CFS risks discussed at Academic committee

Nobuhiro Terunuma, KEK

SCJ committee on Aug. 2018

MEXT → **SCJ**

Commissioned Survey by NRI (2014-17)

1) WW Research trend (FY14)
2) Technology issues (FY15)
3) Large Int'l project (FY16)
4) Risk/safety issues (FY17)

July, 2018

ILC advisory panel report (in English) is available from http://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2018/09/20/1409220_2_1.pdf

ILC Adv. Panel

Organized from 2014 to 2018

Physics WG	**TDR Validation WG**	**Human Resource WG**	**Organization & Manage.WG**
Organized in 2014-15 & 2018	Organized in 2014-15 & 2018	Organized in 2015 -16	Organized in 2017

Review committee for ILC250

Tasks of the committee

- The academic significance of the ILC, importance of the ILC in the elementary particle physics
- Importance of the ILC in the whole academic research
- Significance of the ILC in Japan
- Preparation status for the ILC, budget and human resources necessary for construction and operation

Sub-committee

Tasks of the subcommittee

1 Technical feasibility of large facilities
2 Cost evaluation
3 Economic ripple effect
4 Environmental assessment

Committee members
Prof. Tadashi KOBAYASHI (Philosophy)
Prof. Tatsuyoshi SAIJO (Economics, environmental)
Prof. Takaaki KAJITA (Physics, Nobel Prize)
Prof. Hirokazu TAMURA (Physics)
Prof. Masako YONEDA (Civil Engineering, Vice-chair)
Prof. Yasuhiro IYE (Physics, Chair)
Prof. Mitsuru UESAKA (Physics)
Prof. Naoshi SUGIYAMA (Physics)
Prof. Tomofumi NAGAE (Physics)
Prof. Toshio HIRANO(Biology)

Sub committee members (Chair: Prof. Masako YONEDA)
Prof. Masashi KAMON (Civil Engineering)
Prof. Tohru NAKASHIZUKA (Biology, environmental)
Mr. Tsuneyoshi MOCHIZUKI (Civil engineering)
Dr. Hitoshi TANAKA (Spring-8)
+Prof. Masako YONEDA, Prof. Tatsuyoshi SAIJO and Prof. Yasuhiro IYE

LCWS2018 ILC accelerator by S.Michizono

Meetings of SCJ Committee for ILC-250

#	Main committee	Sub committee	Theme
1	Aug. 10		**Physics, Accelerator**, LCC, Report of MEXT meetings
2		Aug. 20	**Beam dump, CFS**
	Aug. 21		Organization, example of international project
3		Aug. 23	Nomura report and **discussions**, Economic effect
	Aug. 29		Future plans (KEK, JHEP), Comment from Acc. Society in Japan
4	Sep. 11		closed
		Sep. 13	**Risks, CFS utilities (power, safety)**
5	Sep. 18		Items to be discussed → **"discussion note"**
6	Oct. 1		Physics, International co-operations
		Oct. 2	**Answer to the discussion note**
7	Oct. 10		Physics, **Additional answer to the discussion note**
8	Oct. 16		Physics
…	not yet announced		May be closed meetings

Deep discussions especially in the Sub-committee.

“Note to be discussed” has been prepared by committee after several hearings of experts.

It is composed of broad concern due to the diversity of members' specialized fields.

We had replied all of them by documents and short presentations.

Followings are major discussions related to CFS.

Discussion note (technical part)

Accelerator

- When is the positron source selected?
- How do we monitor beam dumps? How do we exchange windows by remote control?
- Is the second beam dump effective?
- If the gate valve of beam dump (abnormally) closes, what will happen by beam irradiation?
- ILC as a giant system
- Interlock system
- How do we deal with leakage of primary cooling water containing radioactive such as tritium?
- Radioactivity of surrounding groundwater

Civil works

- Groundwater discharge and countermeasures.
- Countermeasures and additional costs when encountering construction-difficult parts such as active faults and fracture zones.
- Is there any point that ILC tunnels require stricter specification than normal tunnel construction?

Safety

- Measures on power failure. Duration of emergency power supply.
- Go to the safe side when power loss or malfunction occurs?

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Major discussions link to the CFS

- **Radiation safety**
  - **Beam dump and its Tritium water**
- Long-term power blackout
- Spring water around the tunnel
- Environmental assessment

Issues on Radiation Safety

Major questions:

- **Soundness of beam dump design**
- **Countermeasure against accidents**
- Tunnel wall and a radiation shield
- Handling of the spring water leaked into the tunnel

Answers:

- **Design margin on 18MW(1 TeV ILC) beam dump which will be used for 250 GeV ILC.**
- Radioactive products and their physical property
- **Countermeasure against the dump water leakage; i.e., handling of the Tritium water**
- Concept of radiation control areas and shields

Beam dump parameters

	TDR		250 GeV ILC
Center of mass energy (GeV)	500	1,000 (for future upgrade)	250
Beam energy(GeV)	250	500	125
Repetition (Hz)	5	4	5
Number of bunches	1312	2450	1312
Bunch interval (nsec)	554	366	554
Pulse width (msec)	0.727	0.897	0.727
Number of charges	2×10^{10} (3.2nC)	1.74×10^{10} (2.79nC)	2×10^{10} (3.2nC)
Charges per pulse (μC)	4.20	6.83	4.20
Pulse current (mA)	5.78	7.61	5.78
Pulse energy (MJ)	1.05	3.41	0.53
Average power(MW)	**5.25**	**13.7**	**2.63**

Design：20% margin → **17 MW**

20%

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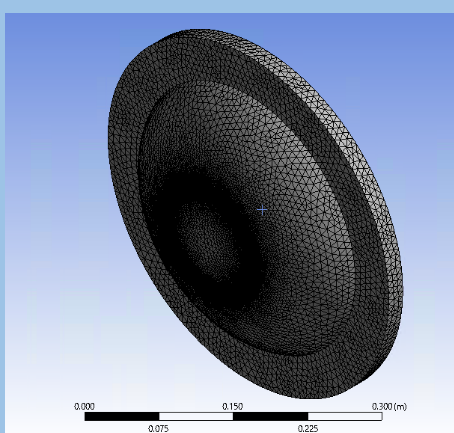
Structural analysis of beam dump

