An Investigation of Laboratory Scale Crown Fire Initiation in Shrubs

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Outline

- Research motivation
- Background information
- Research objective
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- Experimental Setup
- Large Eddy Simulation Setup
- Results
- Future Work
- Conclusions

Research Motivation

Research Motivation

- Fi nd ar
  - 93 w c
- N are go
- In n a sp

Background Information

Wildland fire types

- **G**
- **Su**
  - l
  - es
- **Cr**
  - es

Wildland fire types

- **Gr**
  - I
    s
    h
    I
- **Su**
  - I
    c
    c
- **Cr**
  - S
    c
  - T
  - I

Crown Fire Research

Physical Fire Behavior Model

- Zhou et al. (2007)
  - Governing equations based on the conservation equations for mass momentum, energy and species
  - Predict fuel temperature, spread rate, intensity, fuel depletion, etc...

Crown Fire Research

- **Tachajapong 2008; Tachajapong et al. 2008; Tachajapong et al. 2009**
    - Determined that surface fires through excelsior fuel beds led to ignition of crown fuel matrices when the crown was located within the continuous or intermittent flame regions.
    - Performed research under varying crown fuel bulk density
        - 0.75, 1.75, and 2.75 kg/m^3
        - Concluded that increased crown fuel bulk density enhanced the probability of crown fuel ignition

Research Objective

Research Objective

- Determine how the presence of multiple crown fuel matrices and the distance between adjacent matrices affects:
  - surface fire spread rate
  - transition process from a surface fire to a crown fire and fire transition from crown to crown

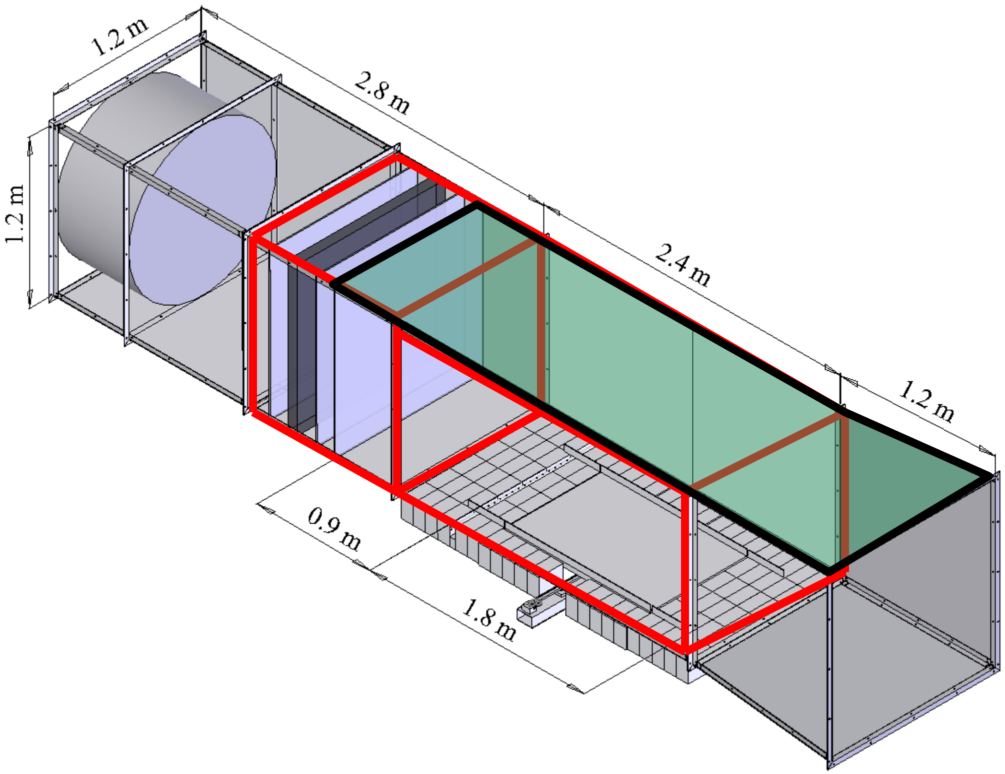
Methodology

- Perform experiments where the distance between adjacent crown fuel matrices is varied while capturing temperature data of branch, air, and surface fire
- Compare experimental results to those attained through use of an Large Eddy Simulation (LES) model

Experimental Tools

Wind Tunnel

- Cross section: 1.2 m x 1.2 m
- Length: 6.4 m
- Flow conditioning section
- Test section length: 2.4 m
  - Fuel bed
  - Thermocouple system
- Open roof
  - Allows fire to propagate undisturbed

