PSFC

CHALMERS

Using SOFT and CODE to study spatiotemporal dynamics of runaway electrons in Alcator C-Mod

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Runaway Electron Meeting, Prague

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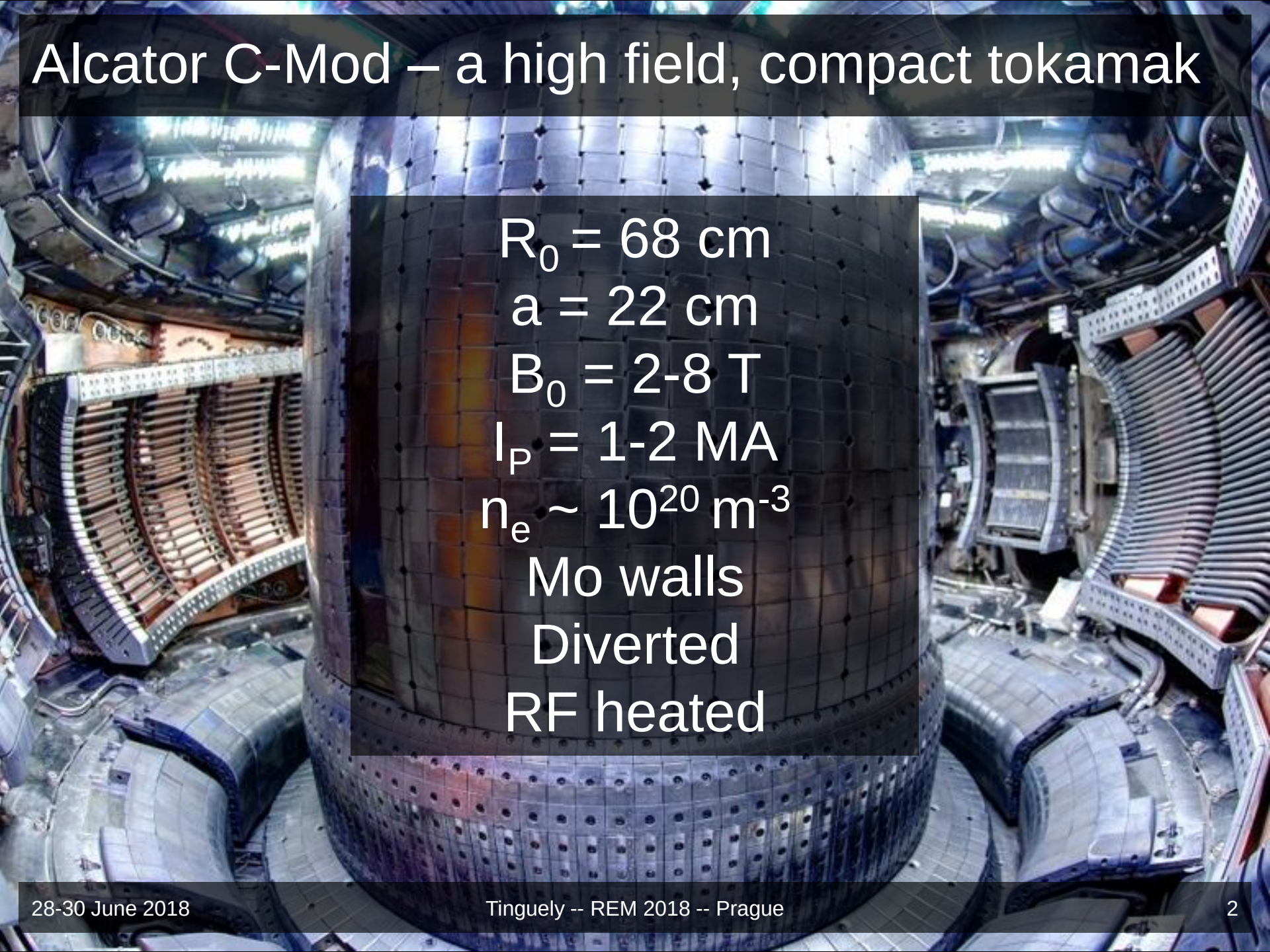
Alcator C-Mod – a high field, compact tokamak



R_0 = 68 cm

a = 22 cm

B_0 = 2-8 T

I_P = 1-2 MA

$n_e \sim 10^{20}$ m^{-3}

Mo walls

Diverted

RF heated

Outline/Summary

Synchrotron images

1. SOFT+CODE needed to accurately reproduce experimental images
2. Gain insight into spatiotemporal dynamics and runaway density evolution

Synchrotron polarization

1. System ‘implemented’ in SOFT (for the first time)
2. Preliminary results are similar to experiment and show promise

Synchrotron images

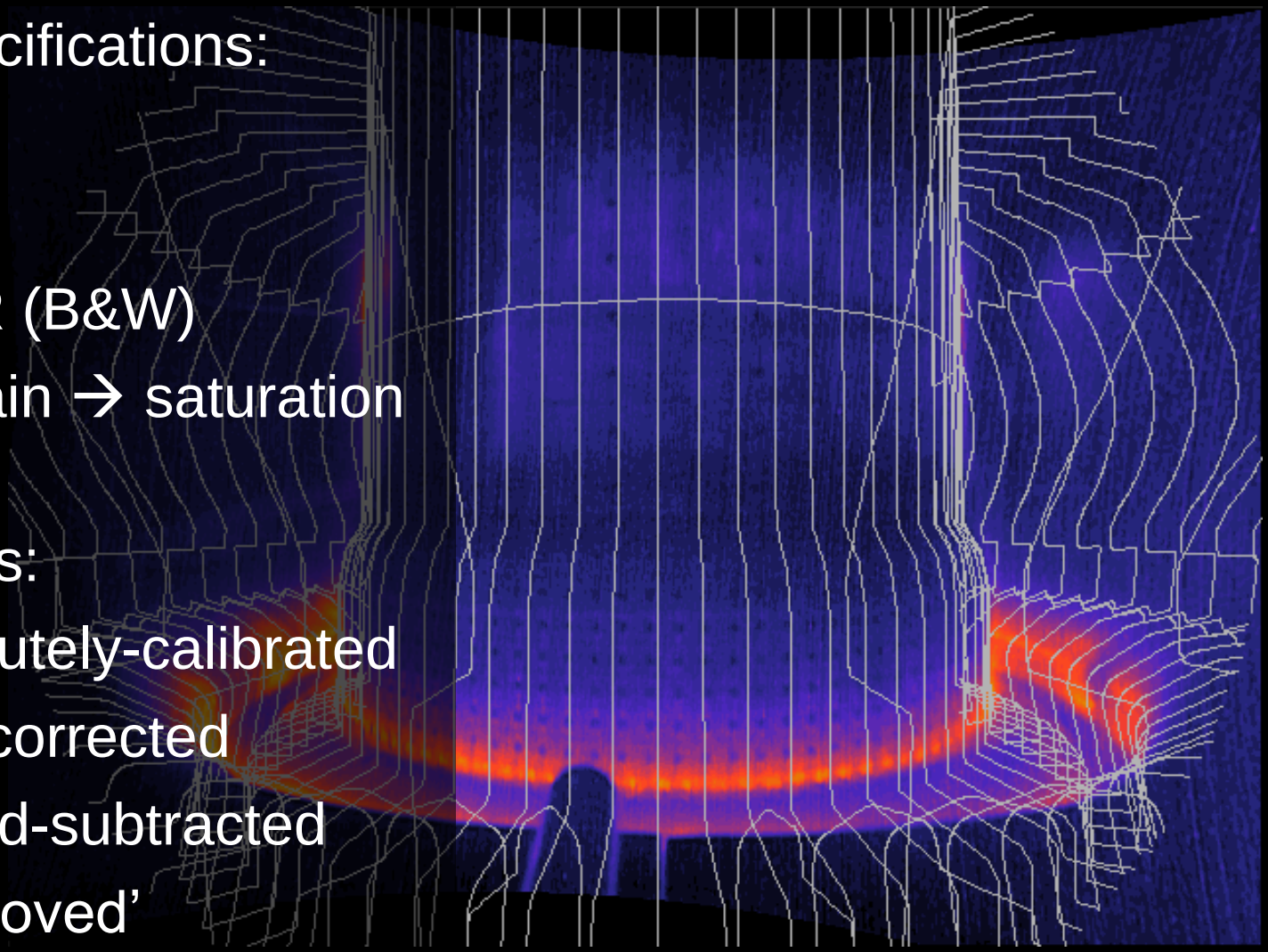
Wide-angle camera captures RE dynamics

Camera specifications:

- Z ~ -21 cm
- ~60 fps
- Visible/NIR (B&W)
- No auto-gain → saturation

Image details:

- NOT absolutely-calibrated
- Distortion-corrected
- Background-subtracted
- HXRs ‘removed’

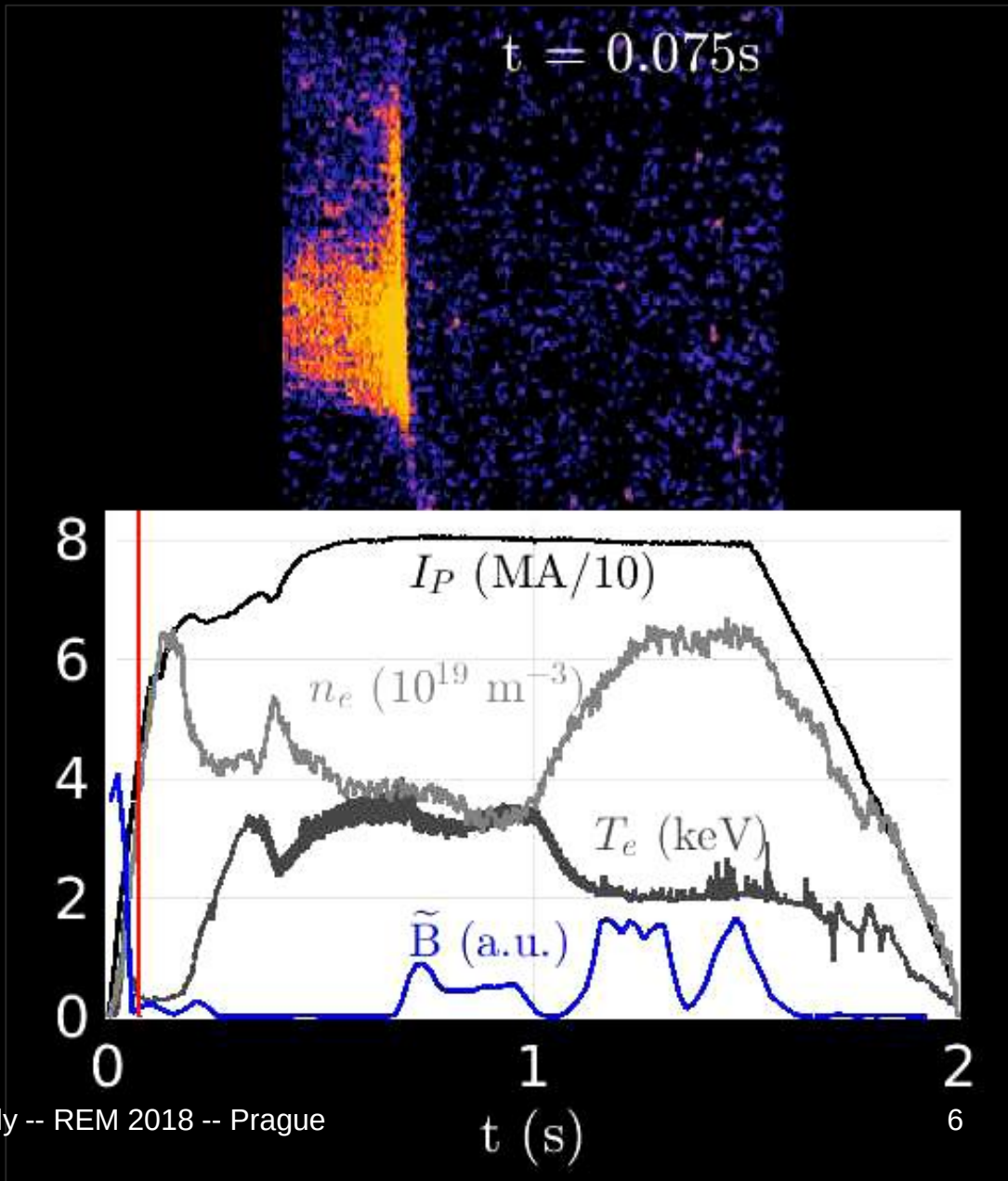


Can we explain/reproduce RE dynamics?

