The Beamline for the DUSEL Long Baseline ν Experiment

APS April Meeting 2009, Denver, CO 1/3/09

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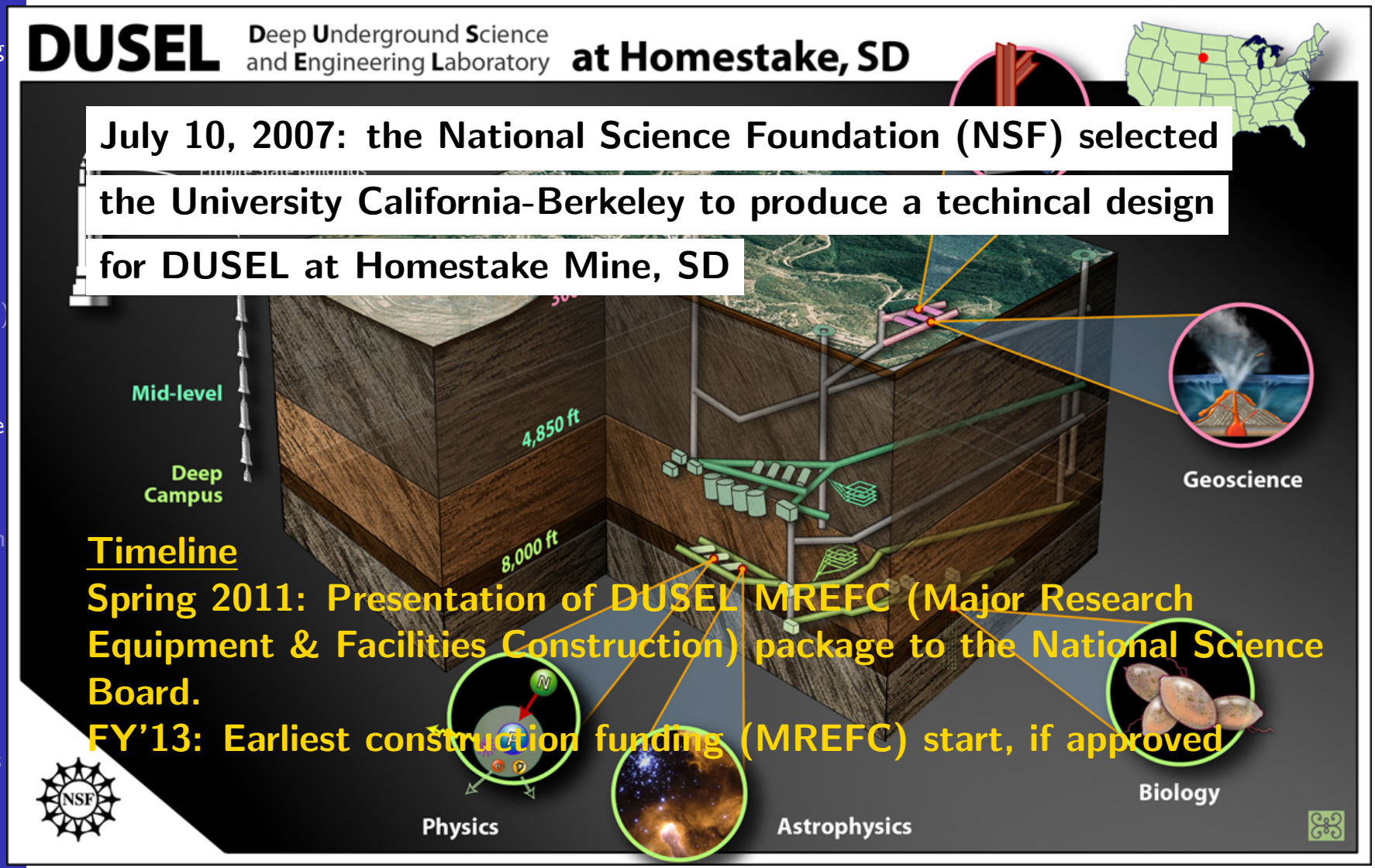
(DUSEL Collaboration)

