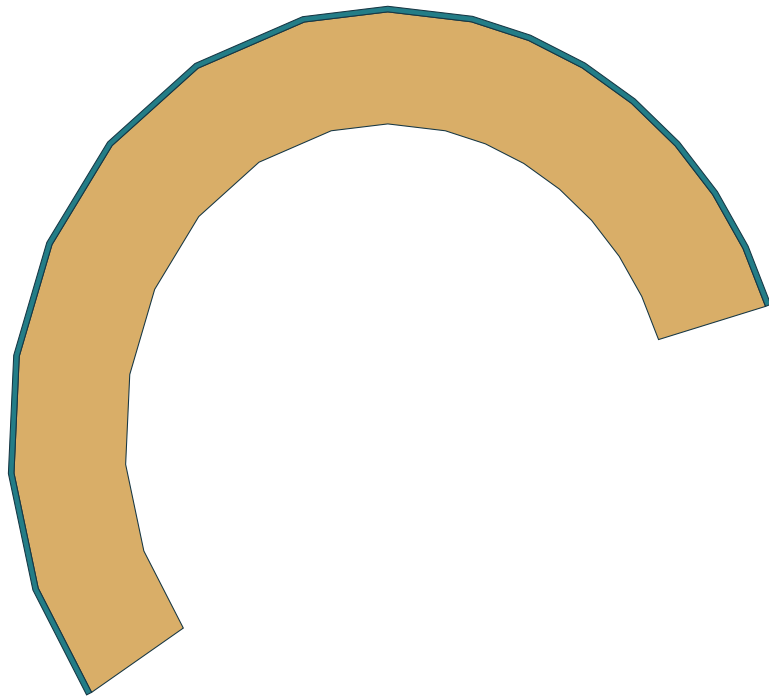


Testing overall shape at matched material mass

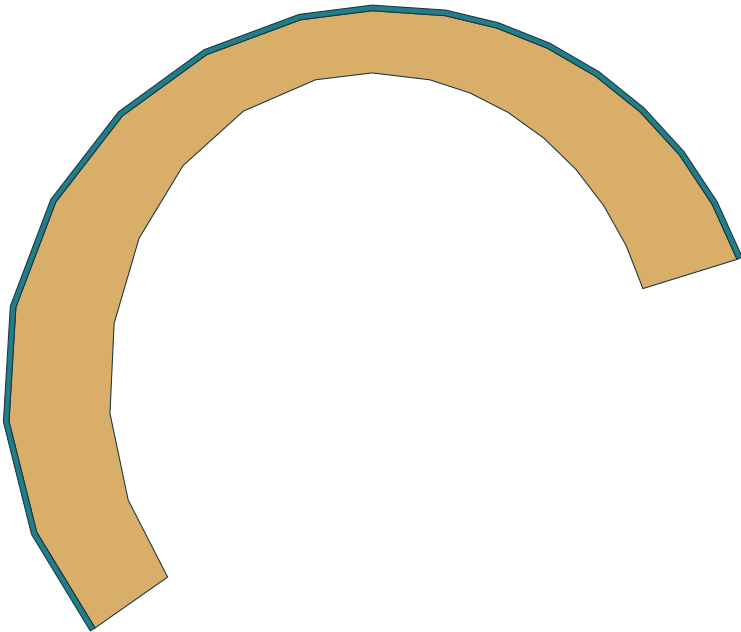
3 shapes x 3 structures x 5 impacts = 45 cases. Head-contact geometry and covered head region are held fixed.

HEAD-FOLLOWING OVAL



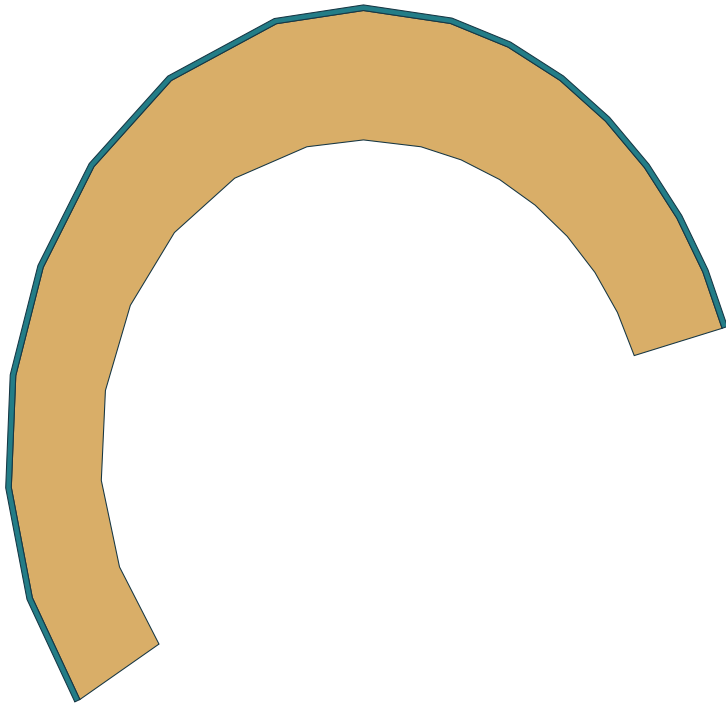
Liner 40.0-40.0 mm | shell 2.000 mm
Foam 0.584 kg | shell 0.514 kg
Sagittal section; front to right; same drawing scale.

