

T2K

status of the experiment First neutrino beam and cosmic tracks

T2K

Tokai 2 Kamiokande

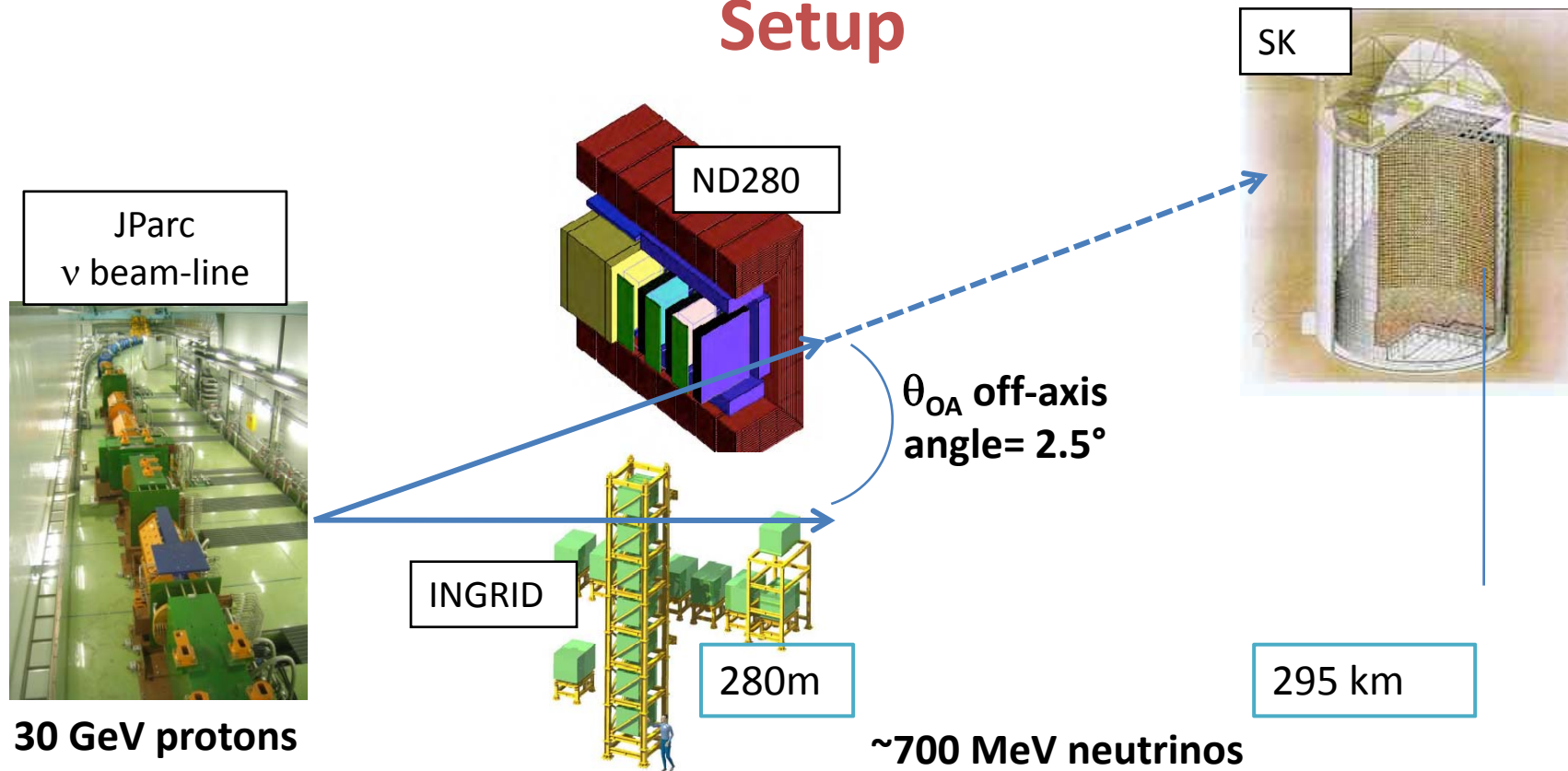


Main goals :

- 1) Measurement of θ_{13} **mixing angle** studying the $\nu_{\mu} \rightarrow \nu_e$ oscillation (ν_e appearance).
- 2) Better precision on Δm^2_{23} and θ_{23} studying the ν_{μ} disappearance.

Beam has started few days ago! ON TIME !!

Setup



Near detectors :

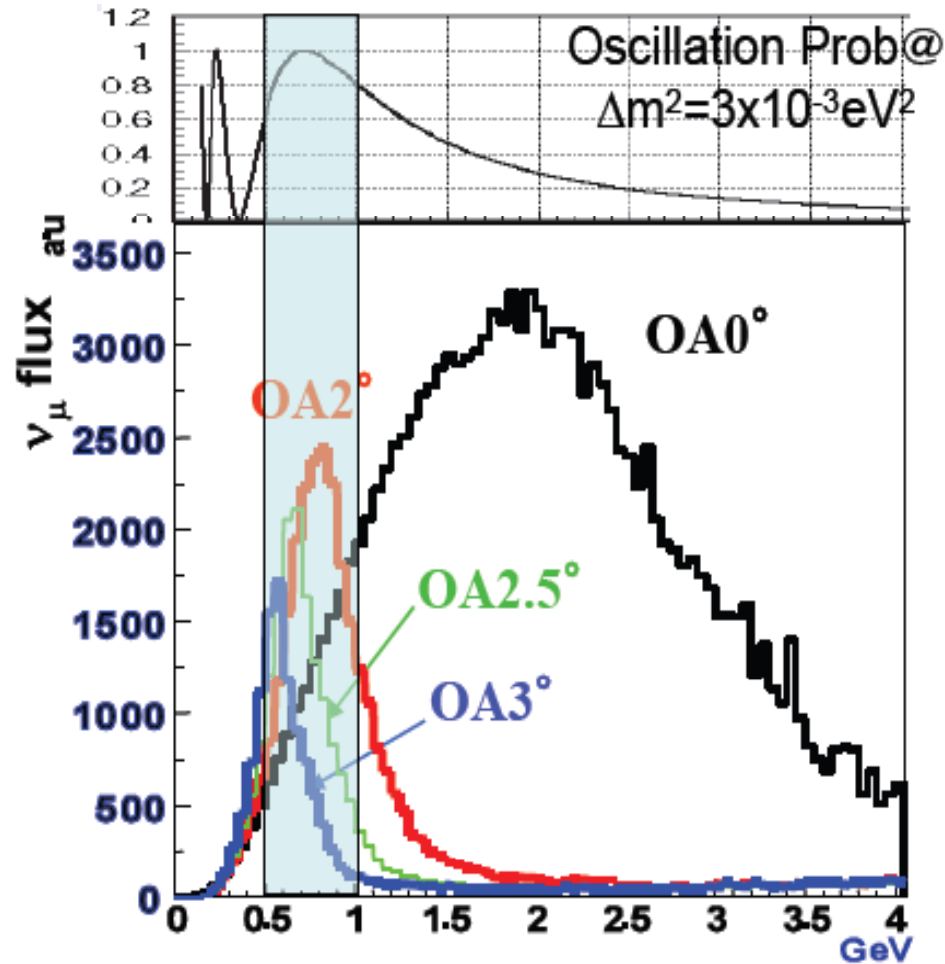
INGRID, on axis : monitoring of the beam direction with neutrino interactions

ND280, off-axis : measurement of systematics :

- cross sections : CC- 1π , NC π^+ (bckg for ν_μ disappearance) and NC π^0 (bkg for ν_e appearance)
- beam flux and spectrum

SK : 22.5 kt water cerenkov, excellent detector for low energy neutrinos

Beam features



Off-axis beam :

- Narrow peak around a maximum oscillation
- Reduce high energy interactions (DIS)
- Reduce the number of beam ν_e

Statistics at SK
 (OAB 2.5 deg, 1 yr, 22.5 kt)
 $\sim 2200 \nu_\mu$ tot
 $\sim 1600 \nu_\mu$ CC
 $\nu_e \sim 0.4\%$ at ν_μ peak

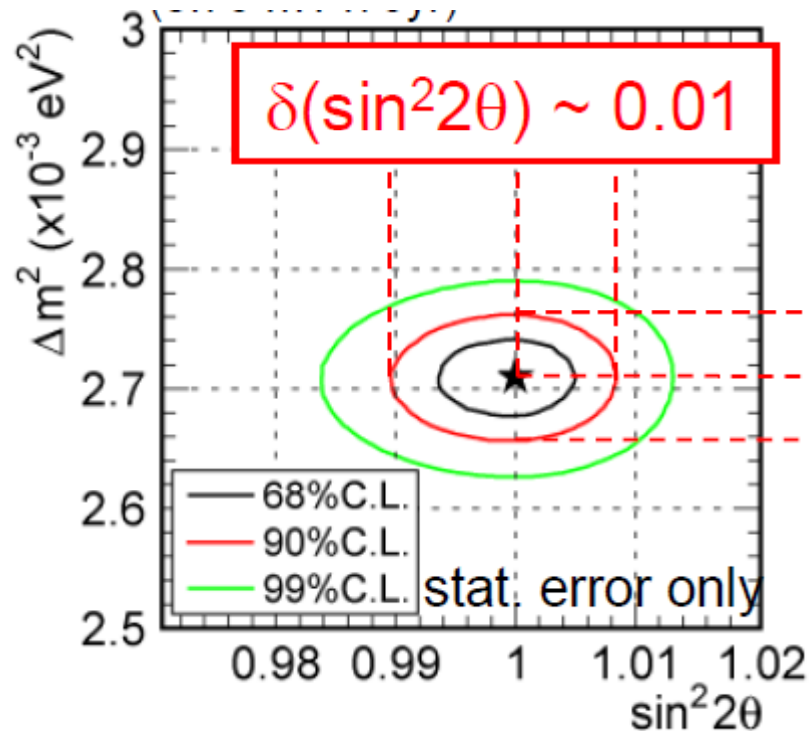
A quasi monochromatic beam !

