TRIUMF

T2K

T2K Near Detector

Fabrice Retière for the T2K collaboration

The T2K collaboration

Canada
U. Alberta
U. B. Columbia
U. Regina
U. Toronto
TRIUMF
U. Victoria
York U.

France
CEA Saclay
IPN Lyon
LLR E. Poly.
LPNHE Paris

Germany
Aachen

Italy
INFN, U. Bari
INFN, U. Napoli
INFN, U. Padova
INFN, U. Roma

Japan
ICRR Kamioka
ICRR RCCN
KEK
Kobe U.
Kyoto U.
Miyagi U. Edu.
Osaka City U.
U. Tokyo

Poland
A. Soltan, Warsaw
H.Niewodniczanski, Cracow
U. Silesia, Katowice
T. U. Warsaw
U. Warsaw
U. Wroclaw

Russia
INR

S. Korea
Chonnam
U. Dongshin
N. U. Seoul

Spain
IFIC, Valencia
U. A. Barcelona

Switzerland
ETH Zurich
U. Bern
U. Geneva

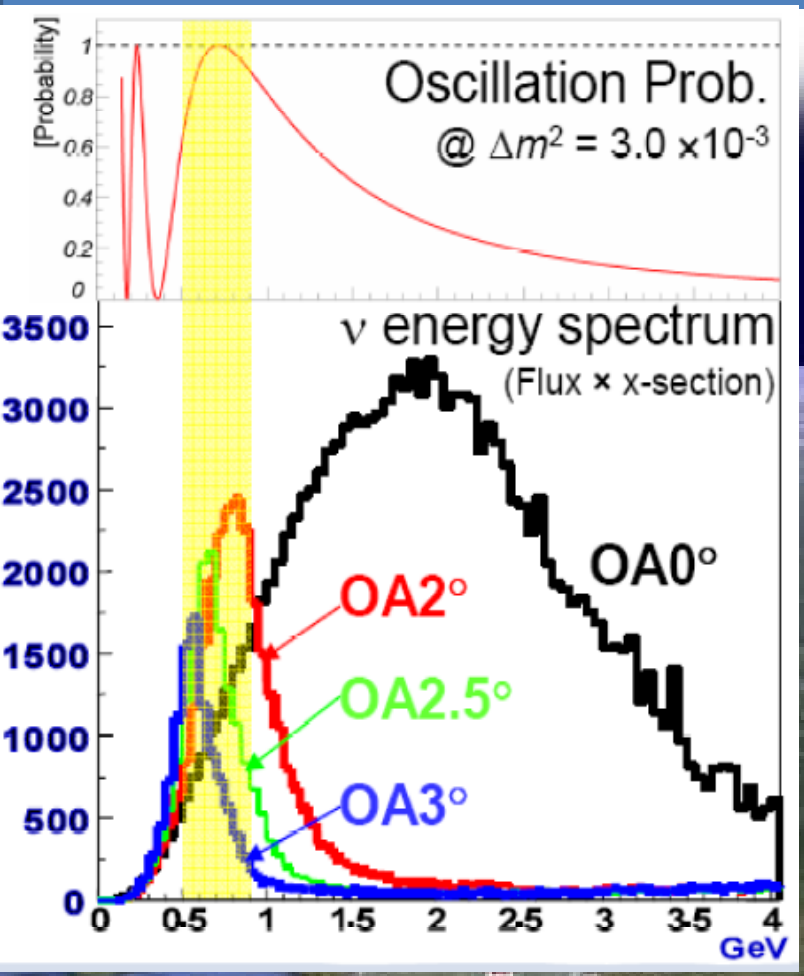
UK
Imperial C. L.
Lancaster U.
Liverpool U.
Queen Mary U. L.
Oxford U.
Sheffield U.
STFC/RAL
STFC/Daresbury
Warwick U.

USA
Boston U.
B.N.L.
Colorado S. U.
U. Colorado
Duke U.
U. C. Irvine
Louisiana S. U.
U. Pittsburgh
U. Rochester
Stony Brook U.
U. Washington

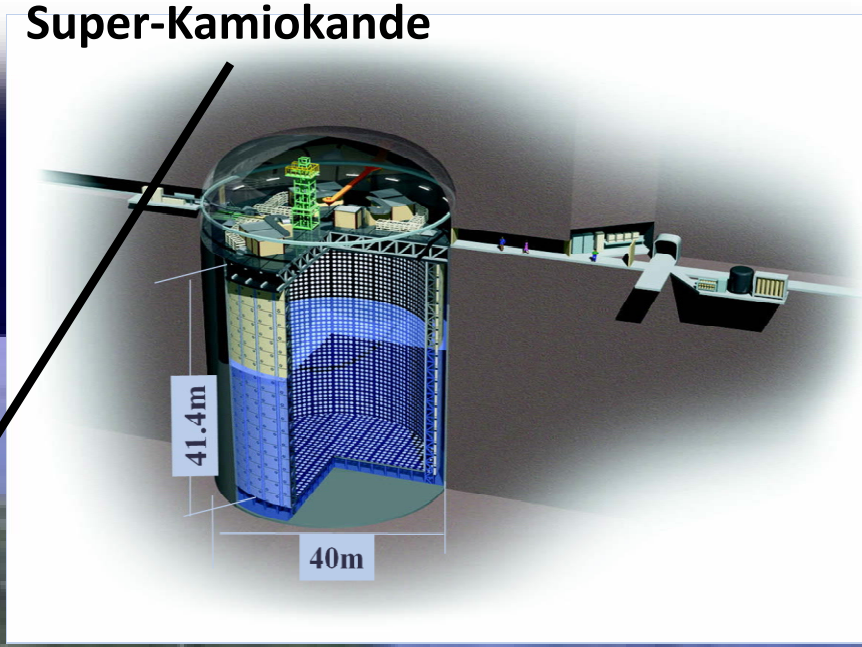
Total:
~500 members
59 institutes
12 countries

Near & Far sites:
KEK/JAEA
ICRR

Tokai 2 Kamioka experiment



Super-Kamiokande



J-Parc at Tokai

-Precise measurement of ν_μ disappearance

-Search for $\nu_\mu \rightarrow \nu_e$ appearance

Neutrino beamline

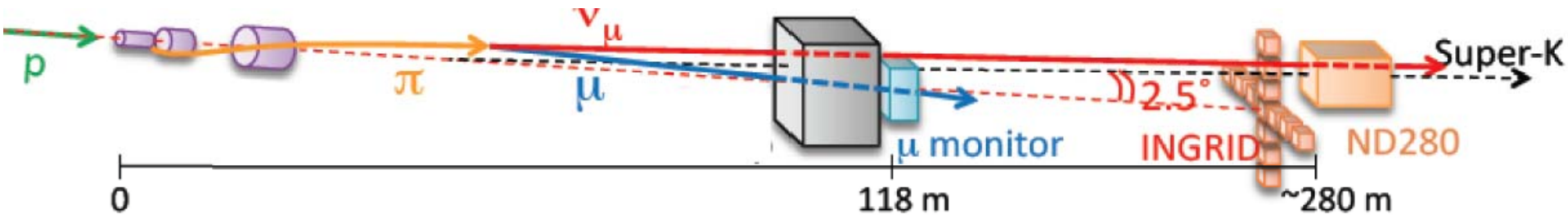
Beam dump &
muon monitors

Neutrino arc
(Super-conducting
combined function
magnets)

Spill cycle: 3.04 sec
8 (6 in 2010) bunches

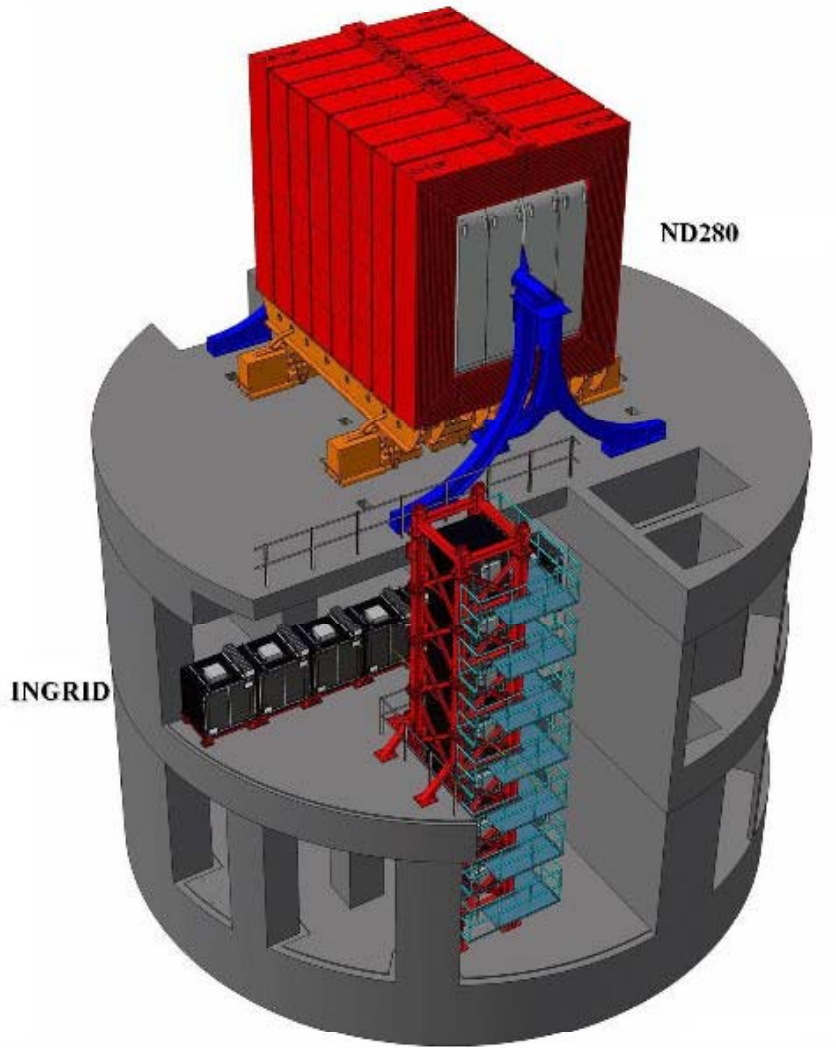
Target and horns(3), decay volume (110m)

Characterizing the neutrino beam



- Oscillation analysis require good understand of the beam and ν cross-sections
- Strategy
  - NA61 at CERN measure the hadron spectra from a target replica
  - Measure the position of the muons at the end of the beam dump
  - Detect a fraction of the neutrino 280 m from the target: the near detector

