ILC-SLACESA TN-2007-2
October 3, 2007

Preliminary Plan for a Hadron Production Facility at the SLAC A-Line and End Station A

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1. Overview

A facility for production of secondary beams of charged hadrons (pions, kaons and protons) in the A-Line at SLAC for use in test beam experiments in End Station A (ESA) is described. The proposed facility would be comprised of a system of bend and focusing magnets, a beryllium (Be) production target, a dump for the primary beam, and a filter to reduce the electron and positron background. The facility would have collimators and beam containment devices to allow primary beam operation up to a power of ~6 kW. ($2 \cdot 10^{10}$ electrons at 25 GeV and 60Hz gives 4.8 kW beam power.) This facility would be located in the long drift section in the A-Line in the Beam Switch Yard (BSY), downstream of the existing A-line bends and just before the entrance to ESA. The hadrons produced in the Be target would be momentum-analyzed and focused into the ESA beamline.

A schematic layout is given in Figure 1. North is up in the figure. The incident electron beam is bent 0.8 deg North in two 10D37 dipole magnets to strike the 15.25 cm (0.427 radiation lengths, X_0) long Be target located offset to the main A-Line. The primary beam continues on past the 10D37 exit bend magnet and quadrupoles into a water-cooled W-Cu-W dump. The hadrons produced at 1.5 deg with respect to the incident beam are accepted into the A-line through a new water-cooled protection collimator PC28, then bent 0.7 deg North into the A-Line by the exit 10D37 bend magnet, and focused by quadrupoles Q29(new), Q30 and Q38 through the collimators in ESA. An electron filter, ~5-7 X_0, can be inserted into the hadron beam to preferentially remove unwanted electromagnetic background. Most hadrons will pass through the filter with some scattering and interaction, and some will be lost on the acceptance collimator.

The components in the proposed design have analogs with components in the existing scheme for hadron production which uses the Be target at its present location in the BSY. PC28 corresponds to the D-10 dump that sets the geometric acceptance of the A-line; the exit dipole 10D37 corresponds to the A-line bends; C37 performs the function of the momentum slit SL10; Q38 provides dispersion correction similar to Q19 and Q20 (but will only be able to zero η, while Q19 and Q20 allow to zero both η and η'); and Q29 and Q30 focus the beam into ESA, with somewhat reduced capability to being able to use Q27, Q28, Q30 and Q38 as is presently done.

The design is preliminary at this stage. It is based on a realistic layout starting with existing components in the A-Line and assumes the new components will be produced from mostly existing equipment. The particle production performance of the system has been estimated extrapolating from existing production rate data.[1,2] Detailed optimization of collimator apertures, target position, filter location and thickness, production rates for the various particles versus beam energy and particle momentum, and optics scenarios for focusing the hadrons into ESA will be done in the future.

