Particle Physics and Detectors

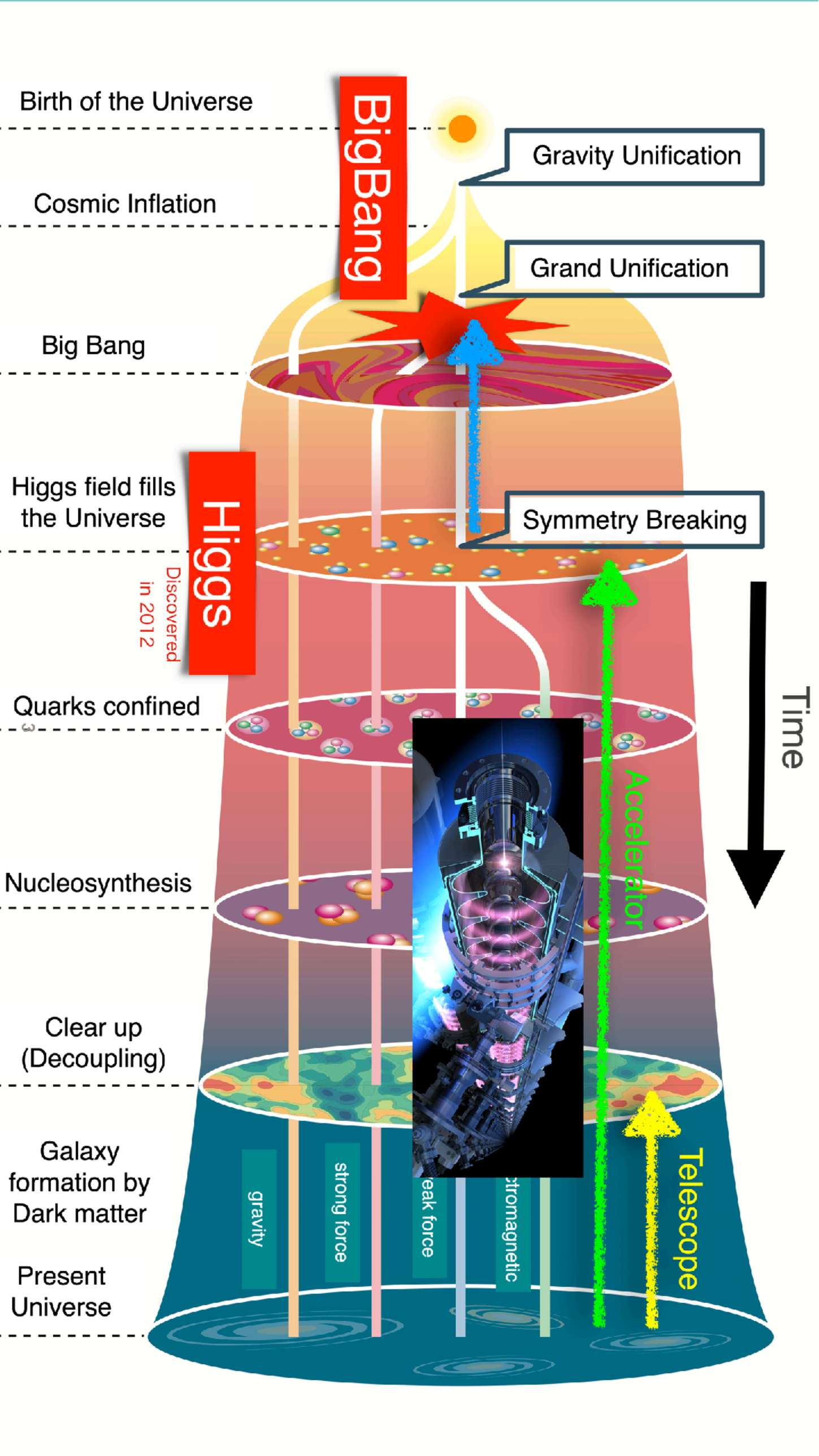
Toshinori Mori

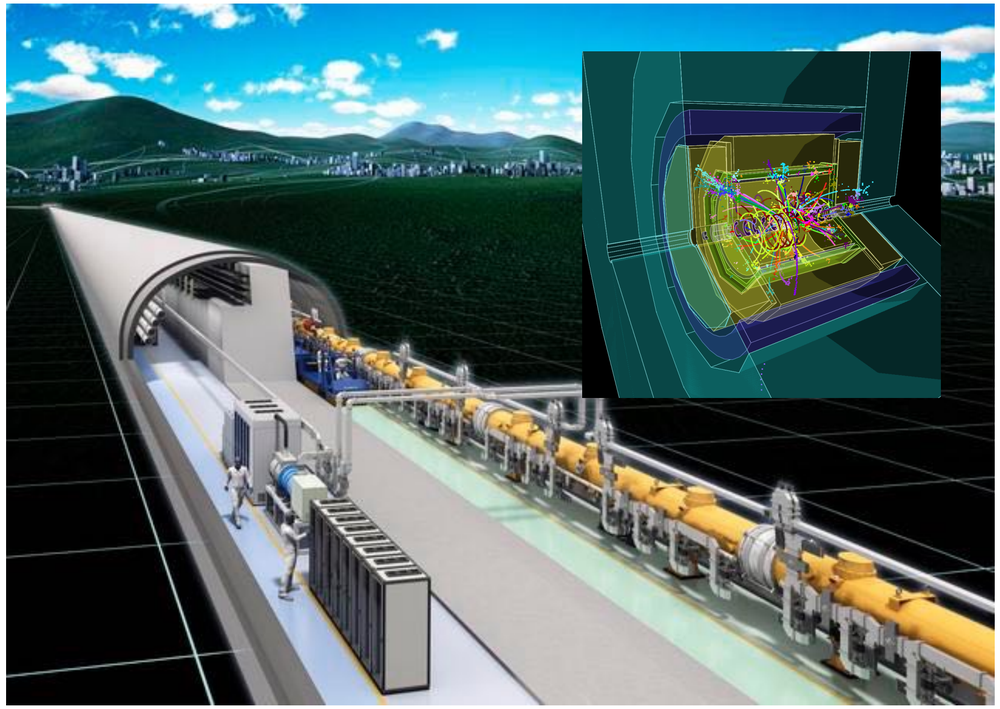
Tetiana Berger-Hryn'ova

What is Particle Physics?

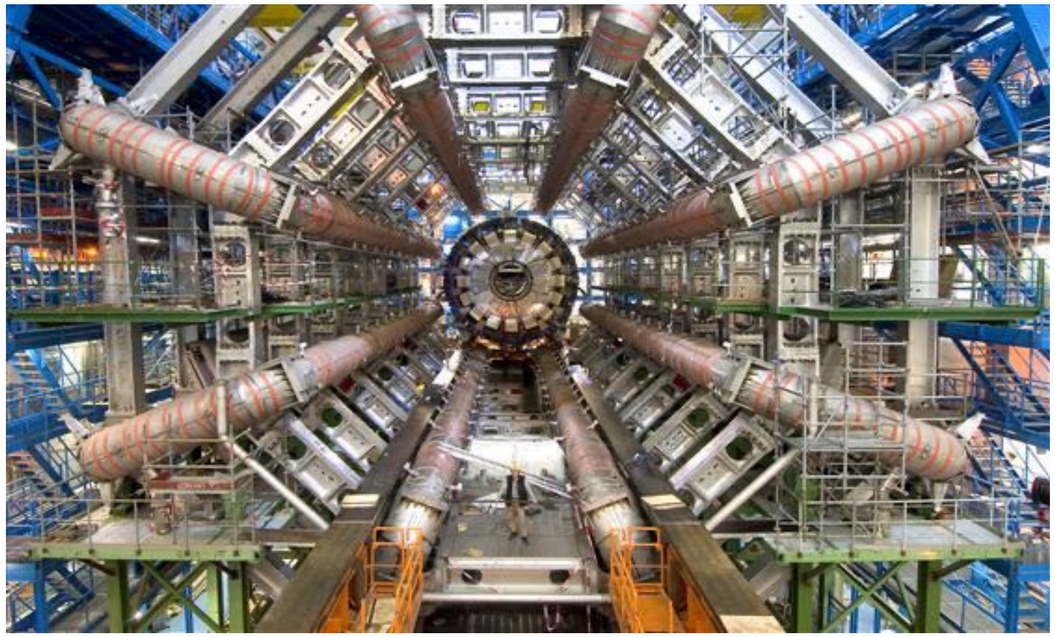
- a scientific discipline that pursues **fundamental laws & constituents** that have been governing the **Universe** since its birth

