Introduction to NBI + J-PARC hadron hall experiences

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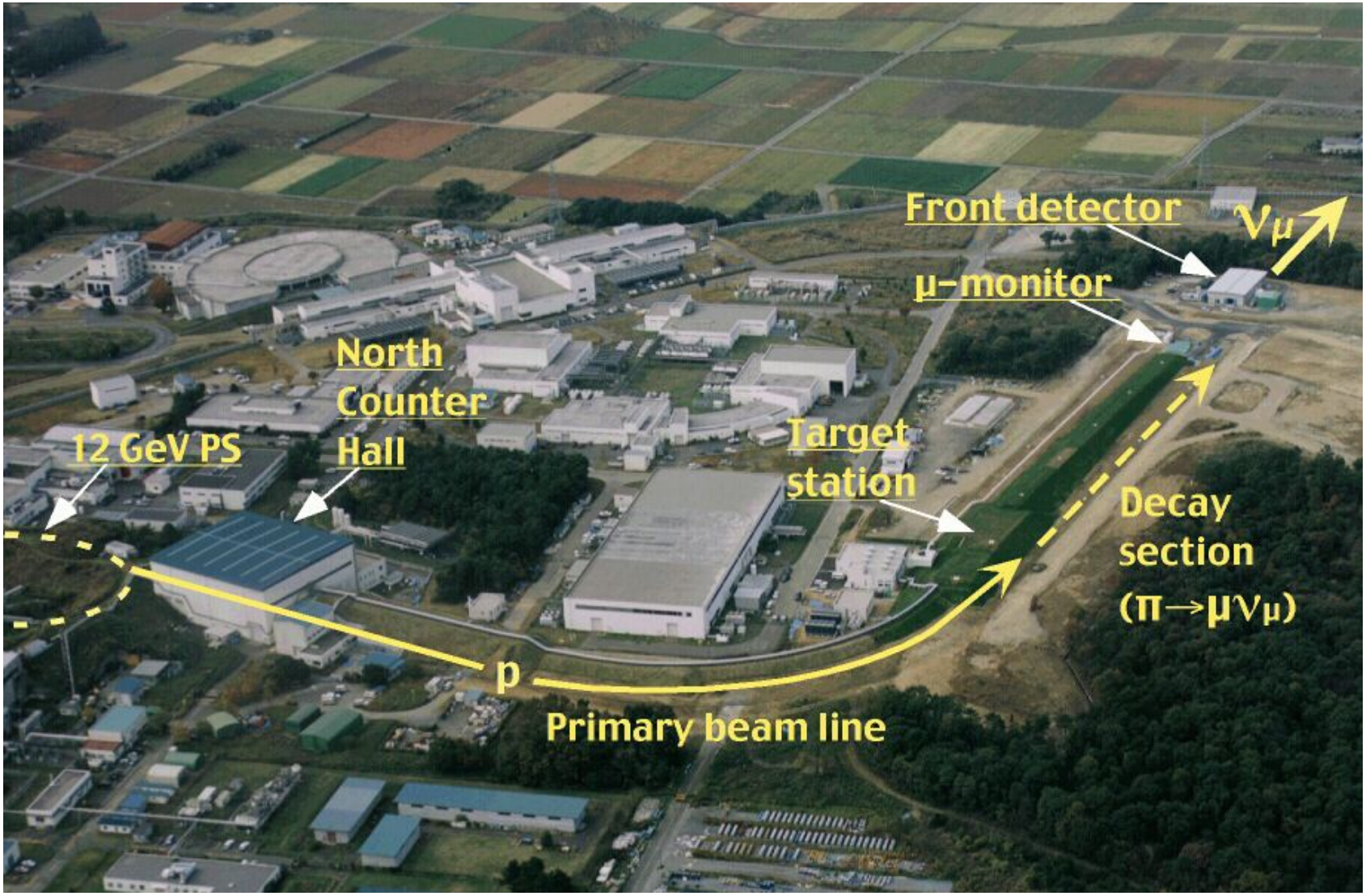
KEK

NBI1999
The first one of the series.

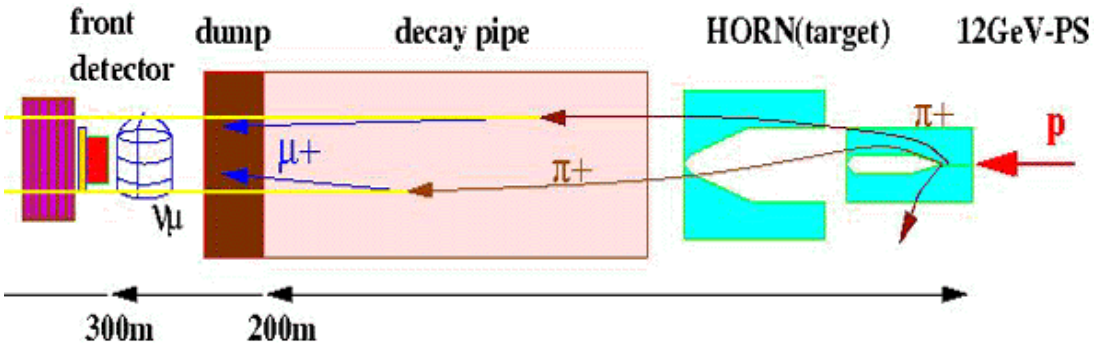
In order to celebrate the first beam for K2K experiment!

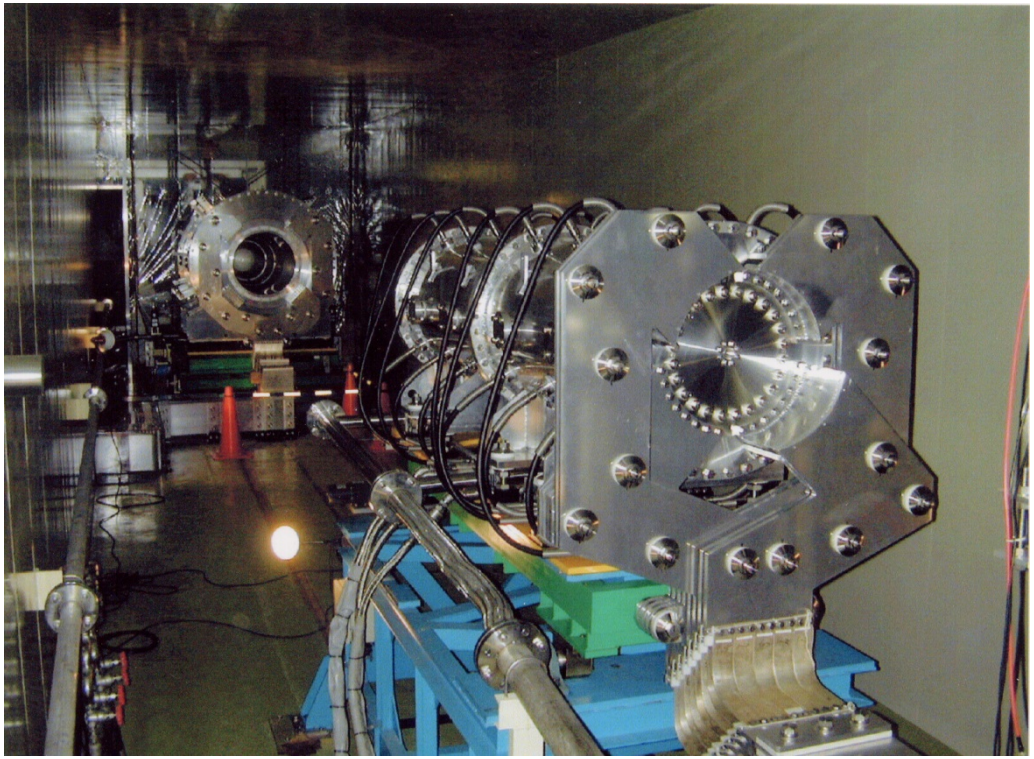
K2K: March 1999, First beam.

Neutrino Beam Facility for K2K



Horns, Target & Decay Volume

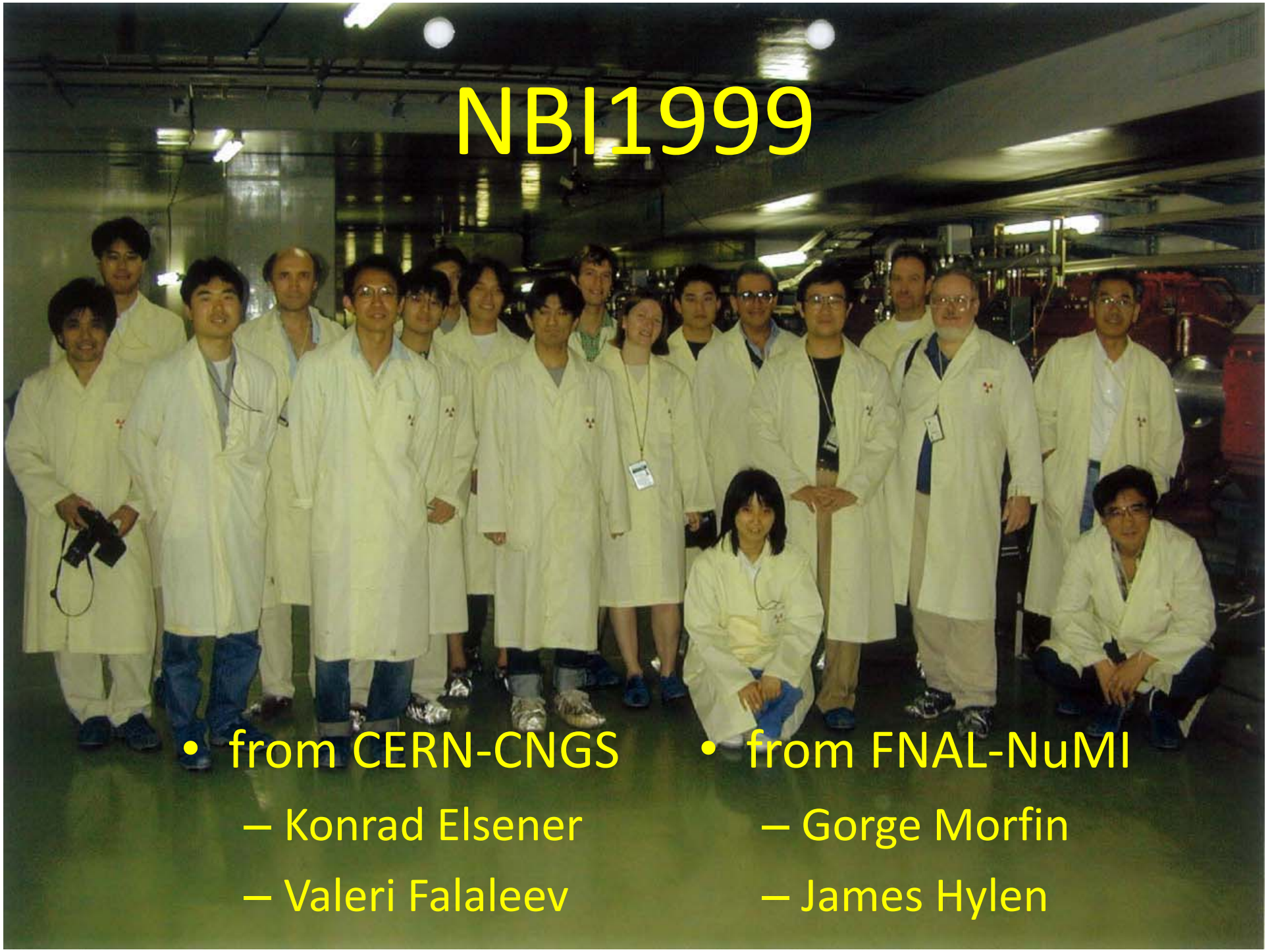




- Two Horns

(Collector & Reflector).

- Built-in Target in Collector
- 250kA Operation
- 10M Excitation with 30mmφTarget
- Transformer near-by
- 200m Decay Volume filled with He.


NBI1999
• from CERN-CNGS
– Konrad Elsener
– Valeri Falaleev
• from FNAL-NuMI
– Gorge Morfin
– James Hylen

At That Time…….

- FNAL
- NuMI Projet
- 120GeV Main Injector
- Several Hundred kW Beam Power
- Long Experience of Neutrino Beams

- CERN
- CNGS project
- 400GeV SPS
- Several Hundred kW Beam Power
- Long Experience of Neutrino Beams

- KEK
- K2K Project
- 12GeV 0.5 micro A – 5kW Beam Power
- No Experience of Neutrino Beams
- **SuperKAMIOKANE**

FNAL, CERN and KEK

NBI Over View (NBI2014)

- This workshop is a unique opportunity for physicists and engineers, working on conventional neutrino beams, to meet together, and discuss intensively their equipment in operating and planned experiments.
- Traditionally, this workshop focuses closely on the actual physical devices that compose neutrino beam facilities, with an emphasis on operating experiments and those at advanced phases of construction or planning.
- This will be the 9th instance of the workshop since the first in KEK in 1999; it has since rotated between the regions of Asia, Europe, and the United States.

