Hall D Forward Drift Chamber Budget

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Abstract

This document details the complete preliminary budget estimate for the GlueX Forward Drift Chamber (FDC) system and is based on an earlier budget estimate contained in GlueX-doc-452-v1. That document followed the Work Breakdown Structure (WBS) categories provided by Elton Smith from GlueX-doc-307 (v10). Our internal goal in forming these estimates was to strive for a budget accuracy for each category of 30%. Any questions or comments should be directed to the authors regarding the numbers and background information contained in this document.

Budget Overview Table

	Category	Budget Amount
1.	Chamber Wire	$13k
2.	High Voltage Cables	$11k
3.	Signal Cables	$105k
4.	Printed Circuit Boards	$48k
5.	Cathode Boards	$125k
6.	Preamplifiers	$45k
7.	Preamplifier Daughter Boards	$61k
8.	Low Voltage System	$11k
9.	Chamber Frames	$66k
10.	Cathode Backing	$15k
11.	Ground Planes	$5k
12.	Mounting and Support System	$60k
13.	Gas System	$50k
14.	Chamber Cooling System	$15k
15.	Components	$20k
16.	Chamber Stringing	$100k
17.	Monitoring System	$15k
	Total	$765k

The following key is used on this budget chart. Categories with dollar amounts listed in black are up-to-date values that are considered final for this estimate. Categories with dollar amounts listed in blue are numbers that are still considered preliminary and work is in progress to finalize. Categories with dollar amounts in red are values from GlueX-doc-452 (2005) and still need work.

1 Chamber Wire

- Assumptions & Background:

◇ Sense wires: 20 or 30 μm diameter Au-plated tungsten or Au-plated Cu-Be.
Field wires: 100 or 120 μm diameter Au-plated aluminum (5056 alloy) or Au-plated Cu-Be.

◇ Length estimate: 1.2 m/wire $\times$ 110 wires/chamber $\times$ 24 planes = 3168 m
- Assume a factor of 50% waste per wind of plane.
$\Rightarrow$ 4752 m length required per wire type.

◇ Cost estimates:

Sense wire: Estimate obtained from California Fine Wire Company on Nov. 9, 2006.
- $1,132 per 1000 m (sold in 1000 m long spools)

Field wire: Estimate obtained from California Fine Wire Company on Nov. 9, 2006.
- $1,417 per 1000 m (sold in 1000 m long spools)

◇ Totals: Sense wire - $1,132 × 5 = $5,660
Field wire - $1,417 × 5 = $7,085
$12,745

- Notes:

1. The Hall B group purchased wire mainly through the California Fine Wire company. Karen Kephart from Fermilab also uses a company called Little Falls Alloys in New Jersey.
2. Karen Kephart from Fermilab states that the price quotes from Little Falls Alloys are comparable to California Fine Wire company.
3. The sense wire cost estimate above was based on 20 μm diameter wire. The cost for 30 μm diameter wire is $995 per spool. The cost for Cu-Be wire is the same as for tungsten wire.
4. The field wire cost estimate above was based on 120 μm diameter wire. The cost for 100 μm diameter wire is $1,311 per spool. The cost for Cu-Be wire is the same as for tungsten wire.

- Current budget allocation: $13k.
- Contacts: John Barney (CFW), Karen Kephart (FNAL)

2 High Voltage Cables

• Assumptions & Background:

◇ HV from CAEN-type system with distribution similar to that in use in Hall B.

◇ A "mother" HV cable feeds 12 "baby" HV cables. The baby cables are 5-kV rated with tefzel insulation. The mother cable is PVC-jacketed.

◇ Granularity: Assume 1 mother cable per plane × 24 planes = 288 HV channels.
Number of wires/HV channel = 20

◇ Assume HV cable length of 30 m (100 ft) to local HV control.

◇ Cost estimates:

Estimate obtained from General Wire on Nov. 20, 2006.

- \$3.54/ft for HV insulated mother cables
- HV connector costs at \$100/cable (source Marc McMullen)

◇ Totals: Cable cost: 1 cable/plane × 24 planes × \$3.54/ft × 100 ft = \$8,500
Connector cost: \$100/cable × 24 cables = \$2,400

\$10,900

• Notes:

1. This estimate does not include costs for the HV mainframe, controllers, modules, or distribution system.
2. If a common HV system is planned for the CDC and FDC systems, cost reductions could be realized (for bulk purchase).
3. How should be ultimately decide on the number of wires controlled by a given HV channel? The current assumption above is 20 wires/channel.

