# High power targets of ILC: beam dump window and positron target

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KEK ILC group

May 31, 2017, FNAL

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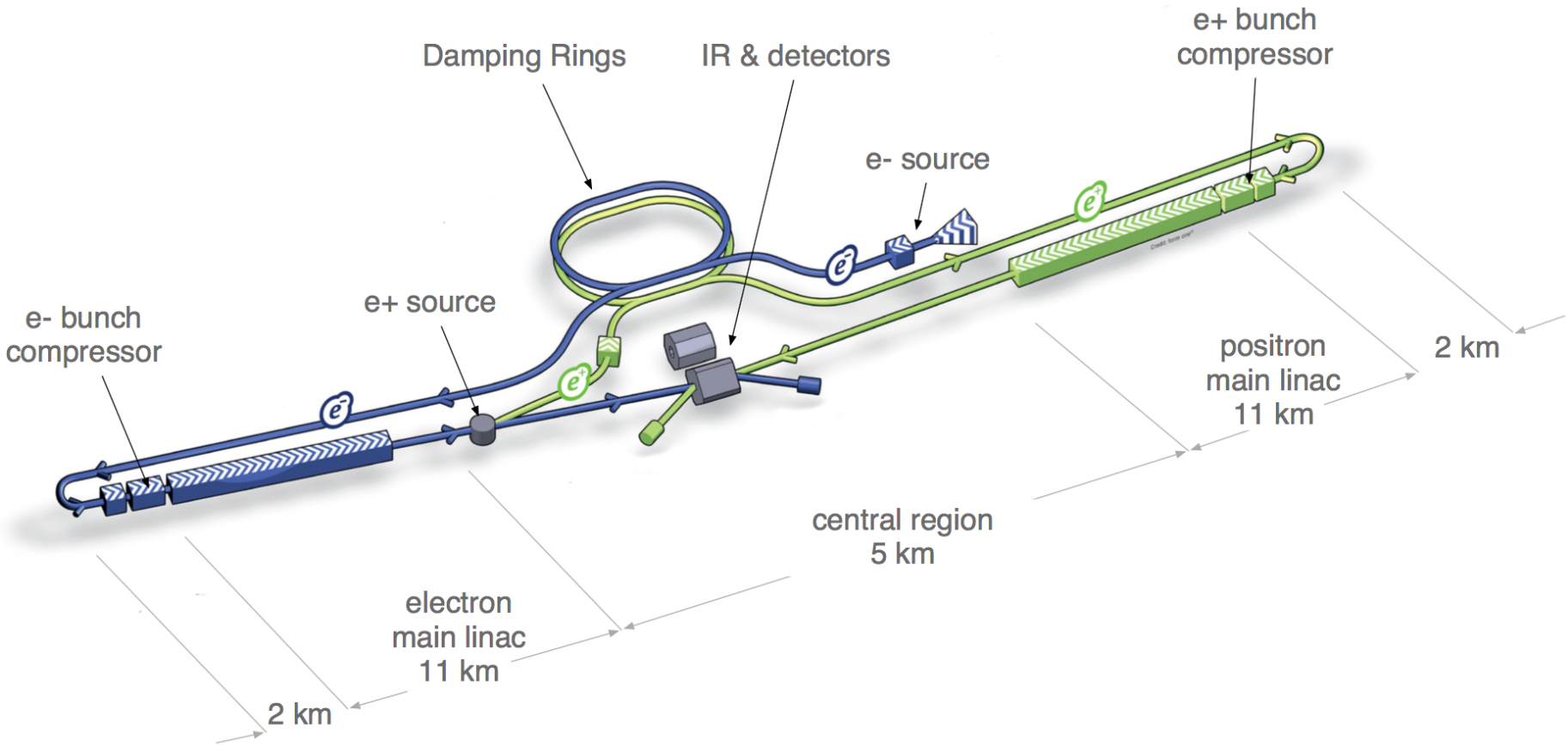
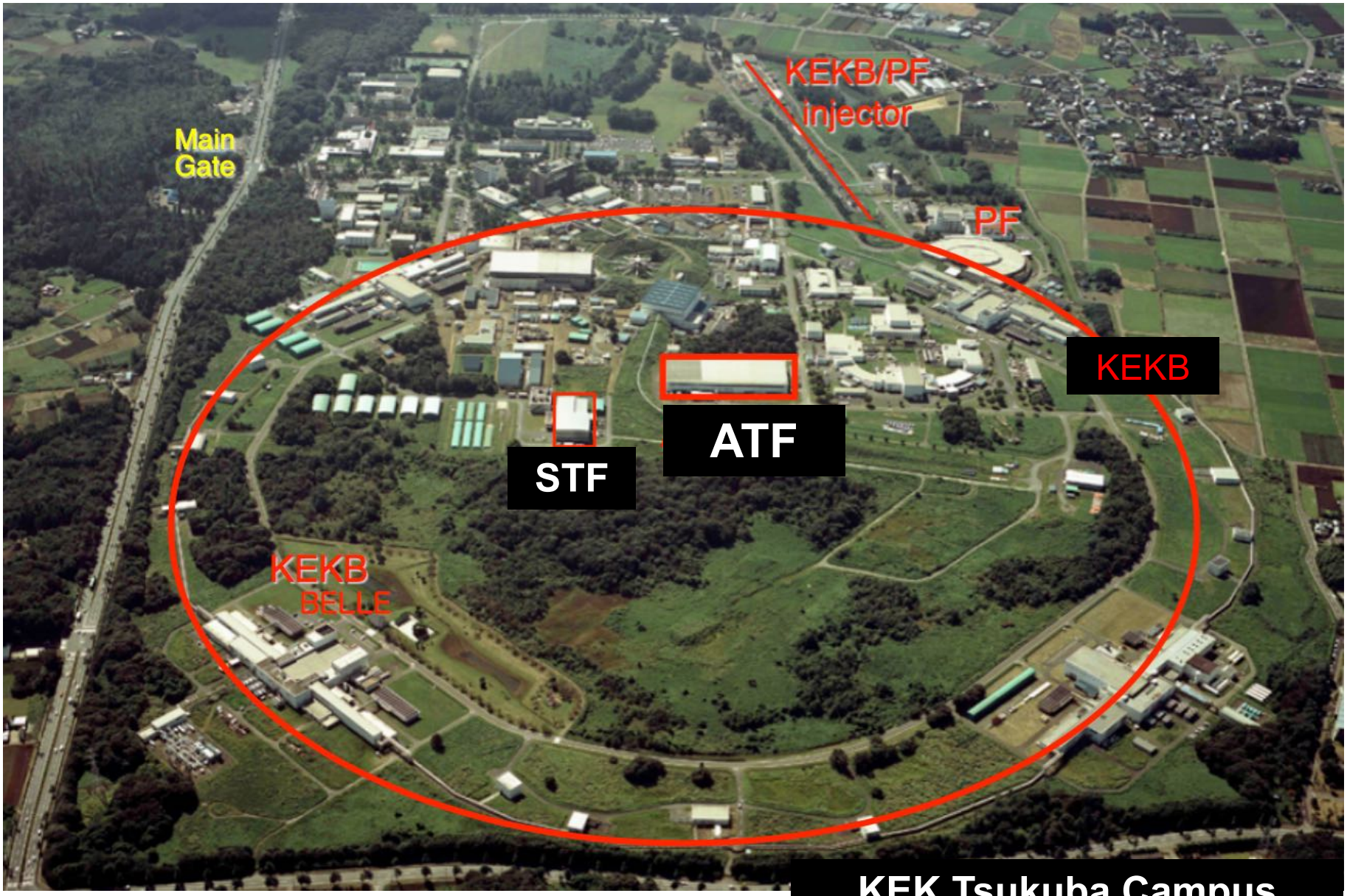
- Feasibility surveys on ILC by the ministry (MEXT)
- Beam dumps
- Positron sources
- Summary - plan for coming years

