Imperial College London

100 years of living science 100

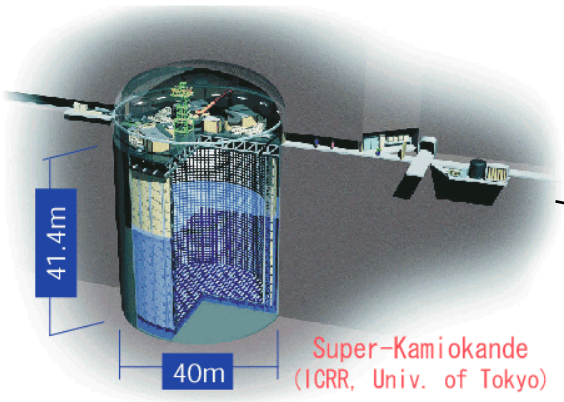
T2K beam line and near detectors

Antonin Vacheret
for the T2K collaboration

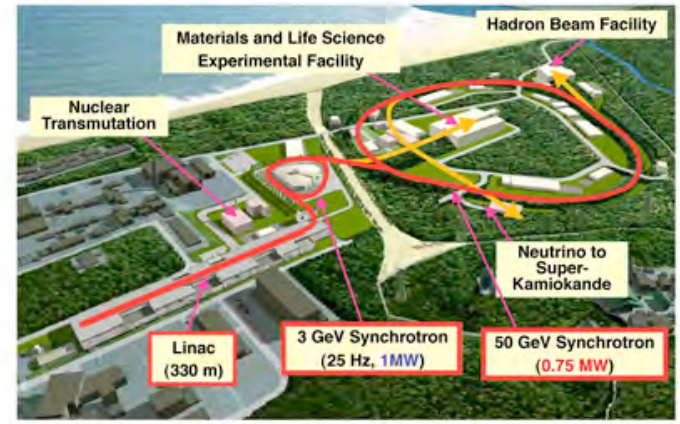
Reptiles(M.C. Escher)

Tokai to Kamioka (T2K)

12 countries, 62 institutions, ~ 350 people

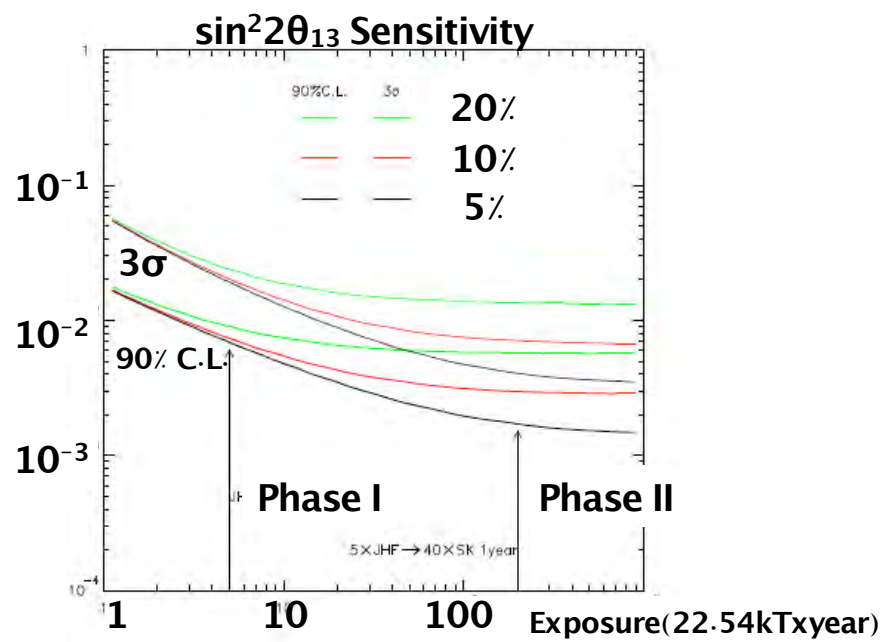


Far detector : Super Kamiokande

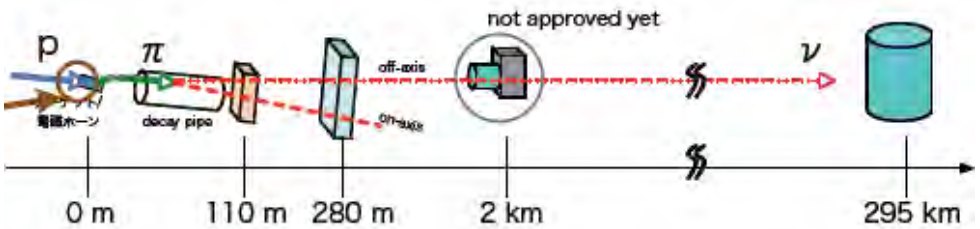


ν beam : J-PARC facility

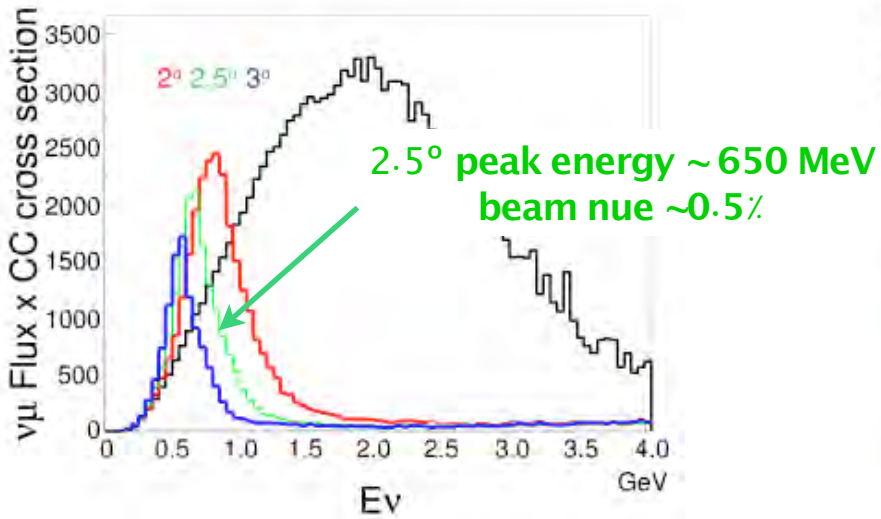
- ➡ 2009 Phase I : θ_{13}, θ_{23}, Δm^2_{23}
  - J-PARC : **0.75 MW** 30 GeV
  - SK-III : **22.5 kT** FV, **full PMT coverage**
- ➡ 2015 Phase II : θ_{13} , δ_{CP} ?
  - J-PARC : **4MW** 50 GeV
  - HyperK : **1 MT scale**



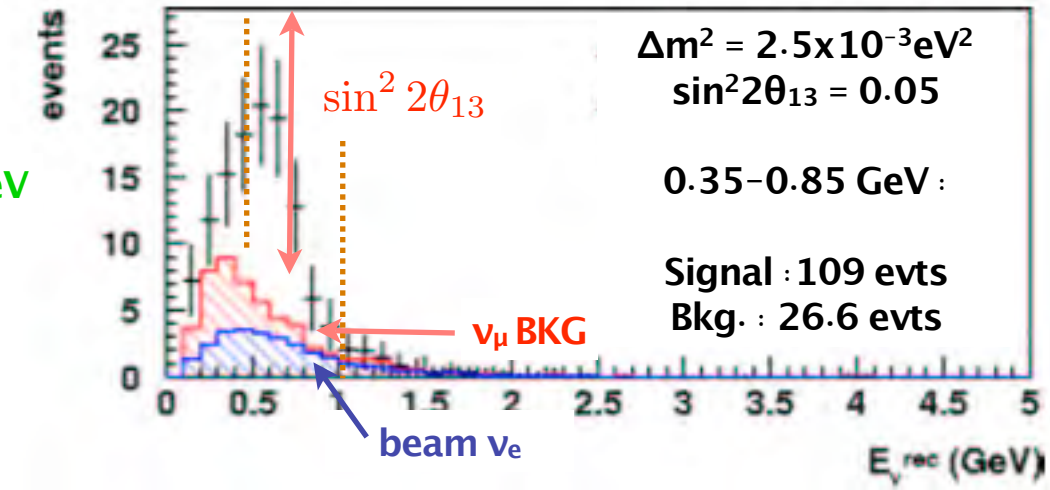
T2K measurements



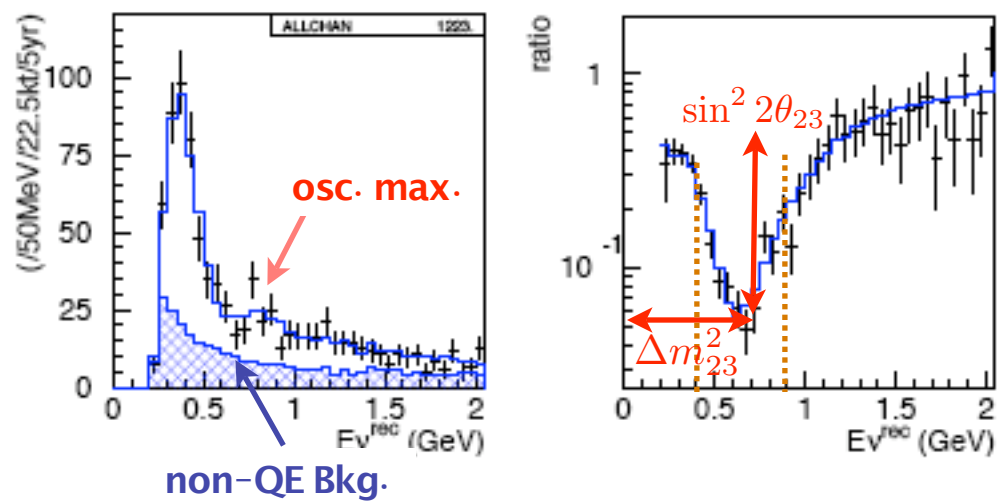
$$E_\nu^{QE} = \frac{2E_l m_N - m_l^2}{2(m_N - E_l + P_l \cos\theta_l)}$$