T2K near detector



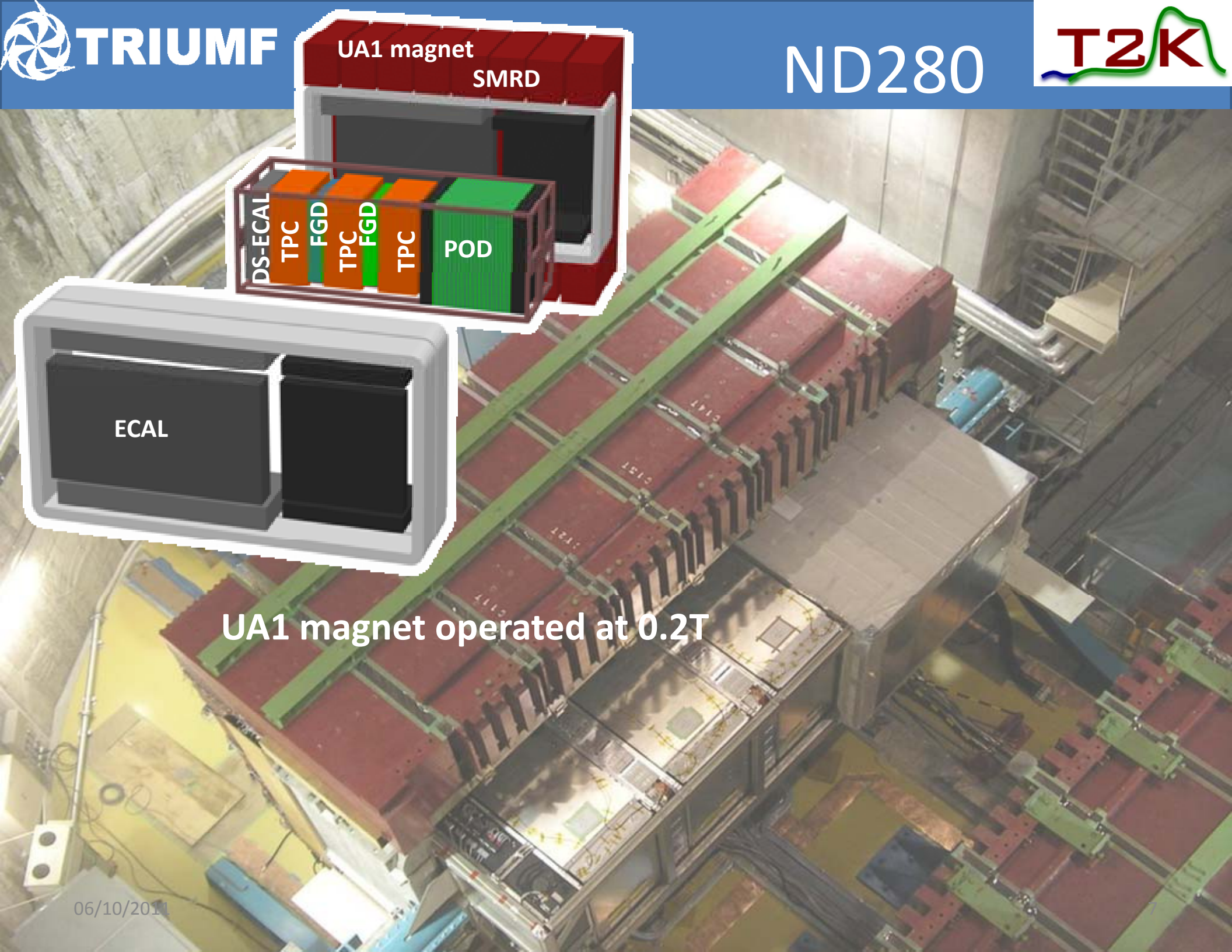
On-axis: INGRID

- Measure beam flux and direction

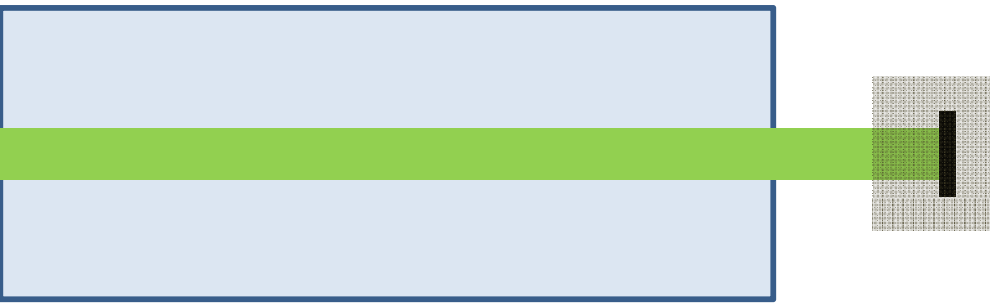
Off-axis: ND280

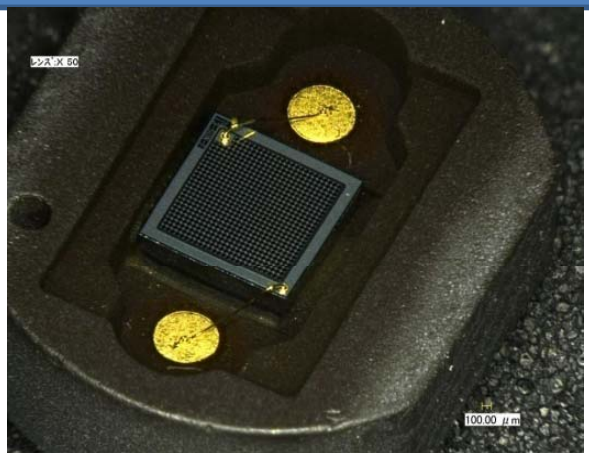
- Measure beam flux off-axis
- Measure neutrino cross-sections
- Allow characterizing different neutrino interactions
  - Tracking capabilities
  - Particle identification
  - Calorimetry

ND280


UA1 magnet
SMRD
DS-ECAL
TPC
FGD
TPC
FGD
TPC
POD
ECAL
UA1 magnet operated at 0.2T

A common building block to all scintillator detectors





- Plastic scintillator
  - Extruded or grooved
  - 5 different kinds
- Wavelength shifting fibers
  - Kuraray Y11, 1 mm diameter

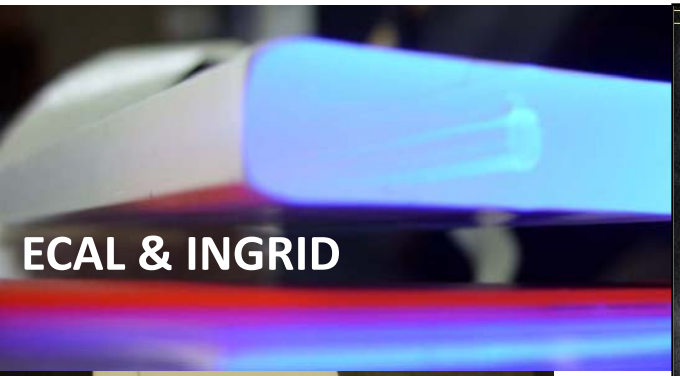
- Hamamatsu Multi-Pixel Photon Counter
  - 1.3×1.3 mm^2
  - 667 pixels (50 μm pitch)
- Fiber-MPPC coupler
  - Custom designed
    - 3 different kinds
- Readout electronics
  - 2 different kinds

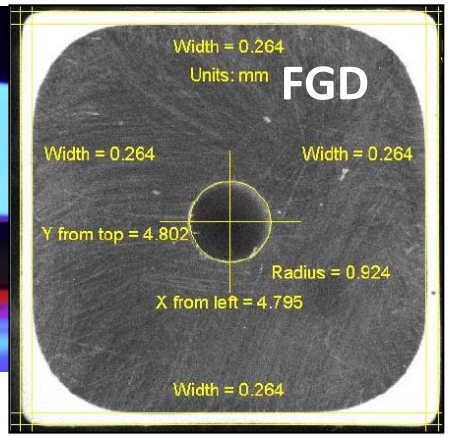
Differences and similarities

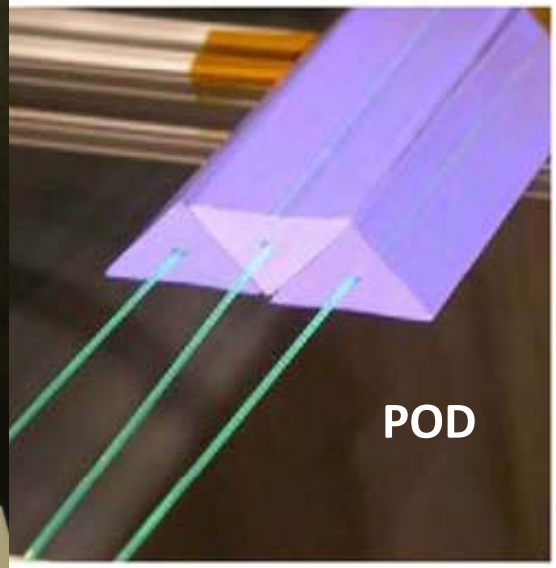
	FGD	DS-ECAL	B-ECAL	INGRID	POD	SMRD
Number of channels	8,448	3,400	18,900	9,592	10,400	4,016
Bar length (mm)	1844	2040	1520, 3840	1119, 1203, 1299	2137, 2268	873
Bar cross-section (mm^2)	9.6x9.6	40x10	40x10	50x10	32.5(B)x17 (H)	170x7
Fiber diameter (mm)	1	1	1	1	1	1
Far end	Mirrored	Readout	Mirrored	Mirrored	Mirrored	Readout
MPPC over- voltage (V)	0.8-1	1.33	1.33	1.33	1.33	~1.4
Most probable # of avalanches per MIP	20-35	20-30	In progress	10-15	30-60*	35-40
Electronics	Waveform	Q-t	Q-t	Q-t	Q-t	Q-t

