JET Shattered Pellet Injector

Preparation for Installation and Experiments on JET

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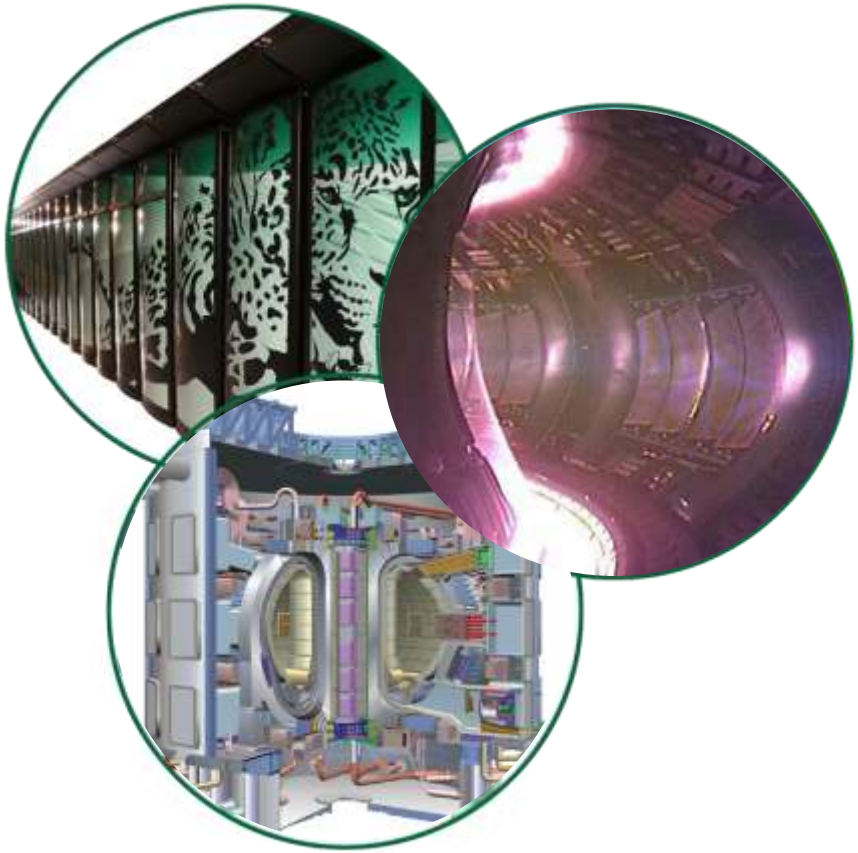
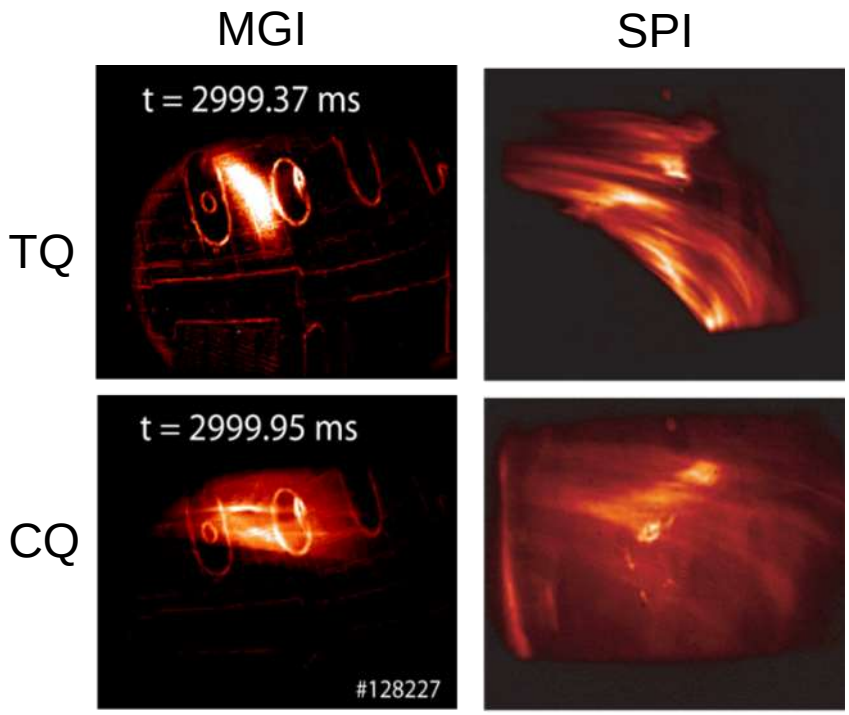
ORNL