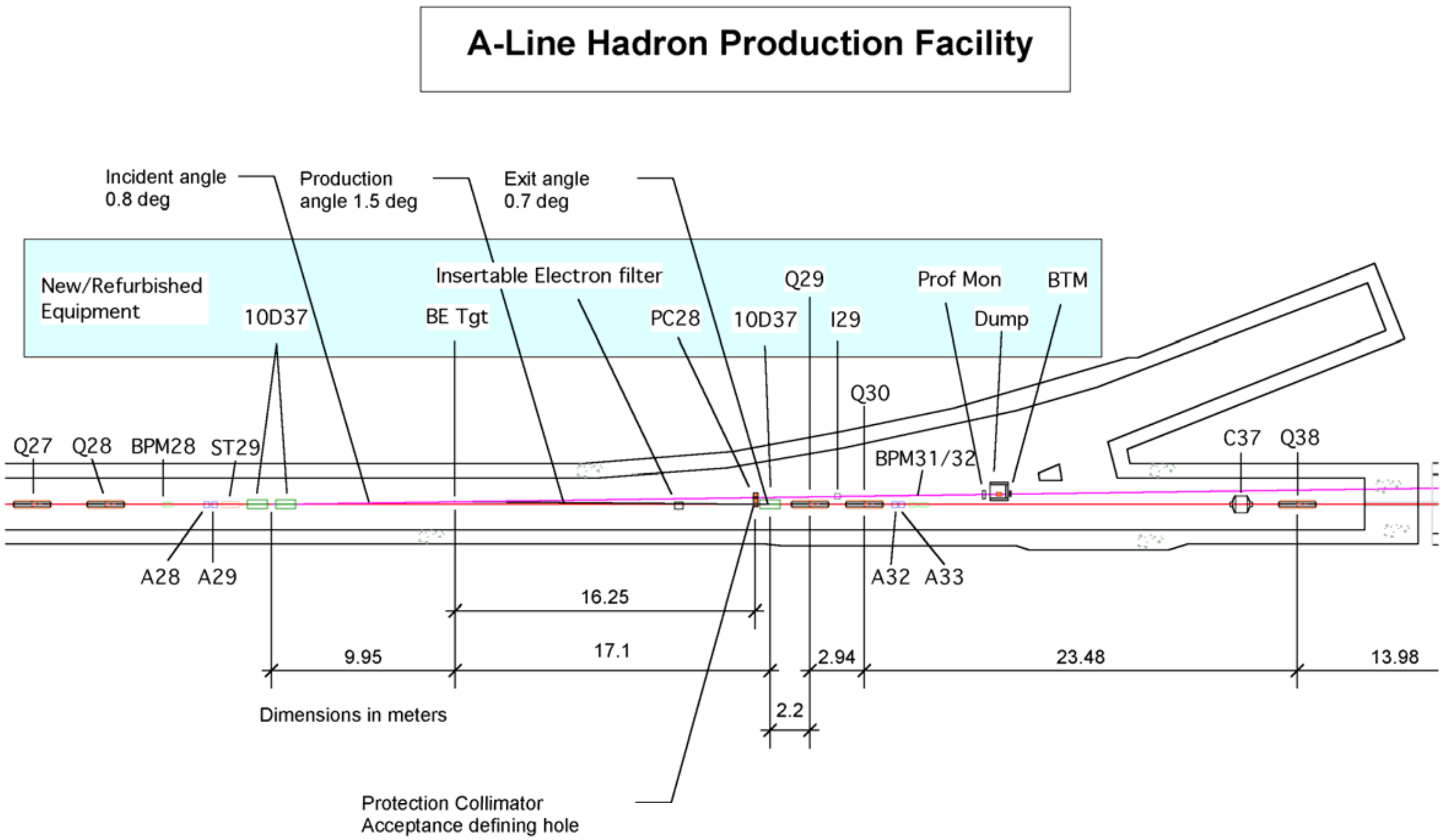

Figure 1. Layout of the Hadron Production Facility in the SLAC A-Line. Changes to the existing beamline are shown in the blue box.

2. Particle rate estimate

Yields of secondary particles from 18 GeV electrons on a Be target were measured in the SLAC ESA shortly after SLAC first turned on and are available in A. M. Boyarski, et al, SLAC Users Handbook, Section C2, (1968).[2] This SLAC Handbook data shows π^+ and π^- particle yields to be ~4×10^{-4} per [incident electron-sr-GeV/c] at 1.5-deg production angle from a 15cm Be target and 2 to 4 GeV/c particle momentum, with an 18 GeV incident electron beam. The maximum acceptance in the proposed hadron production facility in the A-line is set by the collimator PC28, and is about 6 µsr. (The existing A-line acceptance secondary production from the Be target in the BSY is 0.14 µsr.) The momentum dispersion from the exit 10D37 will be corrected at the experiment in ESA by Q38. The maximum momentum acceptance set by C37 and the 3C1 collimator in ESA will be about 11%. (The maximum momentum acceptance in the Aline bend system at the SL10 collimator is 2%.) These acceptance values give estimated rates for π^+ and π^- particle yields in ESA of ~10 pions per beam pulse with 10^{10} incident electrons. Rates for K^+ and protons are factors of 10 to 50 smaller than for π^+. Figure 2 and Table 1 in Appendix I show secondary particle yields and their momentum dependence, measured in earlier SLAC experiments. These data guide what can be expected in the proposed facility. To reduce electron backgrounds, the polarity of the 10D37 dipoles will be chosen to accept positively charged particles into ESA.

There is extensive secondary particle production data with good models and fits that will be used in the future to improve our estimates. Even these crude estimates show that the facility will produce good yields for test beams. The particle rates can be easily adjusted down by tuning the incident beam current from the source and by adjusting the A-Line momentum slit SL10. The C37 collimator just in front of the entrance to ESA can also be used to reduce the flux and narrow the momentum acceptance if desired. C37 has 30 X_0 Cu followed by 30 X_0 W for each of 4 adjustable jaws.

Particle identification will be made by combinations of gas threshold Cherenkov counters in the beam line and calorimetry. Measuring time-of-flight over the roughly 110 m between the Be target and detectors in ESA can also improve the separation of π/K/p. Long pulse operation can allow higher rates and improve the usable kaon and proton flux.

3. Components, new and refurbished

Many components of this facility would be obtained from refurbishment and/or modification of existing equipment. The main elements are:

3.1 Be target

The 15 cm long Be target currently located in the BSY at the center of the pulsed magnet string at the start of the A-Line will be used (Figure 3). It requires some small modifications to the SEM instrumentation and a new vacuum chamber with adjustable support.

3.2 10D37 bend magnets

The 10D37 dipoles were built for the SPEAR injection transport Beam Line 15 that was decommissioned ~1990. Three of these magnets (used most recently in a four-magnet chicane in the spin structure function experiments E143 and E155 in the 1990's) are available and now stored in ESA (Figure 4). Vacuum chambers recently removed from the four 10D37 magnets now installed in the ILC-ESA energy spectrometer test are also available (Figure 5). The magnets need only cleaning and refurbishing of hoses and klixons. The chambers need flanges. They are aluminum and will need an aluminum-to-stainless transition piece to allow welding on stainless conflate flanges.

