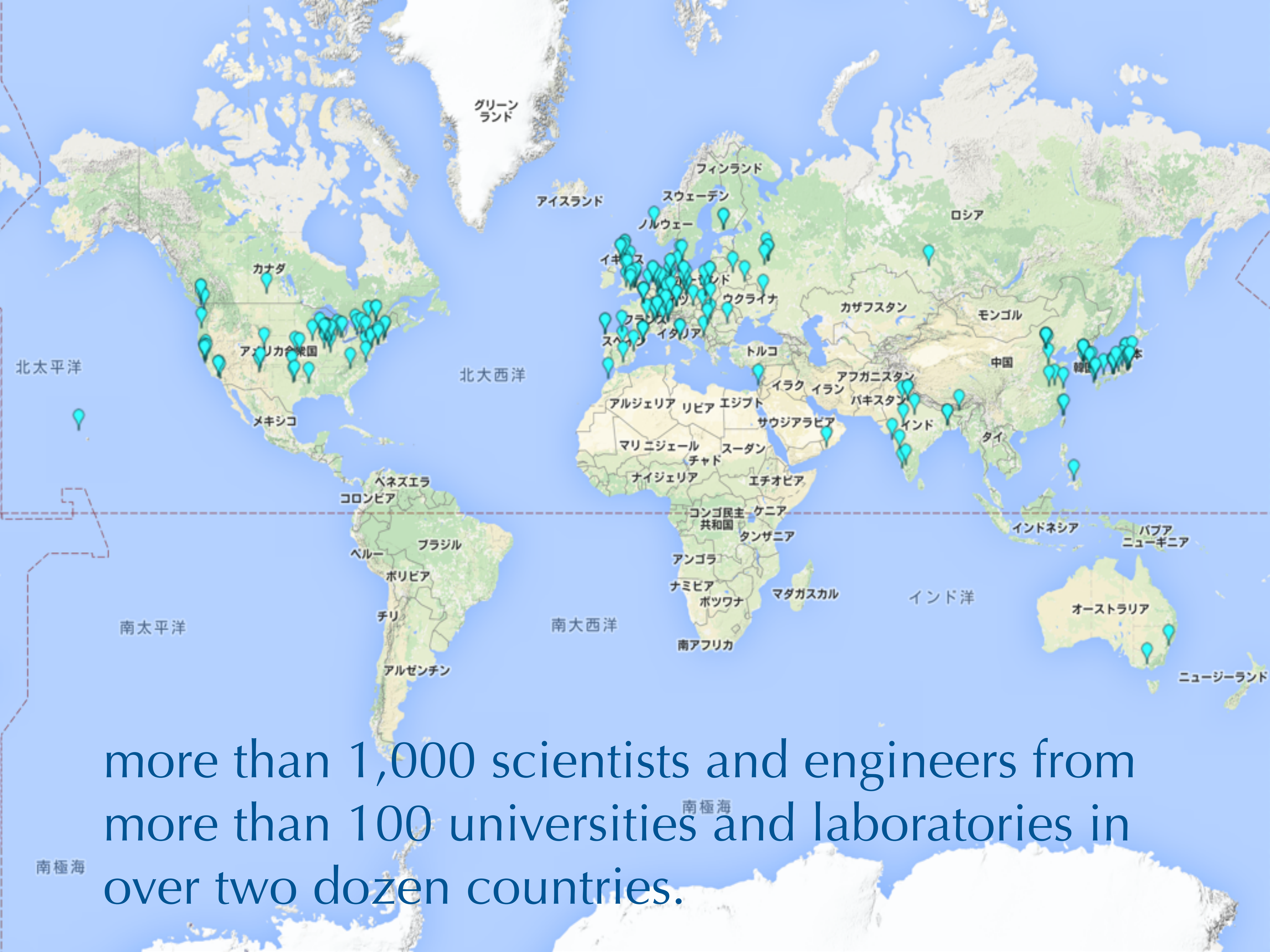
γ-γ collisions at ILC

Tomoyuki SANUKI (Tohoku U.)

1. What is the ILC ?
2. Two photon process in the current ILC study
3. Future prospects

What is the ILC ?

International Linear Collider



more than 1,000 scientists and engineers from more than 100 universities and laboratories in over two dozen countries.

LCC organization from Dec. 2016

ICFA

Linear Collider Board
Tatsuya Nakada
(Lausanne)

