Particle Control and Carbon Transport Experiments on DIII-D

S.L. Allen, *LLNL*
E. A. Unterberg, *ORNL*
N. Brooks, M. Ali Mahdavi, *GA*
D. Whyte, *MIT*
J.W. Davis, A. A. Haaz, B. Fiztpatrick, *Univ. Toronto*

This work is dedicated to Phil West, who "pioneered" these experiments on DIII-D.

Let's get to the data! …

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Fuel (Tritium) Retention Motivates DIII-D Particle Transport Studies

- **Wall inventory of tritium fuel important**
  - Particle balance determined from sources and sinks
  - Cryopumping important (ITER has cryopumping)
- **Tritium will be codeposited with eroded carbon**
  - Determine locations –
    - ^{13}C injection (inner strike point)
    - 2D spectroscopy (flow in SOL)
  - C/D ratio depends on temperature
  - Chemical sputtering small in DIII-D divertor (McLean)
- **Techniques to remove carbon codeposits**
  - Thermal oxidation (Air Bake – quantified by U. Toronto)

Outline of Talk: 4 Main Points

1. **Two different particle balance techniques yield same results**
   - Static (pressure rise after shot)
   - Dynamic (calculated during shot)
   - DIII-D, C-MOD, NSTX measurements
     - 2009 DOE Joint Research Milestone (completed)
     - JO4.08 NSTX with Lithium Conditioning - Skinner
2. **Dynamic balance shows wall retention ≅ 0 in H-mode**
   - DIII-D H-modes with either ECH or NBI and cryopumping
   - C-MOD L-mode in steady-state with cryopumping
3. **Injected ^{13}C concentrated inner strike point**
4. **Preparations progressing for DIII-D Air Bake**

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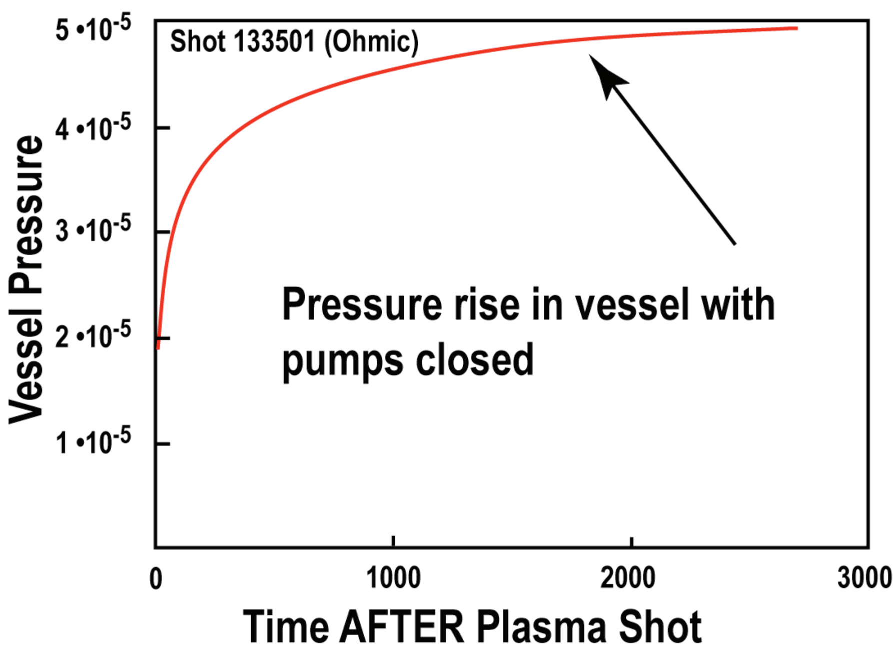
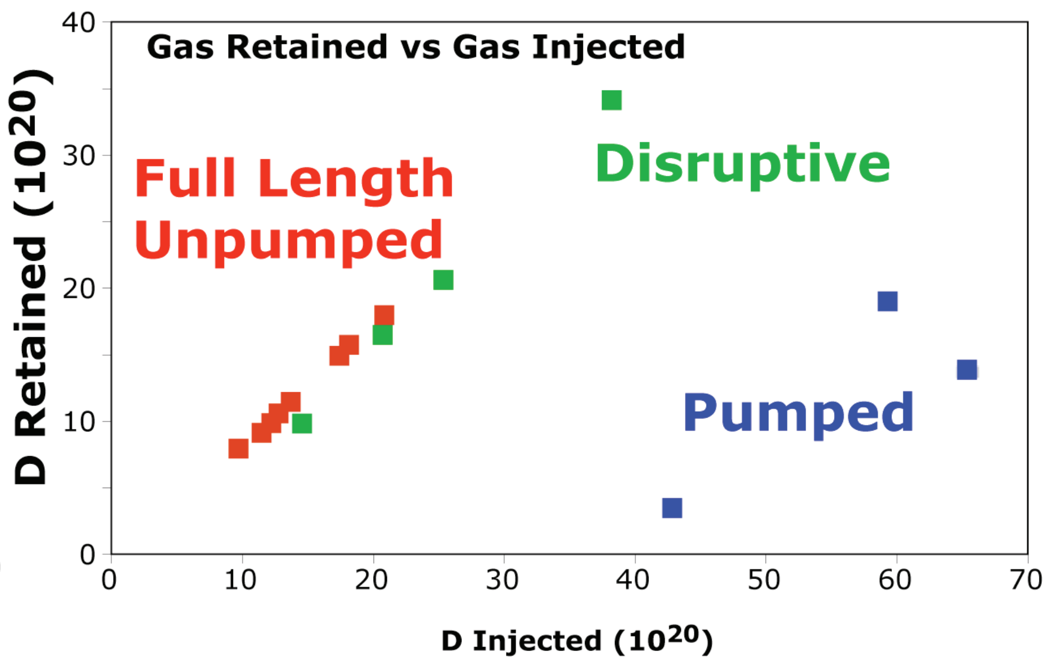
Static Particle Balance (P. West, 2008 APS)

- **Static or shot-integrated (vessel closed)**
  - Gas input for the shot = I_{gas}
  - Pressure rise after shot, (regenerate cryopumps) = ΔPV
  - Difference $I_{gas} - \Delta PV$ = Wall retention – Ohmic plasmas





Phil West, D. Whyte, et al. 2008 APS

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Sources & Sinks Calculated for Dynamic Balance

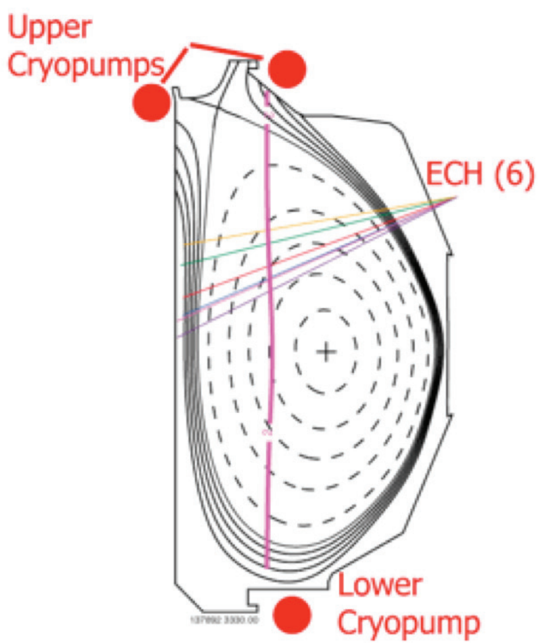
Sources			Sinks		
Gas Input	(NBI Input)	Neutrals	Pump Exhaust	Plasma Density Rise	Wall Flux

$$\Gamma_{Gas} + (\Gamma_{NBI}) + \Gamma_{Neutrals} - \Gamma_{Pump} - \frac{\partial(n_e V)}{\partial t} = \Gamma_{Wall}$$