SuperK selected 1 ring e-LIKE evts



SuperK selected 1 ring μ-LIKE evts



- Appearance

$$\sin^2 2\theta_{13} > 0.01$$

- Disappearance

$$\delta(\sin^2 2\theta_{23}) \approx 0.01$$

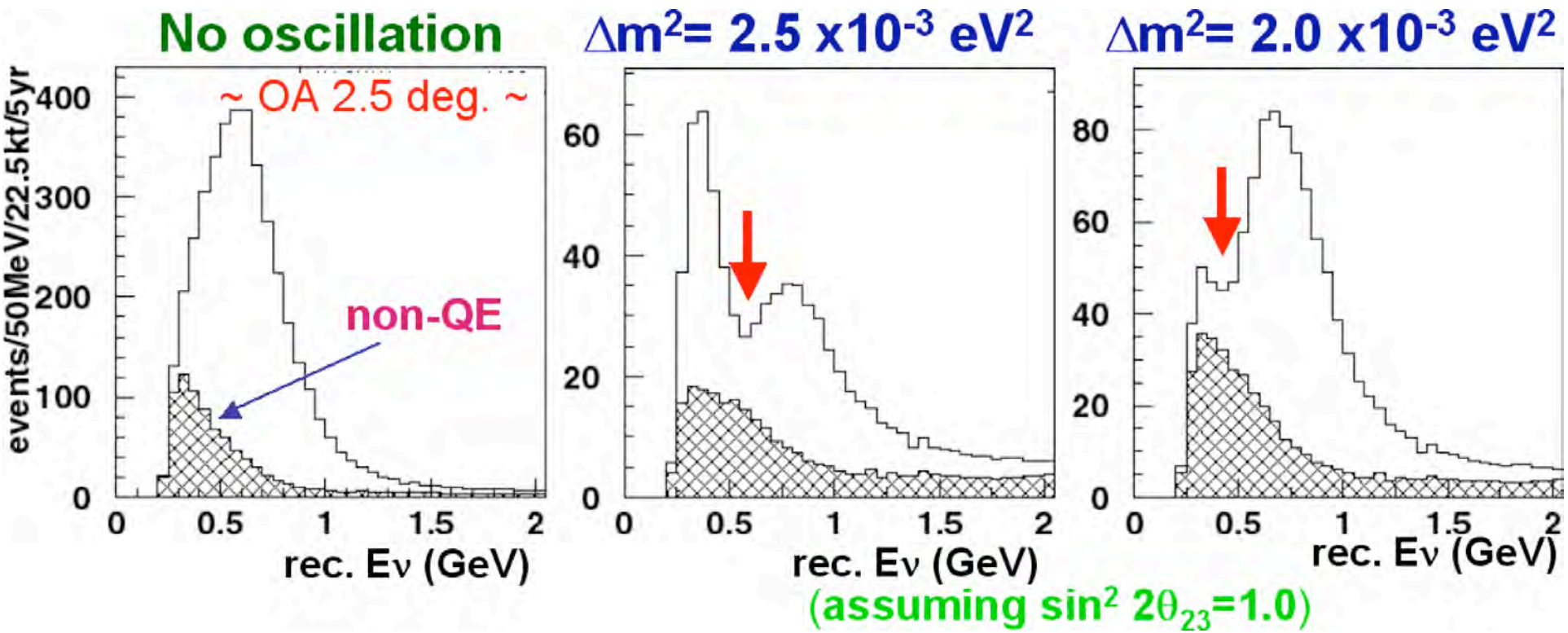
$$\delta(\Delta m^2_{23}) < 10^{-4} eV^2$$

T2K Systematics

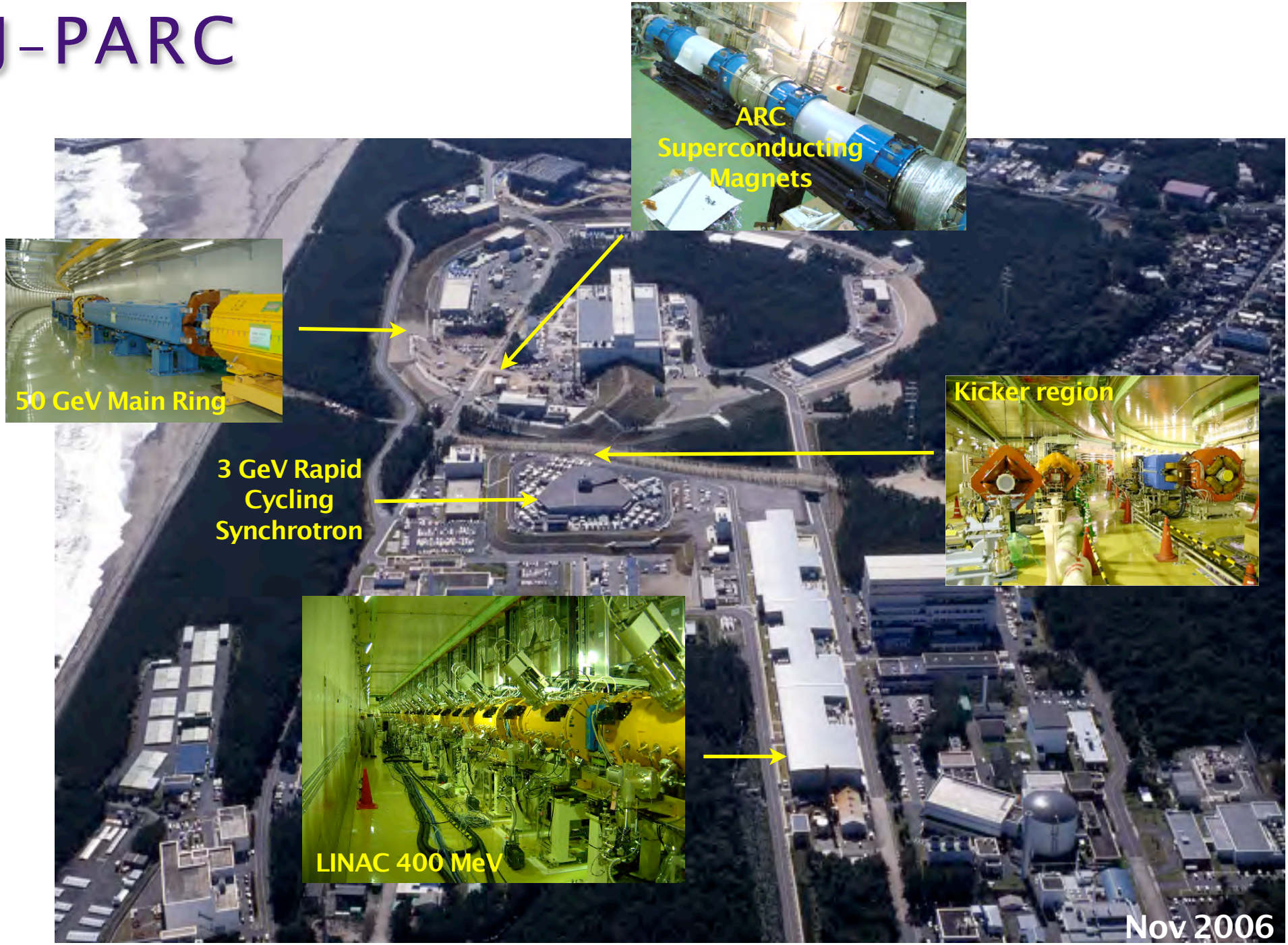
- To be measured before oscillation
  - Beam flux
  - Beam ν_e contamination
  - ν_μ non-QE background

- Near detector tasks :
  - SuperK νe background < 10%
  - ν_μ event normalisation < 5%
  - Energy scale < 2%
  - Beam linear distortion < 20%
  - Width < 10%
  - non-QE/CCQE at 5-10%