Strong Synergy with Other Research Projects of ILANCE

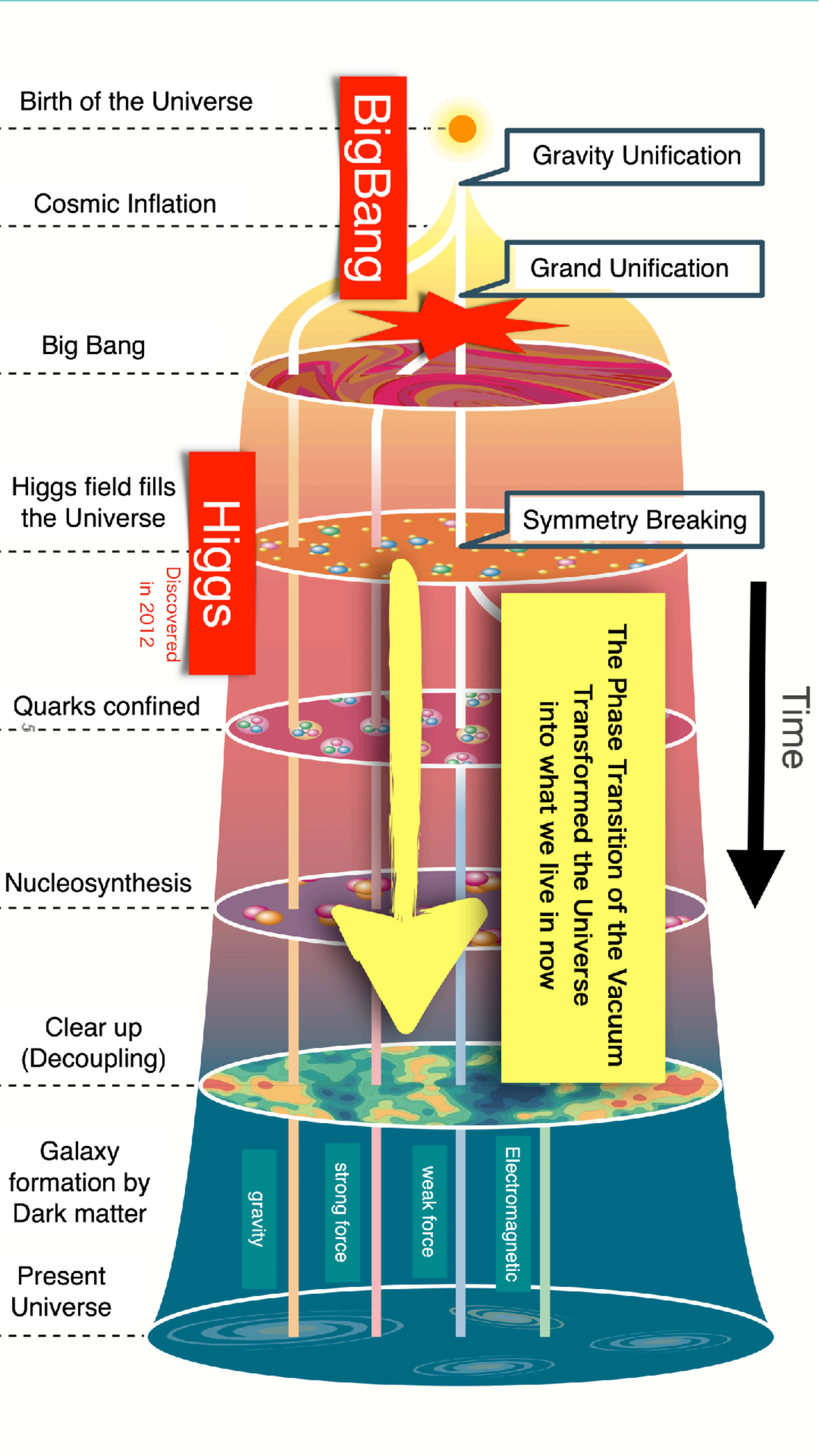

Birth of the Universe
BigBang
Gravity Unification
Cosmic Inflation
Grand Unification
Big Bang
Higgs field fills the Universe
Higgs
Discovered in 2012
Symmetry Breaking
Time
Quarks confined
Accelerator
Nucleosynthesis
Clear up (Decoupling)
Galaxy formation by Dark matter
Telescope
gravity
strong force
eak force
ctromagnetic
Present Universe



