R&D of a Mton water Cherenkov Hyper-K

Masato Shiozawa
Kamioka Observatory, ICRR, U. of Tokyo

共同研究関連部門名及びセンター	宇宙ニュートリノ研究部門	部門主任又は、センター長	中畑雅行

公募事項	(A) 施設名（　　　　） (B) 研究項目（a、b、c、ⓓ e、f） (C)

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下記のとおり，申請者が貴研究所における共同利用研究に従事することを承諾します。

平成　　年　　月　　日　　大学共同利用機関法人

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研究代表者 職名・氏名	教授・中村健蔵	所属機関・部局（住所）	大学共同利用機関法人高エネルギー加速器研究機構・素粒子原子核研究所 〒305-0801　つくば市大穂1－1
		e-mail	kenzo.nakamura@kek.jp　TEL 029-864-5435

研究課題	新規 / ㊥継続	(和文) 100万トン水チェレンコフ検出器（ハイパーカミオカンデ）の開発研究 (英文) R&D of a Mton water Cherenkov Hyper-Kamiokande	実施期間	自 平成 19年 4月 1日 至 平成 20年 3月 31日

参加研究者及び研究補助者	所属・職名・氏名	所属・職名・氏名
	高工研・教授・中村健蔵	
	宇宙線研・教授・梶田隆章	
	東京大学・教授・相原博昭	
	宇宙線研・助教授・金行健治	
	宇宙線研・助教授・塩澤真人	
	宇宙線研・助教授・早戸良成	
	宇宙線研・助手・奥村公宏	

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	中村健蔵	2	3	つくば	神岡	早戸良成	2	3	猪谷	KEK
	中村健蔵	5	1	つくば	柏	奥村公宏	3	1	柏	KEK
	梶田隆章	3	1	柏	KEK					
	金行健治	3	1	柏	KEK					
	塩澤真人	2	3	猪谷	KEK					

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5万円配分

ありがとうございました。

Physics goals of Mton size detector

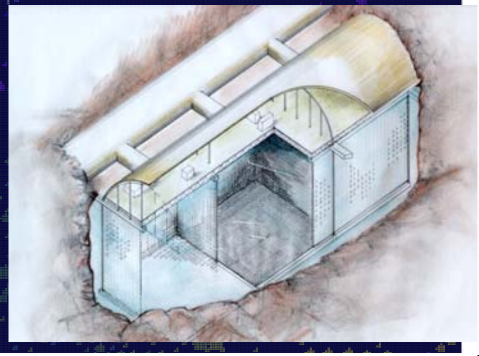
- Neutrino physics
  - (very) long baseline ν oscillation experiment using accelerator ν
    - θ_{13}, CP δ, sign(Δm^2), precise measurements of θ_{23}, Δm^2_{23}
  - Atmospheric neutrinos
    - Octant of θ_{23} and others, supplemental to the accelerator ν
  - Astrophysical neutrinos
    - Solar ν, Supernova ν, relic SN ν
- Nucleon Decay
  - $p \rightarrow e^+\pi^0$, $p \rightarrow \nu K^+$, other decay modes

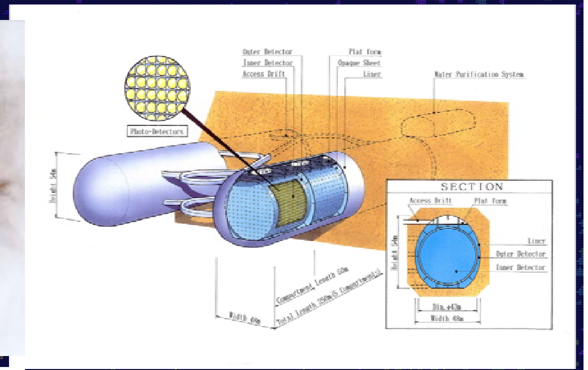
→Prove GUT (unrevealed symmetry) and origin of the matter-antimatter asymmetry of the universe

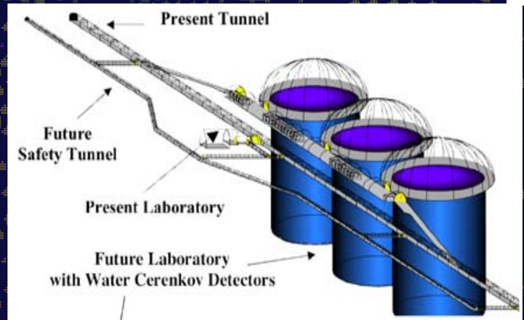
→Extend ν astronomy

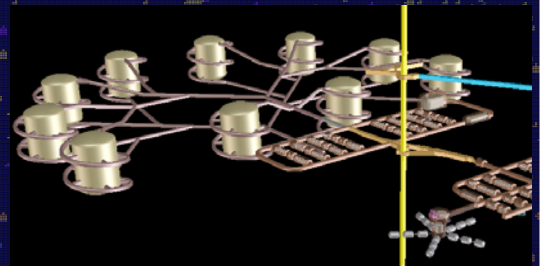
Next-generation neutrino detectors

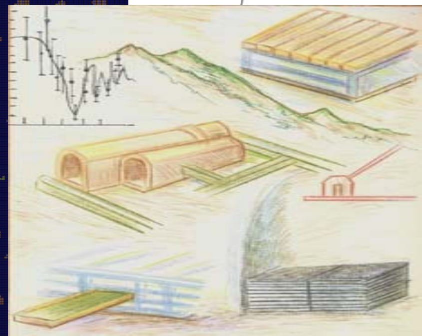
- Liquid imaging detectors
  - Water Cherenkov: Hyper-Kamiokande, UNO, MEMPHYS, 3M (∼0.5Mton)
  - Liquid scintillator: LENA (∼50kton)
  - Liquid argon TPC: GLACIER, LANNDD (∼100kton)
  - Under sea: Deep-TITAND (5Mton), HANOHANO
- Iron tracking calorimeter:
  - INO (∼50kton)

