Planning for Particle Physics: Asia

Geoffrey Taylor
CoEPP and University of Melbourne,
AUSTRALIA

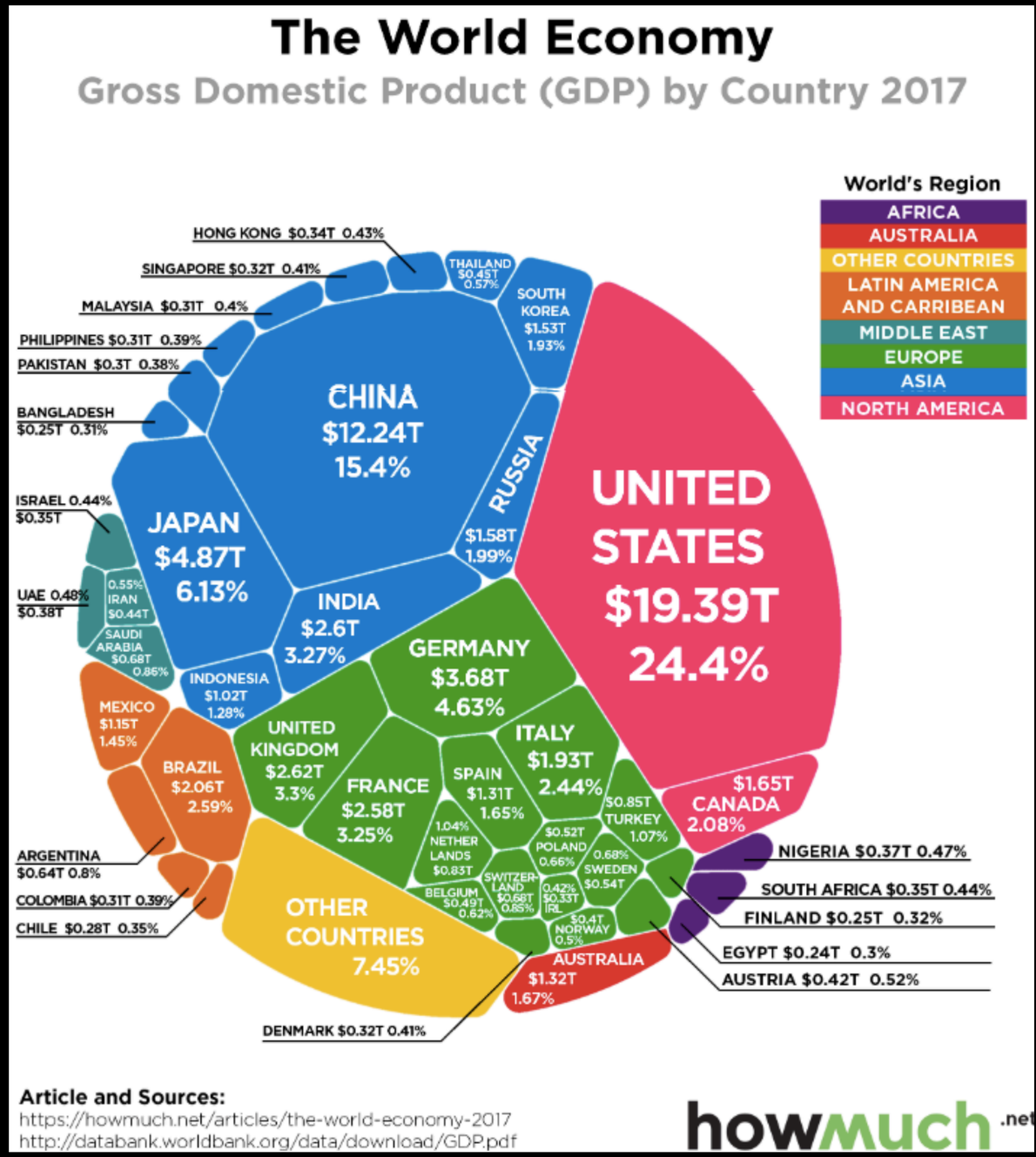
Yes, from Asia!

… but with input from other Asian colleagues

…

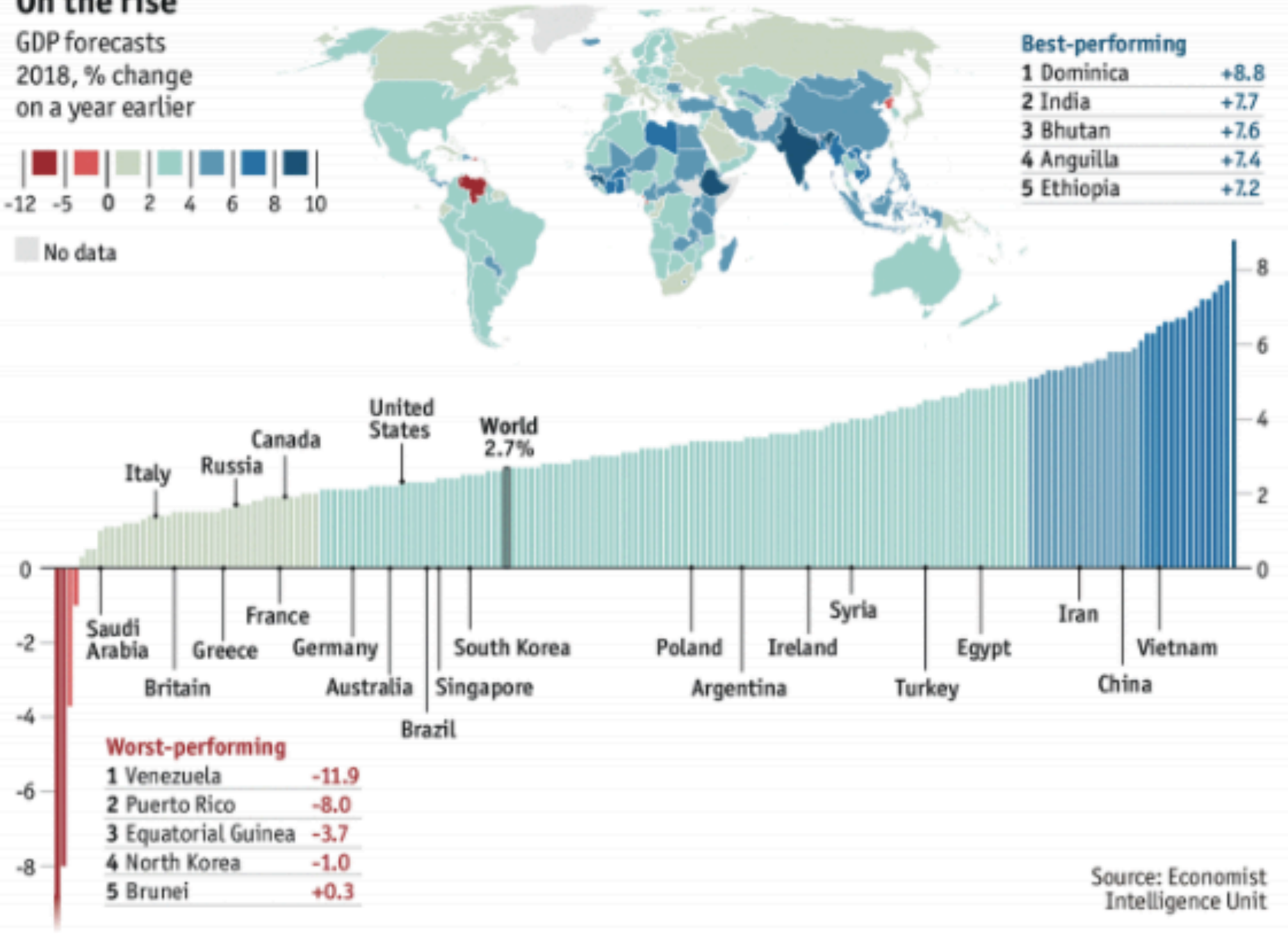
How can Asian projects/ facilities best impact upon the world's particle physics future?

Desire
Resources
People
Technology



On the rise

GDP forecasts 2018, % change on a year earlier



Source: Economist Intelligence Unit

Outline

- **Existing Facilities**
- **Experience in Asian Collaboration**
- **Future Facilities of Impact to Asia and all HEP**

- **Benefits of Asia Hosting Major Facilities**
- **Some Experience with ACFA**

ASIA IS A POWER-REGION in HEP

Projects in Asia (1)

Japan:

- ***SuperKEKB/Belle II: e+e- B-factory***
- ***Super Kamiokande: atmospheric neutrinos/p decay***
- ***J-Parc/T2K: Accelerator neutrino oscillation/CP***
- ***Muon g-2/EDM:***
- ***XMASS: WIMP DM***
- ***ALPACA: Cosmic ray***
- ***KAGRA: Kamioka Gravitational Wave Detector***
- ***ILC: Higgs factory / Future collider***
- ***Hyper-K: atmospheric neutrinos/proton decay***

Thanks to Tao Han, from HKUST Gordon Research Conference, 2019

Projects in Asia (2)

China:

- ***BEPC2/BESS3: e+e- collider program (tau/charm)***
- ***Daya Bay/JUNO: reactor neutrino oscillation***
- ***PANDAX, CEDEX: JinPing lab DM expts***
- ***LHASSO: air shower cosmic rays***
- ***DAMPE: satellite cosmic rays***
- ***AMS: space station observatory***
- ***Ali: CMB polarization / gravitational wave***
- ***LHC ATLAS/CMS/LHCb/ALICE: collider expts***
- ***SuperKEKB/Belle II: e+e- B-factory***
- ***ILC: Higgs factory***
- ***CEPC/SppC: Higgs factory, future colliders***

Listed in Blue → outside of China

Thanks to Tao Han, from HKUST Gordon Research Conference, 2019

Projects in Asia (3)

Korea:

- ***RENO: reactor neutrino oscillation***
- ***CAPP: underground lab at IBS***
  - axion search/proton EDM/muon g-2
  - COMET: mu2e
- ***CUP: underground lab at IBS***
  - COSINE: WIMP DM
  - AMoRE: Double Beta (0n2b) decay
  - NEOS: reactor sterile neutrinos
- ***LHC CMS/ALICE: collider expts***
- ***SHiP @ CERN: long-lived particles***
- ***KEK B/Belle II: e+e- B-factory***
- ***Super K, ICECUBE: neutrinos***

Listed in Blue → outside of Korea

Thanks to Tao Han, from HKUST Gordon Research Conference, 2019

Projects in Asia (4)

India:

- ***LHC ATLAS/ALICE: collider expts***
  - Associate Member, CERN
- ***SuperKEKB/Belle II: e+e- B-factory***
- ***PLANCK: satellite CMB***
- ***LIGO-India: gravitational wave***
- ***India Neutrino Observatory: atmospheric neutrinos***

Hong Kong:

- ***LHC ATLAS: collider expt***
- ***Daya Bay/ JUNO: reactor neutrino experiments***
- ***VLA, SMA, ALMA: radio/optical astrophysics***
- ***Fermi-LAT: gamma-ray astrophysics***

Thanks to Tao Han, from HKUST Gordon Research Conference, 2019

Projects in Asia (5)

Australia:

- ***LHC ATLAS: collider expt***
- ***SuperKEKB/Belle II: e+e- B-factory***
- ***LIGO: gravitational wave***
- ***Axion Search***
- ***SUPL/SABRE: Underground direct dark matter***

Taiwan:

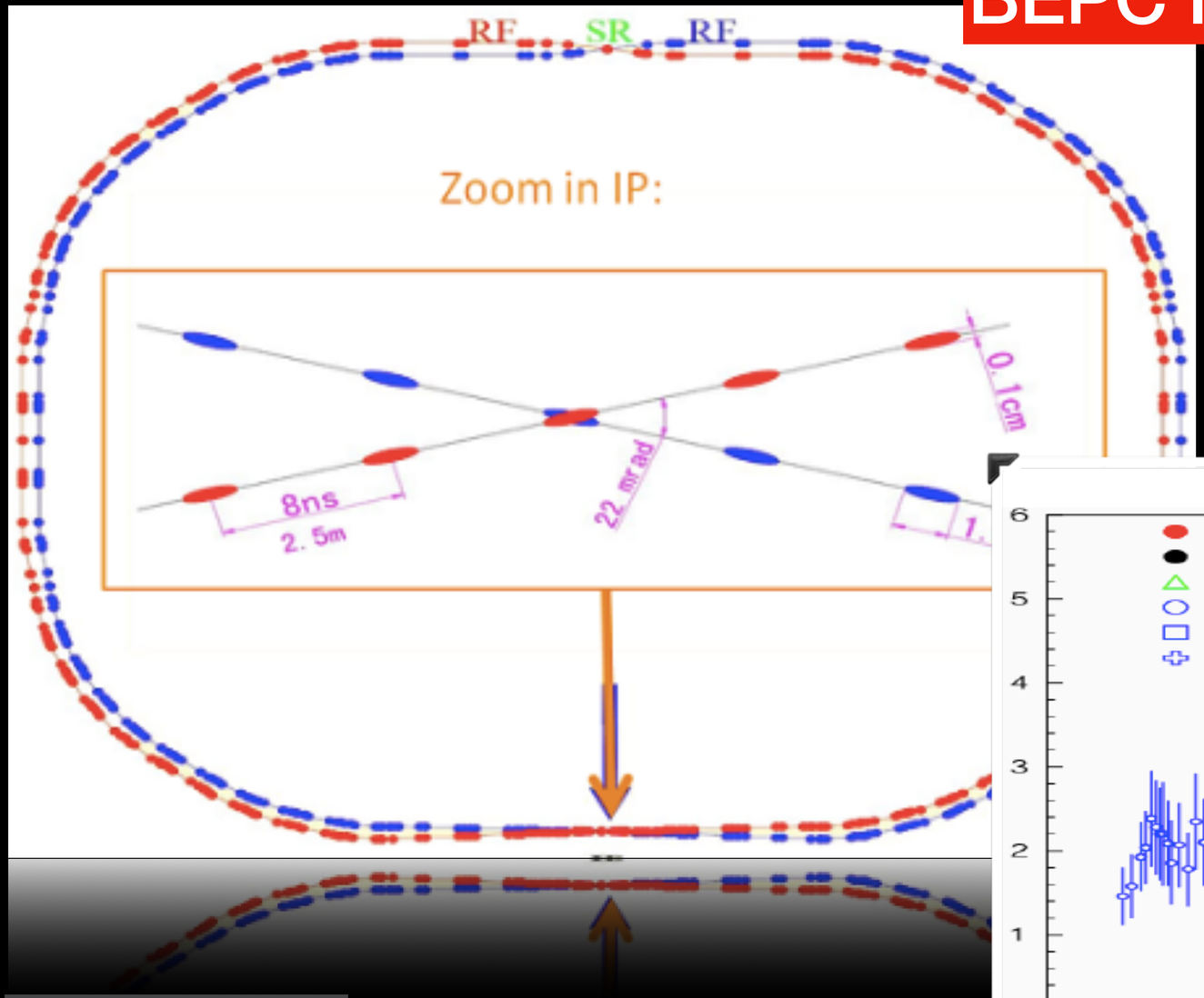
- ***LHC CMS: collider expt***
- ***SuperKEKB/Belle II: e+e- B-factory***

