July 15th, 2009
NUSS09@FNAL

T2K & NOvA

-Accelerator experiments under construction-

T. Nakaya (Kyoto)

Outline

1. Introduction of T2K and NOνA
2. Components of the experiments.
    1. T2K beamline/near-detector/far-detector.
    2. NOνA beamline/near-detector/far-detector.
3. Status of the T2K and NOνA experiments
    1. T2K commissioning and construction schedule/time-line for physics result
    2. FNAL accelerator performance/outlook for NOνA and the schedule of the detector construction.
4. Some details of physics sensitivities
    1. Events Reduction
    2. Signal and Background
    3. Physics Sensitivities, and the complementary issues in experiments.
5. Future Prospect
    1. Possible Upgrade (Niki's talk)


T2K
295km
Super-K
J-PARC
E133°
E135°
E137°
E139°
E141°
N35°
N37°
Kobe
Osaka
Kyoto
Tsu
Nagoya
Gifu
Kanazawa
Nagano
Japan
Sado
Niigata
Kofu
Shizuoka
Maebashi
Hachioji
Saitama
Honshu
Kanagawa
Tokyo
Yokohama
Kawasaki
Funabashi
Chiba
Mito
Fukushi
shima
Image NASA
© 2007 Europa Technologies
Image © 2007 TerraMetrics
© 2007 ZENRIN
Pointer 36° 23'41.59" N 139° 11'54.71" E elev 665 m
Streaming 100%


NOvA
NOvA Far Detector
MINOS Far Detector
Minnesota
Ontario
810 km
Wisconsin
Iowa
Milwaukee
Michigan
Fermilab
Chicago
© 2007 Europa Technologies
Image © 2007 TerraMetrics
Image © 2007 NASA
©2007 Google™
168 km
Pointer 43°34'32.84" N 89°04'55.60" W elev 271 m
Streaming 100%
Eye alt 545.86 km

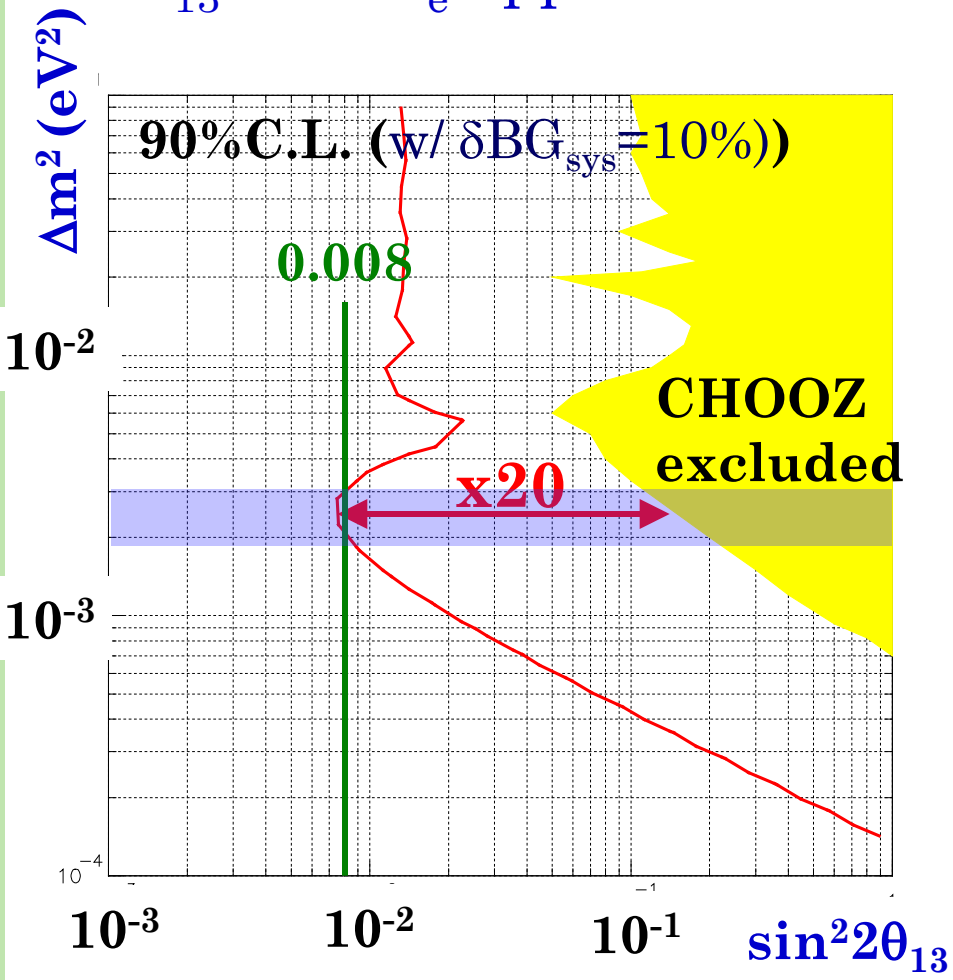
1. Introduction of T2K and NOvA

- The accelerator ν oscillation experiments.
  - Probe θ_{13} by looking for ν_e appearance.
  - Precision measurements of θ_{23} and Δm^2_{23}.
  - Search for sterile neutrinos by measuring the neutral current interactions.
  - Look for the difference of ν oscillations between ν and $\overline{\nu}$.
    - CP violation (δ in the MNS matrix or new interactions)
    - Matter effect and neutrino mass ordering (sign of Δm^2_{23}).

	T2K (2004~2009)	NOvA (2009~2013)
Accelerator	J-PARC MR 750kW (design) New	FNAL MI 700kW (330kw current)
Neutrino Beam	2.5 degree off-axis E_{peak}~700MeV New	~14mrad (0.8 degree) off-axis E_{peak}~2GeV
Near Detector	Fine-Segmented multi-type detectors w/ magnetic field (w/ water target) New	Liquid Scintillator segmented detector (similar as the far detector) New
Far Detector	Water Cherenkov 50ktons (22.5 kt fiducial) 295km away	Liquid Scintillator detector 15 kton 810km away New
Near/Far extrapolation	Hadron production will be measured by CERN NA61 New	Hadron production will be measured by FNAL MIPP New

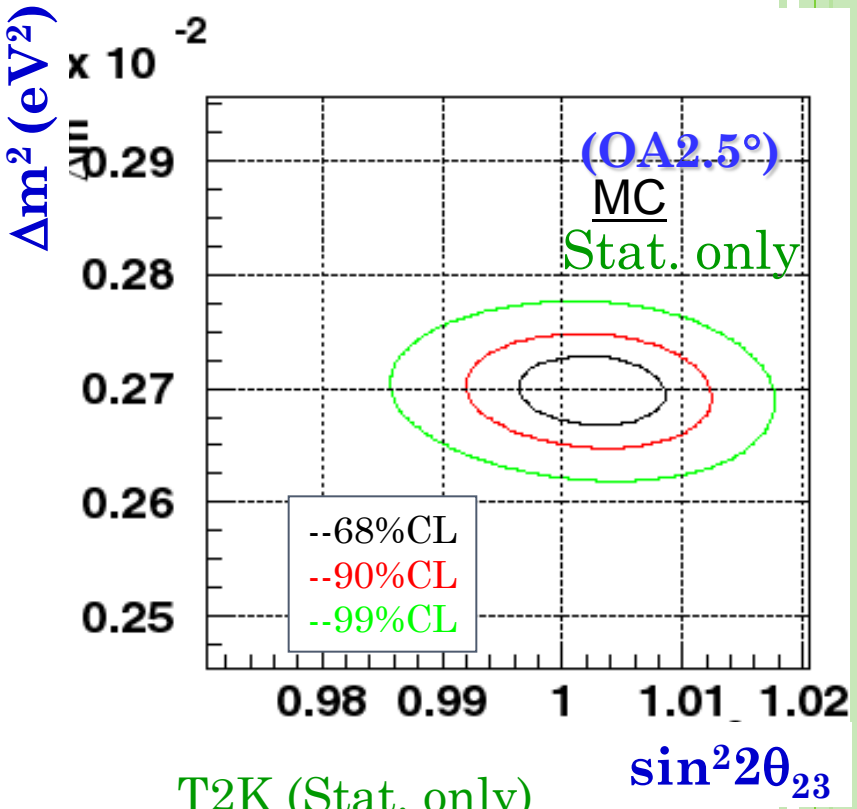
T2K Sensitivity

θ_{13} from ν_e appearance



Assuming $\theta_{23}=\pi/4$ and $\delta=0$

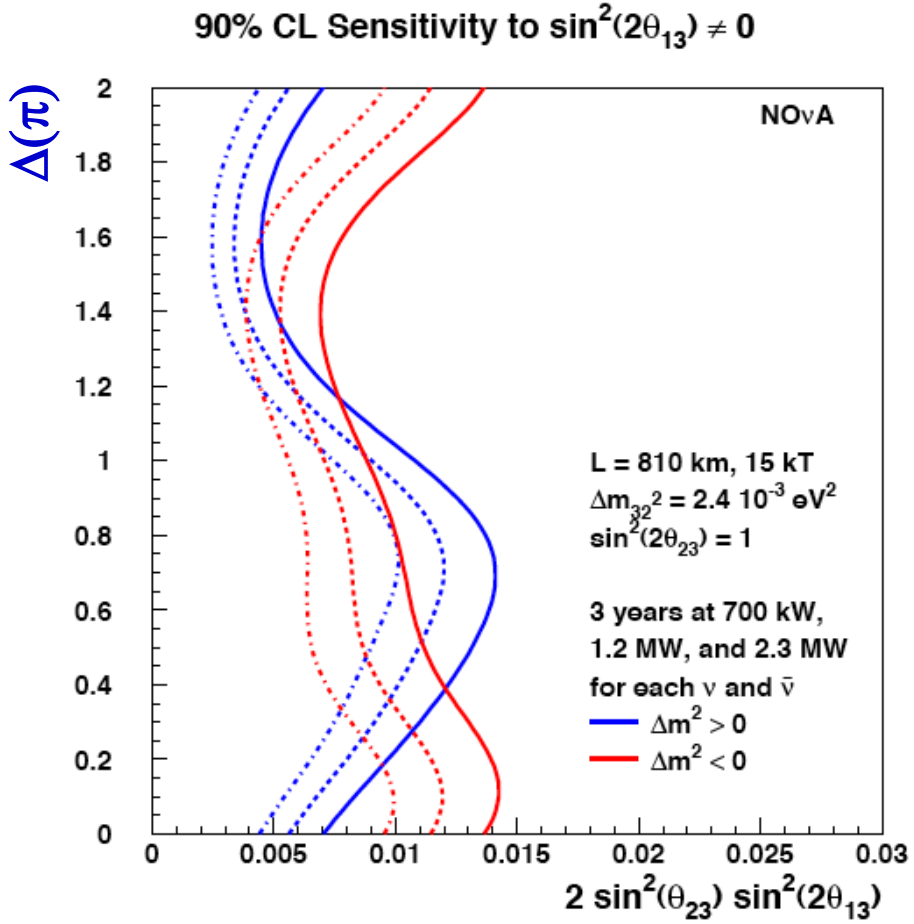
θ_{23} from ν_μ disappearance



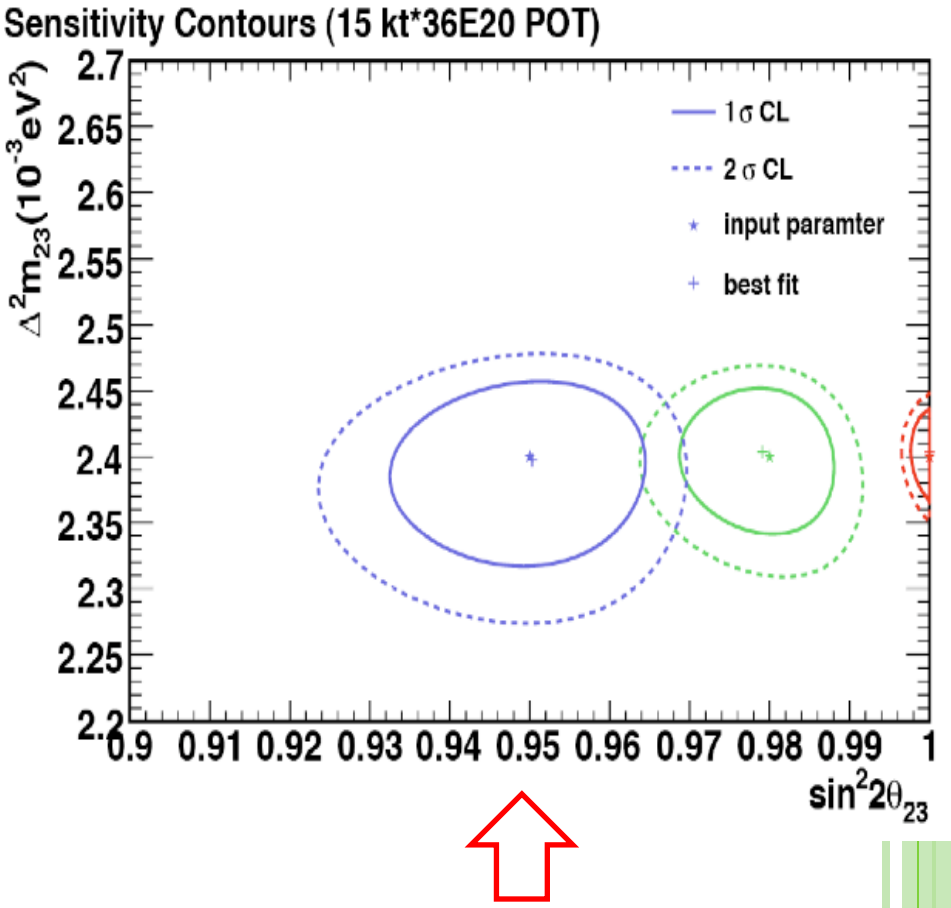
T2K (Stat. only)
@ full Intensity

NOvA Sensitivity

θ_{13} from ν_e appearance



θ_{23} from ν_μ disappearance



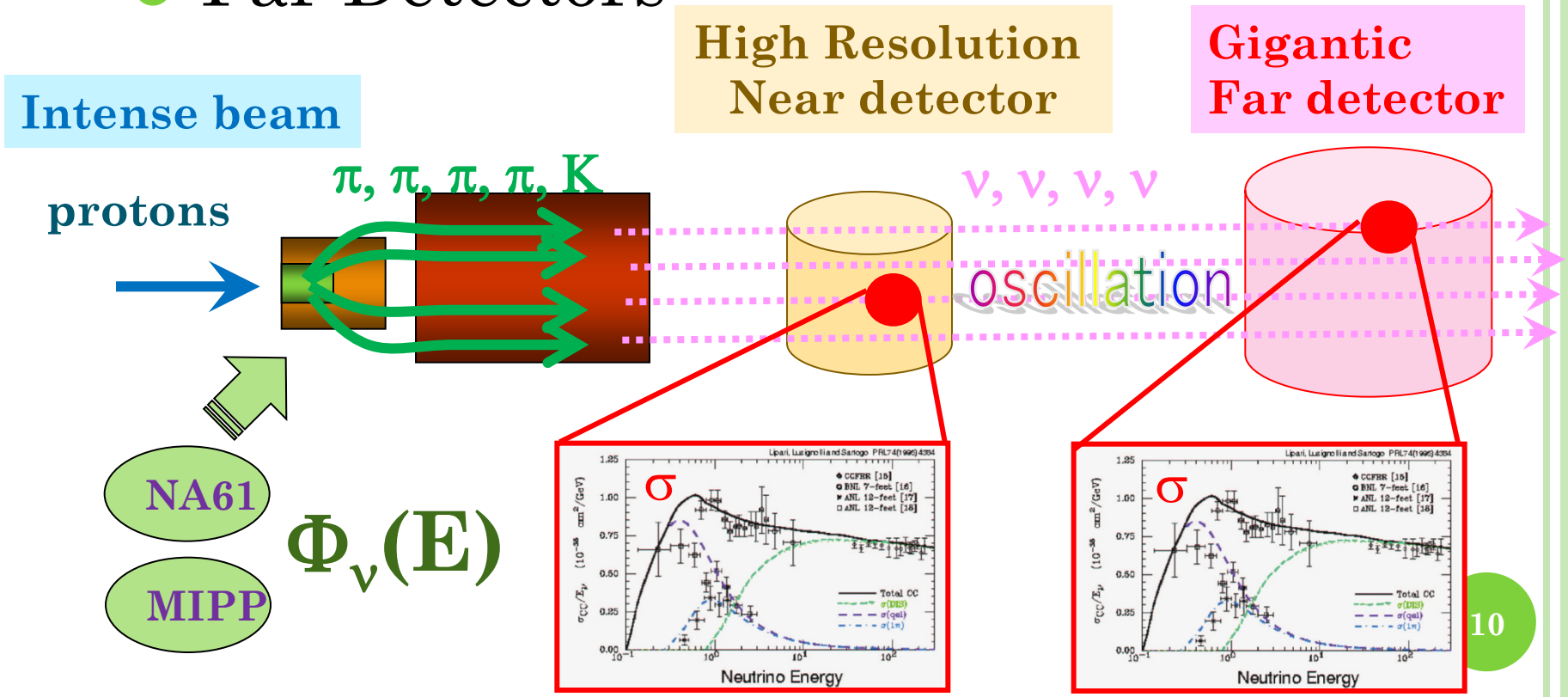
It is a parameterized calculation, which needs to be redone with a full reconstruction.

IMPORTANT THINGS FOR EXPERIMENTS

- The experiments must be realized.
- It is a fun time for an experimentalist to work for
  - the design stage of the experiment
  - the construction of the new equipments
  - the beginning of the commissioning of the experiment
  - the stage that the important physics results are produced.
- You can consider new ideas and possible upgrade of experiments any time.
  - It is the reason why you are physicist, I guess.
  - Examples
    - Physics sensitivity of T2K with anti-neutrino beams
    - Neutrino Interaction physics in the T2K and NOνA near detectors.
    - :
  - Summer school/Workshop is a good opportunity for us to discuss/exchange these ideas

2. Components of the experiments.

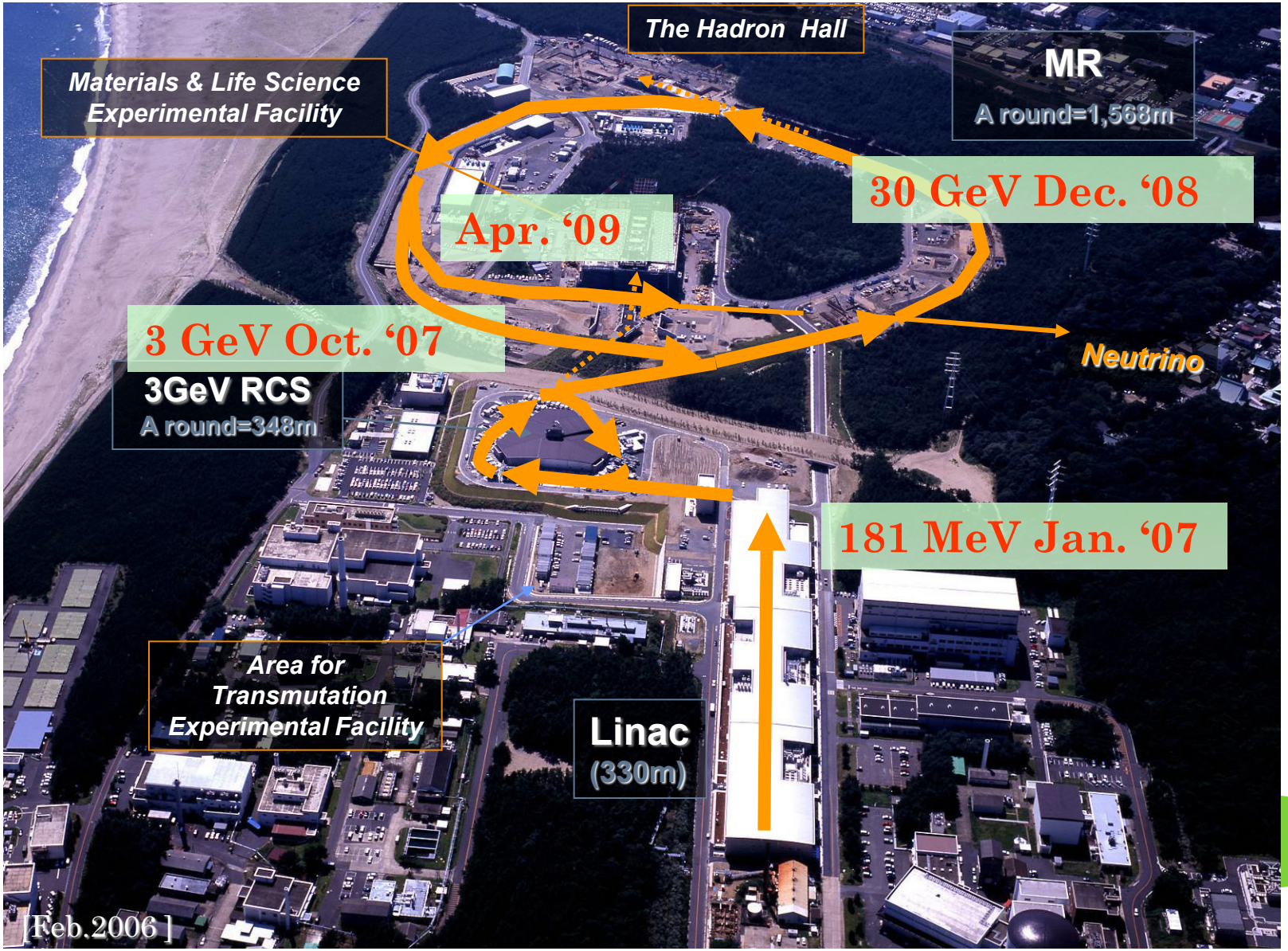
- Accelerator/Neutrino Beams
- Near Detectors
- Far Detectors



2. Components of the experiments.

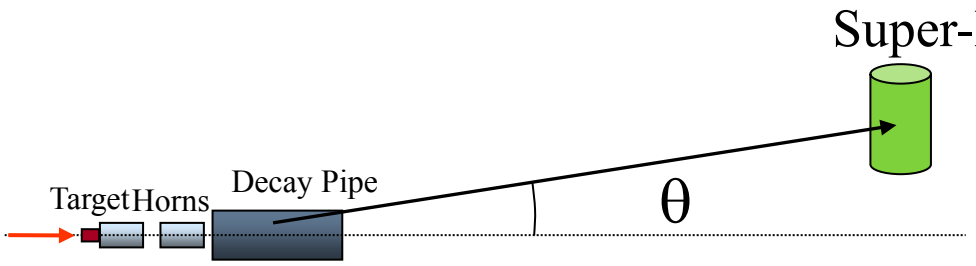
T2K

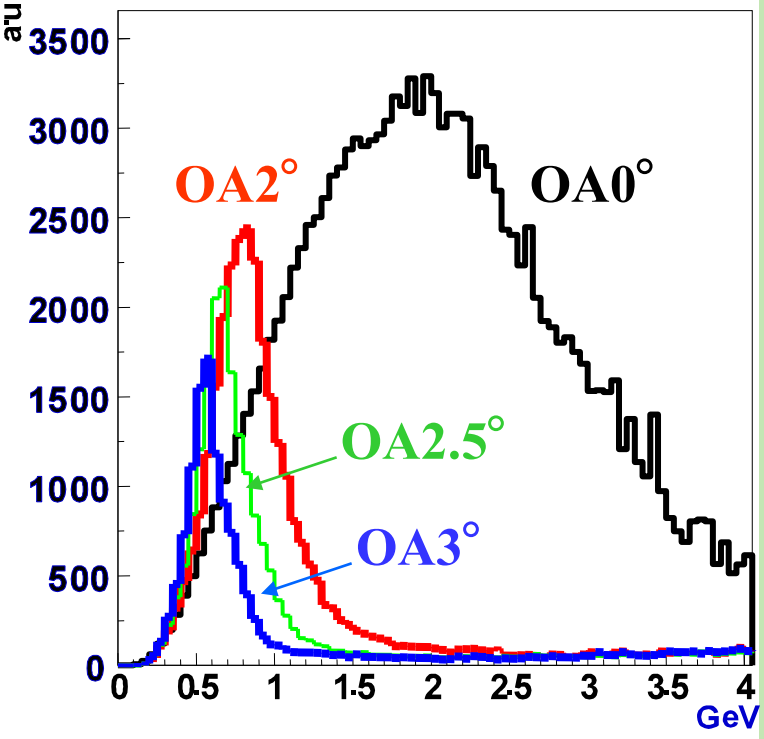
J-PARC Accelerators [750kW Design]



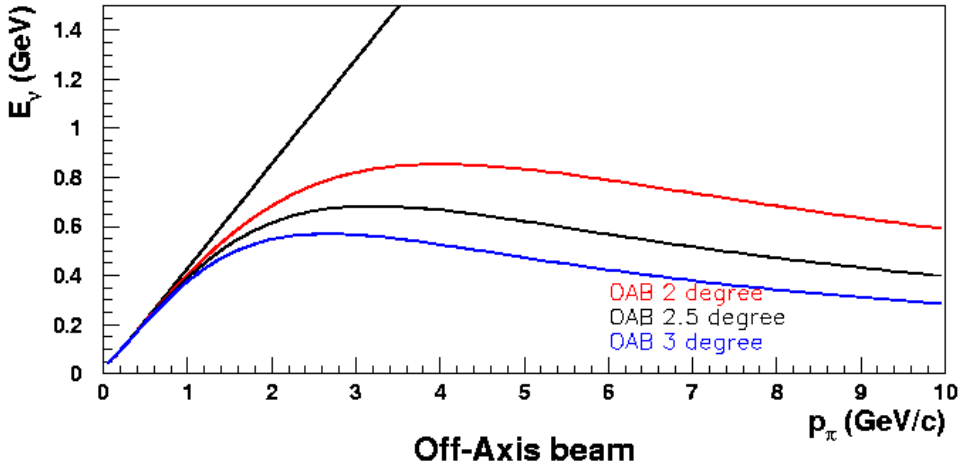
OFF-AXIS ν BEAM

Tuned at oscillation maximum





Decay Kinematics



- **Quasi Monochromatic Beam**

Statistics at SK w/o osci.

(OAB 2.5 deg, 1 yr, 22.5 kt, 40 GeV protons)

~ 2200 ν_μ tot

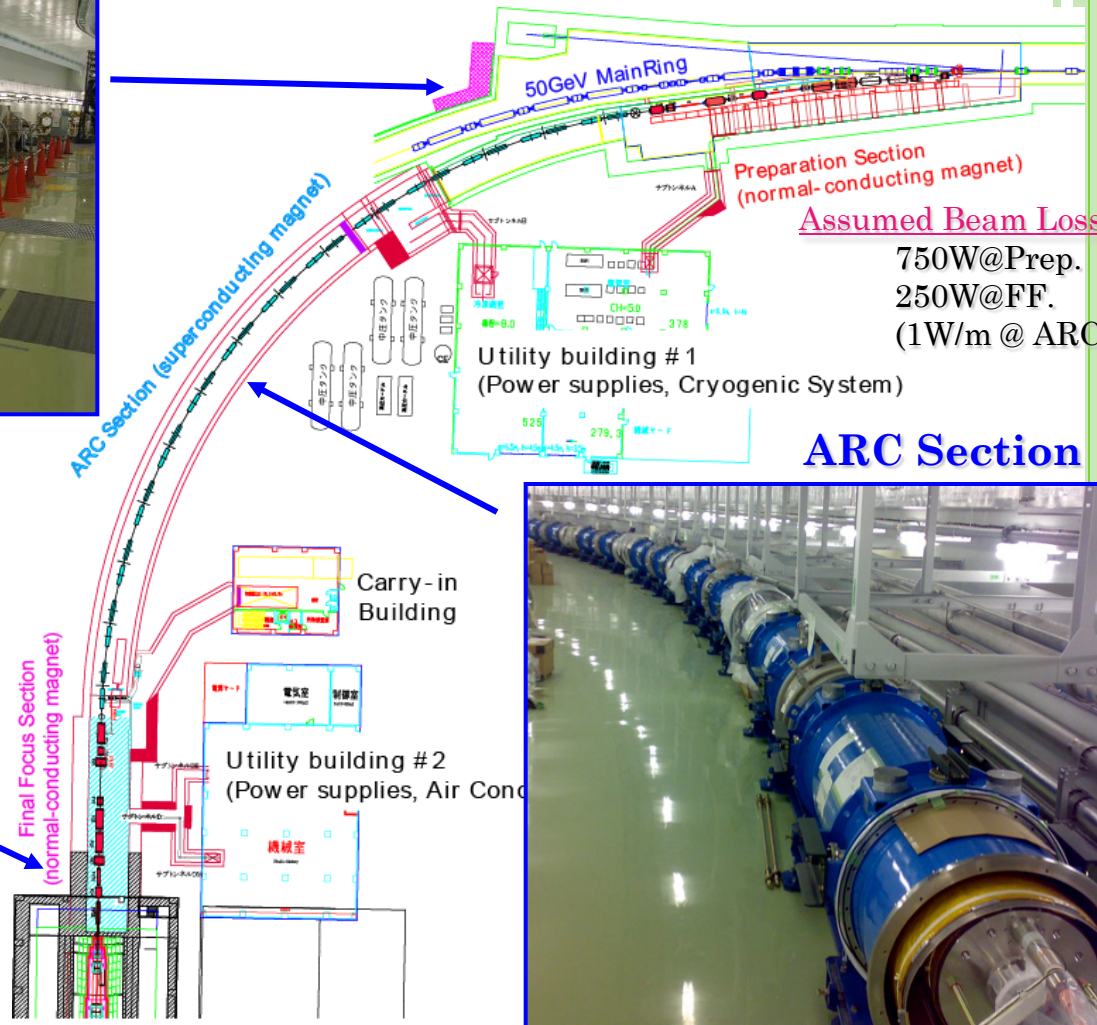
~ 1600 ν_μ CC

ν_e ~0.4% at ν_μ peak

PRIMARY BEAM-LINE

Preparation Section

Final Focusing Section



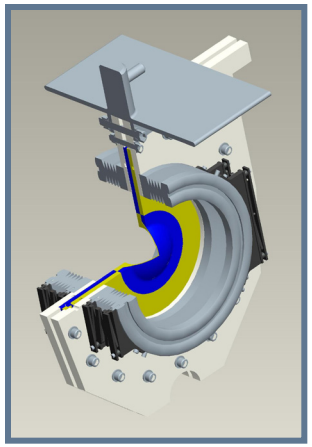
Assumed Beam Loss
750W@Prep.
250W@FF.
(1W/m @ ARC)

ARC Section

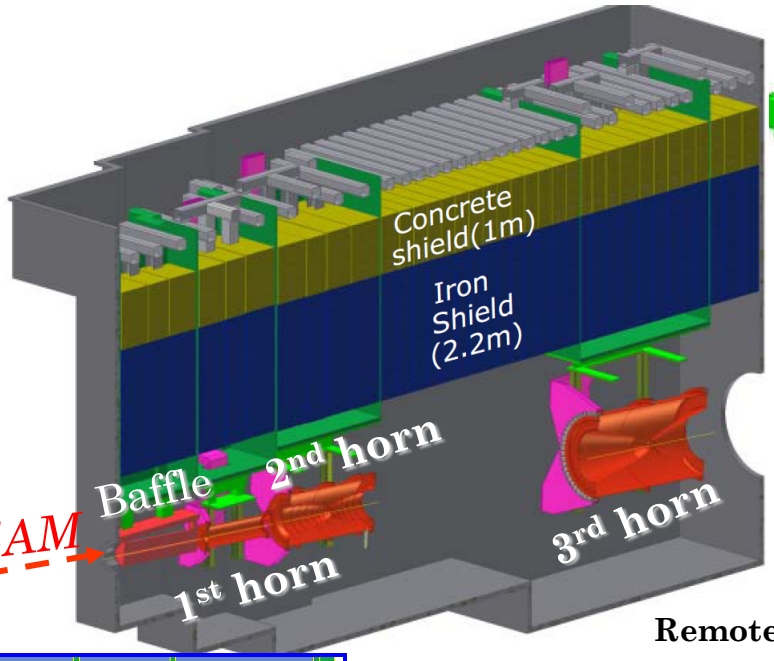
- Beam-line tunnel was completed in December 2006
- Installation finished in 2009

TARGET STATION AND HORNS

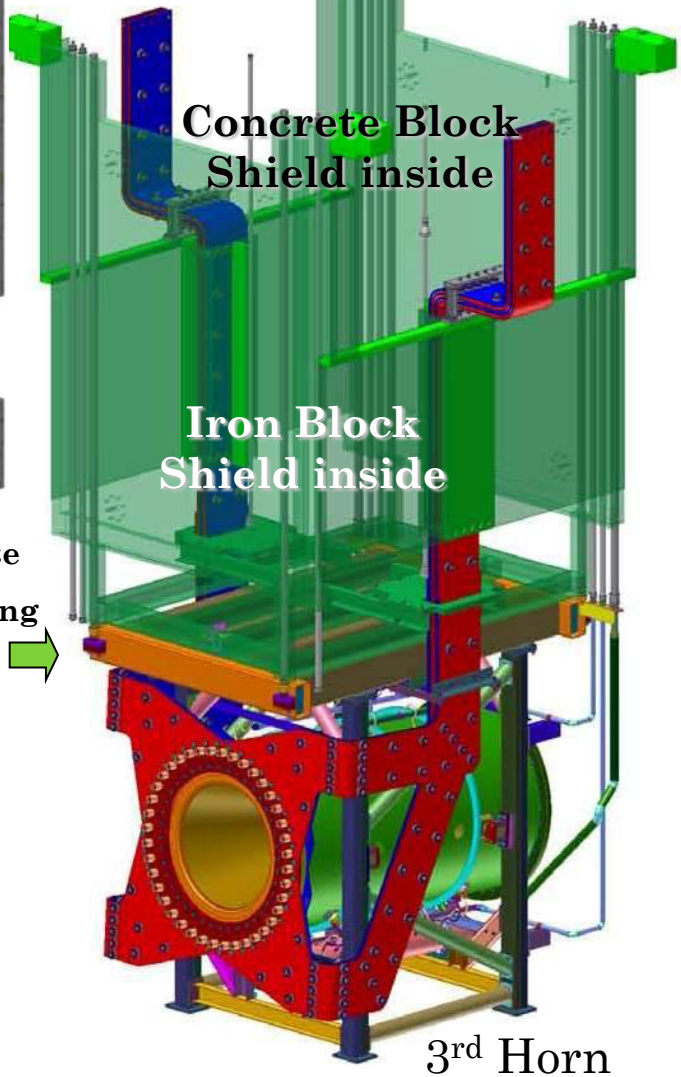
320kA current for the horn system



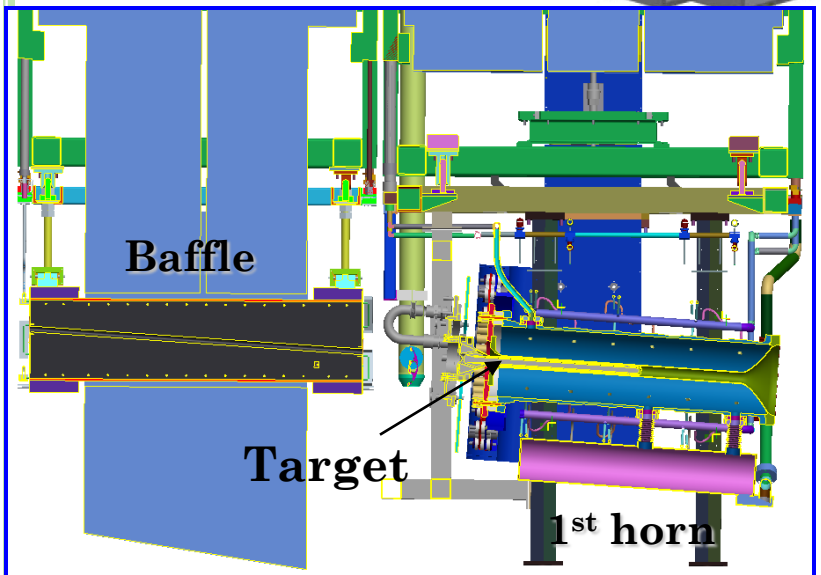
Beam Window
With pillow seal



Support Module



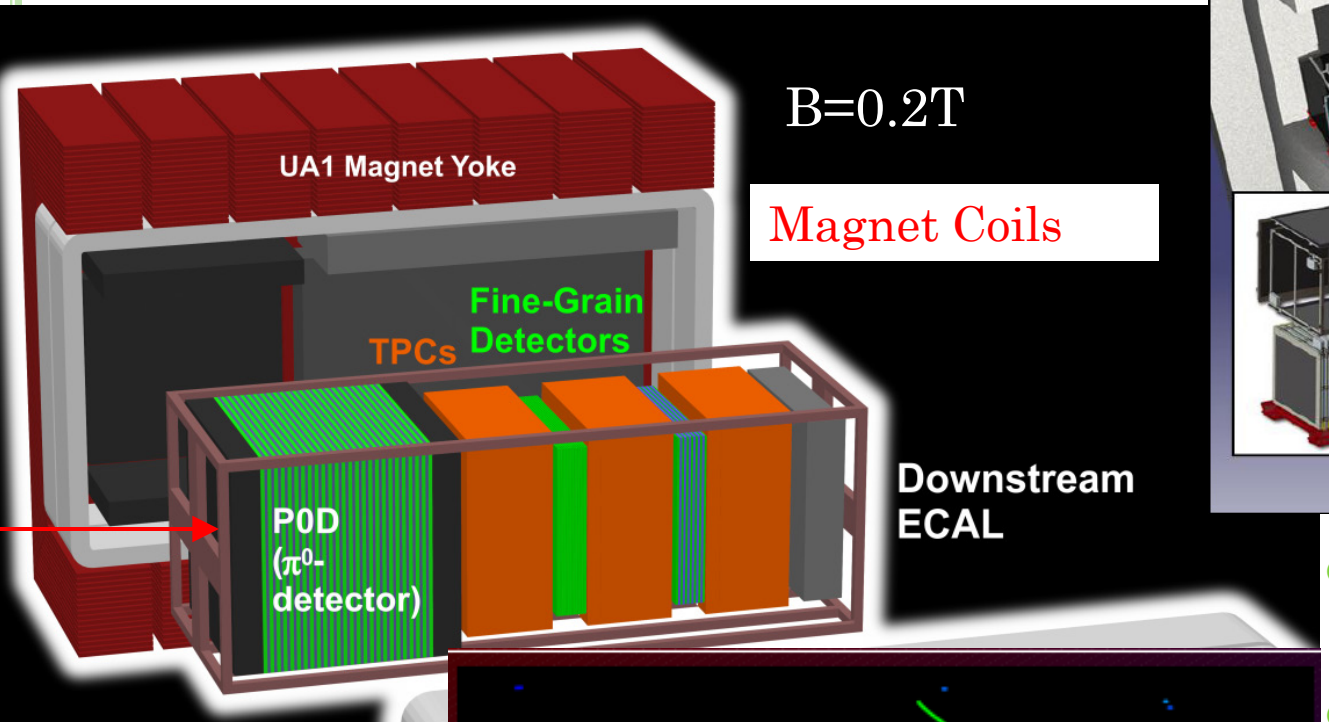
3rd Horn

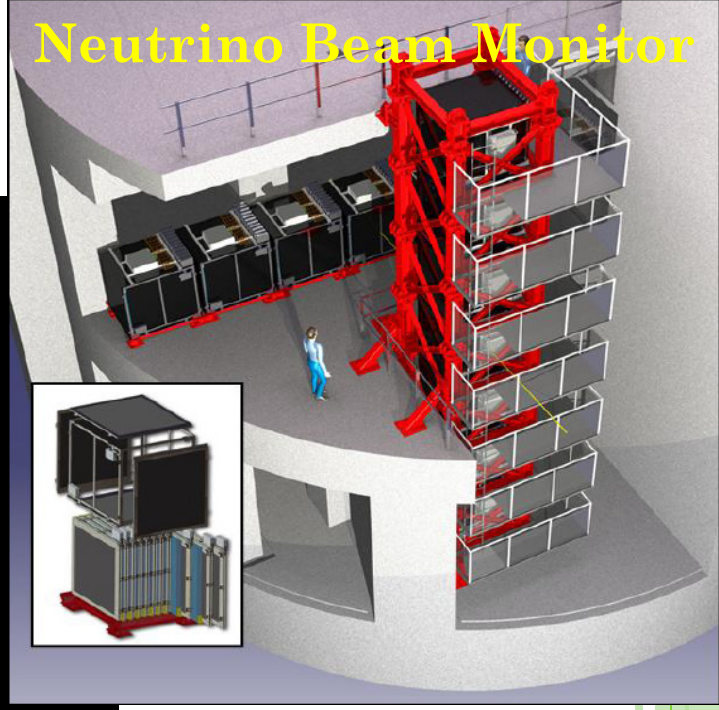


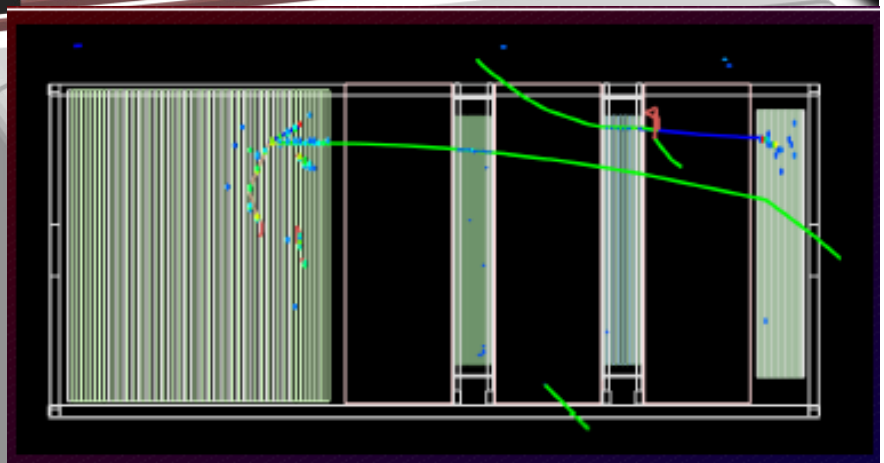
Huge
He vessels

T2K Near Detectors

ND280 Off-axis



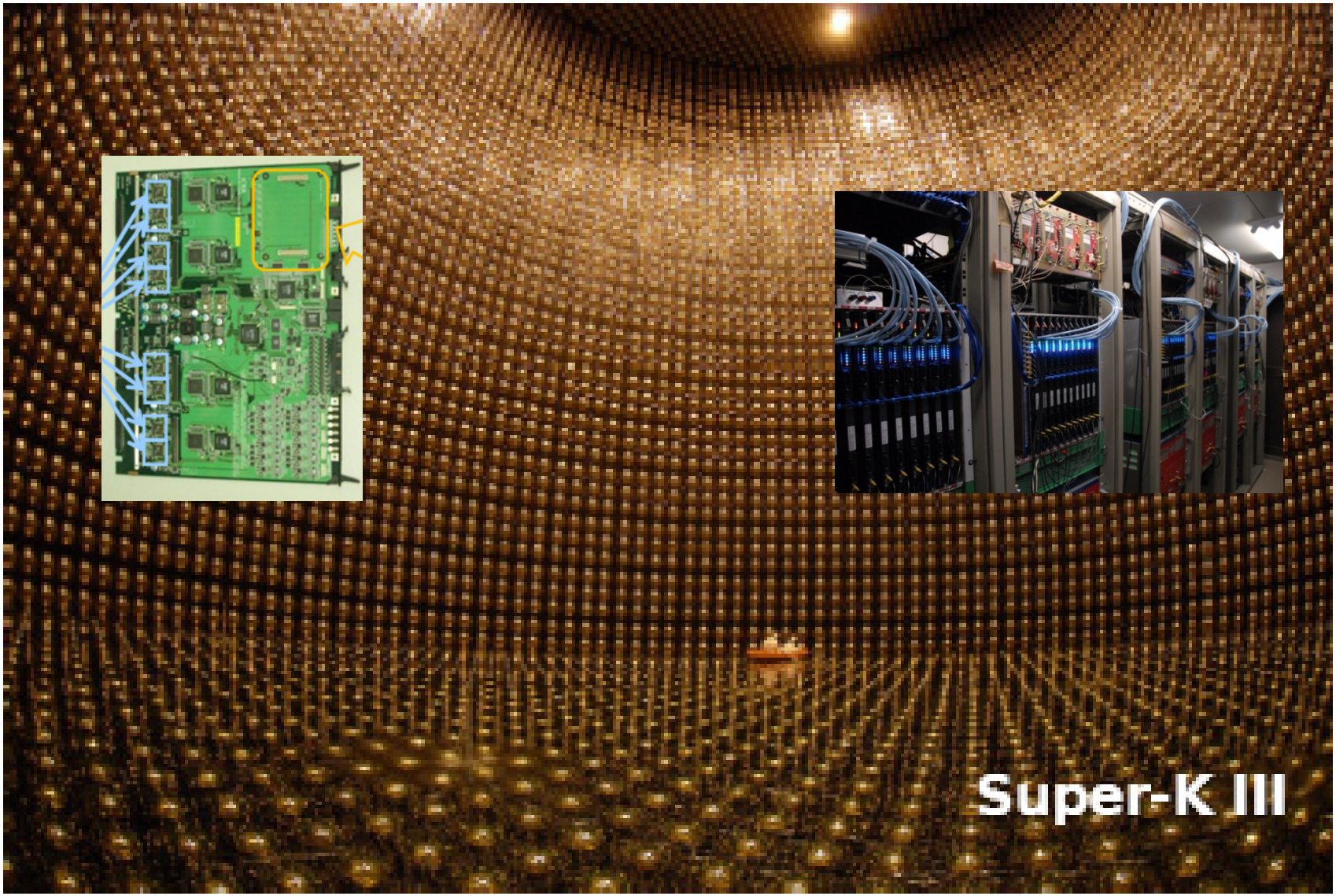




A CC1π interaction in the P0D, with full-bunch background

- Volume:
  - $3.5 \times 3.5 \times 7.0 m^3$
- **P0D:** π^0 Detector
- **FGD+TPC:** Charged Particle tracking
- **EM calorimeter**
- **Side-Muon-Range Detector**