Differences

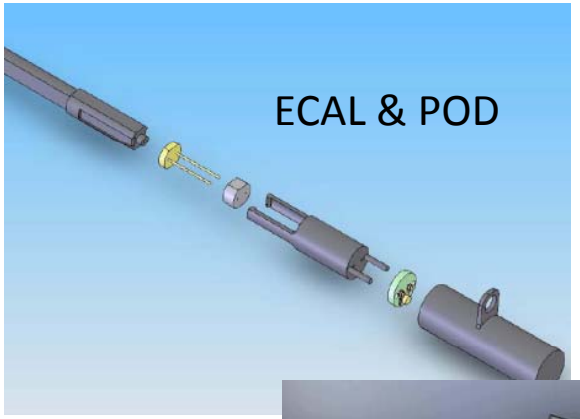
Scintillator bar

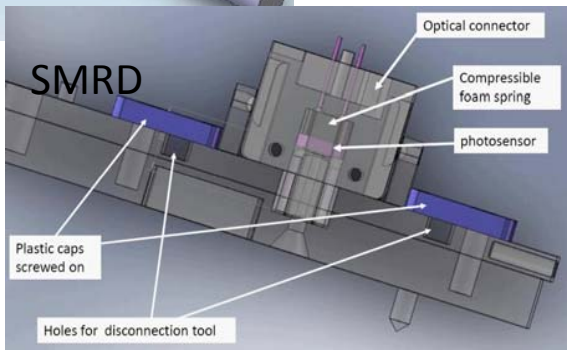


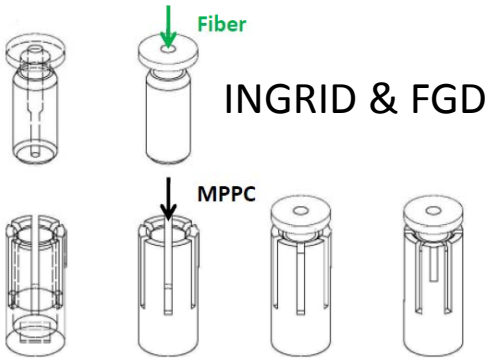




Fiber-MPPC coupler

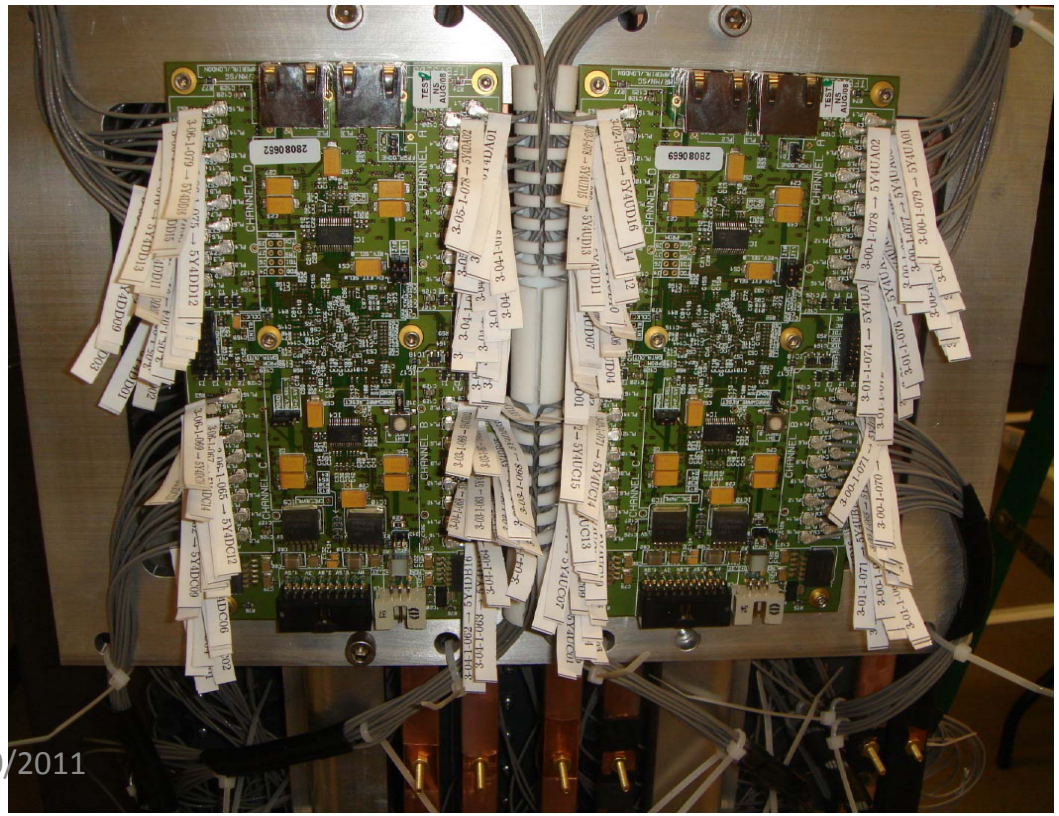


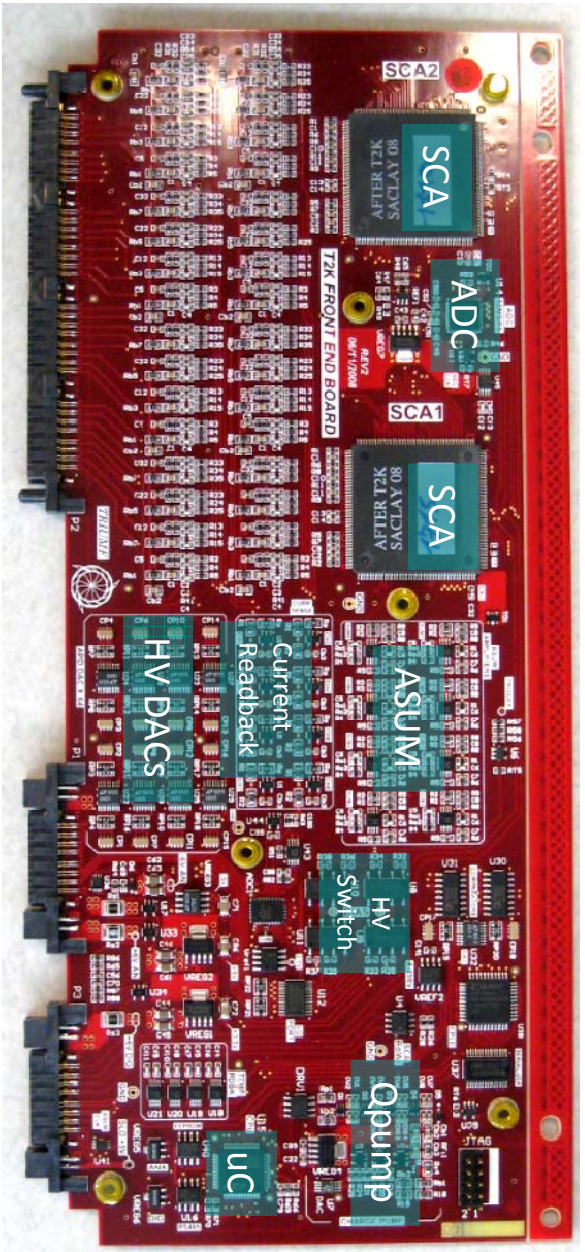




Readout electronics

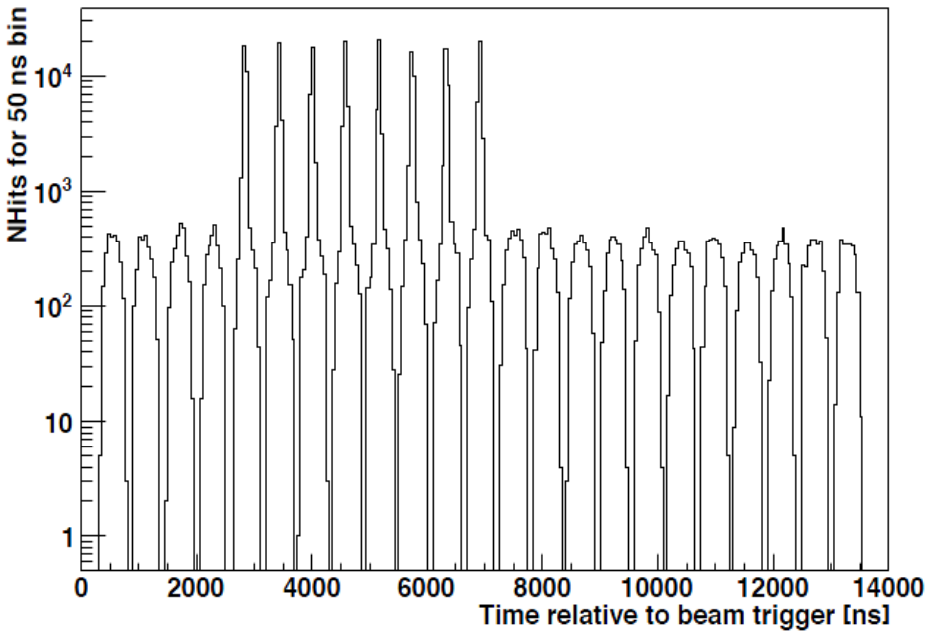
- Two different ASICs
  - TRIP-t: integrator + discriminator
    - ECAL, POD, SMRD
  - AFTER: Switch Capacitor Array
    - FGD



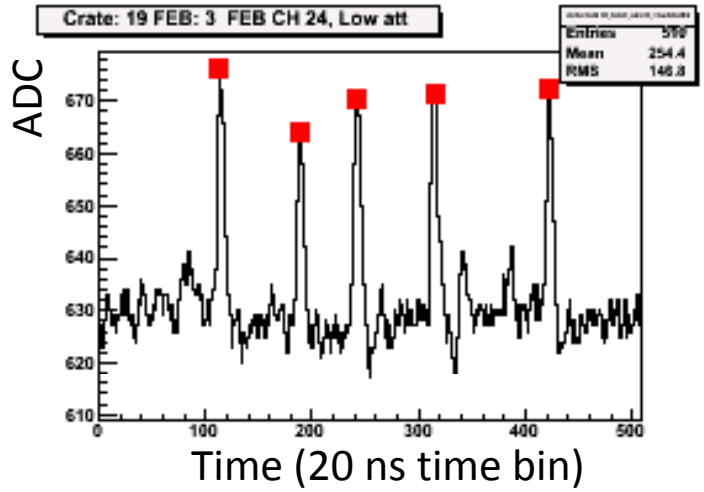


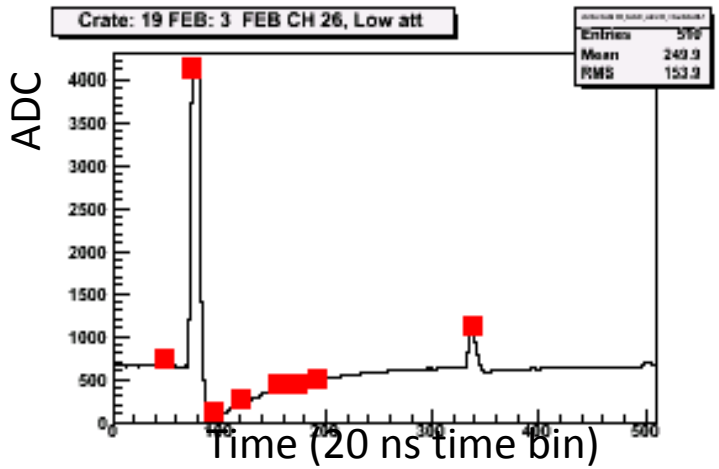
Raw data

- TRIP-t data
  - Integrate charge over 23 cycles(540 ns wide)
    - 100 ns reset between cycles
  - Time: discriminator fires when charge > threshold
    - 1 time per cycle



- FGD-AFTER data
  - Raw waveform
  - Q-t extracted in firmware





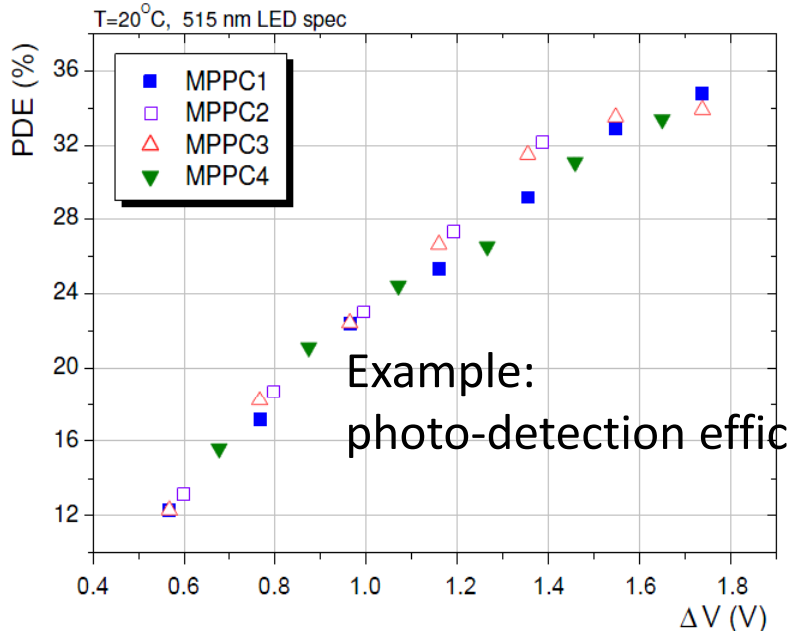
MPPC

- T2K was the first experiment to use large number of MPPCs
  - About 50,000
- Extensive quality assurance before installation
  - Less than 20 MPPCs found bad
    - Was it worth the efforts?
- No MPPC have died while in operation in ND280

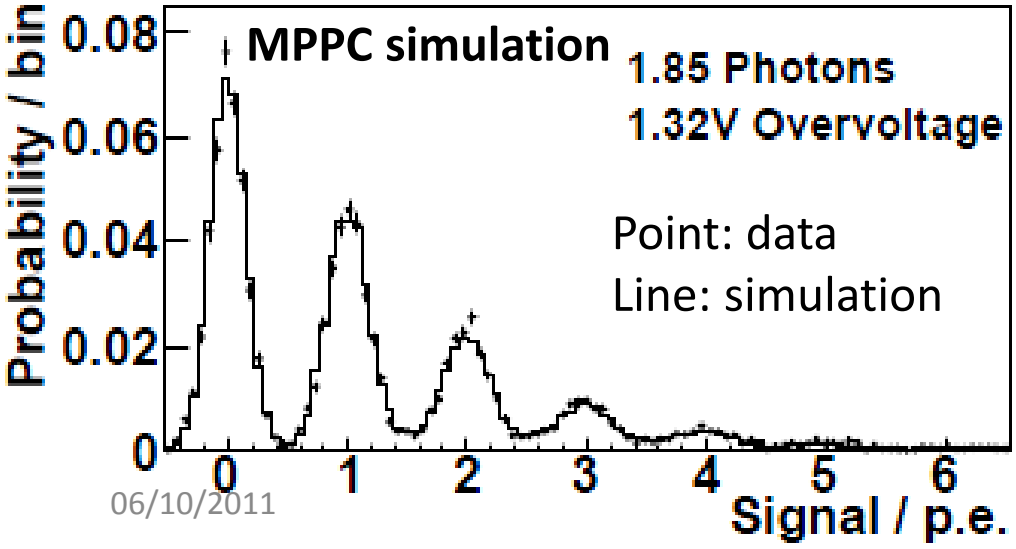
- MPPC response characterization
  - Detail measurements
    - Gain variation and fluctuation
    - Photo-detection efficiency
    - Dark noise
    - After-pulsing
    - Cross-talk
    - Recovery
    - Saturation
  - Information critical for detector simulation, operation and calibration

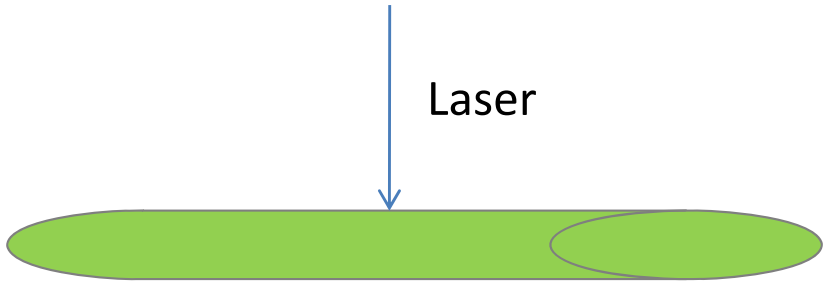
Detector response characterization and simulation