LCC

Linear Collider Collaboration

Directorate
Lyn Evans

Deputy (Physics)
Hitoshi Murayama

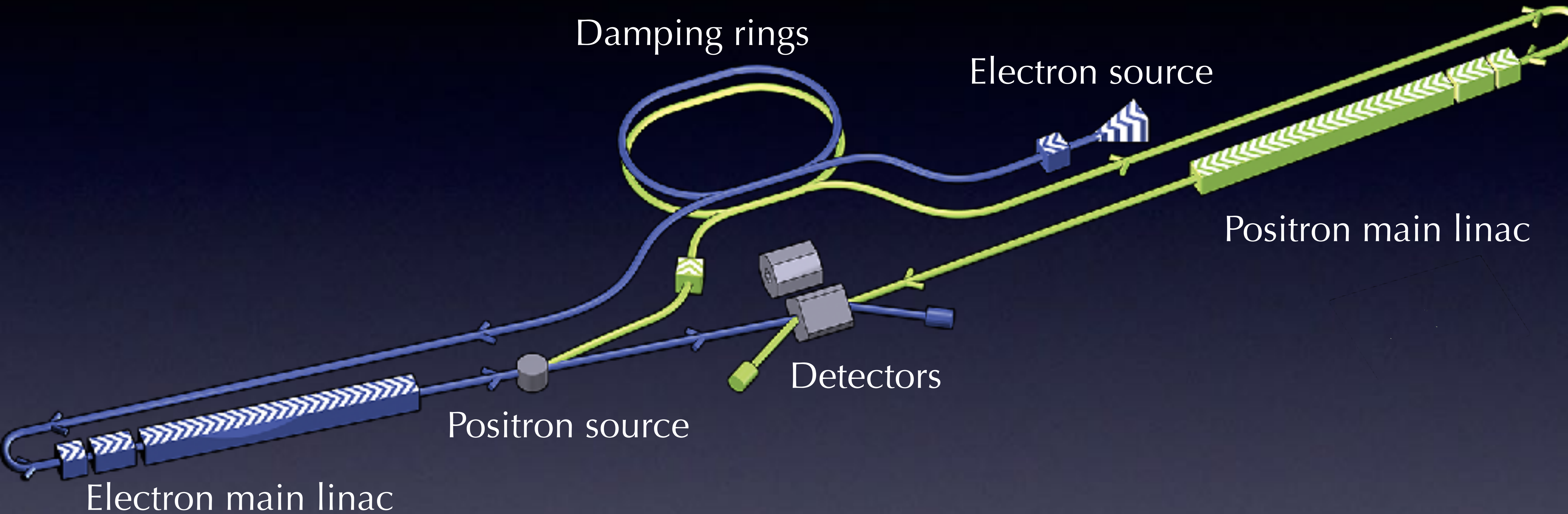
ILC
Shin Michizono

CLIC
Steinar Stapnes

Physics & Detectors
Jim Brau

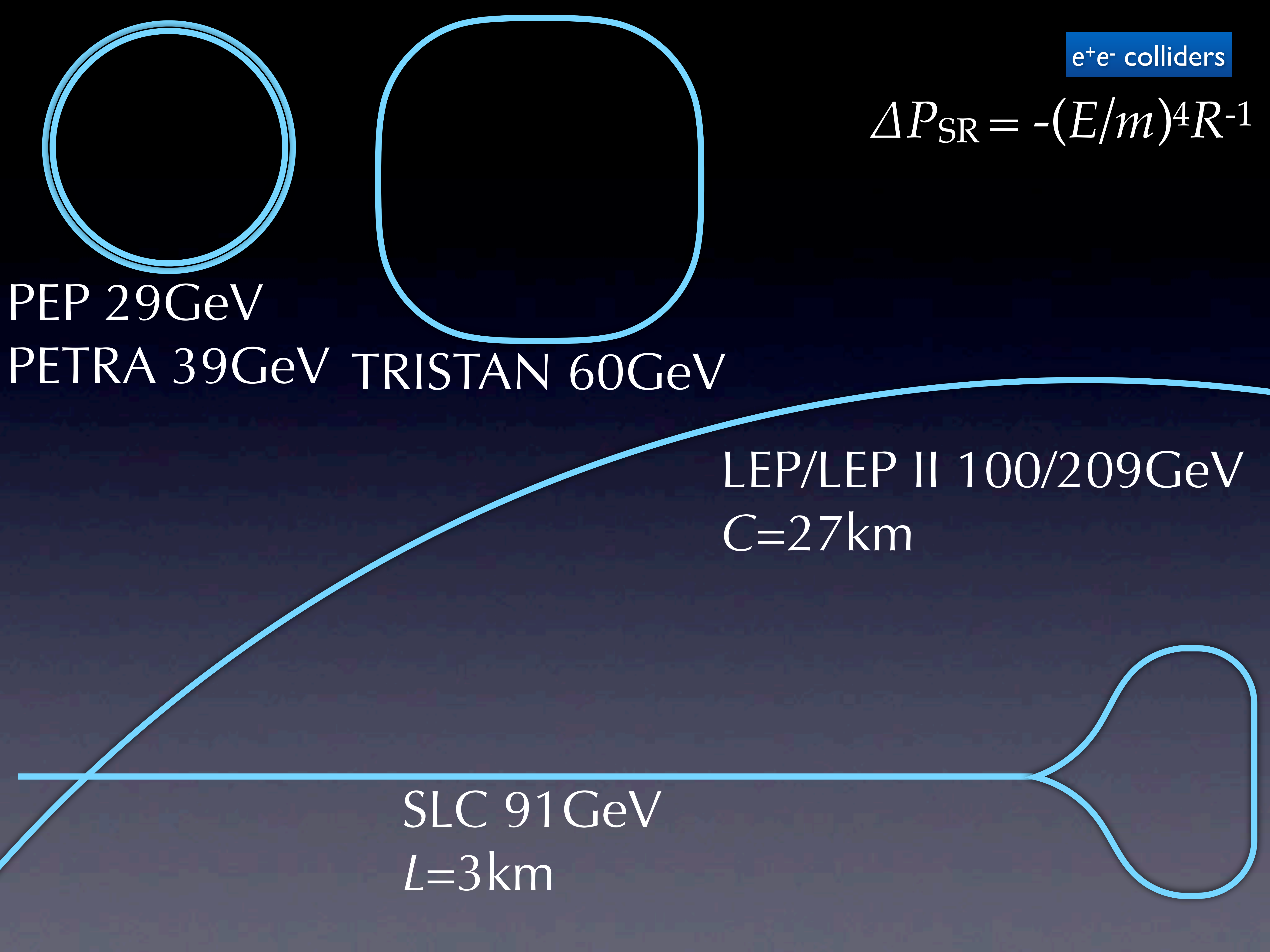
Shin Michizono (ICFA seminar 2017)

ILC



electron+positron accelerator & collider

CM energy : 250GeV → 500GeV → 1000GeV
Total Length : 20km → 30km → 50km
Candidate site: Kitakami mountains (Iwate/Miyagi)


e+e- colliders
$\Delta P_{SR} = -(E/m)^4 R^{-1}$
PEP 29GeV
PETRA 39GeV
TRISTAN 60GeV
LEP/LEP II 100/209GeV
C=27km
SLC 91GeV
L=3km