Far Detector: Super-Kamiokande IV

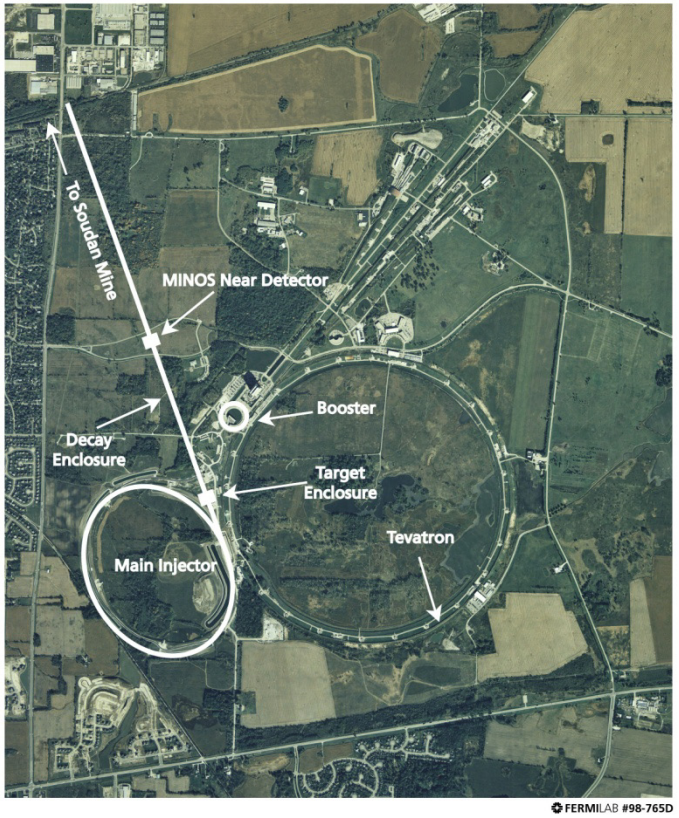


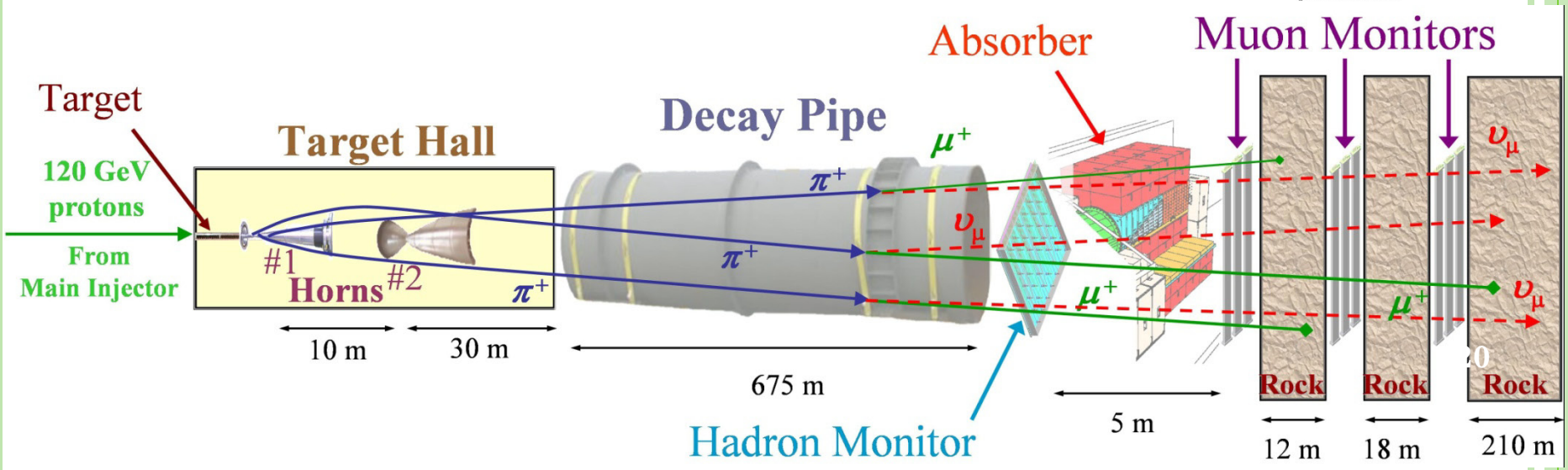
2. Components of the experiments.

NOvA

Fermilab NuMI Beam

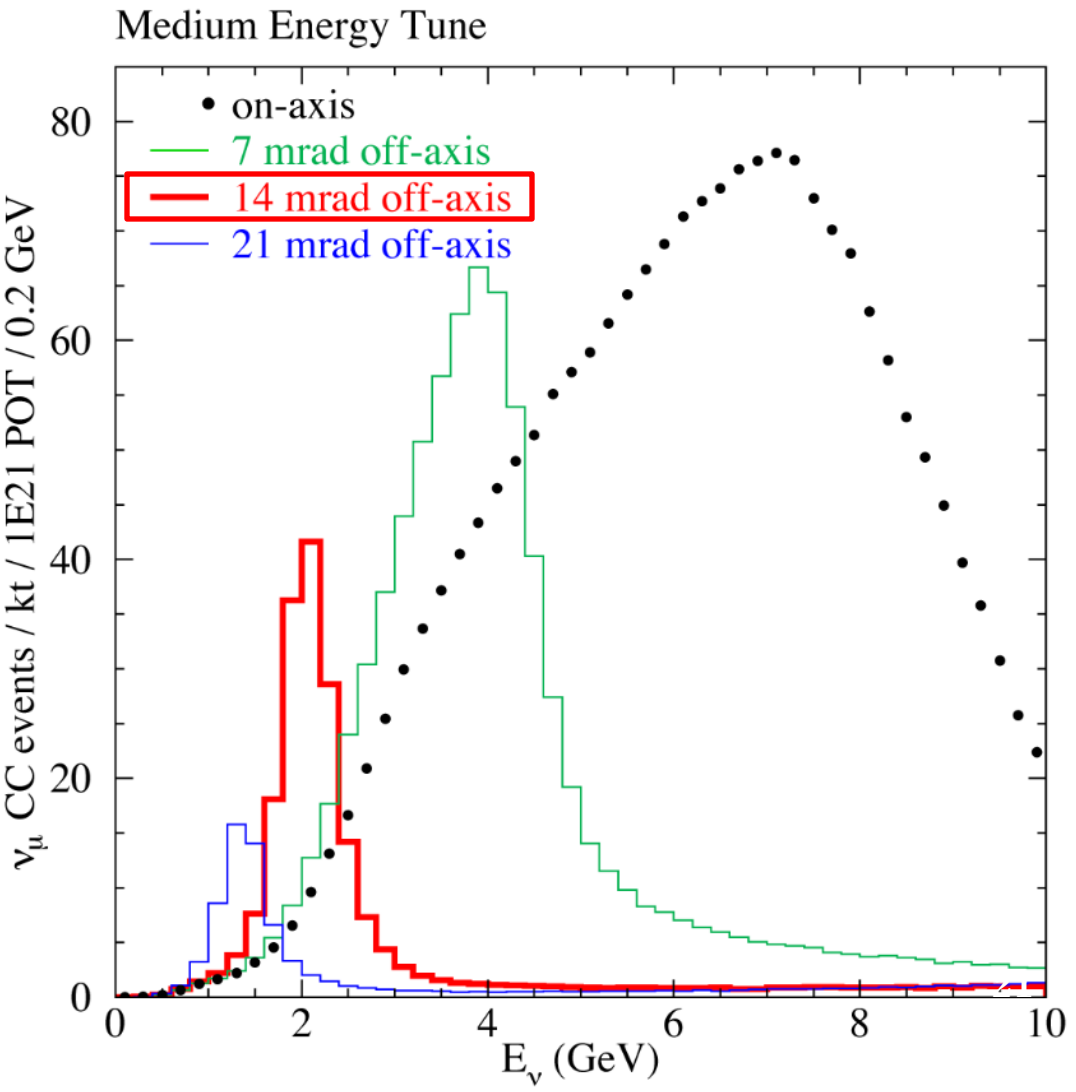
- 120GeV
- 5E13 PPP
- 320kW→700kW





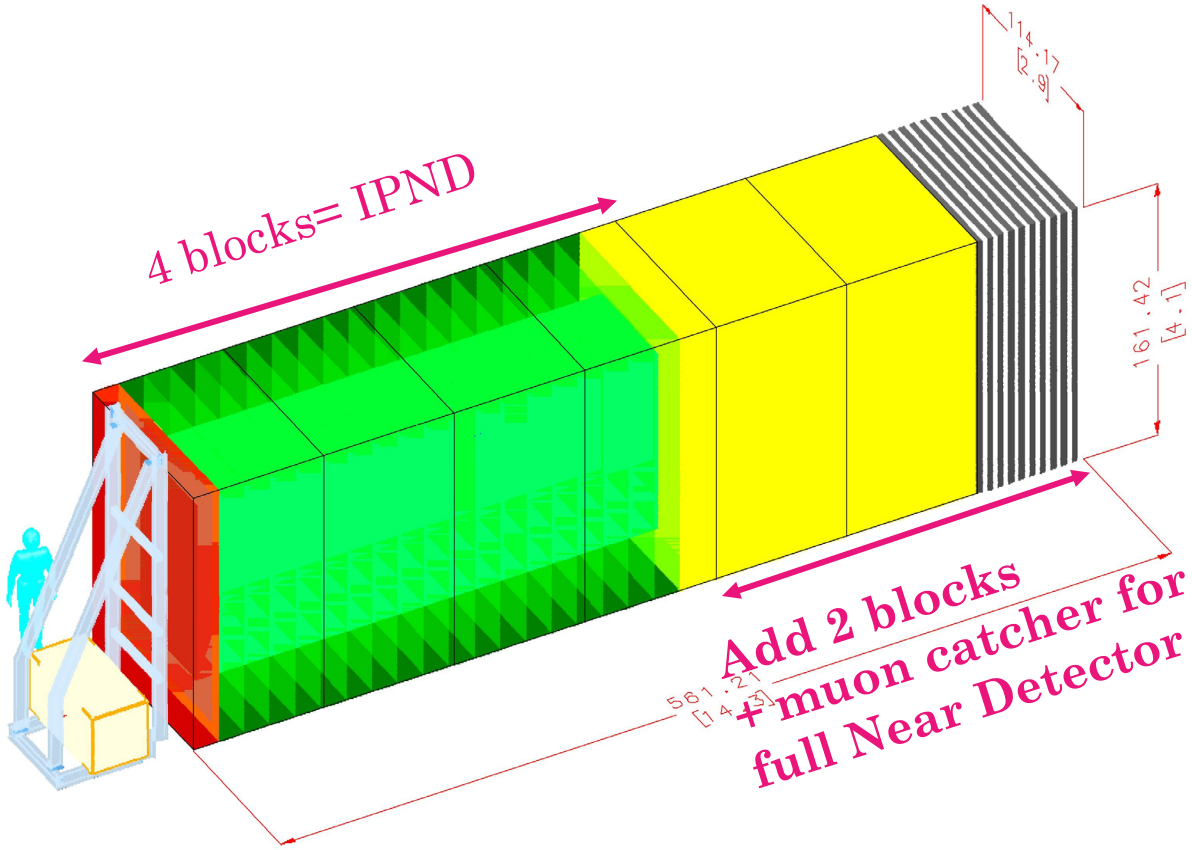
Off-Axis beam features

- Narrow energy distribution
- Tuned Energy by selecting off-axis angle
  - Maximize ν_e appearance
  - Minimize ν_μ
- Higher Intensity at a given energy
- Suppressed high energy tail
  - Reduces NC contamination

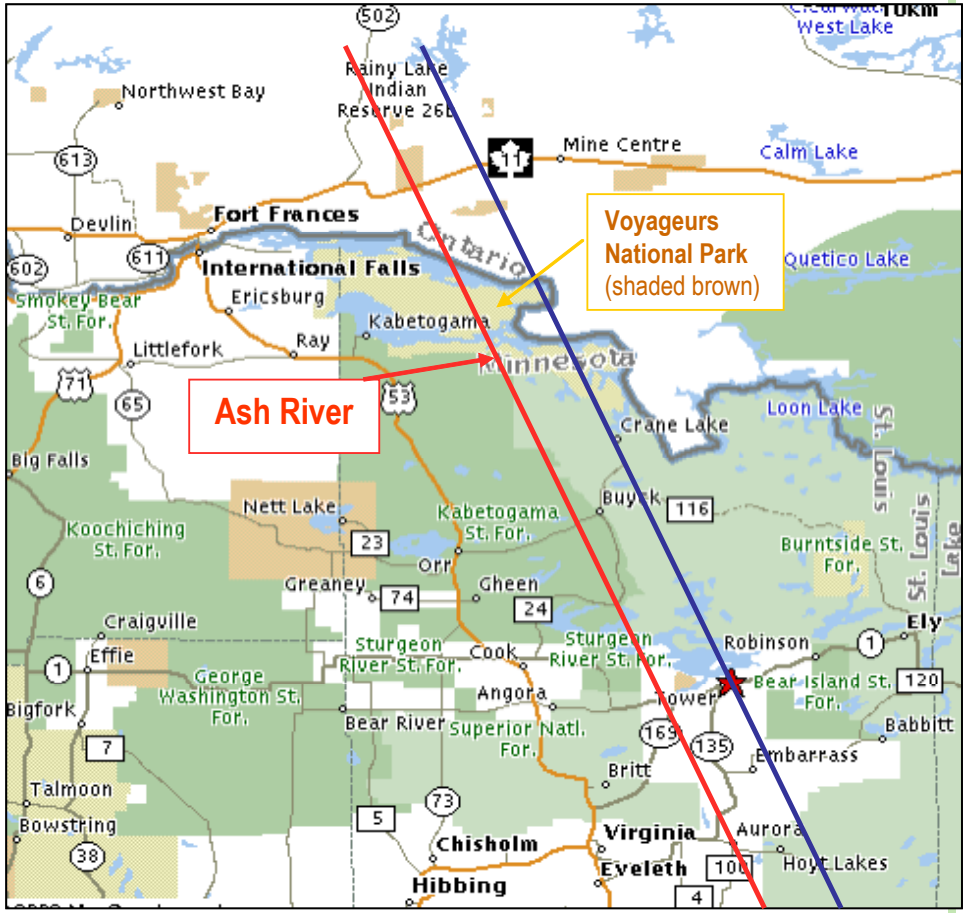


Integration Prototype Near Detector (IPND)

- Constructing prototype detector to run on the surface near MINOS Surface Building
- 4 Blocks (6+)
- 2.9m wide
- 4.2m tall
- 8.4m long (15.3m)



Site for Far Detector: Ash River, MN



- This site is at 810 km from Fermilab, 11.77 km off-axis
- Farthest available site in the U.S. along the NuMI beam

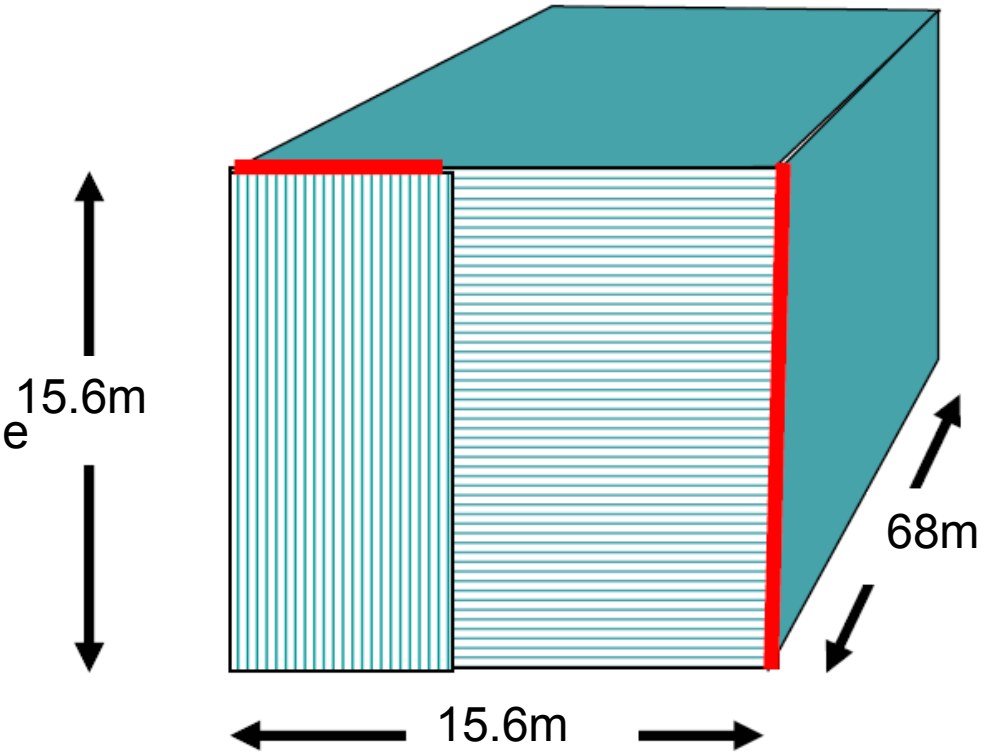
Far Site Status

NOvA

Groundbreaking: Friday, May 1, 2009, at 2:30 p.m.

NOnA Far Detector

- 15 ktons
- 15.6m x 15.6m x 68m
- 1003 liquid scintillator planes, (~73% active)
- Scintillator cells 3.8 x 6.0 x 1540 cms
- Read out from one side per plane with APDs
- Expected average signal at far end of 30pe

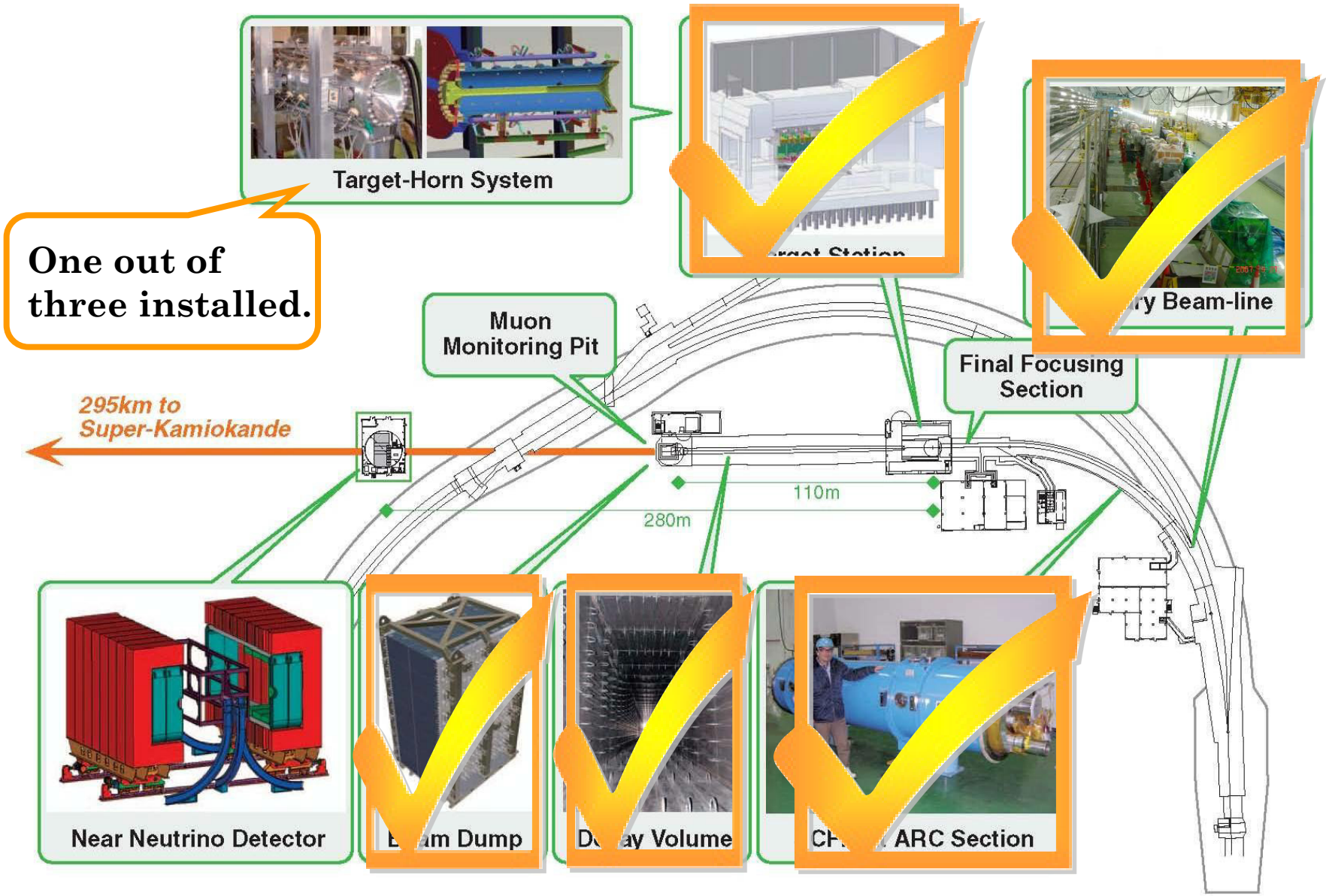


3. STATUS OF T2K AND NOvA.

T2K

- T2K Commissioning/Construction status

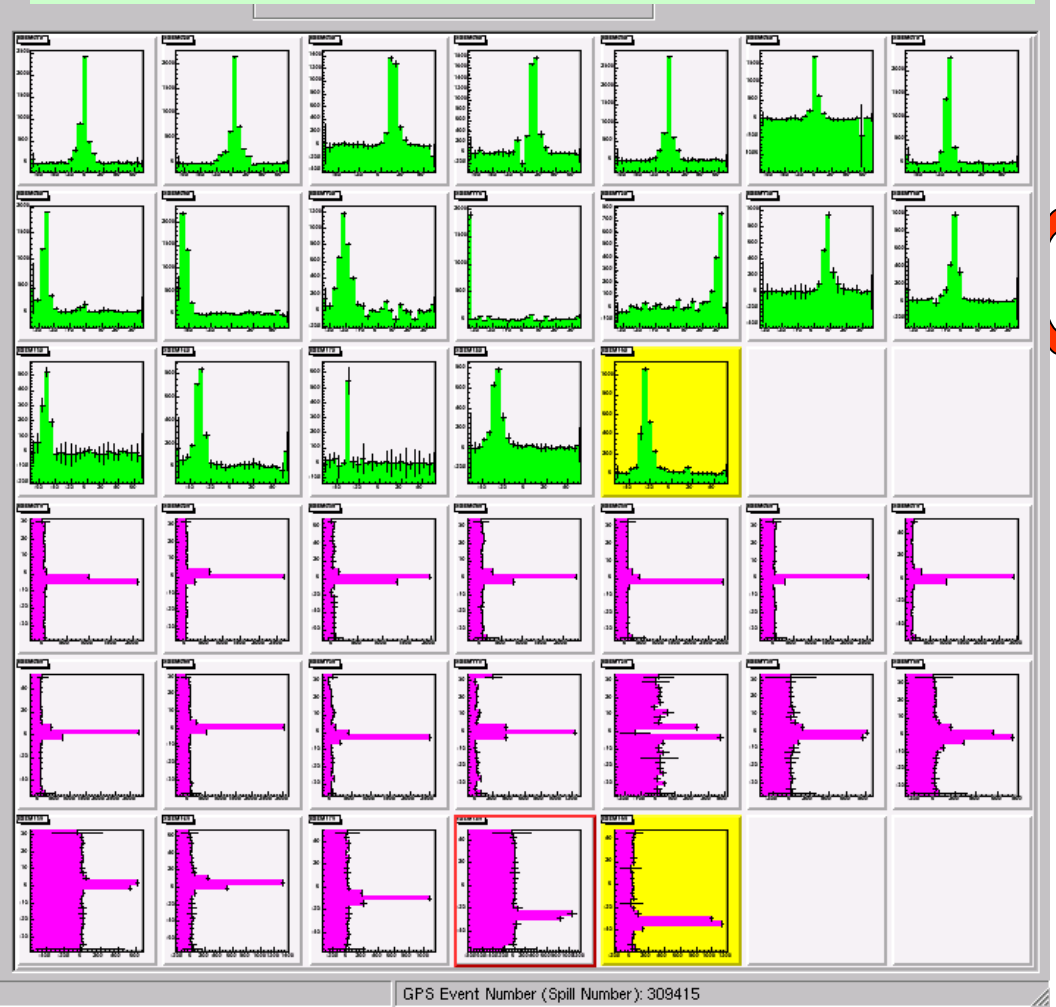
The Neutrino Beam-Line

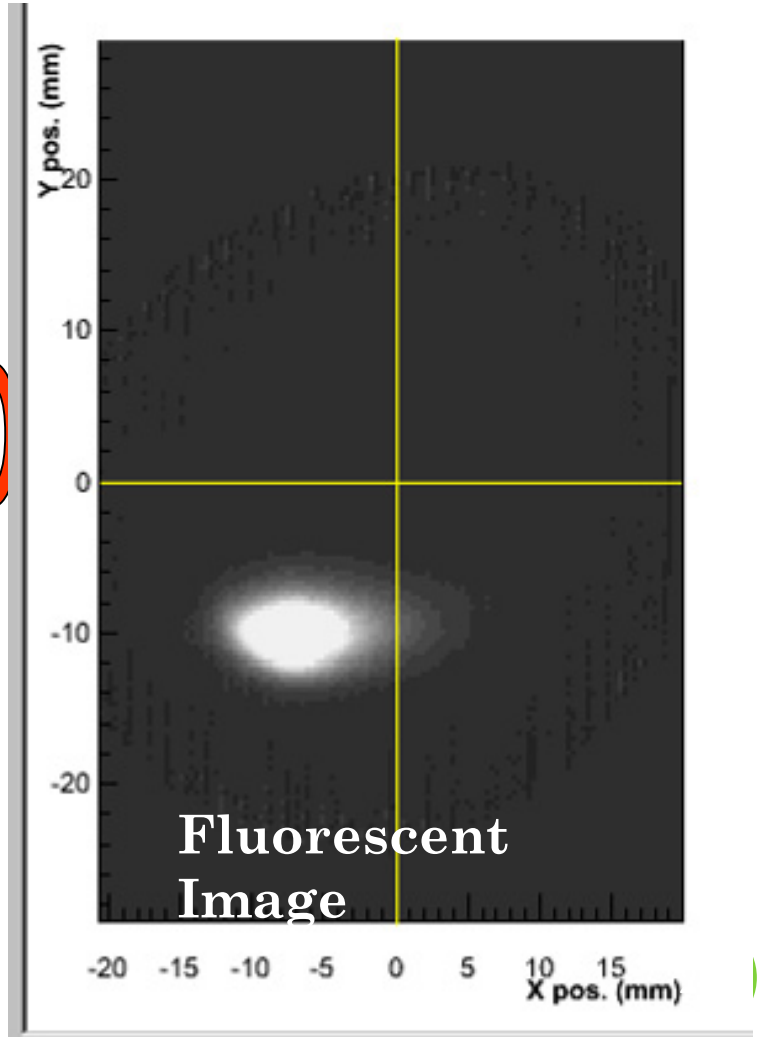


First shot of the proton beam

SSEM

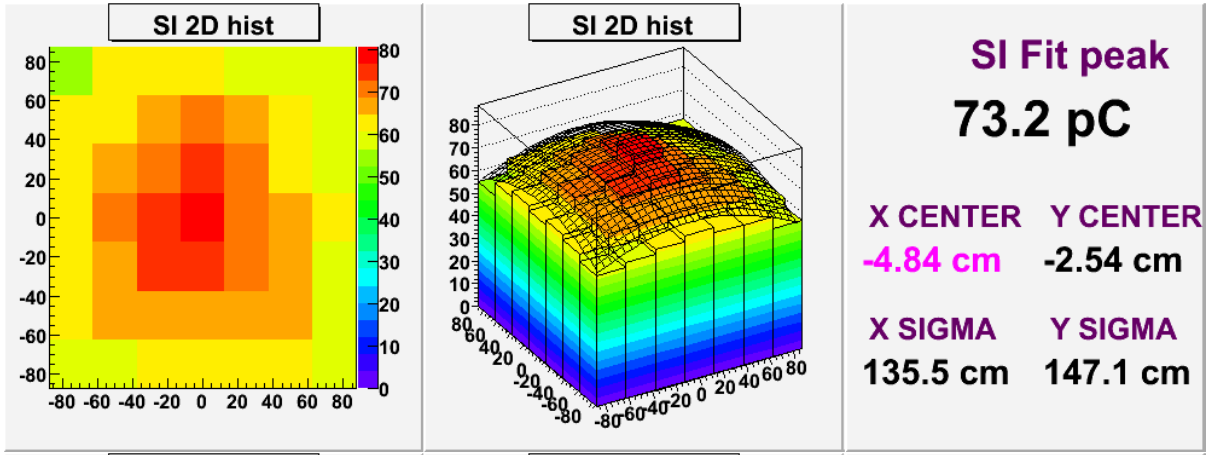
(Segmented Secondary Emission Monitor)



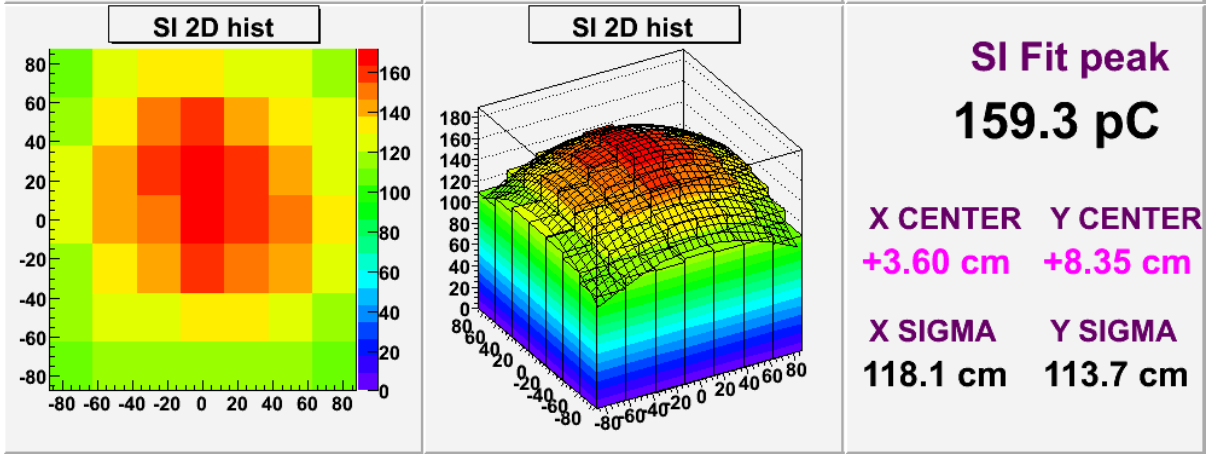


Horn focusing: Muon Monitor Signal

Horn off



Horn on

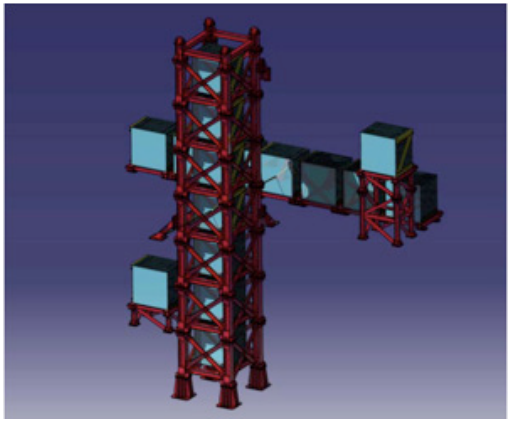


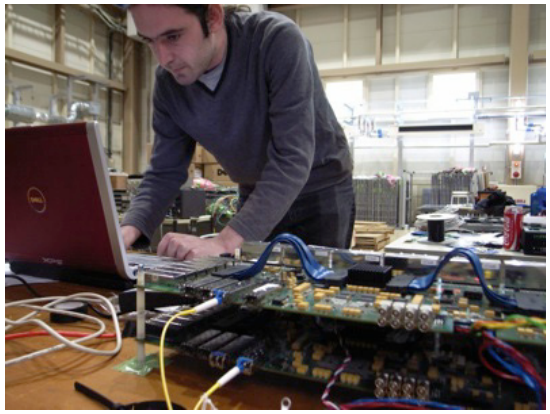
MUMON Silicon PIN photodiode array

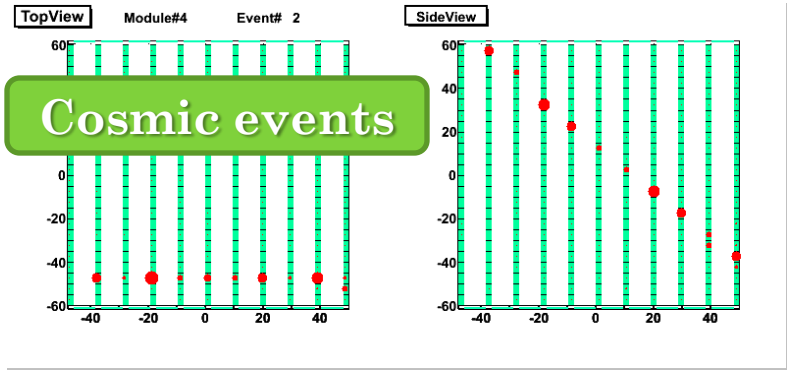
Achievement in April and May

- Nominal intensity: ~4x10^{11} p/bunch, 1 bunch/spill (~0.1% of design intensity)
- Superconducting combined-function magnets are working well as expected.
- Beam monitors are working well.
  - Intensity monitors, beam position monitors, beam profile monitors are working well.
  - Beam position at the target is confirmed with the fluorescent plate.
  - Muons from π decays are observed by MUON MONITOR behind the beam dump.
- The effect of the electromagnetic horn is confirmed.
- Successfully passed the government inspection.