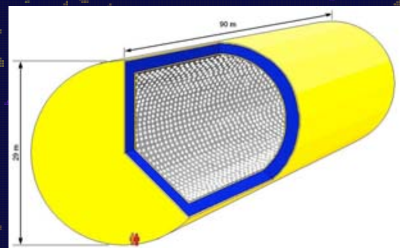


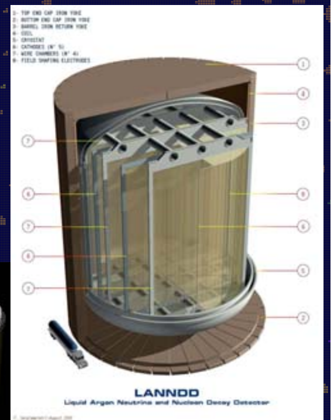


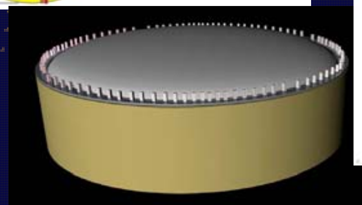


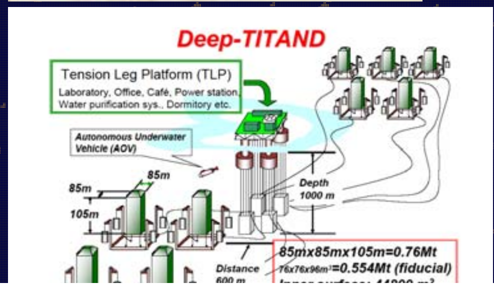


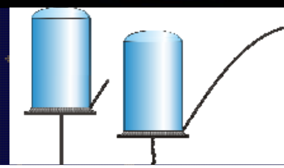






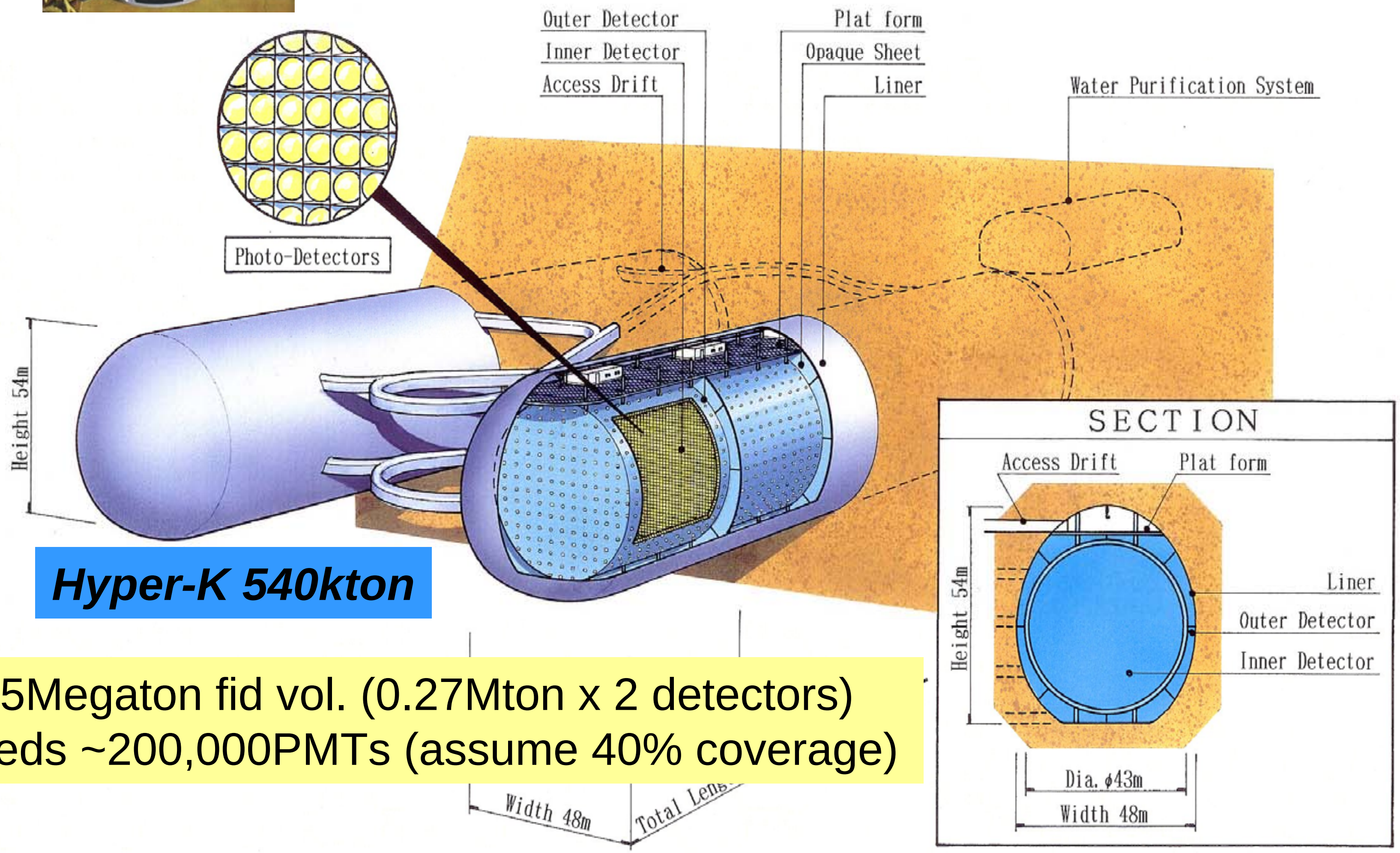






Baseline design of Hyper-K

Super-K 22kton



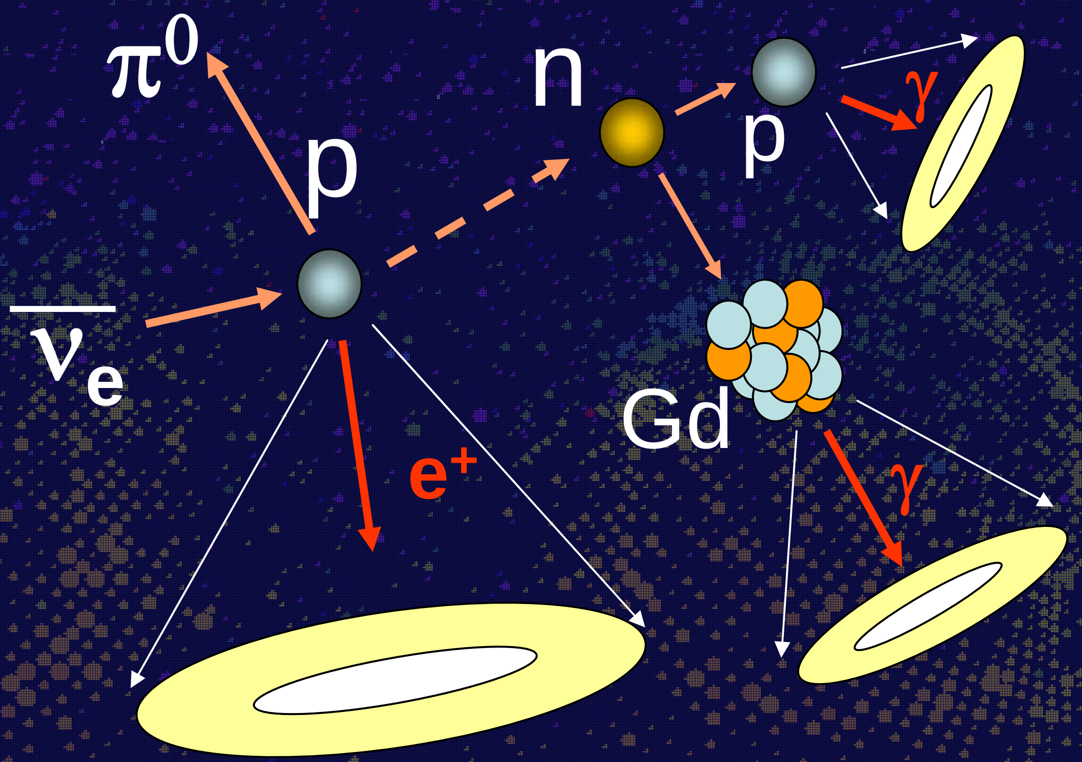
Hyper-K 540kton

~0.5Megaton fid vol. (0.27Mton x 2 detectors)
Needs ~200,000PMTs (assume 40% coverage)

Key issues for realizing the next generation detector (personal opinion)

- Maximize physics motivations
  - Optimize design and maximize physics sensitivities
  - Discovery of nonzero large θ_{13}
  - Discovery of SUSY at LHC or DM search, fine prediction of (hopefully short) proton lifetime…
- Detector technology
  - Large cavity, excavation cost and speed
- Photo sensor
  - Reduce cost (<50%), high production speed, case…

BG reduction by neutron tagging



Possibility 1

n+p→d + γ

2.2MeV γ-ray

ΔT = ~ 200 μsec

Number of hit PMT is about 6 in SK-III

Possibility 2

n+Gd →~8MeV γ

(Visible E: 1~8MeV)

ΔT = ~20 μsec

Add 0.2% $GdCl_3$ or $GdNO_3$

(ref. Vagins and Beacom, PRL93:171101,2004)

R&D is going on

- Issues for Gd:
  - water transparency, how to operate water purification system, corrosion of materials so on
- need high speed DAQ electronics to achieve very low threshold

Further BG reduction?