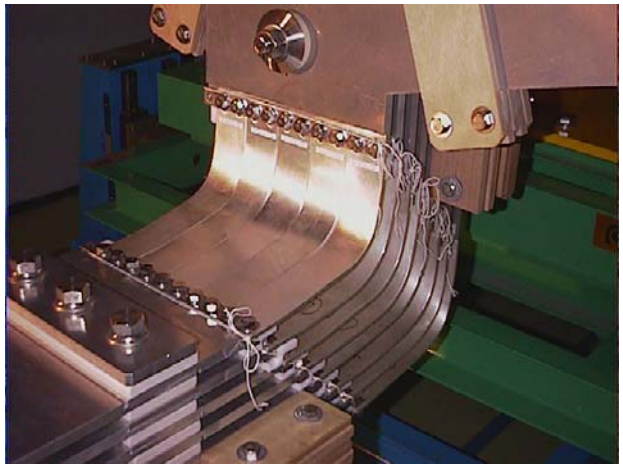
The emphasis of the workshop

- The emphasis of the workshop is detailed descriptions of equipment, tests and results, and in particular, on challenges in the design. The maniac discussion is always welcome.
- Not for one brilliant success, let's discuss hundred failures before the success.
- Let's report serious mistakes in order to avoid further mistakes of the same kinds.
- Let's make straight/frank discussions for future great success!

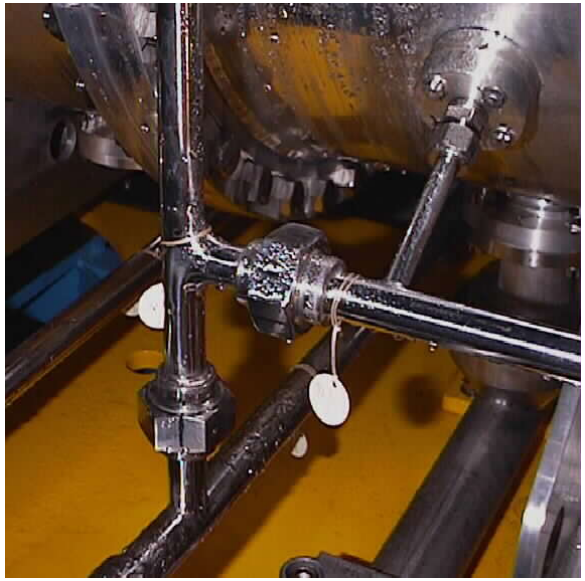
For these purposes

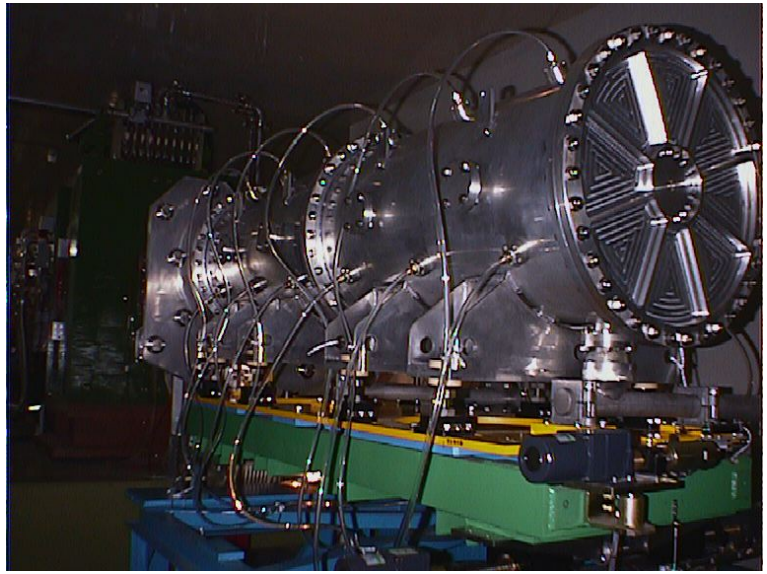
- No write ups and/or no proceedings will be published.
- Only a set of copies of presentations will be kept in the WEB site of NBI.
- Let's reserve one session for real discussion for the construction of real things!

Horn Flexible Feeder Trouble (8.5×10^5 excitations)

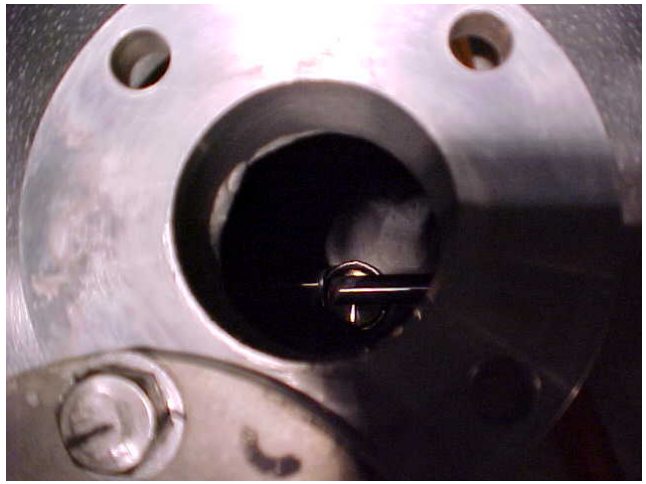


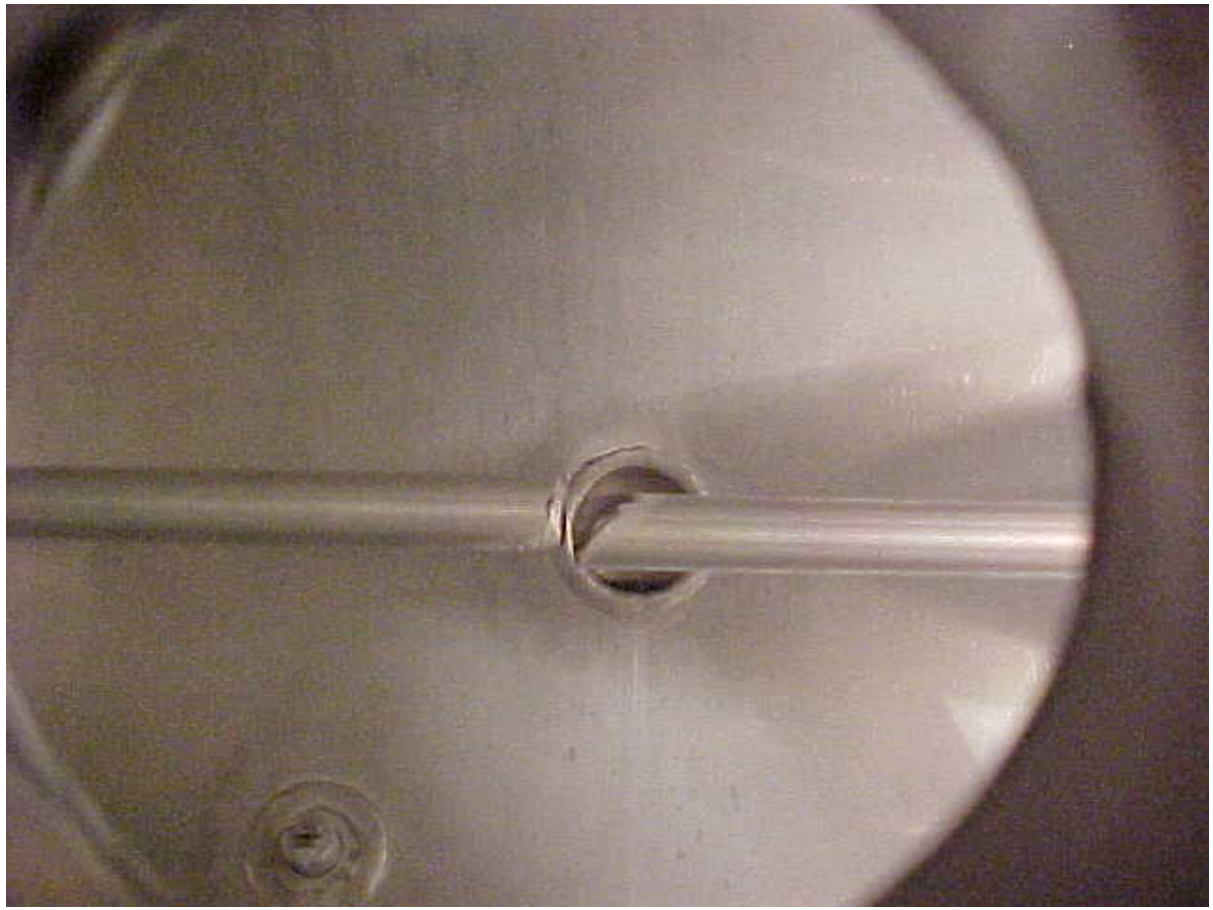
Horn Cooling Water Pipe Trouble (5×10^5 excitations)

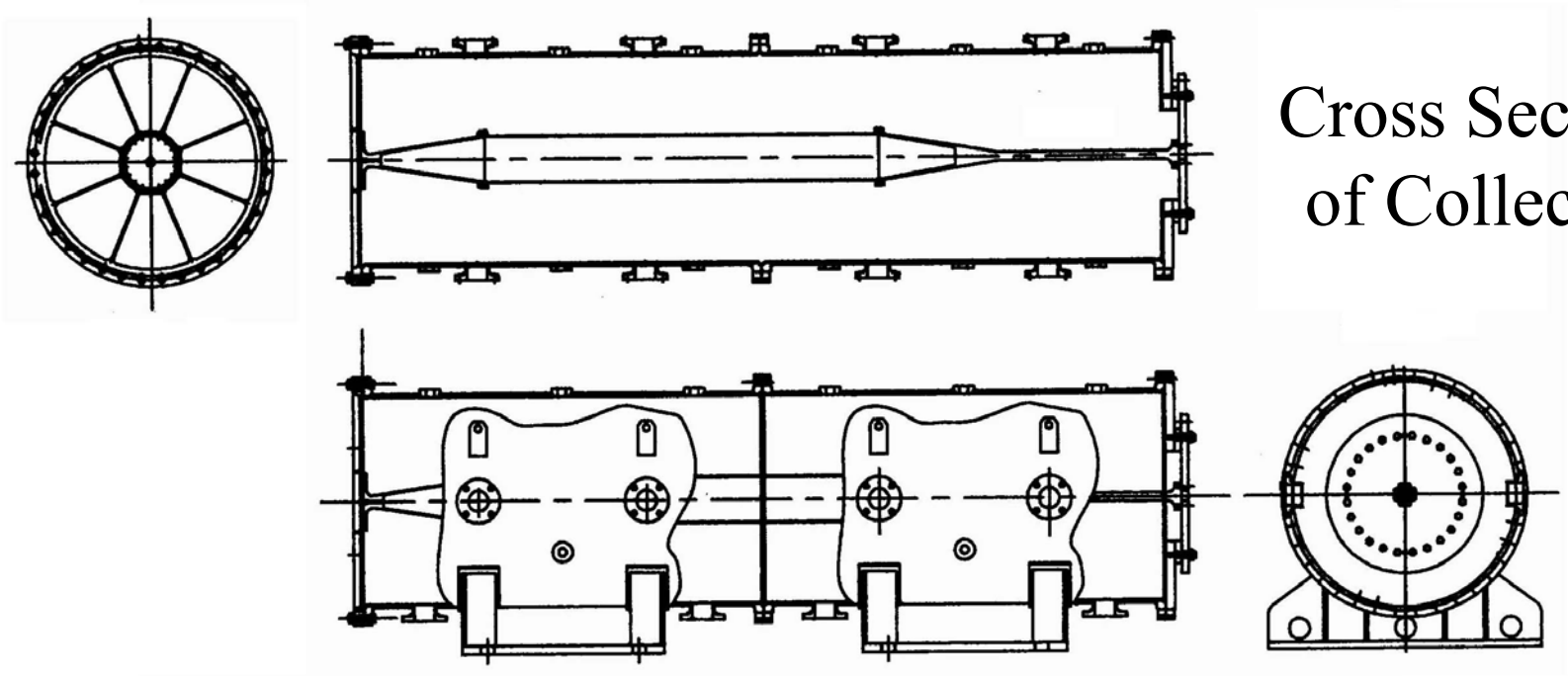




1st Horn Target Rod (20mmF) Break (1.9x10^6 excitations)

