What’s next: Asia

T. Nakaya (Kyoto)
Physics (in WIN conferences)

- Higgs
- Neutrinos
- Flavor Physics
- Astroparticle Physics (w/ Dark Matters)
  - (Gravitational Wave and Cosmology)

<<What are the main contributions (concerning the physics of interest for WIN) we can expect from your region in the coming years?>>

This talk is based on my biased view to particle physics projects in Asia with my limited knowledge. It is NOT a fair review talk.
How can Asian projects/facilities impact upon Europe’s particle physics future?

Desire
Resources
People
Technology

• Characters of the Asian region in my view
  • Growth, Passion, Diversity and Curiosity!
Physics with projects in Asia (presented in WIN2019)

- Higgs
  - Many Asian scientists are working for ATLAS/CMS.
  - Higgs Factory [CepC, ILC]
- Neutrinos
  - Super-Kamiokande -> Hyper-Kamiokande
  - KamLAND -> KamLAND 2
  - Daya Bay -> JUNO
  - T2K w/ J-PARC and ND280 upgrade
  - INO
  - AMoRE
  - NEOS
  - JSNS$^2$
- Flavor Physics
  - BES III
  - Belle II/SuperKEKB
  - J-PARC: K0TO, COMET and $\mu$ g-2
- Astroparticle Physics (w/ Dark Matters)
  - CALET
  - DAMPE
  - HERD on CSS
  - GAPS
  - PANDA-X
  - COSINE
  - SABRE on SUPL (Australia)
  - CDEX
  - NEWAGE
- (Gravitational Wave & Cosmology)
  - KAGRA (Japan)
  - Ngari Observatory (China)
  - GroundBIRD, LightBIRD
Existing Facilities

• **Japan:**
  • SuperKEKB/Belle II - high intensity B-factory
  • SuperKamiokande (T2K) (→ HyperK and Upgraded J-parc)
  • J-parc high intensity, low energy physics - COMET
  • Kamioka U/G Observatory - XMASS-I Direct Dark Matter Search
  • ...

• **China:**
  • Daya Bay (→ JUNO) - Reactor Neutrino Physics
  • BEPC (Proposal: tau/charm factory)
  • LHAASO - Very high energy cosmic ray observatory
  • Jinpin - U/G laboratory - PANDA-X and CDEX Direct Dark Matter Searches
  • ...

• **Korea:**
  • RENO - Reactor neutrino physics
Fundamental Questions
Questions

- GUT: Unification of forces [and leptons and quarks]
- Origin of generations (family structure)
- Origin of neutrino mass
- Strong CP
- Baryon and anti-baryon asymmetry of our universe
- Dark Matter
- Accelerating universe
- Inflation

We do not know the energy scale of New Physics
Should look for wider energy regions

Three arrows are added by TN (neutrino, dark matter and HL-LHC)
Questions

- GUT: Unification of forces [and leptons and quarks]
- Origin of generations (family structure)
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- Strong CP
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- Dark Matter
- Accelerating universe
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→ It is a good time to look over new physics with various ways in many aspects [as a purpose of WIN]
Higgs
Higgs Factory

China and Japan propose a Higgs Factory as the future facility in Asia.

CEPC CDR  https://arxiv.org/abs/1809.00285


Strategy Documents:  
https://ilchome.web.cern.ch/content/ilc-european-strategy-document  
ILC Staging Report 2017  
https://arxiv.org/abs/1711.00568

Prospect in Accelerators by S. Guiducci @ WIN2019
What else do we learn from Higgs?

Many problems of particle physics today relate to Higgs observables

from “Summary: Electroweak Session” in EPPSU2019
• We all understand the importance of a Higgs factory in the world.

• In addition, we also know it is an expensive (and very long-term) facility.

• I think that the support of the international community is essential to realize the Higgs factory.

• It will be the international facility (not only Asia).
Neutrinos
Successful History (in Asia)

- Kamiokande, Super-Kamiokande, K2K/T2K, KamLAND, OPERA
- Daya Bay
- RENO

For the fundamental discovery and exploration of neutrino oscillations, revealing a new frontier beyond, and possibly far beyond, the Standard Model of particle physics.

