B.T.Fleming
Sept. 18, 2009
WIN09

Future Neutrino Experiments

Next generation LBL measurments, Neutrino Factories
and Beta Beams

Neutrino Cross Sections

New measurements,status of phenomenological predictions,
future measurements…

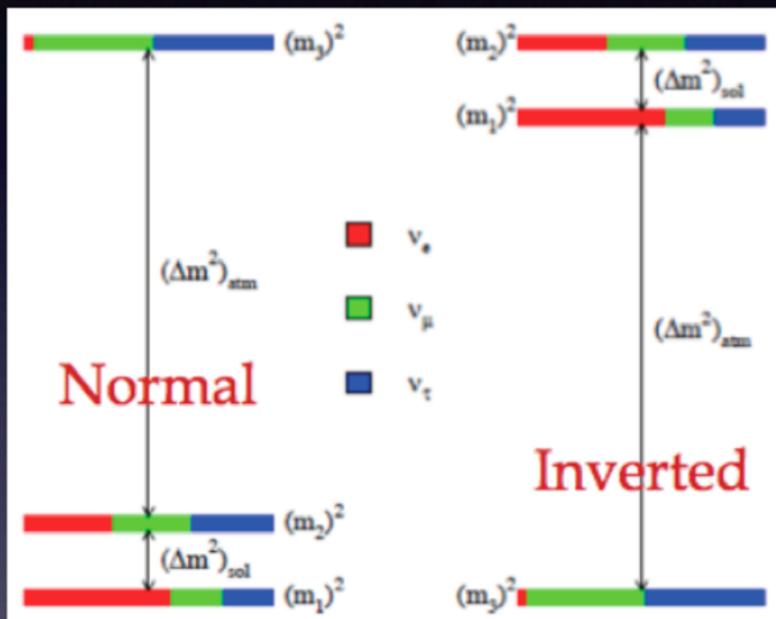
3-flavor neutrino oscillations

$$U = \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix}}_{\Delta m^2_{31}} \begin{pmatrix} c_{13} & 0 & e^{-i\delta} s_{13} \\ 0 & 1 & 0 \\ -e^{i\delta} s_{13} & 0 & c_{13} \end{pmatrix} \underbrace{\begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\Delta m^2_{21}}$$

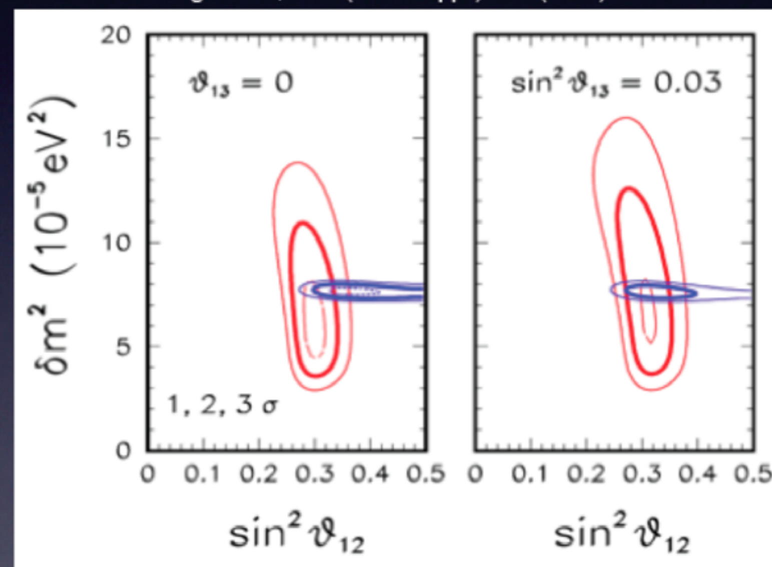
atmospheric+LBL | Chooz | solar+KamLAND

Schwetz, Tortola, Valle, arXiv:0808.2016

Δm^2_{21}	$(7.65^{+0.23}_{-0.20})\ 10^{-5}\ \text{eV}^2$
$\sin^2\theta_{12}$	$0.304^{+0.022}_{-0.016}$
$\lvert\Delta m^2_{31}\rvert$	$(2.40^{+0.12}_{-0.11})\ 10^{-3}\ \text{eV}^2$
$\sin^2\theta_{23}$	$0.50^{+0.07}_{-0.06}$
$\sin^2\theta_{13} < 0.056$ @ 3σ	



G.L. Fogli et al., NPB (Proc. Suppl.) 188 (2009) 27–30

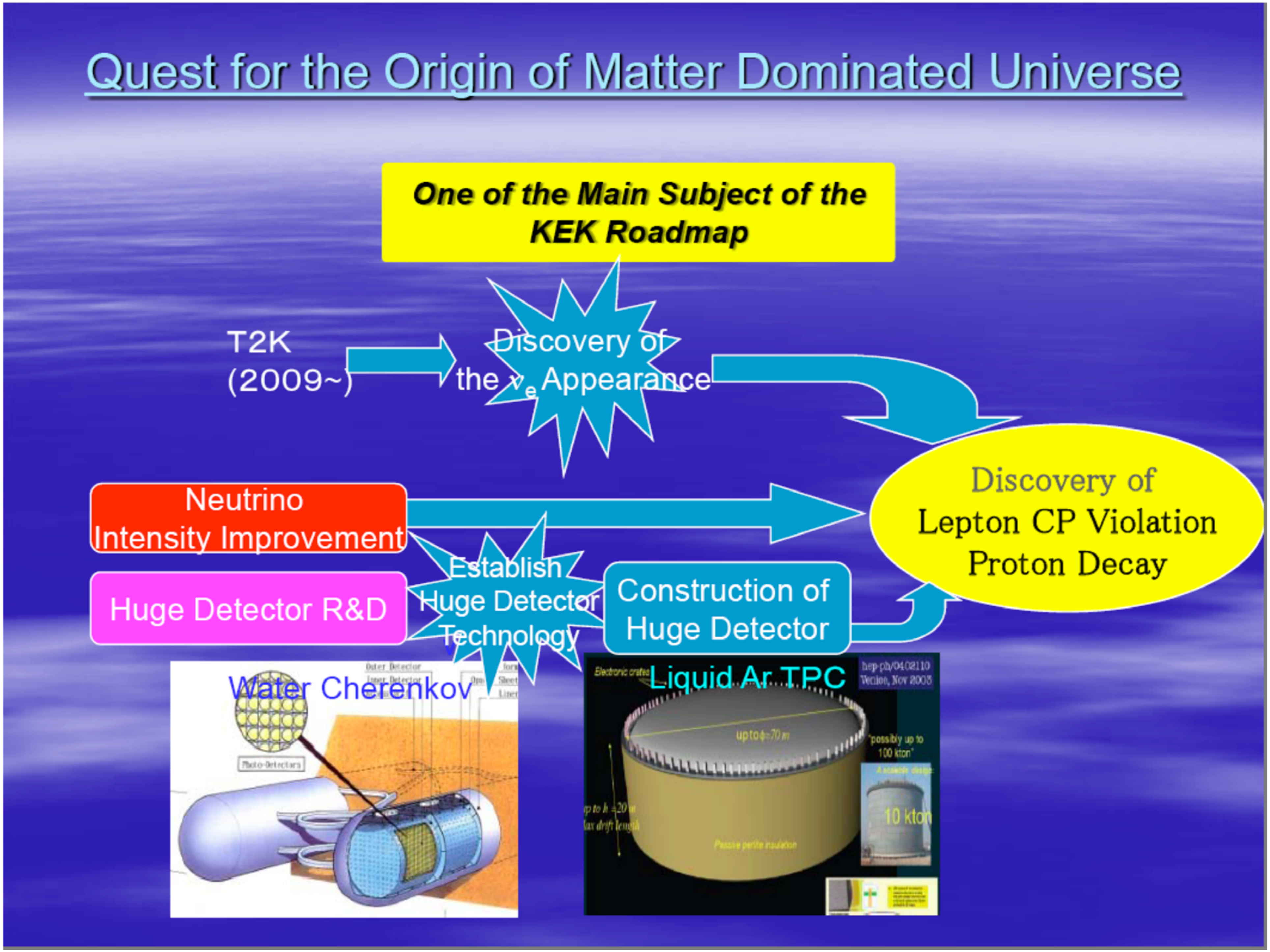


- ★Discover the unknown angle θ_{13}
- ★Discover CP violation ($\delta \neq 0, \pi$)
- ★Determine the mass hierarchy $\Delta m_{31}^2 > 0$ or < 0
- ★Improve knowledge of θ_{23} and Δm_{ij}^2's

Generations of LBL experiments

- Past and possible future long baseline projects (in **Yellow** with European participation)
  - 1st generation: **K2K**, **MINOS**, **OPERA**
    - ✳ 250 km - 730 km, 1.8-22.5 kton
  - 2nd generation: **T2K**, NOVA
    - ✳ 300 km - 830 km, 15-22.5 kton
  - 3rd generation: JPARC, ProjectX/DUSEL, **Europe**
    - ✳ 600 - 2500 km ? 100-1000 kton detectors ?
  - 4th generation: next generation beams (NF/beta)
    - ✳ 2000-7000 km ? 50 kton magnetized ?

J-PARC to Somewhere
Long Baseline Neutrino Experiment
and
Nucleon Decay Experiment
with
Huge Volume Detector


Quest for the Origin of Matter Dominated Universe
One of the Main Subject of the KEK Roadmap
T2K
(2009~)
Discovery of the ν_e Appearance
Neutrino Intensity Improvement
Huge Detector R&D
Establish Huge Detector Technology
Construction of Huge Detector
Discovery of Lepton CP Violation Proton Decay
Water Cherenkov
Outer Detector
Inner Detector
Photo-Detectors
Liquid Ar TPC
Electronic crates
hep-ph/0402110
Venice, Nov 2003
"possibly up to 100 kton"
10 kton

Three Possible Scenario Studied at NP08 Workshop

NP08 is **The 4th International Workshop on Nuclear and Particle Physics at J-PARC**

http://j-parc.jp/NP08

Comparison of Each Scenario

	Scenario 1 Okinoshima	**Scenario 2 Kamioka**	**Scenario 3 Kamioka Korea**
Baseline(km)	660	295	295 & 1000
Off-Axis Angle(°)	0.8(almost on-axis)	2.5	2.5 1
Method	ν_eSpectrum Shape	Ratio between $\nu_e \bar{\nu}_e$	Ratio between 1st 2ndMax Ratio between $\nu_e \bar{\nu}_e$
Beam	5Years $\nu_{\mu,}$ then Decide Next	2.2 Years $\nu_{\mu,}$ 7.8 Years $\bar{\nu}_{\mu,}$	5 Years $\nu_{\mu,}$ 5 Years $\bar{\nu}_{\mu,}$
Detector Tech.	Liq. Ar TPC	Water Cherenkov	Water Cherenkov
Detector Mass (kt)	100	2×270	270+270

Study is continuing to seek for optimum choice

Additional Requirement for Far Detector Optimization

- Proton Decay Discovery Performance

- Realization of the Huge Detector
  - Test of the key components
  - Prove the detector performance experimentally
    - if necessary, good prototyping
      (to be able to predict Huge Detector Performance)

    - Test with the particles is important

*KEK started R&D for Huge Liq. Ar TPC with ETH Zürich

Additional Requirement for Far Detector Optimization

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      (to be able to predict Huge Detector Performance)

R&D
towards
Giant Liquid Argon Observatory
for
Nucleon Decay, Neutrino Astrophysics and CP-violation in the Lepton Sector

irich

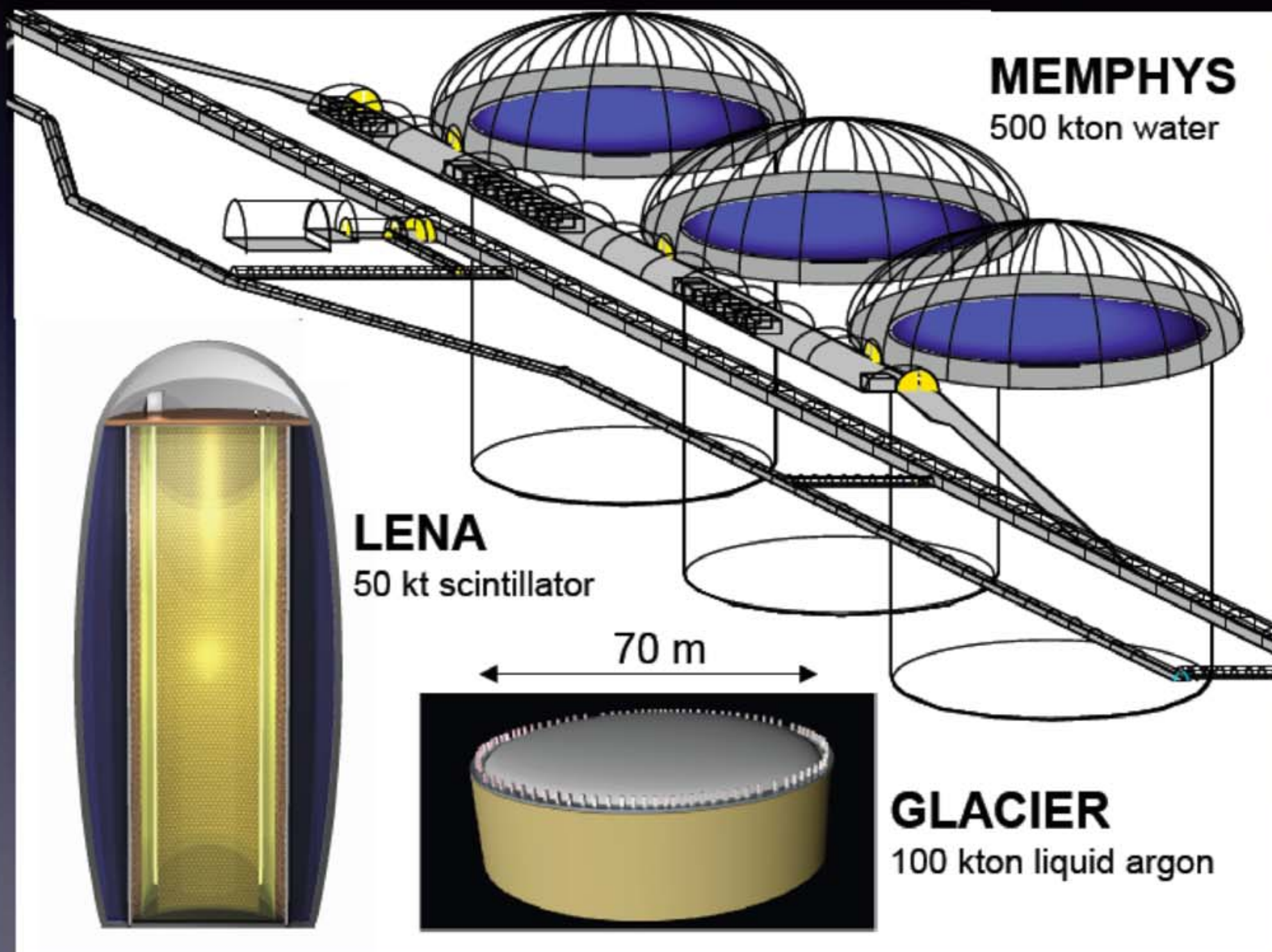
Future long baseline experiments: (potential) options for Europe

André Rubbia (ETH Zurich)

22nd International Workshop on Weak Interactions and Neutrinos
14-19 September 2009
Perugia, Italy

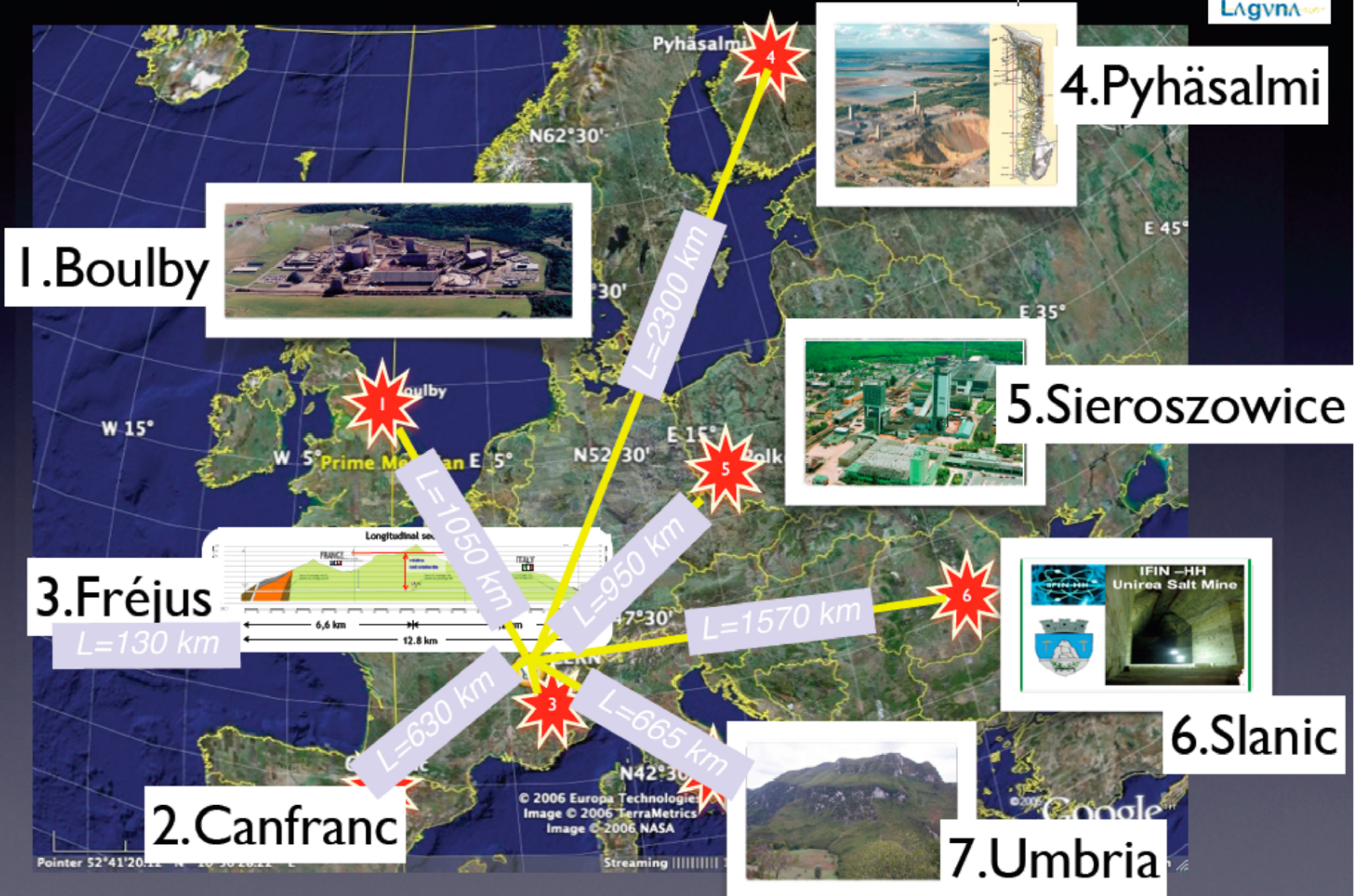
LAGUNA detector options

- A new far detector at a new far site
  - three options considered (MEMPHYS, LENA, GLACIER) with total mass in the range 50-500 kton



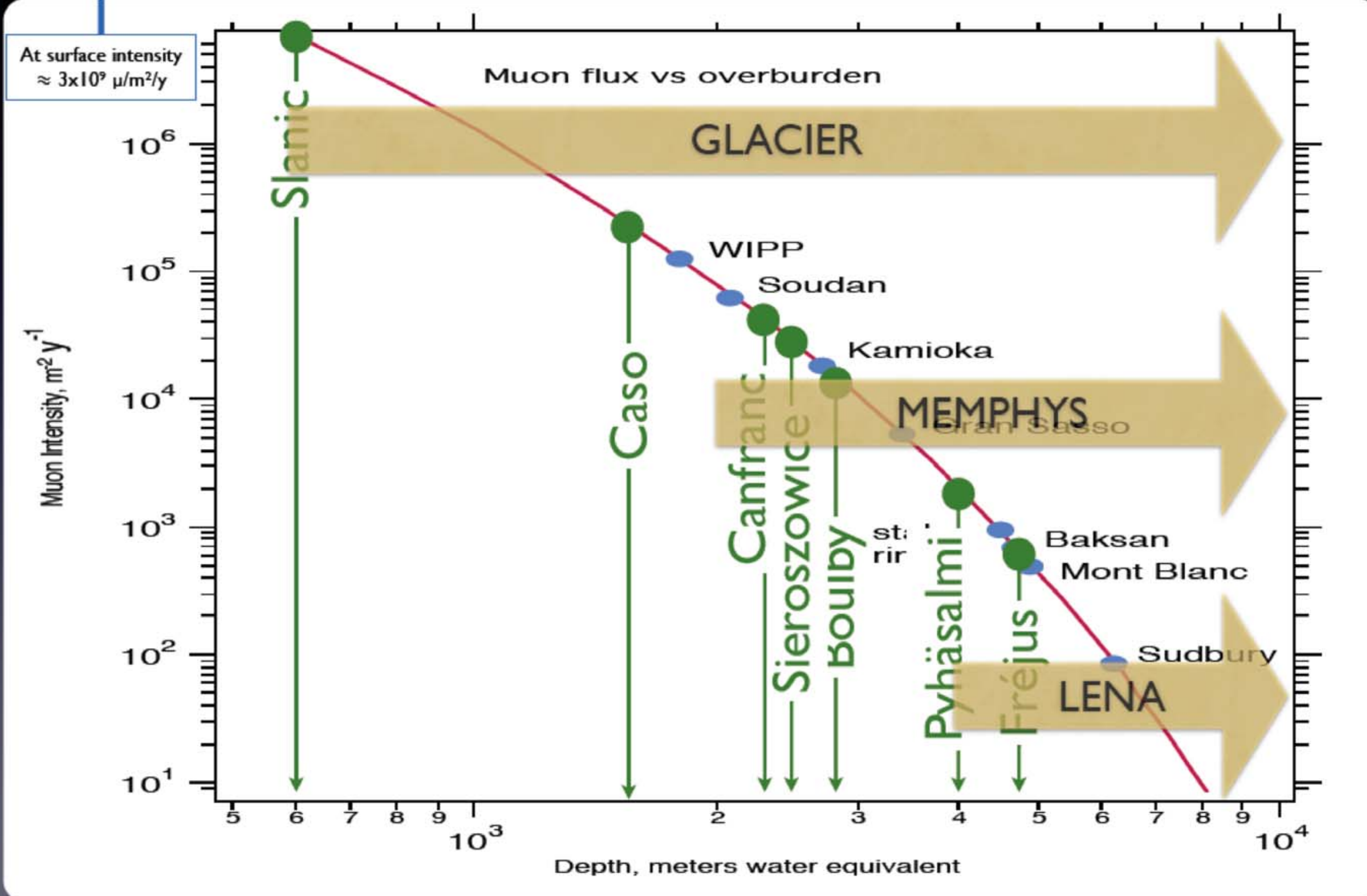
- Water Cerenkov [**MEMPHYS**]
- Liquid scintillator [**LENA**]
- Liquid Argon TPC [**GLACIER**]