# International Linear Collider

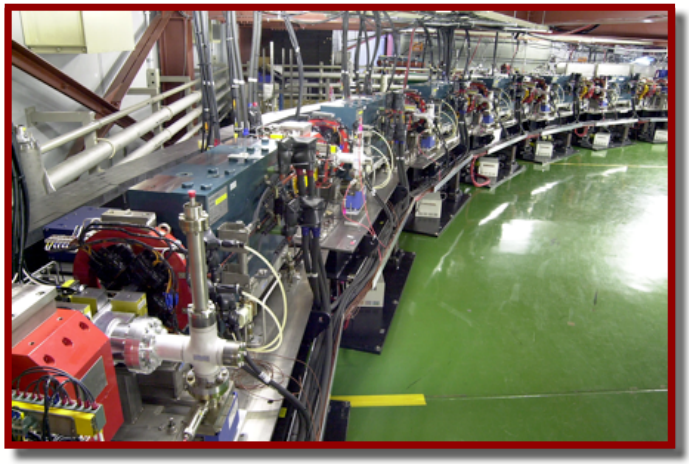





KEK Tsukuba Campus

# KEK ILC nano-beam R&D Facility: ATF

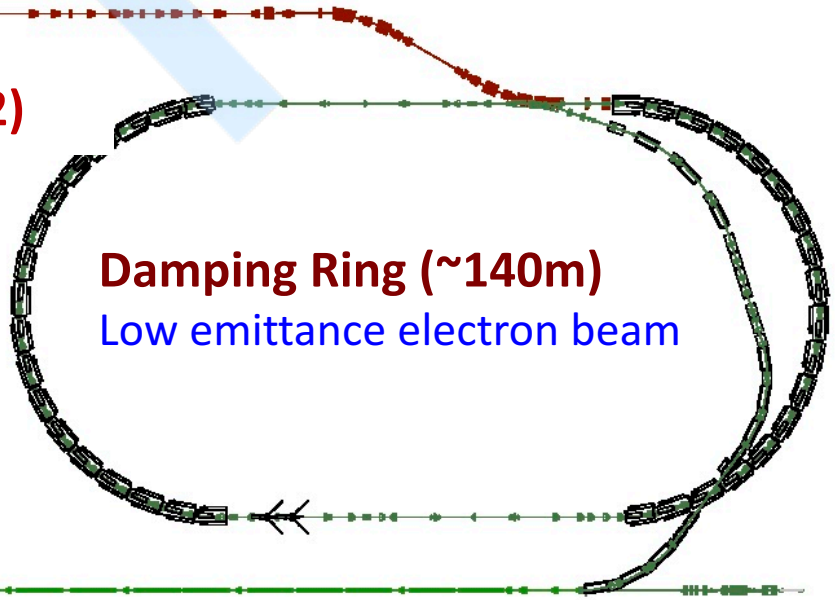
**Layout of ILC**



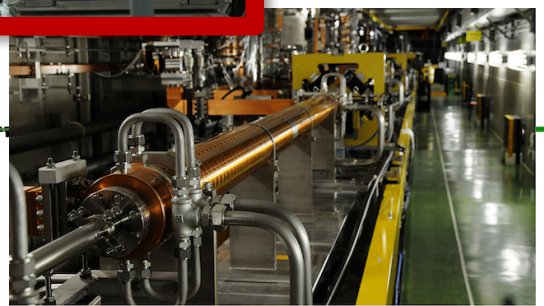
**ATF goal 37nm(ILC 6nm)**

**→ 41nm achieved (2016)**

**Final Focus System Test Beamline (ATF2)**




RF Gun



1.3 GeV S-band Electron LINAC (~70m)

# ILC Advisory Panel in MEXT

1st survey of technological spin-offs and Research tre

2nd survey of technolo sues (FY2015)

Research contract
Nomura Research Institute

Report

3rd survey of large international projects (FY2016)

