ANNOUNCEMENT:

There is enough interest to warrant setting up
a new 5th working group:

the “ Tevatron Fixed Target Working Group “

To sign up for the listserv:

Send an e-mail message to listserv@fnal.gov

Leave the subject line blank

Type "SUBSCRIBE FUTURE_TEV_AT_FERMILAB FIRSTNAME LASTNAME"
(without the quotation marks) in the body of your message.

The NuSOnG Neutrino Experiment

A High-Statistics High-Energy
Neutrino Scattering Experiment at Fermilab

Heidi Schellman
Northwestern University

for the NuSonG Collaboration

3rd Workshop on Physics
with a high intensity proton source

Thanks to Mike Shaevitz

What Is NuSOnG?

A proposed new experiment at FNAL to study TeV-scale physics in neutrino scattering (Neutrino Scattering On Glass)

- High Energy: 800 GeV protons from the Fermilab Tevatron
- High Statistics: Large detector and high intensity, sign-selected beam
- Leptonic Processes: Large fine-grained detector that can measure outgoing electrons with good resolution
- High Precision: Use inverse muon decay and quasi-elastic like processes for normalization plus in situ test beams for calibration

Second-generation experiment that goes beyond the best capabilities of the previous NuTeV and CHARM II experiments.

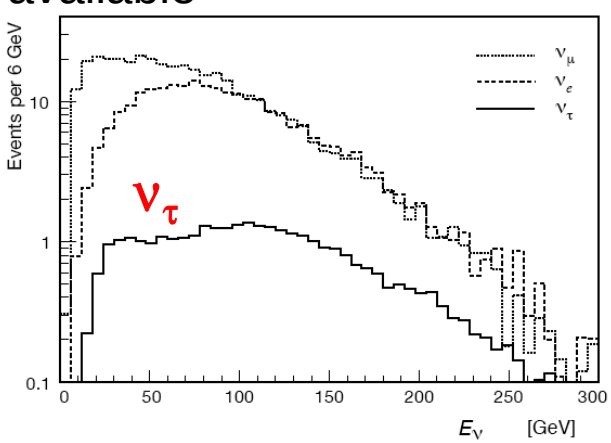
Why high energy neutrinos?

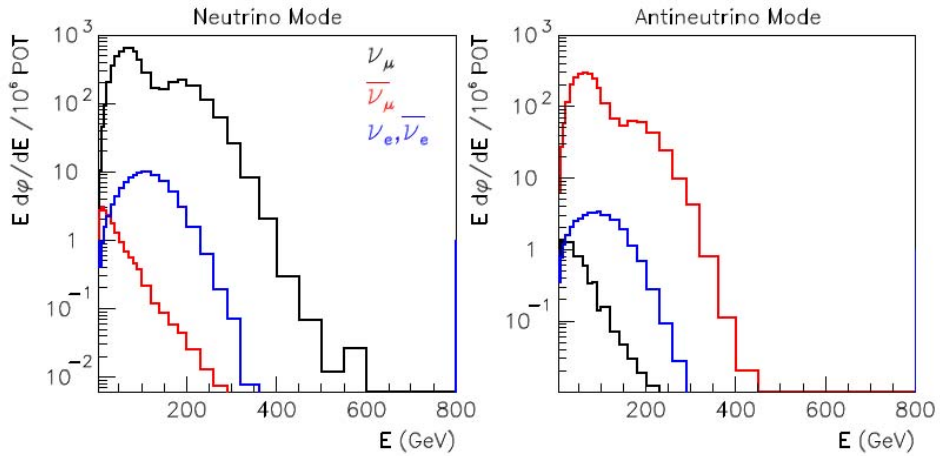
- Leading order physics is very simple and very well understood theoretically
  - events are hard to produce but backgrounds ~ 0 and trigger ~ 100% efficient.
- Still a lot to do
  - Previous high statistics experiments had very crude readout
    - NuTeV ~ (800 56AVP's) and 680 tons of iron
  - Previous high quality readout experiments had lower statistics
    - Bubble Chambers
    - NOMAD
    - CHORUS
  - Have < 10,000 events in pure EWK processes
- Current status of the field is similar to e^+e^- before LEP

