Energy Frontier in Particle Physics, NTU, Taipei, September 29-20, 2007

ILC, Physics and Project Status

Keisuke Fujii (KEK)

September 29, 2017

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Part I

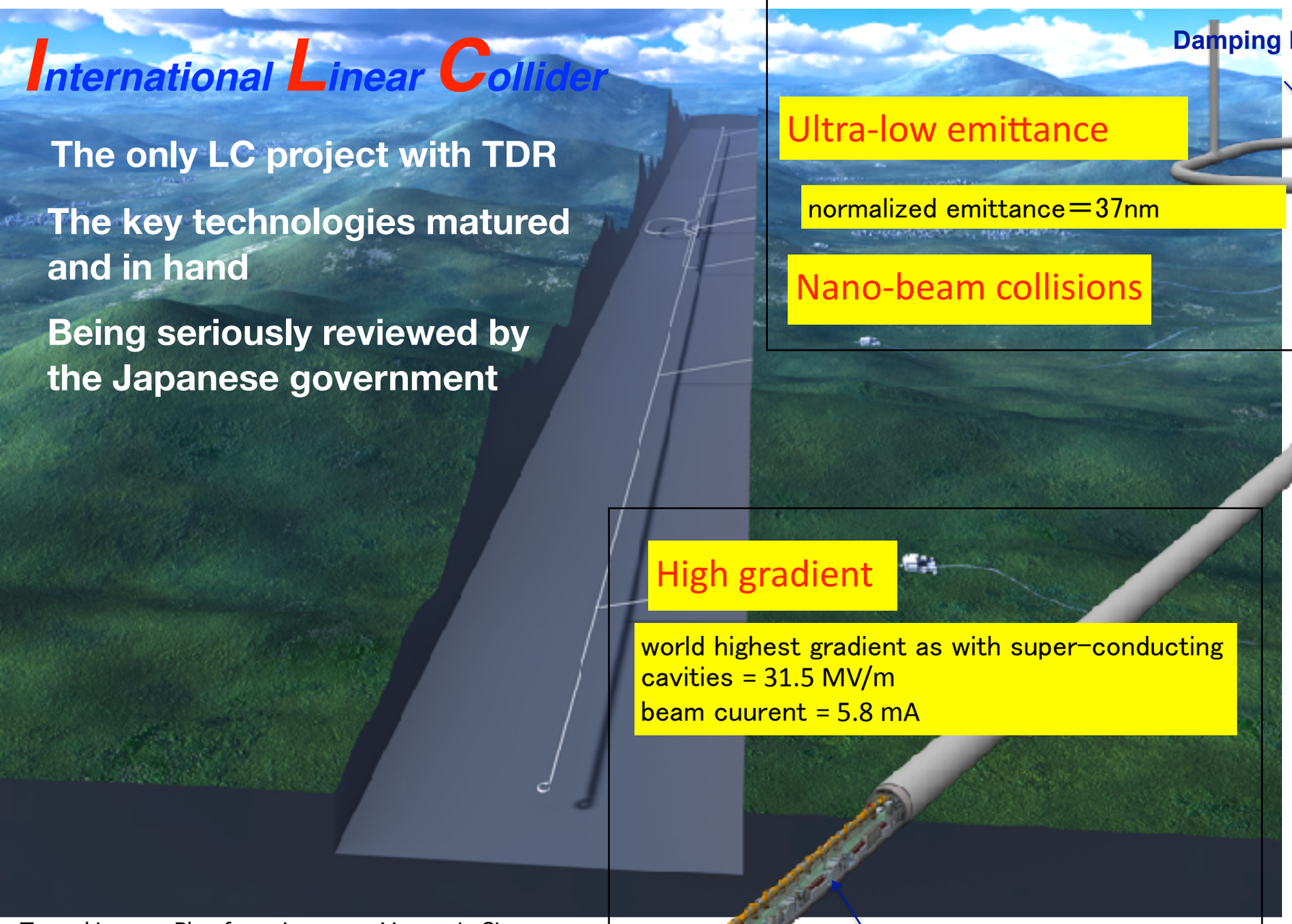
ILC Project Status

Bird's Eye View of the ILC Accelerator

International Linear Collider

- The only LC project with TDR
- The key technologies matured and in hand
- Being seriously reviewed by the Japanese government

