Edge Current Dynamics during ELMs

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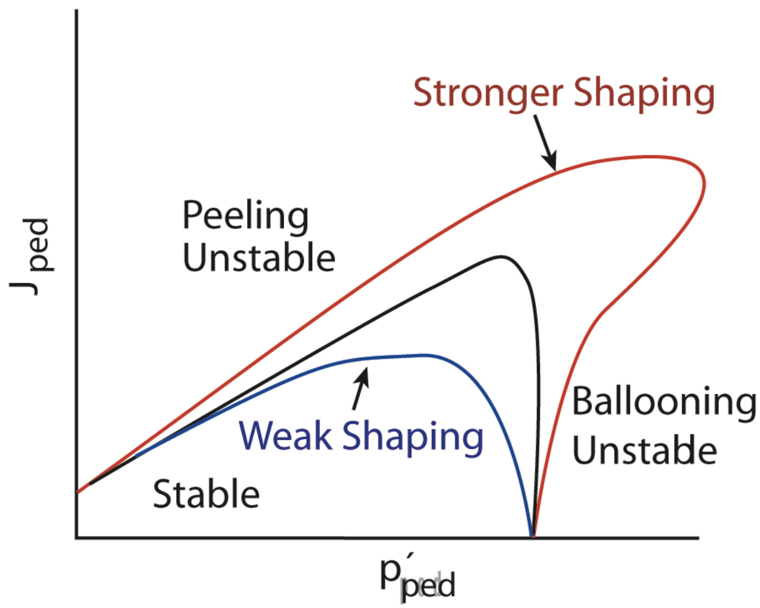
GENERAL ATOMICS

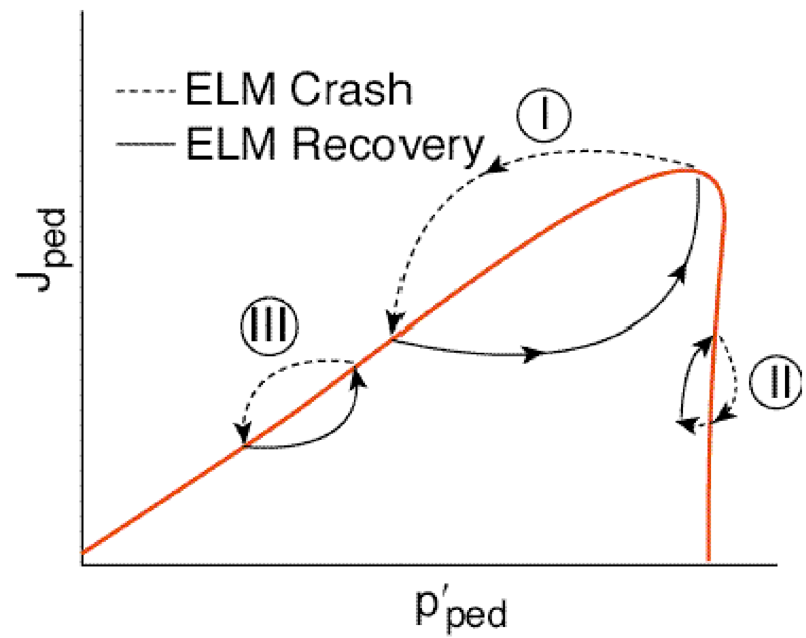
Overview

- **The edge current is an important component of the ELM cycle, but difficult to measure.**
- **We have made measurements of edge B_θ and p_e during Type 1 ELMing, high pedestal discharges on DIII-D (LIBEAM and TS)**
  - Used conditional averaging over multiple ELMs to improve measurement resolution enough to examine different phases of the ELM cycle
  - At the limit of present diagnostic capability for LIBEAM
- **Compare gradients in pressure and poloidal field**
- **See decoupling between current (~ ∇B_θ) and ∇p.**
- **Limitations and prospects**

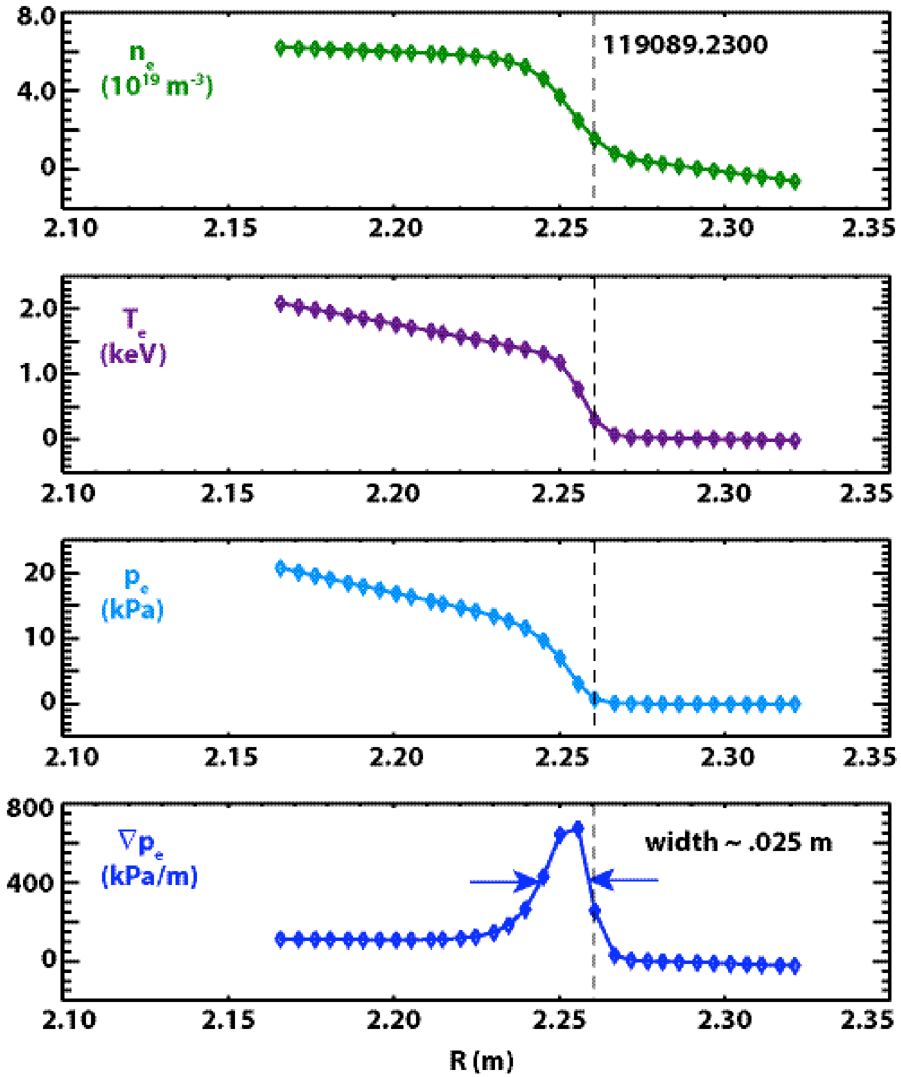
Theoretical picture of ELMs

- Pedestal limit set by coupled peeling/ballooning MHD modes
- Max achievable pedestal pressure is a strong function of shaping
- ELMs represented by various limit cycles in { j, ∇p } space
- Our interest here: can we see these limit cycles evolve experimentally? -- Start with TS & LIBEAM data