$$\Delta P_{SR} = -(E/m)^4 R^{-1}$$

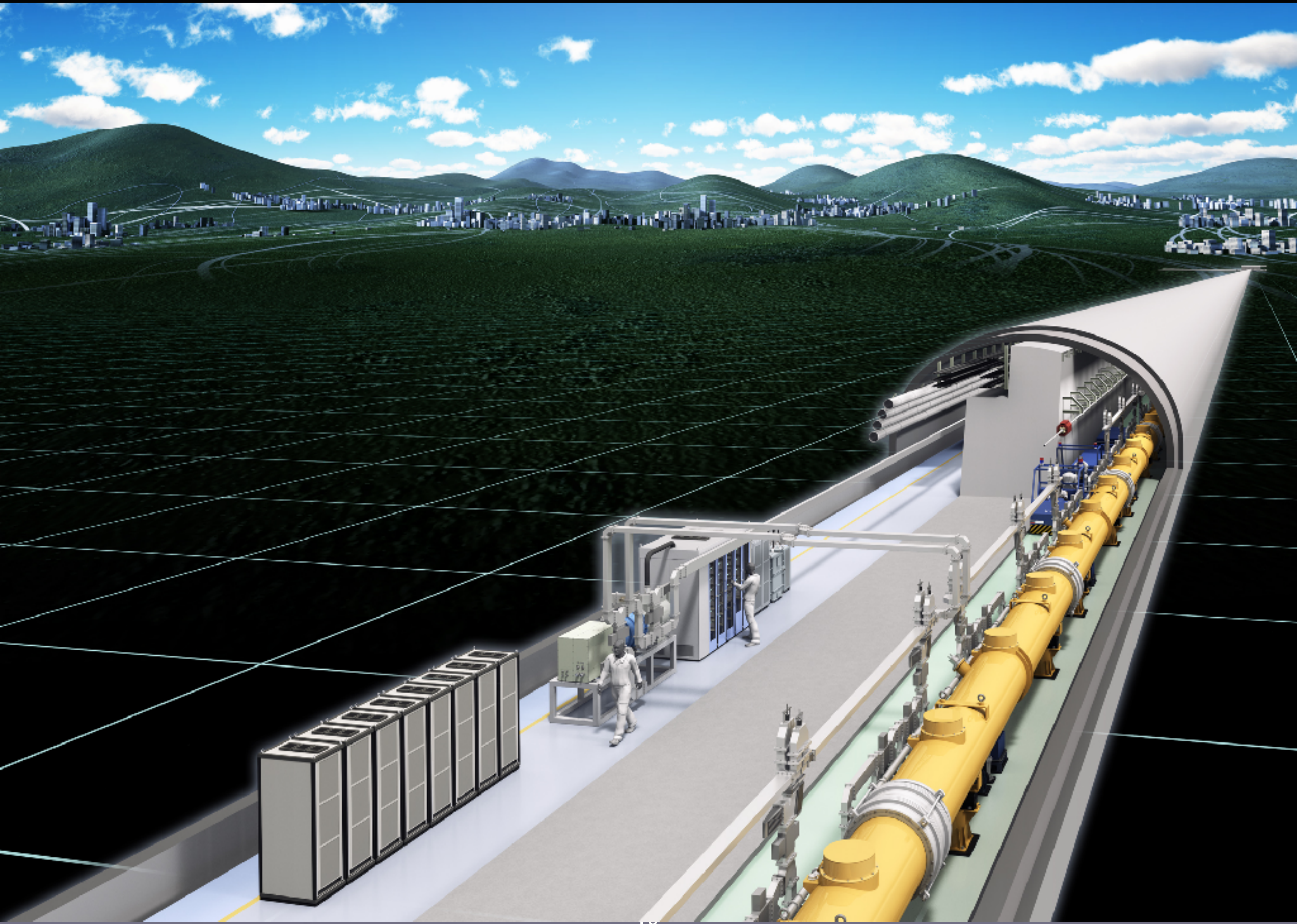
LEP/LEP II 100/209GeV

C=27km

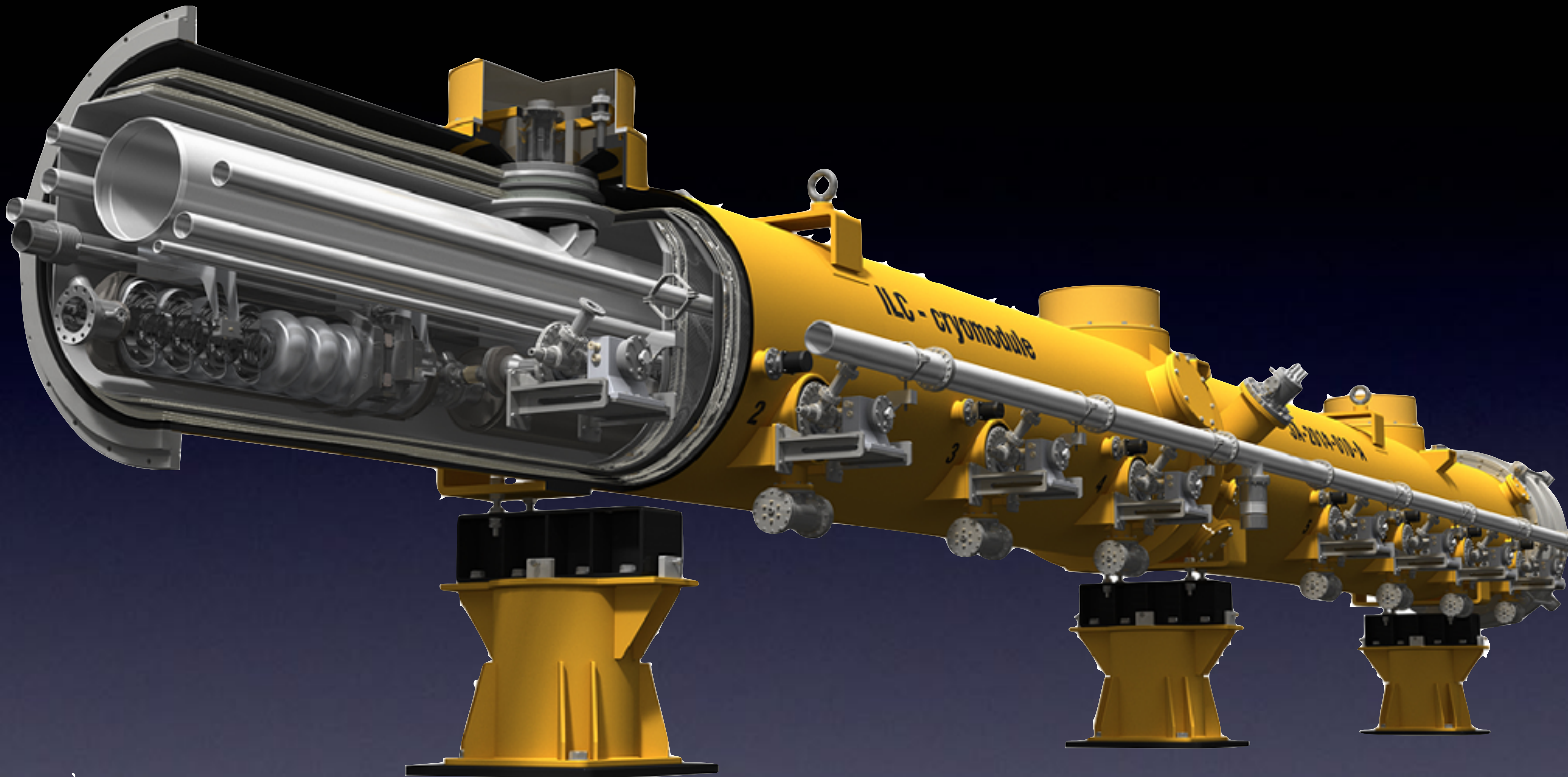
ILC 250GeV - 1000GeV

L=20km - 50km

extendibility to higher energies



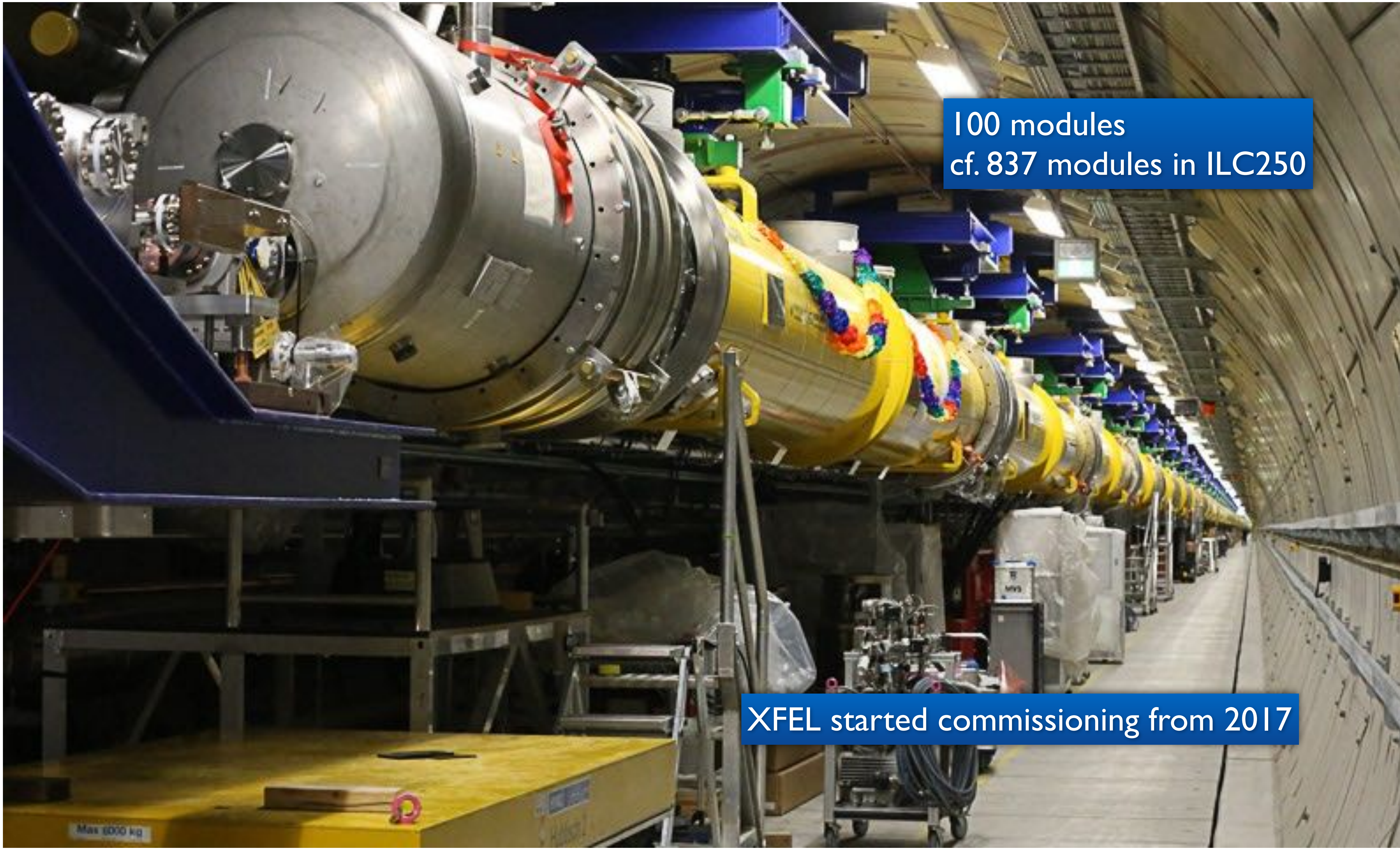
CG by rey.hori


ILC - cryomodule

KEK-STF

https://www.kek.jp/ja/Research/AAT/ILC/

The End of Main Linac Section L3

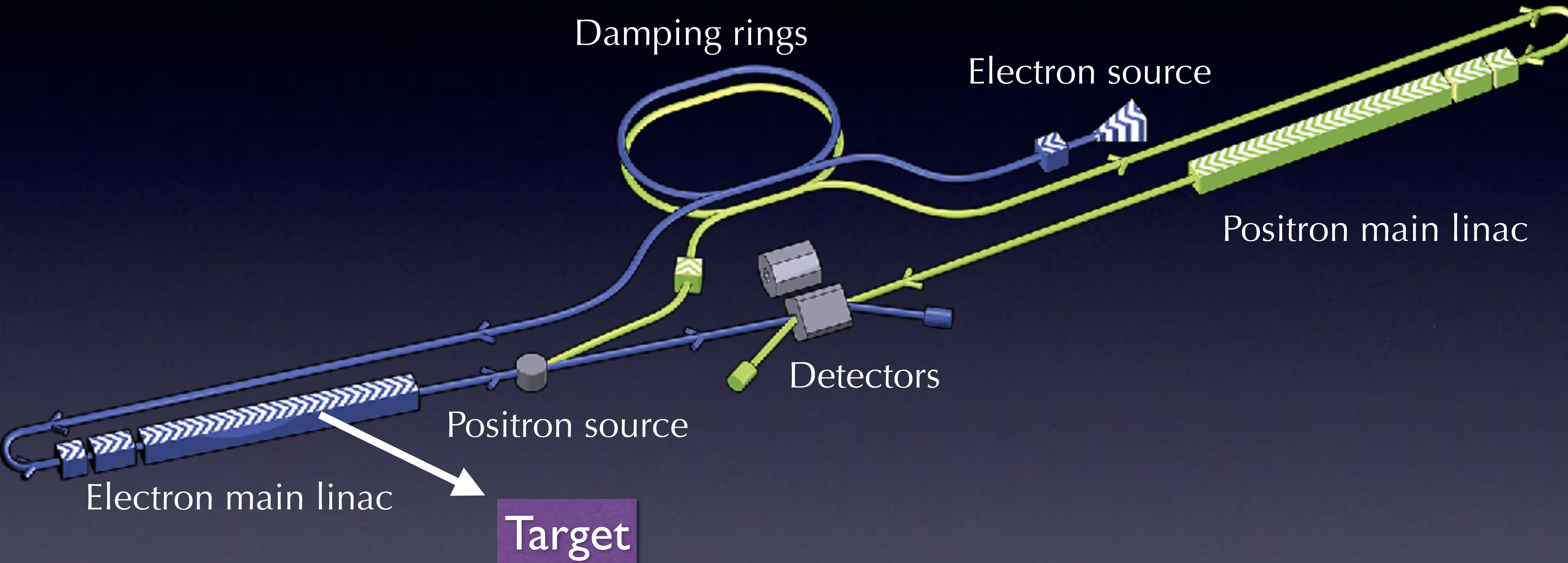


ILC TDR(2013)

Table 2.1. Summary table of the 200–500 GeV baseline parameters for the ILC. The reported luminosity numbers are results of simulation [12]