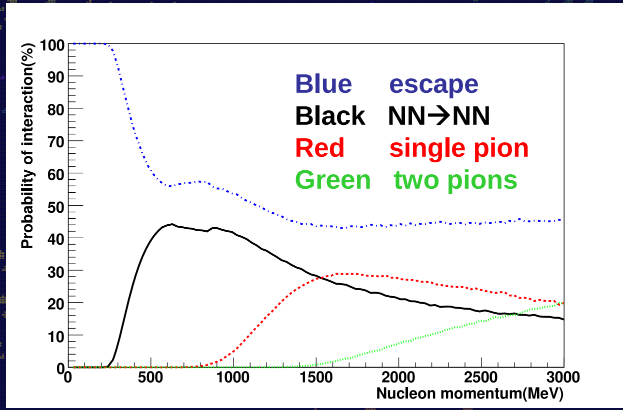
Many BG are accompanied by neutrons

Background events for $p \rightarrow e^+\pi^0$ (4.5Megaton years)

	ν interactions	secondary interactions in water
1	$\nu n \rightarrow e^- p \pi^0$	Neutron production by the proton
2	$\nu p \rightarrow e^- p \pi^+$	Neutron by π^+
3	$\nu p \rightarrow e^- p (\pi^+) \pi^0$	
4	$\nu n \rightarrow \nu p \pi^- \pi^0$	
5	$\nu n \rightarrow e^- p$	Neutron by the proton
6	$\nu n \rightarrow e^- n \pi^+ \pi^-$	
7	$\nu p \rightarrow e^- p (\pi^+) \pi^0$	
8	$\nu p \rightarrow \nu p \rho$	
9	$\nu O \rightarrow e^- O \pi^+$	Neutron by π^+
10	$\nu n \rightarrow n \rho$	neutron and π^- by the neutron

More n should be there because

- Secondary interactions of protons in ^{16}O; $pp \rightarrow pp$, $pn \rightarrow pn$, $pn \rightarrow np$ sometimes produce neutrons (not simulated now)

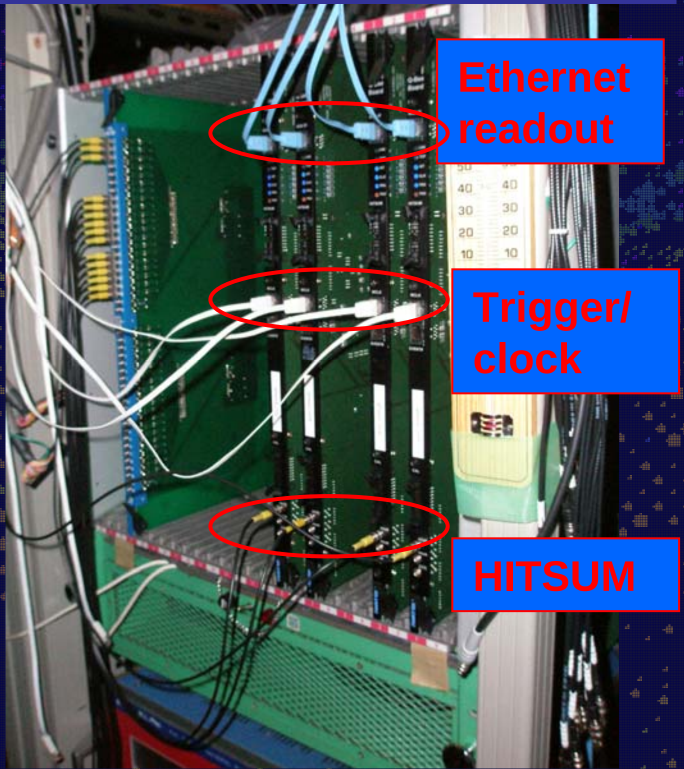


- For Eν 1~10GeV, residual nuclei may become fragment producing additional neutron (not simulated now)
- Stopping π^- absorbed by medium could also cause neutron emission (no simulation now)

Further BG reduction is possible if WC detector can tag neutrons.
(need studies by experimental tests and full MC simulation)
Fraction of BG accompanied by neutron is roughly ~90%.

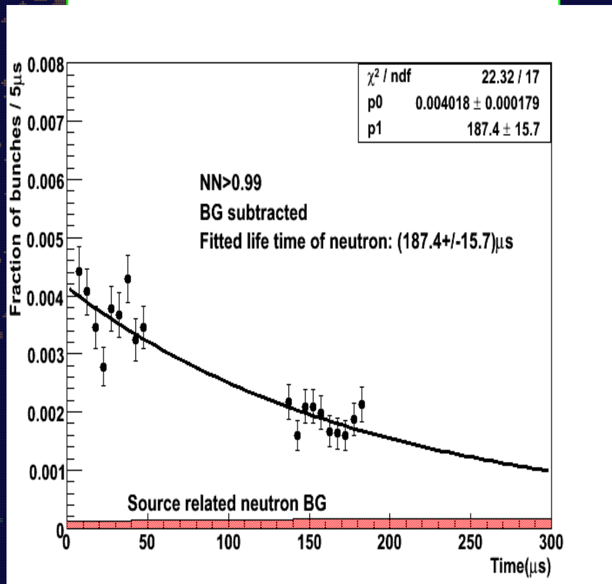
New DAQ erelectronics

QBEE prototype at Super-K



We will replace SK electronics with new *high speed pipelined electronics system* in 2008.
→
start recording faint neutron signature; n+p→d+**γ(2.2MeV)**

Test data @ Super-K

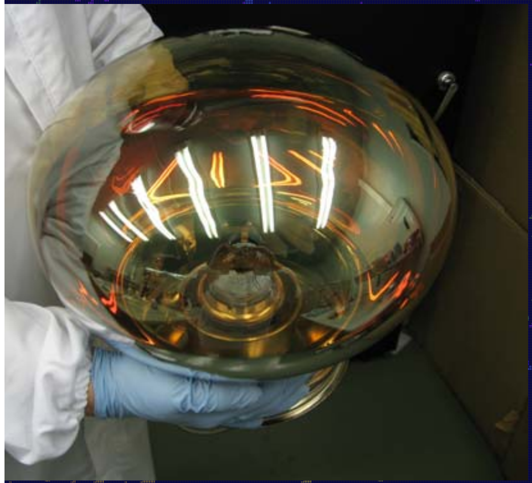


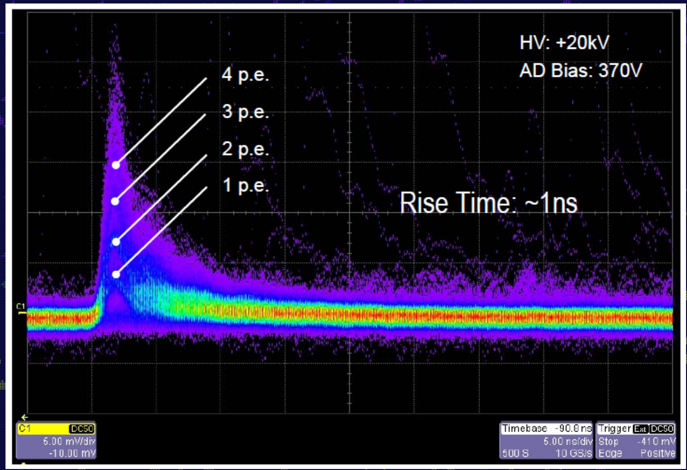
Detection eff.(np→dγ) is small 15~20% (measured at SK).