• Current budget allocation: \$11k

• <u>Contacts</u>: General Wire sales representative, Marc McMullen

3 Signal Cables

- Assumptions & Background:

◇ Readout is via round-jacket shielded flat cable.

- Use 50-pin cable for cathode readout (to FADCs).
- Use 34-pin cable for anode readout (to TDCs).

◇ Channels: (Anode) 96 wires/layer · 24 layers = 2304

$\Rightarrow$ 2304 channels/16 channels/cable = 144 cables

(Cathode) 384 cathodes/layer · 24 layers = 9216

$\Rightarrow$ 9216 channels/24 channels/cable = 384 cables

◇ Assume signal cable length of 30 m (100 ft) to local electronics (TDCs/ADCs).

◇ Cost estimates:

- 34-pin ribbon cable costs at $140/100ft (source Digi-key catalog)
- 50-pin ribbon cable costs at $172/100ft (source Digi-key catalog)
- Signal cable connector costs at $1/connector (source Jeff Wilson)

◇ Totals:

Anode readout cable cost: 144 cables × $140/100ft =	$20,160
Cathode readout cable cost: 480 cables × $172/100ft =	$82,560
Connector cost: $1/connector × 528 cables × 2/cable =	$1,056
	$103,776

- Notes:

1. Can capacitive coupling of the cathode strips be employed to reduce the number of cathode readout cables by a factor of two?

- Current budget allocation: $105k
- <u>Contacts</u>: Marc McMullen, Jeff Wilson, Digi-key catalog

4 Printed Circuit Boards

• Assumptions & Background:

◇ The printed circuit (PC) boards here include only the boards for the wire planes. The cathode planes and the grounding planes are included under separate headings.

◇ Each wire plane consists of 3 signal boards (STBs) and 3 high voltage boards (HVTBs). The total number of STBs is 72 and the total number of HVTBs is 72 for the full FDC system.

◇ Fernando has obtained a quote from Advanced Circuits for the arc-shaped STB and HVTB boards that meet our specifications. The quote is for 4-layer boards.
◇ For this estimate we assume that we will order 6 different boards (3 different STB boards and 3 different HVTB boards). We require 24 of each type of board.
◇ Cost estimate:

STBs: \$200/board × 72 boards =	\$14,400
HVTBs: \$200/board × 72 boards =	\$14,400
Tooling charges:	\$1,000
Testing charges:	\$1,000
Board stuffing: \$100/board × 144 boards =	\$14,400
	\$45,200

• Notes:

1. Component mounting is typically done after the wire winding in order to make sure that they are not in the way. However we may have to design board to allow the board stuffing to occur before winding.
2. Costs do not include boards for spare chamber or prototypes.
3. Board stuffing numbers come from a quote from Brian Kross for a similar size board.

• Current budget allocation: \$48k

• Contacts: Fernando Barbosa, Brian Kross

5 Cathode Boards

- Assumptions & Background:

◇ The cathode boards will be made from "flex"-type boards fabricated from copper-coated kapton. The kapton will be 25-μm thick and will be plated on one side with 1/7 oz of copper.

◇ Each cathode plane will consist of 3 separate flex boards that will make up a circular board roughly 1 m in diameter.

◇ Circuit boards needed for full complement of 24 wire planes. Two cathode planes required per wire plane ⇒ 48 cathode planes.

◇ Cost estimate from CCT Marketing based on the quote for the flex boards being designed for the full-scale FDC prototype:

$25,000 for 10 full cathode planes ⇒ $120,000 for 48 planes.

board stuffing: $100/board × 24 boards = $2,400

⇒ Total cost = $122,400

- Notes:

1. This price quote includes the kapton backing material.
2. Costs do not include boards for spare chamber or prototypes.

- Current budget allocation: $125k
- <u>Contacts</u>: Dave Lasky (CCT Marketing), Brian Kross, Fernando Barbosa

6 Preamplifiers

- Assumptions & Background:

◇ Preamplifiers will be of ASIC (CMOS) design, similar to ATLAS.

◇ ASIC channel density: 8 channels/preamp

- Anode channels: 96 wires/layer × 24 layers = 2304
- Cathode channels: anode channels × 4 = 9216
- Total channels: 11520

⇒ Number of preamps = 11520/8 = 1440

◇ Cost estimates:

- 4000 ASIC preamps = $84,000
- Packaging costs = $2,560
- Bond diagram = $250

◇ 4000 ASIC preamps is a number for the full complement for the CDC and FDC. Given the associated costs above, this amounts to $22 per ASIC which will be used for the estimate here. The following estimate includes the FDC share of the 4000 preamps which is assumed to be 2000.