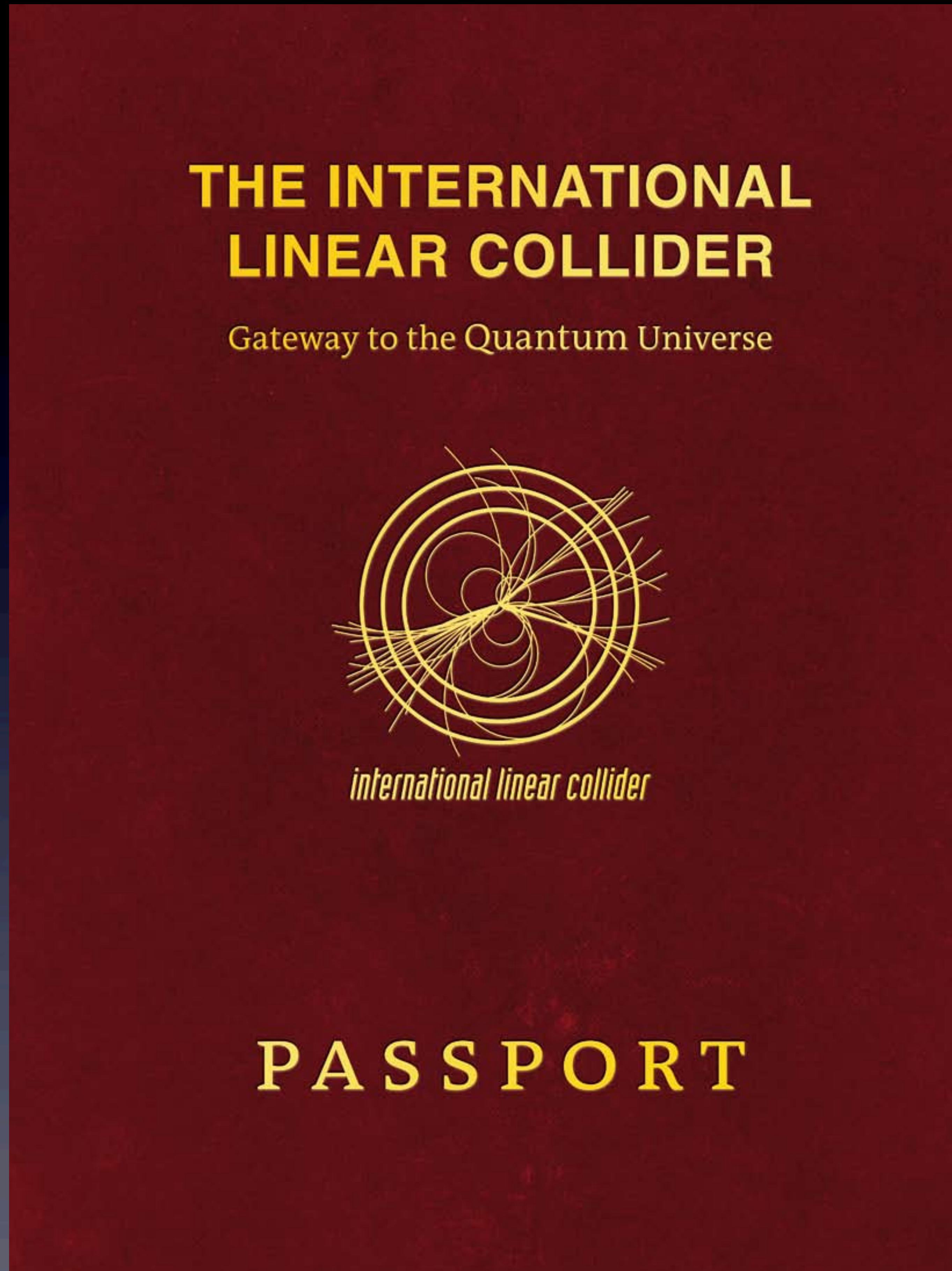
Centre-of-mass energy	E_{CM}	GeV	200	230	250	350	500
Luminosity pulse repetition rate		Hz	5	5	5	5	5
Positron production mode			10 Hz	10 Hz	10 Hz	nom.	nom.
Estimated AC power	P_{AC}	MW	114	119	122	121	163
Bunch population	N	$\times 10^{10}$	2	2	2	2	2
Number of bunches	n_b		1312	1312	1312	1312	1312
Linac bunch interval	Δt_b	ns	554	554	554	554	554
RMS bunch length	σ_z	μm	300	300	300	300	300
Normalized horizontal emittance at IP	$\gamma\epsilon_x$	μm	10	10	10	10	10
Normalized vertical emittance at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35
Horizontal beta function at IP	β_x^*	mm	16	14	13	16	11
Vertical beta function at IP	β_y^*	mm	0.34	0.38	0.41	0.34	0.48
RMS horizontal beam size at IP	σ_x^*	nm	904	789	729	684	474
RMS vertical beam size at IP	σ_y^*	nm	7.8	7.7	7.7	5.9	5.9
Vertical disruption parameter	D_y		24.3	24.5	24.5	24.3	24.6
Fractional RMS energy loss to beamstrahlung	δ_{BS}	%	0.65	0.83	0.97	1.9	4.5
Luminosity	L	$\times 10^{34}$ cm^{-2} s^{-1}	0.56	0.67	0.75	1.0	1.8
Fraction of L in top 1% E_{CM}	$L_{0.01}$	%	91	89	87	77	58
Electron polarisation	P_-	%	80	80	80	80	80
Positron polarisation	P_+	%	30	30	30	30	30
Electron relative energy spread at IP	$\Delta p/p$	%	0.20	0.19	0.19	0.16	0.13
Positron relative energy spread at IP	$\Delta p/p$	%	0.19	0.17	0.15	0.10	0.07

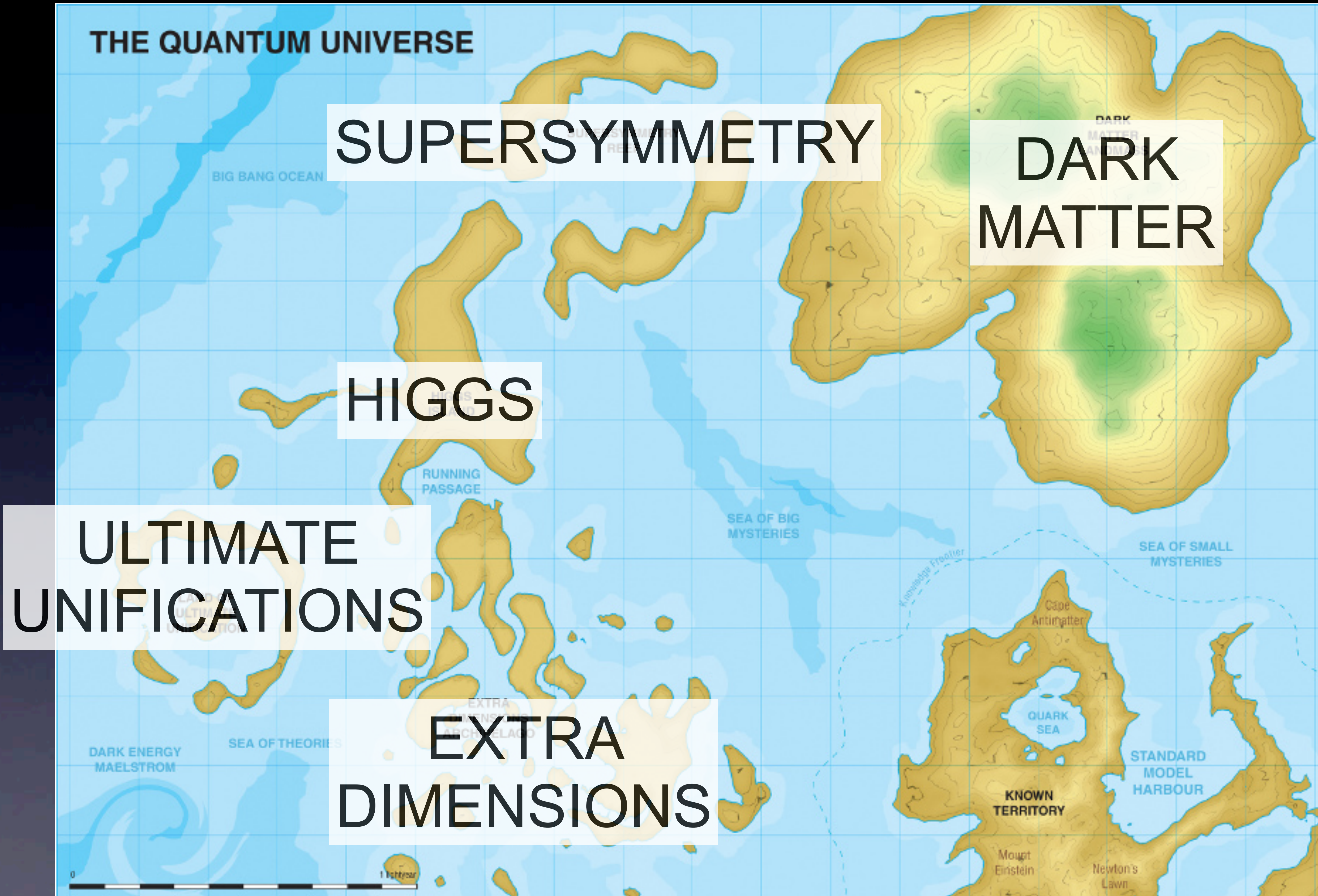
ILC



Fixed target experiment with polarized beam

Physics


THE INTERNATIONAL
LINEAR COLLIDER
Gateway to the Quantum Universe
international linear collider
PASSPORT

