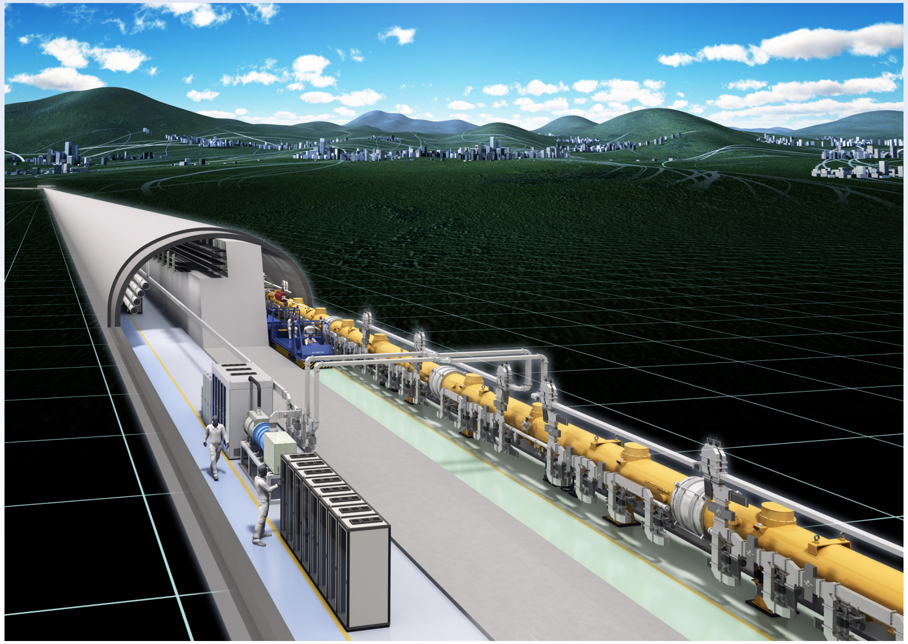


ILC Accelerator Introduction

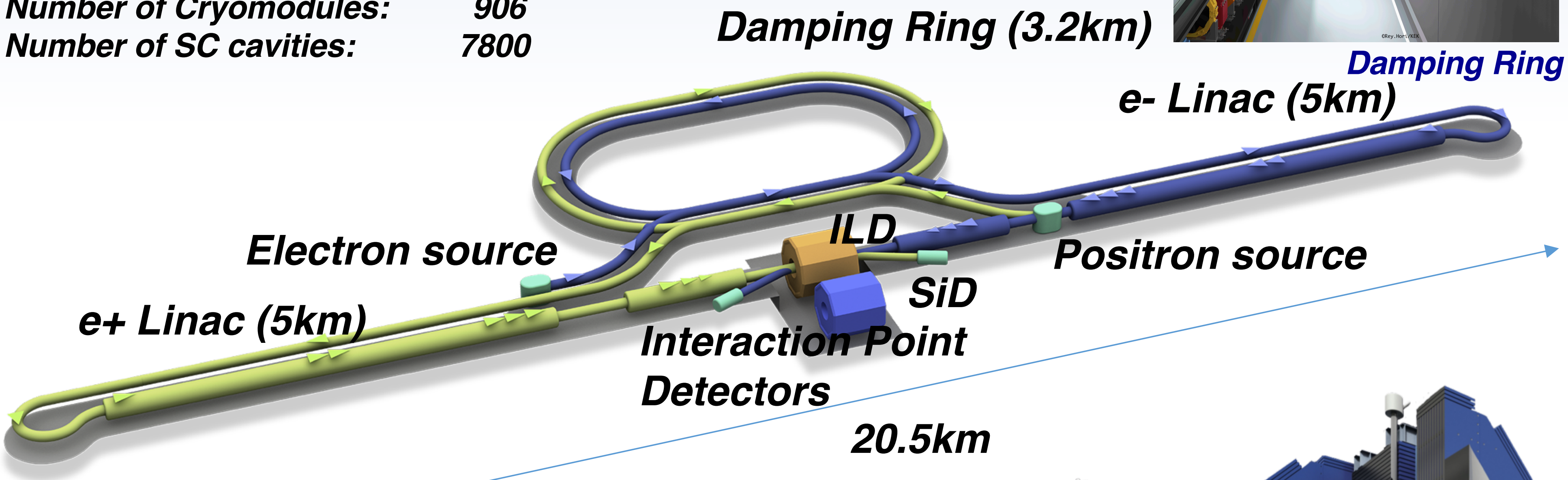
Hitoshi Hayano, KEK   10122018

Configulation of ILC Accelerator

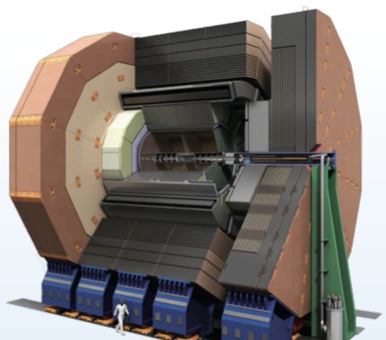
e+, e- Main Linac

Beam Energy : 125GeV + 125GeV = 250 GeV
Total accelerator: 20.5km
SRF Accelerator: 5km + 5km
Number of Klystrons: 218
Number of Cryomodules: 906
Number of SC cavities: 7800