VLT Highlight
28-Nov-2017



SPI Disruption Mitigation Method

- The Shattered Pellet Injector (SPI) utilizes a pipe-gun type injector that forms a cryogenic pellet in-situ from desublimated gas introduced the barrel.
- The pneumatically accelerated pellets travel through a guide tube and encounter a shattering device that is optimized to break the pellets and produce a spray of solid fragments mixed with gas and liquid just before entering the plasma.
- Thus far only studied on DIII-D

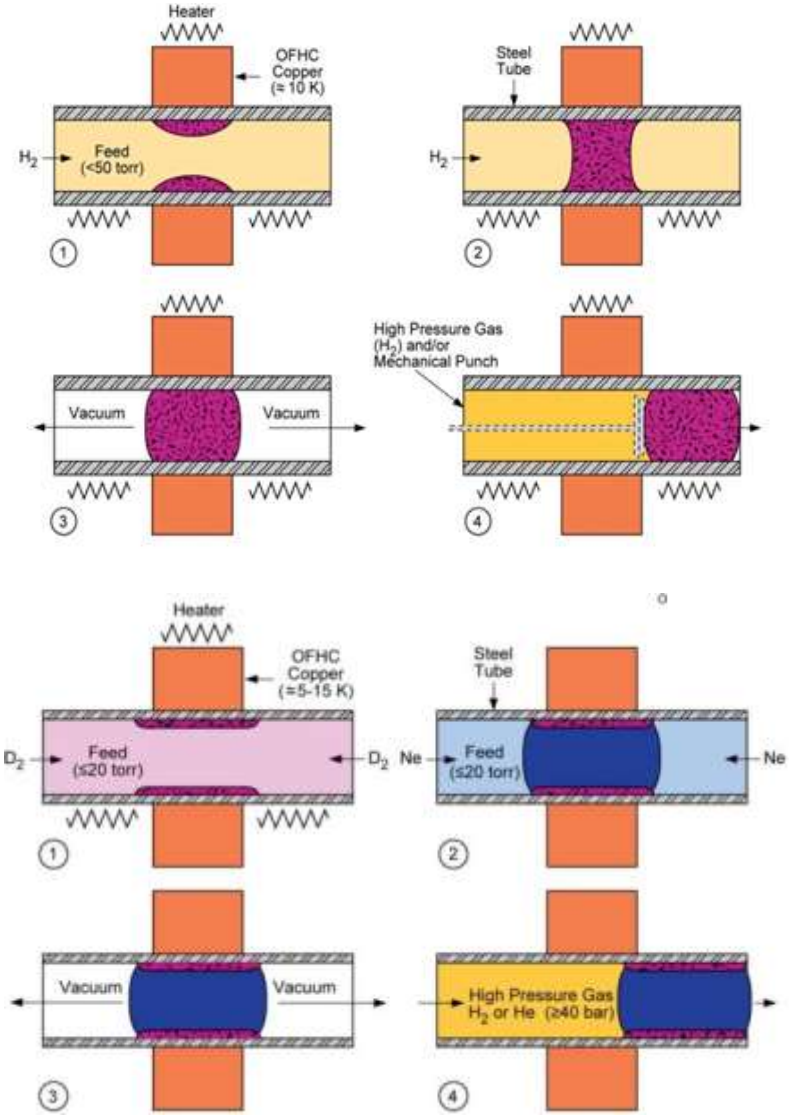


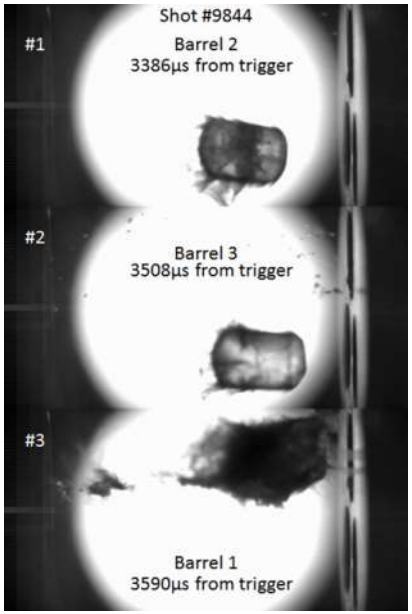
Shattered pellet injection has been tested on DIII-D and found to give deeper penetration and higher density assimilation than massive gas injection.

Commaux, et al., Nucl. Fus. 2011

