ILC Tour for Fixed-Target Options

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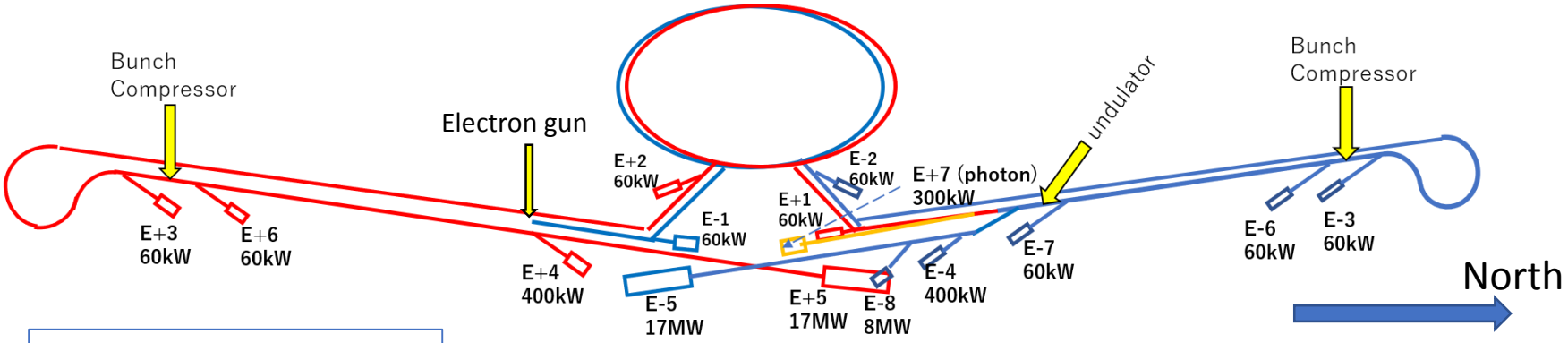
Contents

- Experiments near the main beam dump
  - ✓Behind the main dump (e+e-,μ+μ-,γγ) behind muon shield
  - ✓Positron main dump (ALP)
- Dumpline (from IP to Main Dump)
  - Extraction from dumpline
  - Insert target in the dumpline
- Far detectors (events from IP, e.g., Higgs decay to long-lived particles)
  - ✓Cavern at 50-200m from IP
  - ✓(Actually, this is not a fixed target experiment, in spite of the slide title)
- Extracted beam
  - ✓Parasitic
  - ✓Dedicated

Beam Dumps All Over ILC

- Beam dumps are distributed all over the ILC facility
- Power scales of the dumps have been lowered from the TDR design
- Dumps are classified into 4 categories
  - ✓ MW calss: E+-5 (17MW), E-8 (8MW, for E_{CM}<250GeV)
  - ✓ 400kW: E+-4 (main linac tuning/commissioning)
  - ✓ 300kW: E+7 (photon dump)
  - ✓ 60kW: all others. Many.



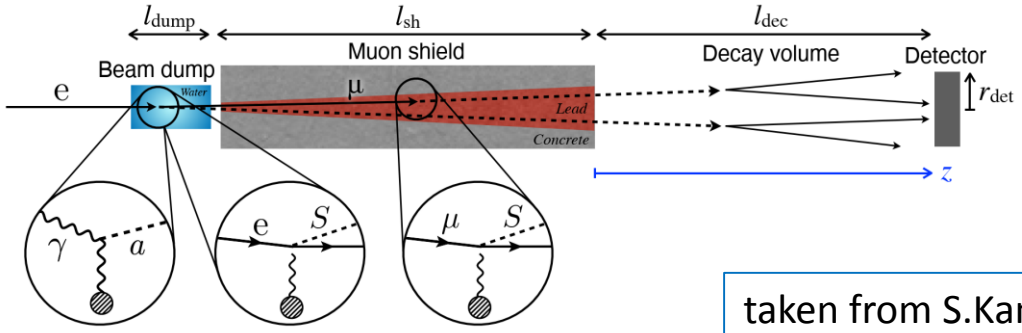
Positron main linac
Electron source

Note: right-left inverted since the old plots to reflect real geometry at Tohoku

Electron main linac
Positron source

Experiments at Main Beam Dump

- Behind the muon shield
  - ✓ Directly behind the target is also possible from accelerator view point.
  - ✓ However, the location directly behind the main dump must carefully take into account the strong muon flux from the dump body
- Muon shield
  - ✓ Right behind the dump there will be ~100m muon shield which is necessary for avoiding activation of the tunnel wall.
  - ✓ It will be split into many pieces so that you can choose appropriate location to insert the detector
- Note that the opposite beam going to the IP is running at the distance ~300m x 14mrad = 4.2m