On-axis detector: INGRID







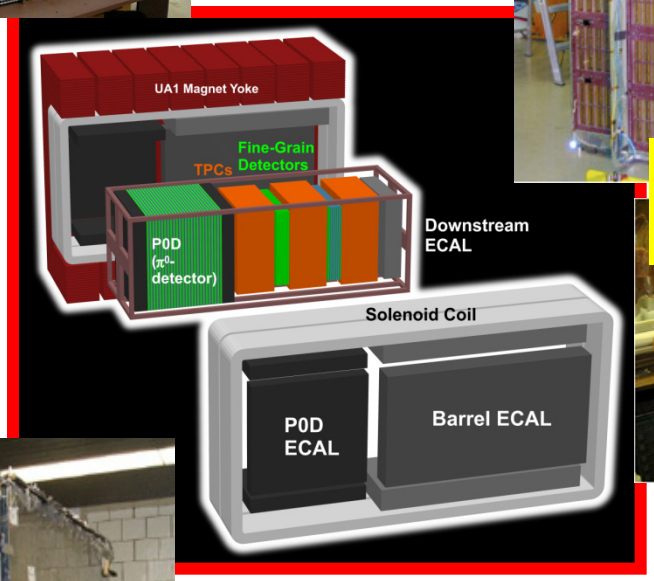
- Assembly of 228 tracking planes completed
- **Looked for neutrino events with one module.**
- Half modules have been installed. (The rest of modules will be installed in August)

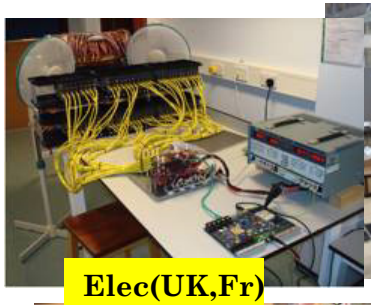
31

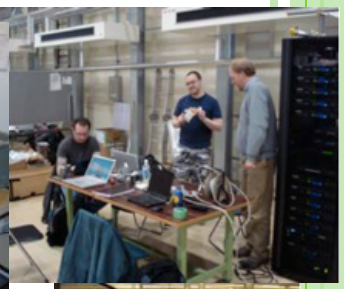
Off-axis Detectors

FGD(Canada, Japan)

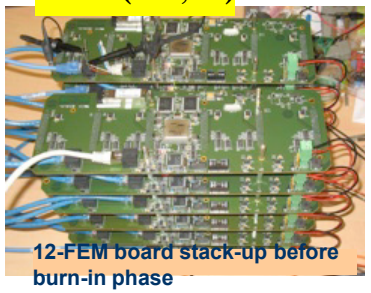
TPC(Canada/France, Spain, Swiss, Italy, German)



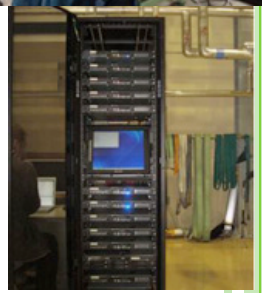




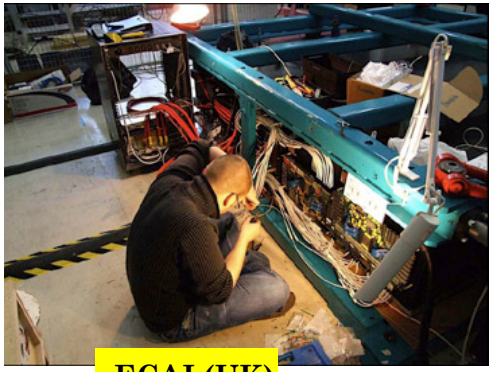
Elec(UK,Fr)



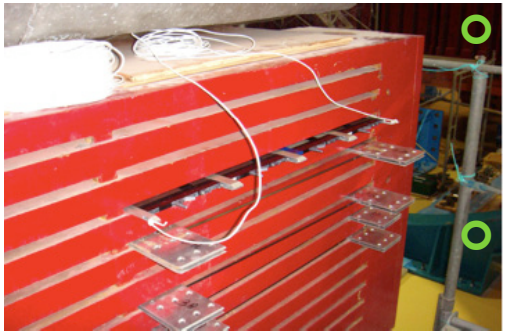
12-FEM board stack-up before burn-in phase



P0D(US)



ECAL(UK)



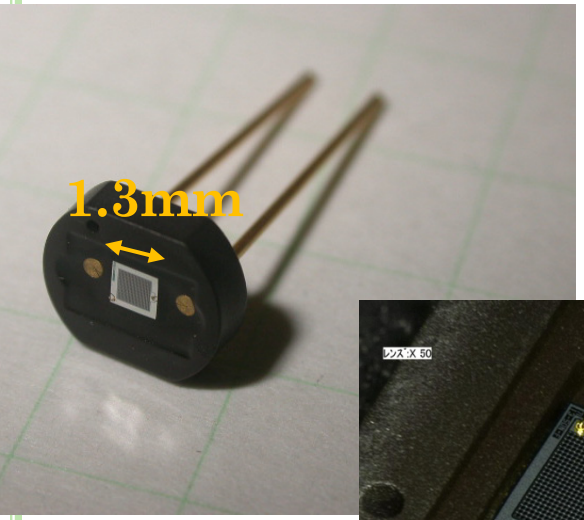
SMRD(Jp,US,Pol,Rus)

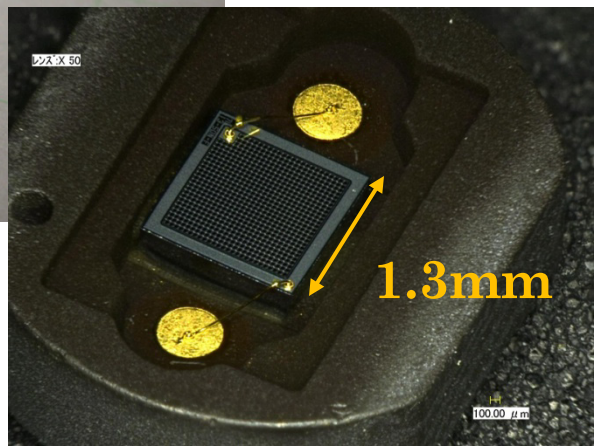
- Most detectors have been arrived in J-PARC.
- Installation will begin in September.
- The detector will be ready by the end of 2009.

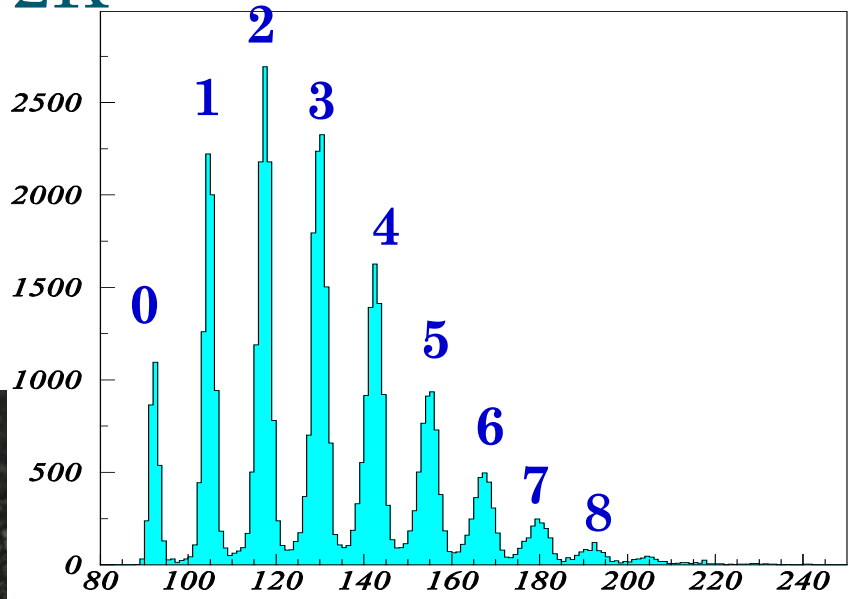
32

HAMAMATSU MPPC

- **M**ulti-**P**ixel-**P**hoton-**C**ounter
  - Multi-pixel APD operating with Geiger mode (667 pixels.) specially developed for T2K
  - New type photo-sensor w/ excellent performance.
  - Insensitive to magnetic field.
- 60,000 production for T2K







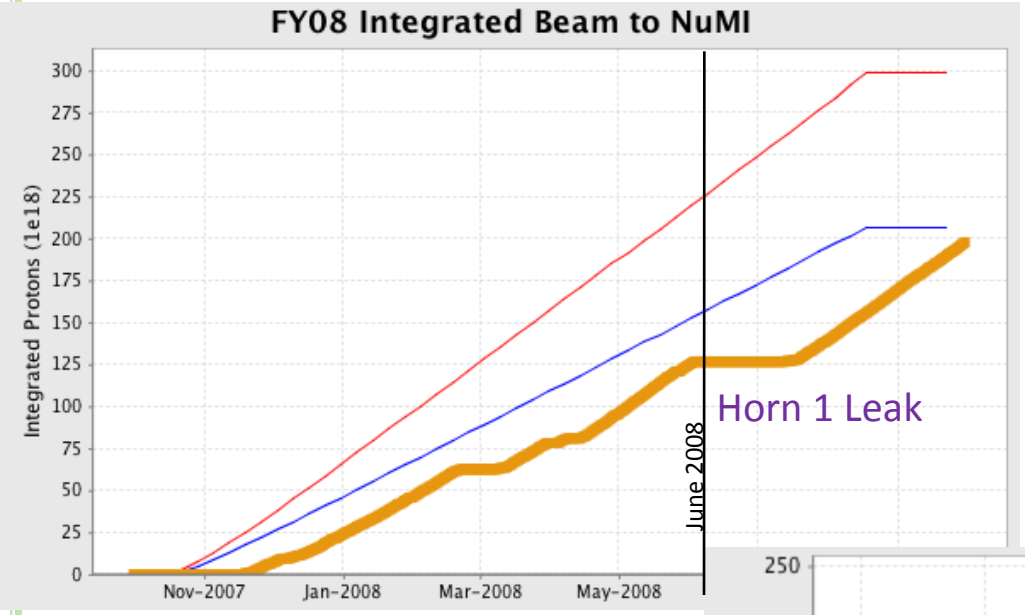
From Now

- **Full horns and ND280 soon**
- **100kW trial in JFY2009**
- **Physics run from 2010 → fist result**
- **Beyond 100kW: 100→750kW(Design)**
  - **Beam loss control**
  - **Linac 400 MeV energy recovery and upgrade of the RCS injection system**
  - **Important Physics result around 2012 (my personal view)**
- **Long-term plan toward power frontier (~1.7 MW)**
  - **KEK roadmap**
  - **Anti-ν running**

3. STATUS OF T2K AND NOvA.

NOvA

NuMI Protons



The amount of beam is limited by losses in the Main Injector tunnel

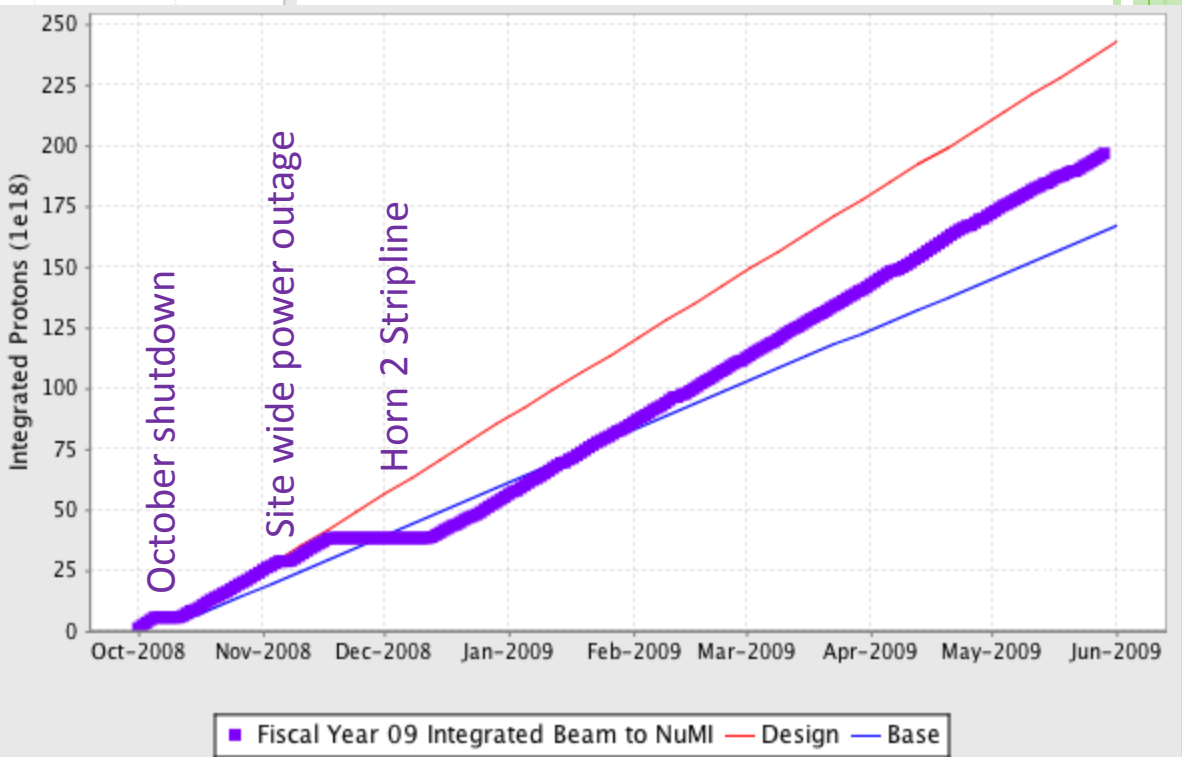
NuMI beam power:

290KW nominal mix mode

330KW NuMI-only mode

11 Batch Slip Stacking (9 batches for NuMI) was implemented in April 2008

A few places where greater slope was due to non stacking periods and NuMI received all 11 btaches



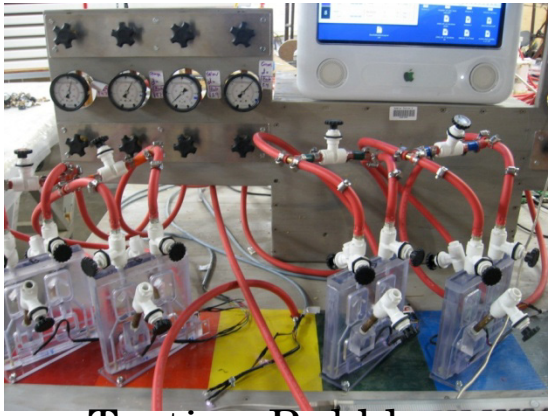
NOvA Ground Breaking
1 May 2009

Progress

- Advances on all fronts
  - Accelerator and NuMI Upgrades (ANU) extensive shutdown plans beginning upgrades necessary for 700kW operation.
  - Module components prepared, or contracts made for prototype detector. (Integration Prototype Near Detector (IPND), and more, where approved)
  - Assembly prototypes under construction
    - Static leak tests, full height, in C0, full pressure.
    - FSAP, Full Size Assembly Prototype
    - FHEP, Full Height Engineering Prototype , 31 planes 2 modules wide

Module Assembly and Testing

Bubbler Construction



Testing Bubblers

Extrusion production

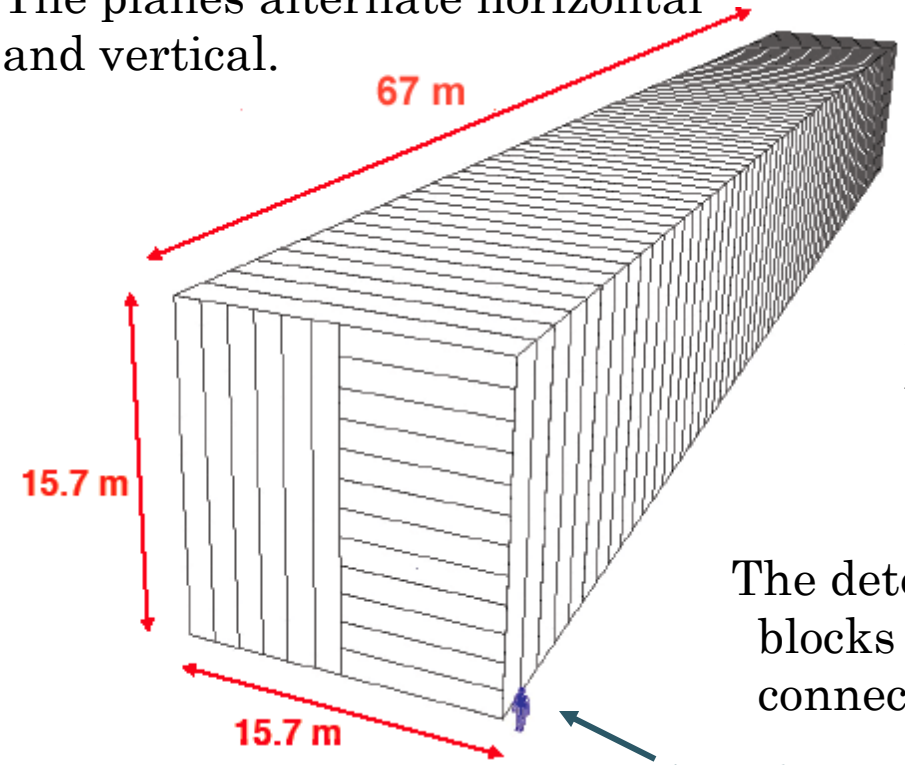
Rolling Lifting Fixture

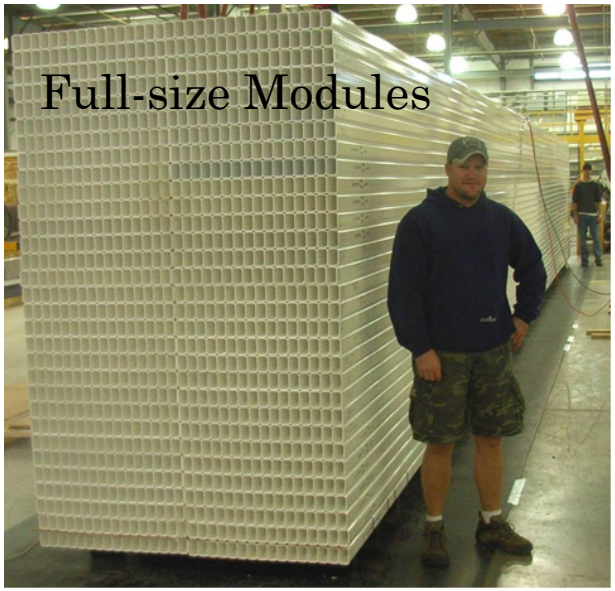
Adhesive Dispenser

Far Detector

The cells are made from 32-cell extrusions.

12 extrusion modules make up a plane. The planes alternate horizontal and vertical.





There are 1003 planes, for a total mass of 15 kT. There is enough room in the building for 18 kT, which can be built if we can preserve half of our contingency.

The detector can start taking data as soon as blocks are filled and the electronics connected.

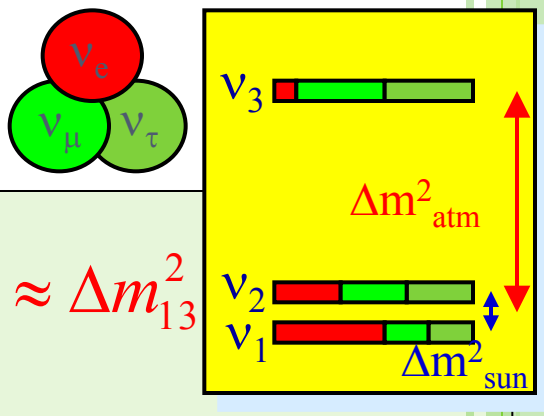
Approximate Schedule of NOvA

- May 2007: US DOE CD-1 Approved
- Sep 2007: Cooperative Agreement signed
- Nov 2007: US DOE CD-2/3A review
  - Baseline, advanced procurement
- Dec 17, 2007 R&D funding for FY08 cut to zero.
- July 1, 2008 Supplementary funding restarts progress
- Sept 15, 2008, Oct 24, 2008: CD-2, CD-3A Approved
- April 2009: Reinvestment Act, and FY09 funding approved
- May 1, 2009 Groundbreaking at Ash River
- Fall 2009 Begin Building IPND modules
- Winter 2009/10 Begin building IPND Blocks
- **Summer 2010 Begin operation of IPND (prototype Near Det.)**
- Summer 2010: Beneficial Occupancy of the Far Detector building
- **Winter 2011: Begin to Install FD, Data taking after a few kT installed**
- **2013 Installation Complete**

4. Physics Sensitivity

T2K

T2K Measurements



Oscillation Probabilities when $\Delta m^2_{12} << \Delta m^2_{23} \approx \Delta m^2_{13}$

- θ_{23} : ν_μ disappearance

$$P_{\nu\mu\to\nu x} \approx 1 - \underbrace{\cos^4\theta_{13}}_{\sim 1} \cdot \sin^2 2\theta_{23} \cdot \sin^2\left(1.27\Delta m^2_{23} L / E_\nu\right)$$

- θ_{13}: ν_e appearance

$$P_{\nu\mu\to\nu e} \approx \underbrace{\sin^2\theta_{23}}_{\sim 0.5} \cdot \sin^2 2\theta_{13} \cdot \sin^2\left(1.27\Delta m^2_{23} L / E_\nu\right)$$

common

- δ : CP violation (T2K-II)

$$A_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)} \cong \cdots$$

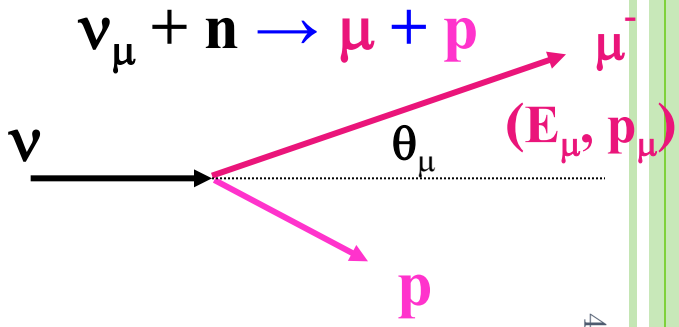
~ 0.18 ($\sin^2 2\theta_{13}$=0.1)

~ 0.58 ($\sin^2 2\theta_{13}$=0.01)

$\cdot \sin\delta$

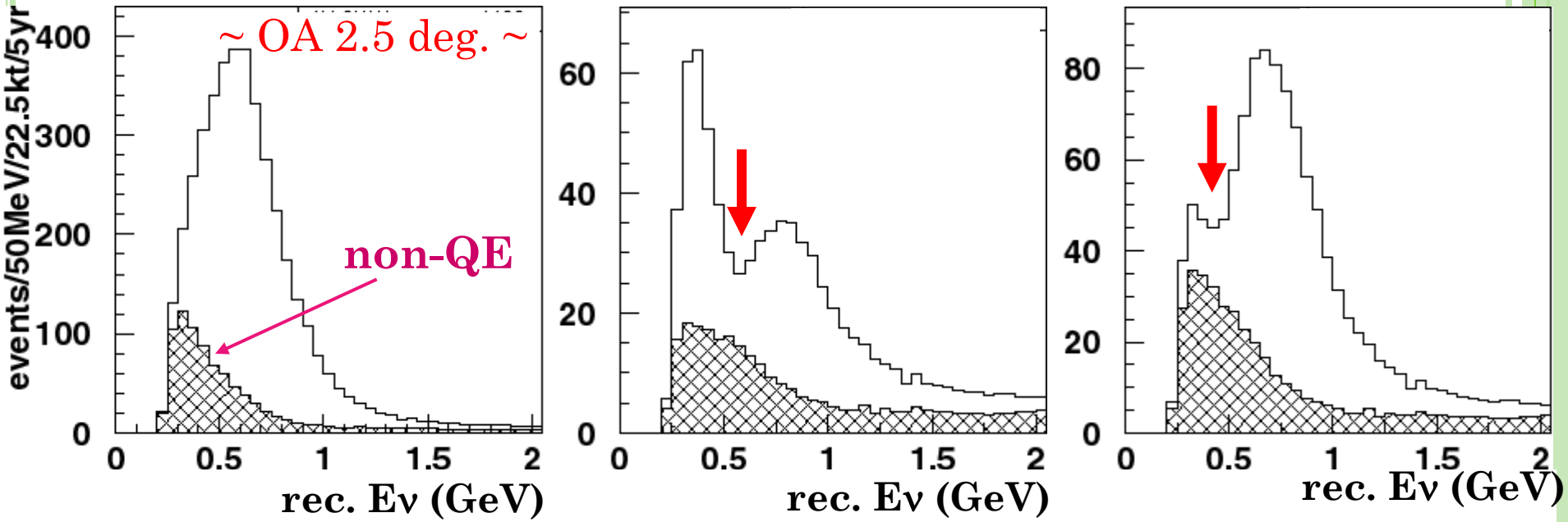
Measurement of θ_{23} , Δm_{23}^2

Use 1 ring μ-like events
(= **Quasi-Elastic** enhanced sample)
to reconstruct neutrino energy.



5 years

No oscillation **Δm^2= 2.5 x10^{-3} eV^2** **Δm^2= 2.0 x10^{-3} eV^2**

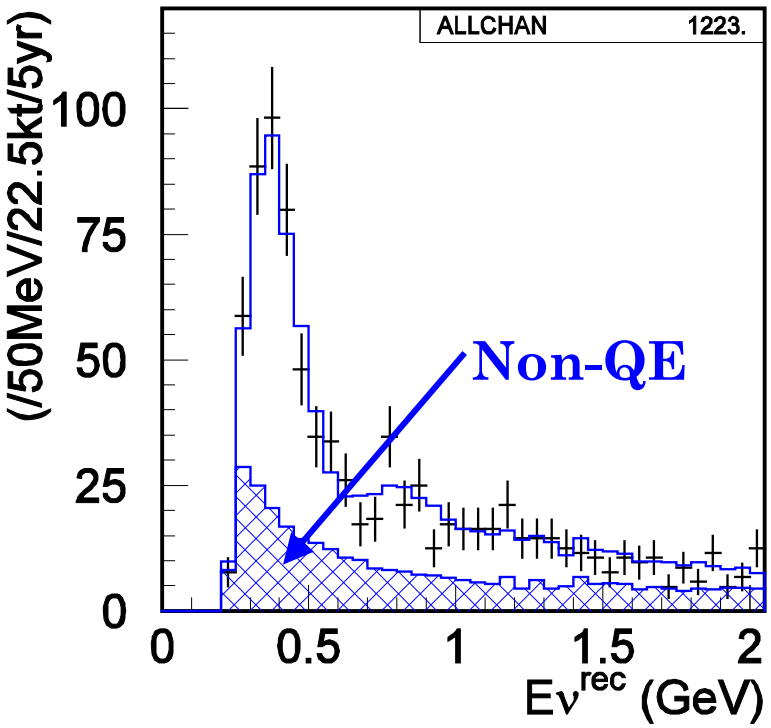


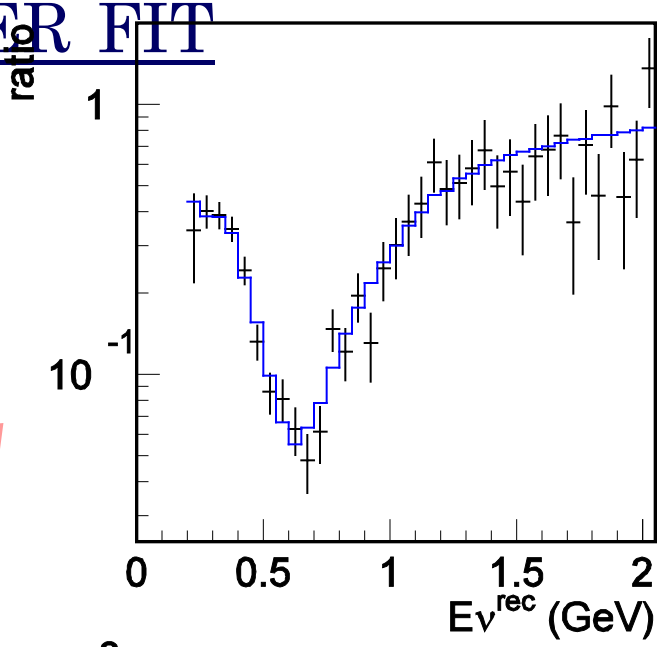
(assuming $\sin^2 2\theta_{23}$=1.0)

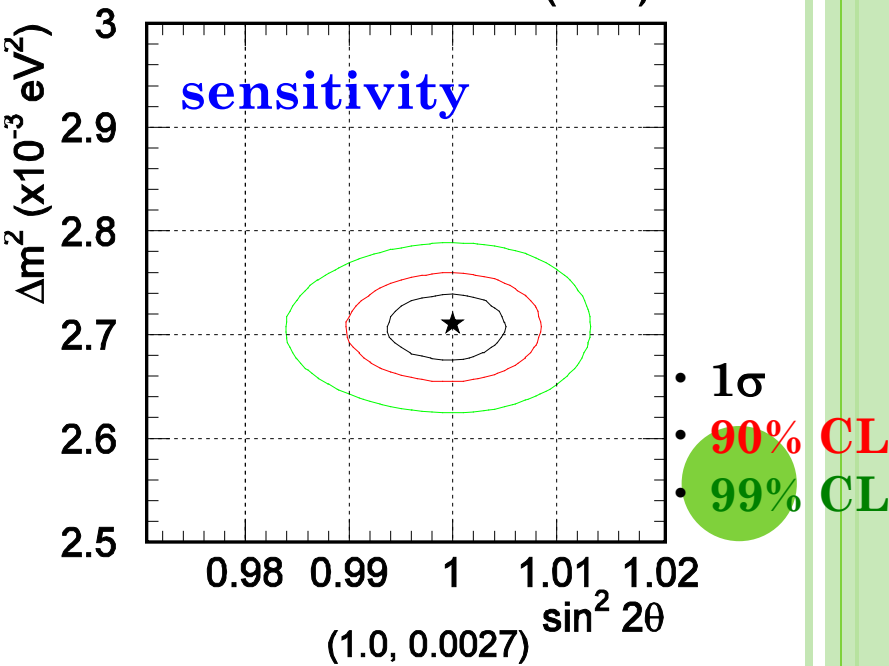
Oscillation Parameter Fit

Ratio of E_ν to non-oscillation

Input:
$\sin^2 2\theta_{23}=1.00$
$\Delta m^2= 2.7 \times 10^{-3}$ eV^2







θ_{13} measurement (ν_e appearance search)

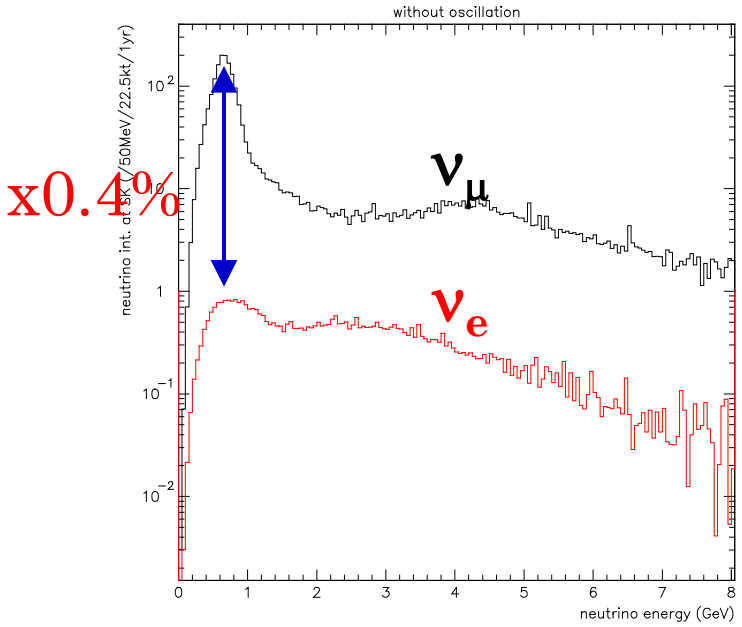
$\sin^2 2\theta_{23}=1$ and $\delta=0$ are assumed.

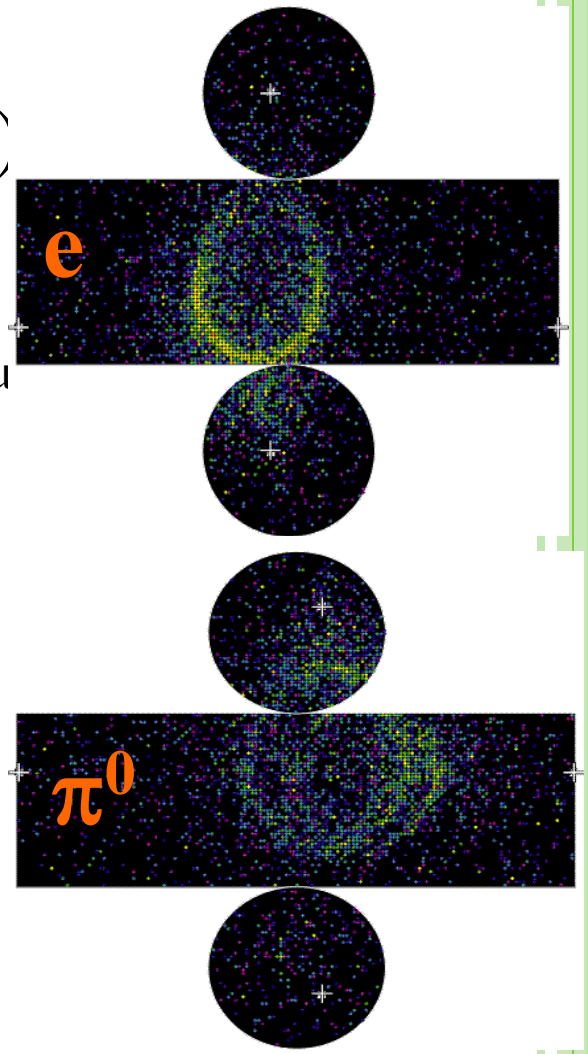
Signal:

- 1ring e-like event (CC QE sample)

Background:

- beam ν_e contamination (0.4% of ν_μ)
- mis-reconstructed π^0 event

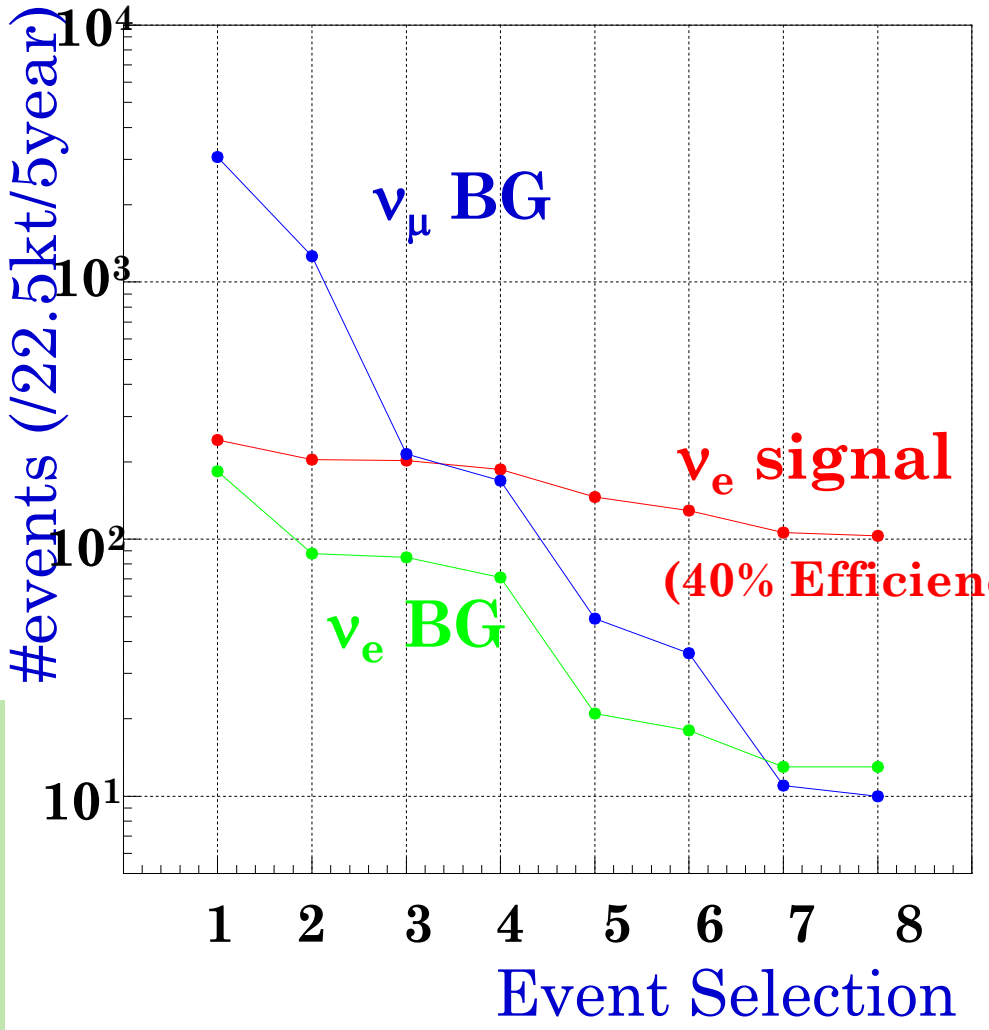


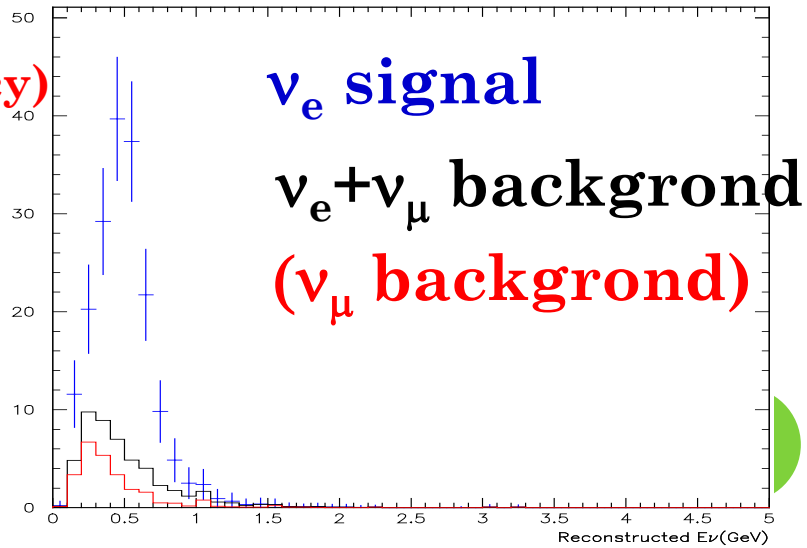


Background Suppression

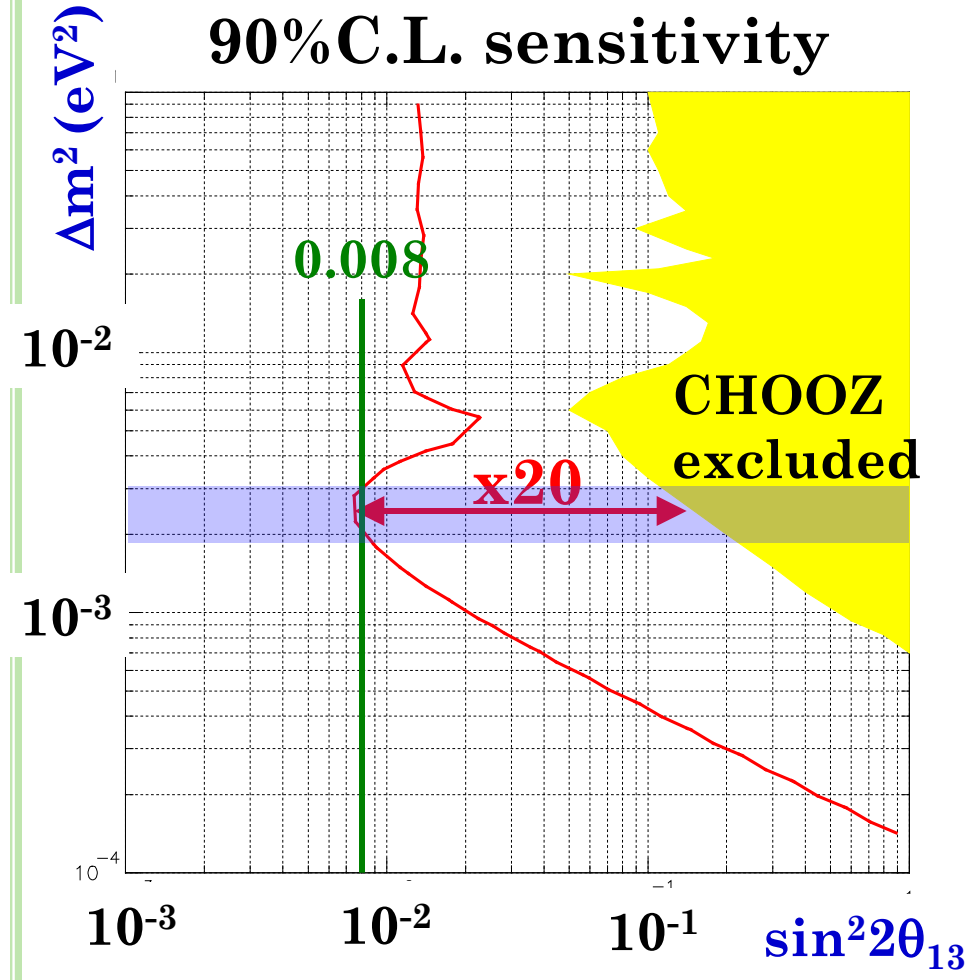
($\Delta M^2=2.5\times10^{-3}eV^2$, $\sin^2 2\Theta_{13}=0.1$)

