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

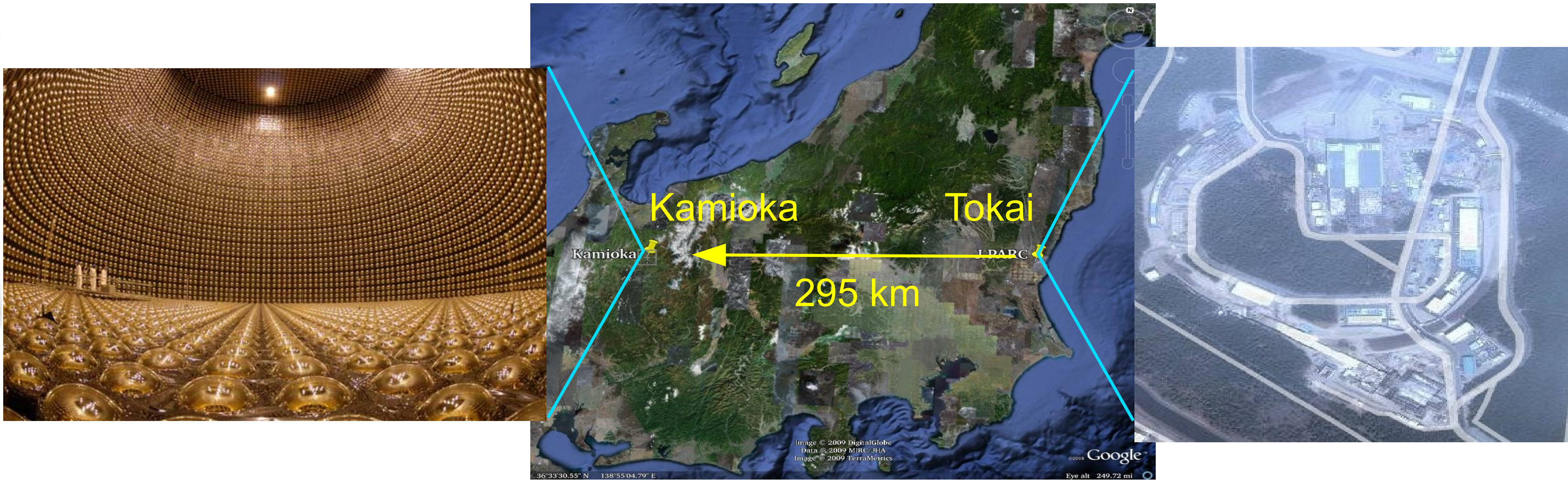
Neutrino Physics

Dark Matter

Cross section Measurements in the T2K ND280 Detector

- T2K Introduction / Signals and Backgrounds
- The Near Detector Suite
- A brief look at prospects for...
  - Charged current Quasi-elastic
  - Inclusive Neutral Current π^0
  - Charged current coherent pion production
- Near Detector Status

T2K



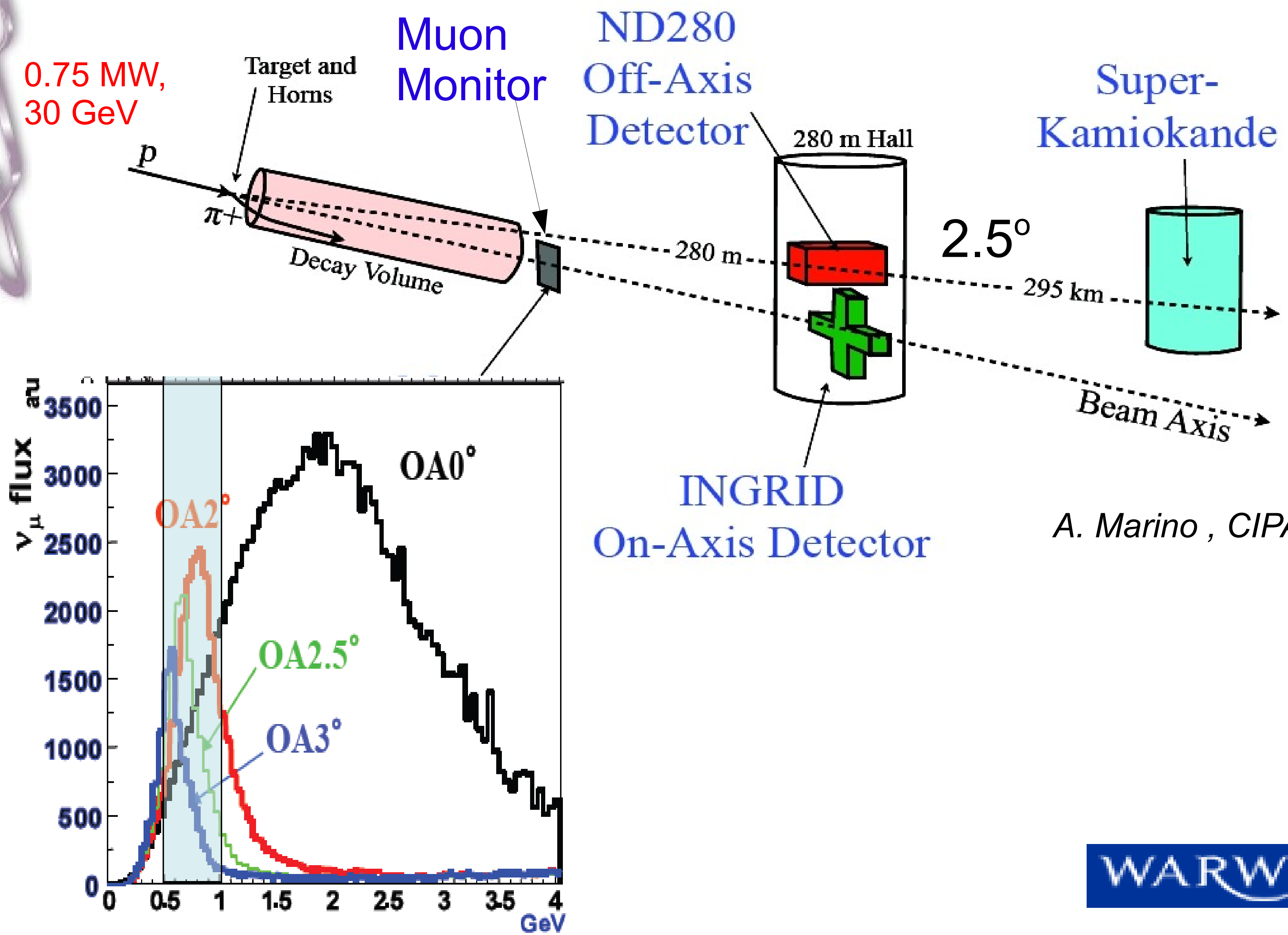
Better measurement of 23-sector : $\nu_\mu \rightarrow \nu_x$

$$\delta(\sin^2(2\theta_{23})) \approx 0.01(0.04) \qquad \delta(m_{23}^2) \approx 10^{-4}(10^{-3})$$

Detection of ν_e appearance : $\nu_\mu \rightarrow \nu_e$

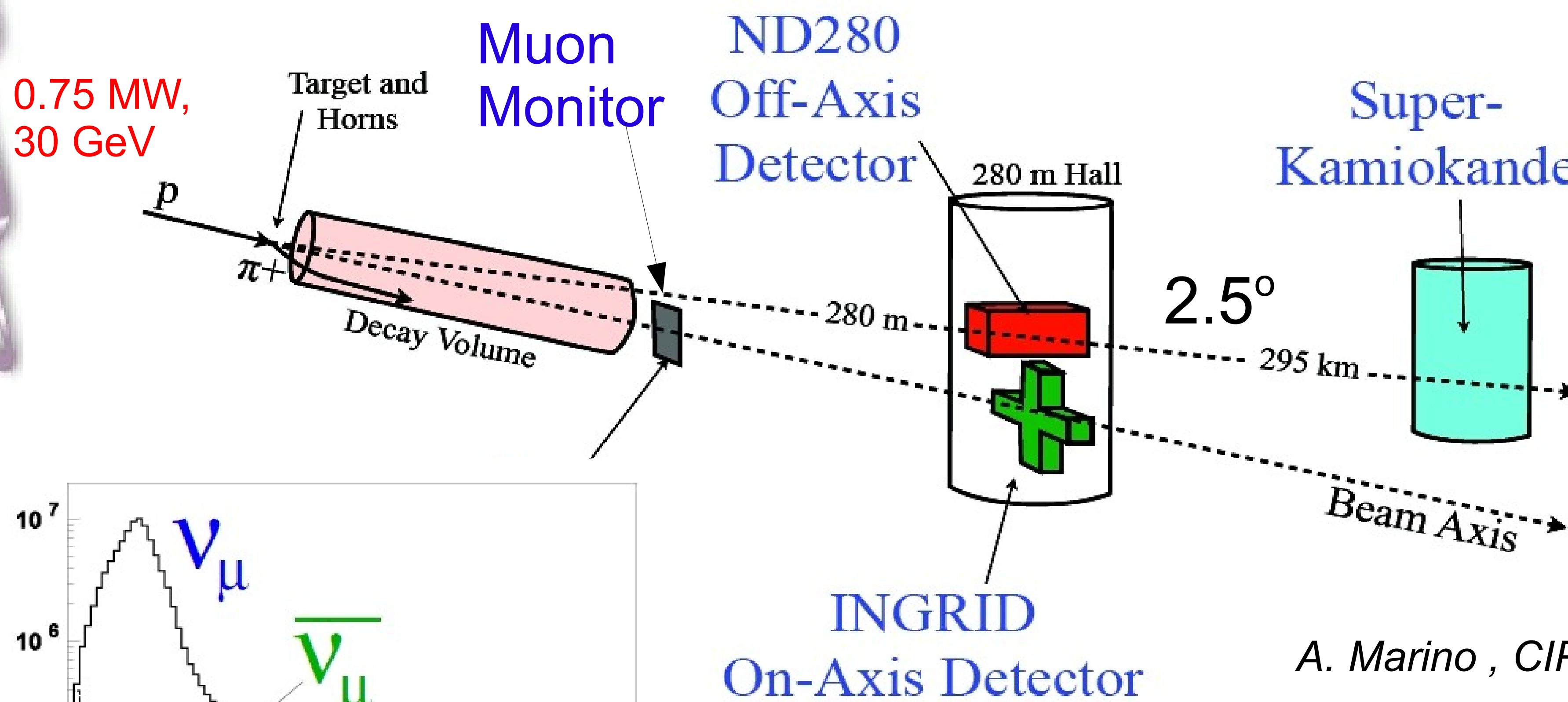
$$\sin^2(2\theta_{13}) < 0.008(90\% \quad CL)(0.14)$$

