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Disruption prediction and avoidance by plasma state monitoring

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Plasma state estimation

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- RT knowledge of plasma state essential for control & disruption avoidance
  - Present estimation: complicated diagnostics
  - Disruption avoidance: algorithms trained on huge data set
  - Future: limited set of simple diagnostics, no disruption allowed
  - Non-measurable quantities become important (i.e. j_{bs} in advanced regime)
  - New approach to state estimation
- Represented by **RA**pid **P**lasma **T**ransport simulat**OR**: [1]
  - Combination of simple diagnostics and reduced set of transport equations
  - Estimate of plasma state based on diffusion equation of ψ and T_e
  - Basic inputs: n_e, I_p, NBI, EC power
  - State estimate correction by Kalman filter using T_e, (T_i, β_p)
  - Outputs related to $T_e(r)$ or $j(r)$, sawtooth crash period …
- Useful improved control, disruption prediction etc…

Disruption prediction: physical limits

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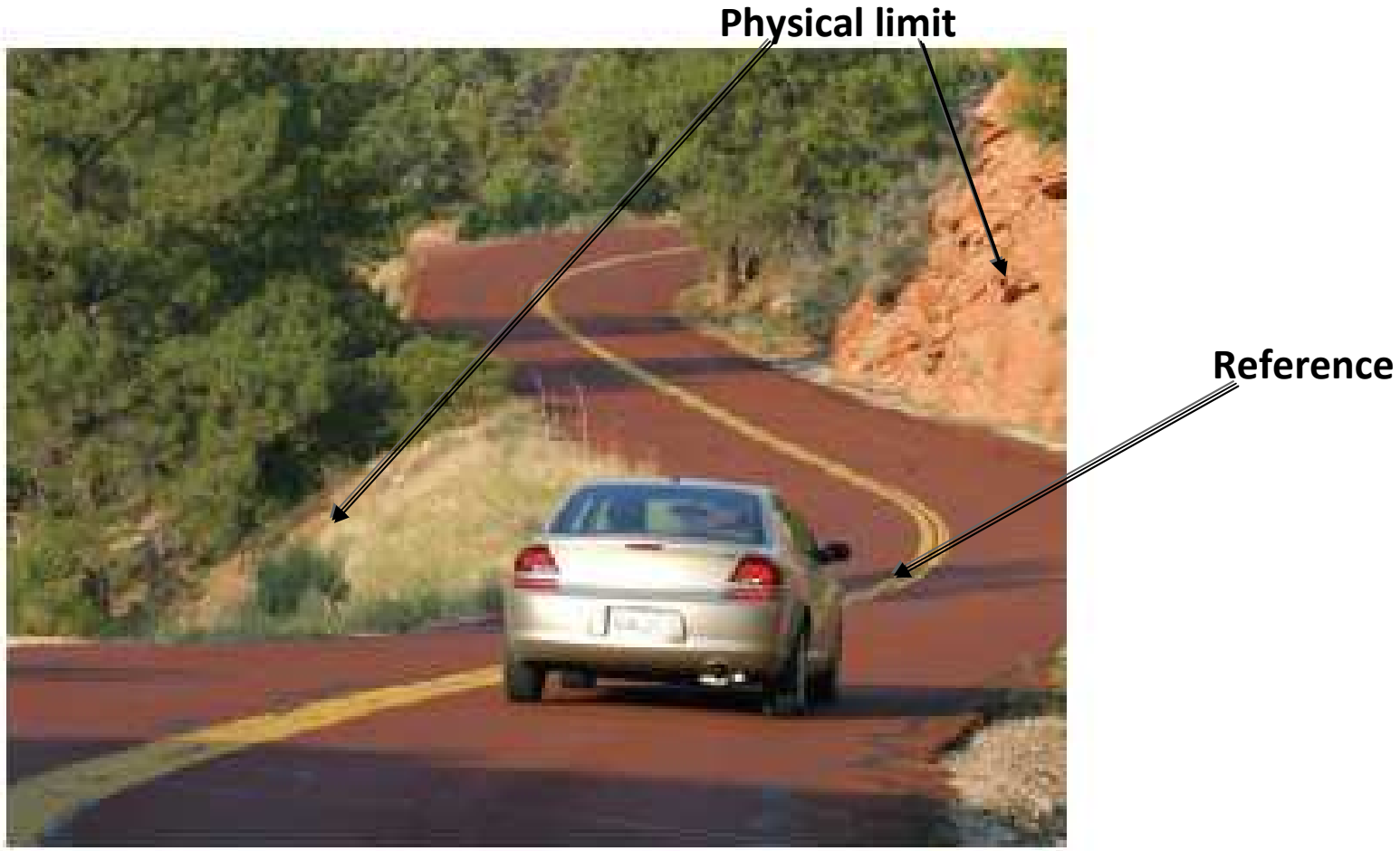
- RT observance of plasma state and comparison with physical limits (q_{95} vs l_i, β_N, n_G)



