Fast Time Response Electromagnetic Particle Injection System for Disruption Mitigation (EPI)

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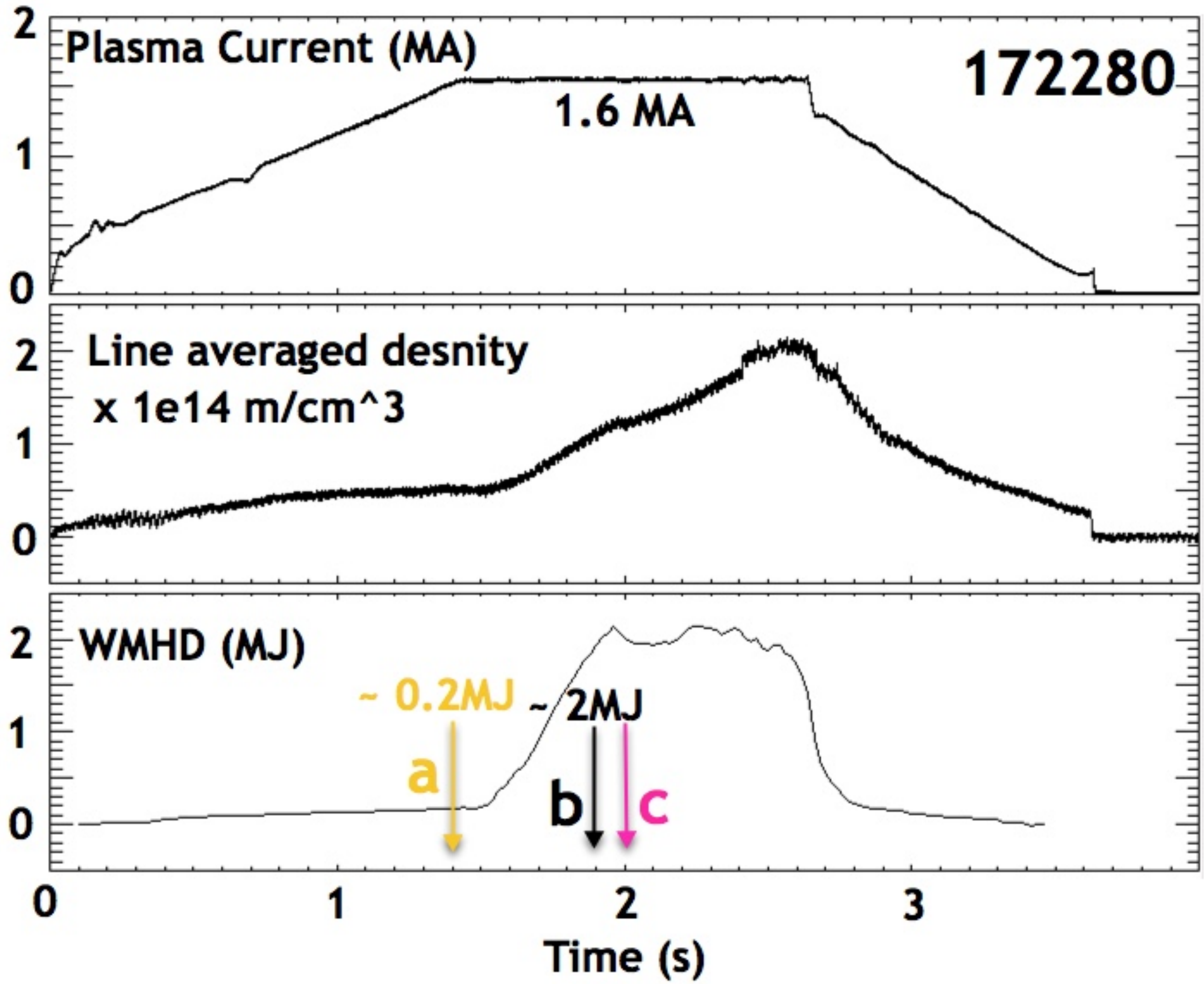
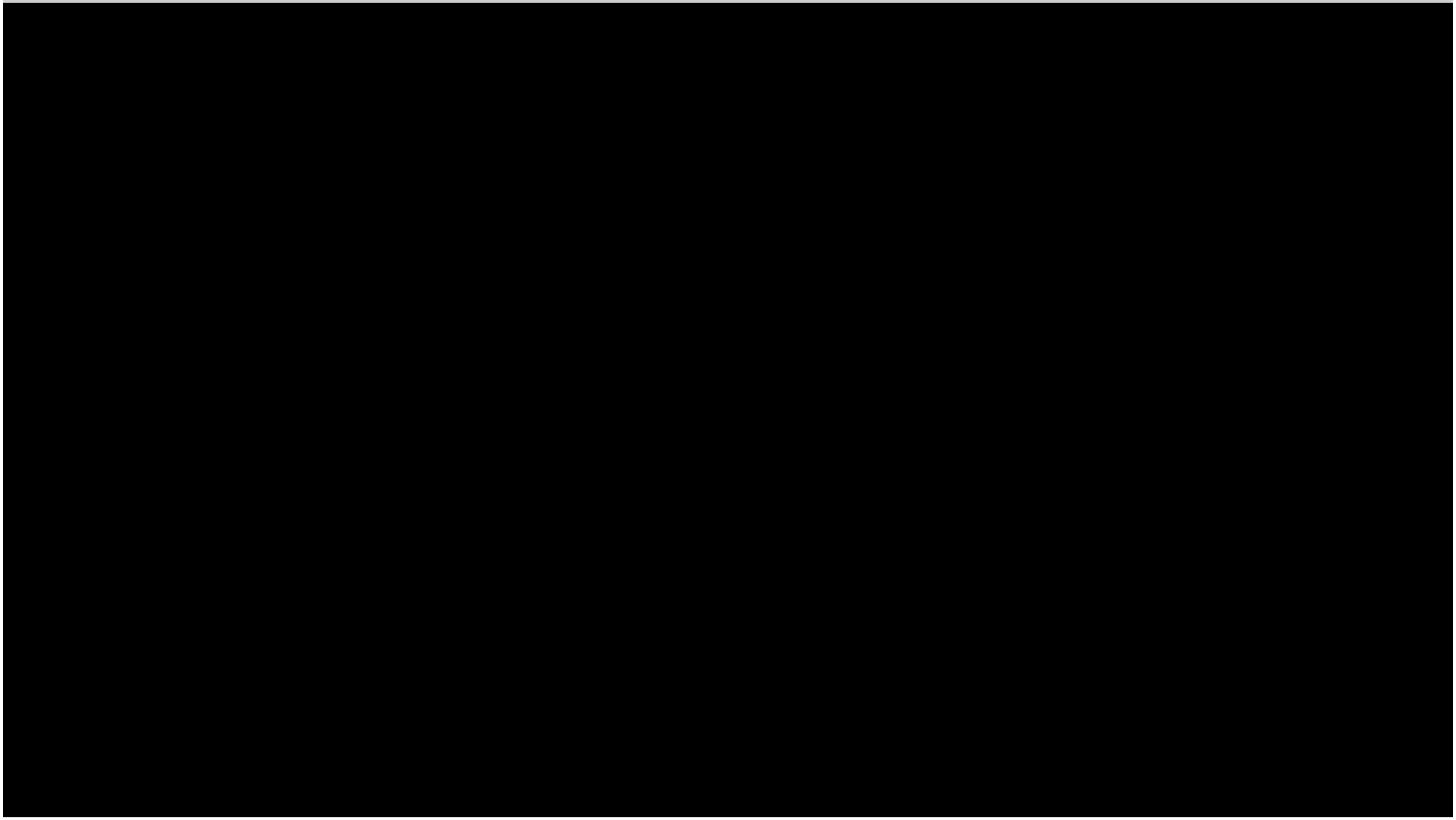
Limitations of Present DM Systems

