18th IDT WG2 DR/BDS/DUMP group meeting

Wednesday Jul 21, 2021, 10:00 PM → 11:00 PM Asia/Tokyo

10:00 PM → 10:20 PM **WBS from the perspective of WP16**
Speaker: Brett Parker (BNL)

10:20 PM → 10:40 PM **Draft document on our progress from 2018 on the issues identified in the Advisory Panel report**
Speaker: Toshiyuki Okugi (KEK)

IDT_okugi_2021072... IDT_okugi_2021072...

Attendees : Stephen Brooks, Karsten Buesser, Philip Burrows, Andy Lankford, Andrea Latina, Thomas Markiewicz, Shin Michizono, Kiyoshi Kubo, Toshiyuki Okugi, Brett Parker, Jean-Luc Vay, Kaoru Yokoya , Mikhail Zobov

B. Parker presented a draft of the WBS for WP16.

- The scope of WP16 should be from Service cryostat to QD0 cryostat, and the cryogenics group should be in charge of the He transfer line from Cryogenics to Service cryostat.
- The QF1 package will require the same WBS as the QD0 package for WP16.

Draft document on our progress from 2018 on the issues identified in the Advisory Panel report
(Original is in Japanese)

Main message to MEXT advisedly committee

- *We have almost finished what we could do with the current system.*
- *Further progress will be difficult without the ILC Pre-Lab!*
  (Preparatory phase in the international framework)

3. 技術的成立性の明確化 [1] ILC加速器等 （ダンピングリング）

有識者会議・学術会議の指摘

- ビームダンプや陽電子源、電子源、ビーム制御、ダンピングリングの入出射システム等についてはいまだ課題が多い。（有識者会議 p.5,12）

2018年以降の取り組み

- KEKのATFにおいて、ILCダンピングリングの入出射システムの高速キッカーシステムの原理実証試験が行われ、設置場所の制約によりビームとのタイミング制御を含めた入出射システムとしてのビームキックの長期安定性試験は出来ていないが、ILCダンピングリングで使用予定の高速キッカーシステムを使った入出射システムの原理実証ができた（2018以前の成果）。
- ILCのために開発を進めてきた高速キッカーシステムは、世界で実現可能な技術として考えられるようになってきており、LBNLなどでは次世代放射光施設におけるSwap-out入射や、CLICダンピングでも高速キッカーシステムが入出射システムに組み込まれるなど、近年高速キッカーへの要求や関心が高まっており、そのための開発研究も進められている。これら世界で進められている高速キッカーの技術をILCに活用することで、ILCダンピングリングの入出射システムをより高性能なものへと高度化することが可能になるとの提案もなされている。
- 2019年10月にKEKの国際WGで高速キッカーシステムの長期安定性試験への対応が議論され、ILCダンピングリングの入出射システムの高度化を包括的に進めるための取り組みと国際協力の候補となる国が報告書に記載されている。そして、国際WGの提案を基に、現在IDT WG2ではILC準備研究所期間中の国際協力によるATFでの高速キッカーを用いた入出射システムの高度化に伴う試験計画を立てている(WP14)。
- 準備研究所期間には、ATF取り出しラインに高速キッカーを使ったビームキック試験が常時行えるビームラインを構築する（国際協力によるビームラインの再構築）ことで、入出射システムとしてのILC高速キッカーのビームキックの長期安定性試験を行うとともに、海外で開発が進められてきた新たなキッカー技術のILCへの適用可能性を調べることが可能になると考えており、これらを通して ILC ダンピングリングの入出射システムの高度化を包括的に進める。

Damping Ring

Table 4.1: Summary of the ILC Advisory Panel's Discussions to Date after Revision. The quoted page numbers refer to those of the ILC Advisory Panel's report.[21]

Page #	R&D Issues
5, 13, 32	[**Damping Ring**] There still remain issues on several subsystems, such as beam dump, positron source, electron source, beam control, and the injection/extraction of the damping ring.