⇒ $22 × 2000 = $44,000

- Notes:

1. The budget numbers here were provided by Fernando Barbosa after interaction with Mitch Newcomer.
2. The 4000 preamps includes spares for the life of the system.
3. The cost estimates here are for production quantities. It is expected that prototype costs may add up to an additional 30% of the production costs. The associated prototyping costs are not included in this estimate.
4. Can capacitive coupling of the cathode strips be employed to reduce the number of channels by a factor of two?

- Current budget allocation: $45k

- <u>Contacts</u>: Fernando Barbosa, Mitch Newcomer, John Schaapman

7 Preamplifier Daughter Boards

• Assumptions & Background:

⋄ Assume that for the cathode planes the daughter boards will contain 3 ASIC chips. For the anode plane daughter boards, they will contain 2 ASIC chips.

⋄ The number of anode daughter boards = 6/layer × 24 = 144 boards.
The number of cathode daughter boards = 16/layer × 24 = 384 boards.

⋄ A detailed cost estimate for each of the different types of board has been prepared by Fernando Barbosa.

The cathode daughter boards costed at $85/board × 400 boards = $34,000.

The anode daughter boards costed at $95/board × 200 boards = $19,000

Turn-key charges for board manufacture (stuffing) = $7,900

⋄ Total board system cost = $60,900

• Notes:

1. Can capacitive coupling of the cathode strips be employed to reduce the number of cathode channels by a factor of two?
2. The cost estimates here include the connections to the cooling system and a securing mechanism and are rough costs.
3. The board stuffing includes procurement of components by the company.

• Current budget allocation: $61k

• Contacts: Fernando Barbosa, Mitch Newcomer

8 Low Voltage System

- Assumptions & Background:

◇ Cost estimates:

- Based on quote from Wiener representative for the PL500 Series PS system.
- System cost is \$675 per 30-A supply.
- Power for each ASIC channel is 40 mW.
- Total number of supplies required determined by total current to supply at 5-V DC.

  $I_{tot} = P_{tot}/V = 40$ mW $\times$ 12000 channels/5 V = 100 A.

  ⇒ number of supplies required is 4 (one per package).

  - Power supply cost = \$2,700
- Fuse and distribution system cost at \$1,500 per supply (including current monitoring).

  - Fuse/distribution system cost = \$6,000

◇ The cabling for the low voltage system will consistent of 1-gauge wire from the supply to the fuse box and Belden 9952-1000-9 multiconductor 16-AWG cable from the fuse box to the chambers. Marc McMullen has stated that the cost is \$533 per 1000 feet. Assume that each chamber will be fed by 6 cables of 100 ft length.

⇒ Total length of cable = 6 × 100 ft × 4 packages = 2400 ft

⇒ Cable cost = \$533 × 3 = \$1,600

- Total: \$10,300

- Notes:

1. Costs for fuse/distribution system from Marc McMullen on Nov. 16, 2006. He gave us an estimate of \$400/chassis for a fuse/distribution system without current readout. He stated at \$1,500/chassis with current readout is a reasonable value.
2. This budget estimate does not include any LV monitoring/control system. This is included in another budget category according to communication from Elton Smith on Nov. 27, 2006.

- Current budget allocation: \$11k
- <u>Contacts</u>: Mark Kibilko (Wiener), Marc McMullen

9 Chamber Frames

- Assumptions & Background:

◇ Frames refer to all g10 and CH_2 chamber frames and spacers.

◇ Multiple frames per chamber layer (similar to FDC prototype).

Layout: cathode sandwich planes = 14
spacers = 6
anode wire frames = 6

Total: 26 frames/package

⇒ 104 frames in total

In each package there are 18 CH_2 frames and 8 G10 frames.

◇ Cost estimate for materials and manufacture:

- The JLab machine shop has provided an estimate of $30,000 for machining holes and cut-outs and for the g10.

- Brian Kross has gotten a quote for the CH_2 of \$96/sheet $\times$ 18 sheets/package $\times$ 4 packages = $6,912.

- The JLab machine shop has provide a quote to machine the CH_2 sheets to the appropriate thickness and flatness of \$400/sheet $\times$ 72 sheets = $28,200.

◇ Total frame costs = $65,112

- Notes:

1. The chamber wire frames should be constructed from g10 and not FR4 to eliminate concerns about outgassing of non-chamber-friendly bromine additive.