Seven potential sites



LAGUNA sites: overburden

Requirement depends on detector technology



LAGUNA sites & CERN

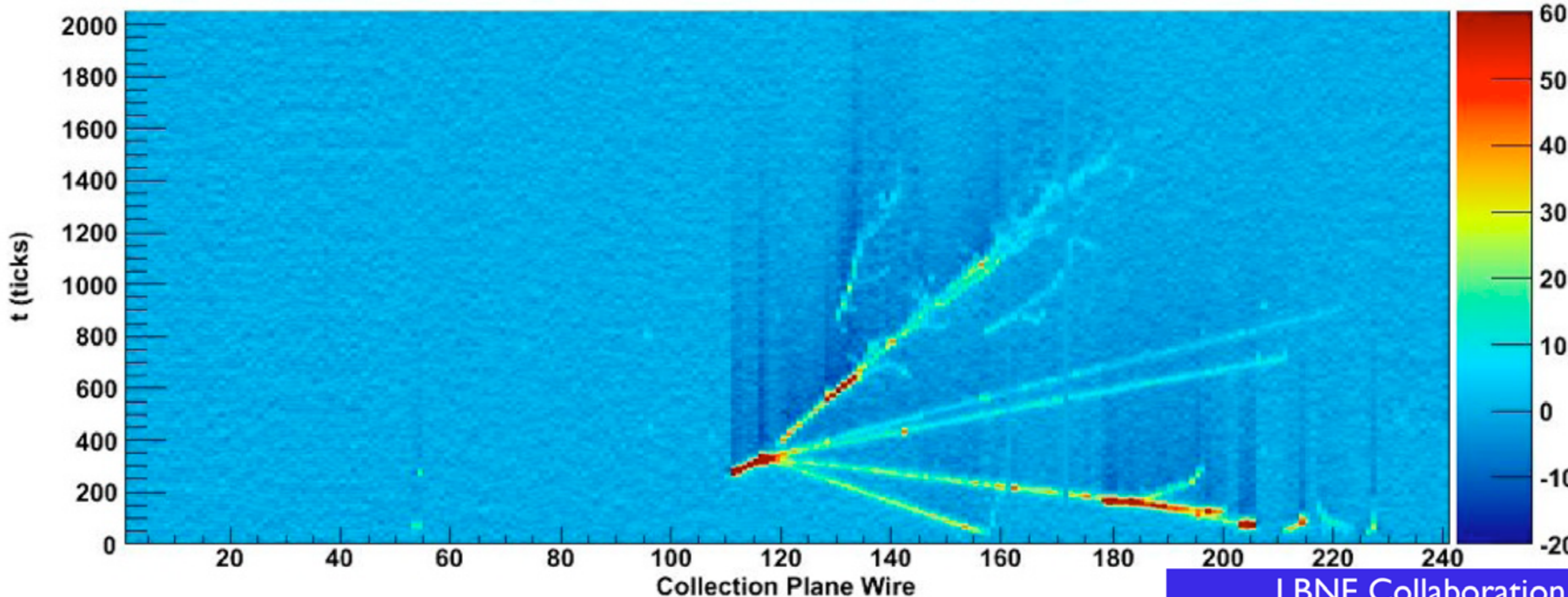
- Two complementary strategies:
  - ➡ Intensity upgraded CNGS beamline
  - ➡ New beam line (in principle to any of the LAGUNA sites)
- At this stage both strategies can be considered

Name	Type	Envisaged Depth (m.w.e)	Distance from CERN (km)	Energy 1st osc. max (GeV)
Fréjus (F)	Road tunnel	$\simeq 4800$	130	0.26
Canfranc (ES)	Road tunnel	$\simeq 2100$	630	1.27
Umbria (IT)	Green field	$\simeq 1500$	665 ($\simeq 1.0^o$OA)	1.34
Sieroszowice (PL)	Mine	$\simeq 2400$	950	1.92
Boulby (UK)	Mine	$\simeq 2800$	1050	2.12
Slanic (RO)	Salt mine	$\simeq 600$	1570	3.18
Pyhasalmi (FI)	Mine	$\simeq 4000$	2300	4.65

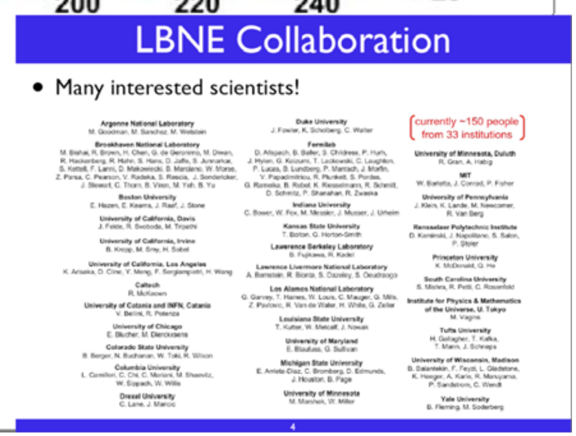
J.Phys.Conf.Ser.171:012020,2009

Future Long Baseline Experiments:

options for U.S.



Mitch Soderberg
Yale University
WIN '09, Perugia, Italy
September 16, 2009

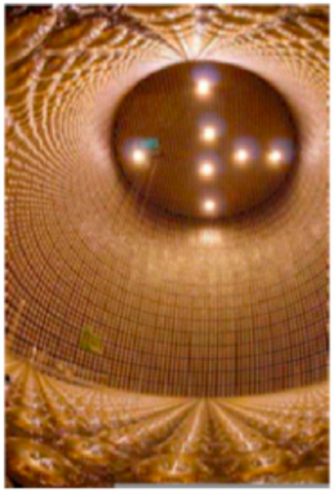


Far Detectors

- Two far detector technologies considered for the future long-baseline neutrino program: Water Cerenkov and Liquid Argon (LAr)
- Water detector aiming for total fiducial mass of **300**ktons, LAr aiming for **60** ktons.
- Both technologies can also potentially look for supernova neutrinos and proton decays.
- **LBNE** group also considering design of beams and near detectors.

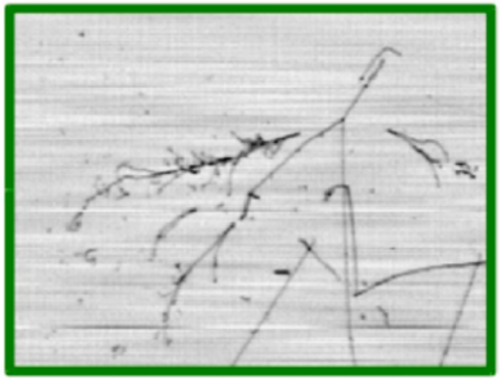
This talk

Water Cerenkov
imaging detector



(3 x 100 kton modules
total = 300 kton)

Liquid Argon TPC
very fine-grained tracking detector



ICARUS event

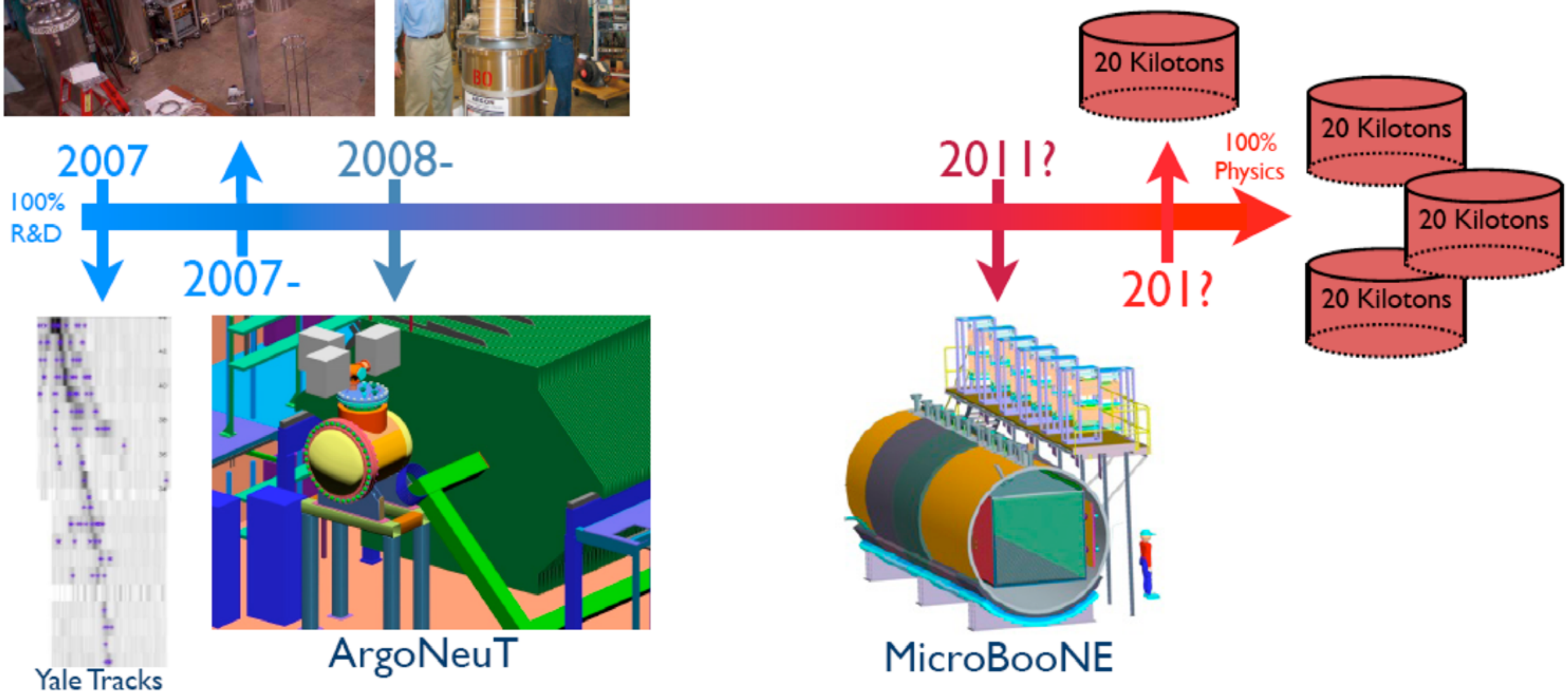
(20-60 kton)

Liquid Argon in the U.S.

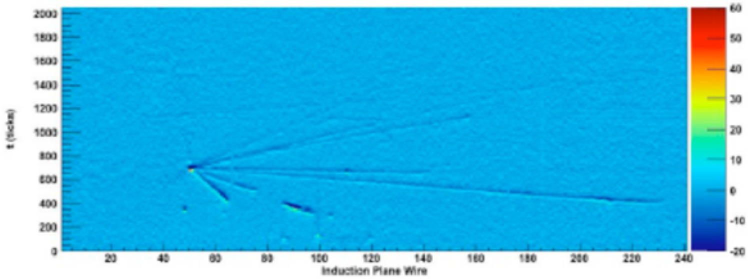
Materials Test Stand

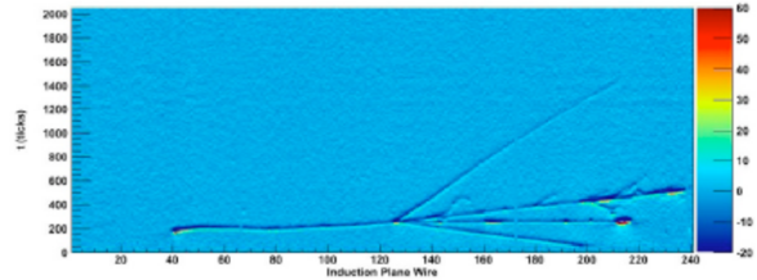
Bo

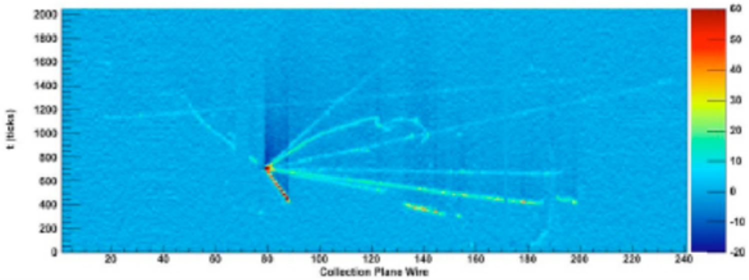
•Rapid progress in LArTPC development.
•Developing an integrated plan to get to final, massive detector(s).

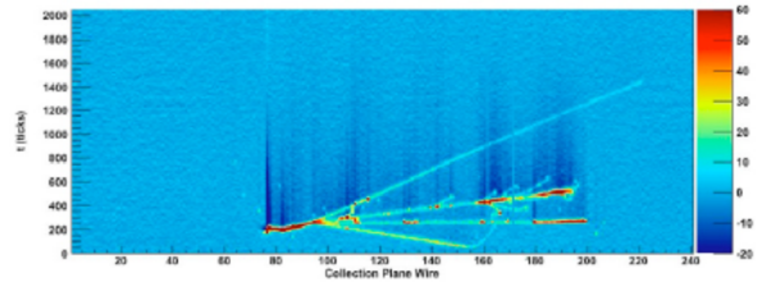


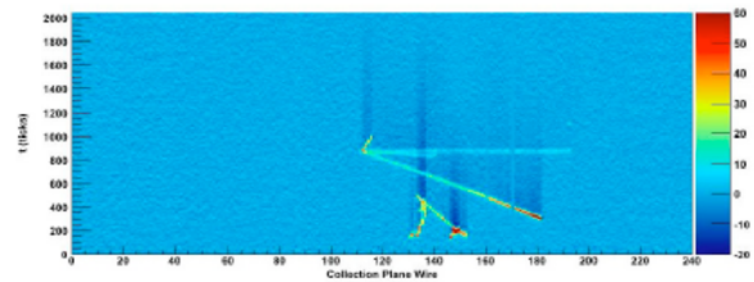
ArgoNeuT Neutrino Events

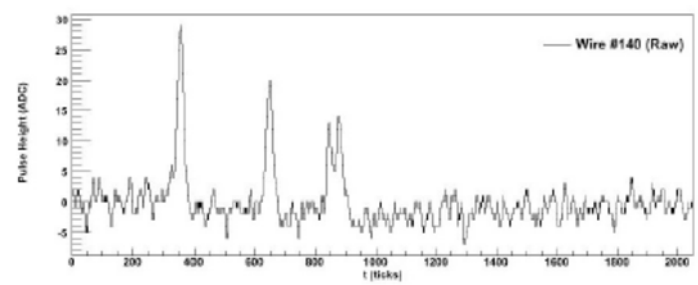








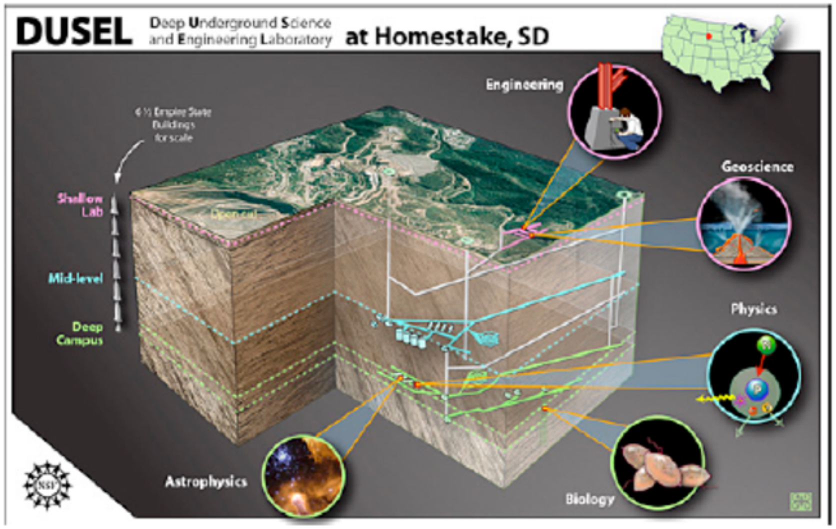


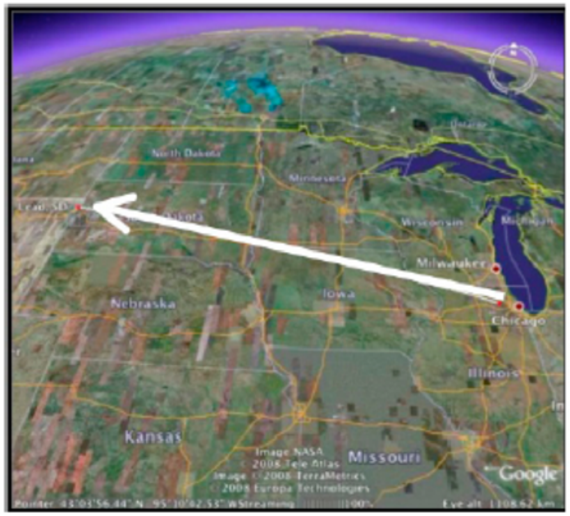


- ArgoNeuT is taking data in the NuMI antineutrino beam now!
- These are the raw data for a few events from neutrino mode.

Massive Detector Location

- Prefer to put this huge detector someplace very deep (e.g. - Homestake Mine in South Dakota, Soudan Mine in Minnesota) to reduce cosmic background.
- Proposed Project X at Fermilab sends intense neutrino beam 1300km to this far-site location.
- LBNE group focused on possibility of massive detector at DUSEL:
  - 1st stage of LBNE plan does not include Project X (starts with 700kW beam, and a large far-site detector module)
  - upgrade to this is Project X (2.3MW) + more modules





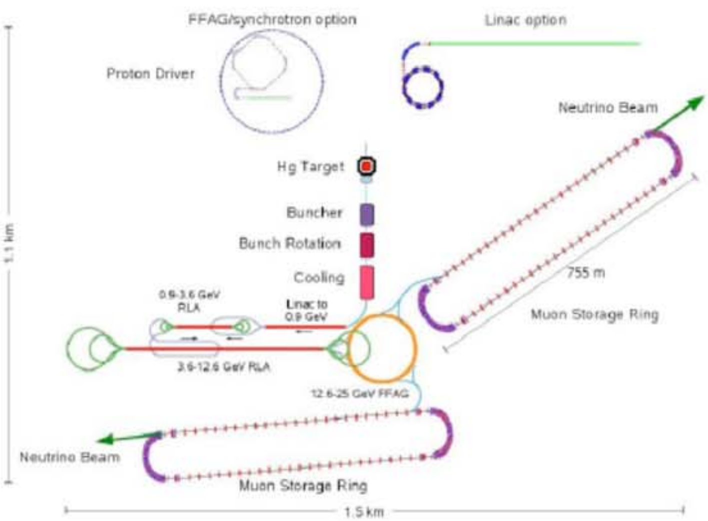
Recommendations from the Report of the P5 Panel to HEPAP, May 29, 2008:

"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 in the technology for a large detector at DUSEL."

Novel Neutrino Beams: R&D and Design Studies in the U.S.