SPI Pipe-Gun Technique

- A helium cooled cold head desublimates gas into a pellet. The pellet is accelerated down the barrel by high pressure gas from a fast pneumatic valve.
- The pipe-gun is capable of firing pure gas species, deuterium layer with a neon core, or a deuterium/neon mixture pellet.
- Pure high-Z pellets have a shear strength that are too high for the propellant gas pressures alone to fire, so a mechanical punch can be added.
- Barrels can be combined into one guide tube and fired simultaneously, or individually.

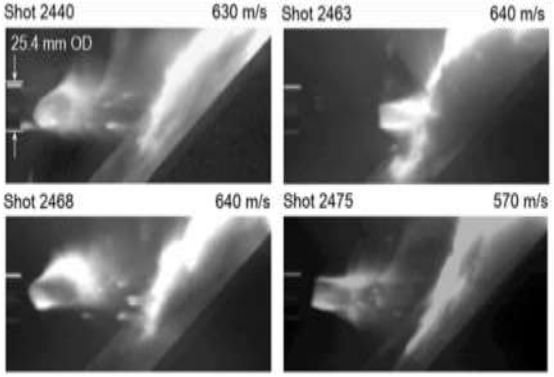




- **The simultaneous firing of 3 pellets was verified.**
- **3 intact, pure D2 pellets had velocities of ~880 m/s**
- **The overall time spread was ~200 μs with no collisions.**

