Introduction to beam dump issues

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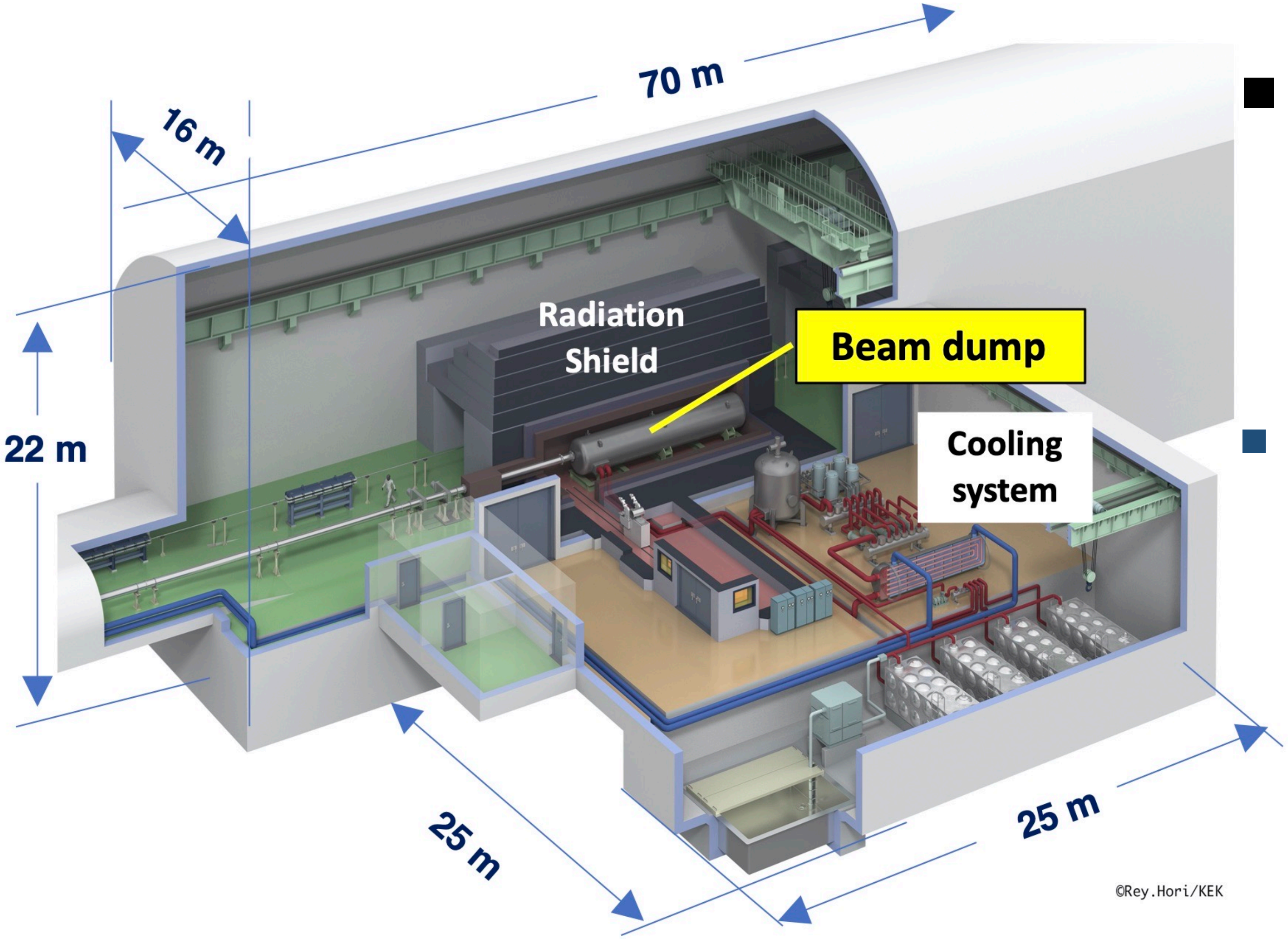
Issues on Main Beam Dump (1: specification)

- Designed for **500GeV beam** (14MW) +20%margin → **17 MW**
  - Rastrer a beam (1312 bunches) with 6cm radius.
- Additional load of **beamstrahlung photons** from IP → **1 MW**
- **Water dump** ← Solid dumps are not acceptable. Heavy heat load.
  - Vortex flow in a tank; **2m in diameter x 11m-long** at least
  - **10 atms** (1 Mpa) pressurized water to avoid boiling.
- Ti-6Al-4V for a beam window
  - Separate a water and vacuum, **30 cm in diameter, a few mm thick.**
  - Remote exchange once every a few years.
  - Radiation level around the window will be 100 mSv/h after a month from the end of run.

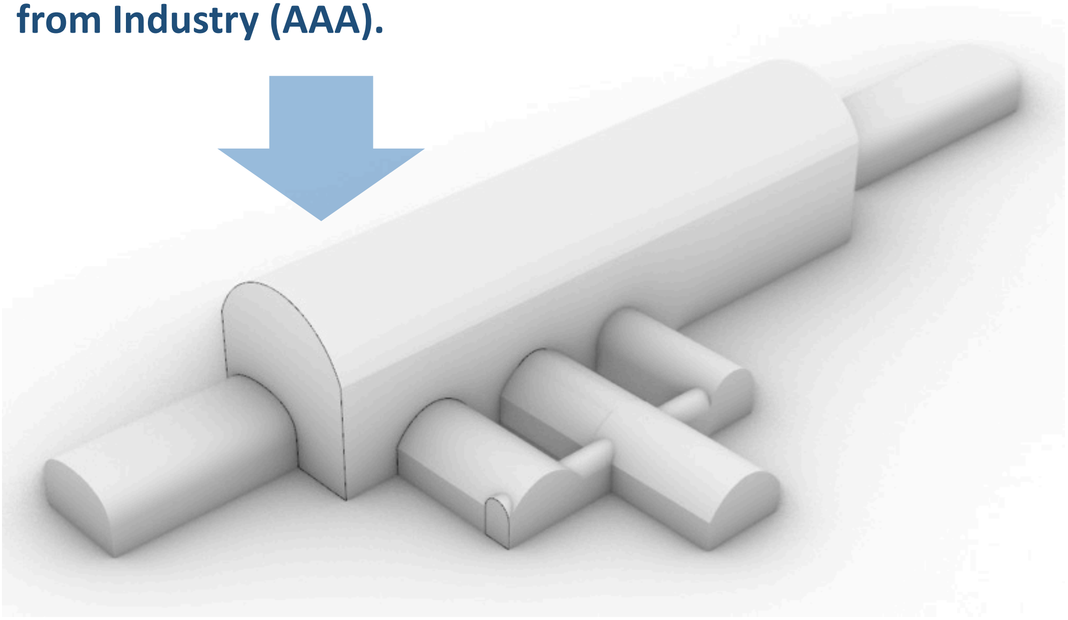
Issues on Main Beam Dump (2: CFS related)

- The beam dump area will be built at about **100m-deep underground,** similar to the IP.
- Located about **300m from IP**
- **A large cavern is required.**
  - **Radiation shields: 0.5m(Fe) and 5.5m(Concrete)**
    - To keep the activation outside the tunnel below the clearance level.
  - More than 50 tons Crane for shield handling.
  - Dump water circulation system is required near the beam dump.
- However, the distance from the dump and BDS line is only 4.2m.
  - **3m shield between BDS → ~20 μSv/h for workers**
  - and other 3m at tunnel wall to minimize the effect on outside environment.