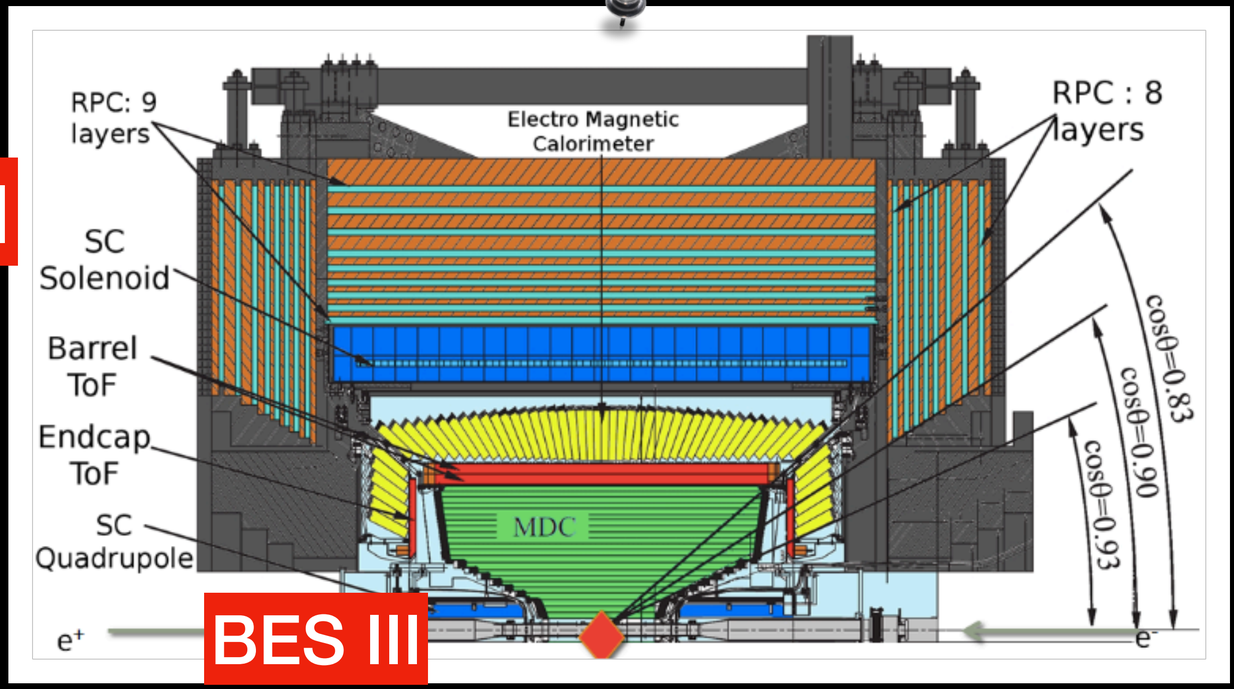
Several smaller efforts across a range of countries

Thanks to Tao Han, from HKUST Gordon Research Conference, 2019

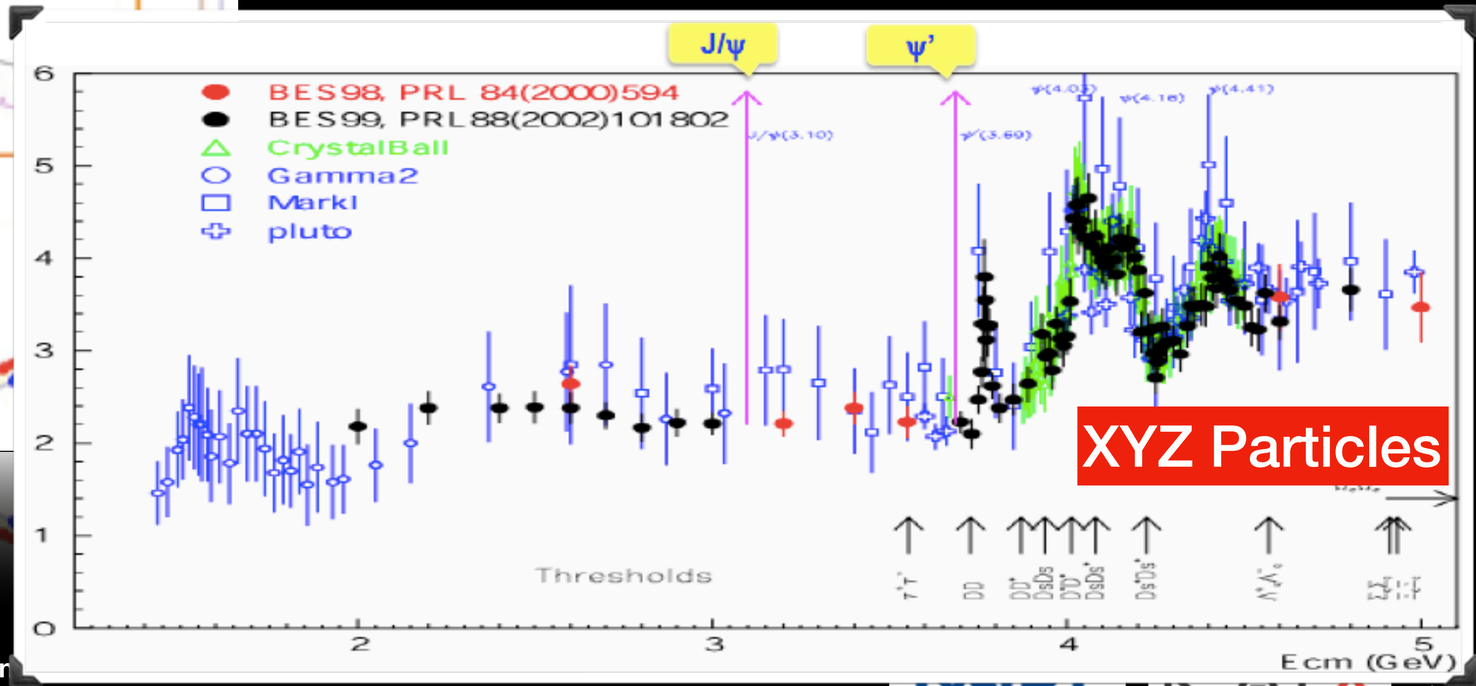
Postcards from China

BEPC II





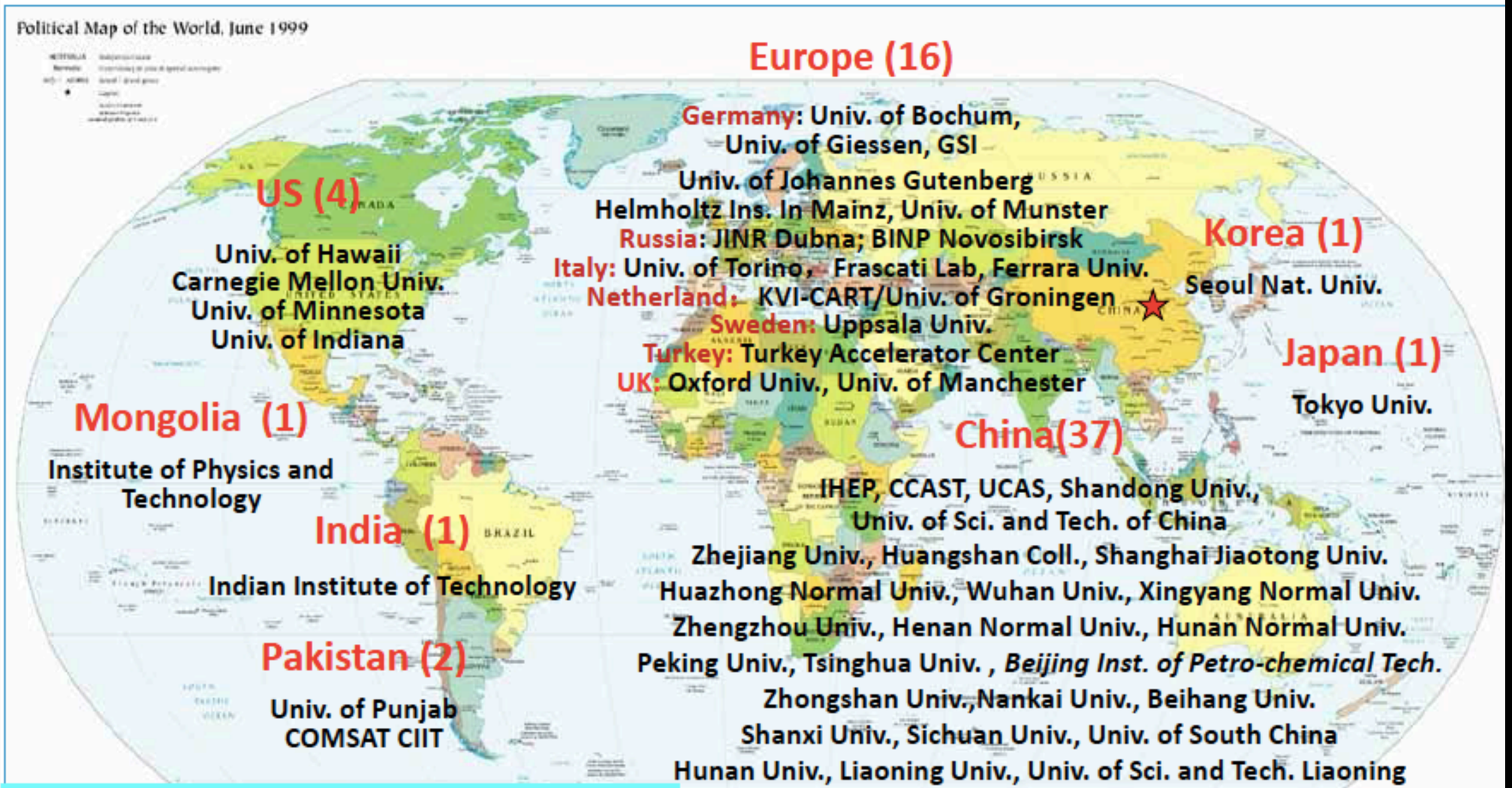
BES III



XYZ Particles

China HEP Hosting Experience

BESIII Collaboration



Europe (16)

Germany: Univ. of Bochum,
Univ. of Giessen, GSI
Univ. of Johannes Gutenberg
Helmholtz Ins. In Mainz, Univ. of Munster
Russia: JINR Dubna; BINP Novosibirsk
Italy: Univ. of Torino, Frascati Lab, Ferrara Univ.
Netherland: KVI-CART/Univ. of Groningen
Sweden: Uppsala Univ.
Turkey: Turkey Accelerator Center
UK: Oxford Univ., Univ. of Manchester

US (4)

Univ. of Hawaii
Carnegie Mellon Univ.
Univ. of Minnesota
Univ. of Indiana

Korea (1)

Seoul Nat. Univ.

Japan (1)

Tokyo Univ.

Mongolia (1)

Institute of Physics and Technology

India (1)

Indian Institute of Technology

Pakistan (2)

Univ. of Punjab
COMSAT CIIT

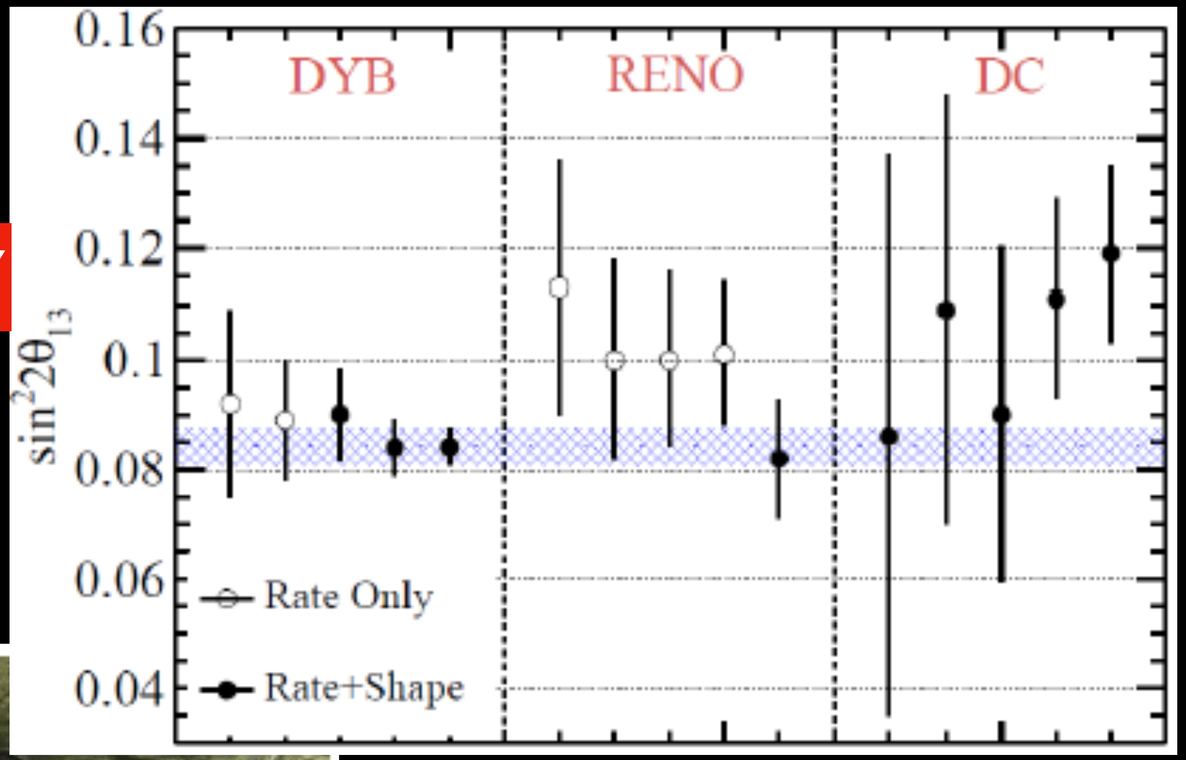
China(37)

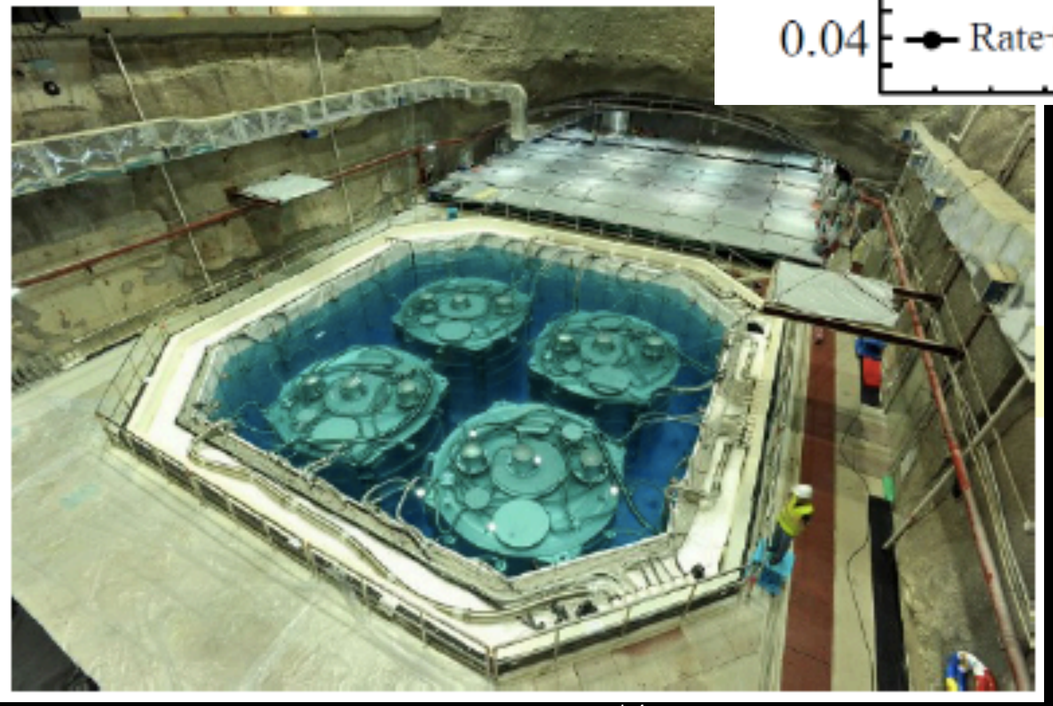
IHEP, CCAST, UCAS, Shandong Univ.,
Univ. of Sci. and Tech. of China
Zhejiang Univ., Huangshan Coll., Shanghai Jiaotong Univ.
Huazhong Normal Univ., Wuhan Univ., Xingyang Normal Univ.
Zhengzhou Univ., Henan Normal Univ., Hunan Normal Univ.
Peking Univ., Tsinghua Univ. , *Beijing Inst. of Petro-chemical Tech.*
Zhongshan Univ.,Nankai Univ., Beihang Univ.
Shanxi Univ., Sichuan Univ., Univ. of South China
Hunan Univ., Liaoning Univ., Univ. of Sci. and Tech. Liaoning
Nanjing Univ., Nanjing Normal Univ., Southeast Univ.
Guangxi Normal Univ., Guangxi Univ.
Suzhou Univ., Hangzhou Normal Univ.
Lanzhou Univ., Henan Sci. and Tech. Univ.
Jinan Univ., Fudan Univ.

