

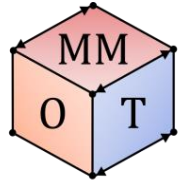
Bioinspired Horn Shaped Oscillators for Mitigating the Effects of Impact

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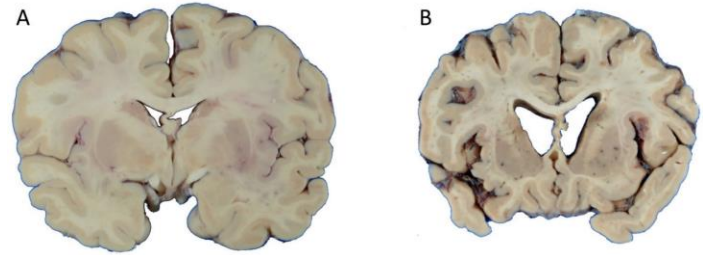
Bucknell University
Mechanics and Modeling of
Orthopaedic Tissues Lab



• **Bucknell**
UNIVERSITY

INTRODUCTION – CTE

- Chronic traumatic encephalopathy (CTE) causes progressive dementia [1]:
 - memory loss
 - impaired judgement and impulse control
 - anger, depression, anxiety
- CTE is likely due to **repeated** impacts to the brain [1]
 - Brain translational and rotational accelerations, tissue strain
- Activities such as American Football are associated with higher rates of CTE [2]



Van Ommeren & Hazrati L-N. *Academic Forensic Pathology*. 2018.



