ILC Beam Dump Issues

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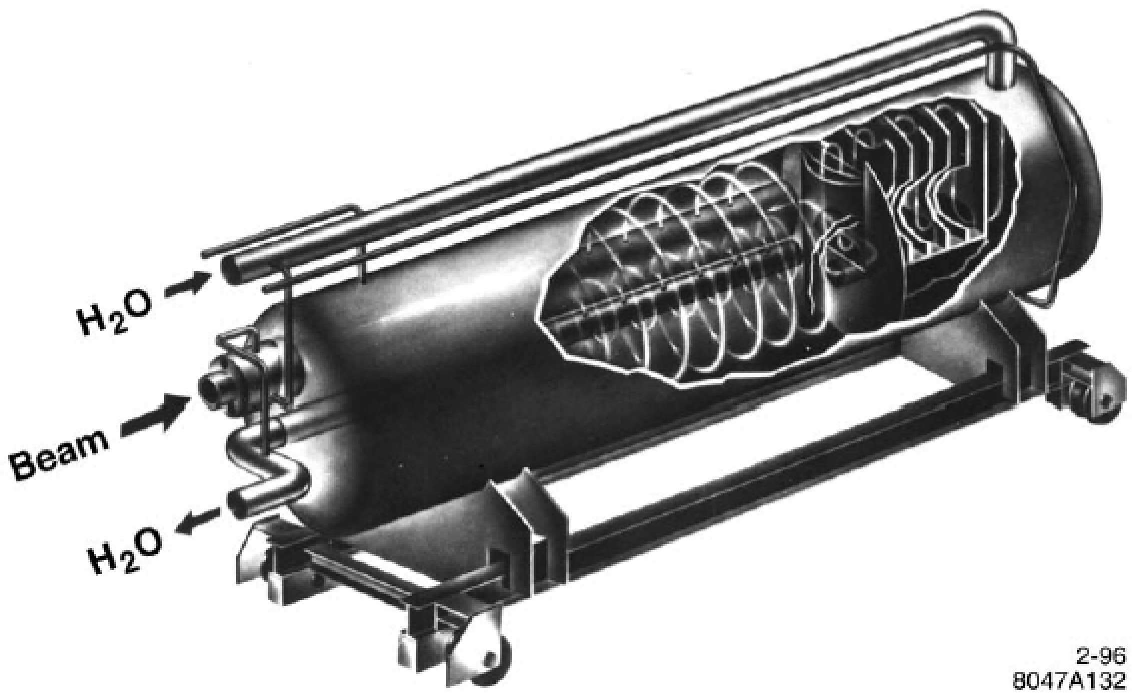
For SLAC BDS in particular, Clay Corvin, Eric Doyle & Dieter Walz
DESY/SLAC/UK Beam Dump Meeting @ DESY
16 February 2006

Historical Perspective

- **1996 - Dieter Walz, SLAC Dumps & Collimator guru, designs parameters of 10MW beam dump for NLC parameters based on existing 2MW water dump he built in 1967**
  - **NLC ZDR, Ch.11A**
  - **http://www.slac.stanford.edu/cgi-wrap/getdoc/slac-r-474-Ch11.pdf**



Issues Raised

- Water velocity ~ 1m/s so that in NLC case the water volume hit by the 192 bunch train moves at least 2 σ during the interbunch 8.3ms period
- Temperature rise during that time sufficiently low to avoid boiling
- Size of tank adequate to absorb shower
- Window
  - thin enough so that, assuming cooling by convection to water and some lateral conductive cooling, temperature rise during bunch train, less than stress limit
  - Small enough that thermal stress within limits for material
- System to recover radioactive isotopes and hydrogen

General Parameters

- R=30cm where beam hits water flow
- Velocity(water) = 1-1.5 m/s
- Pressure water ~8atm so that T(boiling) ~ 160 °C
- Diameter vessel ~ 1.5m
- Length water ~ 6.5m (18 X_0)
- ~ 1m high Z to absorb remainder of shower after water section
- 30cm diameter 1mm thick Cu window

Issues for ILC

- Current/Area of undisrupted beam now higher
  - especially before recent redesign of 20mrad extraction line
- Bunch structure such that ~600 bunches pass before water moves ~200um at 1 m/s
  - Peak temperature and thermal stress on window
- Window size required set by size of disrupted beam

At this time, emphasis has been on increasing bunch size so that energy absorbed by widow during passage of ~600 bunches is < melting or fracture temperatures

We are just beginning an ANSYS analysis to evaluate window stress and temperature rise under various conditions

No results yet, but clearly a challenging problem

Beam Conditions at 20mrad Dumps

CM Energy GeV	Parameters	Current uA	Power/Beam MW	Beamstrahlung MW	Undisrupted sig_x mm	sig_y mm
500	**Nominal**	**45.1**	**11.3**	**0.3**	**0.87**	**0.10**
500	High	45.1	11.3	0.8	1.25	0.12
1000	Nominal	36.1	18.0	0.9	0.51	0.35
1000	High	36.1	18.0	3.2	0.89	0.35

Worst case for window:
(Current/beam area) 5x larger than in ZDR

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Notes from Beam Dump Meeting with Dieter Walz, April 21, 2005

- Designing a survivable window is more of a challenge than designing a water dump to absorb 20 MW
- The ratio of current to beam area at the window is about 5x larger than in the 1996 ZDR. This factor leads to overheating of the window and the water which will cause immediate window failure.
- How to increase the beam size at the window?

Safest {
1. Add ~100m drift to the extraction line
2. Design the extraction line for larger beam at the dump

3. Raster the beam with magnetic or electric fields
4. Introduce metalic vapors into the beam pipe
5. All of the above will require a donut collimator to catch the beamstrahlung and charged particle tals