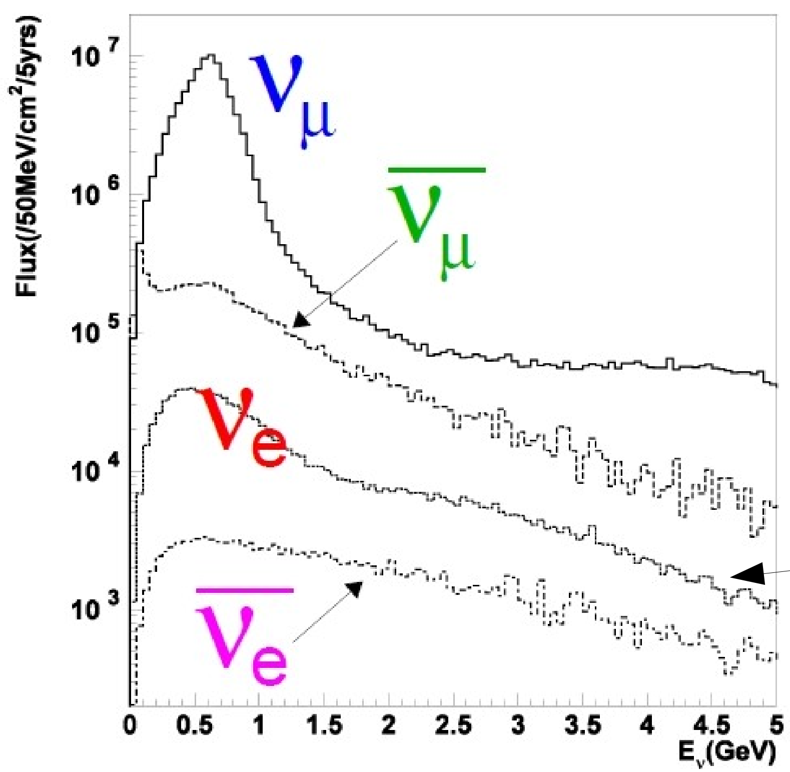
T2K Layout



A. Marino , CIPANP 09

T2K Layout





~ 0.5 % ν_e

contamination at the ν_μ peak

A. Marino , CIPANP 09

Signals and Backgrounds

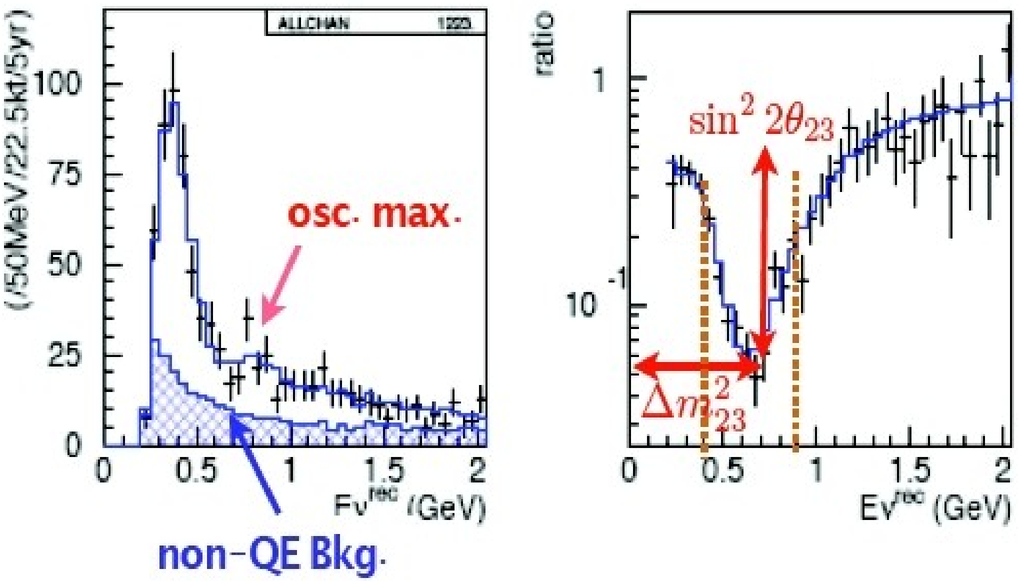
ν_μ disappearance :

S : QE : $\nu_\mu + n \rightarrow \mu^- + p$

→ *can reconstruct ν energy*

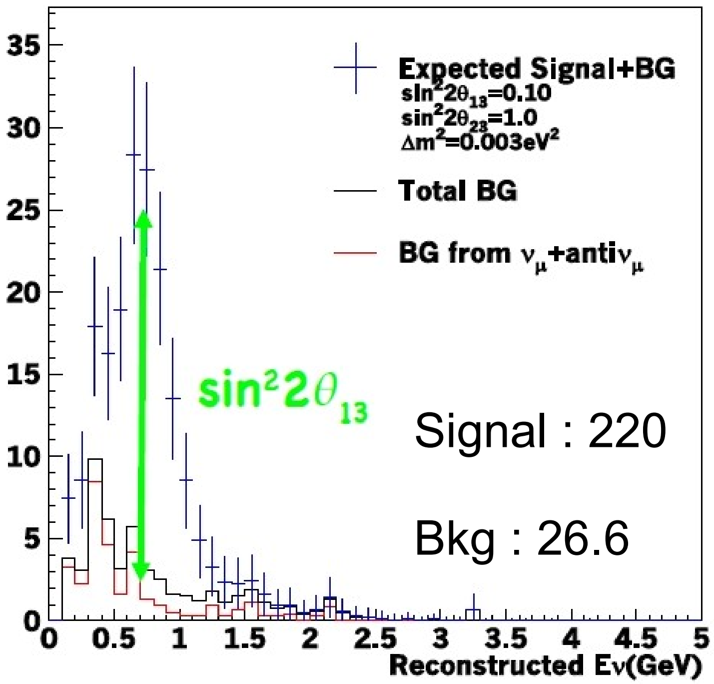
B : non-QE

→ *inelastic background*



Systematic Error Source	Limit	Detectors
Beam direction	<1 mrad	INGRID, ND280, MuMon
Flux shape	<10%	ND280, NA61, INGRID
μ energy scale	< 2%	ND280
μ momentum resolution	<10%	ND280
nonQE/QE ratio	<10%	ND280

Signals and Backgrounds



ν_e appearance :

S : $\nu_\mu \rightarrow \nu_e$ $\quad \nu_e + N \rightarrow e^- + X$

B : Beam $\quad \nu_e + N \rightarrow e^- + X$

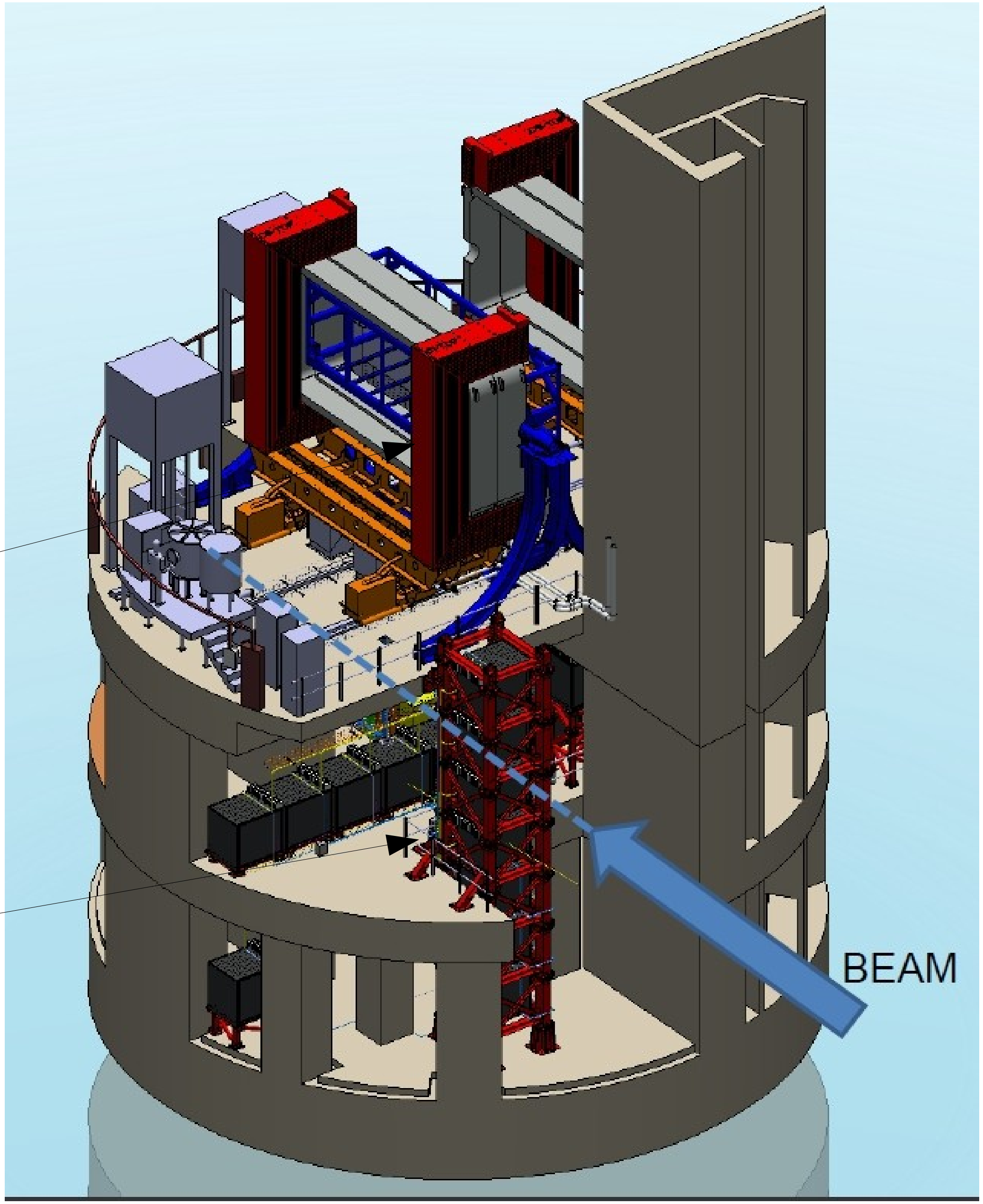
$\nu_\mu + N \rightarrow \pi^0 + X$

Systematic Error Source	Limit	Detectors
Beam direction	<1 mrad	INGRID, ND280, MuMon
Flux shape	<10%	ND280, NA61, INGRID
ν_e component (≈ 0.5%)	<10% (relative)	ND280, NA61
NC 1 π^0 cross section	<10%	ND280