The original stands for the 10D37 magnets are available in storage (Figure 6). They would be modified to replace the top works with new adjustable magnet supports for alignment. These could be extracted from soon-to-be decommissioned bend magnet stands in the HENIT Arc Region, or similar ones could be built using the HENIT designs.

3.3 Quadrupole Q29 – 8 cm BSY quad

Q29 will be a standard 8cm-bore BSY quadrupole identical to the existing Q30 and Q38. We will use Q41 which was removed from the ESA alcove and is currently stored in ESA (Figure 7). An existing quad stand is in storage behind ESA (Figure 7).

3.4 Beam dump

An 8 kW water-cooled beam dump, previously used as ST4 in the SLC arcs, is available (Figure 8). It contains 3 X_0 of W brazed, front and back, to a Cu block of 18 X_0 for a total of 24 X_0. It will be removed from its current stainless steel vacuum chamber connections and mounted in air on a simple stand. The dump will be enclosed in a small enclosure of 6-inch thick iron walls and roof mounted on a suitable stand. This dump shield, known as the "Dog House" and originally used at the FFTB, is in storage in the Research Yard (Figure 8).

3.5 Toroid I29

The toroid I29 is currently located on the A-Line near Q30 and will be repositioned to measure the primary beam going to the dump. A new stand is required.

3.6 Protection collimator PC28

This collimator serves the purpose of protecting the components downstream of the spray from the Be target and from possible mis-steering from the upstream 10D37 magnets and correctors A28 and A29. It also serves as the aperture-defining collimator to protect downstream components of the A-Line. It would serve the same function as the currently existing collimator PC29 located upstream of Q30 that would be removed. PC28 would be a water-cooled Cu structure mounted in vacuum and supported on a stand with suitable adjustment for precision alignment. It would be a new component designed and built from scratch.

3.7 Electron filter

Hadron production in the Be target is accompanied by significant numbers of electrons and positrons. Electrons and positrons can be discriminated against using Cherenkov counters in the beamline, but this has costs in equipment and data rate. A better strategy is to sweep the background out of the beam before it enters ESA. The electromagnetic background can be significantly reduced by inserting a few radiation lengths (5-7 X_0) of material in the hadron beam in front of the momentum-defining magnet. This device would be comprised of a simple slab of material on a remotely actuated mover, powered by an air cylinder. It would be designed and made from scratch to fit into the beam pipe downstream of the Be target. There are many similar mover devices decommissioned in storage that could be used for parts.

3.8 Profile monitor before the dump

This profile monitor would be a chromium-doped Al_2O_3 screen in air viewed by a TV camera to monitor the beam at the entrance to the dump.

3.9 Vacuum pipe sections

Two new drift sections with some special flanges and supports would be needed, one between the upstream 10D37 magnets and the Be target, and a slightly larger one between the Be target and PC28. These are likely to be made from existing pipe sections now in storage in the Research Yard. The main work would be design and manufacture of the required flanges and supports compatible with connections to the Be Target, dump line and support for PC28.

In addition, a few spool sections and bellows of standard design would be required. Many bellows are available from decommissioned beam lines.

3.10 Magnet power and water

Adequate supply of LCW is available in large headers in the BSY for cooling the magnets, the dump and collimators. Edge-cooled dumps and collimators at 3-6 kW do not require radioactive water for cooling. Taps into the headers are required, and appropriate flexible line connections would be made.

Power supplies matched to the magnets are available in Bldg 108. New power cables would be required. Three options for routing new cables (non water-cooled locomotive cable) from Bldg 108 to the BSY are being considered: i) through trenches, up the elevator shaft, and then along a new cabletray to Cableway 4 that goes to the end of the A-line from the Research Yard, ii) through trenches, up the elevator shaft and then through a penetration to the A-line from the utility room alcove that houses heat exchangers, and iii) use existing water-cooled cables from Bldg 108 to the ESA pivot point and then install new cables from there to the ESA west wall and then through penetration holes in this wall to the end of the A-line (there are 6 4"-diameter holes and a 6" "sight hole"). There are also existing power cables that run from the end of the A-line to MCC that could be used if we want to locate appropriate power supplies in MCC.

3.11 MPS and BCS instrumentation

A few devices for machine protection and beam containment are included in this preliminary design. Burn-thru Monitors (BTM) would be placed directly behind PC28 and the dump. At least two sets of double ion chambers are planned, one set on PC28 and one set on the dump. A complete study of the BCS and MPS requirements for protection against accidents and beam mis-steering has not yet been done. Further study may indicate that other instruments are needed.

4. Cost Estimate

A cost estimate is presented in Appendix III. Including overhead and 30% contingency, the total project cost is estimated to be ~550K$.

