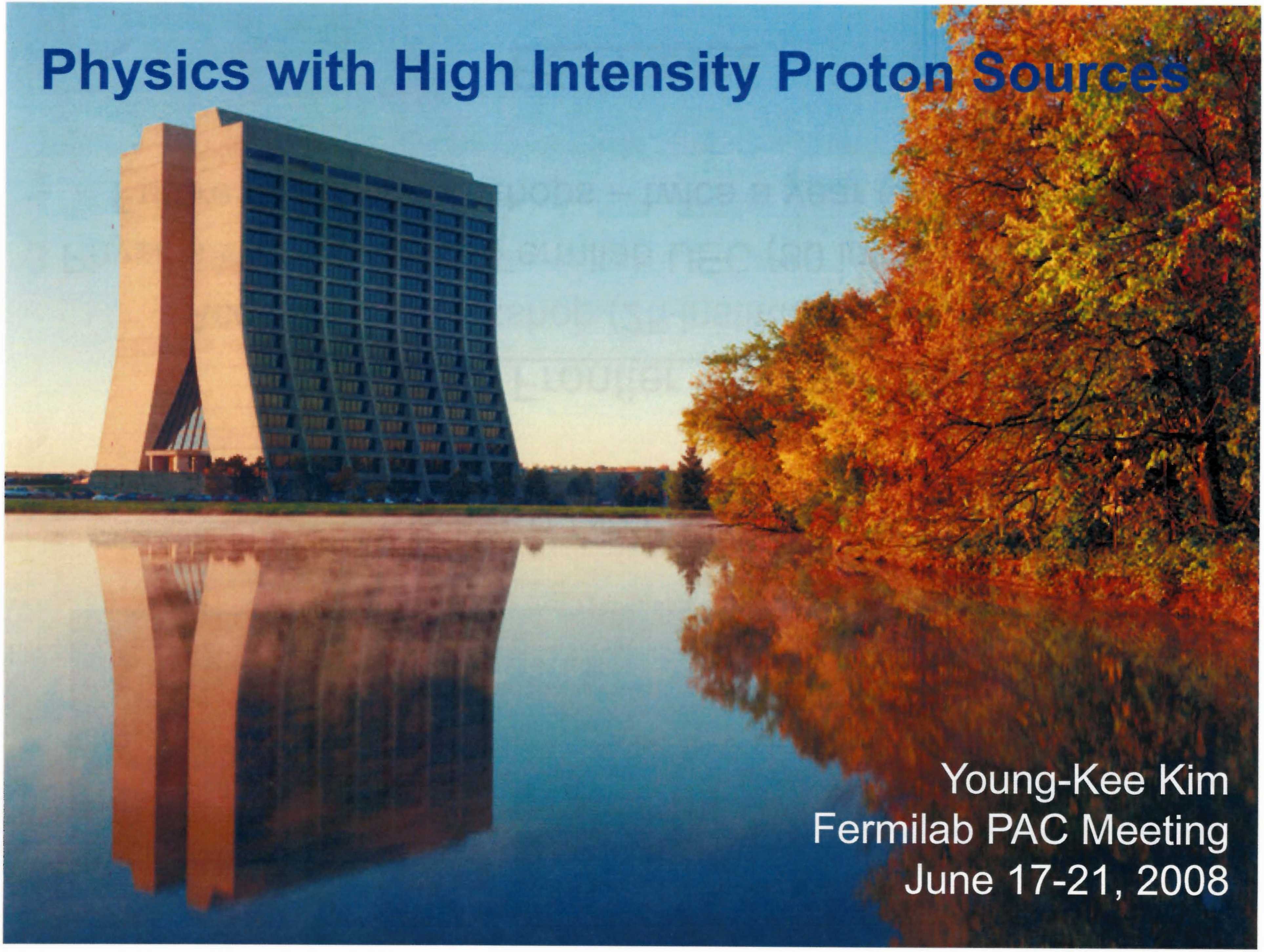
FERMILAB-SLIDES-08-010-DI



Engaging the Community in planning / developing programs, Supporting the Community

Steering Group Process

Intensity Frontier Workshops:

Accelerator Workshop (25 institutions, 4 nations)

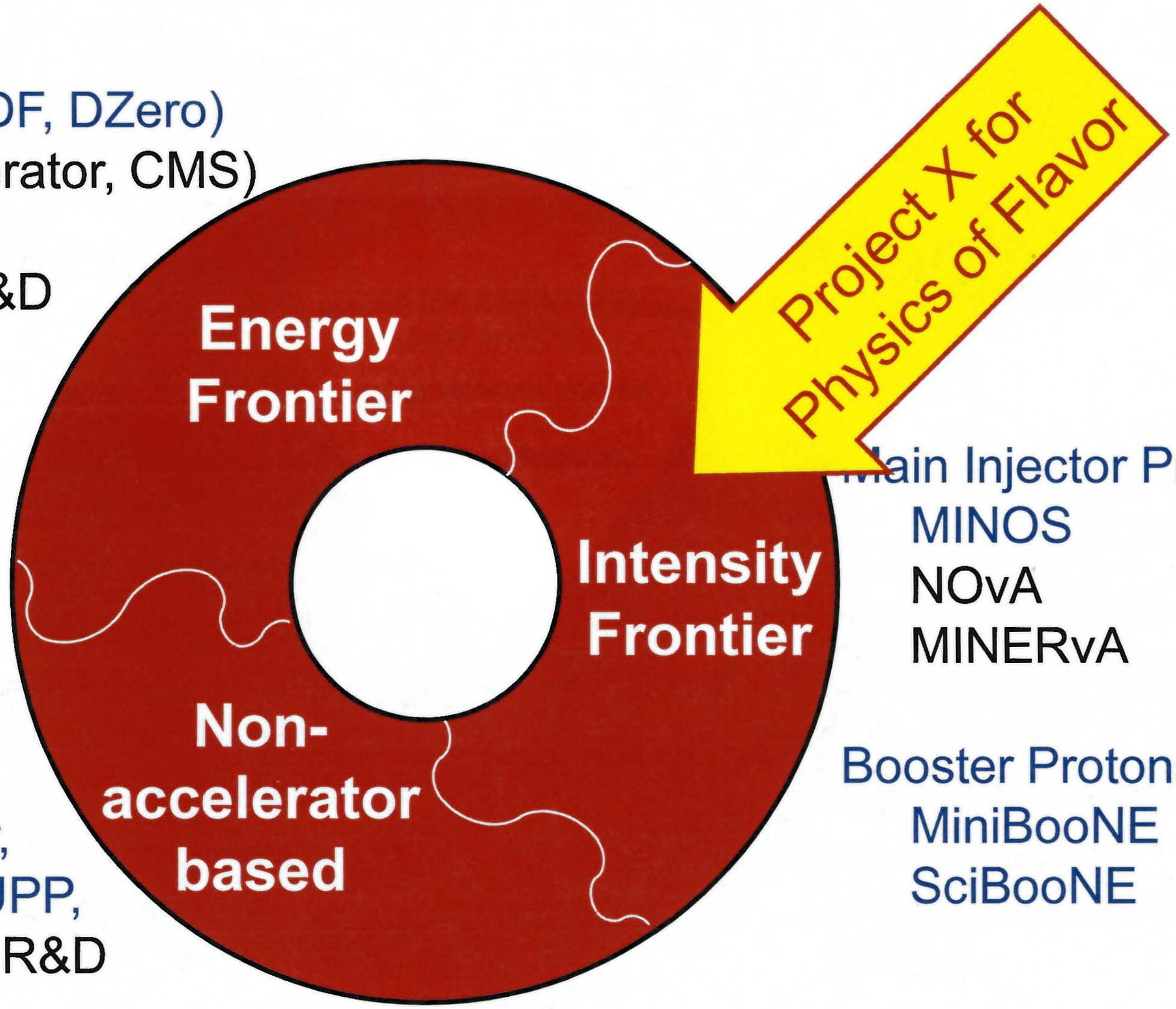
3 Physics Workshops w/ Fermilab UEC (80 institutions, 8 nations)

Future physics workshops – twice a year (Jan. and Jun.)

P5 Process

Tools for Particle Physics at Fermilab

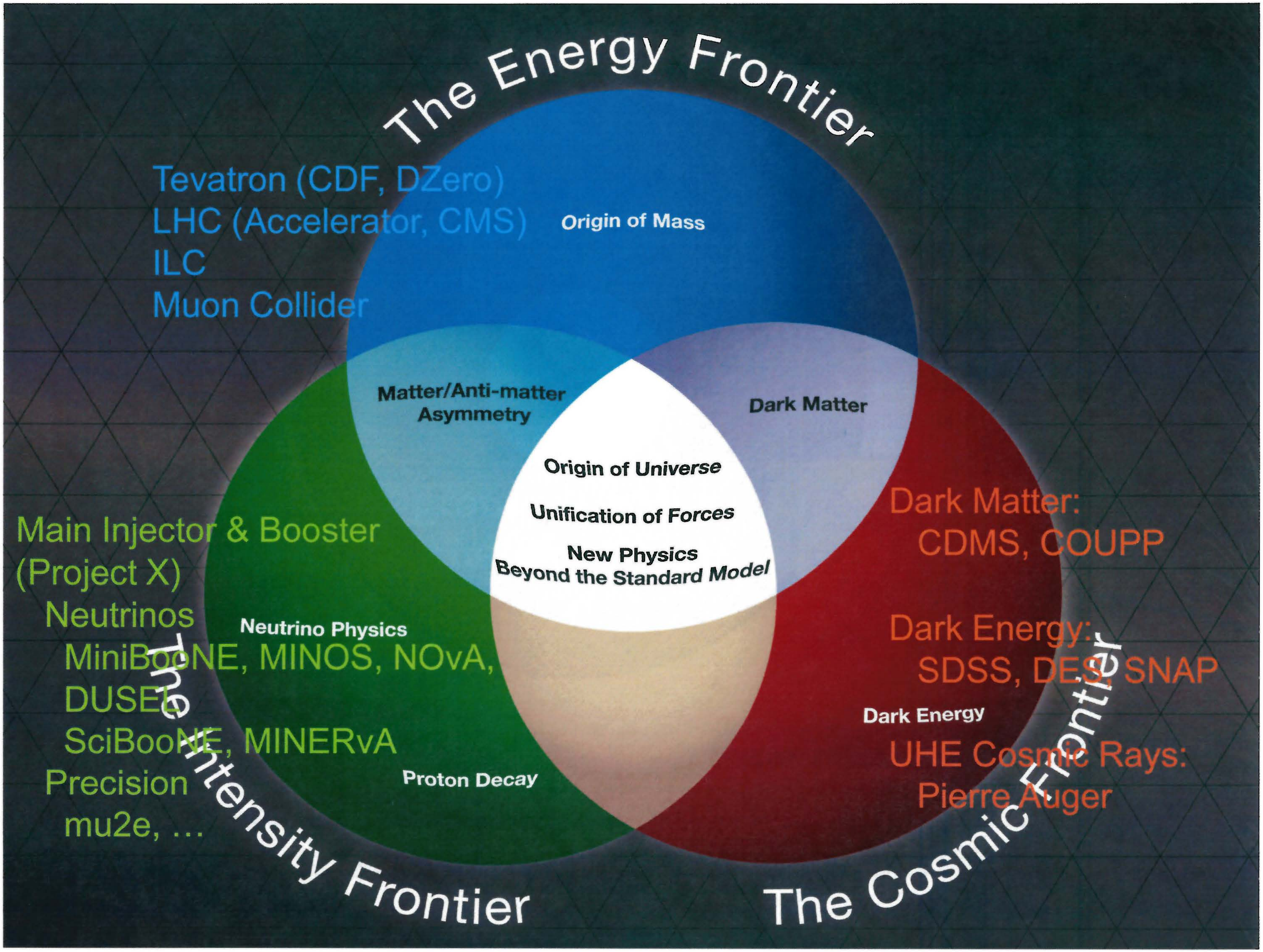
Tevatron (CDF, DZero)
LHC (Accelerator, CMS)
ILC R&D
μ Collider R&D