disappearance : $P(\nu_\mu \rightarrow \nu_\tau) \sim \sin^2 2\theta_{23} \sin^2 (\Delta m_{23}^2 L / 4E)$

appearance : $P(\nu_\mu \rightarrow \nu_e) \sim \sin^2 2\theta_{13} \sin^2 \theta_{23} \sin^2 (\Delta m_{13}^2 L / 4E)$

T2K sensitivity to Δm^2_{23} and θ_{23}

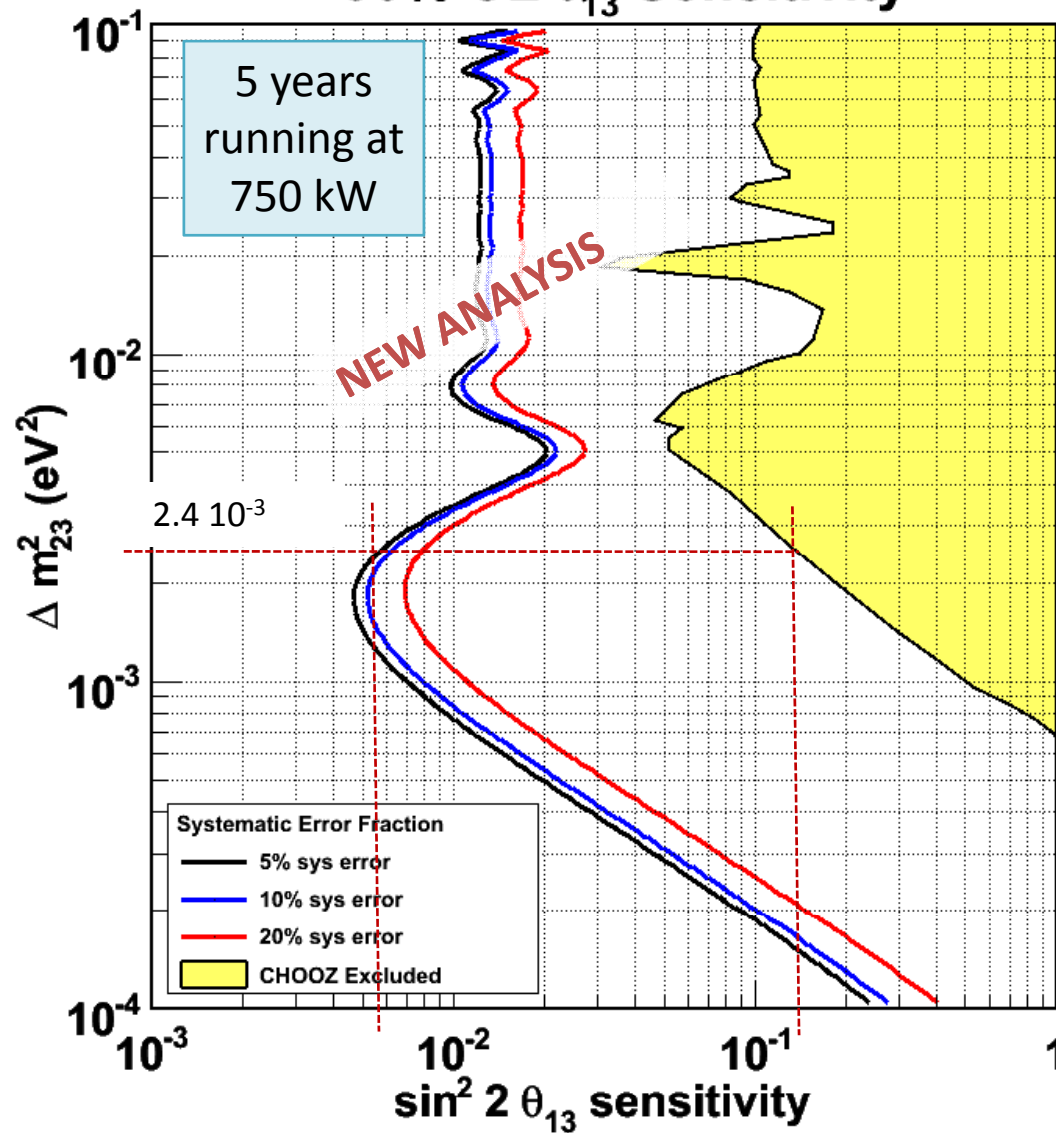
5 years
running at
750 kW



Achievable precision
(@ $\Delta m^2 \sim 2.5 \times 10^{-3} \text{ eV}^2$)
when stat. error dominates

T2K sensitivity to θ_{13}

90% CL θ_{13} Sensitivity



Sensitivity : $\sin^2 2\theta_{13} \sim 6 \cdot 10^{-3}$
with 10% of syst. error

Calculated with :

- 22.5 kt fiducial volume
- « fully contained » events
- Minimum visible energy (100 MeV)
- Single ring + e-like cuts
- several other cuts to eliminate non- ν_e signal ($\mu \rightarrow e$ decays, π^0 , ...).
- Reconstructed neutrino energy : 0.35-0.85 GeV