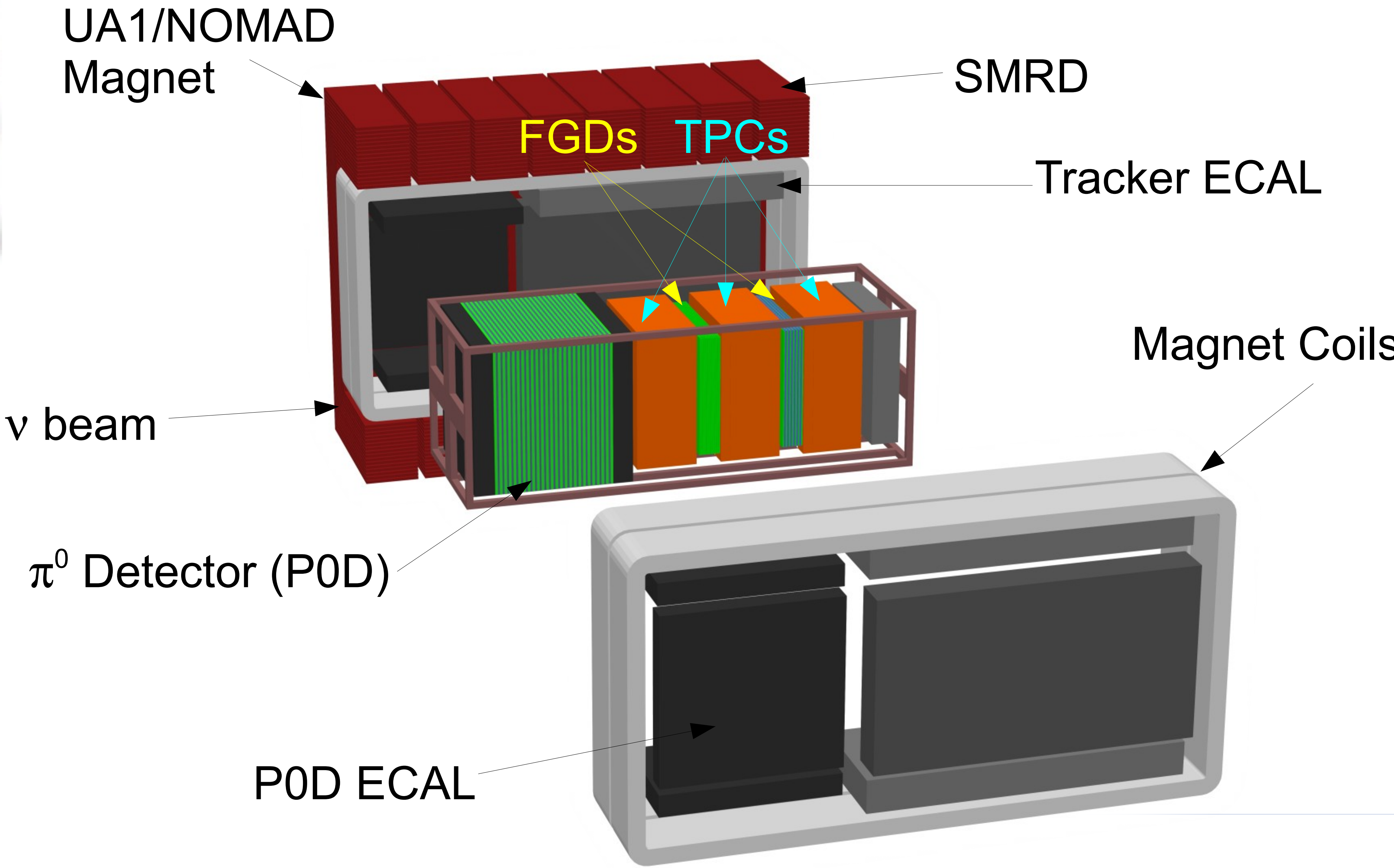
Near Detectors

ND280
off-axis
detector

INGRID
on-axis
detector

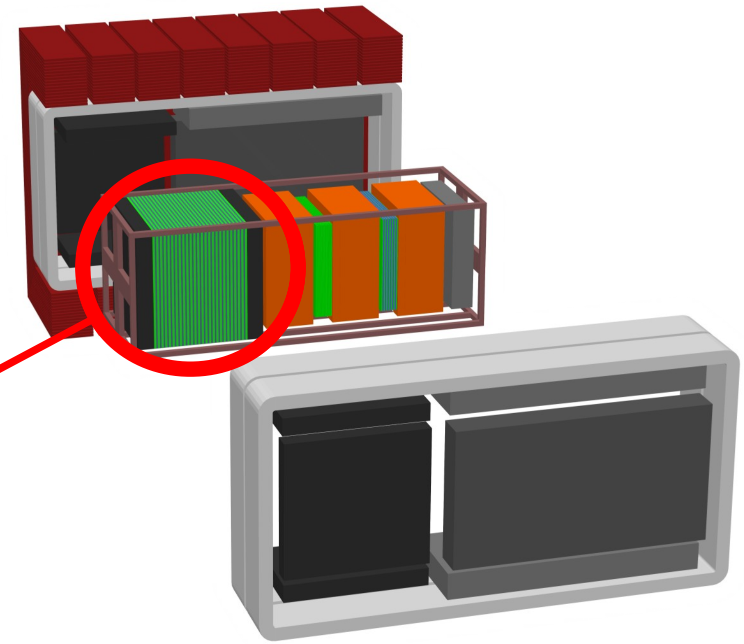


ND280 Near Detector



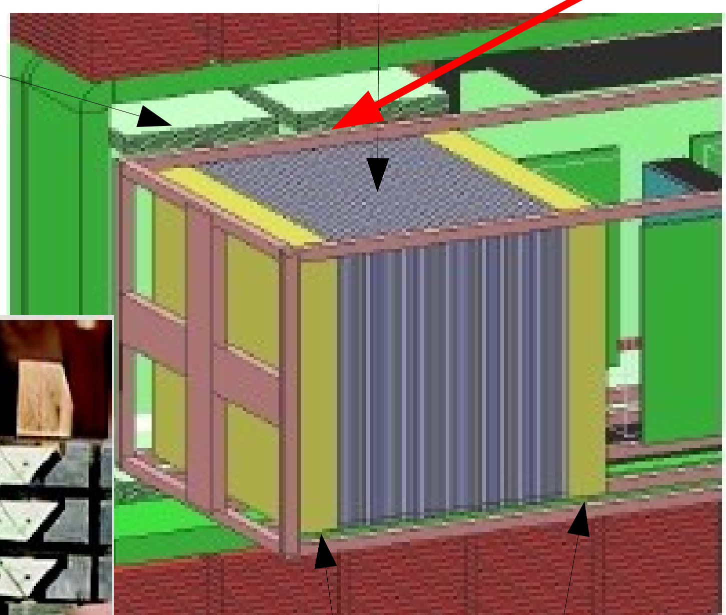
P0D

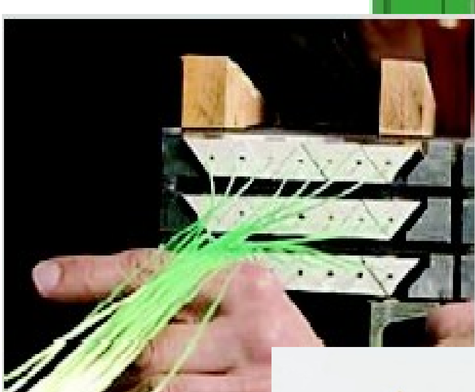
Designed to study π^0 production in NC and CC on water target

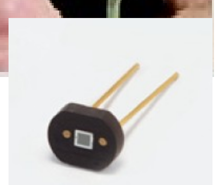


40 XY Brass/Scint tracking planes
Interspersed water volumes
fiducial mass : C/O : 1.8t / 0.9t

Coarse $5X_0$ thick surrounding Pb/Scint calorimeter to tag γ leakage/ mip tagging







$5.7\ X_0$ Forward and Back γ stops

Tracker (FGD/TPC)

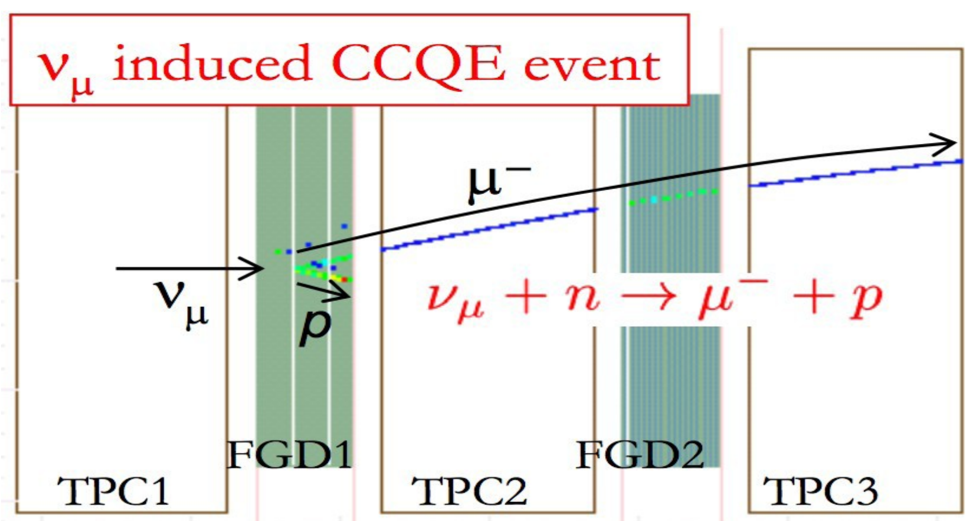
Designed to study exclusive final states (CC and NC)

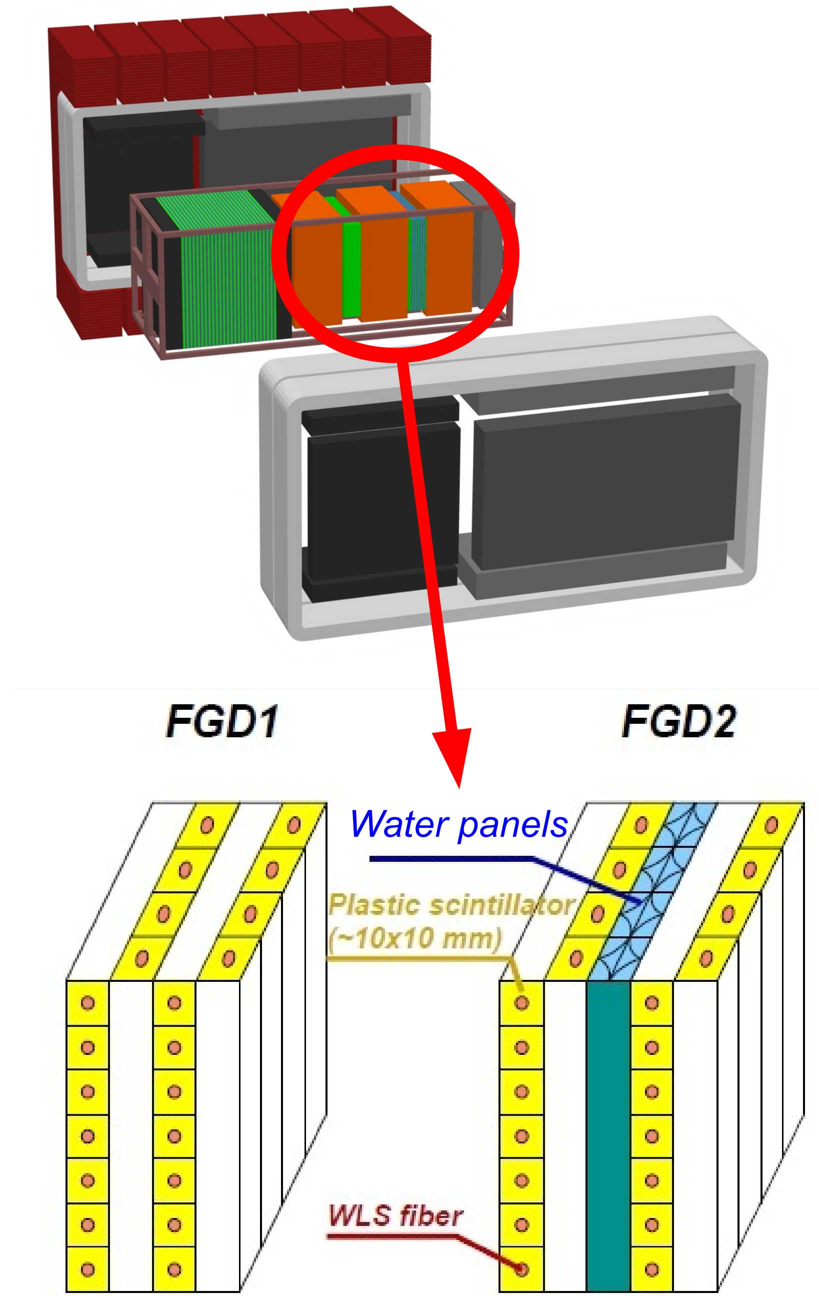
TPCs

- 5σ e/μ separation
- charge/momentum measurement
- $\sigma_p/p < 10\%$
- high resolution tracking

FGDs

- fine grained tracker and target
- 2 x 1.3 ton active target
- 1 cm^2 scintillator bar + WLS fibre readout
- water cross section using subtraction

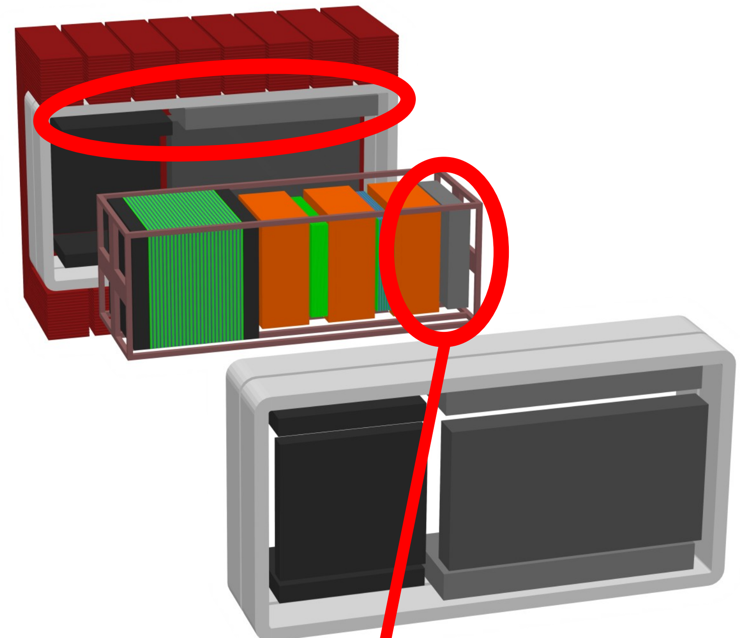




ECAL

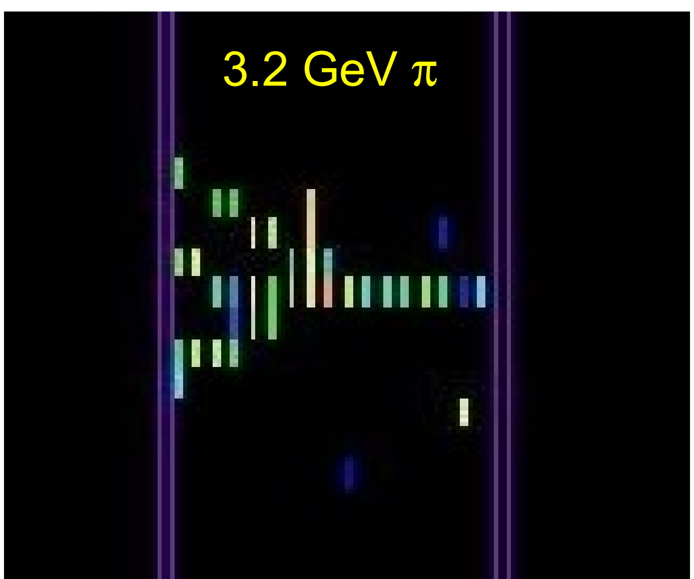
Tracker ECAL :