1. Beam increases in size and intensity as n_e decreases

2. Interesting spatial structure observed (‘third leg’) during locked mode ($\tilde{B}$)

3. Beam decreases in size and intensity as n_e increases



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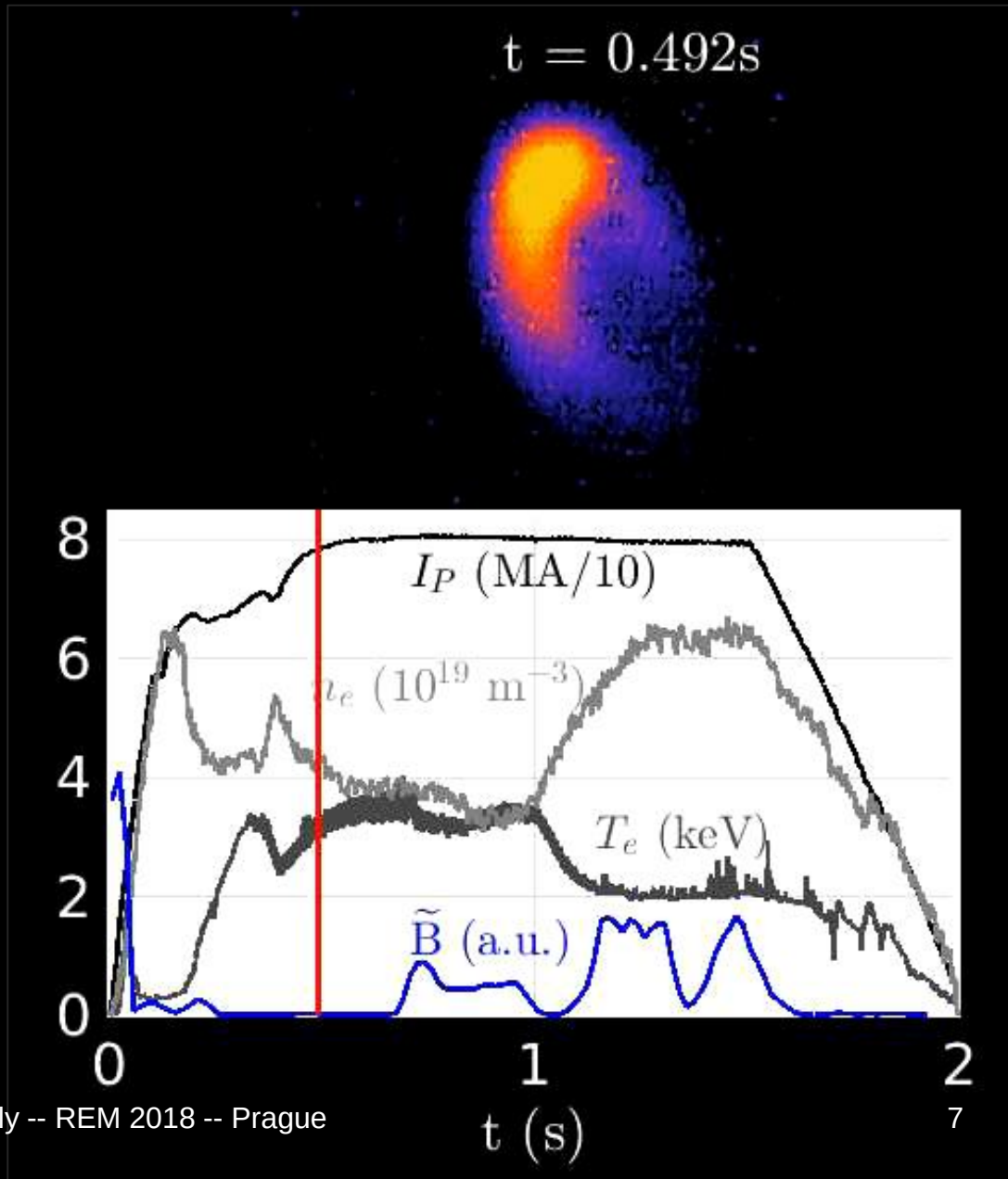

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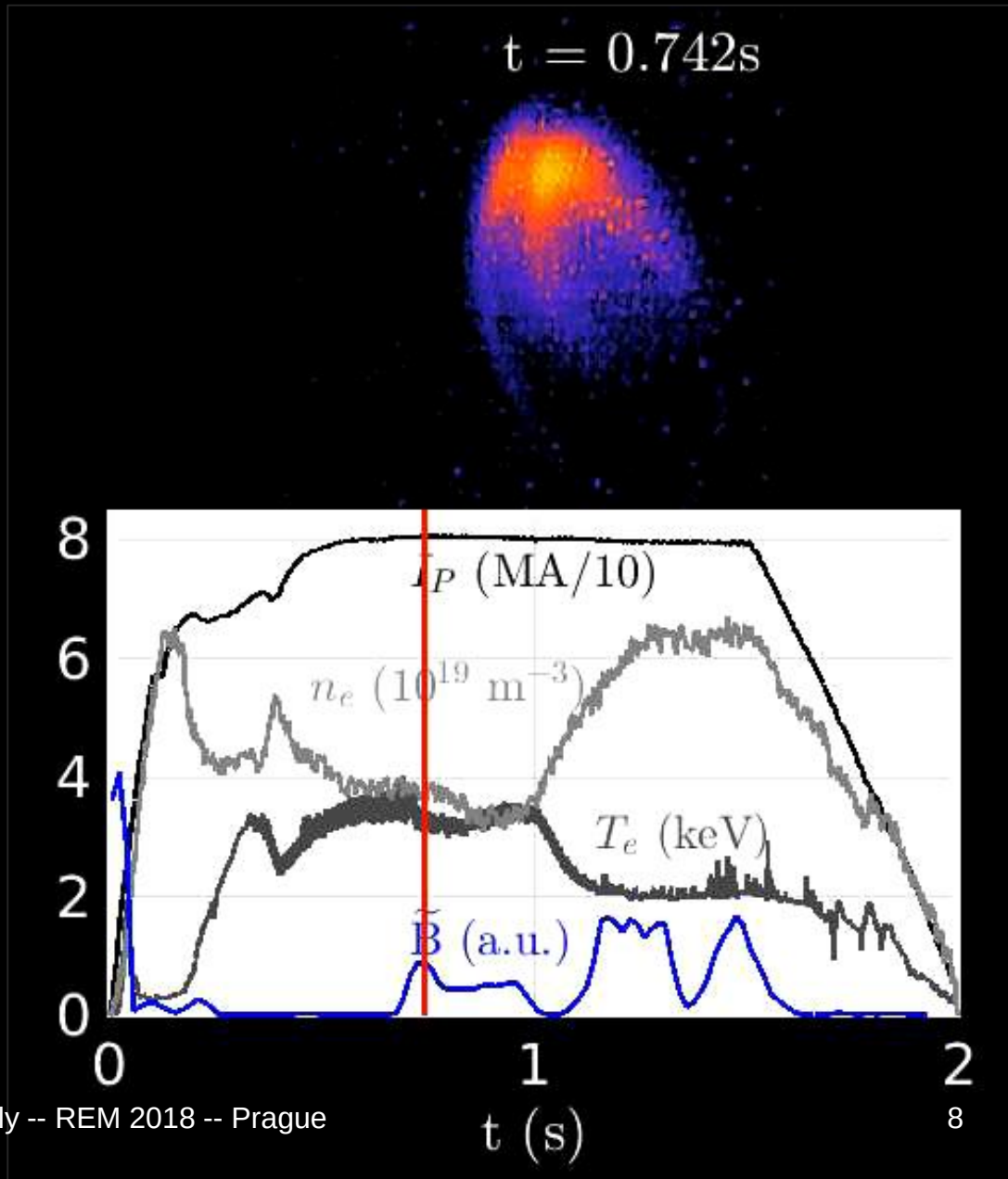

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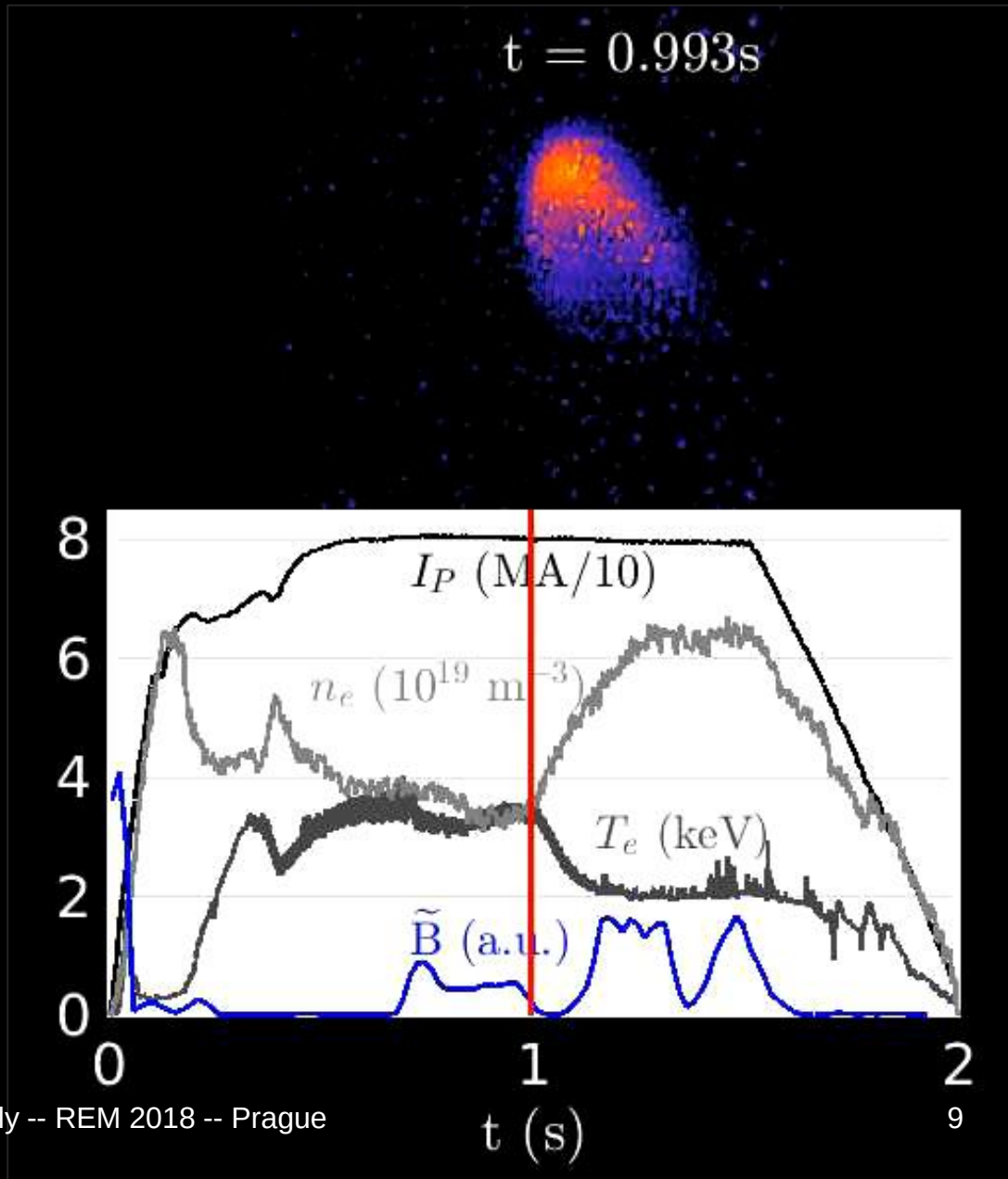