Original draft is in Japanese

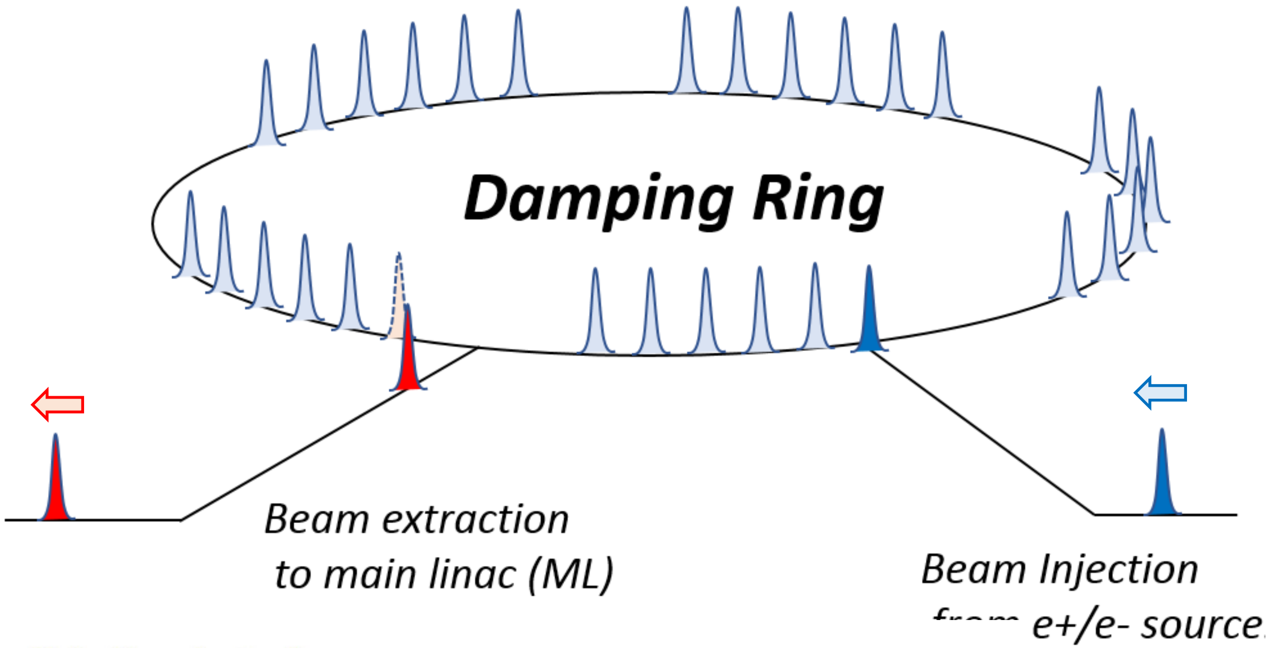
Efforts in 2018 and beyond

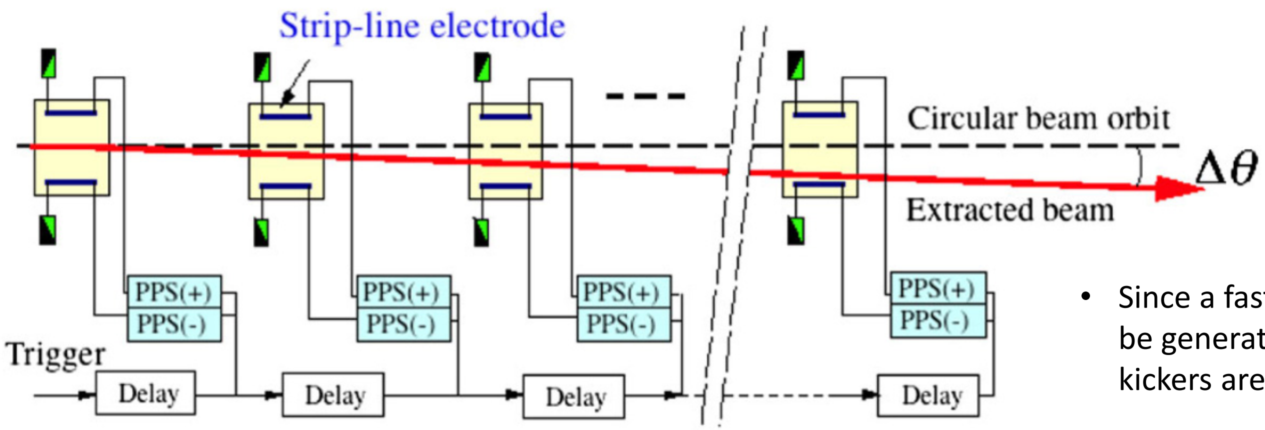
- At the KEK ATF, the proof-of-principle test of the fast kicker system for the injection/extraction system of the ILC damping ring was demonstrated. Although the long-term stability test of the beam kick as the injection/extraction system including the timing control with the beam was not possible due to the limitation of the installation location, the proof-of-principle test of the injection/extraction system using the fast kicker system planned to be used in the ILC damping ring was achieved (results before 2018).
- The fast kicker system, which has been developed for ILC, is now considered as a feasible technology in the world. In recent years, there has been a growing demand and interest in the fast kickers, and research and development of such systems are underway. It has been proposed that by utilizing the fast kicker technology in the ILC, it will be possible to upgrade the injection/extraction system of the ILC damping ring to a higher performance one.
- In October 2019, the KEK International WG discussed the response to the long-term stability test of the fast kicker system, and the report describes the efforts to comprehensively advance the upgrading of the injection/extraction system of the ILC damping ring and the candidate countries for international cooperation. And based on the proposal of the KEK international WG, IDT WG2 is now planning the test plan for the international cooperation during the ILC Pre-Lab period for the upgrading of the injection/extraction system with a fast kicker at ATF (WP14).
- During the ILC Pre-Lab period, we will construct a beamline at the ATF extraction line where the beam kick test using the fast kicker can be performed at all times (reconstruction of the beamline by international cooperation). This will enable us to test the long-term stability of the beam kick of the ILC fast kicker as an injection/extraction system, and to investigate the applicability of new kicker technologies developed overseas to ILC.

ENGLISH

Overview of the injection/extraction system to the ILC damping ring

- The beam from the electron/positron sources are injected into the damping ring using a fast kicker.
- The beam is extracted from the damping ring by picking up the individual beams that are stored in the damping ring.
- A fast kicker must be used for the injection and ejection to avoid affecting the neighboring bunches.





- Since a fast response is required, the kicker voltage that can be generated by a single kicker is limited, and multiple kickers are lined up in series to kick out the beam.

Proof-of-principle test of fast kicker

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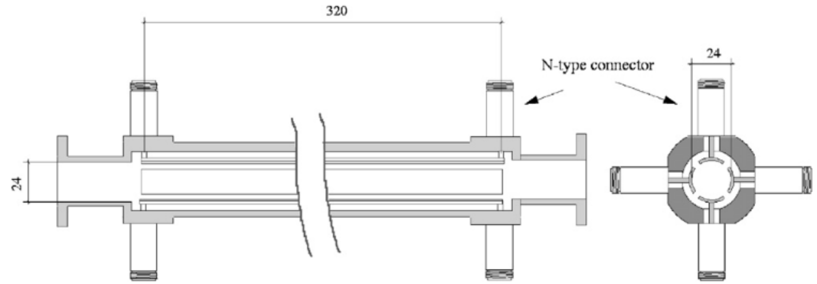
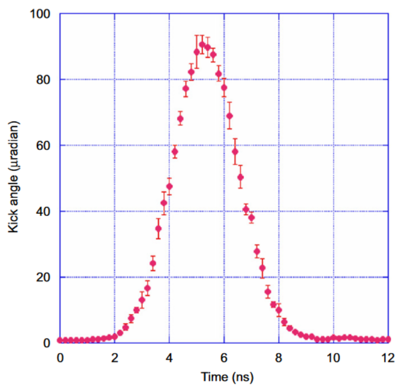
Response time test of fast kicker in ATF damping ring

The time response of the fast kicker and pulsar to be used in the ILC damping ring was verified using a beam.