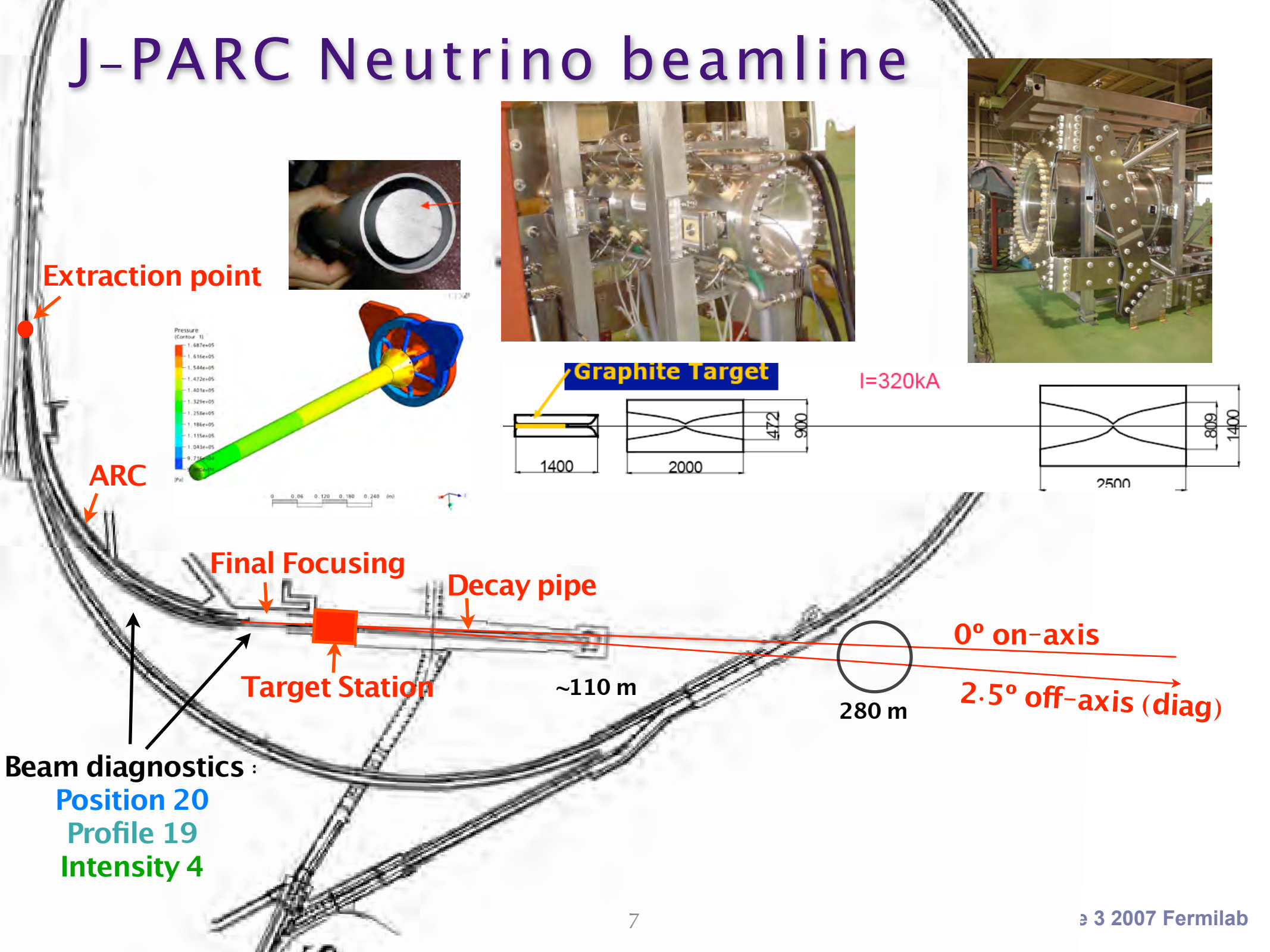
Disappearance background



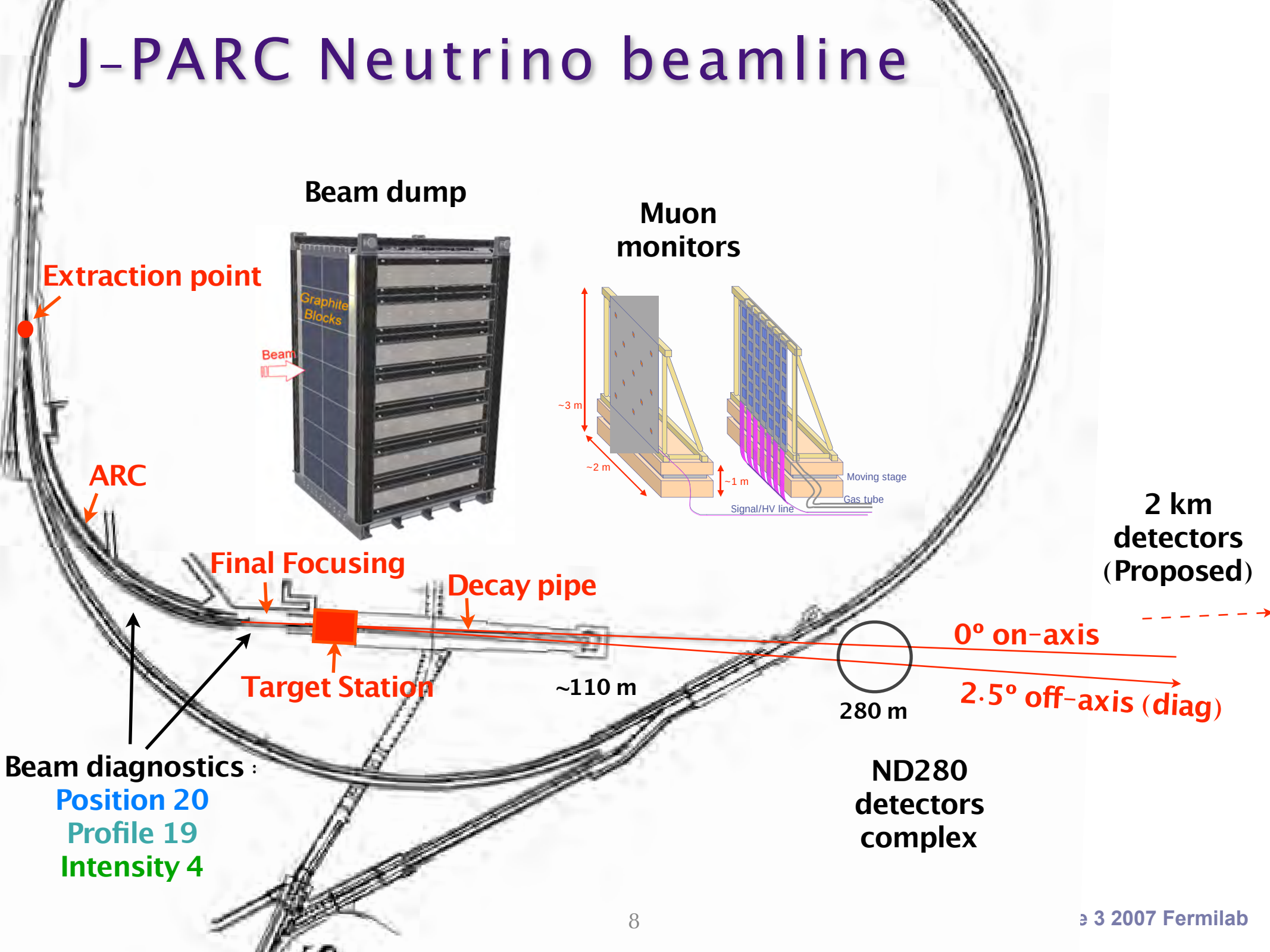
J-PARC


ARC
Superconducting
Magnets
50 GeV Main Ring
Kicker region
3 GeV Rapid
Cycling
Synchrotron
LINAC 400 MeV
Nov 2006

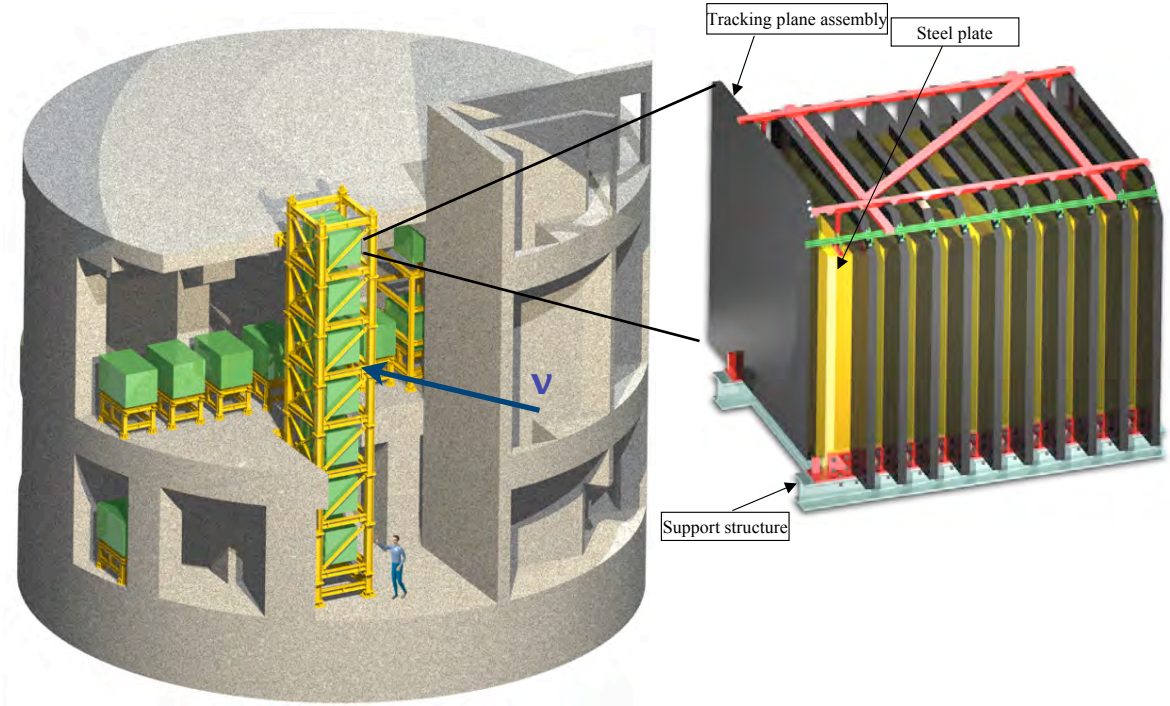
J-PARC Neutrino beamline



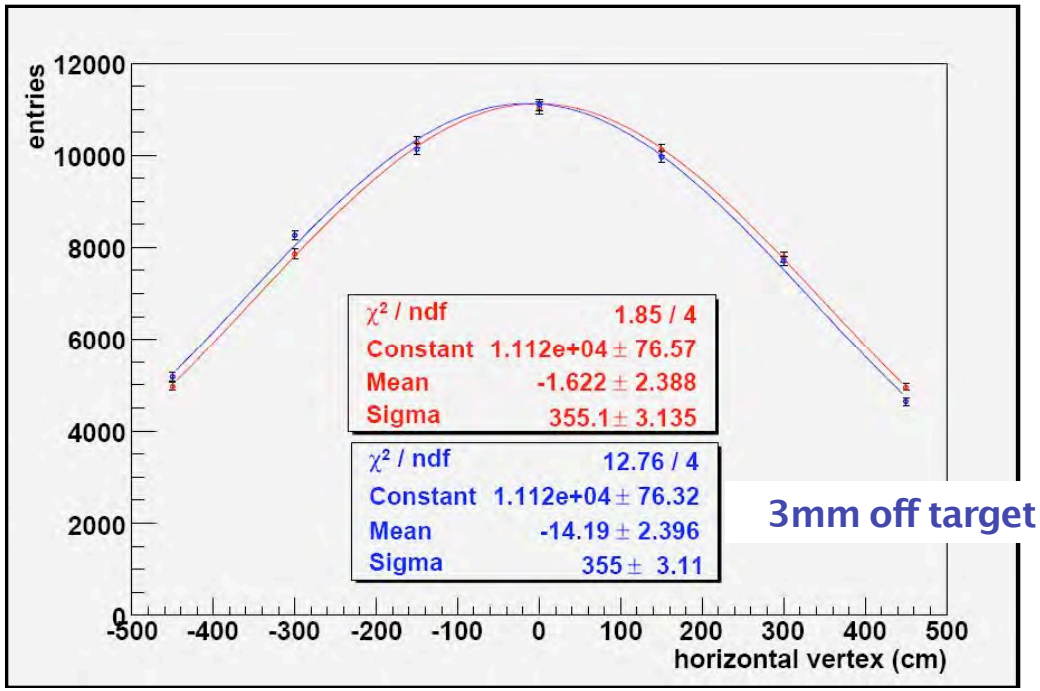
J-PARC Neutrino beamline



280m On-Axis: INGRID



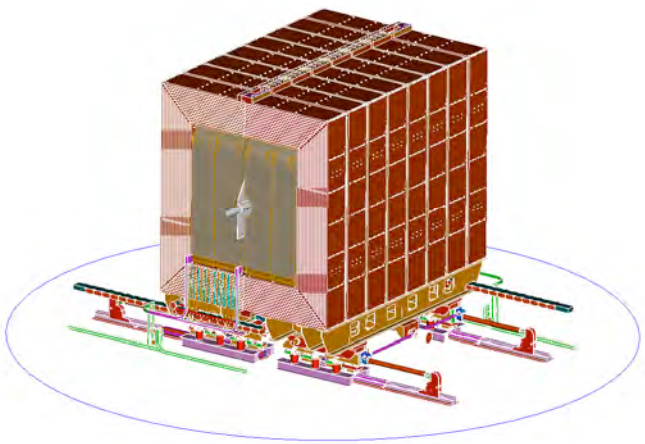
- Monitor beam direction, intensity and mean energy
- Beam coverage 10x10 m
- 16 Modules
  - Fe/Scint (5x1x100cm bar)
- Off-axis angle measurement accuracy : 1mrad (<15MeV)
  - **10k events per day**
- Shift resolution 3cm -> 1mm at target

