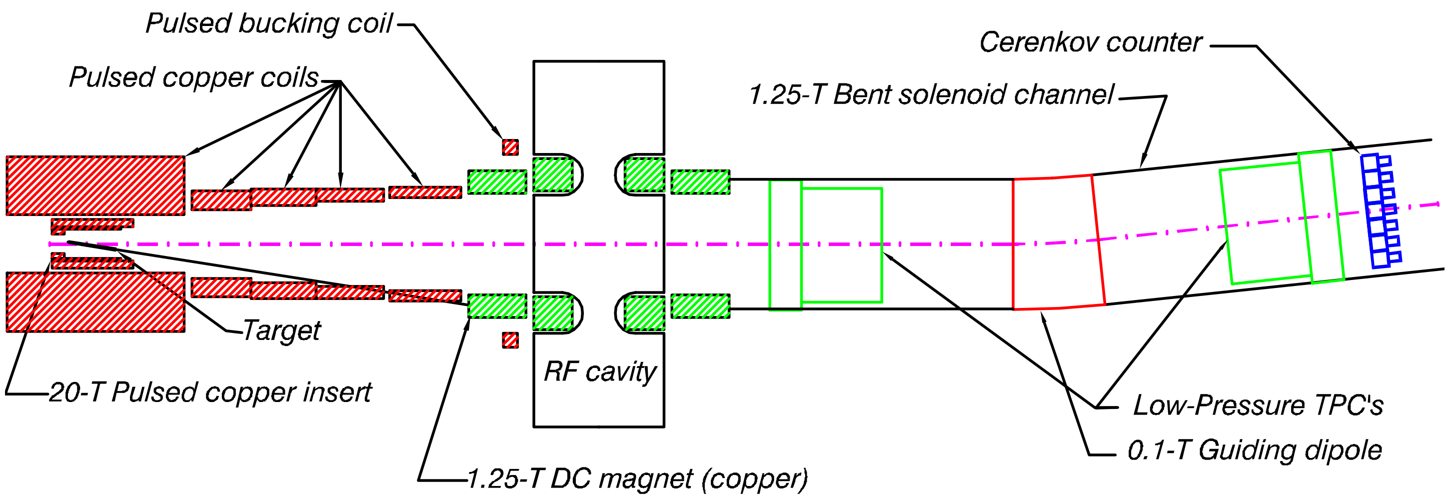
The R&D Program for Targetry and Capture at a Neutrino Factory and Muon Collider Source

(BNL E951)



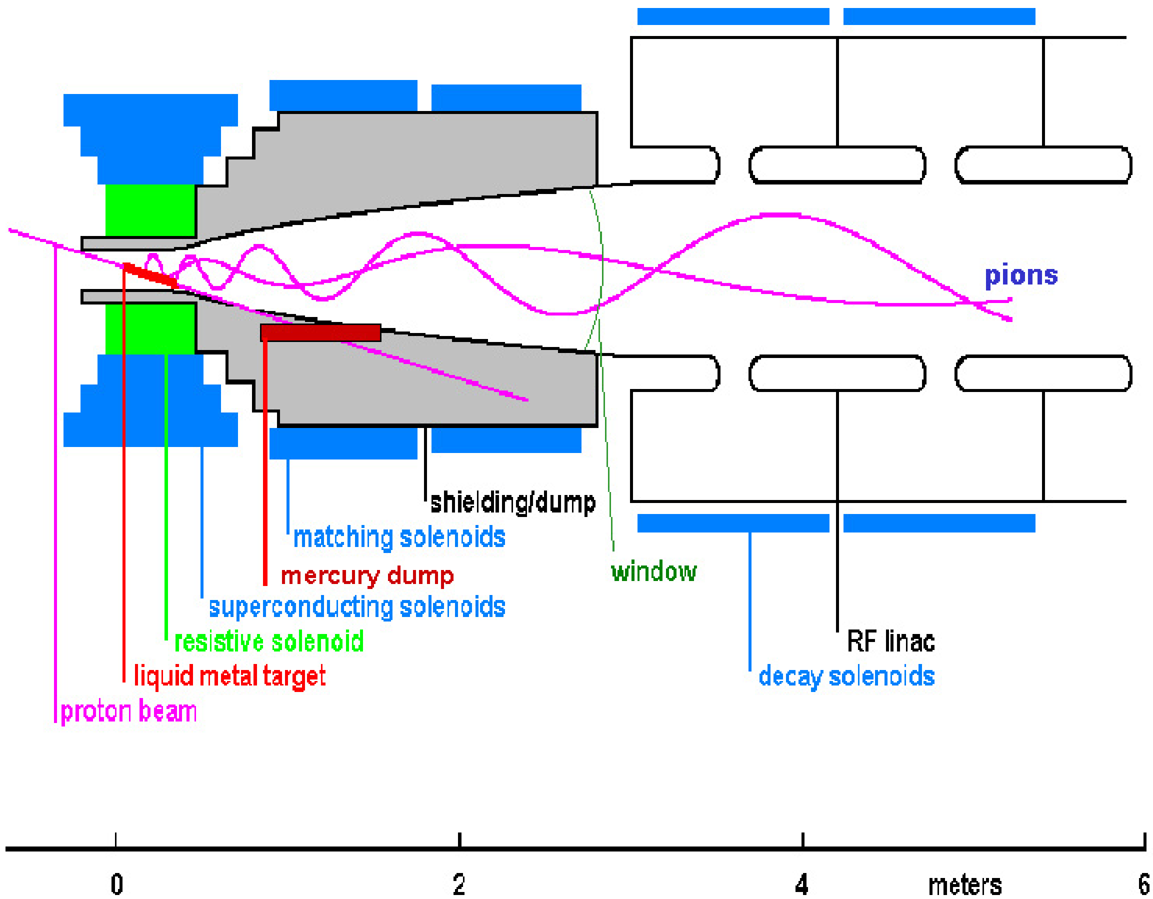
K.T. McDonald
Princeton U.

