Cooled Carbon Support for BTeV Pixel Detectors

Phase 2 Proposal – Pre-Prototype Development

3 Months, $40k Basic, +$40k Options

Energy Science Laboratories Inc.
PI: Timothy R. Knowles, PhD (knowles@esli.com)
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1. Background: ESLI Carbon Thermostructures

ESLI has developed nonpermeable fuzzy carbon tubing that can be assembled into structural heat exchangers rigidized by carbon vapor deposition at high-T. These carbon-carbon structures are suited to high-radiation vacuum environments and offer supports with outstandingly low rad length and high thermal performance.

The Atlas Pixel Detector Support represents current state of the art carbon materials design. That design is characterized by a large diameter ESLI meander tubing in a sandwich panel with dense carbon-carbon facings fabricated by BF Goodrich. These facings contribute most of the rad length and have a 3-ppm/K thermal expansion mismatch with silicon chips.

The BTeV Pixel Detector Support represents advanced carbon materials design. This design, developed in Phase 1 of this project, is characterized by interlocked fuzzy carbon tubing in which discrete carbon fiber is used for structural rigidity. The support has much lower mass than the Atlas support and its thermal expansion matches that of the chips. The porous surface in this design also permits high-thermal-conductance chip attach and enables shingling for "double-coverage" designs. **Table 1** summarizes the benefits of the proposed BTeV support compared with the Atlas design.

Table 1. Compare Atlas and BTeV Designs

	Atlas Single Coverage	**BTeV Single Coverage**	**BTeV Double Coverage**
Rad Length (%)	> 0.5	< 0.2	< 0.2
Max T Variation (K)	> 2	< 1	< 1
Thermal expansion mismatch (ppm/K)	> 3	< 1	< 1
Contact Thermal Conductance (W/K-m^2)	< 2,000	> 5,000	> 5,000
Tubing Diameter (mm)	3 mm	1 mm	3 mm
Cost Estimate ($/plate) production	> $5k 100 plates	< $5k 100 plates	< $8k 50 plates

2. Critical Features to be Demonstrated

Phase 1 resulted in a design recommendation for a cooled-carbon support, consisting of an array of fuzzy carbon tubing (fintubing), in which out-of-plane carbon fiber provides heat transfer between chip and cooled tubing, and in-plane carbon fiber provides rigidity. The design and construction are innovative and, although deemed feasible to fabricate, the thermal-mechanical performance has not been demonstrated. The purpose of Phase 2 is to gain confidence in the effectiveness of the design through demonstration of the critical design features.

Critical Design Features	Risk (1–5)
1 Carbon Tubing	
• Small-gauge nonpermeable tubing	1
• U-tubing with 1-mm diameter on 2-mm centers	3
• Radial high-k carbon fiber fintubing	3
2 Fintubing Array	
• Interlocking U-tubing	3
• Manifolding	4
3 Structural Reinforcements	
• In-plane carbon fibers	3
• Balanced in-plane stiffness and thermal expansion	4
4 Heat Transfer	
• Chip Attach	2
• Convective cooling	3
5 Surface Topography	
• Pedestals for small chips	2
• Shingling supports for large chips	4
6 Total Rad Length	
• Total rad length < 0.4%	2
• Total rad length < 0.2% (goal)	4

3. Pre-Prototype Development

Basic Development Effort — **Cost Estimate**

Task 1. Core Structure Coupon Fabrication and Testing — $25k

- Fabricate two specimens of cooled carbon-carbon panel coupons (~2 cm wide, 30 cm tubing, 10 cm fibrous region) consisting of ESLI carbon fintubing and in-plane carbon reinforcements.
- Characterize room temperature water pressure drop at design flow rate, heat exchanger effectiveness, and out-of-plane rigidity and strength (parallel and perpendicular to the tube direction). Compare with expectations.
- Iterate up to three times (total of 6 specimens), altering tubing shape and reinforcement configuration, aiming at improved performance (higher specific conductance, higher specific rigidity, and isotropy).
- Recommend core design for Cooled Carbon Panel Pre-Prototype design.