Cavern for Main Beam Dump



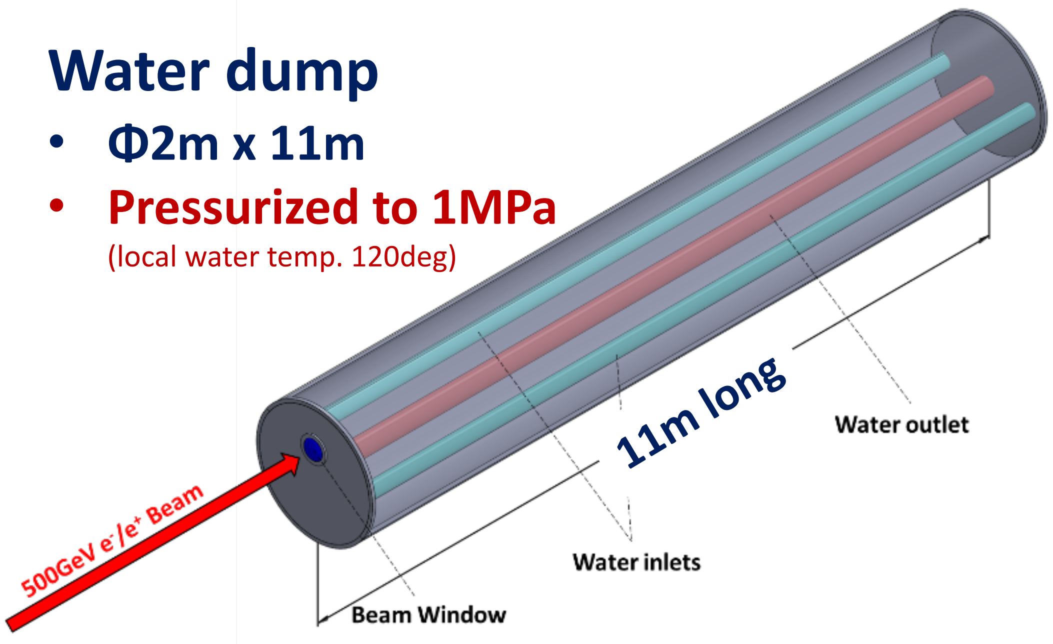
- **Three big caverns**
  - Two main beam dumps
  - e- dump for undulator, low energy collision (5 x 5 Hz)
- The main beam dump has been designed for **1 TeV collisions.**
  - **5 m thick concrete shield in all directions**
  - **17 MW power cooling (wider utility hall)**
  - **¼ volume of detector hall**
- **The civil engineering design is updating with experts from Industry (AAA).**

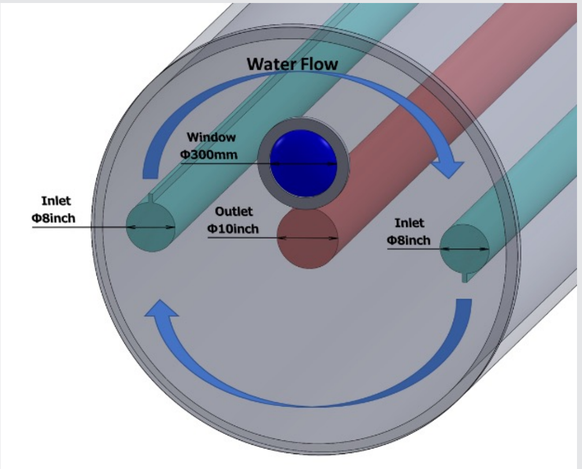


Main Beam Dump

Water dump

- **Φ2m x 11m**
- **Pressurized to 1MPa**
  (local water temp. 120deg)





Vortex flow

- **Move heated water effectively**
- **Beam window is displaced from the central axis of the tank.**

Design for 500 GeV beam (1 TeV collision).

- Use it from 125 GeV ILC.
- **17 MW each** (with 20% margin)

Water as an absorber

- the realistic solution for MW beam power.
- Basic design of ILC main dump was released in 2012, which based on the **2.2 MW water dump** at SLAC.
- Pressurized to **1 MPa (10 atm)** to prevent local boiling.

Beam window:

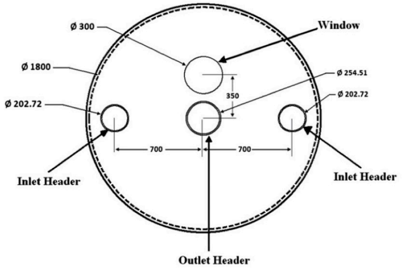
- Diameter will be 30 cm to receive beamstrahlung photons by e+e- collision
- **Beam should be rasterized with a radius of 6 cm.**
- **Titanium arroy (Ti-6Al-4V)** will be used for durability.

Main dump: Beam load in water, simulation FLUKA/ANSYS

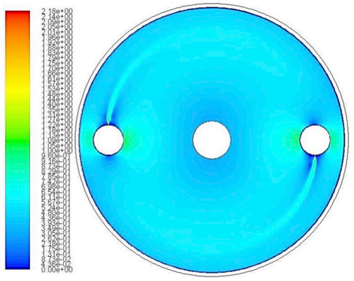
ANSYS simulation

Temperature Evaluation

Geometry



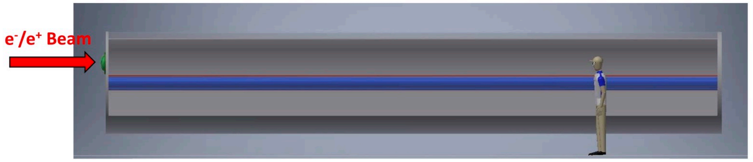
Flow Velocity

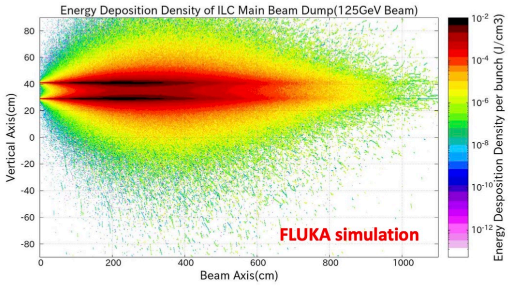


- CFD calculation (ANSYS-FLUENT)
- 2D analysis where peak longitudinal power is observed.
  Z=230cm for 250GeV nominal, Z=280cm for 1TeV status.
- Beam heat is Imported from FLUKA data to each cells.

