

# Quantitative Image Analysis of Fracture Propagation:

Automating time-intensive manual analysis  
methods with machine learning

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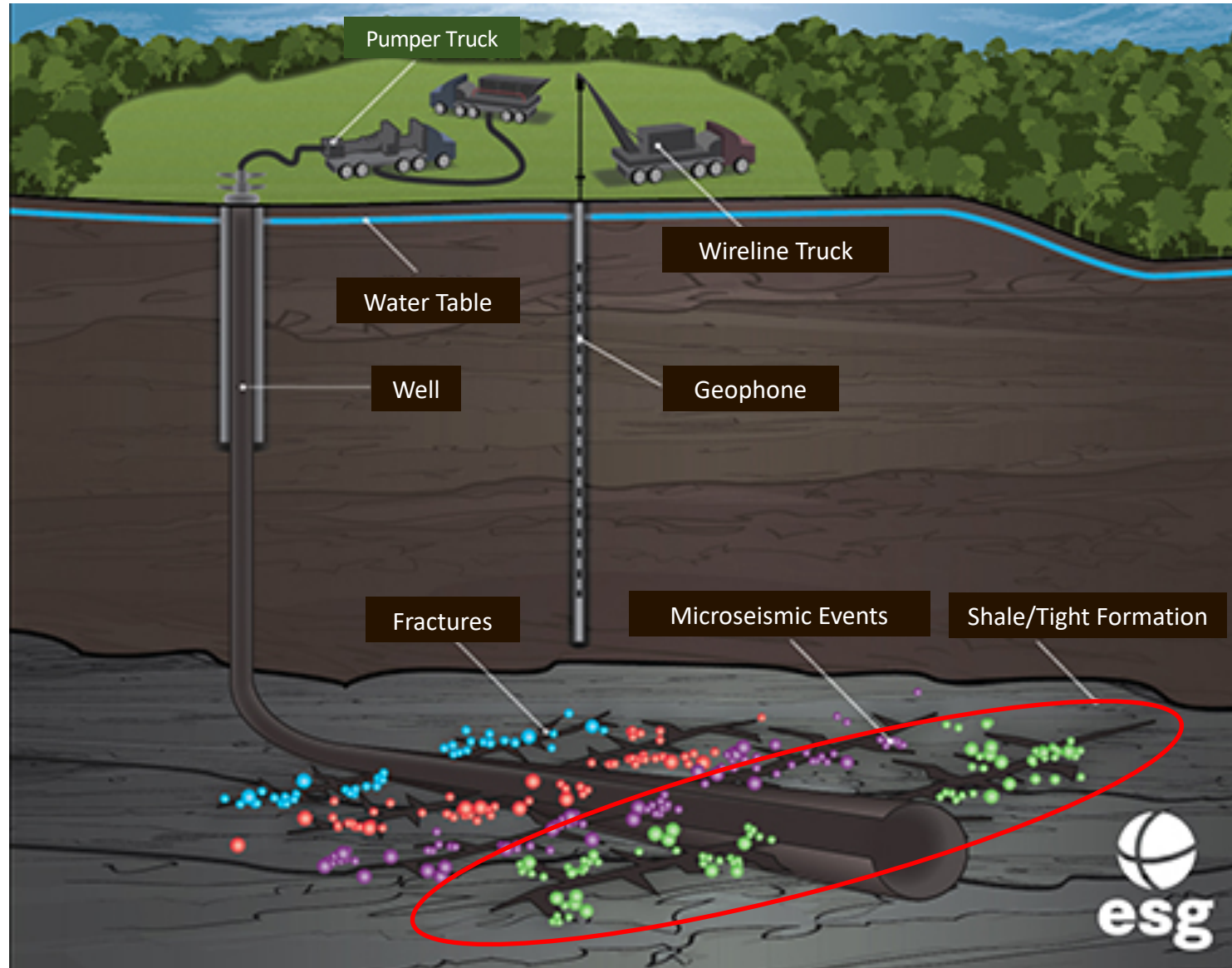
Department of Civil & Environmental Engineering

In collaboration with Professor Herbert Einstein

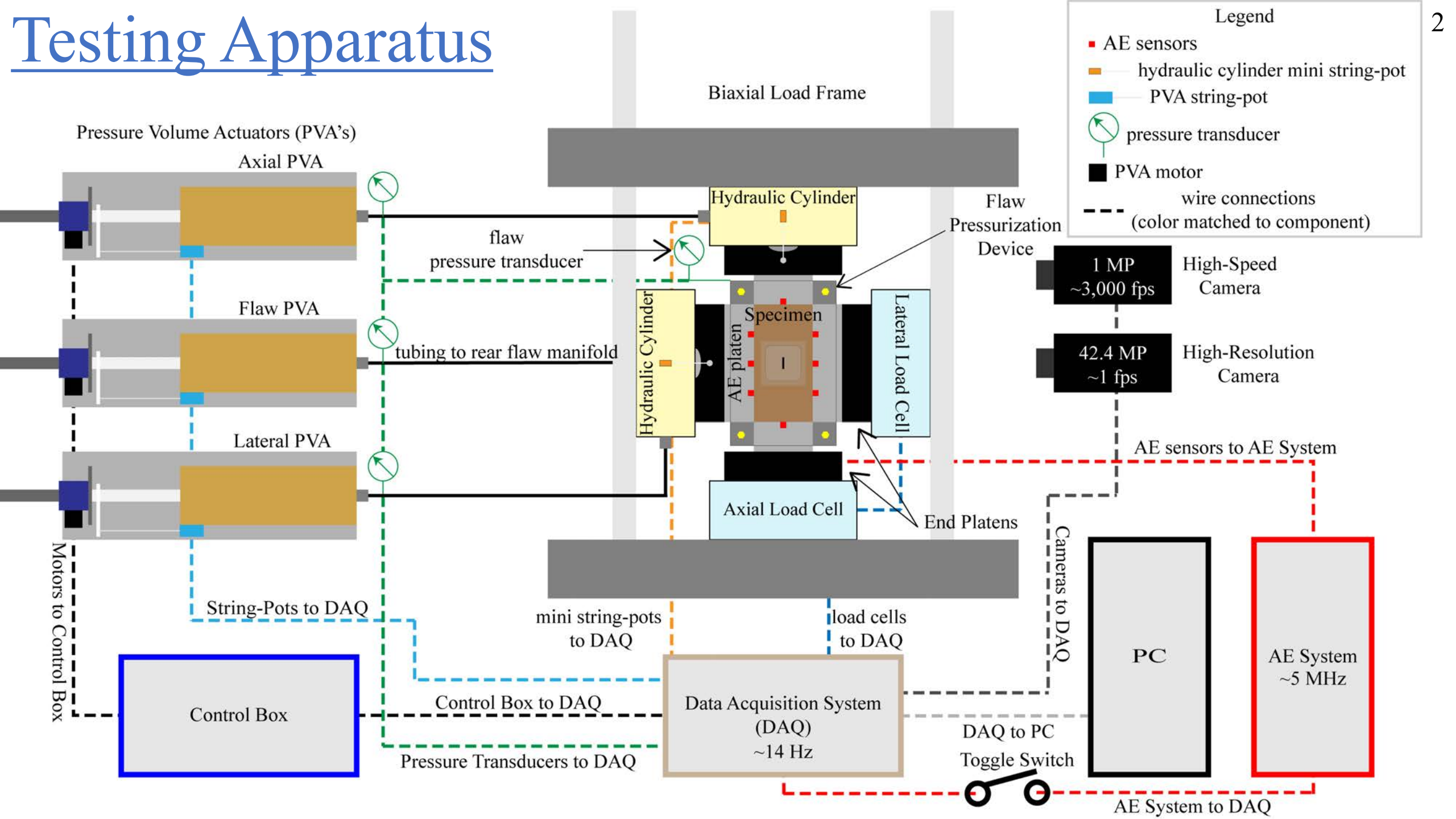
May 25, 2022



# Engineering Fractures



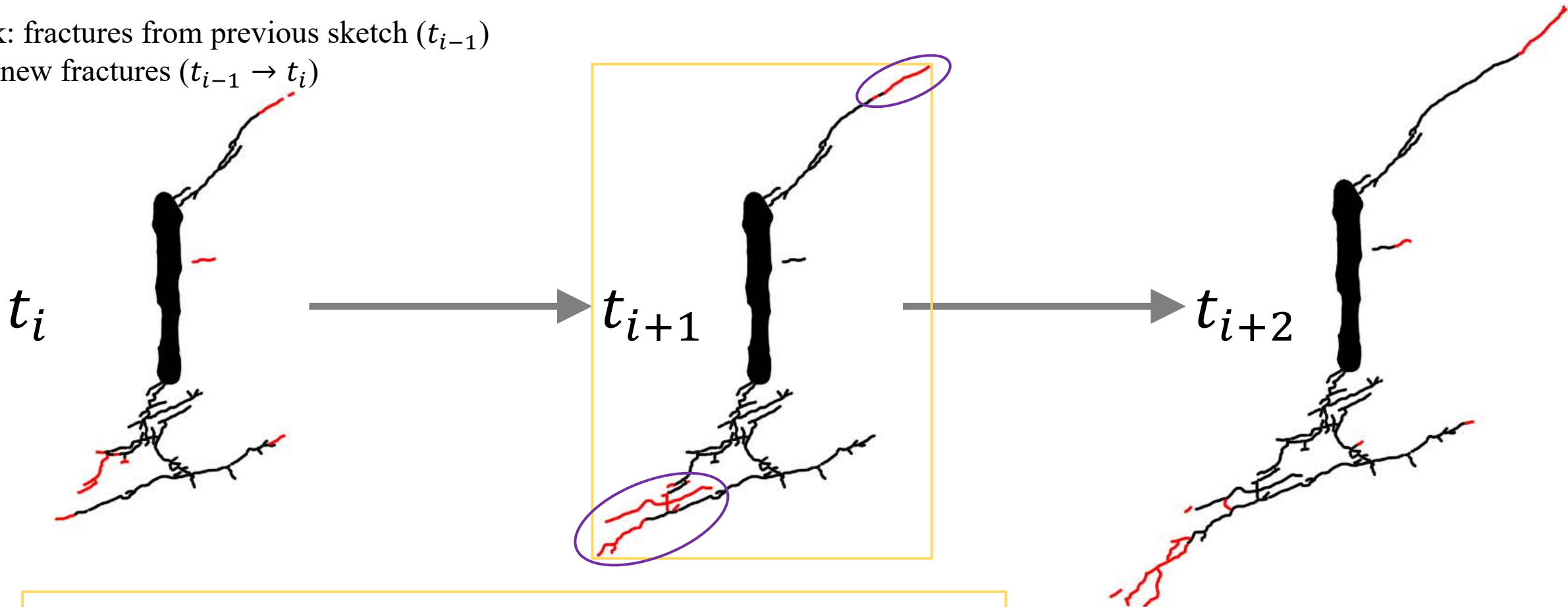
# Testing Apparatus



# Quantitative Analysis: Static vs Dynamic

Black: fractures from previous sketch ( $t_{i-1}$ )