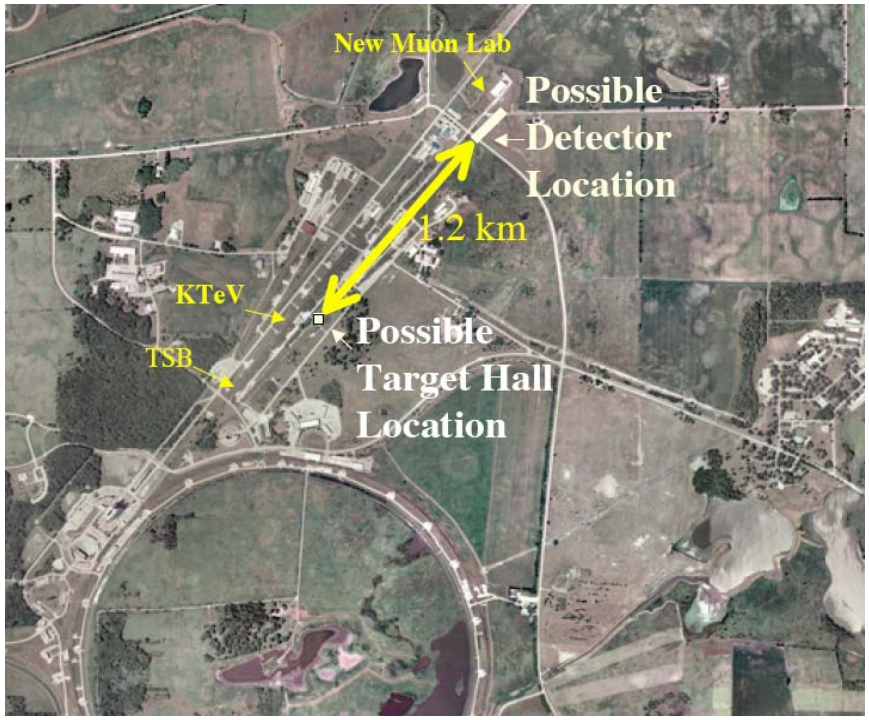
NuSOnG Beam

- Use high-intensity, high-energy NuTeV style Sign-Selected Quad Focused beam
  - Pure neutrino or antineutrino running modes
  - Fairly flat high energy neutrino flux with $\langle E_\nu \rangle$ = 100 GeV
  - Using upgraded Tevatron beam extraction (5 ×10^{19} protons/yr)
    x20 NuTeV intensity

- Also, beam-dump beam with sizeable fraction of ν_τ might be available



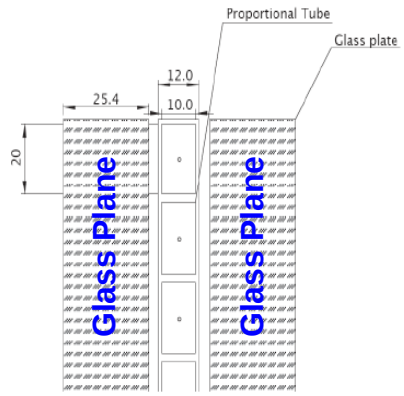




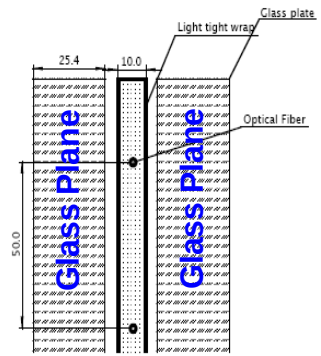
NuSOnG Detector

- Target Calorimeter
  - 2,500 2.5 cm×5m×5m glass planes interspersed with 1 cm prop tubes or scintillator planes.
  - isoscalar material with ¼ X_0 sampling
- Magnetized Iron Muon Spectrometer
  - instrumented with drift chambers
- Low Density Decay Regions
  - search for new long-lived heavy neutral particles

