Operational experience of J-PARC neutrino beam-line

NuFact2017, 2017/09/25

Ken Sakashita (KEK/J-PARC) for J-PARC neutrino facility

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- Beam window replacement
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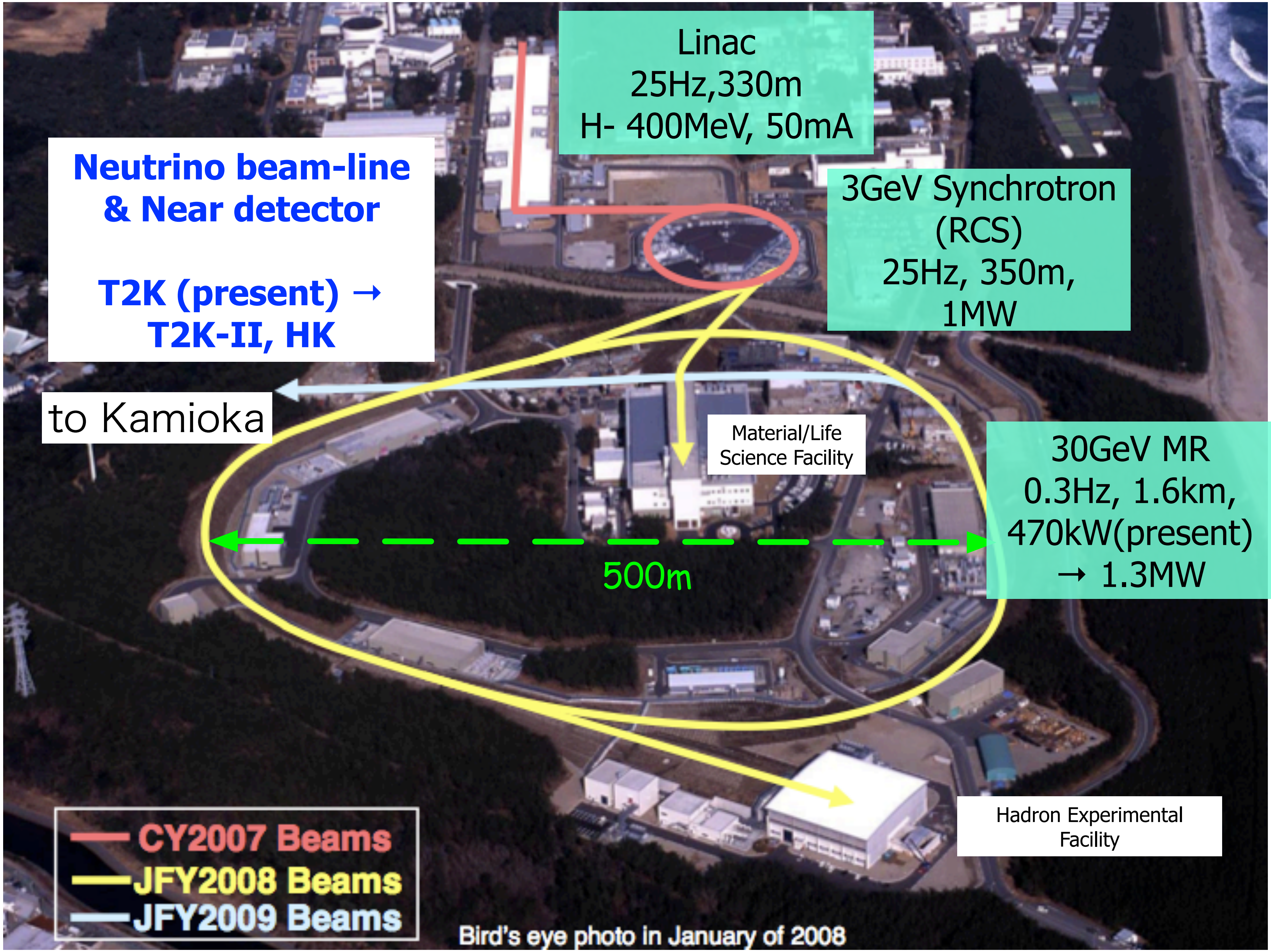
J-PARC & Neutrino beam-line

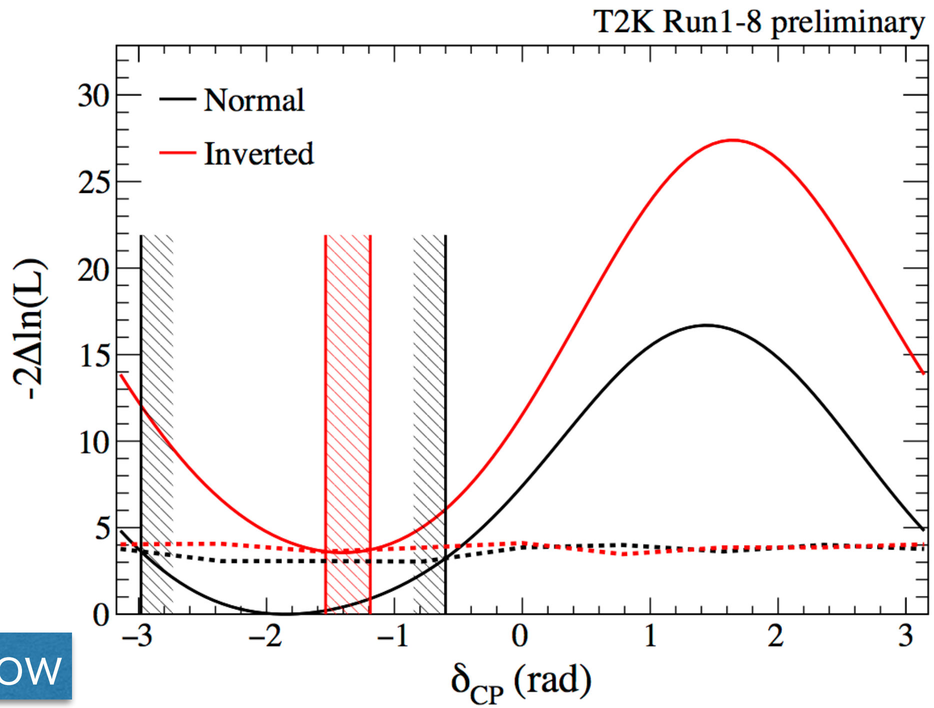


T2K(Tokai-to-Kamioka) experiment

Long base-line neutrino oscillation experiment with muon (anti-)neutrino beam generated at J-PARC and detected at Super-Kamiokande

Physics motivation

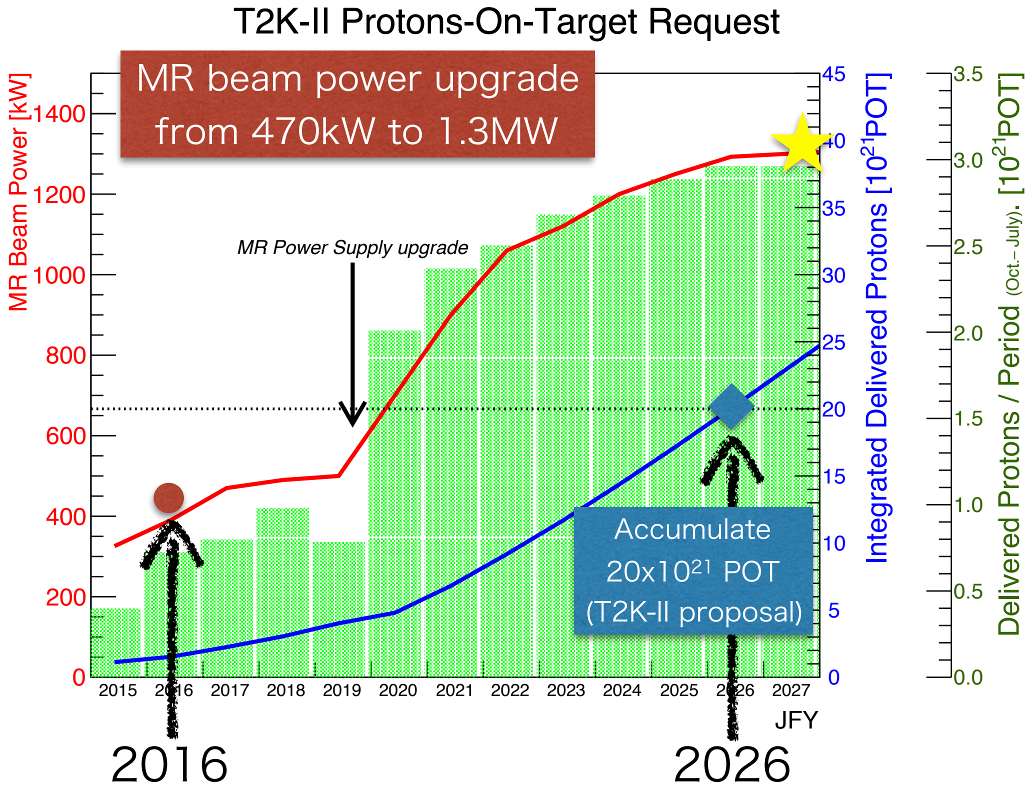
- Physics motivation (after discovery of ν_e appearance) is
  - Lepton CPV
  - 2-3 mixing angle θ_{23} is maximal or not
  - ν_1 mass < ν_3 mass ? (mass hierarchy)
  - Check the 3-flavor mixing framework
- T2K latest results show hint of the lepton CPV
  - CP conservation (δ=0,π) is excluded with 95% C.L.