MPPC characterization

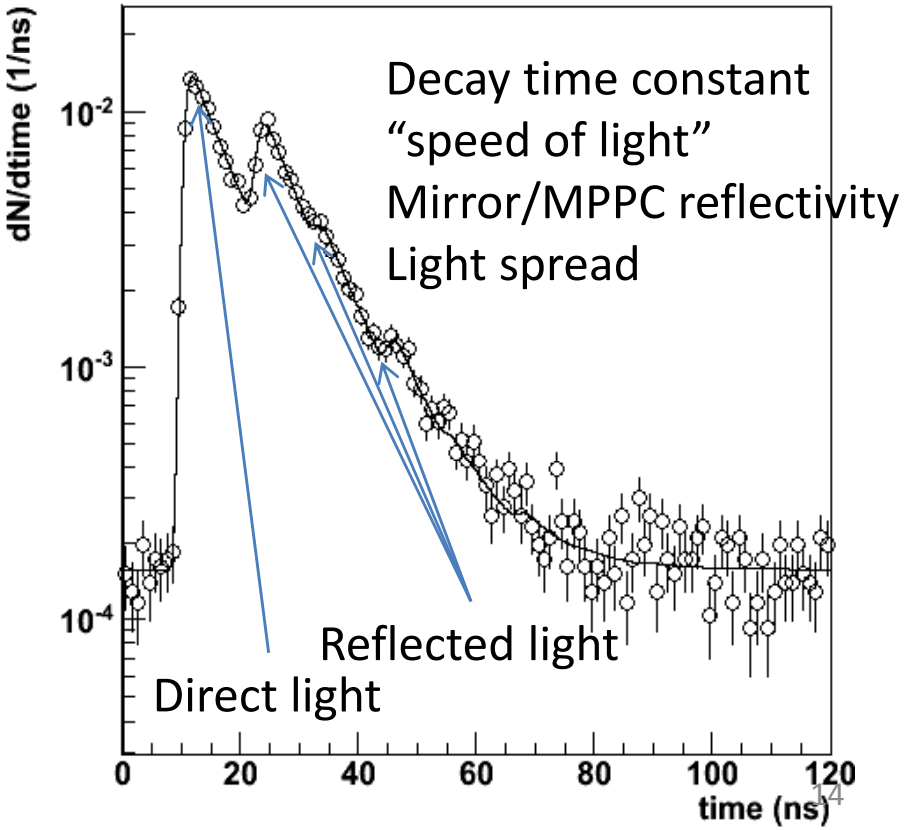


Example:
photo-detection efficiency

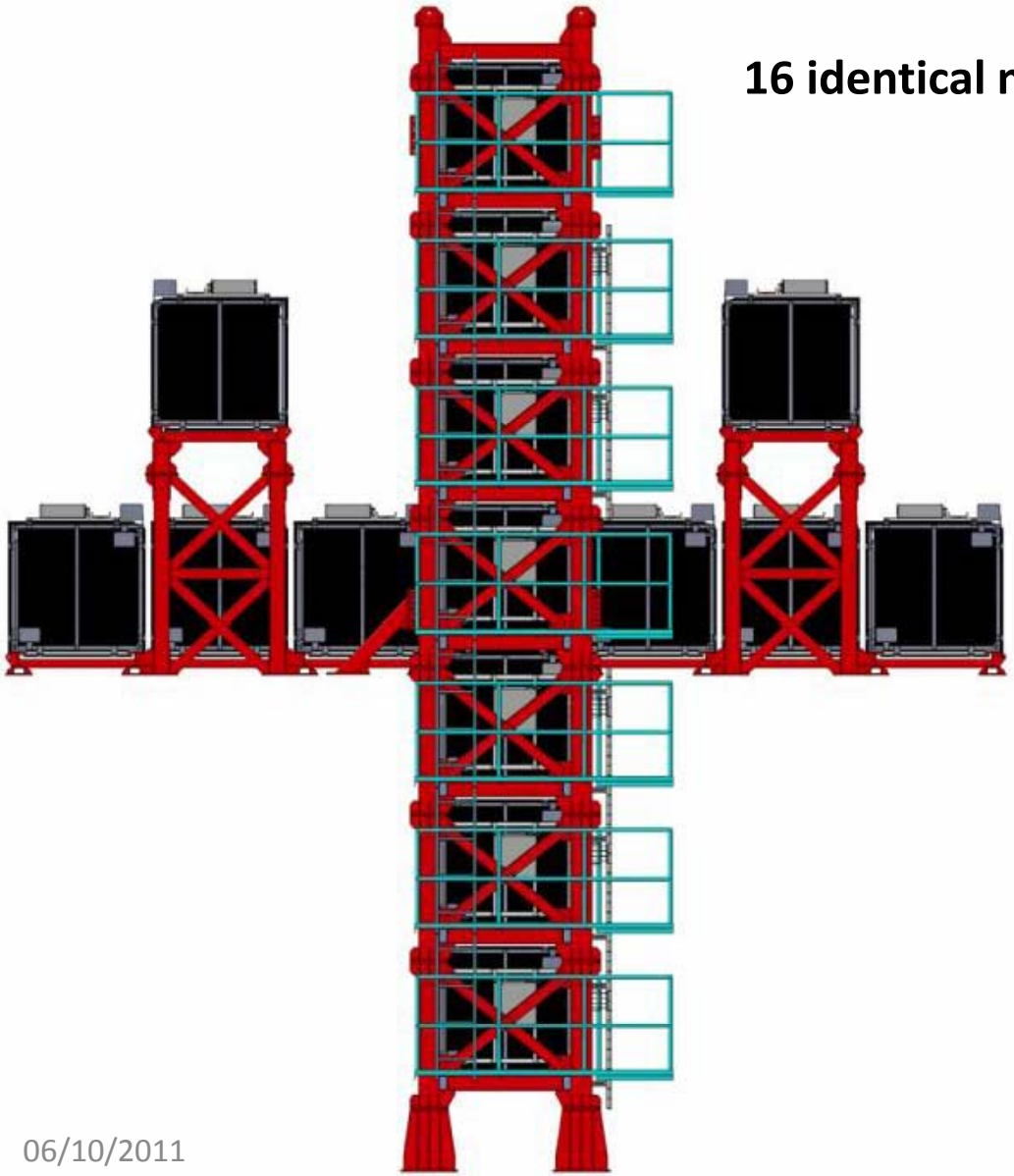




Fiber characterization

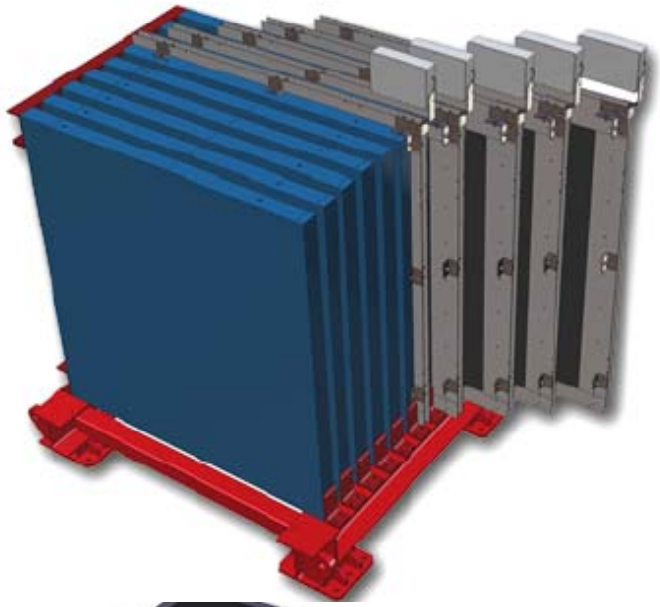


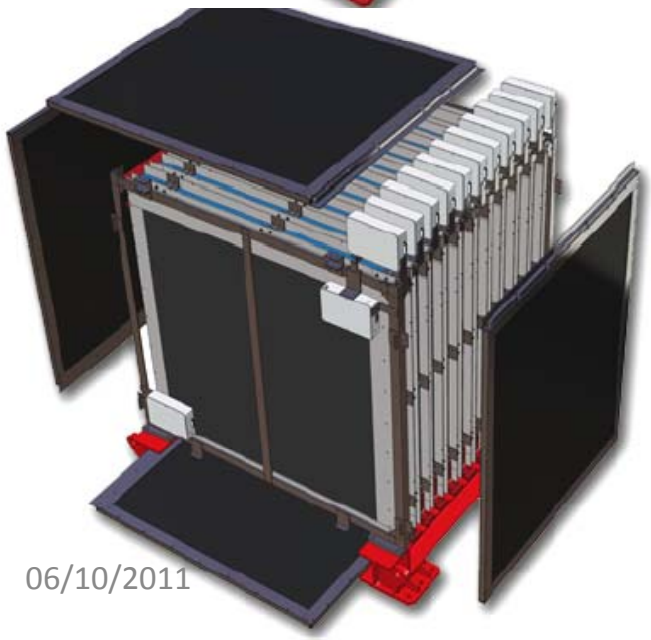
On-axis Interactive Neutrino GRID



16 identical modules

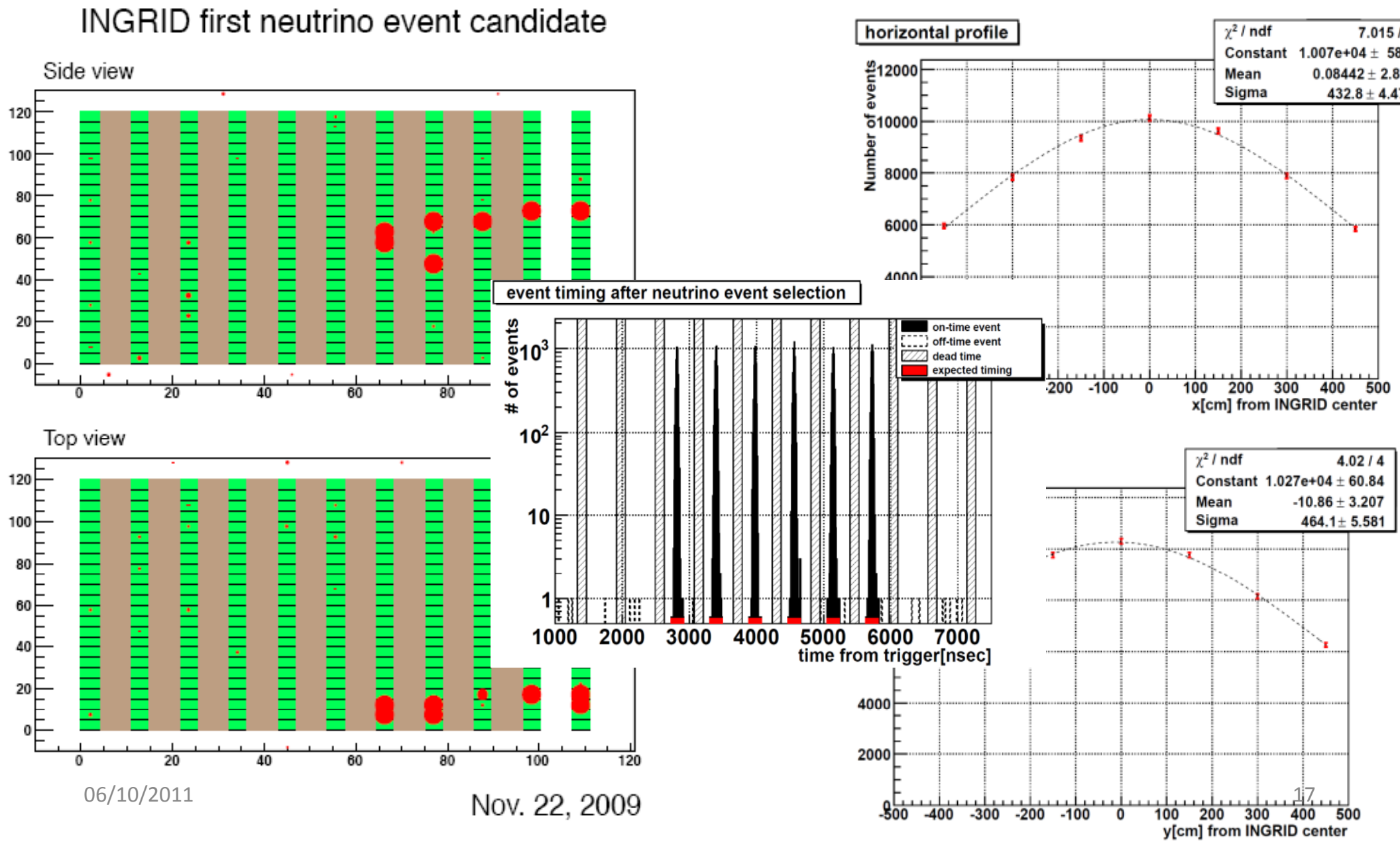
INGRID module





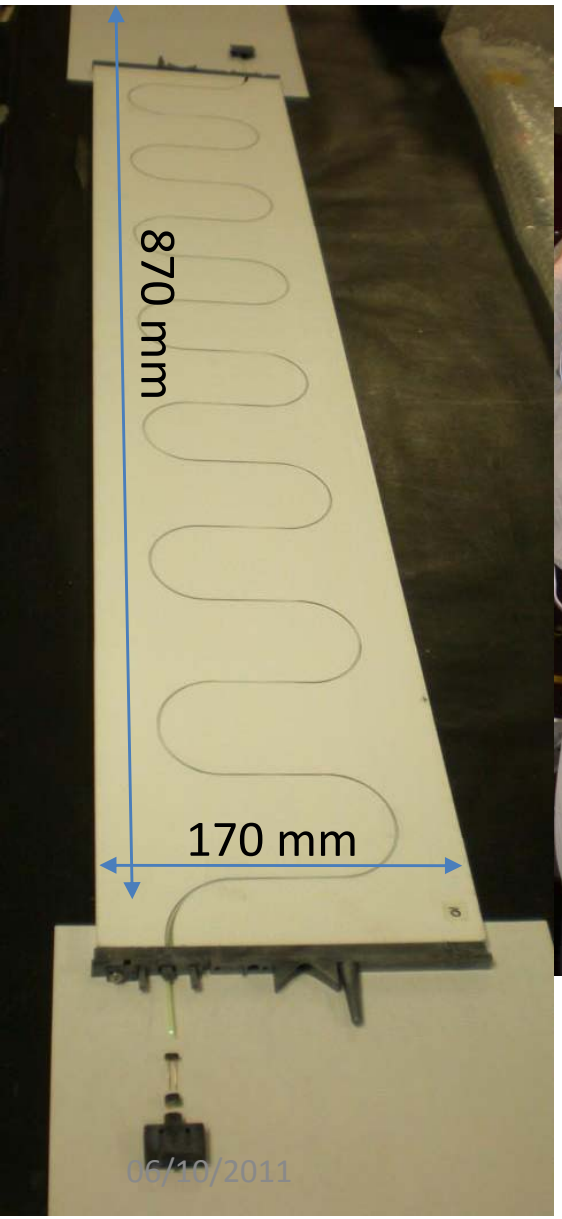
- 9 iron planes
  - 124×124×6.5 cm^3
- 11 scintillator planes
  - 24(X)+24(Y) 1×5×120.3 cm^3 scintillator bars
  - Y11 + Multi-Pixel Photon Counter readout
    - 8448 channels
- 4 veto detectors
  - ~Same bars + Y11 + MPPC
    - 1144 channels

