Development of Rotational Brain Injury Criterion (BRIC)

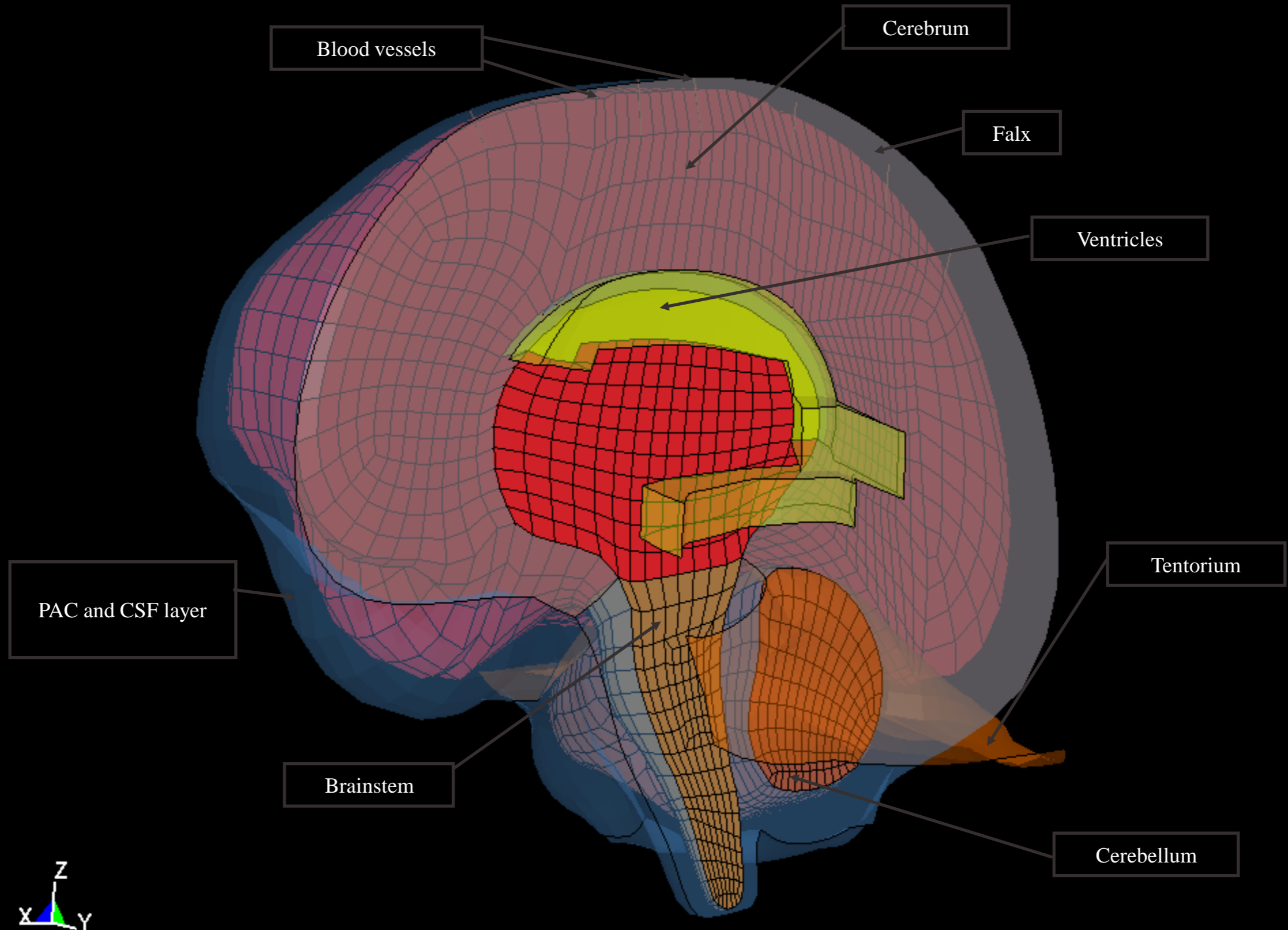## Human Injury Research Division

Procedure

- Develop validated human brain FE model (SIMon)

- Use CSDM as a biomechanical rotational injury criterion

- Use side impact tests with ES-2 dummy and frontal impact tests with HIII dummy instrumented with NAP (make sure the measurements are correct)