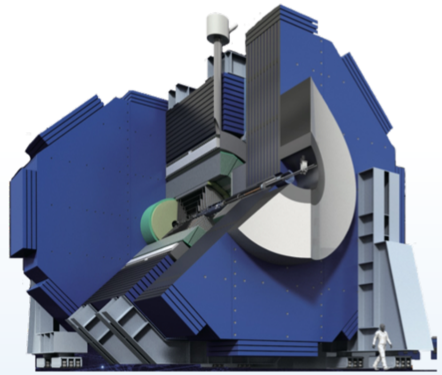
Damping Ring



Main Linac Accelerator

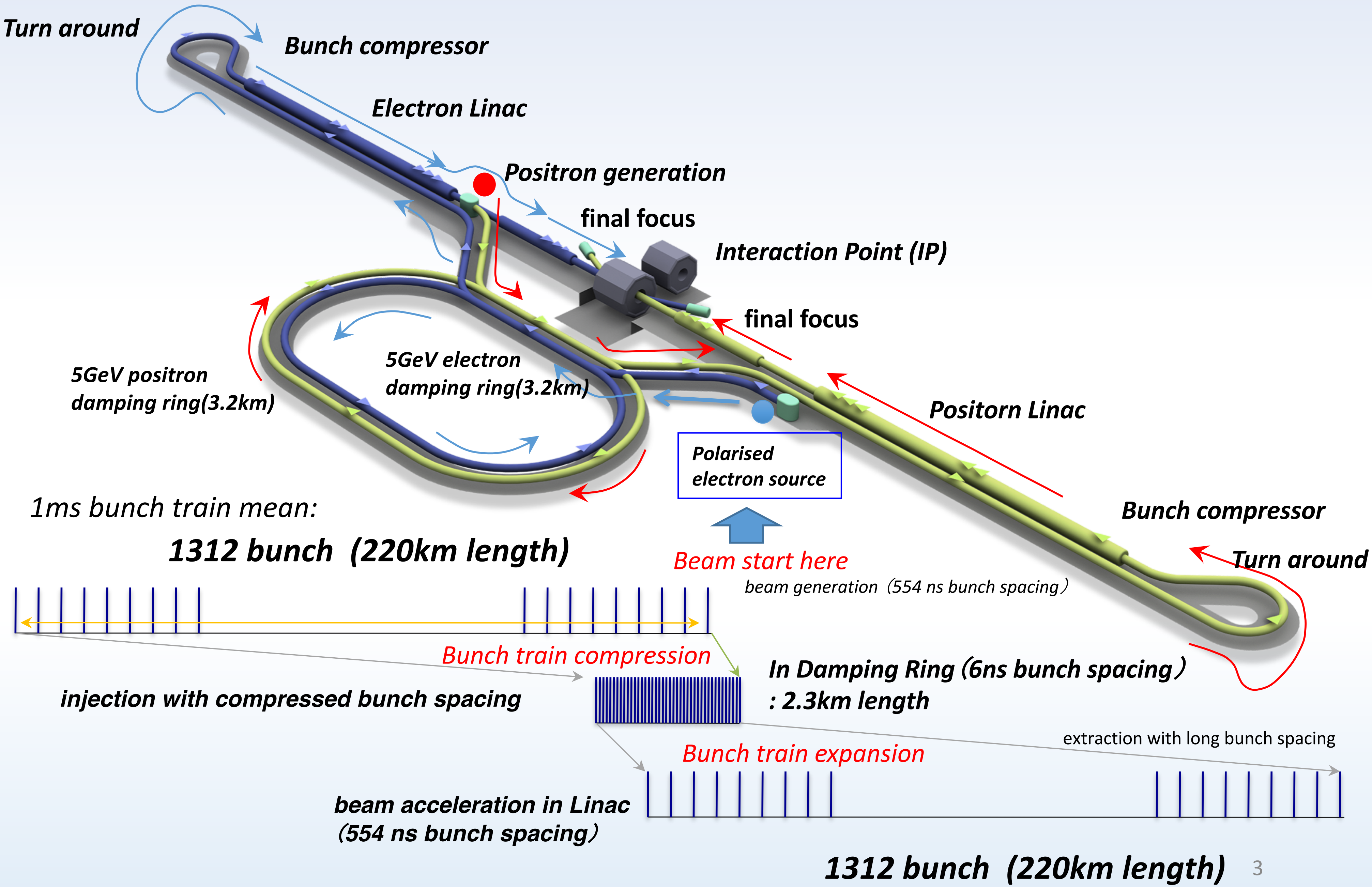


ILD Detector

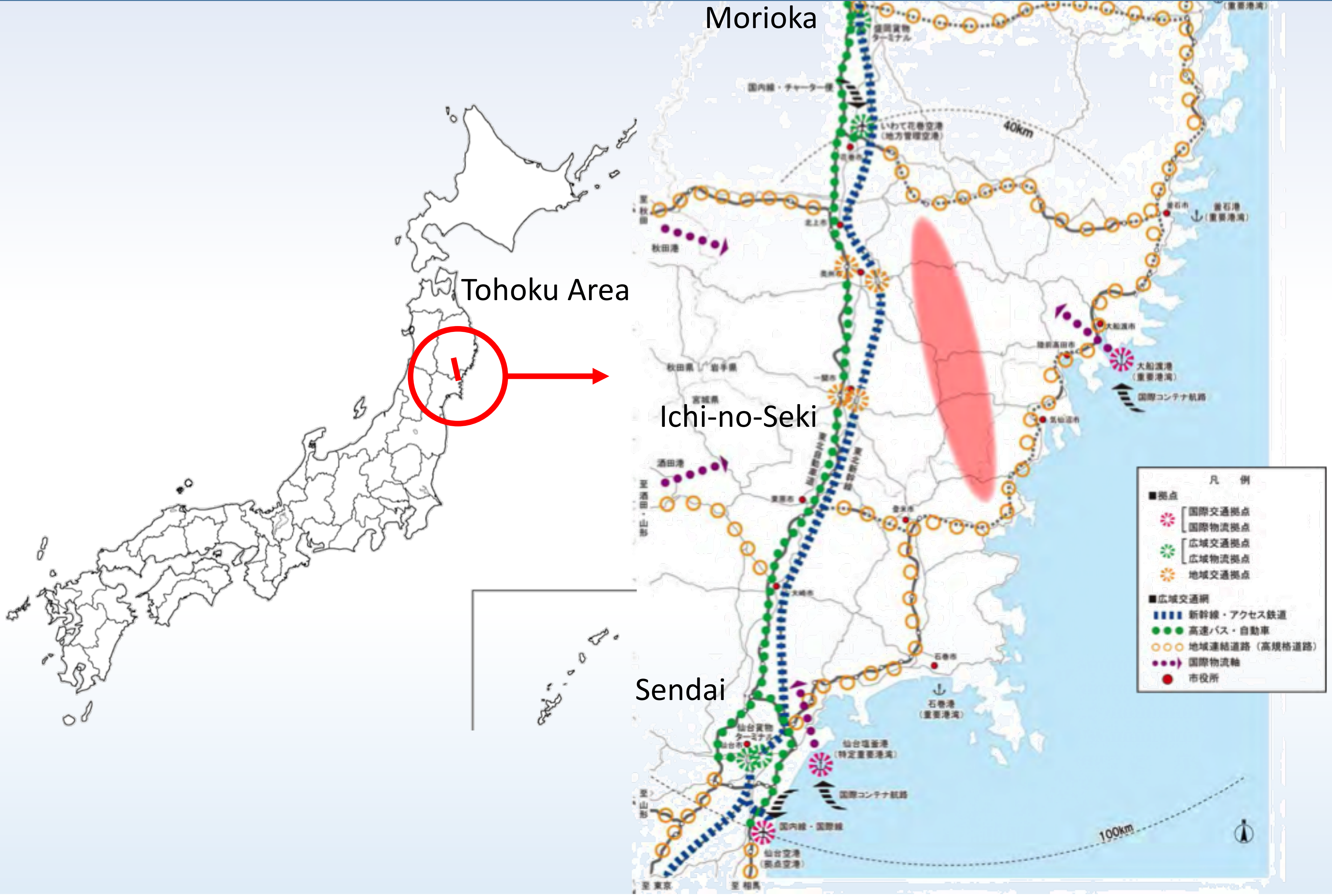


SiD Detector

Beam Acceleration Sequence



Kitakami Candidate Site

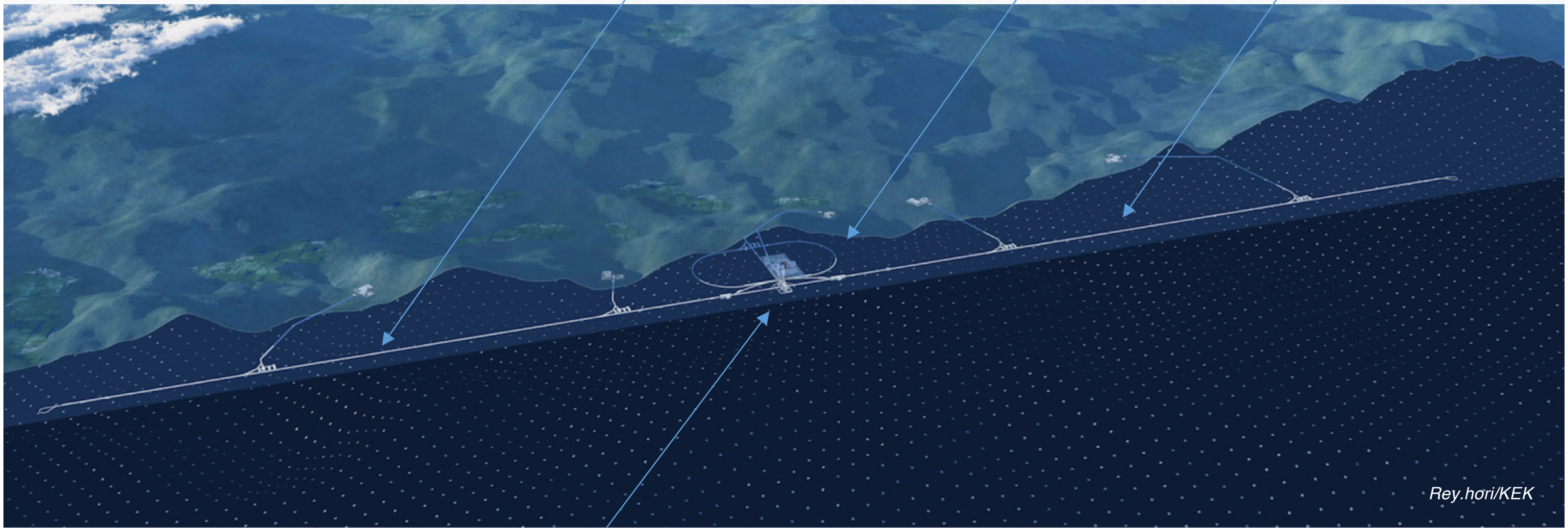


Bird's eye view of ILC in Kitakami candidate site

Positron Linac

Damping Ring

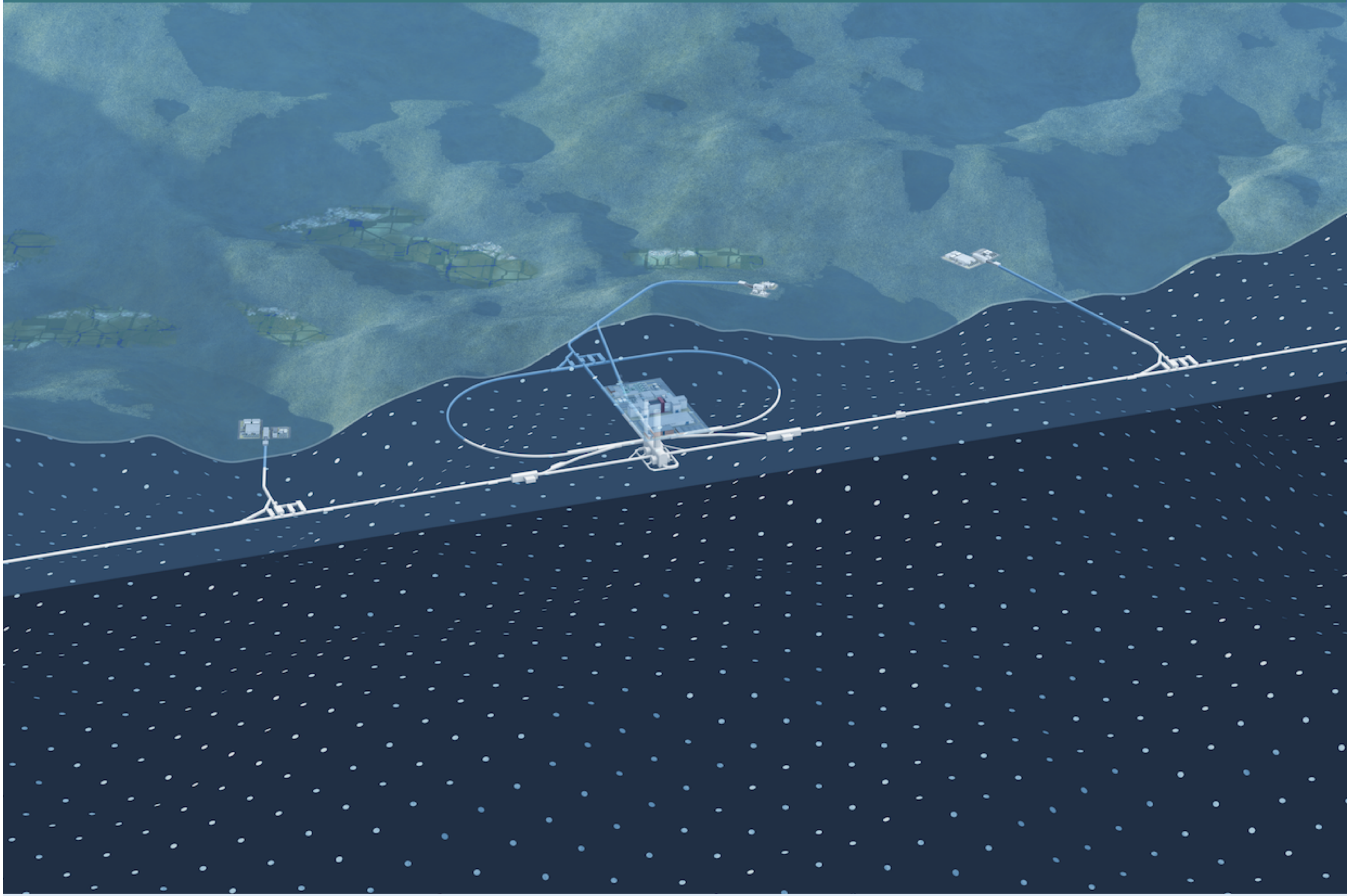
Electron Linac



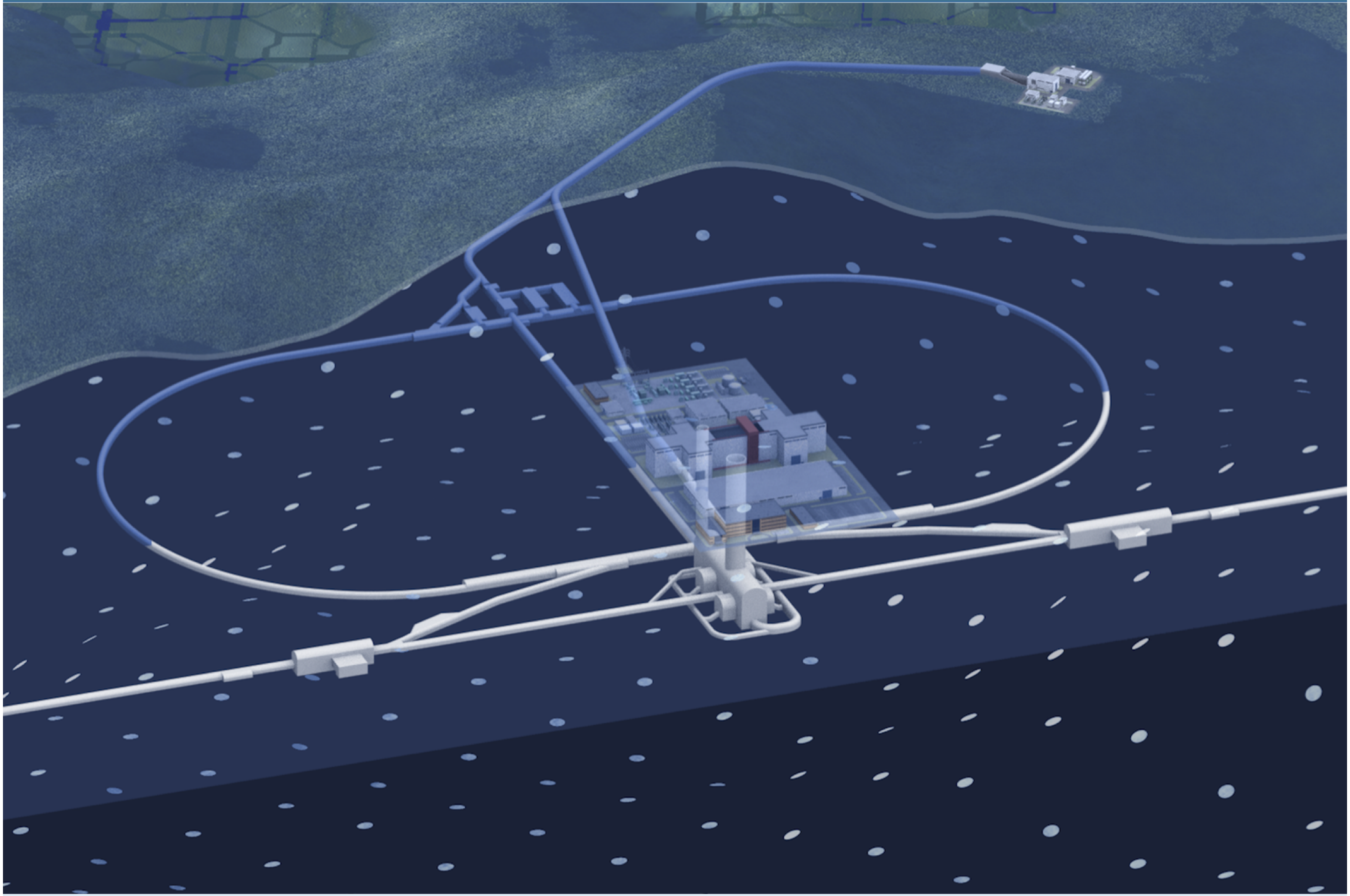
Colliding point

Tunnel design for Kitakami Candidate Site (ILC250GeV 20.5km)

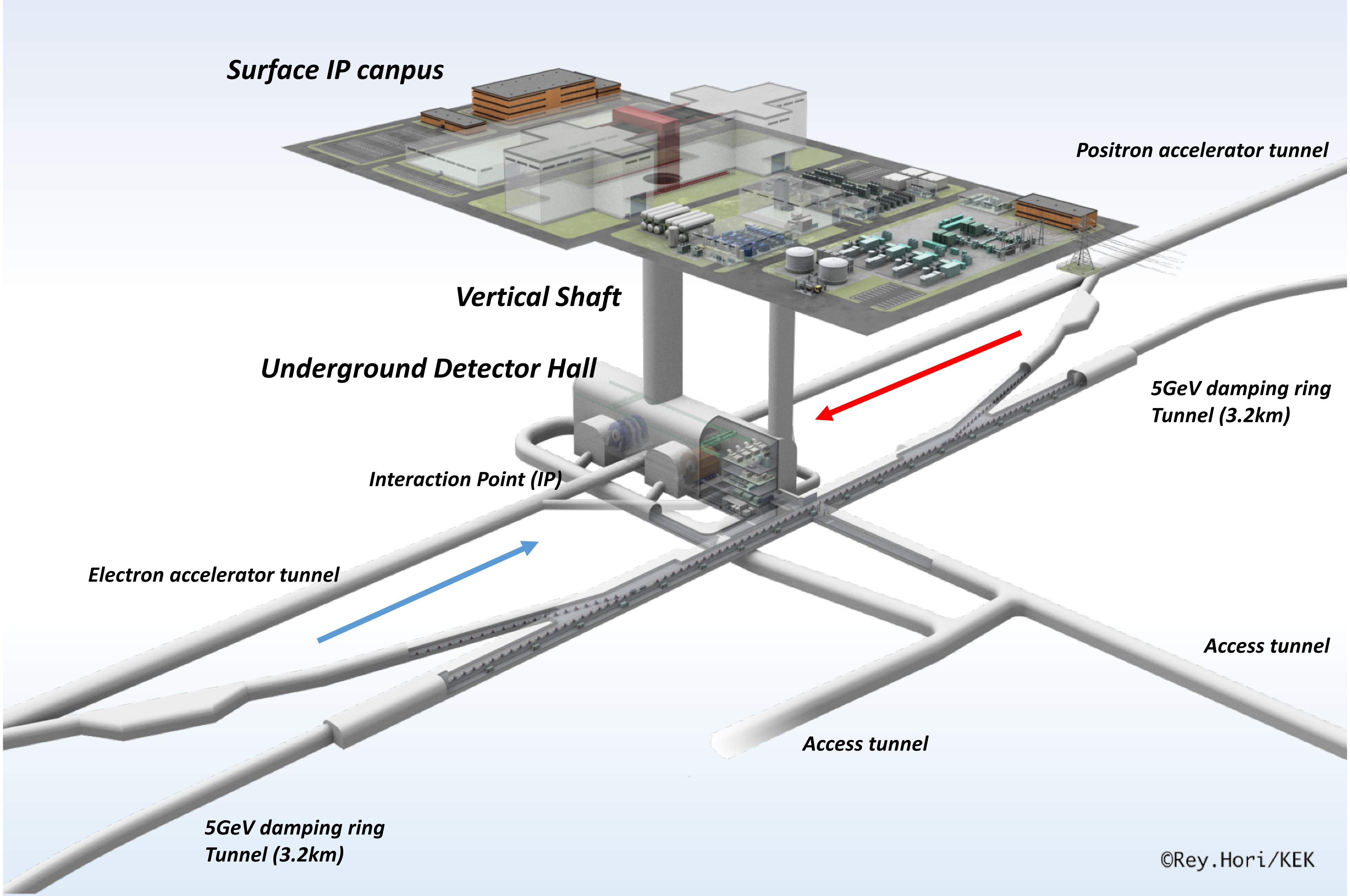
Bird's eye view of ILC in Kitakami candidate site



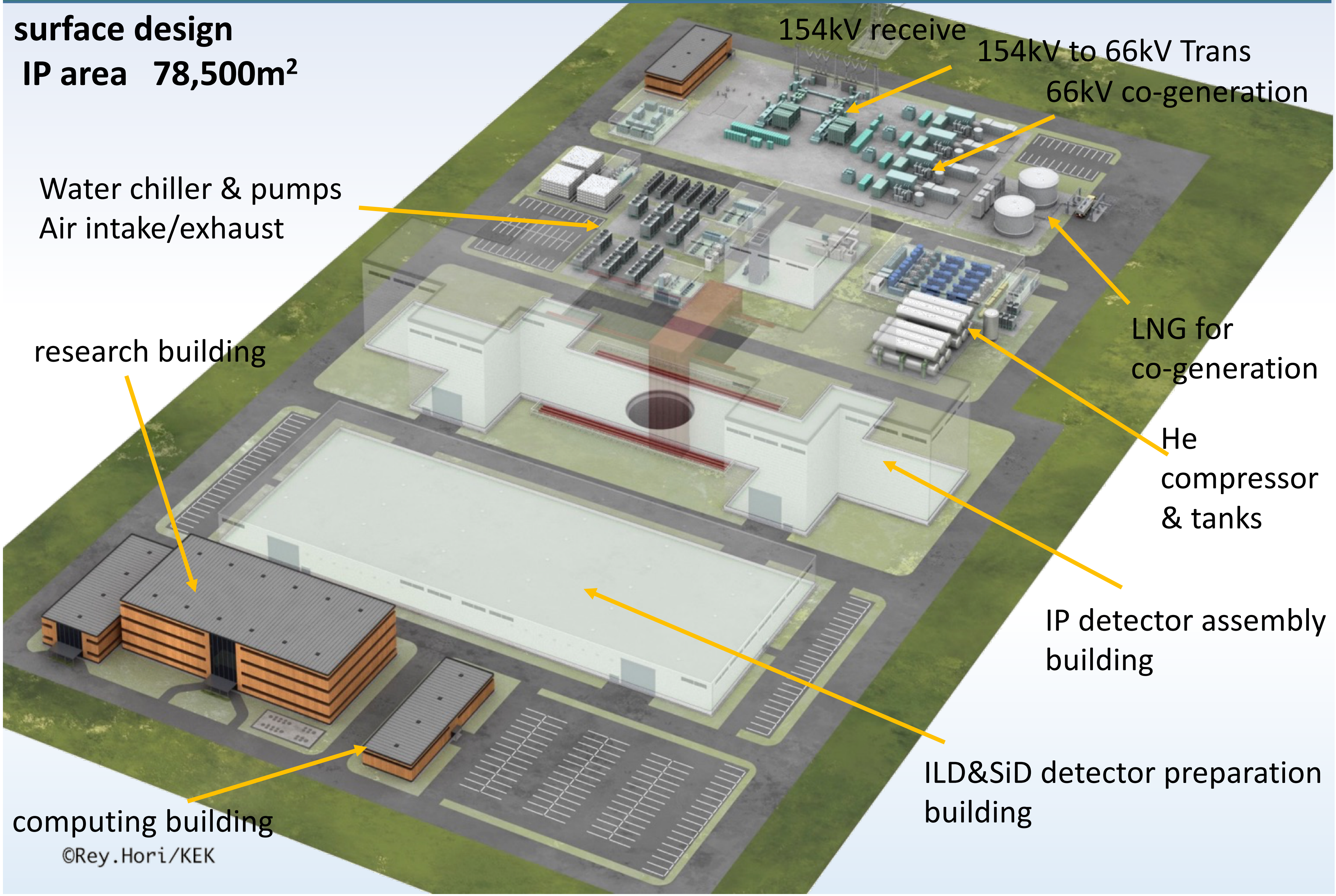
Bird's eye view of ILC in Kitakami candidate site