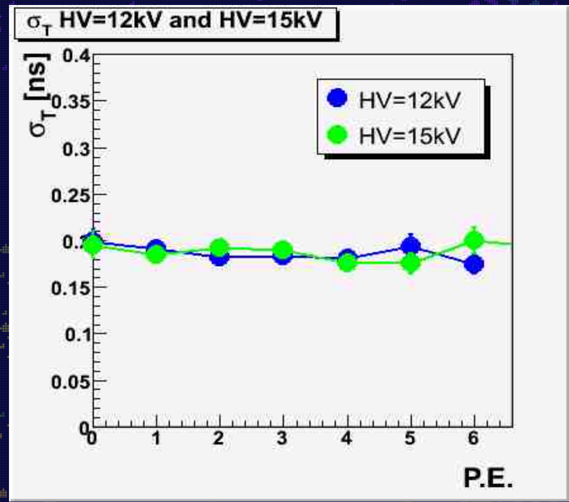
But we can study neutron production probability in atmospheric ν interactions.

13inch HAPD R&D

T.Abe







Parameters*		13inch HAPD	13inch PMT (R8055)	20inch PMT (for SK)
Single Photon Time Resolution (s)		190ps	1400ps	2300ps
Single Photon Energy Resolution		24%	70%	150%
Pulse Response	Rise Time	1ns	6ns	10ns
	Pulse Width	2.2ns	10ns	20ns
Transient Time		12ns	100ns	95ns
Dynamic Range (Signal Intensity in p.e.)		3000 p.e.	2000 p.e.	1000 p.e.
Order of Gain		10^5	10^7	10^7

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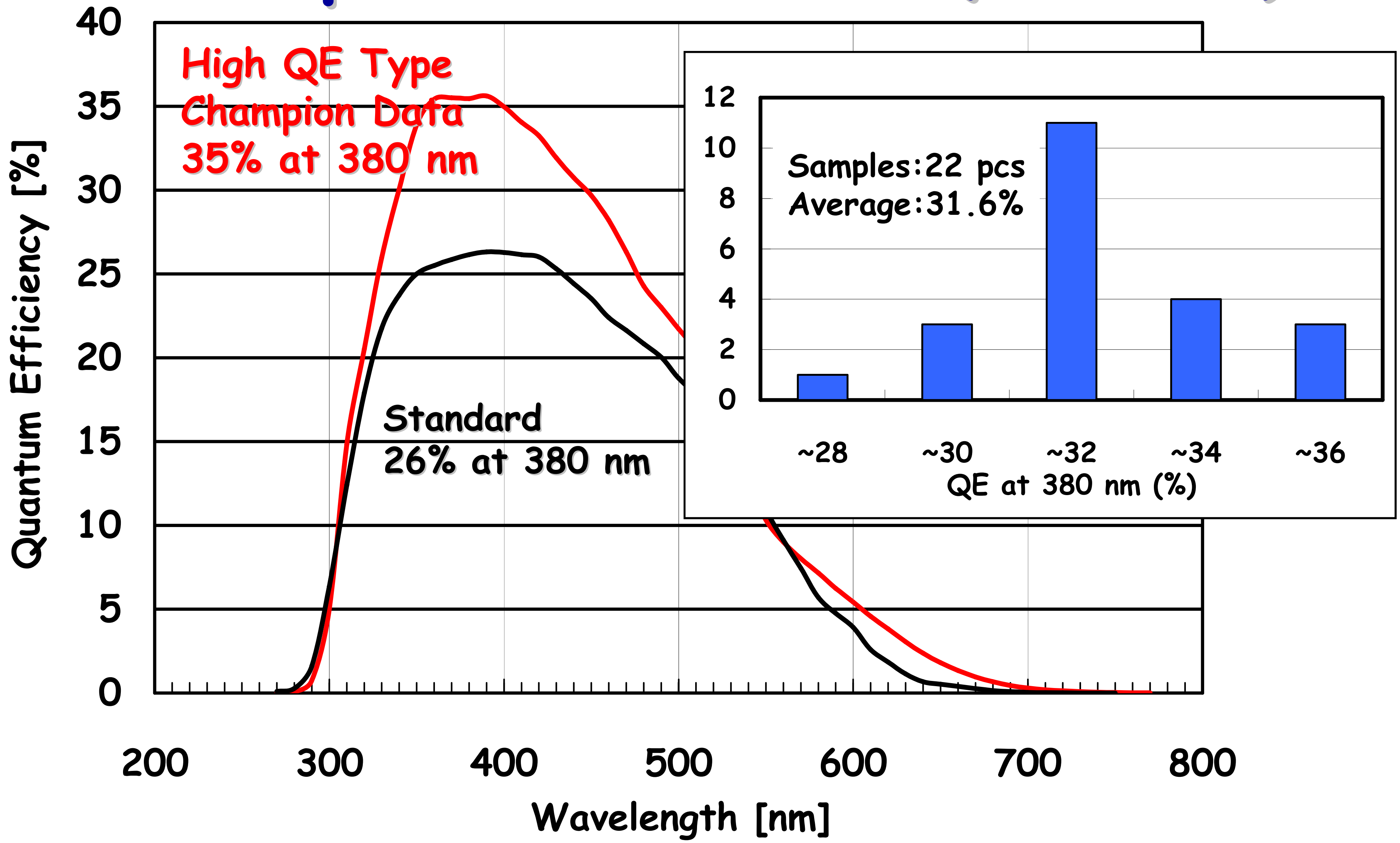
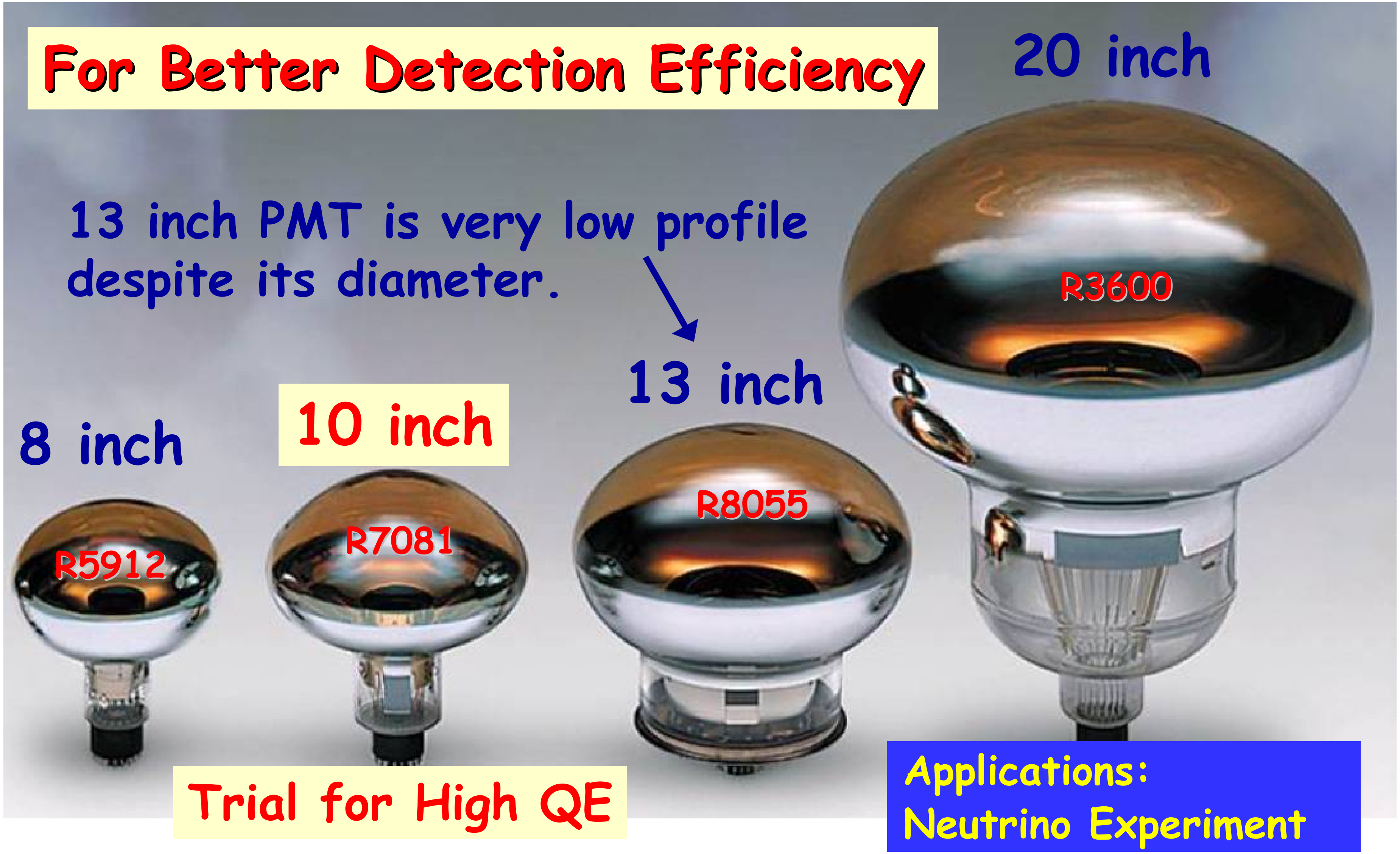
Example data R7081 (10 inch)