SPHERICAL CAP



Liner 22.1-56.0 mm | shell 2.011 mm
Foam 0.584 kg | shell 0.514 kg
Sagittal section; front to right; same drawing scale.

ZONED OVAL



Liner 32.2-46.2 mm | shell 2.001 mm
Foam 0.584 kg | shell 0.514 kg
Sagittal section; front to right; same drawing scale.

CONTROLLED COMPARISON

Foam volume and target foam mass are matched. Shell ply thickness is adjusted to match shell mass.
Spherical geometry has a constant-radius shell reference surface; local liner stroke varies around the same head.
The zoned oval reallocates foam toward crown and lateral regions while preserving total foam volume.
QI_B vs BAL_B isolates ply order. BAL_B vs BAL_AC changes foam materials and their depth placement.
The original 5 kg rigid cap, bonded interfaces and nominal constitutive assumptions are shared across cases.

These are hypotheses tested by an assumed mechanical model.
A favorable numerical response does not demonstrate concussion prevention or establish a production helmet design.

Initial mesh: comparison of impact cases

45 of 45 case histories available; 45 pass the numerical gates. Responses are unfiltered FE outputs.

Shape / structure	Worst linear m/s^2	Worst angular rad/s^2	Worst spin rad/s	Relative score baseline = 1	Cases
Spherical Cap / Selected + B	3901.4	11201.7	15.9	0.974	5/5
Spherical Cap / Conventional + B	3900.1	11187.6	15.9	0.974	5/5
Head-Following Oval / Conventional + B	4223.1	17116.7	16.3	1.000	5/5
Head-Following Oval / Selected + B	4196.1	17291.4	16.4	1.010	5/5
Spherical Cap / Selected + A/C	3455.5	9270.1	16.5	1.010	5/5
Head-Following Oval / Selected + A/C	3653.9	16301.7	18.4	1.127	5/5
Zoned Oval / Selected + B	4320.4	19625.3	20.2	1.237	5/5
Zoned Oval / Conventional + B	4302.3	19691.0	20.2	1.238	5/5
Zoned Oval / Selected + A/C	3756.9	18588.0	21.1	1.289	5/5

HOW THE SCORE WAS DEFINED BEFORE THE SWEEP

For each design, take the maximum linear head-reference acceleration, angular acceleration and angular speed across the five impacts. Divide each by the corresponding worst-case metric of oval_QI_B; the score is the largest of the three ratios. This analyst-selected minimax objective penalizes a tradeoff that worsens any of the three worst-case metrics. It is not an injury probability.

NUMERICAL ELIGIBILITY

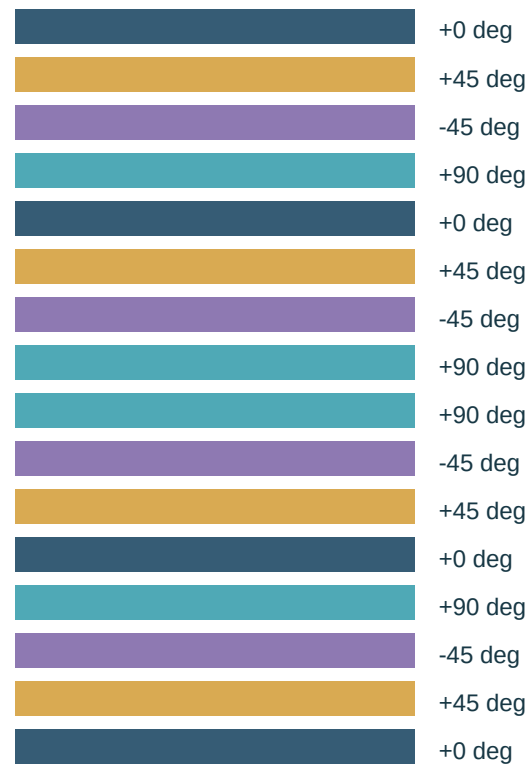
A design needs all five completed, passing cases for this ranking. Failed or truncated cases are withheld rather than treated as low responses. Total model mass spread across completed cases: 0.026%. Mesh sensitivity is reported separately; a coarse ordering alone is not a release decision.

