An R&D Program for Targetry and Capture at a Muon Collider Source

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

An R&D Program for Targetry and Capture at a Muon Collider Source

A Proposal to the BNL AGS Division

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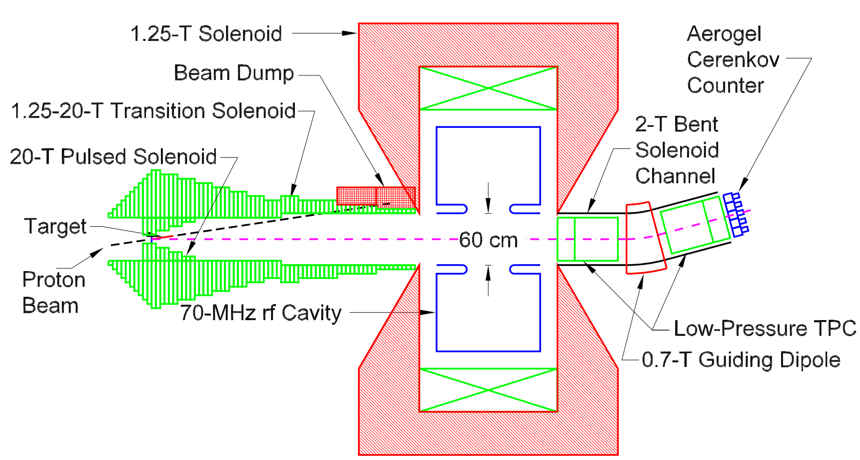

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Targetry Challenges

To achieve useful physics luminosity, a muon collider must produce about 10^{14} μ/sec.

- $> 10^{15}$ proton/sec onto a high-Z target $\Leftrightarrow$ 4 MW beam power.
- Capture pions of $P_\perp \lesssim 200$ MeV/c in a 20-T solenoid magnet.
- Transfer the pions into a 1.25-T-solenoid decay channel.
- Compress π/μ bunch energy with rf cavities and deliver to muon cooling channel.

Issues:

- 400 kW deposited in target.

  $\Rightarrow$ Move target material away from beam and cool remotely.

  A **free liquid metal jet** is presently the preferred option.
- First rf cavity should be ≈ 3 m from target.

Will it work? Need a **Targetry R&D Program**.