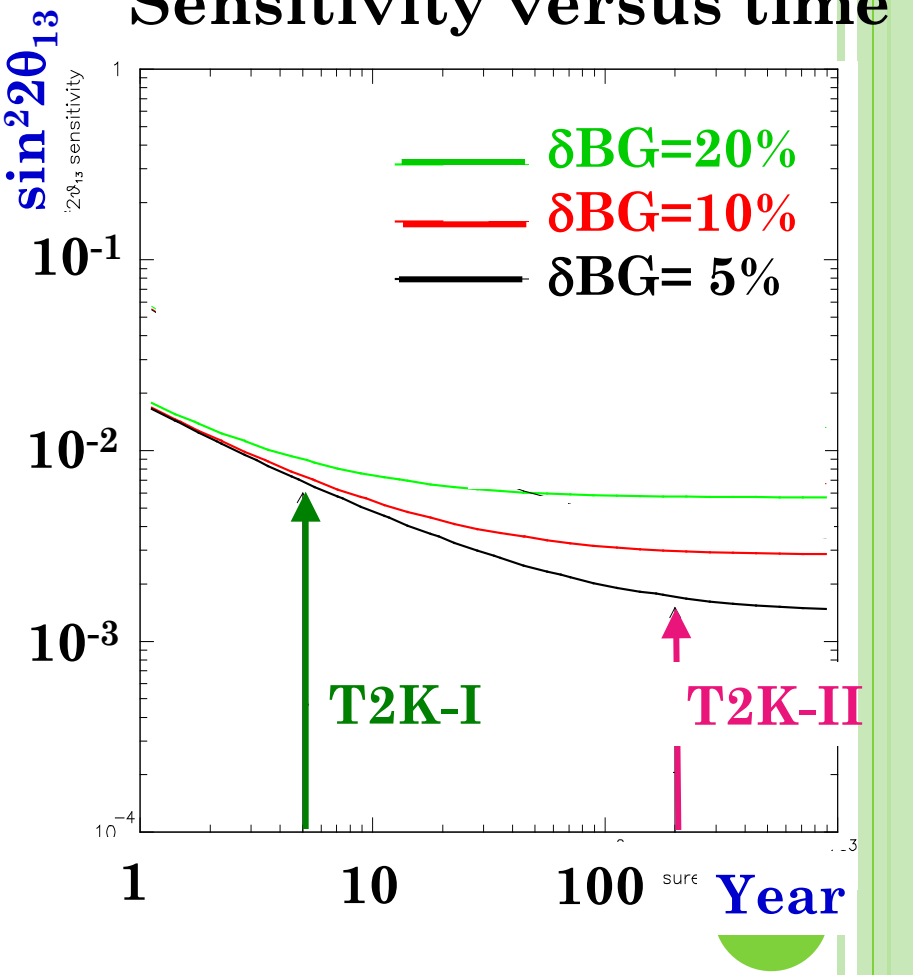
1. FCFV, $E_{vis.}$ >100MeV
2. single ring
3. e-like PID
4. no decay-electron
5. $0.35<E_\nu^{rec}<0.85$GeV
6. $\cos\theta_{\nu e}<0.90$
7. $M_{\pi0}<100MeV/c^2$(π^0 fitter)
8. $\Delta L<80$(π^0 fitter)





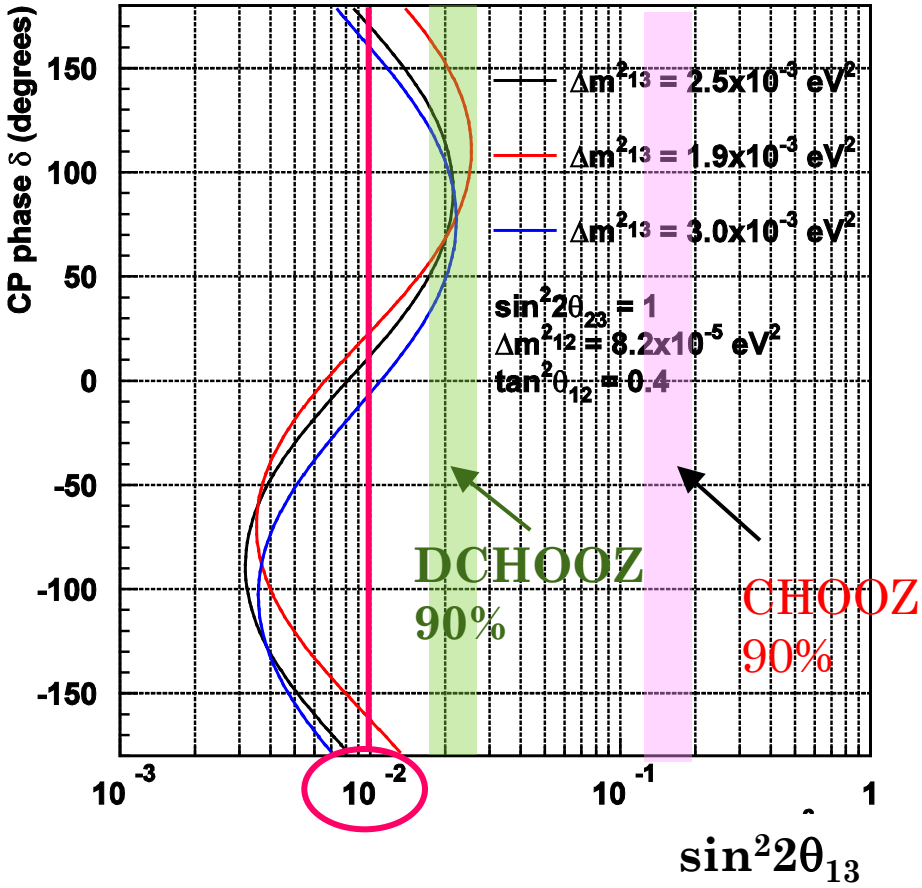
Θ_{13} Sensitivity (w/ ΔBG_{SYS}=10%)

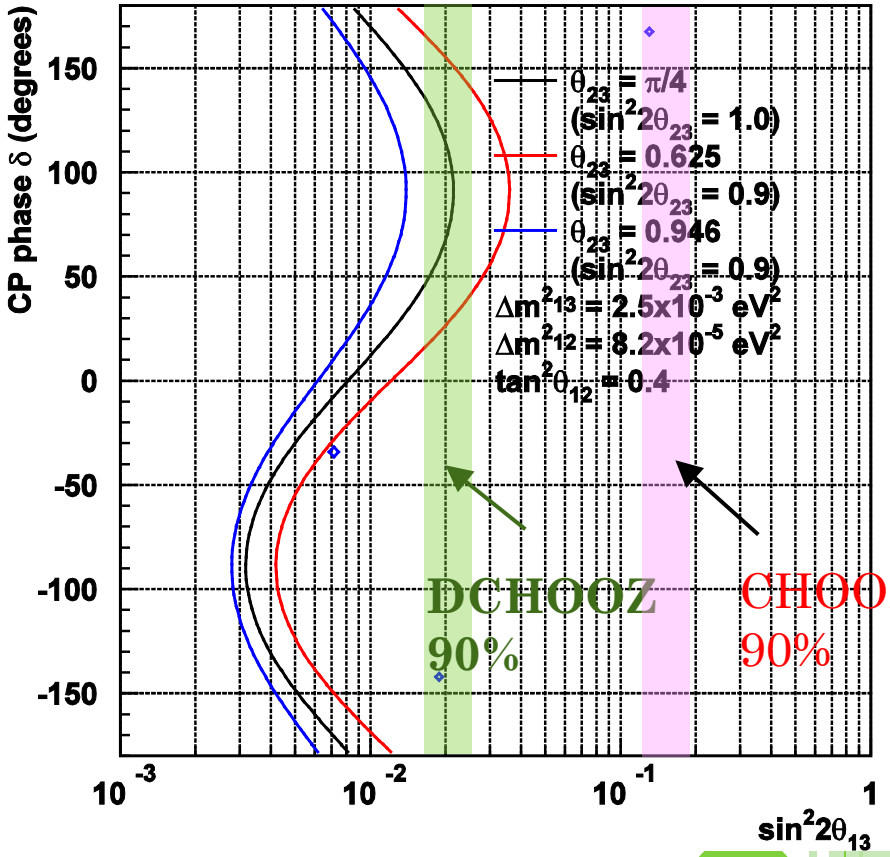




T2K Physics Sensitivity

ν_e appearance
(Strong δ dependence)

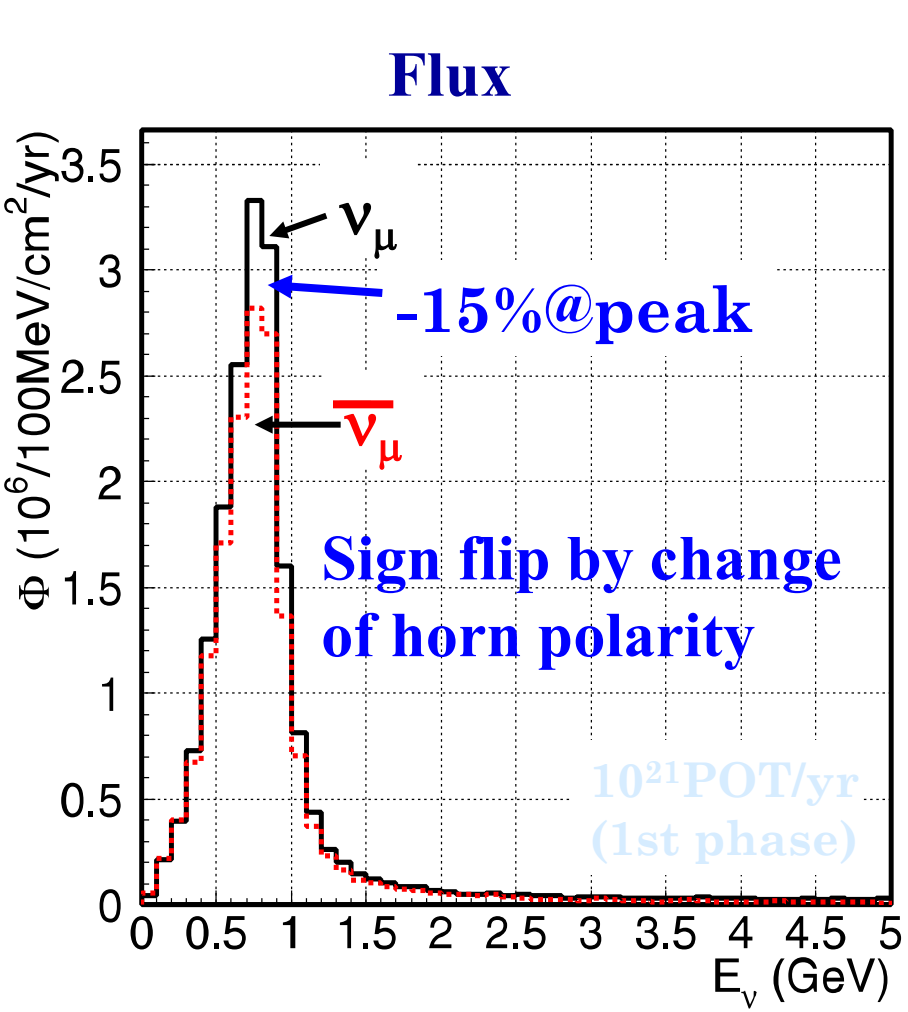


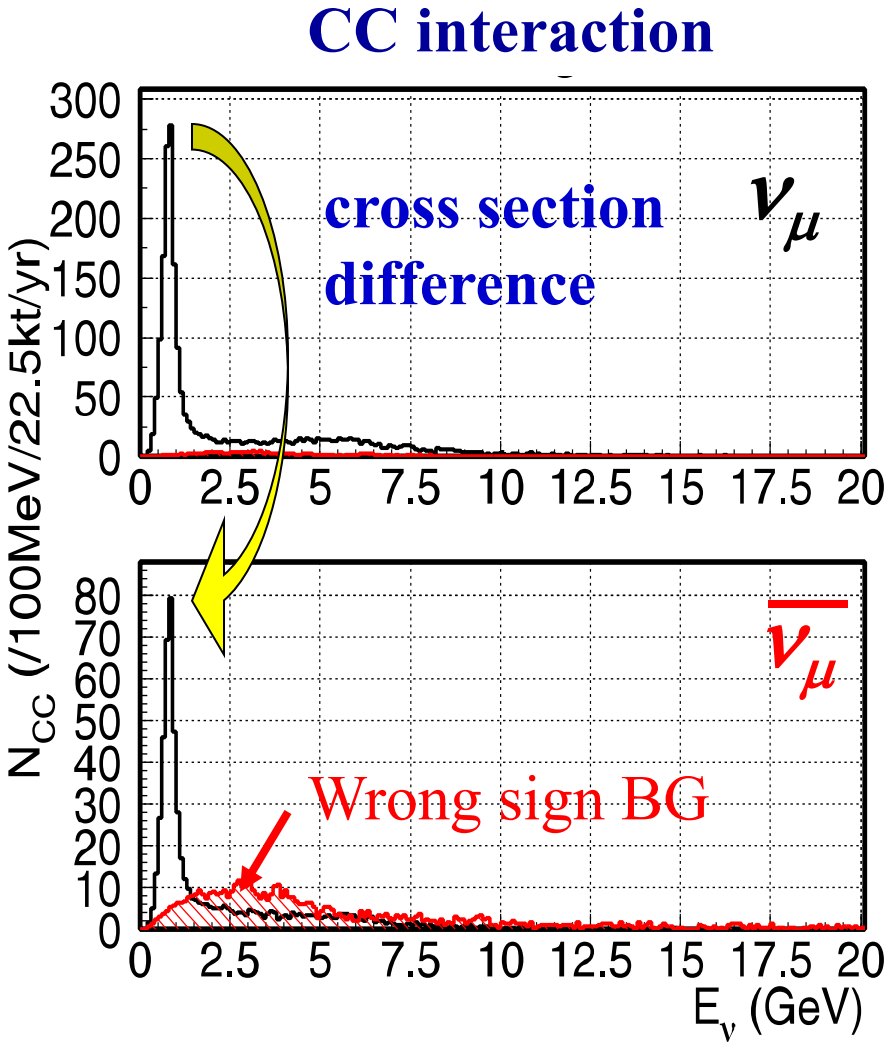


~10 times improvement from CHOOZ

CP VIOLATION STUDY $\bar{\nu}$ *beam is an option*

(Note: Old study with 2° off-axis)





4. Physics Sensitivity

NOvA

E CC EVENT

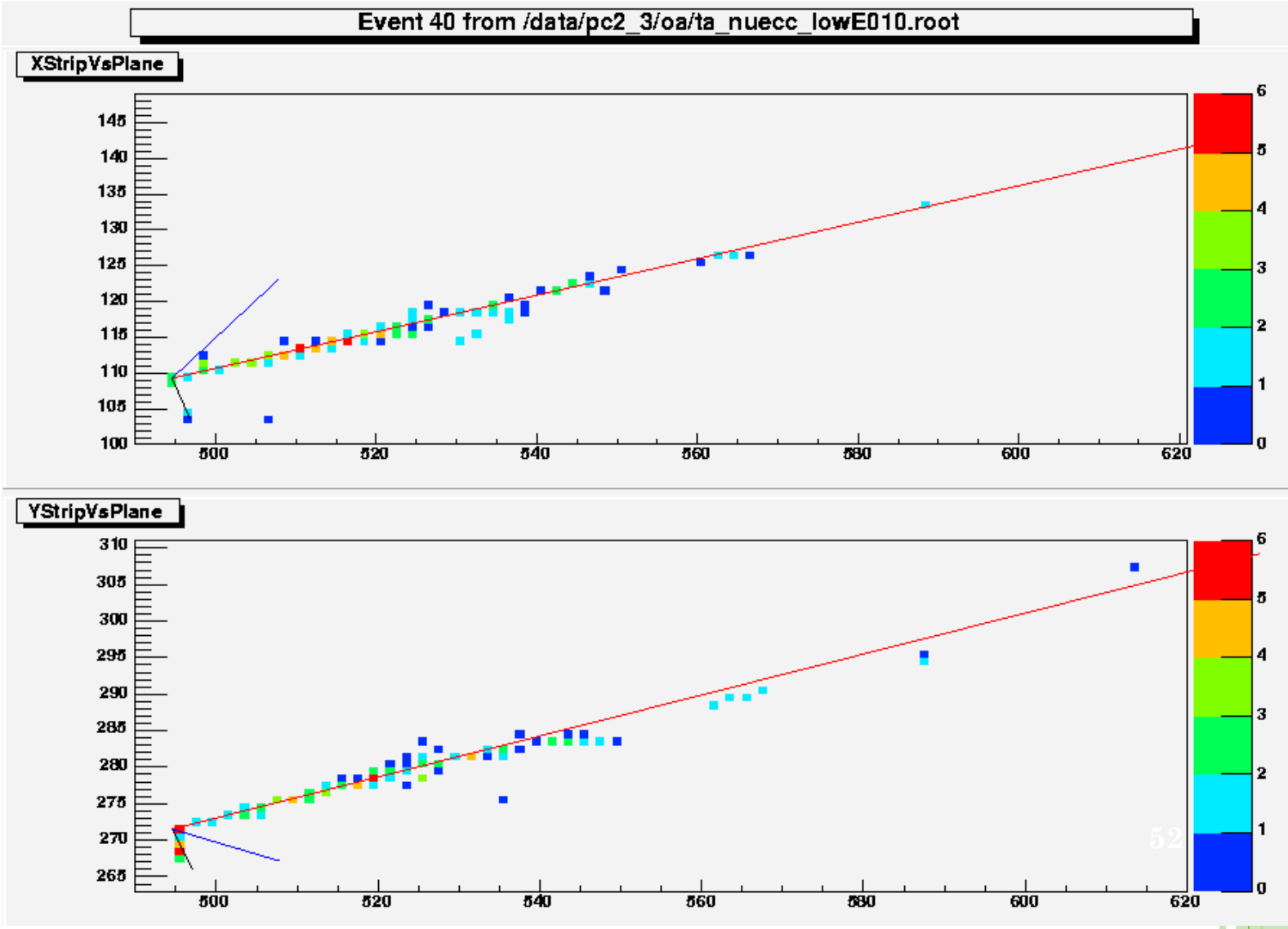
$\nu_e p \rightarrow e^- p \pi^+$

E_ν=2.5GeV

E_e=1.9GeV

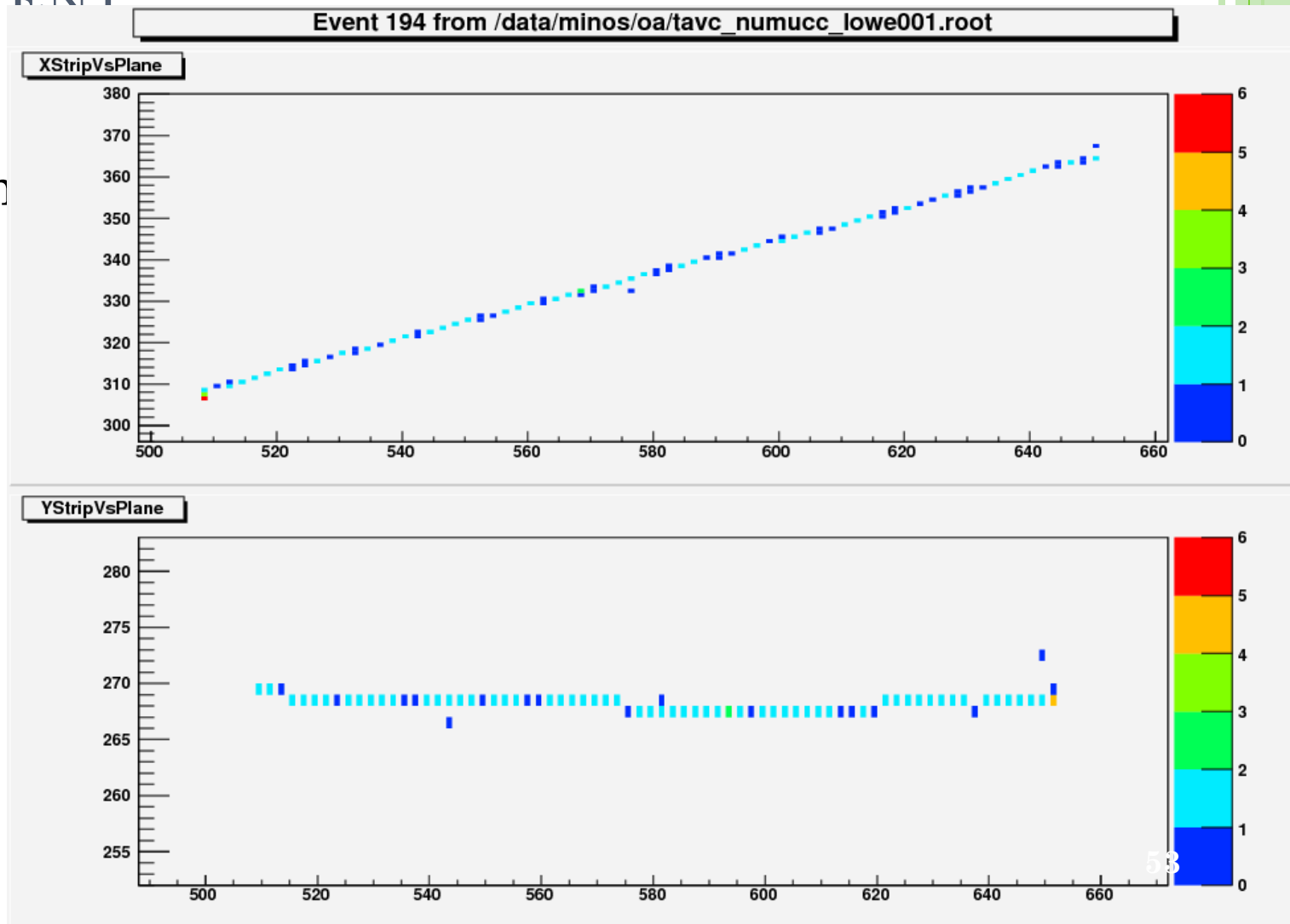
E_p=1.1GeV

E_π=0.2GeV



μ CC EVENT

- 2GeV muon CC event



μ CC EVENT

$\nu_\mu n \rightarrow \mu^- n \pi^+ \pi^o$

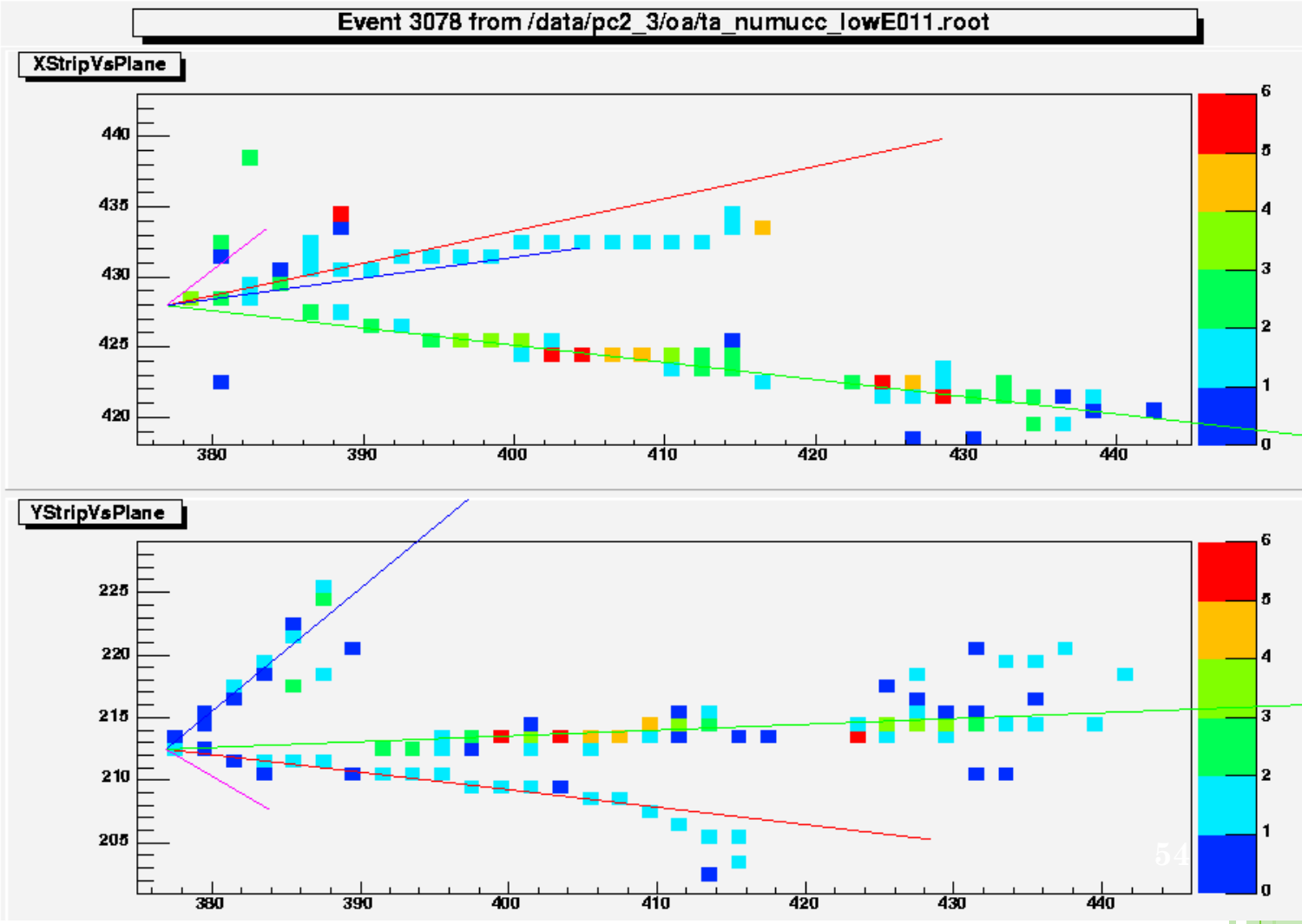
E_ν=2.8 GeV

E_μ=0.5GeV

E_n=1.0GeV

$E_{\pi+}$=0.4GeV

$E_{\pi o}$ =1.8GeV



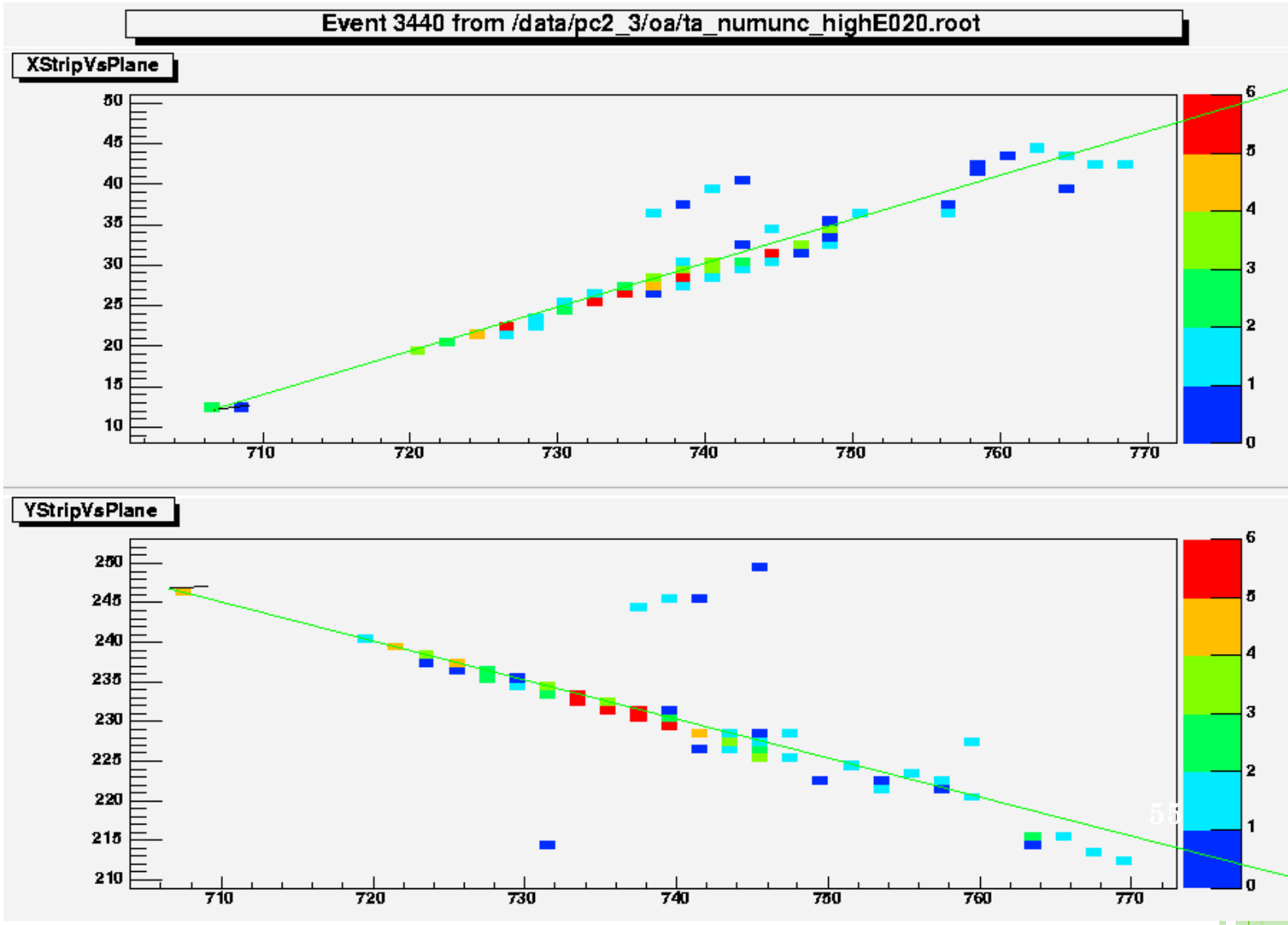
NC EVENT

$\nu_\mu N \rightarrow \nu_\mu p \pi^o$

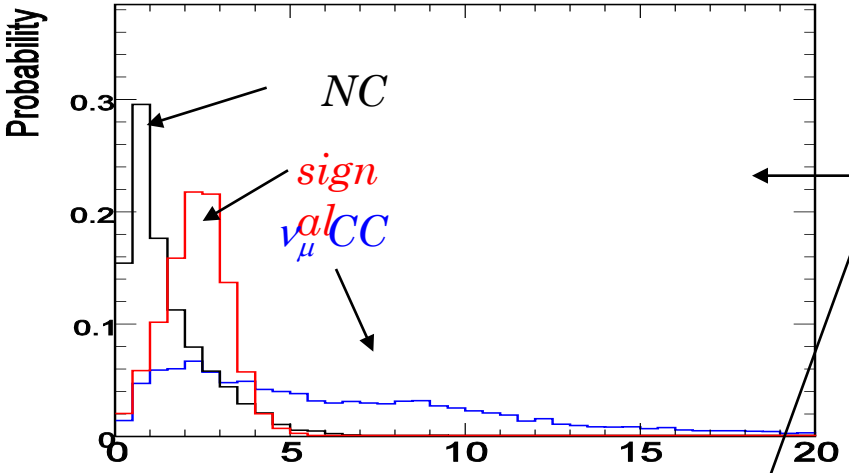
E_ν=10.6 GeV

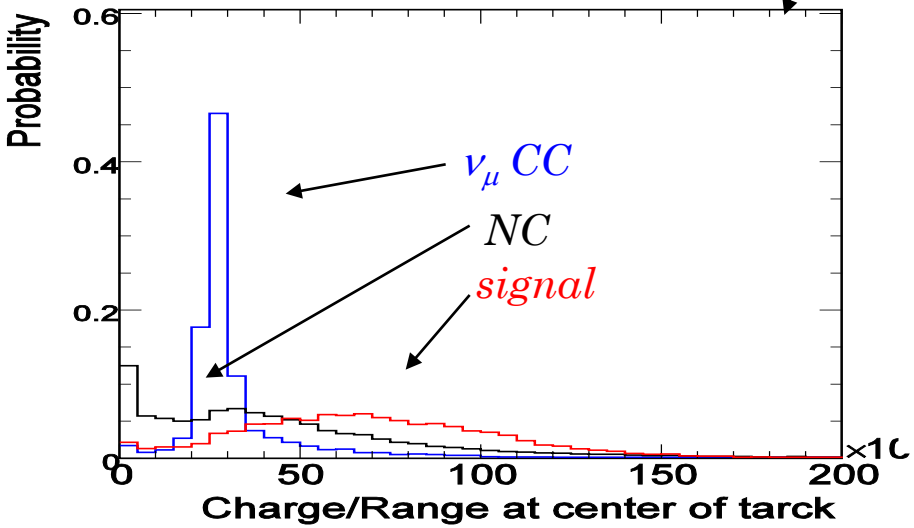
E_p=1.04GeV

$E_{\pi o}$ =1.97GeV



Electron Identification for NOvA (TDR Analysis)

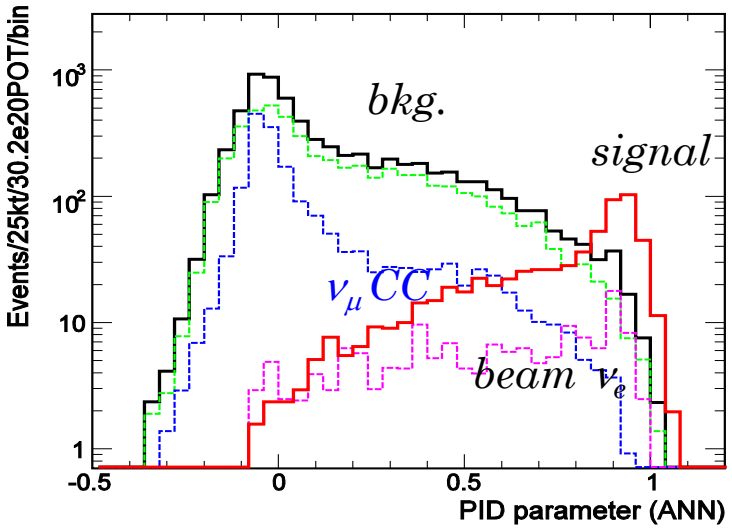




~20 variables in Neural Net

Example distributions

Overall efficiency ~30% (optimizable)



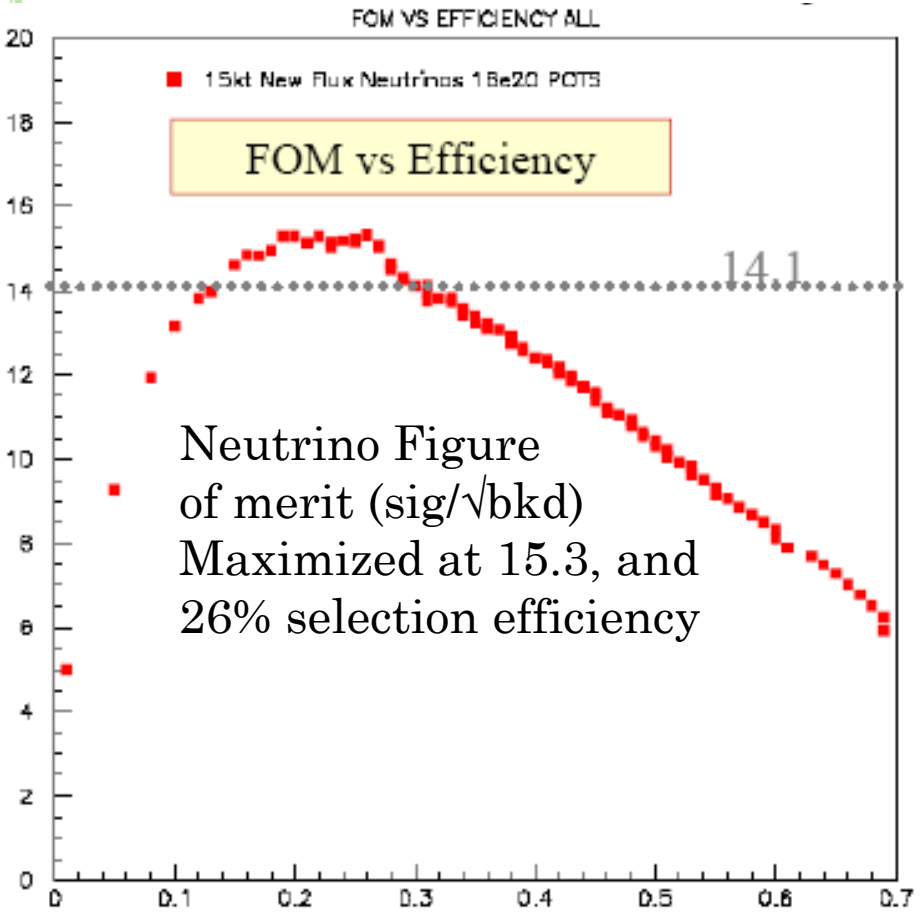
ANN Output

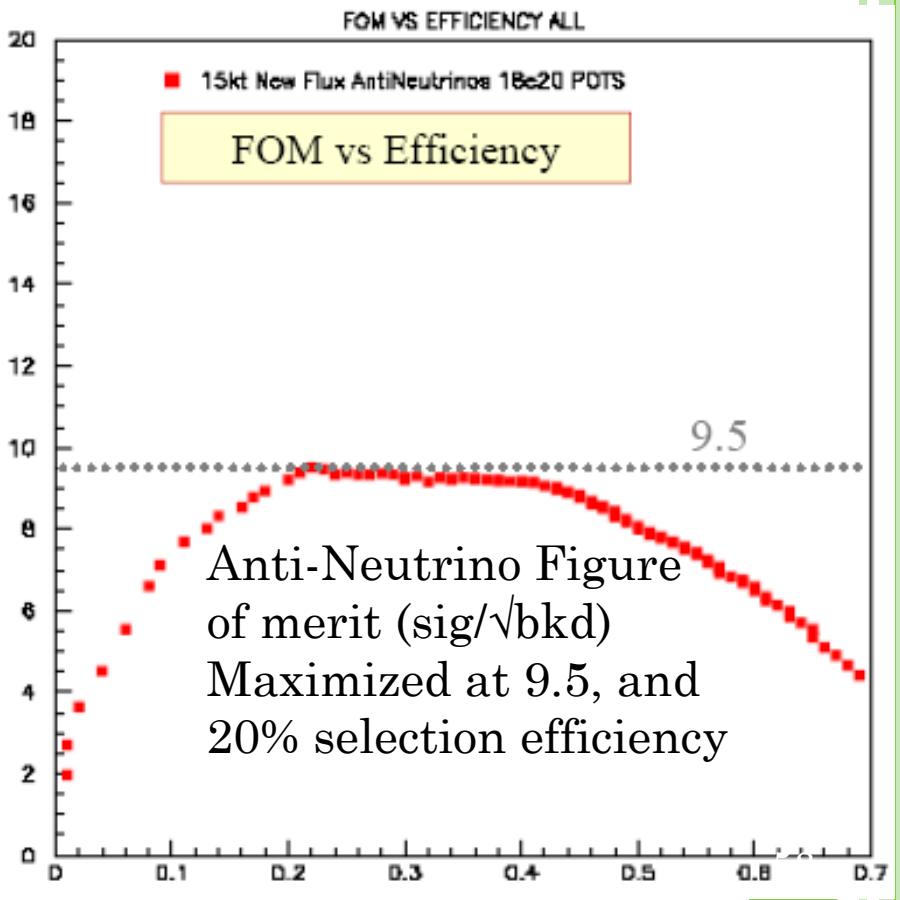
Detector Performance

- Optimize Figure of Merit (FOM=sig/√bkd) performance separately for ν and anti-ν
- Use 18E20 POT, $\sin^2(2\theta_{13})$ =0.1, Δm^2=2.4E-3, no matter effects
- Upgrades to neutrino event generator
- Updates to predicted neutrino flux
- Updated detector mass and configuration
  - 15kT, slightly shorter modules, photodetector readout

