T2K 280m detector

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Representing the ND280 group of the T2K collaboration

Outline

- Brief reminder of the physics goals of the T2K long baseline neutrino oscillation experiment
  - requirements for the near detectors
- Baseline design of the off axis ND280m detector
  - selected technologies
  - expected capabilities
- Timescales for construction and initial operation

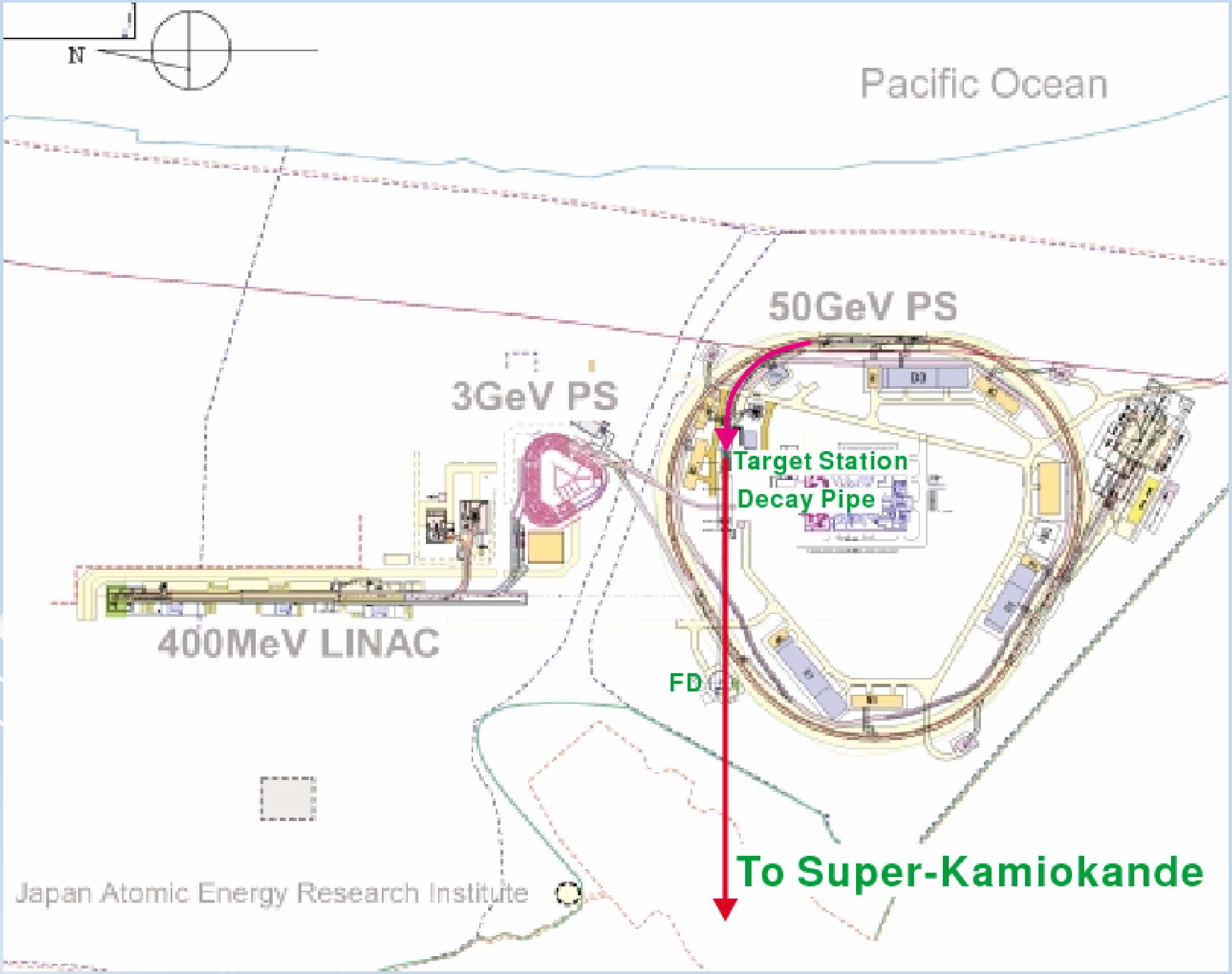
T2K physics program

- The proton beam from the 50 GeV synchrotron under construction at JPARC will be used to produce an intense neutrino beam directed to the Super Kamiokande detector (295 km away)
  - measurement of ν_μ disappearance to improve accuracy for:

$$\sin^2 2\theta_{23} \rightarrow \approx 1\% \qquad \Delta m^2_{23} \rightarrow \approx 2\%$$

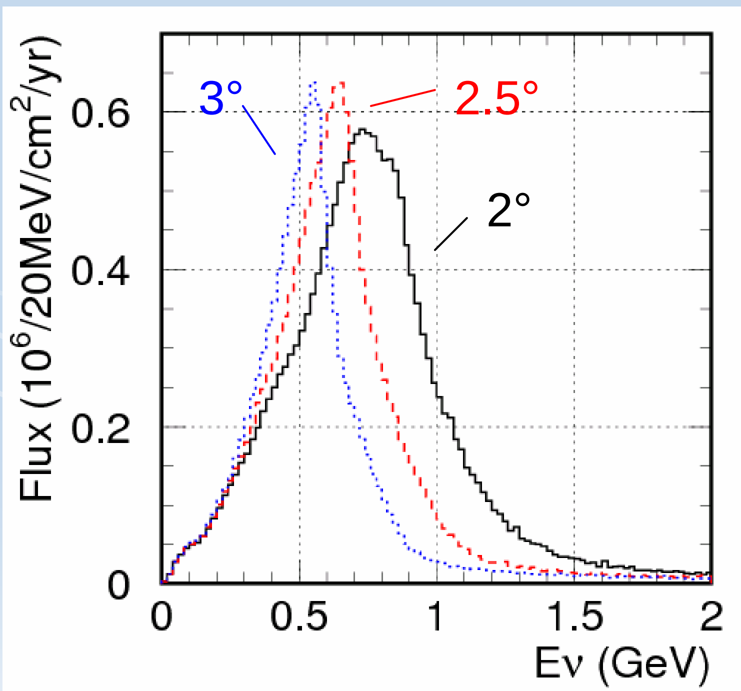
  - measurement of ν_e appearance to improve sensitivity to $\sin^2 2\theta_{13}$ by an order of magnitude