R&D Goals

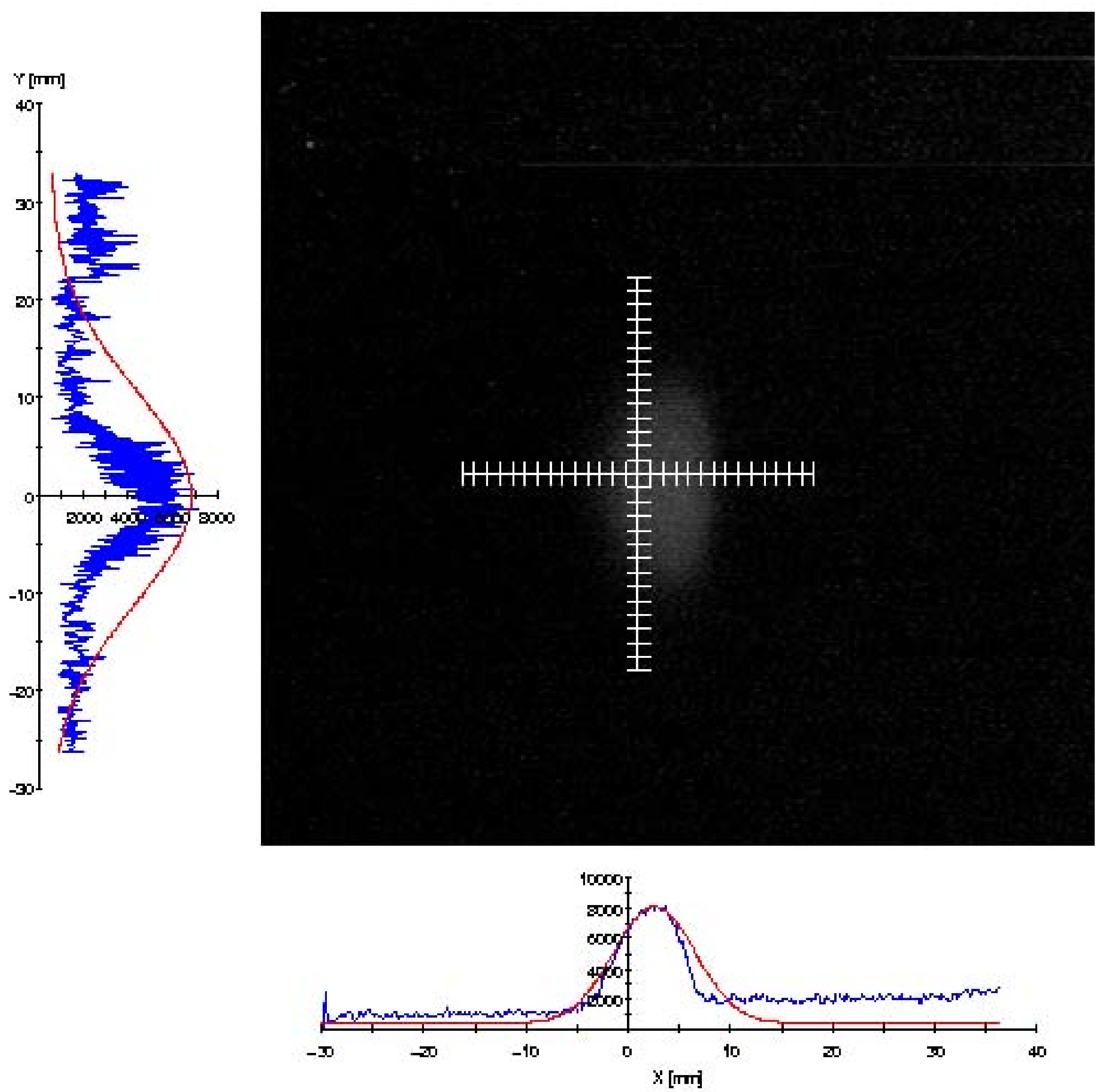
Long Term: Provide a facility to test key components of the front-end of a muon collider in realistic beam conditions.

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

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

Immediate Goal: Upgrade FEB U-Line for Smaller Spot Size and Greater Intensity

-- uf730 Wed Nov 18 06:42:53 1998 --
Framegrabber = seb-fg1
Signal Range = 0 157
Centroid = 7.07032 3.39971 mm
Center = 2.58813 -0.144885 mm
Sigma = 4.01048 10.8851 mm
!!Failed 2D Gauss Fit!!
Intensity = 1152191
Attenuation = 0%



Targetry R&D Budget

FY 99

Task	1st Q	2nd Q	3rd Q	4th Q
Initial Jet Studies				
Beam Test at AGS	80			
3 mm Jet Test	25	25		
Jet Test in 20 T		60		
2cm Jet Test		20	70	
AGS Extraction Upgrade				
Materials	180	330		
Design	30	70		
Assembly			40	55
Pulsed Solenoid Design		25	25	25
RF Systems				
RF Cavity Design				30
70 MHz LBL $\rightarrow$ BNL				50
Simulation Studies	40	40	40	40
Total	355	570	175	200

Total for FY 99: \$ 1300 K

Appendices:

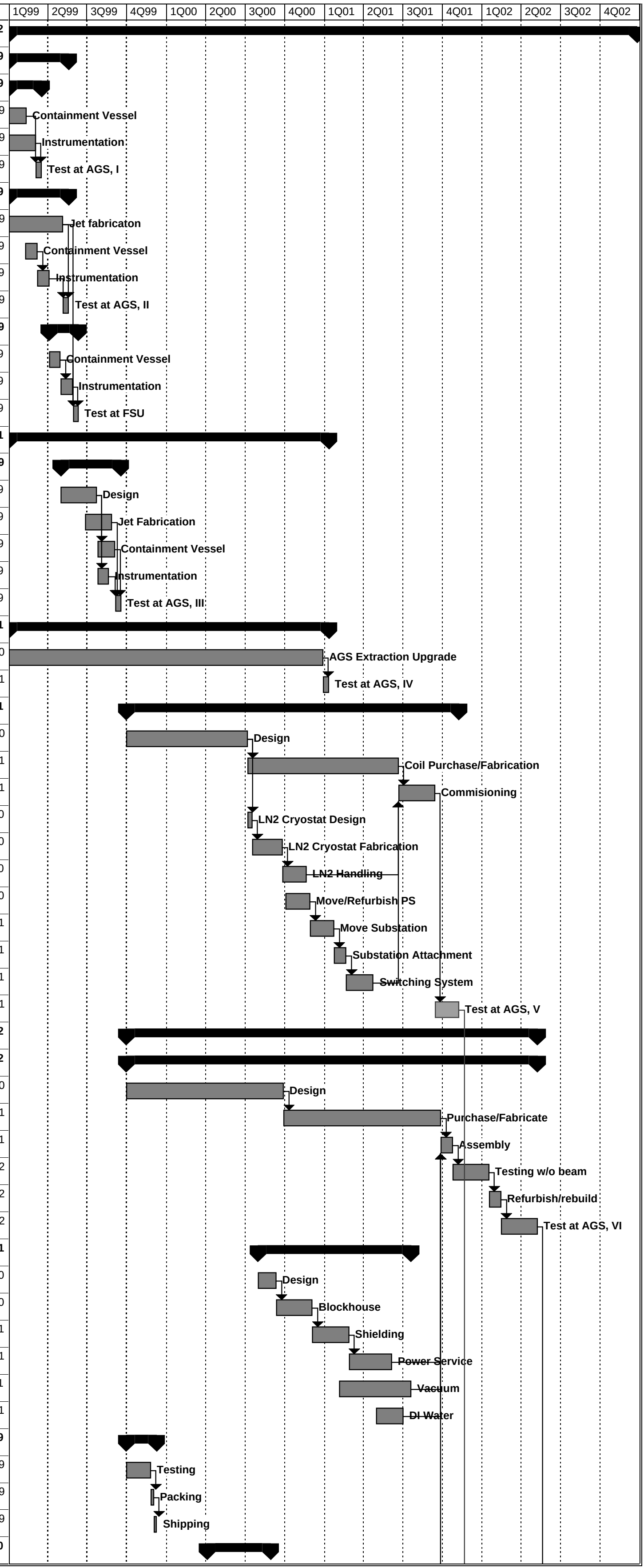
The 8 Steps in the R&D Program

1. Simple tests of liquid (Ga-Sn) targets in the AGS FEB U-line.
2. Test of liquid jet entering a 20-T magnet (20-MW cw Bitter magnet at the National High Field Magnet Laboratory).
3. Test of liquid jet in the FEB U-line (without magnet).
4. Add 20-T pulsed magnet (4-MW peak) to the FEB U-line.
5. Add 70-MHz rf cavity downstream of target in FEB U-line.
6. Surround rf cavity with 1.25-T magnet.
7. Characterize pion yield from target + magnet system in FEB U-line.
8. Ongoing simulation of the thermal hydraulics of the liquid-metal target system.