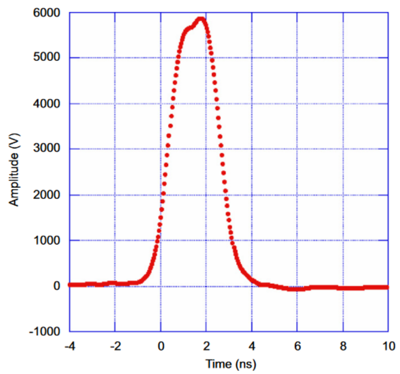
Prototype of ILC stripline kicker



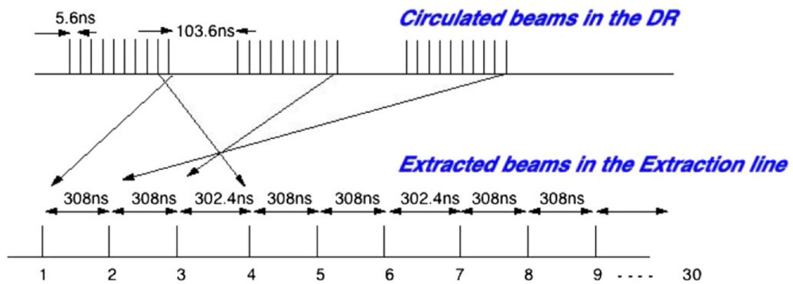
Kick amplitude measurement at ATF DR

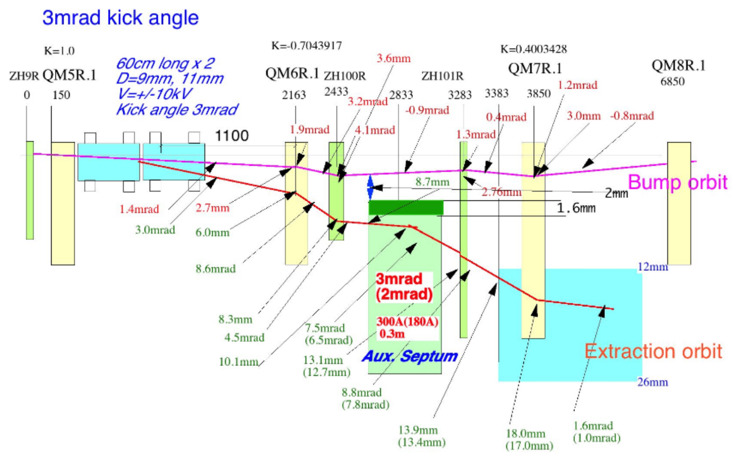


Output voltage of the pulser

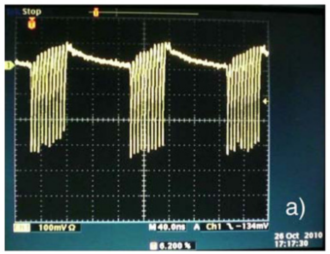


Beam extraction test from ATF damping ring

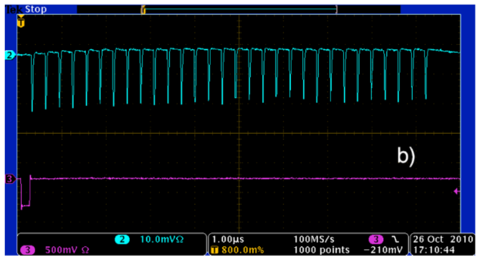




Stored beam in DR



Extracted beam from DR



- Due to the limitation of the space, we had to use devices such as orbital bumps and auxiliary septum, which are not used in ILC, for the fast kicker demonstration.
- In the ATF DR, the beam intensity cannot be increased due to the influence of Synchrotron radiation on the kicker, so it is difficult to use the beam in compatible with other experiments here.

- During the ILC Pre-Lab period, a new kicker test beamline is planned to be constructed at the ATF extraction line to test the long-term stability of the beam kick as an injection/extraction system, including the timing control with the beam.

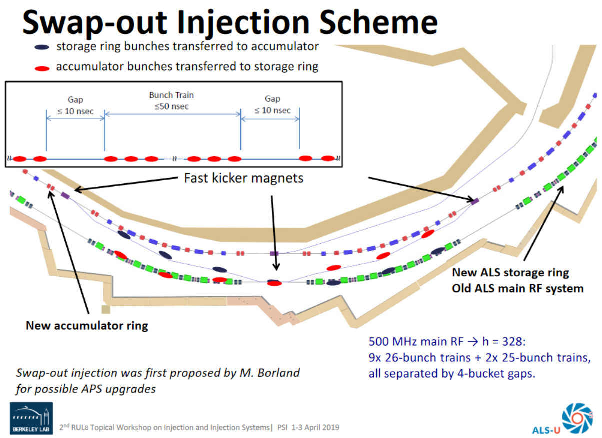
Request for fast kickers other than ILC and cooperation in Pre-Lab period

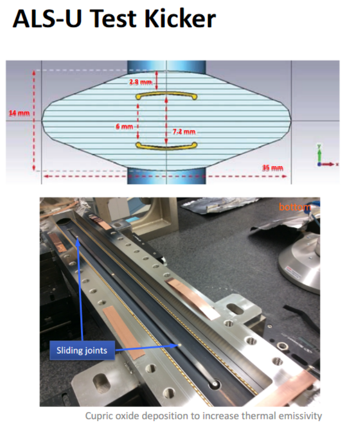
ENGLISH

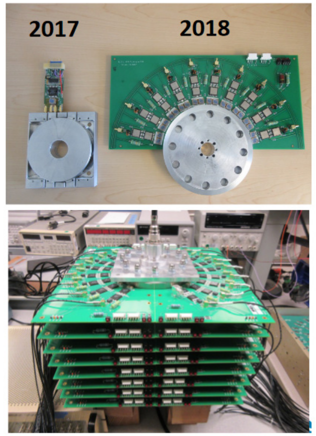
- In recent years, the fast kicker system that has been developed for the ILC has come to be considered as a feasible technology, and looking at accelerators around the world, there is also growing demand for fast kickers outside the ILC.
- During the Pre-Lab period, we are also planning to develop and test a kicker system using similar technology in cooperation with overseas research institutes that are conducting these studies (international cooperation framework is required).

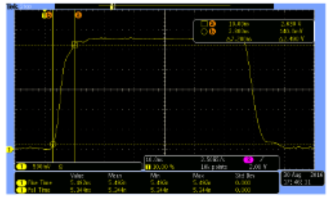
Swap-out injection system being planned at LBNL

In some accelerators in the next generation light source facilities, due to the short beam lifetime, swap-out injection is considered to replace the beam in the light sources with the beam in the storage ring, and a fast kicker is considered to be used.

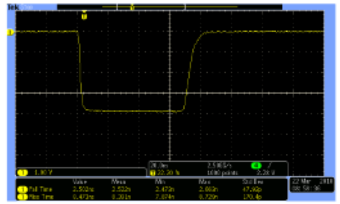








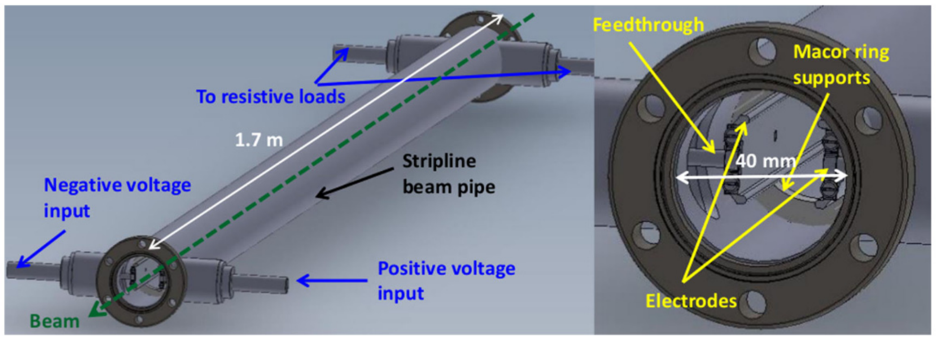
Mod. 2017 –Full kicker

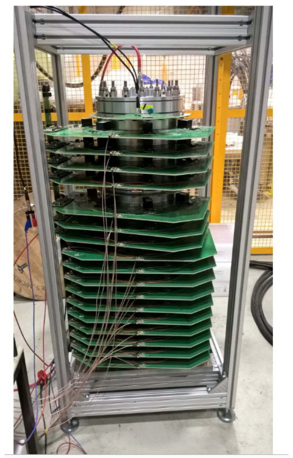


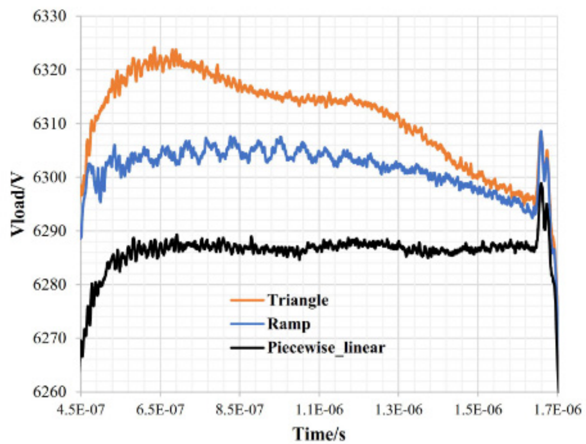
Mod. 2018 –Single stage

Injection/extraction system to CLIC damping ring

A fast kicker will also be used in the CLIC DR injection/extraction systems, and the pulsar technology being studied at CERN will being applied to the ILC to achieve higher pulse voltages.







