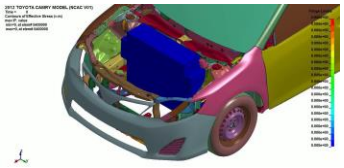
Crash Safety of Batteries for Passenger Vehicles

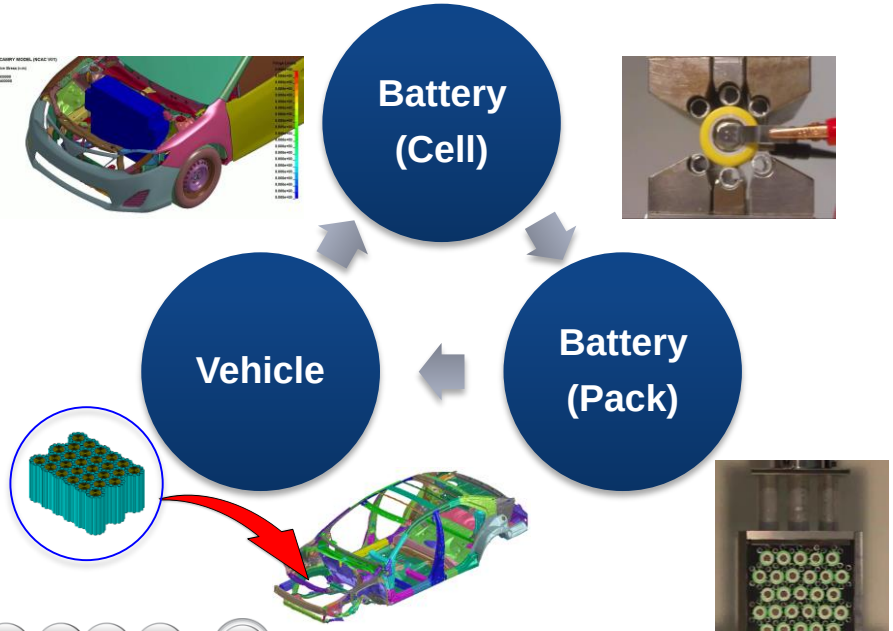
TEAM: Purdue University Research Group

Prof. Wayne Chen, PI, wchen@purdue.edu
Prof. Thomas Siegmund, Co-PI, siegmund@purdue.edu

Technology Overview

- Multifunctional EV structural batteries that:
  - Store electricity during the normal operation
  - Deform and dissipate impact energy during collision
- Hollow sacrificial elements dissipate kinetic energy
- A prototype GBA (Granular Battery System) uses 38 “18650” battery cells
- EV with GBA deceleration during impact equivalent of crash rating 4 to 5





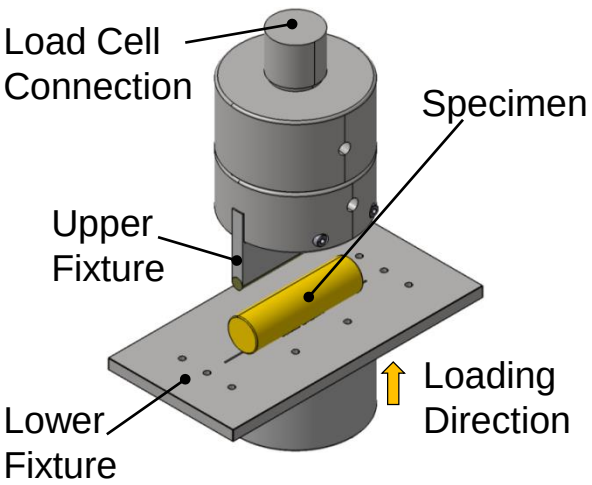
Current Status

- Status: GBA concept was verified by
  - Finite element (FE) analysis
  - Component-level experiments
  - Assembly-level experiments
  - Vehicle-level analysis
  - GBA design optimization / verification
- Next technical target
  - Project collaboration with PSU and ORNL
- Next commercial target
  - Automotive OEM / Tier 1 partners
- Help needed
  - Technical: Obtaining existing vehicle design from OEM
  - T2M: Articulating technology value proposition to secure commercial partners