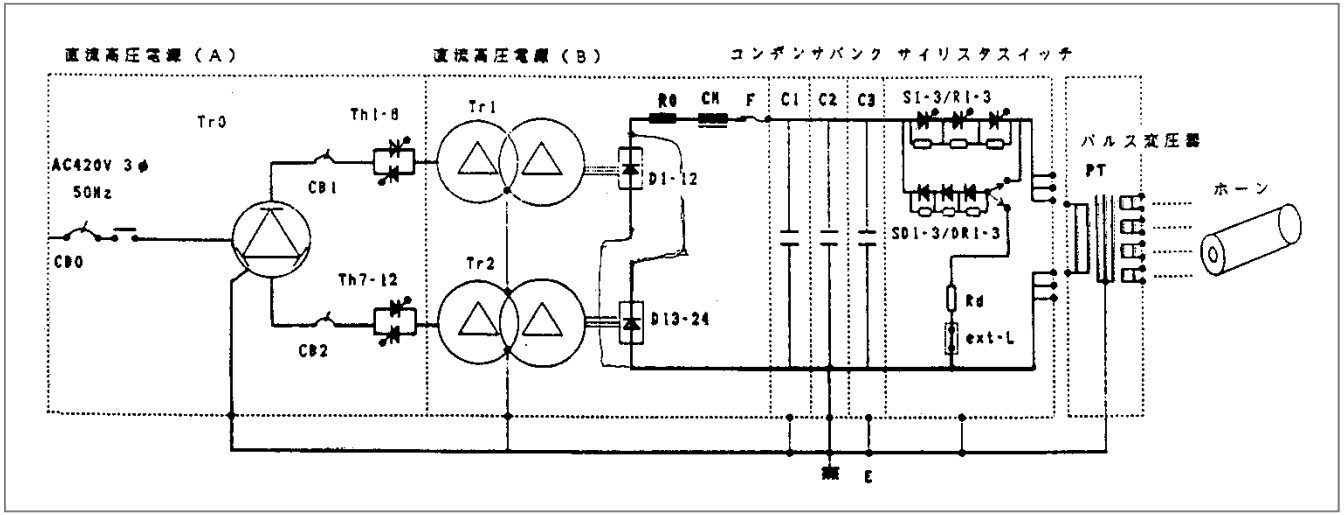




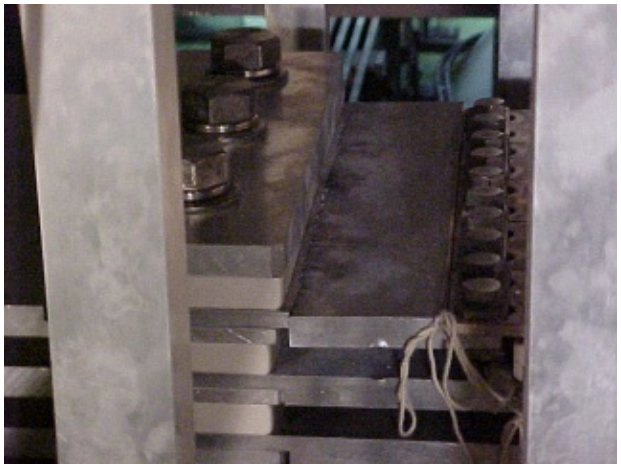


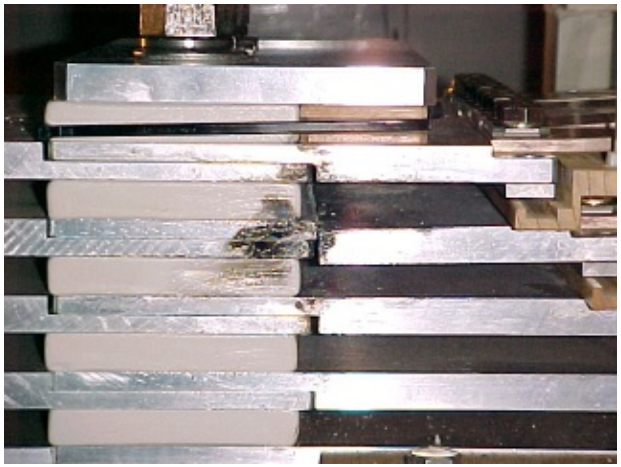
Cross Section of Collector

Power Supply for Horns

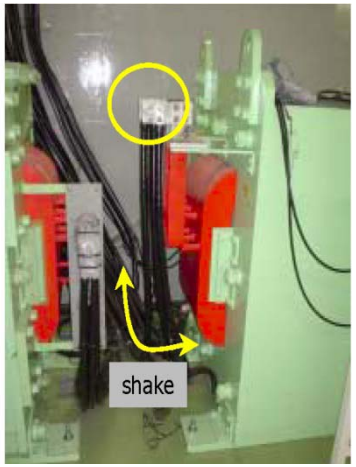


Horn Strip Line Break (4.3×10^6 excitations)





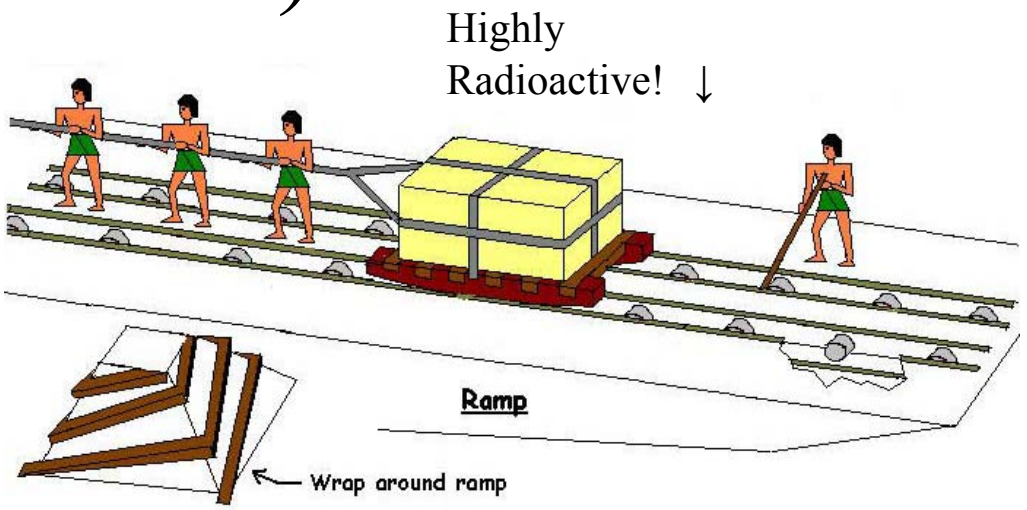
Transformer Flag (primary side) 25.8×10^6 Excitation



On Horns, what we learned are… (at NBI2000)

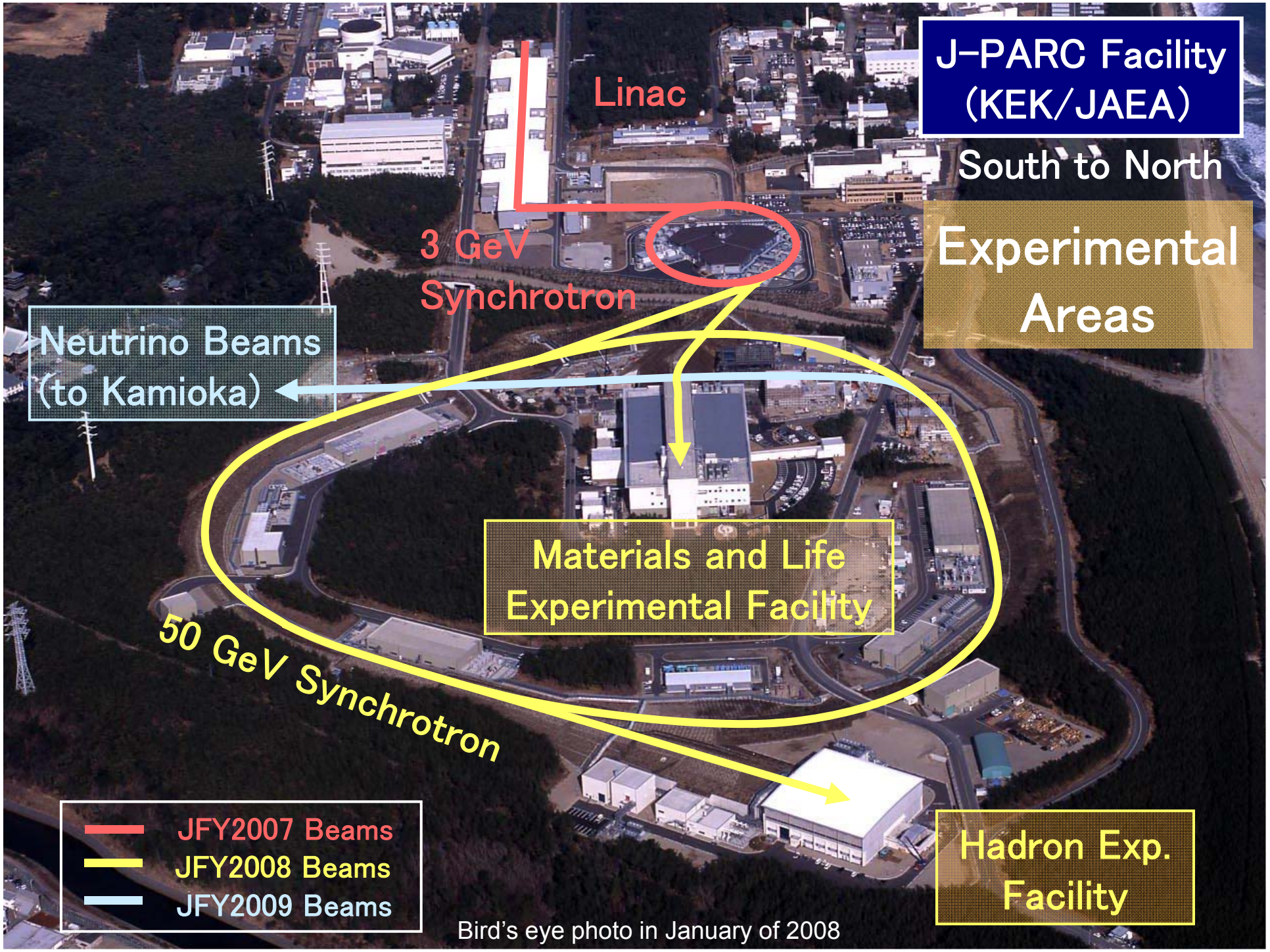
- Horn can work as designed in both mechanically and electrically.
- We should pay attention more and more to peripherals, which can break as designed.
- Test excitation in the actual position should be as many as possible.
- Never compromise with Physicists.
- Sufficient time, money, manpower for R/D and for operation, maintenance.
- Believe yourself.

For the Safety Construction & Maintenance (NBI2002)

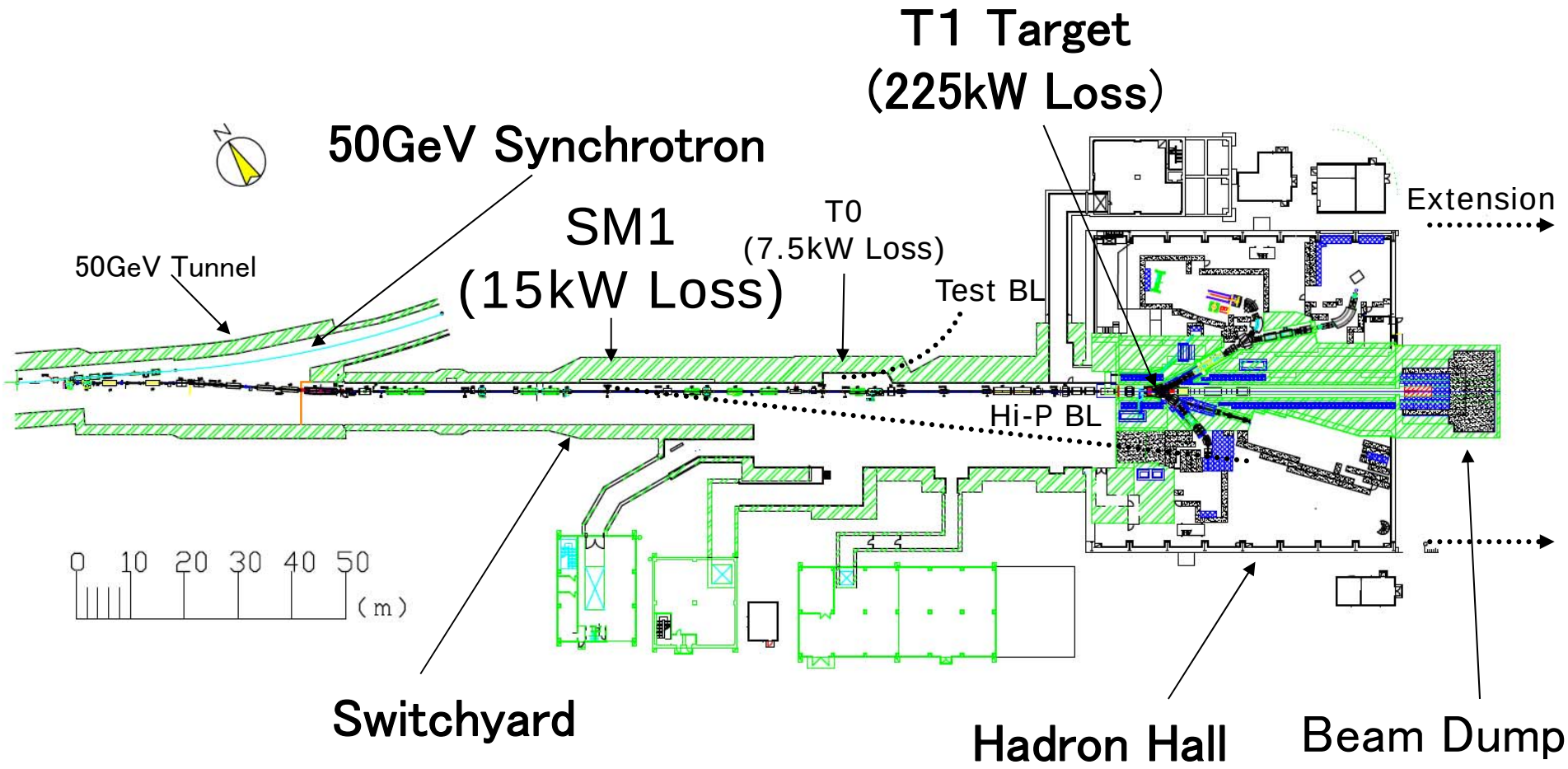


- Often our high-class people says that we should learn Egyptian Technology to save MONEY.
- This may be wrong. We need wider space & Crane to handle highly radioactive beam line elements!