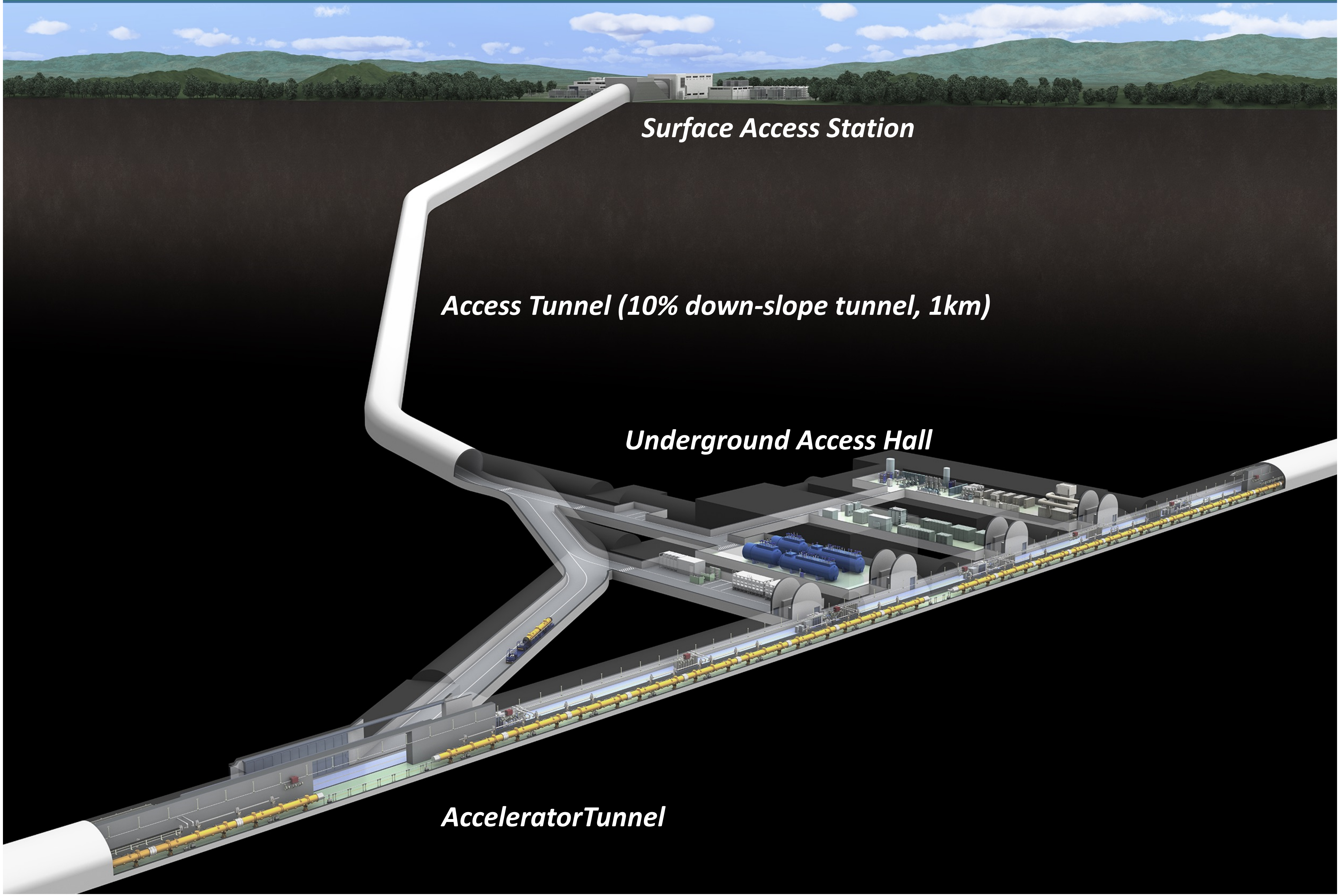
Plan of Interaction point



Interaction Point Campus at Surface

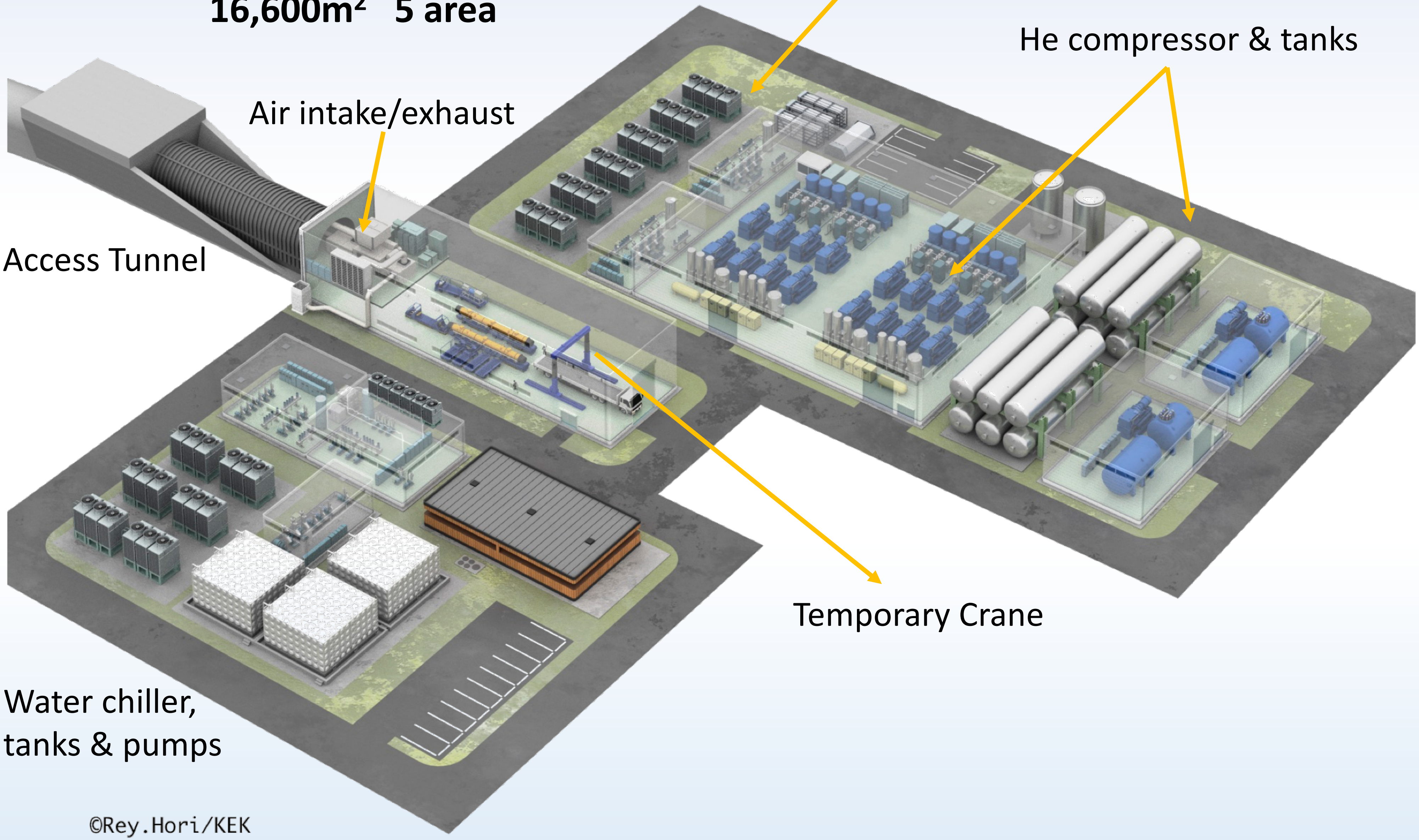


Surface-to-Underground access-tunnel

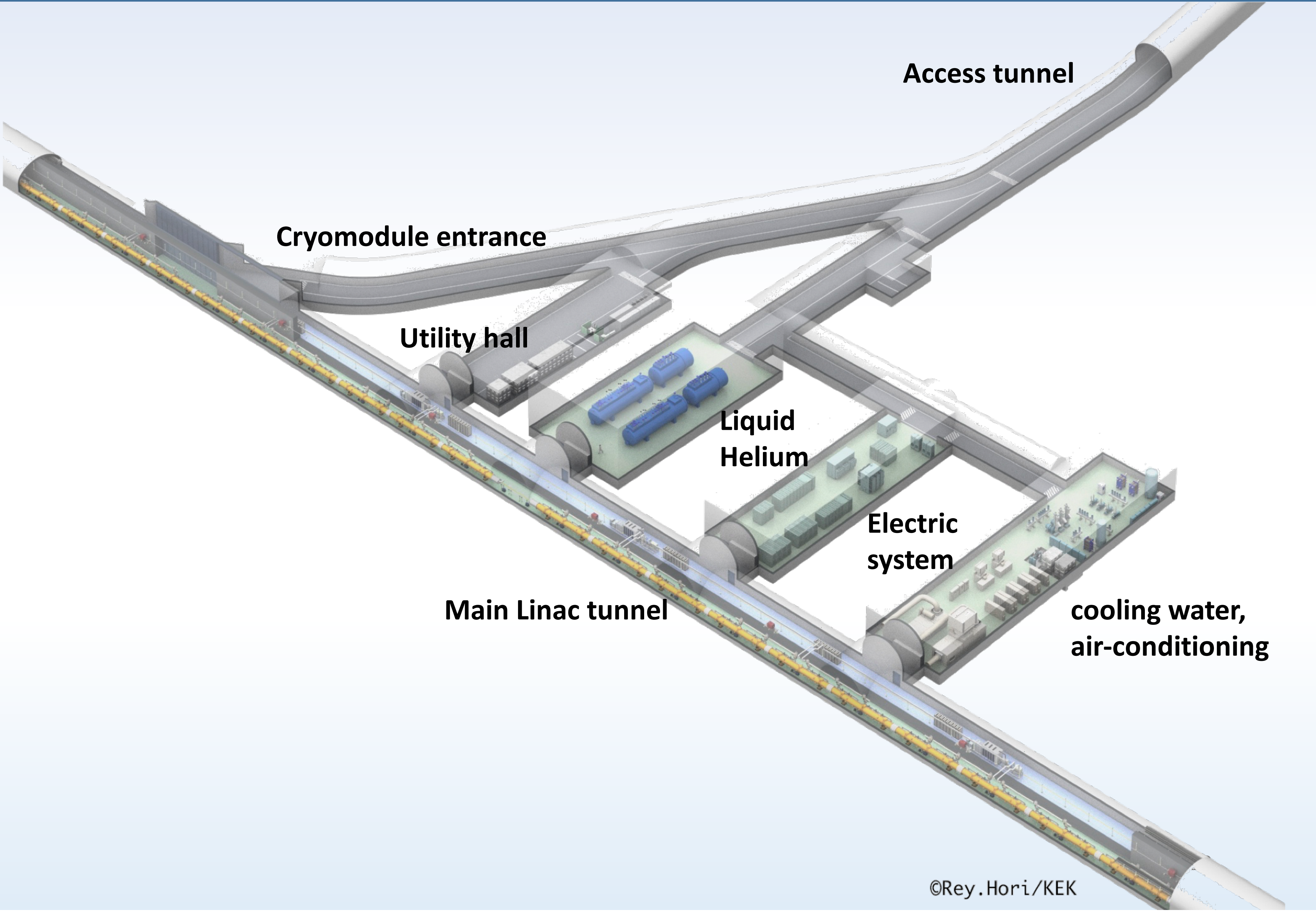


Access-station at Surface

surface design
access stations
16,600m^2 5 area

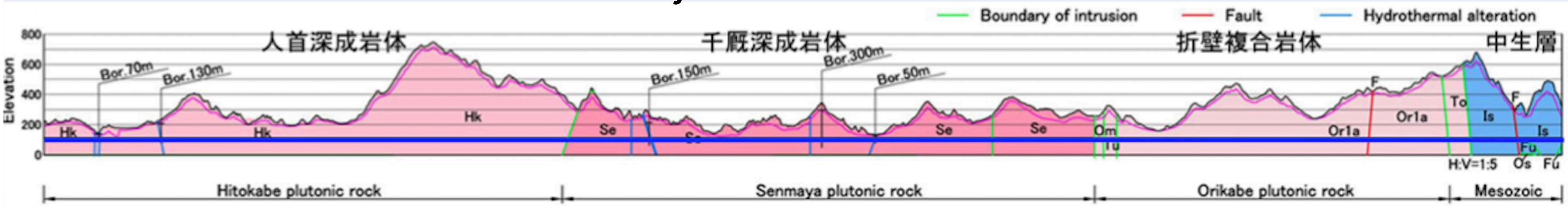


Underground Access-Hall



Underground tunnel is connected by access tunnel

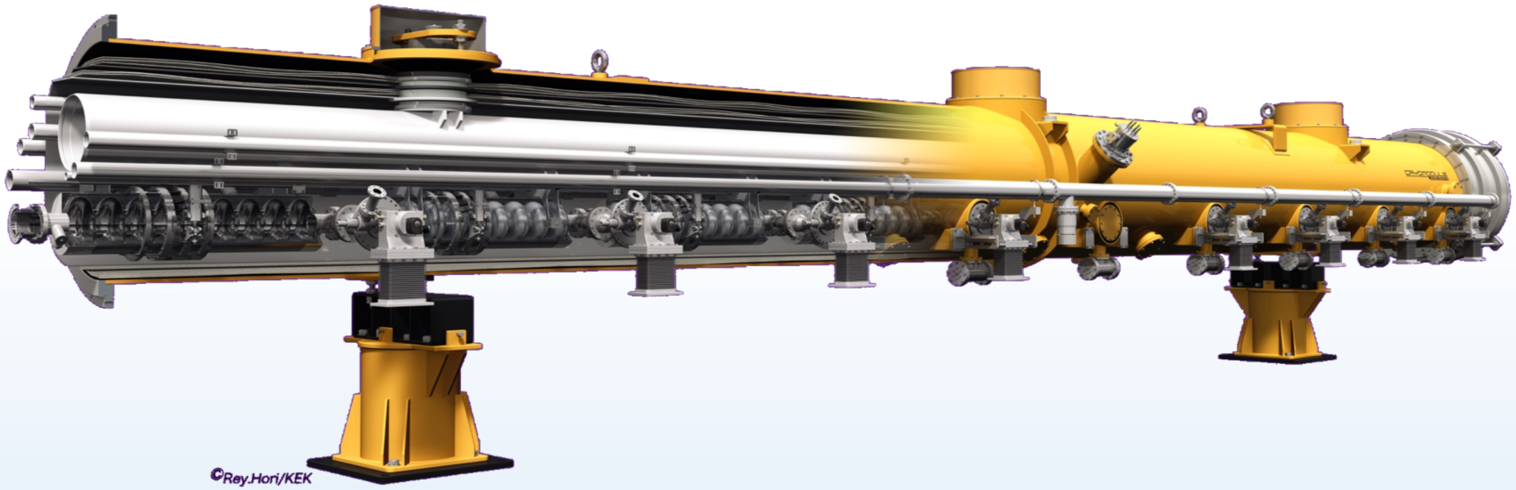
Cross-section of ILC accelerator tunnel at candidate site



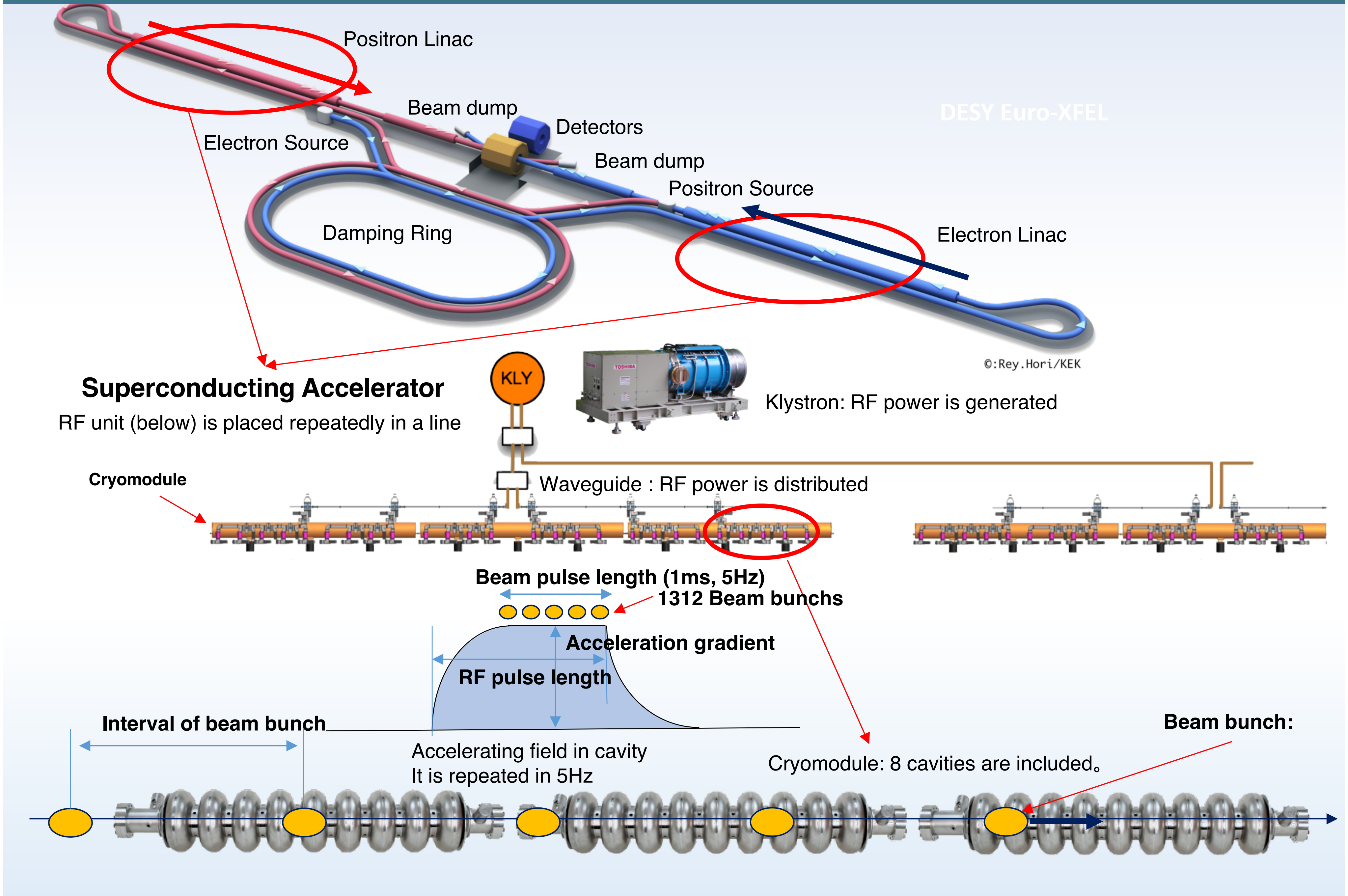
50km

10% slope access tunnel connect to underground accelerator tunnel

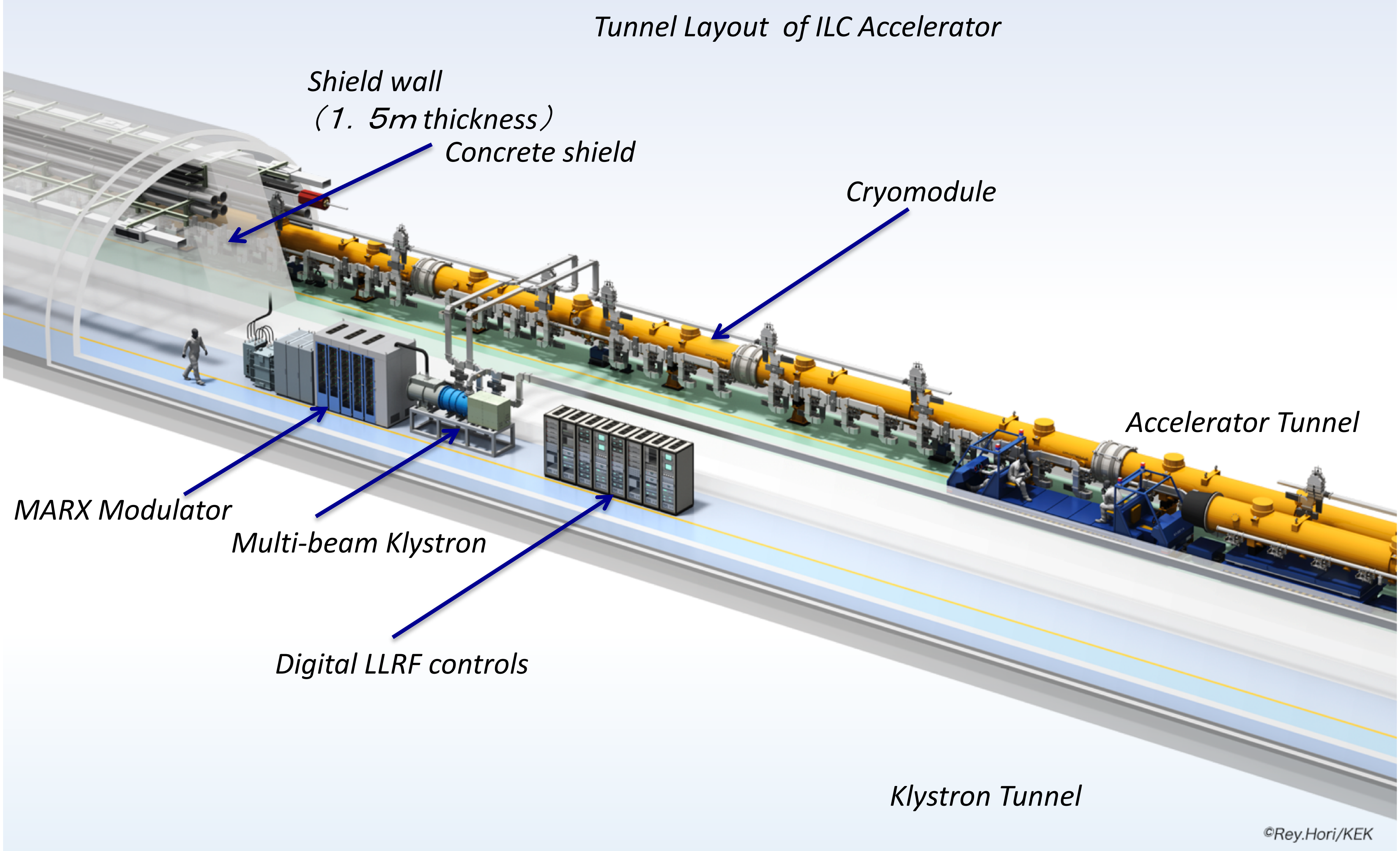
Beam acceleration by Superconducting Cavity