- Most of the DM databases is from MGI experiments, but MGI has been dropped by ITER due to its slow response time.
  - ➢ But, the MGI valve propels the SPI pellet
- The speed of the un-fragmented high-mass / high-Z SPI pellets is about 200-300 m/s due to the use of gas propellant
  - ➢ Shattering process further reduces fragment velocity
- Because of the slow speed and size of the fragmented particles, the penetration depth will be severely restricted in high power ITER discharges
- Will the SPI fragments penetrate sufficiently deep into the much more energetic ITER H-mode pedestal?

There is Dramatic Difference in SPI Penetration in Low and High-Power DIII-D Plasmas



DIII-D SPI Injection Movies (R. Moyer – UCSD / DIII-D)



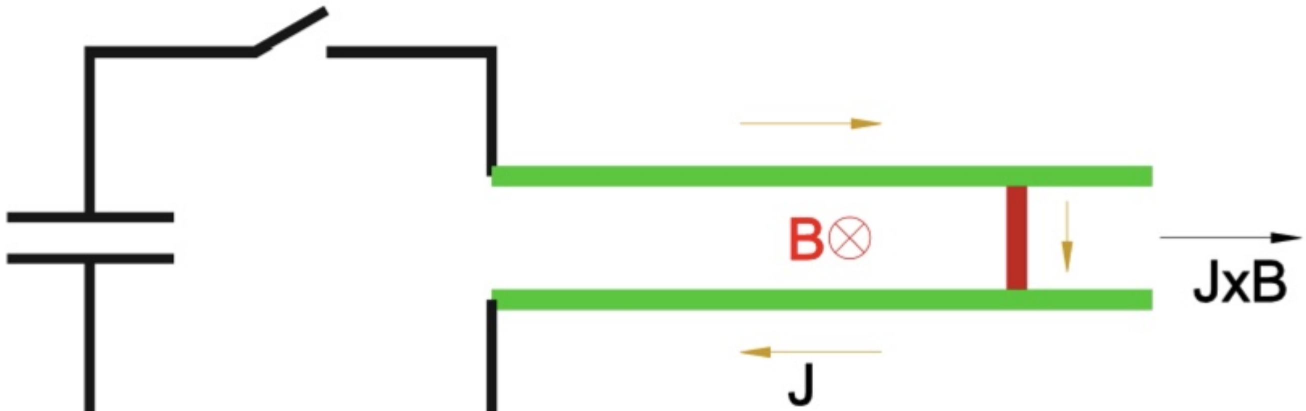
How does the EPI concept address present limitations?

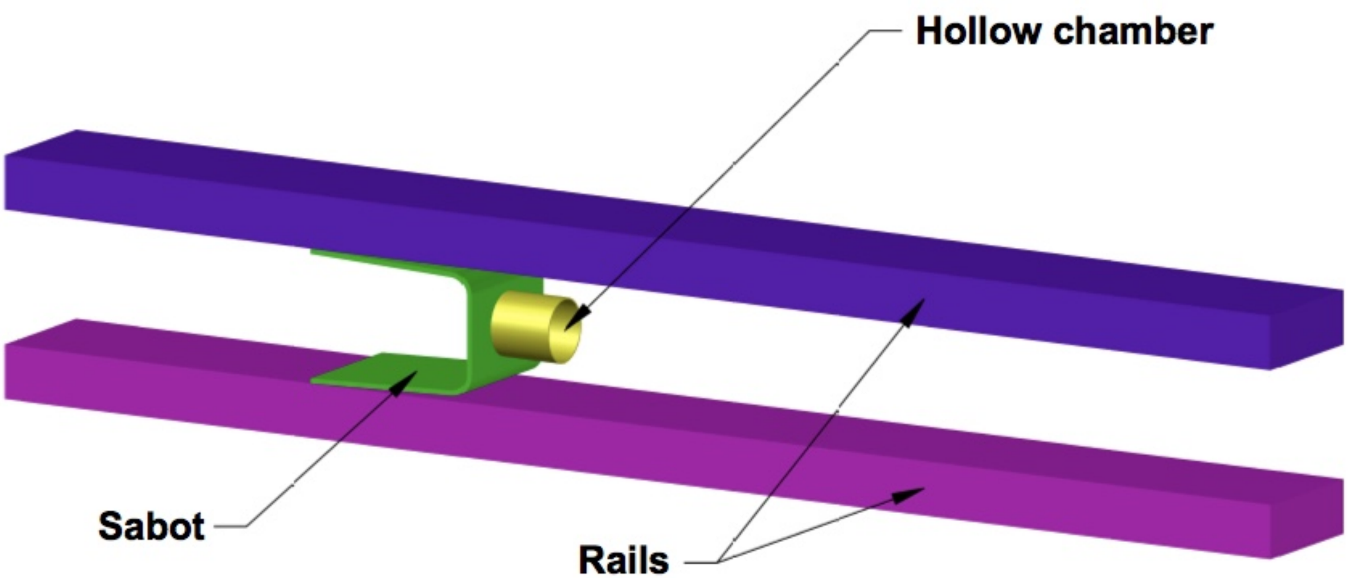
- The EPI concept injects grains of material (of the required size) and at the required velocity – & it does this on a fast time scale (2-3ms)
- Because of this - one can precisely calculate the needed size / velocity combination of a spherical particle for penetrating to the center of any given plasma, including the ITER plasma

How Does the EPI System Achieve These Essential Parameters for a Reactor DMS?