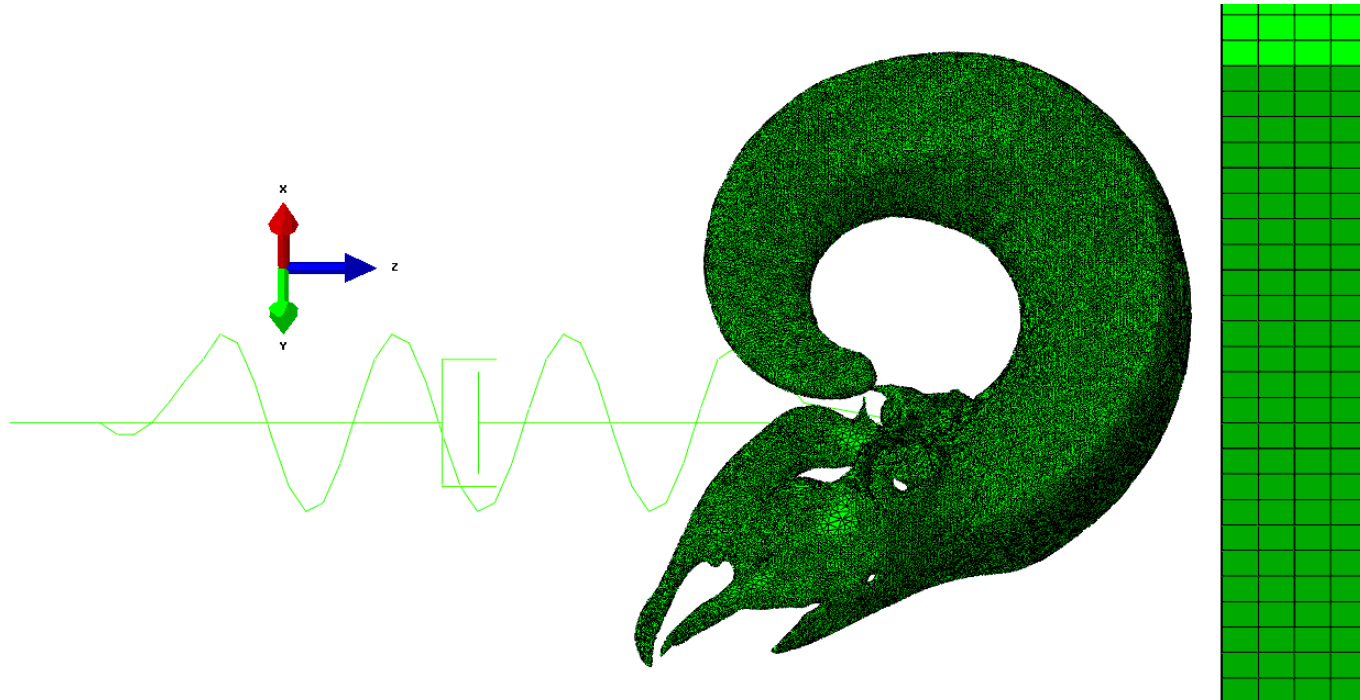
INTRODUCTION – BIGHORN SHEEP

- Male bighorn sheep (*Ovis canadensis*) engage in seasonal ramming bouts [3]
 - 100 kg at 6 m/s → 1.8 kJ
 - ~7 millisecond impact time
- Show limited behavioral signs of brain injury and histological analysis shows mild/moderate brain injury [4]
- **How do the skull and horns protect the brain from severe injury?**





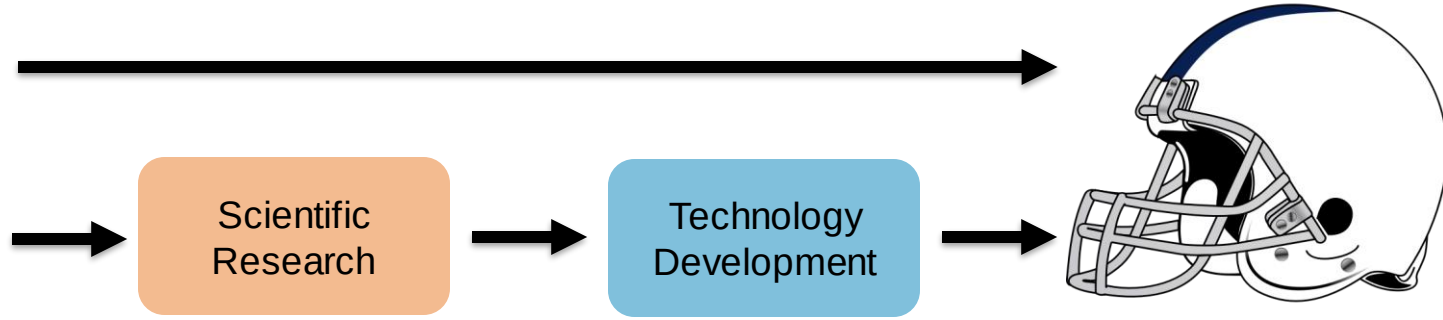
INTRODUCTION – PRIOR MODELING WORK



[5] Drake, *Acta Biomaterialia* (2016). [6] Wheatley, *Bioinspiration & Biomimetics*, (2023).

Horns are important for mitigating brain cavity accelerations – *unique shape and function* [5,6]

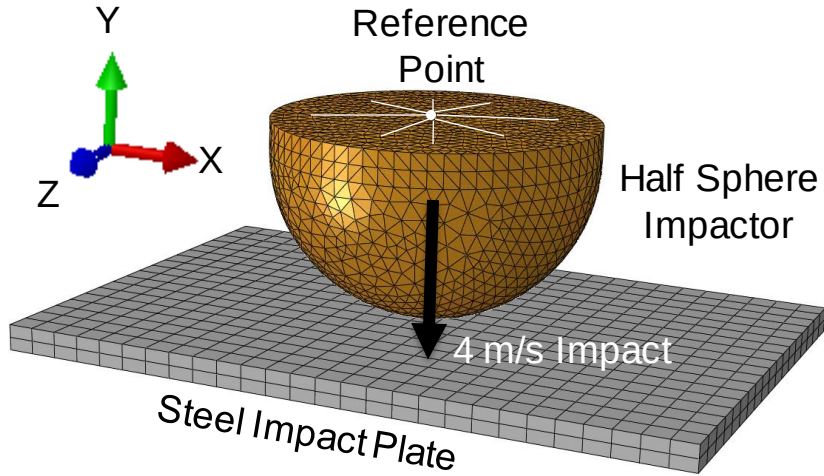
PROJECT GOALS



- Direct integration of horn-like structures onto safety equipment is a logistical challenge
- **Goal:** Study the interaction between number of horns, material properties, and impact acceleration
- **Hypothesis:** More horns, lower accelerations during and after impact