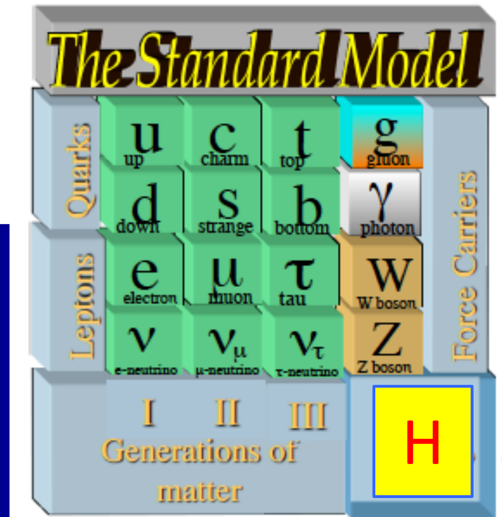

THE QUANTUM UNIVERSE
SUPERSYMMETRY
DARK MATTER
BIG BANG OCEAN
HIGGS
RUNNING PASSAGE
SEA OF BIG MYSTERIES
SEA OF SMALL MYSTERIES
ULTIMATE UNIFICATIONS
Cape Antimatter
QUARK SEA
STANDARD MODEL HARBOUR
KNOWN TERRITORY
EXTRA DIMENSIONS
DARK ENERGY MAELSTROM
Mount Einstein
Newton's Lawn

ICFA Statement, 2017

The discovery of a Higgs boson in 2012 at the Large Hadron Collider (LHC) at CERN is one of the most significant recent breakthroughs in science and marks a major step forward in fundamental physics. Precision studies of the Higgs boson will further deepen our understanding of the most fundamental laws of matter and its interactions.

Important Energies in ILC

125 GeV Higgs discovery reinforcing the ILC importance



Integrated Luminosity (ab^{-1})

2

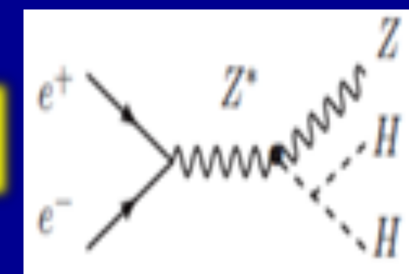
1

Physics confident:

→ **Higgs** and **Top Quark**

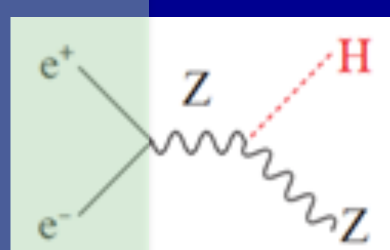
- Learn "everything" about H (125)
- Probe dynamics of EWSB

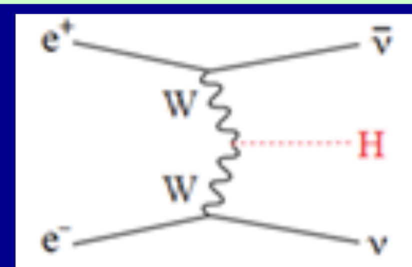
HHZ

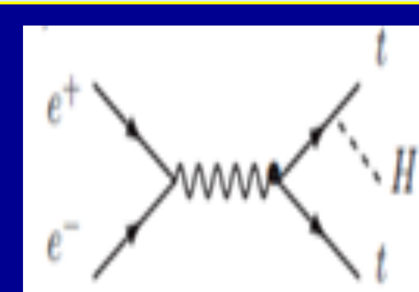


New Physics beyond SM:

- Direct or indirect **DM searches**
- Evidence for BSM physics
- Hints of a new mass scale







