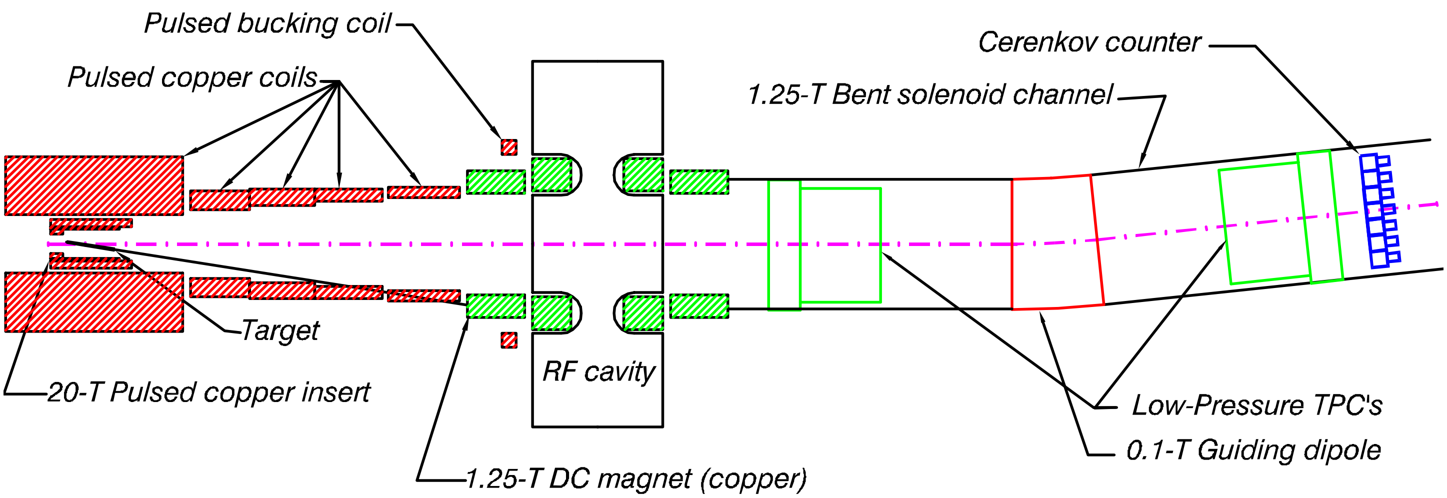
The R&D Program for Targetry and Capture at a Neutrino Factory and Muon Collider Source

(BNL E951)



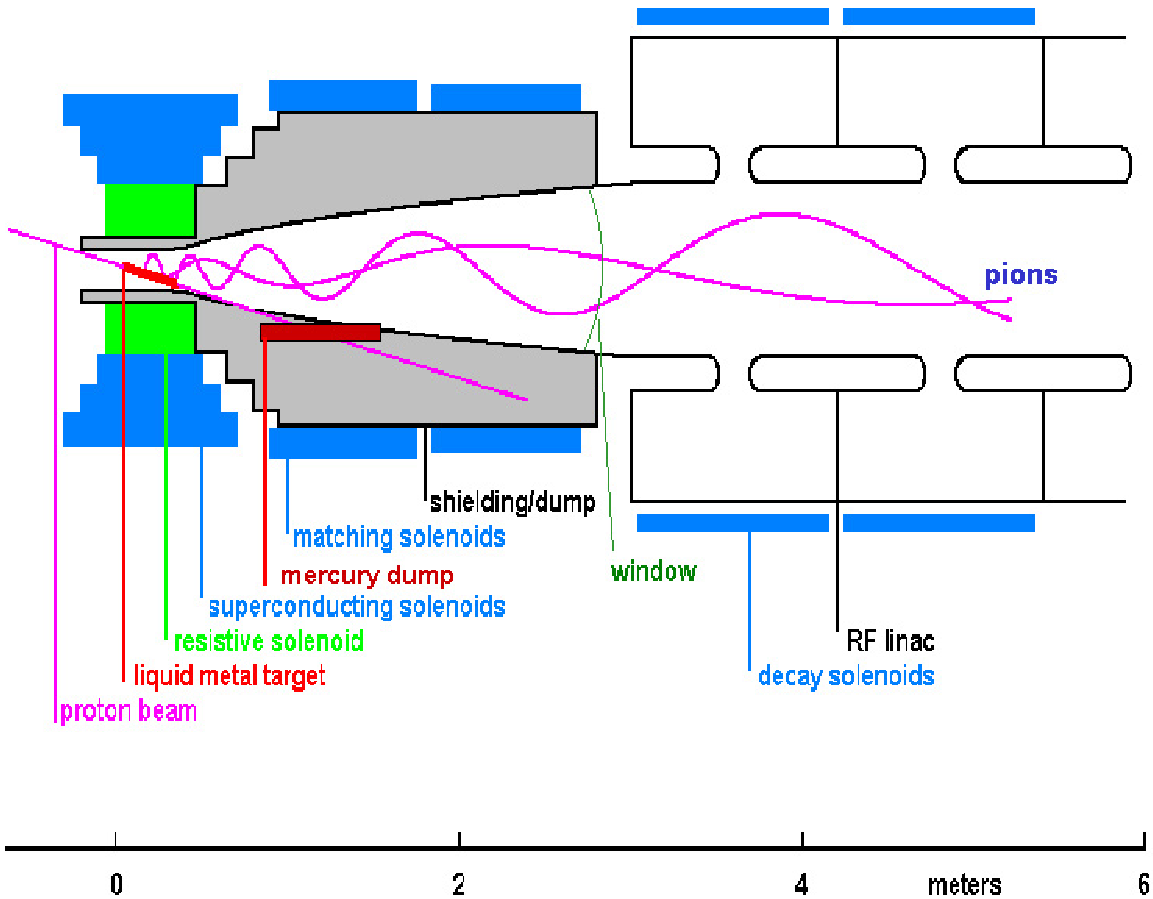
K.T. McDonald
Princeton U.

June 15, 2000

MUTAC Review, BNL

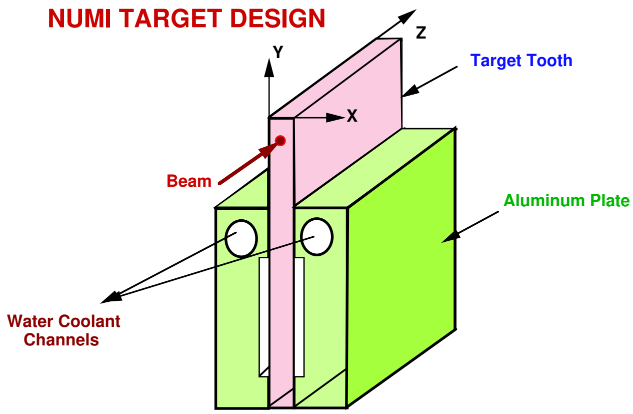
http://puhep1.princeton.edu/mumu/target/

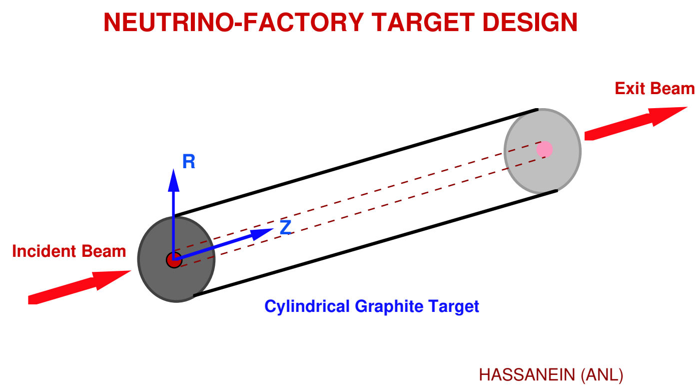
Requirements for Targetry and Capture at a Neutrino Factory/Muon Collider



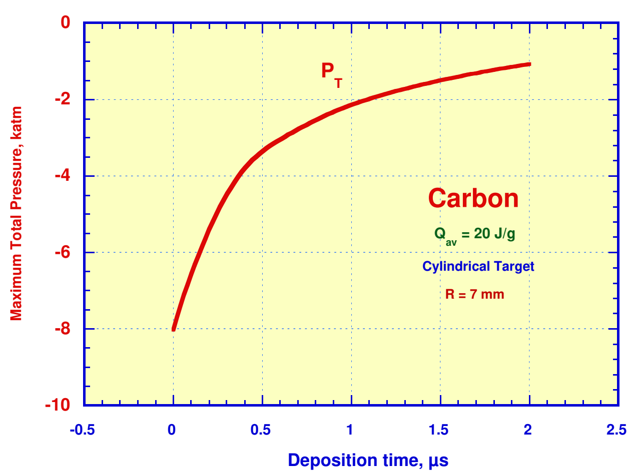
- 1.2×10^{14} $\mu^{\pm}$/s via π-decay from a 4-MW proton beam.
- Proton pulse $\approx$ 1 ns rms.
- Disposable target $\Rightarrow$ mercury jet.
- 20-T capture solenoid followed by a 1.25-T π-decay channel with phase-rotation via rf (to compress the bunch energy).