J-PARC hadron hall experiences

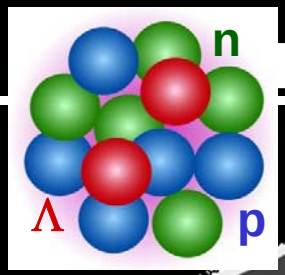

J-PARC Facility
(KEK/JAEA)
South to North
Linac
3 GeV
Synchrotron
Experimental
Areas
Neutrino Beams
(to Kamioka)
Materials and Life
Experimental Facility
50 GeV Synchrotron
Hadron Exp.
Facility
JFY2007 Beams
JFY2008 Beams
JFY2009 Beams
Bird's eye photo in January of 2008

Hadron Experimental Facility (Current Layout)



Hall

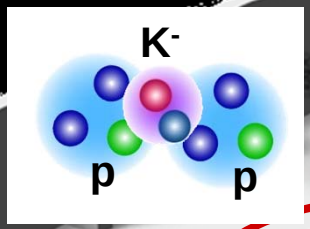
Slide By
H.Tamura



Ξ hypernuclei
ΛΛ hypernuclei
Ξ-atomic X-rays
Λ hypernuclear γ rays
Neutron-rich Λ hypern.
Pentaquark Θ+ search
K-pp bound state

Hyp. weak decay(A=4)
Hyp. weak decay(A=12)
π Double charge exch.
ω mesonic nuclei
Σp scattering

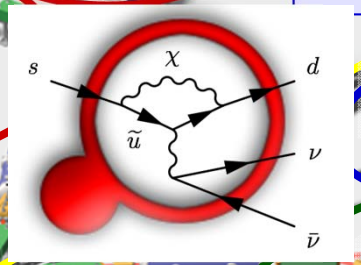
Dump



K1.8

K^0_L rare decays

Hadron mass in nuclei
Nucleon quark structure



K1.8BR

KL

K1.1

High momentum line

K-pp bound states
K- atomic X rays
η mesonic nuclei

K1.1BR

T violation in K+ decay
Universality in K+ decay
Θ+ study by K+n scattering

Φ mesonic nuclei
Λ hypernuclear γ rays
Σ-nuclear systems
YN scatering
Θ+ hypernuclei

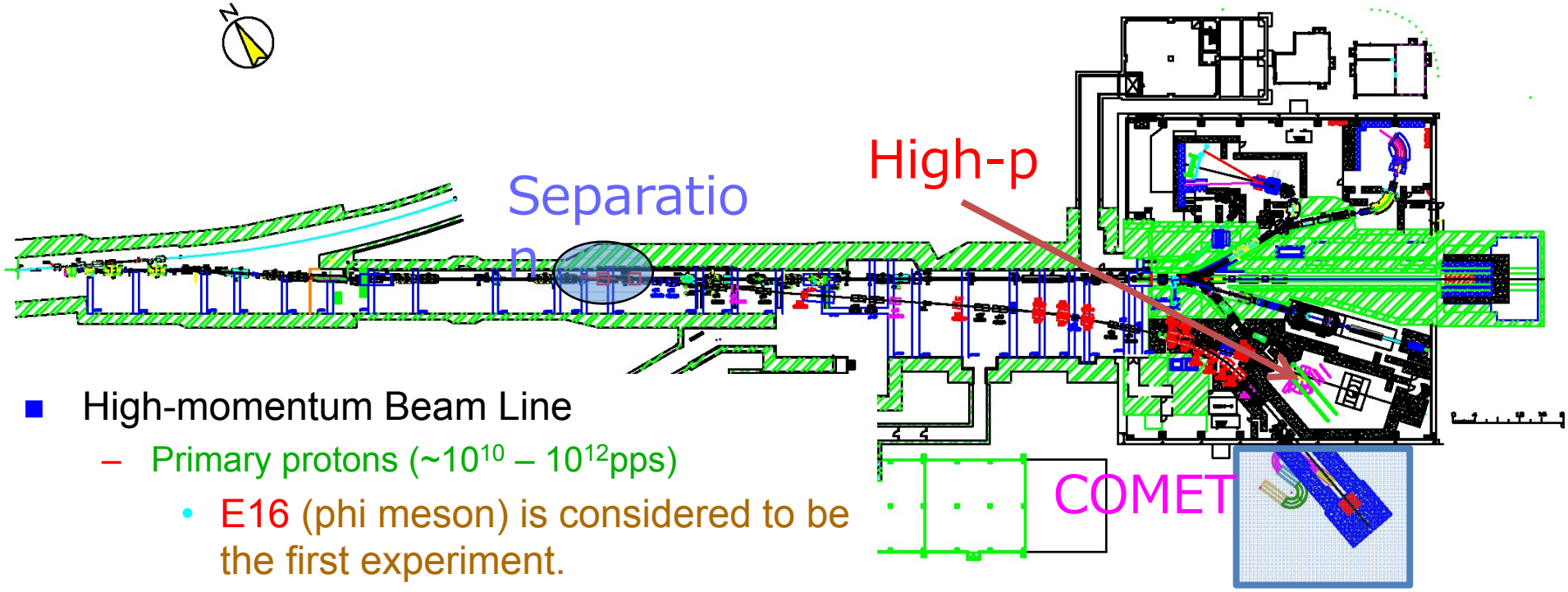
30~50 GeV
primary beam

Approved (stage-2) / (stage-1) / proposed,LOI

μ-e conversion search

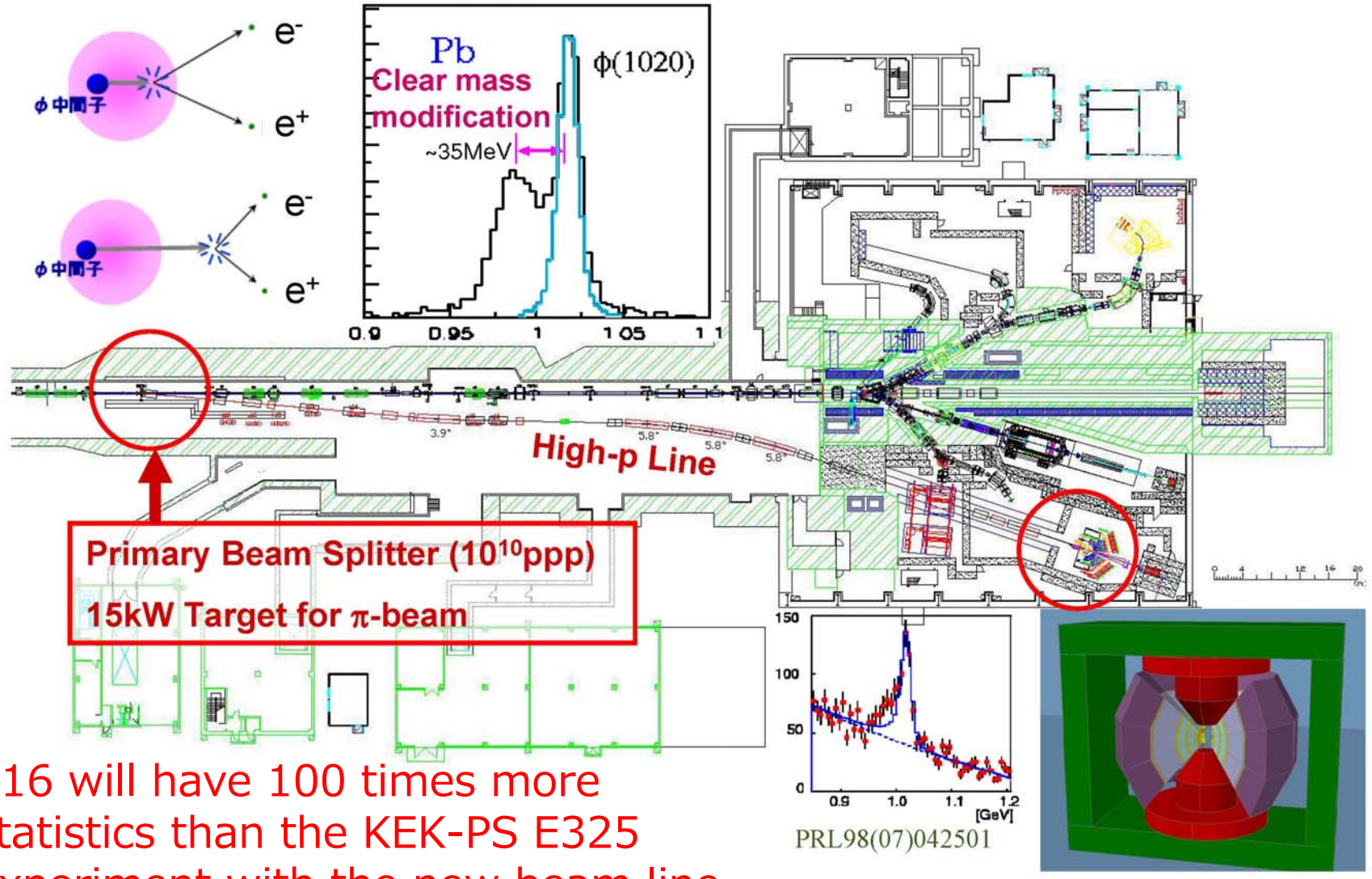
New Primary Proton Beam Line

- New primary Proton Beam Line



- High-momentum Beam Line
  - Primary protons (~10^{10} – 10^{12}pps)
    - E16 (phi meson) is considered to be the first experiment.
  - Unseparated secondary particles (pi, …)
    - High-resolution secondary beam by adding several quadrupole and sextupole magnets.
- COMET
  - Search for μ to e conversion
  - 8 GeV, 50 kW protons
  - Branch from the high-momentum BL
  - Annex building is being built at the south side.