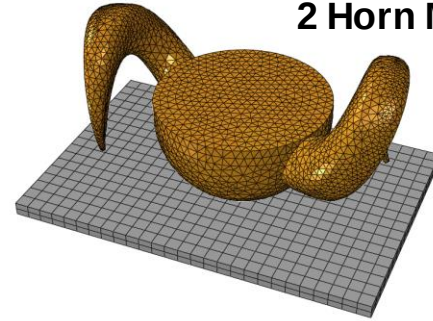
METHODS– FINITE ELEMENT MODELS

Baseline (0 Horn) Model

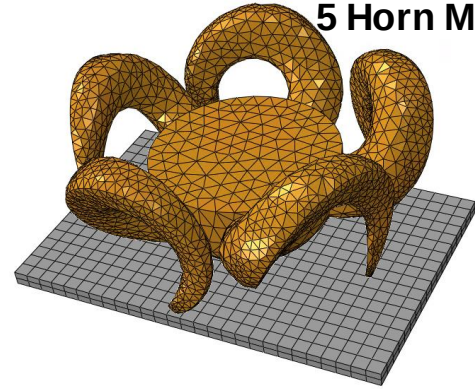


- Reference Point – All displacement boundary conditions fixed *except* Y-displacement
- Density scaled to maintain consistent mass across models

2 Horn Model

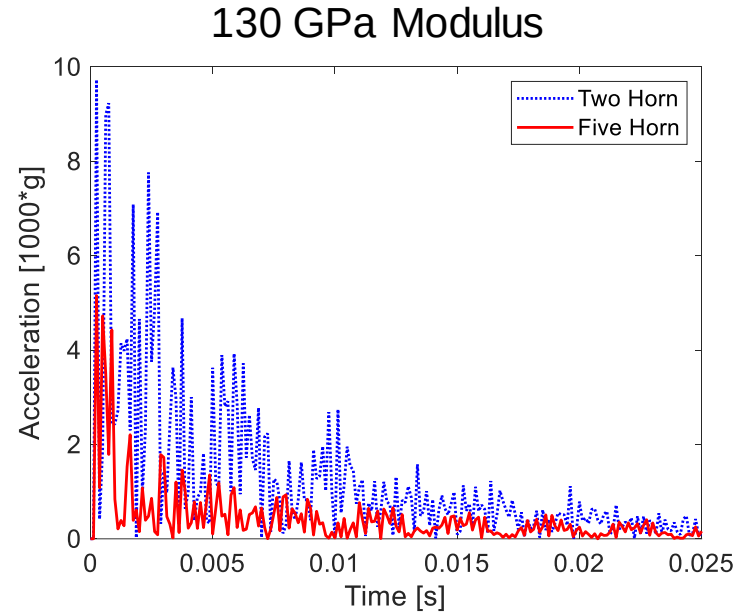


5 Horn Model



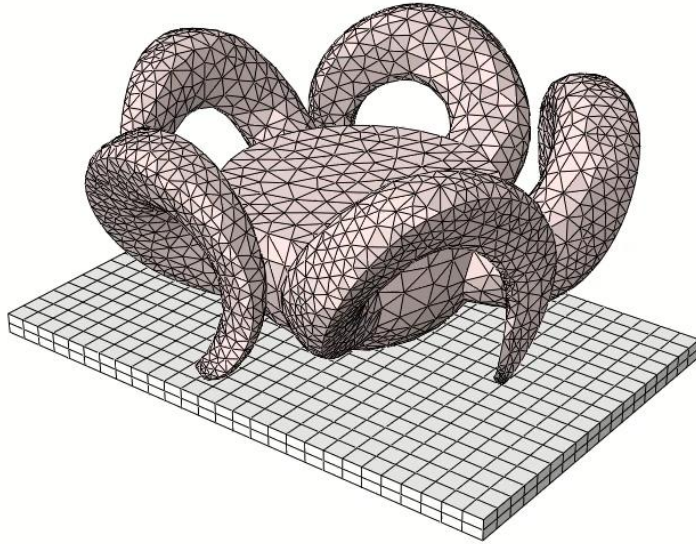
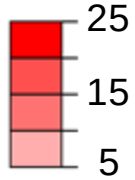
METHODS– INPUTS & OUTPUTS