HZ

$\bar{\nu}\nu H$

$t\bar{t}$

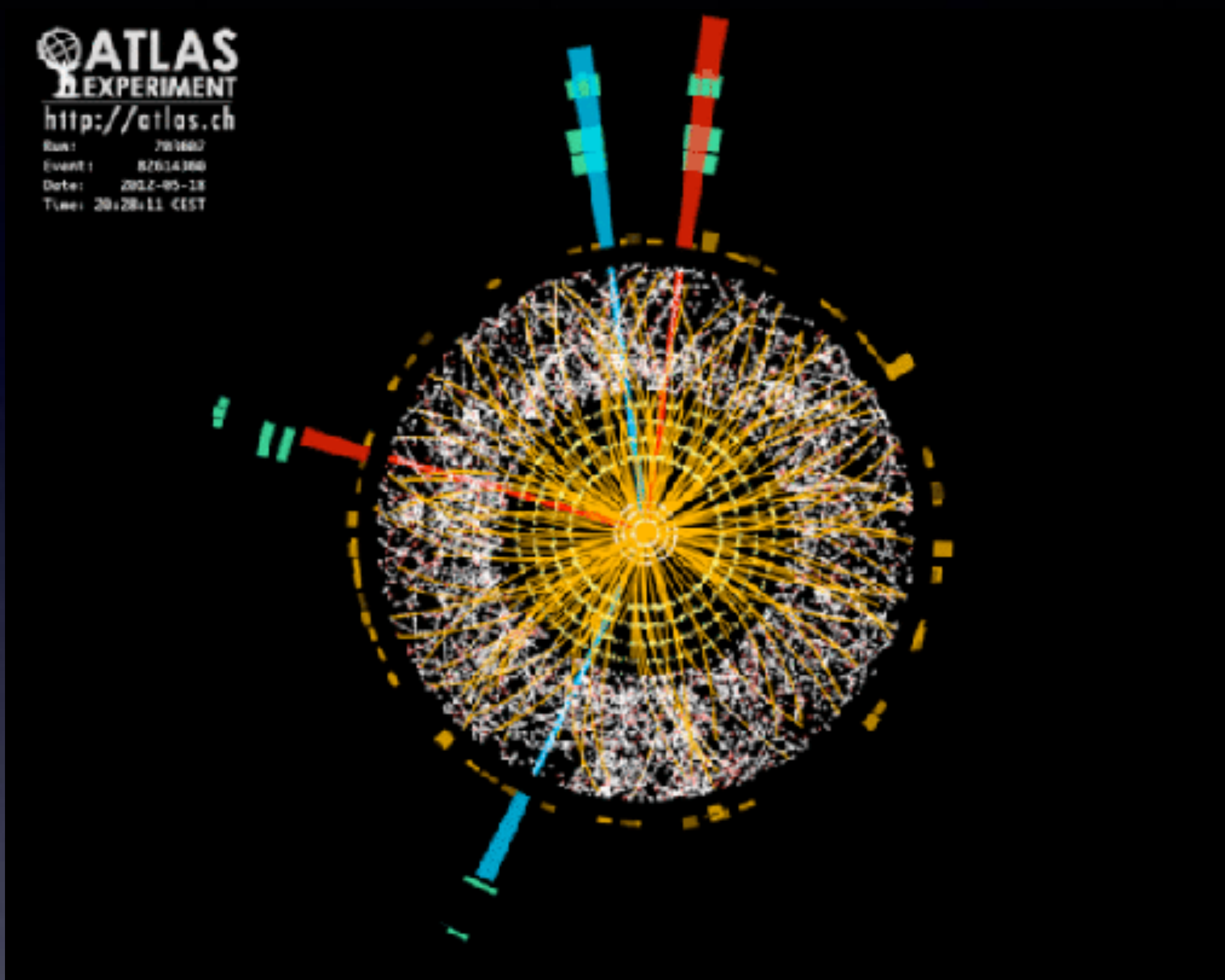
$t\bar{t}H$

LEP reached →

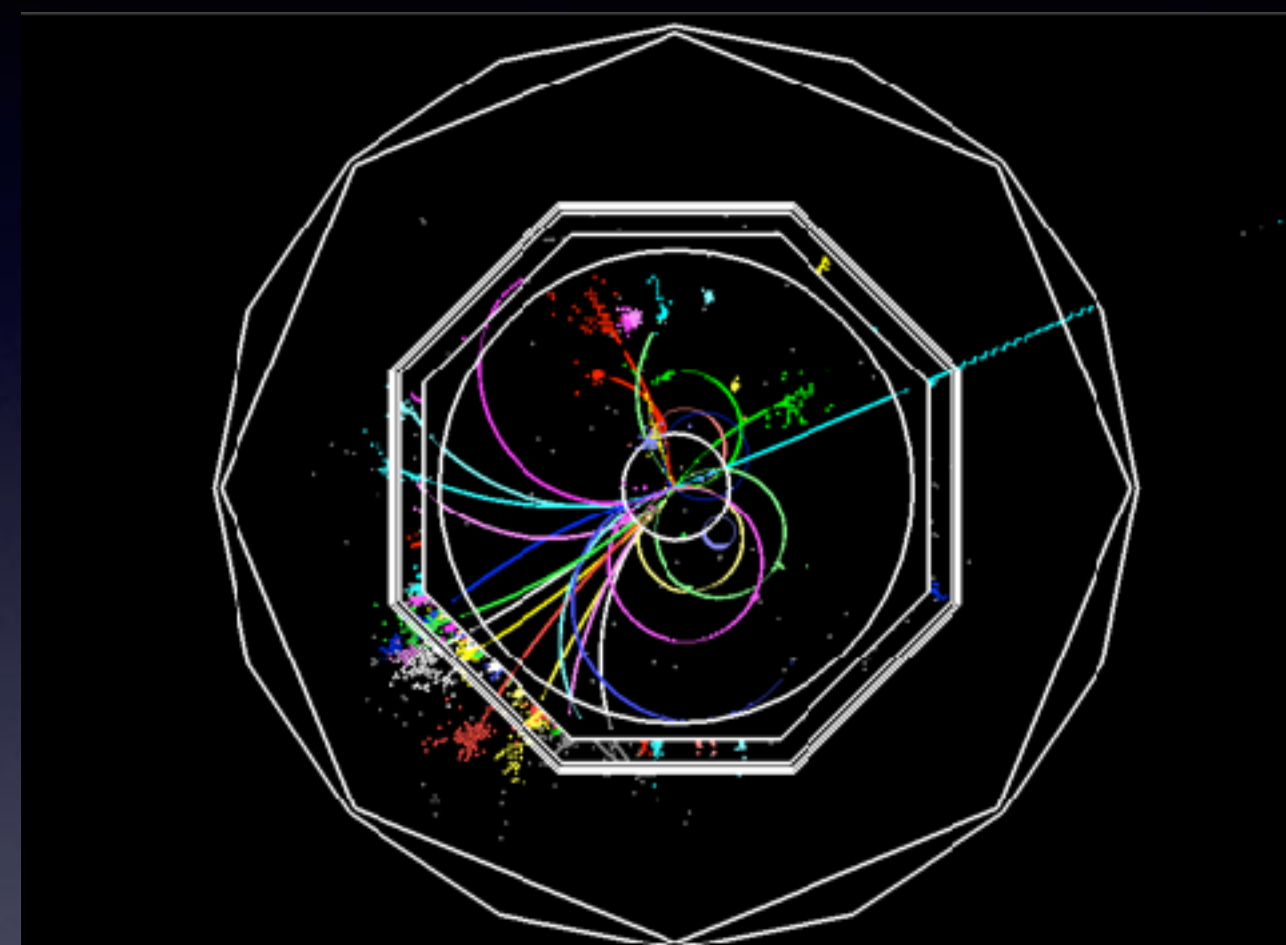
200 300 400 500 600 E_{cm} (GeV)

Shin Michizono (ICFA seminar 2017)