Γ_{NBI}
- = Zero for ECH H-mode
- ~ Minimized during NBI by cycling Torus Isolation Valve

Γ_{Pump} Provided by 3 cryopumps on DIII-D
Exhaust is a function of plasma shape
USN for these shots

$\Gamma_{Neutrals}$ ~ 0



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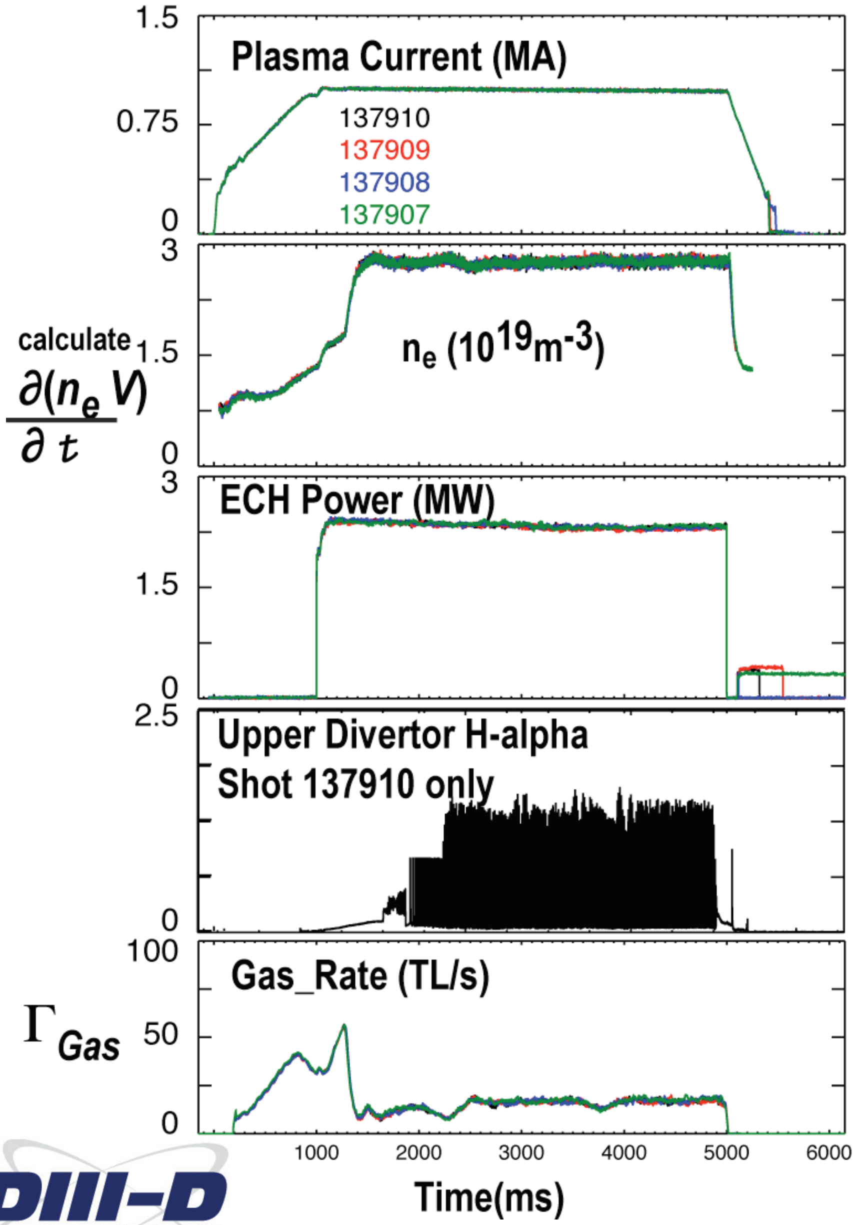
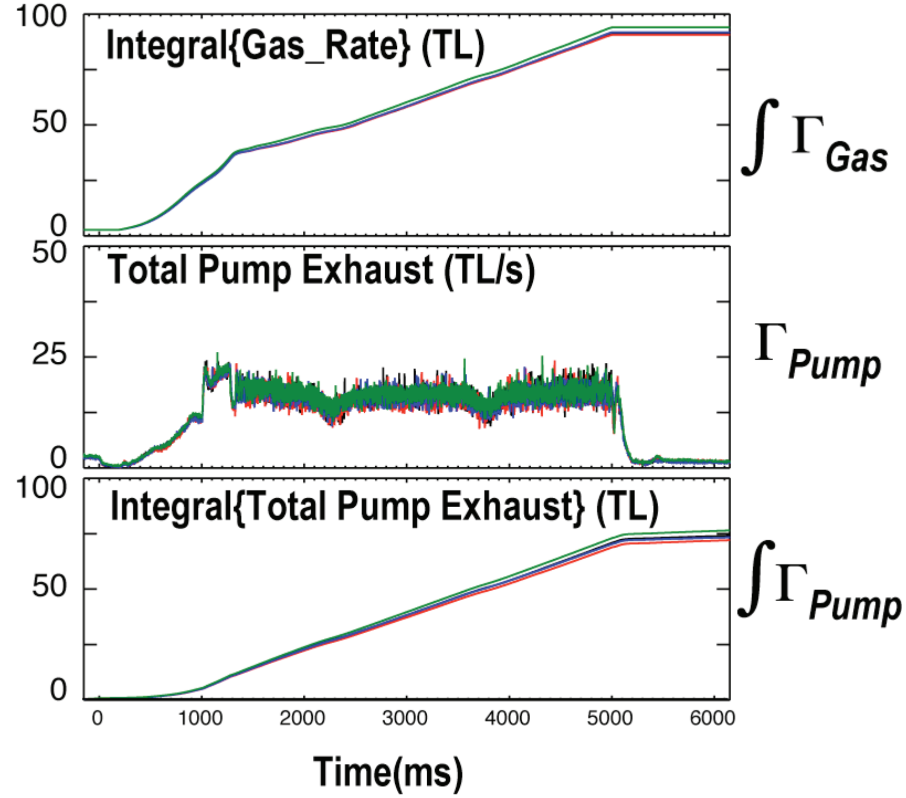
Dynamic Exhaust from Particle Balance, Static from Pressure Rise after 4 shots





After these 4 shots, cryopumps regenerated and pressure rise ΔP measured with Barotron