（water vessel、 beam window）

Original ：Nucl. Instr. and Meth. A 679 (2012) 67–81

Structural Analysis （ANSYS）

Beam interaction （FLUKA）



Beam window

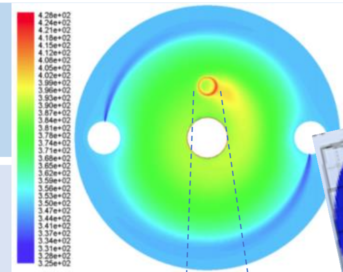
hydro-dynamics

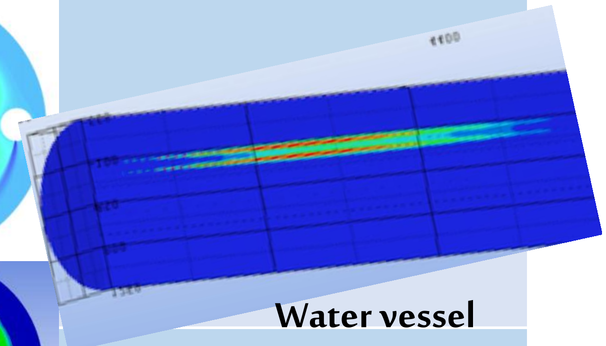
Heat load

Stress

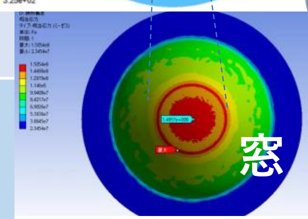
Pressure propagation

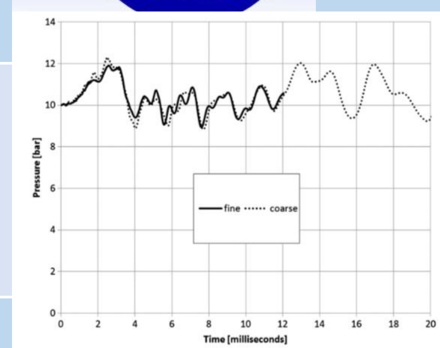
Activation and Radiation Damage

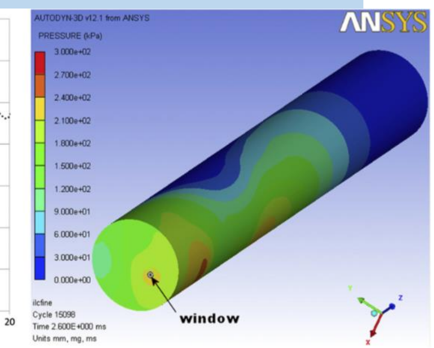


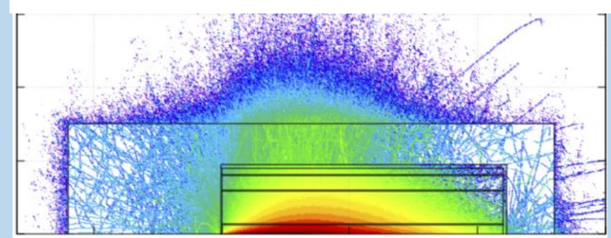


Water vessel

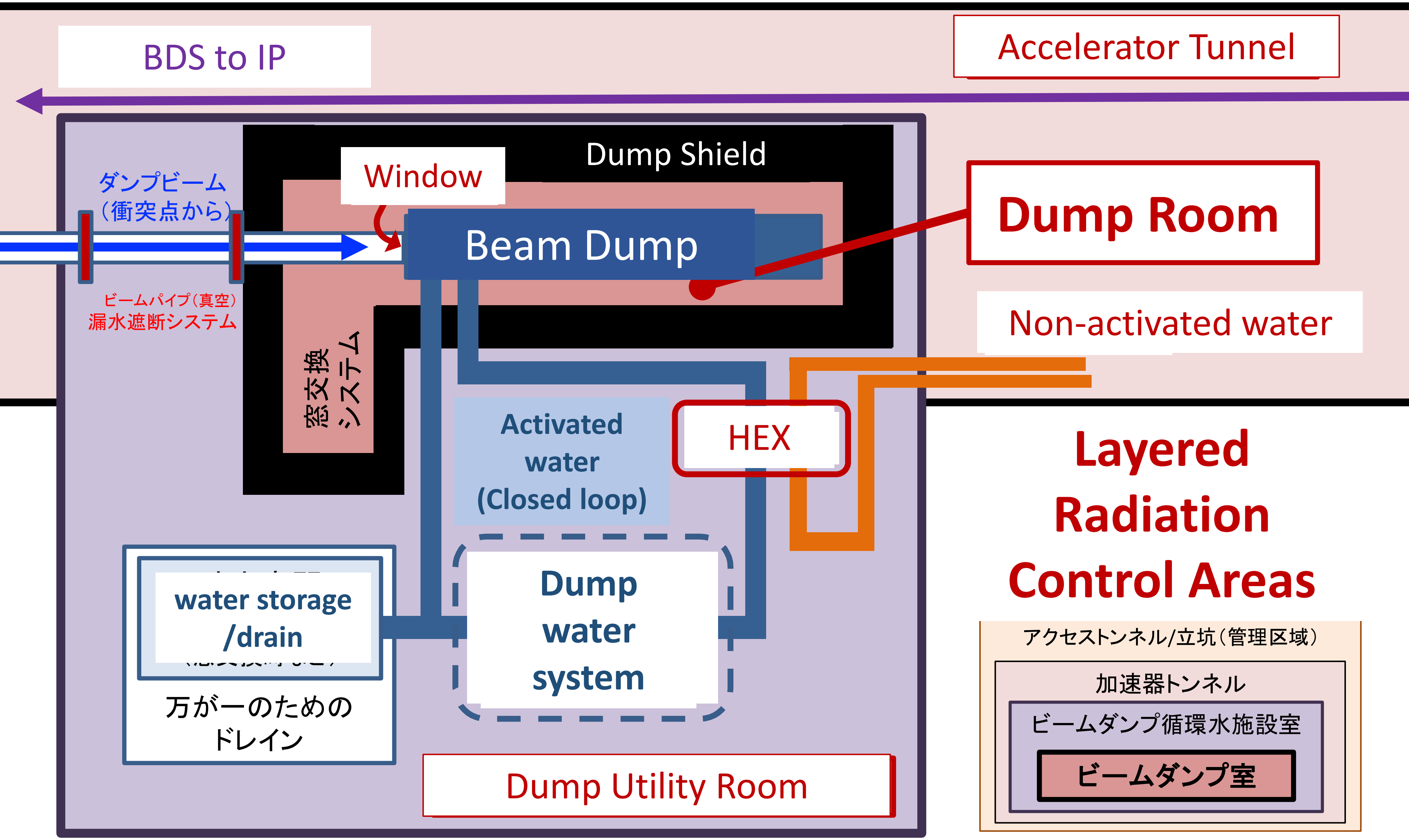








Radiation Safety Concept of Beam Dump Area ムダンプ1



ビームダンプ施設は加速器ビームラインと同じ地下100mに構築

Beam dump water

	TDR beam dump design	ILC-250
Beam energy	**500 GeV**	**125 GeV**
Max. temperature	Circulating Water ： **155℃** Beam window(1mm) ： 74℃	Circulating water ： 73℃ Beam window(1mm) ： 82℃
Recent R&D Window → max.5 mm	Beam window(5mm) ： 110℃	Beam window(5mm) ： **115℃**
Water pressure	**10 atm** （Boiling point 180℃）	**3 atm** （Boiling point 133℃）

Speed of water from the broken window

- Pin-hole
  - Repeat leak, freeze, thaw, leak (to the beam pipe)
  - Many experiences
- Bigger hole
  - Slower speed than the small-hole

Water speed (small hole)	**Max. 45 m/s**	**Max. 24 m/s**

Tritium

^{3}H Half life12.3year β decay 18.6 keV(max.) electron release

Tritium is generated by ^{16}O spallation reaction inside beam dump cooling water.