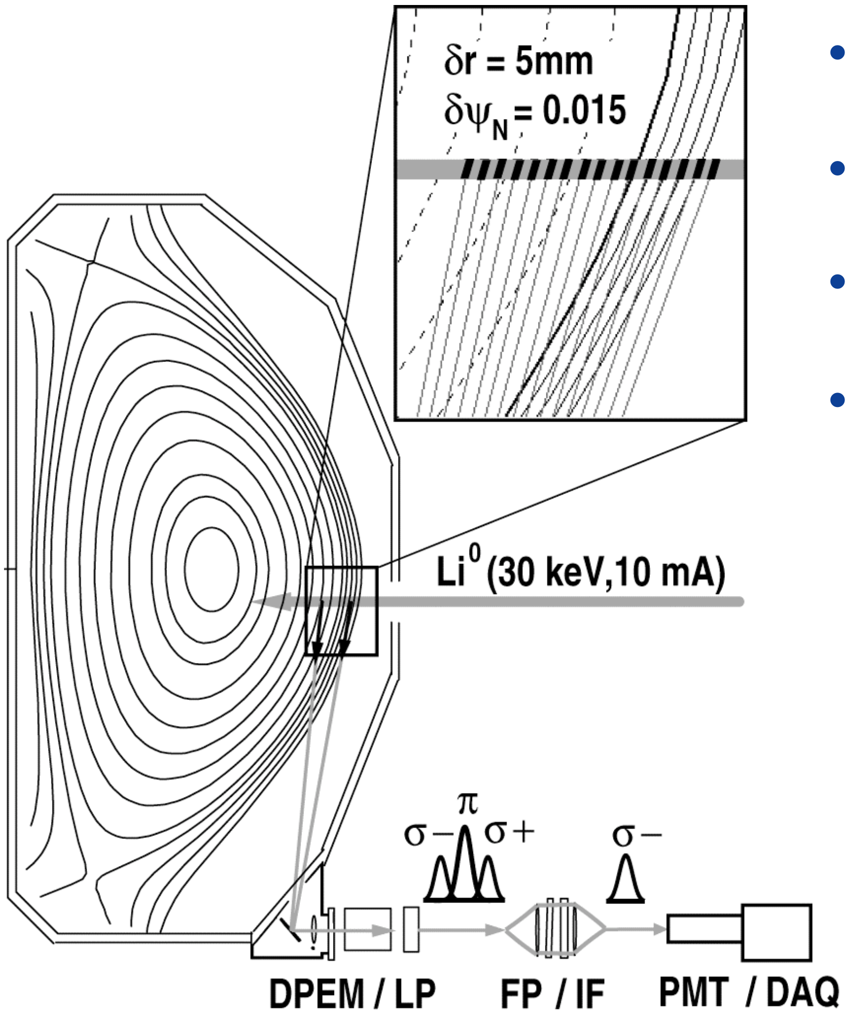


Thomson scattering gives { ∇p_e, Δp_e } in midplane



- The density and temperature fits are mapped to current density measurement location just below the midplane
- Multiply to get P_e
- The radial derivative yields ∇P_e
- The width of the steep gradient region ΔP_e is also calculated
- Data point every 12.5 ms

We measure edge B_{POL} using LIBEAM polarimeter



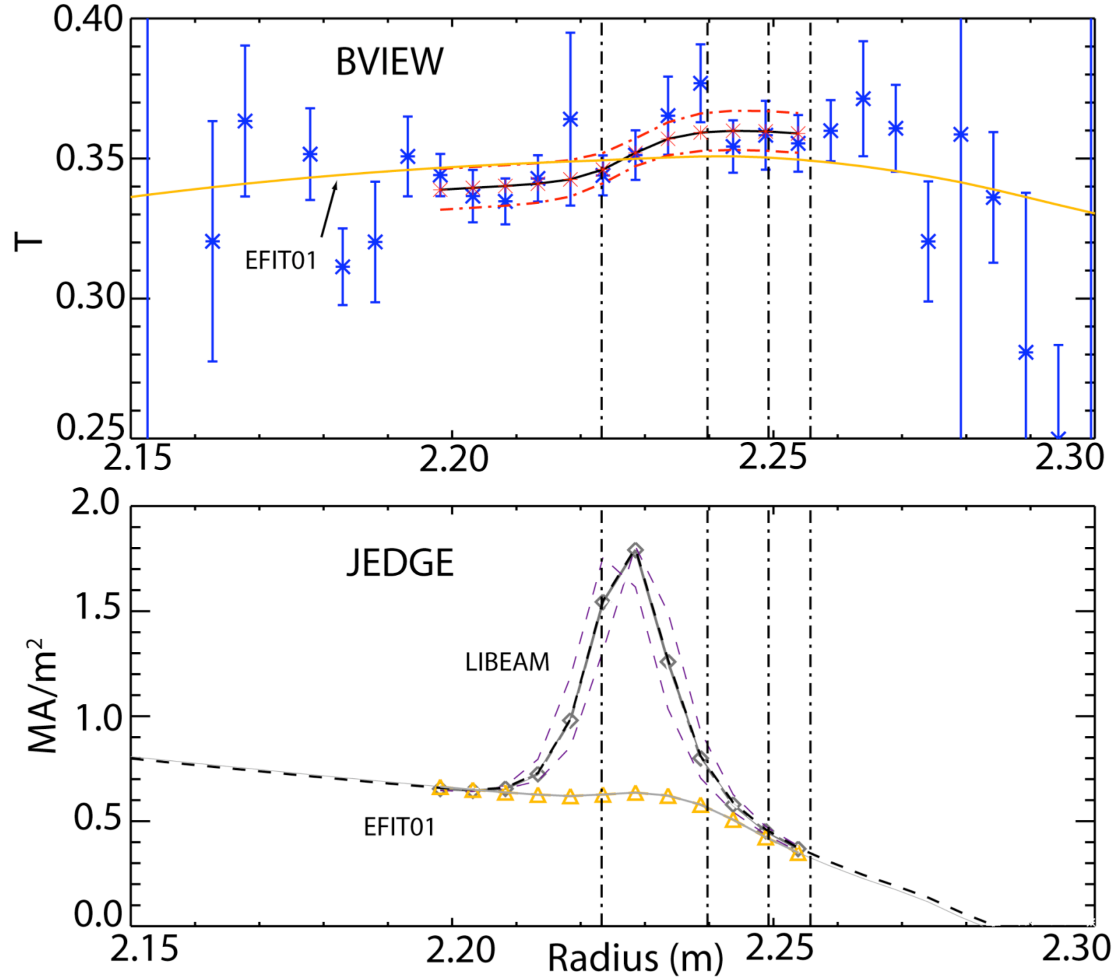
- **Good tangency to flux surfaces for wide variety of discharges**
- **This resolution is required by need to identify localized structure in B_{POL}**
- **Select the σ– line with narrowband filter**
- **Measure ratio of CP to LP using dynamic polarimetry to identify field component along viewchord B_{VIEW}:**
  (D.M.Thomas, RSI 74,3, 1541 (2003).