ilc
international linear collider



ATLAS
EXPERIMENT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gravity
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weak force
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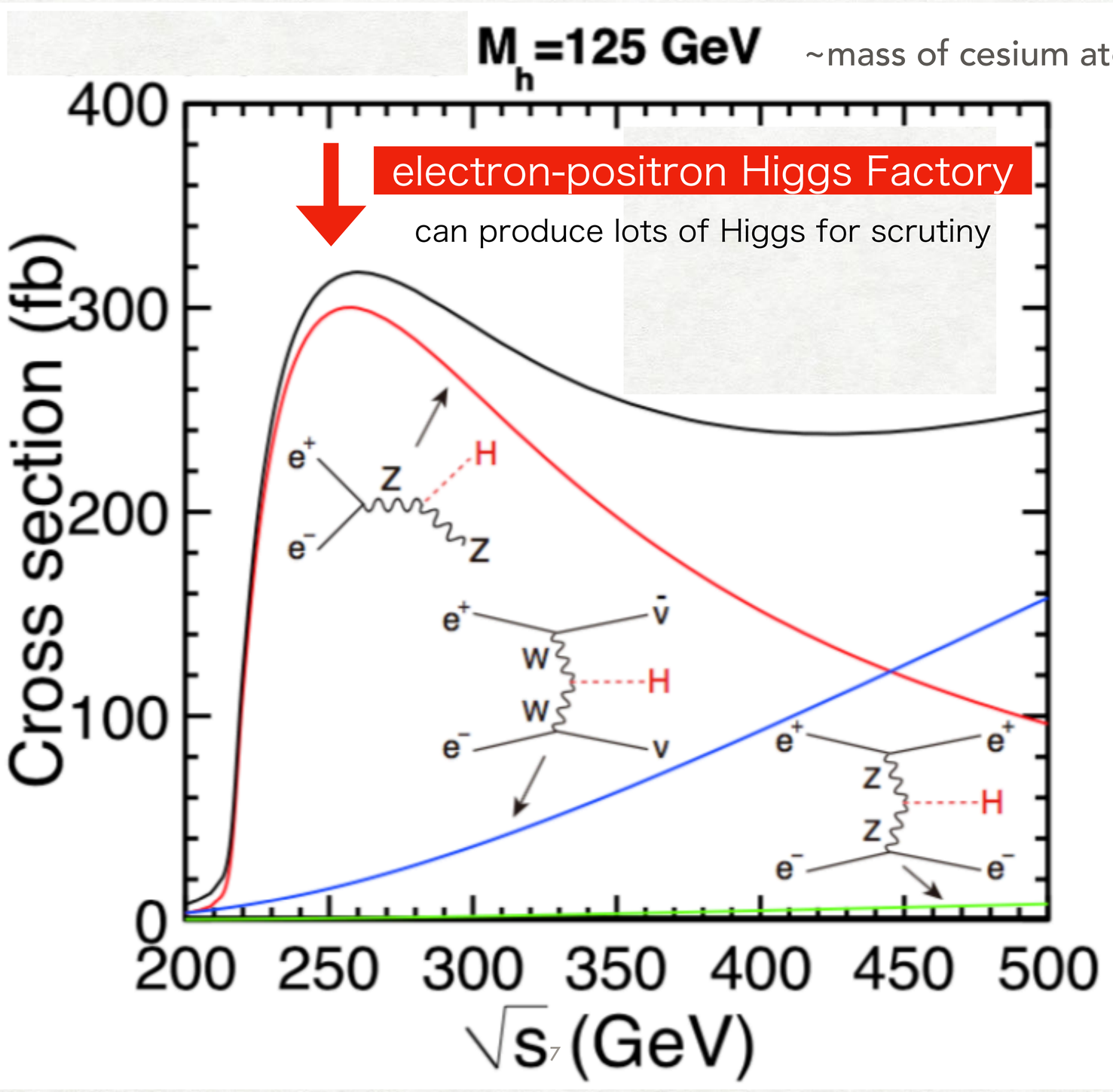
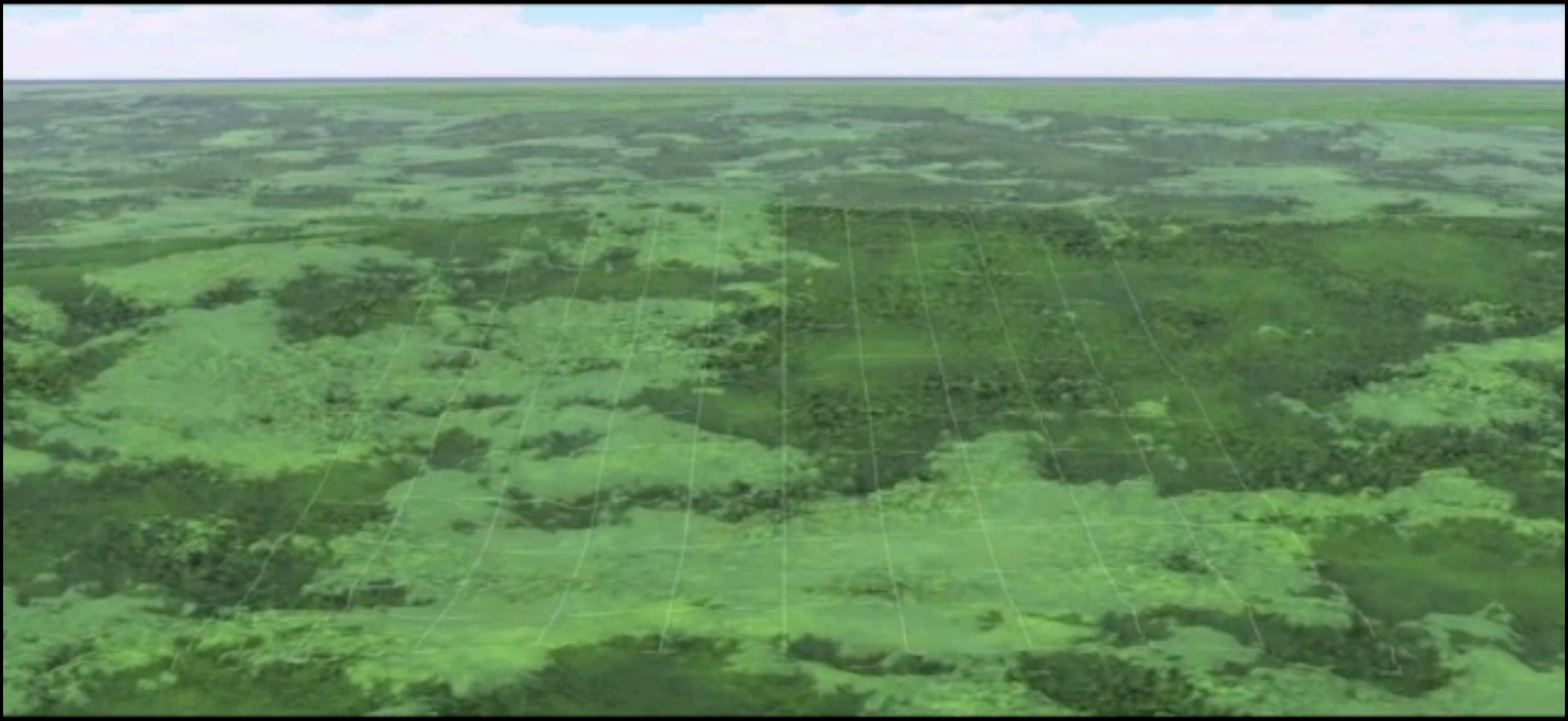
Present Universe

IT'S A HIGH PRIORITY TO UNDERSTAND THE VACUUM OF THE UNIVERSE BY STUDYING THE HIGGS PARTICLE

Higgs is the first of the kind that is hiding in the vacuum — there should be more:
another Higgs that provided neutrino masses, Dark Energy, and Inflaton

Also, great opportunities for discovery of new phenomena such as **Dark Matter** particles!


