High Gain Operation and Polarization Switch with a Distributed Optical Klystron FEL (DOK-1 FEL)

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Acknowledgments

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Outline

- **FEL Upgrade Project at Duke University: 2003 - 2006**
  - **Two New FELs: OK-5 FEL and DOK-1 FEL**
- **High Gain Operation and Polarization Switch with DOK-1 FEL**

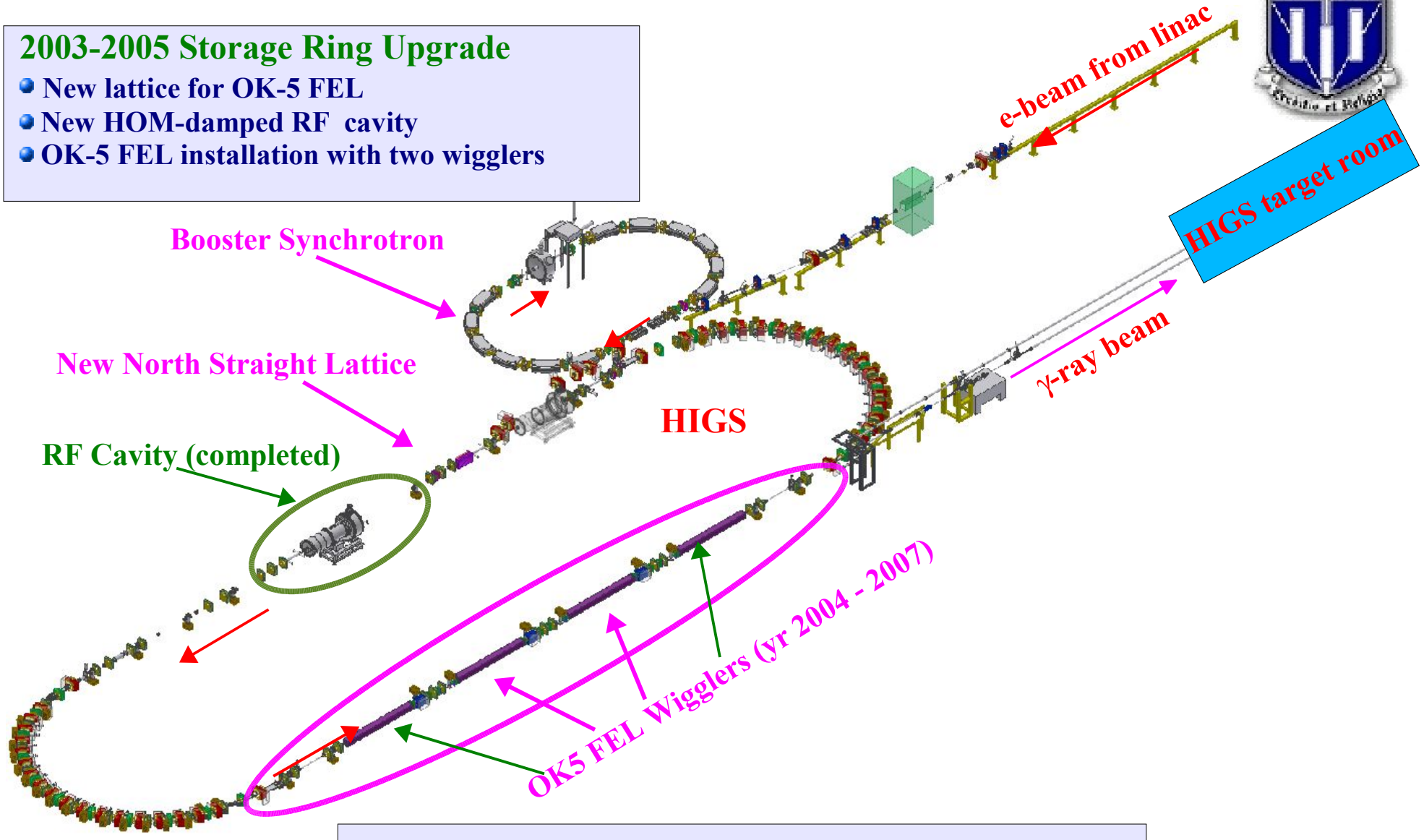
2003 – 2006 FEL Upgrade at Duke

New South Straight Lattice for FELs
HOM-damped RF System
New FELs with two OK-5 wigglers

DFELL Facility after Full Upgrades in 2006

2003-2005 Storage Ring Upgrade

- New lattice for OK-5 FEL
- New HOM-damped RF cavity
- OK-5 FEL installation with two wigglers

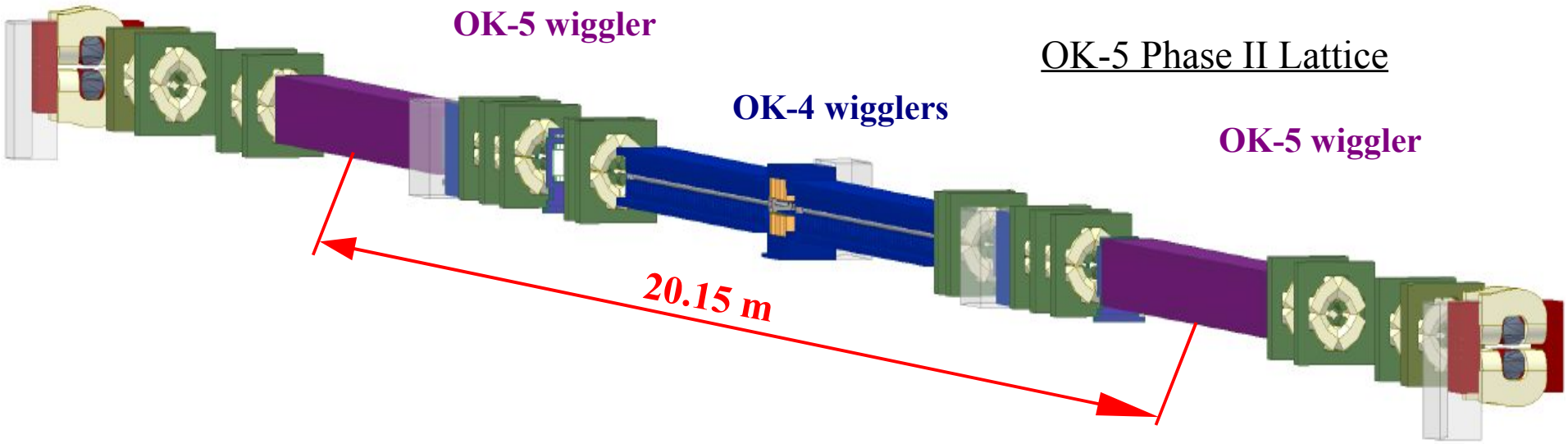


Fully Upgraded Facility (2006)

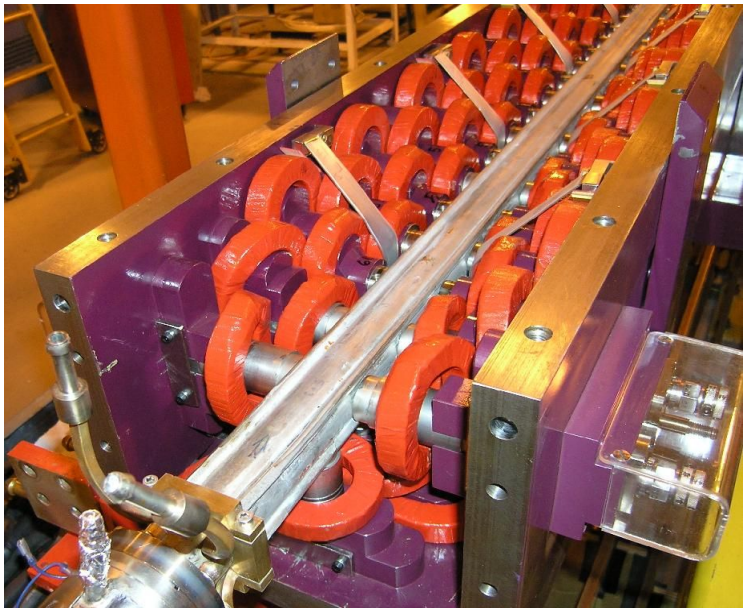
- Top-off injection, continuous gamma-ray operation
- Typical mode: 8-bunch, 20 mA/bunch

OK-5 Phase II Lattice Upgrade (2004-2005)

- Study dynamics impacts of OK-5 wigglers
- Retain OK-4 FEL as the user light source
- Commission main part of OK-5 magnetic optics
- Commission the OK-5 FEL with two wigglers
- Study operation of OK-4 and OK-5 together



