Nu_2: R&D of detectors for future high statistics, high precision experiment

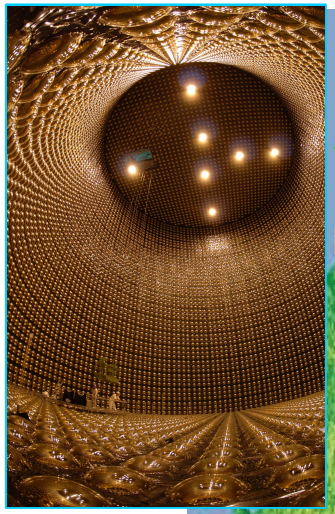
Overview of T2K-ND280

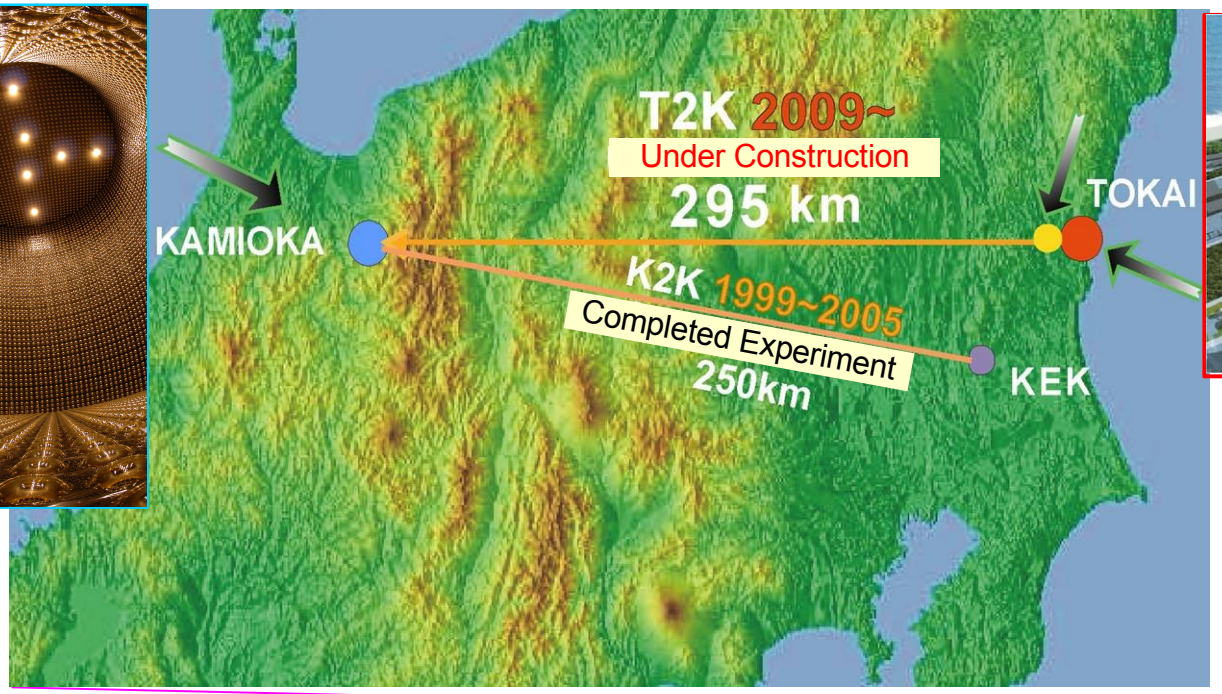
T.Tsukamoto(KEK) @ Workshop FJPPL'07 on 2007/05/09
for the ND280 group of the T2K collaboration

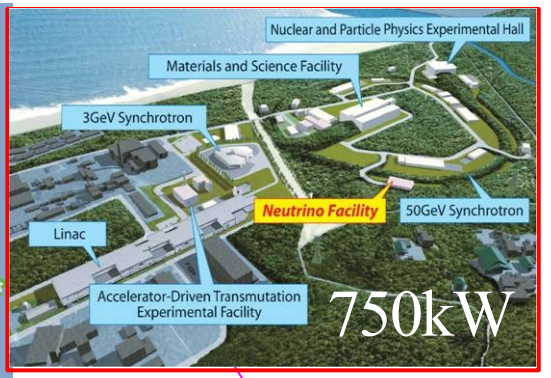
- Introduction
  - T2K & T2K-ND280 @ J-PARC
- Sub-detectors
  - On-Axis : INGRID 2007 proposal
  - Off-Axis : FGD, TPC, P0D, ECAL, SMRD

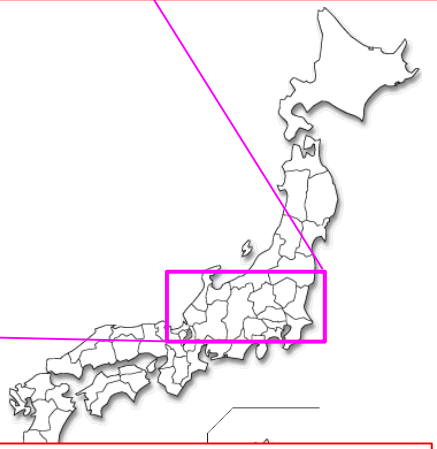
2006 application
2007 proposal

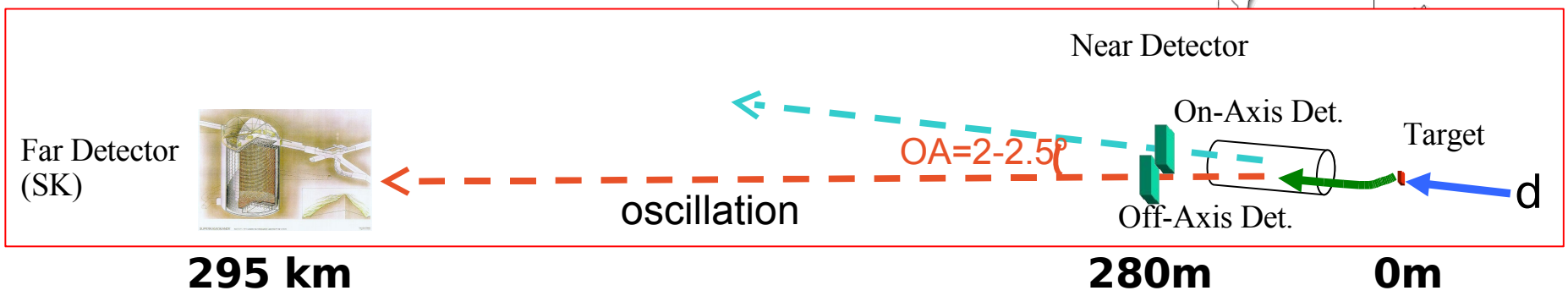
T2K : Tokai to Kamioka long base line neutrino experiment





