Overview :
What we want;
What we did

DUSEL Beam Working Group

Regina Rameika

June 2, 2008

The Intensity Frontier

The accelerator-based neutrino program

- Measurements of the mass and other properties of neutrinos are fundamental to understanding physics beyond the Standard Model and have profound consequences for understanding the evolution of the universe. The US can build on the unique capabilities and infrastructure at Fermilab, together with the proposed DUSEL, the Deep Underground Science and Engineering Laboratory proposed for the Homestake Mine, to develop a world-leading program in neutrino science. Such a program will require a multi-megawatt proton source at Fermilab.

- The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL laboratory and a high-intensity neutrino source at Fermilab.

Neutrino Program (cont)

- The panel recommends proceeding now with an R&D program to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL and recommends carrying out R&D on the technology for a large detector at DUSEL.

- Construction of these facilities could start within the period considered by this report.

- A neutrino program with a multi-megawatt proton source would be a stepping stone toward a future neutrino source, such as a neutrino factory based on a muon storage ring, if the science eventually requires a more powerful neutrino source. This in turn could position the US program to develop a muon collider as a long-term means to return to the energy frontier in the US

Neutrino Program (cont)

- The panel further recommends that in any funding scenario considered by the panel, Fermilab proceed with the upgrade of the present proton source by about a factor of two, to 700 kilowatts, to allow a timely start for the neutrino program in the Homestake Mine with the 700-kilowatt source.

These accelerator-based neutrino measurements are extremely challenging and have ambiguities in the interpretation of results. The proposed U.S. and Japanese programs take complementary approaches that together would greatly enhance the understanding of the underlying science. One particular advantage of the envisioned US program is the long baseline available from Fermilab to the Homestake site.

Neutrino Program (cont)

When they become available by about 2012, the results of θ_{13} measurements and the results of accelerator and detector R&D efforts should be used to optimize the design of the long-baseline neutrino physics program. At that point construction of the beamline and the first stage of a detector should proceed as rapidly as possible. If the decision is made to proceed with the multi–megawatt proton source, construction should start as soon as possible after the completion of the R&D program under all but the lowest funding scenarios. The lowest funding scenario would delay the construction start of a multi–megawatt proton source.

Neutrino Program (cont)

- The panel recommends support for R&D on the technology for a large detector at DUSEL. The nature of such a large detector is not yet clear. The two contending technologies are water Cerenkov and liquid argon. Large-scale water Cerenkov detectors are a mature technology, although at a smaller scale than is envisioned for DUSEL.

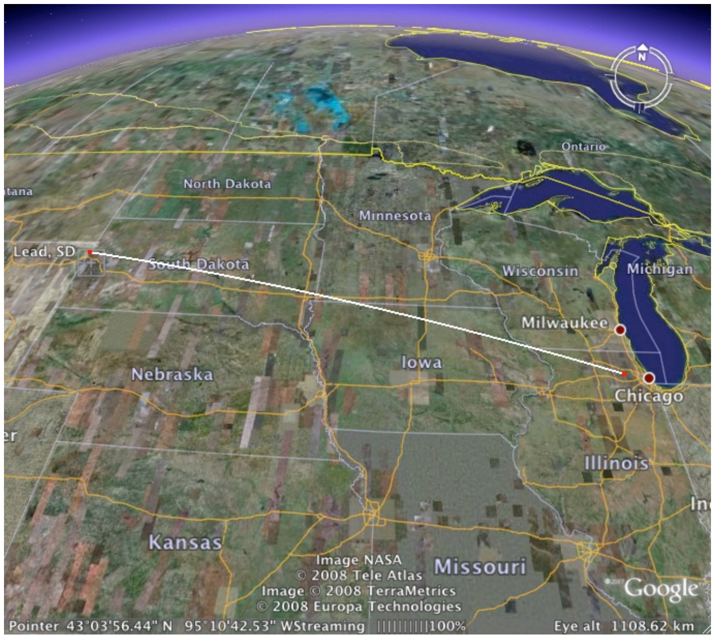
- The panel recommends support for a vigorous R&D program on liquid argon detectors and water Cerenkov detectors in any funding scenario considered by the panel. The panel recommends designing the detector in a fashion that allows an evolving capability to measure neutrino oscillations and to search for proton decays and supernovae neutrinos.

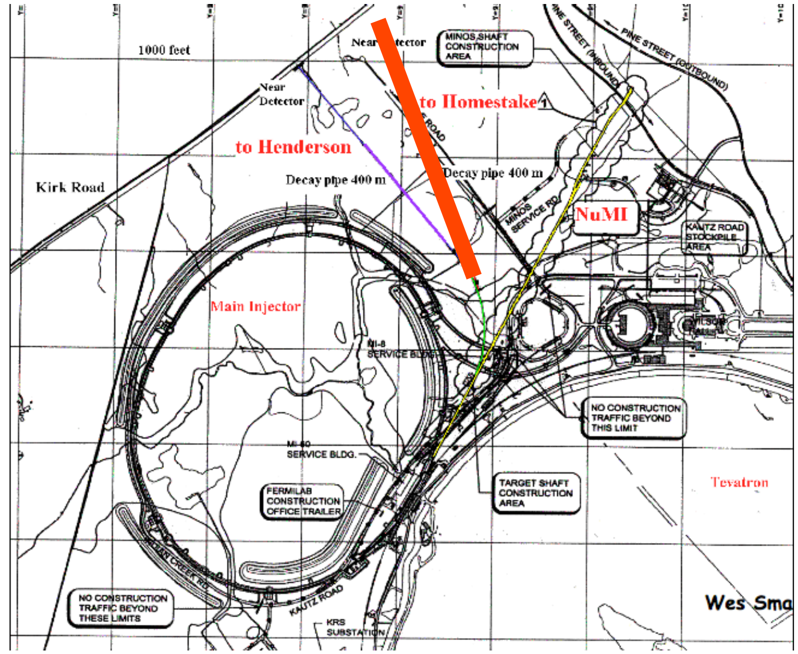
The DUSEL Facility

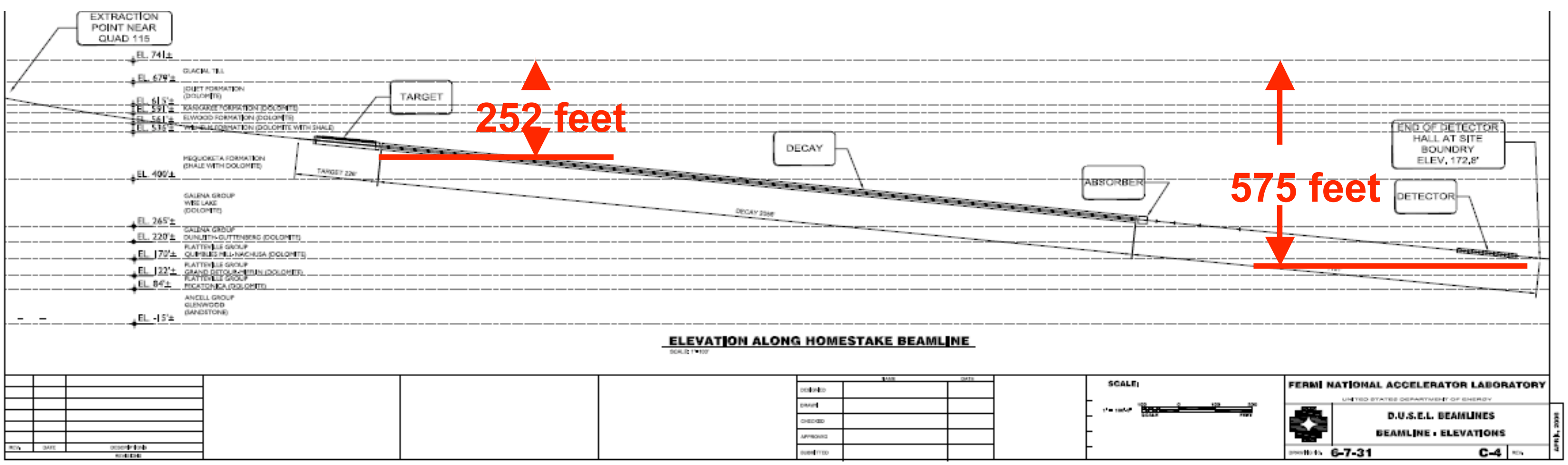
- The physics program of the Deep Underground Science and Engineering Laboratory is of central importance to particle physics. Experiments at DUSEL would address many issues, including neutrino physics, proton decay, dark matter, and neutrinoless double beta decay. DOE and NSF should define clearly the stewardship responsibilities for such an experimental program.