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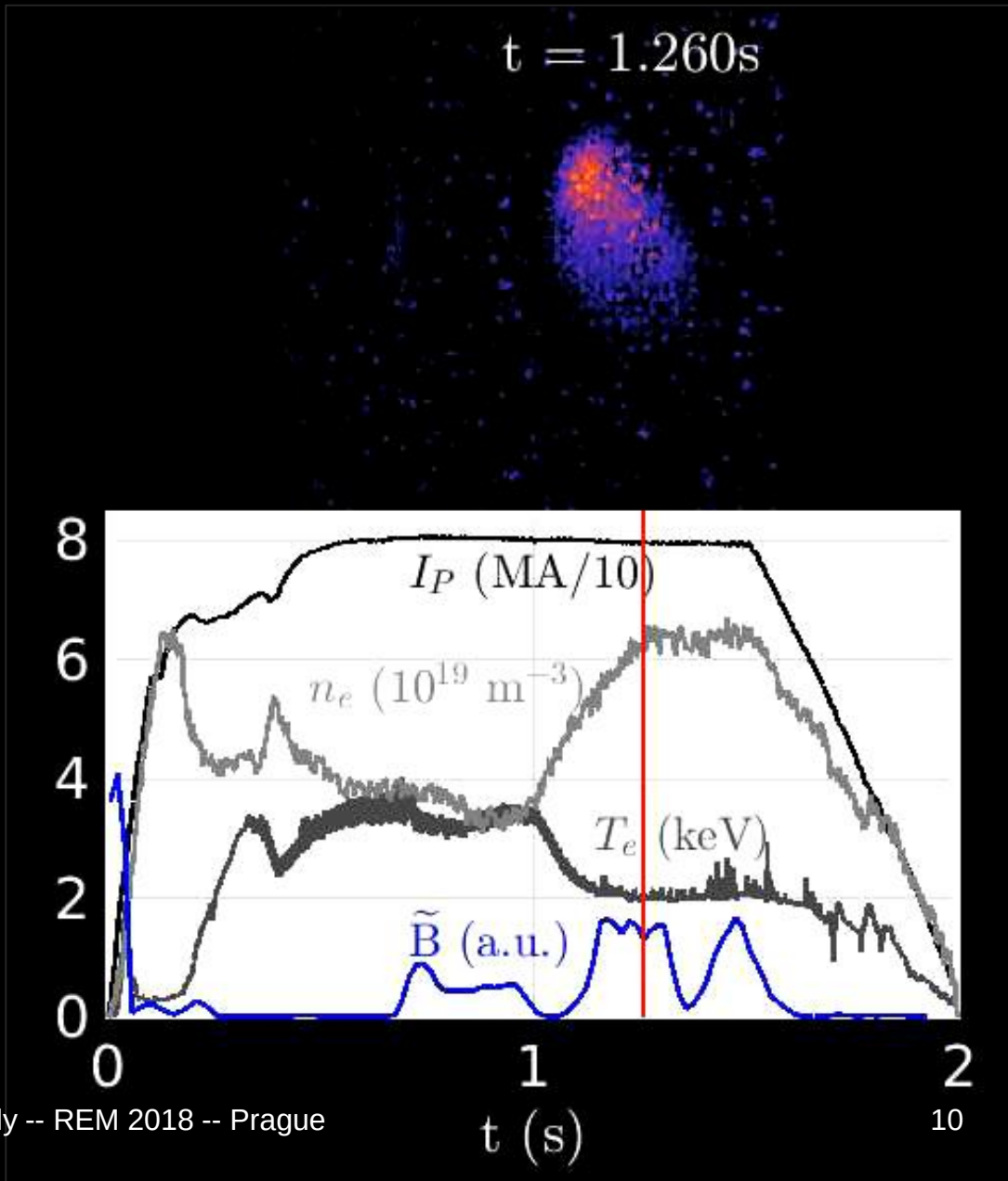
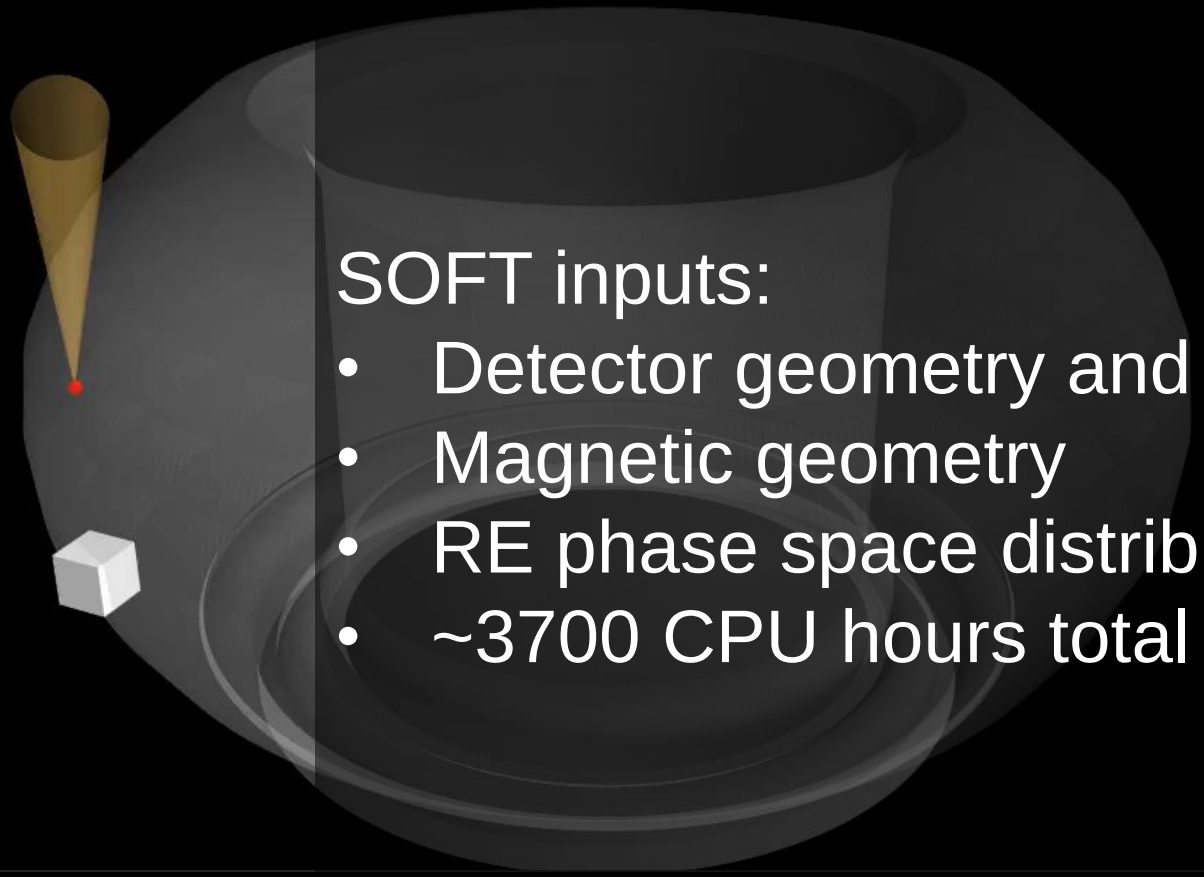


Synchrotron-detecting **O**rbit-**F**ollowing **T**oolkit

Hoppe NF 2018



SOFT inputs:

- Detector geometry and response
- Magnetic geometry
- RE phase space distributions
- ~3700 CPU hours total

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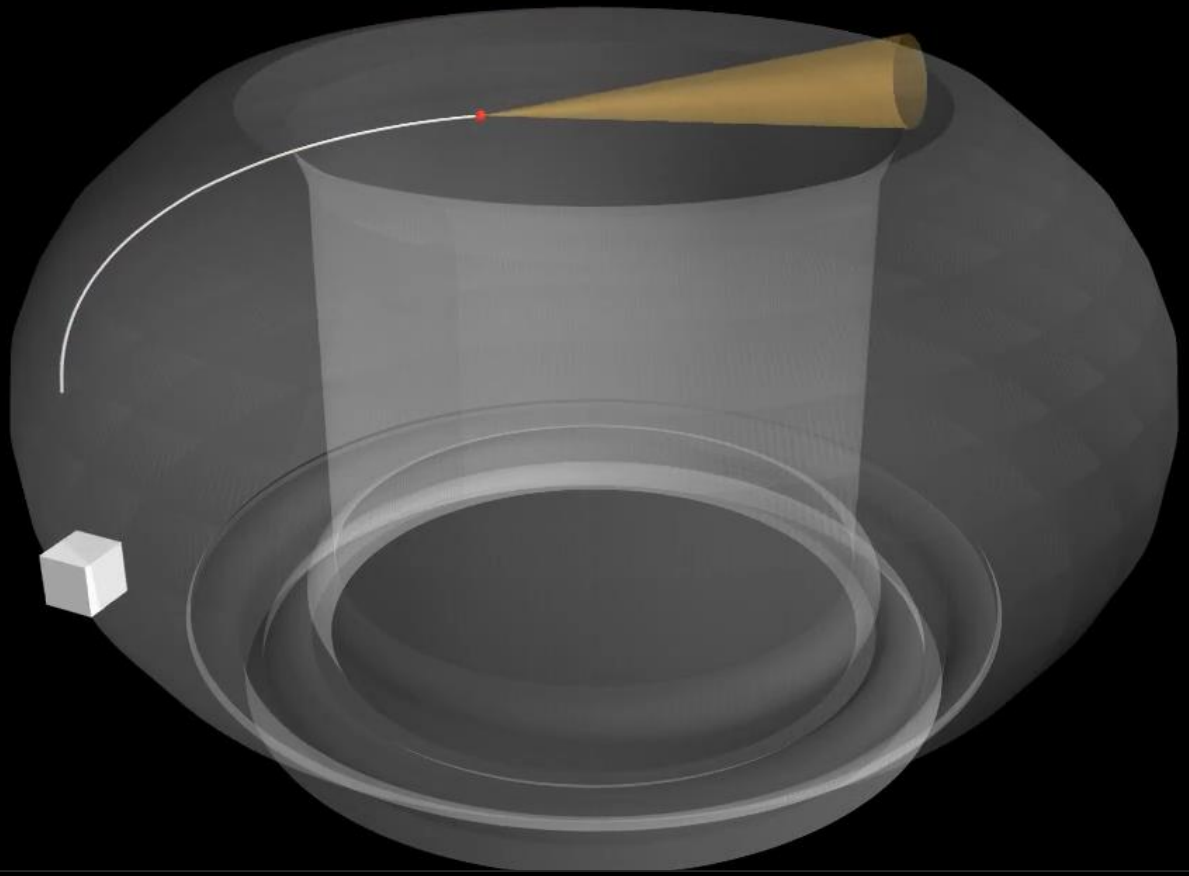

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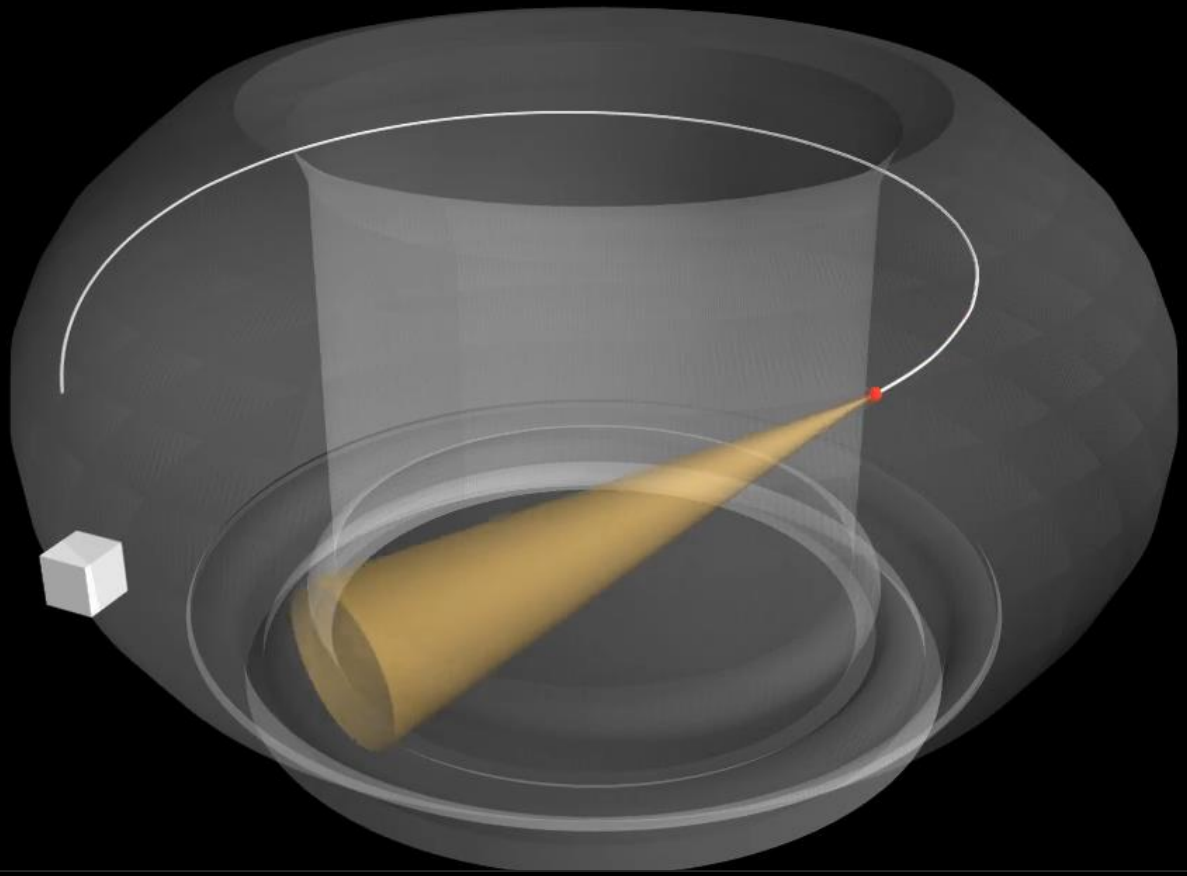