A Carbon Target is Feasible at 1-MW Beam Power

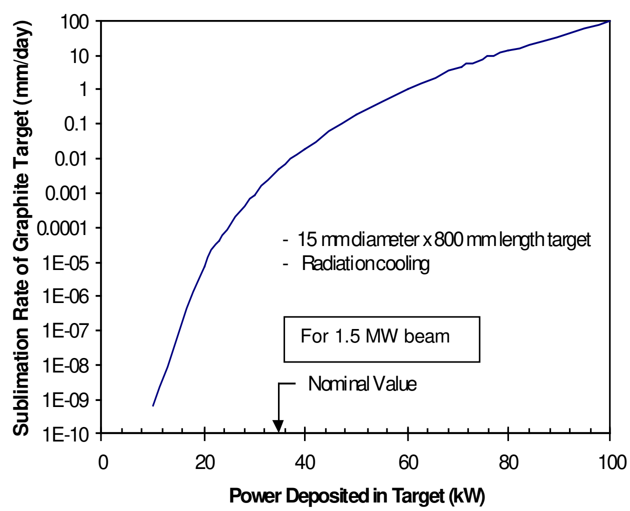




But a 1-nsec beam pulse causes severe pressure waves.



A carbon target sublimates away in 1 day at 4 MW.



Two Classes of Issues

1. Viability of targetry and capture for a single pulse.

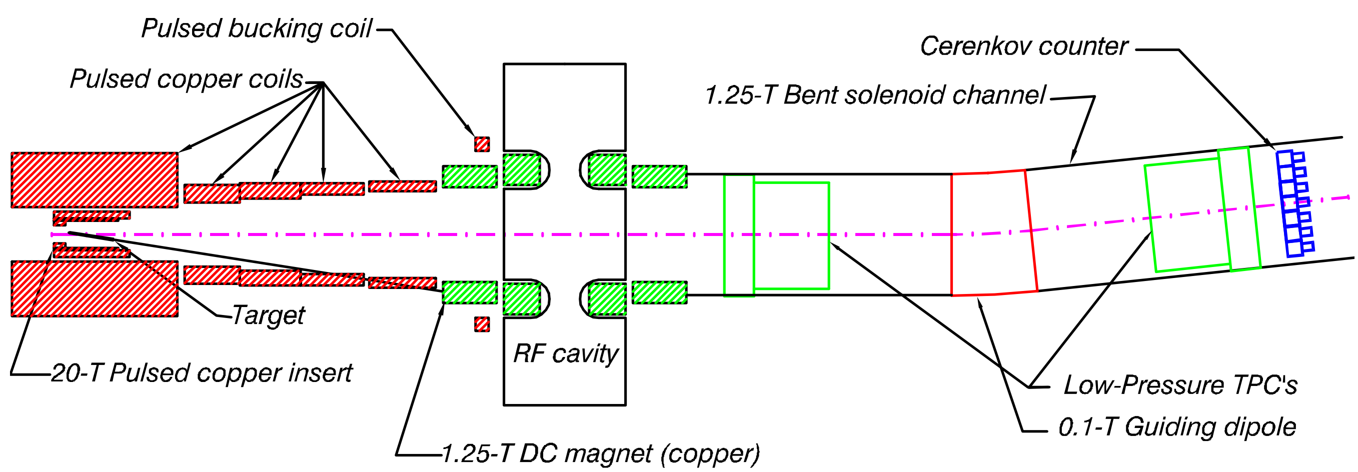
2. Long-term viability of the system in a high radiation area.

E951 Studies the Single Pulse Issues

Overall Goal: Test key components of the front-end of a neutrino factory in realistic single-pulse beam conditions.

Near Term (1-2 years): Explore viability of a liquid metal jet target in intense, short proton pulses and (separately) in strong magnetic fields.

Mid Term (3-4 years): Add 20-T magnet to beam tests;
Test 70-MHz rf cavity (+ 1.25-T magnet) 3 m from target;
Characterize pion yield.



The 8 Steps in the R&D Program

1. Simple tests of liquid (Ga-Sn, Hg) and solid (C, Ni) targets with AGS Fast Extracted Beam (FEB)of 1.5×10^{13} $p$pp.

2. Test of liquid jet entering a 20-T, 20-MW, cw Bitter magnet at the National High Magnetic Field Laboratory).

3. Test of liquid jet and other targets with 10^{14} $p$pp via fast extraction of 6 AGS bunches.

4. Add 20-T pulsed magnet (5-MW peak) to target tests with AGS FEB.

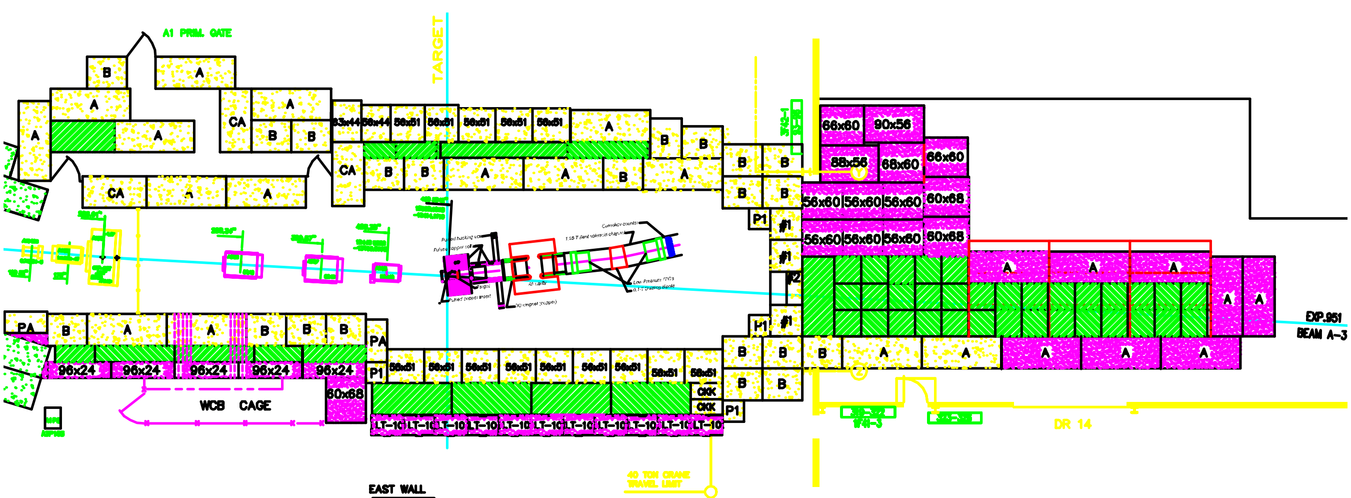
5. Add 70-MHz rf cavity downstream of target in FEB.

