Particle Physics in Asia

August 1st, 2017
DPF Meeting at Fermilab

Sachio Komamiya
The University of Tokyo

Asian Countries at LHC

The IRQ magnet system installed in the LHC accelerator

1995
Minister of Education Culture and Science Kaoru Yosano and CERN DG Christopher Llewellyn Smith

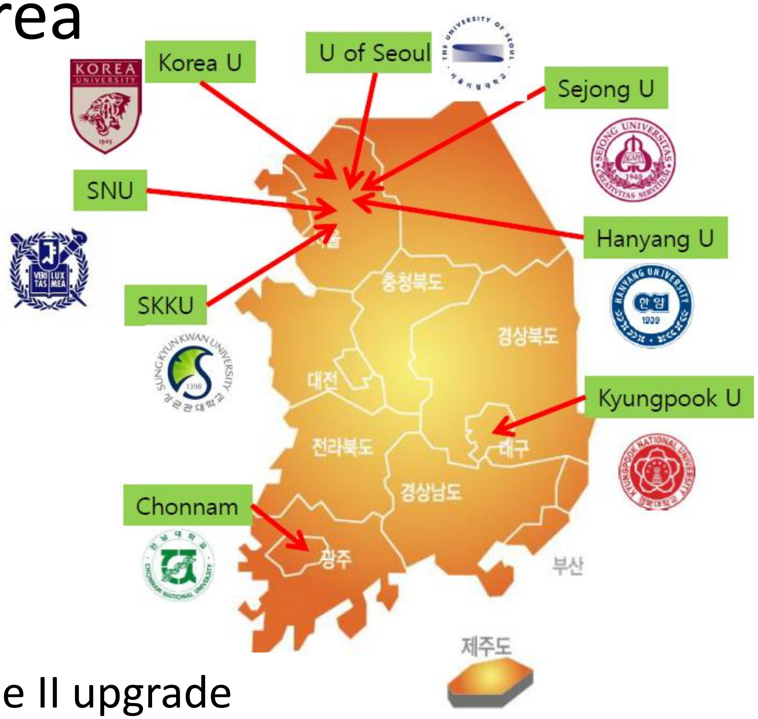
Science contributed to world peace

Thin gap muon trigger chambers of ATLAS was assembled by Pakistani technicians, Israeli engineers and a Japanese physicist.

“Asia” in CMS

China, Korea, Thailand, Malaysia, India, Pakistan, Iran, Uzbekistan, Taiwan, Turkey, Georgia, Armenia

Korea



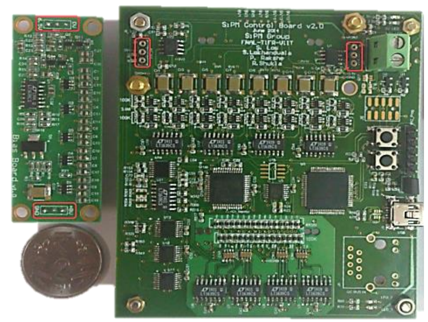
Phase II upgrade

GEM Etching system

GEM Lithography system

India **DAE and DST,: funding agencies**

Multichannel Programmable Power Supply with Temperature Compensation for SiPM



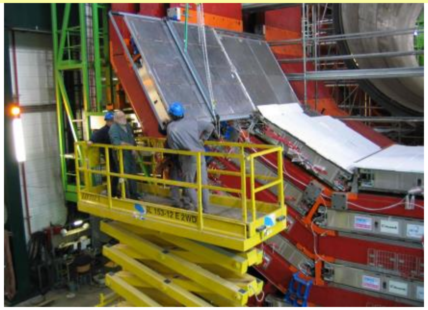
- **Gain stabilized to ~0.5% over 15° C**
- **General purpose, easy to use system suitable for many applications**
- **FNAL-TIFR-VIIT Collaboration**

India: Silicon strip detectors in CMS Pre-shower 1000 detectors (25% of total)

2mm strip-width, 2mm pitch, DC coupled

Ladders

India: Outer Hadron Calorimeter



scintillator tray with WLS fiber readout

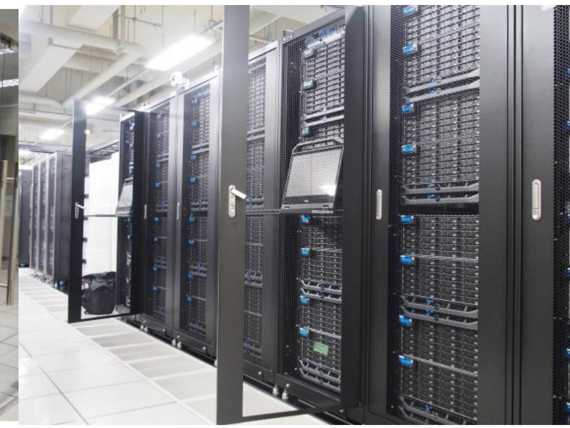
“Asia” in ATLAS

Australia, China, Hong Kong, Israel, Japan, Russia, Taiwan, Turkey

Thin Gap Muon Trigger Chamber
Israel, Japan, China

LHC Computing Grid for ATLAS in Asia

IHEP Beijing Tier-2



ICEPP Tokyo Tier-2

Academia Sinica Taipei Tier-1

China

Chinese Philosophers "Likes" Particle Physics

- 一尺之棰，日折其半，万世不竭 --- 庄子

  Break a ruler by half every day, never finish even after ten thousands generations

  ----- Zhuangzi ~ 350 B.C.

- 物质可以是无限可分的 ---- 毛泽东

  Matter may be break up infinitely -

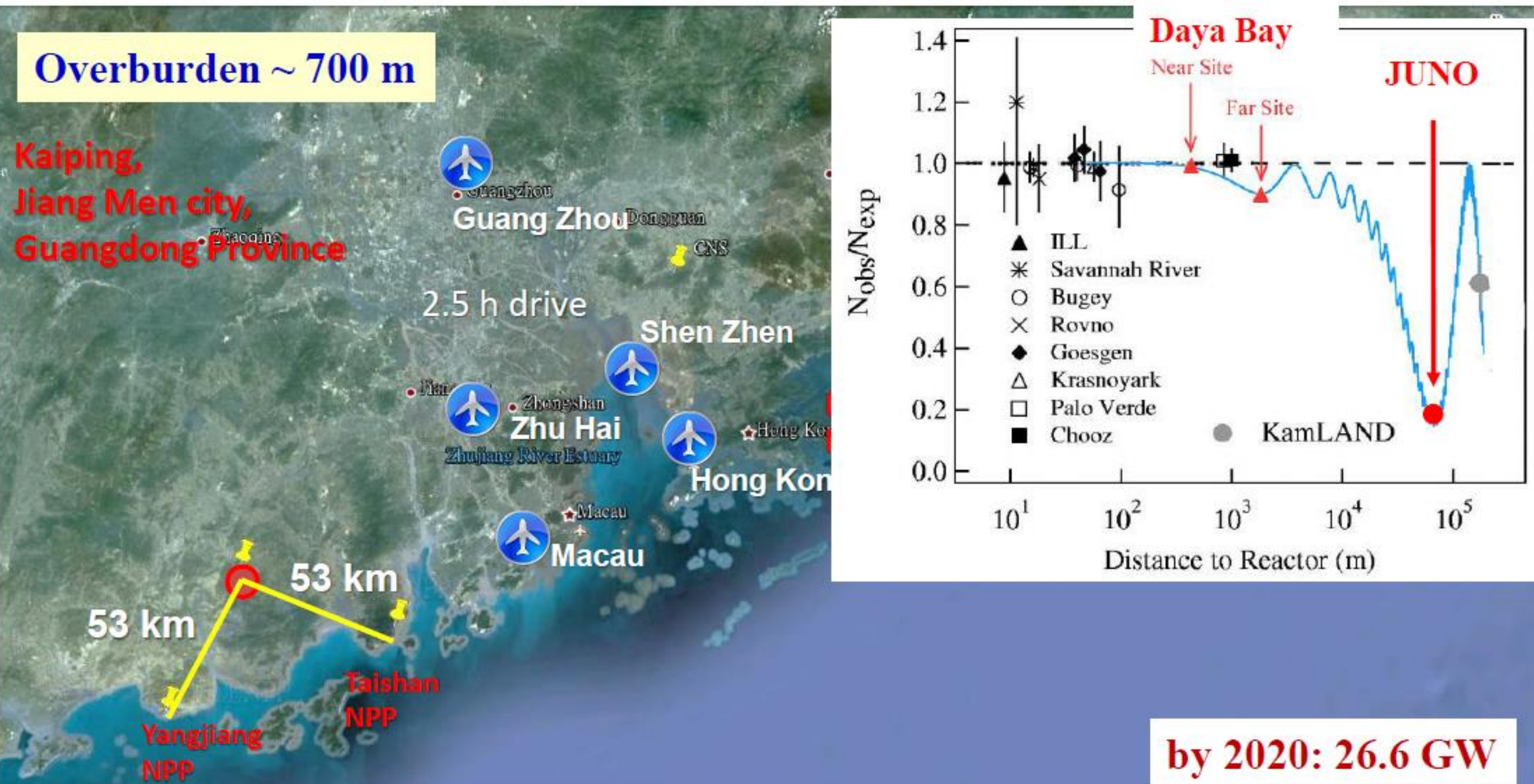
  --- Mao Zedong 1964

Reasonable support to particle physics in China, even in difficult times

Mao Zedong met Sakata in 1964 and discussed particle physics

The JUNO Experiment

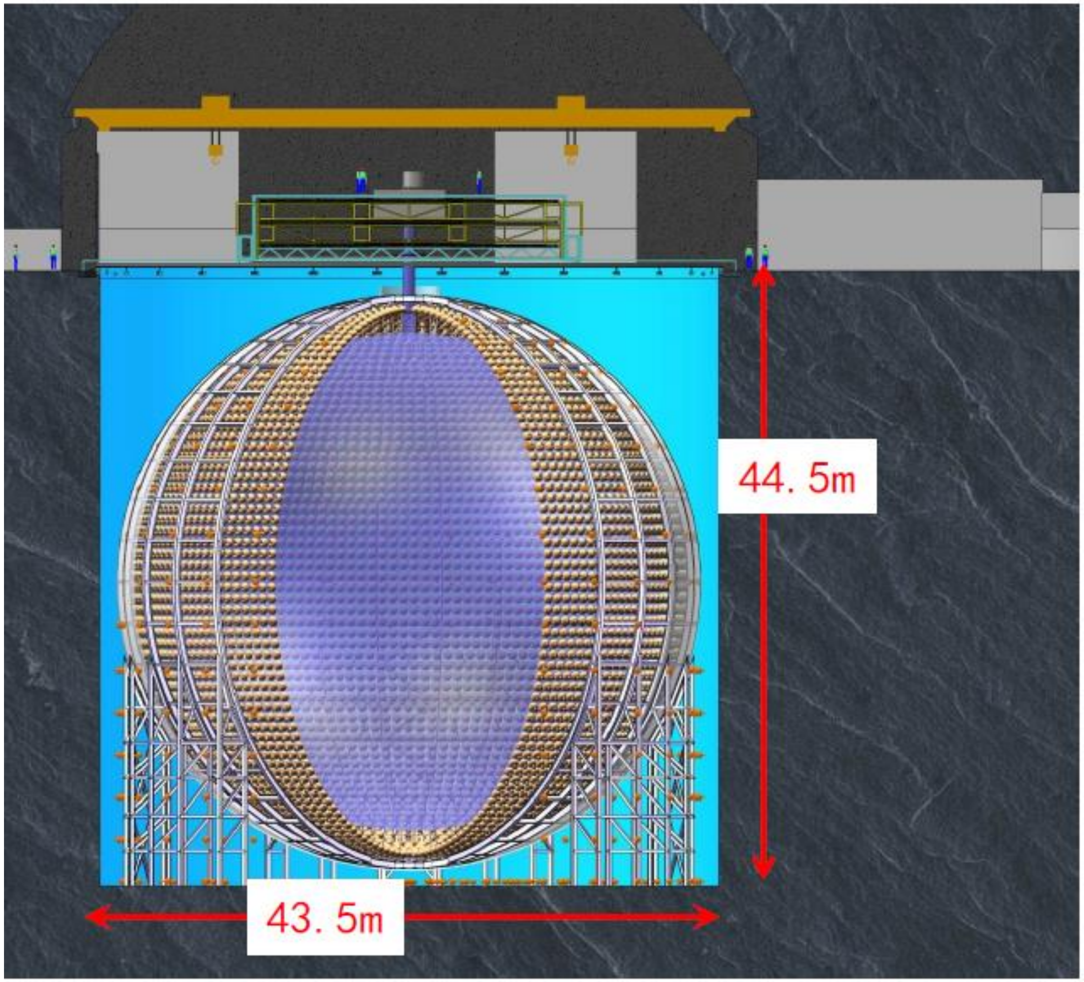
NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW



by 2020: 26.6 GW

JUNO Detector and Challenges

- Largest LS detector ➔ × 20 KamLAND， × 40 Borexino
- Highest light yield ➔ × 2 Borexino， × 5 KamLAND

