BNL very long baseline proposal progress.

- Milind Diwan
- Brookhaven National Laboratory

- 5/14/2004
- APS NEUTRINO STUDY, FERMILAB.

BNL very long baseline proposal progress

- A next generation large detector at a national underground facility with a powerful accelerator neutrino beam and very long baseline.
- Ability to over-constrain the neutrino mixing sector. (3-generation mixing: CP phase can be measured without both polarities.)
- Conceptual and technical progress:
  1. AGS upgrade and Beam
  2. Detector Simulations
  3. Comparison with other ideas (neutrino factory)

AGS superbeam review

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BROOKHAVEN NATIONAL LABORATORY

Memo

date: *April 14, 2004*

to: *W. Weng*

from: *T. Kirk* *Associate Laboratory Director, HENP*

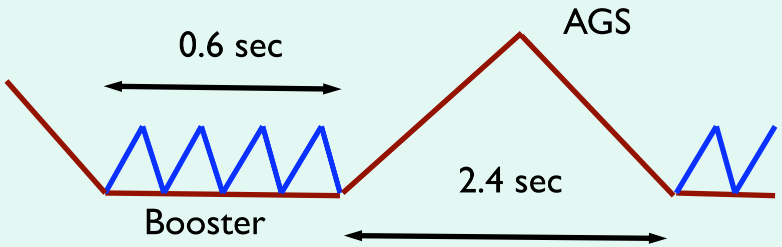
subject: BNL Internal Review of the AGS-Based Super Neutrino Beam Upgrade

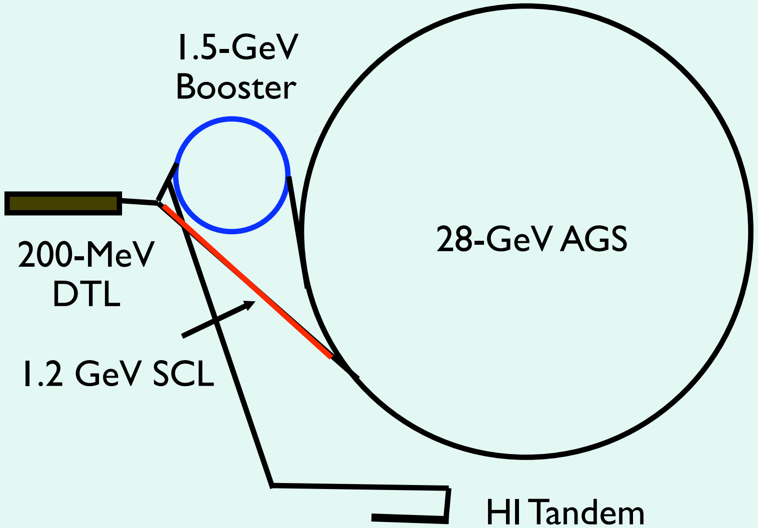
The future plans for BNL to become the Super Neutrino Beam source for a Very Long Baseline Neutrino Oscillations Experiment will depend upon our ability to present a proposal in the coming months for this beam that is based on a well-developed conceptual design, cost estimate and proposed schedule. Your R&D group in the C-AD has been working for several months on a new design report to meet this need. By this memorandum, I am charging you to prepare and present to a BNL Internal Review Committee, the results of your design study and report. We will use this review to critique and improve the coherence of the draft report that you are preparing.

The BNL Internal Review will be held on Thursday and Friday, June 10-11, 2004 in a room to be determined at BNL. The Review Committee will be composed of:

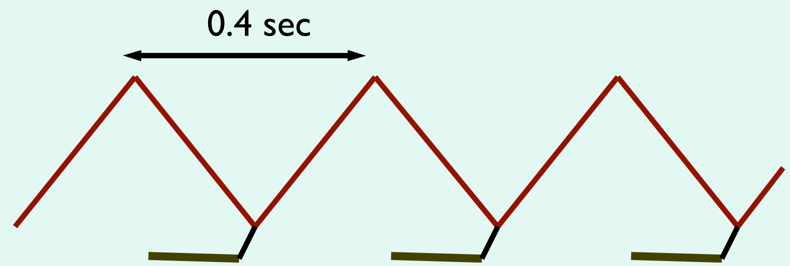
Mike Harrison	Tom Kirk, Chair
Derek Lowenstein	Thomas Roser
Nick Samios	Mike Schaeffer

AGS Upgrade

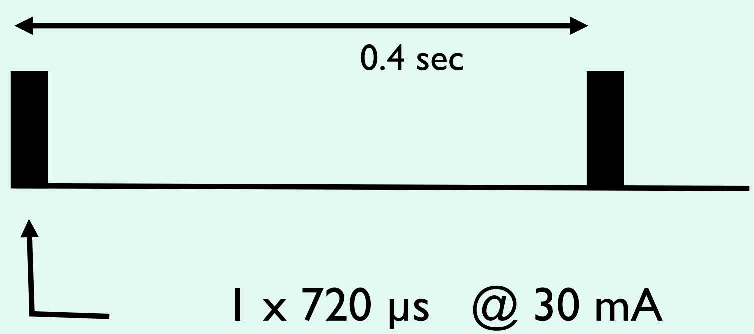




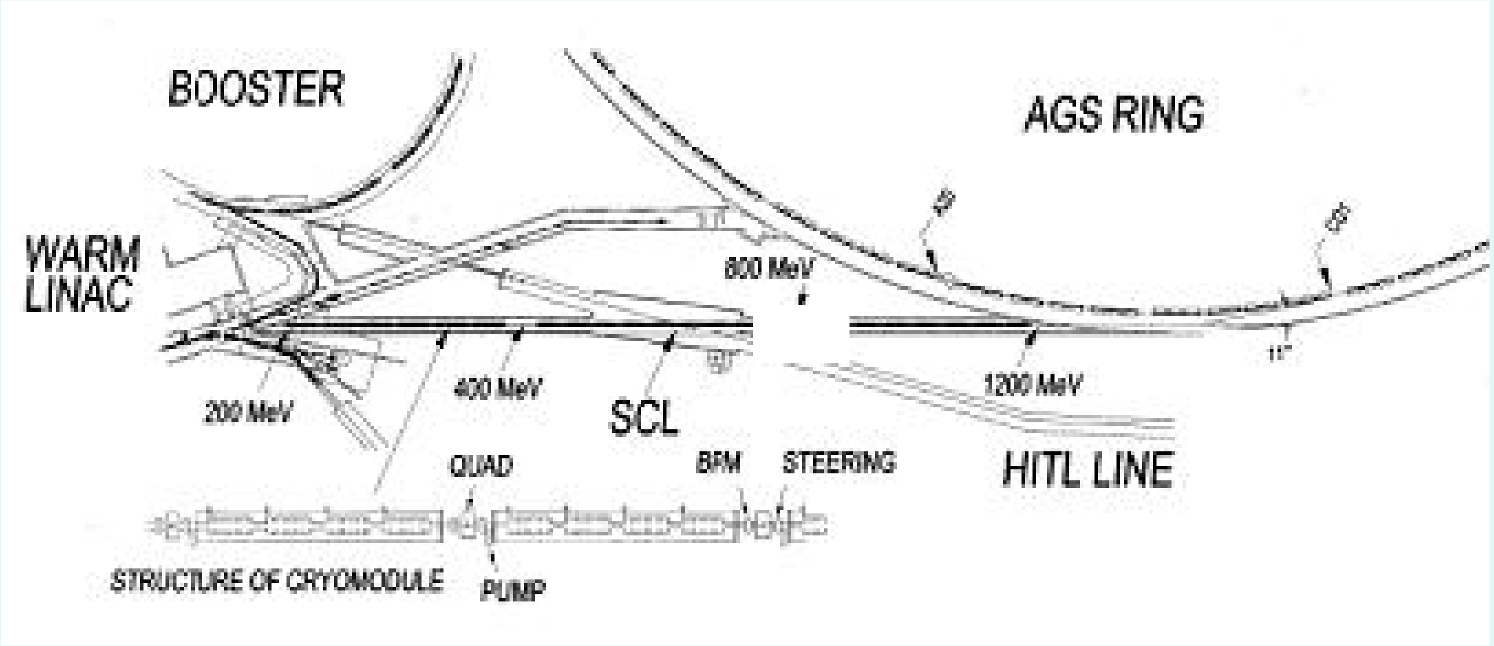
	AGS present	AGS upgrade
Kin. Energy	28 GeV	28 GeV
Rep. Rate	1 / 3 Hz	2.5 Hz
Protons/ Cycle	0.67 x 10^{14}	0.89 x 10^{14}
Ave. Power	0.10 MW	1.0 MW



Typical DTL cycle for Protons



Layout of the 1.2 GeV SCL



Linac design is driven by the length constraint (120 meter)

(1) two frequency 805 and 1610 MHz

(2) 8 cells/cavity (SNS: 6 Cell/cavity) for both frequencies

(3) 4 cavity/cryo-module (SNS:3-4)