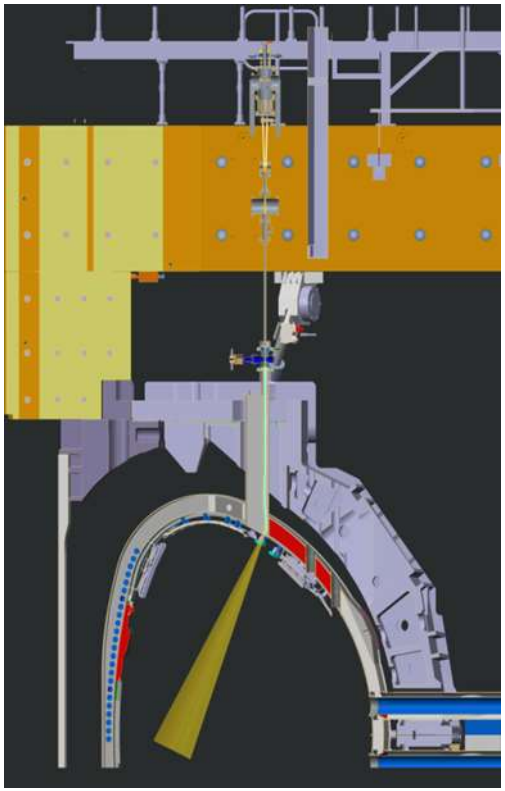
Shatter Tube Development

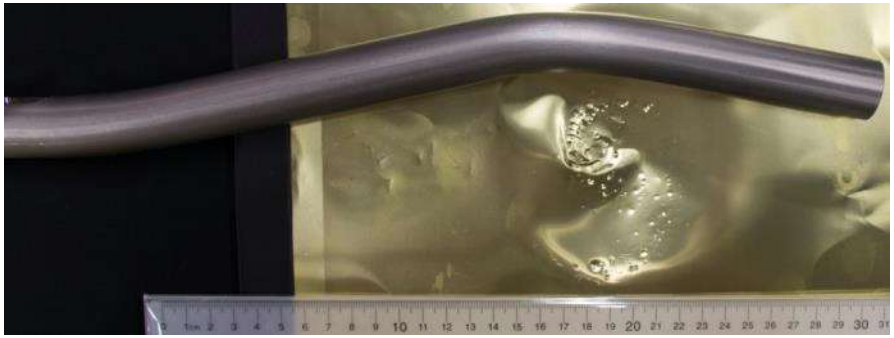
- Shattering of pellets on flat plates was found to yield sprays of fragments and was developed as an injection technique for disruption mitigation.
- Bent tubes were found to produce collimated sprays of pellet fragments and are easy to implement on tokamak devices.
- A “Goldilocks” shattering of pellets is desired. Fragments should not be too large to cause damage or too small that the fragments will not penetrate.
- Shattering is speed and geometry (angle or S-bend) dependent.



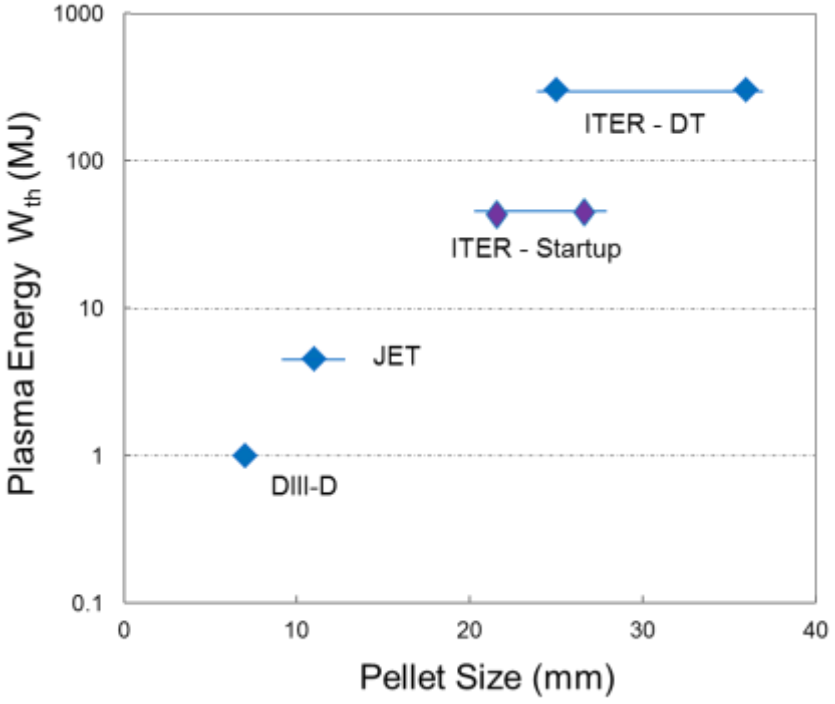
16.5mm D_2 pellet against a 45° plate can allow large pellet fragments.