- Run SIMon with the measurements from ES-2 and HIII and calculate CSDMs

- Correlate CSDMs with kinematic parameters - a combination of angular acceleration and angular velocity such that the value of 1.0 corresponds to 30% of probability of DAI

- Use the same procedure with WorldSID

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SIMon FE Human Brain Model

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- Over 45,000 elements

- 42,500 nodes – solves ~ 120,000 equations simultaneously every microsecond

- Takes 10 hours on high-end workstation to simulate 150 ms loading event

- Utilizes the latest knowledge of material properties of various tissue
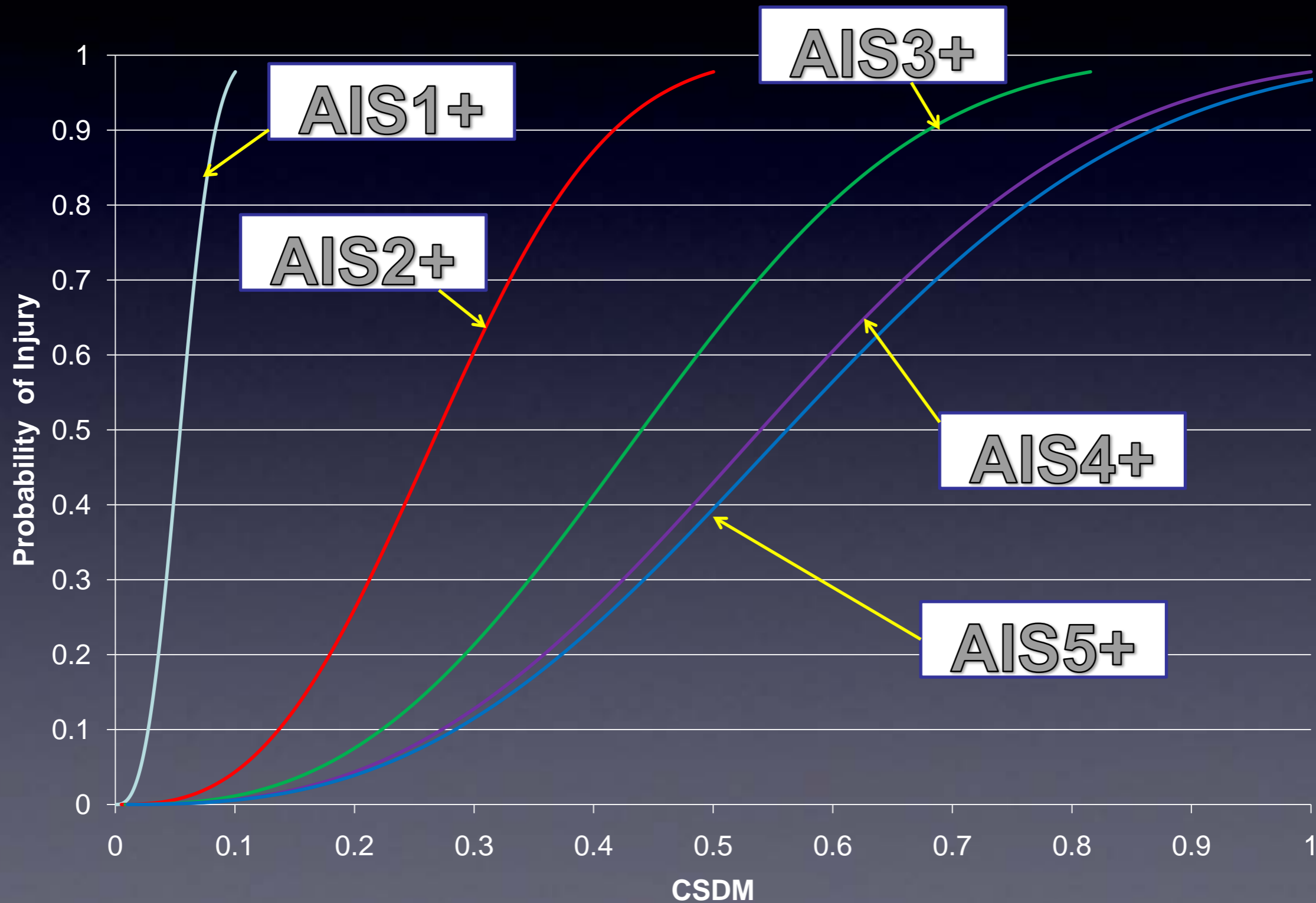
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Cumulative Strain Damage Measure (CSDM)
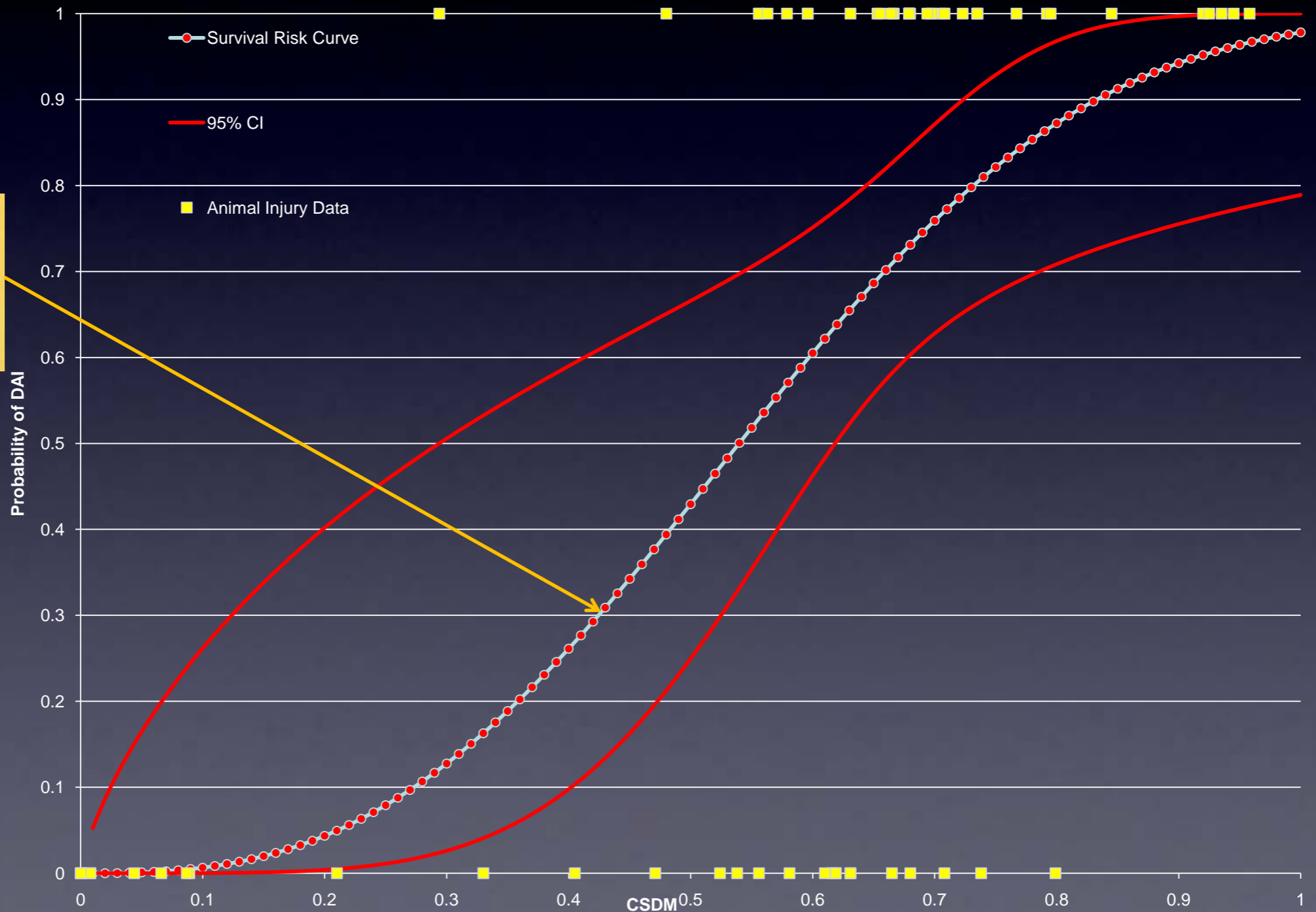
30% probability of DAI -> CSDM (0.25) = 0.425