References

1. *Design and Operation of SLAC Beamline 20-21-22*, F. Winkelmann, SLAC-Report-160, 1973; www.slac.stanford.edu/pubs/slacreports/slac-r-160.html.
2. *SLAC Users Handbook*, 1971 (unpublished; available in SLAC Archives).

APPENDIX I: SECONDARY PARTICLE YIELDS

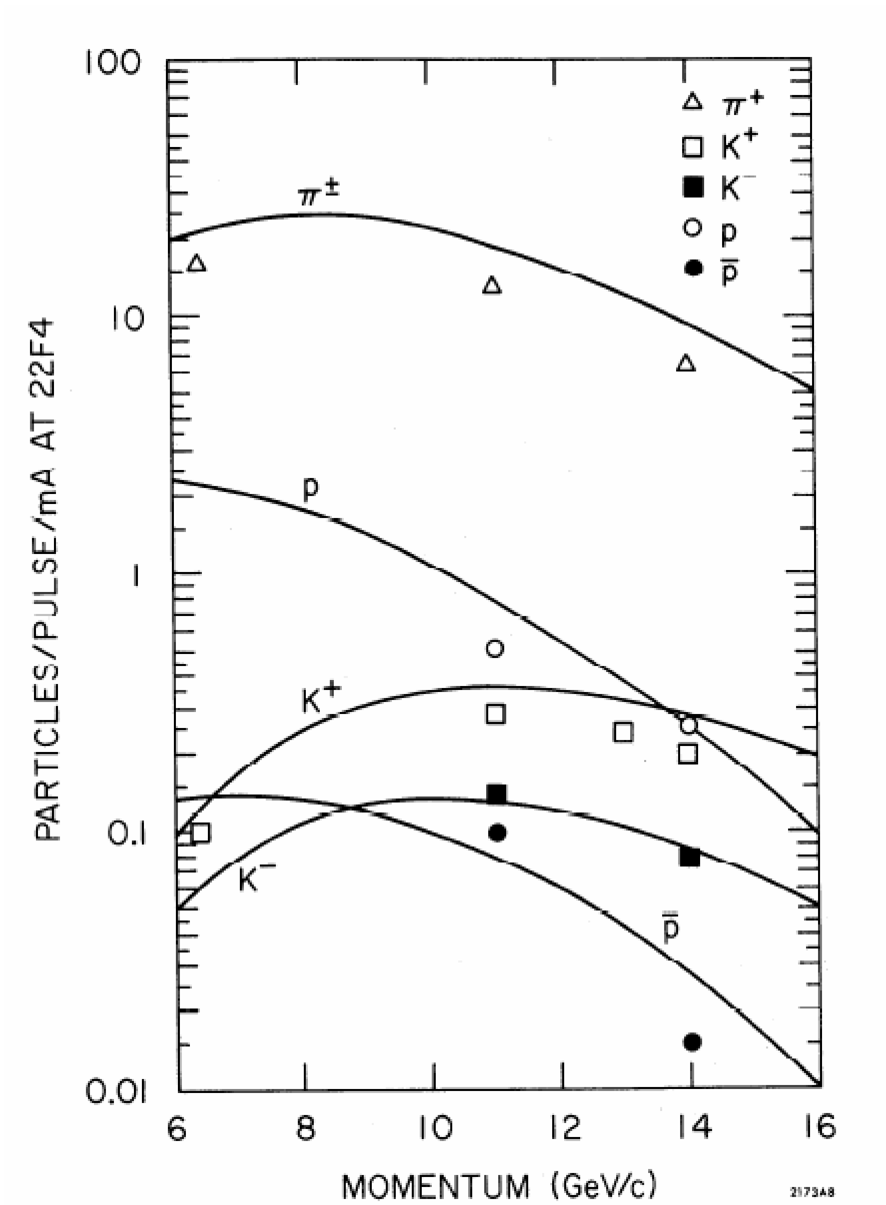

Figure 2: Measured and predicted (curves) particle fluxes of secondary beams in Beamline 22 from Ref. [1]. Primary beam energy is 19.5 GeV. Production target is 0.87 r.l. Be and production angle is 1.5deg. Acceptance is 30 μsr and ±2% $\Delta p/p$.[1,2] Pulse length is 1.6 μs so 1mA corresponds to $1 \cdot 10^{10}$ electrons / pulse.

Table 1: Secondary Particle Yields per pulse from Table IV on page C.2-11 in Reference [2]. Experiment setup is 18 GeV electrons incident on 1 radiation length Be target with $2 \cdot 10^{11}$ electrons per pulse. Production angle is 1 degree. The momentum acceptance is 3% and the geometric acceptance is 40 μsr.