~ 450 members
from 64 institutions in 14 countries

Postcards from China

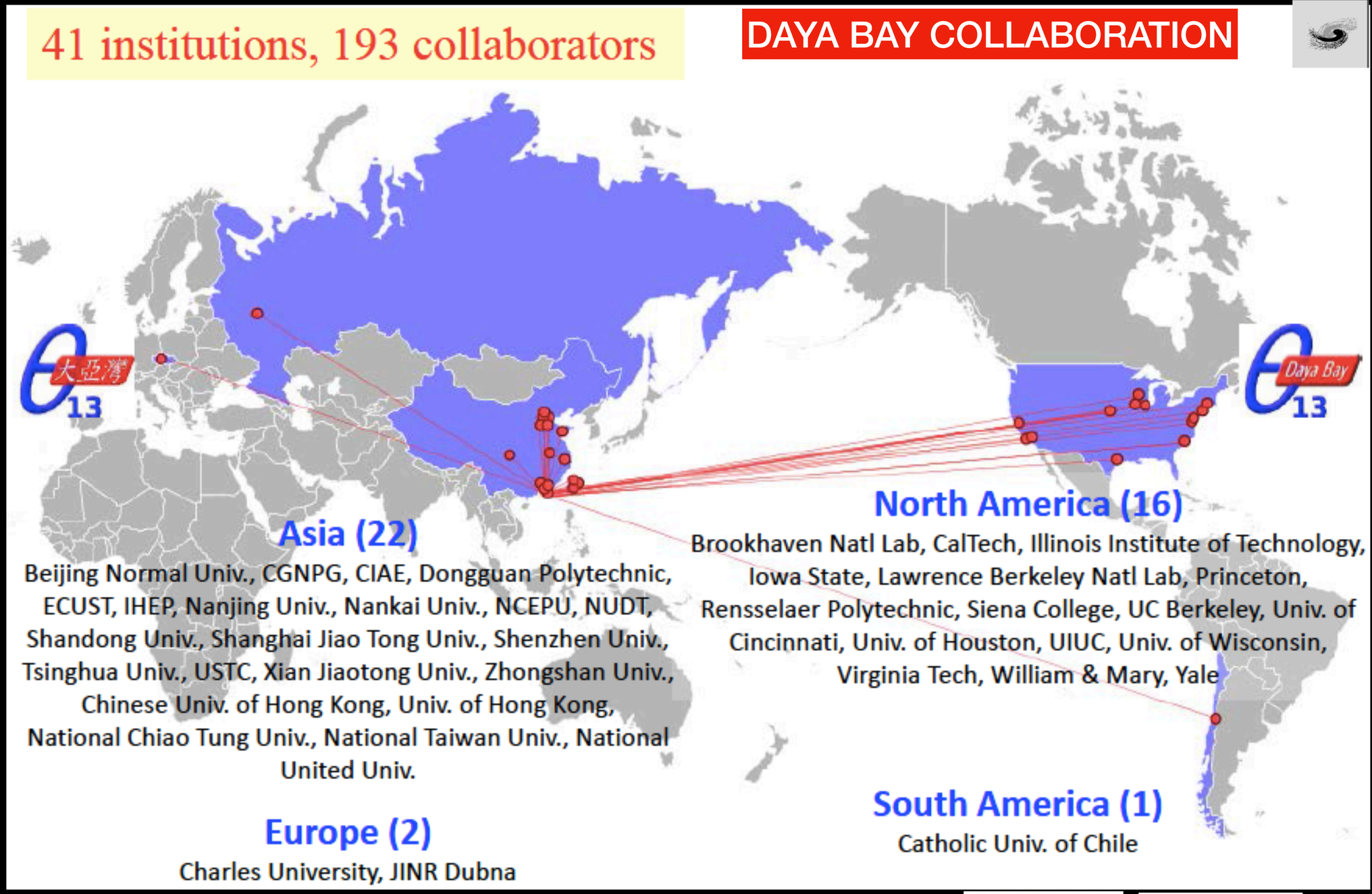
DAYA BAY





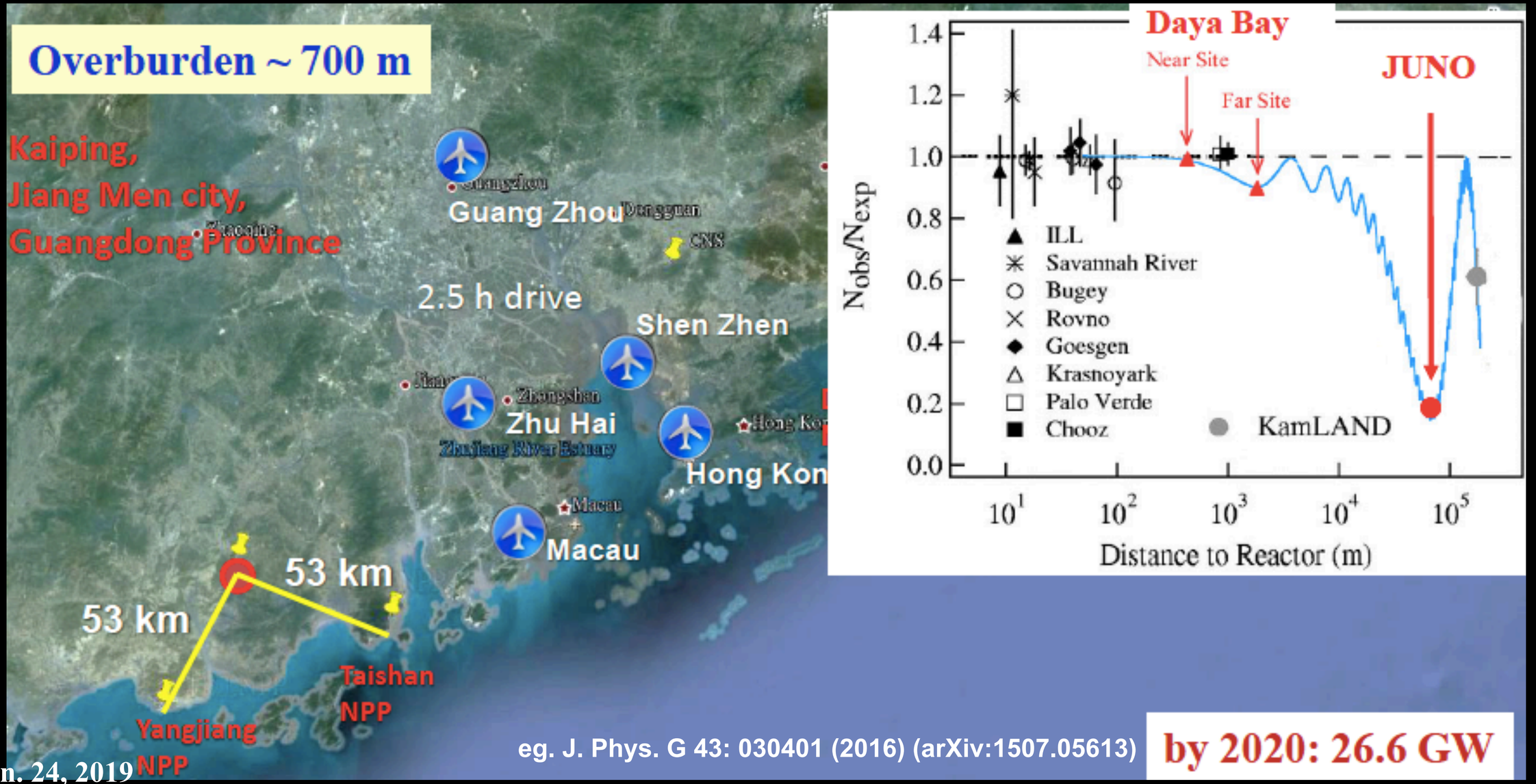
Yifang Wang
IAS-HKUST, Jan. 24, 2019

China HEP Hosting Experience



Postcards from China

JUNO



Yifang Wang
IAS-HKUST, Jan. 24, 2019

China HEP Hosting Experience

17 Countres & regions, 77 institution， 580 members

Europe (28)

Belgium(1)
ULB

Czech(1)
Charles U

Latvia(1)
IECS

Finland(1)
U.Oulu

France(5)
APC Paris
CPPM Marseille
IPHC Strasbourg
Subatech Nantes
CENBG-IN2P3

Italy(8)
INFN-Catania
INFN-Frascati
INFN-Ferrara
INFN-Milano
INFN-Mi-Bicocca
INFN-Padova
INFN-Perugia
INFN-Roma 3

Germany(7)
FZ Jülich
RWTH Aachen
TUM
U.Hamburg
IKP FZI Jülich
U.Mainz
U.Tuebingen

Russia(3)
INR Moscow
JINR
MSU

Slovakia (1)
FMPICU

America(6)

US(2)
UMD
UMD-Geo

Chile(2)
PCUC
UTFSM

Brazil（2）
PUC-Rio
UEL

Asia (38)

China（33）
BJ Nor. U.
CAGS
Chongqing U.
Shanghai JT U.
DGUT
ECUST
Guangxi U.
HIT
IHEP
U. Of South China
Ninan U.
Nanjing U.
Natl. Chiao-Tung U.
Natl. Taiwan U.
Natl. United U.
Nankai U.
NCEPU
Pekin U.
SDU
Sichuan U.
CIAE
SYSU
Tsinghua U.
UCAS
USTC
Jilin U.
Wuhan U.
Wuyi U.
Xi'an JT U.
Xiamen U.
NUU.

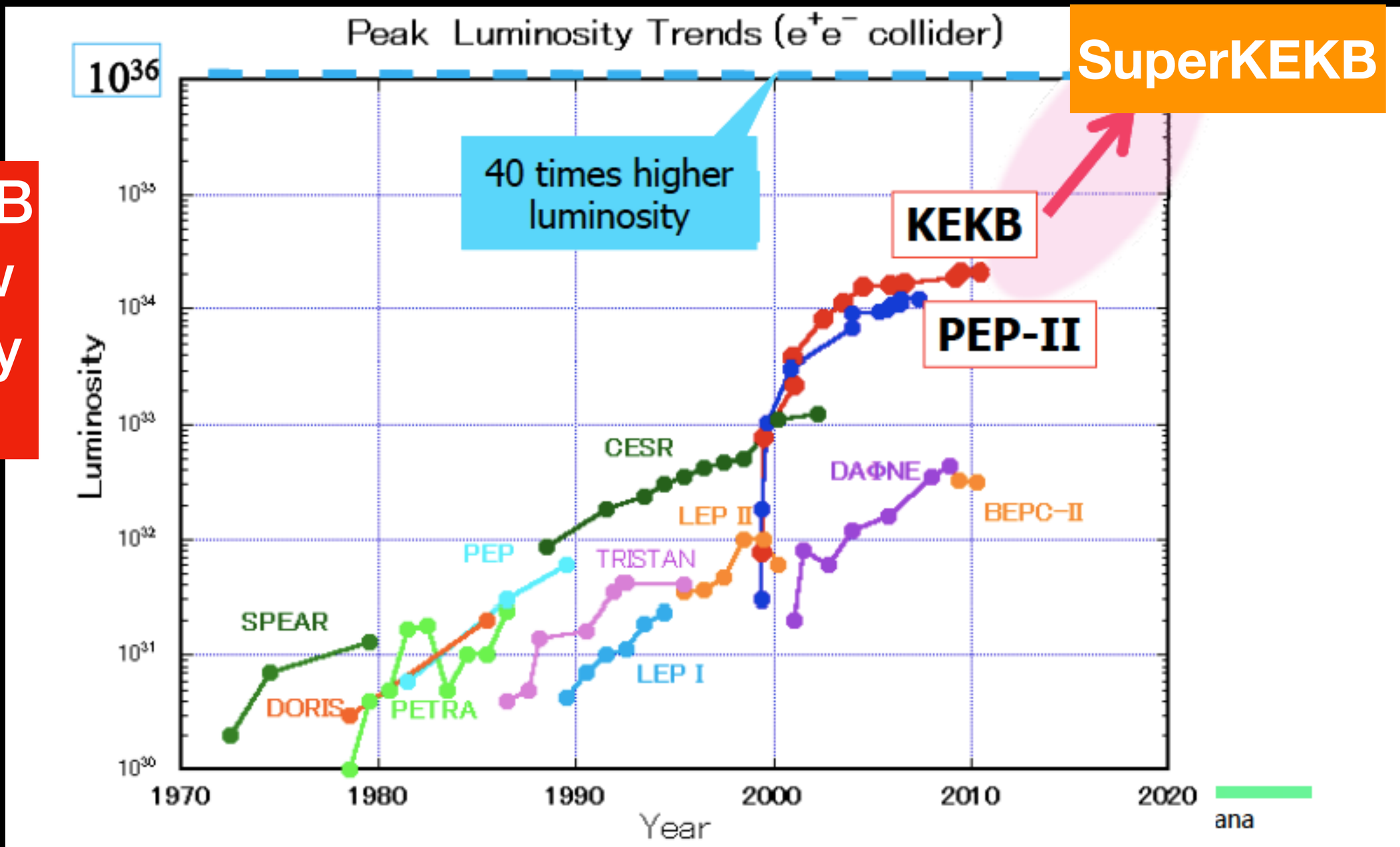
Armenia(1)
Yerevan Phys. Inst.

Thailand(3)
SUT
PPRLCU
NARIT

Parkistan(1)
PINSTECH

Postcards from Japan

SuperKEKB to set new Luminosity Record



CoEPP
ARC Centre of Excellence for Particle Physics at the Terascale

Belle II Collaboration

- Over 800 International Collaborators
- Commencing operation
- Expected to run through 2026+

Belle II - LHCb Comparison

P.Urquijo, U. Melbourne

Belle II
Higher sensitivity to decays with photons and neutrinos (e.g. B→Kνν, μν), inclusive decays, time dependent CPV in B_d, τ physics.

LHCb
Higher production rates for ultra rare B, D, & K decays, access to all b-hadron flavours (e.g. Λ_b), high boost for fast B_s oscillations.

Overlap in various key areas to verify discoveries.

Upgrades
Most key channels will be stats. limited (not theory or syst.).
LHCb scheduled major upgrades during LS3 and LS4.
Belle II formulating a 250 ab^{-1} upgrade program post 2028.