- The EPI system accelerates a sabot
- The sabot is a metallic capsule that can be accelerated to high-velocity using an electromagnetic impeller
- At the end of the acceleration, within 2-3ms, the sabot will release granules of known velocity and distribution – or a Shell Pellet
- The **primary advantage** of the EPI concept over SPI and other gas propelled systems is its potential to meet **short warning time scales**, while accurately delivering the required particle size and materials at the velocities needed for achieving the required **core penetration** in high power ITER discharges.
  - ➢ Delivers radiative payload to the the core where the RE channel is generated

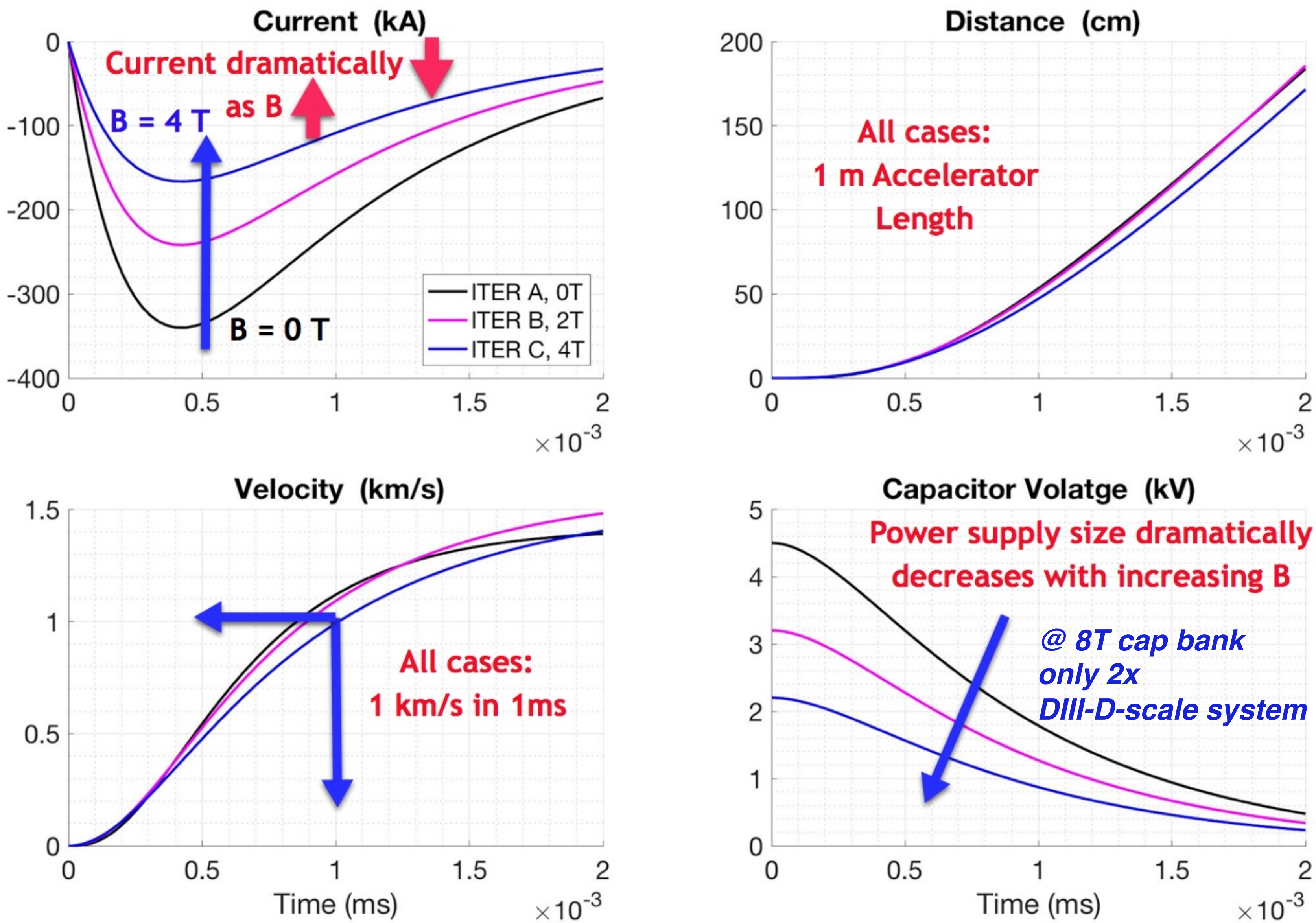
The Ambient B-Field of a High-Field Tokamak such as ITER Can be Used to Improve Device Efficiency