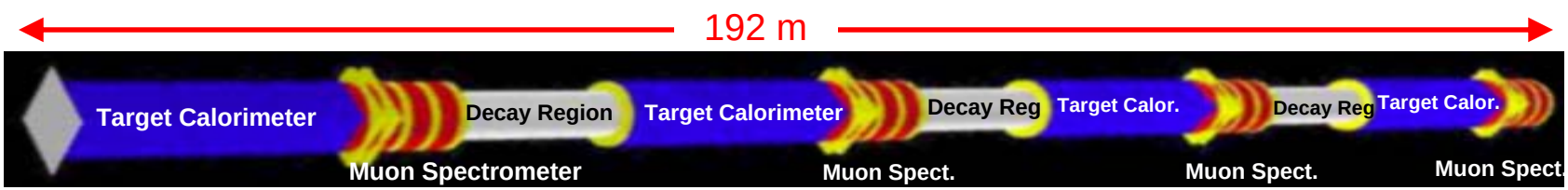
Total Fiducial Mass = 3 kton
×6 NuTeV and CHARM II



Proportional tubes
ArCo2 (80:20)
Gain of 3000 gives 52 fC
250 tubes per plane
500k-1000k total channels



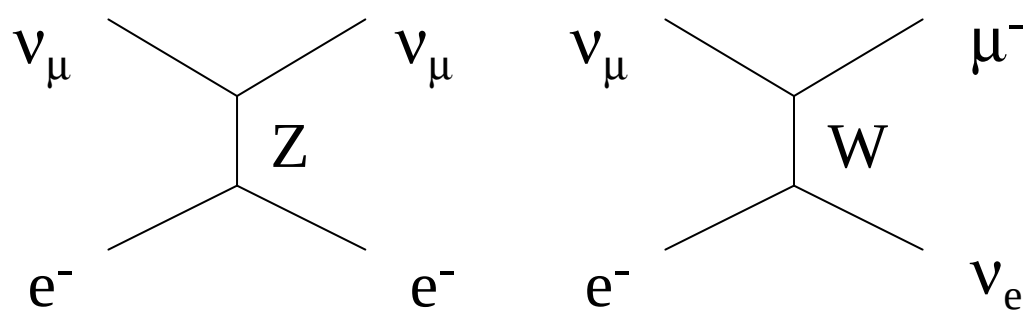
Scintillator planes
18k photons
100 fibers per plane
50k-100k total channels



Expected NuSOnG Event Rates (5 yr Run)

600M	ν_μ CC Deep Inelastic Scattering	×100 NuTeV
190M	ν_μ NC Deep Inelastic Scattering	×100 NuTeV
75k	ν_μ electron NC elastic scatters	×20 CHARM II
700k	ν_μ electron CC quasielastic scatters (IMD)	×40 CHARM II
33M	$\bar{\nu}_\mu$ CC Deep Inelastic Scattering	
12M	$\bar{\nu}_\mu$ NC Deep Inelastic Scattering	
7k	$\bar{\nu}_\mu$ electron NC elastic scatters	
0k	$\bar{\nu}_\mu$ electron CC quasielastic scatters	

A unique opportunity for precision measurements in these channels



NuSOnG Physics Program

- NuSOnG Physics Program
  - Indirect Searches for New Physics
    - ν-e scattering
    - ν-q scattering
  - Direct Searches
    - lepton number violating processes
    - new heavy neutral leptons
  - QCD and Parton Distribution Studies
    - F2 , xF3 , R_L , strange and anti-strange quark sea, charm sea
    - QCD – Λ at high Q^2, transition to non-perturbative at low Q^2

