Recent Status of J-PARC Neutrino Beamline

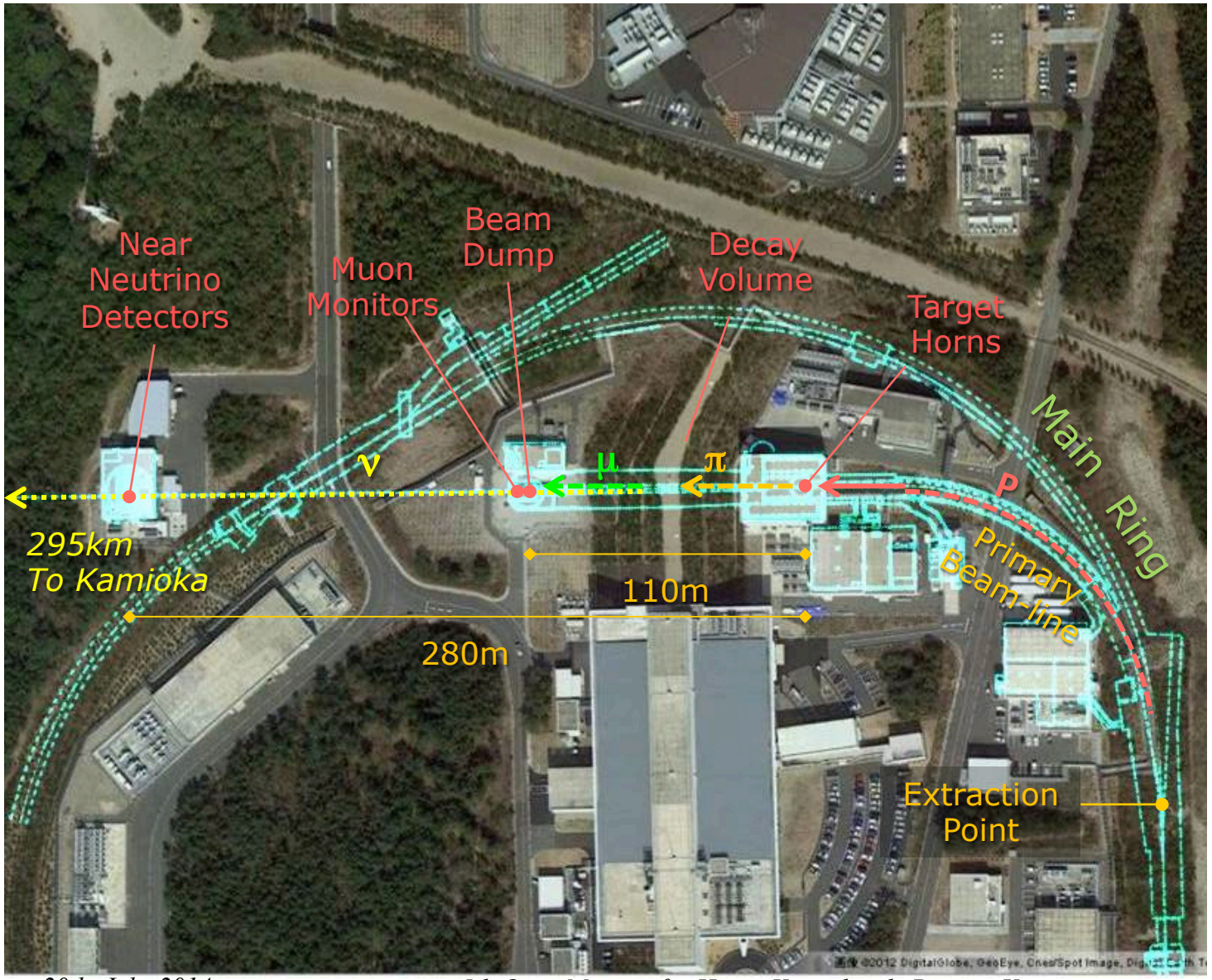
Tetsuro Sekiguchi

IPNS, KEK

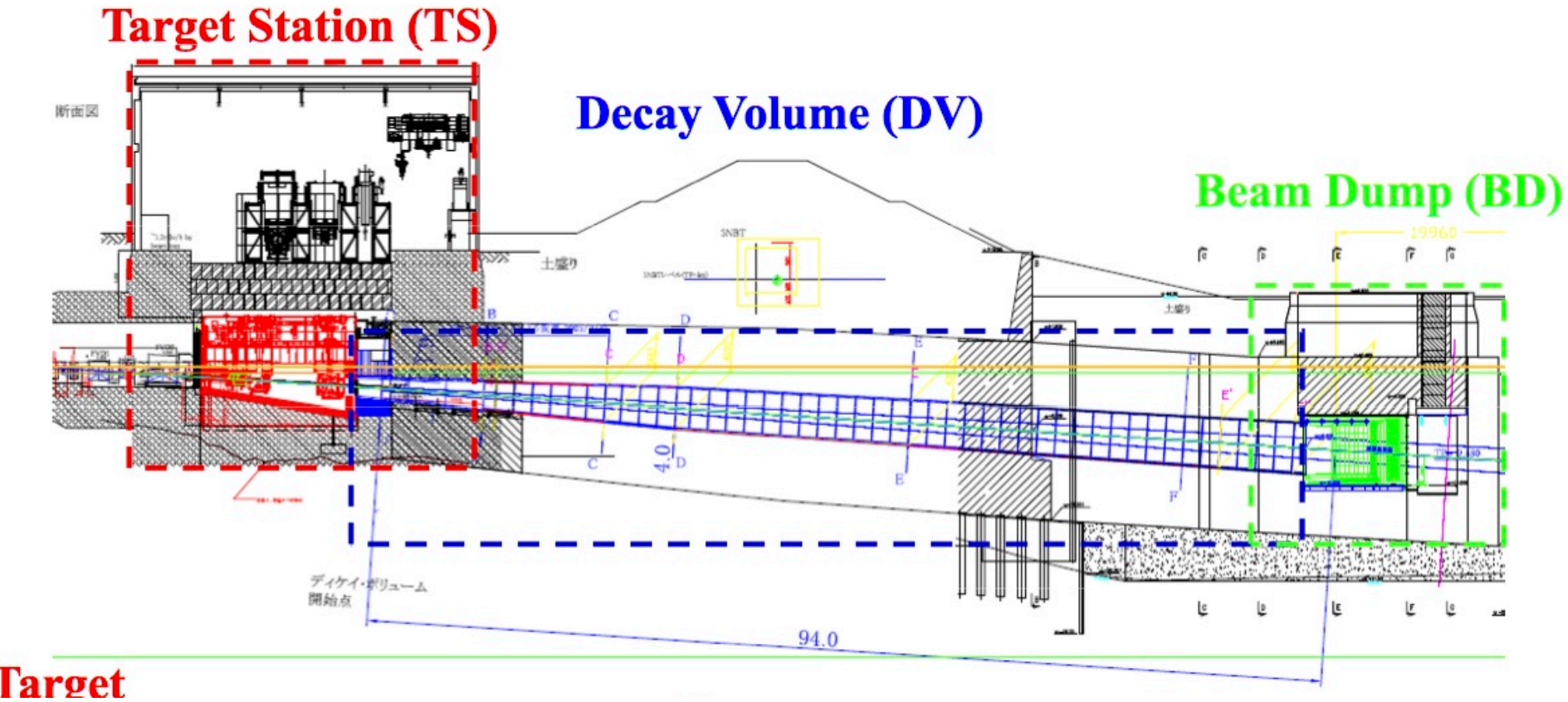
Contents

- **Introduction**
- **Overview of Horn Replacement Work**
- **Operation results after horn upgrade**
- **Summary**