- Neutrino Factory Introduction and Motivation
- Neutrino Factory R&D in U.S.
  - μ production
  - μ acceleration
  - ν detection



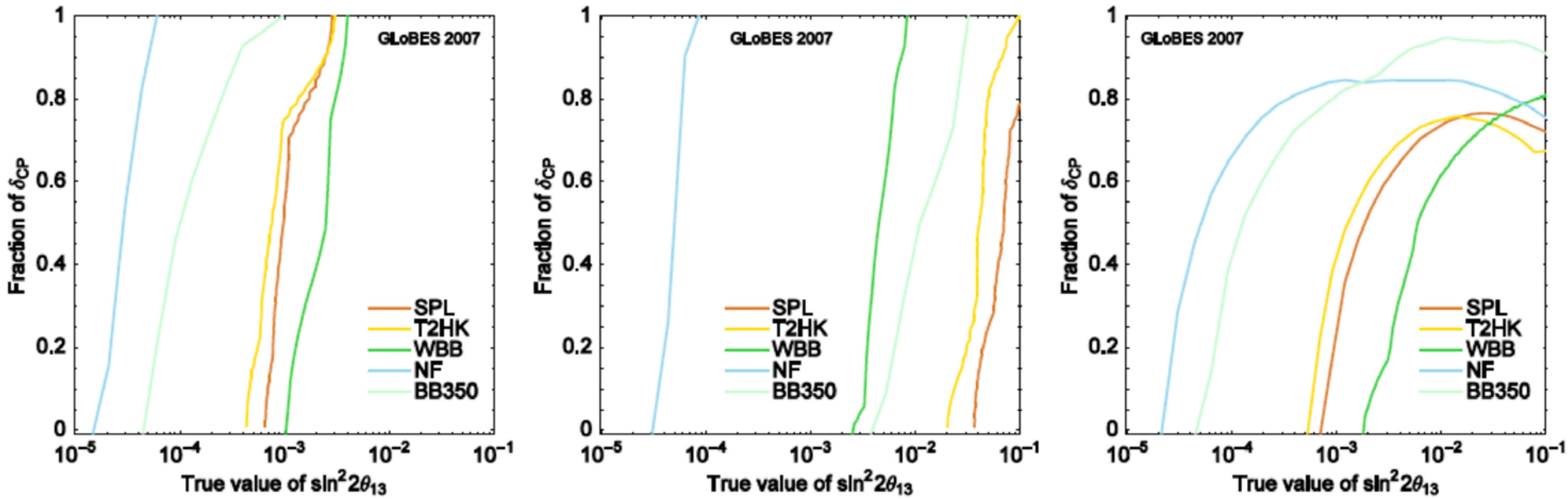
Terry Hart,
University of Mississippi,
WIN 09, Perugia, Italy,
September 16, 2009

NF: Superb Reach in 3ν Mixing Model Parameters Gives Best Chance to See Something *Unexpected*

3σ contours shown

ISS Physics Group Report: arXiv:0710.4947v2

$\sin^2(2\theta_{13})$ | $m_3^2 - m_1^2$ | δ *CP*



SPL: 4MW, 1MT H_2OC, 130 km BL
T2HK: 4 MW, 1MT H_2OC, 295 km BL
WBB: 2MW, 1MT H_2OC, 1300 km BL

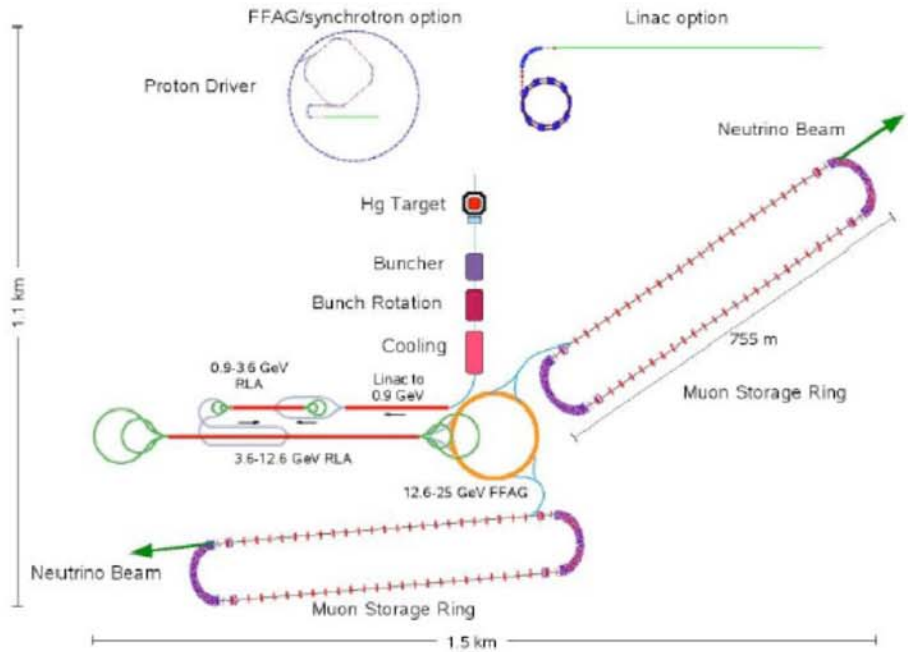
NF: 4MW, 100KT MIND, 4000 km & 7500 km BLs
BB350: γ=350, 1MT H_2OC, 730 km BL

Neutrino Factory and Other Facilities

- NF could generate intense neutrino beams from decays of muons collected into storage rings
  - Large step forward from superbeam $\pi \rightarrow \mu \rightarrow \nu_\mu$
  - NF would collect μ's from superbeam for injection into storage rings
    - NF provides anti-ν_e and ν_μ (or anti-ν_μ and ν_e)
- Potential for ultra-intense muon beams is unmatched and could lead to the Energy Frontier via Muon Collider (MC)
- Program can be staged, doing physics at each stage
- Proton source could possibly drive all the programs

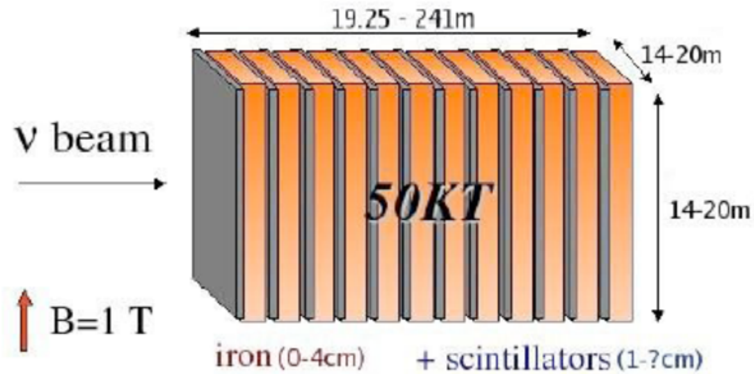
Accelerator R&D Program Overview

- High Power Targetry *(MERIT)*
- Ionization Cooling – *(MICE)*
- 201 (& 805) MHz RF *(MuCool)*
  - RF cavities in magnetic fields
    - High gradients (~15 MV/m)
    - Investigate gas filled RF cavities
- Acceleration
  - Linac for initial acceleration
  - Multi-turn RLA's
  - FFAG's – *(EMMA)*

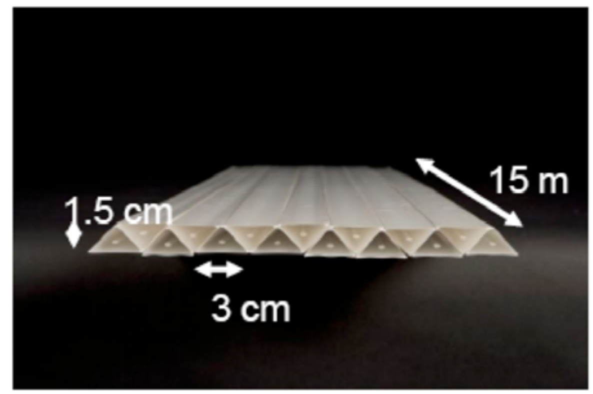


Note: Almost all R&D Issues for a NF are currently under theoretical and experimental study

Neutrino Factory Detector Development



- Magnetized Iron Detector (MIND)
  - For baseline 25 GeV Neutrino Factory
  - Simulations will determine optimization
  - Technology challenges
    - Silicon photomultipliers for detectors
    - Magnetization of large volume



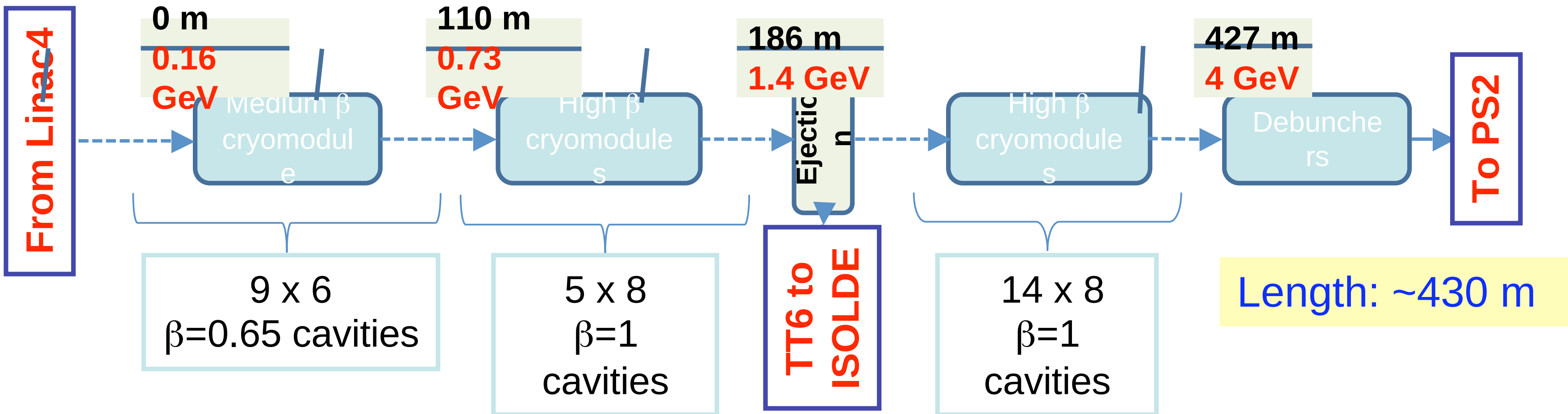
- Totally Active Scintillating Detector (TASD)
  - For low energy Neutrino Factory
  - Using Nova and Minerva concepts
- Liquid Argon
  - Detector concept for DUSEL at Homestake
  - Not part of international R&D for Neutrino Factory

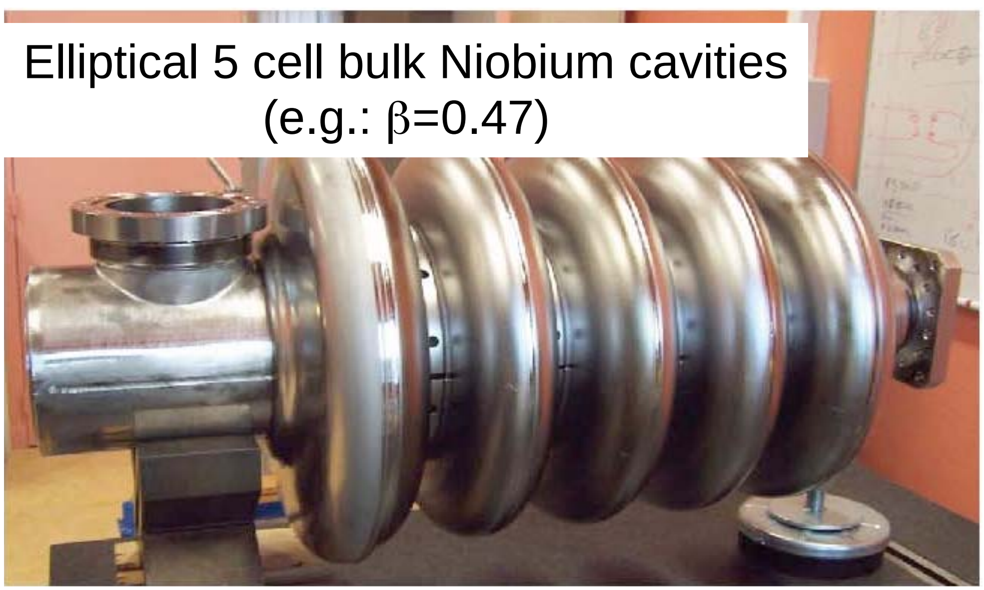
22nd International Workshop on
Weak Interactions and Neutrinos WIN'09
Electroweak Symmetry Breaking
Weak Decays, CP Violation and CKM
Neutrino Physics
Dark Matter

Future Neutrino Oscillation Facilities

Accelerator R&D in EUROPE

The preferred possibility for high power : the SPL
SC-linac (160 MeV → 4 GeV) with ejection at intermediate energy





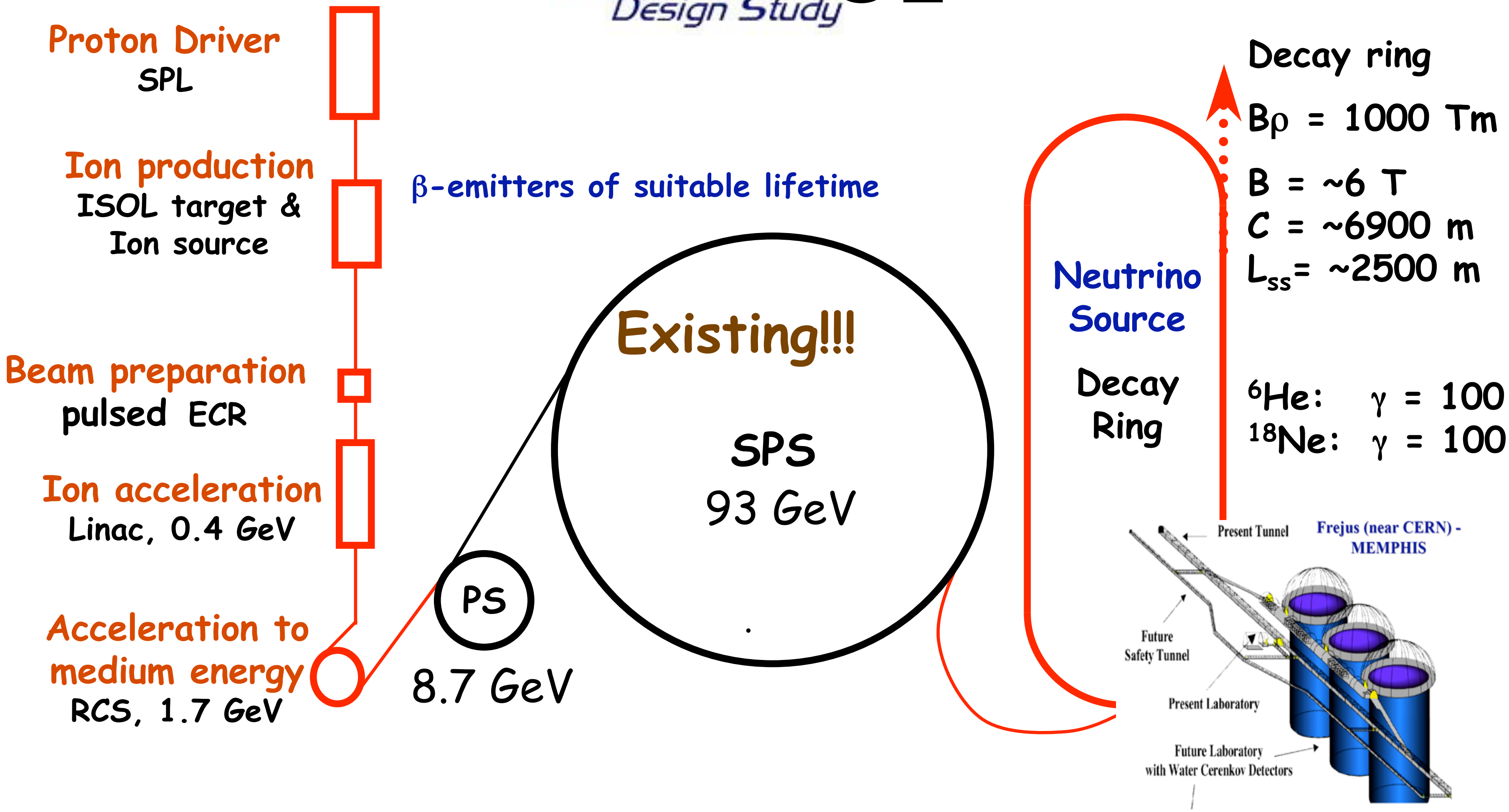
Elliptical 5 cell bulk Niobium cavities
(e.g.: β=0.47)

Low Power - SPL beam characteristics at 4 GeV

Kinetic energy (GeV)	4
Beam power at 4 GeV (MW)	0.12
Repetition period	0.6
Protons/pulse (x	1.1
Average pulse	20
Pulse duration (ms)	0.9

Baseline Beta Beam scenario, EURISOL

EURISOL Design Study

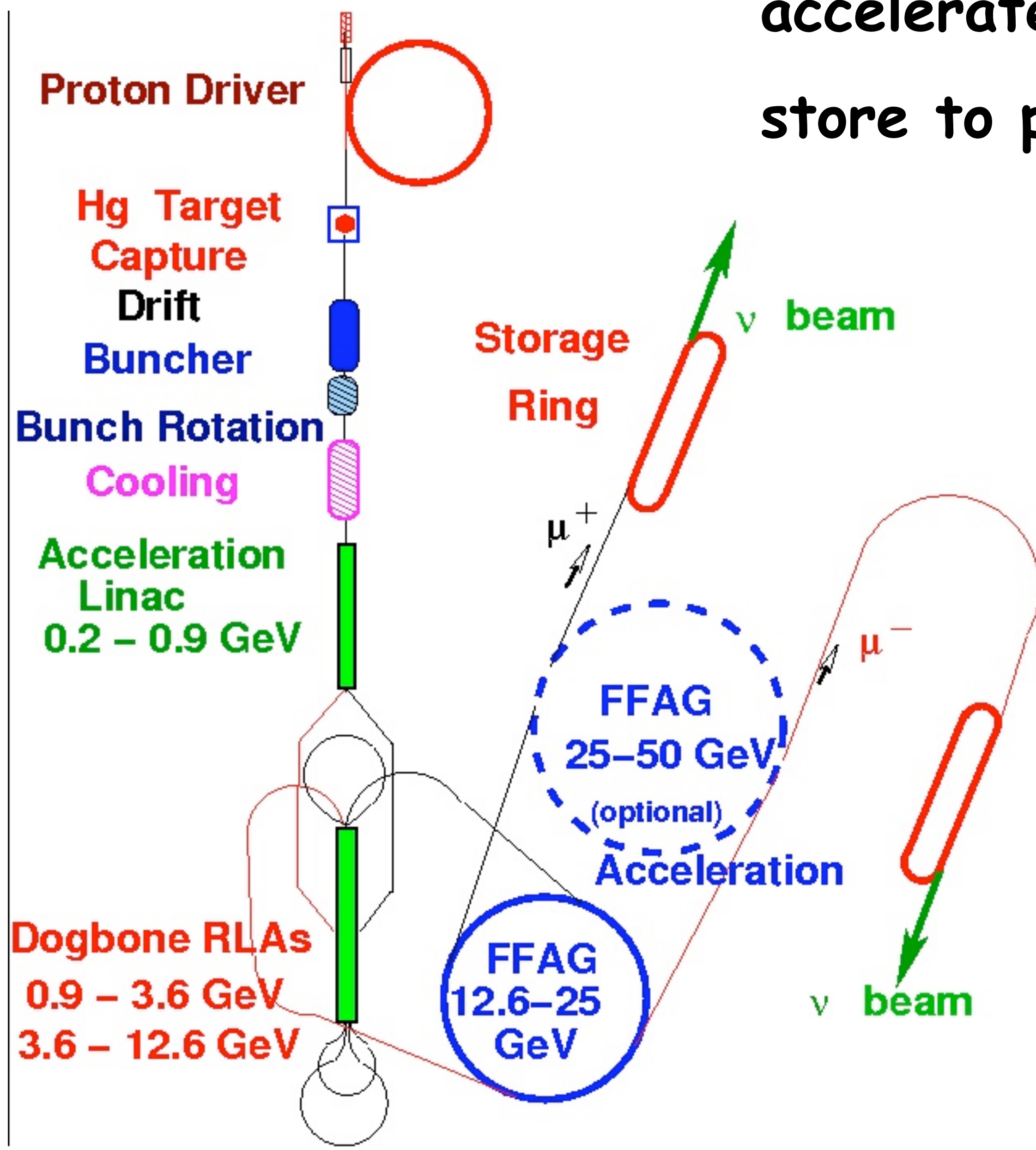


Detector in the Frejus tunnel

neutrino factory:

accelerate muons and

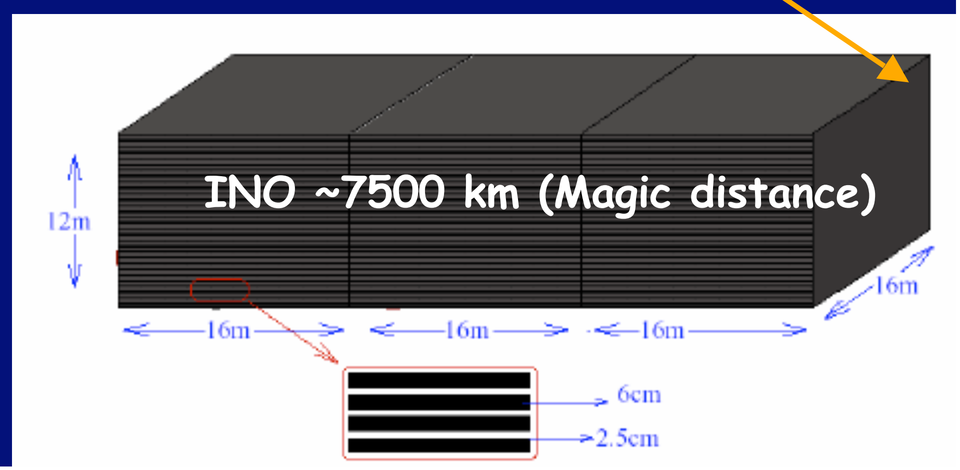
store to produce neutrinos



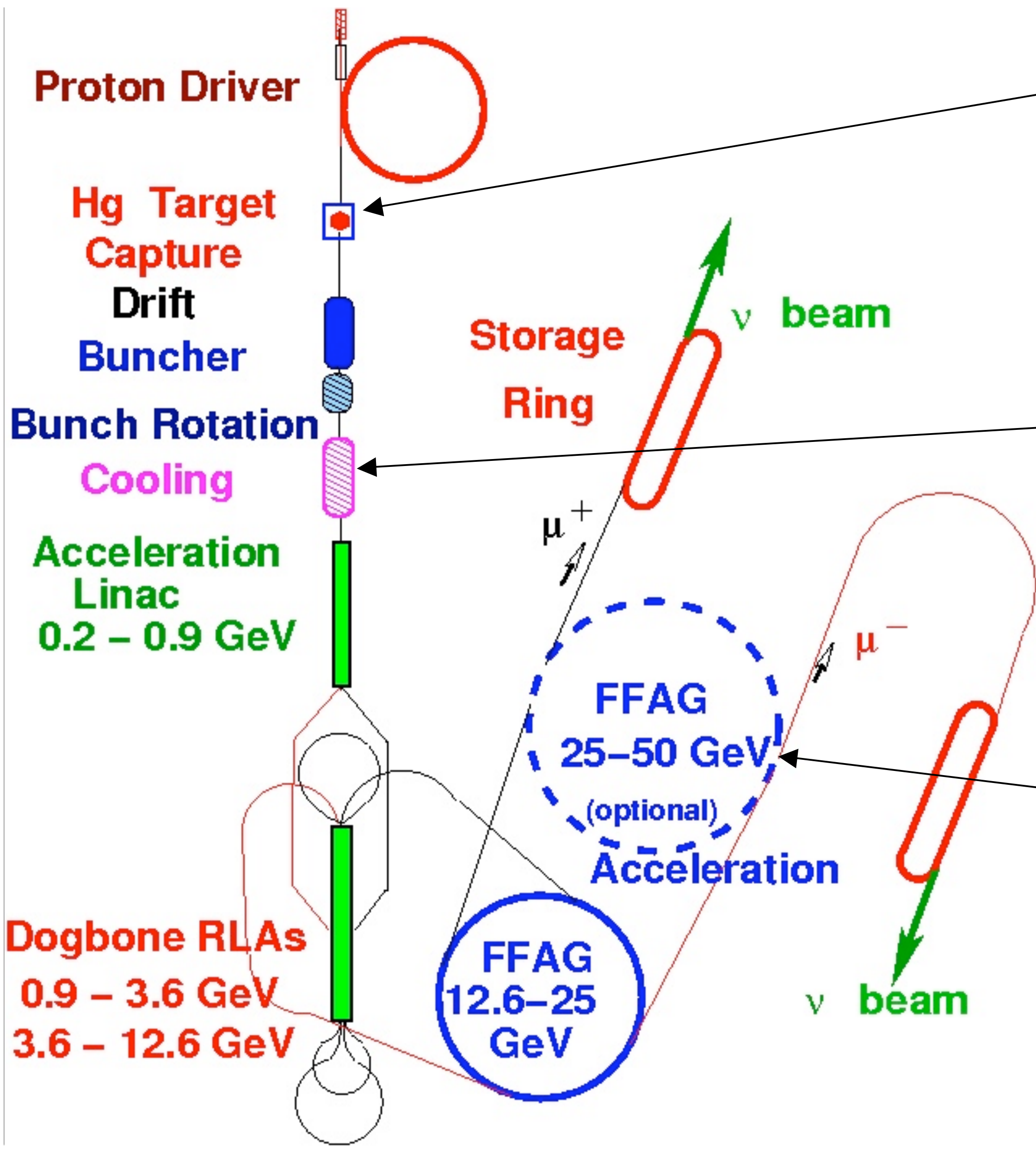
Explore neutrino factory
or muon collider
as an option for the future.
Feasibility, cost

Laguna site!