Static Exhaust = ΔP • Volume

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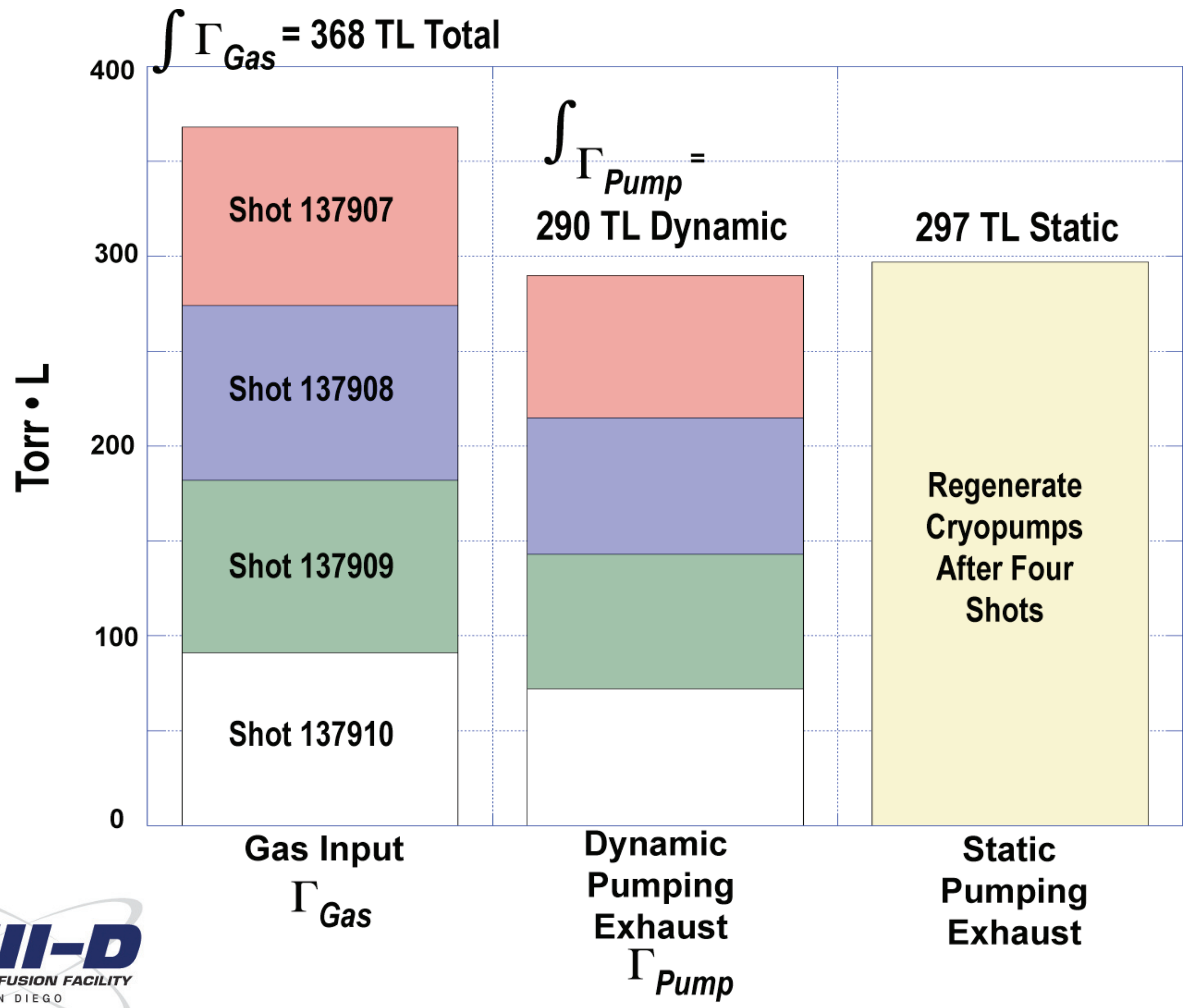
Static and Dynamic Particle Balance Agree



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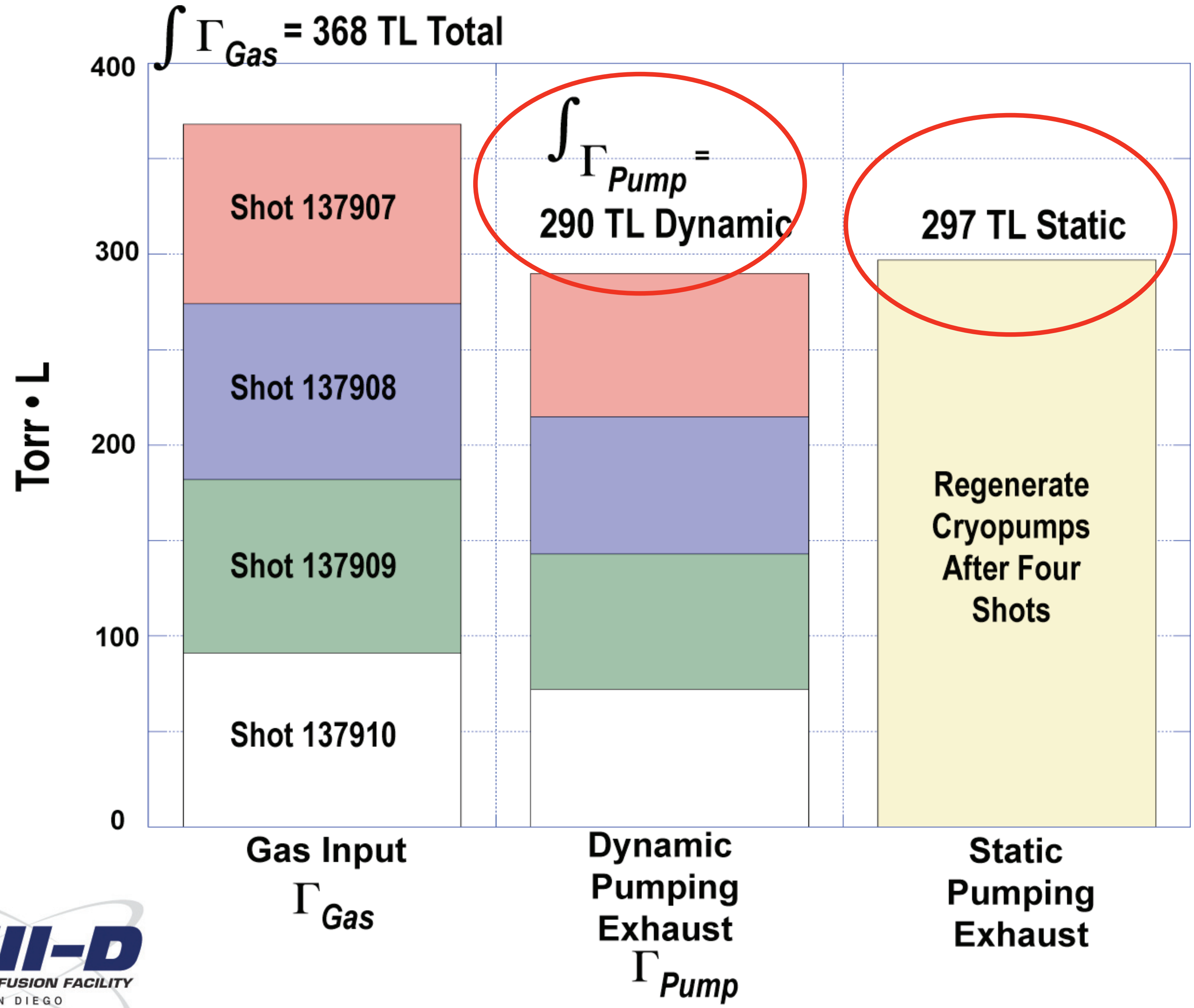
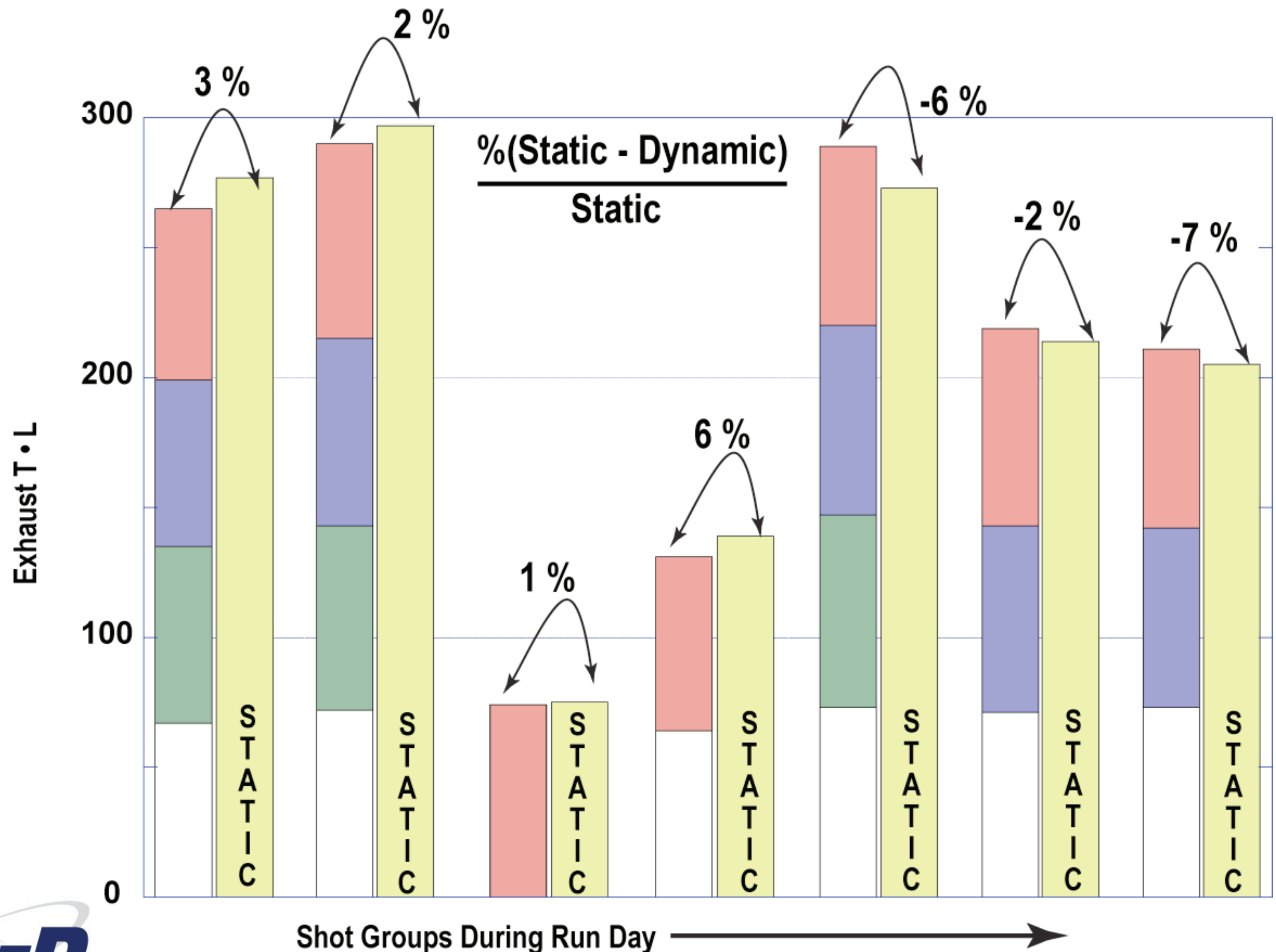