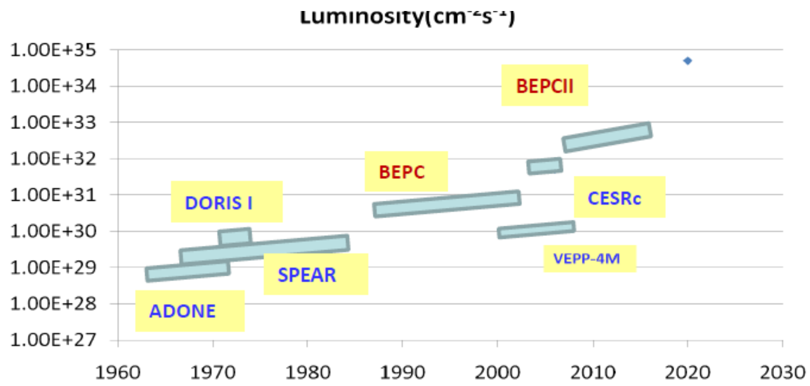


- Huge Cavern:
  - ~ 48m× 70m
- Largest Acrylic tank:
  - Φ 35.4米(13m@SNO)
- 20 kt LS
  - Best attenuation length: 25m (15m @ Daya Bay)
- 20000 20” PMT
  - Highest photon detection efficiency : 30%*100% = 30% （25%*60%=15% @ SuperK）

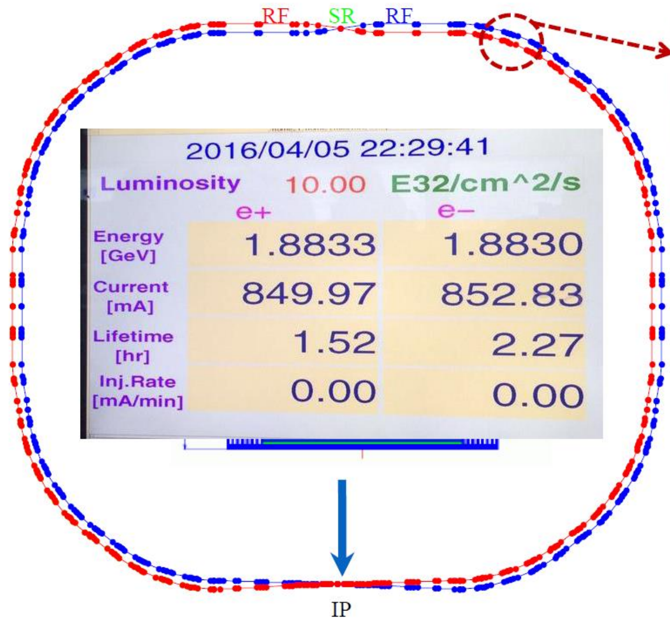
e⁺e⁻ Collider

BES III@BEPC II

The real starting point of Particle Physics in China is the construction of BEPC in late 80's



BEPC II: Operational Since 2009



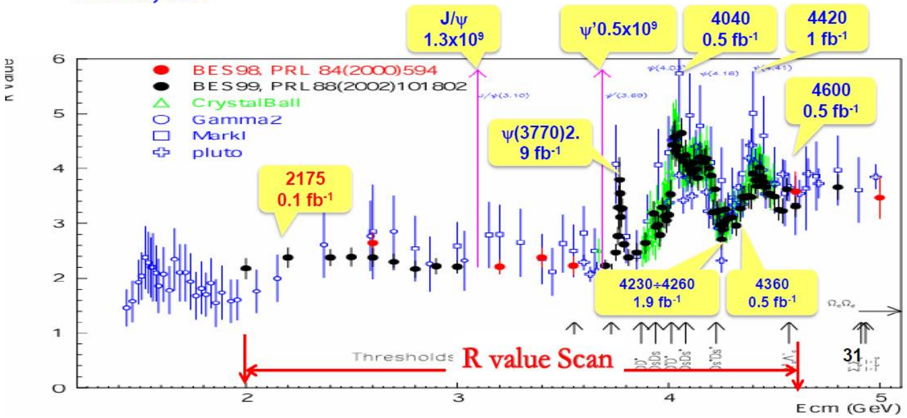
Beam energy:
1-2 GeV
Lumi. @ 1.89 GeV:
1×10^{33} cm^{-2}s^{-1}
No. of bunches:
93
Total current:
0.91 A
SR mode:
0.25A @ 2.5 GeV

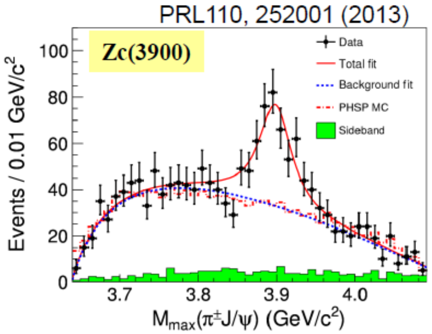
6

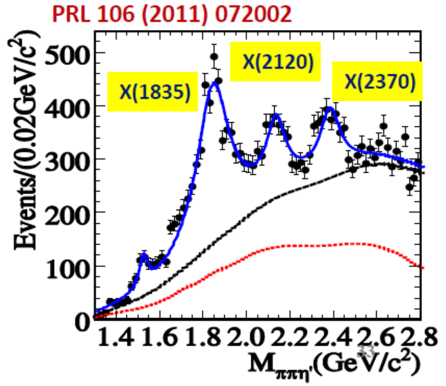
Physics at BESIII

- Hadron spectroscopy and non-conventional hadron searches
- Charmonium production and decays: XYZ states
- Precision study of R, form factors, tau mass, CKM matrix, etc.

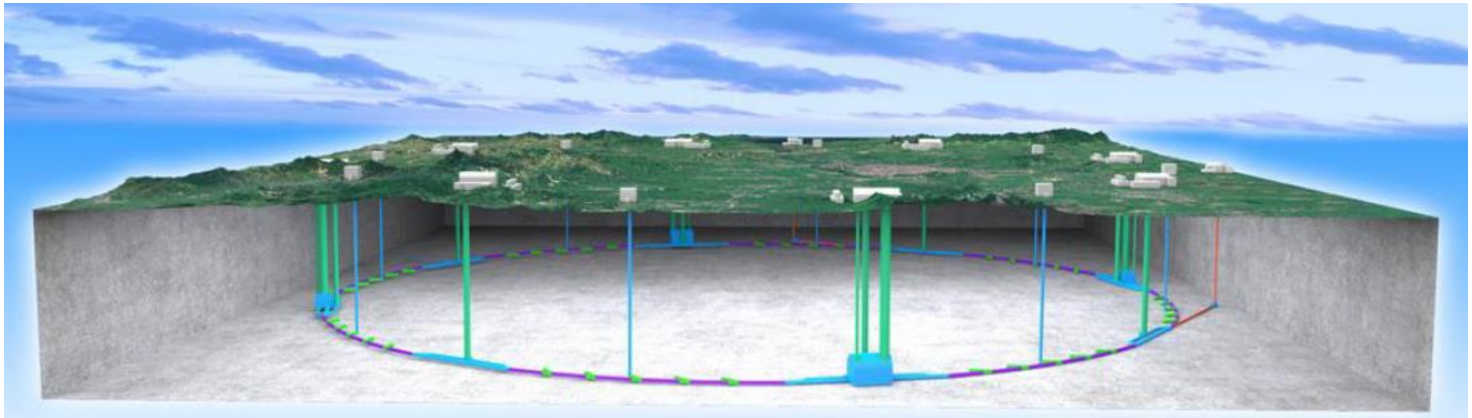
Int. J. Mod. Phys. A, Vol. 24 (2009)







The Future: CEPC+SppC

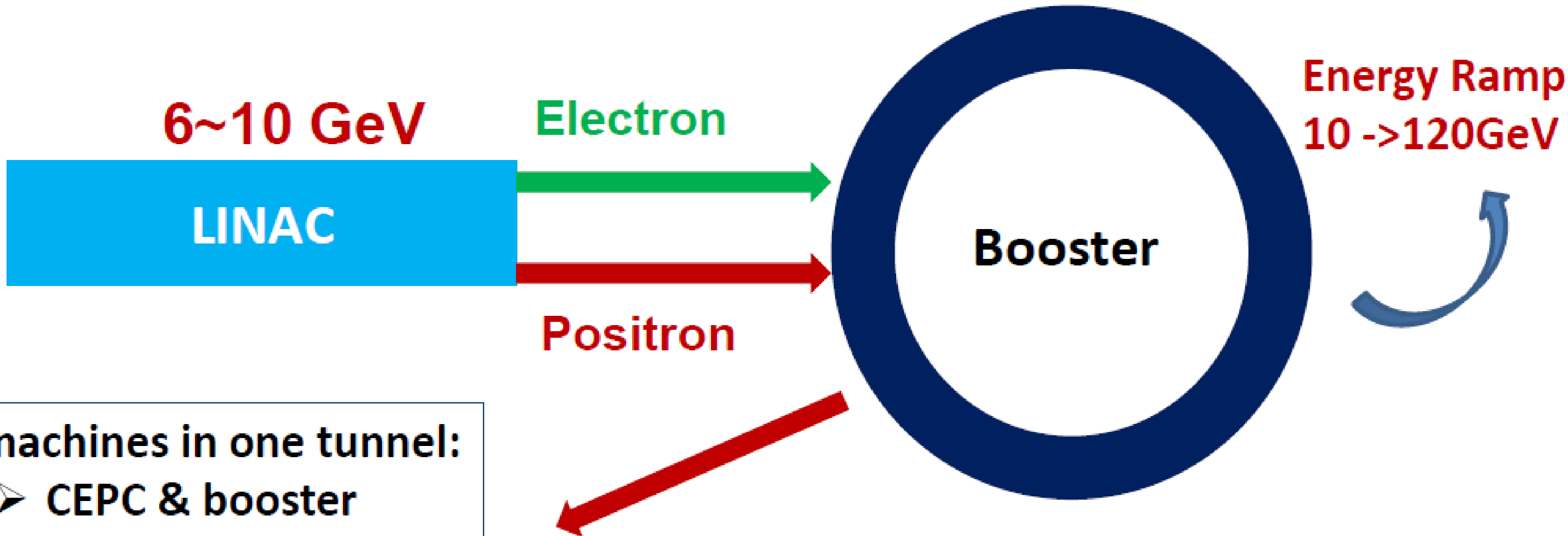


Science Goals

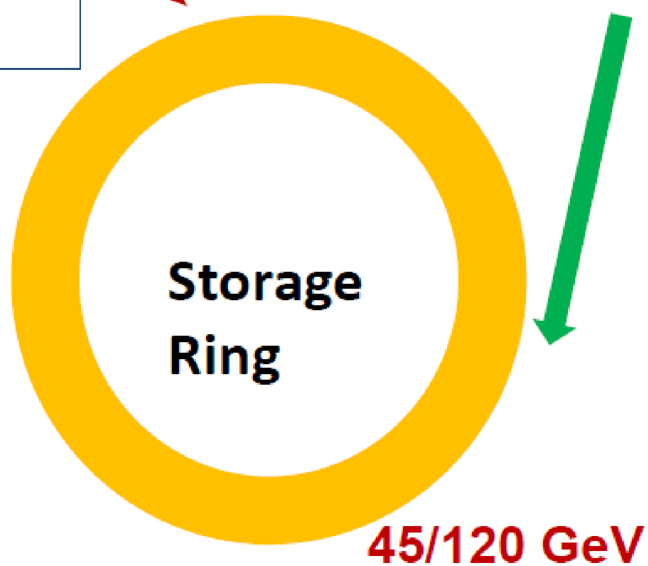
- CEPC (e+e-: 90-250 GeV)
  - Higgs Factory: Precision study of Higgs(m_H, J^{PC}, couplings)
    - Same as SM prediction ? Other Higgs ? Composite ? New properties ? CP effect ?
  - Z & W factory: precision test of SM
    - New phenomena ? Rare decays ?
  - Flavor factory: b, c, τ and QCD studies
- SppC (pp: 50-100 TeV)
  - Directly search for new physics beyond SM
  - Precision test of SM
    - e.g., h^3 & h^4 couplings

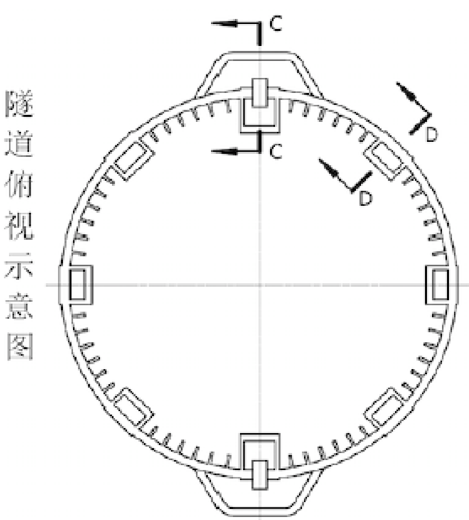
Precision measurement & searches:
Complementary with each other