$$\sin^2 2\theta_{12} = 0.8704$$

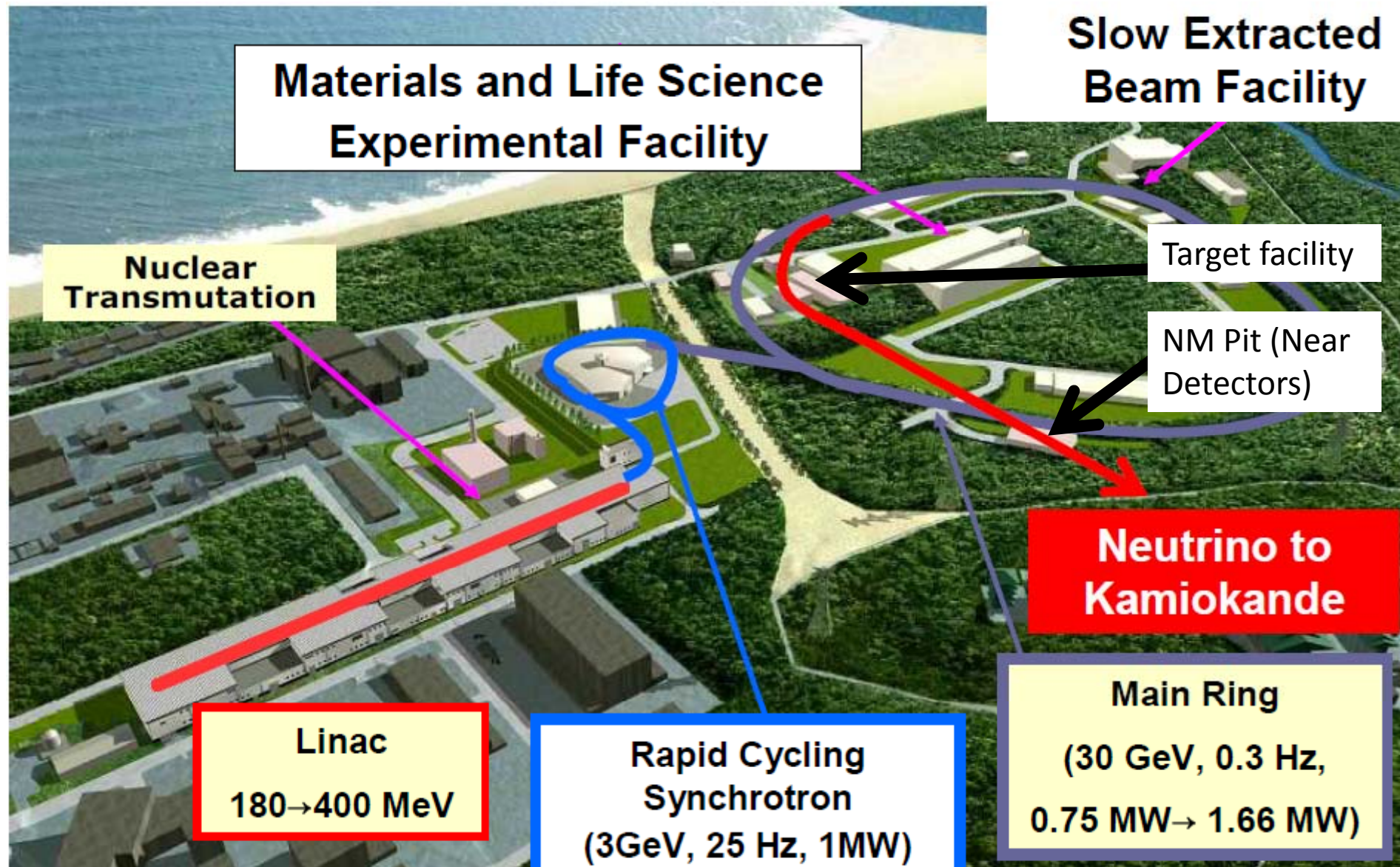
$$\sin^2 2\theta_{23} = 1.0$$

$$\Delta m^2_{12} = 7.6 \times 10^{-5} \text{ eV}^2$$

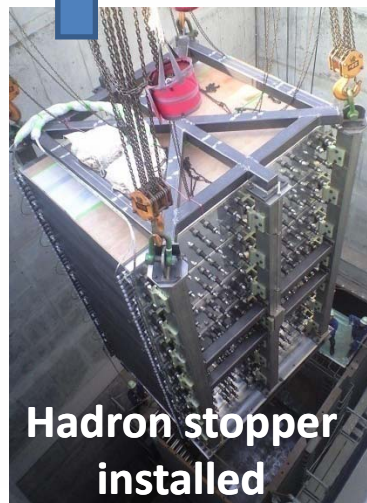
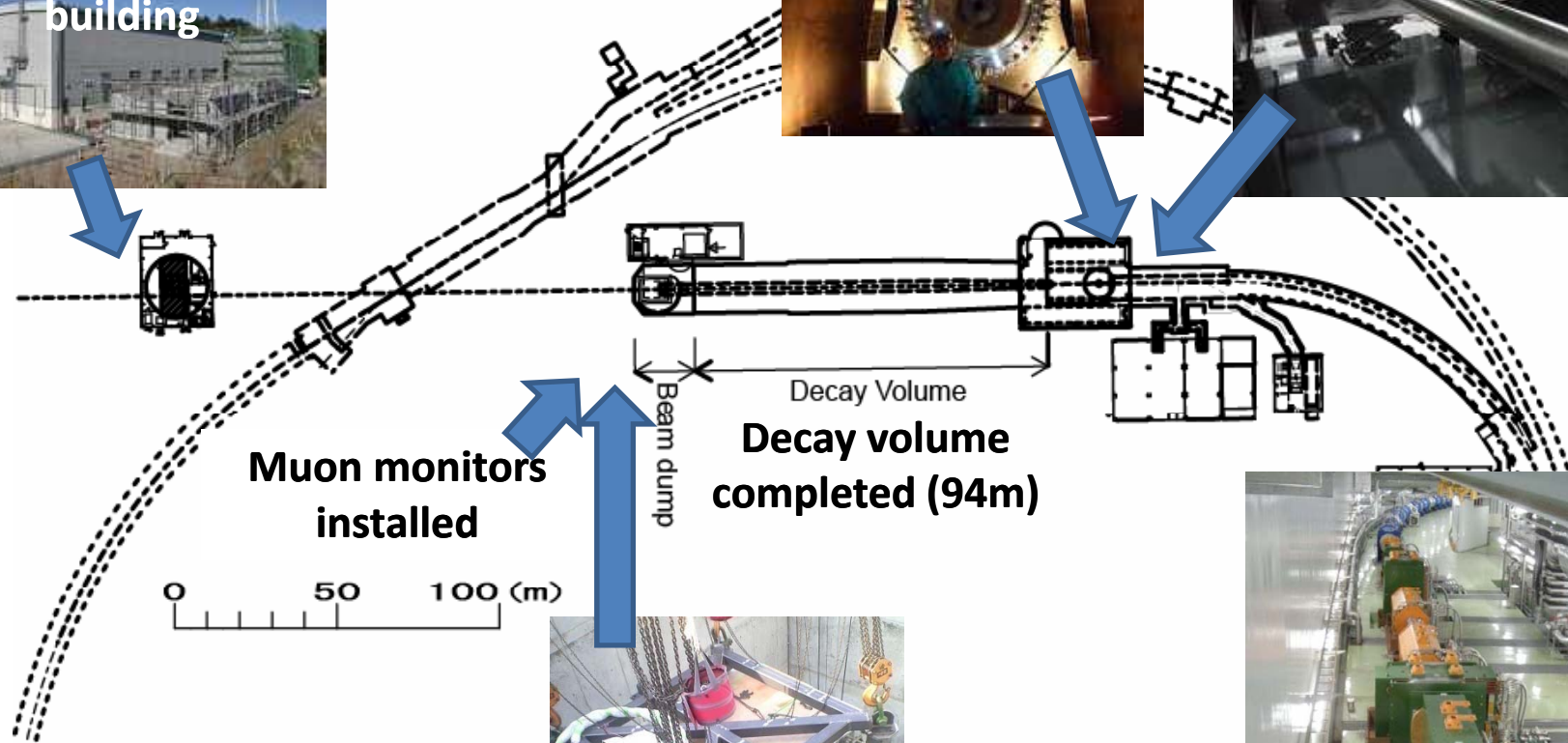
$$\delta_{CP} = 0.$$

~ 110 expected ν_e events at $\sin^2 2\theta_{13} = 0.1$

Status of neutrino facility construction



Status of neutrino facility construction



Beam status (1)

- **Proton beam lines installation is completed**

- 30 GeV protons accelerated in december 08
- slow beam extractions in hadron hall successfull in january 09
- government inspection for radiation safety ok (19 feb 09)



- **Target station :**

- target : 90cm graphite tube (diam. 2.6 cm)
- 1st horn installed 18th jan.
- several issues with horns 2 and 3 (will be installed by this summer)



- **End-line:**

- Beam dump (graphite core) and MUMON installed in muon-pit
- Commissioning of muon monitors ongoing

Beam status (2)

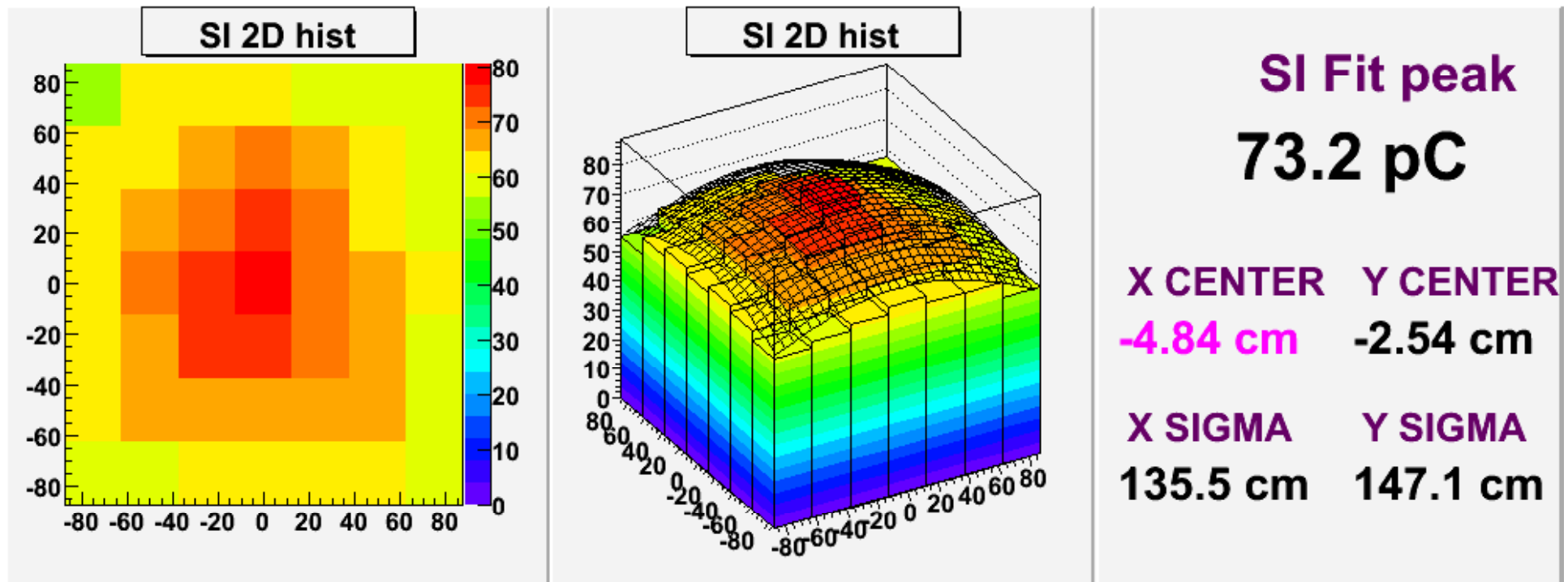
- The beam is running now ! Started last Thursday evening.

- Beam commissioning in April-May 2009 : ~1000 spills (~20 days)
 - ➔ 1 horn only (low intensity but still possible to reconstruct the center of the beam with muon monitors)
- 1% of total integrated intensity expected by summer 2010
 - ➔ First physics results within 2010
 - ~60-70 expected ν_μ at SK (with oscillation)
 - ~2 000 expected ν_μ CC in INGRID
- Next milestone: 10^{21} pot/yr (750 kW)
(At least > several 100kW as soon as possible)
- Final goal for T2K upgrades (T2HK, T2KK) : ~2 MW

Beam status (2)

- The beam is running now ! Started last Thursday evening.

Beam signal in muon monitors



(last Friday evening)

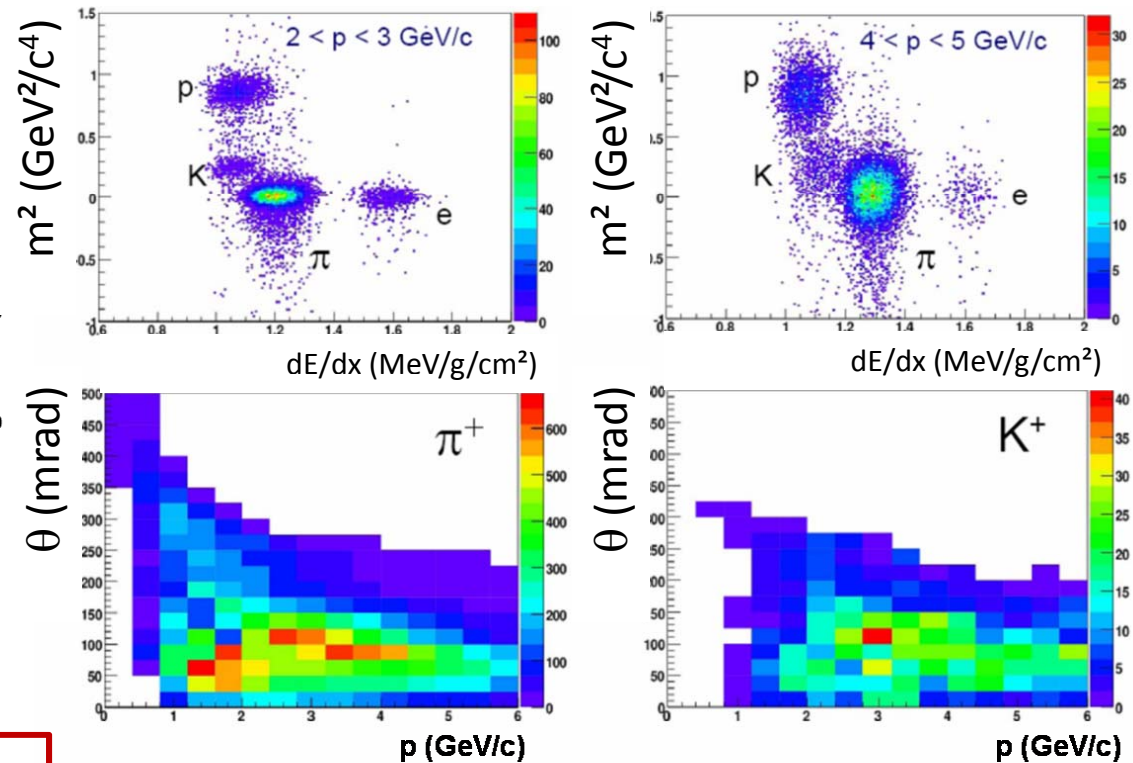
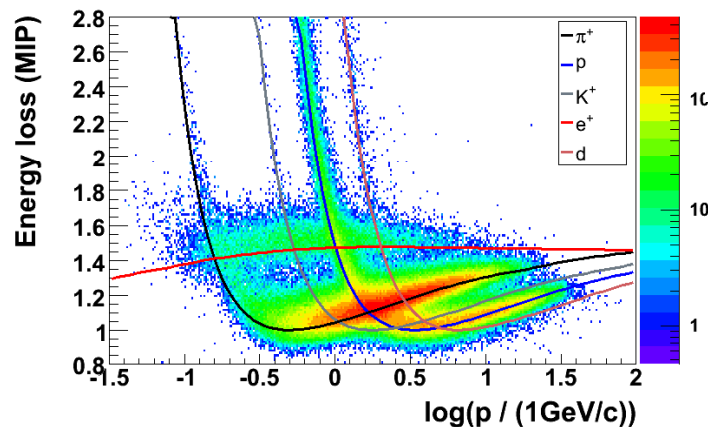
NA61 preliminary results