- The panel endorses the importance of a deep underground laboratory to particle physics and urges NSF to make this facility a reality as rapidly as possible.
- Furthermore the panel recommends that DOE and NSF work together to realize the experimental particle physics program at DUSEL.

Where is DUSEL ?



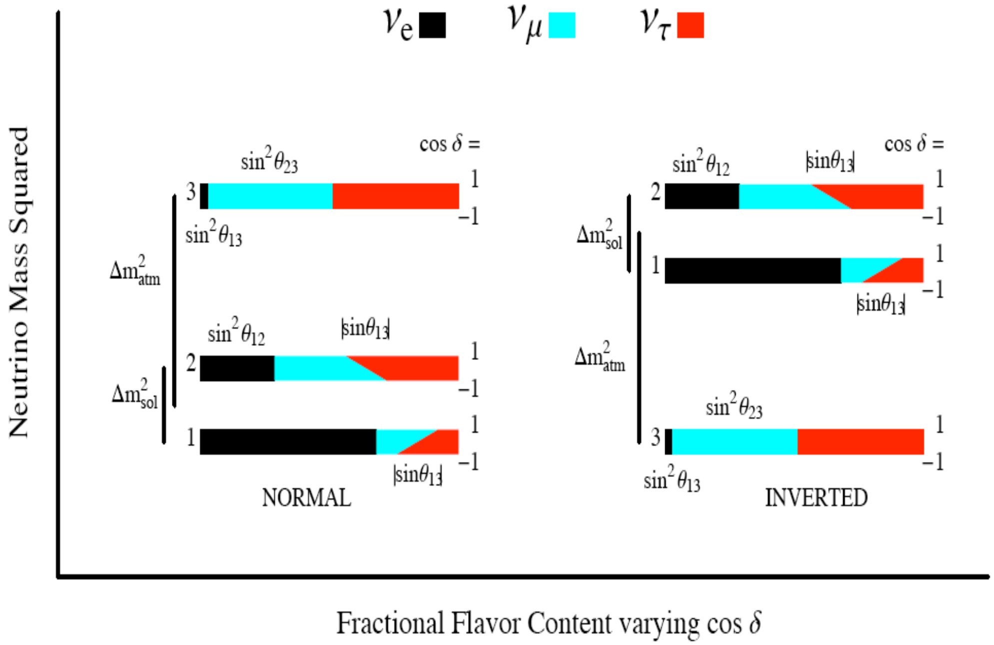




Outline

- What do we need for a DUSEL beam?
  - Experimental Goals
  - Proton beam requirements
  - Neutrino beam requirements
- What did we learn from building NuMI?
  - Summary of the time line
  - Evolution of the project - technical
  - Evolution of the project - cost & schedule
  - Lessons learned

The Questions for Long Baseline Neutrino Oscillation Experiments



- **What is the size of θ_{13}?**
- **Is the hierarch normal or inverted?**
- **What is the value of δ_{CP}?**

$$P(\nu_e \rightarrow \nu_\mu) = \sin^2\theta_{12}\ \sin^2(1.27\Delta m^2_{12}L/E)$$

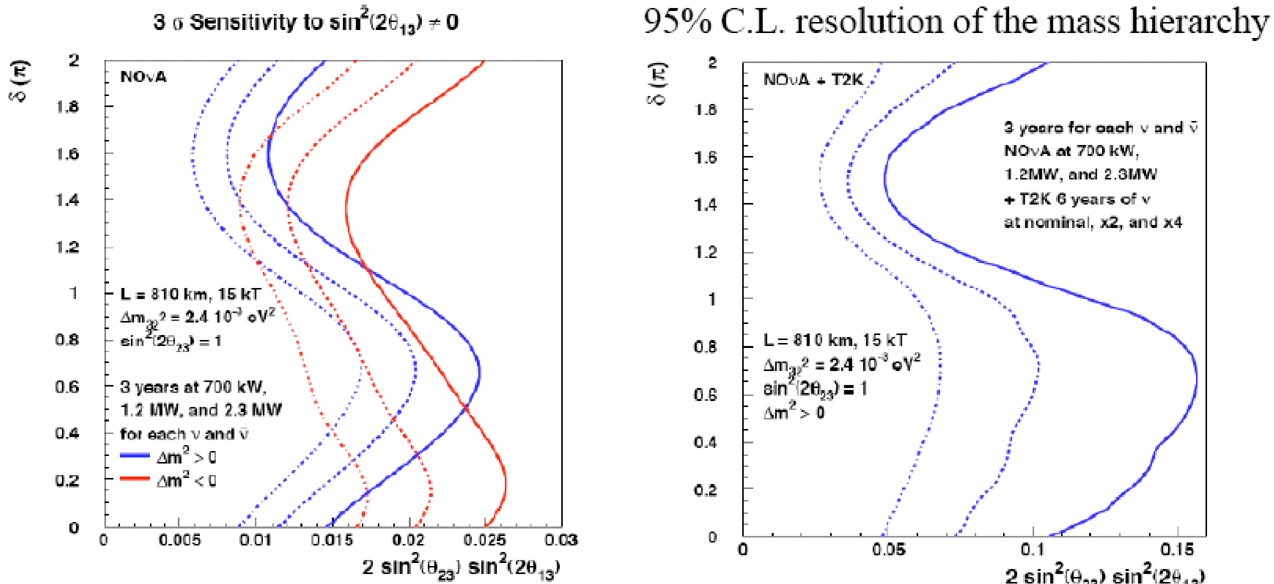
$$P(\nu_\mu \rightarrow \nu_\tau) = \sin^2\theta_{23}\ \sin^2(1.27\Delta m^2_{23}L/E)$$

$$P(\nu_\mu \rightarrow \nu_e) \approx \sin^2\theta_{23}\ \sin^2 2\theta_{13}\ \sin^2(1.27\Delta m^2_{31}L/E)$$

In vacuum; $\delta_{CP} = 0$

An experiment's sensitivity is measured in $\sin^2 2\theta_{13}$ and δ_{CP} space

NOvA Experiment Sensitivities (shown by G.Feldman at P5 2008 SLAC meeting)



