

# Electromagnetic Particle Injector (EPI) for Fast Time Response Disruption Mitigation in Tokamaks

College W&M  
Colorado Sch Mines  
Columbia U  
Comp-X  
General Atomics  
INL  
Johns Hopkins U  
LANL  
LLNL  
Lodestar  
MIT  
Nova Photonics  
New York U  
Old Dominion U  
ORNL  
PPPL  
PSI  
Princeton U  
Purdue U  
SNL  
Think Tank, Inc.  
UC Davis  
UC Irvine  
UCLA  
UCSD  
U Colorado  
U Maryland  
U Rochester  
U Washington  
U Wisconsin

**R. Raman<sup>1</sup>, R. Lunsford<sup>2</sup>, et al.,**  
**<sup>1</sup>University of Washington**  
**<sup>2</sup>Princeton Plasma Physics Laboratory**

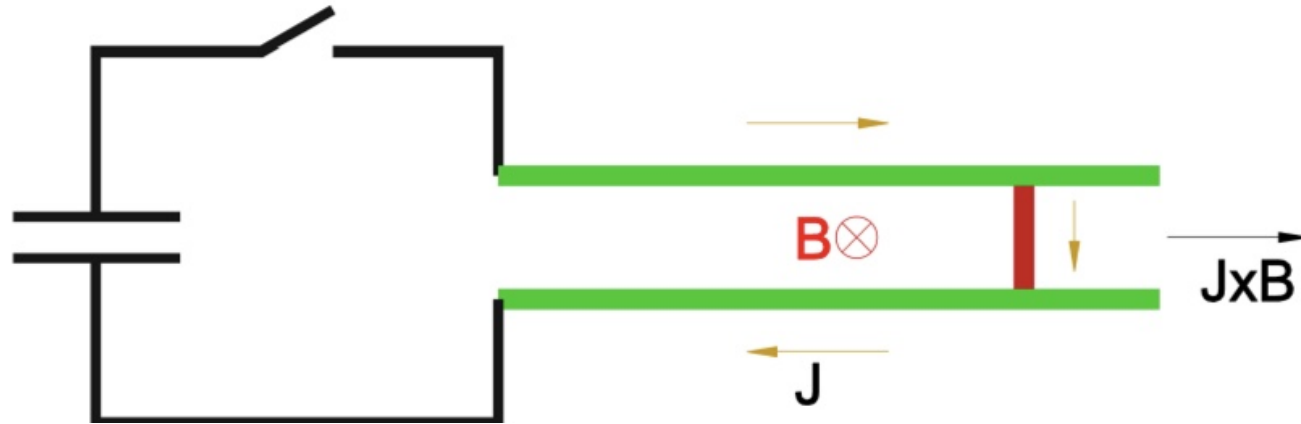
## APS-2019 Invited Talk Outline

29 April 2019

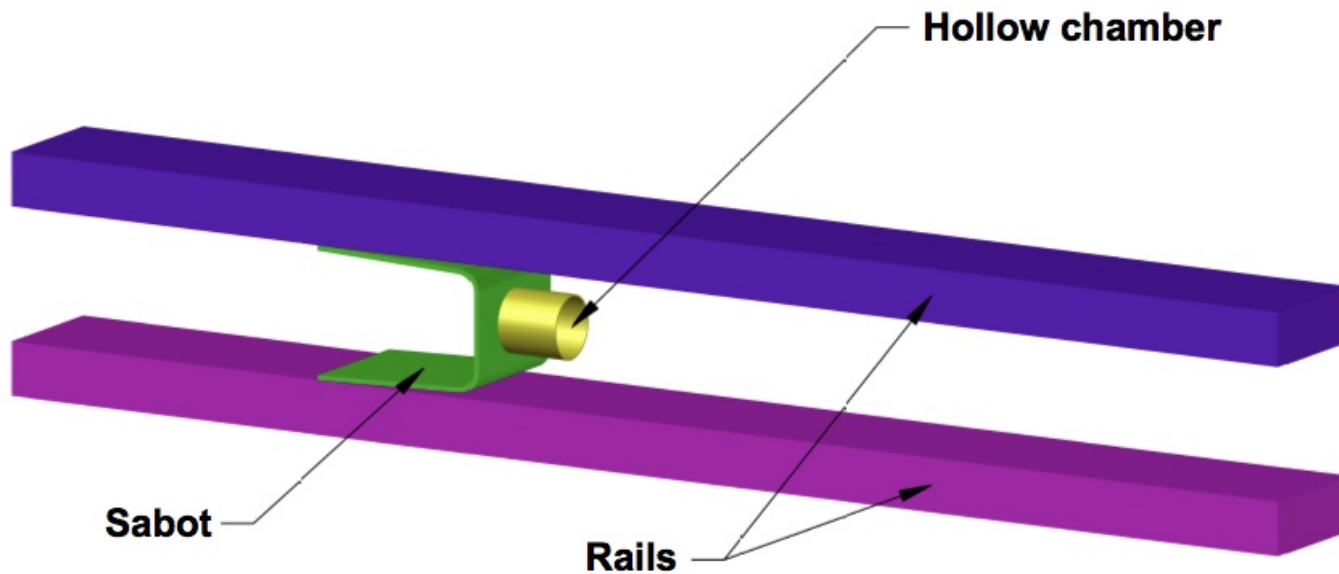
Magnetic Fusion Science Meeting  
B318, PPPL