- For all three geometric models, vary elastic modulus of impactor from:
 - 10 MPa (~silicone) to
 - 200 GPa (~steel)
- Output and compare reference point acceleration area under curve



RESULTS – VISUAL ANALYSIS

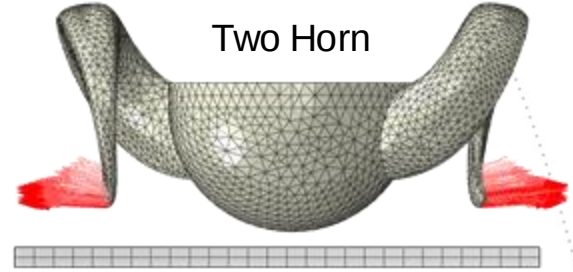
Velocity [m/s]



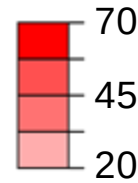
Impact
Direction



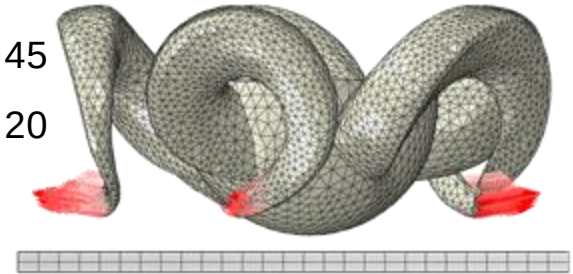
Two Horn



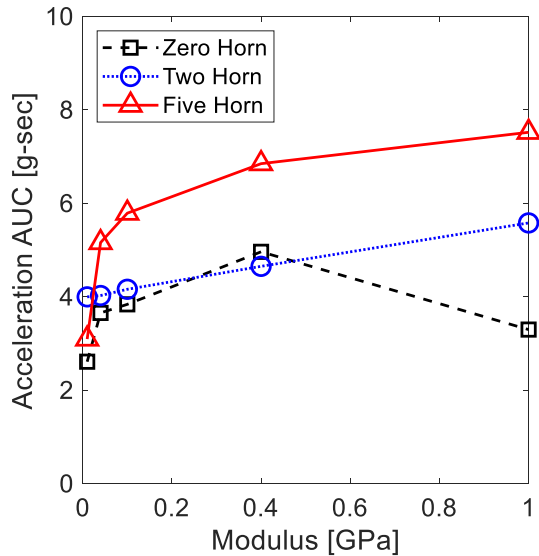
Velocity [m/s]