$$B_{VIEW}(R,z) = |B| \cos(\alpha)$$

1) **Use as EFIT constraint**
2) **Solve directly using Ampere's Law:**

$$\mu_0 j_{TOR} = \frac{\partial B_R}{\partial z} - \frac{\partial B_z}{\partial R} = F\left(B_{VIEW}, \frac{\partial B_{VIEW}}{\partial R}\right)$$

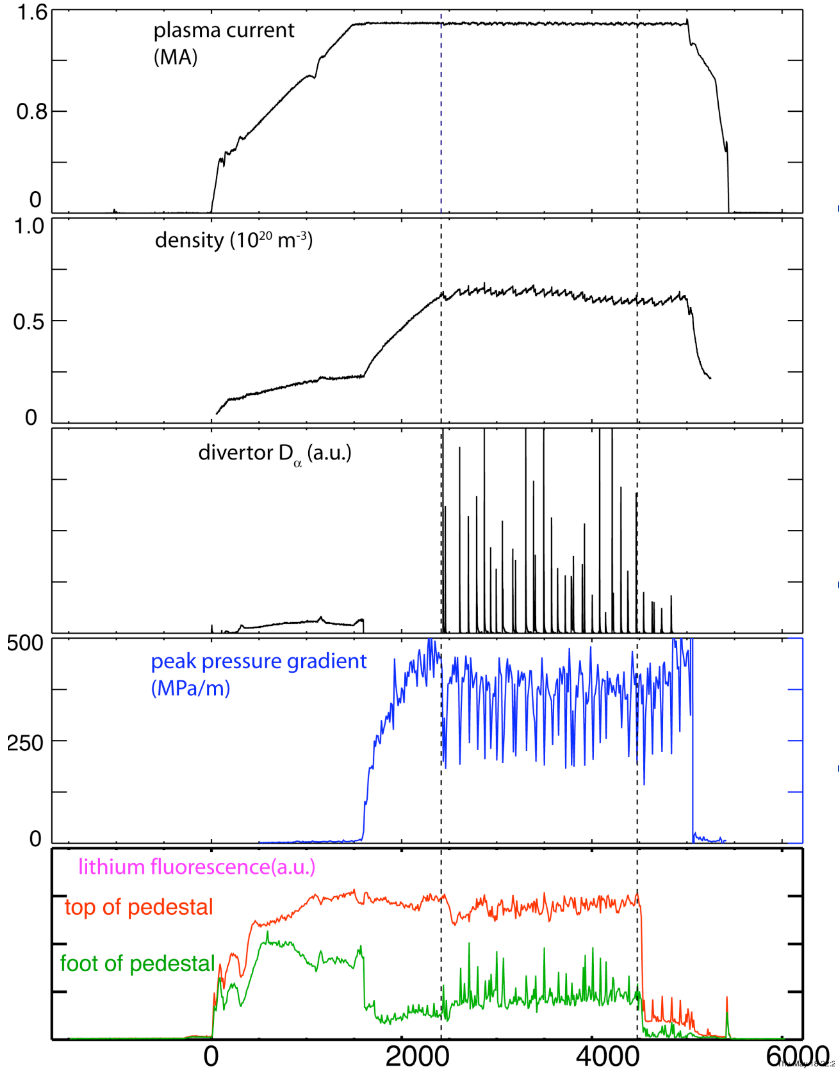
LIBEAM gives high resolution radial profile of B_{POL}



- **B_{POL} ~ B_{VIEW}, the component along viewchord.**
- **Profile can be used to determine toroidal current $j\phi$**
- **Small signal levels + correction of systematic effects limits time resolution.**

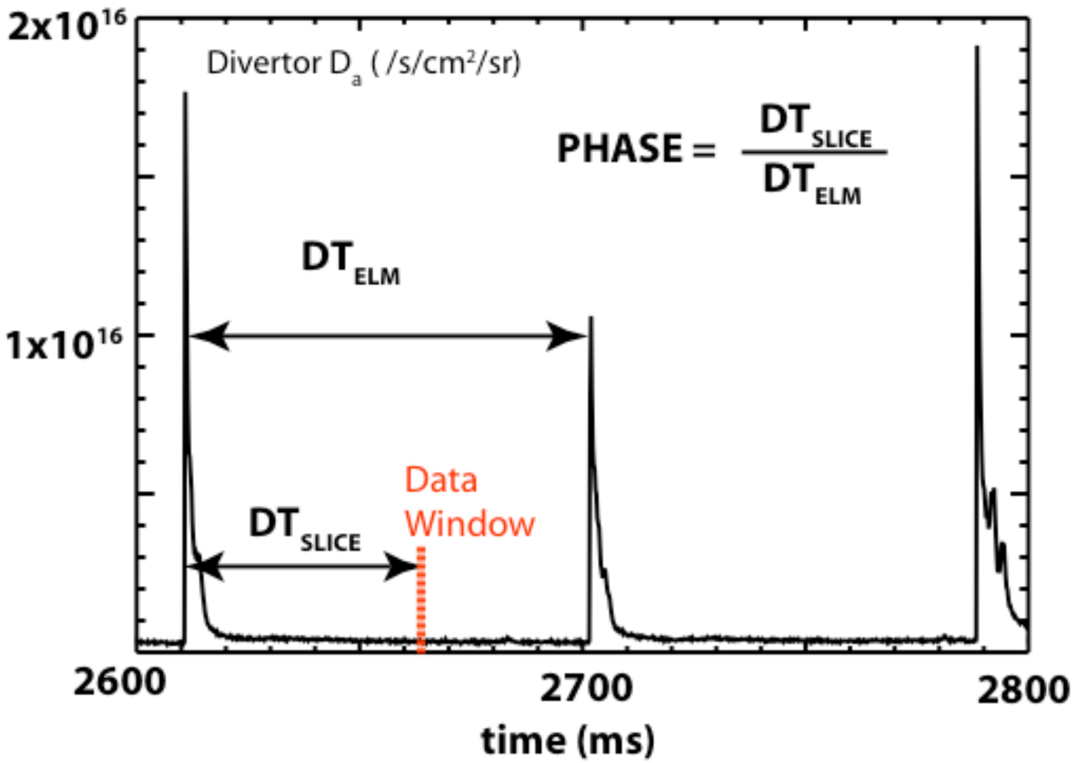
- **This work: push limits of digital lock-in, do multiple ELMs**