- Entire inner volume surrounder by lead scintillator sampling calorimeter
- Improve CCQE efficiency by tagging high angle tracks
- Improve beam ν_e measurement
- Cosmic/Magnet event veto

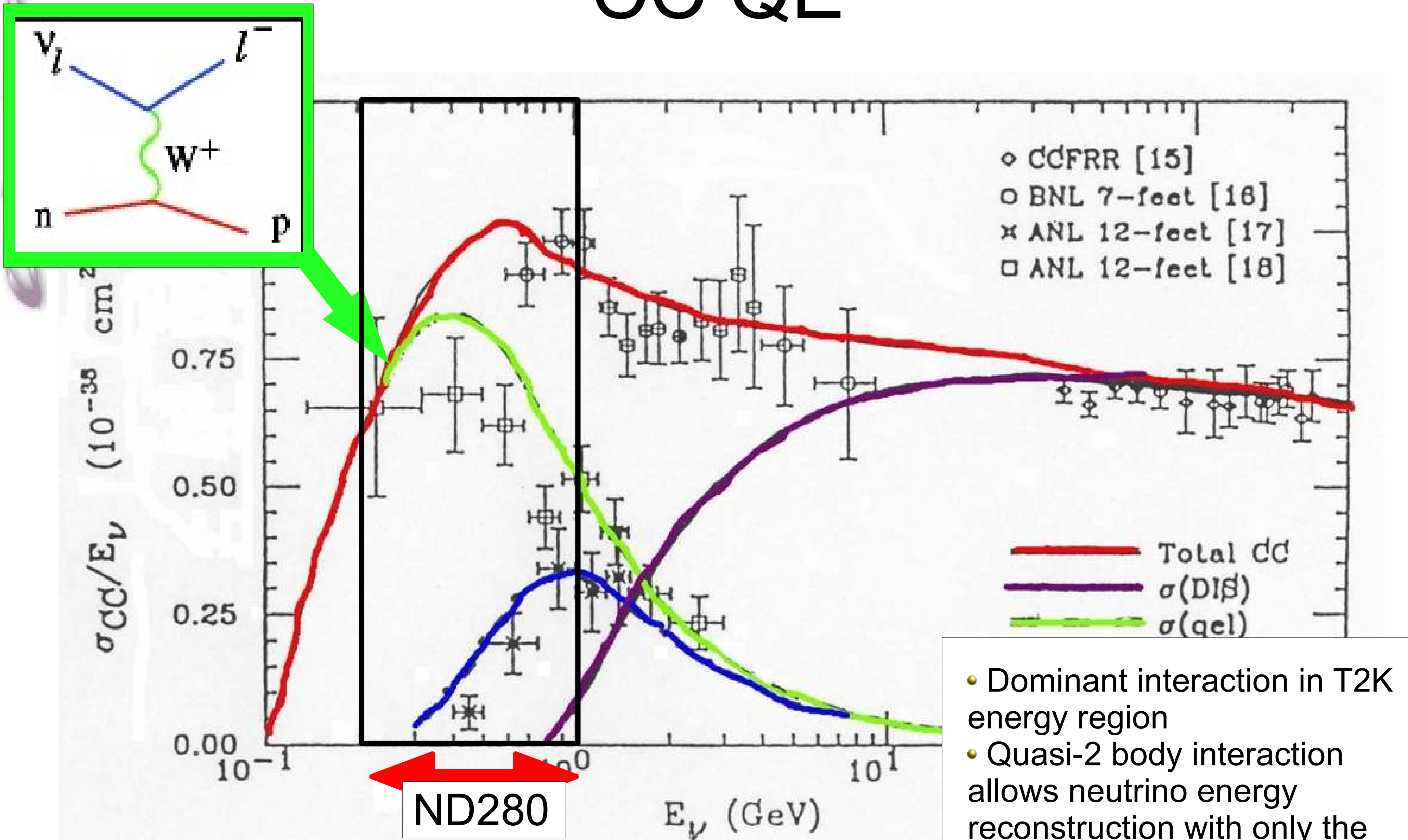


P0D ECAL :

- Coarse lead scintillator sampling calorimeter around P0D
- γ/μ tagger



CC QE



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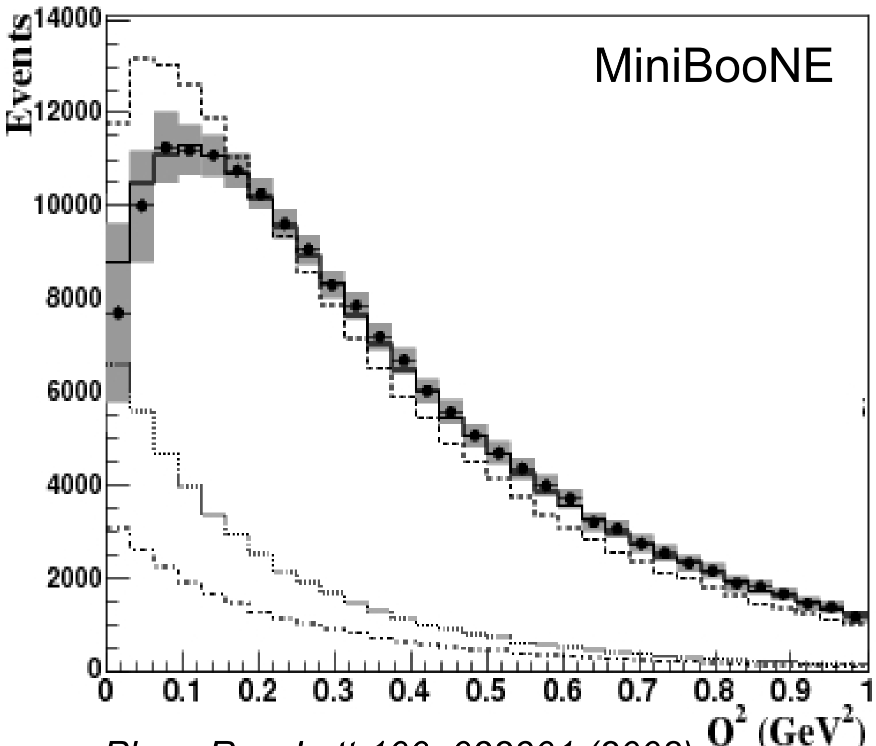
- Dominant interaction in T2K energy region
- Quasi-2 body interaction allows neutrino energy reconstruction with only the primary lepton.

CC QE

Recent data has shown this channel to be more complicated than it seems...



Phys. Rev. Lett 100, 032301 (2008)

Q^2 shape issue common to K2K, MiniBooNE, SciBooNE, MINOS,...

Cross section uncertainty dominated by axial form factor – usually modelled as a dipole (?)

$$F_A(Q^2) = F_A(0)\left(1 + Q^2/M_A^2\right)^{-2}$$

Axial mass measured from Q^2 distribution

Experiment	Target	M_A (GeV/c^2)
MiniBooNE	C	1.35 ± 0.17
MINOS	Fe	1.19 ± 0.15
NOMAD	C	1.07 ± 0.05
K2K	$H_2 0$	1.20 ± 0.12
K2K	C	1.14 ± 0.11
Past World Av.	D_2	1.02 ± 0.03

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

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

Efficiency ~ 70% ; purity ~ 84%

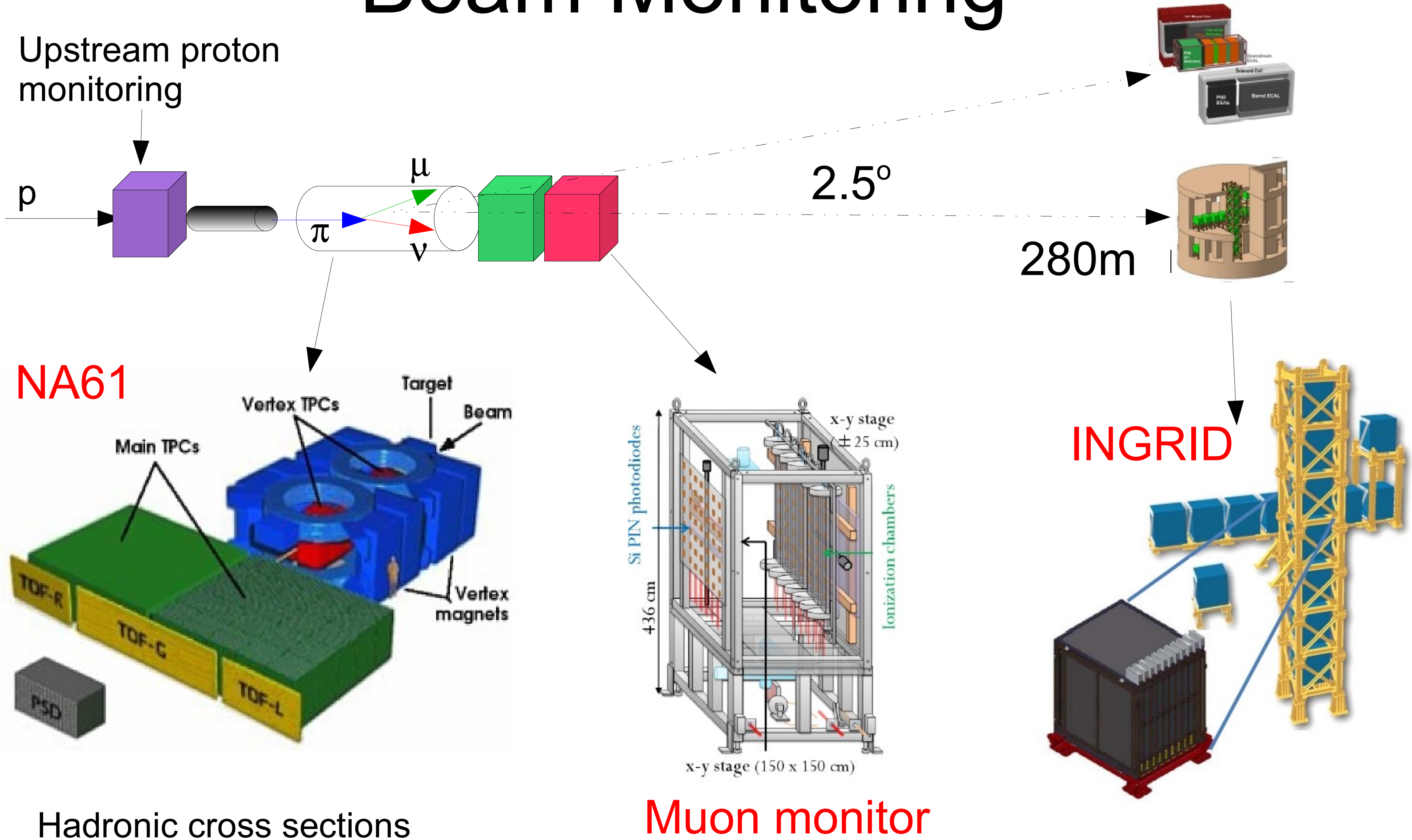
- Only high-statistics measurement on Oxygen.
- Statistical error < 1%
- Systematic errors being evaluated.