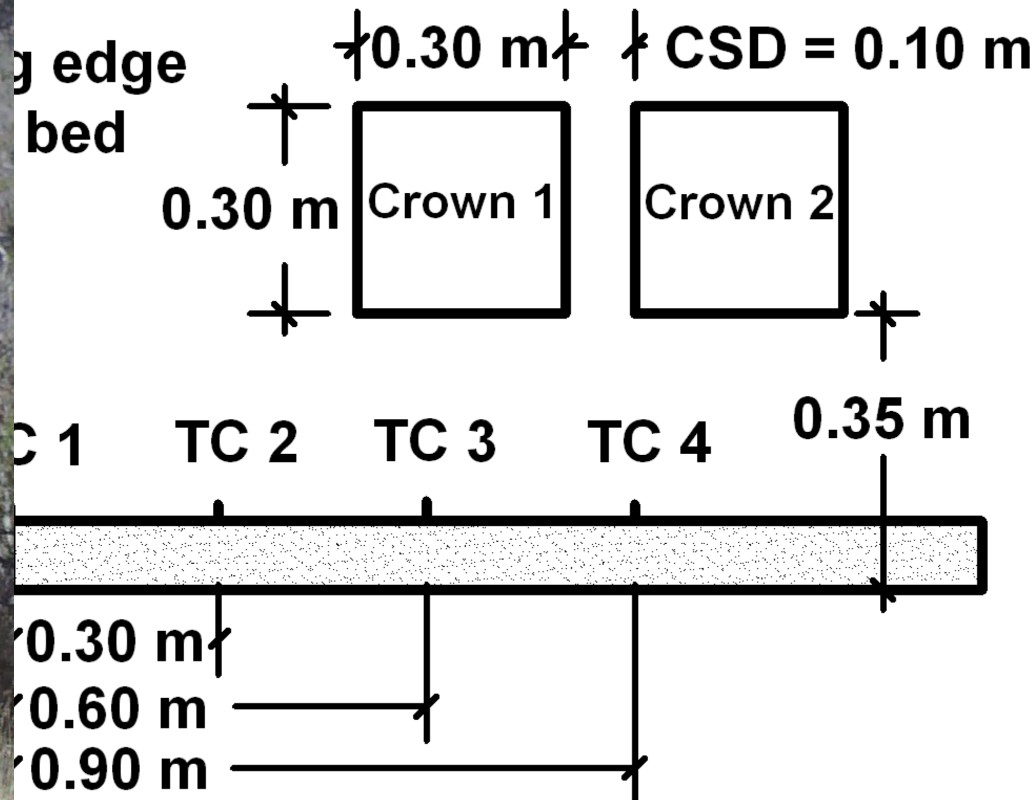


Tachajapong 2008; Lozano et al. 2008; Weise and Biging 1996; Wolff et al. 1991

Experimental Setup

Test Section

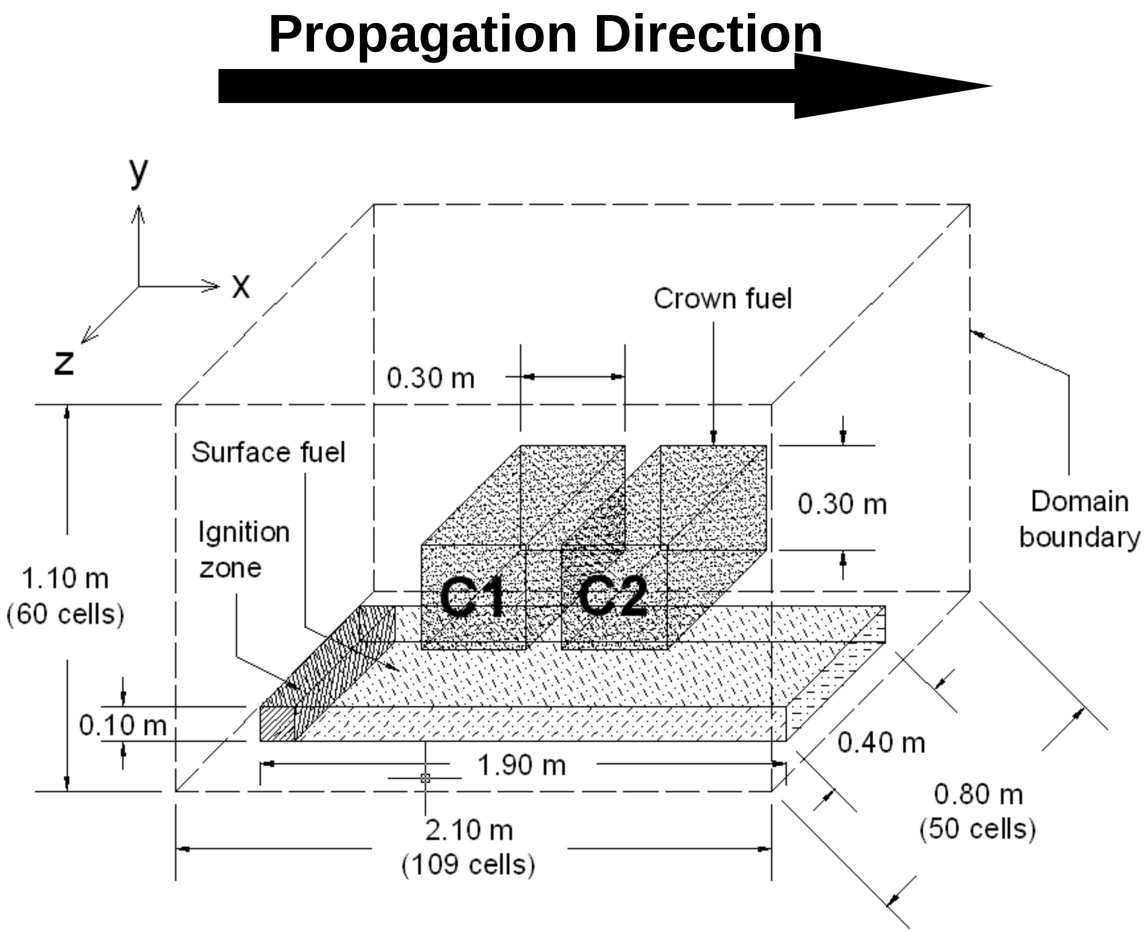
- Multiple crowns



Large Eddy Simulation Setup

Computational Setup

- Domain
  - Length: 2.1 m
  - Height: 1.1 m
  - Width: 0.8 m
- Surface & Crown fuels
  - Same as actual
- Fuel Dimensions
  - Smaller than actual
  - Fuel bed width: 0.4 m
  - Crown fuel width: 0.4 m



Results

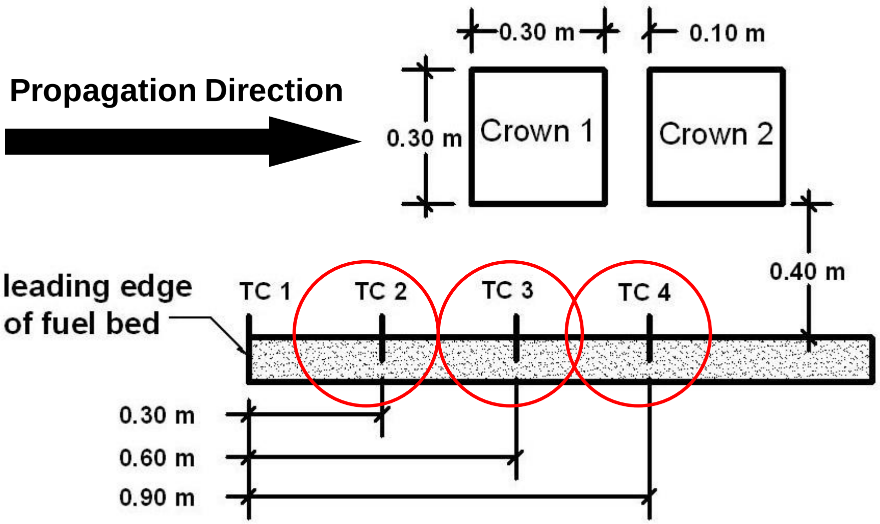
Experiments performed

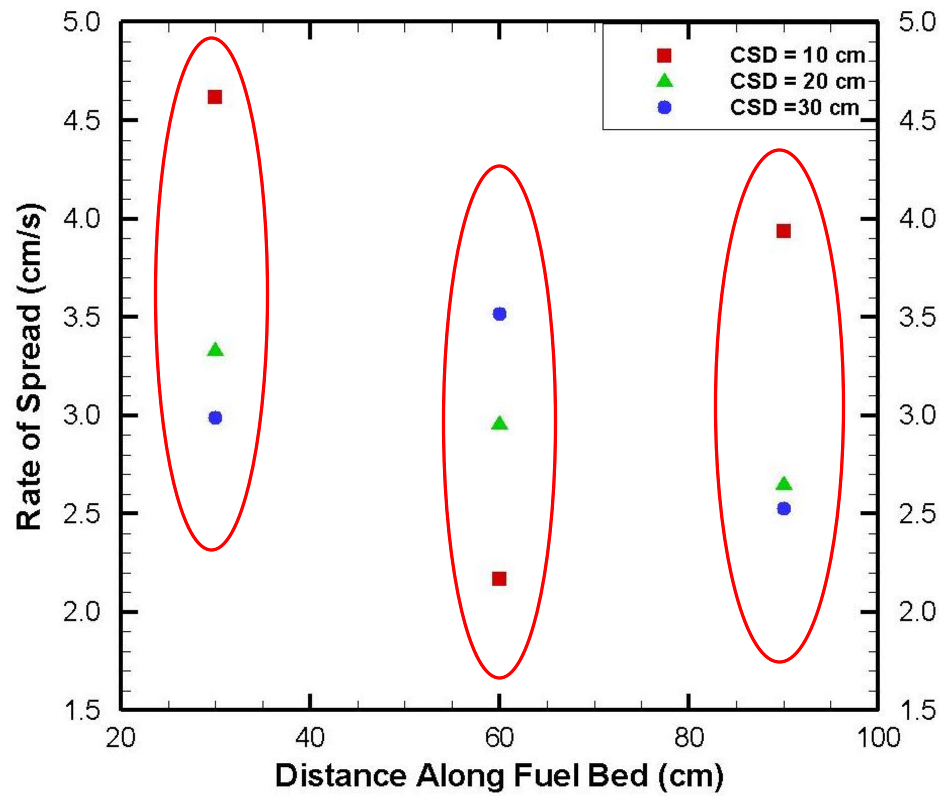
- Crown fuel separation distances: 0.1 m, 0.2 m, and 0.3 m
- Crown within intermittent flame region
- Wind speed: constant at 1.1 m/s
- Each case repeated at least 3 times