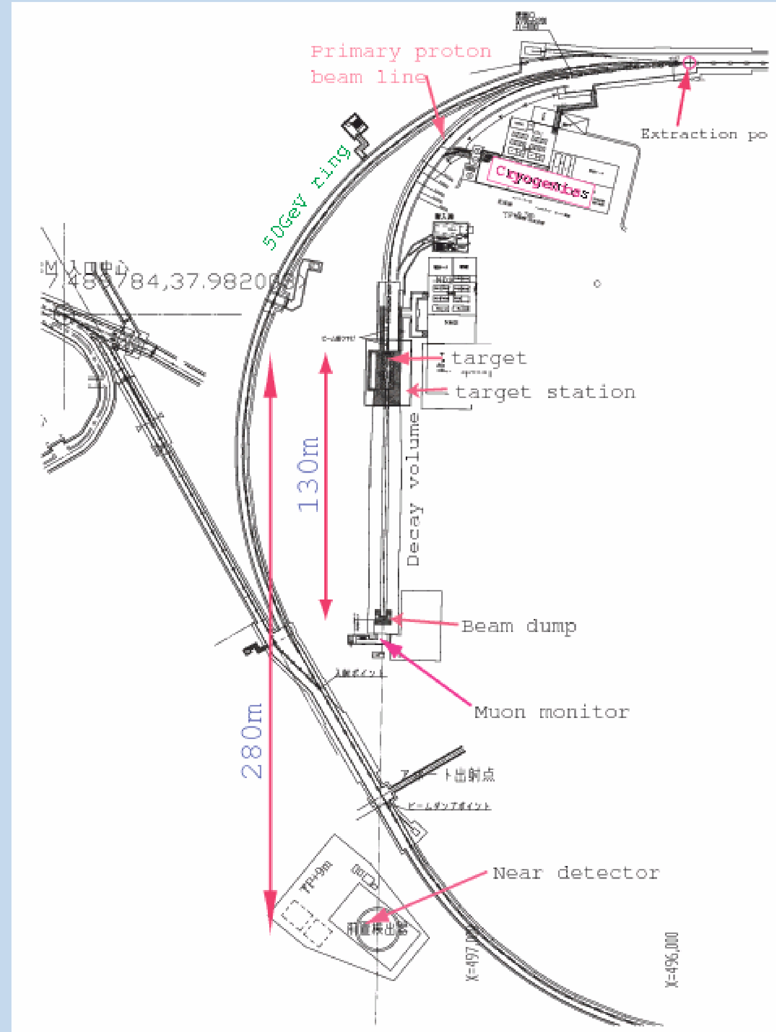
JPARC facility



T2K neutrino beamline

- Use off-axis principle
  - select angle corresponding to oscillation maximum



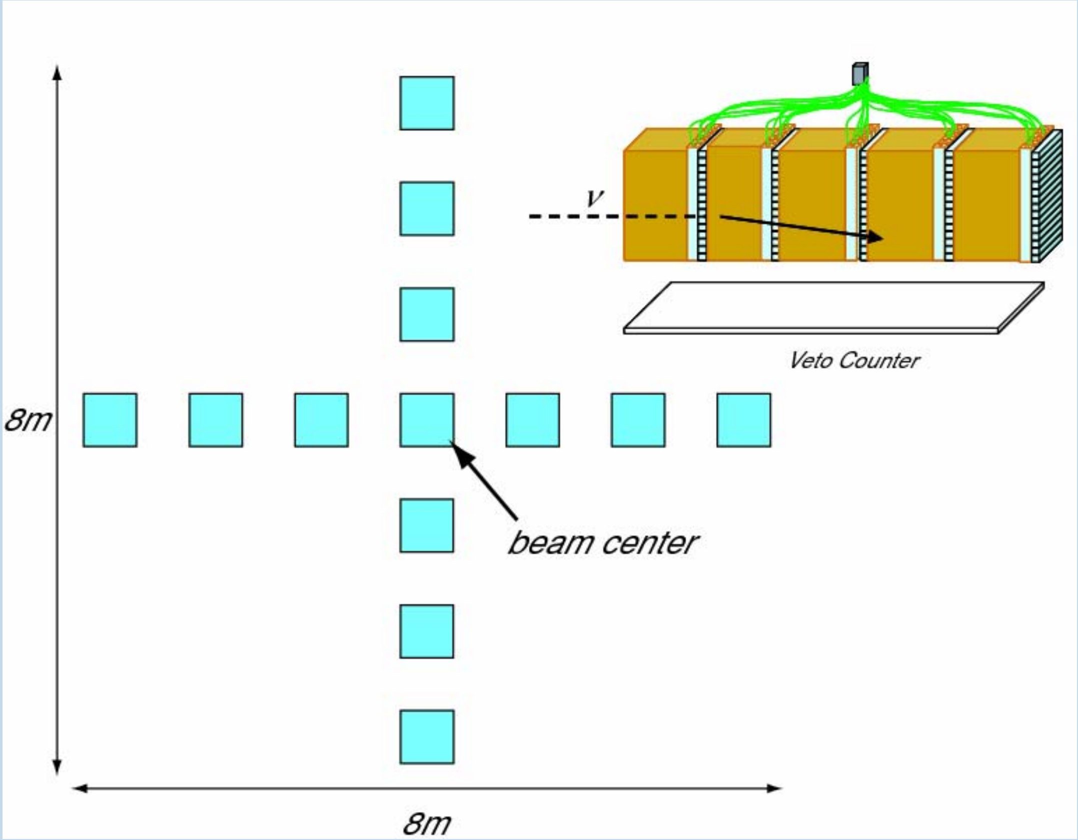


T2K near detectors: muon monitor

- A muon monitor system is directly downstream of the beam dump:
  - a real time status monitor – sensitive to
    - proton intensity
    - proton beam position on target
    - horn performance
- Combination of detector technologies:
  - He gas ion chambers
  - semiconductor detectors – possibly diamond

T2K near detectors: on axis ν monitor

- Located 280 m downstream of the proton target
  - monitor ν beam properties on a day-by-day basis
    - centre
    - profile
  - iron-scintillator stacks



T2K near detectors: off axis ν detector

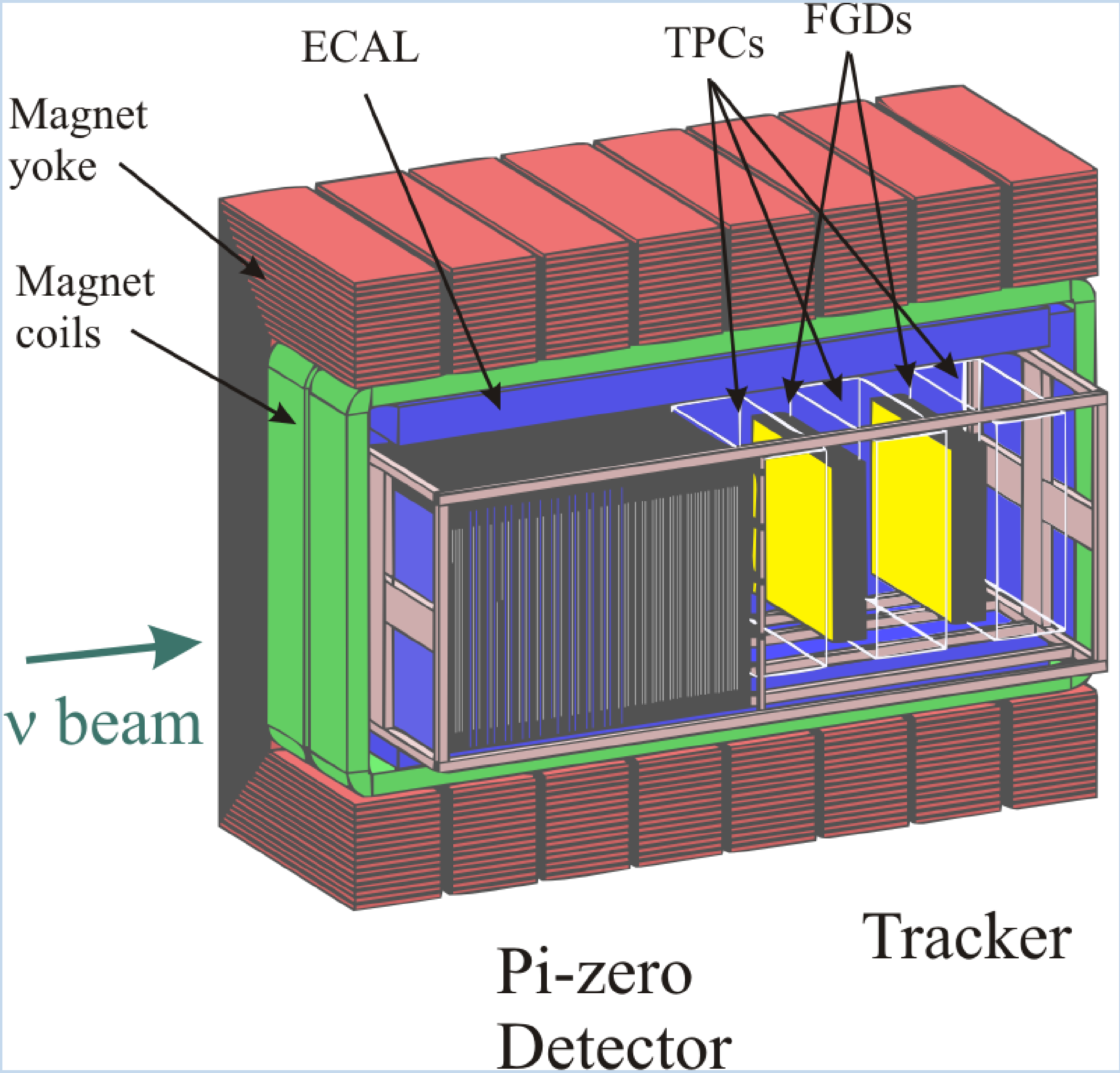
- Located 280 m downstream of the proton target
- measure neutrino beam properties and neutrino interaction cross sections and kinematics
  - ν_μ disappearance:
    - flux and spectrum of ν_μ prior to oscillation
    - study processes that SK will misinterpret and assign an incorrect ν_μ energy
  - ν_e appearance:
    - flux and spectrum of ν_e in beam
    - study processes that SK will misinterpret as coming from ν_e
- requires a large, highly segmented detector
  - charged, neutral energy measurements, particle ID

ND280 group

- Canada
  - UBC, Regina, Toronto, Victoria, TRIUMF, York
- France
  - CEA/Saclay
- Italy
  - Bari, Napoli, Padova, Rome
- Japan
  - Hiroshima, KEK, Kobe, Kyoto, ICRR, Tokyo
- Korea
  - Chonnam, Dongshin, Kangwon, Kyungpook, Gyeongsang, Sejong, Seoul, SungKyunKwan
- Russia
  - INR Moscow
- Spain
  - Barcelona, Valencia
- Switzerland
  - Geneva
- United Kingdom
  - Imperial, Lancaster, Liverpool, Queen Mary, CCLRC, Sheffield, Warwick
- United States
  - Louisiana State, Stony Brook, Rochester, Washington

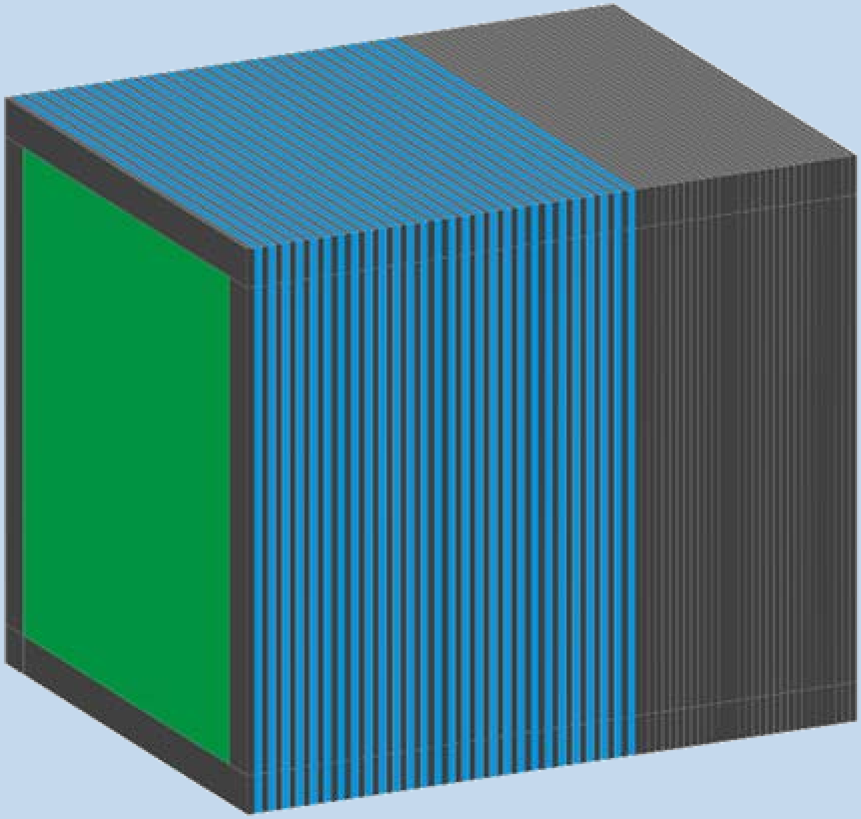
ND280 off axis detector: overview

- UA1 magnet provides 0.2 T B field
- inner volume: $3.5\times3.6\times7.0\ m^3$
- front optimized for π^0 from NC
- rear optimized for CC studies
- surrounded by ECAL and muon detector