Facility	Tritium	
ILC Main dump	100 T Bq. (saturation) e+,e−total 0.3g(^{3}H)/100t=0.003 wppm	• 2.6 MW, 5,000 hour operation • 100m underground • Closed water circulation (e+,e−total 100 m^3)
J-PARC Hg target	92 T Bq. (saturation)	• 1MW, 5,000 hour operation • Hg：Closed circulation1.4 m^3 JAEA-Technology 2009-010
Fukushima fission reactor (Contaminated water)	2,500 T Bq.	• 2016.9.22（Tokyo Electric Power Supply） 2016.11.11TEPCO

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Countermeasure of Beam window failure

Detect water leakage
-Vacuum monitor
-Leakage monitor
A few milliseconds response

Beam abort

Stop circulating water

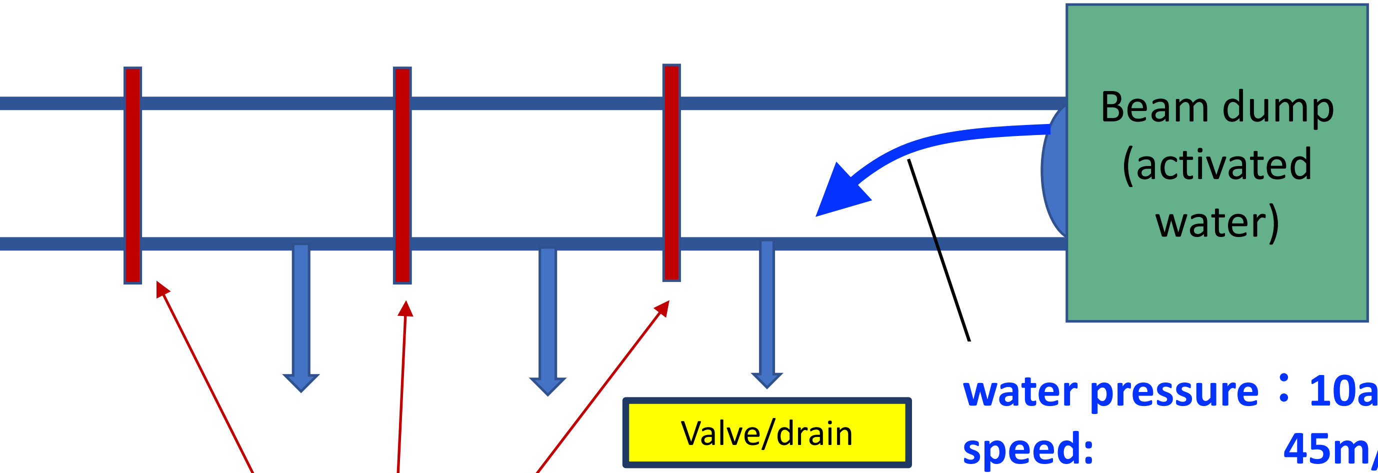
Dump beam line shutdown
High speed vacuum gate valve
~ 40 ms response speed

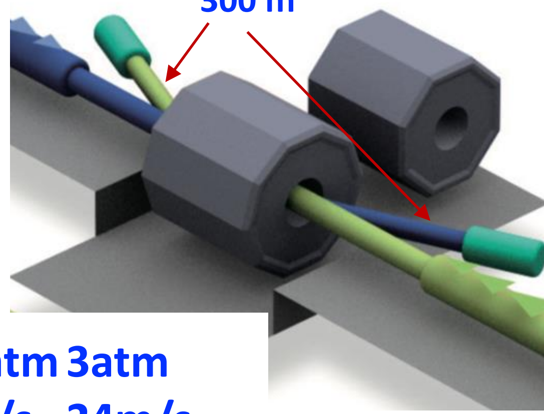
Keep the leakage in the beam pipe of the dump line

Open recovery valve and collect and store in drain

Beam window exchange / restoration

~ 100 msec (from leakage detection to high-speed gate valve shutdown)





water pressure：10atm 3atm
speed: 45m/s 24m/s

Multiple shutoff valves and minimize contamination range

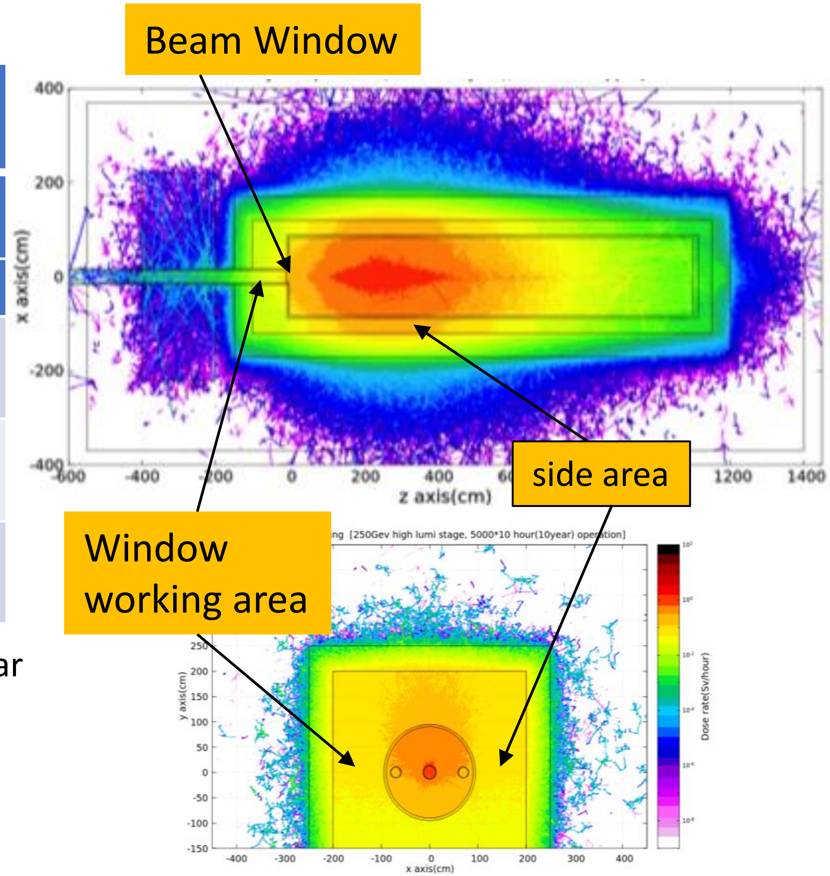
Detailed design of the dump line will be done during preparation phase.

