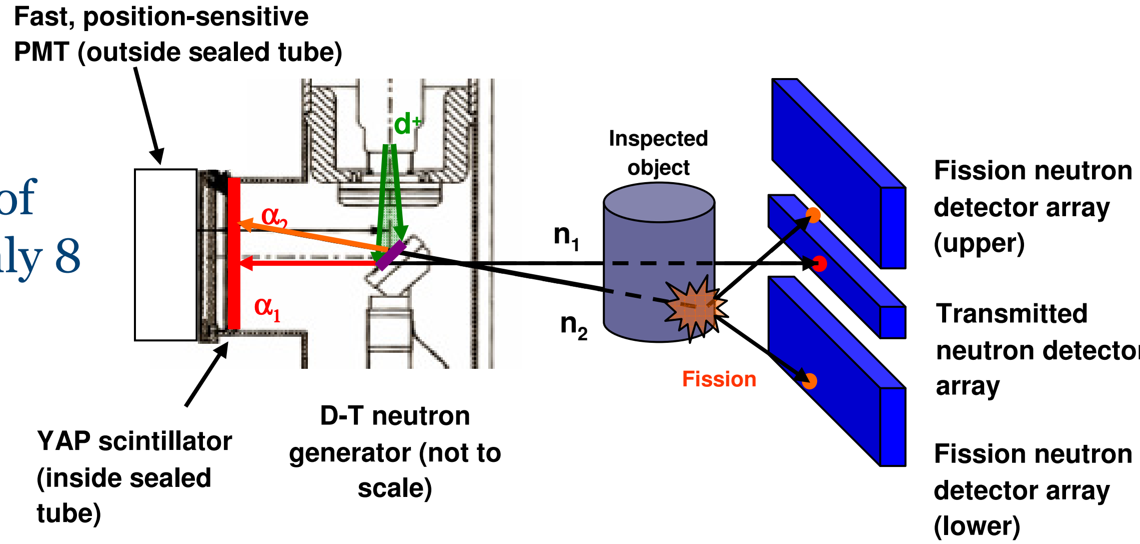
Transmission imaging

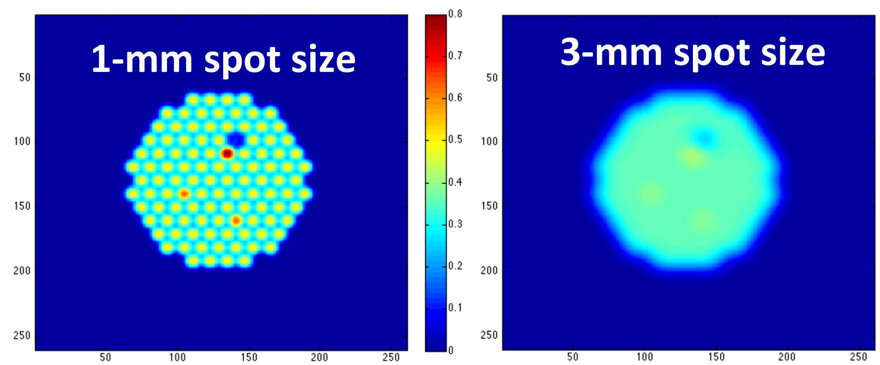
- Eliminating the scattering component extends the range of transmission imaging to roughly 8 times the neutron attenuation length.

Induced fission imaging

- Spatial resolution important
- Dummy and HEU rodlets visible with 1 mm spot size, but not with 3-5 mm size of current system.

(Simulated results)