Normal Ordering

Lines ~represent equal numbers

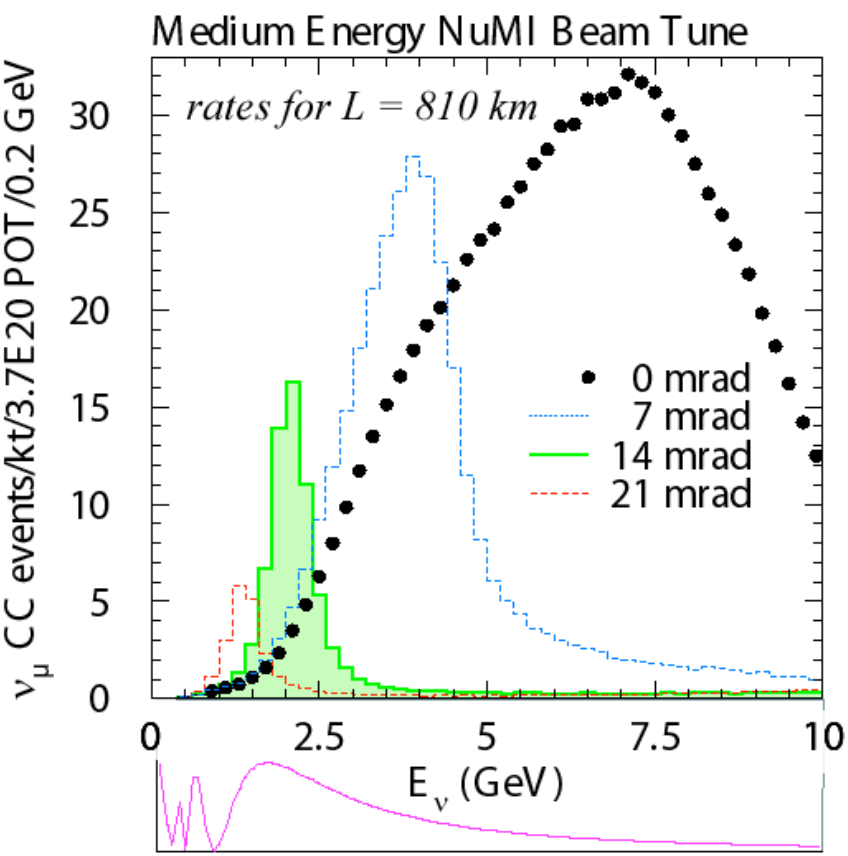
Of signal events for a given set of $\sin^2 2\theta_{13}, \delta_{CP}$

More neutrinos or more mass;