Large Format PMTs



Wakabayashi@NNN07

Study on the Jointed Rock Mass for the Excavation of Hyper-KAMIOKANDE Cavern at Kamioka Mine

Naruki Wakabayashi
Shimizu Corporation Tokyo Japan

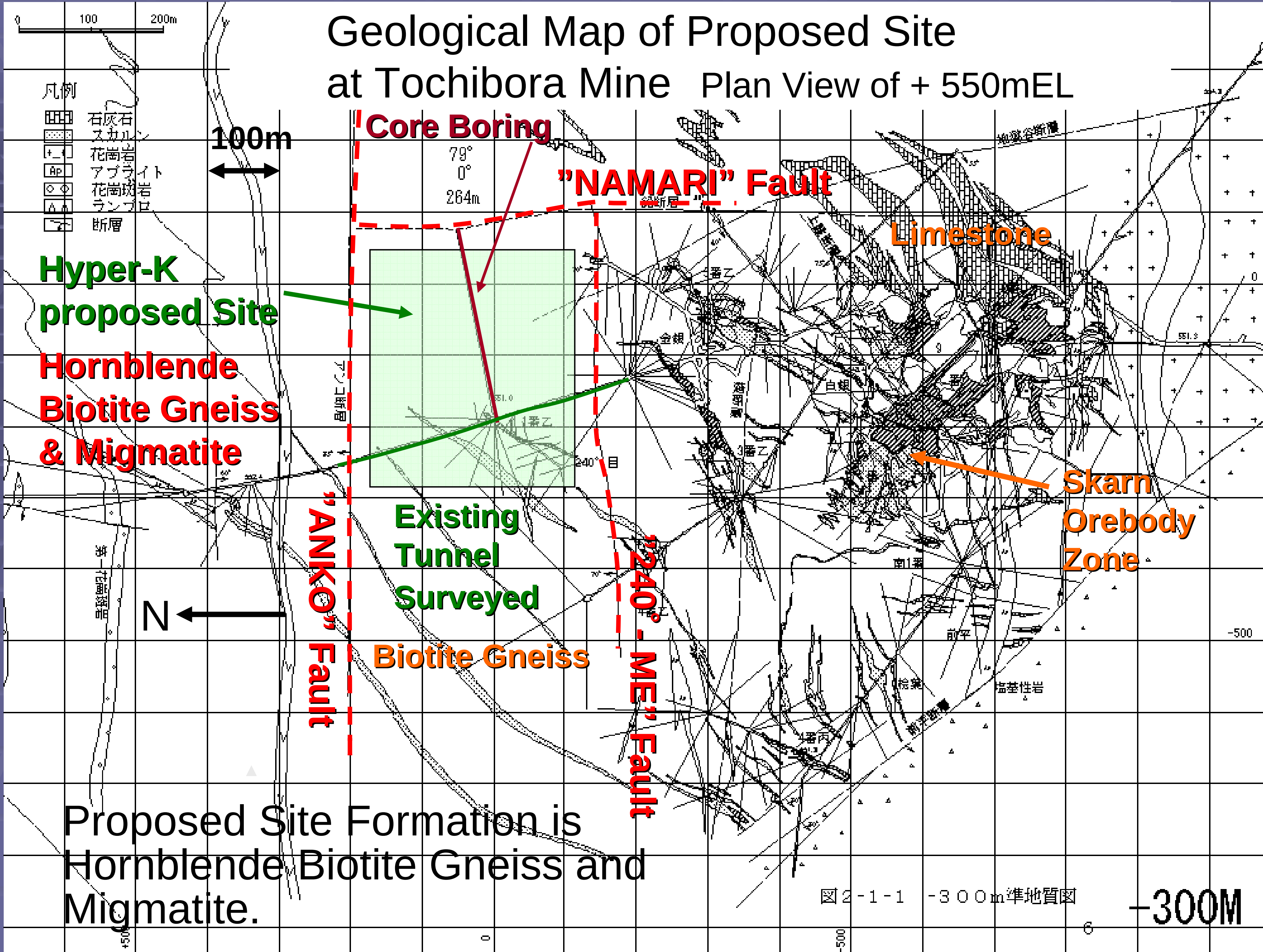
NNN07 Hamamatsu, Japan 3-5 October 2007

Topics

- Previous Geological Survey and Stability Analysis for the Hyper-K cavern
  - Site Selection
  - Isotropic Elastic FEM Analysis for the Investigation of Cavern Shape, Size and Type

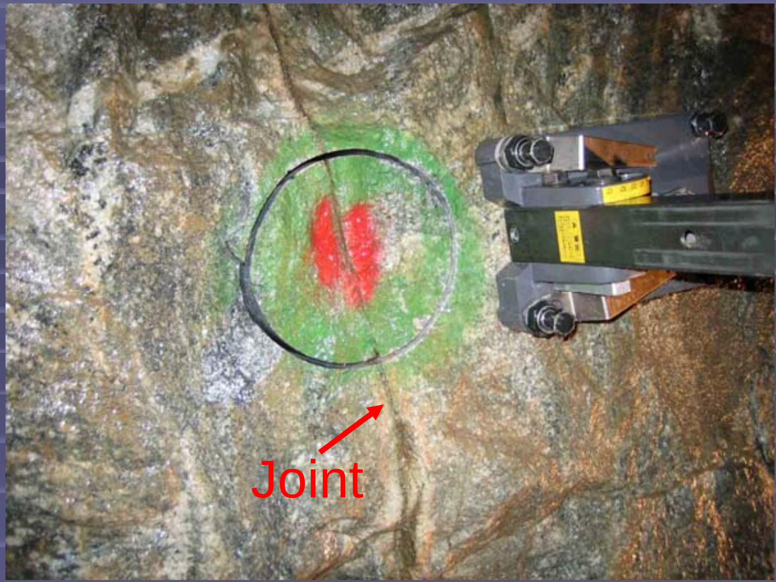
- Ongoing Investigation and Analysis for Jointed Rock Mass
  - Investigation of Joint Orientation
  - Obtaining In-Situ Rock Joints and Investigation of Joint Mechanical Properties
  - Pull-out Test of Two Types of Cable Bolt
  - Two Type Analysis to Consider the Influence of Joint and Support System

Geological Map of Proposed Site at Tochibora Mine Plan View of + 550mEL



Proposed Site Formation is Hornblende Biotite Gneiss and Migmatite.