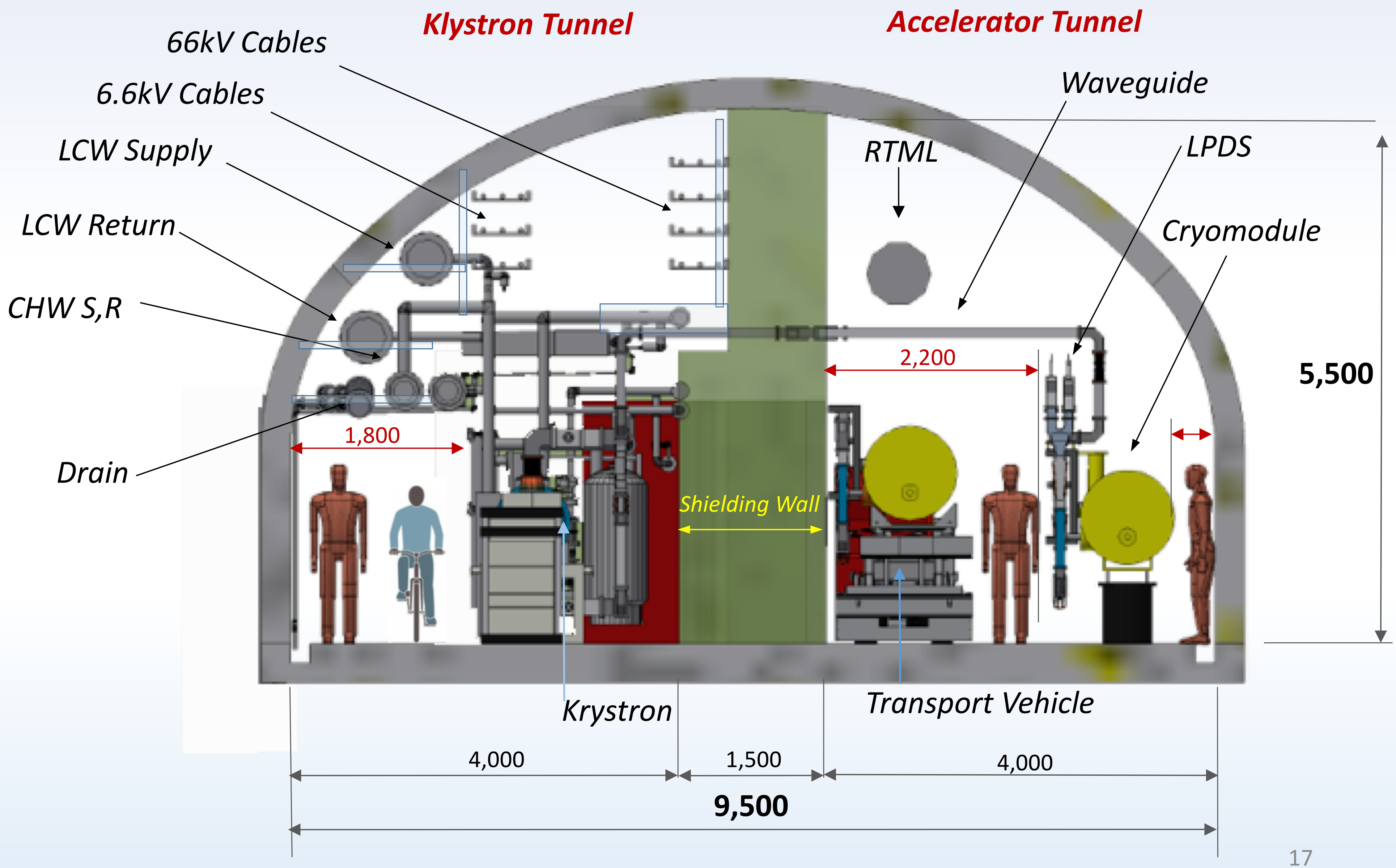
Beam Acceleration in Main Linac



Tunnel layout of ILC Main Linac



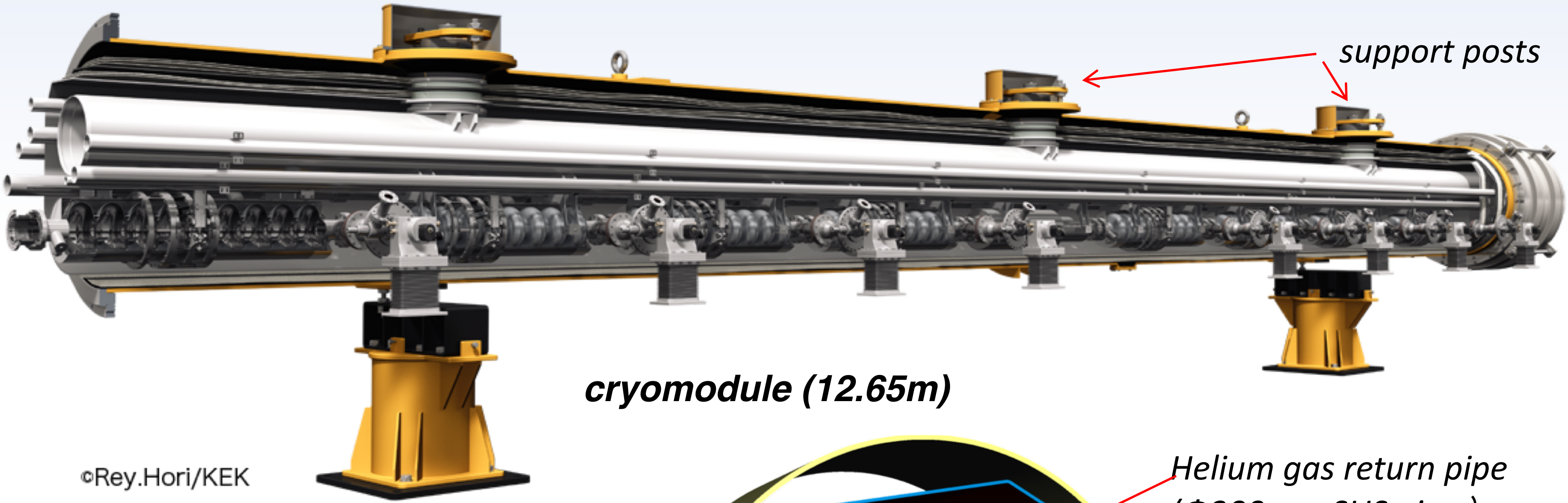
Cross-section of ILC Main Linac Tunnel



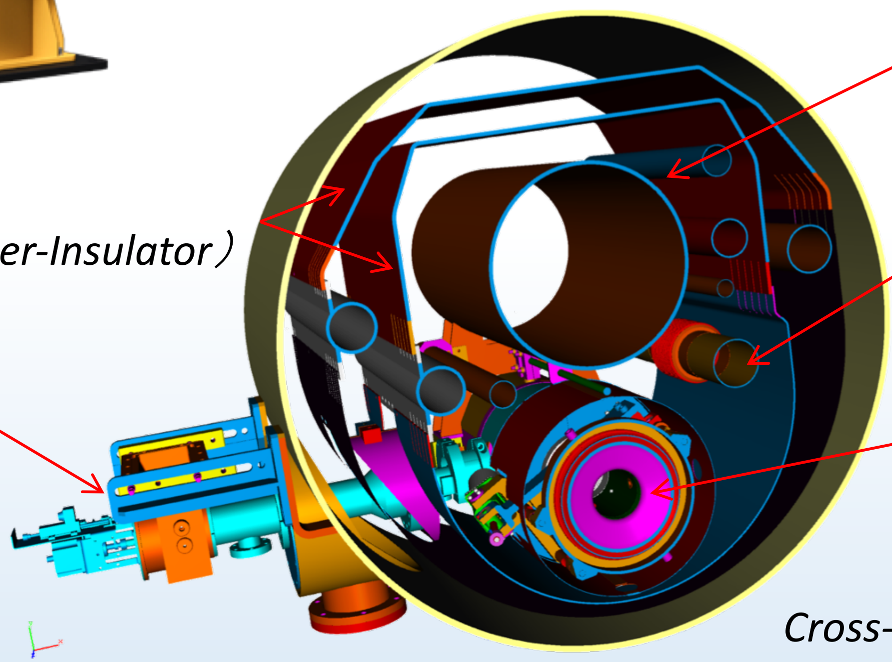
Cryomodule

Type-A (9cavities） 604
Type-B(8cavities+SC-Q magnet） 302

Number of Cryomodules: 906



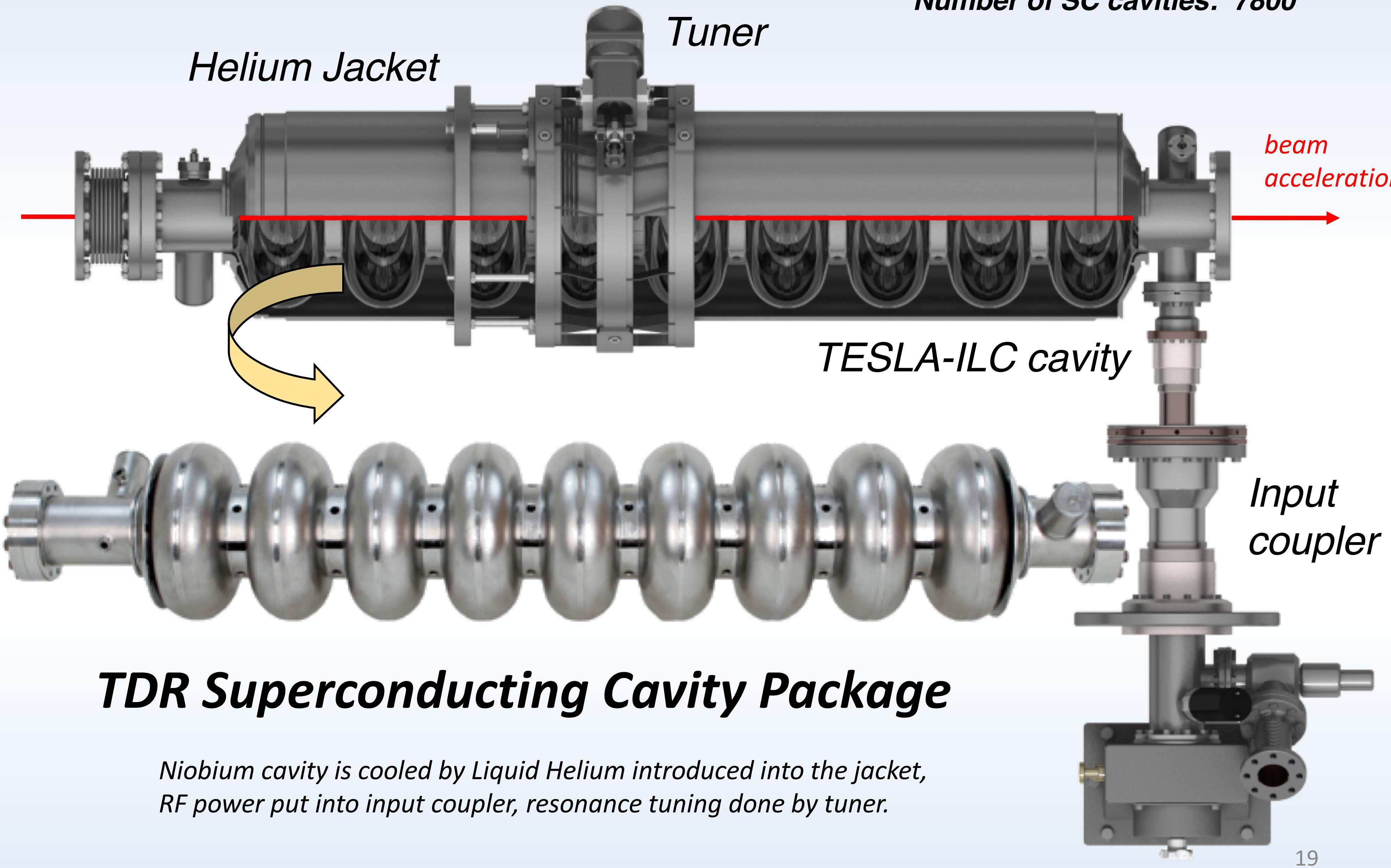
cryomodule (12.65m)