Observable	Current Belle/ Babar	Current LHCb	Belle II (50 ab^{-1})	LHCb (23 fb^{-1})	Belle II Upgrade (250 ab^{-1})	LHCb upgrade II (300 fb^{-1})
CKM precision, new physics in CP Violation						
sin 2β/φ1 (B→ J/ψ Ks)	0.03	0.04	0.005	0.011	0.002	0.003
γ/φ3	13°	5.4°	1.5°	1.5°	0.4°	0.4°
α/φ2	4°	–	0.6°	–	0.3°	–
$\|V_{ub}\|$ (Belle) or $\|V_{ub}\|/\|V_{cb}\|$ (LHCb)	4.5%	6%	1%	3%	<1%	1%
φs	–	49 mrad	–	14 mrad	–	4 mrad
S_{CP}(B→η' Ks, gluonic penguin)	0.08	○	0.015	○	0.007	○
A_{CP}(B→Ksπ^0)	0.15	–	0.04	–	0.02	–
New physics in radiative & EW Penguins, LFUV						
S_{CP}(B_d→K* γ)	0.32	○	0.035	○	0.015	○
R(B→K$^*l^+l^-$) ($1<q^2<6$ GeV$^2/c^2$)	0.24	0.1	0.03	0.03	0.01	0.01
R(B→D*τν)	6.4%	10%	1.5%	3%	<1%	1%
Br(B→τν), Br(B→K*νν)	24%, –	–	4%, 9%	–	1.7%, 4%	–
Br(B_d→μμ)	–	90%	–	34%	–	10%
Charm and τ						
ΔA_{CP}(KK-ππ)	–	8.5×10^{-4}	5.4×10^{-4}	1.7×10^{-4}	2×10^{-4}	0.3×10^{-4}
A_{CP}(D→π$^+$π^0)	1.2%	–	0.2%	–	0.1%	–
Br(τ→e γ)	<120×10^{-9}	–	<12×10^{-9}	–	<5×10^{-9}	–
Br(τ→μμμ)	<21×10^{-9}	<46×10^{-9}	<3×10^{-9}	<16×10^{-9}	<0.3×10^{-9}	<5×10^{-9}

arXiv: 1808.08865 (Physics case for LHCb upgrade II), 1808.10567 (Belle II Physics Book)

○ *Possible in similar channels, lower precision*
– *Not competitive.*

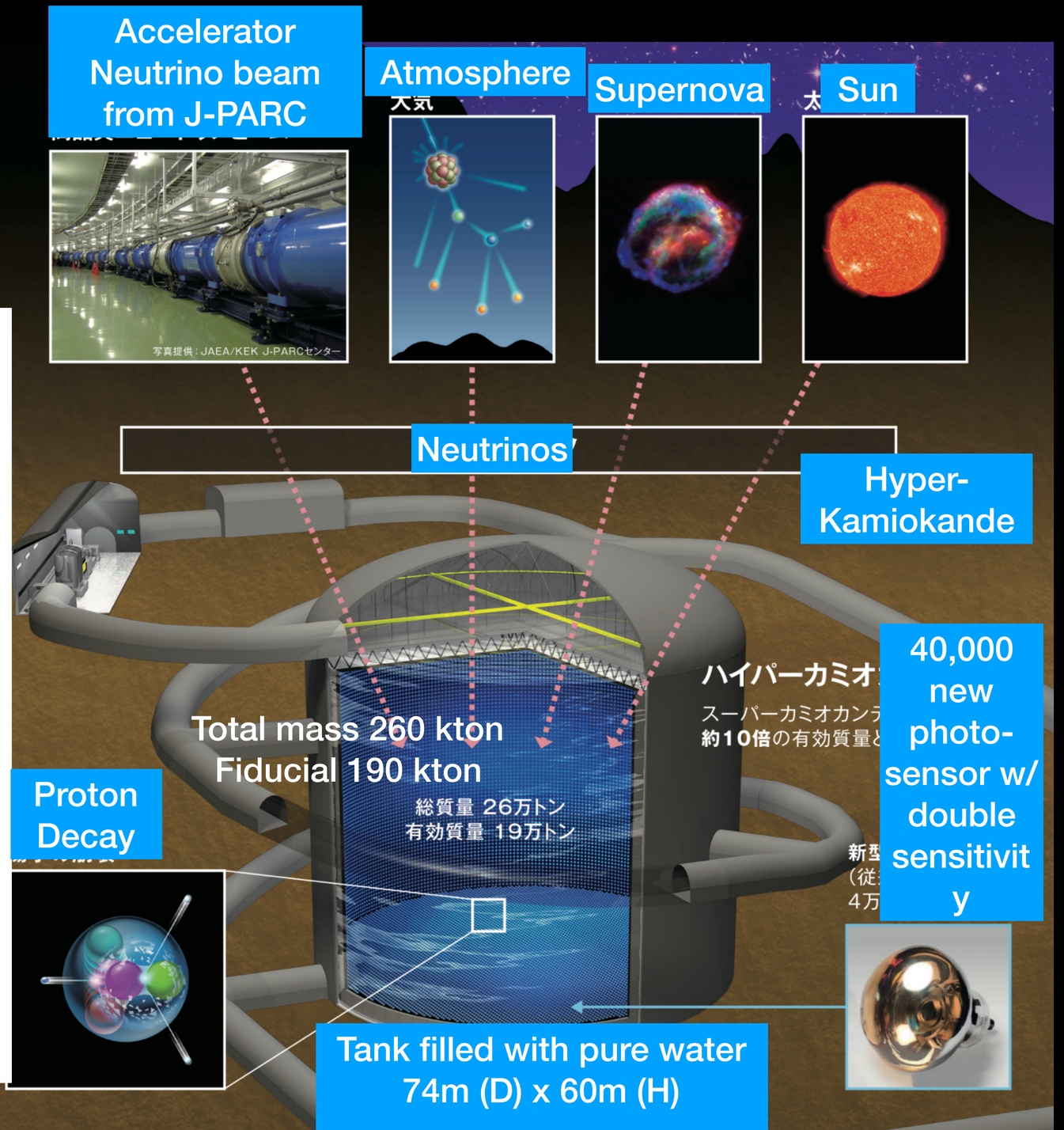
Postcards from Japan - Hyper-Kamiokande

New water Cherenkov detector, Hyper-Kamiokande with 190 kiloton fiducial mass and double-sensitivity PMTs

J-PARC neutrino beam upgrade to 1.3MW with new and upgraded near detectors

Broad science program

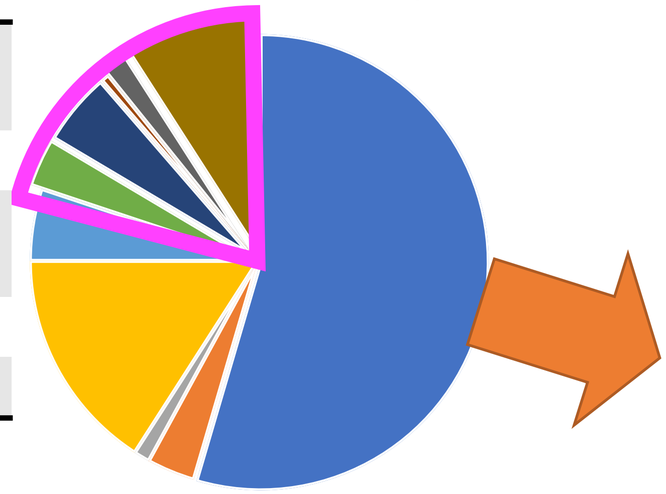
- Precise measurements of neutrino oscillations and CP asymmetry in lepton sector
  δCP accuracy 22°(δ=±90°)
- Proton decay reach to 1035 years ($p \rightarrow e+\pi^0$)
- Rich neutrino astronomy objects: Sun, nearby supernova, diffuse SN neutrinos, GW coincidence ν, etc



European participation in Japan-based neutrino program

Super-Kamiokande (as of Jan.2019)

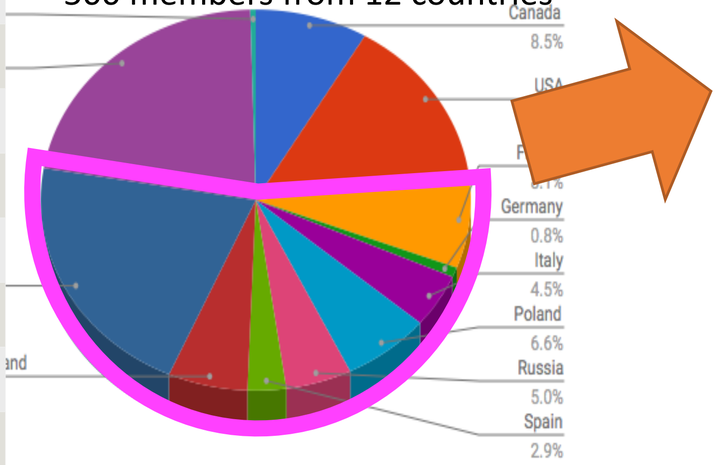
France
Italy
Poland
Spain
UK



T2K (as of Jan 2019)

Europe	266
France	39
Germany	4
Italy	22
Poland	32
Russia	24
Spain	14
Switzerland	29
UK	102

~500 members from 12 countries



CERN joined T2K in March 2019

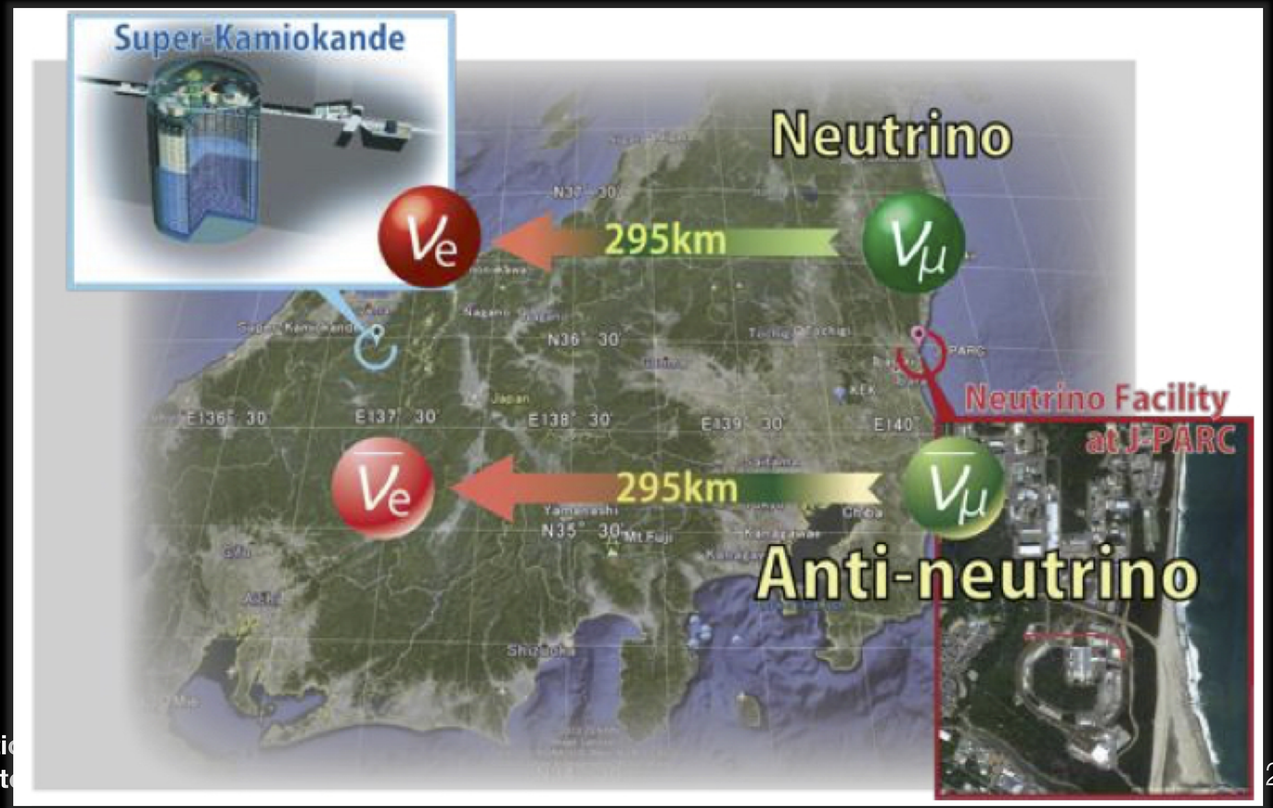
Hyper-Kamiokande (as of Dec. 2018)

Europe (130 people)	Asia (105 people)	Americas (62 people)
Armenia	Korea	Brazil
France	India	Canada
Germany	Japan	USA
Italy		
Poland		
Russia		
Spain		
Sweden		
Switzerland		

25-50% of collaborators are from Europe!

Complementarity of DUNE/LBNF and T2HK

- *Different v-energy*
- *Different Baseline (1300 vs. 295km)*
- *Complementary sensitivity to Lepton-CP Violation and v Mass Hierarchy*



Hyper-Kamiokande Korea?

- **J-Parc Neutrino Beamline —> South Korea:**
  - ***Possible angles: 1^o-3^o***
  - ***Can optimize energy spectrum***
    - Three baselines; additional path in matter
- **Improve neutrino oscillation sensitivities of Hyper-K:**
  - ***Expanded L/E, larger matter-effect, resolution,..***
  - ***Neutrino Mass Hierarchy; theta-23; leptons CP-violation.***
  - ***Probe non-standard neutrino interactions, models, ..***