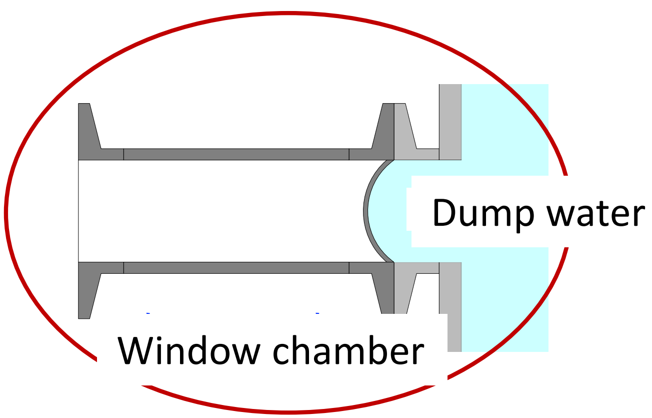
Beam Dump Activation and 2nd Beam Dump

Beam dump has been designed for 17MW at 1TeV and has a margin for 250GeV. To avoid a long-years shutdown if a heavy activated dump is broken, **2nd beam dump** has been proposed.

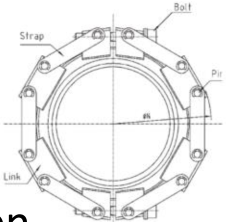
OP. Years	Radiation doze of working area after beam stop (mSv/h)					
	Upper: at window Lower: 1m from the window			Upper: maximum of side area Lower: minimum of side area		
	1 mo	1 y	5 y	1 mo	1 y	5 y
1y	**105** 14	**18** 3	**1** 0.2	**157** 1	**32** 0.2	**2** 0.01
5y	**130** 23	**30** 7	**3** 0.8	**207** 0.9	**56** 0.4	**4** 0.03
10y	**140** 25	**35** 8	**5** 1	**211** 1	**60** 0.5	**8** 0.05

FLUKA simulation: 125GeV beam, nominal intensity, 5000h/year





Clamp-chain flange

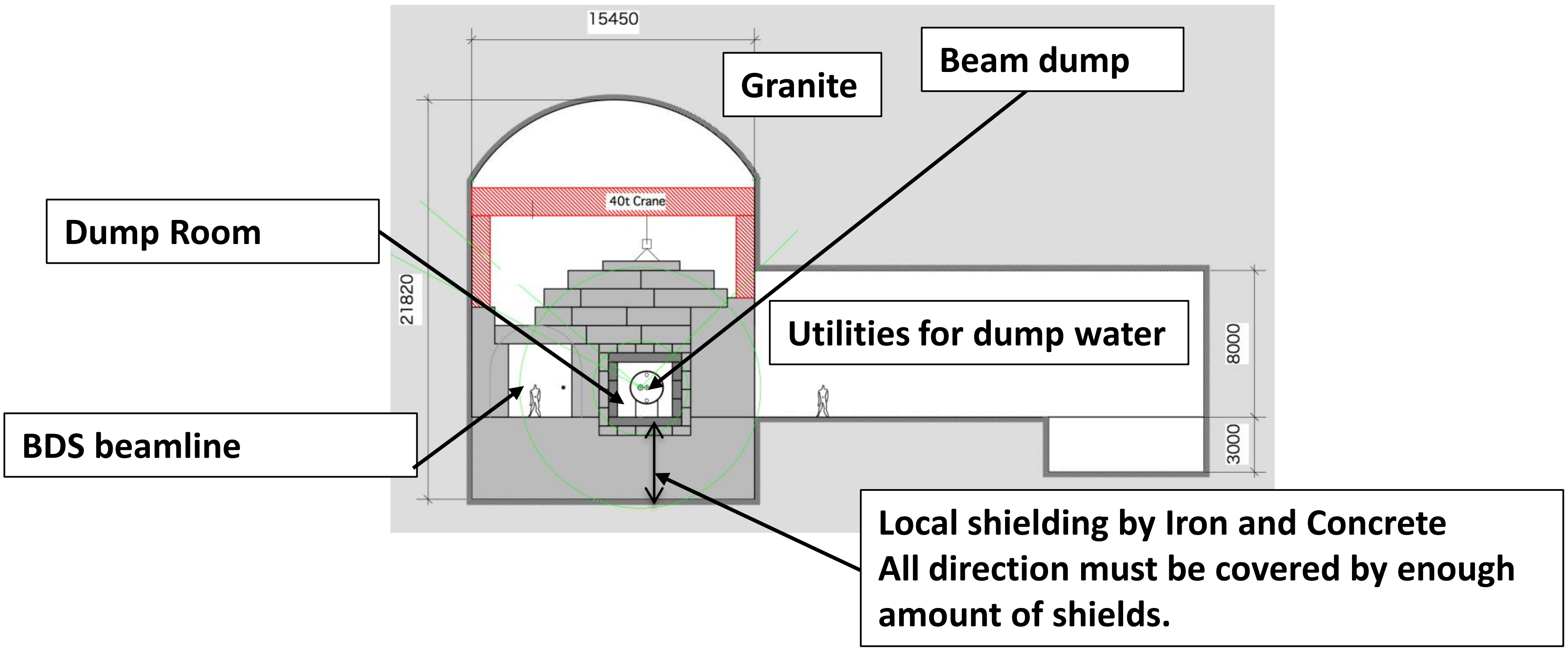


Example of window connection

Countermeasure against a groundwater activation

- Shields are designed to **make an activation of the underground water well below the concentration limit by law**.
- Heavy beam loss area such as a beam dump should have an enough localized shield.
- ML is low loss and the activation is lower than the concentration limit even for the dark current.