M_h=125 GeV
~mass of cesium atom
electron-positron Higgs Factory
can produce lots of Higgs for scrutiny
Cross section (fb)
400
300
200
100
0
200 250 300 350 400 450 500
√s (GeV)
e+
e−
Z
H
Z
W
W
ν̄
ν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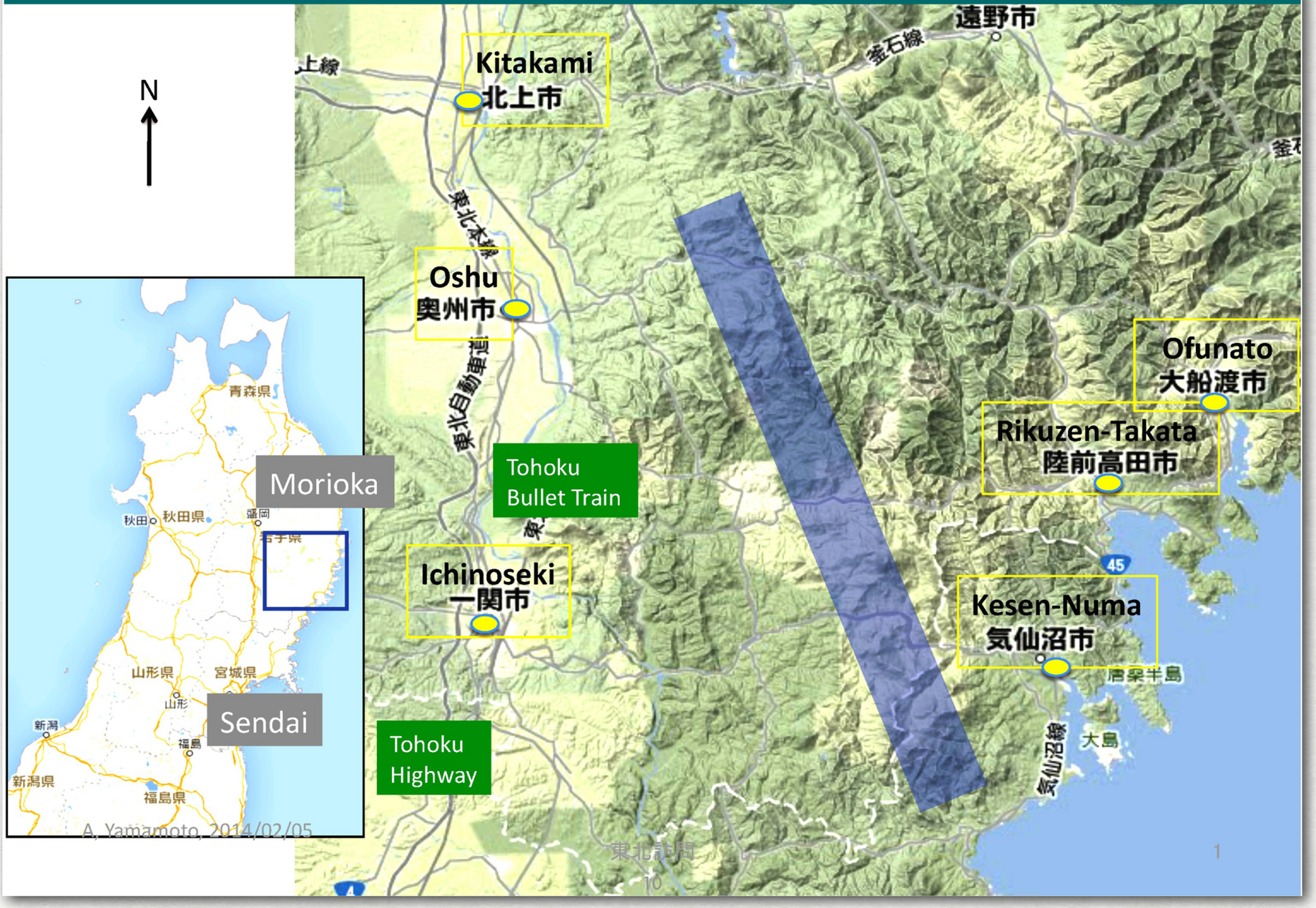
International Linear Collider (ILC)
20 -> 50km

ILC Candidate site in Kitakami, Tohoku



A. Yamamoto, 2014/02/05

ILC Project Timeline

Aug. 2020: ICFA established ILC International Development Team hosted by KEK

1st Phase: International Development Team (1-1.5 yrs)

We're here.

Establish ILC Pre-Lab among national/regional laboratories

Intense Collaboration Expected

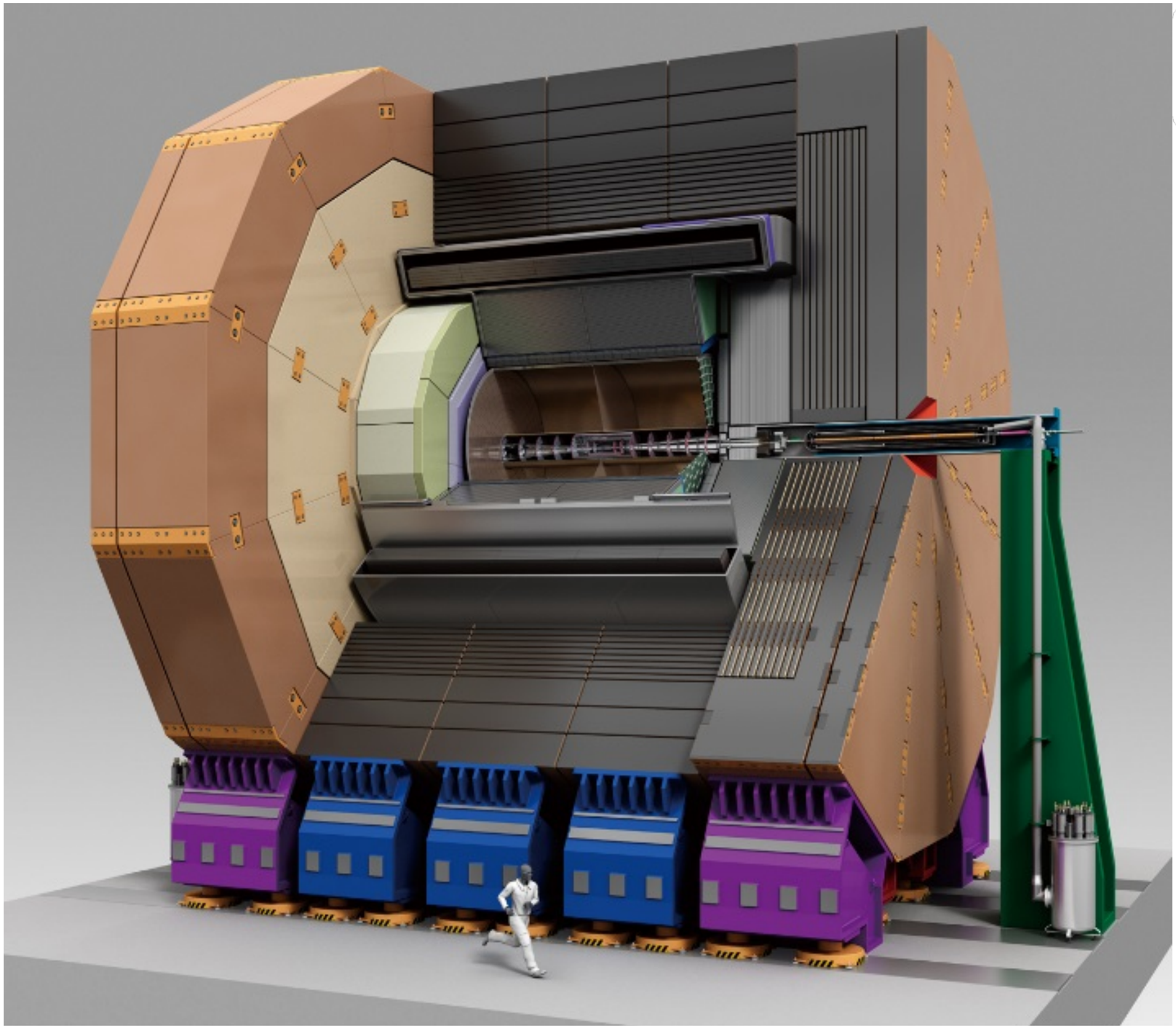
2nd Phase: ILC Pre-Laboratory (~4 years)
→Inter-governmental agreement

Establish ILC Laboratory among partner country/regions

3rd Phase: ILC Construction (~10 years)

Research open to worldwide users

4th Phase: ILC Operation (20+ years)