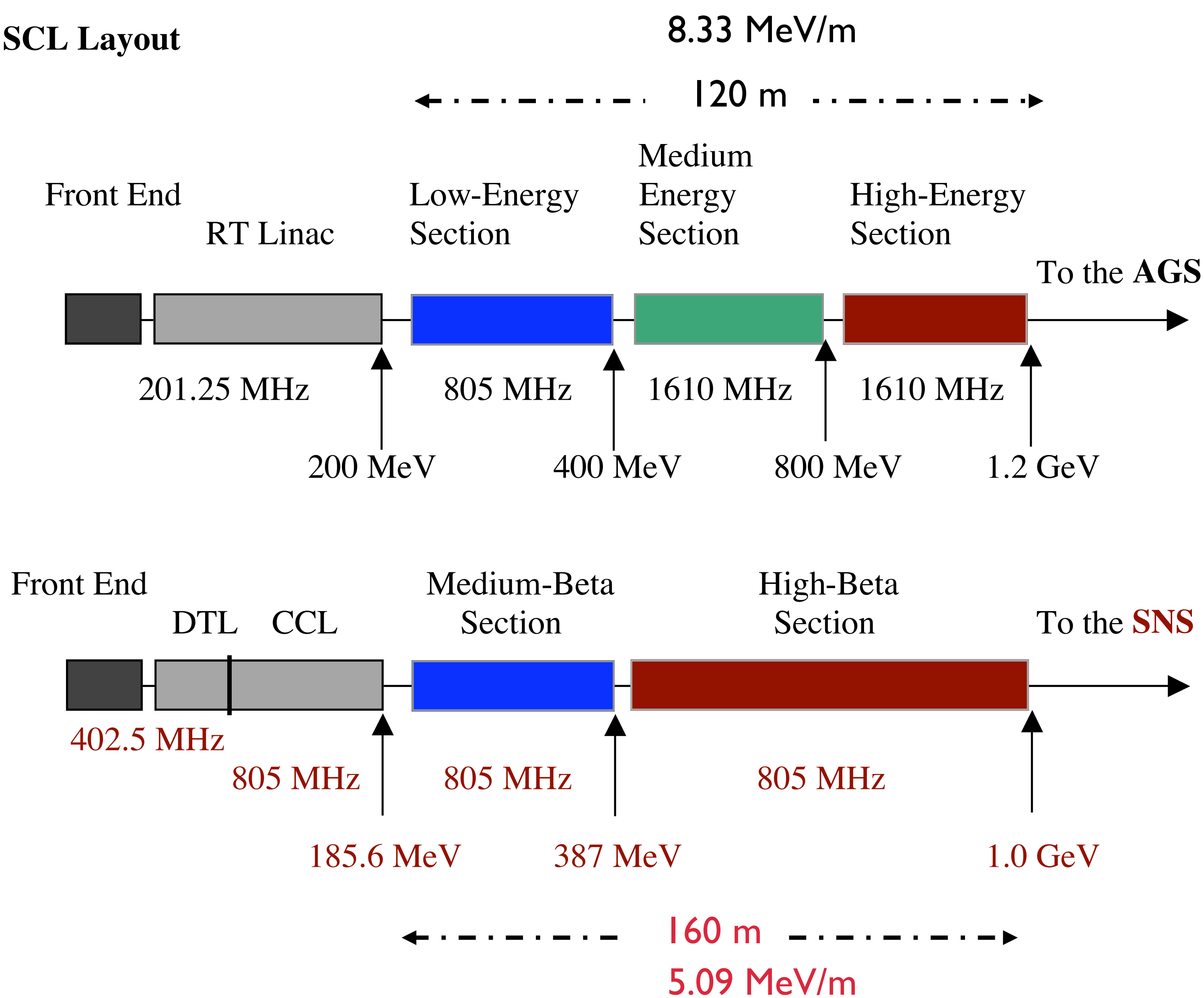
(4) inter cavity space: 32 cm@ 805 and 16cm @1610 Mhz (SNS:38.5 cm)

(5) warm to cold transition: 30 cm (SNS:75 cm)

(6) warm insertion 100-140 cm (SNS:160 cm)

(7) accelerating gradient 10-23 MeV/m (SNS:10-15 MeV/m)

SCL Layout


8.33 MeV/m
120 m
Front End
RT Linac
Low-Energy Section
Medium Energy Section
High-Energy Section
To the AGS
201.25 MHz
805 MHz
1610 MHz
1610 MHz
200 MeV
400 MeV
800 MeV
1.2 GeV
Front End
DTL
CCL
Medium-Beta Section
High-Beta Section
To the SNS
402.5 MHz
805 MHz
805 MHz
805 MHz
185.6 MeV
387 MeV
1.0 GeV
160 m
5.09 MeV/m

AGS Proton Driver Parameters

	present AGS	**1 MW AGS**	**2 MW AGS**	J-PARC
Total beam power [MW]	0.14	1.00	2.00	0.75
Injector Energy [GeV]	1.5	1.2	1.5	3.0
Beam energy [GeV]	24	28	28	50
Average current [μA]	6	36	72	15
Cycle time [s]	2	0.4	0.4	3.4
No. of protons per fill	0.7×10^{14}	0.9×10^{14}	1.8×10^{14}	3.3×10^{14}
Average circulating current [A]	4.2	5.0	10	12
No. of bunches at extraction	6	24	24	8
No. of protons per bunch	1×10^{13}	0.4×10^{13}	0.8×10^{13}	4×10^{13}
No. of protons per 10^7 sec.	3.5×10^{20}	23×10^{20}	46×10^{20}	10×10^{20}

C. R&D Activities

1. Beam Dynamics in the AGS
   - Injection Painting
   - Linac Emittance
   - Transition Crossing
   - Ring Impedances
   - Beam Loss and Collimation
2. AGS Magnet Test
3. New Power Supply Design
4. AGS RF Cavity/Ferrite Test
5. SCL Accelerating Cavity (Join the US SMTF Program)
6. LLRF for Beam Control
7. Design of the 1MW Target/Horn System
8. Target Material Testing (Initiate the US/Japan Collaboration and the BNL LDRD Program)

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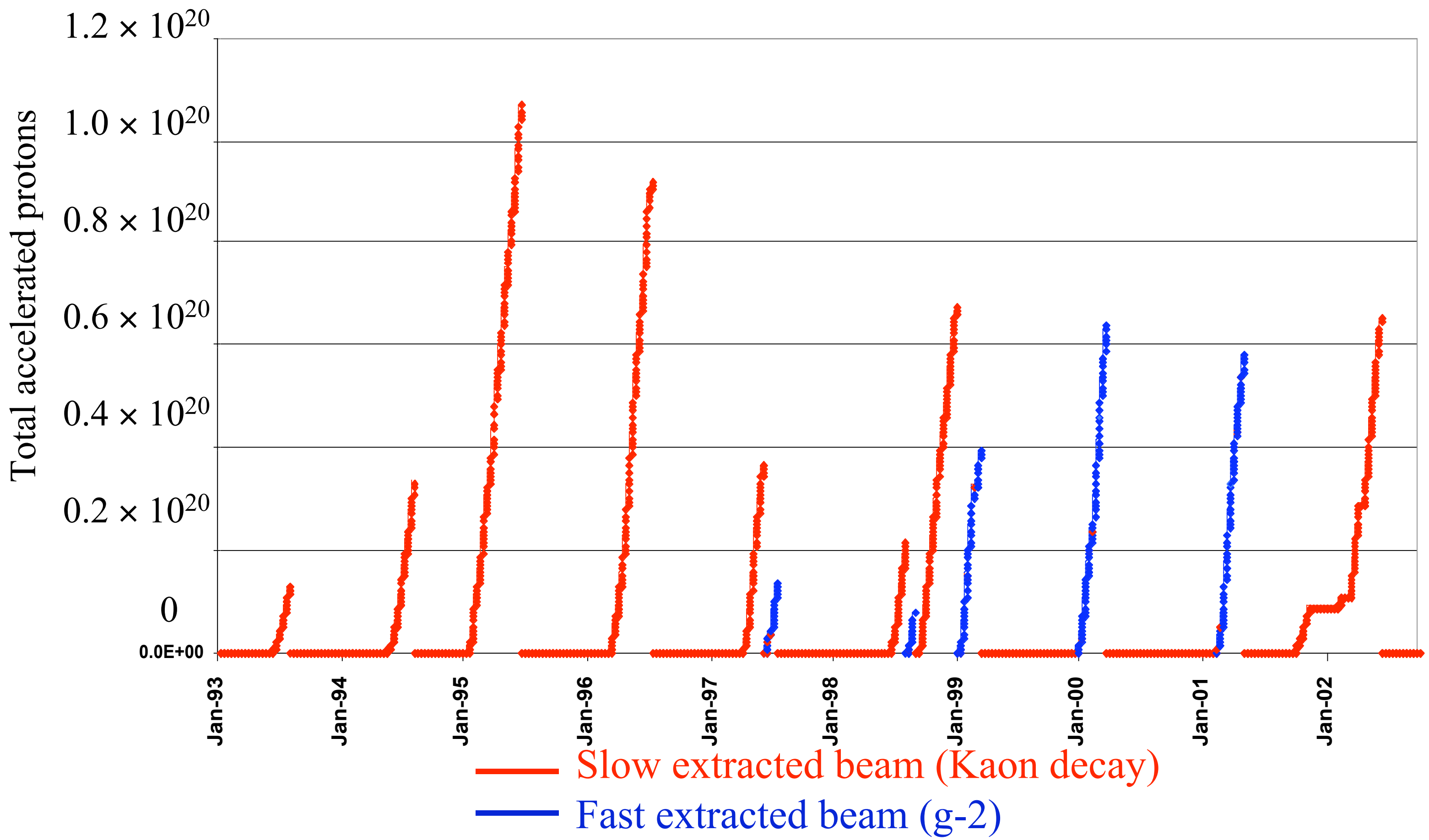
1 MW target and beam design

- Accelerator operations and proton economics.
- Civil construction issues for 2540 km baseline.
- Target materials and cooling.