Hyper-K Korea

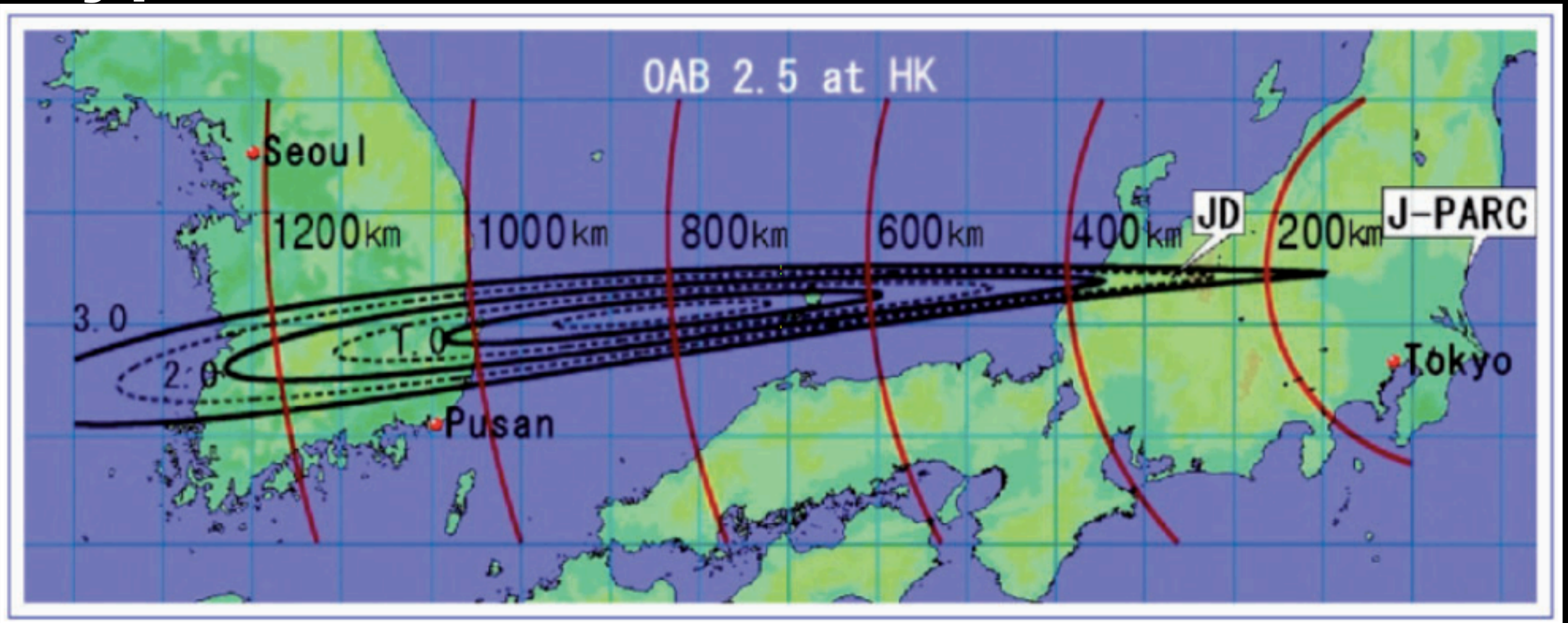
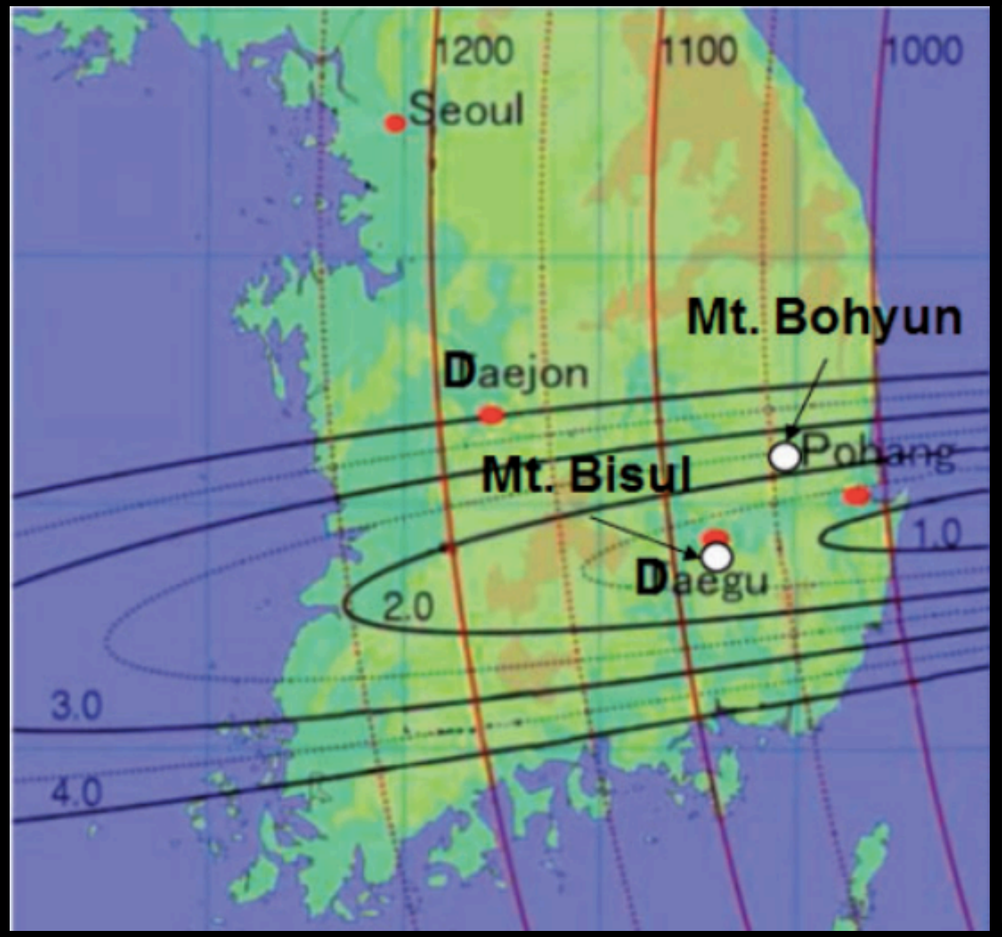
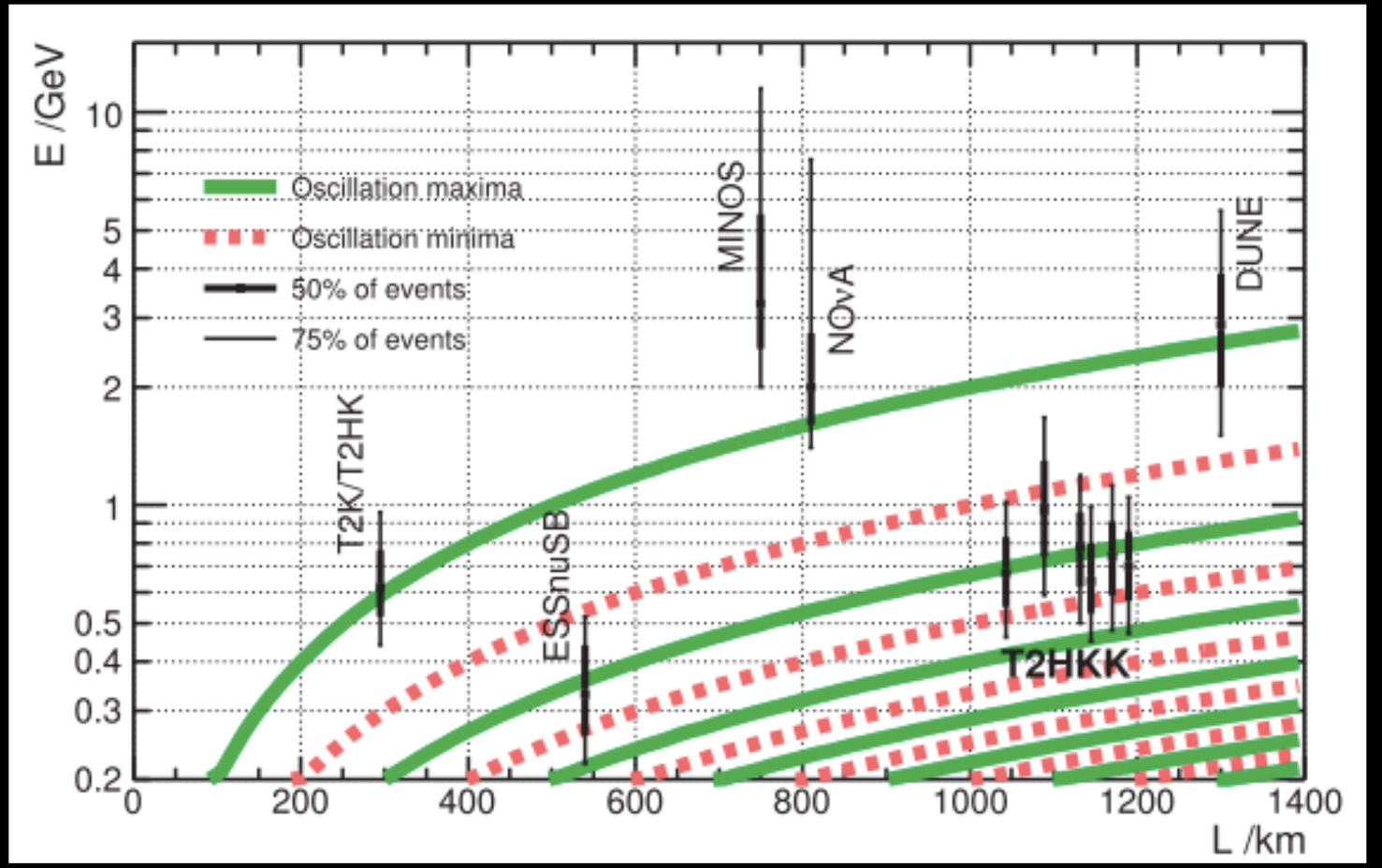


Fig. 1. Map showing the baseline and off-axis angle of the J-PARC beam in Japan and Korea [8,9].





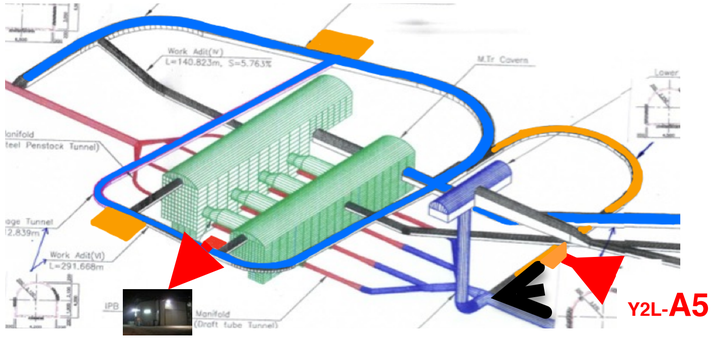
Prog. Theor. Exp. Phys. 2018, 063C01 (65 pages) DOI: 10.1093/ptep/pty044

More from Korea

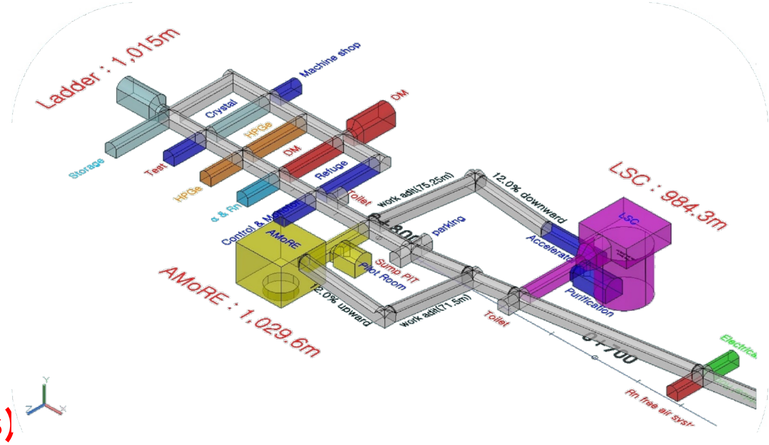
Center for Underground Physics (CUP)

Center for Underground Physics

Yangyang underground laboratory (Y2L)



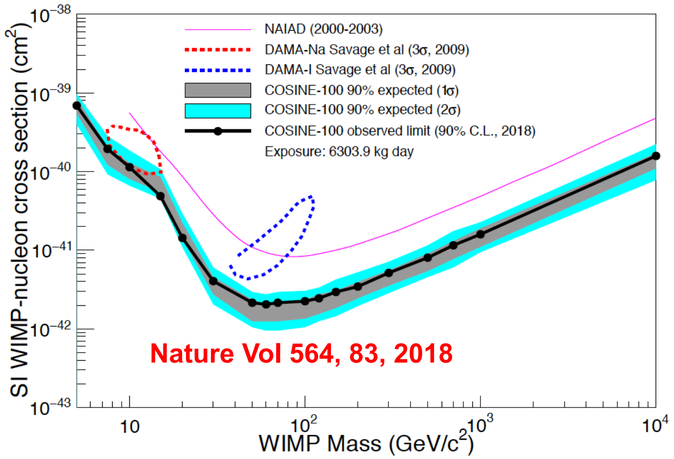
Yemilab : under construction, 1100 m depth.



1. COSINE (Collaboration Of Sodium lodiNe Experiments)

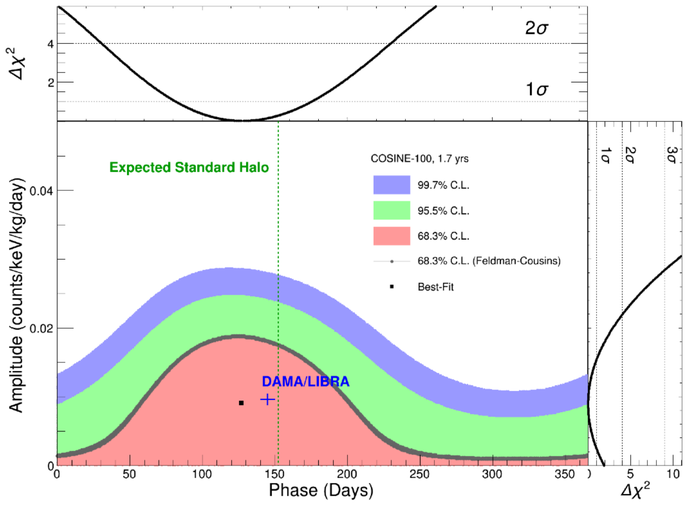
- Purpose – Simple, Check DAMA signal.
- Collaboration : Yale, CUP, Sheffield, San Paulo U.
- Status : COSINE-100 is running at Y2L for 2.5 years.

1. Contradictory to DAMA interpretation as WIMPs with standard halo model.



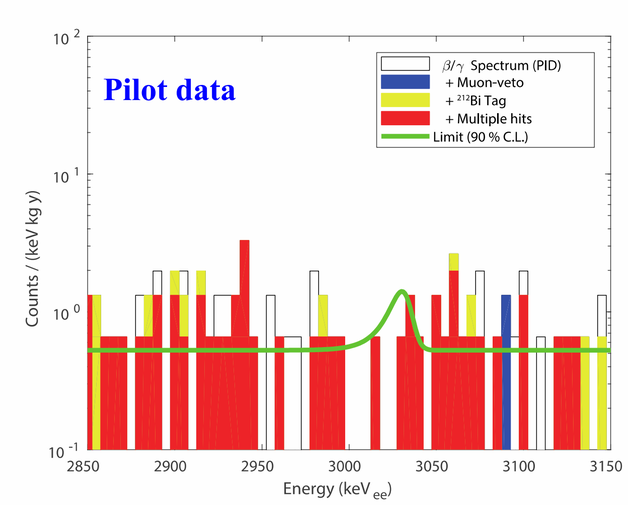
2. Showed ~1.5 sigma sensitivity for DAMA modulation signal with 1.5 years data.

Accepted to PRL

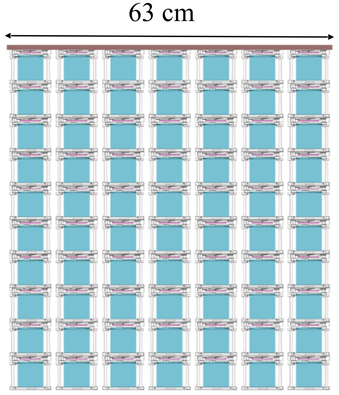


2. AMoRE ββ experiment

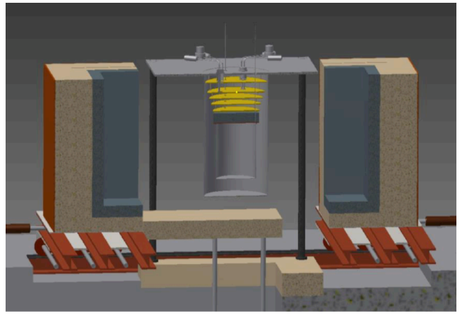
- Purpose of AMoRE : ^{100}Mo double beta decay
- Collaboration : Heidelberg U., PTB, Ukraine, Moscow U. etc. ~ 100.
- Status : Finished Pilot experiment, updating to AMoRE-I setup, and prepare AMoRE-II setup.
- Results :
  - Demonstrated background rejection through PSD.
  - ~1x10^{23} years lifetime limits set for ^{100}Mo with Pilot data.