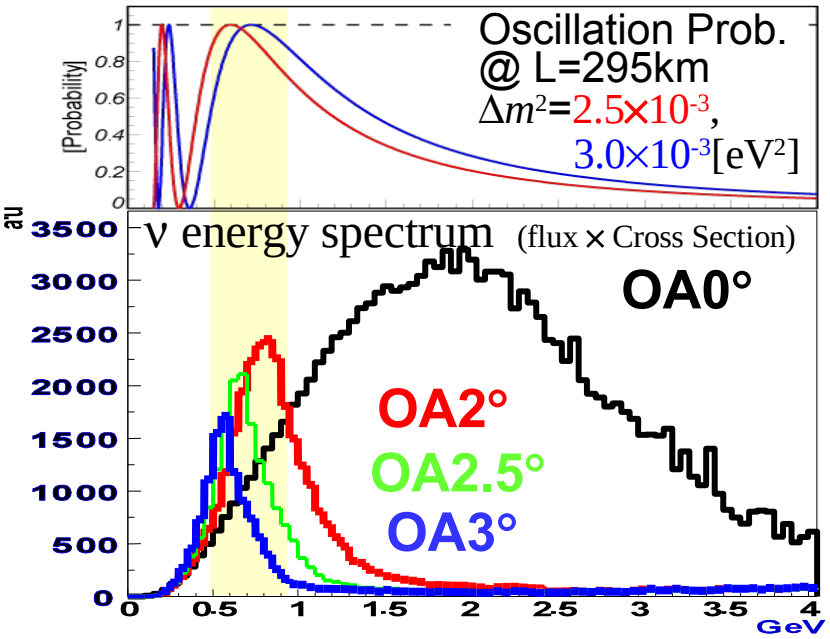


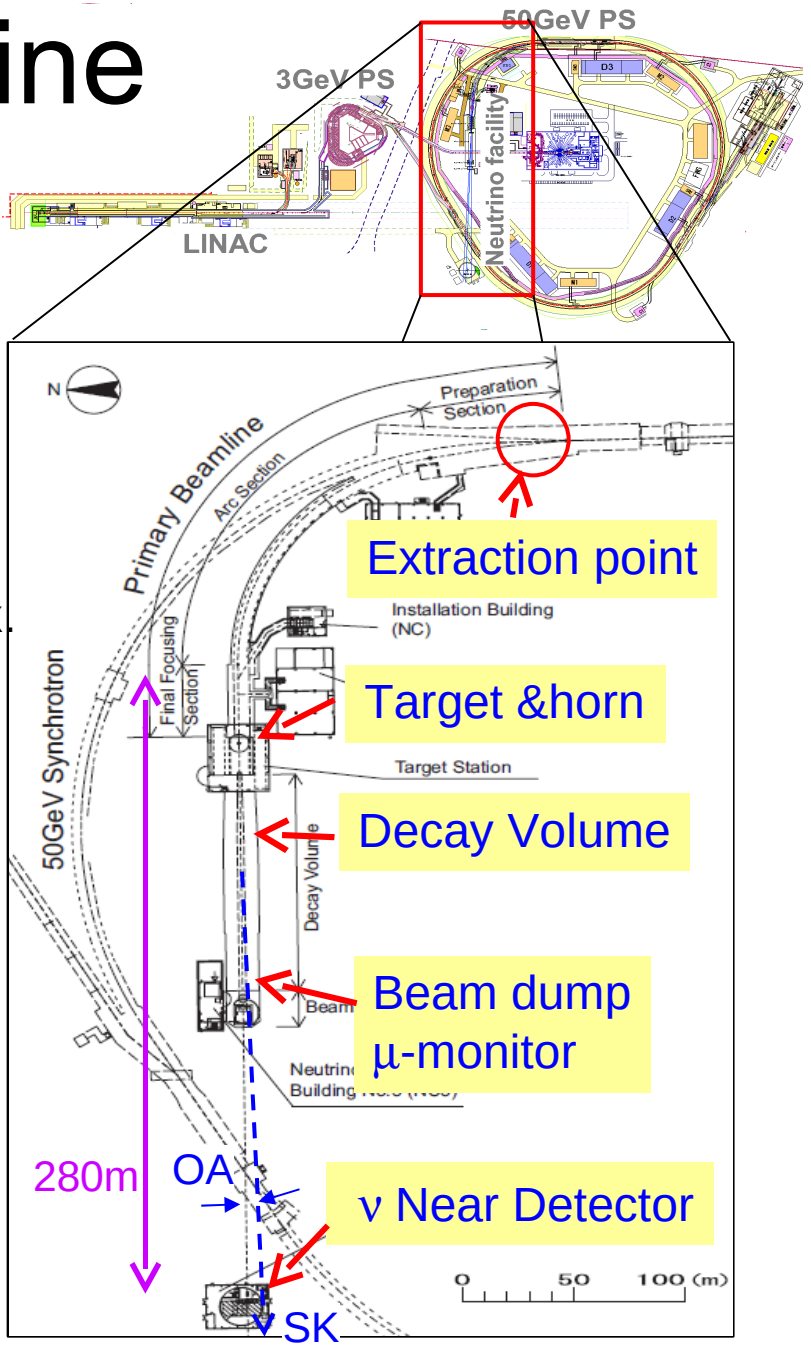




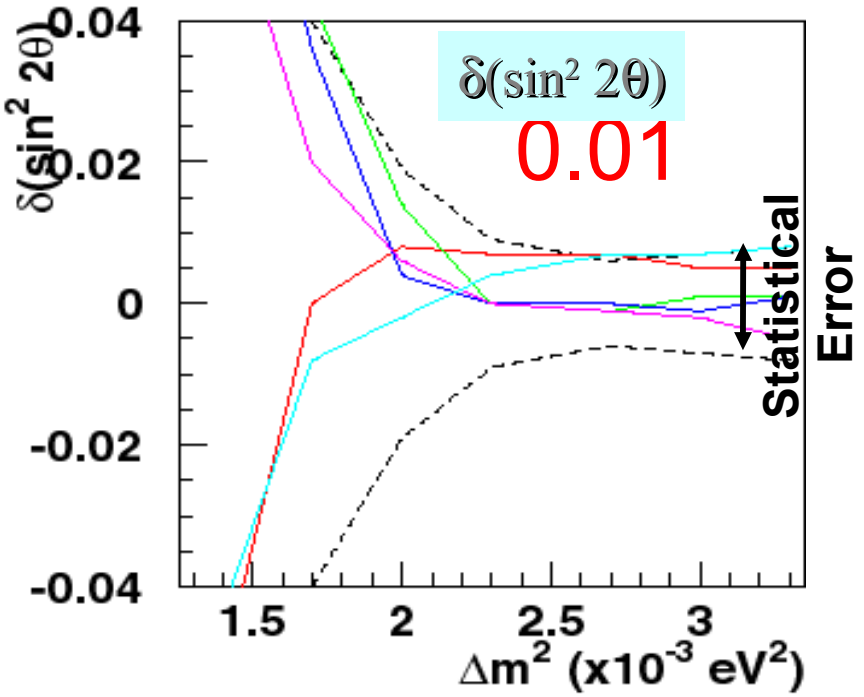
J-PARC ν-beam line

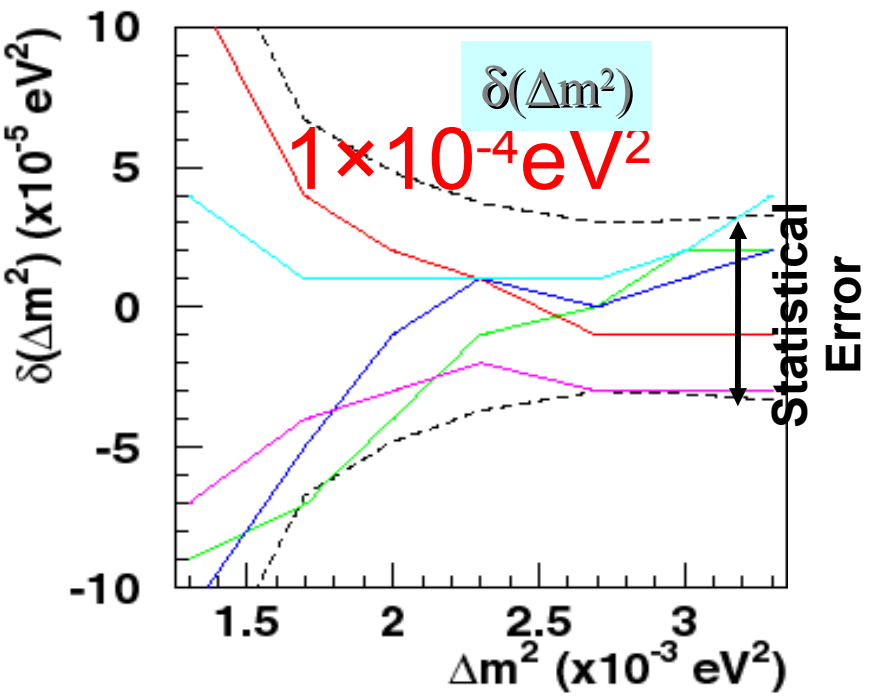
- Conventional ν_μ beam:
  - protons + Graphite target → pions
  - Pions are focused by 3 horns
  - ν_μ from pion decays
- Pseudo-Monochromatic beam by Off-Axis method: (OA = 2° ~ 2.5°)
  - Set peak of (flux × σ_{CC}) @ oscillation max.
  - Small fraction of high energy neutrino.





Sensitivity for $\sin^2 2\theta_{23}$, Δm_{23}^2





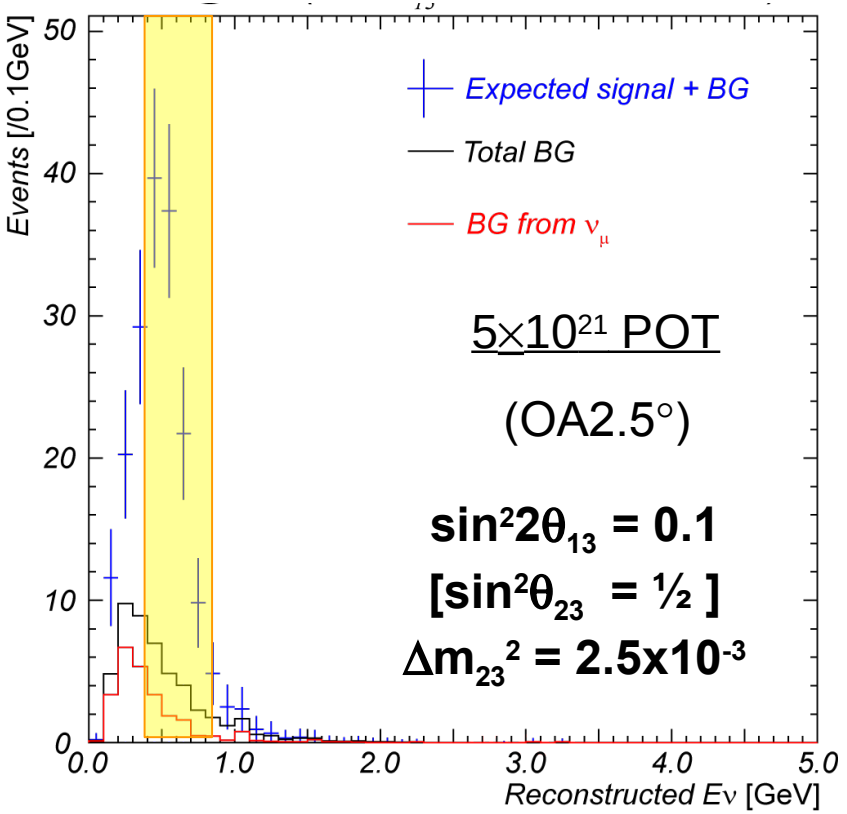
OA2.5°, 5×10²¹ POT

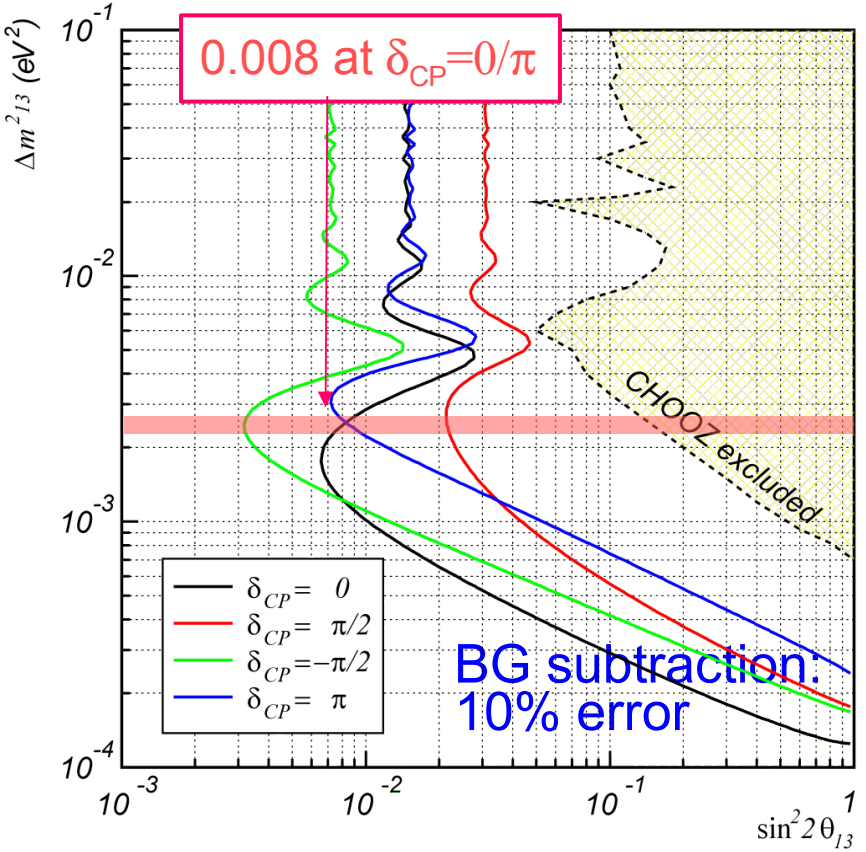
~ 5 years @ full Intensity

Assumed Systematic Errors

Normalization	5%	
non-QE/QE ratio	5%	
Energy scale	1%	
Spectrum Shape	20%	FLUKA / MARS
Beam Width	5%	