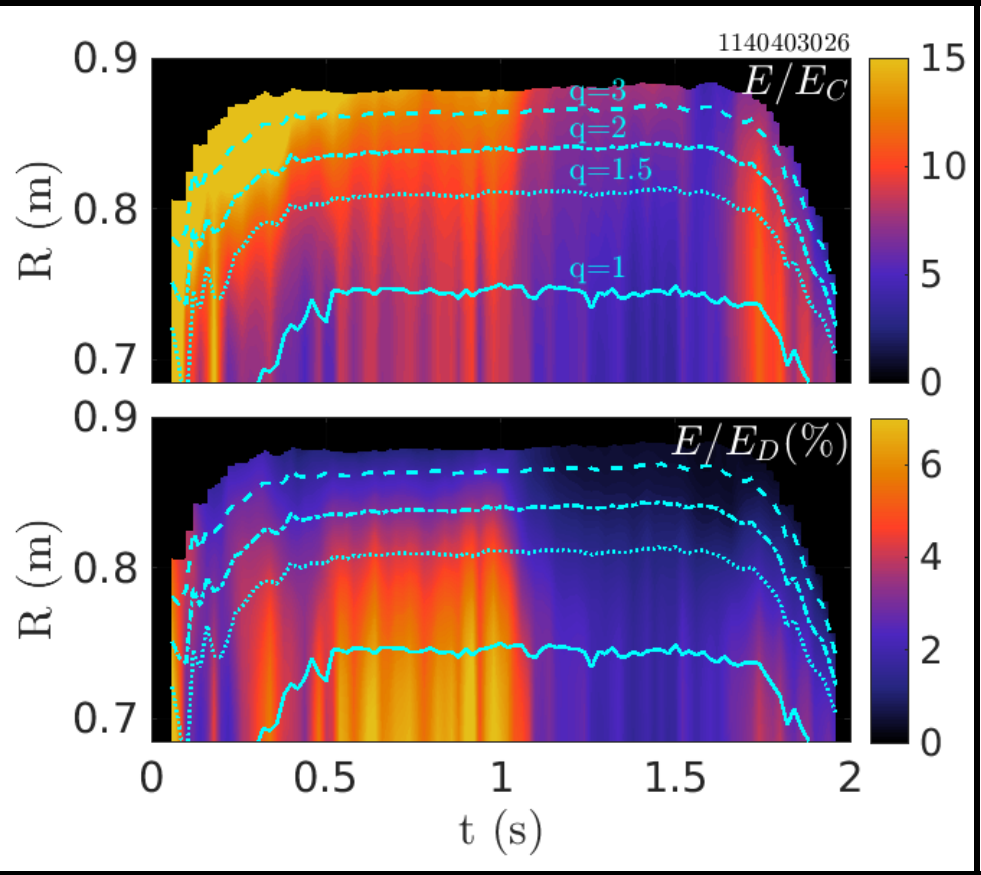
Synchrotron-detecting **O**rbit-**F**ollowing **T**oolkit

Hoppe NF 2018

COllisional **D**istribution of **E**lectrons (~300 CPU hrs)

Landreman CPC 2014, Stahl NF 2016

Inputs



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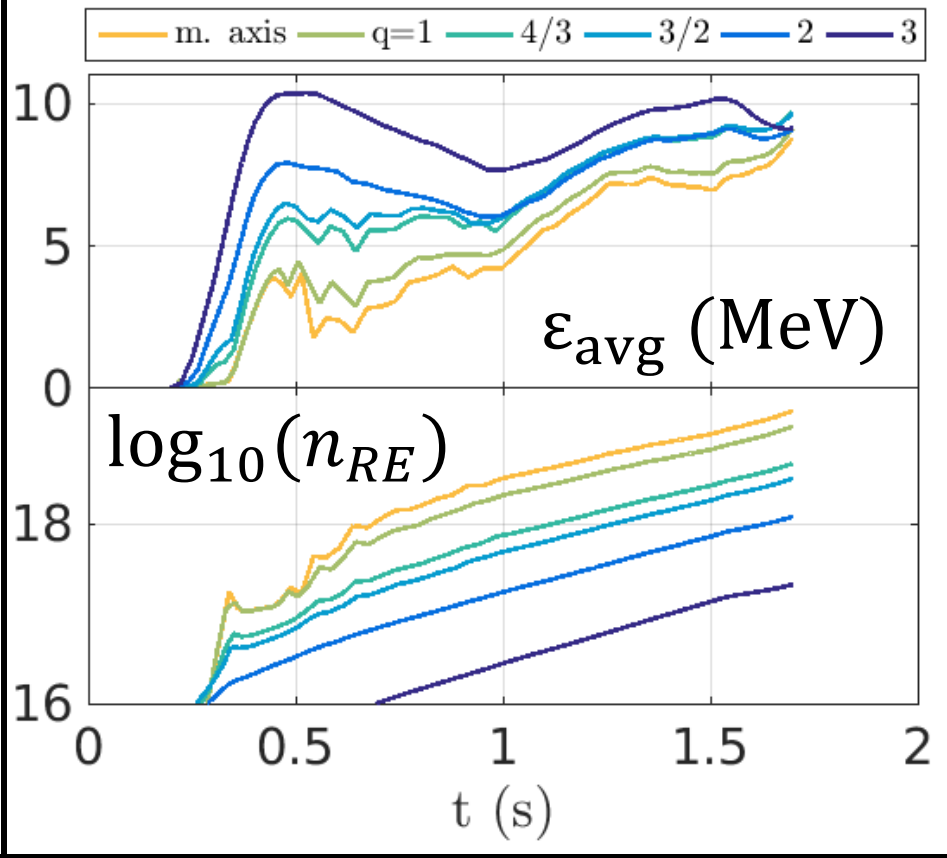
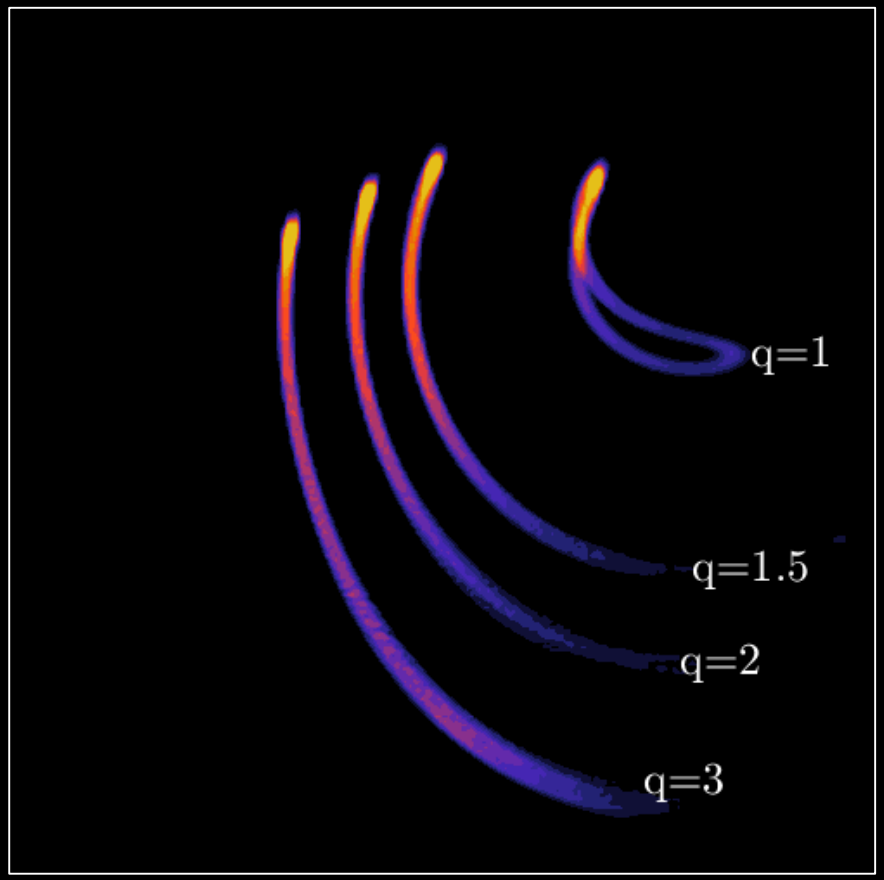
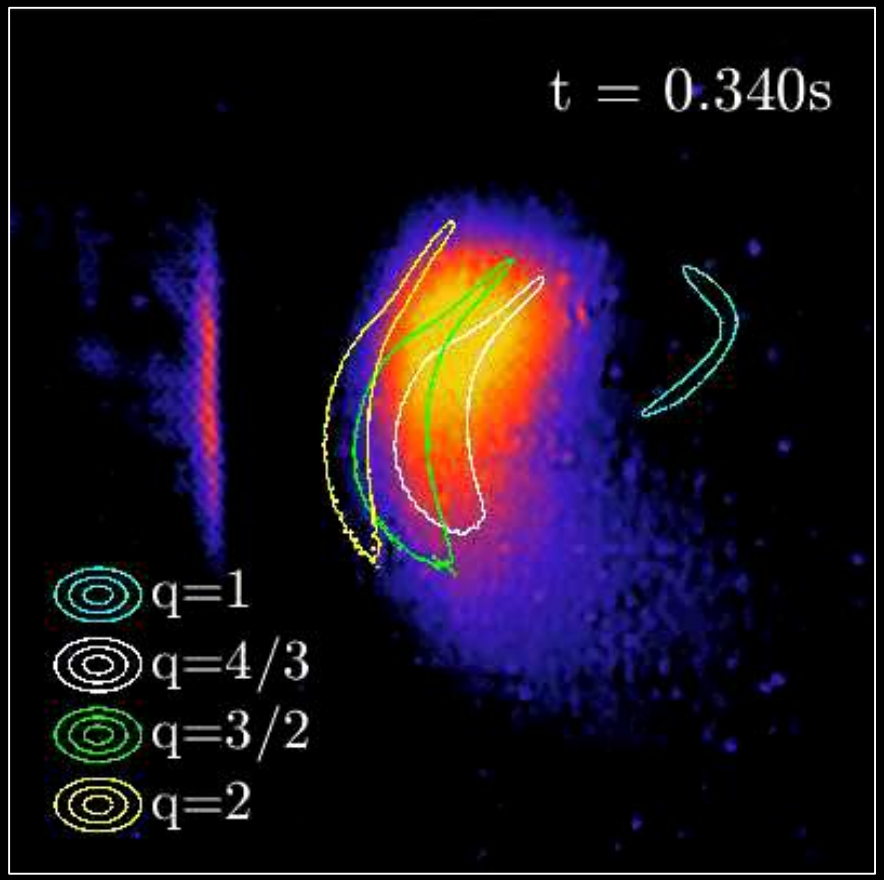


‘Build’ image from q-surfaces like basis functions





Camera does not see REs on the magnetic axis

- Applicable during flattop
- Structure/edges at rational q?

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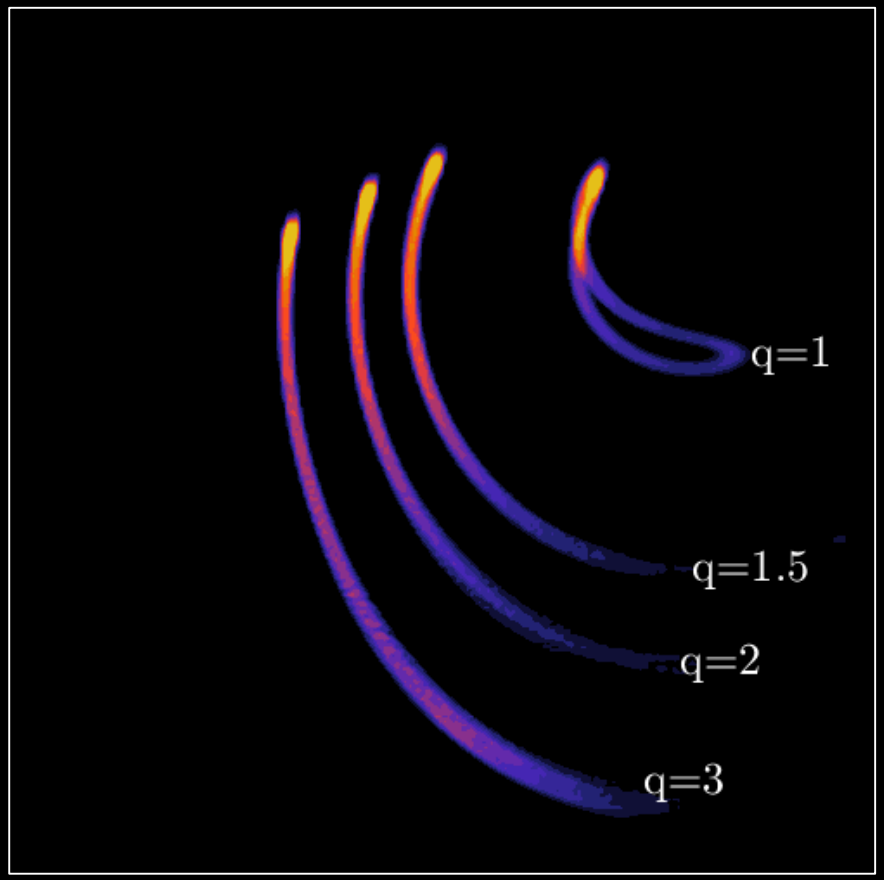