Putting the layered structure to the test

The shell ordering pair and the graded-foam pair answer different questions; all nine input models are delivered.

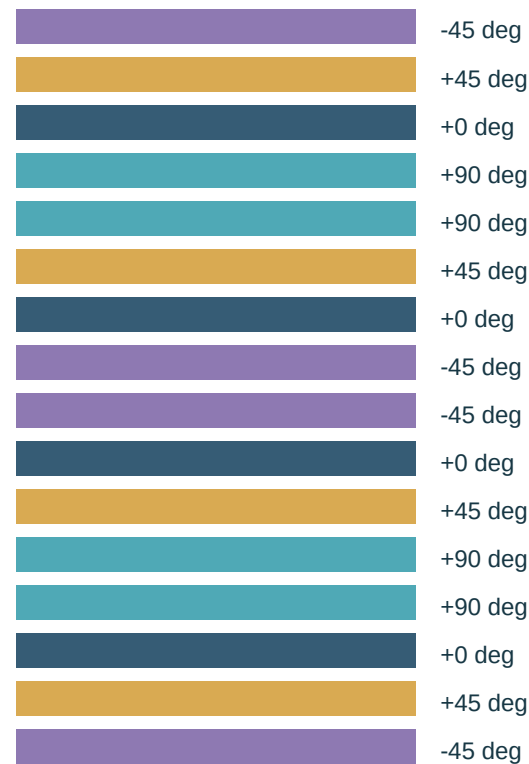
SHELL: 16 PLIES, OUTSIDE TO INSIDE

QI: conventional order



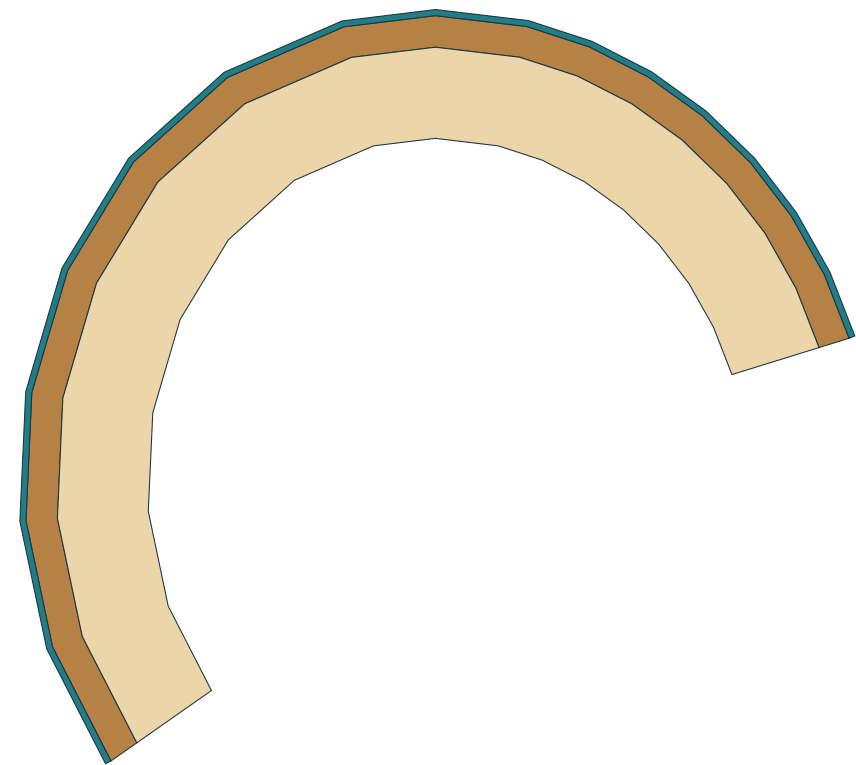
Symmetric, equal angle counts.
Ply thickness = shell thickness / 16.

BAL: selected order



Symmetric, equal angle counts.
Ply thickness = shell thickness / 16.

LINER: MASS-MATCHED MATERIAL PLACEMENT



A inside: density 97.5 kg/m³; 67.84% of foam volume.
C outside: density 183 kg/m³; 32.16% of foam volume.
The depth interface is solved by volume, not a fixed thickness ratio.

OBSERVED PAIRED EFFECTS IN THIS MODEL

Selected versus conventional shell order

Linear peak change across paired cases: -2.0% to +1.0%.
Negative means a lower peak; rotation must also be assessed.