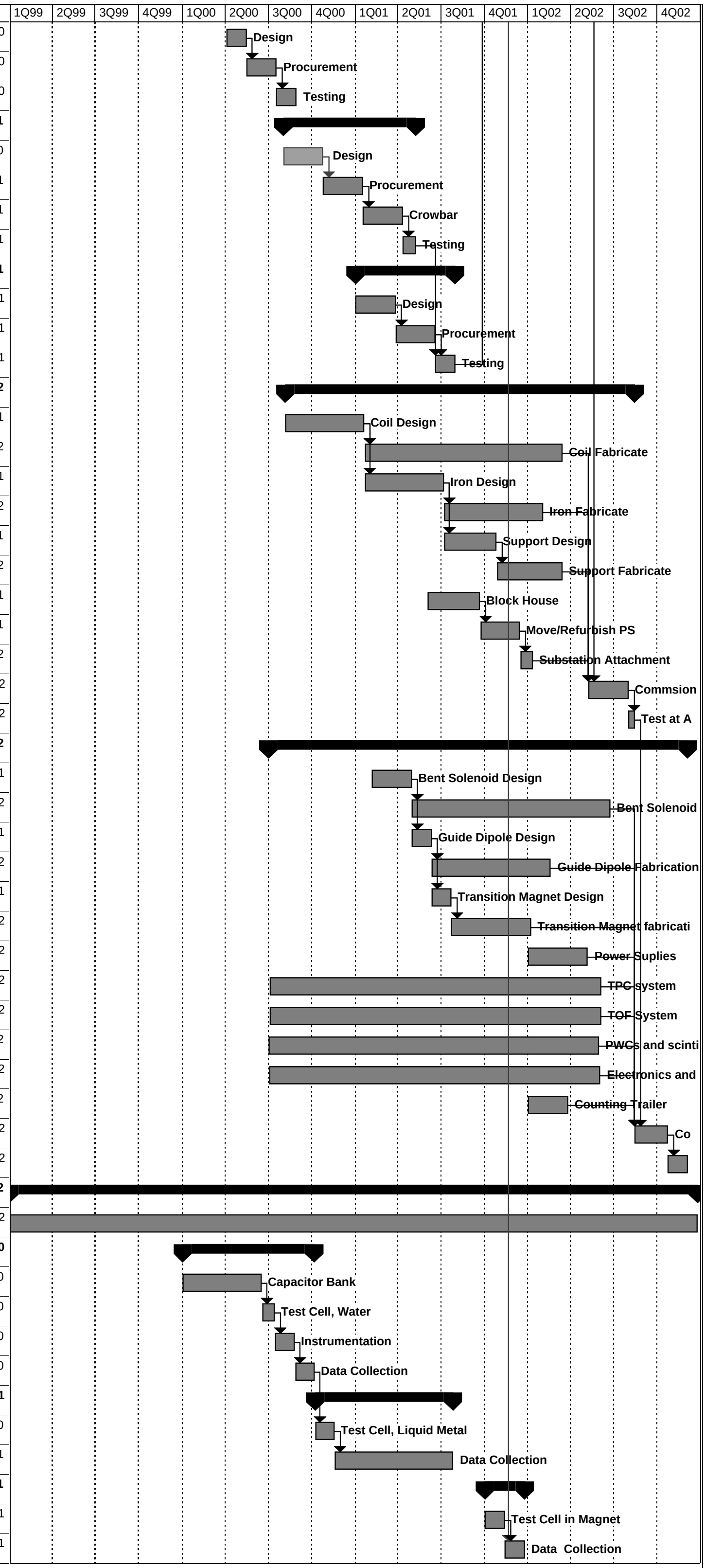
Institutional Involvement

Topic	Institutions
1. Initial Tests	BNL, CERN, ORNL, **Princeton**
2. Liquid jet + 20-T magnet	BNL, **Princeton**, NHMFL
3. Full-scale jet, 10^{14} *ppp*	ANL, **BNL**, CERN, Princeton
4. Full-scale jet + pulsed 20-T magnet	ANL, **BNL**, CERN, Princeton
5. RF cavity + short beam pulse	**BNL**, CERN, Fermilab, LBL, Princeton
6. RF cavity + 1.25-T magnet	**BNL**, LBL, Princeton
7. Pion-production measurement	**BNL**, Fermilab, LBL, Princeton
8. Simulation + exploding wire tests	**ANL**, BNL, Fermilab, ORNL, Princeton