Experiments performed

Propagation Direction

Rate of spread of surface fire

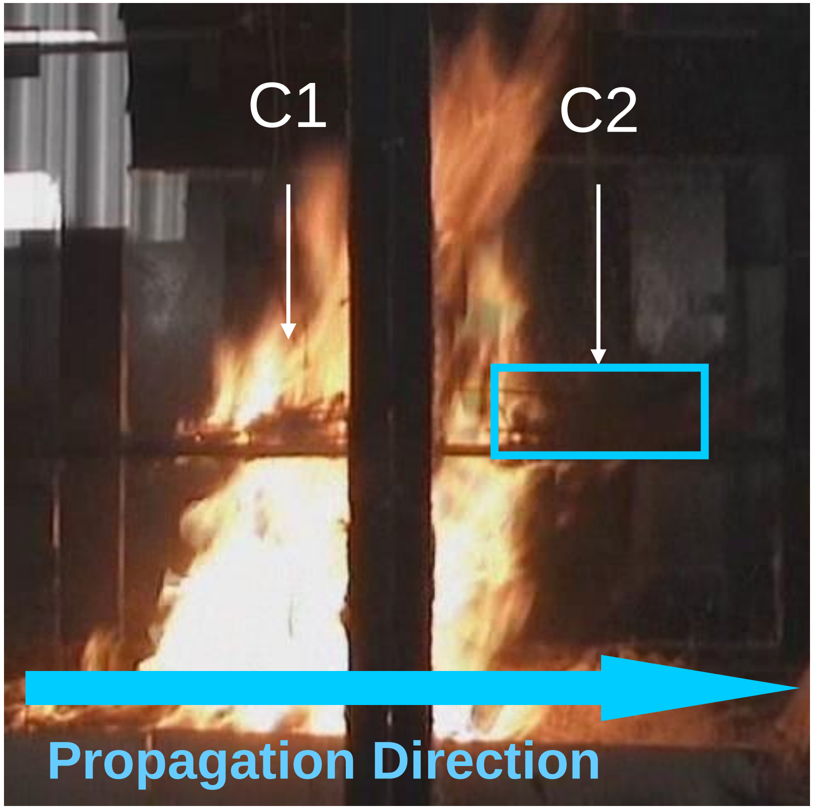




Downwind Distance (cm)	R in cm/s for CSD 10 cm	R in cm/s for CSD 20 cm	R in cm/s for CSD 30 cm
30	4.6	3.3	3.0
60	2.2	3.0	3.5
90	3.9	2.6	2.5