Static = Dynamic Over Whole Run Day



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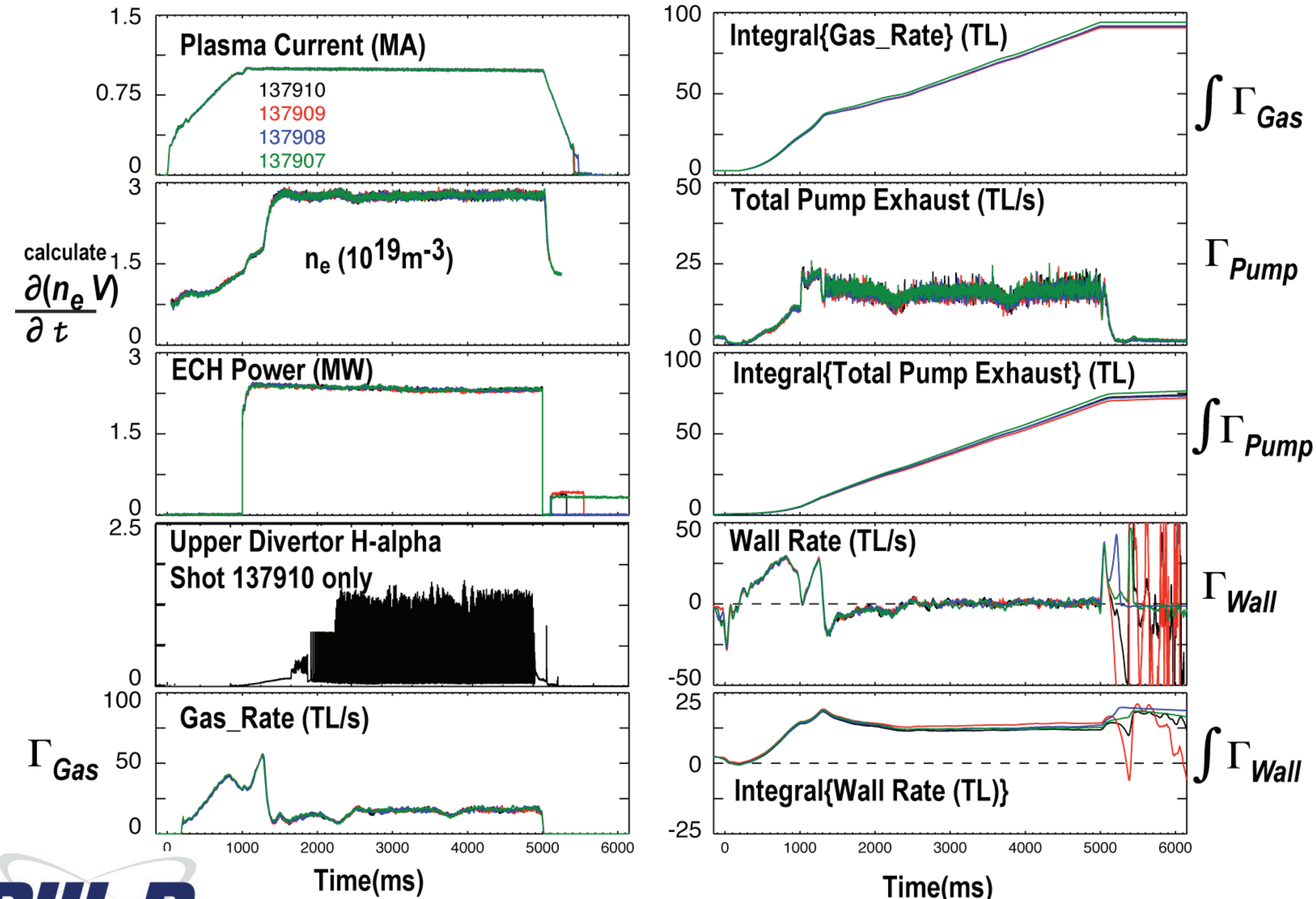
Wall Influx ~0 During ECH H-mode