Culham Sci Ctr  
U St. Andrews  
York U  
Chubu U  
Fukui U  
Hiroshima U  
Hyogo U  
Kyoto U  
Kyushu U  
Kyushu Tokai U  
NIFS  
Niigata U  
U Tokyo  
JAEA  
Hebrew U  
Ioffe Inst  
RRC Kurchatov Inst  
TRINITY  
KBSI  
KAIST  
POSTECH  
ASIPP  
ENEA, Frascati  
CEA, Cadarache  
IPP, Jülich  
IPP, Garching  
ASCR, Czech Rep  
U Quebec <sup>1</sup>

# EPI accelerates a metallic sabot to high-velocity in a simple rail gun configuration



- Injector *can be* positioned very close to the vessel, if EPI is part of the original reactor design



- Can use high-field SC boost coils ( $>8T$ ) if located outside ITER port plug

# Controlling Major Disruptions on ITER and Tokamak-Based Reactors is an Essential Requirement

- The present baseline system for ITER is based on SPI, but this may change, and other improved technologies may be implemented
  - The Electromagnetic Particle Injector (EPI) is a possible candidate
- Disruption mitigation on ITER would be much more challenging
  - High edge  $T_e$  will make radiative penetration to  $q=2$  quite difficult
  - On DIII-D some SPI fragments penetrate to  $q=2$  surface, but simple, single fragment injection, calculations indicate that these would be ablated at the edge in ITER plasmas.
  - Will SPI on ITER be more like MGI on DIII-D?
  - Would MHD mixing be needed to transport the radiative payload to the core (MGI) or would inside-out quench using new technologies be superior and provide greater safety margin on ITER?
  - How well can we control the amount of required radiative material as the plasma energy content changes (to control the current quench time duration)
  - How well would runaway currents be controlled on ITER
- Reliable and safe operation of ITER is absolutely necessary for the future of any tokamak-based reactors, and for magnetic fusion energy in general