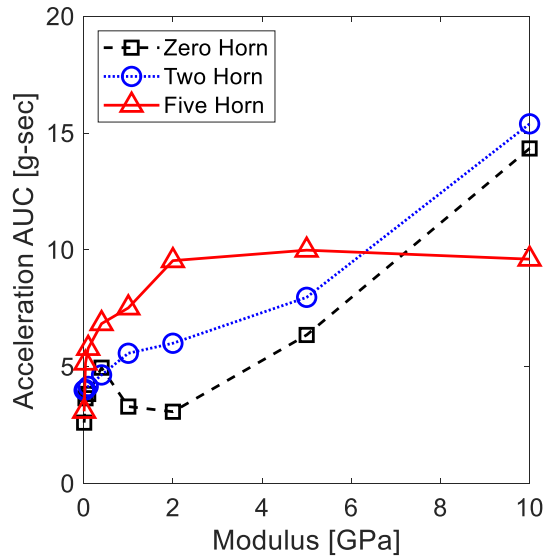
Five Horn



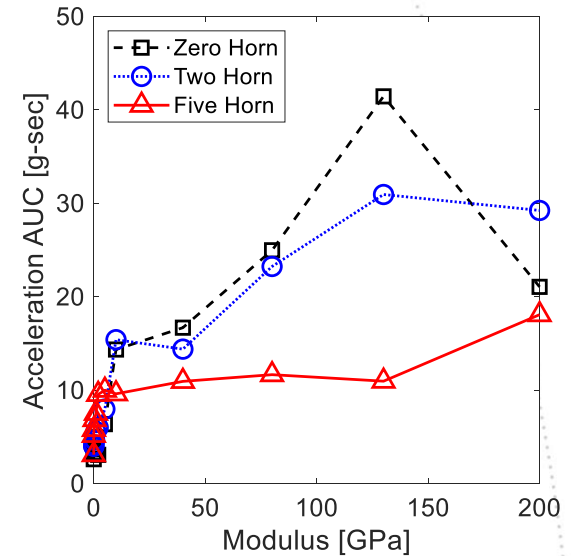
RESULTS – IMPACT ACCELERATION



No benefit at low
moduli (~silicone)



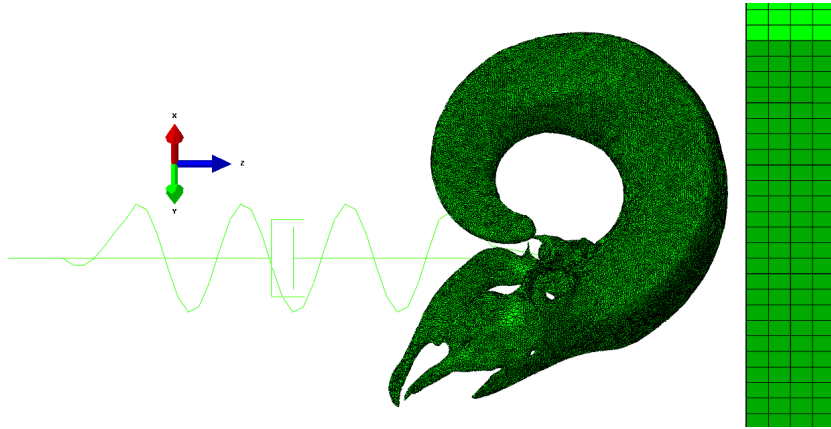
Transition region &
5 horn plateaus



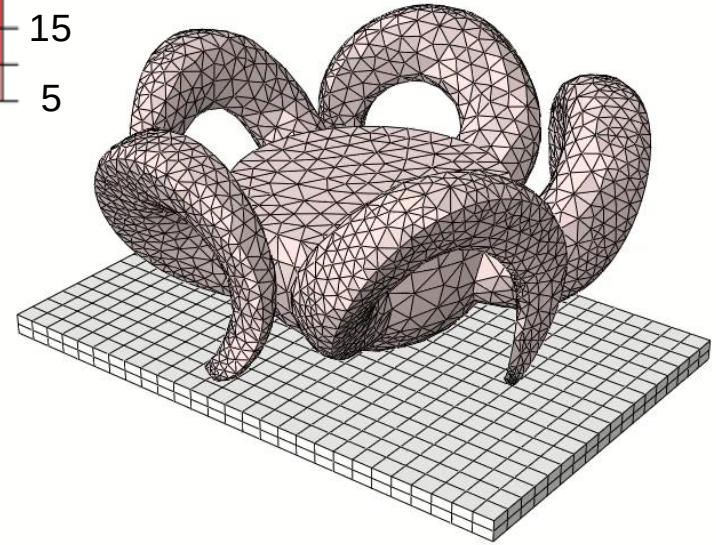
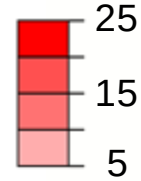
Up to ~75% reduced
AUC at high moduli
(~bone to ~metals)

