EDM Collaboration Meeting

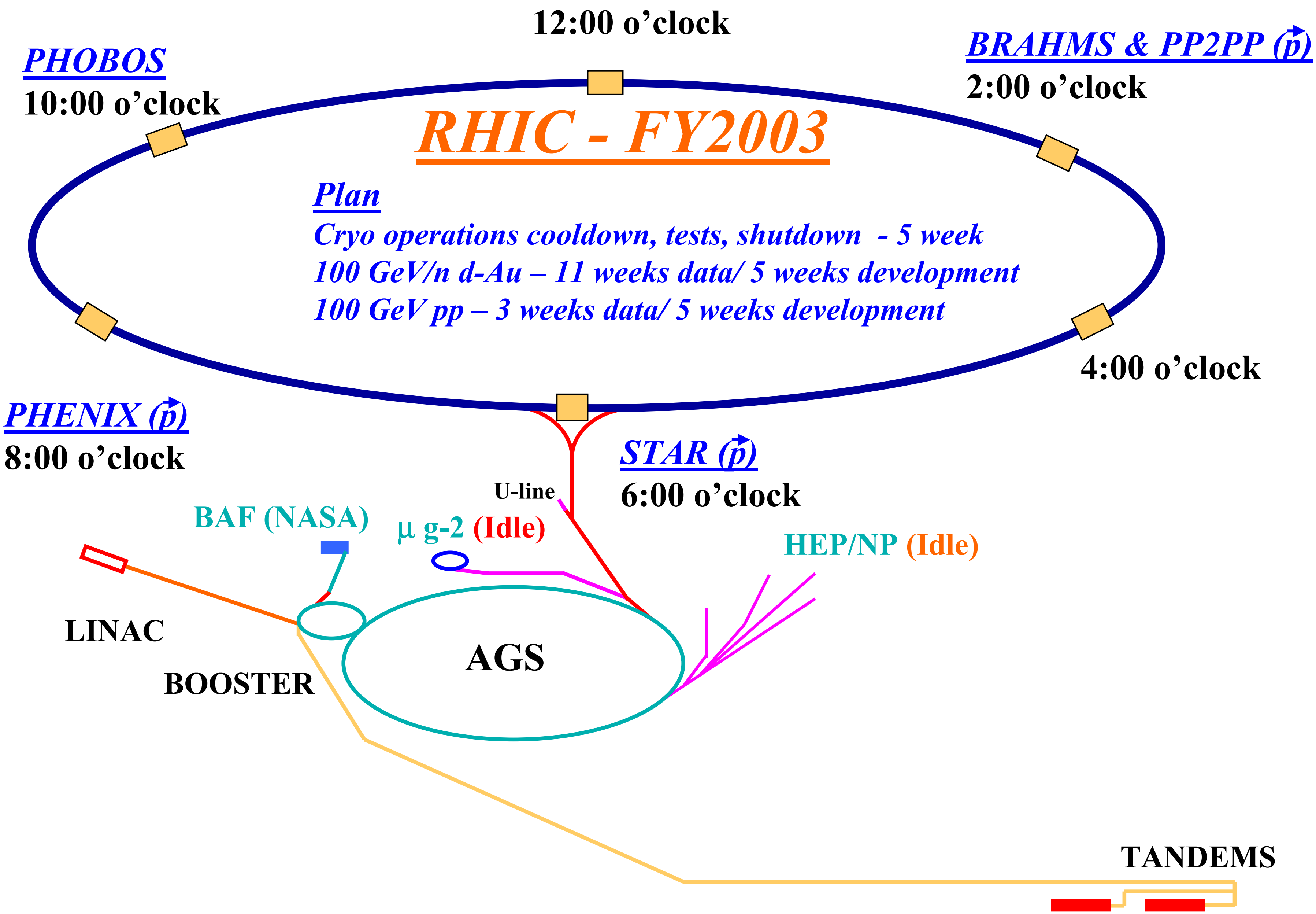
19 November 2002

Current AGS Proton Intensity and Future Plans

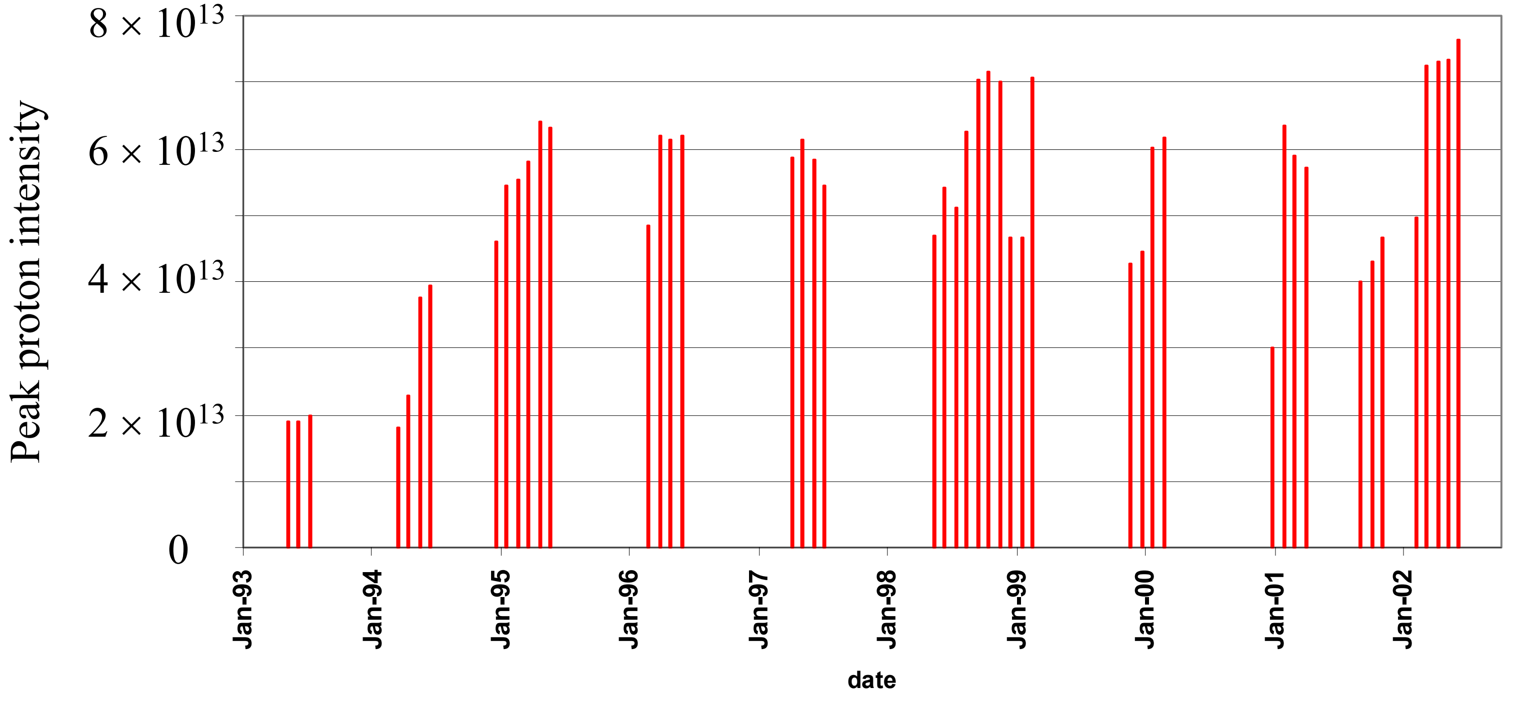
Presented by

Phil Pile

C-AD Experimental Support and Facilities Division

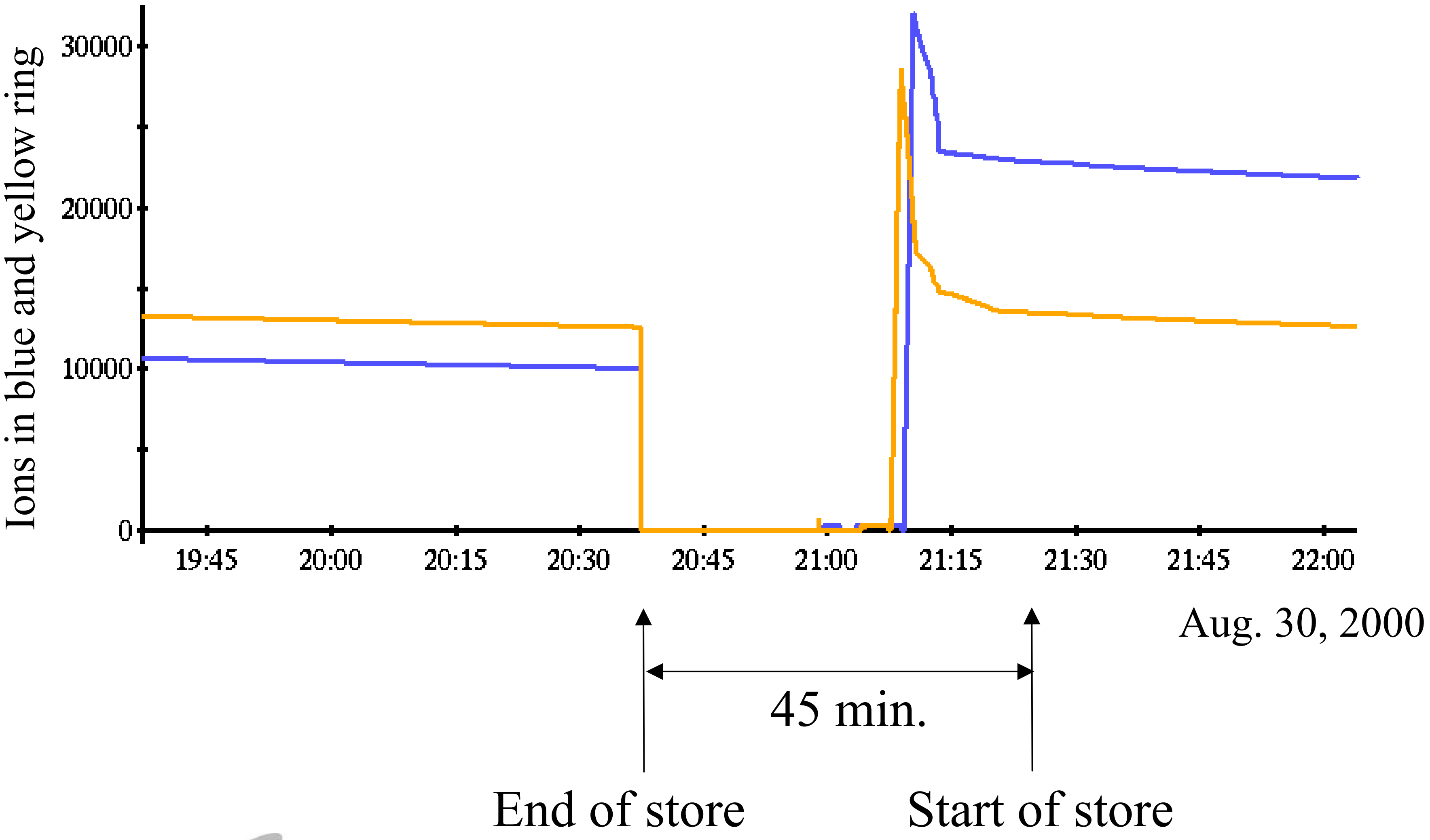

12:00 o'clock
PHOBOS
10:00 o'clock
BRAHMS & PP2PP (p⃗)
2:00 o'clock
RHIC - FY2003
Plan
Cryo operations cooldown, tests, shutdown - 5 week
100 GeV/n d-Au – 11 weeks data/ 5 weeks development
100 GeV pp – 3 weeks data/ 5 weeks development