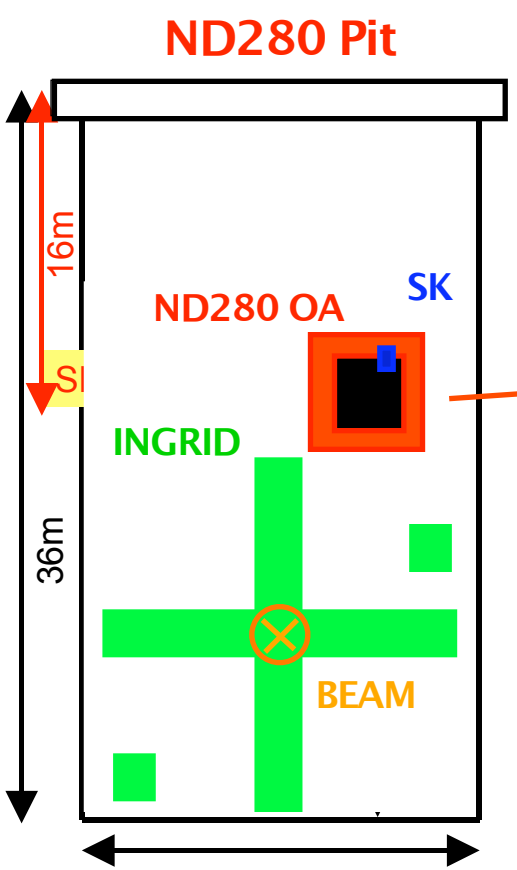


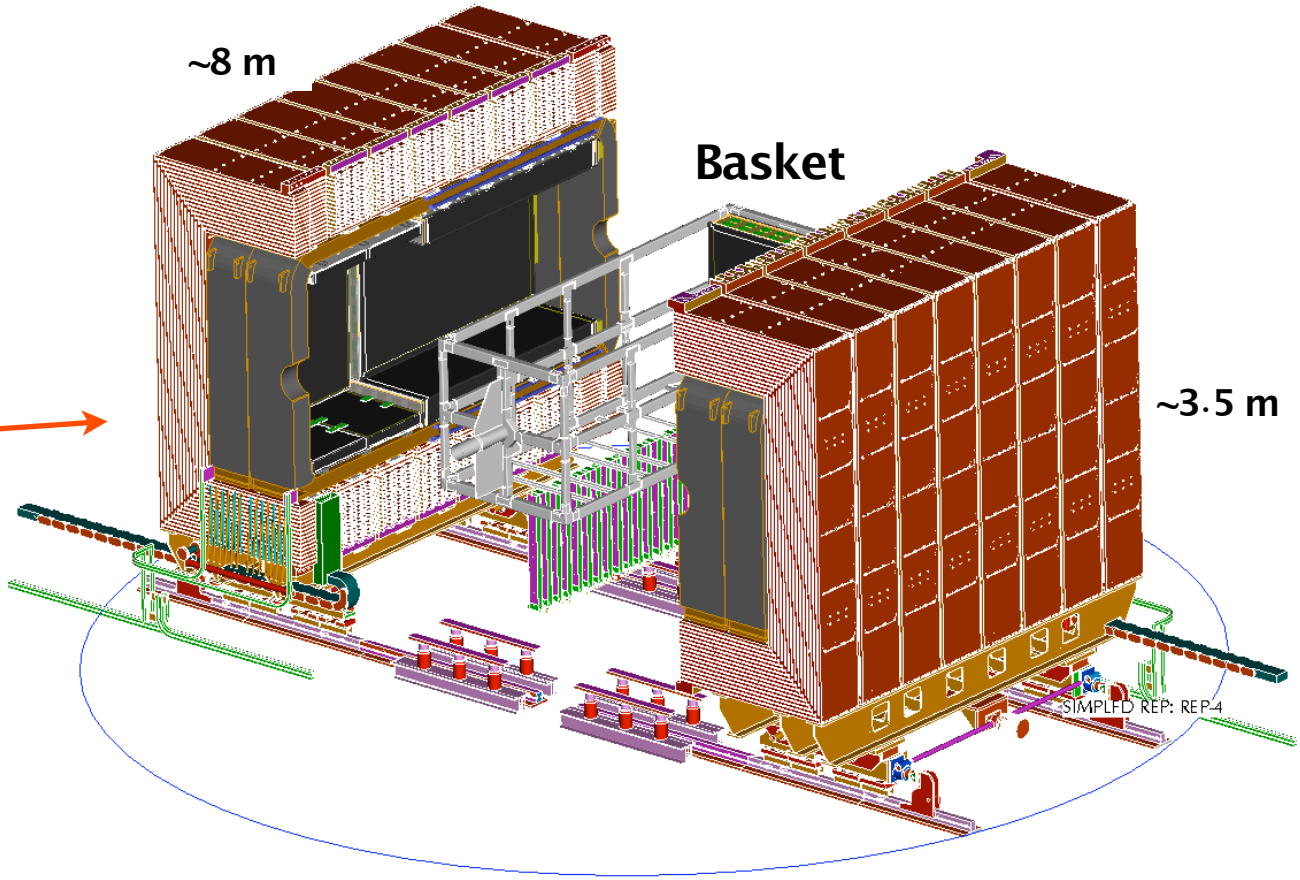
3mm off target

ND280 Off-Axis Detector

- ➡ 2-2.5° Off-axis
- ➡ Re-use UA1 Magnet
  - Uniform dipole field B = 0.2 T
- ➡ Target detectors installed in Basket







ND280 Off-Axis: P0D region

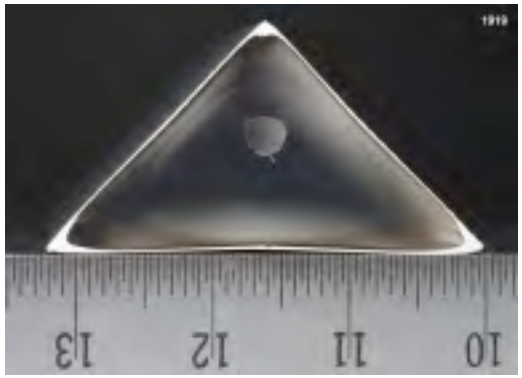
Pi0 detector(P0D) Target

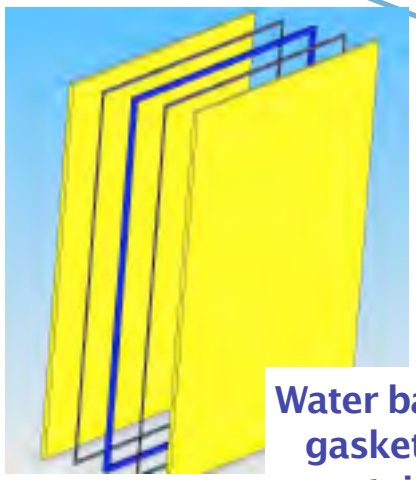
40 X-Y Pb/plastic planes
40% H_20 Passive
6t fiducial mass
10560 total channels

P0D Up/Central Calorimeters Modules

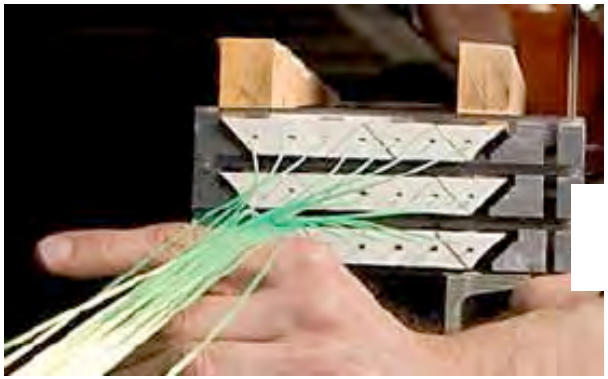
30 cm thick 5.7X0
X-Y Pb/plastic thicker planes
gamma catcher
active veto