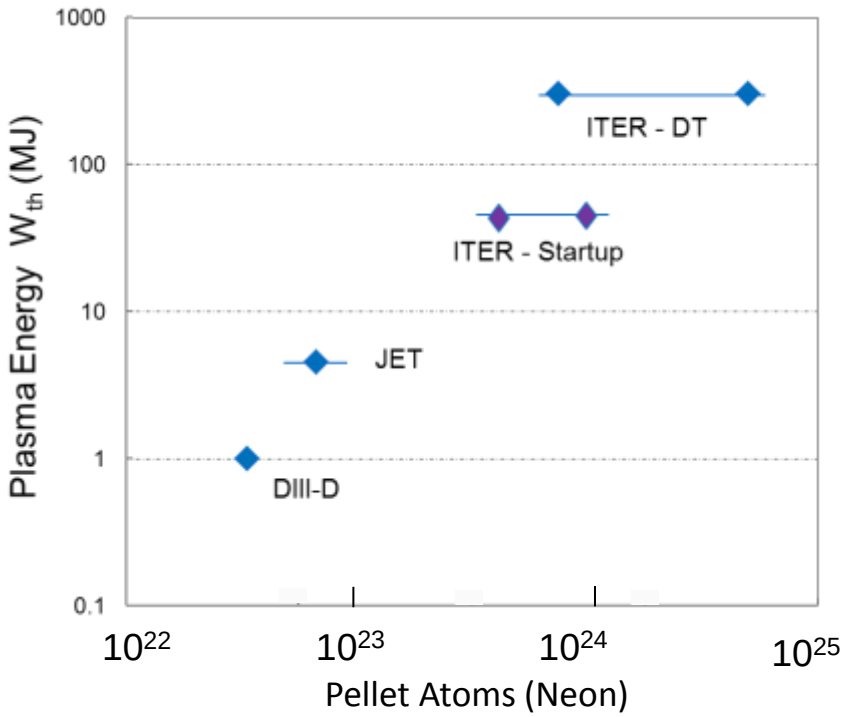
24mm 50/50 Ne/D_2 mixture pellet through 65° miter bend yields mostly gas





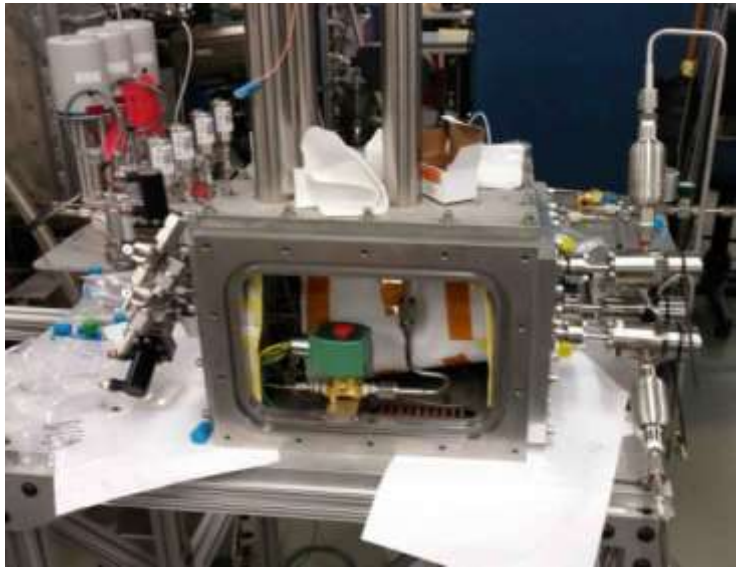
JET Provides Extrapolation Toward ITER and Future Fusion System Energy Dissipation Needs



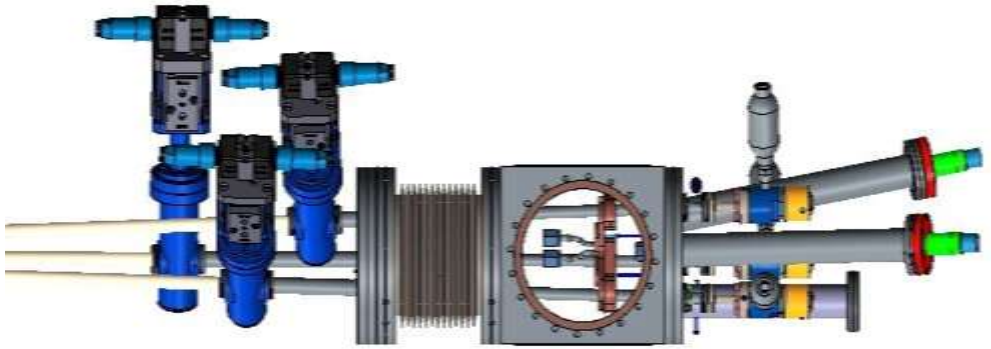


SPI 3-barrel Concept for ITER to be Deployed on DIII-D and JET to Help Answer Key Questions for ITER