Breakthrough Prize  Special Breakthrough Prize  New Horizons Prize  Physics Frontiers Prize


Kam-Biu Luk and the Daya Bay Collaboration  Yifang Wang and the Daya Bay Collaboration  Koichiro Nishikawa and the K2K and T2K Collaboration  Atsuto Suzuki and the KamLAND Collaboration

Arthur B. McDonald and the SNO Collaboration  Takaaki Kajita and the Super K Collaboration  Yoichiro Suzuki and the Super K Collaboration
History of Discoveries at Super-K

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1996</td>
<td>SK Start</td>
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<tr>
<td>1997</td>
<td>K2K start</td>
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<tr>
<td>1998</td>
<td>Discovery of solar neutrino oscillation</td>
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<td>1999</td>
<td>Discovery of atmospheric neutrino oscillation</td>
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<td>2000</td>
<td>Discovery of oscillatory signature (atm.ν)</td>
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<td>2001</td>
<td>Discovery of νe appearance by T2K</td>
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<td>2002</td>
<td>Discovery of ντ appearance (atm.ν)</td>
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<td>2003</td>
<td>Discovery of day/night effect</td>
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<td>2019</td>
<td>SK-Gd start</td>
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</tbody>
</table>

SK-Gd Hope more discoveries

20 Years of Super-Kamiokande and Gd New Era by M. Nakahata @ WIN2019
Hints in neutrinos

• CPV and Mass Ordering!

\[ \delta_{\text{CP}} = 0, \pi \text{ fall outside } 2\sigma \text{ interval} \]

T2K Neutrino Oscillation Results by C. Riccio @ WIN2019

20 Years of Super-Kamiokande and Gd New Era by M. Nakahata @ WIN2019
Water Cherenkov detectors in Japan

- Kamiokande
  - 4.5 (0.68) kton (1983-1996)
  - PMT coverage 20%
  - Neutrinos from SN1987a, deficit of atmospheric neutrinos

- Super-Kamiokande
  - 50 (22.5) kton (1996-)
  - PMT coverage 40%
  - Oscillations of solar and atmospheric neutrinos
  - World leading limit on proton lifetime
  - $\nu_e$ appearance

- Mature, known, scalable technology

- Hyper-Kamiokande
  - 258 (187) kton (~2027-)
    - PMT coverage 40%
    - Proto-collaboration formed January 2015
    - ~300 people, ~80 institutes

J. P. A. M. André for JUNO

Physics prospects of JUNO by J. P. A. M. André @WIN2019

Hyper-Kamiokande by J. Łagoda @WIN2019
"Power Upgrade in 2020-2028"
Prospect in Accelerators by S. Guiducci
@ WIN2019
Check anomalies (eV sterile neutrinos)!

JSNS$^2$

- Detector @ 3rd floor (24m from target)
- Hg target = Neutron and Neutrino source
- 17t Gd-loaded liquid scintillator / detector (total 50tons/detector) (4.5m diameter x 4.0m height) 193 PMTs
- 3GeV pulsed proton beam
- Searching for neutrino oscillation: $\nu^c \rightarrow \nu^e$ with baseline of 24m.
- No new beamline, no new buildings are needed → quick start-up

NEOS

- Overflow buffer calibration access
- Pb 10 cm
- B-PE 10 cm
- $\bar{\nu}_e$ target
- Muon counter

- JSNS$^2$: Data taking will start in 2019.
- NEOS: Under data taking toward the new results in 2020.
Search for the Majorana particle

KamLAND-Zen 400

Zen400
380 kg Xe
’11—’15

KamLAND-Zen 800

Zen800
750 kg Xe
NOW

KamLAND2-Zen

2-Zen
1000 kg Xe
Future

X^{100}MoO_4
200 kg
AMoRE-II

\( ^{40}\text{Ca}^{100}\text{MoO}_4 \)
\(~ 1.5 \text{ kg} \)
AMoRE Pilot

\( ^{40}\text{Ca}^{100}\text{MoO}_4 \)
\(~ 5 \text{ kg} \)
AMoRE-I

arXiv:1610.08883
Limit on Majorana eff. mass

KamLAND-Zen ($^{136}$Xe)

IH

NH

PRL 117, 082503 (2016)
Supernova Relic Neutrinos

At present, we are getting neutrinos from $10^{8}$ supernovae every year.

Horiuchi, Beacom (2010)

Star Formation Rate

Initial Mass Function

$\frac{1}{7}$\,$^6$T$_E$ + $\pi$$_\nu$$_\pi$$_\nu$

We can study star formation history and averaged neutrino spectrum.

The JUNO detector

Top Tracker (TT)

Water Cherenkov Detector (WCD)

Central Detector (CD) – $\bar{\nu}$ target

44 m, 43.5 m (Acrylic Sphere: $\approx 35.4$ m)

Precise $\mu$ tracker

3 layers of plastic scintillator

$$\llap{\sim} 60\%$$ of area above WCD

25 kton ultra-pure water

2.4k 20" PMTs

High $\mu$ detection efficiency

Protects CD from external radioactivity

Acrylic sphere with 20 kton liquid scint.