AMoRE-II Setup



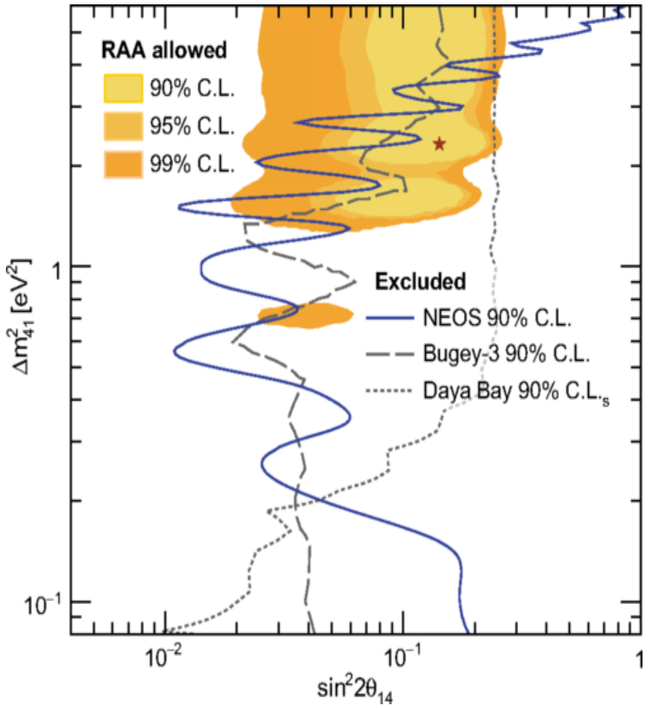
AMoRE-II shielding structure.
Similar design to CUORE.
25cm Pb + 70cm PE



3. NEOS

(Short baseline Reactor Neutrino Oscillation Experiment)

- **3GW thermal Reactor Neutrinos.**
- **Disfavored the best parameters from reactor anomaly. PRL 118, 121802**



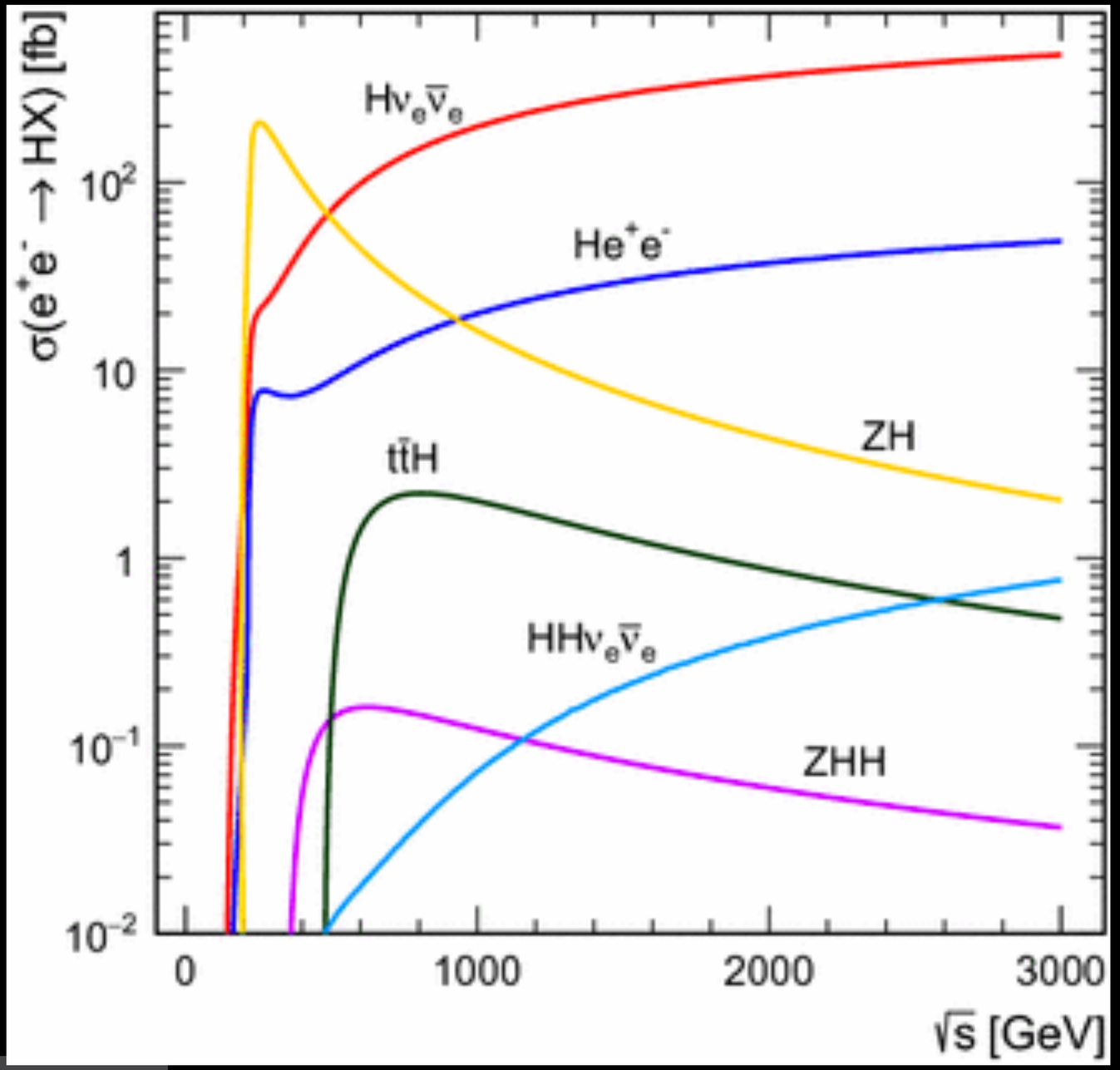
Currently, NEOS-II has run more than 6 months, and will continue summer of 2020.

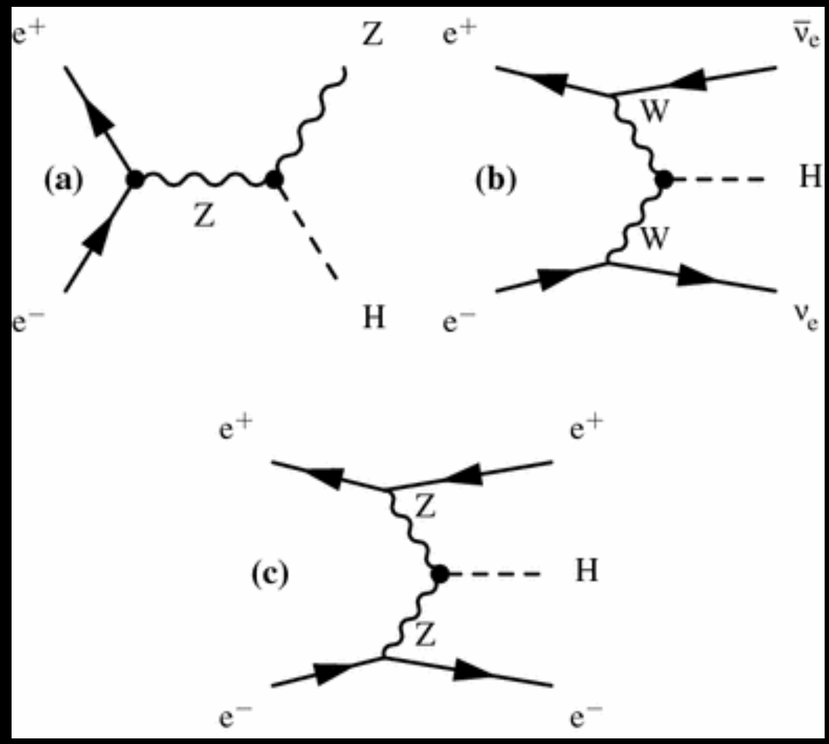
Colliders in Worldwide Planning?

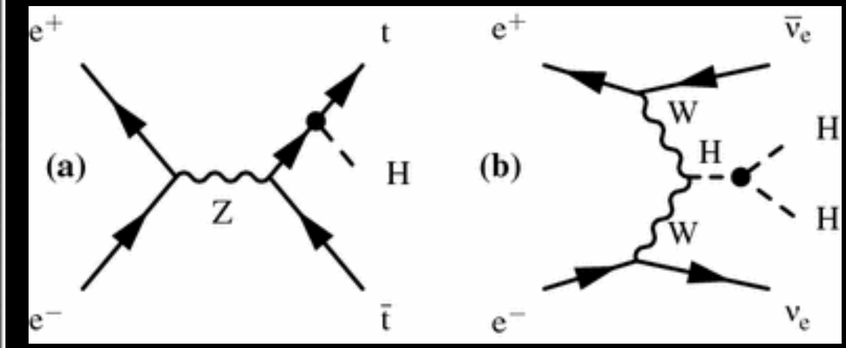
WE ARE AT CRITICAL PLANNING POINT FOR THE ENTIRE FIELD

- e+e- Higgs Factory must be “next cab off the Rank”
- ILC <—> CLIC
- CEPC <—> FCC(ee)
  - *Nature of Impact of these parallels on planning*

- 100km tunnel —>
  - *What route to the High Energy Frontier Proton Collider?*


σ(e⁺e⁻ → HX) [fb]
Hν_eν̄_e
He⁺e⁻
ZH
tt̄H
HHν_eν̄_e
ZHH
10²
10
1
10⁻¹
10⁻²
0
1000
2000
3000
√s [GeV]

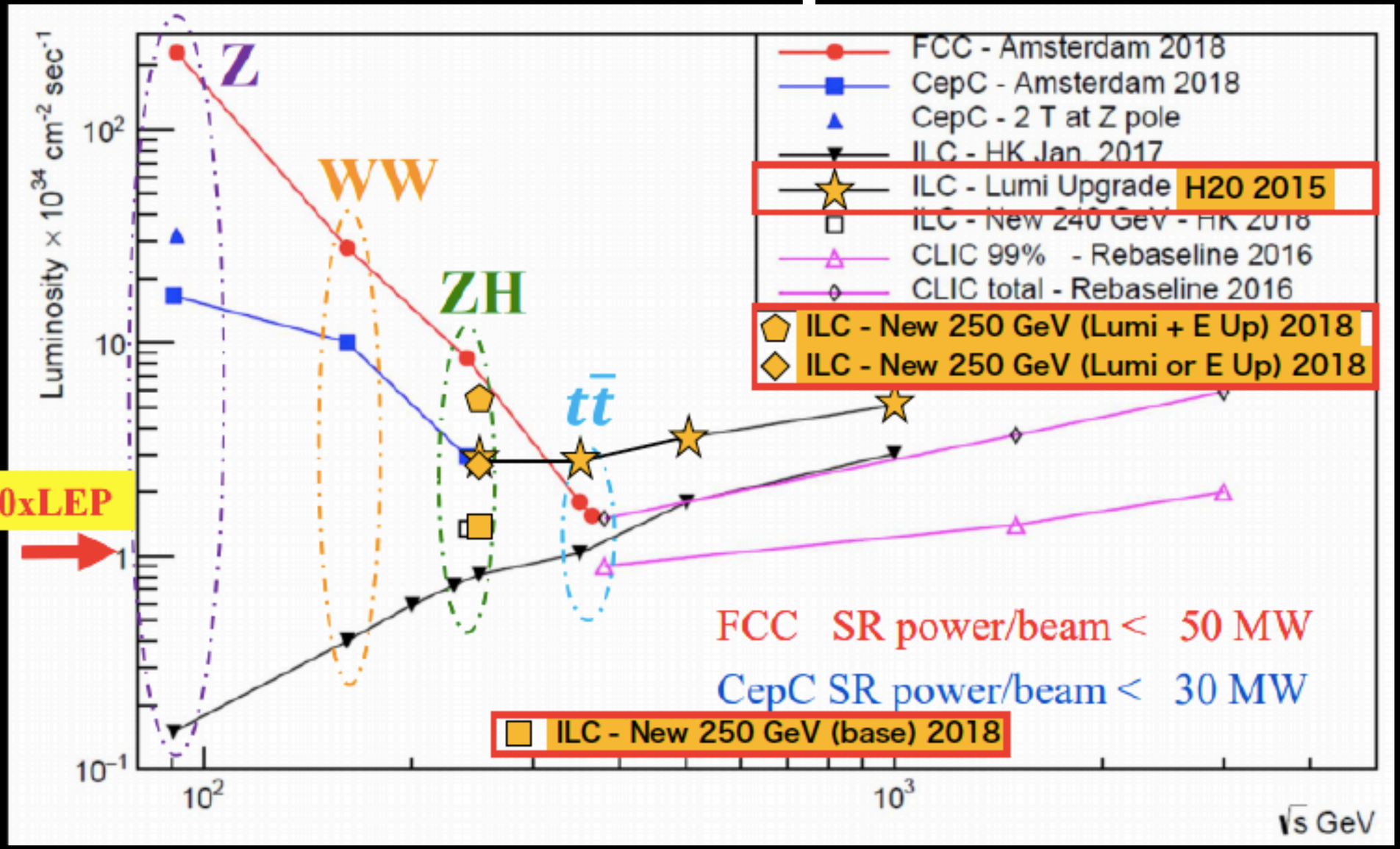

e⁺
Z
(a)
Z
e⁻
H
e⁺
ν̄_e
W
(b)
H
W
e⁻
ν_e
e⁺
e⁺
Z
(c)
H
Z
e⁻
e⁻


e⁺
t
(a)
H
Z
e⁻
t̄
e⁺
ν̄_e
W
H
(b)
H
H
W
e⁻
ν_e

ILC or CLIC?

- **“We need a linear collider!” Lausanne, LC Meeting, 2019**
- **Both are capable of providing the essential “Higgs Factory”:**
  - ***240-250GeV e+e- Collider***
  - ***Extending to high energy:***
    - CLIC initial capability already at 380GeV - top quark threshold
      - ILC up to ~800 -1000GeV - Future upgrade, more $
      - CLIC to multi-TeV - Future upgrade, more CHF
    - both at significant additional cost

e+e- Lumi Comparison



- Original Plot, F. Bedeschi , CEPC Workshop, Rome, May 2018
- Updates Private communication, Keisuke Fujii, IPNS, KEK

Europe: "Should we not just plan for our own requirements?