Concurrent HEP Operation with RHIC

1. From the performance data shown, it is clear that it is possible to operate AGS proton-based HEP research in concurrence with RHIC operation.
2. The available AGS HEP running is about 80% of the total RHIC operation time.
3. The HEP program only have to pay for incremental costs, which is a big savings from independent operation.
4. The co-existence of HEP and RHIC operations is very beneficial for both equipment reliability and personnel training.

Total Accelerated Protons at the AGS



Note: Lower total accelerated protons in later years due to much shorter running time

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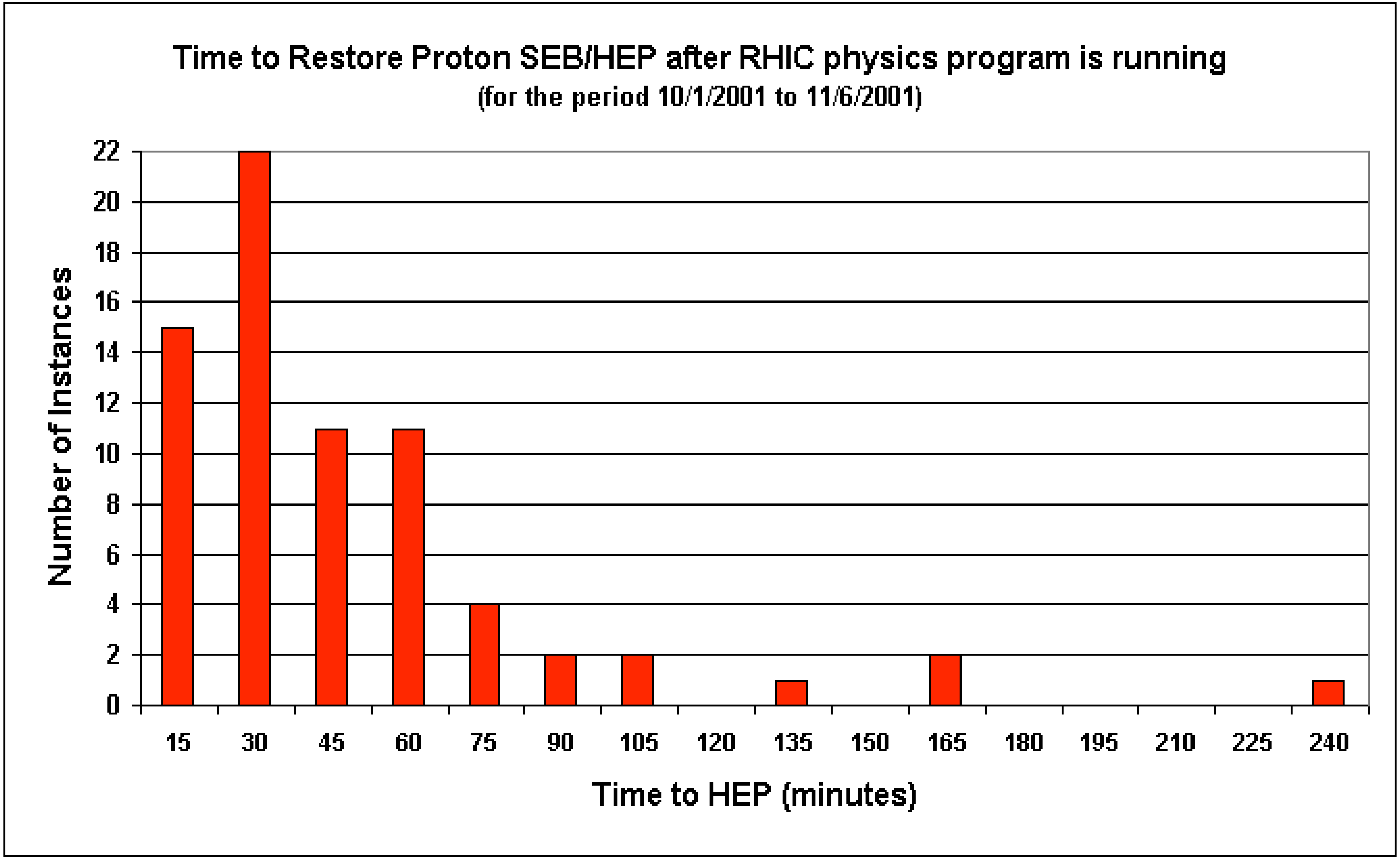
Transition Time to Restore HEP



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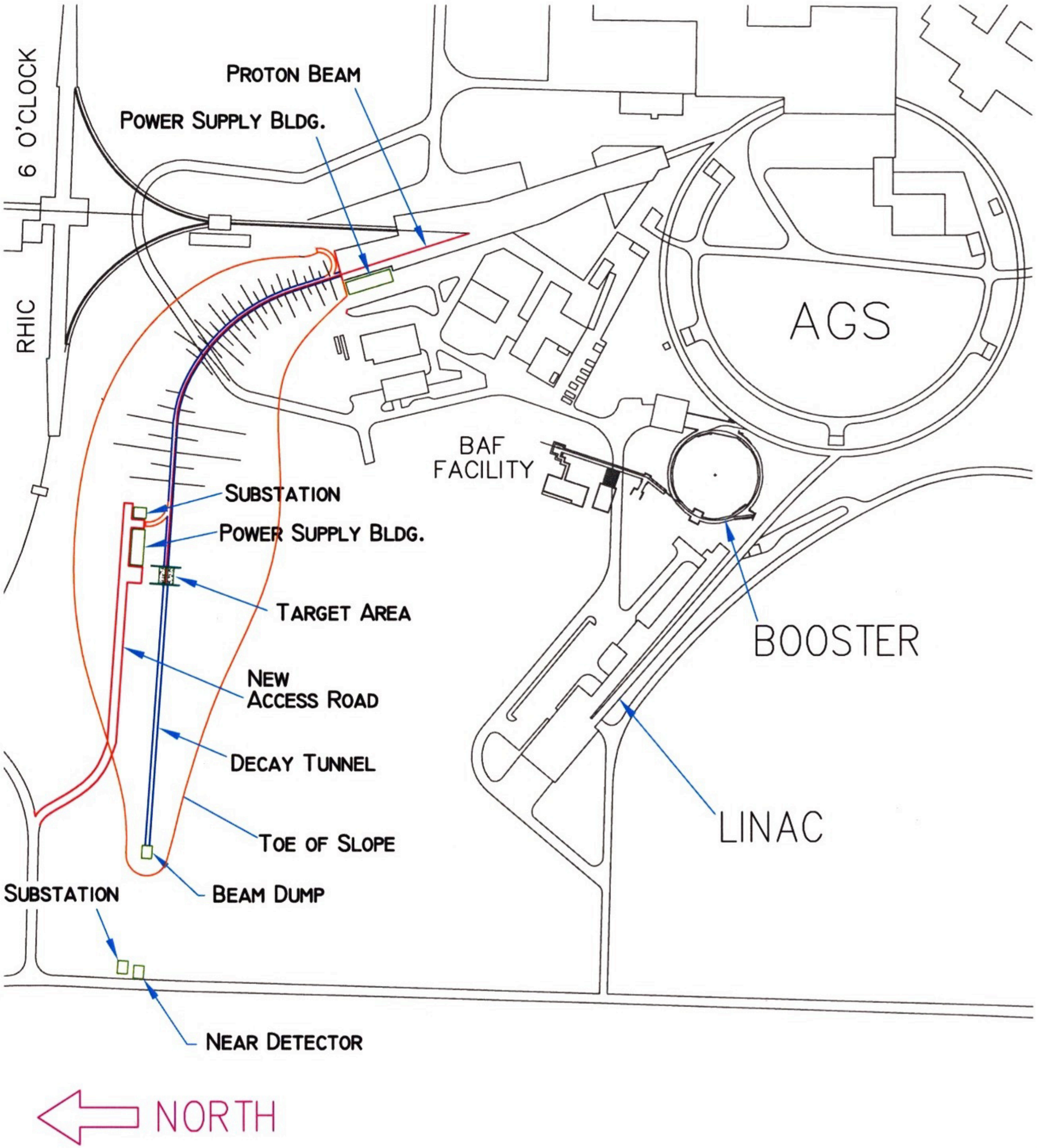
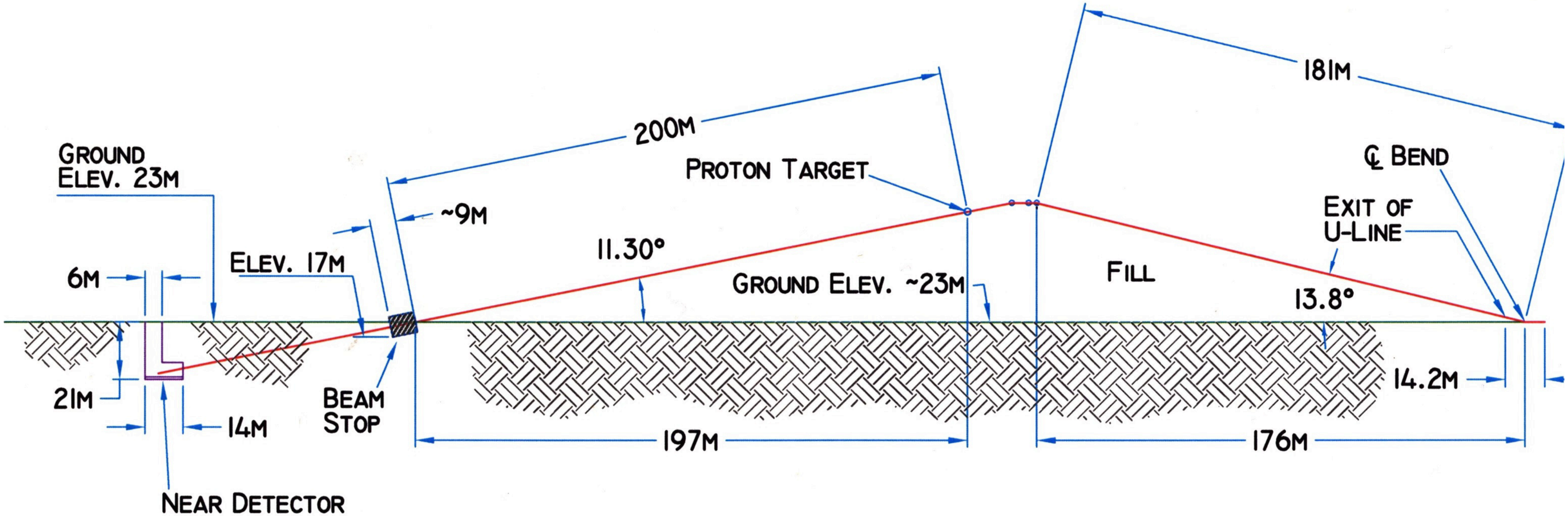
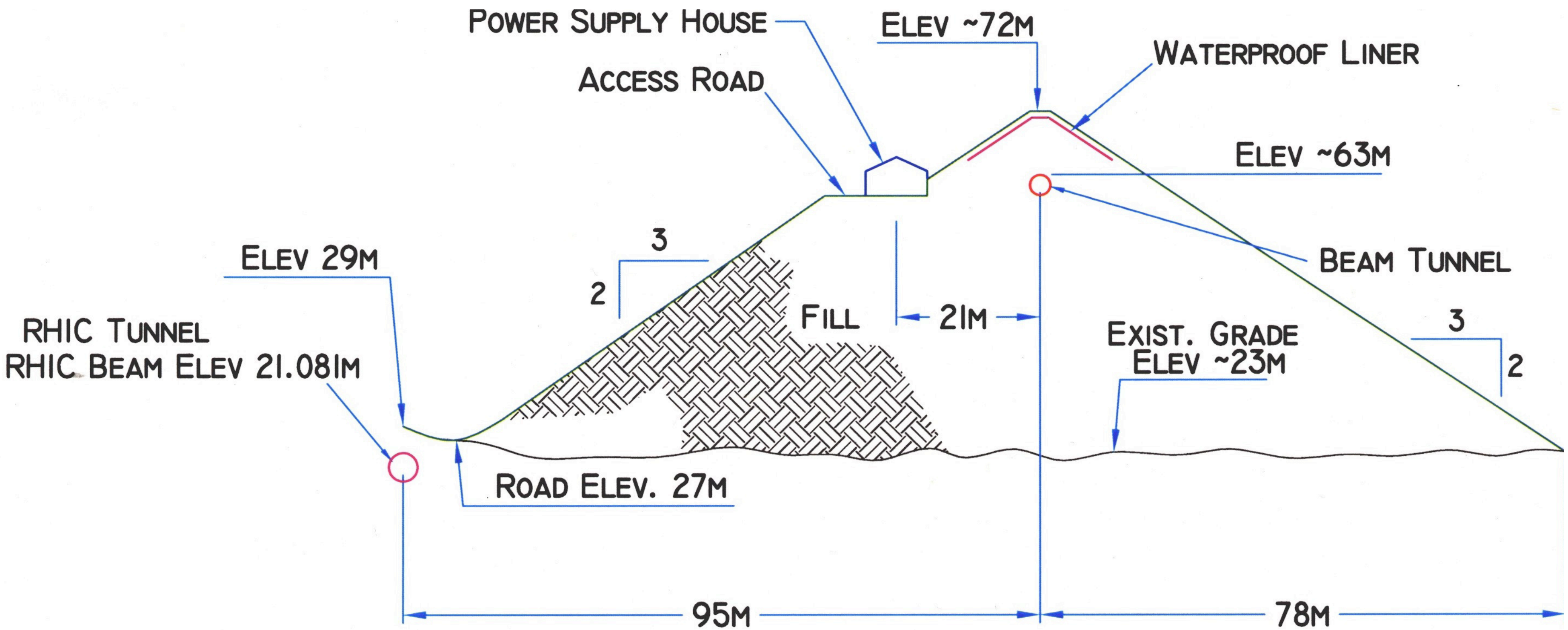
Civil construction issues