Main Injector Protons
- MINOS
- NOvA
- MINERvA

Booster Protons
- MiniBooNE
- SciBooNE

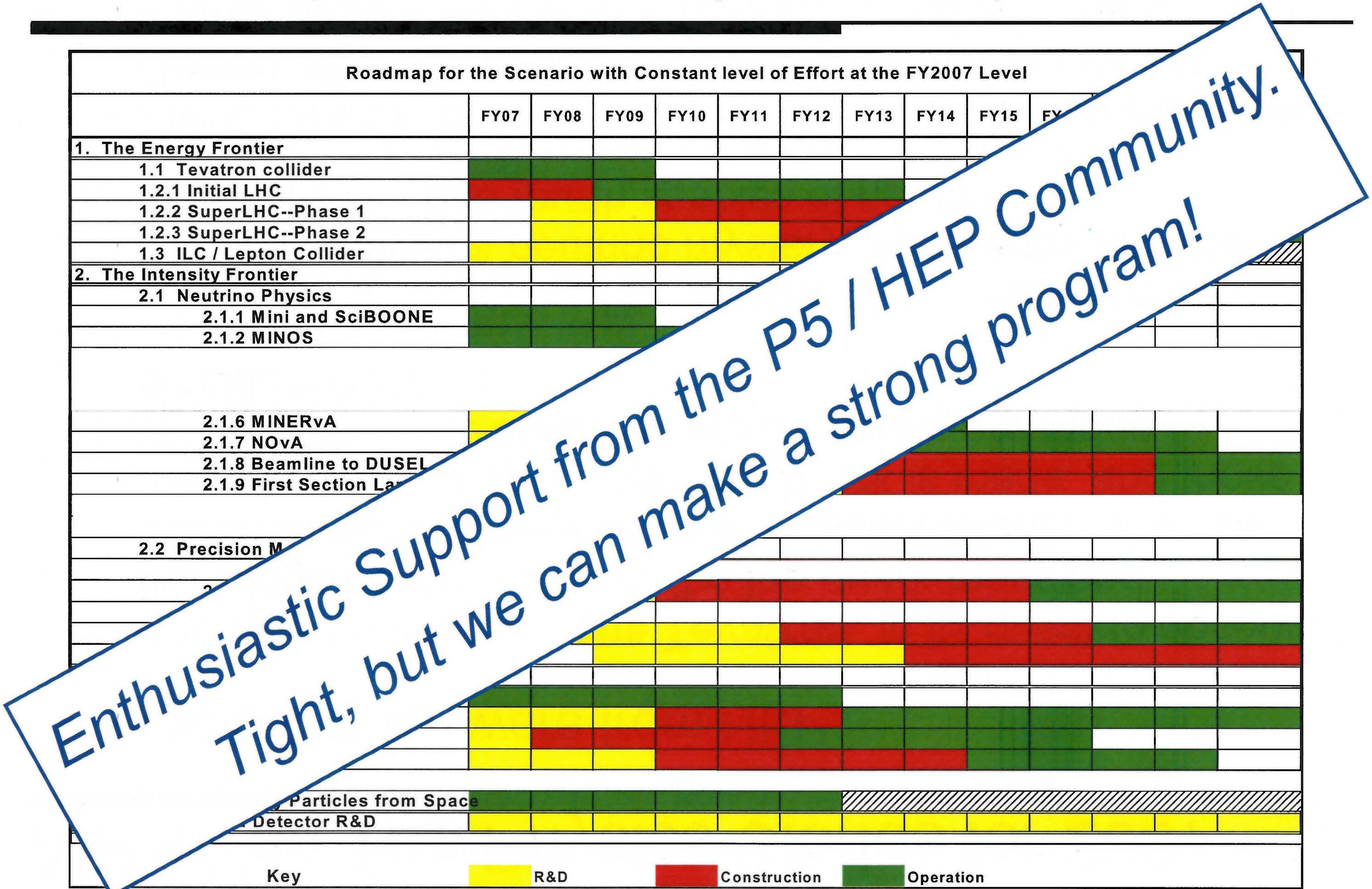
SDSS,
Pierre Auger,
CDMS, COUPP,
DES, SNAP R&D


The Energy Frontier
Tevatron (CDF, DZero)
LHC (Accelerator, CMS)
ILC
Muon Collider
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Main Injector & Booster (Project X)
Neutrinos
MiniBooNE, MINOS, NOvA, DUSEL
SciBooNE, MINERvA
Precision
mu2e, …
Neutrino Physics
Proton Decay
Dark Matter:
CDMS, COUPP
Dark Energy:
SDSS, DES, SNAP
Dark Energy
UHE Cosmic Rays:
Pierre Auger
The Intensity Frontier
The Cosmic Frontier

AIP's Ten Top Physics Stories for 2007

- Three out of ten were from HEP:
  - The Energy Frontier: **The Tevatron**, in its quest to observe the Higgs boson, updated the top quark mass and observed several new types of collision events, such as those in which only a single top quark is made, and those in which a W and Z boson or two Z bosons are made simultaneously.
  - The Intensity Frontier: **The MiniBooNE** experiment at Fermilab solves a neutrino mystery, apparently dismissing the possibility of a fourth species of neutrino.
  - The Cosmic Frontier: Based on data recorded at **the Auger Observatory**, astronomers conclude that the highest energy cosmic rays come from active galactic nuclei.

P5 Roadmap for Scenario B (FY07 Level) - Fermilab



The Intensity Frontier
P5 Roadmap

Scenario B: FY07 Level

Roadmap for the Scenario with Constant level of Effort at the FY2007 Level

	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
2. The Intensity Frontier													
2.1 Neutrino Physics													
2.1.1 Mini and SciBOONE	Operation	Operation	Operation										
2.1.2 MINOS	Operation	Operation	Operation	Operation									
2.1.6 MINERvA	R&D	Construction	Construction	Construction X	Operation	Operation	Operation	Operation					
2.1.7 NOvA	R&D	R&D	Construction	Construction	Construction	Construction	Operation	Operation	Operation	Operation	Operation	Operation	
2.1.8 Beamline to DUSEL			R&D	R&D	R&D	R&D	Construction	Construction	Construction	Construction	Construction	Operation	Operation
2.1.9 First Section Large Det			R&D	R&D	R&D	R&D	Construction	Construction	Construction	Construction	Construction	Operation	Operation
2.2 Precision Measurements													
2.2.2 Mu-e Conv Expt		R&D	R&D	Construction X	Construction X	Construction	Construction	Construction	Construction	Operation	Operation	Operation	Operation
2.2.3 Rare K Decays													
2.3 DUSEL		R&D	R&D	R&D	R&D	Construction	Construction	Construction	Construction	Construction	Operation	Operation	Operation
2.4 High Intens Proton Sce Fermilab			R&D	R&D	R&D	R&D	R&D	Construction	Construction	Construction	Construction	Construction	Construction

Key: R&D — Construction — Operation

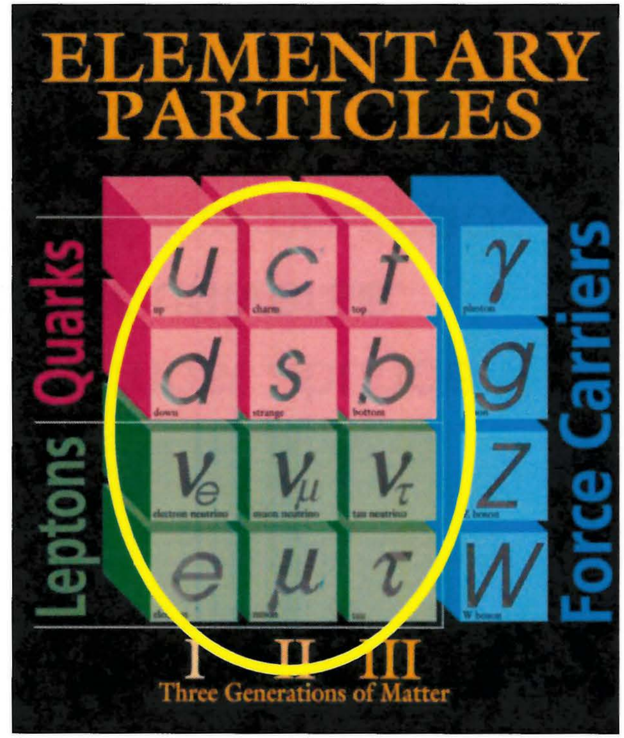
Scenario A: FY08 Level
Scenario C: Double the budget in 10 years

Intensity Frontier Vision at Fermilab
Aligned with P5

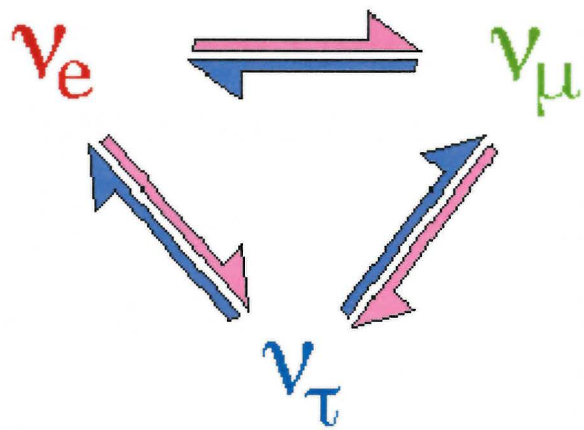
a phased approach with
ever increasing beam intensities
and ever increasing detector capabilities

Physics of Flavor

- Flavor phenomena
  - Essential to shaping physics beyond the SM.
- SM is incomplete:
  - Neutrino Masses (flavor)
    - The only new physics seen so far in the laboratory
  - Baryon Asymmetry of the Universe (flavor)
  - Dark Matter
  - Dark Energy



Neutrinos



The enigmatic neutrinos are among the most abundant of the tiny particles that make up our universe.

To understand the universe, must understand neutrinos.

Behavior is so different from other particles.

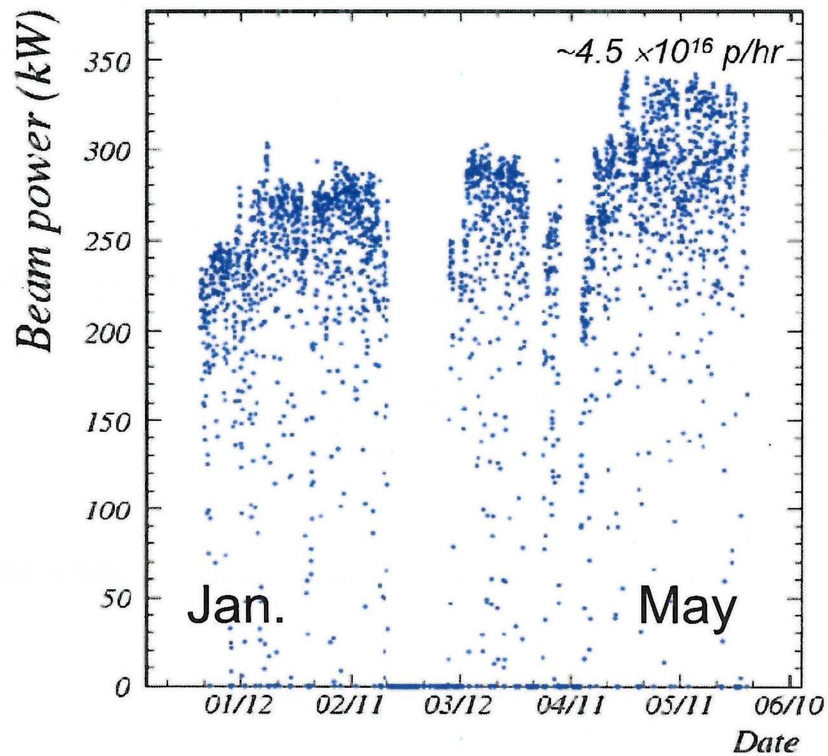
Opening a "new" window

Neutrinos

- Neutrino masses
  - via See-Saw mechanism, point to $m_\nu M = (m_{quark})^2$ new physics at a very high mass scale (unification scale).
- Baryon Asymmetry of the Universe
  - Possible scenarios as the source
    - Electroweak baryogenesis – LHC and ILC.
    - Leptogenesis – Neutrino CP violation would support it.
- The Four Measurements
  - value of $\sin^2 2\theta_{13}$
  - Are neutrino masses Dirac or Majorana?
  - Is the mass ordering normal or inverted?
  - CP violation

The Intensity Frontier: Present

MI beam power at 120 GeV since multi-batch slip stacking become operational



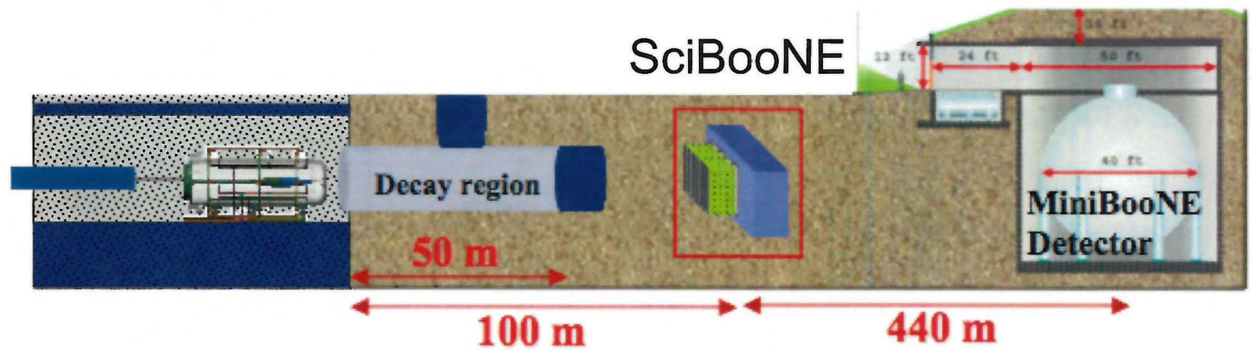
The Intensity Frontier: Early Next Decade