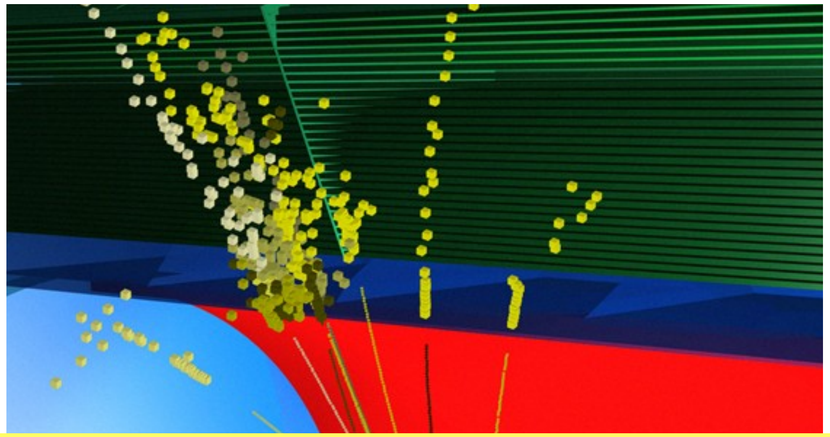


International Large Detector

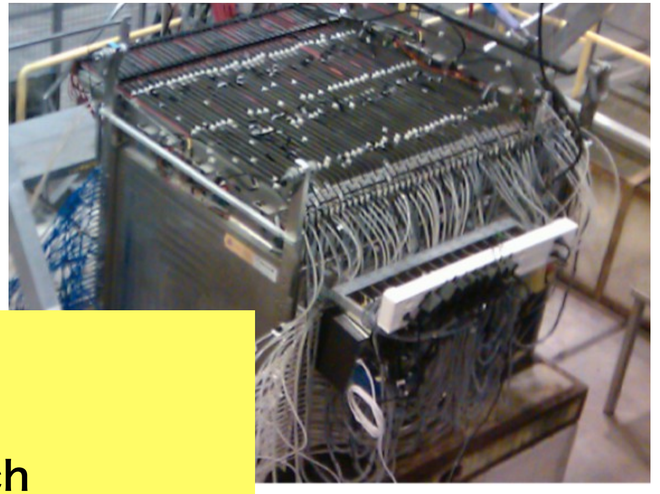
- One of the “Detector Concepts”
- largely Europe-Japan collaboration

Particle Flow Algorithm (PFA)

CALICE Calorimeter for ILC

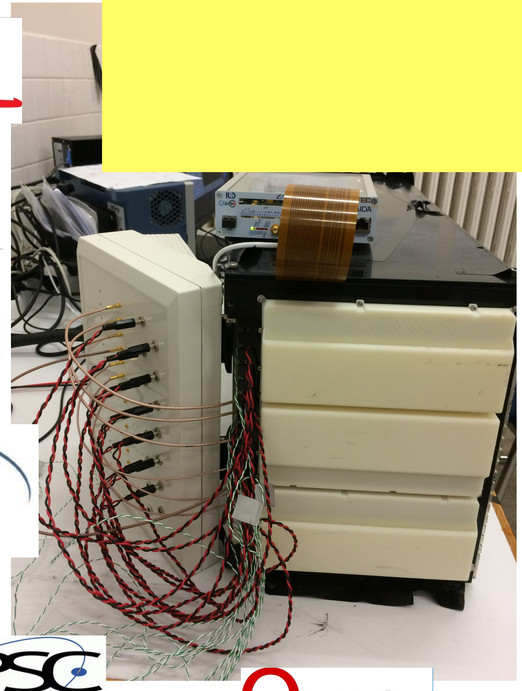


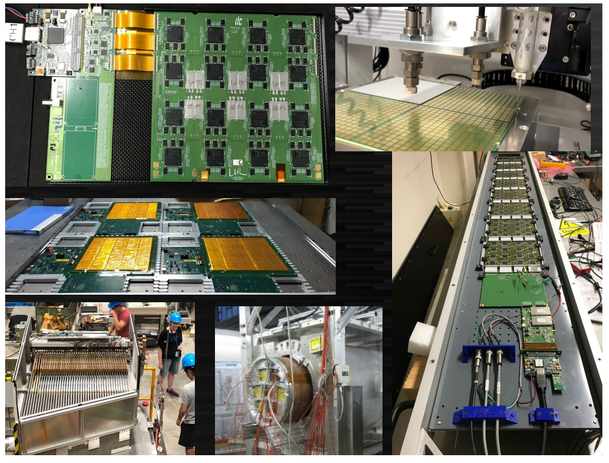
Hadron Calorimeter (HCAL)



~All IN2P3 laboratories that do particle physics research are involved in the ILC activities

EM (





LPC Particules Plasmas Univers applications Laboratoire de Physique de Clermont

OMEGA Microelectronics

IJCLab Irène Joliot-Curie

LPNHE PARIS

LPSC Grenoble

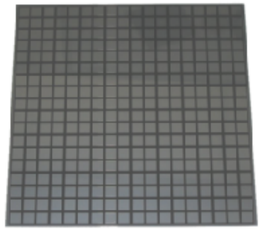
OMEGA Microelectronics

CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

Activities for SiW-ECAL R&D

We are working with Kyushu University.

Technological prototype: FEV13 short slab

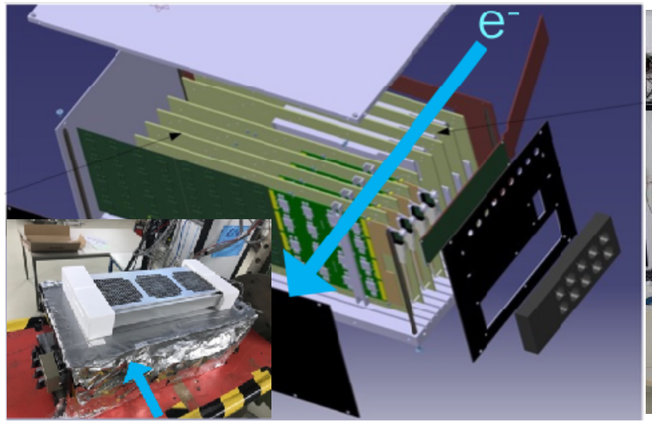


Geometrical structure
- 32 × 32 = 1024 ch / slab
- 4 Si wafers / slab
- 16 ASICs / slab

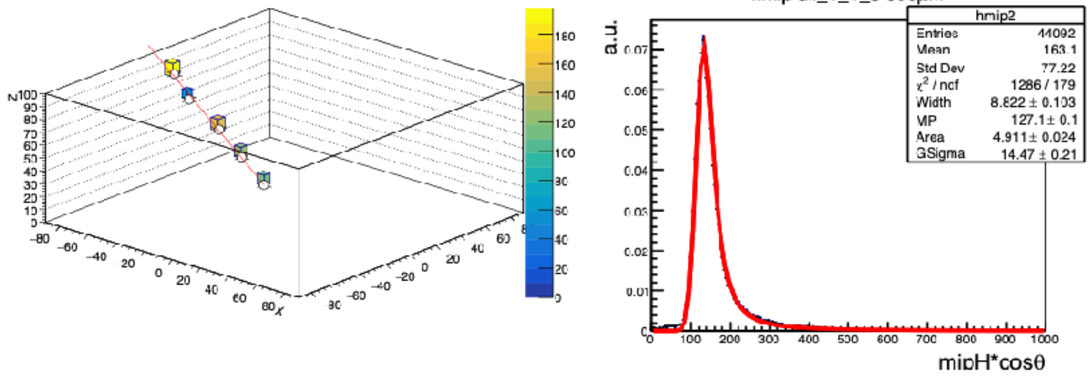
Silicon sensor (Hamamatsu)
- 16 x 16 = 256 P-I-N diodes
- 5.5 x 5.5 mm² pixels
- Thickness: 320, 500, 650 µm