18k 20" PMTs + 25k 3" PMTs

3% energy resolution @ 1 MeV

J. P. A. M. de André for JUNO

WIN 2019

June 4th, 2019

6 / 19
Flavor Physics
Hints of New Physics!

**K (ε’/ε) : 2.8σ deviation from SM**

If $|C_{NP}| \sim 1$

$$\Delta A_{CP} = (-15.4 \pm 2.9) \cdot 10^{-4}$$

**μ g-2: 3.7σ deviation from SM**

New Physics implication from Kaon physics by K. Yamamoto @WIN2019

**CPV in D : 5.3σ**

**R_K in B : ~3σ deviation from SM**

**R_D(∗) in B : 3.1σ deviation from SM**
Recent BESIII results in open charm by K. Ravindran + other BESIII talks @WIN2019

• Rich physics as a tau&charm factory
• Various interesting results coming
B-Factory: Belle II/SuperKEKB

- Physics data taking with the full detector just started in March 2019.
- Many interesting results are expected in the coming years.

Strengths of SuperKEKB and Belle II

- Very clean sample of quantum correlated $B_0\bar{B}_0$ pairs.
- High effective flavor-tagging efficiency (~37%).
- Belle II can also measure $K_S$ and $K_L$.
- Efficient reconstruction of neutrals ($\pi^0$, $K_S$, $K_L$, $\eta$, $\eta'$, $\rho$+ etc.)
- Dalitz plot analyses, missing mass analyses straightforward.
- Systematics quite different than those of LHCb.
- If NP is seen by one experiment, it should be confirmed by the other.

"Phase 3"

- Phase 3: Collision data taking with full Belle II
- STARTED in MARCH 2019!
- Operation had to stop between April 3rd and 22nd due to a fire accident in one of the test facilities at KEK. Not related to SuperKEKB or Belle II!

Beam background remediation is the current focus.

Continuous injection $e^-$ current $e^+$ current Luminosity Collisions with continuous injection
J-PARC: K and $\mu$

- KOTO ($K_L \rightarrow \pi^0 \nu \nu$) experiment starts new data taking after the upgrade.
- COMET ($\mu \rightarrow e$ conversion) and muon g-2 experiments are under preparation.

$\Delta(g-2) = 0.1 \text{ ppm}$
$\Delta\text{EDM} = 10^{-21} \text{ e} \cdot \text{cm}$
Astroparticle Physics (and Dark Matter)
AMS is a pioneer to search for Dark Matter annihilation in Space and to observe the positron and antiproton excess.

There are more observations coming from DAMPE and CALET.
Conclusions

- **GAPS** will search low energy (<0.25 GeV/n) antideuteron in cosmic radiation as indirect signal of dark matter.
- This is a "background free" channel since the secondary antideuteron from CRs interaction is expected to be orders of magnitude lower.
- Complementary detection technique with respect to magnetic spectrometer with exotic nucleus formation and annihilation.
- GAPS will also perform the highest statistical antiproton measurement at these energies and will search for antihelium.
- Construction is proceeding along with simulation and identification studies.
- First flight late 2021 from McMurdo station.

**These results:**

- Confirm the spectral hardening around 300 GeV observed by ATIC/CREAM/PAMELA/AMS-02/CALET
- Reveal a spectral softening above ~10 TeV

The first flight will be late 2021
Underground lab in Asia for Dark Matter Search

CJPL – Deepest underground lab in the world

Labs are built in mines (light blue) and tunnels (dark blue and red).

- Soudan, U.S.
- Y2L, Korea
- Canfranc, Spain
- Kamioka, Japan
- Boulby, U.K.
- Gran Sasso, Italy
- Baksan, Russia
- Modane, France
- SURF, U.S.
- SNO, Canada
- CJPL, China

Science Mag.