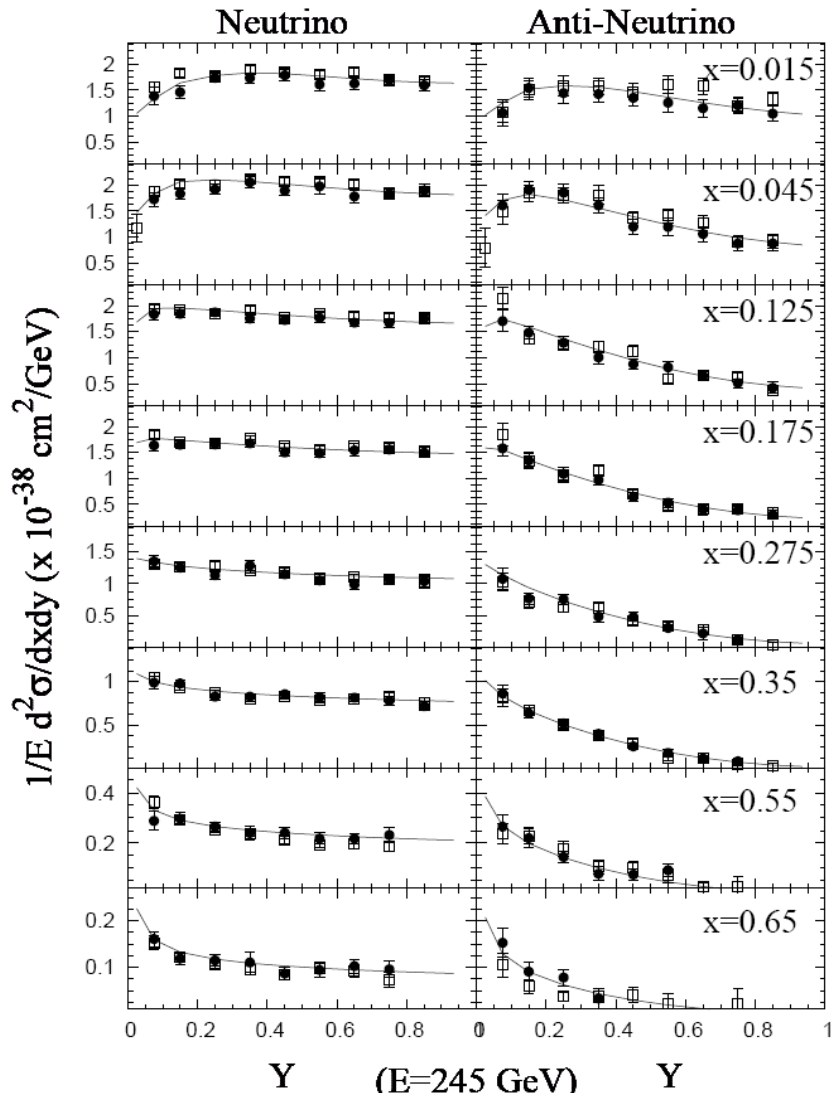
These measurements can only be done at Fermilab where a high-energy, high-intensity neutrino beam is possible.

Many other interesting neutrino experiments are possible – and many can share the beam

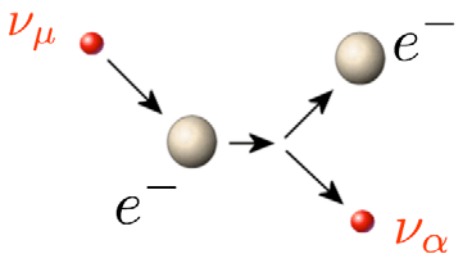
QCD from $d^3\sigma/dxdydE$

Phys.Rev.D74:012008,2006.