Sensitivity to θ_{13}

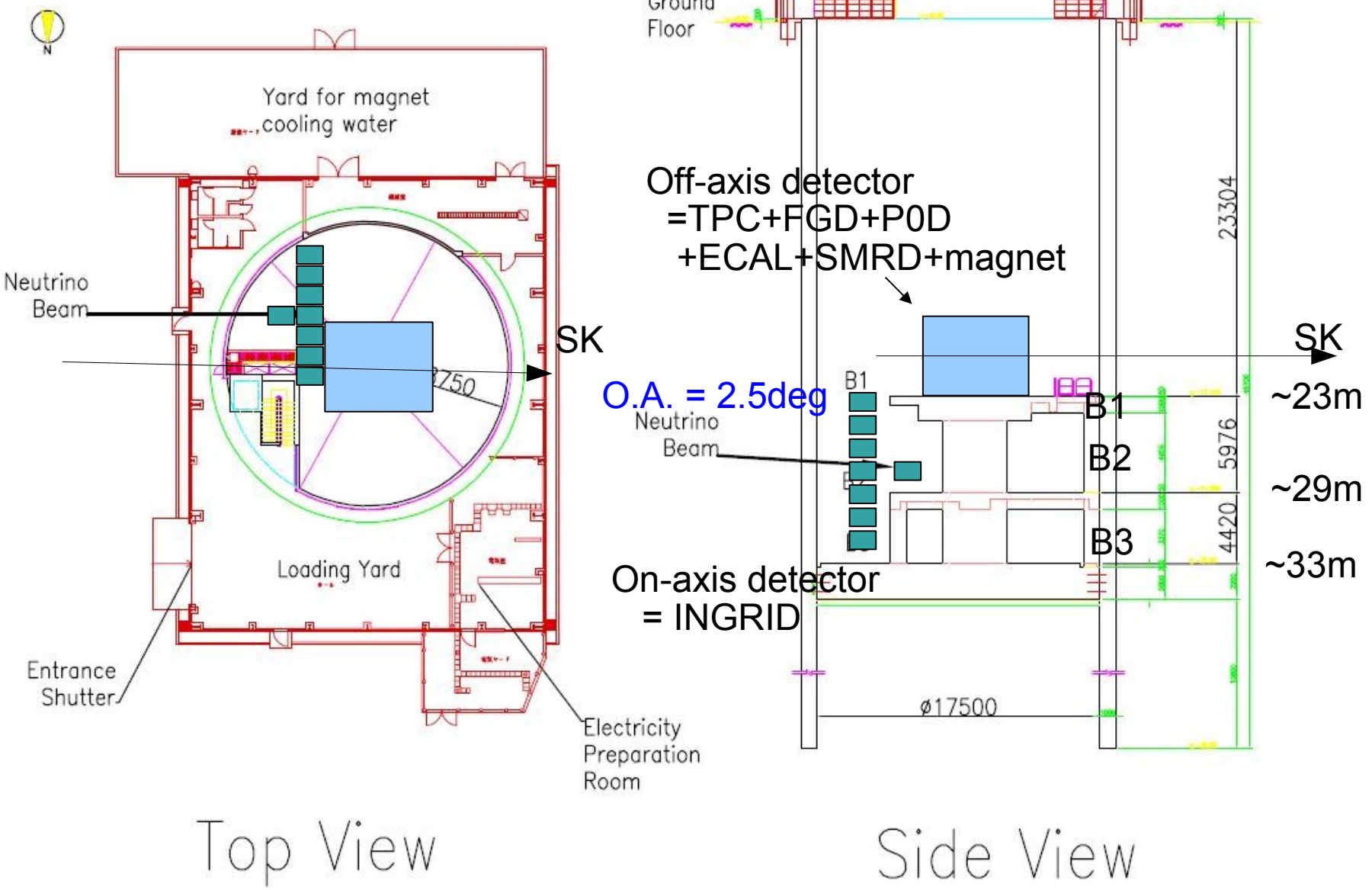




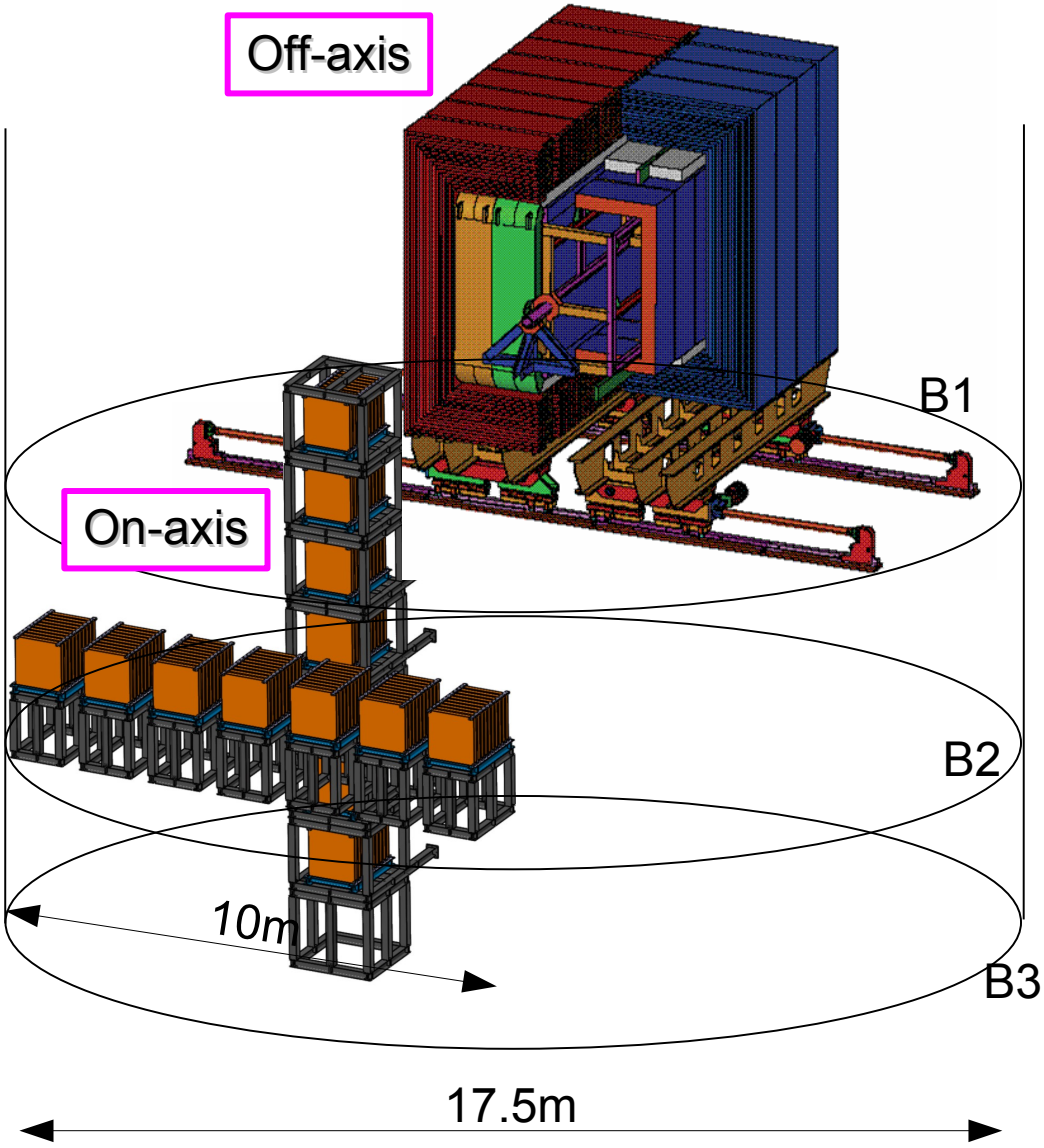
T2K-ND280

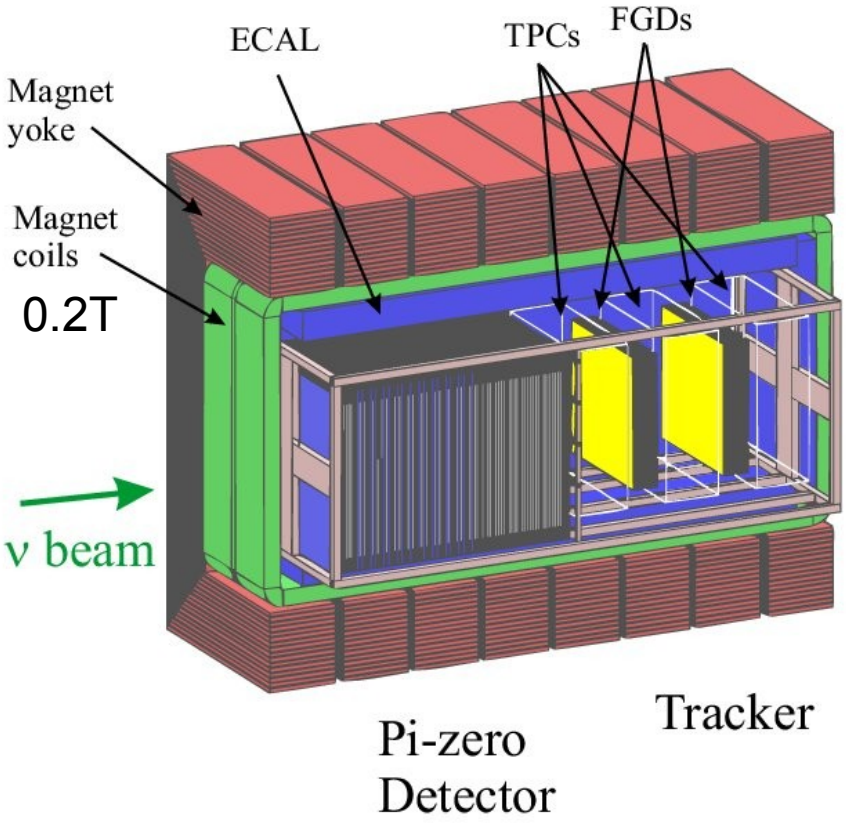
- Located ~280 m downstream of the proton target
- Measure neutrino beam direction by on-axis detector
- Measure neutrino beam properties and neutrino interaction cross sections and kinematics by off-axis detector
  - ν_μ disappearance:
    - flux and spectrum of ν_μ prior to oscillation
  - ν_e appearance:
    - flux and spectrum of ν_e in beam

Building & Pit for ND280



ND280 sub-detectors





- Scintillator + WLS optical fiber + photo sensor
  - INGRID (Interactive Neutrino GRID detector) : On-Axis
  - FGD (Fine Grained Detector) : charged, tracking
  - P0D (Pi-0 detector) : π^0,γ
  - ECAL (Electromagnetic CALorimeter): e,γ
  - SMRD (Side Muon Range Detector): μ
- Gas detector
  - TPC (Time Projection Chamber) : charged, tracking

→Talk by M.Zitto

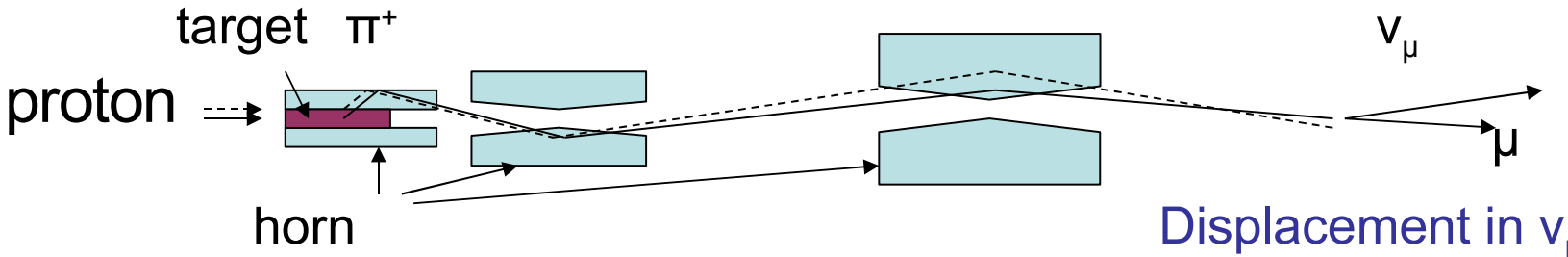
ν target

: Off-Axis

Off-axis detector is in 0.2T magnetic field

INGRID: Physics Motivation

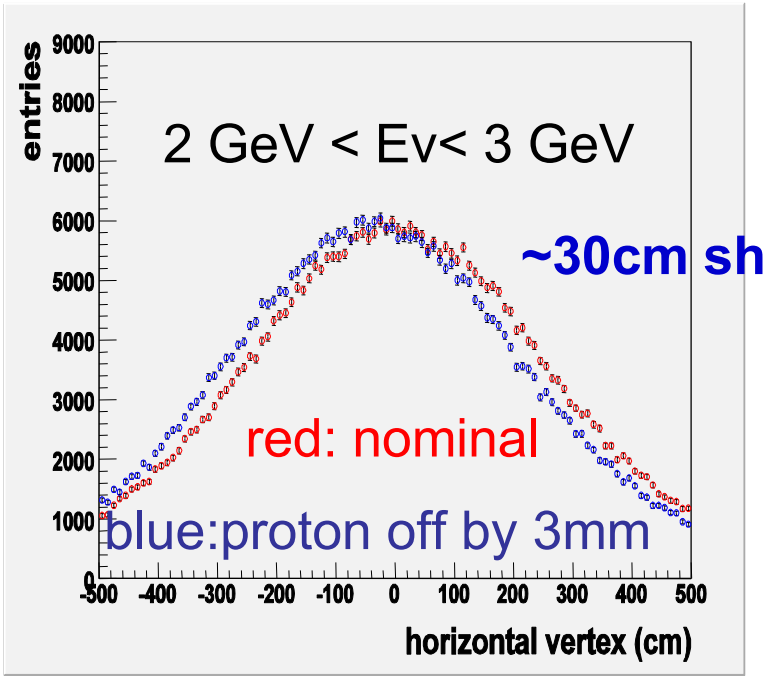
Example: proton beam hits off-center of the target.