taken from S.Kanemura, et.al. 1507.02809.pdf

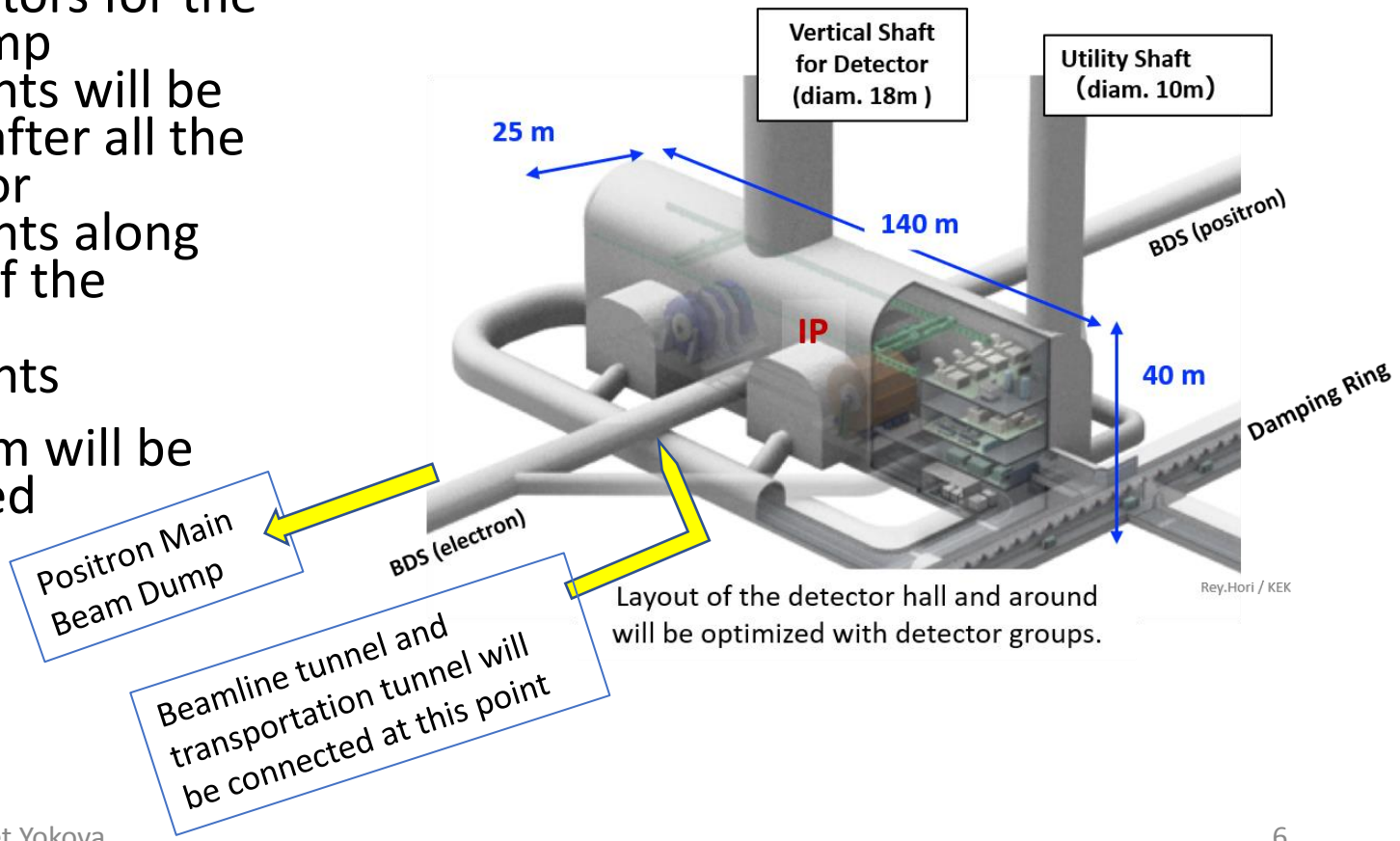
Experiment at the Main Beam Dump (continued)

- What must be considered
  - ✓Size of the required area and CFS (utility)
  - ✓Size of the detector (transportation to the required location)
  - ✓Principle of human access
  - ✓Beam properties

Transportation to the Beam Dump Location

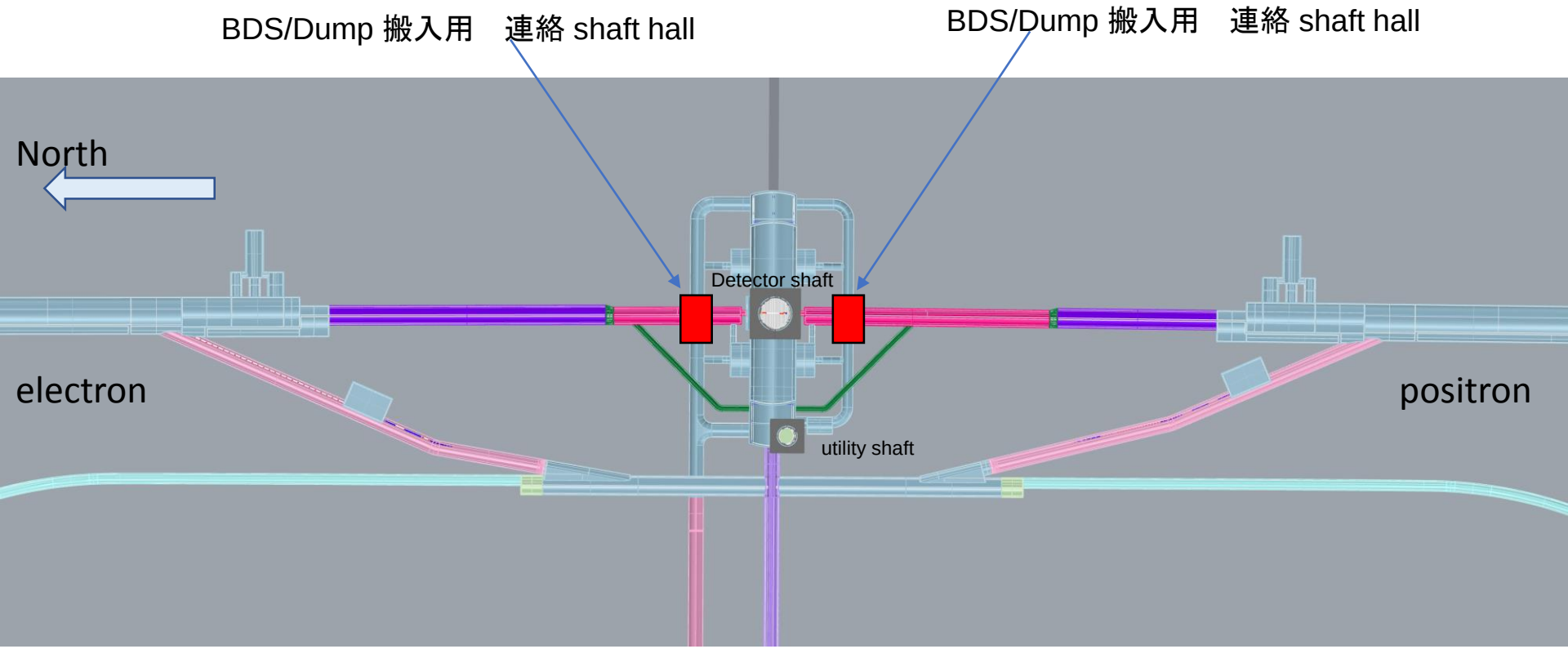
- The body of the beam dump (1.8m ϕ x ~10m) will be transported from the surface through an access tunnel before the installation of other accelerator components