6. Surround rf cavity with 1.25-T magnet. At this step we have all essential features of the source.

7. Characterize pion yield from target + magnet system with slow extracted beam (SEB).

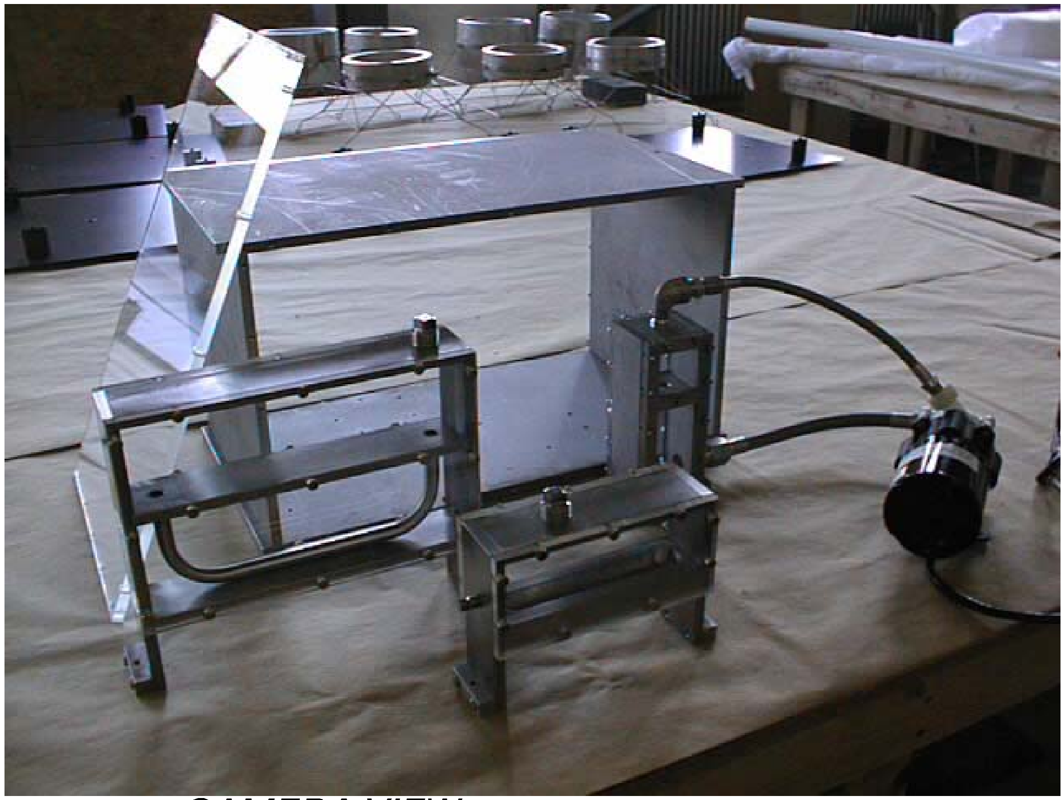
8. Ongoing simulation of the thermal hydraulics of the liquid-metal target systems.

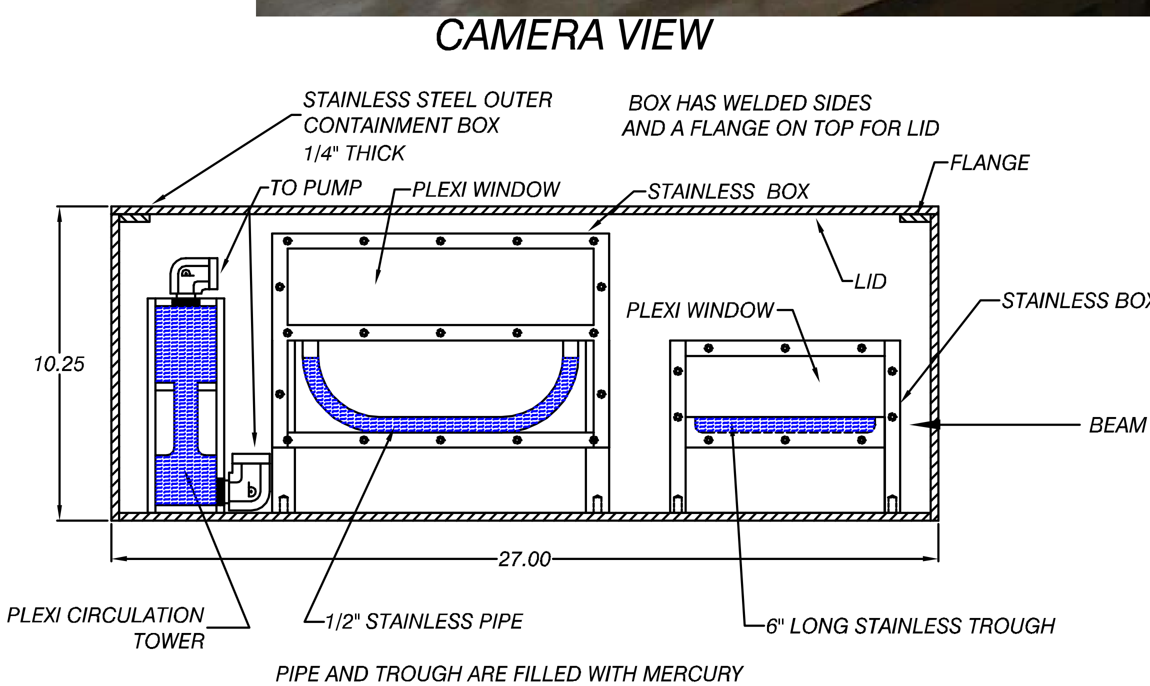
Construction in the A3 Beamline



Simple Target Tests

Simple targets: Pipe, trough, waterfall:





Plus: carbon and nickel targets.

Target Diagnostics

High-speed digital camera (10^6 FPS for 16 frames):

SMD Silicon Mountain Design
EXCELLENCE IN IMAGING
A DALSA Company

SMD 64K1M Camera • 240x240, 1,000,000fps, 12 bits

SMD has solved the problem of real-world interface to hyper-speed cameras

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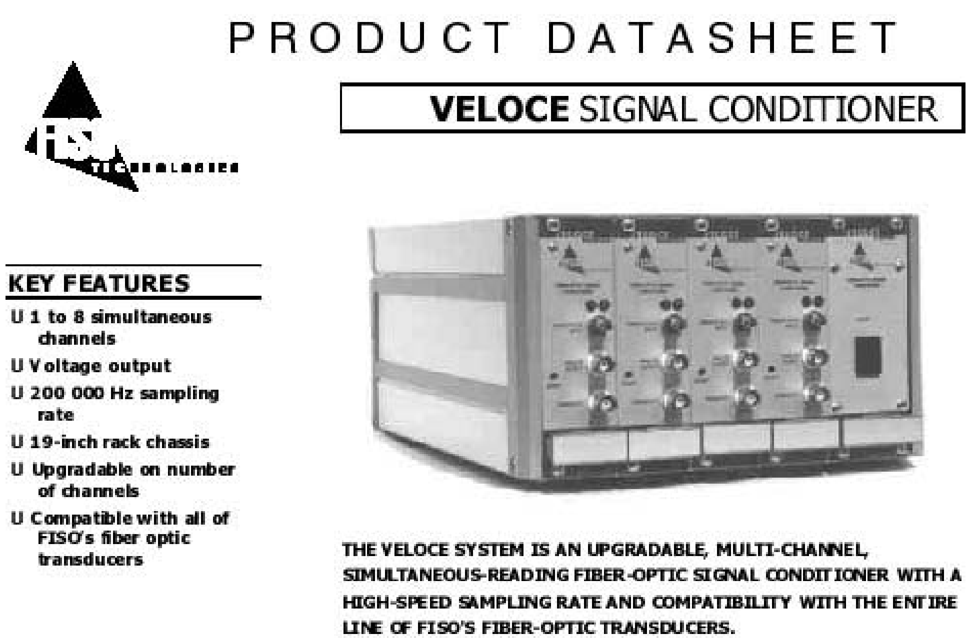
Features

- Ultra High Frame Rate with Electronic Shutter. Up to one million frames per second at 240x240 resolution from a custom-designed interline transfer sensor.
- High Quality Images. The custom sensor's electronic shutter allows crisp, clear images without smearing, even at maximum frame rate. True 12-bit dynamic range preserves superior image quality, even in low light conditions.
- Flexible Data Readout. The sensors's multiple parallel channels of image data are digitized, buffered, and output through four 12-bit wide ports at 10MHz each. Maximum readout is 15 bursts per second of 17 consecutive frames.
- Compact and lightweight. Small form factor to ease system integration.
- Internal/External Sync. Asynchronous-mode frame capture, externally triggerable to within 250 nanoseconds.
- Extended Spectral Response. Sensitive to UV and near IR wavelengths.