more neutrinos → instantaneous intensity+ time

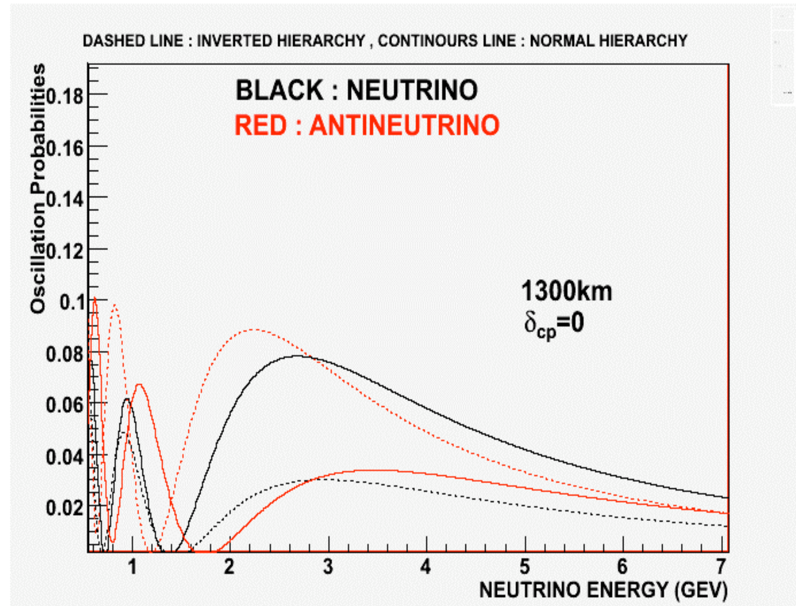
Experimental Techniques

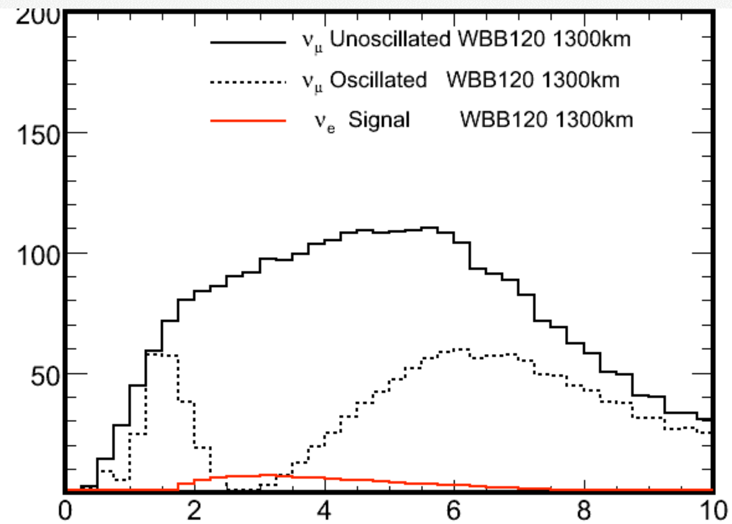
Off-axis/narrow band beam



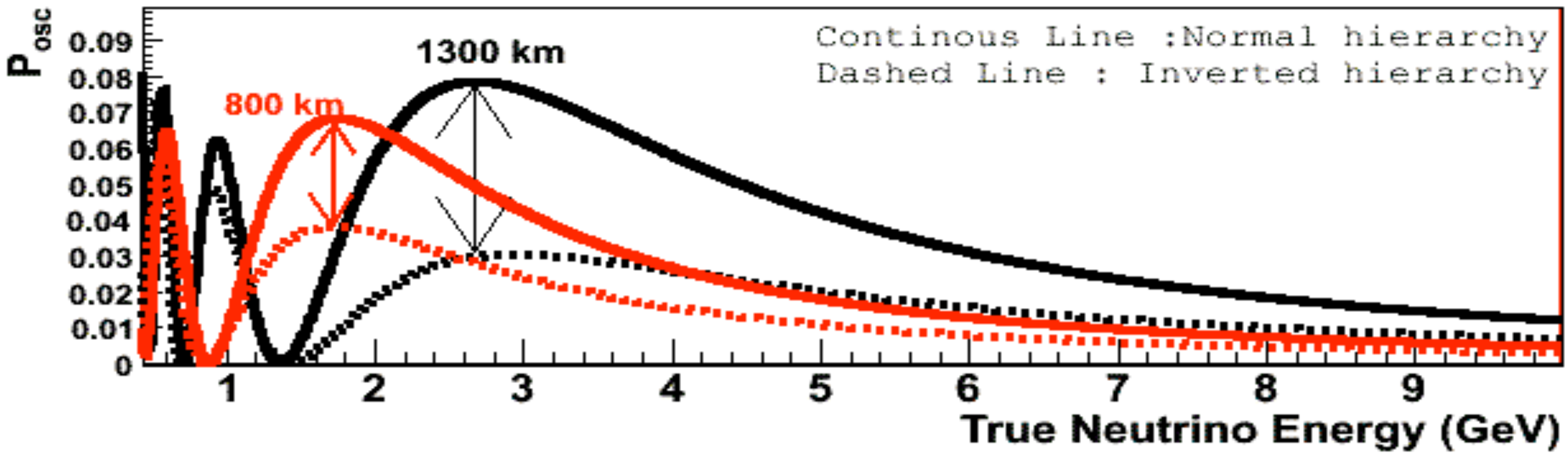
$\nu_\mu \rightarrow \nu_e$

On-axis/wide band beam



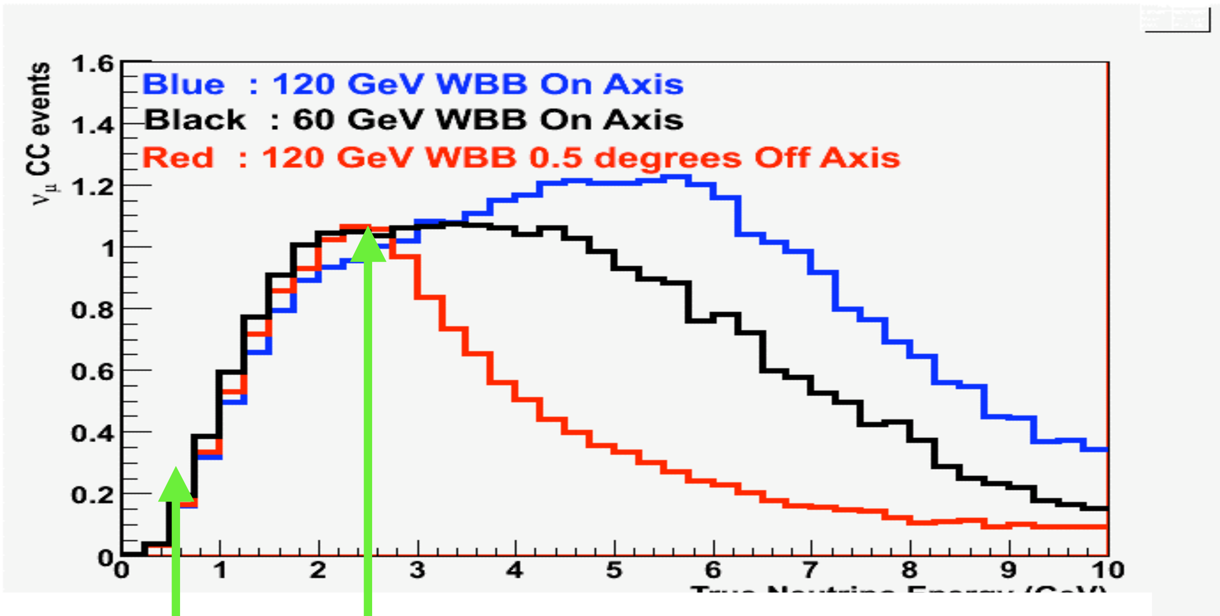


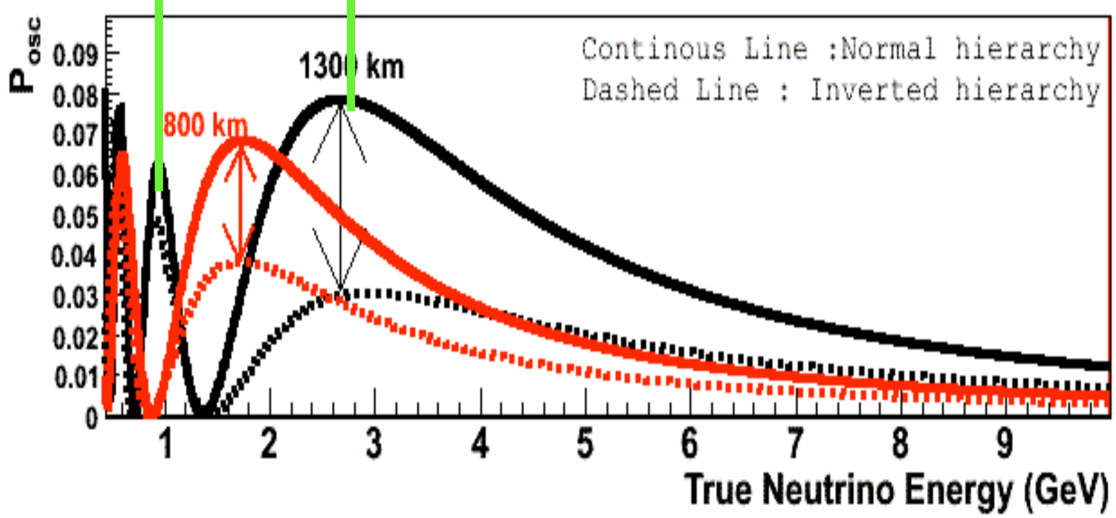
Why is the longer baseline so much better?



- Oscillation maxima are moved to higher energy
- Matter effects are significantly larger

The Main Idea : optimize the spectrum to the oscillation probability





		Neutrino Rates				Anti Neutrino Rates			
Beam (mass ordering)	$\boxed{\sin^2 2\theta_{13}}$	δ_{CP} deg.							
		0°	-90°	180°	+90°	0°	-90°	180°	+90°
NuMI LE 12 km offaxs (+)	0.02	76	108	69	36	20	7.7	17	30
NuMI LE 12 km offaxs (-)	0.02	46	77	52	21	28	14	28	42
NuMI LE 12 km offaxs (+)	0.1	336	408	320	248	86	57	78	106
NuMI LE 12 km offaxs (-)	0.1	210	280	224	153	125	95	126	157
NuMI LE 40 km offaxs (+)	0.02	5.7	8.8	5.1	2.2	2.5	1.6	0.7	3.3
NuMI LE 40 km offaxs (-)	0.02	4.2	8.0	5.7	2.0	2.3	2.2	0.8	3.6
NuMI LE 40 km offaxs (+)	0.1	17	24	15	9.4	6.7	2.8	4.6	8.5
NuMI LE 40 km offaxs (-)	0.1	12	21	16	7.7	6.6	3.4	6.4	9.6
WBLE 1300 km (+)	0.02	141	192	128	77	19	11	18	36
WBLE 1300 km (-)	0.02	58	111	88	35	45	25	45	64
WBLE 1300 km (+)	0.1	607	720	579	467	106	67	83	122
WBLE 1300 km (-)	0.1	269	388	335	216	196	154	196	240
WBLE 2500 km (+)	0.02	61	103	88	46	11	4.6	4.7	11
WBLE 2500 km (-)	0.02	16	36	33	13	28	15	18	31
WBLE 2500 km (+)	0.1	270	361	328	238	27	13	13	28
WBLE 2500 km (-)	0.1	47	92	85	39	103	74	80	109

Charge current events per **100kT mass per 1 MW per 10^7 sec**

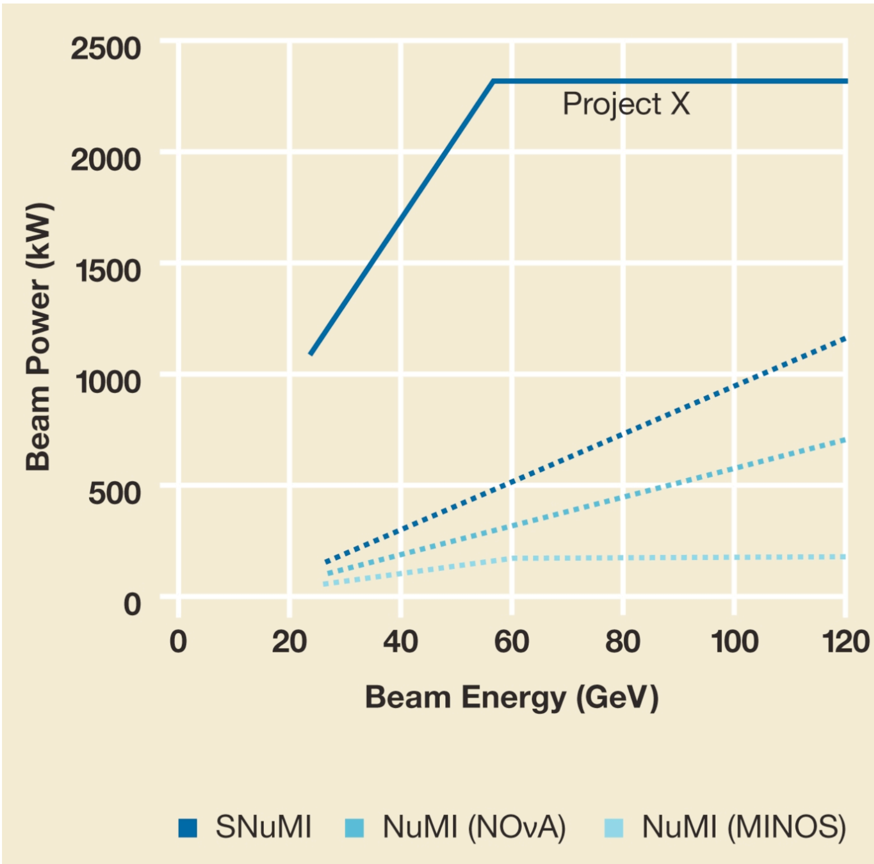
No detector model or backgrounds

(NuMI - 120 GeV
WBLE - 60 GeV)