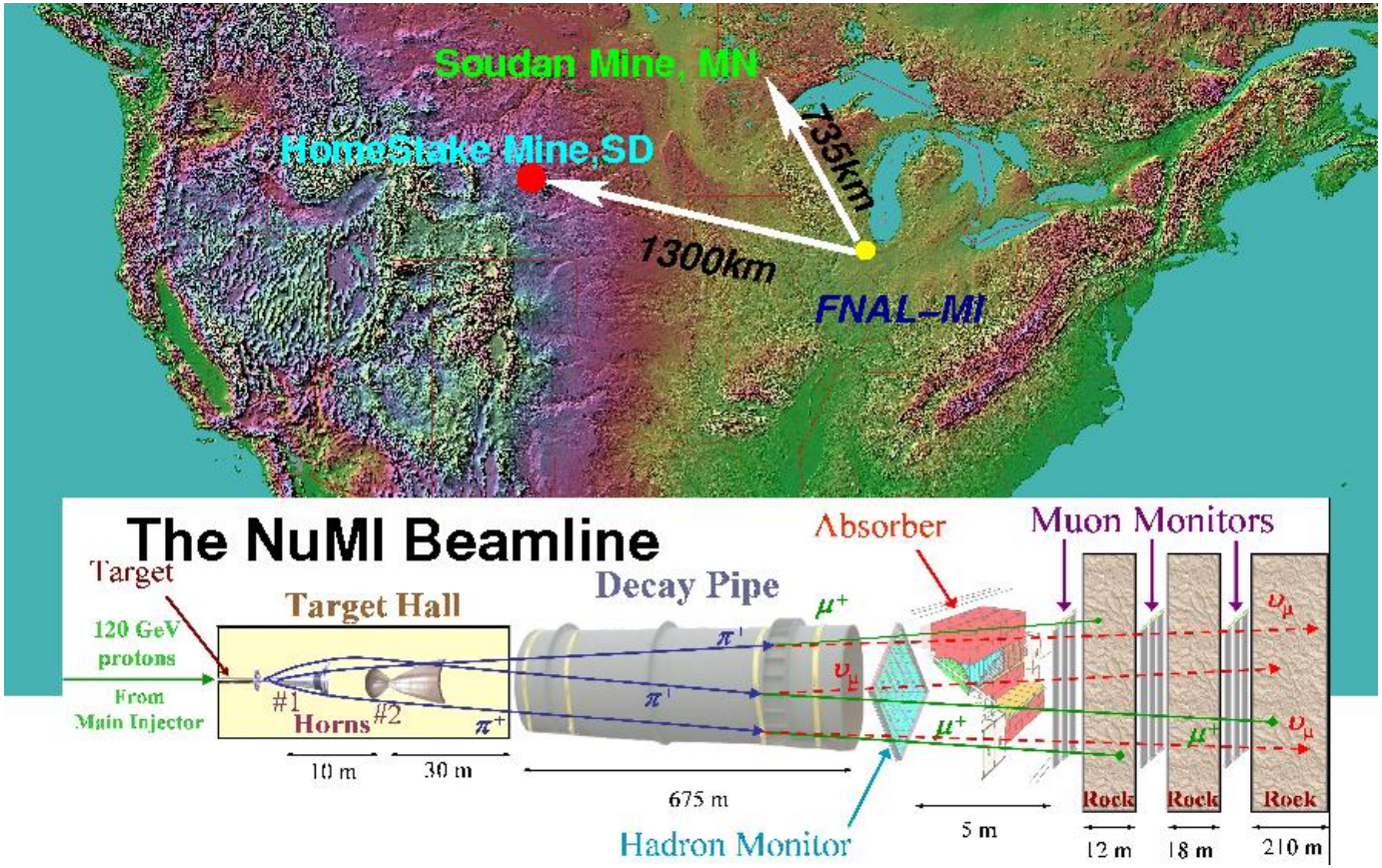
May 2, 2009

Outline

Deep Underground Science and Engineering Laboratory



The DUSEL Long Baseline ν Experiment



GOAL: Search for $\nu_\mu \rightarrow \nu_e$ appearance using massive detectors at DUSEL

See Mark Dierckxsens presentation on DUSEL LBNE physics

Needs a high power, high purity ν_μ beam from Fermilab

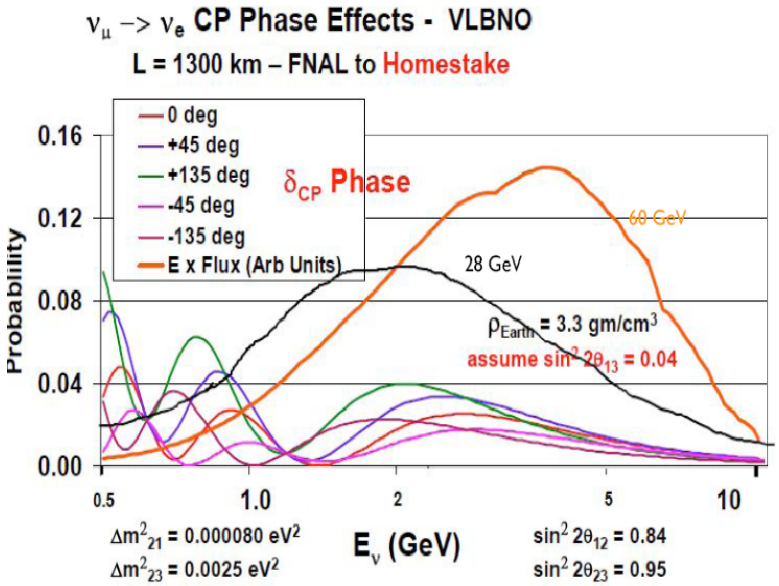
The DUSEL Long Baseline ν Experiment Collaboration

Institutions: ANL, Boston, BNL, Caltech, UC Davis, UC Irvine, UCLA, Chicago, Colorado State, Columbia, Drexel, Duke, FNAL, Indiana, INFN(Catania), Kansas State, LANL, LLNL, LBL, LSU, Maryland, MIT, Minnesota, Minnesota (Duluth), Penn, Princeton, RPI, S. Carolina, Tennessee, Texas, Tufts, Wisconsin, Yale

Collaboration meeting 2/26-2/28, 2009 at UC Davis, CA

Requirements of the FNAL-Homestake Beam

The design specifications of a new WBLE beam based at the Fermilab MI are driven by the physics of $\nu_\mu \rightarrow \nu_e$ oscillations:



L = 1300 km

Requirements:

-Maximal possible neutrino fluxes to encompass the 1st and 2nd oscillation nodes, with maxima at 2.4 and 0.8 GeV.

