

# Radiation-induced magnetization reversal causing a large flux loss in undulator permanent magnets

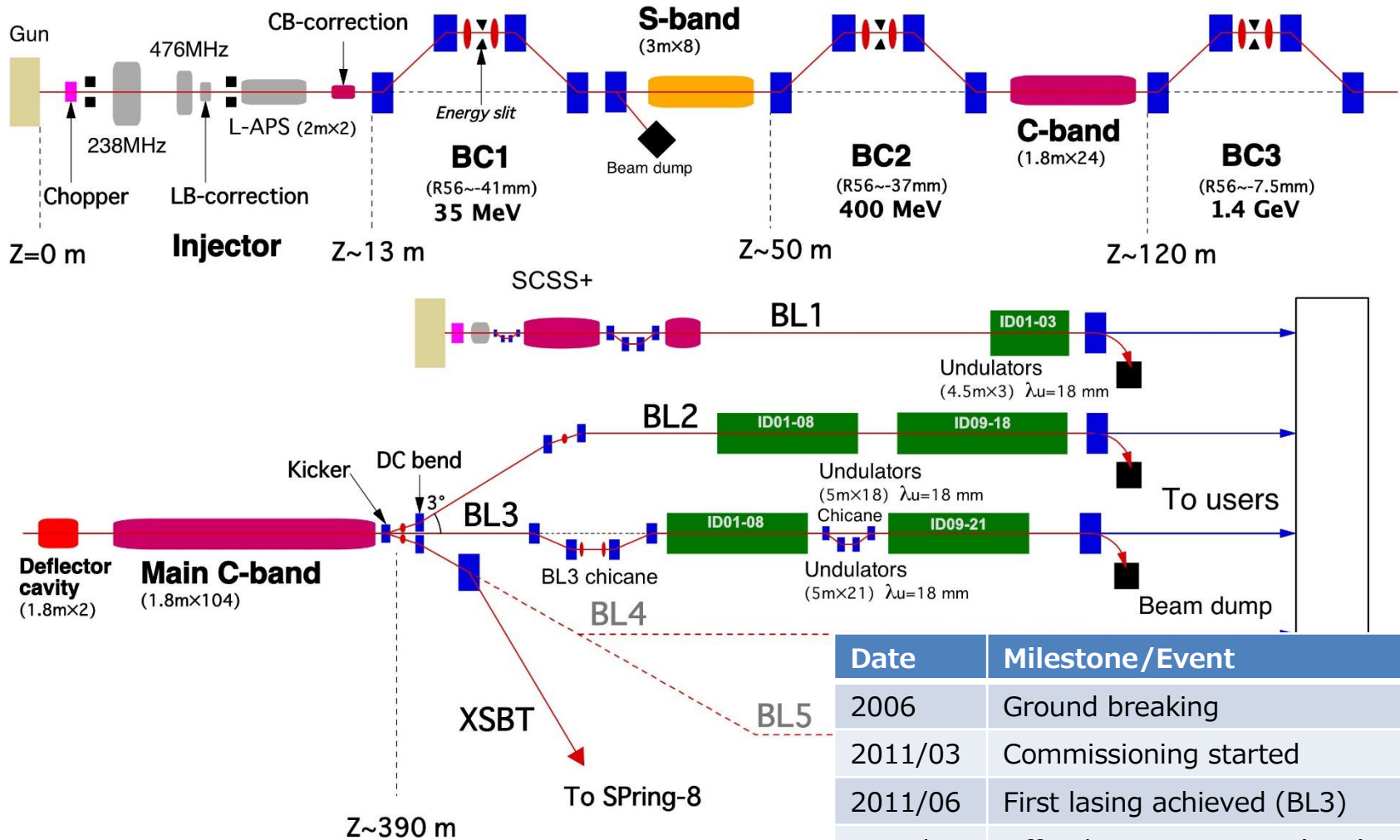
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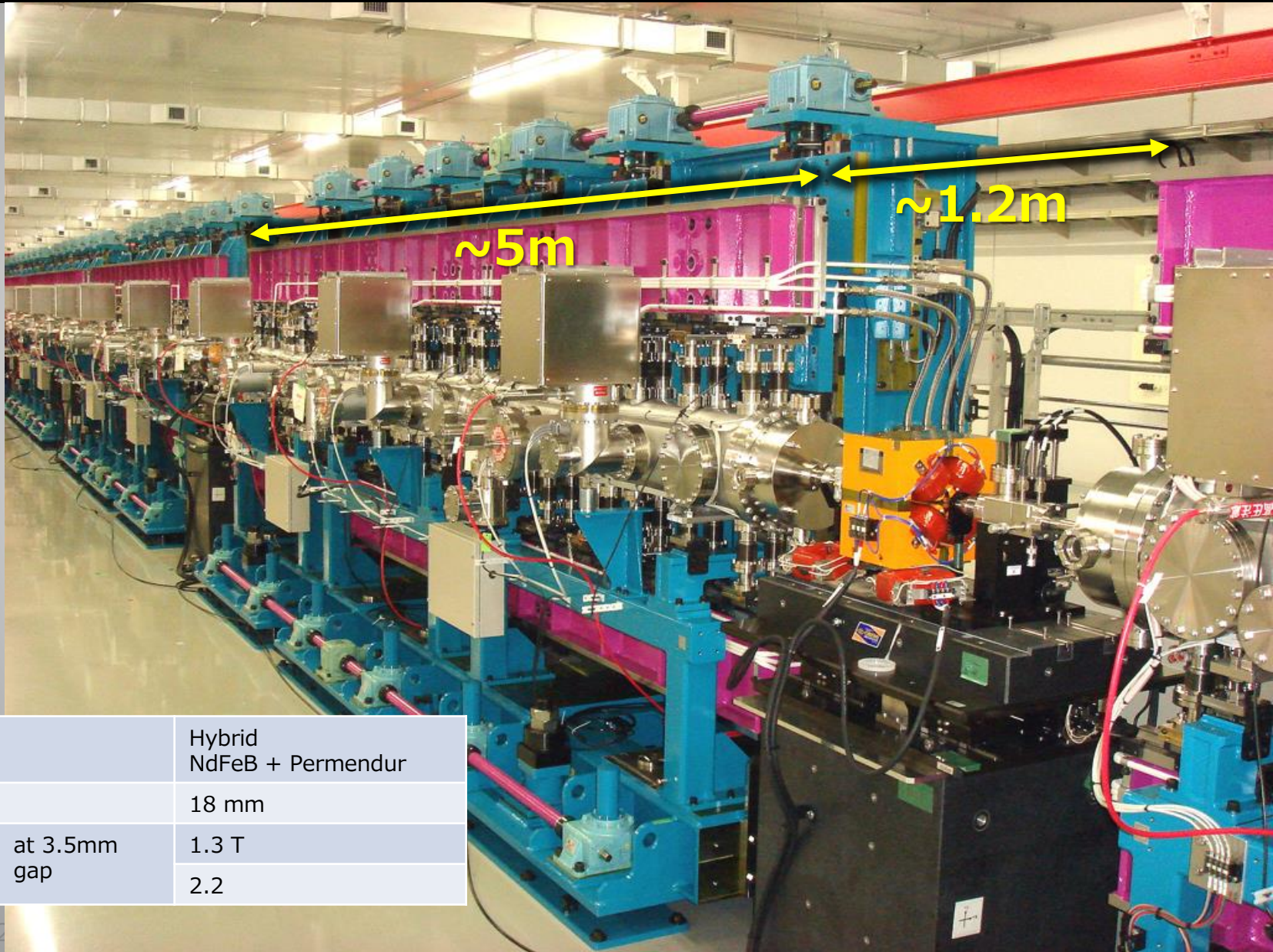
JASRI/SPring-8