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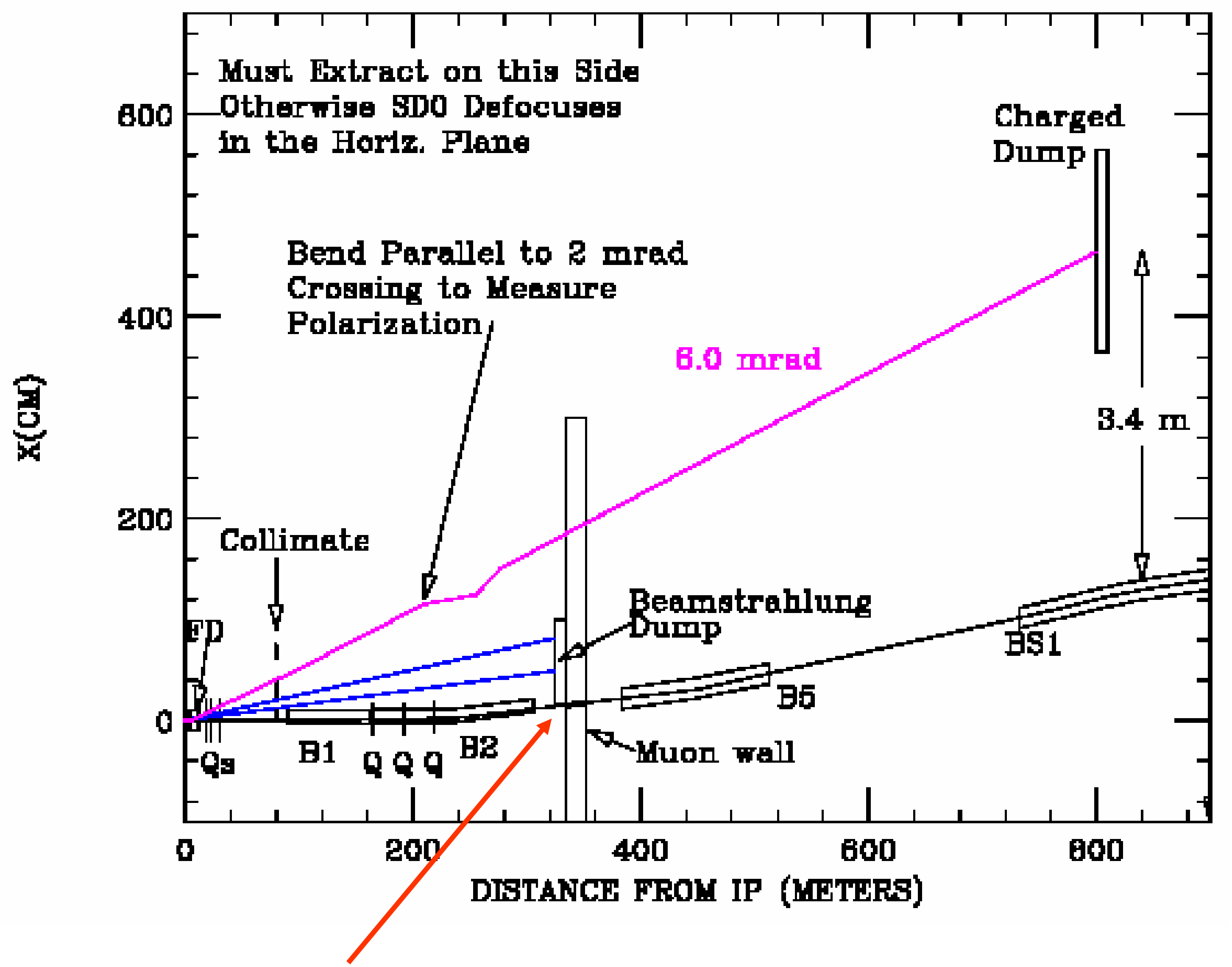
Notes (continued)

- Need to couple the beam line vacuum directly to the dump. This will necessitate putting fast valves into the extraction line.
- Offset the window with respect to the dump center to put the shower directly at the point of maximum water circulation. This requirement can be used to reduce the distance between the dump center and the incoming beam line.
- It would be prudent to include an automatic window exchange mechanism, a la Beam Dump East, since everything around the dump will be very hot.
- For the 2 mrad extraction line it should be relatively easy to put a beam pipe through the beamstrahlung dump for the incoming beam if that should prove necessary.

2 mrad Extraction Layout



Note proximity of beamstrahlung dump to the incoming beam – may need to put the incoming beam line pipe through the water tank.

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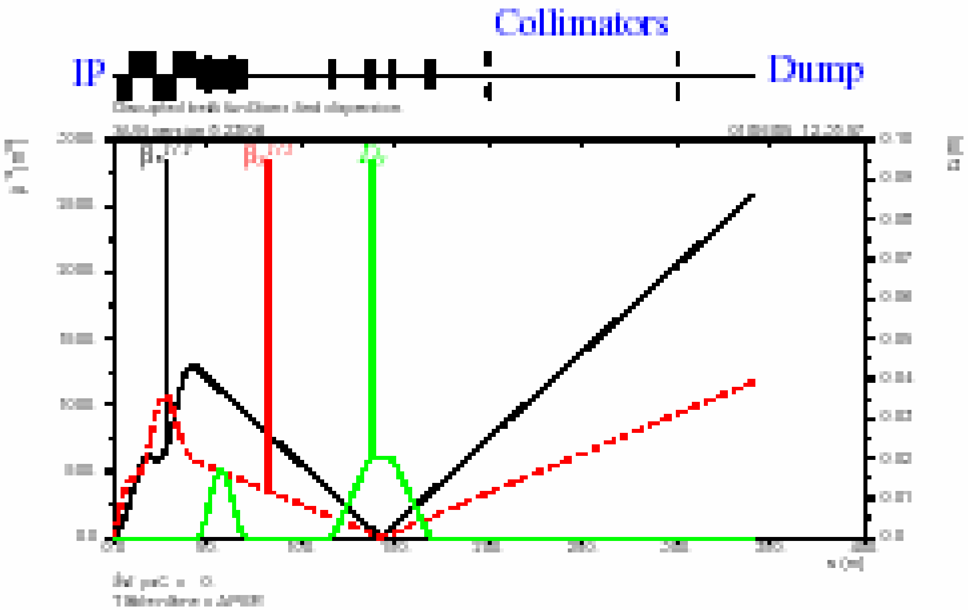
20 mrad Extraction Line with Enlarged Beam Size at Dump

- In the present optics, the undisrupted beam size at dump is too small for a practical dump design. At 0.5 TeV CM, the present value of undisrupted $\sigma_x\sigma_y$ = 0.87 x 0.10 mm^2 at dump needs to be increased a factor of 10.
- The proposed solution is to allow the beam size grow naturally in a field-free region by moving the dump from s = 200 m to 340 m with respect to IP. Also, the quad doublet after the polarimeter chicane is removed to cancel focusing at the dump.
- To fit the divergent disrupted electron and beamstrahlung photon beams for the dump window, two round collimators with r = 8.8 cm and 13.2 cm are placed at s ~ 200 m and 300 m, respectively, to reduce maximum beam size at dump to 15 x 15 cm.