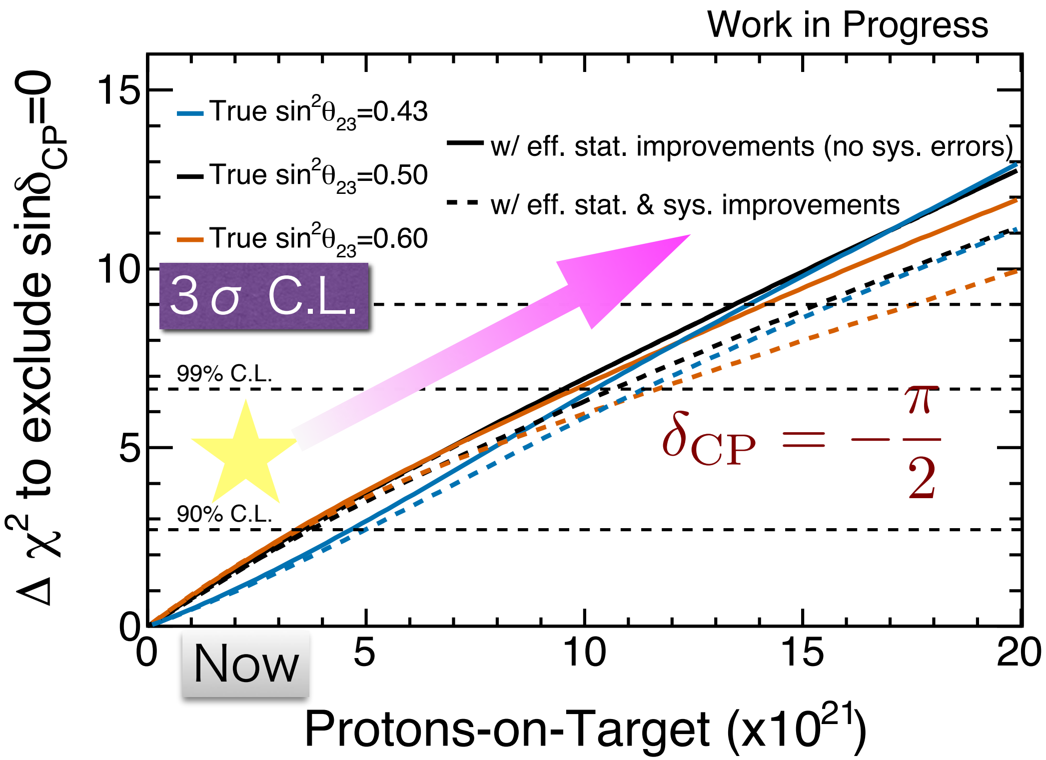


more details by K.JIAE talk tomorrow

Toward lepton CPV

- Accumulate more data with improving the beam power

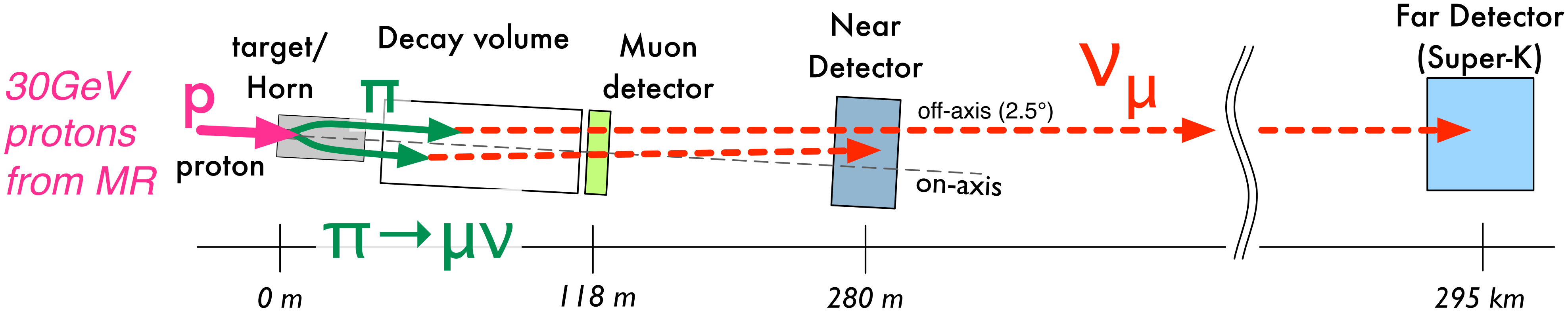




My talk : Operational experience of neutrino beam-line so far

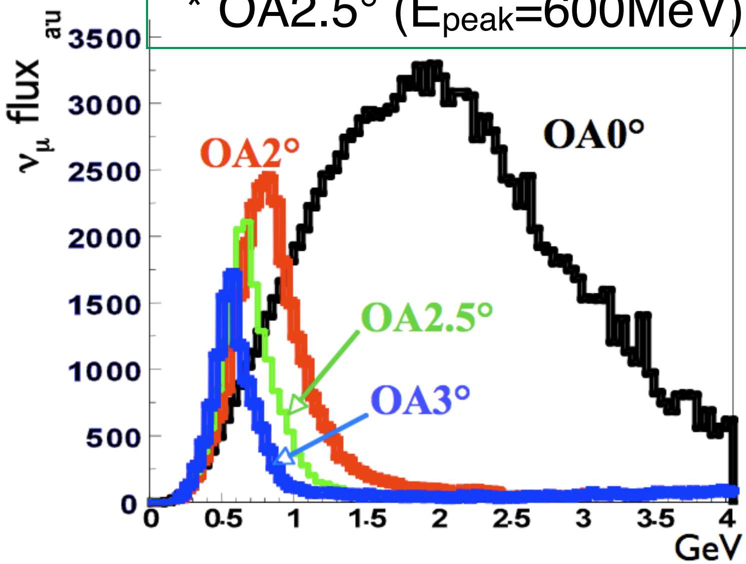
Next (Sekiguchi-san's) talk : Upgrade of J-PARC accelerator and neutrino beam-line toward 1.3MW

T2K neutrino beam



- Accelerator-based ν beam
- ν energy is narrow with off-axis method L = 295km → oscillation peak at 0.6GeV
- ν / $\overline{\nu}$ can be switched by flipping horn polarity

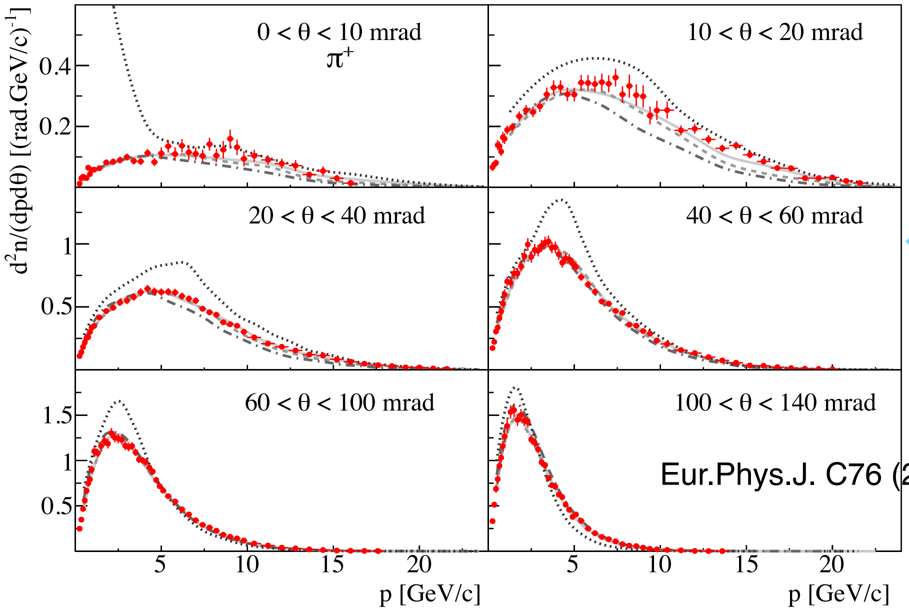
T2K beam :
* OA2.5° (E_{peak}=600MeV)



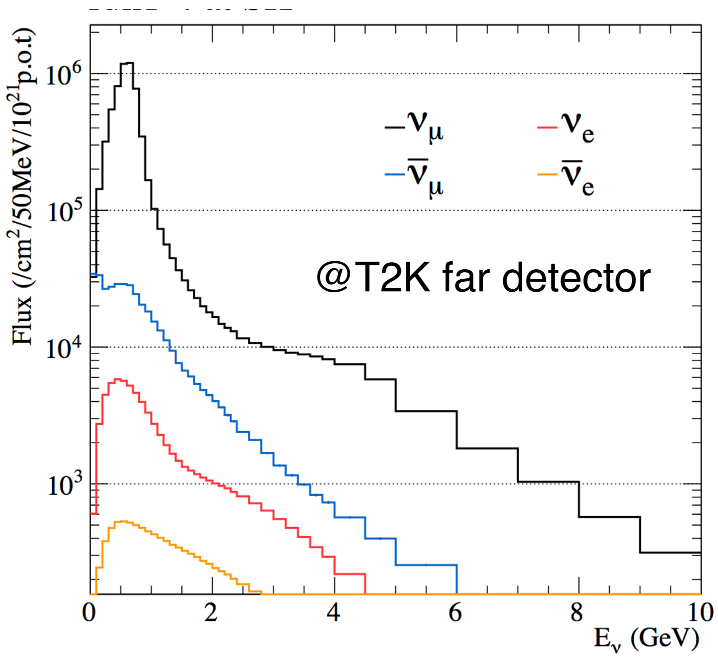
Neutrino flux and its error

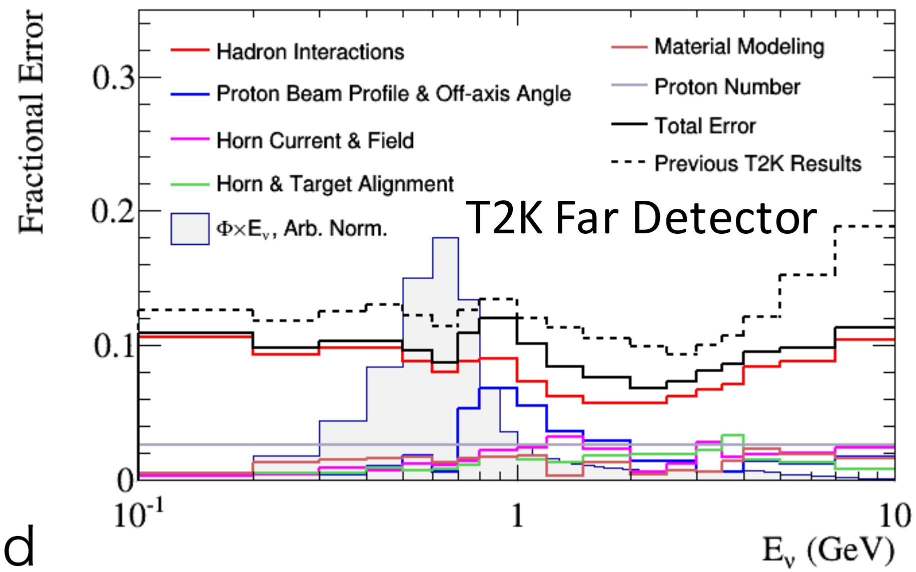
- ν flux is calculated based on
  - measurement of proton beam profile
  - π, K yield measurements by CERN NA61/SHINE experiment