Example for the beam dump shields



Major discussions link to the CFS

- Radiation safety
  - Beam dump and its Tritium water
- **Long-term power blackout**
- Spring water around the tunnel
- Environmental assessment

Emergency response at ILC

	ILC	LEP/ LHC
Power failure	1) <30 sec.：Battery（Control, monitor） 2) >30sec.：Emergency generator（light, drainage, **He storage**） （Note：**He system should be kept <+1atm. Quick storage will be necessary.**） 3) <3 days：power recovery (Generator fuel stockpile)	1) <30 sec.：Battery（Control, monitor） 2) >30sec.：Emergency generator（light, drainage） （Note：**He system can be ~20atm.**） 3) <1 days：power recovery (Generator fuel stockpile)
Fire	1) Kamaboko-tunnel, Retreat to non-fire side/tunnel -> evacuation 2) The air conditioning circulation speed is controlled below the moving speed of a person. Evacuation faster than smoke (distance: <2.5 km + access tunnel) Note: Fire-resistive cable	1) Retreat to non-fire side -> evacuation 2) The air conditioning circulation speed is controlled below the moving speed of a person. Evacuation faster than smoke (distance: <3.4 km + elevator) Note: Fire-resistive cable
He leakage	1) Carry an oxygen tank, retreat along the tunnel bottom (He diffuses and stays at the top of the tunnel) (No liquid nitrogen underground) 2) Other than He leakage point (Cryo-unit), normal He recovery	1) Carry an oxygen tank, retreat along the tunnel bottom (He diffuses and stays at the top of the tunnel) (No liquid nitrogen underground) 2) Other than He leakage point (Cryo-unit), normal He recovery
Earthquake	1) Stand by next to stable large equipment. 2) Evacuate after the decay of the shake. Note: Earthquake vibration is relaxed to ~ 1/5 level at depth of 100 m	1) No large earthquake experience in this area. 2) No special guidelines.
Spring water	• Detection at advanced pit, drainage enhancement • Evacuate to the beam tunnel side (no drain pump) · evacuate. • In case of overflowing spring water, via service tunnel, detector hall → radiation monitor → natural drainage.	• Prevention of spring water by the freezing method of the surrounding soil (during CMS shaft construction) • There is no large spring water in tunnel after completion of construction. Trace amount of spring water is pumped up, radiation monitor and drainage.
Tunnel access・ **License/ Equipment**	1) Issue license after lecture and examination 2) Equipment at entry: - ILC-ID (Licensed) - Radiation worker batch (with monitor) - Helmet (LED search light attached - Portable oxygen tank (<30 minutes), - Oxygen concentration meter (with alarm) · Bicycle, electric working vehicle (option)	1) Issue license after lecture and examination 2) Equipment at entry: - CERN-ID (Licensed) - Radiation worker batch (with monitor) - Helmet (LED search light attached - Portable oxygen tank (<30 minutes), - Oxygen concentration meter (with alarm) · Bicycle, electric working vehicle (option)

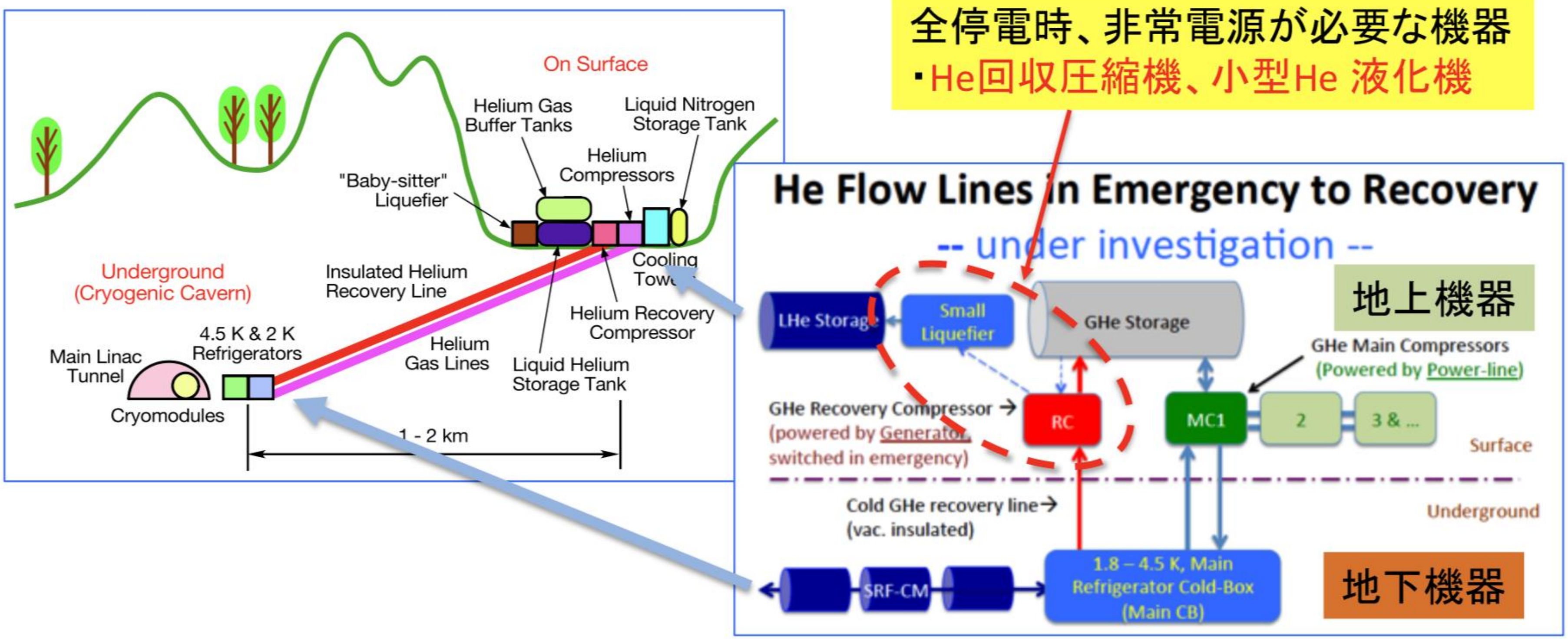
Countermeasure against the Power failure

	ILC	LEP/ LHC
< 30 sec.	Battery （Control, monitor）	Battery （Control, monitor）
> 30sec.	Emergency generator （light, drainage, **He storage** ） （Note：**He system should be kept <+1atm. Quick storage will be necessary.**）	Emergency generator （light, drainage） （Note：**He system can be ~20atm.**）
More…	< **3 days:** power recovery (Generator fuel stockpile）	< **1 days**: power recovery (Generator fuel stockpile）

ILC 超伝導加速器・冷却システム

地上・地下機器配置及び全停電時非常対応に必要な機器

全停電時、非常電源が必要な機器
・He回収圧縮機、小型He 液化機



地上・地下に配置された冷凍機、超伝導加速器システム

Major discussions link to the CFS

- Radiation safety
  - Beam dump and its Tritium water
- Long-term power blackout
- **Spring water around the tunnel**
- Environmental assessment