4:00 o'clock
PHENIX (p⃗)
8:00 o'clock
STAR (p⃗)
6:00 o'clock
U-line
BAF (NASA)
μ g-2 (Idle)
HEP/NP (Idle)
LINAC
BOOSTER
AGS
TANDEMS

AGS Peak Proton Intensities



World record proton synchrotron intensity!

Refill of RHIC



AGS Intensity Upgrade Plans (1/2)

1) <u>100 TP Upgrade</u> for K0PI0, RSVP Experiment, $K^0 \rightarrow \pi^0 \nu \bar{\nu}$

- Funding ($4.5M C$) is through a Canadian Foundation for Innovation (CFI) Grant (contingent upon NSF RSVP MRE funding – reasonable probability)

- The Plan – Upgrade Booster extraction/AGS injection from 1.9 GeV with large mismatch, to 2.0 GeV without mismatch (improve space charge limit and transfer efficiency)
  - Modify Booster F3 extraction Pulse Forming Network (PFN) to allow efficient operation at 2 GeV.
  - New AGS A5 Injection Kicker and PFN to allow efficient 2 GeV injection into AGS
  - 100TP/spill – duty factor ~2.2sec/spill (0.8sec Booster injection + 1.2sec ramp up/down + 0.2 sec flat top)
  - Beam Power @ 28 GeV ~ 28GeV*100TP*1.6x10^{-19}/2.2s = 0.2 MW
  - 1.6 x 10^{17} protons/hour