Pressure and poloidal field data are analyzed during ELMing phase of shot



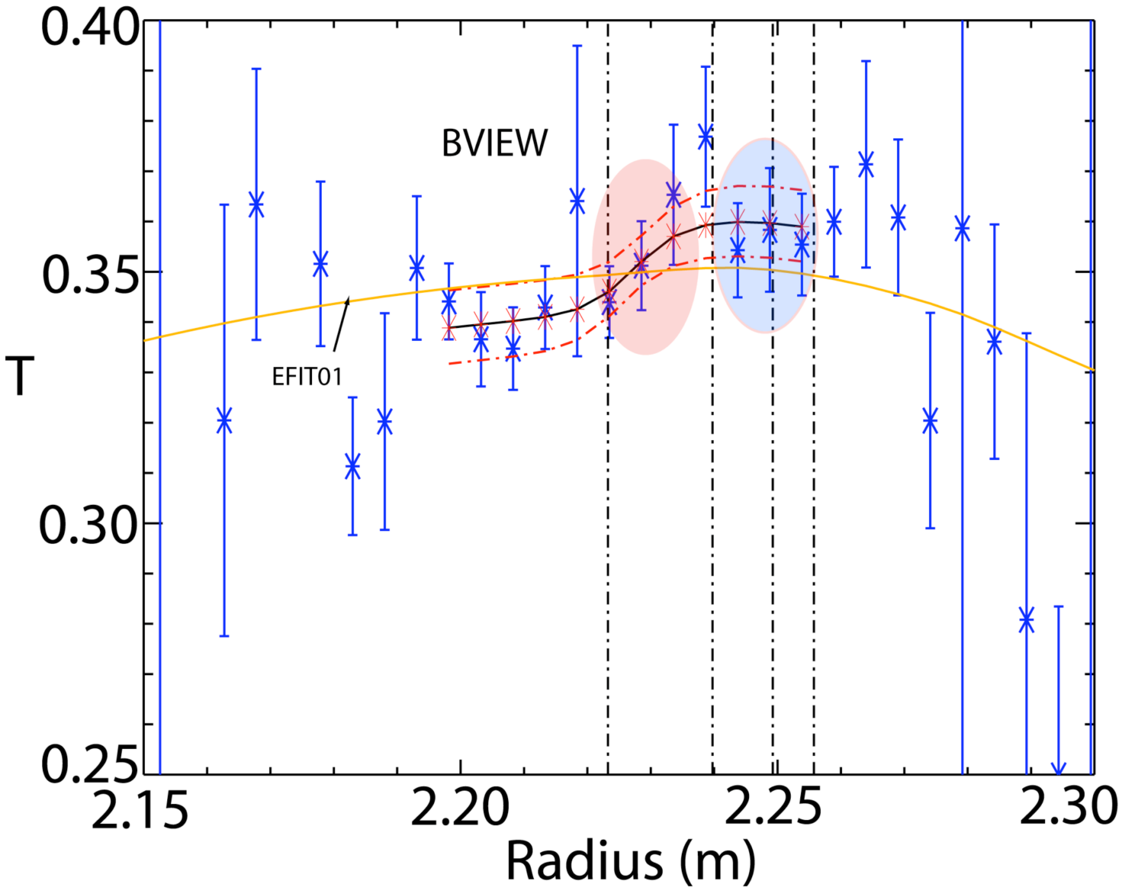
- Examine period from beginning of Type 1 ELMs until termination of lithium beam injection.
- Data for this particular shot covers 26 ELM cycles.
- T_{ELM} varies from 50-150 ms.

ELM analysis - conditional averaging



- **Use multiple ELMs to improve signal-to noise**
- **Poloidal field analysis is done over many short time periods**
  δt_{LOCKIN} ~ 0.5 - 2.0 ms,
  dt_{AVG} ~ 3 - 5 ms
  Δt_{ELM} ~ 50 - 150 ms
- **Bin data according to phase of cycle**

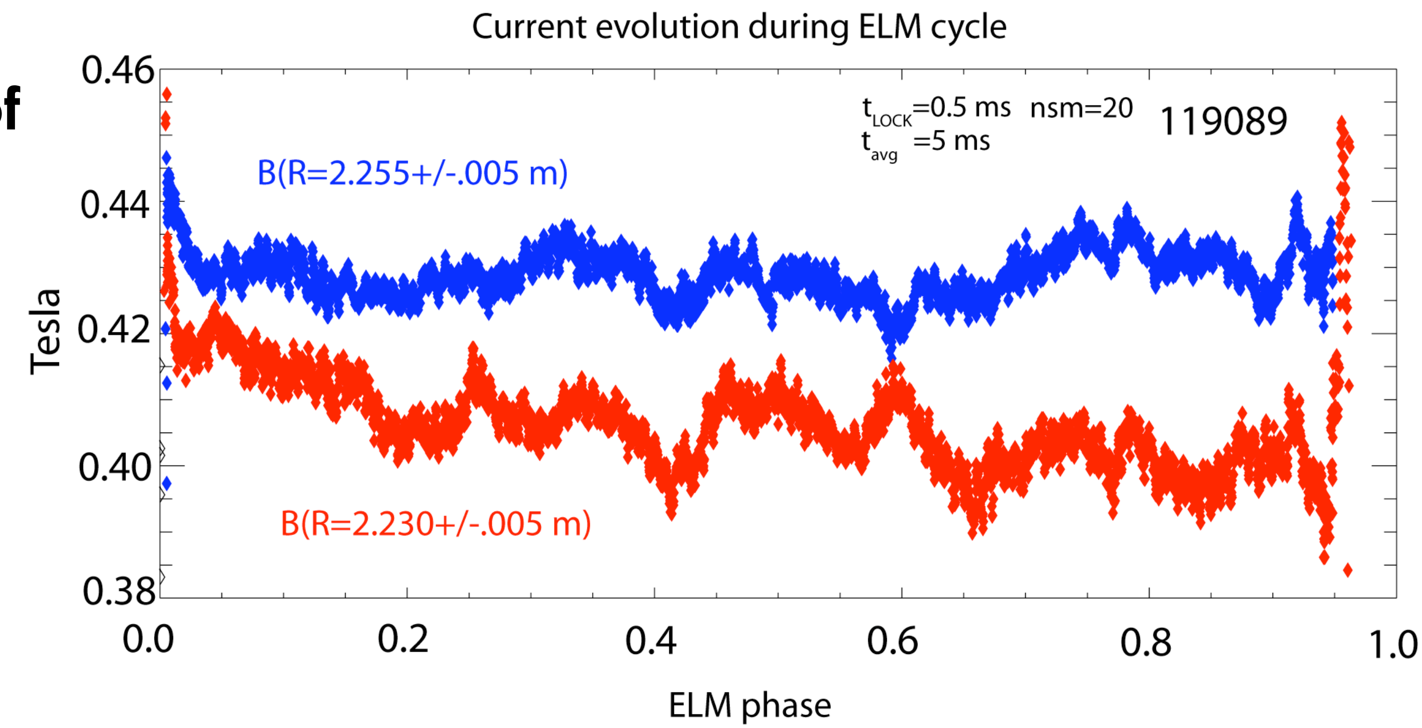
First step: look at difference in poloidal field vs time