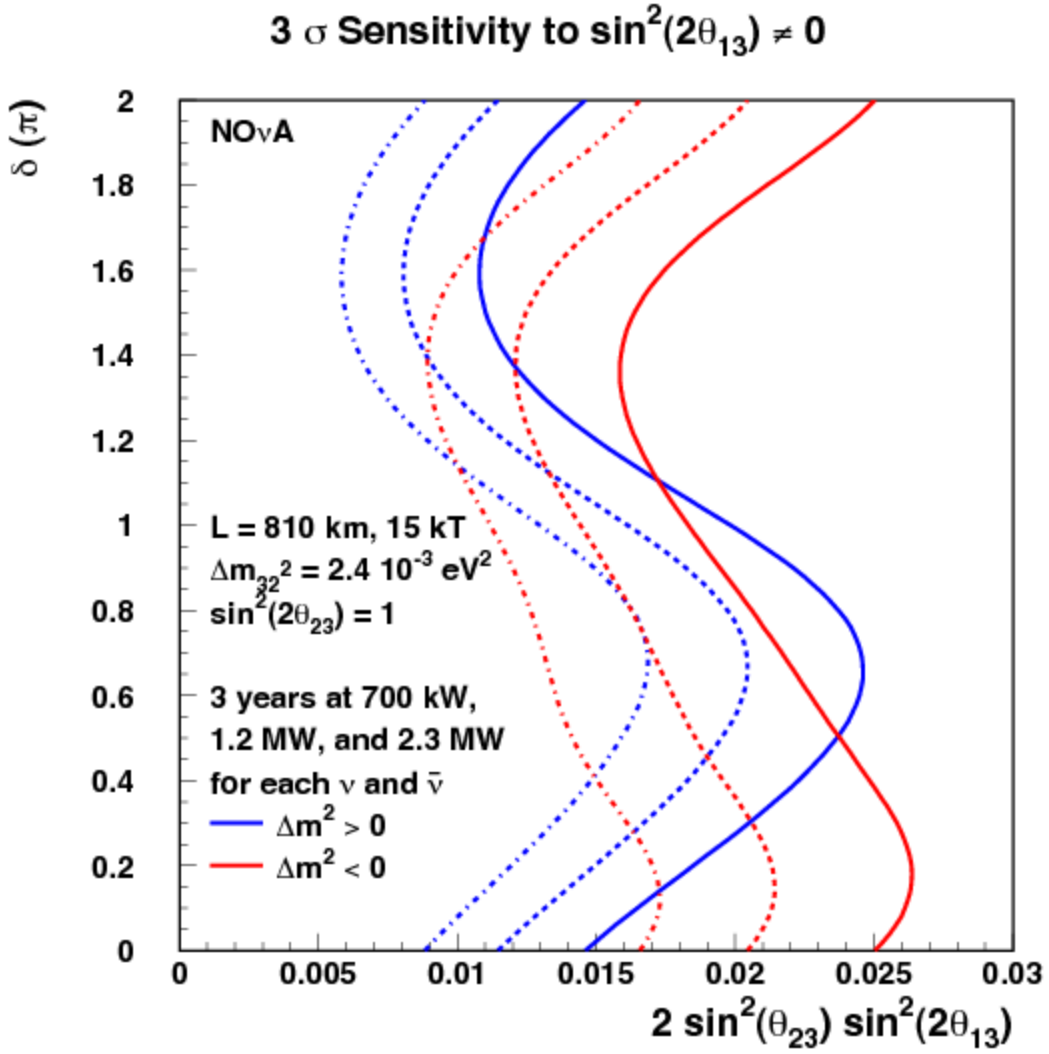
Performance optimization

Combined Figure of merit 18.0





3 Sigma Sensitivity to $\sin^2(2\Theta_{13}) \neq 0$

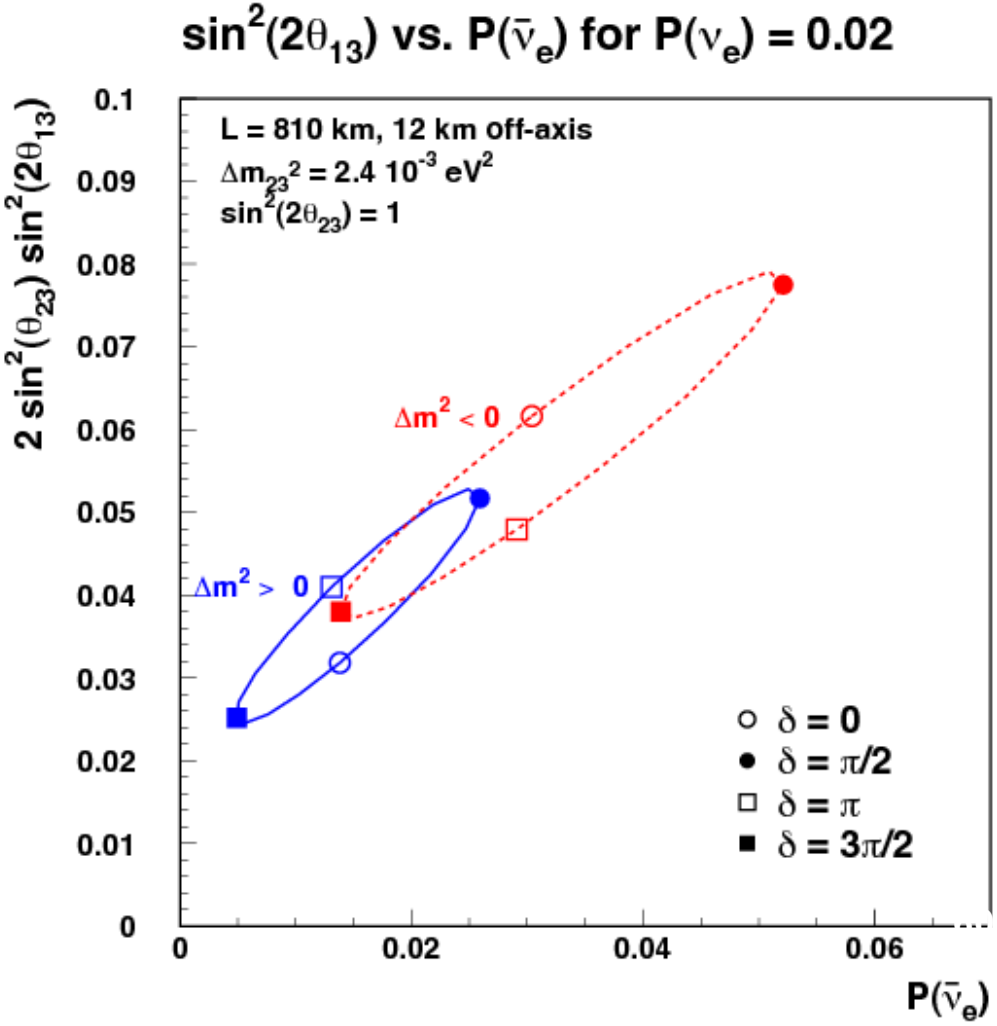


Sensitivity vs δ for non-zero $\sin^2(2\theta_{13})$ at 700kW, 1.2MW, and 2.3MW

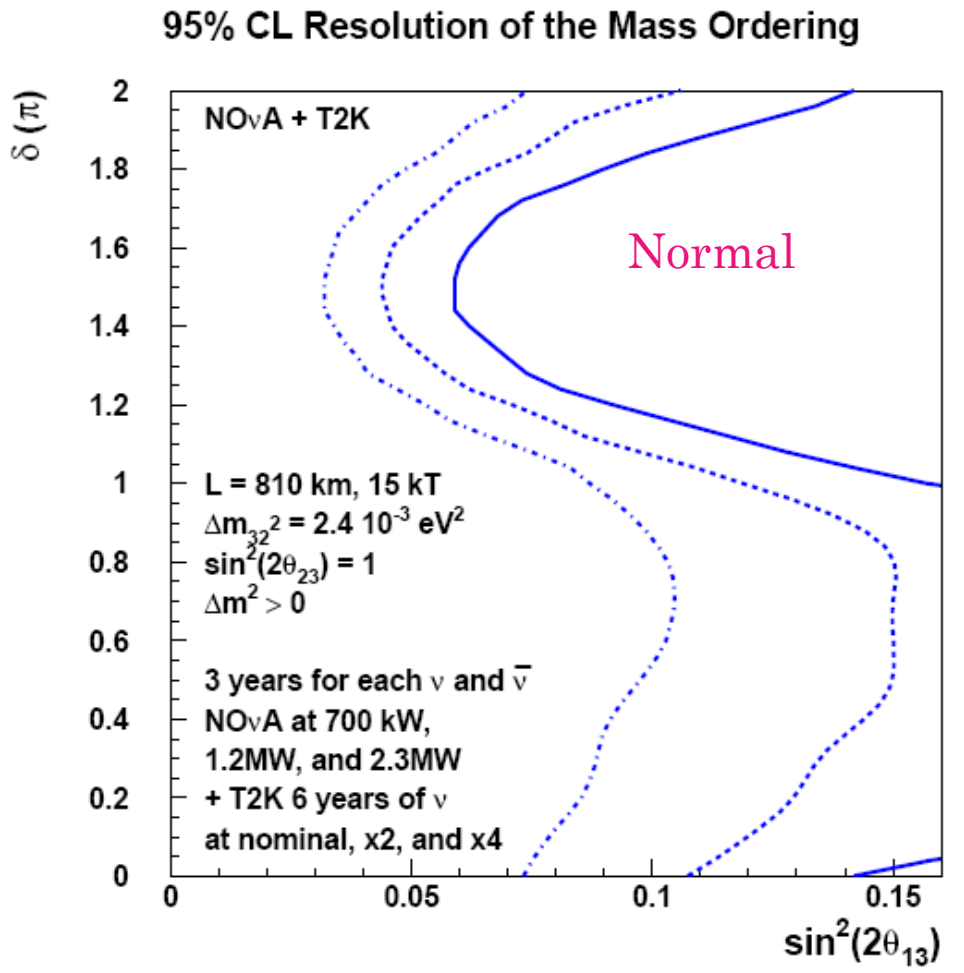
Mass Hierarchy Resolution

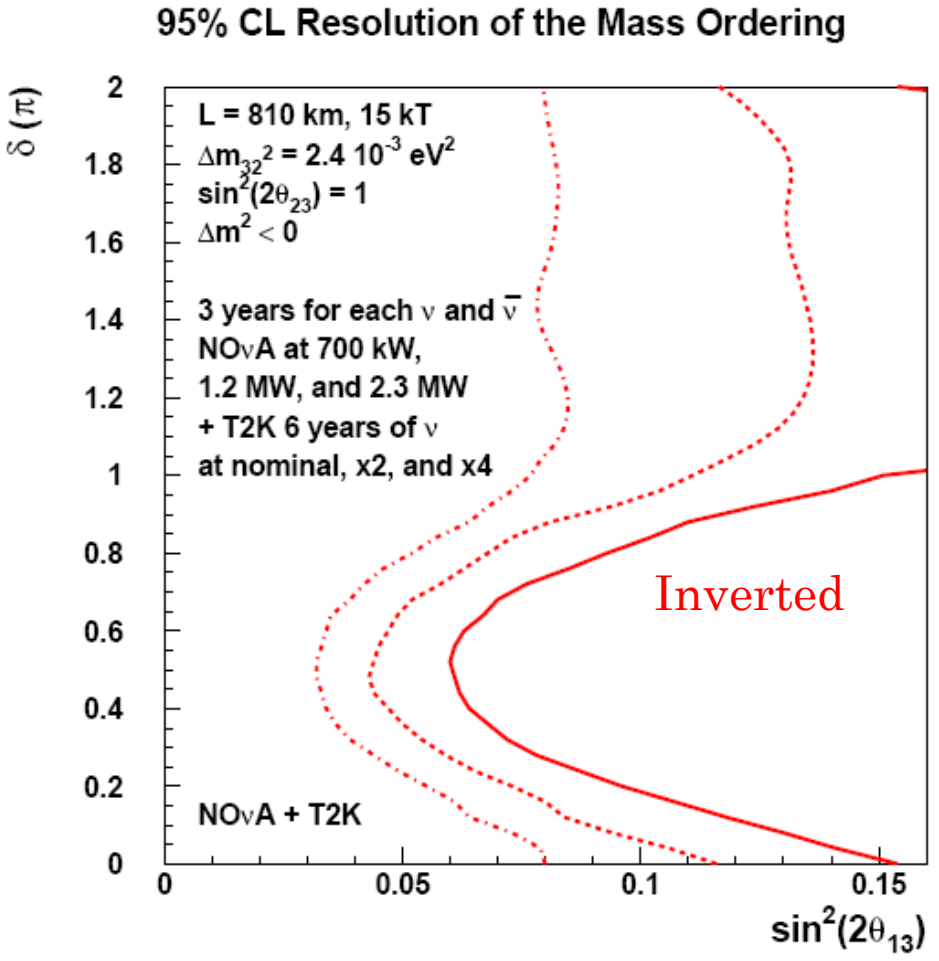
If you assume a measurement of $P(\nu_e)=0.02$, what does that imply about θ_{13} and the mass hierarchy, and how can you distinguish them.

Determine P using anti-neutrinos and/or measure θ_{13} in reactor experiment.

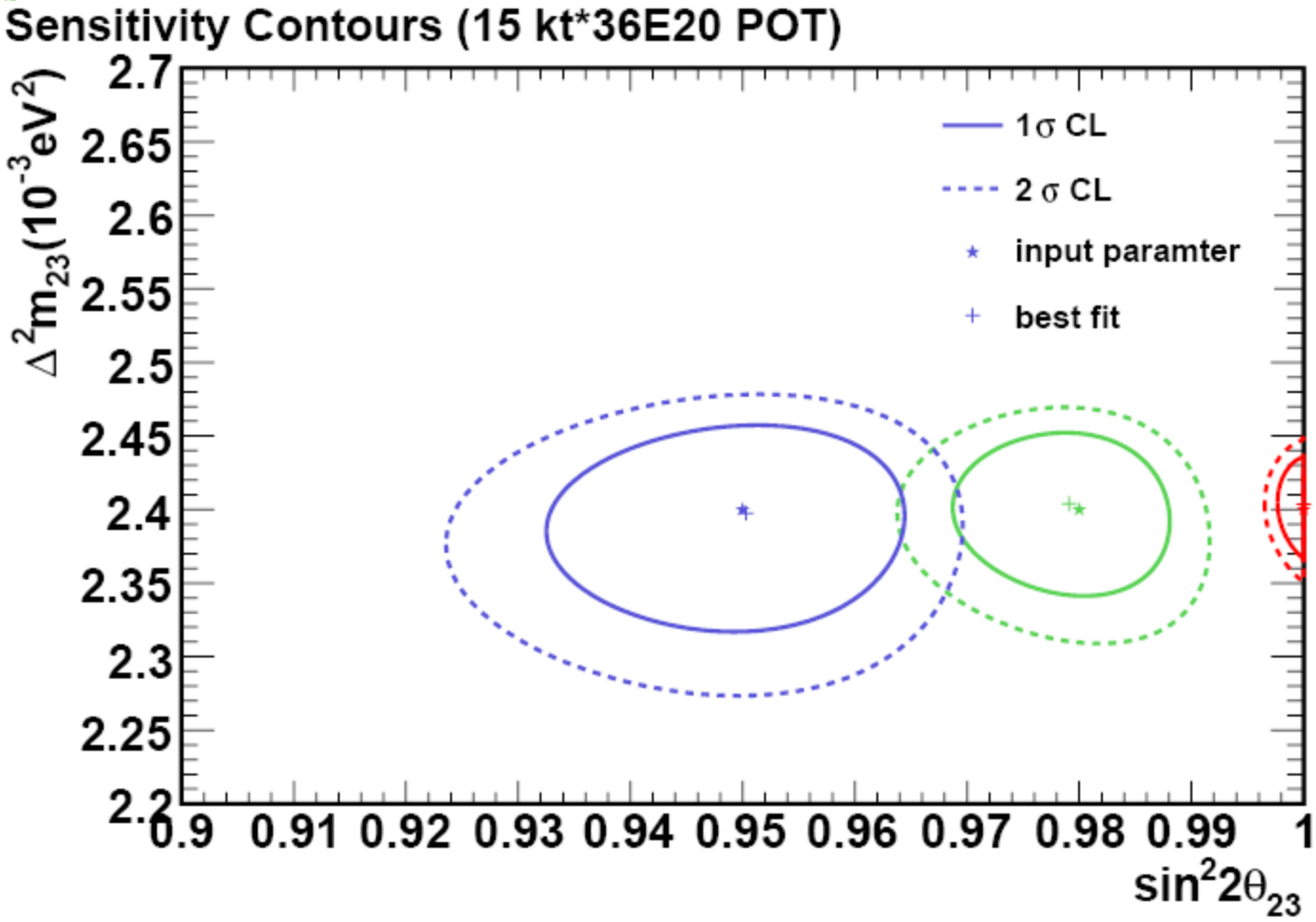


95% CL Sensitivity to the Mass Ordering





Measurement of $\sin^2(2\Theta_{23})$

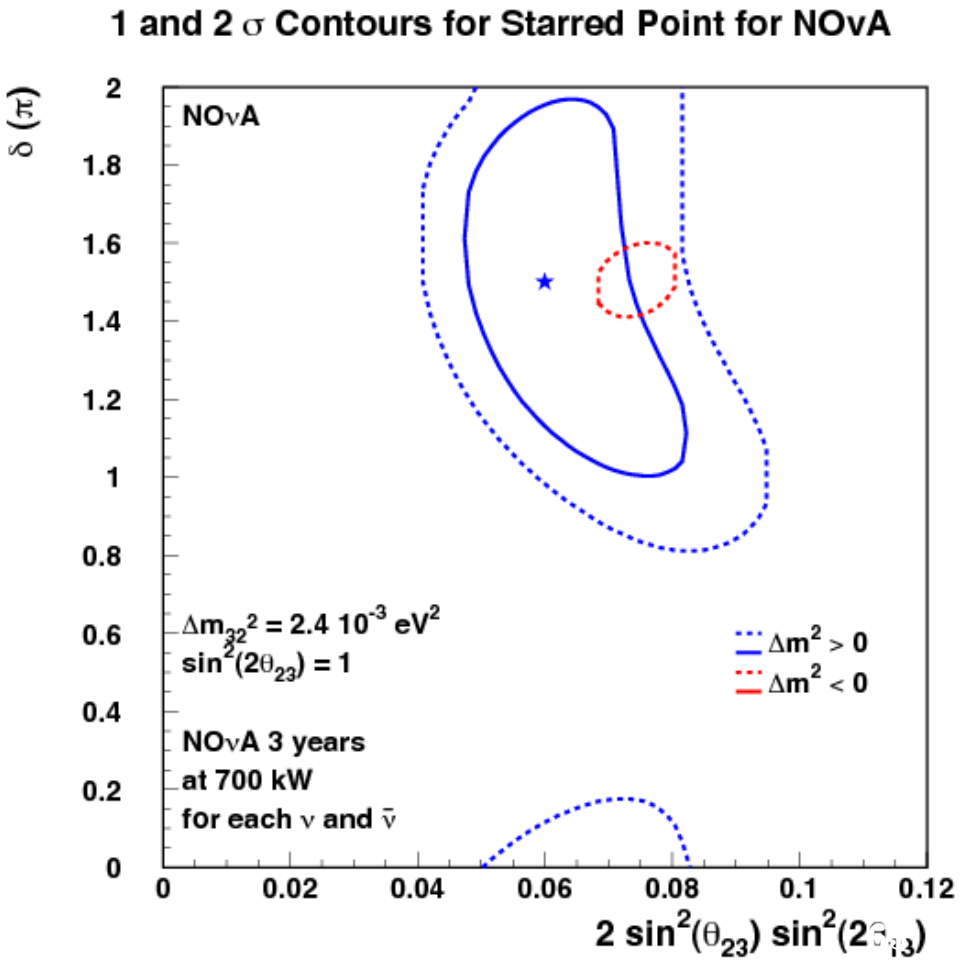


If $\sin^2(2\theta_{23}) = 1$, then it can be measured to 0.004.

Otherwise, it can be measured to ~0.02.

CP PHASE

- Assuming a normal hierarchy, and oscillation at the starred point, NOνA measurement resolves the mass hierarchy, and constrains δ_{CP} to the top half of the plane.



5. Future Prospect

- The topics are main subjects of the next lectures.
- Only introduce the Japanese scenario briefly.

T2K Beyond

Study Symmetry Violation between ν and $\overline{\nu}$

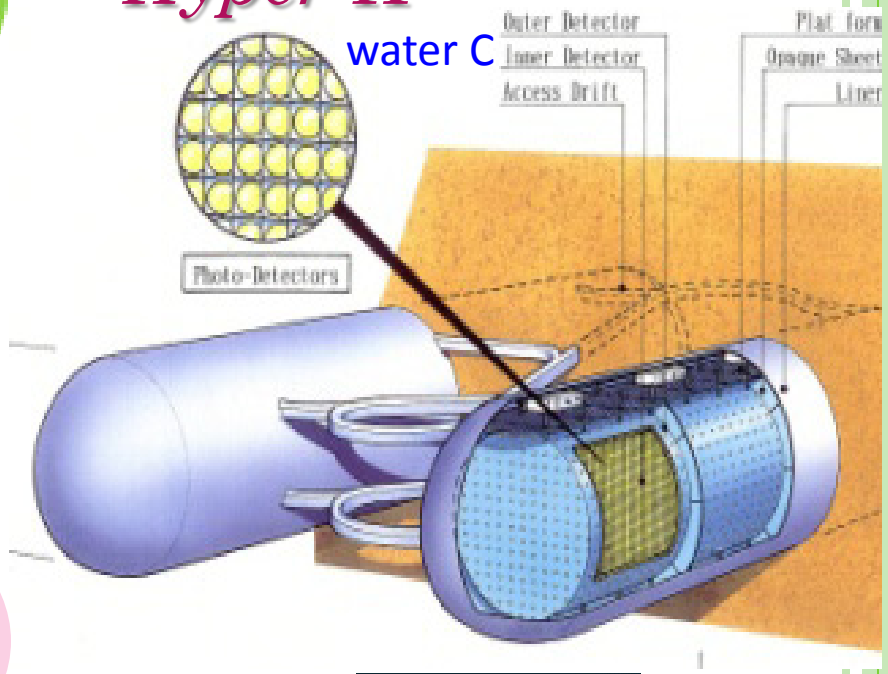
J-PARC Upgrade
KEK Roadmap
→1.7MW

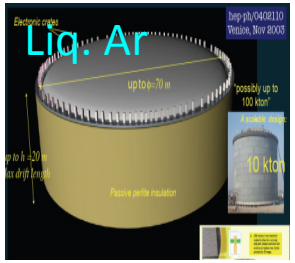
Best Optimization

Huge ν detector
- Water Cherenkov
- Lq. Ar TPC

O(~100k)ton

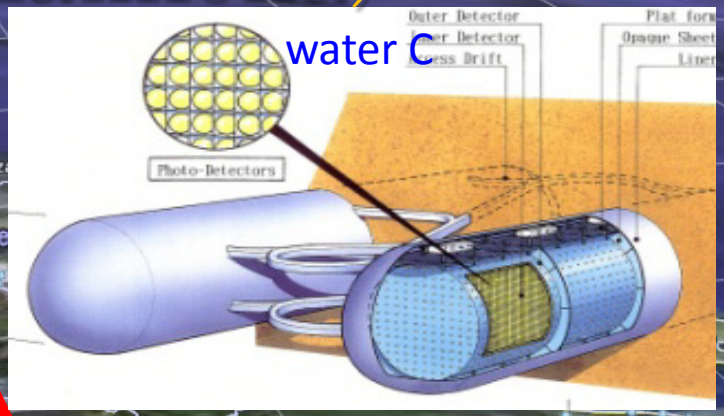
Hyper-K



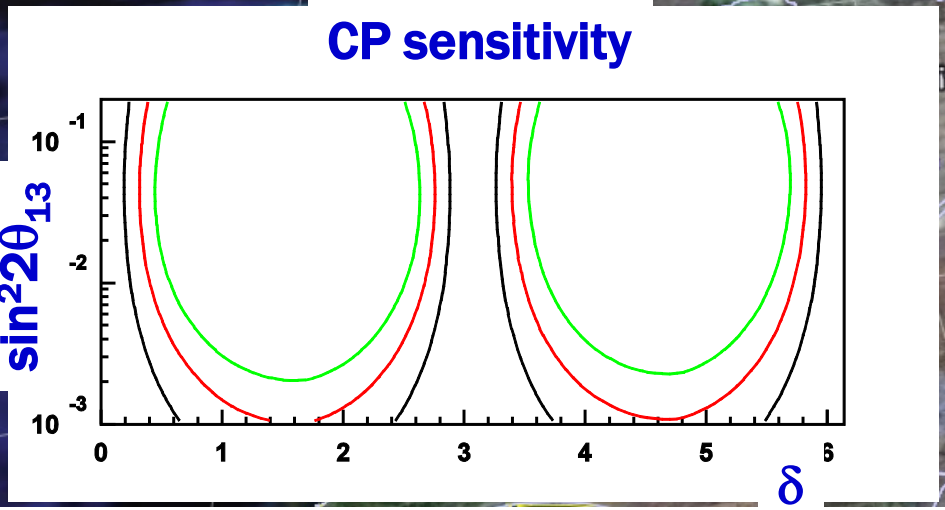


GUT
Proton Decay

Scenario 1 (Hyper-K @ Kamioka)



295km



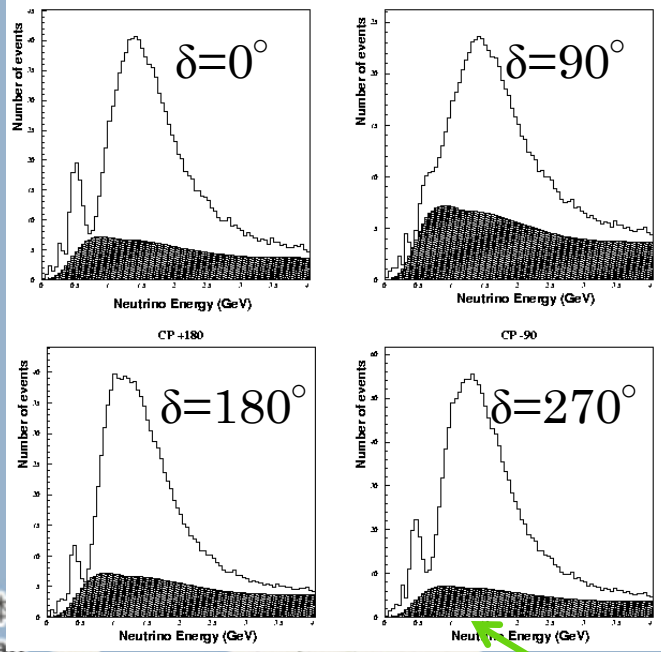
CP discovery on δ in the range of
20° ～160° and 200° ～340°

Scenario 2

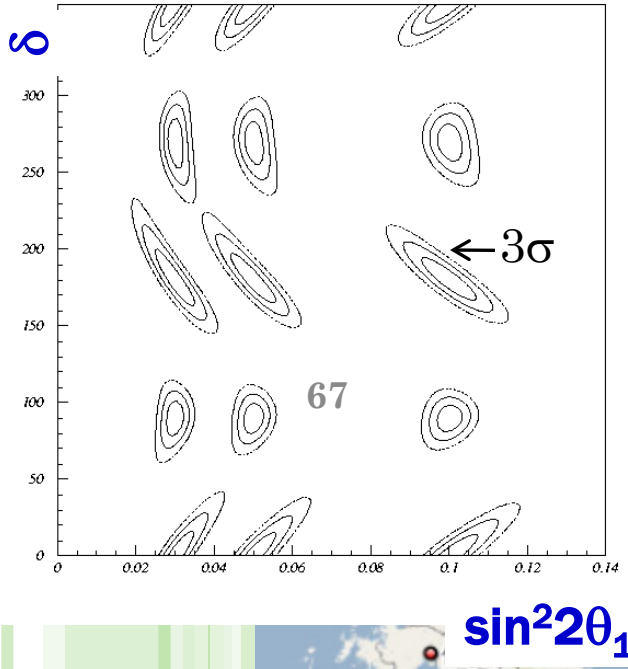
- 100kton Lq. Ar TPC @ 658km?
- ν beam only

ν_eSpectrum

$\sin^2 2\theta_{13}$=0.03,Normal Hierarchy



CP Measurement Potential



NP08, arXiv:0804.2111

Conclusion

- **The next generation ν oscillation experiments beyond T2K and NOνA depend on the outcome of the on-going experiments (MINOS, OPERA, T2K, NOνA. DCHOOZ, Daya-Bay, RENO, and many double beta decay experiments)**

- **So, the future depends on YOUR discovery.**

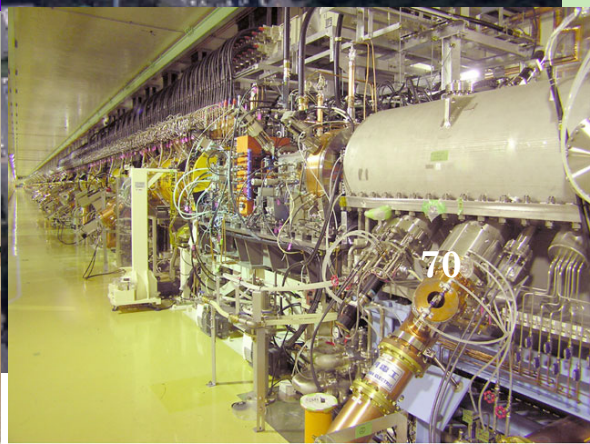
BACKUP -T2K -

Status of J-PARC

MR commissioning May, Jun, Dec~ in 2008

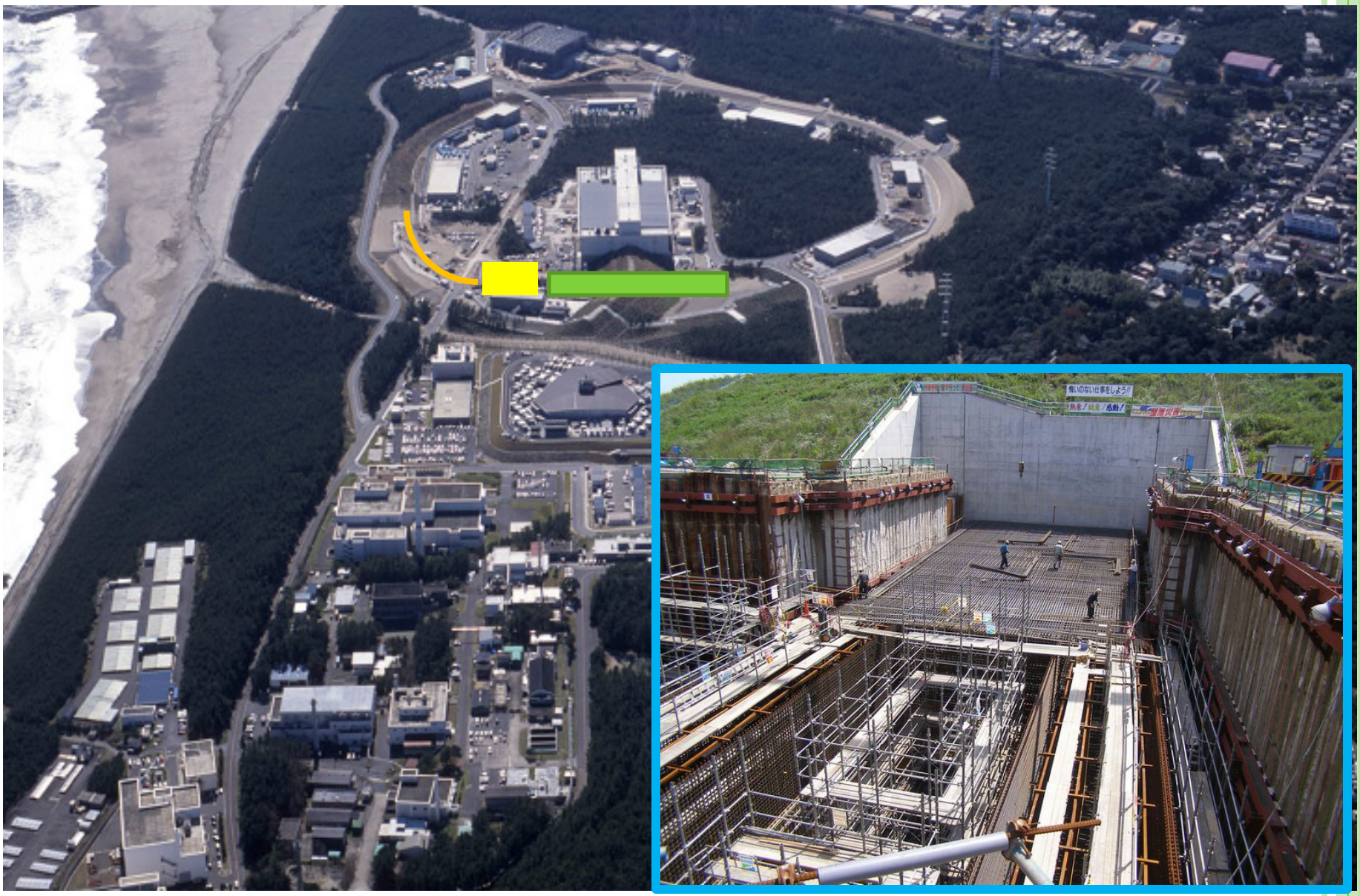
3 GeV RCS beam commissioning succeeded in Nov. 2007

Linac succeeded in 181 MeV acceleration in Jan. 2007



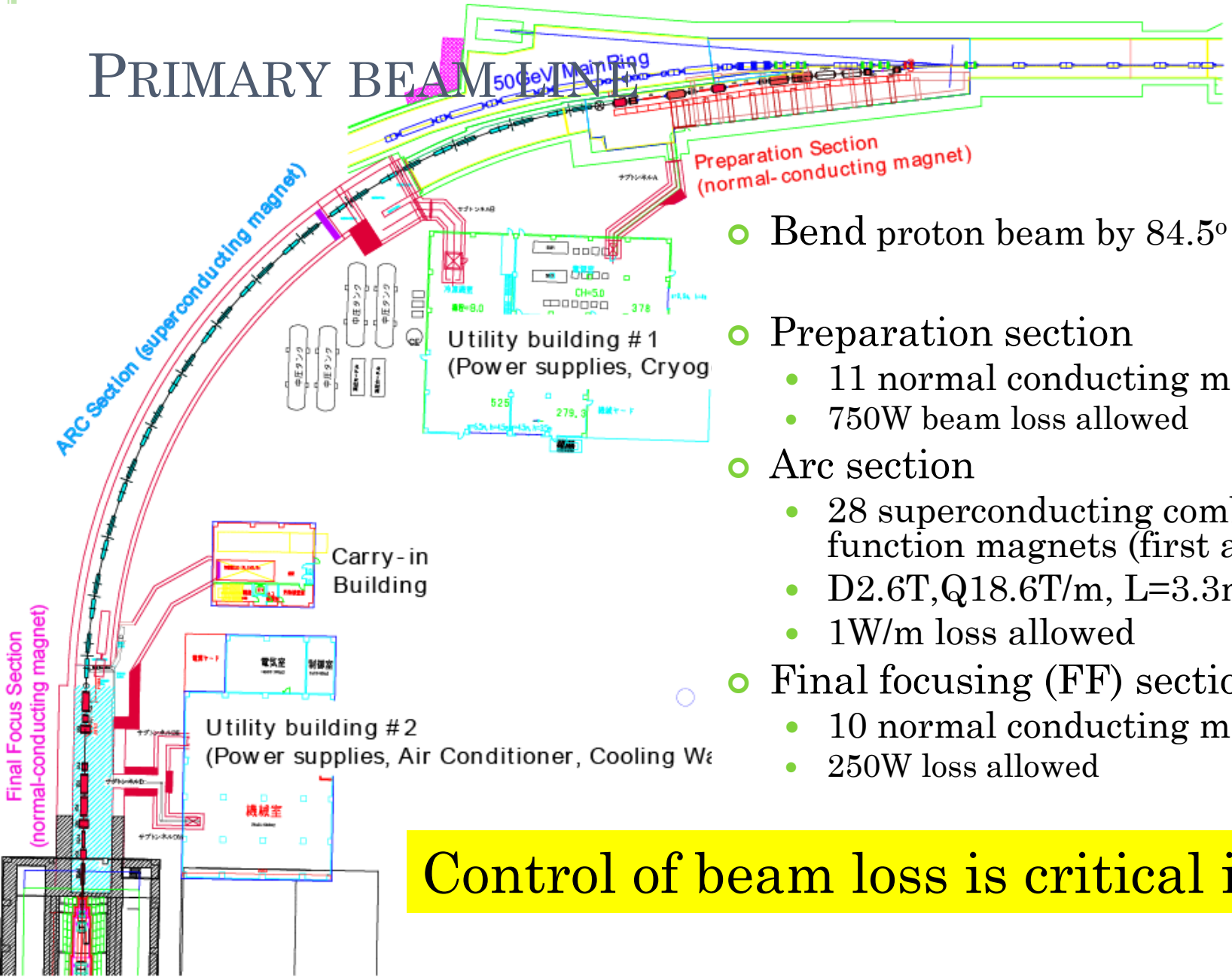
3.1 ニュートリノビーム/J-PARC

3.1 ニュートリノビーム/J-PARC



3.1 ニュートリノビーム/J-PARC

Primary beam line



- Bend proton beam by 84.5°
- Preparation section
  - 11 normal conducting magnets
  - 750W beam loss allowed
- Arc section
  - 28 superconducting combined function magnets (first application)
  - D2.6T,Q18.6T/m, L=3.3m
  - 1W/m loss allowed
- Final focusing (FF) section
  - 10 normal conducting magnets
  - 250W loss allowed

Control of beam loss is critical issue

Primary Line Component (1)

Superconducting magnets

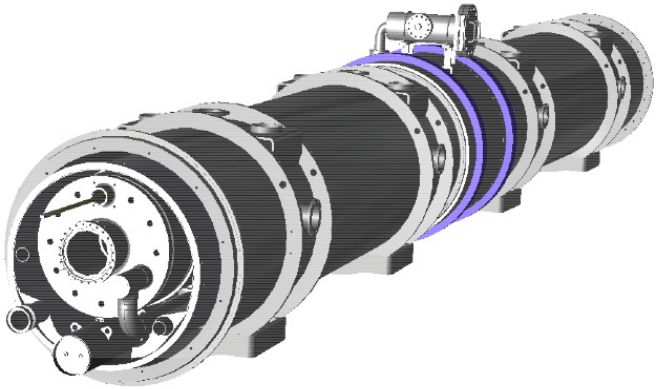
- 26 (/28) mags, 11 (/14) "doublets" completed
- 6 doublets already installed in the tunnel
- Up to 28 mags, 12 dblt's in FY2007 (by Mar.2008)
- 4 corrector mags are produced by BNL. 2 are delivered to KEK, 2 more being fabricated
- Magnet safety system (MSS) by Saclay
  - Hardware being constructed almost on time (Delivery to KEK in June)

Correctors

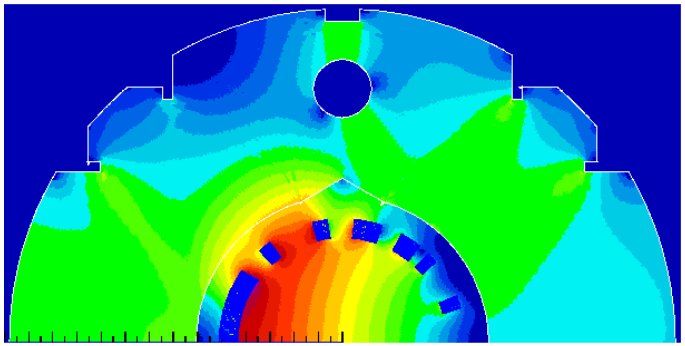
MSS

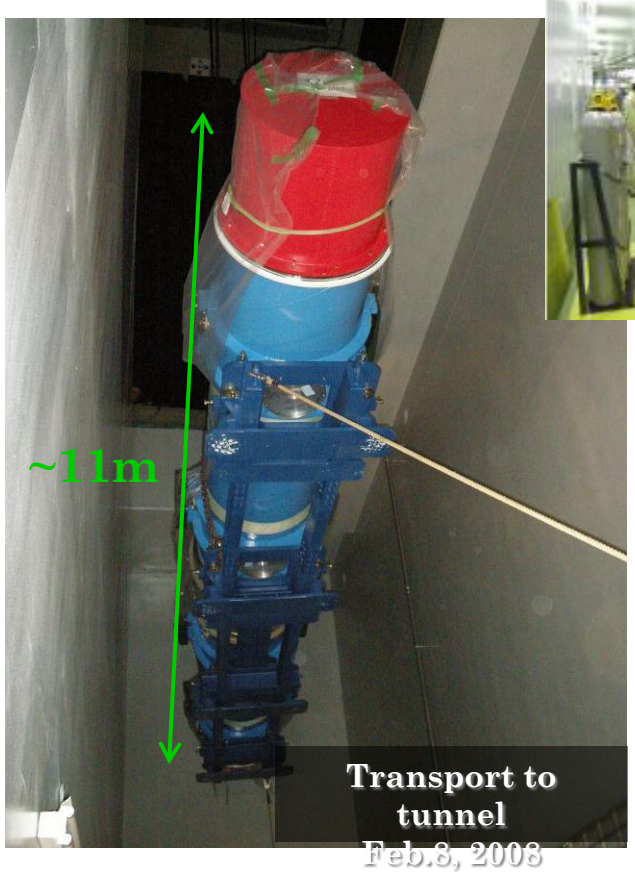
Superconducting magnets (doublet) in Tunnel

Superconducting Magnets



Two magnets in cryostat "doublet"
14 doublets + 2 spare doublets
+ 4 corrector magnets by BNL





SCFM : Superconducting Combined Function Magnet
D: 2.6 T, Q: 18.6 T/m, Length: 3.3m, Current: 7,345A@ 50GeV

- 11 doublets in beam-line, Cryogenics installation on time.
- Entire system will be completed by December 2008

PRIMARY LINE COMPON

Normal-conducting magnets

- **11 mags in prep.section installed and aligned.**
- Installation of FF magnets starts in March 2008.

Misc.

- Installation of vacuum components / beam plug started.
- Level meas. in progress to monitor ground sink.