Energy Deposition in water– Side View

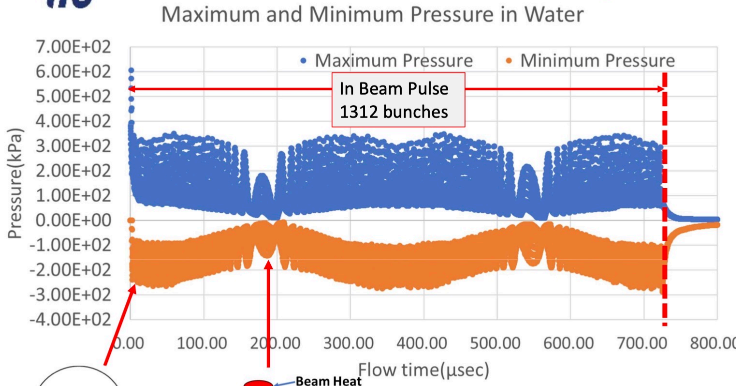
[Energy Deposition in water]

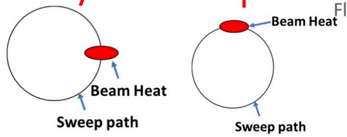




ANSYS simulation

Max and Min Pressure Intensity



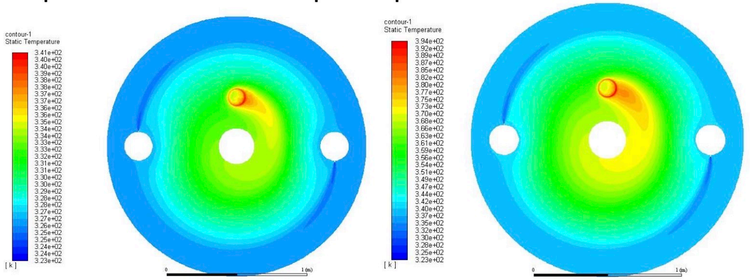


- Bunch space is 556nsec
  ⇒pressure wave will advance 0.92mm.
  (wave velocity=1650m/sec)
- Heat distribution is σx=2.55mm, σy=0.53mm.

ANSYS simulation

Max Temperature

Temperature Distribution when Beam pulse complete



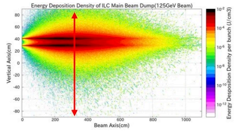
250GeV nominal Status
(125GeV, 1312bunch/pulse, 5pulse/sec)

1TeV Status
(500GeV, 2450bunch/pulse, 4pulse/sec)

【Max Temperature】250GeV-nominal : 68℃ , 1TeV : 121℃

Longitudinal Power

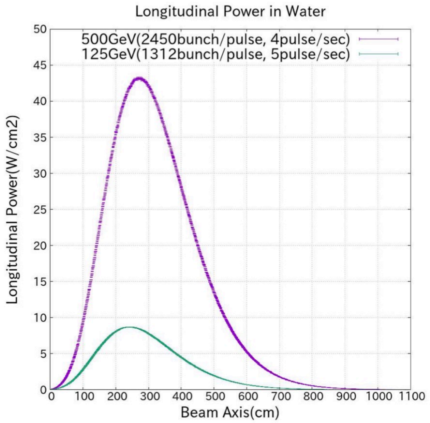
FLUKA simulation



Integrate transverse

【250GeV nominal】
Max Longitudinal Power =
43kW/cm @ Z=280cm

【1TeV stage】
Max Longitudinal Power =
8.4kW/cm @ Z=230cm



ANSYS simulation

Pressure wave simulation

◆ Pressure Wave Evaluation

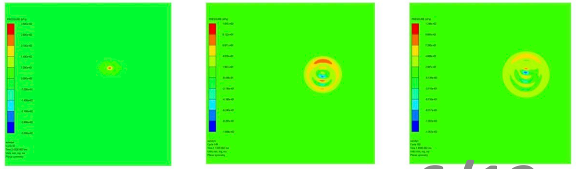
- Mie Gruneisen Shock Equation $P = P_H + \Gamma\rho(e - e_H)$ ⇒ $\delta P = \Gamma\rho\delta e$

  Γ:Gruneisen Gamma, ρ : density, e : energy deposition density
  Γ=0.32 for 60℃ water

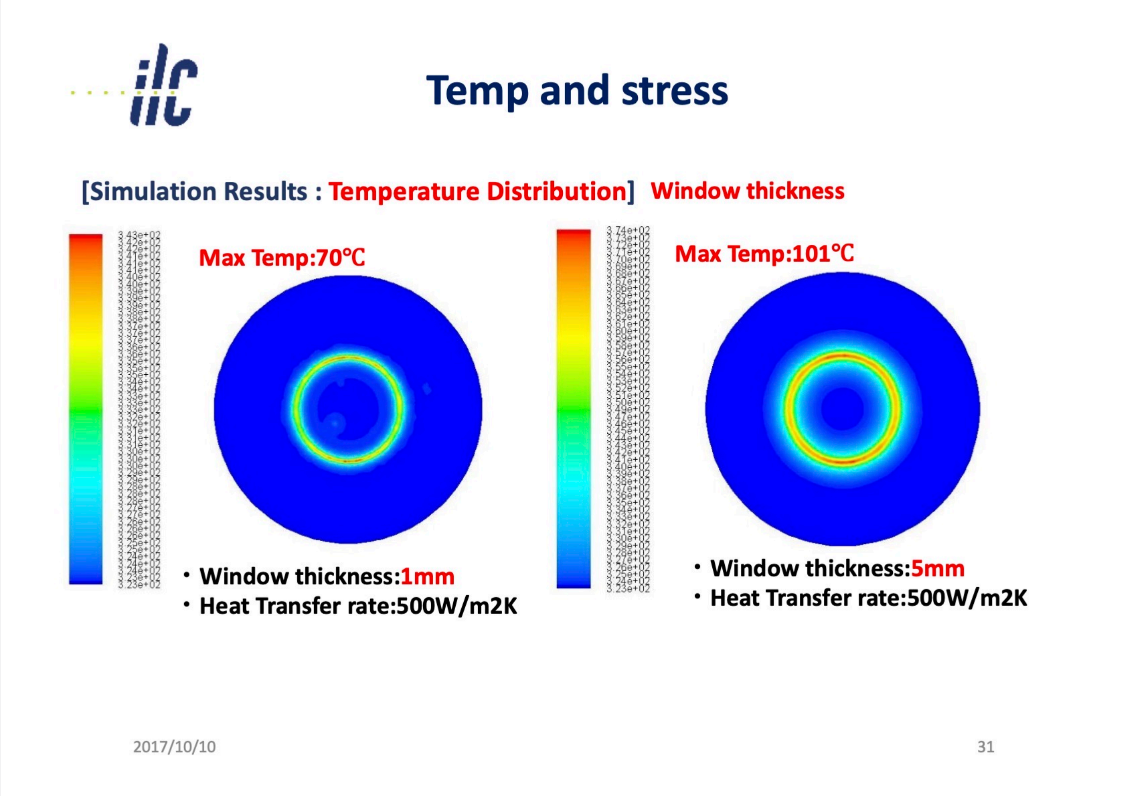
  ⇒ 1bunch pressure rise dP=0.32 × 1.2J/cm3 = 3.84bar