ID	Task Name	Duration	Cost	Start	Finish
1	**Targetry R&D**	**1040 days**	**$7,110,000**	**Fri 1/1/99**	**Thu 12/26/02**
2	**Liquid Metal I**	**100 days**	**$130,000**	**Fri 1/1/99**	**Thu 5/20/99**
3	**Initial Beam Test**	**55 days**	**$80,000**	**Fri 1/1/99**	**Thu 3/18/99**
4	Containment Vessel	30 days	$30,000	Fri 1/1/99	Thu 2/11/99
5	Instrumentation	45 days	$40,000	Fri 1/1/99	Thu 3/4/99
6	Test at AGS, I	10 days	$10,000	Fri 3/5/99	Thu 3/18/99
7	**3 mm Jet Test**	**100 days**	**$50,000**	**Fri 1/1/99**	**Thu 5/20/99**
8	Jet fabricaton	90 days	$20,000	Fri 1/1/99	Thu 5/6/99
9	Containment Vessel	20 days	$10,000	Tue 2/9/99	Mon 3/8/99
10	Instrumentation	20 days	$10,000	Tue 3/9/99	Mon 4/5/99
11	Test at AGS, II	10 days	$10,000	Fri 5/7/99	Thu 5/20/99
12	**Jet Test at FSU Magnet**	**50 days**	**$60,000**	**Mon 4/5/99**	**Fri 6/11/99**
13	Containment Vessel	20 days	$20,000	Mon 4/5/99	Fri 4/30/99
14	Instrumentation	20 days	$20,000	Mon 5/3/99	Fri 5/28/99
15	Test at FSU	10 days	$20,000	Mon 5/31/99	Fri 6/11/99
16	**2 cm Jet, 1e14 p's**	**530 days**	**$600,000**	**Fri 1/1/99**	**Thu 1/11/01**
17	**2 cm Jet**	**100 days**	**$90,000**	**Mon 5/3/99**	**Fri 9/17/99**
18	Design	60 days	$20,000	Mon 5/3/99	Fri 7/23/99
19	Jet Fabrication	45 days	$20,000	Mon 6/28/99	Fri 8/27/99
20	Containment Vessel	30 days	$20,000	Mon 7/26/99	Fri 9/3/99
21	Instrumentation	20 days	$20,000	Mon 7/26/99	Fri 8/20/99
22	Test at AGS, III	10 days	$10,000	Mon 9/6/99	Fri 9/17/99
23	**1e14 ppp**	**530 days**	**$510,000**	**Fri 1/1/99**	**Thu 1/11/01**
24	AGS Extraction Upgr	520 days	$500,000	Fri 1/1/99	Thu 12/28/00
25	Test at AGS, IV	10 days	$10,000	Fri 12/29/00	Thu 1/11/01
26	**Pulsed Solenoid**	**550 days**	**$1,020,000**	**Fri 10/1/99**	**Thu 11/8/01**
27	Design	200 days	$100,000	Fri 10/1/99	Thu 7/6/00
28	Coil Purchase/Fabrication	250 days	$500,000	Fri 7/7/00	Thu 6/21/01
29	Commisioning	60 days	$100,000	Fri 6/22/01	Thu 9/13/01
30	LN2 Cryostat Design	7 days	$50,000	Fri 7/7/00	Mon 7/17/00
31	LN2 Cryostat Fabrication	50 days	$100,000	Tue 7/18/00	Mon 9/25/00
32	LN2 Handling	40 days	$20,000	Tue 9/26/00	Mon 11/20/00
33	Move/Refurbish PS	40 days	$40,000	Wed 10/4/00	Tue 11/28/00
34	Move Substation	40 days	$40,000	Wed 11/29/00	Tue 1/23/01
35	Substation Attachment	20 days	$20,000	Wed 1/24/01	Tue 2/20/01
36	Switching System	45 days	$30,000	Wed 2/21/01	Tue 4/24/01
37	Test at AGS, V	40 days	$20,000	Fri 9/14/01	Thu 11/8/01
38	**RF Systems**	**680 days**	**$1,650,000**	**Fri 10/1/99**	**Thu 5/9/02**
39	**RF Cavity**	**680 days**	**$950,000**	**Fri 10/1/99**	**Thu 5/9/02**
40	Design	260 days	$120,000	Fri 10/1/99	Thu 9/28/00
41	Purchase/Fabricate	260 days	$600,000	Fri 9/29/00	Thu 9/27/01
42	Assembly	20 days	$20,000	Fri 9/28/01	Thu 10/25/01
43	Testing w/o beam	60 days	$30,000	Fri 10/26/01	Thu 1/17/02
44	Refurbish/rebuild	20 days	$150,000	Fri 1/18/02	Thu 2/14/02
45	Test at AGS, VI	60 days	$30,000	Fri 2/15/02	Thu 5/9/02
46	**Site Preparation**	**254 days**	**$300,000**	**Tue 8/1/00**	**Fri 7/20/01**
47	Design	30 days	$30,000	Tue 8/1/00	Mon 9/11/00
48	Blockhouse	60 days	$150,000	Tue 9/12/00	Mon 12/4/00
49	Shielding	60 days	$30,000	Tue 12/5/00	Mon 2/26/01
50	Power Service	70 days	$20,000	Wed 2/28/01	Tue 6/5/01
51	Vacuum	120 days	$50,000	Mon 2/5/01	Fri 7/20/01
52	DI Water	45 days	$20,000	Tue 5/1/01	Mon 7/2/01
53	**LBL Transfer**	**50 days**	**$50,000**	**Fri 10/1/99**	**Thu 12/9/99**
54	Testing	40 days	$40,000	Fri 10/1/99	Thu 11/25/99
55	Packing	5 days	$5,000	Fri 11/26/99	Thu 12/2/99
56	Shipping	5 days	$5,000	Fri 12/3/99	Thu 12/9/99
57	**Low Level RF**	**105 days**	**$40,000**	**Wed 4/5/00**	**Tue 8/29/00**