π^+ yield from 30GeV p+C interaction



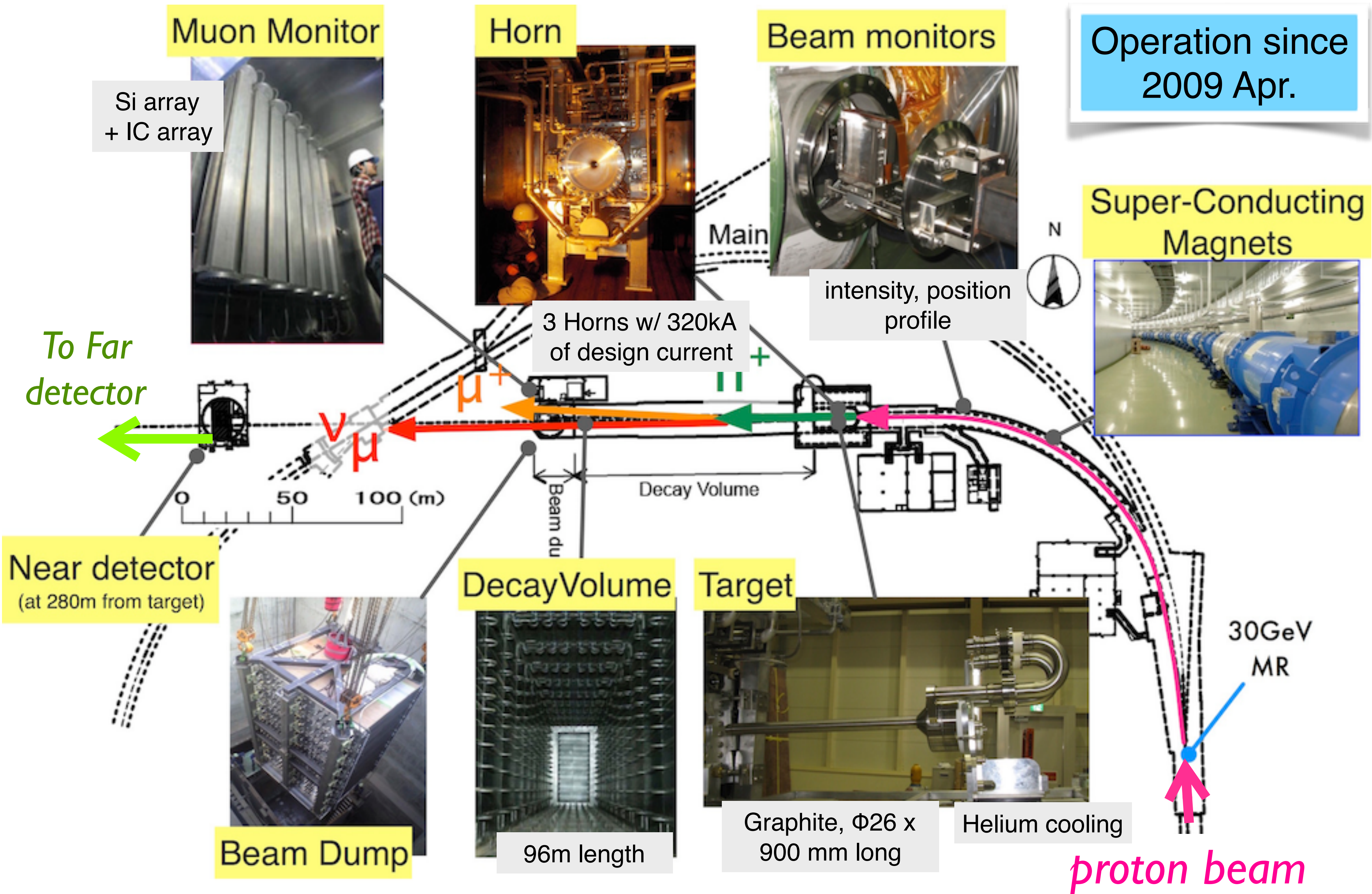
Eur.Phys.J. C76 (2016) no.2, 84





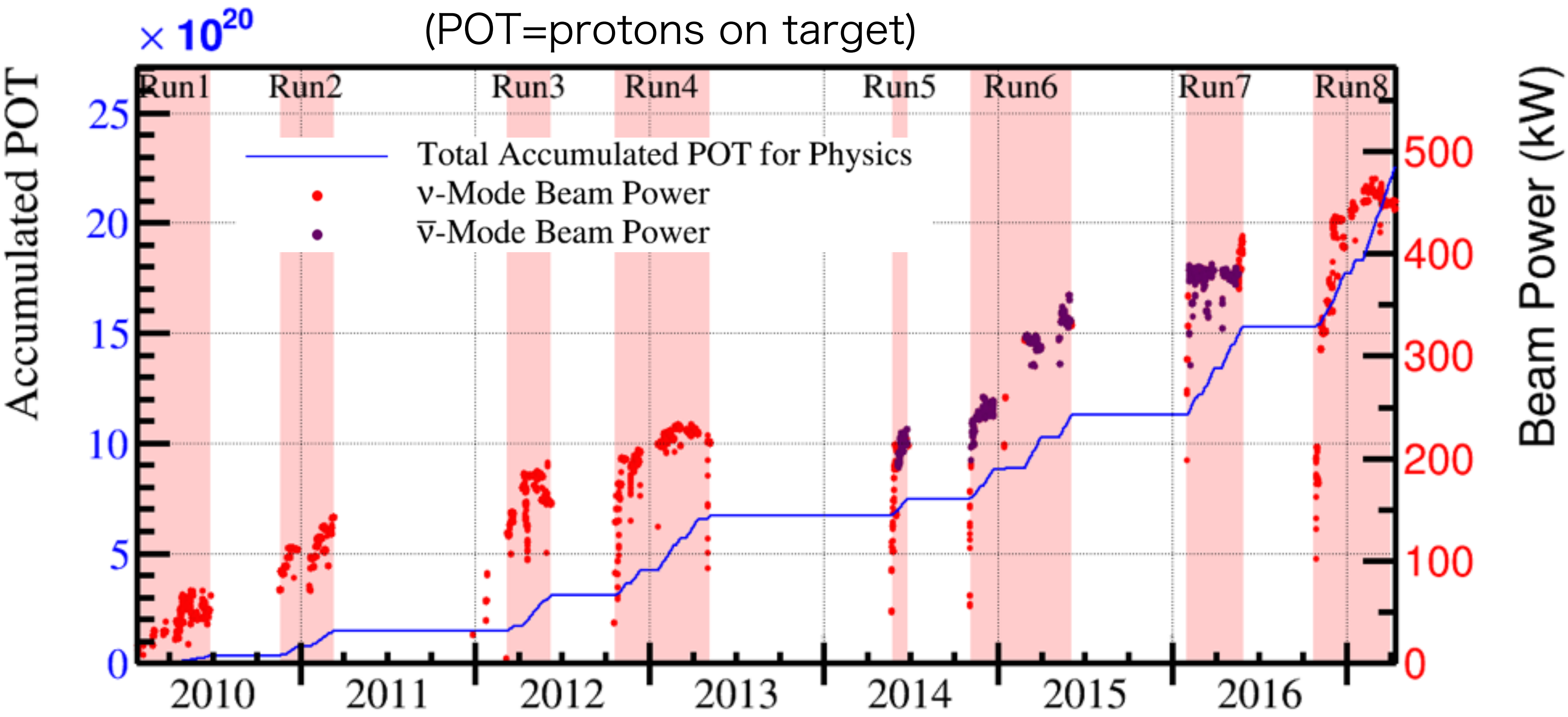
- Total absolute flux uncertainty is ~10% (similar size for anti-nu beam)
- Far-to-near extrapolation is also calculated

J-PARC Neutrino facility



Accumulated POT and beam power

(POT=protons on target)