3. 技術的成立性の明確化　[1] ILC加速器等　（ビーム伝送システム）

有識者会議・学術会議の指摘

- ビームダンプや陽電子源、電子源、ビーム制御、ダンピングリングの入出射システム等についてはいまだ課題が多い。（有識者会議 p.5,12）
- ビーム収束及び位置合わせに関する制御・フィードバック系に関する技術の確立や、衝突点サイトにおける常時微細動の許容レベルに関する定量的評価が必要。（学術会議 p.7）

2018年以降の取り組み

- KEKのATFではナノビーム技術（ビームを絞り、位置安定化も図る）の開発を国際協力で進めてきた。ビームサイズは2016年には41nmとほぼATFでのゴール（37nm、ILCの7.7nmに相当）に到達、ビーム安定性も多バンチでの安定化に必要な短時間でのフィードバック（仕様の366ns以下を満たす133ns）を実現している。これらの成果は 2020年のATFの国際レビュー委員会で高く評価していただいた。
- ILCの設計バンチ内粒子数(2e10)でのビーム誘導電磁場（Wakefield ）の影響はATFにおける(1-2e9)と等価であり、ATFでは更に多くのバンチ内粒子数で運転することが可能なことから、ILCでのビーム誘導電磁場の影響を研究するために最適な環境である。
- 2018年以降は、ILC焦点でのビームサイズのビーム誘導電磁場の影響の研究を中心に進めている。 ATFでの研究を通して、ILCでのビーム誘導電磁場の影響の抑制にも目処が立ってきたが、 ILCの条件で更にビーム誘導電磁場を低減するためには、ビーム誘導電磁場源となるビームダクト等の改造、ATFのアップグレードが必要である。
- ビーム収束及び位置合わせの長期安定化試験のためには、ビームモニター等の増設・アップグレード及び建物の温度安定化などが必須で、これらにもATFのアップグレードが必要になる。
- 長期安定性、ビーム強度依存性の研究のためのビームライン改造計画はATF3計画と呼ばれ、準備研究所機関に国際協力の枠組みで進める予定である(WP15)。2019年10月のKEK国際WGからの報告書には、今後の取り組みの提案と国際協力の候補となる国が記載されている。また、ATF3計画は2020年の国際レビュー委員会で提起され、国際レビュー委員会の委員の方々にもご理解いただいている。
- 衝突点サイトにおける常時微細動の主要因と考えられる最終収束電磁石の振動試験は、準備研究所期間における技術準備計画(WP16)として、国際協力のもと海外研究所の施設で評価をする予定である。

9

Beam delivery system

Table 4.1: Summary of the ILC Advisory Panel's Discussions to Date after Revision. The quoted page numbers refer to those of the ILC Advisory Panel's report.[21]

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5, 13, 32	[**Damping Ring**] There still remain issues on several subsystems, such as beam dump, positron source, electron source, beam control, and the injection/extraction of the damping ring.

Table 4.2: Technical issues pointed out in the report by the Science Council of Japan.[22]

R&D Issues
[**Interaction Region**] The technology for the control and feedback system related to the beam focusing and position control needs be established. The acceptable level of microtremor in the interaction region needs to be quantified.

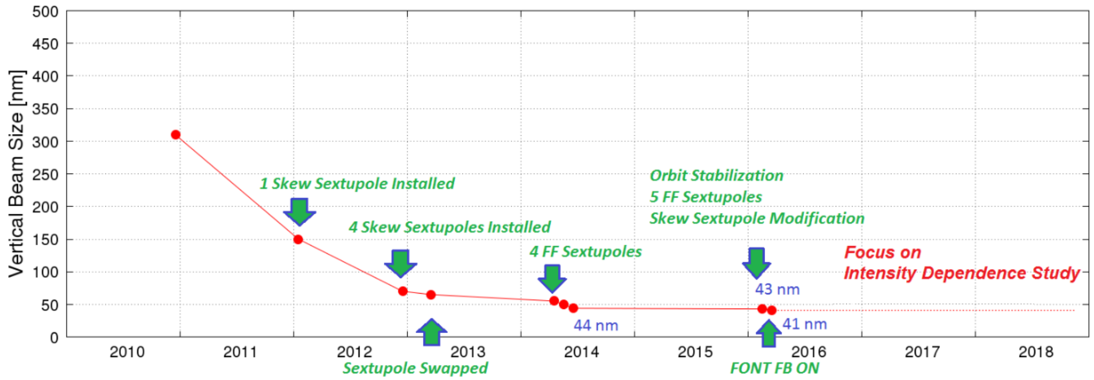
Efforts in 2018 and beyond

Original draft is in Japanese

- The development of nano-beam technology (small beam size and also stabilizing its position) has been promoted in the KEK ATF through the ATF international collaboration. The beam size has almost reached the ATF goal of 41 nm in 2016 (37 nm, equivalent to 7.7 nm in ILC), and the beam stability has achieved the short feedback time (133 ns, which satisfies the specification of 366 ns or less) required for stabilization within the bunch separation of ILC. These results were highly evaluated by the international review committee of ATF in 2020.
- The effect of the wakefield at the ILC design bunch population (N=2e10) is equivalent to that at ATF (N=1-2e9), and ATF is the appropriate environment to study the effect of the wakefield at ILC because it can be operated with much more bunch population.
- From 2018 onwards, we are focusing on studying the effects of wakefield on IP beam size for the ILC. Through the research at the ATF, we have been able to suppress the effect of wakefield at the ILC. However, in order to further reduce the wakefield under the ILC conditions, we need to modify the beam ducts, etc., which are the sources of the wakefield, and we need to upgrade the ATF.
- For long-term stability tests to focus the IP beam size and to stabilize its position, additional and upgraded beam monitors, etc., and temperature stabilization of the building are required, and ATF upgrades are also necessary.
- The beamline modification plan for long-term stability and beam intensity dependence studies is called the ATF3 project, and will be pursued in the framework of international cooperation with the ILC Pre-Lab Organization (WP15); the report from the KEK International WG in October 2019 includes proposals for future efforts and candidate countries for international cooperation. In addition, the ATF3 project has been proposed at the 2020 ATF International Review Committee meeting and is understood by the members of the International Review Committee.
- The vibration test of the Final Focus magnet, which is considered to be the main cause of the vibration at the IP site, will be evaluated at the facilities of overseas laboratories under international cooperation as the Technical Preparation Plan (WP16) during the Pre-Lab period.

ENGLISH

History of beam size at ATF focus point



The results by 2020 were compiled into a report through international cooperation, and the ATF review was held in September 2020.