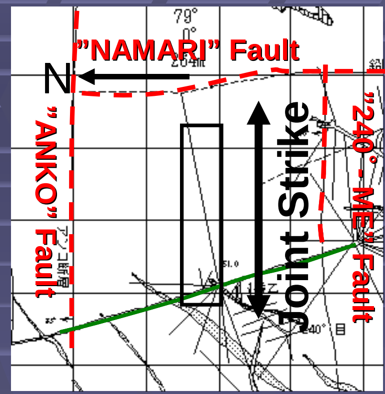
Situation of Obtaining In-Site Rock Joints



Discontinuous Analysis by DEM

DEM Analysis is Performed to Establish the Behavior of Jointed Rock Mass and the Effect of Support System.

Cavern Direction is East and West

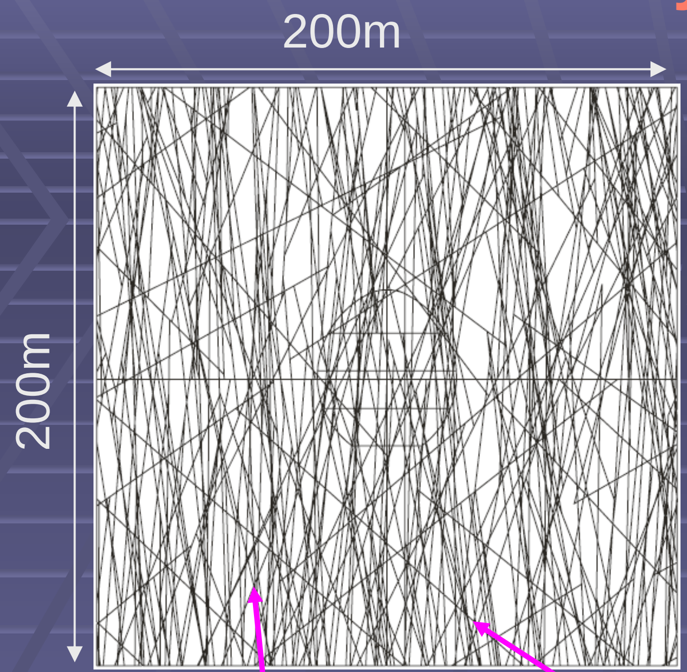


Cavern Shape and Direction

Analysis Cases

	Support	In-Situ Stress
Case 1	Without Support	Isotropic Stress σH=σv=14.4 (N/mm²) (Overburden:500m)
Case 2	Rock Bolt (Length=6m :Space=2m) Double PC-Cable Bolt (Length=15m :Space=2m)	
Case 3	Rock Bolt (Length=6m :Space=2m) Double ST-Cable Bolt (Length=15m :Space=2m)	

Procedure of Analysis

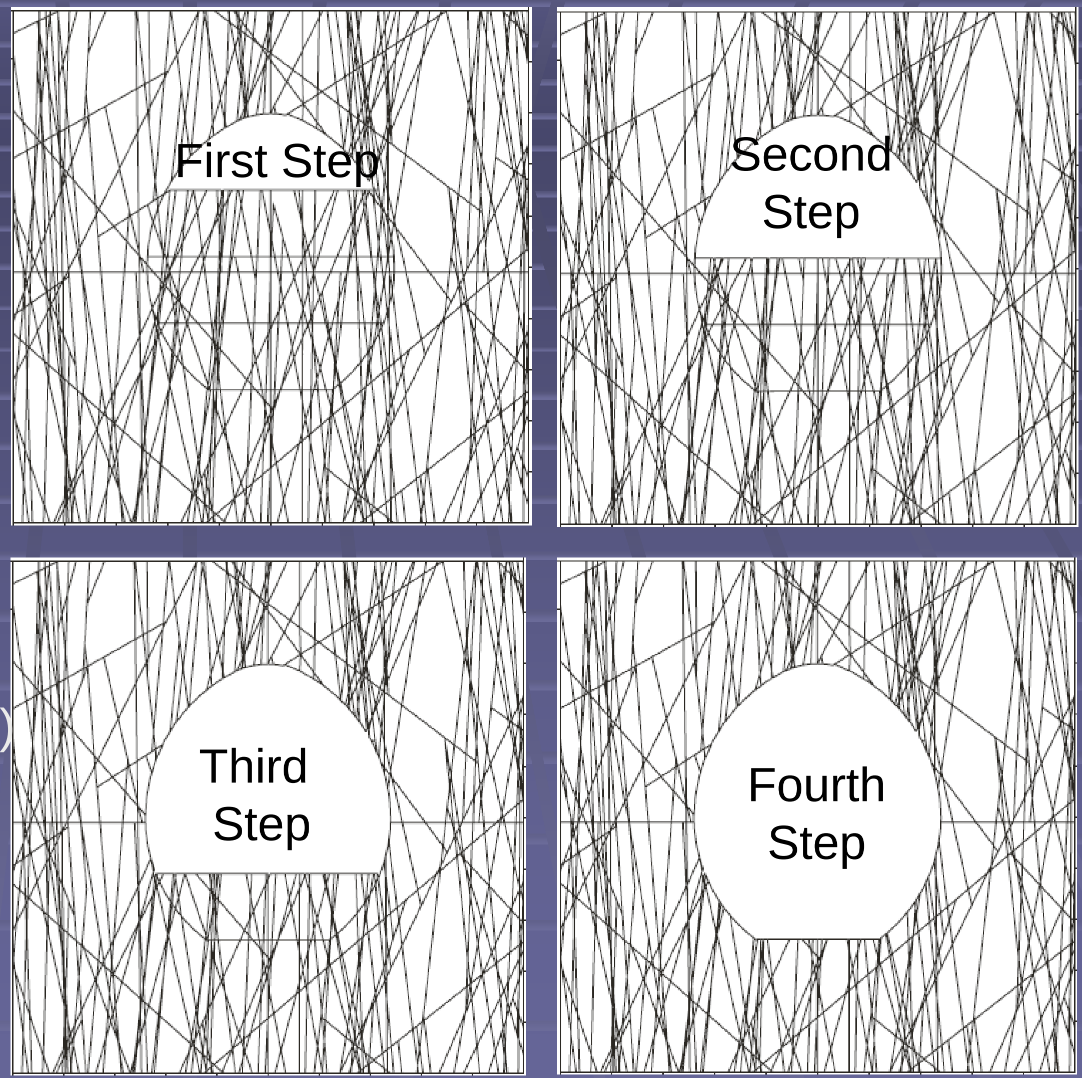


Strike E-W
Dip ±70～90°
(Major Joint Set)