High-p Line and E16 Spectrometer

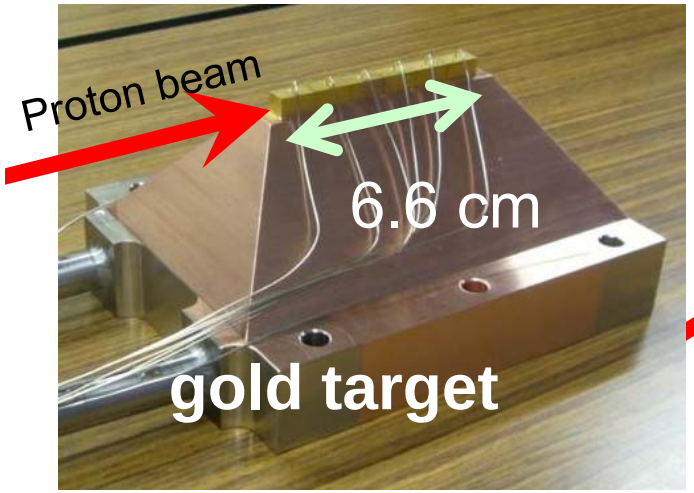


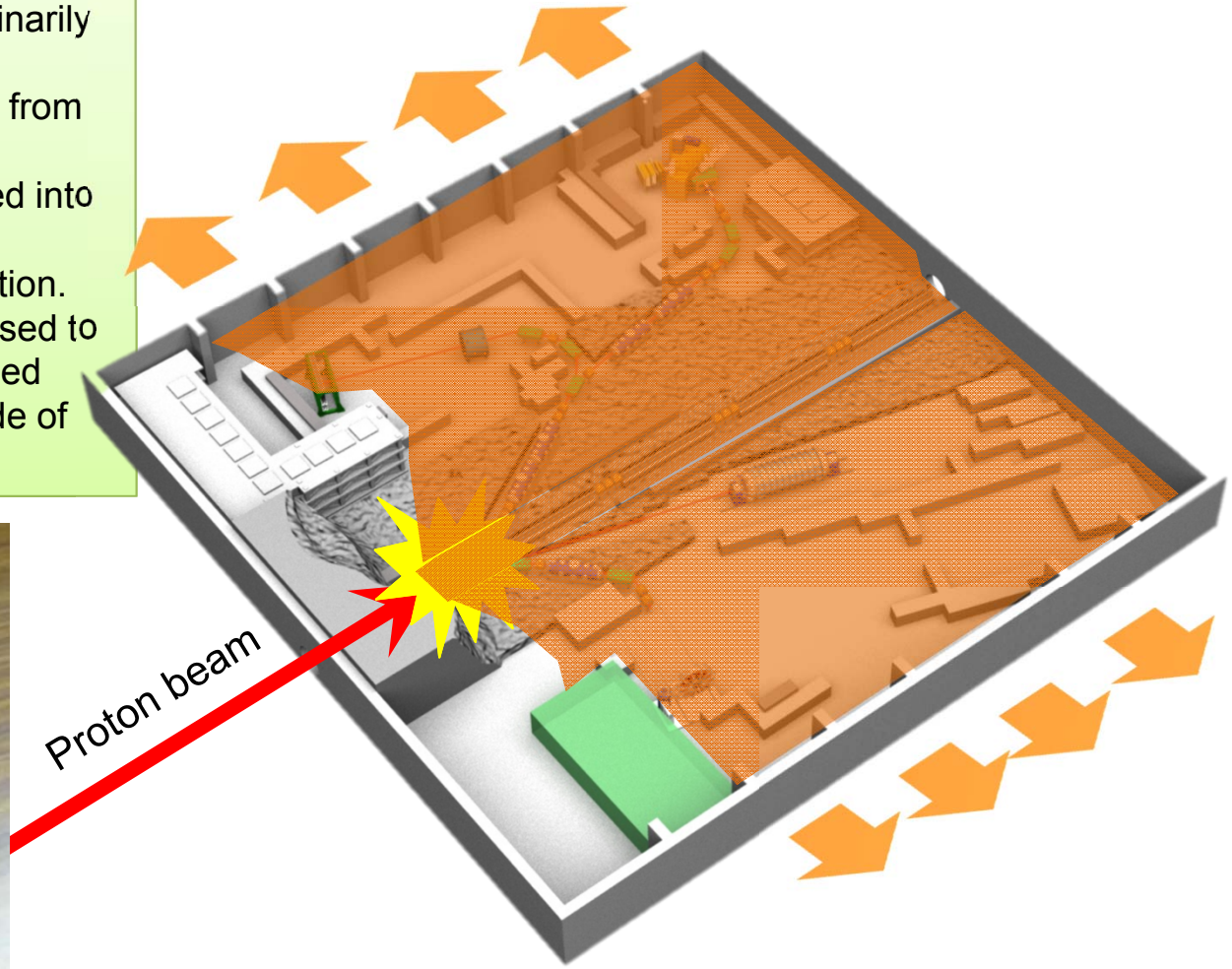
E16 will have 100 times more statistics than the KEK-PS E325 experiment with the new beam line and the spectrometer

Outline of the Accident

11:55 on May 23

- An abnormal proton beam was injected to the gold target.
- The target heated up to a extraordinarily high temperature.
- Radioactive material was released from the target.
- The radioactive material was leaked into the HD hall.
  → Workers were exposed to radiation.
- The radioactive material was released to the outside of the radiation controlled area and to the environment outside of the HD hall.

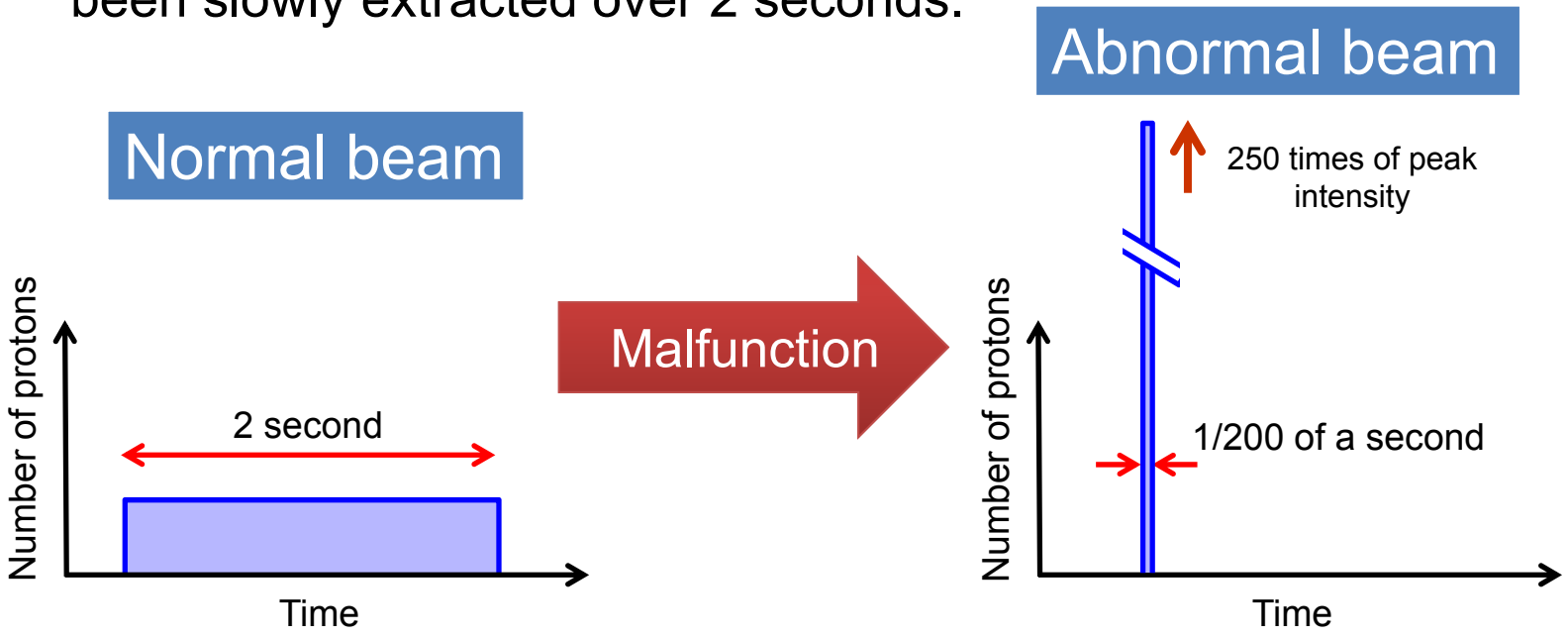




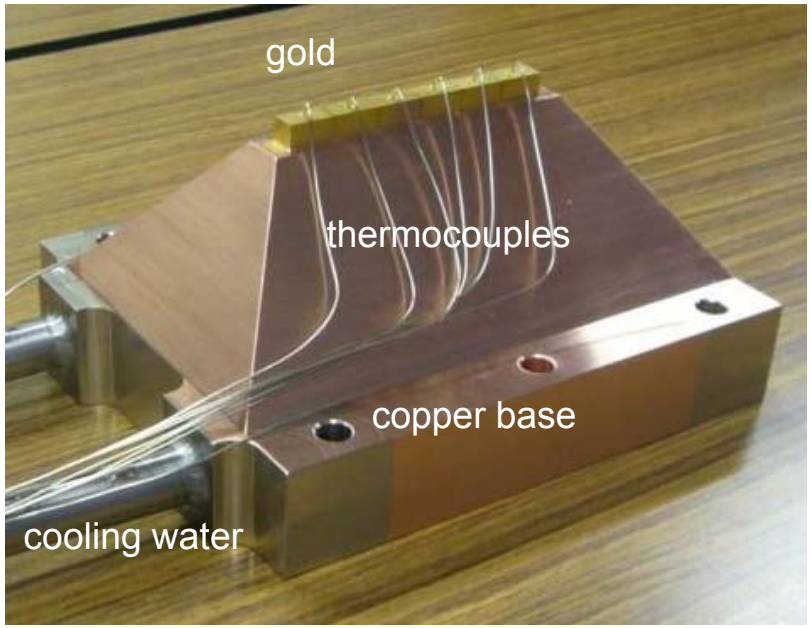
Abnormal Beam

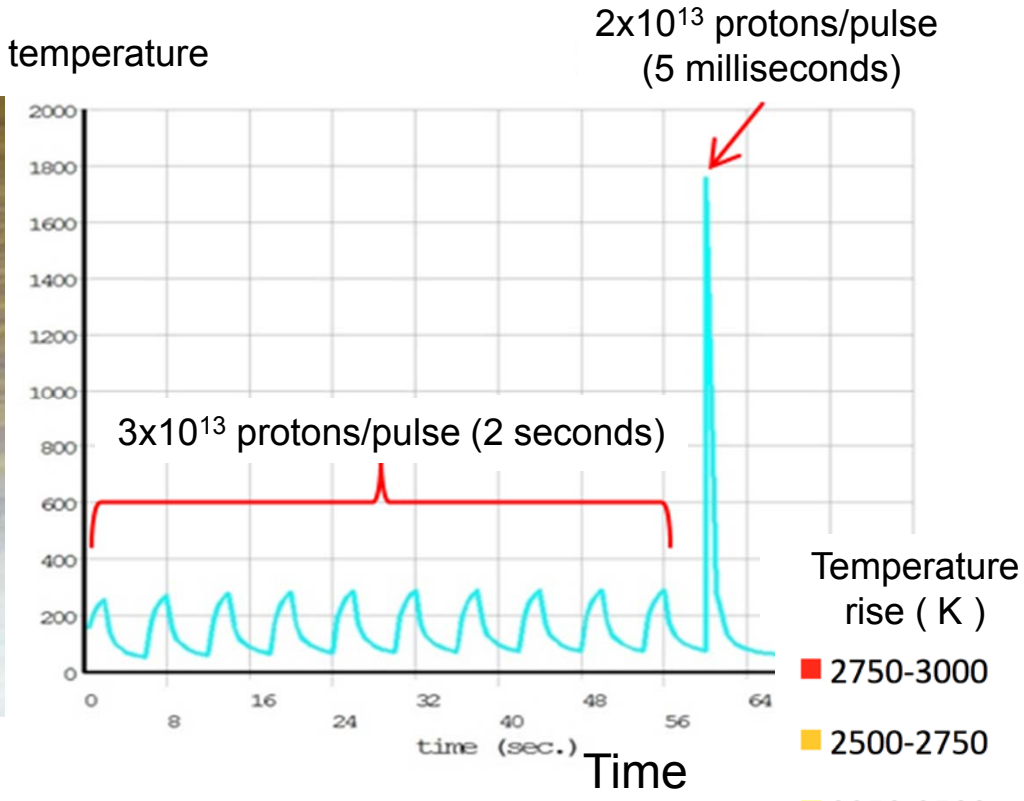
- At around 11:55 on May 23, the power supply system of a special magnet in the 50 GeV Synchrotron malfunctioned.

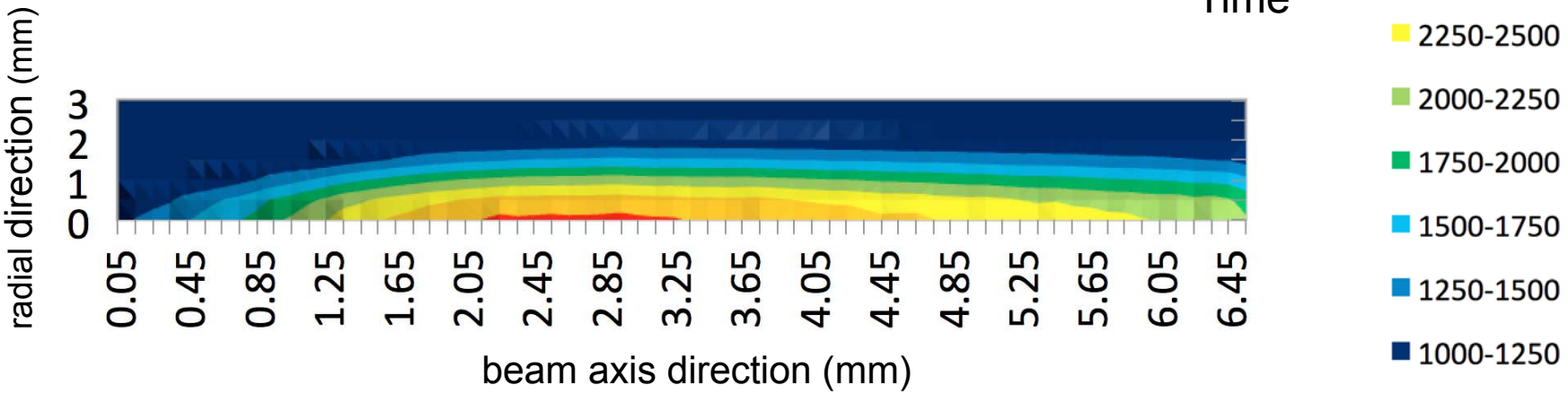
  → 2×10^{13} protons were extracted in a very short period of 5 milliseconds, while in normal operation 3×10^{13} protons should have been slowly extracted over 2 seconds.