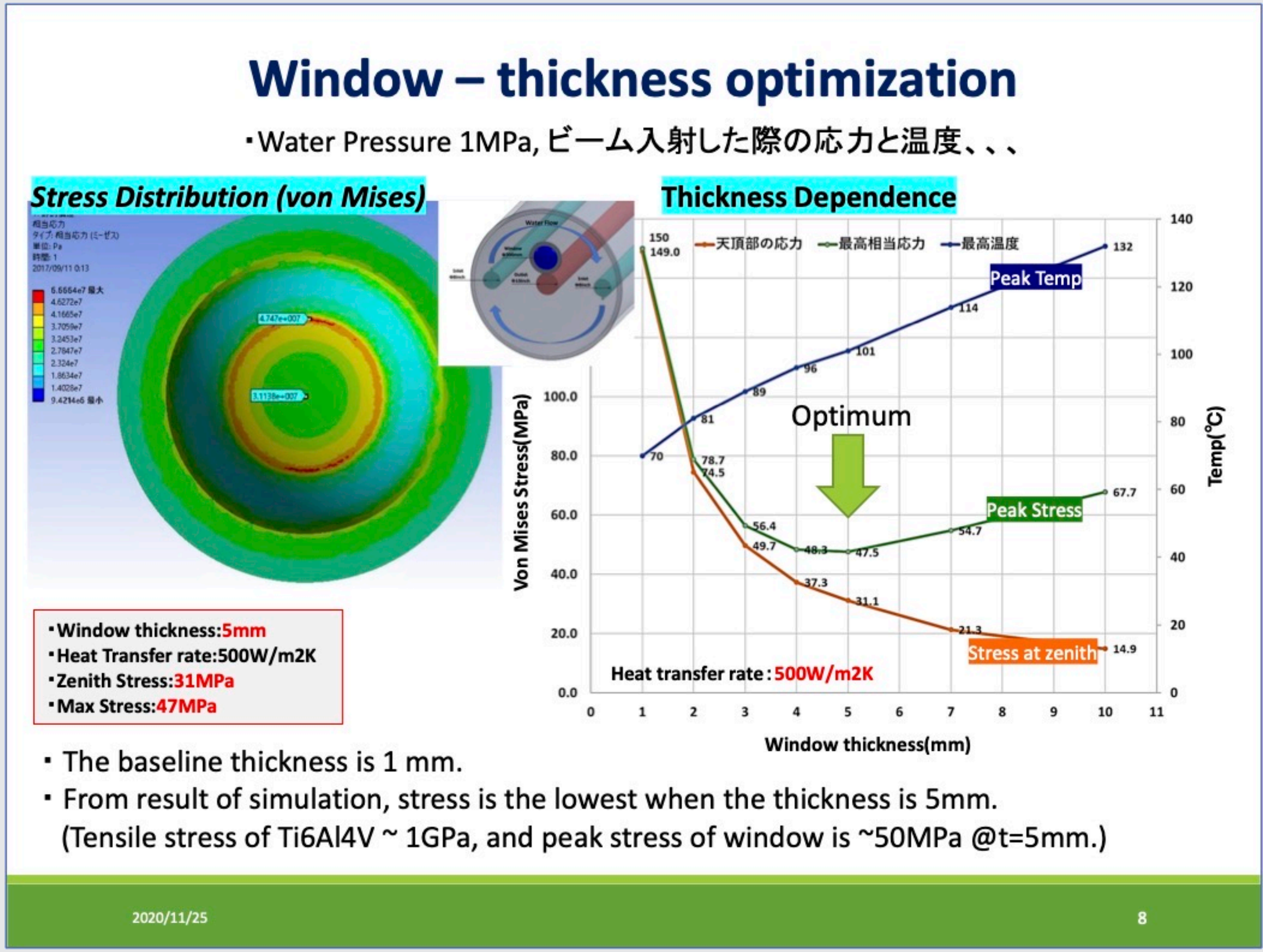
◆ Pressure Wave Simulation

- Thermal shock can be evaluated by Hydrocode(This time, I used Autodyn).
- 2D simulation @Peak Energy Deposition density observed(Z=115cm) to evaluate the negative pressure in water(Cavitation)

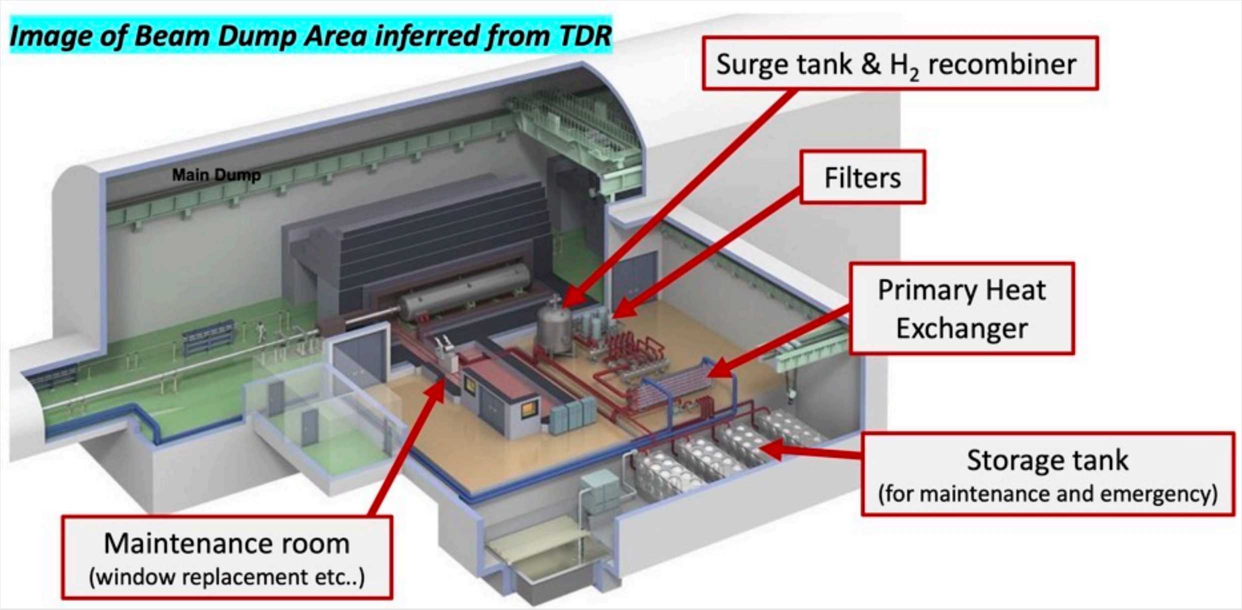


Main dump: Beam load on window, FLUKA/ANSYS





Technical Preparation of the main beam dump (1)



- **The SCJ and MEXT's ILC Advisory Panel** had pointed out subjects to be proceed are, …

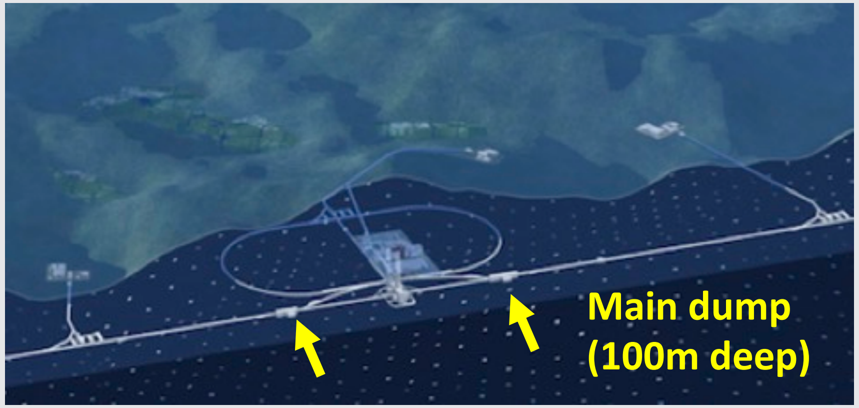
  reliability, earthquake protection, and stability of the window of the main beam dump, reaction between the high-energy beam and water, and containment of activated water.