- The detectors for the beam dump experiments will be installed after all the accelerator components along the side of the beamline components
- Width ~2m will be guaranteed



Detector Hall 周回トンネルとBDS加速器トンネルを結ぶ BDS/Dump搬入用連絡Shaft案

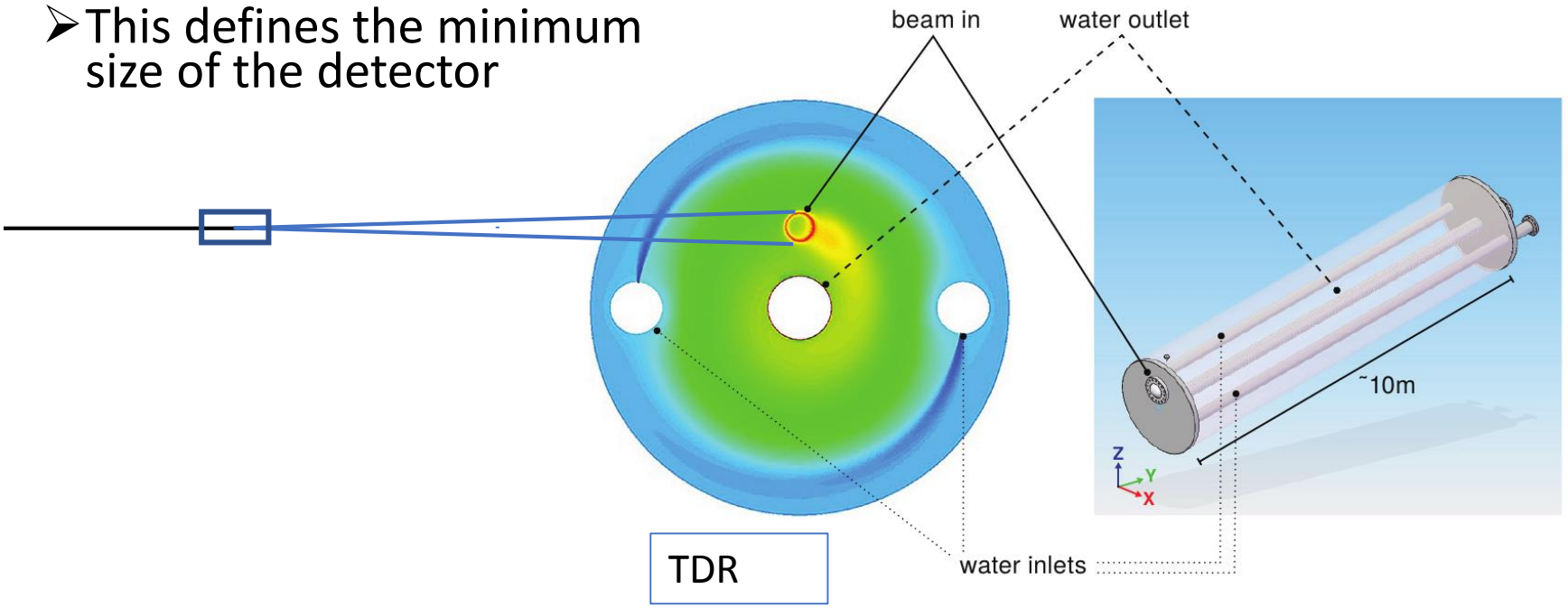
Proposed shaft for transportation linking the tunnel around the detector hall and the BDS accelerator tunnel