Tunnel Layout Plan for a Japanese Mountain Site



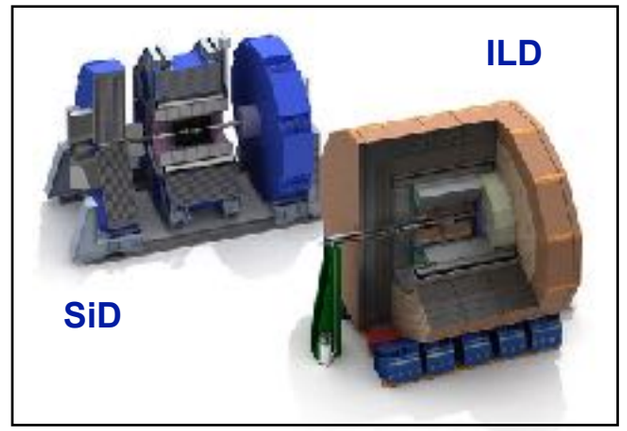
Ultra-low emittance

normalized emittance＝37nm

Nano-beam collisions

High gradient

world highest gradient as with super-conducting cavities = 31.5 MV/m
beam cuurent = 5.8 mA



High resolution high granularity detectors

e+, e- Main Linac

Energy : 250GeV + 250GeV
Length : 11km + 11km
# of DRFS Klystron: 7280 total
# of Cryomodules : 1680 total
# of Cavities : 14560 total

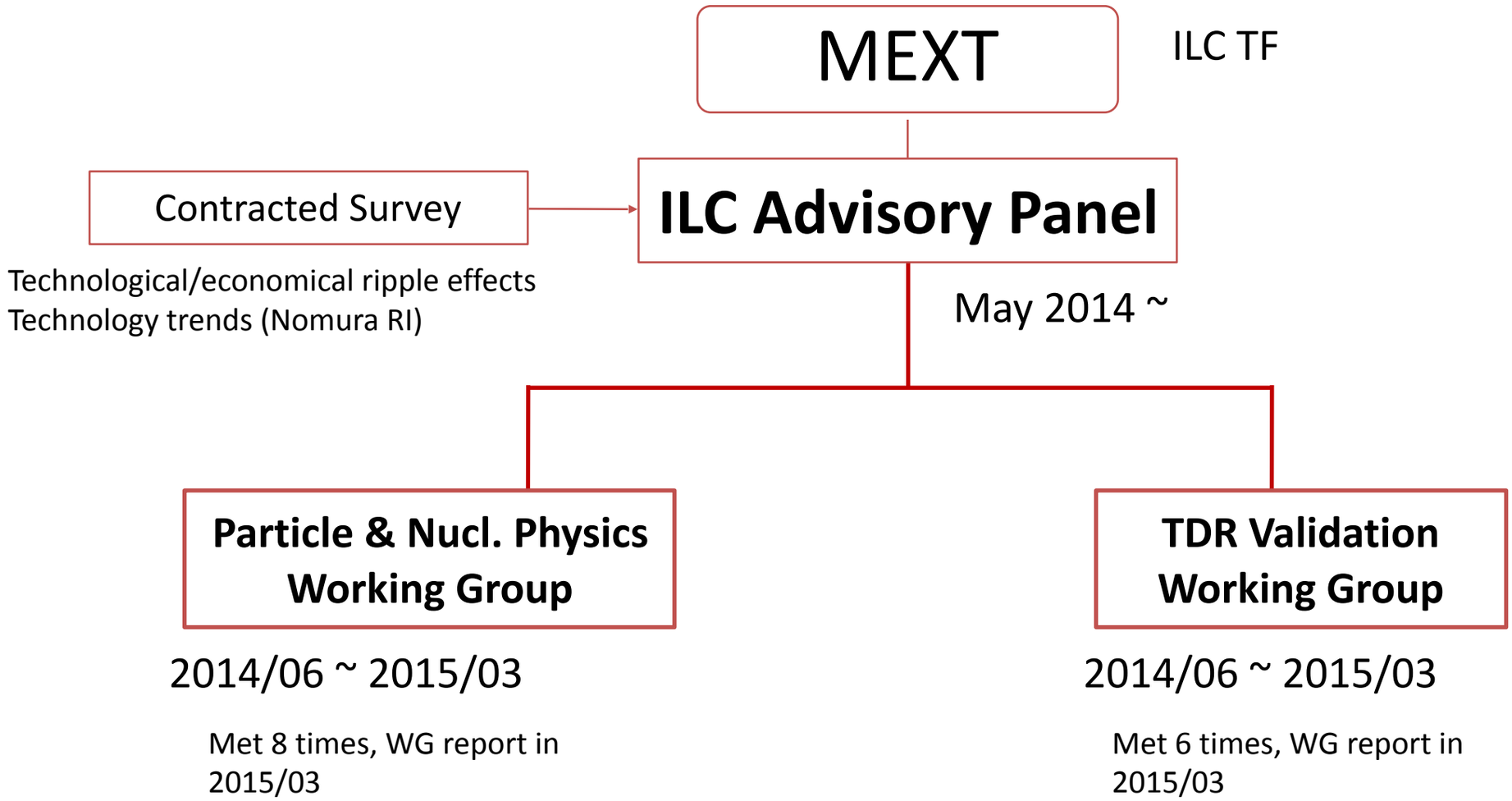
Expecting decision by the Japanese government in < 2 years!