October 3, 2000

NF&MCC Technical Board Meeting, LBL

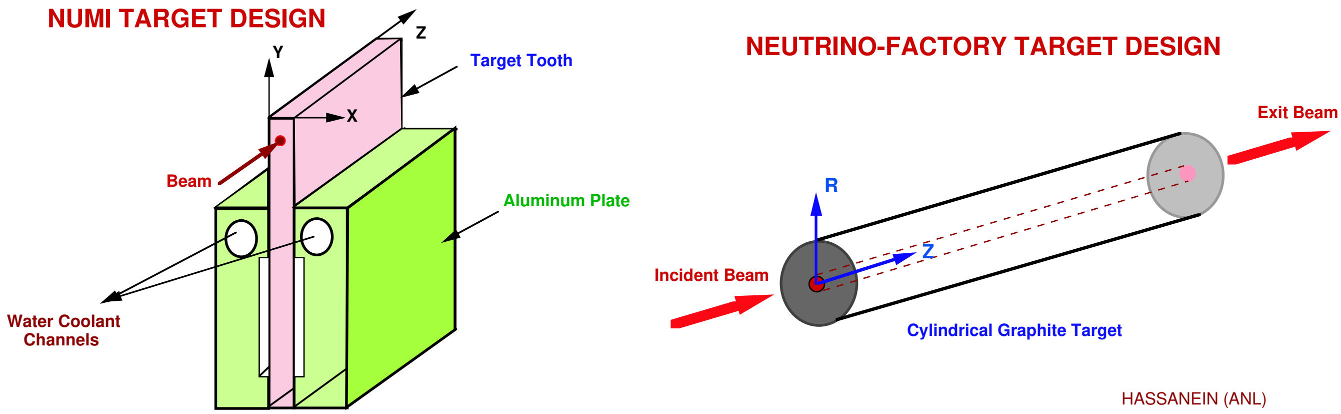
http://puhep1.princeton.edu/mumu/target/

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

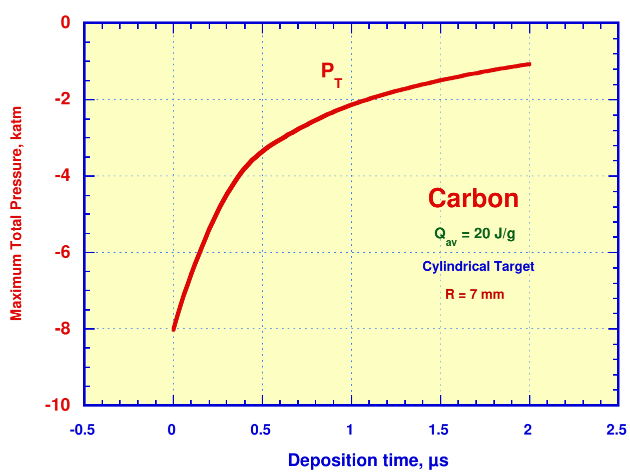


- 1.2×10^{14} $\mu^{\pm}$/s via π-decay from a 4-MW proton beam.
- Proton pulse $\approx$ 1 ns rms.
- Disposable target $\Rightarrow$ mercury jet.
- 20-T capture solenoid followed by a 1.25-T π-decay channel with phase-rotation via rf (to compress the bunch energy).

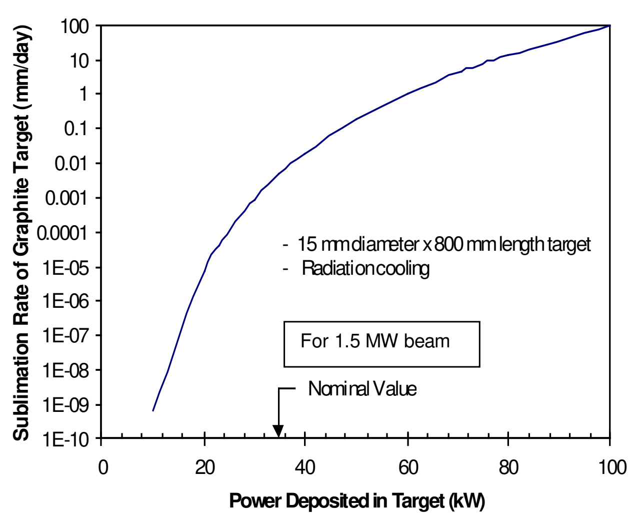
A Carbon Target is Feasible at 1-MW Beam Power



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.