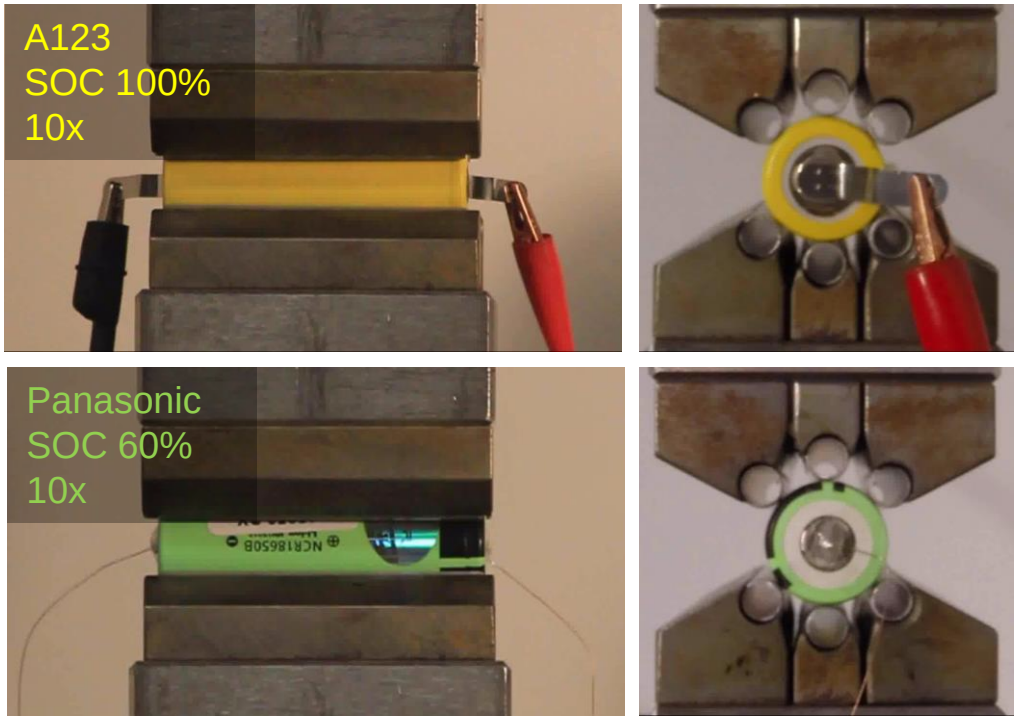
Project Statistics

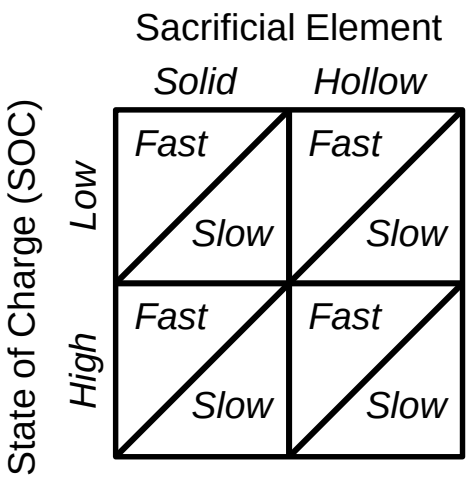
Award Amount	$0.8 M (RANGE)
Award Timeline	Dec. 2013 – Dec. 2015
Next Stage Target	ARPA-E Plus up
Collaborations Sought	PSU and ORNL (Technical)