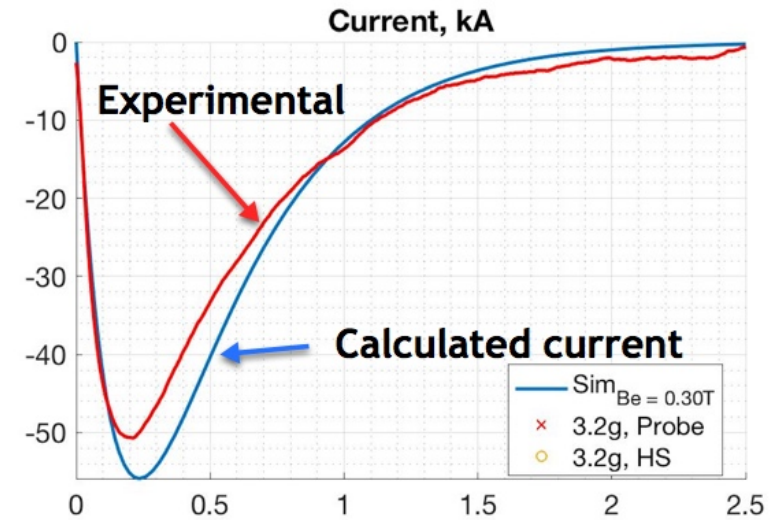
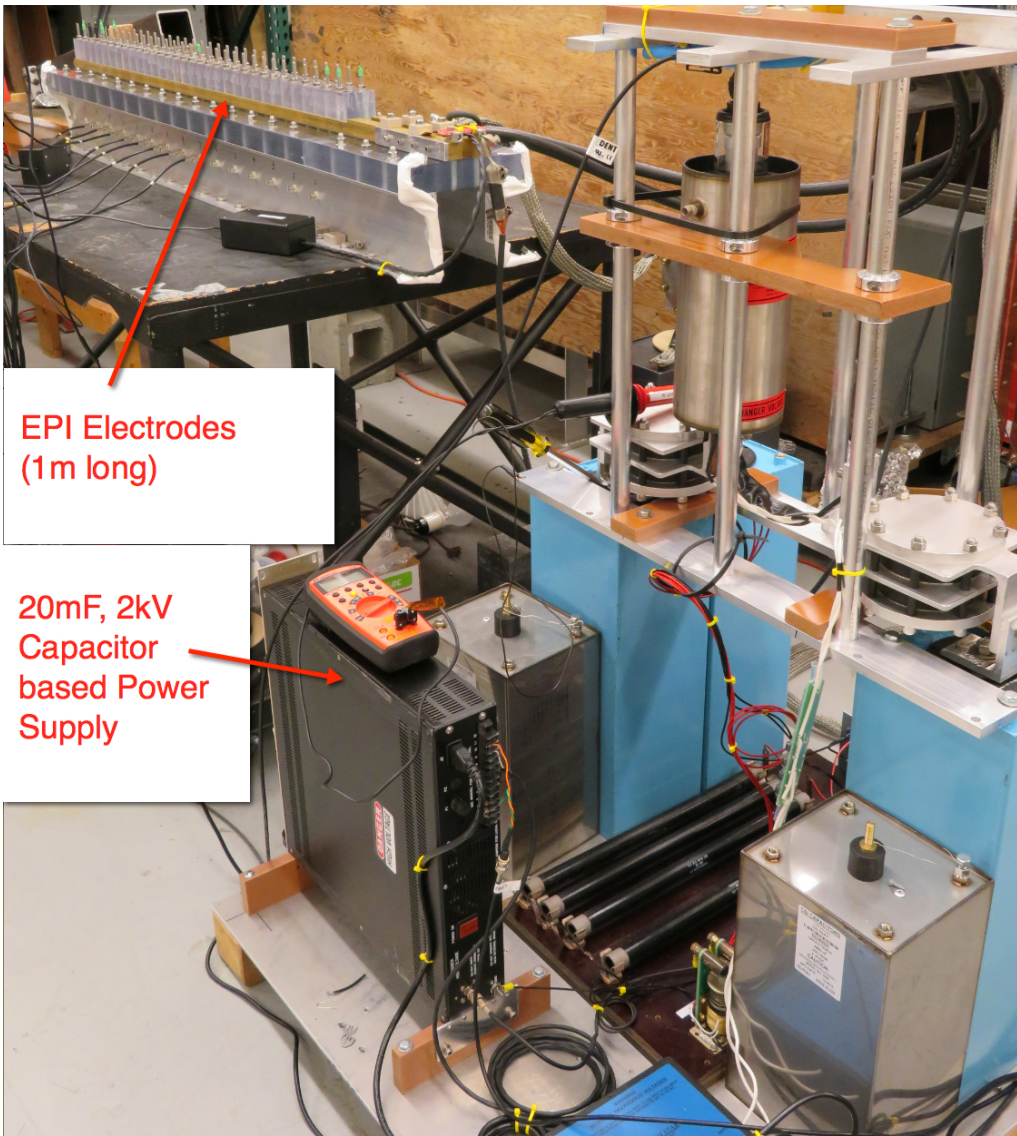
# Major uncertainties exist in the present baseline DMS for ITER