AGS Intensity Upgrade Plans (2/2)

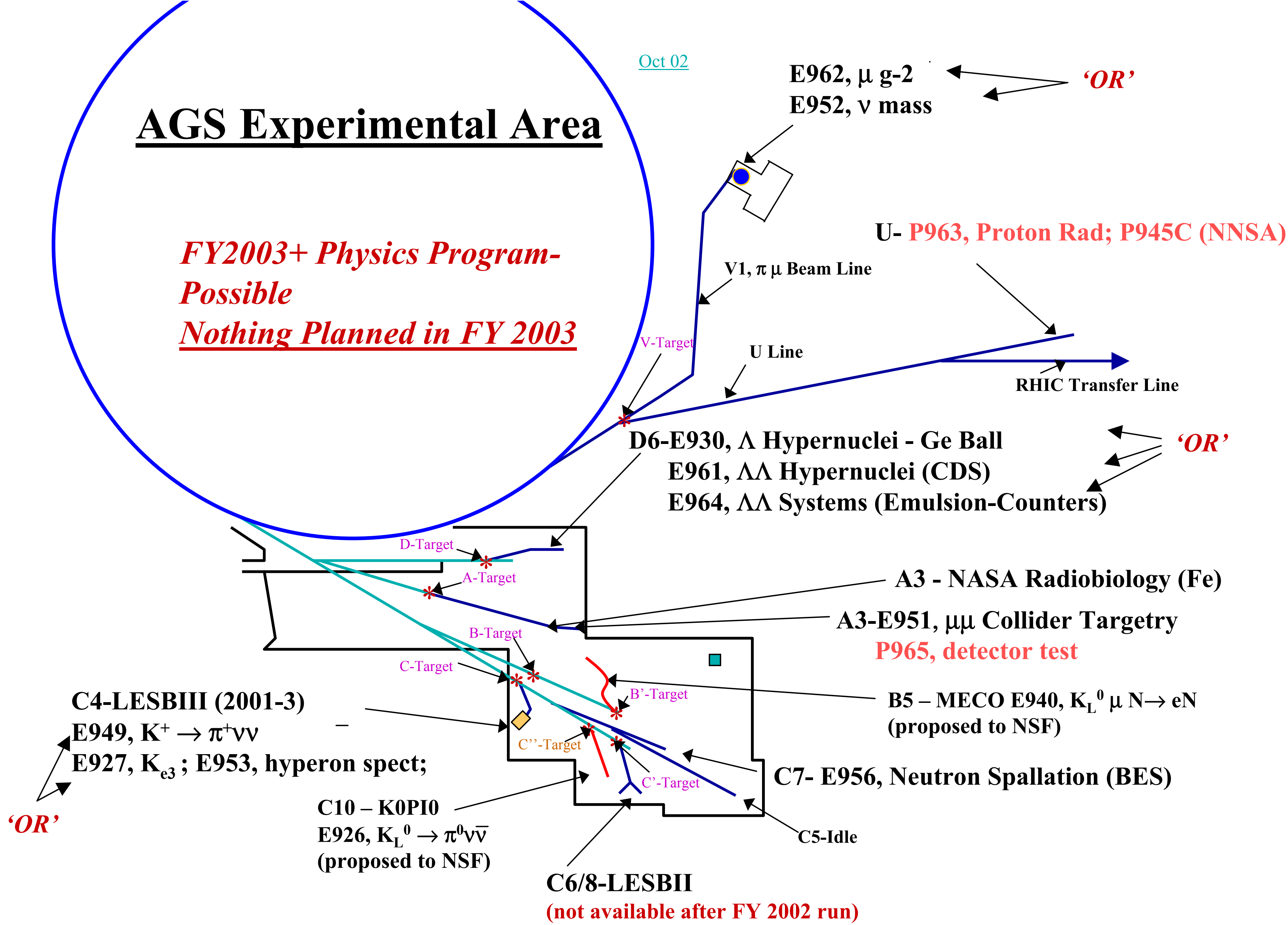
2) <u>0.17 – 1 MW AGS – Diwan LOI "Neutrino Physics with Detectors at Baselines of 100-1000km from BNL"</u>

- Addition of 1 GeV superconducting LINAC to end of present 200 MeV LINAC
  - Bypass Booster and inject 1.2 GeV protons directly into AGS – Eliminates 6 Booster Cycles AGS fill time (~0.8 sec)
  - Power = 28GeV*100TP*1.6E-19/1.4s = .32 MW
  - 2.6 x 10^{17} protons/hour
  - Cost (direct w/o contingency and EDIA) = $90M