Long baseline detectors: Magnetized Iron, emulsions, liquid argon
Good baselines are: ~3000-5000 depending on muon threshold + 7500 km



Major challenges tackled by R&D expts



High-power target
. 4MW
. good transmission
MERIT experiment (CERN)

Fast muon cooling
MICE experiment (RAL)

Fast, large aperture accelerator (FFAG)
EMMA (Daresbury)

ISS baseline

International Design Study
IDS-NF

International Design Study of the **Neutrino Factory** Steering Group

A.Blondel, K.Long (chair), M.Zisman, Y.Kuno

Physics and Performance Evaluation:
A.Donini, P.Huber, S.Pascoli, W.Winter

Accelerator:
S.Berg, Y.Mori, C.Prior, J.Pozimski

Detector:
A.Bross, A.Cervera, N.Mondal, P.Soler

https://www.ids-nf.org

EU component is part-funded via EUROnu

Aim: produce CDR for 2012

'CDR' implies:

- Physics performance of *costed* scenario
- Conceived as input to cost/performance comparison required at C.E.R.N. Council Strategy Group 2012 decision point

The collaboration

ASTeC • Brookhaven National Laboratory • Brunel University West London • CERN • Durham University • Fermilab • Illinois Institute of Technology • Imperial College London • IN2P3 • INFN • Jefferson Lab • Berkeley Lab • Max-Planck-Institut für Kernphysik • Michigan State University • Muons, Inc. • Osaka University • Princeton University • Julius-Maximilians-Universität Würzburg • Université de Genève • UC Riverside • University of Delhi • University of Glasgow • University of Oxford • The University of Warwick • York University

Status of MICE

The International

Muon
Ionisation
Cooling
Experiment

WIN09
22° Int Workshop on Weak Interactions and Neutrinos
Perugia, Italy, 16/9/09

V. Palladino
on behalf of the MICE Collaboration
University & INFN Napoli, Italy

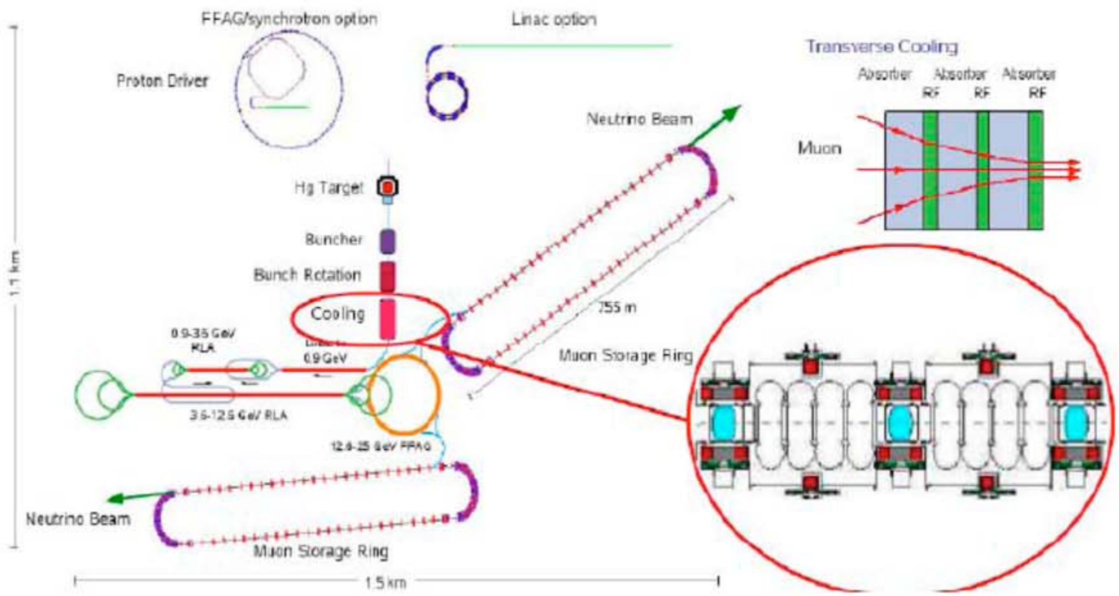
MICE is a decisive milestone

(feasibility demonstration)

for

Neutrino Factory

- Baseline design for a Neutrino Factory from International Design Study
- Design includes a Muon Ionization Cooling stage

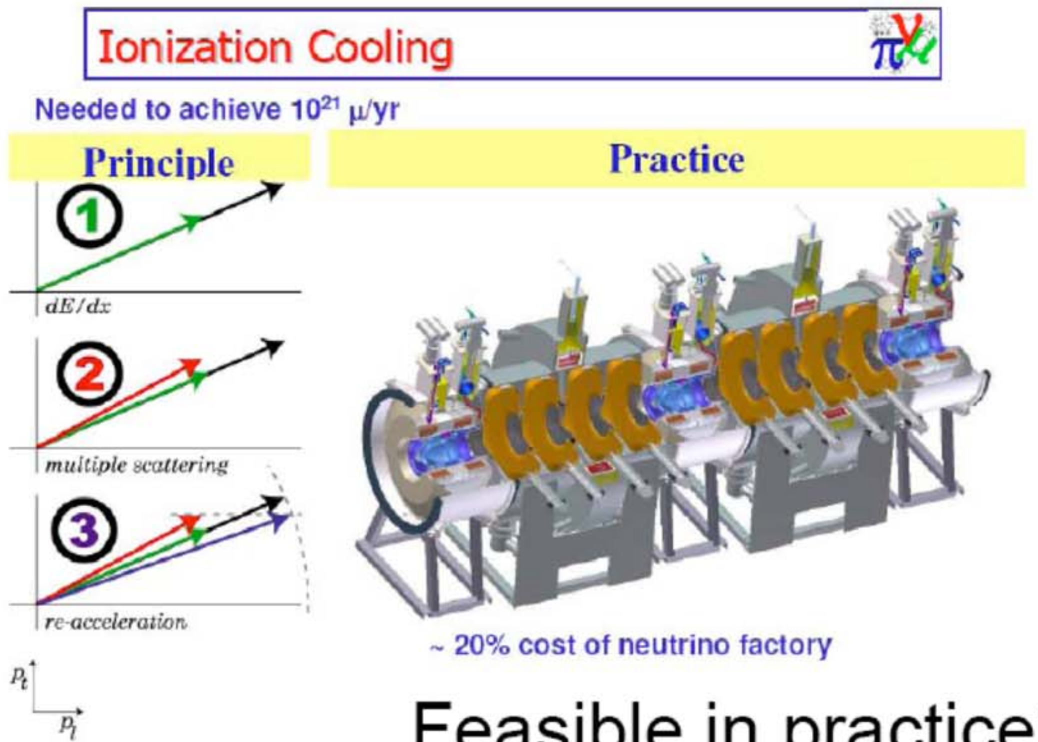


solenoidal geometry

Simple…energy loss+re-acceleration

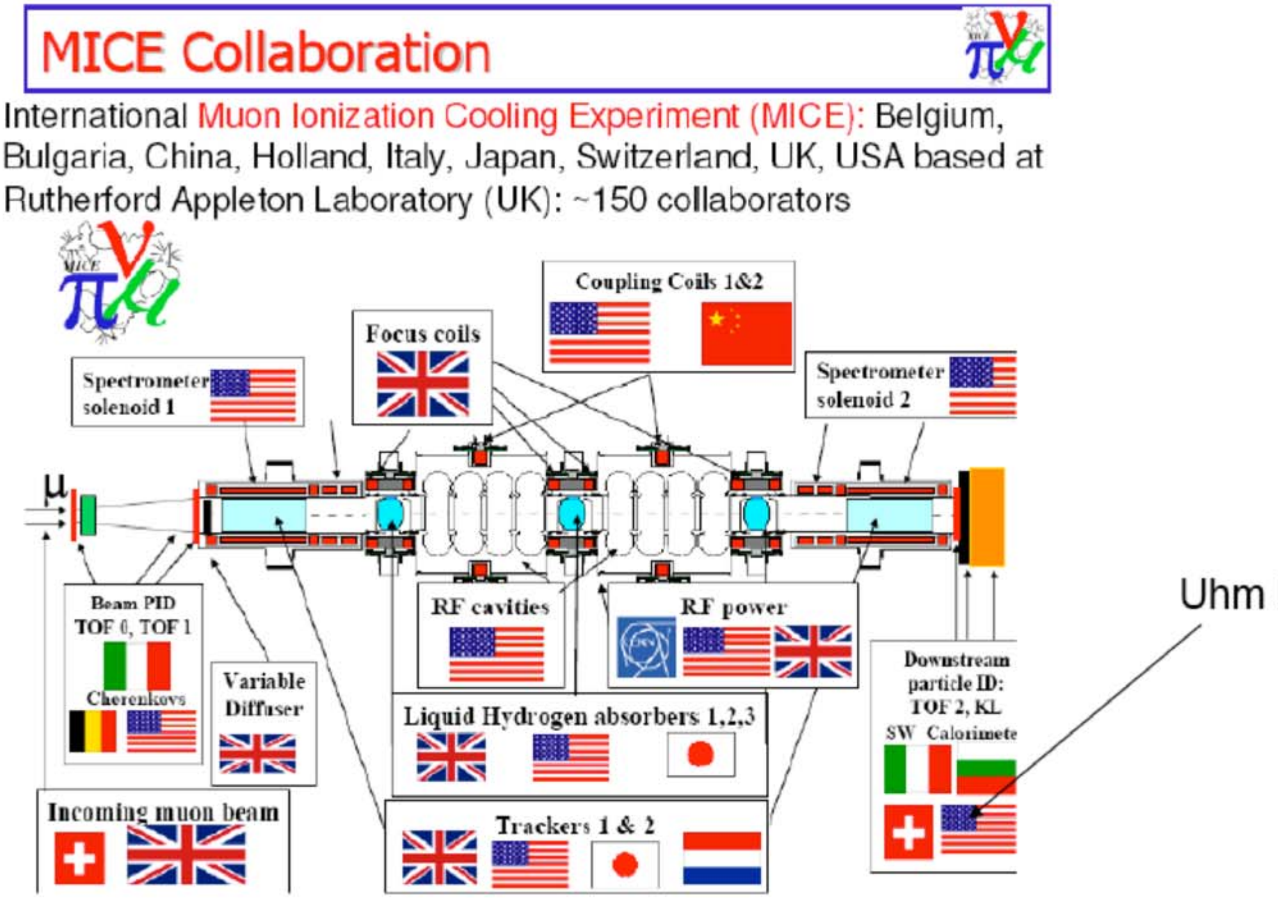
essentially, a linear accelerator filled with matter

A cloud turns into a pencil



Feasible in practice?
Industrially viable?

MICE is a truely global project

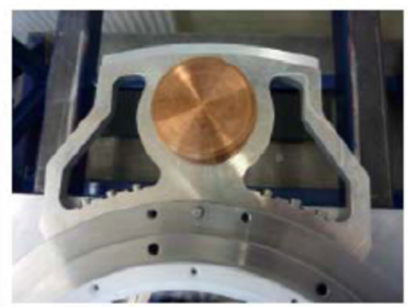


The diffuser: a full range of ε_{in}

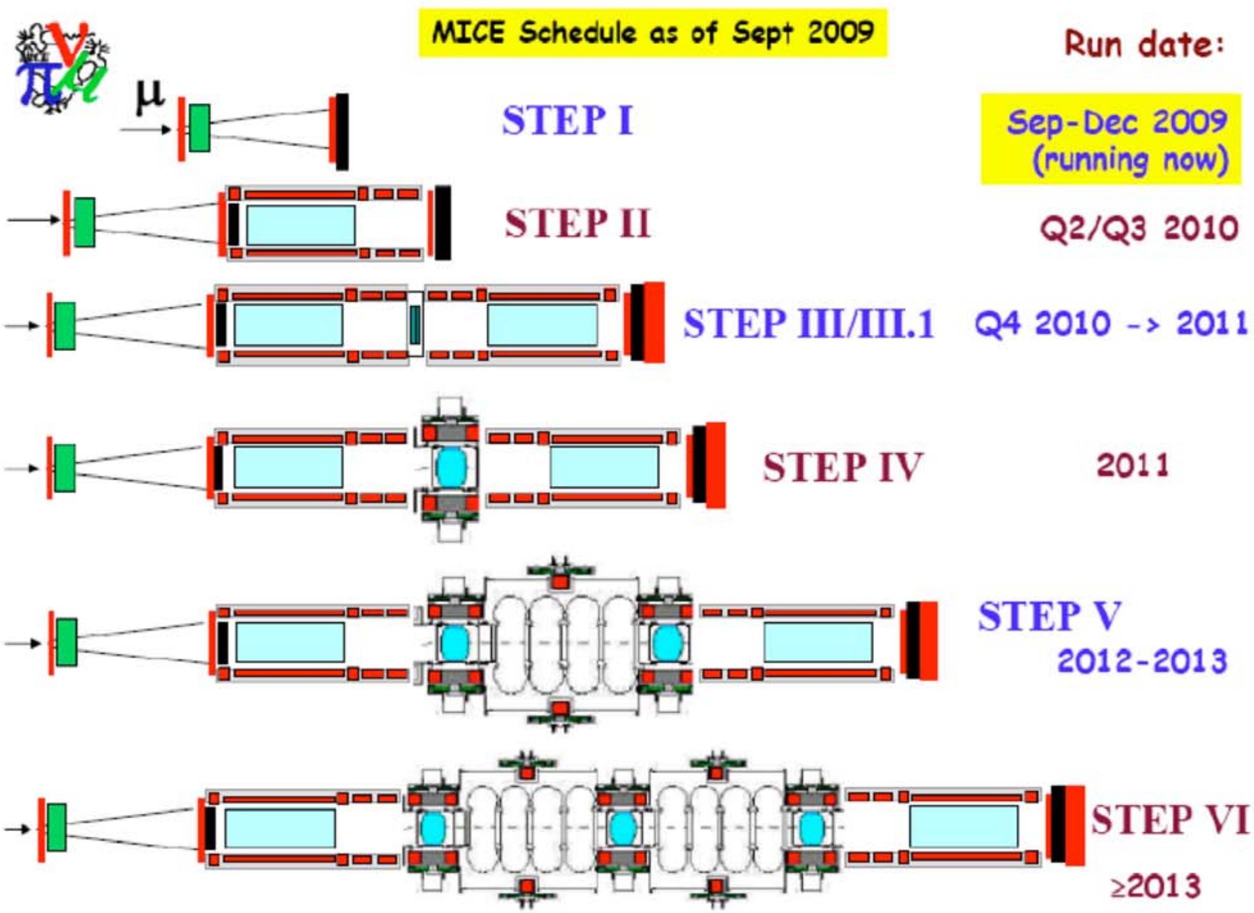
MICE Beamline

- All magnets in MICE beamline installed (fish-eye lens view):

- Diffuser: rotating wheel with different thicknesses of material to blow up beam for large emittance beams
  - To be ready Sept 09



Six steps to full IC demonstration



WIN09, 16 Sep 09 "Status of MICE", V. Palladino

Resolving CP Violation by Standard and Nonstandard Interactions in Neutrino Oscillation

Shoichi Uchinami
(Tokyo Metropolitan University)

with
A.M. Gago, H. Minakata, H. Nunokawa, R. Zukanovich Funchal

arXiv:0904.3360

Motivation

Future "precision measurement" experiments have potential for New Physics Search

in this talk
we concentrate on Non-Standard neutrino Interaction (NSI)

$$\mathcal{L}_{\text{eff}}^{\text{NSI}} = -2\sqrt{2}\,\varepsilon_{\alpha\beta}^{fP} G_F (\overline{\nu}_\alpha \gamma_\mu P_L \nu_\beta)\,(\overline{f}\gamma^\mu P f)$$

Wolfenstein '78, Guzzo-Masiero-Petcov '91
Grossman '95 ...

Contribution to Oscillation Probability of NSI

perturbation formula

small parameters:

$$O(\epsilon) \sim \sin\theta_{13} \sim \frac{\Delta m_{21}^2}{\Delta m_{31}^2} \sim \frac{\Delta m_{21}^2}{2Ea} \sim \varepsilon_{\alpha\beta}$$

$$\begin{aligned} &P(\nu_e \to \nu_\mu; \varepsilon_{e\mu}, \varepsilon_{e\tau}) \\ &= 4\left| c_{12}s_{12}c_{23}\frac{\Delta m_{21}^2}{a}\sin\left(\frac{aL}{4E}\right)e^{-i\Delta_{31}} + s_{13}s_{23}e^{-i\delta}\frac{\Delta m_{31}^2}{a}\left(\frac{a}{\Delta m_{31}^2 - a}\right)\sin\left(\frac{\Delta m_{31}^2 - a}{4E}L\right)\right. \\ &\quad + \varepsilon_{e\mu}\left[c_{23}^2\sin\left(\frac{aL}{4E}\right)e^{-i\Delta_{31}} + s_{23}^2\left(\frac{a}{\Delta m_{31}^2 - a}\right)\sin\left(\frac{\Delta m_{31}^2 - a}{4E}L\right)\right] \\ &\quad \left. - c_{23}s_{23}\varepsilon_{e\tau}\left[\sin\left(\frac{aL}{4E}\right)e^{-i\Delta_{31}} - \left(\frac{a}{\Delta m_{31}^2 - a}\right)\sin\left(\frac{\Delta m_{31}^2 - a}{4E}L\right)\right]\right|^2, \end{aligned}$$

$c_{ij} \equiv \cos\theta_{ij}$, $s_{ij} \equiv \sin\theta_{ij}$, and $\Delta_{31} \equiv \frac{\Delta m_{31}^2 L}{4E}$

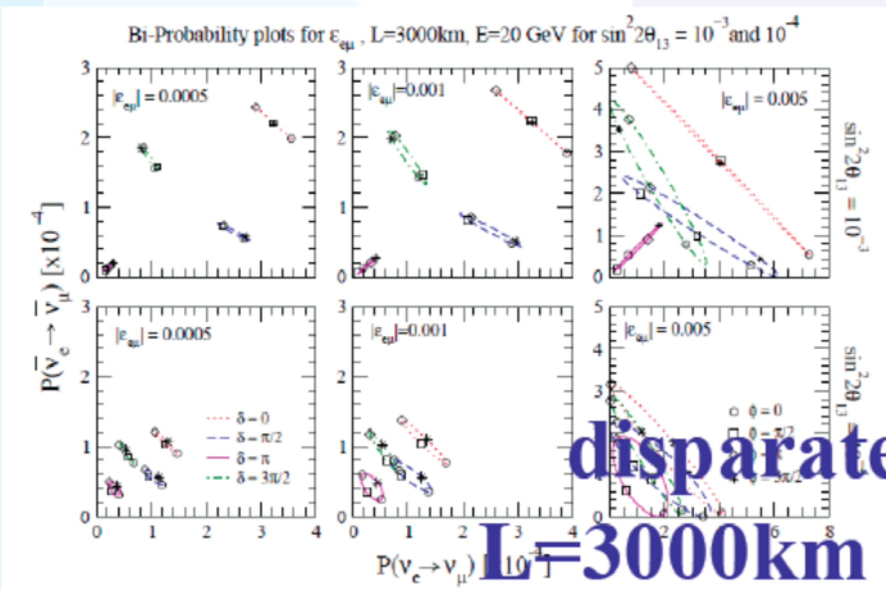
Neutrino Factory with Two Detectors

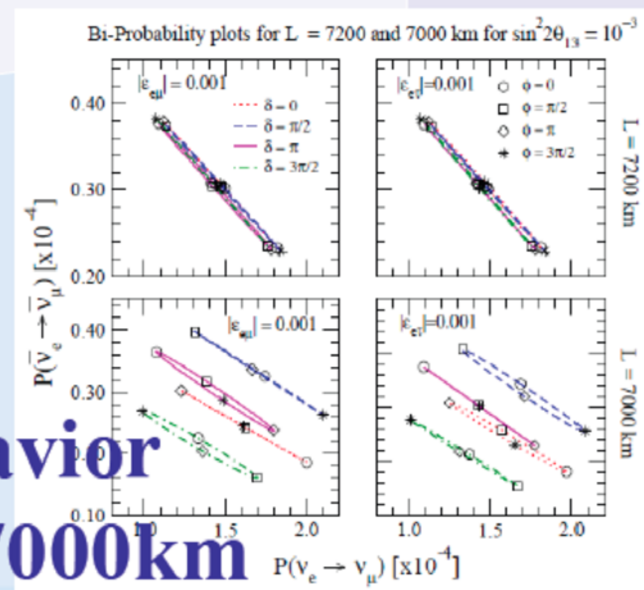
$$P(\nu_e \to \nu_\mu) \;=\; 4\left| e^{-i\delta} s_{13}\frac{\Delta_{31}}{a}\sqrt{X} + e^{-i\frac{\Delta_{31}L}{2}} c_{12}s_{12}\frac{\Delta_{21}}{a}\sqrt{Z}\right|^2$$

Kikuchi Minakata S.U.
JHEP 0903:114,2009

$$e^{-i\delta}s_{13}\frac{\Delta_{31}}{a} + s_{23}\varepsilon_{e\mu} + c_{23}\varepsilon_{e\tau}$$

$$c_{12}s_{12}\frac{\Delta_{21}}{a} + c_{23}\varepsilon_{e\mu} - s_{23}\varepsilon_{e\tau}$$





disparate behavior
L=3000km and 7000km

Summary

- Neutrino Factory have powerful potential to discover Non-Standard Interaction

→ $|\varepsilon_{e\mu}| \sim 10^{-3}\text{-}10^{-4}$, $|\varepsilon_{e\tau}| \sim 10^{-3}$