- EPI has the potential for protecting the ITER infrastructure (fast response time & high velocity)
- Off-line setup (with EPI-2) has demonstrated key aspects of concept, including 300 m/s velocities with 1.5ms response time consistent with calculations. (@ ~50% energy of EPI-1 for 150m/s)
  - Payload separation from sabot and sabot capture demonstrated at 160m/s and the concept can be extended to >2km/s
- Goals for APS Talk
  - Briefly summarize key results on radiative payload penetration from present experiments (will SPI on ITER be more like MGI on DIII-D)
  - Describe the EPI concept with results from EPI-1 and EPI-2
    - On EPI-2, extend operation to full 2T (possibly higher) boost coil fields
    - Possible test inside a vacuum chamber
  - Include a M3D-C1 simulation on typical EPI fragment injection into a DIII-D/KSTAR scale plasma

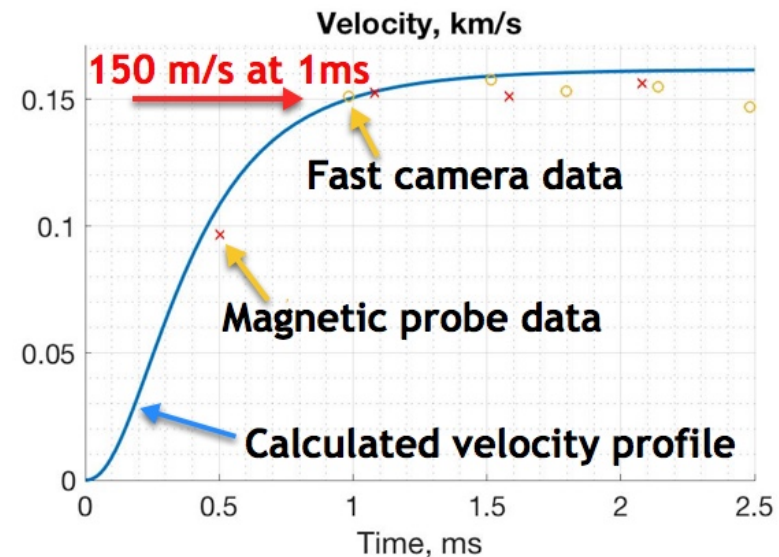
# Back-up slides

---

# Measured EPI-1 system parameters with 0.3T B-field augmentation in agreement with calculations



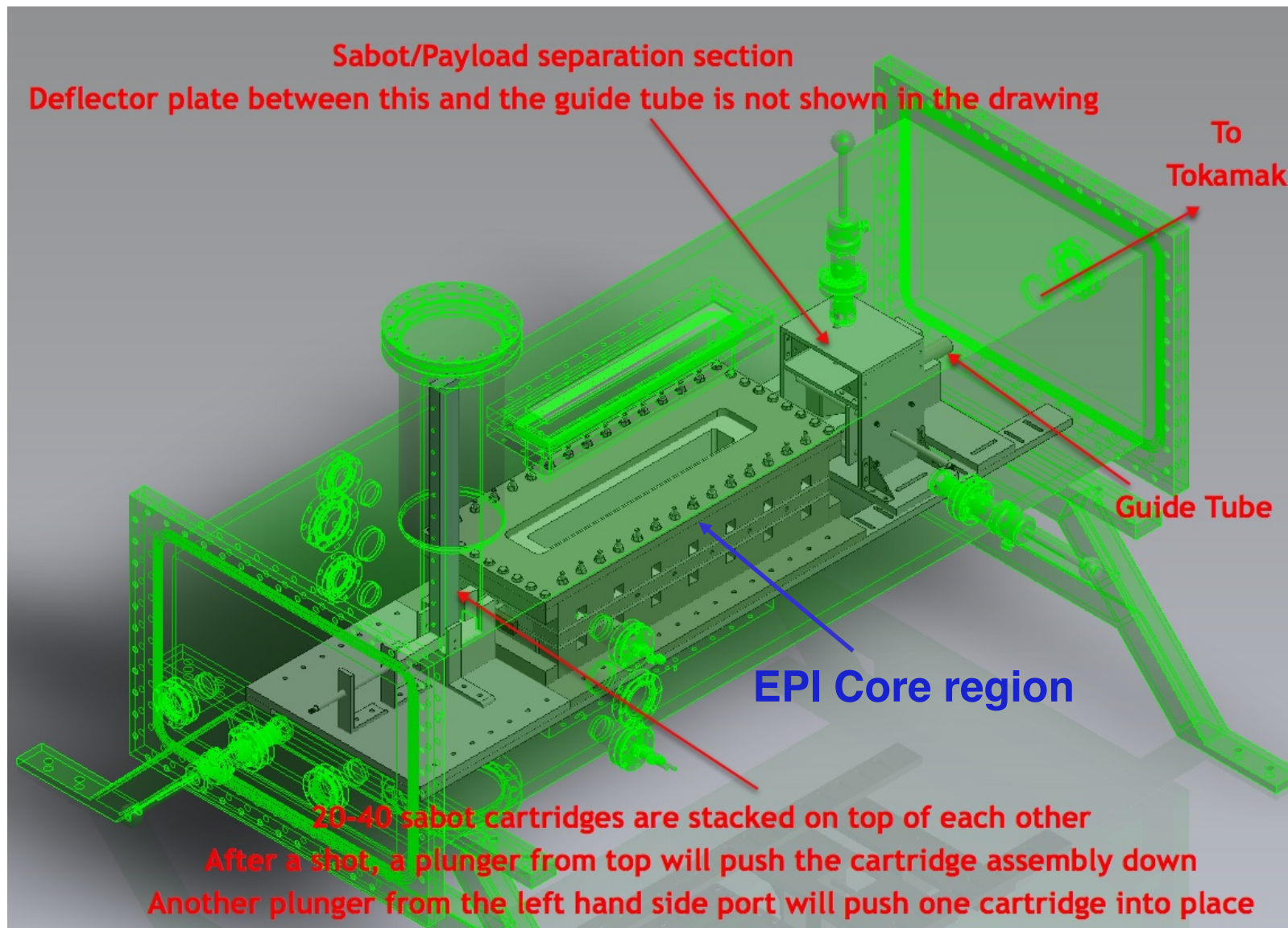
Maximum velocity limited by power supply limits