MEXT

Under ILC TF headed by State Minister of MEXT

**ILC Advisory Panel**

Established in May 2014

**Par cle and Nuclear Phys s Working Group**

E blished i ne 2014

**TDR Validation Working Group**

Established in June 2014

**Human Resources Working Group**

Established in Nov. 2015

**Organization and management Working Group**

Established in Feb 2017

- Cost reduction study with new technology

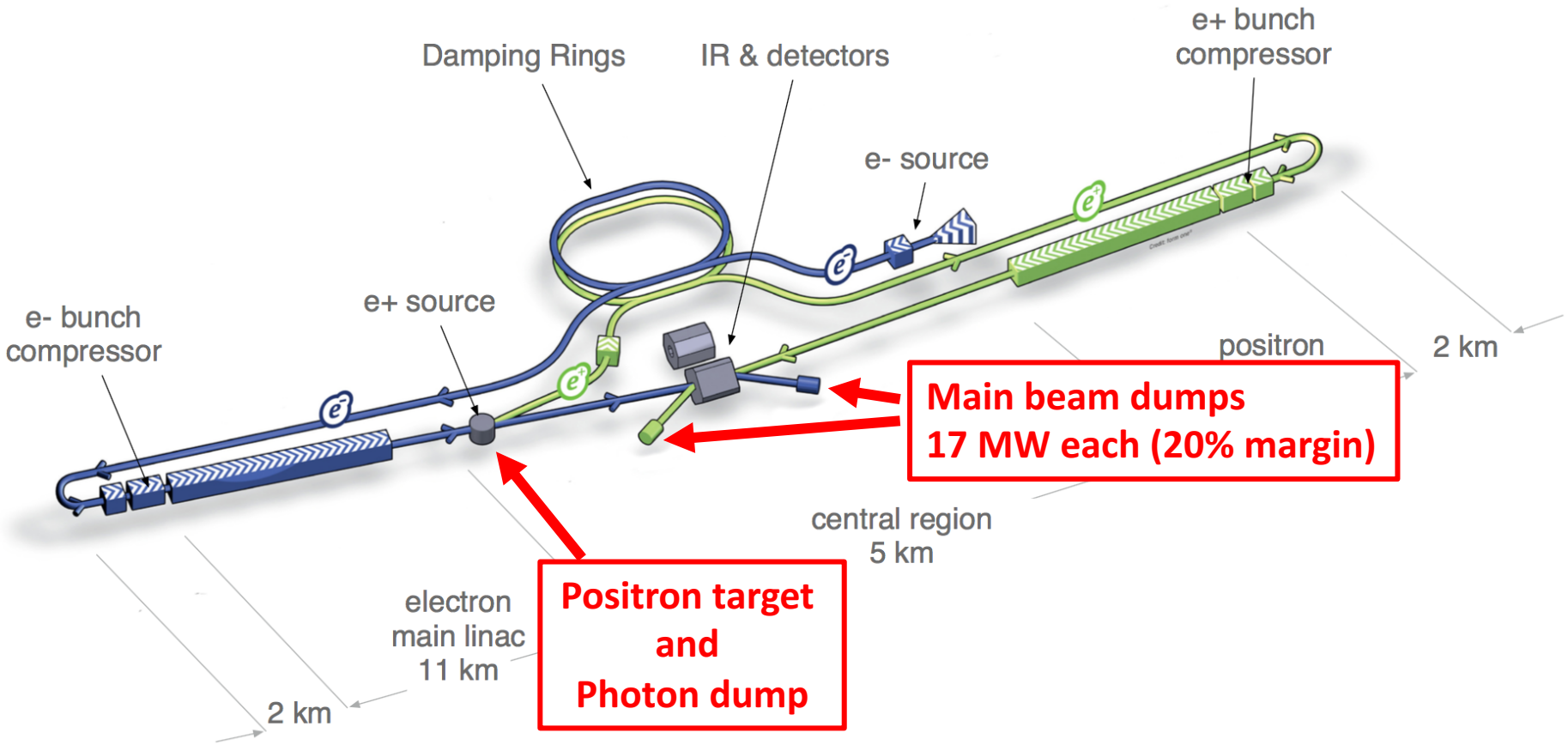
  **US-Japan cost-reduction R&D**

- Feasibility study with current technology

  **Positron source: international collaboration**

  **Beam-dump: CERN-KEK,...**

# International Linear Collider



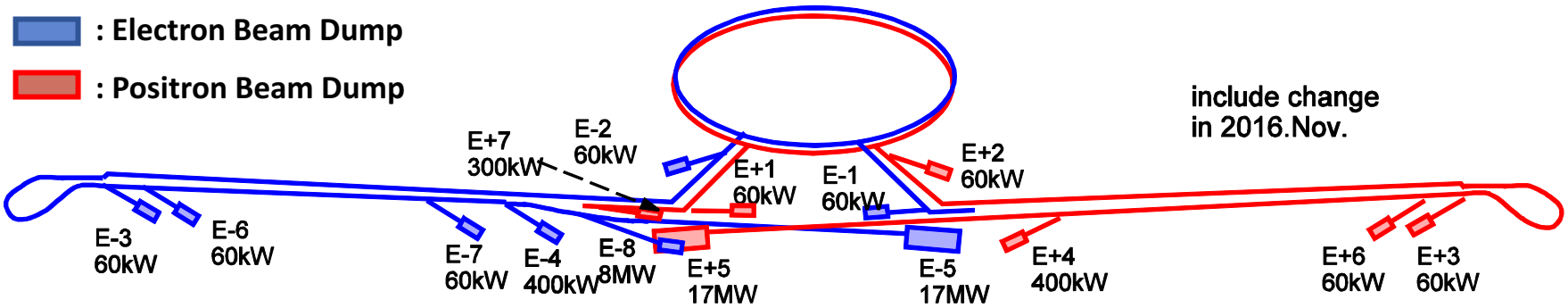
# Beam parameters: ILC TDR (2013)

| Center-of-mass energy | | Staging scenario 2017(*) 250 GeV | Baseline 500 GeV | Luminosity Upgrade 500 GeV | ECM Upgrade 1 TeV |
|---|---|---|---|---|---|
| **Beam energy** | **GeV** | **125** | **250** | **250** | **500** |
| **Bunch population** | | **$2x10^{10}$ (3.2nC)** | **$2x10^{10}$ (3.2nC)** | **$2x10^{10}$ (3.2nC)** | **$1.74x10^{10}$ (2.78nC)** |
| Bunch separation | ns | 554 | 554 | 366 | 366 |
| **Number of bunches per pulse** | | **1312** | **1312** | **2625** | **2450** |
| Pulse length | ms | 0.727 | 0.727 | 0.961 | 0.897 |
| Pulse charge | μC | 4.20 | 4.20 | 8.40 | 6.83 |
| Pulse current | mA | 5.78 | 5.78 | 8.74 | 7.61 |
| Pulse energy per beam | MJ | 0.525 | 1.05 | 2.10 | 3.41 |
| **Repetition rate** | **Hz** | **5** | **5** | **5** | **4** |
| **Average power per beam (Main beam dump)** | **MW** | **2.63** | **5.25** | **10.5** | **13.7** |
| Luminosity ($10^{34}$ $cm^{-2}s^{-1}$) | | 0.75 | 1.8 | 3.6 | 3.6 |