# SACLA Accelerator Layout



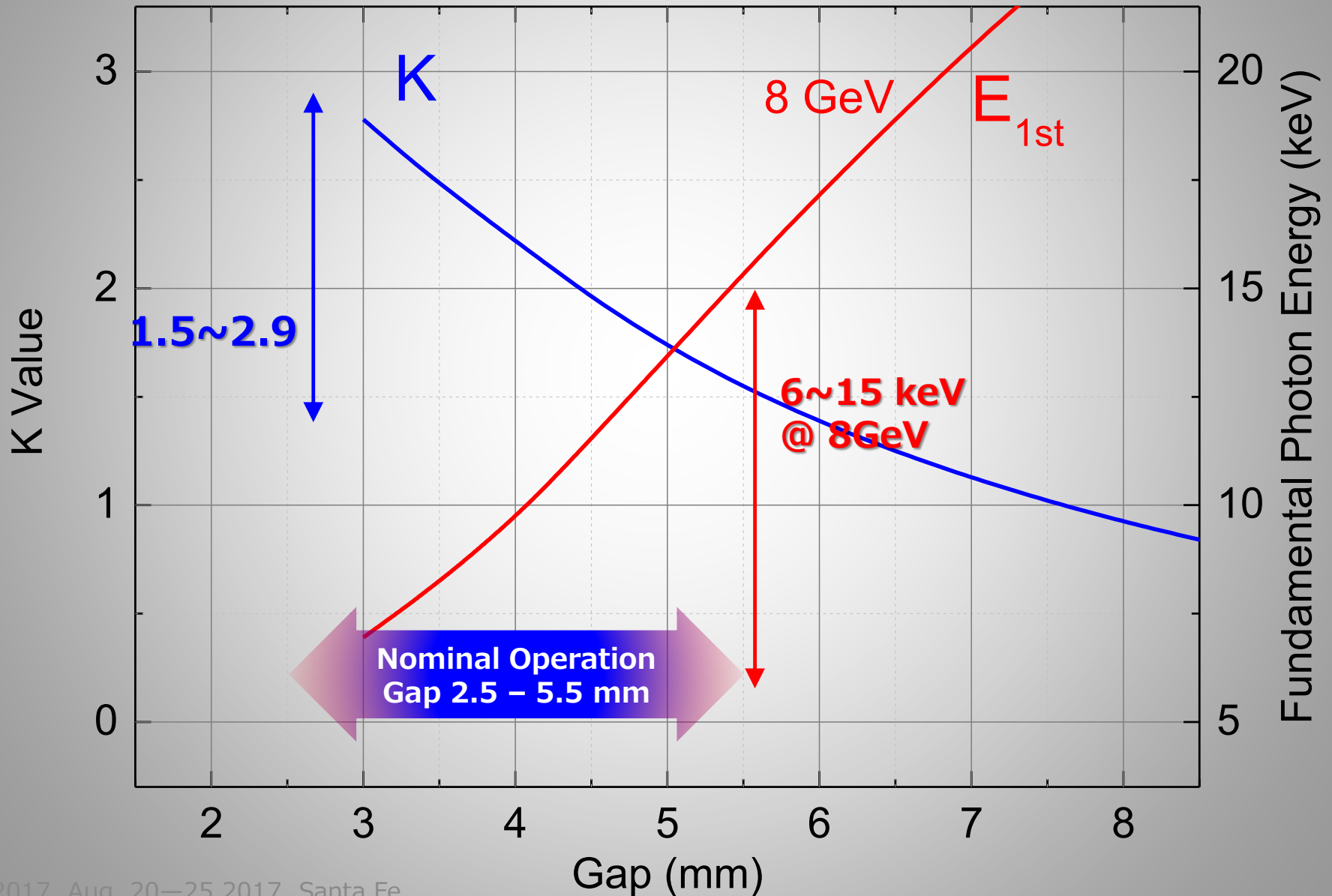
Date	Milestone/Event
2006	Ground breaking
2011/03	Commissioning started
2011/06	First lasing achieved (BL3)
2012/03	Official user operation (BL3) started
2015/06	User operation in BL2 started
2016/04	User operation in BL1 started