ID	Task Name	Duration	Cost	Start	Finish
58	Design	30 days	$10,000	Wed 4/5/00	Tue 5/16/00
59	Procurement	45 days	$20,000	Wed 5/17/00	Tue 7/18/00
60	Testing	30 days	$10,000	Wed 7/19/00	Tue 8/29/00
61	**Pulsing System**	**200 days**	**$110,000**	**Thu 8/3/00**	**Wed 5/9/01**
62	Design	60 days	$30,000	Thu 8/3/00	Wed 10/25/00
63	Procurement	60 days	$30,000	Thu 10/26/00	Wed 1/17/01
64	Crowbar	60 days	$30,000	Thu 1/18/01	Wed 4/11/01
65	Testing	20 days	$20,000	Thu 4/12/01	Wed 5/9/01
66	**Power Combiner**	**150 days**	**$200,000**	**Wed 1/3/01**	**Tue 7/31/01**
67	Design	60 days	$80,000	Wed 1/3/01	Tue 3/27/01
68	Procurement	60 days	$100,000	Wed 3/28/01	Tue 6/19/01
69	Testing	30 days	$20,000	Wed 6/20/01	Tue 7/31/01
70	**RF Solenoid**	**529 days**	**$1,110,000**	**Mon 8/7/00**	**Thu 8/15/02**
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 5/10/02	Thu 8/1/02
81	Test at AGS, VII	10 days	$10,000	Fri 8/2/02	Thu 8/15/02
82	**Capture Experiment**	**634 days**	**$1,770,000**	**Mon 7/3/00**	**Thu 12/5/02**
83	Bent Solenoid Design	60 days	$30,000	Tue 2/6/01	Mon 4/30/01
84	Bent Solenoid Fabrication	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 Fabrication	180 days	$150,000	Tue 6/12/01	Mon 2/18/02
87	Transition Magnet Design	30 days	$20,000	Tue 6/12/01	Mon 7/23/01
88	Transition Magnet fabricat	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 DAQData	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 8/16/02	Thu 10/24/02
96	Test at AGS, VIII	30 days	$30,000	Fri 10/25/02	Thu 12/5/02
97	**Simulation & Validation**	**1040 days**	**$770,000**	**Fri 1/1/99**	**Thu 12/26/02**
98	Simulation	1040 days	$600,000	Fri 1/1/99	Thu 12/26/02
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 Meta	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**	**60 days**	**$20,000**	**Wed 10/3/01**	**Tue 12/25/01**
108	Test Cell in Magnet	30 days	$10,000	Wed 10/3/01	Tue 11/13/01
109	Data Collection	30 days	$10,000	Wed 11/14/01	Tue 12/25/01