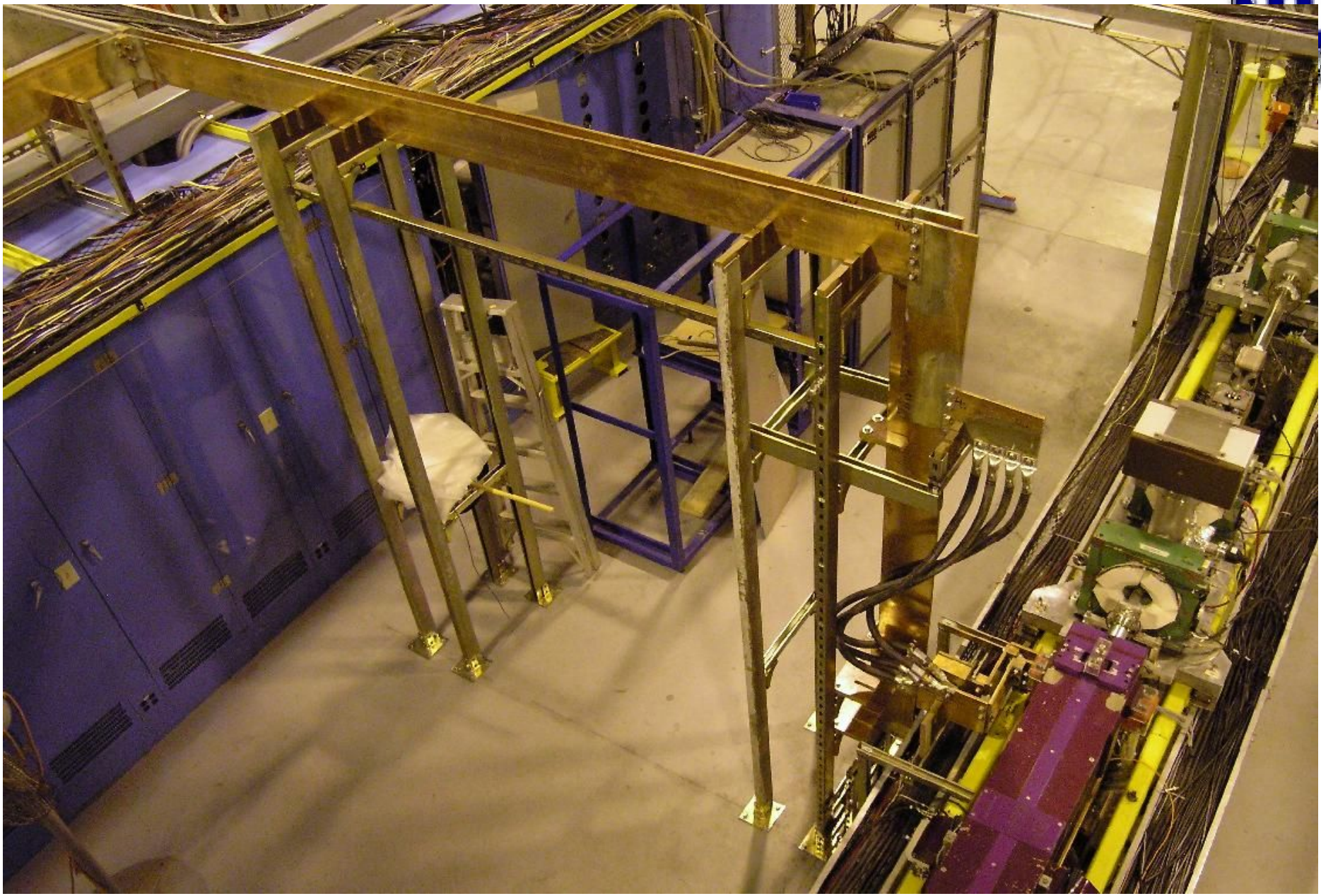
OK-5 Wiggler Installation



T-Rex Power Supplies for Wigglers (0-3000 A)

Wiggler Bussbars

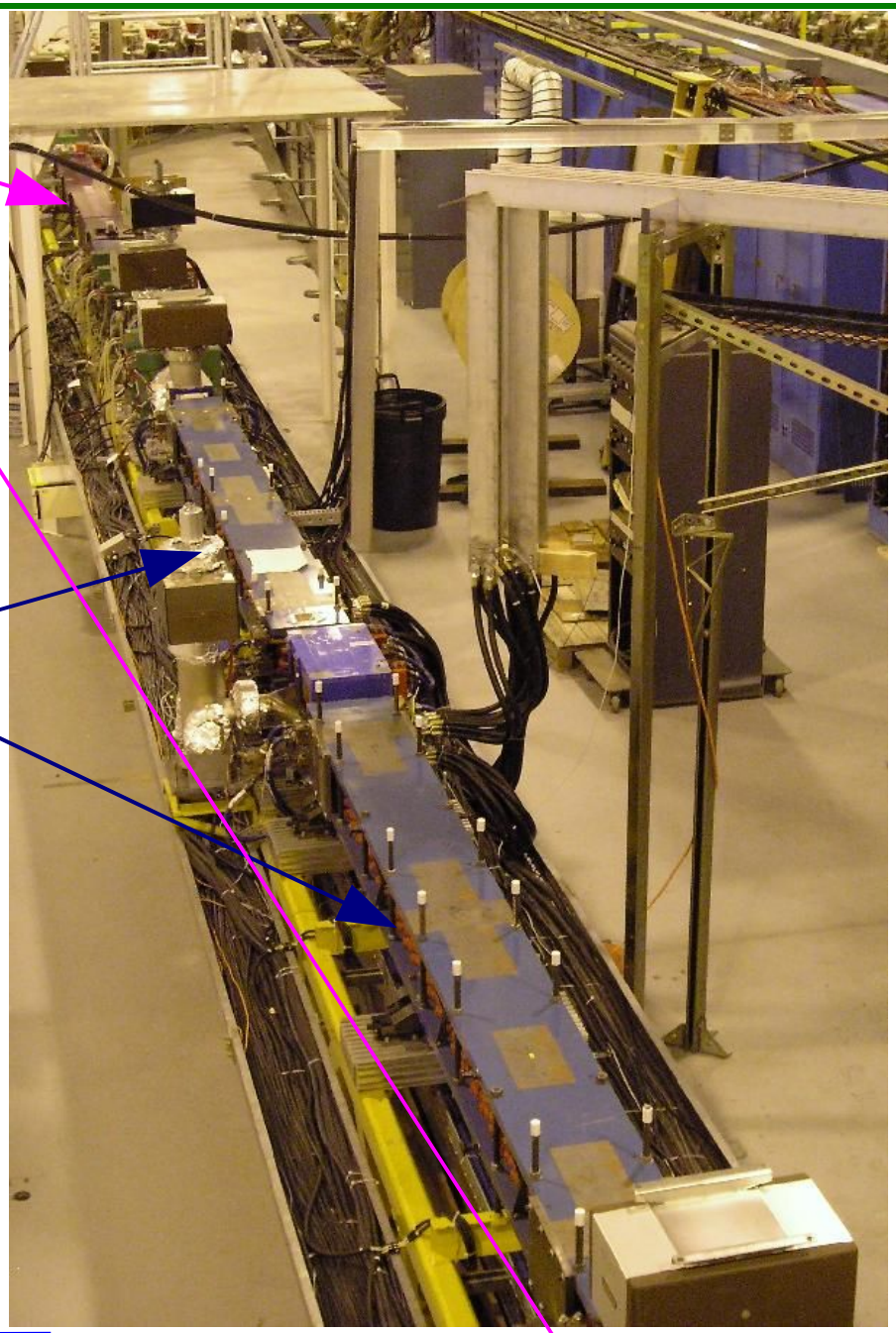
Bussbar System



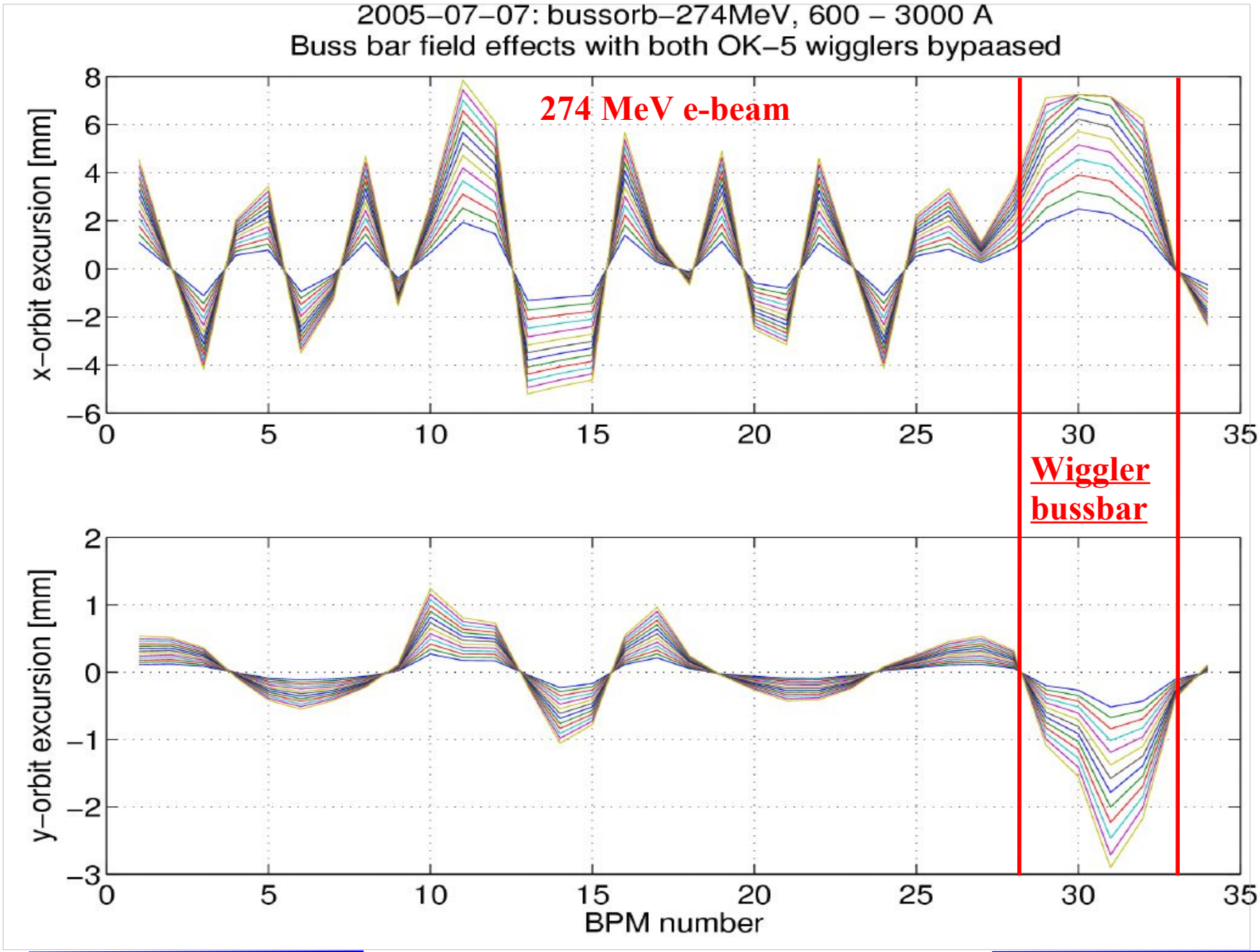
OK-5 and OK-4 FELs (Aug. 2005)