# SACLA IVUs

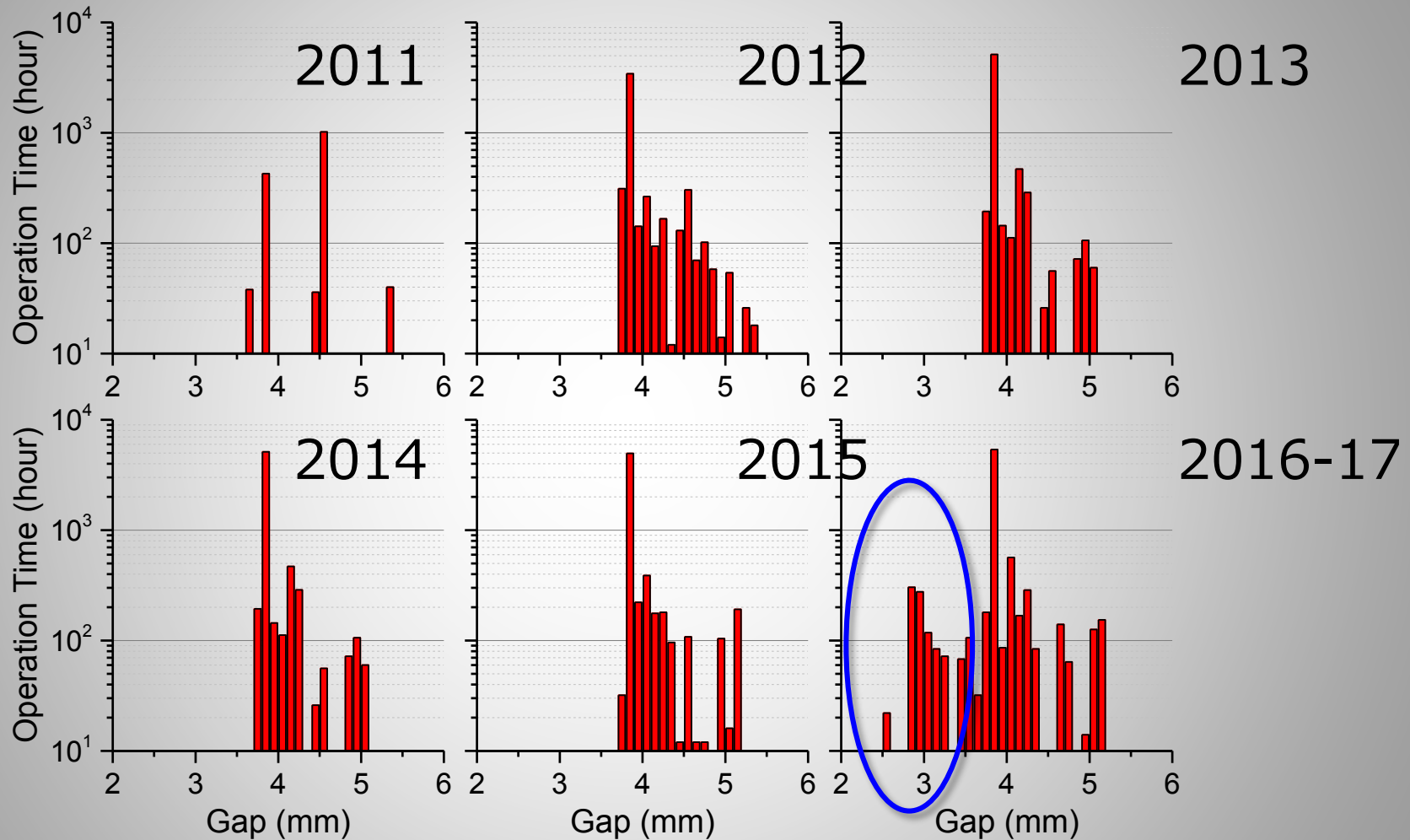


Magnet Circuit		Hybrid NdFeB + Permendur
Period Length		18 mm
Peak Field	at 3.5mm gap	1.3 T
K Value		2.2