Cross-section *from D. Kostin*

Superconducting Cavity Package

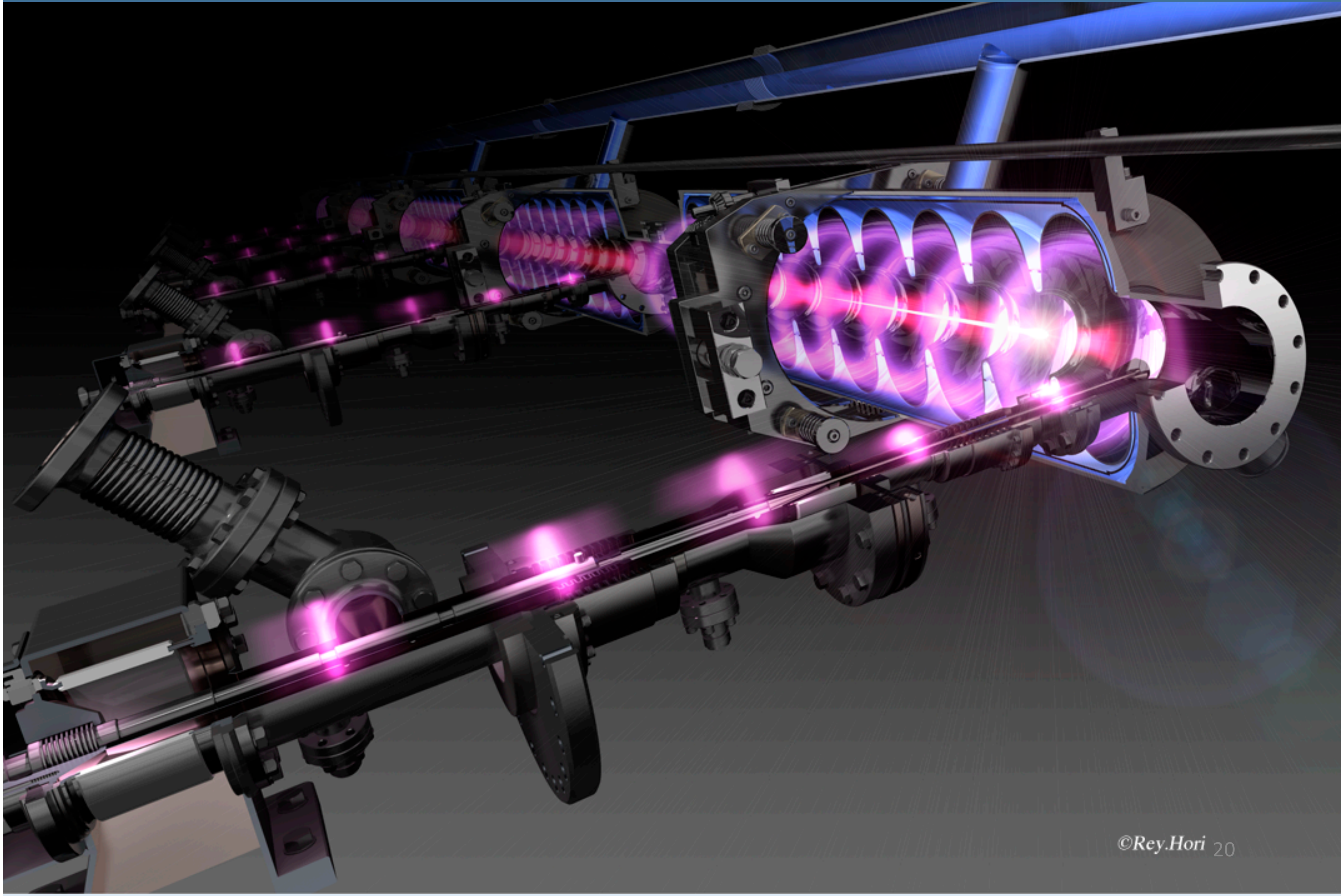
Number of SC cavities: 7800



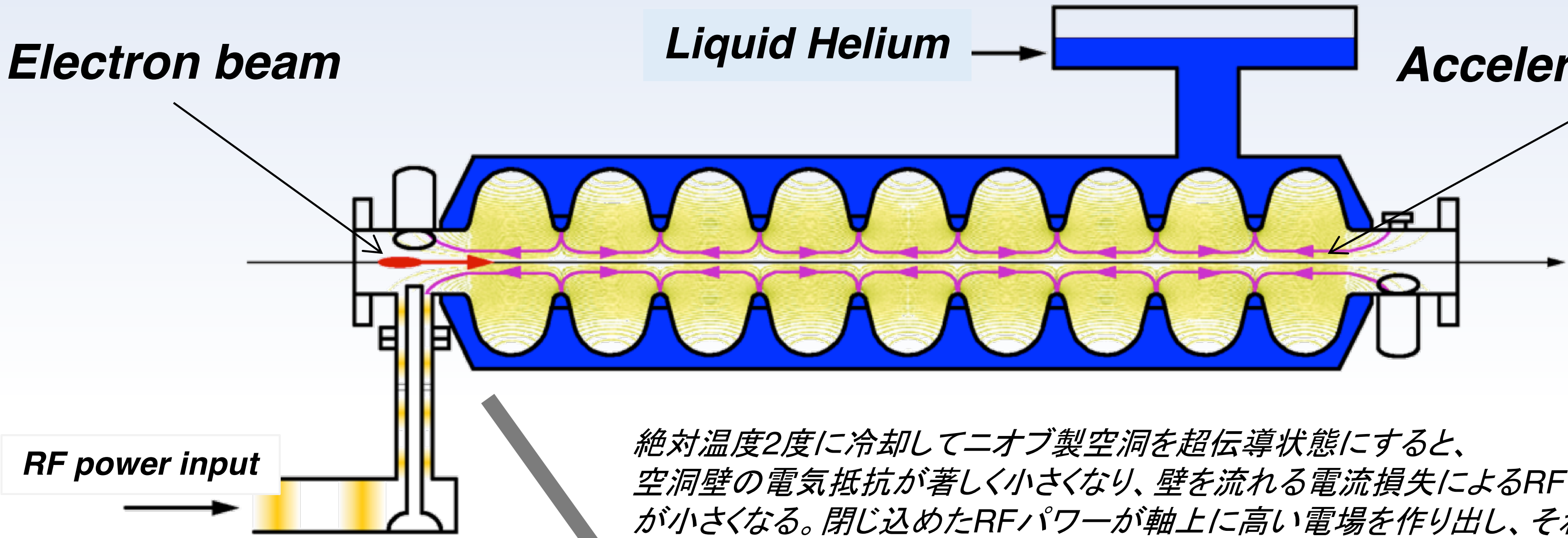
TDR Superconducting Cavity Package

Niobium cavity is cooled by Liquid Helium introduced into the jacket,
RF power put into input coupler, resonance tuning done by tuner.

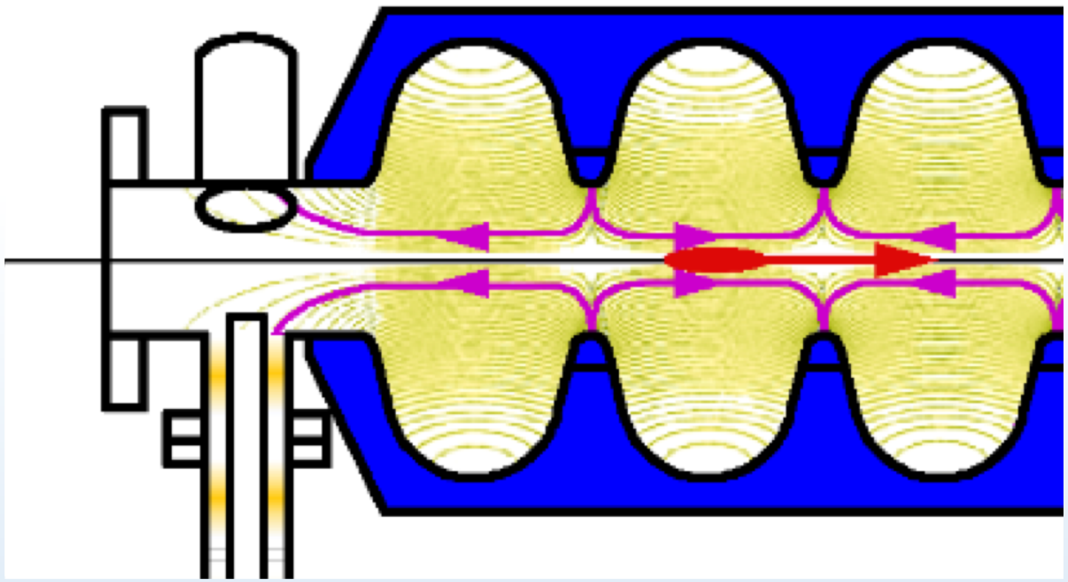
Electric field, magnetic field inside cavity



Beam Acceleration by RF field



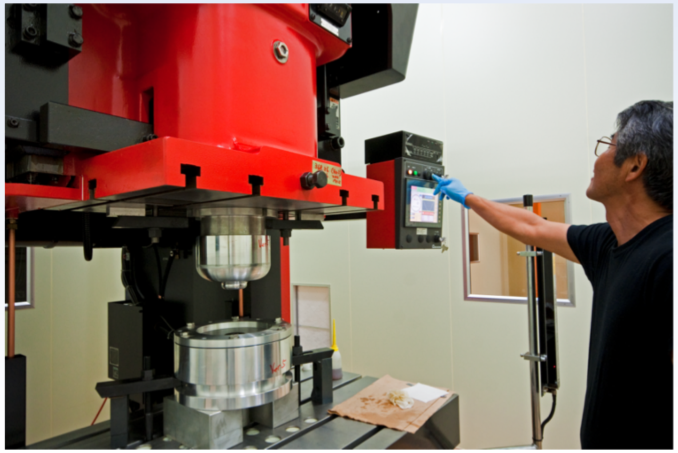
絶対温度2度に冷却してニオブ製空洞を超伝導状態にすると、
空洞壁の電気抵抗が著しく小さくなり、壁を流れる電流損失によるRFのパワー損失
が小さくなる。閉じ込めたRFパワーが軸上に高い電場を作り出し、それが長く持続する。



黄色およびピンクの線は
加速電場を表している。
その向きは、光の速度で
入れ替わる。
ビームも光の速度で進行
するので、うまいタイミングで
通過させると、どのセルでも
電場の向きを加速の向きに
合わせる事ができる。

TM_{010} π – mode
1.300 GHz

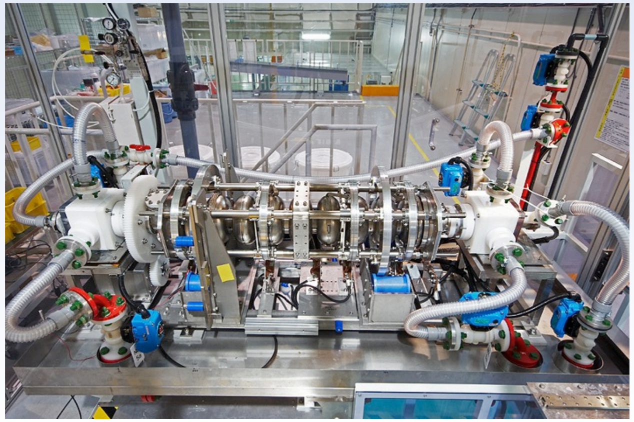
Technologies for high performance SRF cavity



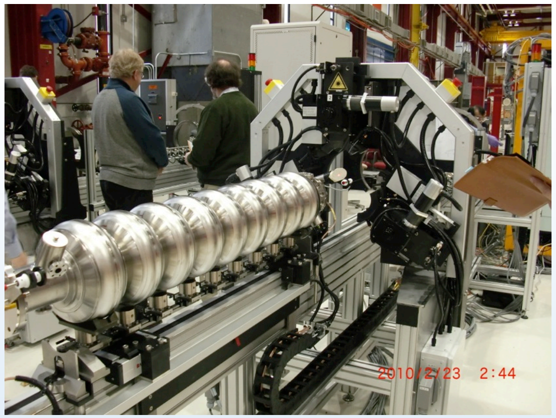
Press

EBW

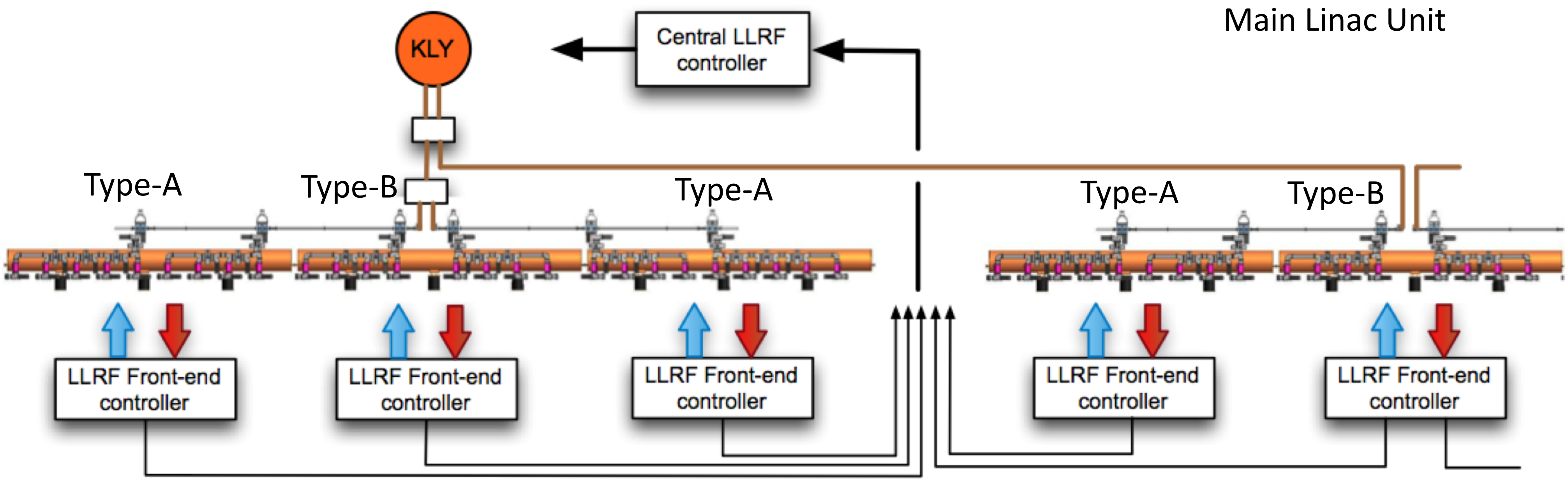
EP



Clean Room



Basic RF unit of Main Linac



Basic unit（RF power supply unit）

10MW Klystron 1

Klystron pulse power supply 1

Cryomodule 4.5

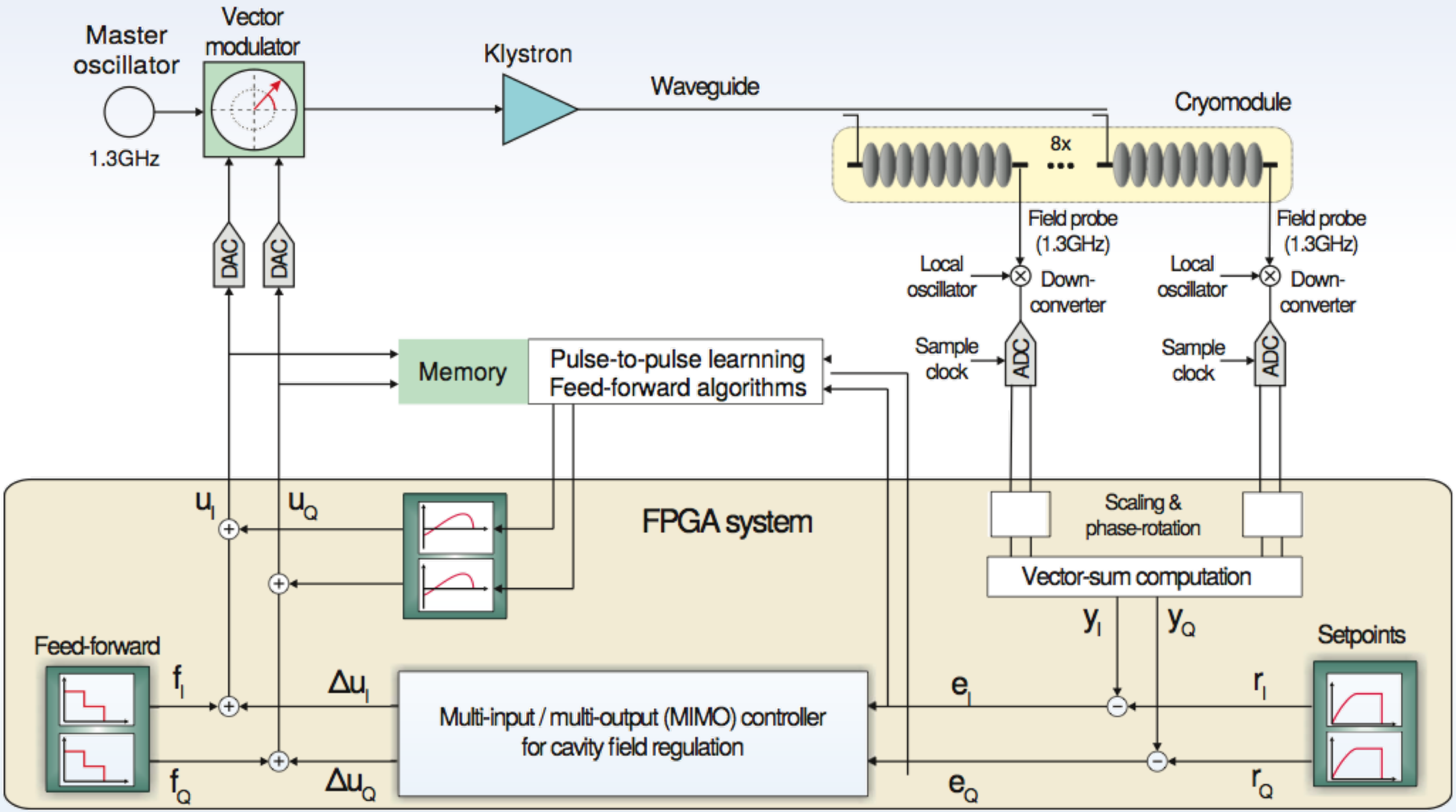
SC cavity 39

SC Quadrupole magnet 1.5

Digital LLRF control 1

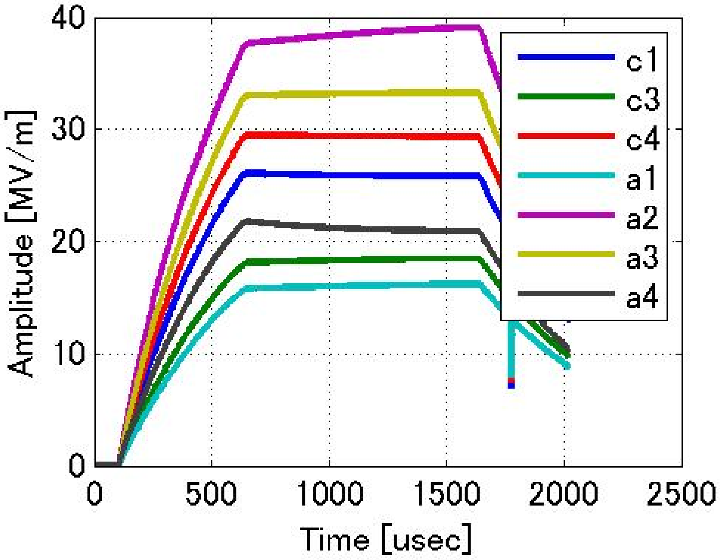
Vector-Combined signal of 39 cavities is fed back to klystron input