DUSEL rates

~10-1000 evts

- 60 -120 GeV protons from the Main Injector fed by Project X



20-40x10^{20} POT/yr

10x10^{20} POT/yr

6x10^{20} POT/yr

3x10^{20} POT/yr

Recent sensitivity studies are being done for 120x10^{20} POT each ν and $\overline{\nu}$ (120 GeV)

$$POT(10^{20}) = \frac{1000 \times BeamPower(MW) \times T(10^7 s)}{1.602 \times E_p(GeV)}$$

Proton Beam Intensity Requirements

- Integrated intensity goal
  - 240 (480) x 10^{20} POT @ 120 (60) GeV
- Annual intensity goal
  - 20 (40) x 10^{20} POT @ 120 (60) GeV
- Instantaneous intensity
  - Single turn extraction (10μs every 1.4 sec)
    - No rate effects at far detector
  - 15×10^{14} per spill $\rightarrow$ 2 MW at 120 GeV

Neutrino Beam Requirements*

- The maximal possible neutrino fluxes to encompass at least the 1st and 2nd oscillation nodes, which occur at 2.4 and 0.8 GeV respectively
- Since neutrino cross-sections scale with energy, larger fluxes at lower energies are desirable to achieve the physics sensitivities using effects at the 2nd oscillation node
- To detect $\nu_\mu \rightarrow \nu_e$ at the far detector, it is critical to minimize the neutral-current contamination at lower energy, therefore minimizing the flux of neutrinos with energies greater than 5 GeV where there is little sensitivity to the oscillation parameters is highly desirable
- The irreducible background to $\nu_\mu \rightarrow \nu_e$ appearance signal comes from beam generated ν_e events, therefore, a high purity ν_μ beam with as low as possible ν_e contamination is required

**From "Simulation of a Wide-Band Low-Energy Neutrino Beam for Very Long Baseline Neutrino Oscillation Experiments", Bishai, Heim, Lewis, Marino, Viren, Yumiceva*

The general concept to date

- The present extraction of the Main Injector into the NuMI primary beam-line will be used.
- An additional tunnel will be constructed starting from the approximate location of the NuMI lower Hobbit door, at the end of the carrier tunnel, in order to transport the proton beam to the west.
- The radius of curvature of the tunnel bending west will be similar to the Main Injector curvature which will enable protons with energies up to 120 GeV to be steered along the bend using conventional magnets
- The target hall length is ≤ 45 m.
- A decay tunnel length of up to 400 m can be accomodated on the site assuming the near detector is 300m from the end of the decay pipe.
- The low energy neutrino flux can be enhanced by increasing the decay pipe radius. A radius of ~2 m would be desirable.
- For a ~2MW beam the concrete shielding needed around the decay pipe will be ~2.5m

Specifics : Targets and Horns

TABLE I: Target and beam parameters: NuMI and WBLE

Component	NuMI	WBLE
Target		
Shape:	47 rectangular segments	solid cylindrical rod
	each 6.4mm wide $\times$ 18mm high	12mm diameter
	and 20mm long	
	$= 0.954$ m total length	0.8 m total length
Material:	graphite	carbon-carbon composite
Density:	1.784 g/cm^3	2.1 g/cm^3
Cooling:	water cooling tubes	Helium flow cooled

TABLE II: Horn parameters: NuMI and WBLE

Component	NuMI	WBLE
Focusing magnetic horn 1		
Shape:	Double parabolic	AGS geometry
Conductor:	Al	Al
Inner conductor thickness:	2mm min	2.5 mm
	4.5mm (max at neck)	
Outer conductor :	12.07 inch ID 12.76 inch OD	15.75 inch ID 16.93 inch OD
	constant	maximum
Minimum aperture		
field-free neck:	9mm radius	7mm radius
Length:	3.3 m	2.19m
Current:	$\leq$ 200 kA	$\leq$ 250 kA
Cooling:	Water spray	Water spray

Focusing magnetic horn 2

Shape:	Double parabolic	AGS geometry
Conductor:	Al	Al
Inner conductor thickness:	3mm min 5mm max	1.5 mm
Outer conductor :	29.13 inch ID 29.82 inch OD constant	35.43 inch ID 37.26 inch OD maximum
Minimum aperture field-free neck:	3.9cm radius	5.8cm radius
Length:	3.58m	1.57m
Current:	$\leq$ 200 kA	$\leq$ 250 kA
Distance from H1 upstream end	10m	10m
Cooling:	Water spray	Water spray

Been there, done that…

NuMI : Chronology, Cost
Experience and Lessons Learned

NuMI Long Baseline Initiative

- May 1989 : Main Injector Physics Workshop : Soudan II as a long baseline neutrino detector
- March 1991 : Proposal for a Long Baseline Neutrino Oscillation Experiment using the Soudan 2 Neutrino Detector - P-822
- April 1991 - Conceptual Design Report : Main Injector Neutrino Program, Physics goals, Technical Concepts and Civil Construction: Chapter 3 - Long Baseline Neutrino Oscillation Experiments
- November 1991 : Long Baseline Neutrino Oscillation Workshop
- March 1992 : Update of P822, the Soudan 2 Proposal for a Long Baseline Neutrino Oscillation Experiment
- June 1993 : June 1993 update to the P822 proposal for a long baseline neutrino oscillation experiment
- October 1993 : Progress report and revised P822 proposal for a long baseline neutrino oscillation experiment from Fermilab to Soudan
- November 1993 : Project Definition Report, Rev. 0
- June 1994 : Project Definition Report, Rev. 1

- July 1994 : Open letter from J. Peoples to Physics community
  - Outlined Fermilab plan for short and long baseline experiments using a neutrino beam from the Main Injector
  - Time scale for starting 2000…
- December 1994 : Fermilab Director forms the NuMI Project
- February 1995 : P875 (MINOS) : A Long Baseline Neutrino Oscillation Experiment
- June 1995 : MINOS Proposal approved
- June 1995 : DOE conducts first cost review of the NuMI/MINOS project

Project definition evolution

Value Engineering

- PDR Rev. 0
  - Nov. 1993
  - LBL MI-60 (deep)
  - 320 m decay
- PDR Rev. 1
  - June 1994
  - LBL MI-60 (shallower)
  - 320 m decay
- Enclosure depth → construction technique
  - Rev. 0 *vs* Rev. 1
- Access shaft diameter vs depth requires optimization
  - Rev. 2+ *vs* Rev. 2
- PRD Rev. 1
  - June 1995
  - LBL MI-60
  - 800 m decay

Schedule

- Critical path is Civil Construction
  - $\rightarrow$ technically driven !
  - FY96
    - » conceptual design work
    - » Title I
  - FY97
    - » TitleII
  - FY98 - 00
    - » decay tunnel and target enclosure excavation ~ 2yrs
    - » begin experimental hall simultaneous with tunnels
      - benneficial occupancy of hall mid-00

The real issue : How much does it cost?