Particle	**P=4.4 GeV/c**	**P=12 GeV/c**
e^+	4500	180
π^+	1200	1600
K^+	12	25
p	160	30
e^-	LARGE	~30,000
π^-	1200	1600
K^-	5	10
pbar	8	3

APPENDIX II: Schematics and Pictures of Equipment to be used

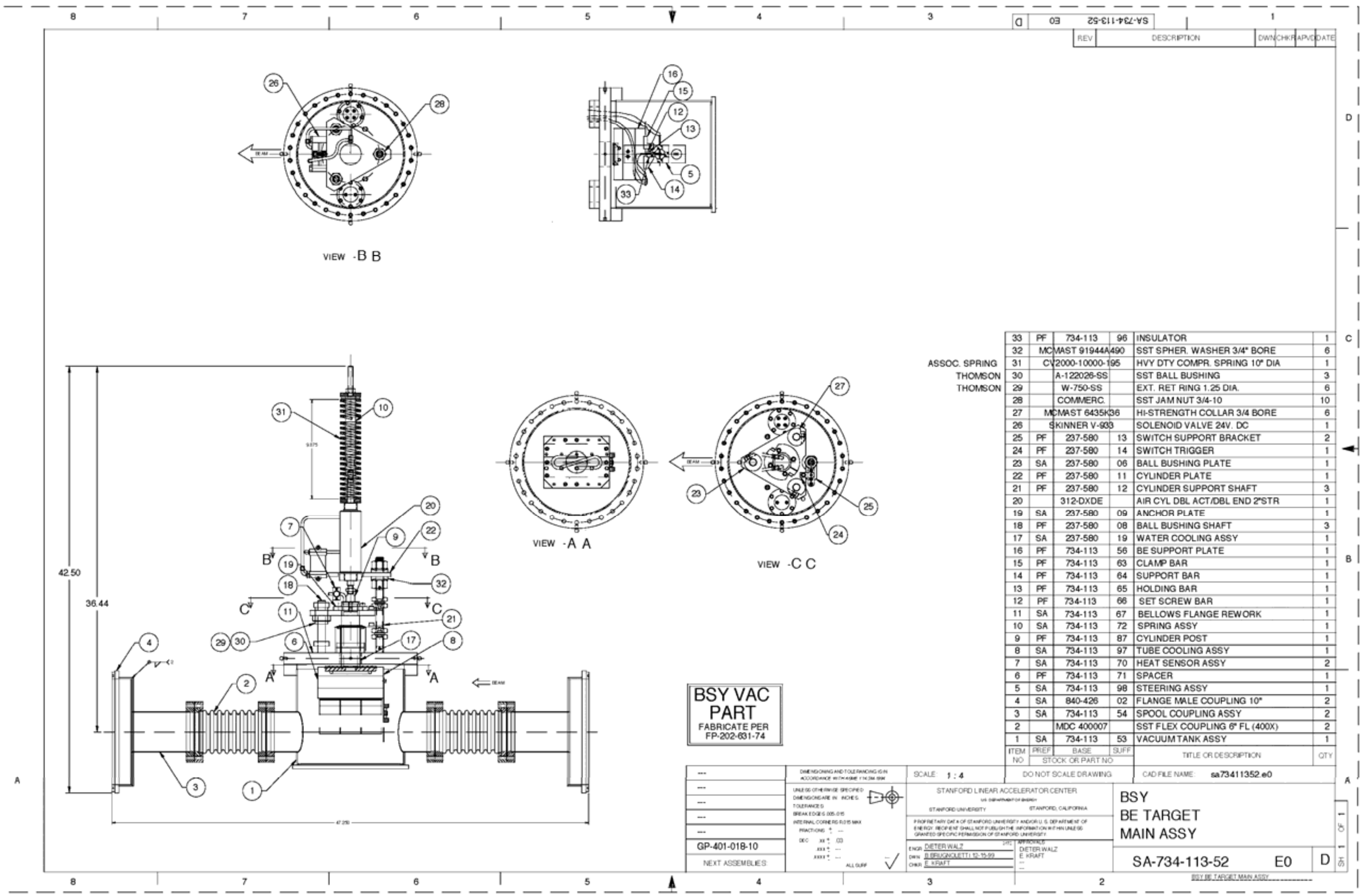

Figure 3: Top level assembly drawing of the Be target now in the BSY.

Figure 4: 10D37 magnets in ESA.