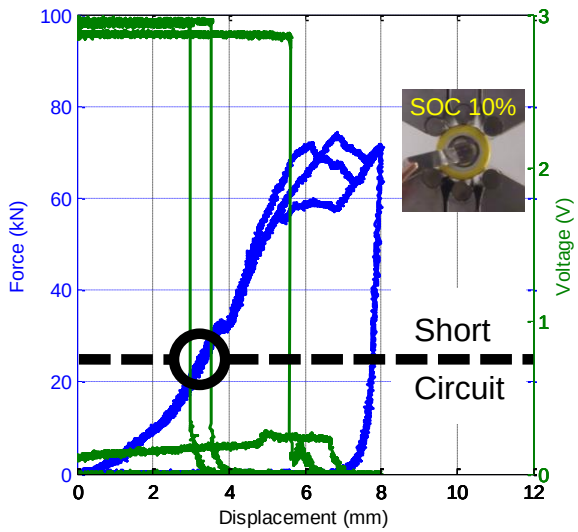
Cell-level Analysis



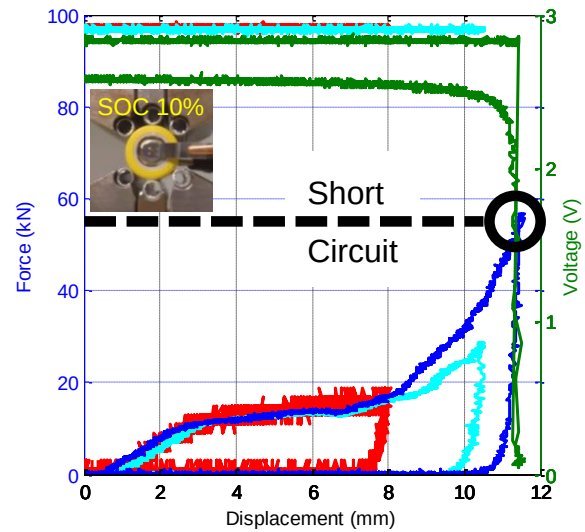
MTS Machine







Solid Sacrificial Elements

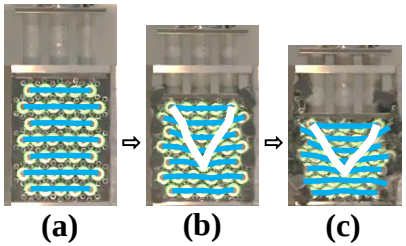


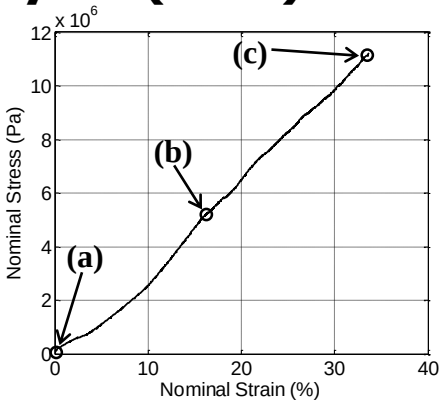
Hollow Sacrificial Elements

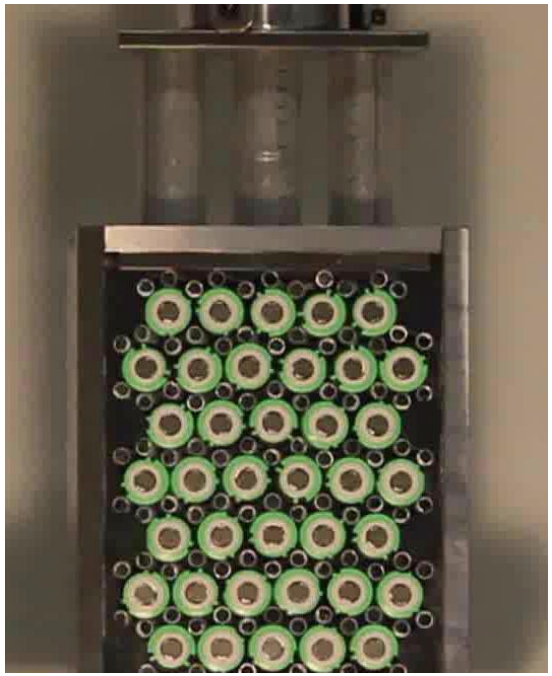
White lines: Shear zones

Pack-level Analysis

Quasistatic Analysis (MTS)