	1999	2000	2001	2002	Total
Targetry R&D					
Liquid Metal I					
Initial Beam Test					
Containment Vessel	$30,000				$30,000
Instrumentation	$40,000				$40,000
Test at AGS, I	$10,000				$10,000
3 mm Jet Test					
Jet fabricaton	$20,000				$20,000
Containment Vessel	$10,000				$10,000
Instrumentation	$10,000				$10,000
Test at AGS, II	$10,000				$10,000
Jet Test at FSU Magnet					
Containment Vessel	$20,000				$20,000
Instrumentation	$20,000				$20,000
Test at FSU	$20,000				$20,000
2 cm Jet, 1e14 p's					
2 cm Jet					
Design	$20,000				$20,000
Jet Fabrication	$20,000				$20,000
Containment Vessel	$20,000				$20,000
Instrumentation	$20,000				$20,000
Test at AGS, III	$10,000				$10,000
1e14 ppp					
AGS Extraction Upgrade	$250,962	$249,039			$500,000
Test at AGS, IV		$1,000	$9,000		$10,000
Pulsed Solenoid					
Design	$33,000	$67,000			$100,000
Coil Purchase/Fabrication		$252,000	$248,000		$500,000
Commisioning			$100,000		$100,000
LN2 Cryostat Design		$50,000			$50,000
LN2 Cryostat Fabrication		$100,000			$100,000
LN2 Handling		$20,000			$20,000
Move/Refurbish PS		$40,000			$40,000
Move Substation		$23,000	$17,000		$40,000
Substation Attachment			$20,000		$20,000
Switching System			$30,000		$30,000
Test at AGS, V			$20,000		$20,000
RF Systems					
RF Cavity					
Design	$30,462	$89,539			$120,000
Purchase/Fabricate		$152,308	$447,692		$600,000
Assembly			$20,000		$20,000
Testing w/o beam			$23,500	$6,500	$30,000
Refurbish/rebuild				$150,000	$150,000
Test at AGS, VI				$30,000	$30,000
Site Preparation					
Design		$30,000			$30,000
Blockhouse		$150,000			$150,000
Shielding		$9,500	$20,500		$30,000
Power Service			$20,000		$20,000
Vacuum			$50,000		$50,000
DI Water			$20,000		$20,000
LBL Transfer					
Testing	$40,000				$40,000
Packing	$5,000				$5,000
Shipping	$5,000				$5,000
Low Level RF					
Design		$10,000			$10,000
Procurement		$20,000			$20,000
Testing		$10,000			$10,000
Pulsing System					
Design		$30,000			$30,000
Procurement		$77,125	($47,125)		$30,000
Crowbar			$30,000		$30,000
Testing			$20,000		$20,000
Power Combiner					
Design			$80,000		$80,000
Procurement			$100,000		$100,000
Testing			$20,000		$20,000
RF Solenoid					
Coil Design		$52,500	$7,500		$60,000
Coil Fabricate			$410,000	$90,000	$500,000
Iron Design			$60,000		$60,000
Iron Fabricate			$168,000	$32,000	$200,000
Support Design			$40,000		$40,000
Support Fabricate			$23,000	$27,000	$50,000
Block House			$20,000		$20,000
Move/Refurbish PS			$30,000		$30,000
Substation Attachment			$11,000	$9,000	$20,000
Commsioning				$120,000	$120,000
Test at AGS, VII				$10,000	$10,000
Capture Experiment					
Bent Solenoid Design			$30,000		$30,000
Bent Solenoid Fabrication			$291,667	$208,333	$500,000
Guide Dipole Design			$20,000		$20,000
Guide Dipole Fabrication			$120,833	$29,167	$150,000
Transition Magnet Design			$20,000		$20,000
Transition Magnet fabrication			$95,833	$4,167	$100,000
Power Suplies				$100,000	$100,000
TPC system		$61,440	$125,280	$53,280	$240,000
TOF System		$30,720	$62,640	$26,640	$120,000
PWCs and scintillators		$39,000	$78,300	$32,700	$150,000
Electronics and DAQData acquisition		$200,000			$200,000
Counting Trailer				$60,000	$60,000
Commisioning				$50,000	$50,000
Test at AGS, VIII				$30,000	$30,000
Simulation & Validation					
Simulation	$150,577	$150,000	$150,577	$148,846	$600,000
Exploding Wire I					
Capacitor Bank		$60,000			$60,000
Test Cell, Water		$10,000			$10,000
Instrumentation		$30,000			$30,000
Data Collection		$10,000			$10,000
Exploding Wire II					
Test Cell, Liquid Metal		$10,000			$10,000
Data Collection		$5,000	$25,000		$30,000
Exploding Wire III					
Test Cell in Magnet			$10,000		$10,000
Data Collection			$10,000		$10,000
Total	$795,000	$2,039,170	$3,058,198	$1,217,633	$7,110,000