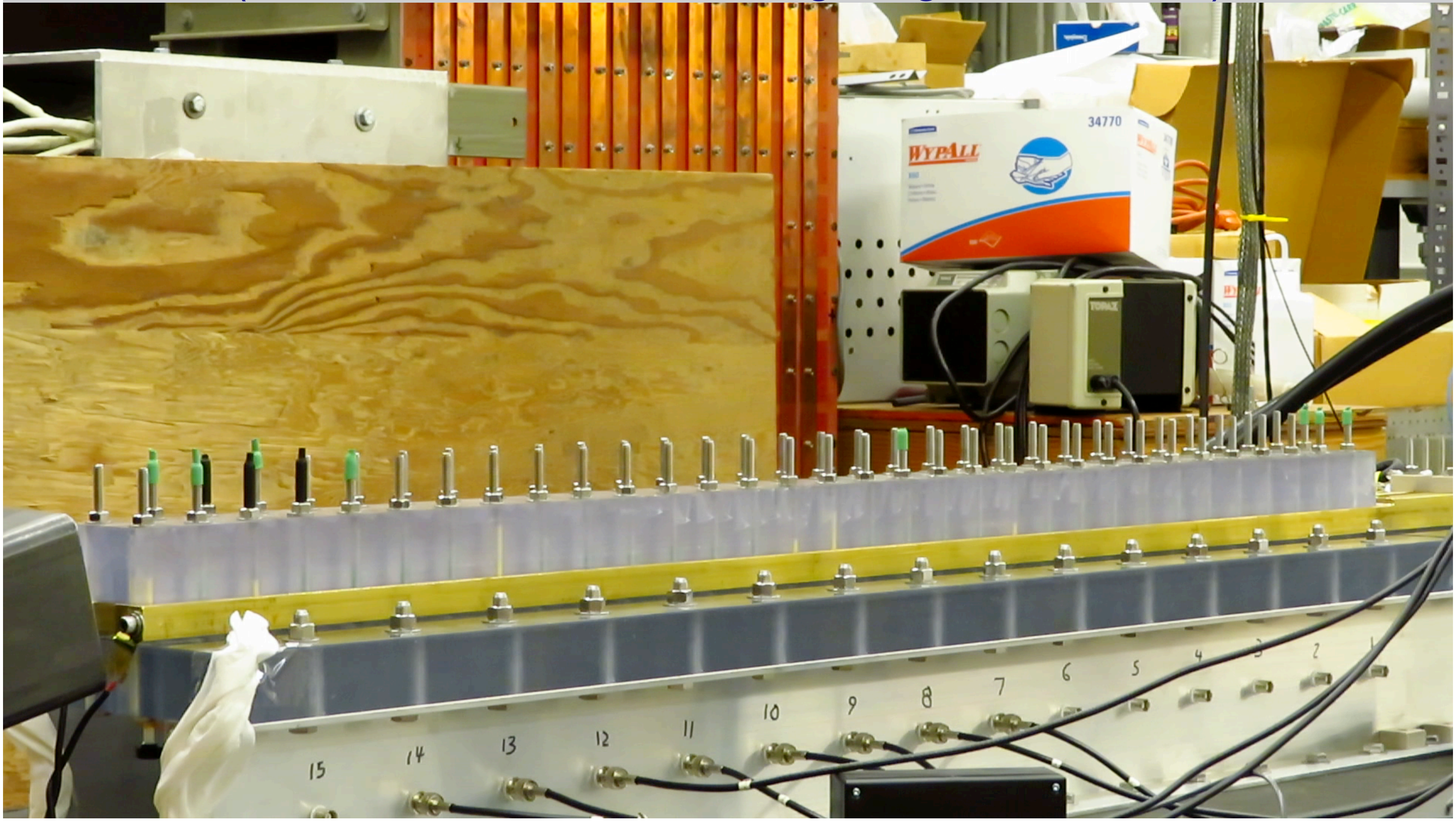


- Injector can be positioned very close to the vessel, which further improves the system response time
- Use high-field SC boost coils (>8T) if located outside port plug