INGRID performances



Side Muon Range Detector (SMRD)

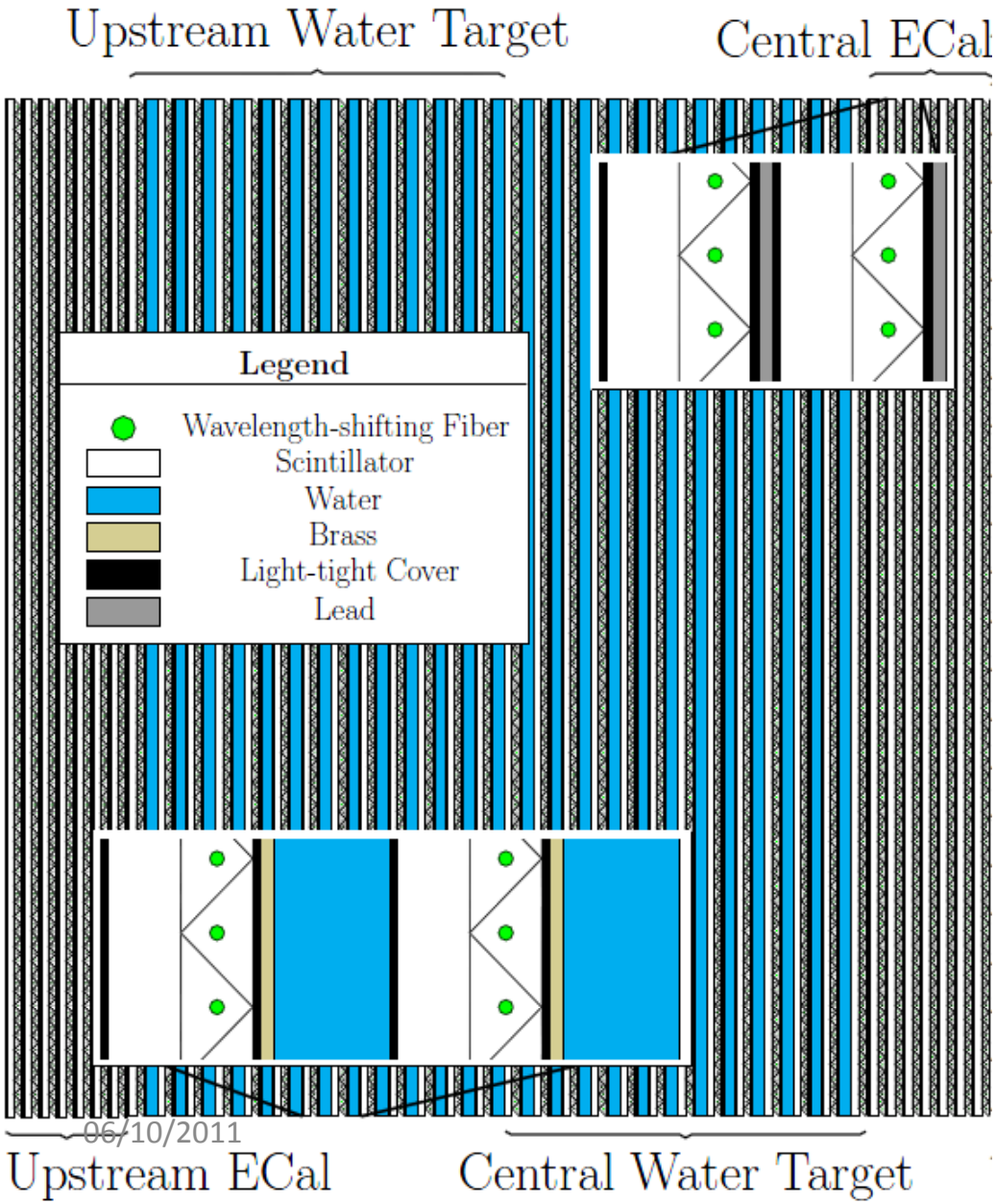
Colorado State U., Cracow, Katowice, Kobe U., INR Moscow, Louisiana State U., U. Pittsburg, Warsaw, Wroclaw



- Purpose
  - Measure muon from neutrino interaction
  - Provide a cosmics trigger
- Inserted in UA1 magnet
- Special feature
  - “Snaking” fiber
  - Provide position resolution by reading out both ends

Pi zero detector (POD)

Colorado State U., U. Pittsburg, U. Rochester, Stony Brook U., U. Washington



- Purpose: Study specifically π^0 production cross-section
- Check out N. Buchanan's slides for details (yesterday's ν session)

Electromagnetic calorimeter (ECAL)

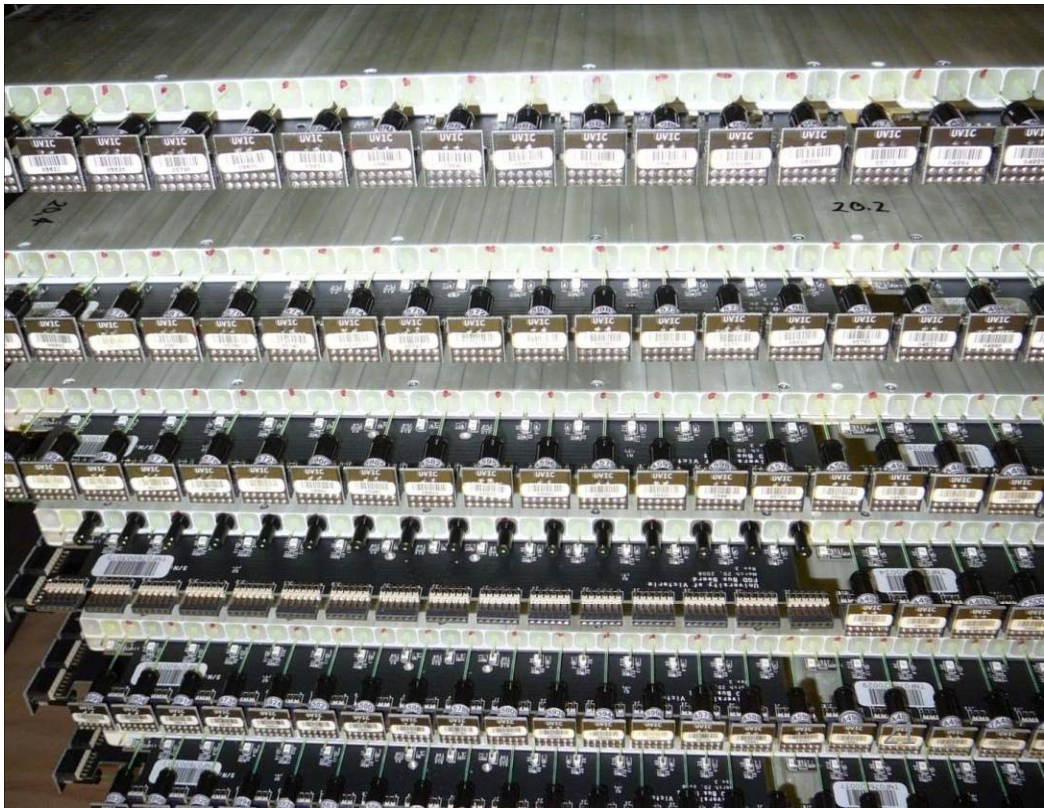
Imperial college, Lancaster U., U. Liverpool, Oxford U., Queen Mary U., RAL/Daresbury, Sheffield U., U. Warwick

- Purpose
  - Detect and measure energy of photons and electrons produced by neutrino interaction
- Sandwich of lead and scintillator bar
- Check out R. Sacco's slides at yesterday calorimeter session

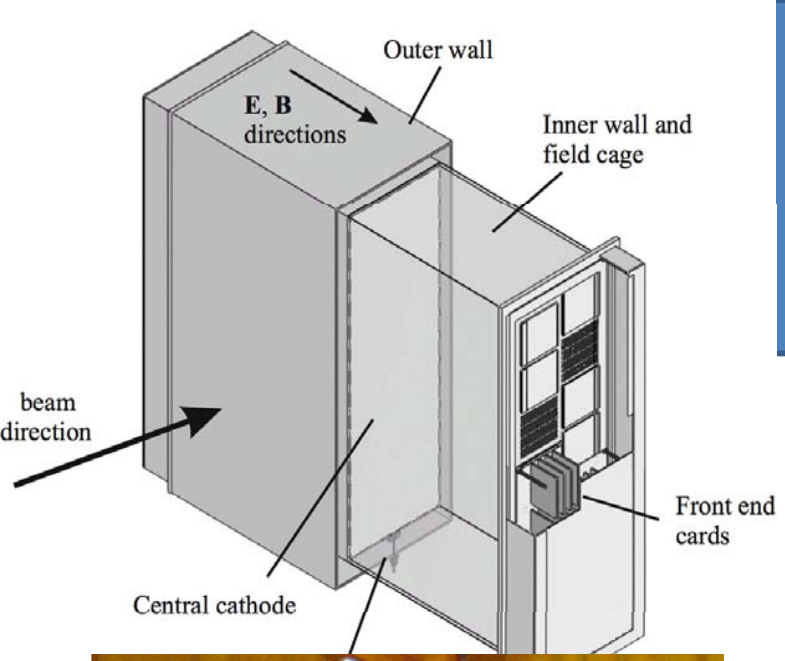
The Fine Grained Detector

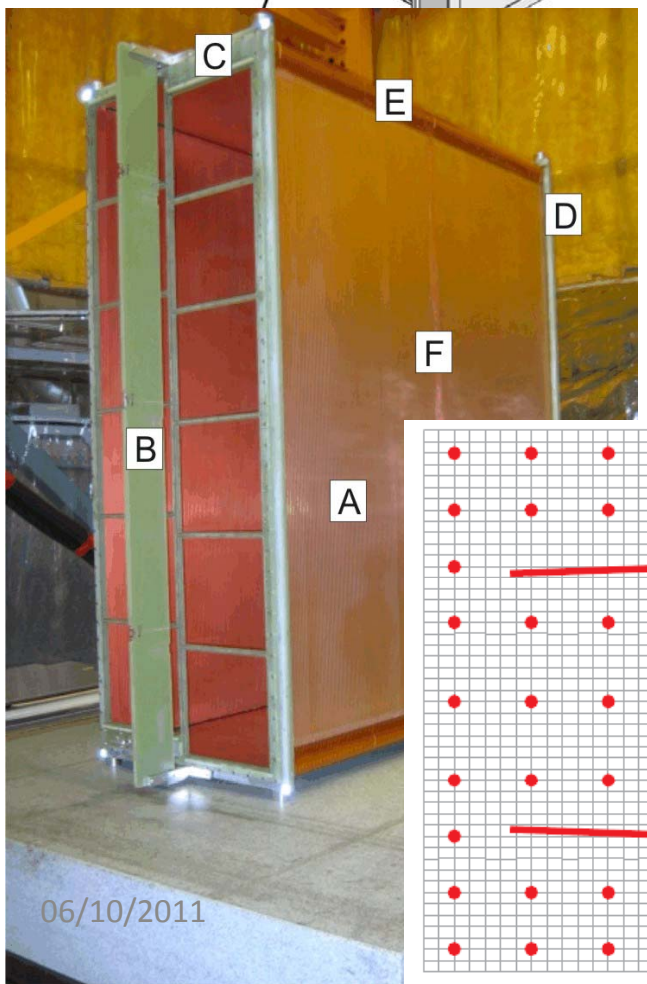
U. British Columbia, Kyoto U., U. Regina, TRIUMF, U. of Victoria

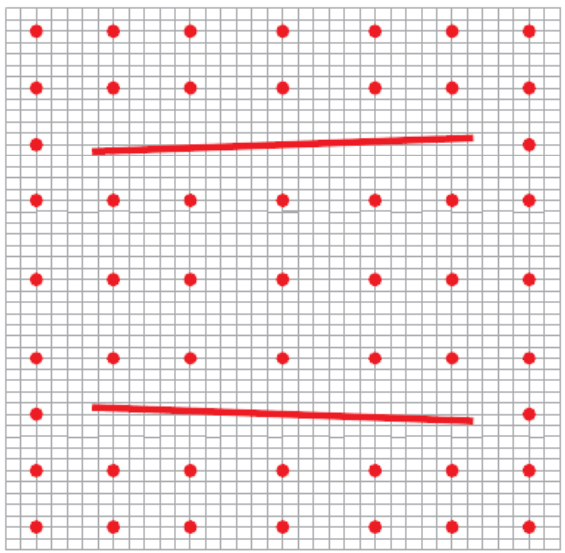
- Purpose
  - Target for neutrino interaction
  - Track particles produced by neutrino



