Korean HEP Activities

Dongchul Son
Kyungpook National University
and Center for High Energy Physics
Korea Association of HEP

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Outline

- Some Backgrounds on Korean HEP
- Some Selected Current Projects
  - Dark Matter Search and Double Beta Decay Experiments
  - Korea-CERN Programs
    - CMS and CMS Tier-2
  - Rare Isotope Science Project (and future)
  - RENO (Reactor Neutrino Experiment)
- Future Planning
  - Roadmap for Korean Accelerator-based HEP Programs
  - Roadmap for Korean CMS Computing
  - Underground HEP Facility for Proton Decay and Long-baseline Neutrino Physics Experiment
- Future Directions and Conclusion

Some backgrounds on Korean HEP

HEP Organizations

(Institutes, Centers, WCU Teams)

Center of Excellence
CHEP (2000) — Kyungpook NU (host)
WCU (2009)

Center of Excellence
CQUeST (2005) — Sogang U (host)

KPS
Particles and Fields
Nuclear Physics
Astrophysics
Plasma Physics

KHEP: Association of Korean HEP (2005)

WCU-IEU (2009) — Ewha W U (host)
MEMSTEL (2006)

Korea-CERN Coop. (2007)

RENO (2006)

Center of Excellence
KNRC (2009) — Seoul NU (host)
WCU (2009)
DMRC (2000)

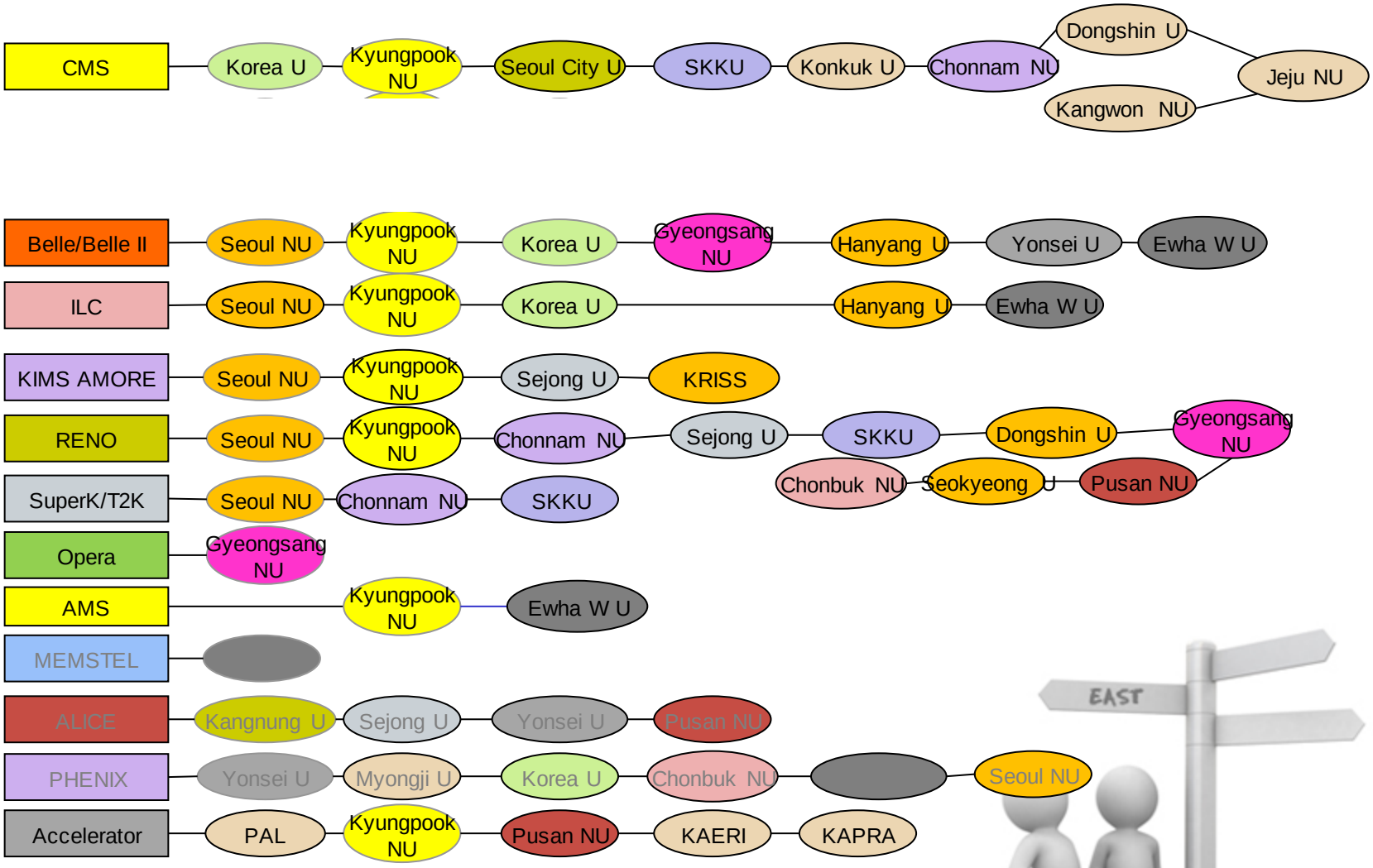
KODEL (1997) — Korea U

Emulsion Group — GSNU

PAL (1988) — POSTECH (host)
APCTP (1997) — POSTECH (host)
CTP (1990) — Seoul NU (host)
KIAS (1996) — KAIST (host)

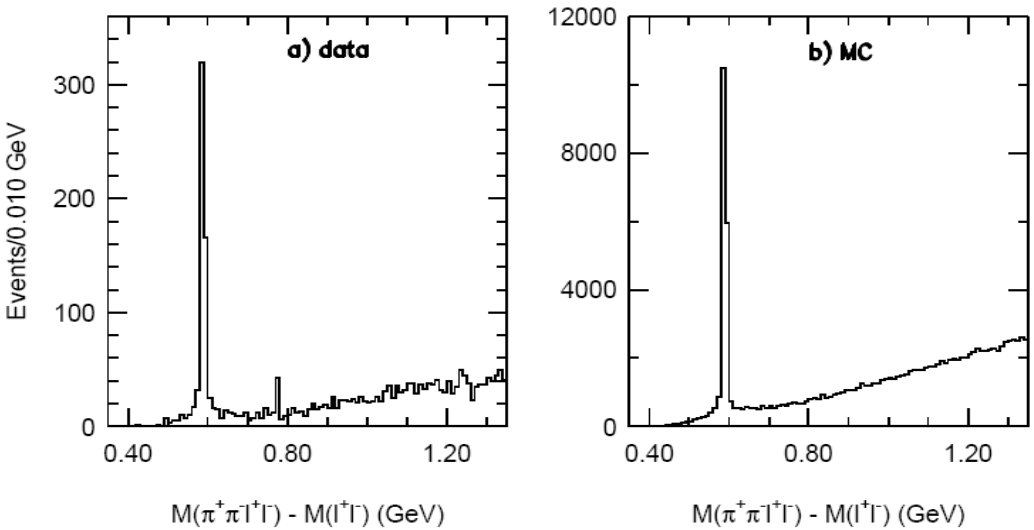
And others (KAERI, etc.)

HEP teams in Korea



Discovery of X(3872)

Observation of a narrow charmonium-like state in exclusive B → K π+ π- J/ψ decays [PRL 91, 262001 (2003)]



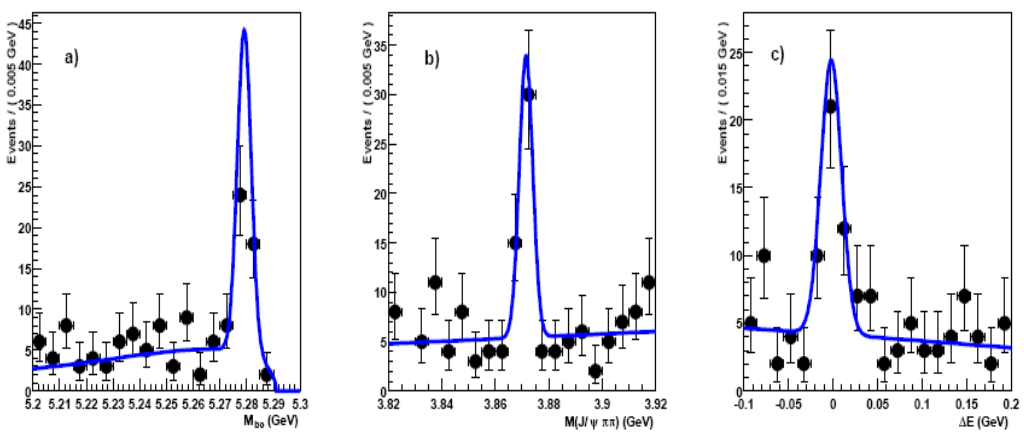


FIG. 2: Signal-band projections of (a) $M_{\rm bc}$, (b) $M_{\pi^+\pi^- J/\psi}$ and (c) ΔE for the $X(3872) \to \pi^+\pi^- J/\psi$ signal region with the results of the unbinned fit superimposed.

- **With Belle Collaboration, major role by Prof. S.K. Choi**
  - Yield: 35.7 +- 6.8 events
  - mass: 3871.5 +- 0.6 MeV
  - width: 2.5 +- 0.5 MeV
- **Many very interesting follow-up researches and discoveries of XYZs have been done throughout the world!**

Some Selected Current Projects

YangYang Underground Laboratory(Y2L)

(Upper Dam)

(Power Plant)

(Lower Dam)

양양양수발전소

Y2L

- Located in a tunnel of Yangyang Pumped Storage Power Plant Korea Middleland Power Co.
- Minimum depth : 700 m
- Access to the lab by car (~2km)

Experiments:

- KIMS: DM search exp. in operation
- AMORE: DBD Search exp. in preparation

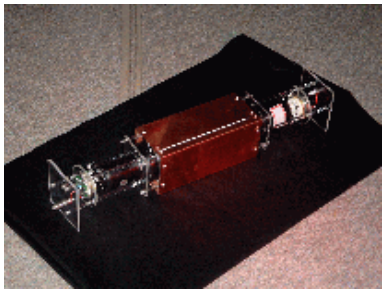
KIMS(Korea Invisible Mass Search)