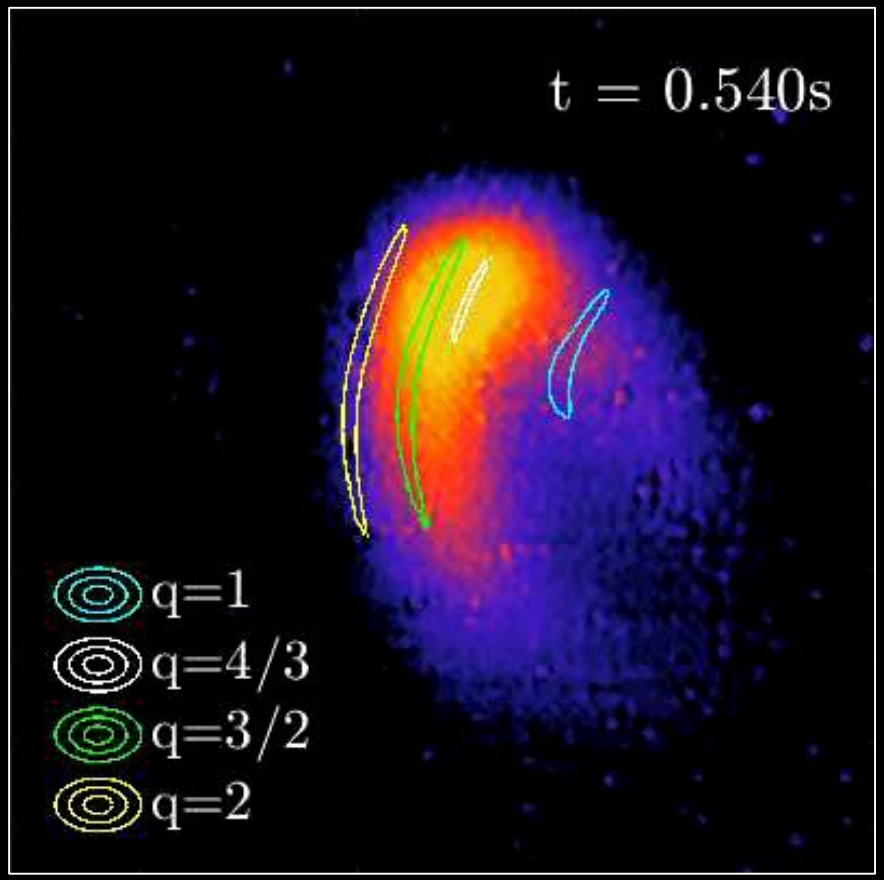

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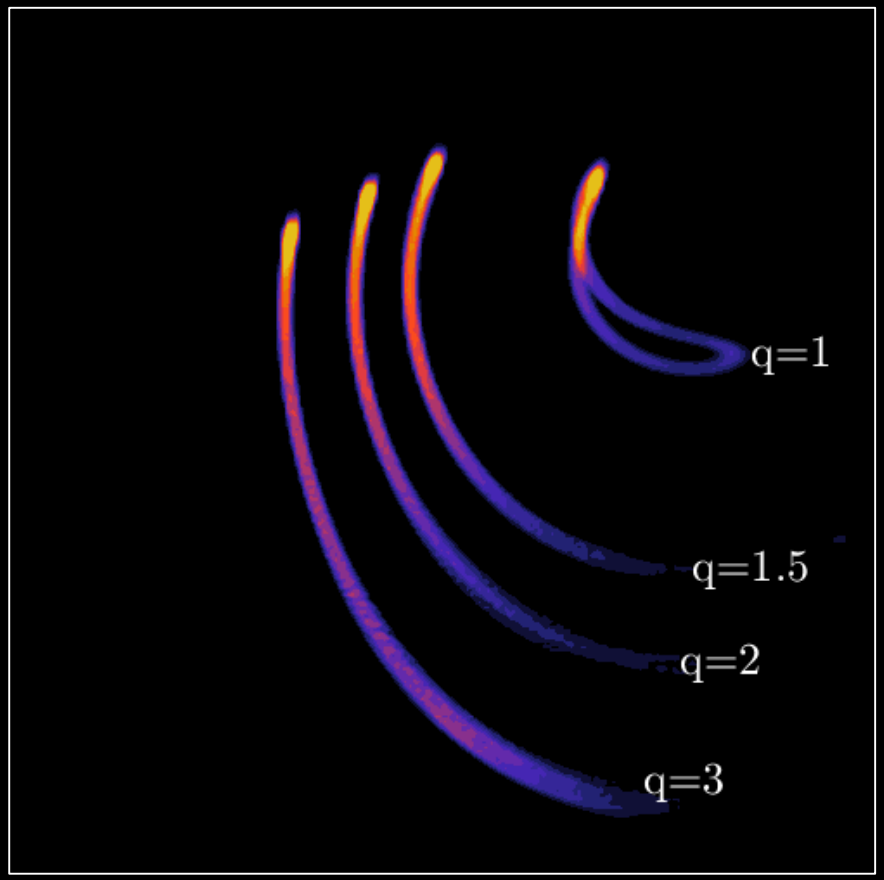

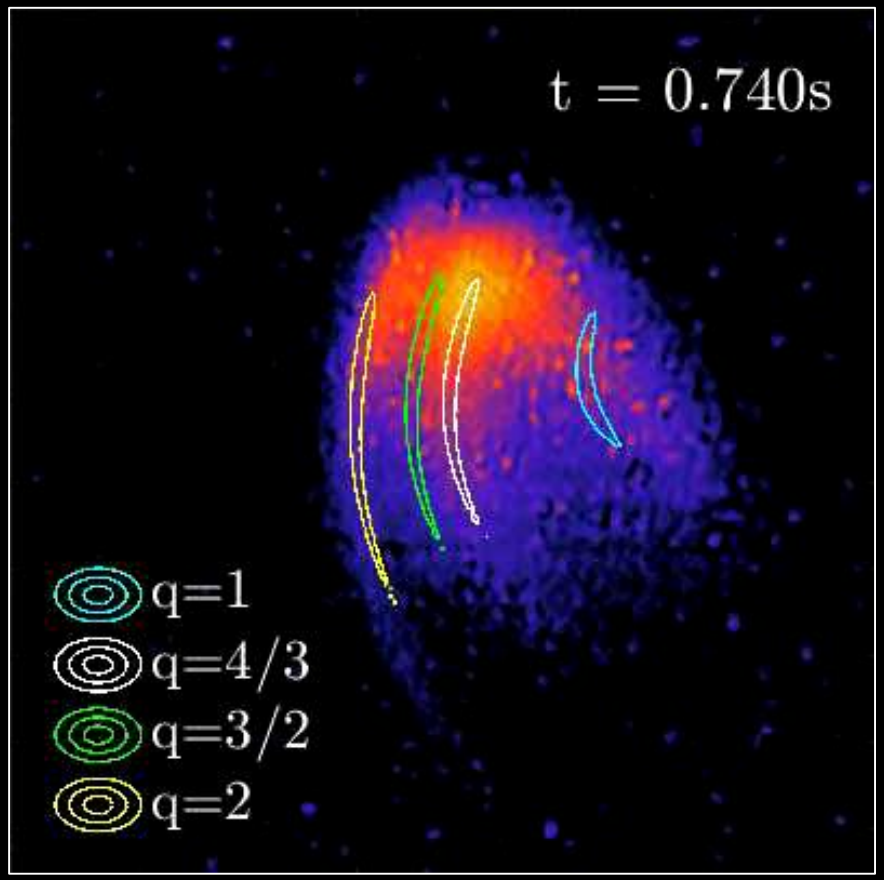

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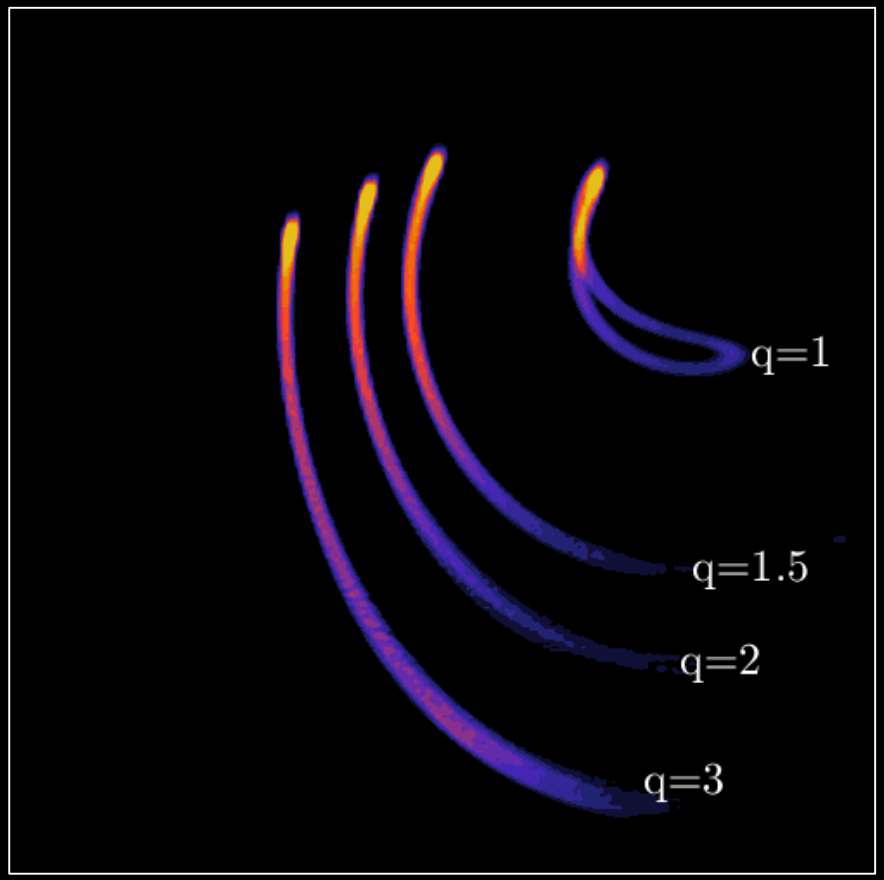