MEXT's ILC Review

MEXT = Japan's **M**inistry of **E**ducation, **C**ulture, **S**ports, **S**cience and **T**echnology

ILC Advisory Panel

Set up in May 2014 under MEXT ILC Task Force to investigate various issues concerning the possibility of hosting the ILC in Japan



http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/index.htm

The panel published an Interim Summary in 2015

Interim Summary

http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/gaiyou/1360593.htm

- ILC Advisory Panel published an interim summary of their discussions based on the reports from the two working groups (Particle & Nuclear Physics WG and TDR Validation WG).

- The interim summary recommended the following actions:
  - Obtain clear vision for international cost sharing
  - **Make clear scientific merits (not only precision studies of Higgs and top but also possibilities of new particle discoveries) that match the investment**
  - **Monitor, analyze, and examine the development of LHC experiments.**
  - Solve remaining technological issues and **mitigate cost risk**.
  - Get **understanding from the general public** and other scientific communities.
  - Investigate issues concerning necessary human resources

Interim Summary

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→ **Org.&Man. WG**

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→ **HR WG**

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MEXT — ILC TF

ILC Advisory Panel

May 2014 ~

Contracted Survey

Technological/economical ripple effects
Technology trends (Nomura RI)

Most recent meeting of the panel on July. 28, 2017

- the O&M WG report
- Plan: (LHC Run II, Staging, cost reduction)

Particle & Nucl. Physics Working Group

2014/06 ~ 2015/03
Met 8 times, WG report in 2015/03

TDR Validation Working Group

2014/06 ~ 2015/03
Met 6 times, WG report in 2015/03

Human Resources Working Group

2015/11 ~ 2016/07
Met 6 times, WG report in 2016/07

Organization & Management Working Group

2017/02 ~ 2017/06
Met 6 times, *WG report in 2017/08*

English translation is being prepared.

http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/index.htm

Linear Collider Collaboration (LCC)

is working on issues raised in the Interim Summary

http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/gaiyou/1360593.htm

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  - **Monitor, analyze, and examine the development of LHC experiments.** → **LCC homework 2**
  - Solve remaining technological issues and **mitigate cost risk**.
  - Get **understanding from the general public** and other scientific communities. → **LCC homework 3**
  - Investigate issues concerning necessary human resources

LCC Physics WG & Parameters WG

Physics Case for the ILC
arXiv: 1506.05992, Jun.19, 2015

ILC Operating Scenarios
arXiv: 1510.05739, Oct.19, 2015

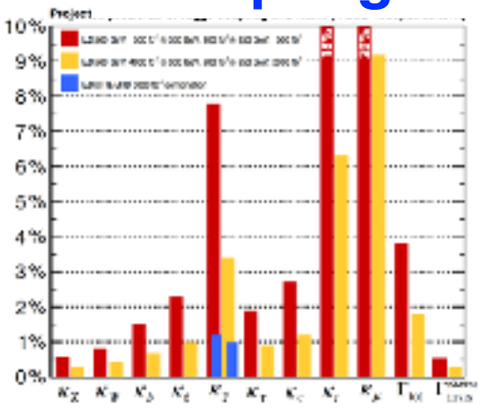
Implication of the 750 GeV γγ Resonance as a Case Study for the ILC
arXiv: 1607.03829, Jul. 31, 2016

The Potential of the ILC for Discovering New Particles
arXiv: 1702.05333, Feb. 17, 2017

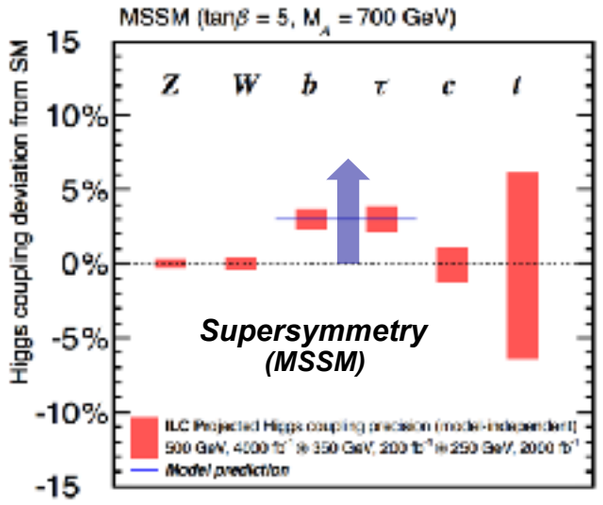
ILC Brochure
LCC communicators & phys. WG