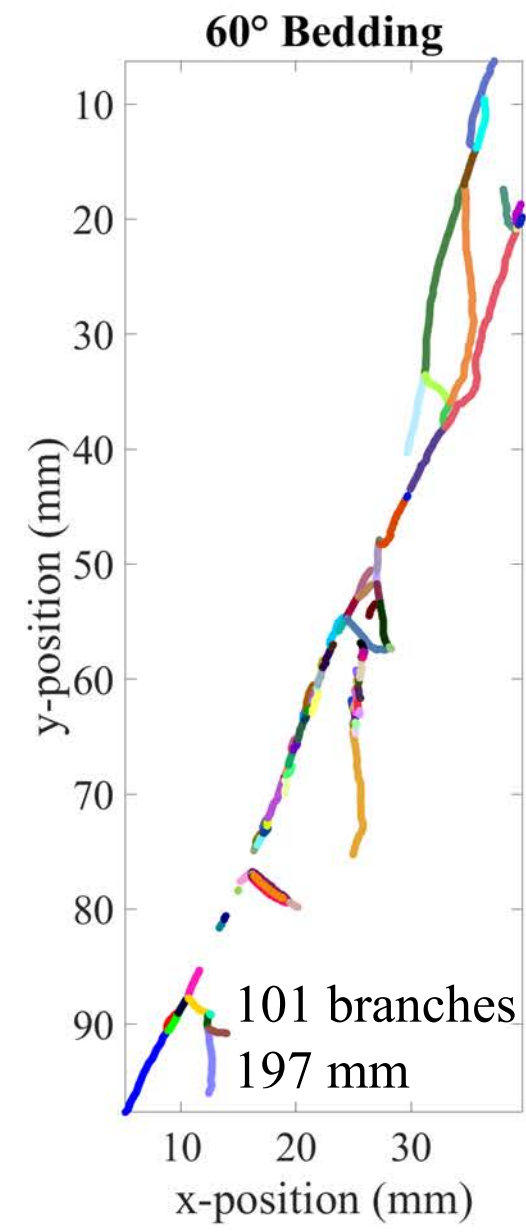
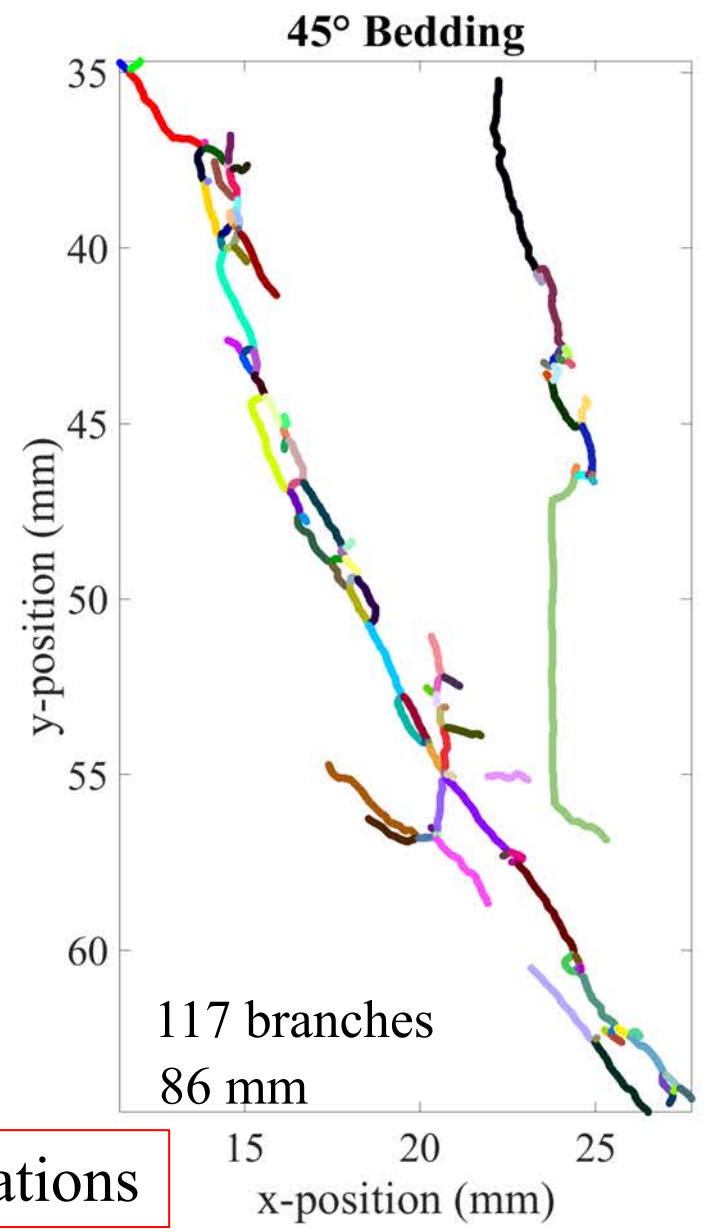
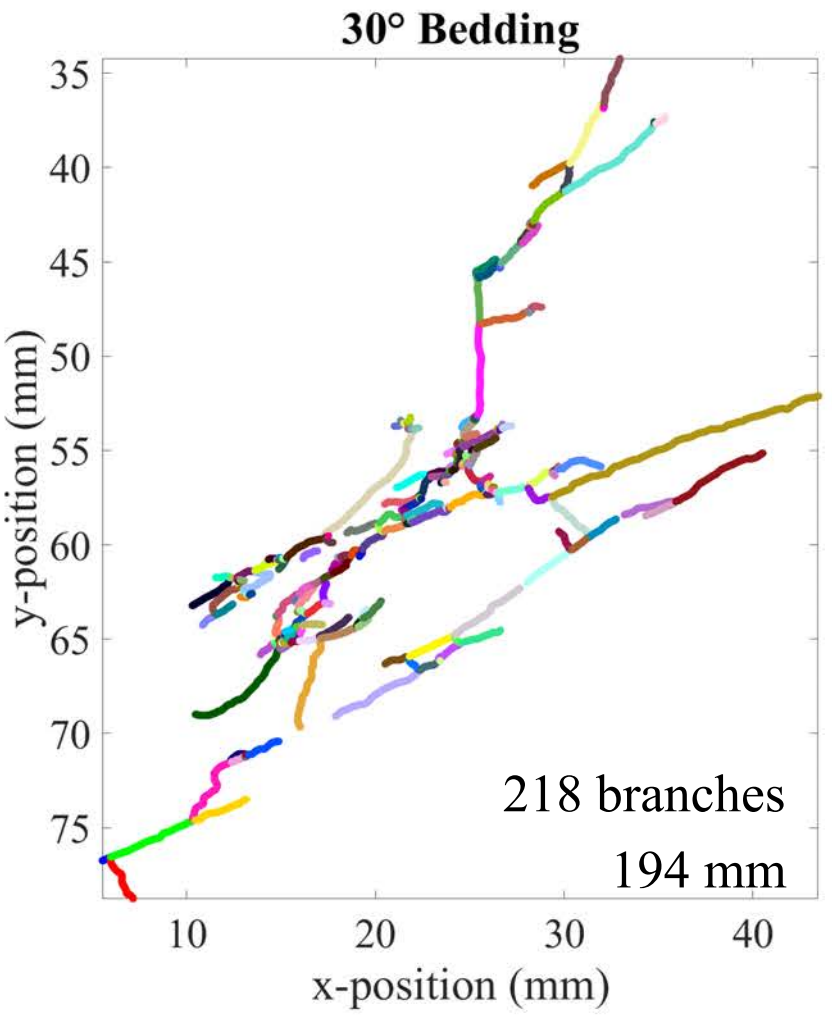
Red: new fractures ( $t_{i-1} \rightarrow t_i$ )



Static: All fractures in each sketch (red & black)

Dynamic: only incremental fracture growth in each sketch (red only)

# Static Analysis

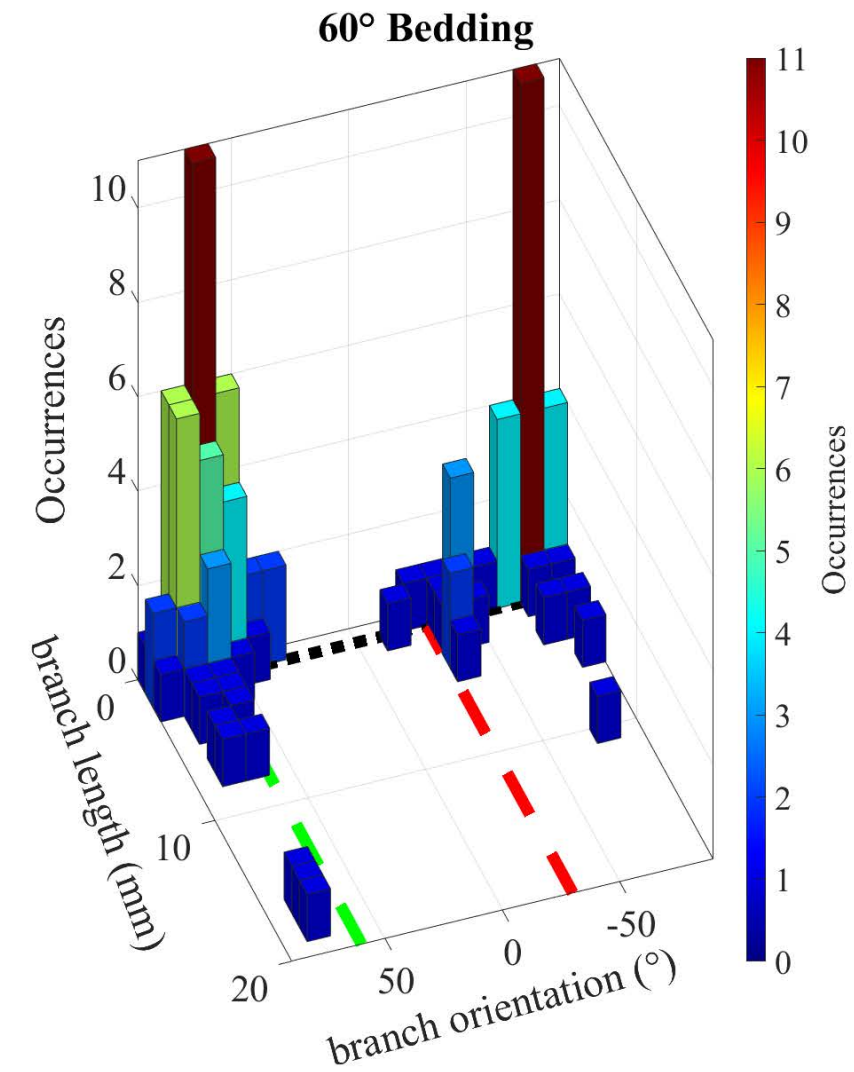
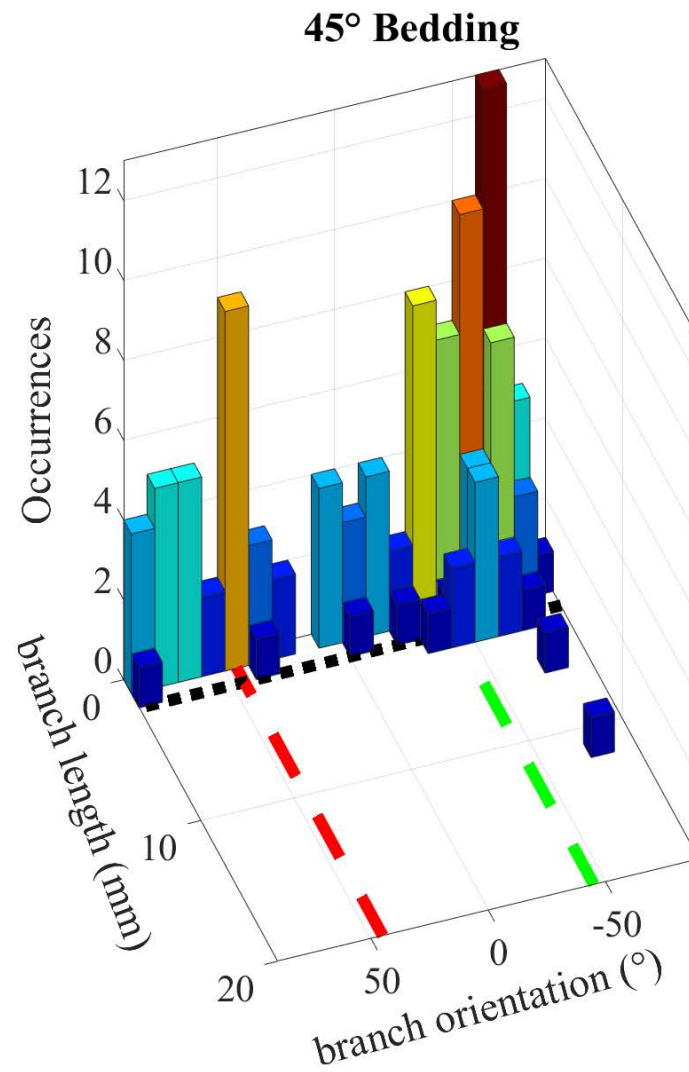
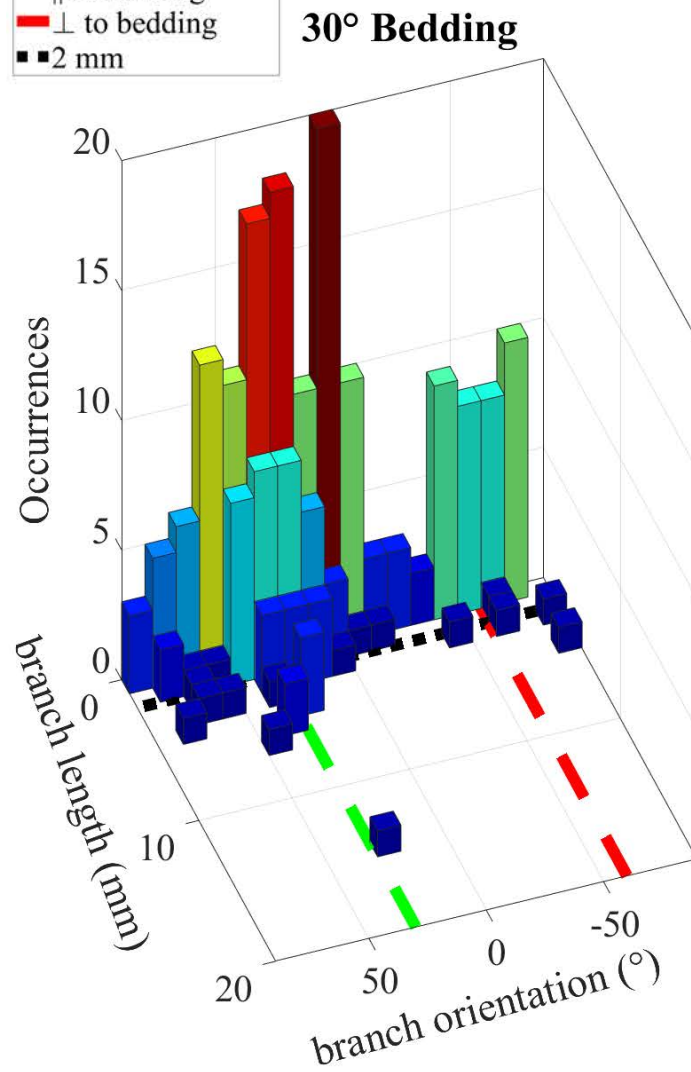