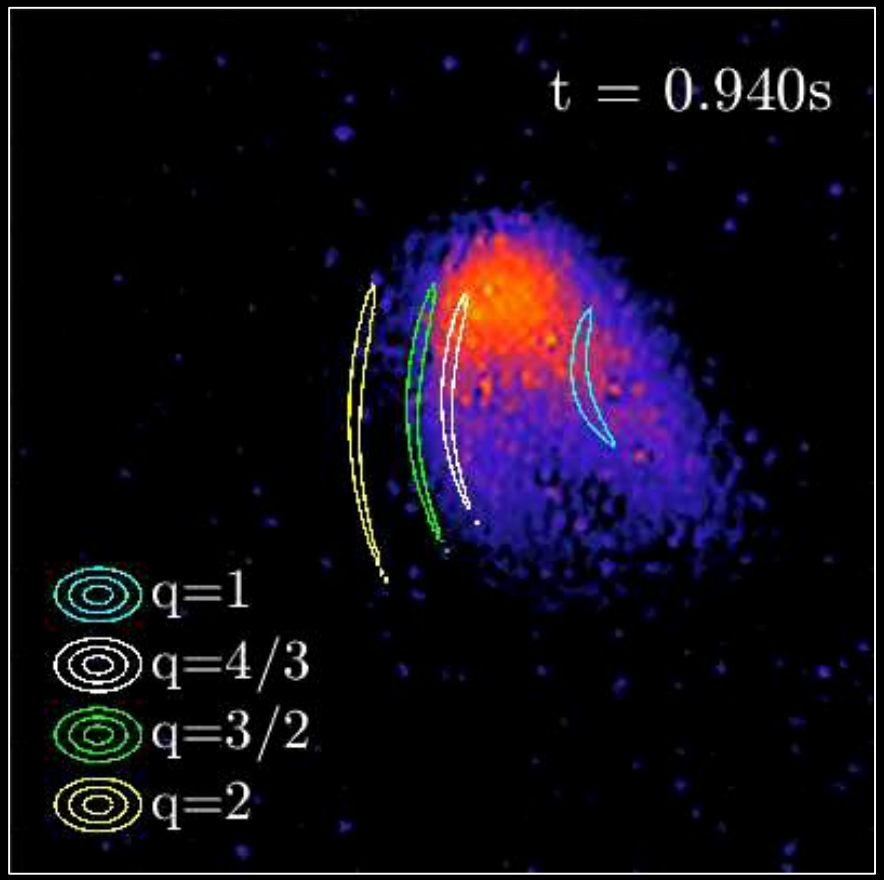

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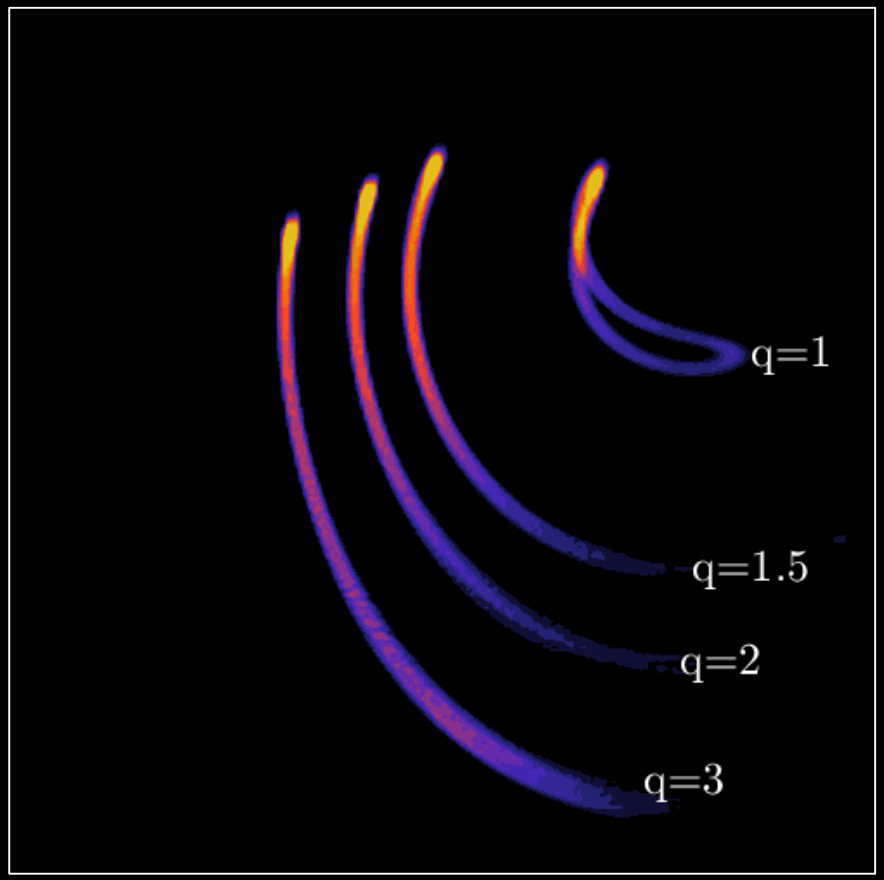

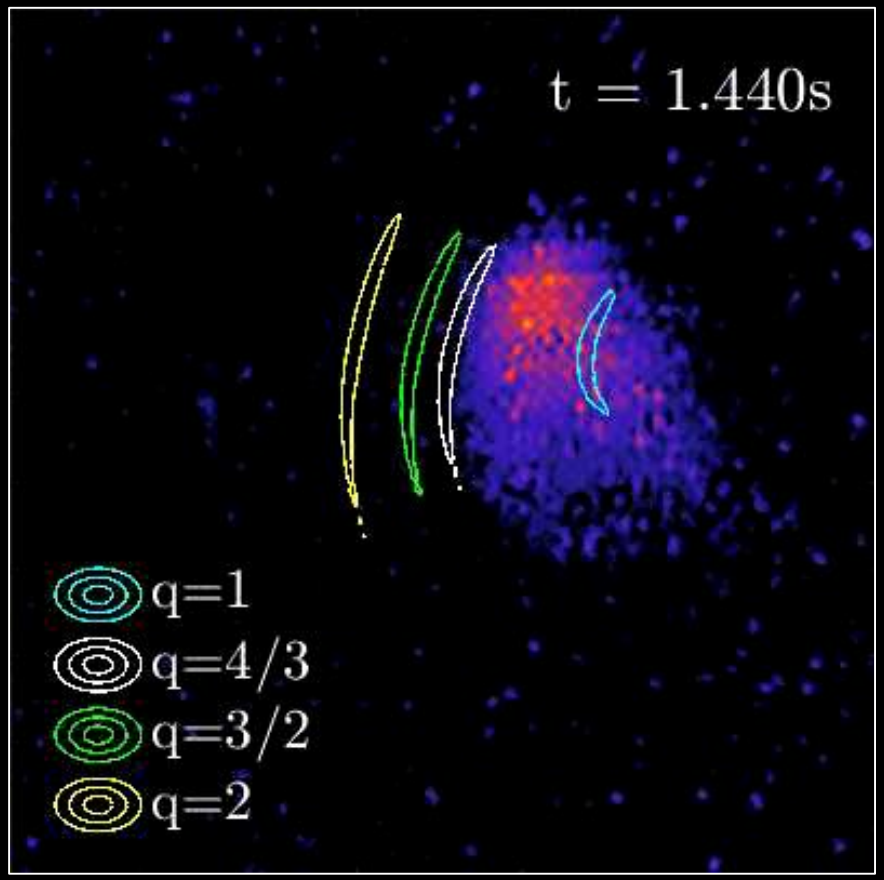

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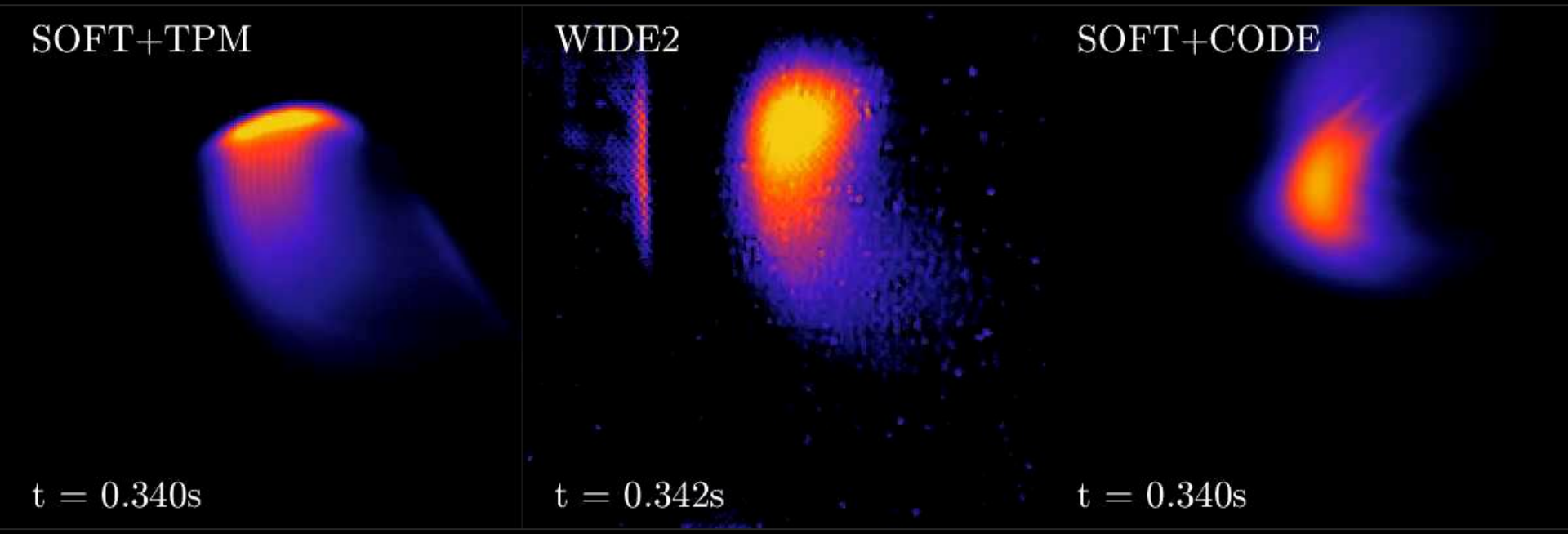
Comparing test-particle model to CODE



Full momentum-space distribution functions from CODE

- Capture full vertical extent of image
- Pose a challenge during early times (during I_p ramp)
- Most accurately reproduce spatial features (later)

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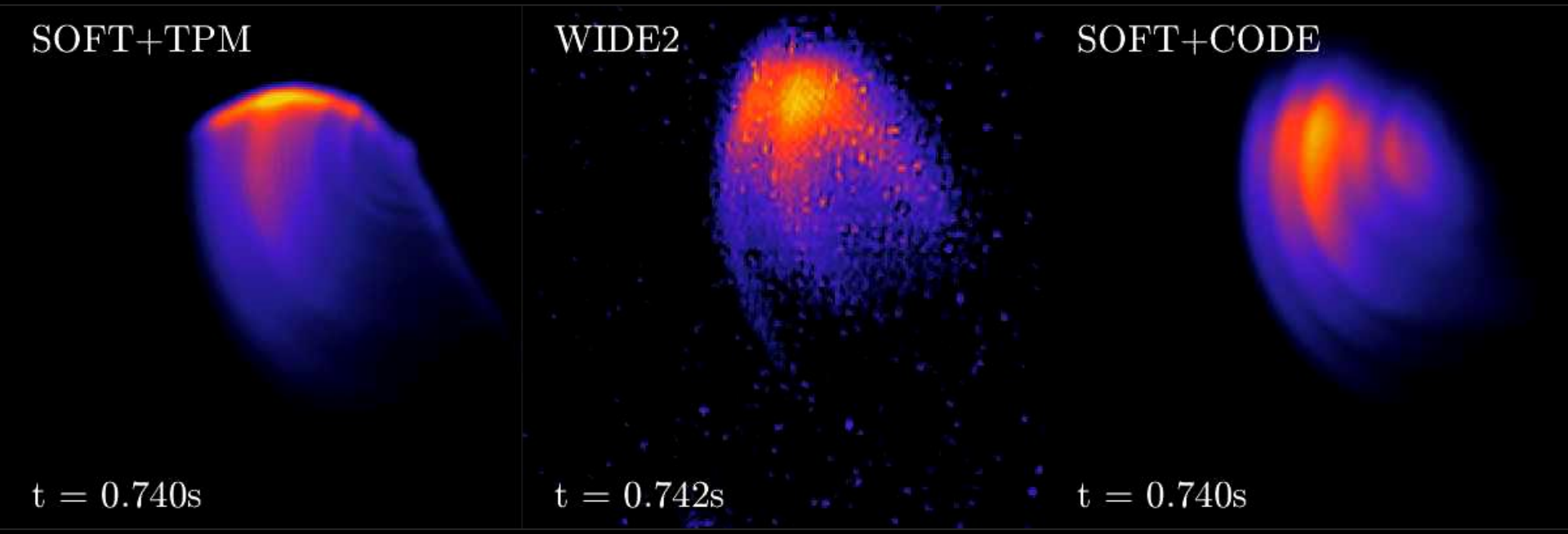

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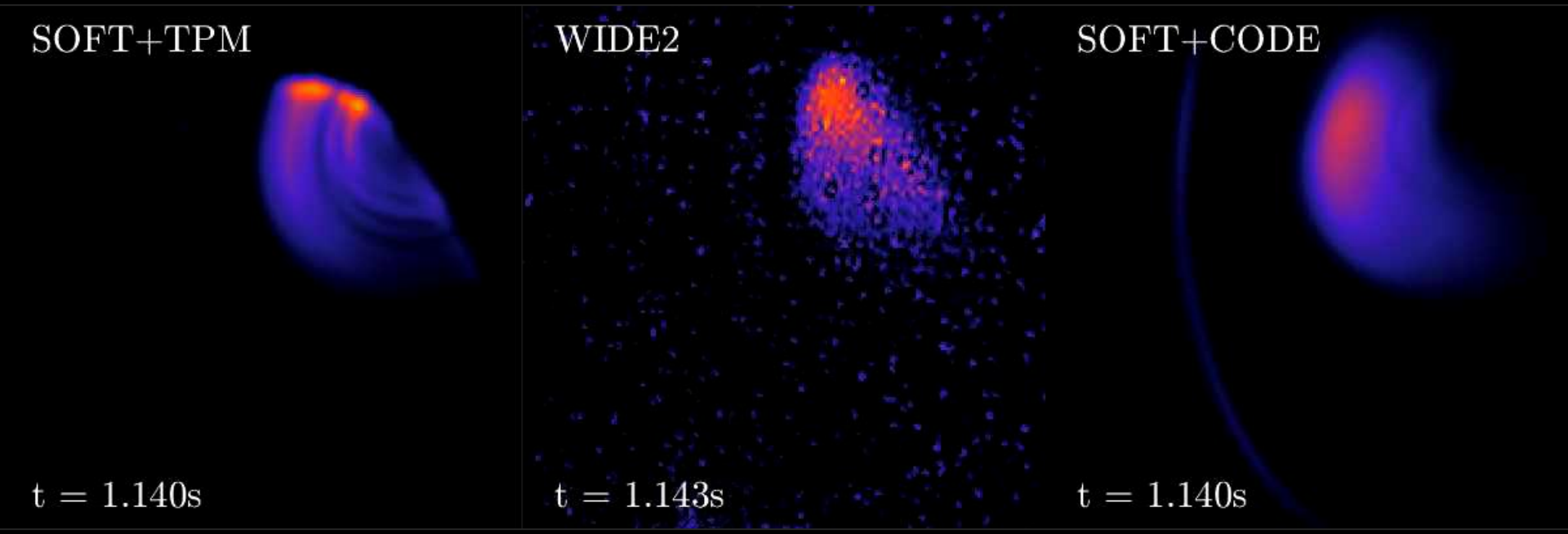