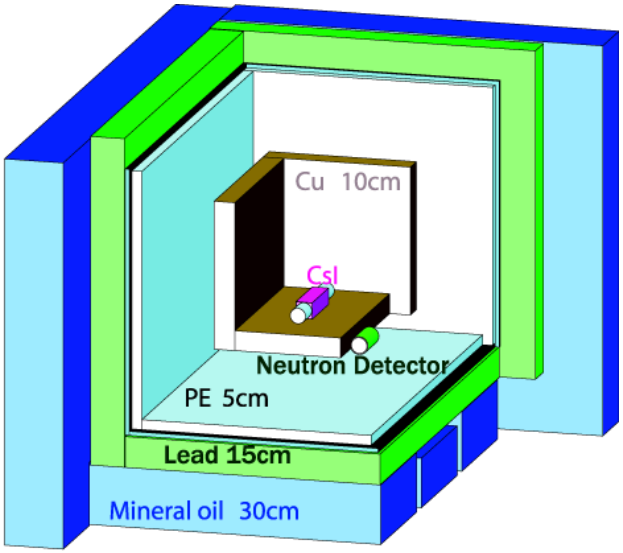
DM search experiment with CsI crystal

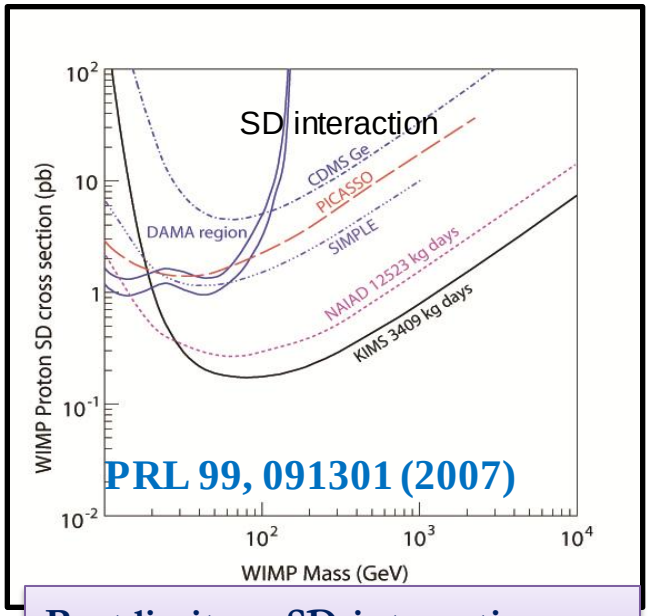
CsI(Tl) Crystal 8x8x30 cm^3 (8.7 kg)

3" PMT (9269QA) : Quartz window, RbCs photo cathode

~5 Photo-electron/keV





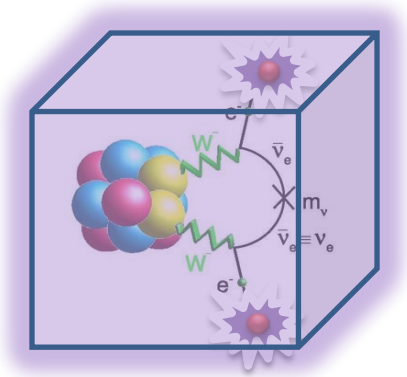


Best limit on SD interactions in case of pure proton coupling

12 crystals(104.4kg) running

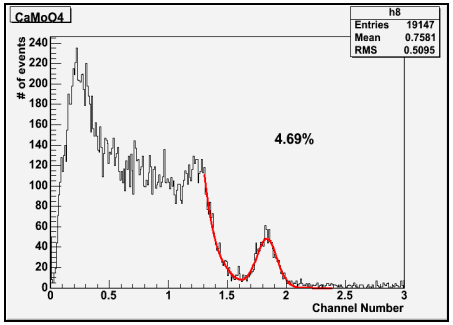
- Stable data taking for more than a year
- Unique experiment to test DAMA annual modulation

AMORE Experiment at Y2L



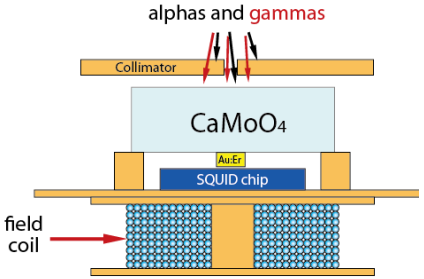
Double beta decay search with $^{40}Ca^{100}MoO_4$ crystal
Int. Collaboration : Korea, Russia, Ukraine, China
in preparation

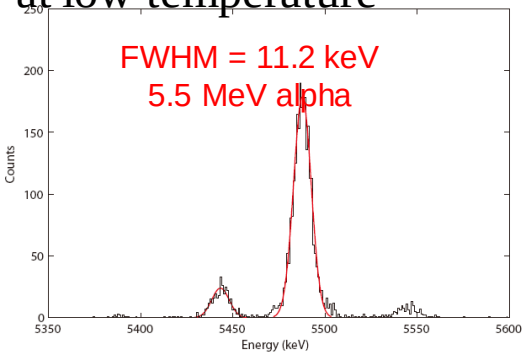
$^{40}Ca^{100}MoO_4$ crystal
- Unique in the world (depleted Ca + enriched Mo)
- Scintillation crystal + Cryogentic detector



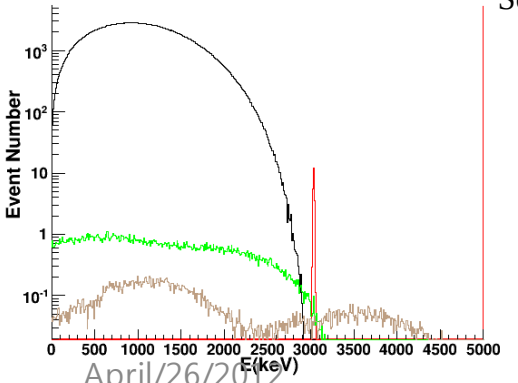
Energy spectrum for 600 keV gamma
Scintillation readout

MMC+CMO at low temperature



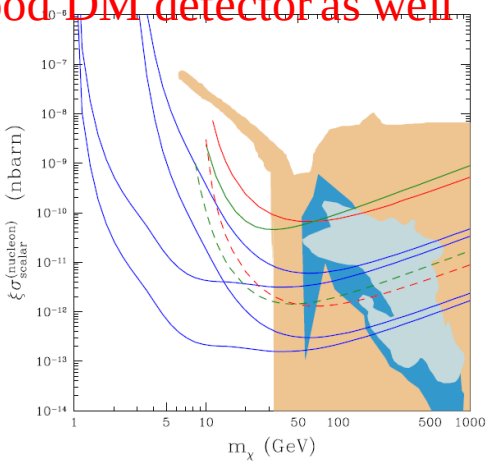


good DM detector as well



Cryogenic $CaMoO_4$ Sensitivity

0.5% FWHM → 15 keV FWHM for low temp.
5 years, 100 kg $^{40}Ca^{100}MoO_4$:
$T_{1/2} = 7.0 \times 10^{26}$ years → <m> = 20 – 70 meV
Fully covers inverted hierarchy



AMORE Collaboration

- Korea (35)
  Seoul National University : H.Bhang, S.Choi, M.J.Kim, S.K.Kim, M.J.Lee, S.S.Myung, S.Olsen, Y. Sato, K.Tanida, S.C.Kim, J.Choi, S.J.Lee, J.H.Lee, J.K.Lee, H.Kang, H.K.Kang, Y.Oh, S.J.Kim, E.H.Kim, K.Tshoo, D.K.Kim (21)
  Sejong University : Y.D.Kim, E.-J.Jeon, K. Ma, J.I.Lee, W.Kang, J.Hwa (5)
  Kyungpook national University : H.J.Kim, J.So, Gul Rooh, Y.S.Hwang(4)
  KRISS : Y.H.Kim, M.K.Lee, H.S.Park, J.H.Kim, J.M.Lee (5)
- Russia (16)
  ITEP(Institute for Theoretical and Experimental Physics) : V.Kornoukhov, P. Ploz, N.Khanbekov (3)
  Baksan National Observatory : A.Ganggapshev, A.Gezhaev, V.Gurentsov, V.Kuzminov, V.Kazalov, O.Mineev, S.Panasenko, S.Ratkevich, A.Verensnikova, S.Yakimenko, N.Yershov, K.Efendiev, Y.Gabriljuk (13)
- Ukraine(11)
  INR(Institute for Nuclear Research) : F.Danevich, V.Tretyak, V.Kobychev, A.Nikolaiko, D.Poda, R.Boiko, R.Podviianiuk, S.Nagorny, O.Polischuk, V.Kudovbenko, D.Chernyak(11)
- China(2)
  Tsinghua University : Y.Li, Q.Yue(2)

4 countries
8 institutions
64 collaborators

Korean Contribution to CMS

- Swiveling System for the SC Magnet
  - Korean CMS teams
- RPC gaps for Endcap Muon Chambers
  - led by Korea University team
- DAQ and Online-Computing
  - led by CHEP and Kyungpook National Univ.
- Core Computing: CMS Tier-2
  - by CHEP and Kyungpook National Univ.

Korean CMS institutions and members

- Kyungpook National University (10 Ph.D.)
  - D. Son, G.N. Kim, D. Kim, S. Uozumi, H.K. Park, D.J. Kong, J.E. Kim, Y.D. Oh, S.E. Lee, T. Kamon, + 3 software engineers
- Korea University (5 Ph.D.)
  - S.K. Park, B.S. Hong, S.Y. Choi, K.S. Lee, T.J. Kim+3 technicians
- Sungkyunkwan University (4 Ph.D.)
  - Y.I. Choi, I.T. Yu, H.K. Suh, M.S. Kim
- University of Seoul (3 Ph.D.)
  - I. Park, C. Park, J.H. Kim
- Kangwon National University (2 Ph.D.)
  - S.K. Nam, T.Y. Kim
- Chonnam National University (1 Ph.D.)
  - J.Y. Kim

CMS Tier-2 Center

at the Center for High Energy Physics

CPU (HEP-SPEC06)	4,670 (64bit)
Disk Storage	300 TB (RAID-6)
Tape Library	46 TB
WAN (Networking)	KREONET : 10 Gbps KOREN : 10 Gbps
Grid System	LCG-EGI
Support	CMS Experiment
CMS Computing Role	Tier-2