ATF Review 2020

29 Sep 2020, 19:30 → 30 Sep 2020, 00:00 Asia/Tokyo

ATF Report 2020:
https://agenda.linearcollider.org/event/8626/attachments/35702/55436/ATF_Review_Report_2020_0831.pdf

ATF Review:
https://agenda.linearcollider.org/event/8626/

Charge 1: Evaluate the scientific results at ATF/ATF-2

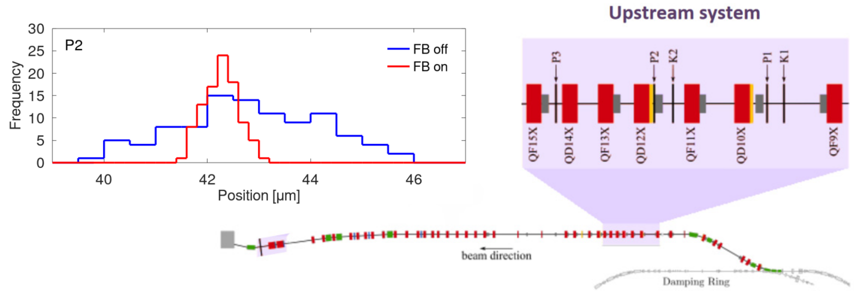
Charge 2: Evaluate future ATF operation for LC R&Ds

Charge 3: Evaluate future ATF operation (other than LC)

Masahiro Katoh Hiroshima U.
Katsunobu Oide (chair) KEK/CERN
Tatiana Pieloni EPFL
Vladimir Shiltsev FNAL
Zhentang Zhao SARI

Beam position stabilization at ATF focus point

- Confirmation of IP beam position jitter by FONT intra-train FB



	Beam Size	Position Jitter	
		FB-OFF	FB-ON
FONTP2	4.2 μm	1.39 ± 0.10 μm	0.34 ± 0.02 μm
FONTP3	8.9 μm	0.93 ± 0.07 μm	0.27 ± 0.02 μm

- Extrapolation to position jitter at ATF2 IP (beam size 37 nm)
  2.9 nm (FB-OFF) ⇒ **1.2 nm (FB-ON)**

Report of the ATF Review Committee

Scientific results at ATF/ATF2

*The committee has been impressed on **outstanding and unique results achieved in ATF/ATF2**:*

- *The smallest spot size, 40 nm, in any accelerators.*
- *Intra-train bunch orbit feedback (FONT).*
- *Vertical emittance in the ring, 4 pm, smallest at the beginning of the century.*

Future ATF operation for LC R&Ds

*The committee recognizes that the achievements at ATF/ATF2 have already verified the minimum technical feasibility on the beam focusing and control for the ILC. However **there will be a number of possibilities for further extensions** to investigate:*

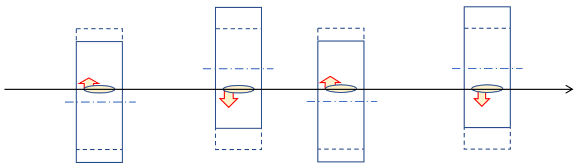
- *intensity dependent effects on the spot size*
- *optical aberrations, esp. with smaller horizontal β**
- *beam halo and collimation*
- *even smaller spot sizes with higher chromaticities*

ENGLISH

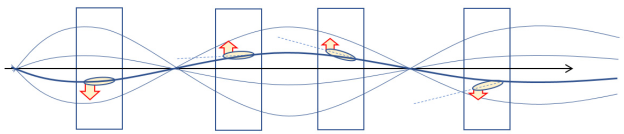
Comparison of the effects of the wakefield at the ILC250 and ATF2 IP

- A beam size of 41 nm was achieved at N=1e9 in ATF.
- The effect of the wakefield on the designed bunch population of ILC (2e10) is equivalent to (1-2e9) in ATF.

Effect of static wakefield （generated by misalignment）



Effect of dynamic wakefield （generated by orbit jitter）



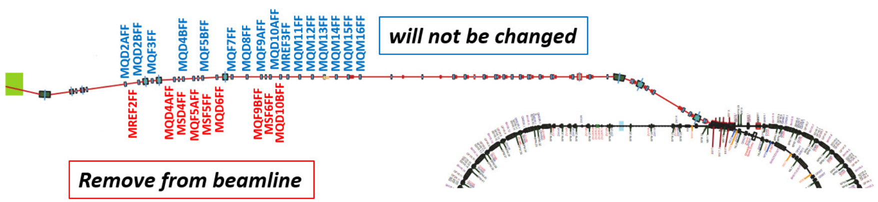
Relative effect of misalignment and orbit jitter at ILC and ATF2

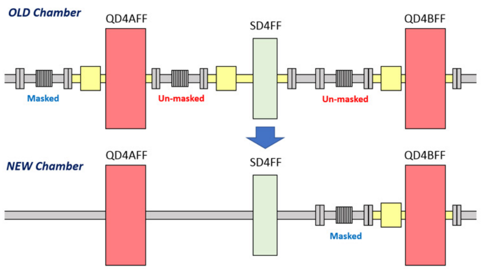
	ILC	ATF	Ratio of effect (ILC/ATF)	
			misalignment	orbit jitter
Beam Energy	125 GeV	1.3 GeV	0.01	0.01
Bunch Length	0.3 mm	7.0 mm	0.5	0.5
Emittance	0.16 pm	12 pm	8.7	1
Sum of β_y	390 km	61 km	2.5	6.7
Total			0.11	0.032

The ATF is an ideal environment to study the effects of wakefield at the ILC, since it can be operated with a larger bunch population.

Wakefield causes the intensity dependence of IP beam size

- Since the effect of Wakefield is proportional to the bunch population, it appears as an intensity dependence of the IP beam size.
- The relationship between the wakefield and the beam intensity dependence of the IP beam size was investigated by reducing the wakefield source along the beamline.

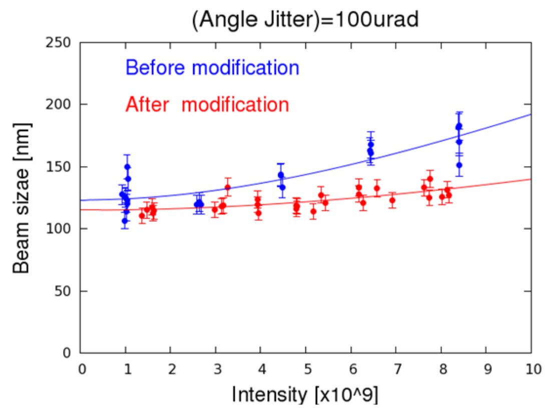




Number of elements overall ATF2 beamline

	Cavity BPM	*Un-mask Bellows*	*Flange gap*
OLD setup	*23*	*11*	*87*
NEW setup	*15*	*5*	*69*
Difference	*8*	*6*	*18*

- By reducing the wakefield sources, the beam intensity dependence was reduced for the same angular jitter size.
- The wakefield was found to be a major factor in the beam intensity dependence.



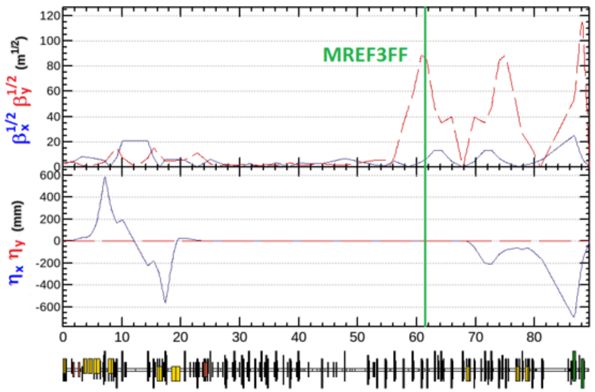
ENGLISH

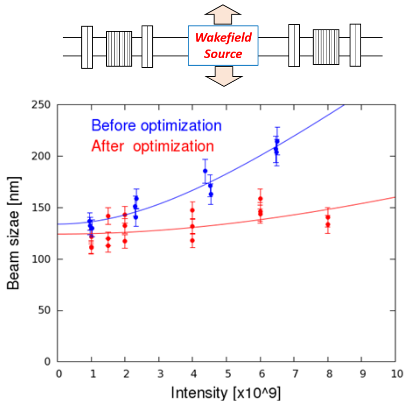
Reduction of the effects of static wakefield

Static wakefield reduction test at ATF

A movable wakefield source is placed in the beamline and its position is optimized to cancel the effect of the wakefield on the entire beamline.