- Current budget allocation: $66k

- Contacts: Brian Kross

10 Cathode Backing

- Assumptions & Background:

◇ The cathode board backing material will be low-density Rohacell foam.

◇ Cost estimate:

  - We have purchased 49 in × 49 in sheets for \$200 per sheet.
  - Totals = \$200/sheet × 12 sheets/package × 4 packages = \$9,600

    Machining costs of \$100/sheet × 12 sheets/packages × 4 packages = \$4,800

    ⇒ Total cost = \$14,400

- Notes:

1. The \$200 per sheet estimate comes from the small order that we have already made.
2. The machining costs come from Brian Kross.

- Current budget allocation: \$15k
- Contacts: Brian Kross

11 Ground Planes

• Assumptions & Background:

◇ The ground planes are part of the cathode sandwich construction with one ground plane between each layer and one on each end of the chamber. The total number of these planes per package is 7 and the total number of ground planes for the FDC is 28.

◇ The ground planes will be graphite-coated mylar or kapton with the graphite sprayed on. We have also considered using aluminized mylar sheets.

◇ Cost estimate:

- The cost for the backing material and graphite is estimated at $5,000.

• Notes:

1. Alternative conducting material besides graphite that may be attractive is India Ink which can also be sprayed or painted on. Each of these different technologies has roughly the same costs.

• Current budget allocation: $5k

• <u>Contacts</u>: Brian Kross

12 Mounting and Support System

• Assumptions & Background:

◇ Thompson rails will be part of the FDC assembly structure and be used to transfer the FDC in and out of the solenoid. The support structure will consist of aluminum welded ribs, skin, and rails. It will support the FDC structure and stay with the FDC at all times.

◇ An elevated work platform will be used at the installation site to install the FDC, as well as to perform minor repairs. This platform will be removable by crane when not needed.

◇ The crane in the hall will be used to transfer the assembly onto the installation work platform.

◇ The cost estimate includes:

- Support frame = $15,000
- Chamber assembly fixture = $2,000
- Work table in lab for complete assembly = $3,000
- Installation/repair platform = $30,000
- Rail system inside Barrel Calorimeter = $3,000
- Cable trays and cable support system $,5,000

⇒ Total cost = $58,000

• Notes:

1. The budget numbers here were put together by Tim Whitlatch who put together the system design.

• Current budget allocation: $60k

• <u>Contacts</u>: Brian Kross, Chuck Hutton, Tim Whitlatch

13 Gas System

- Assumptions & Background:

◇ Gas system costs include all parts, controllers, and monitoring computers.

◇ The initial design for the FDC gas system will not include gas recirculation.

◇ Brian Kross has received quotes for the different components of the FDC gas system. The input side costs came from MKS and the output side costs came from Panametrics.

◇ Input side: 8-channel mass flow controller (with values and cables) = $16,167.

Alcohol bubblers = $2,000/package × 4 = $8,000

Automatic cylinder change-over system = $2,115/system × 2 = $4,230

Stainless steel tubings and fittings = $3,000

Valves and connectors = $5,000 + $3,000 = $8,000

◇ Output side: The outlet of each chamber package will be monitored for water and oxygen content. Brian Kross has obtained a quote from Panametrics on a complete system to perform this monitoring. The cost for this system is $10,000.

◇ Total cost of system: Input side ($39,397) + Output side ($10,000) = $49,397

- Notes:

1. We currently plan on using a gas mixture of 90-10 Ar-CO_2. The system that we have designed can handle three component mixtures with minor rearrangement.
2. The automatic gas cylinder change-over system was priced from GTS.

- Current budget allocation: $50k
- Contacts: Dick Jacobs (MKS), Brian Kross

14 Chamber Cooling System

• Assumptions & Background:

◇ Conduction will be used to bring the heat out of the preamps and into the FDC support structure. The support structure will be used as a heat sink.

◇ A combination of radiation and convection will take heat out of the support structure. A dry air blower will be used to force air into the FDC area via small duct work that will be distributed to cool the heat sinks.

◇ The costs include:

- Conductive heat transfer hardware = $4,000
- Dry air blower = $6,000
- Air duct work = $5,000

⇒ Total system cost = $15,000

• Notes:

1. The budget numbers here were put together by Tim Whitlatch who put together the system design.

• Current budget allocation: $15k

• Contacts: Brian Kross, Mitch Newcomer, Tim Whitlatch, Chuck Hutton, Fernando Barbosa

15 Components

- Assumptions & Background:

◇ This category is includes all parts, materials, equipment, on-chamber electronic components.