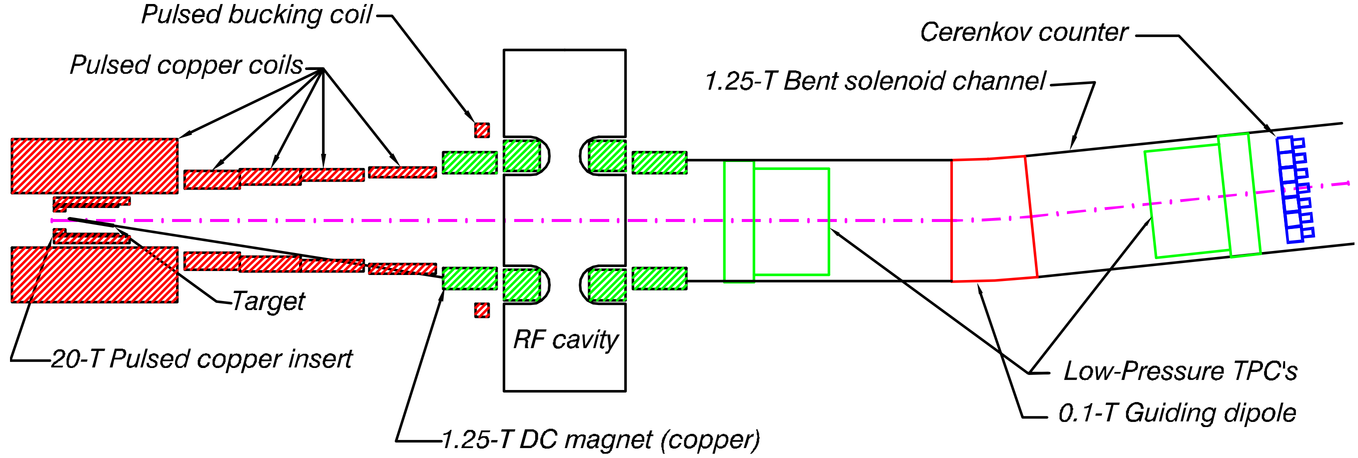
2. Long-term viability of the system in a high radiation area.

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.

Activities During FY01

- E951 given DOE approval by J. O'Fallon on Sept. 12.
- Preparation of the A3 beamline at BNL:
  - Work only 80% complete as of Oct. 1; nearly on budget.
  - Slowdown during Sept.-Dec. 2000 due to RHIC shutdown.
  - A3 complete $\approx$ March 2001.
- Preparation for initial target tests:
  - Target types: Hg in trough, Hg in pipe, Hg vertical jet, Hg horizontal jet, Wood's metal in trough, C rod, graphite composite rod, BN rod...
  - Finfrock, Greene, Thieberger join BNL targetry effort.
  - Target containment vessels must be redesigned for greater safety.
  - Nominal beam energy deposition stress ordinary materials (Be, Al, Ti, stainless steel) too close to yield.
  - Use invar (Fe 64% / Ni 36%) where beam impacts.

– Use "bulletproof" glass laminate for viewports on primary containment vessel for mercury.

– Stainless steel outer containment vessels with ports using conflat flanges.

– High-speed digital camera system being assembled.

- Construction of Hg jets:

  – CERN: using fast electropneumatic valve. "Copy" to be built at BNL.

  – Princeton: using "chopper".

  – One or both to be tested in 20-T at the NHMFL in FY01.

- 20-T pulsed magnet system:

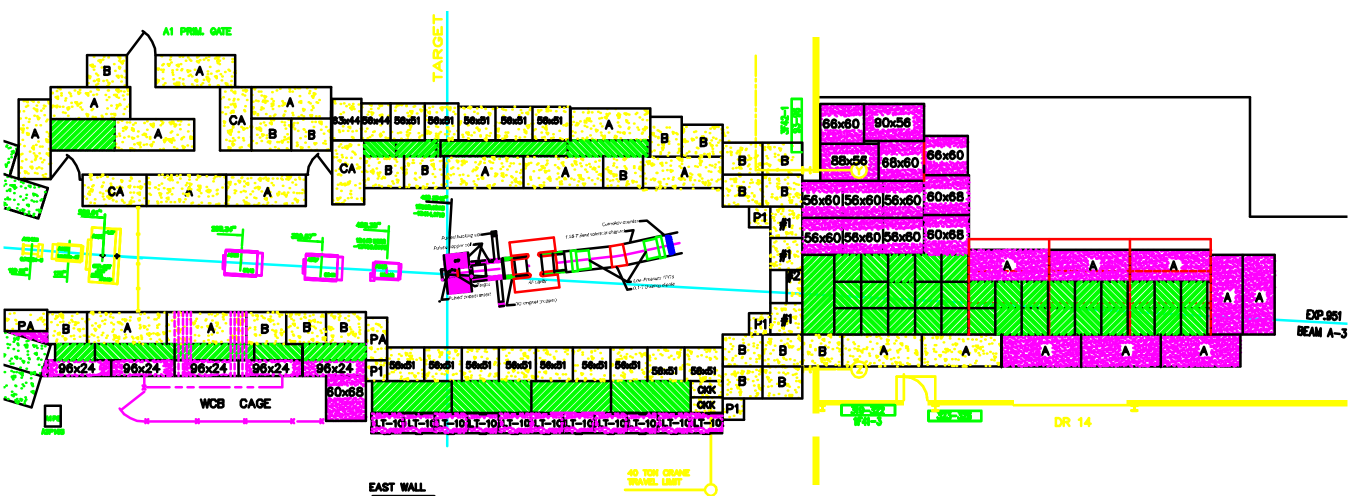
  – "Factorize" design into main pulsed coils, pulsed bucking coils, and DC coils.