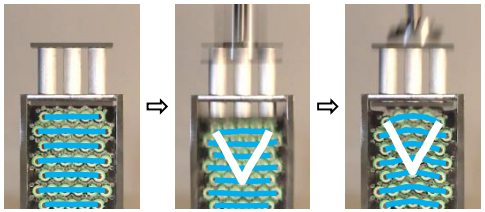


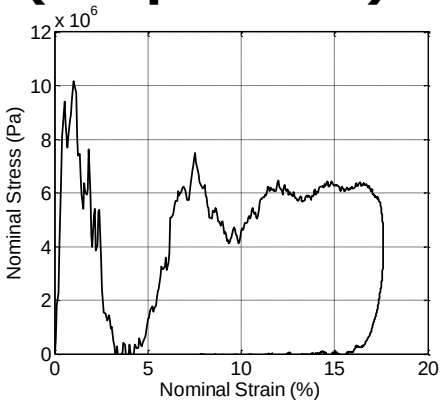


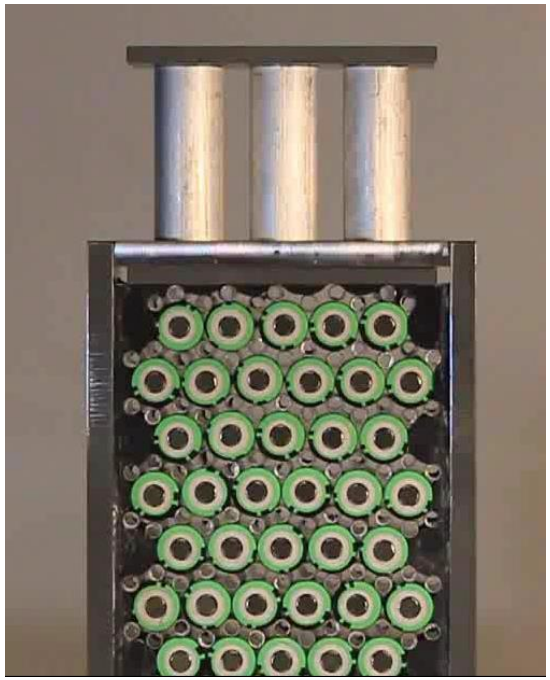


Strain rate: 10^{-3} /s
(Video speed: 10x)

Dynamic Analysis (Drop Tower)