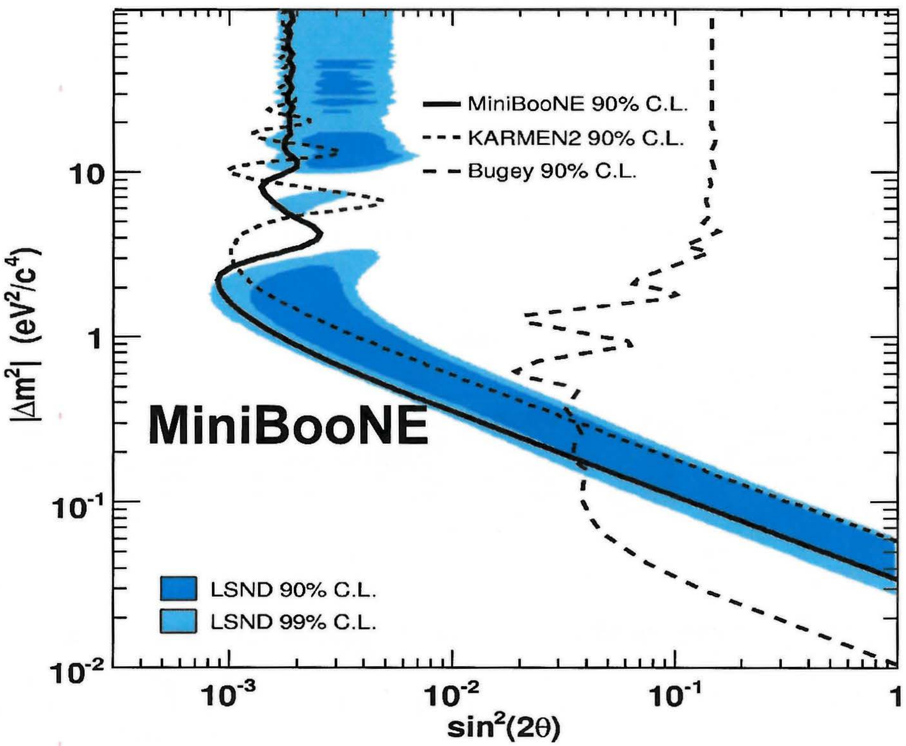
Neutrino Oscillation

MiniBooNE
MINOS
NOvA

MiniBooNE: $\nu_\mu \rightarrow \nu_e$

8 GeV Proton Beam
from Booster

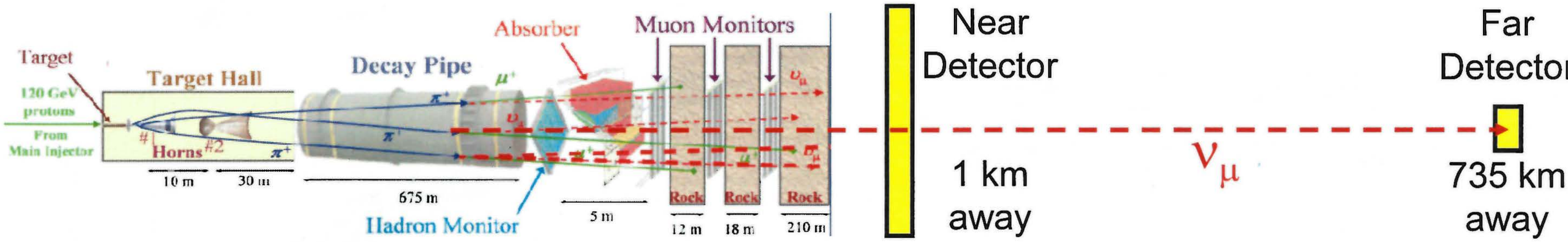


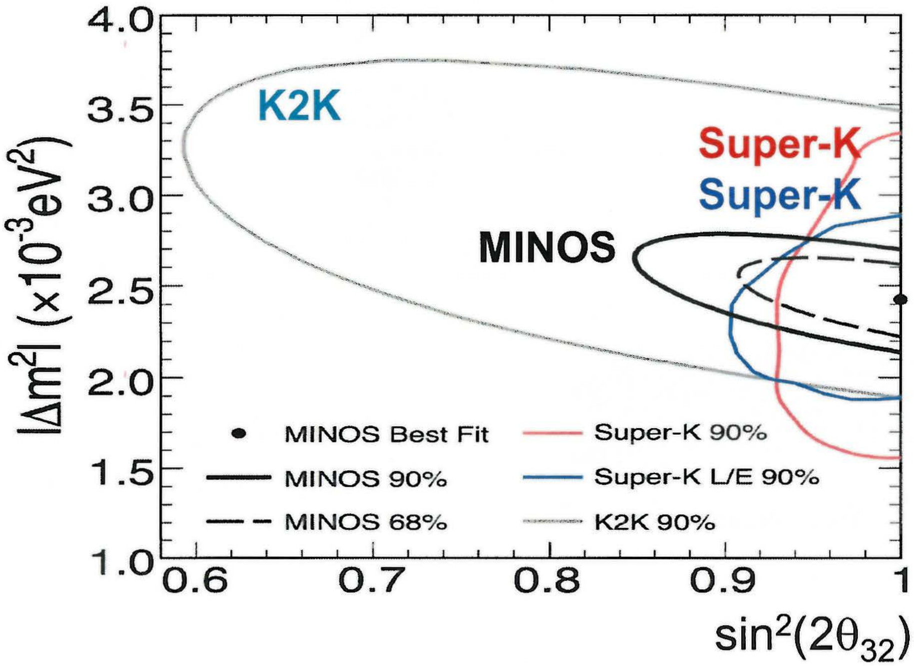


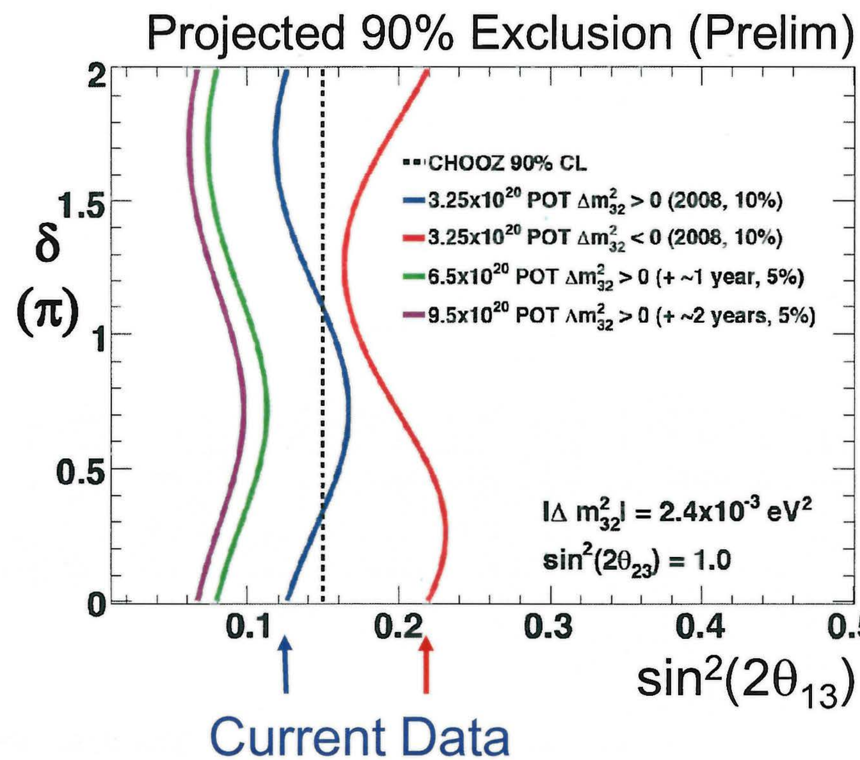
The LSND result requires the 4th neutrino.

MiniBooNE ruled out the LSND result.

MINOS: $\nu_\mu \rightarrow \nu_x$, $\nu_\mu \rightarrow \nu_e$

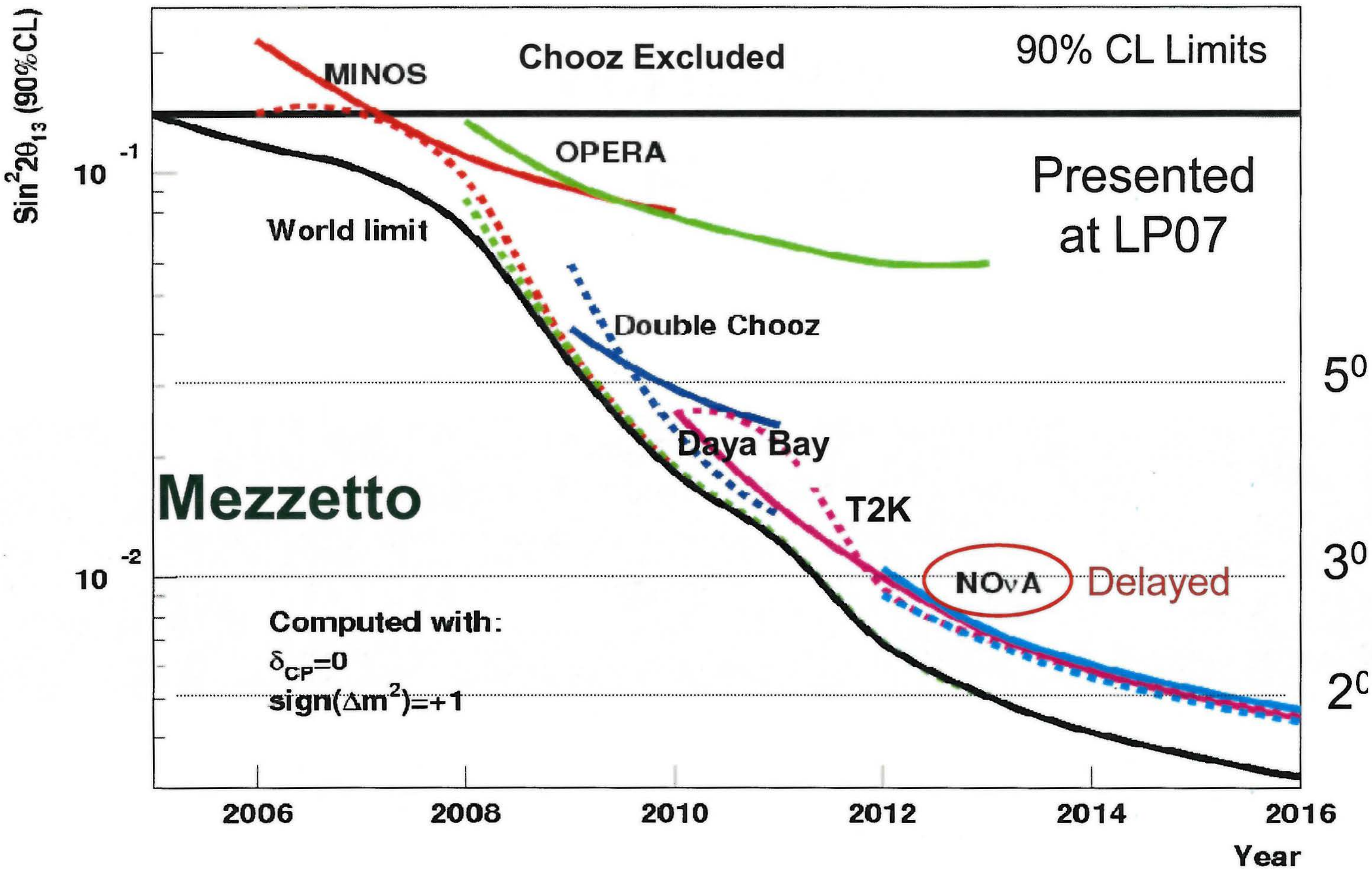






Best Δm^2_{32} measurement! Possibly an early glimpse on θ_{13}

NOvA: Outlook of $\sin^2 2\theta_{13}$, Mass Ordering



NOvA could provide the first glimpse of the mass hierarchy for large θ_{13} - the only near term probe of hierarchy in the world.

Neutrino's Interactions with Matter

SciBooNE

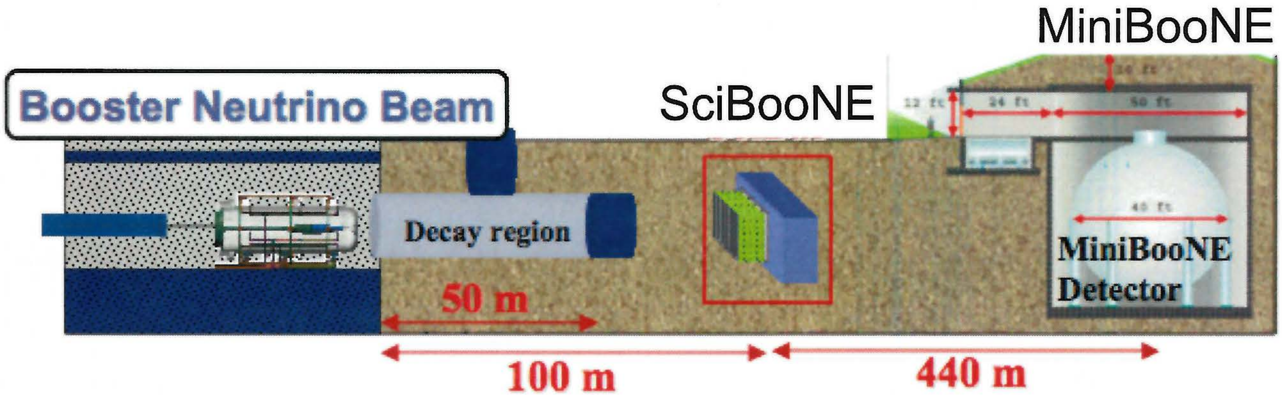
MINERvA

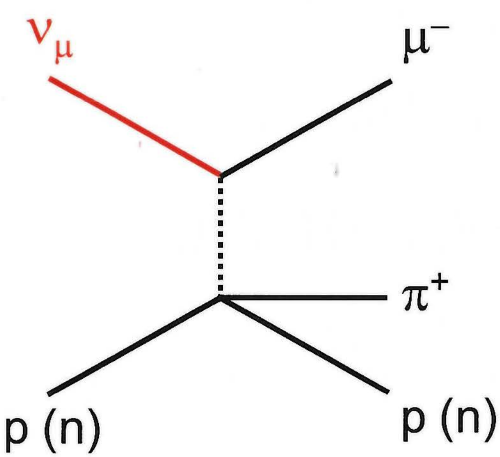
How do neutrinos interact with matter?

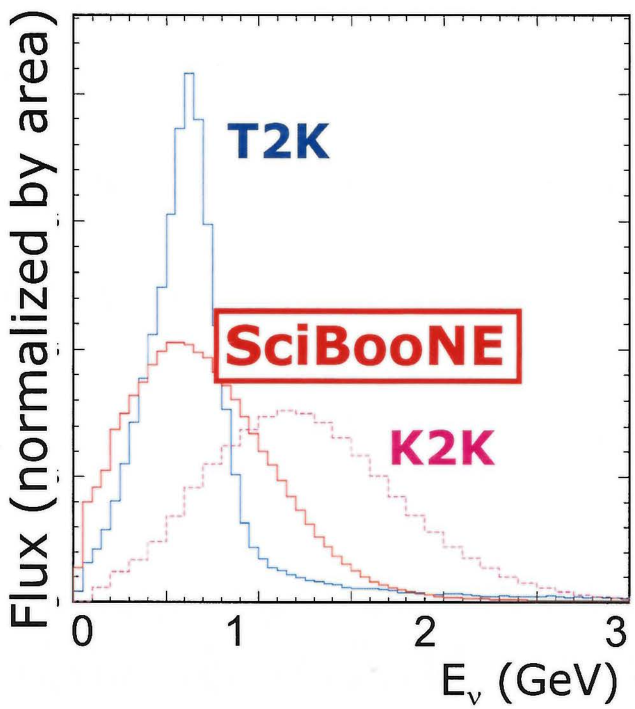
- We are entering
  - a precision era in neutrino oscillation physics.
- It requires
  - precise determination of the neutrino reaction and production cross sections.