# Wavelength Tunability with gap

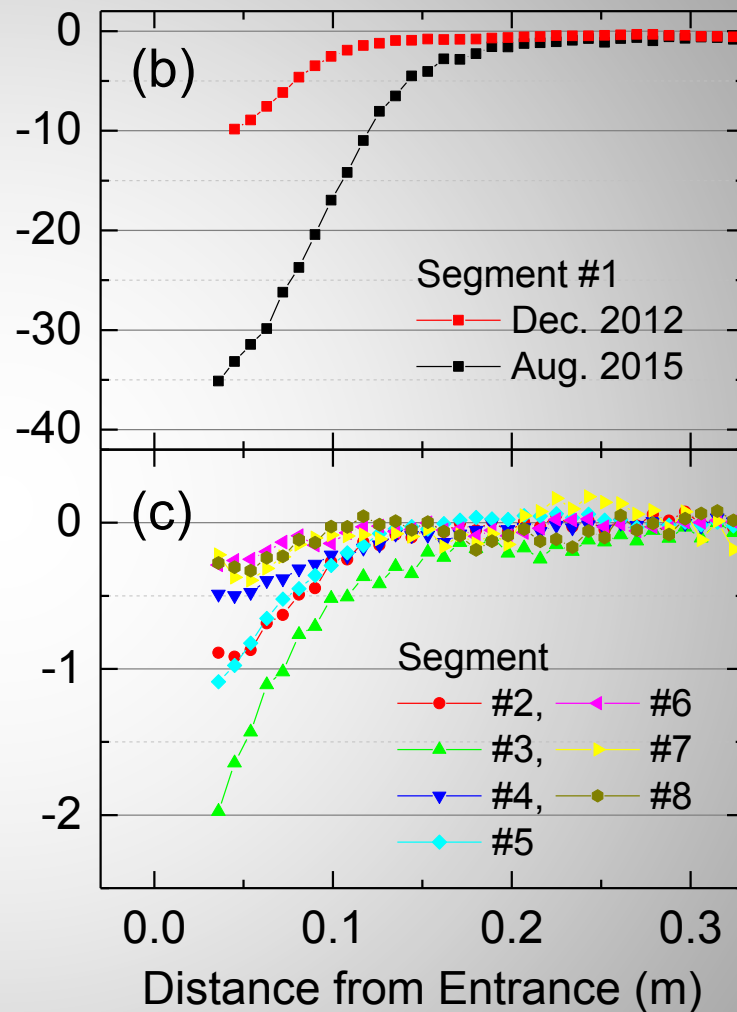
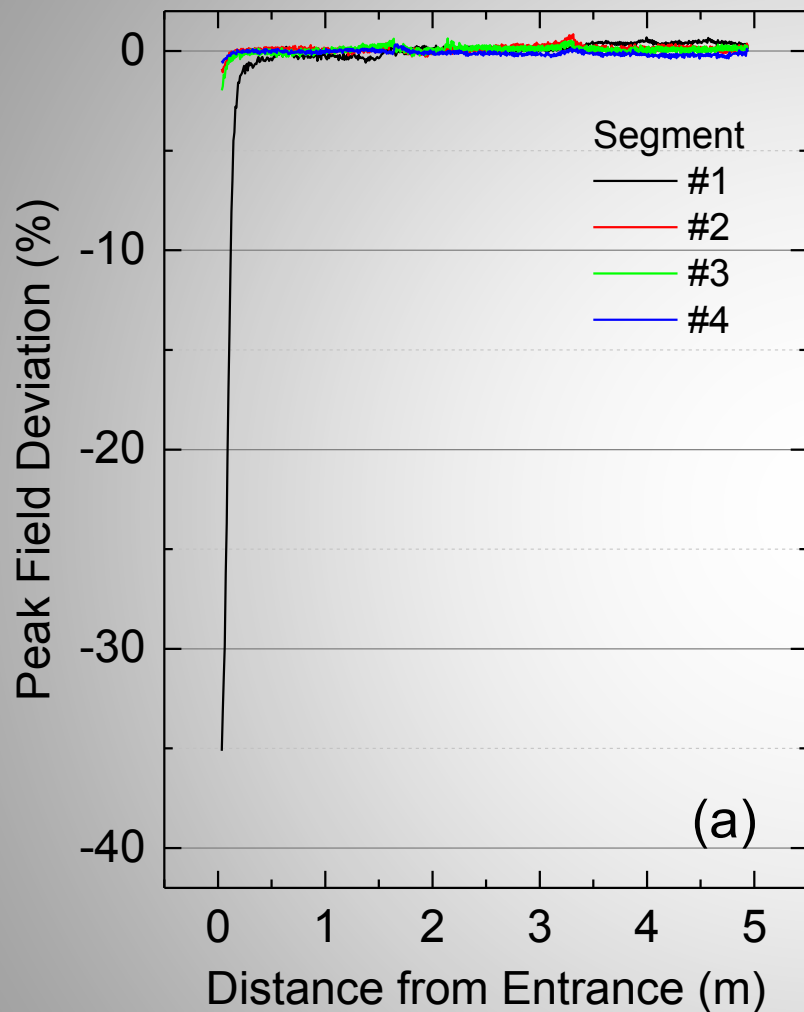