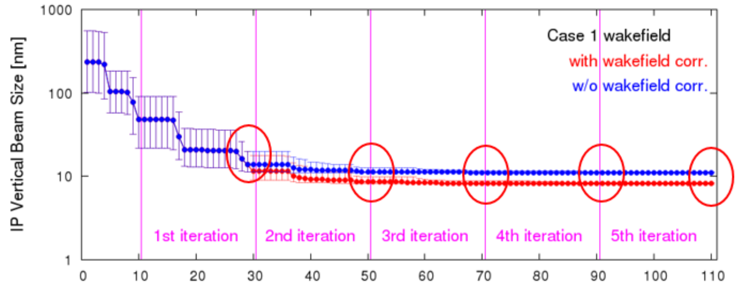
=> The intensity dependence coused by wakefield was reduced.

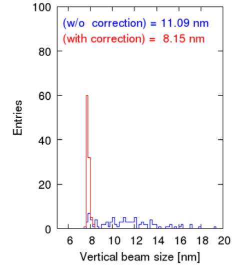




Simulation of the reduction of static wakefield effect for ILC250

- Prepare a beamline that assumes the wakefield source assumed for ILC250.
- Insert to the beam tuning process a tuning mechanism using a movable wakefield source that has been proven effective at ATF.
- It was found that the effect of the wakefield can be suppressed at the ILC beam intensity (N=2e10).

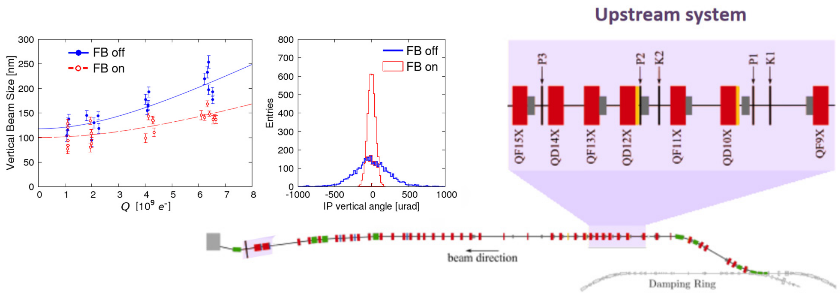




Reduction of the effects of dynamic wakefield

Dynamic wakefield reduction test at ATF

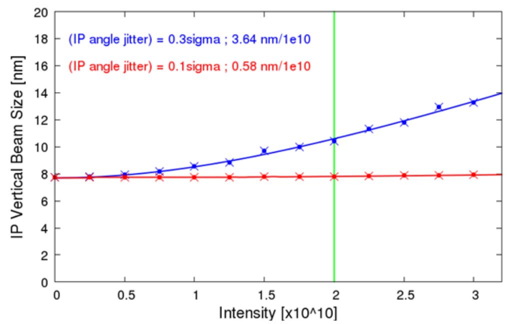
By reducing the beam jitter through FONT feedback, the beam intensity dependence of the IP beam size due to the wakefield was also reduced.



	IP angle jitter	Intensity dependence
Single bunch operation	220 μrad	25.1±1.5 nm/$1\times10^9 e^-$
2 bunch operation without FB	215 μrad	27.4±1.9 nm/$1\times10^9 e^-$
2 bunch operation with FB	50.6 μrad	16.9±1.6 nm/$1\times10^9 e^-$

Simulation of the reduction of dynamic wakefield effect for ILC250

- Prepare a beamline that assumes the wakefield source assumed for ILC250.
- By comparing the effect of beam intensity dependence caused by the wakefield source with different beam jitter magnitudes, it was found that jitter reduction by feedback is also effective for the ILC250.



30% jitter	10.57 nm (37.96%)
10% jitter	8.06 nm (5.27%)

Optimization of the wakefield source for the ILC beamline can further reduce the requirements for feedback, etc.

3. 技術的成立性の明確化 ［1］ILC加速器等 （ビームダンプ）

Original Draft in Japanese

有識者会議・学術会議の指摘

- 特に、ビームダンプについては、衝突エネルギーが500GeVから250GeVになったことで、設計の尤度は増加したものの、ハイパワーのビームを定常的かつ高い信頼性をもって受け続けられる窓の耐久性や窓の定期的な交換作業技術、耐震性能等を含め、本準備期間においてダンプシステムとして技術を完成させる必要がある。（有識者会議 p.42）
- 窓材の健全性モニタリング、遠隔操作による交換作業システムの具体的設計、高エネルギービームと水との反応で起こる事象の詳細については、準備期間に十分な検討が進められなければならない。（学術会議 p.7）

2018年以降の取り組み

ILCビームダンプの基本設計は、SLACの2.2MW水ダンプをもとに海外研究者が中心となってまとめられた。KEKは国内外の高出力ビーム標的・ビームダンプの研究者と協議を進め、設計の具体化に取り組んできた。

- 国内外の主なビームダンプ・標的の視察と担当者との協議・連携
  - J-PARC：中性子、ミューオン標的システム
  - SLACおよびJLAB (CEBAF)の水ダンプ
  - CERN LHCビームダンプ
  - 高出力ビーム標的・ビームダンプの国際研究コラボレーションであるRADIATEからの支援
- ビームダンプ地下空洞の基本設計：AAAプロジェクト推進部会 安全・防災WGと連携

次は主要部品（ビーム窓およびその遠隔交換システム等）のプロトタイプ作成と実際のダンプシステムの詳細技術設計作業を行う段階である。

2019年10月にKEKの国際WGにより技術課題への対応が議論され、取り組みと国際協力の候補となる国が報告書に記載されている。

準備期間に国際協力で課題を解決するよう、IDTで検討を行っている。

Beam Dump

Translated by DeepL

Technical issues pointed out in the report by the ILC Advisory Panel and SCJ

- The whole beam dump system should be developed in the main preparatory phase. The required technologies include durability of the window, where continuous high-power beam pass through, and its maintainability and resistance to earthquakes. (ILC Advisory Panel)
- The soundness monitoring of the window material, the concrete design for a remote- controlled replacement/exchange system, and the detail of the reaction between a high energy beam and water need to be adequately studied during the main preparatory phase. (SCJ)

Development after 2018

The basic design of the ILC beam dump was compiled mainly by overseas researchers based on the 2.2 MW water dump at SLAC. KEK has been discussing with domestic and overseas researchers of high power beam targets and beam dumps to materialize the design.