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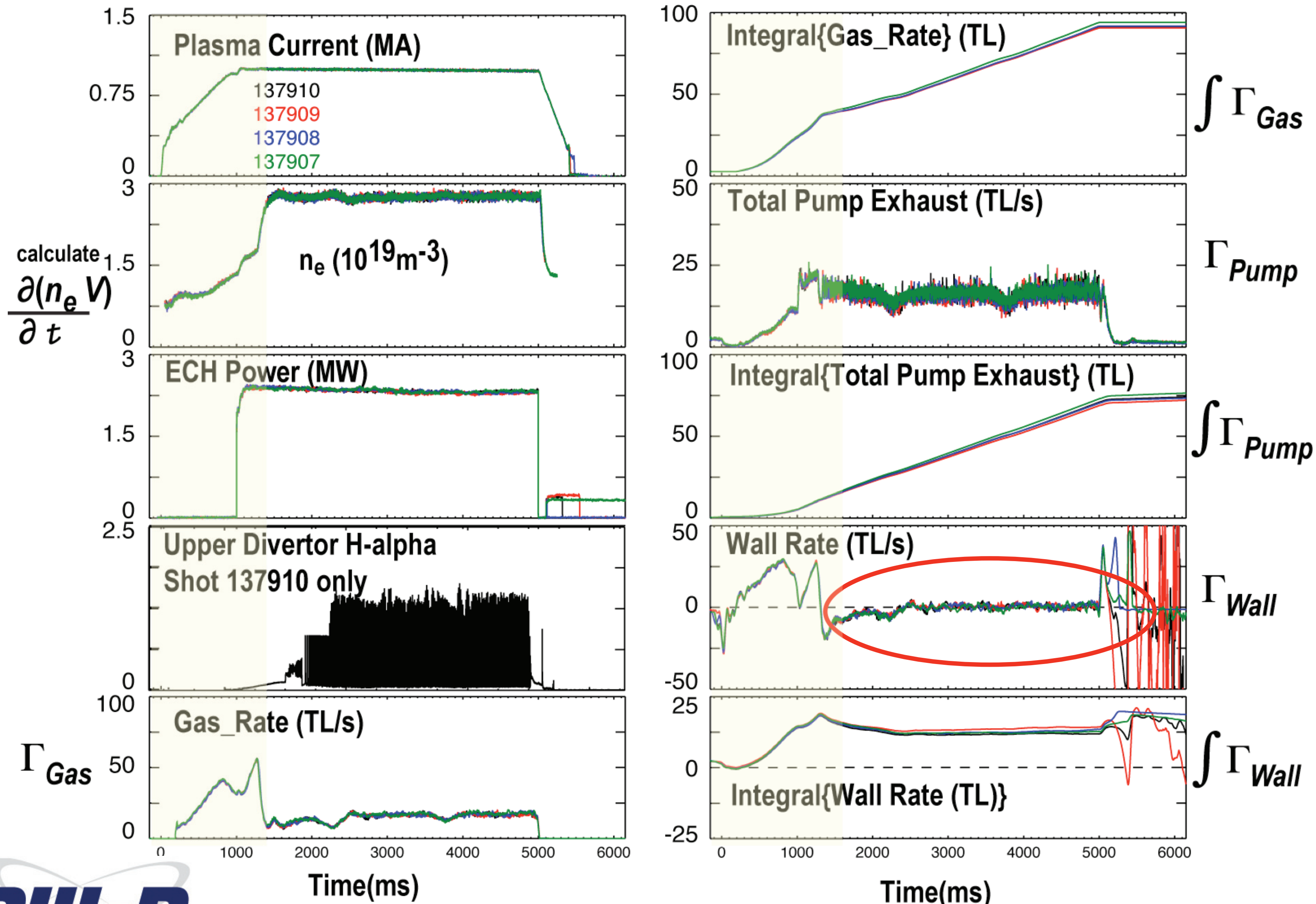

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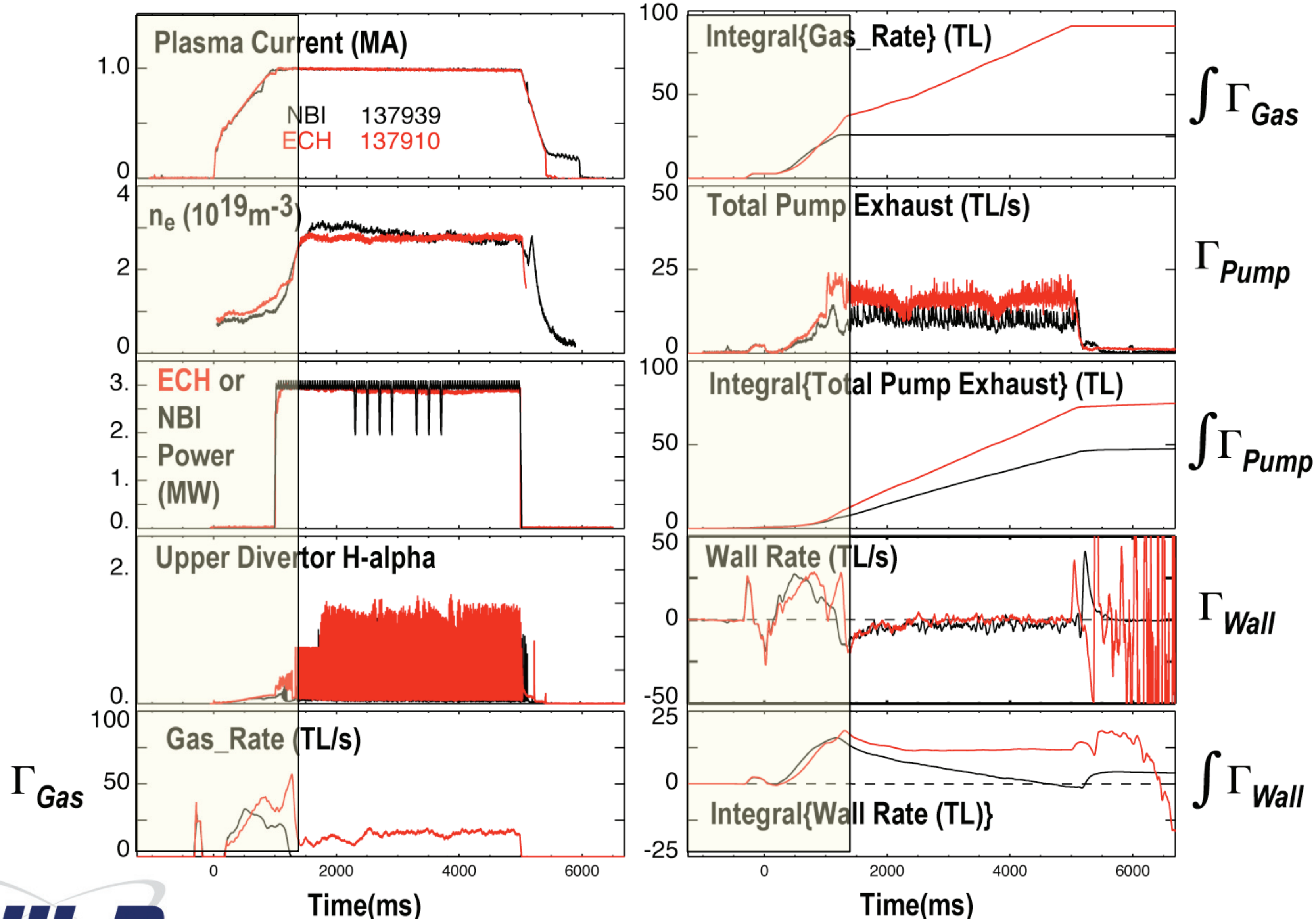
ECH H-mode (Red) Compared with NBI (Black)