* for initial cost reduction, under discussion

**20 % margin**
**→ 17 MW**

# ILC Beam Dumps




| Purpose | N | Beam Power | Absorber | |
|---|---|---|---|---|
| Commissioning | 9 | 60 kW | Solid | at the end of sub-systems |
| Commissioning & MPS | 2 | 400 kW | Solid | at the end of main LINAC<br>ref. Euro-XFEL (300kW) |
| Photon Dump | 1 | 300 kW | Gas, water? | downstream of the positron target<br>Photon beam can not be deflected/swept. Hits at same point of<br>under discussing in the ILC positron collaboration |
| 5 + 5 Hz Operation for positron generation below e-beam 125 GeV | 1 | 8 MW | Water | near the main beam dump |
| Main Beam-Dump | 2 | 17 MW | Water | 300 m downstream of IP<br>20% margin is included. |

# NRI Report
## Technology Survey contracted by MEXT

It pointed out issues about the main dumps ...

- **No prototype exists (17 MW)**
  - the performance not validated
  - SLAC 2 MW dump is not considered to be a prototype.
- **Erosion/corrosion of the window**
  - by the cooling water flow under high radiation level
- **Measure in case of accidents of breaking window**
  - Can happen, for example, if the beam sweep system is down
- **Treatment of radioactive material**
  - Tritium by the water dump

**A real-scale prototyping with beam is impossible but a feasible and a controllable design should be established.**

# What's Needed

- **Simulation of heat and radiation**
  - Within our expertise though lack of manpower now
  - Detailed studies have done for ILC and CLIC
  - Improvement is needed but can be done in the construction stage
- **Window**
  - Material study
  - Experiment is presumably hard
- **Safety issues**
  - Maintenance by remote handling system
  - Accident study
    - What happens if the window is broken (however stiff the window is)?
    - Repair by robotics
  - Engineering design of the dump hall and the surface facility
- **We need help from institutes (in particular CERN), universities and industries**

# Detailed Reports

- **"Design of an 18MW vortex flow water beam dump for 500GeV electrons/positrons of an international linear collider",**

  P. Satyamurthy, et.al., NIM A 679 (2012) p67-81.

- **"FLUKA and thermo-mechanical studies for the CLIC main dump",**

  A. Mereghetti, et.al., CLIC-Note-876, CERN-OPEN-2011-030

  http://cds.cern.ch/record/1355402/files/CERN-OPEN-2011-030.pdf

- **SLAC Beam Dump**
  **"Beam dumps, energy slits and collimators at SLAC– their final versions and first performance data",**