- Minimize effect on RHIC running schedule and operations.
- Minimize environmental impact: construction of radiation area well above water table. Maximum use of on-site soil.
- Control tolerances: allow for settlement of hill.
- Upgrade of some infrastructure: on-site power grid.
- Near detector facility below water table.

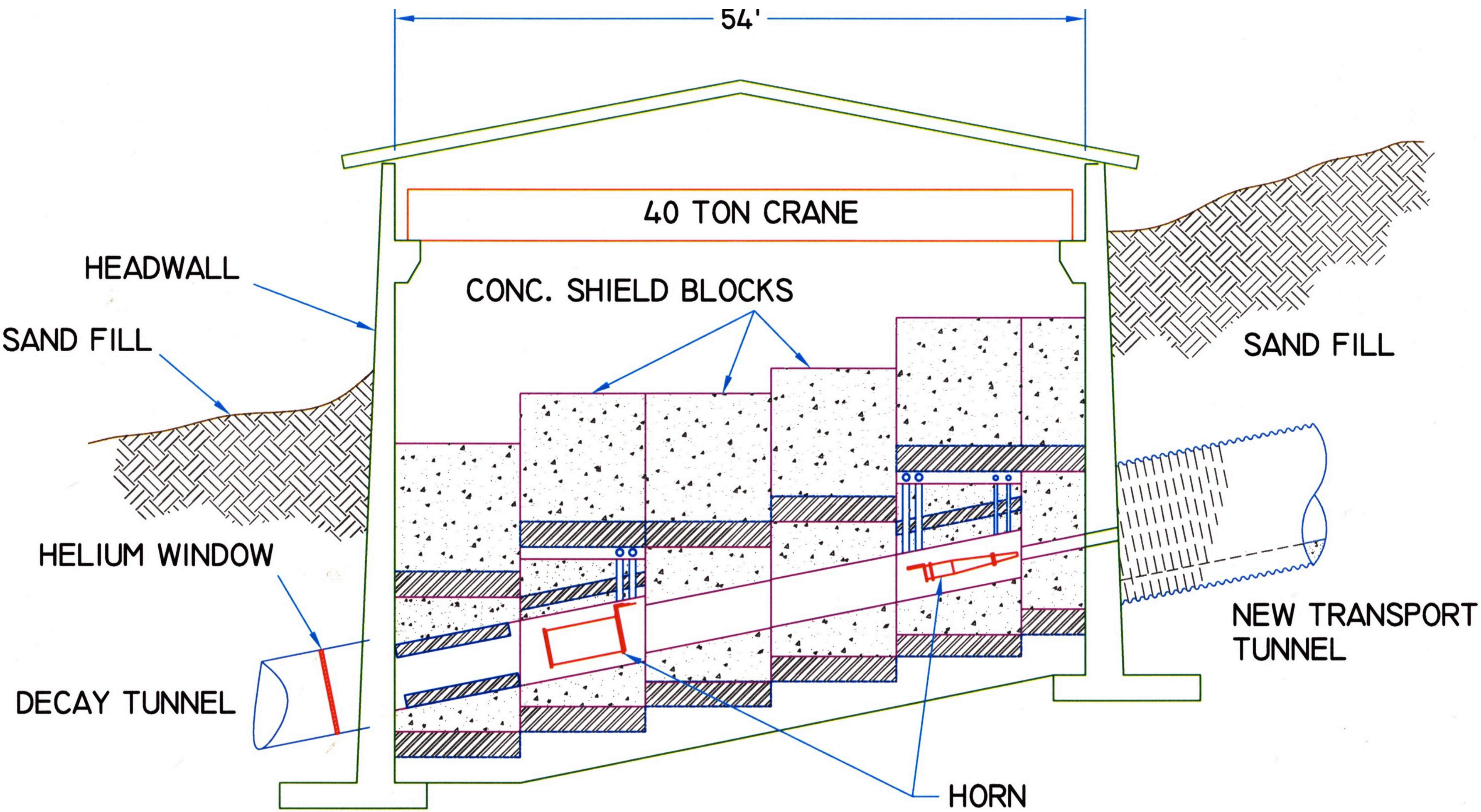

6 O'CLOCK
RHIC
PROTON BEAM
POWER SUPPLY BLDG.
AGS
BAF
FACILITY
SUBSTATION
POWER SUPPLY BLDG.
TARGET AREA
BOOSTER
NEW
ACCESS ROAD
DECAY TUNNEL
LINAC
TOE OF SLOPE
BEAM DUMP
SUBSTATION
NEAR DETECTOR
NORTH