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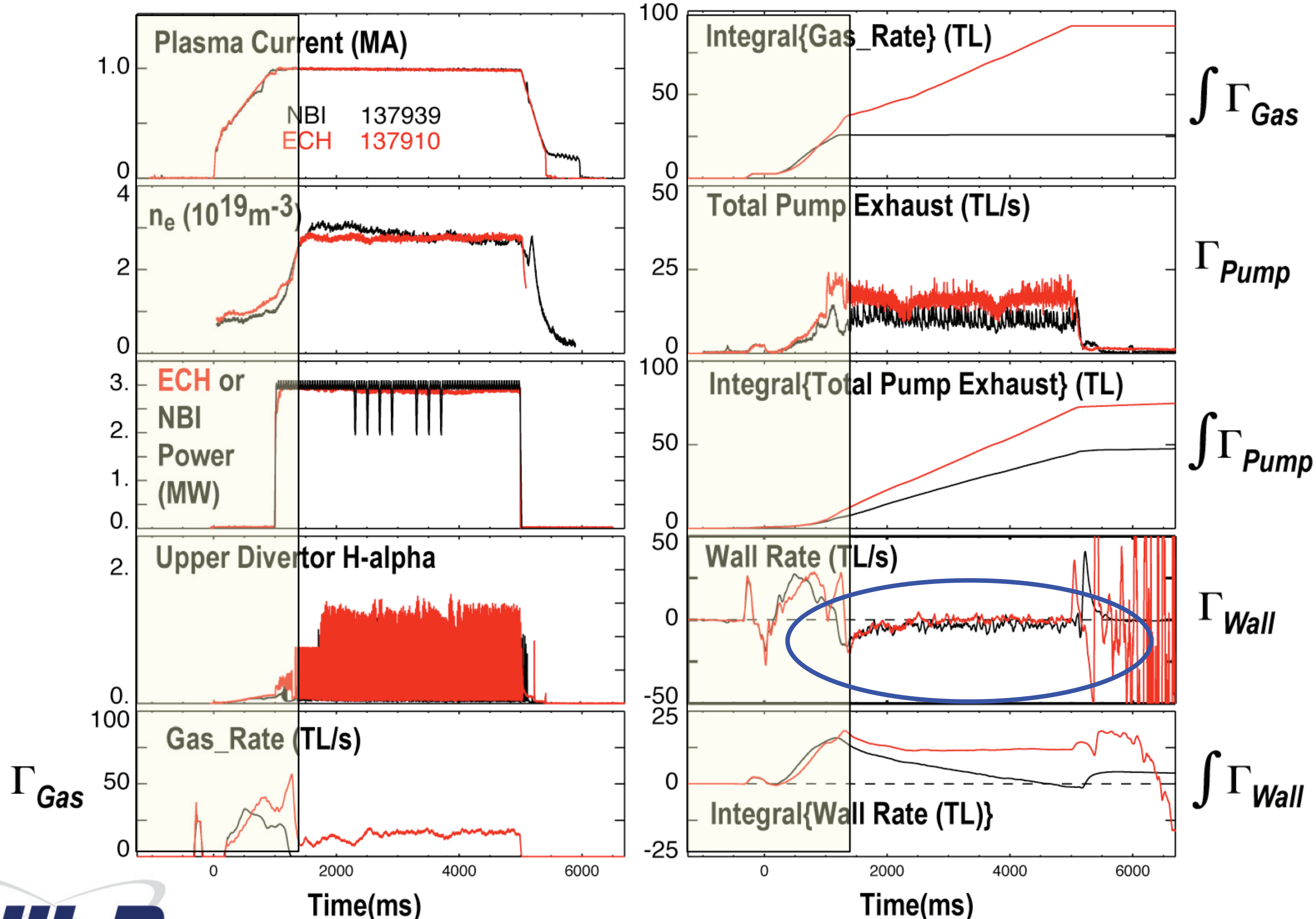

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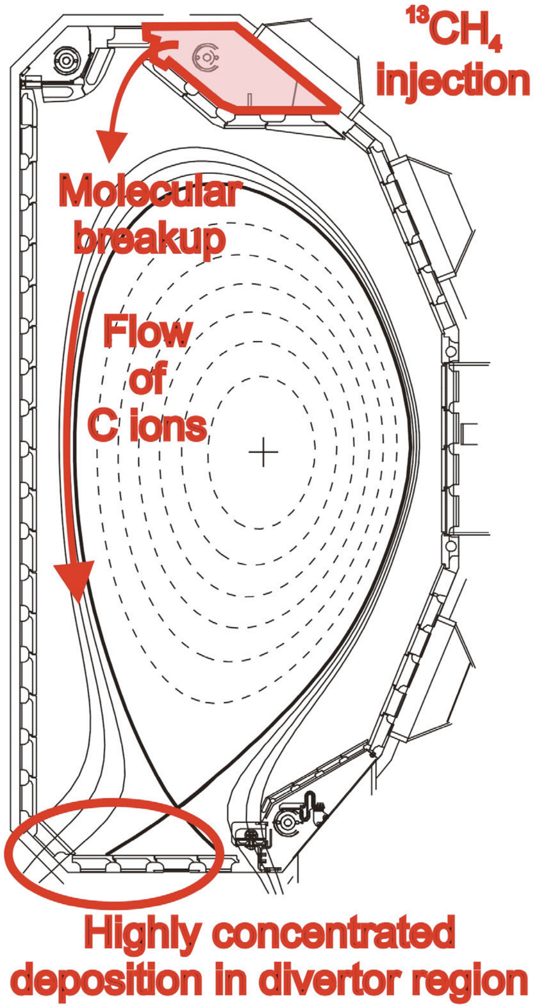
Topic 3: Injected ^{13}C Concentrated at Inner Divertor



- Injection of $^{13}CH_4$ in toroidally symmetric upper pumping plenum
- 10-15 repeat shots to establish pattern
- Experiment completed at end of campaign
- Tiles removed and analyzed by Sandia & MIT