Calculate Branch Lengths & Orientations

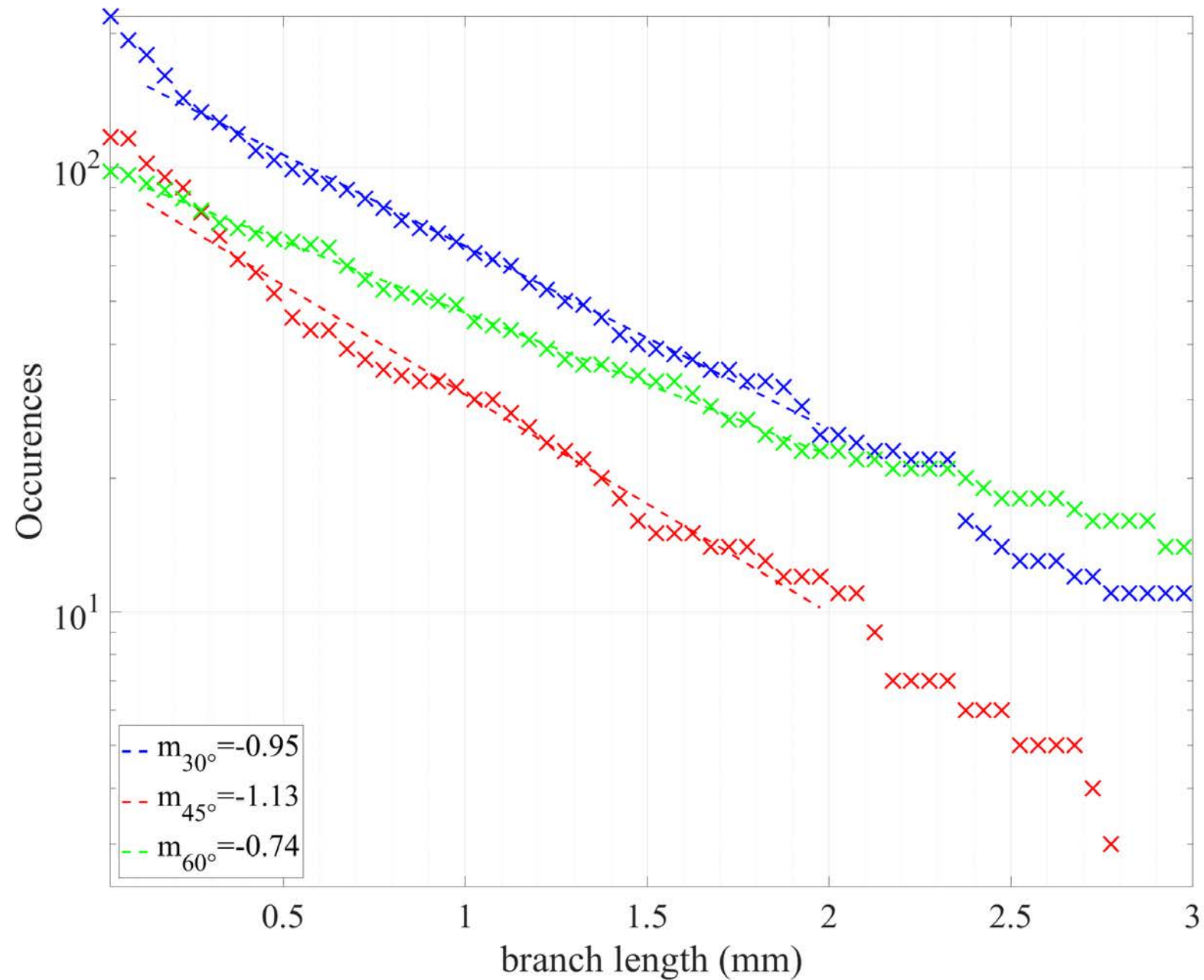
# Branch Length & Orientation Distributions

Trends: 1: *short*  $\parallel$  *bedding*      2: *short*  $\perp$  *bedding*      3: *long*  $\parallel$  *bedding*