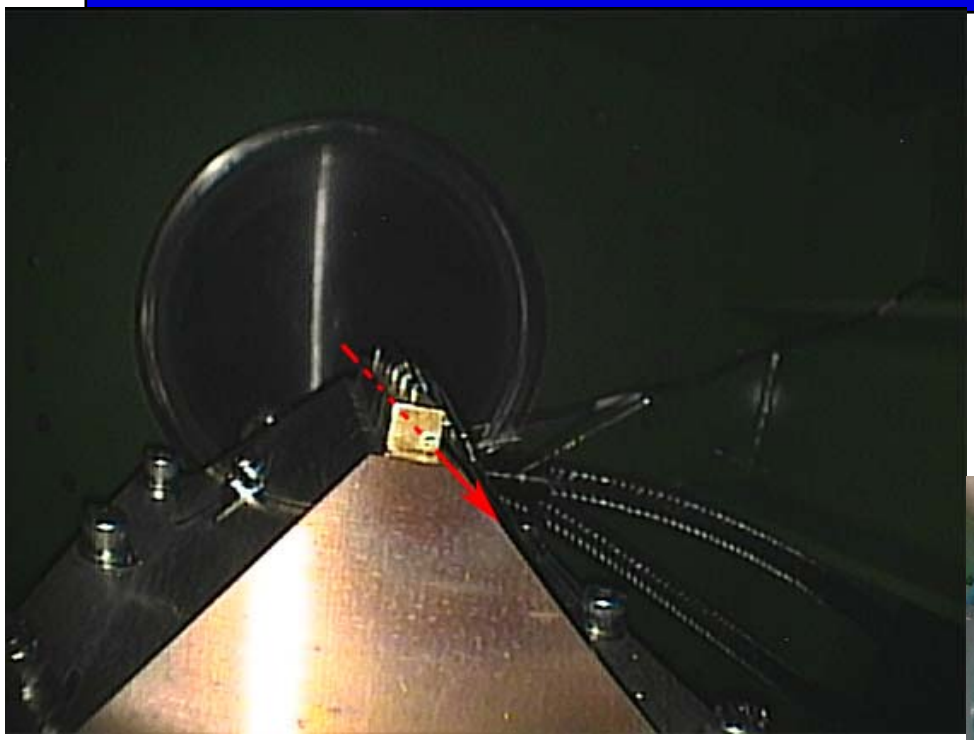
Target Temperature（Simulation Results）





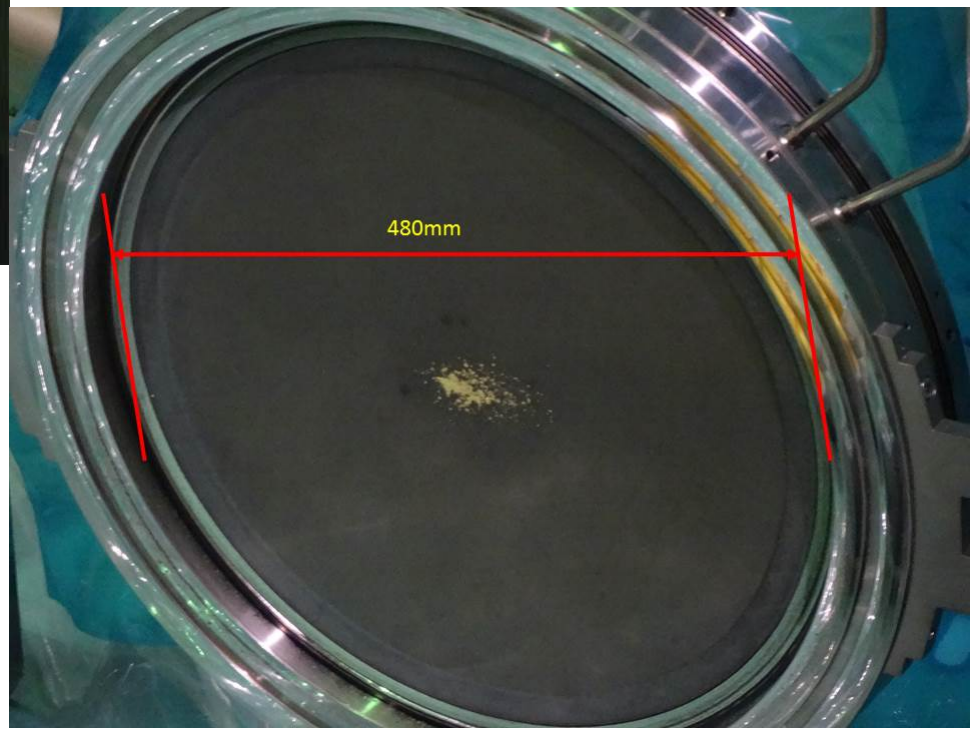


Observed Au Target



Au target observed from the downstream: a 1mm in diameter hole was seen at the downstream end.

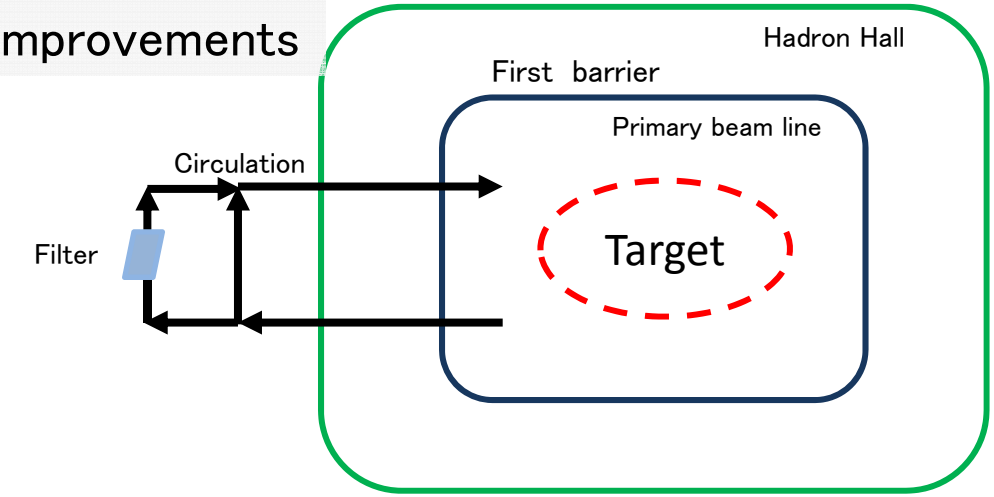
Traces of sprayed-out melting gold at the Be window at the downstream



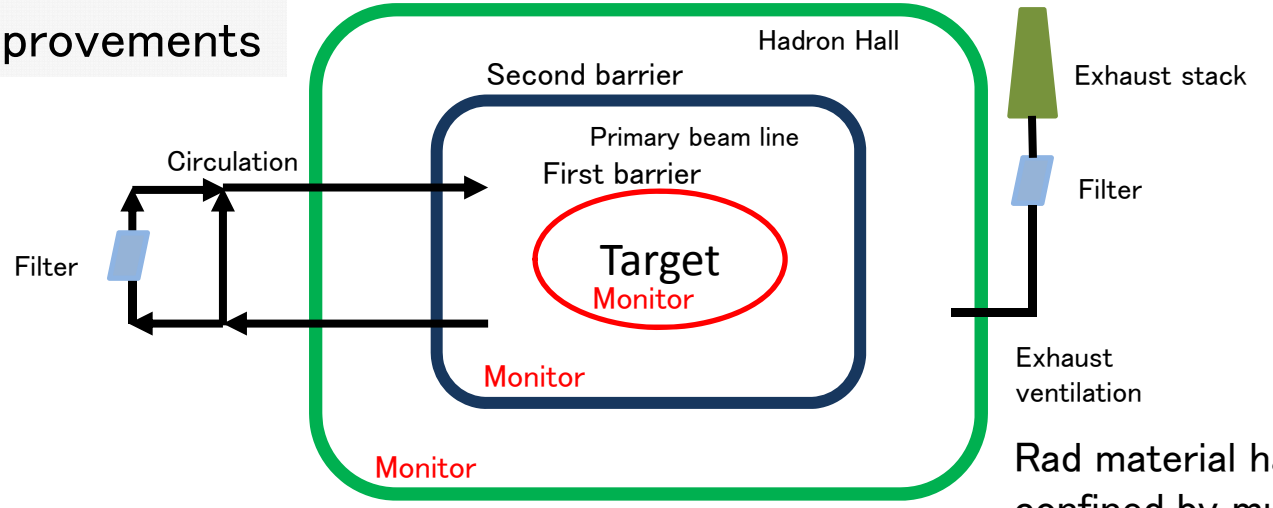
These observations well match with our simulation results.

Concept of the improvements of the Hadron facility

Before the improvements



After the improvements



Rad material has to be confined by multiple barriers.

Hadron Hall – facility renovations

HH ventilation system with a monitor and a stack

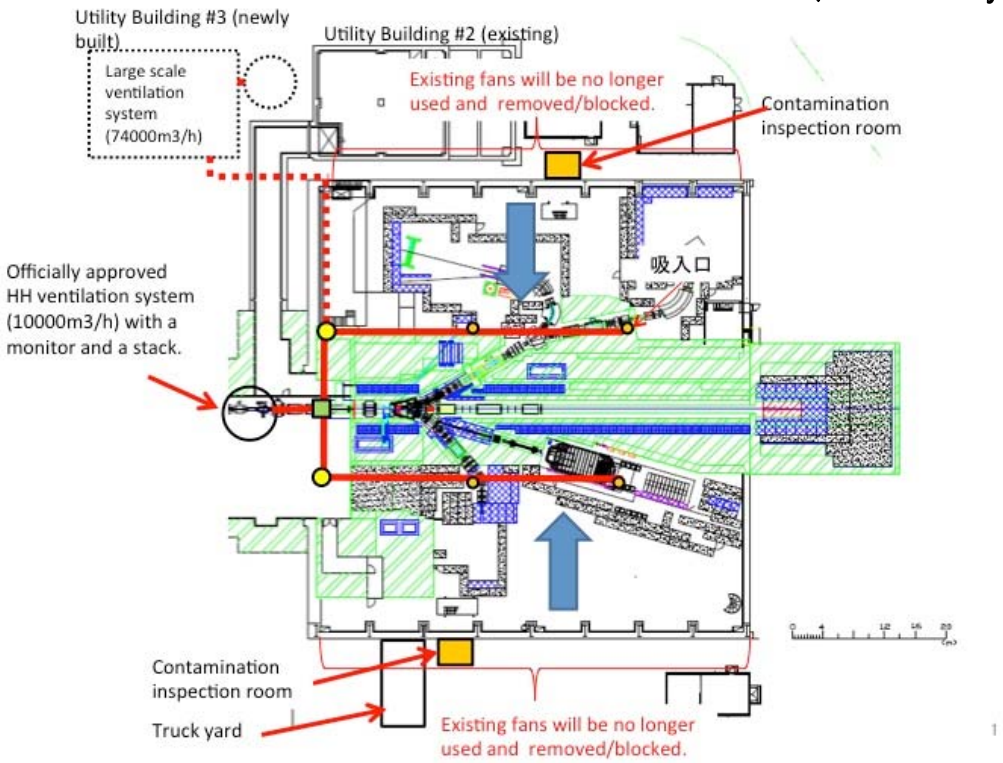
(authorized on 2014.March.19, inspected on April.22)

exhaust duct

stack

filters

ventilator (10,000 m³/h)



North exhaust fans: removed and sealed (2014.January.10)

Truck yard (tent)

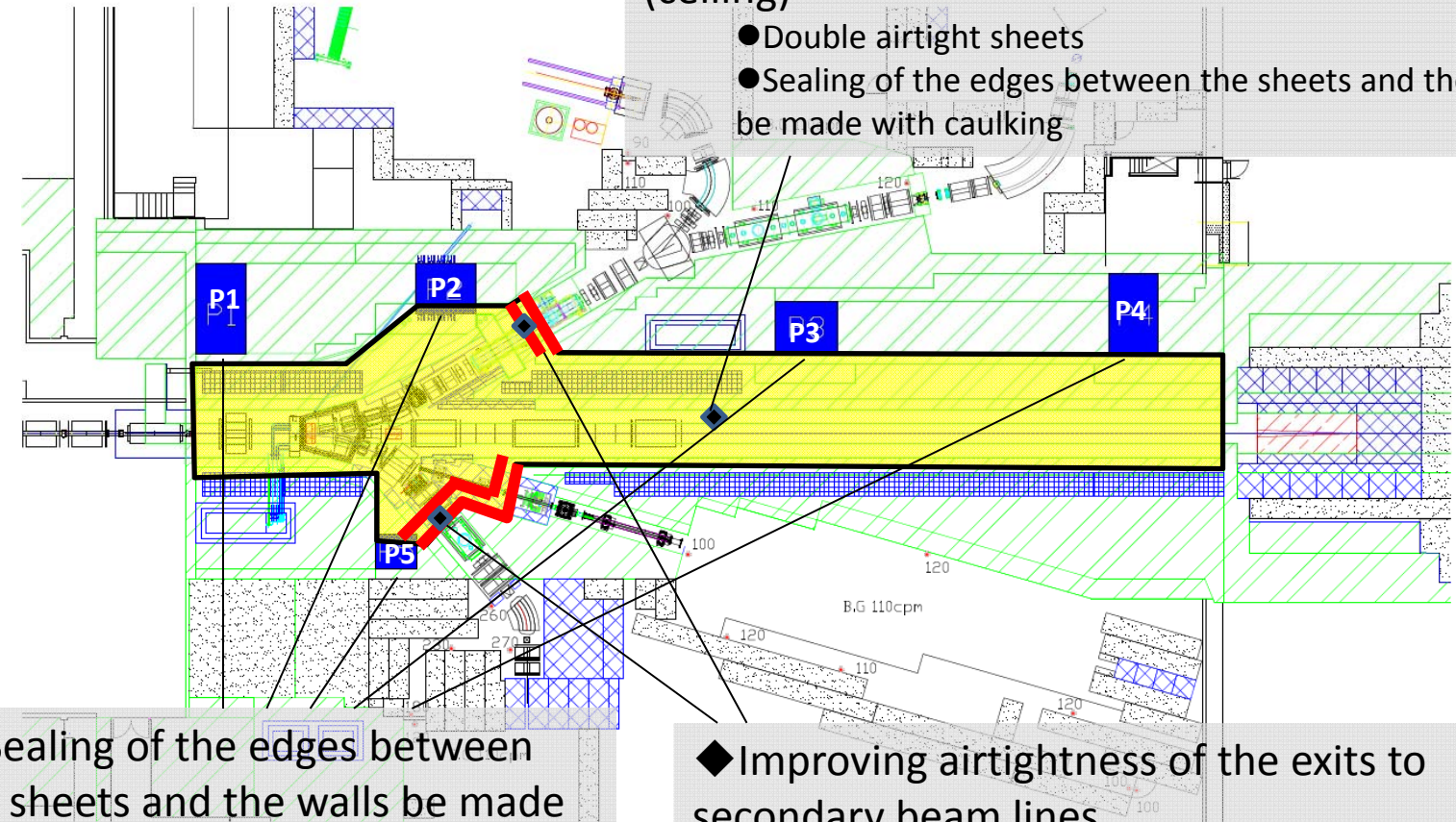
South exhaust fans: removed and sealed (2014.January.10)