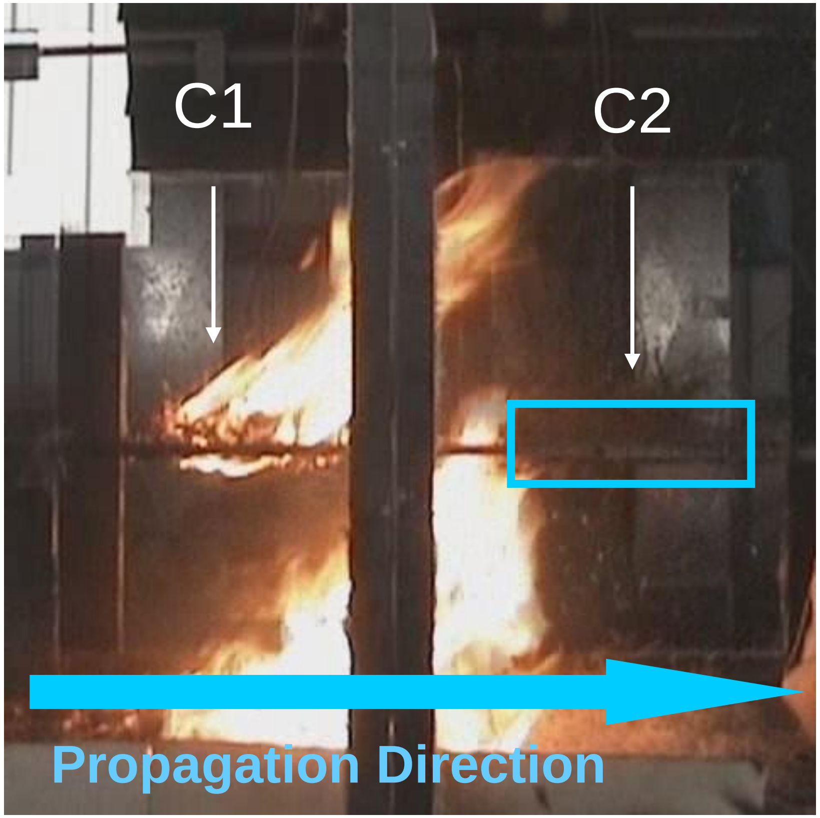
Fire front characteristics

- **CSD of 10 cm**
  - As C2 ignites, fires are merged



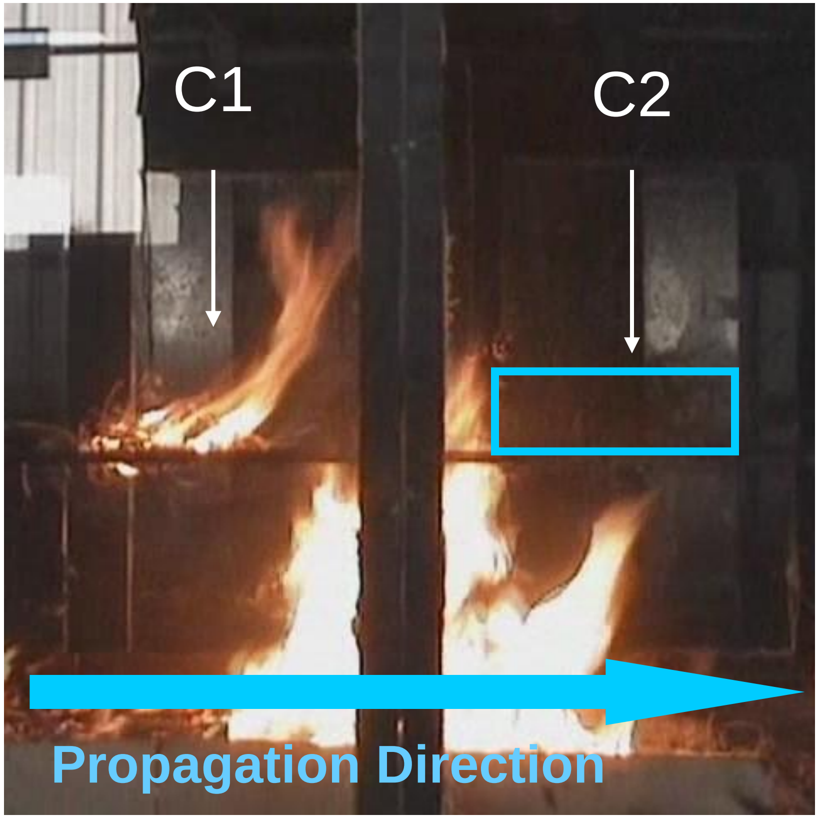
Fire front characteristics

- **CSD of 20 cm**
  - As C2 ignites, fires separate and remain separated



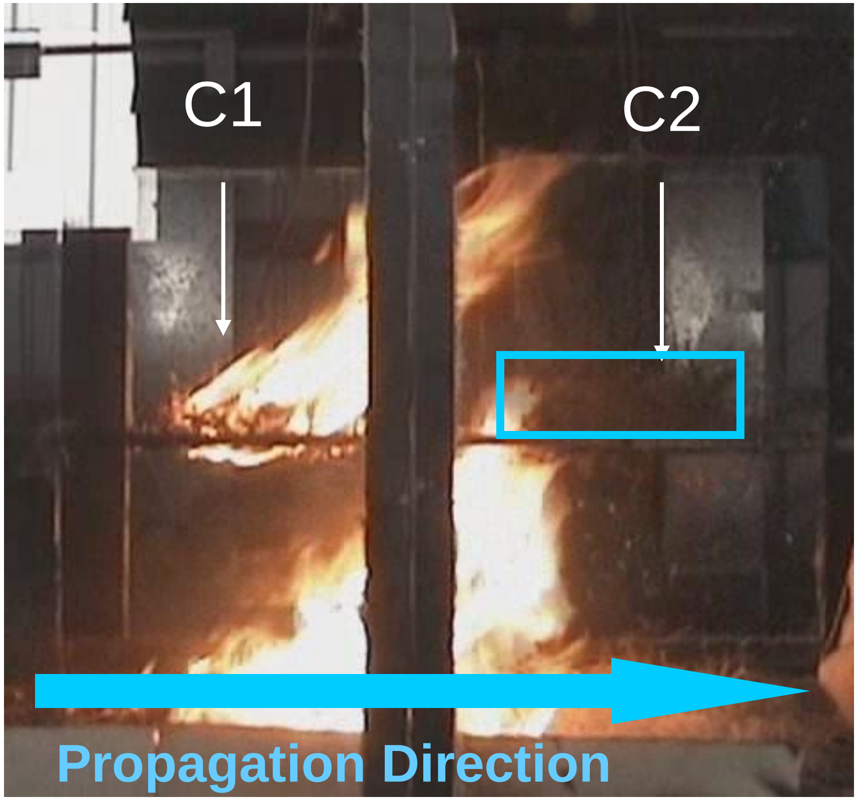
Fire front characteristics

- **CSD of 30 cm**
  - As C2 ignites, fires separate and remain separated

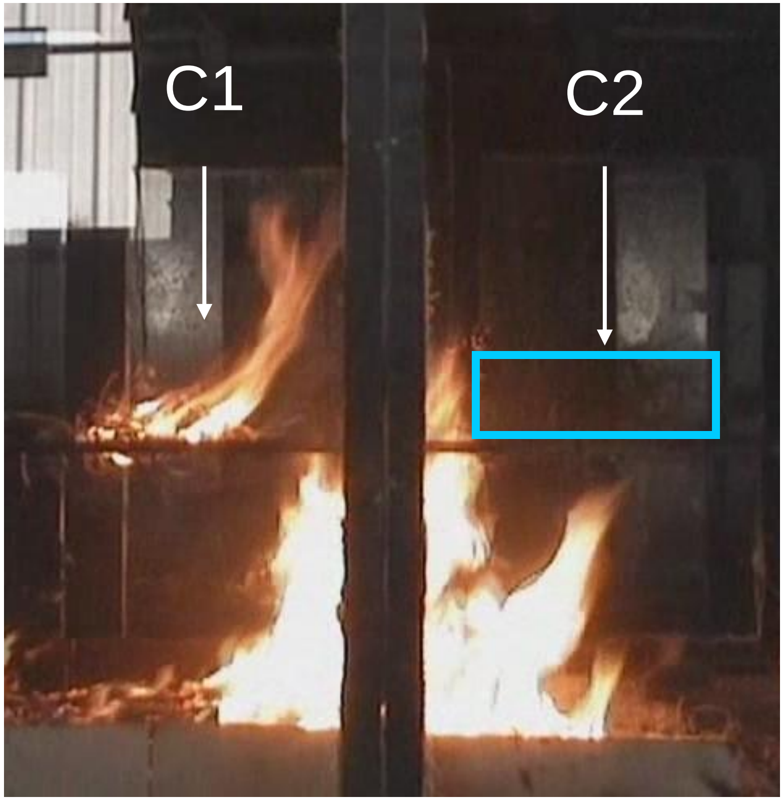


Fire front characteristics

- **CSD of 20 & 30 cm**
  - As C2 ignited, for case of CSD of 20 cm, fire is more intense than that at a CSD of 30 cm