H. Hayano

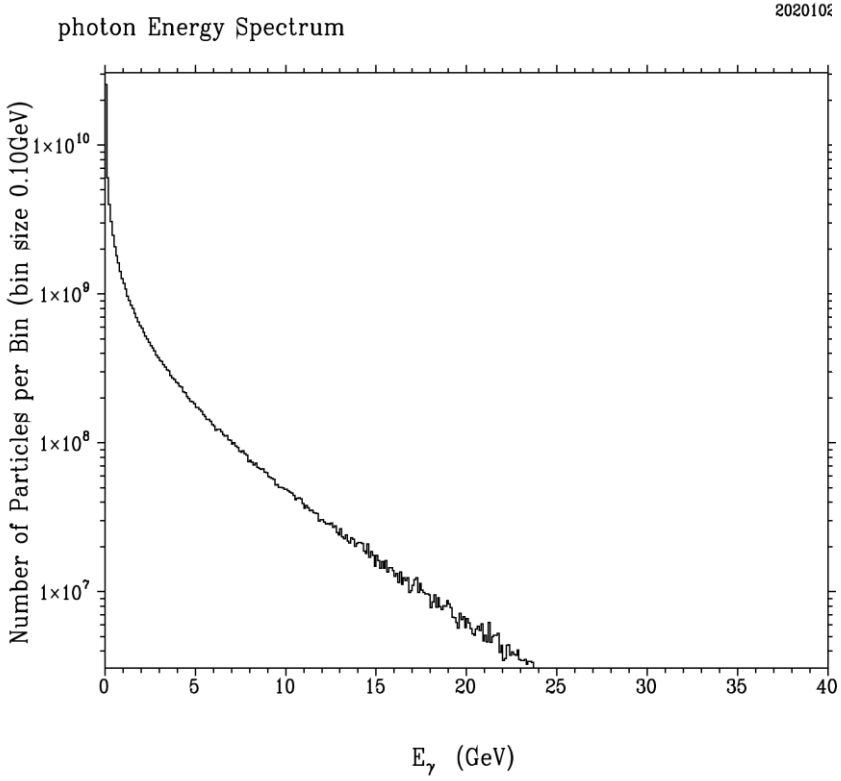
Experiment at the Main Beam Dump (continued)

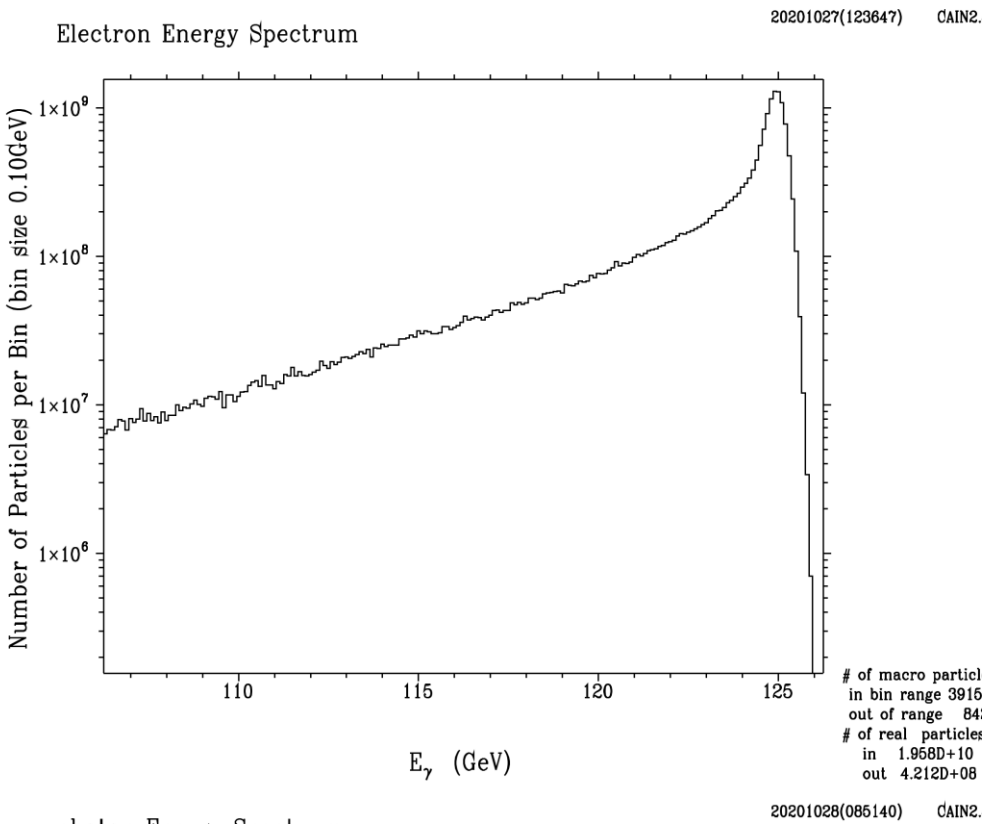
- The size of the electron/positron beam entering the dump window is a few mm in r.m.s. However, note the beam is swept such that the beam spot draws a circle of radius 6cm on the window during ~1ms pulse. This is to avoid concentration of the heat in the water (avoid boiling).
- The sweeper is located at ~150m upstream so that the kick angle is ~0.4mrad
- This defines the minimum size of the detector



Beam energy spectrum

- At the window of the main dump
- Just as an example
- The detail depends on the collision control





What else is needed?
Can even provide particle deck.