# History of Operation Gap (BL3)



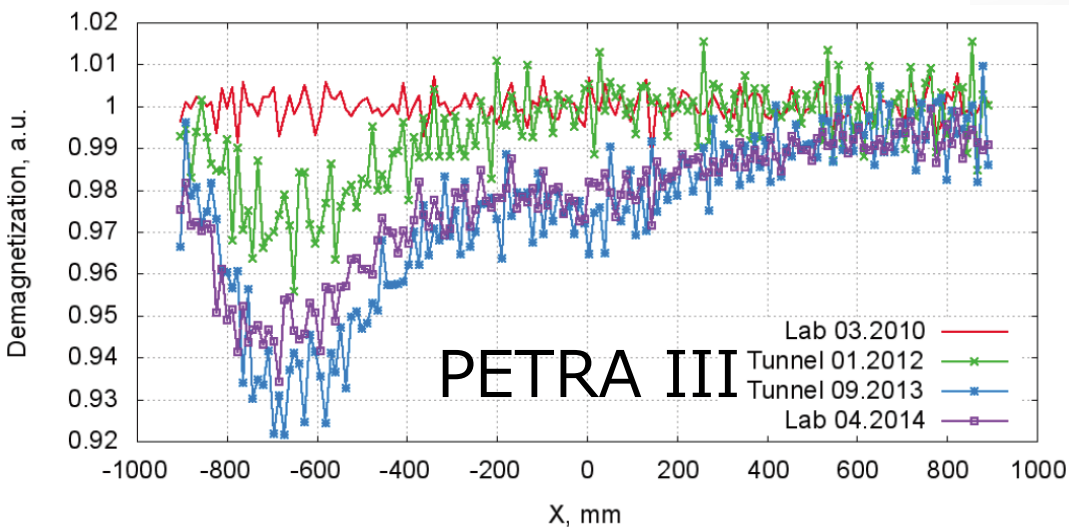
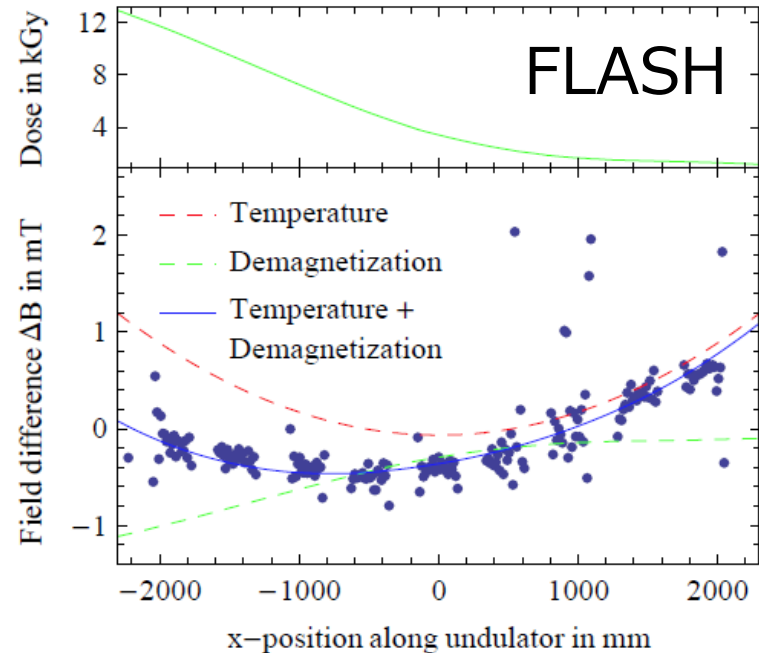
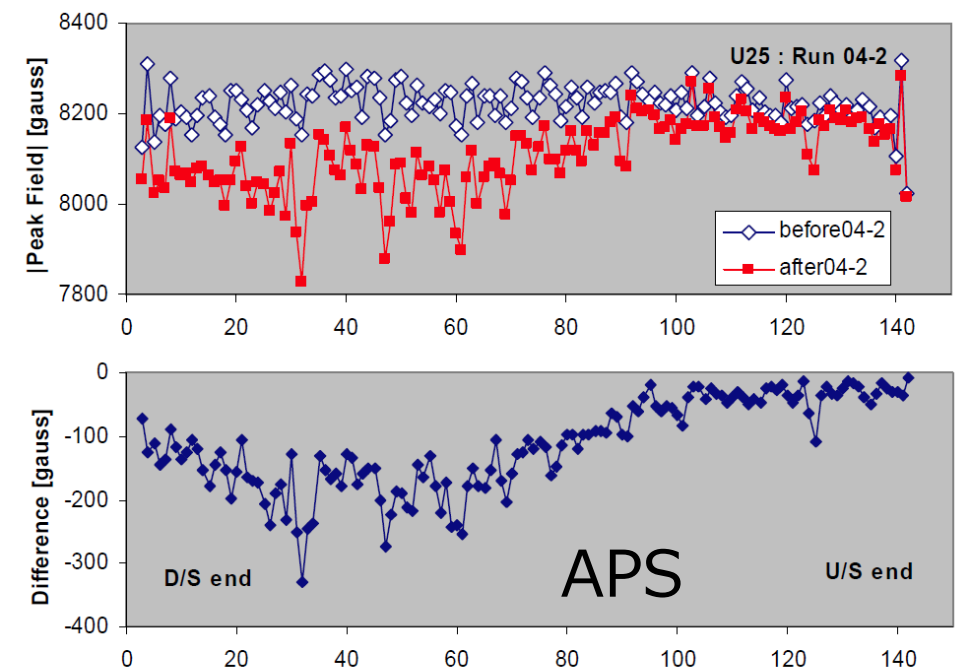
Variable gap IVUs give an opportunity to try a more narrow gap without any change

# Field Loss Profiles



- ✓ Large field loss exceeding 30%
- ✓ Localized in a narrow range ( $\sim 0.1\text{m}$ )