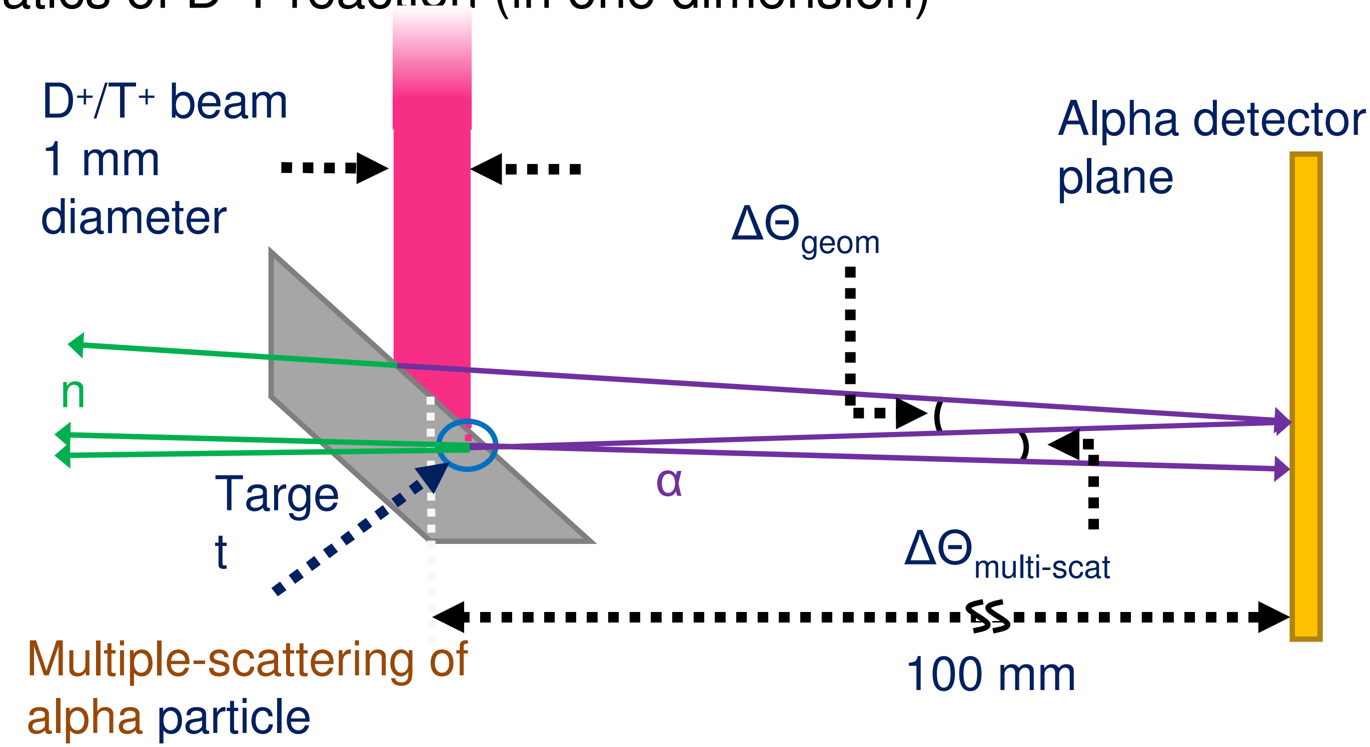
- **simulations by Paul Hausladen, ORNL**

Needed: Higher spatial resolution, higher intensity for faster measurement

Imaging Resolution

co. J. Tinsley, STL

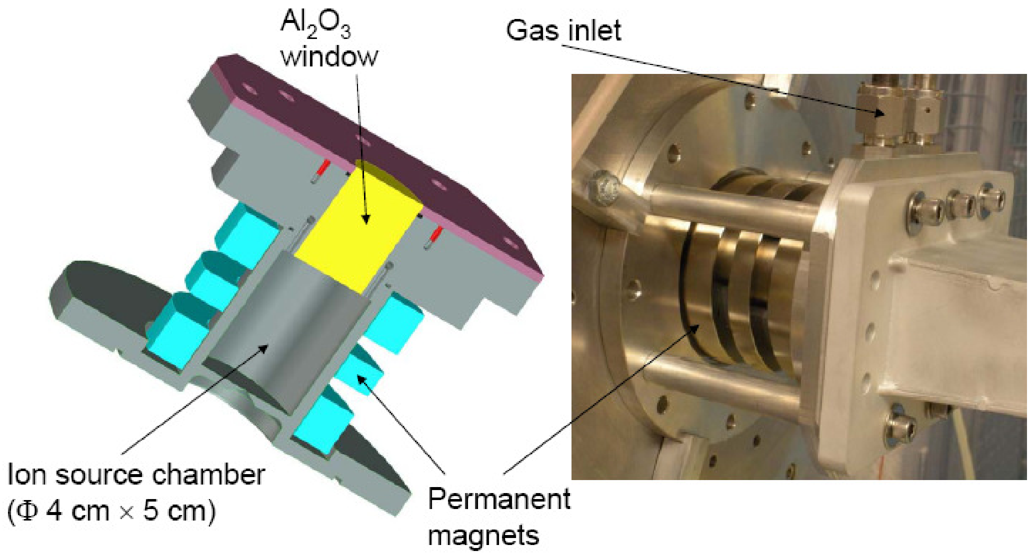
- Contributions to angular uncertainty:
  - Geometry: beam spot size on target, distance to alpha detector
  - Position resolution of alpha detector (ideally << spot size)
  - Multiple-scattering of alpha particle in target
  - Kinematics of D-T reaction (in one dimension)