  D. Walz, et.al.

  http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=4324681

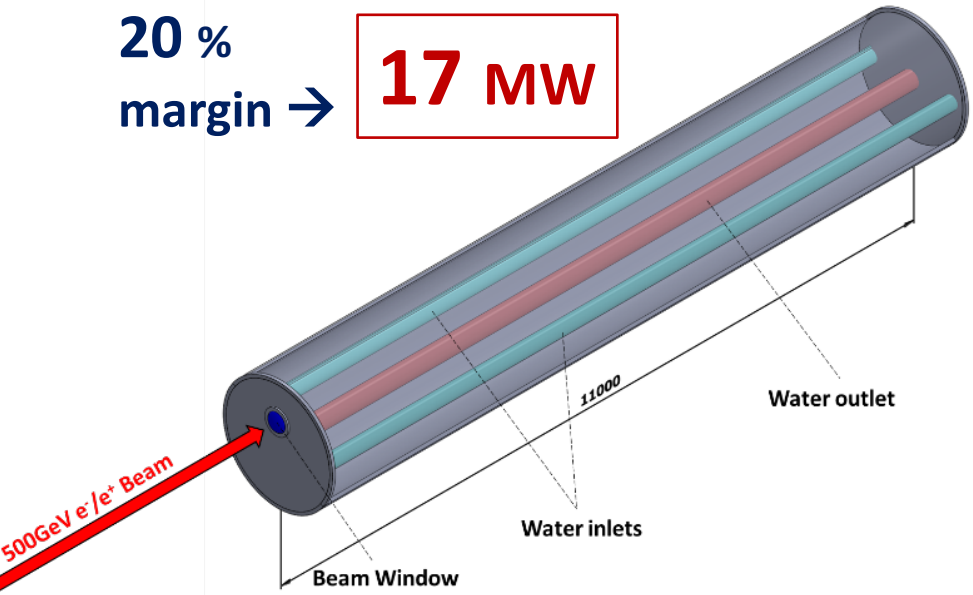
# Conceptual Design of Main Beam Dump

## Design for $E_{CM}$ 1 TeV

500 GeV × 2.79 nC × 2450 bunches × 4 Hz:

**13.7 MW**

20 % margin → **17 MW**




P. Satyamurthy, et.al.,

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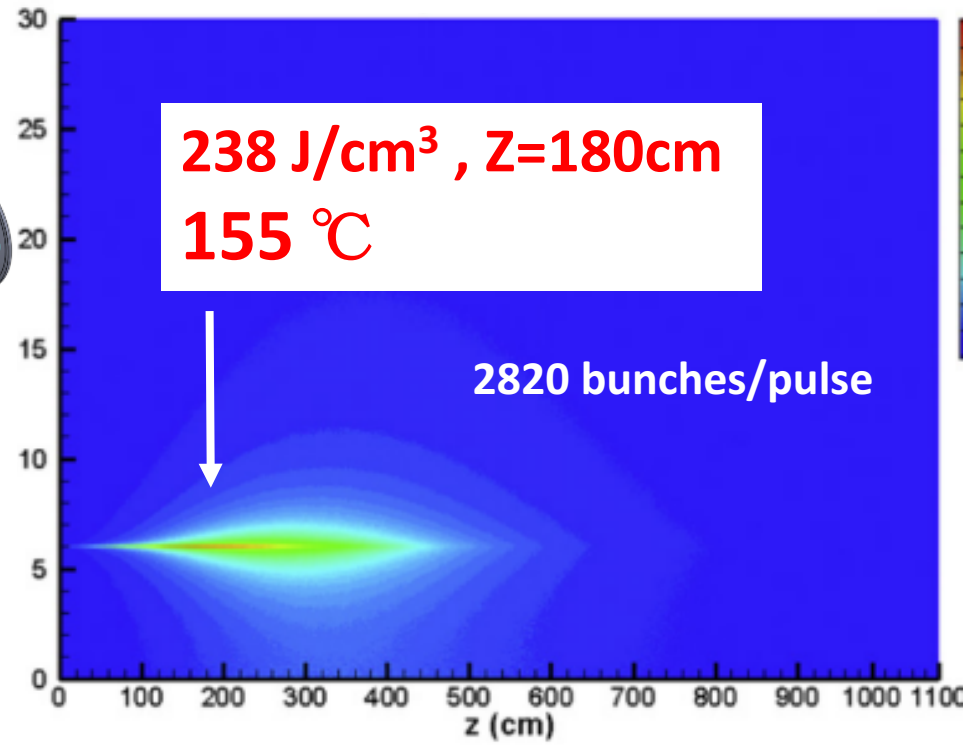
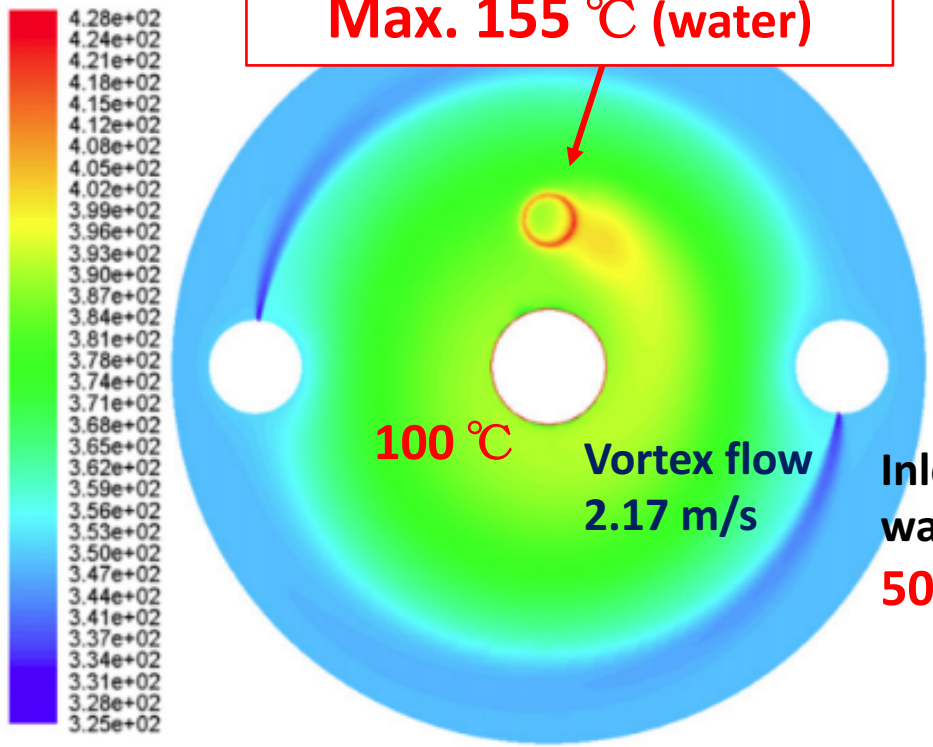



- Cylindrical Water Container (ϕ1.8 m × 11 m : 28 m³).
- Vortex flow
- Suppress the water boiling: 10 bar → boiling threshold 180 ℃