Strike NS-WS
Dip ± 40～50°
(Another Joint Set)

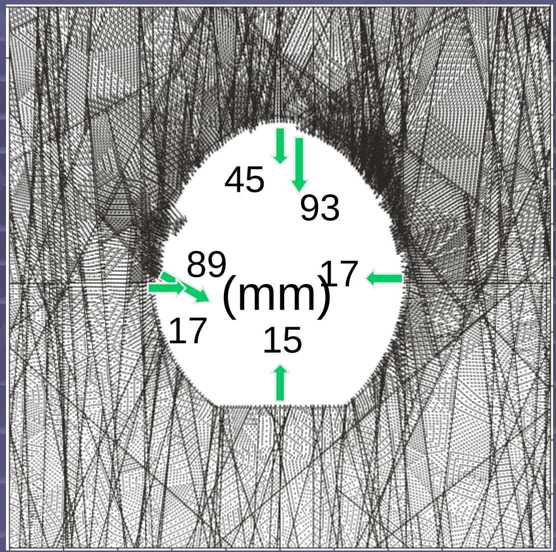
Analysis Model

Joints are Generated Statistically According to the Joint Orientation

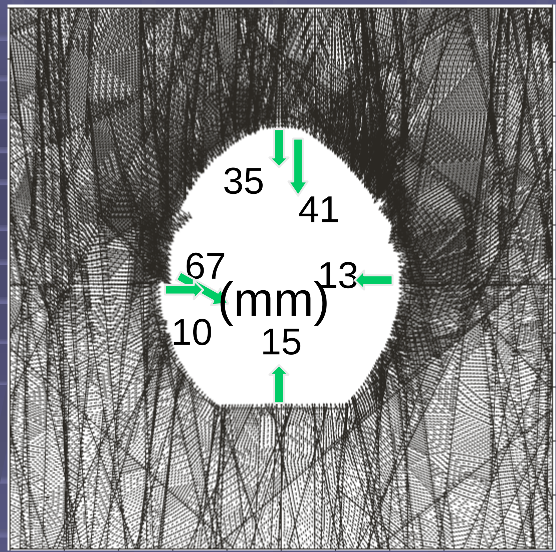


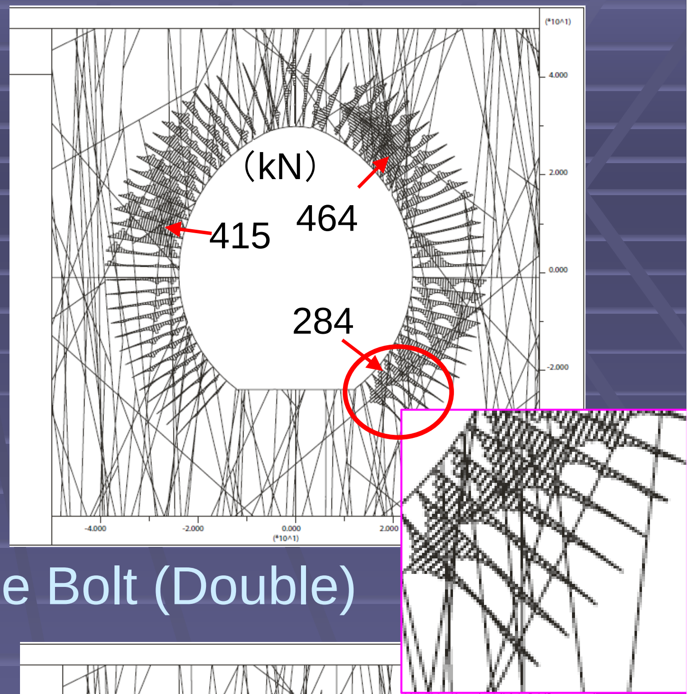
Establishing Support System after Each Excavation Step

Displacement Vector and Cable Axial Force



Case 1：Without Support

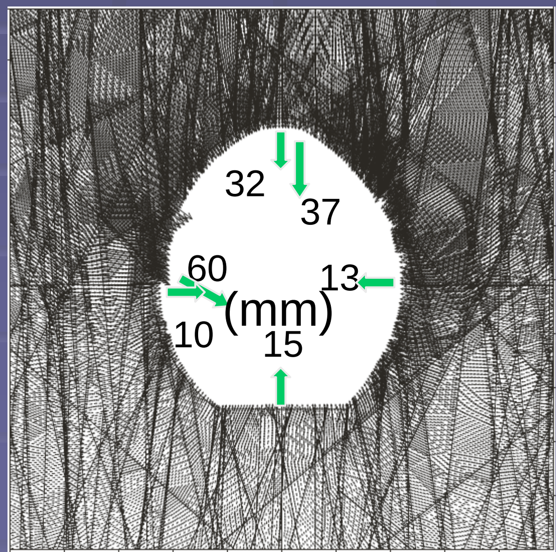


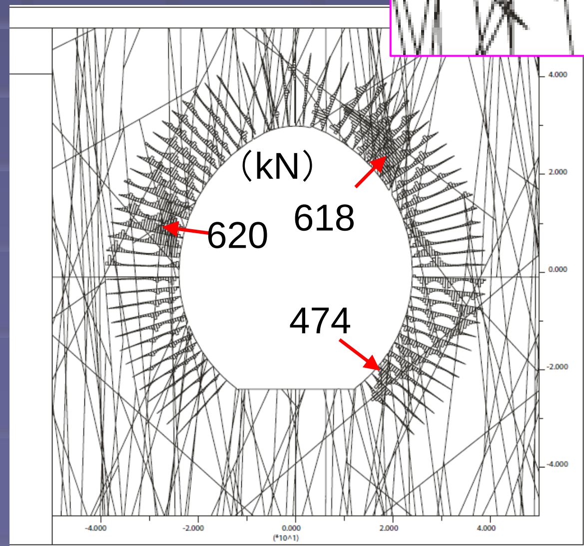


Case 2：RB+PC-Cable Bolt (Double)

Displacement of Right and Left Side Wall are nearly same because of Symmetrical Joint Dip Angle (±70～90°).

Displacement of Case-3 is smaller than Case-2 because of Support Effect of ST Cable Bolts





Case 3: RB+ST-Cable Bolt (Double)

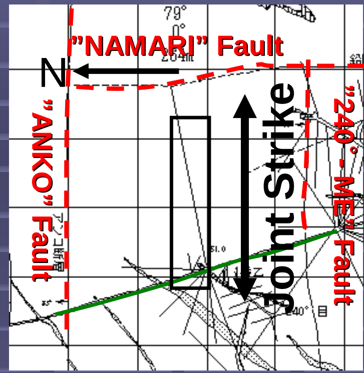
Equivalent Continuum Analysis by Crack Tensor

Crack Tensor Analysis is Performed to Estimate the Relation between Tunnel Direction and Joint Orientation.