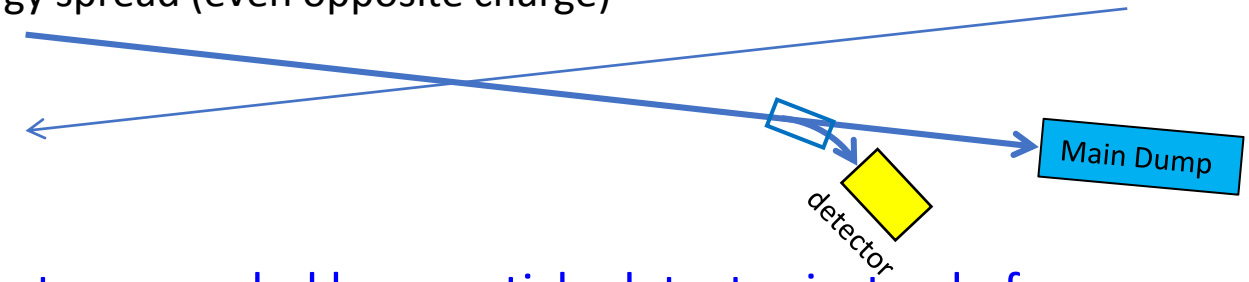
e+ Beam Dump Experiments

- Positron annihilation with atomic electrons.
- Excellent source of ALPs in the reaction $e^+e^- \rightarrow \gamma +$ ALP (E_{cm}= 350MeV)
- A well-segmented electromagnetic calorimeter, of depth about 5 m, in the region directly behind the e+ beam dump, or behind about 10 m of shielding.

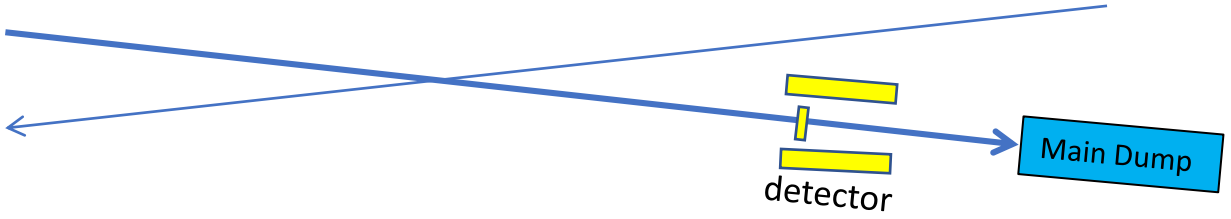
- This experiment with positron cannot be done at the same beam dump as the previous experiment.
- Hence, previous one must be at the electron side if both experiments are done.
- Feasible

Use of the beam between IP and Main Dump

- Extraction from somewhere downstream of IP
  - ✓ Parasitic with collision experiment, if possible
  - ✓ This requires beam bending in the dump line. This is actually very hard because of the large energy spread (even opposite charge)



- Or, put a thin target surrounded by a particle detector instead of extracting the beam
  - ✓ Seems to be very hard. The target must be extremely thin. The window of the main dump is made of Ti alloy of 1mm thick (~0.03X_0, TDR value) This is cooled by high pressure water from inside. (Thickness is determined by the water pressure inside, 10atm. We increased it to 5mm for safety.) So, if a target is to be inserted, it must consist of two plates with cooling water in between. CFS people wouldn't like it (tritium water, possible accident). Can the water be replaced with something else (e.g., gas helium)? Or, even thinner target? No cooling?



- After all, we conclude that the use of the beam in the dump line is not feasible

Far Detector

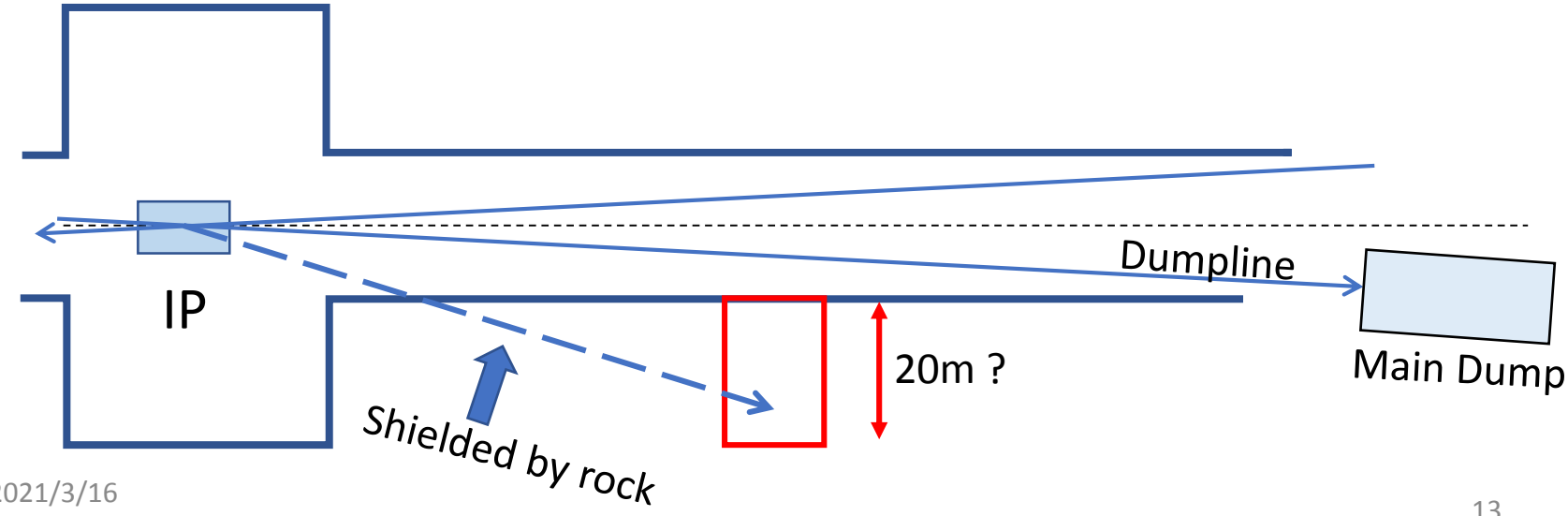
- Extraction from fixedtargetrequest.pdf