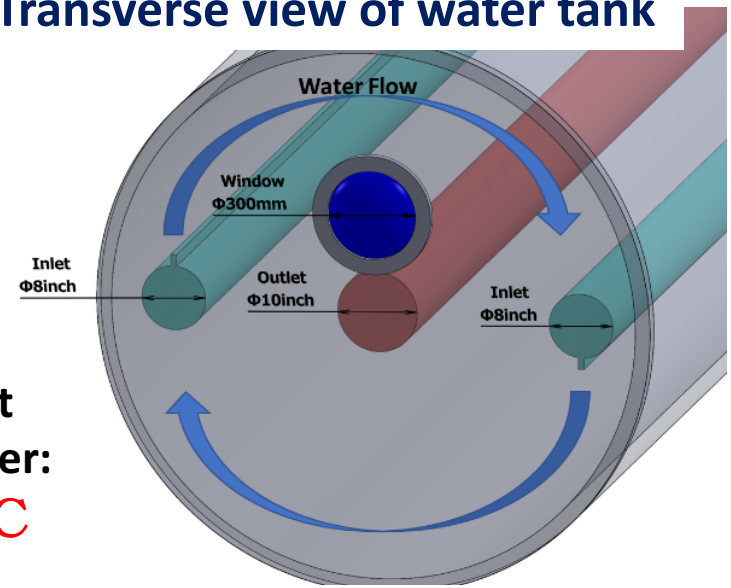
# Heat/stress analysis

**Swept beam/pulse**
**Max. 155 ℃ (water)**




Inlet water: 50℃

**Transverse view of water tank**



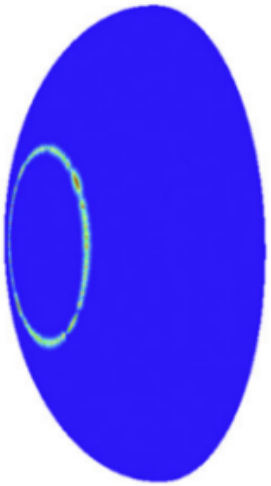

## Beam Window: Ti-6Al-4V

- Diameter **300** mm for Beamstrahlung photon from IP
- Thickness **1** mm

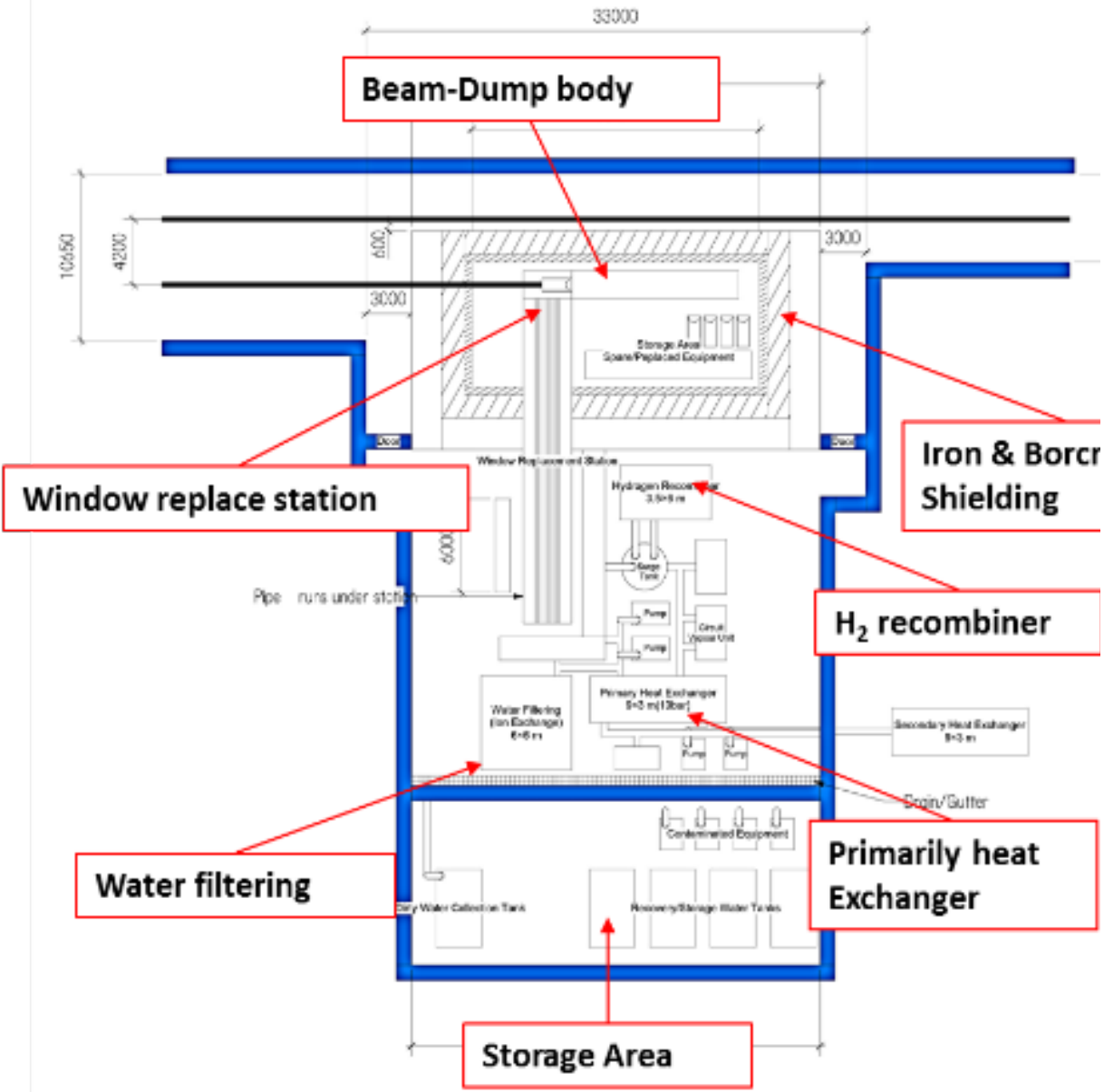
Tolerable **32 bar** ← 10 bar water

**Beam Sweep Radius**
**6 cm**

**Max.**
**21 J/cm³**
**74 ℃**



# Underground facility for Main beam dump




## Need details for ...

## Maintenance of window

- exchange periodically
- Remote handling

## Radioactive substances

- $^{7}Be$ and $^{3}H$ in water

## Radiolysis substances

- $H_2$ generation by water splitting.

→ $H_2$ rate: 0.24 mol/sec

$H_2$ recombiner:

$2H_2 + O_2 \rightarrow 2H_2O$

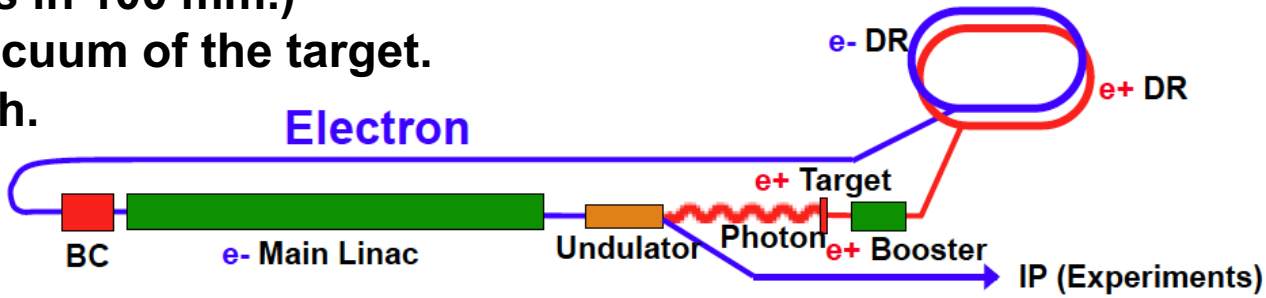
# ILC Positron Source

## ILC requires HUGE number of positrons; $Ne^{+}_{ILC} = 30 \times Ne^{+}_{SLC}$.

## Our Approach: Baseline and Backup

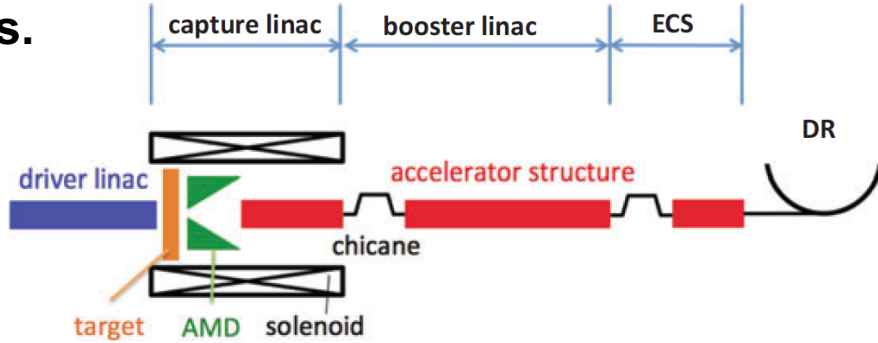
### (I) Baseline: Undulator-based Source (Use main linac beam, Polarized)

- Use e- beam in the main linac.
- Creates 1300 bunches of $e^{+}$s in 1 m sec. Heat load in a short time is an issue.
- It requires the challenging rotation target (100 m/s). (spreads 1300 bunches in 100 mm.)
- Difficulty in keeping vacuum of the target.
- ~ 2.5 kW for 1300 bunch.
- Radiation cooling.
- Non-penetrating shaft with magnetic bearing.