200M
181M
GROUND ELEV. 23M
PROTON TARGET
℄ BEND
~9M
EXIT OF U-LINE
ELEV. 17M
11.30°
FILL
6M
GROUND ELEV. ~23M
13.8°
14.2M
21M
BEAM STOP
14M
197M
176M
NEAR DETECTOR



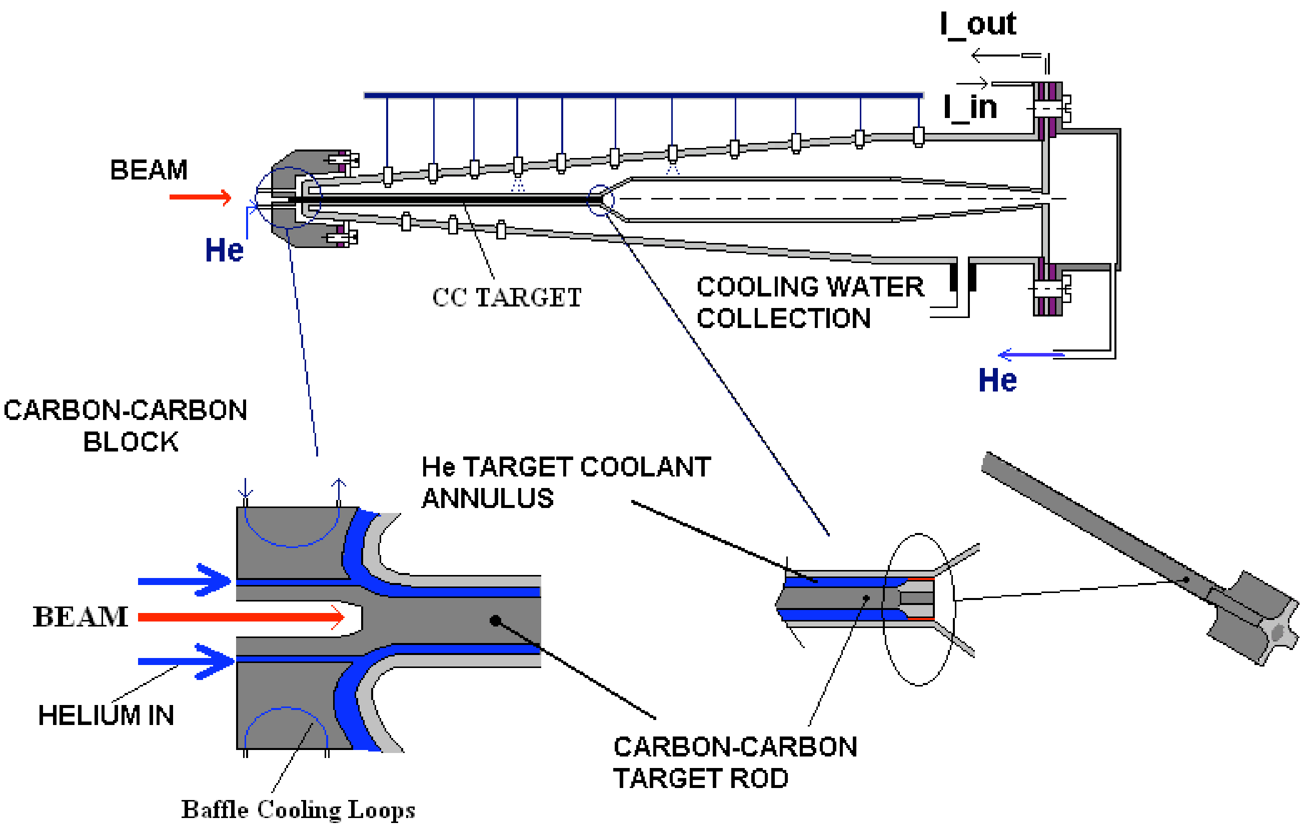
POWER SUPPLY HOUSE
ELEV ~72M
WATERPROOF LINER
ACCESS ROAD
ELEV ~63M
3
BEAM TUNNEL
ELEV 29M
2
FILL
21M
3
RHIC TUNNEL
RHIC BEAM ELEV 21.081M
EXIST. GRADE ELEV ~23M
2
ROAD ELEV. 27M
95M
78M


54'
40 TON CRANE
HEADWALL
CONC. SHIELD BLOCKS
SAND FILL
SAND FILL
HELIUM WINDOW
NEW TRANSPORT
TUNNEL
DECAY TUNNEL
HORN

1 Degree off-axis options

1. 4 meter diameter tunnel allows for this option.
2. Large (~1.3 m) movement needed at the target station. Main difficult is moving proton beam.
3. Allow horizontal movement of target station including shielding (1000 ton). Solutions exist.
4. Could build both on-axis and off-axis options from the start.

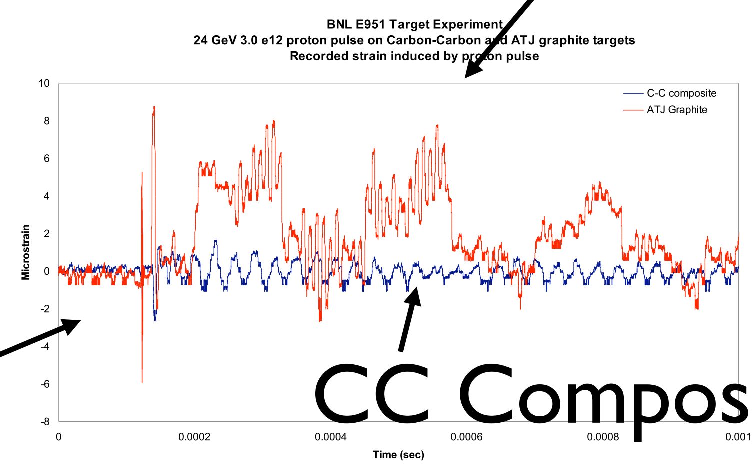
BNL CONCEPT DESIGN FOR TARGET & HORN



Selection of carbon-carbon composite based on comparison with graphite (from BNL E951 experimen

GRAPHITE

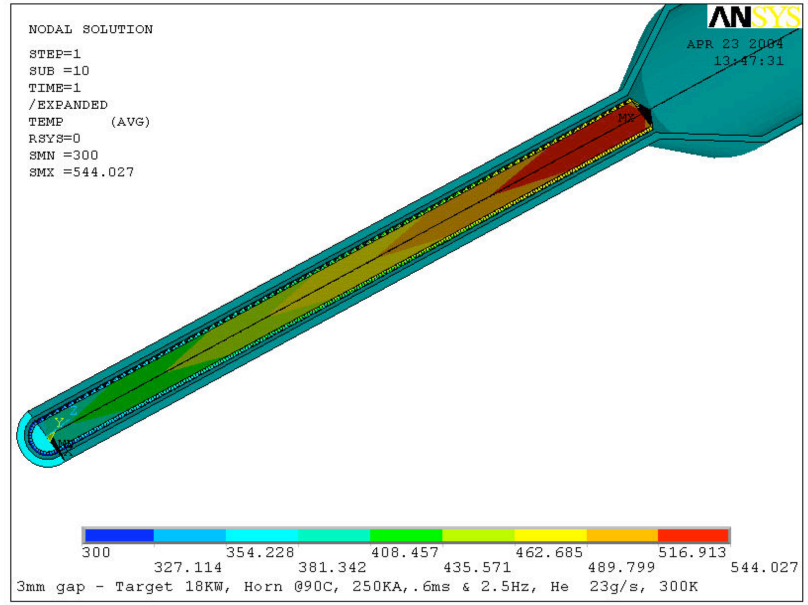
Response of graphite and CC composite targets to AGS beam. CC (blue) handles shock far better. Unknown are irradiation effects on CC



CC Composite

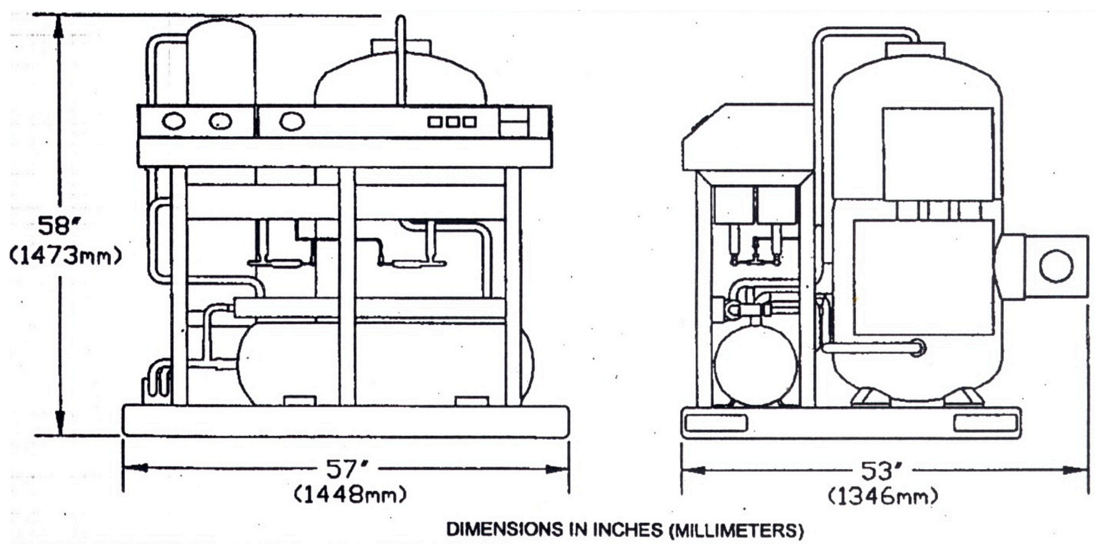
BNL SuperNeutrino Beam Facility
Target-Horn Cooling