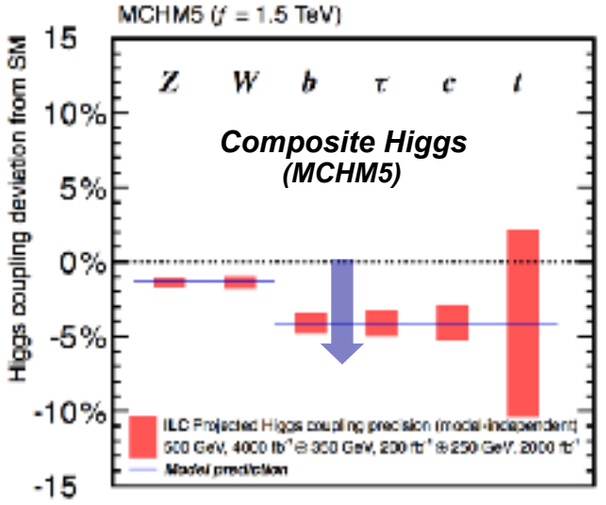
http://www2.kek.jp/ilc/ja/contents/docs/E_ExploringtheFabricoftheUniverse170419.pdf

Higgs Couplings

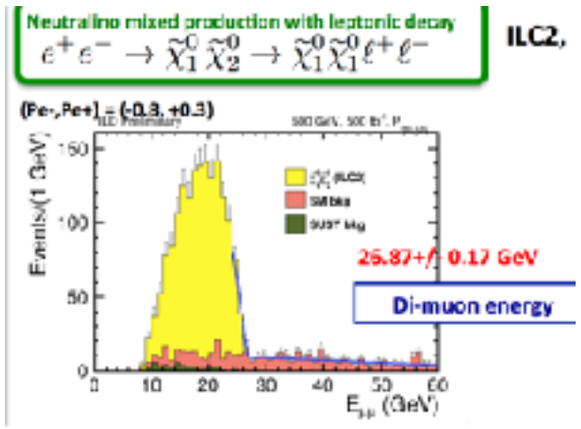


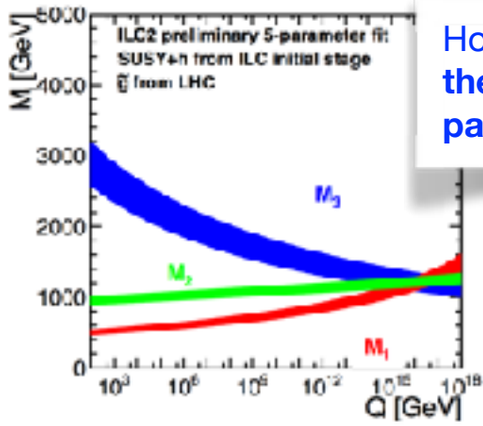
Elementary v.s. Composite?

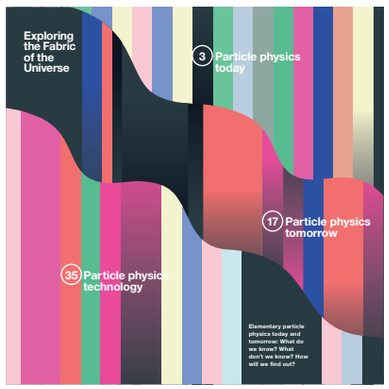




X750 was found dead but the exercise proved ILC's capability to probe new physics operating behind a possible heavy new particle beyond its direct reach







Homework 1: Provide a clear vision on **the discovery potential of new particles**

Homework 2: **Monitor, analyze, and examine the development of LHC experiments.**

Homework 3: Get **understanding from the general public** and other scientific communities.