DIII-D SPI-2



JET SPI



SPI-2 has been installed and on DIII-D in February 2017– initial experiments have been performed. (D. Shiraki, N, Eidietis)

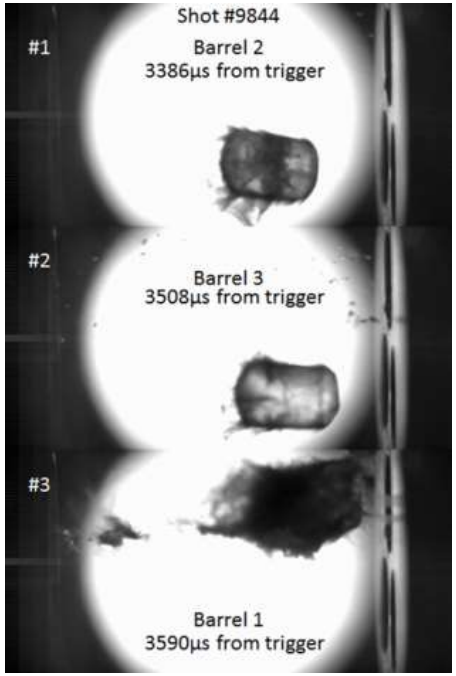
3 pellets can be fired together or serially.

An SPI for JET has been designed based on the same design. Limits pellet size to 12.5mm (6 bar-L of neon).

Major difference is Tritium compatibility requiring more rigorous QA. Good practice for ITER.

JET SPI capabilities

- Three pellets of different sizes
  - D_2/Ne/Ar or D_2/Ne mixture
  - ~0.1 bar.L to 6 bar.L (10^{21} – 10^{23}) per pellet
  - 12.5*, 8, 4 mm sizes - *argon punch
- Independent firing
  - timed or simultaneous (±0.2ms)
  - (signal delay TBC)
- Pellet speed ~100–250m/s (max 500m/s with D_2)
  - flight time ~20-50ms
  - Plasma edge arrival time known to <2 ms



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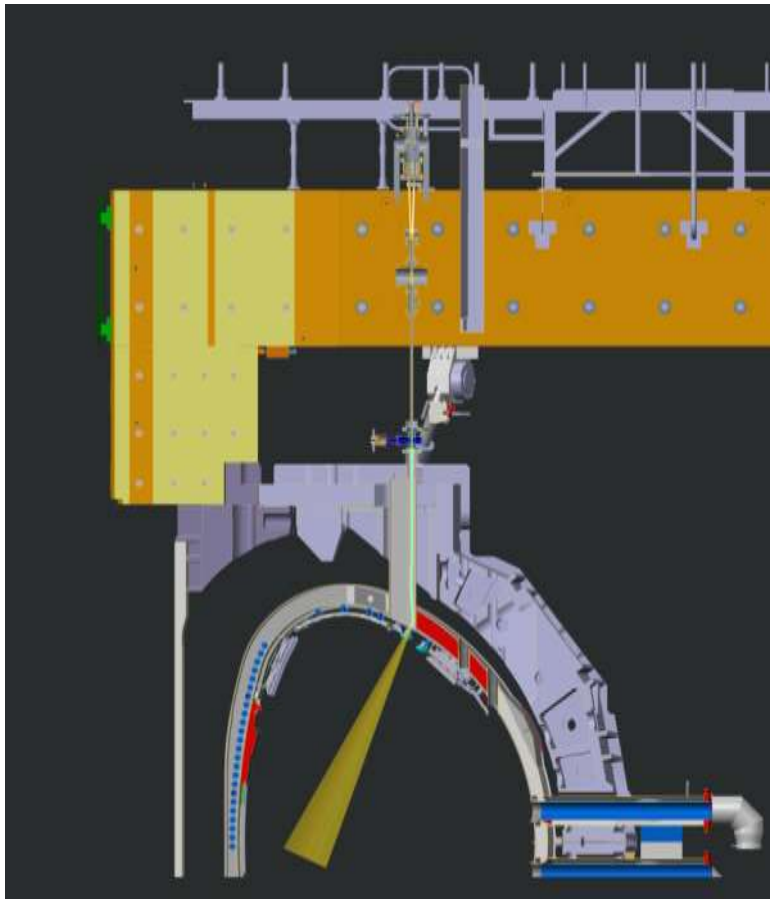
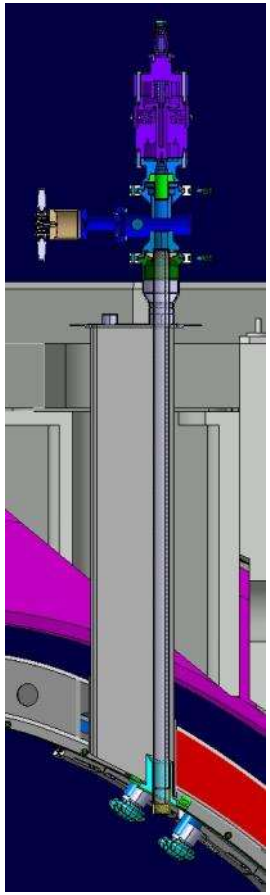
SPI Configuration on JET