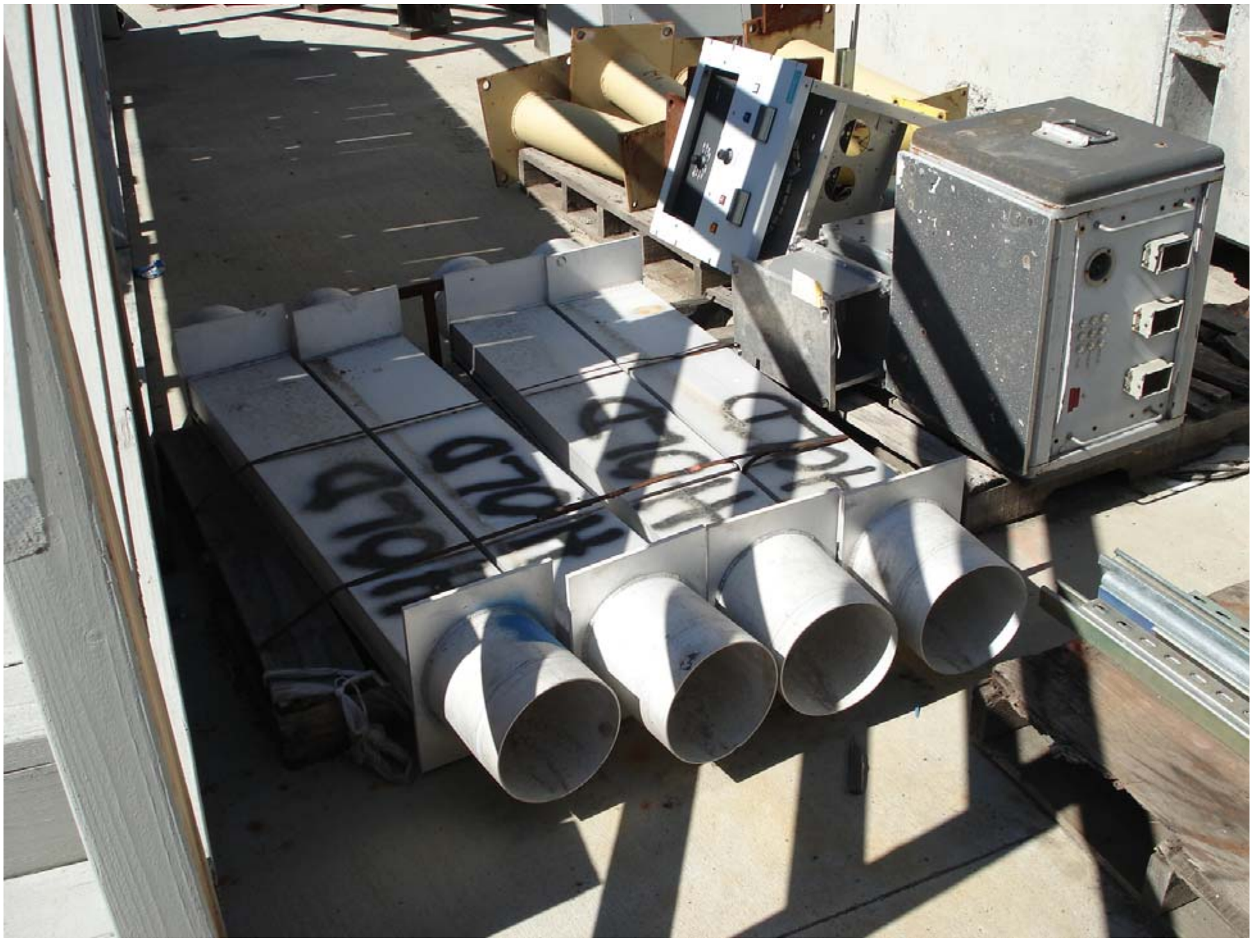

Figure 5: Original vacuum chambers for the 10D37 bend magnets from SPEAR Beamline 15 in storage in the Research Yard.

Figure 6: Stands for the 10D37 magnets from old SPEAR Beam Line 15 in the Research Yard.

Figure 7: 8cm-bore BSY quad in ESA (top) and a quad stand in the Research Yard (bottom)