Time Projection Chamber



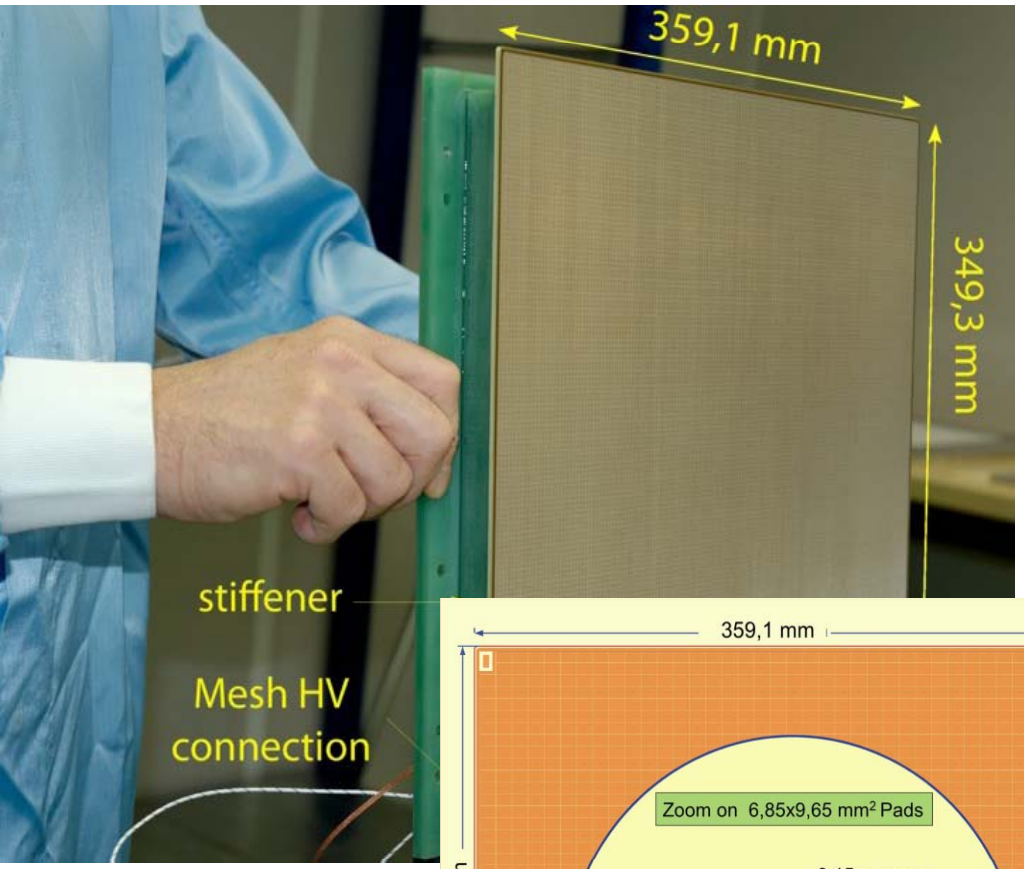


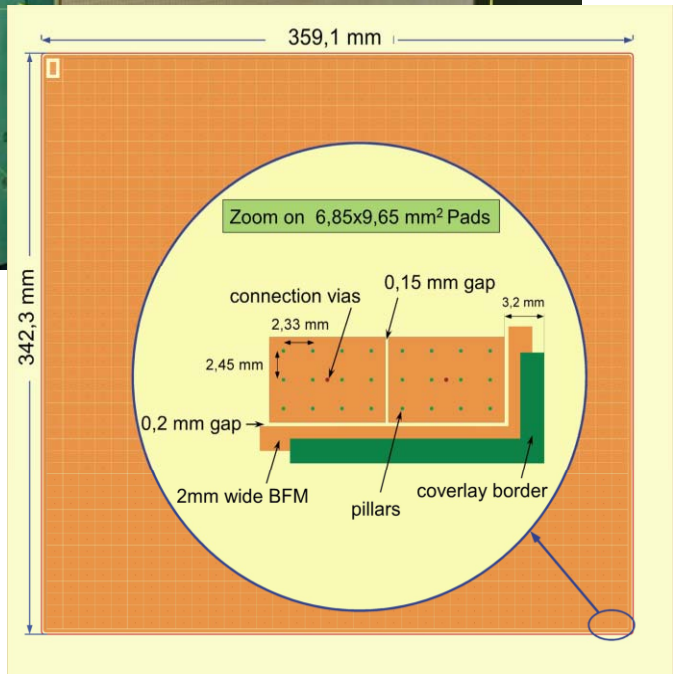


UBC, IPP, TRIUMF, U. Victoria (Canada), CEA-Saclay, in2p3-Paris (France), RWTH Aachen (Gernamy), INFN Bari, INFN Padova , U. Padova (Italy), IFAE Barcelona, U. Valencia (Spain), U. Geneva (Switzerland)

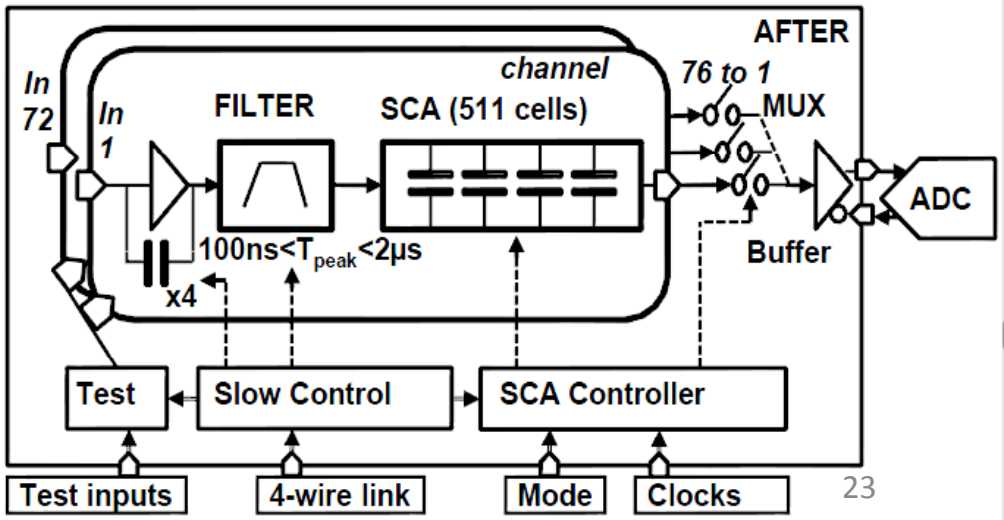
- Field cage
  - Inner box: 2.3x2.4x1m^3
  - 1 m drift from central cathode
  - Cathode patterned for calibration with laser
- Gas: Ar:CF_4:iC_4H_{10} (95:3:2)

TPC: readout plane and electronics

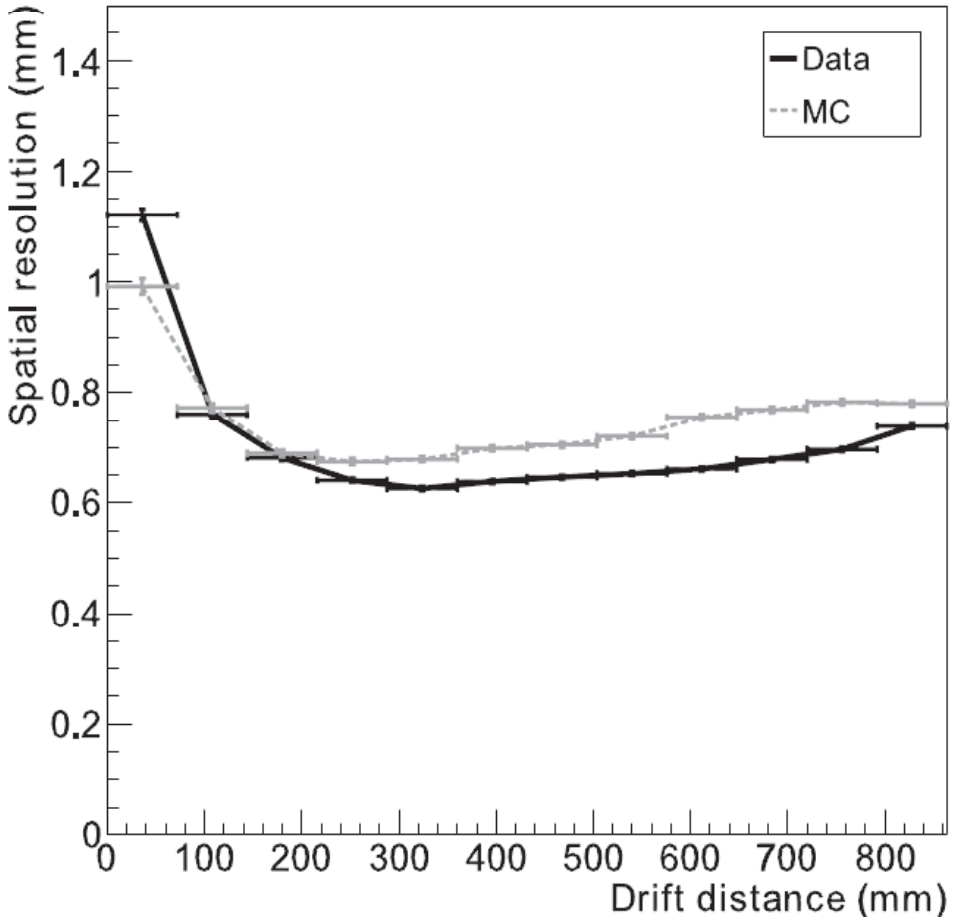




- Bulk Micromegas
  - 12 modules 34.2x35.9 cm^2
  - 7x9.8 mm^2 pads
- Custom electronics
  - ~120,000 channels
  - Based on AFTER ASIC: preamp-shaper + Switch Capacitor array

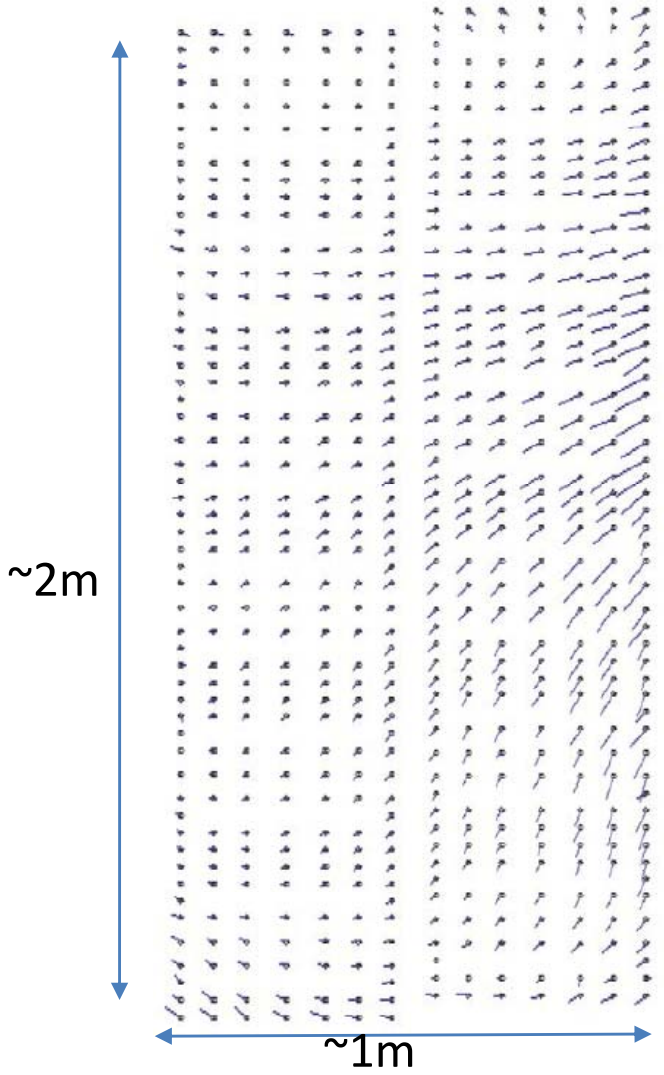


TPC: position resolution



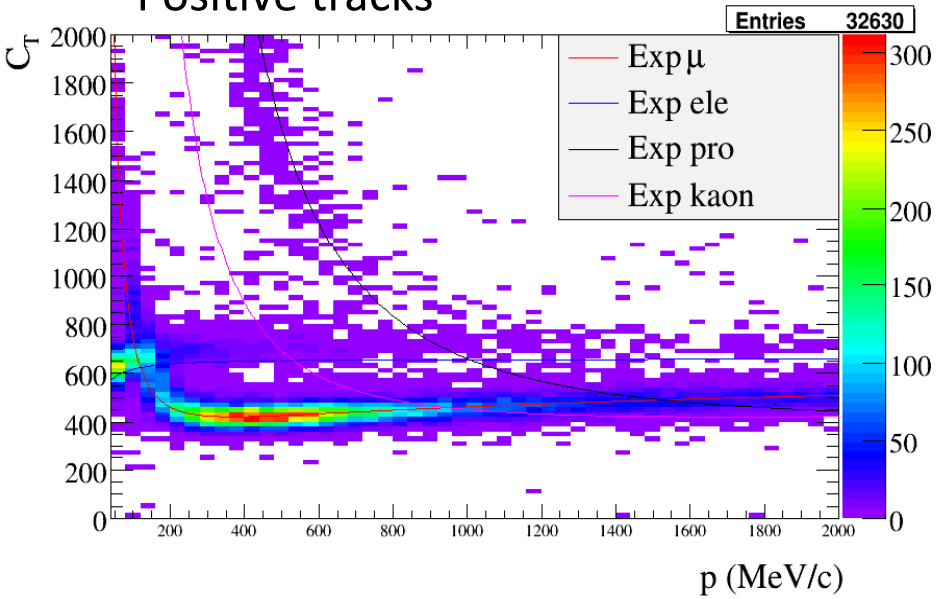
Momentum resolution driven
by this position resolution better than 10%
as specified