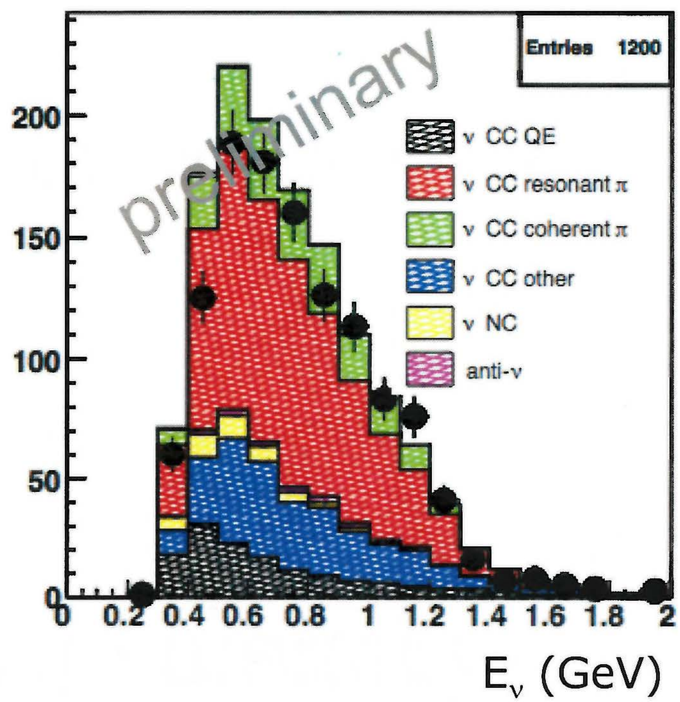
SciBooNE

8 GeV Proton Beam
from Booster

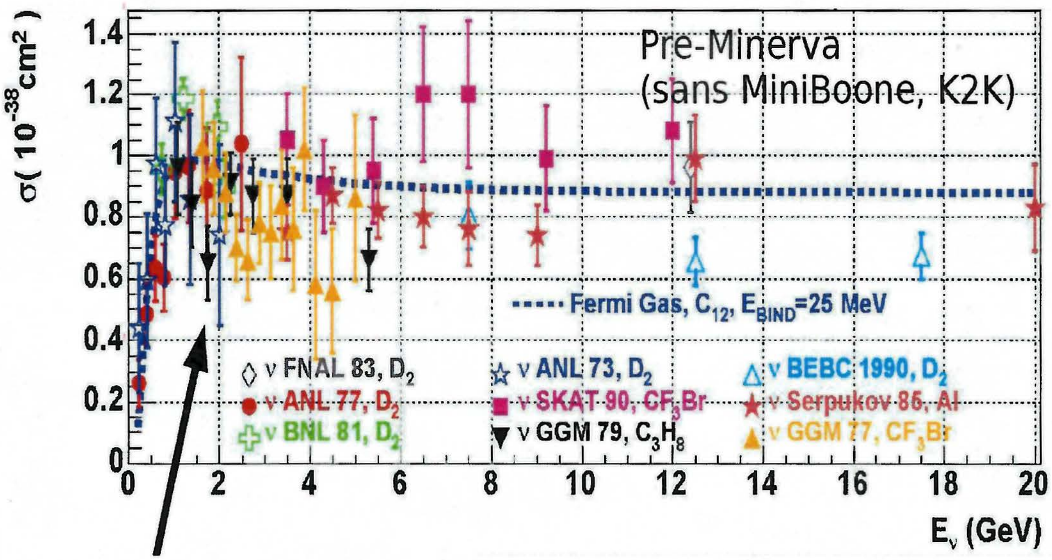


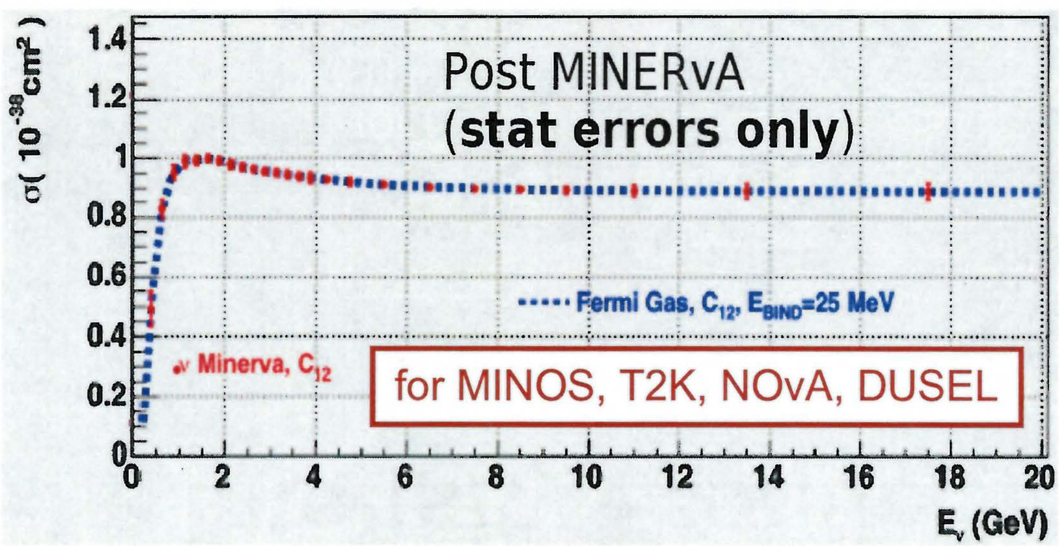






MINERvA





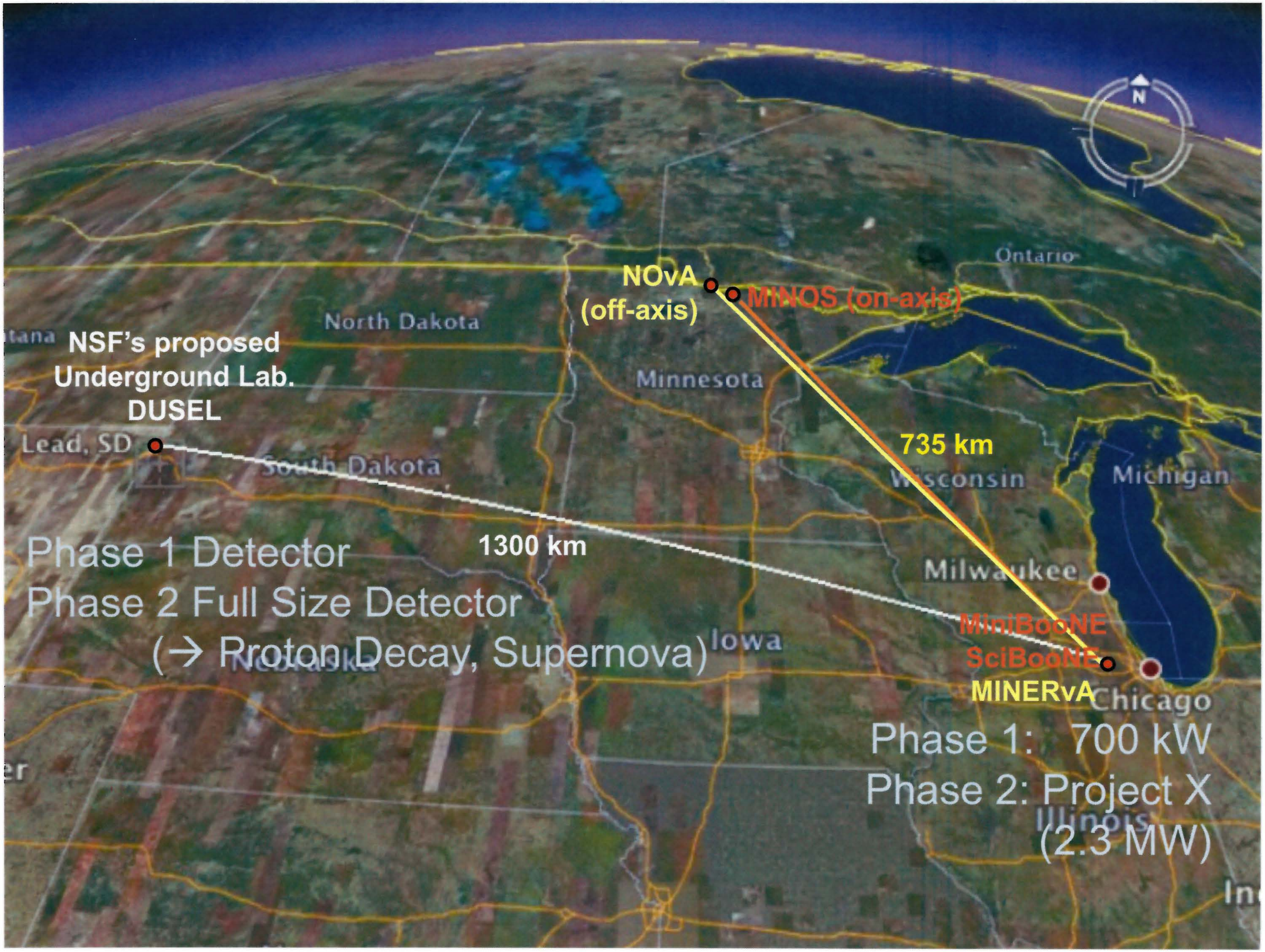
Construction has begun
Data taking in end 2009

The Intensity Frontier:

Toward DUSEL

Neutrinos to DUSEL:

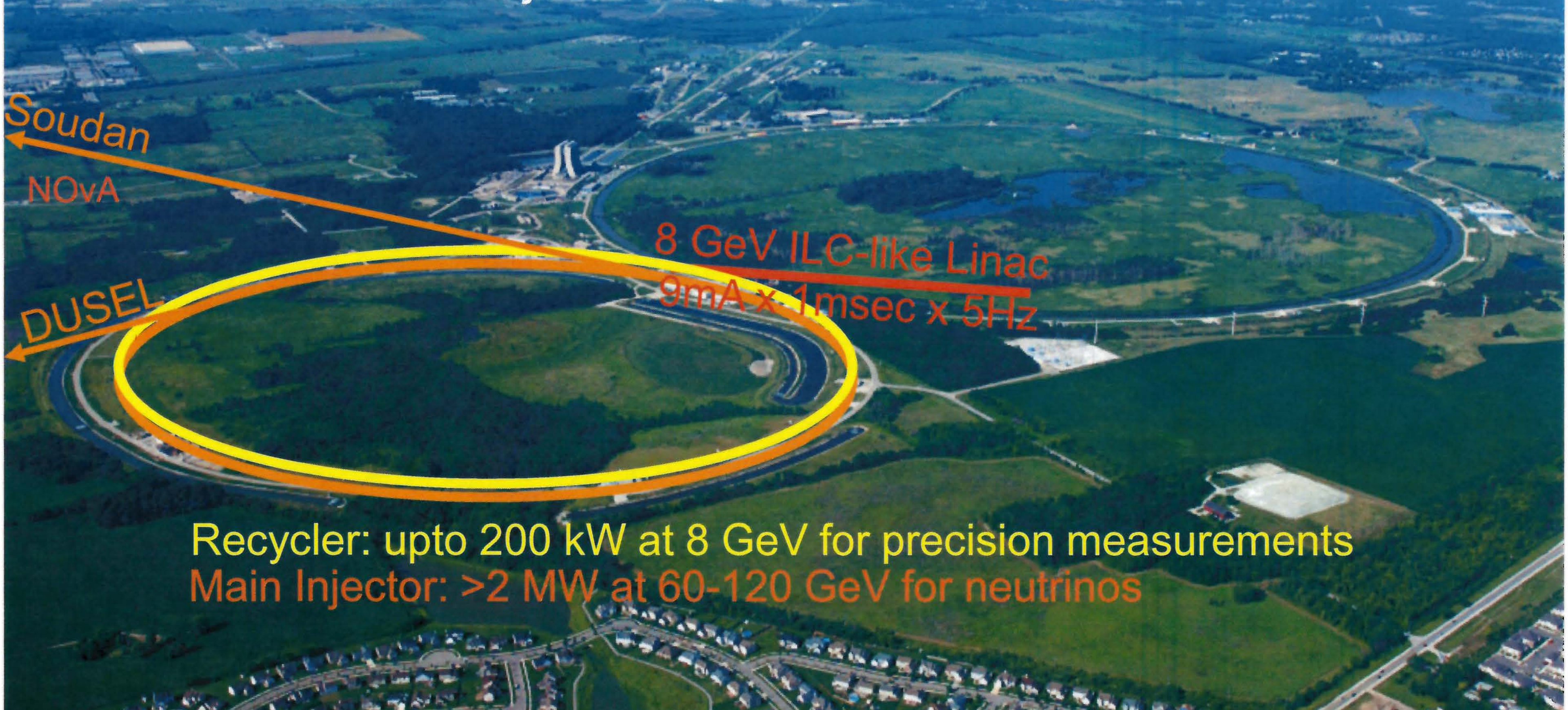
DUSEL Beamline Working Group formed to develop a conceptual plan of the beamline (beam extraction, civil construction, targeting, beamline optics / components / instrumentation, near detector hall)


NOvA
(off-axis)
MINOS (on-axis)
Ontario
North Dakota
NSF's proposed
Underground Lab.
DUSEL
Minnesota
Lead, SD
South Dakota
735 km
Wisconsin
Michigan
Phase 1 Detector
Phase 2 Full Size Detector
(→ Proton Decay, Supernova)
1300 km
Milwaukee
MiniBooNE
SciBooNE
MINERvA
Iowa
Nebraska
Chicago
Phase 1: 700 kW
Phase 2: Project X
(2.3 MW)
Illinois