-High purity ν_μ beam with negligible ν_e

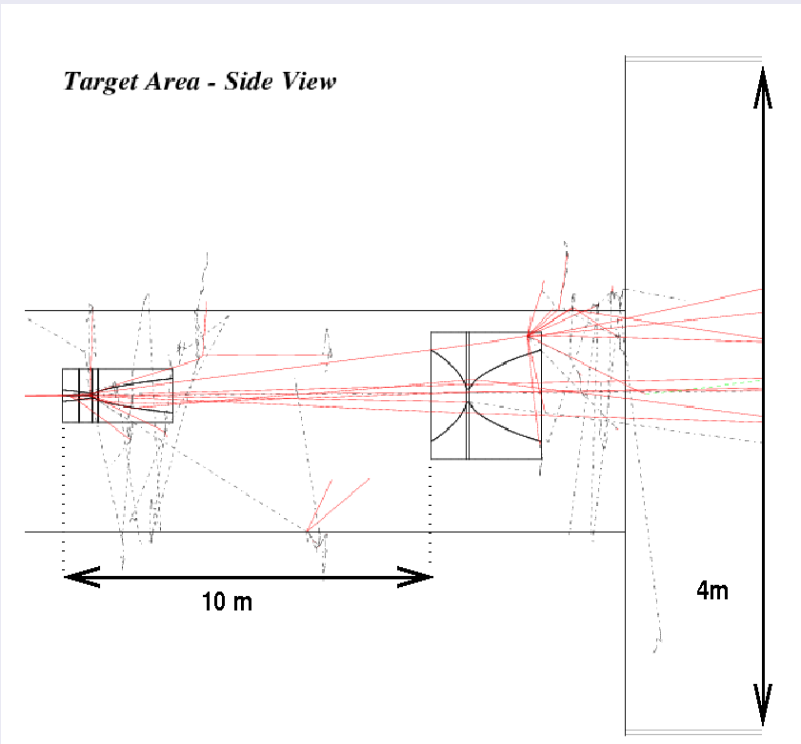
-Minimize the neutral-current feed-down contamination at lower energy, therefore minimizing the flux of neutrinos with energies greater than 5 GeV is highly desirable.

Need to produce a conceptual design for the beamline by 2010

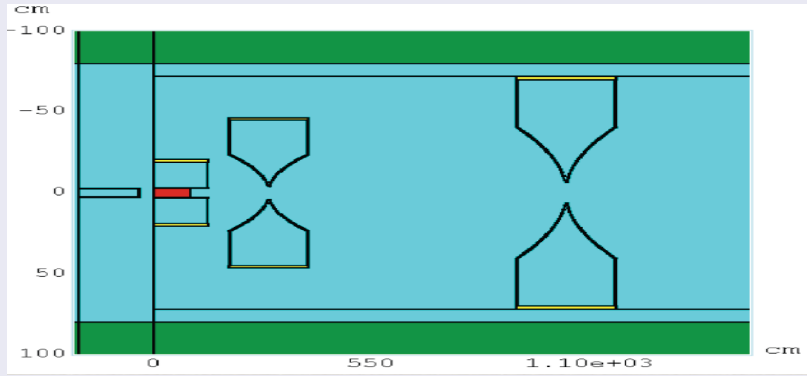
Focusing system alternatives

Two *INDEPENDANT* efforts on focusing system designs

M. Bishai Fluka05/GEANT3 (NuMI)



B. Lundberg MARS (T2K-like)

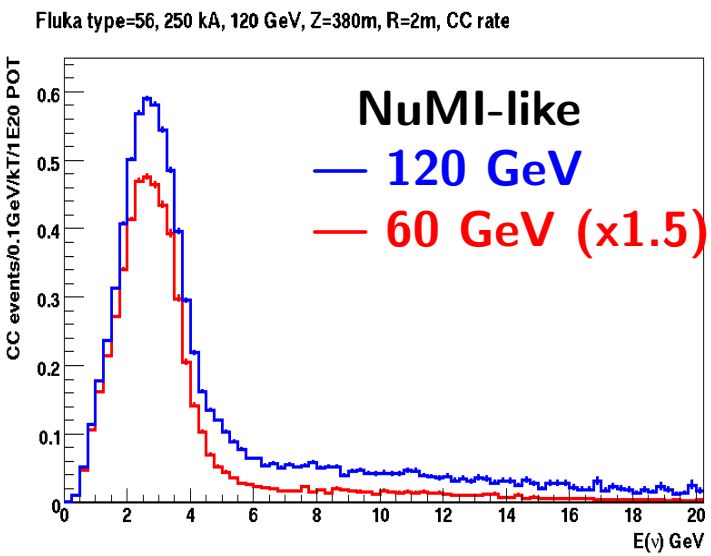


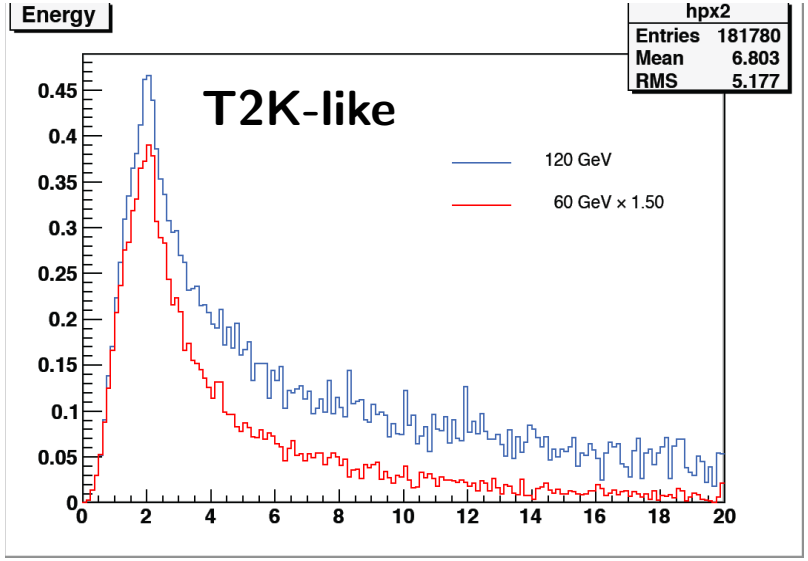
Both designs use fully embedded carbon targets and similar horn 2

In a 2 horn system, optimal separation = 6m (both designs)