- we can discover non-standard CP Violation

if $0.1 < \phi_{e\mu}/\pi < 0.9$ with $|\varepsilon_{e\mu}| >$ a few $\times 10^{-3}$

if $0.1 < \phi_{e\tau}/\pi < 0.9$ with $|\varepsilon_{e\tau}| > 10^{-2}\text{-}10^{-3}$

two detector combination (L=3000km and 7000km) is important

Neutrino cross section in GeV region

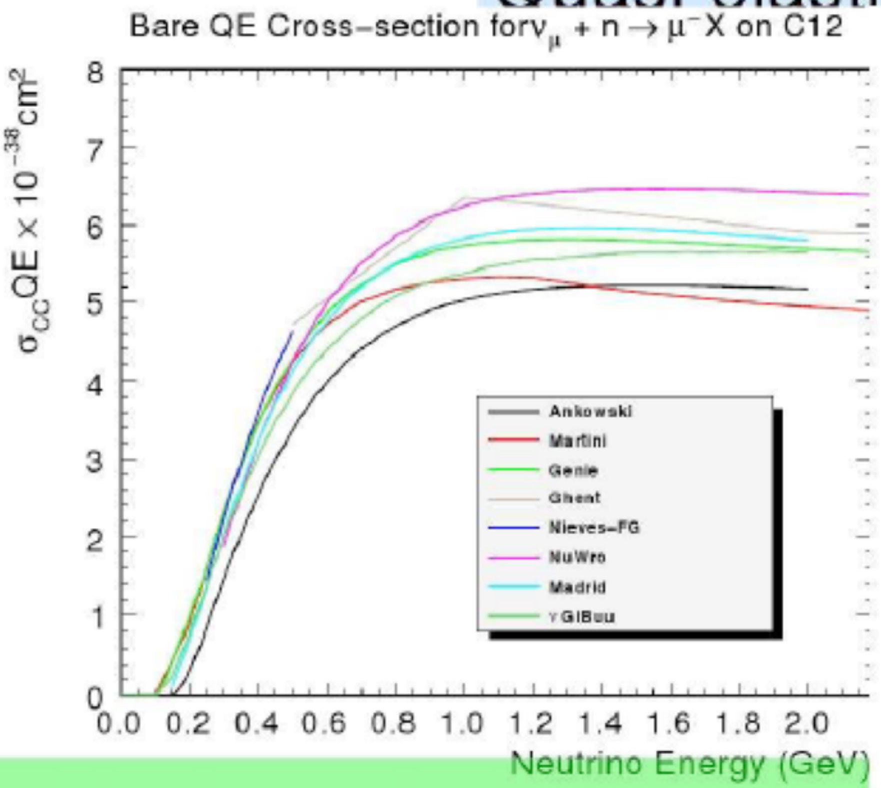
Olga Lalakulich

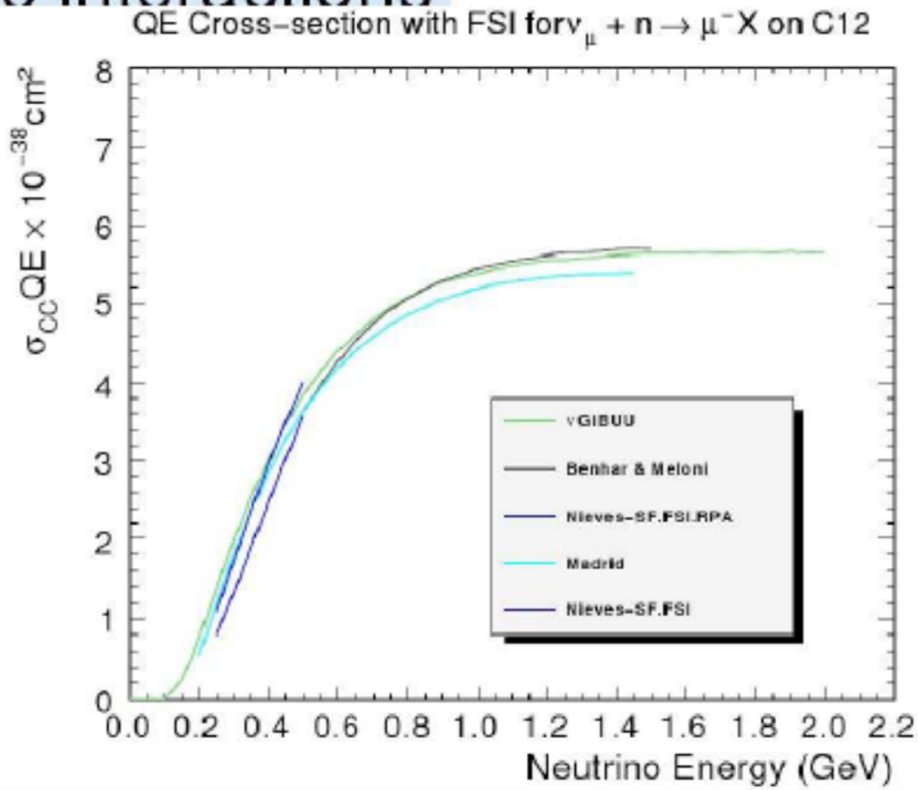
Justus–Liebig University Giessen, Germany

Outline

1. Nucleon target
   - Quasi–elastic scattering
   - 1-pion production = resonances + background
   - DIS
2. Nuclear effects
   - Fermi gas model
   - Modern models of nuclear effects
   - Giessen Boltzman–Uehling–Uhlenbeck transport model
   - Comparison of different models
   - Coherent neutrino scattering

Quasi-elastic interactions





Monte Carlo generators: Genie, Neut (for oxygen) and NuWro are very similar;

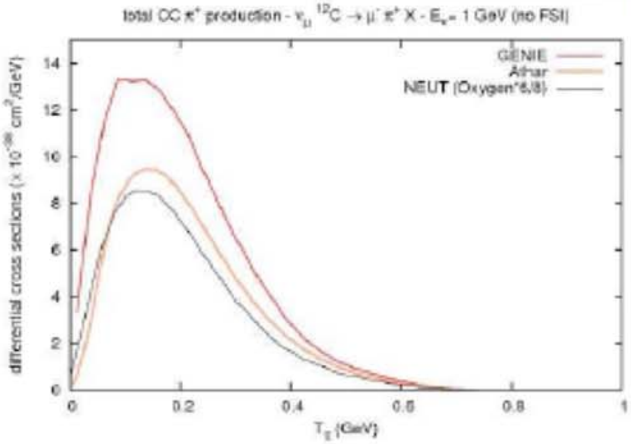
Genie -> Ma=0.99, BBBA FF, Fermi gas

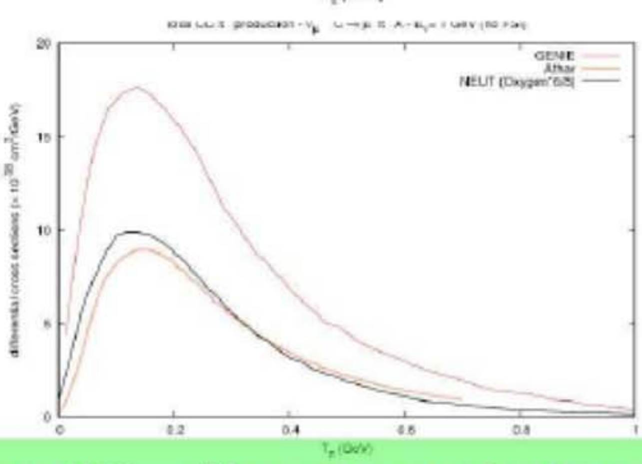
NuWro-> Ma=1.1, dipole FF, „effective spectral function"

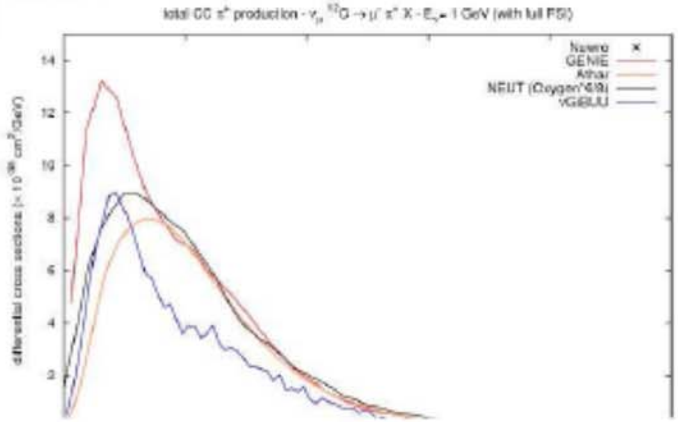
Neut -> Ma=1.2, Fermi gas

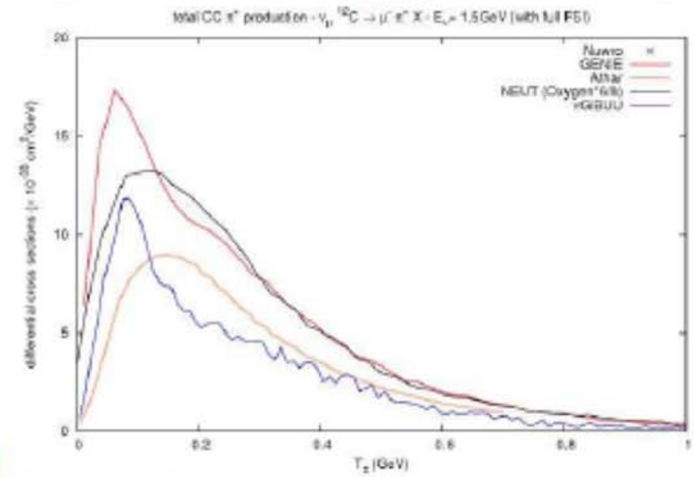
FSI does not change the integrated and muon differential cross section

Single Pi+ production





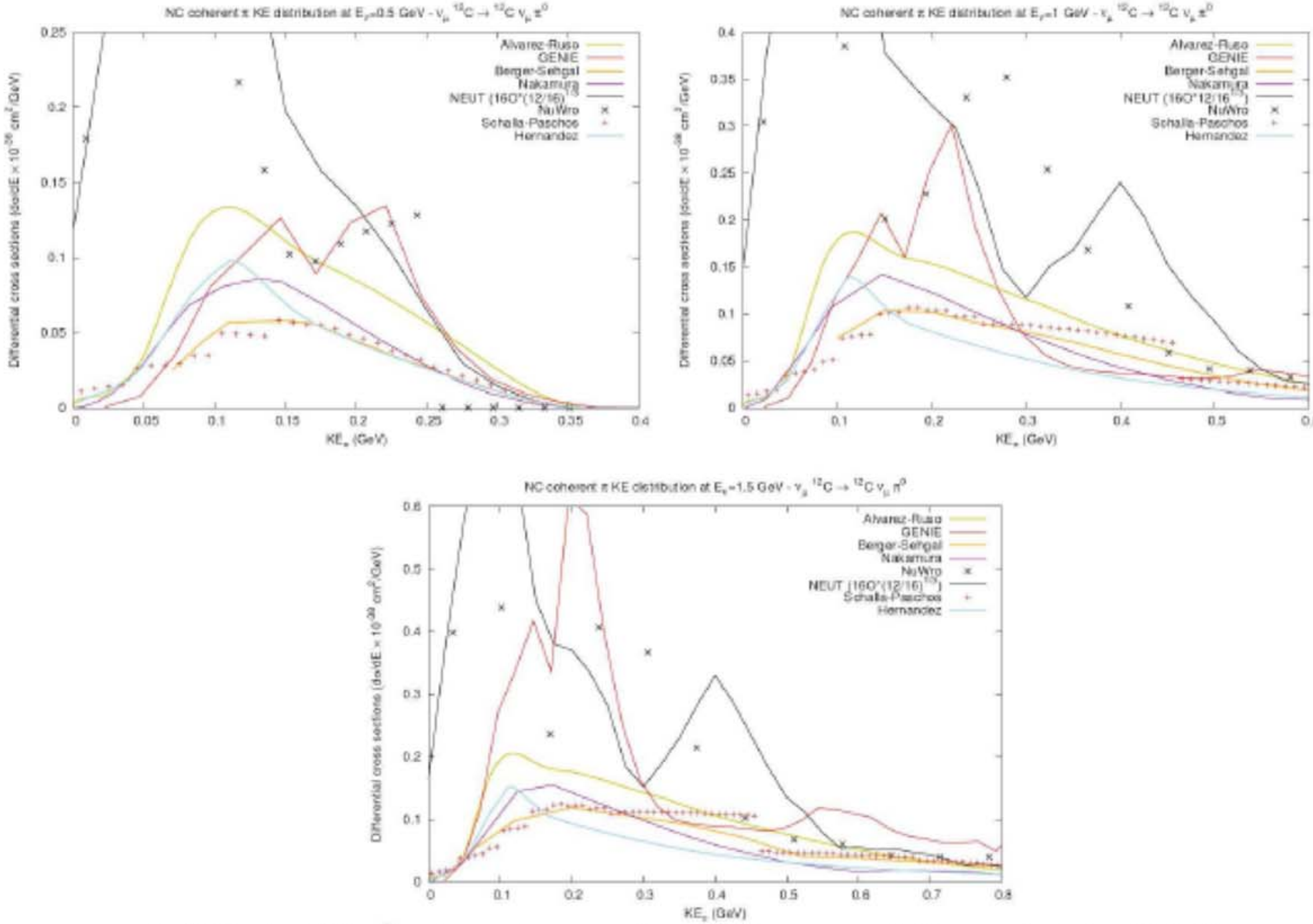




- no FSI -- differences are due to normalization, shapes seem to be similar
- with FSI – large differences
- GiBUU and Athar predict similar integrated cross section, but the shapes are different
- GiBUU has a contribution from primary QE vertex

19/05/09 Comparison of nu-nucleus computations 29

Results II



$d\sigma/dT_\pi$ for NC π^0 coherent production on Carbon and $E_\nu = 0.5, 1.0, 1.5$ GeV

NUINT09. Sitges, 19-May-2009 – p. 13/1

Conclusions

- Neutrino calculations always include vector and axial part. Vector part is generally well understood. Electroproduction is a benchmark for neutrinoproduction.
- Theorists need experimental values on the cross section to fit thier parameters concerning the axial part
- Experimentators need theoretical predictions to build event generators
- Nuclear corrections are noticeable. Several working models for nuclear effects.
- A lot of new calculations and theoretical developments are available from theory side. Experimentators use event-generators based on old simplified calculations. The main purpose is to come and move forward together.

Study of neutrino interactions using the FNAL booster neutrino beam

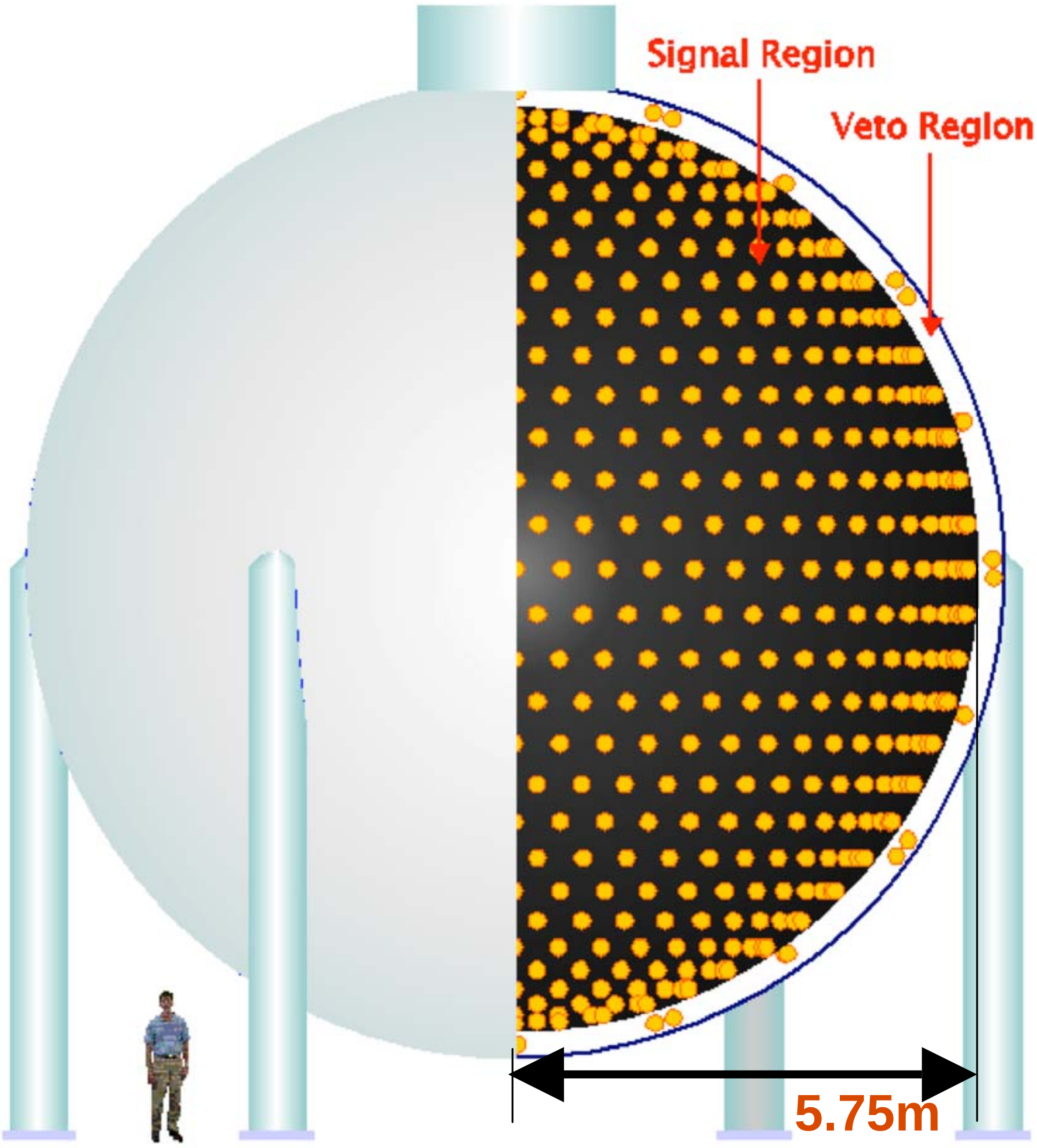
Yoshinari Hayato
(Kamioka, ICRR, U. Tokyo)

1. Introduction
2. FNAL Booster neutrino beam-line
   and two neutrino experiments
   MiniBooNE and SciBooNE.
3. Quasi-elastic scattering and elastic scattering
4. Single pion productions
5. Summary

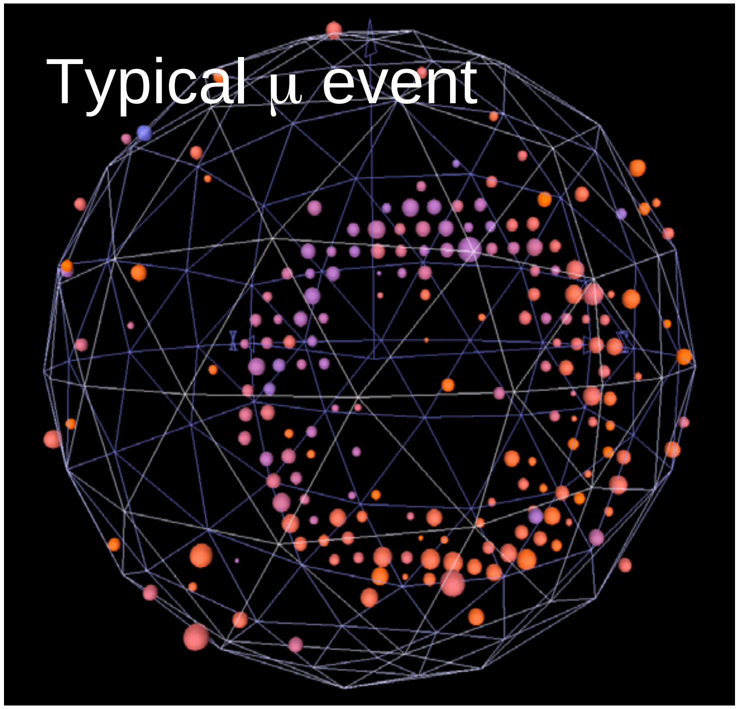
(Thank to the MiniBooNE collaboration
for providing the MiniBooNE figures and plots.)

MiniBooNE detector

Experiment started in August 2002.



- 800 ton CH_2 detector
- Signal region
  1280 8inch PMTs
- Veto region
  240 8inch PMTs
- Use Cherenkov light
  and scintillation light



SciBooNE detectors

(Data taking: June 2007 to August 2008.)

SciBar (Used in K2K experiment)

- Full active tracking detector

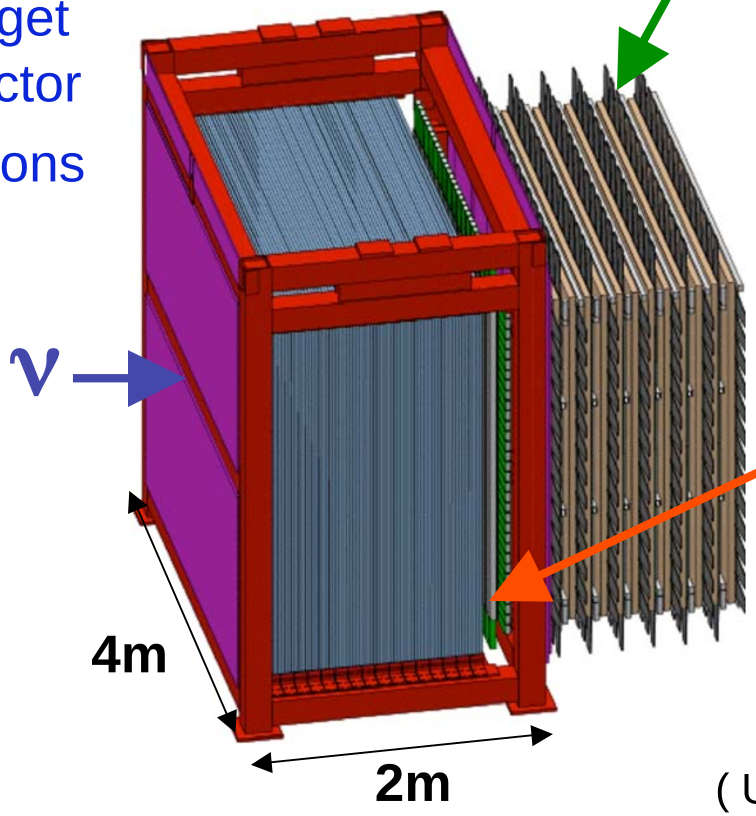
  15 tons of scintillator (14336 bars)

  also acts as the interaction target.