Charged and Beamstrahlung Losses in the 20 mrad Extraction Line

E_{CM}	y-offset (nm)	e-loss in collimators (kW)		γ-loss in collimators (kW)		Max. e-loss density in magnets (W/m)		
		Coll. 1	Coll. 2	Coll. 1	Coll. 2	SC quads	Warm quads	Bends
0.5 TeV nominal	0	0	0	0	0	0	0	0
	200	0	0	0.15	0.05	0	0	0.13
0.5 TeV high lumi	0	47.4	74.5	2.8	0.7	15 (2.1*)	60	37
	120	47.2	95.3	151	10.3	3.8 (0*)	95	372
1 TeV nominal	0	0.85	0	0	0	0	1.8	4.8
	100	4.8	0.11	0	0	0	7.1	77
1 TeV high lumi	0	64.1	43.6	1.5	0.2	1106	4379	2032
	80	129	15.4	69	9.5	1071	5391	7362

* After increasing aperture in QDEX1C and QFEX2A to r = 25 and 36 mm, respectively.

*** Coll. 1 at 200 m, coll. 2 at 300 m, beam dump at 340 m**

*** Maximum beam size (charged and beamstrahlung) limited to ± 15 cm**

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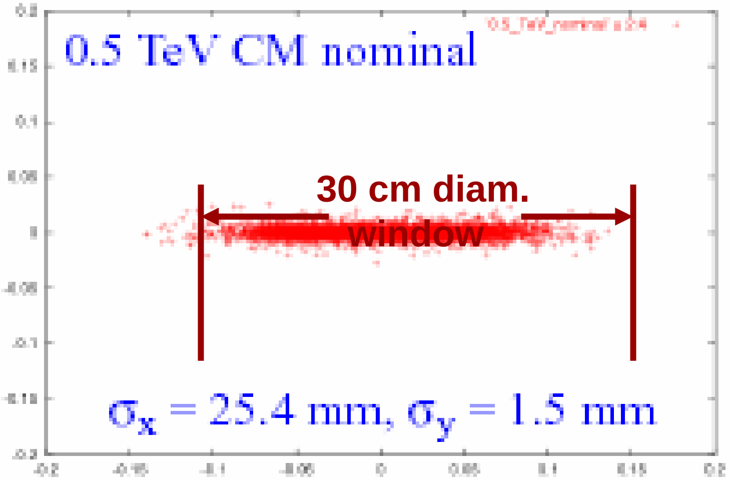
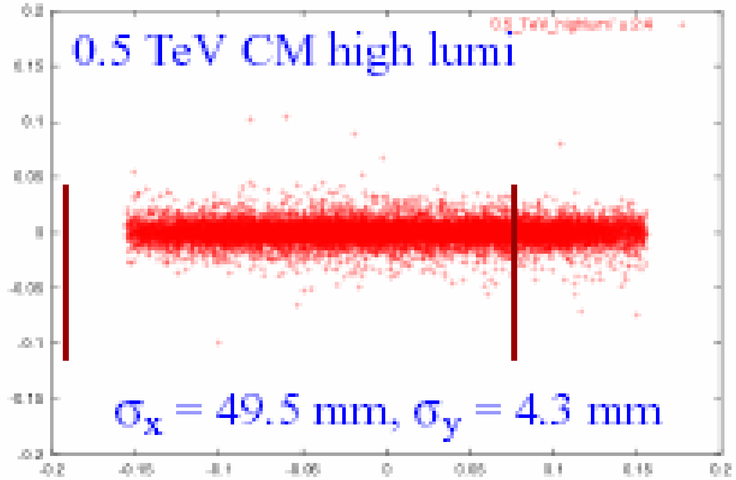
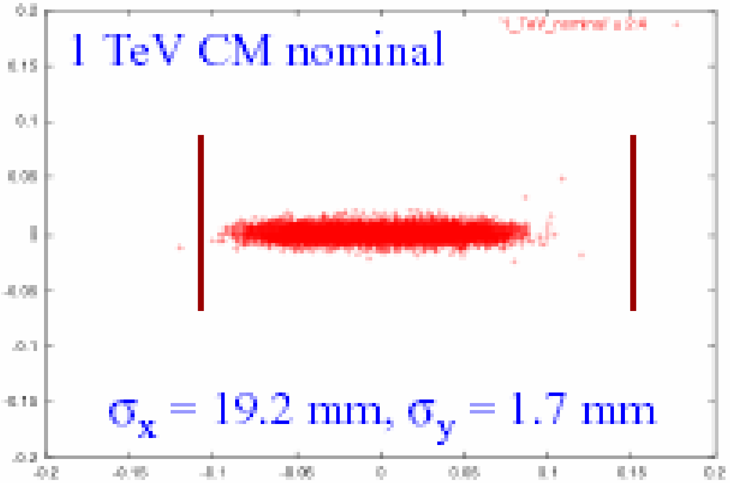
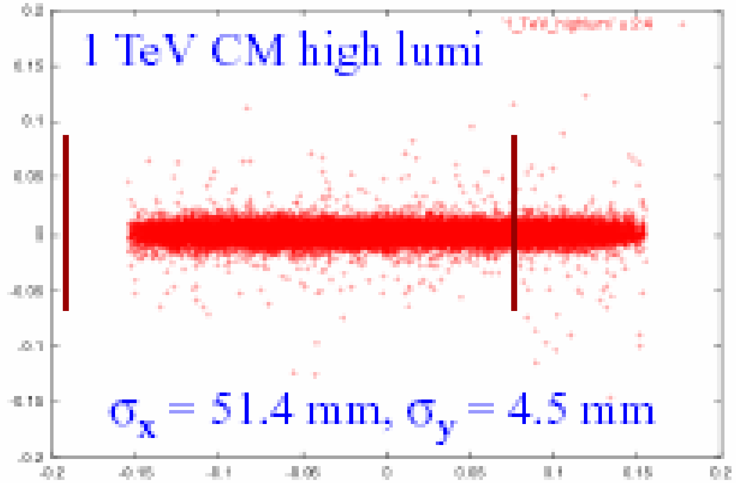
X-Y disrupted distribution at dump (no IP offset)

(scale in meters)