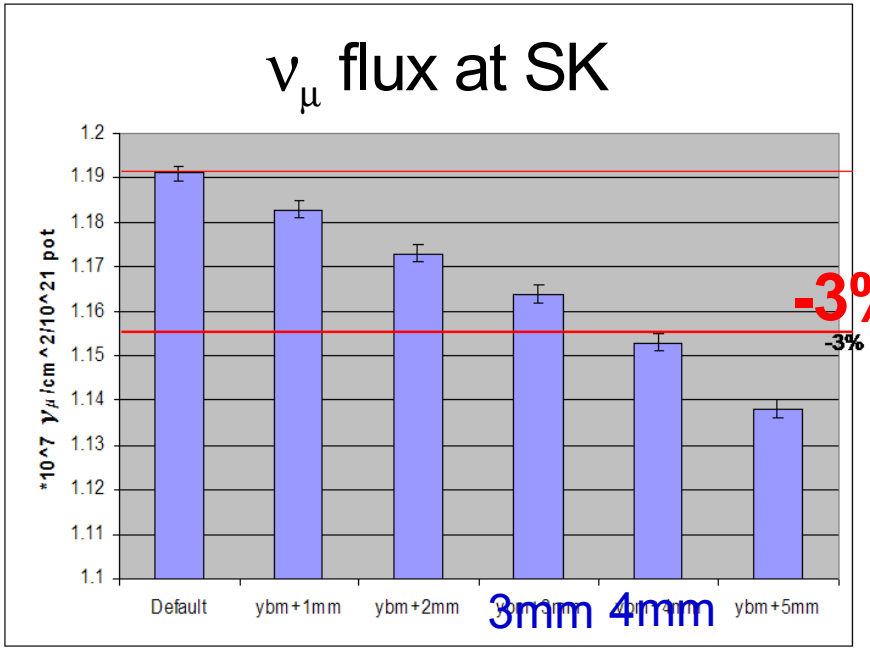


Displacement in ν_μ

---> change at SK

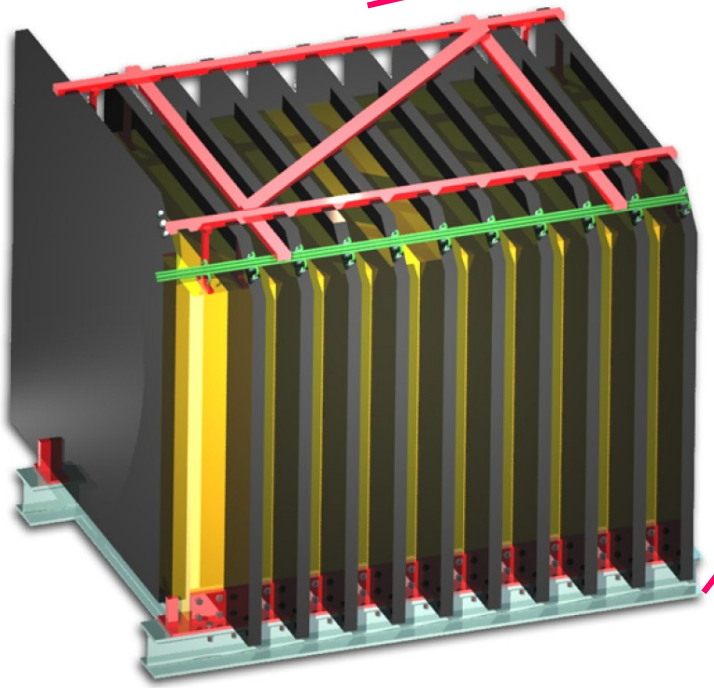
Profile of neutrino interaction @INGRID

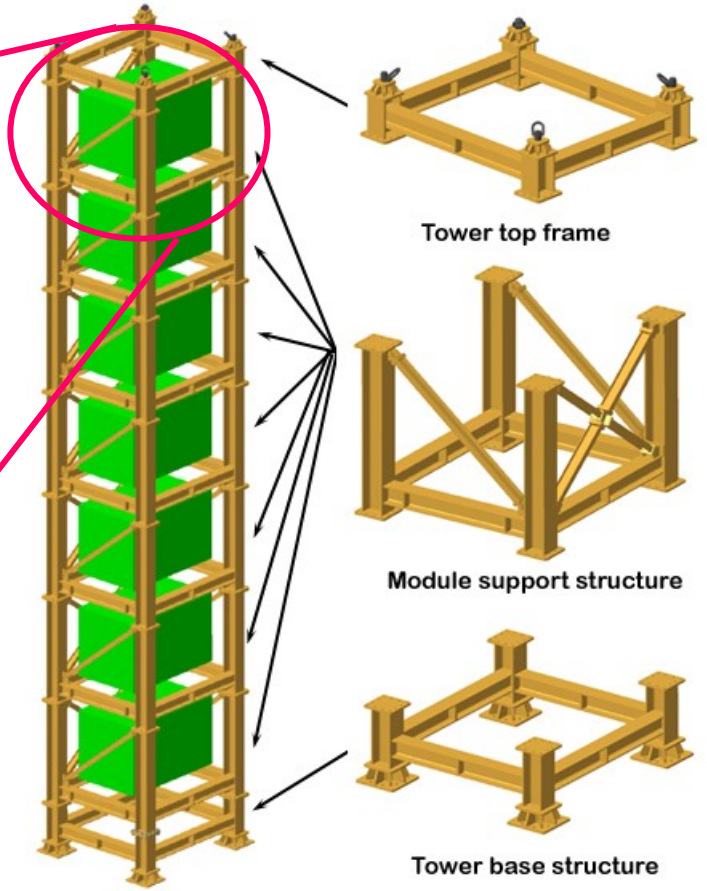




- INGRID (on-axis detector)
  - Iron(10cm) / Scintillator(1.25cm) sandwich 1mx1m
  - Profile centre : $\Delta < 5$cm --> systematics 2% between modules
    ---> can be achieved with scintillator plane with eff =99.5%,
    which was achieved in K2K SciBar