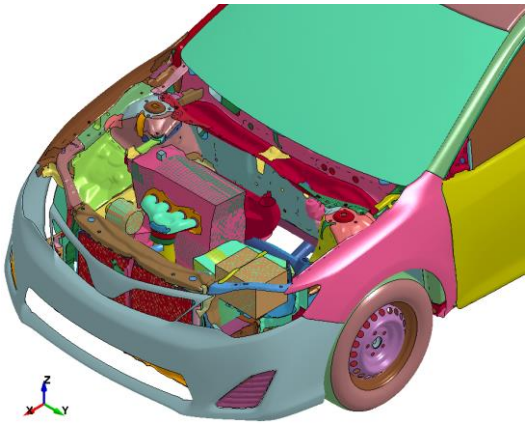






Impact velocity: 8.6 m/s
Drop mass: 28.9 kg

Vehicle-level Analysis: Setup

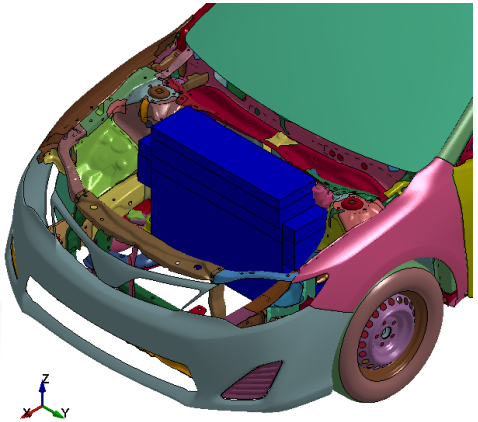


Original model*
FEM model of Toyota Camry 2012 with an engine & its components

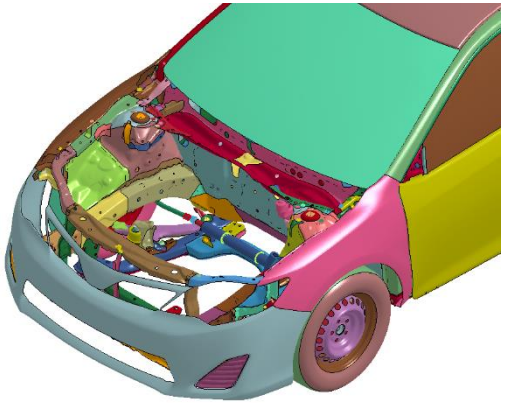
Tool:
LS-DYNA

Remove parts

Install batteries



EV model
FEM model of Toyota Camry 2012 with GBA block in engine space

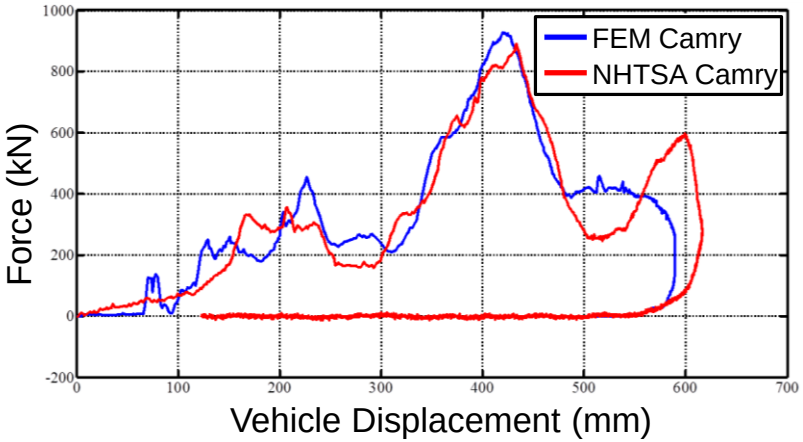


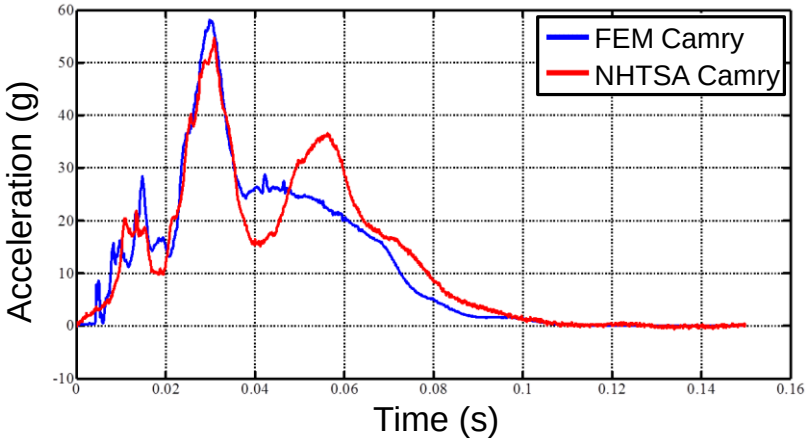
Empty model
FEM model of Toyota Camry 2012 without an engine & its components

*Source: National Crash Analysis Center, George Washington University, http://www.ncac.gwu.edu/vml/models.html