Drainage concept of Underground Water

排水システムの概念

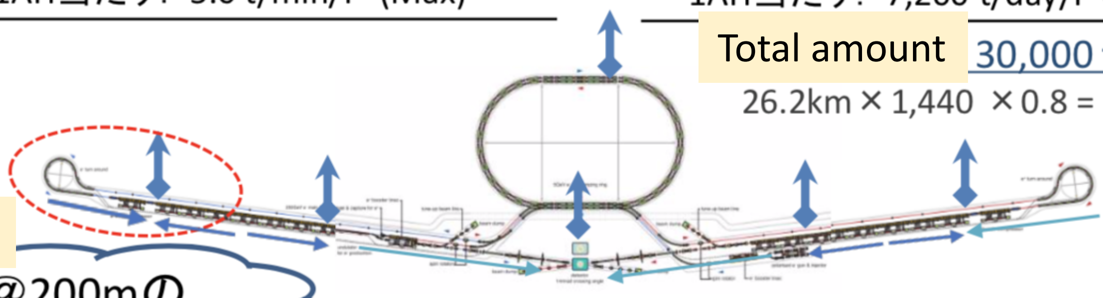
Amount of spring water estimated by results of tunnels in Japan

- 1km当たり： 1.0 t/min/km
- 1AH当たり： 5.0 t/min/P (Max)

- 1km当たり： 1,440 t/day/km
- 1AH当たり： 7,200 t/day/P (Max)

Total amount 30,000 t/day

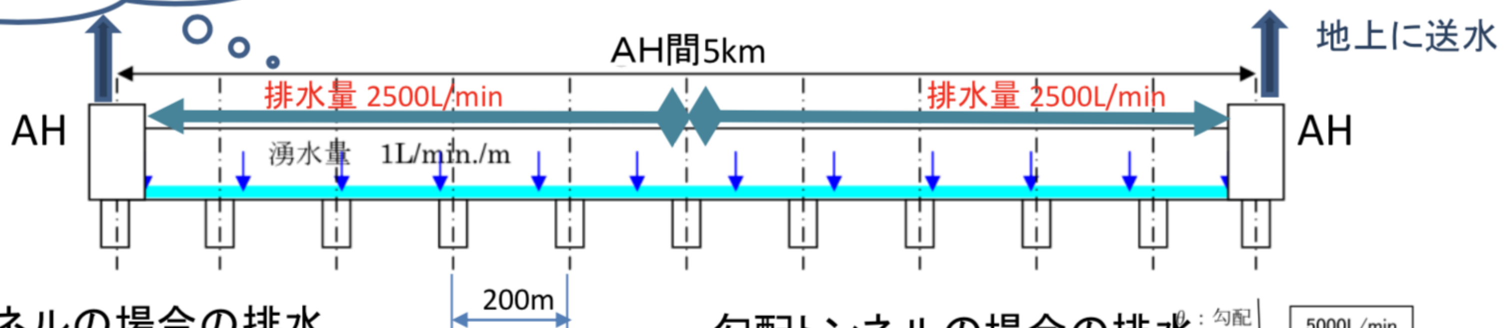
26.2km × 1,440 × 0.8 = 30,180 t



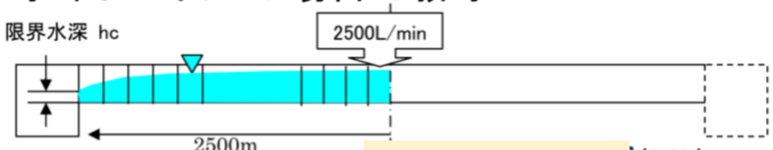
Spring water/pump

ポンプ槽間隔@200mの
湧水量＝200ℓ/min

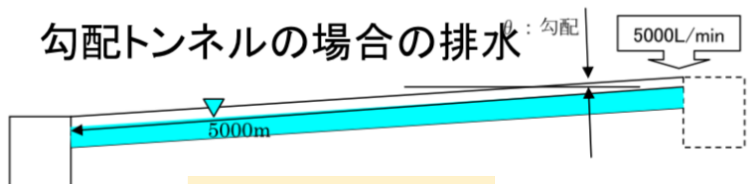
水平トンネルにおける湧水処理



水平トンネルの場合の排水



勾配トンネルの場合の排水



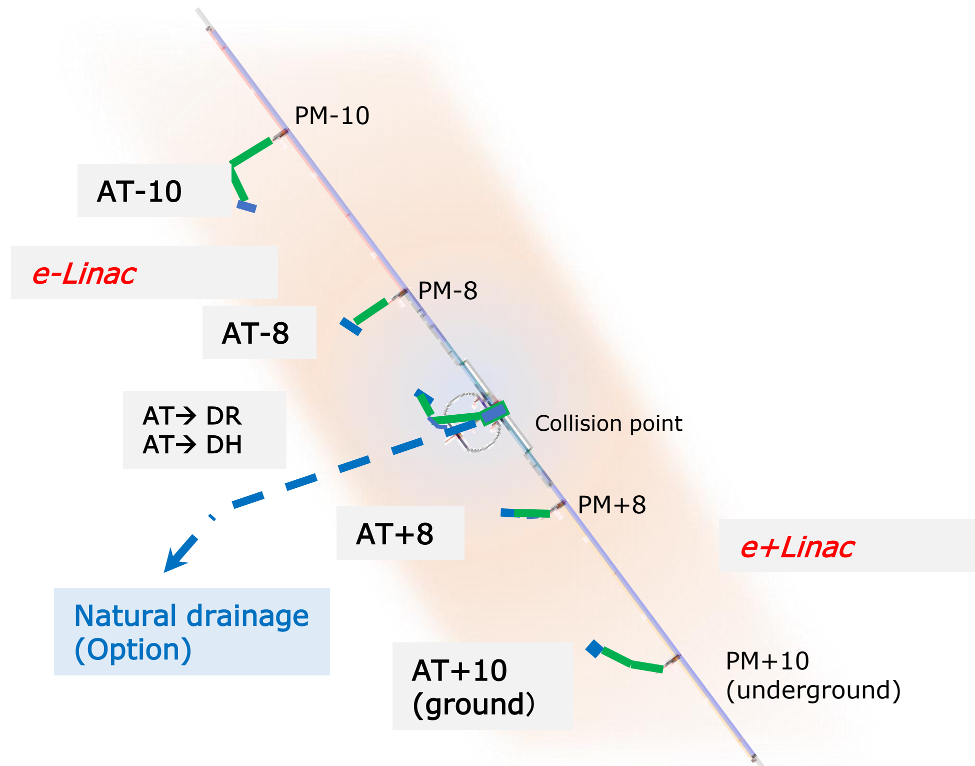
Geoid tunnel (ML)

Laser straight (BDS)

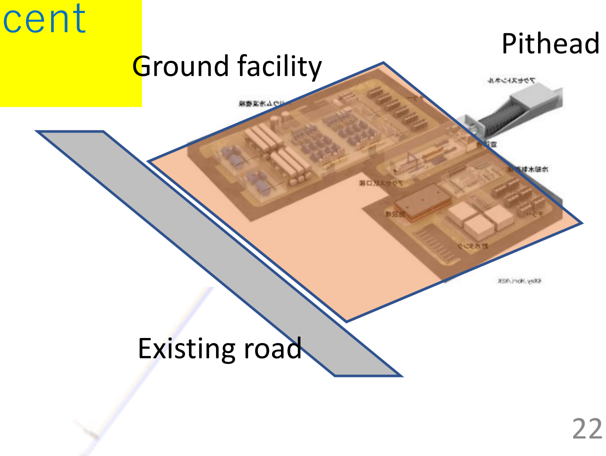
ILC tunnel optimization (Tohoku survey)