Field distortion map (full drift)
Exaggerated 10 times
Most non-uniform TPC region

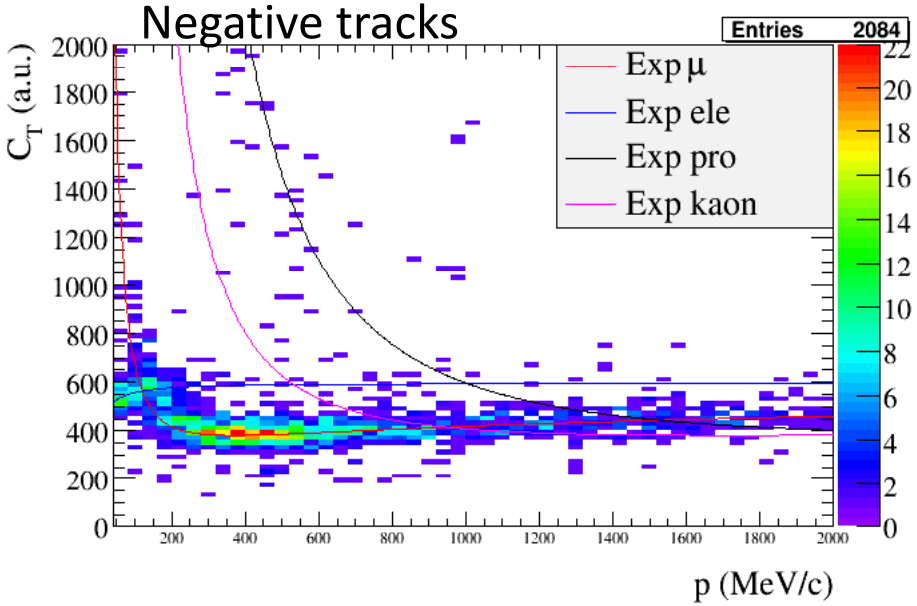


TPC performance: dE/dx

Positive tracks



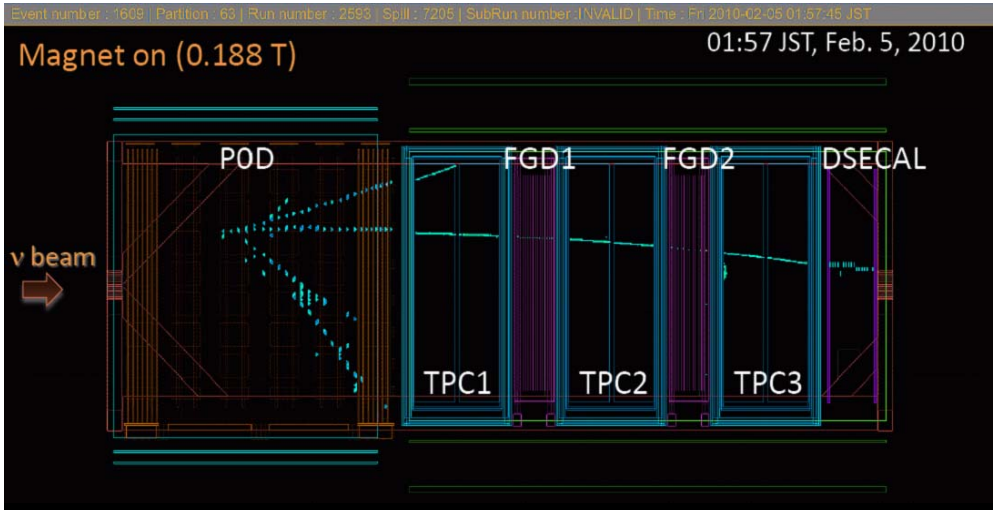
Negative tracks



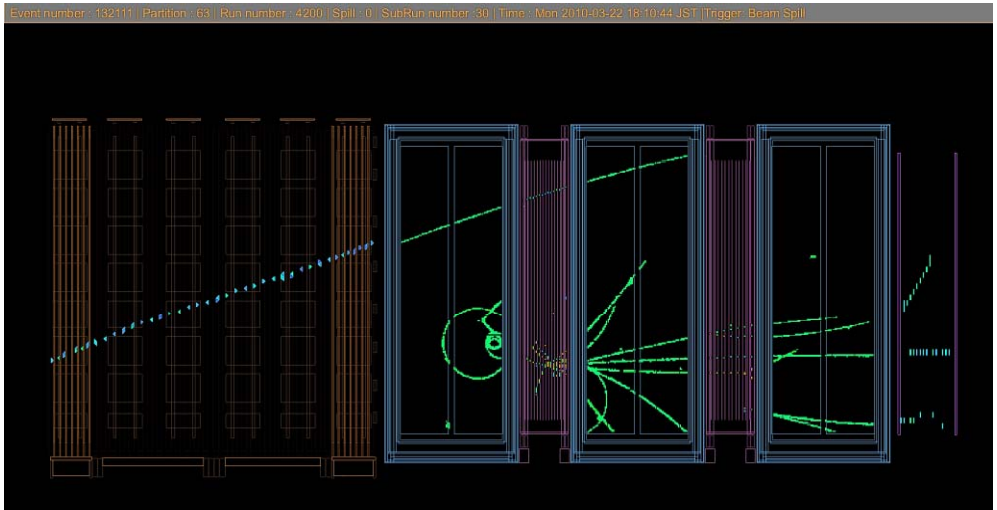
Desired 8% resolution achieved

For more details on ND280 TPC, see B. Jamieson's talk tomorrow in gas detector session.

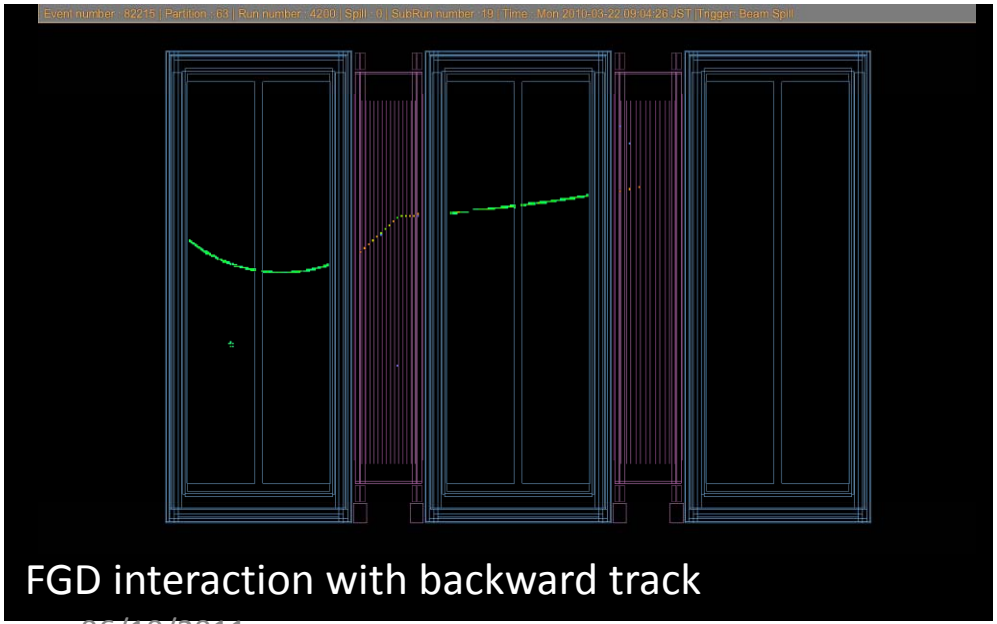
Example off-axis events



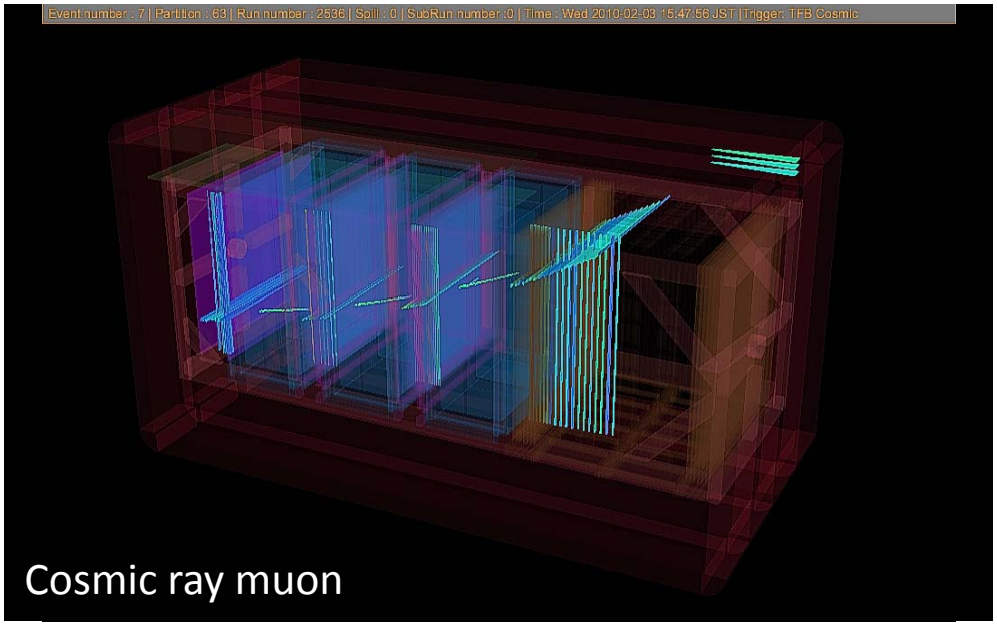
Interaction in P0D: View from (north) side