  – Seeking vendor involvement in design/fabrication of main pulsed coils.

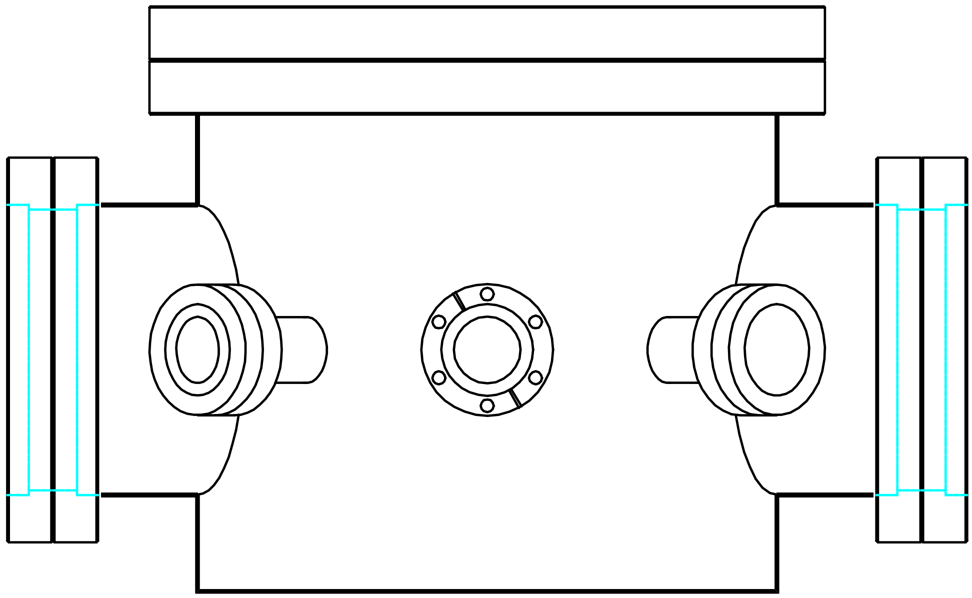
  – Dyna Power performed a preliminary design study for a 5-MW power supply.

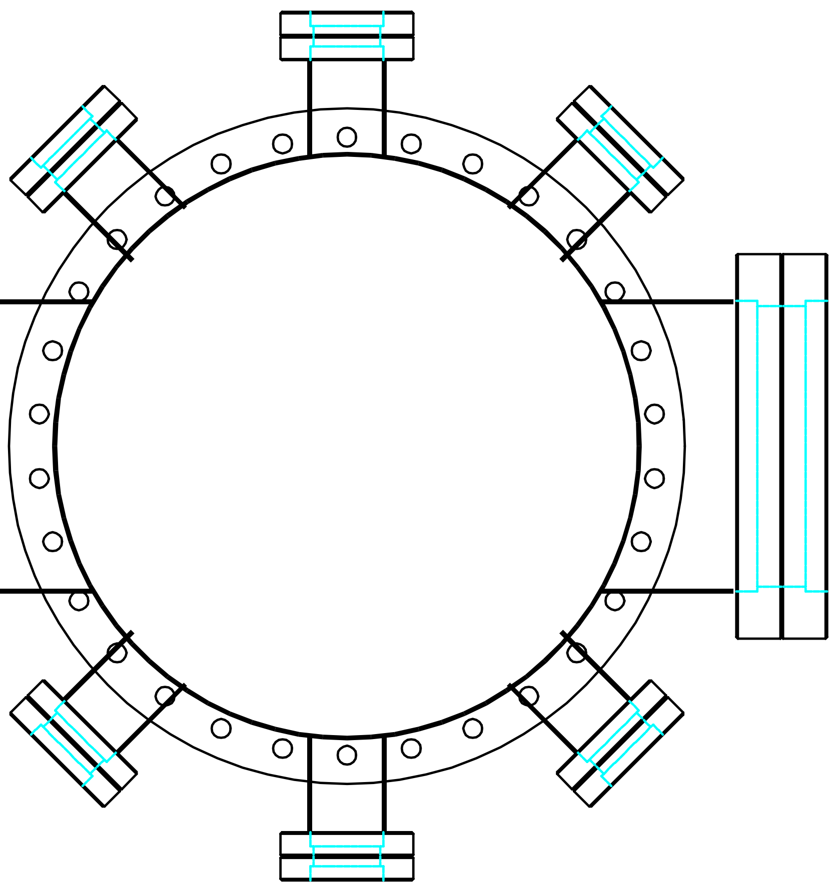
- Low frequency rf systems:
  - CERN: Small 200 MHz rf cavity operated without sparking at peak fields of 50 MV/m a few m downstream of the ACOL target with 50-ns pulses of 10^{13} protons.
  - Preliminary 70-MHz RF cavity design by AES.
  - Recomissioning of the 8973 tubes almost complete at LBL.
- Simulations:
  - Pion production, neutron dose via MARS, GEANT.
  - Effect of beam energy deposition in target via ANSYS, FRONTIER, HEIGHTS.
  - But little work yet on magnetohydrodynamics, or on materials activation.
- Carbon targets:
  - Considered in Feasibility Study 1.
  - Recent test of a carbon rod at LANL: 10^{13} protons, 800 MeV, $\lesssim 1\ \mu$s pulse.