PROTON BEAM MONI

Position: 20 x ESMs

Profile: 19 x SSEM s

Intensity: 5x CTs

- **Being assembled**
- **Installation started in prep sect**

Loss: 50 x Ionization chambers

- **Twenty monitors are purchased in this FY**

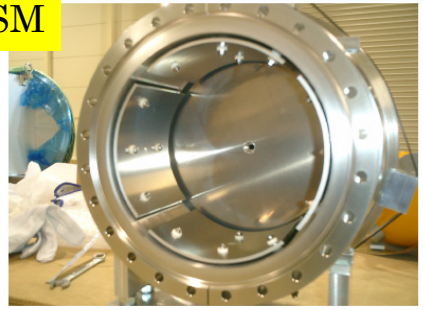
OTR detector (provided by Canada)

- Provide all-time profile just in front of target
- **Mirrors, rad-hard camera delivered**
- Manufacturing, assembling in progress

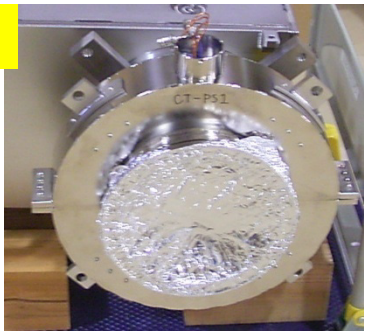
Electronics

- FADC for CT/ESM being produced by US
- FADC for SSEM prepared by Korea

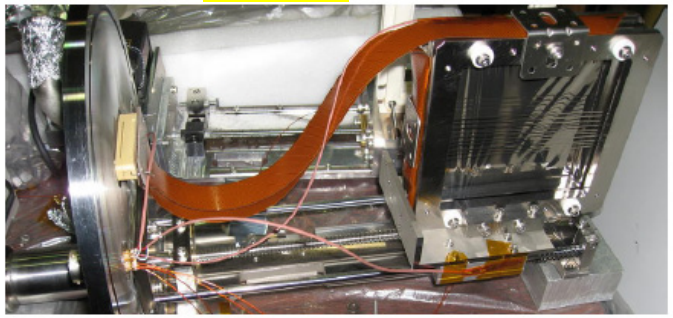
ESM



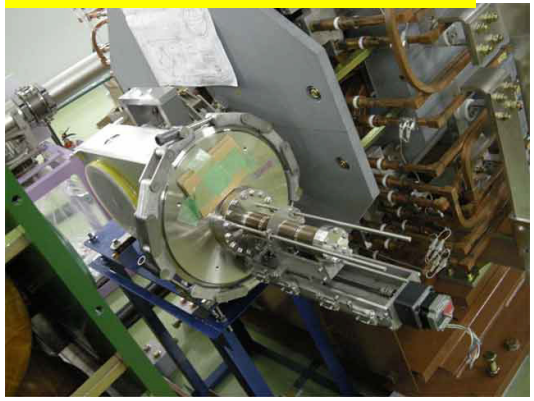
CT



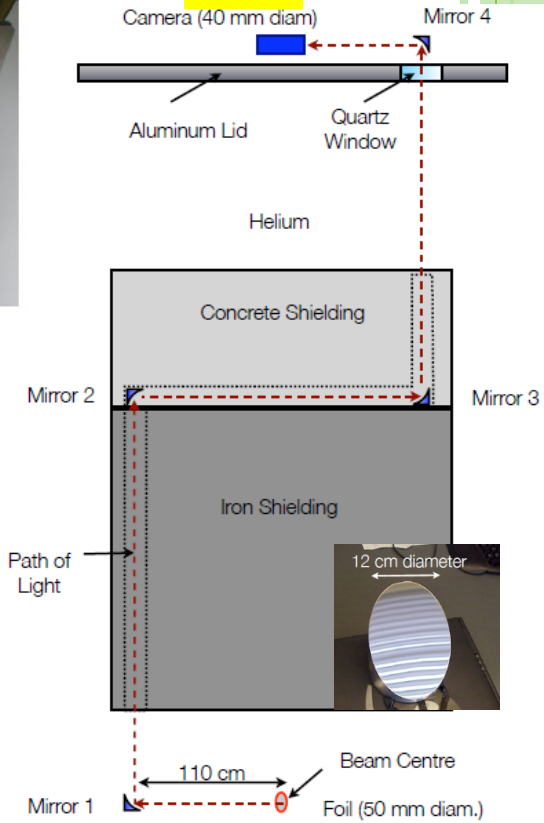
SSEM



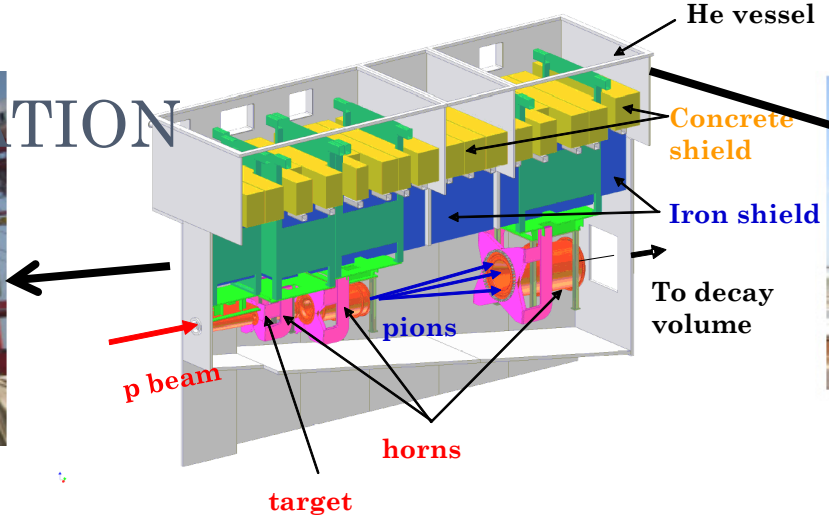
Installed monitor chamber



OTR

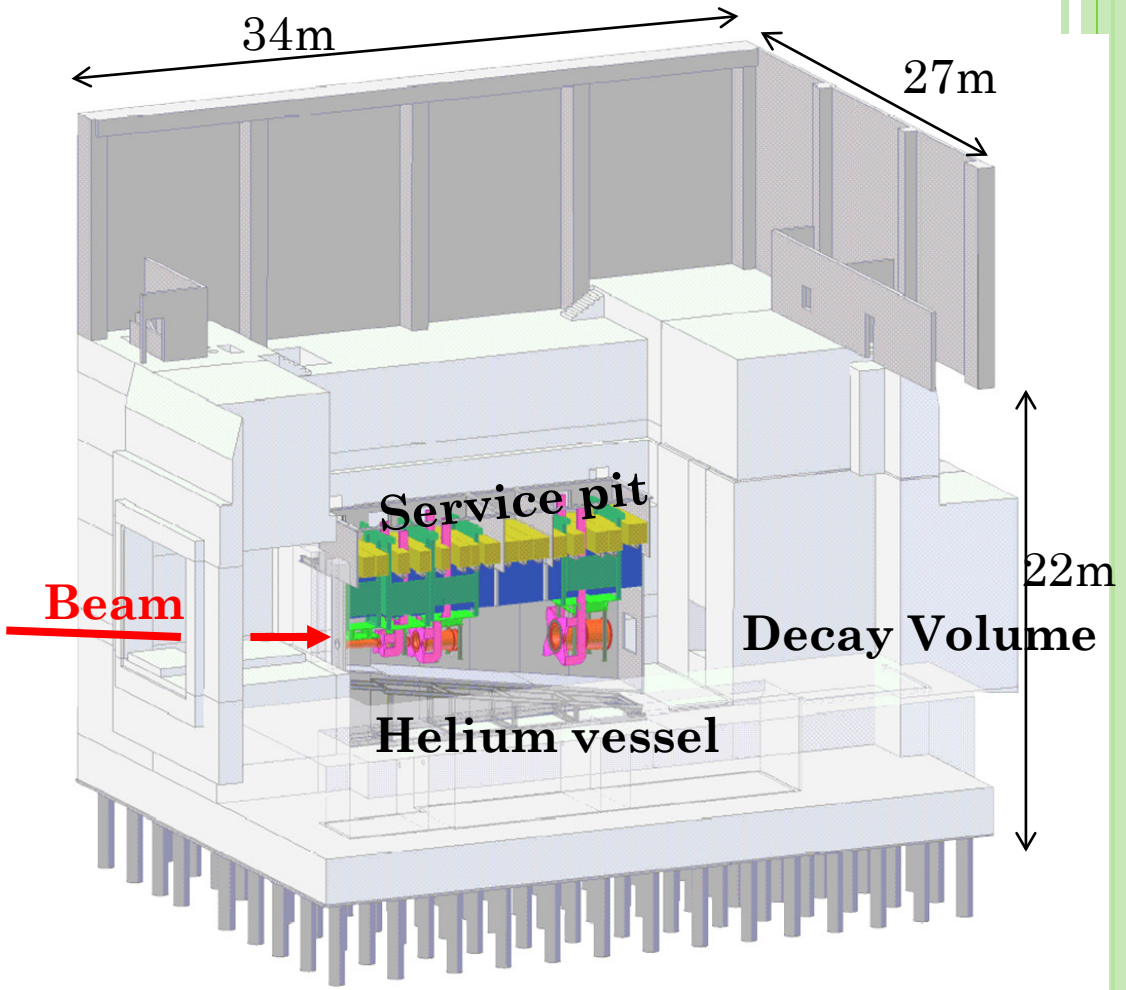


Target Station



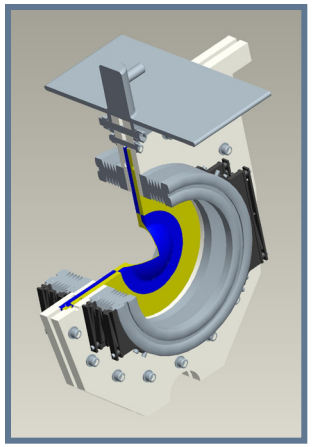
- Overcame water food problem during excavation in early 2007
- Installation of the helium vessel(~470ton, 1000m^3) finished, passed vacuum test in Nov. 2007 **as scheduled**
- Construction of surface building starts soon and will finish in June 2008.

Target Station

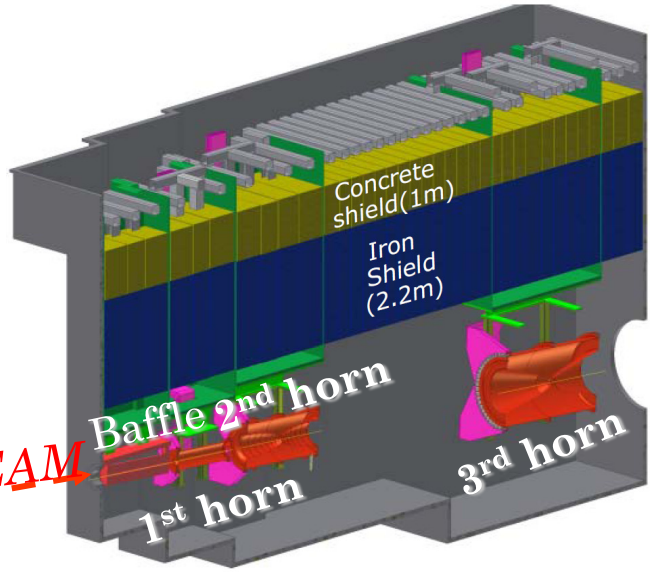


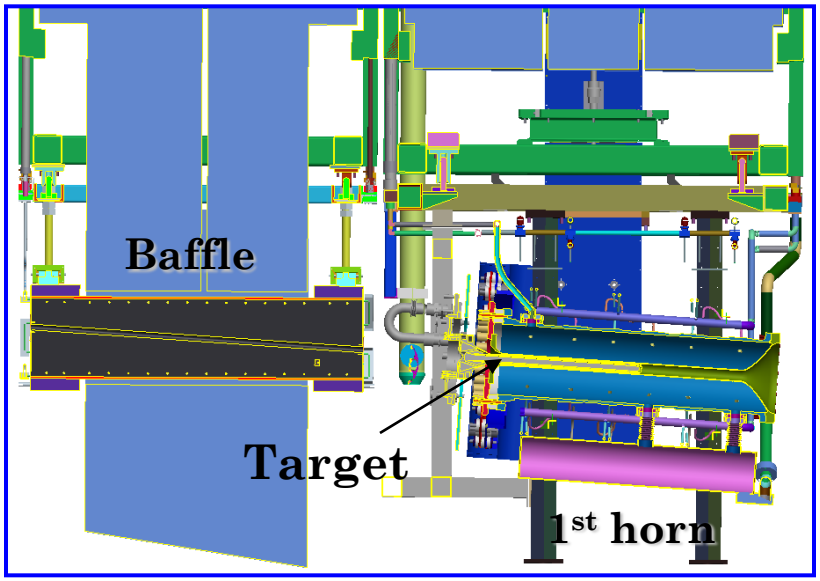
- 40t crane for remone maintenance installed on March '08
- Construction of the building to be completed in June 200

APPARATUS IN THE TS VESSEL

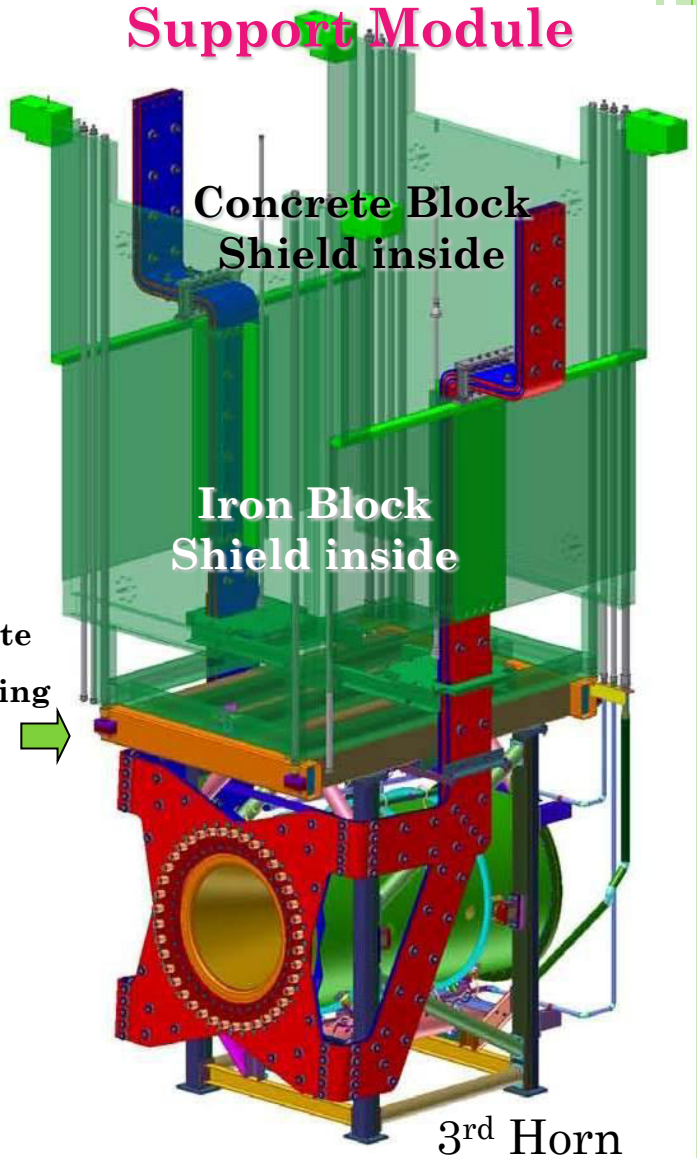


Beam Window
With pillow seal

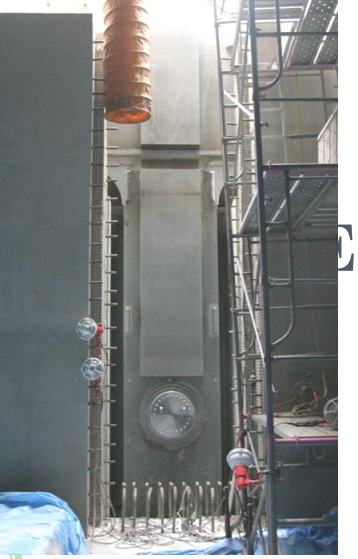




Support Module



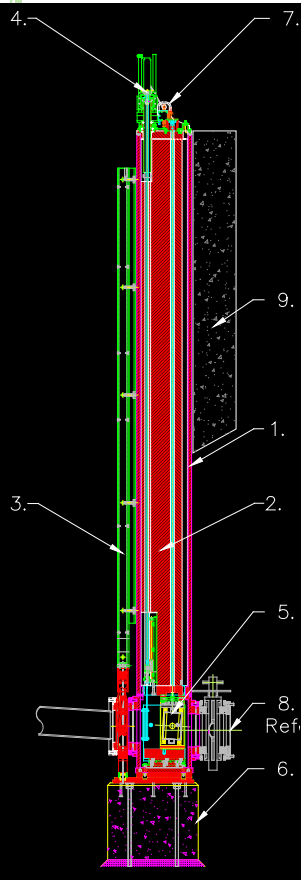
3rd Horn



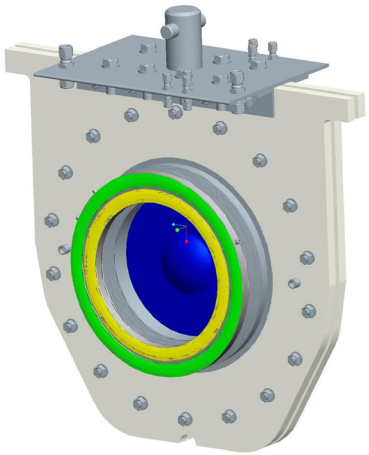
Downstream dome Upstream dome

Downstream plate Upstream plate

Pillow seal flange for window

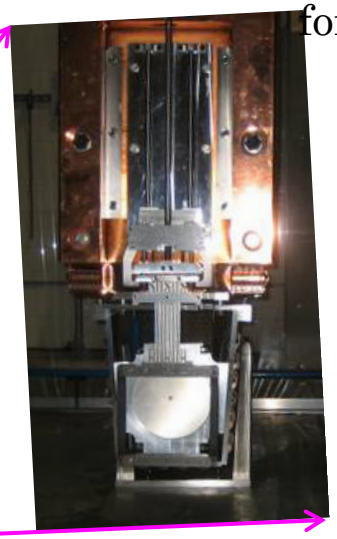


Beam window @RAL



Monitor chamber @TRIUMF

Mockup monitor

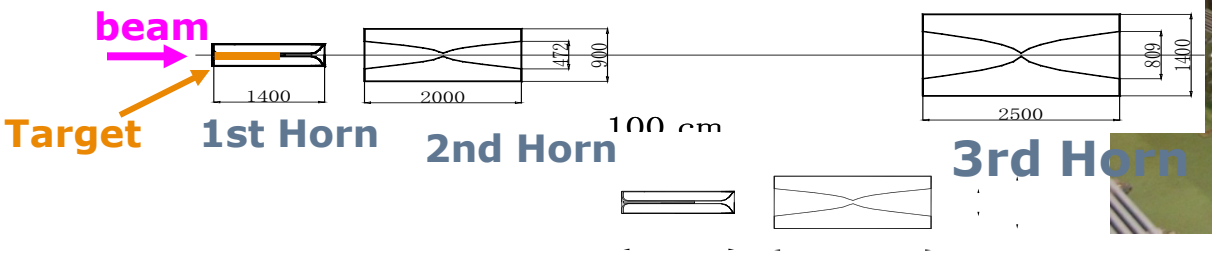


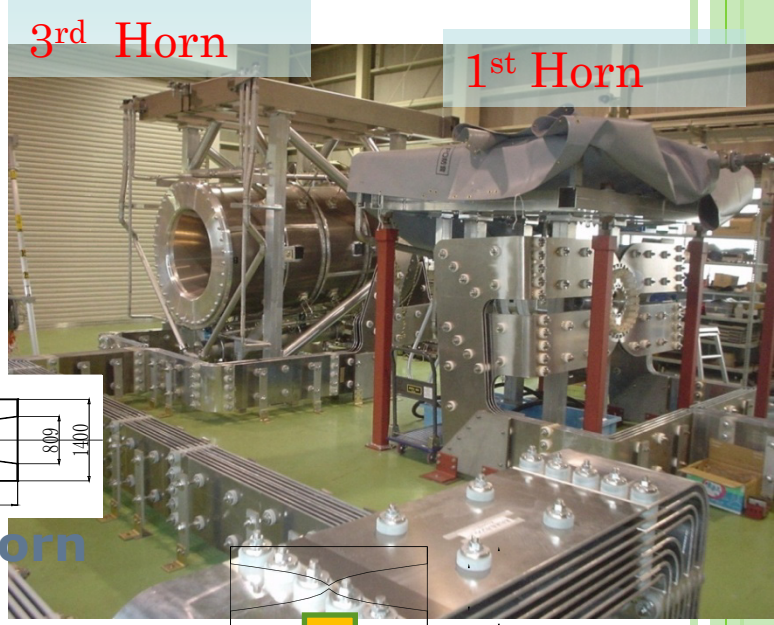
Pillow seal flange for monitor chamber

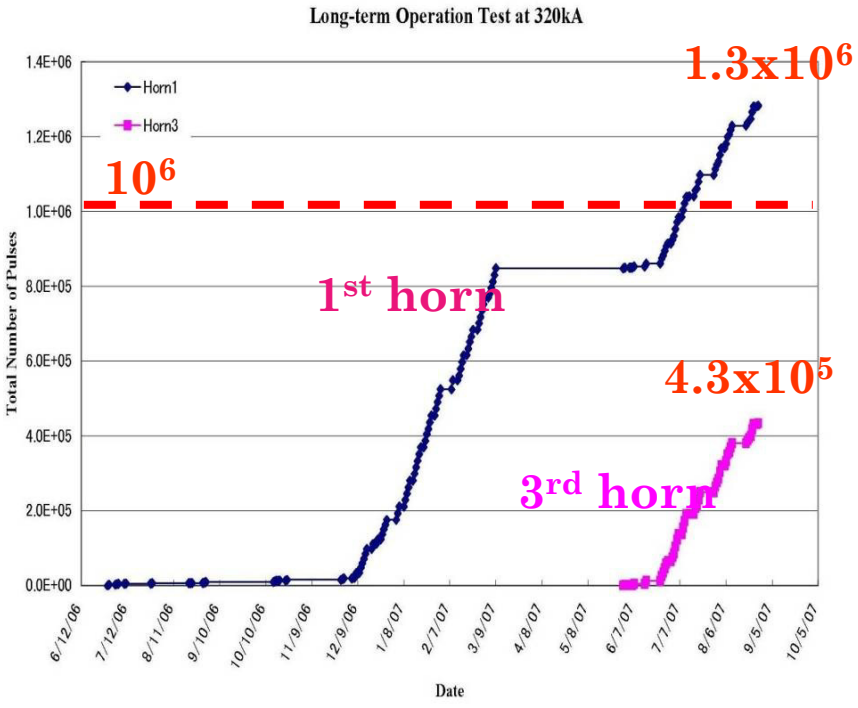
Beam window and monitor chamber are under assembly at RAL/TRIUMF and will be installed into TS from July 2008.

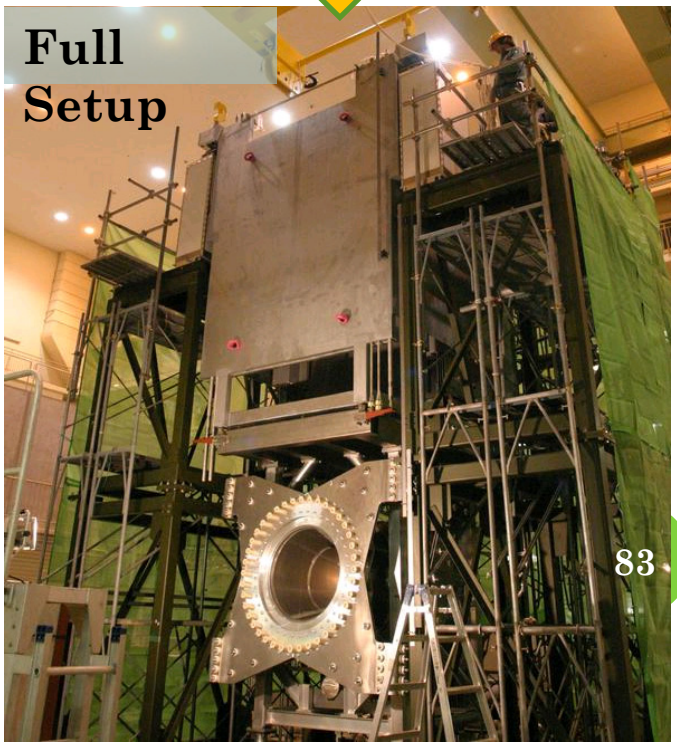
電磁ホーン(π収束装置)

- 3 ホーンシステム
  - 320kA運転で長期試験









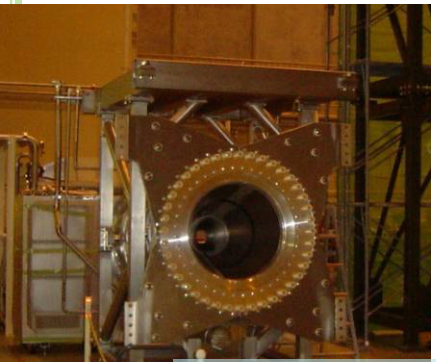
Full system setup Test of Horn and Demonstration of its Remote Maintenance Scenario at Fuji, KEK

In preparation now.

The 320 kA test operation soon.

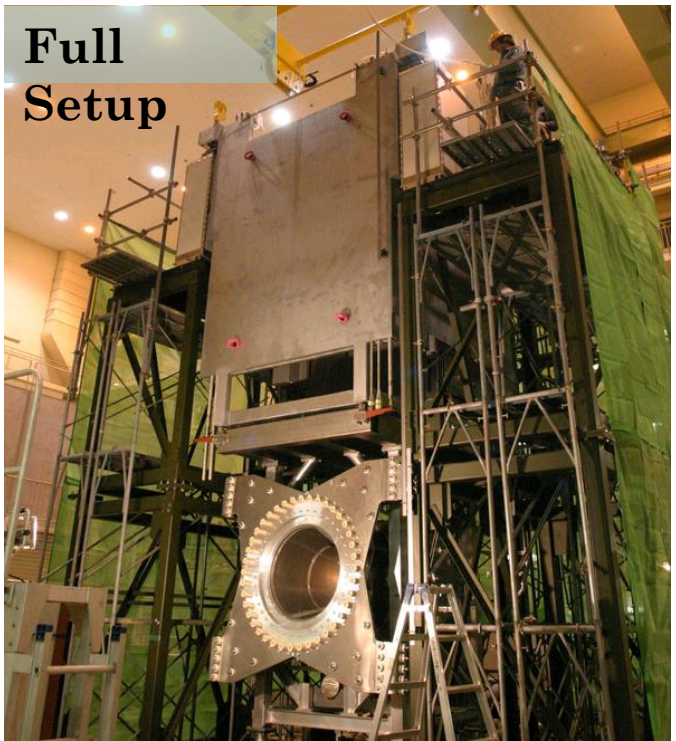
Necessary improvements are identified and being solved.

Support Module



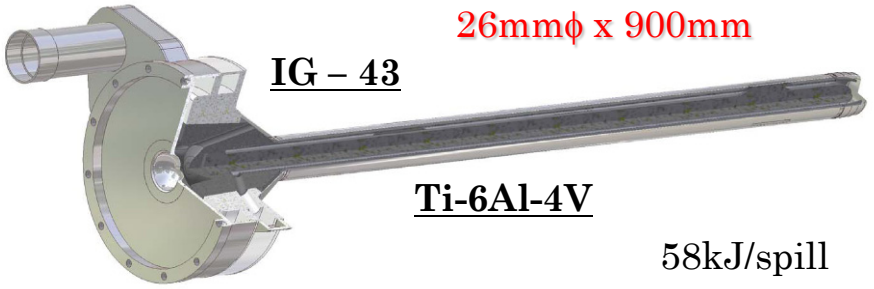
3rd Horn

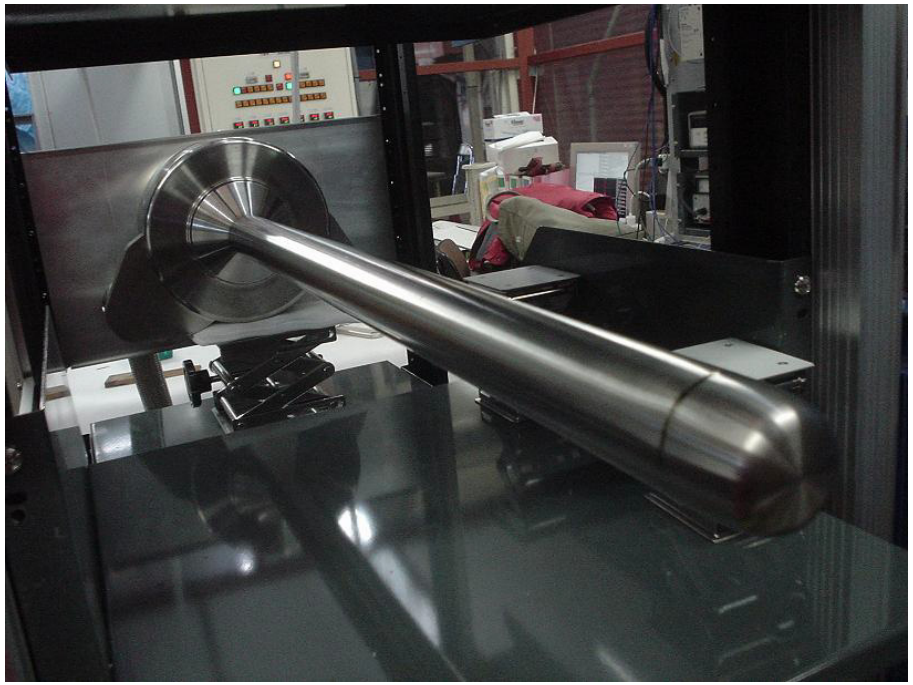
Full Setup



Hung by remote sling tool

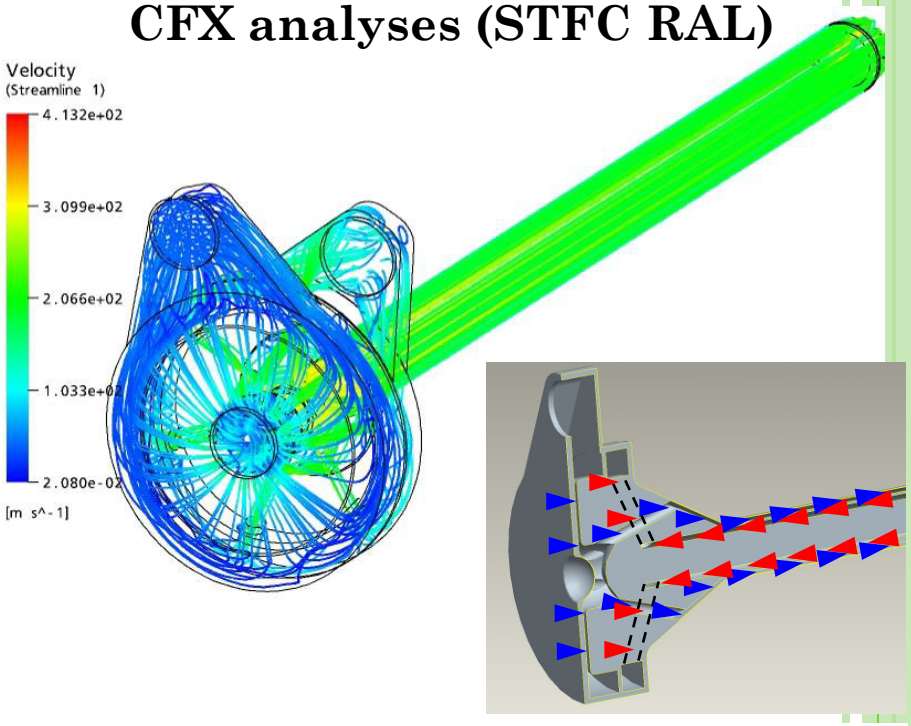
TARGET

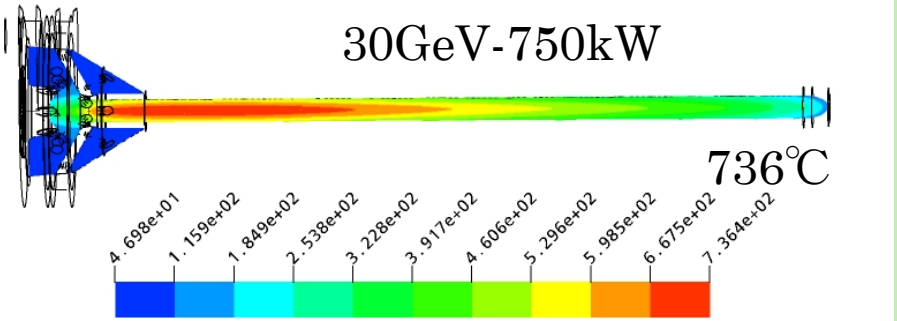




- Full prototype delivered in Dec. ’07
- He gas flow test, achieve 650Nm^3/h (200m/s)

CFX analyses (STFC RAL)

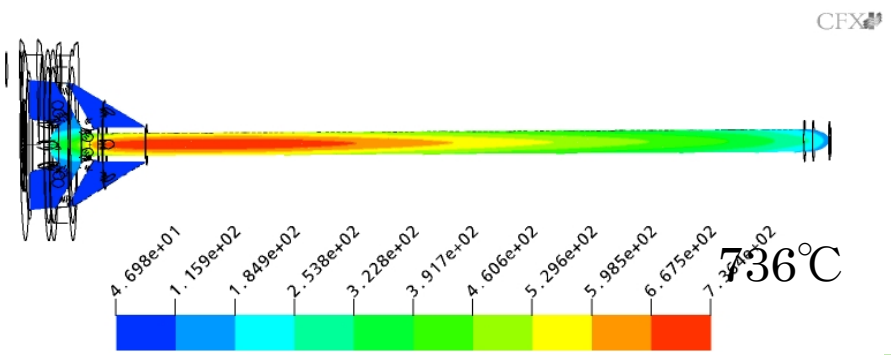




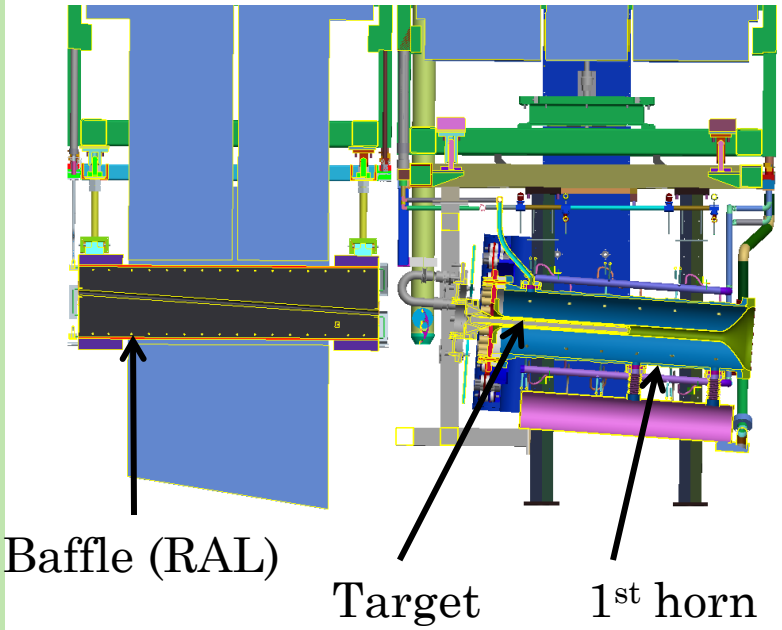
ΔT~200K ~7MPa(Tensile 27MPa)

標的

- グラファイト:
  - 26mm(D)x900mm(L)
- ヘリウム冷却

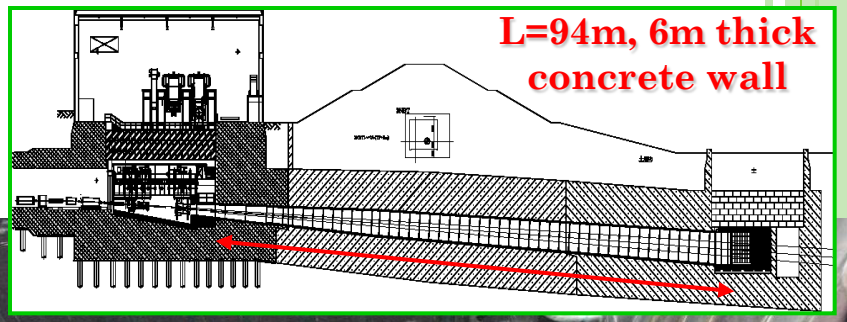


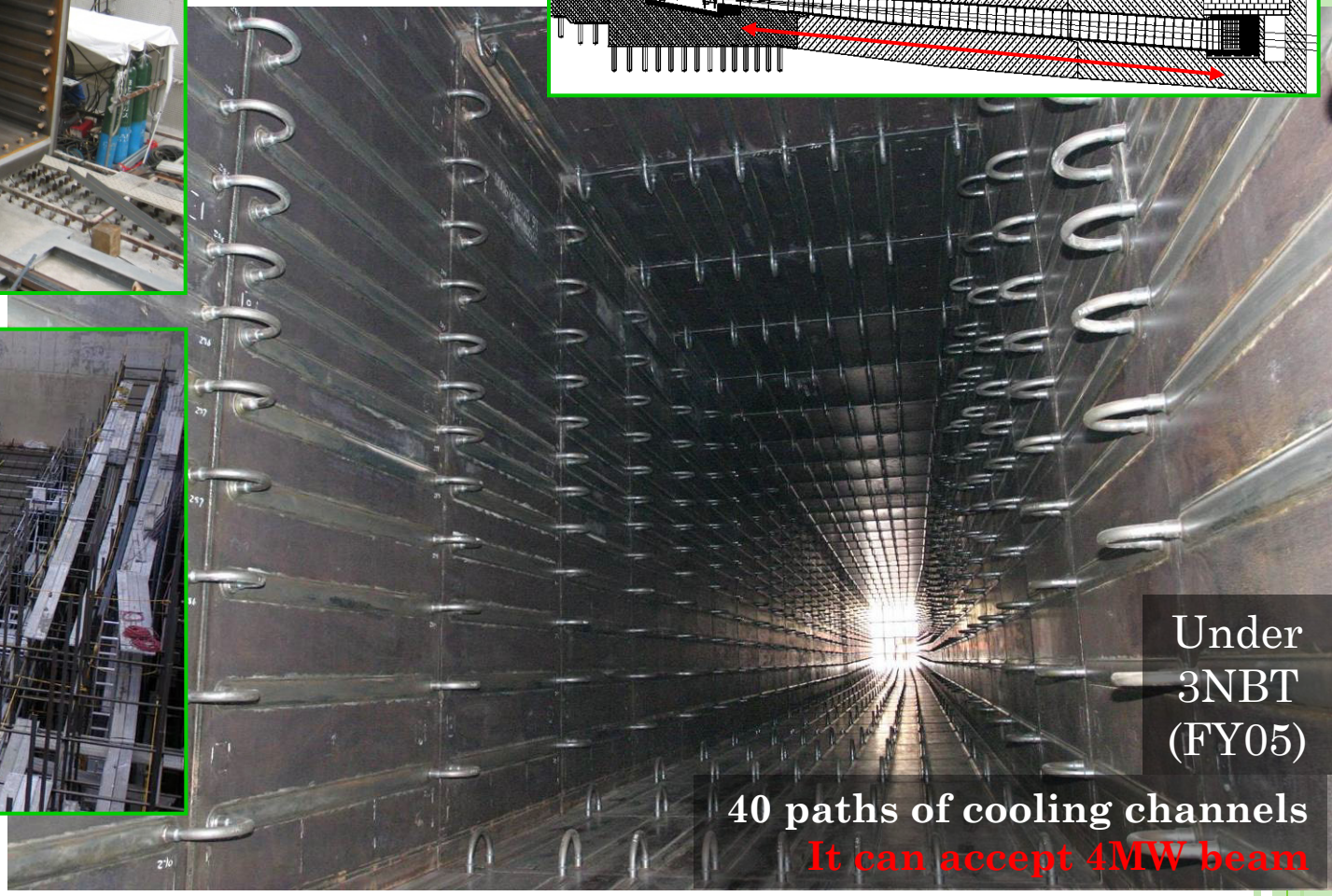
ΔT~200K ~7MPa(Tensile 27MPa)



Beam Volume

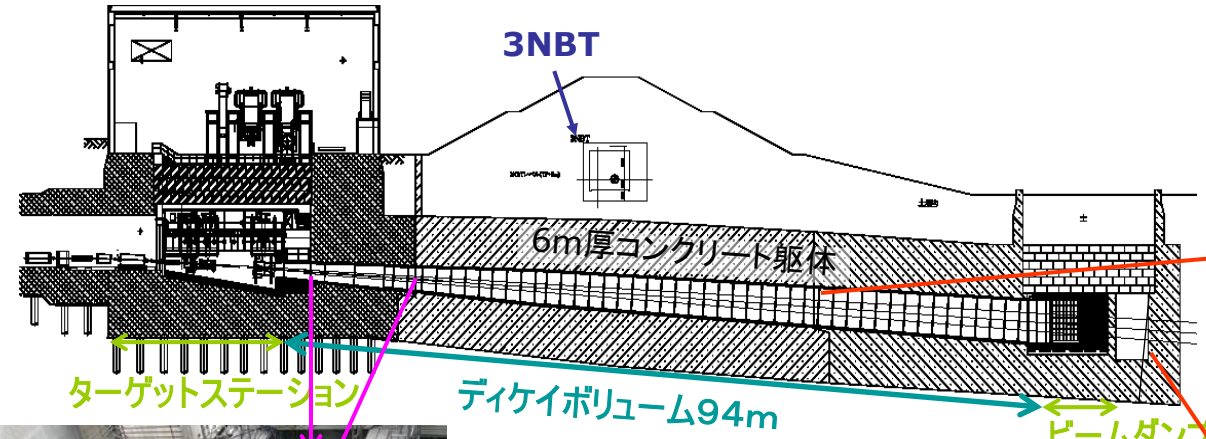
2008/03/07

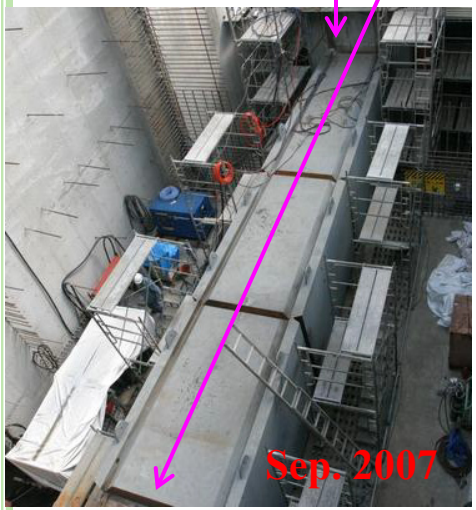




Decay Volume

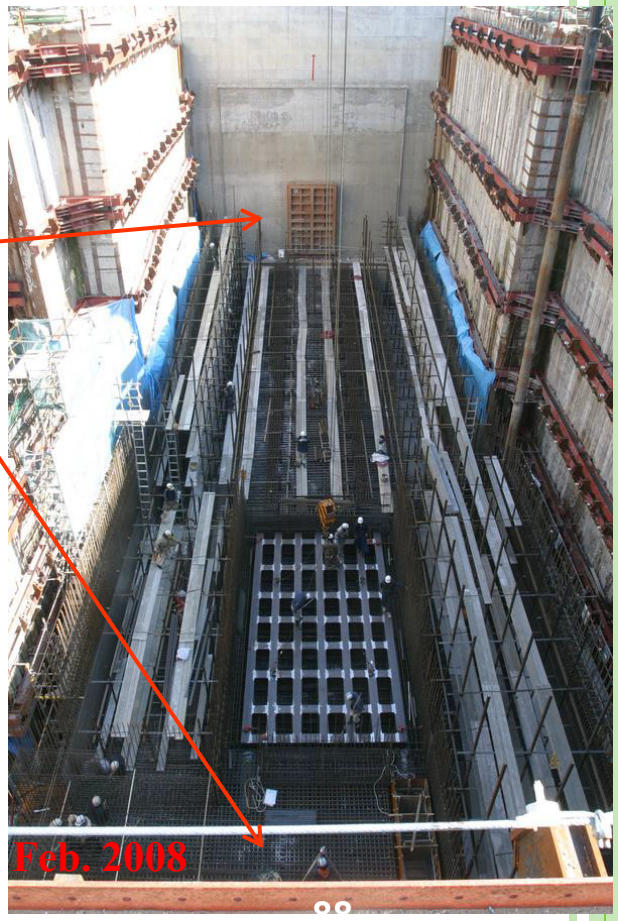
- Upstream part (20cm^{t} Iron) was installed & tested in Nov 2007.
- Anchor frame for BD core was embedded in concrete in Feb. 2008.
- Civil construction of downstream part will be finished by Aug.
- Construction of He vessel:
  for DV: just started, for BD: will start in Aug. 2008.