Vehicle-level Analysis: FEM Simulation

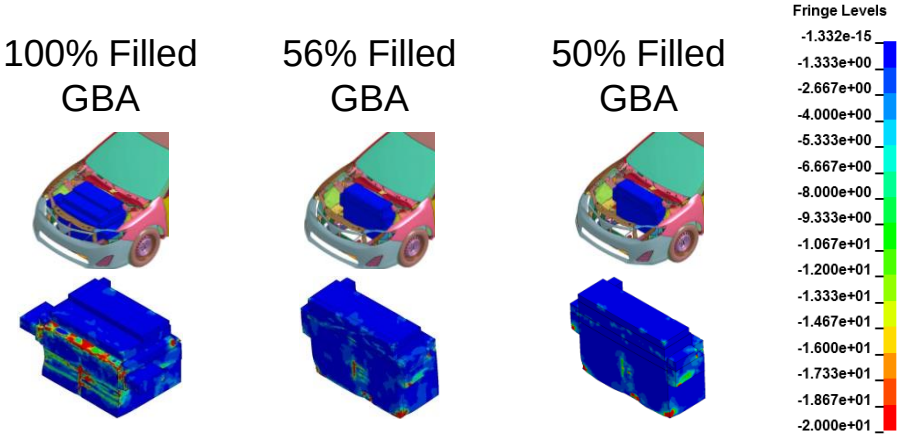
Verification of FEM Model

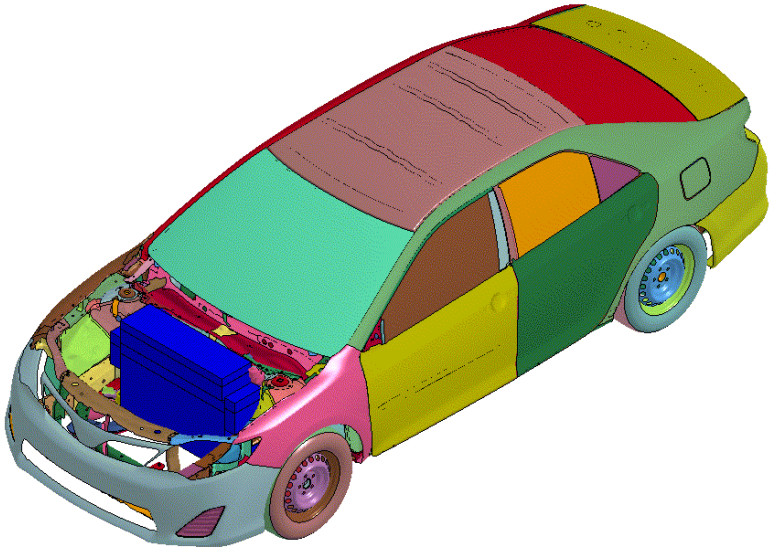




→ Verified the validity of our FEM model using NHTSA Test Data (35 mph, 56 km/h NCAP Frontal Impact)

Source: Safercar-NHTSA, http://www.safercar.gov/Vehicle-Shoppers/5-Star+Safety+Ratings/2011-Newer+Vehicles/Vehicle-Detail?vehicleId=6270