Neutrino Facility

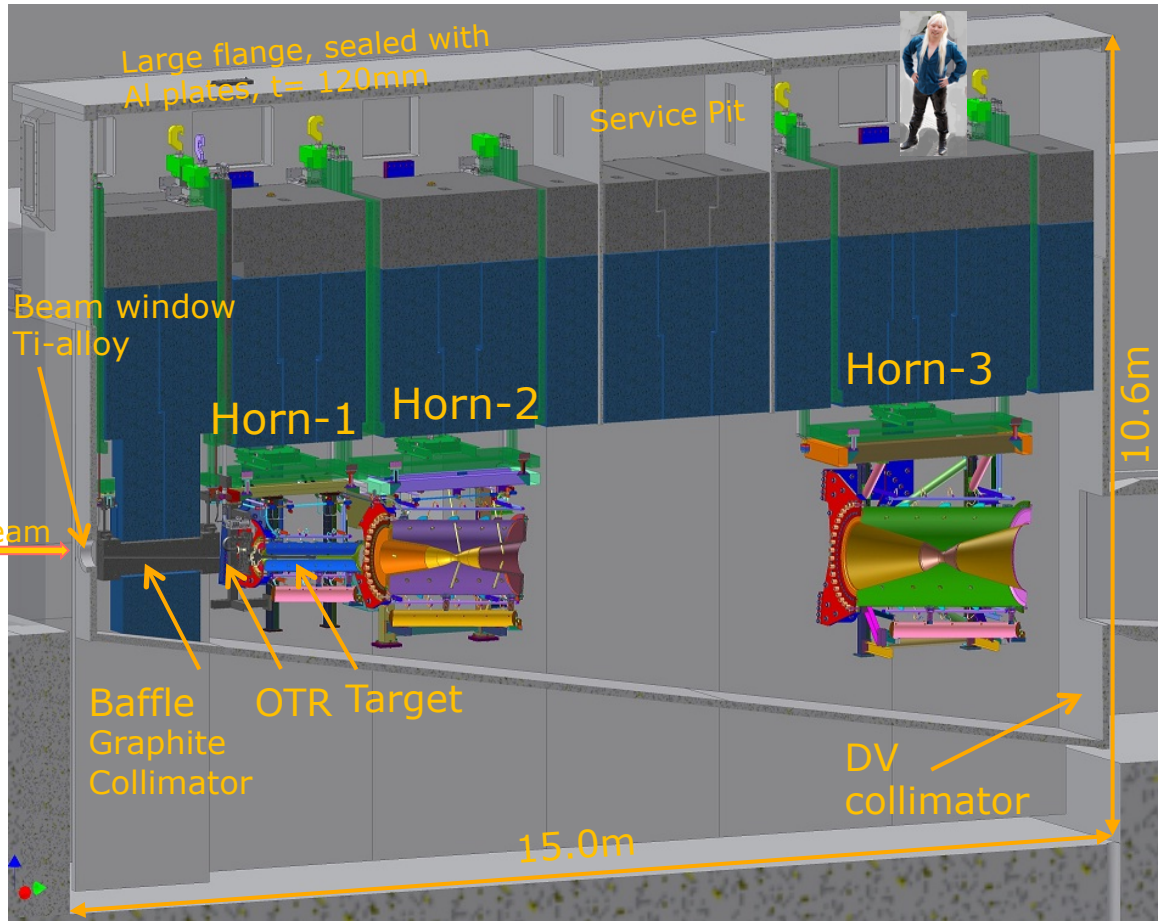


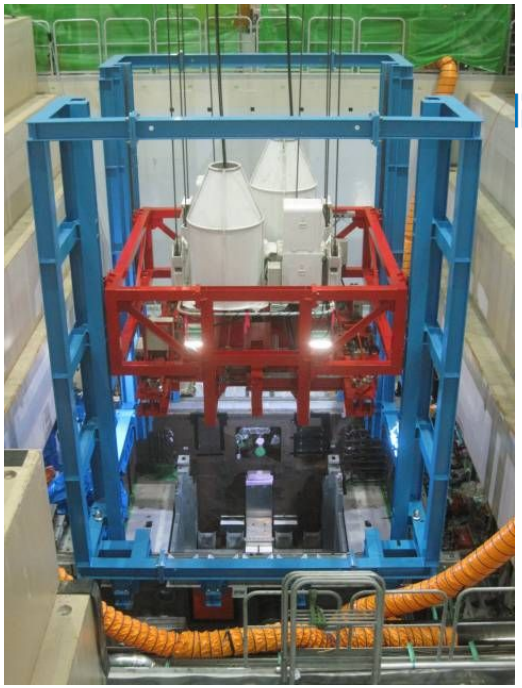
Secondary Beamline



- Target Station (target and horns inside He vessel)
- Decay volume
- Beam dump

Target Station





- **3 horns / a baffle are placed inside He vessel**
- **Apparatus on the beam-line highly irradiated after beam.**
- **Handled by remote-controlled crane.**

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Acceptable Beam Power

- **Acceptance of each component for high power beam**
  - **Target**
    - Mechanical: **0.75MW**
    - Cooling: **0.75MW**
  - **Horn**
    - Cooling for conductors: **1.85MW**
    - Cooling for striplines: **0.4MW**
    - Hydrogen production: **0.3MW**
    - Power supply: **0.4Hz, 250kA**

    } **These components limit the beam power**
  - **He vessel, Decay Volume & Beam Dump**
    - Cooling: **4MW**(HV&DV), **3MW**(BD)
  - **Facility**
    - Water disposal: **0.5MW**
    - Radio-active air: **0.5MW**

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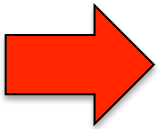

Necessity for upgraded horn system

  - **He vessel, Decay Volume & Beam Dump**
    - Cooling: **4MW**(HV&DV), **3MW**(BD)
  - **Facility**
    - Water disposal: **0.5MW**
    - Radio-active air: **0.5MW**

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    Oyama-san' talk.
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    Covered by my talk. → **Necessity for upgraded horn system**
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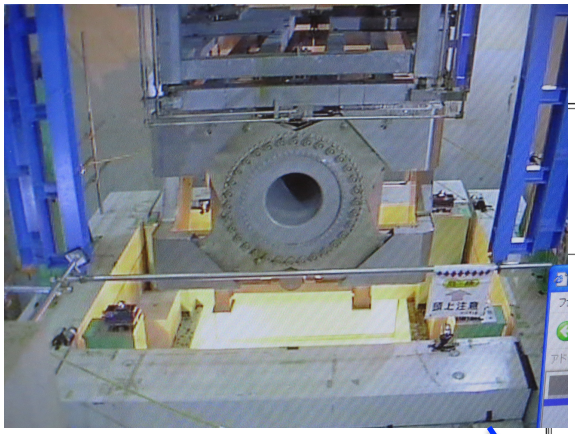
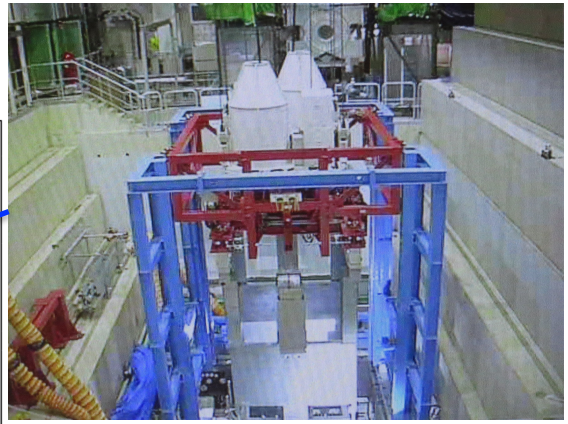
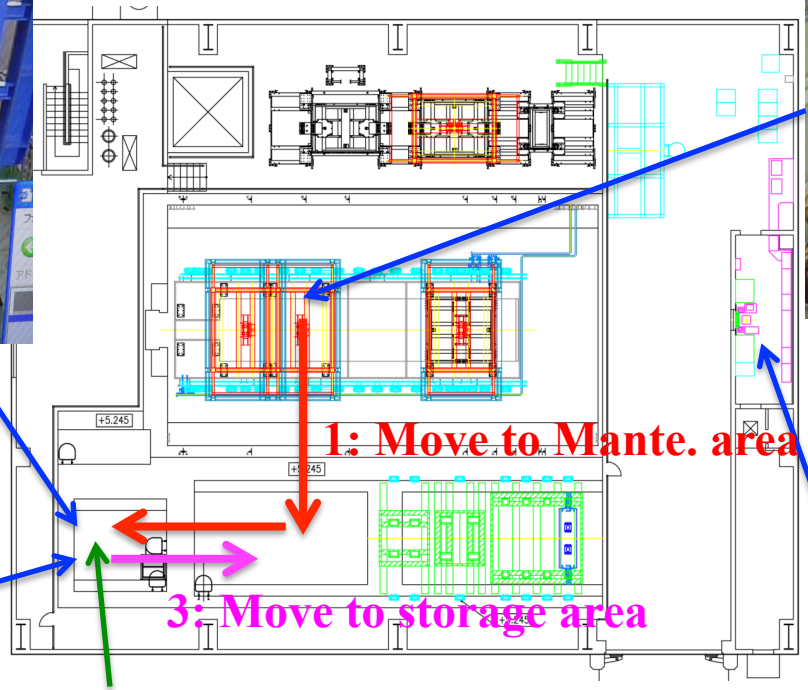
    Oyama-san' talk.