JET SPI to be located where DMV1 MGI valve was installed for vertical injection



The 40mm opening constrains the shatter tube geometry that can be employed.

JET

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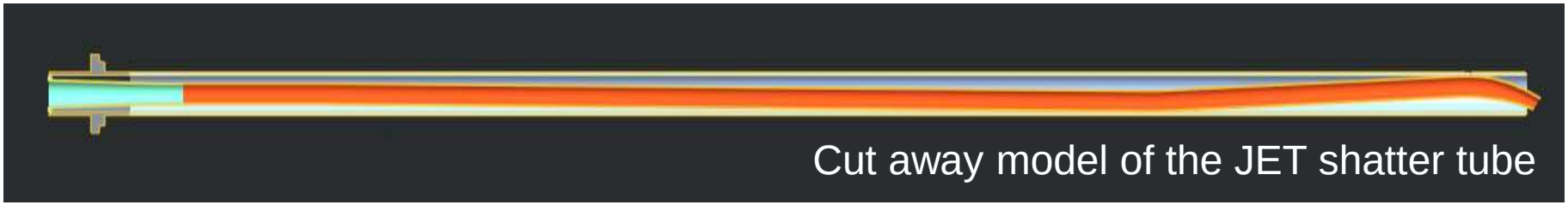
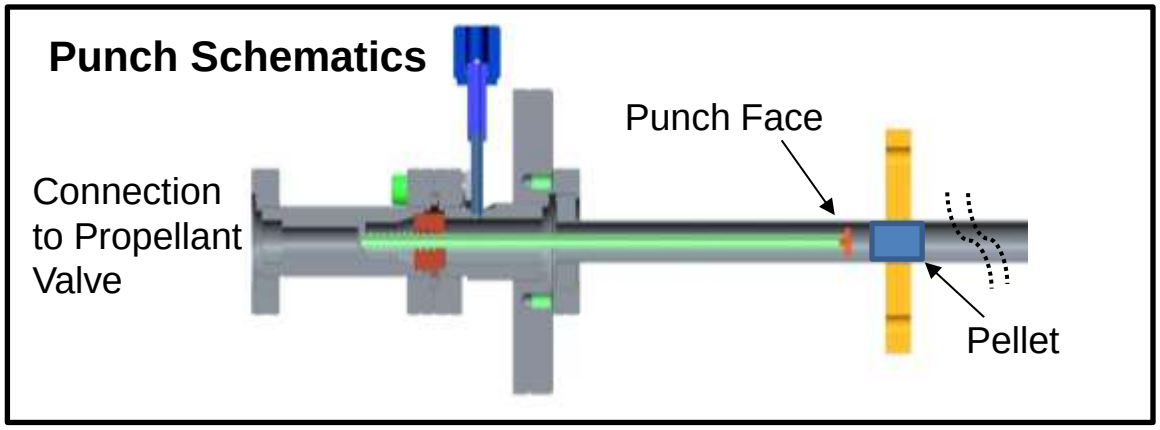
The JET Shatter Tube was Tested at ORNL Using Argon Pellets Launched with a Prototype Mechanical Punch