Bin: 10° 1.00 mm  
 $\parallel$  to bedding  
 $\perp$  to bedding  
 2 mm



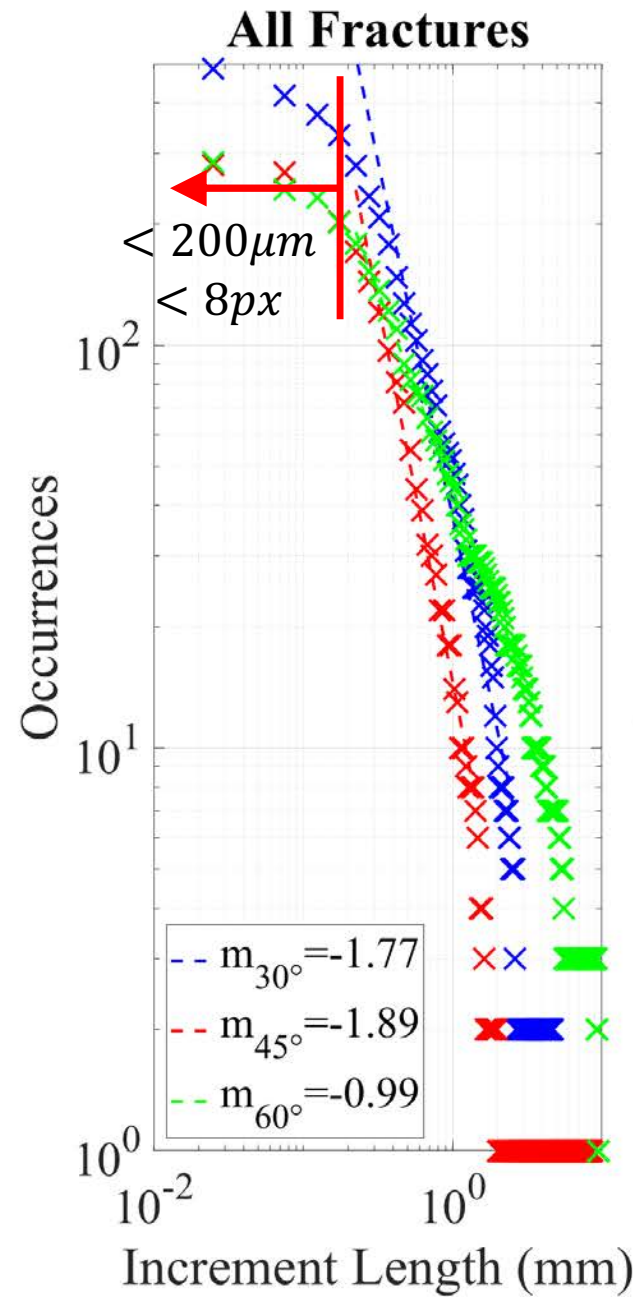
# Static Fracture Network Distributions



Exponential

$$\lambda \approx 1$$

# Dynamic Fracture Propagation Behavior



## Power Law

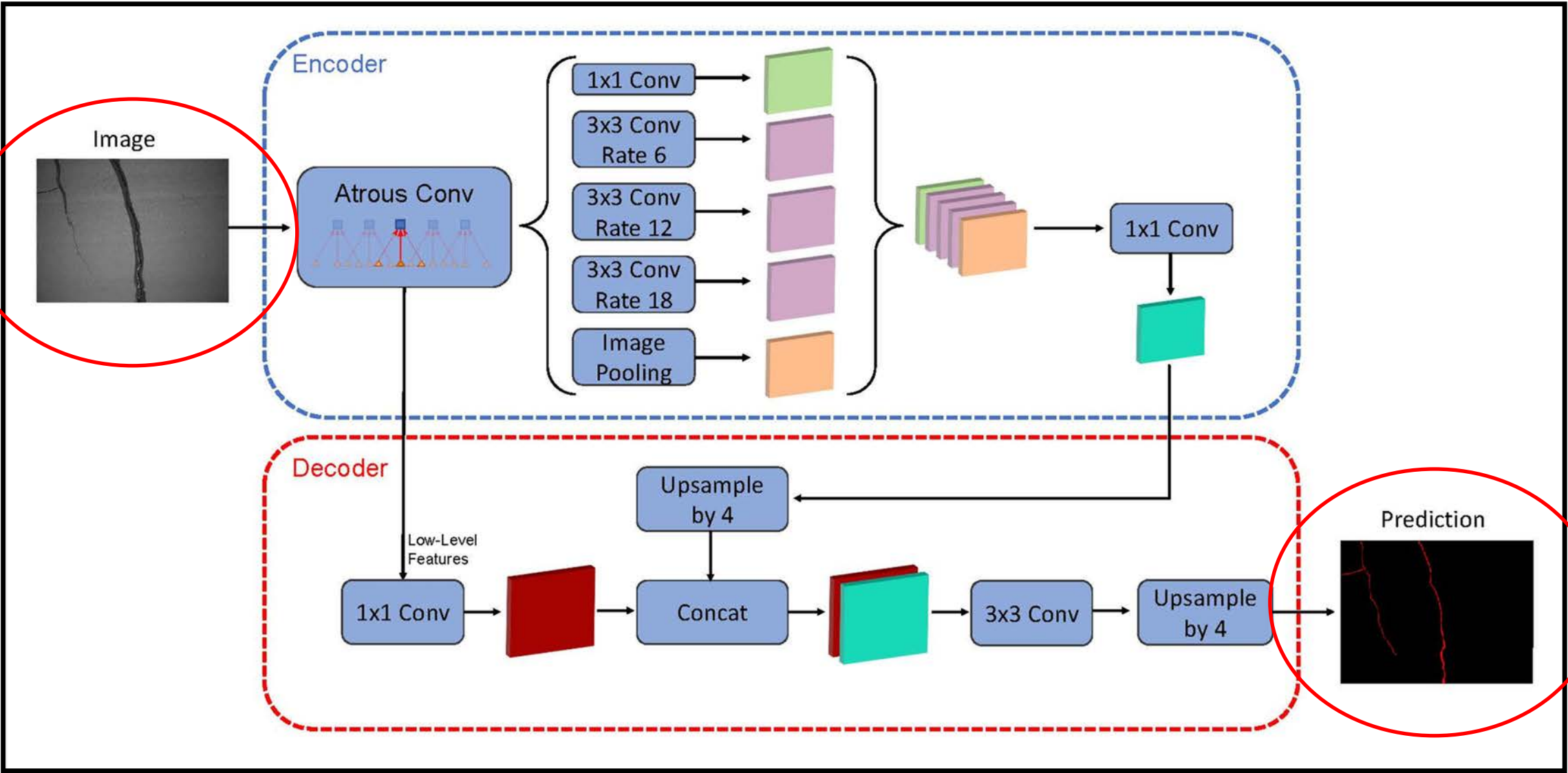
$n$  of (10mm+)  
 $\rightarrow 10n$  of (1mm+)  
 $\rightarrow 100n$  of (0.1mm +)  
 $\rightarrow \dots$





# CNNs for Semantic Segmentation

DeepLabv3+ Architecture

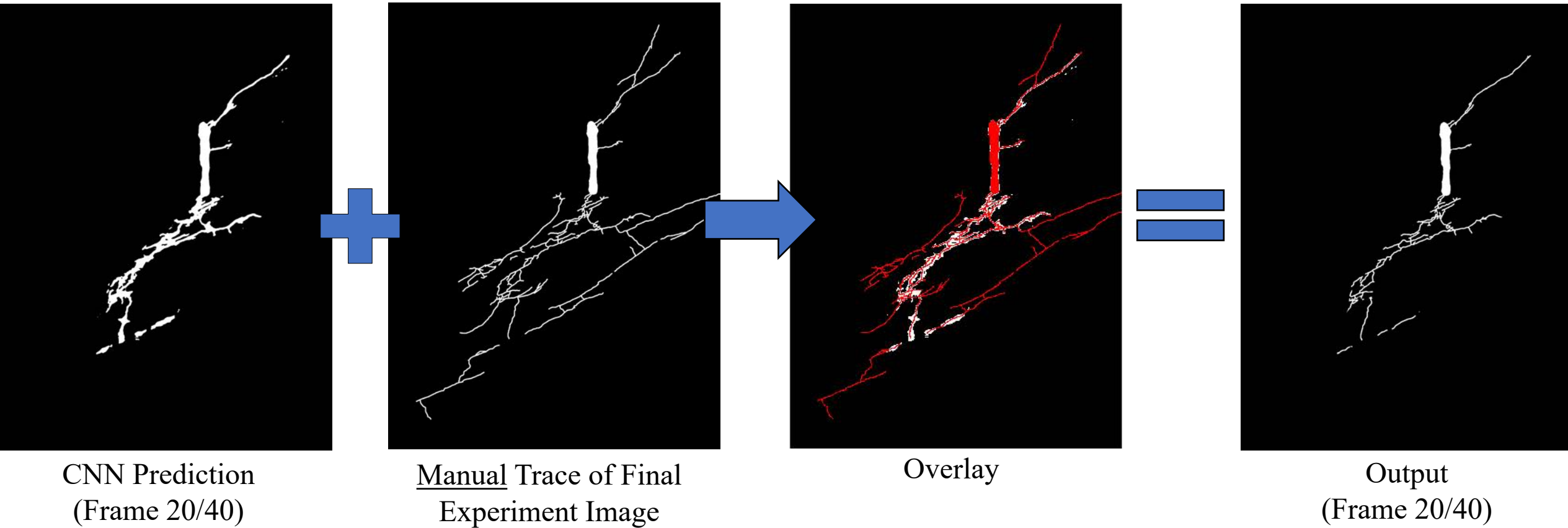


From: (Chen et al. 2018)



# CNN Output Trimming

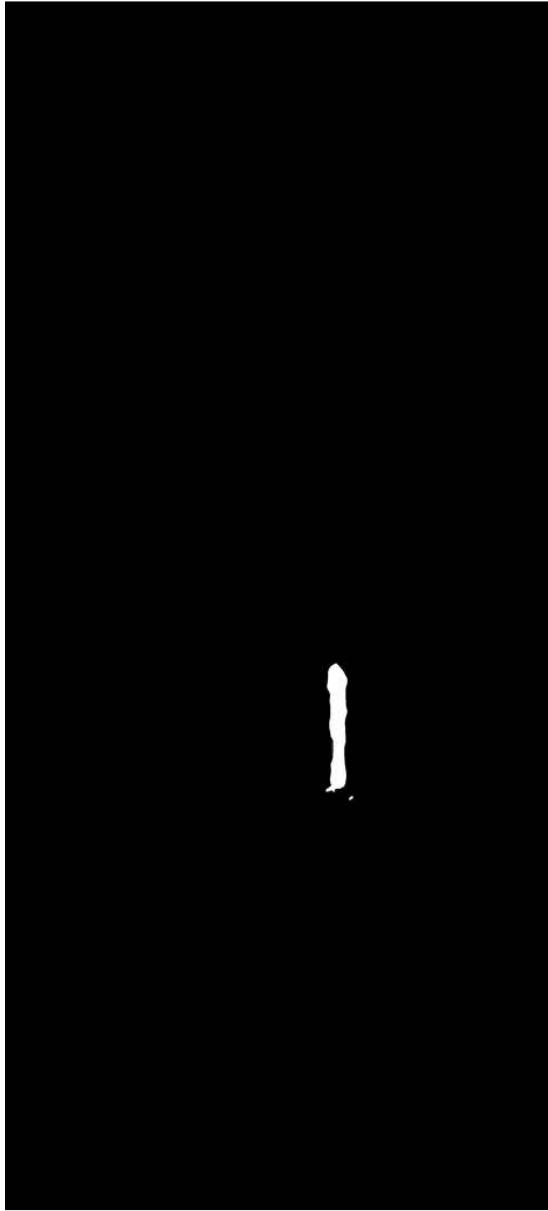
Spatio-temporal coherence in each successive frame of an experiment allows improved accuracy provided a single manual trace of the final frame.