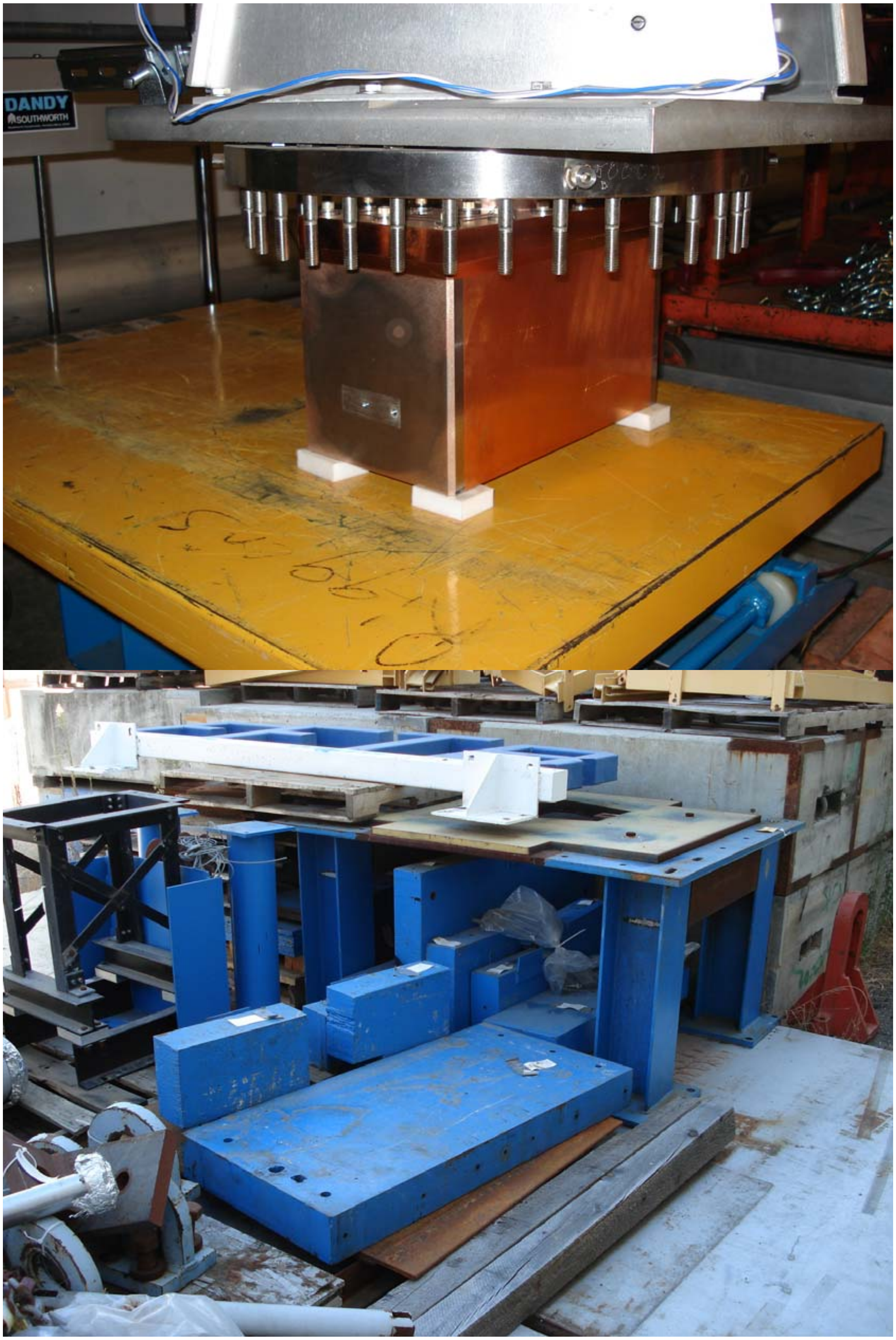

Figure 8: W-Cu-W water-cooled dump in ESA (top); steel blocks and stand parts for the "doghouse" dump shield from FFTB (bottom)

Appendix III: Hadron Production Facility Cost Estimate

PROJECT: Hadron Production Facility in A Line 9/29/2007

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ENGINEER: Ray Arnold **REVISION:v5** 1