DISCUSSION

- Horns oscillate as a secondary structure (not impacted)

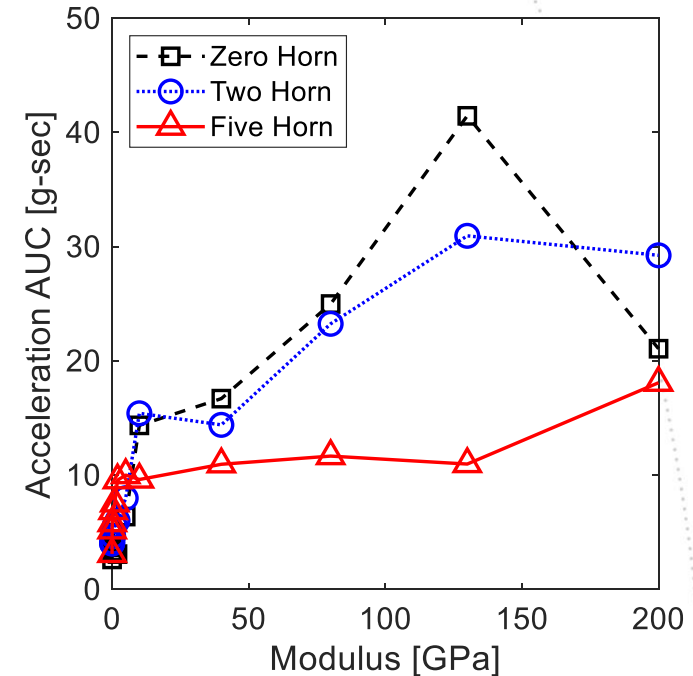


Velocity [m/s]



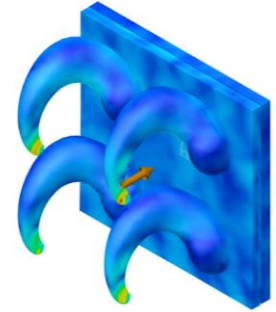
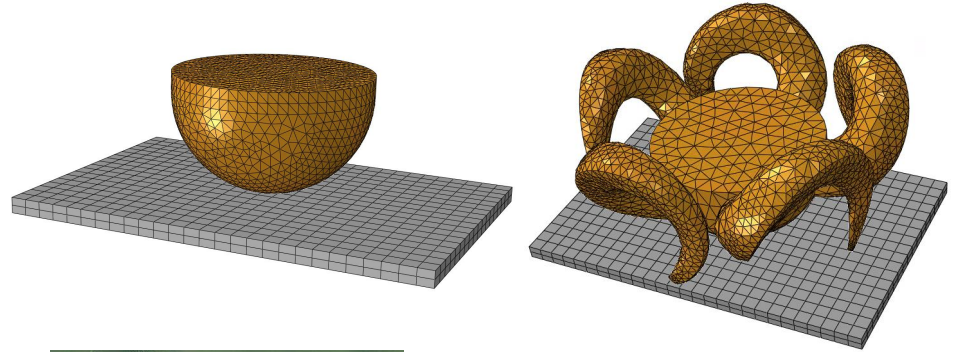
DISCUSSION

- Horns oscillate as a secondary structure (not impacted)
- Impact acceleration affected by number of horns and modulus of material
 - *Low modulus*, small or negative affect of horns
 - *High modulus*, 5 horn model exhibited lower accelerations than 2 or 0 horn models

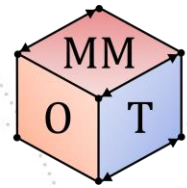


DISCUSSION

- Limitations
 - Difficulties comparing impact structures of differing volume
 - No payload
- Future work
 - Other bioinspired protective structures
 - Optimization of horn size, shape, and orientation
 - Inclusion of payload