OK-5 wigglers

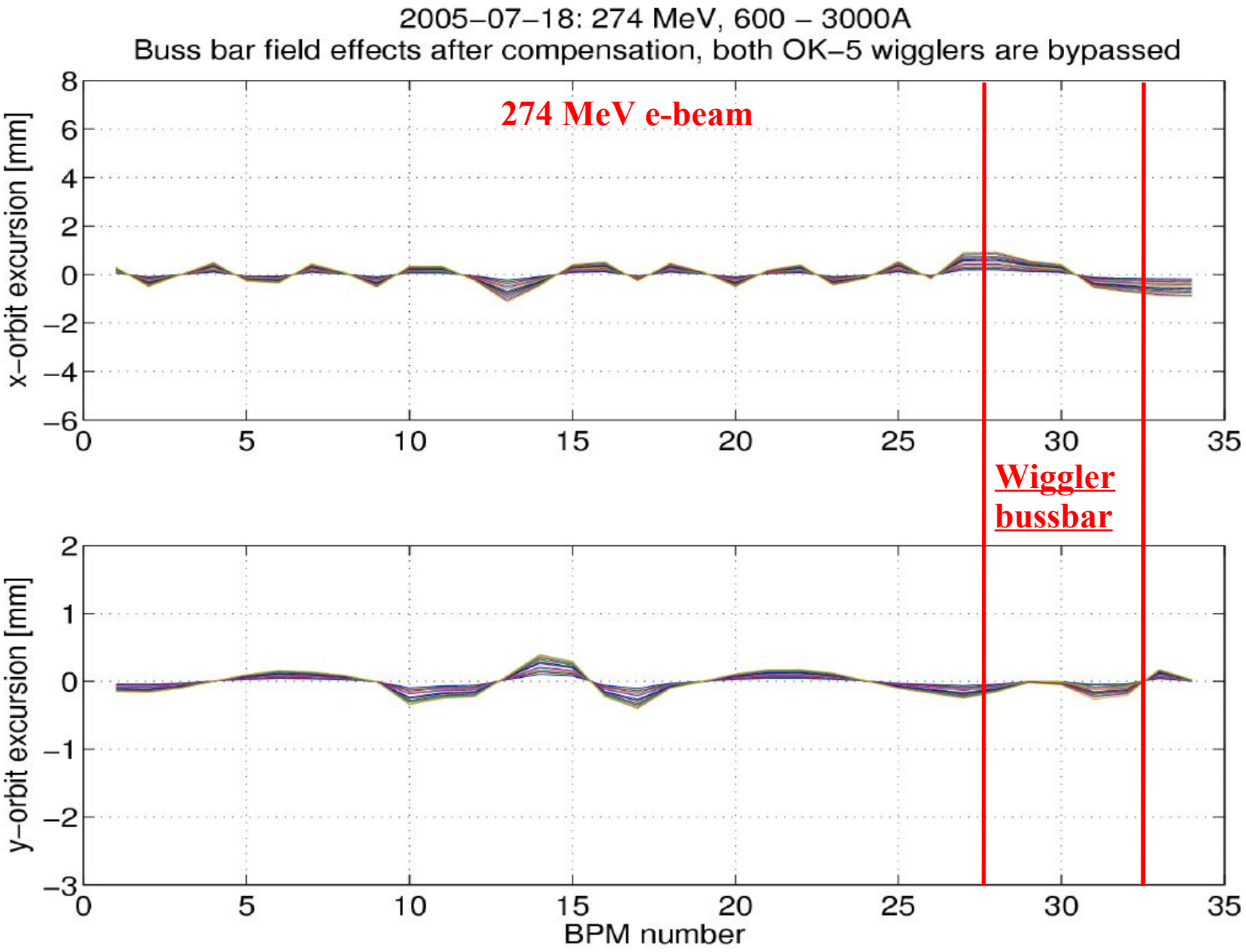
OK-4 wigglers



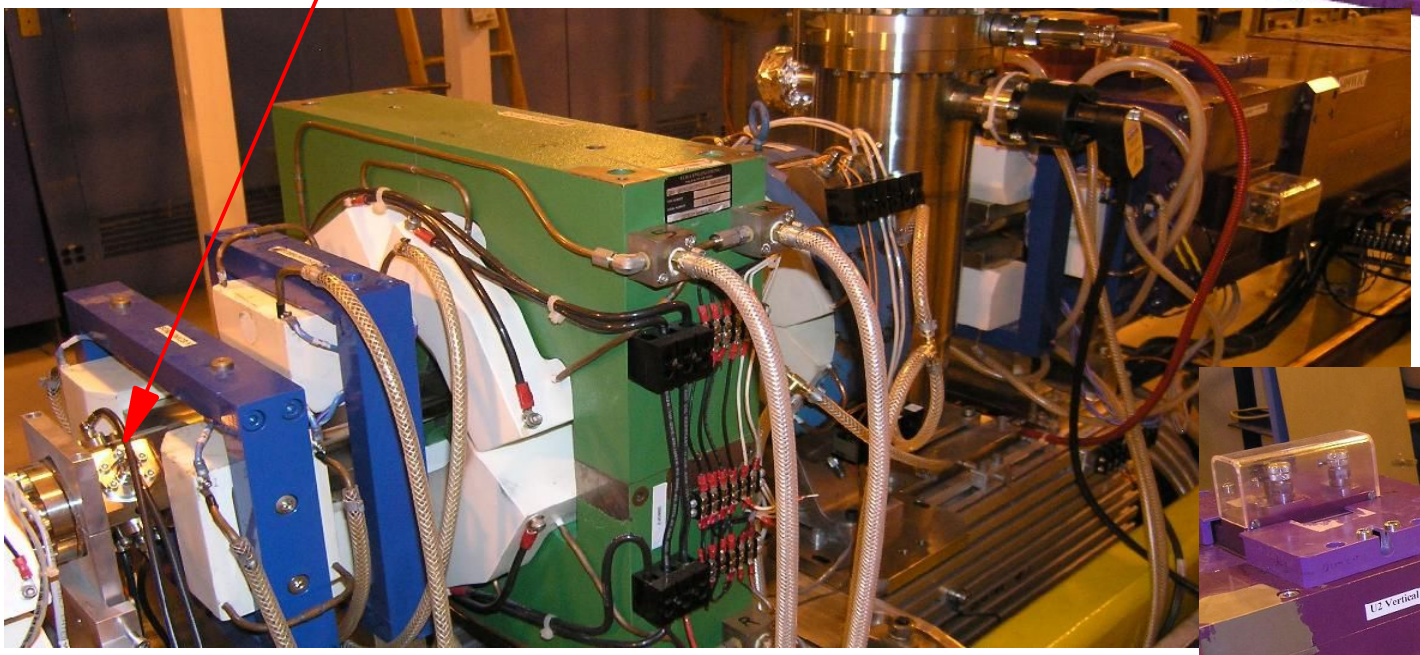
Bassbar Impact on Beam Orbit

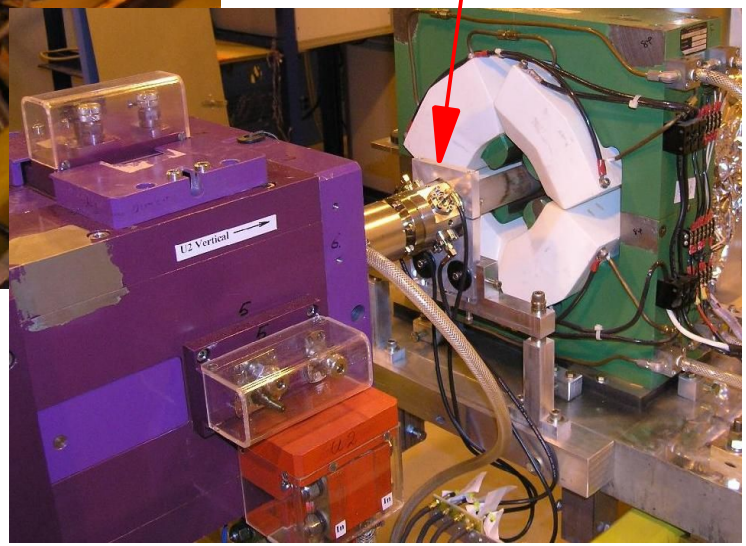


Bassbar Impact on Beam Orbit

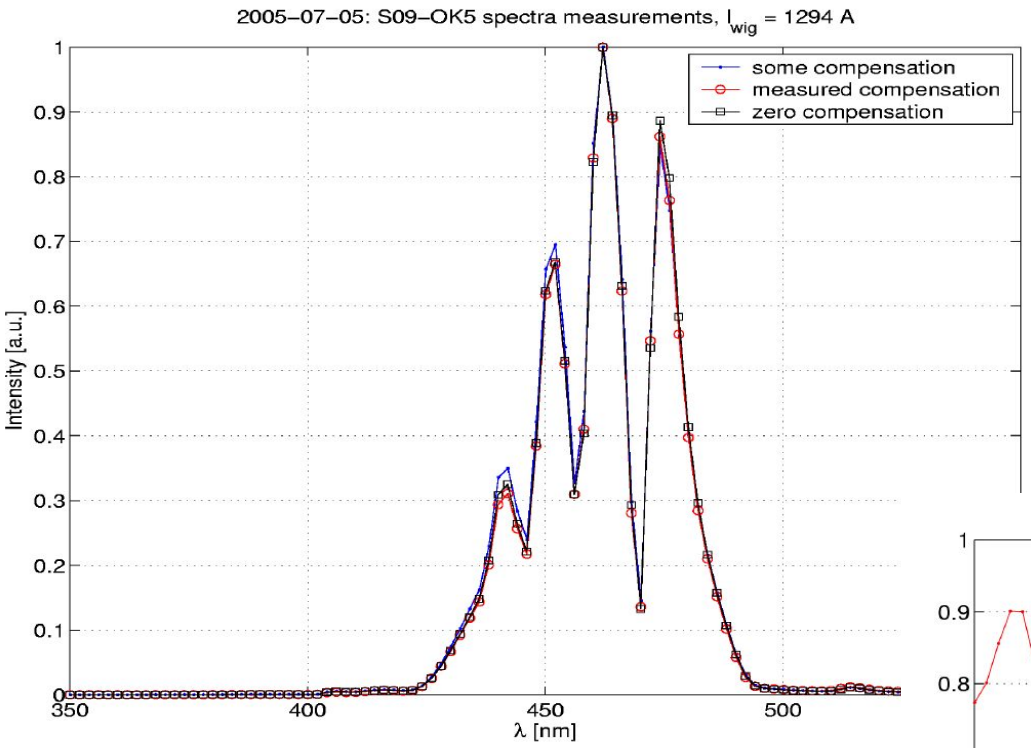


Limited Beam Diagnostics Capabilities