• Summary of Cost and Schedule

September 1997 - Project validation review

Facility cost based on June 97 CDR
Technical components (1st pass)
Detector - reference design (APTs & 4cm steel)

Presently preparing resource loaded schedules :

starting with ~ technically driven tasks;
adjusting to expected available resources

July 1998 - Project baseline review

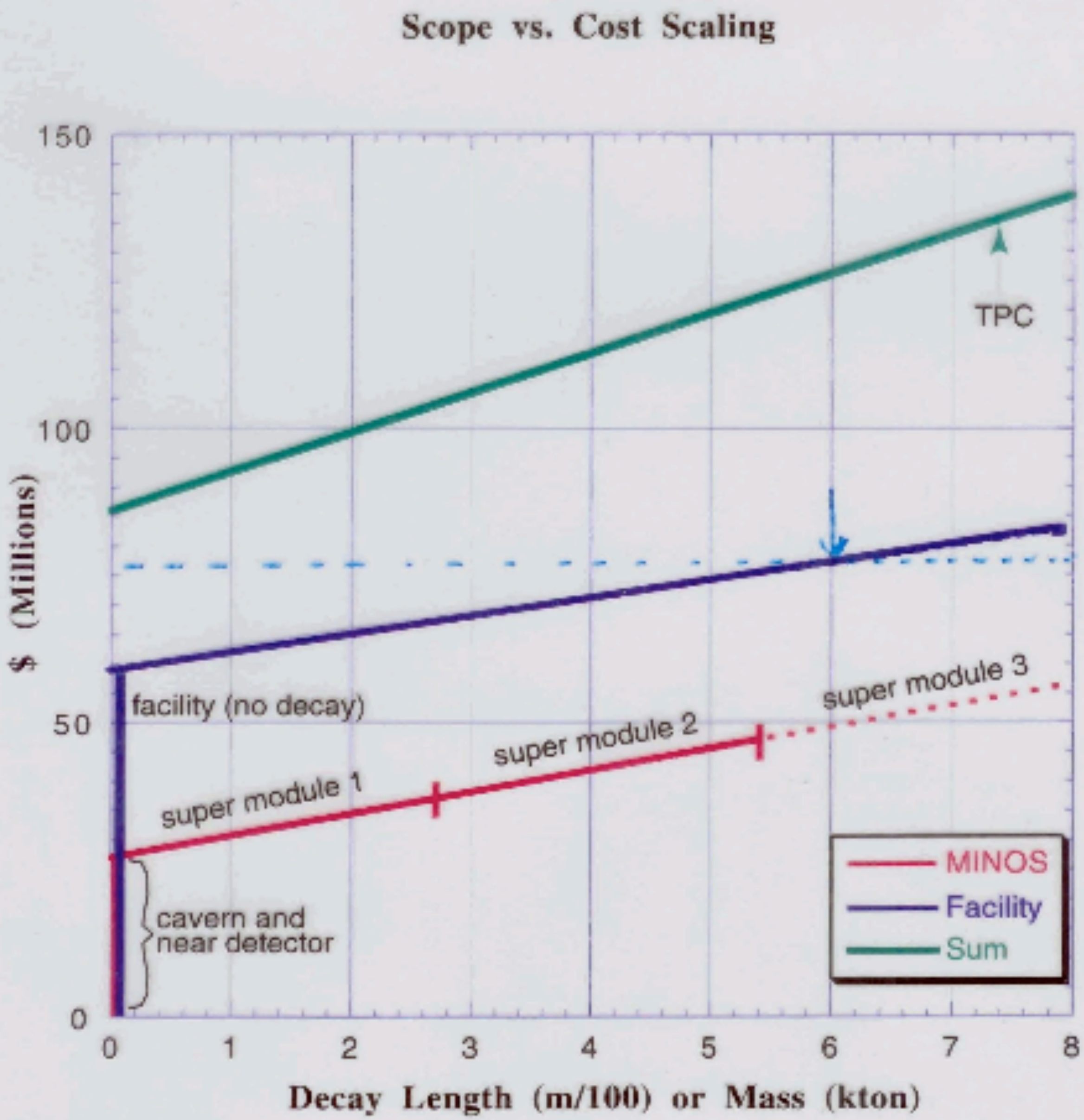
FY 99 CPDS* Funding Profile from DOE

	Prior	FY98	FY99	FY00	FY01	FY02	Total
TEC		\$5,500K	\$14,300K	\$28,000K	\$18,000K	\$10,000K	**\$ 75,800K**
OPC	\$1,300 K	\$1,500K	\$ 5,000K	\$19,500K	\$21,000K	\$11,200K	\$ 59,500K
TPC	\$1,300 K	\$7,000K	\$19,300K	\$47,500K	\$39,000K	\$21,200K	**\$135,300K**

*DOE Construction Project Data Sheet (Schedule 44)

The NuMI Project - Costs in the TPC

WBS		FY98	FY99	FY00	FY01	FY02	Total
1	**NuMI Facility Project**						
1.1	**Technical**	**0.44**	**1.57**	**2.78**	**3.36**	**1.92**	**10.07**
	EDIA	0.34	0.46	0.20	0.10	0.10	1.20
	Components(M&S,Instal.)		0.81	2.08	2.56	1.42	6.87
	Contingency	0.10	0.30	0.50	0.70	0.40	2.00
1.2	**Civil Construction**	**4.47**	**14.00**	**22.95**	**13.11**	**3.26**	**57.79**
	EDIA (Sum; incl. contingency)	4.47	1.20	1.15	1.10	0.24	8.16
	Contracts + Contingency		12.80	21.80	12.01	3.02	49.63
1.3	Project Management	0.59	1.43	2.27	1.54	0.82	6.65
	Direct SWF	0.25	0.50	1.00	0.50	0.25	2.50
	Total Indirect (G&A)	0.34	0.93	1.27	1.04	0.57	4.15
	TEC	**5.50**	**17.00**	**28.00**	**18.00**	**6.00**	**74.50**
2	NuMI Long baseline Detectors						
	MINOS Baseline detector		**3.00**	**7.00**	**15.00**	**7.00**	**32.00**
	Management Reserve			3.00	5.00	5.00	13.00
Sub-total			3.00	10.00	20.00	12.00	45.00
3	Other Project Costs						
3.1	Detector Prototypes	1.30					1.30
3.2	Conceptual Design	0.10					0.10
3.3	**Soudan Laboratory**	0.10	**2.00**	**3.00**	**1.00**		**6.10**
Sub-total		1.50	2.00	3.00	1.00		7.50
	TPC FY98-02	**7.00**	**22.00**	**41.00**	**39.00**	**18.00**	**127.00**
	Minnesota Internal Bonding		-2.00	-1.00			
	Repayment of UMinn loan				1.00	2.00	
	Net DOE Funding Required	**7.00**	**20.00**	**40.00**	**40.00**	**20.00**	
	DOE Guidance (FY99-02)		**20**	**40**	**40**	**20**	



Scope vs. Cost Scaling
150
100
50
0
$ (Millions)
0
1
2
3
4
5
6
7
8
Decay Length (m/100) or Mass (kton)
TPC
facility (no decay)
super module 1
super module 2
super module 3
cavern and
near detector
MINOS
Facility
Sum

- June 1996 : DOE Issues Mission Need Statement (~CD-0)
- September 1997 : Conceptual Design for the Technical Components of the Neutrino Beam for the Main Injector (NuMI) (TM-2018)
- May 1997 : Budget Validation Review
- September 1997 : Project Validation Review (~ CD-1)
- October 1997 : $5.5M appropriated for Conceptual Design
- October 1998 : The NuMI Facility Technical Design Report
- November 1998 : Project Baseline Review (~CD-2)