- NuTeV cross sections
- ~2M events
  - x ~ parton momentum fraction
  - $y \sim (1 + \cos\theta_{cm})/2$
  - 17 energy bins
- QCD evolution fits yield Λ_{qcd}
- PDF fits tell q from anti-q
  - but nuclear corrections remain an issue



Using NuSOnG EWK to Probe for New Physics



$$\sim \frac{1}{\Lambda^2}\left[\nu^\dagger_{L\mu}\bar{\sigma}\nu_{L\alpha}\right]\left[\cos\theta\ e^\dagger_L\bar{\sigma}e_L + \sin\theta\ e^\dagger_R\bar{\sigma}e_R\right]$$

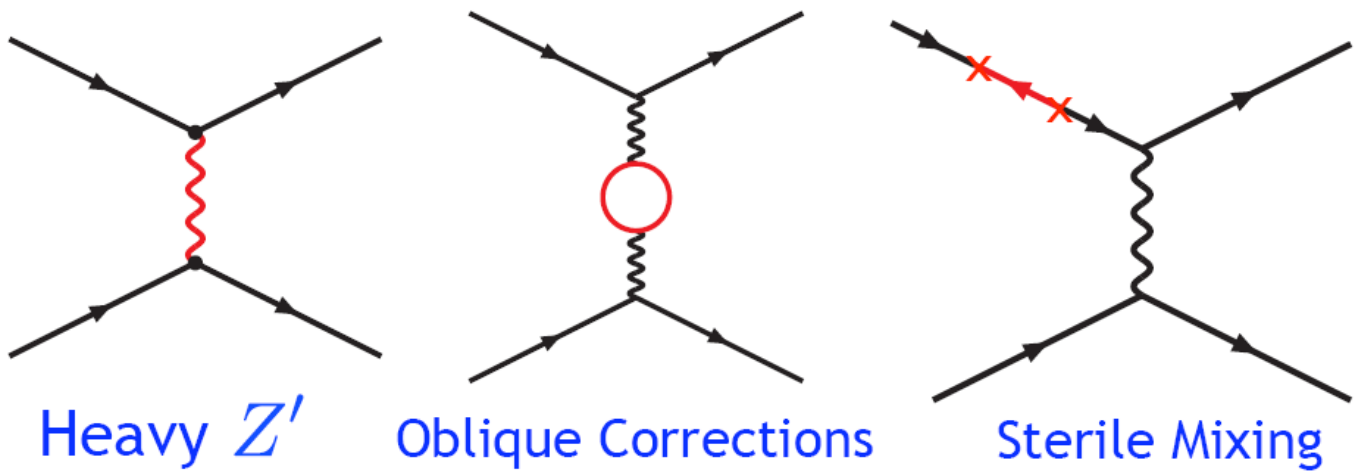
Standard Model (No new physics)

$$\frac{1}{\Lambda^2} = 4\sqrt{2}G_F$$

$$\cos\theta = g^e_L g^\nu_L = \frac{1}{2}\left(-\frac{1}{2} + \sin^2\theta_W\right)$$

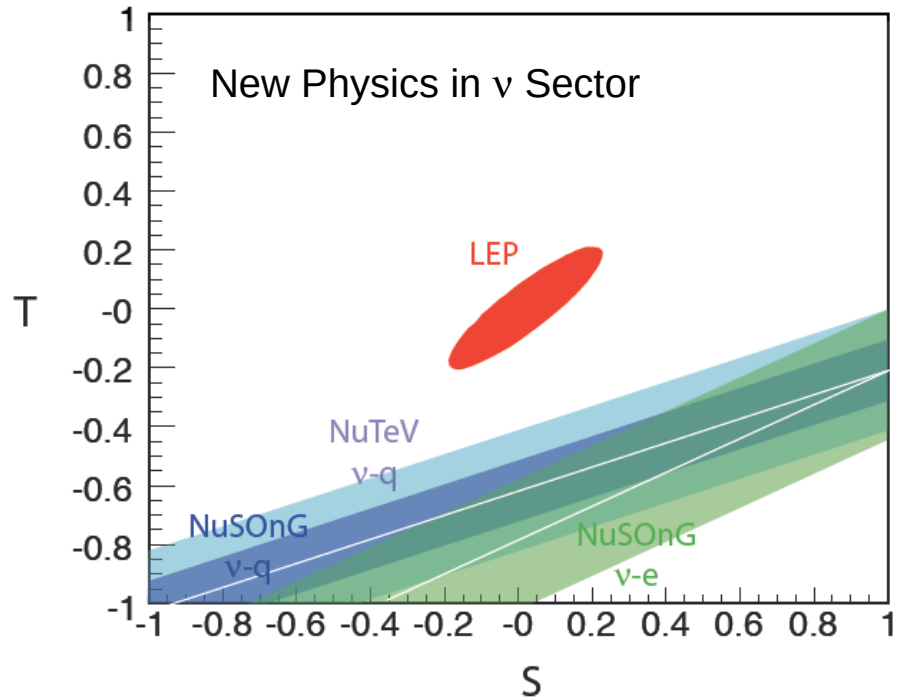
$$\sin\theta = g^e_R g^\nu_L = \frac{1}{2}\sin^2\theta_W$$