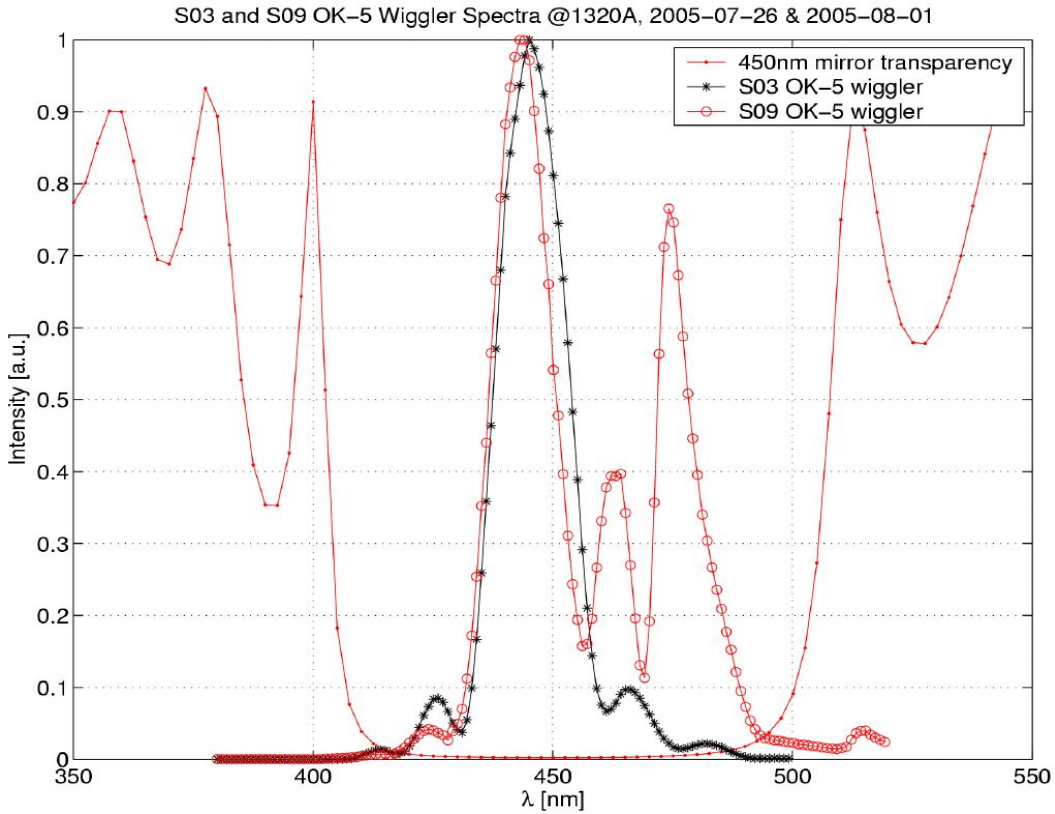


Spectra Improvement for OK-5 Wigglers (Horizontal Polarization)

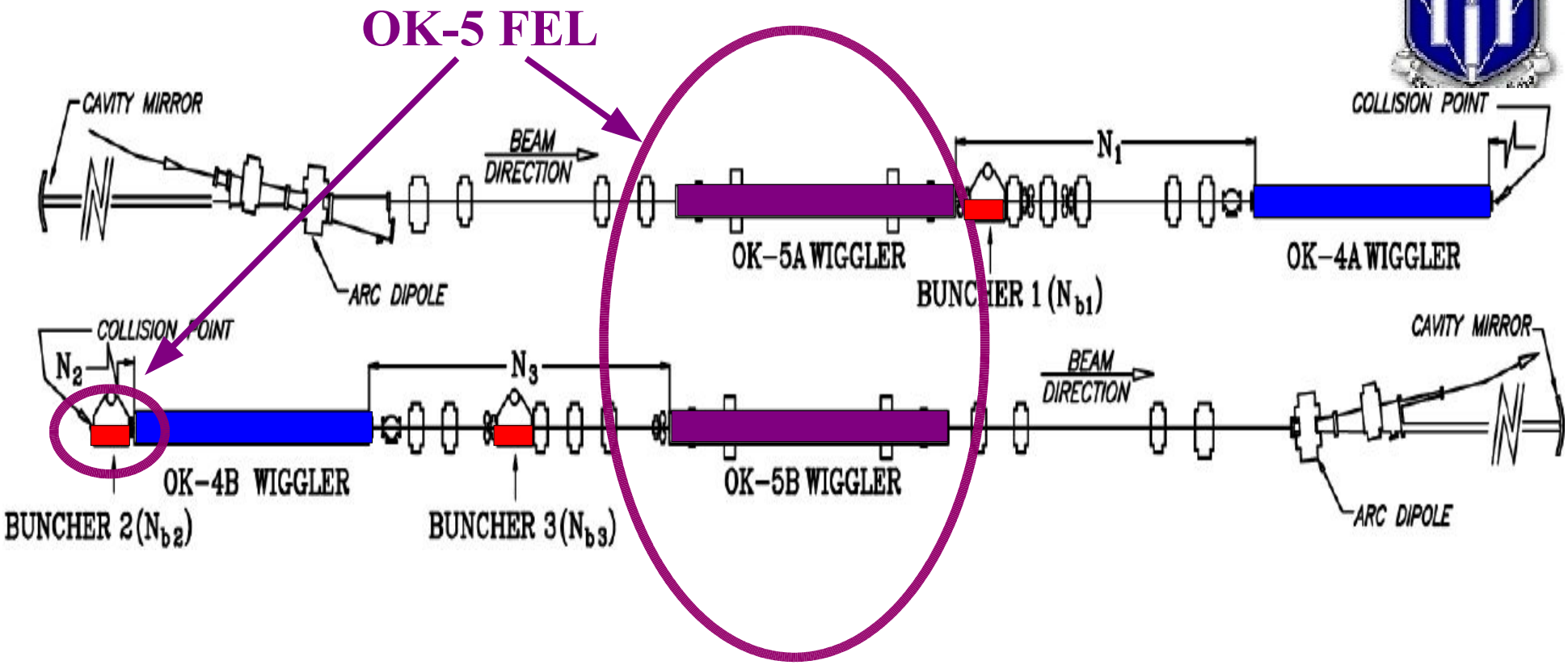


Before orbit correction:
Two wigglers together

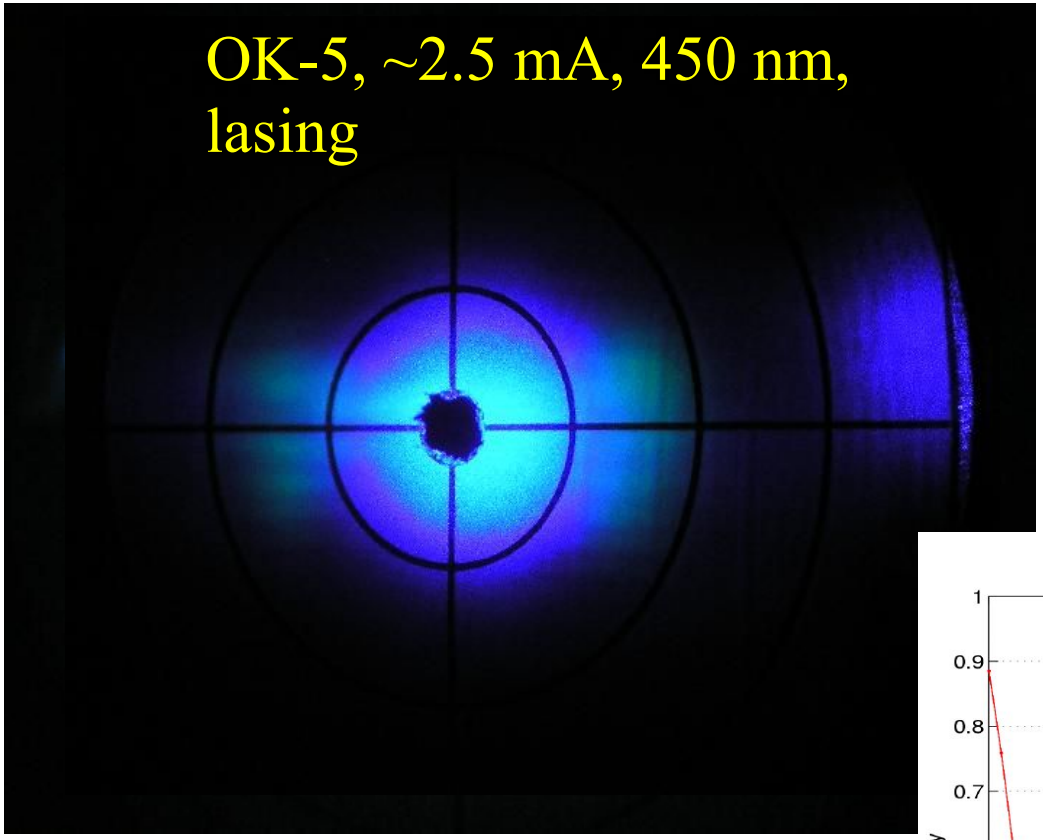
After orbit correction:
individual wigglers