An additional Tier-3 is established

HEP-SCEC06 : unit of a computing node's performance

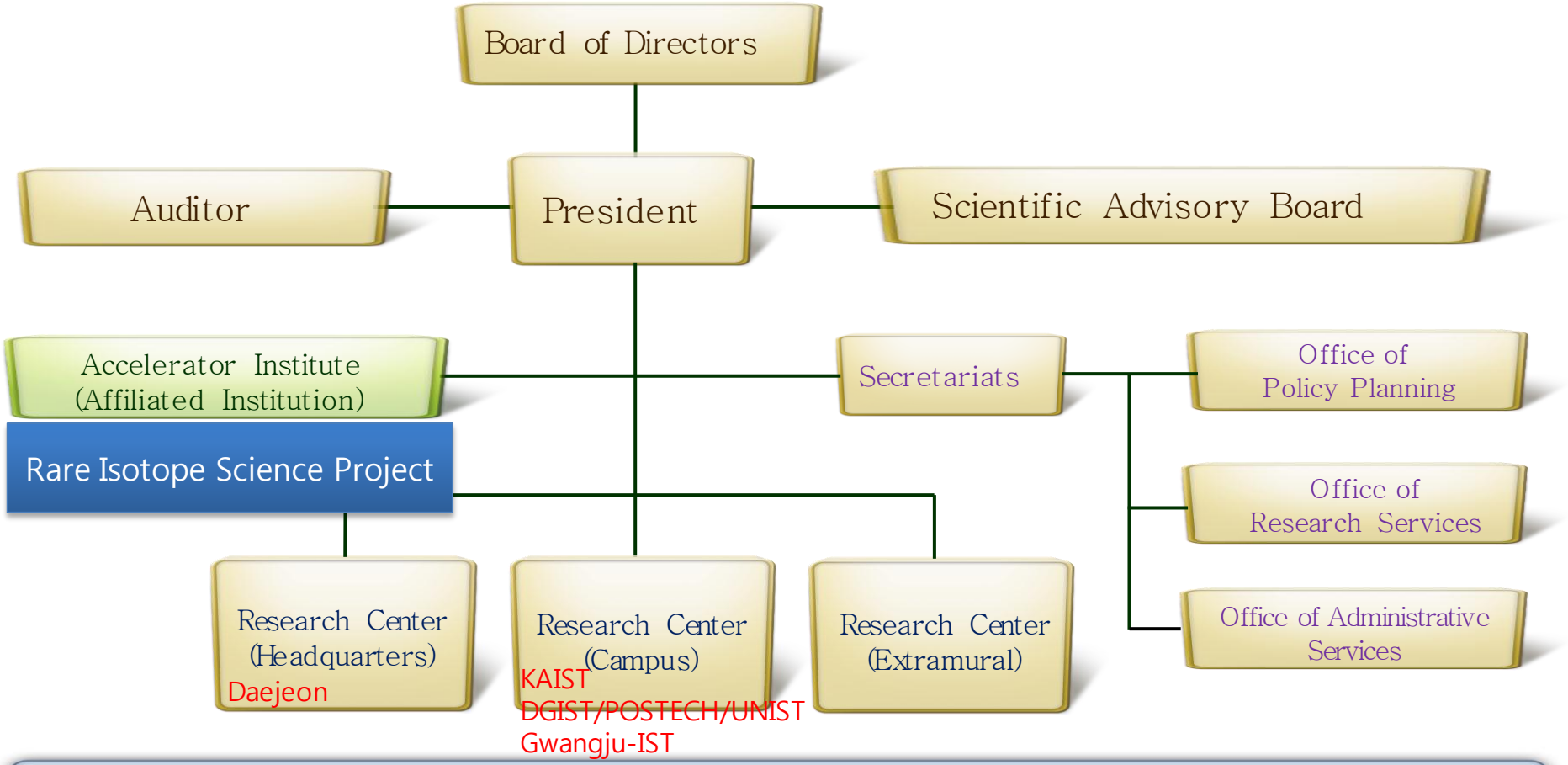
Rare Isotope Science Project (RISP)

Courtesy Slides by Sun Kee Kim

기초과학연구원
Institute for Basic Science

Science Business Belt

Organization of IBS (Institute for Basic Science)



- The number of staff: 3,000 (2017, including visiting scientists and students)
- Annual Budget: USD 610 million (2017, including operational cost for the Accelerator Institute)

Research Topics with Rare Isotopes

- **Nuclear Physics**
  - Exotic nuclei near the neutron drip line
  - Superheavy Elements (SHE)
  - Equation-of-state (EoS) of nuclear matter

Origin of Elements

Stellar Evolution

- **Nuclear Astrophysics**
  - Origin of nuclei
  - Paths of nucleosynthesis
  - Neutron stars and supernovae

- **Nuclear data with fast neutrons**
  - Basic nuclear reaction data for future nuclear energy
  - Nuclear waste transmutation

- **Atomic/Particle physics**
  - Atomic trap
  - Fundamental symmetries

- **Material science**
  - Production & Characterization of new materials
  - β-NMR / μSR

- **Medical and Bio sciences**
  - Advanced therapy technology
  - Mutation of DNA
  - New isotopes for medical imaging

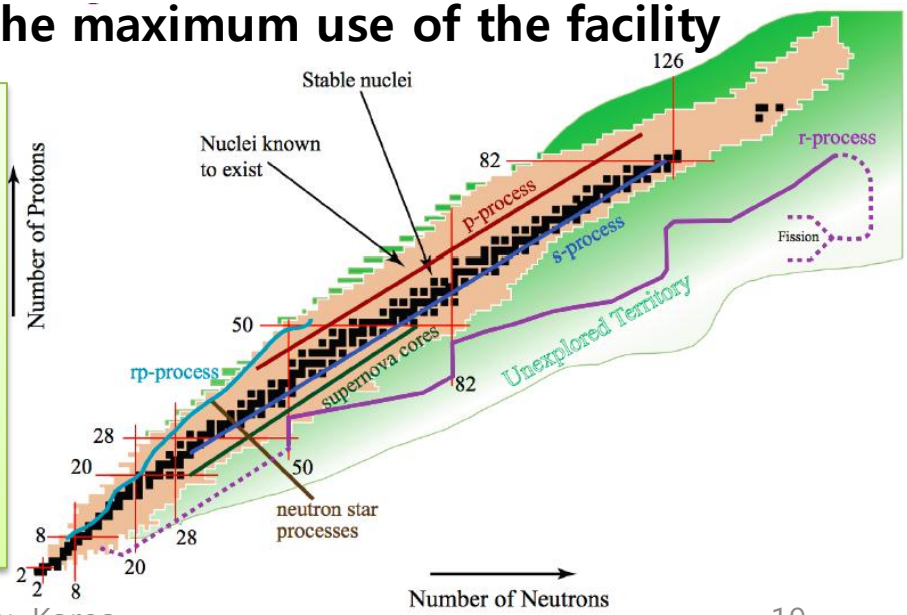
Application of Rare Isotopes

Rare Isotope Factory

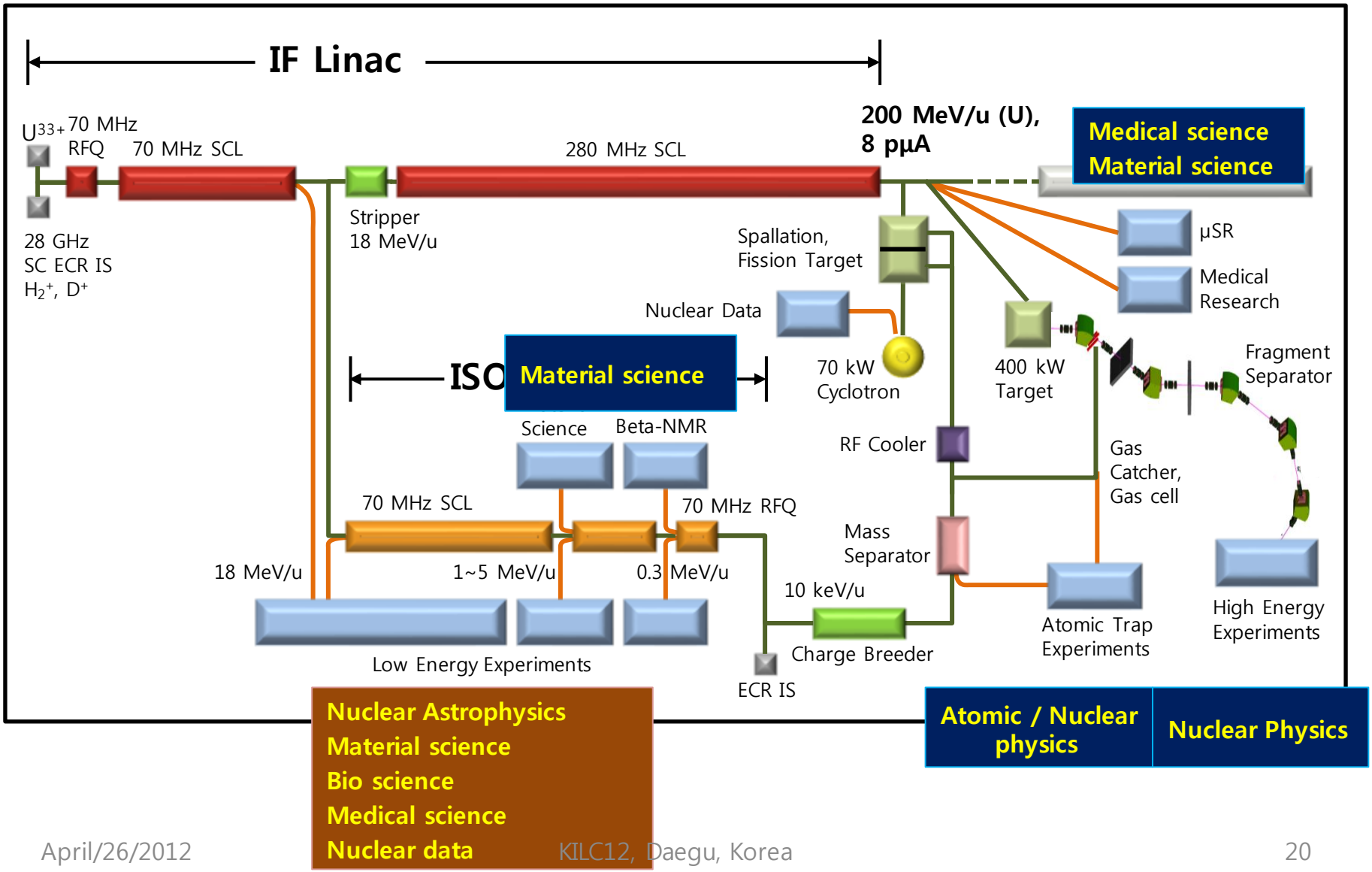
- High intensity RI beams by ISOL & IF
  - 70kW ISOL from direct fission of ^{238}U induced by 70MeV, 1mA p
  - 400kW IF by 200MeV/u, 8pμA ^{238}U
- High energy, high intensity & high quality neutron-rich RI beams
  - ^{132}Sn with up to ~250MeV/u, up to 9x10^{8} pps
- More exotic RI beams by ISOL+IF+ISOL(trap)
- Simultaneous operation modes for the maximum use of the facility

ISOL(Isotope Separator On-Line)
p → thick target (eg. Uranium Carbide)
fission fragments → rare isotopes

IF(In-Flight Fragmentation)
Heavy ion beam → thin target
projectile fragmentation
→ high energy RI beam or
→ stopping and reacceleration



Concept of the Accelerator Complex



Facilities for the scientific researches

- Design of the experimental facilities in conceptual level
- User training program with the international collaboration

Nuclear Structure	Multi-Purpose Spectrometer
Nuclear Matter	Large Acceptance Multi-Purpose Spectrometer (LAMPS)
Nuclear Astrophysics	KoRIA Recoil Spectrometer (KRS)
Atomic physics	Atom & Ion Trap System
Nuclear data by fast neutrons	neutron Time-of-Flight (n-ToF)
Material science	B-NMR/NQR Elastic Recoil Detection (ERD) Laser Selective Ionizer
Medical and Bio sciences	Heavy Ion Therapy Irradiation Facility