### (II) Backup: E-Driven Source (Independent/Conventional, Un-Polarized)

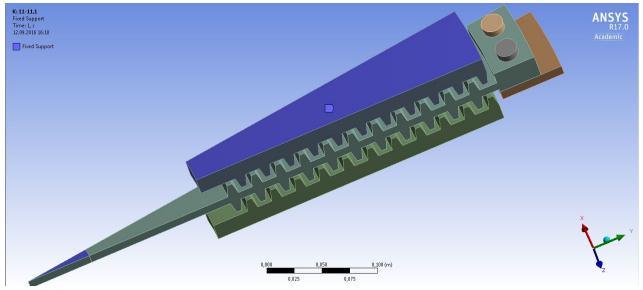
- Use 3 Gev E-linac as a driver.
- Creates 1300 bunches of e+s in 63 m sec (stretching in time).
- Employ much slower speed target: 5 m/s.
- ~ 16 kW for 1300 bunch.
- Water cooling.
- Penetrating shaft with ferrofluid seal.

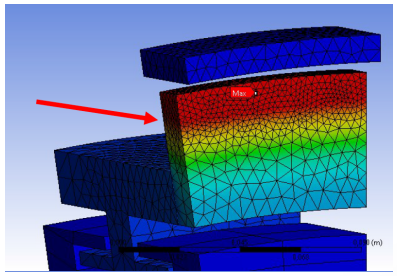


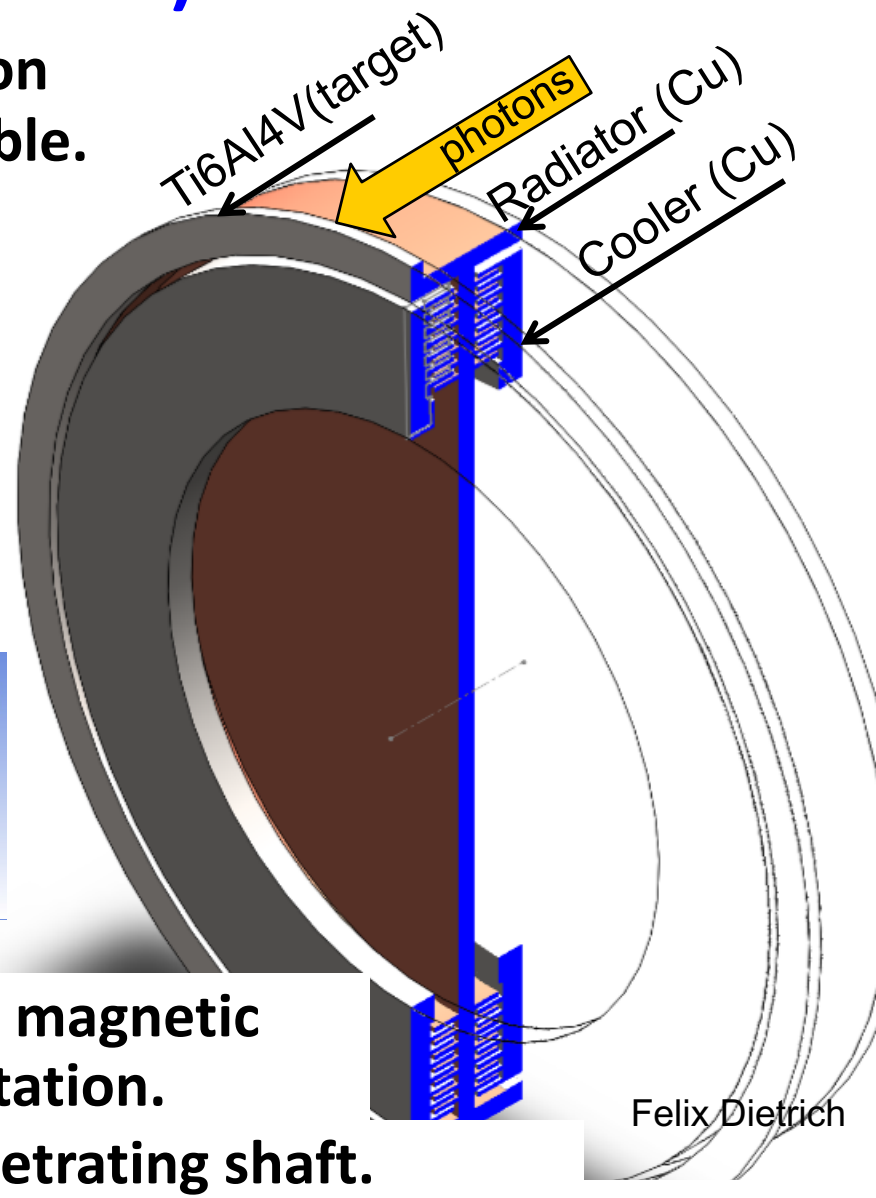

*Slide by T. Omori (KEK)*

# Radiation Cooling Target
## for the undulator (baseline) $e^+$ source

- Thermal heat is removed by radiation
- Temperature and stress is manageable.
- Create positrons in 1 msec.
- Fast rotation is required (100 m/s).
- Good vacuum is required ($10^{-6}$ Pa) for the capture RF.