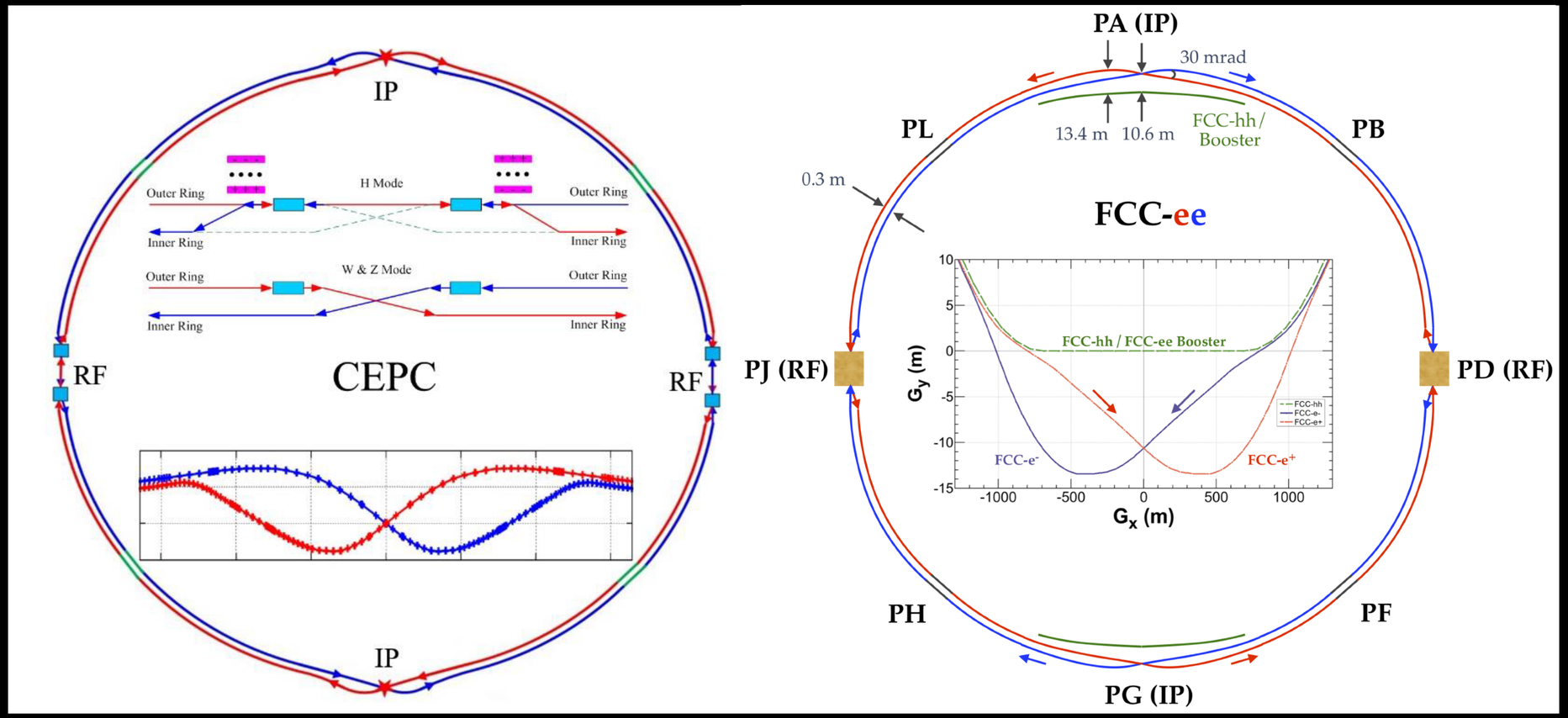
ILC:

- ***It has taken a long time to get this far***
  - ***(SLC), NLC, GLC, JLC ….***
- ***But finally ILC - International Linear Collider***
  - **ILC250 as first phase**
  - **Japan as Host, with strong participation by all regions**
- ***So why so hard?***
  - **4.8-5.3BILCU pricetag with about half from Japan**
    - Very big additional national investment in HEP
  - **"Zero Sum Gamers" (non-HEP scientists) in Japan (… but remember the SSC)**
  - **Process, cultural differences: perhaps our expectation of the process unrealistic**
- ***Are we there yet?***
  - **No! but Very Positive Signals**
  - **Still hoping for international negotiations to start soon, construction from 2023-24**

CepC or FCC(ee)

- **Similar and becoming more so!**

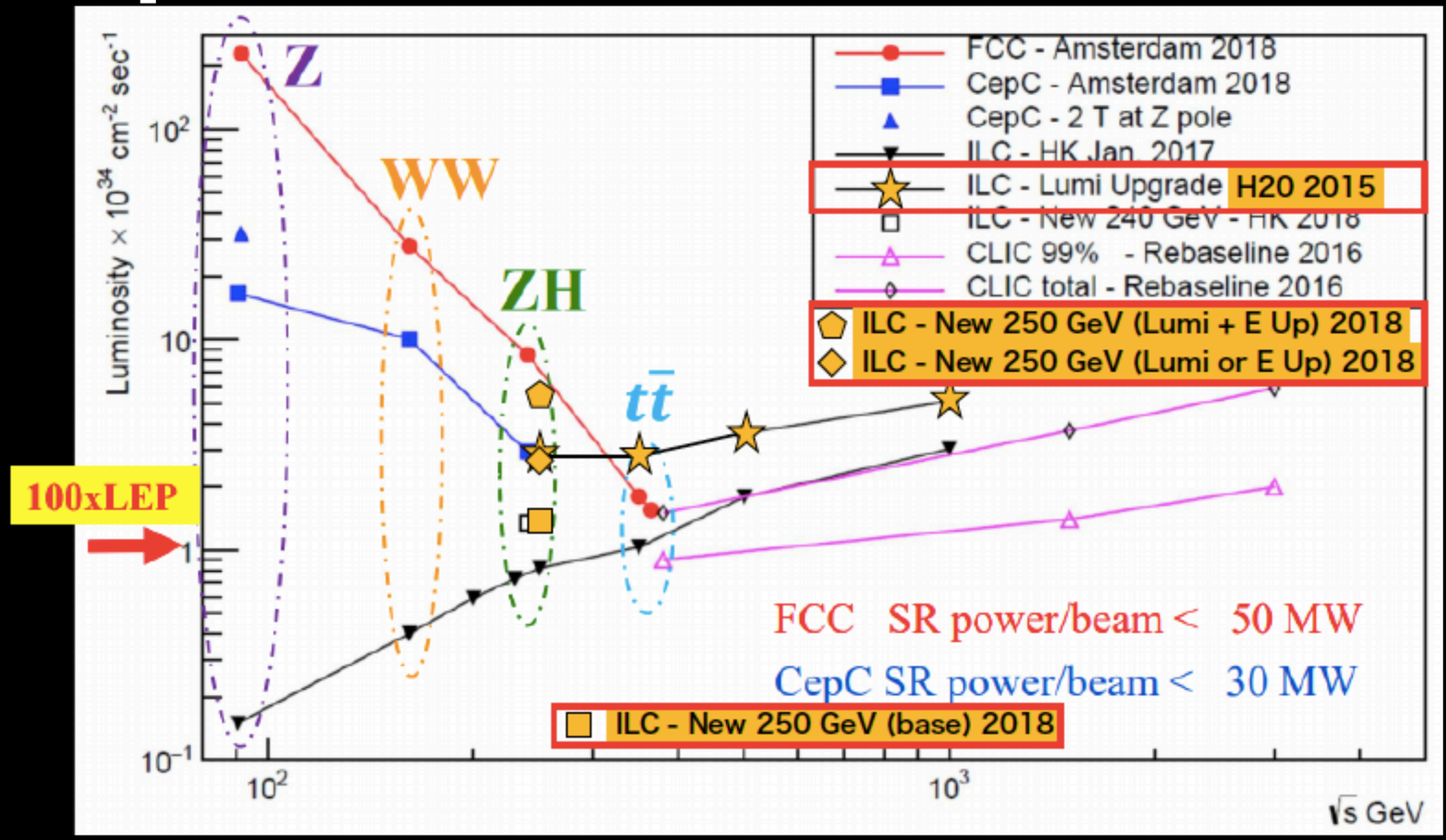
  (different constraints applied in design details)



Also, CEPC Conceptual Design Report Volume 1 - Accelerator IHEP-CEPC-DR-2018-01

e+e- Lumi Comparison

- **Complementary nature:**
  - ***Circular colliders have very high luminosity at low energy***
  - ***Linear colliders have high energy development path***



- Original Plot, F. Bedeschi , CEPC Workshop, Rome, May 2018
- Updates Private communication, Keisuke Fujii, IPNS, KEK

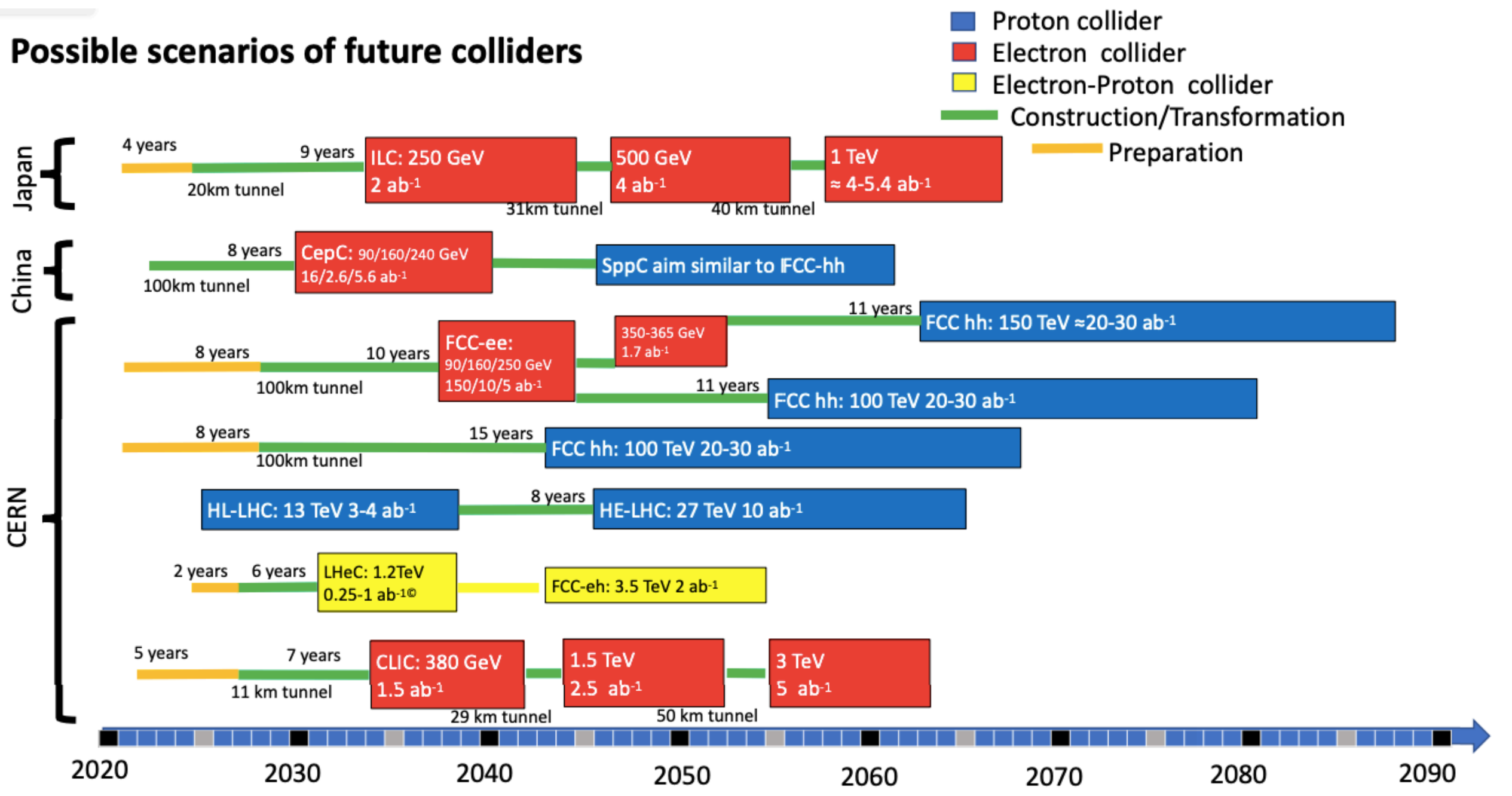
Asian Perspective

- CepC represents additional resources to our field.
  - *~$6B additional resource is very significant.*
- Possible to have CepC operational by early-to-mid-2030?
  - *Considerably ahead of FCC(ee)*
- China wishes to achieve international status with large scientific projects
  - *We should try very hard to gain from this strategy.*
- Circular and Linear Solution to (initial) Higgs factory have different development strengths
  - *Complementary solutions*

Western attitude to China?

- This and other cultural differences need to be overcome
  - *Both Real and Imagined.*
- China would be well advised to pursue a CERN-like approach to operation
  - *We need to give support / encouragement for real internationalisation of this major initiative*
- Can CERN provide the example and leadership in this goal?
  - *Highly regarded at scientific and government level*
  - *We hope so!!*

Possible scenarios of future colliders



13/05/2019 Ursula Bassler

Akira Yamamato's View on Relative Timelines

Timeline	~ 5	~ 10	~ 15	~ 20	~ 25	~ 30	~ 35
Lepton Colliders							
SRF-LC/CC	Proto/pre-series	**Construction**		**Operation**		**Upgrade**	
NRF—LC	Proto/pre-series	**Construction**		**Operation**		**Upgrade**	
Hadron Collier (CC)							
8~(11)T NbTi /(Nb3Sn)	Proto/pre-series	**Construction**		**Operation**			**Upgrade**
12~14T Nb_3Sn	Short-model R&D		Proto/Pre-series		**Construction**		**Operation**
14~16T Nb_3Sn	Short-model R&D			Prototype/Pre-series			**Construction**

2T per Decade!!!

Note: **LHC experience**: **NbTi (10 T)** R&D started in 1980's --> (**8.3 T**) Production started in late 1990's, in **~ 15 years**

A. Yamamoto, 190513bb

The Needs of Particle Physics

- A e+e- collider higgs factory ASAP
  - *… and, yes, in time, t-tbar, ttH, HH, ..*
- A new energy frontier facility following HL-LHC
  - *even without a specific physics driver, as yet*
  - *pp, ion-ion and ep all possible*
- An active field, with multiple activities in parallel:
  - *particle physics data taking and analysis*
  - *accelerator physics, including μμ colliders and plasma acc'n*
  - *detector development*
  - *advanced computing techniques*

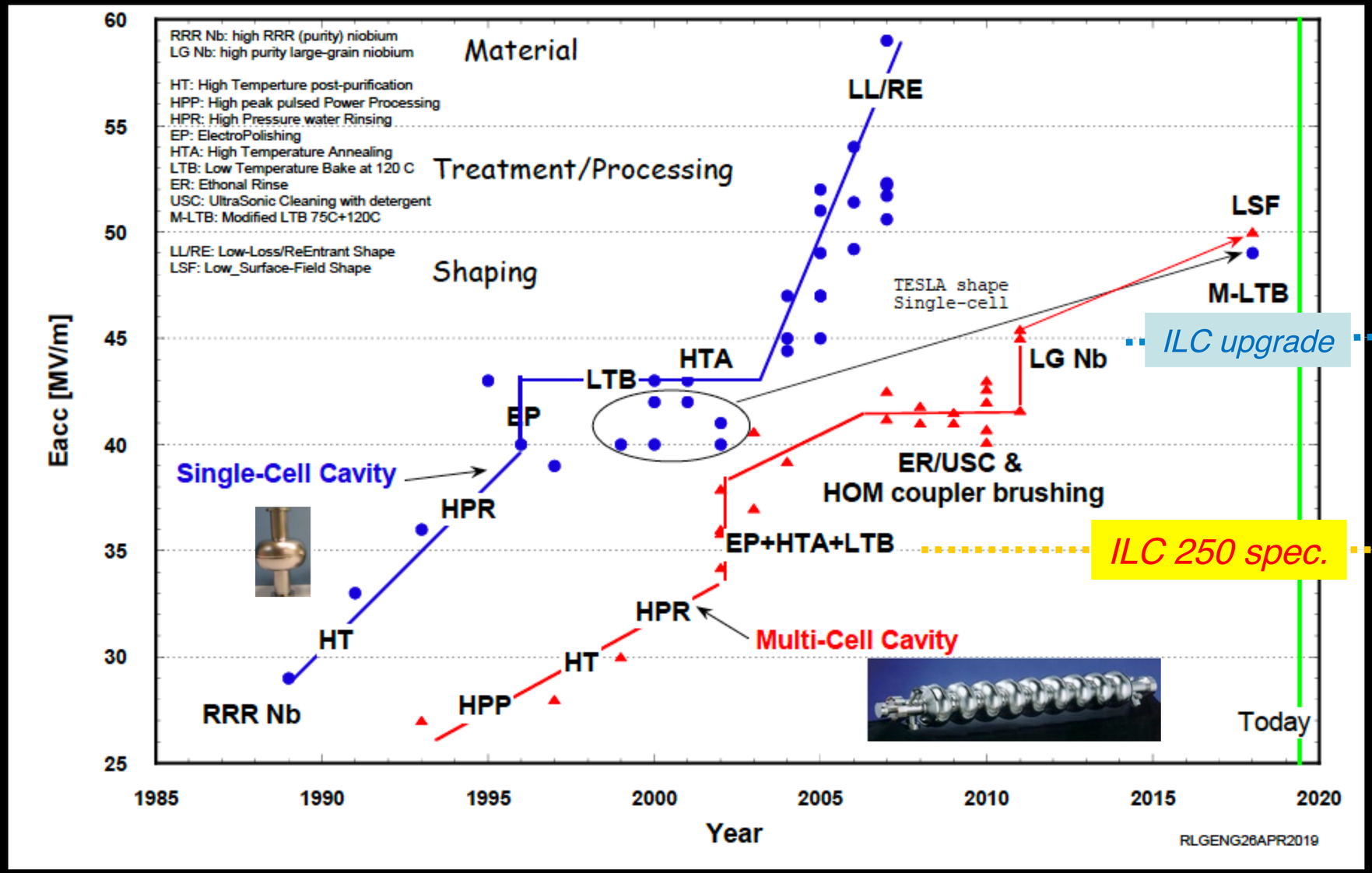
The ILC/CepC Benefit for HEP

- **Allows CERN to concentrate immediately on proton, high energy future**
  - ***CERN essential for the energy frontier.***
  - ***Proton and high-field magnet expertise***
  - ***The ONLY laboratory capable of seriously commencing a new proton-collider, now.***
- **CERN infrastructure in proton beams should surpass the fear of a second 100km tunnel.**
  - ***Is it possible to see a new proton collider at CERN by mid-2040s (not mid 2060s, but also not 100TeV)***