Sheet1

WBS	Description	Rev. 0 Nov-93	Rev. 1 Jun-94	Rev. 2 May-95	Rev. 2.1 Jun-95
	NuMI Civil Construction Cost Analysis and Estimates				
1.2.1	**SITE WORK**				
1.2.1.1	Wetlands Mitigation	400,000	500,000	350,000	350,000
1.2.1.2	Site Work and Utilities	1,535,000	1,604,000	3,003,000	3,003,000
1.2.1.3	Landscaping	180,000	180,000	180,000	180,000
	SUBTOTAL 1.2.1	2,115,000	2,284,000	3,533,000	3,533,000
1.2.2	**Facilities Construction**				
1.2.2.1	Extraction enclosure	293,000	164,000		
1.2.2.2	Carrier pipe	1,011,000	460,000	445,000	459,000
1.2.2.3	Pretarget enclosure	2,326,000	358,000	758,000	777,000
1.2.2.4	Target tube enclosure	2,334,000	3,463,000		
1.2.2.5	Target hall				
1.2.2.5.1	Shaft and Cavern	4,337,000	1,382,000	3,491,000	3,565,000
1.2.2.5.2	Service Building	1,026,000	960,000	1,067,000	1,067,000
1.2.2.6	Decay Pipe	4,330,000	4,273,000	6,360,000	6,377,000
1.2.2.7	Dump				
	Shaft and Cavern	2,256,000	1,812,000	1,898,000	1,917,000
	Service Building	77,000	77,000	82,000	82,000
1.2.2.8	Experimental Hall				
	Shafts and Cavern	4,596,000	3,283,000	7,104,000	4,893,000
	Service Building	1,679,000	1,724,000	2,725,000	2,275,000
	SUBTOTAL 1.2.2	24,265,000	17,956,000	23,930,000	21,412,000
	SUBTOTAL 1.2.1 & 1.2.2	**26,380,000**	**20,240,000**	**27,463,000**	**24,945,000**
	Subcontractor OH&P	3,957,000	3,036,000	4,119,450	3,741,750
	SUBTOTAL	30,337,000	23,276,000	31,582,450	28,686,750
	Testing Services	625,000	625,000	625,000	625,000
	SUBTOTAL	30,962,000	23,901,000	32,207,450	29,311,750
1.2.3	**EDIA Site Work/Facilities**	6,502,020	5,019,210	6,763,565	6,155,468
	SUBTOTAL	**37,464,020**	**28,920,210**	**38,971,015**	**35,467,218**
	Contingency	4,121,042	3,181,223	4,286,812	3,901,394
	Management Reserve	4,121,042	3,181,223	4,286,812	3,901,394
	TOTAL	**45,706,104**	**35,282,656**	**47,544,638**	**43,270,005**

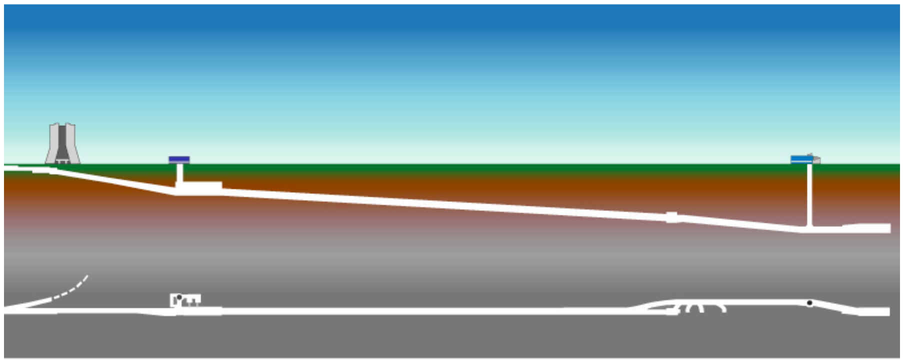
June ‘95
Civil ~ $45 M

Soudan Cavern Cost Estimates

	Feb-95 Proposal	Apr-98 TDR	Escallation	% increase
Pre-Construction				
Boring and Testing	$23,000	$13,173		
Shaft, Hoisting System and Shaft Station	$150,000	$129,727		
EAW and SHPO		$33,428		
Construction Preparation		$76,104		
Sub-total Pre-construction	**$173,000**	**$252,432**	$79,432	45.91%
EDIA				
CNA Design	$327,799	$689,524		
DNR consultant		$25,000		
Construction Supervision	$327,799	$510,113		
Sub-total EDIA	**$655,598**	**$1,224,637**	$569,039	86.80%
Construction				
Mobilization and Bond	$150,000	$291,412		
Surface Preparation and Rehabilitation	$25,000	$101,570		
Entrance Tunnel	$162,500	$174,061		
Laboratory Excavation	$1,147,500	$1,376,852		
Muck Hoisting and Disposal	$478,125	$705,685		
Shotcrete	$92,500	$144,375		
Shotcrete Rebar	$41,000	$51,185		
Rockbolts	$123,750	$184,858		
Tunnel to Soudan 2	$135,000	$70,956		
Concrete floor	$127,500	$134,074		
Finishing	$50,000	$98,742		
Trucking Premium for Concrete	$76,700	$95,791		
Sub-total Construction	**$2,609,575**	**$3,429,561**	$819,986	31.42%
Permanent Ventilation	$125,000	$170,610		
Permanent Electrical Sytem and Lighting	$100,000	$381,167		
Fire Supression	$30,000	$69,224		
Crane and Crane Support	$400,000	$252,200		
Drainage		$16,081		
Steel Structures		$91,931		
Finishing		$100,300		
Sub-total Outfitting	**$655,000**	**$1,081,513**	$426,513	65.12%
Hoisting Operations				
DNR Personnel	$360,000	$341,070		
Electricity and Equipment Replacement	$100,000	$77,520		
Hoist trips		$602,303		
Sub-total Hoisting	**$460,000**	**$1,020,893**	$560,893	121.93%
Contingency	20%	25%		
EDIA		$182,662		
Pre-construction	$30,000	$38,312		
Construction	$521,915	$857,390		
Outfitting	$131,000	$270,378		
Hoisting	$92,000	$255,223		
Sub-total Contingency	**$774,915**	**$1,603,965**	$829,050	106.99%
Grand Total	**$5,328,088**	**$8,613,001**	**$3,284,913**	61.65%
Expected Minnesota contribution	**$3,350,000**	**$3,600,000**		
Required NuMI Project Funds	**$1,978,088**	**$5,013,001**		

Actual : $10,769

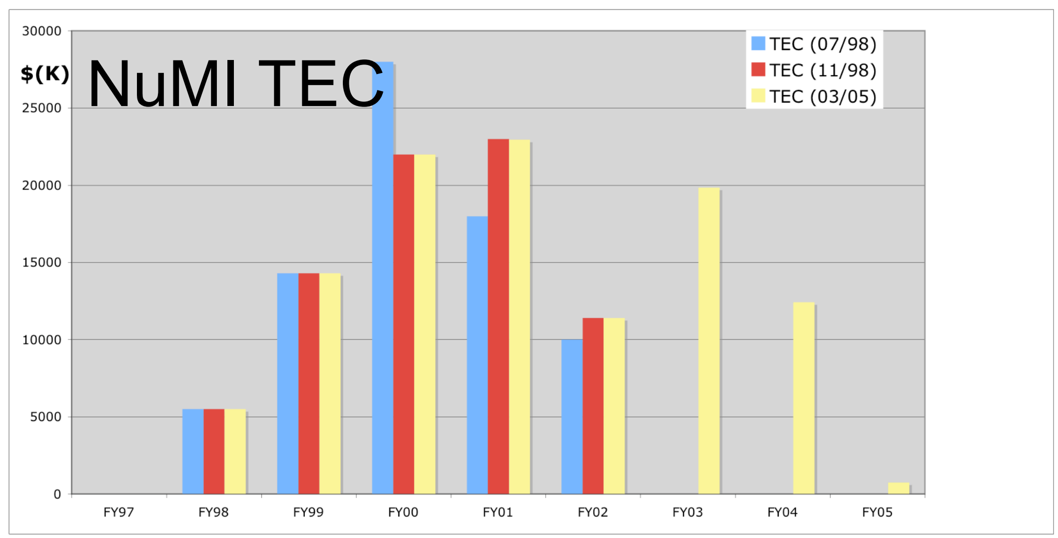
Finally, a ν beam project ….