Depth in meters

0 500 1000 1500 2000 2500

NEWAGE detector

- NEWAGE-0.3b
- Detection Volume: 31×31×41 cm³
- Gas: CF₄ at 0.1 atm (50 keVee threshold)
- Gas circulation system with cooled charcoal

COSINE at A5 tunnel

Situated at YangYang Pumped Storage Power Plant

YangYang Laboratory (Y2L)

Upper Dam

Depth 700 m

Power Plant

Seoul

Lower Dam

Kamioka

China Jinping Deep Underground Laboratory (CJPL)

Front Year Dam

CDEX

PandaX

CDEX – Deepest underground lab in the world

Panda X Dark Matter and Neutrinoless Double Beta Decay Programs by HAN Ke @14th Rencontres Du Vietnam “International Symposium on Neutrino Frontiers” in 2018

There are activities of underground lab in India and Australia
(Gravitational Waves & Cosmology)
KAGRA in Kamioka

Timeline of the Project

- 2010: Project started
- 2014: Tunnel Excavation Finished
- 2016: iKAGRA
- 2018: bKAGRA-phase1
- Present: bKAGRA-phase2, joining O3

"Status of KAGRA: the underground- and cryogenic gravitational-wave detectors" by K. Kokeyama at the 5th Kagara International Workshop/ The 1st Kagra-Virgo-3G Detectors Workshop in Perugia, Italy.

- Almost ready to join O3!
Gravitational Wave Telescope in China

• We hear the big investment on the Gravitational Wave Telescope in China.

• It is very interesting to follow how the project is going.
  • I am not the expert of this subject, and I just find the following news on the web.

#NgariObservatory: Construction of gravitational wave telescopes in #Tibet under way
People's Daily | March 15, 2018

China is under smooth progress towards the world’s highest altitude gravitational wave telescopes in Tibet Autonomous Region to detect the faintest echoes resonating from the universe, a project insider disclosed, writes Bai Yang of People’s Daily.
ISAS selects LiteBIRD as the strategic large mission #2!

2019-05-21

ISAS has confirmed that LiteBIRD completed activities planned during Prephase-A2 (previously called as Phase-A1) and has selected LiteBIRD as the strategic large mission #2.

Big leap from LIGO/VIRGO to LiteBIRD

within Einstein's theory of general relativity

beyond Einstein

The 2017 Nobel Prize in Physics

LIGO/VIRGO: gravitational waves with classical origin

LiteBIRD: gravitational waves with quantum origin

M. Hazumi
Large sky coverage with high-speed rotation scan @ Canary island, soon

Observation range

Earth rotation

f_{sky} = 0.44

View at Teide observatory

https://youtu.be/MQX4mM-fXhE

Model predictions for Primordial B-modes

Throughput = 33 \text{ sr} \times \text{cm}^2 (800 Detectors)

Mar. 8, 2019
Proton Decay
Hyper-Kamiokande program

Accelerator Neutrino beam from J-PARC

Atmosphere  Supernova  Sun

Neutrinos

Hyper-Kamiokande

Total mass 260 kton
Fiducial 190 kton

Proton Decay

Tank filled with pure water 74m (D) x 60m (H)

New photo-sensors
People from Asia
Participation from Asia

Participation in HEP

• Japan
• China
• India
• Korea
• Taiwan
• Hong Kong
• Australia
• Thailand, Vietnam, Indonesia …

Considerable contributions to European and US programs
A project of building a neutrino group at IFIRSE, Quy Nhon, Viet Nam

Nguyen Thi Hong Van

Institute of Physics (IOP), Vietnam Academy of Science and Technology, Ha Noi
Institute for Interdisciplinary Research in Science and Education (IFIRSE), Quy Nhon

October 28, 2016

Where to build the group?

ICISE - International Center for Interdisciplinary Science and Education

- Location: Quy Nhon, Binh Dinh, Vietnam (20 hectares site between mountains and sea),
- Founders: Tran Thanh Van and Le Kim Ngoc
- Activities: 10-12 high level international scientific conferences a year → welcome more than 1000 scientists over the world every year. → International schools on specific subjects.

IFIRSE, beside ICISE, is created to promote scientific research and education in Quy Nhon and Vietnam.

IFIRSE is supposed to become an Institute of high level with an international environment and collaboration.

Director: Tran Thanh Van

Theoretical Physics Group
- Le Duc Ninh (got PhD in France, spent postdoc in Germany)
- Dao Thi Nhung (got PhD in Germany, spent postdoc in Germany)
- more people are welcome

Experimental Physics Group
- Tsuyoshi Nakaya (Prof. at Kyoto univ., Japan)
- Cao Van Son (got PhD in US, postdoc at Kyoto univ. & KEK, Japan)
- N. T. Hong Van (got PhD in France, working at IOP)
Summary

• Many new results are coming in the next few years.
• Several new experiments will be online. The decision on the new facility will occur in the near future.

• The WIN conferences will grow including more projects in Asia.
• We pursue particle physics research with
  • Growth, Passion, Diversity and Curiosity!
Backup
Various Physics subjects

- The **mass** of the detector with the **wide energy coverage** is the Key to probe new physics.
- It is an only unique choice to search for the proton decay up to $10^{35}$ years.