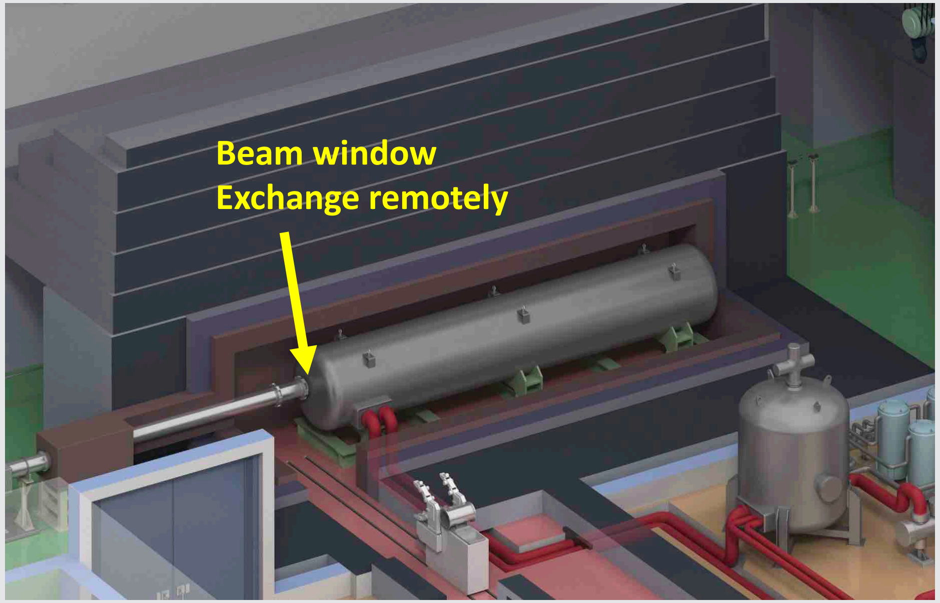
Realization of the system

- **Engineering design of water flow system:** Vortex flow in the dump vessel, Hydrogen recombiner, heat exchanger of MW power, and heat transfer chain to the ground.
- **Stability of the window:** confirm by the perspective of radiation damage and mechanical robustness.

  The Ti alloy, Ti6Al4V, was selected as a window material **following the experiences involving high-power targets and dumps** globally, which was mostly **conducted by proton beams.** Further studies that increase the robustness will continue through collaboration.

Technical Preparation of the main beam dump (2)



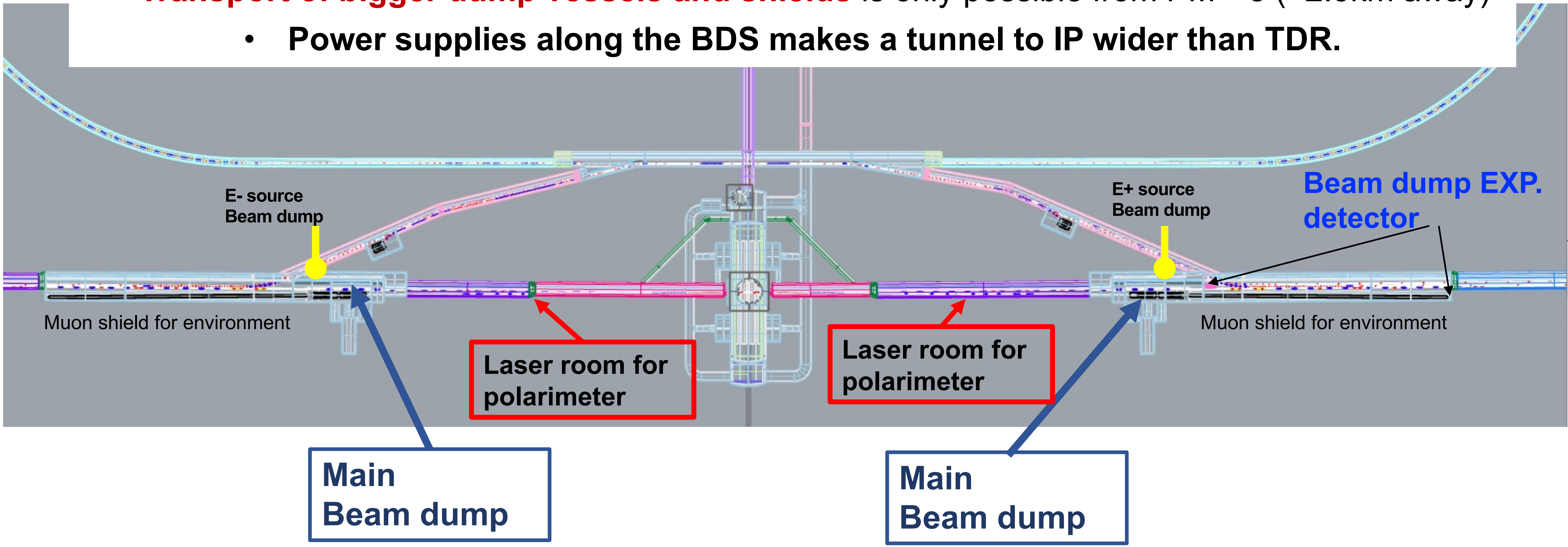


Containment of activated water

- **Tritium** accumulates in the water; roughly **50 TBq/20years** in each main dump. Drainage of diluted water at the mountain site is not realistic and not agreed by local people.
- **Engineering design for safety:** including **seismic and failure countermeasures**, will be addressed with industry.
- **Remote handling of the window:**
  - highly activated beam dump area
  - **prototyping of the sealing**
  - **demonstration of the remote exchange**