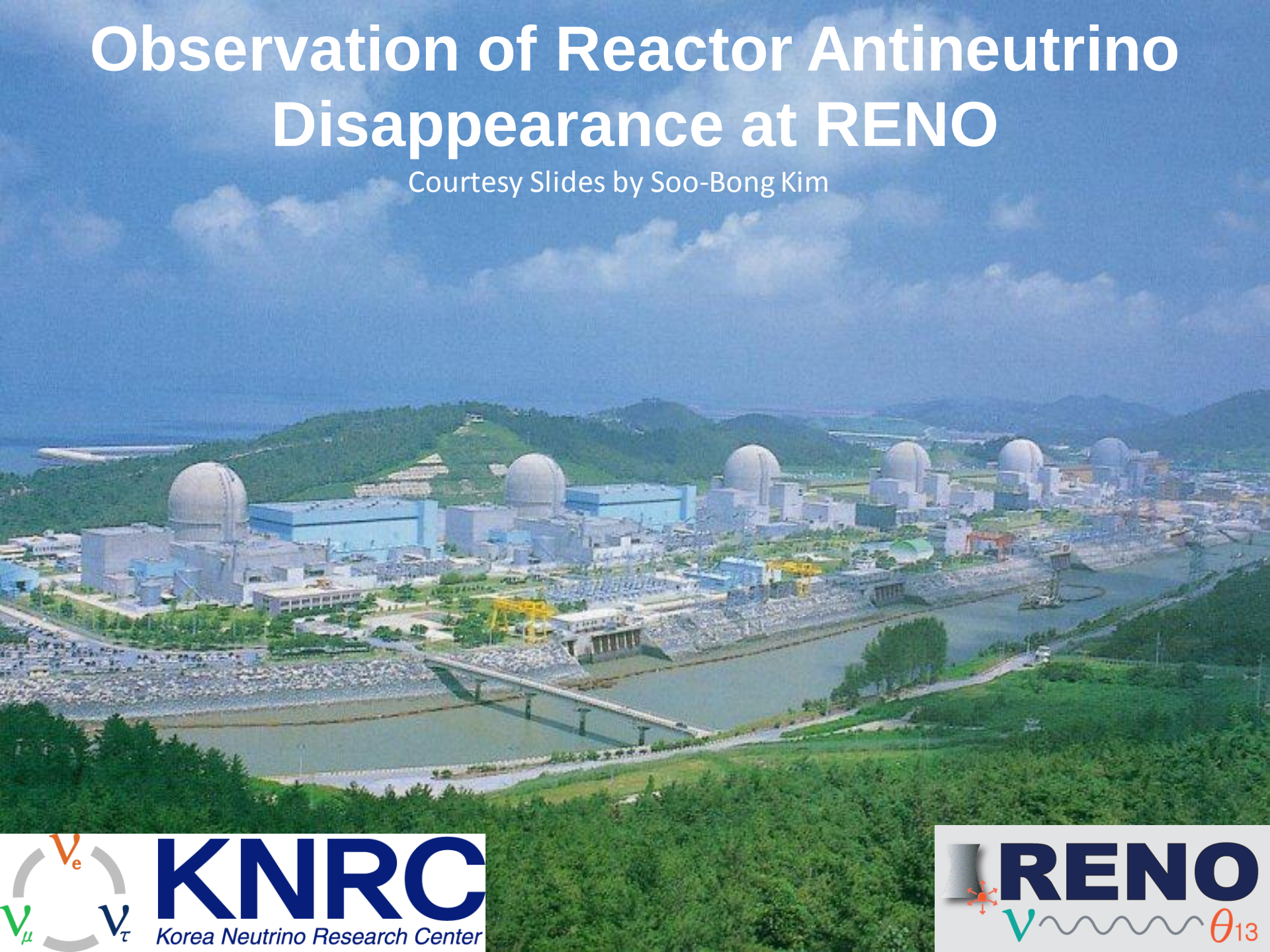
KoRIA user community

Status and Plan

- Conceptual Design report (Mar. 2010 - Feb. 2011)
- IAC review (Jul. 2011 – Oct. 2011)
- **Rare Isotope Science Project started in IBS (Dec. 2011)**
- RISP Workshop on accelerator systems (May 6 – 9, 2012)
- TAC (May 10, 2012), IAC(June 5, 2012)
- **Technical Design Report (by Jun. 2013)**

Observation of Reactor Antineutrino Disappearance at RENO

Courtesy Slides by Soo-Bong Kim



KNRC
Korea Neutrino Research Center

RENO
ν θ_{13}

RENO Collaboration

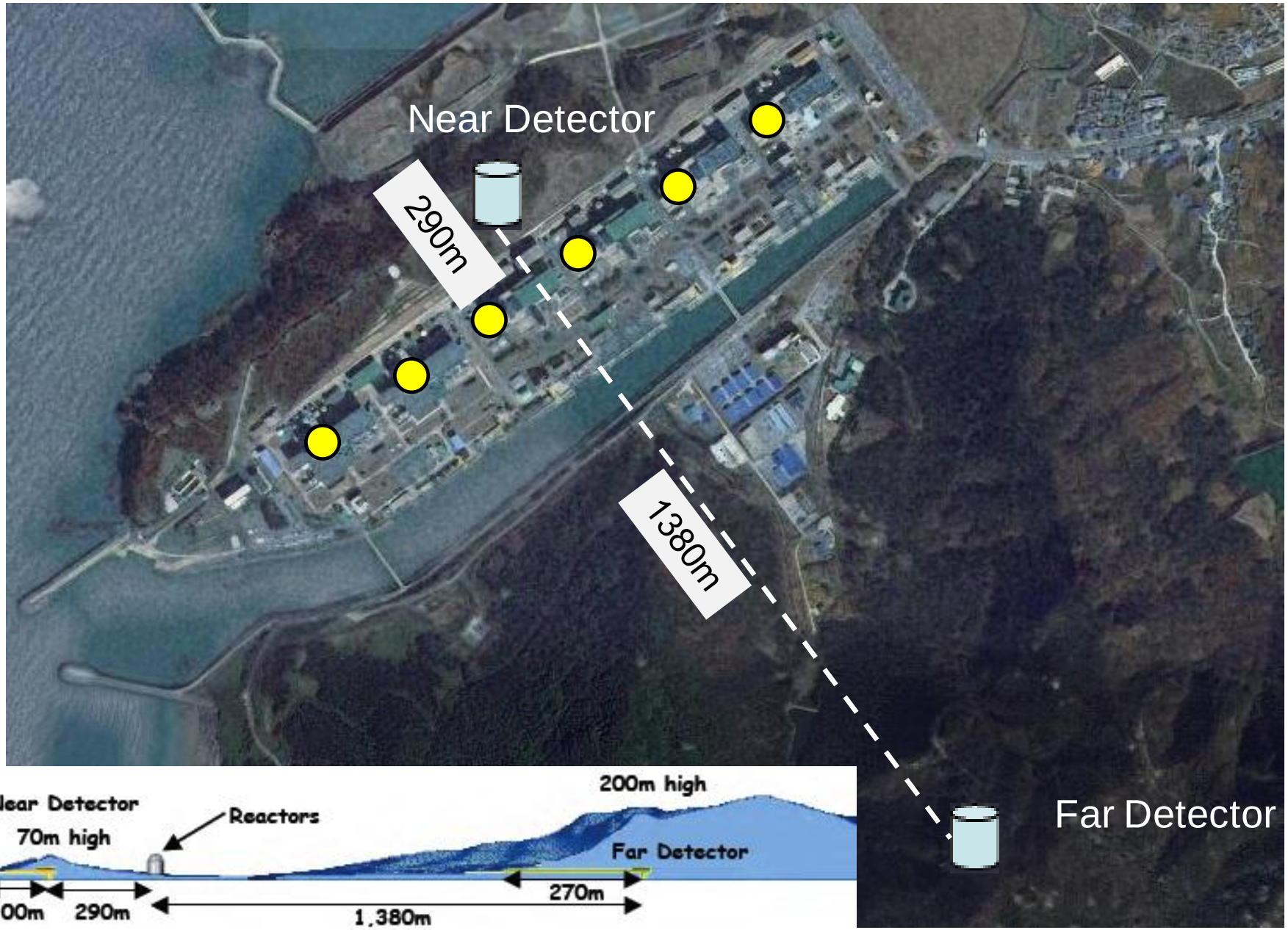
(12 institutions and 40 physicists)

- Chonbuk National University
- Chonnam National University
- Chung-Ang University
- Dongshin University
- Gyeongsang National University
- Kyungpook National University
- Pusan National University
- Sejong University
- Seokyeong University
- Seoul National University
- Seoyeong University
- Sungkyunkwan University

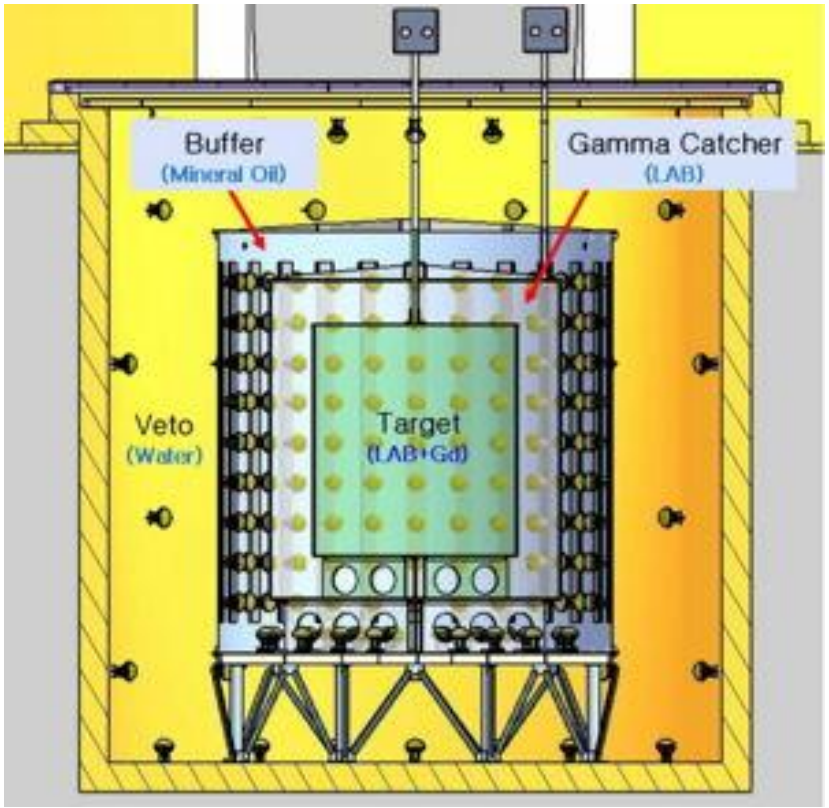
- Total cost : $10M
- Start of project : 2006
- The first experiment running with both near & far detectors from Aug. 2011

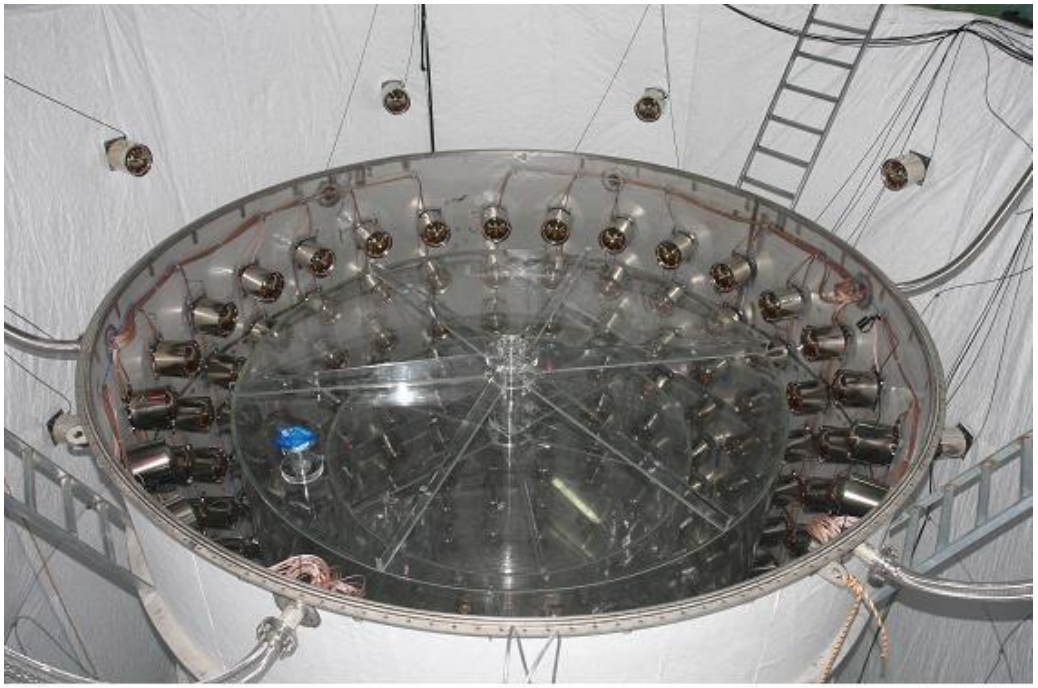
YongGwang (靈光) :