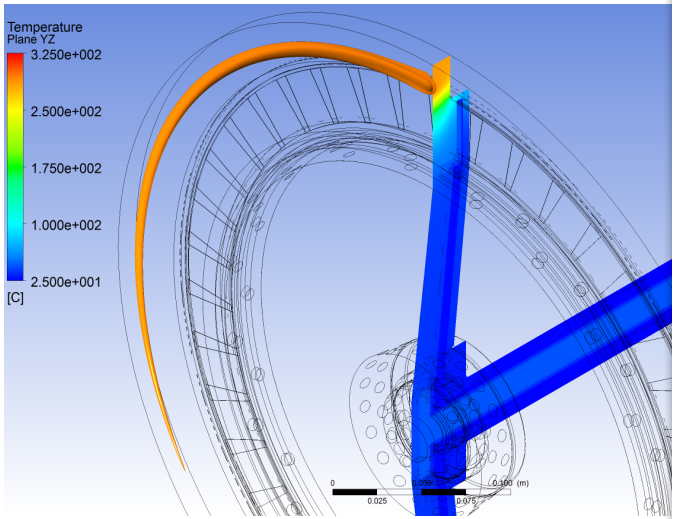


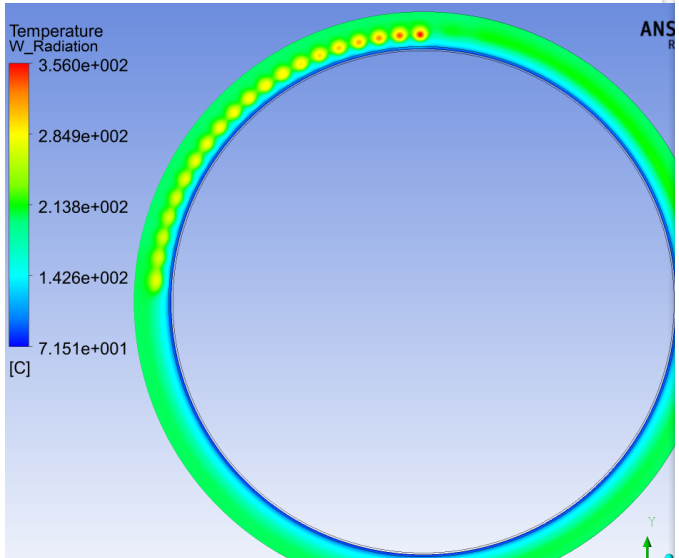

- Non-Penetrating shaft concept with magnetic bearing is employed for very fast rotation.
- Next step will be designing non-Penetrating shaft.

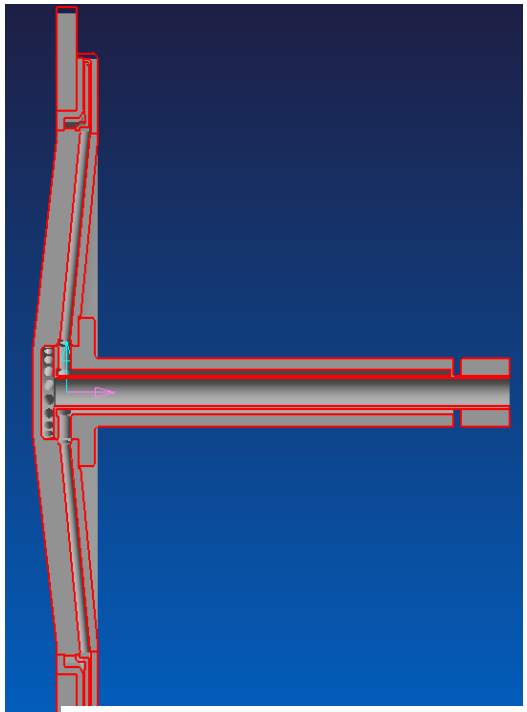
*Slide by T. Omori (KEK)*

# Water Cooling Target
## for the E-driven (backup) $e^+$ source

- Thermal heat is removed by water flow.
- Penetrating shaft by employing ferrofluid rotating seal.
- Temperature and stress is manageable.
- Create positrons in 63 msec (stretching in time for mitigation).
- Slow rotation is employed (5 m/s).
- Good vacuum is required ($10^{-6}$ Pa) for the capture RF.
- Vacuum test with the prototype is under way.
- Irradiation test was completed at the dose of three ILC year.



*Slide by T. Omori (KEK)*

# Parameters for ILC dump window and positron target

| | Pulse intensity | Average intensity | Beam pattern | Energy | Species | Spot size | Special requirement |
|---|---|---|---|---|---|---|---|
| Main beam dump **window** | 2.8 nC/bunch | 7.61 mA/pulse | 2450 bunches (366 ns spacing) /pulse<br>x<br>4 Hz | 500 GeV | Electrons or positrons | 2.4 mm (H) x 0.3 mm (V) | • 10-bar water dump |
| Positron **target (Undulator case)** [1)] | $8 \times 10^{12}$ photons /bunch | Average 59 kW on target | 1312 bunches (554ns spacing) /pulse<br>x 5Hz | Average ~9 MeV | Photons | 2.4mm rms (~ round) | • Rotating target<br>• Cooling |
| **Positron target**<br><br>**(e-driven case)** | $2 \times 10^{10}$ electrons/ bunch | Average 63 kW | mini-train<br>66 bunches (6.15 ns spacing) x 300 Hz<br><br>total 1287 bunches /pulse x 5Hz | 3GeV | Electrons | 2.0 mm rms (round) | • Slow rotating target |
| Photon dump **window** [2)] | $3 \times 10^{13}$ photons /bunch | ~300kW | 2625 bunches (366ns spacing) /pulse<br>x 10Hz | Average ~ 9 MeV | Photons | ~ 2.5 mm (3x larger if 1km distance) | • high density photons by 230-meter long undulator |

1) For 1st stage ($E_{CM}$=250GeV, 1312 bunches/pulse, 5Hz, 230m long undulator)
2) For the severest case in upgraded stages ($E_e$=125GeV, 2525 bunches, 10Hz)

Parameters for 1) and 2) are still under optimization.

# Plan for coming years

## 17 MW main beam dump and window

- A study group in KEK has been organized in early 2017.
- Revisit the previous studies done by 2012 and follow-up the simulations of a heat, a mechanical stress, a radiation, ...
- Detailed system design should be completed in a few years, including a safety; i.e., a remote maintenance and an emergency management.

## Positron source target

- An international collaboration is leading the studies.
- Detailed studies on the undulator-based positron source are in progress to rise a feasibility for a severe beam condition.
- Another scheme based on the electron-driven positron source is in progress as a backup by conventional technologies.
- A robust target is desired in both of them anyway.

**Discussions and cooperation with people around HPT are very much important and helpful for the ILC .**