Tunnel	length (m)	Existing road -> Access hall
Acc. tunnel		
e-: RTML-turn	2,438	
ML	4,950	
BDS	3,489	
e+: BDS	2,361	
ML	4,795	
RTML-turn	2,516	
{Total}	{20,500}	
Access tunnel：		
(w=8 m, h=7.5 m)		
AT-10	1,503	adjacent
AT-8	691	~50 m
AT→DR	763	adjacent
AT→DH	693	adjacent
AT+8	283	adjacent
AT+10	943	adjacent
{total}	{4,876}	
Natural drainage (Option)	4,335	

Note: Tunnel and ground access optimization:
Tunnel to good rock, altitude capable of natural drainage,
Ground facility adjacent to an existing road
Shorten access tunnel length
Access downward slope: <10% (average <9%)
Optimization support by tunnel optimization program (TOT) (CERN - KEK - Tohoku cooperation)



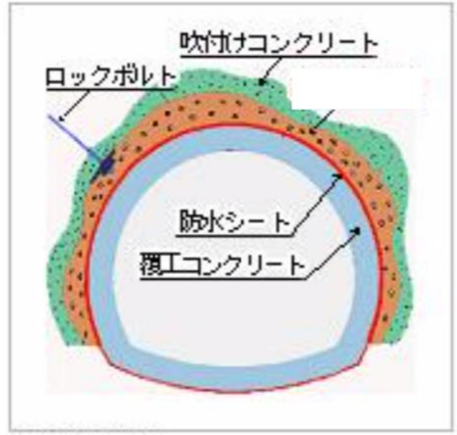
Ground facility adjacent to existing road



参考資料:　山岳トンネル-防水工法　施工標準

Example: Standard structure of the tunnel

1.掘削・ズリ出し
2.コンクリート吹付け
3.ロックボルト・アンカー工
3.防水シート張り
4.鉄筋・型枠組立て
5.覆工コンクリート打設



▲工法概念図

類似トンネル施設工事状況

Before Linings (waterproof sheet)

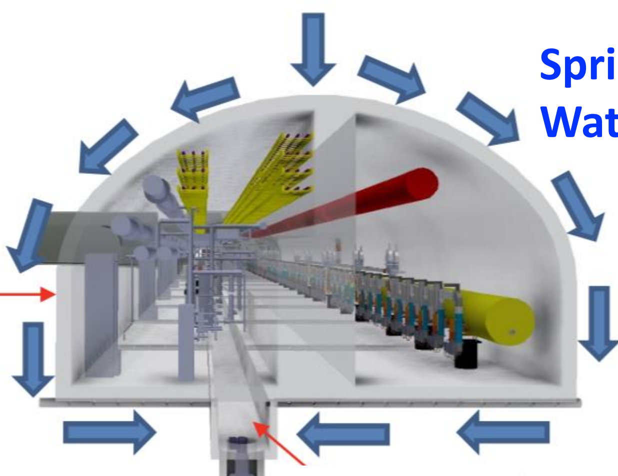
Lining Concrete （30cm）

Frame for Linings

ILCトンネルML標準断面

Spring Water

覆工コンクリート厚30cm



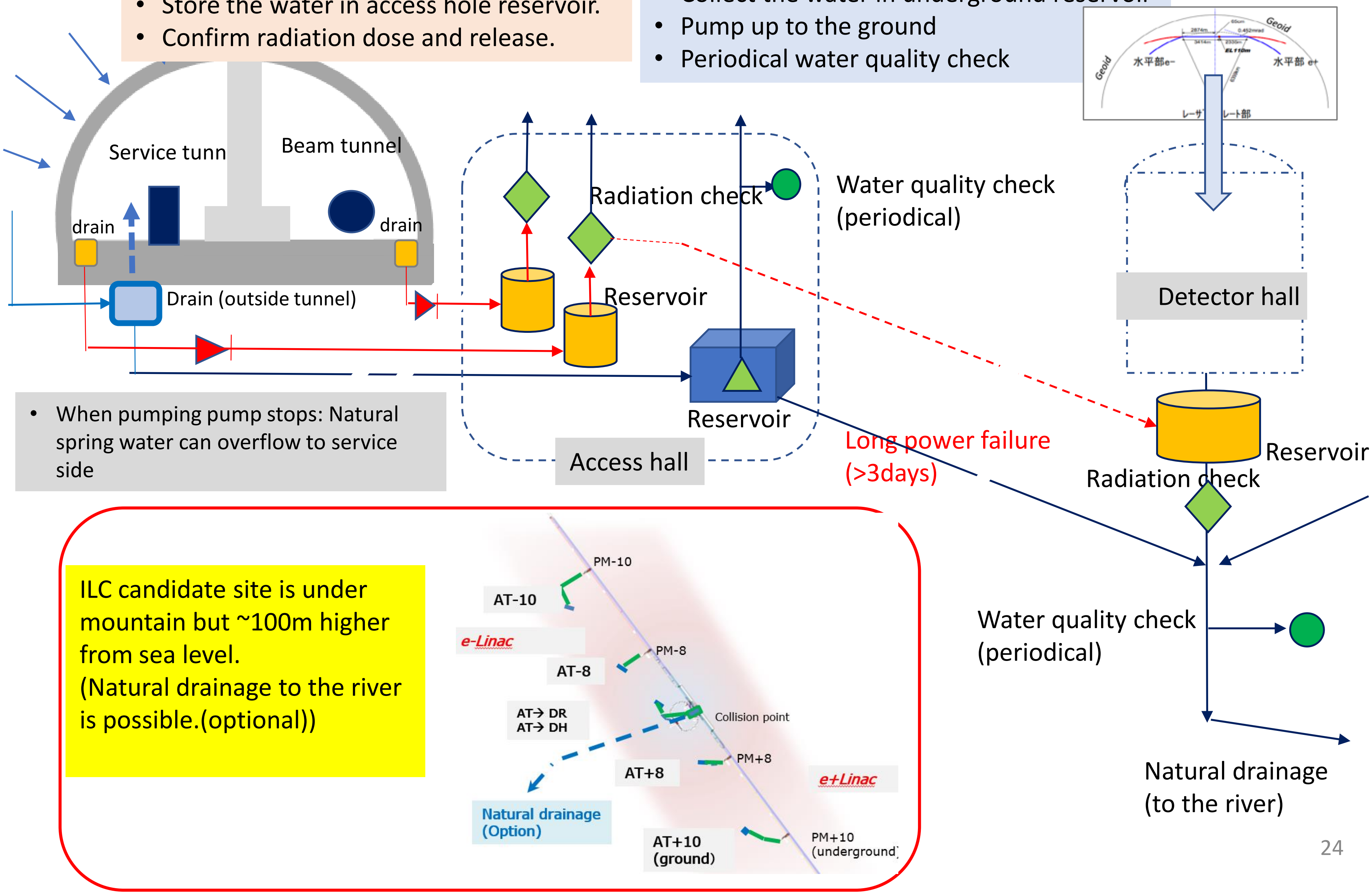
Drainage trench

(W1.0m× H1.0m)

ILC tunnel drainage concept

Tunnel inside drain (managed drainage)
- Store the water in access hole reservoir.
- Confirm radiation dose and release.