High Intensity Proton Accelerator: Project X

8 GeV ILC-like Linac + Recycler + Main Injector

National Project with International Collaboration



Recycler: upto 200 kW at 8 GeV for precision measurements

Main Injector: >2 MW at 60-120 GeV for neutrinos

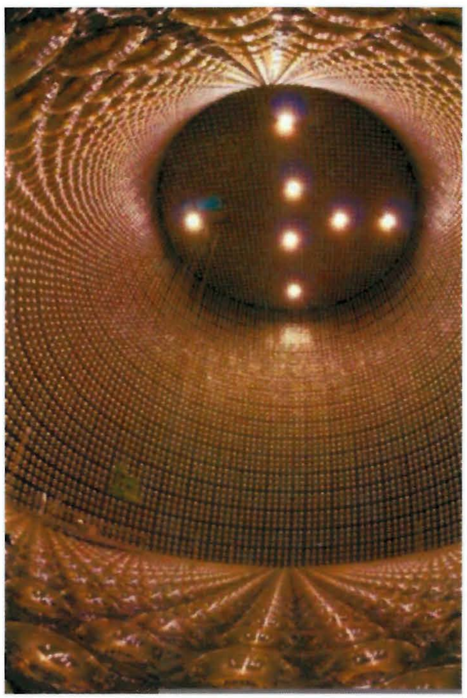
Project X: Naming Contest

http://www.fnal.gov/directorate/Longrange/Steering_Public/Name-ProjectX.html

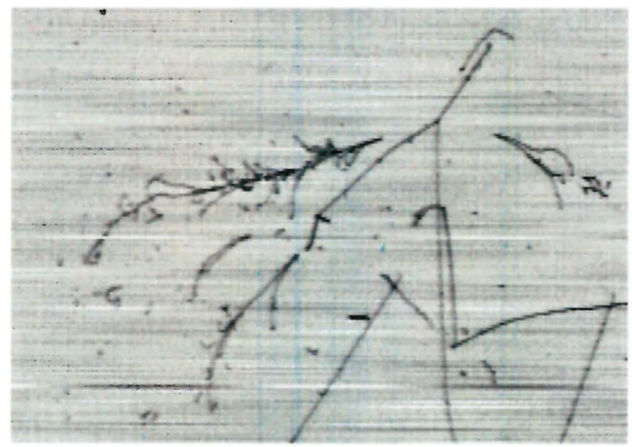
Neutrino / Proton Decay "Massive" Detectors

Options under consideration:
~300 kt WC, ~100 kt LAr, or some combination of the two.
Fermilab supports both technologies.

- Water Cerenkov
  - Known technology

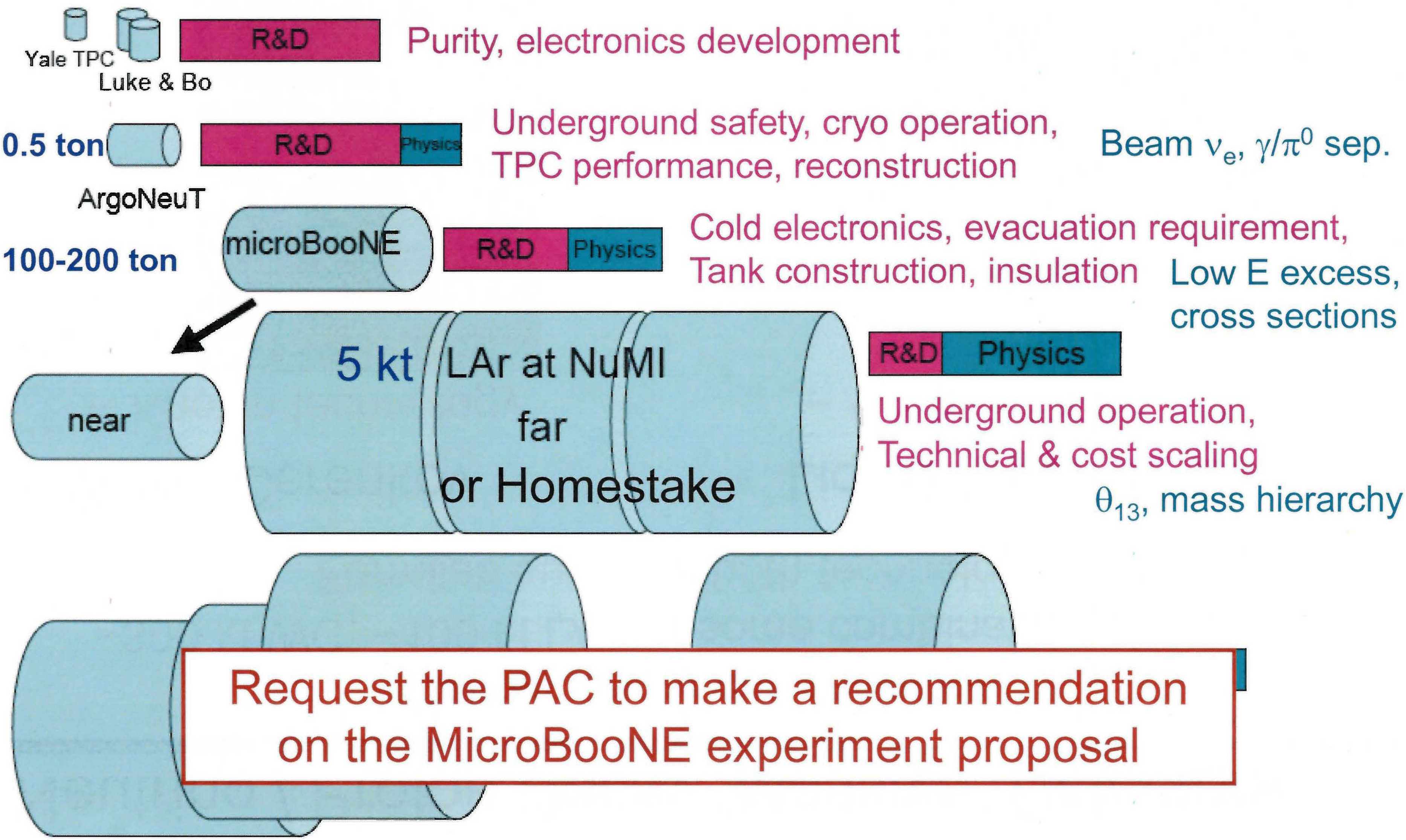


- Liquid Argon TPCs
  - Great promise (x 3-4)



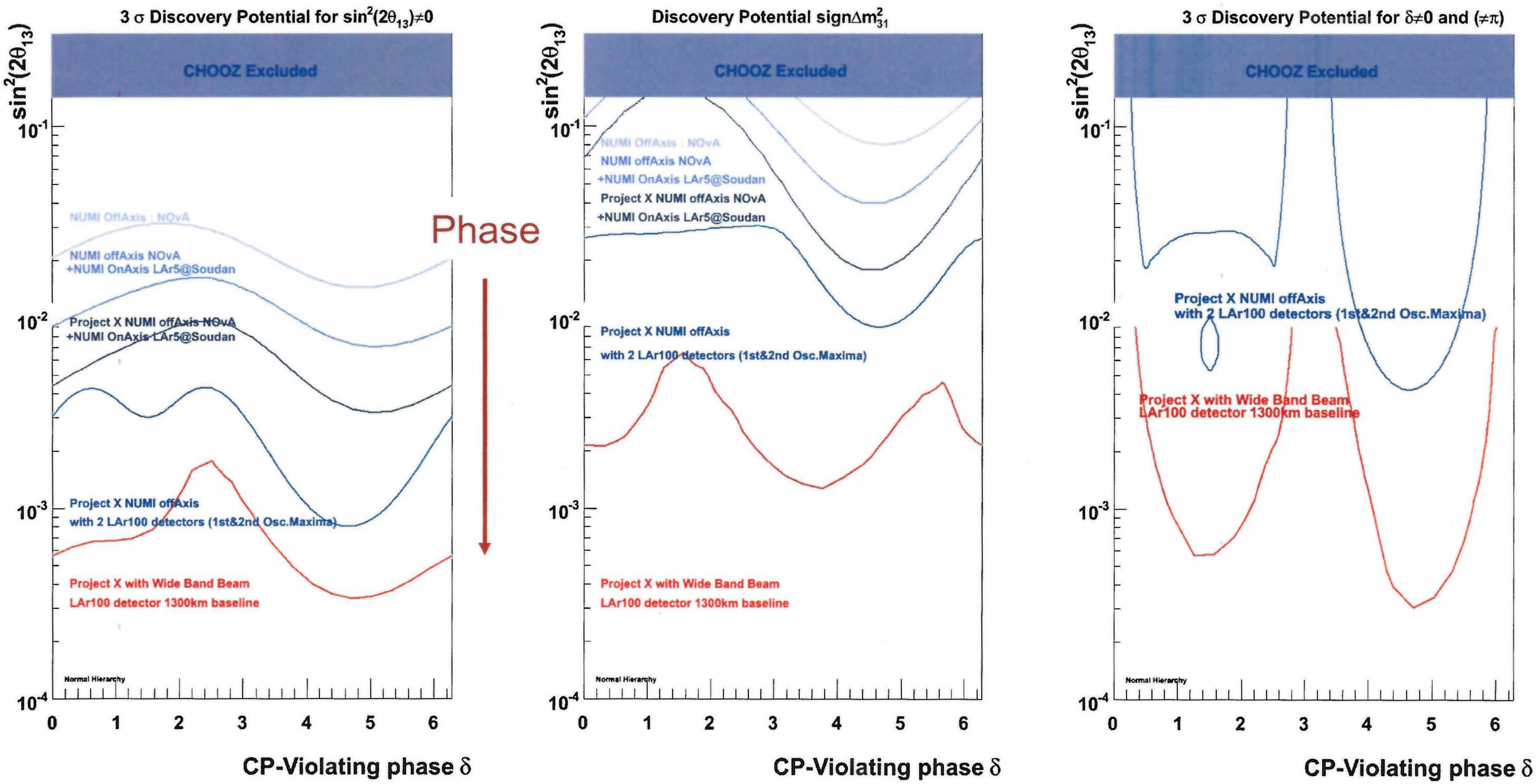
LAr TPC R&D / Physics Program

Reviewed by External Review chaired by Bob Kephart.



The 3σ Reach of the Successive Phases

$\sin^2 2\theta_{13}$ — Mass Ordering — CP Violation



Precision Measurements

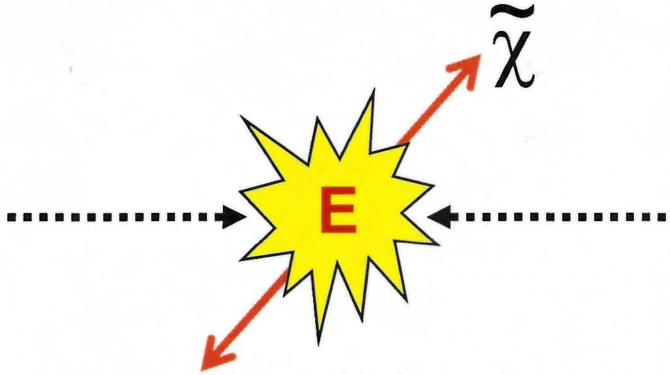
Precision Meas.s: Energy – Intensity Connection

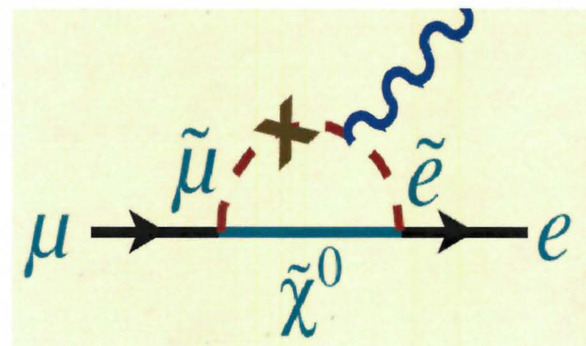
Energy Frontier Facility | **Intensity Frontier Facility**