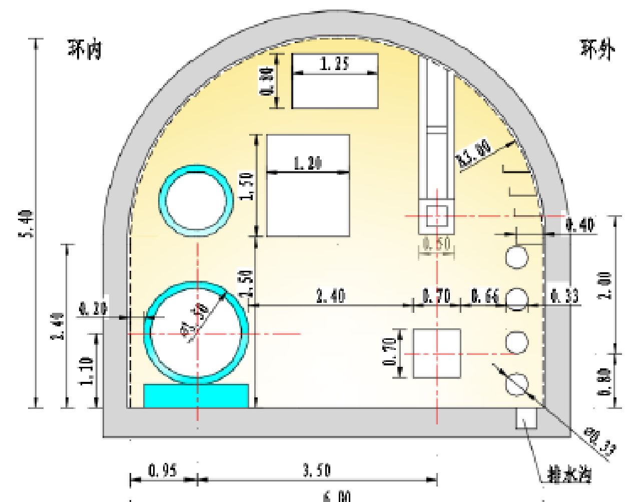
CEPC Accelerator design



3 machines in one tunnel:
- CEPC & booster
- SppC







Current Status and the Plan for CEPC

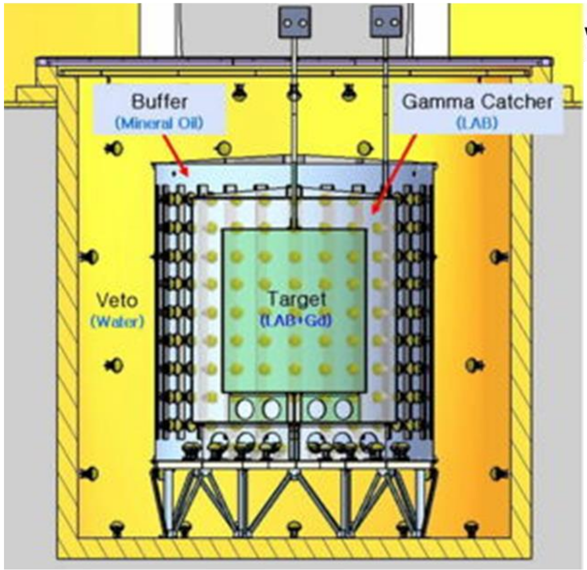
- Working towards CDR
  - A working machine on paper
  - Ready to be reviewed by government at any moment
- R&D issues identified and funding request underway
  - Seed money from IHEP: 12 M RMB/3 years
  - MOST: 36 M/5 yr approved, ~40 M to be asked this year
  - NCDR: ~0.8 B RMB/5 yr, failed in a voting process
  - CAS: 40M/5 yr + 6M/3 yr + 12/yr approved
  - CNSF: ~ 20M/5 yr approved, few M/yr expected
  - Beijing Municipal Government: 500 M/4 yr for a R&D platform

Not just for CEPC , but mainly for a new photon source in Beijing

- A new international organization for CEPC will be organized
  - A new format: not ITER, CERN, ILC, …
- An international advisory board is formed
- Seeking international coordination

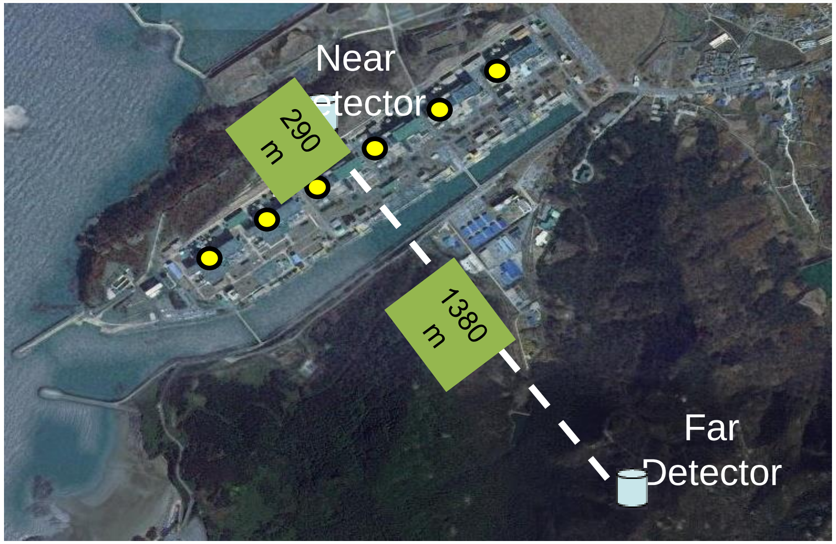
Korea

Reactor Experiment Neutrino Oscillation

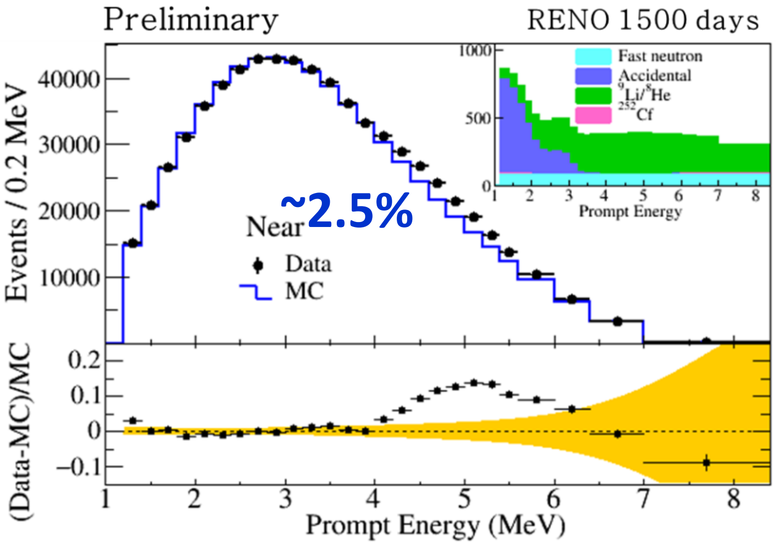


w.e.

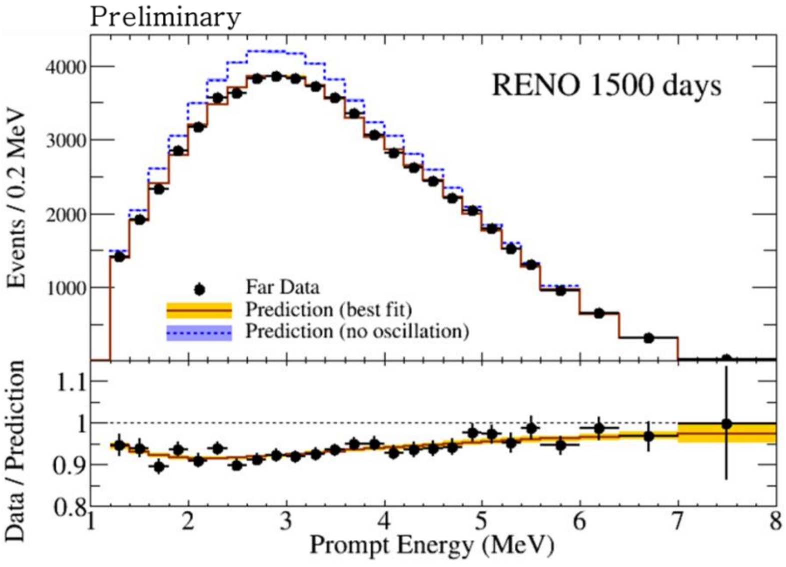
RENO



5 MeV excess in



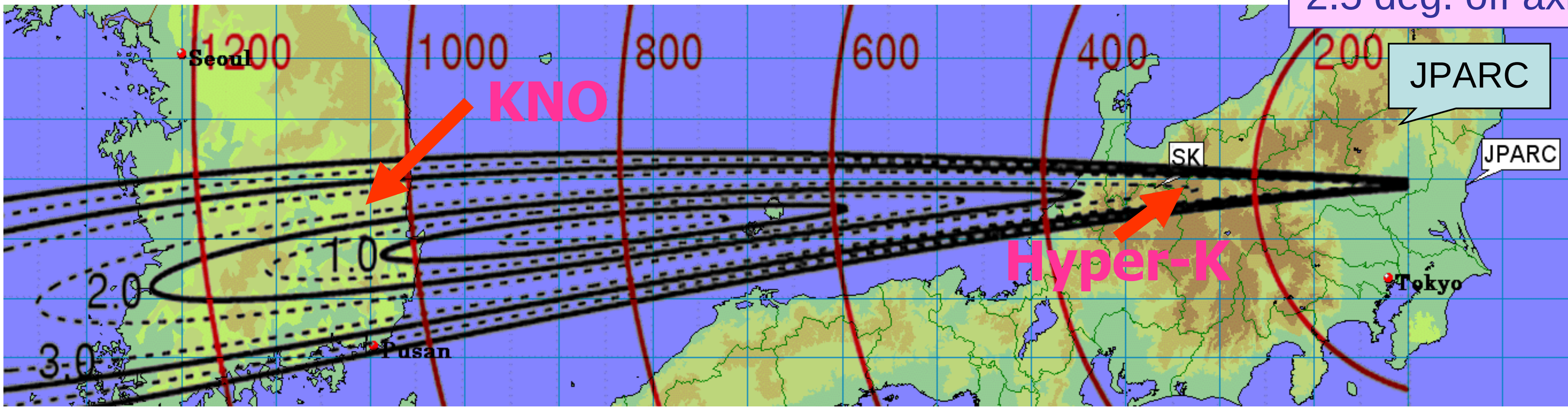
Energy dependent antineutrino disappearance

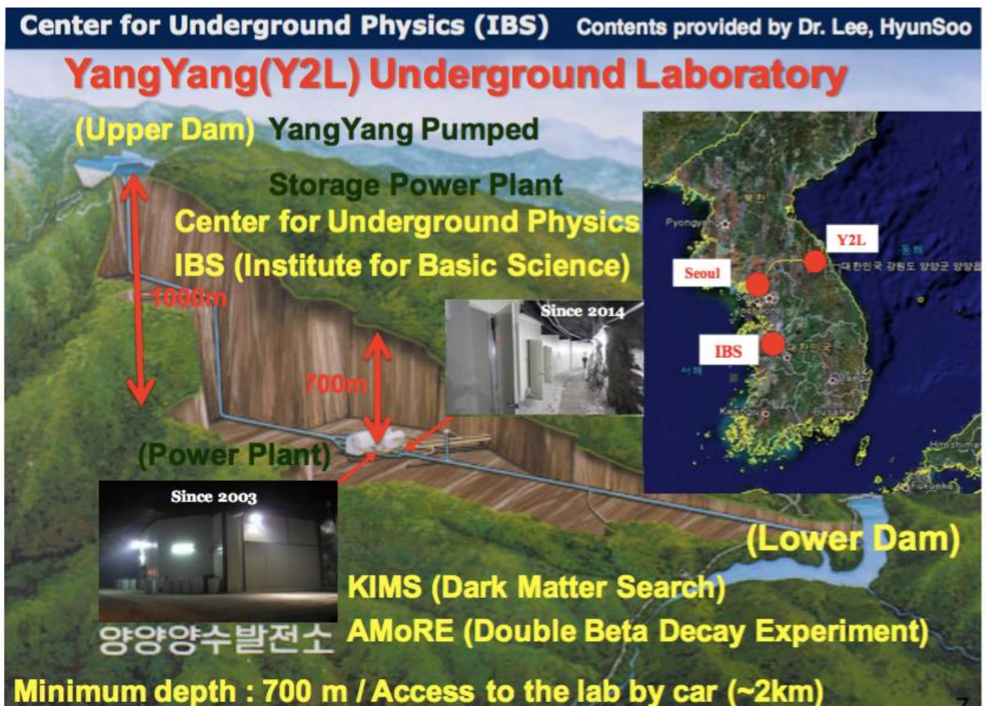


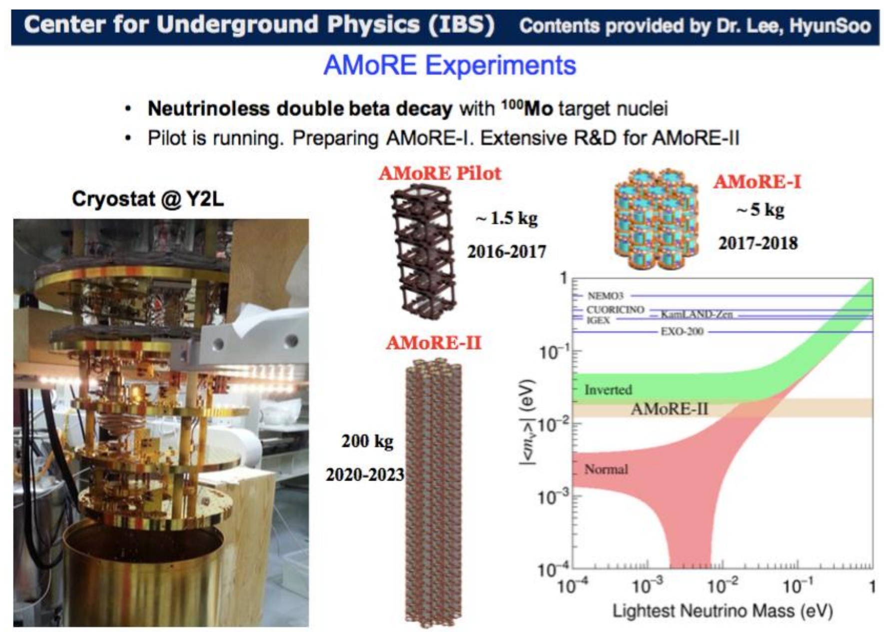
Korean Neutrino Observatory (KNO)

The J-PARC ν beam comes to Korea.