Test beam 2019 at DESY

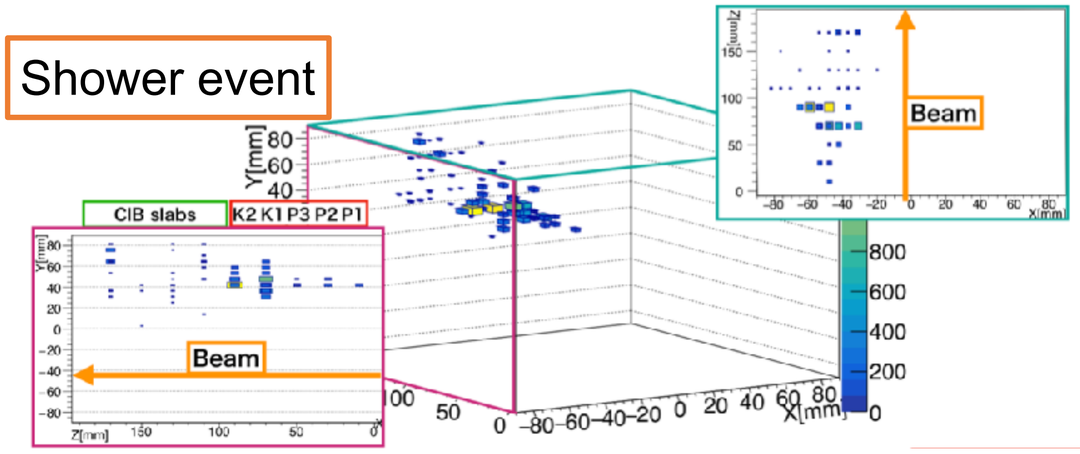
- The latest beam test using electron beam (1-5 GeV)
- Collaboration with LAL/LLR
- We obtained pedestal uniformity/stability, S/N, shower etc.
- The recent test beam plans were canceled due to pandemic.



Cosmic ray track, MIP spectrum



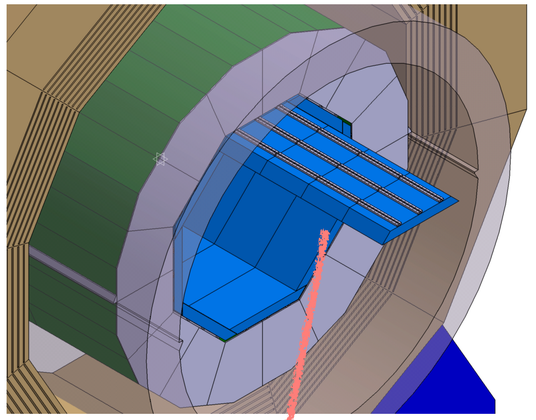
Shower event

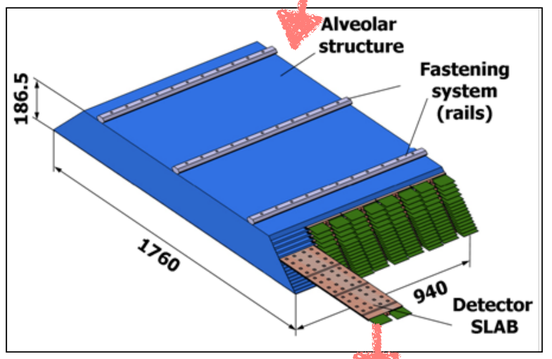


Scintillator-ECAL for ILC

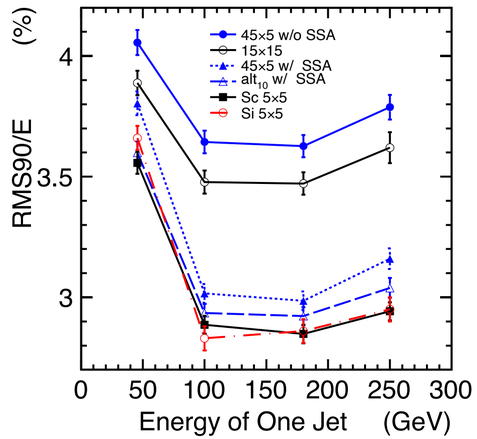
- **Scintillator-Tungsten ECAL (ScW-ECAL)**
  - High granularity calorimeter for PFA calorimetry at ILC detector (R&D coordinated by CALICE collaboration)
  - Scintillator strip (45mm×5mm×^{t}2mm) readout by SiPM
  - Virtual segmentation of 5×5mm^2 by strips aligned alternately in horizontal and vertical orientations
  - Significant reduction of readout channels($10^8 \rightarrow 10^7$) retaining performance
- **Full layer (32 layers) technological prototype**
  - Jointly developed by R&D groups for CEPC and ILD
  - Construction completed
  - To be tested in DESY test beam later this year

ScW-ECAL

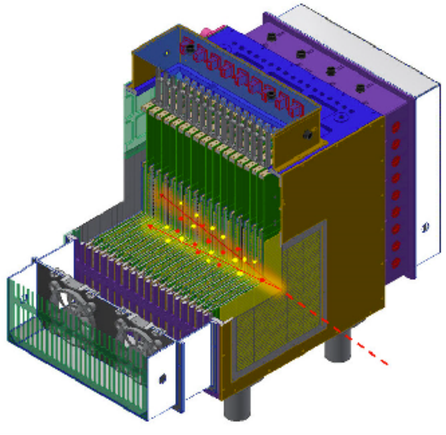


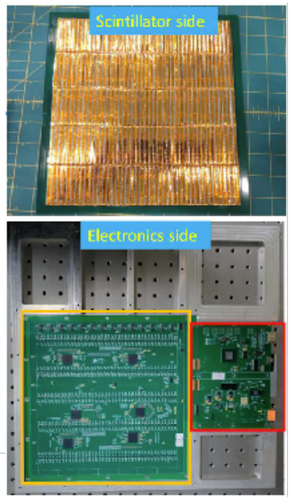


Jet energy resolution



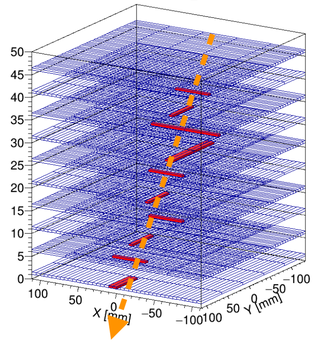
Full layer prototype for ScW-ECAL

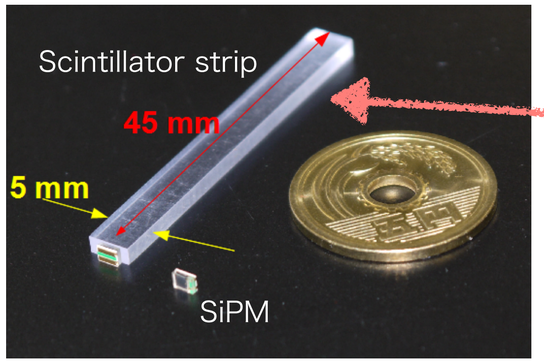


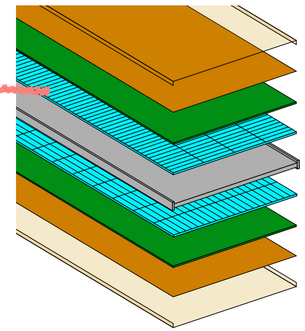


Construction completed

Commissioning (CR test)