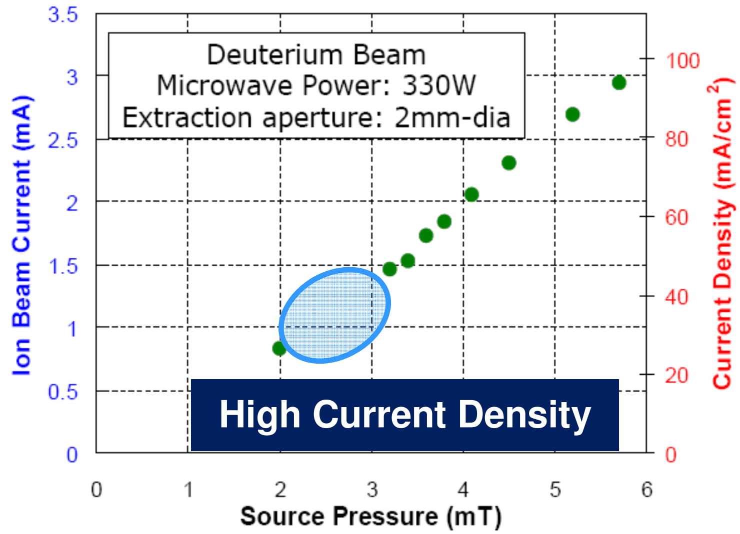


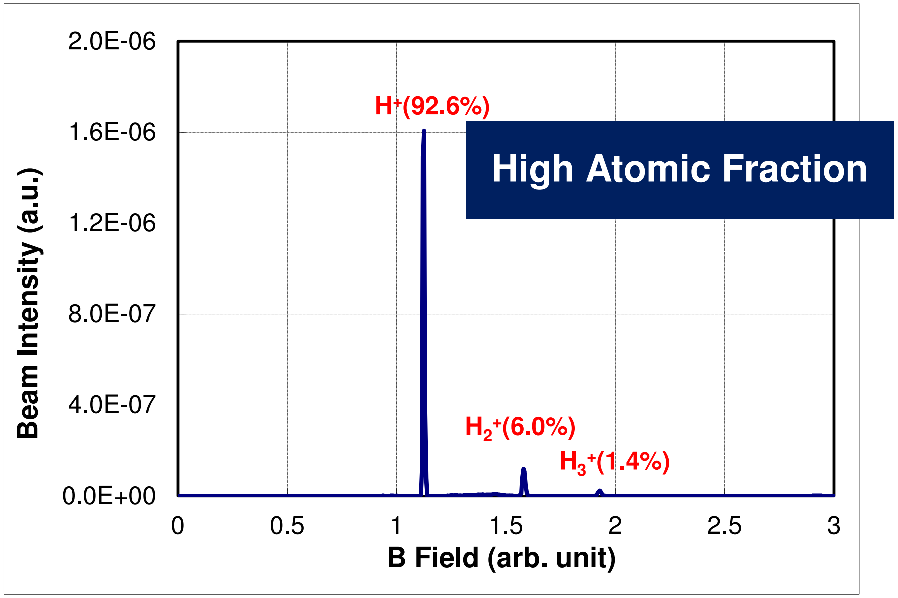
Approach

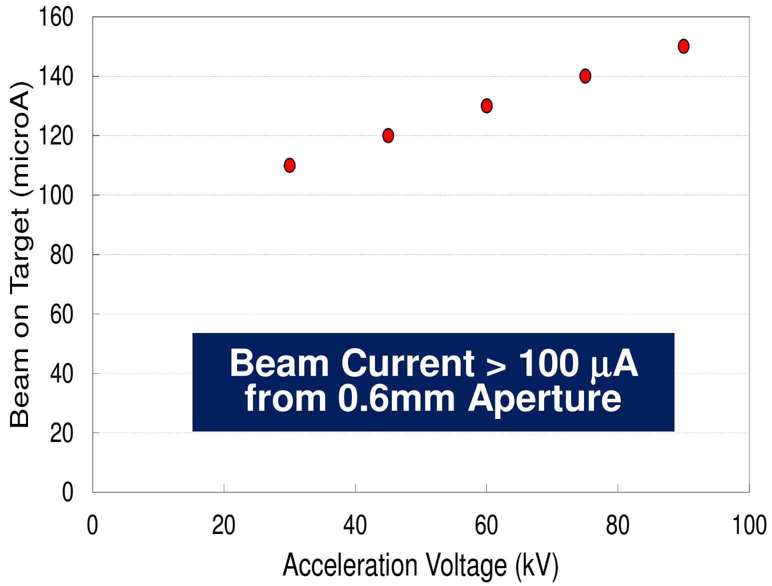
- Goals
  - Reduce the size of the beam spot on the neutron production target to 1 mm in diameter
    - a several-fold increase in directional resolution
  - Increase the maximum attainable neutron yield (~ 10^9 neutrons/sec)
    - approximately one order of magnitude over existing sources.
- Technical approaches
  - Microwave-driven ion source
    - Produces sufficient beam current density
    - High atomic fraction
    - Operates at low gas pressure
  - To achieve small beam spot size on target
    - No active beam focusing
    - Use extraction aperture of high aspect ratio
  - Alpha detector with rel. high position resolution (pixel size < beam spot size)
  - Source on HV, target on ground
    - to avoid electron acceleration into alpha detector