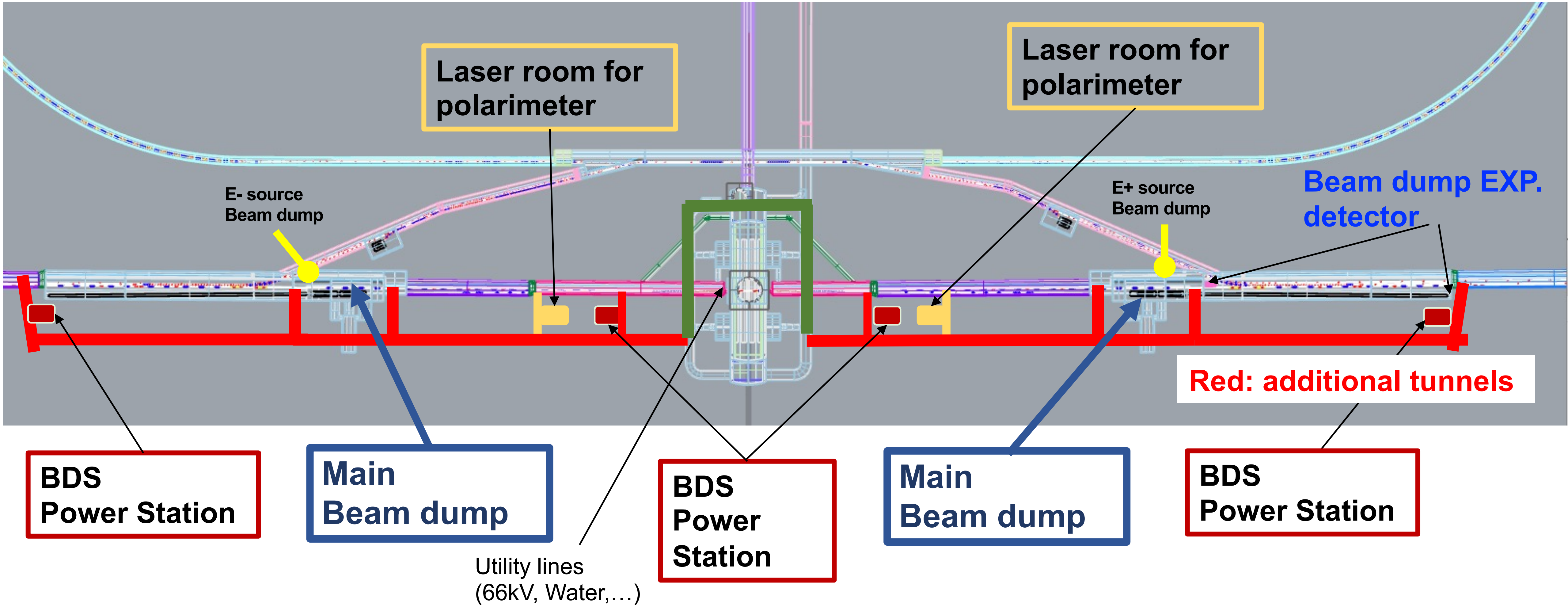
Concerns at near-IP accelerator tunnels

- **Laser room for polarimeter** is requested at a middle between IP and dump (narrow trunnel?).
- **Transport of bigger dump vessels and shields** is only possible from PM±8 (~2.5km away)
- **Power supplies along the BDS makes a tunnel to IP wider than TDR.**

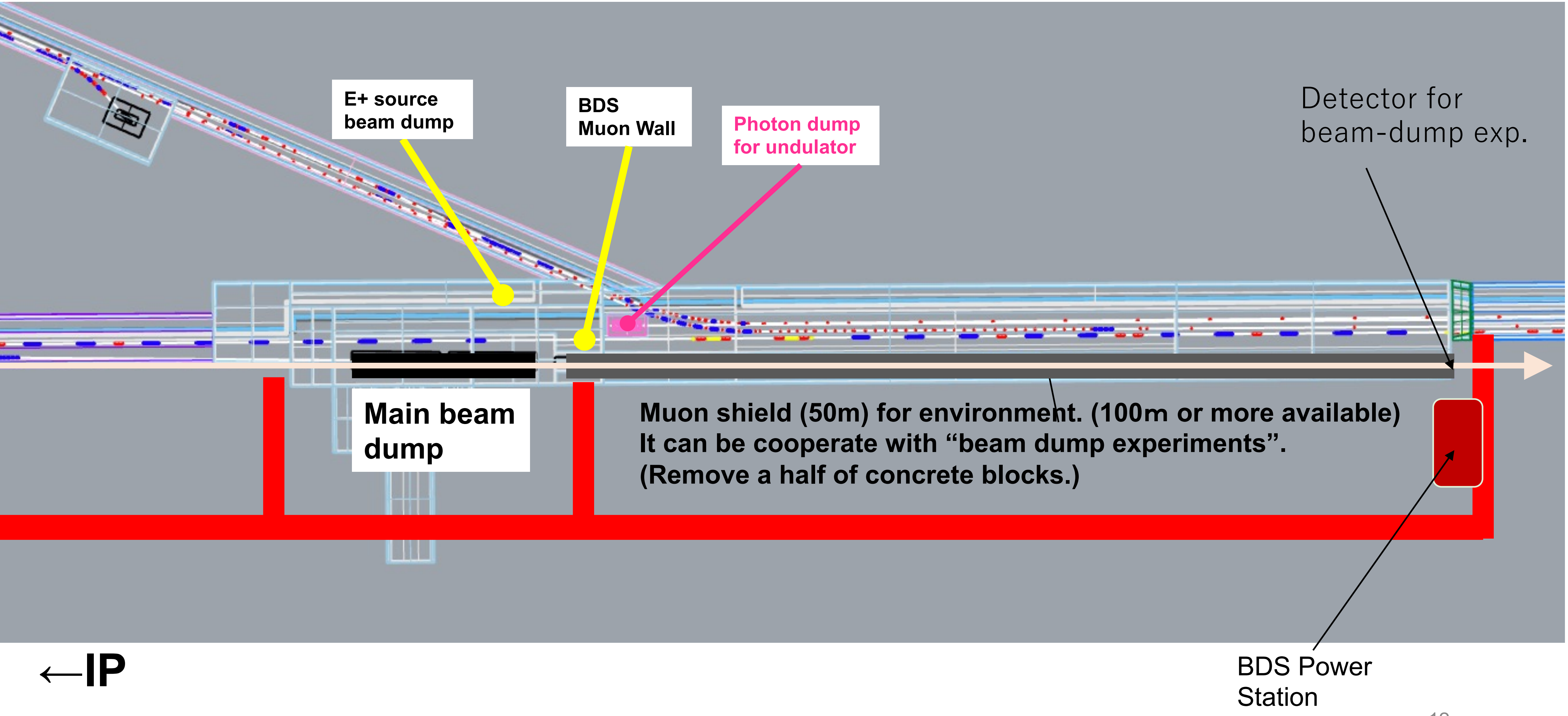


Access tunnel near the collision point (under discussion by CFS)

- For transportation: dumps, shields and laser equipment of polarimeter
  - Access to dump utilities, laser, beam-dump-experiment,…

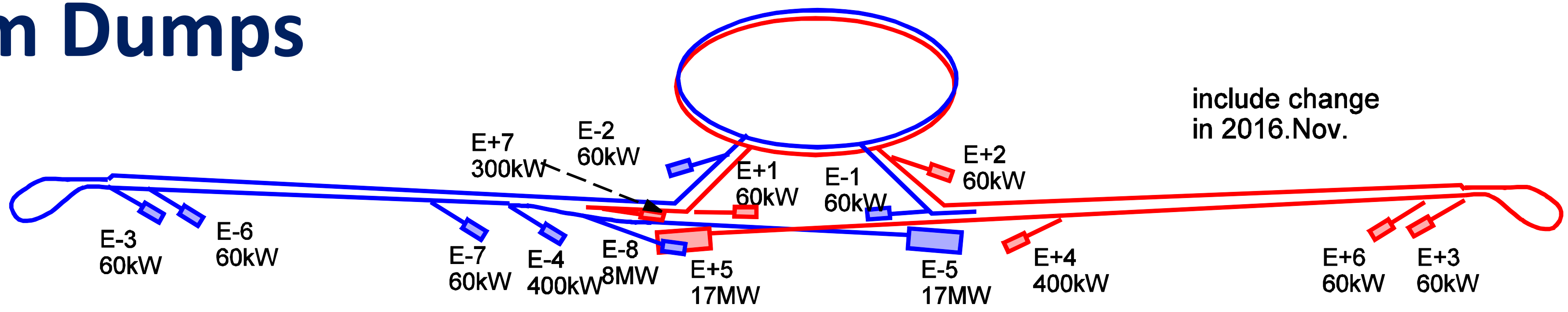


Possible layout of the proposed “Beam dump experiments”