RENO Experimental Setup



RENO Detector



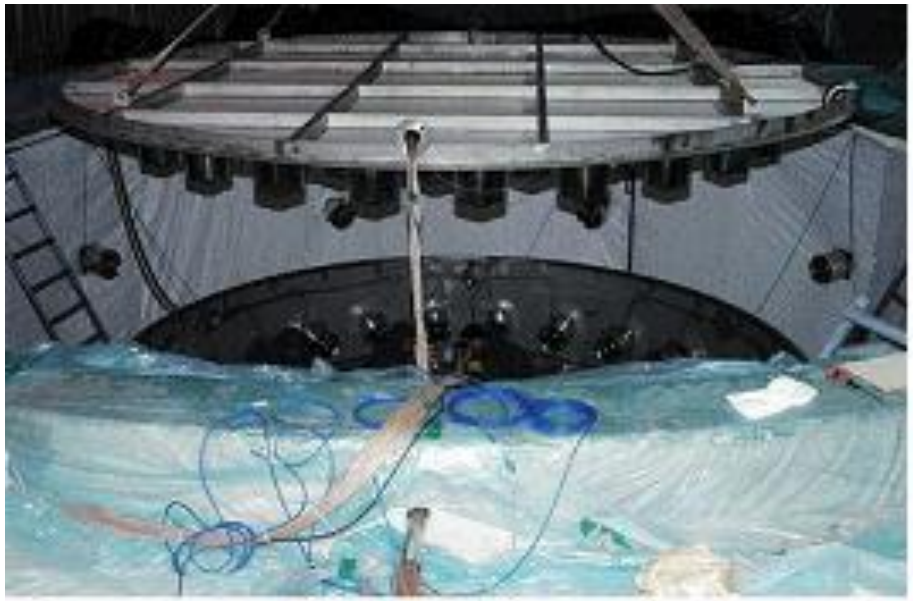


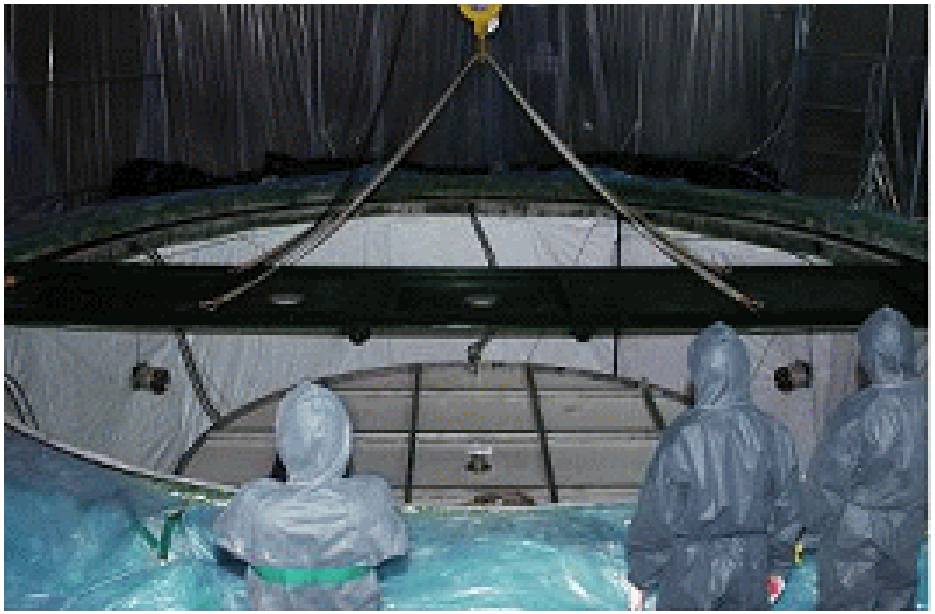
- 354 ID +67 OD 10” PMTs
- Target : 16.5 ton Gd-LS, R=1.4m, H=3.2m
- Gamma Catcher : 30 ton LS, R=2.0m, H=4.4m
- Buffer : 65 ton mineral oil, R=2.7m, H=5.8m
- Veto : 350 ton water, R=4.2m, H=8.8m

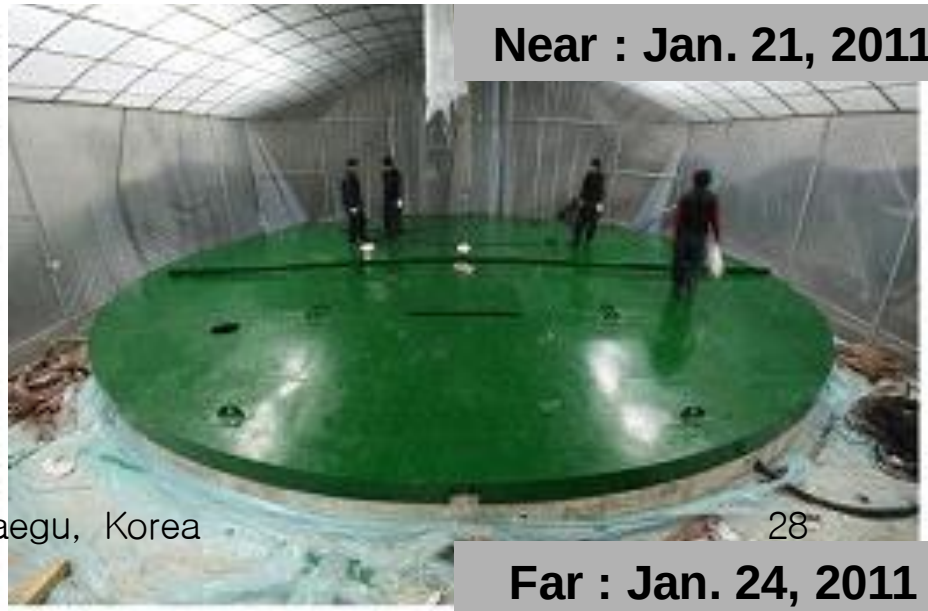
Summary of Detector Construction

- 2006. 03 : Start of the RENO project
- 2008. 06 ~ 2009. 03 : Civil construction including tunnel excavation
- 2008. 12 ~ 2009. 11 : Detector structure & buffer steel tanks completed
- 2010. 06 : Acrylic containers installed
- 2010. 06 ~ 2010. 12 : PMT test & installation
- 2011. 01 : Detector closing/ Electronics hut & control room built
- 2011. 02 : Installation of DAQ electronics and HV & cabling
- 2011. 03 ~ 06 : Dry run & DAQ debugging
- 2011. 05 ~ 07 : Liquid scintillator production & filling
- 2011. 07 : Detector operation & commissioning
- 2011. 08 : Start data-taking

Detector Closing (2011. 1)





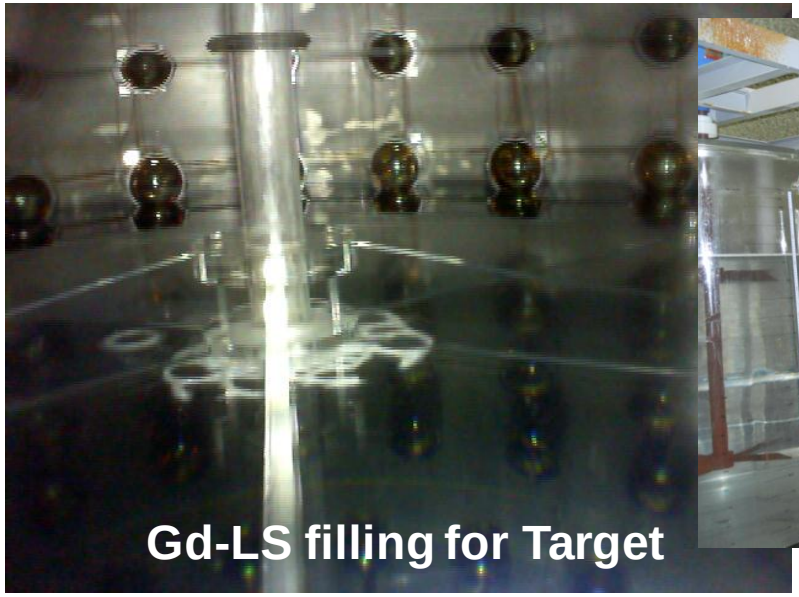


Near : Jan. 21, 2011

Far : Jan. 24, 2011

Liquid(Gd-LS/LS/MO/Water) Production & Filling (May-July 2011)