Cumulative Strain Damage Measure (CSDM) for each AIS

BRIC Formulation

$$BRIC = \frac{\omega_{\max}}{\omega_{cr}} + \frac{\alpha_{\max}}{\alpha_{cr}}$$

ω_{max} and ω_{cr} -> maximum and critical rotational velocities respectively

α_{max} and α_{cr} -> maximum and critical rotational accelerations respectively

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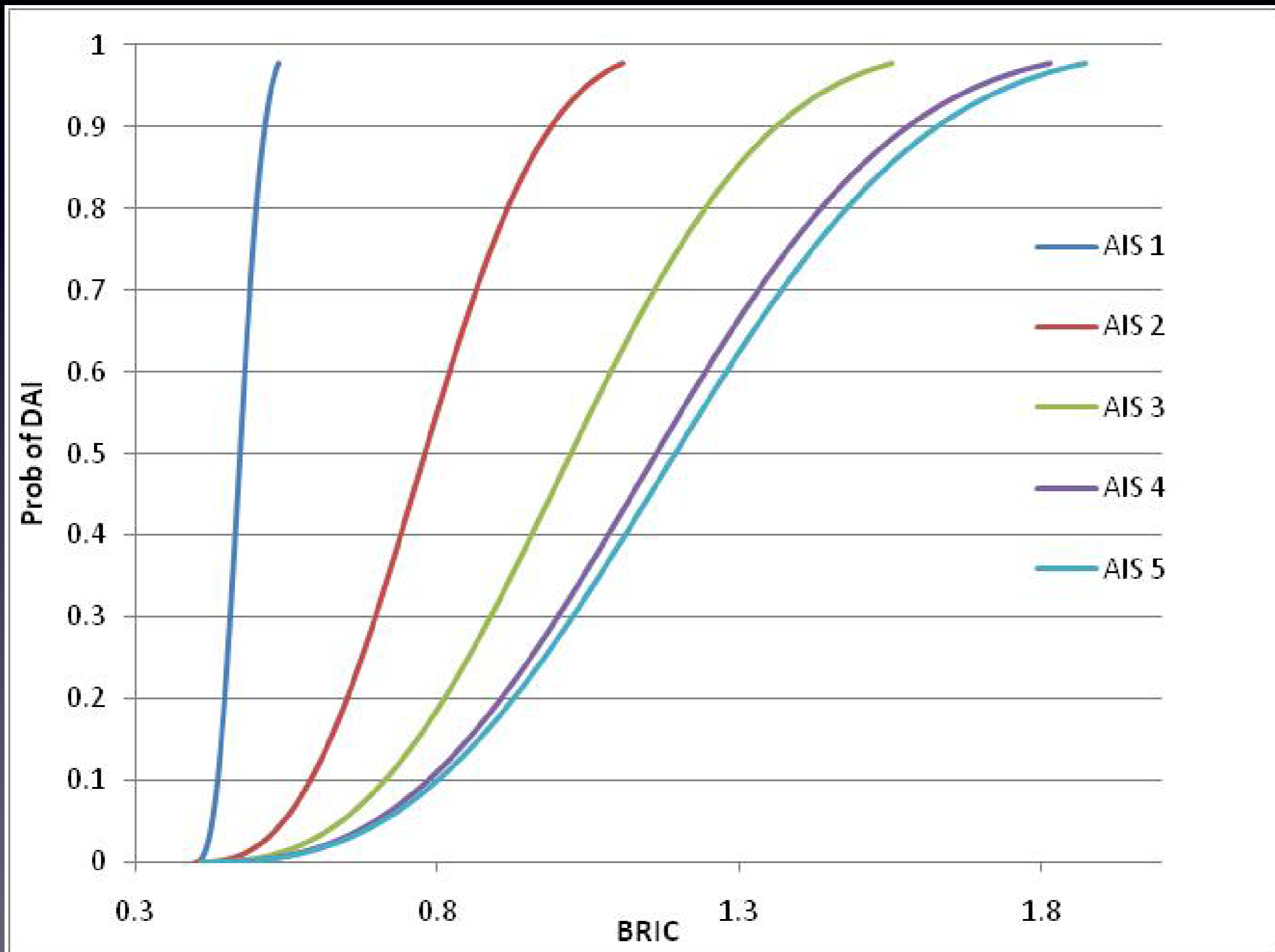
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Results (Frontal Impact Tests with HIII Dummy)