2.5 deg. off axis

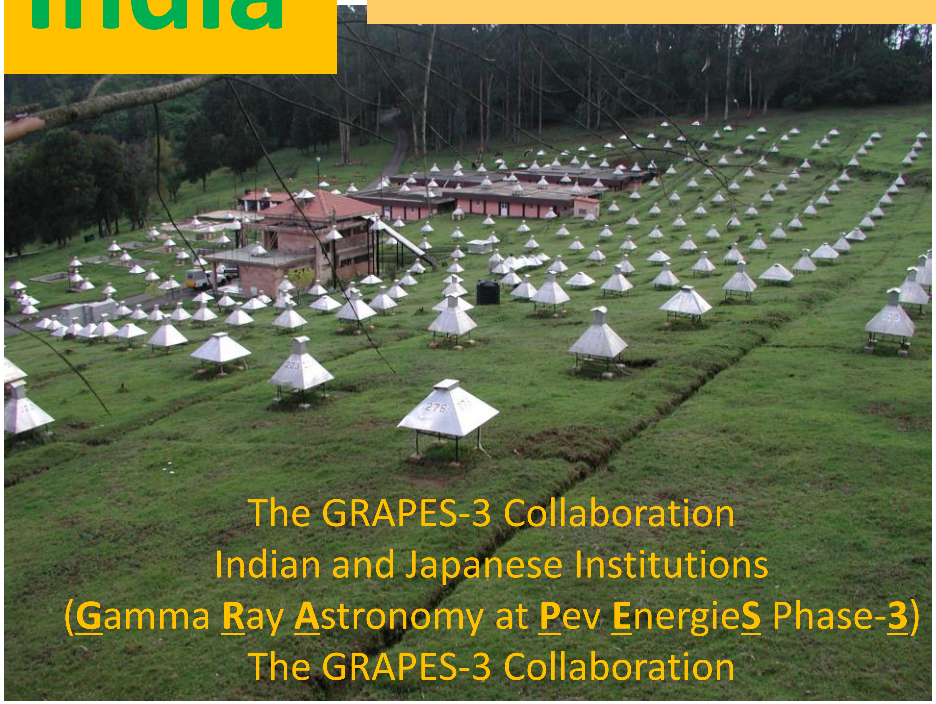






India

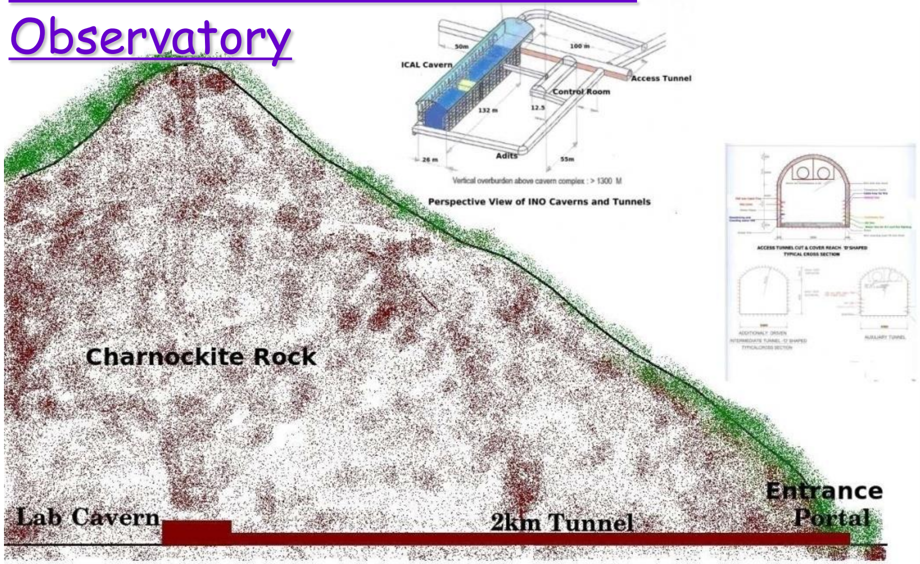
Non-accelerator based astro-particle physics



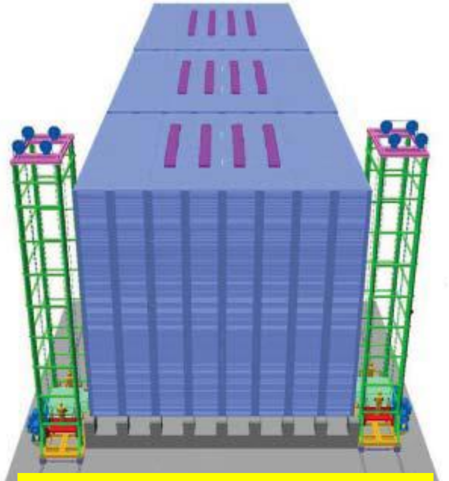
The GRAPES-3 Collaboration
Indian and Japanese Institutions
(Gamma Ray Astronomy at Pev EnergieS Phase-3)
The GRAPES-3 Collaboration

High Altitude GAmma Ray (HAGAR) Telescope Array at 4250 m Altitude in Hanle, Ladakh
One of seven Telescopes (GeV-TeV-PeV γ ray)

INO : India-based Neutrino Observatory



- Sanctioned by the Indian government.
- Total cost is a few hundred M€.
- Construction is about to begin.
- International collaboration are welcome.
- Other non-accelerator particle physics experiments are planned in the same cavern.



50 kton magnetized iron module(s) with 30,000 channel RPC

Taiwan

EXPTs: ATLAS, CMS, AMS-02, BELLE, Belle II, θ13 (大亞灣), JUNO, TEXONO, COMPASS, KOTO

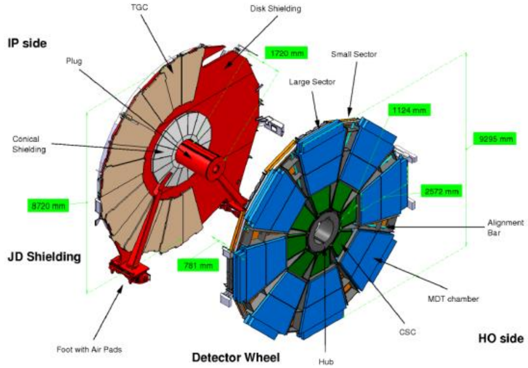
INSTs: AS, NCU, NCKU, NCTU, NTU, NTHU, NUU, FJU

Major (MOST) Grants since 2010

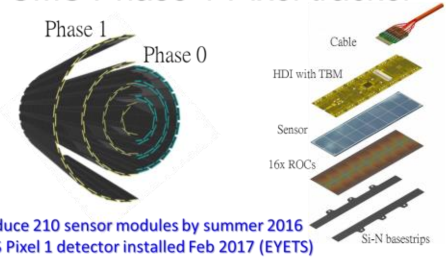
Academic Summit Project:	**CMS Phase 1 Upgrade (NTU)**
Vanguard Project:	**AMS-02 (NCU/AS)**
Vanguard Project:	**Belle II (NTU)**

ATLAS Tier-1

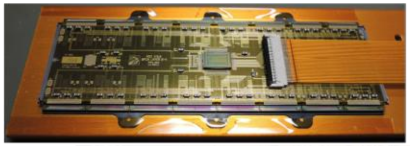
Small wheel muon system

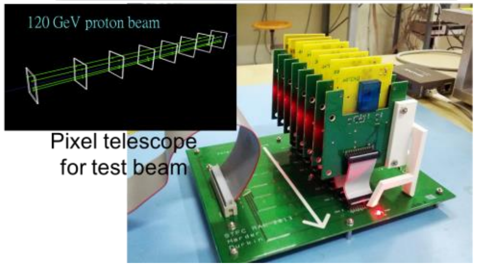


CMS Phase 1 Pixel tracker



Produce 210 sensor modules by summer 2016
CMS Pixel 1 detector installed Feb 2017 (EYETS)





Japan

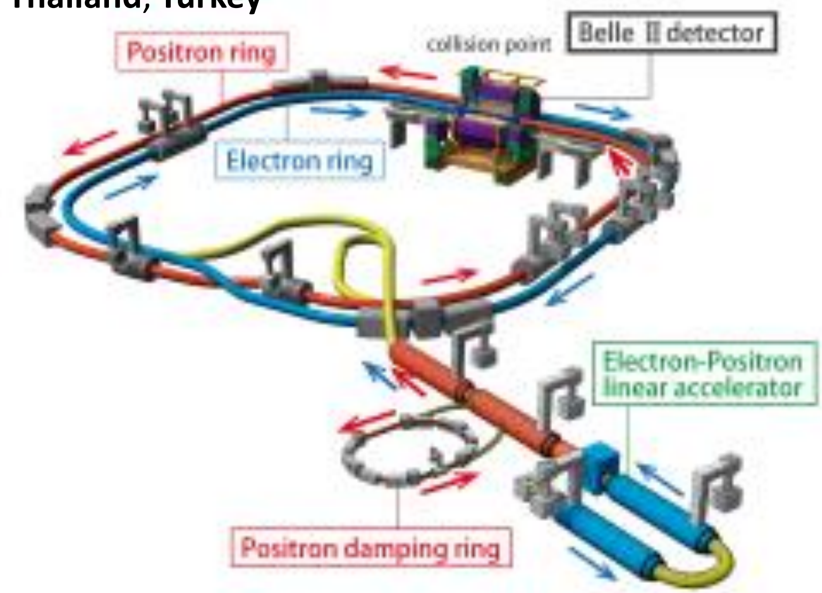
Belle-II @ Super KEKB

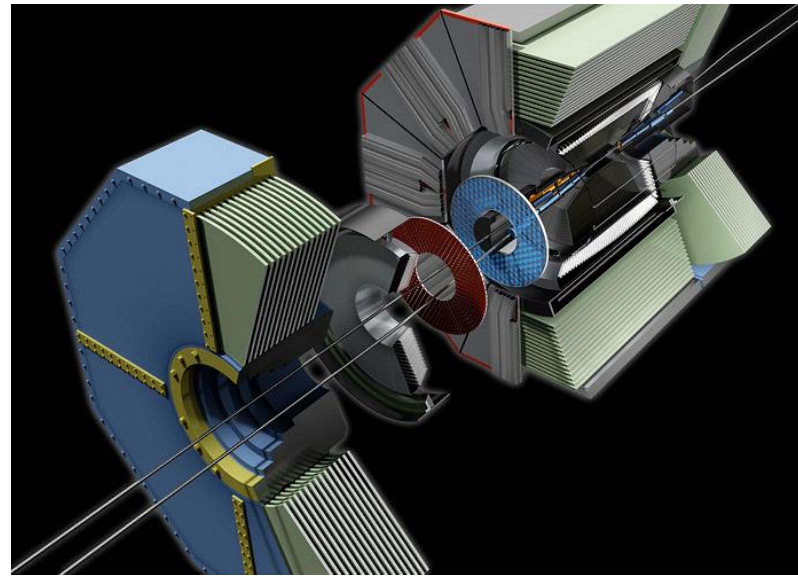
$e^+e^- \rightarrow \Upsilon(4S) \rightarrow \bar{B}B$

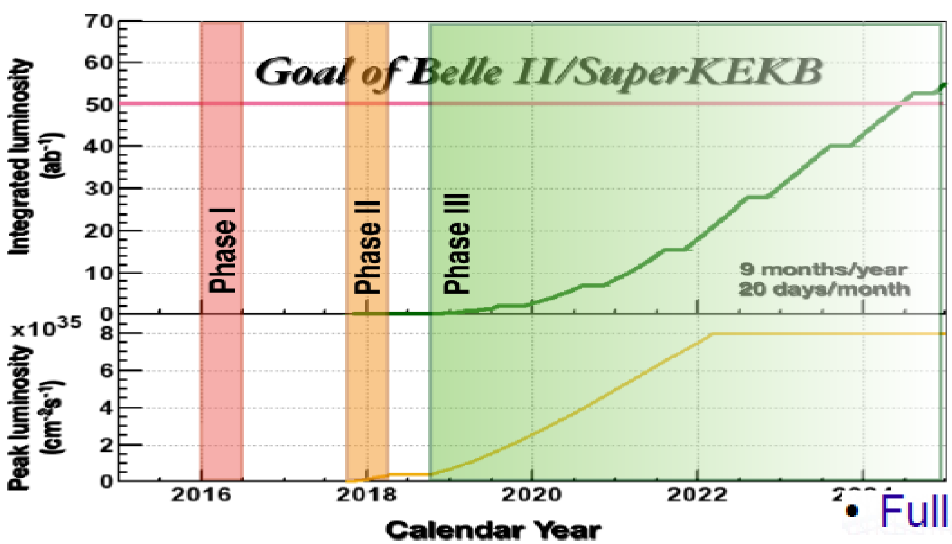
$L = 8 \times 10^{35}\ cm^{-2}s^{-1}$

Japan, Germany, USA, Italy, **Russ**ia, **Korea**, **India**, Australia, **China**, Canada, **Taiwan**, Slovenia, Austria, Mexico, Poland, Czech Republic, **Malaysia**, Spain, Saudi Arabia, Ukraine, **Vietnam**, **Thailand**, **Turkey**

$E(e^+) = 4$ GeV, $E(e^-) = 7$ GeV







Phase 1 – Succesfull commisioning of the main ring (February – June 2016)
Installation of outer detectors (finished in December 2016)

Phase 2 – Start of the collisions, detector commissioning (Nov 2017 – spring 2018) **without vertex detector.** **First physics runs on Y(4S) and Y(6S)!**

Phase 3 - full detector operation by the end 2018

- Full data sample (50 ab^{-1}) to be collected by 2025

Physics case for Belle-II

Charged Higgs Effects :

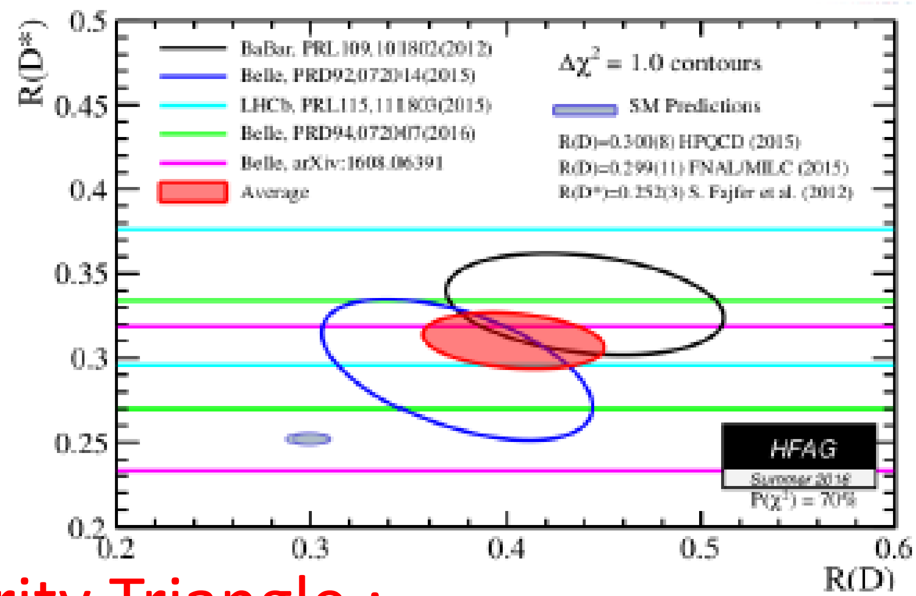
$B^0 \to \tau\nu$ via $W^\pm$ or $H^\pm$