The Gauge Sector
Higgs
EWSB

↔

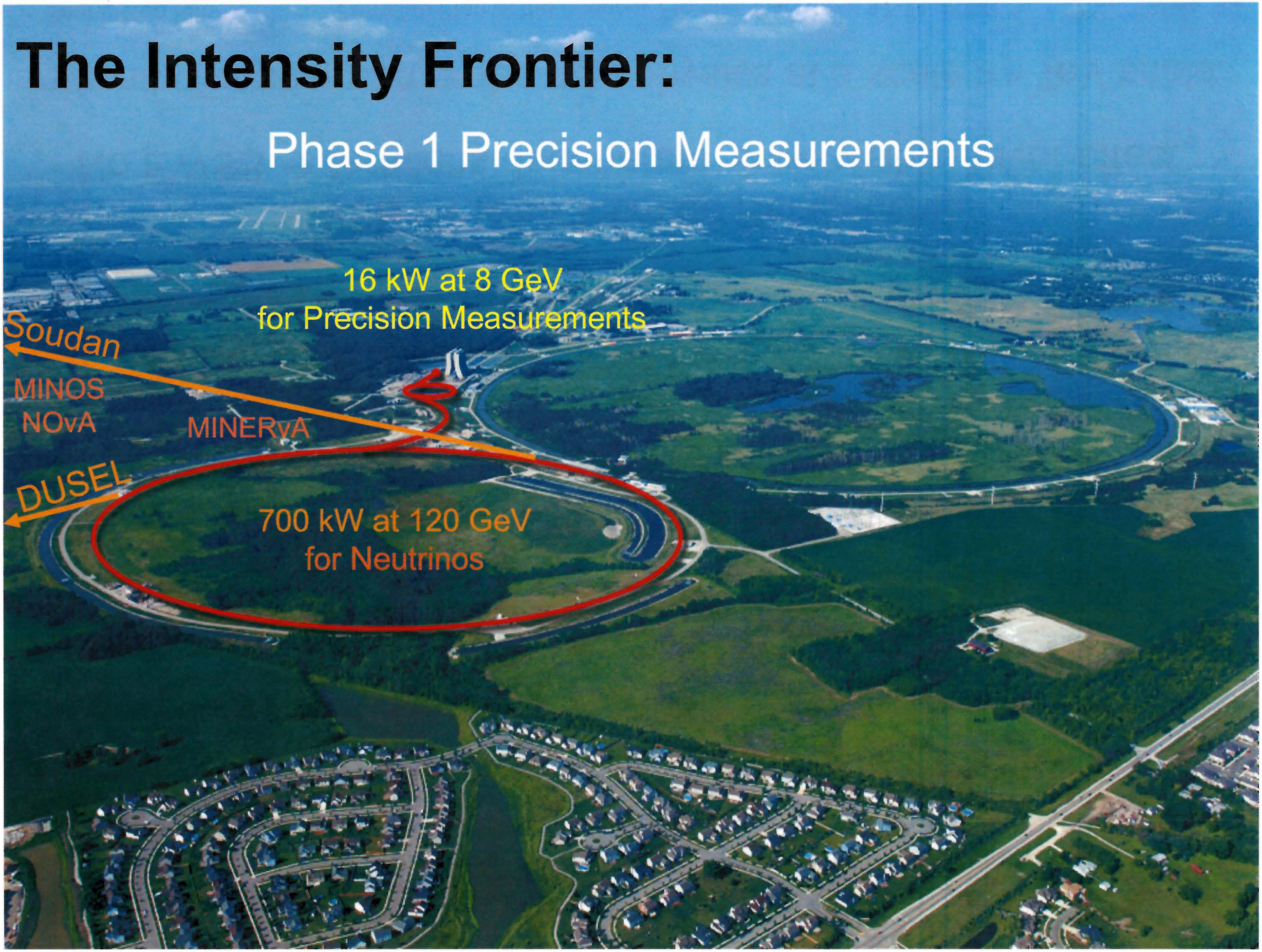
The Flavor Sector
Mixings, Masses,
CPV, FCNC, LFV, …

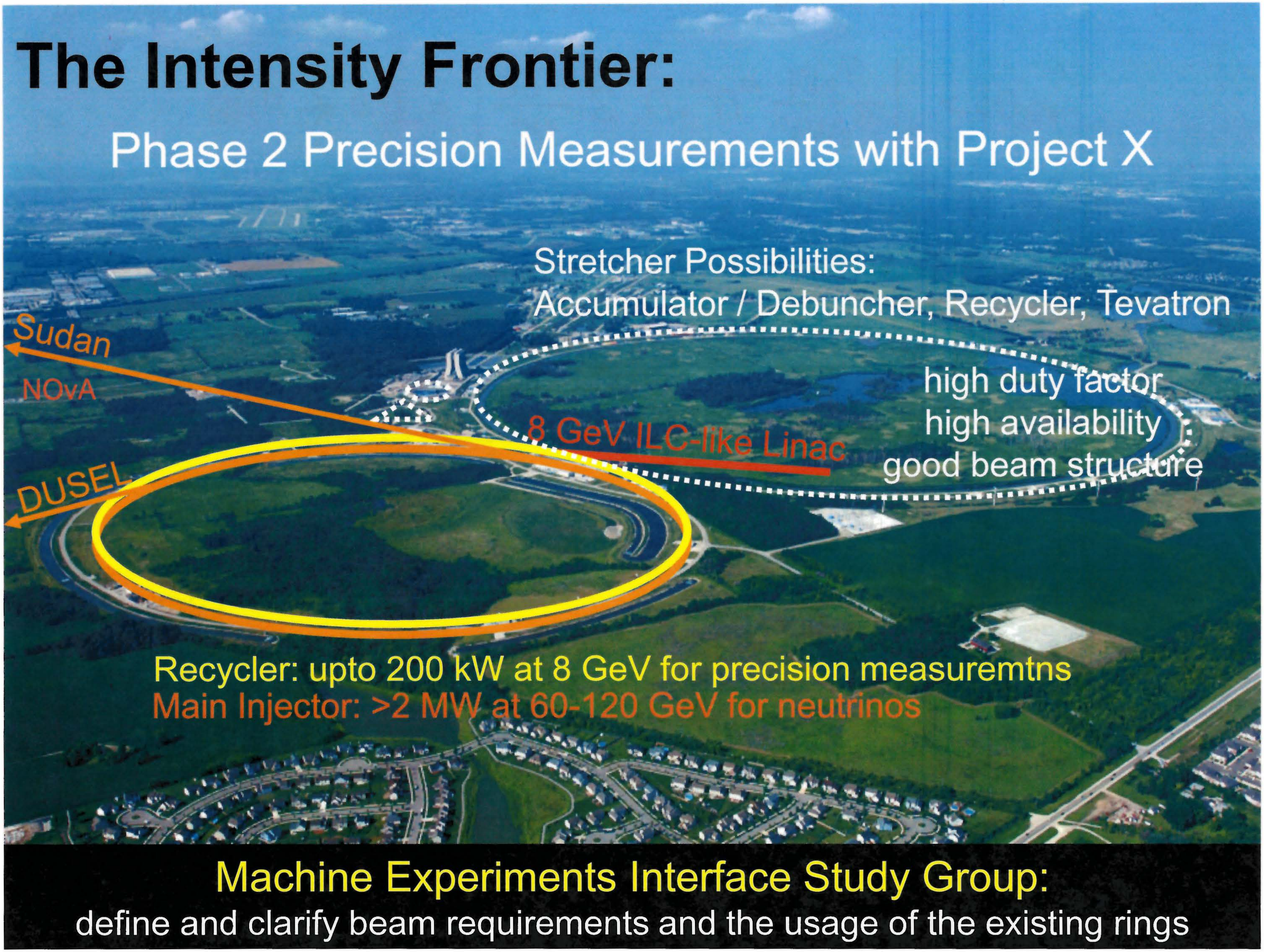




EWSB – Flavor Intimate Relationship:
No EWSB → fermions degenerate → no visible flavor effect

Intensity Frontier can probe new physics at a scale >> TeV scale.


The Intensity Frontier:
Phase 1 Precision Measurements
16 kW at 8 GeV
for Precision Measurements
Soudan
MINOS
NOvA
MINERvA
DUSEL
700 kW at 120 GeV
for Neutrinos

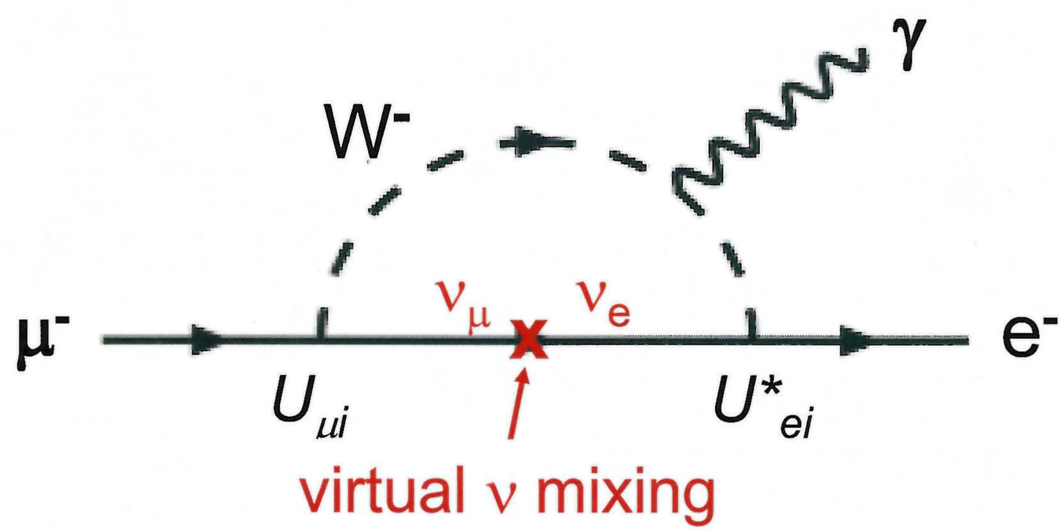

The Intensity Frontier:
Phase 2 Precision Measurements with Project X
Stretcher Possibilities:
Accumulator / Debuncher, Recycler, Tevatron
Sudan
NOvA
high duty factor
high availability
good beam structure
8 GeV ILC-like Linac
DUSEL
Recycler: upto 200 kW at 8 GeV for precision measuremtns
Main Injector: >2 MW at 60-120 GeV for neutrinos
Machine Experiments Interface Study Group:
define and clarify beam requirements and the usage of the existing rings

Muons

Neutrinos change from one kind to another.

Do charged leptons do, too?

In SM



γ can be real ($\mu \rightarrow e\gamma$) or virtual (μ + neucleus → e + neucleus)

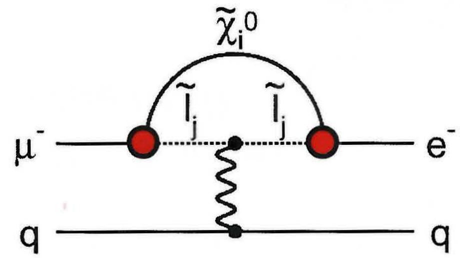
Experimental reach ~ 10^{-13} ($\mu \rightarrow e\gamma$), 10^{-17} ($\mu N \rightarrow eN$)

$$Br(\mu \rightarrow e\gamma) = \left| \frac{3\alpha}{32\pi} \sum_{i=2,3} U^*_{\mu i} U_{ei} \frac{\Delta m^2_{1i}}{M^2_W} \right|^2 < 10^{-54}$$