Task 2. Pre-Prototype Cooled Carbon Panel (5 x 10 cm^2) Fabrication — $25k

- Draft design of the Pre-Prototype panel
- Fabricate <u>two</u> 5x10 cm2 panels using 40-cm long tubing
  - Prepare tooling
  - One "Flat Panel" straight tubing, fuzzy surface, in-plane reinforcements
  - One "Shingle Panel" straignt tubing, fuzzy surface, in-plane reinforcements
  - Rad length <0.4%
- Attach manifold
  - Investigate soldered and polymeric manifolding options

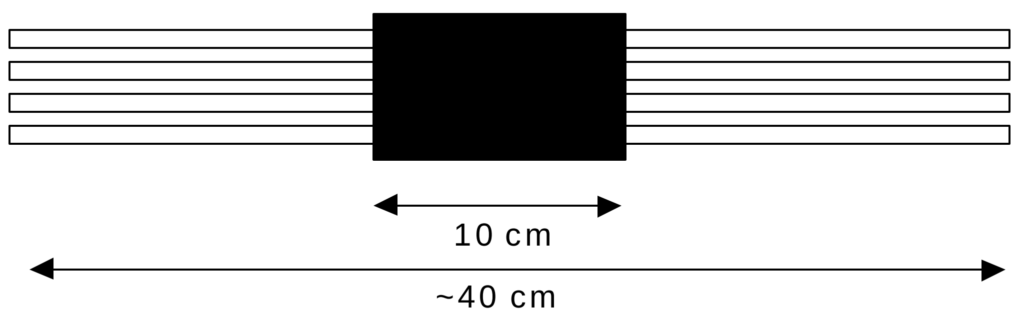
Reference: SOW Document ELSIph2btev.doc (S. Zimmerman, 20-Sep-99)

Phase 2 B-TeV Pixel Mounting Plate Prototype Program

The Phase 1 design study with ESLI has shown that there is a possibility of producing a carbon fiber plate with interior cooling for the Pixel Detector. The next step is to confirm the simulations and study the mechanical structures properties. ESLI will also try construction techniques to produce the required stiffness in the plate.

The first test unit will be a four to eight straight tube assemble to confirm the cooling calculations done earlier. This unit will also be used to test stiffening methods orthogonal to the pipes. This test unit will have carbon "fuzz" on which heaters will be attached. These heaters will provide various power levels to the test plate for measuring the temperature of the coolant and the plate surface.

Below is a cartoon of the proposed test unit. The black rectangle is the area covered with fuzzy carbon. The width,



size and number of pipes is left to ESLI to determine based on the mechanical and thermal test they need to perform. The thickness of the unit should not exceed 2.5 mm between the chip mounting surfaces. The manifold for these tests can be done with tubing. A carbon manifold is not necessary for the first test unit.

The temperature measurements should be conducted both for straight through flow and counter flow in the pipes. The test fluid should be water glycol (or other suitable fluid) that is cooled to 0° C, 10° C and 20° C. The power applied should be the nominal 300 mW/cm^2 on each side. At a minimum, tests should also be run at twice this power density.

The tests should answer questions about:

- temperature uniformity at the chip mounting surface
- mechanical rigidity of the plate
- temperature gradient difference between straight and counter-flow
- minimum thickness of the plate (or conversely the maximum size of the piping) to achieve the desired heat capacity
- construction methods and trade-off's to achieve mechanical stiffness
- possibilities to minimize the radiation length of the plate and still achieve the mechanical and thermal goals
- vibration induced by the cooling fluid flow
- radiation length of the structure (this measurement will be performed by FNAL)

The results from the test unit will be used to define a **prototype pixel plate that has the mechanical and thermal properties required for the experiment.**

Based of the current information and some guesses the prototype plate will be ~2 mm thick between mounting faces. The surface will be a series of slanted surfaces (similar to factory shed roofs) on which the detectors will be mounted in a shingle fashion. These surfaces will probably be at a shallow angle, ~5° from horizontal. The shingling on each side will be orthogonal. The prototype unit should also study the manifolding of the small tubes onto a larger tube (secondary manifold). The secondary manifold will be the point at which the plate disconnects from the main cooling delivery system. The Field Replicable Unit (FRU) will be the double-sided pixel plate along with the secondary manifold.

A more detailed drawing will be furnished to ESLI upon evaluating the test unit. This evaluation will be done in concert with ESLI.