Full momentum-space distribution functions from CODE

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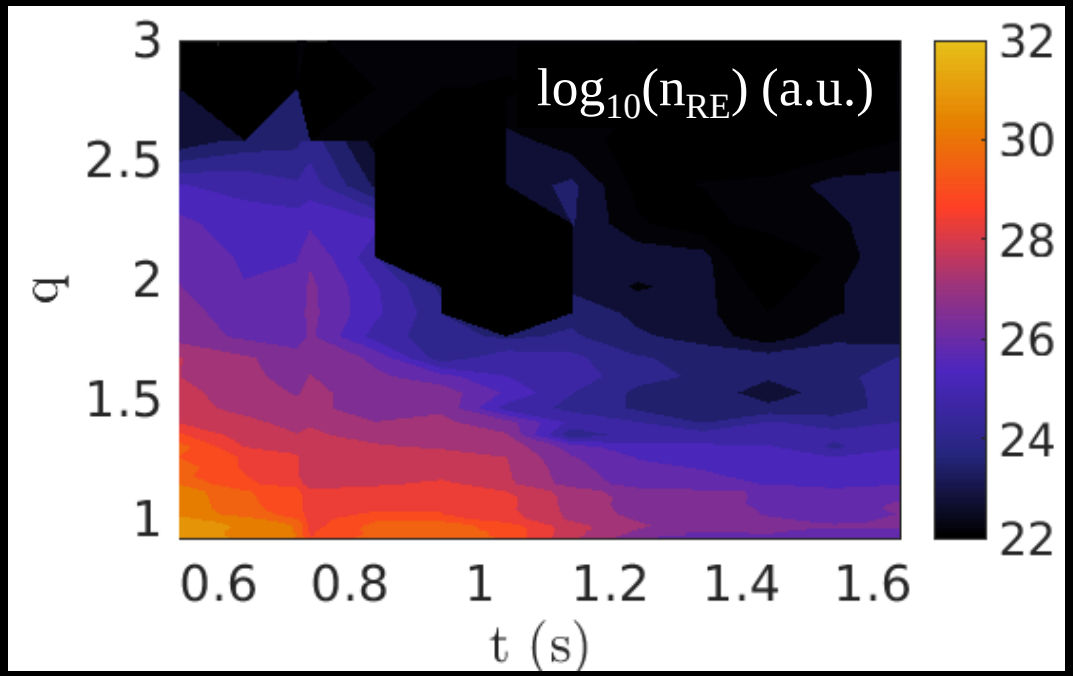
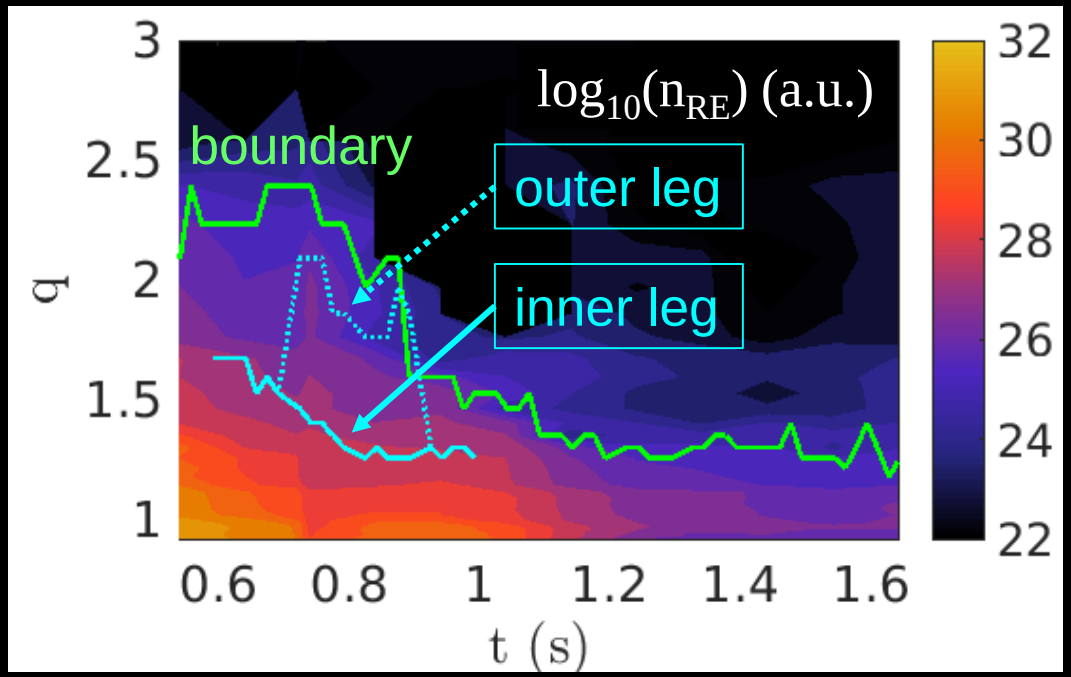
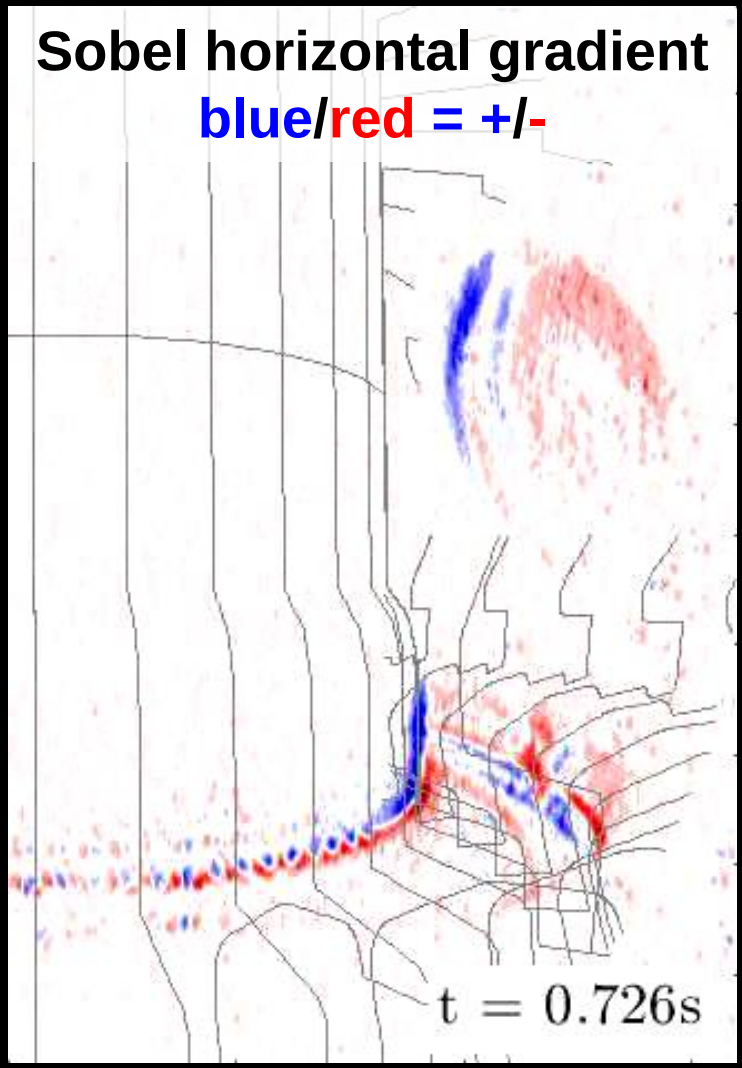
Gain insight into spatiotemporal evolution

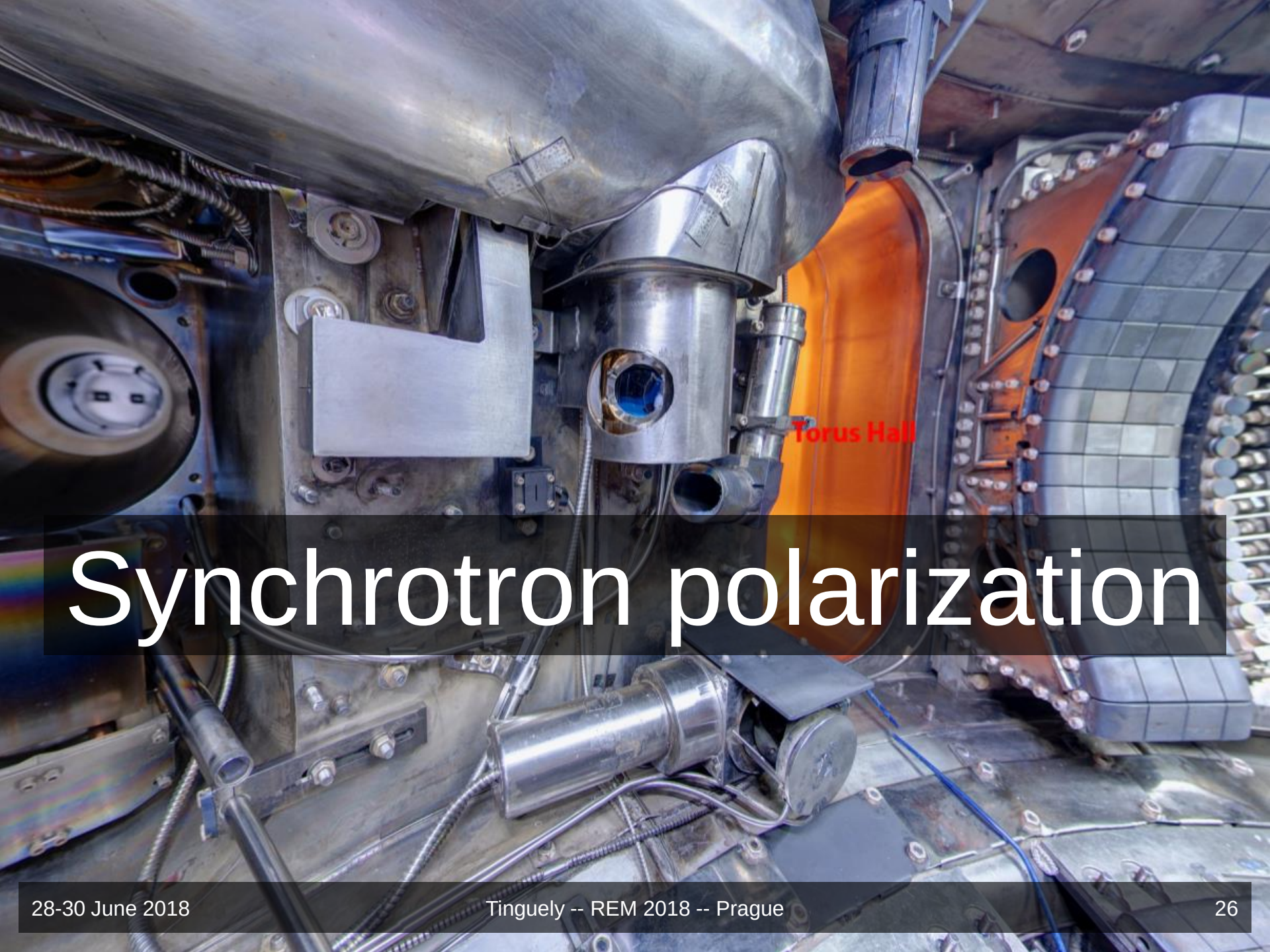
- Beam shrinks in size, starting at locked mode
- Runaway density decreases as n_e increases



Use edge detection to track spatial features







Synchrotron polarization

10-channel system* measures polarization info:

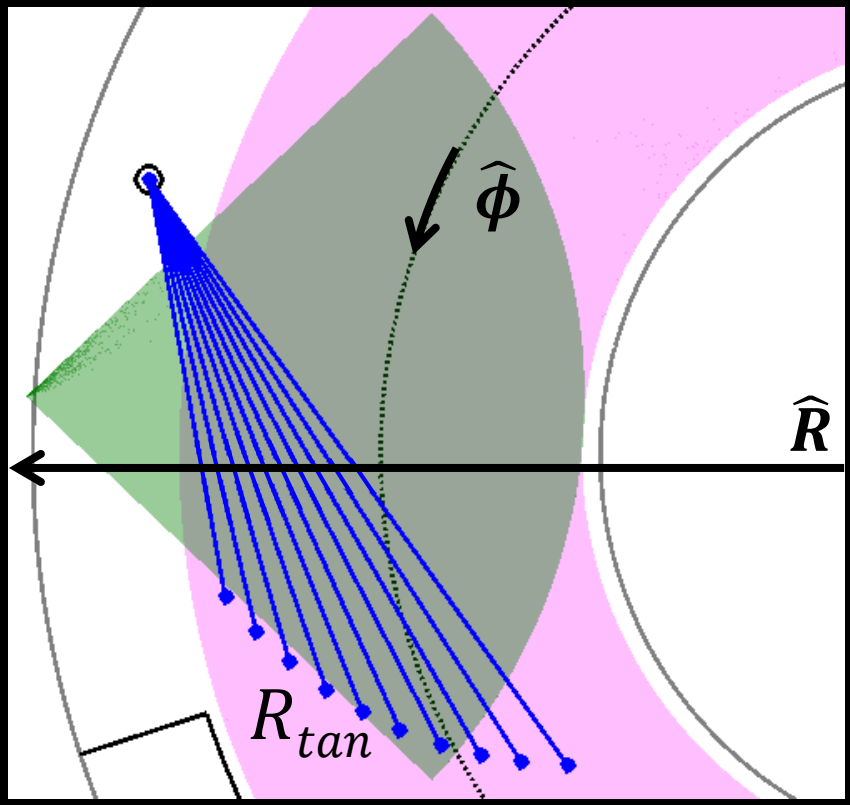
*MSE Diagnostic

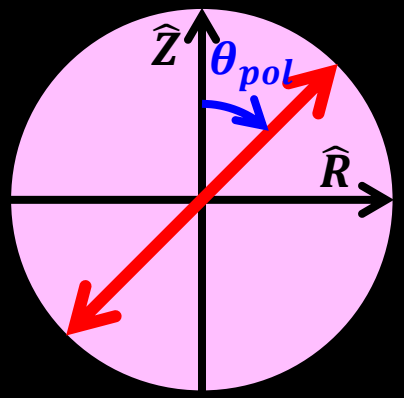
- Stokes vector $[I, Q, U, V]$
- Fraction of linearly-polarized light

$$DOLP = \frac{\sqrt{Q^2 + U^2}}{\mathrm{I}}$$

- Linear polarization angle

$$\theta_{pol} = \frac{1}{2}\,\mathrm{atan}\left(\frac{U}{Q}\right)$$

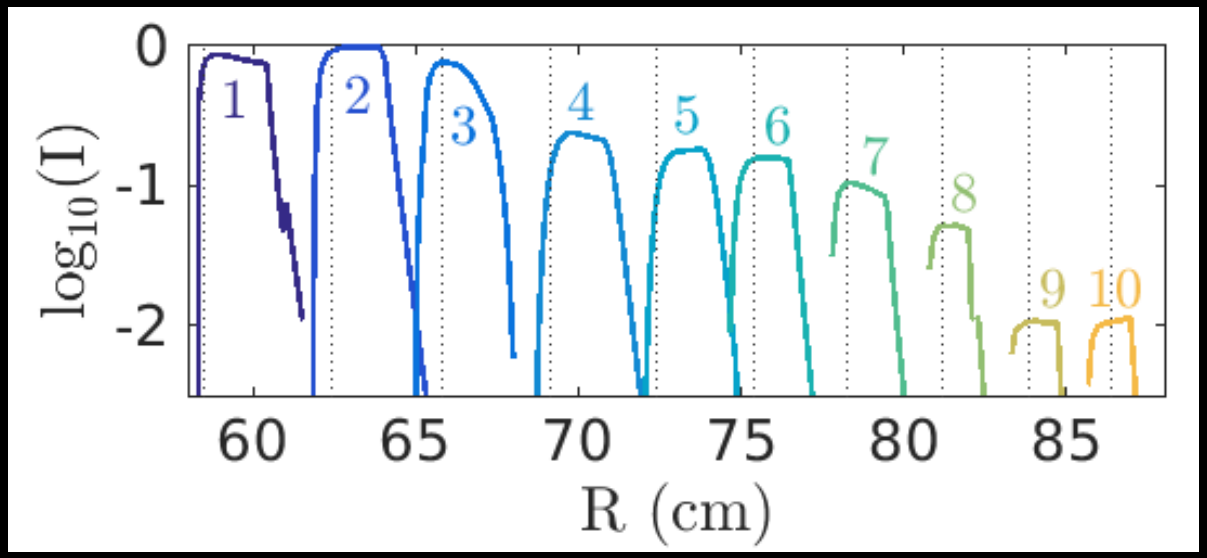


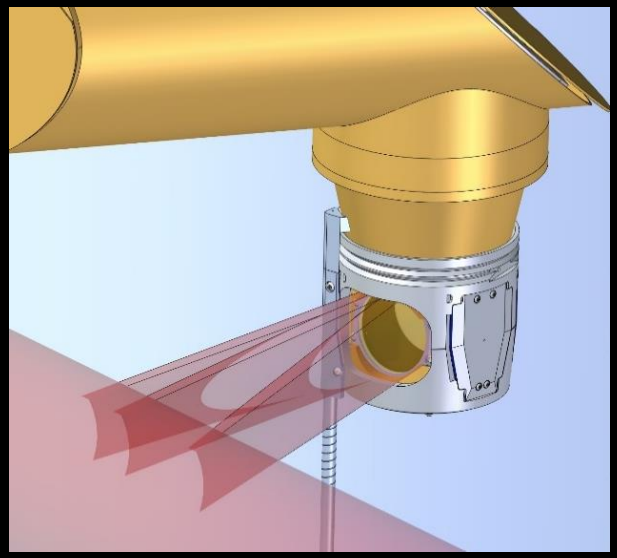


10-channel system has been modeled in SOFT

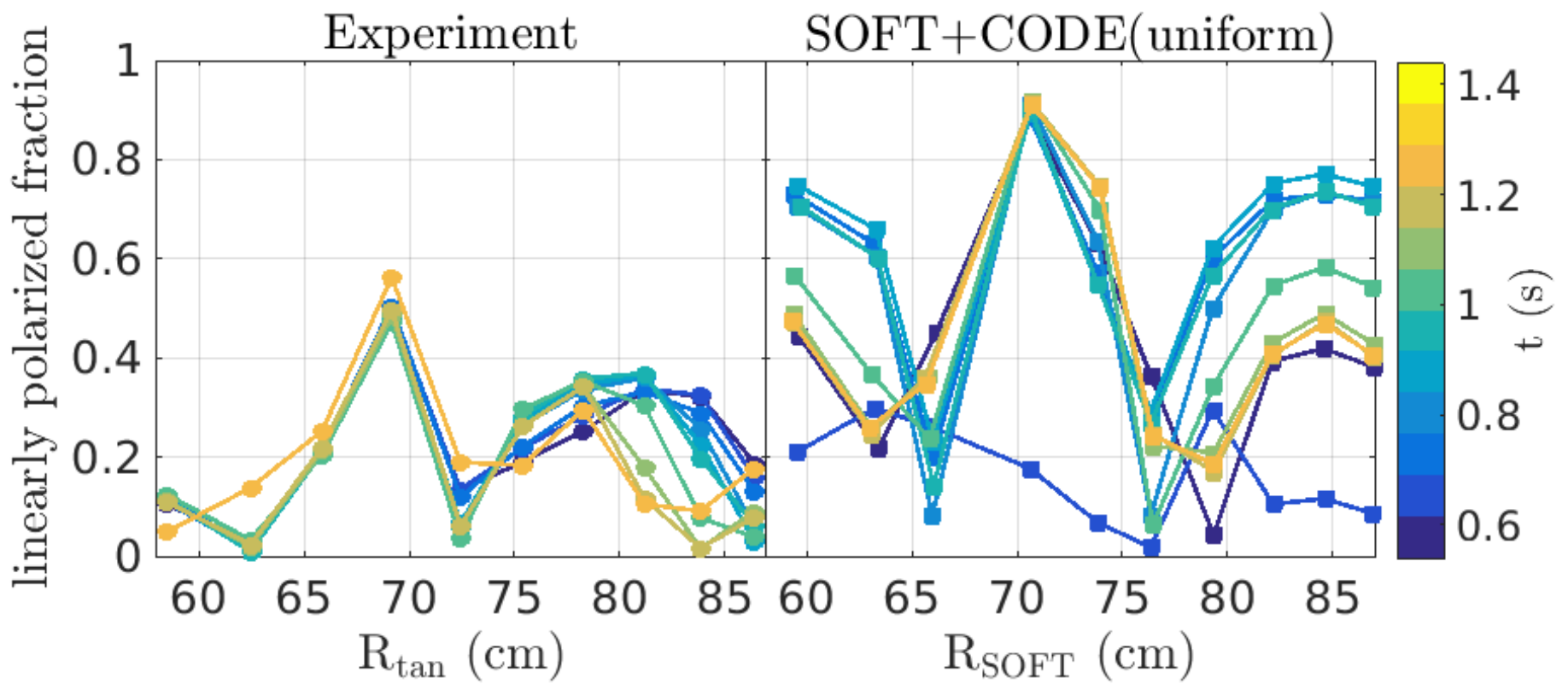
- Localized measurements of synchrotron emission
- Some measurements (DOLP, θ_{pol}) ~independent of local intensity

Courtesy of R. Mumgaard



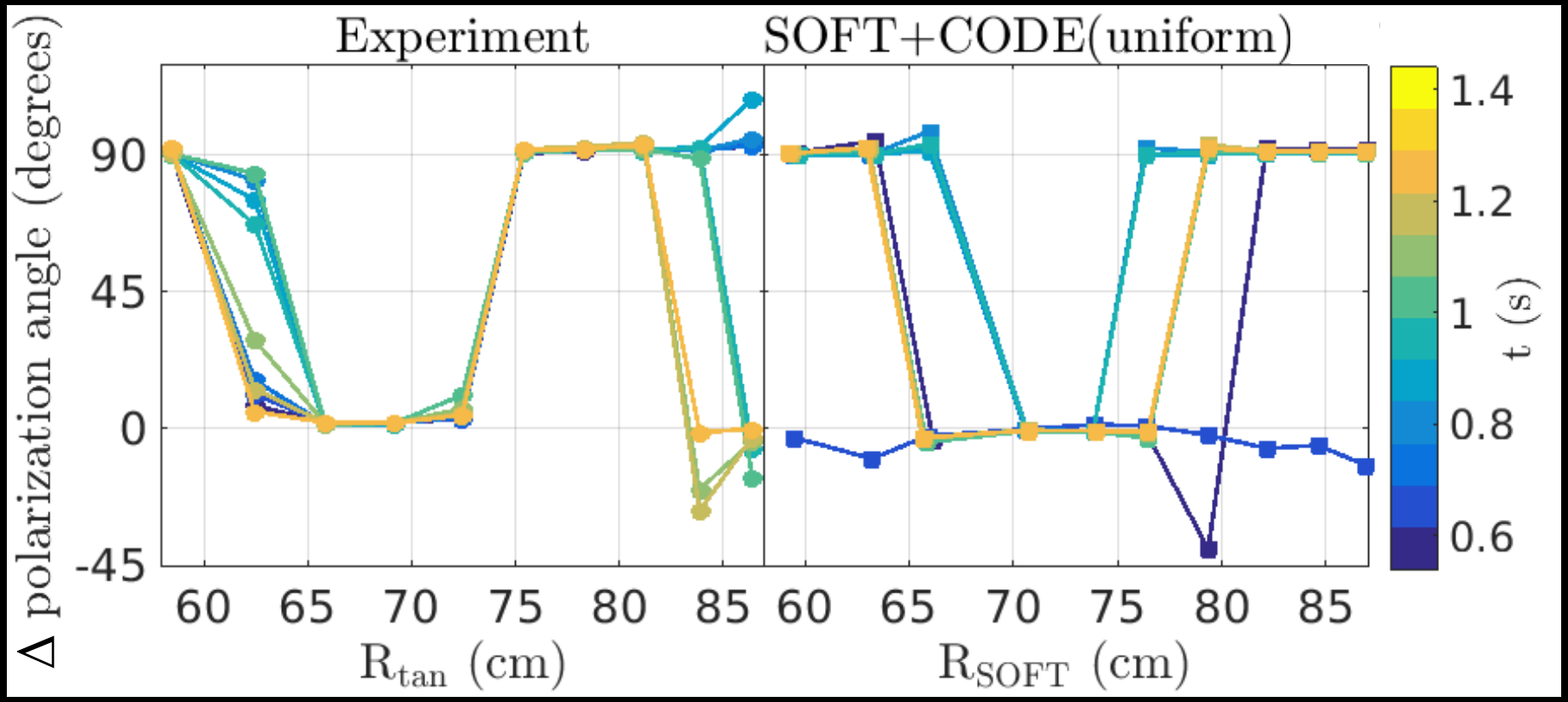


First simulations of DOLP show similar features



- Experimental data is shifted toward smaller R compared to SOFT – perhaps due to RE drifts?
- Amplitude difference could result from background light?

First look at polarization angle shows promise



- Again, experimental data is shifted toward smaller R…
- Working to clarify experimental and SOFT geometries for appropriate comparison of angles

Summary

Synchrotron images

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