Work continuing to optimise CCQE selection

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

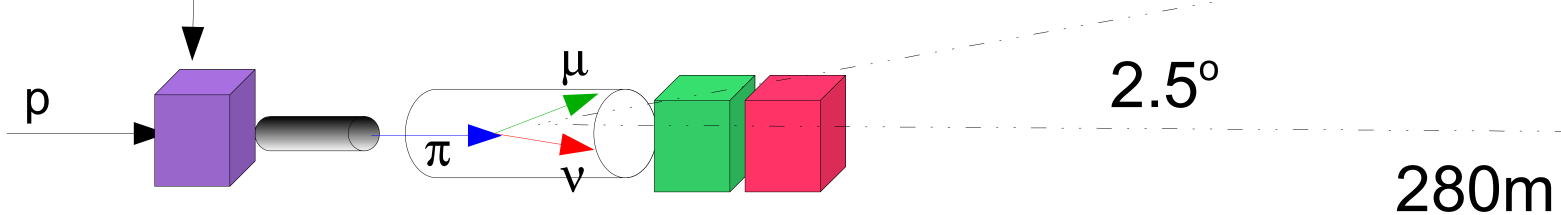
WARWICK

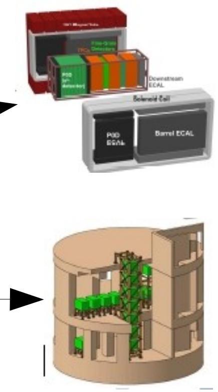
Beam Monitoring



Beam Monitoring

Upstream proton monitoring

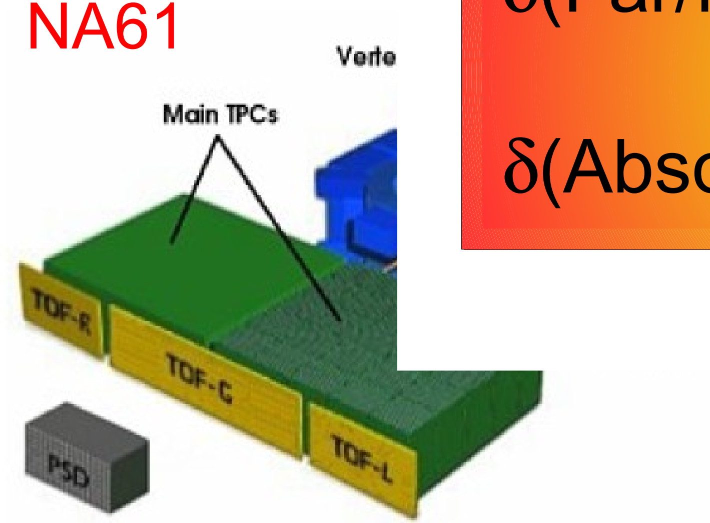




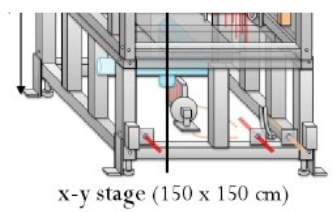
δ(Far/Near ratio) : ~ 2-3%

δ(Absolute flux) : ~ 5%

NA61

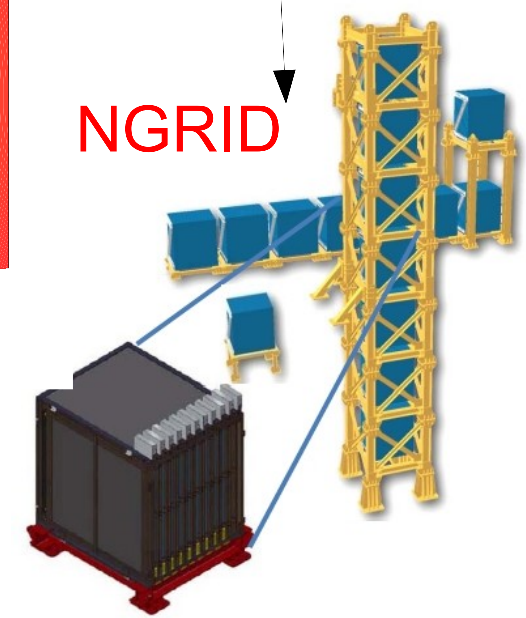


Hadronic cross sections



Muon monitor

NGRID



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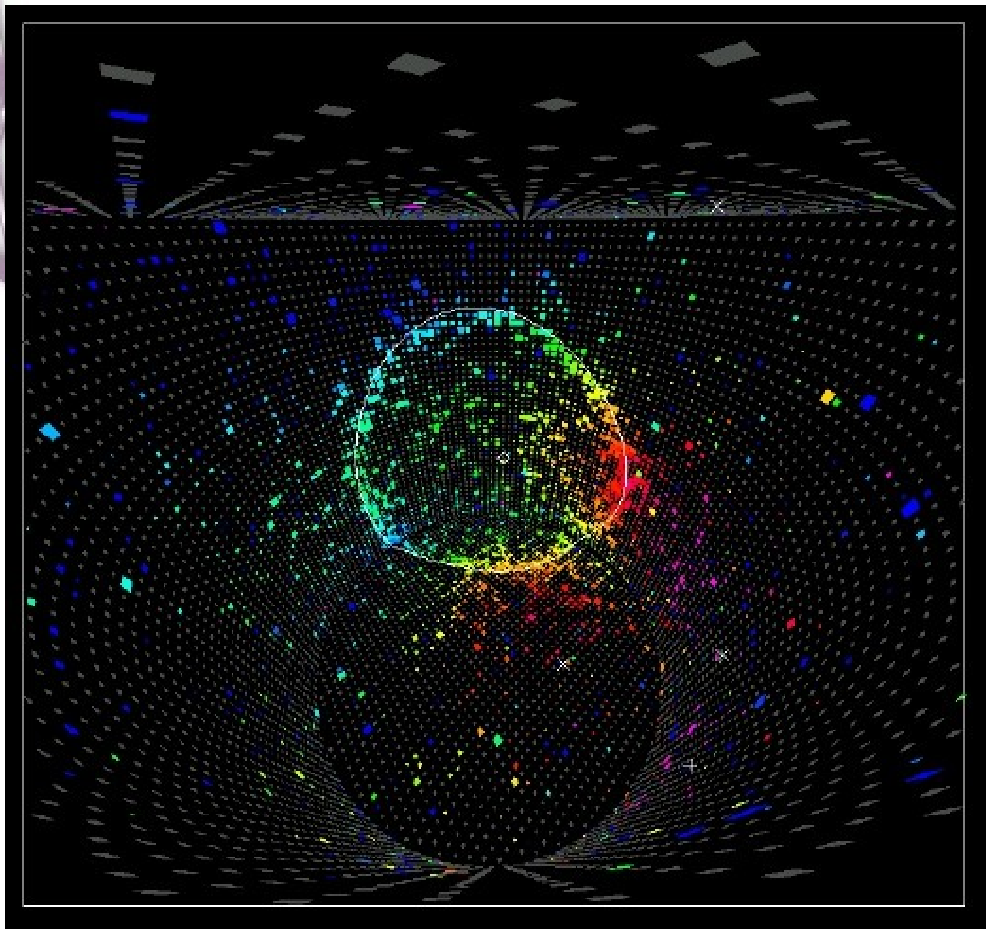
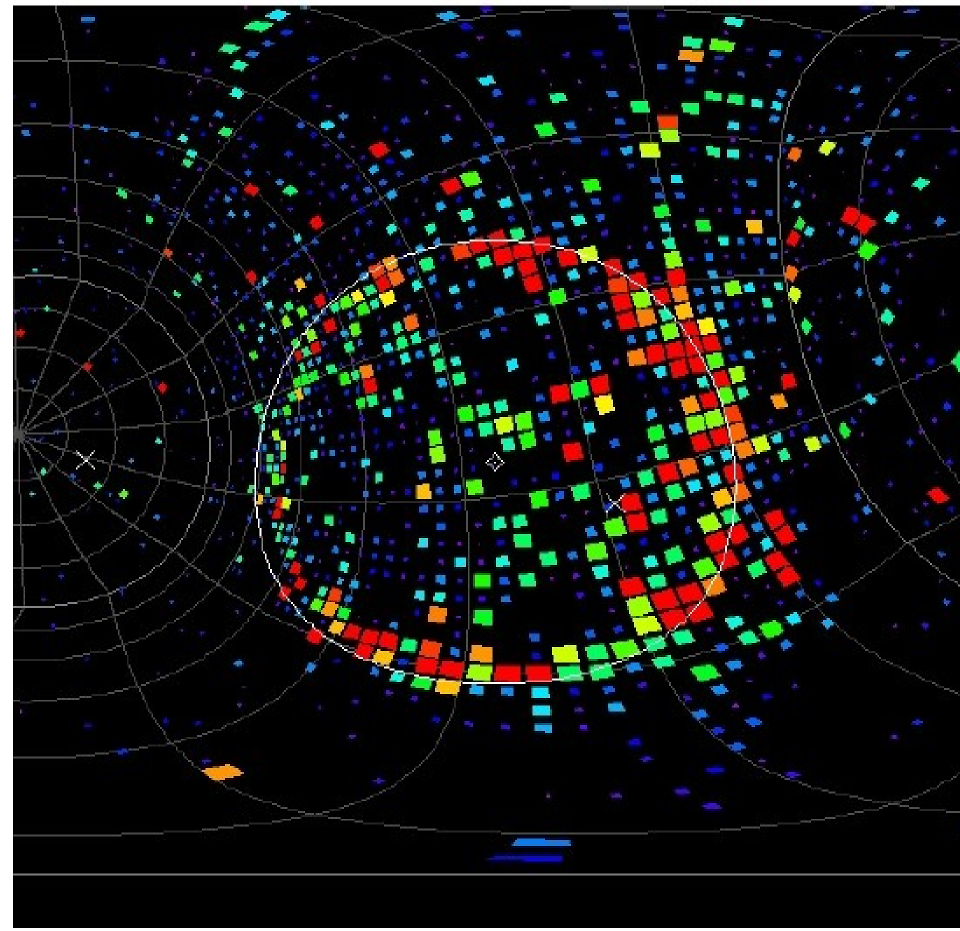
Inclusive NC π^0





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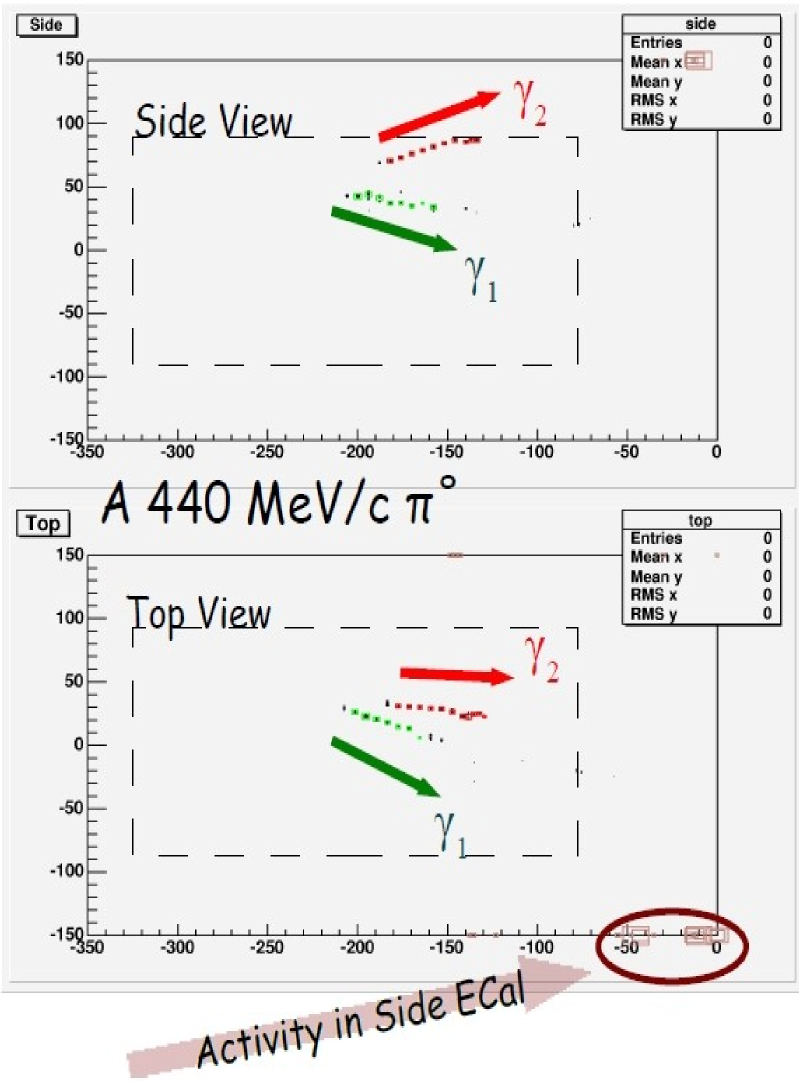
Inclusive NC π^0