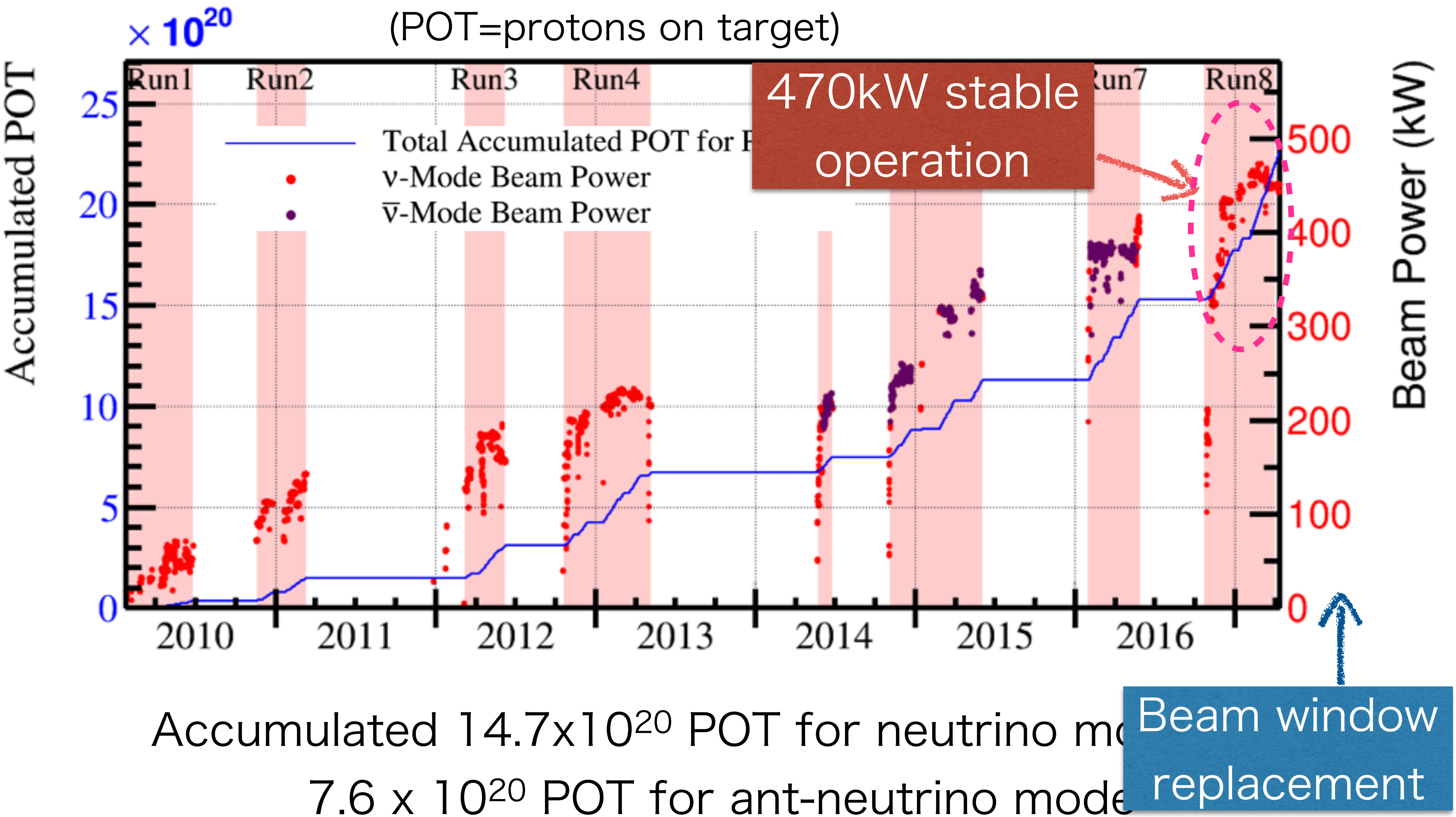
Accumulated 14.7x10^{20} POT for neutrino mode and

7.6 x 10^{20} POT for ant-neutrino mode

(total POT corresponds to 29% of the T2K approved POT)

Accumulated POT and beam power

(POT=protons on target)



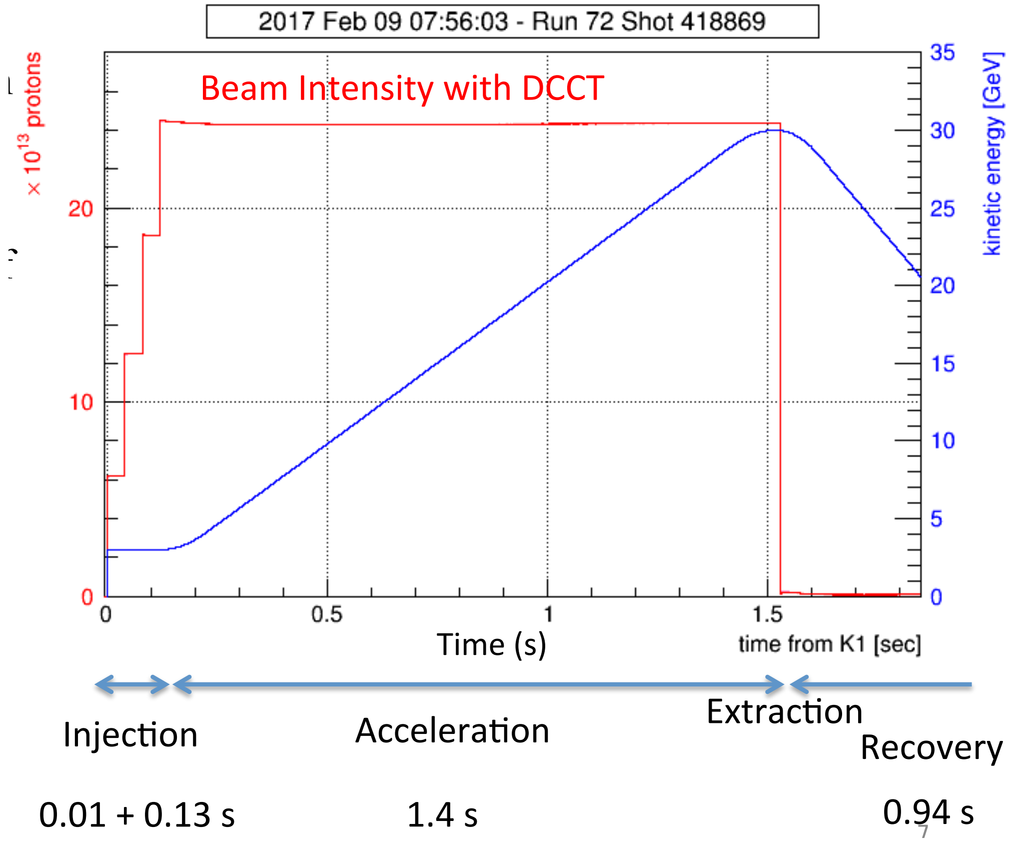
Accumulated 14.7x10^{20} POT for neutrino mo

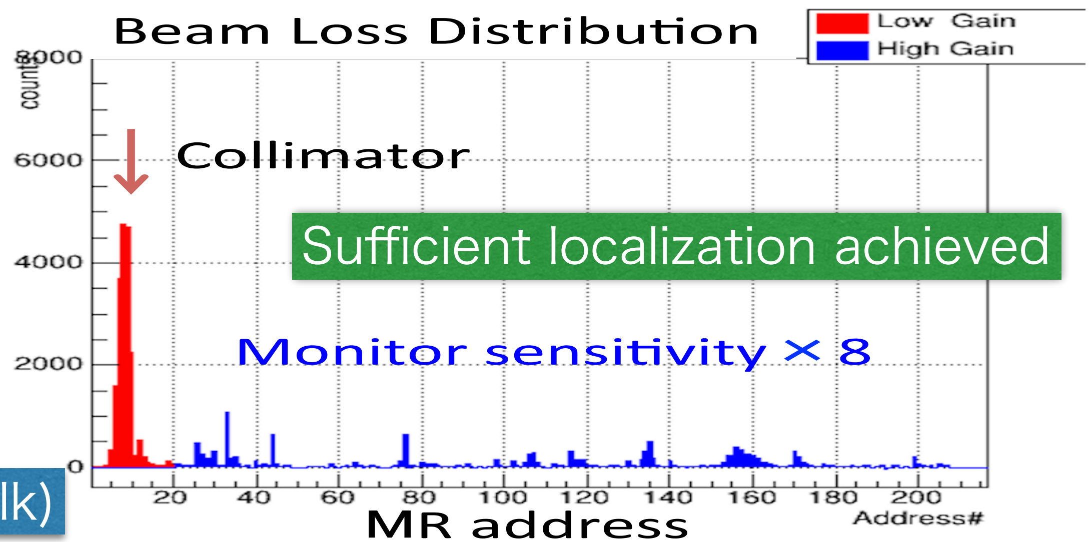
7.6 x 10^{20} POT for ant-neutrino mode

(total POT corresponds to 29% of the T2K approved POT)

470kW operation

- Power 471kW
- 3.1×10^{13} protons per bunch (ppb) x 8 at injection
- 2.44×10^{14} ppp @end of acc.
- Loss at MR ~800W which is less than the MR collimator limit of 2kW
- Loss at 3-50BT is 100W which is less than the 3-50BT collimator limit of 2kW
- RF anode power supply tripped several times by the current limit. limited the beam power
- Longitudinal instability happened frequently > 480kW