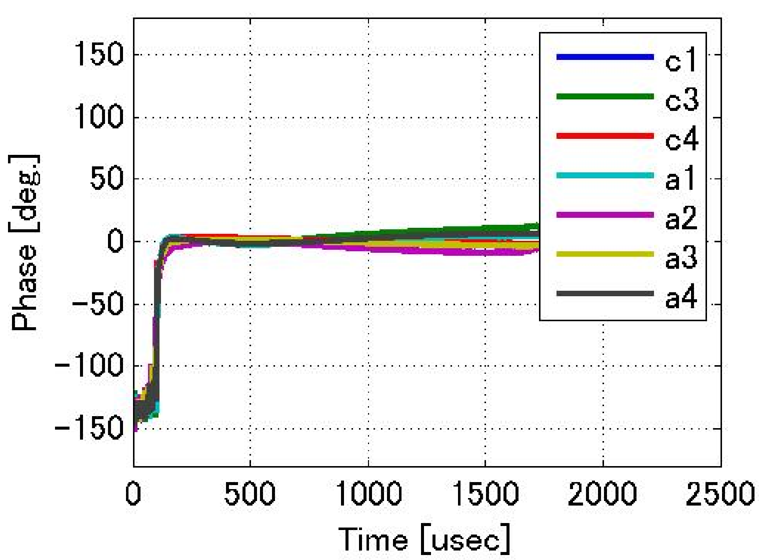
RF Amplitude & Phase stabilization by digital feedback

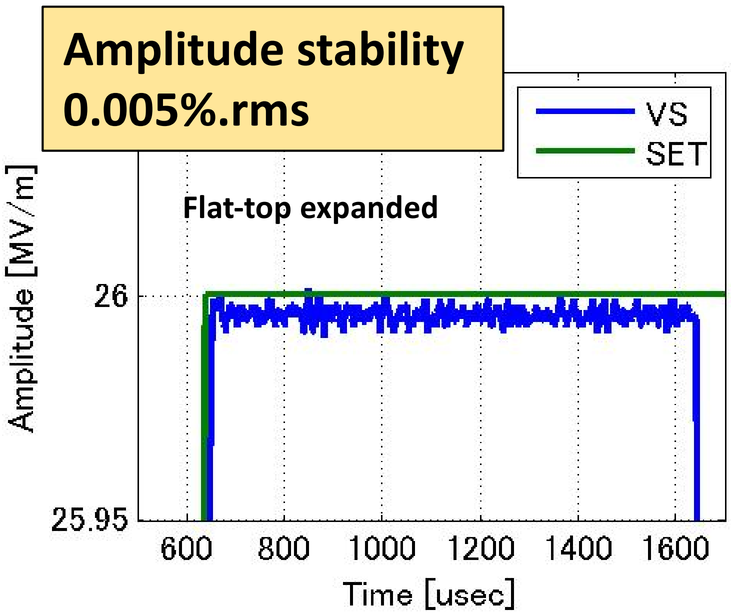


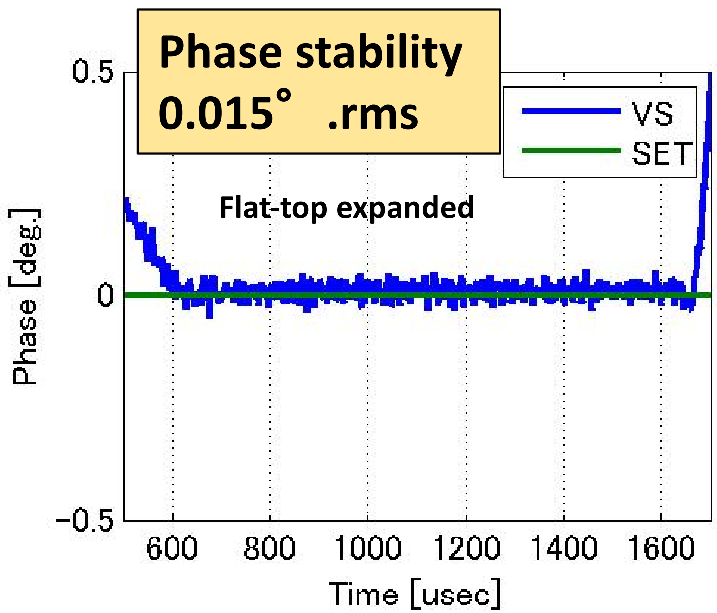
Stabilized RF amplitude and phase

Vector sum operation of 7 cavities with LLRF control as an example



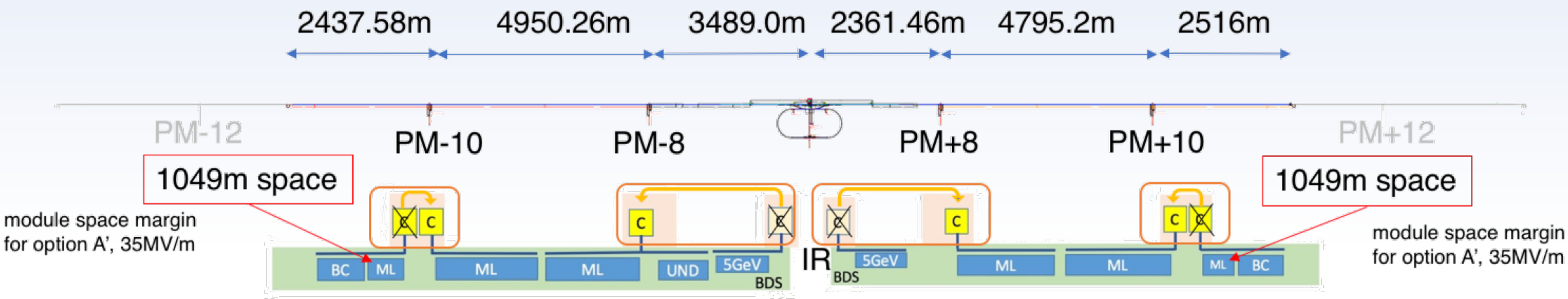






Basic RF unit configulation of ILC 250GeV

Option A' **ECM=250GeV** **SRF 35MV/m**



	BC				e+inj	Ecm=250GeV	e-inj				BC	
	51	90	189	189	24	module space	24	180	189	90	51	
	51	4.5	189	189	24	cryomodules	24	180	189	4.5	51	
	17	1	42	42	8	RF unit	8	40	42	1	17	
e^- 135.6GeV =	10.0	1.4	59.6	59.6	5.0	E gain (GeV)	5.0	56.7	59.6	1.4	10.0	= e^+ 132.7GeV

+6.2%margin

The International Linear Collider Machine Staging Report 2017
Addendum to the International Linear Collider Technical Design Report published in 2013

Linear Collider Collaboration / October, 2017
Editors:Lyn Evans and Shinichiro Michizono

Total tunnel length = 20549.5m (20.5km)

ILC 250GeV = 218 RF unit

10MW klystron 218
Klystron power supply 218
Cryomodule 906
SC Cavity 7800

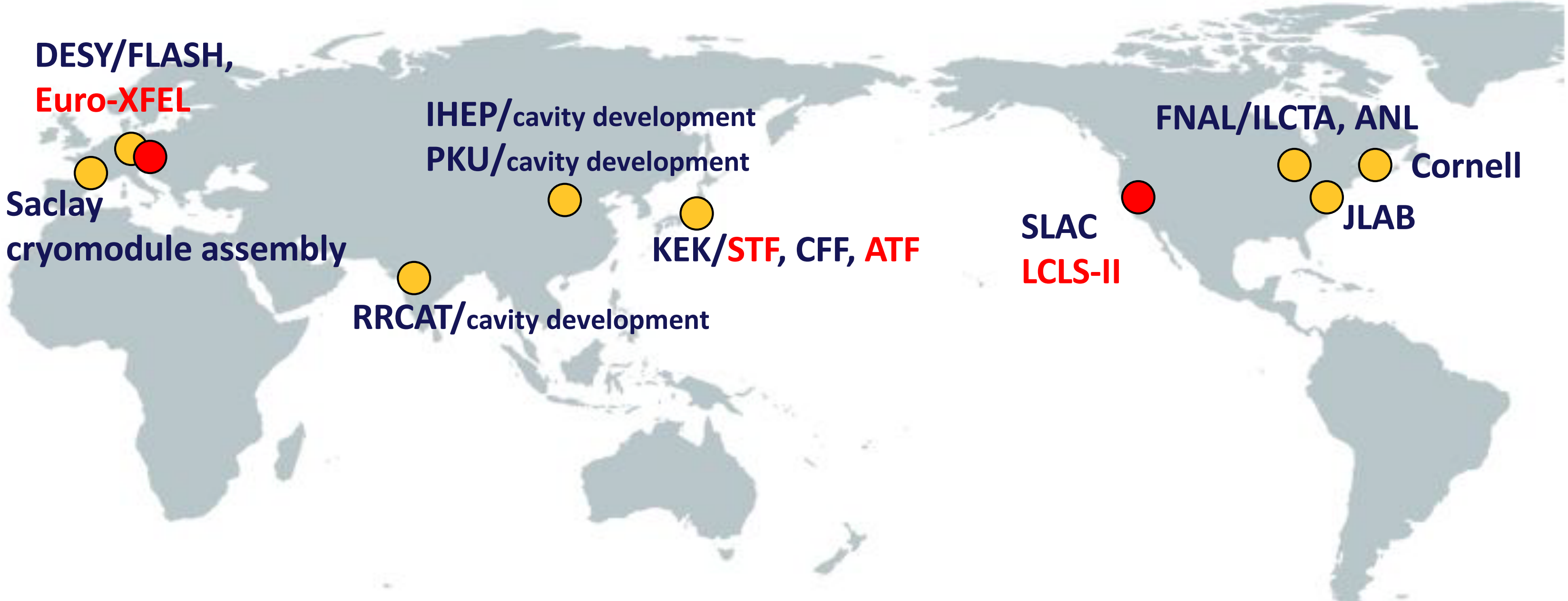
ILC SRF accelerator development

STF :Superconducting RF Test Facility at KEK

ATF :Accelerator Test Facility at KEK

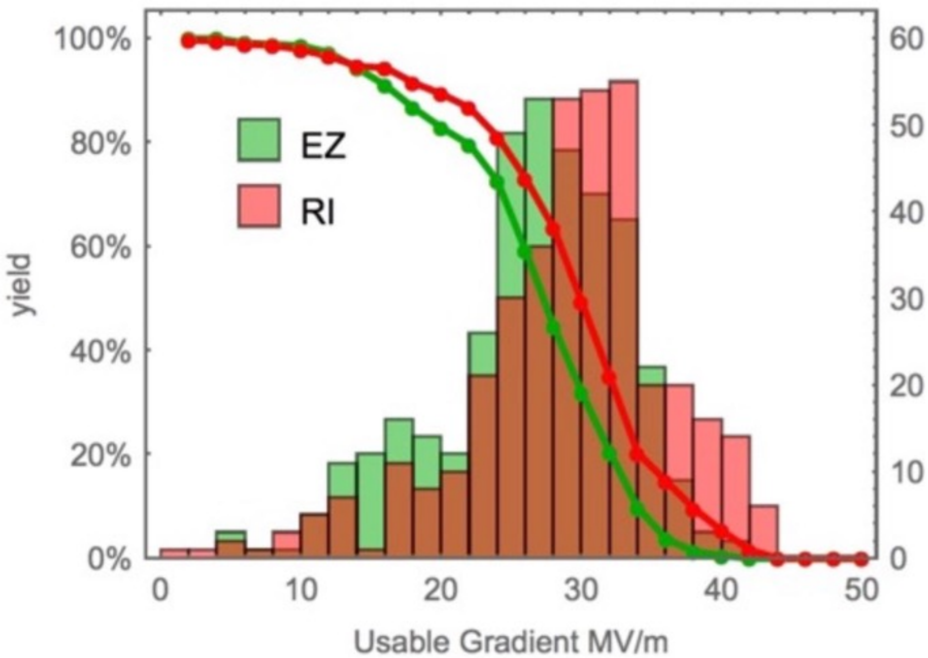
Euro-XFEL in Germany

LCLS-II in US



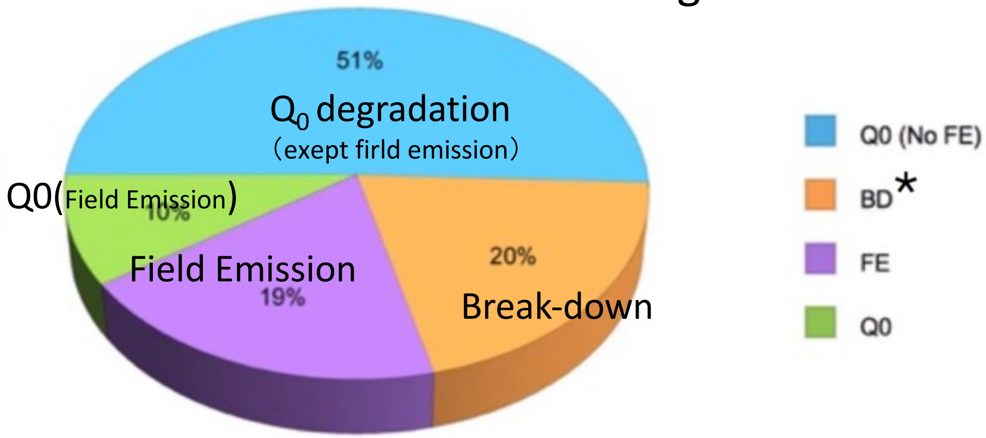
ILC accelerator development by International Collaboration

Test results: USABLE GRADIENT



"As received" test

Reasons of Usable Gradient degradation

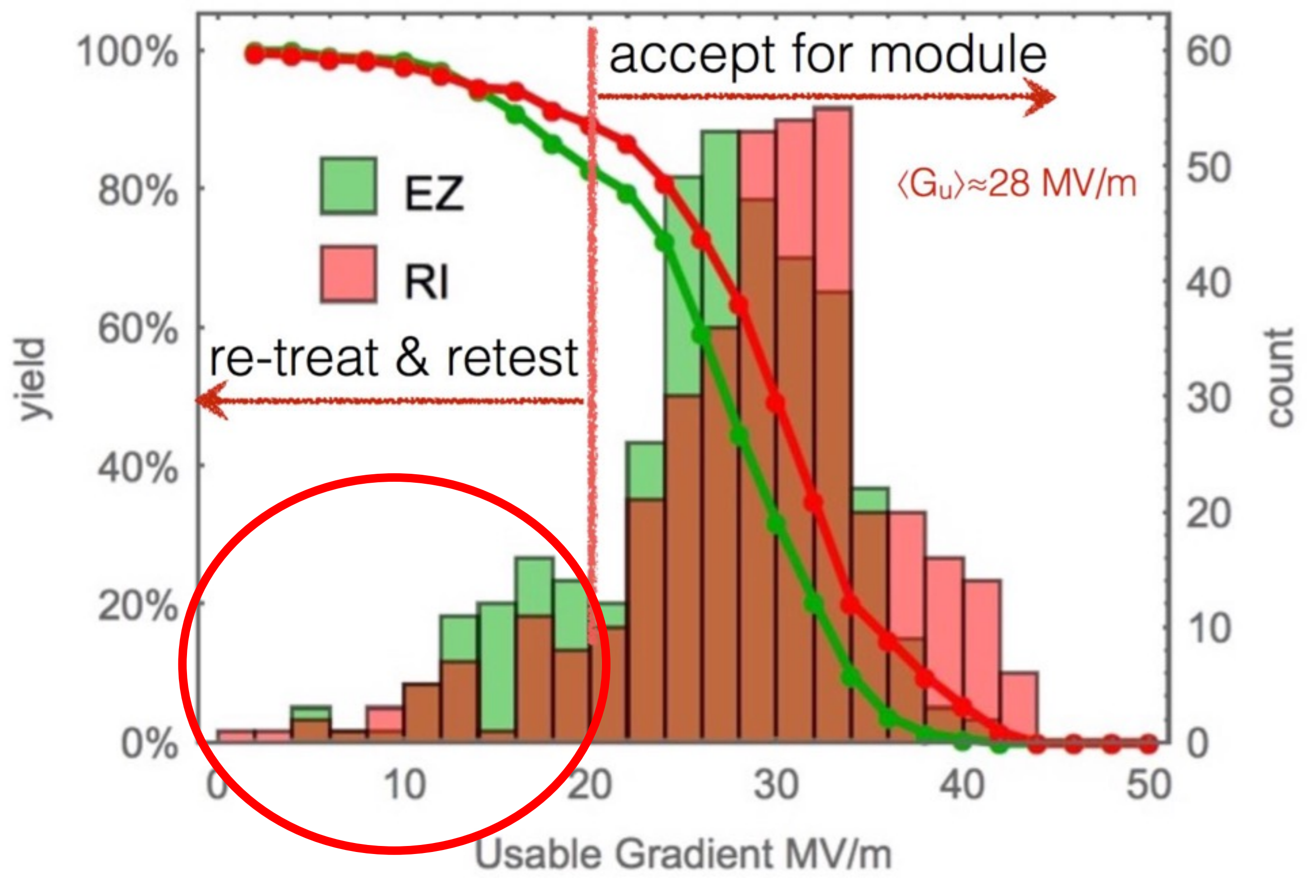


* few cases of power limitation, HOM coupler heating etc.