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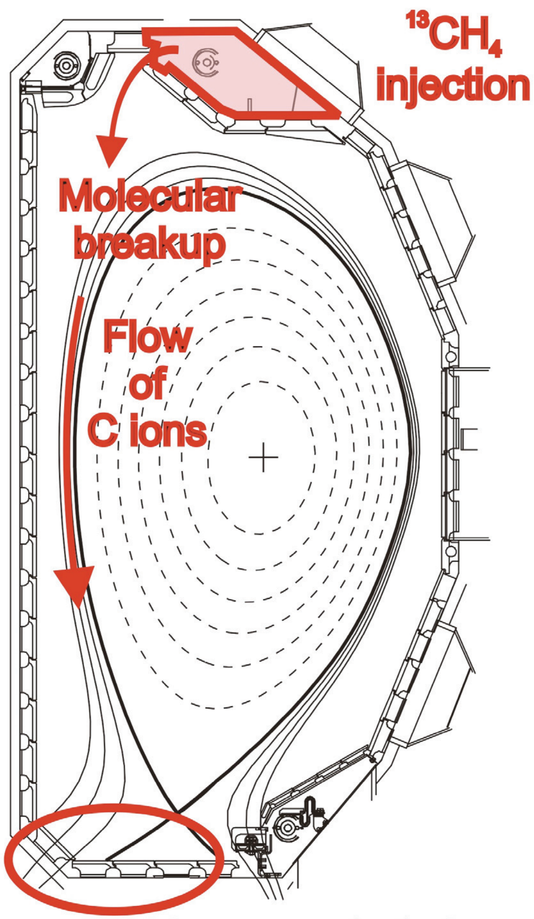
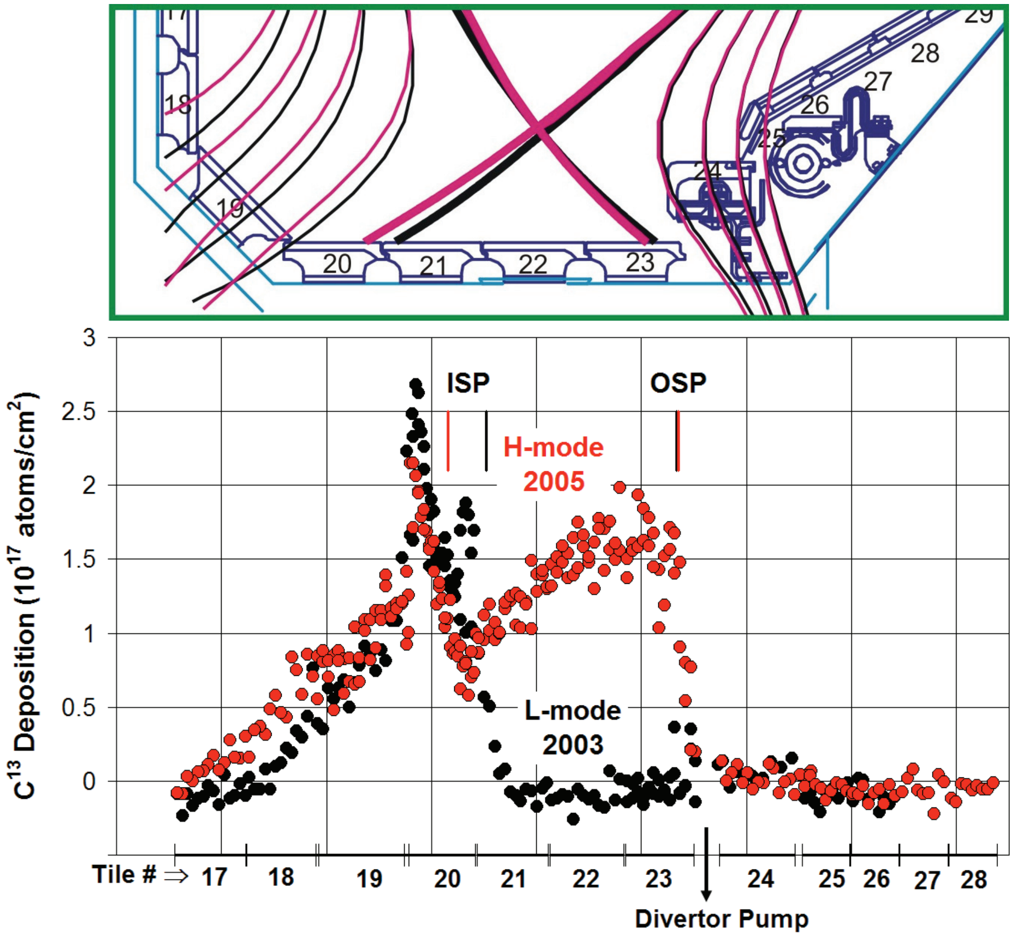


$^{13}C(^{3}He,p)^{15}N$ nuclear reaction analysis
W.R. Wampler, Sandia National Laboratories



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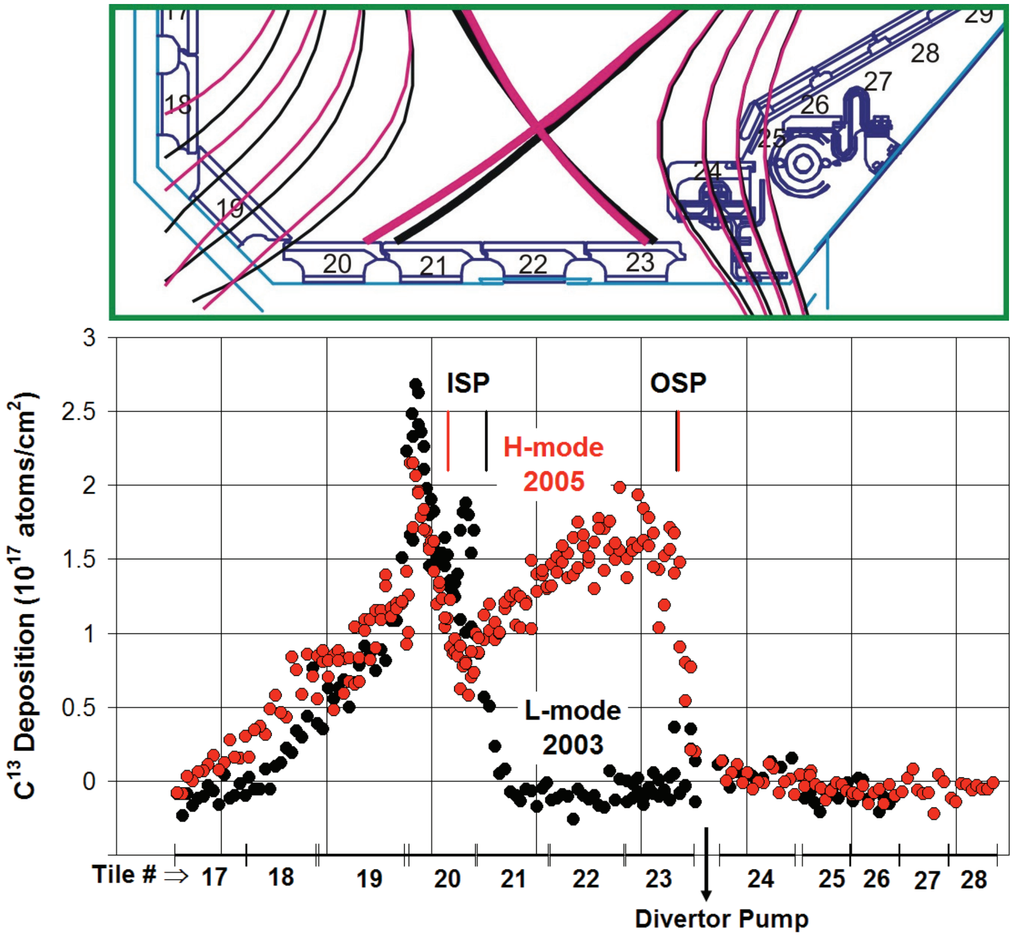
Topic 3: Injected ^{13}C concentrated @ inner divertor

$^{13}C(^{3}He,p)^{15}N$ nuclear reaction analysis
W.R. Wampler, Sandia National Laboratories

- Concentation at inner divertor
- ELMs "fill in" private flux region
- Spectroscopy suggests SOL flow