Goal : study the hadron production in proton-carbon interactions (F/N ratio in T2K has to be known at $\sim 2\text{-}3\%$)

2007 and 2008 run @ CERN SPS – 30 GeV protons – T2K replica target used (90 cm long graphite cylinder of 2.6 cm diameter)

TOF detectors (m^2) and TPCs (dE/dx)

Positive particles

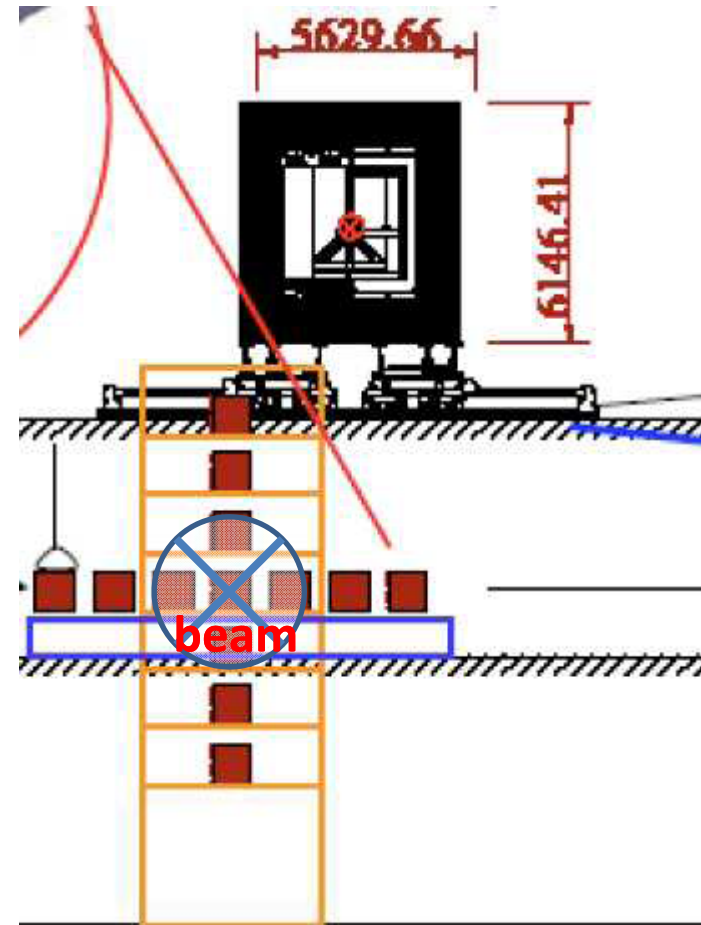


Need more statistics to study :

- $\theta:p$ histogramms with a fine binning
- π/k ratio
- Secondary interactions in a 90 cm long target

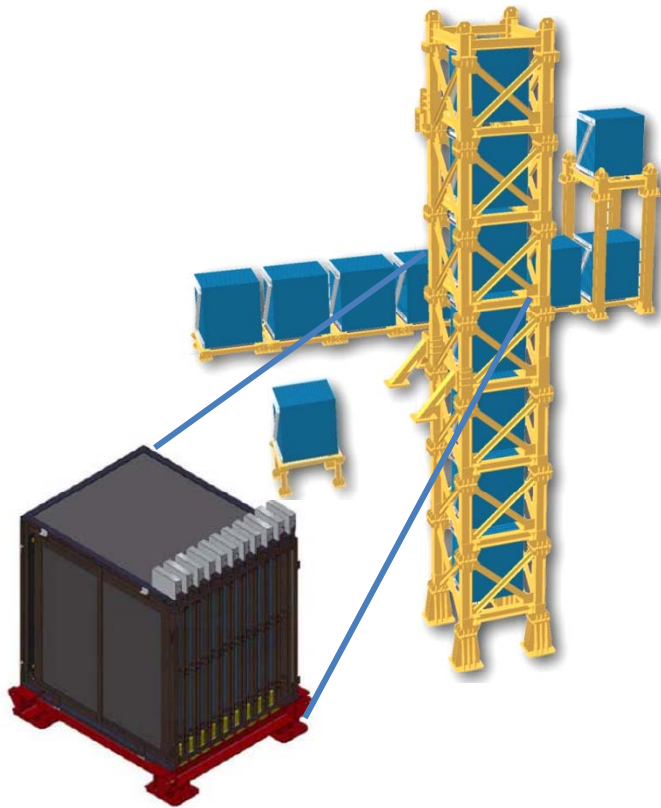
Shape in agreement with the present simulations.

Near Detectors



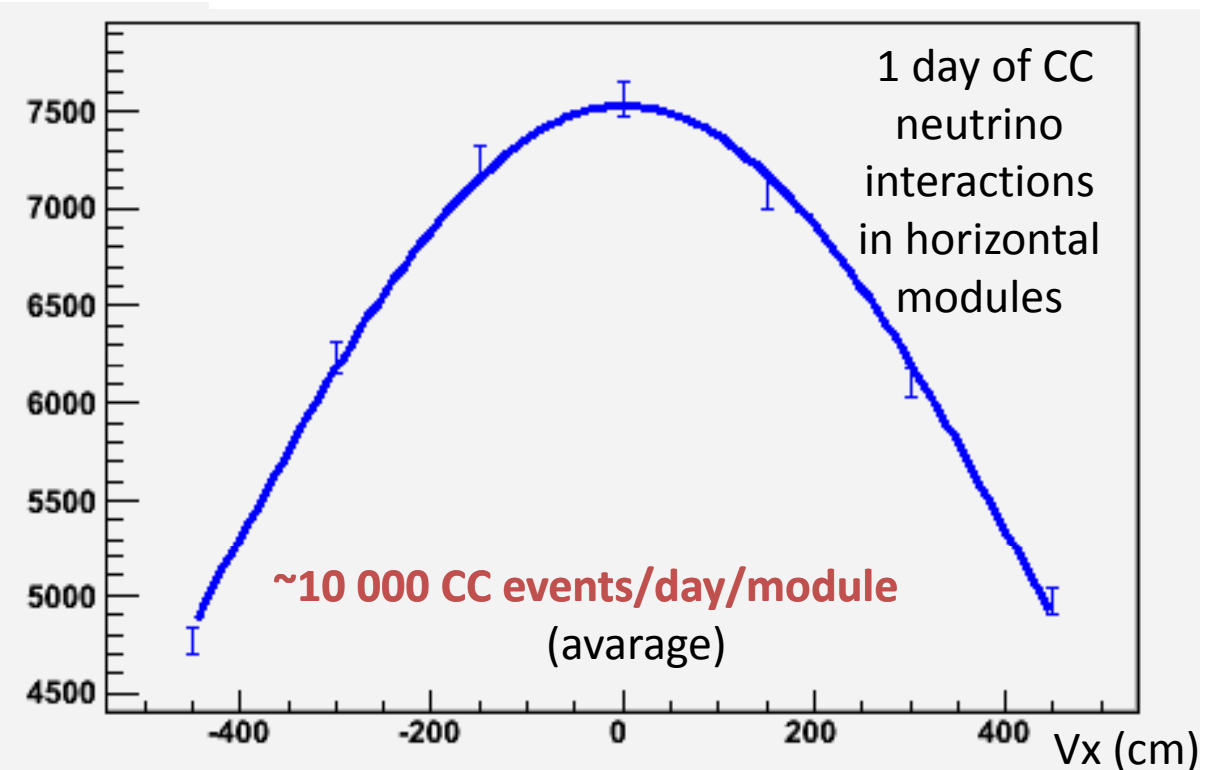
イングリッド INGRID (on-axis detector)

Goal : give a daily measurement of the off-axis angle – beam angle error < 1 mrd



- 16 modules
- 11 xy scintillator planes interleaved with 10 (9) iron blocks
- 1 movable module without iron (« Proton module ») will be added within 2011 : Reconstruction of proton tracks for QE and RES events → better vertex reconstruction

MC reconstruction – horizontal profile :



INGRID status



First module :

- Assembly finished on feb. 10th
- Installation in the pit on march 12th
- commissioning with cosmic events ongoing