Beam spectra from 2 alternatives

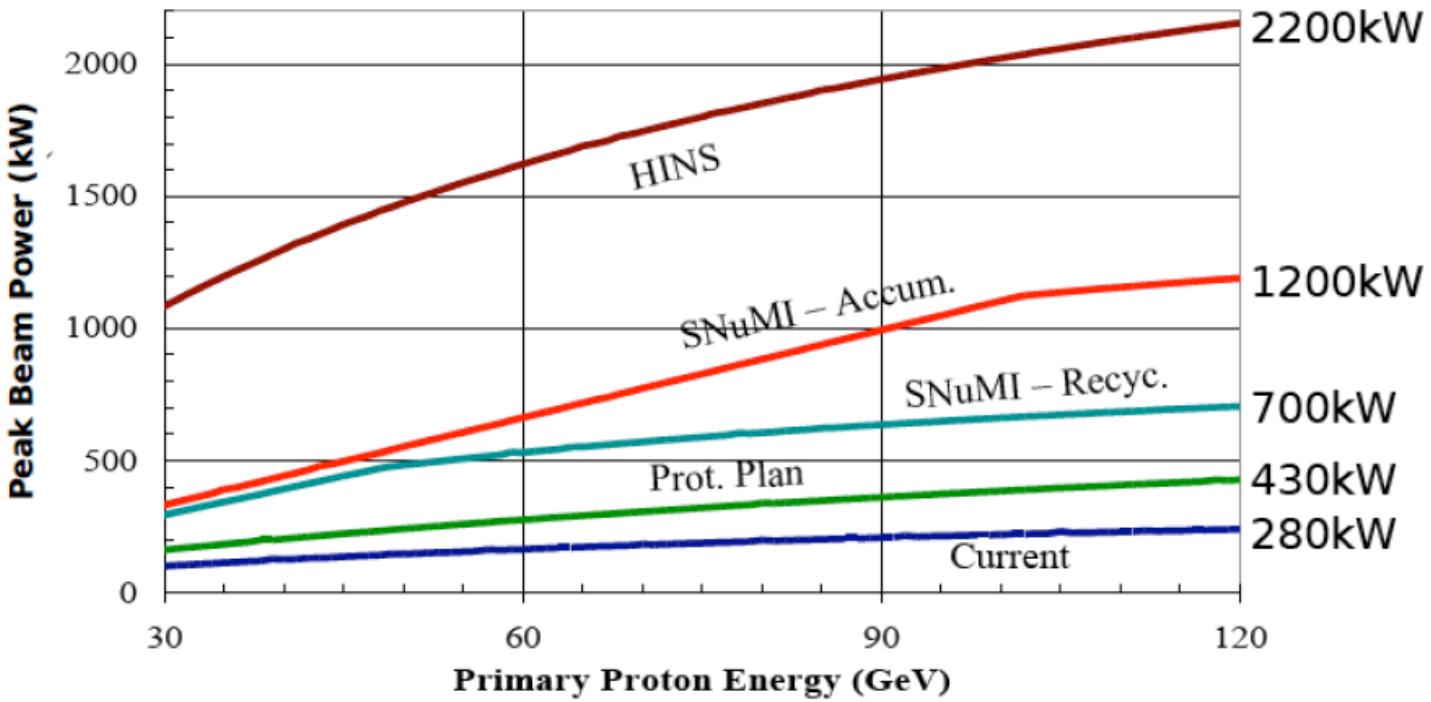
Using a decay pipe of 4m diameter and 250/280m (T2K/NuMI-like) decay length ON AXIS flux (CC events/0.1 GeV/kT/10^{20} protons):





Simulation	0.8 GeV Rate	Peak Rate (E)	6 GeV Rate
	CC events/GeV/kT/MW.yr at 1300km		
T2K-like (120 GeV)	17	46 (2.0 GeV)	13
T2K-like (60 GeV)	23	52 (2.0 GeV)	9
NuMI-like (120 GeV)	12	61 (2.4 GeV)	7
NuMI-like (60 GeV)	15	66 (2.4 GeV)	3.6