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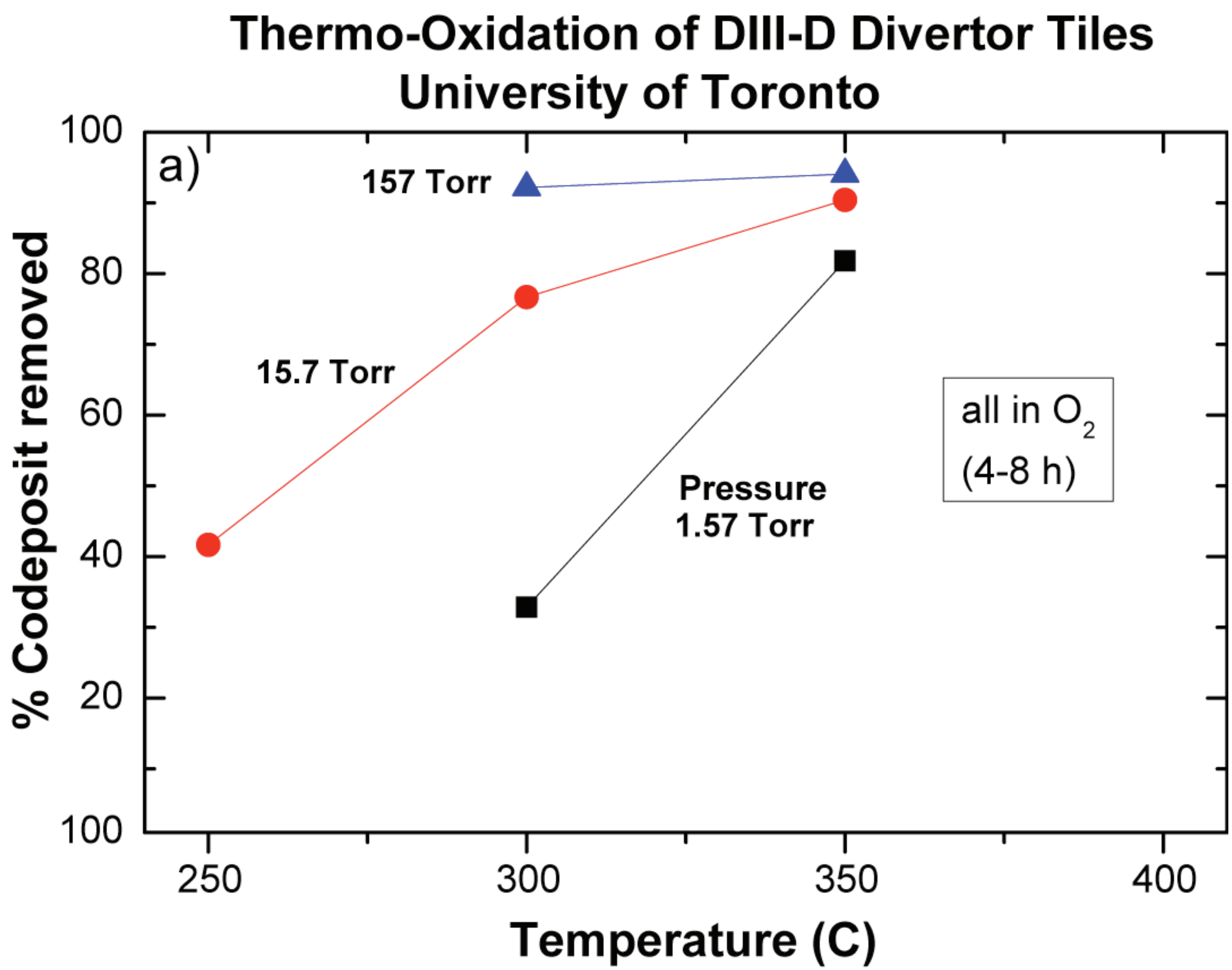
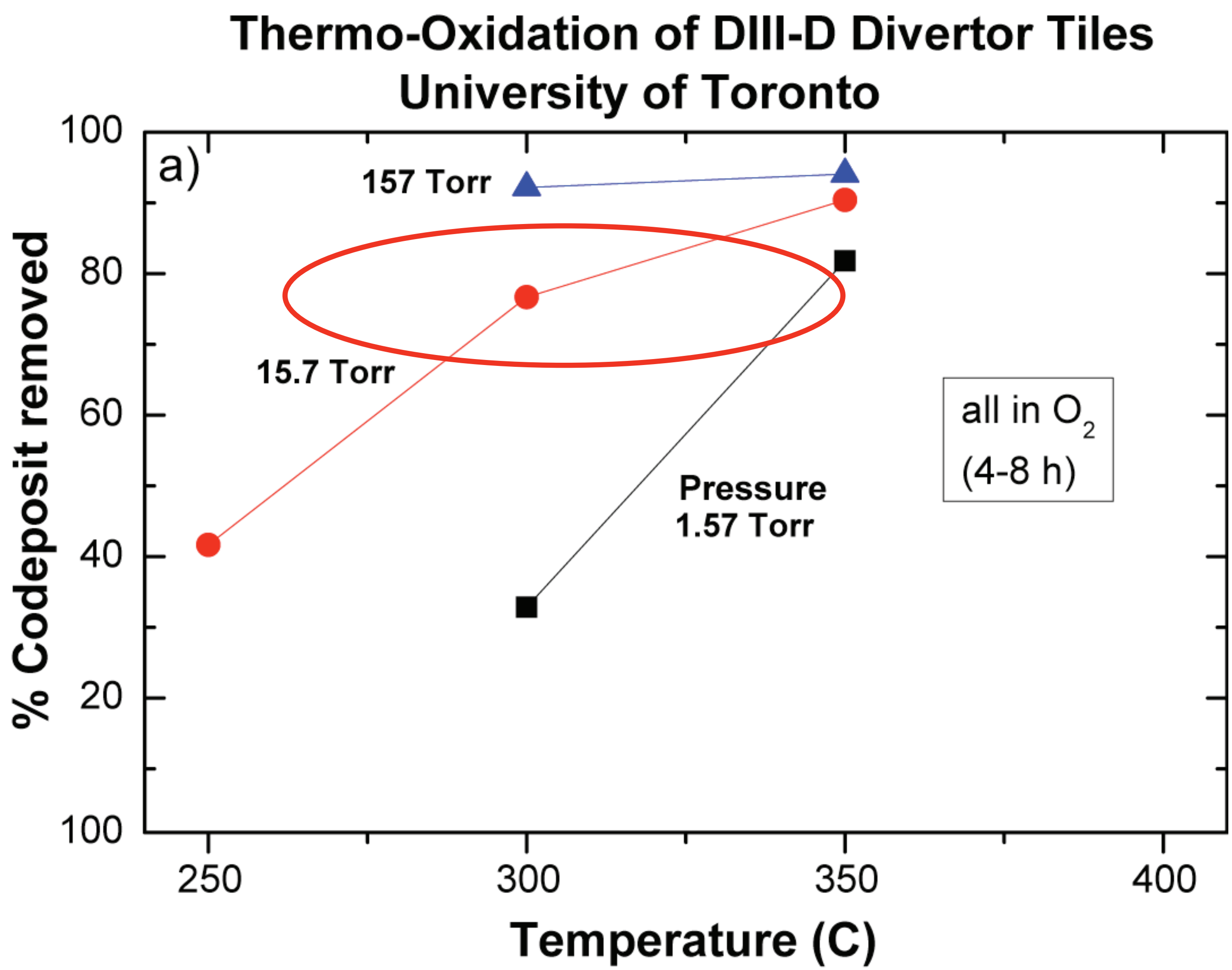
Topic 4: Air Bake Removes *DEPOSITED* Carbon

- Toronto test chamber
- DIII-D tiles
- Pressure & Temperature Important
- AIR is OK



Topic 4: Air Bake Removes *DEPOSITED* Carbon

- Toronto test chamber
- DIII-D tiles
- Pressure & Temperature Important
- AIR is OK
- DIII-D:
  - 10 Torr
  - 250 & 350 C
  - 2 hours



Tests for "Collateral Damage" – Toronto & DIII-D

LLNL Air Bake Chamber at DIII-D

- **Most components OK**
- **Copper components need careful testing**
  - Cryopump OK
  - Remove one Fast Wave Antenna
- **DIII-D Operations reviews in progress**
- **Possible test in April 2010**
- **Will measure removal of ^{13}C layers deposited at end of campaign**
- **Attempt plasma operations after Air Bake**

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Outline of talk: 4 main points

1. **Two different particle balance techniques yield same results**
   - Static (pressure rise after shot)
   - Dynamic (calculated during shot)
2. **Static $\Gamma_{wall}/ \Gamma_{gas}$ ~ 20% has 2 parts:**
   - Significant wall uptake during plasma startup
   - Nearly zero uptake in H-mode
   - Important to minimize duration of startup
3. **Injected ^{13}C concentrated inner strike point**
4. **Preparations progressing for DIII-D Air Bake to test codeposit removal**

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