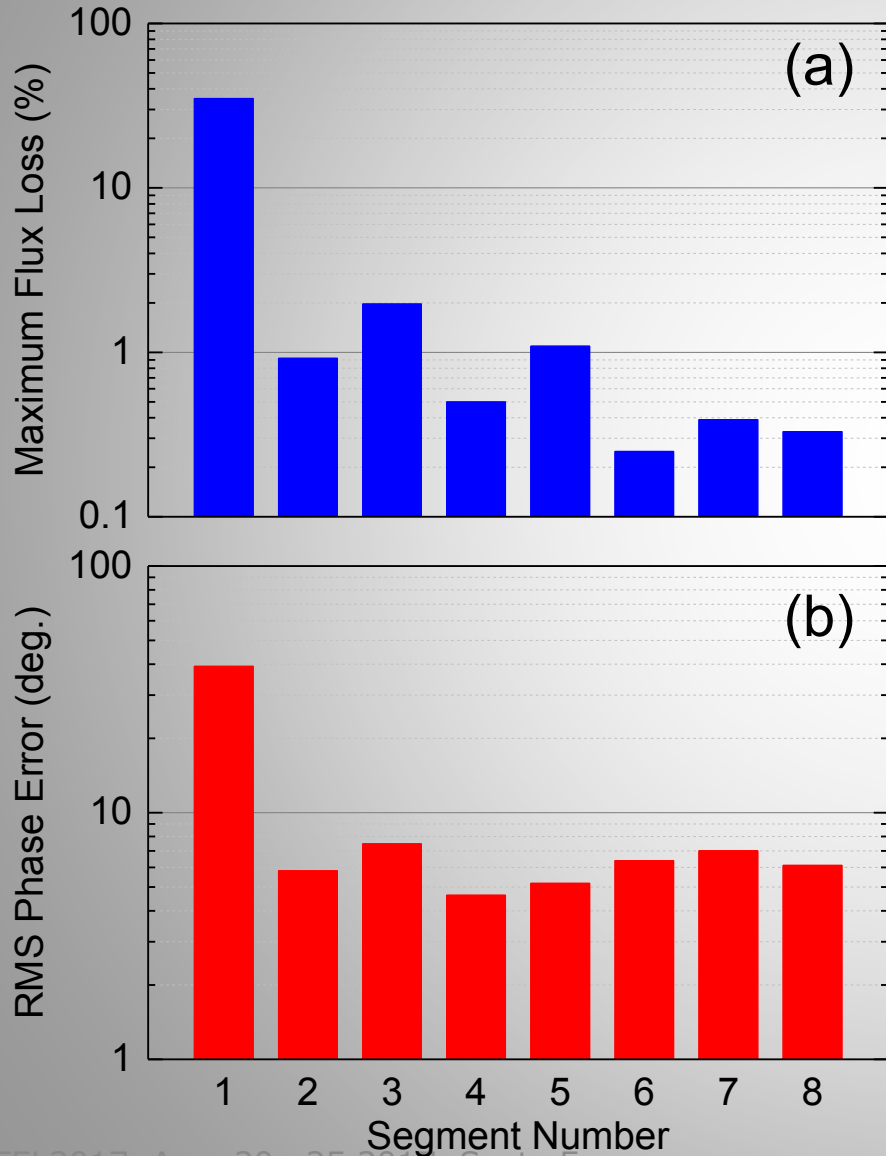
# Results from Other Facilities



- ✓ Out-vacuum hybrid
- ✓ Several % field loss
- ✓ Field loss observed in long range (1–2 m)

Secondary particle  
 direct Electron Halo

# Maximum Field Loss & Phase Error vs. Undulator Number



Maximum field losses

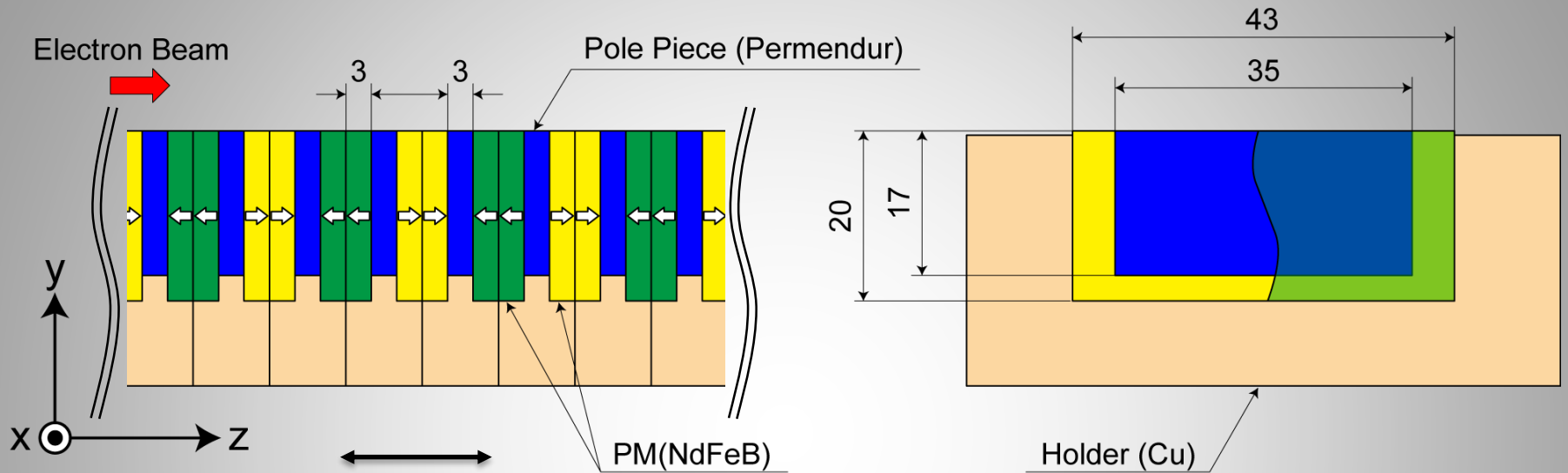
- #1 is outstanding
- Oscillatory behavior