Impact of primary proton energy on spectrum

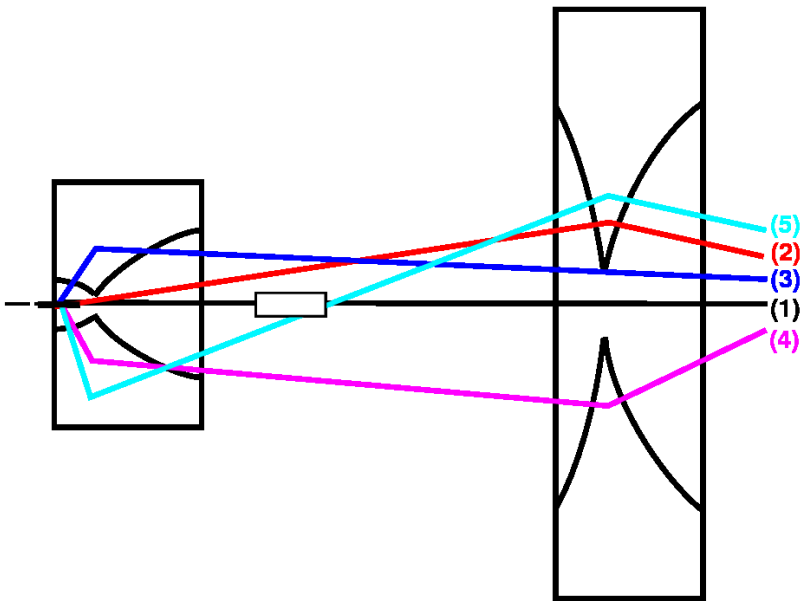


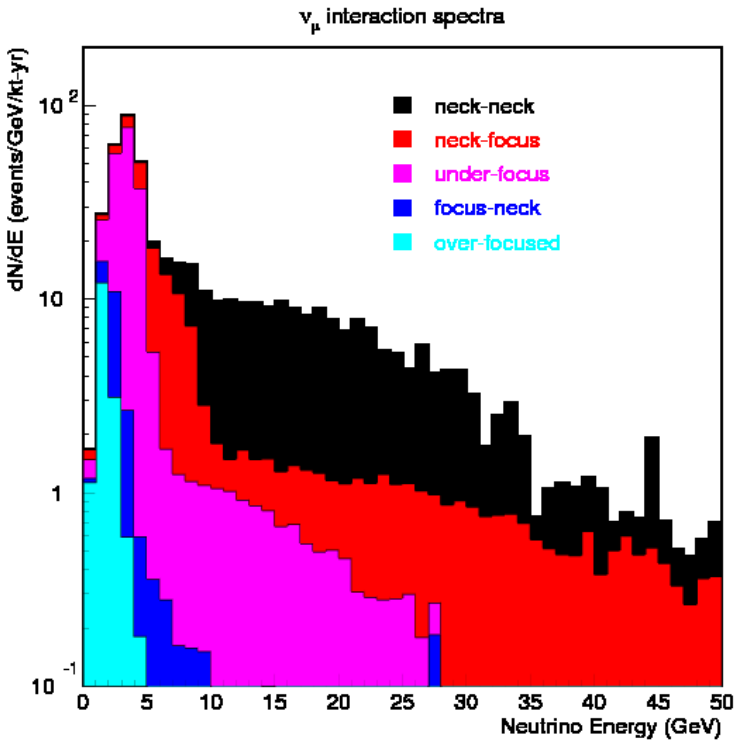
Lowering the beam energy is very effective at reducing HE tails and increases flux at lower beam energies - BUT we lose power!.
Power(60 GeV)$\approx$ 3/4$\times$ Power(120 GeV)

Design beamline to operate at 60-120 GeV.

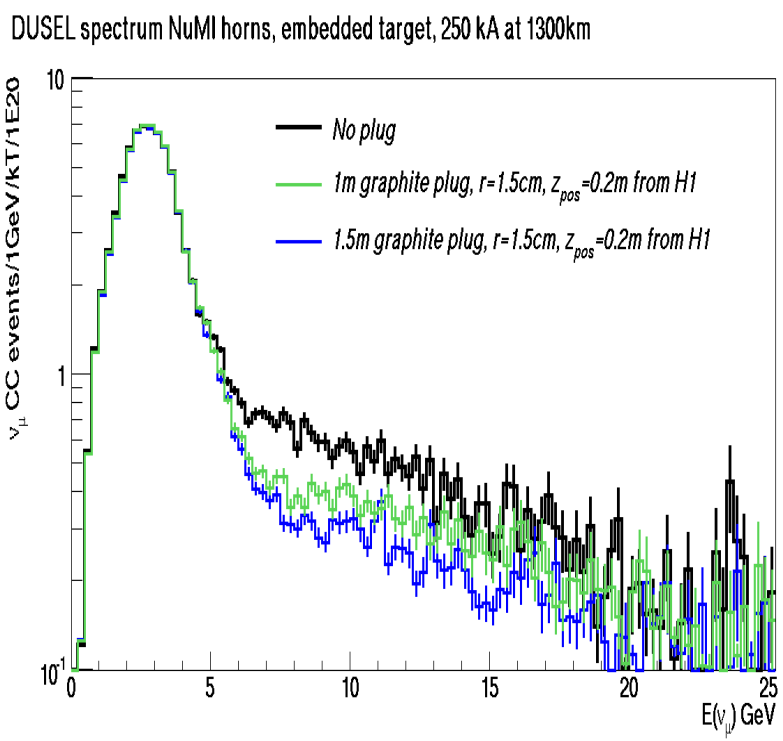
Whats a beam "plug"?

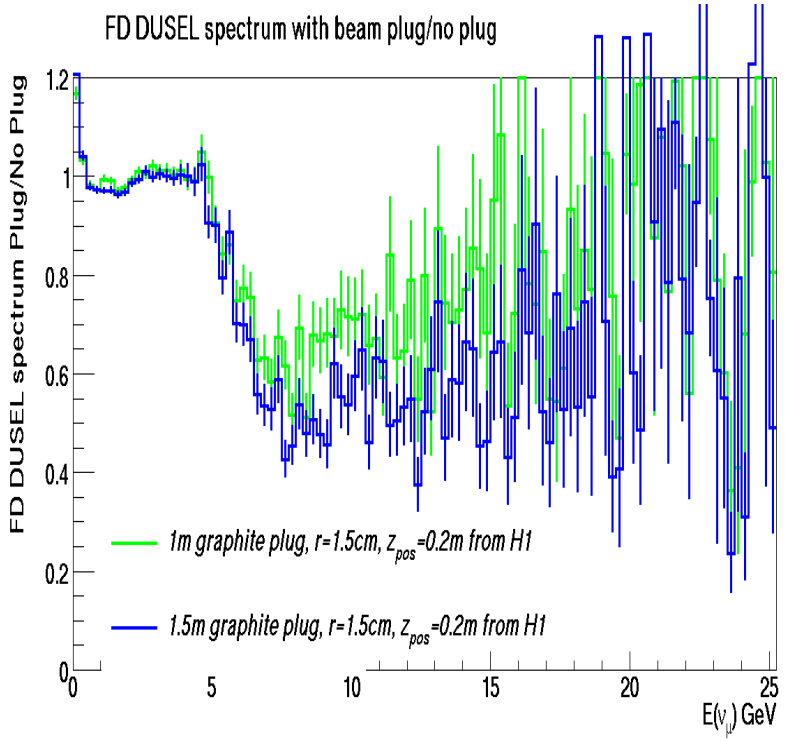
Suggested by Jim Hylen (NuMI/FNAL) to cut down the contribution from the high energy tail:





DUSEL/NuMI spectra with different plugs





With 1.5m plug

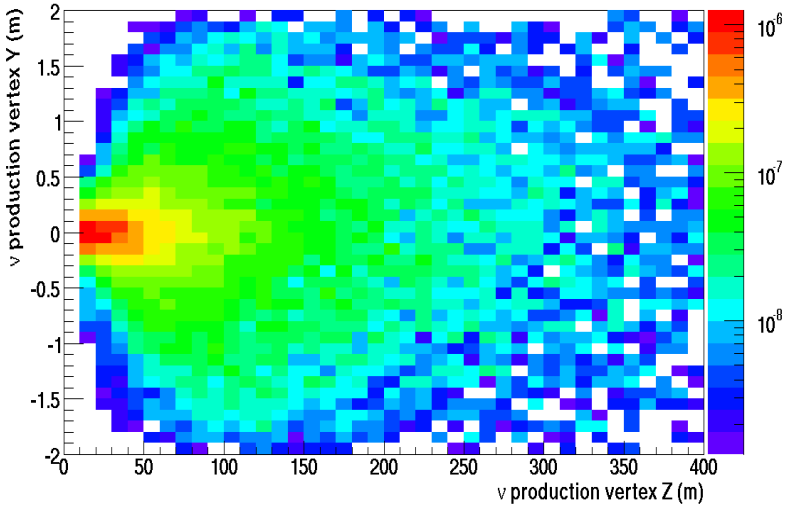
$$\frac{\text{plug}}{\text{no plug}}(> 5\text{GeV}) = 0.62 \qquad \frac{\text{plug}}{\text{no plug}}(< 5\text{GeV}) = 0.99$$

PROS: Reduces the HE flux exactly where you need it > 5 GeV without any impact at low energy

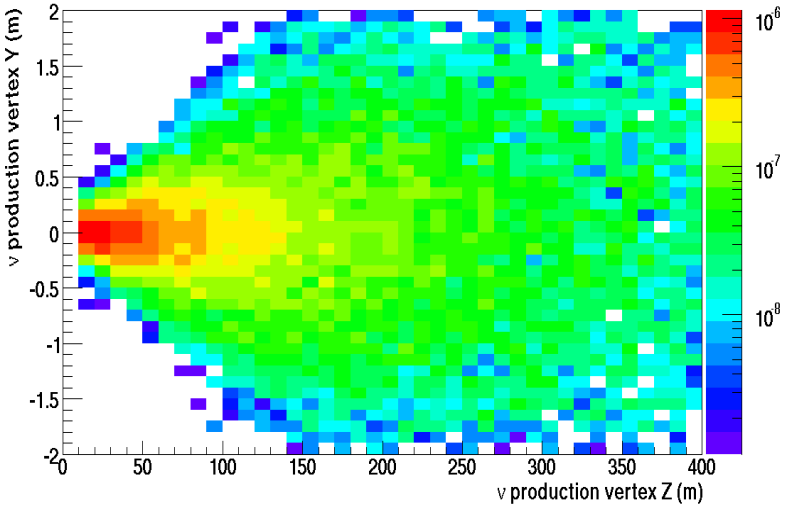
CONS: Requires expensive material R&D and engineering