- Add new power supplies to AGS ring to allow rapid AGS cycling (2.5 Hz) and upgrade RF system for rapid acceleration.
  - 100TP @ 0.4 sec/spill = 1 MW beam
  - 9 x 10^{17} protons/hour
  - Cost (direct w/o contingency and EDIA) = $50M

- Path to 4 MW
  - 1.5 GeV LINAC
  - 5 Hz AGS

			RHIC Beam/Mode		
			AGS Beam Mode		S
			Charged	Approved	Sep
Beam	Exp #	Experiment Spokespersons	Hours	Hours	3 9 17 24
		or Activity			
Unscheduled AGS Experiments					
A3	951	McDonald	165	3600	
B5	940	Molzon	4	4000	
C2	953	Manley/Spinka/Nefkens	0	450	
C2	927	Nefkens/Comfort	233	2280	
C3	926	Bryman/Littenberg/Zeller	272	8000	
C4	949	Bryman/Kettell/Sugimoto	2402	6000	
C7	956	Bauer/Haines/Shapiro/Watanabe	90	-	
D6	930	Tamura	1002	1428	
D6	961	Fukuda/Rusek/Chrien	0	1200	
D6	964	Imai/Nakazawa/Tamura	0	1400	
V1	952	Cushman	56		
V1	962	Hughes/Roberts/Morris	0	2000	
Proposed AGS Experiments					
A3	965	McDonald	0	100	
U	945C	Greene	0		
U	963	Morris	0		
LOI AGS Experiments					
D6	MRS	May			
V1	EDM	Miller/Semertzidis			
NEW	ν's	Diwan			


Oct 02
AGS Experimental Area
FY2003+ Physics Program-
Possible
Nothing Planned in FY 2003
E962, μ g-2
E952, ν mass
'OR'
U- P963, Proton Rad; P945C (NNSA)
V1, π μ Beam Line
V-Target
U Line
RHIC Transfer Line
D6-E930, Λ Hypernuclei - Ge Ball
E961, ΛΛ Hypernuclei (CDS)
E964, ΛΛ Systems (Emulsion-Counters)
'OR'
D-Target
A-Target
A3 - NASA Radiobiology (Fe)
A3-E951, μμ Collider Targetry
P965, detector test
B-Target
C-Target
B'-Target
B5 – MECO E940, K_L^0 μ N→ eN
(proposed to NSF)
C4-LESBIII (2001-3)
E949, $K^+ \to \pi^+ \nu\nu$
E927, K_{e3} ; E953, hyperon spect;
'OR'
C''-Target
C'-Target
C7- E956, Neutron Spallation (BES)
C10 – K0PI0
E926, $K_L^0 \to \pi^0 \nu\bar{\nu}$
(proposed to NSF)
C5-Idle
C6/8-LESBII
(not available after FY 2002 run)

http://server.c-ad.bnl.gov/estd

11/15/02

C-A Accelerator Operations Plan - FY 2002-2010

- Running
- If approved/funded
- Construction/upgrades
- Commissioning/tests

Program Element	Experiment	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12
RHIC Operation												
♦ **RIC Cryo Plant Operations**												
♦ **BRAHMS** [Videbeak]	**Ions & pp**											
♦ **PHENIX** [Zajc]	**Ions & pp**											
♦ **PHOBOS** [Busza]	**Ions & pp**											
♦ **PP2PP** [Guryn]	**pp**											
♦ **STAR** [Hallman]	**Ions & pp**											
AGS SEB Operations												
♦ **E949** [Bryman,Kettell,Sugimoto	$K^+ \rightarrow \pi^+\nu\bar{\nu}$											
♦ **E952** [Cushman]	ν_μ **Mass**											
♦ # **E926** [Bryman,Littenberg,Zeller]**-K0PI0**	$K^0 \rightarrow \pi^0\nu\bar{\nu}$		R&D									
♦ # **E940** [Molzon]-**MECO**	$\mu^- N \rightarrow e^- N$		R&D									
♦ **Test Runs** [R&D for E926/E940]												
♦ **E931**[Hungerford,Quinn,Denhard]	**ΔI=1/2 Rule**											
♦ **E927**[Nefkens,Comfort]	**Ke3 decay**											
♦ **E953**[Nefkens]	**Hyperon spectroscopy**											
♦ **E913/958**[Sadler]	**Baryon spectroscopy**											
♦ **E930**[Tamura]	**Λ Hypernuclei**											
♦ **E961**[Fukuda,Rusek,Chrien]	**ΛΛ Hypernuclei**											
♦ **E964**[Nakazawa,Imai,Tamura]	**S=-2, Emulsion**											
♦ **P965**[McDonald]	**ν Detector Test**											
AGS FEB Operations												
♦ **E962 [Hughes,Roberts,Morse]**	**μ g-2**											
♦ **E951[McDonald]**	**μμ collider**											
♦ **E955/P963[Hartouni,Morris]**	**Radiography**											
♦ **P945C[Greene]**	**Energy deposition**											
Radiobiology												
♦ **AGS**												
♦ **BAF**												