ACKNOWLEDGEMENTS, THANK YOU & QUESTIONS



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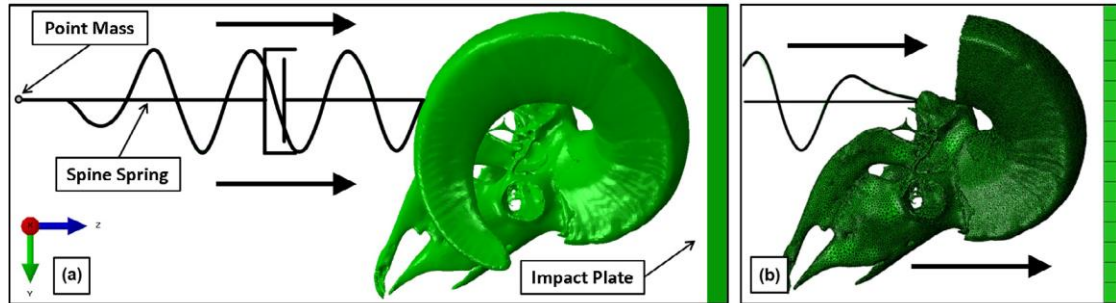


Aaron Drake, MS



PRIOR WORK – BIGHORN SHEEP HORN MECHANICS

- FE model of anatomically accurate bighorn sheep ramming [cite]
 - Compared full horn model to half horn model



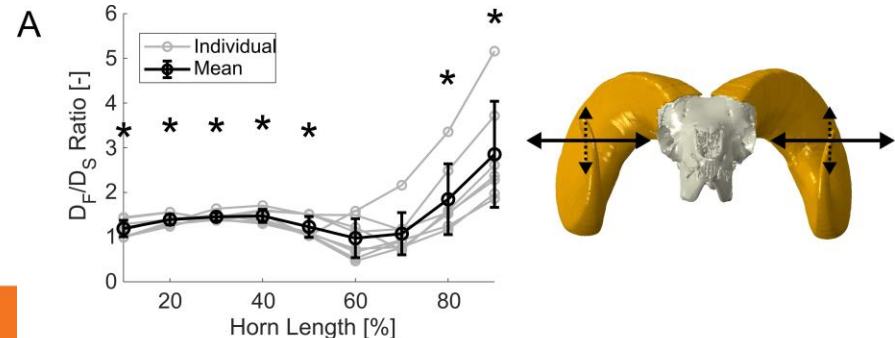
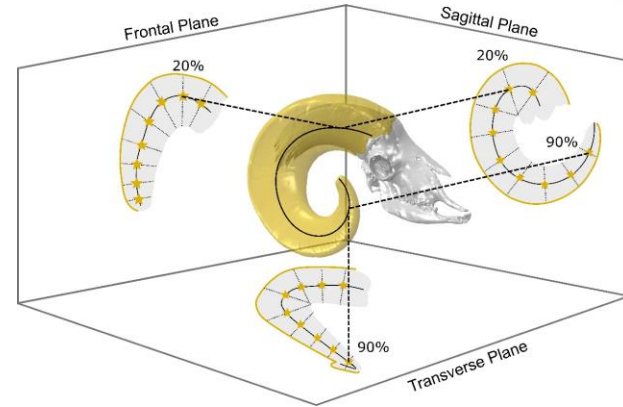
- Horn structure is important for reducing brain cavity accelerations by **~50%**

Translational accelerations

	Maximum (m/s^2)		Area under curve (m/s^2)*s	
	Value	% Δ	Value	% Δ
Full Model	4043	–	1.32E+08	–
Half Horn Model	6014	49%	1.62E+08	22%

PRIOR WORK – BIGHORN SHEEP HORN MECHANICS

- Shape characterization of bighorn sheep horns
 - Second moment of area properties along horn in cross-section
- Horns exhibit preferred medial-lateral bending direction



PRIOR WORK – BIGHORN SHEEP HORN MECHANICS

- FE model of simplified horn and half sphere with three different horn cross sections (baseline, circular, rotated)
- Increases in head injury criterion compared to baseline geometry:
 - **Circular: 125% increase**
 - **Rotated: 48% increase**
- Tapered spiral directs horn tip oscillations perpendicular to impact direction