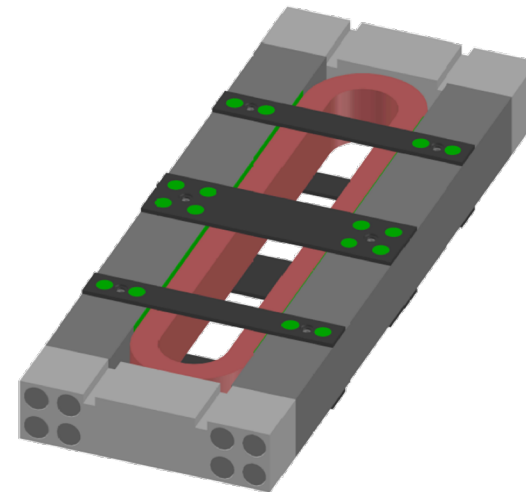
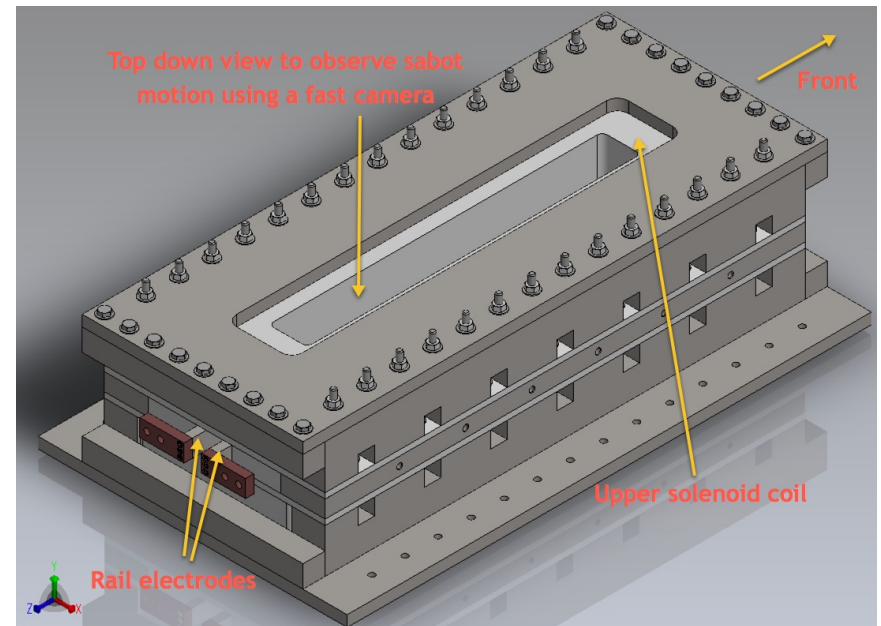
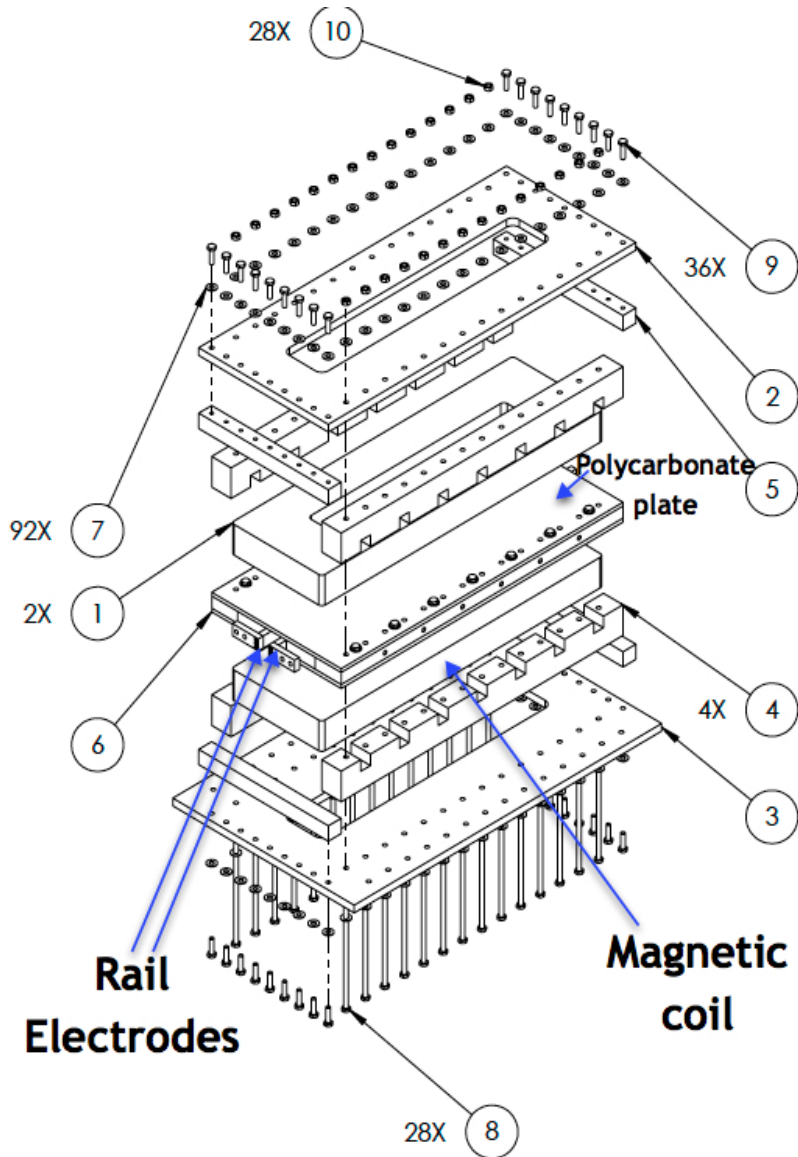
R. Raman, et al., Nuclear Fusion 59 (2019) 016021

# EPI-3 Conceptual Layout (KSTAR configuration)

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



# EPI-2 Core Components (KSTAR Configuration)



Racetrack Coil with supports



# All key components of EPI-2 (except vacuum operation) have been tested