Gd Loaded Liquid Scintillator


Gd-LS filling for Target

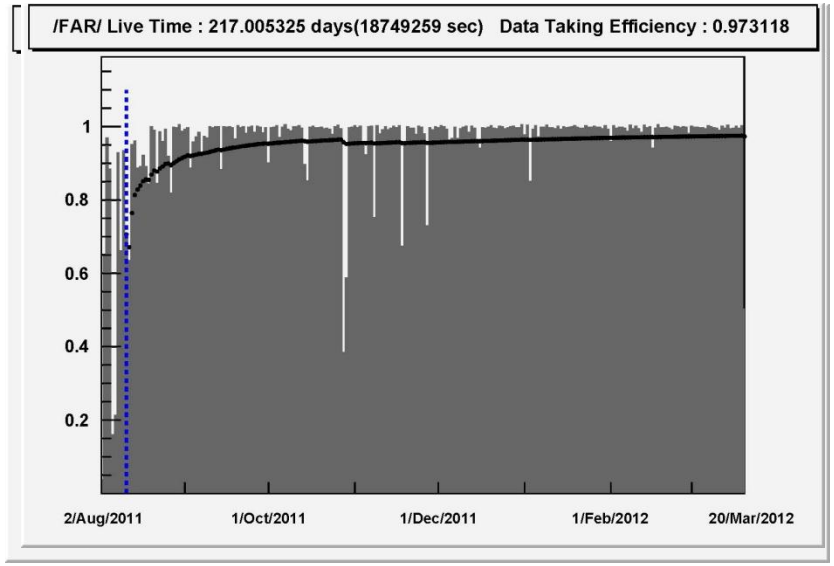

Water filling for Veto

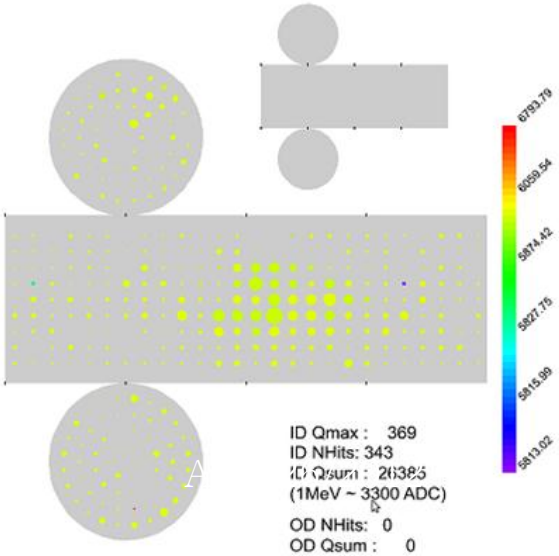

LS filling for Gamma Catcher

Data-Taking & Data Set

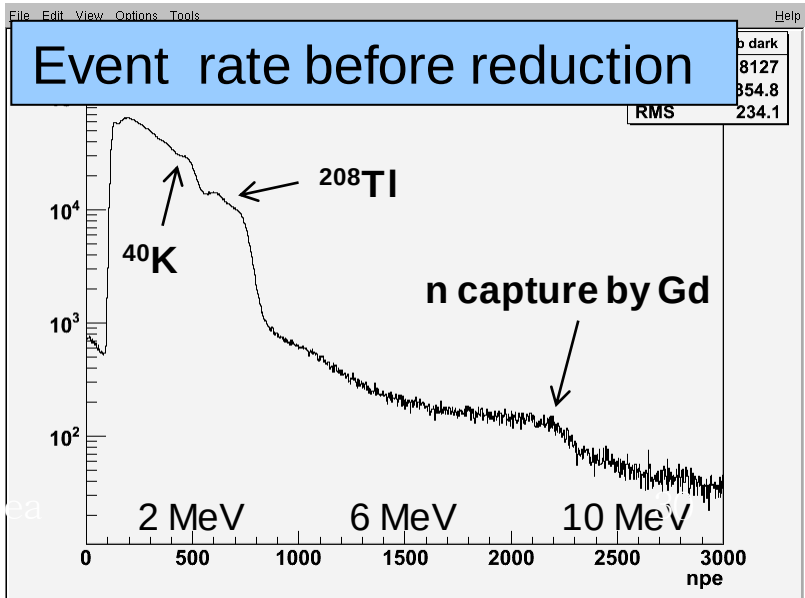
- Data taking began on Aug. 1, 2011 with both near and far detectors.
- Data-taking efficiency > 90%.
- Trigger rate at the threshold energy of 0.5~0.6 MeV : 80 Hz
- Data-taking period : 228 days
  Aug. 11, 2011 ~ Mar. 25, 2012

- Data-taking efficiency





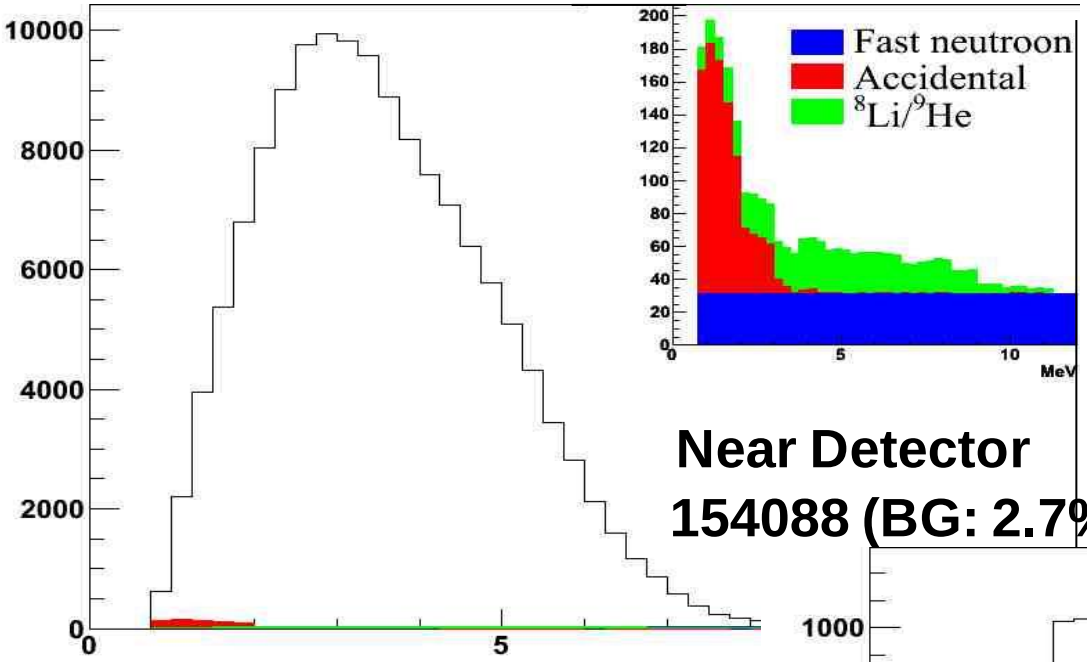
A candidate for a neutron capture by Gd



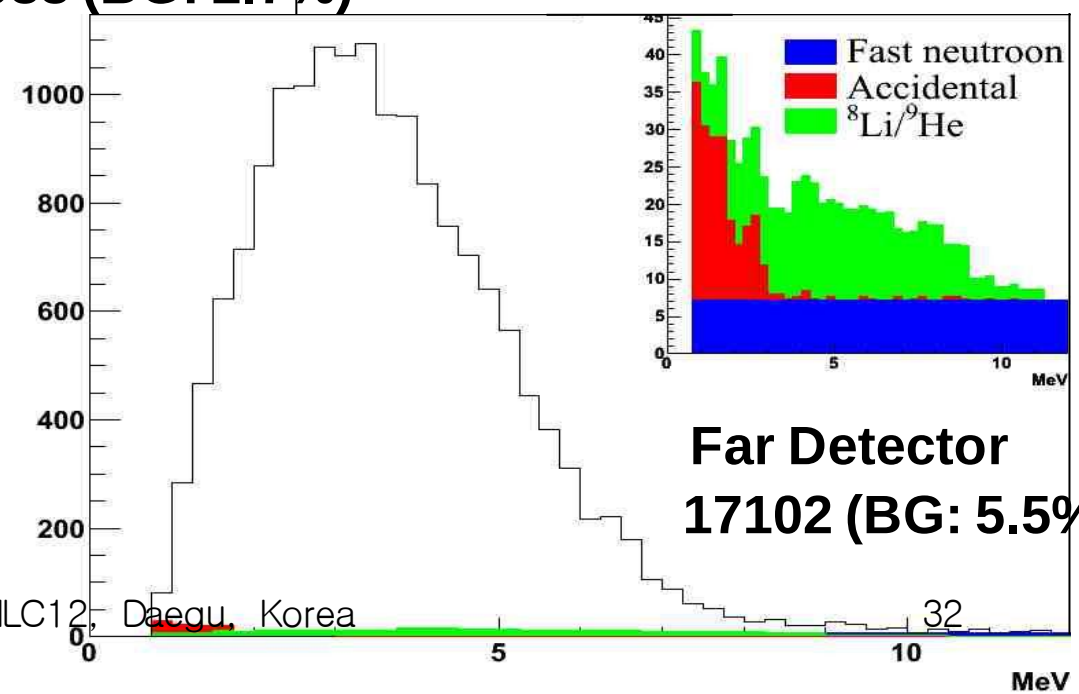
Summary of Final Data Sample

Detector	Near	Far
Selected events	154088	17102
Total background rate (per day)	21.75±5.93	4.24±0.75
IBD rate after background subtraction (per day)	779.05±6.26	72.78±0.95
DAQ Live time (days)	192.42	222.06
Detection efficiency (ϵ)	0.647±0.014	0.745±0.014
Accidental rate (per day)	4.30±0.06	0.68±0.03
^{9}Li/^{8}He rate (per day)	12.45±5.93	2.59±0.75
Fast neutron rate (per day)	5.00±0.13	0.97±0.06

Measured Spectra of IBD Prompt Signal



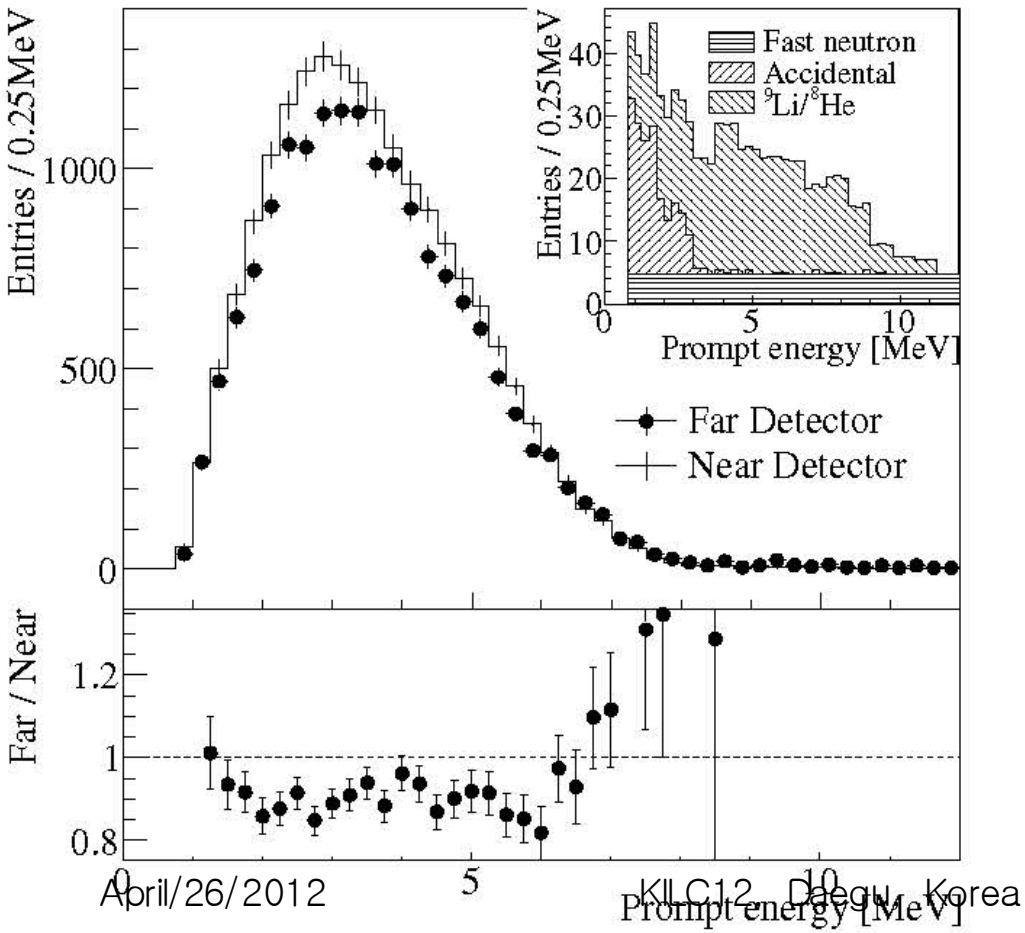
Near Detector
154088 (BG: 2.7%)



Far Detector
17102 (BG: 5.5%)

Reactor Antineutrino Disappearance

$$R = \frac{\Phi^{Far}_{observed}}{\Phi^{Far}_{expected}} = 0.920 \pm 0.009(stat.) \pm 0.014(syst.)$$