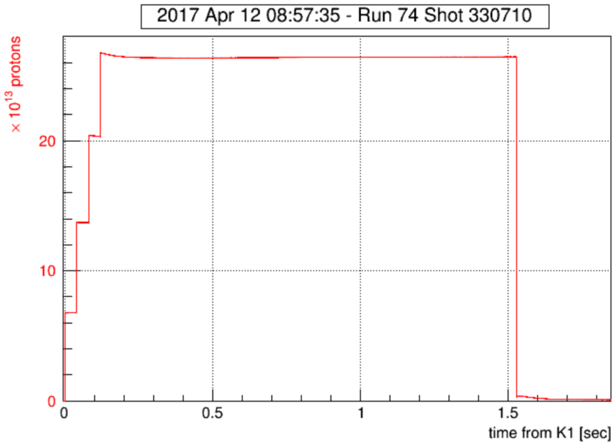


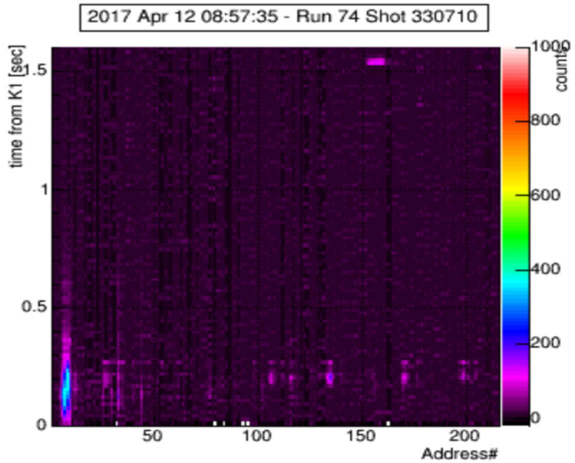
(see also Y.Sato's talk)

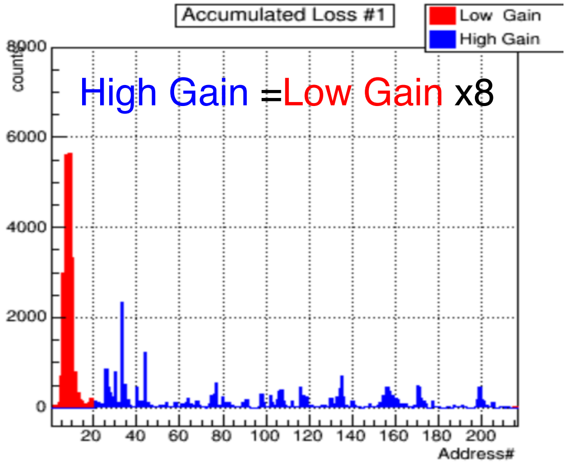
510kW trial

- Betatron tune (21.35, 21.45)
- 2^{nd} harmonic rf

(S.Igarashi at NBI2017)







Extracted beam : 2.64 e14 ppp

Total beam loss ~ 1.7 kW

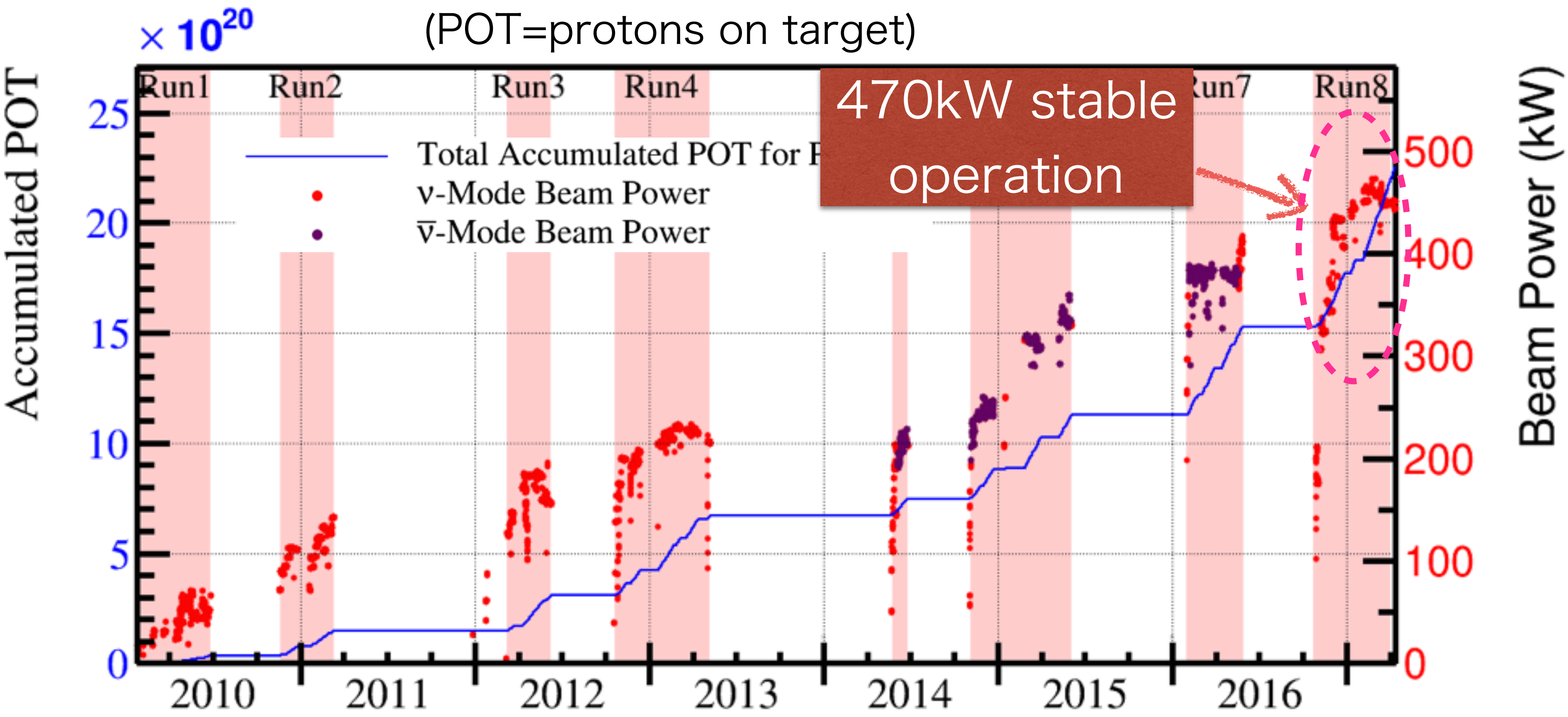
	Protons per pulse	Bunch number	Repetition period (sec)	Beam power (kW)	Beam loss (kW)	Notes
1	2.64e14	8	2.48	511	1.7	measurement
2	2.64e14	8	1.16	1092	3.6	estimation

The MR has capability to achieve >1MW with the high repetition rate operation.

Also, we can successfully extract 510kW beam to ν beam-line without no major issues at ν beam-line

Accumulated POT and beam power

(POT=protons on target)



2010.Jan~2016.May [Phys. Rev. Lett. 118(2017) no15, 151801]

$7.5\text{x}10^{20}$ $\bar{\nu}$ mode | $7.5\text{x}10^{20}$ ν mode

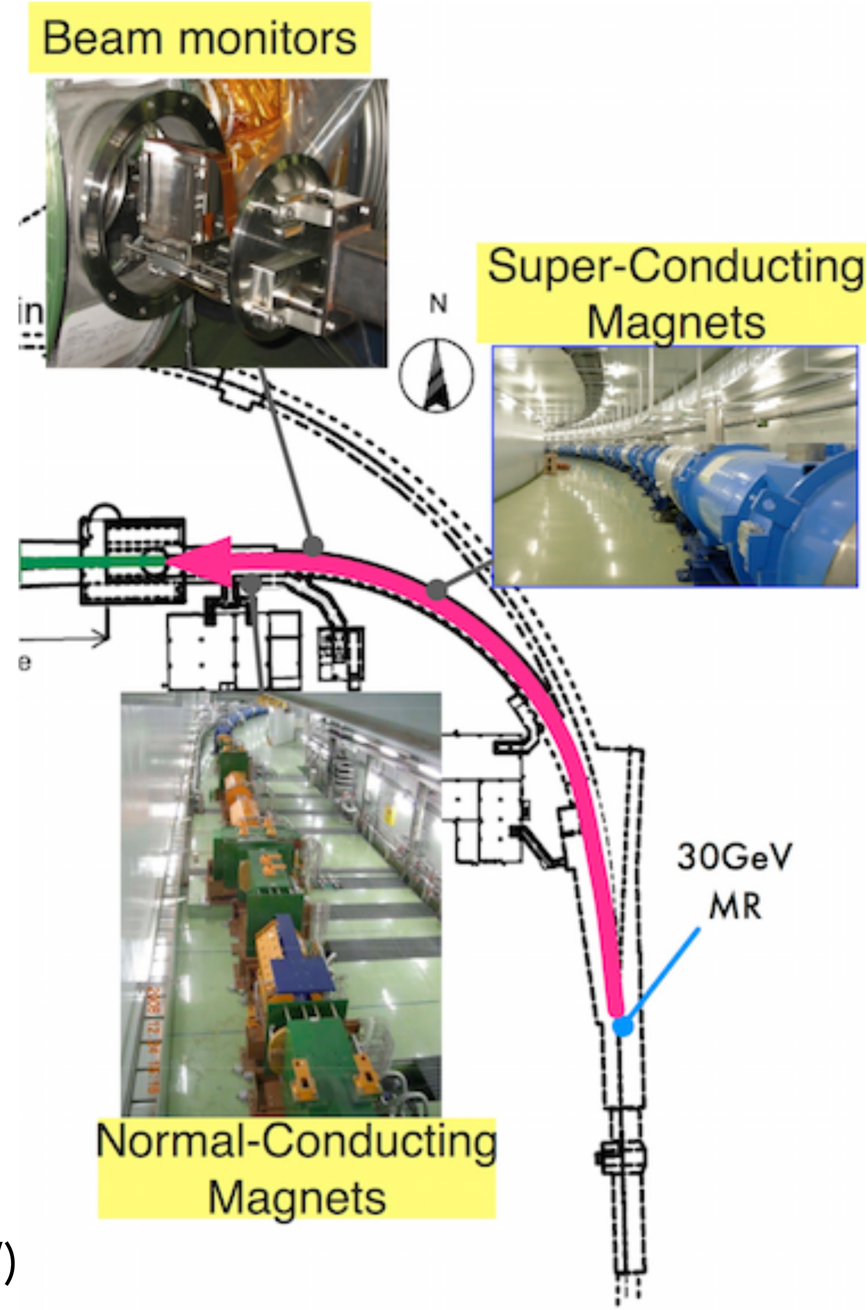
Double ν data in this 6month run !