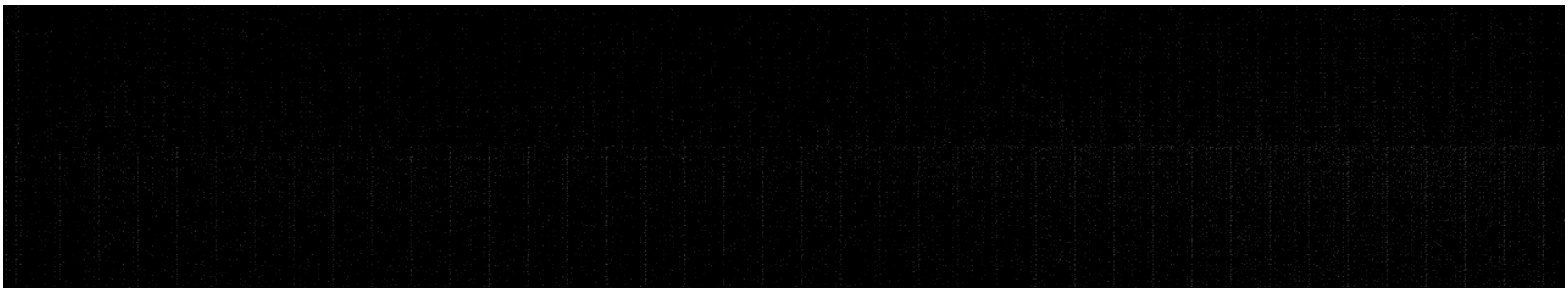
ITER Scale Injector Should Attain 1 km/s in ~1 ms



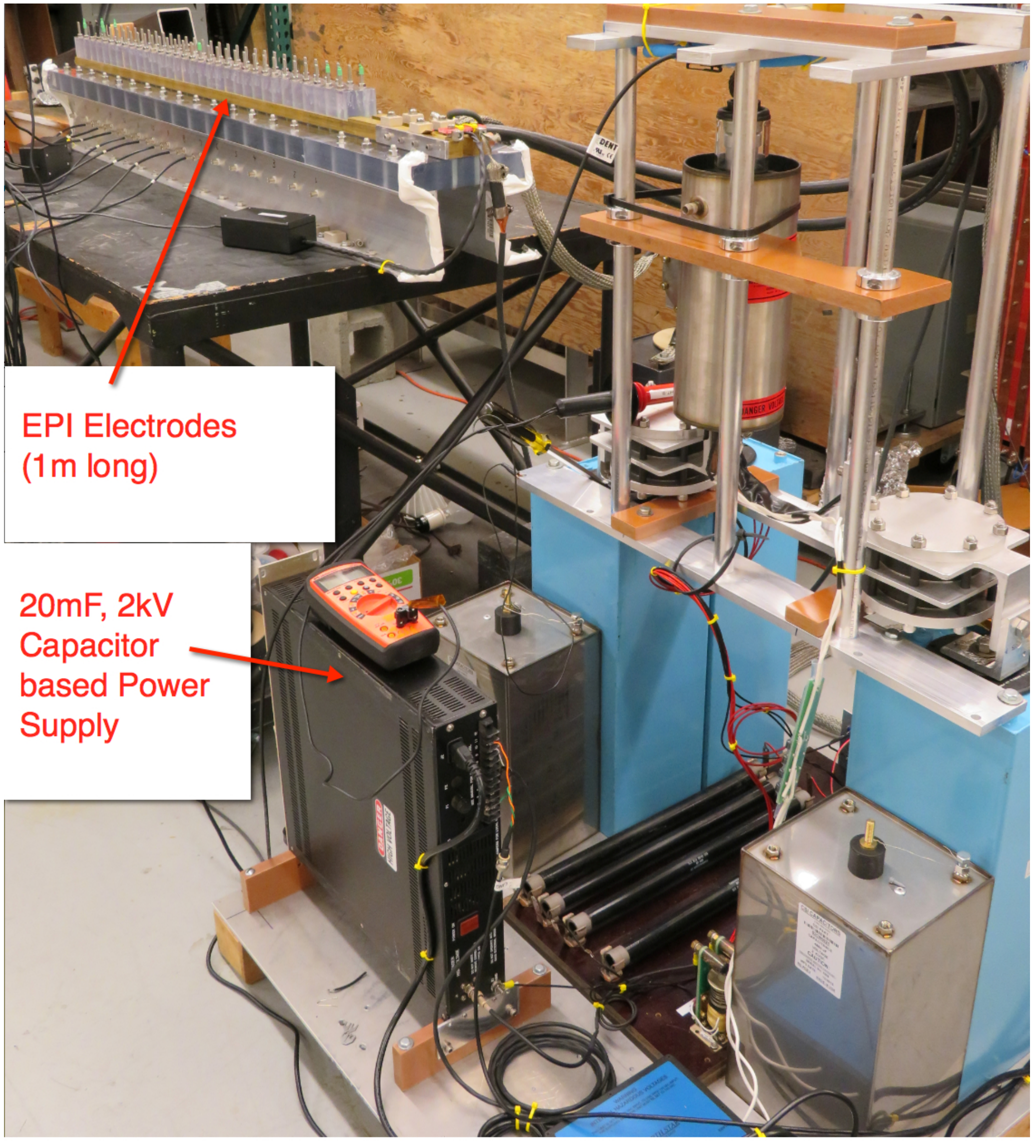
Small Scale System Built To Test Critical Parameters
(Sabot motion tracked using magnetic Probes)