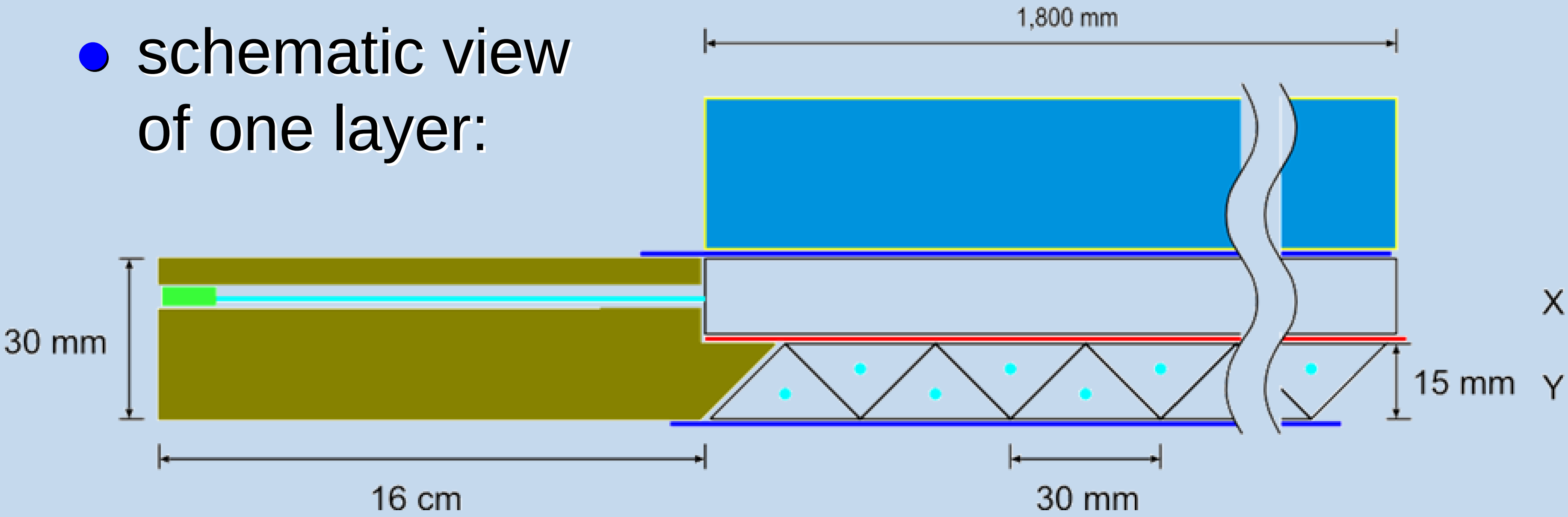
Pi-zero detector

- designed to make high statistics measurements of ν interactions with electromagnetically showering particles
  - scintillating bar tracking planes
  - front section interleaved with passive water layers (blue)
    - statistical subtraction of events in rear from front used to determine oxygen cross sections



Pi-zero detector

- schematic view of one layer:

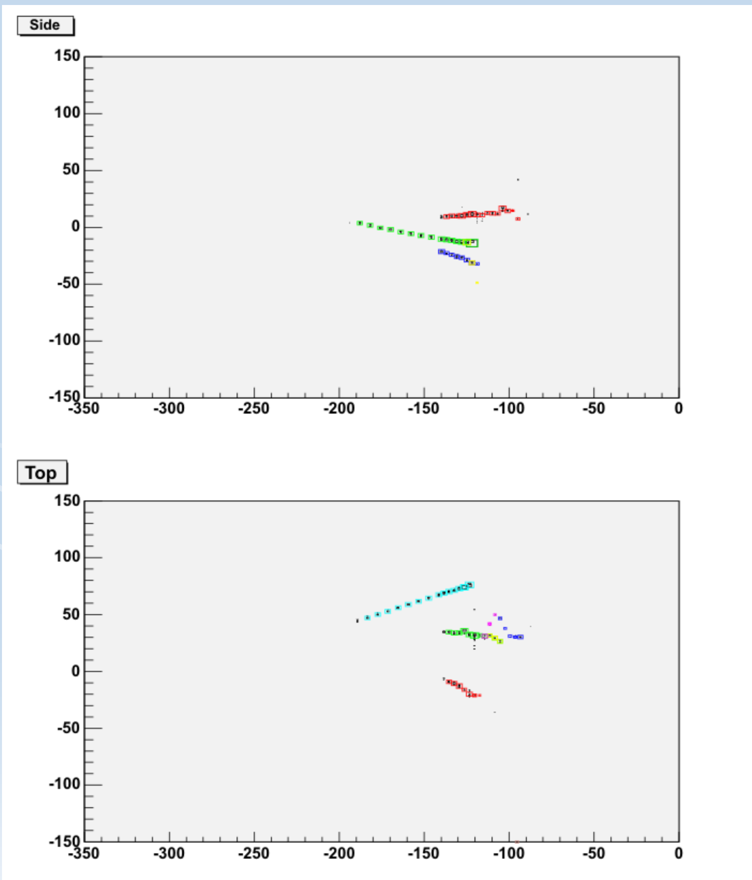


- co-extruded triangular polystyrene bars with TiO_2 reflective layer and central hole with WLS fiber
- thin (0.6 mm) lead sheets (red) to promote photon conversion

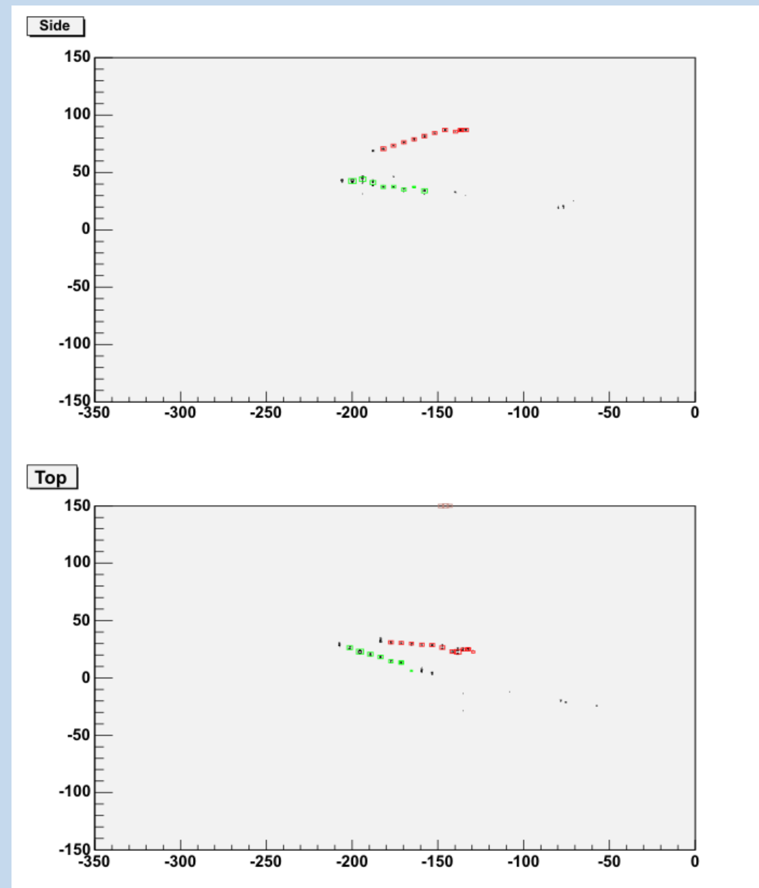
Pi-zero detector

- Typical NC single π^0 production events:

0.5 GeV/c π^0 + 1 GeV/c proton



0.5 GeV/c π^0 + undetected neutron



Pi-zero detector

- With a fiducial mass of 1.7 tons of water, expect ~17×10^3 NC single π^0 events in the water target for 10^{21} protons on target (one nominal year)
  - must determine water cross sections by statistical subtraction (from total of ~60×10^3 such events)
  - eff. for π^0 reconstruction, $p > 200$ MeV/c: 50-60%
  - π^0 fake rate ~ 20%

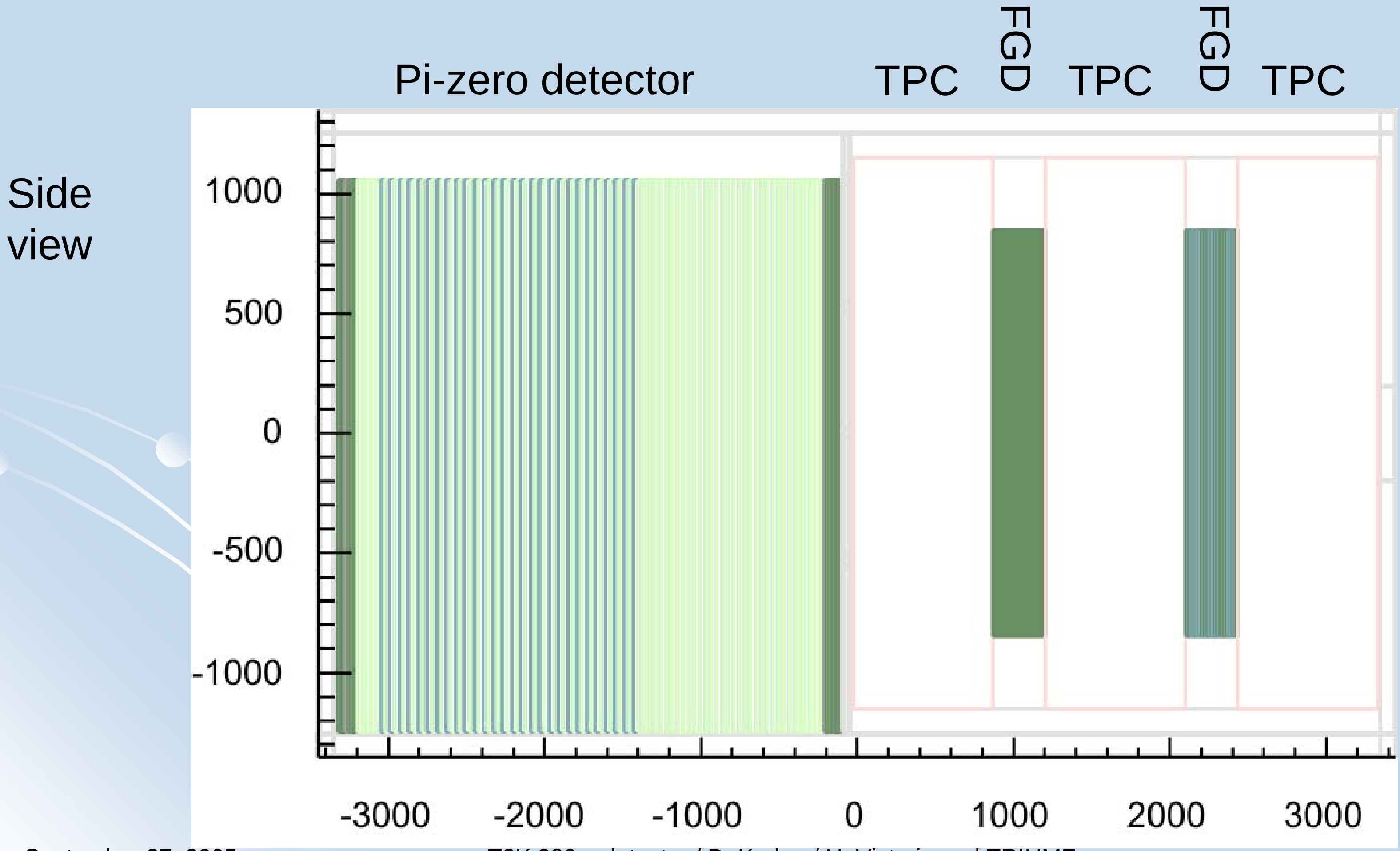
- Ample statistics to help improve MC simulations