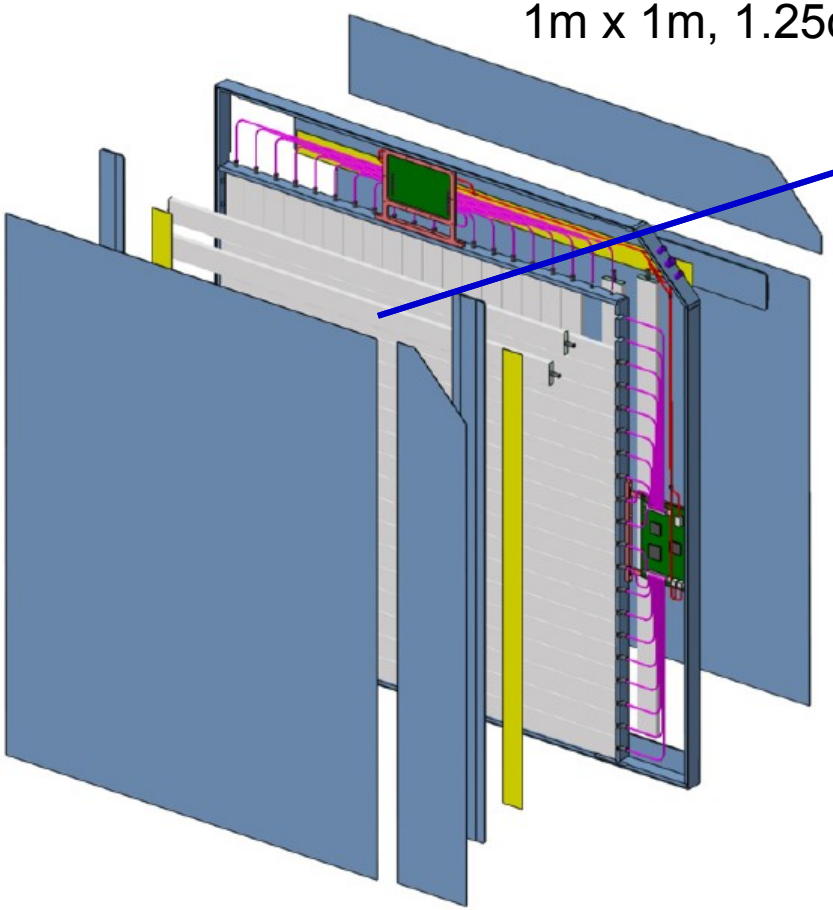
Veto counters will surround each layer



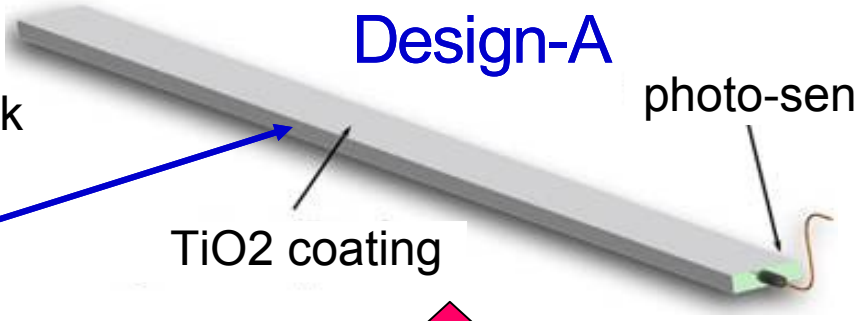


Active component of INGRID

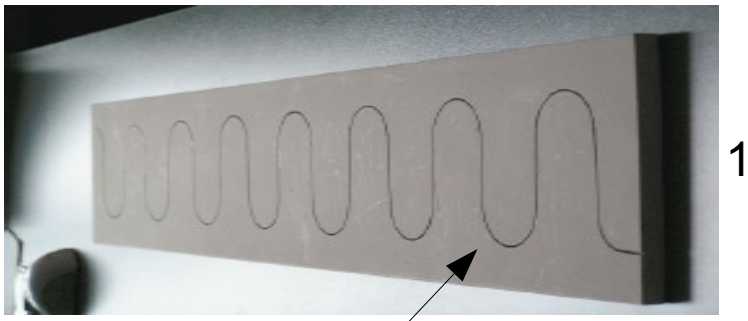
1m x 1m, 1.25cm thick



Design-A



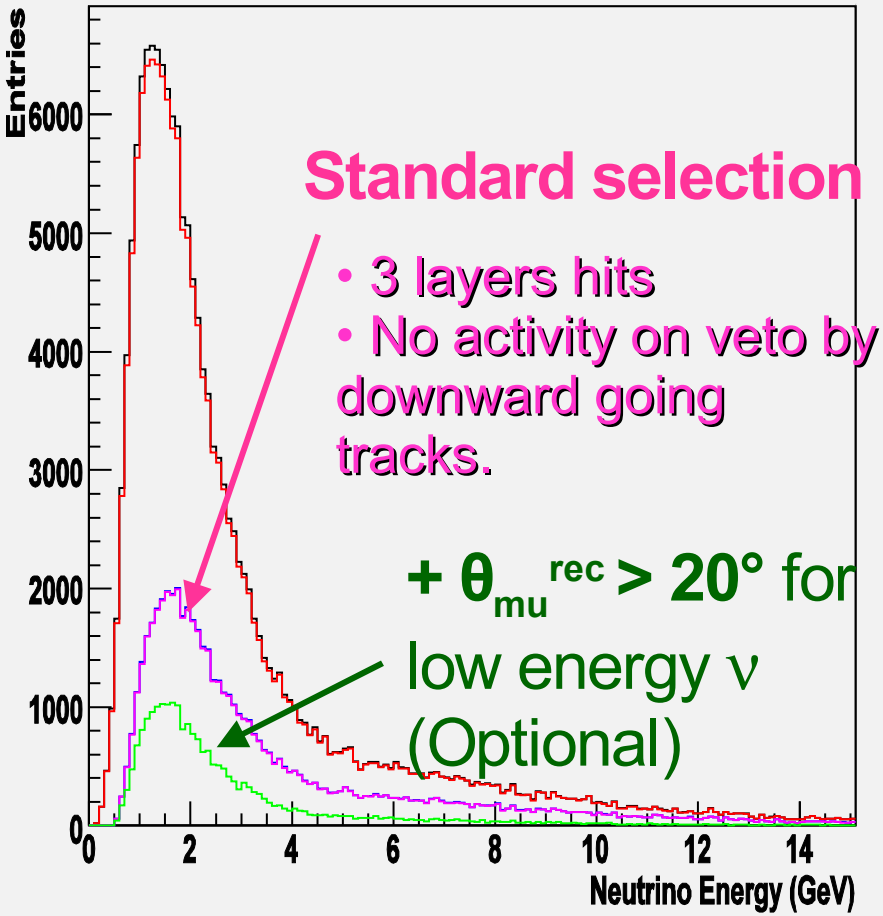
Design-B



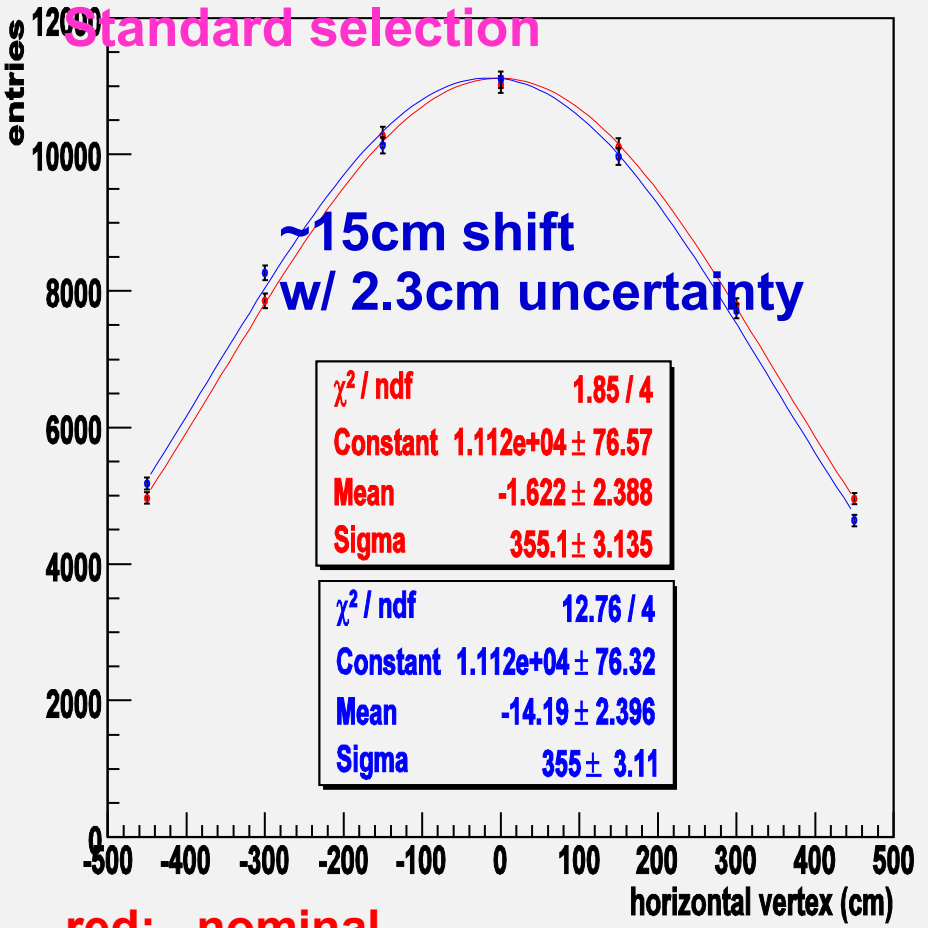
Study on scintillator is being performed to select the type.

INGRID event reconstruction.

Neutrino energy



Profile



red: nominal

blue: proton off by 3mm

- FGD
  - Scintillator bars arranged in alternating X-Y planes
    - fine segmentation needed to track low energy protons, in order to distinguish CCQE and non-elastic interaction
  - Two modules
    - ~1ton target material/module, 36.5cm thickness/module
    - Back FGD will contain water target layers
      - 2.5cm water layers between each x-y scintillator plane

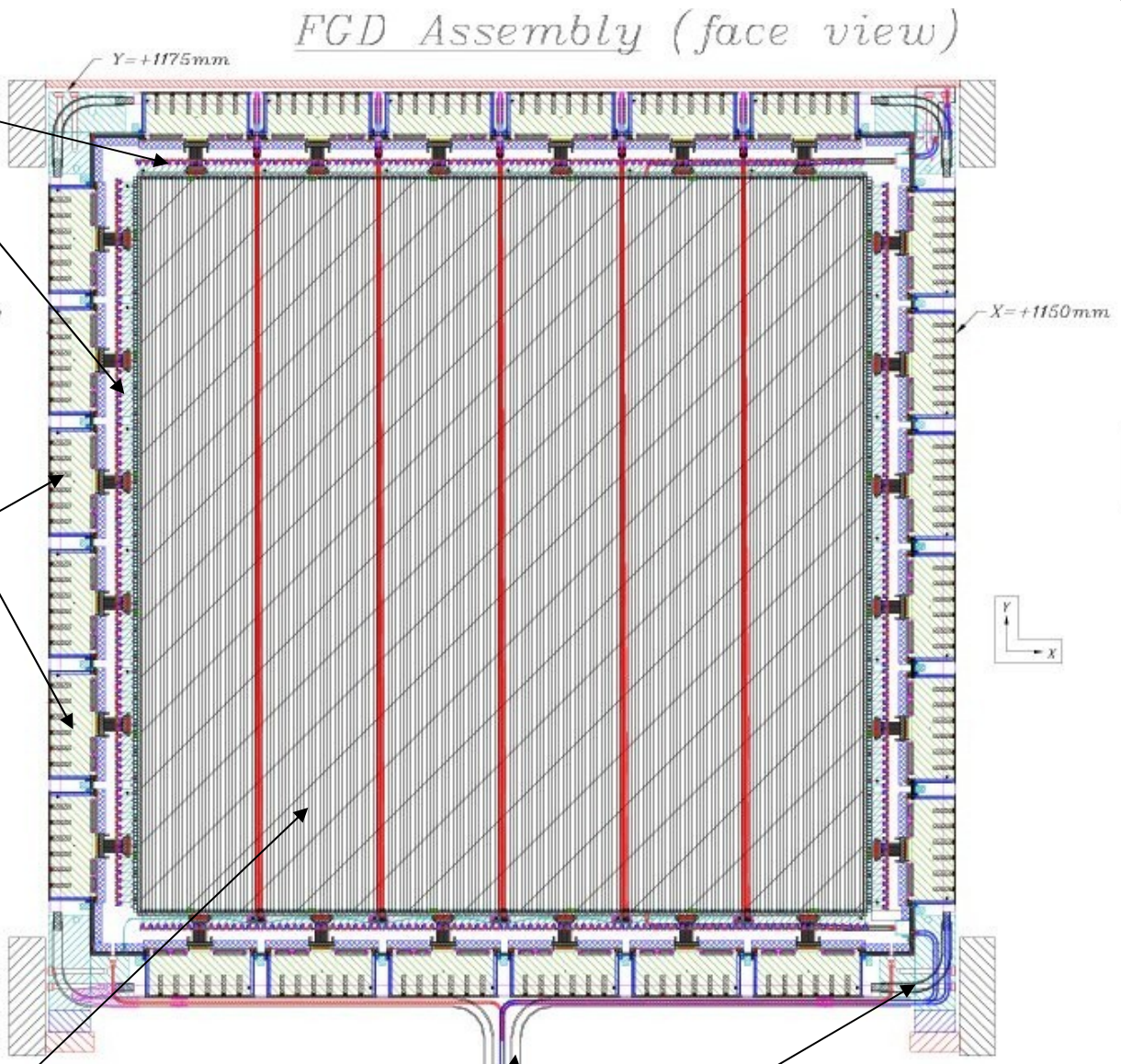
FGD

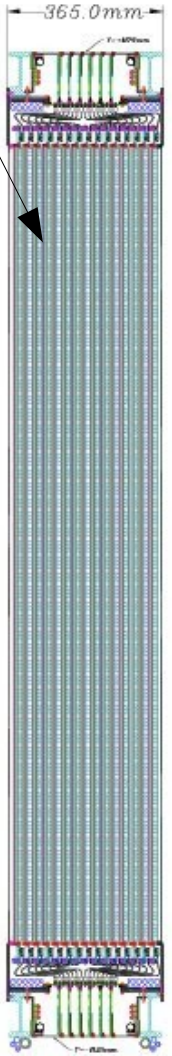
Alternating X-Y scintillator planes
9.6mmx9.6mm bars
30 X-Y planes /14 planes with water target