Sabot Motion also Tracked Using Fast Video Camera



Measured EPI system parameters with 0.3T B-field augmentation in agreement with simulation predictions



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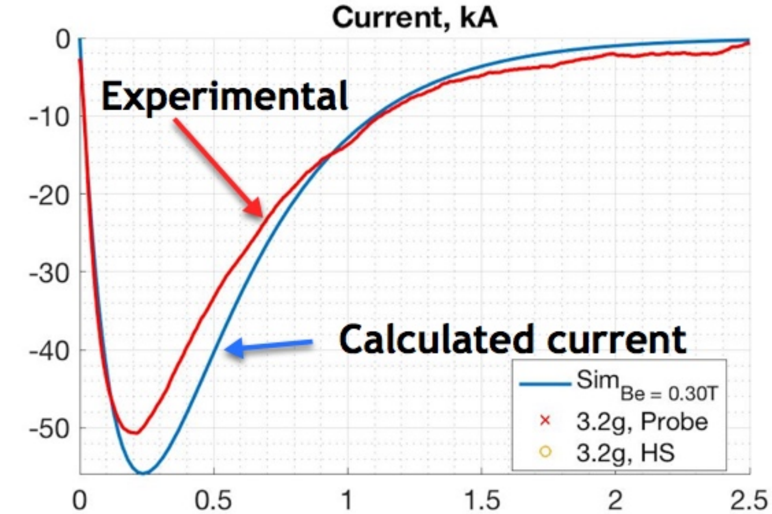
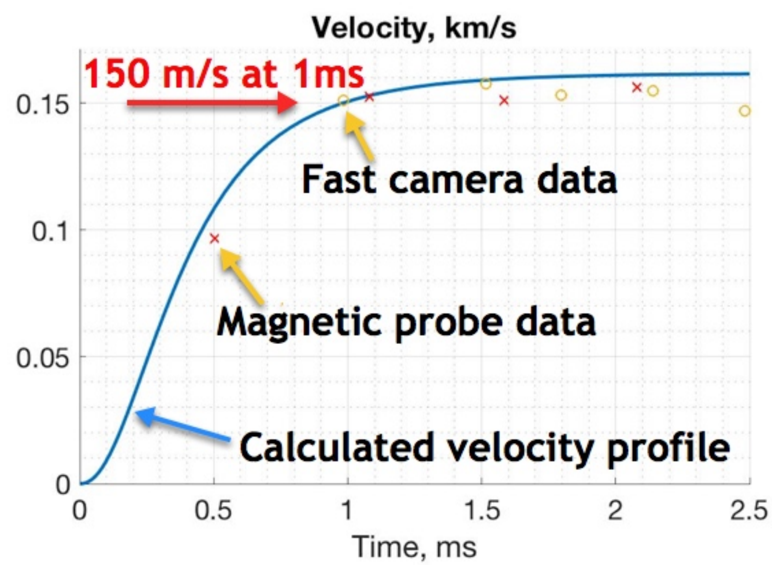
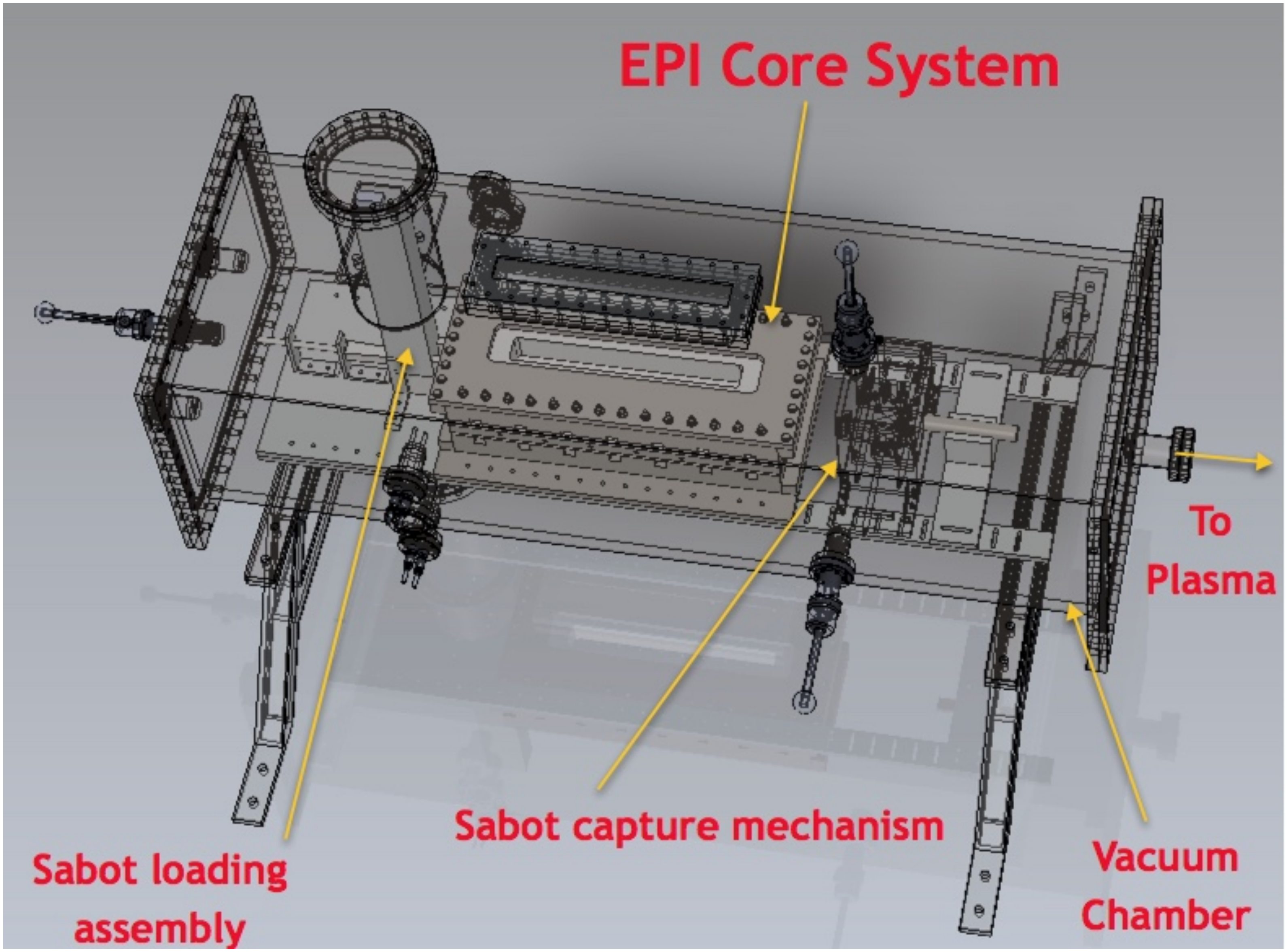




Next Step is to Conduct an EPI Test on a Tokamak

Vacuum Chamber Dimensions (1.5m x 0.6m x 0.5m)



EPI can Deliver Radiative Payload Deep into the Tokamak Plasma on a Fast 2-3 ms Time-scale

- EPI concept accelerates a metallic sabot to high velocity, which releases grains of particles of the required size and velocity

- The EPI system has features needed for a reactor DMS
  - Can deposit payload in the RE channel – triggering an inside out thermal quench
  - It uses a single reliable actuator, and payload that is solid at room temperature – so it should be very reliable
  - It can be located close to vacuum vessel further improving response time

- Off-line setup at U-Washington has demonstrated key aspects of concept, including 150-200 m/s velocities with 1.5ms response time consistent with calculations

- Tokamak tests are the next logical next step for concept development
  - Develop experimental data base on solid particle injection for theory simulations