Fiberoptic strain sensors (Need to improve the frequency response):



PRODUCT DATASHEET

VELOCE SIGNAL CONDITIONER

KEY FEATURES

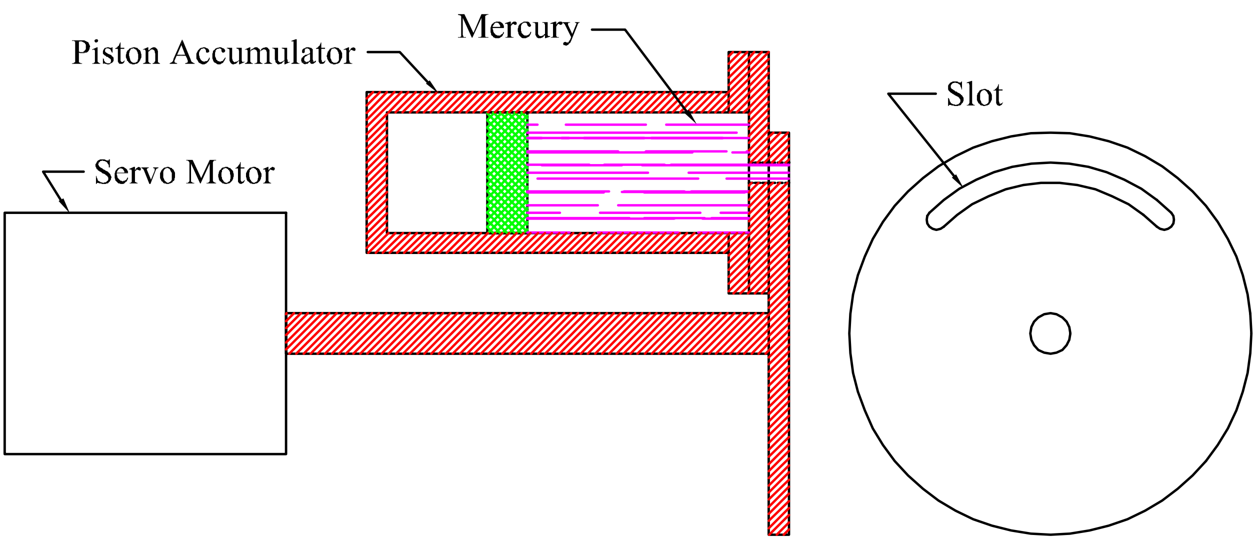
- 1 to 8 simultaneous channels
- Voltage output
- 200 000 Hz sampling rate
- 19-inch rack chassis
- Upgradable on number of channels
- Compatible with all of FISO's fiber optic transducers

THE VELOCE SYSTEM IS AN UPGRADABLE, MULTI-CHANNEL, SIMULTANEOUS-READING FIBER-OPTIC SIGNAL CONDITIONER WITH A HIGH-SPEED SAMPLING RATE AND COMPATIBILITY WITH THE ENTIRE LINE OF FISO'S FIBER-OPTIC TRANSDUCERS.

Prototype Mercury Jets

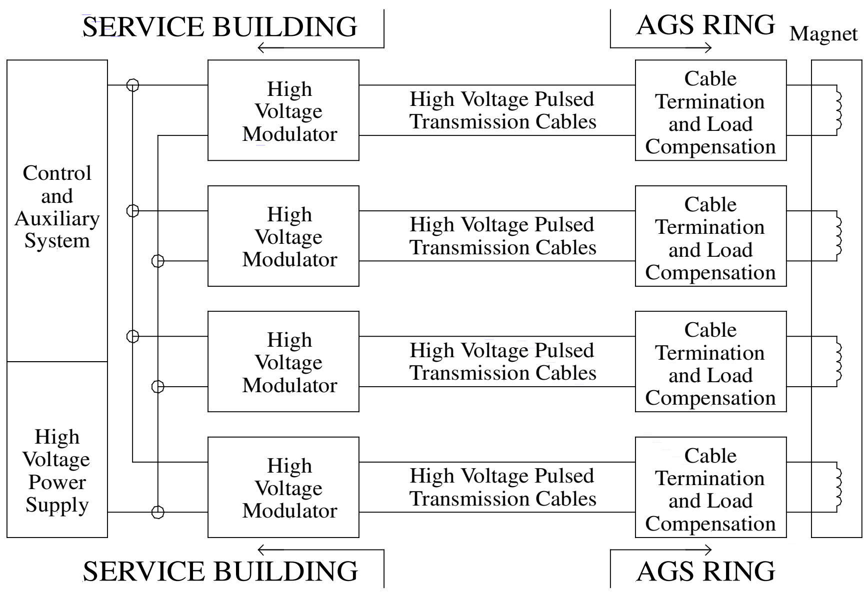
CERN:

Princeton:



AGS Full Turn Fast Extraction

- A single AGS proton bunch can have 1.6×10^{13} protons.
- Can have 6 bunches in the AGS $\Rightarrow 10^{14}$ protons.
- Must upgrade pulse forming network of the G10 fast kicker to permit single-turn extraction of all 6 bunches.
- Arlene Zhang of the AGS is beginning a design study.

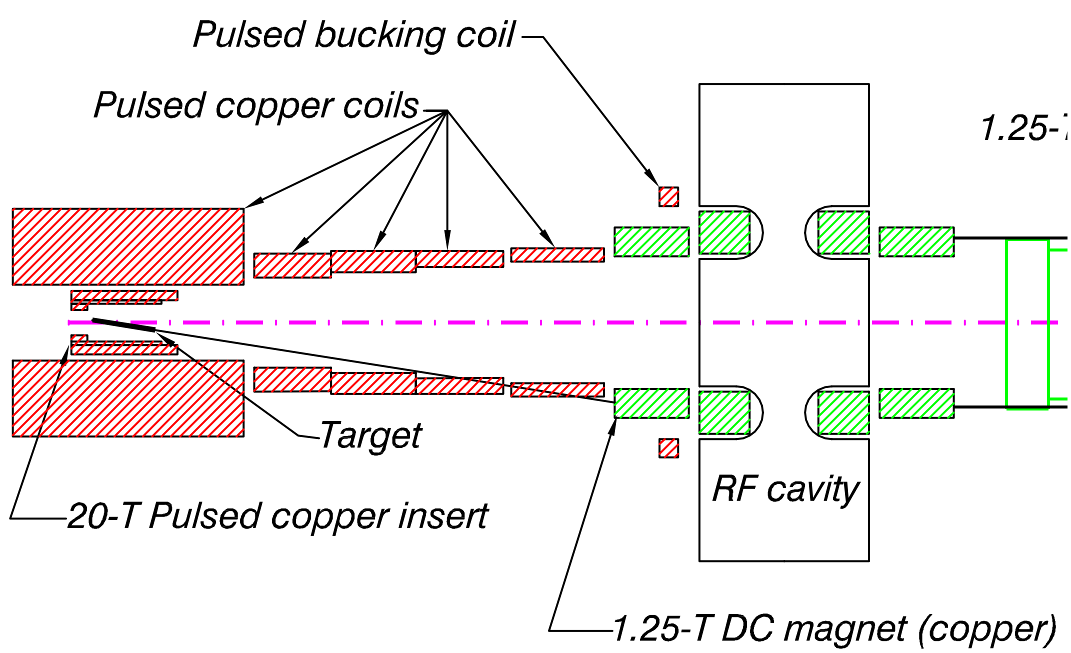


AGS FULL TURN EXTRACTION KICKER SYSTEM

- The LANL Proton Radiography Project also desires the AGS kicker upgrade – and may have a budget for this. However, they want somewhat greater capability than we need, and foresee a longer schedule – completion in FY03.