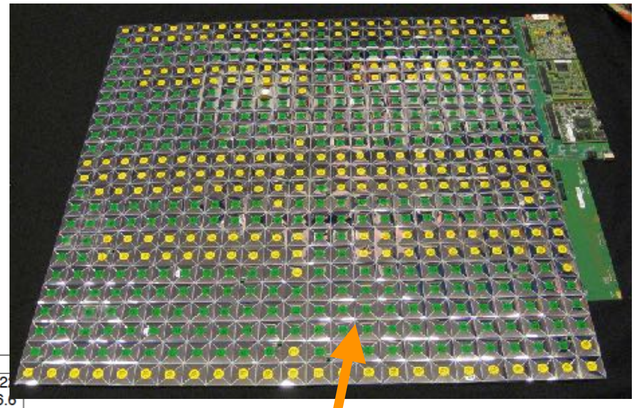


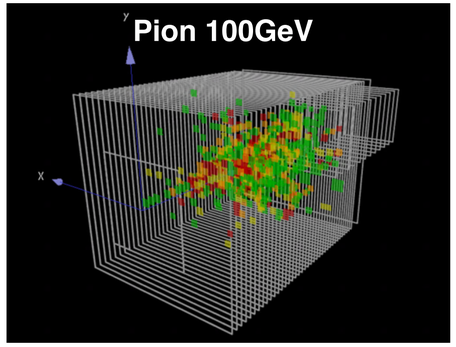
Scintillator-HCAL for ILC

- **Scintillator-Steel HCAL (AHCAL)**
  - "SiPM-on-tile" technology
  - Transverse segmentation: 8×10^6 scintillator cell ($30\times30\times3mm^3$) + SiPM ($1.3\times1.3mm^2$)
  - Longitudinal segmentation: 48 layers of detection module + steel(or tungsten) absorber ($\sim6\lambda_I$)
- **Full layer (38 layers) technological prototype**
  - 38 layers (almost full layers) of $0.7\times0.7m^2$, 22k tiles
  - ~1% of full ILD barrel part
  - Beam test at CERN/SPS H2 beam line (May 9-23 and Jun. 27-Jul.4, 2018)

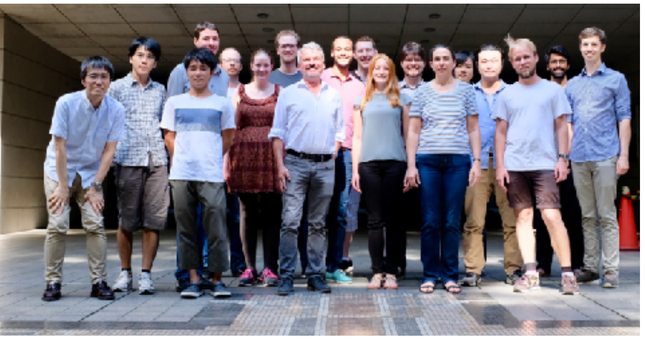
Large technological prototype

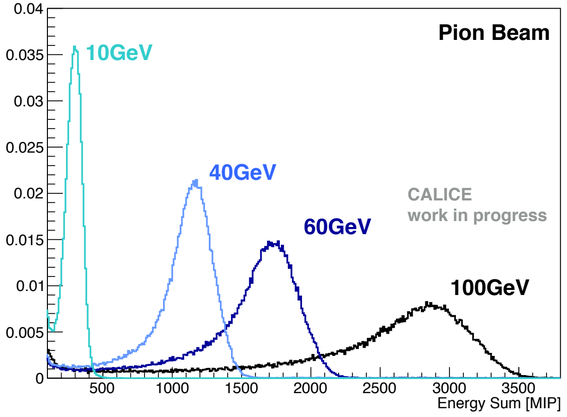
Detection layer module (576 tiles)

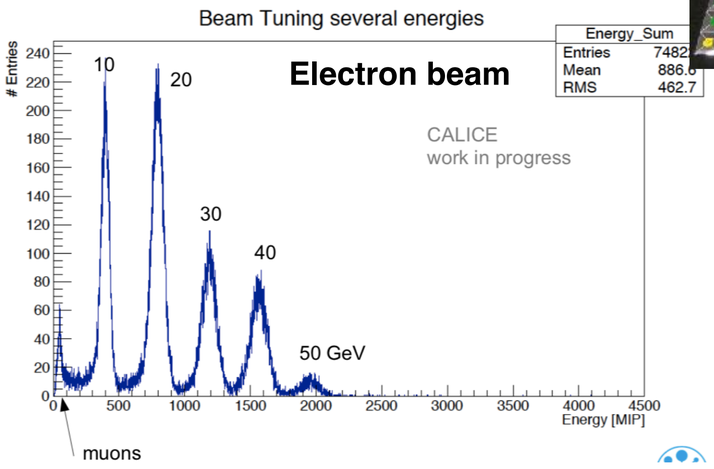


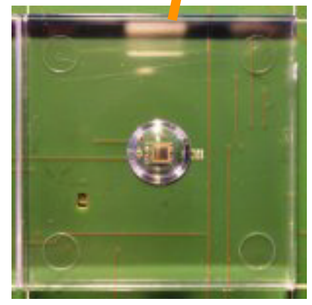


Analysis workshop@UTokyo 2018.8







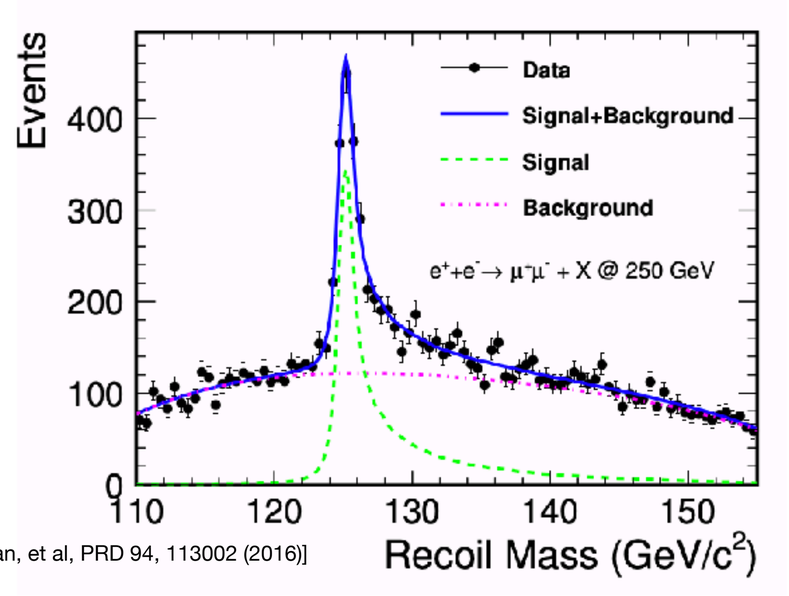


Scintillator tile with SiPM on readout PCB

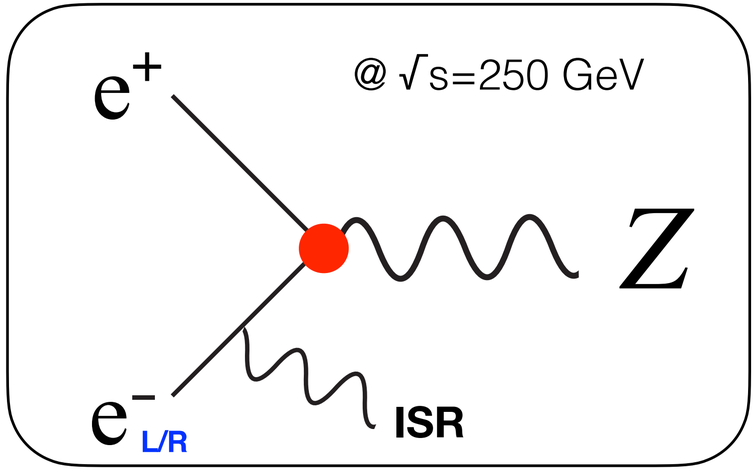
ILC Physics: Higgs & EW

- Precision Higgs Physics
  - Higgs mass, CP & couplings to SM particles
  - Higgs self-couplings using both double- and single-Higgs processes
  - prod. cross section & decay branching ratios (collaboration with LLR)