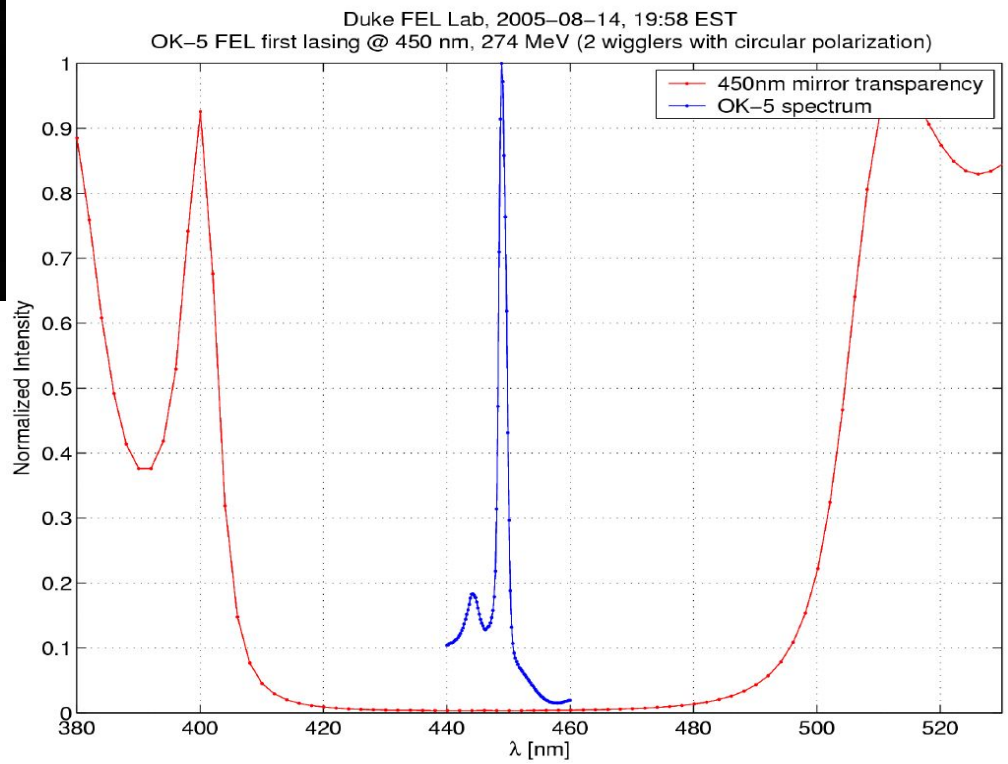


OK-5 FEL and DOK-1 FEL Layout



OK-5 FEL: No Lasing vs Lasing (450 MeV)

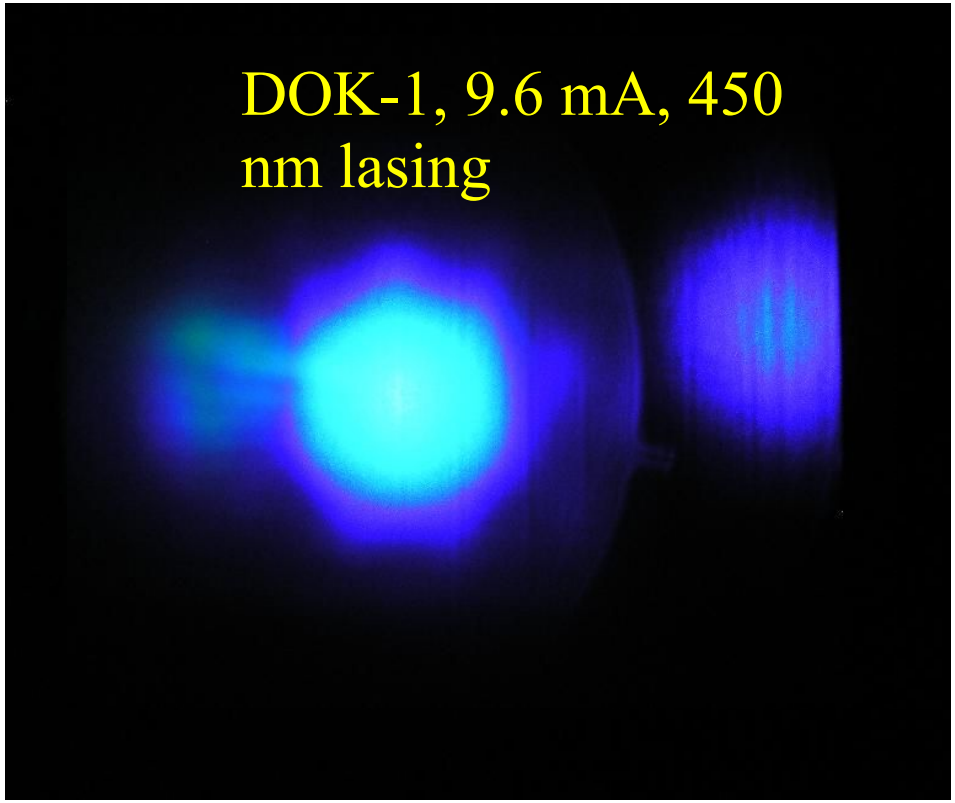


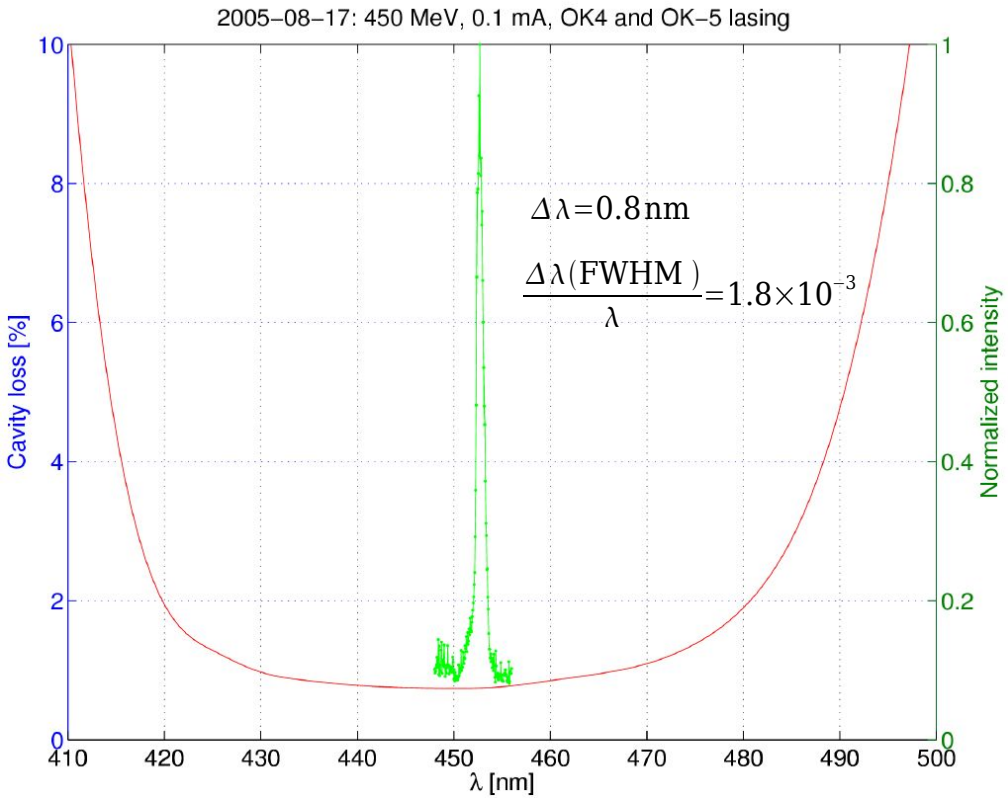


OK-5 FEL (Circular):

two helical wigglers, 20 m apart

DOK-1: No Lasing vs Lasing (450 MeV)





DOK-1 FEL (Mixed Polarization):