20-T Pulsed Solenoid and 70-MHz RF Cavity

- We now propose to build a new 5-MW pulsed power supply. (J. Sandberg)
- We now propose that the 70 MHz rf cavity have resistive coils within its nosepieces to provide 1.25-T field on axis. (B. Weggel)
- The rf frequency will actually be 71.2 MHz $= 16 \times$ AGS frequency for six 24-GeV bunches.
- The rf cavity will provide 6 MeV/m accelerating gradient at 4.5 MW power. (J. Rose)
- The rf power is from six 1.5-MW 8973 tetrodes. (J. Corlett)



R&D on High Power, Low Frequency RF Sources

Inductive Output Tubes (Marconi, Thomson):

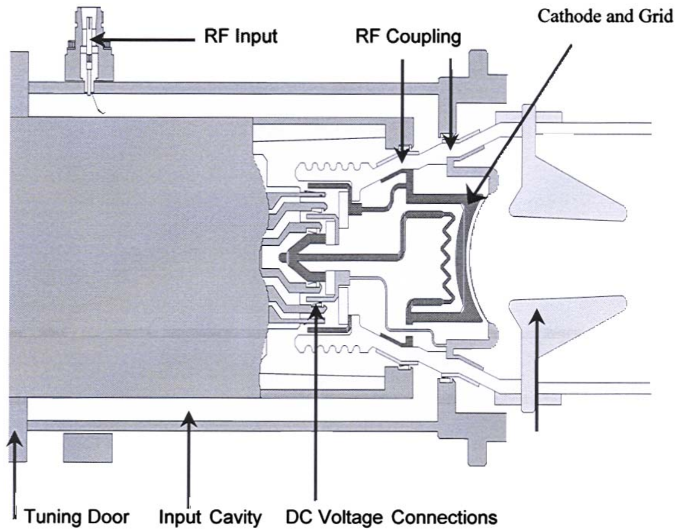
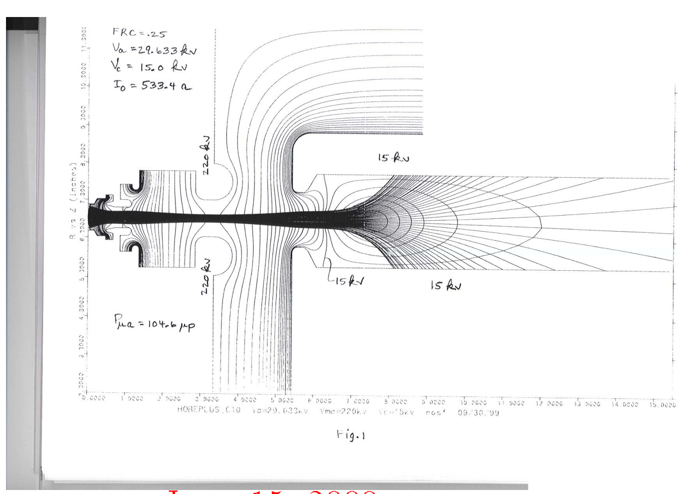


Figure 3.2 Schematic of how a standard television IOT interfaces with the input cavity.

IOT Option - 50 MW RF Output Power at 70 MHz						
Number of beams	1	6	12	24	36	48
Peak Single beam perveance ($\times 10^{-6}$)	1.3 $AV^{-3/2}$	1.3 $AV^{-3/2}$	1.0 $AV^{-3/2}$	1.0 $AV^{-3/2}$	1.0 $AV^{-3/2}$	1.0 $AV^{-3/2}$
IOT perveance ($\times 10^{-6}$)	1.3 $AV^{-3/2}$	7.8 $AV^{-3/2}$	12. $AV^{-3/2}$	24 $AV^{-3/2}$	36 $AV^{-3/2}$	48 $AV^{-3/2}$
Efficiency	73 %	73 %	73 %	73 %	73 %	73 %
Peak DC power	68.5 MW	68.5 MW	68.5 MW	68.5 MW	68.5 MW	68.5 MW
Pulsed Cathode voltage	500 kV	243 kV	203 kV	154 kV	130 kV	116 kV
Peak tube current	460 A	934A	1098 A	1450 A	1687 A	1896 A
Peak cathode current / beam	460 A	156 A	91 A	60 A	47 A	40 A
Total current with no RF	25 A	54 A	84 A	96 A	126 A	144 A
Idle current per beam with no RF	25 A	9 A	7 A	4 A	3.5 A	3 A
Mean current density of M-type cathode	2.5 Acm^{-2}	2.5 Acm^{-2}	2.5 Acm^{-2}	2.5 Acm^{-2}	2.5 Acm^{-2}	2.5 Acm^{-2}
Area of emitter	184 cm^2	62 cm^2	37 cm^2	24 cm^2	19 cm^2	15.8 cm^2
Cathode diameter	15 cm	9 cm	6.8 cm	5.5 cm	4.9 cm	4.5 cm
Gain	25 dB	25 dB	25 dB	25 dB	25 dB	25 dB
Drive power	158 kW	158 kW	158 kW	158 kW	158 kW	158 kW
Height	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m	2.5 m
Diameter	2 m	2.0 m	3 m	3 m	3.5 m	3.5 m

Table 1.3 Approximate parameters for single and multiple beam IOTs to deliver 50 MW output power at 70 MHz. (Figures are only indicative).

Hobetron (Litton):



PROPOSAL FOR LOW-FREQUENCY, HIGH-POWER PULSE COMPRESSION BY A THYRATRON SWITCH

Y. Zhao, BNL (April, 2000)

PRINCIPLE:

A **superconducting storage cavity** is charged by a tetrode. Its output line is a λ/2 line ended with a thyratron, which is open during charging, so that only a little energy leaks out.

Once the thyratron is fired by a trigger pulse, the cavity is coupled to the load and discharged rapidly.

KEY ISSUE:

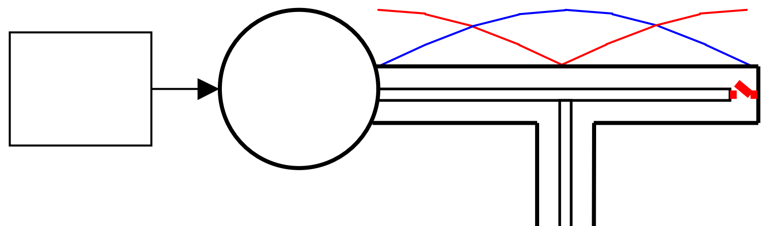
Thyratrons usually work at video frequency, but brief operation at RF frequency is possible before breakdown occurs.

POWER COMPRESSION RATIO:

Reduced by leakage in the switch and by transmission loss.

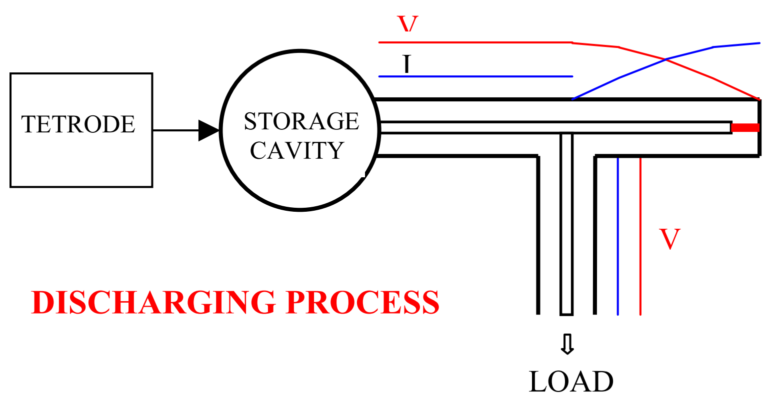
Theoretical analysis indicates a **gain of more than 1000 is possible.**

Initial R&D goal: **power gain of 20** or more.