Horn Replacement Work

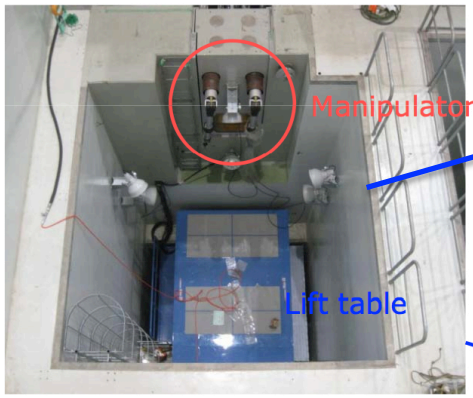
- **Highly radioactive after several year running**
  - ~150mSv/h for horn1 (6.7×10^{20} POT exposure after 1year cooling)
- **Remote handling is a key for horn replacement work.**







Maintenance area



Horn Replacement Work

- **Replacement of horns was successfully done with remote handling.**
  - Remote handling for T2K horns were established.

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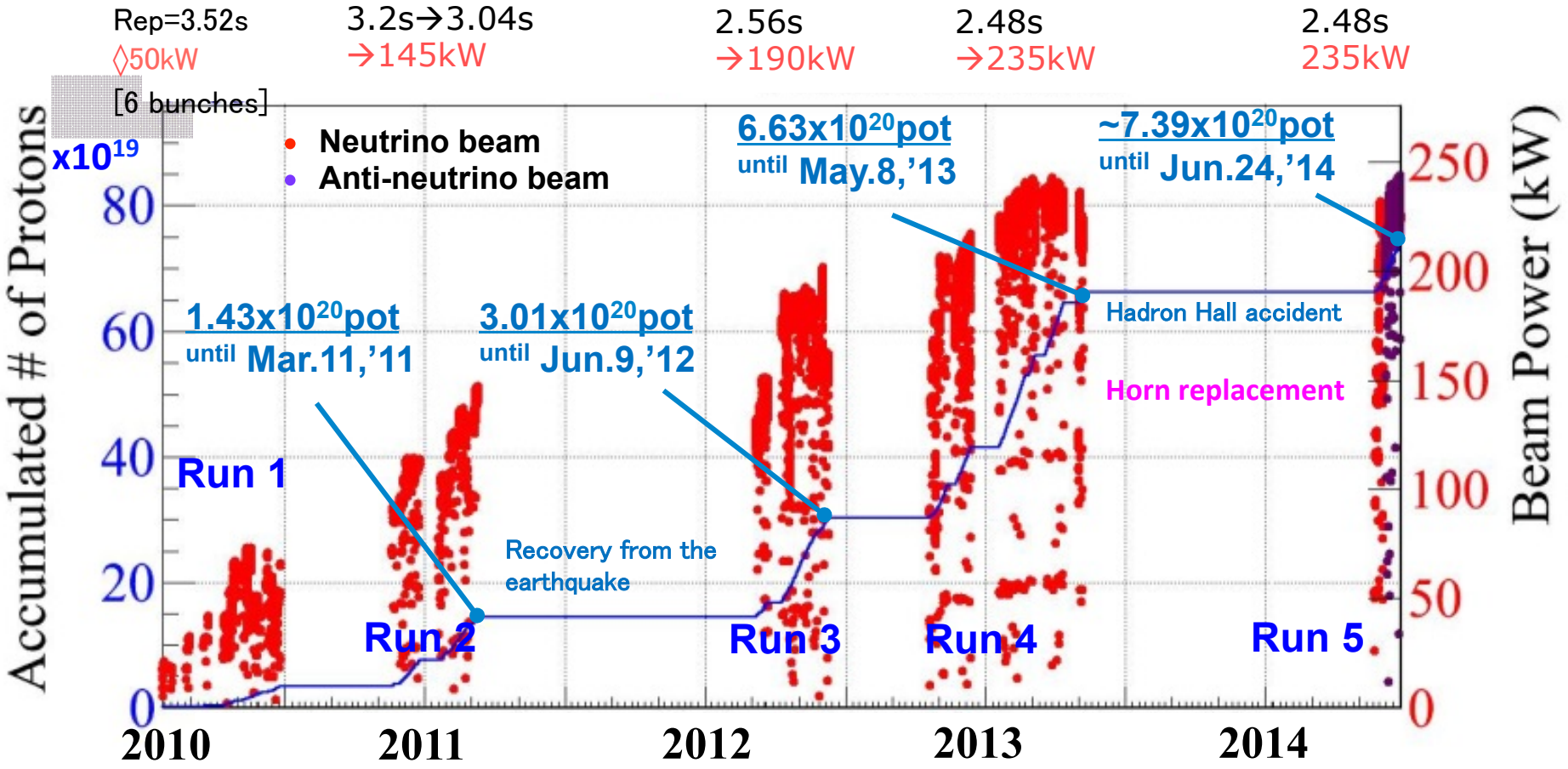
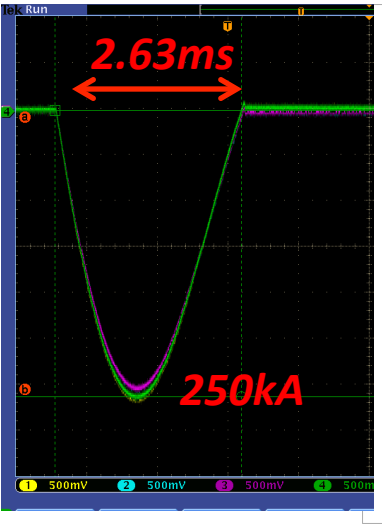
Operation History

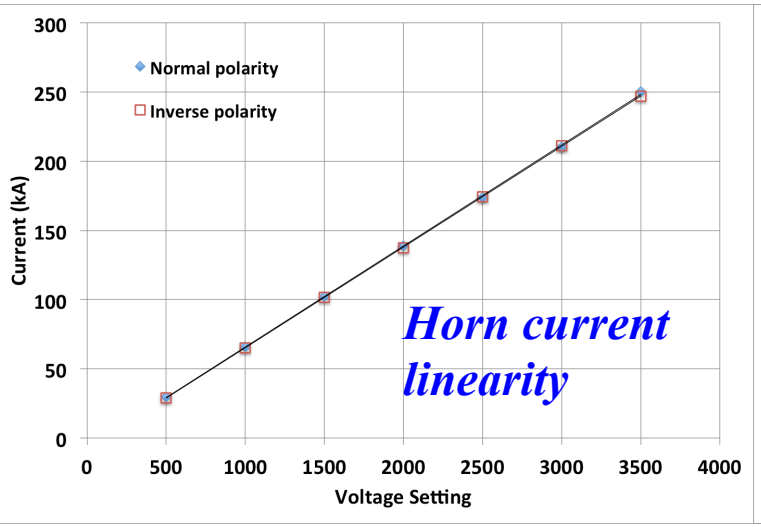


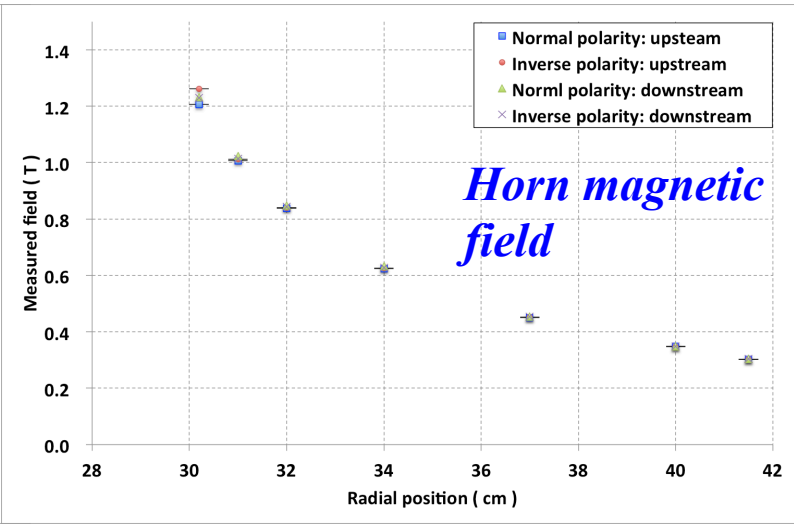
- Stable operation at 230kW
  - 1.2×10^{14} ppp: world record of extracted protons/pulse for synchrotron
- Accumulated POT so far: 7.39×10^{20}
  - 0.51×10^{20} in anti-neutrino mode operation.

Highlight in T2K Run5

- **Horn operation with inverse polarity successfully done.**
  - Horn polarity change scheme was established.
  - No significant difference in horn current and magnetic field between normal and reverse modes.
  - Very stable operation during Run5 period.