Photosensor boards

Mini-crates

Scintillator



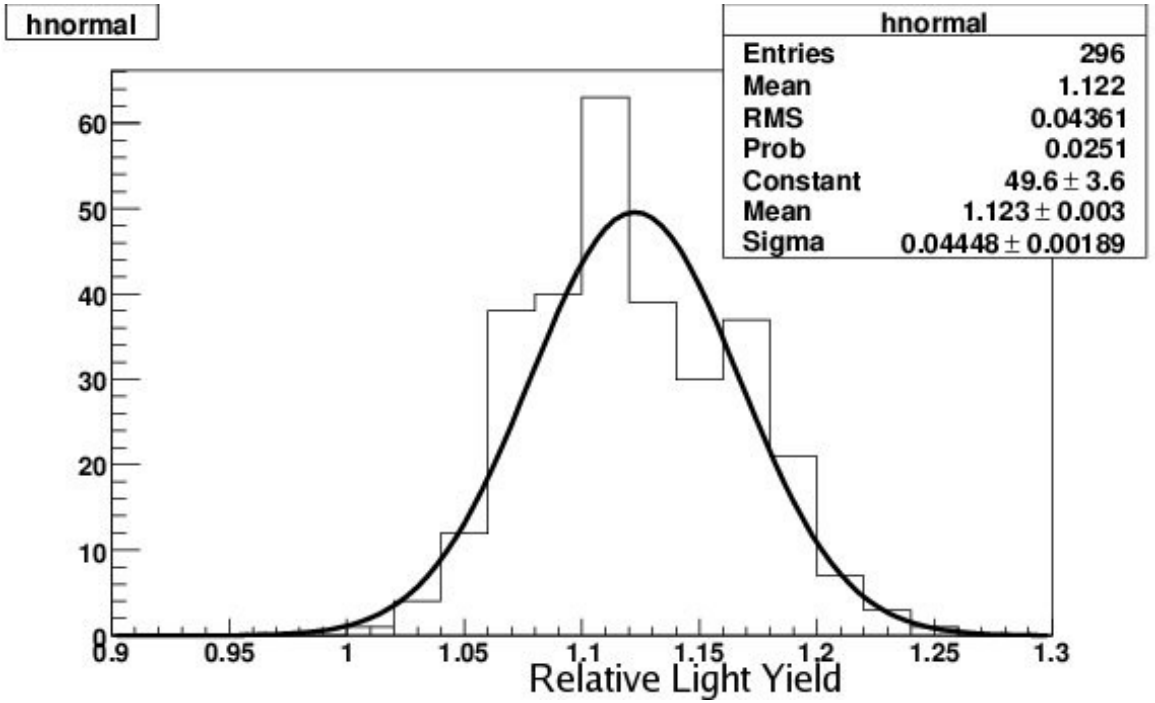


Side View

Cooling lines

FGD scintillator bars

Scintillator production run in Nov '06: ~11500 bars produced. All bars checked for blocked holes, and sampled for size and light yield.



Light yield as measured with bar scanner and radioactive source is consistent to 4% (RMS) across the whole run.

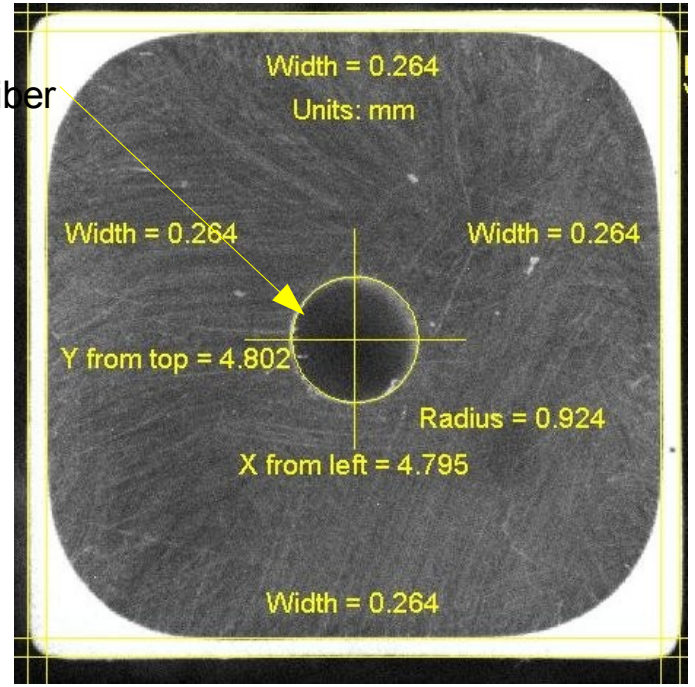
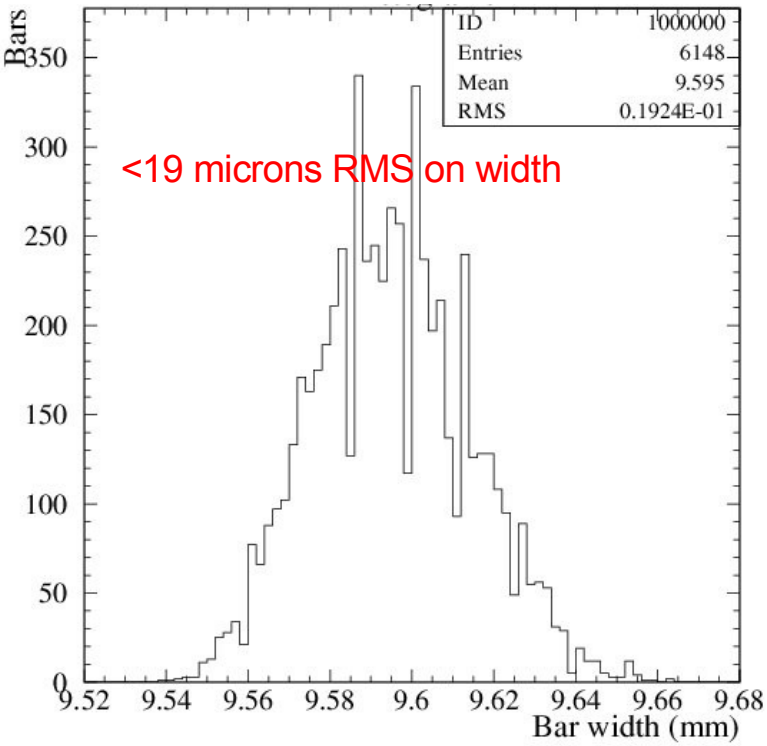
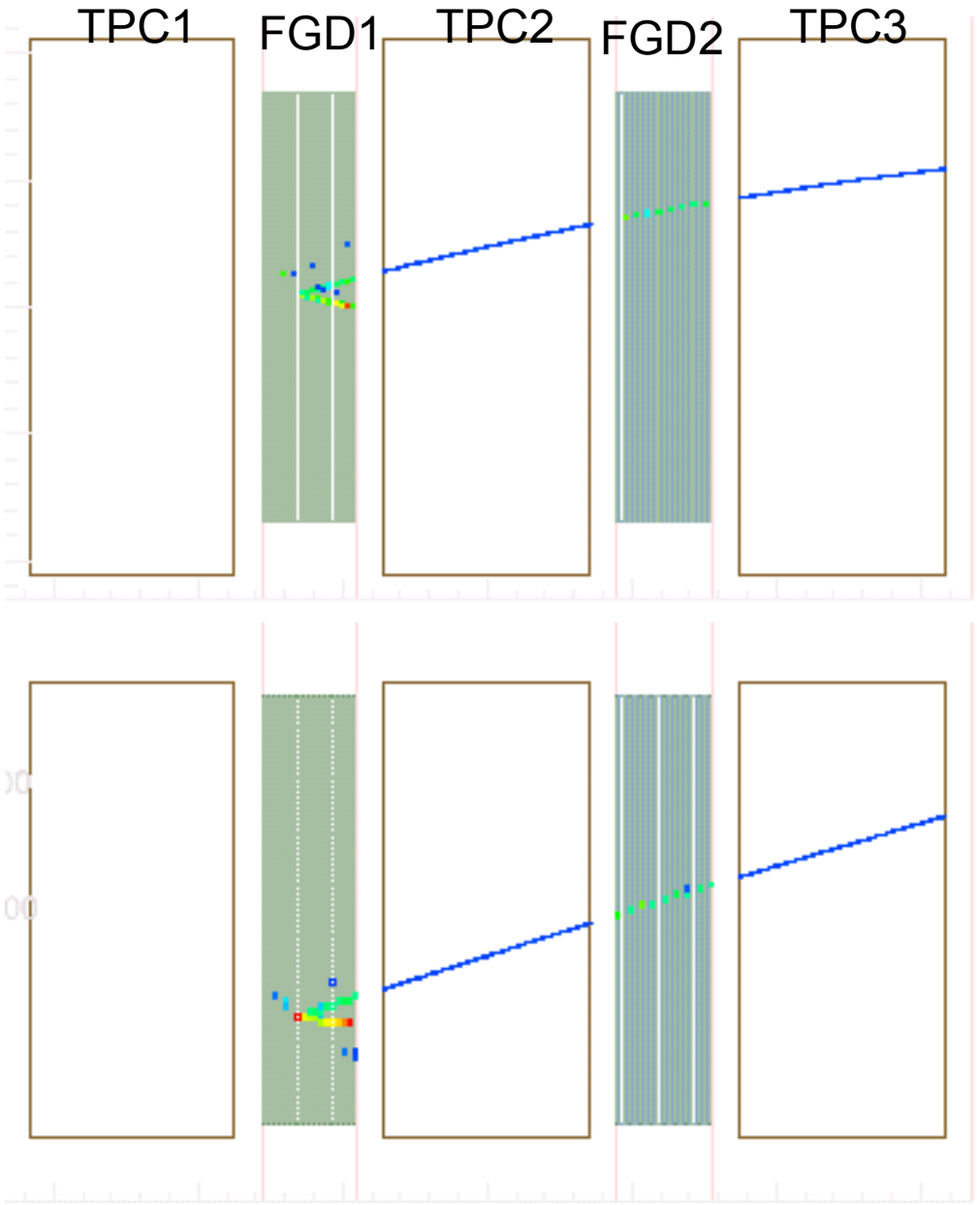


Photo of production bar



MC ν_μ CCQE (Charged Current Quasi-Elastic) event



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

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

Located in

Basket_0/TRK_0/Active_1/ScintX1_136/bar_37278

Informational particles

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

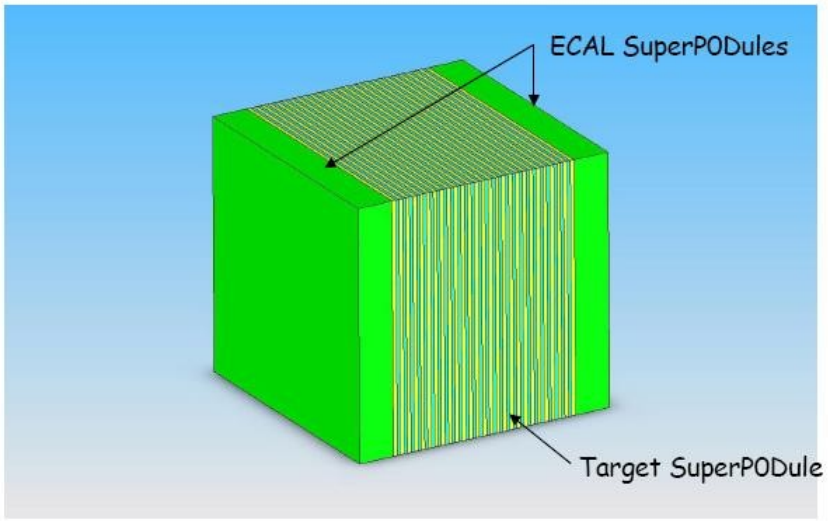
Primary particles

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

P0D configuration

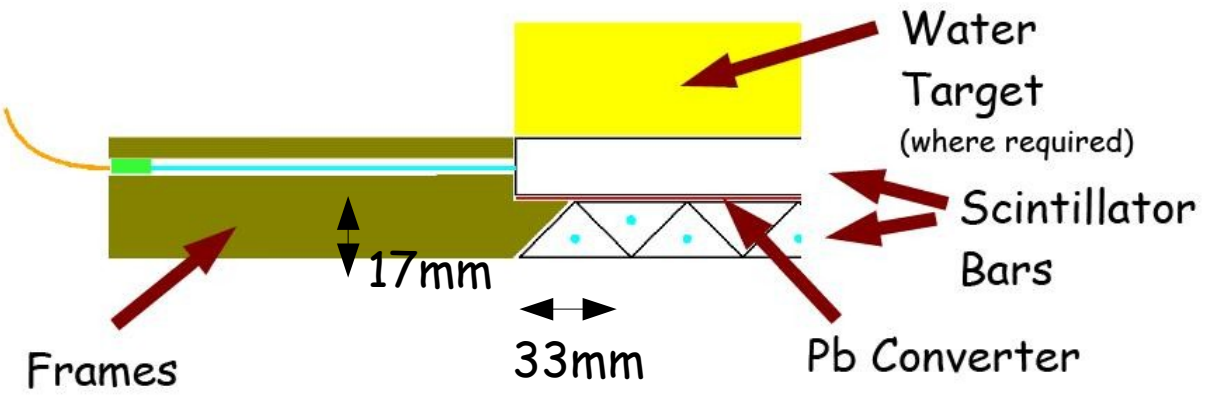
Dimensions:
2200mm wide
2340mm tall
2413mm long