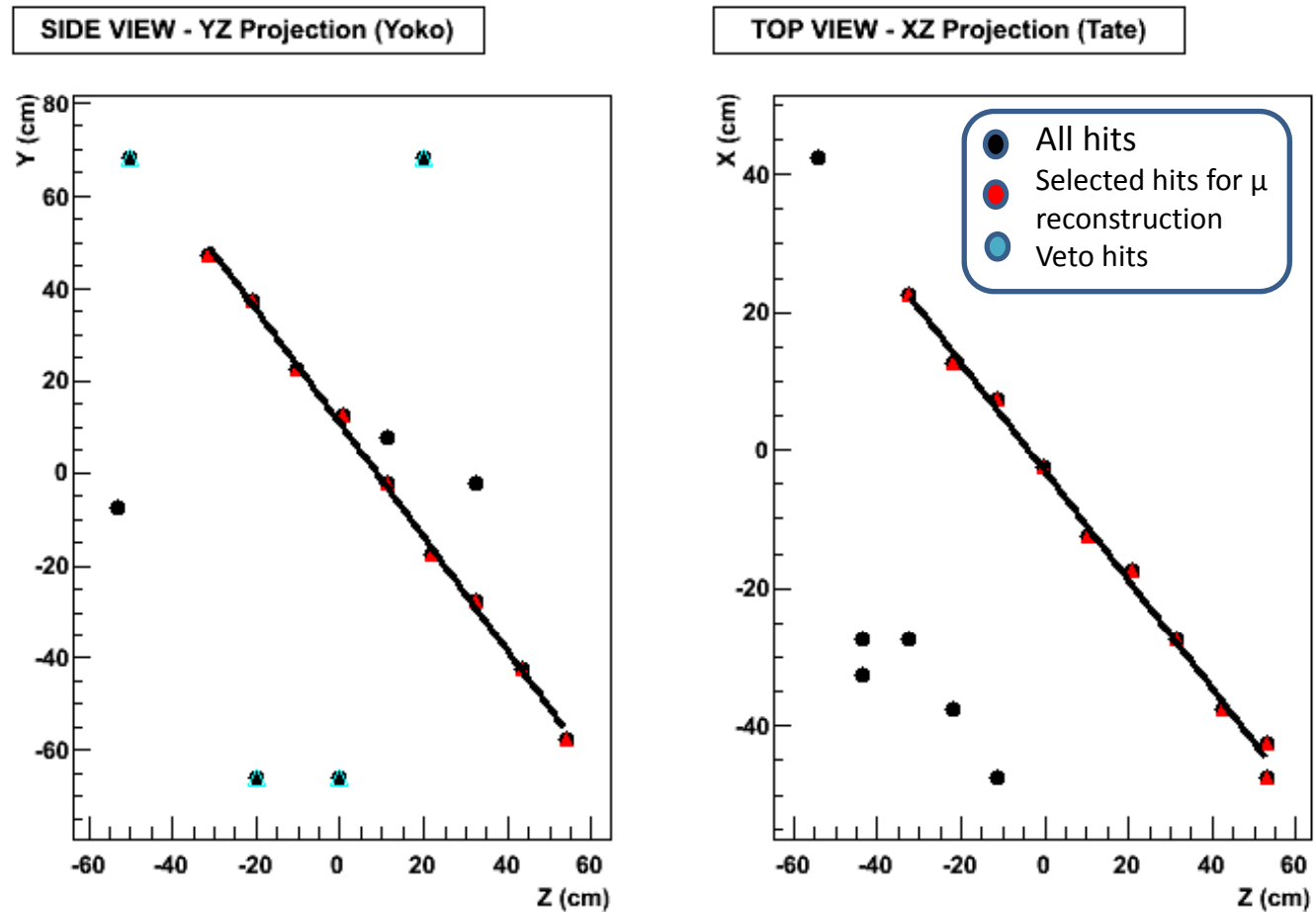


Schedule :

- Installation of horizontal modules by the end of june
- Vertical modules by the end of july

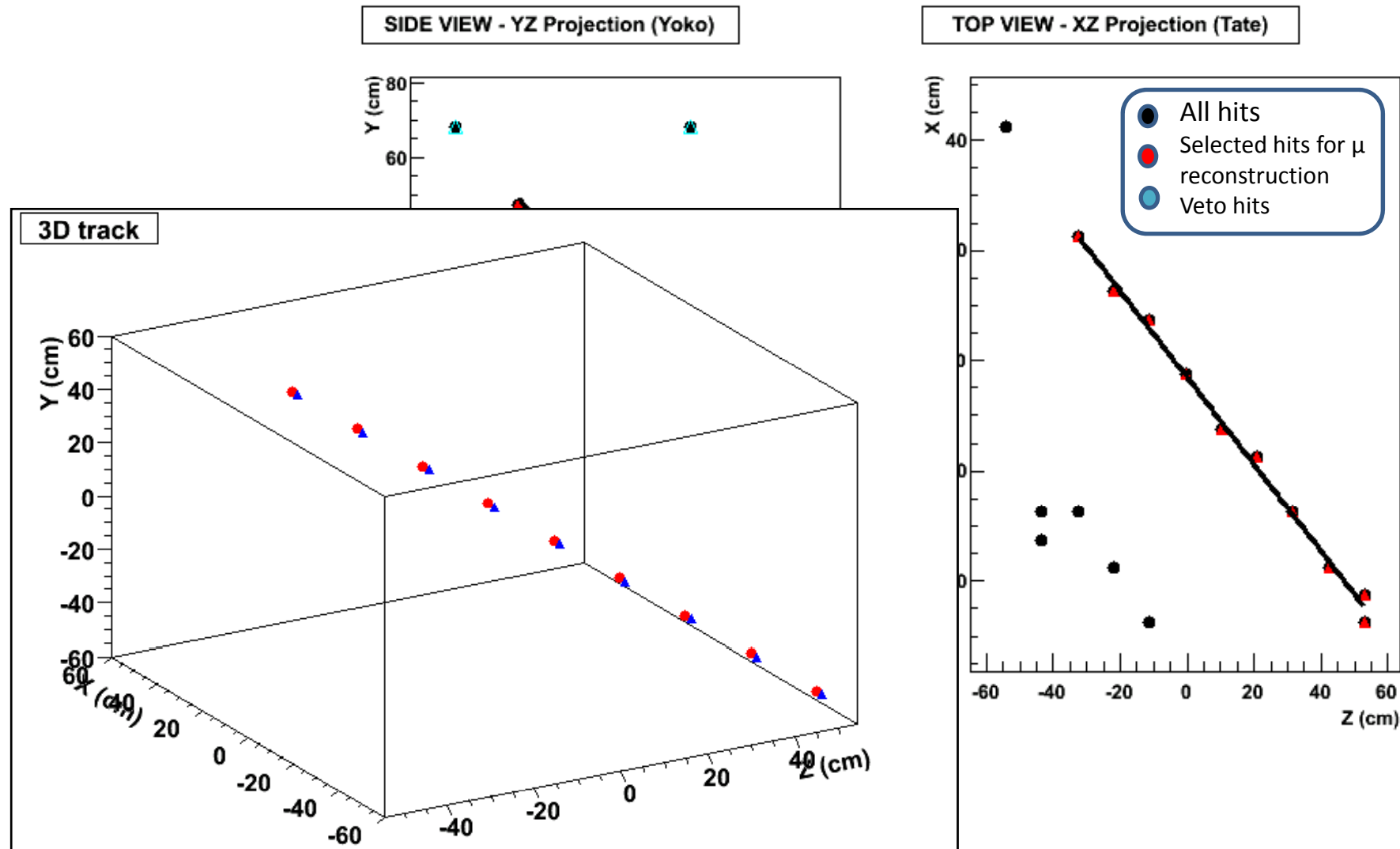
First cosmic events in INGRID module

Exemple of a reconstructed cosmic track



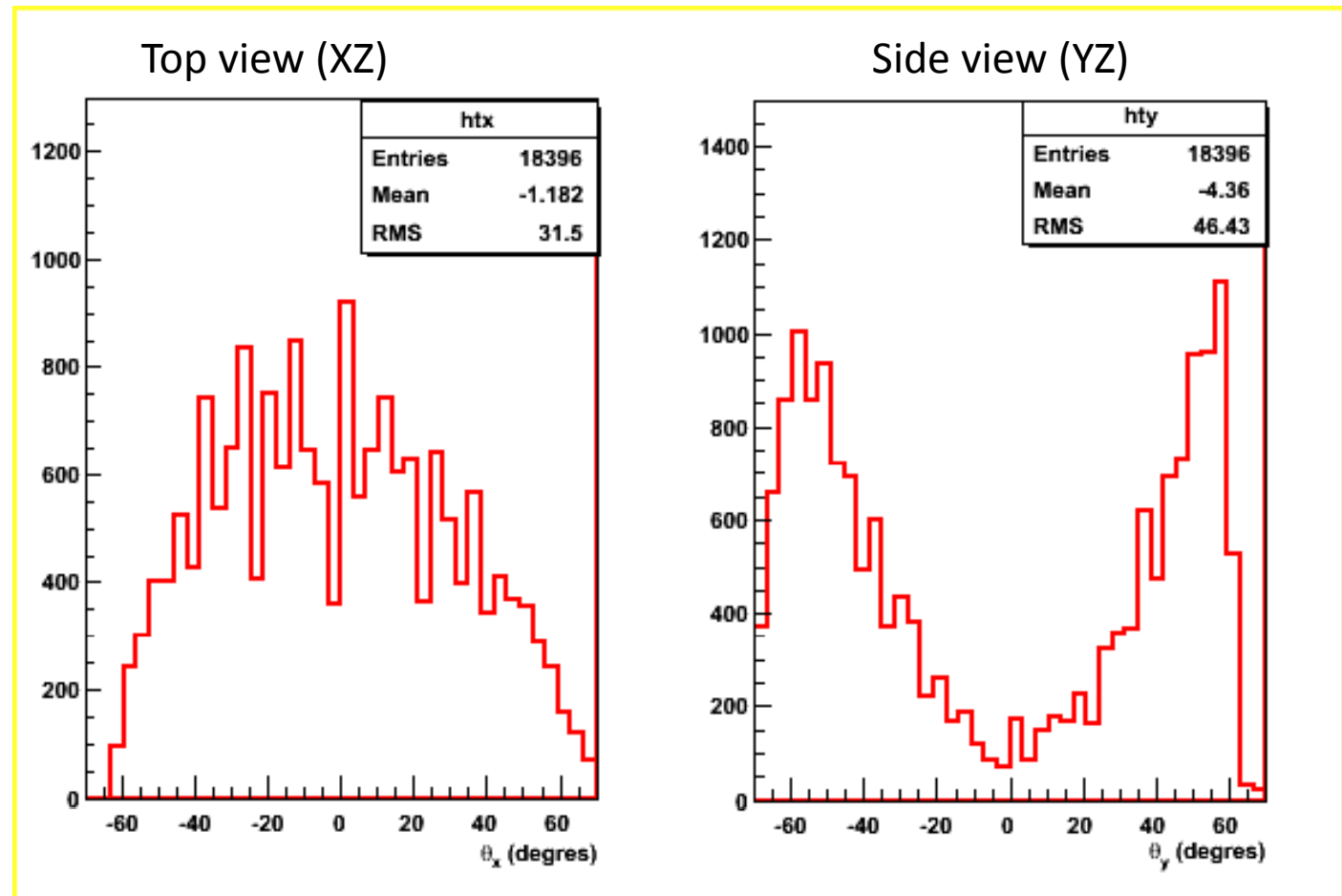
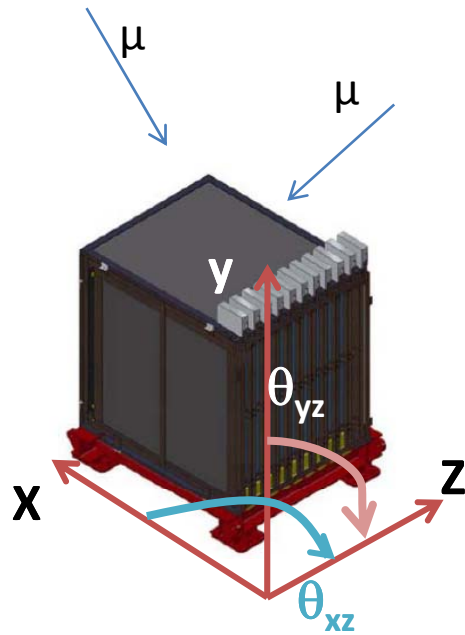
First cosmic events in INGRID module