NuMI Civil construction : $75M
NuMI Technical components : $30M
AY$ at project completion 03/05

2001 re-baseline added
*$33M to the TEC**
More recent projects have been required to incorporate larger initial contingency

Civil construction included:
2 access shafts
Target & absorber halls
2m diameter x
675m shielded decay tunnel
By-pass tunnel
Near Detector hall



**OPC was only slightly adjusted to match re-baseline schedule*

TEC Actuals : 2005 AY $

		Direct	Indirect	% indirect	Comment
1.1.1	Technical components	4892	1094	22%	SWF + M&S
1.1.2	Neutrino Beam Devices	9520	2279	24%	SWF + M&S
1.1.3	Power Supply System	4407	1072	24%	SWF + M&S
1.1.4	Hadron Decay and absorber	1294	290	22%	SWF + M&S
1.1.5	Neutrino Beam Monitoring	455	26	6%	university
1.1.6	Alignment Systems	192	60	31%	mostly SWF
1.1.7	Water, vacuum and Gas	1747	434	25%	SWF + M&S
1.1.8	I & I	1738	415	24%	SWF + M&S
1.1	Total	24245	5670	23%	SWF + M&S
1.2.1	Conceptual Design	49	21	43%	FESS
1.2.2	EDIA - Title I	1254	184	15%	sub-contract
1.2.3	EDIA - Title II	2620	355	14%	sub-contract
1.2.4	**Construction**	**68572**	1596	2%	procurement
1.2	Total	72495	2156		
	EDIA total	3874			
	% EDIA	**6%**			
1.3	Project Management	2413	768	32%	
	% Project Management	**2%**			
1	TEC Total	99153	8594	9%	

IV. FUNDING SUMMARY (K$)

Funding Summary (as of 2/28/2005), amounts in thousands

YEAR	TEC (NuMI Facility) Appropriations	OPC (MINOS, Soudan) Obligations Actual costs through FY04. Plan from Baseline Change Proposal	
Prior FY's	0	1,417 actual	
FY98	5,500	2,348 actual	
FY99	14,300	4,114 actual	
FY00	22,000	11,324 actual	
FY01	22,949[1]	13,598 actual	
FY02	11,400	17,227 actual	
FY03	19,842[1,2,3]	7,067 actual	
FY04	12,426[2,4]	2,109 actual	
FY05	745[2,3,4,5]	2,996	
TOTALS	**109,162**	**62,200**	171,362

Note [1]: FY01 Rescission removed $51K from plant line and $26K from OPC. We planned the restoration of these funds in FY03.

Note [2]: FY03, FY04, and FYY05 plant line funds as recommended for inclusion in the Baseline Change Proposal by the September DOE Review and approved in December 2001. This is the $33.042M in additional funding in the rebaseline proposal from Project Management.

Note [3]: FY03 Rescission removed $251K from plant line. We show the restoration of these funds in FY05.

Note [4]: FY04 Rescission removed $73.750K from plant line. FY05 Rescission removed $6.256K. This funding was NOT restored and the TPC of the project was correspondingly reduced.

TEC Funding Appropriated,
Not yet authorized
0

Total TEC funding authorized
109,162[5]

TEC Obligations to date, (Not including requisitions in progress)
108,169 59,562 **OPC Obligations to date**

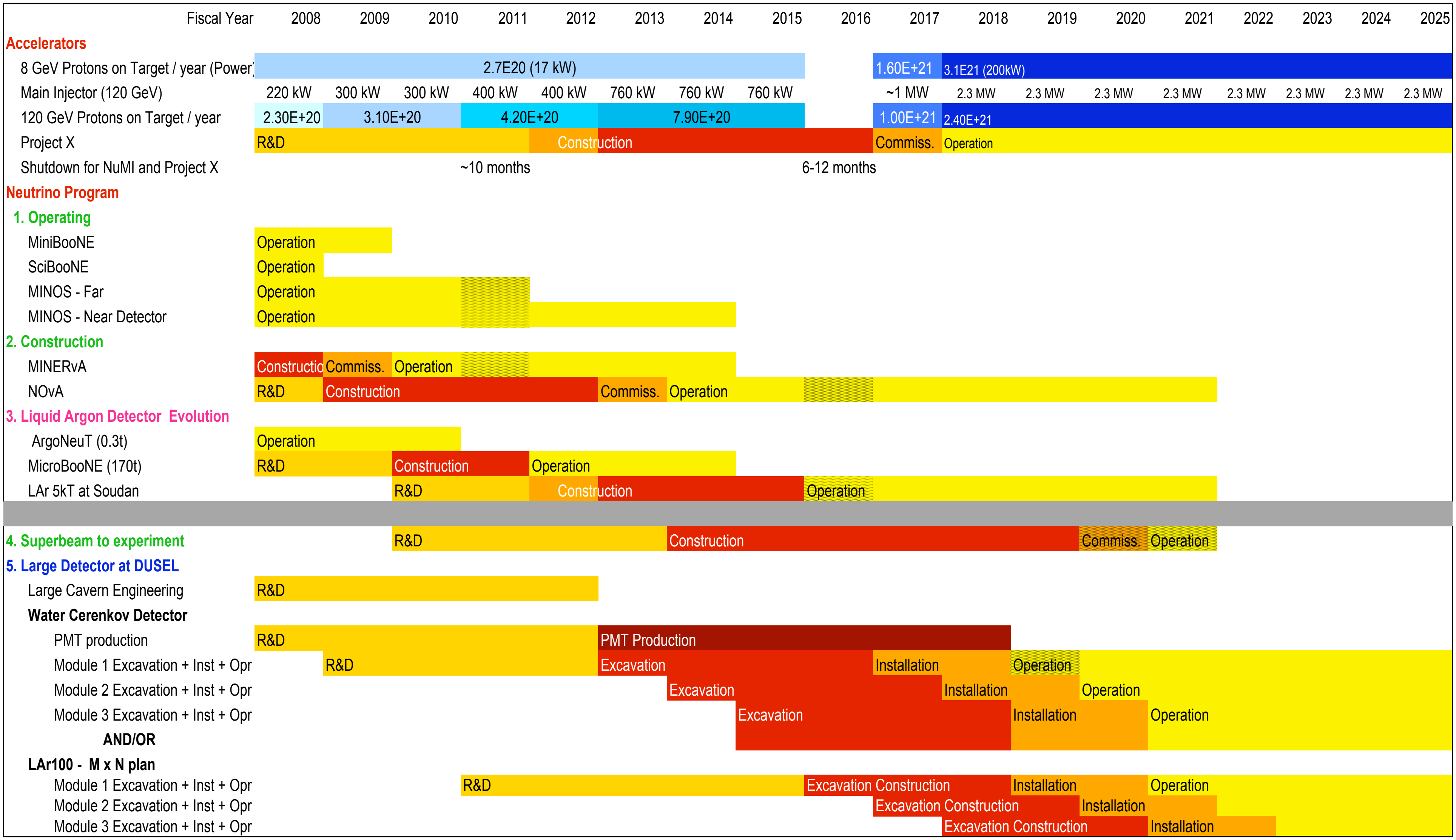
TEC Funding authorized but not obligated
993

Note [5]: Full FY05 allocation.

Lessons Learned

- Every project takes longer than you think it will
- Every project costs more than you think it will/should
- Projects planned over a long period of time will experience lots of rule changes
- Over a 10 year period of planning a project, there is a good chance that the Physics goals and world wide context of the project will change
- Projects planned over a long period of time need to have scope flexibility (even though that is generally against the rules…)
- Most important : In the early stages (first 5 years) the NuMI Project design team was pitifully understaffed, and supported in words only (NO real engineering resources allocated), leading to a prolonged project launching

Program Evolution



Roadmap for Funding Scenario B