Construction in the A3 Beamline



Proposed Outer Target Containment Vessel





Target Diagnostics

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


Silicon Mountain Design
EXCELLENCE IN IMAGING
A DALSA Company

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

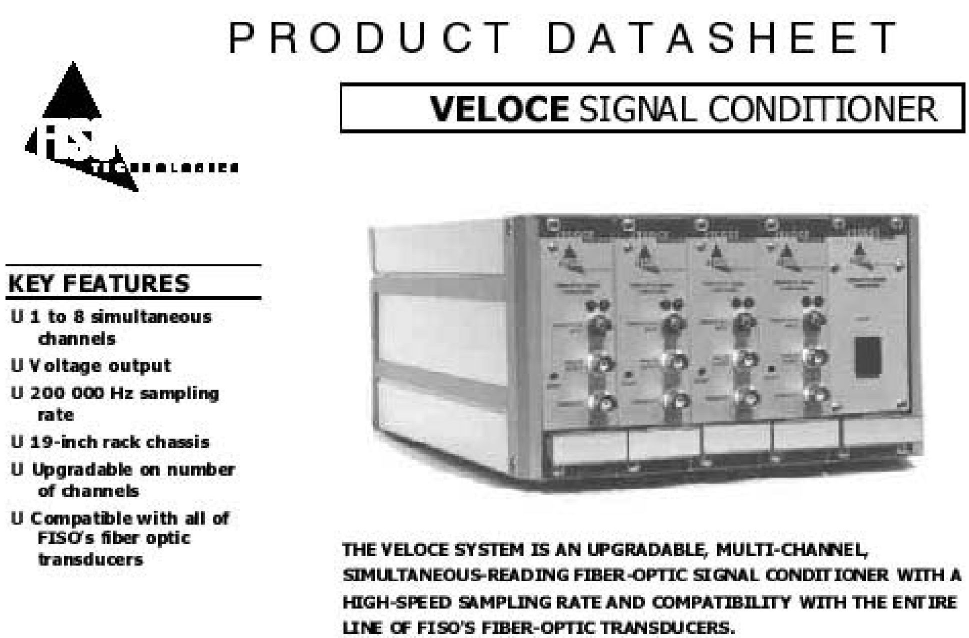
SMD has solved the problem of real-world interface to hyper-speed cameras

Contents: Features | Applications | Description | Specifications

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

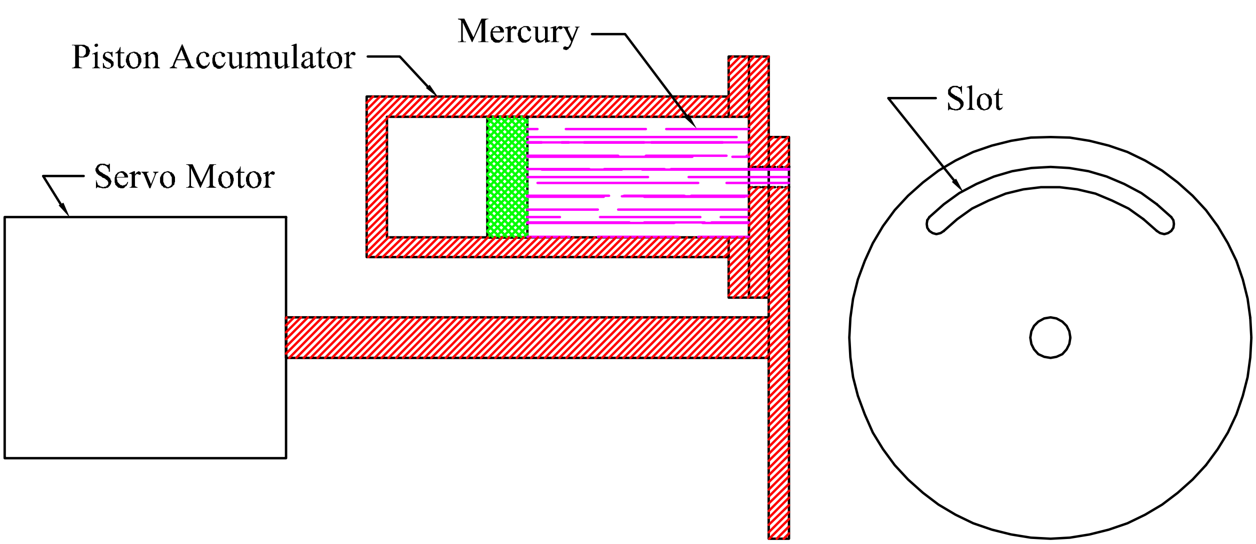
- 1 to 8 simultaneous channels
- Voltage output
- 200 000 Hz sampling rate
- 19-inch rack chassis
- Upgradable on number of channels
- Compatible with all of FISO's fiber optic transducers