								B&H						ED&I		
			MATERIAL					LABOR								
ITEM	REF #	MEAS	# UNITS	UNIT COST	**TOTAL**	# UNITS	UNIT HRS	TOTAL HRS	$/HR	**TOTAL**	# UNIT	UNIT HRS	TOTAL HRS	$/HR	**TOTAL**	**LINE TOTAL**
Major Equipment Items						**Fabrication/Refurbish**										
Bend magnets (existing)		ea	3	500	1,500	3	36	108	60	6,480			0		0	7,980
Quad (existing)		ea	1	500	500	1	36	36	60	2,160			0		0	2,660
Be Target (mod existing)		ea	1	0	0	1	24	24	70	1,680			0		0	1,680
Electron filter (new)		ea	1	3,000	3,000	1	40	40	70	2,800			0		0	5,800
Protection/aperture collimator(new		ea	1	8,000	8,000	1	100	100	70	7,000			0		0	15,000
Toroid (existing)		ea	1	0	0	1	8	8	70	560			0		0	560
Profile monitor		ea	1	250	250	1	16	16	70	1,120			0		0	1,370
Dump (existing)		ea	1	0	0	1	24	24	70	1,680			0		0	1,680
Dump shield house(existing)		ea	1	0	0	0	0	0	0	0			0		0	0
All magnets exist: 10D37 bends, 8 cm BSY quad, require refurbishment, flushing and testing.																
Be target in BSY will be relocated. Needs new vac chamber and support. SEM needs to be repositioned.																
Electron filter is 7 rl radiator on insertable mechanism, make from existing parts.																
Protection/aperture collimator is 8 kW water cooled Cu in vac, new.																
Profile monitor is Al2O3 screen in air with TV camera.																
Dump is existing 8 kW water cooled W/Cu SLC dump. Shielding is FFTB iron "Dog House."																
Vacuum Components						**Fabrication/Refurbish**										0
Bend chambers (existing)		ea	3	1,000	3,000	3	12	36	70	2,520			0		0	5,520
Quad chamber (existing)		ea	1	0	0	1	0	0	70	0			0		0	0
Drift bend-to-Be tgt (new)		ea	1	400	400	1	8	8	70	560			0		0	960
Be target chamber (new)		ea	1	1,000	1,000	1	40	40	70	2,800			0		0	3,800
Divergent chamber (new)		ea	1	1,500	1,500	1	40	40	70	2,800			0		0	4,300
Spool sections (new)		ea	5	300	1,500	5	4	20	70	1,400			0		0	2,900
Bellows (new)		ea	2	500	1,000	0	2	0	70	0			0		0	1,000
Bend chambers exist, need new flanges and aluminum-to-stainless transition. The quad chamber exists installed in magnet. Drift chambers make from existing pipe with new flanges.																
Most bellows will be salvaged and refurbished from existing decomissioned equipment.																
Support Stands						**Fabrication/Refurbish**										
Bend mag stands(modify existing)		ea	3	0	0	3	8	24	70	1,680			0		0	1,680
Bend mag adjust support(mod exis		ea	3	0	0	3	16	48	70	3,360			0		0	3,360
Quad stand, adjustable(refurb exis		ea	1	0	0	1	8	8	70	560			0		0	560
Be tgt stand, adjustable(new)		ea	1	1,000	1,000	1	24	24	70	1,680			0		0	2,680
Collimator stand adjustable(new)		ea	1	1,000	1,000	1	24	24	70	1,680			0		0	2,680
Dump and shield support (new)		ea	1	1,000	1,000	1	48	48	70	3,360			0		0	4,360
Earthquaking stands			1	5,000	5,000	1	40	40	70	2,800			0		0	7,800
Bend mag stands exist, from old SPEAR injection 15 line. Need adjustable top works.																
Bend mag adjustable supports reclaimed from PEP 2 HENIT line to be decomissioned.																
Quad mag adjustable stand exists, standard BSY equipment.																
Dump and shield house supports new, make from existing parts.																
Collimator supports new, make from existing parts.																
Magnet Power						**Fabrication**										
Power supplies bend(existing)		ea	2	0	0	2	80	160	60	9,600			0		0	9,600
Power supplies quad(existing)		ea	1	0	0	1	80	80	60	4,800			0		0	4,800
Cables bend power		ea	8	800	6,400	5	32	160	55	8,800			0		0	15,200
Cables quad power		ea	4	800	3,200	5	16	80	55	4,400			0		0	7,600
Cable trays		ea	1	15,000	15,000	3	40	120	55	6,600			0		0	21,600
Cables mag control		ea	3	500	1,500	5	16	80	55	4,400			0		0	5,900
Power supplies will need to be EEIPed and recommissioned, similar to work done for power supplies for ESA chicane magnets used in 2007.																
LCW - Mags Colls Dump						**Fabrication**										
Header modifications		ea	6	1,500	9,000	6	4	24	70	1,680			0		0	10,680
Flow switches		ea	8	1,000	8,000	8	8	64	70	4,480			0		0	12,480
Water flex lines		ea	14	500	7,000	14	8	112	70	7,840			0		0	14,840
New water lines are installed on each magnet and integrated into the existing water system. Dump and Collimators use standard non rad LCW.																
I & C						**Fabrication**										0
BTM		ea	2	500	1,000	2	40	80	70	5,600			0		0	6,600
Ion chambers (existing)		ea	4	100	400	4	24	96	70	6,720			0		0	7,120
Profile monitor		ea	1	250	250	1	4	4	70	280			0		0	530
Cables						**Fabrication**										0
MPS/BCS BTM&IC		total								5,000						5,000
Be tgt mover,SEM		total								2,000						2,000
Electron filter mover		total								2,000						2,000
ED&I										0						0
Magnet engineering		total			0			0		0	0	0	0	90	0	0
Vacuum engineering		total			0			0		0	0	0	0	90	0	0
Facilities engineering		total			0			0		0	0	0	0	90	0	0
Mechanical engineering		total			0			0		0	1	160	160	90	14,400	14,400
Plumbing design		total			0			0		0	0	0	0	90	0	0
Vacuum design		total			0			0		0	0	0	0	90	0	0
Facilities design		total			0			0		0	0	0	0	90	0	0
Mechanical design		total			0			0		0	1	640	640	90	57,600	57,600
Installation										0						0
Vacuum installation		total			2,000	3	40	120	70	8,400			0		0	10,400
Alignment / QC		total			0	3	40	120	70	8,400			0		0	8,400
Riggers		total			0	3	40	120	60	7,200			0		0	7,200
Welding		total			100	1	40	40	70	2,800			0		0	2,900
Cleaning, painting		total			0	1	40	40	70	2,800			0		0	2,800
Disassembly		total			0	2	40	80	70	5,600			0		0	5,600
Precision installation		total			500	2	20	40	70	2,800			0		0	3,300
Mechanical assembly		total			500	2	80	160	70	11,200			0		0	11,700
SUBTOTAL					84,500					172,080					72,000	328,580
30% CONTINGENCY					25,350					51,624					21,600	98,574
LAB SUPPORT COST					7,690					80,533					33,696	121,919

TOTAL B&H		$421,777
TOTAL ED&I		$127,296
PROJECT TOTAL		$549,073