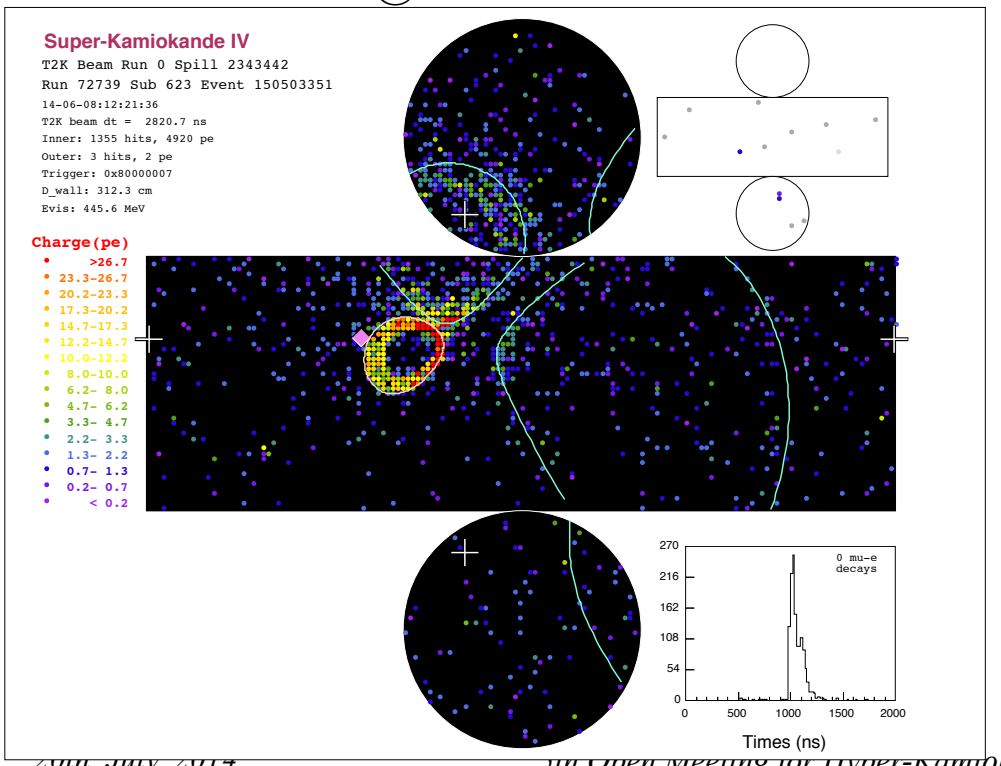




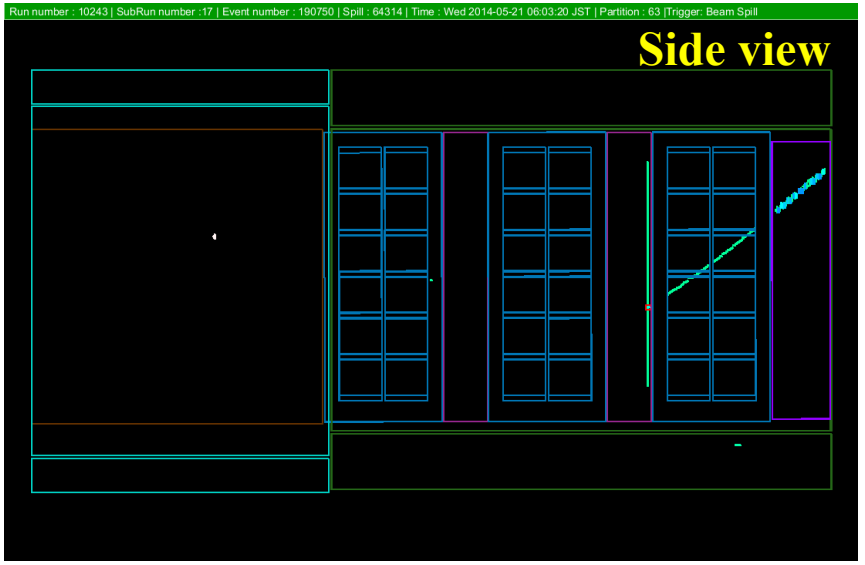
Highlight in T2K Run5

- **Physics run with anti-neutrino mode for three weeks.**
  - **0.51×10^{20}** POT accumulated in **anti-neutrino** mode.
  - Very stable beamline operation was achieved.

First event @ SK in anti-ν mode



First anti-ν event @ND280 in anti-ν mode



Acceptable Beam Power

- **Acceptance of each component for high power beam**
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    - Water disposal: **0.5MW**
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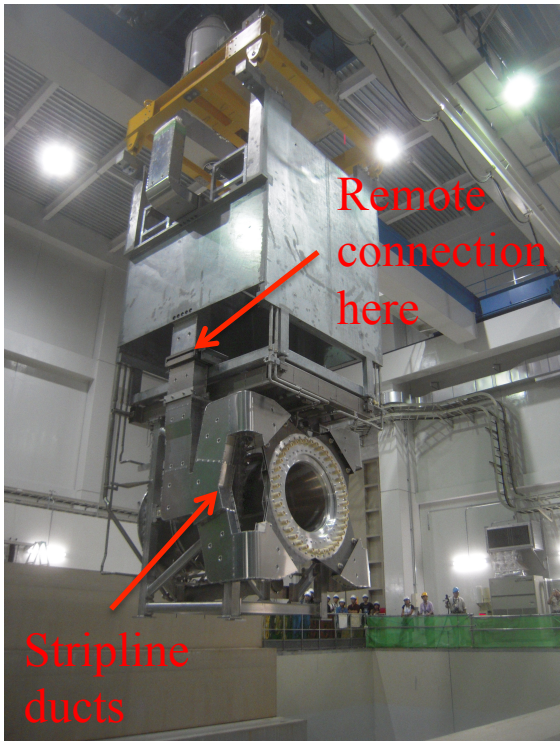
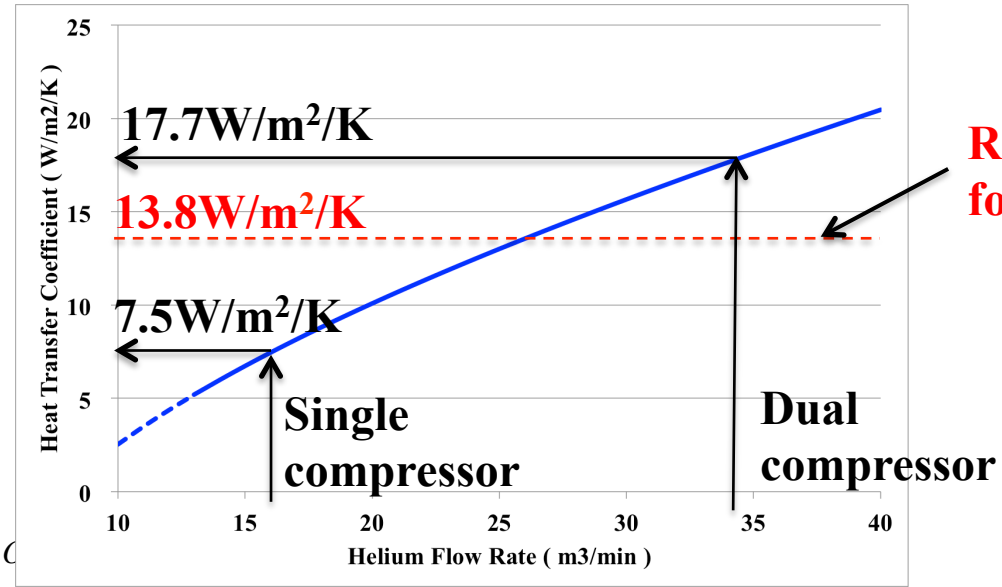
Stripline Cooling

- **Heat load at striplines**
  - Non-negligible heat load: beam heating + Joule heating
  - Stripline duct covers striplines + forced helium flow
- **Problem at old horns**
  - Large amount of He gas leaked at stripline remote joints
    - No effective cooling expected.
      → only natural convection assumed.
      → Beam power is limited to **400kW.**
  - Stripline ducts were drastically improved.
    - **No leak around stripline joints**.
    - He cooling should be improved.



Stripline Cooling

- **Actual He flow rate was measured with new horns.**
  - 16m^3/min with current setup
    - Not enough for 750kW → 26m^3/min is needed.
- **If we add another helium compressor,**
  - Flow rate will be 34m^3/min. → **~1MW is acceptable.**
  - Dual compressors should be setup before upgrade to 750kW.
    - A spare compressor exists → installation and plumbing needed.