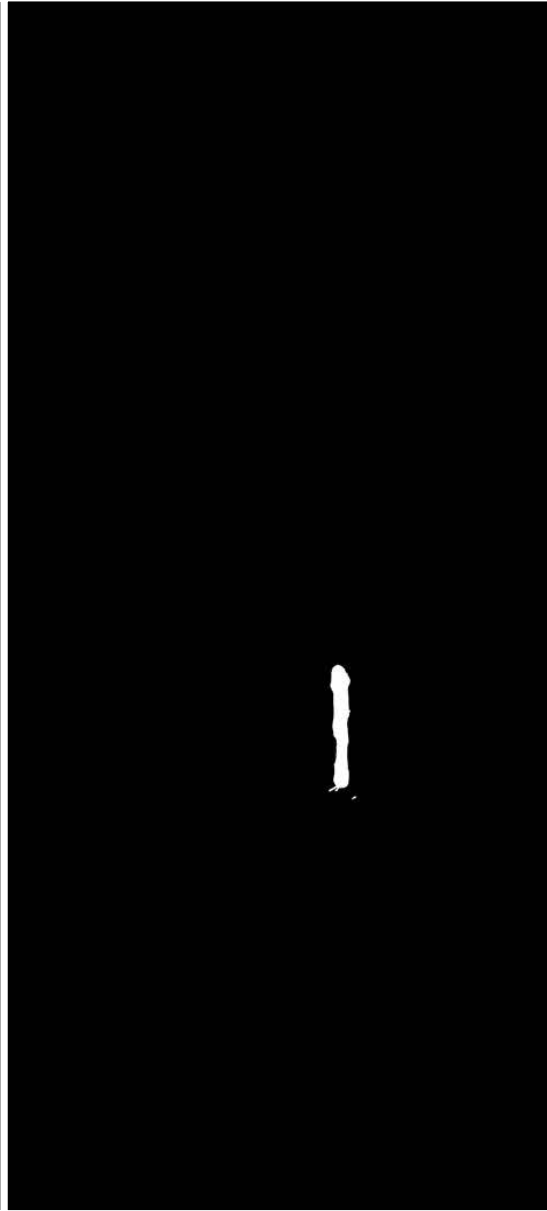
Original



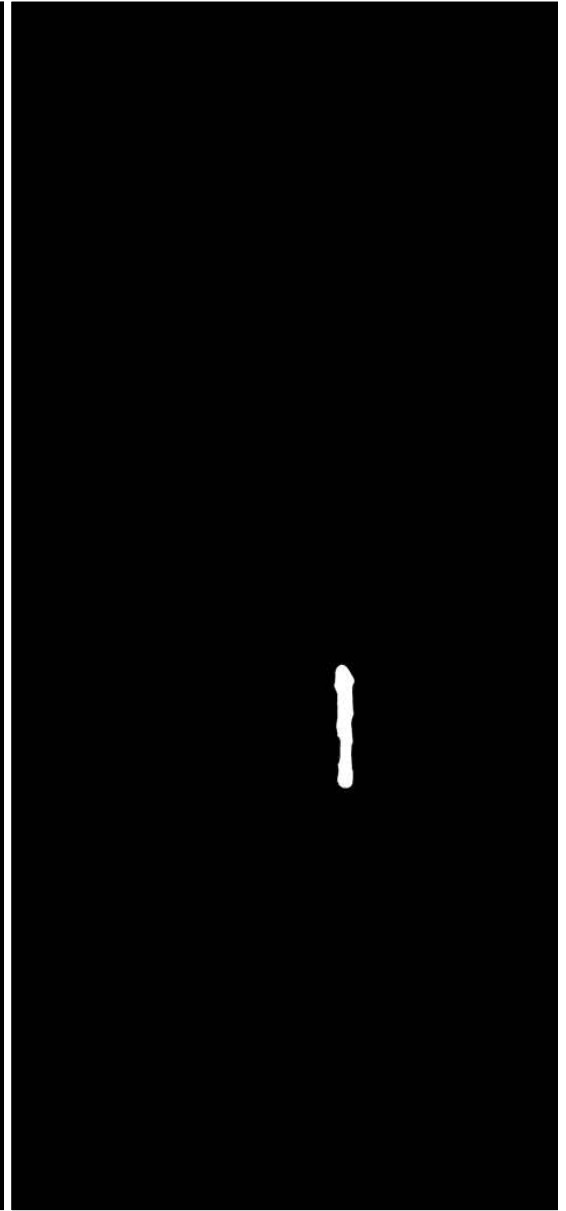
Untrimmed



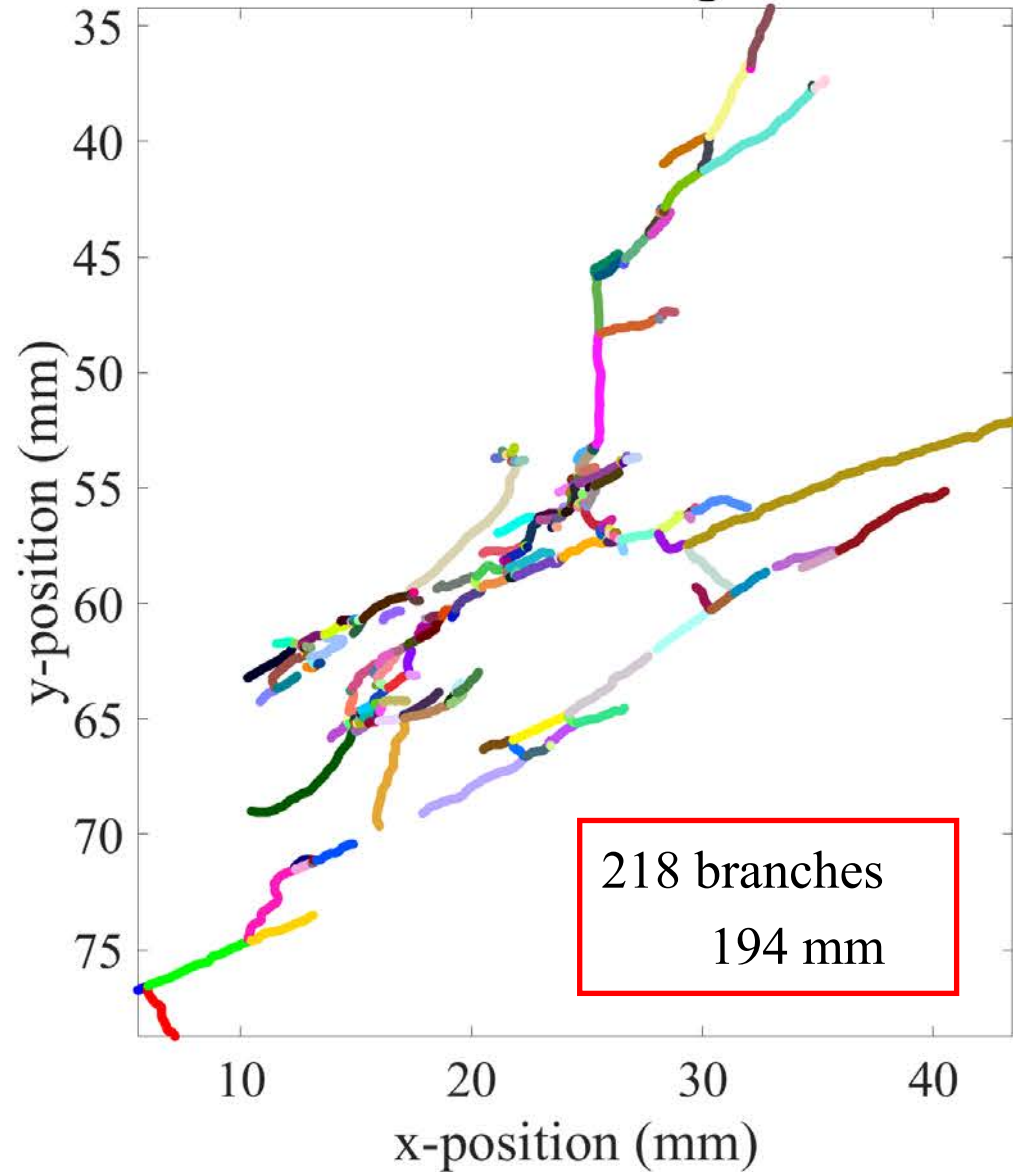
Trimmed



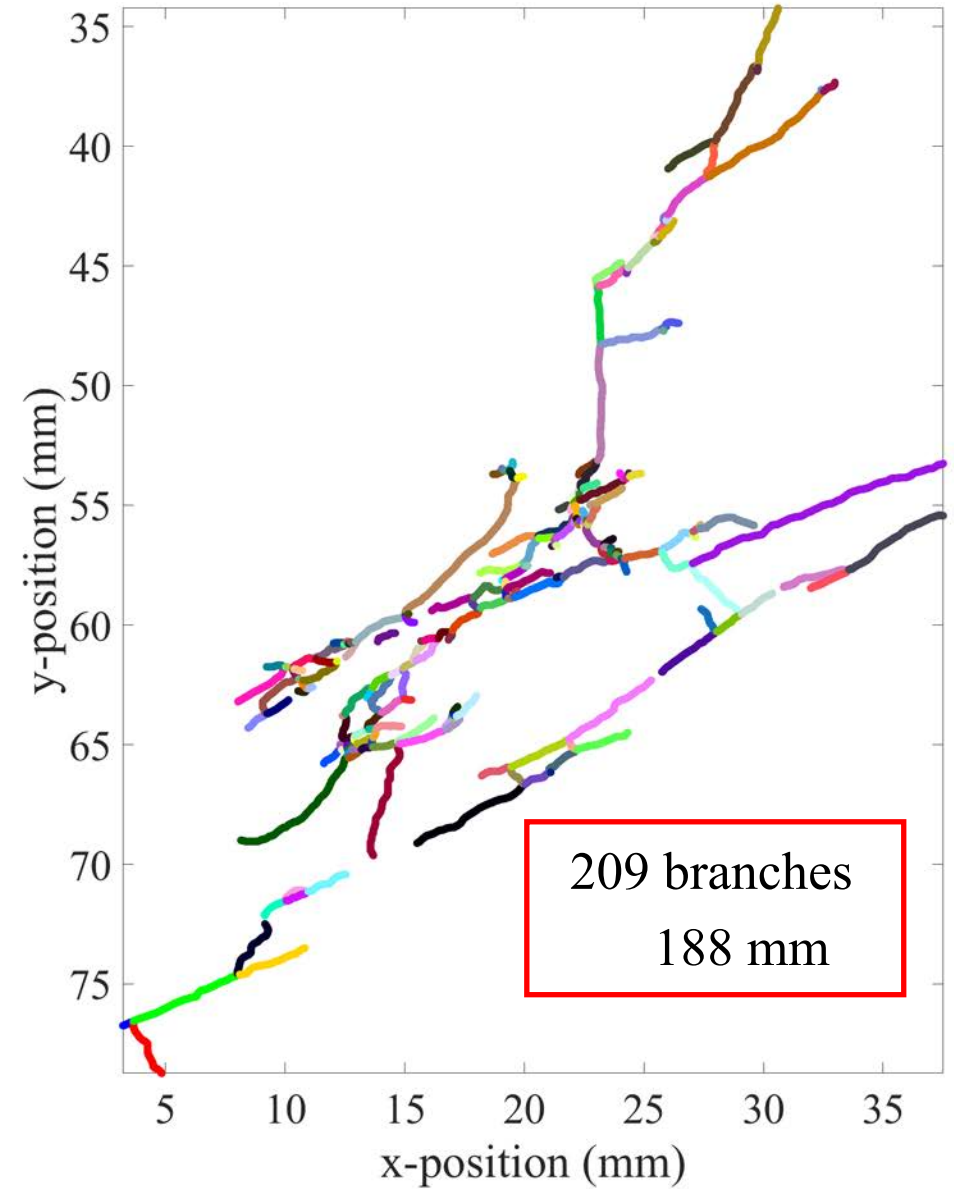
Manual



## Manual

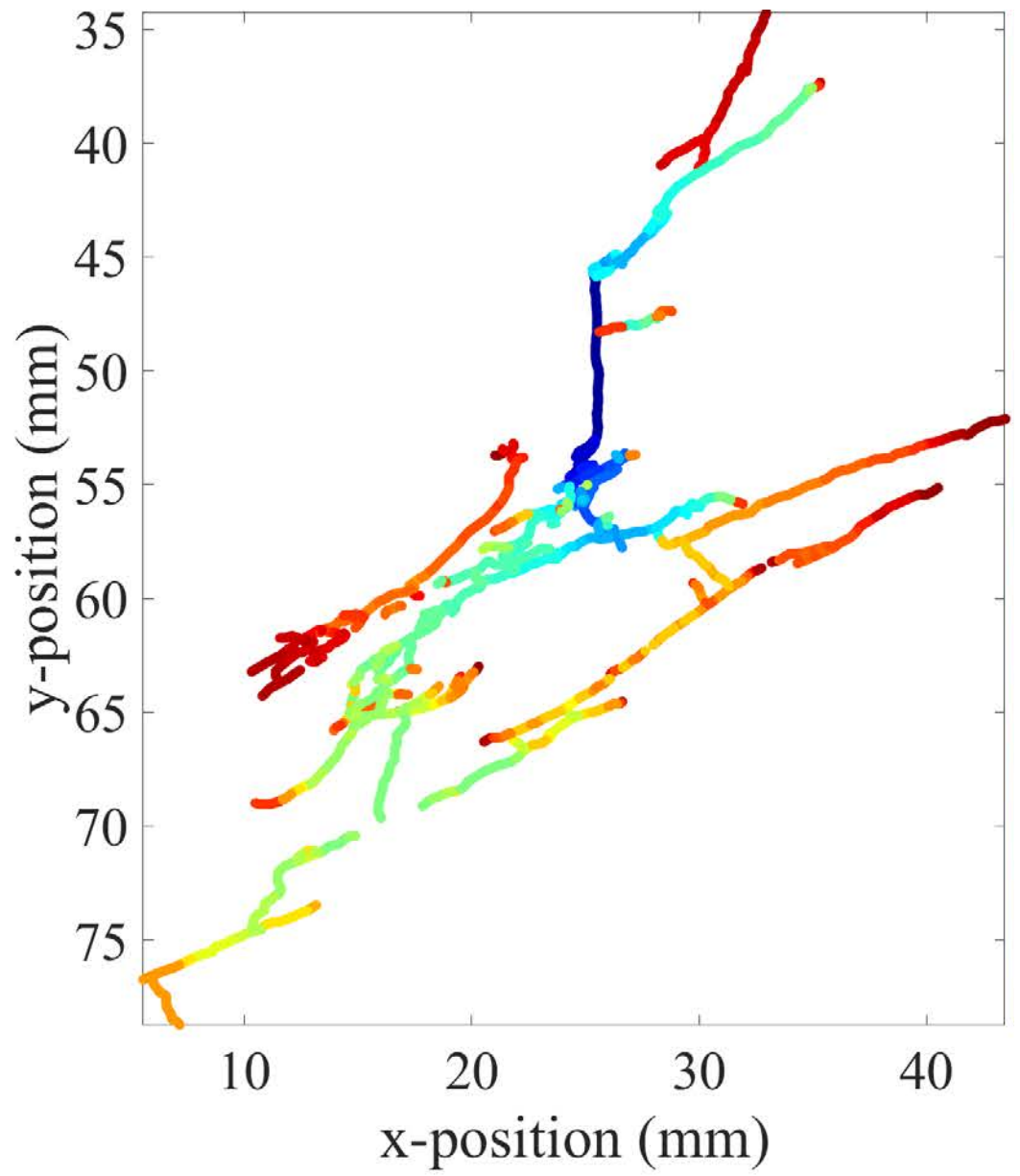


## ML

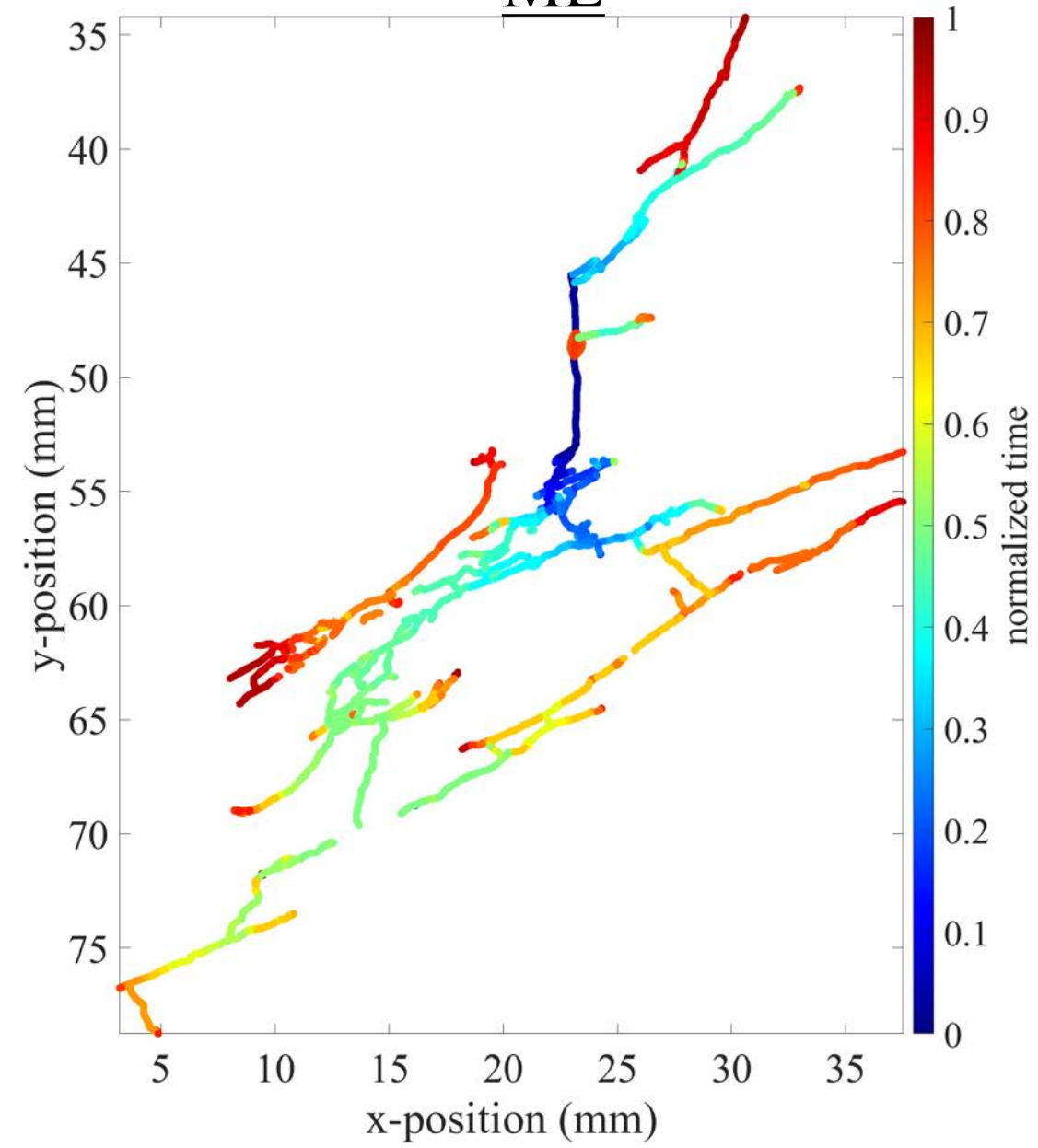