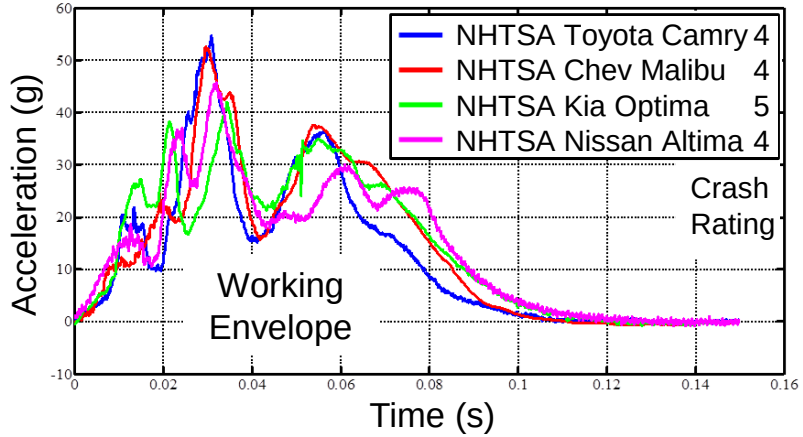




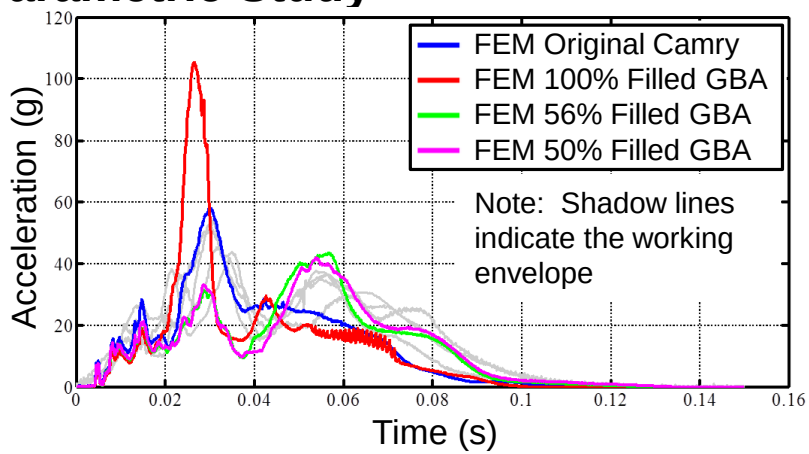
Frontal Impact FEM Simulation

Vehicle-level Analysis: Summary

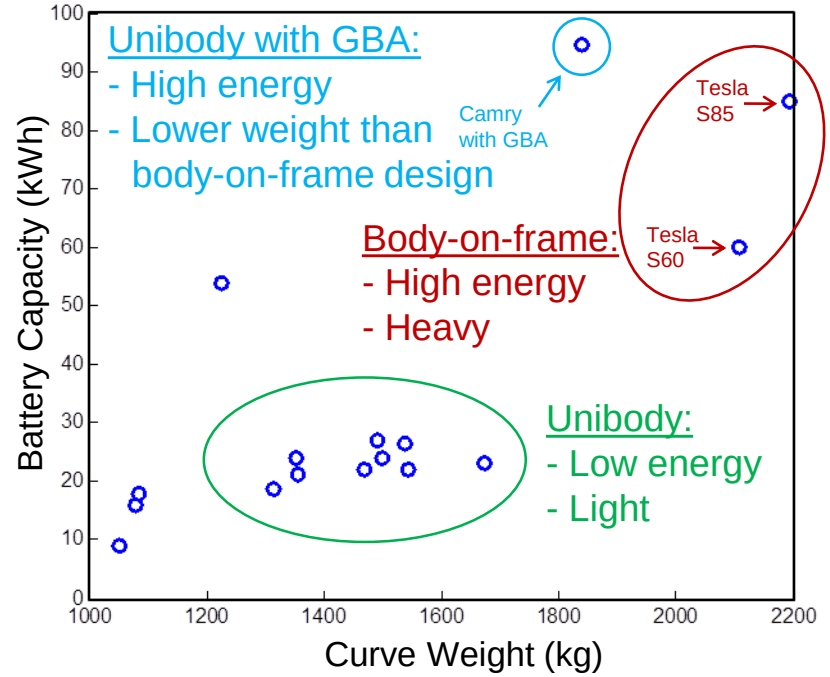
Calculation of Working Envelope



Parametric Study



→ 50% and 56% Filled GBAs is equivalent of vehicles with 4 to 5 star NHTSA safety rating



	Range (mi)	Curb Weight (kg)	Battery Capacity (kWh)	Energy-to-weight ratio (kWh/kg)
BMW i3	150	1315	18.8	0.0143
Mitsubishi i-MiEV	99	1080	16.0	0.0148
CM Spark EV	82	1356	21.3	0.0157
Nissan LEAF	50	1500	24.0	0.0160
Tesla S60	233	2108	60.0	0.0285
Tesla S85	265	2193	85.0	0.0388
Camry with GBA	**-**	**1838**	**94.7**	**0.0515**