Phase error(spec.  $< 10^\circ$ )

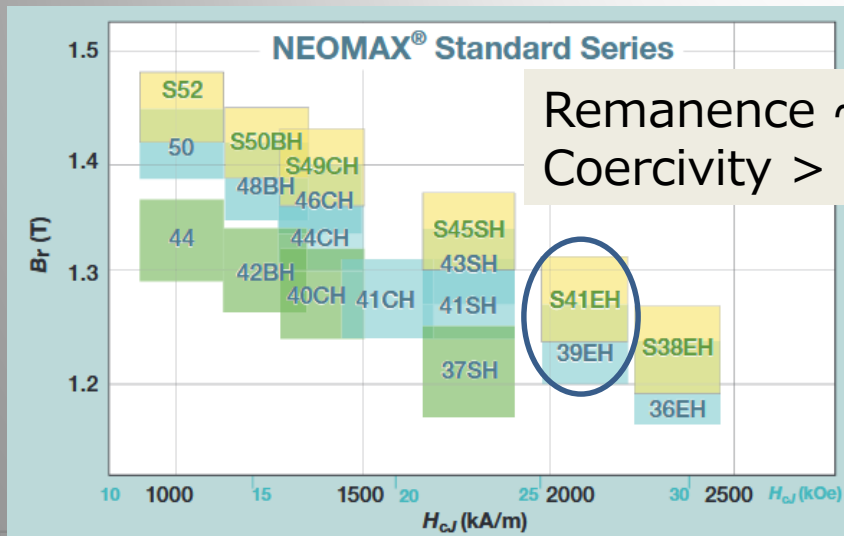
- #1  $\sim 40^\circ$  ( $\sim 5^\circ$  without 6 periods from entrance)
- Negligible change after #2 segment