- 23 g/sec @ 16 atm supply Pressure through 3mm annular gap between target & horn
- FEA & CFD models indicate approx 250 deg rise in Target Material



Aluminum Horn Cooled by External H20 spray nozzles

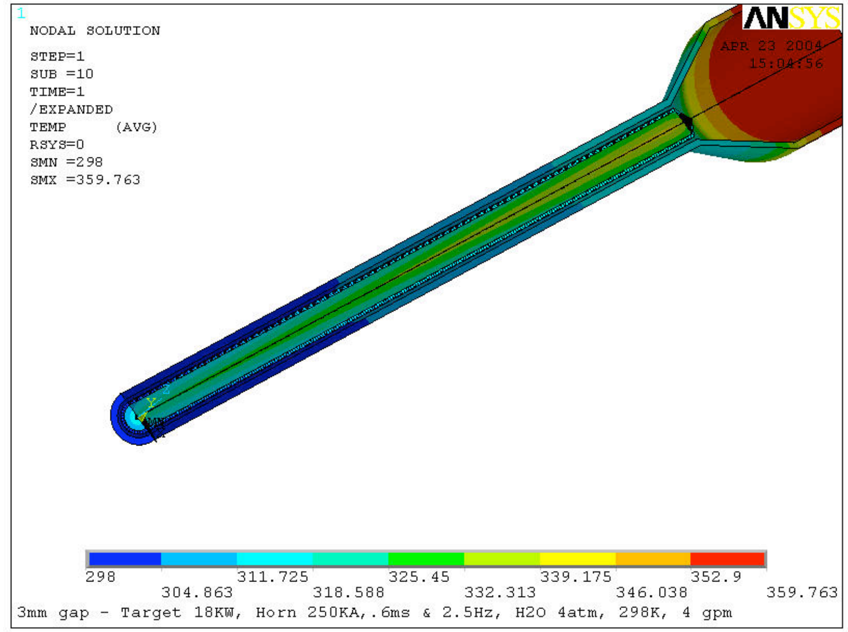
110 KW Rotary Screw



BNL SuperNeutrino Beam Facility
Target-Horn Cooling (H2O alternate)

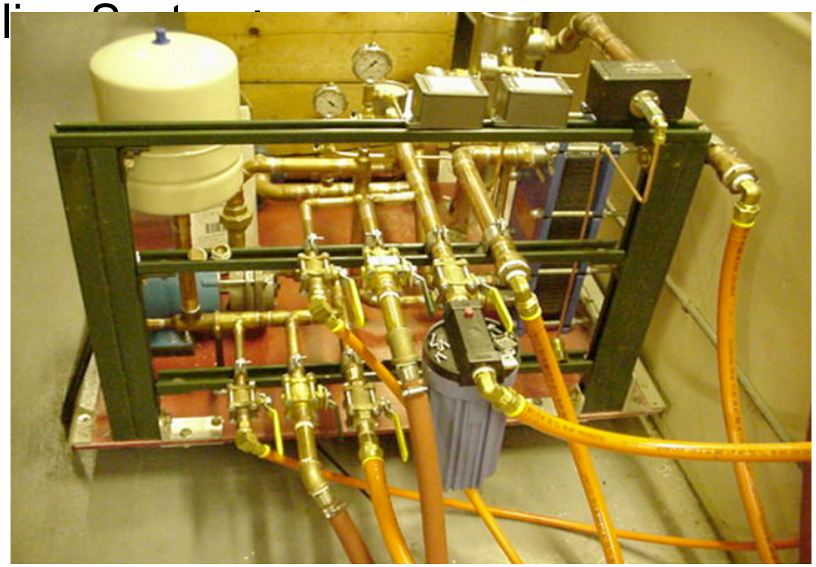
C-C Target cooled by external H_2O Liquid (alternate method)

- 4 gpm @ 2 atm supply Pressure through 3mm annular gap between target & horn
- FEA & CFD models indicate approx 60 °C rise in Target Material



2 HP H_2O

Cooli



NEUTRINO BEAM TARGET & HORN MATERIAL STUDIES

PHASE I (completed):

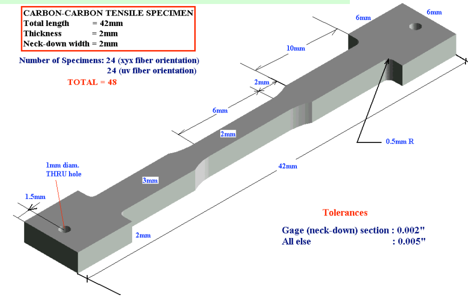
Irradiate candidate target and horn materials at the BNL facilities. These include Carbon-Carbon, AlBeMet, nickel-plated aluminum (NUMI horn material)

PHASE II (in preparation):

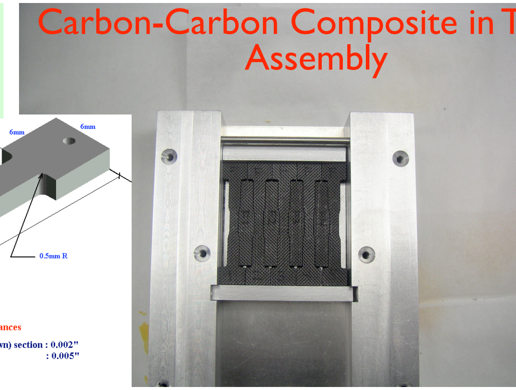
Interrogate irradiated materials for changes in key physical/mechanical properties – Perform key thermal shock and heat removal verification experiments for target/ horn system

Tensile CC Specimen

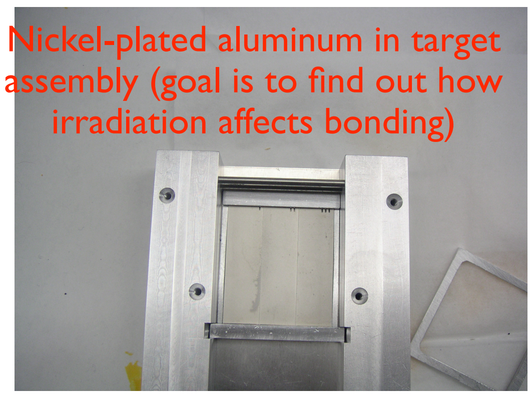
Length = 42mm



Carbon-Carbon Composite in Target Assembly



Nickel-plated aluminum in target assembly (goal is to find out how irradiation affects bonding)



Material Matrix currently under study at BNL

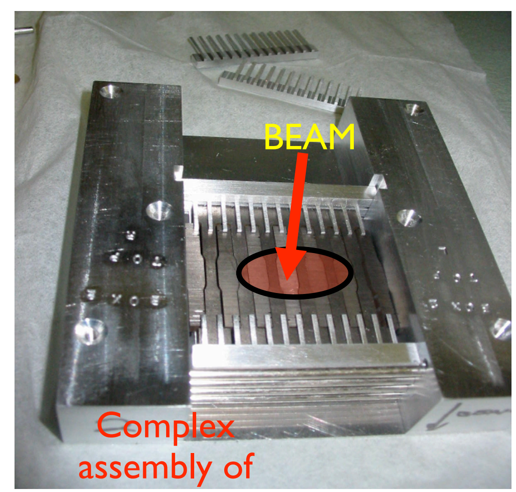
- Carbon-Carbon Composite (BNL)
- Toyota "Gum Metal" (KEK)
- Graphite (IG-43) (KEK)
- AlBeMet (BNL)
- Beryllium (BNL)
- Ti Alloy (6Al-4V) (SLAC)
- Vascomax (BNL)
- Nickel-Plated Alum. (BNL-FNAL-KEK)