- Evaluate and sum three channels inside and outside of high pressure gradient region
- Proxy for toroidal current density, since $\nabla B_\theta \sim j_\phi$ (Ampere's Law)
- This approach minimizes the effect of small changes in width on j_ϕ

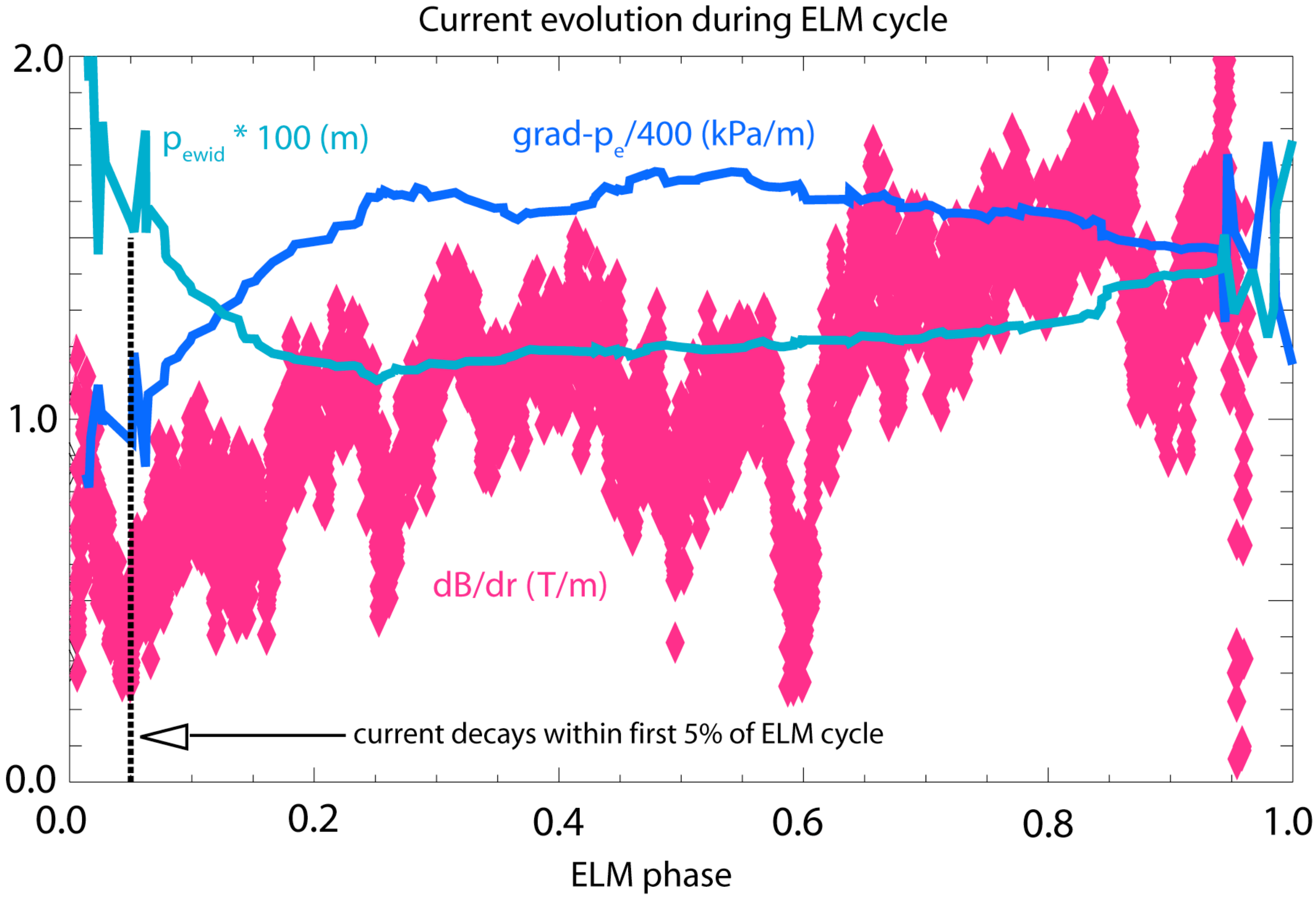
Effect of phase binning (26 cycles)

- **Divergence of curves ==> gradient increases.**
- **indicates growth of current in this region during ELM period.**

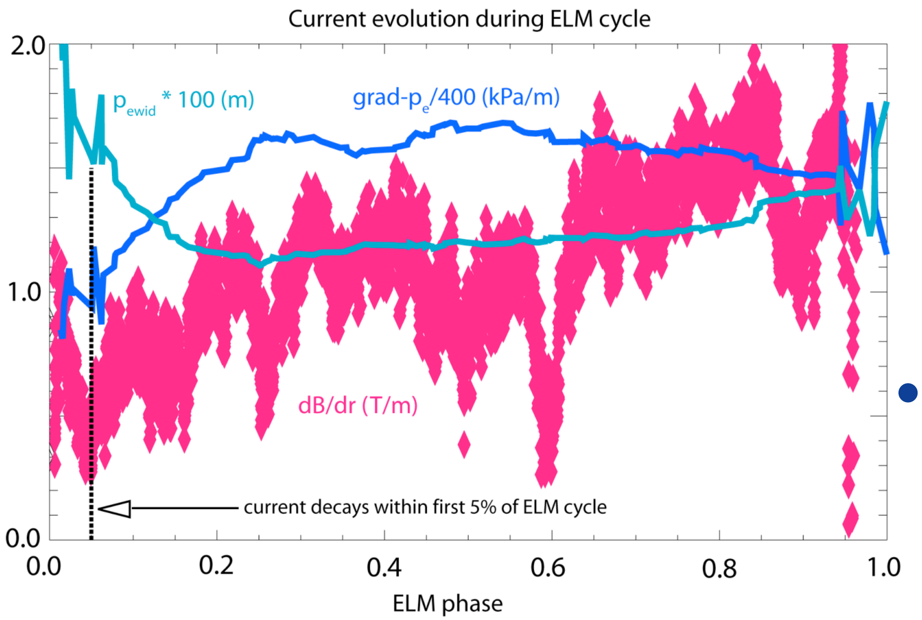


- **Still cannot examine phase of period during or immediately after an ELM because of background light**
  - Sets upper bound on resolving dynamics of j
- **For Thomson Scattering, random nature of laser pulses sets minimum phase resolution for resolving dynamics of ∇p,**