Tracker

- The tracker is optimized to study neutrino interactions that produce charged particles:
  - ν_μ CC quasi-elastic (CCQE) interactions to measure the ν_μ flux and spectrum prior to oscillation
  - ν_μ CC in-elastic interactions that can be misinterpreted by SK to be CCQE, and thus assigning an incorrect ν_μ energy
  - ν_μ NC in-elastic interactions that produce π^+ and π^- that can be misinterpreted by SK to be CCQE
  - ν_e CCQE interactions, to determine the ν_e flux and spectrum, an important background to ν_e appearance at SK

Tracker

- consists of solid active target modules (FGD) and gas time projection chamber modules (TPC)

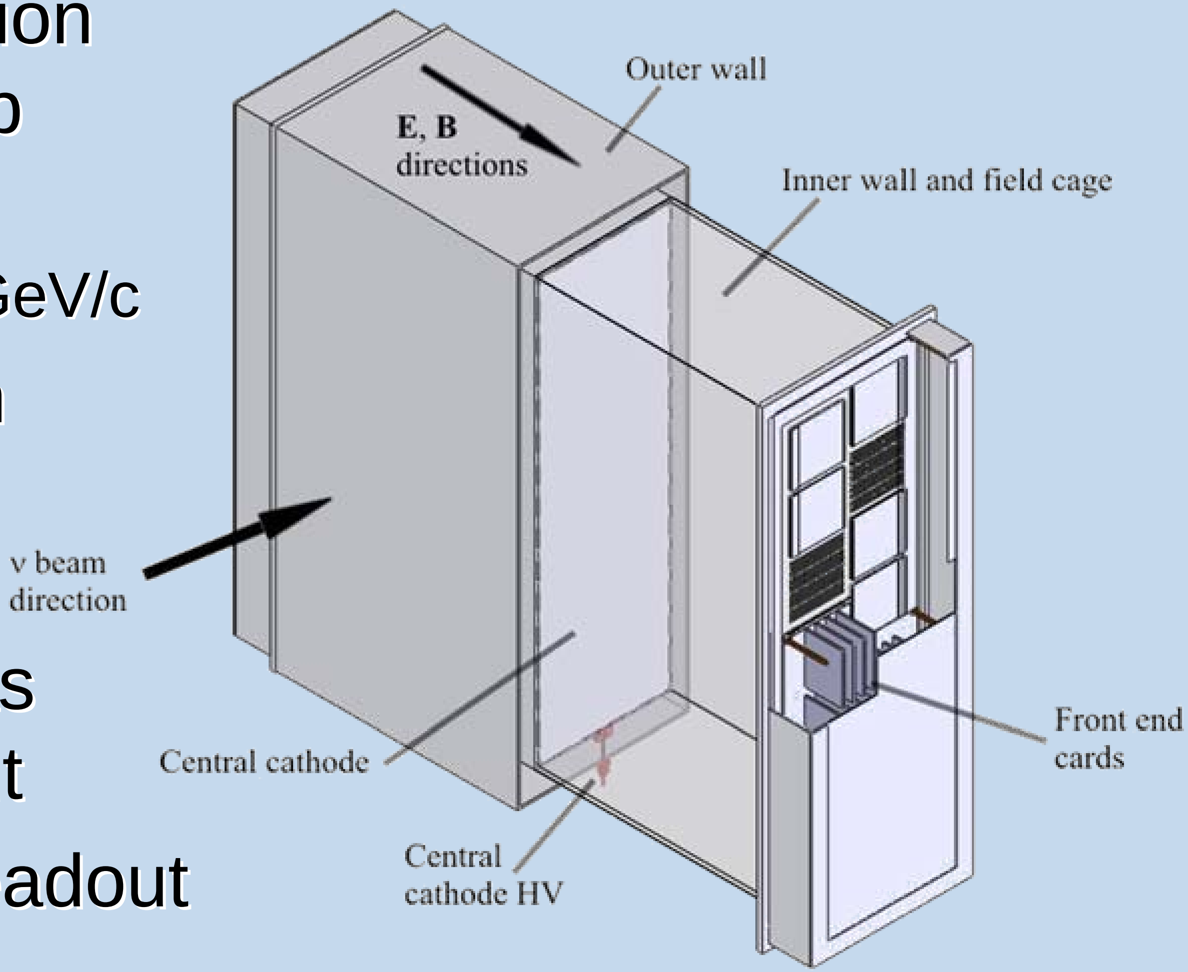


Tracker - FGD

- each FGD: $2 \times 2 \times 0.3$ m^3 target volume
- scintillator bars: $1 \times 1 \times 200$ cm^3 arranged in alternating x-y planes
  - fine segmentation needed to track low energy protons, in order to distinguish CCQE and non-elastic
- the back FGD will contain water layers
  - initially 3~cm passive water layers between each x-y scintillator plane
  - active program to produce water-based scintillator for a future upgrade
- plan to use “SiPM” devices for readout

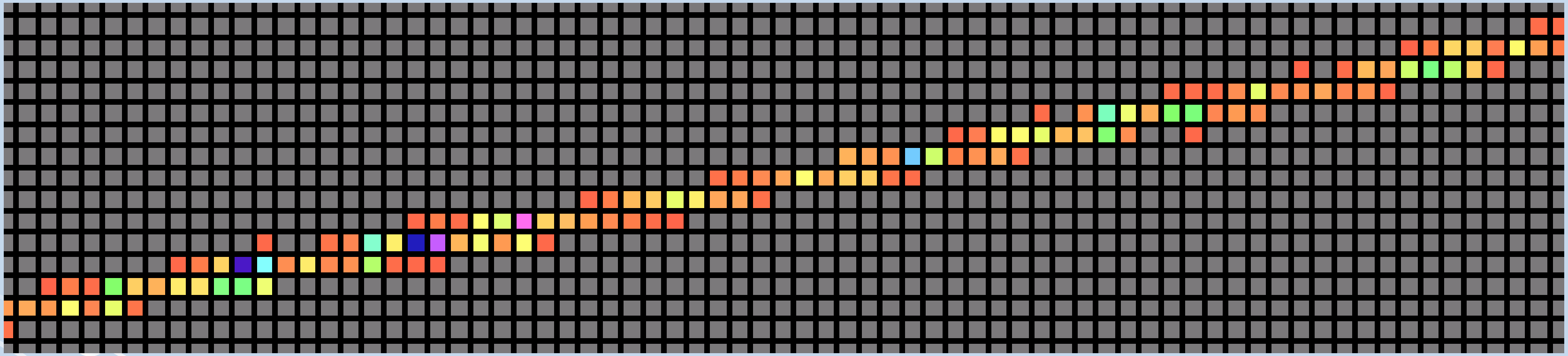
Tracker - TPC

- use a low diffusion gas to achieve p resolution goal:
  - 10% for p < 1 GeV/c
- double wall with field cage as inner wall
- micropattern gas detector readout
- custom ASIC readout electronics



Tracker - TPC

- readout segmented into 8×8 mm^2 pads
- width of active volume: 600 mm per module
  - detailed full simulation:

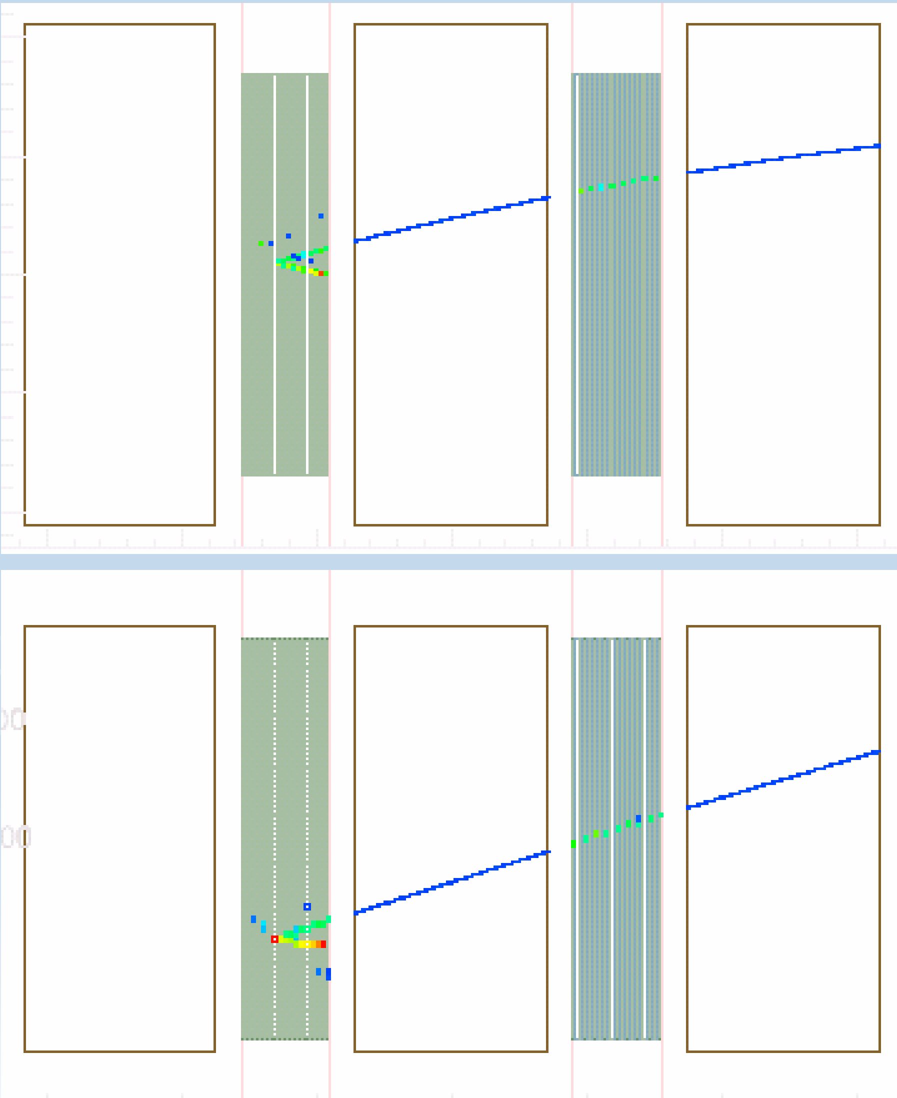


  - full reconstruction: $\delta p/p < 10\%$ for $p < 1$ GeV/c
  - dE/dx resolution: ~ 7%
    - sufficient for μ / e separation