+ 2016.Nov~2017.Apr

$7.6\text{x}10^{20}$ $\bar{\nu}$ mode | $14.7\text{x}10^{20}$ ν mode

Primary beam-line

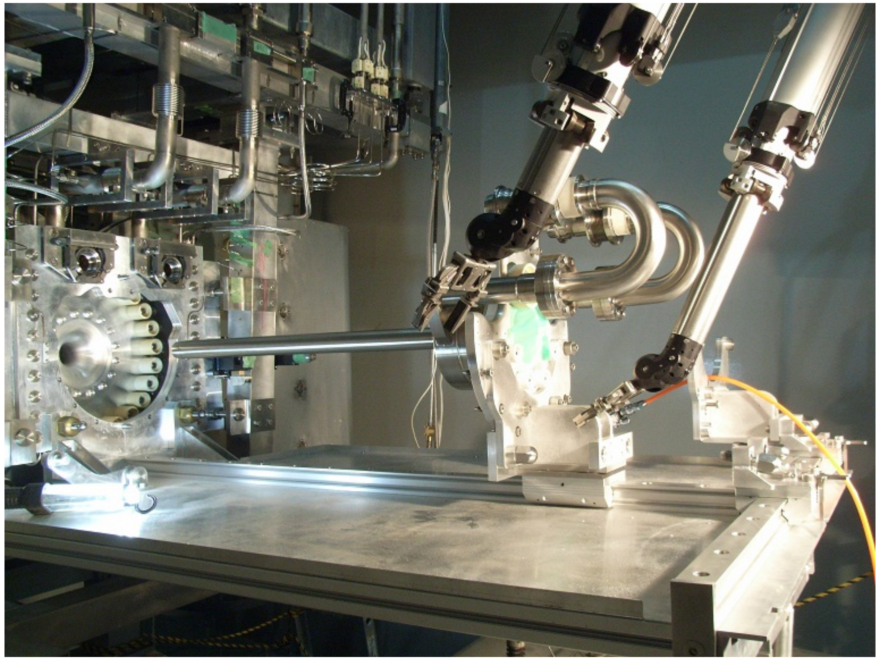
- Beam orbit from the extraction to the target is controlled anytime to keep less beam loss
- Successfully handling the 470kW beam stably with less beam loss
    - residual dose is generally low (~10μSv/h)
    - high residual dose at most downstream of beam-line (~4.5mSv/h)
        - suspected source is back scattering from the collimator, target or beam window
        - remote maintenance of the beam-line equipment is necessary if we need some work just after the beam running
- Basically ready for high beam power up to 750kW (several improvement needed for 1.3MW)



Target and horn

Target

- Graphite Φ26mm x 900mm long
- Designed to work at 750kW
- Replaced in 2013 when horn1 replaced
- He pipe leaked and repaired in 2015



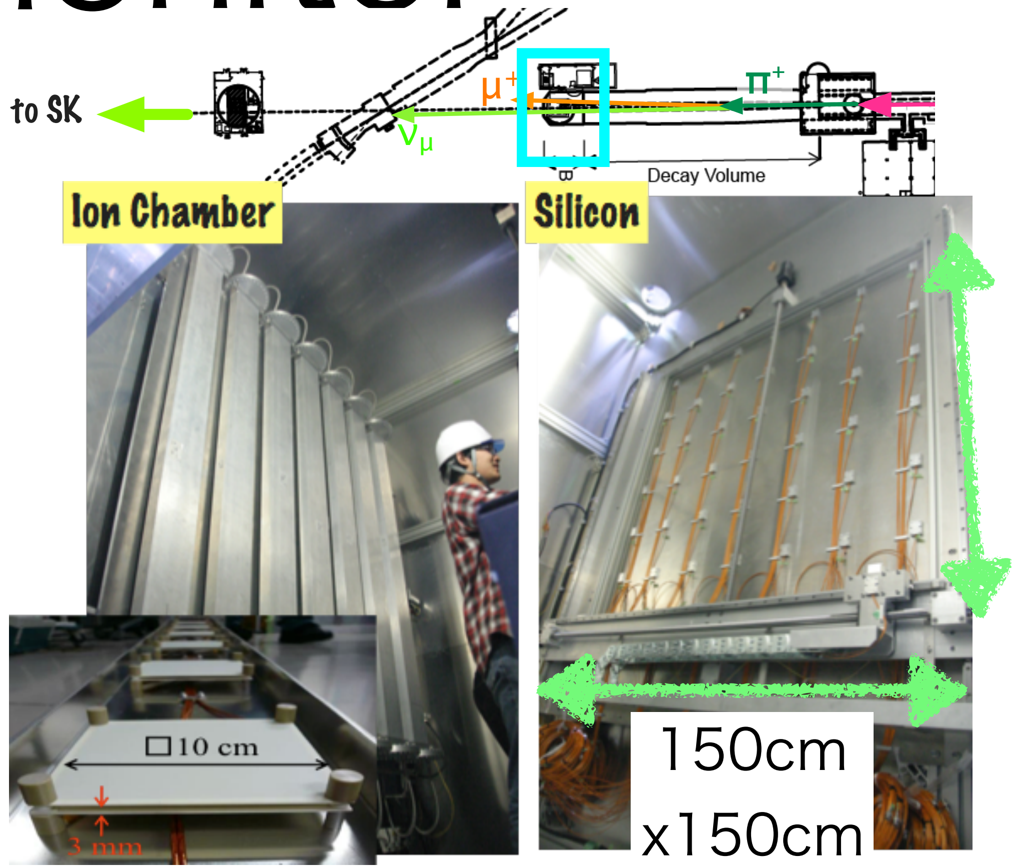
Horn

- Three horns
- Operating (250kA) stably with no major trouble
- Replaced in 2013 with some improvements
- Needs three sets of new power supplies/ trans for 1.3sec & 320kA operation

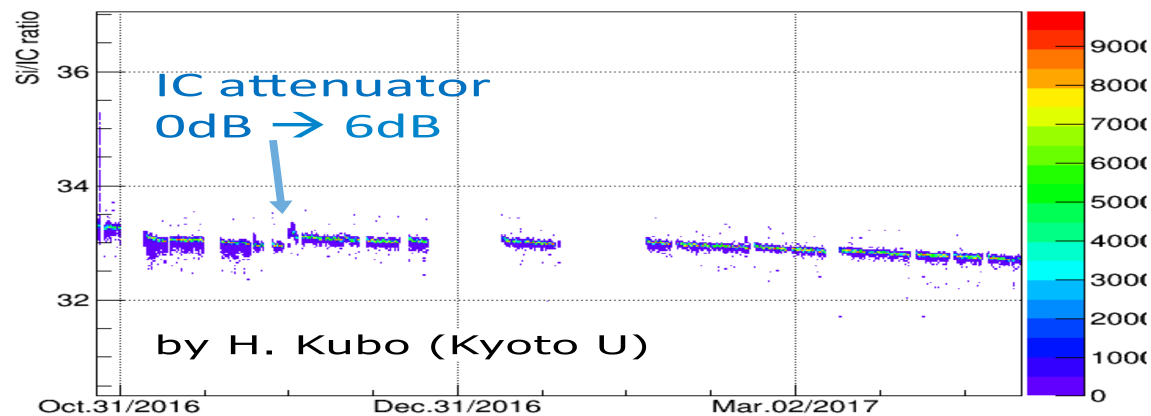
Both target and horn stably operated with 470kW
Some improvement is necessary for 750kW and beyond
(see Sekiguchi-san's talk)

Muon monitor

- Monitor the beam direction and intensity of muons every spill (every bunch)
- Stably operated with 470kW (good performance of direction and intensity measurement)
- Some problems are appearing as beam power increases
  - new detector R&D is in progress



Si yield / IC yield in Run8 (Last Run)



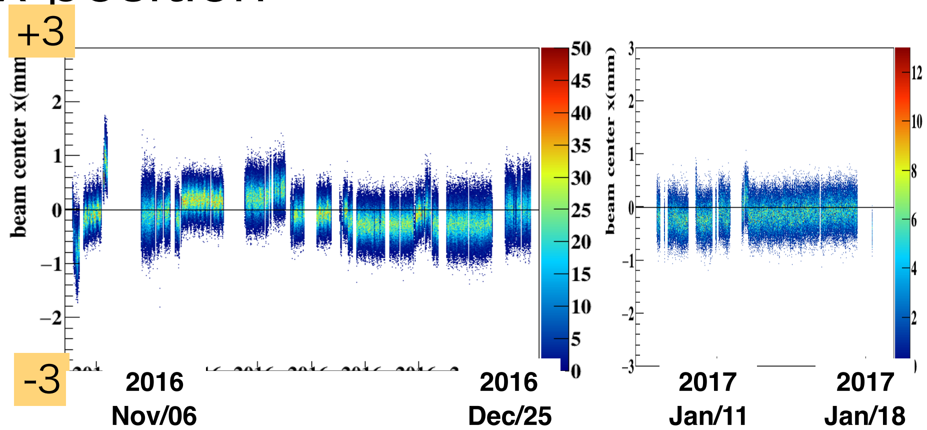
signal decrease (1%/ 5e20POT) was observed (could be radiation damage of Si. Under investigation)