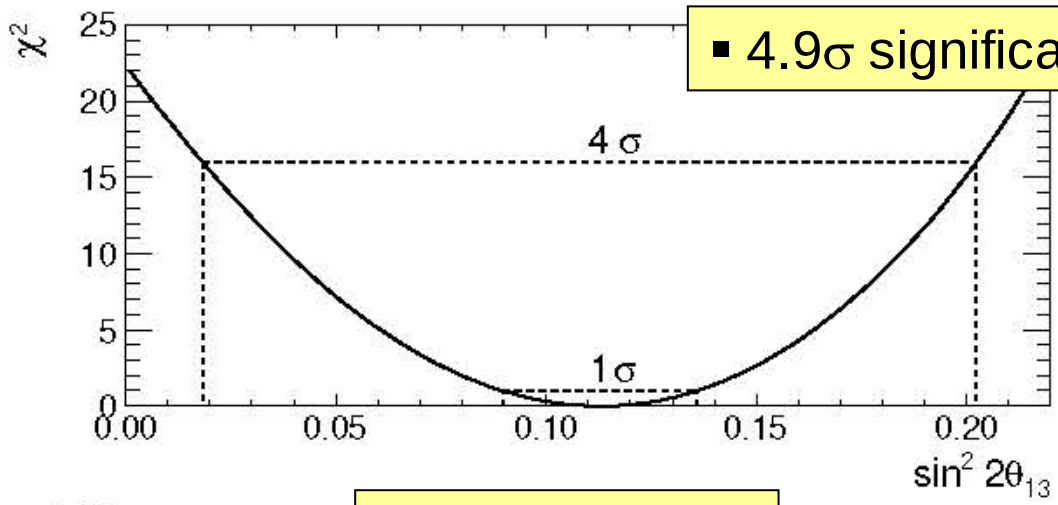


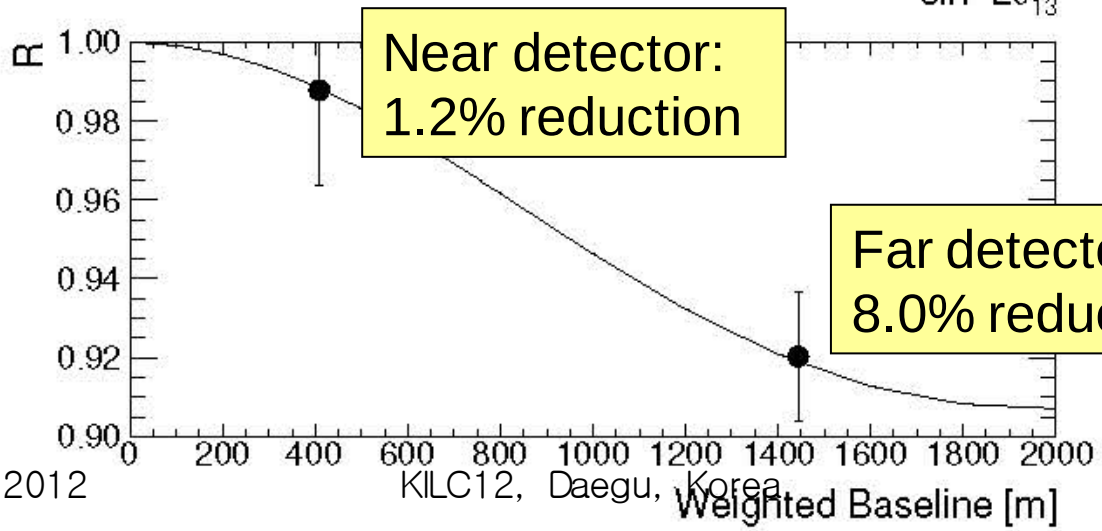
- A clear deficit in rate (8.0% reduction)
- Consistent with neutrino oscillation in the spectral distortion

Definitive Measurement of θ_{13}

$$\sin^2 2\theta_{13} = 0.113 \pm 0.013(stat.) \pm 0.019(syst.)$$

- 4.9σ significant signal





Near detector:
1.2% reduction

Far detector:
8.0% reduction

Future Efforts for Precision Measurement of θ_{13}

RENO

$$\sin^2 2\theta_{13} = 0.113 \pm 0.013(stat.) \pm 0.019(syst.)$$

Daya Bay

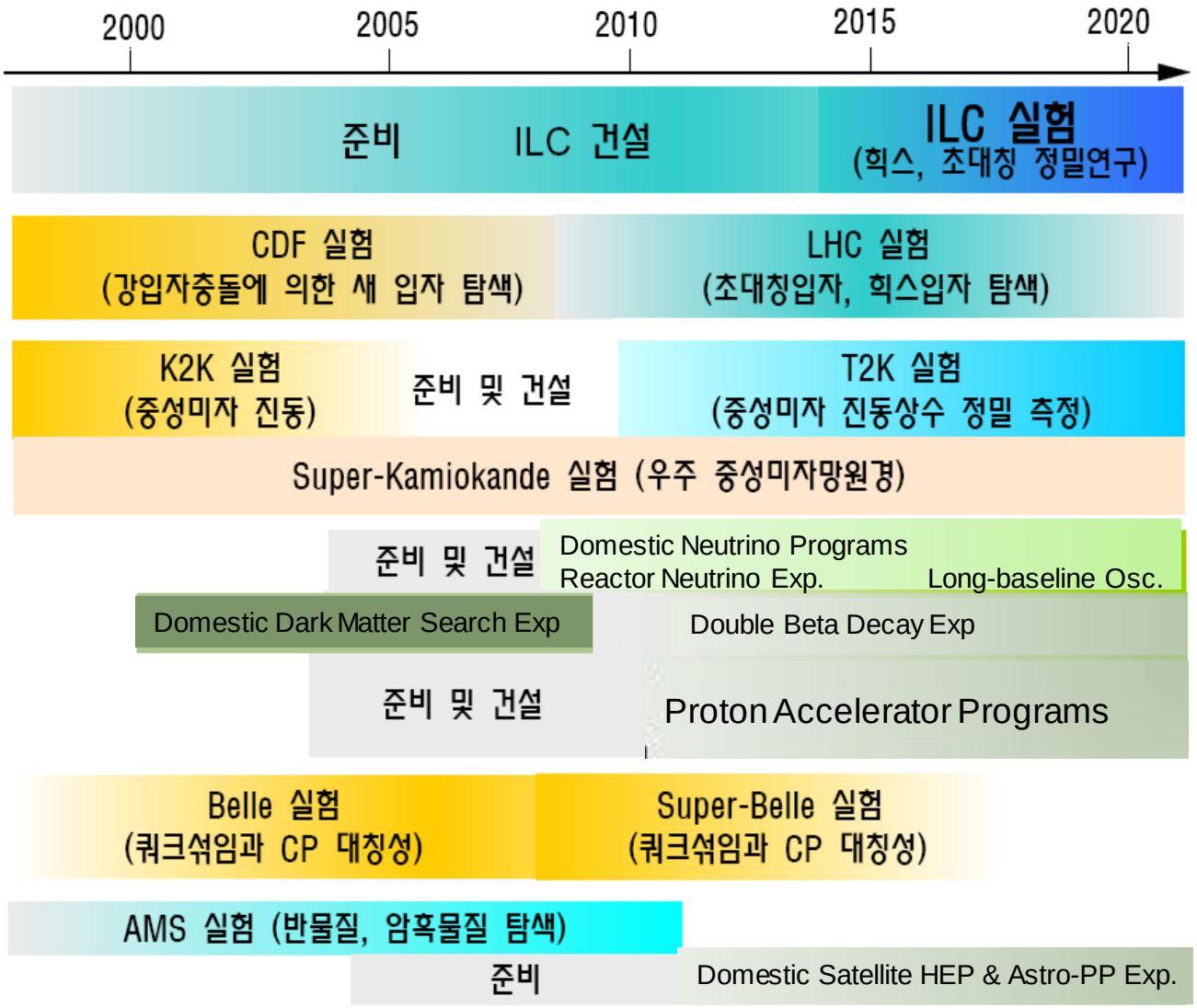
$$\sin^2 2\theta_{13} = 0.092 \pm 0.016(stat.) \pm 0.005(syst.)$$

- Contributions of the systematic errors :
  - Background uncertainties : 0.0165
    (far : 5.5%×17.7% = 0.97%, near : 2.7%×27.3% = 0.74%)
  - Reactor uncertainty (0.9%) : 0.0100
  - Detection efficiency uncertainty (0.2%) : 0.0103
  - Absolute normalization uncertainty (2.5%) : 0.0104

- Remove the backgrounds !
- Spectral shape analysis

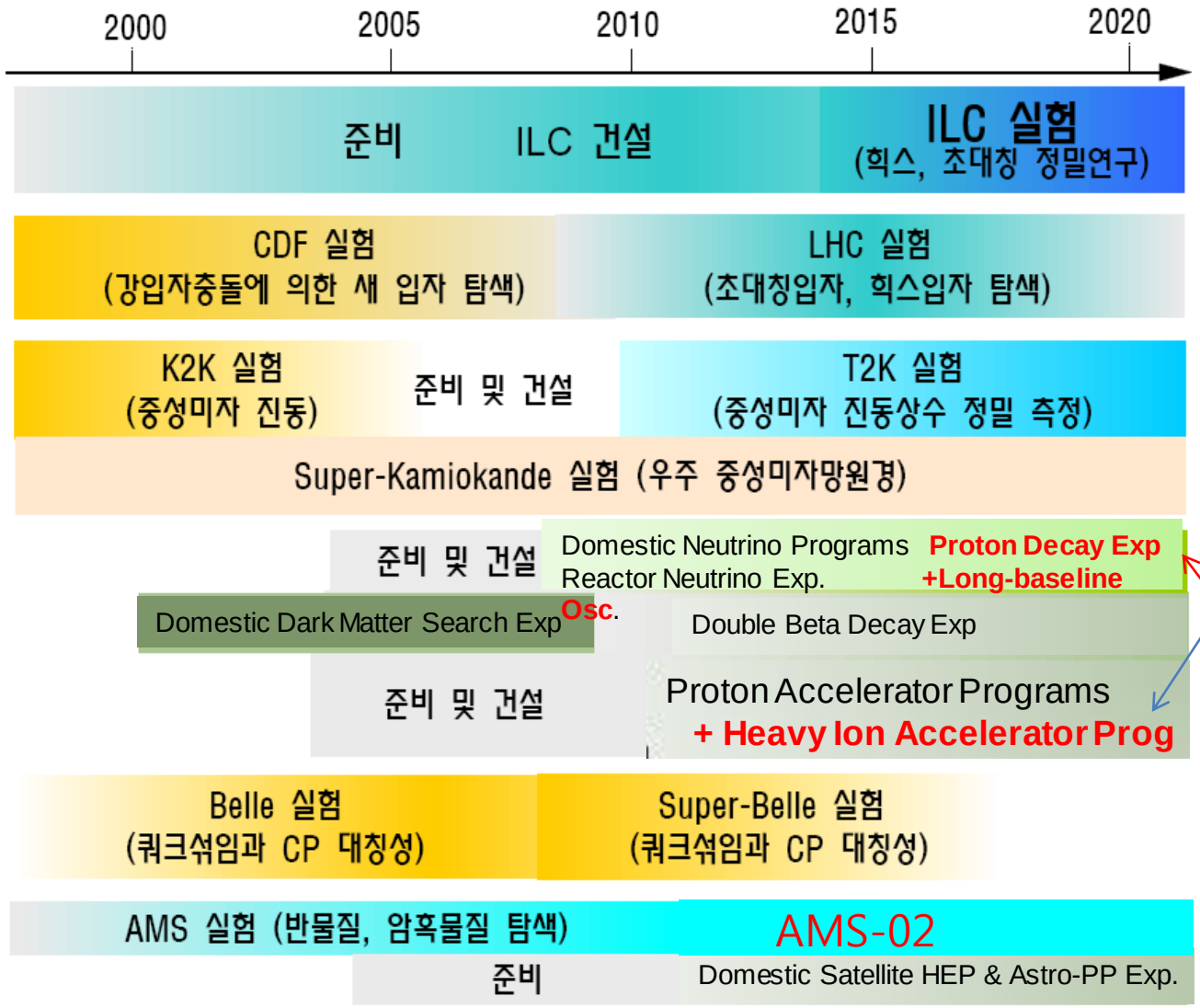
Future Planning

Korean HEP Roadmap (2005)