  If some ILC reactions — especially, Higgs decay to exotic species — lead to long-lived particles, it would be interesting to set up a detector at a distance of 50-200 m from the interaction point to observe the decays of those particles. Thus, we require:

  A cavern of size 20 m located at a distance of 50-200 m from the ILC interaction point, to set up an experiment to search for long-lived particles. An underground experimental area is much preferable to an experiment on the surface, to mitigate the cosmic ray background.

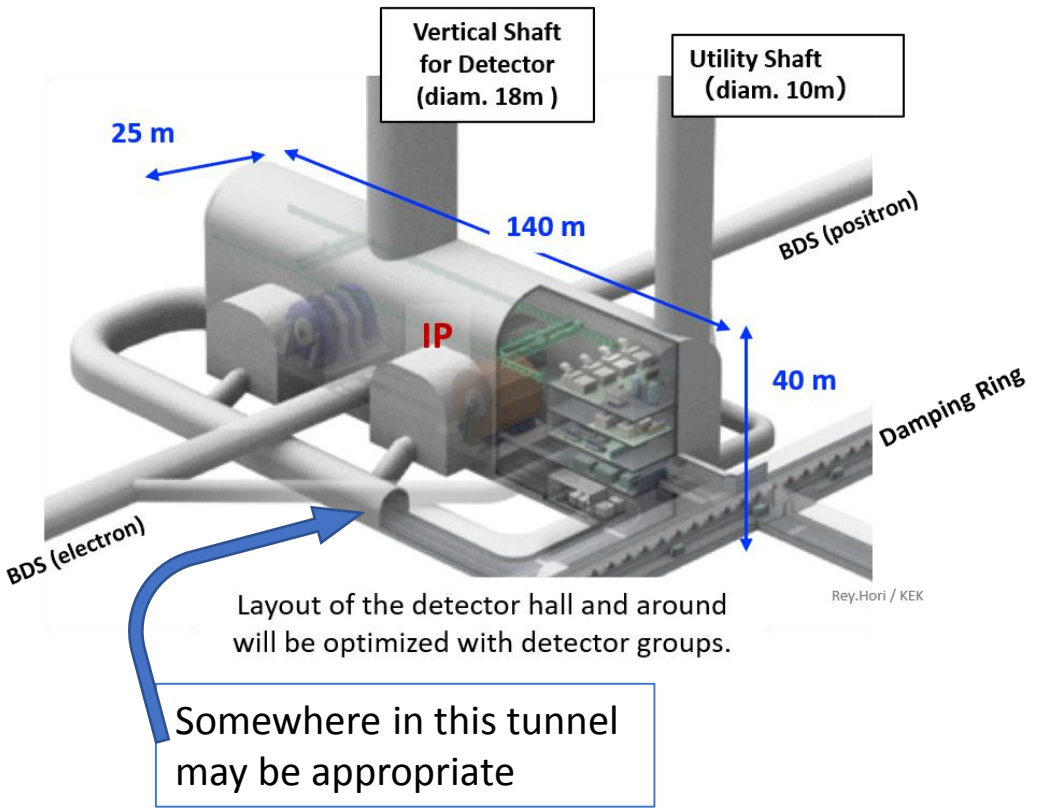
Far Detector (continued)

- This is to detect long-lived particles which were produced at IP and travelled through the detector, magnets, rock, …
- Muons from the IP must be shielded
- 50-200m from IP
- Should not be on the surface (shielding of cosmic ray)
- Cavern size ~20m (depth of the cavern?)
- Sounds feasible
- What must be considered
  - ✓ How big is the detector?
  - ✓ Transportation in the tunnel



Far Detector (continued)

- Another possible location may be a cavern to be constructed somewhere in the access tunnel surrounding the detector hall.
- Trucks can be used for transportation.
- Natural rock serves as the shield
- The distance from the IP should be chosen carefully.



Extracted Beam

- Various requirements
  - ✓Intense beam
    - Nuclear physics, strong QED
    - Same beam as the colliding beam but extracted to somewhere else (such as E-4)
  - ✓Weak beam
    - Many low-intensity bunches
    - Repeated as high as possible, ideally CW