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

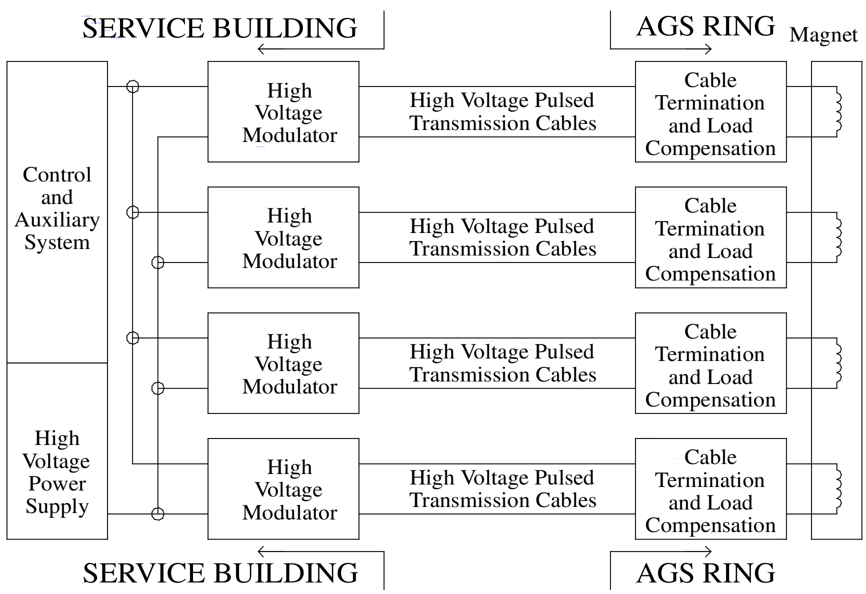
CERN:

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/Jim Fockler beginning a design study.