Supplementary slides

ILC Beam Dumps

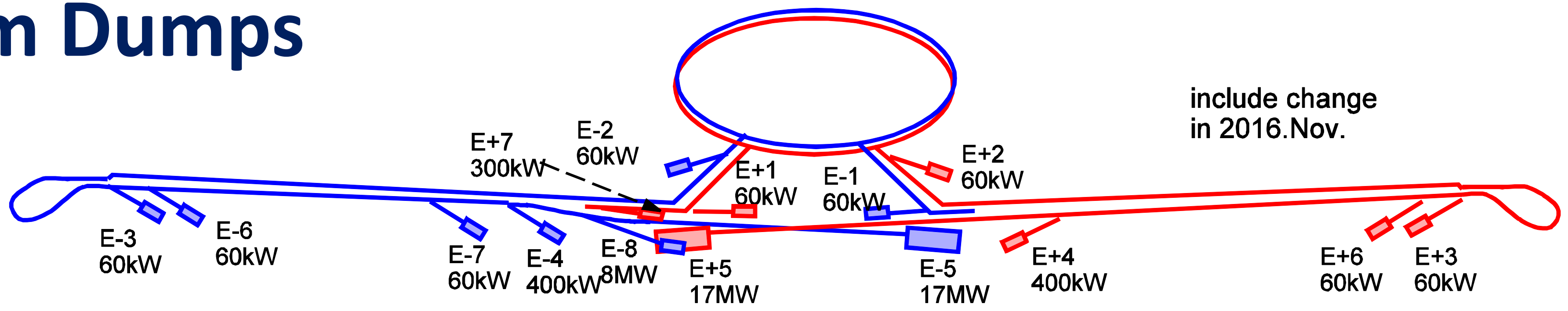


(1) Dump for beam tuning (and emergency abort)

Type	Max. Power	Num	Examples (design)	Beam Absorber
Tune-up for source, DR, Bunch Compressor	60 kW	9	XFEL, LCLS-II, CEBAF, SLAC's, …	**Solid** (Graphite,Copper, Aluminum…) cooled by water
Tune-up for ML	400 kW	2	XFEL (300kW), Al sphere (400kW), …	*Same as above*

- These maximum power are for machine tuning under the limited beam parameters, e.g., bunch number and repetition rate, and they can be optimized further.
- There are many examples for tune-up dump, therefore **no prioritized technical preparation is expected for tune-up dumps.**

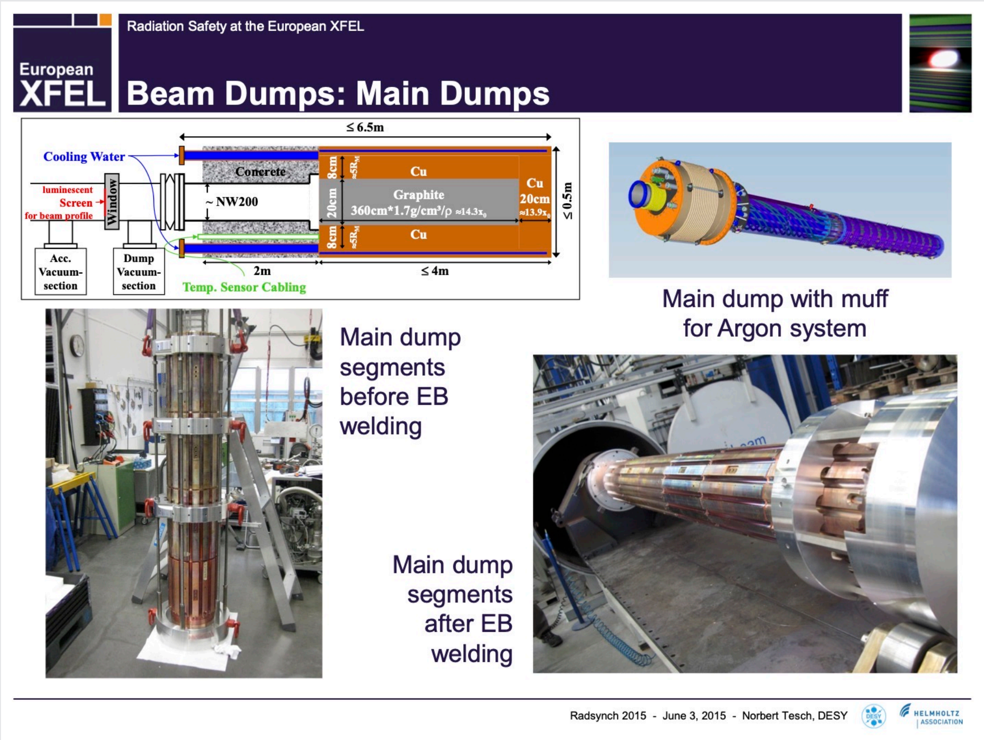
ILC Beam Dumps



(2) Dump for normal operation

Type	Max. Power	Num	Examples (design)	Beam Absorber
Main beam dump (after collision)	**17 MW** (1TeV, 20% margin)	**2**	**Water dumps: SLAC (2.2MW), JLAB (1MW)**	**Water (vortex flow, 10 atm, 11 m-long)**
Undulator 5+5Hz, electron dump	**8 MW**	1	*The same water dump as the main dump is used.* In low energy collisions, an additional e- beam (+5Hz) will be accelerated for positron generation by undulator scheme. An additional dump is required.	
photon dump for undulator (2km after the positron target)	**300 kW** (for 10Hz ILC)	**1**	**No example**	**Conceptual designs (Water or Graphite based)**

Examples for Tune-up Dump



- XFEL main Dump
  - Graphite and water cooled Copper
  - 300 kW

- Aluminum Sphere Dump (SLAC)
  - Water cooled Aluminum Sphere
  - 400 kW

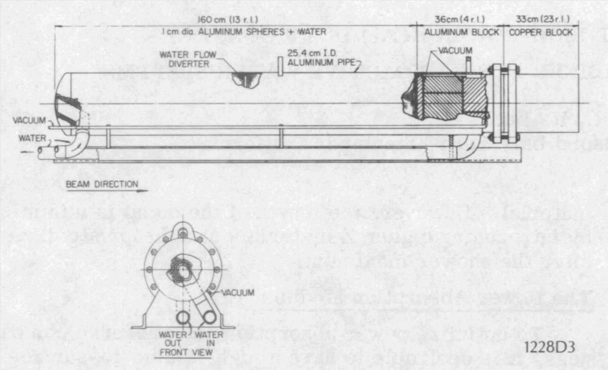


FIG. 1--Schematic of sphere beam dump.