ν Production in the Decay Pipe

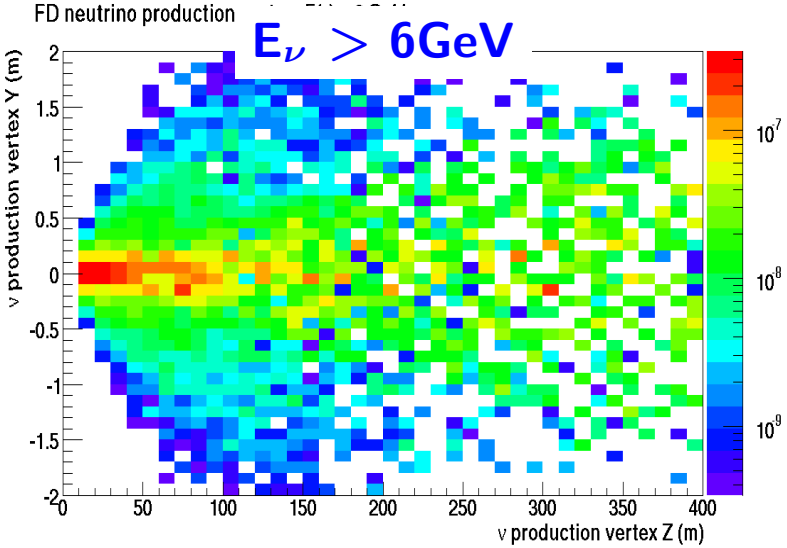
ν production in DP $E_\nu < 2$GeV



$2 < E_\nu < 6$GeV

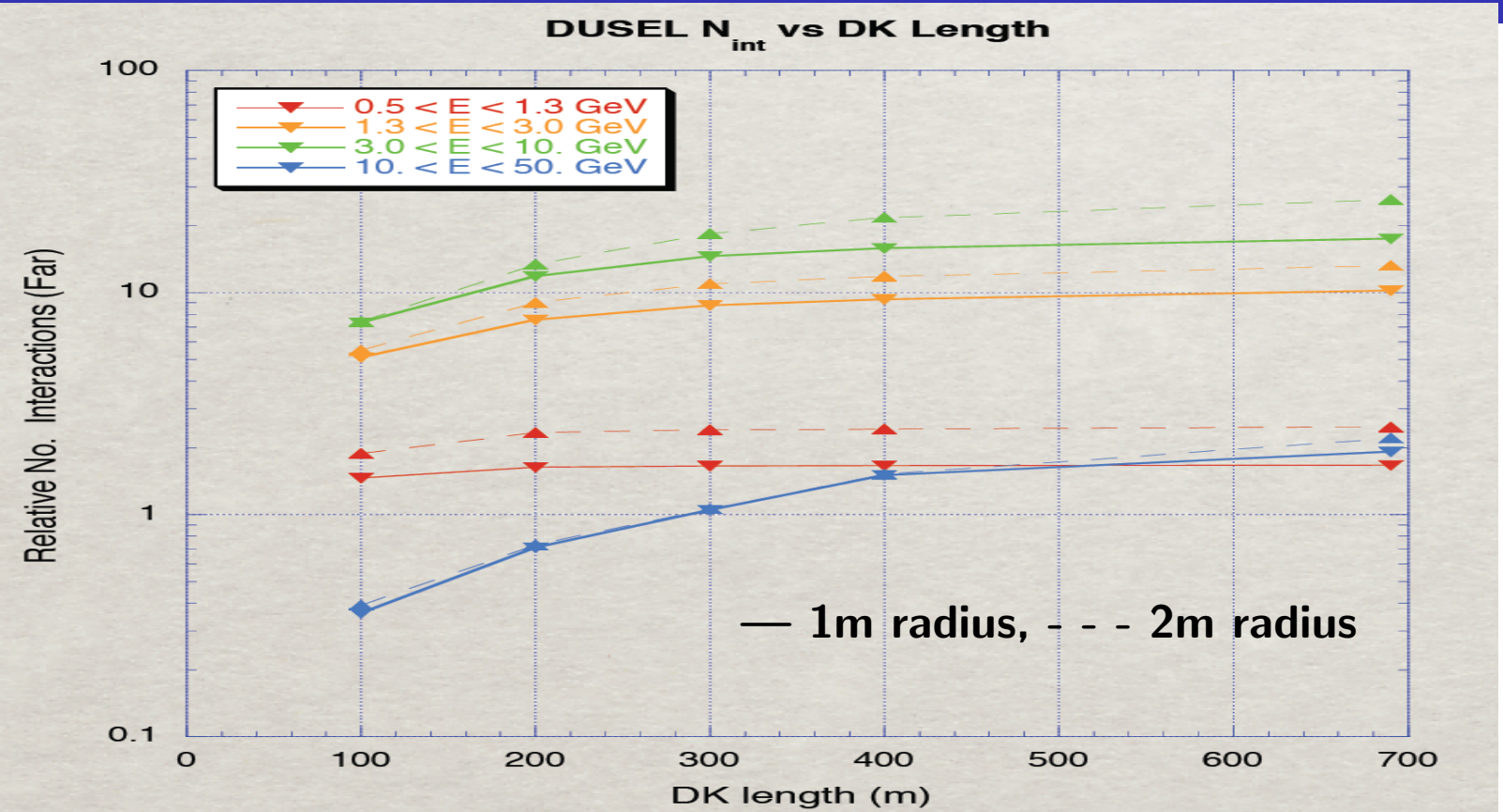


$E_\nu > 6$GeV



Decay pipe width and length need to be optimized

Decay pipe shape optimization

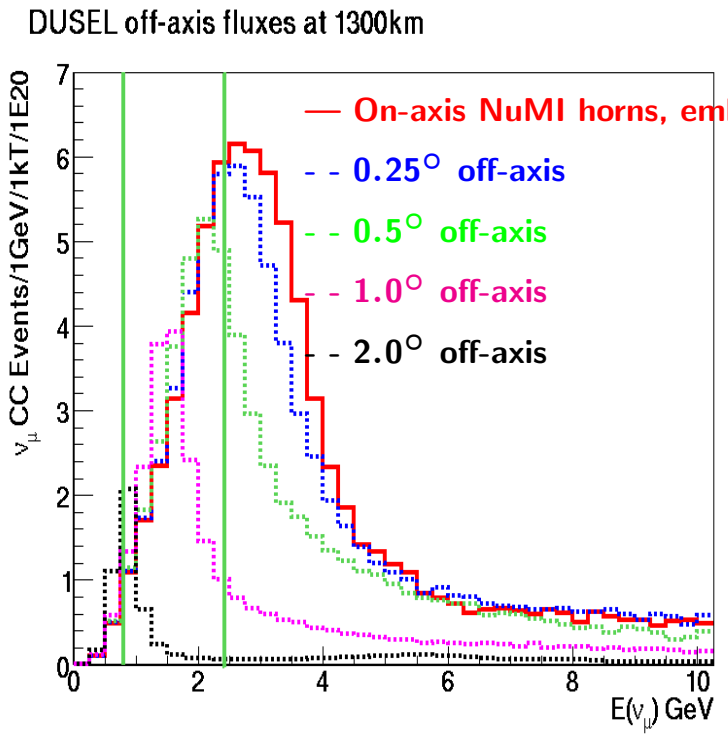


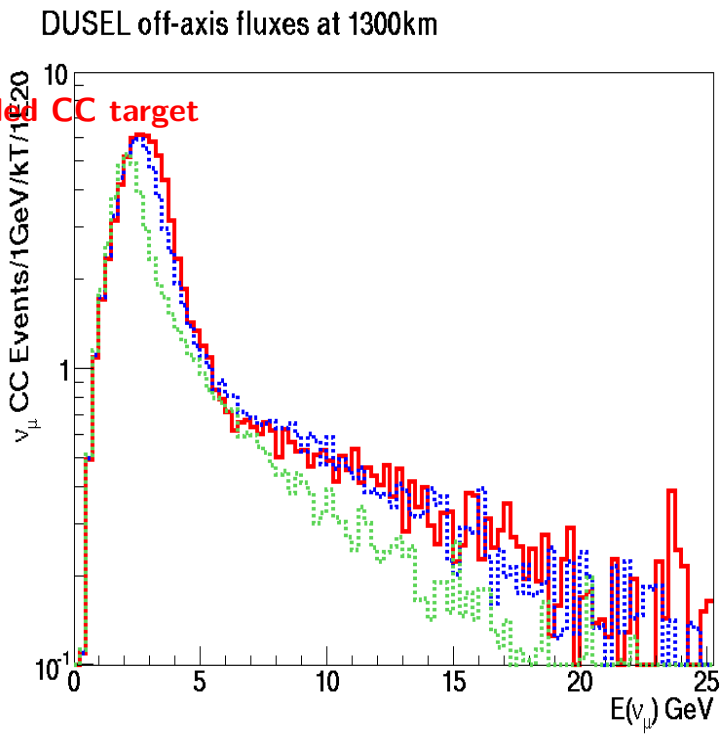
DP length	Rate 0 — 2 GeV	Rate 2 — 6GeV	Rate > 6GeV
180m	3.1	11	6.3
280m	3.5	14	8.1
380m	3.6	16	9.7
480m	3.7	17	11
580m	3.7	17	11

Decay pipe dimensions: 2m radius, 300 $\pm$ 50 m length

Going off-axis

Another alternative to cutting down the high energy tails is going off-axis - redo calculation with optimized on-axis beam:

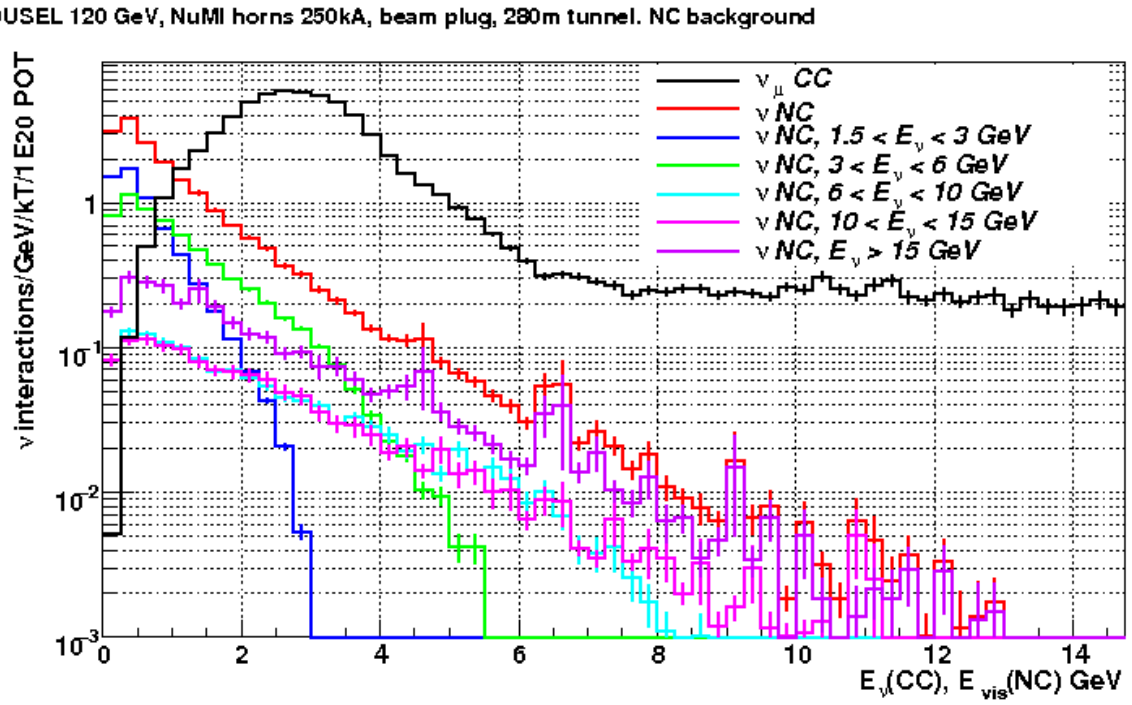




On axis flux is best for broad-band coverage

Beam designs and NC backgrounds

Used NUANCE to model $E_{visible}$ from NC interactions in a water Cerenkov detector:



Simulation	CC/NC 0.5-1.5 GeV events/GeV/kT/MW.yr at 1300km	CC/NC 1.5-6 GeV events/GeV/kT/MW.yr at 1300km
NuMI-like (120 GeV)	16/31	156/19
NuMI-like (120 GeV) with plug	15/27	153/15
NuMI-like (120 GeV) 0.5° o.a	16/22	105/13
NuMI-like (60 GeV)	19/24	158/10

Status of DUSEL LBNE design

- **DUSEL LBNE detailed studies of two targeting and focusing system designs. We have LO designs that can do the physics!!.** *But only simulated not engineered*.
- **Consensus on dimensions of gas filled decay pipe for input to civil: DP $\sim$ cylindrical, r $= 2^{+0.5}_{-0.2}$ m, l $= 300 \pm 50$ m.**
- **We have also determined that the target hall length is $<$ 20m - details are now up to engineering, civil construction.**
- **Primary proton beam power: 90 ± 30 GeV. We have a preliminary primary beam extraction, transport, and semi-detailed layout.**

Mark Dierckxsens will present the physics potential of the different beam designs.