Tracker – ν_μ CC event

Side view

Top view



Event No.: 24 Reaction code: 1 Position in File: 24

Primary Vertex [mm]: (-423, 53, 808)

Located in

Basket_0/TRK_0/Active_1/ScintX1_136/bar_37278

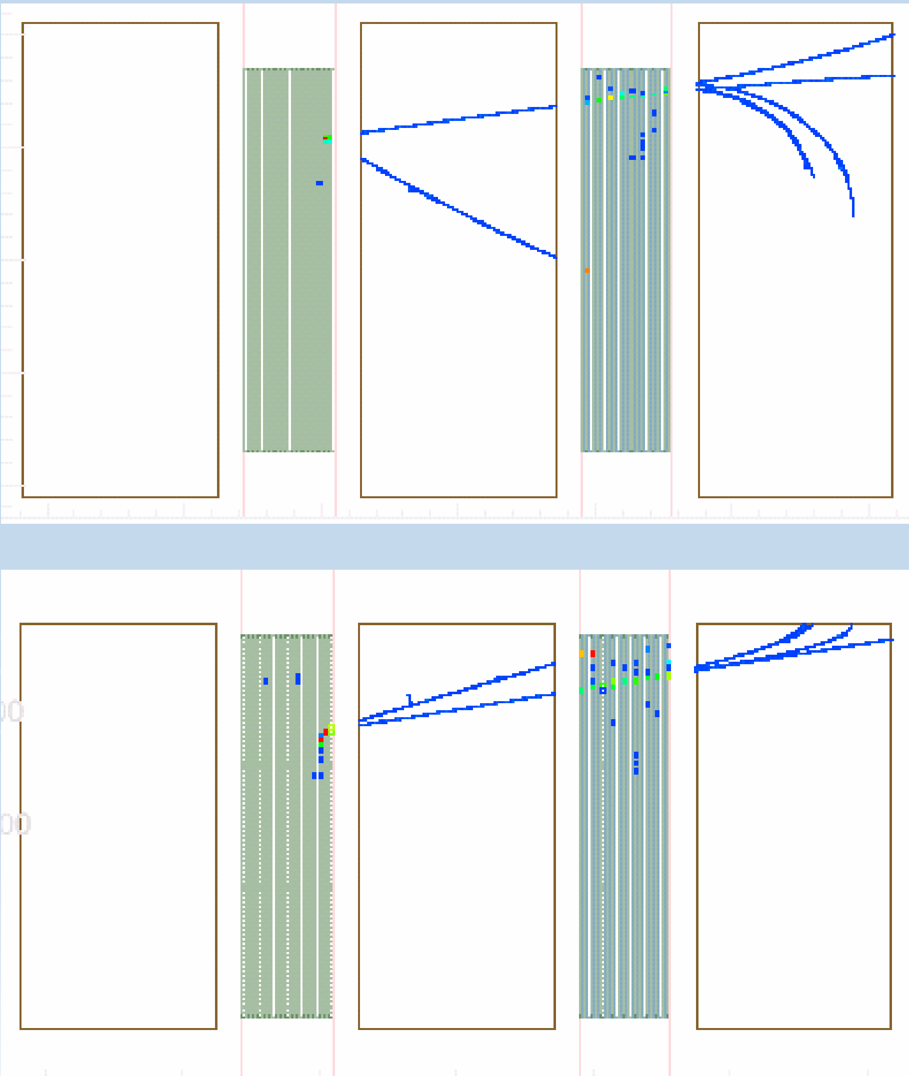
Informational particles

ν_μ (14)	Trk -1,	KE= 1340 MeV
n (2112)	Trk -1,	KE= 0 MeV

Primary particles

μ^- (13)	Trk 1,	KE= 938 MeV
p (2212)	Trk 2,	KE= 170 MeV
n (2112)	Trk 3,	KE= 72 MeV
p (2212)	Trk 4,	KE= 12 MeV
p (2212)	Trk 5,	KE= 3 MeV
p (2212)	Trk 6,	KE= 3 MeV
γ (22)	Trk 7,	KE= 6 MeV

Tracker – ν_e CC event



Event No.: 13 Reaction code: 1 Position in File: 13

Primary Vertex [mm]: (423, 543, 985)

Located in

Basket_0/TRK_0/Active_1/ScintX1_145/bar_39527

Informational particles

ν_e	(12)	Trk -1,	KE= 2893 MeV
n	(2112)	Trk -1,	KE= 0 MeV

Primary particles

e^-	(11)	Trk 1,	KE= 2578 MeV
n	(2112)	Trk 2,	KE= 46 MeV
p	(2212)	Trk 3,	KE= 15 MeV
p	(2212)	Trk 4,	KE= 117 MeV
p	(2212)	Trk 5,	KE= 86 MeV
p	(2212)	Trk 6,	KE= 14 MeV
γ	(22)	Trk 7,	KE= 4 MeV

Tracker

- With ~ 1.2 ton total mass in each FGD module, expect ~ 4×10^5 neutrino interactions in the tracker in a nominal year (10^{21} POT)
  - fiducial cuts, efficiency reduce this, but ample statistics for tuning MC simulations

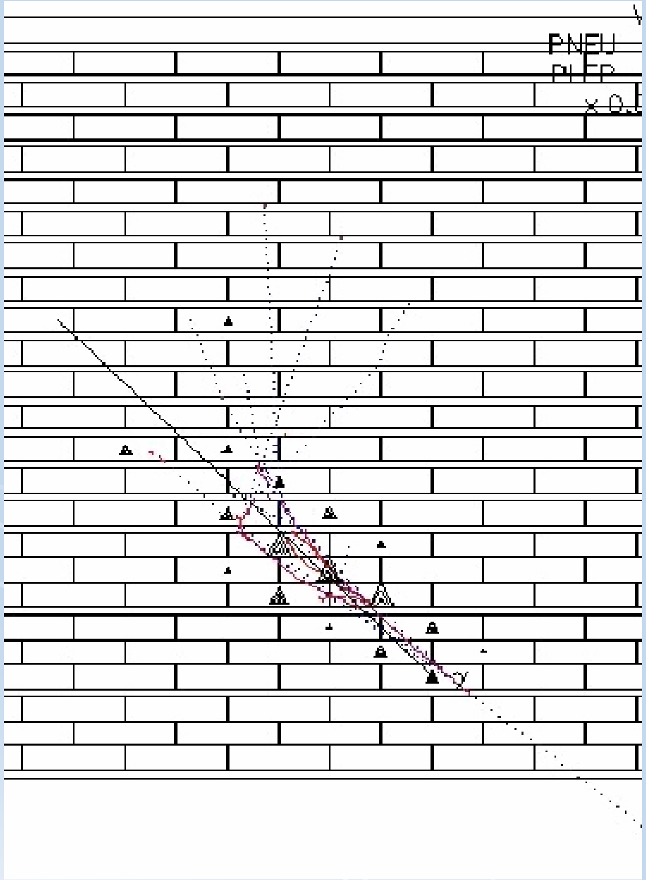
- Note that combined, the TPC inner volumes hold ~ 16 kg gas, resulting in ~ 2×10^3 neutrino interactions in a nominal year
  - an interesting sample – all charged particles tracked

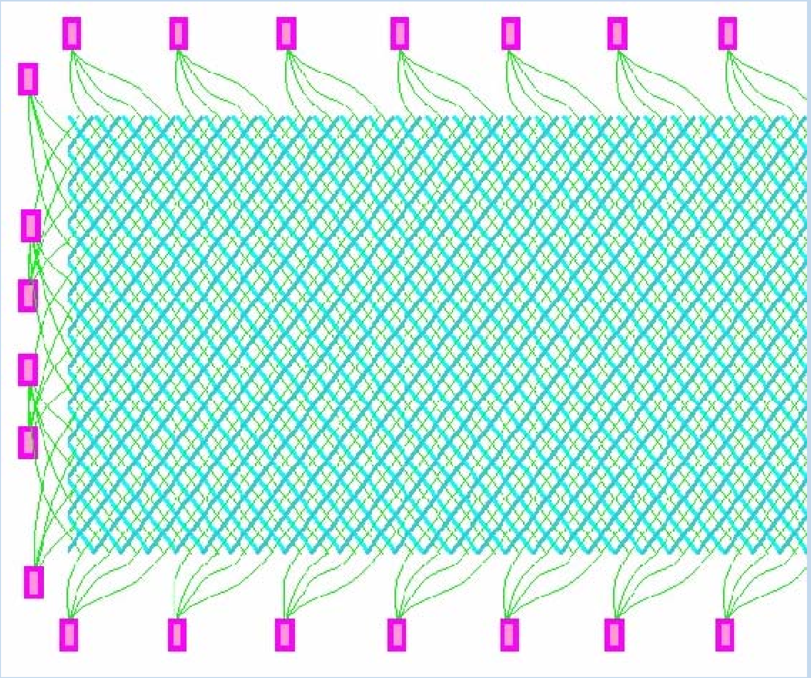
ECAL

- An electromagnetic calorimeter surrounds the Pi-zero detector and the Tracker:
  - to measure photons, primarily from π^0 production
  - to distinguish e and μ
- Conceptual design not complete
  - lead/scintillator stack
  - reasonable lateral and longitudinal segmentation appears to provide sufficient pointing accuracy for reconstructing π^0 's from neutrino interactions in the Tracker
    - π^0 mass cut helps purity and to identify which FGD plane was involved

ECAL

- segmentation schemes under study





Side muon range detector (SMRD)

- The yoke of the UA1 magnet was made with 1.7 cm gaps between iron plates
- SMRD will consist of 6-7 layers of the gaps instrumented with scintillator slabs
  - muons produced in the FGD at an angle near 90° or those produced at large angles in the Pi-zero detector cannot be measured by the TPCs – the SMRD can provide muon energy measurement to < 10%
  - in addition SMRD will be useful to veto activity from neutrino interactions in magnet or walls, and will form the basis for a cosmic trigger for calibrations if the inner detectors