Upstream part

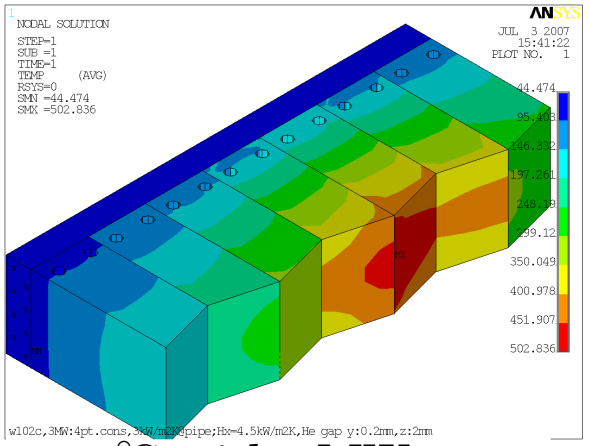
Anchor frame for BD core



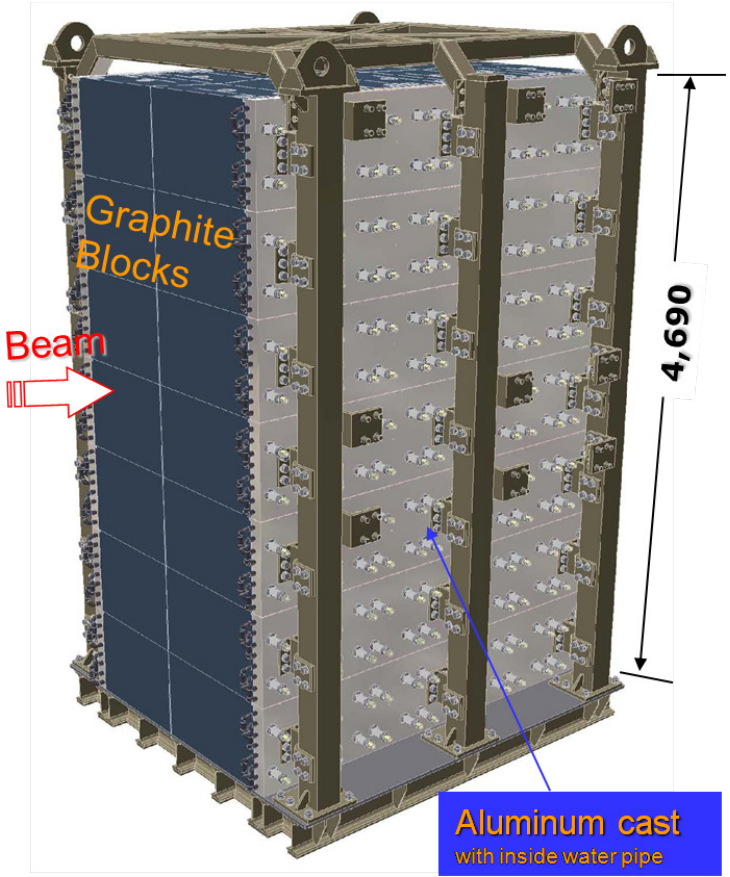
Downstream part

ビームダンプ

- 98 グラファイトブロック
- Core will be Installed into He vessel in Oct/Nov 2008.



500℃ with 3MW
[Assuming phase-I target]

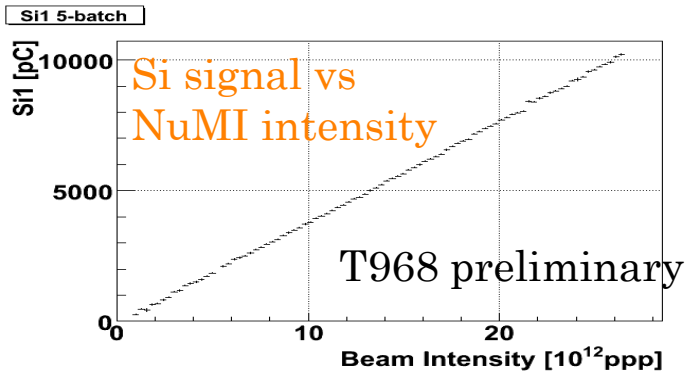


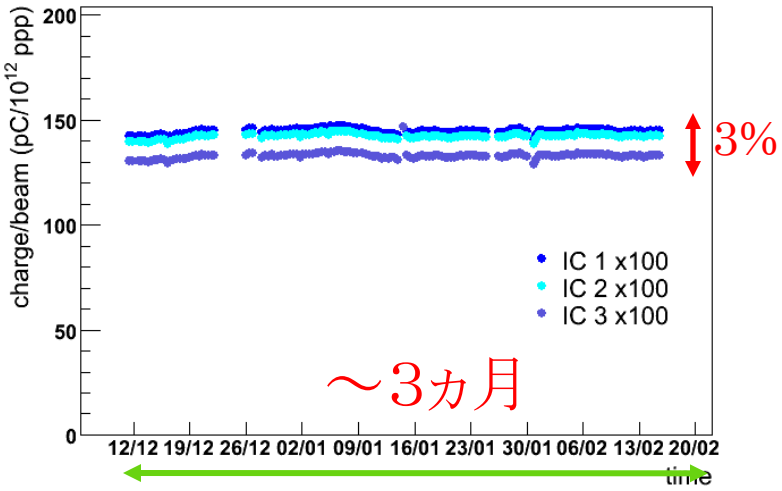
1st assembled module

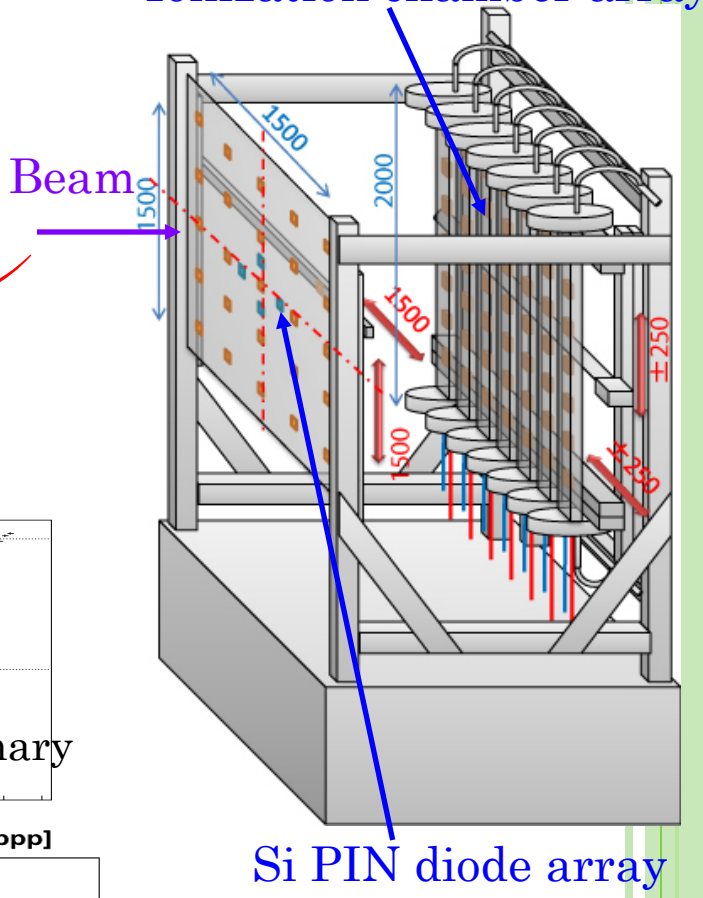
ミューオンモニター

- パルス毎にニュートリノビームをモニター
  - 強度、方向、プロファイル
- フェルミ研T968として、NuMIビームラインでプロトタイプの長期試験中
- 2008年冬に設置予定。

NuMI/MINOSに設置されたT2K-ミューオンモニター試作機







26pZj：15:45～

- 松岡
- 久保

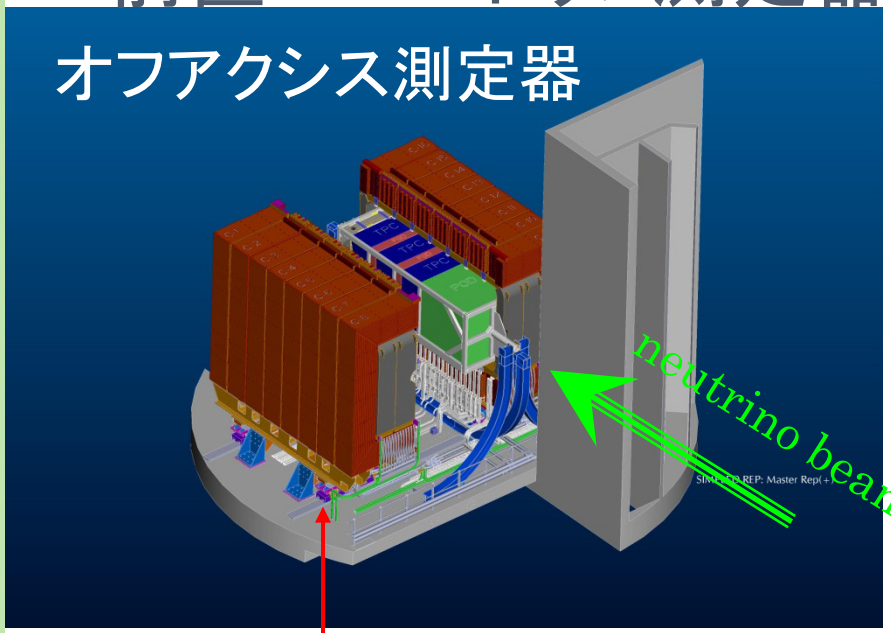
90

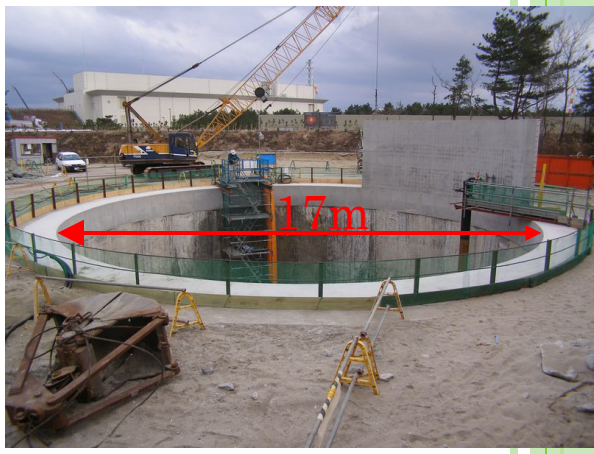
Summary of Status

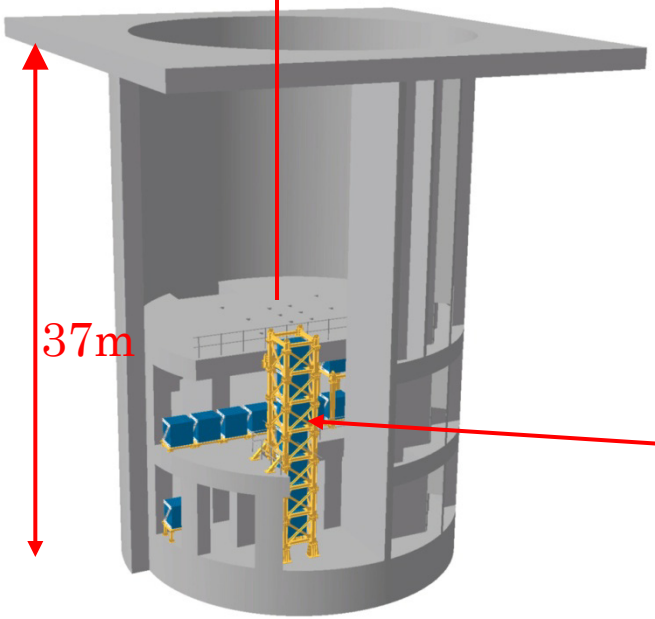
	Conceptual Design	Engineering Design	Real Production	Installation
Proton Beam monitor				Feb.~
Superconducting magnets				Feb~
Cryogenics				Apr~
Normal Conducting magnets				
Vacuum system				
Target				Aug.~
Horn				Aug.~
Target Station				
Beam Window				Jul~
Decay Volume				
Beam Dump				Aug~
Muon monitor				08/09

- All components are in production phase
- Installations are starting as scheduled

前置ニュートリノ測定器: ND280





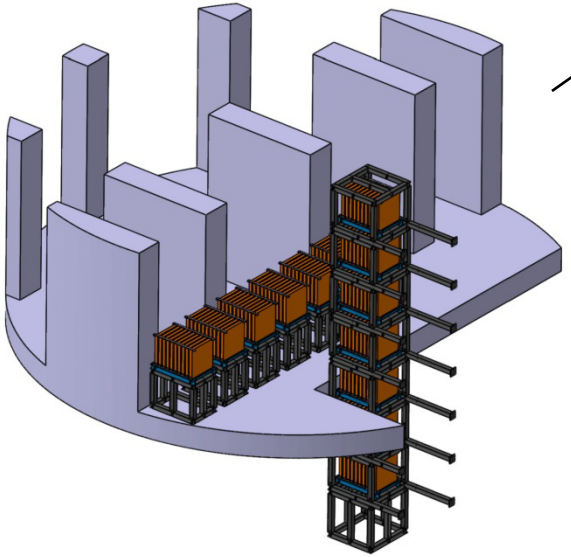


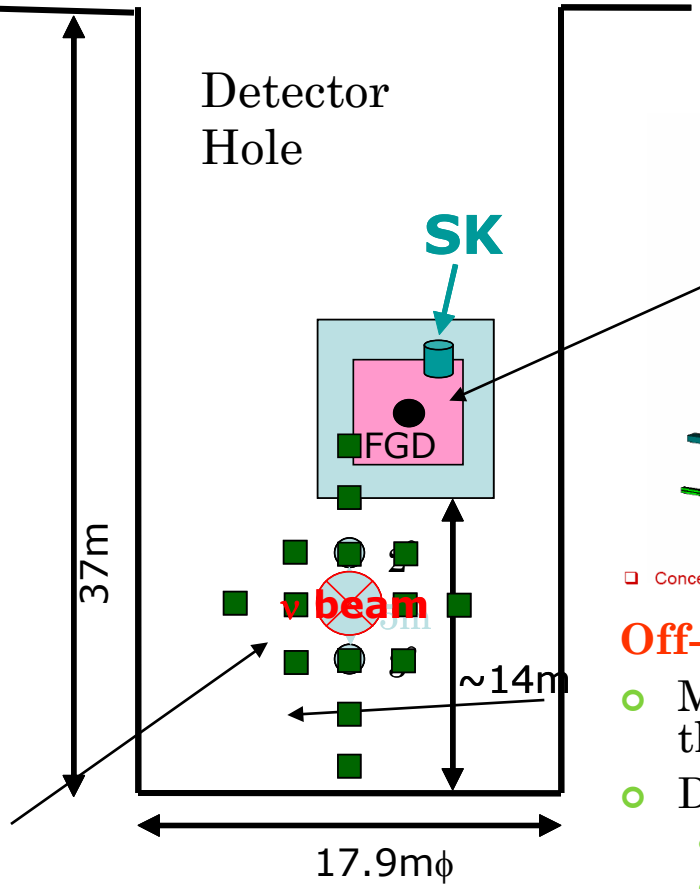
ニュートリノモニター:
INGRID

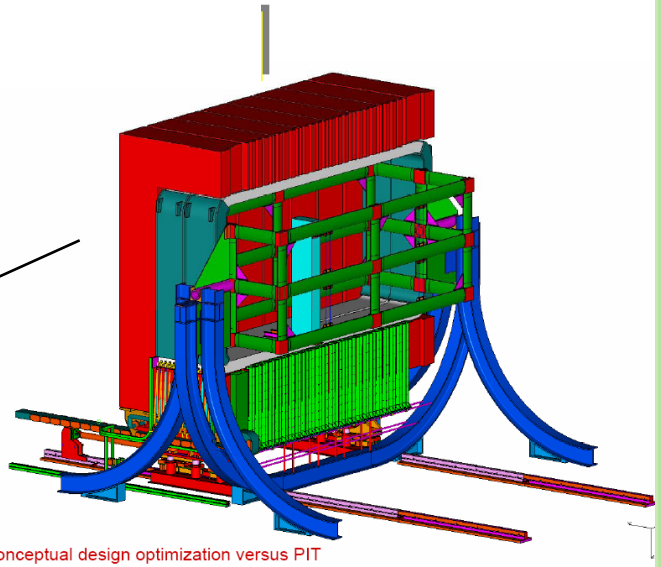
前置測定器

On-axis neutrino monitor

- Monitor
  - Profile
  - Direction
  - Intensity (& Energy)
- Iron-Scintillator sandwich detector
  - 1mx1mx10cm Iron
  - 1.25cm thick extruded Scinti.
  - New Photo-Sensor (MPPC/SiPM)







❑ Conceptual design optimization versus PIT

Off-axis detector

- Measurement of ν flux and σ in the SK direction.
- Detector components.
  - UA1 magnet (0.2T)
  - TPC
  - Fine-Grained Scintillator detector (FGD)
  - Lead/Scintillator tracking detector for π^0
  - Electromagnetic Calorimeter
  - Muon Range Detector in mag
- Key technologies
  - Photo-sensor, Micromegas

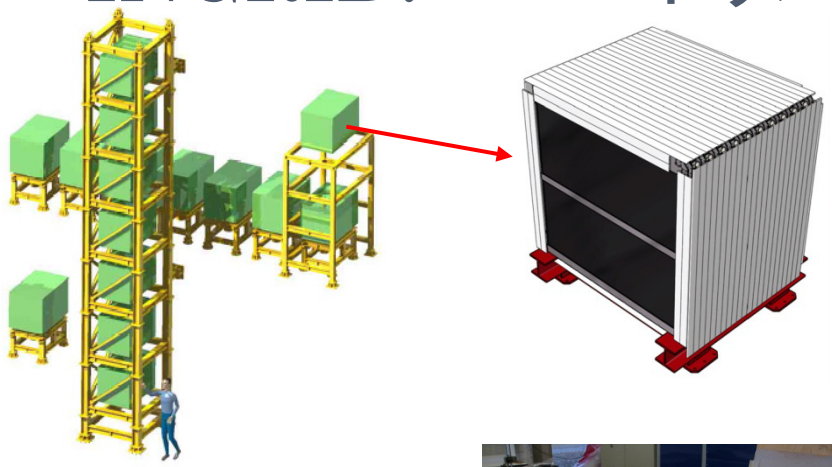
Off-axis Detector

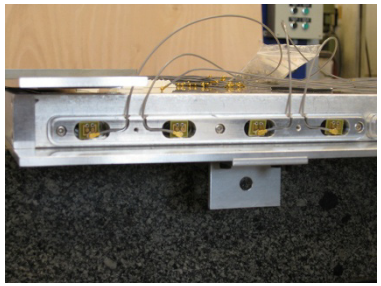
- Measure ν_μ flux: <5%
- Measure ν_μ energy scale: <2%
- Measure intrinsic ν_e content of beam: <10%
- Measure non-CCQE backgrounds for both ν_μ disappearance and ν_e appearance: <10%
- Magnetic field, fine segmentation, excellent tracking
- Major non-Japanese contributions
- High complexity and non-trivial integration

280M DETECTOR HOLE CONSTRUCTION

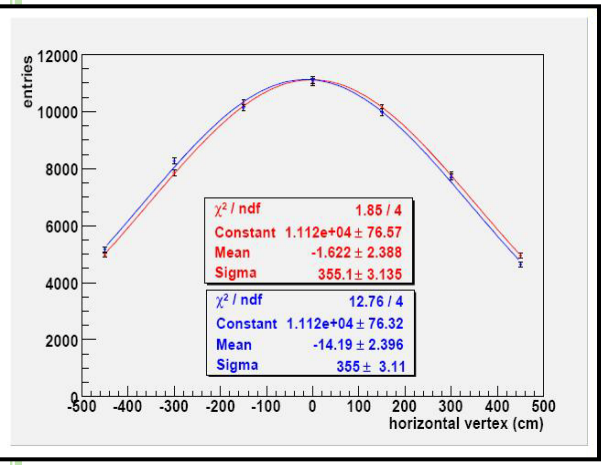
- 17.5m-ϕ x 33.5m deep hole excavation finished in Jan 2009
- Underground floors being constructed.
- UA1 magnet installation Apr-Jun, 2008
- **Construction is on schedule**

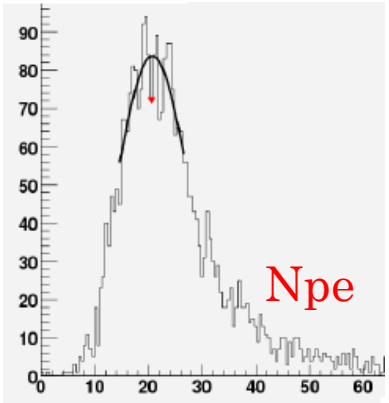
INGRID: ニュートリノビームモニター



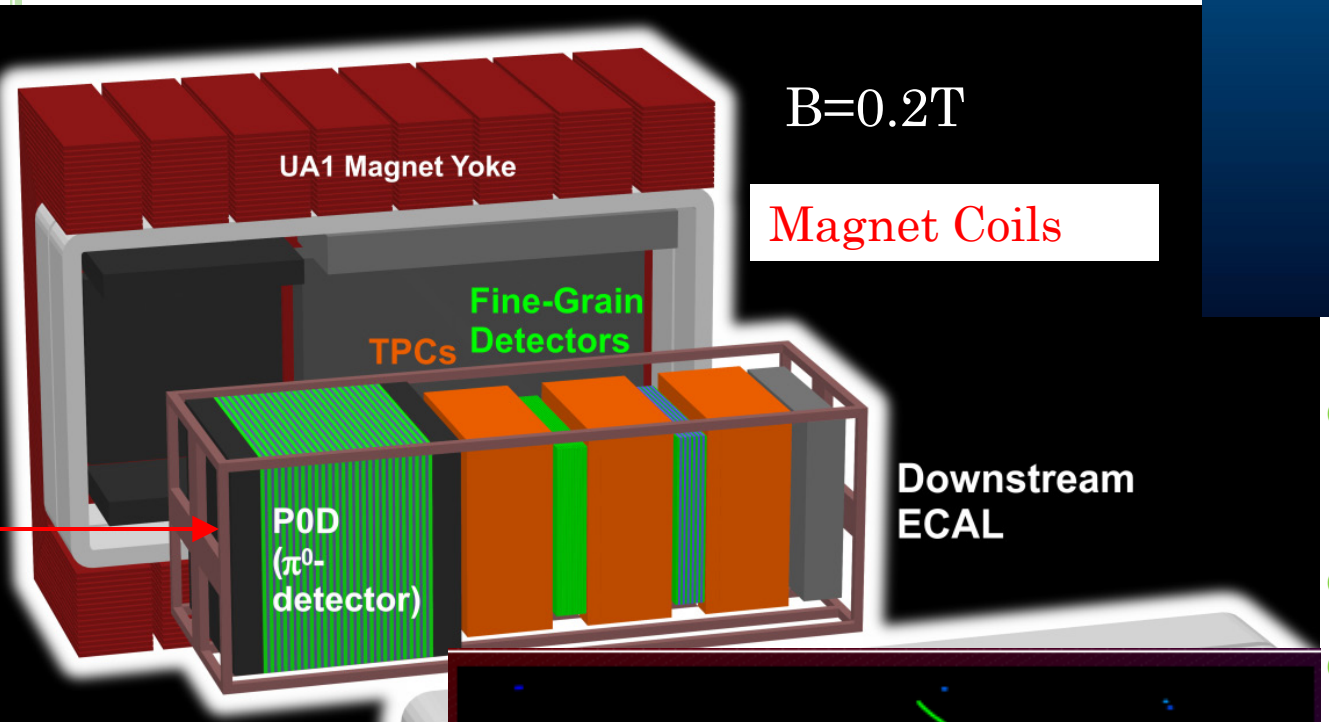


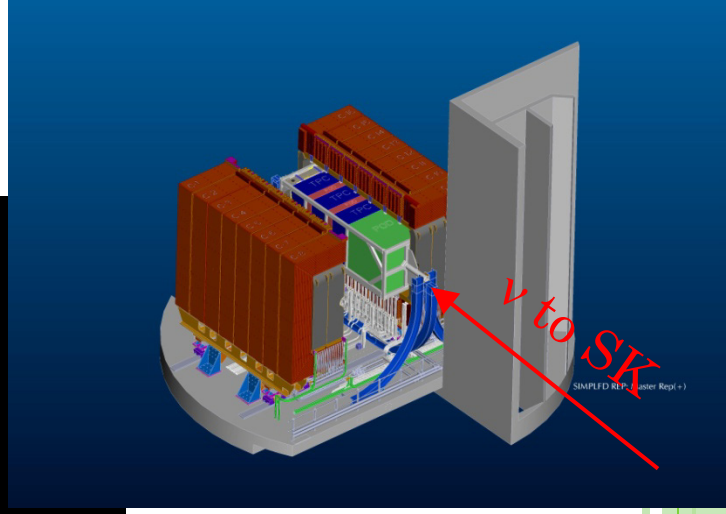
- 7+7+2モジュール
  - 10,000事象/モジュール/日
  - ニュートリノ強度、ビーム方向、スペクトル安定性をモニター
- 120×5×1cm^{3}シンチレータ
  - 約10,000本
  - 波長変換ファイバー読出し
  - 光測定器：浜フォトMPPC
  - 平均光量：　～15p.e./cm
- 2009年4月測定開始

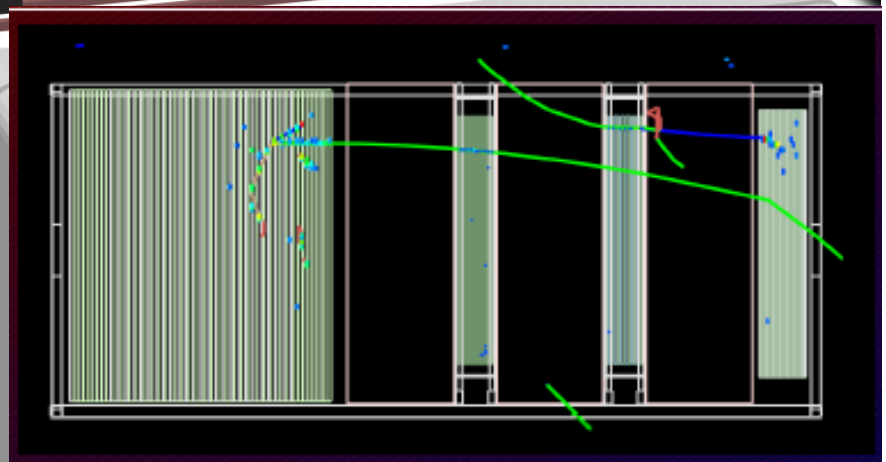




オフアクシス測定器





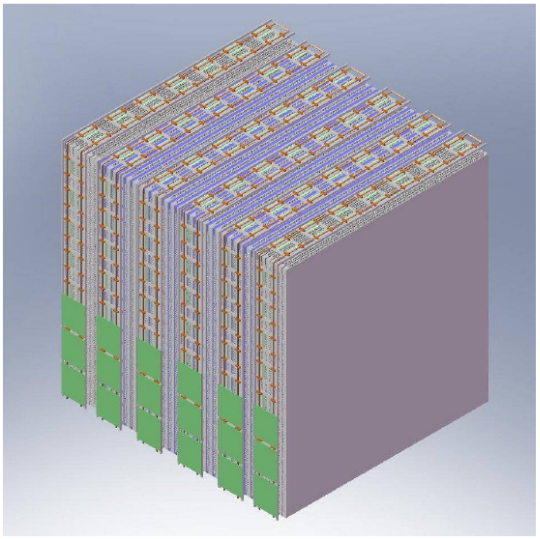


A CC1π interaction in the P0D, with full-bunch background

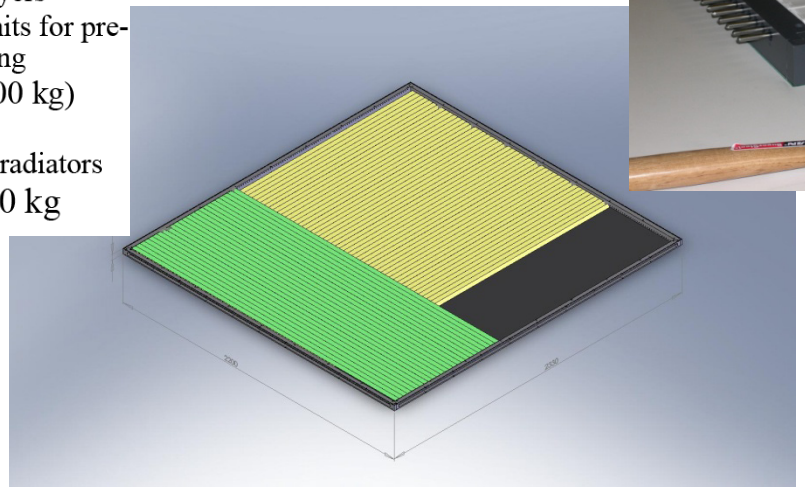
- 測定器容量:
  - $3.5 \times 3.5 \times 7.0 m^3$
- P0D π^0 測定器
- FGD+TPC:
  - 荷電カレント反応測定
- 電磁カロリメータ
- サイドミューオン飛程測定器

P 0 D

- Scintillator bars – lead/brass sandwich – water targets. Mass: 17.6ton total, 2.9ton water
- Optimized for NC π^0 production measurements
- Runs with/without water: C/H_2O scaling
- 17,000 NC 1π^0 events/year in water
- MINERVA bars, WLS fibres, MPPCs, TRIP-t electronics
- Construction: May-December 2008

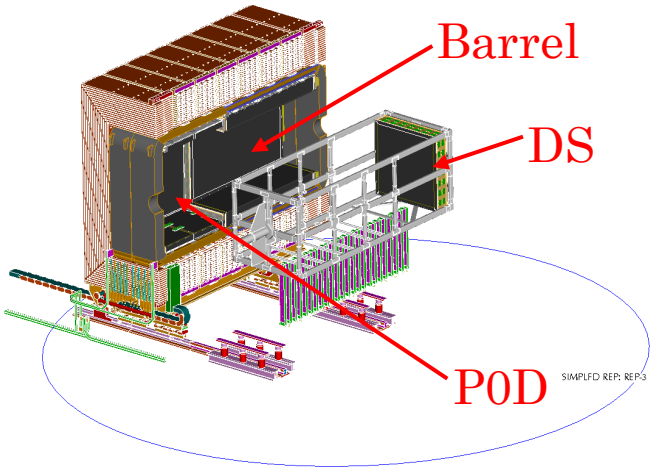


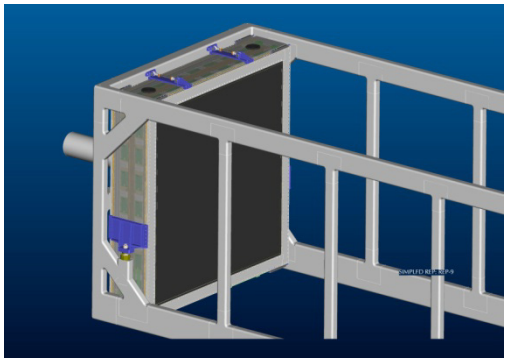
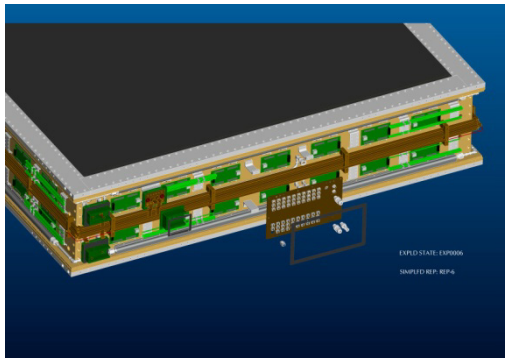
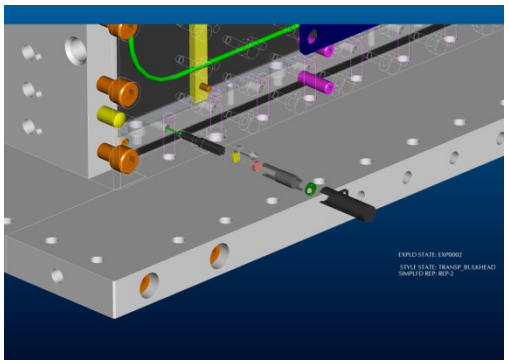
- 3 Super-PØDules
  - Upstream ECAL (3200 kg)
    - 7 PØDules
    - 7 4mm-thick lead radiators
  - Target (11000 kg)
    - 2857.3 kg water
    - 26 PØDules
    - 25 1.6mm brass radiators
    - 25 Water target layers
    - Split into 2 sub-units for pre-installation handling
  - Central ECAL (3200 kg)
    - 7 PØDules
    - 7 4mm-thick lead radiators
- Total Mass is 17600 kg

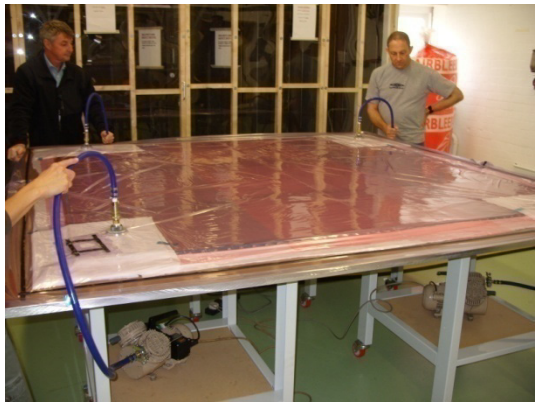
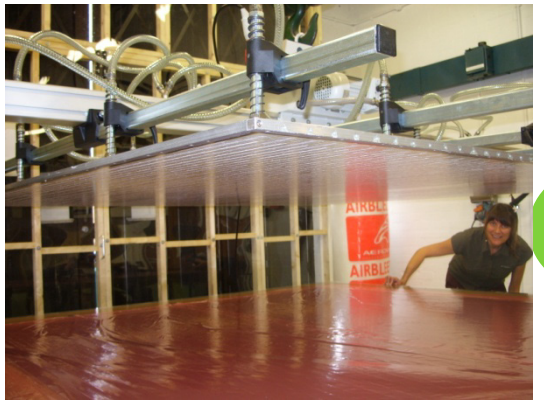


ECAL

- Reconstruct π^0, identify e/μ/π
- Lead-scintillator sampling calorimeter
- 4cm x 1cm scintillator, WLS fibre, MPPCs, TRIP-t readout
- 32 layers, 1.75mm Pb, $10X_0$
- DS ECAL ready for installation summer 2009; Barrel in 2010

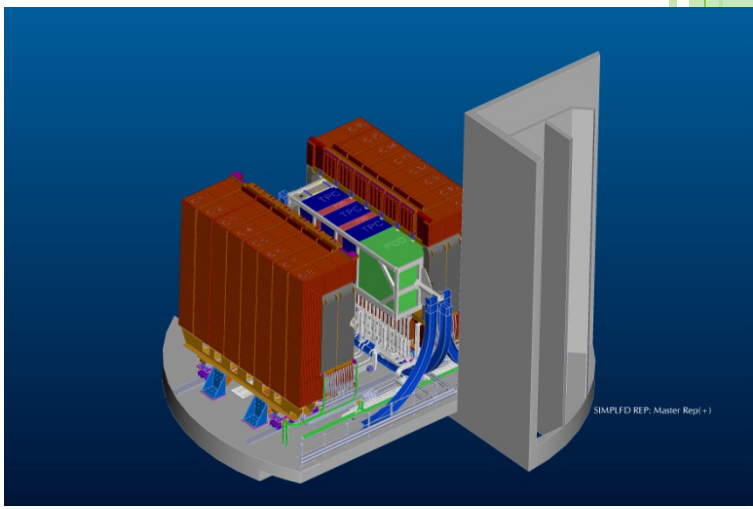


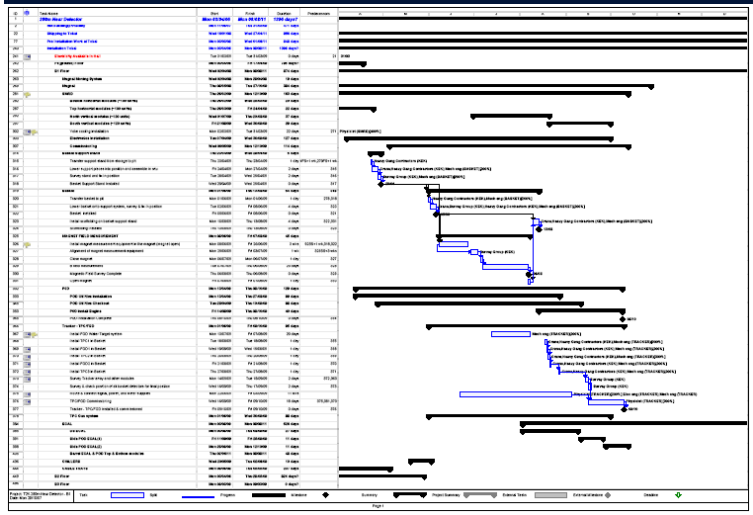




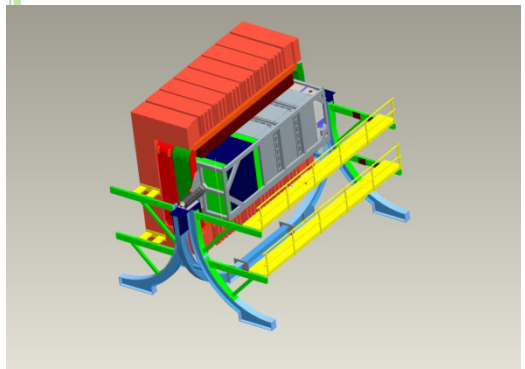



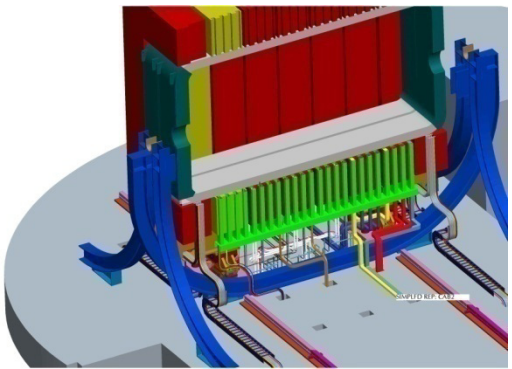
Integration

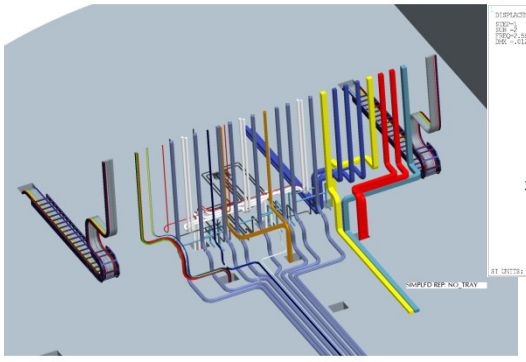
- Complex dependencies and interactions in space and time
- Technical Board, installation co-ordinators
- Central 3-D pit description, including services routing
- Central project file
- Seismic studies
- Environmental studies (temperature, humidity)