Permanent-magnet Microwave-driven Ion Source

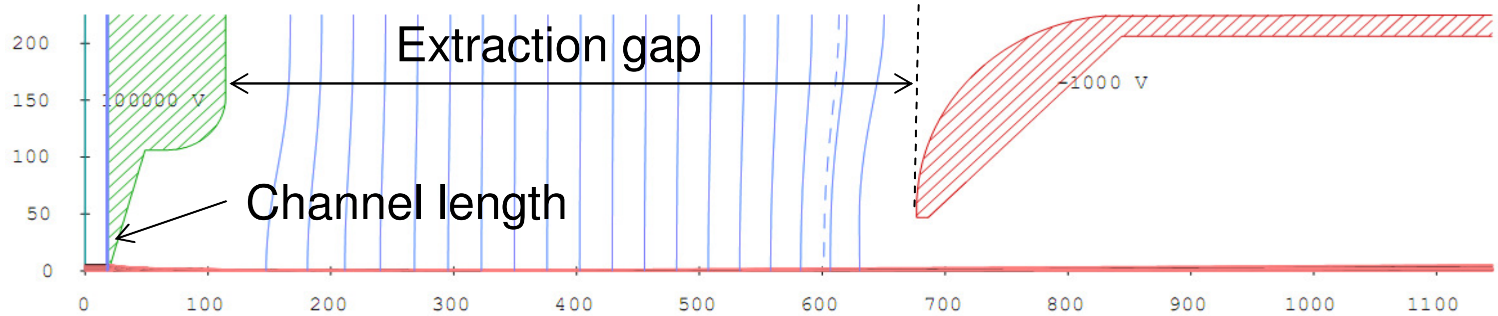




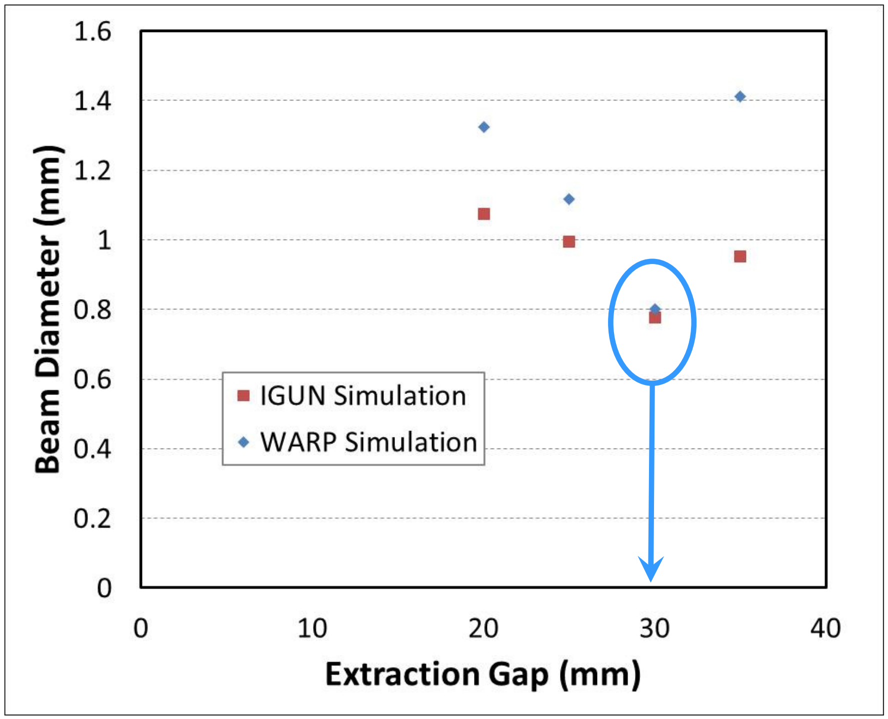




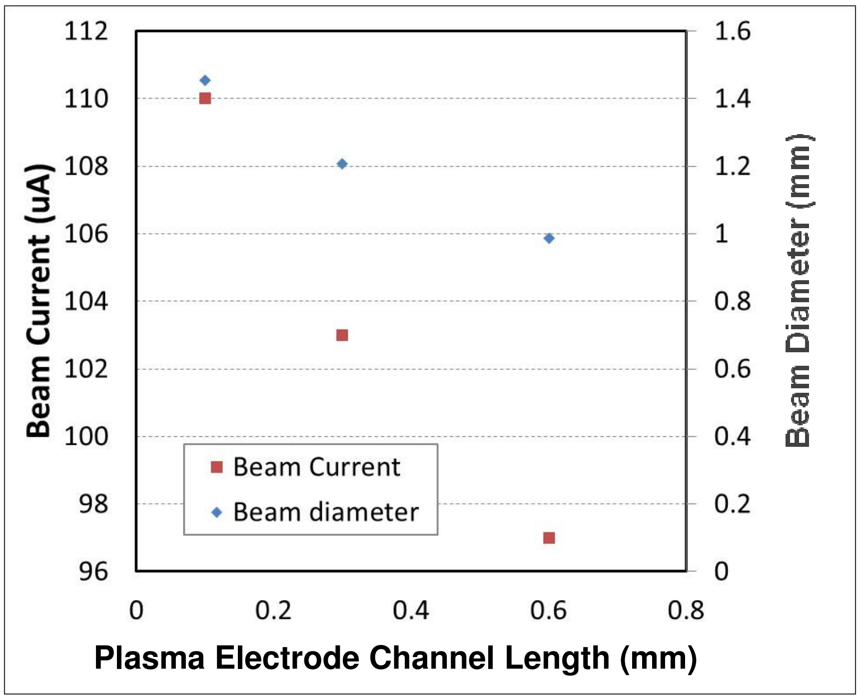