Beam stability

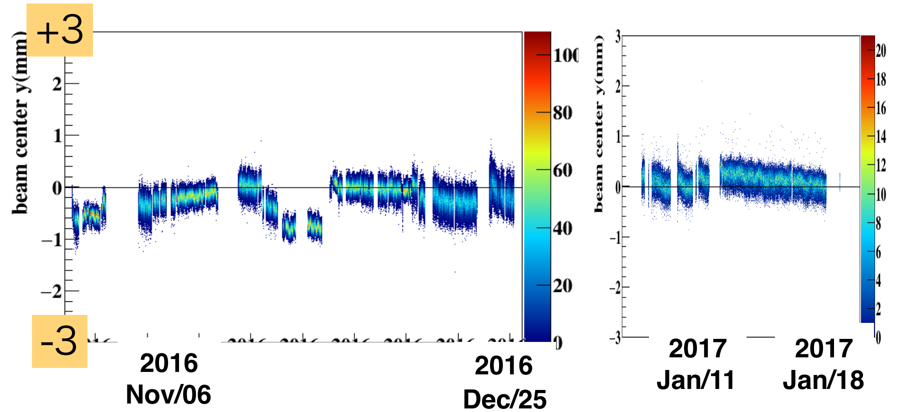
- Proton beam position, angle and width at target is controlled to make the ν beam direction stable