# Dynamic Analysis

Manual

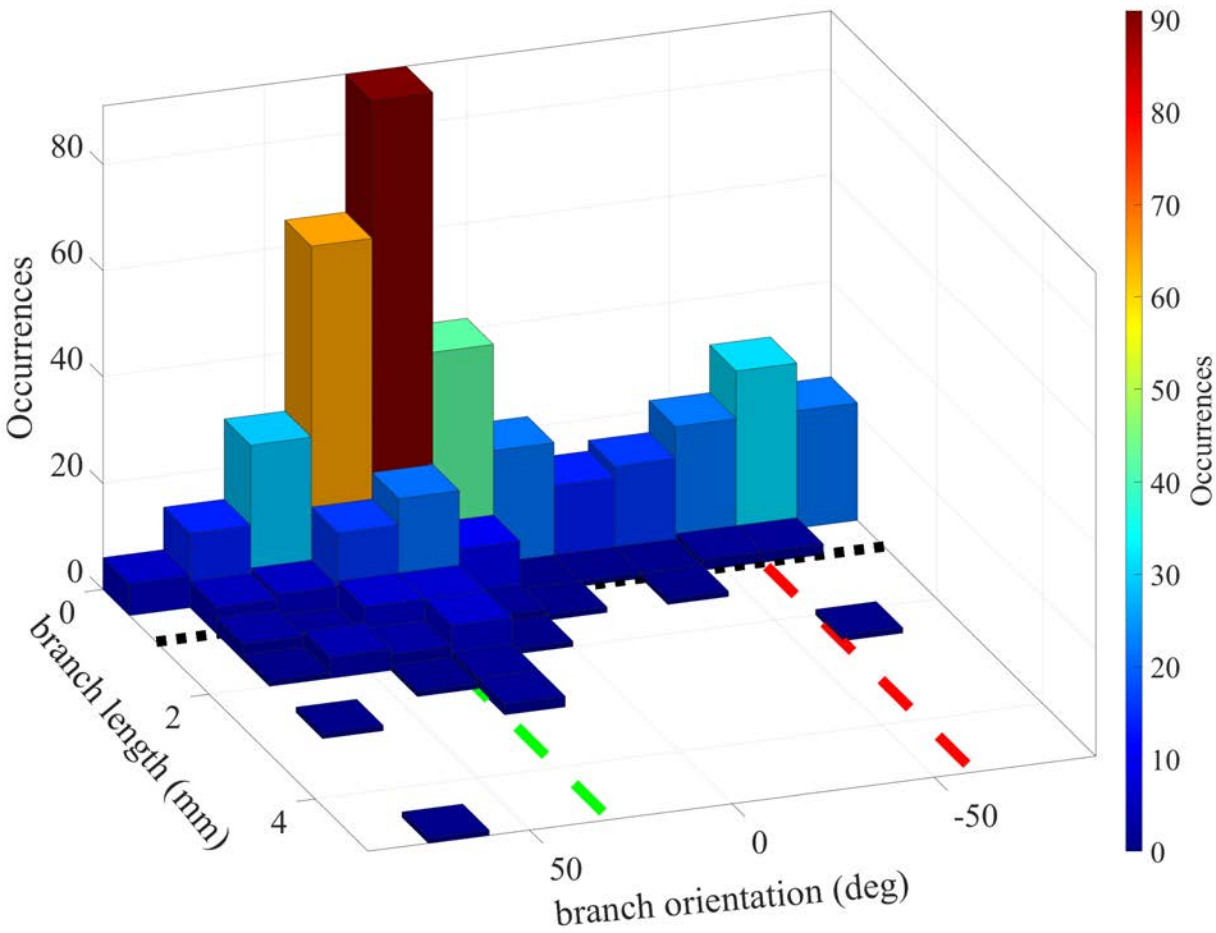


ML

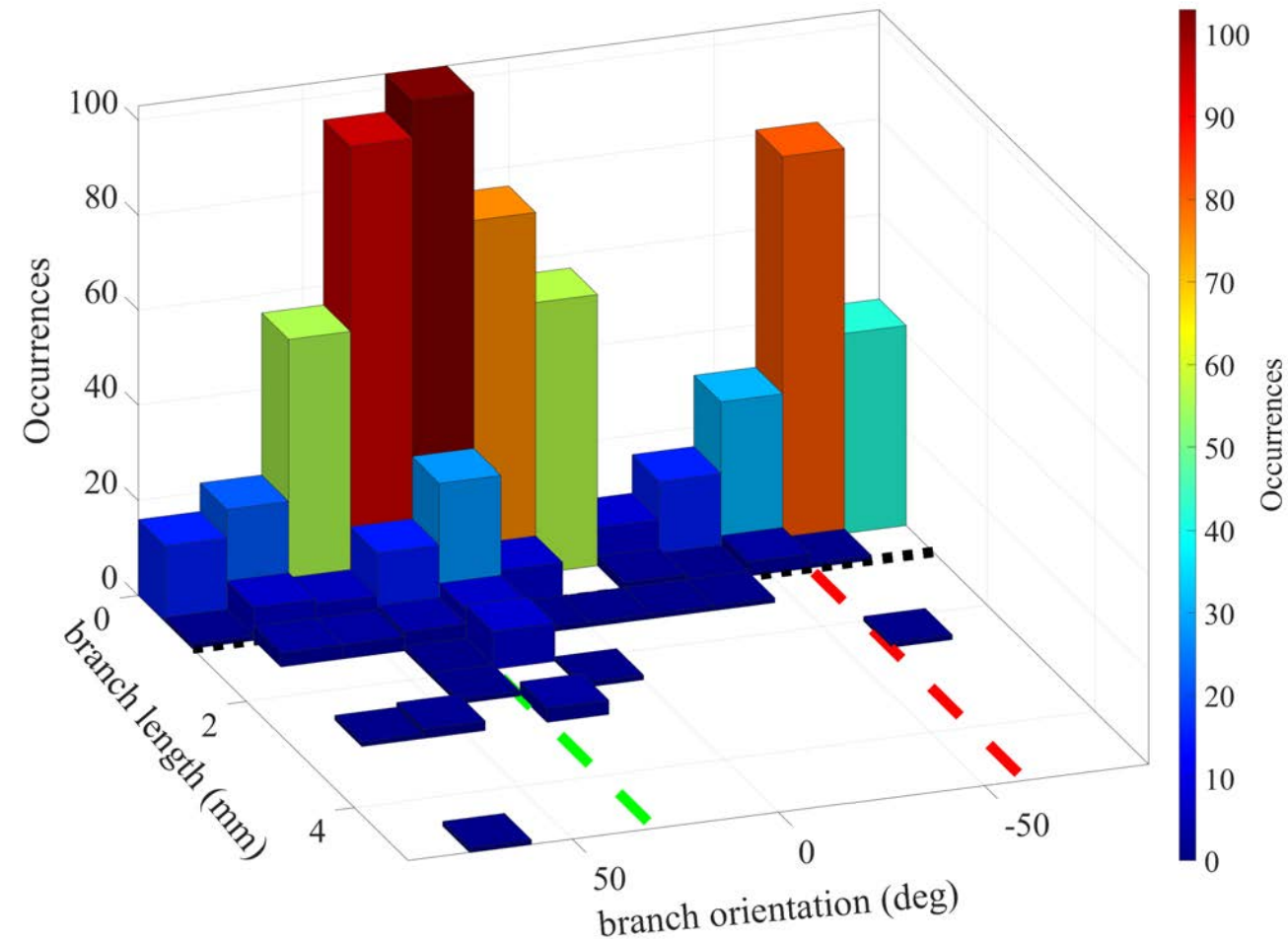


# Branch Length & Orientation Distributions

Manual

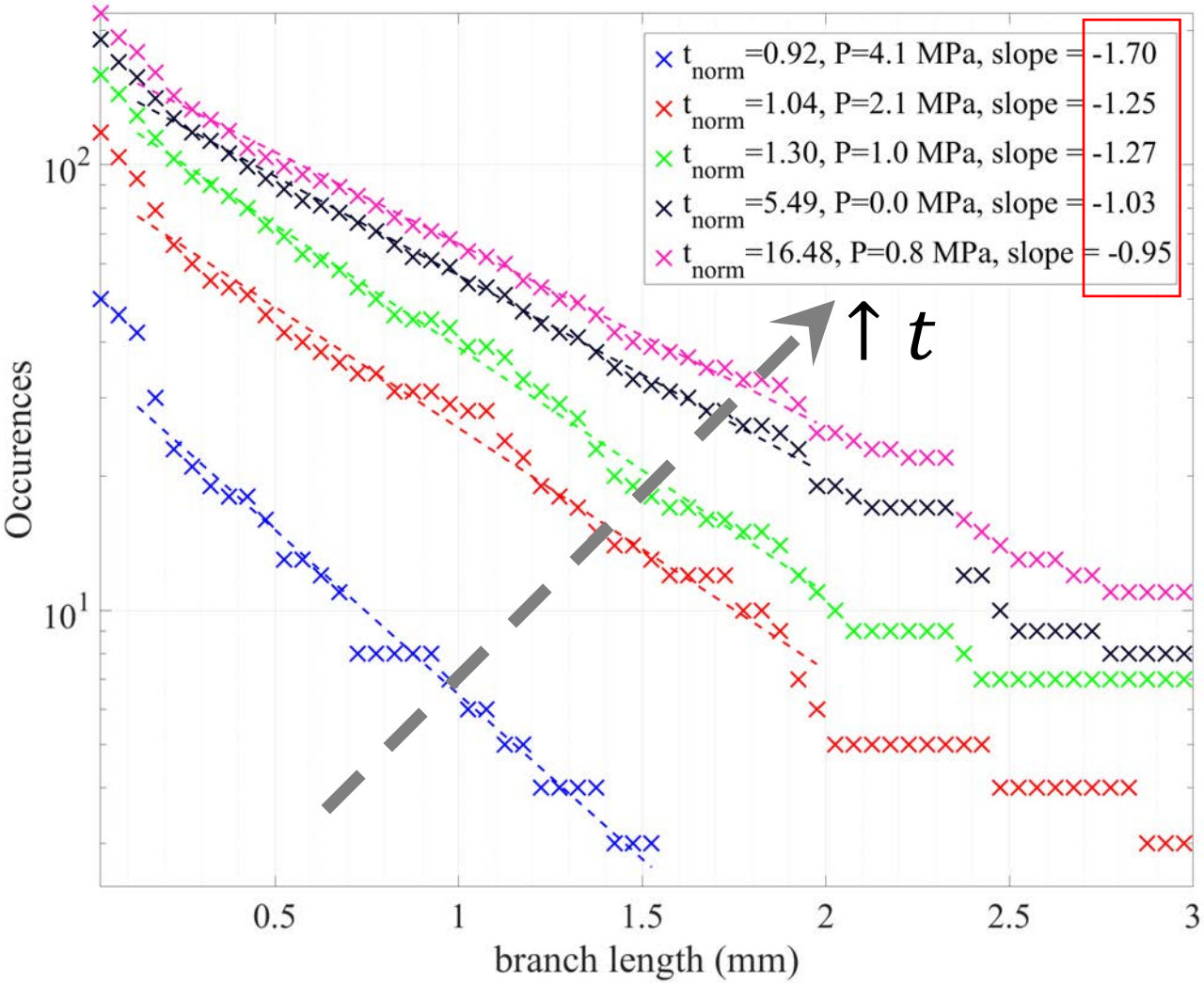


ML

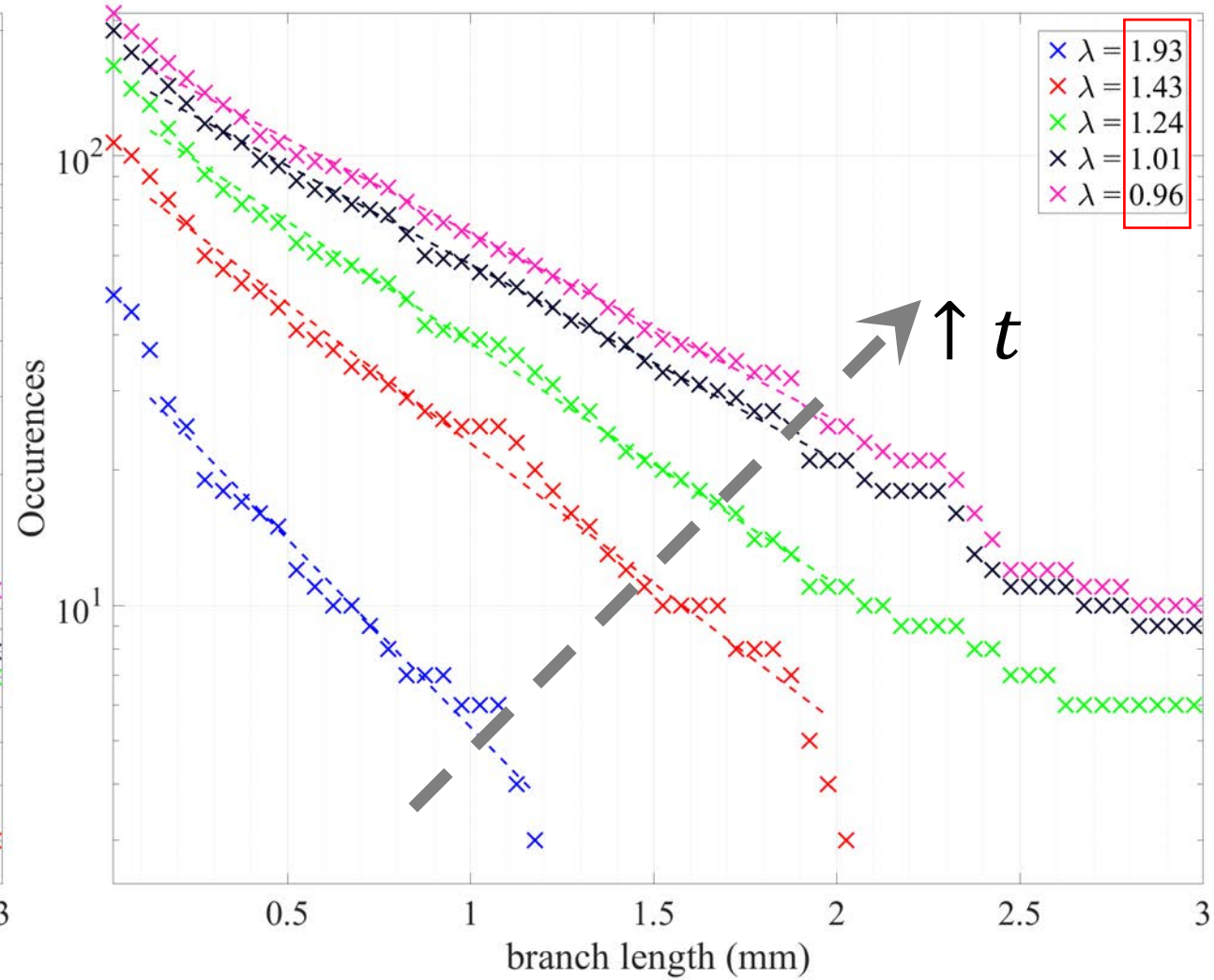