Minerva bar

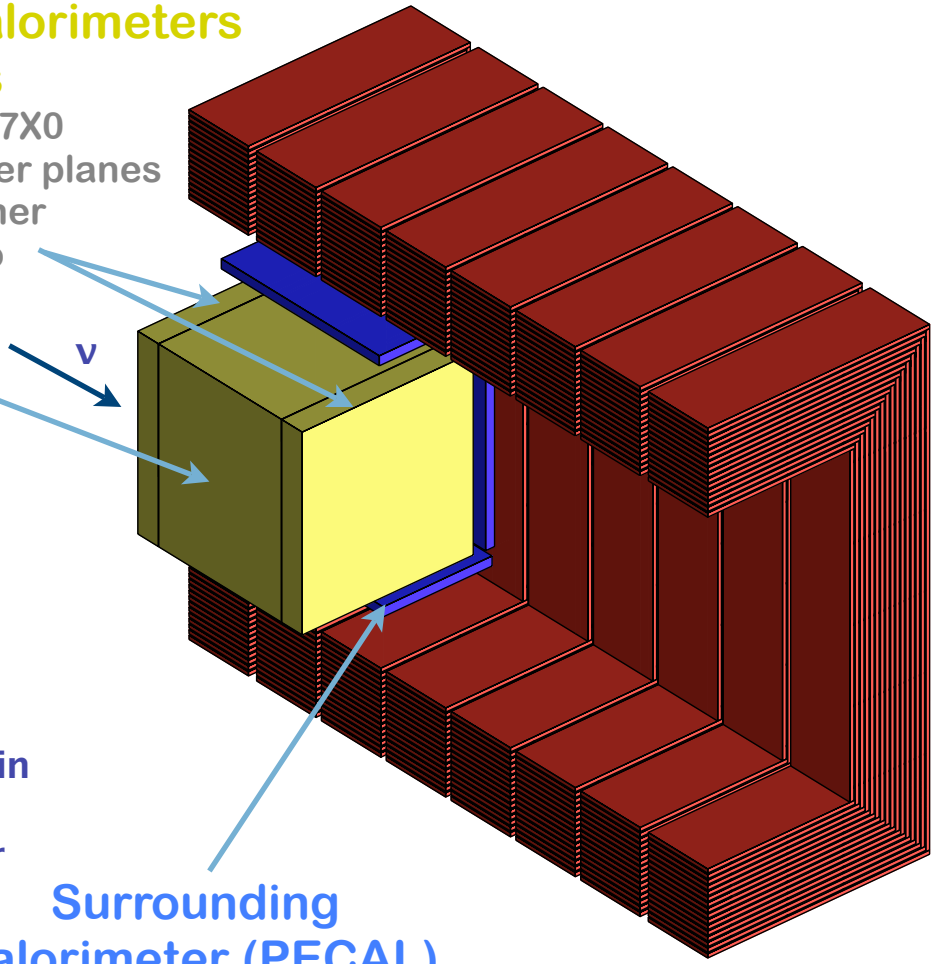




Water bag in gasketed container



Scintillator Planes layout

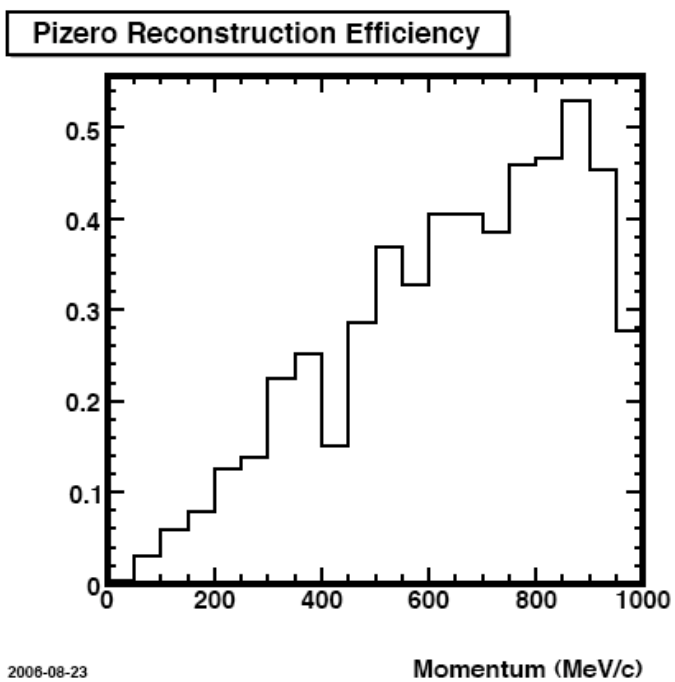


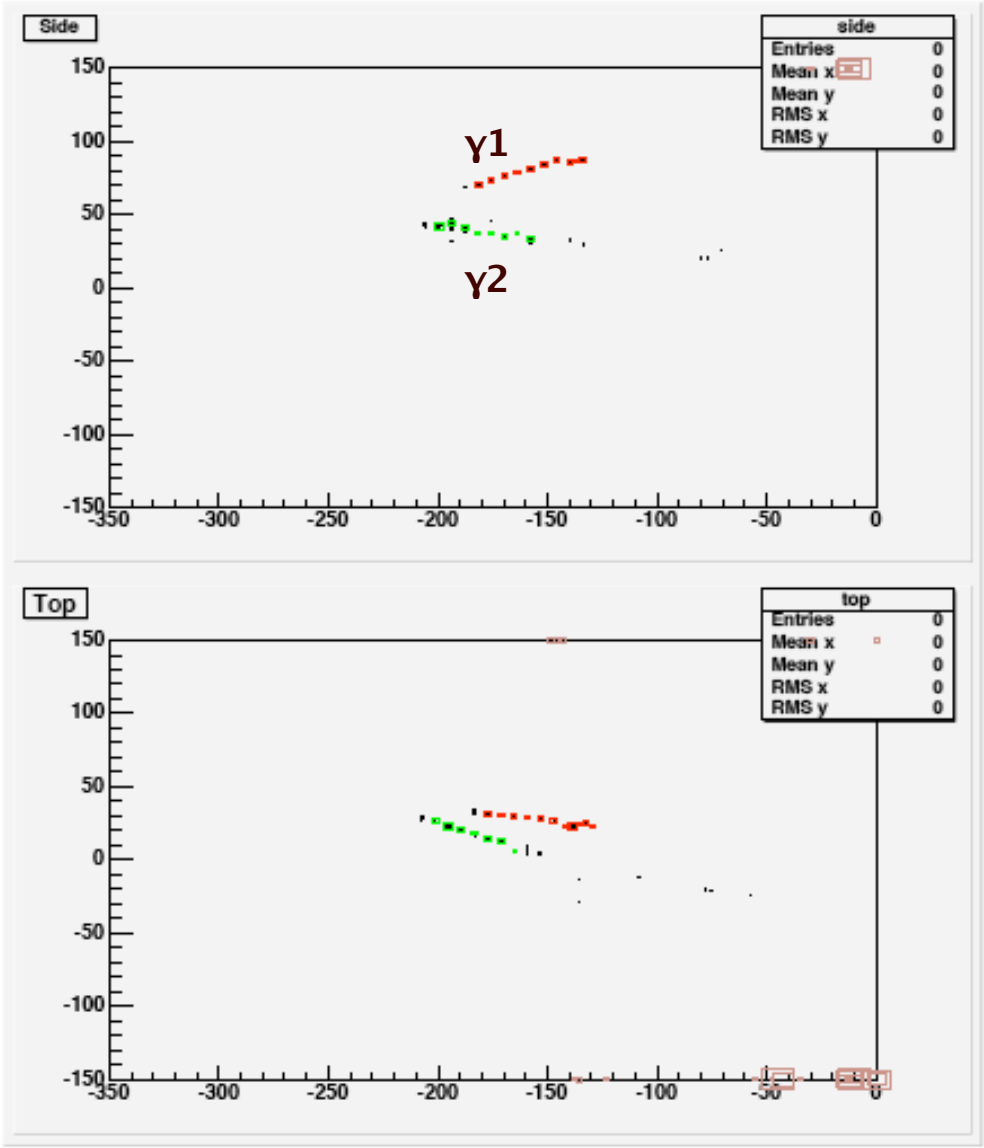
Surrounding Calorimeter (PECAL)

Coarse Pb/Plastic (4x1cm bar)
10cm thick ~5.0X0
γ catcher
MIP tagging
~2k Channels

P0D : NCπ^0 measurement

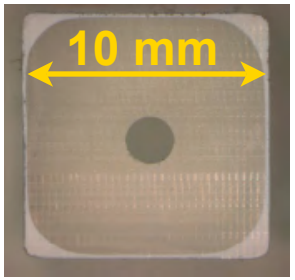
- Dedicated to appearance backgrounds
  - **1.7x10^4 NC-Res1π^0** events in H_20 target per year
  - **~6000 π^0 reconstructed**
  - **Water in/out** periods : C/H_20 differences
  - Inclusive NC/CC production
  - Beam ν_e

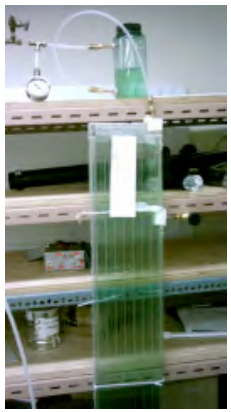


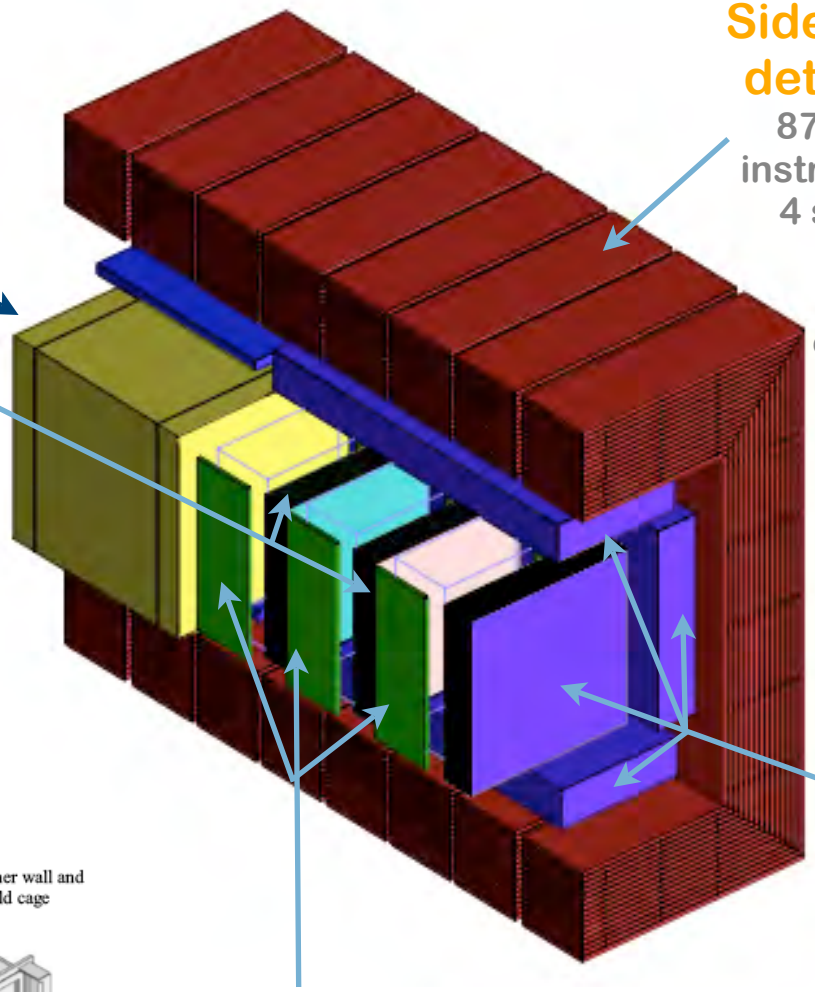


ND280 Off-Axis: Tracker region

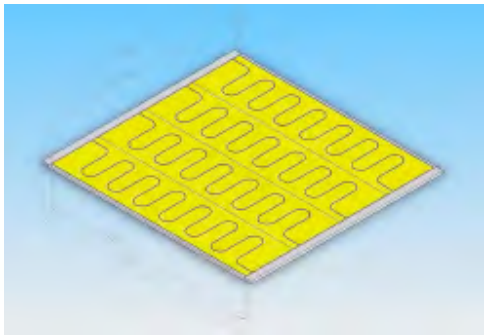
2 Fine Grained 2x1.3t target detectors (FGD)
FGD1(C): X-Y plastic
FGD2(H_2O): X-Y plastic
+passive water target
8k channels