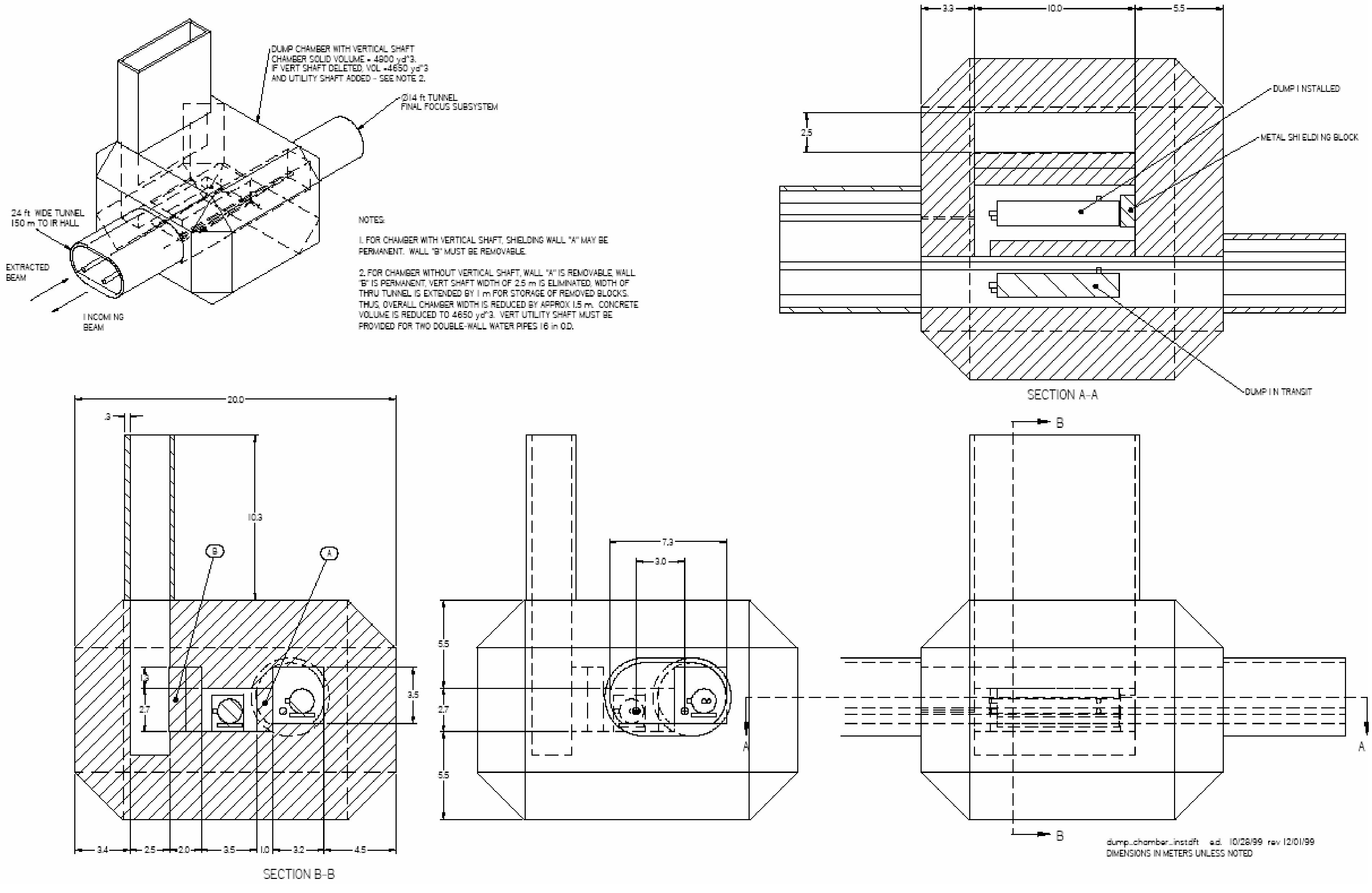






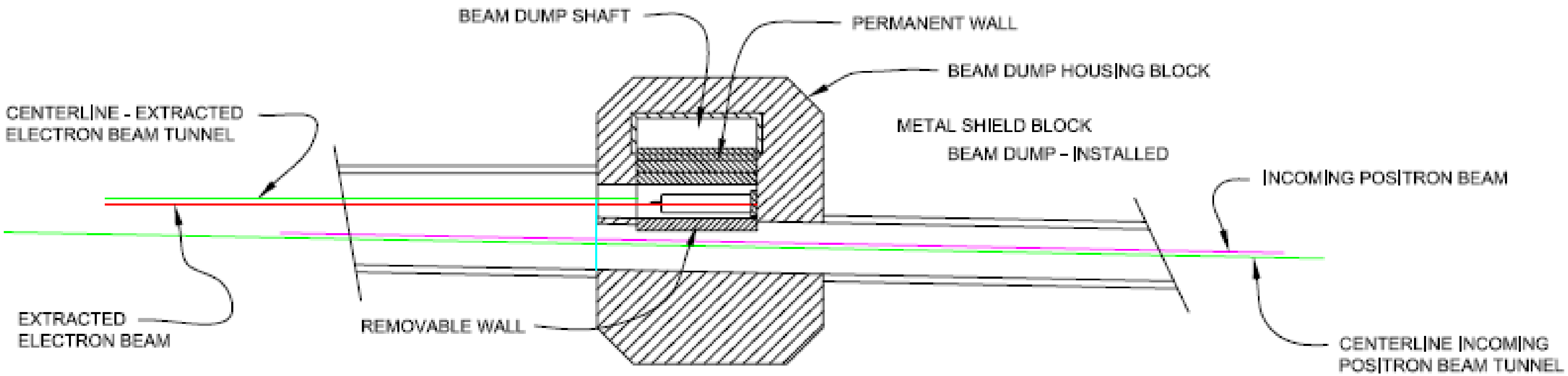


Beam Dump – Overview



International Linear Collider at Stanford Linear Accelerator Center

Beam Dump – General Arrangement Plan View