NSF Initiave (RSVP)

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Backup Material

Presented by

Phil Pile

BTA Upgrade to 2 GeV

Upgrade BTA + AGS injection from
1.9 GeV with large mismatch to
2.0 GeV without mismatch

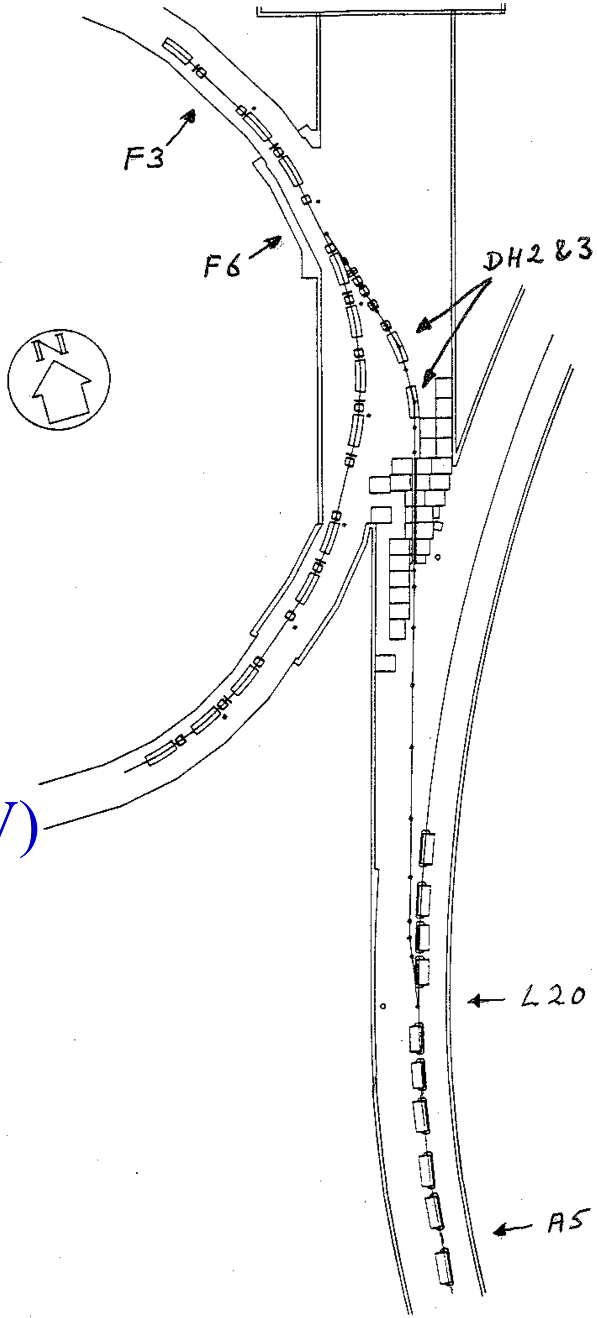
→ improved space charge limit and no halo formation (“1 ms loss”)

All elements except kickers are OK

A5: Increase strength by ~ 30 % (1.5 to 2 GeV)
new PFN with better rise and fall time

F3: modify PFN

→ Design study for new A5 kicker system



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Parameters for A5 kicker upgrade

Table 1: A5 Injection Kicker Parameters

		Present	Upgrade
Magnetic field	[G]	239	—
Magnetic length	[m]	0.861	—
Integrated strength	[Gm]	206	279
Vertical Gap	[mm]	57.15	—
Gap Width	[mm]	127	—
Current	[A]	1100	—
Rise time	[ns]	< 140	< 100
Flat top (protons)	[ns]	360	500
Flat top (gold)	[ns]	1100	1800
Fall time	[ns]	< 140	< 100
PFN Voltage	[kV]	32.5	—