Schedule

- Neutrino beamline commissioning: April 2009
- ND280 groups now seeking construction funding

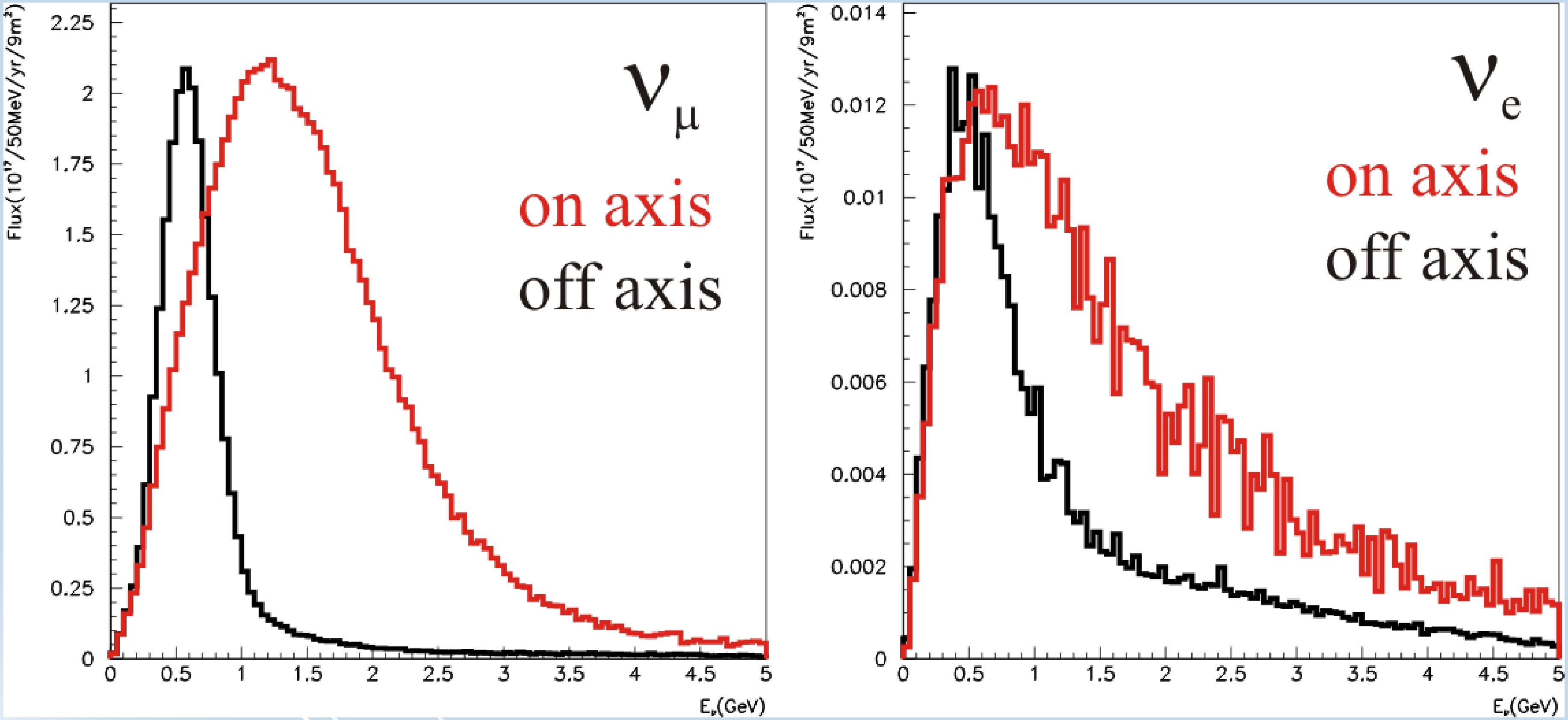
- Apr 2007: ND280 hall construction start
- May 2008: Install magnet
- Aug-Dec 2008: complete ND280 building
- Jan 2009: begin installation of ND280 detectors
  - on axis detector
  - off axis Tracker
- Summer/Fall 2009: install remaining detectors

Summary

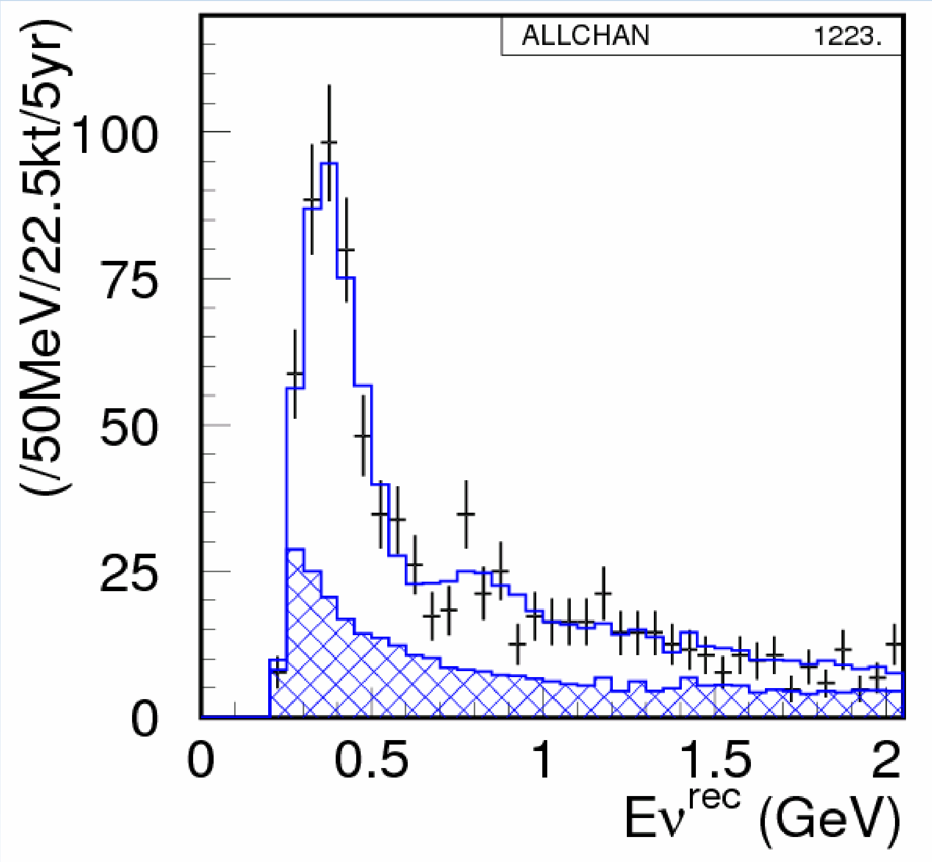
- T2K experiment is an exciting opportunity to extend our understanding of neutrino oscillations
- A number of detectors near the proton target are necessary to achieve the physics goals
- The off axis near detector is expected to provide a wealth of information on low energy neutrino interactions
- A lot of work ahead of us – a real challenge to be ready in time!