two circular (OK-5) wigglers

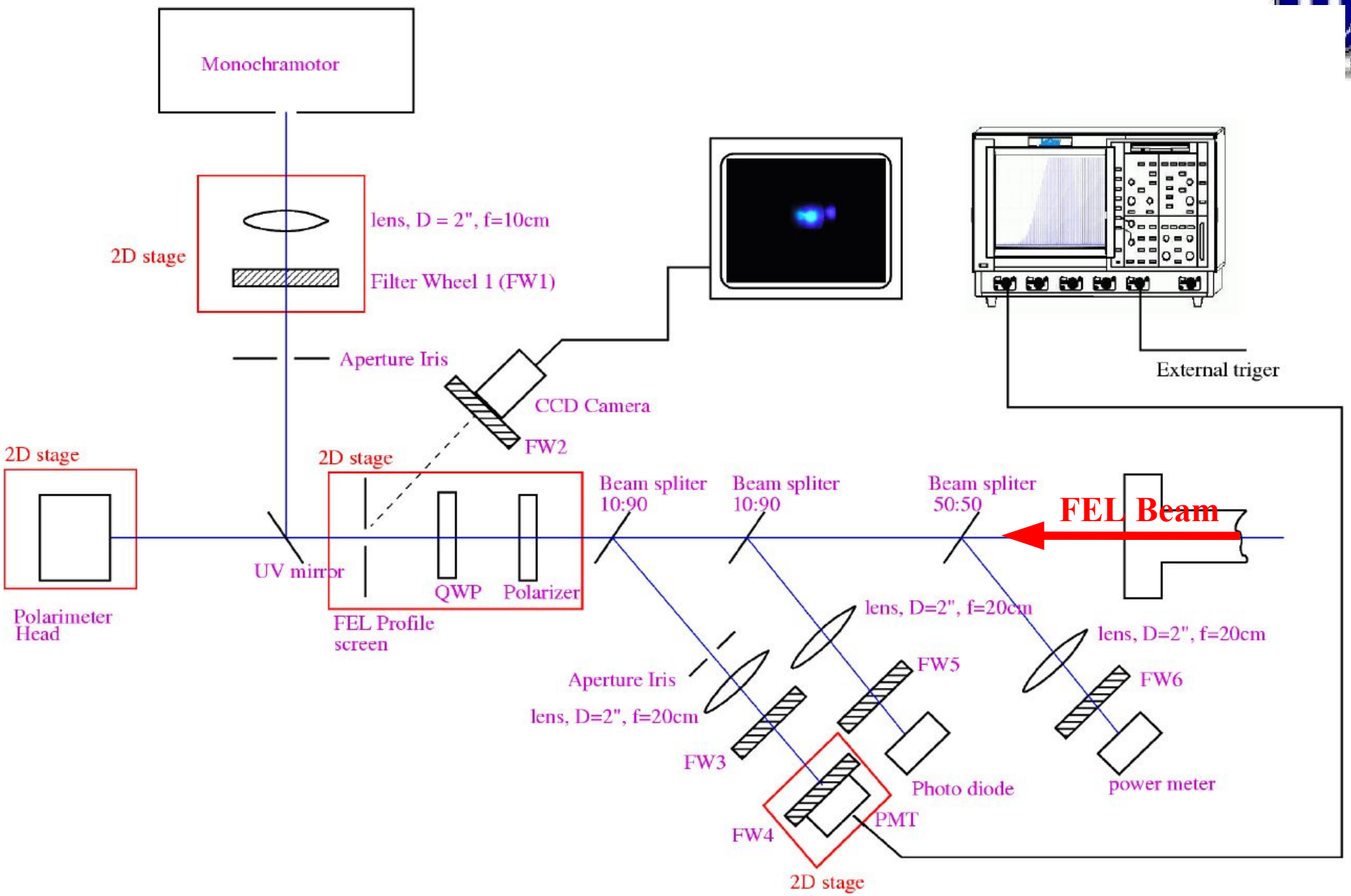
+

two horizontal (OK-4) wigglers

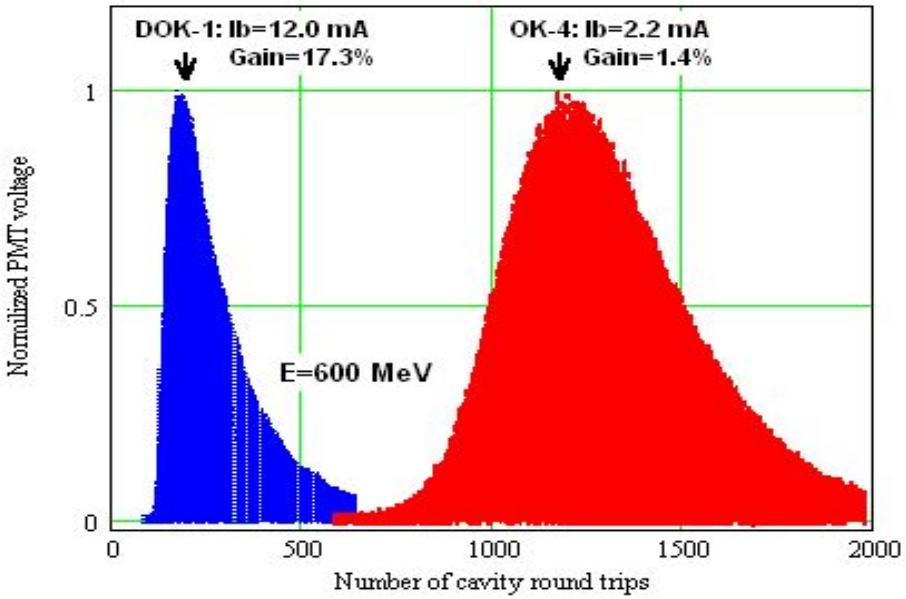
Recent DOK-1 FEL Measurements

High Gain Operation and Polarization Switch

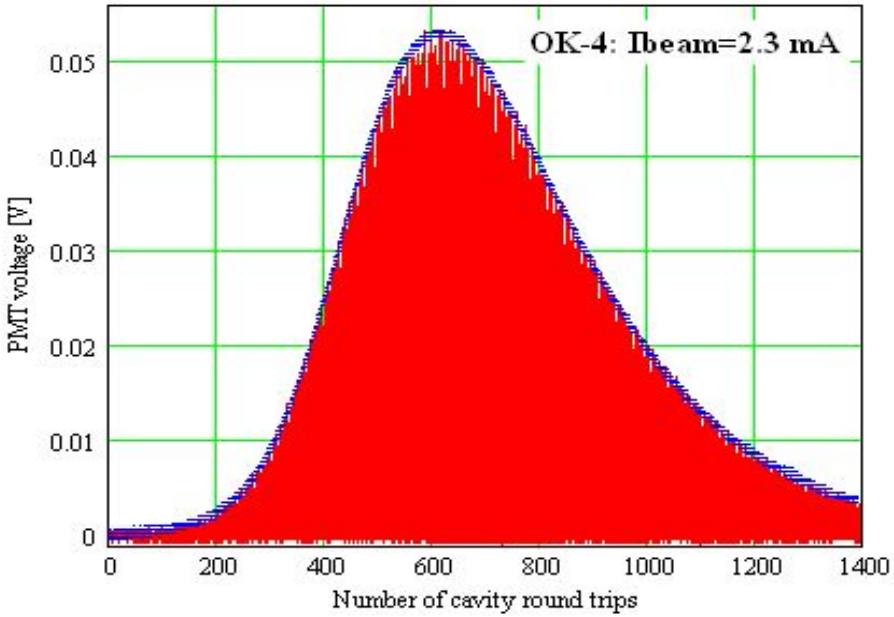
FEL Measurement Setup

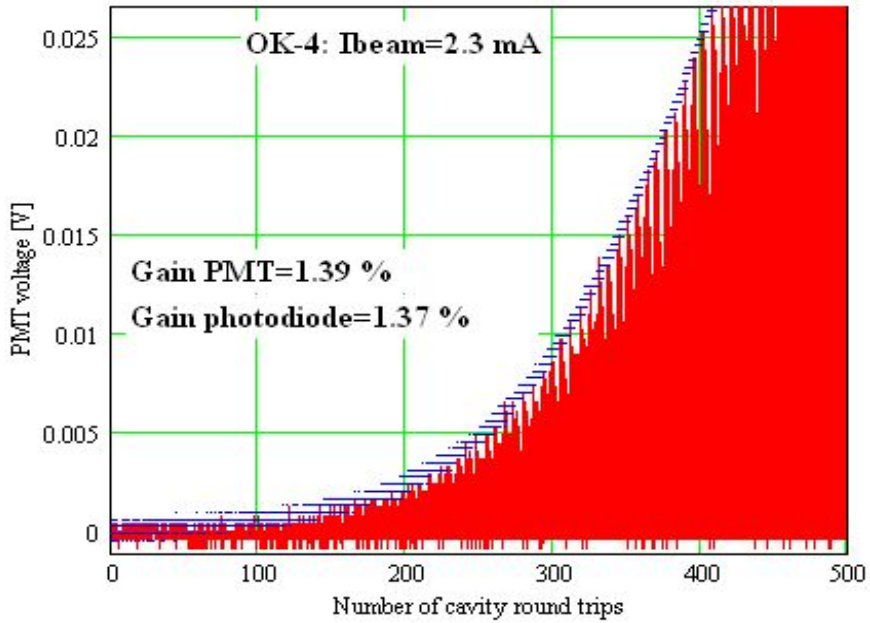