Home works from MEXT ILC Panel

Interim Summary

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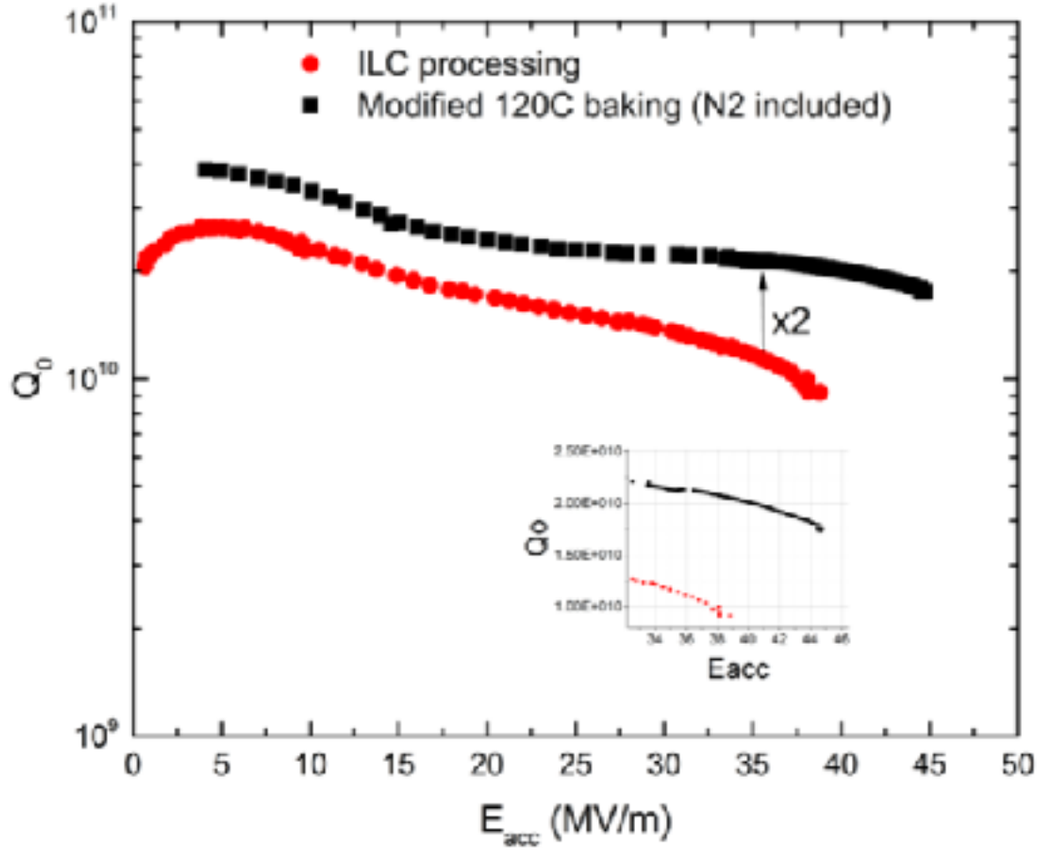
→ US-J

MEXT-DOE Discussion Group

- At the end of May 2016, high level officers from MEXT visited their DOE counter part and it was agreed to start a US-Japan discussion group co-chaired by Director of Office of Science of DOE and a corresponding level officer in MEXT. They decided to meet every 2-3 months.

- In their Oct. 2016 meeting, it was agreed to start ***US-Japan collaborative research for ILC cost reduction:*** aiming at 10-12% cost reduction of the ILC machine construction.
  - Cost reduction in Nb material preparation
  - High-Q high-gradient SCRF cavity using nitrogen infusion



So we are doing our homework and

MEXT is doing their homework very seriously!

Support from Diet Members and Industrial Sector in Japan

- ***Federation of Diet Members for the ILC*** (since 2008 with >150 members from both the governing and opposition parties)
- ***Advanced Accelerator Association*** *Promoting Science & Technology* (AAA) (since 2008 with 100 companies and 40 universities and research institutions)
- Event in Washington DC on Feb. 2016 coordinated by Hudson Institute and AAA. 4th visit to Washington by Diet members with MEXT officials. *Another one happened in spring 2017.*

From LC NEWSLINE

http://newsline.linearcollider.org/2016/03/03/us-japan-symposium/

Hon. Shionoya is recommending the Kasoku Kids cartoon book to the roundtable discussion chaired by Dr. William Schneider, Jr. (Hudson Institute)

Science First with the ILC - Keynote speech by Takeo Kawamura *from LC NEWSLINE*

http://newsline.linearcollider.org/2016/12/08/science-first/

In his keynote at LCWS2016, former MEXT Minister Takeo Kawamura stressed that while fundamental research may have application in the long run, it's the science that is most important.

Hon. Takeo Kawamura giving a keynote speech at the LCWS2016 in Morioka, japan. Image: LCWS2015 LOC

LCWS2016 in Morioka, japan.

Standing ovations for Hon. Takeo Kawamura's speech by LCWS2016 participants. Image: LCWS2016 LOC

Staging Discussion

- In LCWS 2016, Nov. in Morioka, it was agreed to start seriously considering a staging scenario of the ILC ***to significantly reduce the initial construction cost***.
  - ***1st stage as a Higgs factory***
  - ***and later stages taking advantage of flexible energy expandability of a linear collider.***
- Linear Collider Board (LCB) and Linear Collider Collaboration (LCC) are working on possible staging scenarios to build consensus among the worldwide HEP community.
- Japan Association of High Energy Physicists (JAHEP) set up an ad hoc committee (the Asai Committee) to independently review the physics case of the 1st 250 GeV stage.