Table 2: Maximum A5 Kick for Various Proton Kinetic Energies

K(GeV)	cp(GeV)	$B\rho$(Tm)	Present ϕ(mrad)	Upgrade ϕ(mrad)
1.50	2.25	7.5069	2.74	3.72
1.60	2.36	7.8671	2.62	3.55
1.70	2.47	8.2250	2.50	3.39
1.80	2.57	8.5810	2.40	3.25
1.90	2.68	8.9352	2.30	3.12
1.94	2.72	9.0764	2.27	3.07
2.00	2.78	9.2879	2.22	3.00

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5 AGS Upgrade

The Alternating Gradient Synchrotron (AGS) at BNL is presently the world's highest intensity, multi-GeV proton accelerator and is a natural candidate for the proton driver needed to provide multi-megawatt proton beams (superbeams) for the next generation of neutrino oscillations research program in the U.S. Taking this qualitative fact to the next level, accelerator scientists at BNL have created a credible and effective plan for upgrade of the AGS to the 1 MW proton source needed by the neutrino program advocated in this paper. The increase is a factor of 6 from the present 0.17 MW beam power level. Furthermore, this plan could be time phased to evolve in stages from a 0.4 MW source available in a few years to an ultimate capability of up to 4 MW if such driver power is needed to complete the neutrino research program. At present, we believe a 1 MW source will be adequate for the foreseen program.

Our planned upgrade path would begin with the addition of a 1 GeV superconducting extension to the existing 200 MeV Cu LINAC that currently feeds the Booster ring. The resulting 1.2 GeV hybrid LINAC would bypass the Booster and inject directly into the AGS. The purpose here is to eliminate the need for six complete Booster cycles to fill the AGS and to inject all the needed 1.2 GeV protons in about 0.7 milliseconds. This step increases the average AGS power from 0.17 MW to 0.4 MW, enough to credibly begin the proposed neutrino oscillations program. By next adding new power supplies for the AGS ring, plus added RF power to rapidly accelerate the beam to 28 GeV, the AGS will be operational at the 1 MW power level. Further upgrades could increase the power level to as high as 4 MW if this becomes necessary.

We also note that the technical basis for the proposed upgrade has been documented in a recent study for a muon storage ring, "Feasibility Study-II of a Muon-Based Neutrino Source", June 14, 2001 [24]. Here we present a brief summary of the parameter lists for the required AGS upgrade, along with a summary of the direct costs that were derived in the muon storage ring study. The 1 MW requirements are summarized in Table 2 and a layout of the upgraded AGS is shown in Figure 37.

5.1 Superconducting LINAC

The superconducting LINAC (SCL) accelerates the proton beam from 200 MeV to 1.2 GeV. The presented configuration follows a similar design described in detail in [27] and [28]. All

Table 2: AGS Proton Driver Parameters.

Total beam power	1 MW	Protons per bunch	0.4×10^{13}
Beam energy	28 GeV	Injection turns	230
Average beam current	42 μA	Repetition rate	2.5 Hz
Cycle time	400 ms	Pulse length	0.72 ms
Number of protons per fill	9×10^{13}	Chopping rate	0.75
Number of bunches per fill	24	LINAC average/peak current	20/30 mA

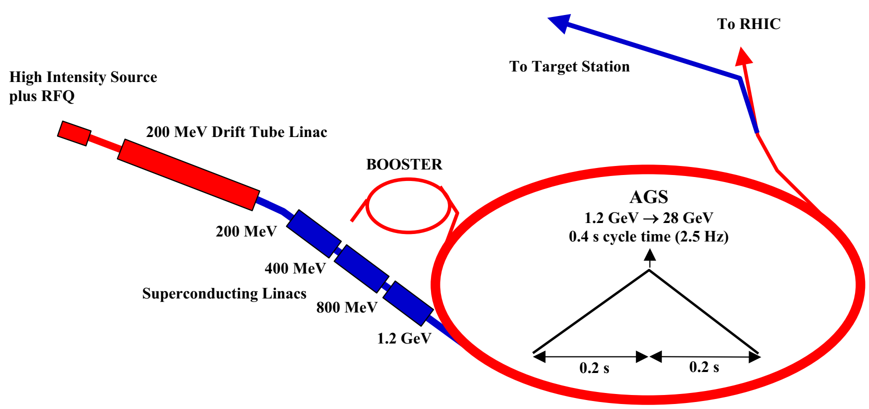

Figure 37: AGS Proton Driver Layout.

three LINACs are built up from a sequence of identical periods. The major parameters of the three sections of the SCL are given in Table 3. The low energy section operates at 805 MHz and accelerates proton from 200 to 400 MeV. The following two sections, accelerating to 800 MeV and 1.2 GeV respectively, operate at 1.61 GHz. A higher frequency is desirable for obtaining a larger accelerating gradient with a more compact structure and reduced cost. The SCL will be operated at 2^oK for the assurance of reaching the desired gradient.