  Cell size : **2.5 x 1.3** x 300cm^3

  WLS fiber readout, 64ch MA-PMT

- ν Interaction target & tracking detector
- Identify interactions
- PID (p/π ID) using dE/dx



Muon Range Detector (MRD)

- 12 2"-thick steel layers + scintillator planes (alternate x & y)
- Measure μ momentum using range (up to ~ 1.2 GeV/c)

(Components are recycled from past experiment)

Electron Catcher (EC)

- Spaghetti calorimeter
- 2 planes (11 X_0)

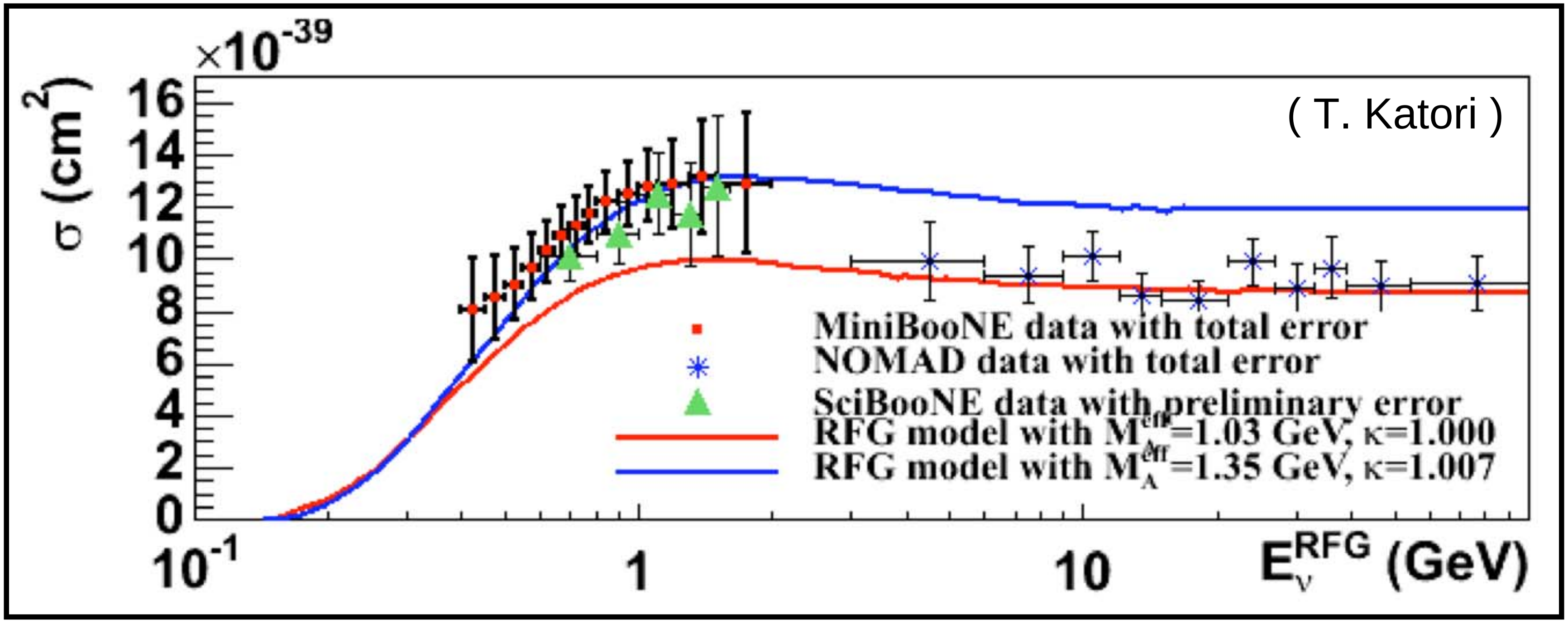
  4 x 4 cm^2 cell x 128

- Identify π^0 and ν_e

(Used in CHORUS, HARP and K2K)

Charged current Quasi-elastic scattering

Current status of the cross-section measurements



Recently, NOMAD released their results as shown in this figure.

(V. Lyubushkin et al., arXiv:0812.4543 [hep-ex])

Their M_A value was consistent with the world average.

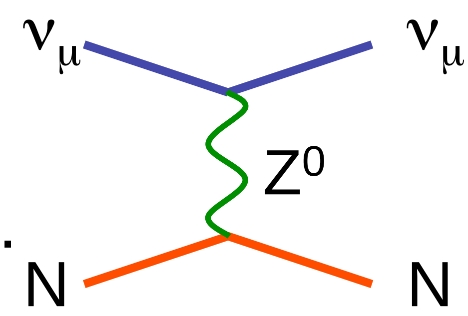
→ Still need further studies.

- a few GeV region : MINERνA, MINOS
- less than 1 GeV : T2K-near detectors ...

Neutral current elastic scattering

$\nu_\mu + N \rightarrow \nu_\mu + N$

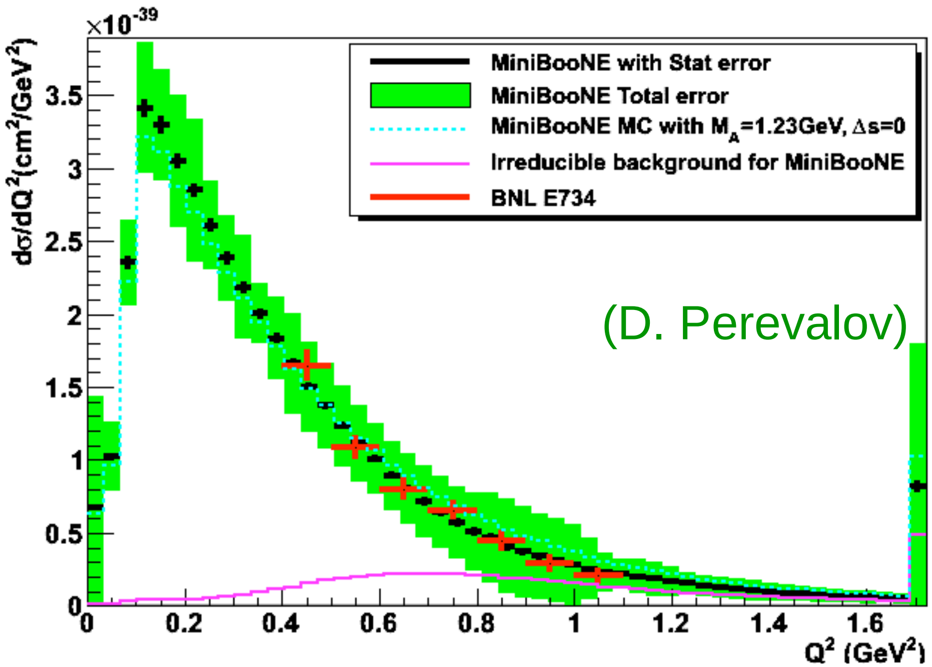
Use recoil proton to tag this kind of events.



MiniBooNE

of candidate events : 94,500
(purity 65%, efficiency 26%)

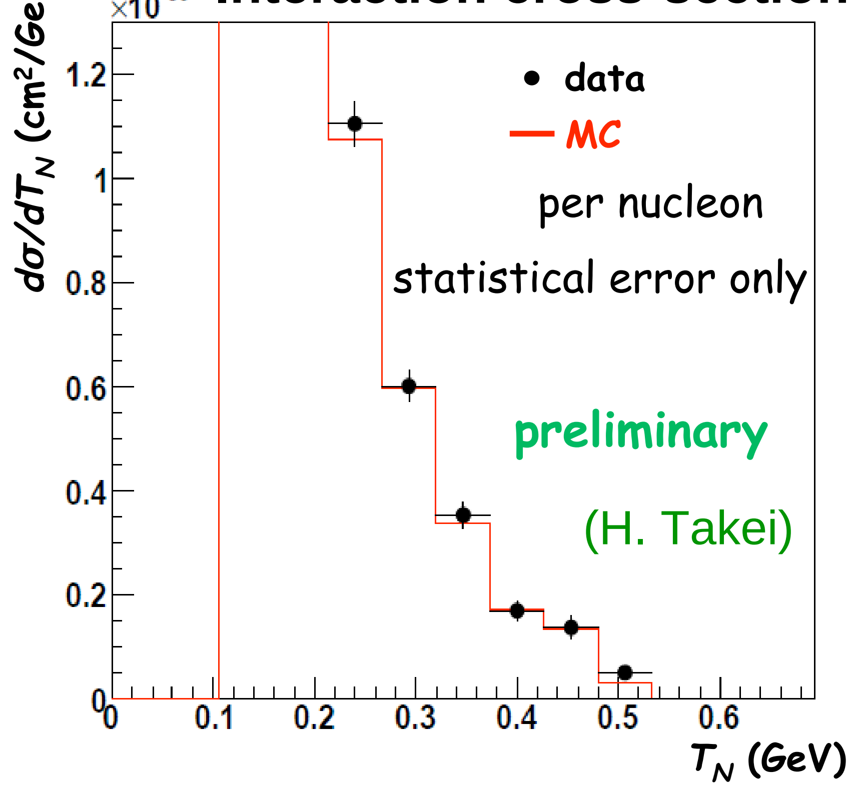
Differential cross-section($d\sigma/dq^2$)



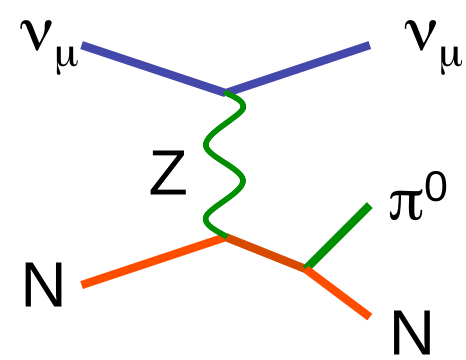
SciBooNE

of candidate events : 8,441
(purity 57%)

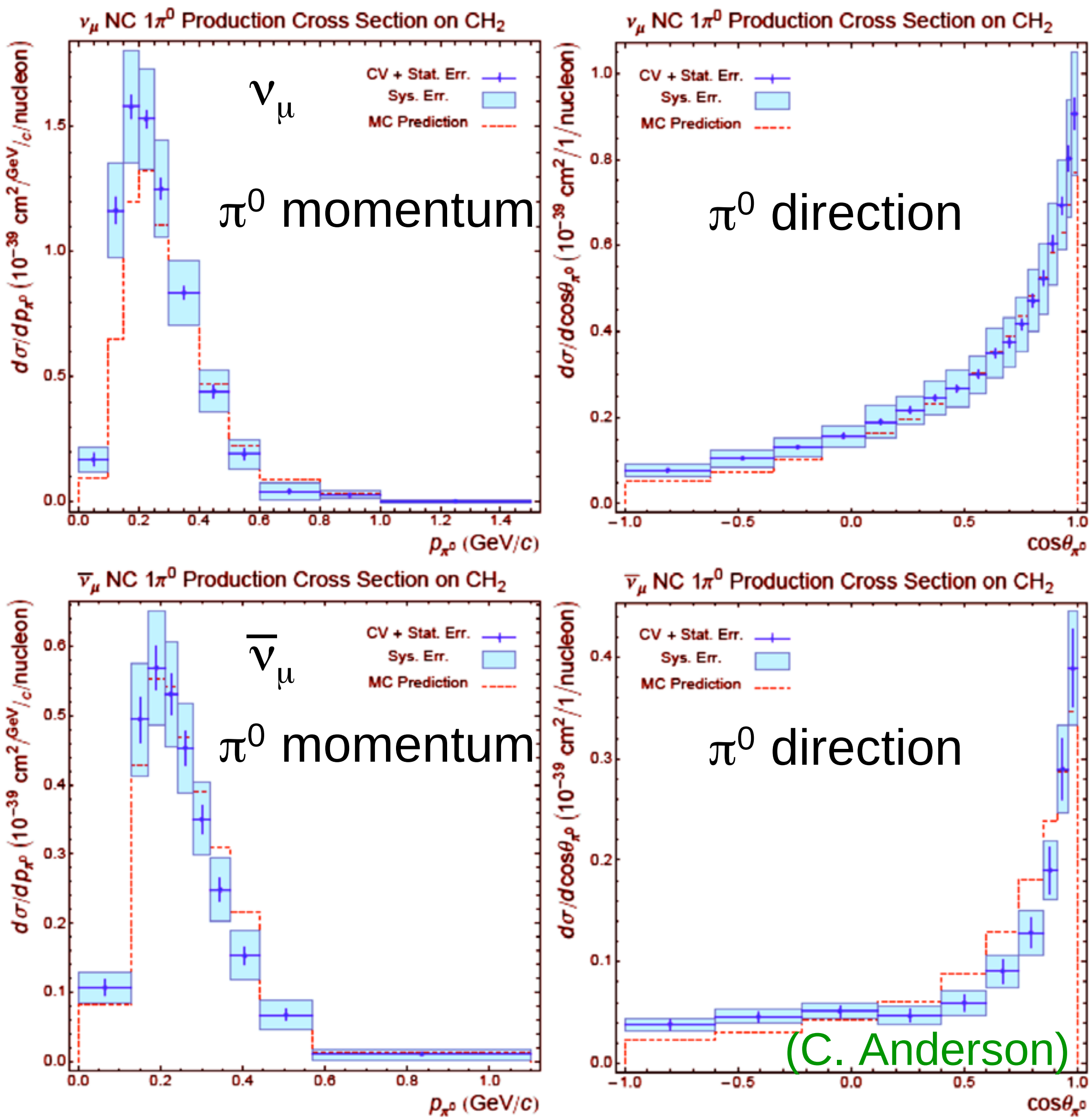
Interaction cross-section



Neutral current single π^0 production



MiniBooNE

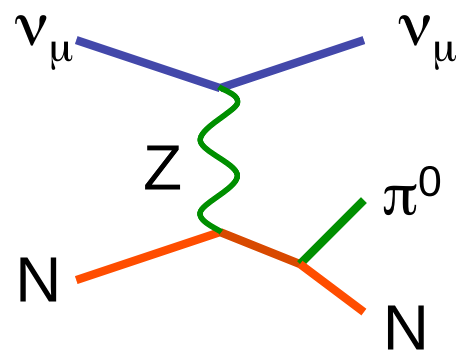


Obtained cross-sections

ν_μ induced π^0 production
4.54±0.04 (stat.)±0.71 (sys) $\times 10^{-40}$cm^2

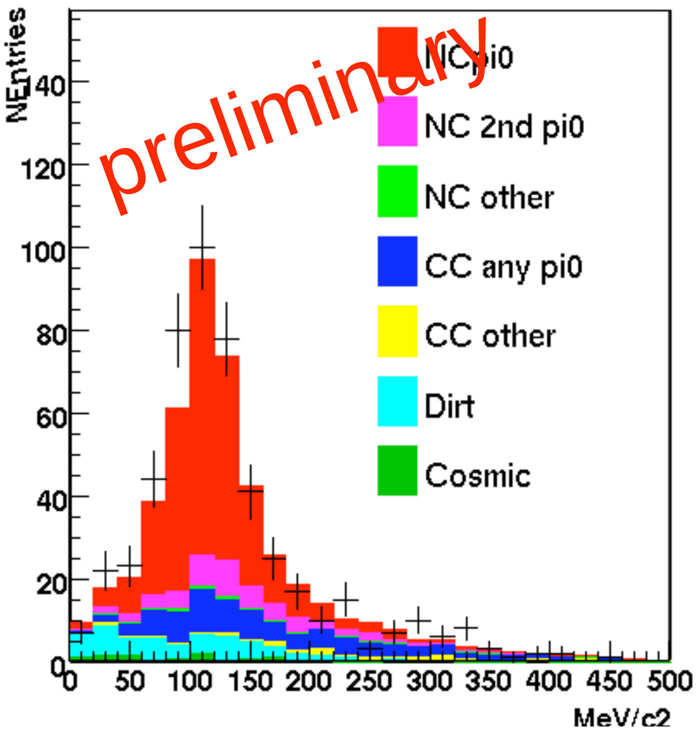
$\bar{\nu}_\mu$ induced π^0 production
1.43±0.03 (stat.)±0.23 (sys) $\times 10^{-40}$cm^2

Neutral current single π^0 production

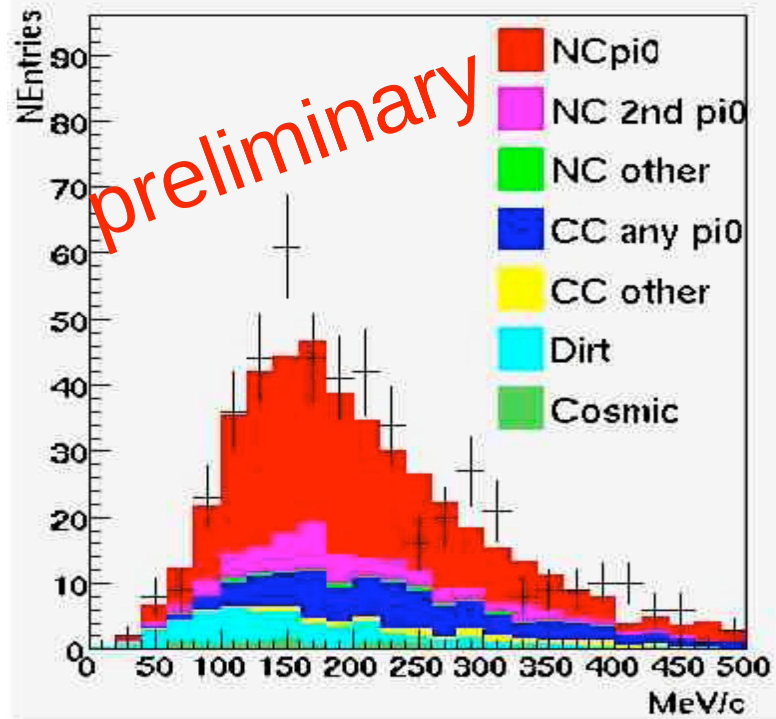


SciBooNE

Reconstructed mass of π^0



Reconstructed mass of π^0



$$\frac{\sigma(\mathrm{NC}\ \pi^0)}{\sigma(\mathrm{CC\ inclusive})} = 7.7 \pm 0.6(\mathrm{stat}) \pm 0.6(\mathrm{prelim\ syst}) \times 10^{-2}$$

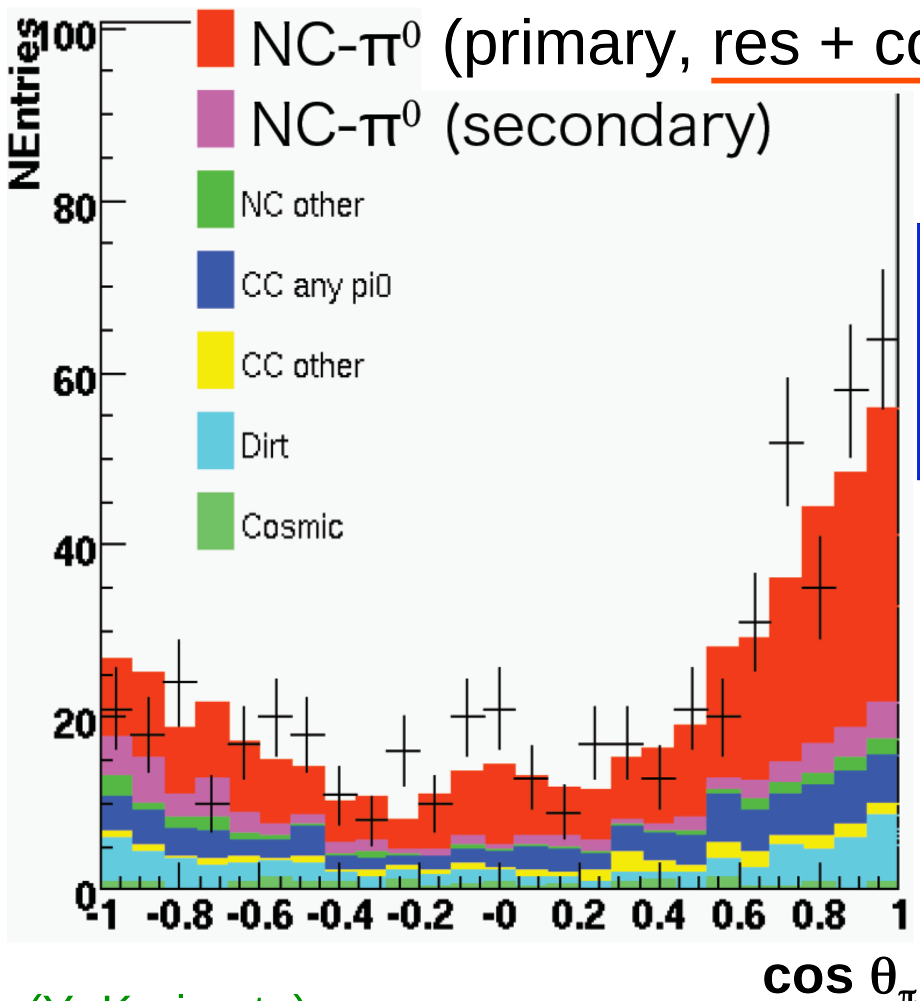
- agrees with NEUT prediction (6.8×10^{-2})

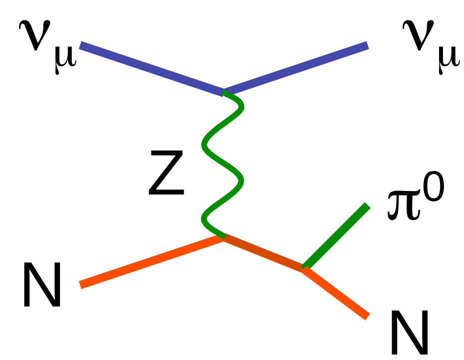
(Y. Kurimoto)