	RI	EZ	Total
Tests	375	367	742
G_{AVG} (MV/m)	29.1	26.4	27.8
G_{RMS} (MV/m)	7.4	6.6	7.1
yield @ 20MV/m	89%	83%	86%
yield @ 26MV/m	73%	59%	66%
yield @ 28MV/m	63%	45%	54%

Average loss from max: ~4 MV/m

Test results: Re-treatment



"As received" test

In general, first re-treatment is a standard High-Pressure Rinse (HPR)

Second (if required) is BCP

HPR treatment for <20MV/m cavities

Extrapolation to ILC - VT

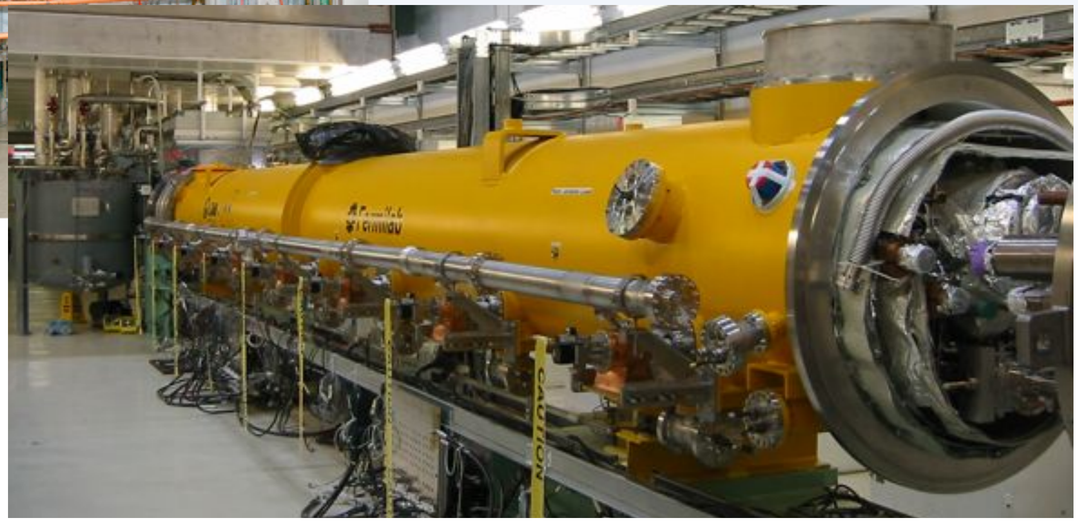
- ILC TDR assumed VT acceptance > 28MV/m (XFEL >20 MV/m)
  - Average of 35 MV/m (XFEL 26 MV/m)
  - Assumed first-pass yield: 75%
  - 25% cavities retreated to give final yield of 90% >28 MV/m (35 MV/m average)
    - ➡ 10% over-production assumed in value estimate

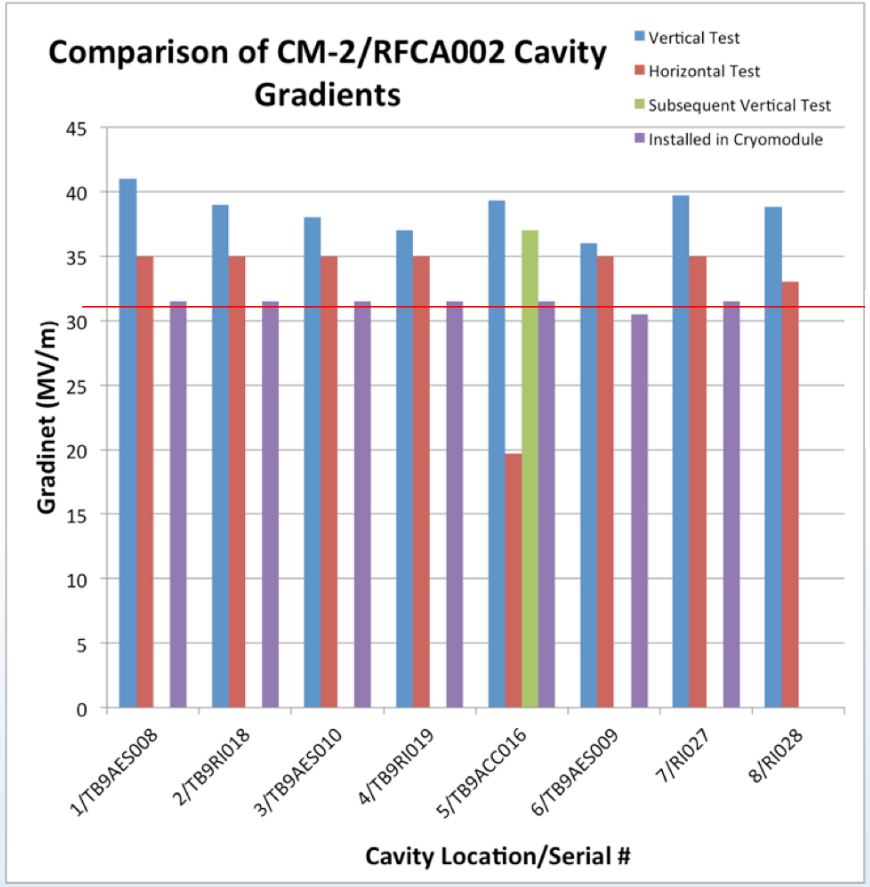
RI results only (ILC recipe)		ILC TDR (assumed)	XFEL max	XFEL usable
First-pass	Yield >28 MV/m	75%	85%	63%
	Average >28 MV/m	35 MV/m	35.2 MV/m	33.5 MV/m
First+Second pass	Yield >28 MV/m	90%	94%	82%
	Average >28 MV/m	35 MV/m	35.0 MV/m	33.4 MV/m
First+Second+third pass	Yield >28 MV/m	-		91%
	Average >28 MV/m	-		33.4 MV/m

but close!

More re-treatments - but mostly only HPR
Number of average tests/cavity increases from 1.25 to 1.55 (1st+2nd) or 20% over-production or additional re-treat/test cycles ➡ $$$

FNAL :Test Cryomodule Performance





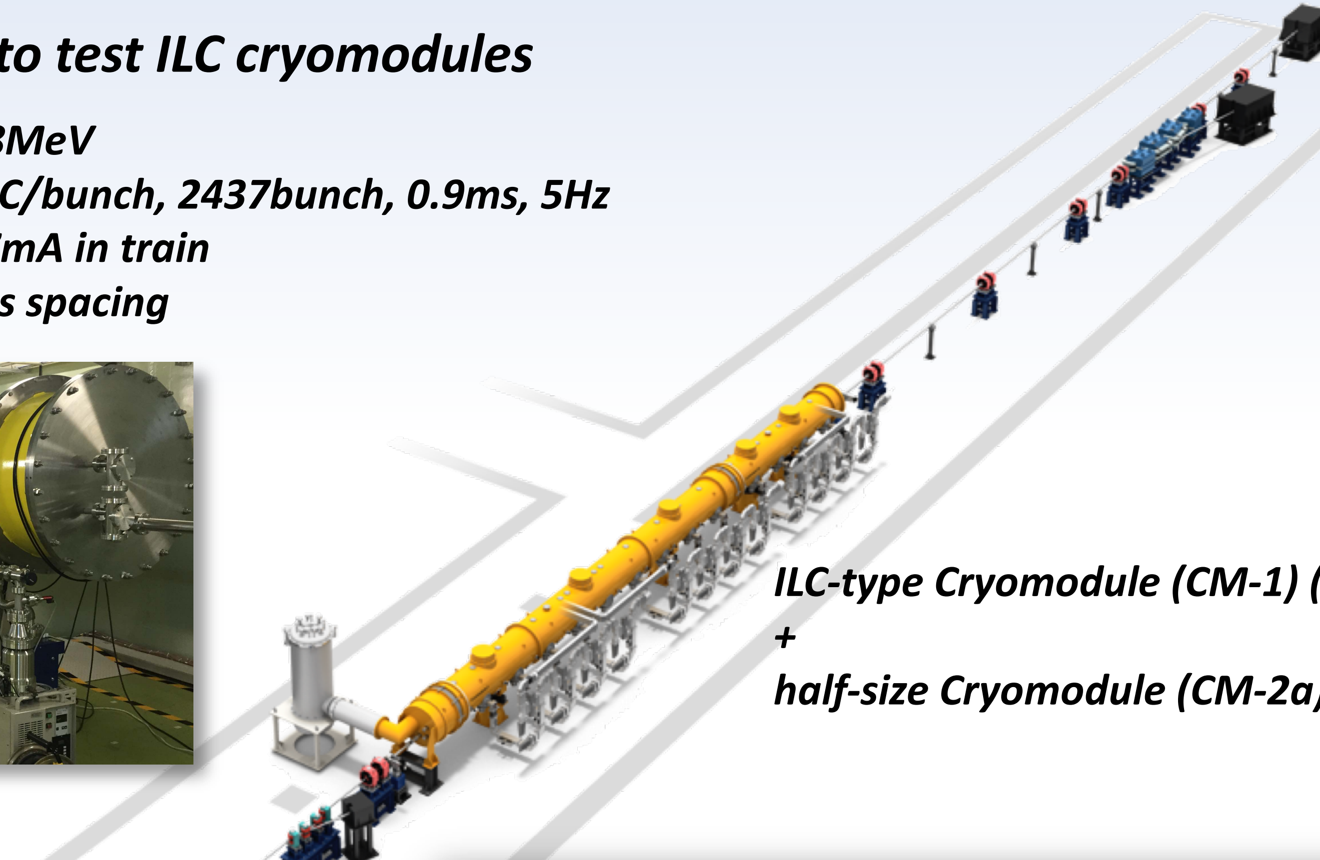
ILC Milestone
31.5MV/m

FNAL CM-2 has achieved the average cavity gradient of 31.5 MV/m with all 8 cavities powered simultaneously

KEK-STF :Superconducting RF Test Facility

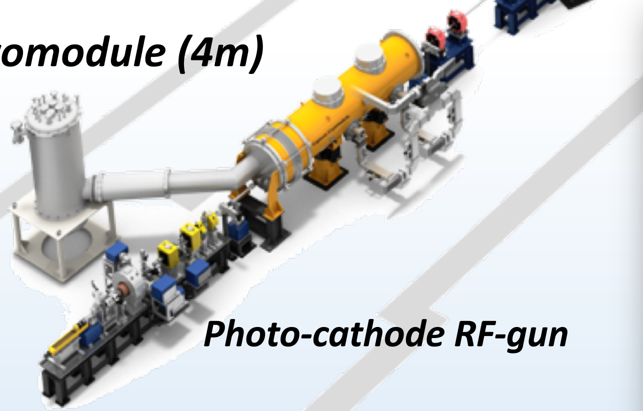
Test Accelerator to test ILC cryomodules

Beam Energy :418MeV
Beam Charge : 2nC/bunch, 2437bunch, 0.9ms, 5Hz
Beam current: 5.7mA in train
Bunch train: 369ns spacing



Beam Dump

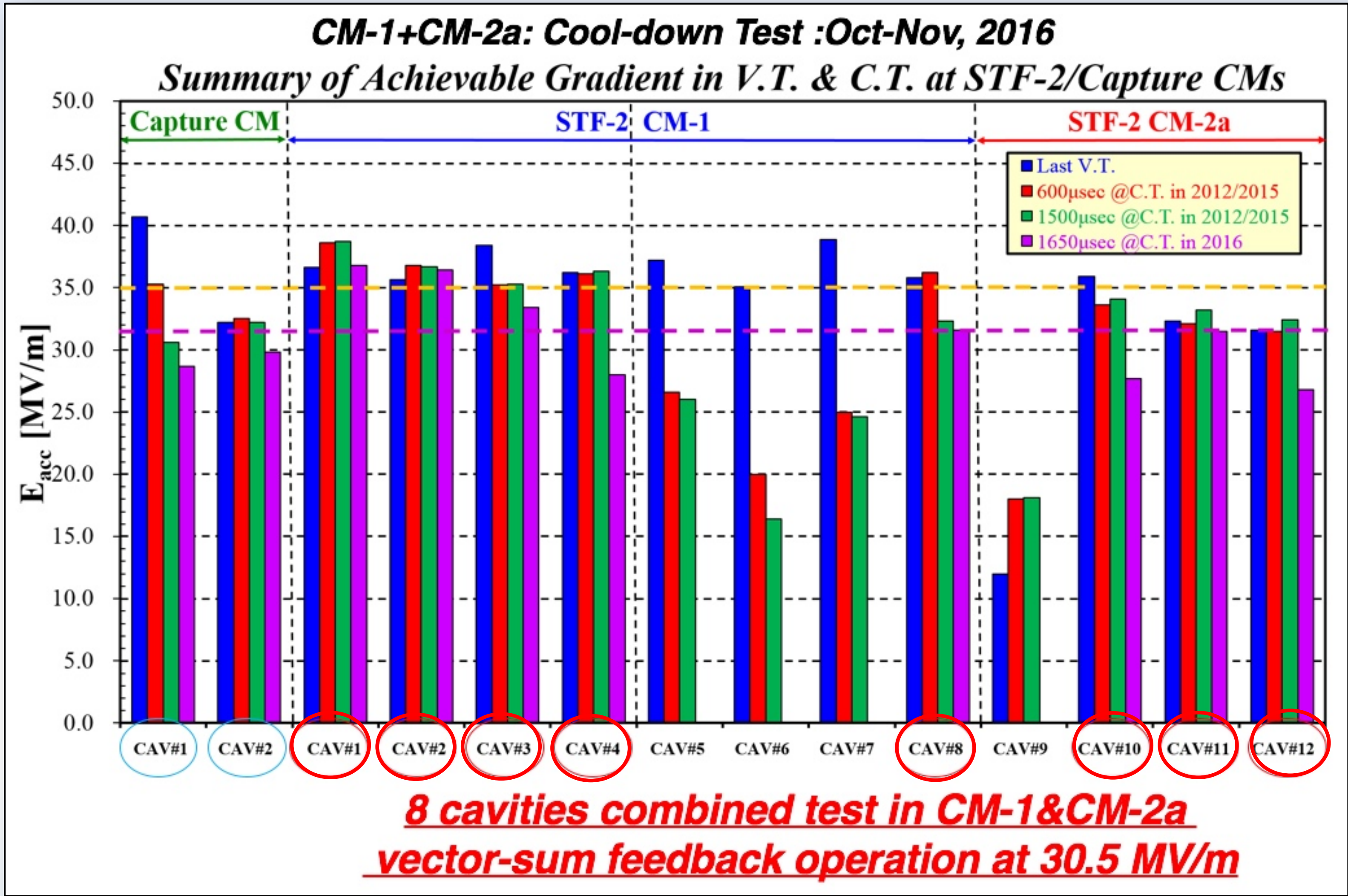
ILC-type Cryomodule (CM-1) (12m)
+
half-size Cryomodule (CM-2a) (6m)



Capture Cryomodule (4m)

Photo-cathode RF-gun

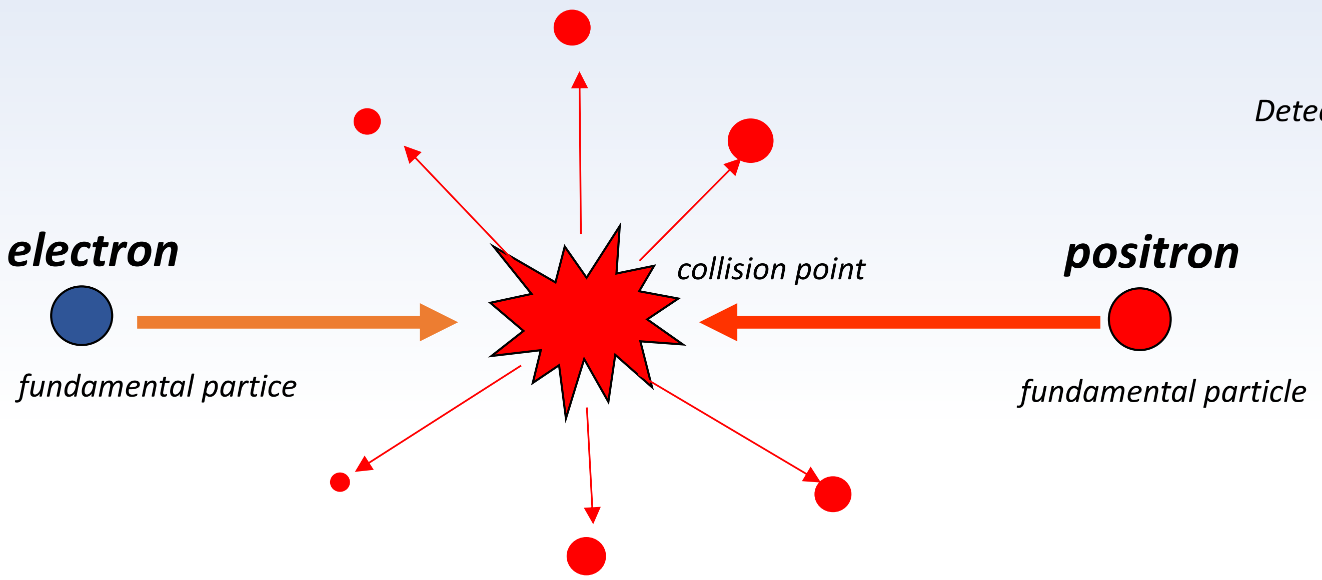
Achieved Gradient in STF



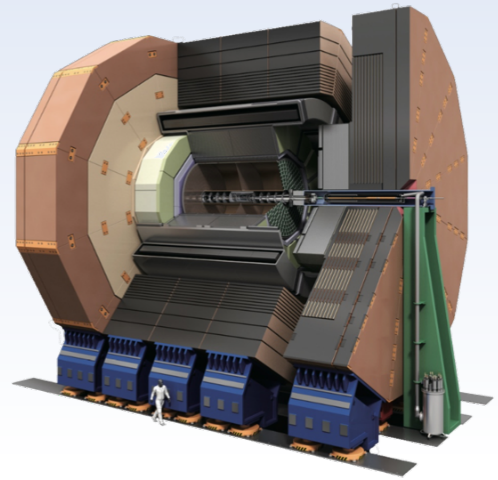
Combined 8 cavities(marked one) with vector-sum LLRF, operated at 30.5 MV/m