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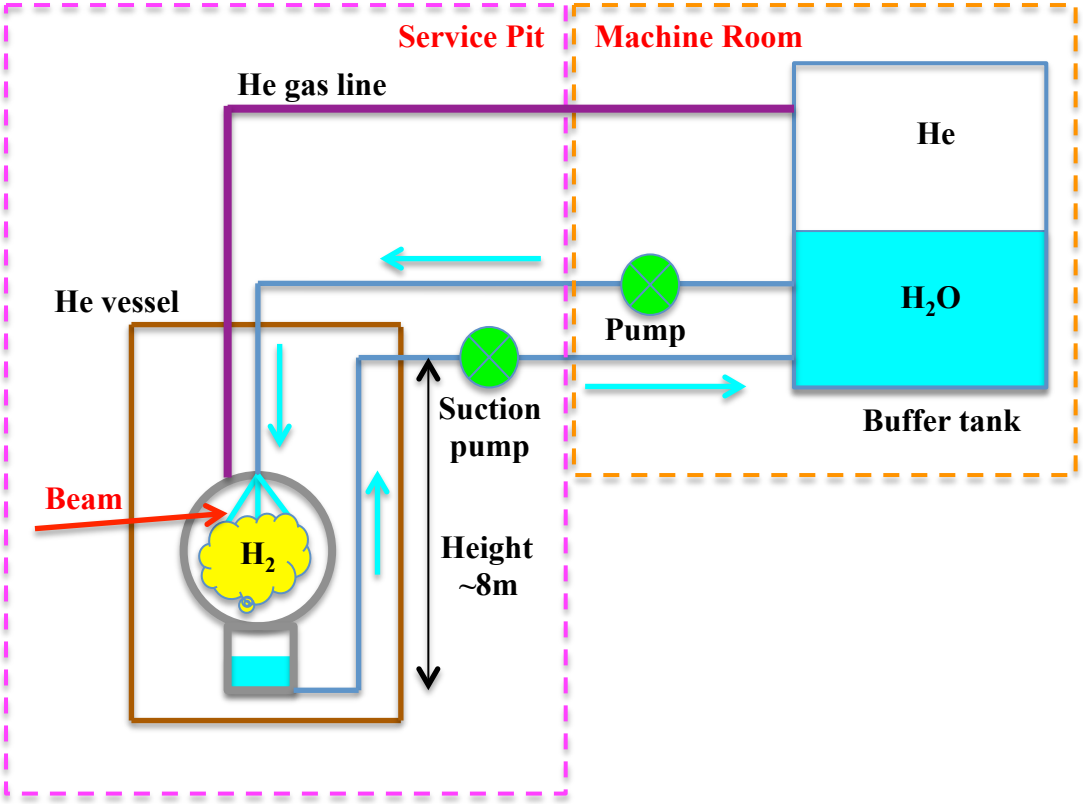
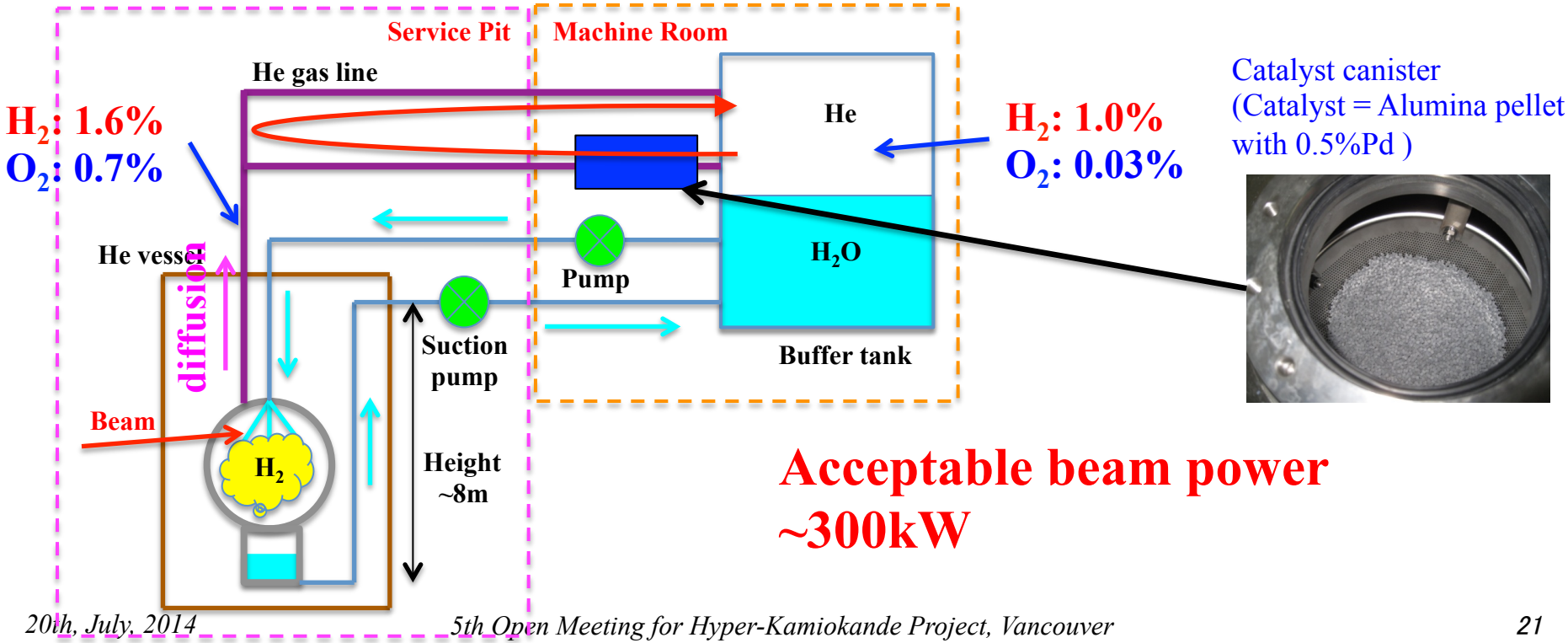
Hydrogen Production in Horn

- **H_2 production by water radiolysis ($2H_2O \rightarrow 2H_2+O_2$)**
  - H_2 production rate: **40L/day (0.7%/day) @750kW**
  - H_2 must be removed. → **H_2 recombination** ($2H_2+O_2 \rightarrow 2H_2O$)



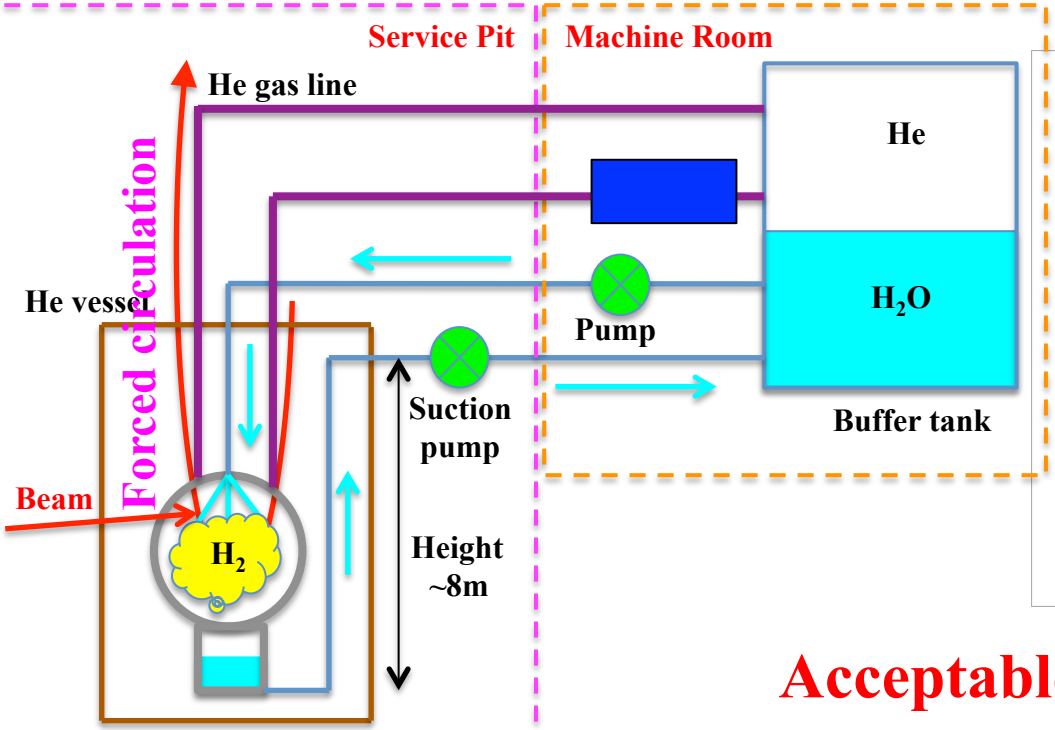
Hydrogen Production in Horn

- **Problem before horn replacement**
  - No forced He circulation inside horns
  - H_2 density after 1week 220kW beam.
    - 1.6% in horns (produced~1.5%) → No H_2 removal.
    - 1.0% in tank → recomb. doesn't proceed due to a lack of O_2.