BEAM PARAMETERS

200 MeV protons

~ 70 mA for 2 weeks

Spot size FWHM ~ 14 mm



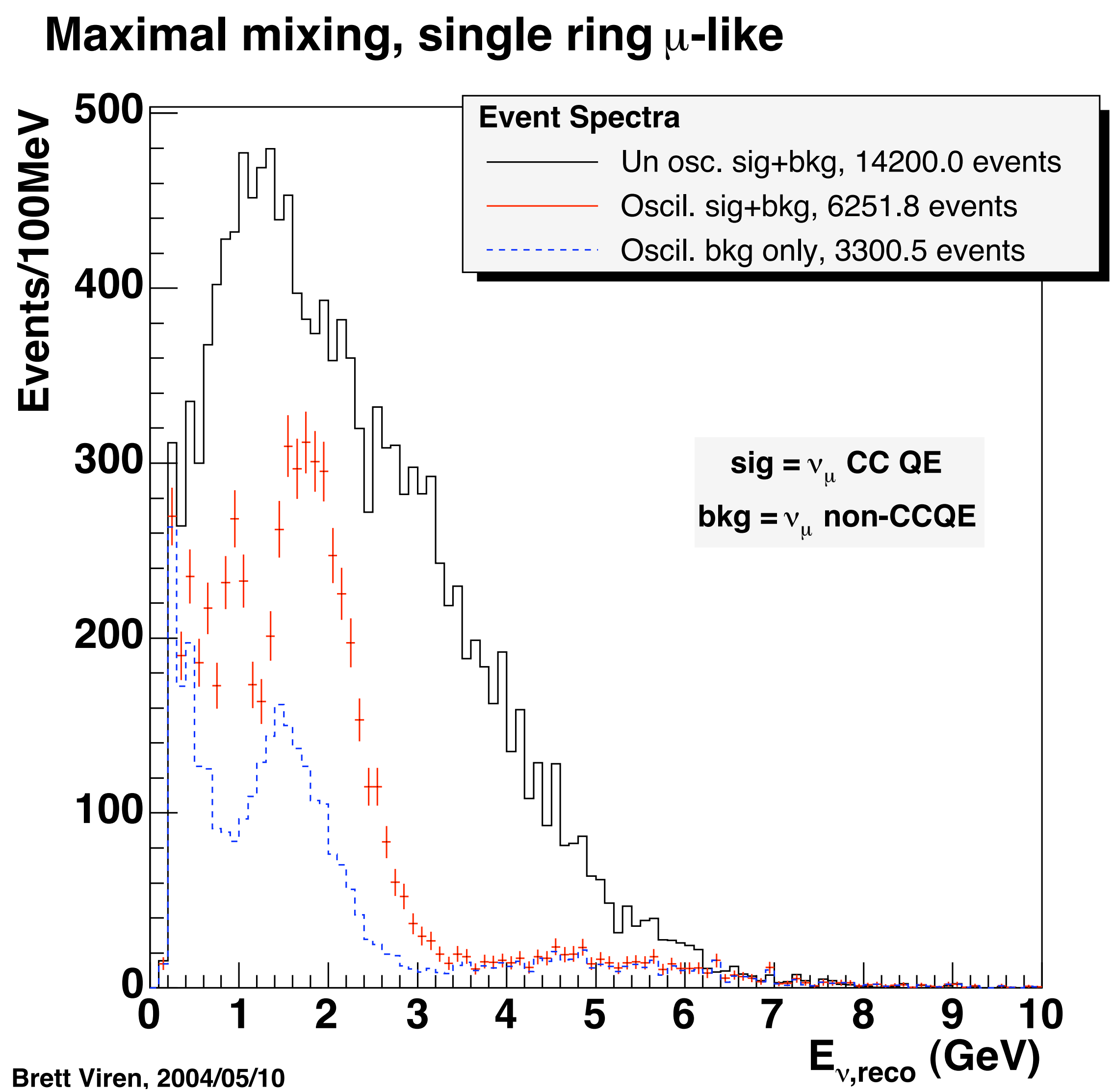
Complex assembly of target materials

WC Detector simulations and design

- New software for water Cherenkov in the works (in collaboration with USB-StonyBrook)
- Temporary studies with SuperK software (run by third parties).
- Optimizations of detector size, shape, PMT granularity limited by manpower.
- Strong effort on PMT cost optimization needed.

Muon neutrino disappearance

- Full Simulation using SuperK software.
- Simple reconstruction requiring single muon only.
- Fiducial volume cuts biased to simulate a 40m dia fiducial inside a 50m dia. detector.
- No other cuts.

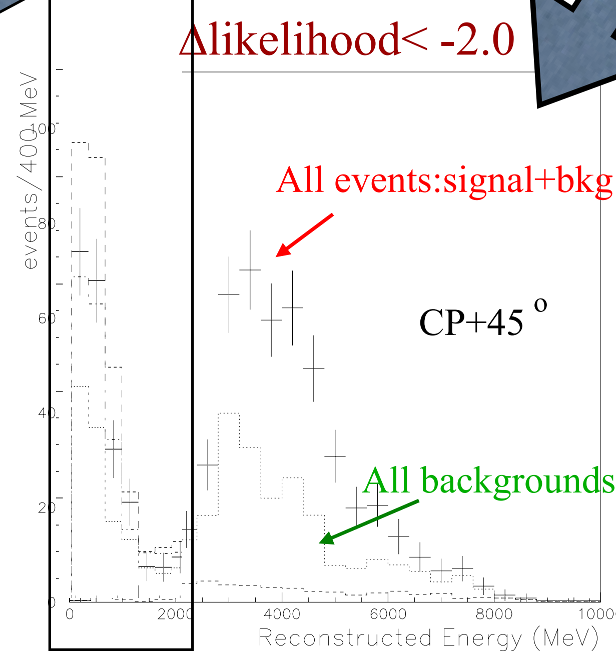


Electron simulation (Chiaki Yanagisawa)

Wideband, with cuts optimized for high E

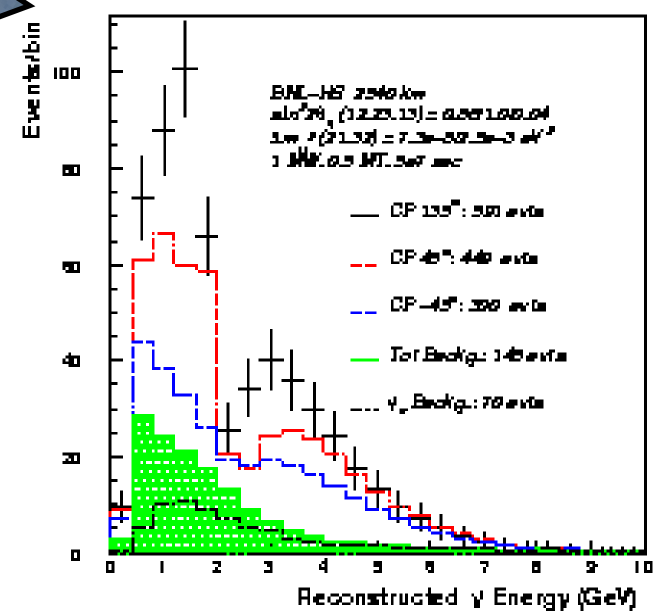
1deg off-axis
sig:150
bkg:85

Other lines for diff CP



Signal 251 events
(49% QE events)
All bkgs 253

BNL Report



Signal 303 events
All bkgs 146

Should expect better performance in larger detector

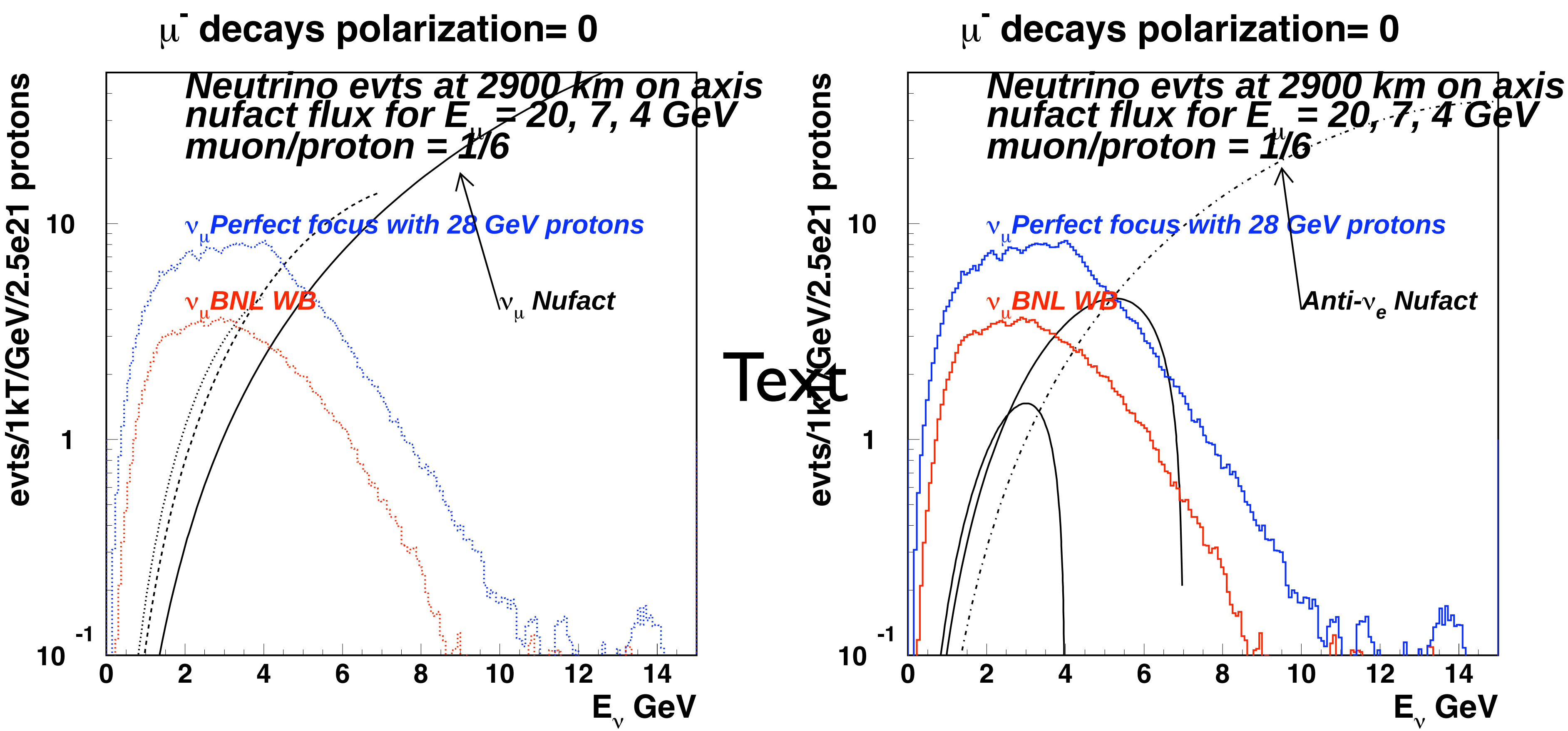
Some Issues for conventional vs nufact beams (work-in-prog.)