Disruption prediction: distance from normal state

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- Fog => “physical limits” not obvious, stay close to reference
- Reference state estimated by RAPTOR
- Normal state perturbed before disruption- no information in RAPTOR
- Find a variable that changes a lot before many disruption types

Sawtooth period before disruption

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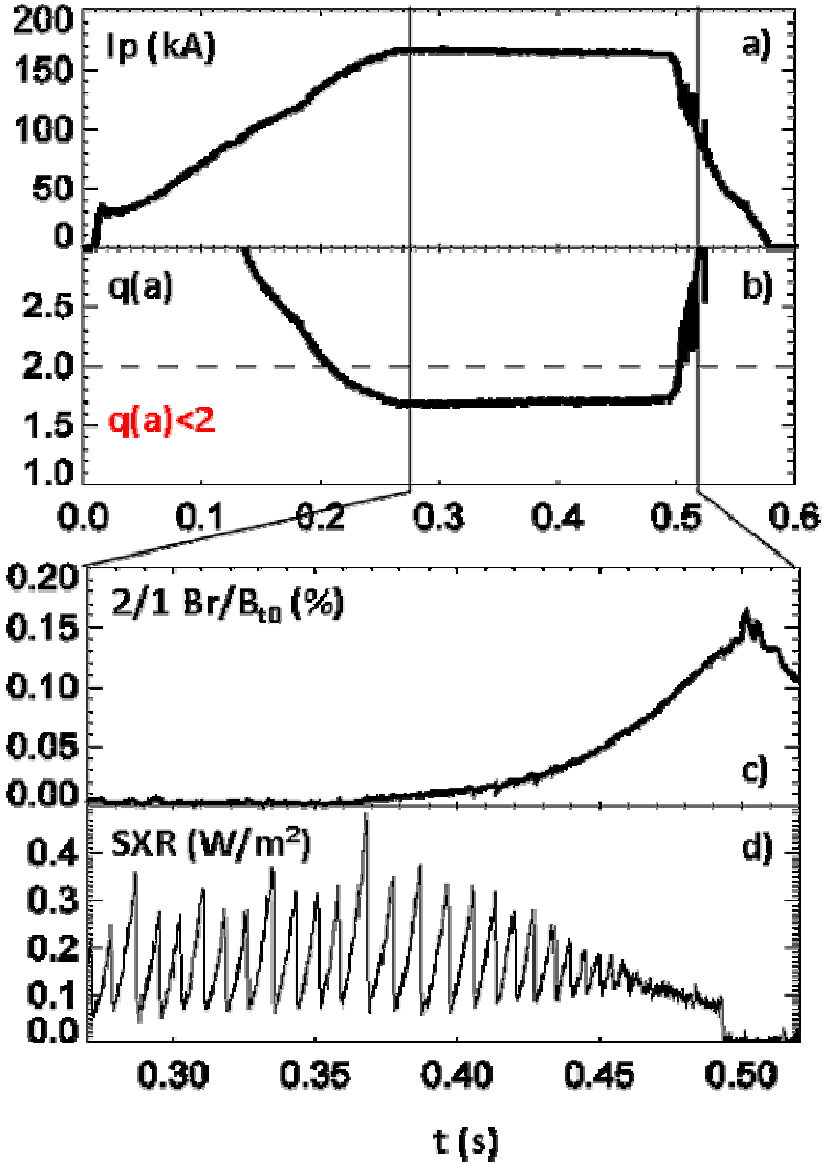
- Normal ST behavior can be modeled by RAPTOR [2]
- Some disruptions preceded by modified ST behavior
  - RWM, LM disruption
  - density limit, impurity accumulation disruption
- Attempt: measure of “distance from reference” using sawtooth period

ST behavior before disruption- RWM, LM

- RFX-mod: discharges with $q_a < 2$ controlled actively
- Control off: 2/1 RWM grows (no information in RAPTOR)
- ST smaller and more frequent, later disappear
- The disappearance is followed by disruption
- Prediction: 20-40 ms before on RFX