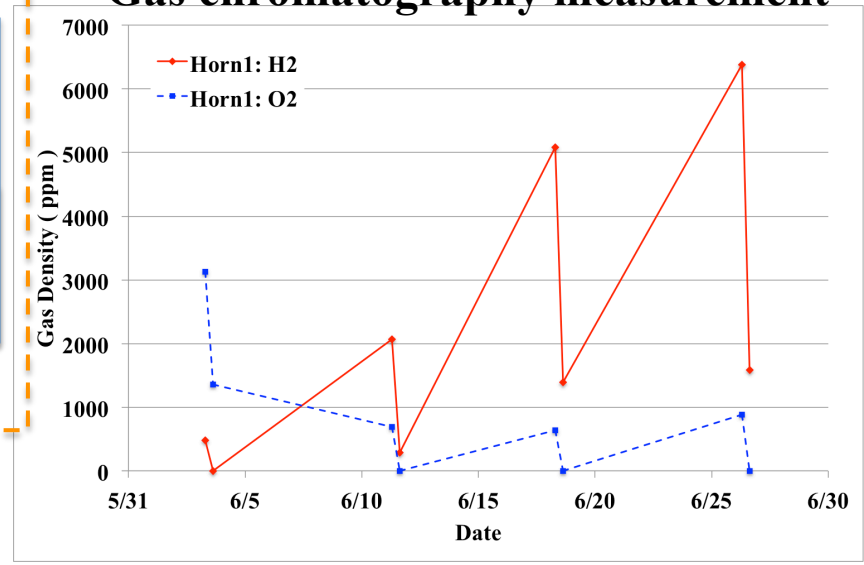


Hydrogen Production in Horn

- **Forced circulation inside horns**
  - **Small H_2 density with rich O_2**
  - **Recombination doesn't proceed due to a lack of O_2.**
    - Low O_2 density due to larger O_2 solubility than H_2.
    - Need some countermeasures for reliable operation.



Gas chromatography measurement



Acceptable beam power ~0.75MW

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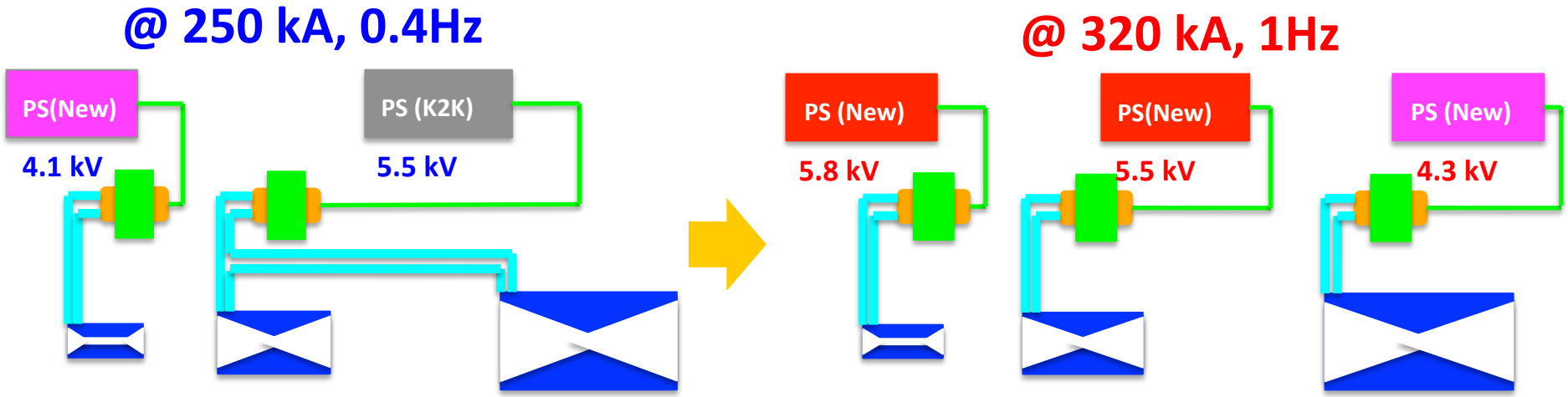
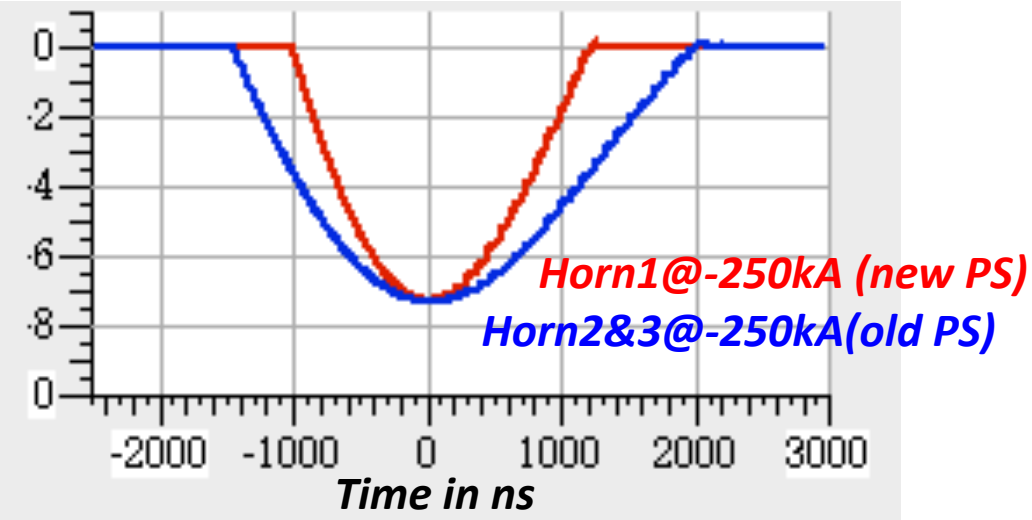
Horn Power Supply

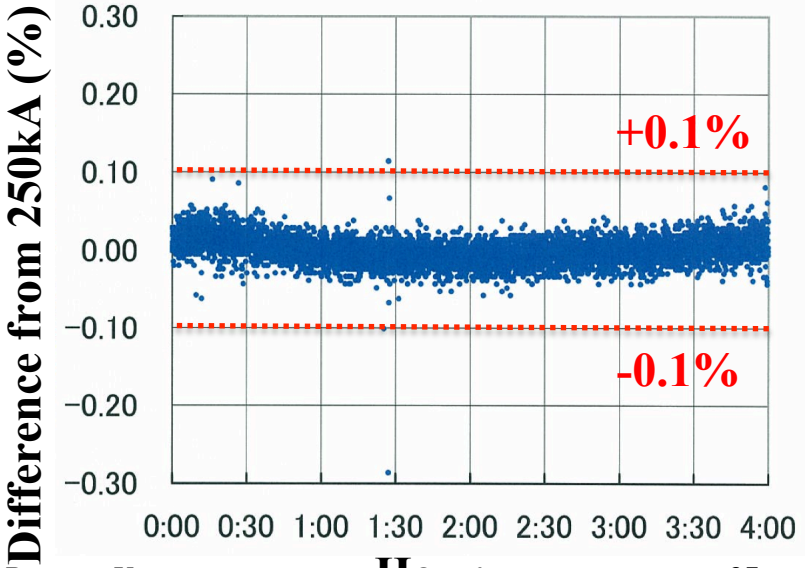


- **New power supply production for 1Hz operation,**
  - Designed for **320kA** operation
  - **Energy recovery** (~50% of stored energy recycled)
  - Low input load
    - One horn is operated with a power supply
    - Low impedance striplines are also developed
- **Production was completed and already delivered.**

Power Supply Commissioning

- **One of new power supplies was used in Run5.**
  - 250kA operation
  - No problem due to PS happened at all during whole period.
  - Current stability originated from PS was within 0.1% (of 250kA).
- **Three power supply operation for 1Hz**
  - Need 2 or 3 new compact transformers. (space is very tight)





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    - Cooling for striplines: **0.4MW** → **~1MW** (with dual comp.)
    - Hydrogen production: **0.3MW** → **~0.75MW** (but need modification)
    - Power supply: **0.4Hz, 250kA** → **1Hz, 320kA** (with new trans.)
  - **He vessel, Decay Volume & Beam Dump**
    - Cooling: **4MW**(HV&DV), **3MW**(BD)
  - **Facility**
    - Water disposal: **0.5MW**
    - Radio-active air: **0.5MW**