Neutral current single π^0 production

SciBooNE

Directional distribution of π^0





Together with the vertex activity, it will be possible to enhance NC coherent π^0 events.

$$\nu_\mu + {}^{12}C \rightarrow \nu_\mu + {}^{12}C + \pi^0$$

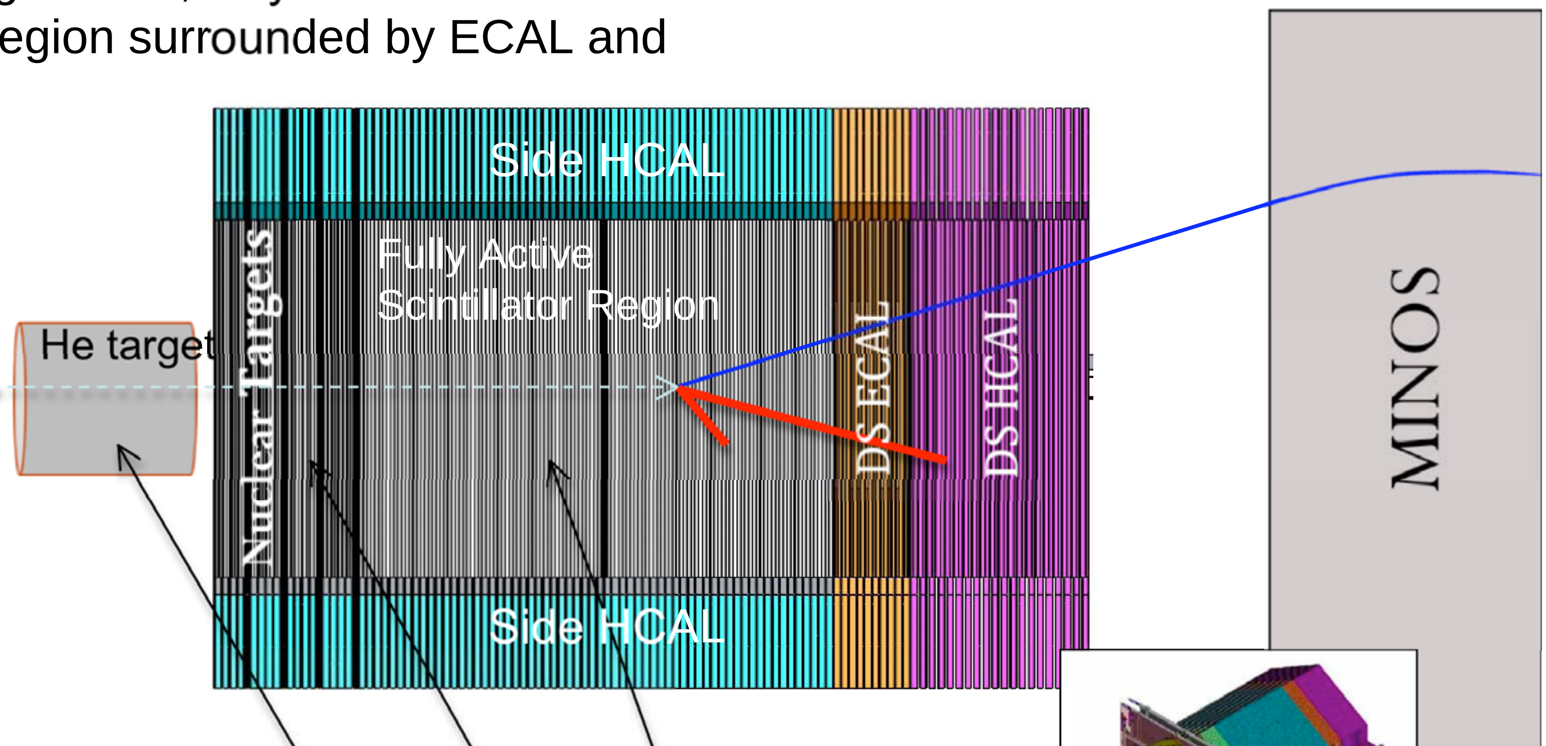
There will be no activity around the interaction vertex.

(Y. Kurimoto)

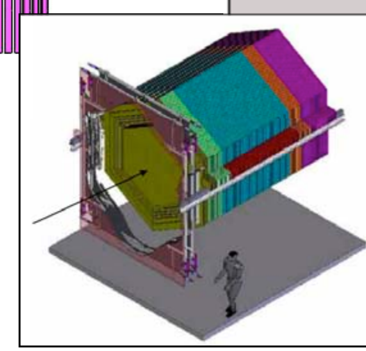
MINERνA

- MINERνA is a dedicated **<u>neutrino-nucleus cross-section</u>** experiment

Finely segmented, fully active scintillator tracking region surrounded by ECAL and HCAL



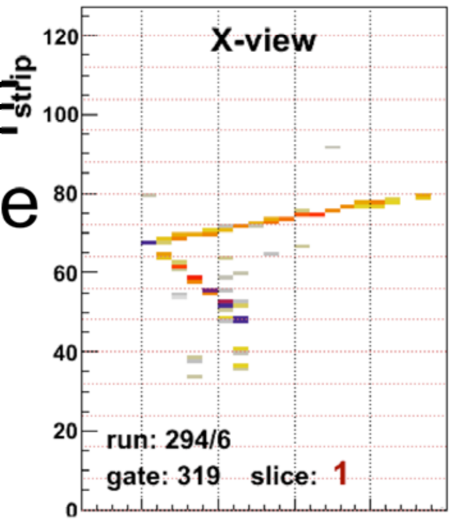
makes use of the existing high intensity NuMI neutrino beam at Fermilab



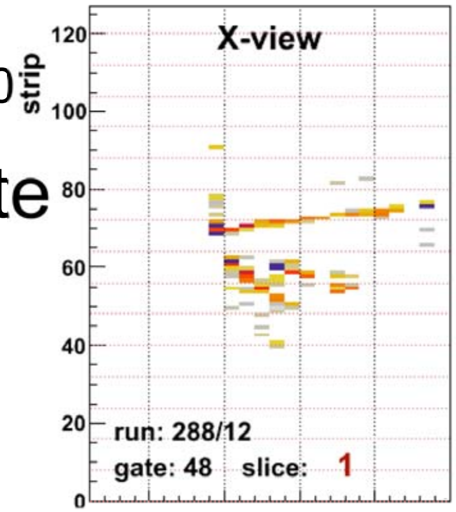
<u>range of nuclear targets</u> **(He, C, Fe, Pb, CH)** for study of **nuclear effects** in neutrino interactions

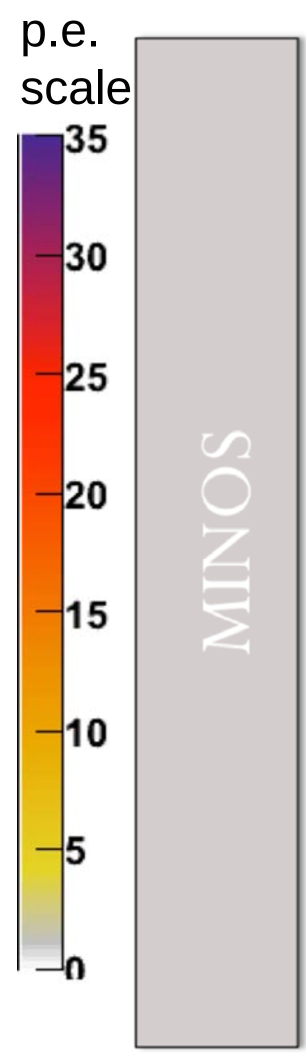
MINERνA Tracking Prototype

ν_μ CCQE candidate event



ν_μ CC π^0 candidate event

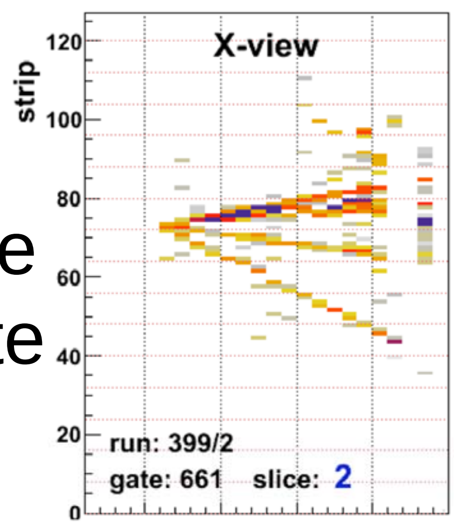




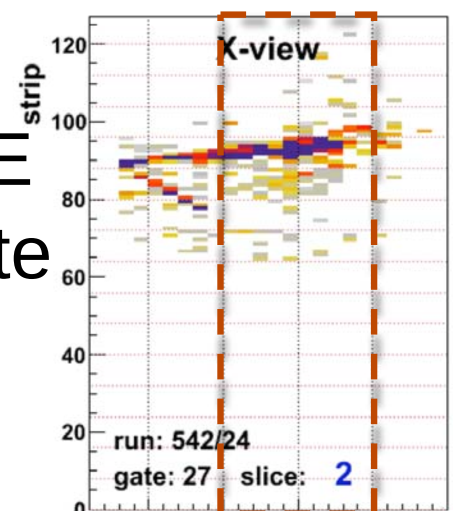
NuMI

Beam

Deep Inelastice candidate event

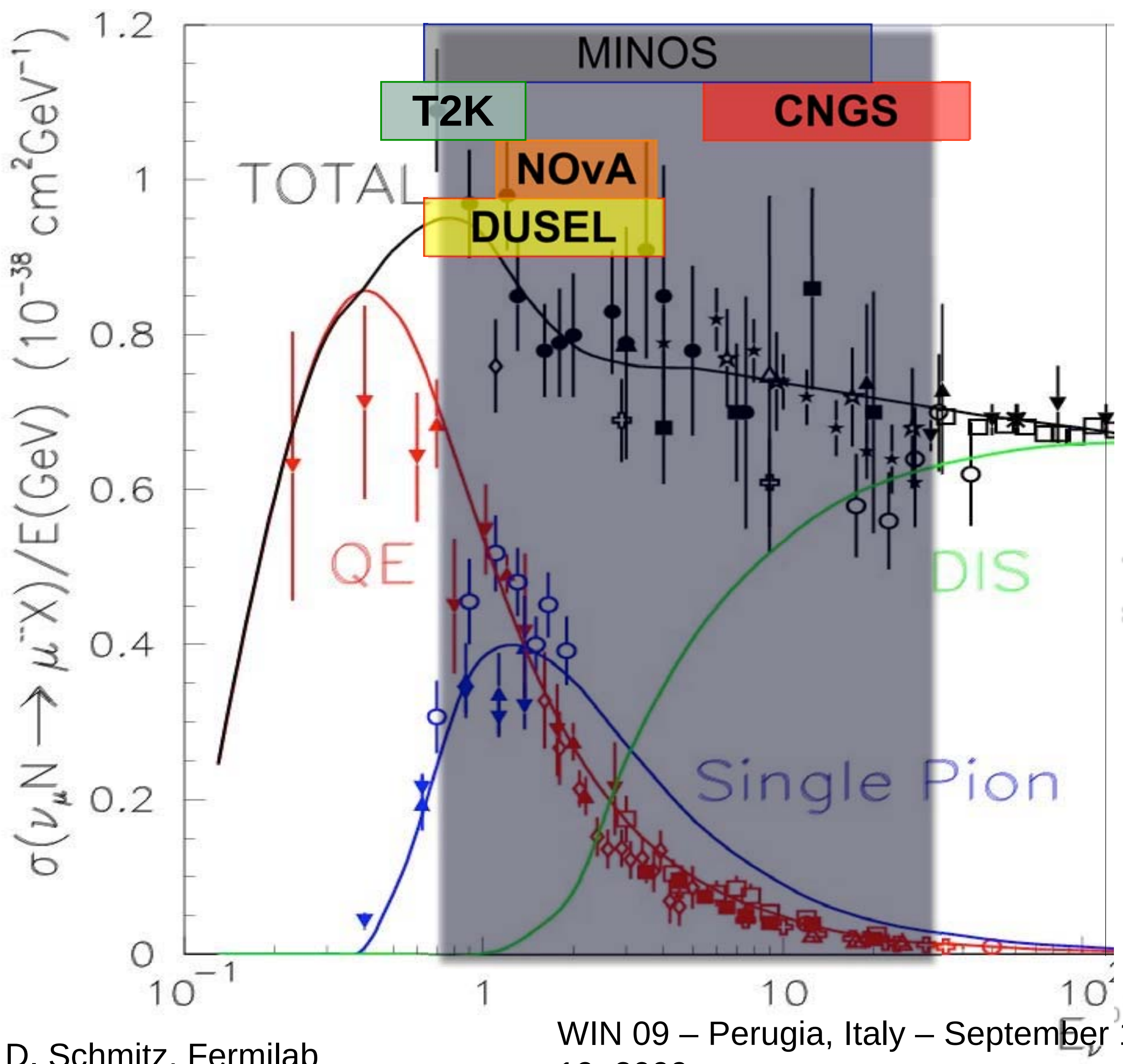


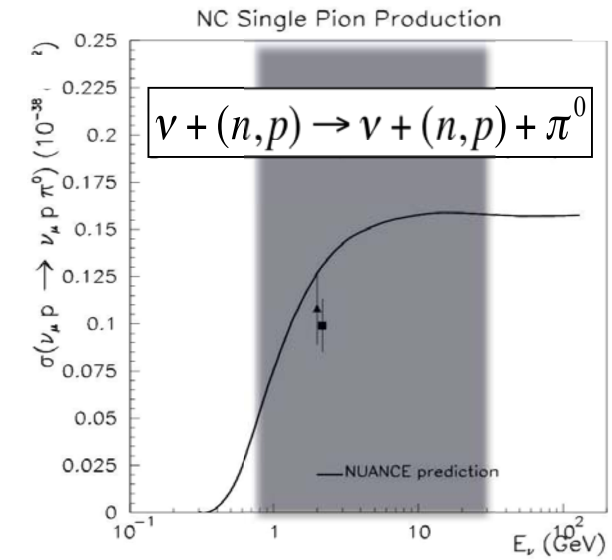
ν_e CCQE candidate event

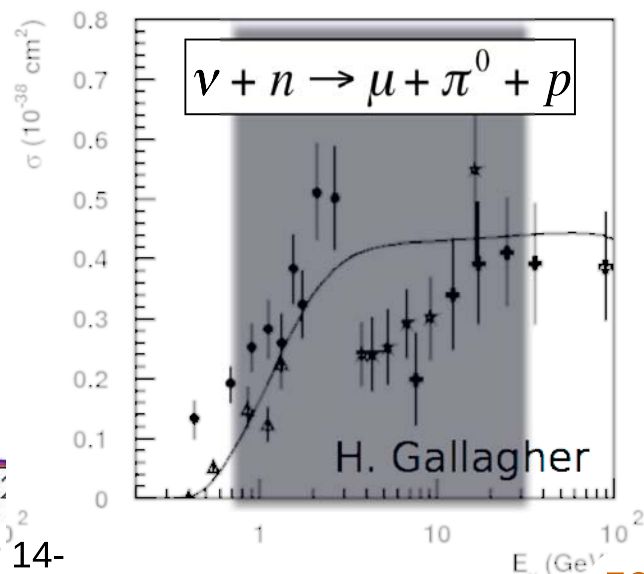


ECAL

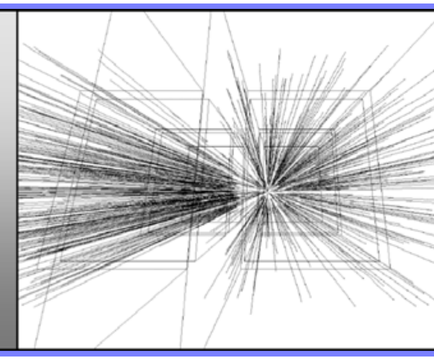
MINERνA Energy Range







Hadro-production measurements for the T2K experiment with the NA61/SHINE detector at the CERN SPS



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Claudia Strabel, ETH Zurich
For the NA61/SHINE Collaboration

WIN‘09 Workshop
14.-19.09.09, Perugia

Physics Goals (I)

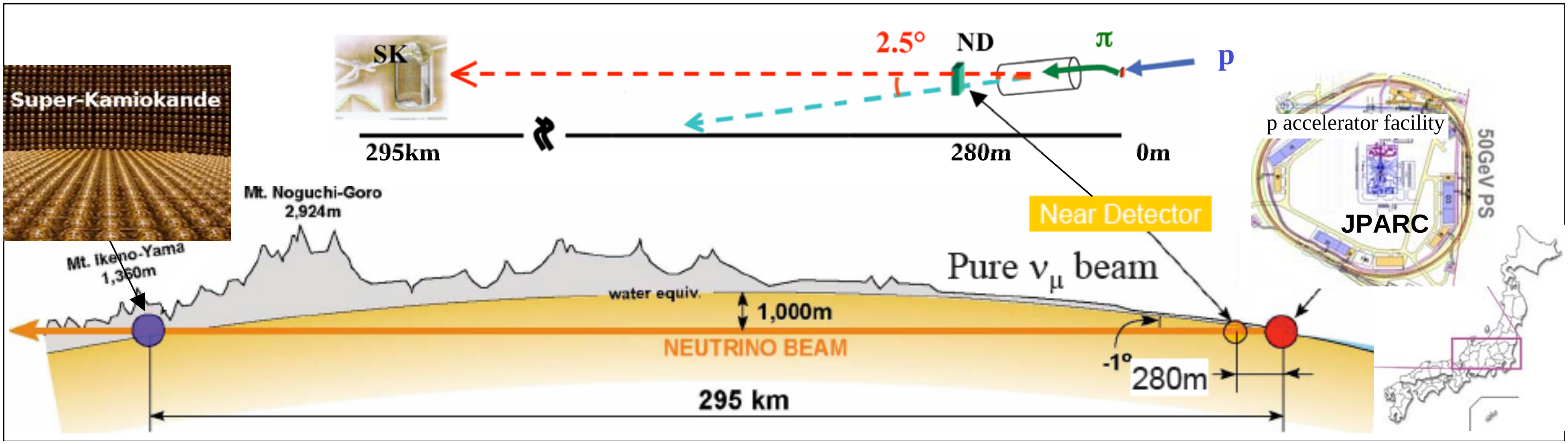
- One of the main physics goals of NA61/SHINE:

Precision measurements of hadron production

for the prediction of ν-fluxes at T2K

- T2K @ JPARC (Japan):

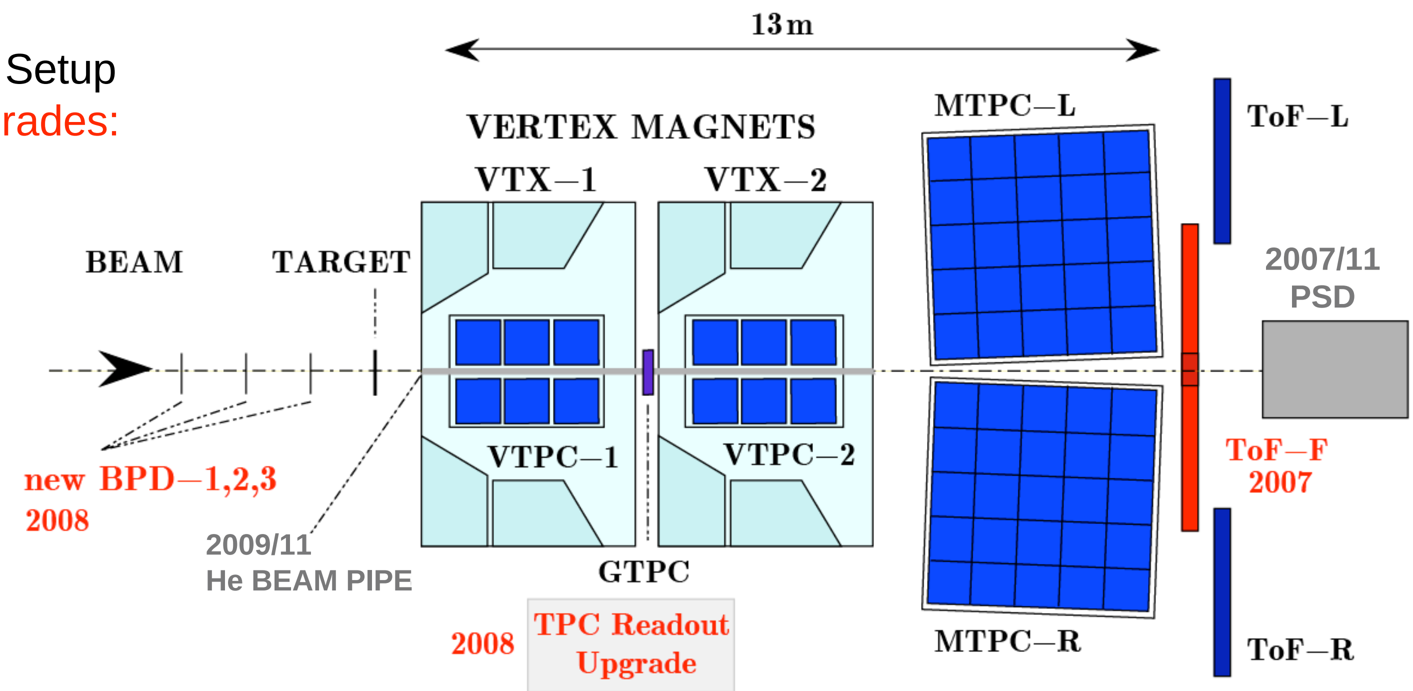
- Long baseline (295km) neutrino oscillation experiment
- Protons (30-50GeV) + carbon target (90cm) → intense ν_μ–beam
- Neutrino spectra measured off-axis at the near and far detectors: ND280 and SK



NA61/SHINE – Fixed Target Experiment at CERN SPS

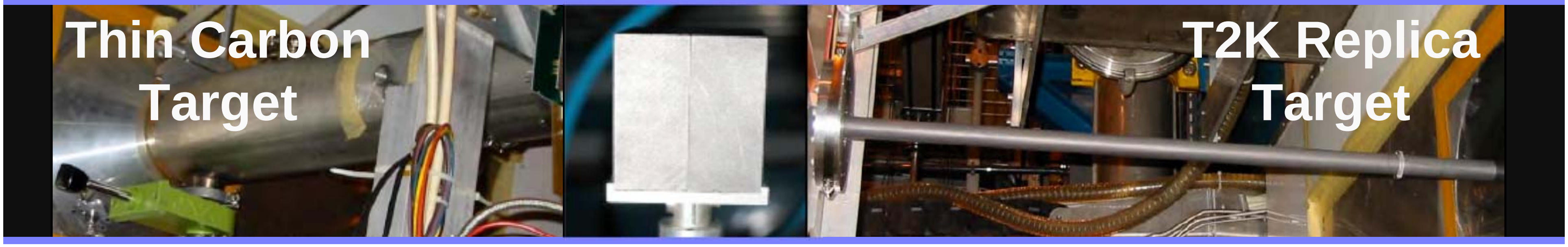
NA49 Setup

+ Upgrades:



- Large acceptance (up to 70%) spectrometer for charged particles
- TPCs as main tracking devices
- 2 dipole magnets with bending power of max 9 Tm over 7 m length (2007-Run: 1.14 Tm)
- High momentum resolution: $\sigma(p)/p^2 \approx 10^{-4}$ (GeV/c)$^{-1}$
- Good particle identification: σ(ToF-L/R) ≈ 100 ps, σ(dE/dx)/<dE/dx> ≈ 0.04, $\sigma(m_{inv})$ ≈ 5 MeV
- New ToF-F to entirely cover T2K acceptance (σ(ToF-F) ≈ 120 ps, $1 < p < 3$ GeV/c, $50 < \Theta < 150$ mrad)

Setup of Beam Line – Target



- 2 different carbon targets (isotropic graphite, ρ = 1.84 g/cm^3):

Thin Carbon Target:
- 2.5 x 2.5 x 2cm^3,
- int. length ~0.04
- used to evaluate inclusive x-sections

T2K Replica Target:
- Ø= 2.6cm x 90cm,
- int. length ~1.9
- used to study secondary interactions

- Aims of the first NA61 run in October 2007:

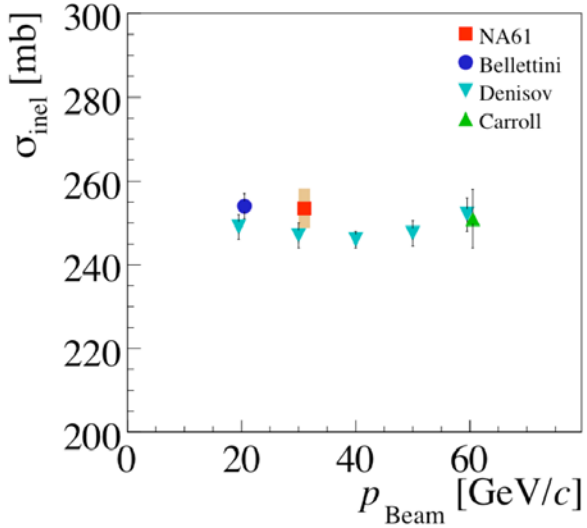
- to set up and test the NA61 apparatus and the detector prototypes
- to take pilot physics data for T2K with 30.9 GeV/c protons:

Thin target: ~660k events

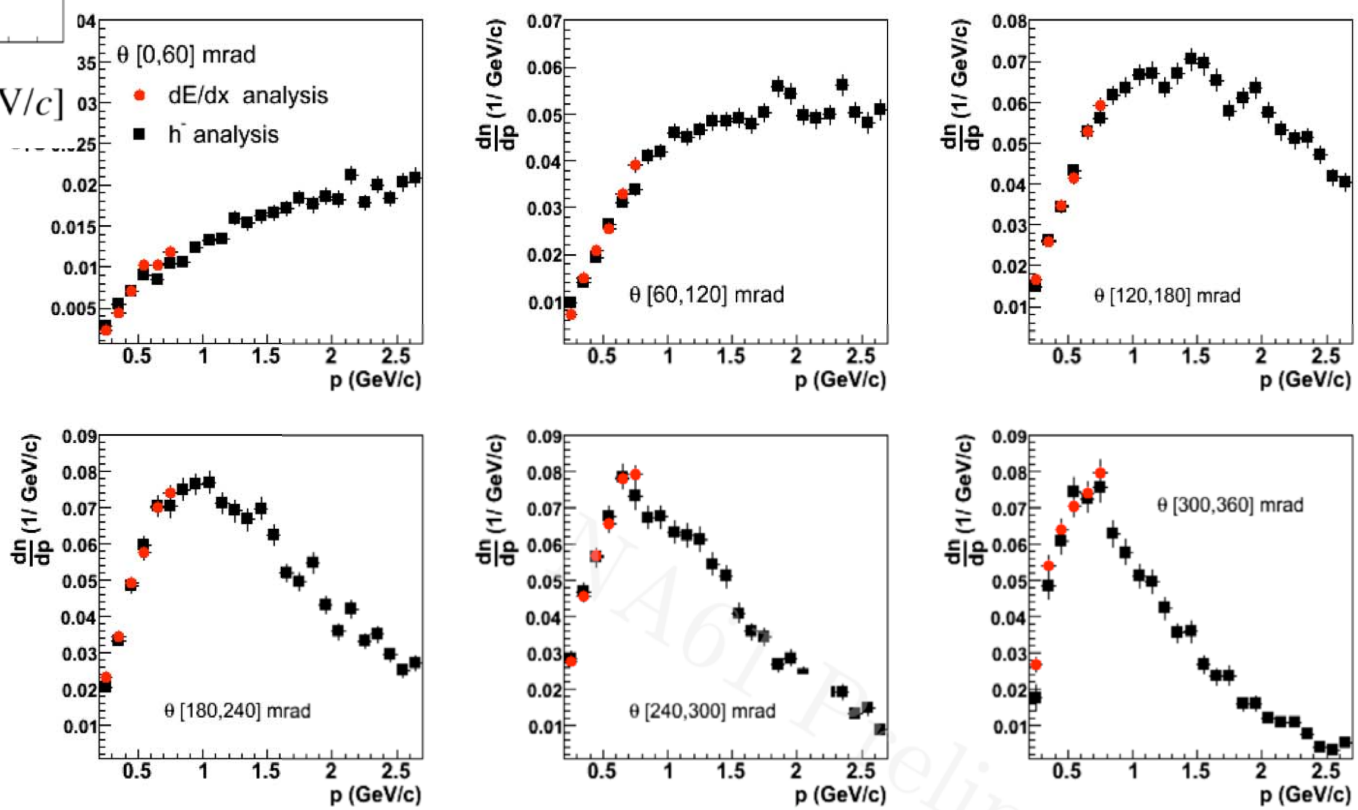
Replica target: ~230k events

Target out: ~80k events

Results from dE/dx and h$^-$ Analyses – π^-



Systematical error below 20%



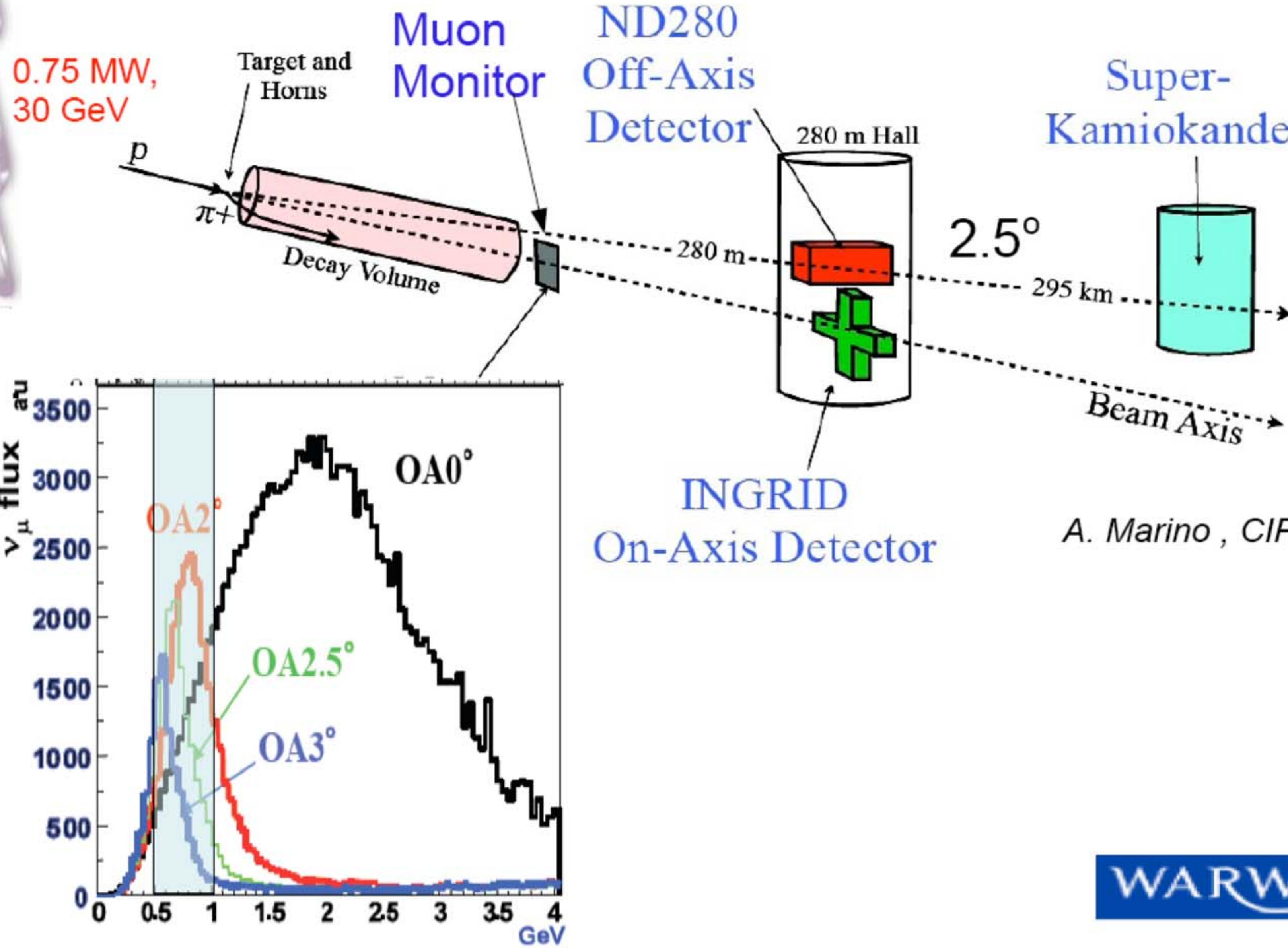
Cross section Measurements in the T2K ND280 Detector

Steve Boyd
on behalf of the T2K Collaboration

22nd International Workshop on
Weak Interactions and Neutrinos WIN'09
Electroweak Symmetry Breaking
Weak Decays, CP Violation and CKM
Neutrino Physics
Dark Matter

WARWICK

T2K Layout

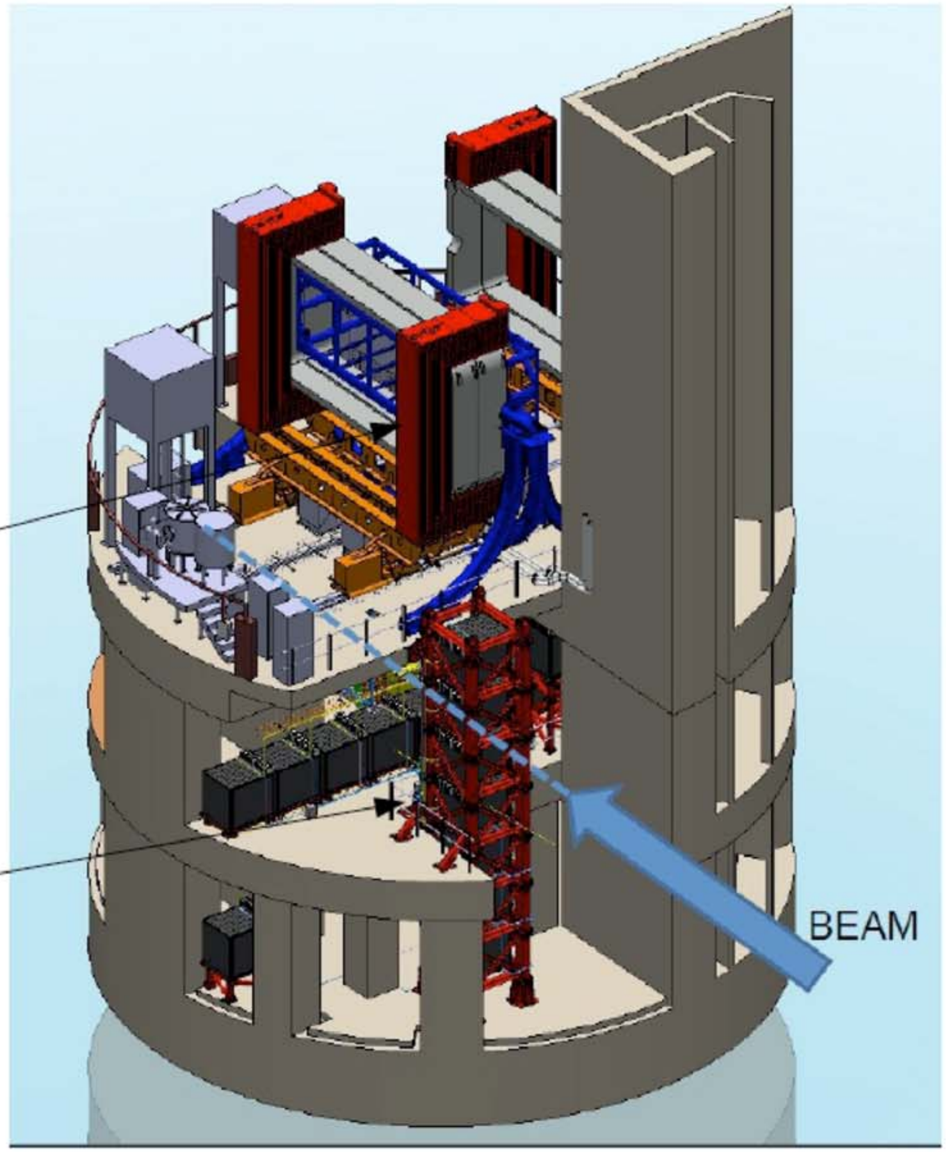


A. Marino , CIPANP 09

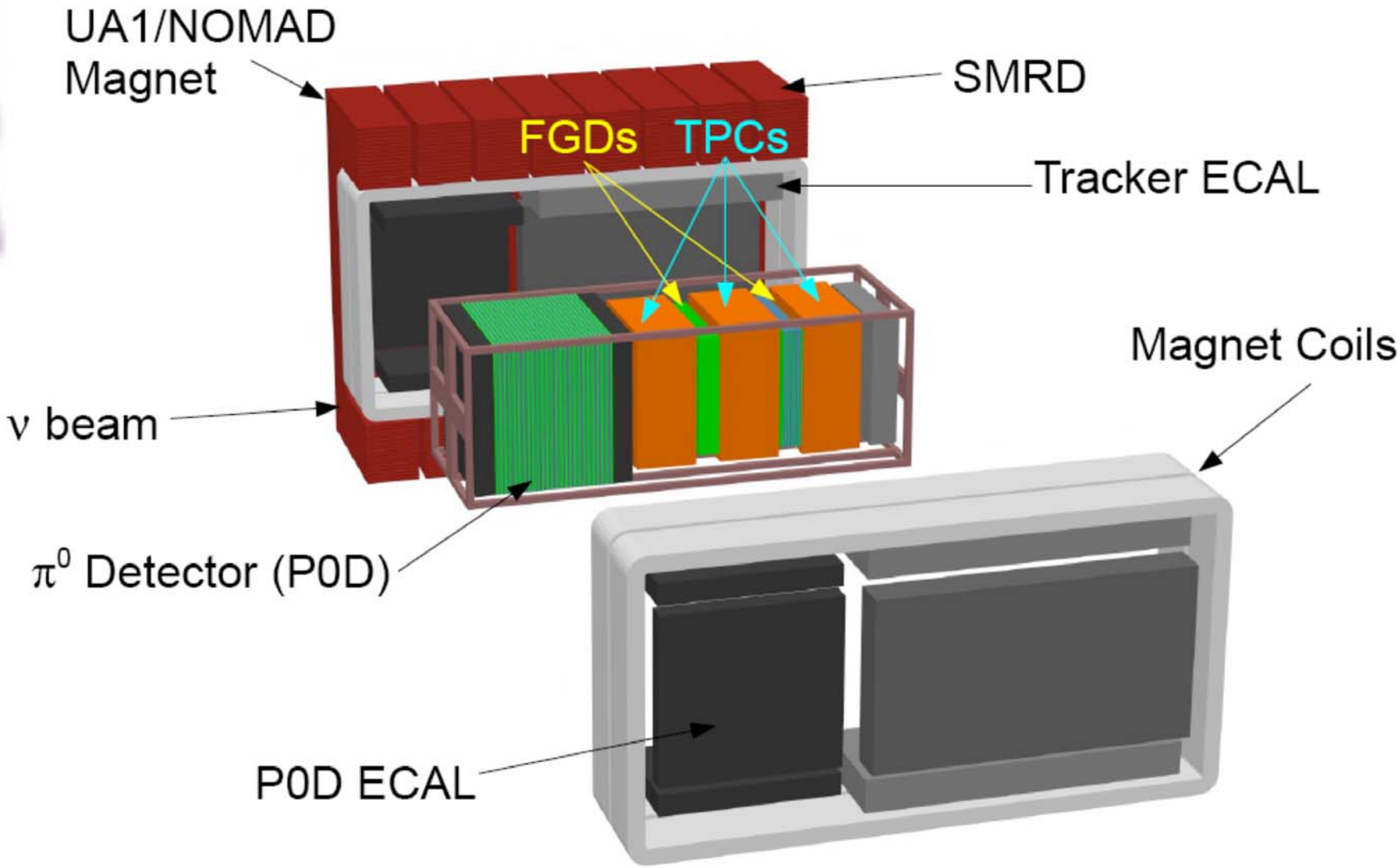
Near Detectors

ND280
off-axis
detector

INGRID
on-axis
detector



ND280 Near Detector



CCQE Event Rates

PRELIMINARY

Experiment	Target	CCQE
T2K	C/O	300k/150k
SciBooNE*	C	11k
MiniBooNE*	C	112k
MINERvA	C	800k
MINOS*	Fe	210k
NOMAD*	C	7k
K2K (SciBar)*	C	5k
K2K (SciFi)*	O	7k

(*)Numbers corrected for quoted purity

MINOS: M. Dorman, NuInt09
MiniBooNE : T. Katori, Nuint09
SciBooNE : J.L. Alcaraz-Aunion, NuInt09
NOMAD : V. Lyubushkin, NuInt09
K2K : F. Sanchez, NuInt07
Phys. Rev. D 74, 052002

Nominal 5 yr (10^{21} POT/yr) in Tracker

Efficiency ~ 70% ; purity ~ 84%

- Only high-statistics measurement on Oxygen.
- Statistical error < 1%
- Systematic errors being evaluated.

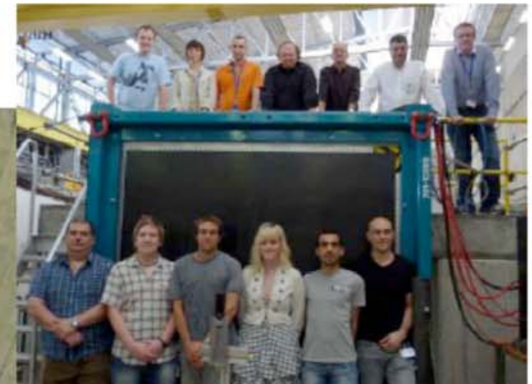
Work continuing to optimise CCQE selection

WARWICK

Status of ND280 Detector

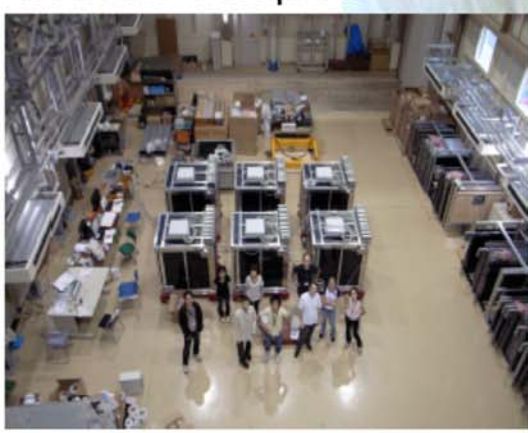
P0D being installed now

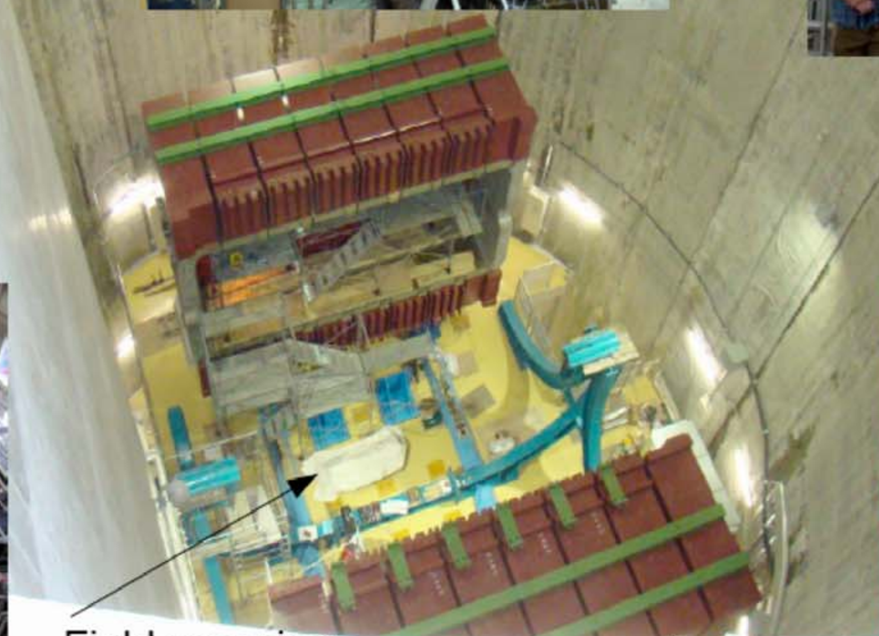
Both FGDs shipped
2of 3 TPCs complete



DSECAL in Japan
40% of rest by end of the year

INGRID Complete





Field mapping underway

SMRD Installed

Many new results in particular in neutrino cross section measurements

Exciting future for next generation measurements

Many thanks to all the speakers!