Exemple of a reconstructed cosmic track



First cosmic events in INGRID module

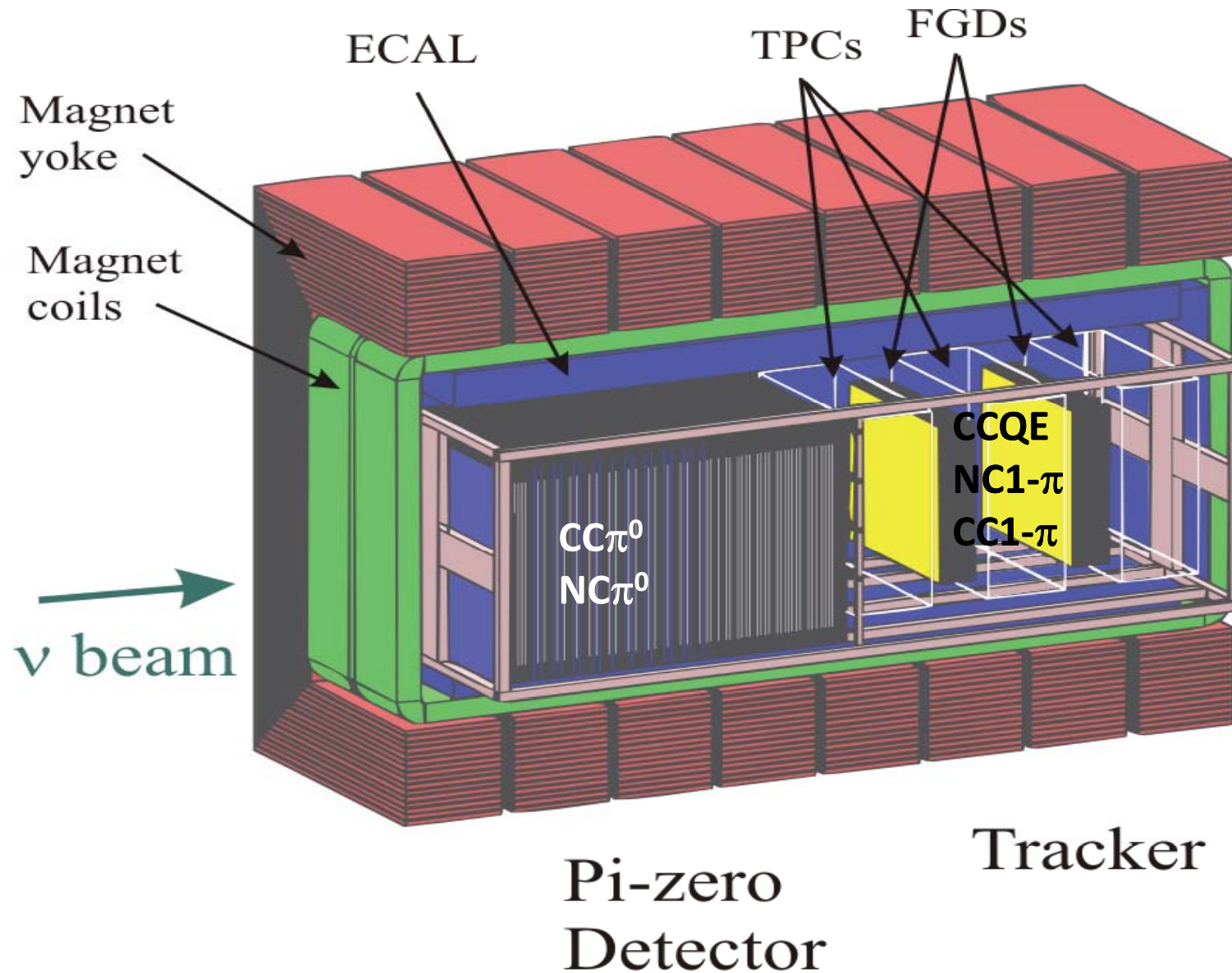
Angular 2D distributions



The data taking is ongoing and the first module is ready to take neutrino data

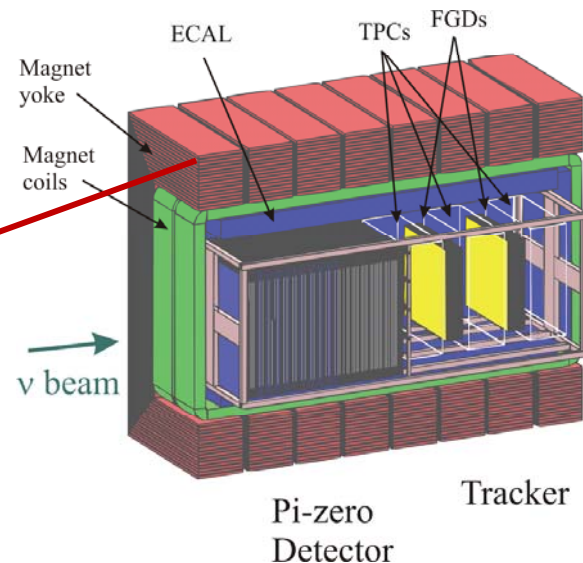
ND280

Goal : calculate beam fluxes
 measure several cross sections



ND280

UA1 magnet + SMRD (Side Muon Range Detector)



8+8 C-shape elements constituted of iron blocks interleaved by 17mm air gaps.

The gap will be instrumented with **scintillators (S-shape WLS)**.

➔ **Muon detection and measurement of muon energy**

$\sigma(E) < 10\%$ for all angles and momenta

SMRD status :

2130 scintillators in total, all tested and arrived at JPARC in april.

25% SMRD inserted.

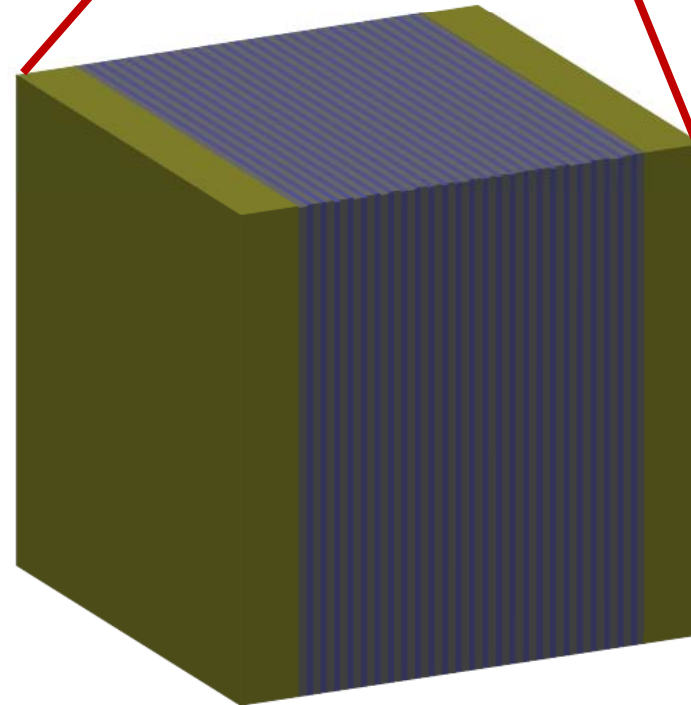
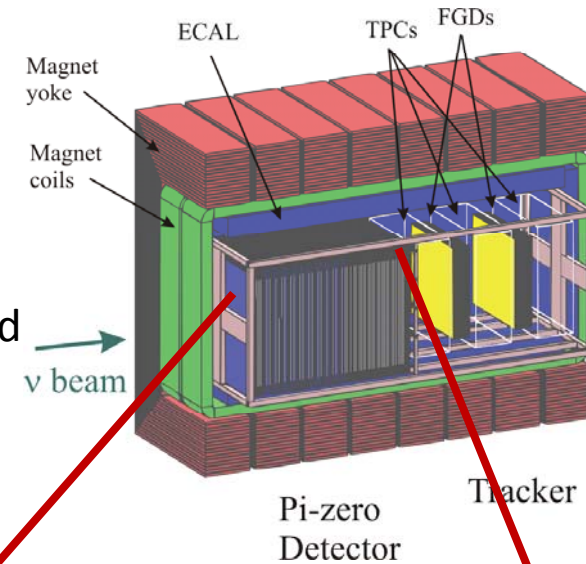
First tests with cosmics will start soon.



ND280

POD

- Will measure π^0 production in neutrino interactions (ν_e appearance background).
+ cross sections on water.
- 3 PODules :
 - upstream and downstream : EM calorimeter (lead foils and scintillator planes)
 - middle PODule : xy planes of scintillator bars covered with lead, interleaved with water layers
- Status :
 - 3 PODules shipped in Japan and ready to be installed.
 - Installation in summer



ND280

FGD and TPC

TPC :

e/ μ separation with dE/dx

3 Micromegas TPC, each 24 modules

Status :

-1st TPC finished, will be shipped in may.