$B \to D^{(*)} \tau\nu$ via $W^\pm$ or $H^\pm$

$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}(\overline{B} \to D^{(*)} \tau \nu)}{\mathcal{B}(\overline{B} \to D^{(*)} \ell \nu)}$$

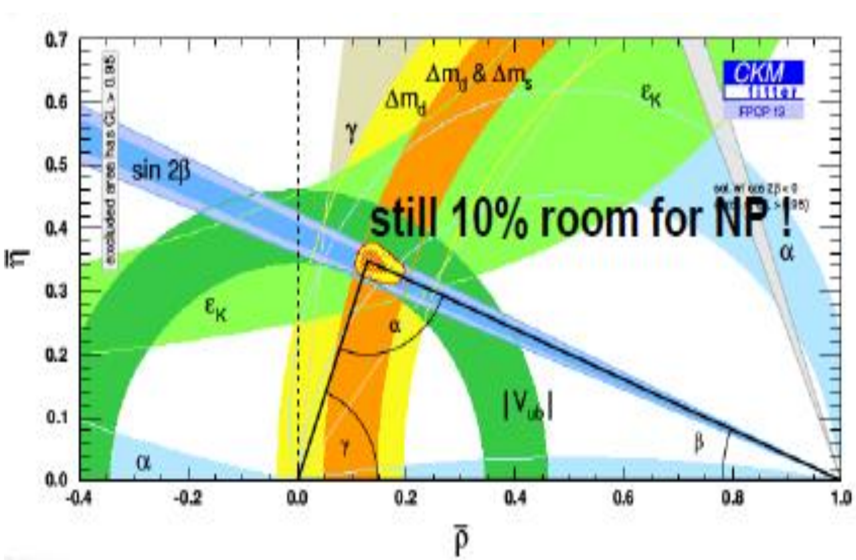
Currently, 4σ deviation from SM prediction

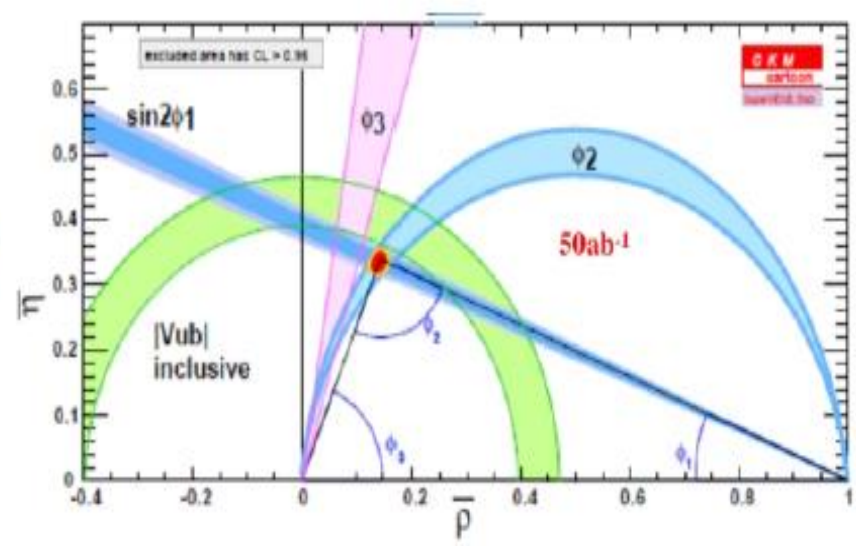
Belle-II accuracy ~ 3% for 50 ab^{-1}



Precise measurements of Unitarity Triangle :

Δα, Δβ, Δγ are 1°, 0.3°, 1.5° at 50 ab^{-1}



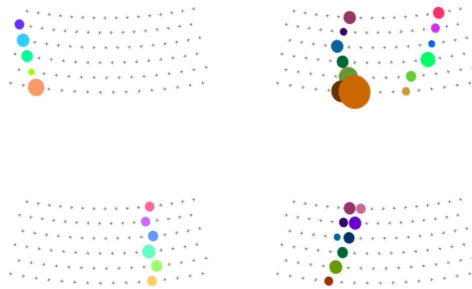


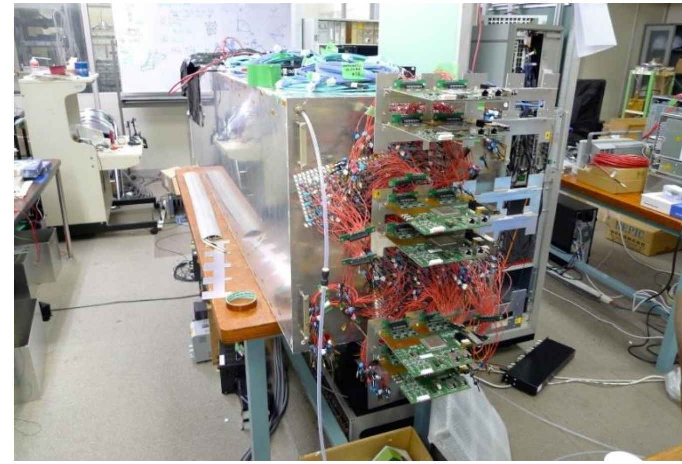
Korean in Belle II

Leadership E. Won: IB chair (2011-2013)

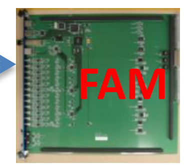
- Drift chamber based online 3D track trigger (Korea U)
  - Track segment finder finds segments in KU chamber with cosmic rays

Track candidates triggered by TSF logic by us (Apr. 2015)





- DSSD assembly (KNU)
- Calorimeter trigger construction (Hanyang)



India in Belle-II (SVD assembly by TIFR team)

Wire-bonder

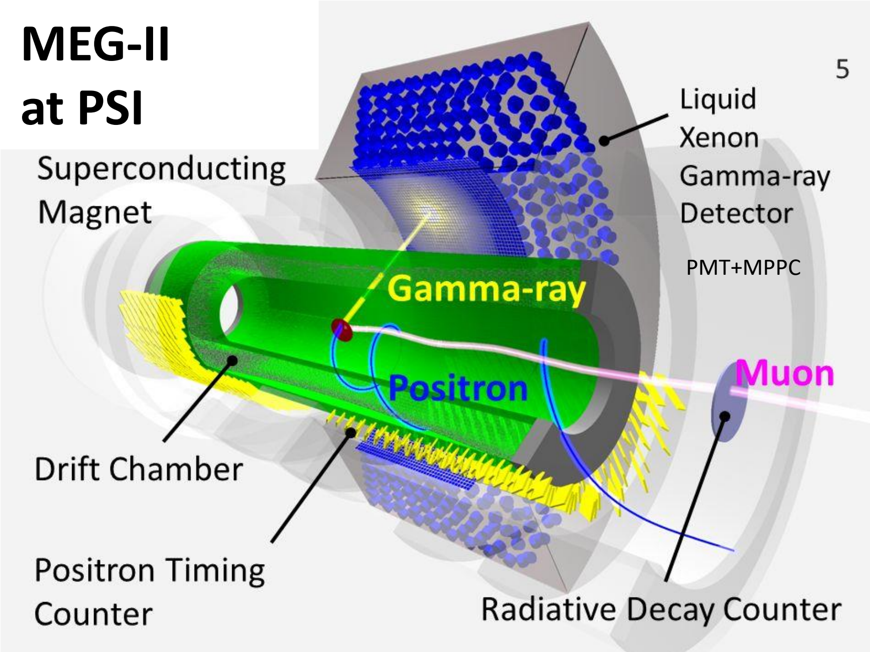
Pull-tester

Gluing robot

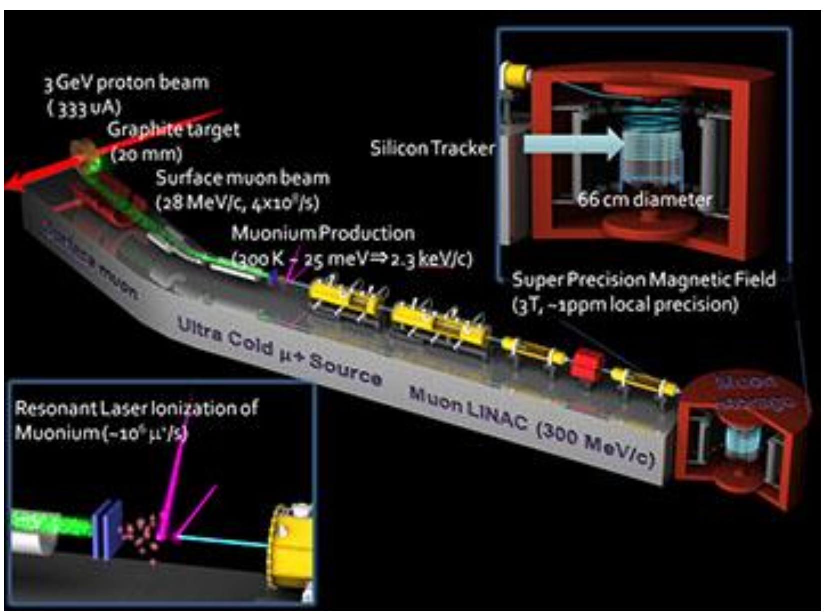
Muon experiments

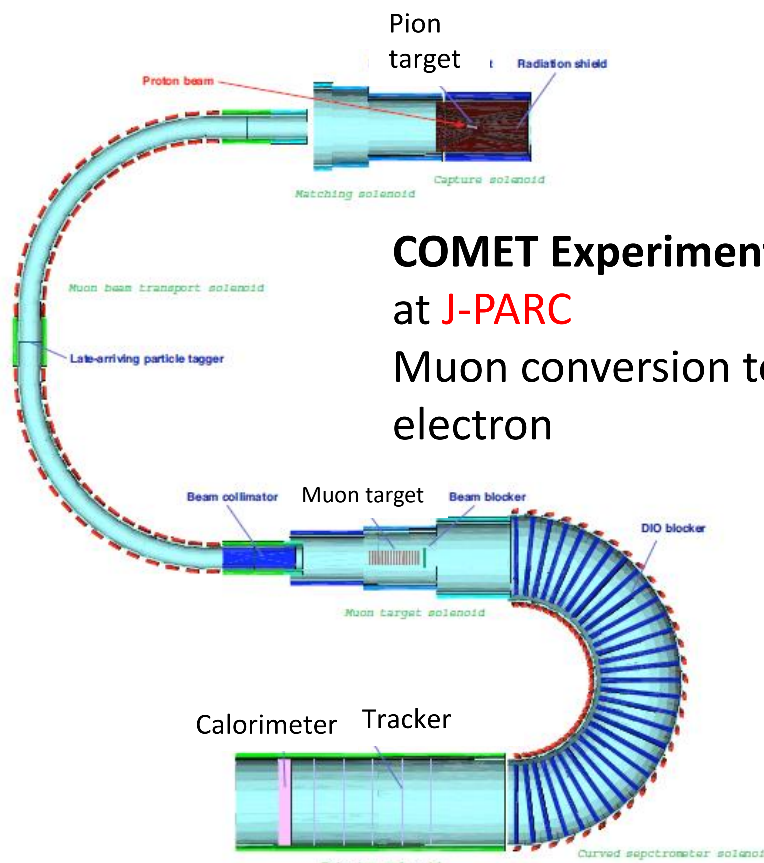
MEG II@PSI (μ→e γ)
COMET@J-PRAC (μ→e conversion)
g-2 and EDM@J-PARC

MEG-II at PSI



Muon g-2 and EDM experiment at J-PARC
Magic momentum is not used

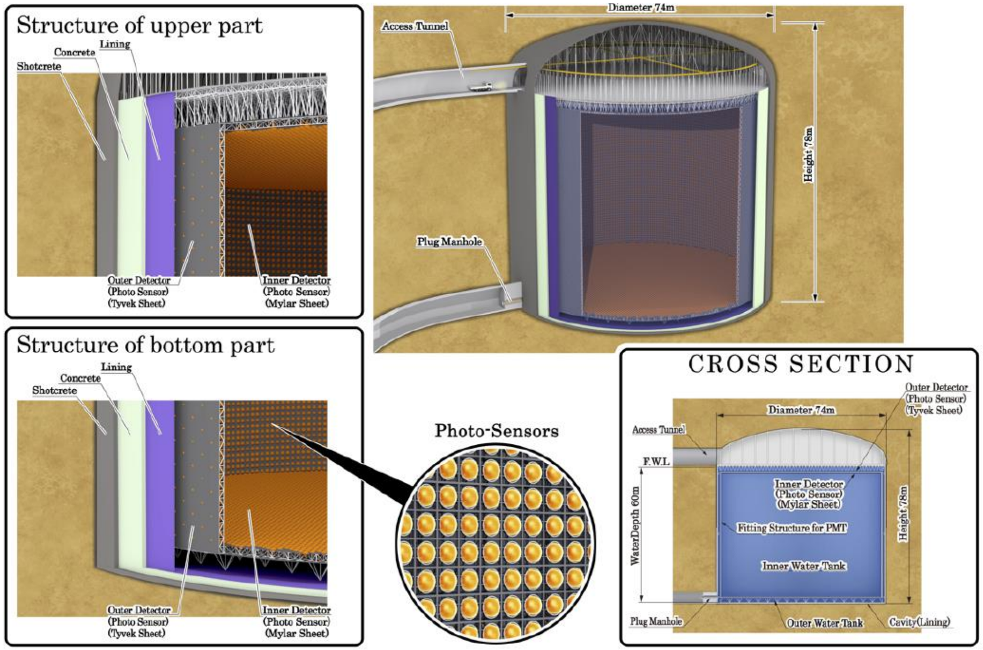




COMET Experiment
at J-PARC
Muon conversion to electron

Hyper-Kamiokande for Neutrino CP and Nucleon Decay

International Collaboration of 12 countries (Brazil, Canada, France, Italy, **Japan**, **Korea**, Poland, **Rus**sia, Spain, Switzerland, UK, USA)