- Visits to major beam dumps and targets in Japan and abroad, and discussions and collaborations with personnel in charge
  - J-PARC: Neutron and muon target system
  - SLAC and JLAB (CEBAF) water dumps
  - CERN LHC beam dump
  - Advices from RADIATE, an international research collaboration for high power beam target and beam dump
- Basic design of underground cavity for beam dump: AAA Project Steering Group: working with Safety and Disaster Prevention WG

The next step is the prototyping of the main components (e.g., beam windows and their remote replacement systems) and the detailed technical design work of the actual dump system.

In October 2019, the International WG of KEK discussed how to deal with the technical issues, and the methods and candidate countries for international cooperation were described in the report.

In the IDT, a Work Package was compiled to solve the issues through international cooperation during the preparation period.

Original Draft is in Japanese

International Cooperation for ILC Beam Dump Design

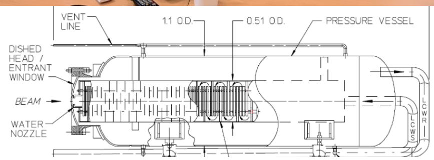
- **Cooperation with CERN LHC dump experts (2017~)**

Visit of the LHC beam dump(CERN)

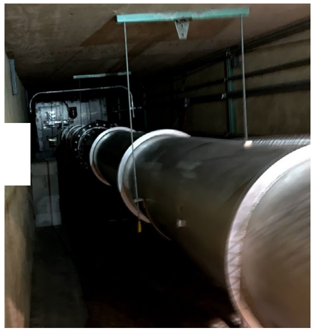
LHC beam dump window

- **Cooperation with SLAC and JLAB**

Visit of SLAC 2.2MW water dump (2019)



Visit of JLAB 1MW water dump (2019)



- **Advices from RADIATE, an international research collaboration for high power beam target and beam dump (2017~)**

- **Cooperation with J-PARC experts**

- Activated water system
- Manupulator design
- Terget handling design

Neutron target and Remote Maintenance System (2018)

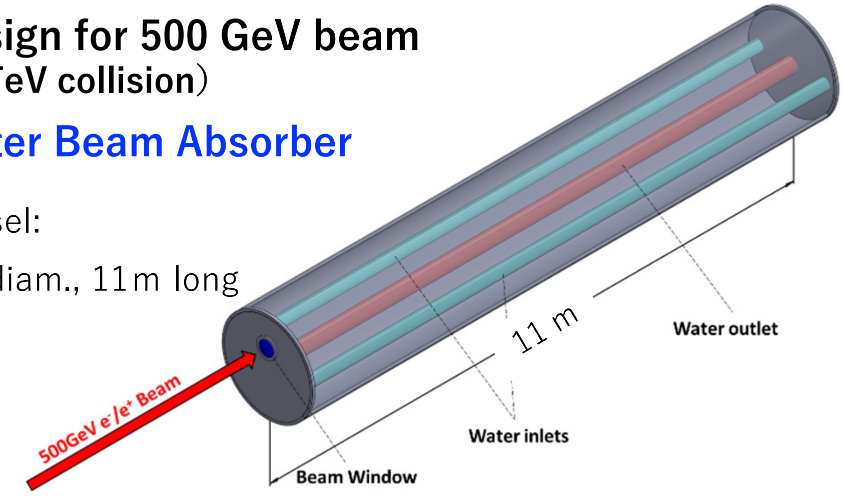
ILC Beam Dump

Design for 500 GeV beam
（1TeV collision）

Water Beam Absorber

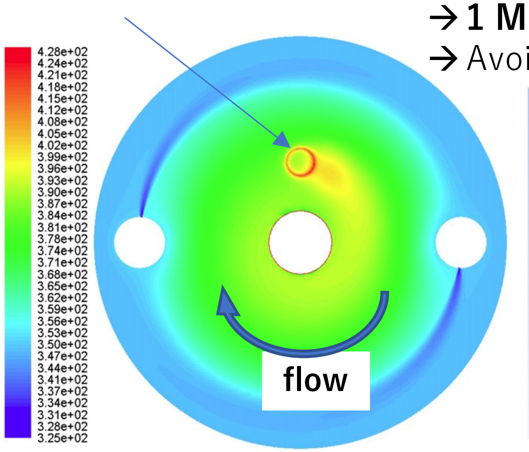
Vessel:

2m diam., 11m long



Diffusion of beam heat by vortex flow

Beam

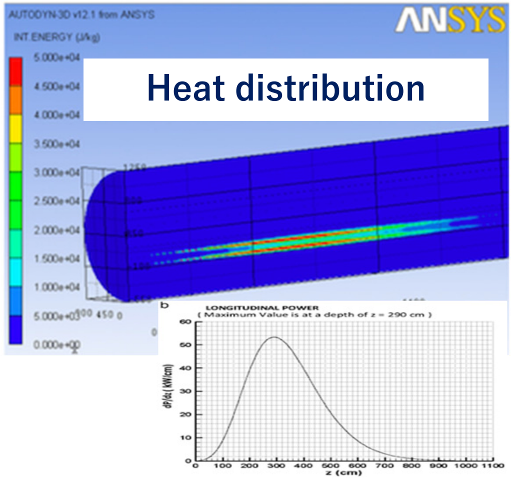


Max water temperature: 155 ℃

→ **1 MPa** to suppress a boiling

→ Avoid cavitation

Heat distribution



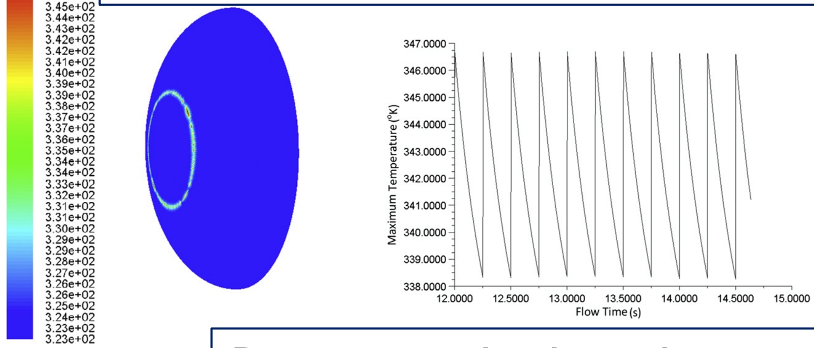
Original Draft is in Japanese

Design by simulations

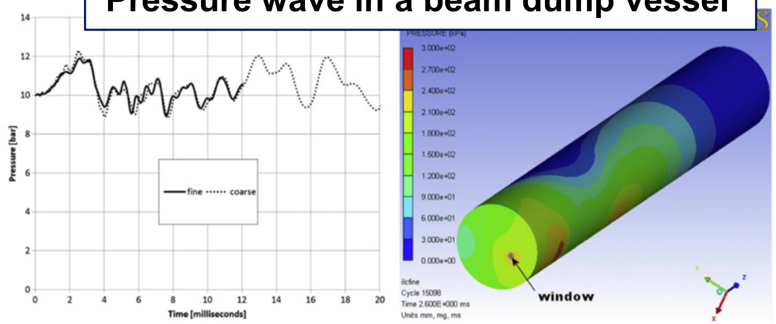
ANSYS: Fluid analysis, thermal load and stress analysis, pressure propagation analysis