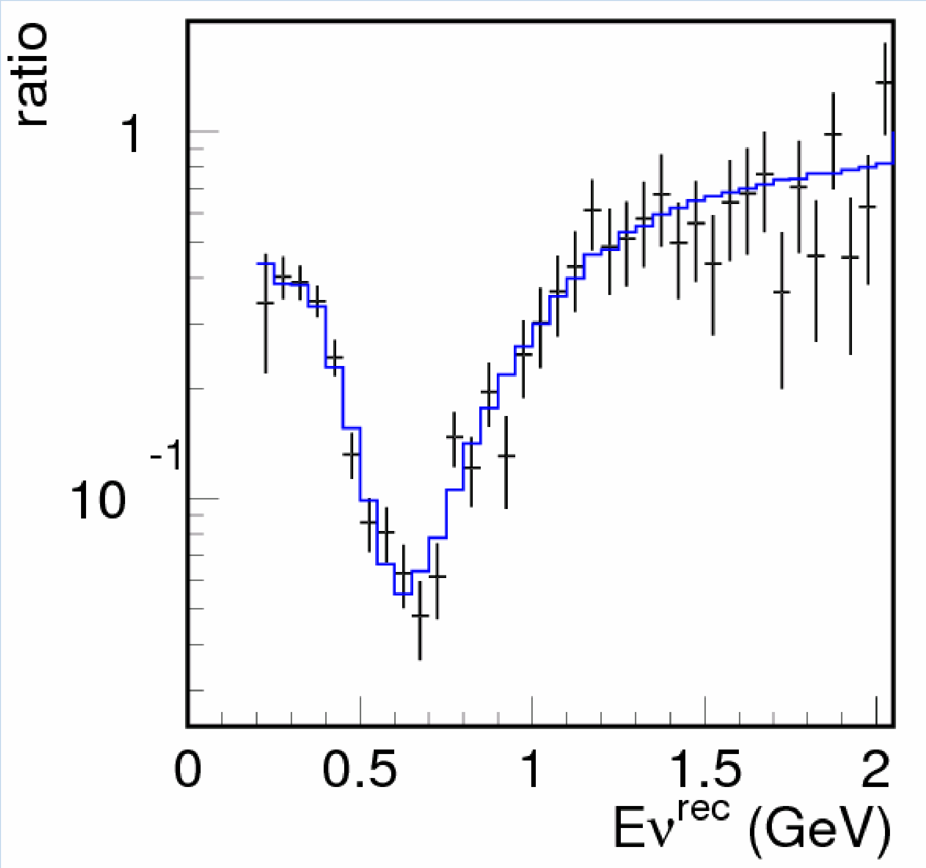
Extra slides

neutrino spectra

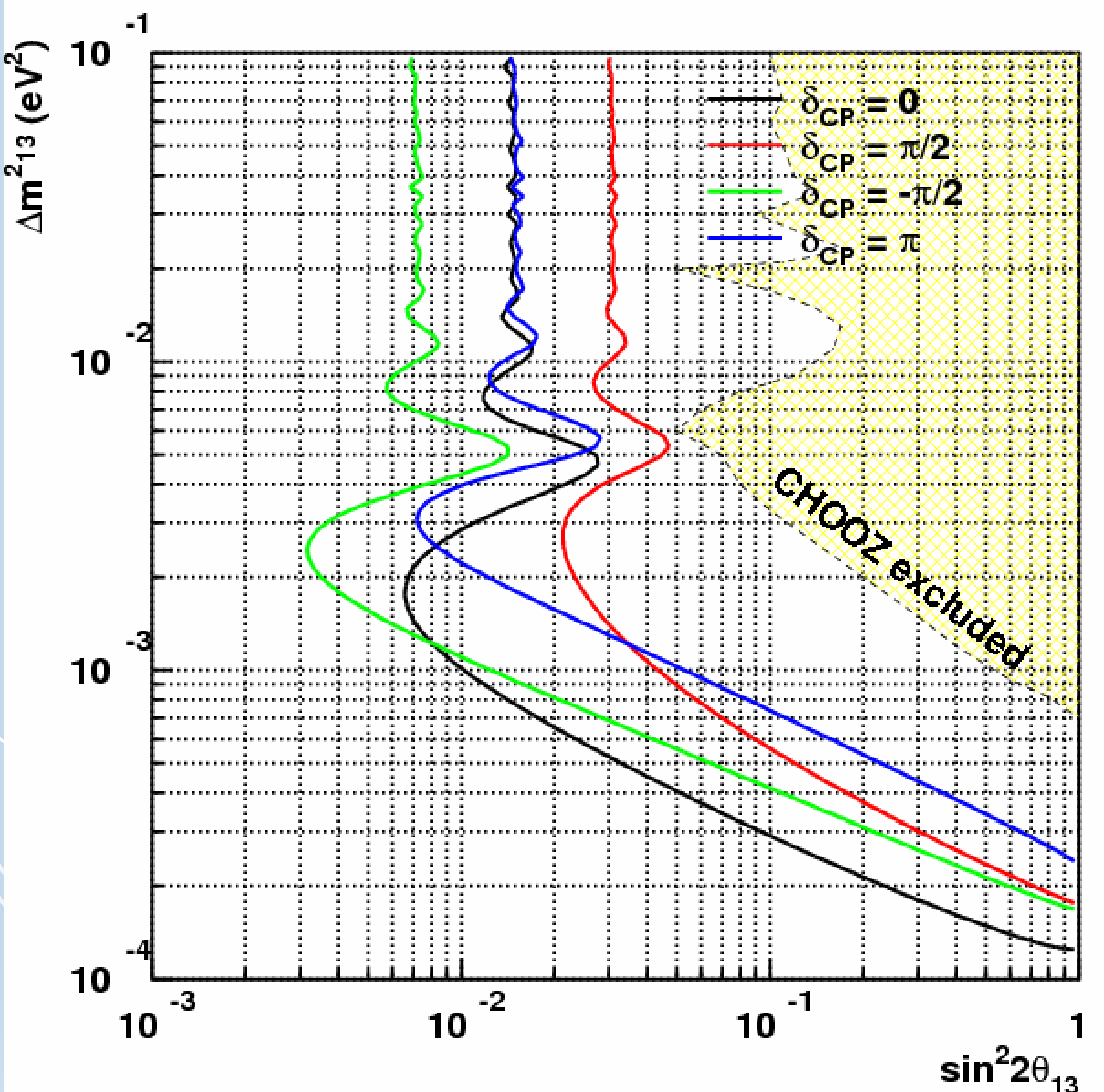


muon disappearance

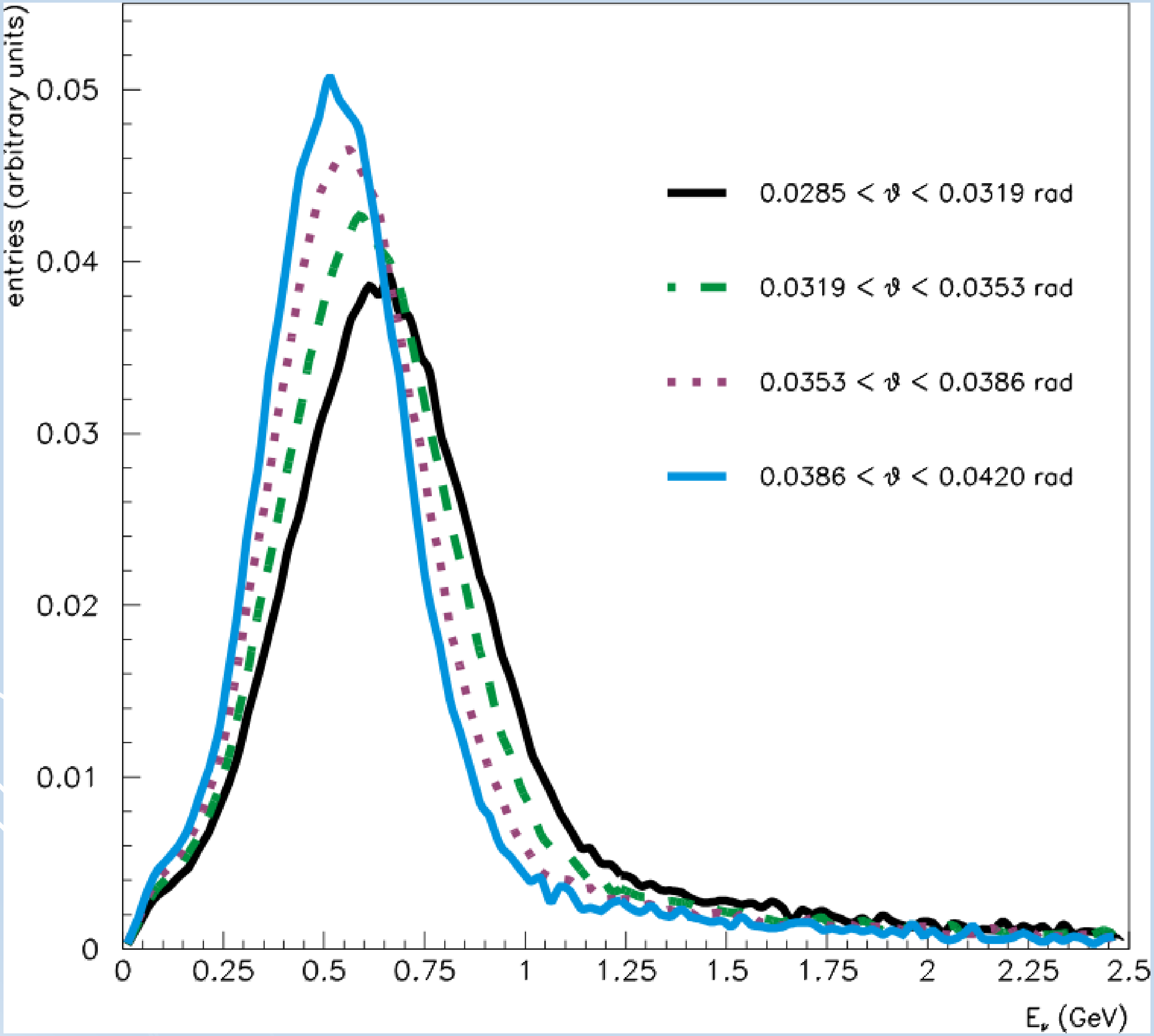




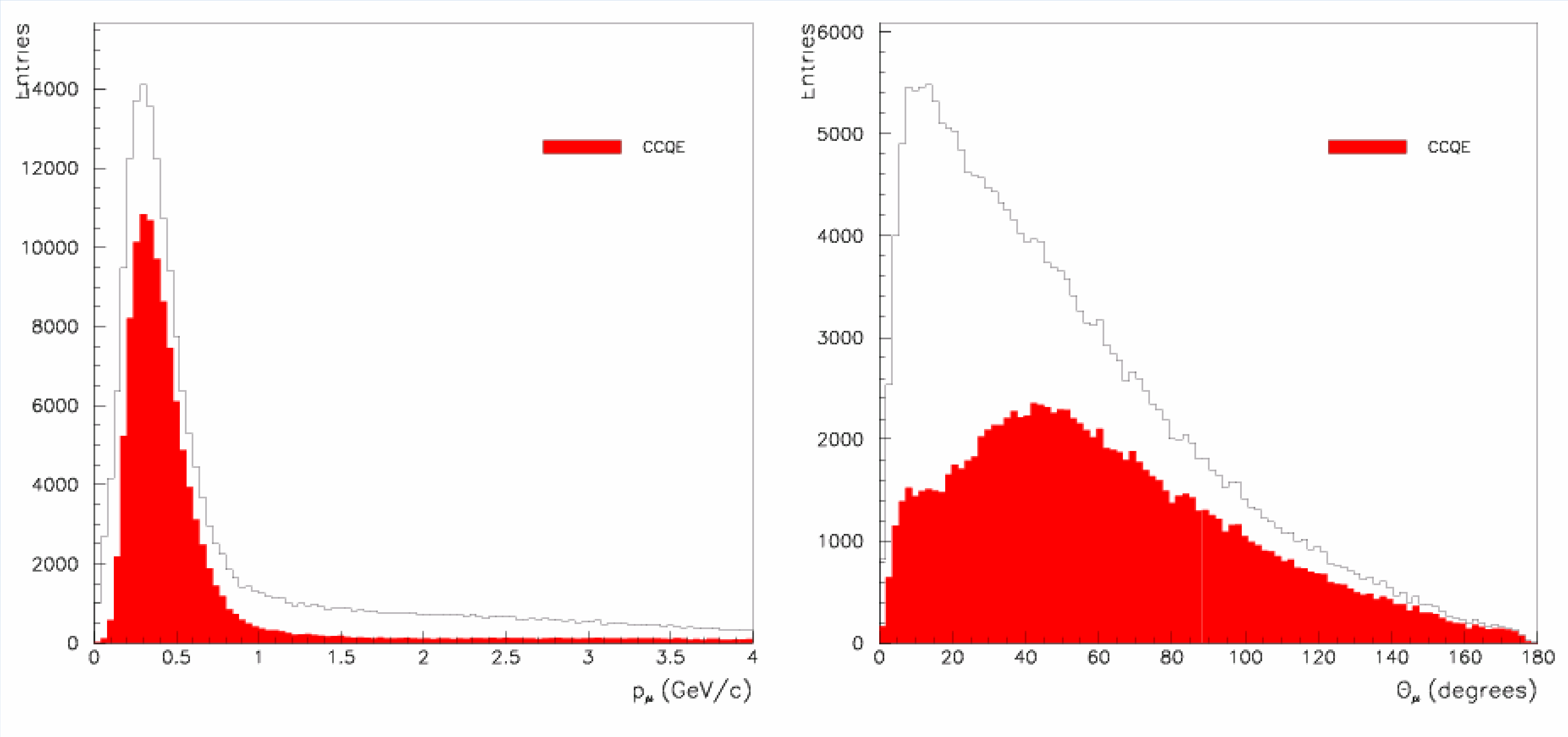
sensitivity to θ_{13}



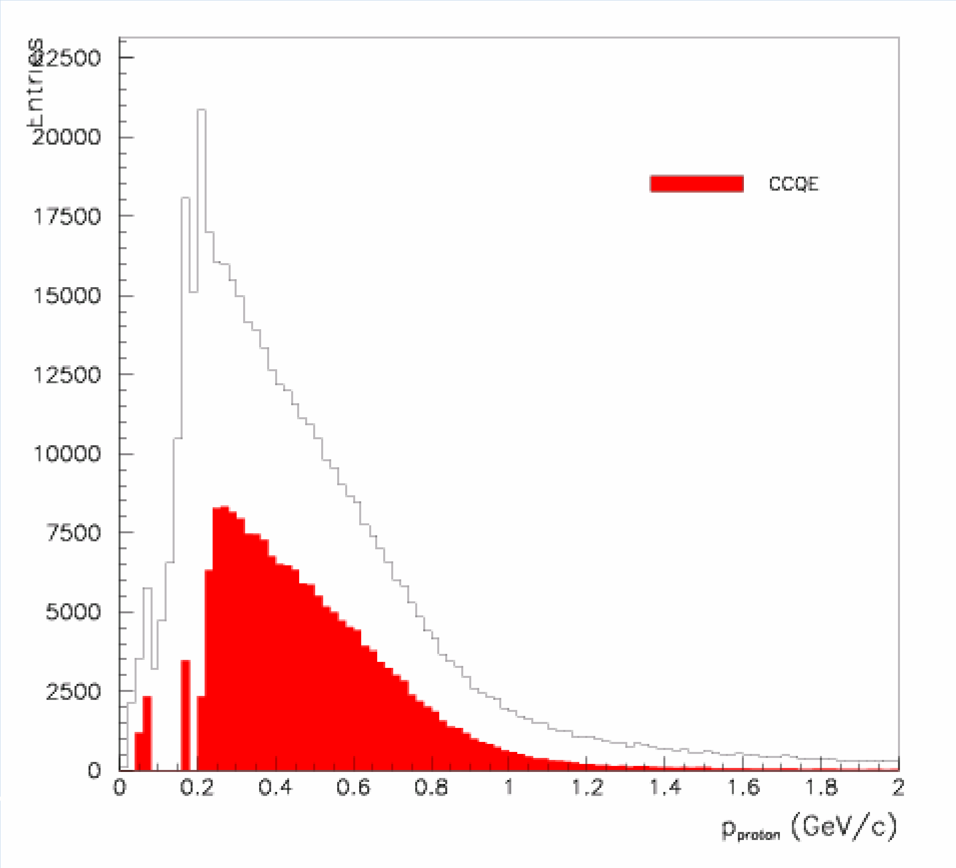