Sand Muon & FGD interaction



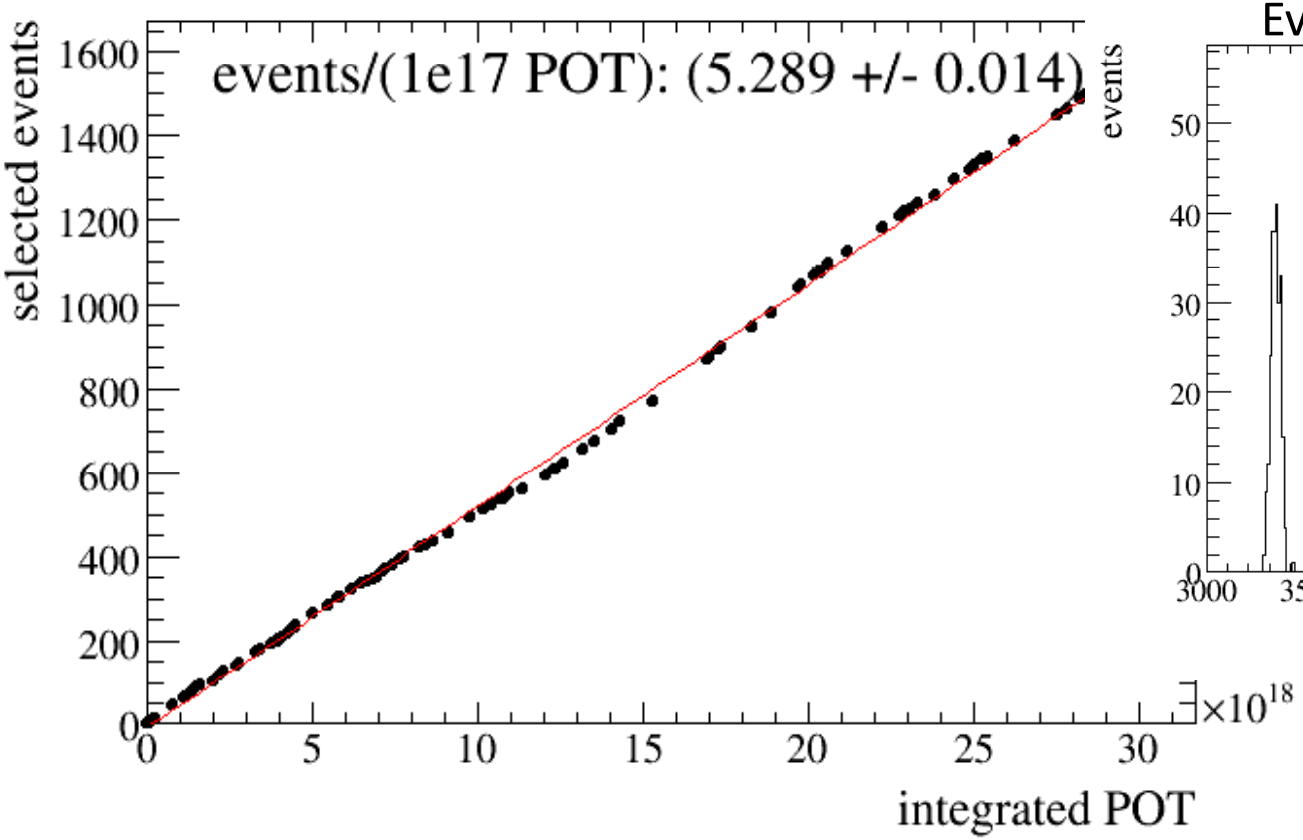
FGD interaction with backward track



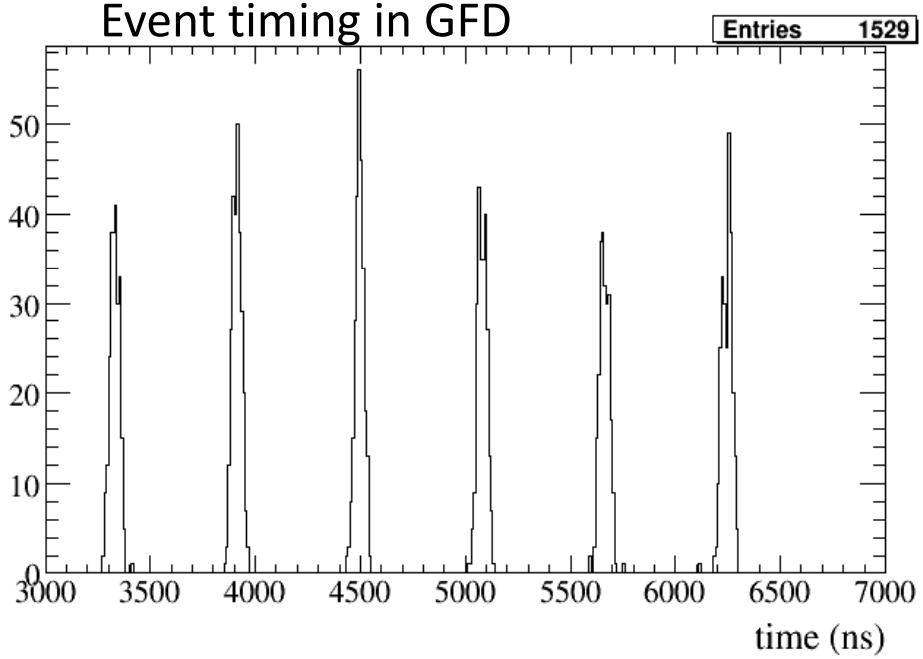
Cosmic ray muon

Event rate and timing

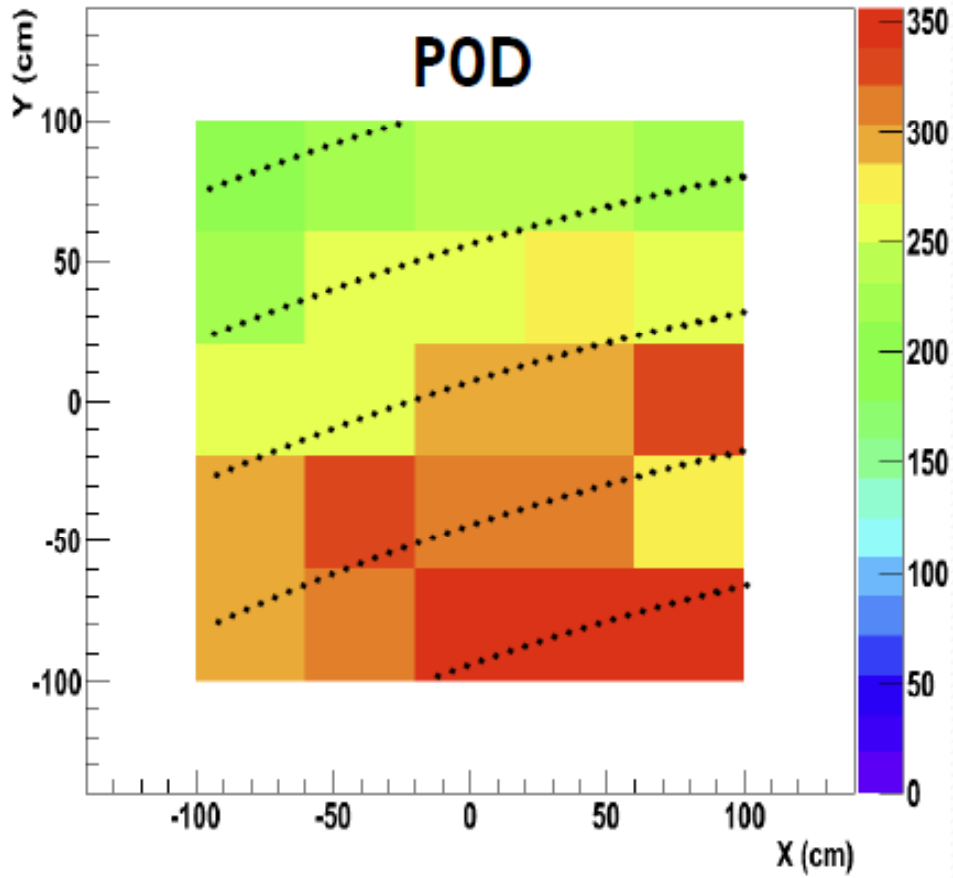
Number of selected events in FGD

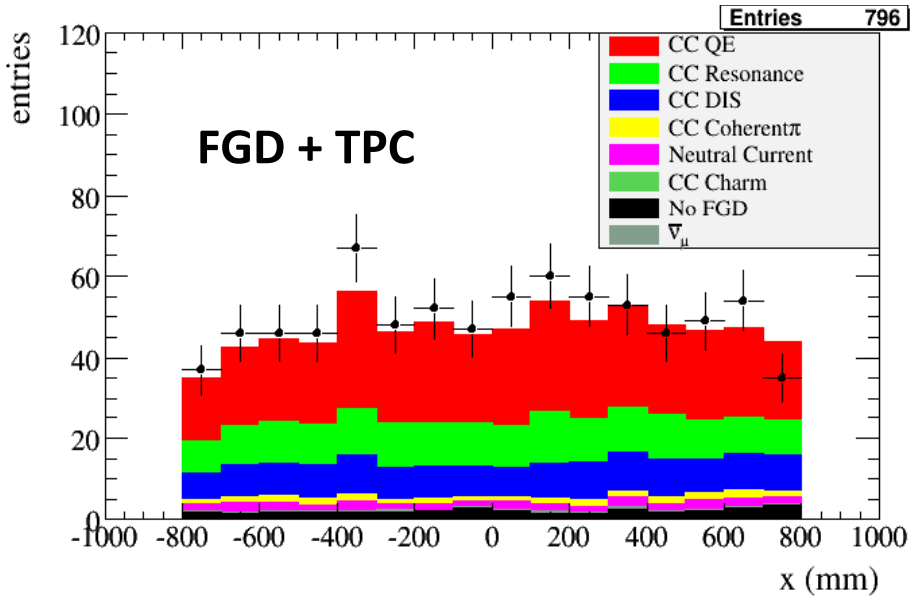


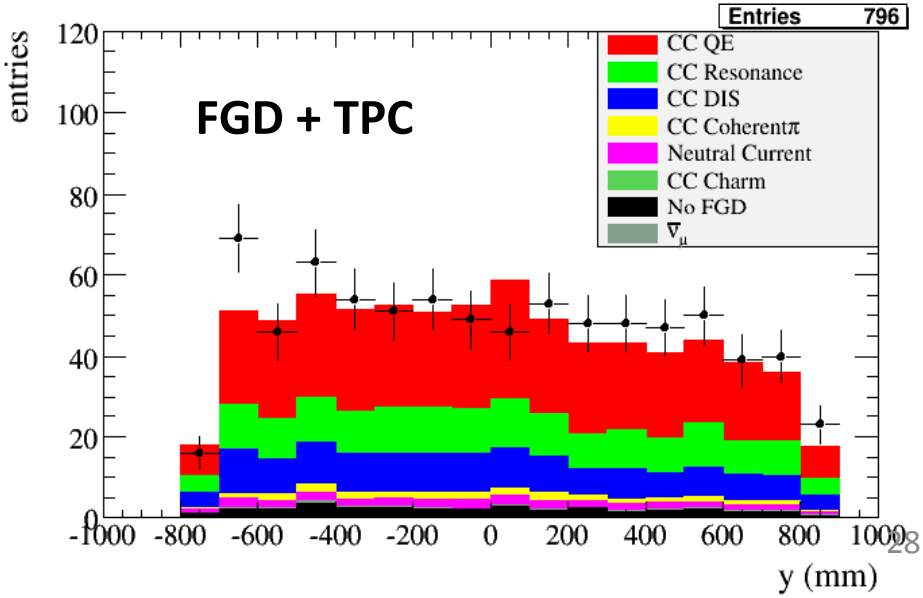
Event timing in GFD



Beam spatial distribution

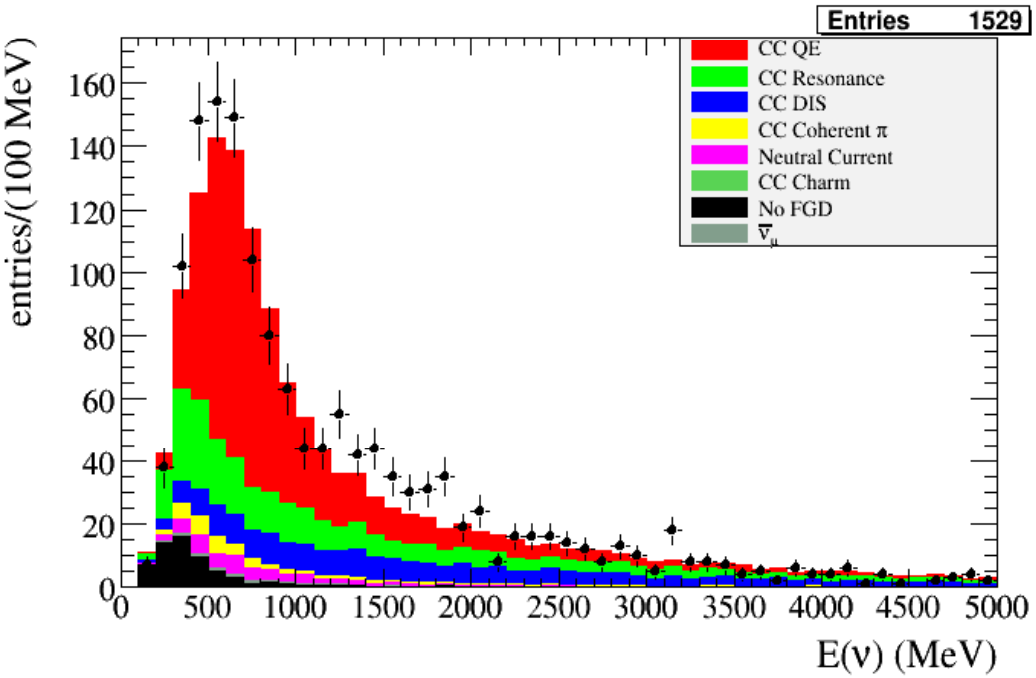






Summary

- T2K near detector fully operational since January 2010
  - Smooth operation, very good performances
  - To date, no serious damages due to earthquake identified
- High quality data being collected
  - First physics results coming out
- Detailed detector characterization work going on



Several detector papers from T2K:

- MPPC After-pulsing, Nucl. Instr. and Meth. A 596 (2008) 396
- Performance of Multi-Pixel Photon Counters for the T2K near detectors, Nucl. Instrum. Meth. A622 (2010) 567–573.9
- Time Projections Chambers for T2K near detectors , submitted to NIM
- Characterization and simulation of the response of MPPCs to low level, submitted to NIM, arxiv
- The T2K experiment, submitted to NIM
- The T2K Fine Grained Detector, in preparation
- Characterization of the Y11 fiber response, in preparation