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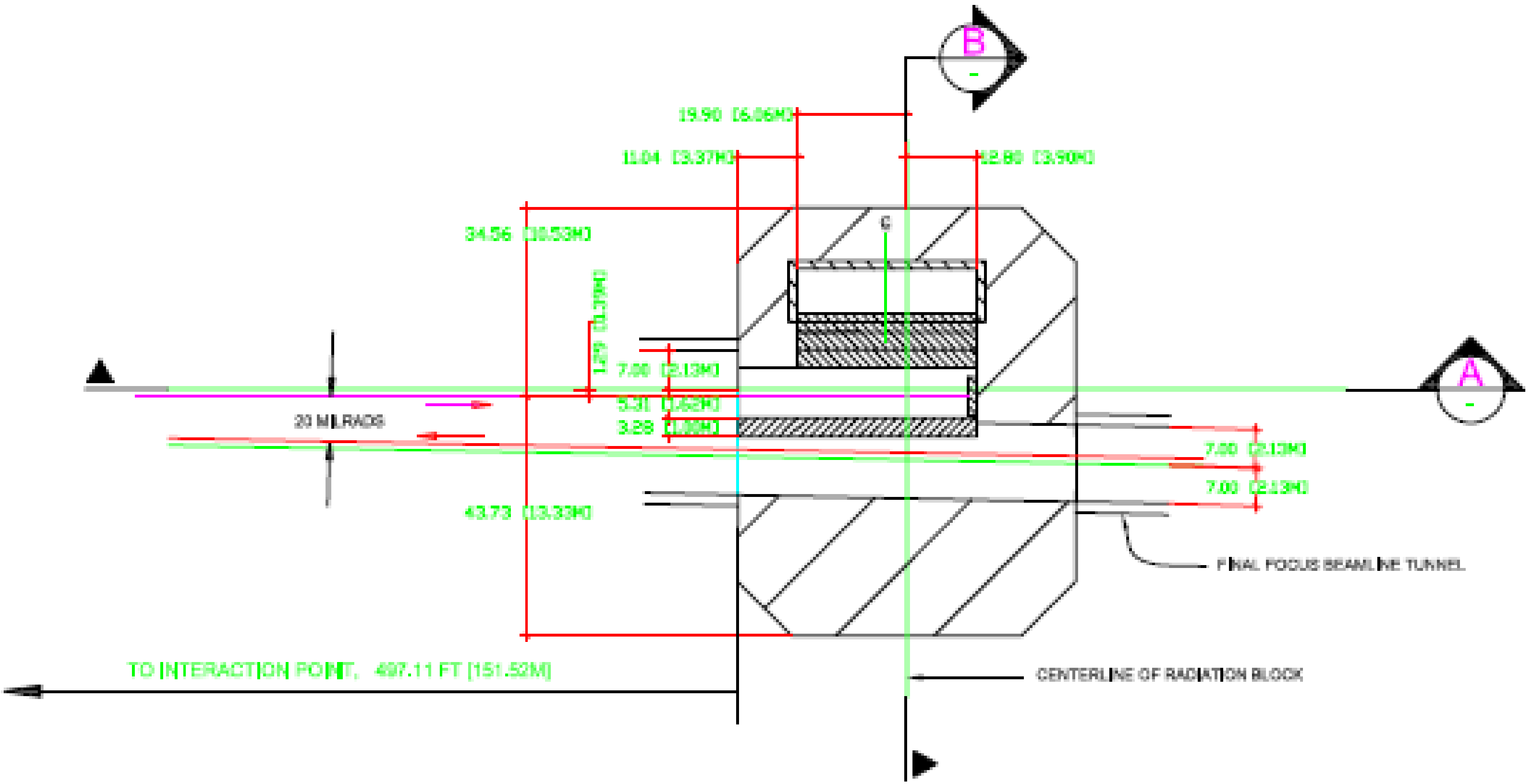
Beam Dump Housing Block
Plan View



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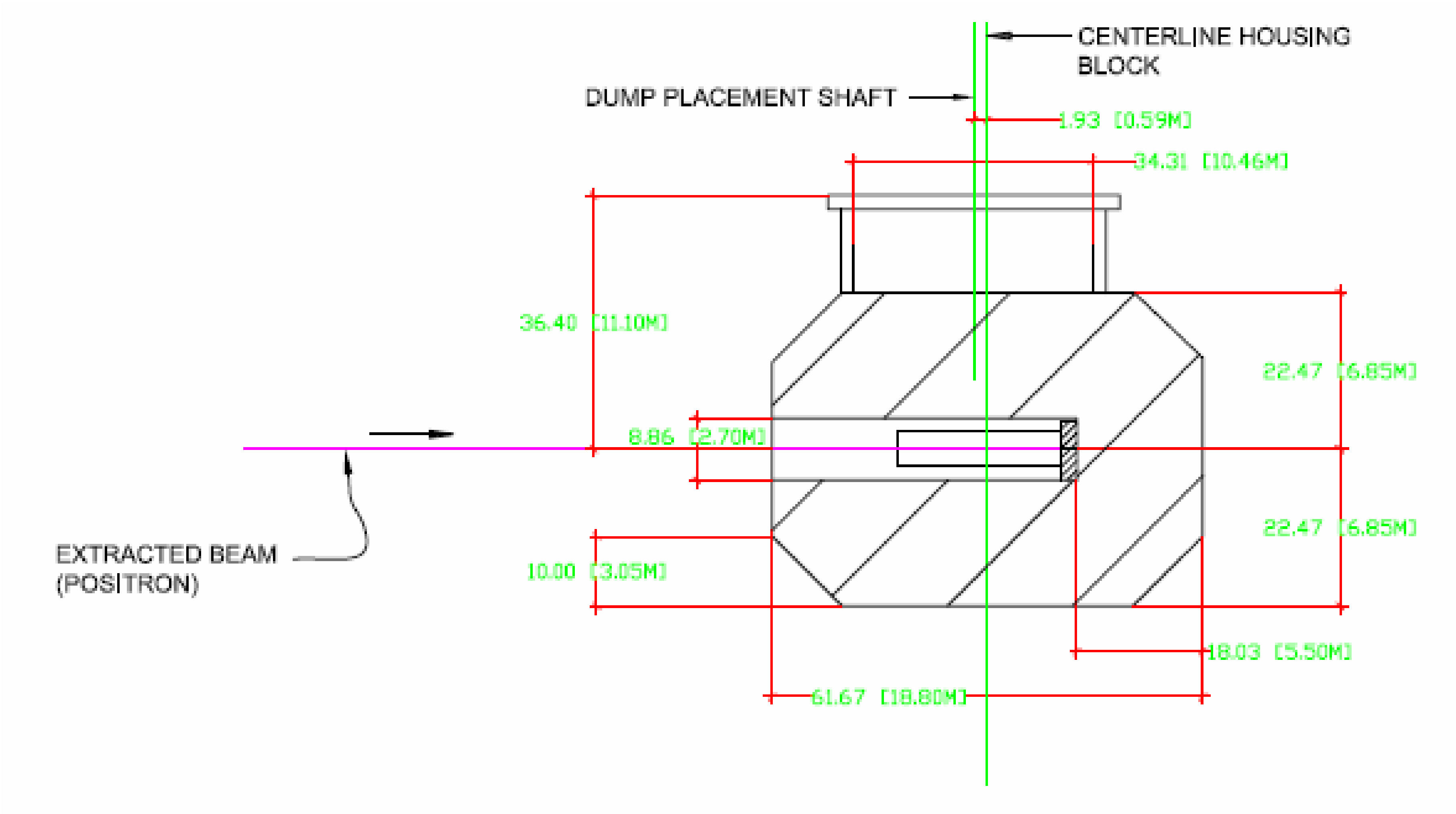
Beam Dump Housing Block
Section A-A