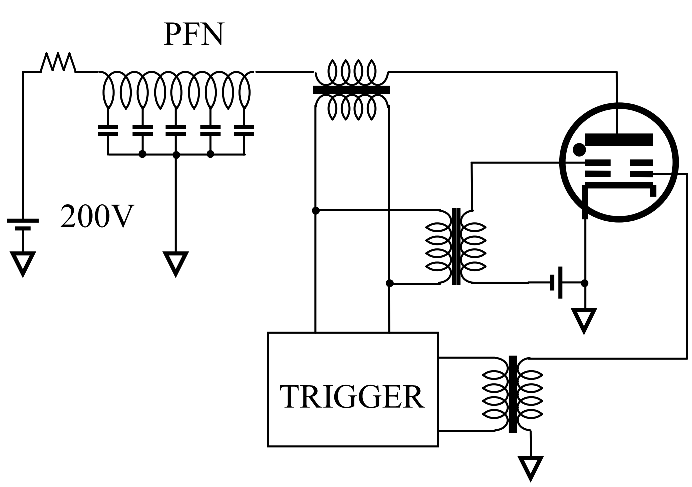
CHARGING PROCESS

SWITCH CLOSED --- TOTAL ENERGY TO LOAD



DISCHARGING PROCESS

THYRATRON FIRING CIRCUIT



Simulations

[Talk by S. Kahn]

1. Pion production: MARS, FLuka. (H. Kirk, N. Mokhov)
2. Pion decay, phase rotation: MARS, GEANT, ICOOL.
   (Y. Fukui, H. Kirk, N. Mokhov, S. Kahn)
3. Neutron doses: MARS, LAHET/MCNP. (N. Mokhov, ...)
4. Radionucleide inventory: LAHET/MNCP
5. Beam-induced pressure waves in targets.
   (A. Hassanein, P. Drumm, R. Samulyak, N. Simos)
6. Magnetohydrodynamics of liquid metal jets. (C. Lu)

Beyond E951

[Talk by P. Spampinato]

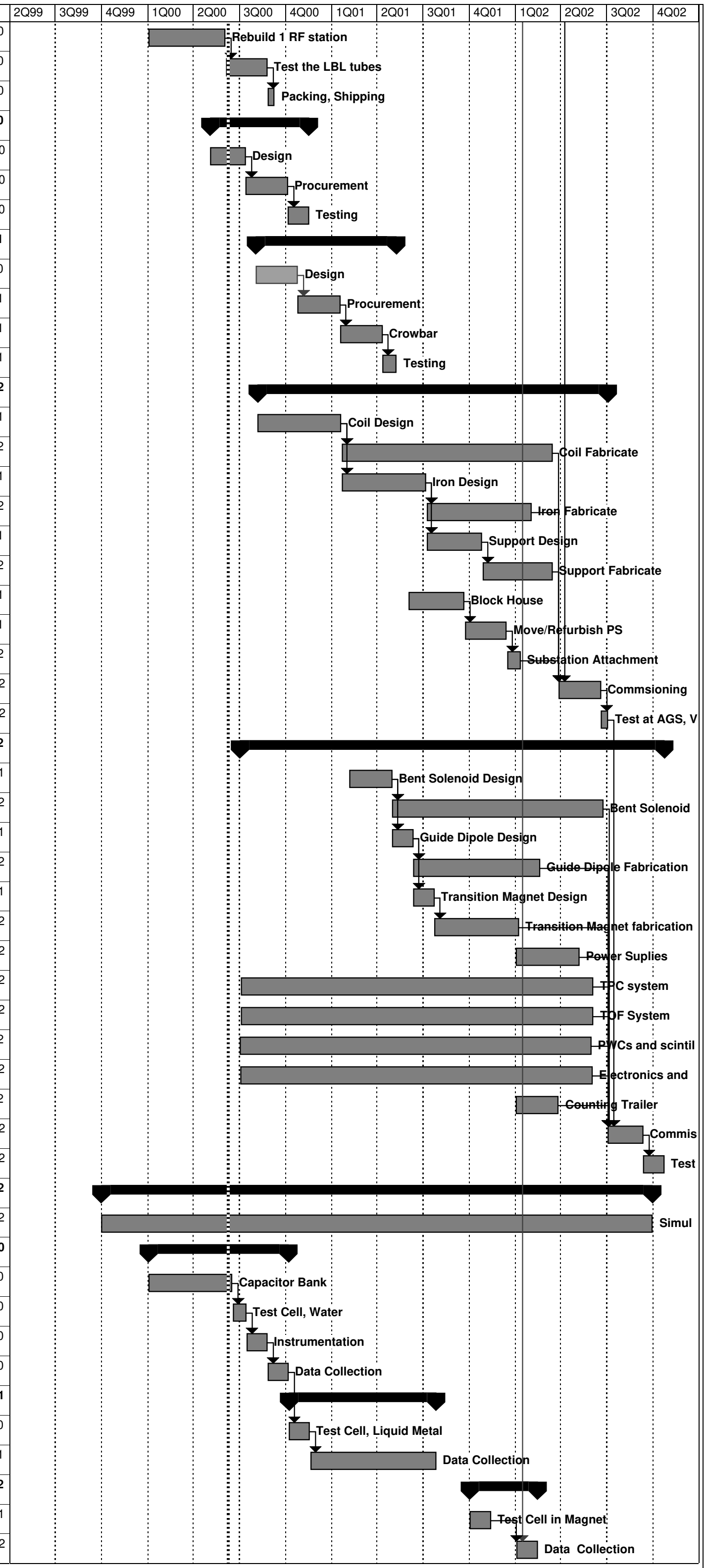
- Target station infrastructure (ORNL).
- Radionucleide issues (BNL, ORNL).
- Neutron damage to materials (BNL, MSU, ORNL).
- Large exposure tests of targets at neutron spallation facilities (BNL, LANL, ORNL).

E951 Schedule

- FY99:
  Prepare A3 area at the AGS (Step 1);
  Begin work on liquid jets, magnet and rf systems (Steps 2, 4-6).
- FY00:
  Complete A3 line (Step 1);
  Continue work on jet, magnet and rf systems (Steps 2, 4-6);
  Begin work on AGS extraction upgrade (Step 3).
- FY01:
  First test of targets in A3 (Step 1);
  Liquid jet test in 20-T magnet at NHMFL (Step 2);
  Continue work on extraction, magnet, and rf systems (Steps 3-6).
- FY02:
  Complete extraction upgrade, magnet, and rf systems (Steps 3-6);
  Test targets with 10^{14} ppp (Step 3);
  Begin work on pion yield diagnostics (Step 7);
  Option to study mercury dump in vertically pitched beam (Step 3.5).
- FY03:
  Beams tests of target + 20-T pulsed magnet + rf cavity (Steps 4.6);
  Complete pion detectors; test yield with low intensity SEB (Step 7).