Now, plotting difference reveals temporal behavior for j--can compare with ∇p

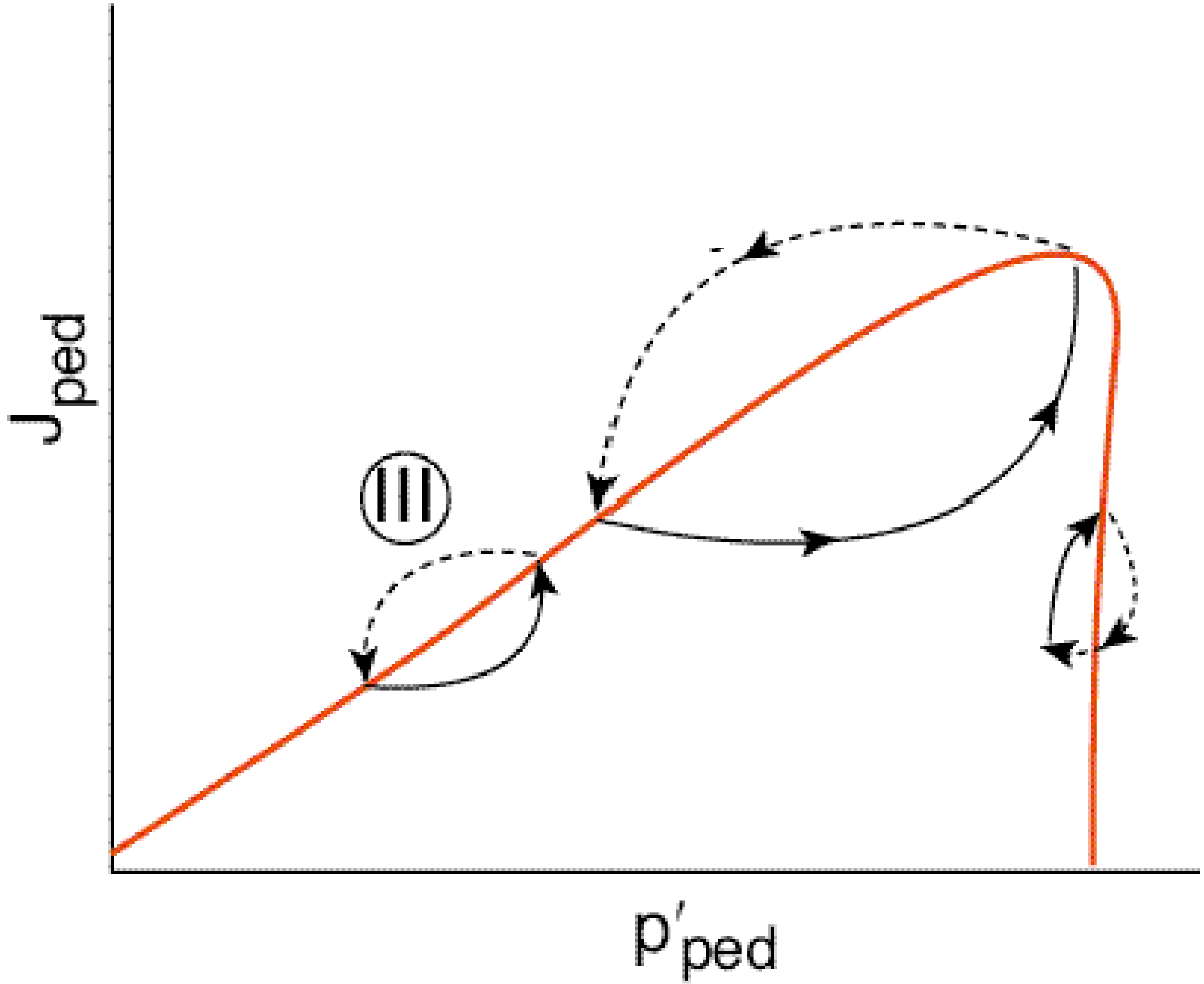


Conclusion: Edge j_ϕ is decoupled from ∇p for most of the ELM cycle



- Edge pressure gradient:
  - Drops rapidly(within ms) to approximately half the pre-ELM value
  - then recovers within ~25% of the ELM cycle.
  - Width shows similar temporal behavior.
- dB/dr ~ Edge current density :
  - Drops rapidly(within few ms)
  - then increases throughout the cycle (even after pressure gradient has saturated)