proton beam

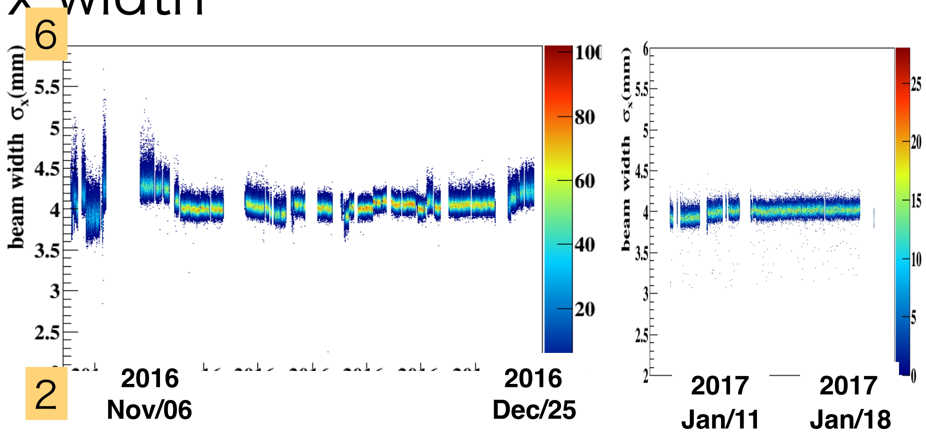
x position



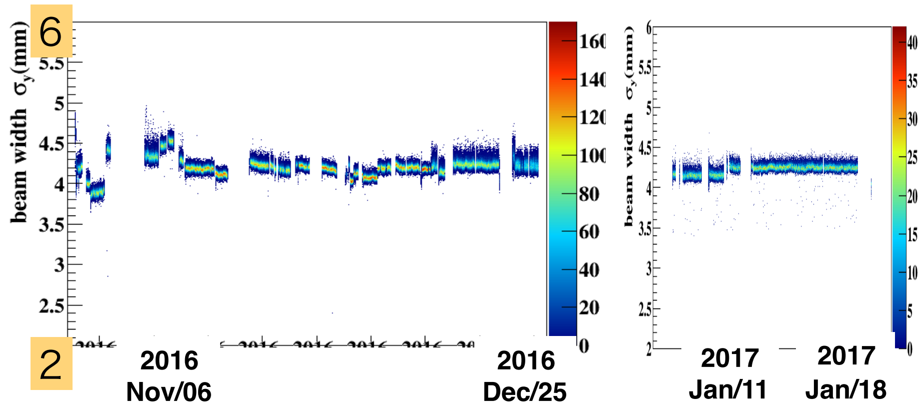
y position



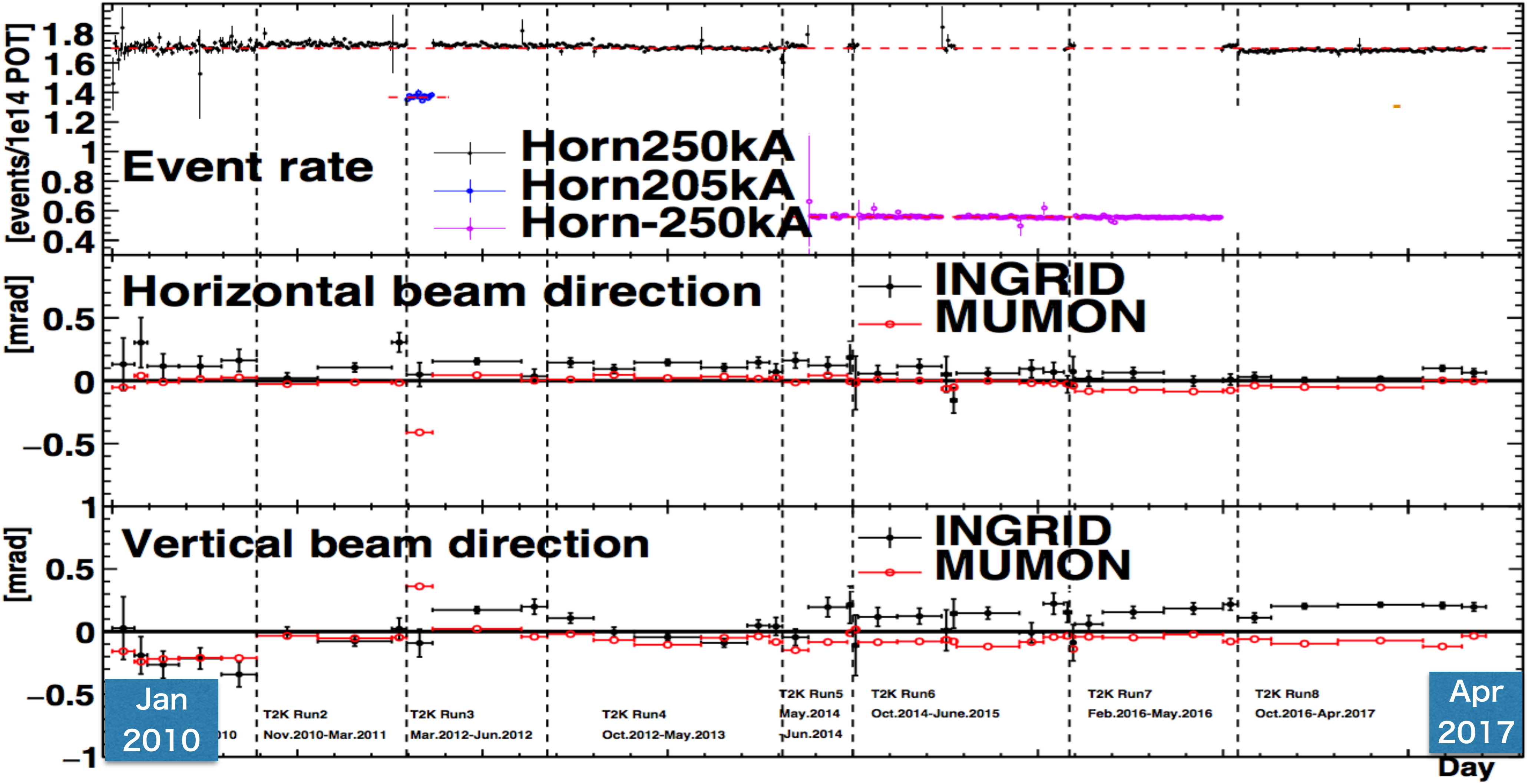
x width



y width



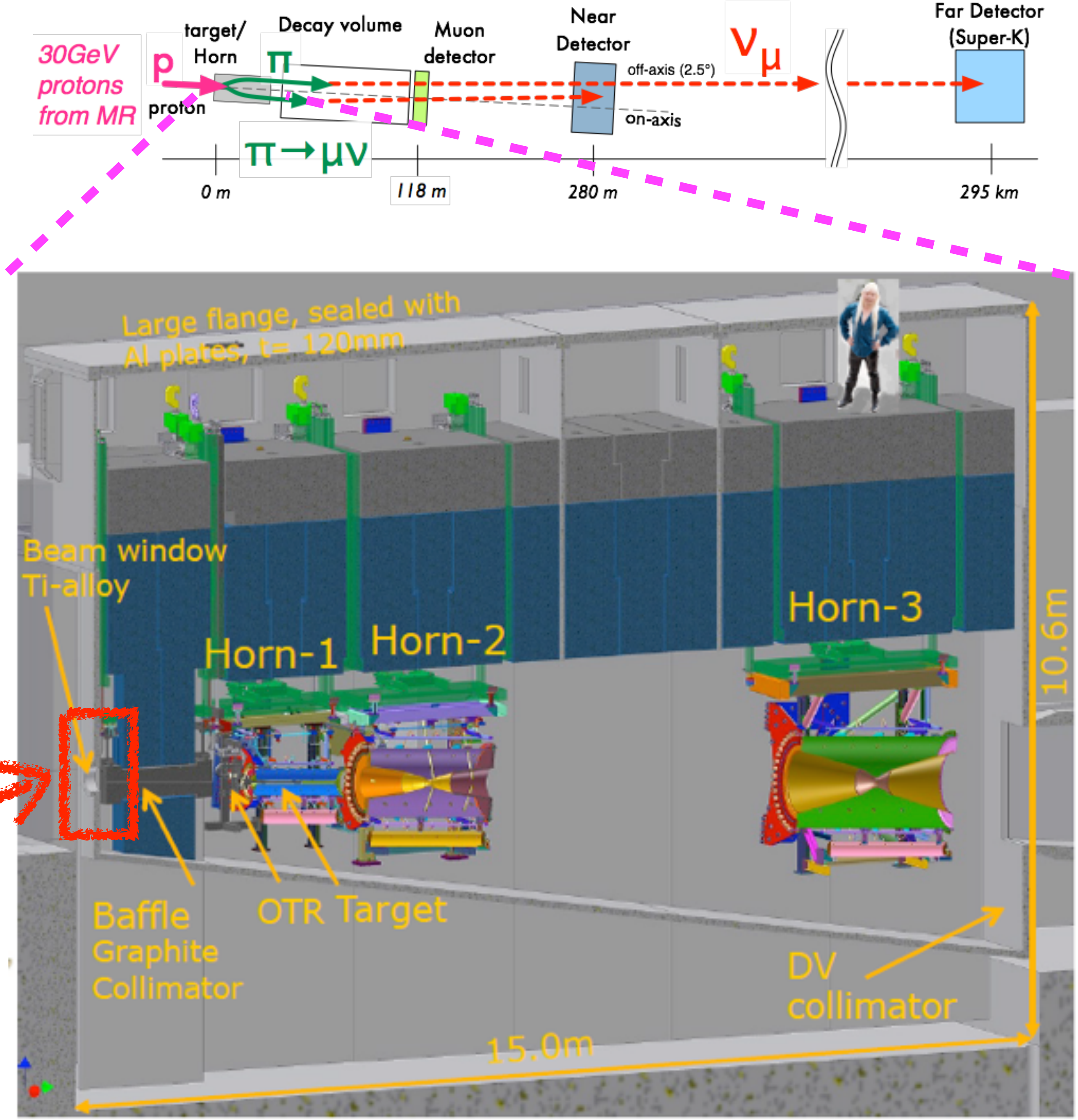
Beam stability



- Event rate is stable ~1%
- Beam direction is stable within much better than 1mrad
  - 1mrad corresponds to a 2% shift of peak ν energy at SK

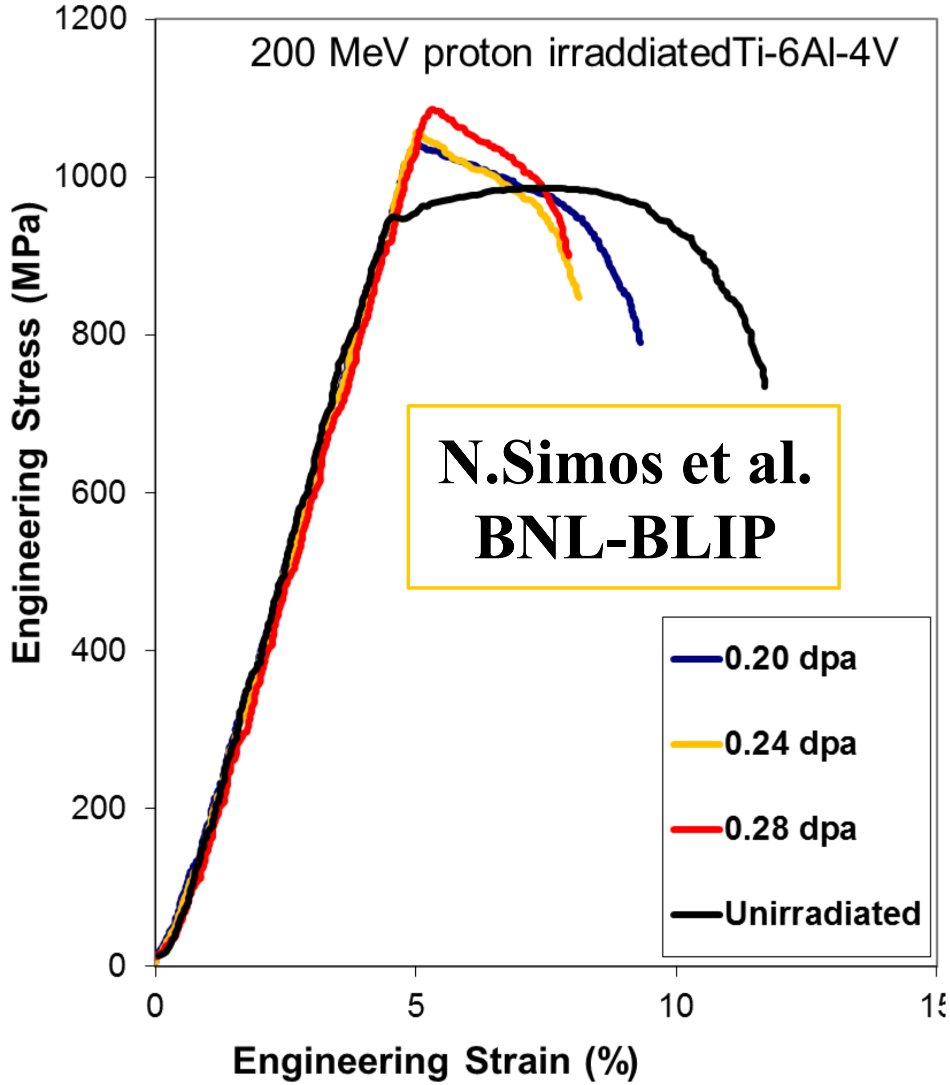
Beam window replacement

- Beam window separates the proton beam-line vacuum and He vessel
- 0.3mm Ti, double layered, He flow in gap for cooling



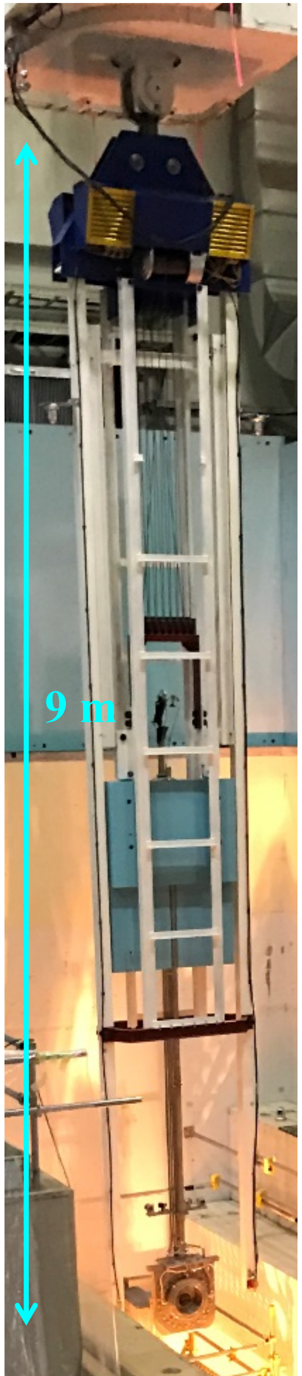
Beam window replacement

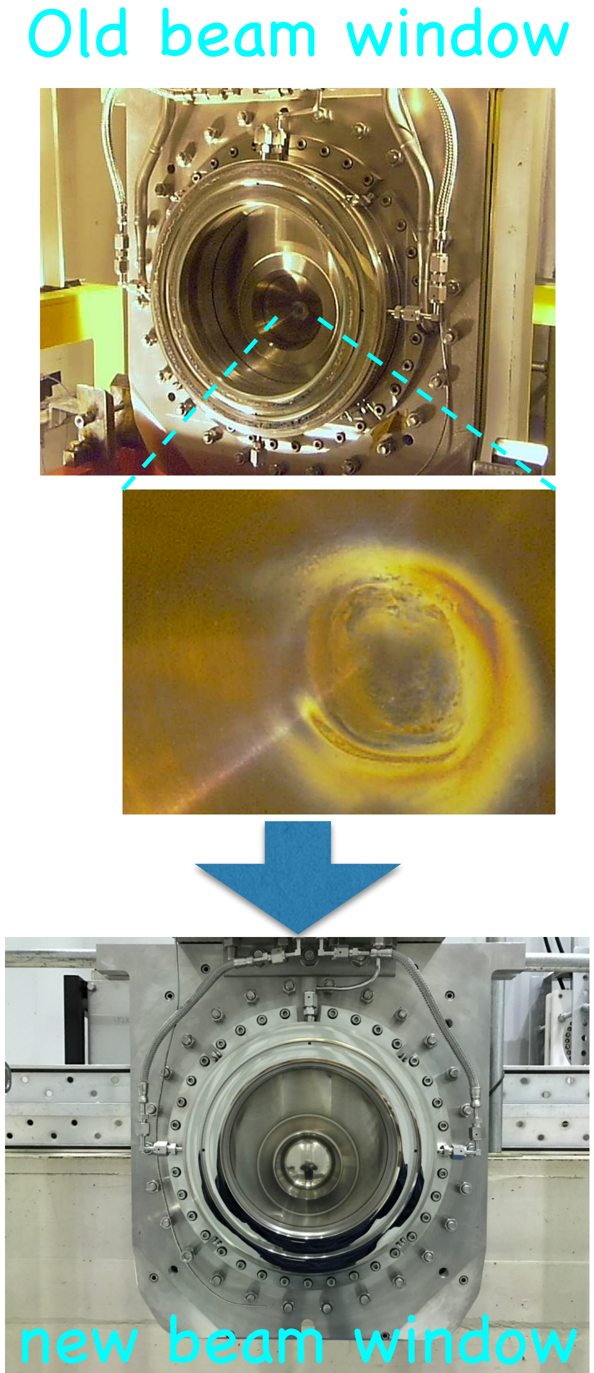
- Initial beam window used since 2009 until 2017
- The present beam window has been exposed to 2.2×10^{21} protons
  - It corresponds to 1.8DPA (displacement per atom)
- This value exceeds the existing measurement
- This motivates to replace the present beam window with new one for safe operation



Beam window replacement

- Since the beam window is activated, the replacement was performed with a remote maintenance scheme
- **Successfully replaced with a new beam window**
  - from visual inspection, some damage on the old beam window was found. Further investigation on going





Summary

- J-PARC MR and neutrino beam-line 470kW stable operation is achieved
  - there is no major issue
- Beam window replacement was successfully performed
- Based on the operational experience so far, we plan to improve some beam-line equipment for future high beam power operation