TECHNOLOGY DEVELOPMENT ESSENTIAL

S/C Technology for HEP in Asia

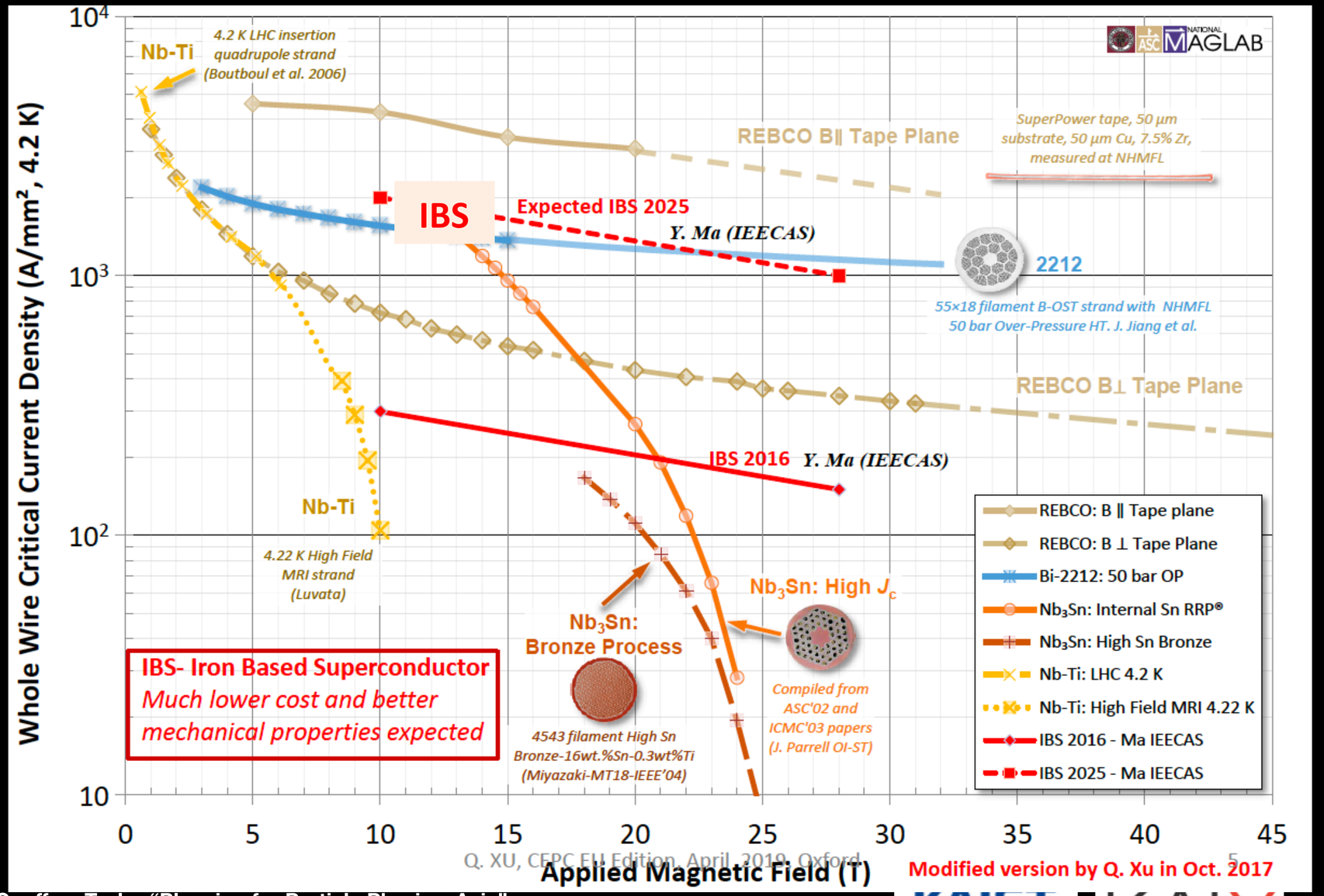
High Gradient SRF



Geoffrey Taylor "Planning for Particle Physics: Asia",
Workshop for Future Particle Accelerators, KAIST, 9 July, 2019

S/C Technology for HEP in Asia

eg.High Field SC Magnets



Some Comments from Granada…

- If we are planning for decades into the future, we must get the opinions and involvement of the younger members of our community (Peter Jenni)
- Experts are telling us that high field magnets take decades to develop. “Are we going to spend the next 3 or 4 decades waiting for 16T magnets…” anon.
  - *100km tunnels may be the easy part of the next generation high energy frontier (with circular machines, at least)*
- For new physics 14TeV μ+μ- ☞ 100TeV pp (Vladimir SHILTSEV)
  - *need to pursue muon collider vigorously*
- When will plasma acceleration be central to planning?

COMPETITION CRITICAL

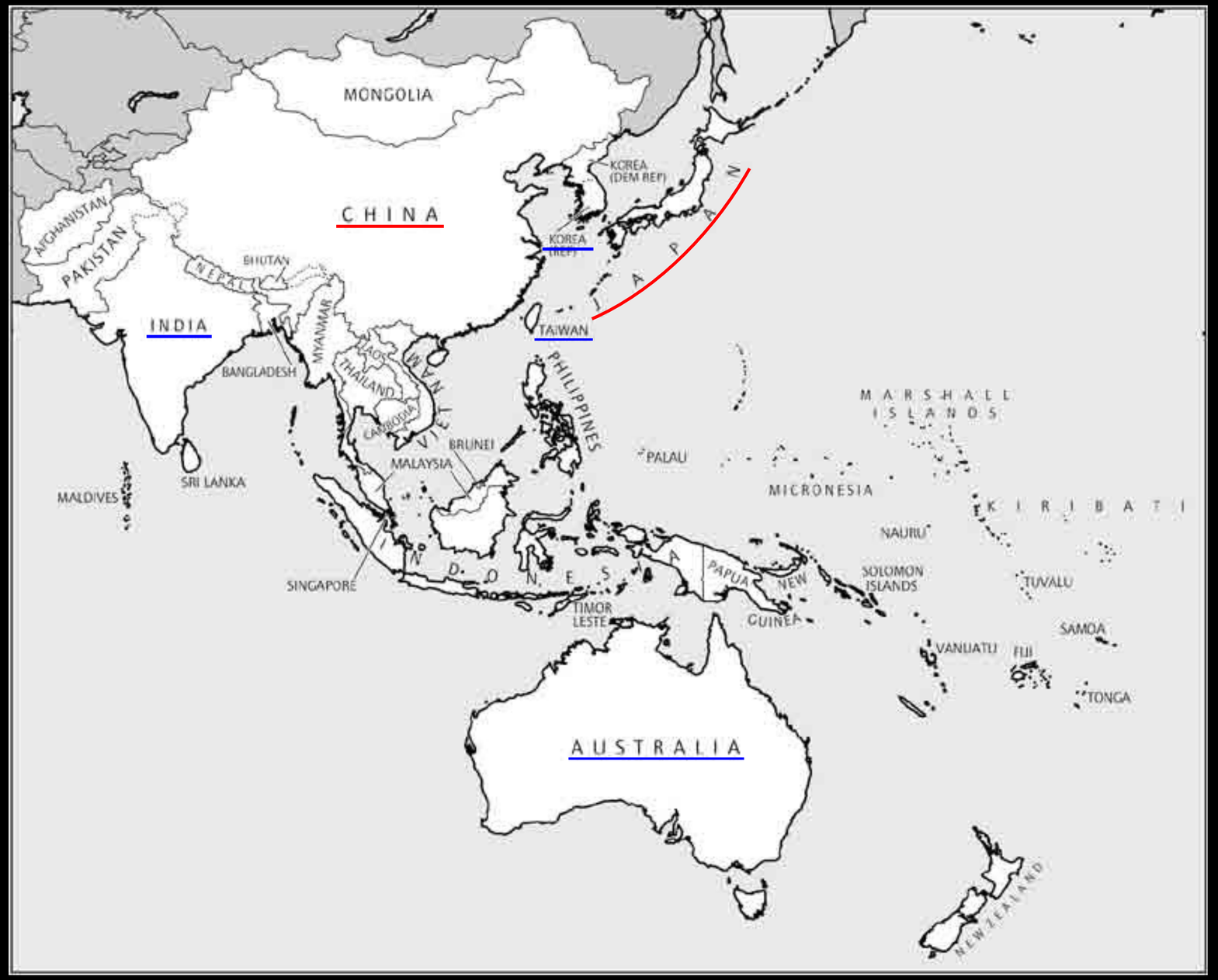
NOT SURE HOW or WHERE TO GET *BOTH*

e+e- Higgs Factory & Energy Frontier Proton Collider

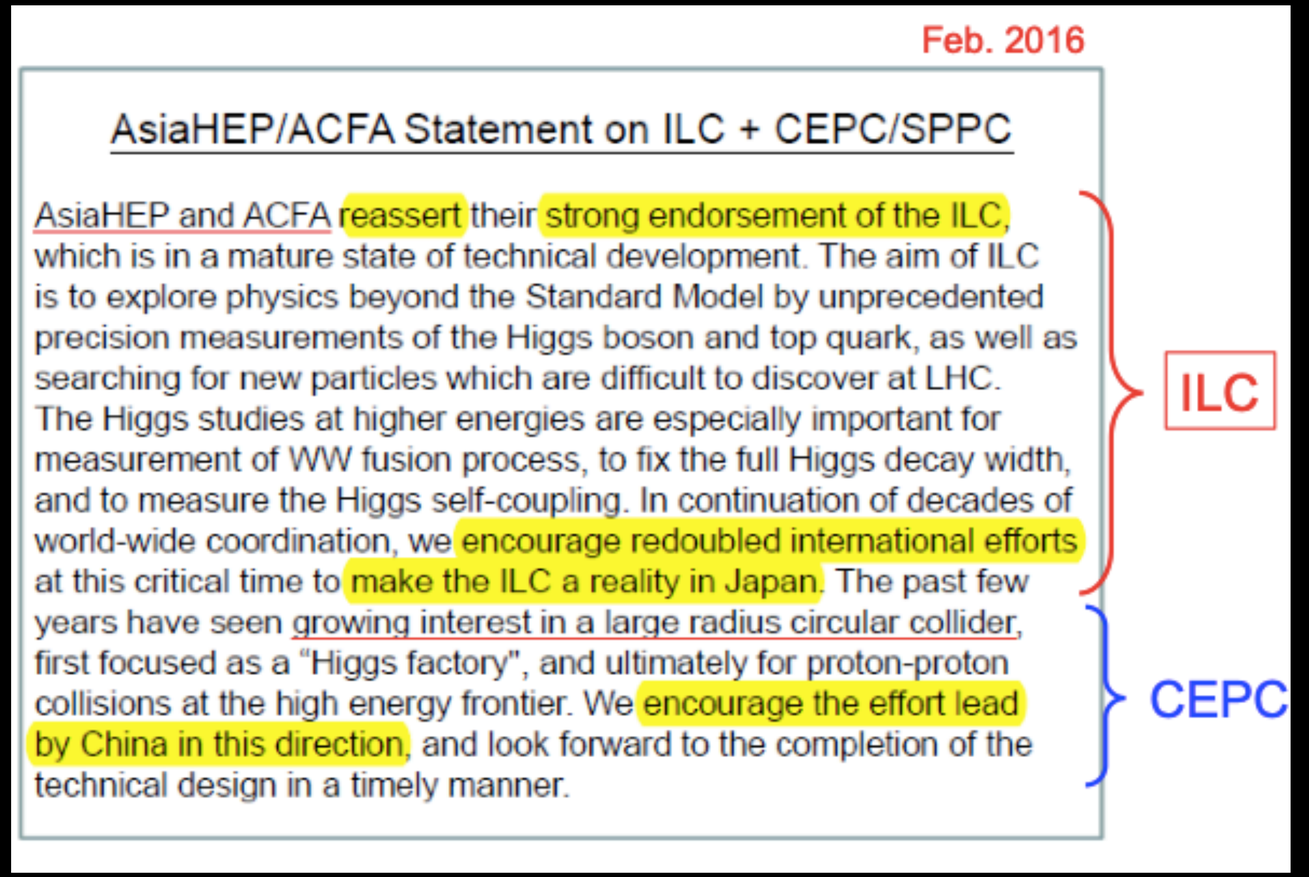
BUT

MUST MAINTAIN COOPERATIVE COMPETITION

ACFA / AsiaHEP



ACFA to Coordinate ??? … at least support with a single voice



Feb. 2016

AsiaHEP/ACFA Statement on ILC + CEPC/SPPC

AsiaHEP and ACFA reassert their strong endorsement of the ILC, which is in a mature state of technical development. The aim of ILC is to explore physics beyond the Standard Model by unprecedented precision measurements of the Higgs boson and top quark, as well as searching for new particles which are difficult to discover at LHC. The Higgs studies at higher energies are especially important for measurement of WW fusion process, to fix the full Higgs decay width, and to measure the Higgs self-coupling. In continuation of decades of world-wide coordination, we encourage redoubled international efforts at this critical time to make the ILC a reality in Japan. The past few years have seen growing interest in a large radius circular collider, first focused as a "Higgs factory", and ultimately for proton-proton collisions at the high energy frontier. We encourage the effort lead by China in this direction, and look forward to the completion of the technical design in a timely manner.

ILC

CEPC

Final Comments

- Asian Physics is Very Strong
  - *Not always well known just how much is going on.*
- Asian Economies are Very Strong
  - *This is benefit, not to be feared*
- Asia is not Europe
  - *There are various bi-lateral / multi-lateral arrangements*
  - *But nothing like the EU nor a united states of Asia.*
- Asia will continue to development in strength
  - *BUT needs to develop capacities as international hosts*