Beam Collision

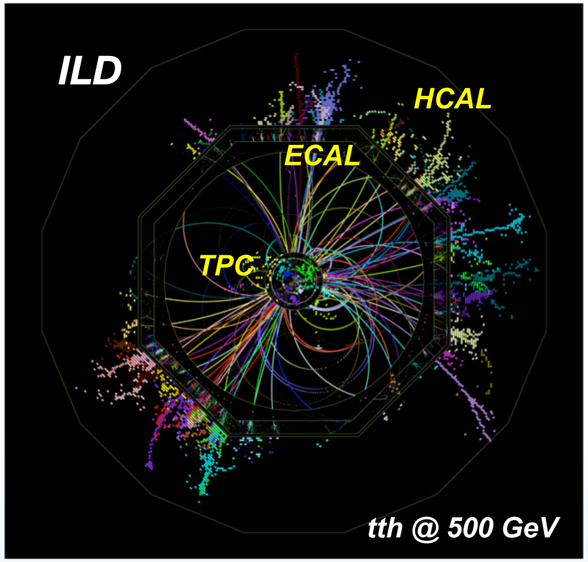
Electron and Positron collision



Detector

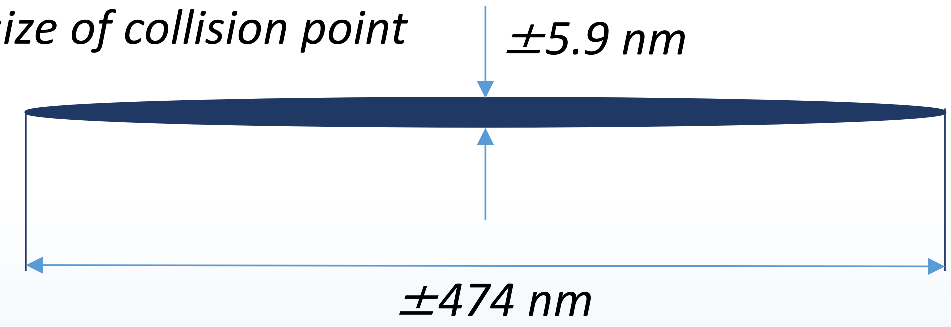


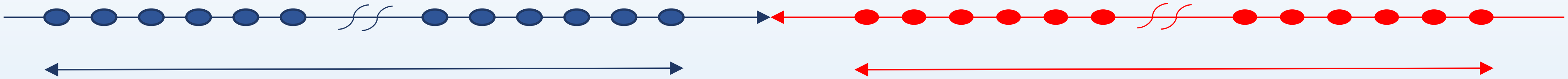
simulation of collision event in ILD



Beam = group of electrons (positrons)

Beam size of collision point



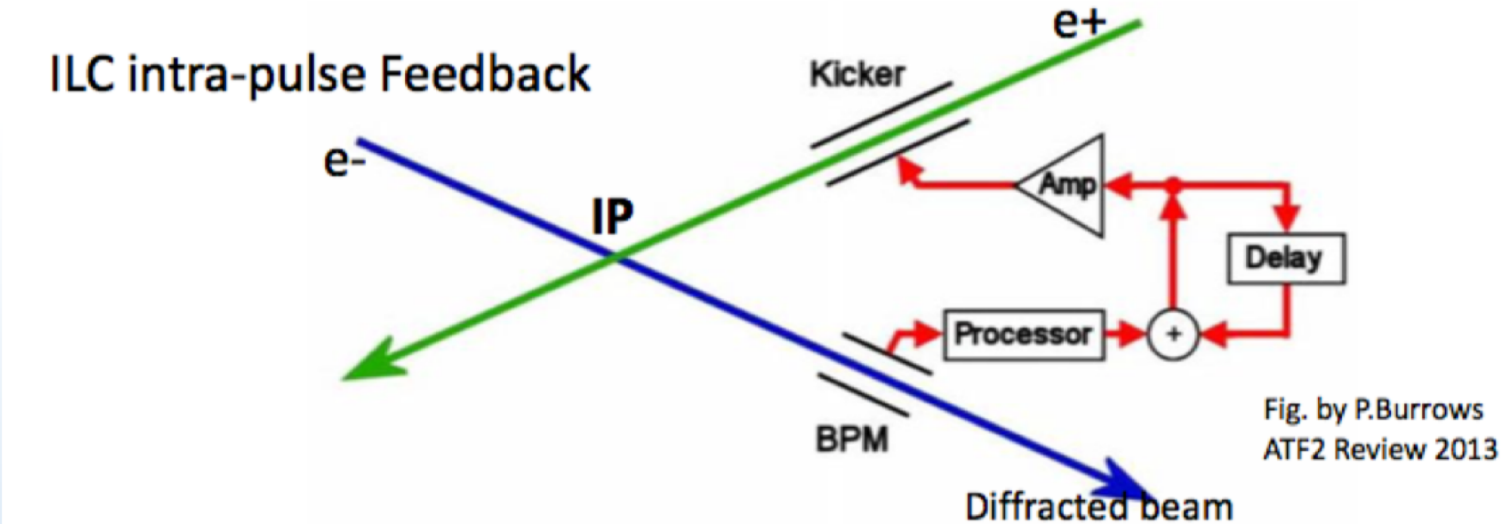


Electron buch 1312
length 300μm bunch spacing 166m
repetition 5Hz Energy 125 GeV

Positorn bunch 1312
length 300μm Bunch spacing 166m
repetition 5Hz Energy 125 GeV

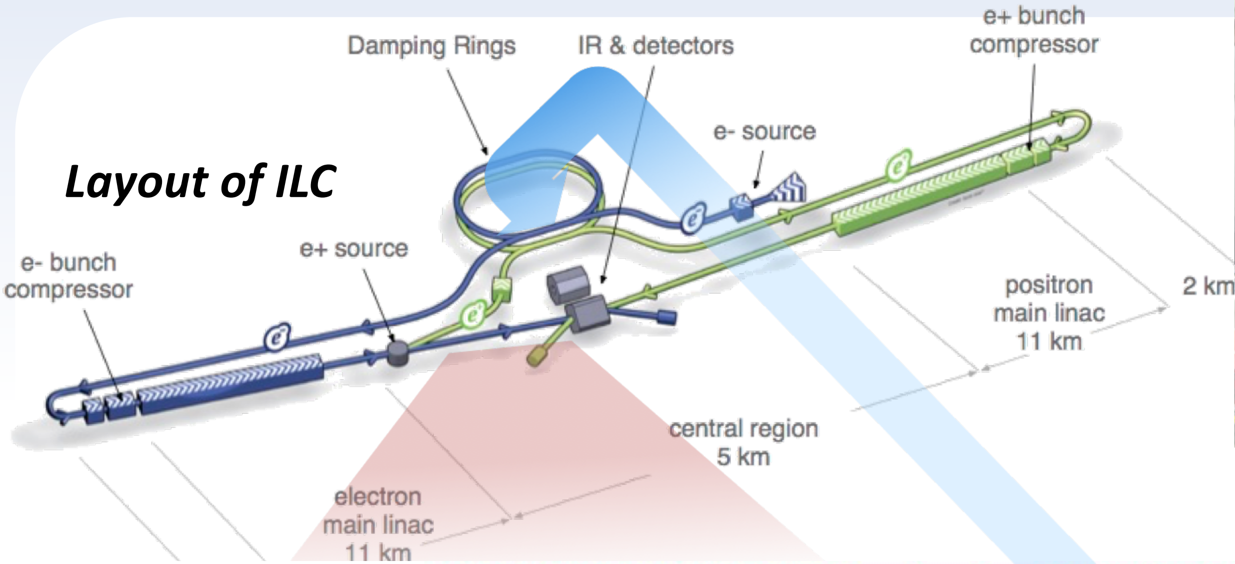
Keep the beam size small, keep the collision stable

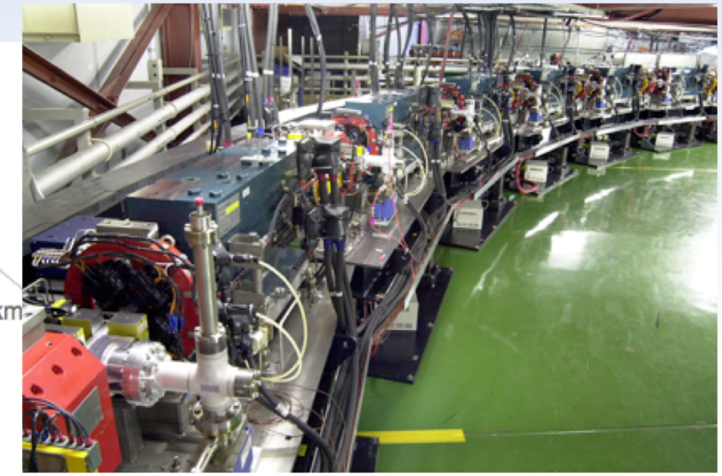
- ***Damping Ring to realize beam emittance ultra-small***
- ***Final Focus Beam Line to make vertical beam size ultra-small***
- ***No-vibration accelerator Floor - > Deep undergroud, stiff rigid Rock-base mountain***
- ***Fast Beam feedback to keep beam collision stable***



ATF : Accelerator Test Facility in KEK

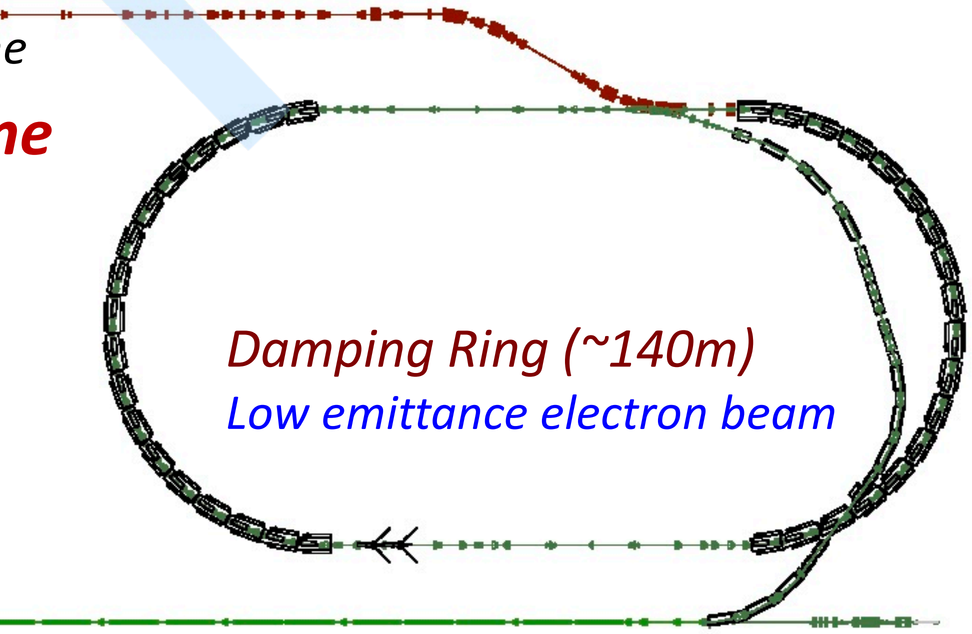
Layout of ILC



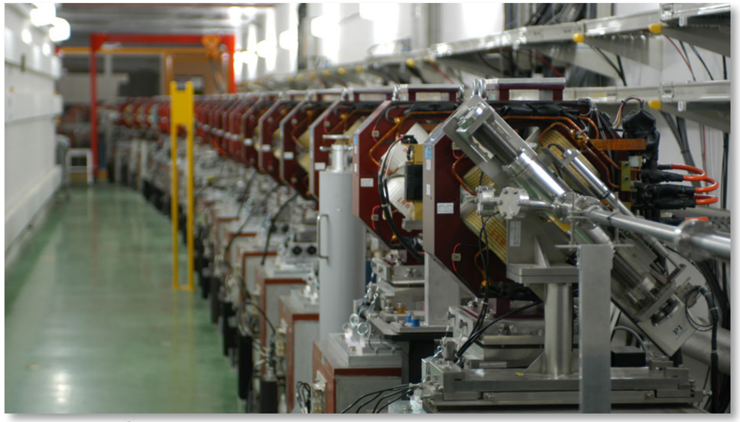


ATF Damping Ring

target low emittance is already attained



ATF2: Final Focus Test Beamline



Development of beam focus with low energy (ATF2)

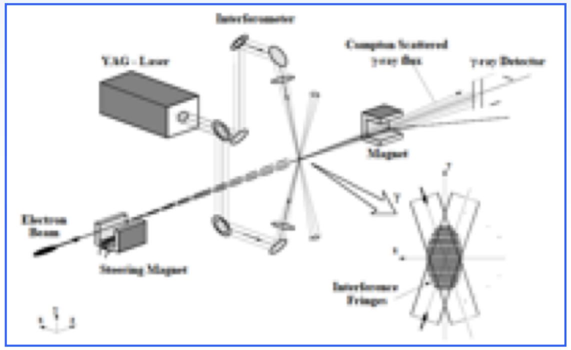
- ***Nano-beam development by international collaboration***

  25 laboratories with more than 100 researchers
- ***The same optical design of ILC final focus beam line***
- ***Scale down of beam energy to 1.3GeV***
- ***Target of beam size***

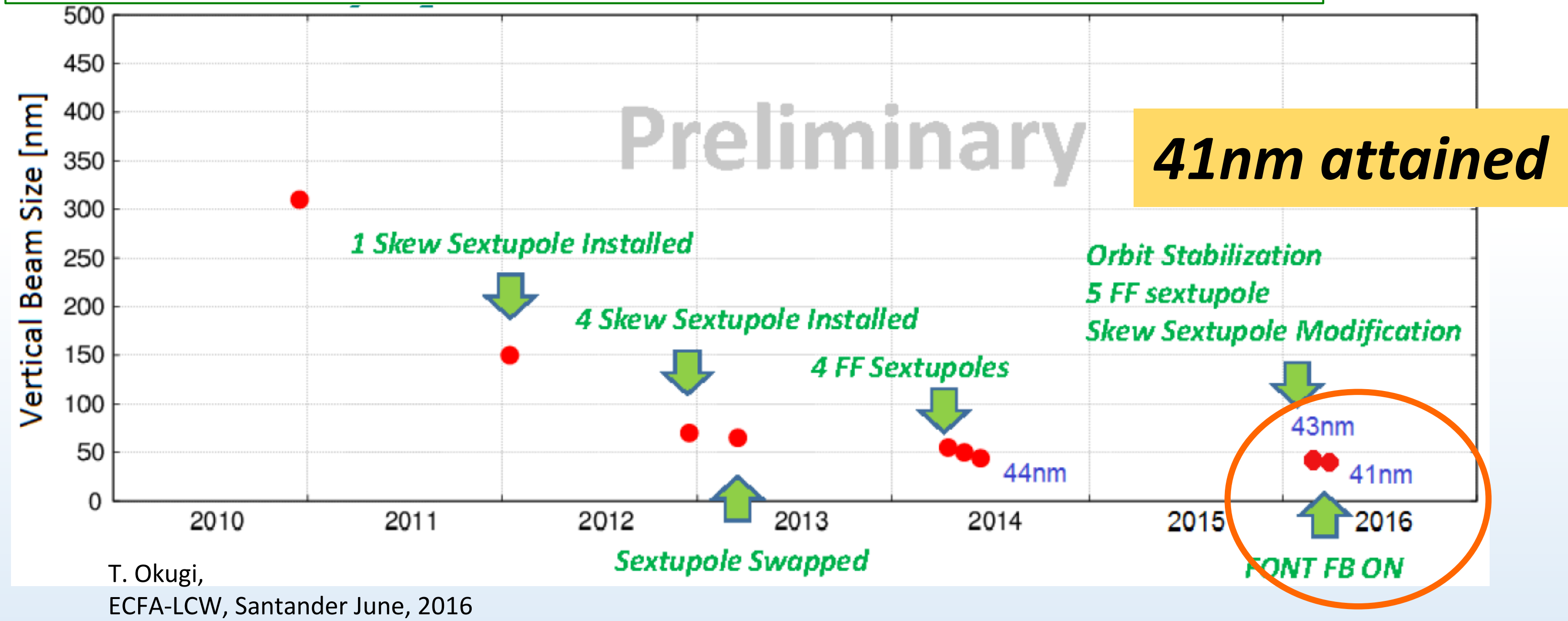
  37 nm vertical size (→ correspond to ILC 5.9 nm)
- ***Recent Status***

  41 nm beam size （with FONT Feedback）

  Parameters dependence to beam size are under research



Beam size monitor using laser interferometer



T. Okugi,
ECFA-LCW, Santander June, 2016

Summary

ILC (International Linear Collider) uses superconducting accelerator for the electron-positron collision experiment.

Euro-XFEL fabricated 100 cryomodules for the accelerator,
The cavity performance was very close to ILC requirement.

KEK-STF is developing superconducting accelerator,
KEK-ATF and ATF2 are developing damping ring and beam focus.

Plan of ILC installation into Tohoku-area are presented.
Tunnel, buildings and water&air will be by Japan,
High-tech accelerator part will be shared by US, Europe, and Asia.

END

Thank you for attention