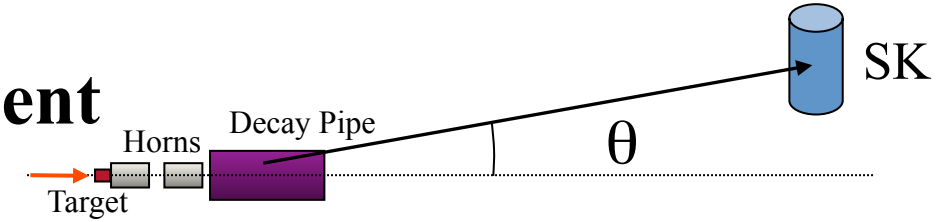
Summary

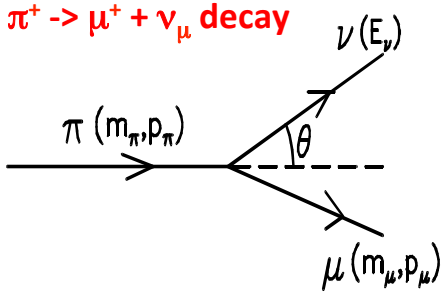
- All three old horns were **replaced with the upgraded horns** during a long shutdown between Run4 and Run5.
- **Very stable beam operation during Run5.**
  - **7.39×10^{20}** POT so far
  - **0.51×10^{20}** POT with anti-neutrino mode.
- **Acceptable beam power is updated after new horn installation.**
  - Some components can be improved but some additional works should be needed.

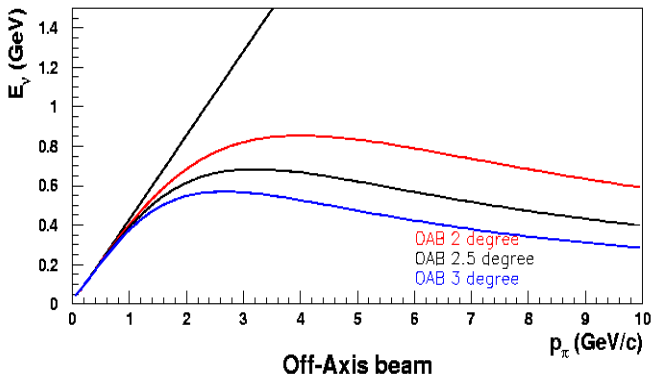
Supplementary Slides

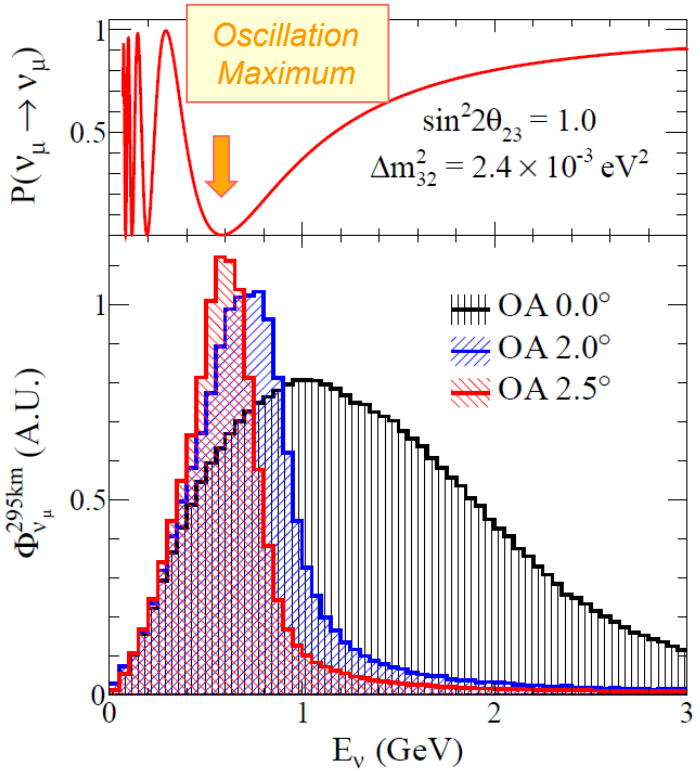
Neutrino Beamline

- **Conventional neutrino beam**
  - $p + C \rightarrow \pi^+ \rightarrow \mu^+ + \nu_\mu$
- **Designed for T2K experiment**
  - High intensity beam
    - **750kW** proton beam (30 GeV, 3.3×10^{14} protons/pulse)
  - **Off-axis** beam (2~2.5°)
    - Narrow band beam ~ 0.6 GeV
      - 1st oscillation maximum

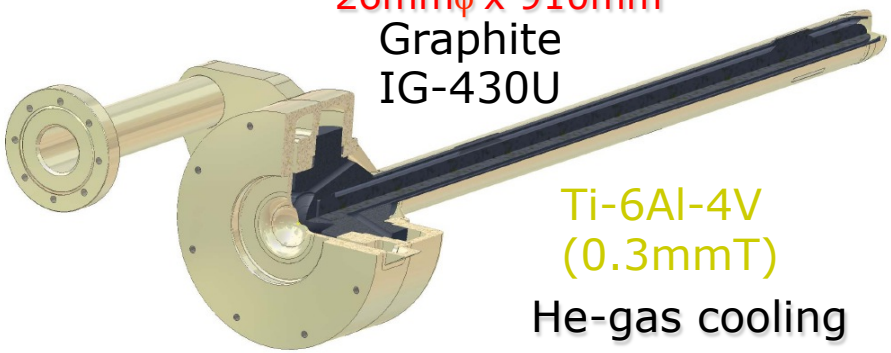


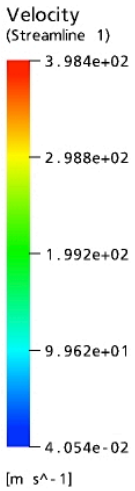






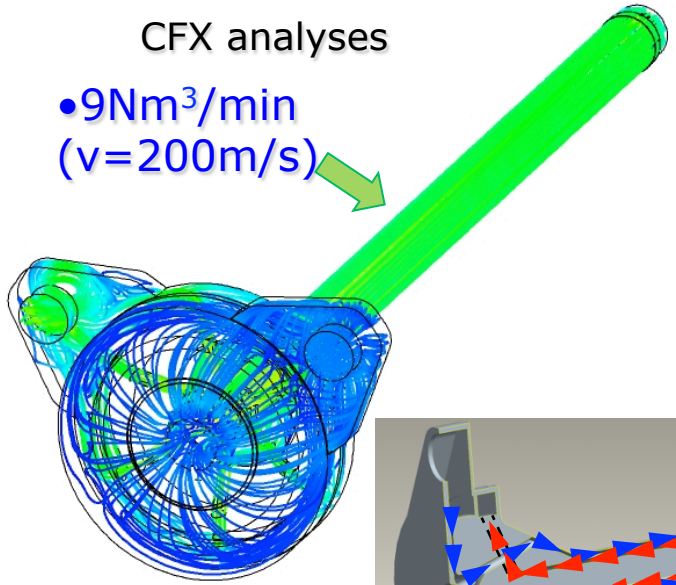
Target

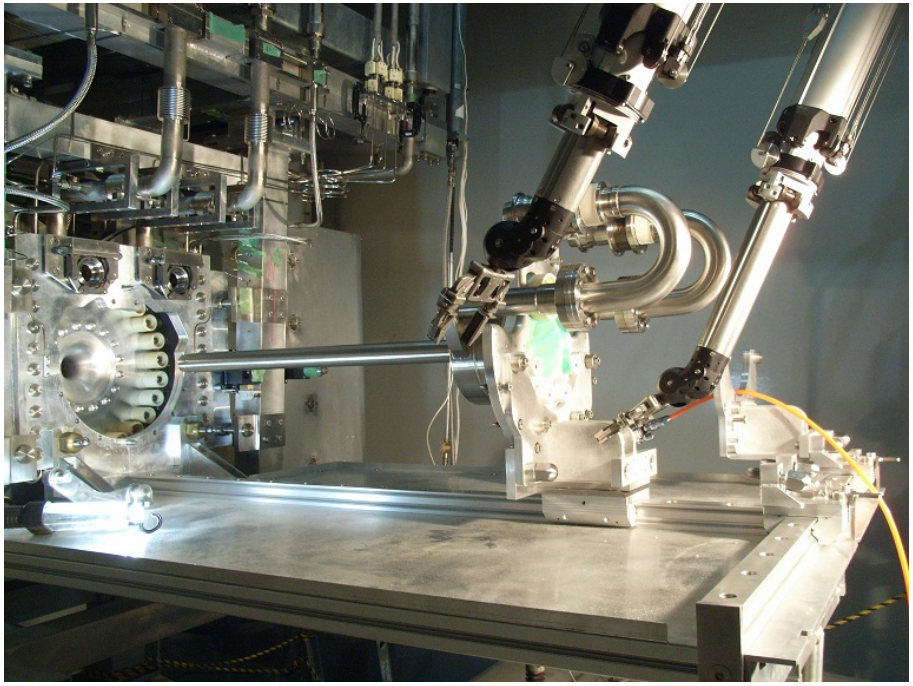


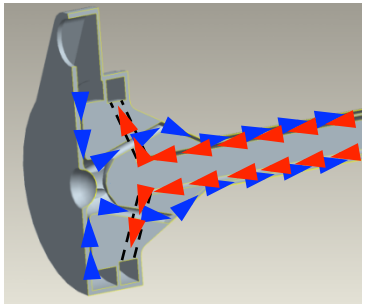


CFX analyses

•9Nm³/min
(v=200m/s)