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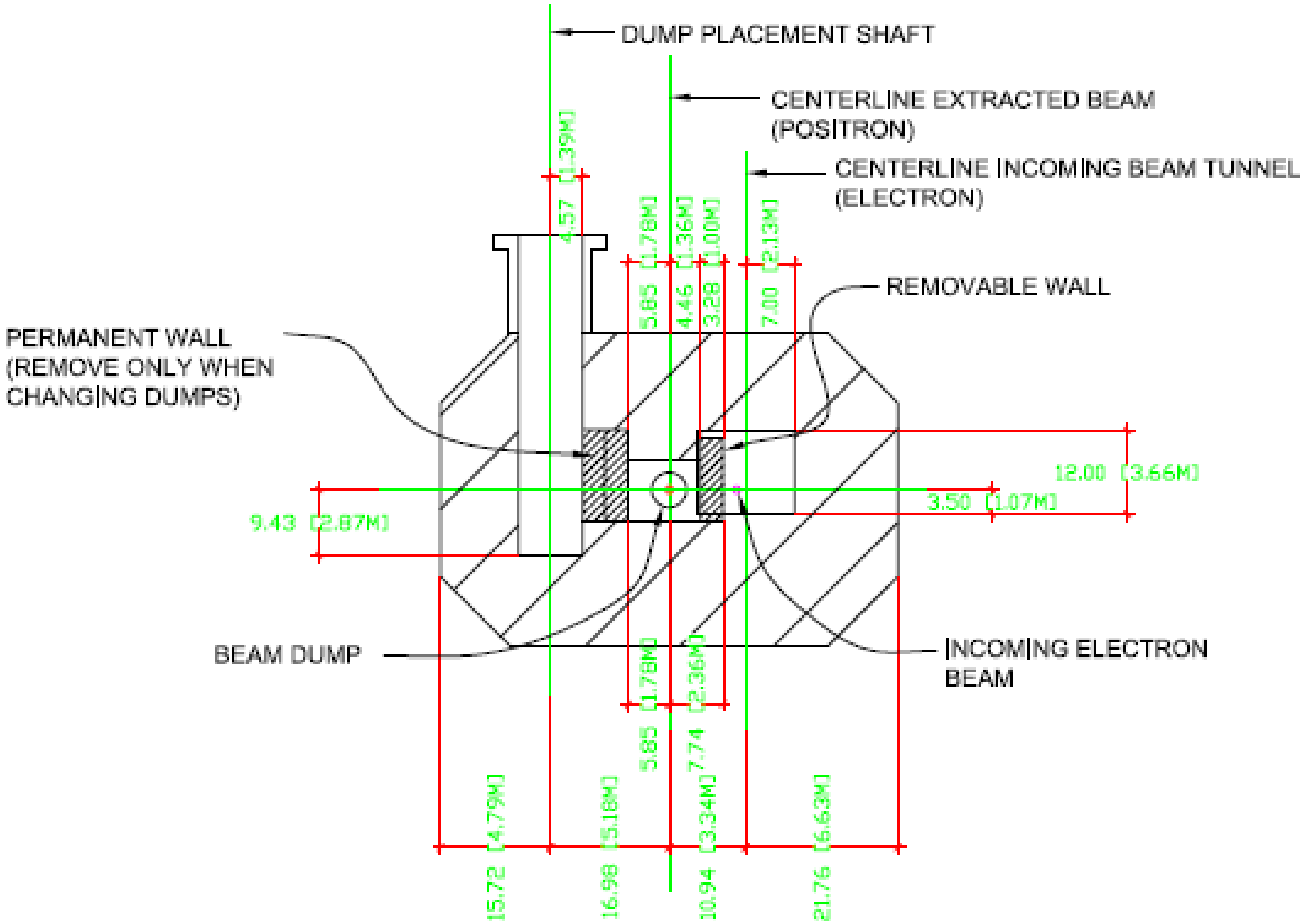
Beam Dump Housing Block
Section B-B



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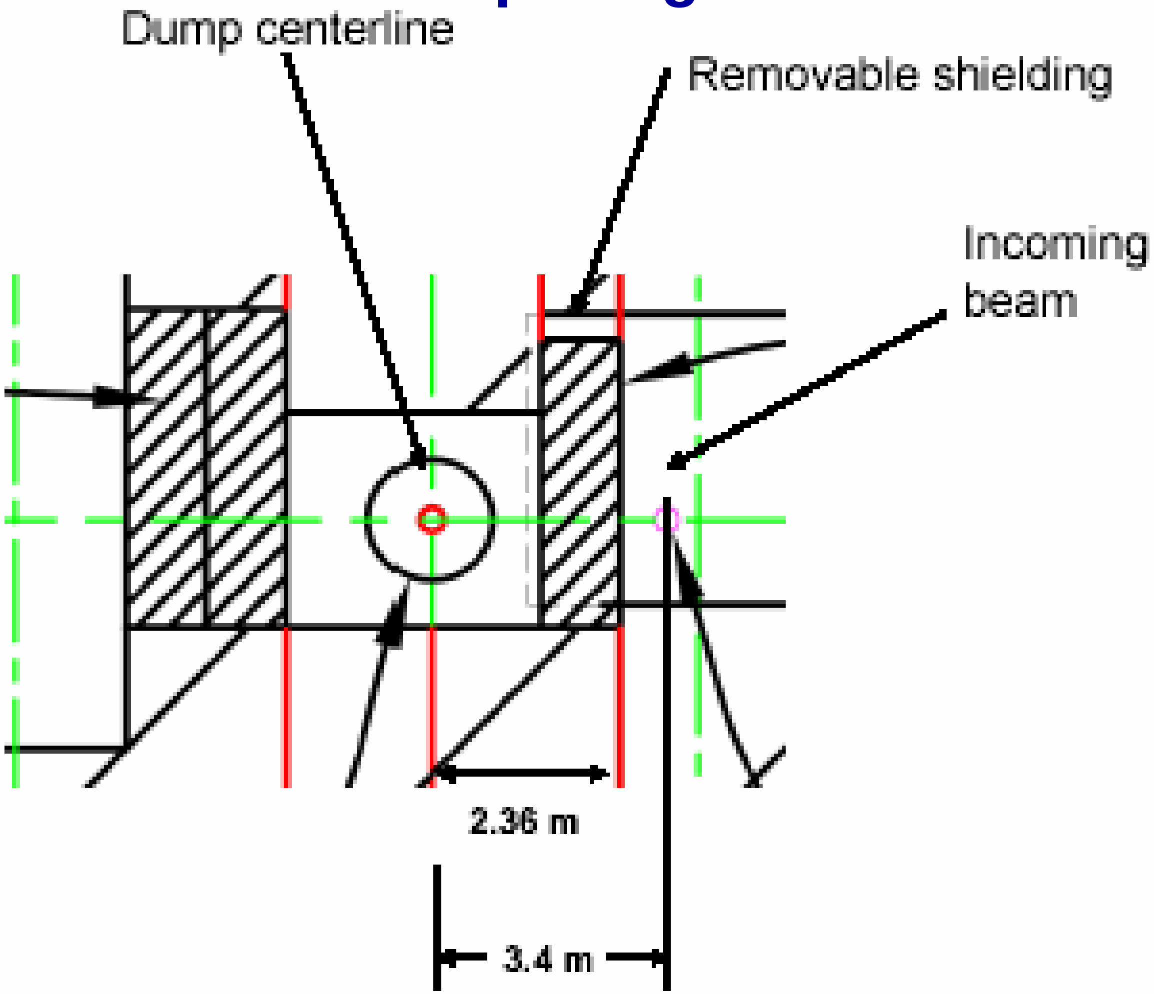
Detail Showing Required Transverse Spacing