- Flux and event rate comparison. Is there a good way to compare ?

- Can mu storage ring beam be used in the same way as wide band conventional beam for CP measurement ?

- For the applicable range of parameters does is nufact baseline optimum ? $0.01 > \sin^2 2\theta_{13} < 0.0001$

Flux comparison



Plot for 28 GeV protons. Disregarding muon production, at any energy some break even point. ~Ep/4.

CP strategy I for large $\sin^2 2\theta_{13} > 0.01$

CP Figure of Merit

Assume that total measured rate from oscillations

$$N = N_0 + N_{cp}$$

per energy bin.

Additional rate due to CP violation

$$f = N_{cp}/N \propto \alpha/E$$

Error on CP rate after subtraction of N_0

$$\delta N_{cp} = \sqrt{N}$$

Figure of merit per energy bin is deviation is sigma-squared

$$F.O.M. = (N_{cp}/\delta N_{cp})^2 = f^2 \times N$$

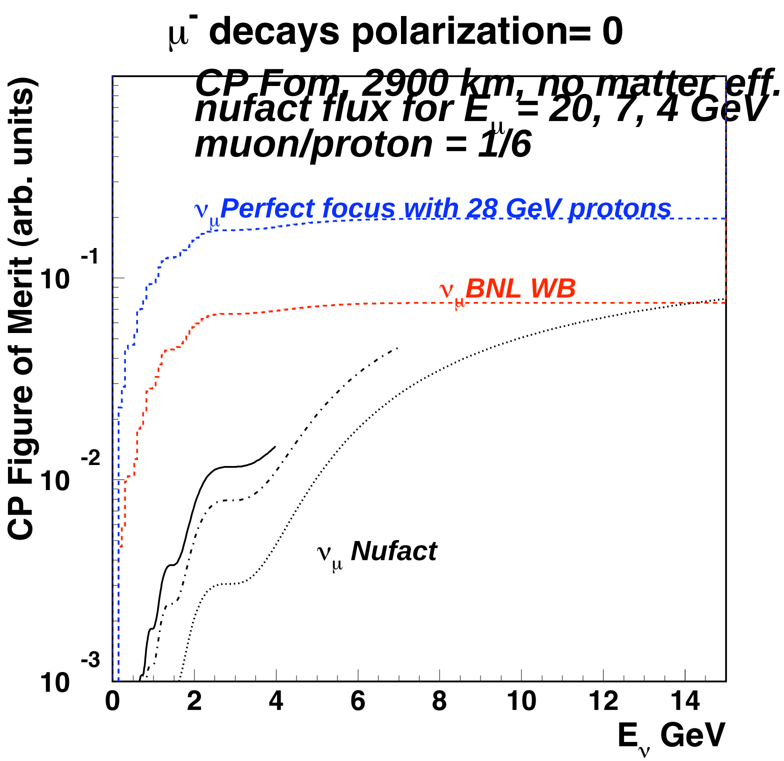
$$N \approx \int \phi(E)\sigma(E)\sin^2(\Delta m^2 L/4E)dE$$

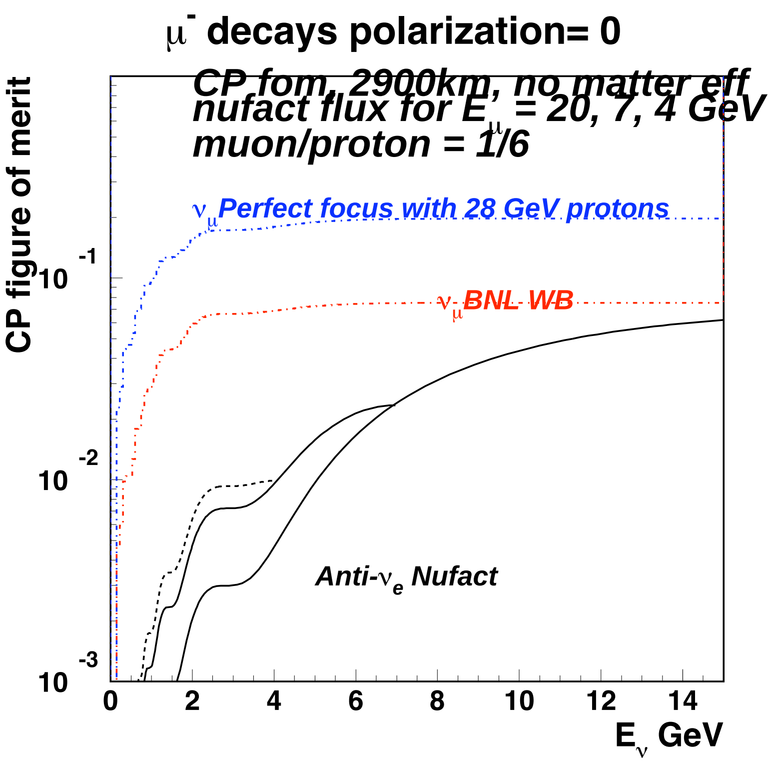
Figure of Merit is integral number of sigma squared

$$\int (F.O.M.)dE \propto \int (\alpha/E)^2 \times \phi(E)\sigma(E)\sin^2(\Delta m^2 L/4E)dE$$

This argument is approximately valid with/without matter effects.

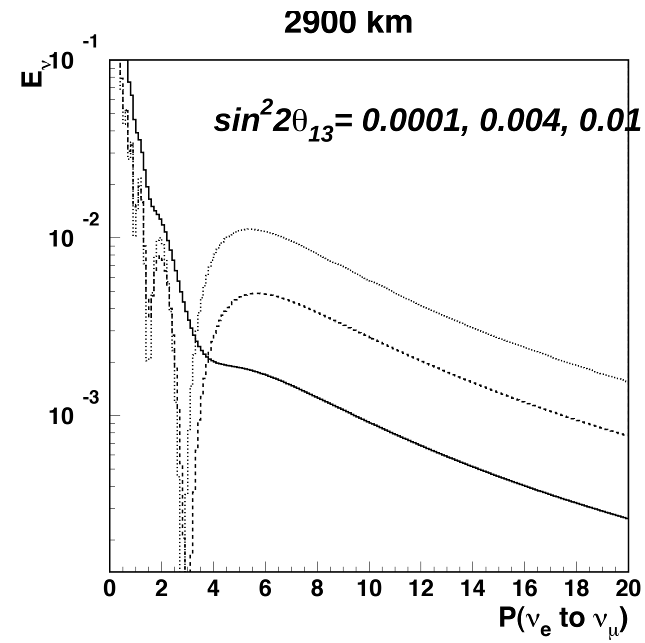
Large θ_{13} F.O.M.

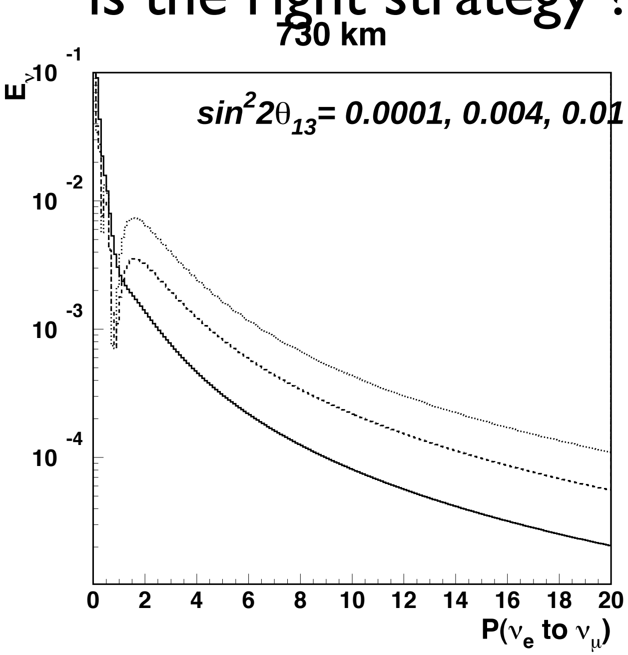


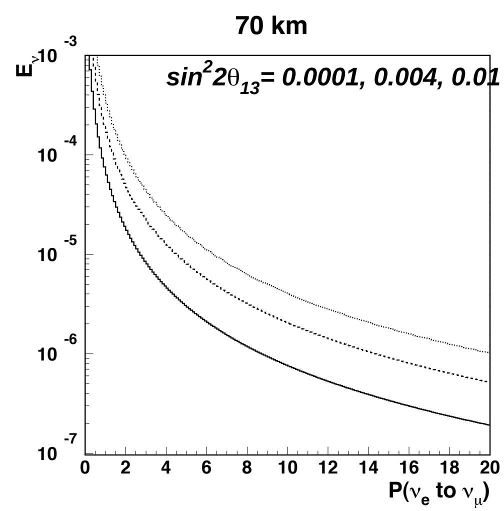


Nufact baseline optimization

- Was 3000 km chosen for CP or for q13 sens. ?
- If q13 very small and competes with solar what is the right strategy ?







Conclusions

- AGS upgrade cost estimate in June
- Better understanding of building 1 MW super beam.
- Beam cost estimate in June will be much more robust
- First order WC studies. Backgrounds probably acceptable but still need improvement.
- Solution exists for 500 kT det, but need more R&D