FULKA: Quantification of activation and radiation dose, calculation of shielding

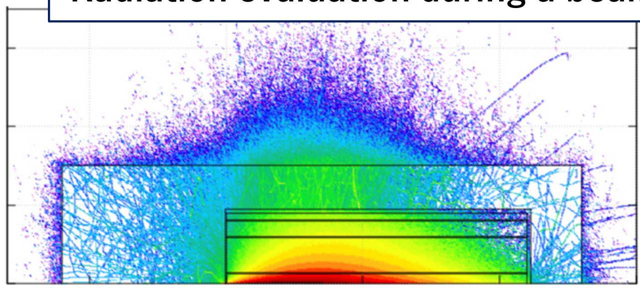
Stress in a window due to repetitive beam



Pressure wave in a beam dump vessel

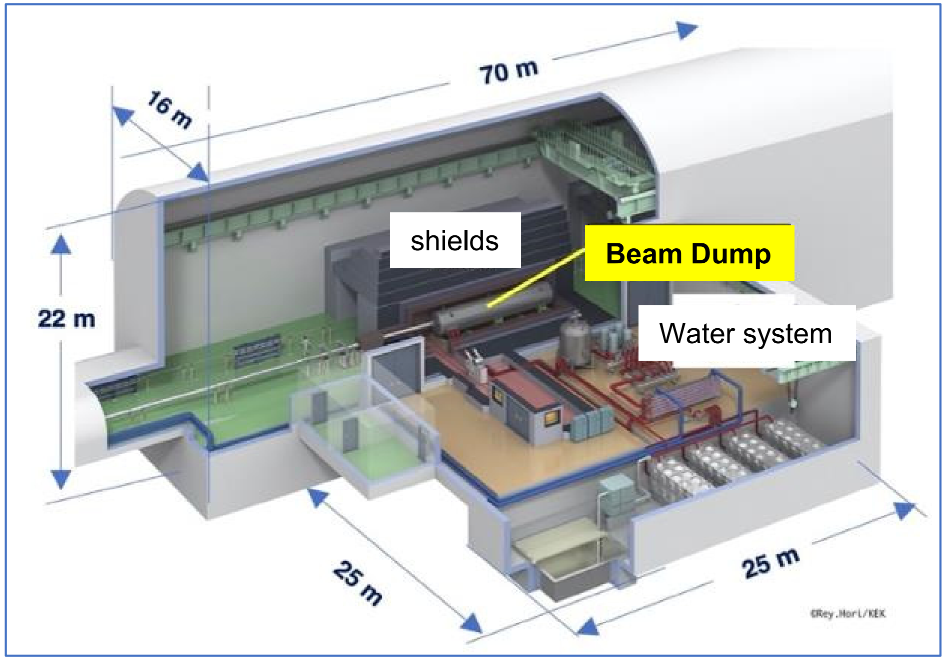


Radiation evaluation during a beam



Original Draft is in Japanese

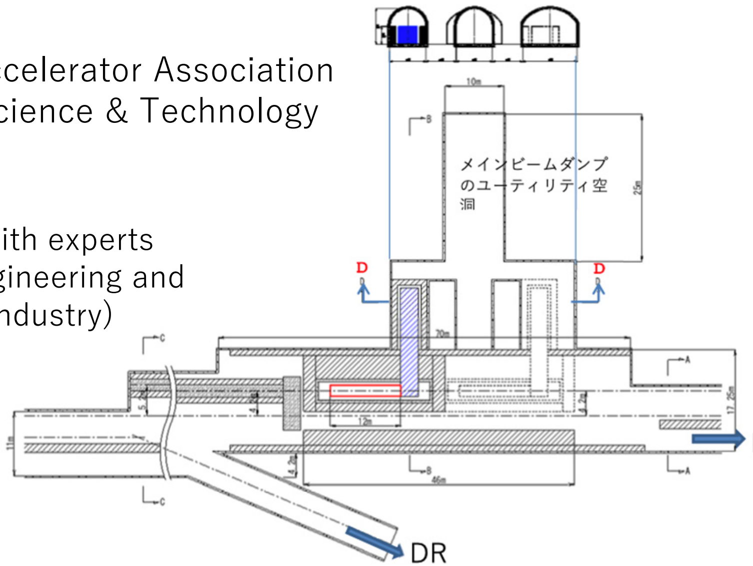
Design of Beam Dump Facility



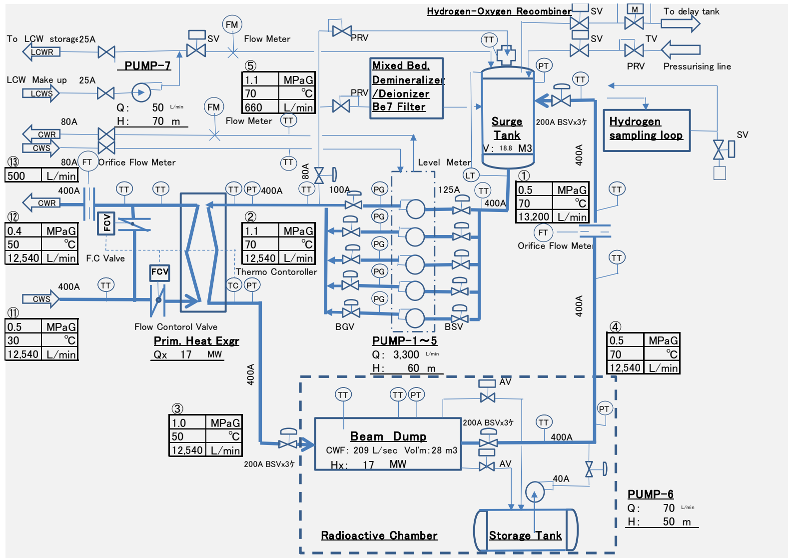
Civil Engineering design by AAA (2019)

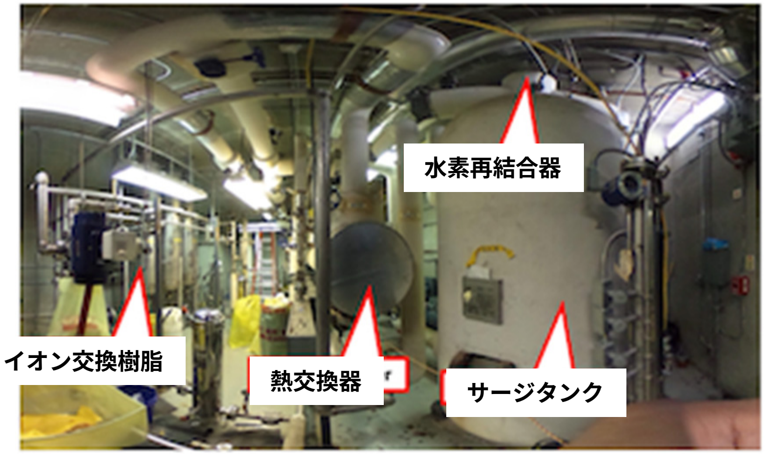
Advanced Accelerator Association Promoting Science & Technology (AAA)

(Discussion with experts in the civil engineering and construction industry)



Design update of circulating water system (2020)





Visit of JLAB: CEBAF 1MW water dump, circulating water system (2019)