Beam Optics Optimization



Extraction Gap of 30 mm

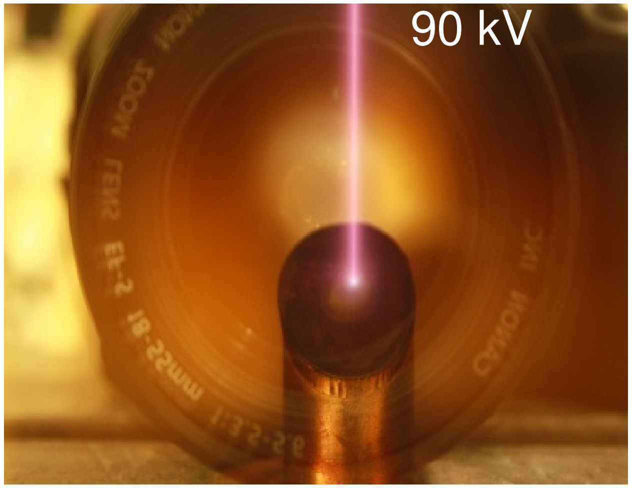


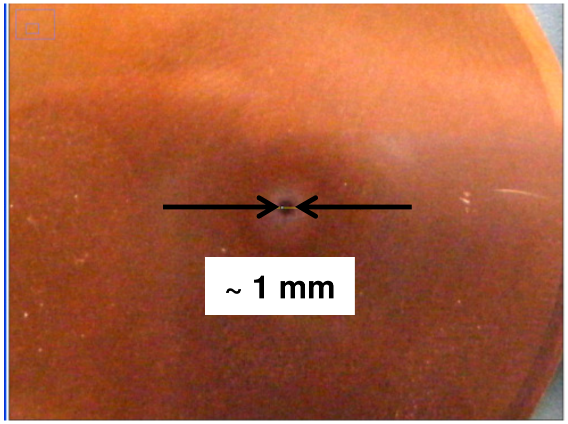
Longer Channel length → Smaller Diameter