Experimental behavior consistent with theoretical picture



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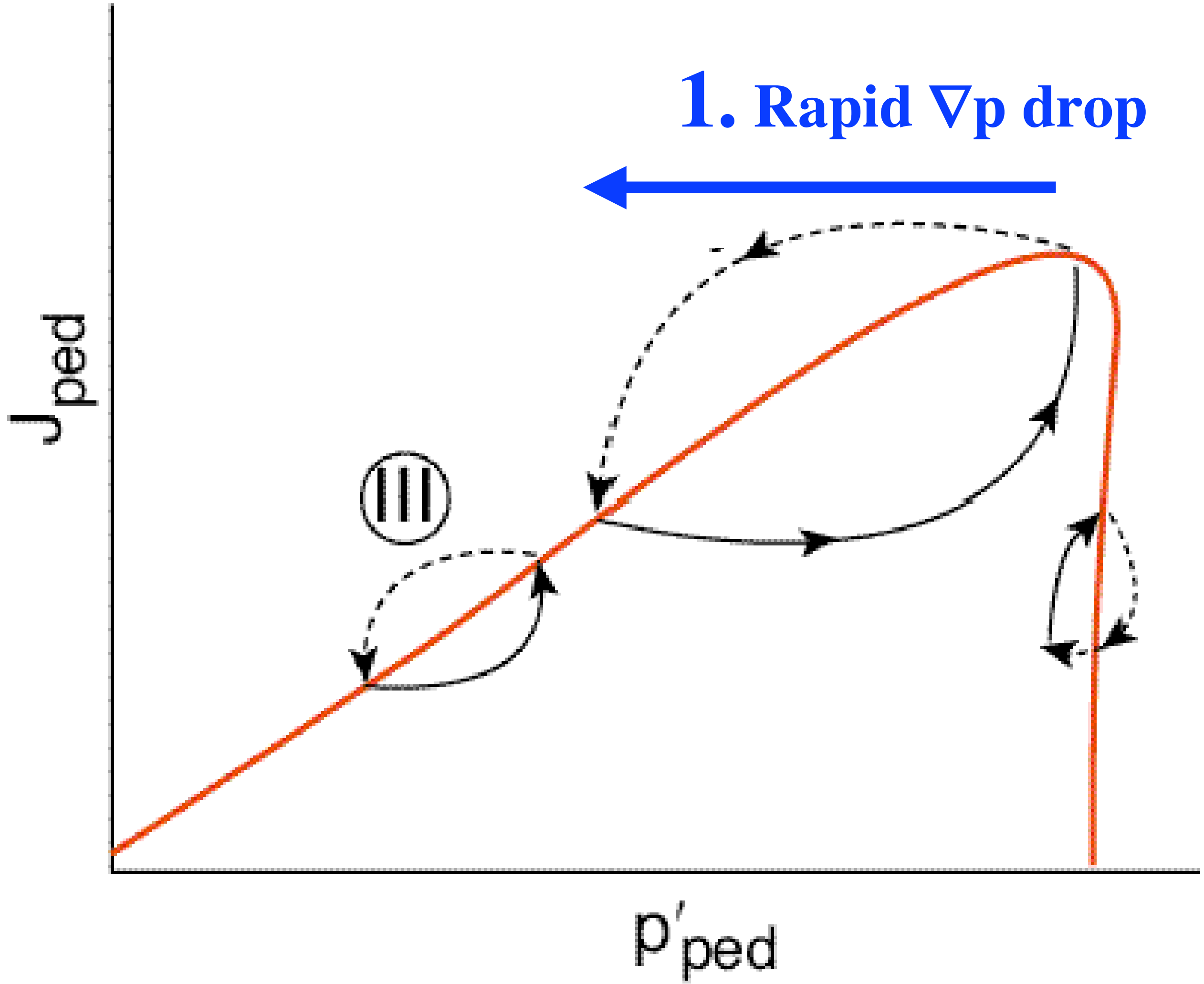

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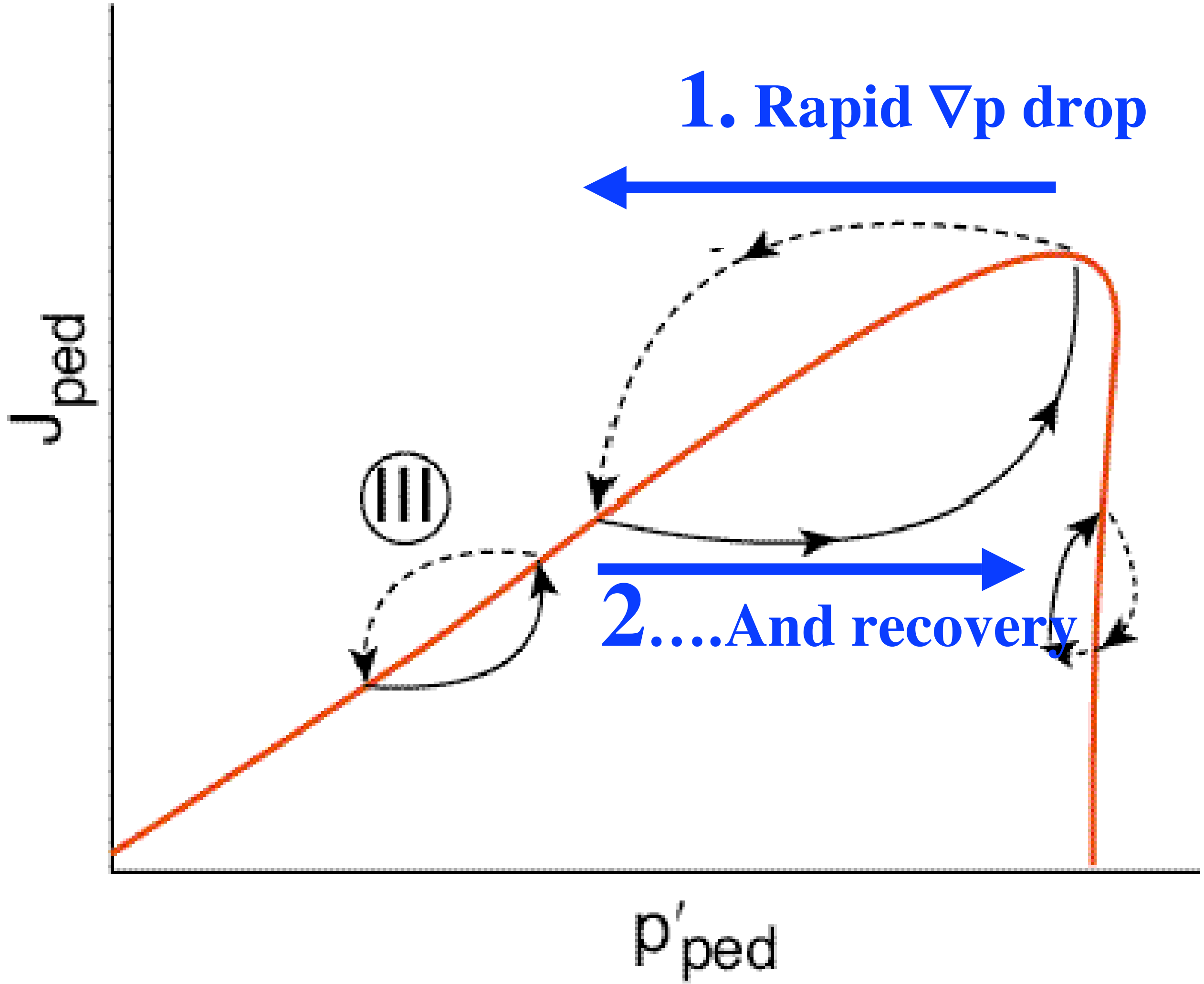