- Electroweak Precision Observables
  - potential of Z-pole physics at ILC250 using radiative return process
  - focusing on left-right asymmetry A_{LR} with polarized beams



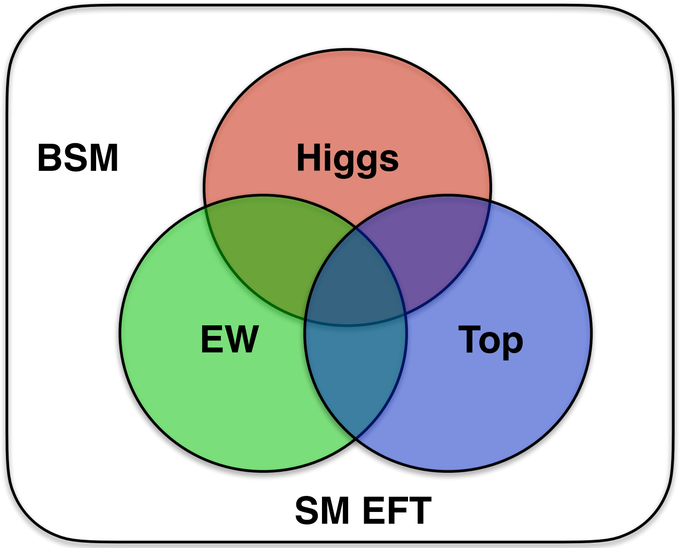
[Yan, Tian, et al, PRD 94, 113002 (2016)]



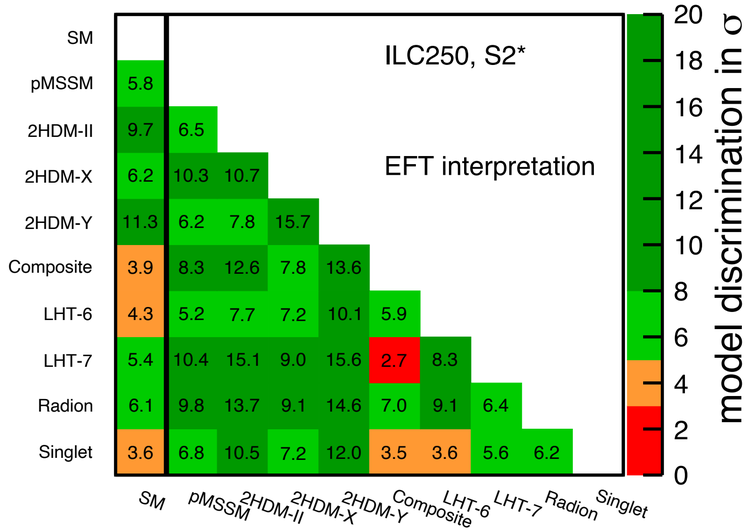
[Fujii, Mizuno, Tian, LoI for Snowmass 2021]

ILC Physics: SMEFT & Global Interpretation

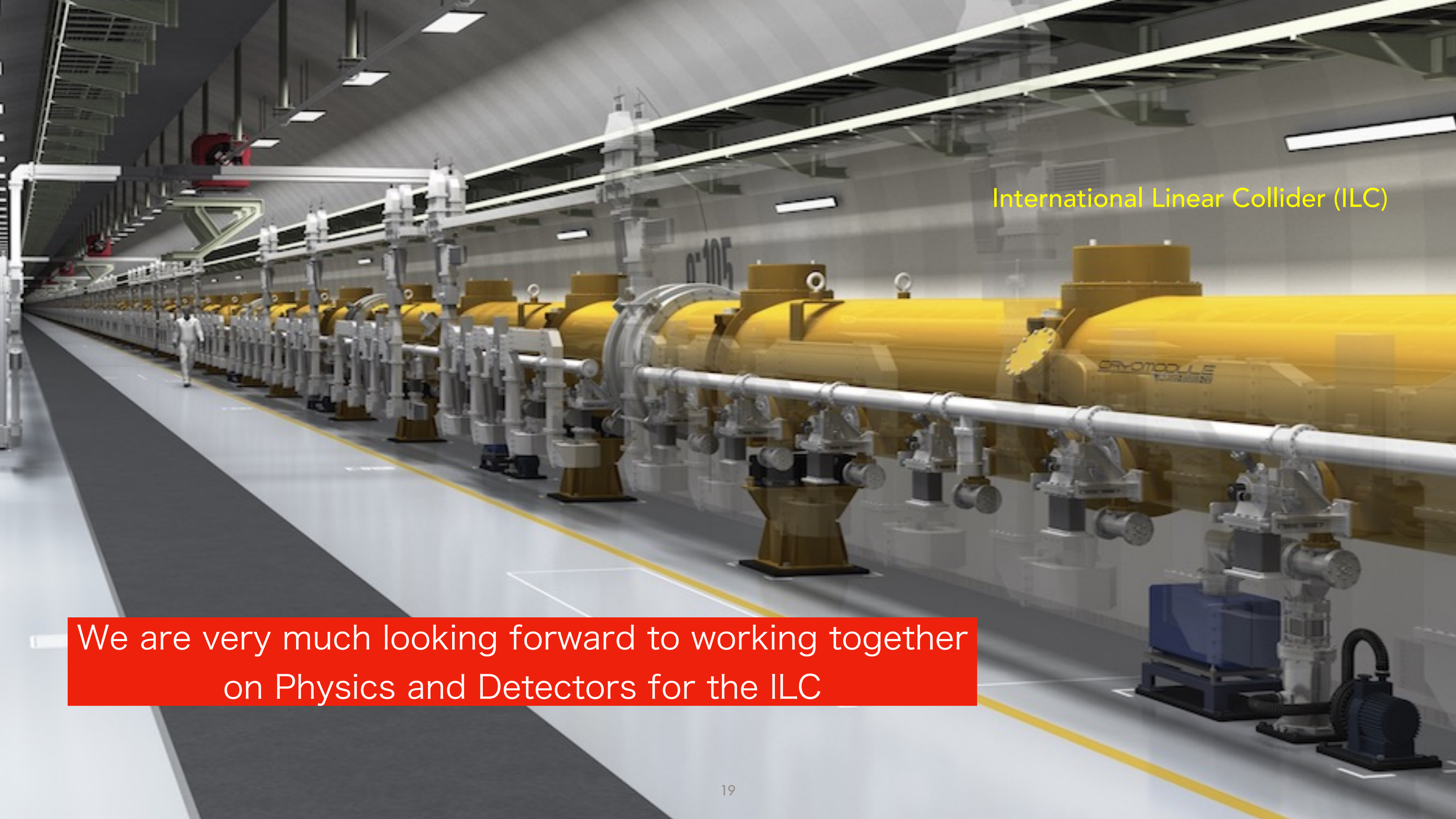
- SM Effective Field Theory
  - Unified prescription for new physics effects in SM precision measurements
  - Synergies between ILC, LHC, and all low-energy experiments (Belle, neutrino)
  - Impact of meas. at Z-pole, Top-quark pair production, and beam polarizations



- Global Interpretation
  - Deviations in concrete BSM models
  - Higgs inverse problem: how various BSM models can be identified and discriminated based on global fit of precision meas.
  - Synergies with direct searches



[Barklow, Fujii, Jung, Peskin, Tian et al, PRD 97 (2018) 053004; PRD 97 (2018) 053003; arXiv:2006.14631]



We are very much looking forward to working together on Physics and Detectors for the ILC