Japan **A**ssociation of **H**igh **E**nergy **P**hysicists

Town Meeting

on July 22

to receive the report from the Asai Committee and discuss the JAHEP statement based on it.

JAHEP Statement

Scientific Significance of the ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2

http://www.jahep.org/files/JAHEP-ILCstatement-170722-EN.pdf

The JAHEP chair, Hiroaki Aihara, gave an opening address, explaining background information that led to this town meeting. Shoji Asai then, as a chairman of the committee on ***"the Scientific Case of ILC250 Higgs Factory"***, presented the final report (in Japanese) from the committee.

Yasuhiro Okada then presented ***a draft JAHEP statement on the ILC250 as a Higgs factory***.

JAHEP Statement

***The draft was approved by the JAHEP** in the town meeting after 3 hours of discussions with small suggested modifications.*

http://www.jahep.org/files/JAHEP-ILCstatement-170722-EN.pdf

It was shown to LCB on August 9 and revised a little bit.

The updated statement is available from

http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf

***The English version of the Report from the Asai Committee** was just made public the day before yesterday.*

http://www.jahep.org/files/ILC250GeVReport-EN-FINAL.pdf

JAHEP Statement (July 22 revised on Aug.16)

http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf

Asai Committee's conclusions

- ILC250 should run concurrently with HL-LHC to enhance physics outcomes from LHC.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes that are nearly comparable to those previously estimated for ILC500 in precise examinations of the Higgs boson and the Standard Model.
- The ILC250 Higgs factory, together with HL-LHC and SuperKEKB, will play an indispensable role in the discovery of new phenomena originating from new physics with the energy scale up to 2–3 TeV and the elucidation of the origin of matter-antimatter asymmetry.
- A linear collider has a definite advantage for energy-upgrade capability. ILC250 possesses a good potential for its upgrades to reach the higher energy of new physics that the findings of ILC250 might indicate.

Remarks

- *The Asai committee consists of non-ILC members from ATLAS, Belle II, and theory (with Junping Tian as an only exception) and was charged* ***to review "the scientific case of ILC250 Higgs factory" from a neutral point of view.***

- *The report emphasizes* ***the synergy of various projects (including HL-LHC, Belle II, T2K)*** *expected to produce outputs in 2030-2040.*

- *The report was not meant for the funding agency nor the world HEP community. It is a report to the JAHEP precisely as charged.*

Summary of Part I

- ***MEXT is seriously investigating various issues to be solved to host the ILC in Japan.***
- KEK/JAHEP is taking ***various actions together with the LCC*** to address issues pointed out by the MEXT ILC Advisory Panel.
- ***MEXT-DOE joint discussion group*** started.
- ***US-Japan joint effort on cost reduction*** is on-going.
- There are important ***political interactions happening also in Europe and Asia,*** which I had no time to cover today.
- Serious discussions on ***staging from 250 GeV*** is on-going.
- As Hon. Kawamura said in LCWS 2016, ***2017-2018 will be a very important time for the ILC.***

2017-2018 Crucial!

- MEXT ILC Advisory Panel will finish its discussions and ***Japanese government will make decision in time*** for next European Strategy and US P5 discussions.

- ***Government level discussion (MEXT-DOE) is happening between the U.S. and Japan***, resulting in the on-going cost reduction efforts.