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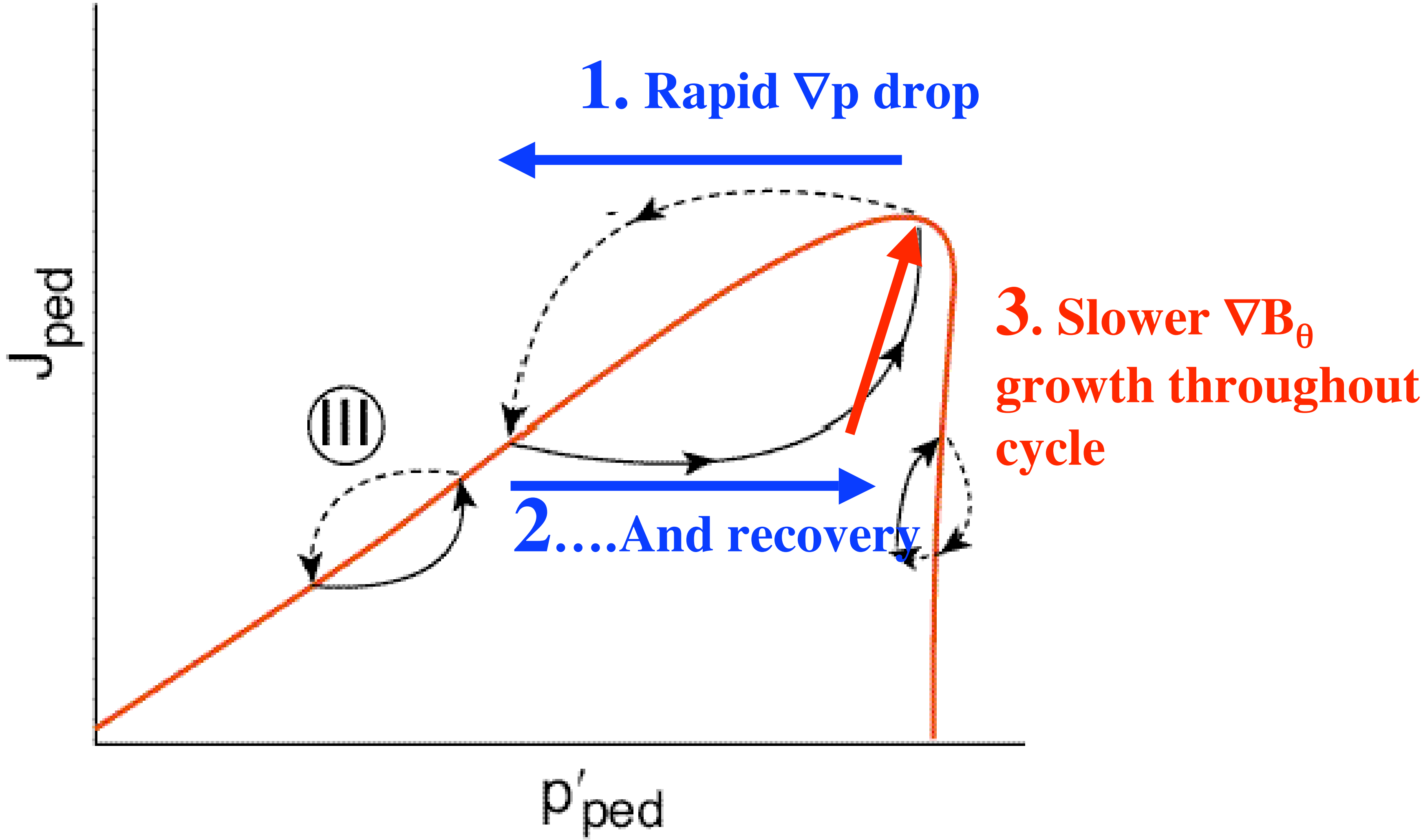
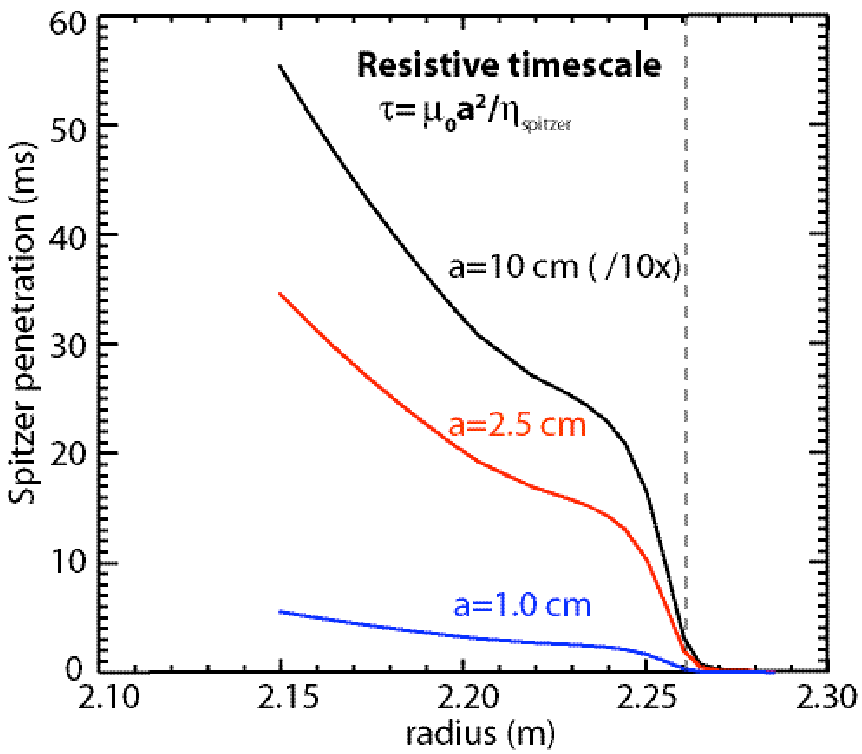


Speculations

- Early current collapse is most likely due to Pfirsch-Schluter current disappearing with collapse of pedestal gradient
- Later slow increase, after pressure gradient has been restored, is probably due to continued growth of j-parallel throughout ELM cycle (but not ∇p term)
- Since it is the current that keeps increasing while the pressure gradient appears to have stalled/saturated, it may be the current that is the actual ELM trigger.
- Why is current evolution so slow?

Resistive timescales vary widely across region of interest, but still too short to explain?



- **Current diffusion time <u>much shorter</u> than measured response on outboard side**
  - (**couple of ms** to diffuse width of gradient region)
- **τ is somewhat higher on inboard side (~10 ms)**
- **Still short compared to measured evolution time for j_{TOR}**

What's next?

- **Near term, this is about as good as it gets.**
  - Rerun experiment with longer ELM periods, multiple shots
  - (Re)process data with multipeaks (FFT/Lockin) analysis.
- **We hope to improve the signal-to noise ratio in the future through:**
  - Detector improvements
  - Current upgrades on beamline (energy and current)
  - Components of OFE diagnostic initiative proposal
- **Suggestions welcome!**