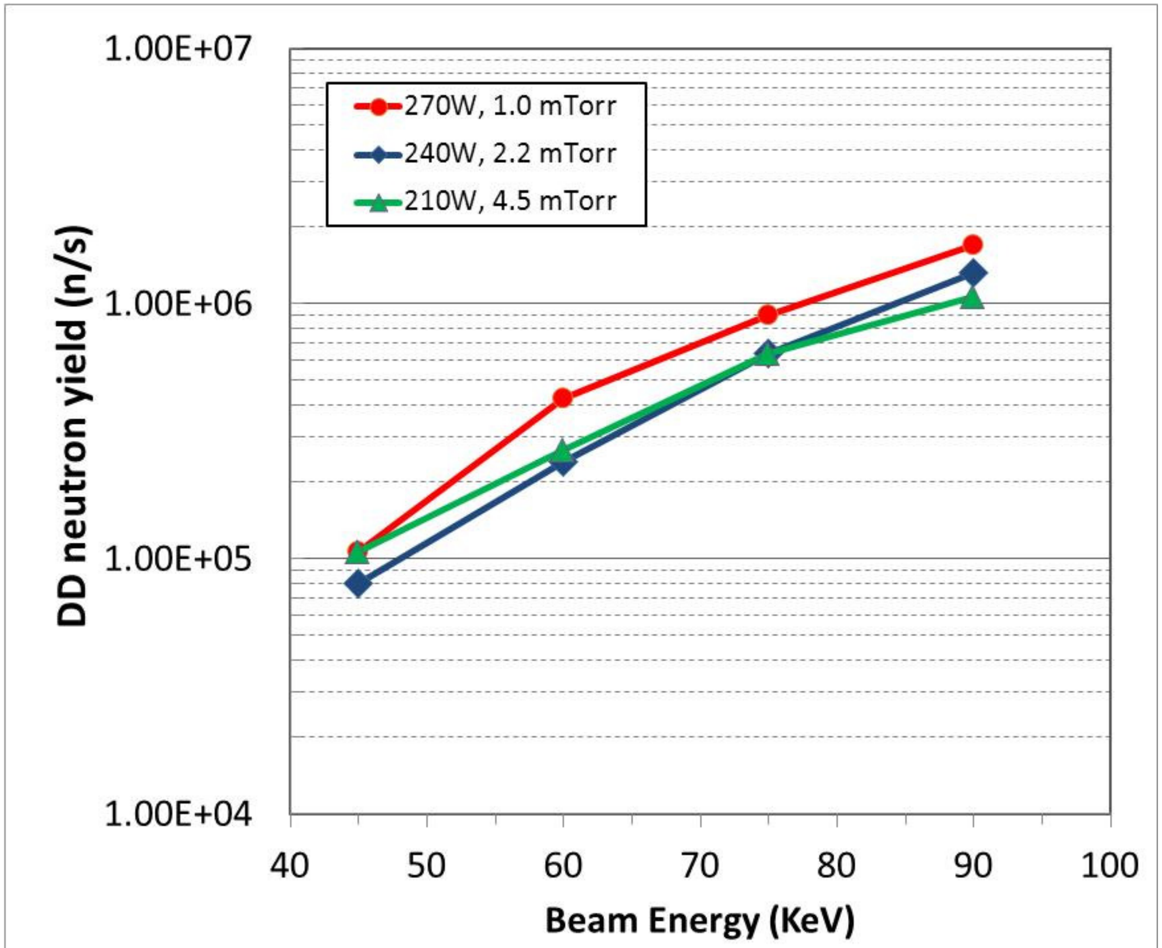
Achieving 1-mm Beam Spot Size

- No active focusing element
  - Longer channel of the ion source extraction aperture
- Small extraction aperture
  - 0.6 mm in diameter
- Ion optics simulation to guide system design
  - Various code
    - IGUN
    - PBGun
    - WARP