Giant Pulse Operation

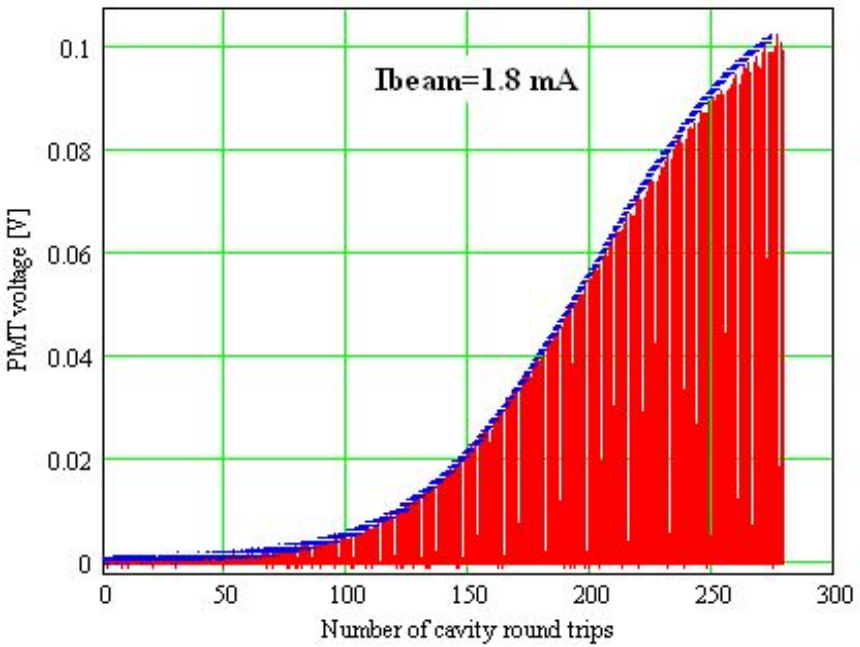


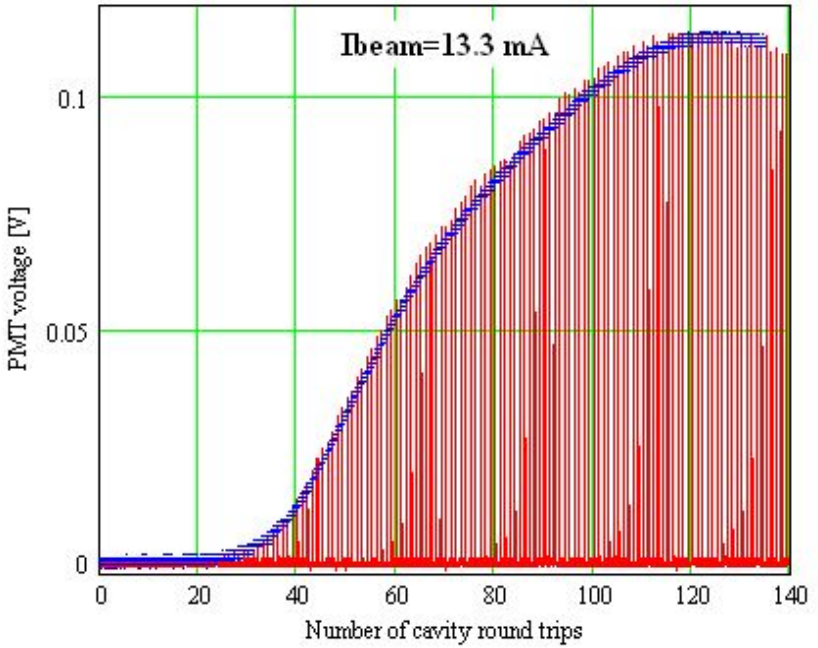
T= 0.36 μs

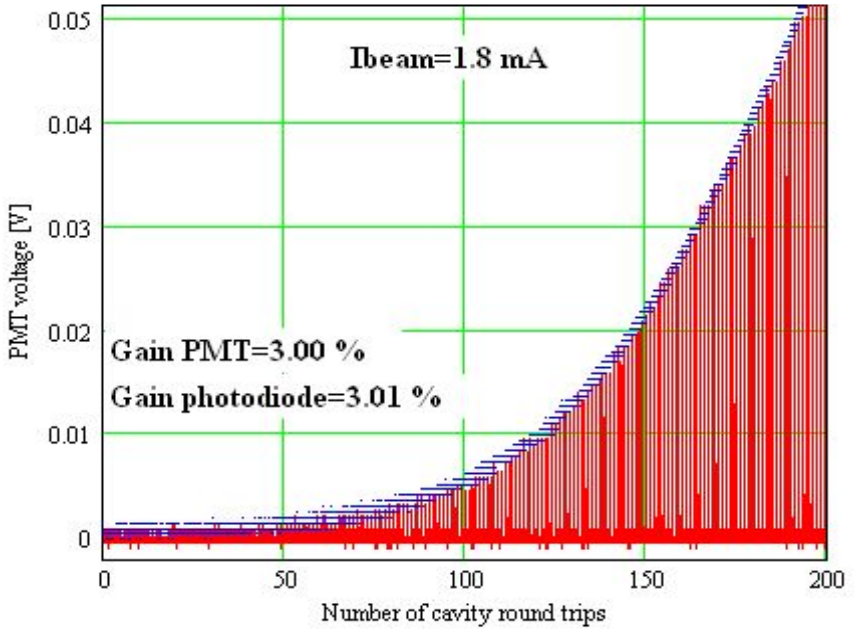


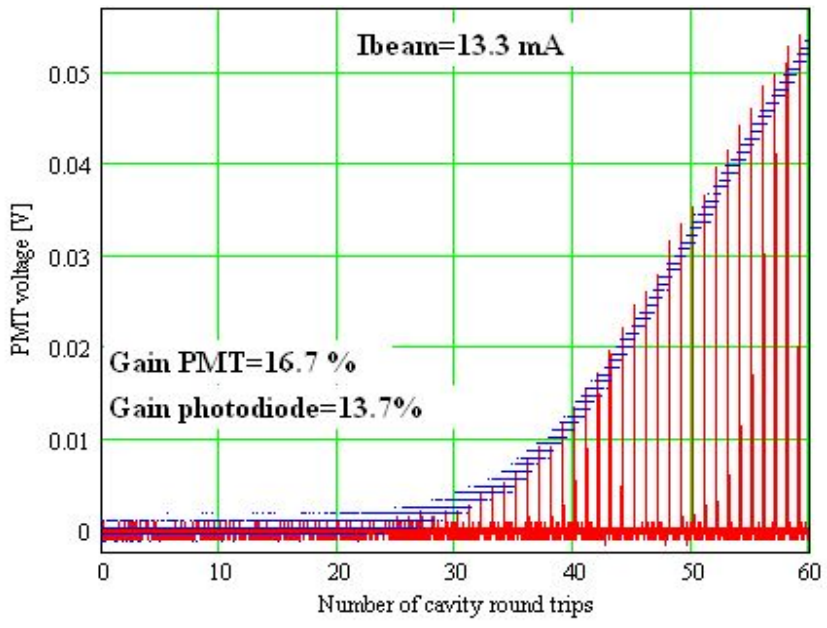


PMT vs Photo-diode

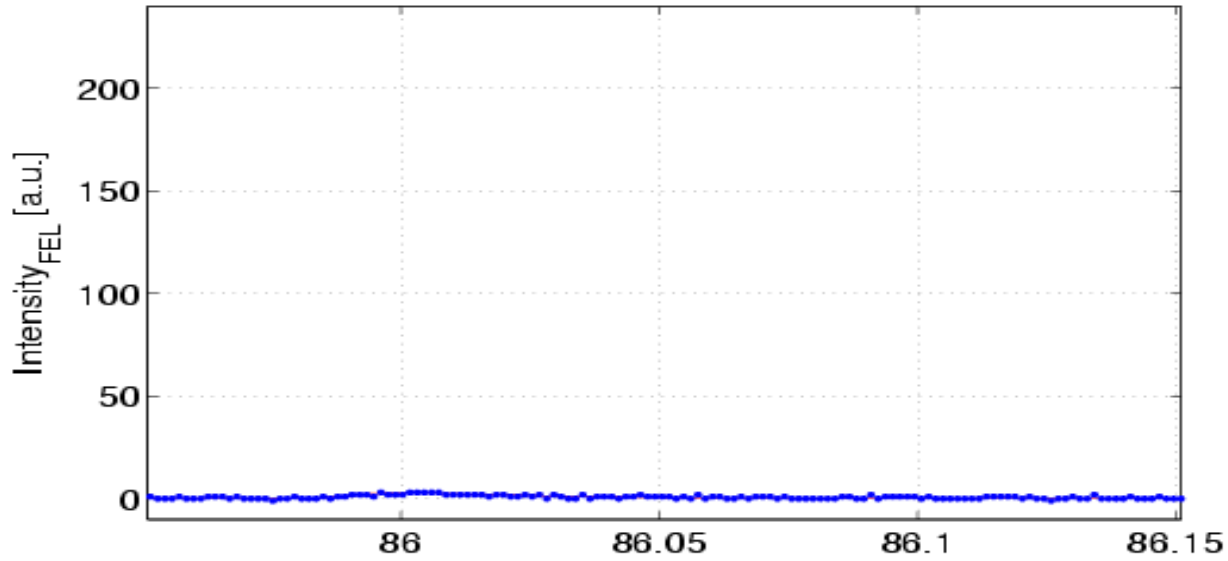


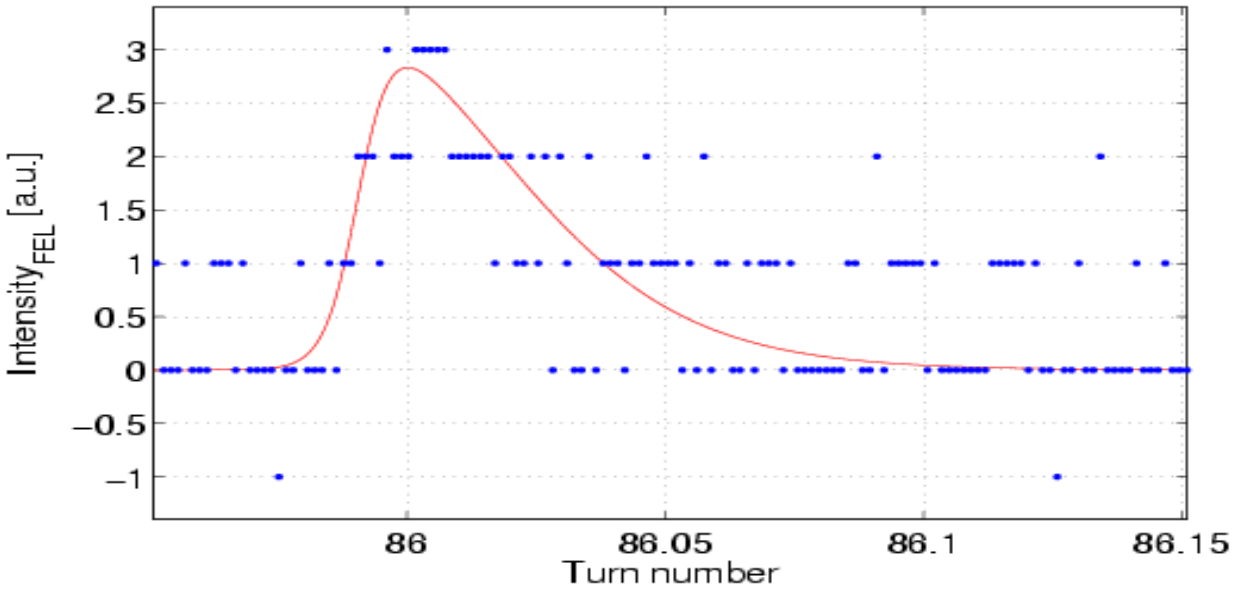






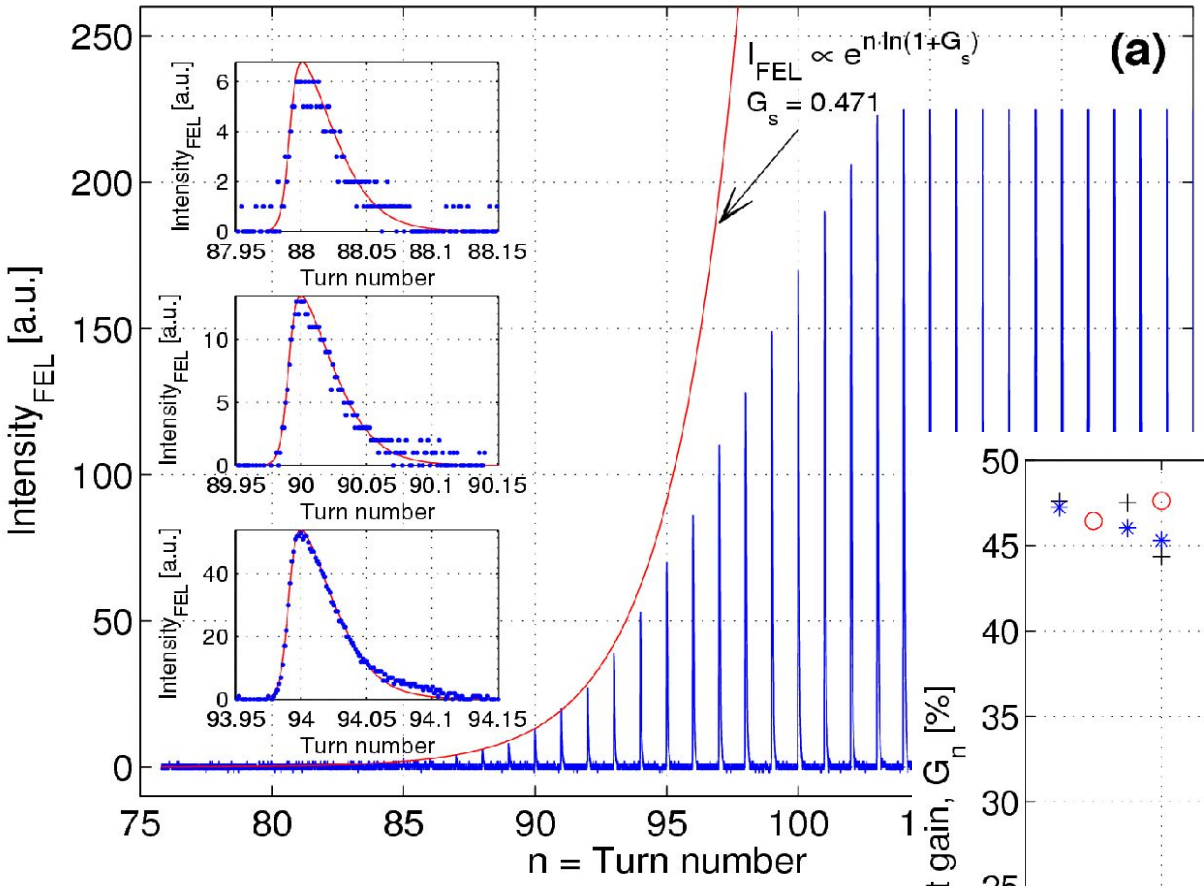