(a) CSD 20 cm



(b) CSD 30 cm

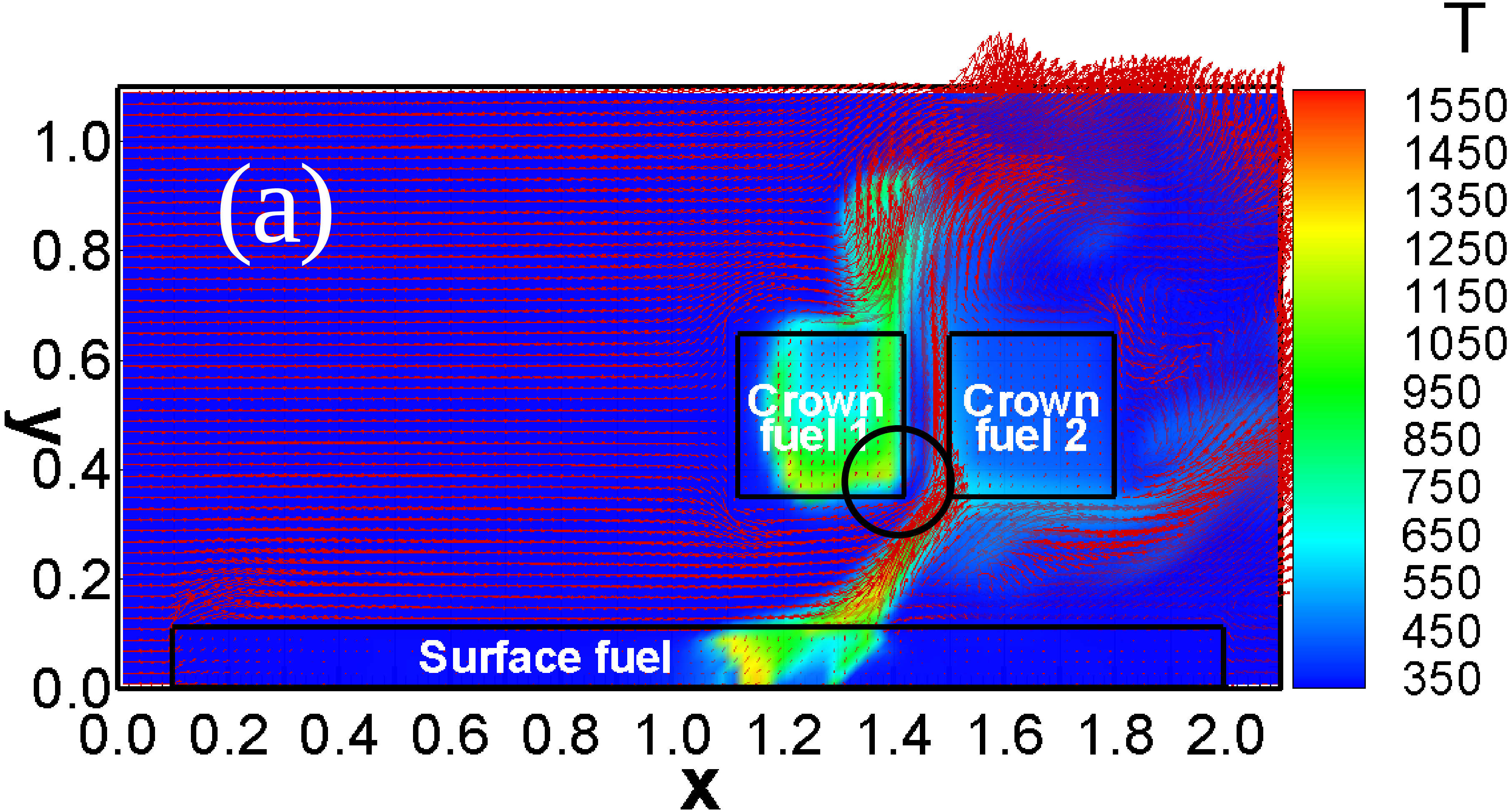
Preliminary LES results

- 2D slice at midplane
- Temperature contours and velocity vector field
- Crown separation distances investigated
  - 10 cm
  - 20 cm
  - 30 cm

Ignition of crown 1 @ 10cm

t = 83 sec $T_{max,C1}$ = 1550 K $T_{min,C1}$ = 343 K

- Ignition occurred at lower edge of downstream face

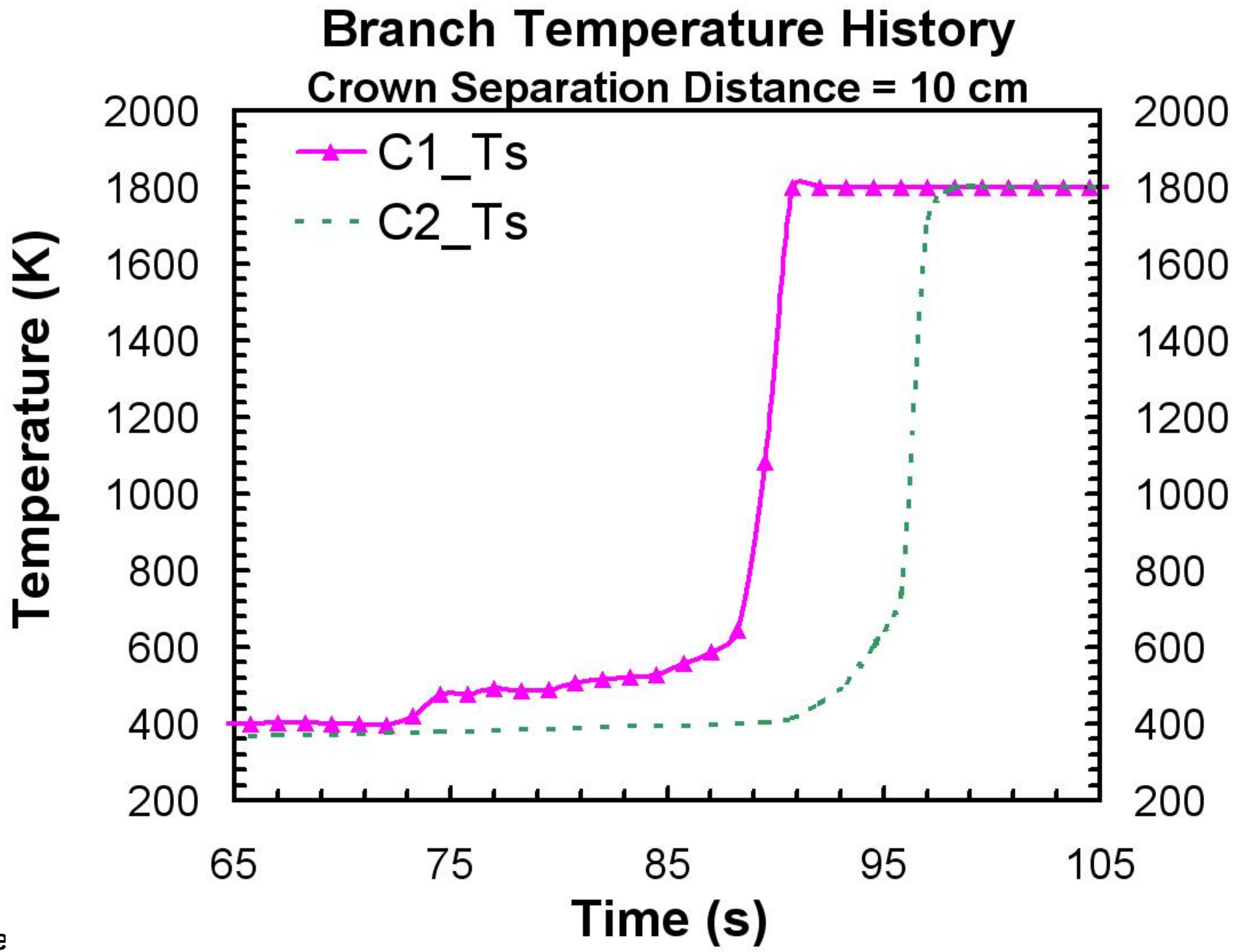


Ignition of crown 1 @ 10cm

Crown ignition lag time:

t = 7 sec   LES

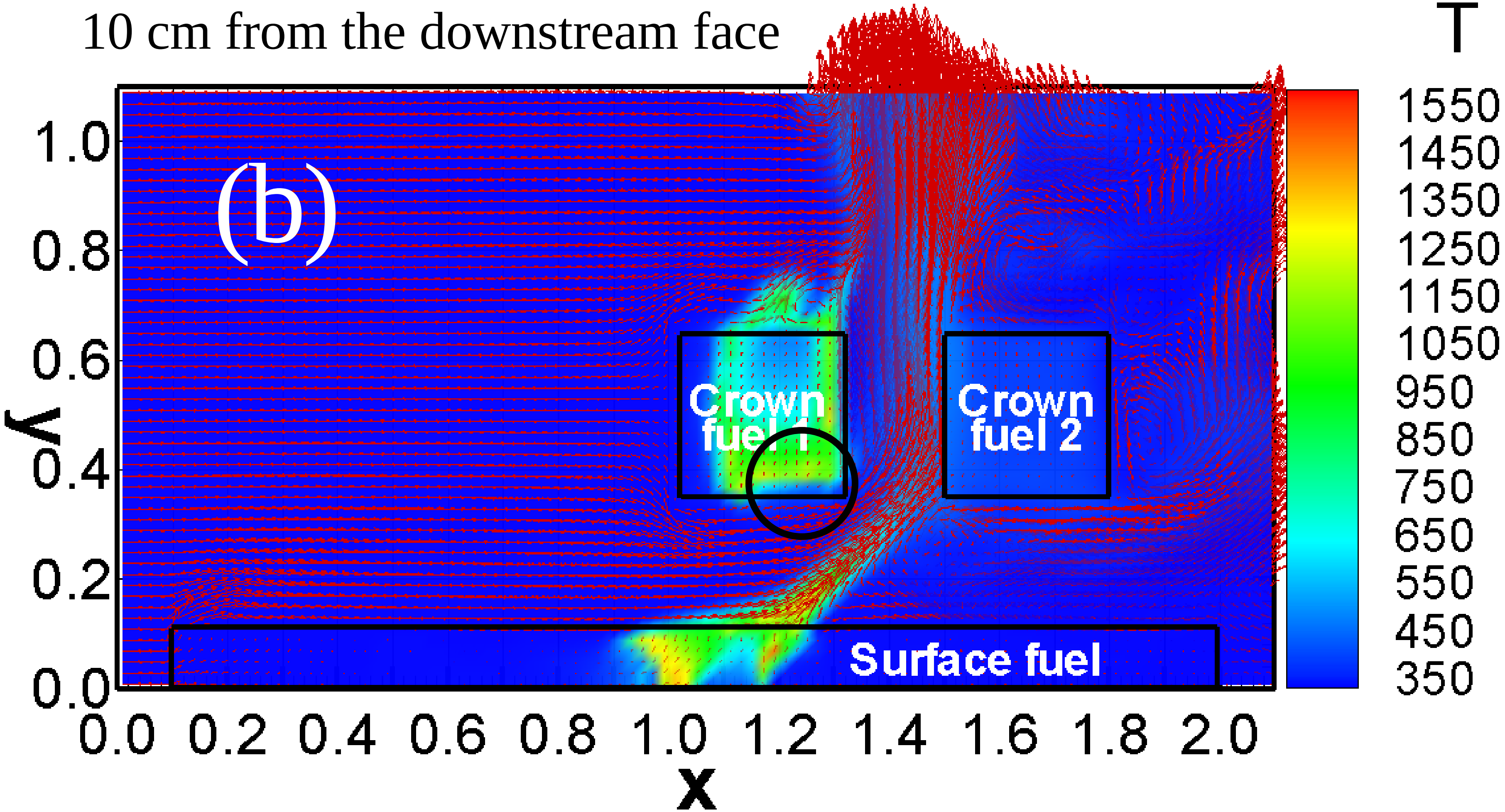
t = 11 sec   EXP



Ignition of crown 1 @ 20cm

t = 72 sec $T_{max,C1}$ = 1273 K $T_{min,C1}$ = 347 K

- Ignition occurred at the bottom at a location approximately 10 cm from the downstream face

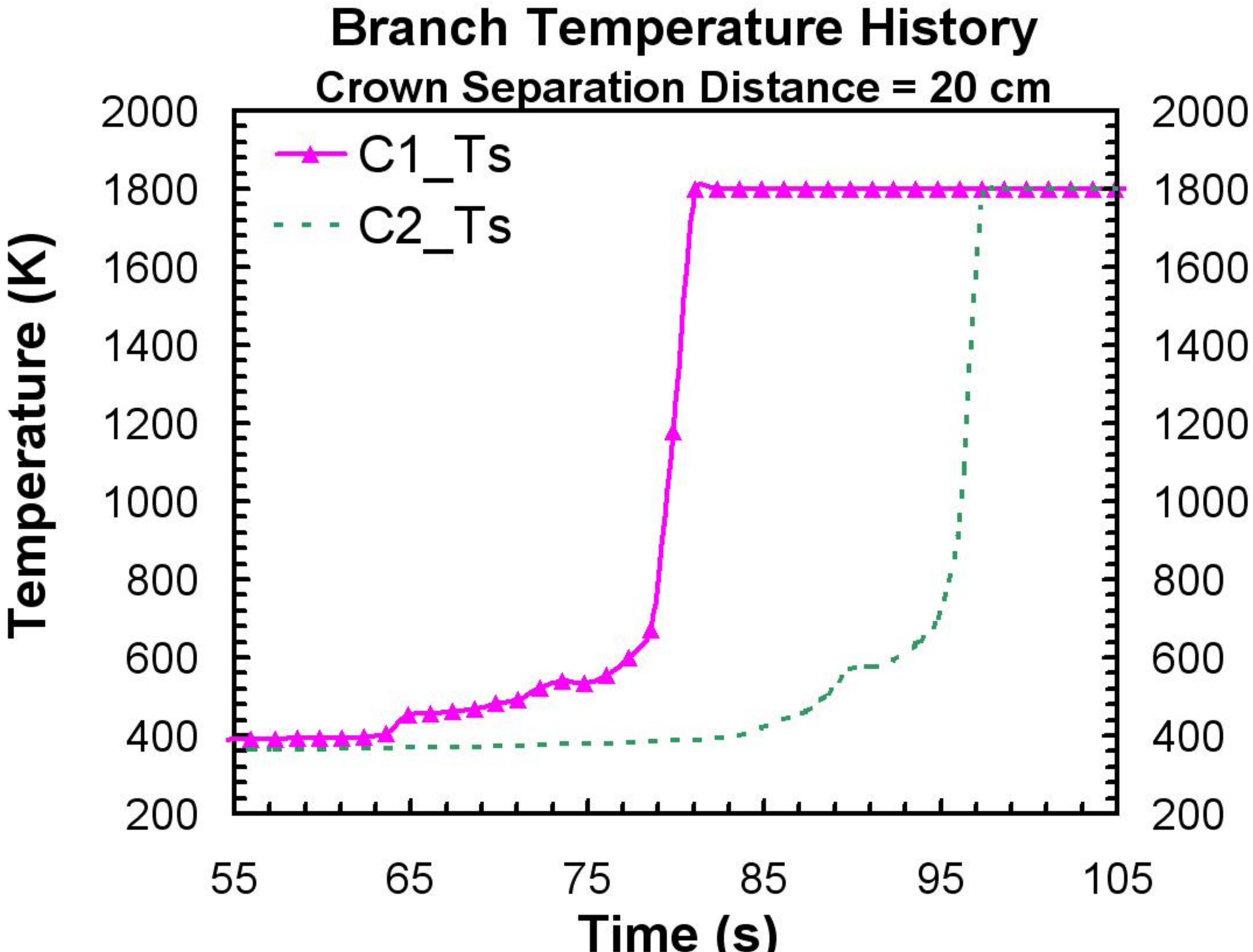


Ignition of crown 1 @ 20cm

Crown ignition lag time:

t = 16 sec   LES

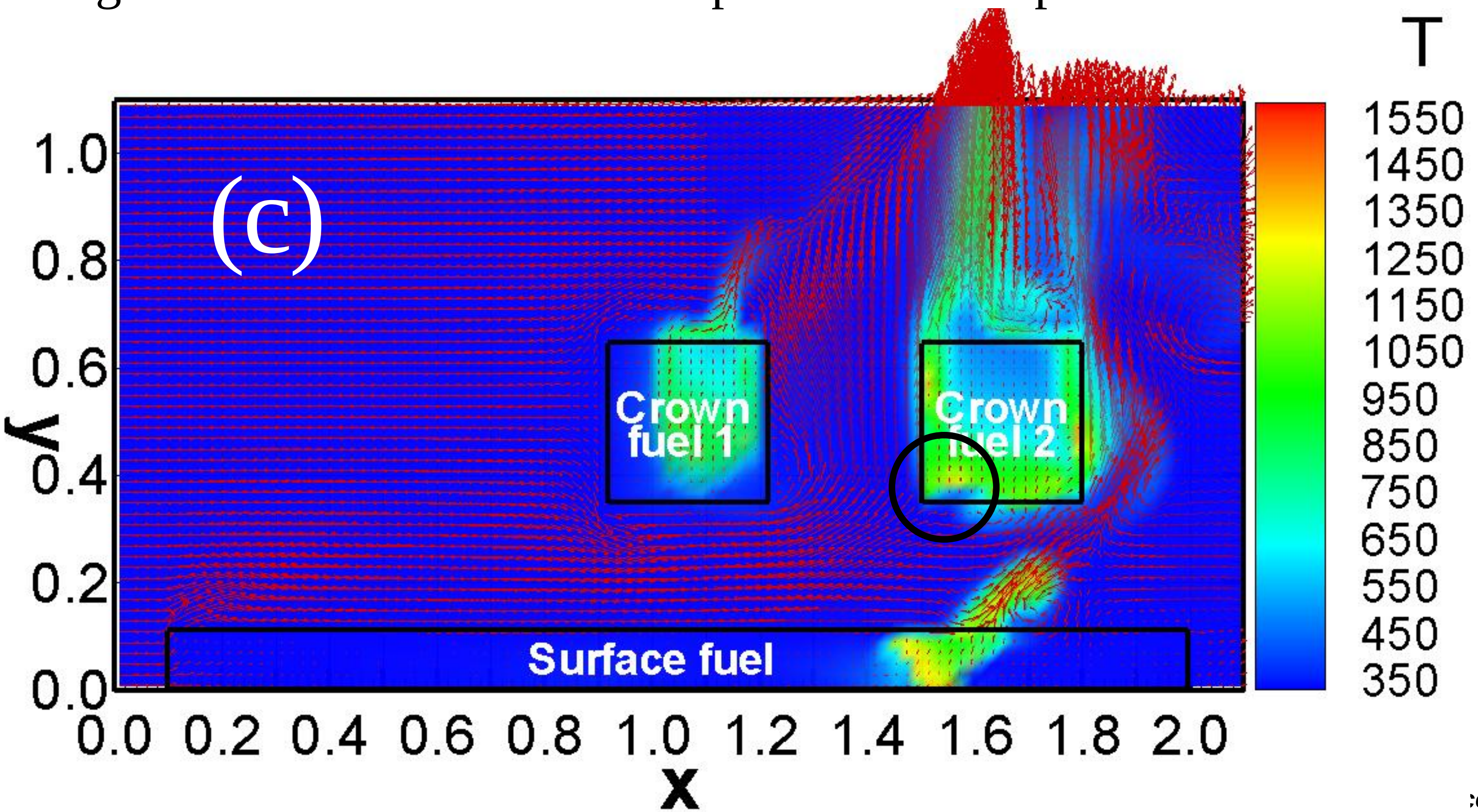
t = 21 sec   EXP



Ignition of crown 2 @ 30cm

t = 106 sec $T_{max,C2}$ = 1301 K $T_{min,C2}$ = 493 K

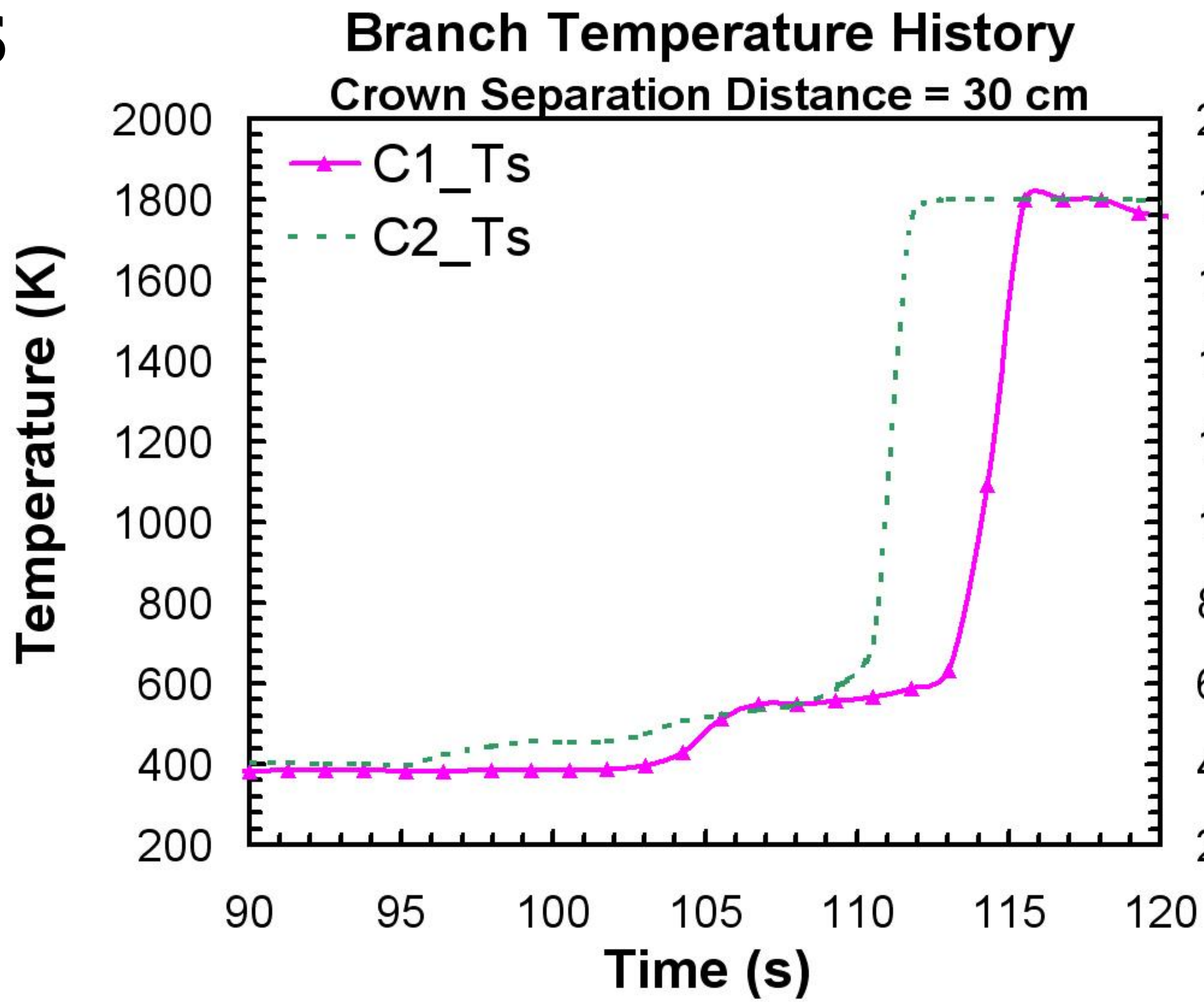
- Ignition occurred at the lower portion of the upstream face



Ignition of crown 2 @ 30cm

Crown ignition lag time:

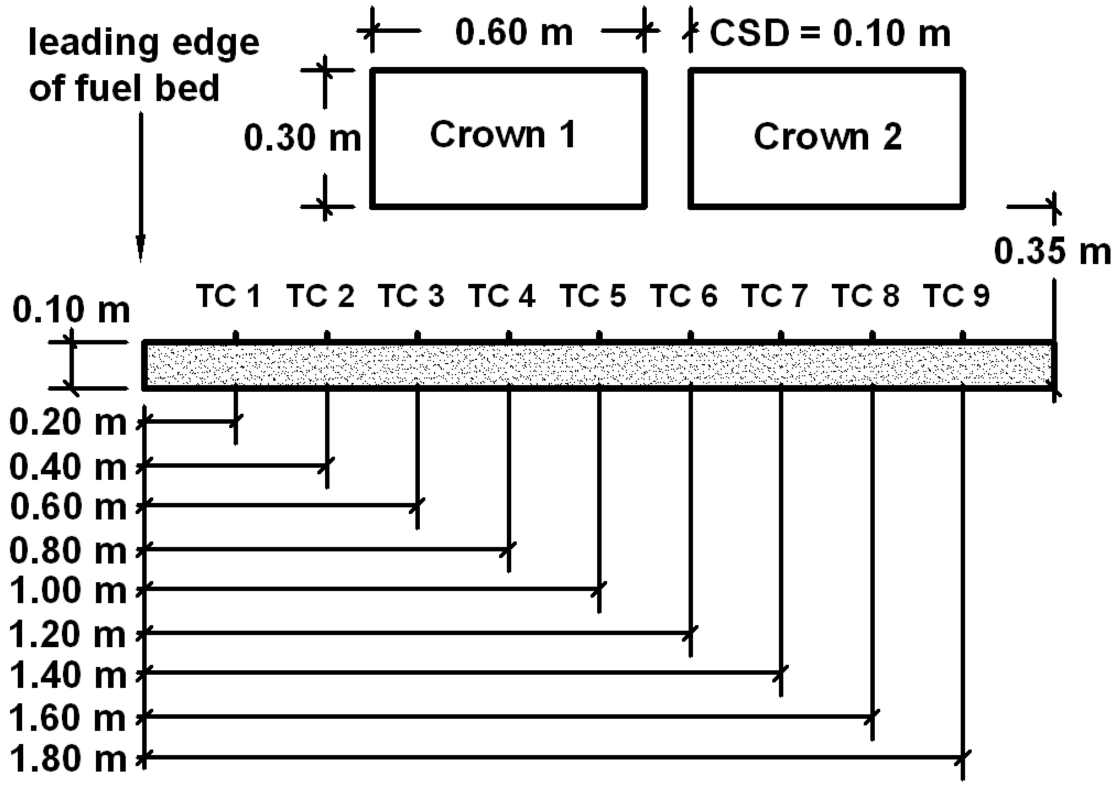
t = 4 sec   LES



Future Work

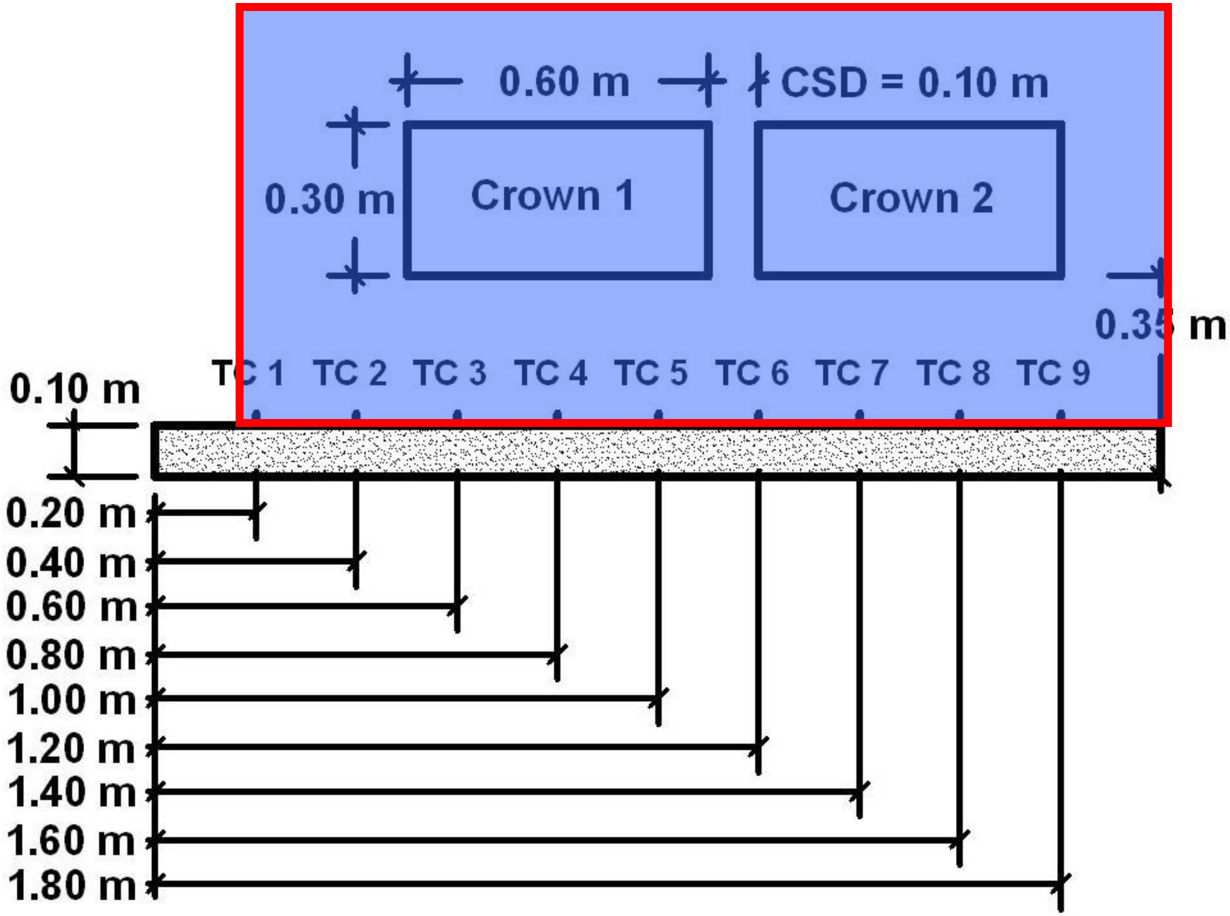
Future Work-ROS

- longer fuel bed: 2.4 m
  - more TC's for better *ROS* resolution
- longer crowns: 0.6 m
  - more TC's for a better *ROS* resolution
- Parameterize distance between crowns
- Capture heat flux data for convection and radiation heat transfer



Future Work-PIV

- PIV system
  - Observe the velocity field surrounding the crown fuel matrices



Conclusions

- Variation in *R* indicates the influence of the crown fuel matrices on surface fire propagation.
  - A more detailed study is required
  - More surface fuel thermocouples required at shorter distance intervals
- Crown separation distance influenced fire front behavior
  - At a CSD of 10 cm, the surface fire merged with C2 fire and remained merged while C1 ignited
  - At a CSD of 20 cm and 30 cm, the surface fire and C2 fire merged briefly, but separated as C1 ignited and remained separated
  - At instant when C1 ignited, the fire intensity of C2 was higher at a CSD of 20 cm than that of a CSD of 30 cm; shown by larger C2 flames

Conclusions

- Preliminary LES results comparison to actual experiments
  - At 10 and 20 cm crown separation difference, crown 1 ignited before crown 2
  - At 30 cm, in the LES model crown 2 ignited before crown 1 and in the actual experiments crown 1 ignited before crown 2

- Additional experiments are required to get a better understanding about how crown fuel separation affects the dynamics of multiple crown fire initiation

END