◇ Components: We have a quote of \$0.25 per component (resistors, capacitors) and there are an estimated 2,500 components/package × 4 packages = \$2,500.

◇ The HV connections to the wires will be made with Reynolds connectors. The connectors cost \$30 each. The cost is then 12 connectors/plane × 24 planes × \$30 = \$8,640.

◇ All on-chamber gas connectors. Estimated cost is \$3,000.

◇ Chamber O-rings, epoxy, cleaning supplies estimated at \$5,000.

⇒ Total cost: \$19,140

- Notes:

1. We have obtained price quotes from the Digi-key catalog for the resistors, capacitors, HV connectors, and o-ring material.

- Current budget allocation: \$20k
- Contacts: Brian Kross

16 Chamber Stringing

• Assumptions & Background:

⋄ We are presently planning to have the FDC wire planes strung at Fermilab as they have the infrastructure and equipment to handle this work.

⋄ There are 24 wire planes in the FDC system. The current design includes both sense and field wires, totaling 105 each per plane. Total wires to string is thus ∼5100.

⋄ The budget for FDC wire winding has been set at $100,000 (source Elton Smith).

⋄ The budget for this item includes costs to deaden the wires about the central beam hole to a radius of ∼5 cm and to perform measurements of the wires after placement, including tension measurements and wire positions.

• Notes:

1. We have been in contact with Karen Kephart at FNAL regarding stringing of all FDC chamber planes.
2. With the chambers wound elsewhere, we need to have the infrastructure in place at JLab to make repairs on the chambers.
3. At the current time JLab does not have the infrastructure or equipment to wind chambers of the 1 m scale.

• Current budget allocation: $100k

• Contacts: Brian Kross, Karen Kephart (FNAL)

☐ **Brian has been in contact with Karen Kephart to get a quote on the winding, the deadening, and the tension and spacing measurements.**

17 Monitoring System

• Assumptions & Background:

◇ The monitoring system includes components to measure the temperature at various points in the FDC system as well as to monitor humidity. The cost estimates include sensor, cables, and readout electronics for a 64 board system.

◇ The costs associated with element of this system include:

Sensor PC boards: $3.00 each x 64 = $192

Temperature sensors: $1.50 each x 64 = $96

Humidity sensors: $30.00 each × 64 = $1,920

Connectors: $2.00 each x 2 x 200 = $800

Stuffing: $640 / 64 mini-boards

Shielded ribbon cable: $1.00/ft x 100 ft x 64 = $6,400

Distribution board+chassis: ($100 / 32 channels) x 6 = $600

34-conductor socket-to-socket cable with connectors: $20/assembly x 2 x 6 = $240

VME boards: $2000/module x 2 = $4,000

◇ Total system cost = $14,888

• Notes:

1. The cost for the sensor boards was based on the quote that Fernando provided for the preamplifier daughter boards based on a bulk order.
2. The temperature sensors were priced from the Analog Devices web page.
3. The connectors were priced from the Digi-key catalog.
4. The cable numbers come from the information collected for the signal readout cables.
5. The socket-to-socket cables were priced from the Digi-key catalog.

• Current budget allocation: $15k

• <u>Contacts</u>: Fernando Barbosa

18 Notes

1). No costs associated with labor are included in this budget estimate.

2). Off-chamber electronics (TDCs, ADCs, discriminators), along with electronics racks and crates are **NOT** part of the FDC WBS and are listed under separate budget categories (from Elton Smith communication Nov. 27, 2006). All FDC on-chamber electronics are included within the FDC budget.

3). Estimates here do **NOT** include the costs associated with the high voltage mainframe, controllers, or modules. This system is listed under a separate budget category (from Elton Smith communication Nov. 27, 2006).

4). Costs here do **NOT** include any R&D funds required to complete the system design and prototyping. This are included under a separate budget category known as *"PED"* for Project Engineering and Design.

5). Costs associated with spare chambers are **NOT** included here. They are under a separate budget category.

6). On-chamber electronics and cables presently estimated does not account for any possible reduction of cathode readout channels due to capacitive coupling techniques. This could be an important cost consideration.

7). Estimates here do not include any monitoring/control system for the FDC HV system. This system is listed under a separate budget category (from Elton Smith communication Nov. 27, 2006).

8). Estimates here do not include any accounting for the pulser calibration system. This will be built into the readout electronics (FADCs, TDCs). The requisite design costs for the preamp daughter boards include this capability.