5.2 Upgrade to 4 MW

The AGS-based neutrino superbeam can be further upgraded to 4 MW by: 1) increasing the LINAC energy to 1.5 GeV, 2) increasing the AGS intensity to 1.8×10^{14} ppp, and 3) increasing the AGS rep rate to 5.0 Hz. The associated problems in beam dynamics, power supply, RF system, beam losses and radiation protection are under study and appear to be feasible if such a capability is required by the physics experiments.

Table 3: General Parameters of the SCL.

LINAC Section	LE	ME	HE
Average Beam Power, kW	7.14	14.0	14.0
Average Beam Current, μA	35.7	35.7	35.7
Initial Kinetic Energy, MeV	200	400	800
Final Kinetic Energy, MeV	400	800	1200
Cell Reference β_0	0.615	0.755	0.887
Frequency, MHz	805	1610	1610
Cells/Cavity	8	8	8
Cavities/Cryo-Module	4	4	4
Cavity Internal Diameter, cm	10	5	5
Total Length, m	37.82	41.40	38.32
Accelerating Gradient, MeV/m	10.8	23.5	23.4
Cavities/Klystron	1	1	1
Norm. rms Emittance, πmm-mrad	2.0	2.0	2.0
Rms Bunch Area, π^oMeV (805 MHz)	0.5	0.5	0.5

5.3 Cost of the AGS upgrade

A preliminary cost of upgrading the accelerator complex to 1 MW is shown in Table 4. This upgrade could be done in phases if required by the funding plan. We are still in the process of creating a detailed staging plan.

6 Neutrino Beam Design

The geographic location of BNL on one side of the continent allows us to send beams to a variety of distances including very long baselines of 2000 km or more. This is shown in Figure 38. The distances from BNL to Lead, SD (Homestake), and WIPP in NM are 2540 and 2880 km, respectively. The respective dip angles are 11.5, and 13.0 degrees. The difficulty of building the beam and the cost increases with the dip angle but all these angles and distances are feasible.

Our conceptual design for a beam to Homestake is shown in Figures 39 and 40. It can be adapted to any far location in the Western direction. Our design addresses a number of

Table 4: Preliminary direct costs of upgrading the AGS to 1 MW. These costs do not include EDIA, contingency, and overheads.

1.2 GeV Superconducting LINAC	
LE SC LINAC	\$36.1 M
ME SC LINAC	\$25.9 M
HE SC LINAC	\$28.2 M
AGS upgrades	
AGS Power Supply	\$32.0 M
AGS RF upgrade	\$8.6 M
AGS injection channel	\$ 3.7 M
Full turn extraction	\$ 5.5 M
Total	\$140 M

issues. At BNL we are constrained to keep the beam line above the water table which is at a shallow depth ($\sim$ 10 m) on Long Island. Therefore the beam has to be constructed on a hill that is built with the appropriate 11.5 degree slope. Fortunately, it is relatively easy, and inexpensive to build such hills on Long Island because of the flat, sandy geology. It is important to keep the height of the hill low so that the costs are not dominated by the construction of the hill. The proton beam must be elevated to a target station on top of the hill. The cost of the hill can be lowered by bending the proton beam upwards as quickly as possible. We have, however, chosen the design and the bend angle used for the RHIC injection lines in our proposal because the RHIC injection lines have well known costs.

The proposed fast-extracted proton beam line in the U-line tunnel will be a spur off the line feeding RHIC. It will turn almost due west, a few hundred meters before the horn-target building. In addition to its 90 degree bend, the extracted proton beam will be bent upward through 13.76 degrees and then down by 15 degrees to strike the proton target. The downward 11.30 degree angle of the 200 meter meson decay region will then be aimed at the 4850 feet level of the Homestake laboratory. This will require the construction of a 54 meter hill to support the target-horn building, so as to avoid any penetration of the water table. At its midpoint (about Lake Michigan) the center of the neutrino beam will be roughly 120 km below the Earth's surface.