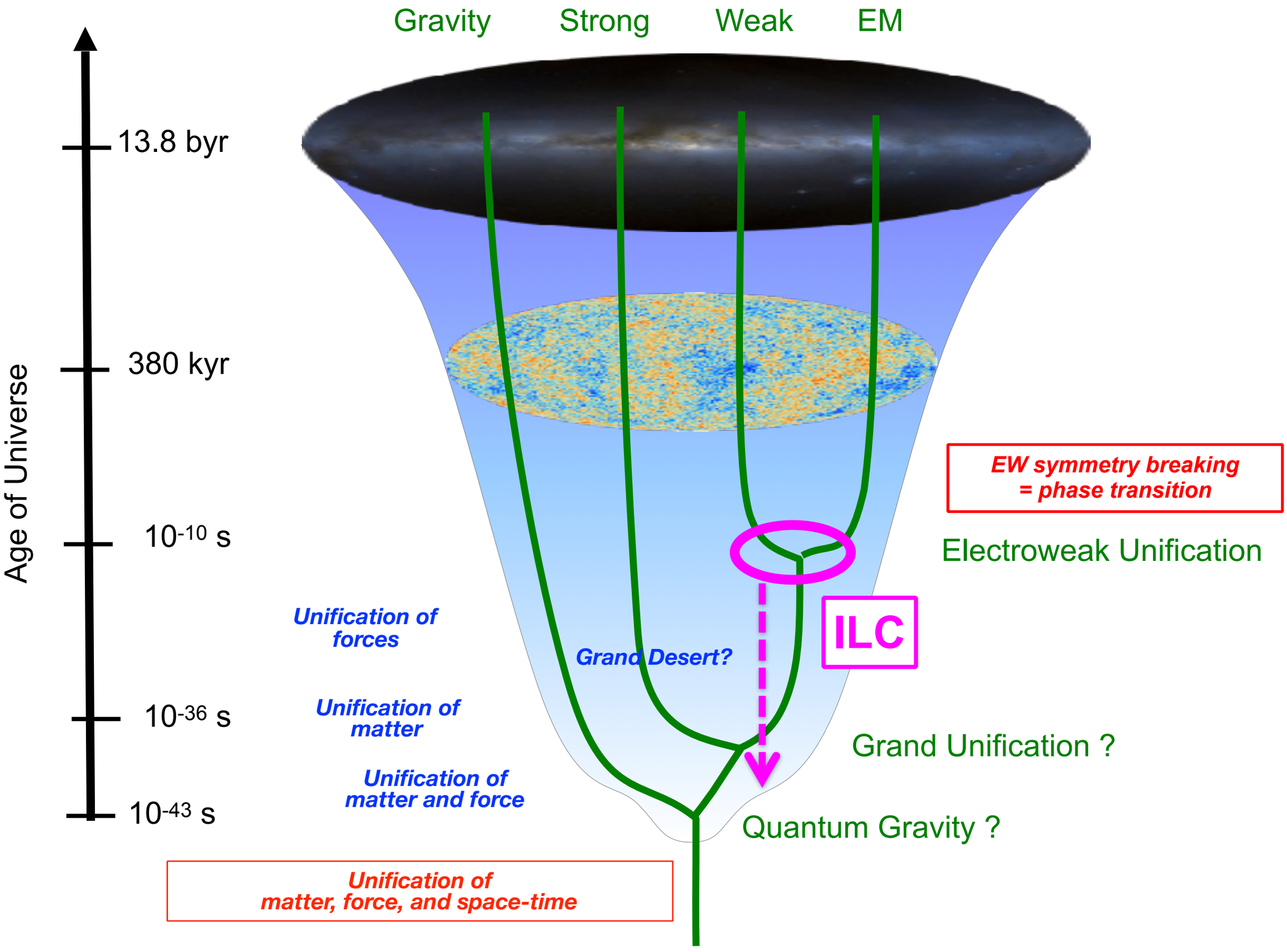
- ***Government level dialogue is starting between European countries and Japan also.***
  (According to Lyn Evans (the LCC director), “Without commitment, begin discussion on possible scenarios of sharing of cost, technology, and human resources.”)

Part II

ILC Physics

arXiv: 1506.05992 (ILC Physics Case)
arXiv: 1506.07830 (ILC Run Scenarios)
arXiv: 1306.6352 (ILC TDR: Physics)
EPJC (2015) 75:371 (LC Physics)
arXiv: 1702.05333 (ILC New Particles)

Towards ultimate unification



Why is the EW scale so important ?

Why is the EW scale so important?

Mystery of something in the vacuum

With the discovery of H125 at LHC we know that ***our vacuum is filled with "something" having weak charge.*** This something is called ***the Higgs field,*** but we don't know its true character, its multiplet structure, or its underlying dynamics.

The SM does not explain *why the Higgs field developed a vacuum expectation value and why at the EW scale.*