# Magnetic Dimension of SACLA IVUs



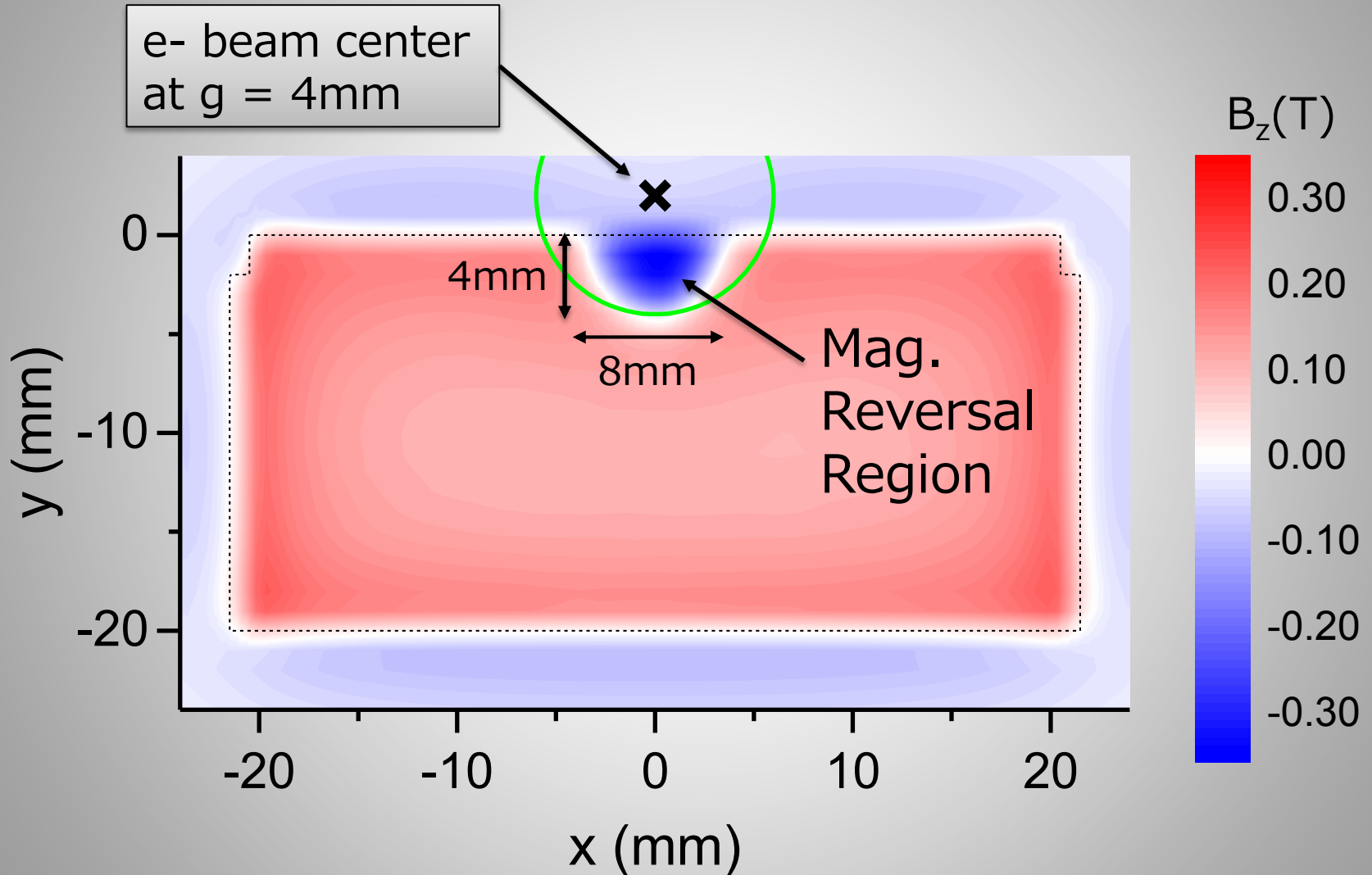
$\lambda_u = 18 \text{ mm}$



3 mm



# Surface Field Mapping of PM

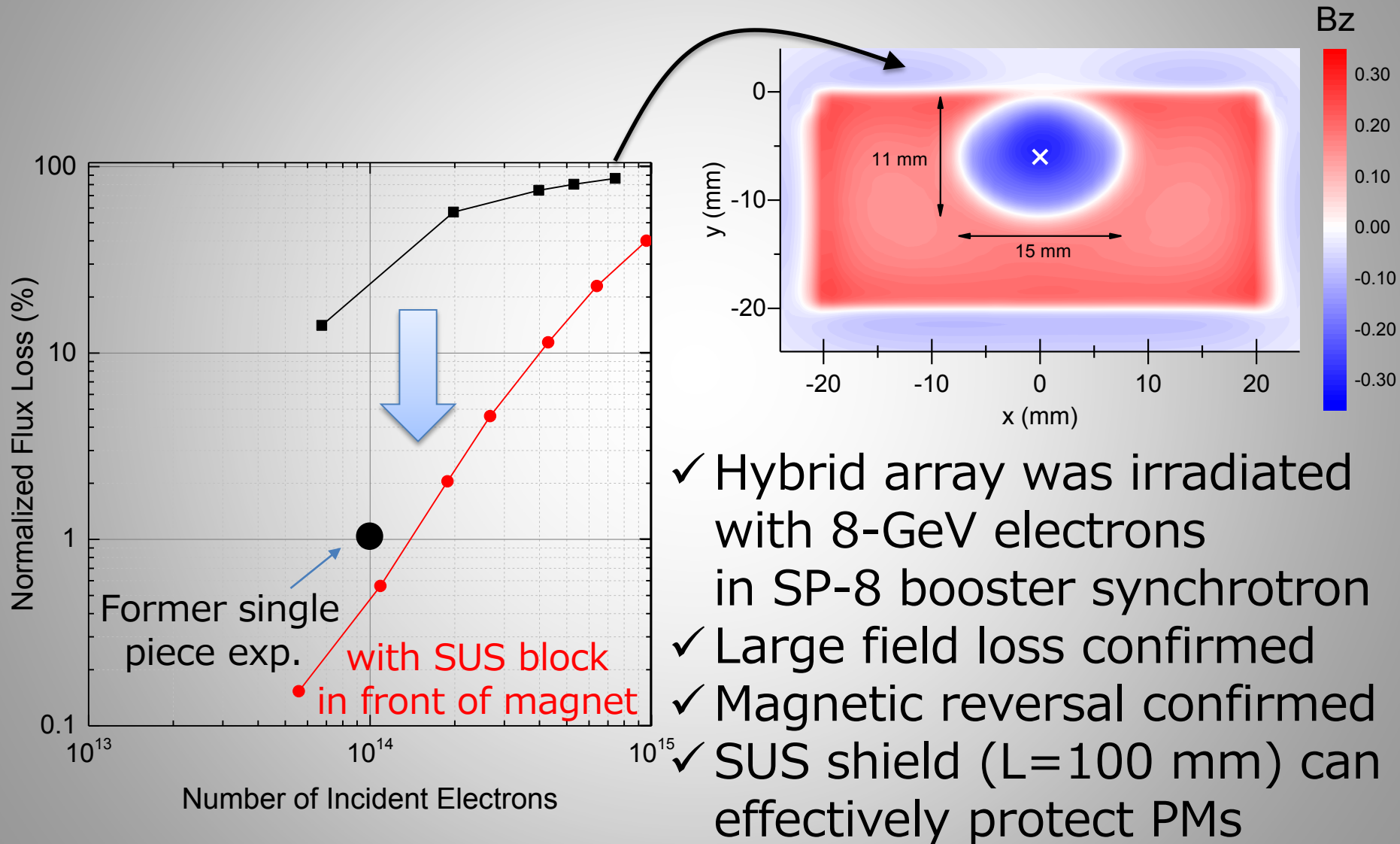


# Demag. in SACLA: Brief Summary

- Field loss rate unexpectedly large!
  - %/ $10^{14}$ e- (with a single piece NdFeB)
  - $10^{13}$  incident electrons for 5 years (by halo monitor)
- Localized near entrance, suggesting shielding effects of PMs themselves
- “Radiation-induced magnetization reversal” occurred in a macroscopic range

Phenomena never been reported;  
interesting to experimentally reproduce

# Irradiation Experiment of Hybrid Array



# Conclusion

- Demagnetization rate found in SACLA-IVUs is much larger ( $\sim 2$  orders) than our experience
- Reverse field in short-period hybrid magnet is  $\sim 3$  times larger than self demagnetizing field of single piece magnet.
  - Magnetization reversal process is a highly non-linear process with respect to the reverse field
    - # T. Bizen et al., Sci. Rep. 6, 37937 (2016)
- However, simple SUS shield ( $L = 100$  mm) works fine as radiation shield
  - Already installed in 1<sup>st</sup> undulator of BL3
  - More effective collimator to be installed

Thank you for attention