Extracted Intense Beam

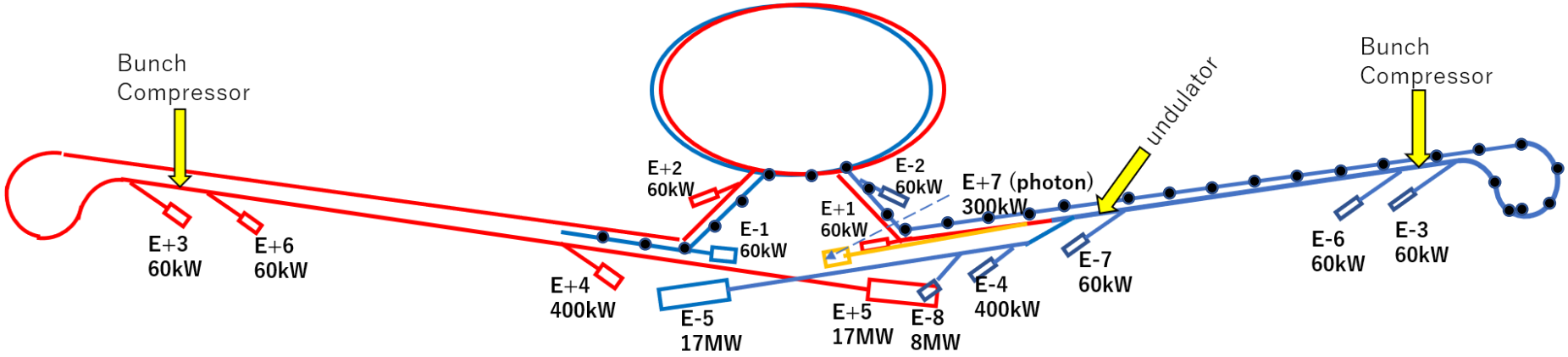
- Nuclear physics, strong QED
- Same beam as the colliding beam but extracted to somewhere else (such as E-4)
- Dedicated experiment (non-parasitic)
- Unfortunately, E-4 dump is limited to 400kW
  - ✓ All of E+-4 and E+-5 were 17MW big dumps in TDR
  - ✓ However, we reduced the power limit of most dumps except the two main dumps in autumn 2016 (ILC Change Request no.13, EDMS No: D*01145035)
  - ✓ This was to avoid too many “dirty” areas. Cost was not the main reason.
  - ✓ Changed the policy of machine commissioning
- But, is this experiment possible at all even at enlarged E+-4?
  - ✓ How do you design the detector?
  - ✓ The main dump requires high-pressure, running water to stop the several MW beam!!
  - ✓ If the high bunch charge is essential, what about 400kW with reduced number of buches?

Extracted Weak Beam: Required Beam Property

- Low bunch intensity but high repetition rate
  - ✓ CW beam is ideal but impossible due to the klystron pulse length (order ~1ms). Note that some light source linacs such as LCLS II allow CW operation. This is possible because the accelerating gradient is low.
- Bunch interval must be larger than 20-40 ns (25-50 1.3GHz buckets)
  - ✓ 1-10 events per bunch at most
  - ✓ Question from accelerator side:
    - What about N/25 particles in every 1.3GHz bucket, instead of N particles in 25th bucket ?
    - Do you have to identify from which bunch an event is generated?
- Energy spread and emittance
  - ✓ Numbers suggested by Maxim
    - Energy spread ~0.3%, transverse emittance 4mm x 0.4mrad
      - ~0.3% is comparable to 125GeV colliding beam
      - 4mm x 0.4mrad is 10^5 larger than the horizontal emittance of the colliding beam
  - ✓ Some people may require different values

Extracted Beam: Possible Bunch Pattern (1)

- For electron
  - ✓ Pulse length at most ~1ms, limited by klystron
  - ✓ Repetition rate 5Hz (10Hz possible in later stage)
  - ✓ Bunch pattern can be changed, if Damping Ring need not be used (no low emittance)
    - 1.3 GHz bucket filling (bunch interval 1/1.3 ns)
    - Or, every n-th bucket filled
    - Bunch charge < 2x10^10 (3.2nC)
    - Beam current in a pulse is limited below 5.8mA
  - ✓ Need additional electron gun with ~60MeV line
    - Or just use different laser? (every 4th bucket due to 325MHz subharmonic buncher)



Beam route without damping (black dots)

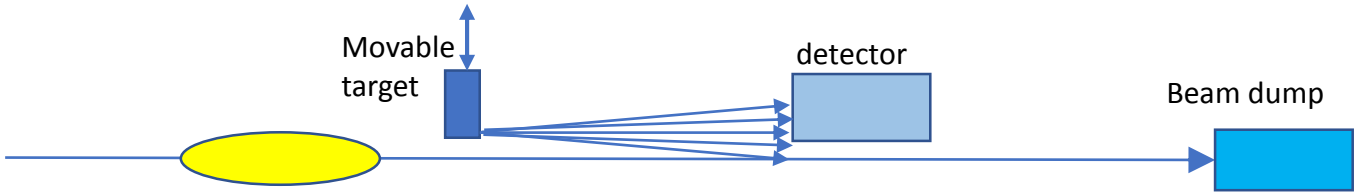
- Can use the straight section of DR with a DC dipole at the injection/extraction point
- Or, construct a parallel beam line in the DR tunnel (not expensive)

Extracted Beam: Possible Bunch Pattern (2)

- Positron
  - ✓Undulator scheme
    - The electron beam with the bunch pattern described in the previous page can generate a positron beam with the same pattern
    - But the energy spread and the emittance are much worse because DR cannot be used
      - Energy spread > x10, Horizontal emittance > $x10^4$, vertical emittance > $x10^6$
    - Intense studies of beam dynamics for the transportation of such a beam are necessary
  - ✓Electron-driven scheme
    - Pulse of 1ms is impossible. Only order of μs.
    - Possibility of using DR and slow extraction???
      - Lots of studies needed