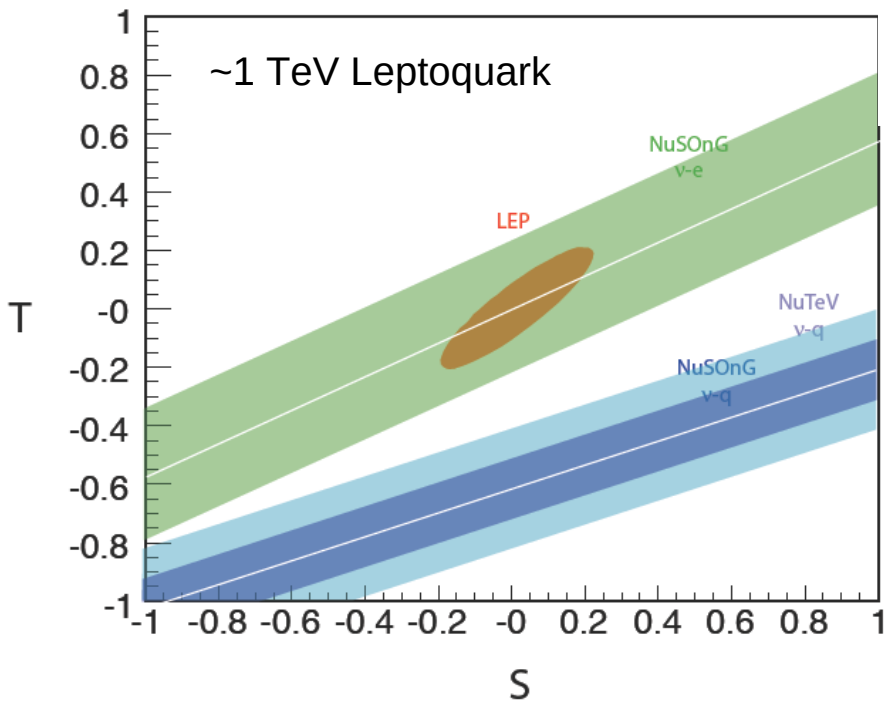
New Physics can change Λ and θ

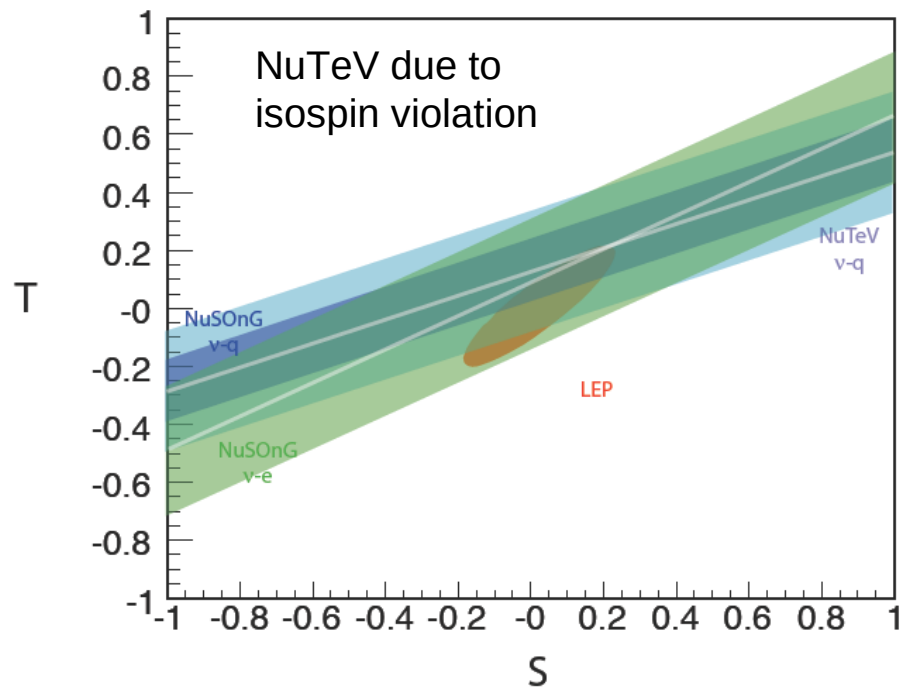


Various New Physics Scenarios

NuSOnG is complementary to LHC searches and may provide help to discover and unravel any new physics signals (See arXiv:0803.0354)







NuSOnG Cost and Schedule Estimate

- Total NuSOnG with 5yrs Operations = $236M
  - New Tevatron ν Beam: $22M
  - NuSOnG Detector Hall: $18M
  - NuSOnG Detector: $100M
  - Tevatron Operations @$15M/yr: $75M

- Schedule
  - Fall, 2007: Expression of Interest submitted to Fermilab
  - Spring, 2008: Physics case publications submitted (arXiv:0803.0354)
  - Fall, 2008: Submit Letter of Intent to Fermilab
  - 2009: Submit Proposal to Fermilab
  - 2011: Begin construction
  - 2016: Start data taking

NuSOnG Summary

- A Tevatron neutrino program offers a unique opportunity to probe for new physics coupled to the neutrino sector at high mass scales
- The high-energy and high-intensity will allow very precise measurements of the purely leptonic process $\nu_\mu e \rightarrow \nu_\mu e$ along much better ν-quark measurements.