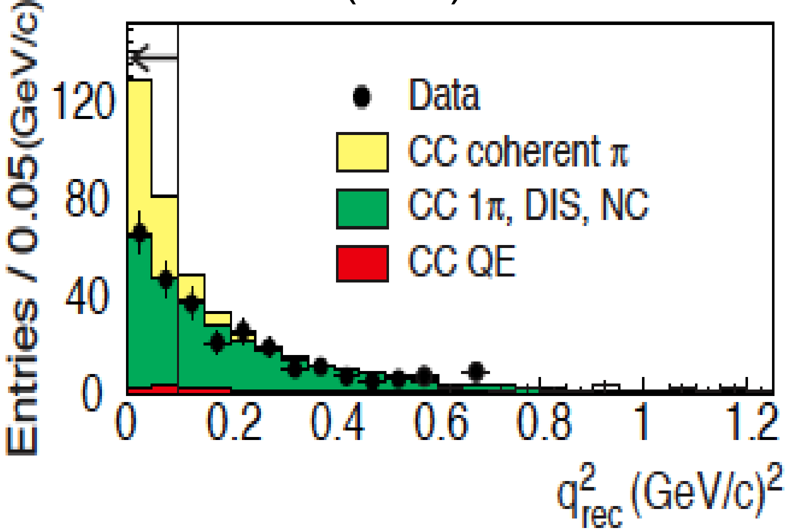
5 year , $1\text{x}10^{21}$ POT/yr $\varepsilon_{\pi 0}$ ~ 55% ; purity ~ 60%

P0D Event Rate		
Event Type	C/Pb/Brass	Water
NC π^0	20k	8k
NC multi π^0	6k	6k
ν-Background	10k	4k
External Background	0.4k	0.3k

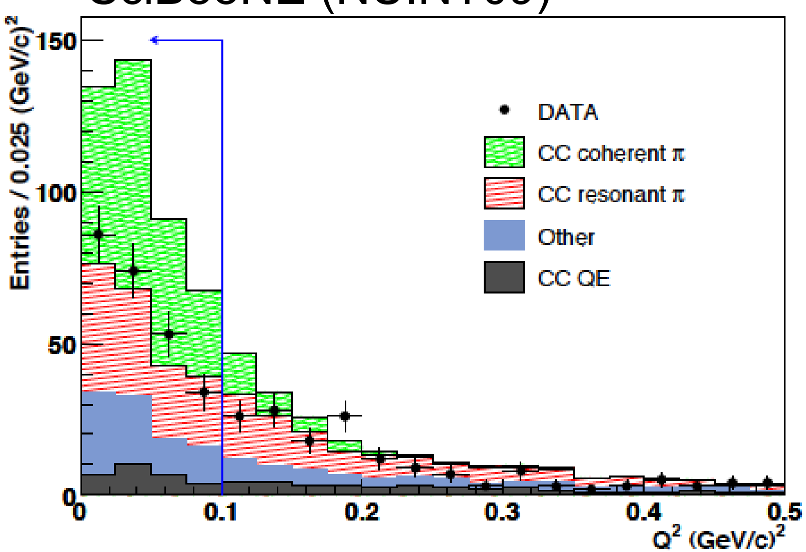
Systematic Source	Size
multi-π0 production	15%
Background σ	20%
External Background	50%
Fiducial Volume	3%
Weighted Total	8%

CC Coherent π^+

SCIBAR (K2K)



SciBooNE (NUINT09)

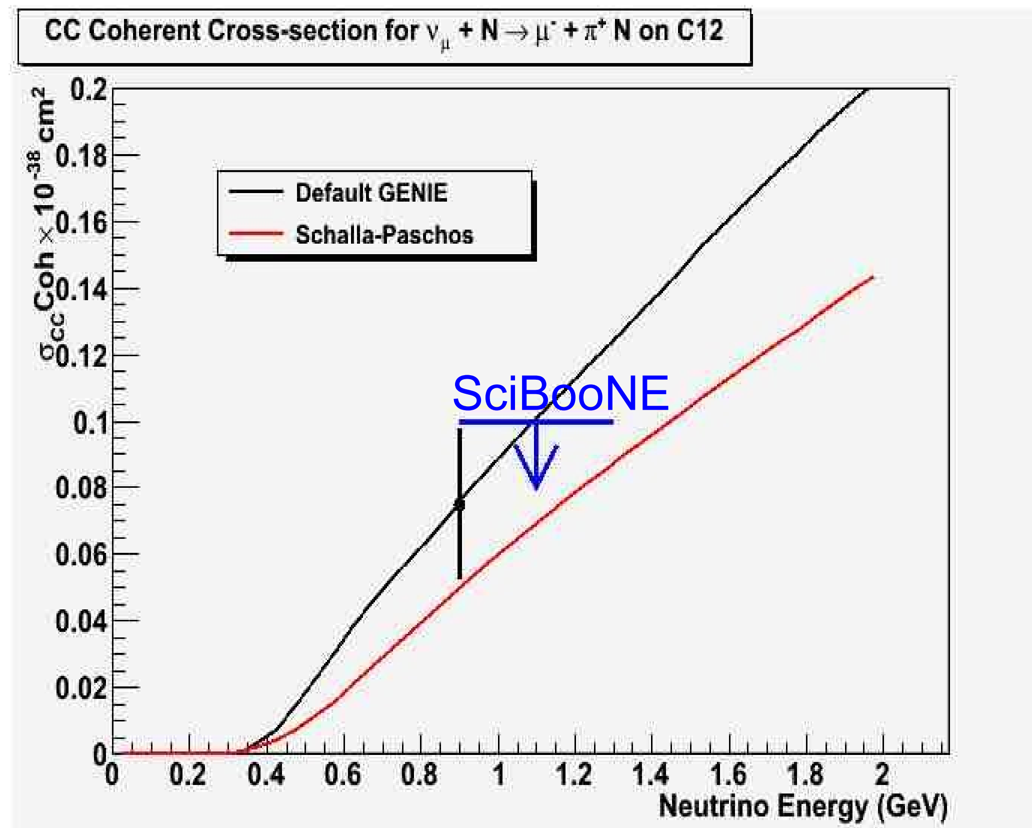


*SciBooNE see some indication of a signal in antineutrino running.