Higgs looks like

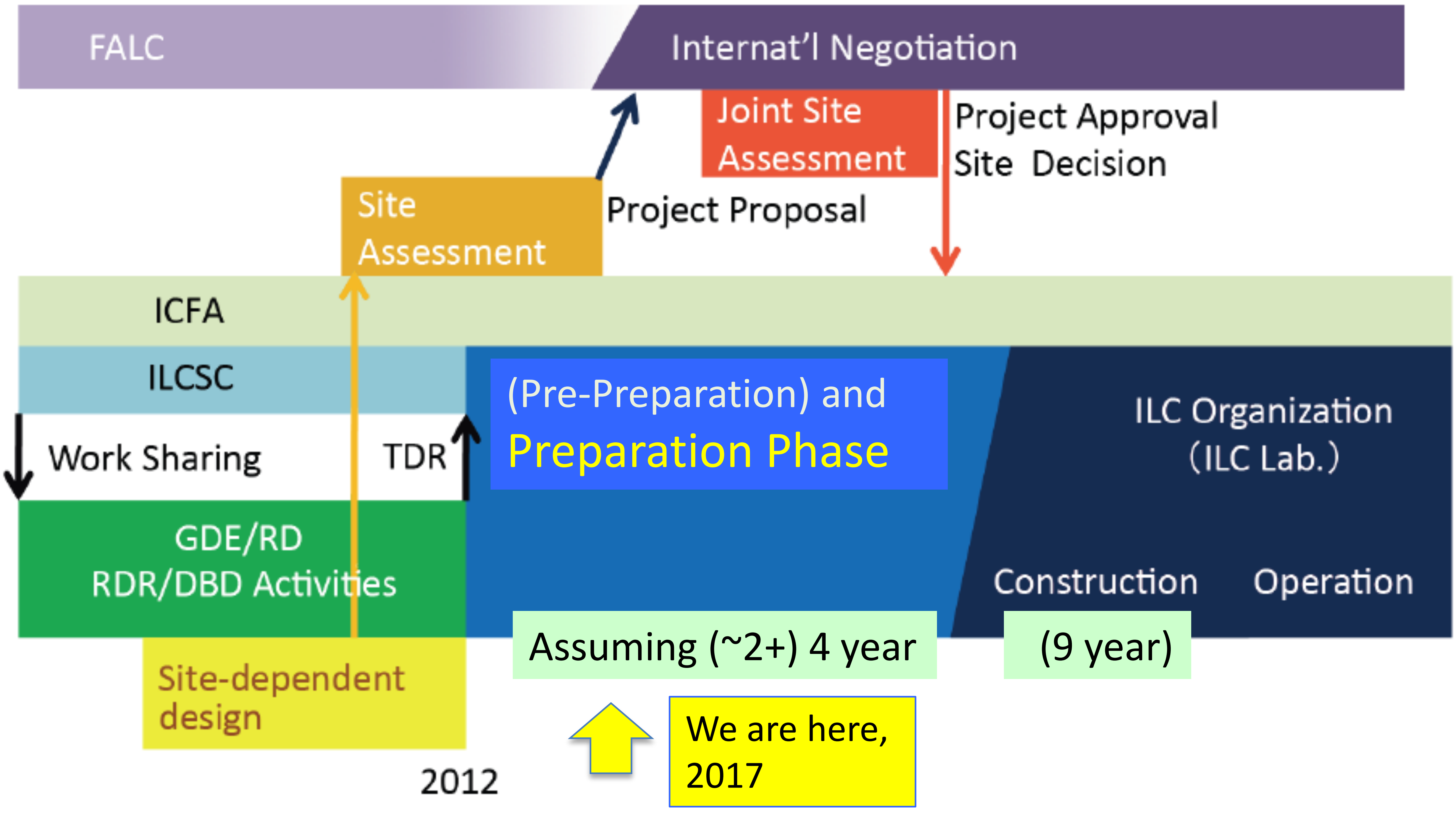


LHC : p+p

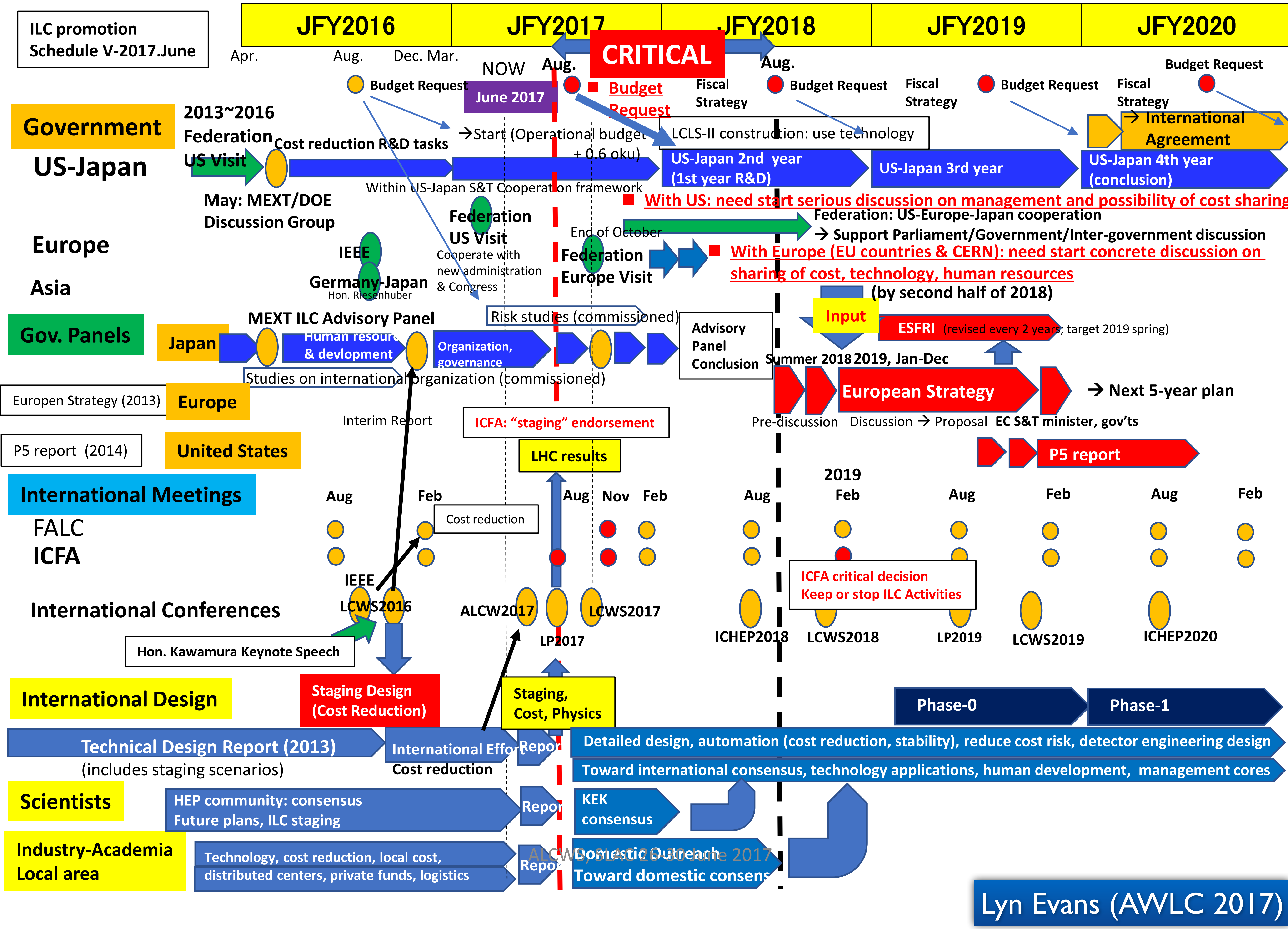


ILC : e^+e^-

ILC Time Line: Progress and Prospect



Shin Michizono (ICFA seminar 2017)



ILC promotion Schedule V-2017.June
JFY2016
JFY2017
JFY2018
JFY2019
JFY2020
Apr.
Aug.
Dec. Mar.
NOW
Aug.
CRITICAL
Aug.
June 2017
Budget Request
Budget Request
Fiscal Strategy
Budget Request
Fiscal Strategy
Budget Request
Fiscal Strategy
Budget Request
Government
US-Japan
2013~2016 Federation US Visit
Cost reduction R&D tasks
→Start (Operational budget + 0.6 oku)
LCLS-II construction: use technology
→ International Agreement
US-Japan 2nd year (1st year R&D)
US-Japan 3rd year
US-Japan 4th year (conclusion)
Within US-Japan S&T Cooperation framework
May: MEXT/DOE Discussion Group
With US: need start serious discussion on management and possibility of cost sharing
Europe
Federation US Visit
End of October
Federation: US-Europe-Japan cooperation
→ Support Parliament/Government/Inter-government discussion
IEEE
Cooperate with new administration & Congress
Federation Europe Visit
With Europe (EU countries & CERN): need start concrete discussion on sharing of cost, technology, human resources
Asia
Germany-Japan
Hon. Riesenhuber
(by second half of 2018)
Gov. Panels
MEXT ILC Advisory Panel
Risk studies (commissioned)
Input
ESFRI (revised every 2 years; target 2019 spring)
Japan
Human resource & devlopment
Organization, governance
Advisory Panel Conclusion
Summer 2018
2019, Jan-Dec
Studies on international organization (commissioned)
Europen Strategy (2013)
Europe
European Strategy
→ Next 5-year plan
Interim Report
ICFA: "staging" endorsement
Pre-discussion
Discussion → Proposal
EC S&T minister, gov'ts
P5 report (2014)
United States
LHC results
P5 report
International Meetings
Aug
Feb
Aug
Nov
Feb
Aug
2019 Feb
Aug
Feb
Aug
Feb
Cost reduction
FALC
ICFA
IEEE
ICFA critical decision
Keep or stop ILC Activities
International Conferences
LCWS2016
ALCW2017
LP2017
LCWS2017
ICHEP2018
LCWS2018
LP2019
LCWS2019
ICHEP2020
Hon. Kawamura Keynote Speech
International Design
Staging Design (Cost Reduction)
Staging, Cost, Physics
Phase-0
Phase-1
Technical Design Report (2013)
(includes staging scenarios)
International Effort
Cost reduction
Report
Detailed design, automation (cost reduction, stability), reduce cost risk, detector engineering design
Toward international consensus, technology applications, human development, management cores
Scientists
HEP community: consensus Future plans, ILC staging
Report
KEK consensus
Industry-Academia Local area
Technology, cost reduction, local cost, distributed centers, private funds, logistics
Report
Domestic Outreach
Toward domestic consensus
ALCW, SLAC 26-30 June 2017
Lyn Evans (AWLC 2017)

ILC

- Linear Collider
  - “economical” machine (ΔP_{SR})
  - extendibility to higher energies
- Electron-Positron Collider
  - “clean” environment
  - large discovery potential
  - precision studies of the Higgs boson

Two photon process in the current ILC study

Summary of Backgrounds

The background sources have been investigated in various studies. For example, the beam-beam interaction and pair generation, radiative Bhabhas, disrupted beams and beamstrahlung photons for the 500 GeV ILC were studied with GUINEAPIG [333]. Also, the $\gamma\gamma$ hadronic cross section was approximated in the Peskin-Barklow scheme [2]. Based on these studies densities of particles which will reach the different sun-detectors have been estimated. Table I-1.3 summarises these estimates.

Table I-1.3
Background sources for the nominal 500 GeV beam parameters.

Source	#particles per bunch	$< \mathrm{E} >$ (GeV)
Disrupted primary beam	2×10^{10}	244
Bremstrahlung photons	2.5×10^{10}	244
e^+e^- pairs from beam-beam interactions	75k	2.5
Radiative Bhabhas	320k	195
$\gamma\gamma \rightarrow$ hadrons/muons	0.5 events/1.3 events	–

γγ = background !!

1312x5=6560 BX's/sec

Hadron Production in Photon-Photon Processes at the ILC and the BSM signatures with small mass differences

American Workshop for Linear Colliders

Swathi Sasikumar, Jenny List, Mikael Berggren

26-30th June 2017

HELMHOLTZ ASSOCIATION

Collaborative Research Centre 676
Particles, Strings, and the Early Universe
The Structure of Matter and Space-Time
Deutsche Forschungsgemeinschaft DFG

PIER
Partnership of Universität Hamburg and DESY

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DESY

DBD simulations for $\gamma\gamma \rightarrow$ low pt hadron events

- In DBD simulations:
  - Overlaid number of $\gamma\gamma$ events on each physics event (1.7 evnts/BX)
  - $\gamma\gamma \rightarrow$ low p_T hadron event generation by Tim Barklow
    - $\sqrt{s_{\gamma\gamma}}$ < 10 GeV - dedicated generator by Tim (Barklow generator)
    - $\sqrt{s_{\gamma\gamma}}$ > 10 GeV - Pythia
- Removal of $\gamma\gamma$ backgrounds by applied k_T algorithm method
- In most of the cases k_T algorithm method a success to regain the physics performance
- Analysis for higgsinos still an exception to k_T algorithm method - the low pt visible decay products misidentified as $\gamma\gamma$ overlay in exclusive mode and discarded