- Construction of 2nd TPC ongoing, shipment foreseen in june.

- 3rd TPC expected for october @ JPARC.

FGD :

Fine grain Tracker → discriminate CCQE from multihadronic final states

2 modules of xy planes of scintillator bars

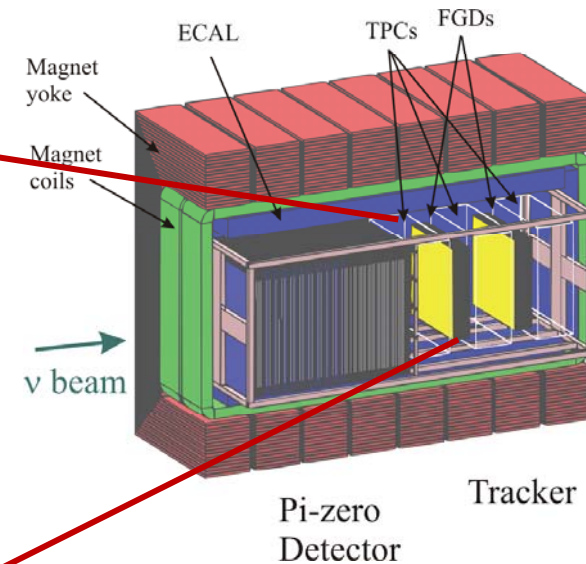
2nd module : planes are interleaved with water

Status :

Construction finished.

Test beam ongoing at Triumf.

Shipment of first module in june, 2nd module (water) in july.



Very high statistics :

TPC : $2 \cdot 10^3$ ν /yr

FGD : $4 \cdot 10^5$ ν /yr

TPC-FGD Test beam at Triumf



M11 Test beam from september 2008

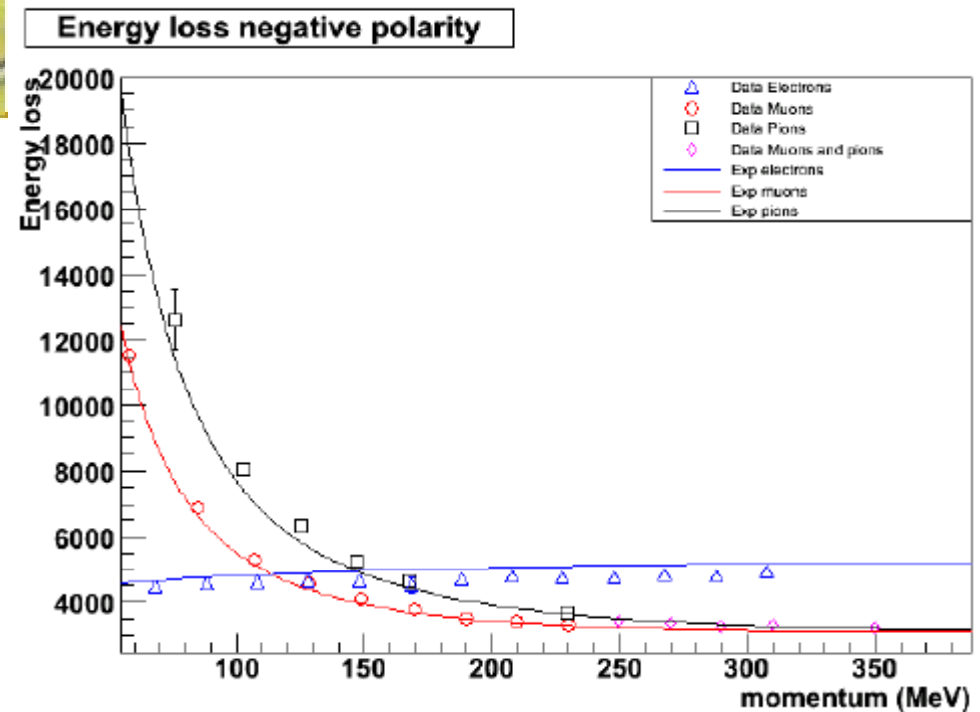
1 TPC + 1 FGD module

→ e, μ, π with momentum up to 400 MeV/c

TOF detector to separate each kind of particle

- Good agreement between data and MC for dE/dx curves.

- e/μ separation $> 5\sigma$
for momentum > 200 MeV/c



TPC-FGD Test beam at Triumf



M11 Test beam from september 2008

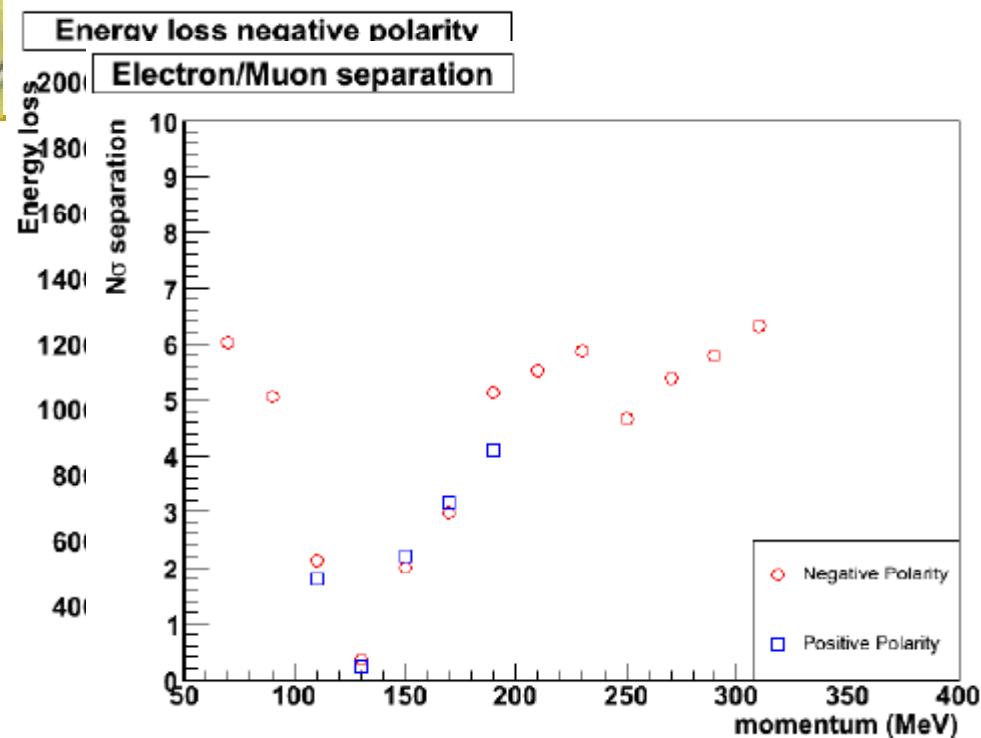
1 TPC + 1 FGD module

→ e, μ, π with momentum up to 400 MeV/c

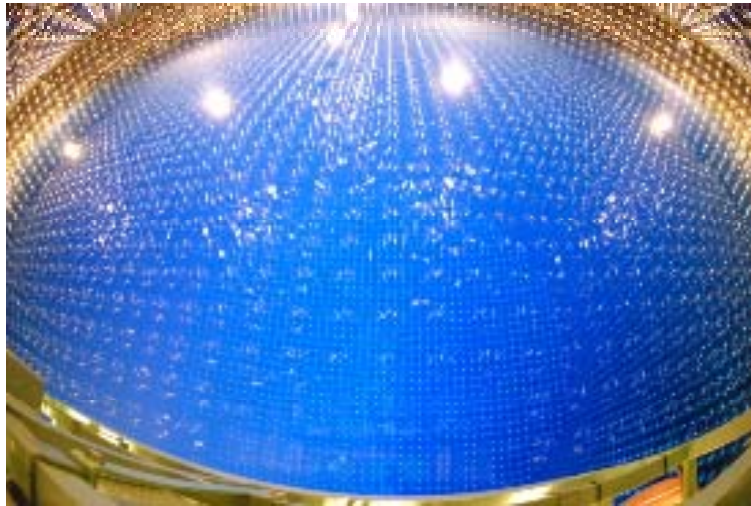
TOF detector to separate each kind of particle

- Good agreement between data and MC for dE/dx curves.

- e/μ separation $> 5\sigma$
for momentum > 200 MeV/c



Status @SK



Detector calibration

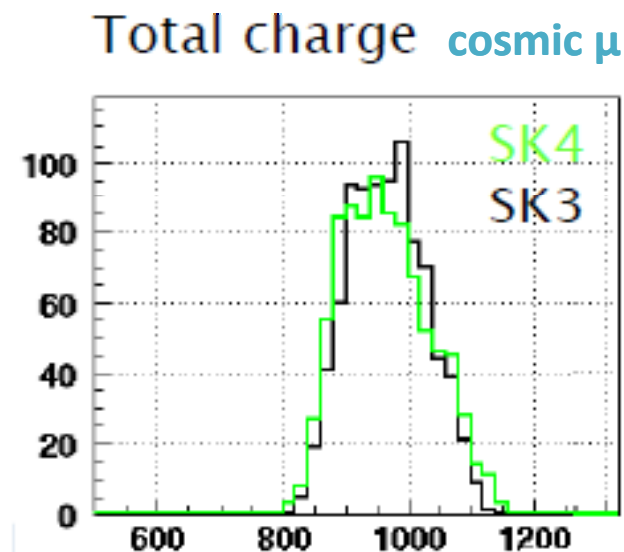
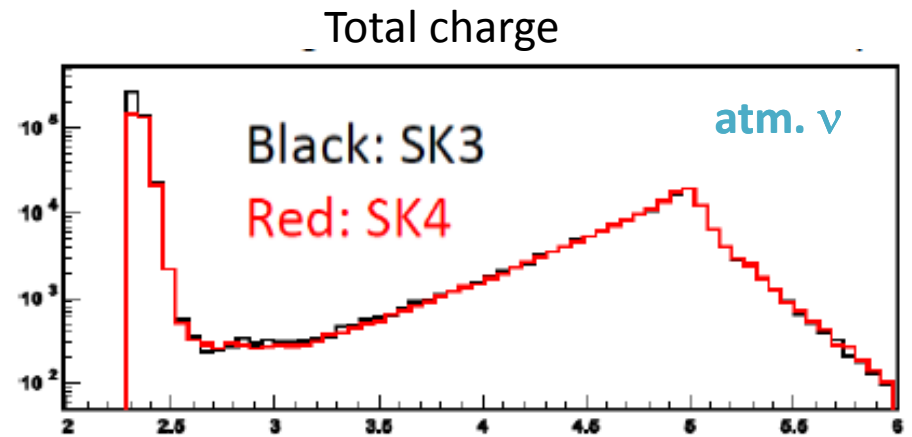
OK

Check data: comparisons SK3/4
with atm. ν and cosmic μ

OK

SK-IV is ready for T2K data taking !