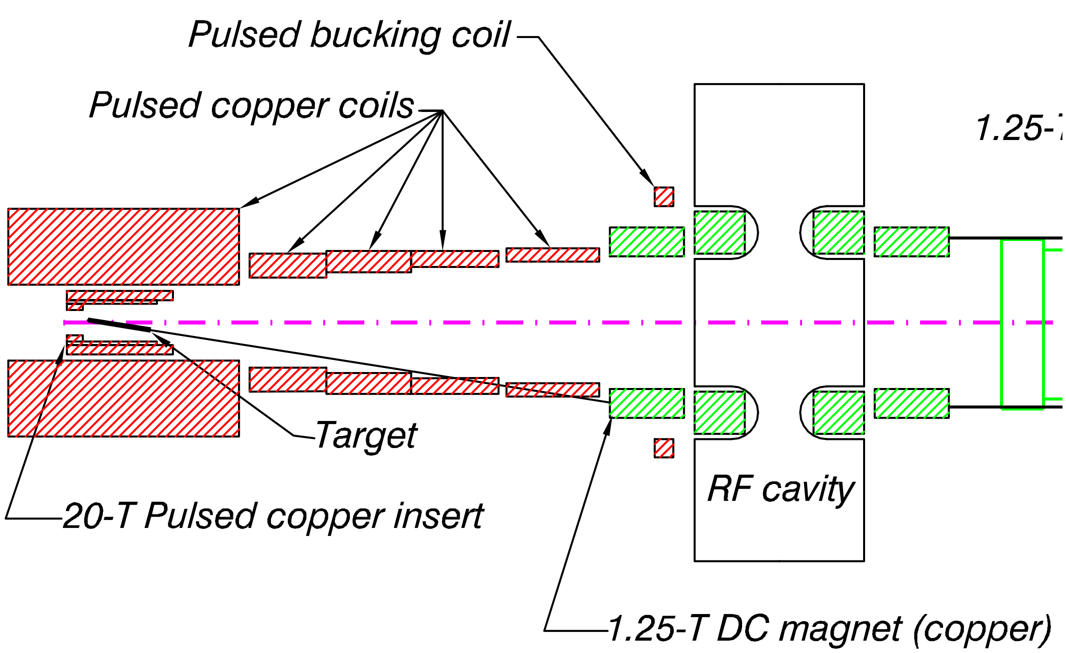


AGS FULL TURN EXTRACTION KICKER SYSTEM

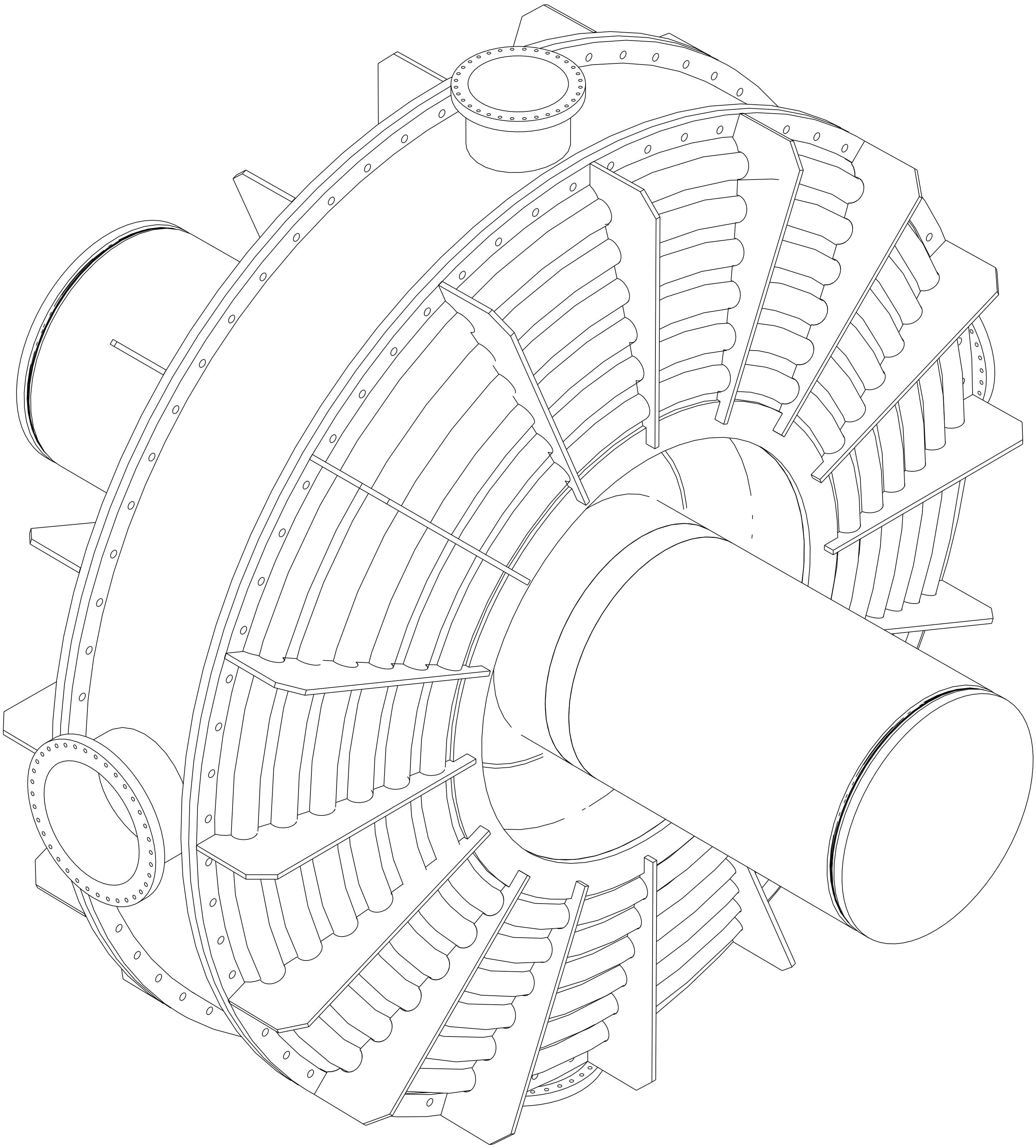
- The LANL Proton Radiography Project also desires the AGS kicker upgrade – and may have a budget for this. However, they want somewhat greater capability than we need, and foresee a longer schedule – completion in FY03.

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 four 1.5-MW 8973 tetrodes. (J. Corlett)