Construction at the South Area

Hadron Hall – renovations in the Experimental Hall

◆Improving airtightness of the upper shielding (ceiling)

- ●Double airtight sheets
- ●Sealing of the edges between the sheets and the walls be made with caulking



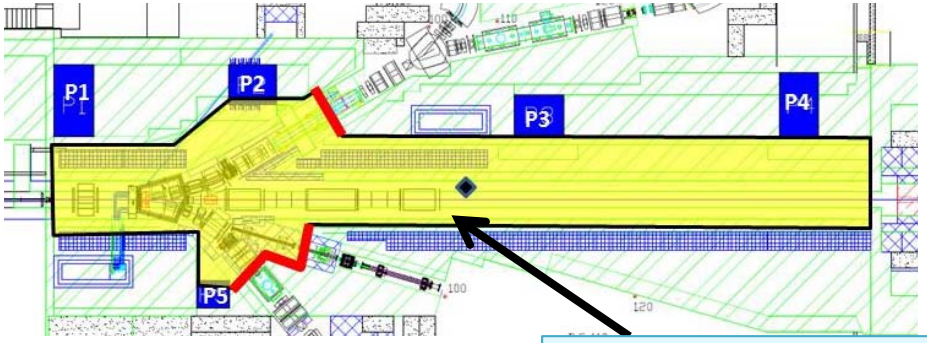
◆Sealing of the edges between the sheets and the walls be made with caulking

- ●Strengthening seals of gaps and cable exits

◆Improving airtightness of the exits to secondary beam lines

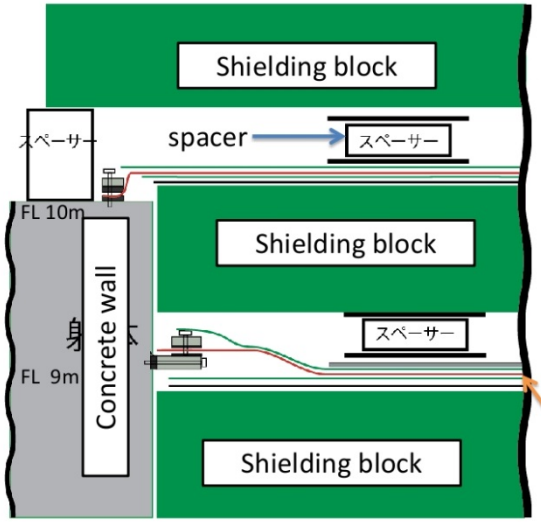
- ●Double air-partitions
- ●Sealing of the edges with caulking