Event Properties of old and new Barklow generator

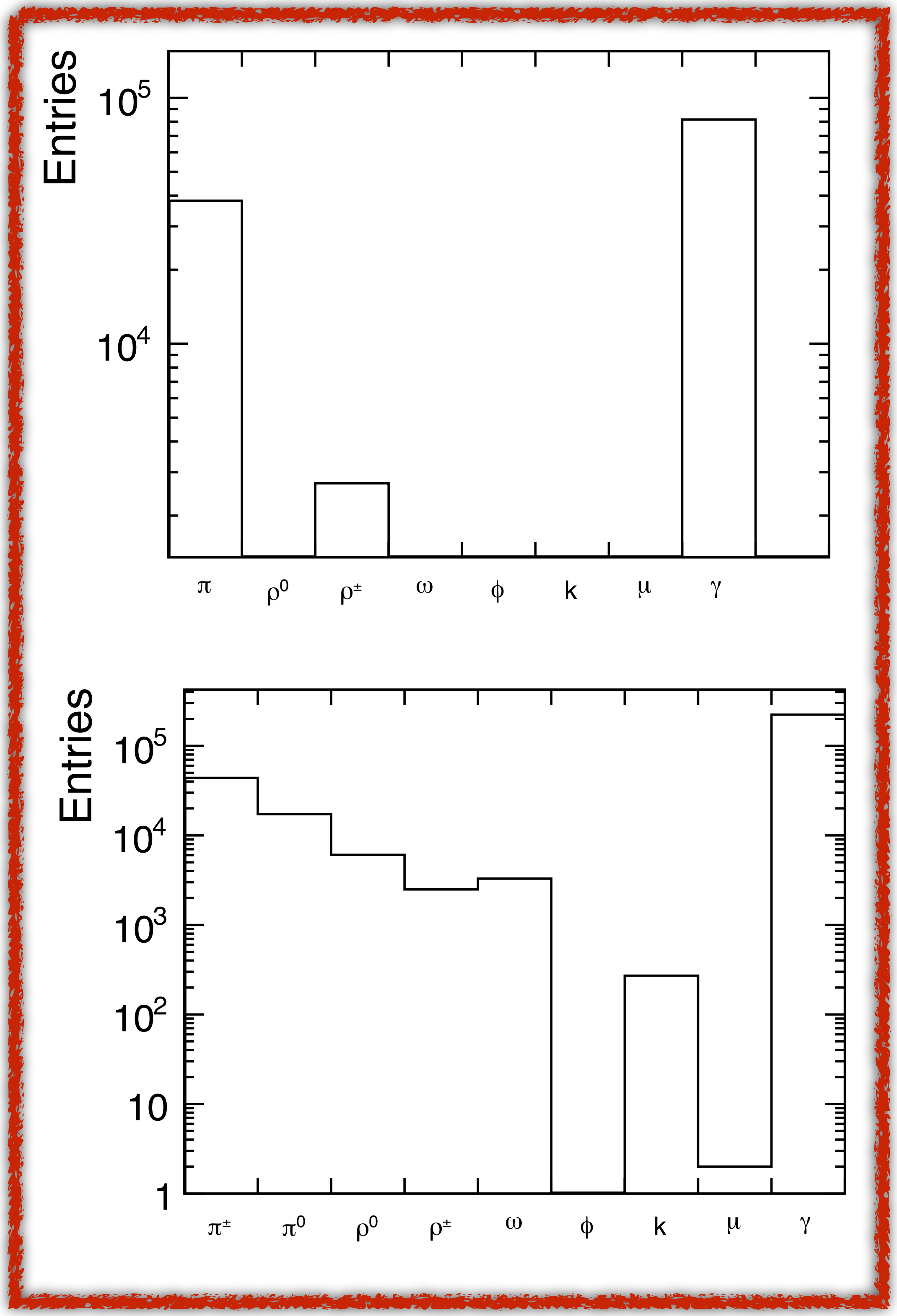
- Improvements implemented in Barklow generator for $\sqrt{s_{\gamma\gamma}}$ < 2 GeV

- Event Properties before improvements:
  - Barklow generator produced $\gamma\gamma \rightarrow$low Pt hadron processes with very simple events
    - $\pi^+\pi^-$
    - $\pi^\pm\rho^\pm$
    - $\rho^+\rho^-$
  - No neutral mesons included - no ρ^0 or π^0

- Event Properties after improvements:
  - The Barklow generator produces different events like

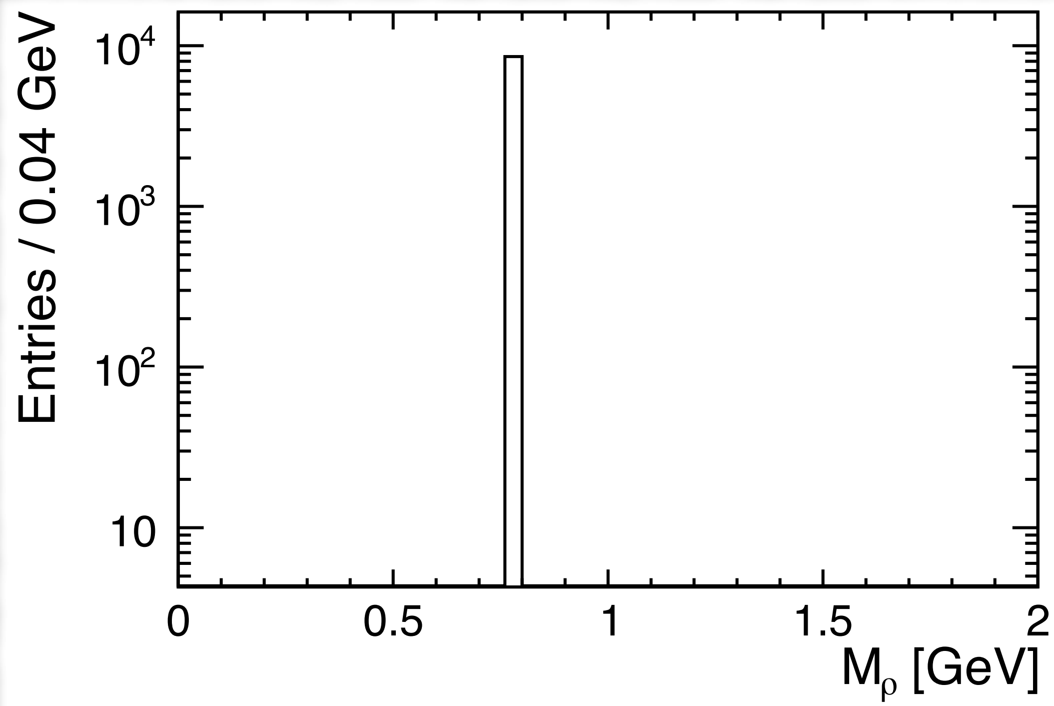
$$\gamma\gamma \rightarrow \pi^0\pi^0, \pi^\pm, \rho^0\rho^0, \rho^\pm, \omega$$

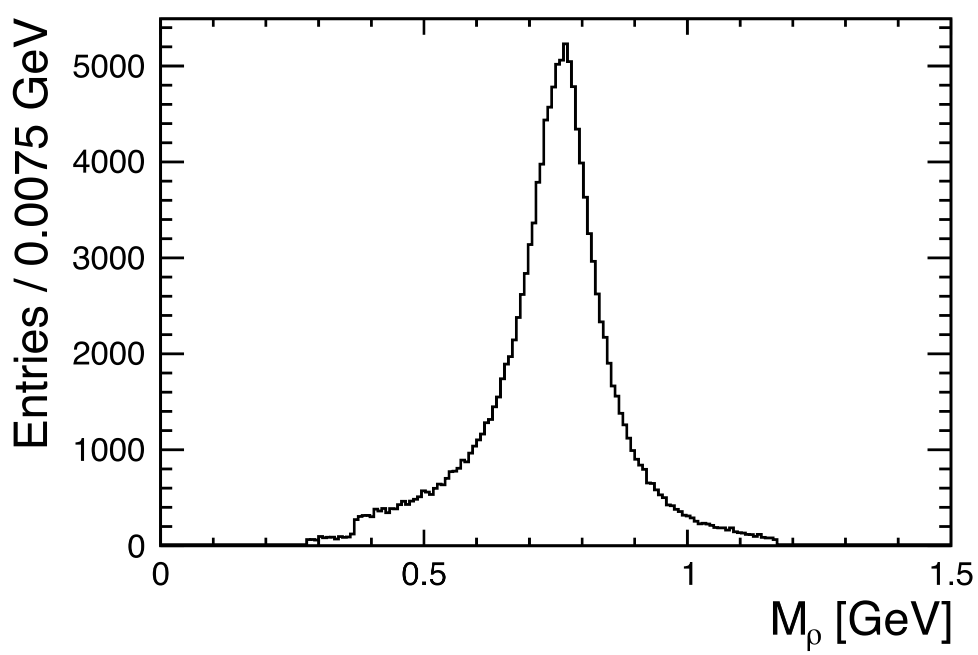
  - The cross-sections for producing ρ^0 is greater than that for $\rho^\pm$



Event Properties of old and new Barklow generator

- PDG: m_ρ= 770 MeV and Γ_ρ = 145 MeV
- Before improvement:
  - Barklow generator produced rho meson without natural width - peaked at 770 MeV
- After improvement:
  - The improved generator now produces rho mesons with full natural width





Summary and Outlook

- Although physics environment at ILC is very clean $\gamma\gamma$ backgrounds is still important
- The impact of this overlay is found on a very few specific but important events
- A better generator to produce $\gamma\gamma \rightarrow$ low pt hadrons was developed with more realistic particle contents for events
- Investigating whether different z_vtx position and vector meson tag can be used to remove the backgrounds
- Work in progress!!
- OUTLOOK:
  - The method developed will be applied on higgsino samples and Hale Sert's study would be repeated but with inclusion of $\gamma\gamma$ overlay

- Few studies of two photon processes, so far

Future prospects

- Improve / implement γ-γ generator is essential for future study

Summary

- ILC
  - extendibility to higher energies
  - precision studies of the Higgs boson
  - waiting for "Green Light"
- Two photon process
  - Few studies, so far.
  - Improve / implement γ-γ generator is essential for future study