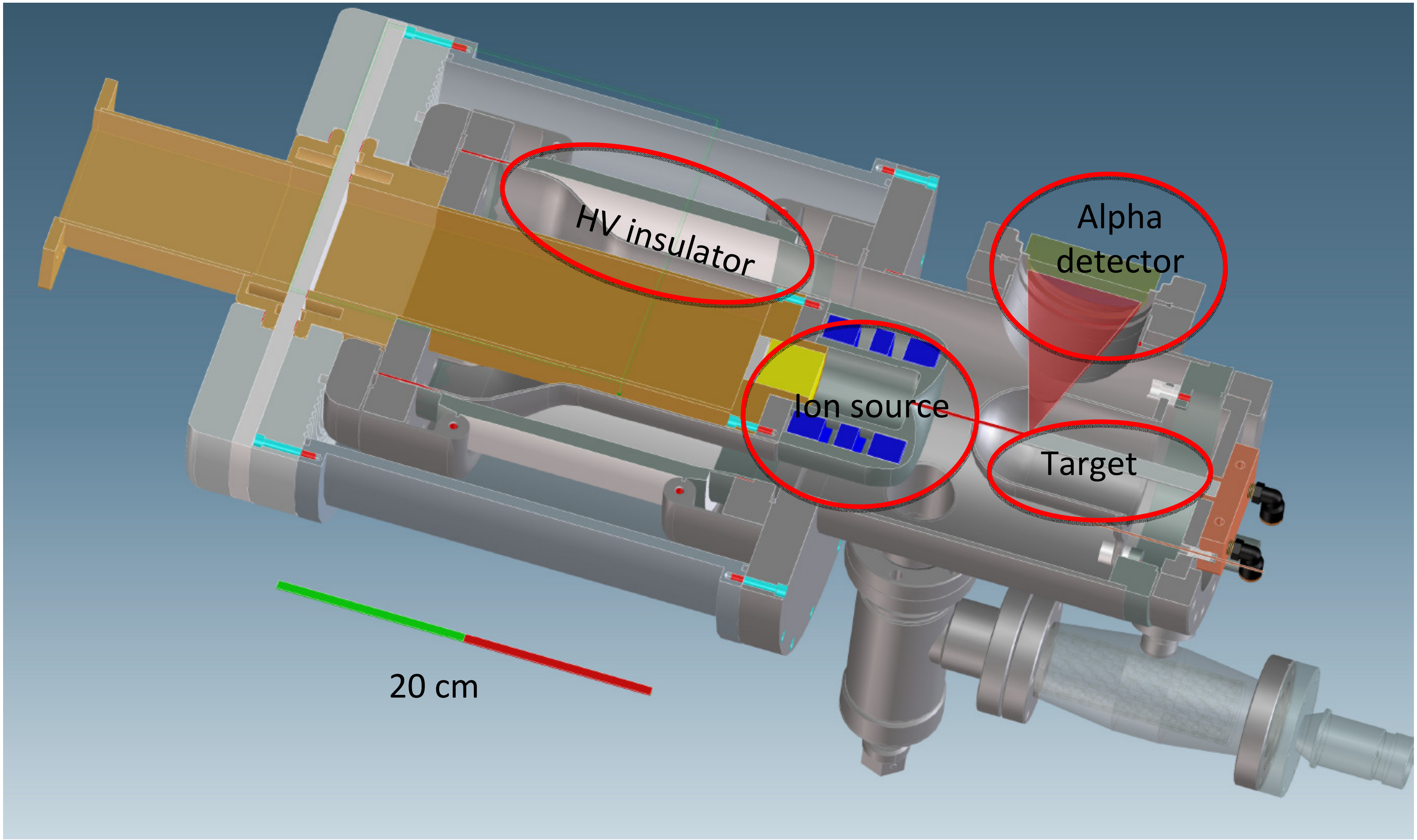
Sealed-tube Operation of Ion Source Successfully Tested



- the DT neutron yield is ~100x higher than the DD neutron yield at ~80 keV
- we test with DD to avoid T contamination issues

Note:
Power refers to the input power of the magnetron head, the efficiency of microwave output is ~ 60-70%.
Target was not cooled, which may have affect the neutron production by reducing D retention.

Design for compact implementation



Summary

- A compact microwave-driven ion source is capable of delivering over 100 µA of beam current (sufficient to produce 10^9 n/s) onto a 1 mm spot size.
- The API system with a microwave-driven neutron generator will offer improved imaging resolution and faster analysis times
- applications include characterization of fissile material configurations, detection of concealed nuclear materials, contraband etc.