Hadron Hall – renovations in the Experimental Hall

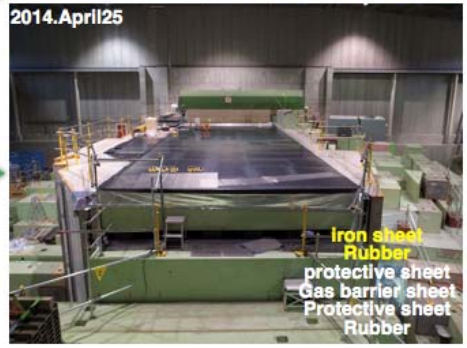


improving air-tightness
of Primary Beam Line

side view

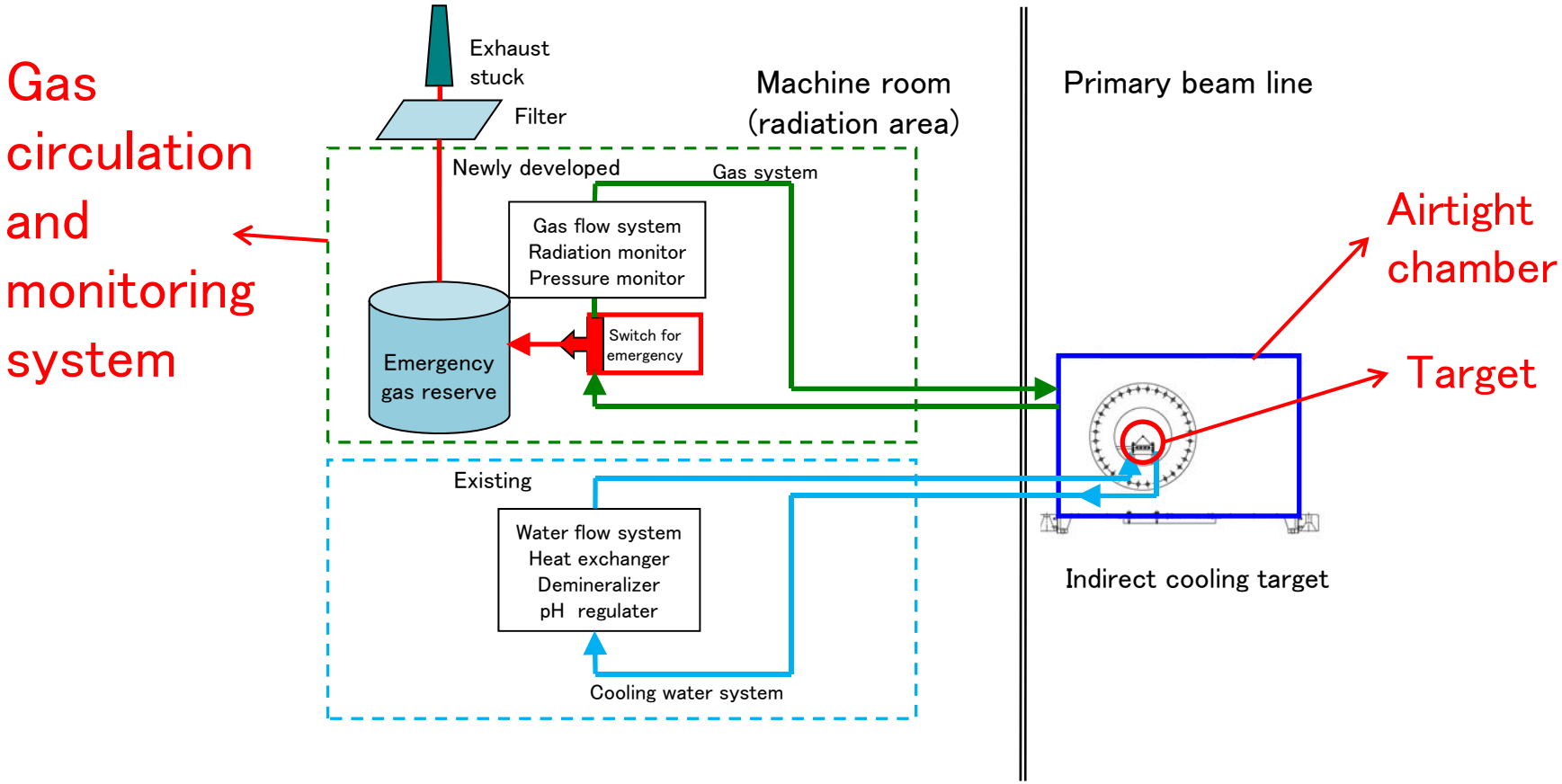


Gas barrier sheet
Protective sheet
Rubber



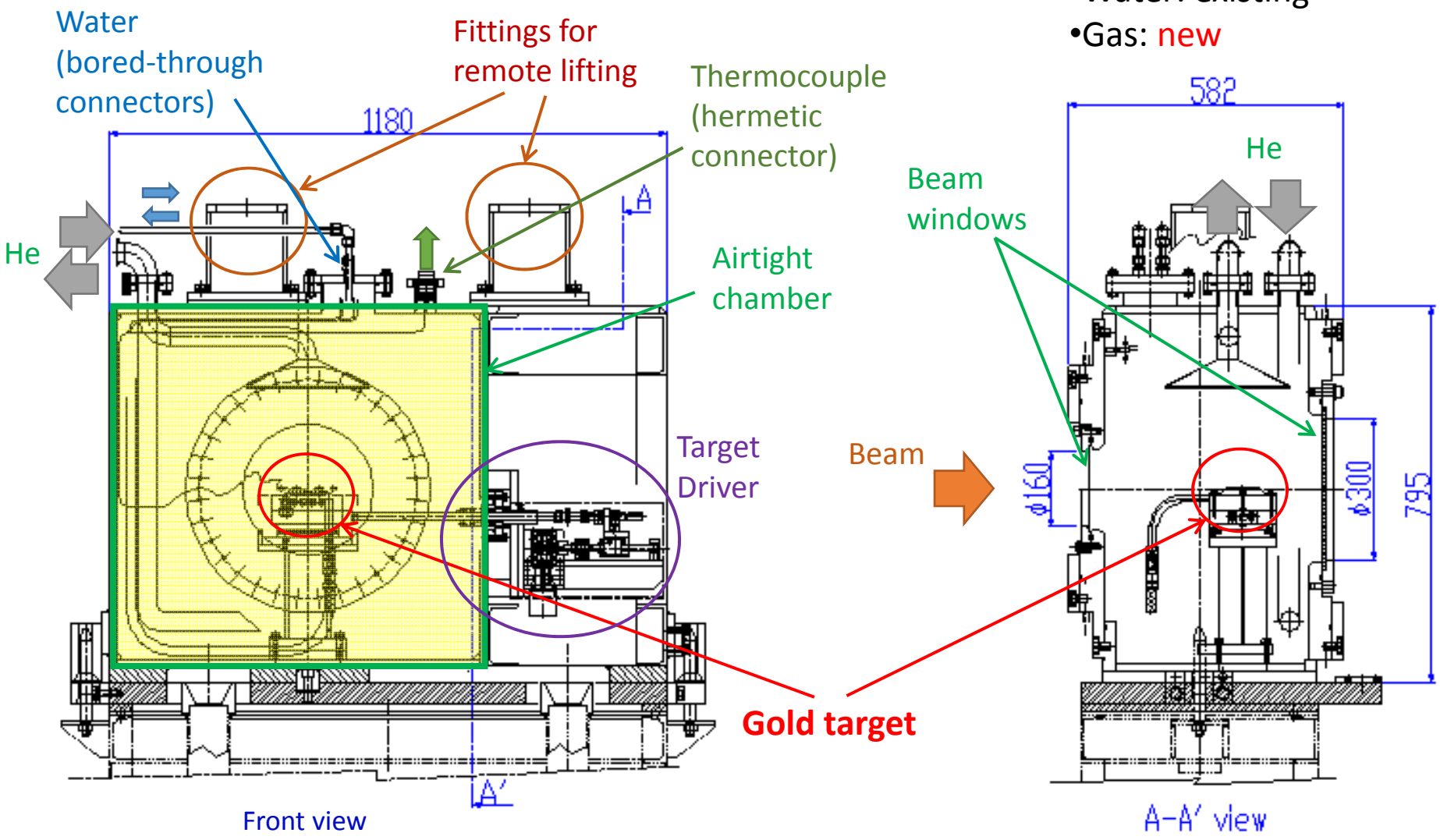
South Area of the Hadron Hall

Scheme of the target system



Structure of New Target chamber

Circulation System
- Water: existing
- Gas: new

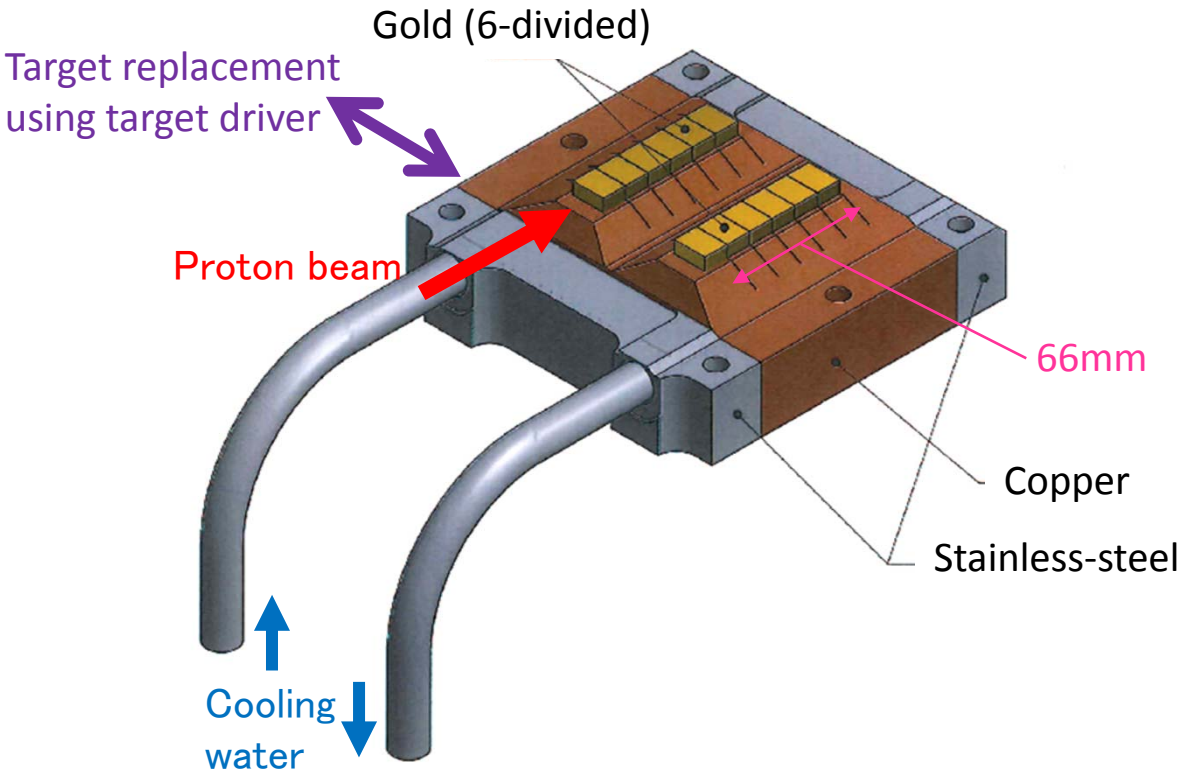


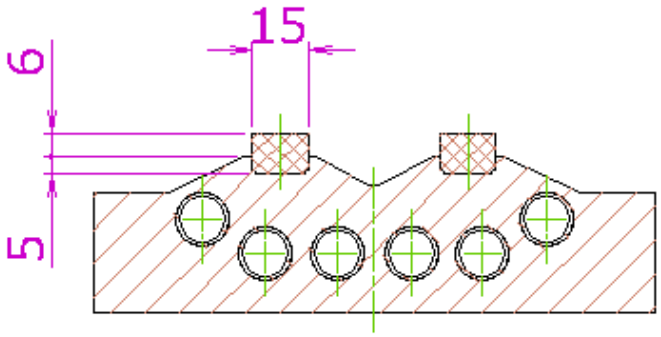
Since the beam windows are always exposed to a primary beam directly,
we designed the windows to keep their soundness even in the case of 5-μs pulse beams.

* 5-μs = revolution of Main Ring


2519 標的組込作業写真

Structure of New Target



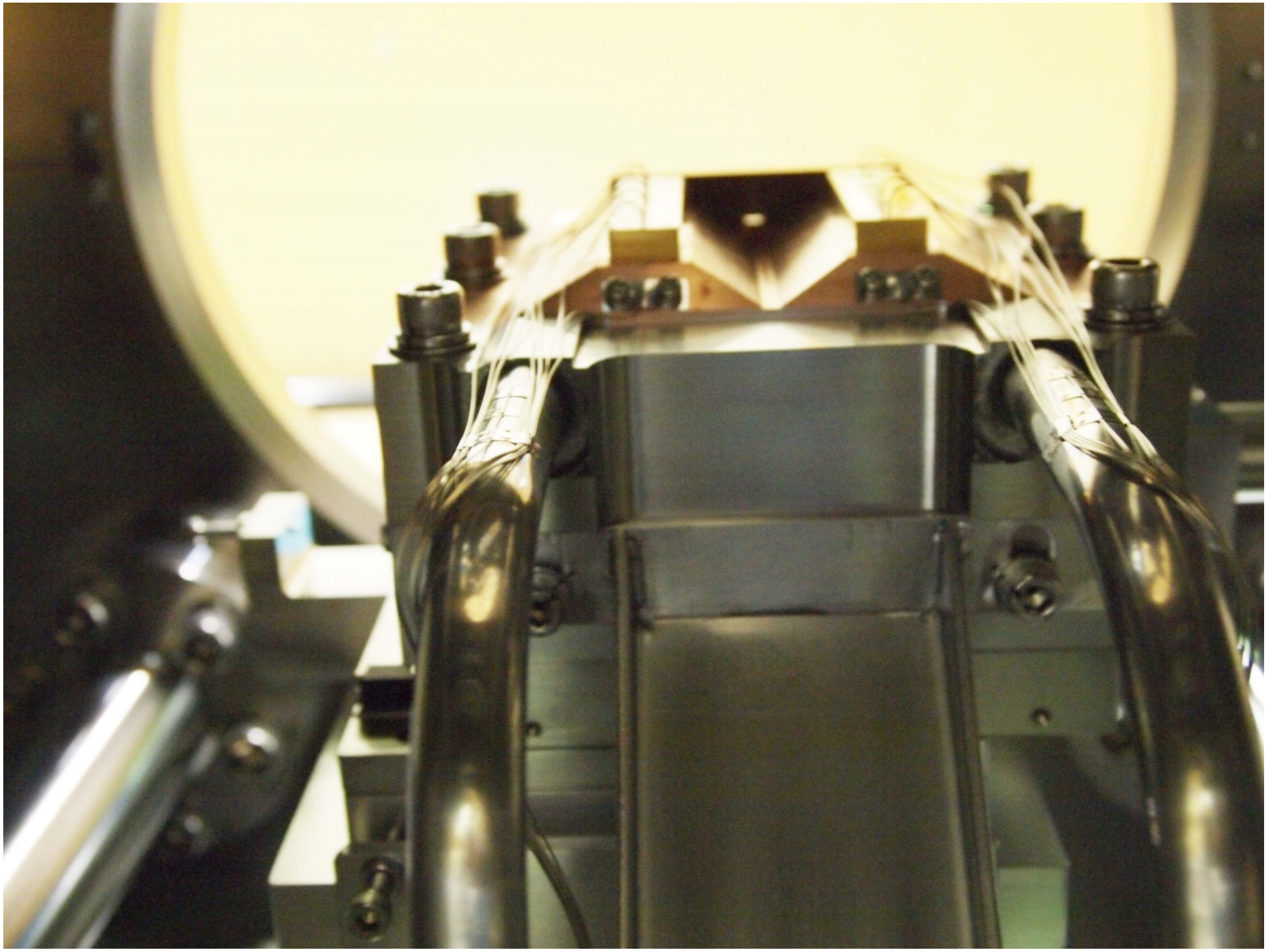


Cross-sectional view

*Gold, copper, and stainless-steel are bonded by **HIP (Hot Isostatic Pressing)**

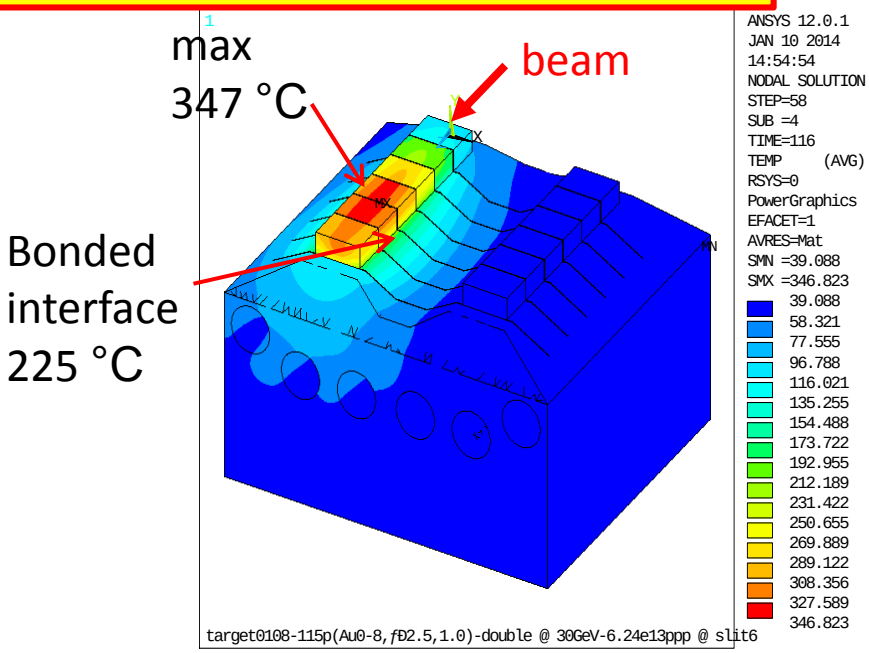
Improvements

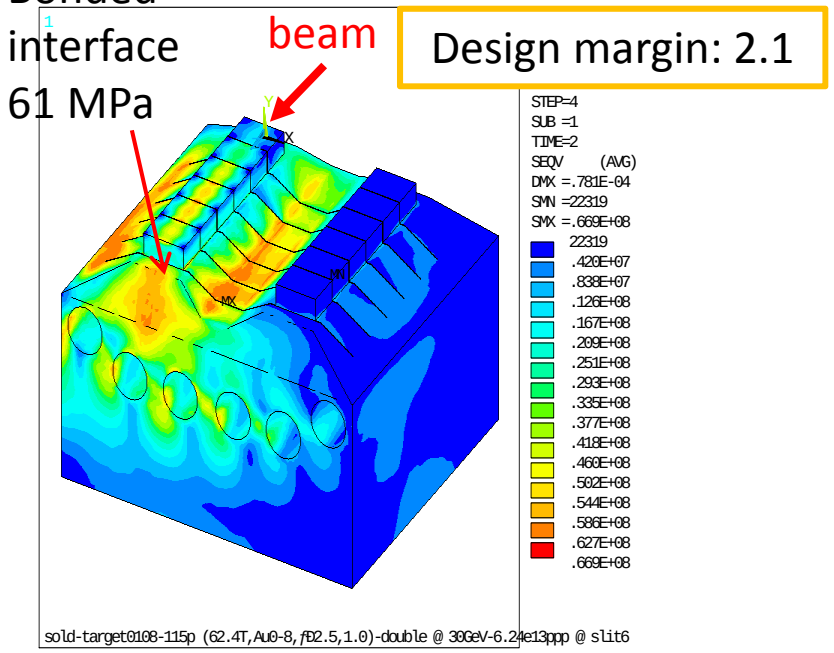
- Gold is partially sunk in copper block to avoid instantaneous separation of gold from copper.
- Cooling pipes are located closer to gold for efficient cooling.
- Width of gold is incleased (6 => 15) for wider beam.
- 2-headed structure for quick and remote replacement of target.



Result of Thermal Analysis of Target (50kW)

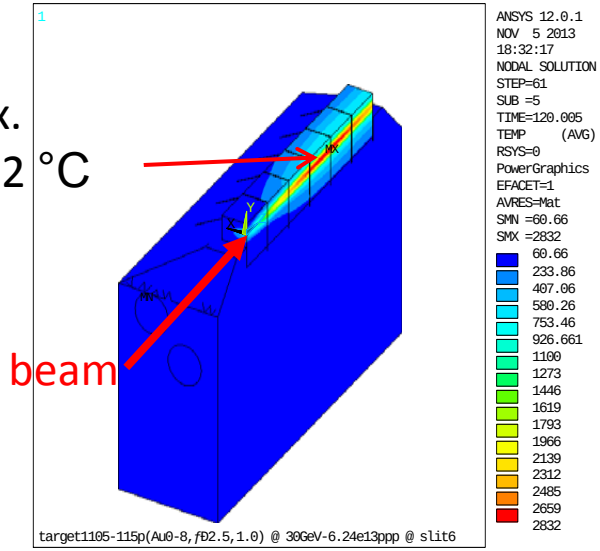
In normal operation (2-sec extraction)





In accident (5-msec extraction)

max.
2832 °C



*Latent heat and radiation cooling are not included.

Bonding strength:
171MPa(@25°C)
137MPa(@200°C)
76MPa(@400°C)
linear interpolation:
129MPa(@225°C)

Milestone

Repair tasks have been underway to recover and improve the hadron experimental facility.

- ~ End of 2014
  - Target replacement → Now
  - Sealing of the primary beam line
  - After measures are completed, we will ask the authorities and local governments to allow us to resume the operation.

Major Events up to now

2013

- May 23 — The accident at the hadron facility
- July 19 — ν_e appearance physics finding
- September 26 — Report to MEXT on the accident
- December 8 — The gold target observation
- December 26 — Local government's approval

2014

- January 17 — Linac 400 MeV energy upgrade
- February 17 — MLF restarted operation at 300 kW
- April 28 — MR started test
- May 26 — Neutrino restarted experiment

Repair tasks have been underway to recover and improve the hadron experimental facility.