Muons: μ to e Conv.($\mu N \rightarrow eN$) in New Physics

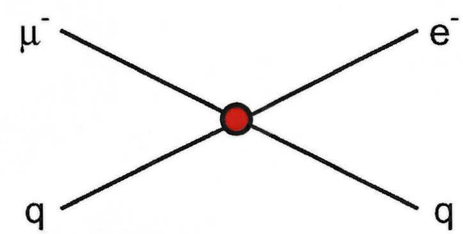
Supersymmetry

rate ~ 10^{-15}



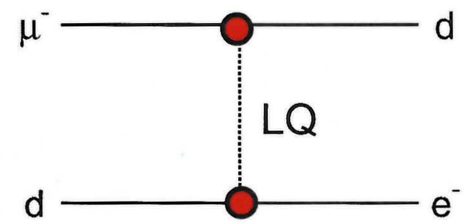
Compositeness

Λ_c ~ 3000 TeV



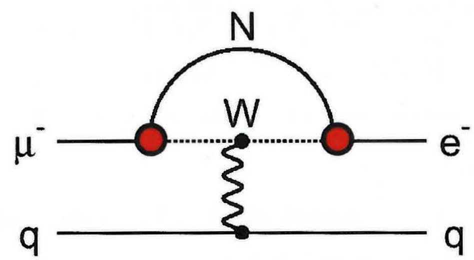
Leptoquark

M_{LQ} =
3000 $(\lambda_{\mu d}\lambda_{ed})^{1/2}$ TeV/c^2



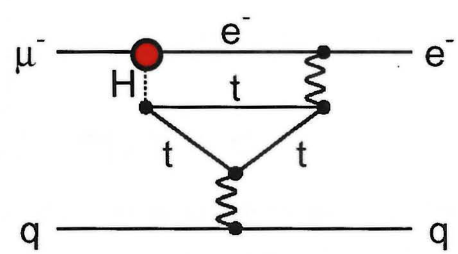
Heavy Neutrinos

$|U_{\mu N}U_{eN}|^2$ ~ 8×10^{-13}



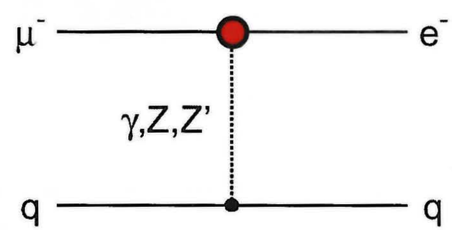
Second Higgs Doublet

$g(H_{\mu e})$ ~ $10^{-4} g(H_{\mu\mu})$



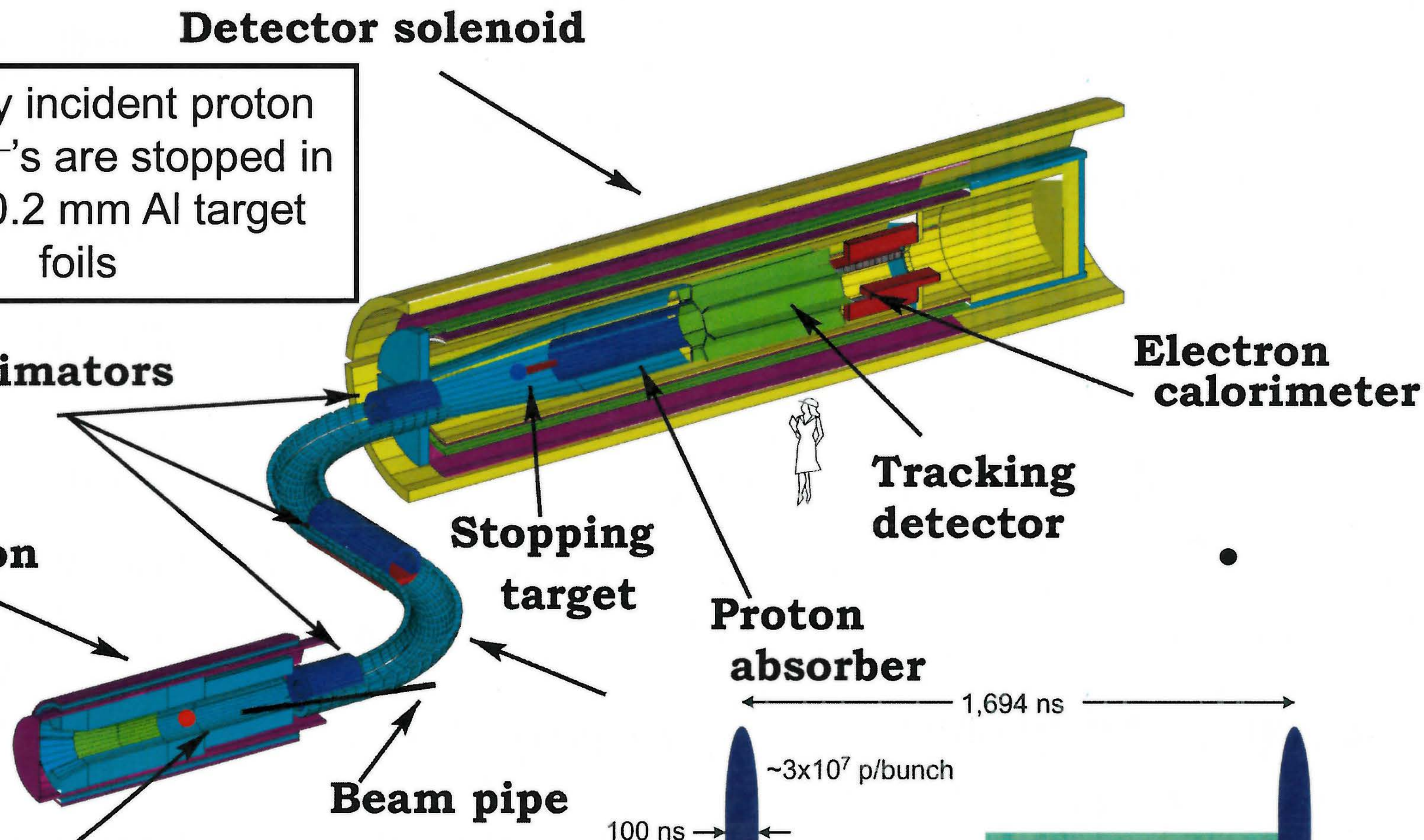
Heavy Z' Anomal. Z Coupling

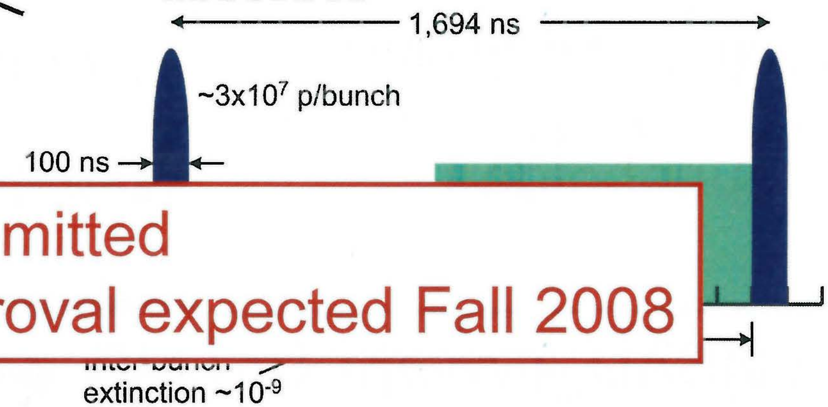
$M_{Z'}$ = 3000 TeV/c^2



mu2e Muon Beam and Detector

for every incident proton 0.0025 μ^{-}'s are stopped in the 17 0.2 mm Al target foils



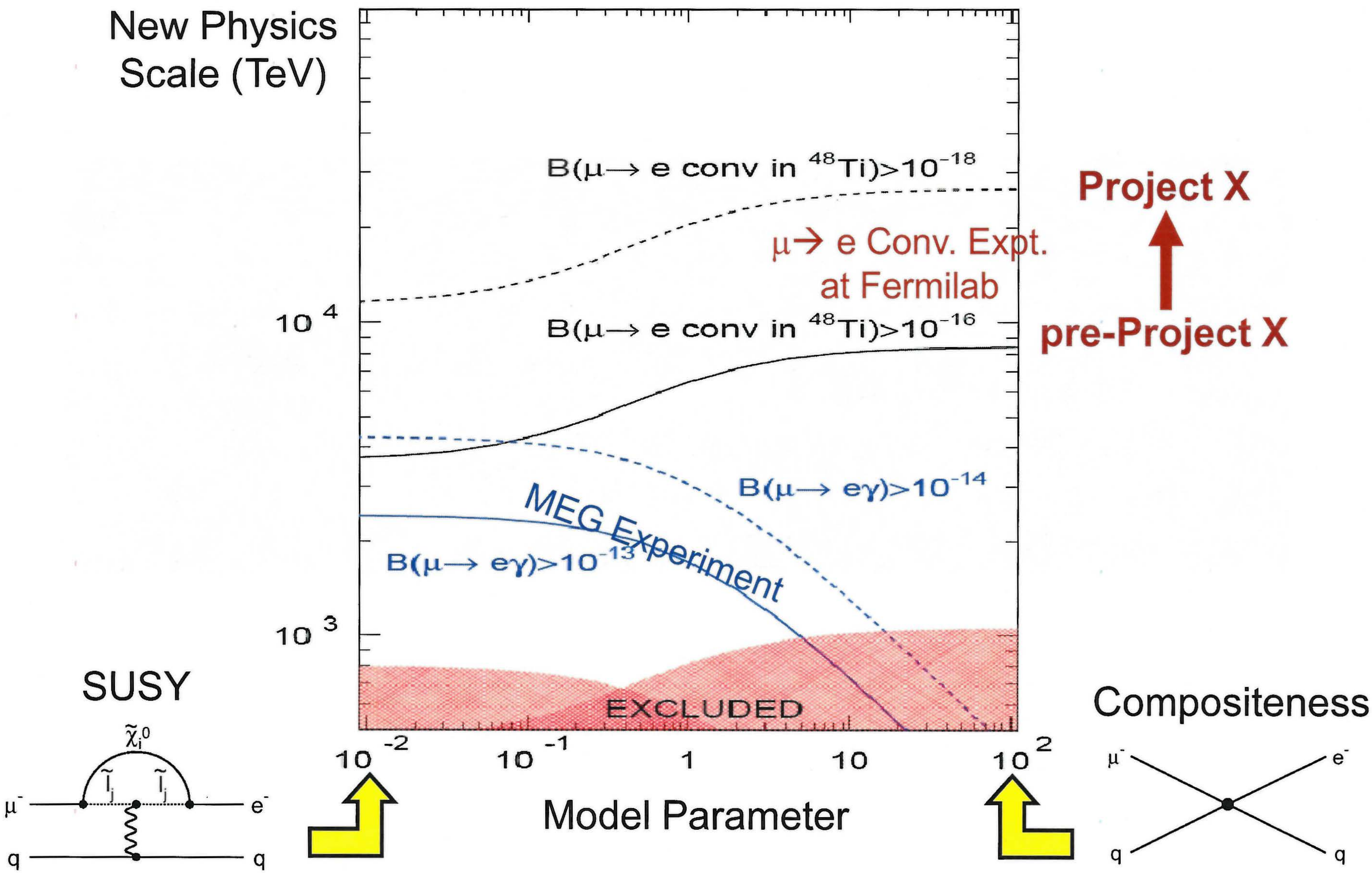


LOI submitted

Proposal for Stage 1 Approval expected Fall 2008

MEC

mu2e can probe $10^3 - 10^4$ TeV.



Japan-US MOU in progress
(Japan-US Project Funds)

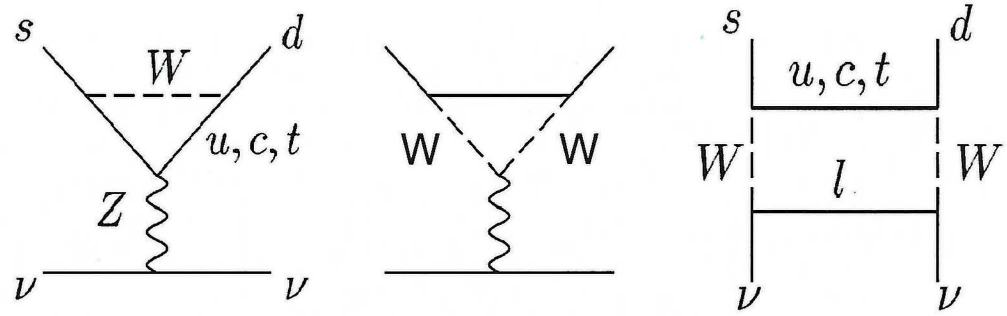
Japan-US workshops in discussion

Other Possibilities:

depending on
Budget,
Future Discoveries (e.g. LHC),
.....

Kaons: Rare Decays

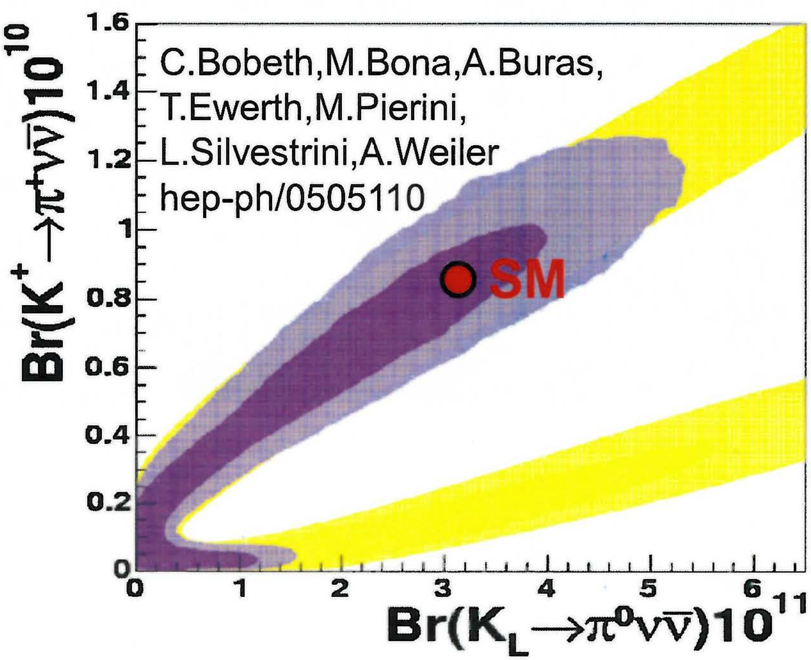
Standard Model
$Br(K^+ \rightarrow \pi^+\nu\nu) = 8 \times 10^{-11}$
$Br(K_L \rightarrow \pi^0\nu\nu) = 3 \times 10^{-11}$



An almost-Minimal Flavor Violation World:

Measuring small deviations from SM is important.

MFV SUSY Effects on $K \rightarrow \pi\nu\nu$



Kaons: Rare Decays

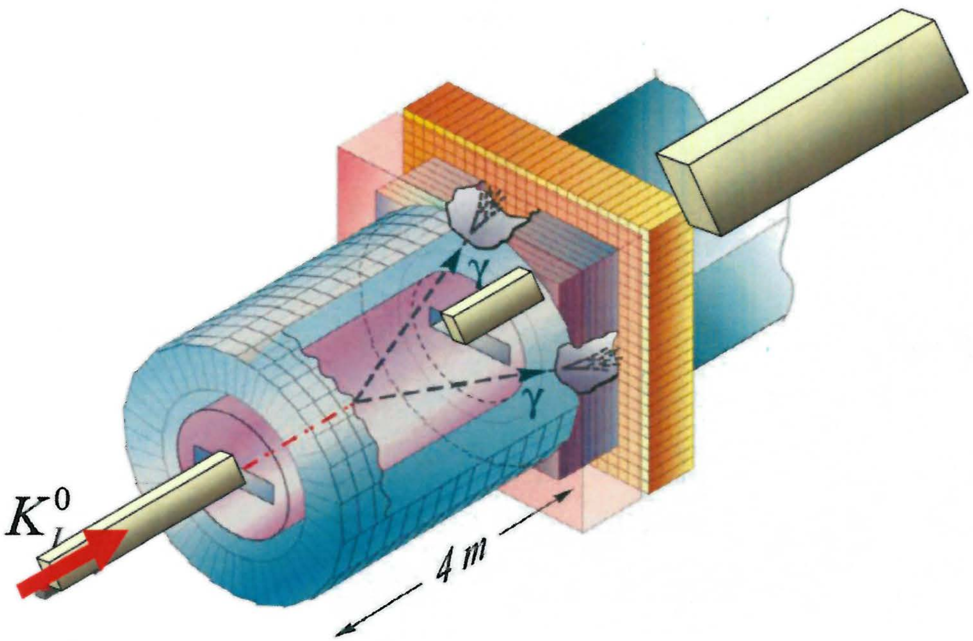
Experimental focus:

Theoretically & experimentally clean – a few % uncertainty

~1,000 clean Kaon events with Project X

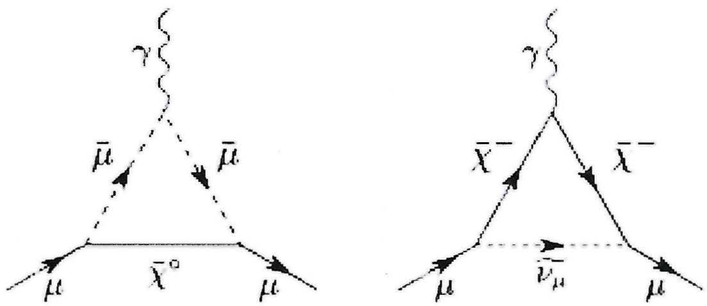
$K_L \rightarrow \pi^0 \nu\nu$

Experiment Concept

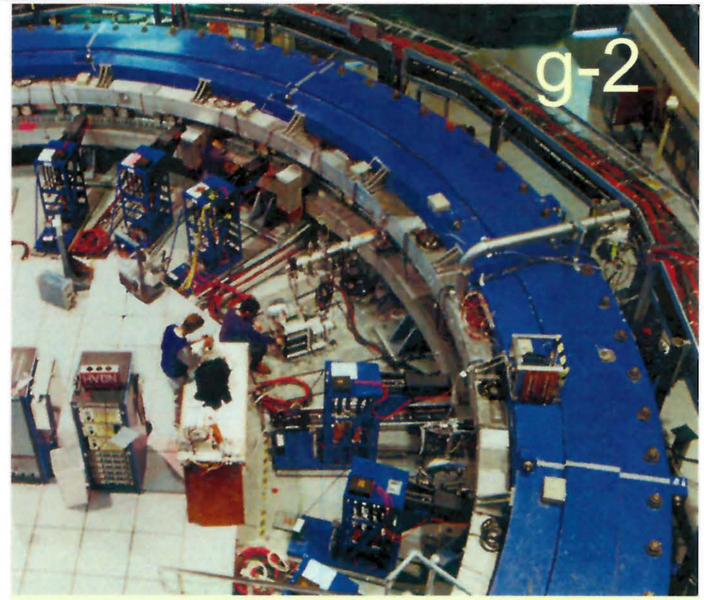


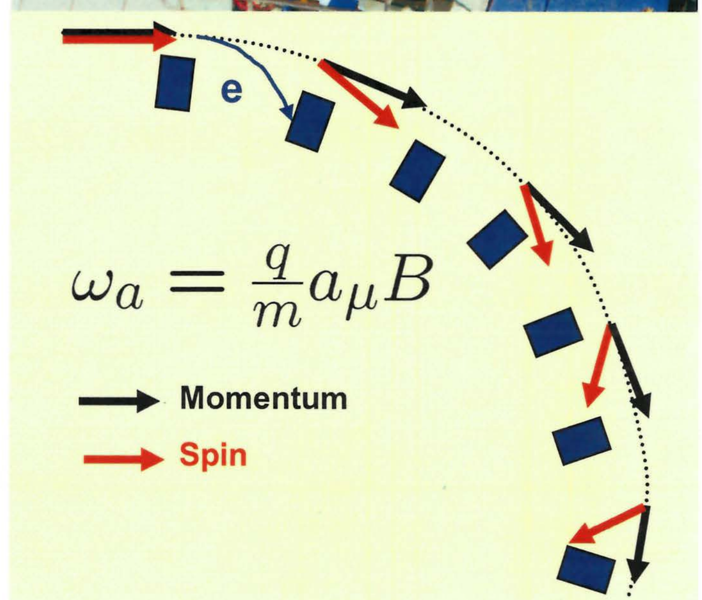
Muons for g-2

- Also sensitive to physics at a high mass scale



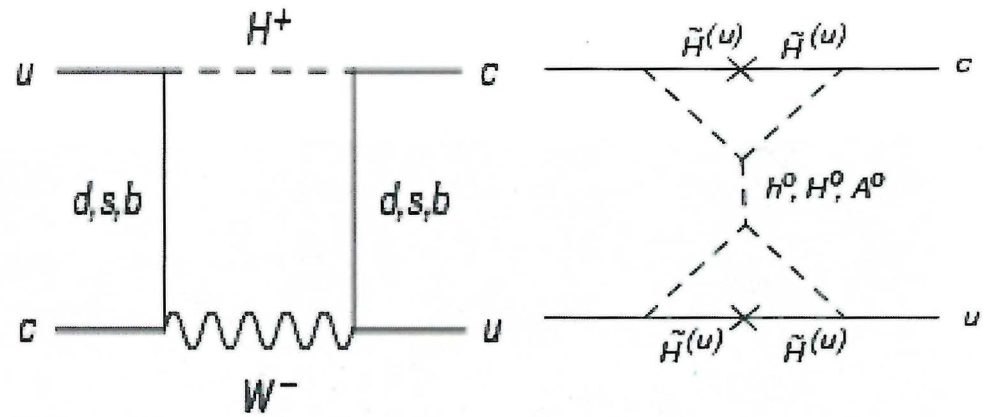
- With higher precision, could help determine the SUSY parameters
  - tanβ
  - sign(μ)



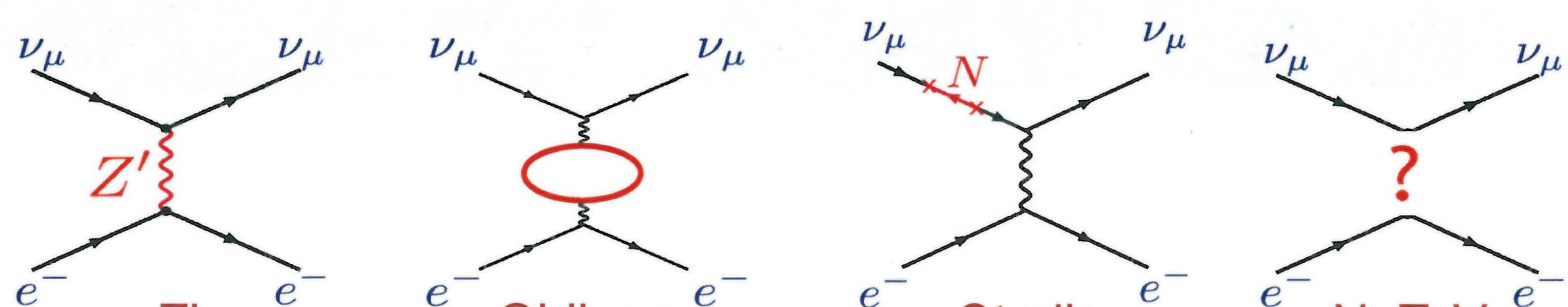


New Physics in Other Precision Meas.s

- Charms
  - $D^0 - \overline{D}^0$ mixing



- TeV-based Neutrinos (NuSOnG)
  - Electroweak Precision

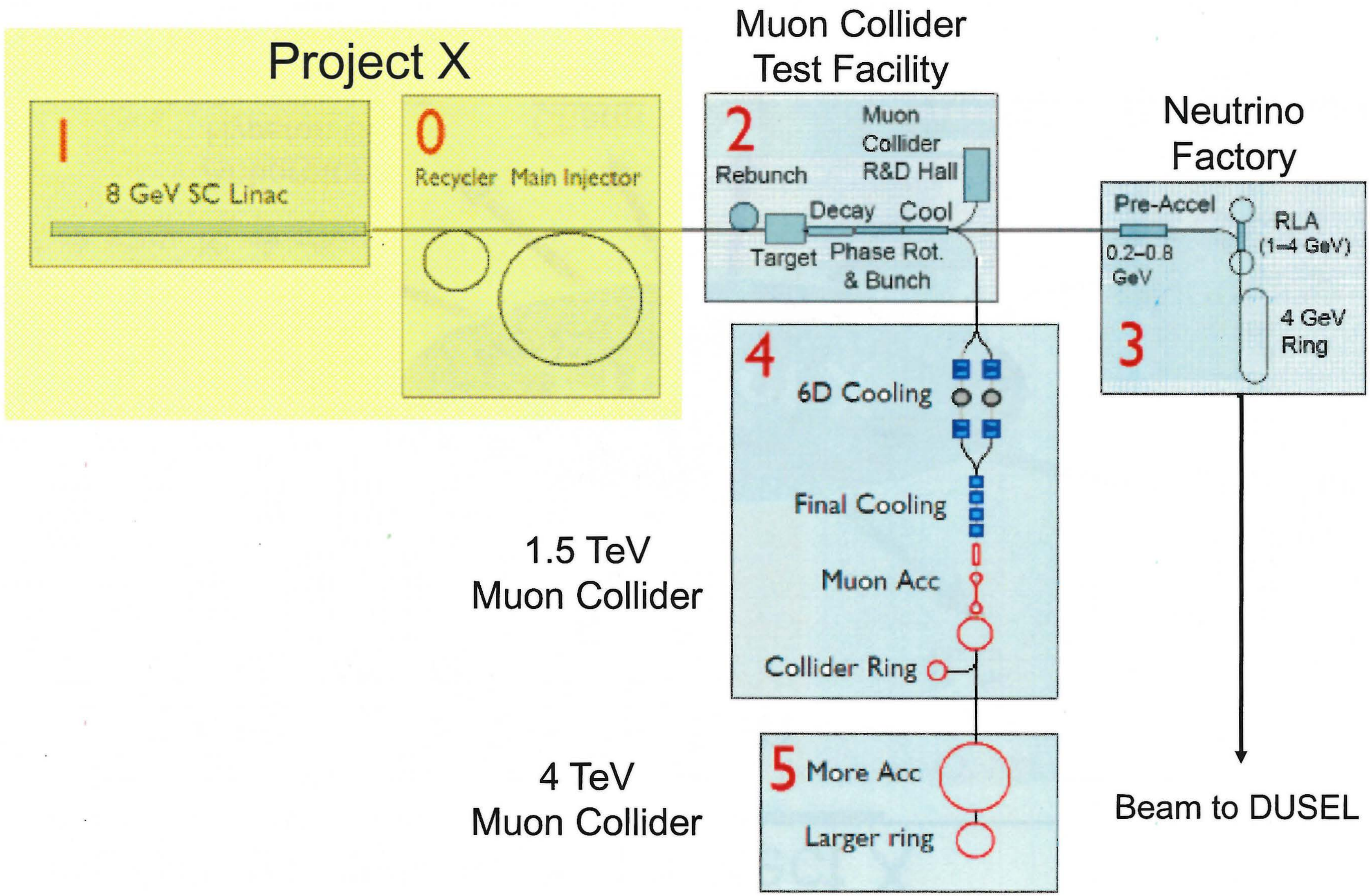


Z' | Oblique Corrections | Sterile Mixing | NuTeV Anomaly?

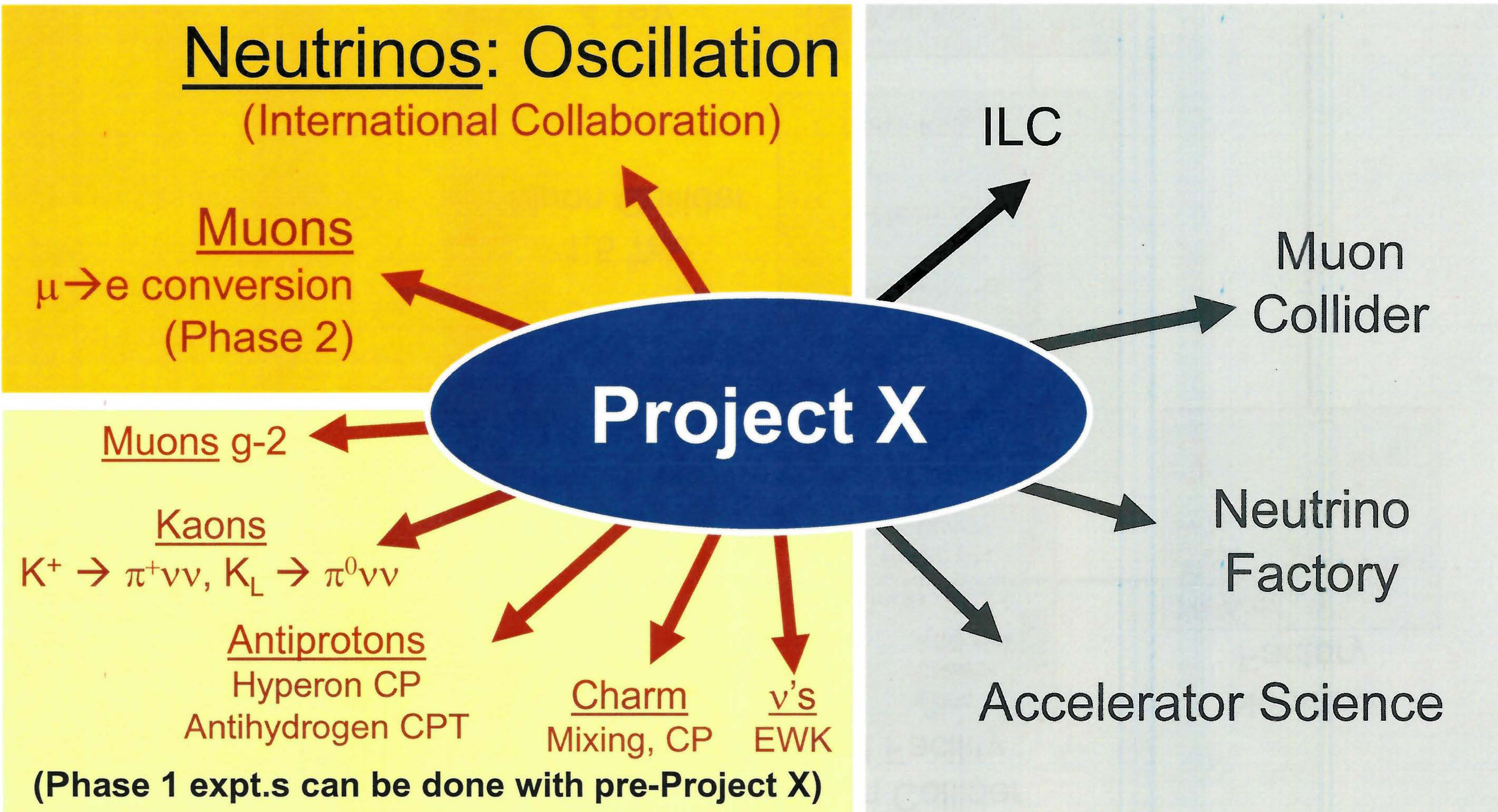
Project X:

Evolutional Path to ν-Factory & $\mu^+\mu^-$ Collider

Evolutionary Path to ν-Factory & $\mu^+\mu^-$ Collider



Opportunities with Project X



Need international coordination & collab.

Documented in Golden Book

Intensity Frontier Vision at Fermilab
Aligned with P5

a phased approach with
ever increasing beam intensities
and ever increasing detector capabilities