ID	Task Name	Duration	Cost	Start	Finish
1	**Targetry R&D**	**863 days**	**$8,859,000**	**Tue 7/6/99**	**Thu 10/24/02**
2	**AGS Extraction Upgrade**	**324 days**	**$1,049,000**	**Tue 7/6/99**	**Fri 9/29/00**
3	E864 Removal	75 days	$177,000	Tue 7/6/99	Mon 10/18/99
4	Upgrade A3 Beam Line	240 days	$704,000	Tue 10/19/99	Mon 9/18/00
5	FEB Instumentation	150 days	$168,000	Mon 3/6/00	Fri 9/29/00
6	**Liquid Metal Jet**	**359 days**	**$310,000**	**Wed 3/1/00**	**Mon 7/16/01**
7	**Initial Beam Test**	**163 days**	**$80,000**	**Wed 3/1/00**	**Fri 10/13/00**
8	Containment Vess	75 days	$30,000	Fri 3/3/00	Thu 6/15/00
9	Instrumentation	100 days	$40,000	Wed 3/1/00	Tue 7/18/00
10	Test at AGS, I	10 days	$10,000	Mon 10/2/00	Fri 10/13/00
11	**Jet Test at FSU Magne**	**93 days**	**$60,000**	**Fri 5/5/00**	**Tue 9/12/00**
12	Containment Vess	63 days	$20,000	Fri 5/5/00	Tue 8/1/00
13	Instrumentation	20 days	$20,000	Wed 8/2/00	Tue 8/29/00
14	Test at FSU	10 days	$20,000	Wed 8/30/00	Tue 9/12/00
15	**3 mm Jet Test**	**192 days**	**$50,000**	**Mon 7/3/00**	**Tue 3/27/01**
16	Jet fabricaton	130 days	$20,000	Mon 7/3/00	Fri 12/29/00
17	Containment Vess	75 days	$10,000	Wed 11/1/00	Tue 2/13/01
18	Instrumentation	20 days	$10,000	Wed 2/14/01	Tue 3/13/01
19	Test at AGS, II	10 days	$10,000	Wed 3/14/01	Tue 3/27/01
20	**5 mm Jet**	**139 days**	**$120,000**	**Wed 1/3/01**	**Mon 7/16/01**
21	Design	20 days	$20,000	Wed 1/3/01	Tue 1/30/01
22	Jet fabrication	45 days	$20,000	Wed 1/31/01	Tue 4/3/01
23	Containment Vess	30 days	$20,000	Wed 1/31/01	Tue 3/13/01
24	Instrumentation	20 days	$20,000	Wed 3/14/01	Tue 4/10/01
25	Test at AGS, III	10 days	$10,000	Wed 4/11/01	Tue 4/24/01
26	Test at AGS, IV	10 days	$10,000	Tue 7/3/01	Mon 7/16/01
27	**AGS Extraction Upgrade**	**290 days**	**$1,400,000**	**Mon 1/3/00**	**Fri 2/9/01**
28	Design	90 days	$100,000	Mon 1/3/00	Fri 5/5/00
29	Purchase parts	100 days	$800,000	Mon 5/8/00	Fri 9/22/00
30	Installation	200 days	$500,000	Mon 5/8/00	Fri 2/9/01
31	**Pulsed Solenoid**	**590 days**	**$1,020,000**	**Fri 10/1/99**	**Thu 1/3/02**
32	Design	240 days	$100,000	Fri 10/1/99	Thu 8/31/00
33	Coil Purchase/Fabricati	250 days	$500,000	Fri 9/1/00	Thu 8/16/01
34	Commisioning	60 days	$100,000	Fri 8/17/01	Thu 11/8/01
35	LN2 Cryostat Design	7 days	$50,000	Fri 9/1/00	Mon 9/11/00
36	LN2 Cryostat Fabricatic	50 days	$100,000	Tue 9/12/00	Mon 11/20/00
37	LN2 Handling	40 days	$20,000	Tue 11/21/00	Mon 1/15/01
38	Move/Refurbish PS	40 days	$40,000	Wed 10/4/00	Tue 11/28/00
39	Move Substation	40 days	$40,000	Wed 11/29/00	Tue 1/23/01
40	Substation Attachment	20 days	$20,000	Wed 1/24/01	Tue 2/20/01
41	Switching System	45 days	$30,000	Wed 2/21/01	Tue 4/24/01
42	Test at AGS, V	40 days	$20,000	Fri 11/9/01	Thu 1/3/02
43	**RF Systems**	**650 days**	**$1,505,000**	**Fri 10/1/99**	**Thu 3/28/02**
44	**70-MHz RF Cavity**	**650 days**	**$950,000**	**Fri 10/1/99**	**Thu 3/28/02**
45	Design	230 days	$120,000	Fri 10/1/99	Thu 8/17/00
46	Purchase/Fabricat	260 days	$600,000	Fri 8/18/00	Thu 8/16/01
47	Assembly	20 days	$20,000	Fri 8/17/01	Thu 9/13/01
48	Testing w/o beam	60 days	$30,000	Fri 9/14/01	Thu 12/6/01
49	Refurbish/rebuild	20 days	$150,000	Fri 12/7/01	Thu 1/3/02
50	Test at AGS, VI	60 days	$30,000	Fri 1/4/02	Thu 3/28/02
51	**Site Preparation**	**205 days**	**$270,000**	**Mon 4/3/00**	**Fri 1/12/01**
52	Design	30 days	$30,000	Mon 4/3/00	Fri 5/12/00
53	Blockhouse	60 days	$150,000	Mon 5/15/00	Fri 8/4/00
54	Power Service	70 days	$20,000	Mon 8/7/00	Fri 11/10/00
55	Vacuum	40 days	$50,000	Mon 11/13/00	Fri 1/5/01
56	DI Water	45 days	$20,000	Mon 11/13/00	Fri 1/12/01
57	**70-MHz Test at LBL**	**180 days**	**$135,000**	**Mon 1/3/00**	**Fri 9/8/00**

ID	Task Name	Duration	Cost	Start	Finish
58	Rebuild 1 RF statio	110 days	$45,000	Mon 1/3/00	Fri 6/2/00
59	Test the LBL tubes	60 days	$75,000	Mon 6/5/00	Fri 8/25/00
60	Packing, Shipping	10 days	$15,000	Mon 8/28/00	Fri 9/8/00
61	**Low Level RF**	**140 days**	**$40,000**	**Fri 5/5/00**	**Thu 11/16/00**
62	Design	50 days	$10,000	Fri 5/5/00	Thu 7/13/00
63	Procurement	60 days	$20,000	Fri 7/14/00	Thu 10/5/00
64	Testing	30 days	$10,000	Fri 10/6/00	Thu 11/16/00
65	**Pulsing System**	**200 days**	**$110,000**	**Thu 8/3/00**	**Wed 5/9/01**
66	Design	60 days	$30,000	Thu 8/3/00	Wed 10/25/00
67	Procurement	60 days	$30,000	Thu 10/26/00	Wed 1/17/01
68	Crowbar	60 days	$30,000	Thu 1/18/01	Wed 4/11/01
69	Testing	20 days	$20,000	Thu 4/12/01	Wed 5/9/01
70	**RF Solenoid**	**499 days**	**$1,110,000**	**Mon 8/7/00**	**Thu 7/4/02**
71	Coil Design	120 days	$60,000	Mon 8/7/00	Fri 1/19/01
72	Coil Fabricate	300 days	$500,000	Mon 1/22/01	Fri 3/15/02
73	Iron Design	120 days	$60,000	Mon 1/22/01	Fri 7/6/01
74	Iron Fabricate	150 days	$200,000	Mon 7/9/01	Fri 2/1/02
75	Support Design	80 days	$40,000	Mon 7/9/01	Fri 10/26/01
76	Support Fabricate	100 days	$50,000	Mon 10/29/01	Fri 3/15/02
77	Block House	80 days	$20,000	Mon 6/4/01	Fri 9/21/01
78	Move/Refurbish PS	60 days	$30,000	Mon 9/24/01	Fri 12/14/01
79	Substation Attachment	20 days	$20,000	Mon 12/17/01	Fri 1/11/02
80	Commsioning	60 days	$120,000	Fri 3/29/02	Thu 6/20/02
81	Test at AGS, VII	10 days	$10,000	Fri 6/21/02	Thu 7/4/02
82	**Capture Experiment**	**604 days**	**$1,770,000**	**Mon 7/3/00**	**Thu 10/24/02**
83	Bent Solenoid Design	60 days	$30,000	Tue 2/6/01	Mon 4/30/01
84	Bent Solenoid Fabricati	300 days	$500,000	Tue 5/1/01	Mon 6/24/02
85	Guide Dipole Design	30 days	$20,000	Tue 5/1/01	Mon 6/11/01
86	Guide Dipole Fabricatic	180 days	$150,000	Tue 6/12/01	Mon 2/18/02
87	Transition Magnet Desi	30 days	$20,000	Tue 6/12/01	Mon 7/23/01
88	Transition Magnet fabri	120 days	$100,000	Tue 7/24/01	Mon 1/7/02
89	Power Suplies	90 days	$100,000	Wed 1/2/02	Tue 5/7/02
90	TPC system	500 days	$240,000	Wed 7/5/00	Tue 6/4/02
91	TOF System	500 days	$120,000	Wed 7/5/00	Tue 6/4/02
92	PWCs and scintillators	500 days	$150,000	Mon 7/3/00	Fri 5/31/02
93	Electronics and DAQDa	500 days	$200,000	Tue 7/4/00	Mon 6/3/02
94	Counting Trailer	60 days	$60,000	Thu 1/3/02	Wed 3/27/02
95	Commisioning	50 days	$50,000	Fri 7/5/02	Thu 9/12/02
96	Test at AGS, VIII	30 days	$30,000	Fri 9/13/02	Thu 10/24/02
97	**Simulation & Validation**	**782 days**	**$695,000**	**Fri 10/1/99**	**Mon 9/30/02**
98	Simulation	782 days	$525,000	Fri 10/1/99	Mon 9/30/02
99	**Exploding Wire I**	**200 days**	**$110,000**	**Mon 1/3/00**	**Fri 10/6/00**
100	Capacitor Bank	120 days	$60,000	Mon 1/3/00	Fri 6/16/00
101	Test Cell, Water	20 days	$10,000	Mon 6/19/00	Fri 7/14/00
102	Instrumentation	30 days	$30,000	Mon 7/17/00	Fri 8/25/00
103	Data Collection	30 days	$10,000	Mon 8/28/00	Fri 10/6/00
104	**Exploding Wire II**	**210 days**	**$40,000**	**Mon 10/9/00**	**Fri 7/27/01**
105	Test Cell, Liquid M	30 days	$10,000	Mon 10/9/00	Fri 11/17/00
106	Data Collection	180 days	$30,000	Mon 11/20/00	Fri 7/27/01
107	**Exploding Wire III**	**97 days**	**$20,000**	**Wed 10/3/01**	**Thu 2/14/02**
108	Test Cell in Magne	30 days	$10,000	Wed 10/3/01	Tue 11/13/01
109	Data Collection	30 days	$10,000	Fri 1/4/02	Thu 2/14/02