A/C grading versus uniform B foam

Linear peak change across paired cases: -31.6% to -6.5%.
Negative means a lower peak; rotation must also be assessed.

Fiber angles are measured in each element tangent plane. The 0-degree direction is projected front-to-back, with a flagged alternate chart near singular projections. These are material axes, not manufacturable continuous fiber paths. The shell is elastic with no damage model; foam unloading, tension and rate behavior are not experimentally calibrated here.

Numerical evidence and interpretation

The experiment checks model behavior. Physical validation is still required before choosing a protective helmet design.

VERIFICATION AND SCREENING GATES

Material axes	Analytical solid and 0/45/90-degree laminate energy checks; element BETA equivalence.
Head motion	Planted translation/rotation/acceleration recovered; removing rotation fails the check.
Contact	Freeflight has negligible response; frictionless oblique impact preserves tangential momentum.
Energy	Maximum balance residual 0.131%; maximum hourglass fraction 0.132%.
Foam domain	Every foam element, eight Gauss locations per saved 0.25 ms frame; not every solver step.
Run length	Unfinished contact is continued by checked restart; histories remain joined and auditable.

MESH REFINEMENT / ASSUMPTION SENSITIVITY

9/9 medium-mesh oblique checks; 4 fine-mesh checks; 4 additional friction checks. The largest coarse-to-medium change among the three response metrics is 53.2%. These responses are mesh-sensitive; a numerically passing case is not proof of convergence. The coarse ranking is provisional and no winning helmet is established. Detailed paired comparisons are retained in refinement_summary.json.

WHAT REMAINS UNMEASURED

The synthetic head has no neck or brain. Interfaces are fully bonded, without a calibrated slip/debonding model. There is no facemask, retention system, shell failure or repeated-impact damage. Foam curves use published single-rate compression anchors with assumed unloading and tension; the model has no strain-rate dependence. Wall friction 0.2 is an assumption. The test set is not a certification protocol.

SOURCES AND REPRODUCTION

OpenCourant Windows latest-20261011; official distribution hash is retained with the prior solver installation.

Foam anchors: Bailly et al. (2020), Applied Sciences 10, 8286. DOI 10.3390/app10228286.

Elastic composite constants: PMC10450760, Table 3. Original geometry and all constitutive assumptions are documented.

GIGI stores the input specifications and measured summaries; OpenCourant computes the mechanical response.

The package includes decks, geometry, manifests, histories, numerical checks, continuation inputs and GIGI readback receipts.

How much does the numerical answer change?

A passing energy check does not establish mesh convergence. These comparisons expose resolution and contact sensitivity.

OBLIQUE IMPACT: CHANGE FROM 24 x 8 TO 32 x 10 SURFACE MESH

Shape / structure	Linear peak	Angular peak	Angular speed
oval_BAL_AC	-8.4%	-43.1%	-31.9%
oval_BAL_B	-12.1%	-52.9%	-26.4%
oval_QI_B	-13.7%	-53.2%	-25.8%
sphere_BAL_AC	-12.4%	+22.5%	+29.4%
sphere_BAL_B	-16.2%	+22.4%	+25.7%
sphere_QI_B	-17.3%	+22.3%	+25.9%
zoned_BAL_AC	+8.3%	-31.4%	-31.0%
zoned_BAL_B	+13.6%	-38.0%	-30.9%
zoned_QI_B	+9.9%	-35.7%	-30.2%

FINE-MESH CANDIDATE VERSUS BASELINE AT THE SAME RESOLUTION

sphere_BAL_B / side	+24.0%	+76.1%	+15.1%
sphere_BAL_B / oblique	+18.5%	-3.0%	-5.9%

INTERPRETATION

Top table: negative means the response fell when the mesh was refined; this is numerical sensitivity, not a design improvement. Lower table: negative means the candidate response is below the baseline at the same fine resolution. A comparison of selected impacts does not establish the worst case over all directions on the fine mesh. Friction sensitivity and every raw value are included in refinement_summary.json.

Illustrative concept cutaway

AI-generated presentation of the oval A/C concept. Hardware and cosmetic details are not simulated; this is not exact CAD.

GIGI / LAYERED HELMET CONCEPT

Oval geometry study



Facemask and retention shown for context; not simulated

Concept visualization • Geometry and hardware are illustrative • No safety claim

Illustrative design presentation

AI-generated presentation of the oval A/C concept. Hardware and cosmetic details are not simulated; this is not exact CAD.