- Such a facility would provide a rich physics program covering direct and indirect new physics searches along with unique QCD and nucleon structure measurements.

The TeVatron neutrino beam is a great facility for precision physics – let's use it!

Estimates of NuSOnG Uncertainties

$$R = \frac{\sigma_{\nu_\mu e}}{\sigma_{IMD}}$$

$$\frac{\delta R}{R} = \frac{\delta \sin^2 \theta_W}{\sin^2 \theta_W}$$

	IMD Uncertainty	ES Uncertainty	Uncertainty on Ratio
Statistical Uncertainty	0.18%	0.46%	0.49%
Resolution Smearing			
$\delta(E_\mu) = \pm 2.5\%$	0.00%	0.00%	0.00%
$\delta(\theta_\mu) = \pm 2.5\%$	0.04%	0.00%	0.04%
$\delta(E_e) = \pm 1.5\%$	0.00%	0.01%	0.01%
$\delta(\theta_e) = \pm 2.5\%$	0.00%	0.09%	0.09%
Energy Scale			
$\delta(\text{Escale}_\mu) = 0.5\%$	0.37%	0.00%	0.37%
$\delta(\text{Escale}_e) = 1.5\%$	0.00%	0.19%	0.19%
Flux			
Normalization	3.00%	3.00%	0.00%
High energy flux up 1%	0.25%	0.25%	0.00%
Low energy flux up 1%	0.15%	0.13%	0.02%
IMD Background: statistical error	0.06%	0.00%	0.06%
2.0% systematic error	0.26%	0.00%	0.26%
ν_μe Background: statistical error	0.00%	0.12%	0.12%
3% systematic error	0.00%	0.19%	0.19%
		Total Syst. Uncertainty on Ratio	0.54%
		Total Stat. Uncertainty on Ratio	0.51%
		Total Uncertainty on Ratio	0.74%