40 module layers
10,560 channels



Total mass ~ 16 ton
Target ~ 10 ton (water ~4 ton)

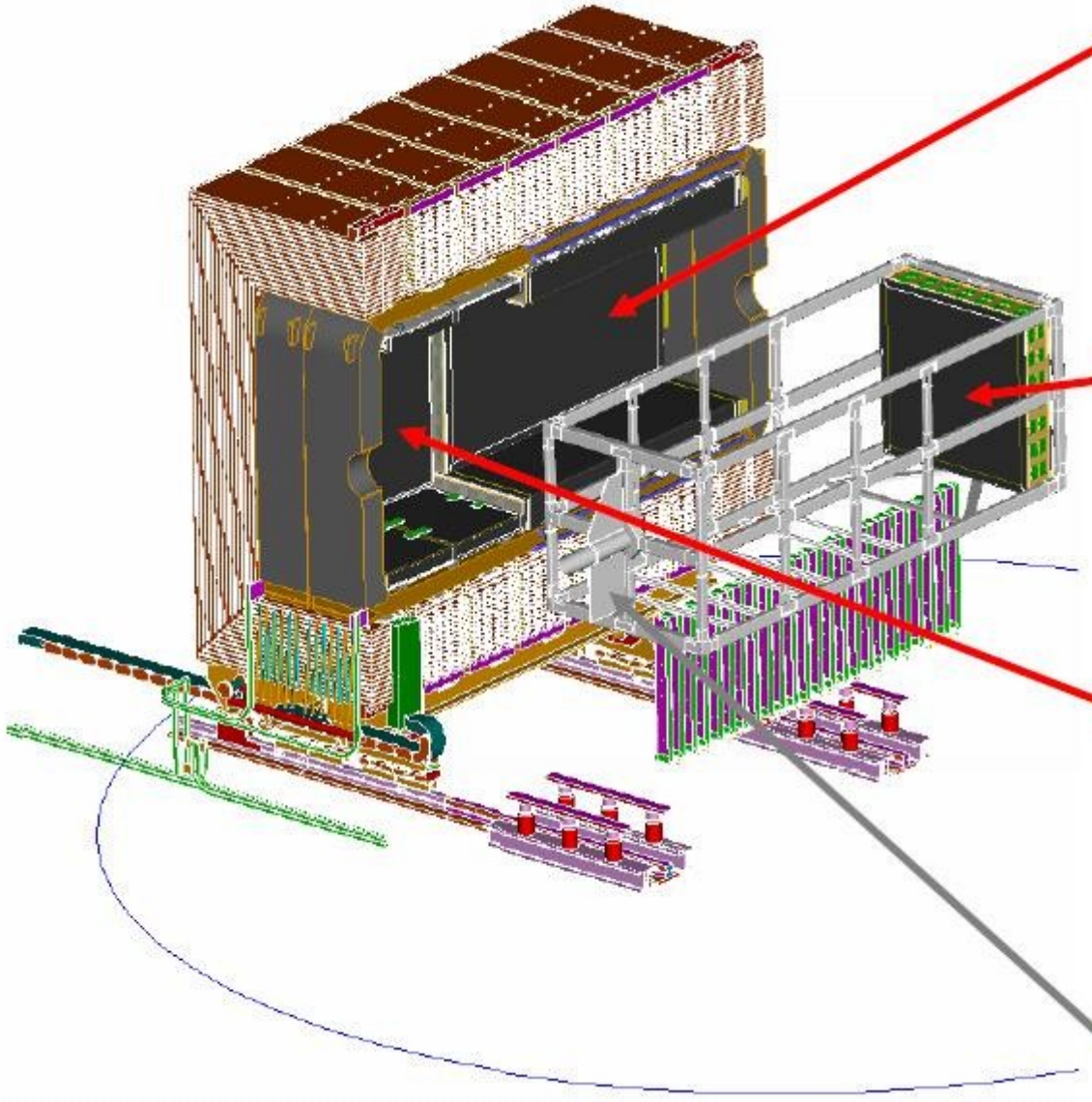
Use "same" module design for all PØD elements



Differences Between Target and ECal PØDules

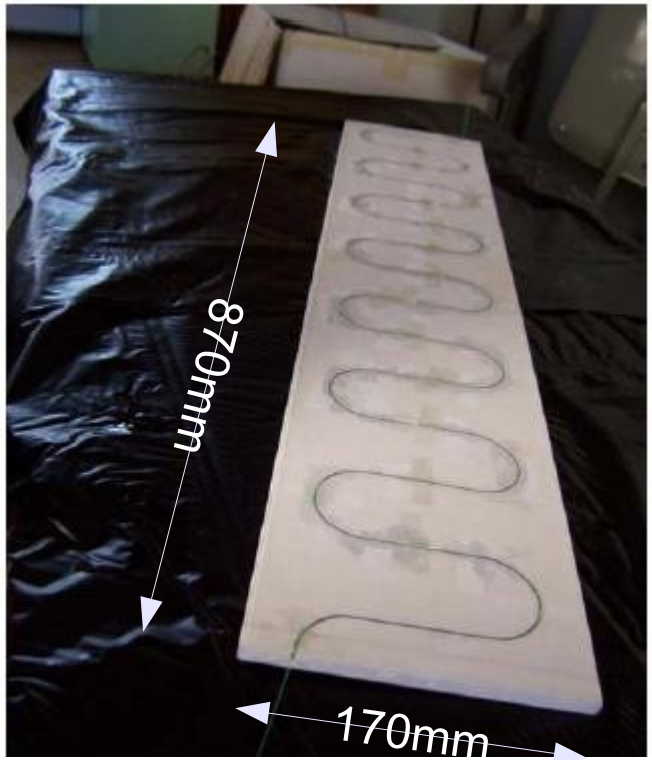
- Target PØDules
  - 0.6 mm Lead to convert γs
  - 26 PØDules
- ECal PØDules
  - Pb is ~2 mm (x2) to contain showers
  - 16 PØDules

ECAL

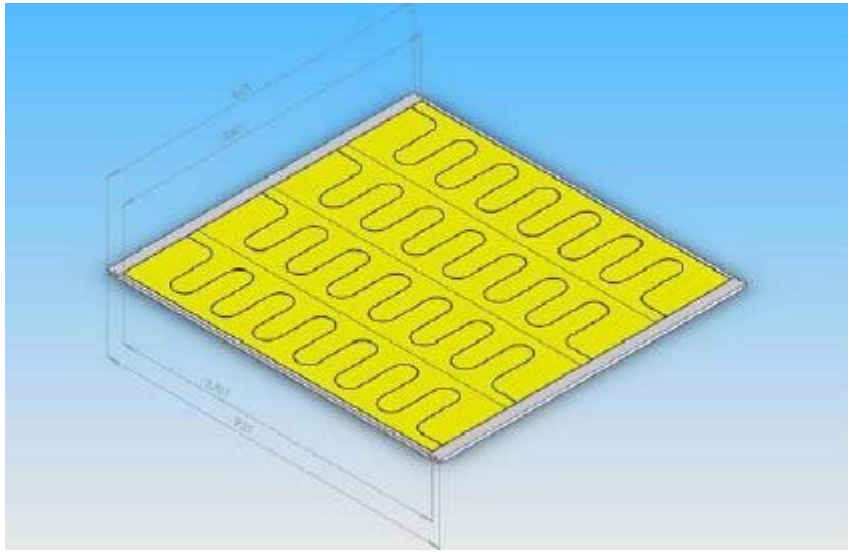


- Barrel-ECAL $10.5X_0$
  - 32 layers, (4cm x 1cm) scintillator bars
  - 31 layers, 1.75mm Pb
- DS-ECAL $11X_0$
  - 34 layers, (4cm x 1cm) scintillator bars
  - 33 layers, 1.75mm Pb
- POD-ECAL $4.5X_0$
  - 6 layers, (17cm x 1cm) scintillator slabs
  - 5 layers, 5mm Pb
- Basket