★ ***In other words the SM does not answer the question:***

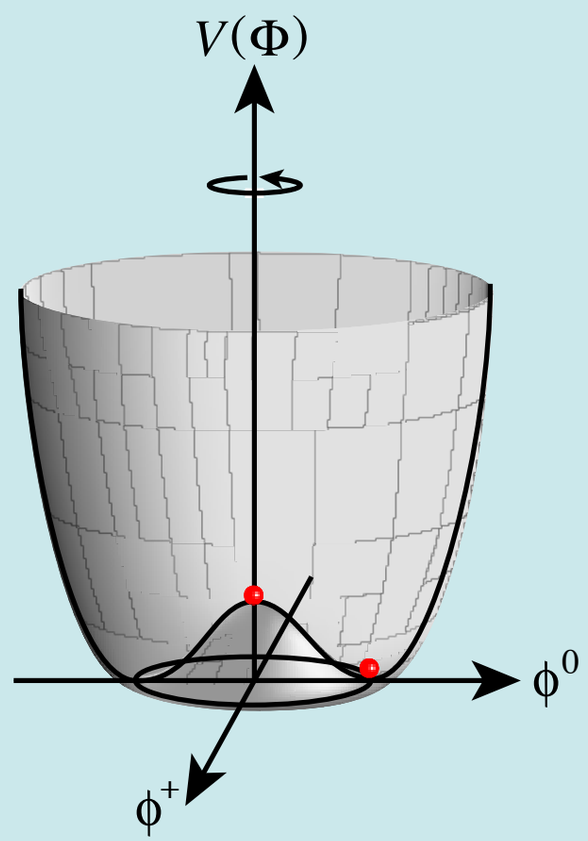
Why $\mu^2 < 0$?

★ ***To answer this question,***

we need to go beyond the Standard Model!

Depending on BSM models, ***future ahead of us forks in three ways!***

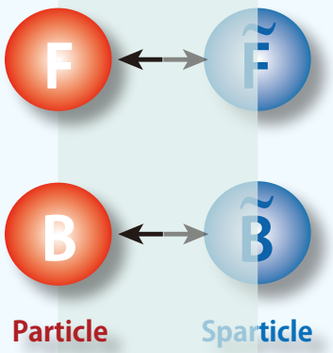
$$V(\phi) = \mu^2|\phi|^2 + \lambda|\phi|^4$$



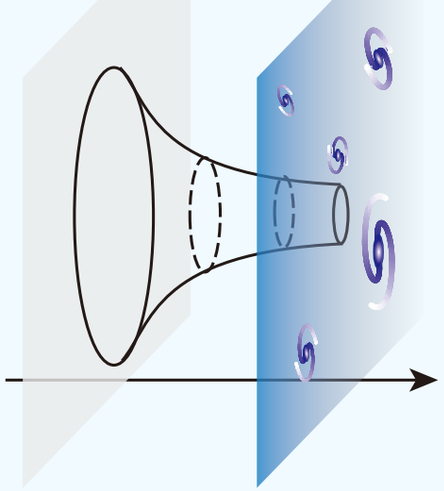
Big fork ahead of us!

Revolution in the concept of space-time
Big step towards ultimate unification
Key = Precision Higgs and Top couplings
SUSY particle discovery

Fermionic Extra -dim. = SUSY



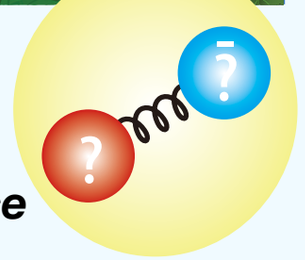
Bosonic Extra -dim. = RS (ADD)



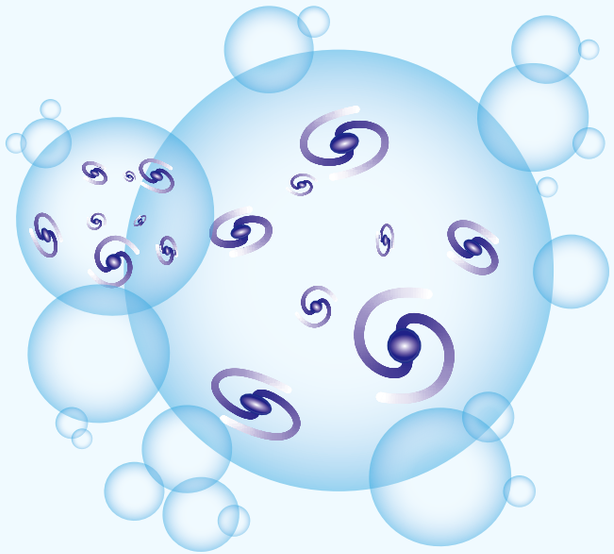
Jungle of new heavy (composite) particles in the TeV+ scale
Key = Precision Higgs and Top couplings

Composite Higgs

New strong force



Copernican revolution ?
Key = precision m_t and m_h measurements



Multi-verse
+ Anthropic Principle
or totally new principle?

The 1st Road: Existence of another dimension

The 2nd Road: Existence of a new stratum of Nature

The 3rd Road: Existence of a myriad of universes ?

No deviation from SM

ILC

The 3 major probes for BSM at ILC:

Higgs, *Top*, and search for *New Particles*

Since now the focus is on the 250 GeV initial stage, we need to re-optimize our strategy for the BSM Searches.

The 3 major probes for BSM at ILC:

Higgs, *Top*, and search for *New Particles*