Natural spring water (unmanaged drainage)
- Collect the water in underground reservoir
- Pump up to the ground
- Periodical water quality check



Major discussions link to the CFS

- Radiation safety
  - Beam dump and its Tritium water
- Long-term power blackout
- Spring water around the tunnel
- **Environmental assessment**

Environmental assessment at CERN-LHC

https://cds.cern.ch/record/348945/files/LHC-etude-impact.pdf

Contents of the environmental assessment report (384 pages):

1. Scientific significance of LHC
2. LHC accelerator
3. LHC experiment
4. Construction plan
5. Promotion of construction
6. Confirmation of initial environmental conditions
7. The impact of LHC on the environment
8. Environment conservation, impact reduction / compensation measures

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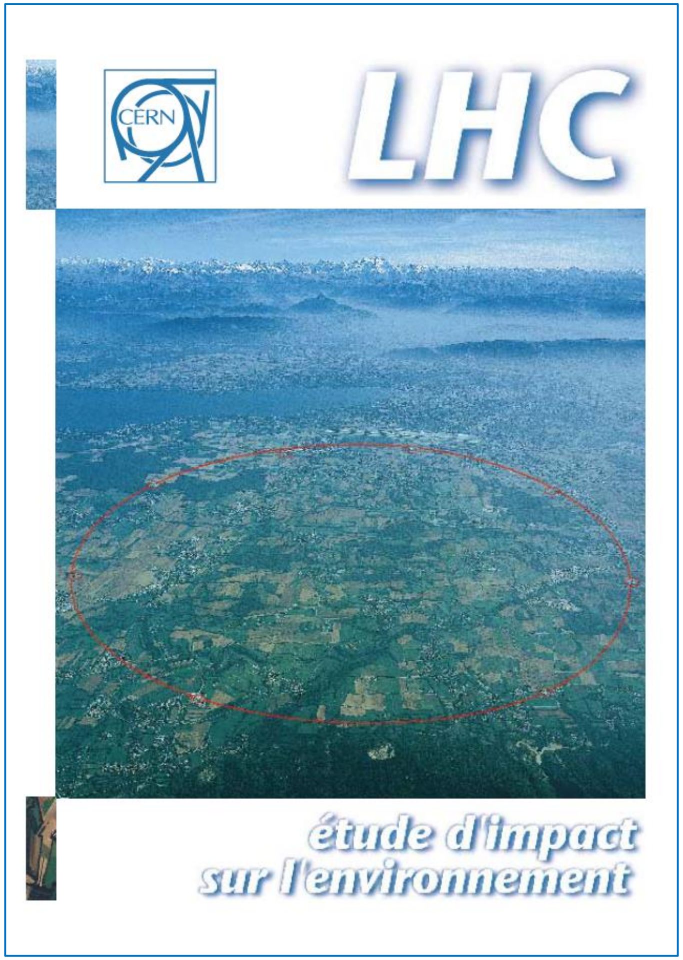
Note:
Site planning is concretely summarized.(as a result of mutual understanding through dialogue with local municipalities /residents (> 2 years))

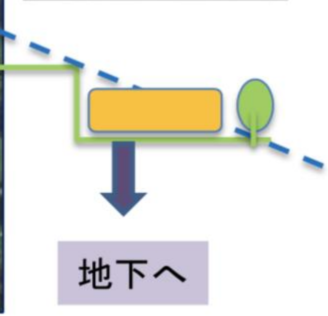
These experiences at CERN-LHC can be applied to ILC.



自然環境と調和するCERN-LHC 地上アクセス施設 (P4)

- 斜面切取窪地に地上施設を配置。 安全、環境、景観に効果的に対処
- ILCでの地上施設(アクセスポイント)での構想として参照

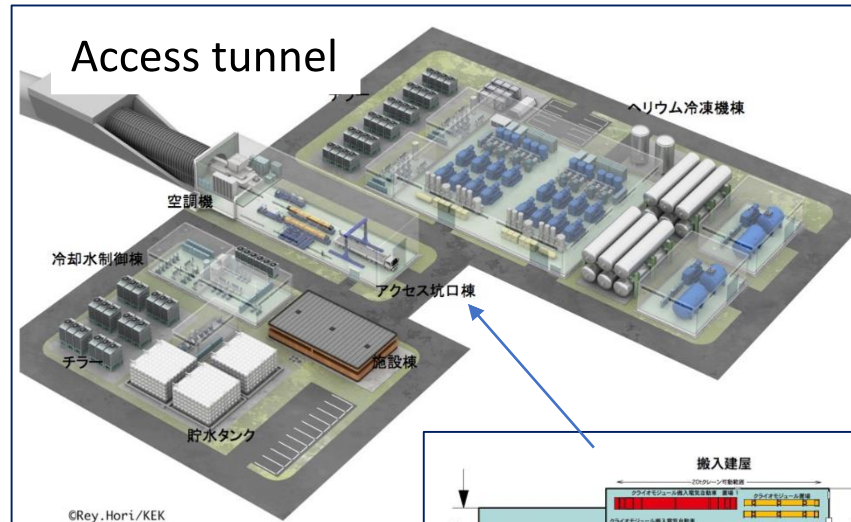
- 景観、自然環境に配慮した地上アクセス施設
- 木々に囲まれ、斜面・窪地を活用した自然水の排水



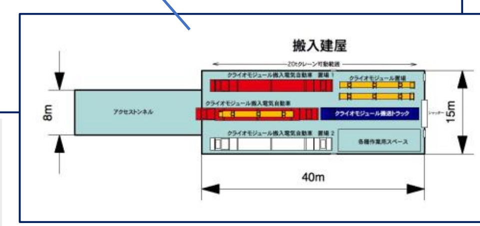
ILC ground facility (reference: LEP/LHC/P4)

LEP/LHC/P4：
Cut high slope to the left

establish a campus design to preserve the landscape.
(After dialogue with residents of the village on the mountain side)



ILC Ground facility outline.
The left side is the entrance of the access tunnel
("Tohoku" plan)



Ground building overview

Thank you for your attention!