# Static Fracture Network Distributions (over time)

## Manual

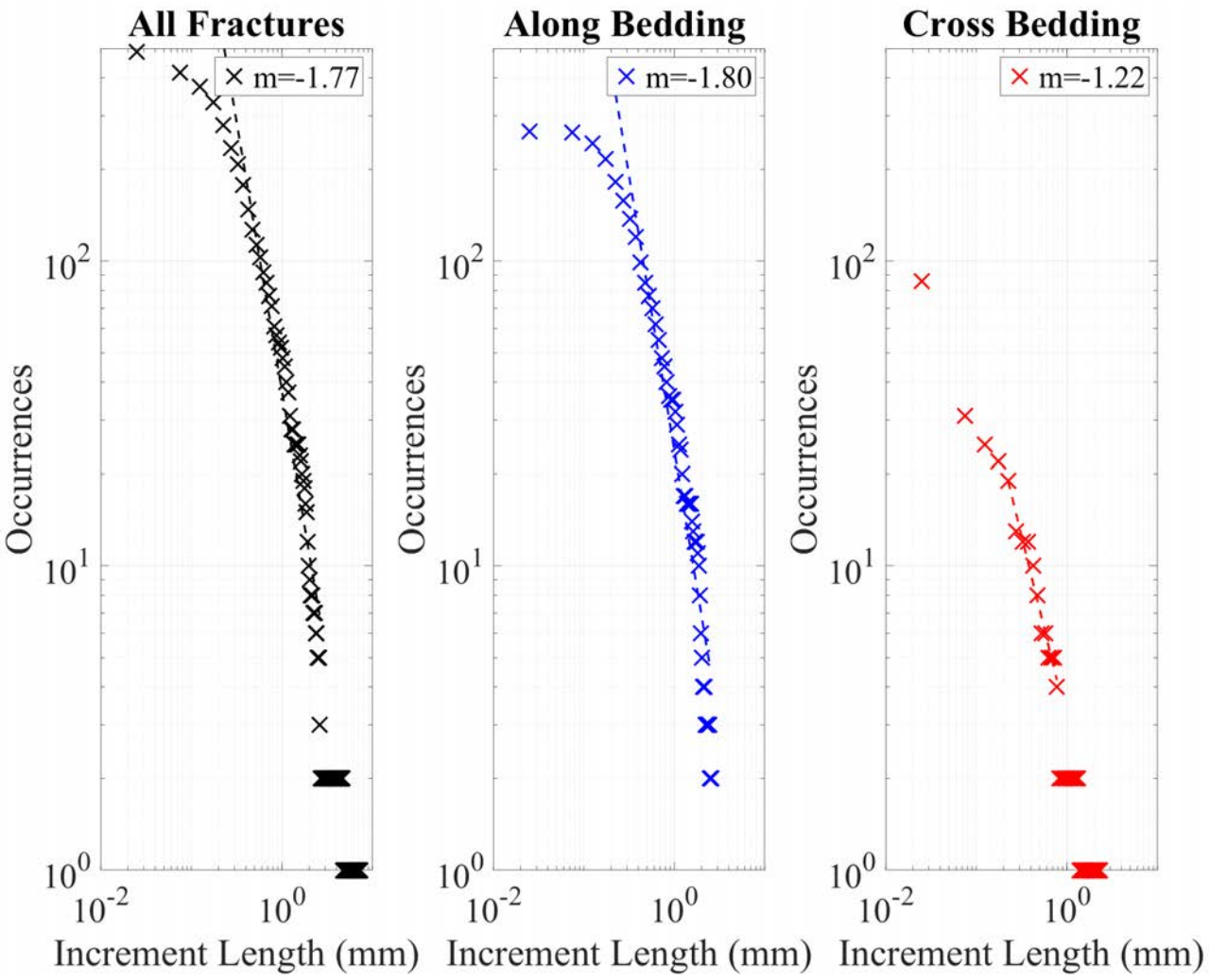


## ML

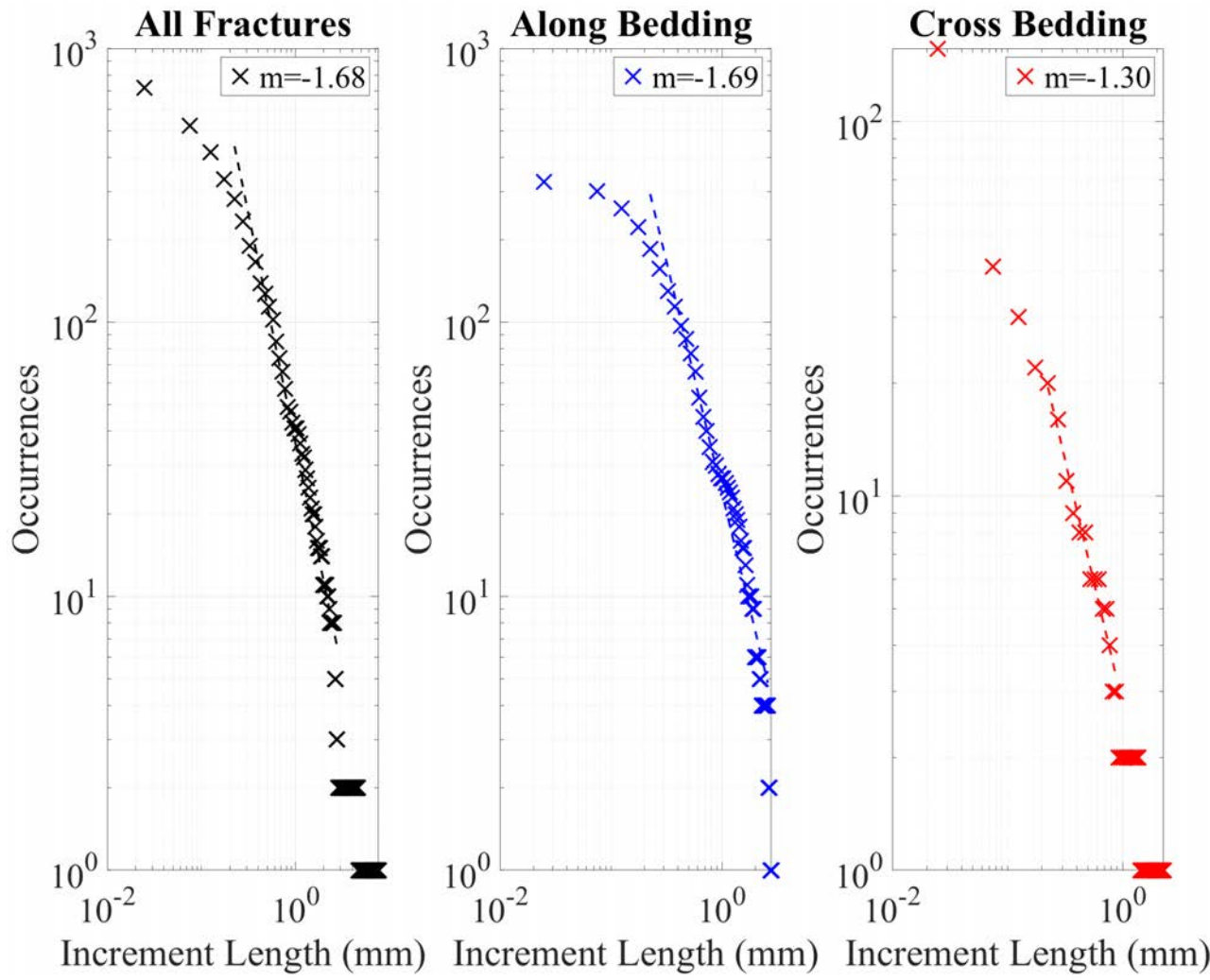


# Dynamic Fracture Propagation Behavior

## Manual



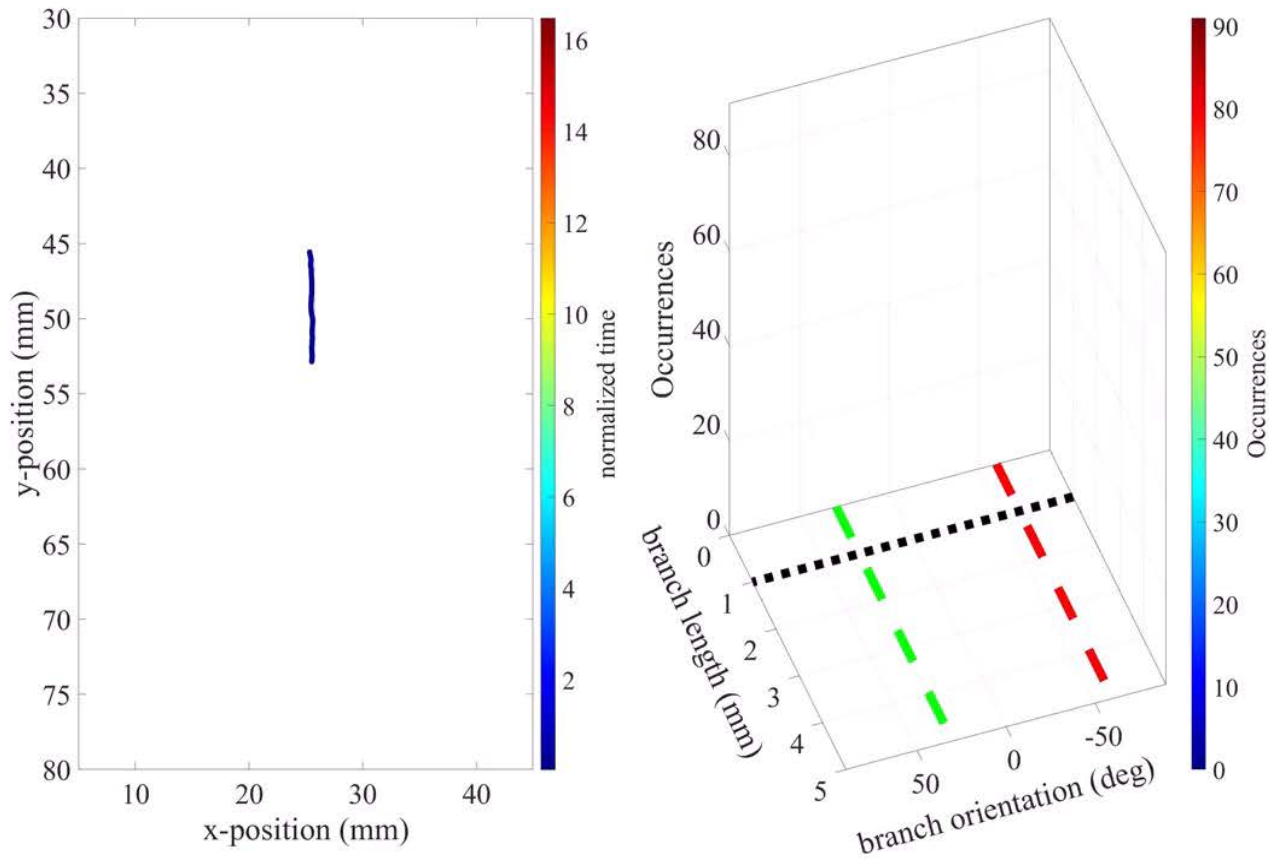
## ML



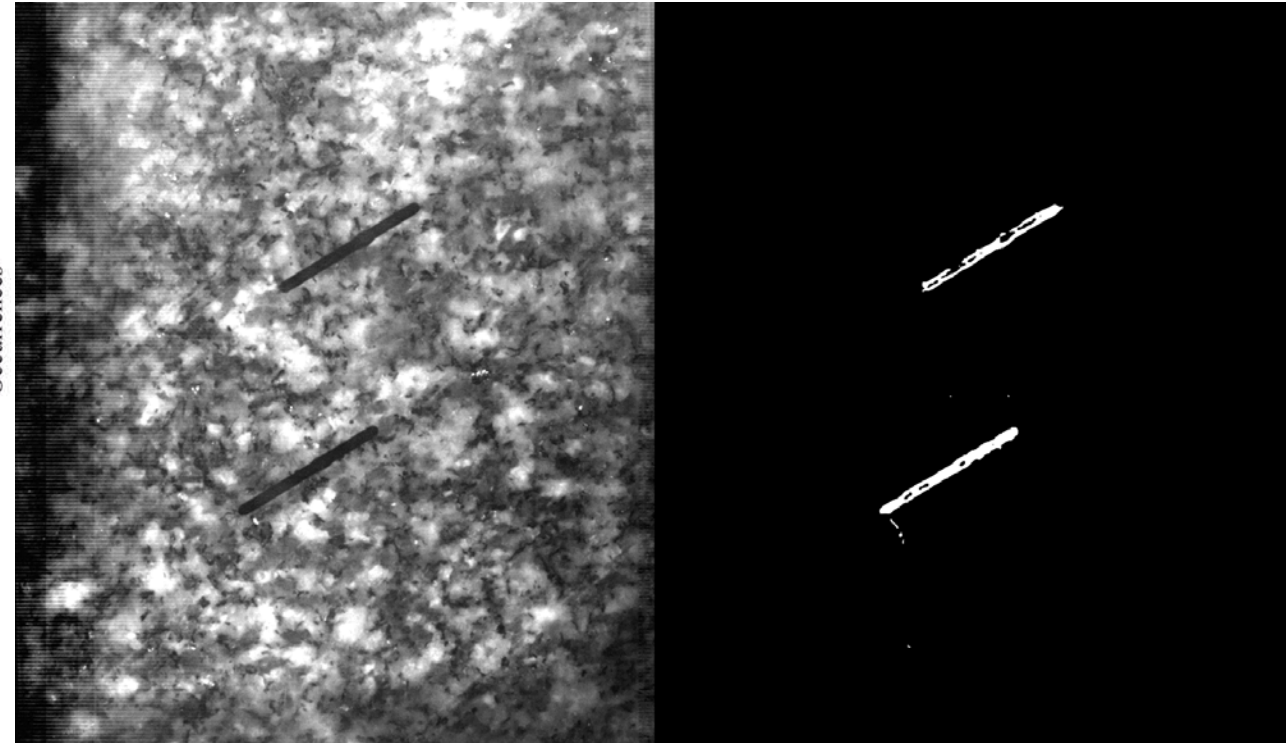


# Conclusions

## Quantitative Analysis



## ML Fracture Detection



Hydraulic Fracture of Granite



# Questions?

## Quantitative Image Analysis of Fracture Propagation:

Automating time-intensive manual analysis  
methods with machine learning

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