GIGI / OVAL LAYER ARCHITECTURE

Illustrative design development

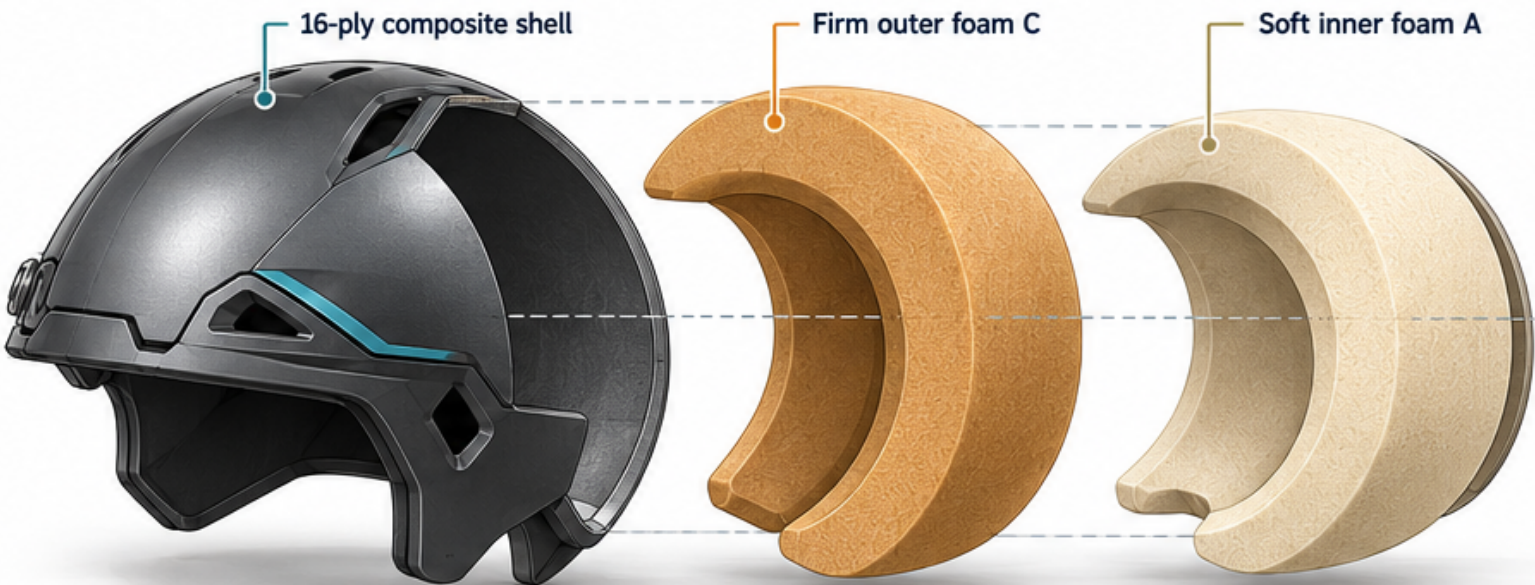
01 FRONT VIEW



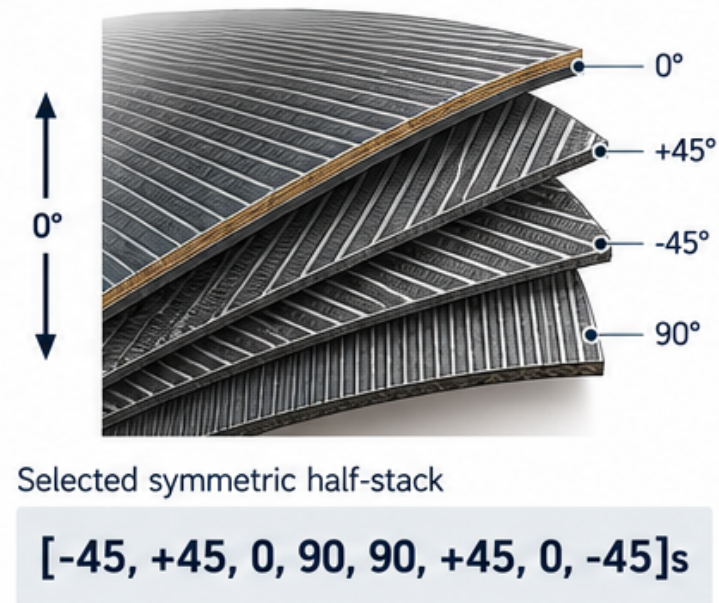
02 SIDE VIEW



03 EXPLODED LAYERS



04 FIBER ORIENTATION



Concept plate — not dimensioned CAD

Facemask, vents and retention are illustrative and not included in the impact model.

GIGI RESEARCH / CONCEPT 01 / 2026