Prototype of SMRD module



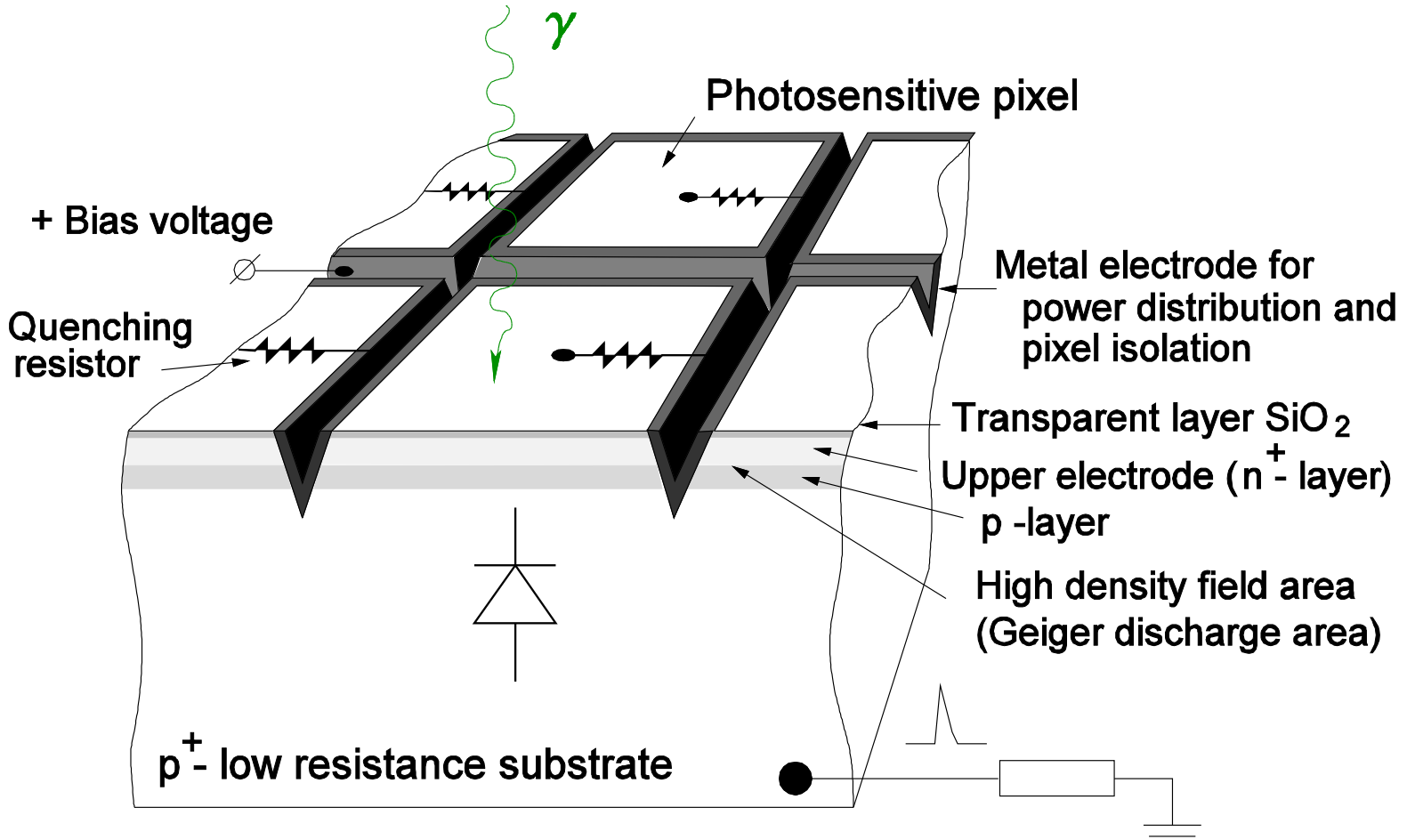
4-slabs in one module



In the yoke gaps
--> Iron(yoke)
+ scintillator
==> range detector

Photo sensor for ND280

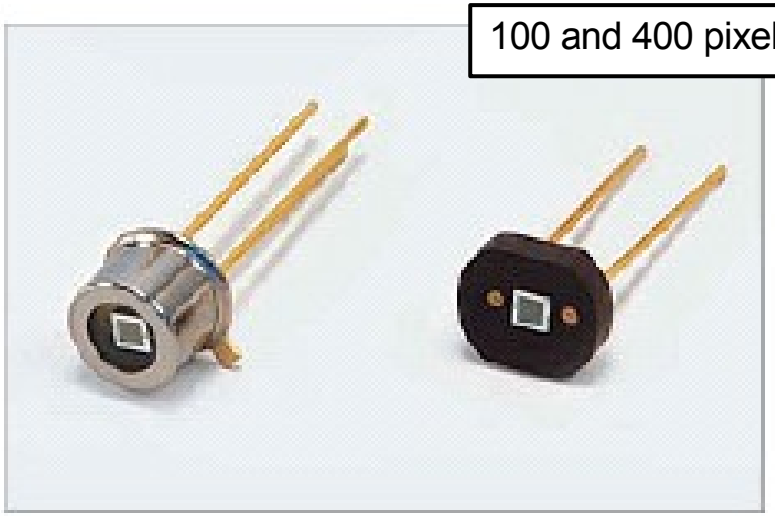
Multi-pixel Geiger mode avalanche photodiode



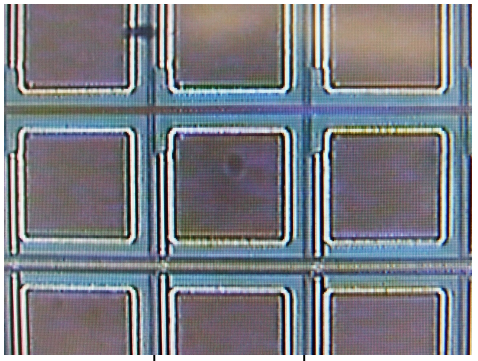
Signal ~ **number of fired pixels => digital**

Photon detection efficiency (PDE) ~ $QE \times \varepsilon_{pixel} \times \varepsilon_{Geiger}$

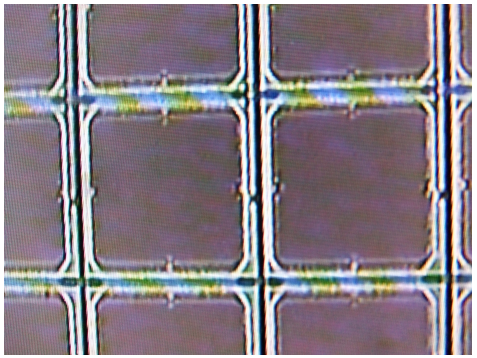
MPPC (Hamamatsu)



Microstructure of 100 pixel device

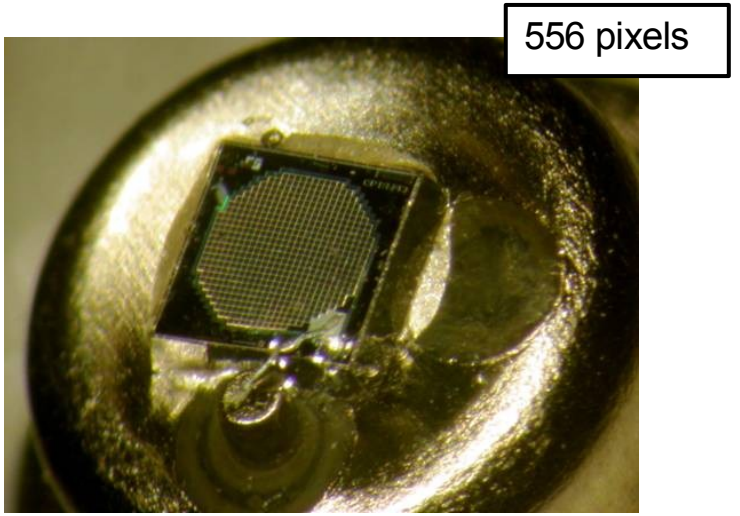


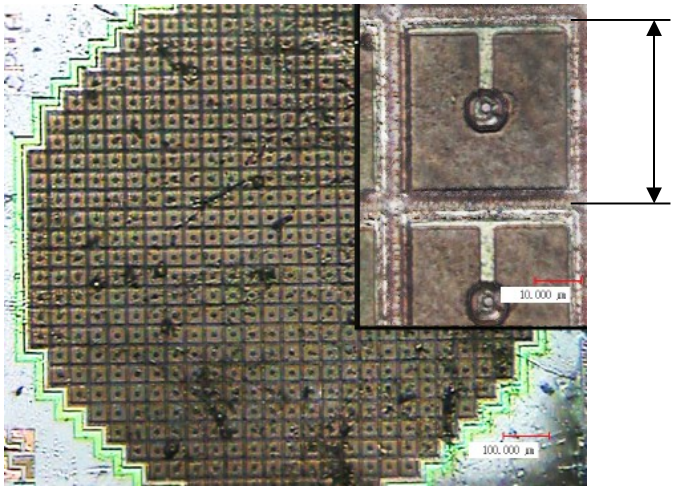
100 μm



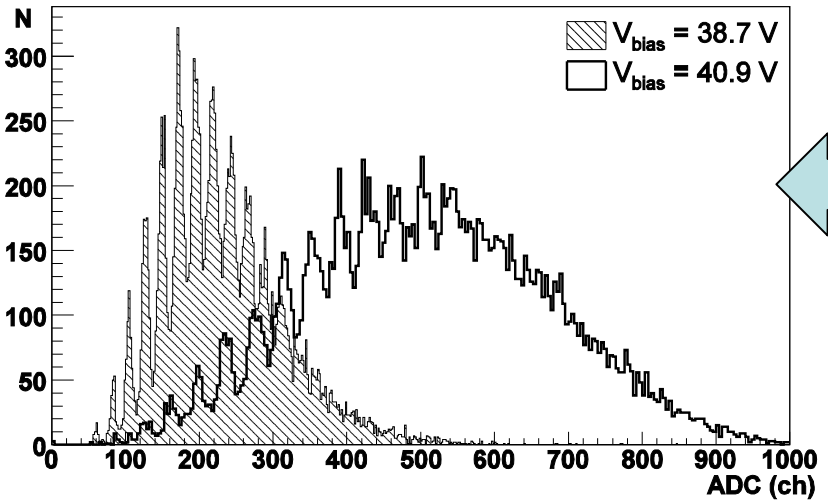
new design

MRS APD (CPTA, Moscow)





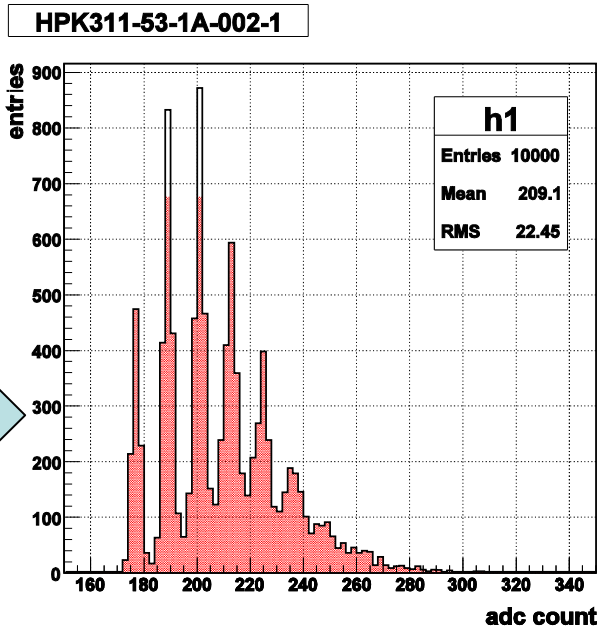
Spectrum of MRS APD & MPPC



MRS APD:
ADC spectra of Sci/WLS counter for MIP's

Digital counting
--> peaks of 1p.e., 2p.e, 3p.e.,,,,

MPPC:
ADC spectra from LED



Main parameters of photo-sensors

	MRS APD	MPPC
Sensitive area	**~ 1.1 mm^2**	**~ 1 mm^2**
Number of pixels	**556**	**100/400**
Geometrical efficiency	**70-80 %**	**70-80%**
PDE for green light	**15-30%**	**15-30%**
Bias voltage range	**25-50 V**	**60-70V**
Gain	**(0.3-0.8)x10^6**	**(0.5-3.0)x10^6**
Cross talk	**5-10%**	**20-35%**
Dark rate (th=0.5 p.e.)	**< 1MHz**	**<0.5 MHz**
Stability, life time	**OK*)**	**OK**)**
Sensitivity to magnetic field	**no**	**no**

*) Should be measured for MRS sensors in new package

**) Will be tested using large number of MPPC's

==> Almost all parameters are OK
Optical connectors for sensors are being designed, will be tested.
500 samples of MPPC are delivered and will be tested soon.

- Summary of T2K-ND280 status
  - Design of sub-detectors will be fixed soon
  - Prototyping and tests are being performed and in good shape
  - Photo-sensors (APD MRS, MPPC) are almost ready for ND280 use
  - Production and assembling is scheduled for installation at J-PARC in early 2009