5 year , 1x10[21] POT/yr

Study ongoing

Tracker / C+O	P0D / C+O
8k	12k



Assumes 30% efficiency, 30% systematic error

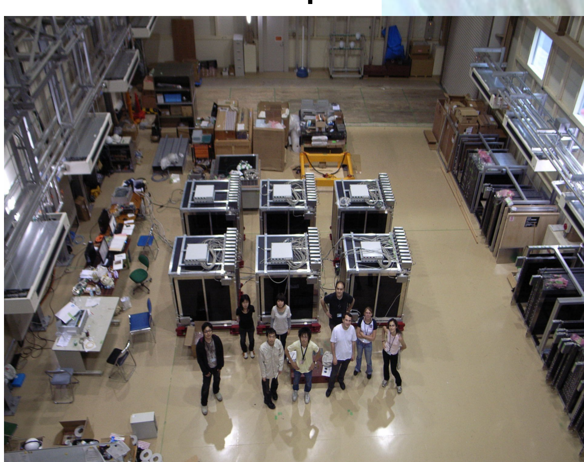
Status of ND280 Detector

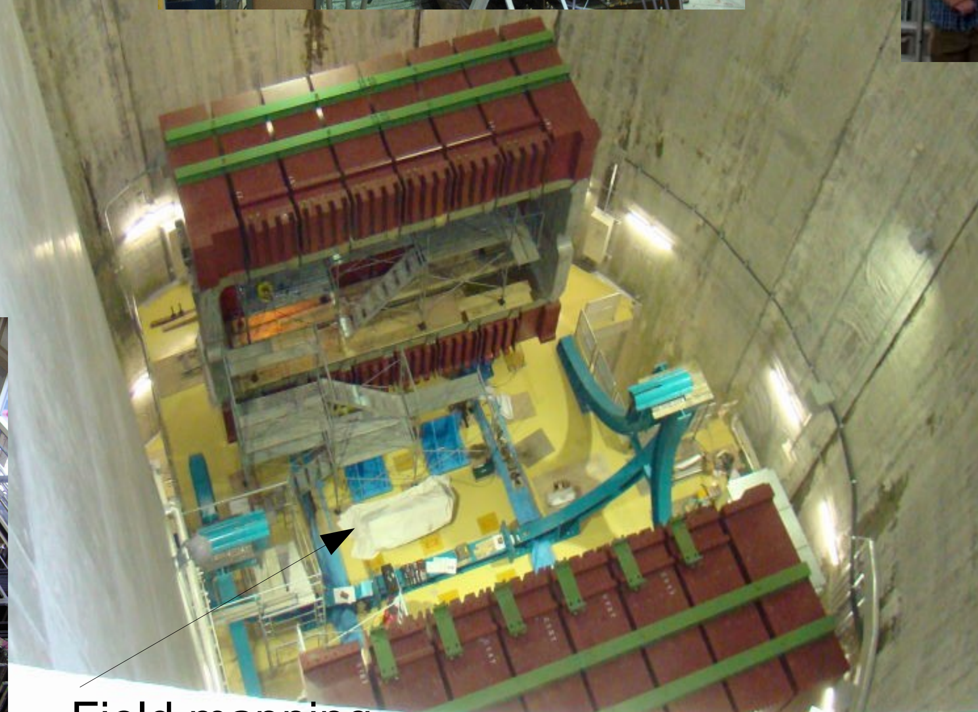
P0D being installed now

Both FGDs shipped
2of 3 TPCs complete

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

INGRID Complete





Field mapping underway

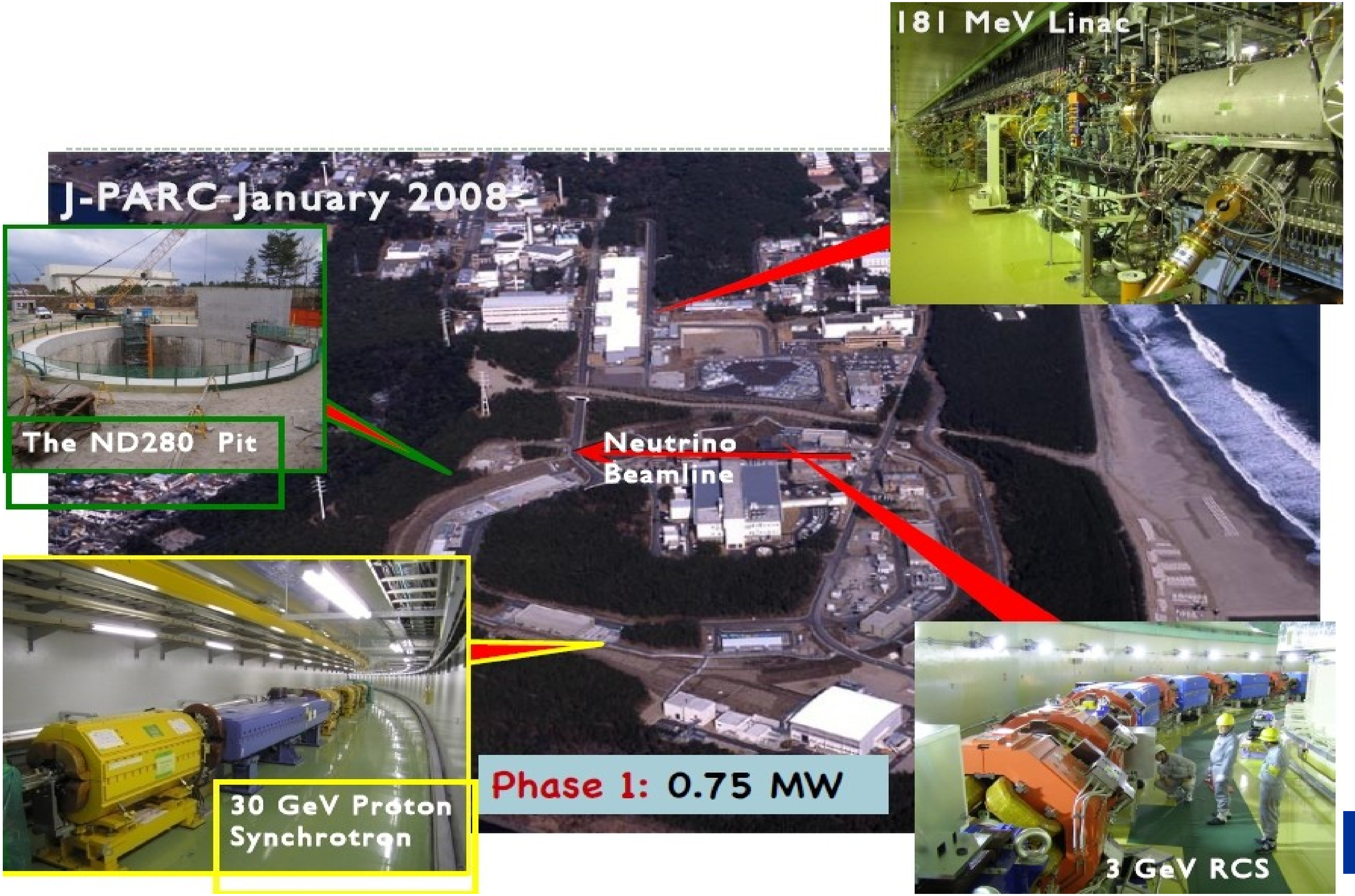
SMRD Installed

Summary

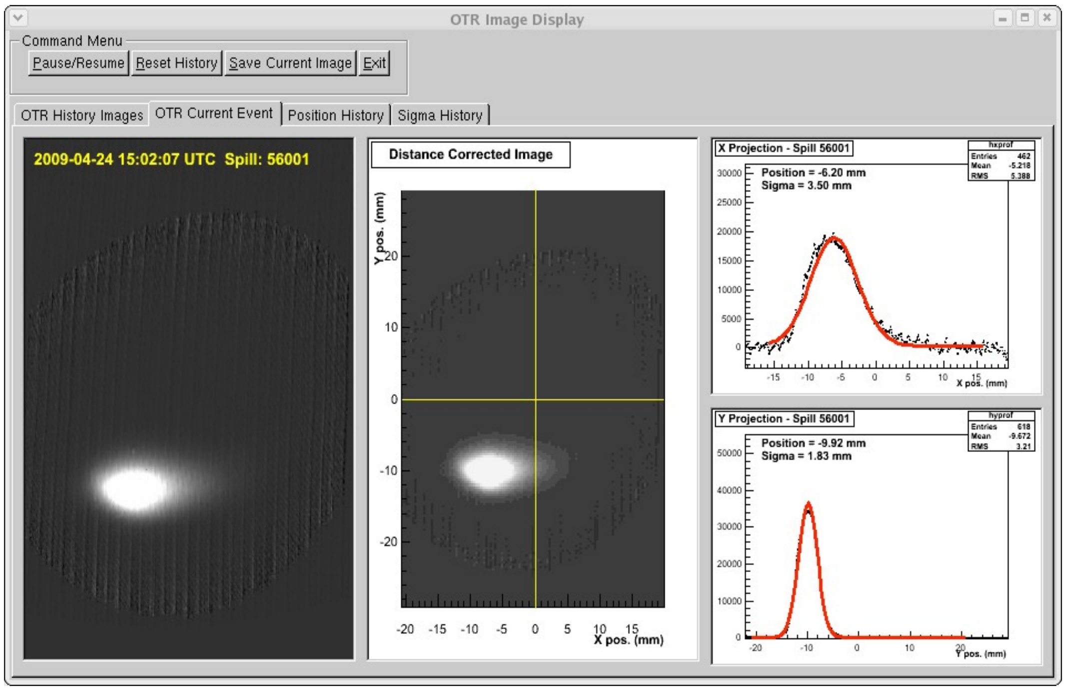
- T2K Near Detector suite will provide the largest measurement of sub-GeV neutrino cross sections on oxygen to date
  - P0D designed to look at inclusive π^0 production
  - Tracker will look at exclusive final states
  - Flux shape and absolute normalisation constrained by a system of flux monitors and new hadron production cross section measurements
- Lot's of activity to build and install subdetectors in the NOMAD magnet. Build is largely on-schedule. Subdetectors being commissioned – installation in magnet in Nov, 2009
- First beam particles have been put on the T2K target and first muons seen in muon monitor. Beamline up and running!

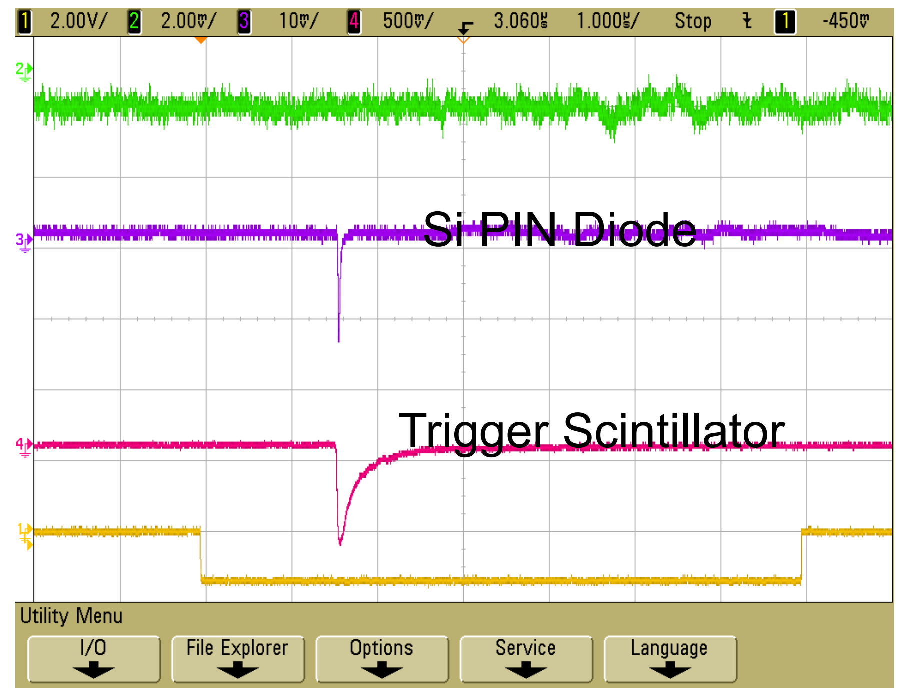
Backup Slides

JPARC


181 MeV Linac
J-PARC January 2008
The ND280 Pit
Neutrino
Beamline
30 GeV Proton
Synchrotron
Phase 1: 0.75 MW
3 GeV RCS

First Beam

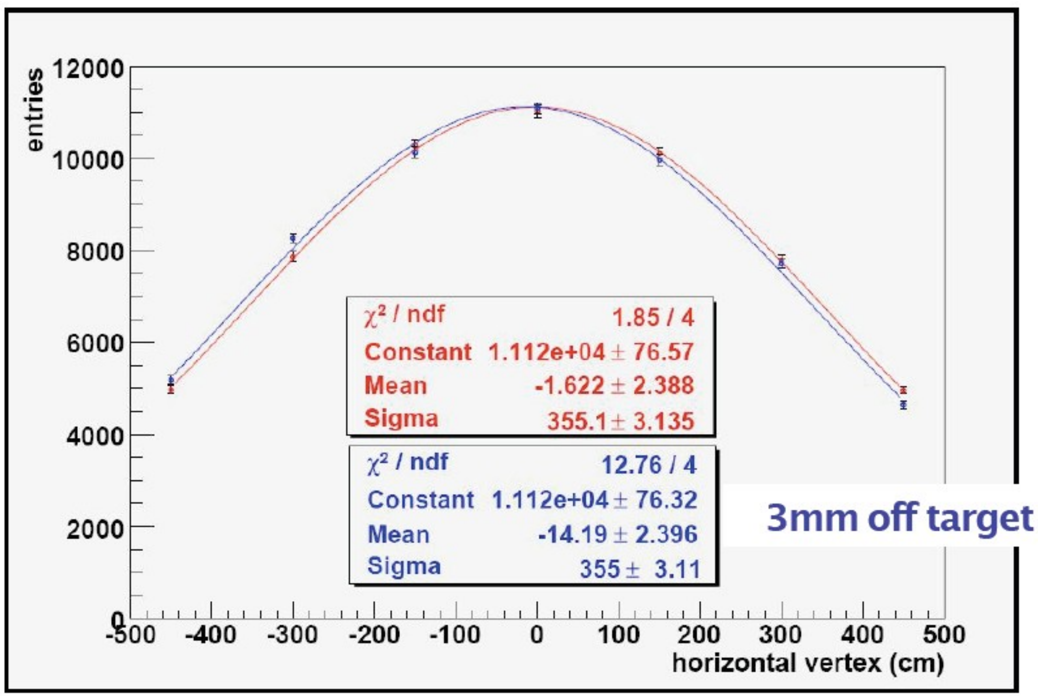


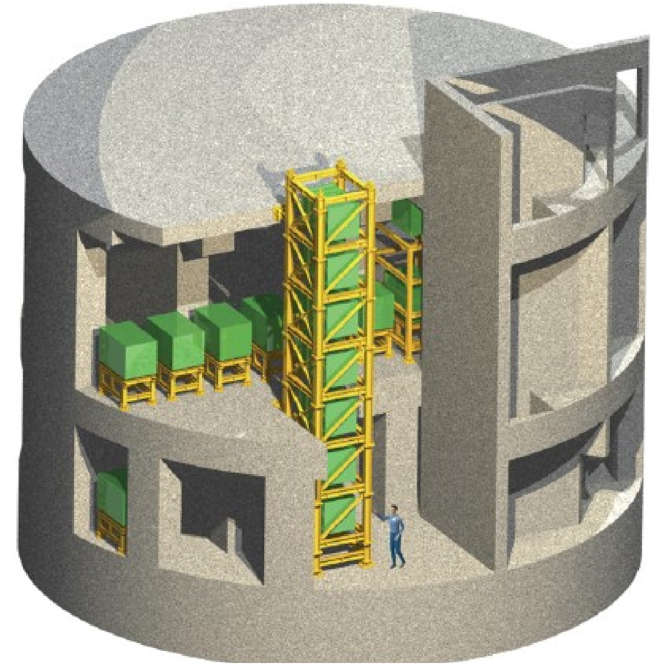


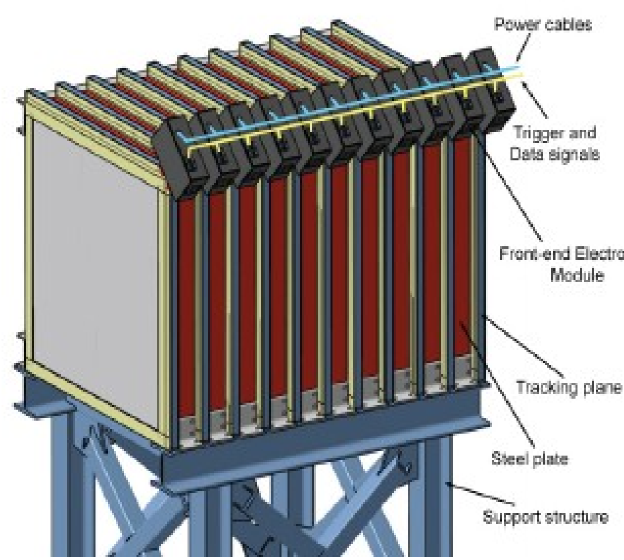
First protons on target, and decay muons detected on April 23rd 2009

INGRID

- 16 modules in the shape of a cross.
- Each module is an iron/scintillator calorimeter