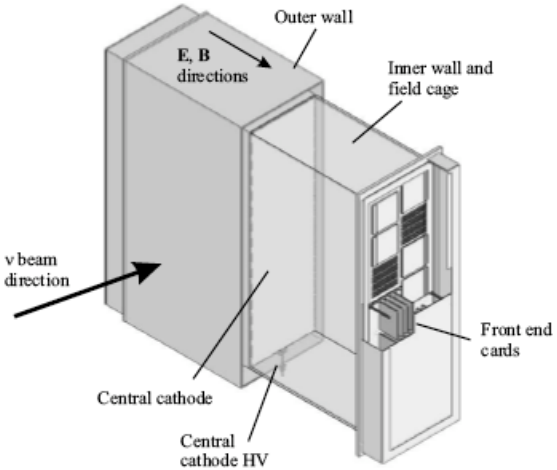




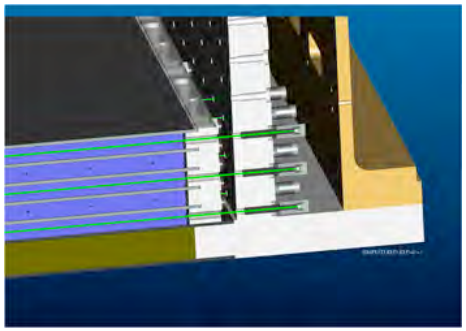
Side muon ranging detector (SMRD)
87x17x1cm planes
instrumenting air gaps
4 slabs per planes
μ ranging
active veto
cosmic trigger

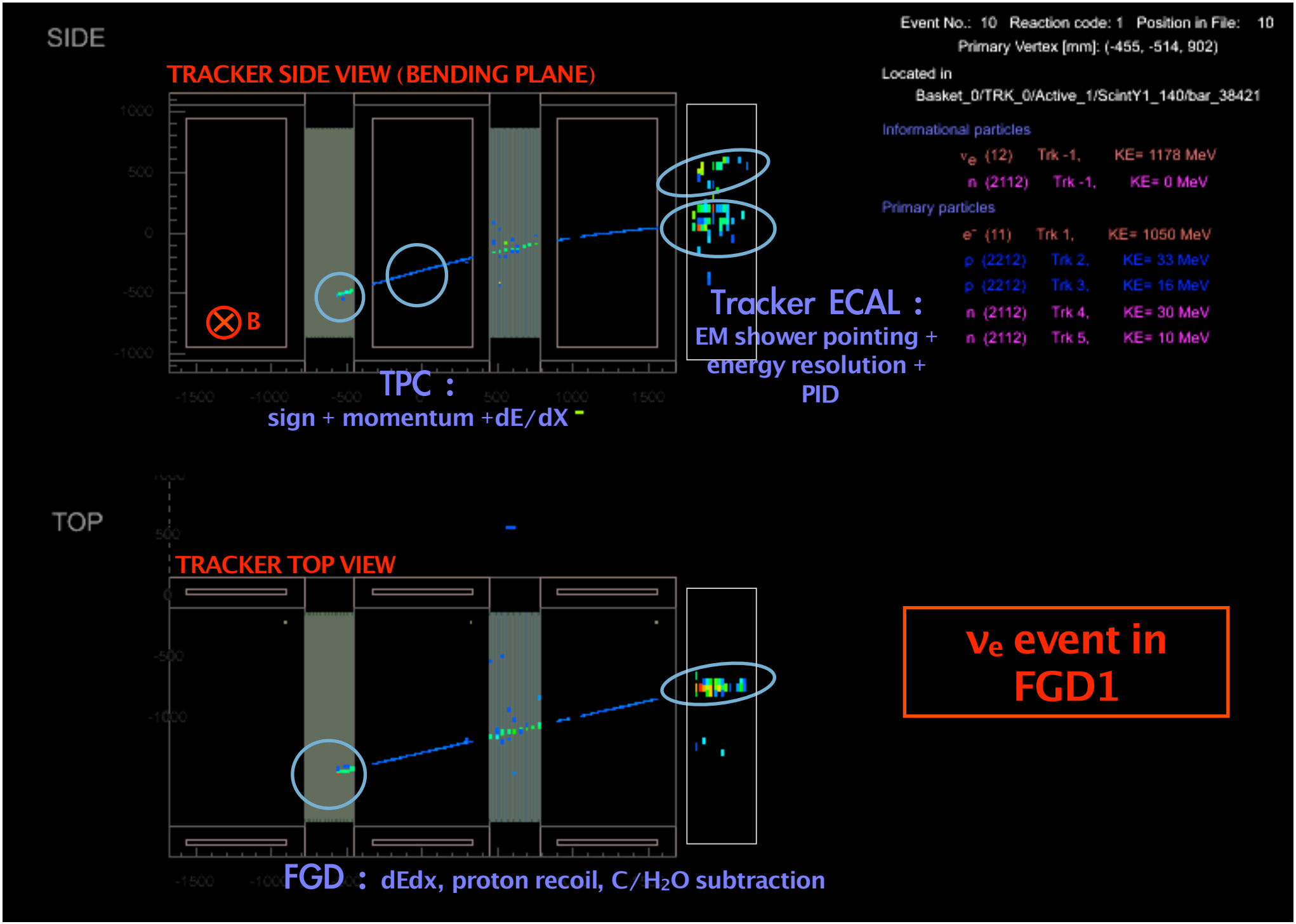


Tracker Calorimeter
X-Y fine grained Pb/Plastic
(4x1cm bar)
Eres ~7.5%/√E
20K channels



3 TPC modules
Micromegas modules
Position resolution < 0.8 mm
Mom resolution to 1GeV <7-8%



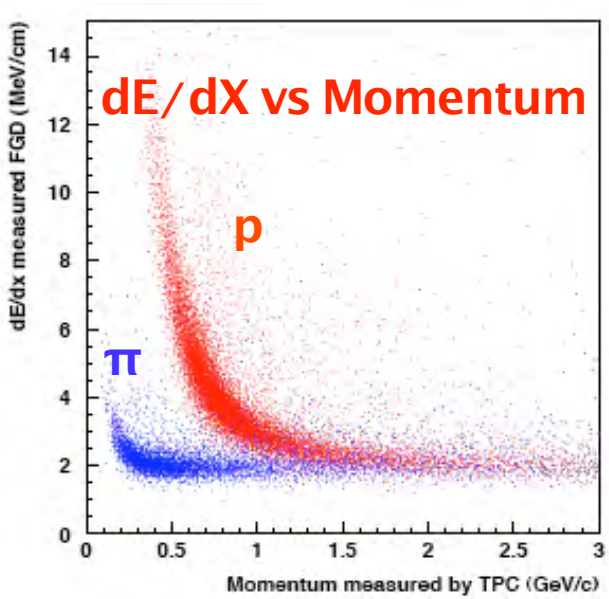

SIDE
TRACKER SIDE VIEW (BENDING PLANE)
Event No.: 10 Reaction code: 1 Position in File: 10
Primary Vertex [mm]: (-455, -514, 902)
Located in
Basket_0/TRK_0/Active_1/ScintY1_140/bar_38421
Informational particles
νe (12) Trk -1, KE= 1178 MeV
n (2112) Trk -1, KE= 0 MeV
Primary particles
e- (11) Trk 1, KE= 1050 MeV
p (2212) Trk 2, KE= 33 MeV
p (2212) Trk 3, KE= 16 MeV
n (2112) Trk 4, KE= 30 MeV
n (2112) Trk 5, KE= 10 MeV
B
Tracker ECAL :
EM shower pointing + energy resolution + PID
TPC :
sign + momentum +dE/dX
TOP
TRACKER TOP VIEW
FGD : dEdx, proton recoil, C/H2O subtraction
νe event in FGD1

FGD-TPC-Tracker ECal-SMRD

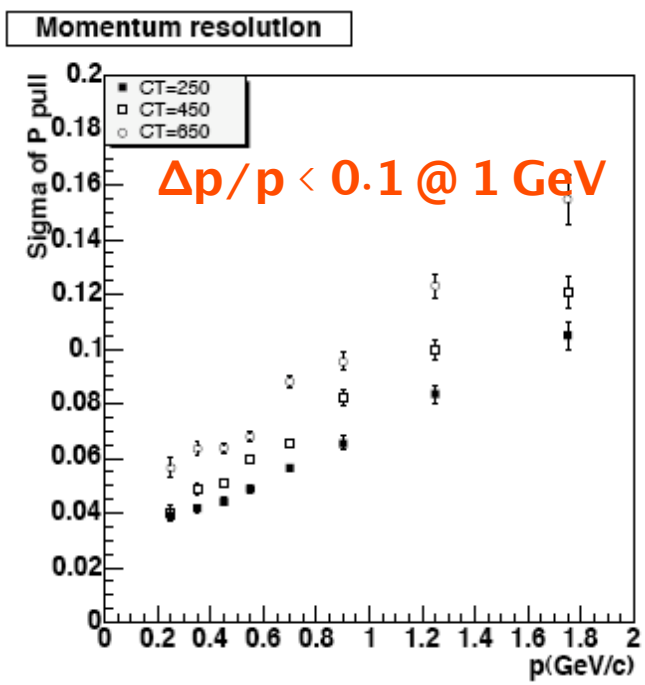
- ➡ Off-axis beam flux and energy spectrum measurement
  - Select pure QE events
- ➡ Background measurements (CC-1π^+, NC-1π^0)
  - Select/ reject CC-1π events
- ➡ Cross-section studies

	total	CCQE	CCQE eff.	CCQE purity
generated	5000	1767	1	0.3534
negative track in TPC	1971	1086	0.614	0.551
π^+ veto in TPC	1700	1084	0.613	0.638
π^+ veto in FGD	1577	1080	0.611	0.685
photon veto in Ecal	1303	1054	0.596	0.809
μ^- ID in Ecal	1270	1049	0.594	0.826