Cut away model of the JET shatter tube



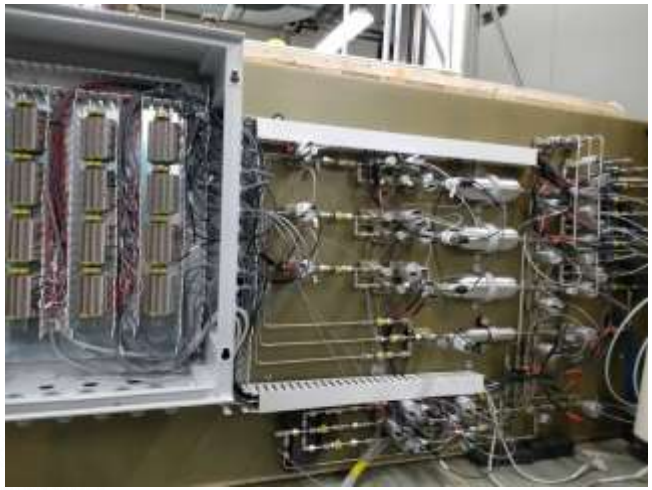
JET shatter tube installed on test stand in Pellet Lab

S. Meitner,

Exit of shatter tube as viewed by the fast camera

JET SPI Commissioning

- The JET SPI was assembled leak checked and began commissioning testing in Sept 2017.
- A minimum temperature of 4.6 K was reached during an initial cool-down test.
- All pneumatic valves were operated via a Siemens PLC supplied by JET.
- JET Staff participated in on-site testing to gain experience and verify performance.



SPI Gas Manifold

SPI Controls

JET SPI Commissioning

- All three barrels were tested with D2, D2-Ne mixtures and Ne.
- A mechanical punch was successfully tested on the 8.1mm barrel using Ne and Ar pellets.
- The entire injection line was duplicated in the lab with the microwave cavity and a copy of the JET shatter tube.
- Verification of shattering was recorded with a fast video camera

Ne Fragments Exiting Shatter Tube

JET SPI Timeline

- JET SPI shatter tube shipped and installed Oct 2017
- JET SPI commissioning completed Oct 2017
- JET SPI packaged and shipped Nov 2017
- Receipt of JET supplied vacuum and cryogenic components in Feb 2018
- Installation of SPI begins Feb 2018
- Commissioning run week May 21-25
- Experiments to be run June-Sept 2018

JET SPI Experimental Plans

Thermal Mitigation – ~16 Sessions

- Optimization of D2/Ne mixture
- TM with fixed amount of Ne and different amounts of D2 (vary pellet size)
- Mitigation of a near disrupting plasma – wounded duck
  - Dependence on locked mode location WRT SPI location

JET SPI Experimental Plans

RE Studies – ~17 Sessions

- RE dissipation with Ar/Ne SPI using punch
  - Variation of particle size as function of speed
  - Multiple pellets possible – Ar, Ne
  - JET is working on vertical position control to allow longer lasting RE beams
- RE Avoidance – D2/Ne mixtures, possible Ar-D2 layer pellets

Summary

- The need for a reliable DMS on ITER have motivated a strong international effort on JET (ITER, USITER, USDOE, EUROfusion, CCFE all working well together)
- SPI will be installed on JET in Feb 2018 for commissioning and experiments starting in May 2018, and could with further development be integrated into JET DMS in future.
- JET SPI Benefits to ITER
  - Commissioning and Operational Experience
  - Data on TM heat loads, halo currents, and RE mitigation/dissipation
  - Modeling, simulation, extrapolation to ITER
- JET disruption taskforce has identified over 20 experiments that will use 30+ sessions

Questions?