neutrino specta across off axis detector



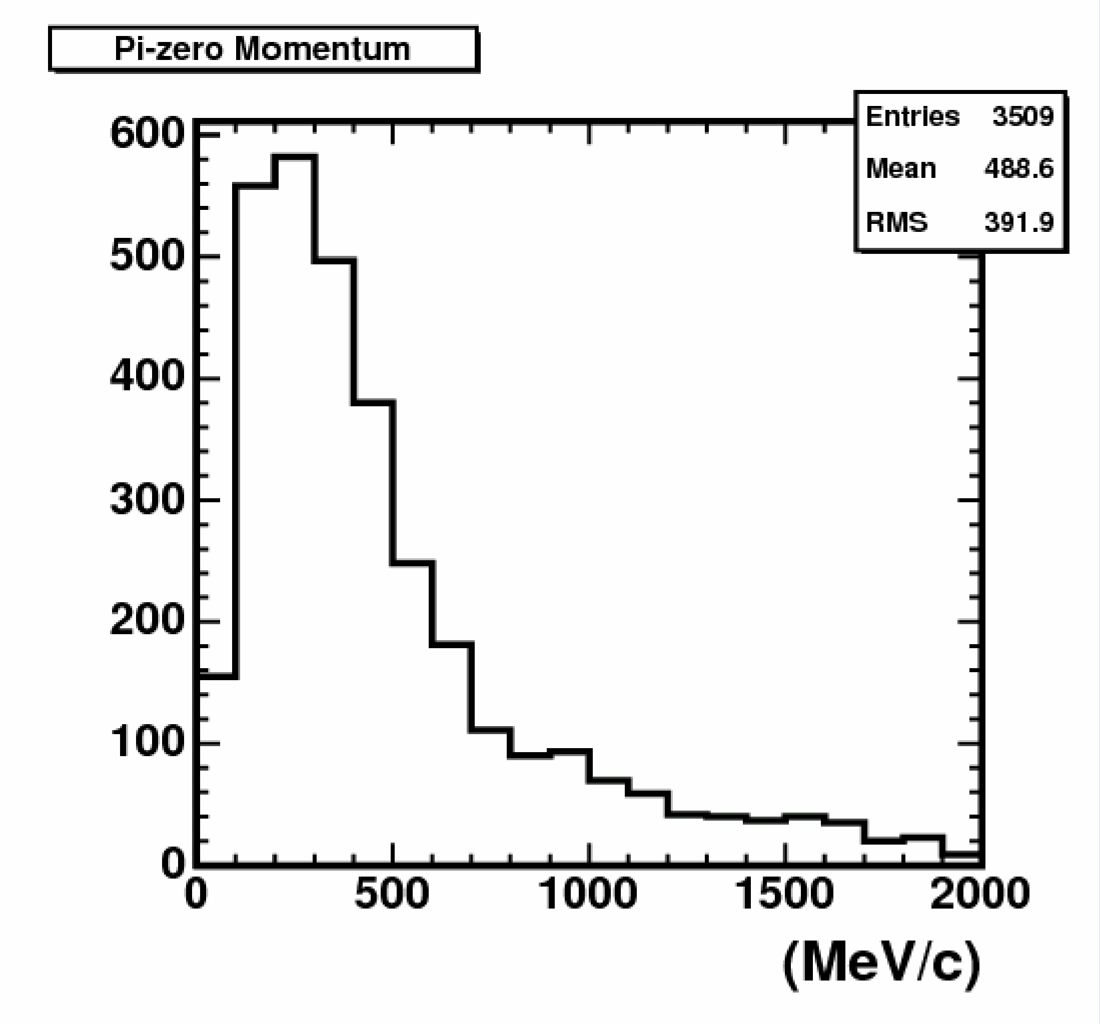
muon properties in ND280



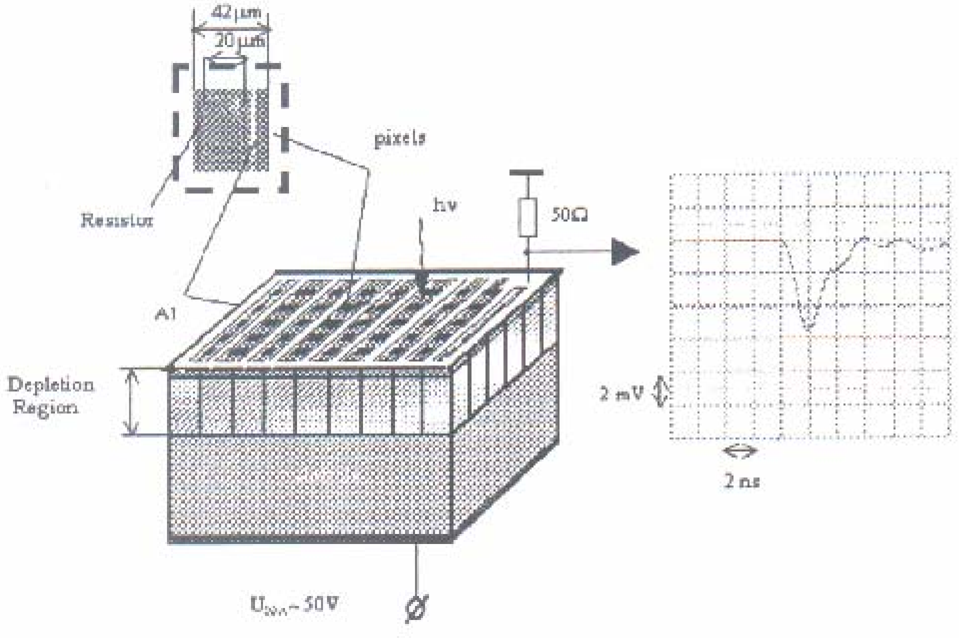
proton momenta at ND280

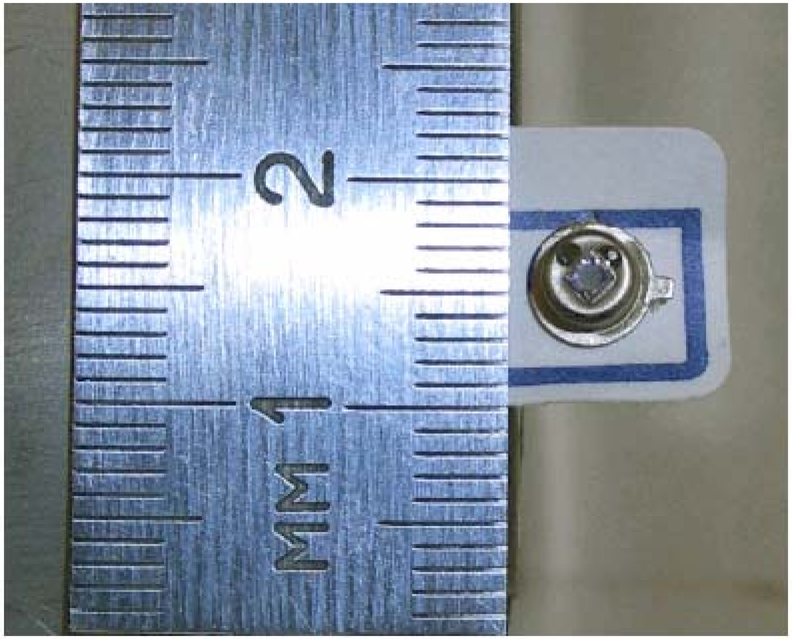


pi-zero distribution in ND280



Silicon Photomultiplier





Beam power at JPARC