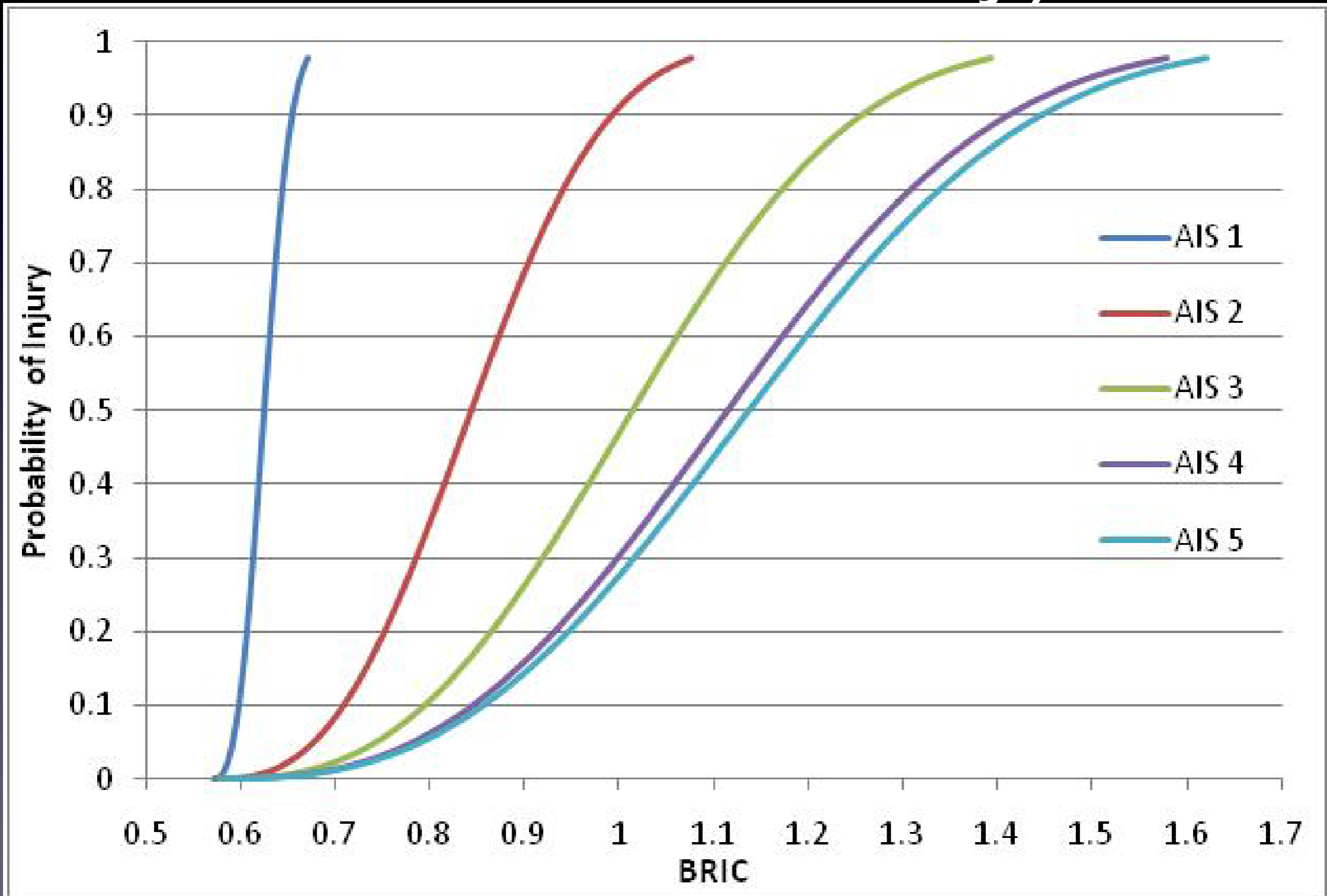
Results (Side Impact Tests with ES-2re Dummy)
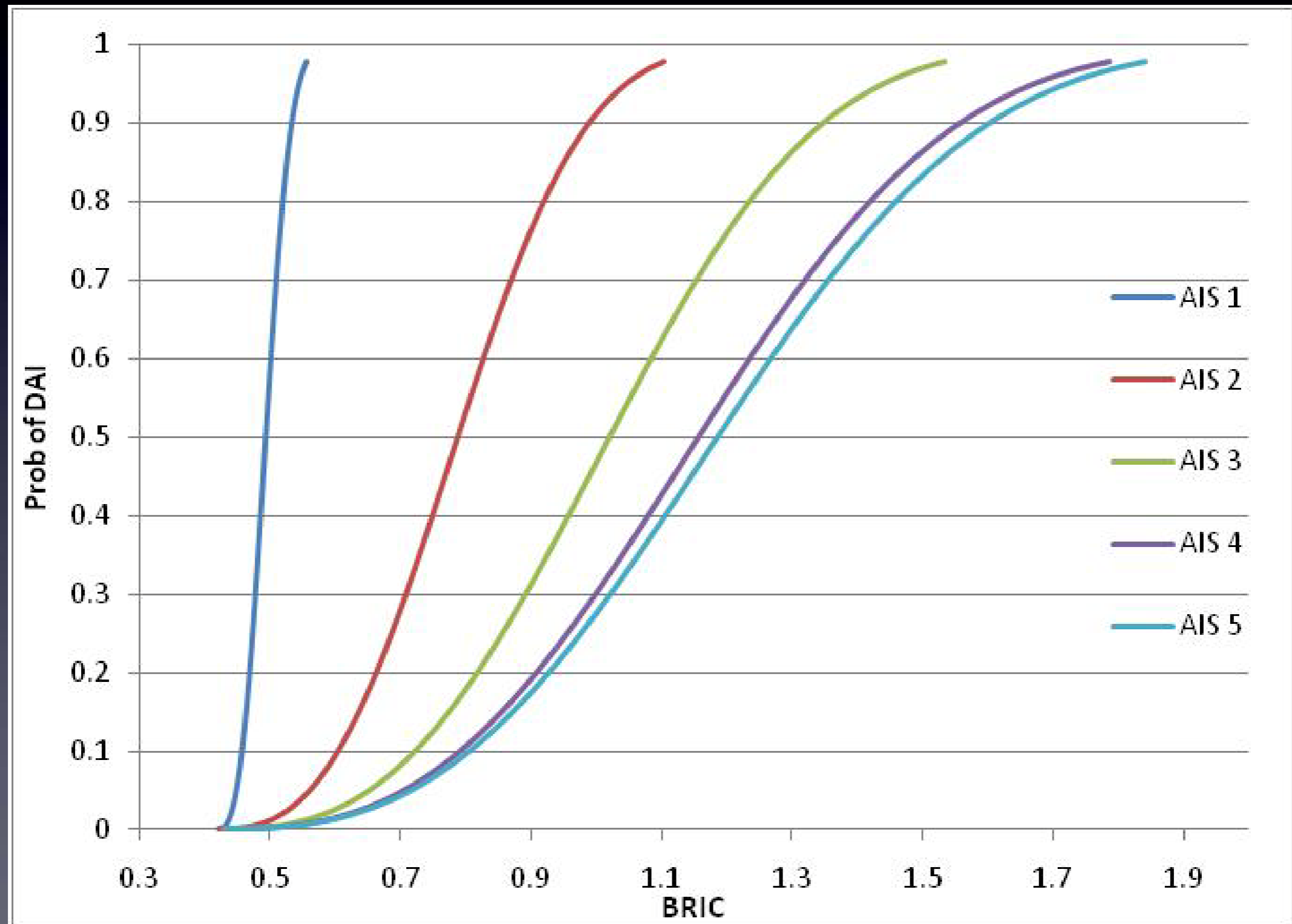
Results (Side Impact Tests with WorldSID Dummy)

Discussion

- BRIC is different for different dummies and human athletes.

- Concussive (AIS 2+) values of BRIC for humans varied from 0.60 when scaled directly from animal data (Ommaya, 1985) to 0.68 when obtained directly from the college football players.

- The risk of AIS 3+ TBI for BRIC = 0.68 when using the Hybrid III dummy as an assessment tool is approximately 1%, when using ES-2re dummy it is approximately 7%, and when using the WorldSID it is also about 8%.

- BRIC for the 30% risk of AIS 3+ TBI is 0.92 if measured with HIII dummy, 0.89 if measured with ES-2re and WorldSID dummies.

- BRIC should be used in combination with HIC. However, the risk of TBI for combination of rotational and translational loading modes should be investigated in the future.