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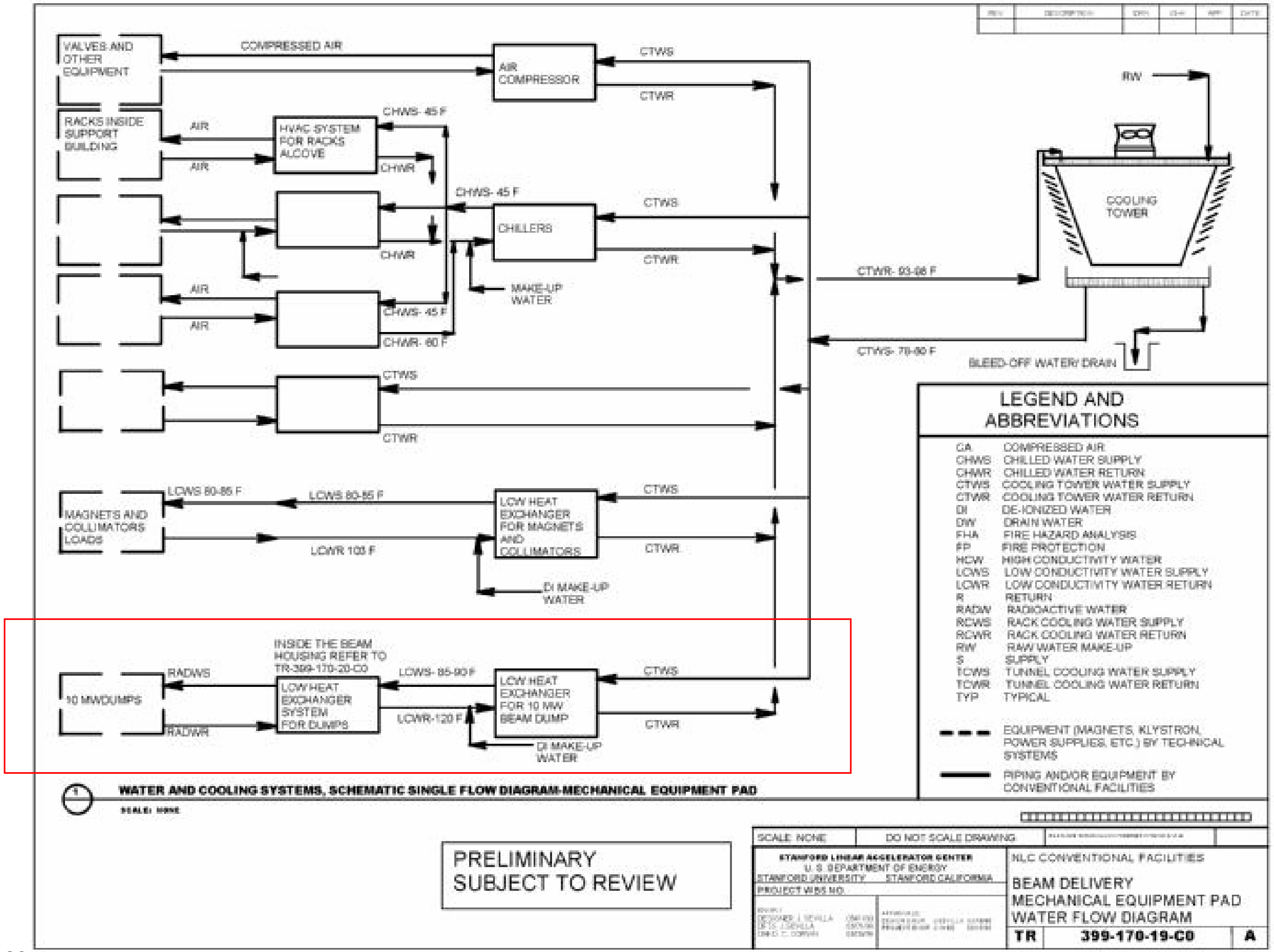
1999 NLC Mechanical Requirements



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1999 Dump Cost Estimate
Civil & Mechanicals (Corvin & Sevilla)

- [1,798,403] Housing Positron IR1 Dump Line and Dump
  - [700,785] Housing Positron IR1 Dump Housing
    - [503,995] Positron IR1 Dump Housing Structure
    - [10,070] Positron IR1 Dump Housing Power
    - [186,720] Positron IR1 Dump Housing Cooling
  - [1,097,618] Housing Positron IR1 Dump Line
    - [892,912] Positron IR1 Dump Line Structure
    - [17,858] Positron IR1 Dump Line Power
    - [186,848] Positron IR1 Dump Line Cooling

- [393.70 LF] Housing Positron IR1 Dump Line and Dump
  - [2,000.00 SF] Housing Positron IR1 Dump Housing
    - [0.00] Positron IR1 Dump Housing Structure
    - [0.00] Positron IR1 Dump Housing Power
    - [0.00] Positron IR1 Dump Housing Cooling
  - [393.70 LF] Housing Positron IR1 Dump Line
    - [0.00] Positron IR1 Dump Line Structure
    - [0.00] Positron IR1 Dump Line Power
    - [0.00] Positron IR1 Dump Line Cooling