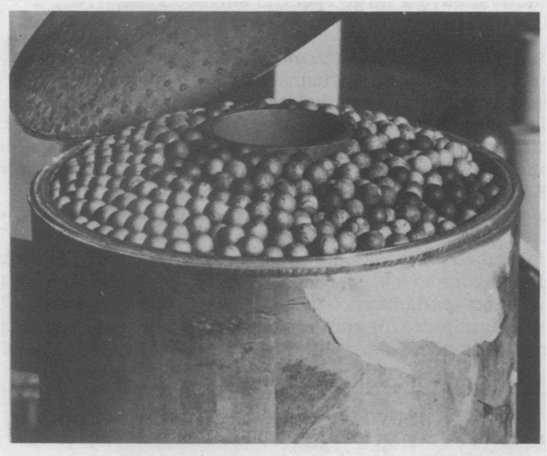


Fig. 2--Front view of sphere beam dump

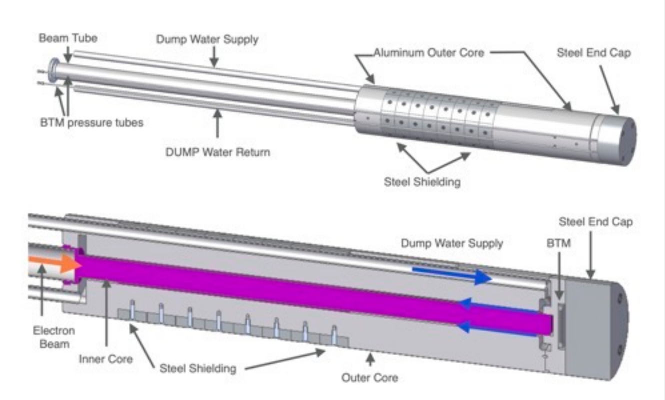


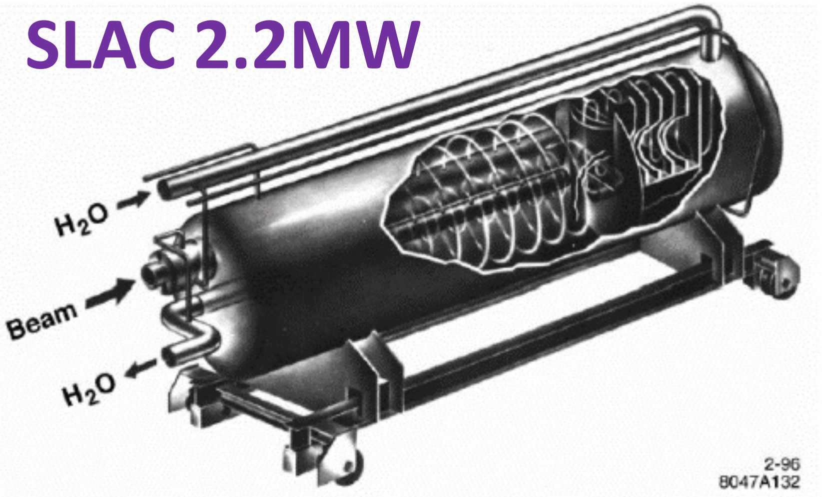
Figure 1: Dump subassembly.

- LCLS-II Dump
  - Water cooled Aluminum
  - 120 kW and 250 kW (rasterized beam)

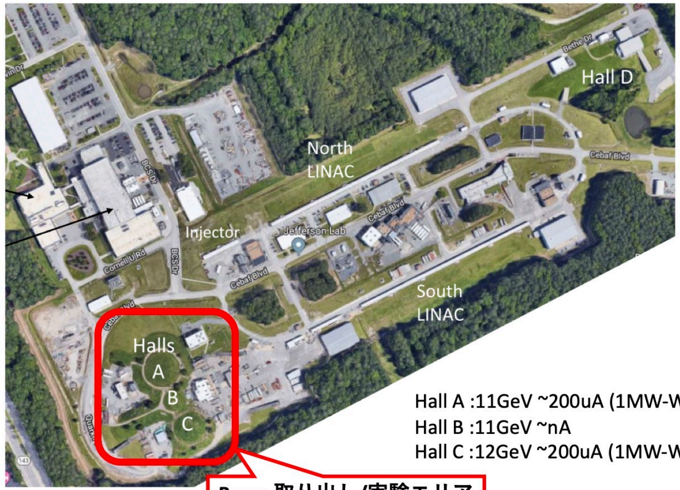
And more kW-dumps in the world,...

Water Dump Examples at SLAC and JLAB

SLAC 2.2MW



JLAB CEBAF 1MW



Hall A :11GeV ~200uA (1MW-Water dum
Hall B :11GeV ~nA
Hall C :12GeV ~200uA (1MW-Water dump)

Beam 取り出し/実験エリア

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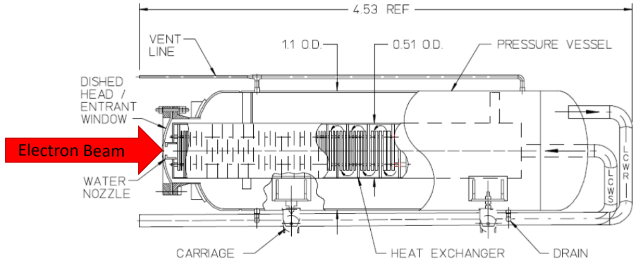
1MW-Water Beam Dump



- Originally design for
  - 200 µA max current up to 5 GeV
  - 1MW up to 10 GeV
- Hall C dump is in service since fall 1994 and Hall A since fall 1995

- Beam dump and pipes are all aluminum
  - Transition to St. Steel pipes at flanged pipe connections in dump tunnel
- The beam dumps are essentially a water cooled plate fin heat exchanger
  - 70% power absorbed in aluminum
  - 30% power absorbed in water

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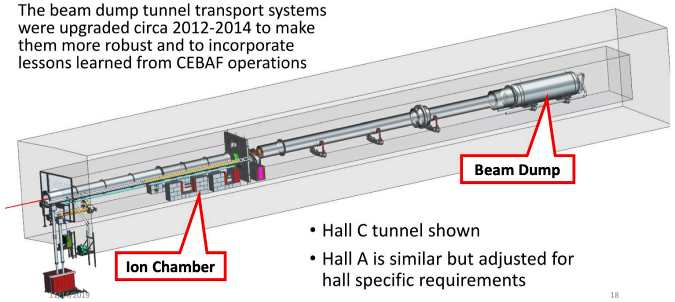
Beam Dump Area Design

High Power Dump Tunnel Transport System

The beam dump tunnel transport systems were upgraded circa 2012-2014 to make them more robust and to incorporate lessons learned from CEBAF operations



- Hall C tunnel shown
- Hall A is similar but adjusted for hall specific requirements

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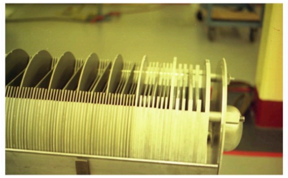
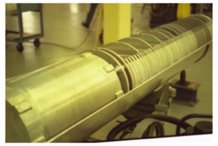
Water Beam Dump

1 MW Beam Dumps

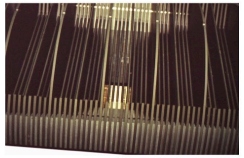
- Central heat exchanger 19.25 inch ID
  - Shown before top half welded on
- Plate thicknesses vary through the length to match the beam shower
  - Assumed 16 cm^2 beam spot size (ignored radial shower)
  - Plate thickness sized to limit the heat transfer to the water to 200 w/cm^2


Front section with nozzle

Rear section 30" long and edge cooled



Top view of HX plates. Thinnest plates 3/16" thick



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