Targetry and Capture Budgets, I

Yearly Projections (made in 1998)

Category	FY99	FY00	FY01	FY02	FY03	Total
Base Program	\$0.5M	\$1.5M	\$2M	\$2M	\$1M	\$7M
AGS Operations		\$0.2M	\$0.2M	\$0.4M	\$0.4M	\$1M
RF Power Source	\$0.05M	\$0.5M	\$1M	\$1M	\$1M	\$3.5M

Targetry FY99, Allocated

Task	ANL	BNL	LBL	Princeton	Industry	Total
Initial Target Studies		20		85		105
AGS Beamline Upgrades		100				100
Pulsed Solenoid Design		50				50
RF Systems		65	75		50	190
Simulation Studies	75			5		80
Total	75	285	75	90	50	**\$525k**

Total Targetry FY00, Allocated

Task	ANL	BNL	LBL	ORNL	NHMFL	Prin.	MSU	Total
Initial Target Studies		25				50		75
AGS Beamline Upgrades		1338						1338
Magnet Systems		240			25	40		305
RF Systems		295	75					370
Simulation Studies	80					10		90
Target Station				50				50
Radiation Damage							20	20
Carryover		−100						−100
Total	80	1798	75	50	25	100	20	**$2148k**

FY00 Targetry Allocation: Details

1. **Initial Target Studies** **$75k**
   - Remote positioner for target box (BNL) $25k
   - Target box, targets, cameras (Princeton) $50k
2. **AGS Beamline Upgrades** **$1338k**
   - Labor (11,000 hours, BNL) $1100k
   - Beamline Instrumentation (BNL) $120k
   - Radiation Safety (BNL) $38k
   - 6-Bunch kicker design (BNL) $80k
3. **Magnet Systems** **$305k**
   - Mech. engineer (BNL) $170k
   - 1/4 Mech. engineer (Princeton) $40k
   - 1/6 Mech. engineer (NHMFL) $25k
   - Design of 5 MW magnet power supply (BNL) $70k

4. **RF Systems** **$370k**

   - Recommissioning of the 8973 power supplies (LBL) . $75k
   - 1 1/2 RF engineer (BNL) $255k
   - Materials (BNL) $40k

5. **Simulation Studies** **$90k**

   - (ANL) $80k
   - (Princeton) $10k

6. **Target Station Studies (ORNL)** **$50k**

7. **Radiation Damage Studies (MSU)** **$20k**

8. **Total** **$2248k**

FY01 Targetry Request: Details

1. **Initial Target Studies $200k**
   - Engineering support for A3 target station (BNL) ... $50k
   - Mercury jet for BNL/NHMFL tests (Princeton) $50k
   - [Carbon target studies (BNL, ORNL, LANL) ..... $100k]
2. **AGS Operations: 3 weeks, A3 + linac costs $200k**
3. **AGS Beamline Upgrades $900k**
   - Labor (1,000 hours, BNL) $100k
   - 6-Bunch kicker fabrication (BNL) $800k
4. **Magnet Systems $1200k**
   - Mech. engineer + designer (BNL) $280k
   - 1/2 Mech. engineer (NHMFL) $80k
   - 1/4 Mech. engineer (Princeton) $40k
   - Fabrication of 5 MW magnet power supply (BNL +) $400k
   - Fabrication of pulsed & DC magnet coils (BNL +) .$400k

5. **RF Systems** **$1335k**

- Shipping of 8973 rf gear from LBL to BNL $20k
- Materials for 8973 power source (BNL) $100k
- 1 1/2 RF engineer (BNL) $255k
- Mech. engineer (BNL) $160k
- 2 × 1/2 Technician (BNL) $100k
- Fabrication of the 70 MHz rf cavity $400k
- [RF switch R&D (BNL) . . . . $50k]
- [Industrial development of 10-50 MW power sources $250k]

6. **Simulation Studies** **$360k**

- 1/2 FTE (ANL) $80k
- 1/2 FTE (BNL) $80k
- [1/2 FTE (BNL) . . . . $80k]
- [1/2 FTE (ORNL) . . . . $80k]
- 1/4 FTE (Princeton) $40k

7. [Target Station Studies (ORNL) . . . . $100k]

8. [**Neutronics** . . . . **$150k**]

   - [Radiation Damage Studies (MSU) . . . . $50k]
   - [Neutron dosimetry studies in A3 (BNL+) . . . . $100k]

9. **Total** **$4445k**

[Items in brackets are beyond the E951 base program]

[Total for items beyond the base program $810k

Summary of FY01 Targetry Budget, Requested

Task	ANL	BNL	ORNL	NHMFL	Prin.	MSU	Ind.	Total
Initial Target Studies		50	100		50			200
AGS Operations		200						200
AGS Beamline Upgrades		900						900
Magnet Systems		1080		80	40			1200
RF Systems		1085					250	1335
Simulation Studies	80	160	80		40			360
Target Station			100					100
Neutronics		100				50		150
Total	80	3575	280	80	130	50	250	**$4445k**

Comments on the FY01 Targetry Budget Request

1. Of the $4435k requested, $810k are for intiatives beyond the E951 base program.
2. Support for Neutronics may be available from the NSF.
3. Support for AGS Operations may be available from DOE Facilities Operations.
4. Support for the AGS kicker upgrade may be available from the LANL Proton Radiography project.
5. Support for industrial development of rf power sources might be available from DOE BES or elsewhere.
6. Candidates for support by other than DOE Advanced Accelerator Projects total $1400k.