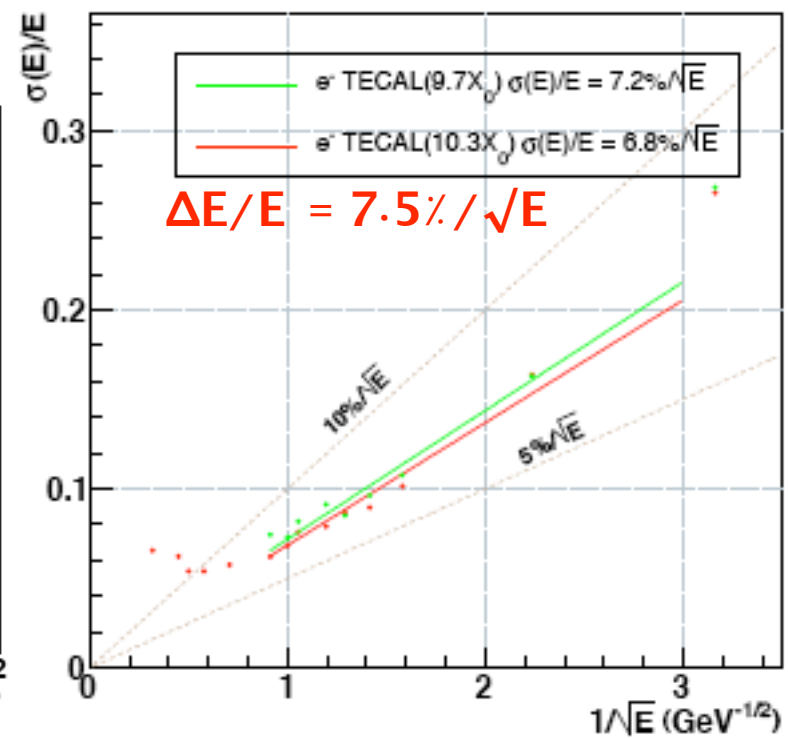
FGD



TPC

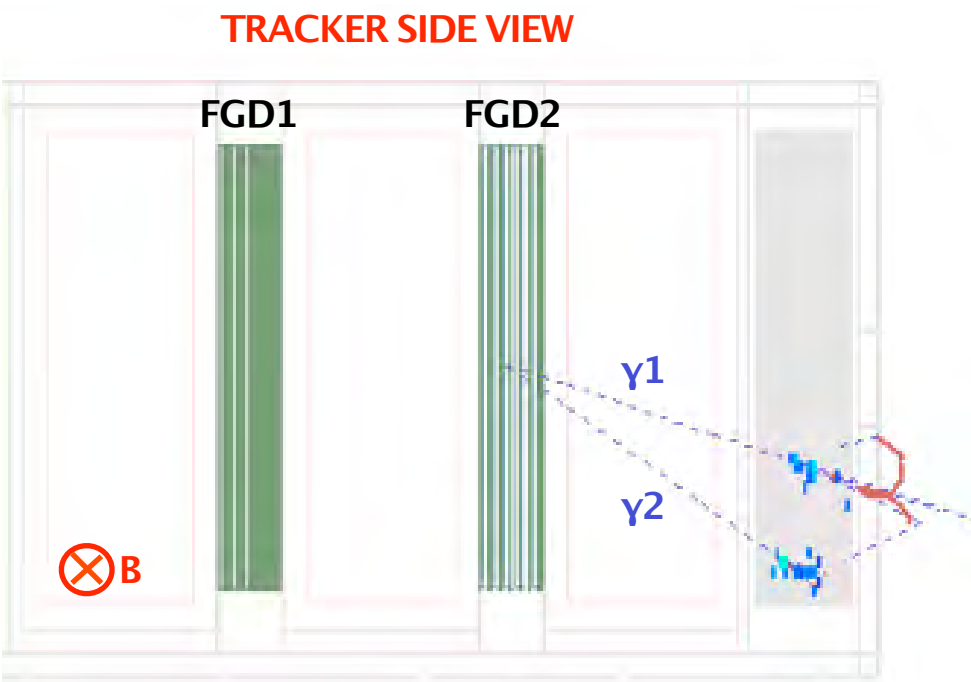


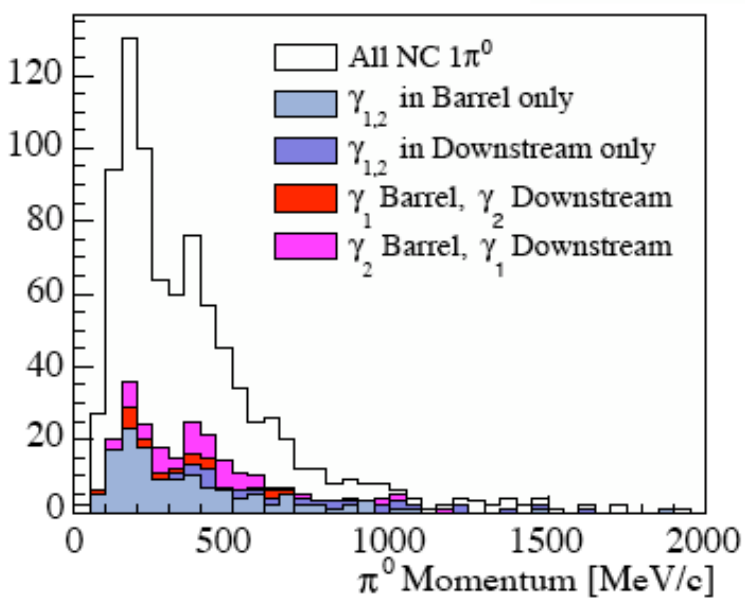
Tracker ECAL

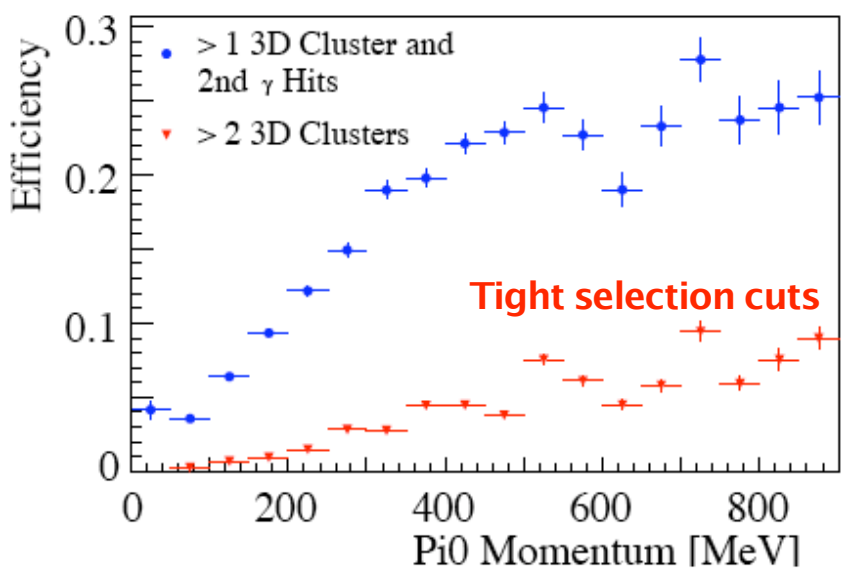


NC-1π^0: FGD-Tracker ECal

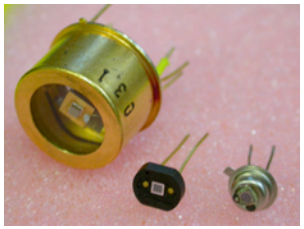
- Exclusive NC-1π^0
- Statistically limited
  - ~ 800 NC-π^0 evts/year(10^{21} POT)
- use Tracker ECAL fine shower sampling and pointing capability to reconstruct π^0 decay





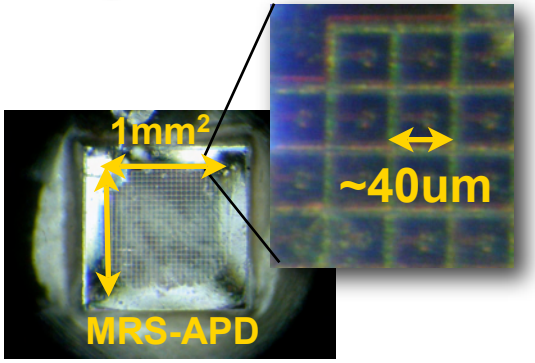


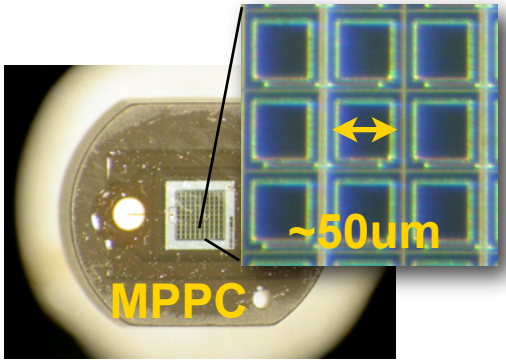
Novel type of photosensor : Geiger Mode multi- pixels APD



ND280 Scintillator Detectors Constraints :

- Magnetic Field
- Very tight space constraints
- Low light yield at end of WLS fibre
- High number of channels
- Detector operation 5 years



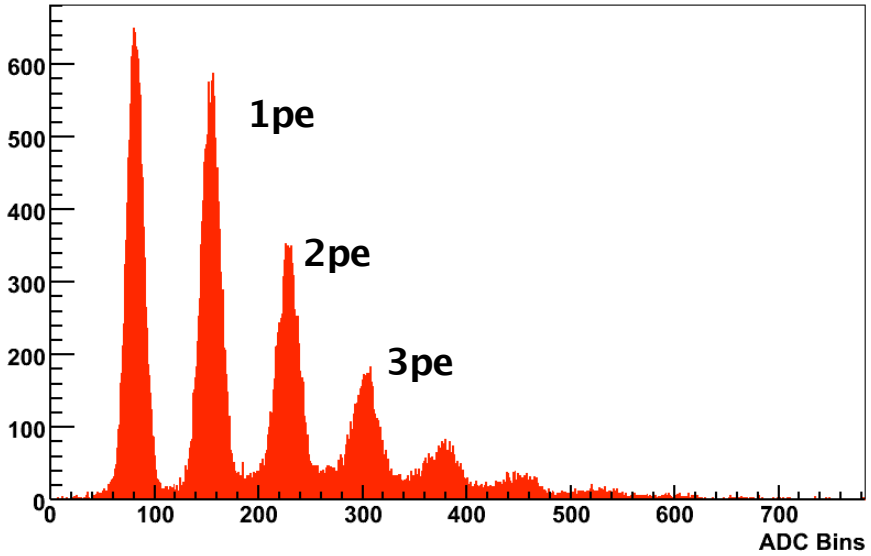


$$Signal = \sum_i Q_i^{pixel}$$

Photo-electron resolution
+ dynamic range combined in 1 sensor

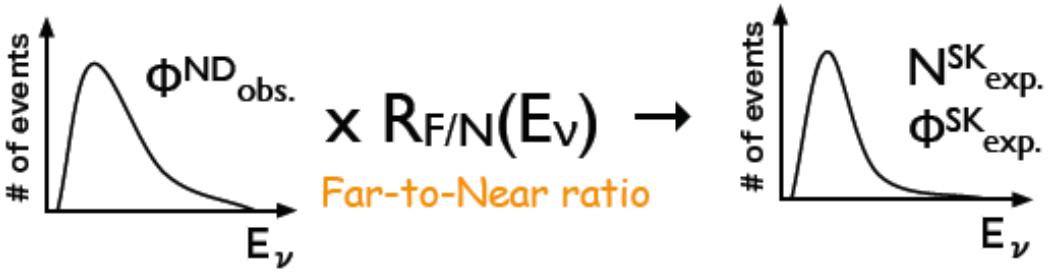
GM-APDs

- Insensitive to magnetic field, tested to 4T
- Small (active area ~1mm^2)
- Bias voltage 50V
- Photon detection efficiency >20% at 500nm
- Gain G~ 5x10^5
- Low power consumption
- Dark count rate ~0.5MHz/mm^2 at 25°C
- Longevity OK