If the construction starts in April 2018 ⇒ Experiment starts in April 2026

Early start with a single detector

Water tank

74mϕ、60m height 260kt

Fiducial Volume ⑩xSK 190kt

PMT Photo sensitivity x ② better

40,000 sensors

Time resolution x ② better

Two detectors in the future

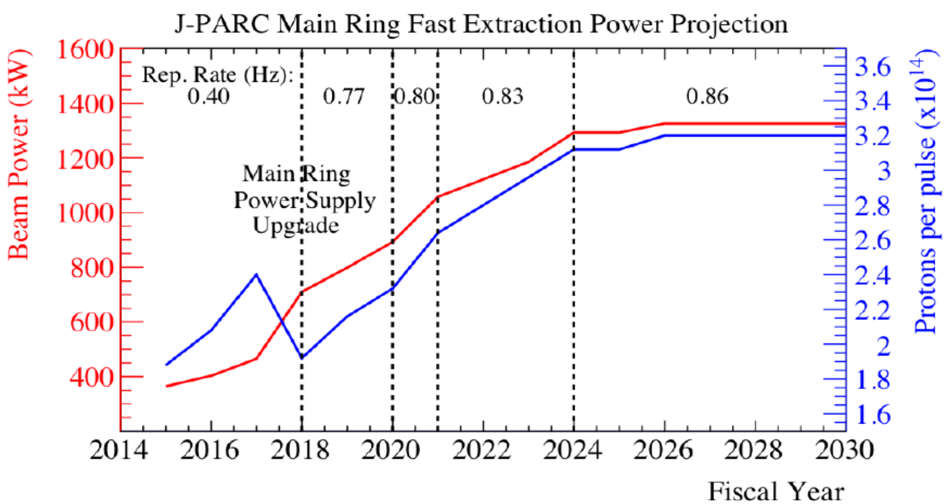
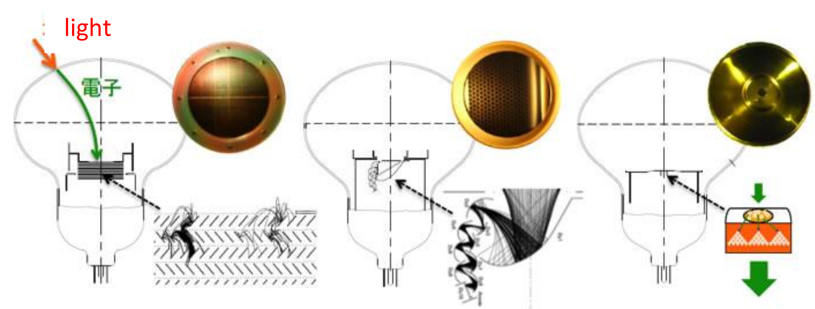
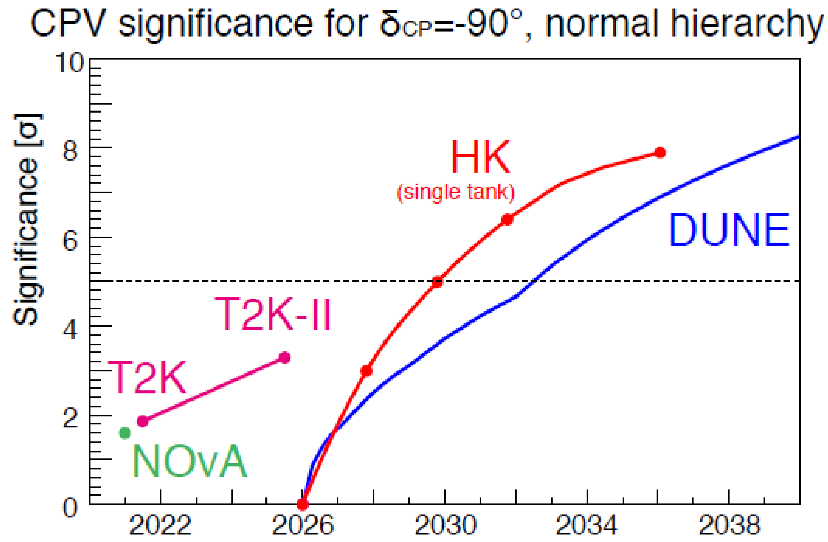


Photo-detector decision in 2017

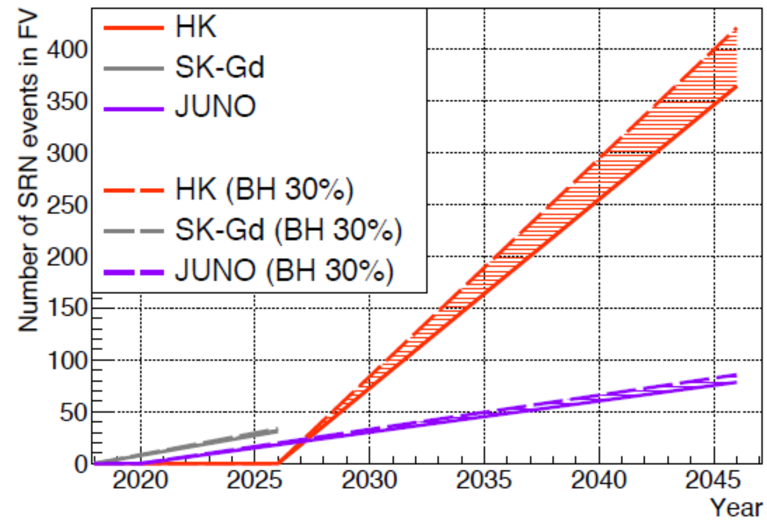


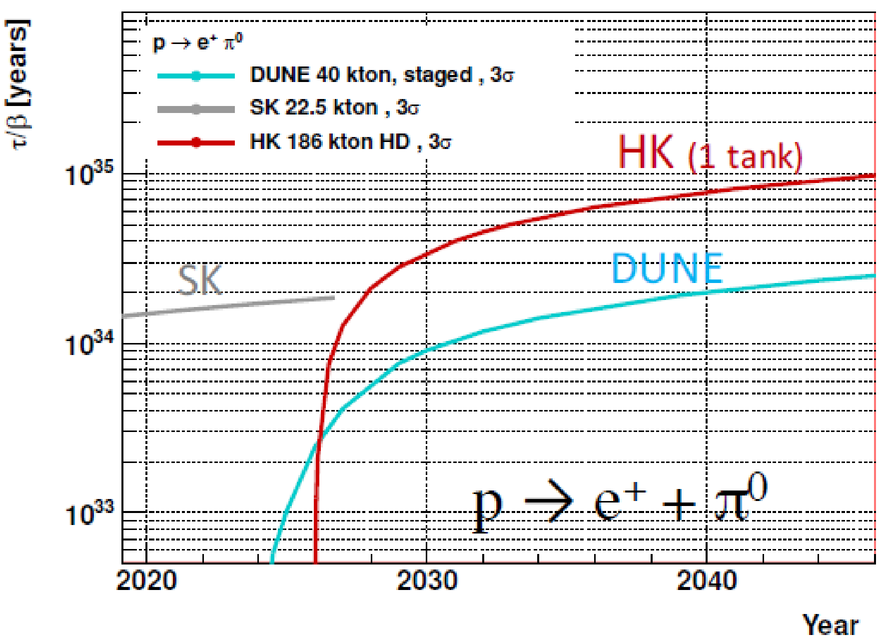
SK PMT   Box&Line PMT   HPD

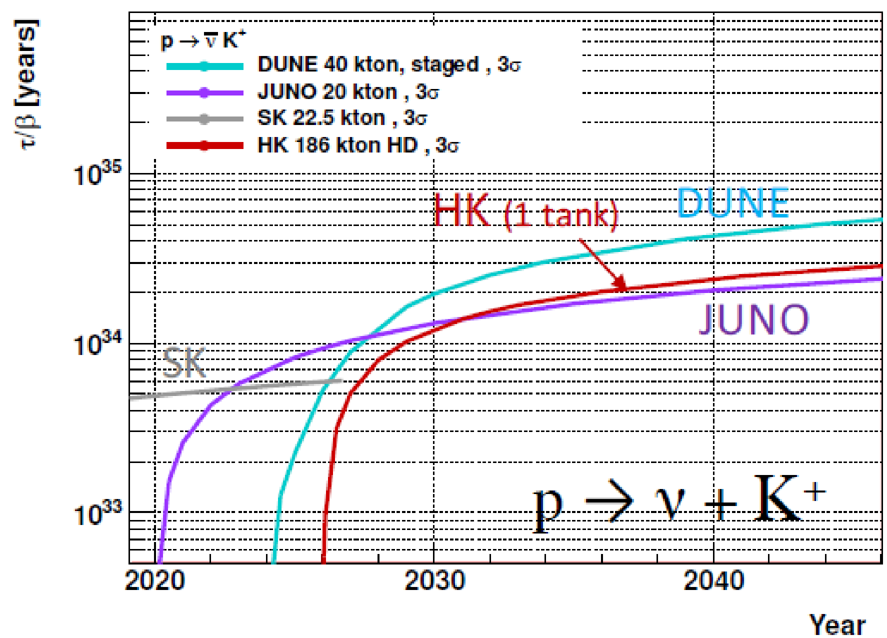


CPV curves depend on the starting points of experiments and beam intensity

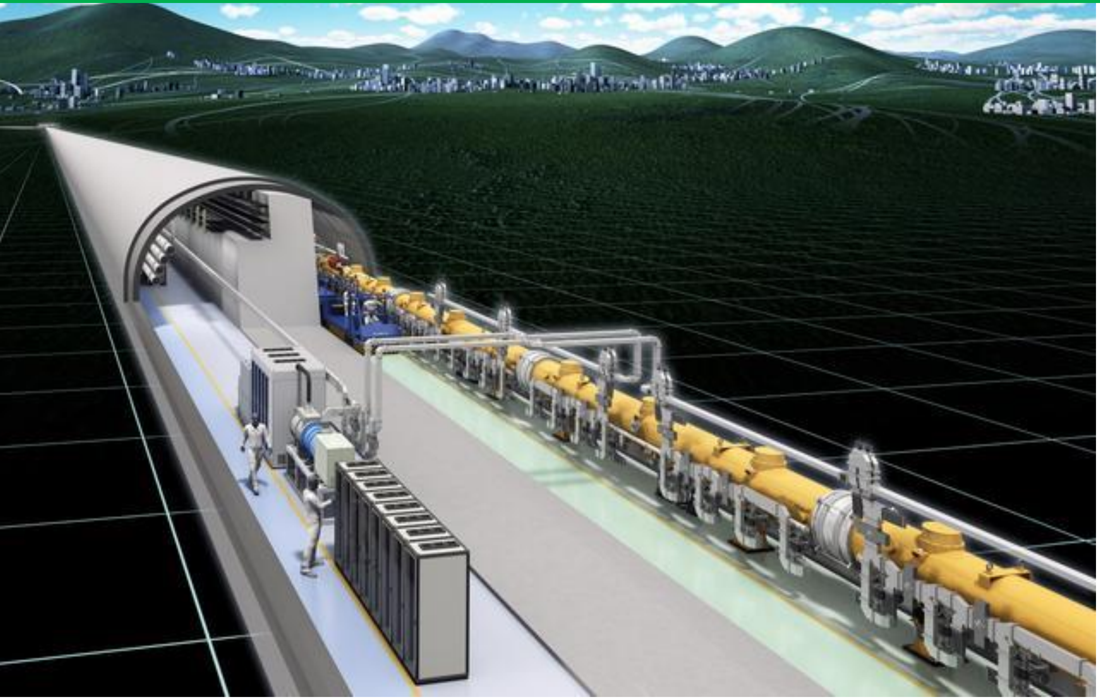
(This plot was made by Yokoyama of HK)







ILC (International Linear Collider)



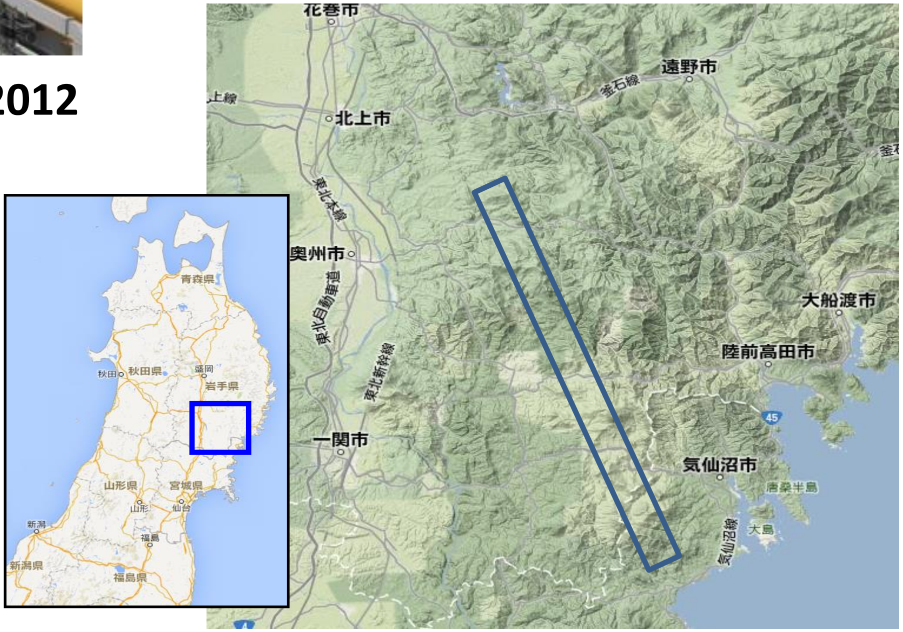
Advantages of linear colliders

(1) No energy loss due to synchrotron radiation
(c.f. Circular Colliders $-\Delta E/\text{turn} \propto (E/m)^4 R^{-1}$)
(2) Energy extendability: length, (gradient) ⇒ energy
(3) Beam Polarization