Strategy Planning Study for ILC (MEST, 2005)

Korean HEP Roadmap to be modified now



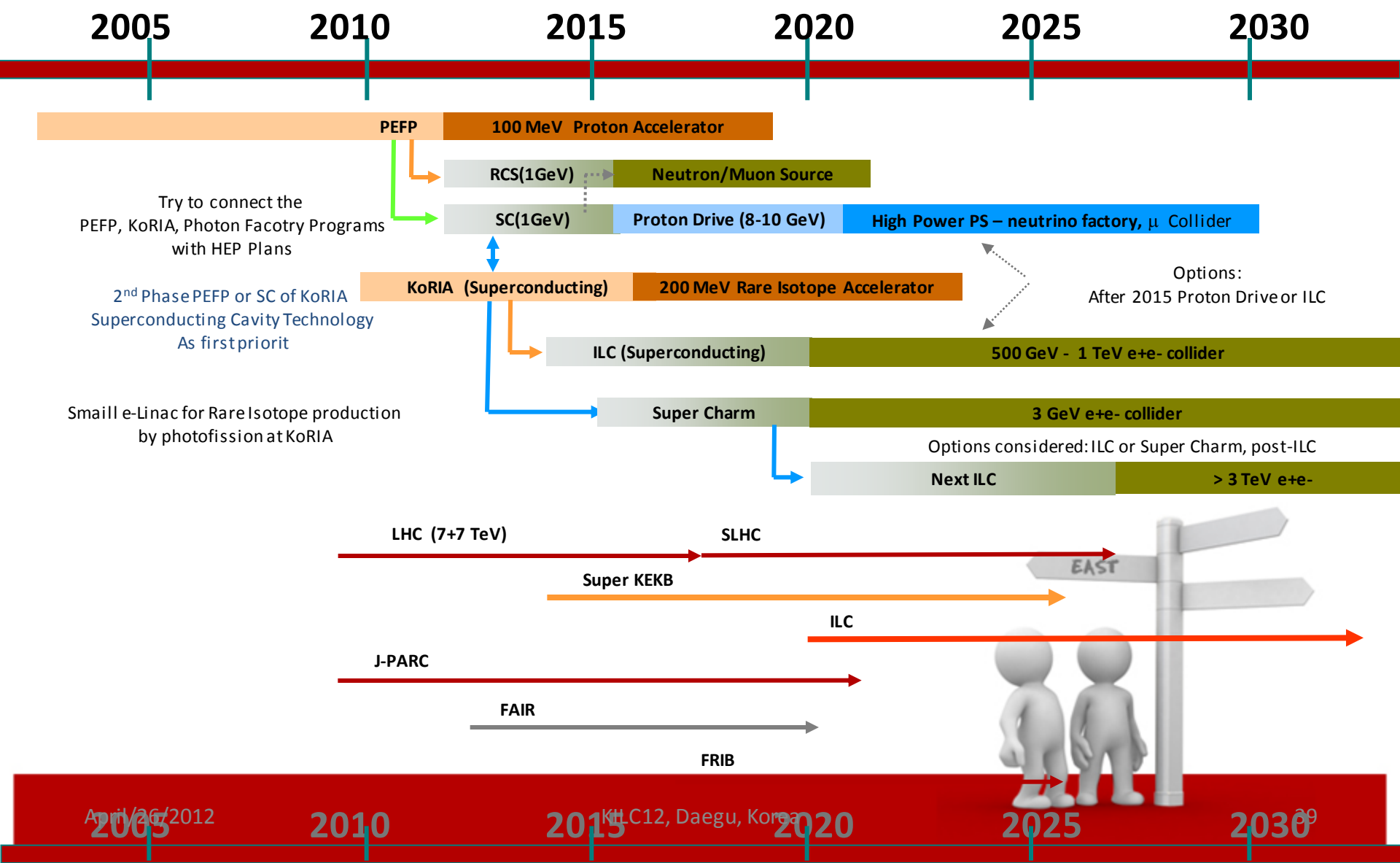
Slipped by 5+years

Adopted in the NFRM

NFRM: National Facility Roadmap by MEST (2011)

Accelerator Based HEP Roadmap

(2009.4, KHEP Association)



KOREAN CMS COMPUTING ROADMAP

by the CMS-T2 team

	2005	08	10	12 today	15	20	25	30
K CMS T2 upgrade					x5	x50	x100	x200	x500
CPU (kHS06)	2.0			4.7	21	210	420	840	2100
DISK (PB)	0.115			0.30	1.2	12	24	48	120
K CMS T1					Install	upgrade	x5		
CPU (kHS06)					10 20		100		
DISK (PB)					2.4		12		
Tape (PB)					6.0		30		
K CMS T3 sites			1	2	3 4	5	6		10

	2005	10	15	20	25	30
LHC/CMS Expectation						
CM Energy		7 TeV	8 TeV	13/14 TeV	14 TeV	14 TeV
Int. Lum (/fb)		6	22	~280	~600	3000
Expected Amount of Data (year)		1	x5 ('14)	x50 ('18)	x100 ('21)	x500 ('30)
Moore's law			1 ('13)	2 ('16) 4 ('19)	8 ('22)	16 ('25) 32 ('28) 50 ('30)

A Vision of Future Korean HEP Facilities

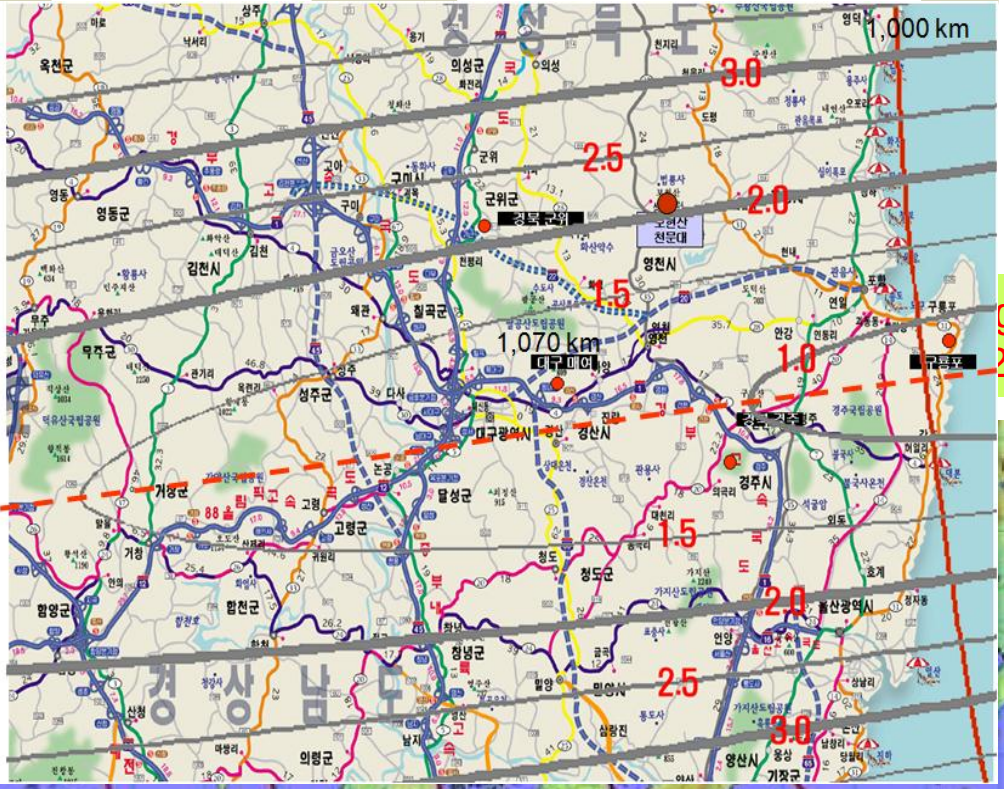
Yangyang Underground Lab (operating)
- Dark matter, Double beta decays

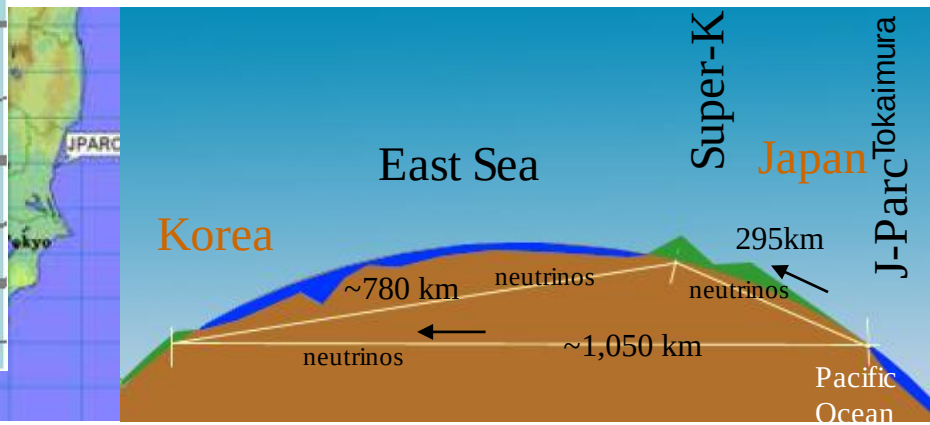
Reactor Neutrino Program
- RENO (started operation)

40~200 GeV Proton accelerator?
KoRIA for HEP, ILC?

LCG Tier-2s (CMS, ALICE)
CMS Tier-1 (CMS, proposal stage)

g baseline neutrino Exp & Proton Decay Exp.
2KK (working for a proposal)





Future Directions and Conclusions

- Full exploitation of on-going Experiments
  - CMS, AMS, KIMS/AMORE, RENO, etc.
- R&D for the Next Energy Frontier Accelerator-based HEP
  - SCRF, BPM, and other ILC accelerator components and detectors
  - Working together with the Proton Linac and KoRIA programs
- R&D for the coming-soon High Luminosity B-physics experiment
  - Belle-II and/or rare-decay programs
- R&D for the Large Scale Underground HEP Facility
  - Proton decay and Long-baseline neutrino exps.
- We are gaining experience and momentum toward better contribution to the world science community