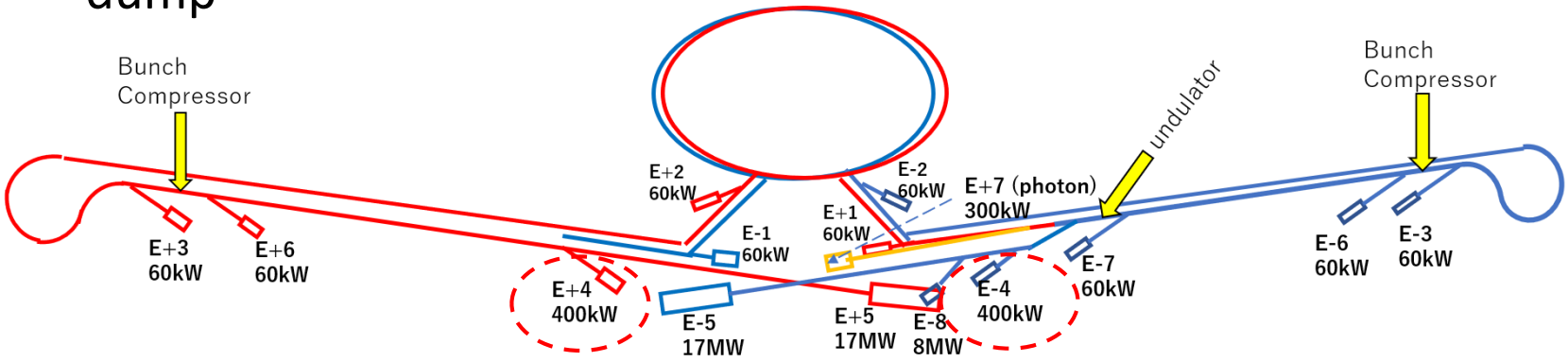
Extracted Beam: Beam Control

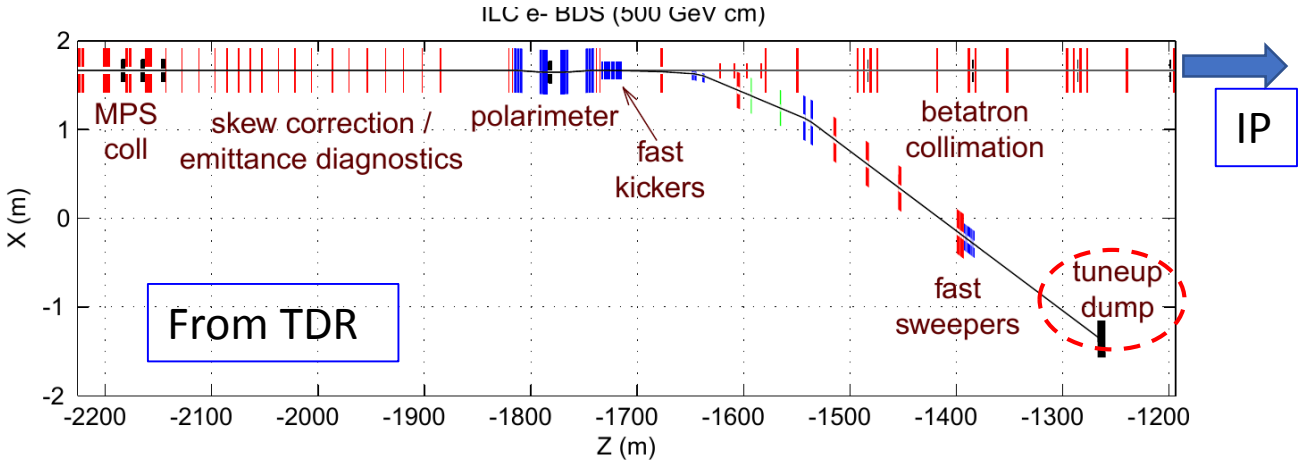
- The required beam seems to be very weak
  - ✓ It is not easy to convert 1-10 events at 20-40 ns interval into the beam current (Ampere).
  - ✓ If, for example, 10^4 electrons per bunch with 20-40 ns interval , the beam current in the pulse is $O(10^{-7})$ A, 5 orders of magnitude lower than the normal condition ($2x10^{10}$ x 1312 bunches in 0.7ms = 5.8 mA)
- This beam is not visible by BPM (Beam Position Monitor)
- Possible solution
  - ✓ Pilot bunch(es) of high intensity (visible) followed by weak bunches (invisible)
    - To create such a bunch is a bit acrobatic, but may be possible
    - Pilot bunch by the normal gun, injected into DR by normal fast kicker
    - Weak bunches by additional gun, use the parallel beam line in DR tunnel (DC → kicker)
    - Some (accelerator) people say the “weak bunches” can be “dark current origin”.
      - This is the cheapest solution from accelerator side but the beam quality would be the worst. Energy spread may be 100%.
  - ✓ Or, use only the halo part of the bunches by introducing “collimator/target”



Extracted Beam: Location

- I do not know how we can use the region from IP to Main dump
- But the main dump will not be needed because the beam is weak
- The best position of the measurement is the 400kW tune-up dump





Summary

- Fixed target experiments are very attractive and enhance the value of ILC
- There are several possibilities of using ILC beam for fixed target experiments
- Candidates
  - ✓Behind the main beam dump
  - ✓Far detector in a cavern near the dump line or along the access tunnel
  - ✓Extracted beam with pulse length up to ~1ms and bunch interval ns to tens of ns
- Use of the beam between IP and main dump is very difficult