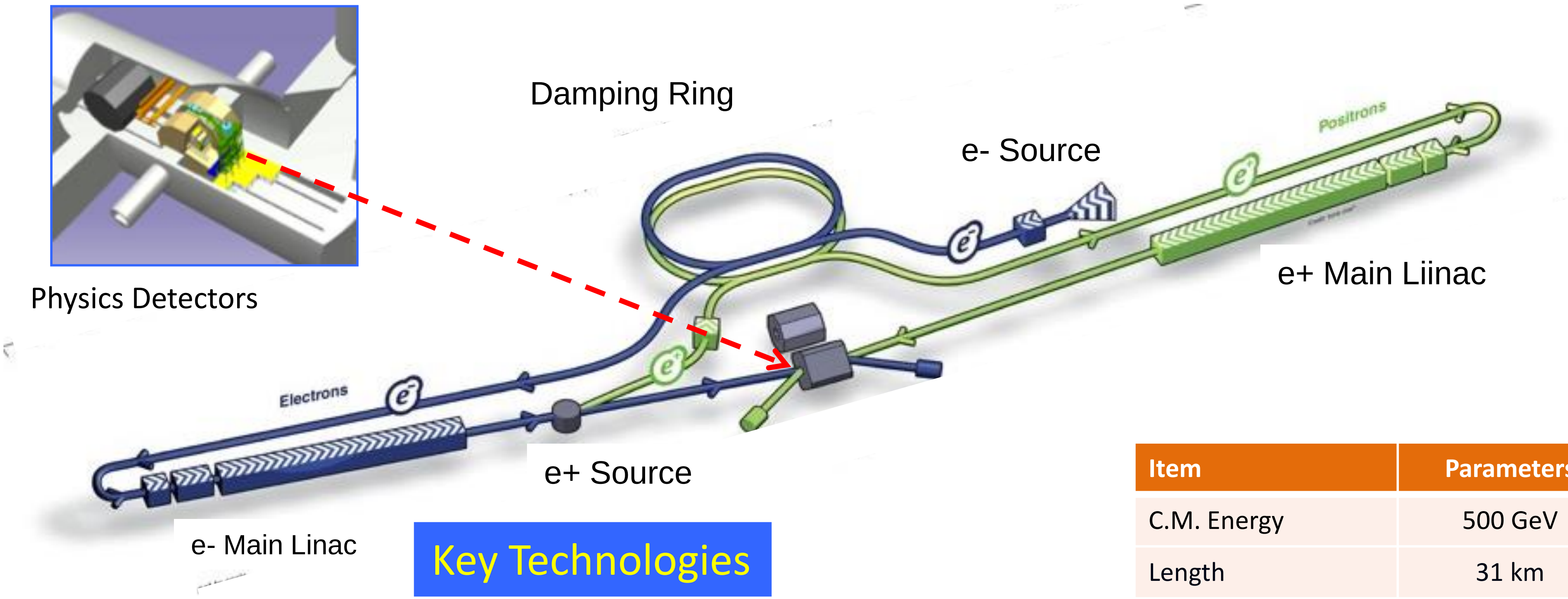
Discovery of the 125 GeV Higgs Boson at LHC in 2012
⇒ obvious physics target (Higgs is a portal of physics beyond the Standard Model)
⇒ triggered early construction of the ILC

ILC Site Candidate Location in Japan: Kitakami

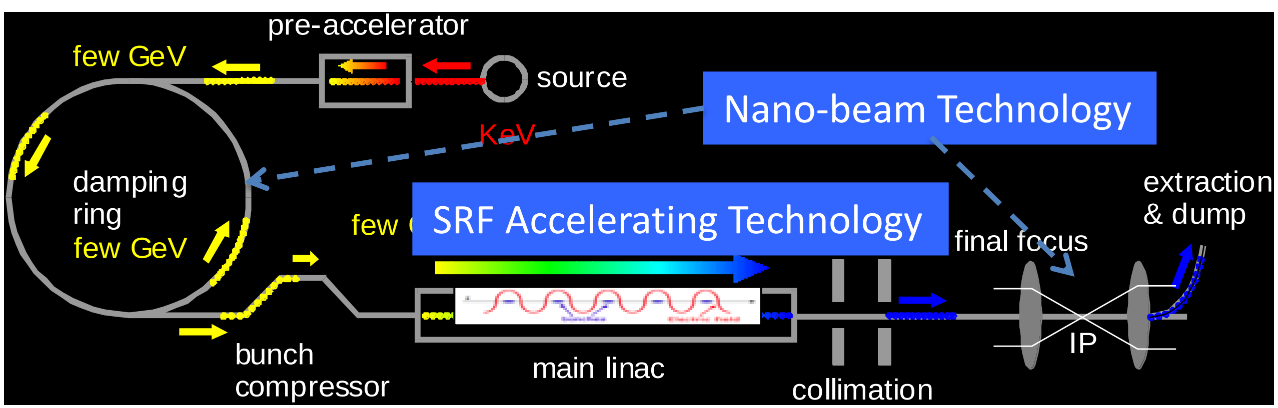
Earthquake-proof stable bedrock of granite.
No faults cross the line.



ILC Acc. Design Overview (in TDR)



Key Technologies



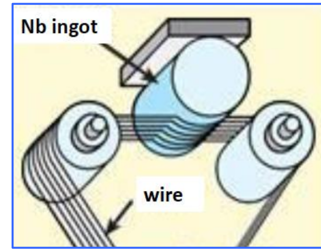
Item	Parameters
C.M. Energy	500 GeV
Length	31 km
Luminosity	1.8 $\times 10^{34}$ $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	**5.9** nm
SRF Cavity G. Q_0	**31.5** MV/m $Q_0 = 1\times 10^{10}$

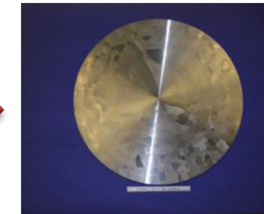
“DoE-MEXT ILC Discussion Group” was formed in October 2016

cost reduction and **management of the ILC lab** are the main issues

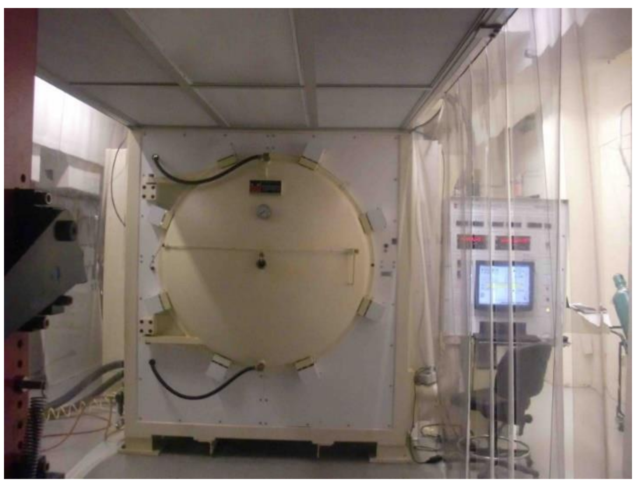
1. Cost reduction in Nb material preparation

- Optimize the ingot purity with a lower residual resistivity ratio (RRR).
- Simplify the manufacturing method such as forging, rolling, slicing and tube forming.

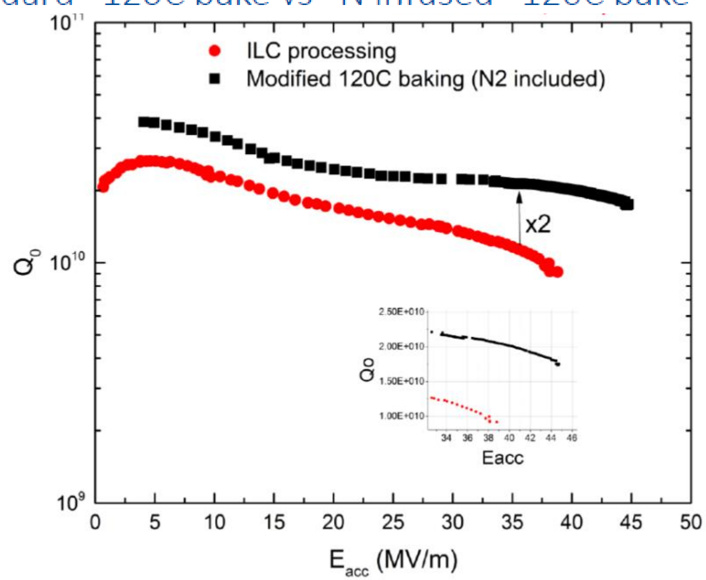




2. High-Q high-gradient SRC with nitrogen infusion at Fermilab



“standard” 120C bake vs “N infused” 120C bake



Achieved:
45.6 MV/m → 194 mT
with Q ~ 2×10^{10}
Q ~2.3×10^{10}
at 35MV/m

ILC spec:
Q = 0.8×10^{10}
at 35 MV/m

Increase in Q factor of two, increase in gradient ~15%

- **Confirm reproducibility of the nitrogen infusion method to improve Q and field gradient of SC RF cavity developed at Fermilab. ⇒ Understand the underlying physics**
- **High statistics test of the yield by fabricating 8 9-cell cavities.**

Cost reduction by SCRF technology is O(10%).

We need more !

Energy reduction is needed for the initial phase of the project
down to the energy which is enough to scrutinize the Higgs boson (250 GeV)
to investigate the direction of the physics beyond the Standard Model.

Cost reduction is more than 30 %. (31km → 20km)
⇒ ～40% cost reduction in total + reduction of running cost

Make sure the scientific significance of the staged 250 GeV ILC.
⇒ Japan Association of High Energy Physics set up a committee and complete the investigation.
The Linear Collider Collaboration physics group also studied the issue.

Consensus of the international science community and understanding of the governments are necessary.

We will discuss in the ICFA/LCB at Guangzhou, China in the next week
The final words will be ready during the ICFA Seminar in Canada, on 6-9 November

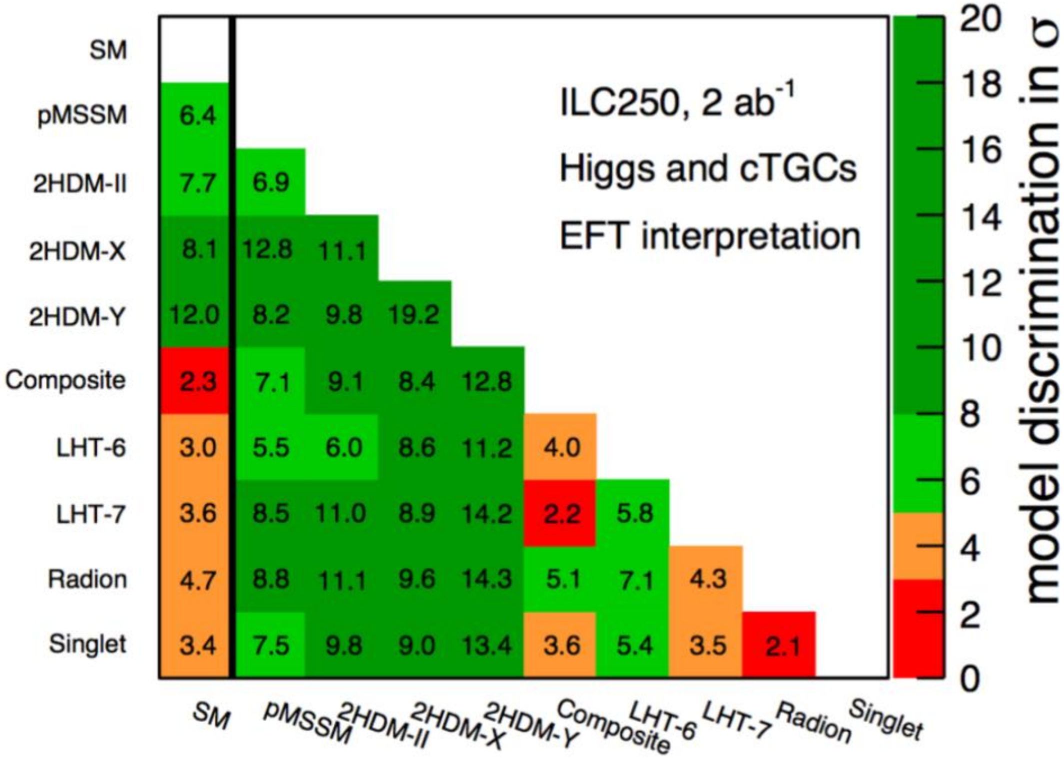
Conclusions of “Committee on the Scientific Case of ILC250 Higgs Factory (Chair: Shoji Asai)“

Commissioned by the Japan Association of High Energy Physicists

An independent review of the scientific case of the ILC by ATLAS, Belle II, Theory members