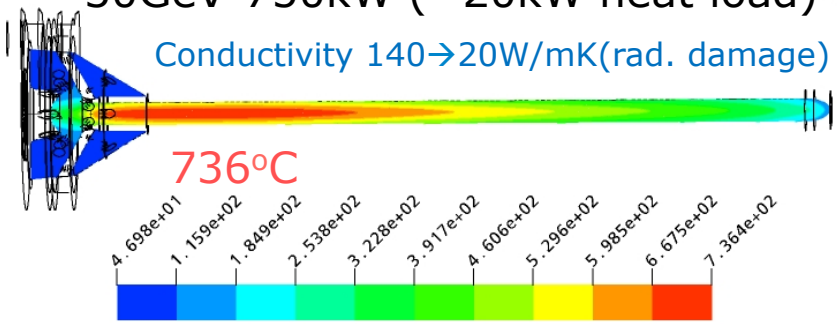






30GeV-750kW (~20kW heat load)

Conductivity 140→20W/mK(rad. damage)

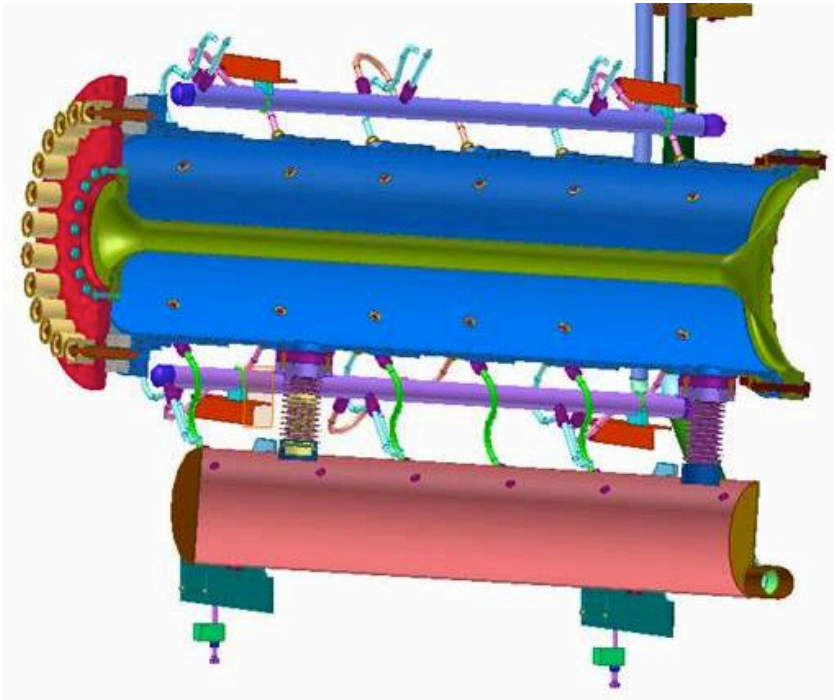


- **Remote maintenance**

ΔT~200K ~7MPa (Tensile strength 37MPa)

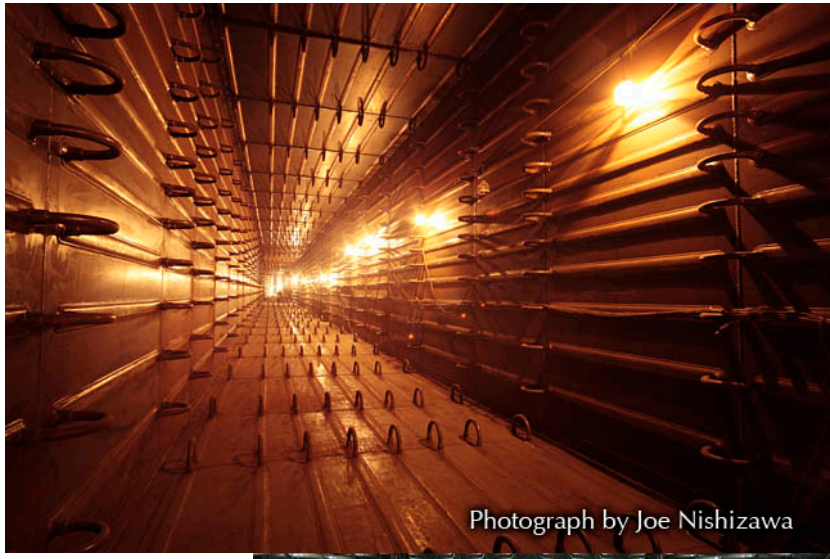
Magnetic Horns

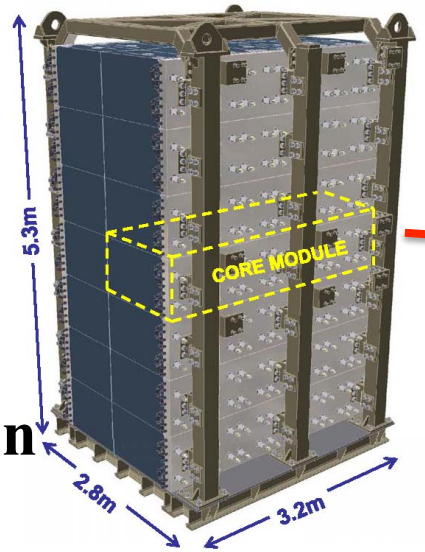
- **Aluminum alloy conductor (A6061-T6)**
  - Double cylinder (inner: t3mm, outer: t10mm)
  - Tensile strength: 310MPa → 95MPa after 5×10^8 cycle
  - 25MPa allowable stress (taking into account corrosion)
  - Safety factor ~ 2
- **320kA pulsed current (rated)**
  - 2.1 T (max.) toroidal field
  - 2~3ms pulse width
  - 0.4Hz rep. rate → 1 Hz for 750kW
- **Water cooled**
  - Total heat load: 25kJ @ 750kW
    - 15kJ (beam) + 10kJ (Joule)
  - Spraying water to inner conductor

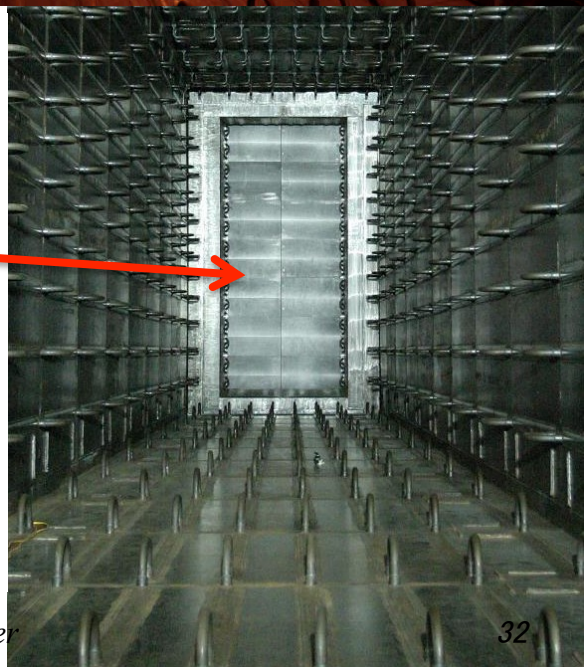


Decay Volume & Beam Dump

- **Decay Volume**
  - 100m-long
  - Water cooled iron walls ➔ 4MW
  - 2~2.5^{o} OA angle for SK and HK
- **Beam Dump**
  - Graphite core
  - Water cooled ➔ 3MW







Designed for multi-MW beam since no access is possible after beam operation due to irradiation