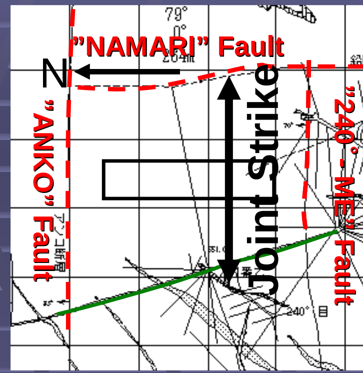
In-Situ Stress is Isotropic
$\sigma H = \sigma v = 14.4$ (N/mm^2)

Case 1:Cavern Direction is East and West, parallel to Joint Strike

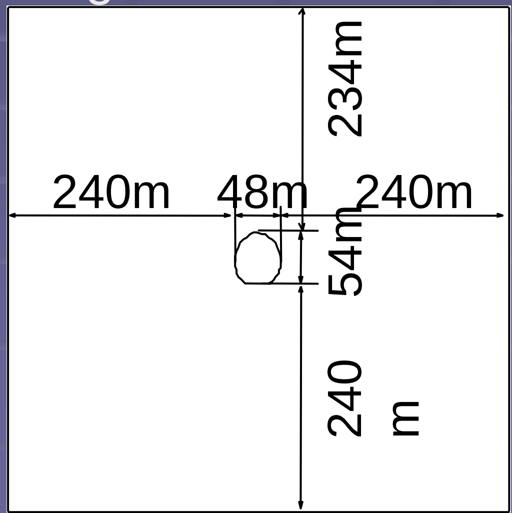
Case 2:Cavern Direction is North and South, right-angled to Joint Strike



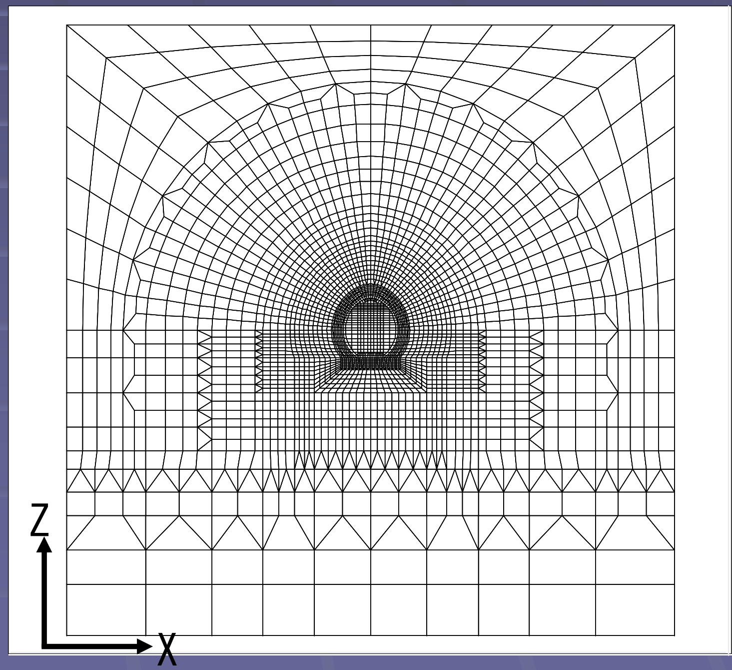
Case 1



Case 2



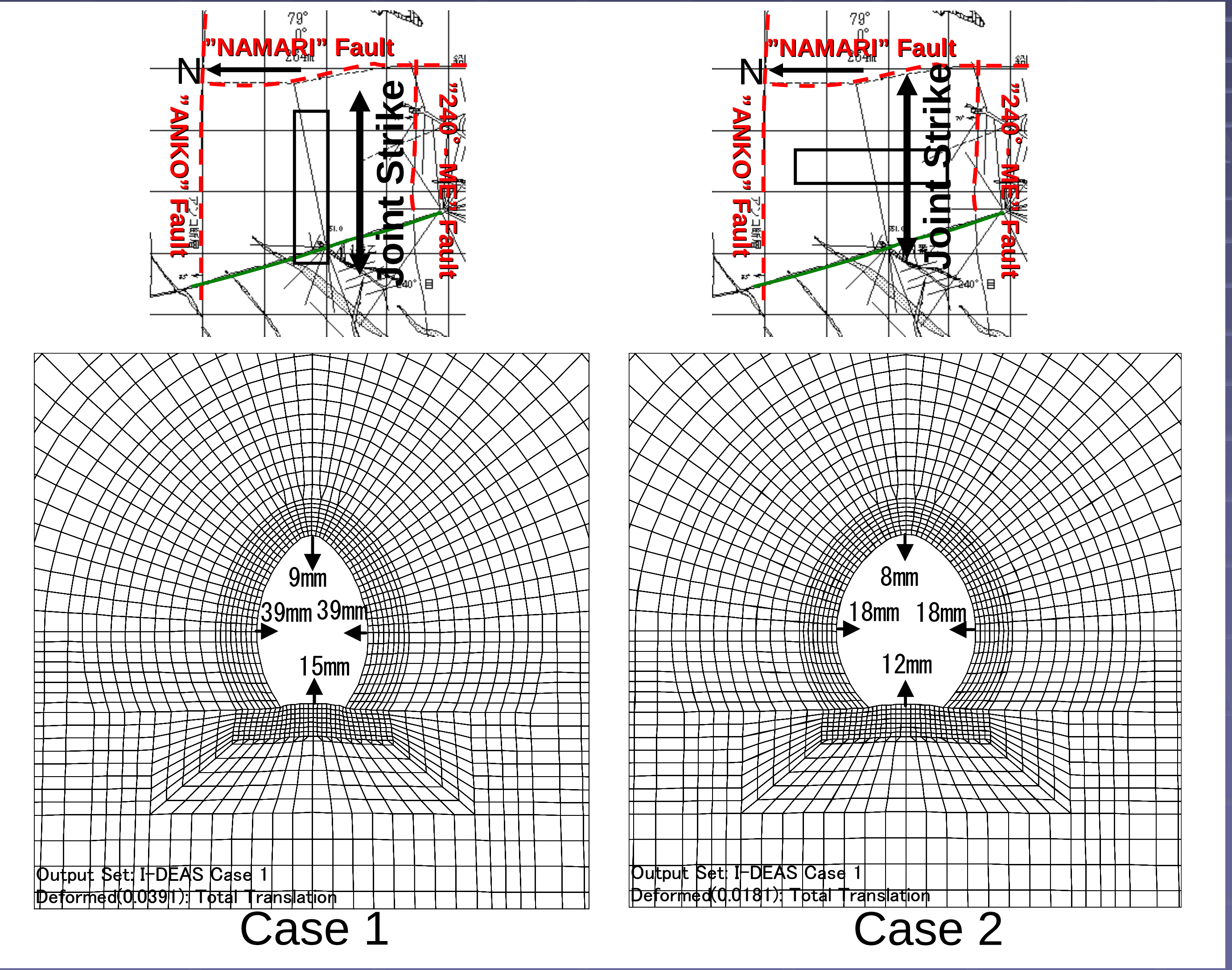
Cavern shape and Region (528m×528m)



Model

Displacement

Side Wall Displacement of Case 1 is 2 times Larger than Case 2 because of influence of Joint Strike Direction.



Summary

Joint Orientation : At Proposed Site in Tochibora Mine, Major Joint Set Strike Direction is E-W and Dip Angle is ±70～90°

Joint Properties : Normal and Shear Stiffness, Shear Strength are Estimated.

Cable Bolt Properties : Shear Strength and Stiffness of ST and PC Cable Bolt are Estimated. Shear Strength of ST-Cable Bolt is 5 Times Higher than PC-Cable Bolt. ST-Cable Bolt is very Effective Support.

Results of Analysis : Discontinuous and Equivalent Continuum Analysis are able to Estimate the Effect of Rock Support System and the Anisotropic Behavior of Jointed Rock Mass. Joint Orientation is very Important factor to decide the Cavern Direction.

Further Investigation : It is Necessary for Estimation of Accurate Joint Orientation to investigate in Different Direction Tunnel or Bore Hole Additionally. Measurements of In-Situ Initial Stresses and In-Situ Tests on Rock Mass Deformability are indispensable.