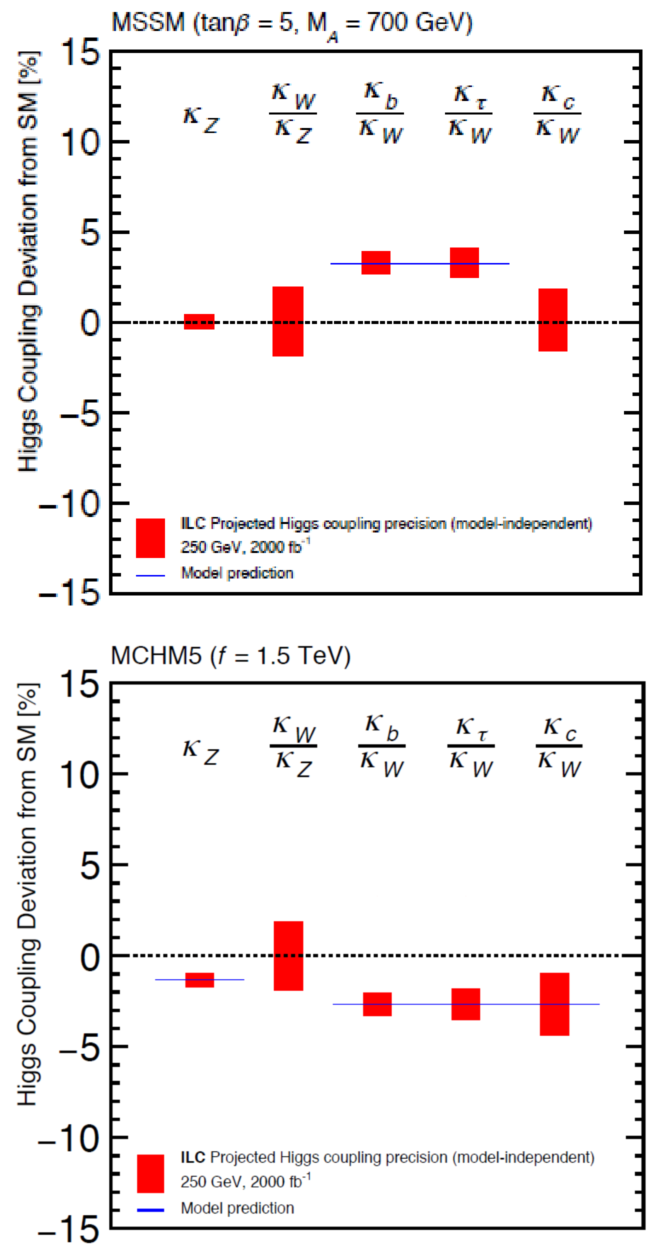
- In order to make the most out of the HL-LHC physics results, concurrent running of the ILC250 is desired.
- Because the energy scale of new physics is currently not known, the reach of precision Higgs and other SM probes of ILC250 are comparable to those of ILC500.
- Combining with HL-LHC, SuperKEKB, and other experiments, ILC250 “Higgs Factory” will play an indispensable role: fully cover new phenomena up to Λ~2-3 TeV & uncover the origin of matter-antimatter asymmetry
- The inherent advantage of a linear collider is its energy upgradability. Thus the ILC250 can not only uncover the energy scale of new physics, but has the potential to fulfill this requirement by an energy upgrade.

ILC 250 Higgs factory allows us to discover new physics beyond the reach of LHC and to discriminate possible models of new physics at high confidence.



◎Significance of model discrimination
◎For Models which cannot be directly discovered at LHC
◎Most of the models can be discriminated by 3 σ or more.

SUSY vs Composite Higgs



Necessary steps and time line for the ILC project

Japan has to have the initiative

Scientists
MEXT
Leaders in industry (AAA)
Politicians (alliance of Diet members)
Local governments

The Prime Minister and the Cabinet

Trigger the **green light** for ILC

Willingness of **the other countries** is essential for this process

~1 year Preparation period for the green light
4 years Preparation for the ILC construction and international negotiations
8-9 years Construction of 250 GeV ILC
  5-6th year Start installation
  7-8th year Start of step-by-step accelerator test
1 year Beam commissioning

>10 years Physics run
  Luminosity upgrade

Looking at the results from ILC250 and those from HL-LHC,… world economy,…
upgrade energy and schedule will be discussed

Summary

Asian particle physicists are very active in the international collaboration in experiments at CERN (LHC accelerator, ATLAS, CMS) and also Belle, Daya Bay, J-PARC, Kamiokande.

Many underground and surface astro-particle physics and cosmic ray experiments are going on in Asian countries.

In the near future Belle-II, Hyper-Kamiokande and Juno experiments … will take place.

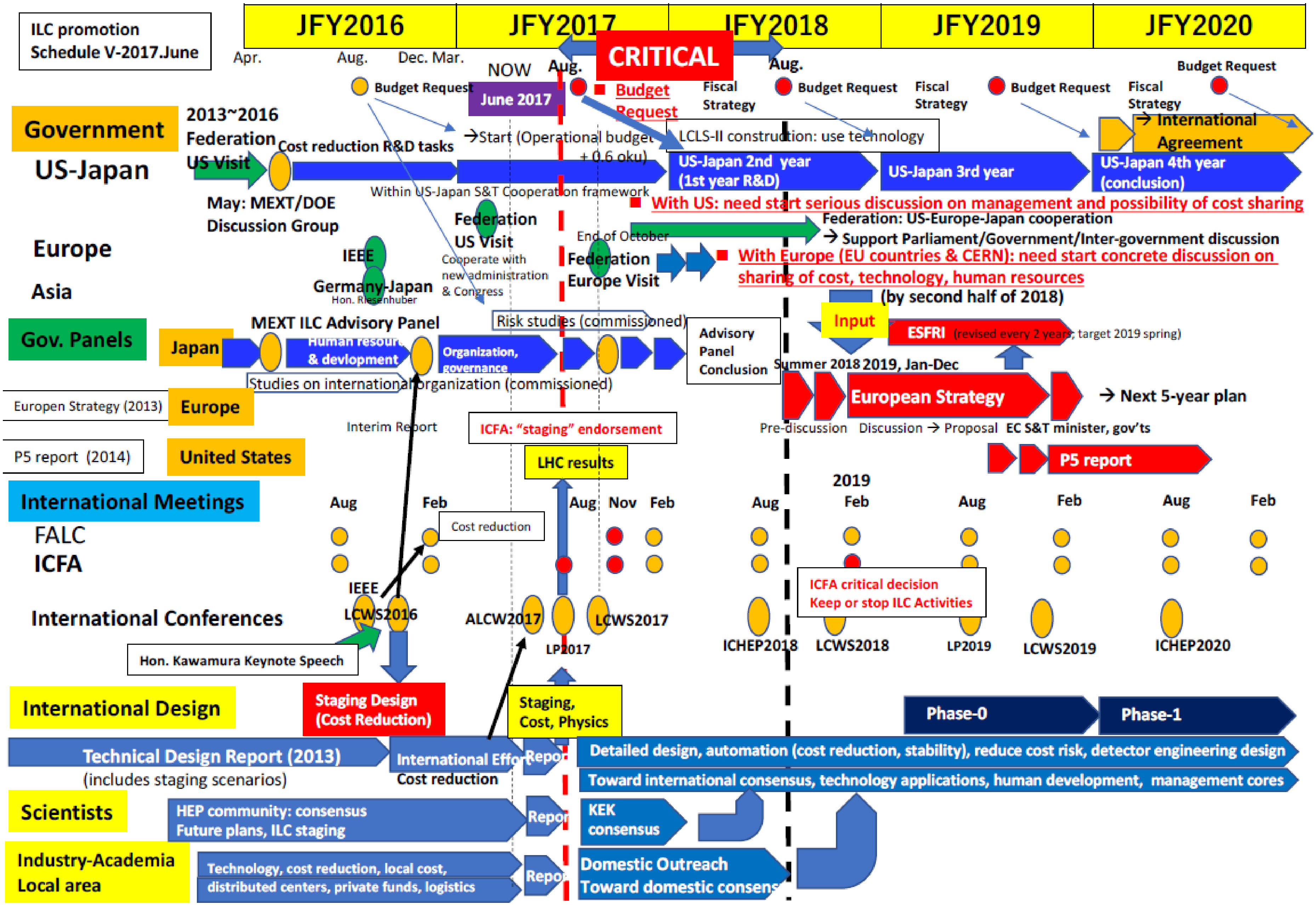
ILC is planning to start with Higgs Factory with significant cost reduction.
Energy upgrade of ILC can be done by extending the main linac and/or by increasing the accelerator gradient. Technology is matured and the time is ripe.

In China CEPC/SppC is planning . This project may interfare with ILC and/or FCC, hopefully In a positive way.

I thank my colleagues in Asia for the contribution to this talk.
Specially,
Prof. Yifang Wang (IHEP, China)
Prof. Eunil Won (Korea University)
Prof. Tariq Aziz (Tata Institute, India)
Prof. George Wei-shu Hou (Taiwan National University)
Prof. Tom Browder (University of Hawaii)
Prof. Masanori Yamauchi (KEK, Japan)

Spare slides

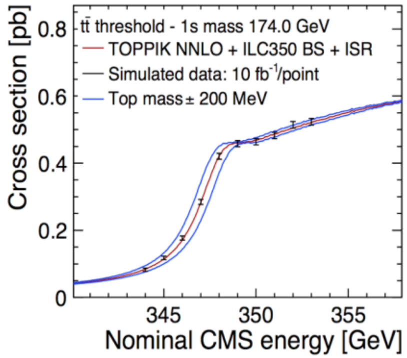
ILC Schedule for coming years



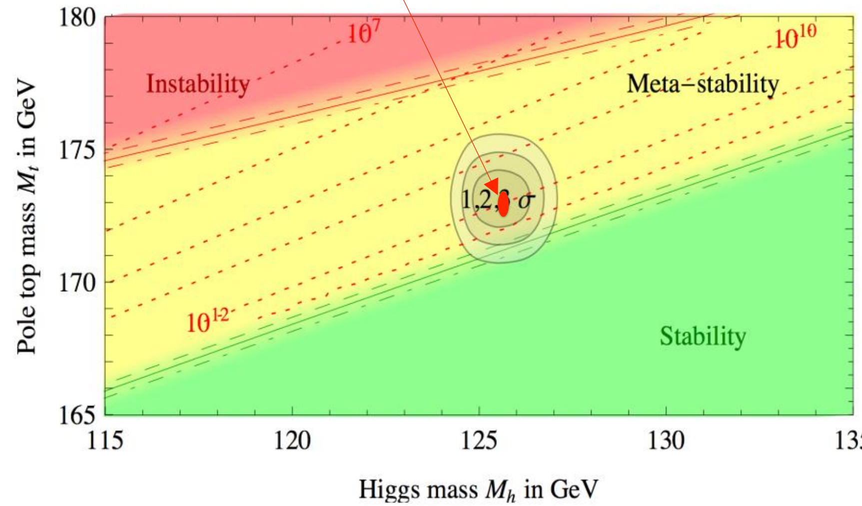
Physics beyond 250 GeV ILC

(1) Precise top quark mass is measured by energy scanning

⇒ vacuum stability



Energy scan around the Top pair threshold at ILC



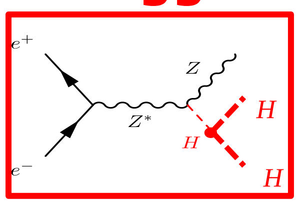
$\Delta m_H = 30$ MeV

$\Delta m_t(\overline{MS})$ = 60 MeV (200-300MeV@LH-LHC)

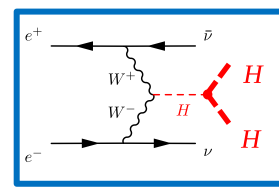
This may be enough

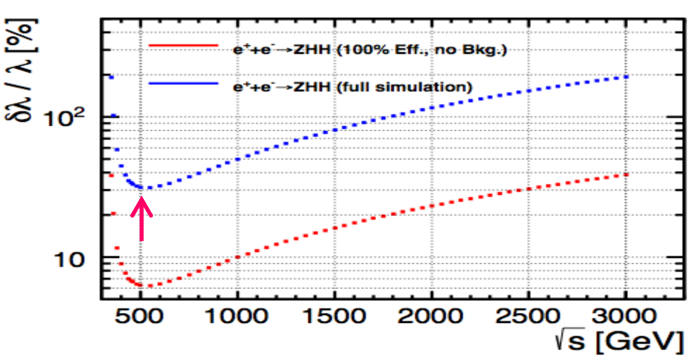
(2) Measurement of Higgs self-coupling

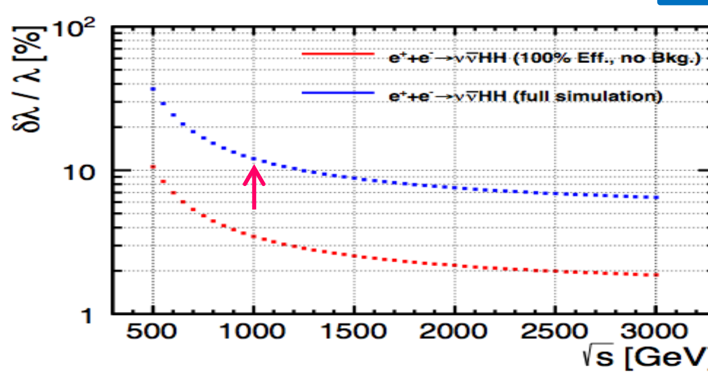
ZHH √s =500 GeV



νvHH √s = 1 TeV







Large rooms for improvement

Current studies ⇒ Δλ/λ~30% at 500 GeV, δλ/λ~10% at 1 TeV