AUG: density limit case

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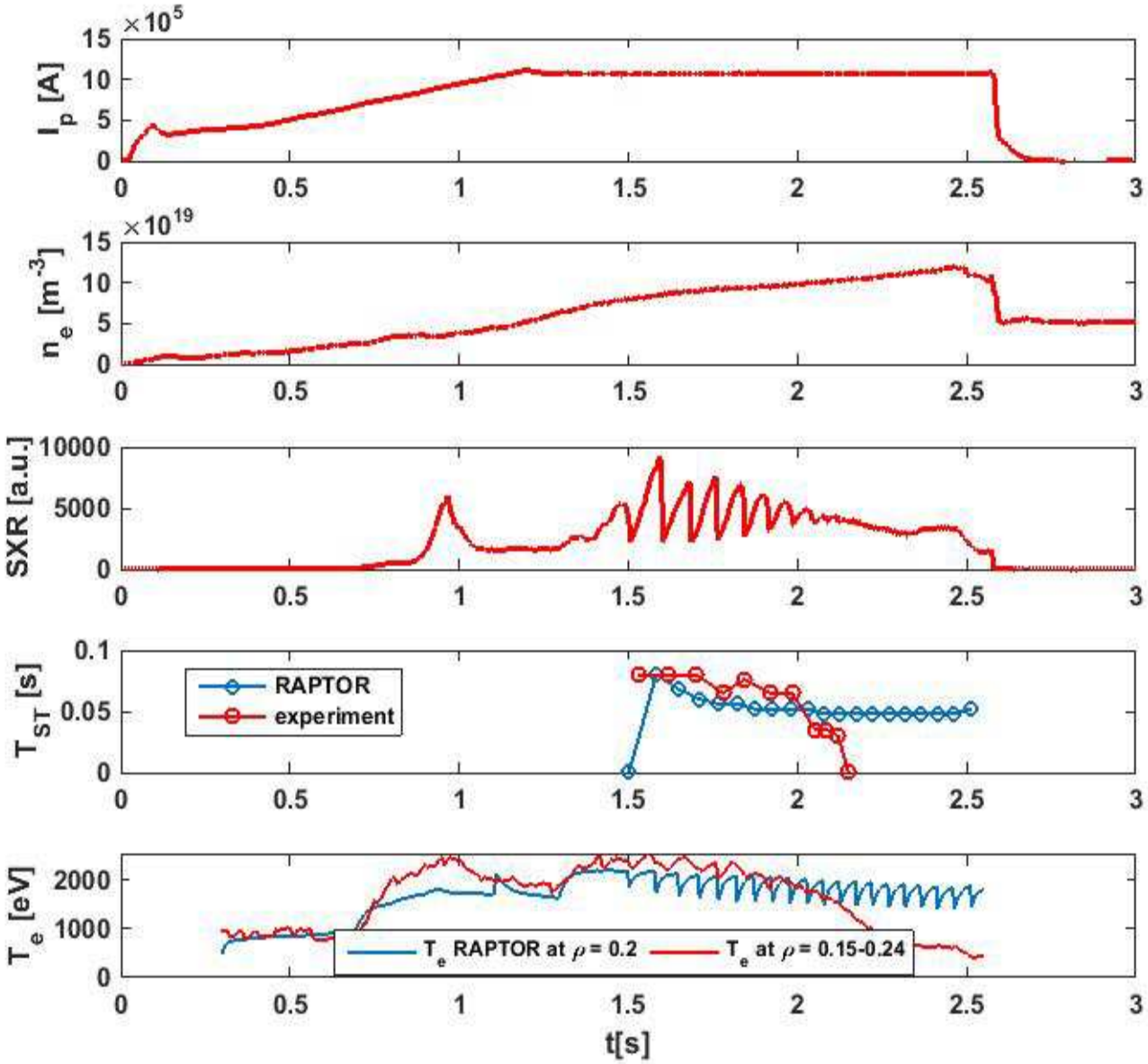
- Density ramp
- NBI on, H-mode
- Similar ST behavior until density reaches certain limit and core radiation increases
- Afterwards, temperature and ST period drop, RAPTOR predicts just low decrease
- Disruption could be predicted on T_e difference



Conclusions & future plans

- Disruption prediction by plasma state monitoring feasible on RFX
- AUG: promising results, but some RAPTOR improvements needed
- IC heating
- Population of fast ions estimate

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References

[1] F. Felici at al, NF 2011

[2] C. Piron, PhD thesis, 2015, Universita degli Studi di Padova