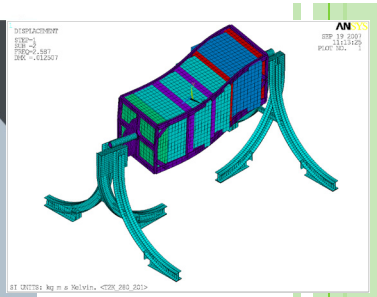










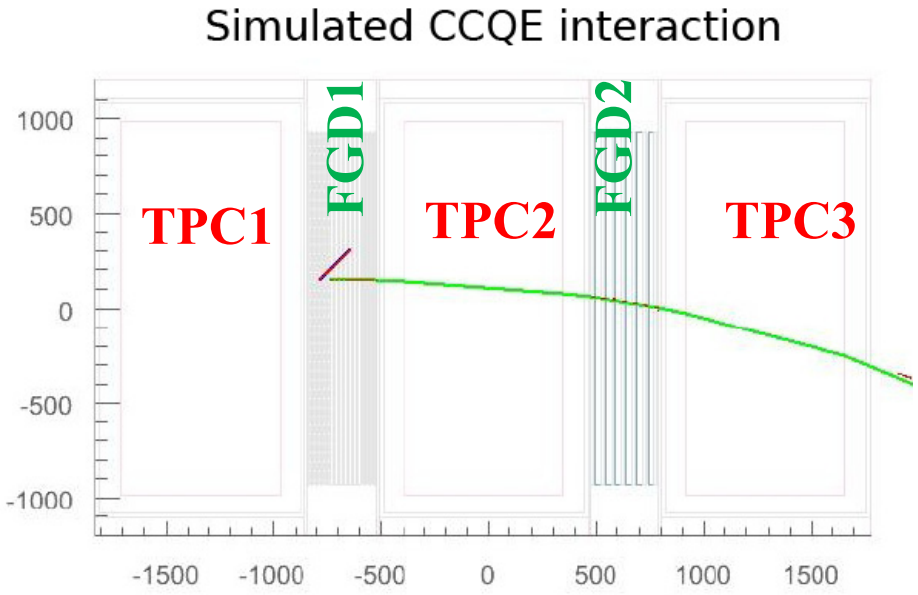


UA1 MAGNET

- UA1実験のダイポールマグネットをCERNより輸送。
  - J－PARCに設置終了
- TPCと組み合わせて運動量測定
  - 0.2Tで運転
  - 高精度＋大立体角で荷電粒子測定。

FINE GRAIN DETECTORS

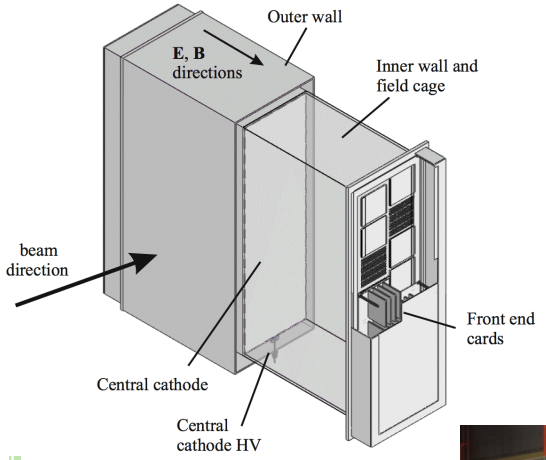
- ニュートリノバーテックス測定器
- 1cm x 1cm シンチレータ, 波長変換ファイバー＋MPPC
- 2009年夏にインストール

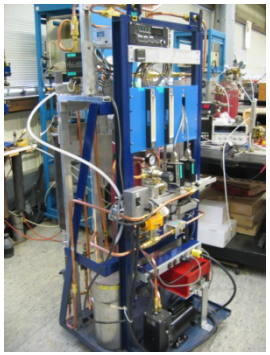


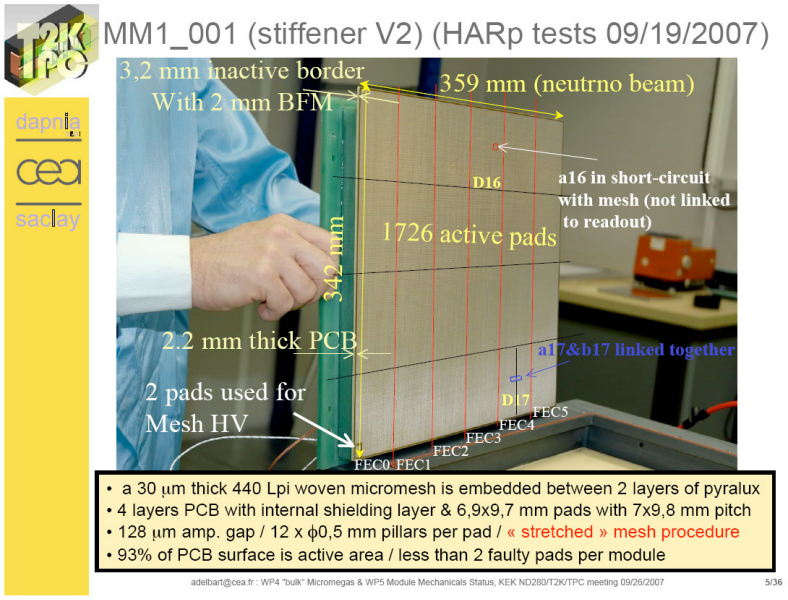
Tracker volume

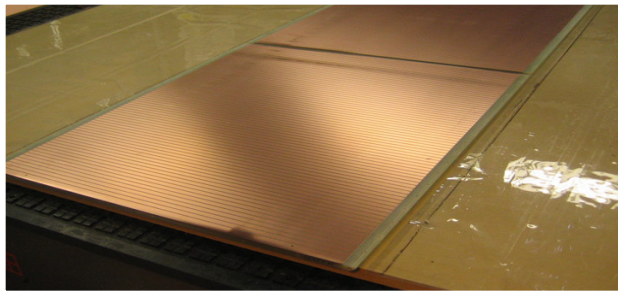
TPC

- 3TPC, MicroMegas 読み出し (8mm × 8mm パッドサイズ)
- 10% 運動量分解能 (p<1GeV/c), ~10% dE/dx 分解能
- MicroMegas試作機はCERNでテスト。=>　生産開始へ！
- 2009年夏に2台のTPCを設置予定。



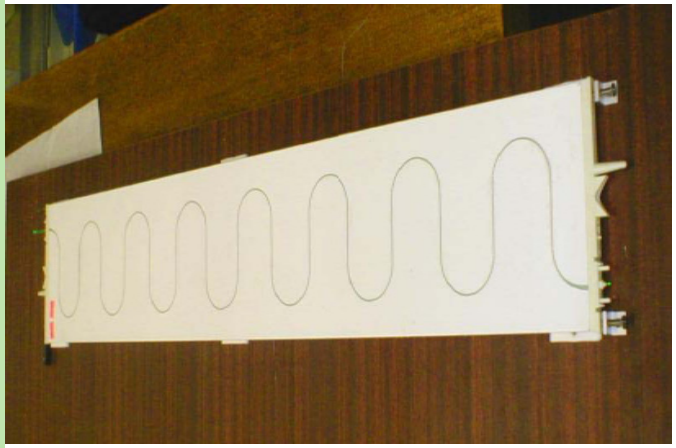


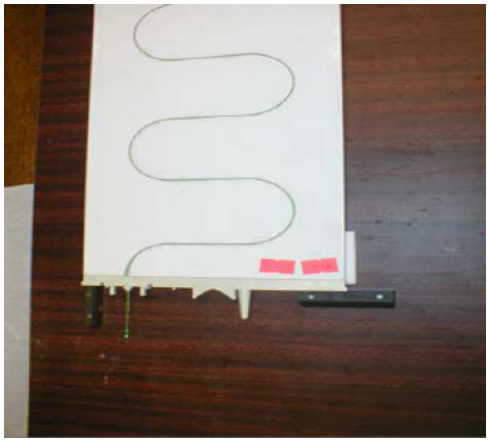


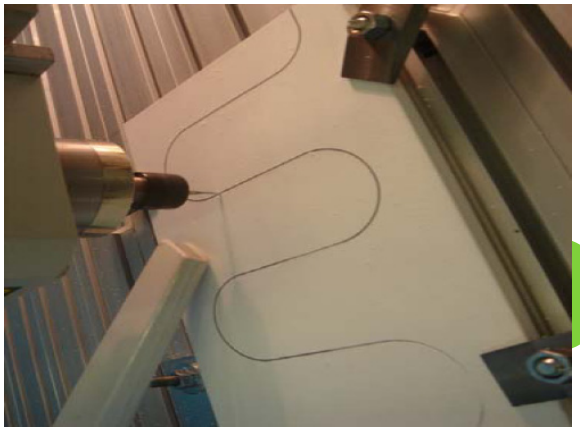


Side Muon Range Detector

- 磁石ヨークのギャップ(1.7cm厚)にシンチレータ挿入。
  - 7mm厚シンチレータ – 波長変換ファイバー＋MPPC
- ミューオン検出、外部からの事象のVETO、宇宙線トリガー

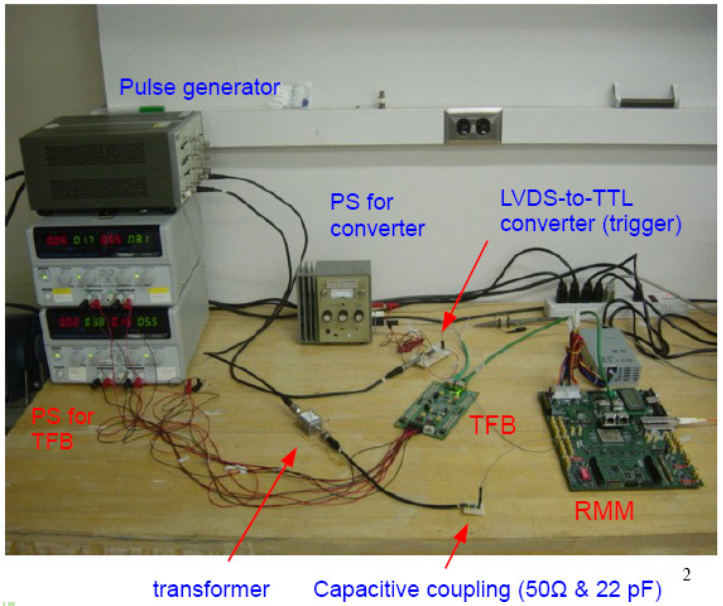




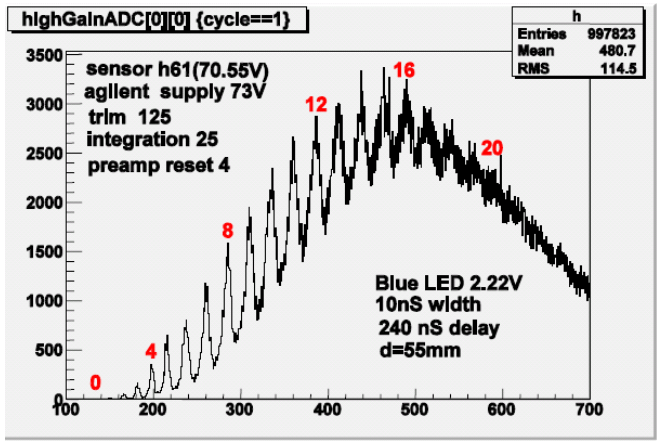


Readout electronics

- Two solutions for Front End Electronics:
  - UK system using FNAL TRIP-t chip: INGRID, P0D, ECAL, SMRD
  - French system using Saclay AFTER chip: FGD, TPC
- Prototypes for both systems operational
- Back End Boards and DAQ system by RAL (common to all)
- Slow Control: MIDAS (TRIUMF)



TFB system in US lab

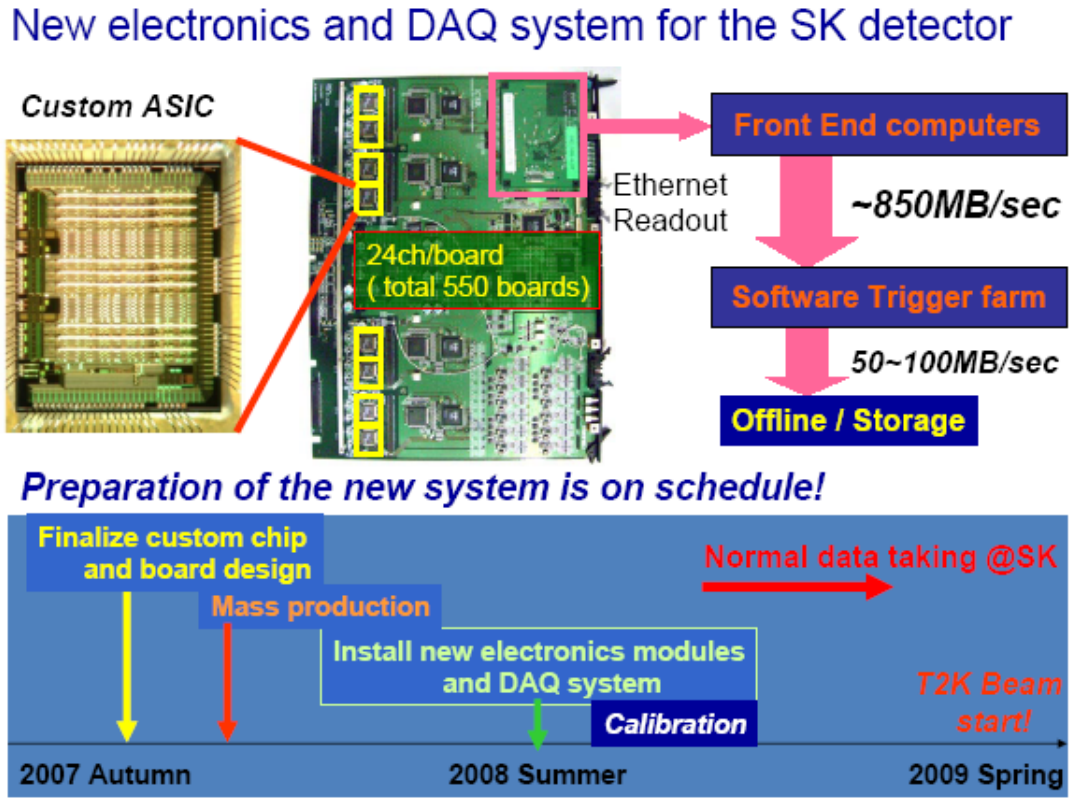


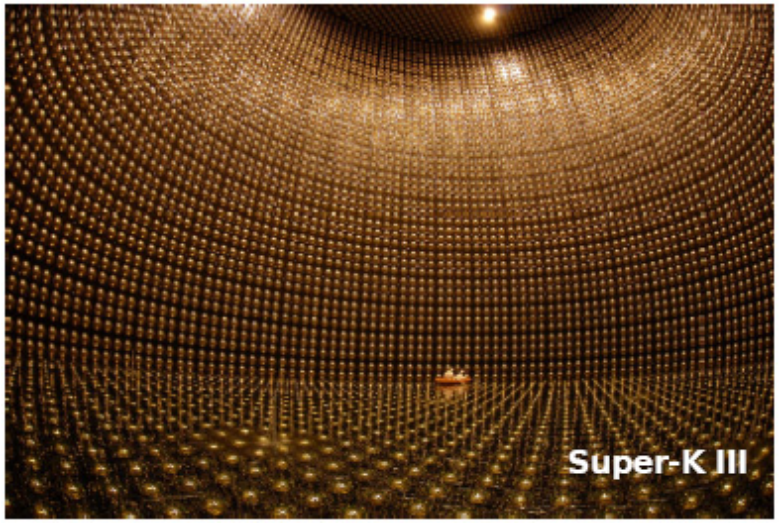
MPPC spectrum with prototype TFB, BEB, and DAQ

AFTER chip and card

SUPERKAMIOKANDE

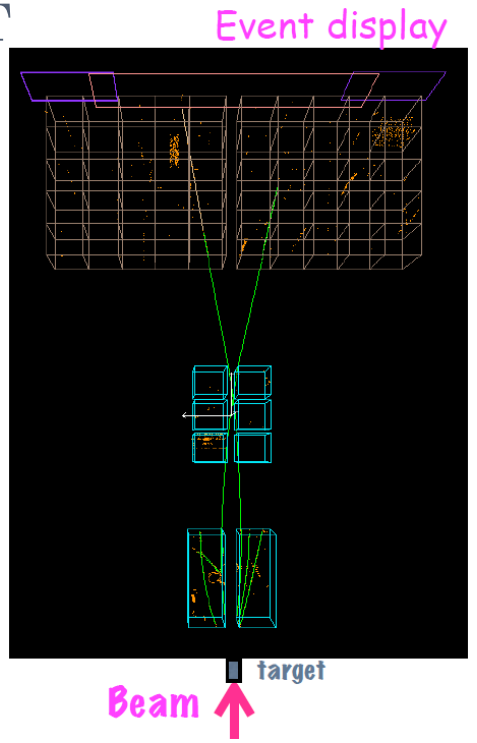
- Refitted SuperK, major next upgrade: electronics (higher dynamic range – faster – no dead time – stability >10 years)
- Installation starting September 2008
- New Online, spill time information transferred from J-PARC over private line, allow to flag and record ±500μs around each spill
- Reconstruction and simulation will be adapted

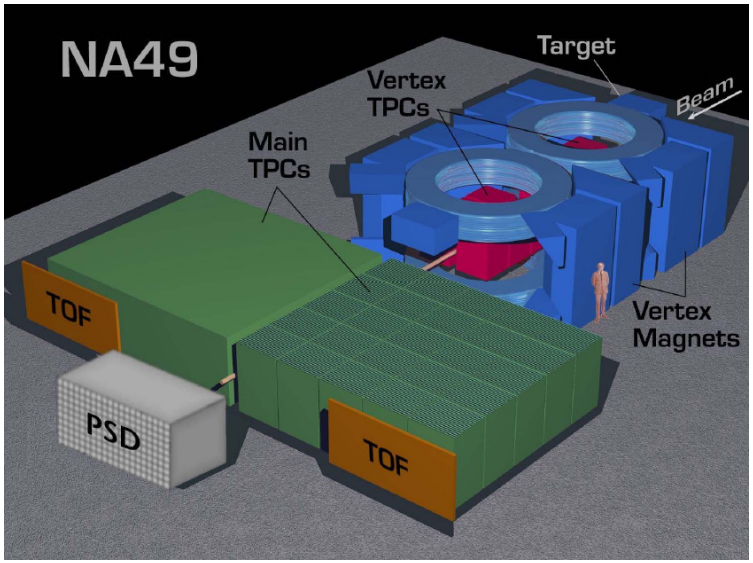


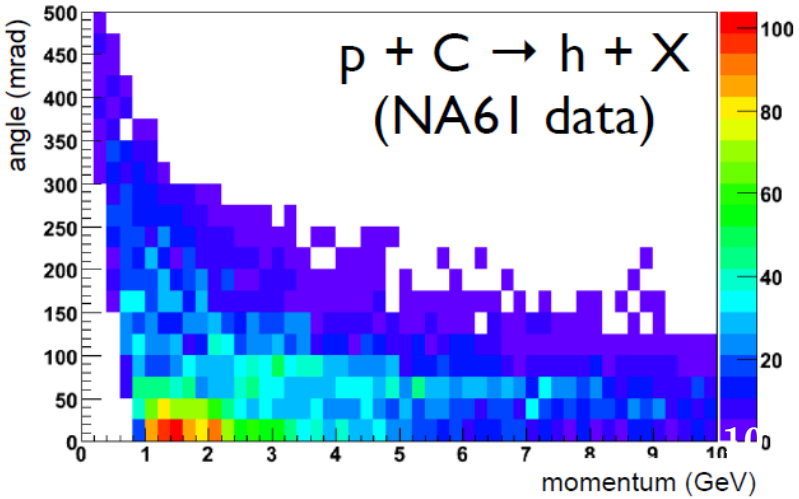


CERN-SPS NA61 (SHINE) EXPERIMENT

- Measure π/K prod. from Graphite target to predict
  - Near and far energy spectra (<2~3%)
  - Near to far spectrum extrapolation (<2~3%)
  - ν_e contami. (from K, μ) (<2~3%)
- **First data taking in Oct., 2007 (1month)**
  - Beam: 30GeV proton
  - Thin target (2cm^t 4%int):~ 500k int.
  - Replica target (90cm, 80%int): ~180k int.
- Measurements in 2008 planned



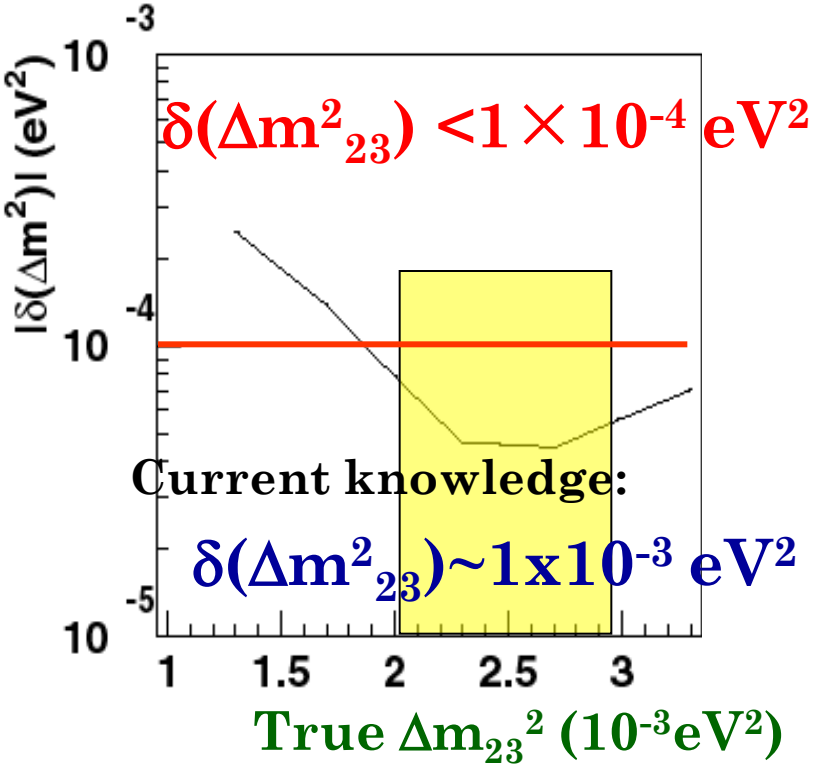


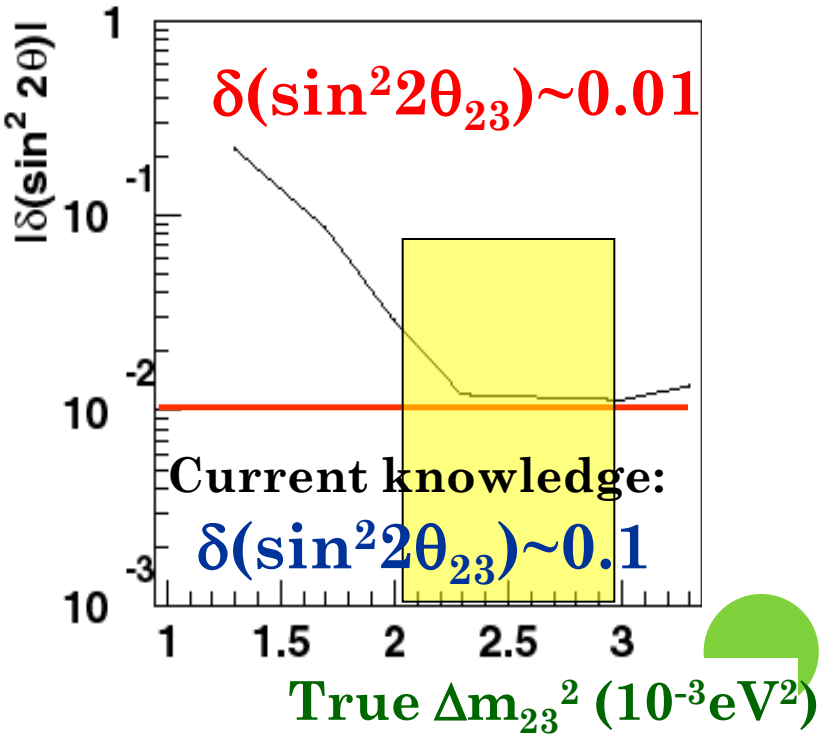


First look of data
(PID, acceptance not corrected)

T2K-I sensitivity with systematic errors

- normalization (5%)
- non-qe/qe ratio (5%)
- E scale (2%)
- Spectrum shape (20%)
- Spectrum width (5%)





Future Prospects in a Few-year Scale

- We are requesting 100kW operation of MR for more than 10^7s(several months) to the accelerator group before 2010 summer shutdown
  - This is vitally important, in order to get the 1st result with enough impact.

To achieve the request, to inclease rep. rate is a preferable solution, without significant hardware upgrades:

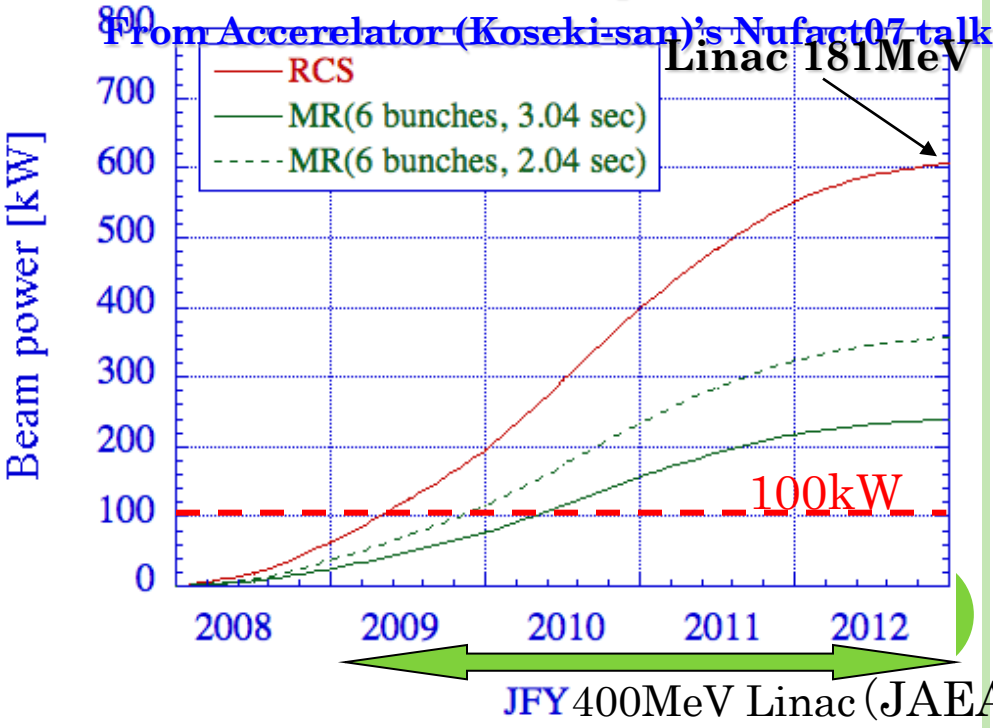
Cycle: 3.04→2.04sec, 30GeV

- Acc1.9 →1.1sec
- Reset 0.87 →0.67sec

- # of bunches to be recovered from 6 to 8 (design).
- Nominal beam power: 30GeV-9uA (270kW), to be achieved in JFY2012 or earlier.

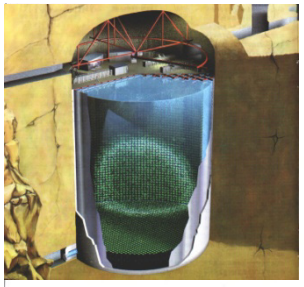
[J-PARC Director's order: "Nagamiya Chart"]

From Accerelator (Koseki-san)'s Nufact07 talk

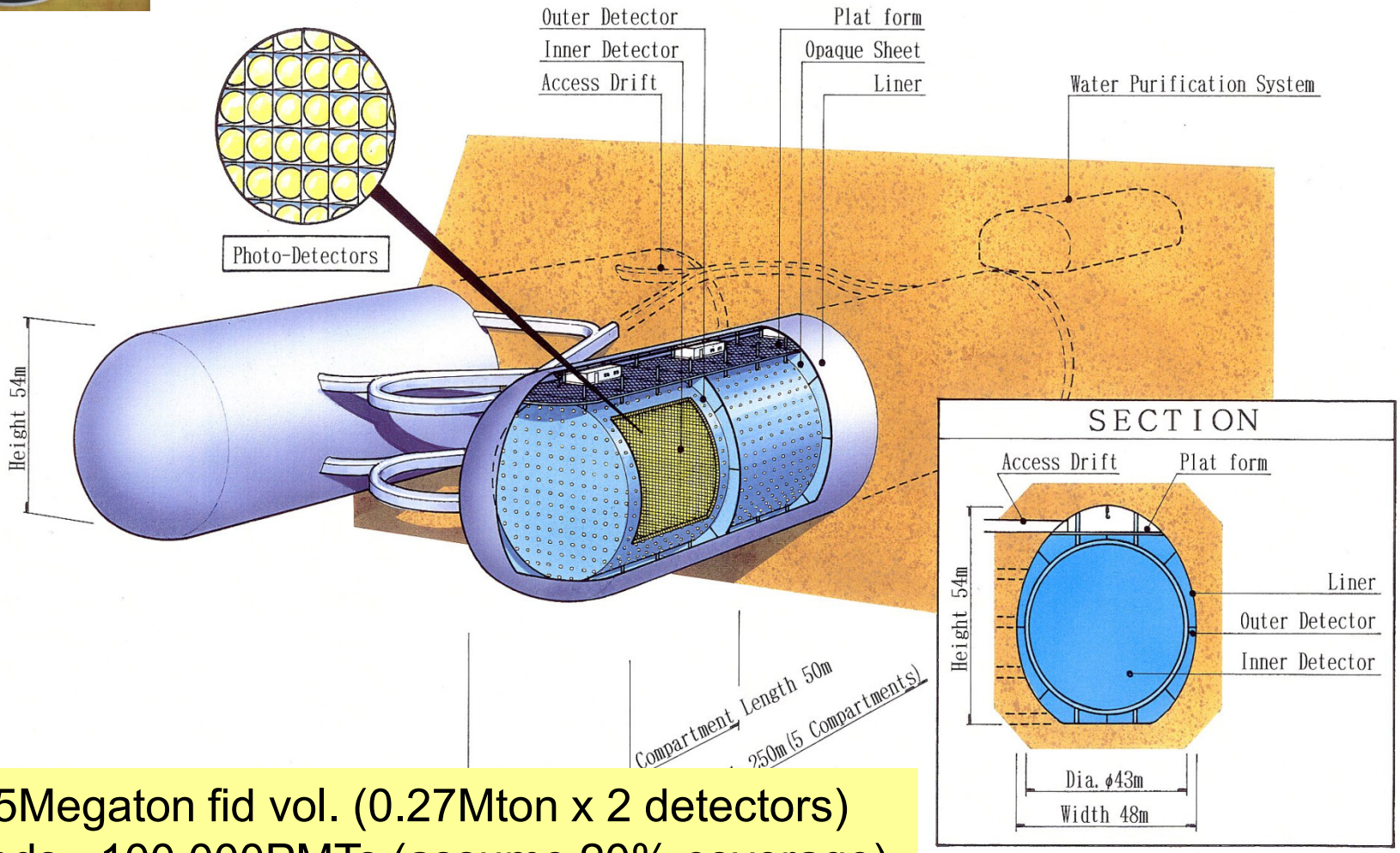


Power Upgrade for Future Projects

- Future projects to investigate Lepton sector CPV / neutrino mass hierarchy
  - Key components: J-PARC power upgrade (750kW→**MW) & massive far detector(s)
  - Proton decay
  - Intensive discussion is being started to prepare the best proposal towards 2012.
- Need continuing upgrades for accelerator components for the purpose.
  - For Linac: 181MeV → 400MeV with ACS Installation
    - Just after completion of J-PARC: Apr.'09 ~
    - 4 year (3 year in case R&D in 2008 goes smoothly)
  - For RCS/MR RF: Improvement for the magnetic alloy cut core
    - To achieve the high field acceleration as designed (25kV/m)
    - To improve procuction process / Water → Oil (paraffin) cooling
    - This will further increase the rep. rete
  - For MR Fx kicker:
    - To improve slow rise time 1.6us→1.1us (#b 6→8)
    - Without causing discharge
  - 30GeV →40(50)GeV energy boot-up
- MR intensity upgrade scenario
  - Increasing repetition rate (cycle=3.04 to 1.92sec)
  - Reduce harmonic number of RCS from 2 to 1
    - 1x8 injections instead of 2x4: Almost twice of beam injected to MR.
  - KEK roadmap: 1.66MW
- We will learn a lot more by the successful operation of the neutrino beam-line !



Hyper-Kamiokande



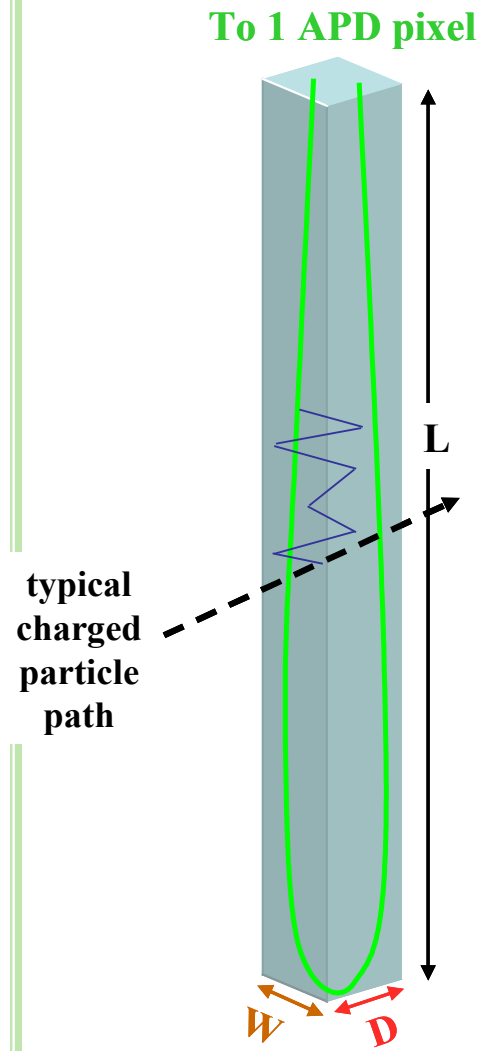
~0.5Megaton fid vol. (0.27Mton x 2 detectors)
Needs ~100,000PMTs (assume 20% coverage)

BACKUP
-NOvA -

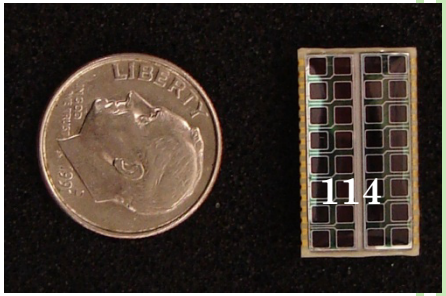
Proton Plans

	Present Operating Conditions (May 2007)	Proton Plan Multi-batch Slip-stacking in MI	NOνA Multi-batch Slip-stacking in Recycler
8 GeV Intensity (p/Batch)	4.3 - 4.5x10^{12}	4.3x10^{12}	**4.3x10^{12}**
Number of 8 GeV Batches to NuMI	7	11	**12**
MI Cycle Time (sec)	2.4	2.2	**1.3**
MI Intensity (protons per pulse or ppp)	3.3x10^{13}	4.5x10^{13}	**4.9x10^{13}**
MI to NuMI (ppp)	2.45x10^{13}	3.7x10^{13}	**4.9x10^{13}**
NuMI Beam Power (kW)	192	320	**700**
Protons/year to NuMI	2x10^{20}	3x10^{20}	**6x10^{20}**
MI Protons/hour	4.95x10^{16}	7.3x10^{16}	**1.3x10^{17}**

The Basic Detector element

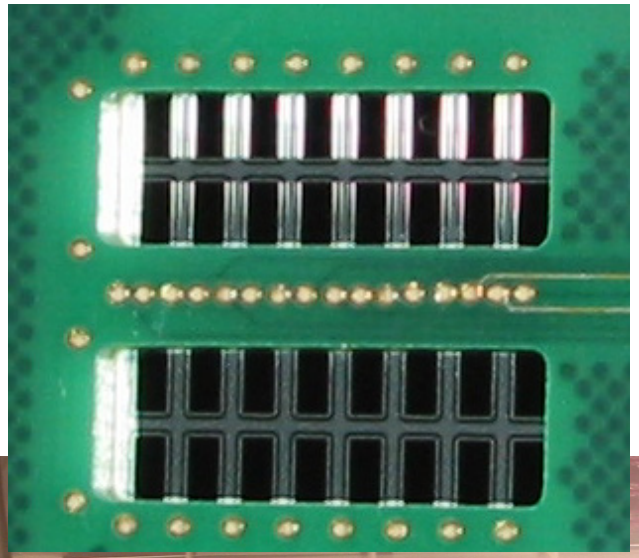


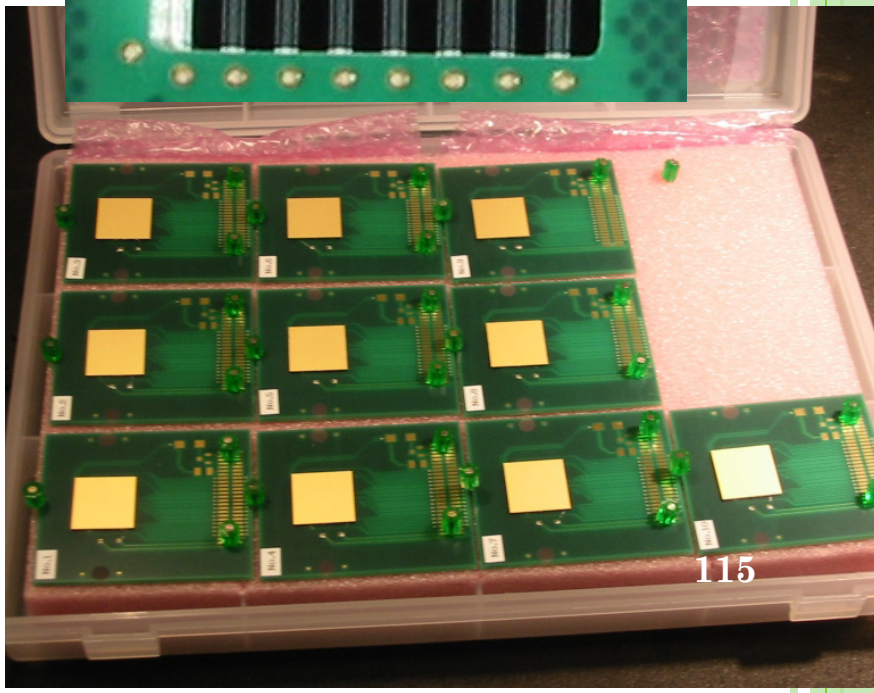
- Liquid Scintillator
  - 4.1% pseudocumene as scintillant
  - Mineral oil and waveshifters (PPO, bis-MSB)
- PVC cell for primary containment
  - Horizontals:3.87 cm x 6.0 cm x 15.4 m long
  - Verticals: 3.76 cm x 5.7 cm x 15.4 m long
  - Highly reflective, 15% titanium dioxide
- Looped wavelength shifting fiber to collect light
  - 0.7 mm diameter, double clad, K27 waveshifter
  - Almost perfect mirror, 3.6*light in 1 fiber
- Avalanche Photodiode
  - 85% quantum efficiency
  - Gain of 100, operate at -15°C
- Low noise amplifier



APD Photodetector

- Hamamatsu
  Si Avalanche Photodiode (APD)
  - S11211(X) Custom Variant of commercial S8550 SiAPD
  - Custom design to match to fiber aspect ratio
  - Bare die mounted to PCB via bump bonding





APD Advantage