~1999 Cost Model & Caveats
Dump Vessel

Welded low-carbon stainless (316L) plate with robotic/semi-robotic window replacement

- **While few US facilities could handle the size, not really a technical challenge**
- **Welds X-rayed**
- **1965 costs scaled by Walz to produce 1996 estimate, which in turn scaled by Eriksson/Doyle to produce 1999 and 2001 estimate 0f $165k**
  - At the time materials estimated to cost $50k
- **Recent discussions with Walz/Doyle lead do $1.5M upper limit for industrial production of a 20MW sized dump**

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~1999 Cost Model & Caveats
Civil

Three features dominate cost discussion:

- **Depth**
- **Geology (how wet)**
- **Length of tunnel requiring "road-header" for excavation as opposed to tunnel boring machine**

2001 Model

- **Dry cavern with 145m of beamline @ 15m**
  - Surface pit construction techniques for both beamlines & vault
    - 3x more expensive if deep
    - 2x more expensive if wet
    - 3x more expensive per unit L x Area to road-head tunnel

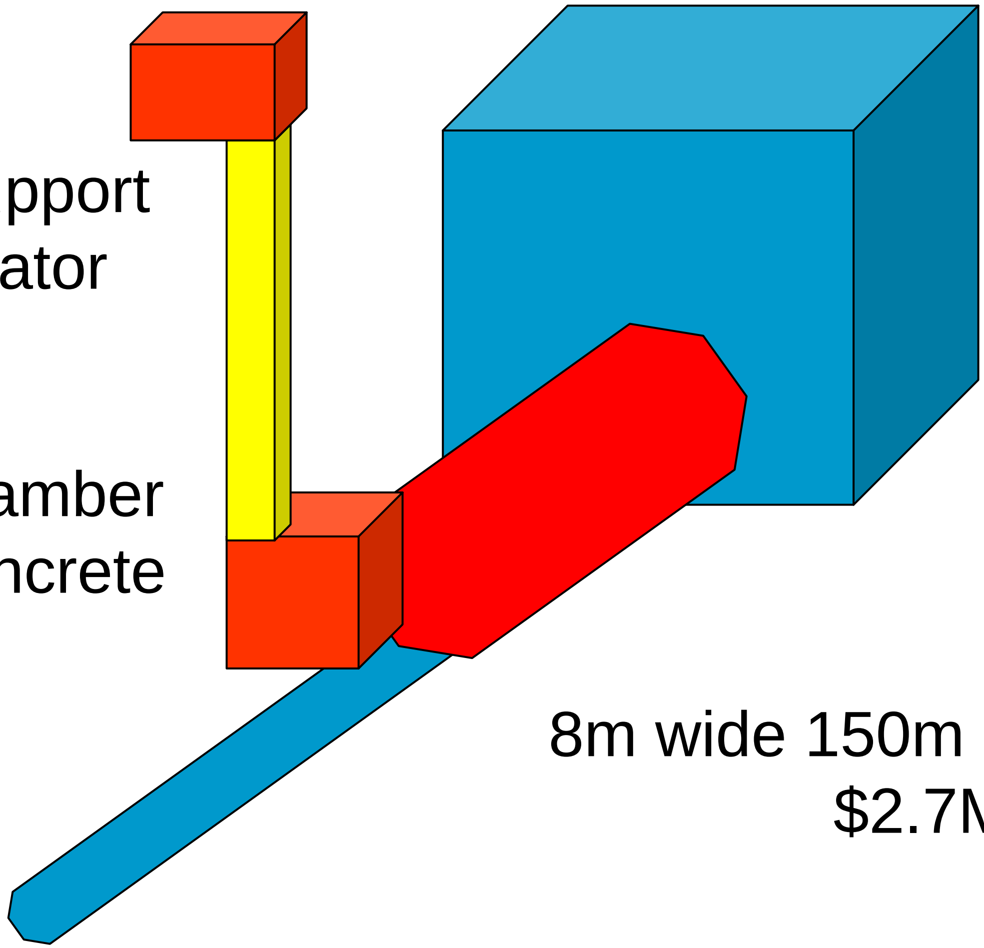
ILC sites all wet &/or deep with beamlines 400-800m long

~1999 Civil Costs

Support Bldg.
0.7M

Full access support shaft w/ elevator
0.5M

400 sq. ft. chamber with 5.5m Concrete walls
$2.8M



IR Hall

8m wide 150m long tunnel
$2.7M

1999 Mechanical Costs

10MW cooling system (1st level)	$165k
Piping up support shaft	$80k
Intermediate cooling system	$225k
Cooling Tower	$137k
Total	$607k

Total Costs

Item	NLC-1999	Deep, Long, Wet ILC	ILC
Dump Vessel	$0.2M	x10	$1.5M
Mechanicals	$0.6M	Shaftx10	$1.4M
Civil-Dump Installation	$4.0M	x3x2	$24M
Civil-Extraction Lines	$2.7M	X3-6	$8-16M
Radioactive Waste	$0M		$0M
Total	$8.5M		$35-43M
	1999-2006 @ 3%/yr=1.23		$43-$53M

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Beam Dump Cooling Schematic from SLAC-TN-67-29

Technical Considerations

- **Water**
  - **Prevent mass boiling of water ($\Delta T=30°C$): Flow=1800 gpm**
  - **Prevent localized boiling (1 train): v=1.5 m/sec**
- **Window**
  - **Prevent burn through**
    - Use Cu for transverse conduction
    - Local velocity and coolant temp. prevent film boiling
  - **Prevent window fatigue**
    - Semi-hard or full-hard materials
- **Vessel Installation/Removal**
  - **Elevator or double wide tunnels or downstream burial pit**

Technical Considerations
Cooling System

- **H_2 generation**
  - **Catalytic H_2/O_2 recombiner**
- **Radio-Isotope Production**
  - **^{15}O – delay access 20 minutes**
  - **^{11}C – delay access 3 hours**
  - **^{7}Be – dual filters**
  - **$^{3}H_2$ – periodic disposal of radiated water**
- **Isolation of RAD water from cooling tower**
  - **Intermediate heat exchanger system**
  - **Insure favorable Δp**

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Summary

- **Still our belief that dump should not be an issues except for the window**
- **More work needed before we can say that there is or is not a problem**