70 MHz Cavity Design by AES

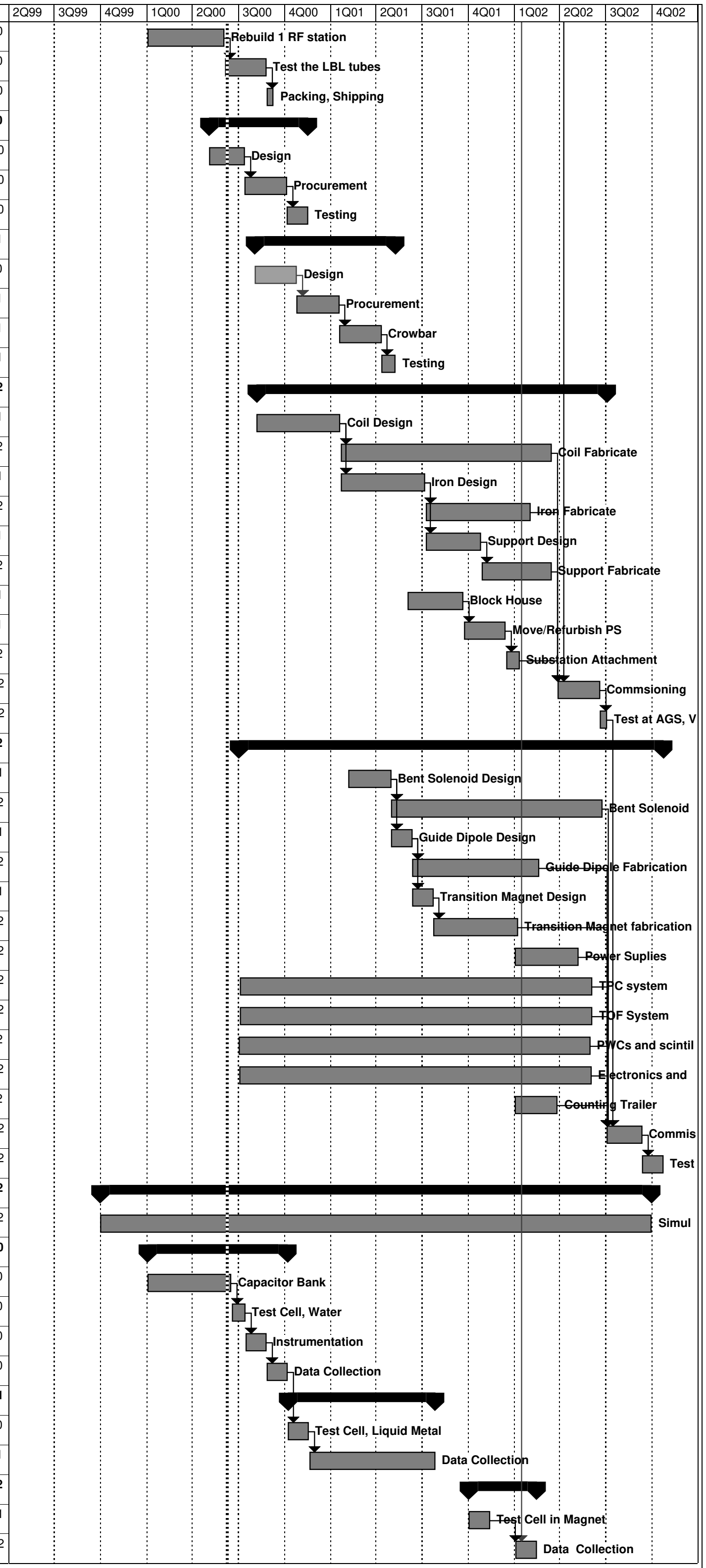


E951 Schedule

- FY99:
  Prepare A3 area at the AGS (Step 1);
  Begin work on liquid jets, magnet and rf systems (Steps 2, 4-6).
- FY00:
  Continue preparation of the 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:
  Complete preparation of the A3 line (Step 1);
  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).

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 Fabricatio	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**
   - Recmmissioning 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**

R&D Priorities in FY01

1. Completion of the A3 line and running of initial beam tests.
2. Liquid jets tests in a 20-T magnet at the NHMFL.
3. Letting a contract for the 20-T pulsed magnet coils.
4. Simulations.
5. Other work the pulsed magnet system.
6. Completion of the commissioning of the 8973 power tubes.
7. Other work on the rf system.
8. Work on the AGS fast extraction kicker.

FY01 Targetry Request: Details

Updated 9/28/00. The requests of 6/1/00 are given in parentheses before the lines of dots.

[Items in brackets are beyond the E951 base program]

1. **Initial Target Studies ($200k) $355k**
   - 1/2 FTE Engineer (BNL) $80k
   - 1/2 Technician (BNL) $75k
   - Target test instrumentation (BNL) ($50k) $100k
   - Target test instrumentation (Princeton) ($50k) $50k
   - [Carbon target studies (ORNL) ($100k) .... $50k]
2. **AGS Operations:**
   3 weeks, A3 + linac costs ($200k) $200k

3. **AGS Beamline Upgrades ($900k) $110k**

- Labor (1,000 hours, BNL) ($100k) $100k
- 6-Bunch kicker design study (Fockler) ($800k) $10k

4. **Magnet Systems ($1200k) $710k**

- Mech. engineer (BNL) $170k
- [1/2 Mech. engineer (NHMFL) ($80k) . . . . $0k]
- 1/4 Mech. engineer (Princeton) $40k
- Design/fabrication of 5 MW magnet power supply (BNL +) ($400k) $0k
- Design/fabrication of pulsed & DC magnet coils (BNL +) ($400k) $500k

5. **RF Systems ($1335k) $185k**

- Complete recomissioning of 8973 rf gear (LBL) $40k
- Shipping of 8973 rf gear to BNL (LBL) ($20k) $15k
- Materials for 8973 power source (BNL) ($100k) $0k
- 1/2 RF engineer (BNL) ($255k) $0k
- 1/2 Mech. engineer (BNL, Wang) ($160k) $80k
- $2 \times 1/2$ Technician (BNL) ($100k) $0k
- Continue design study for 70 MHz rf cavity $50k
- Fabrication of the 70 MHz rf cavity ($400k) $0k
- [RF switch R&D (BNL) ($50k) . . . . $0k]
- [Industrial development of 10-50 MW power sources ($250k) . . . . $0k]

6. **Simulation Studies ($360k) $140k**

- 1/4 FTE (Hassanein, ANL) ($80k) $20k
- 1/2 FTE (Samulyak, BNL) ($80k) $60k
- [1/4 FTE (Todosow, BNL) ($80k) .... $20k]
- [1/2 FTE (ORNL) ($80k) .... $20k]
- 1/4 FTE (Lu, Princeton) ($40k) $20k

7. [Target Station Studies (ORNL) ($100k) .... $0k]

8. **[Neutronics ($150k) .... $0k]**

- [Radiation Damage Studies (MSU) ($50k) .... $0k]
- [Neutron dosimetry studies in A3 (BNL+) ($100k) ... $0k]

9. **Total ($4445k) $1700k**

[Total for items beyond the base program ($810k) ..... $90k]

Summary of FY01 Targetry Budget, Requested

Task	ANL	BNL	LBL	ORNL	Prin.	Indust.†	Total
Initial Target Studies		255		50	50		355
AGS Operations		200					200
AGS Beamline Upgrades		100				10	110
Magnet Systems		170			40	500	710
RF Systems		80	55			50	185
Simulation Studies	20	80		20	20		140
Total	20	885	55	70	110	560	**$1700k**

† Industry contracts to be let by BNL.