Near/Far extrapolation

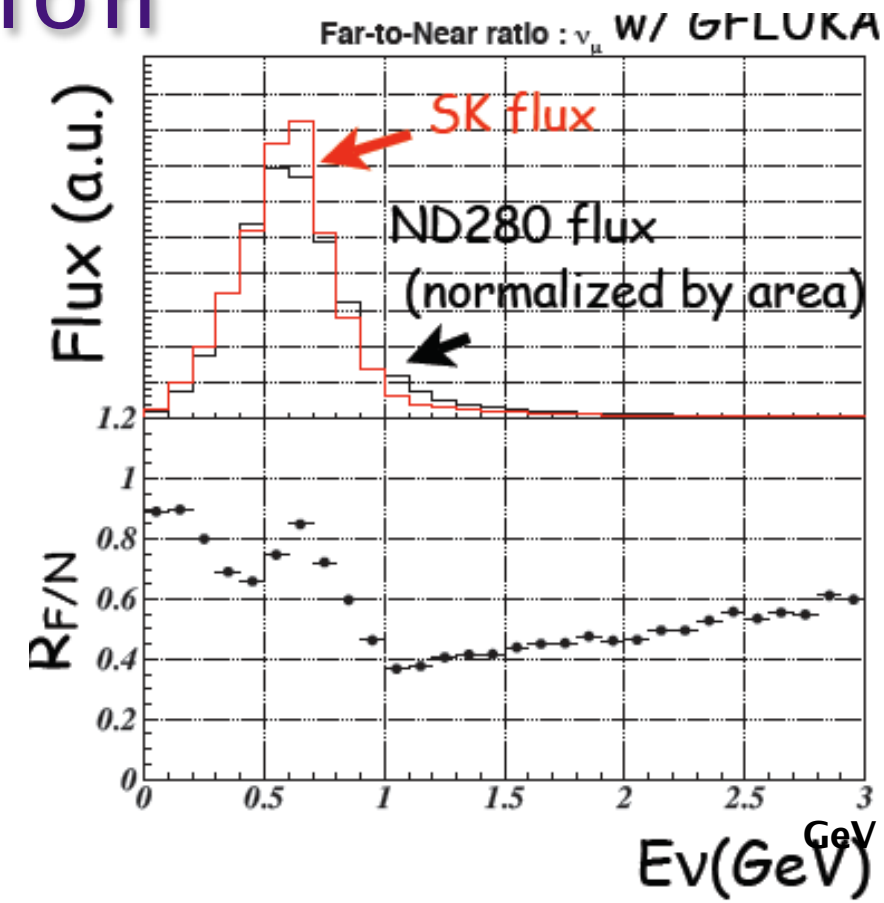
Example of K2K F/N method :



T2K requirement

$$\delta R_{F/N}(E_\nu) < 2\text{-}3\%$$

(for each 100 MeV/bin in E_ν: 0-1.5GeV)

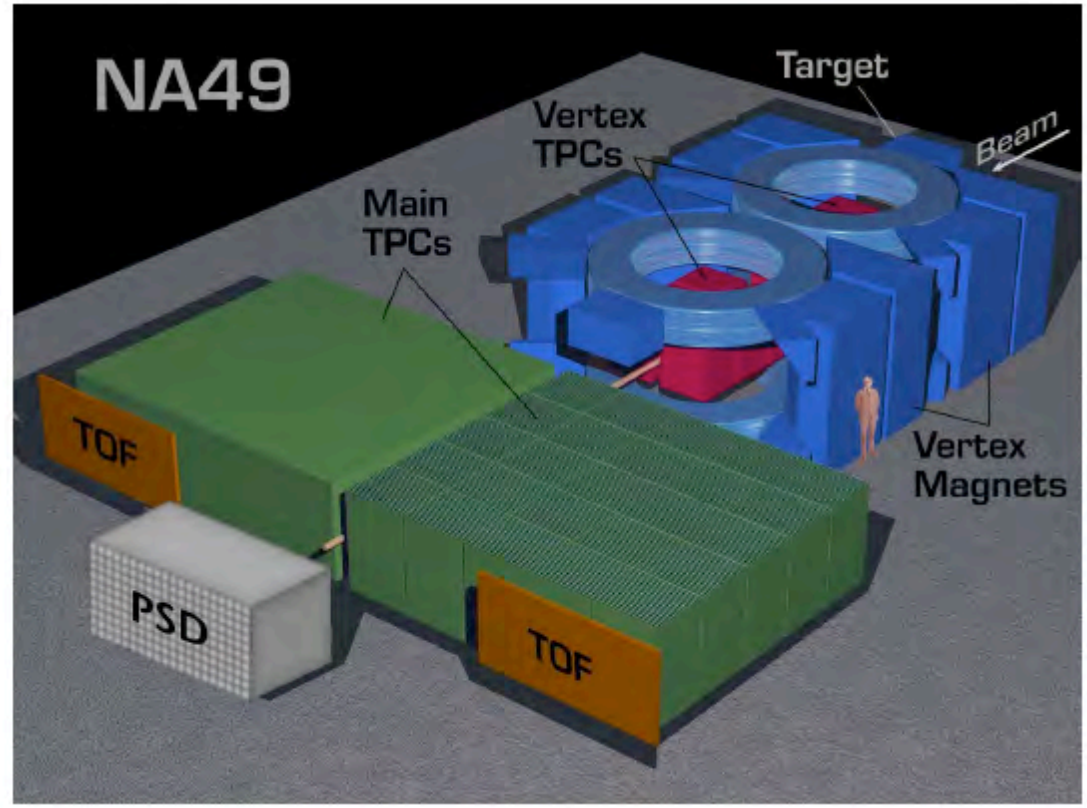


- ➡ Finite acceptance at ND280
  - **Extrapolation very sensitive** to energy scale and flux shape
- ➡ Need to reduce systematic errors in hadron production distributions
  - **No data available in the 30-50 GeV region**

NA61 at CERN

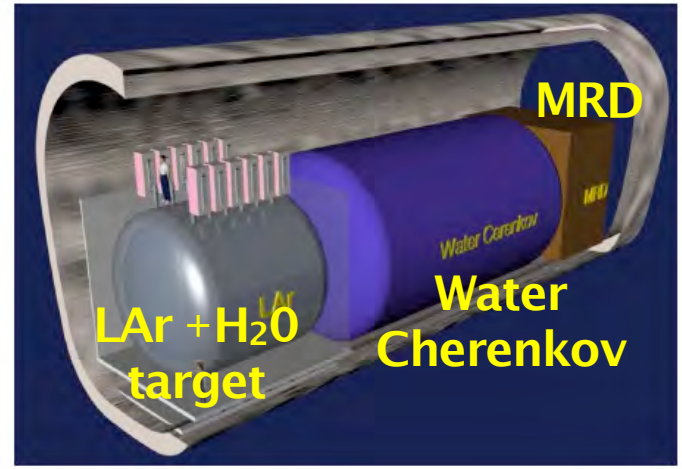
15 countries, 25 institutions, ~ 100 Physicists

- ➡ Physics program
  - Quark-Gluon Plasma transition
  - **Measure hadron production (p+C reactions in 30-50GeV range)**
- ➡ Re-use NA49 set-up + minor upgrades
- ➡ 3 targets: thin, thick and copy of T2K
  - Pions and Kaons productions
  - Study primary interactions
- ➡ Fully approved in April 2007 !
- ➡ Data taking start at end of September 2007

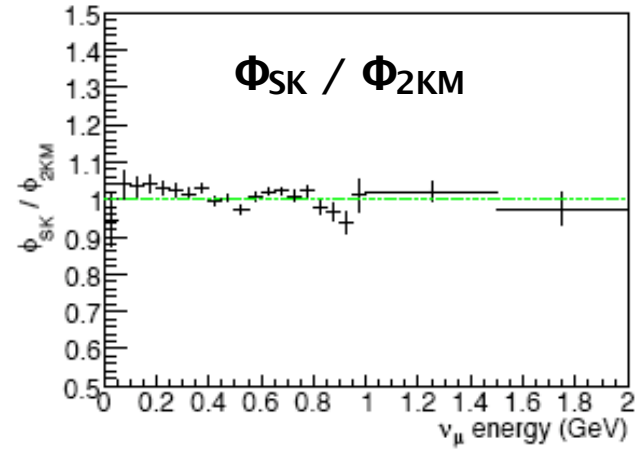


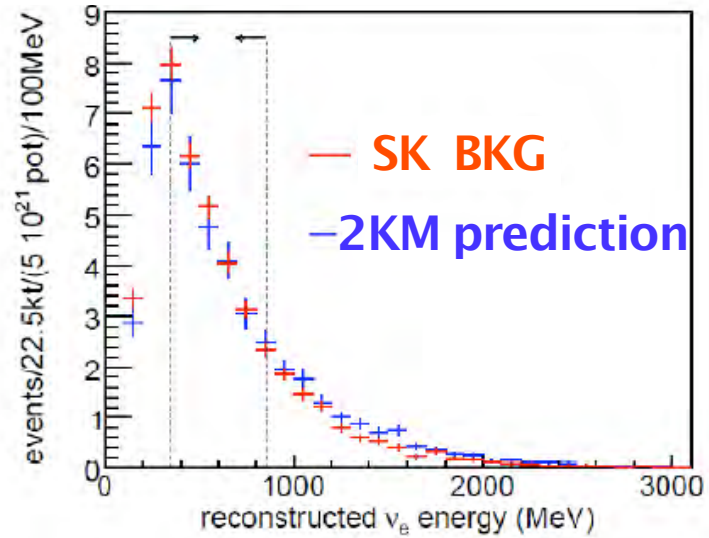
vertex resolution $\sigma_z \sim 5$ mm
momentum resolution $\Delta p/p^2 \sim 10^{-4}$

2KM Proposal



- ➡ Strengthen prediction of far detector flux through measurement (~2 km away) using :
  - Almost **same beam flux as far detector**
  - **Same target material**
  - **Same detector technology** and reconstruction analysis
- ➡ Check ND280+NA61 prediction before oscillation
- ➡ Combine ND280+2kM measurements
  - Reduce further the systematic errors
  - Understand better the νe backgrounds





T2K Schedule

➡ Beam line construction started	Apr. 2004
➡ ND280 pit construction start	Jul. 2007
➡ UA1 magnet installation	Apr. 2008
➡ Completion of ND280 building	Mar. 2009
➡ Neutrino beam line commissioning	Apr. 2009
➡ T2K data taking starts	Apr. 2009
➡ ND280 Commissioning	Oct. 2009
➡ ND280 Data taking	Nov. 2009...