SK-IV data taking started on september 6th 2008.
DAQ has been quite stable.



Conclusion

- First data :

- T2K beam started on April 23rd, observed in beam and muon monitors.
Low intensity because of 2 missing horns.

- First module of INGRID is working well on cosmic tracks. Ready to take neutrino data.

- All the near detectors will be installed and commissioned by the end of this summer.

- Upgrade of intensity : 1% of full integrated intensity foreseen by summer 2010 (expected : 100 kW) .

- SK-IV is ready to take T2K data.

- First T2K physic results expected for 2010.**

What's next (probable schema)

2010-2012: first T2K results

No sign of ν_e
signal

Increase statistics

→ **Beam power @ ~2MW**

T2K phase II :

Ex :100 kt LAr detector between
Japan and Korea with a small OA

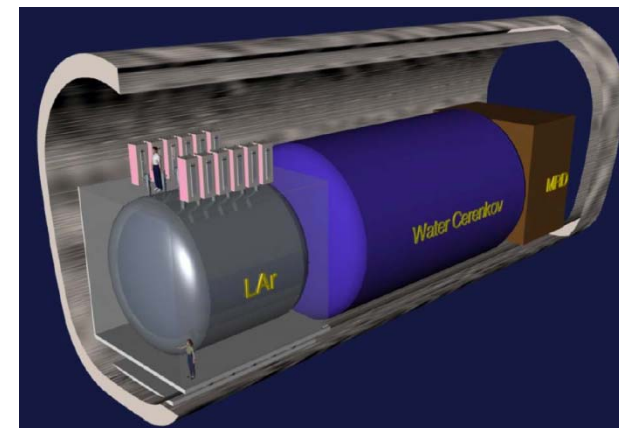


Sign of ν_e signal

Better understanding of systematics

→ **2-km detector**

(fine grained LAr detector wrt
ND280-like ?)



Scintillator-WLS readout : MPPC

T2K Requirements :

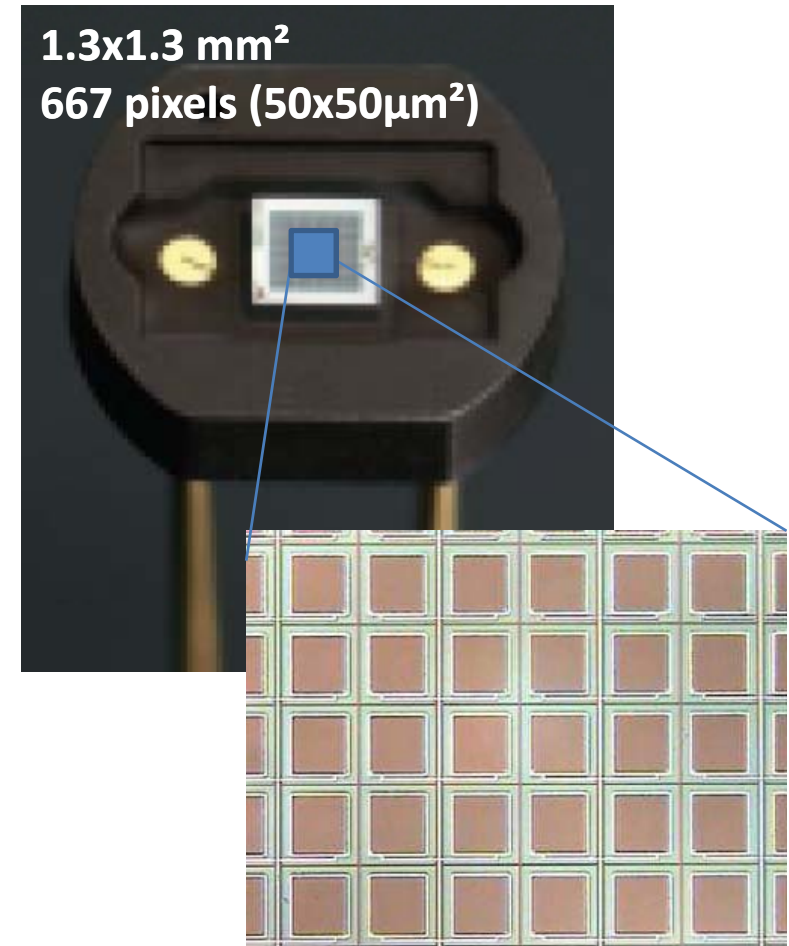
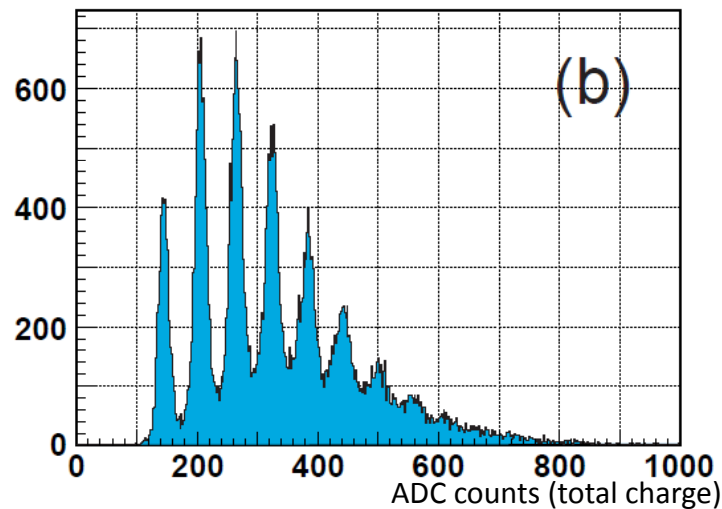
- Good photo-detection efficiency
- Compact
- Usable in magnetic field
- Low cost for large production

MPPC !

$Q(\text{pixel})$ does not depend on number of photoelectron ($N_{p.e.}$) detected

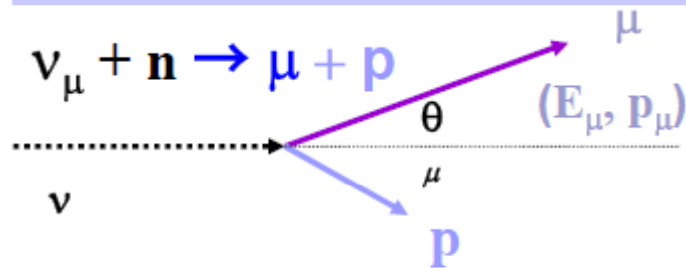
But if $N_{\text{pixel}} \gg N_{p.e.}$

- ➔ N_{pixel} touched proportional to $N_{p.e.}$
- ➔ Total charge proportional to $N_{p.e.}$



60 000 MPPCs have been produced for the T2K experiment, used in several sub detectors :
INGRID, POD, SMRD, FGD

E_ν determination at low E



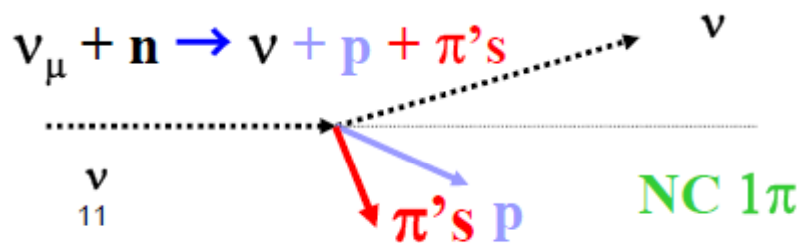
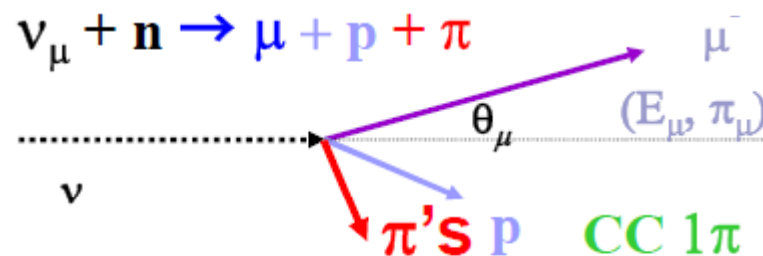
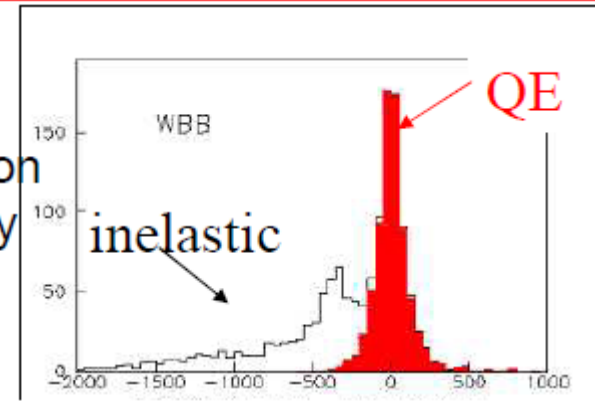
Quasi-Elastic process

QE fraction

Inelastic from high energy

$$E_\nu^{\text{rec}} = \frac{m_N E_\mu - m_\mu^2/2}{m_N - E_\mu + p_\mu \cos \theta_\mu}$$

$$\delta E \sim 60 \text{ MeV} \quad \delta E/E \sim 10\%$$



E_ν (reconstructed) - E_ν (true)