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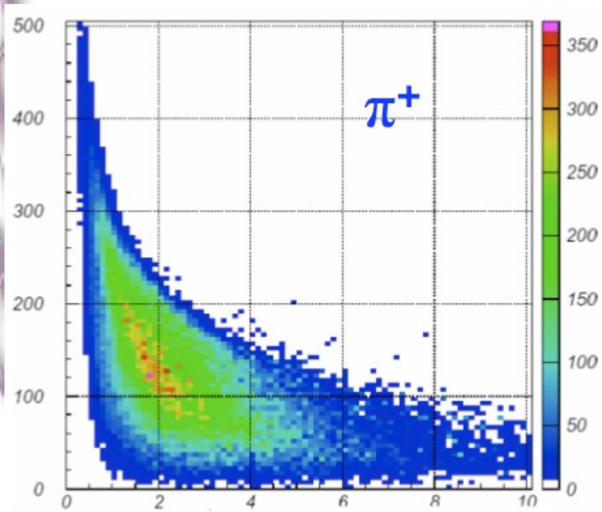
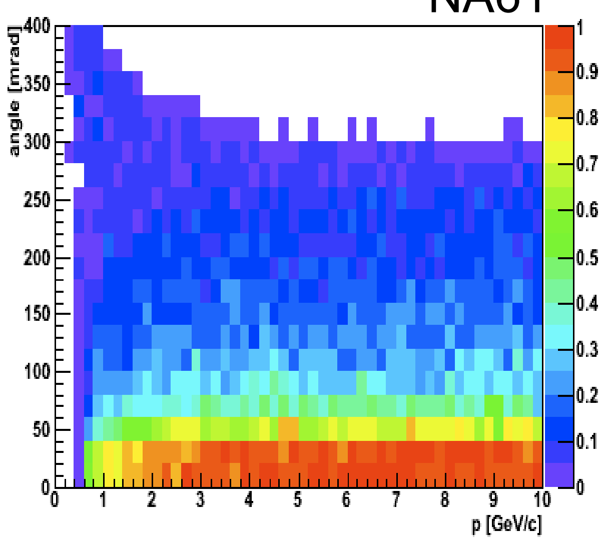
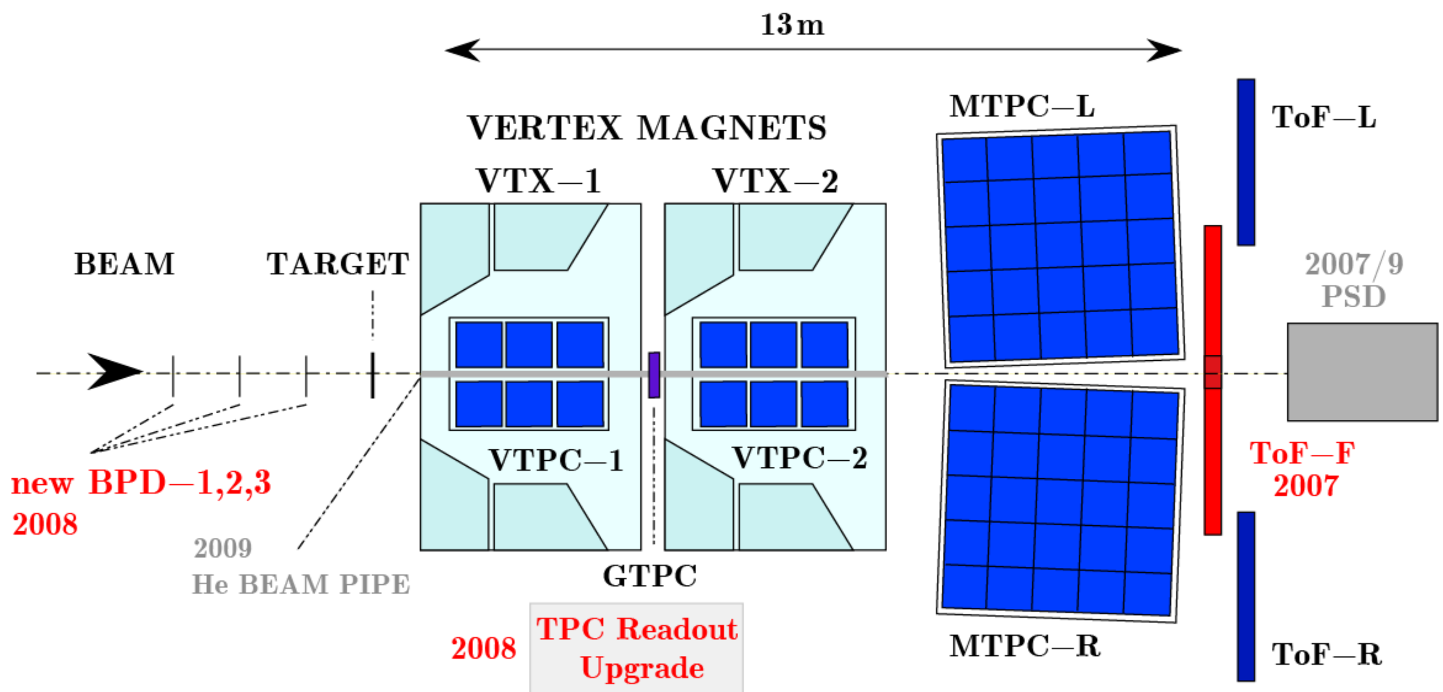
NA61

T2K



NA61





- Large acceptance spectrometer
- Measure secondary π/K production cross sections
- Will run 30 GeV protons on thin / thick C targets

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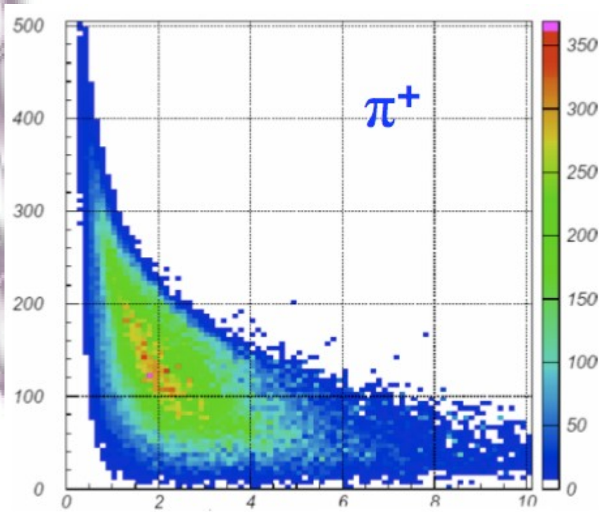
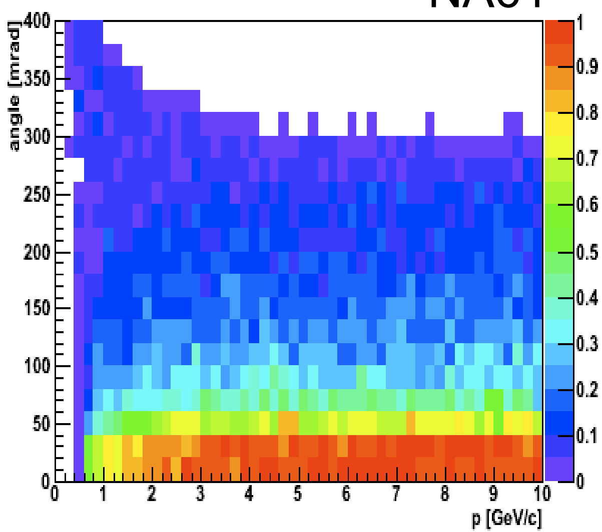
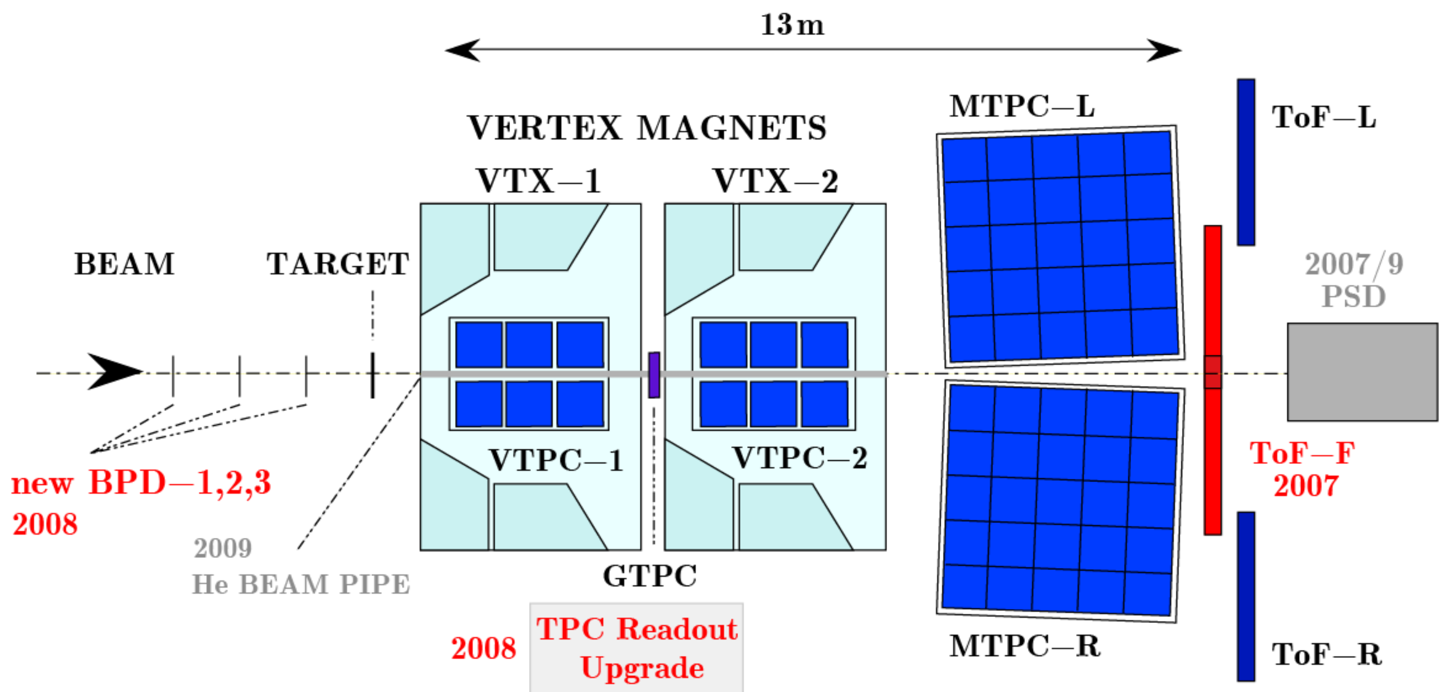
NA61

T2K



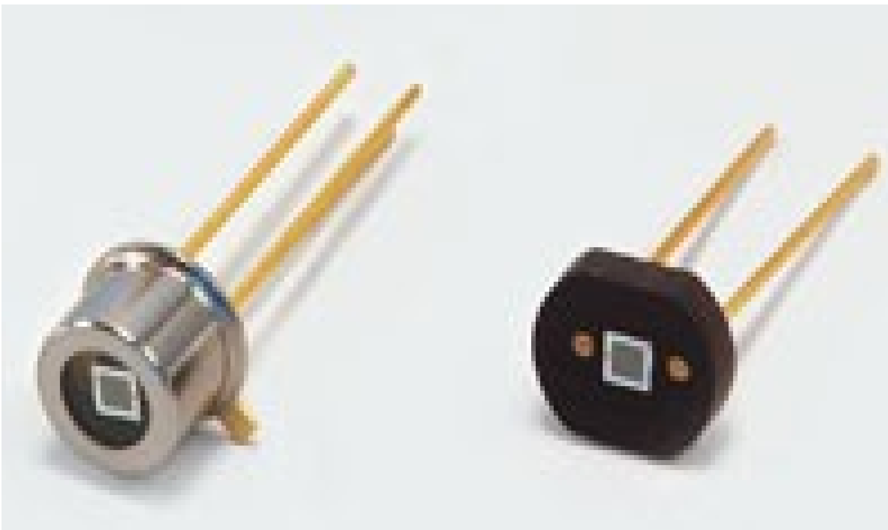
NA61

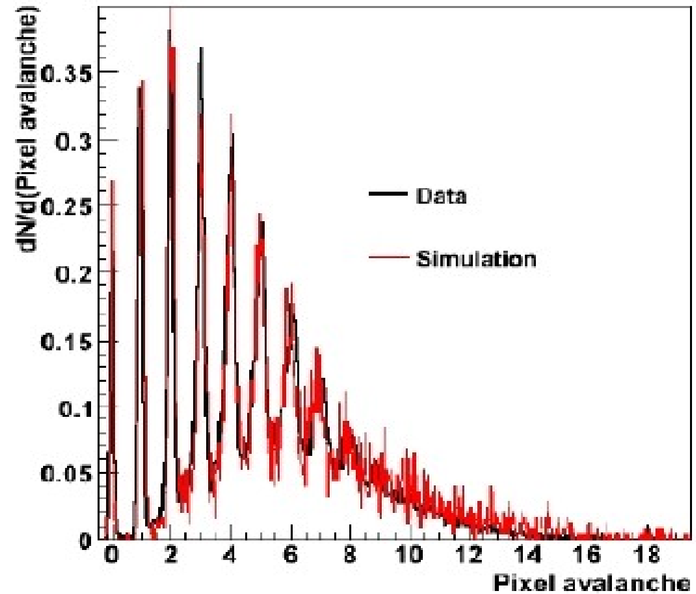




- Estimate $\delta(F/N) < 3\%$, absolute flux $< 5\%$
- Thin target π^-,p data almost ready
- More thin target, and thick target running this year

MPPC





- Active area ~ 1.0-2.0 mm^2
- Gain ~ 10^6
- Fast (<1ns pulses possible)
- PDE ~ 10-15%
- Bias voltage ~ 70 V
- Cross-talk/Afterpulsing effects
- Strong temperature dependence

- Mechanically robust
- Better matched to WLS spectrum
- Insensitive to magnetic fields.
- Same cost (per channel) as MAPMTs