Evolution of a Macropulse



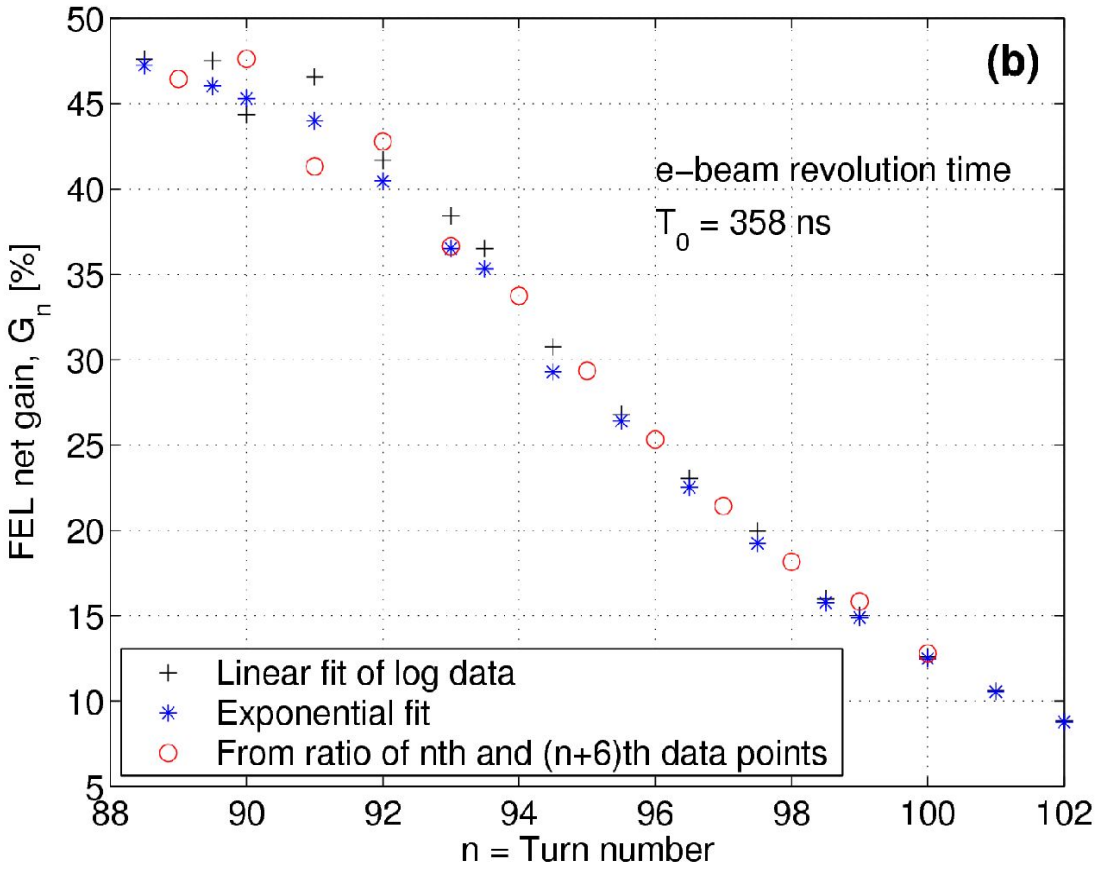


Gain-Switched Operation
Gain Modulator (*I. V. Pinayev)*

DOK-1 FEL Gain Measurement



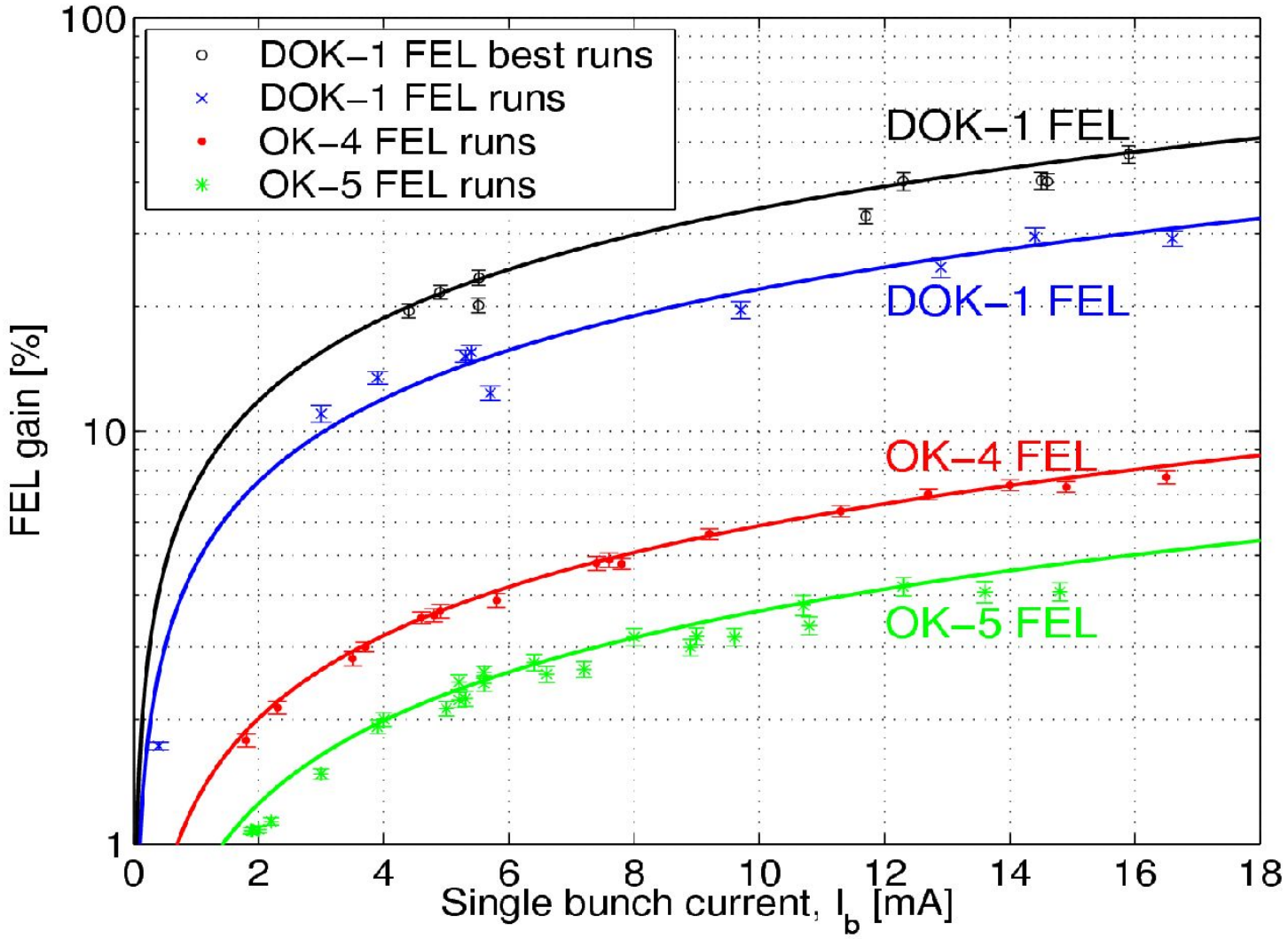
V. N. Litvinenko, *High gain distributed optical klystron*, NIMA 304, 1991



Max Gain: 47.8% (+/-2.7%)
with 16 mA of bunch current

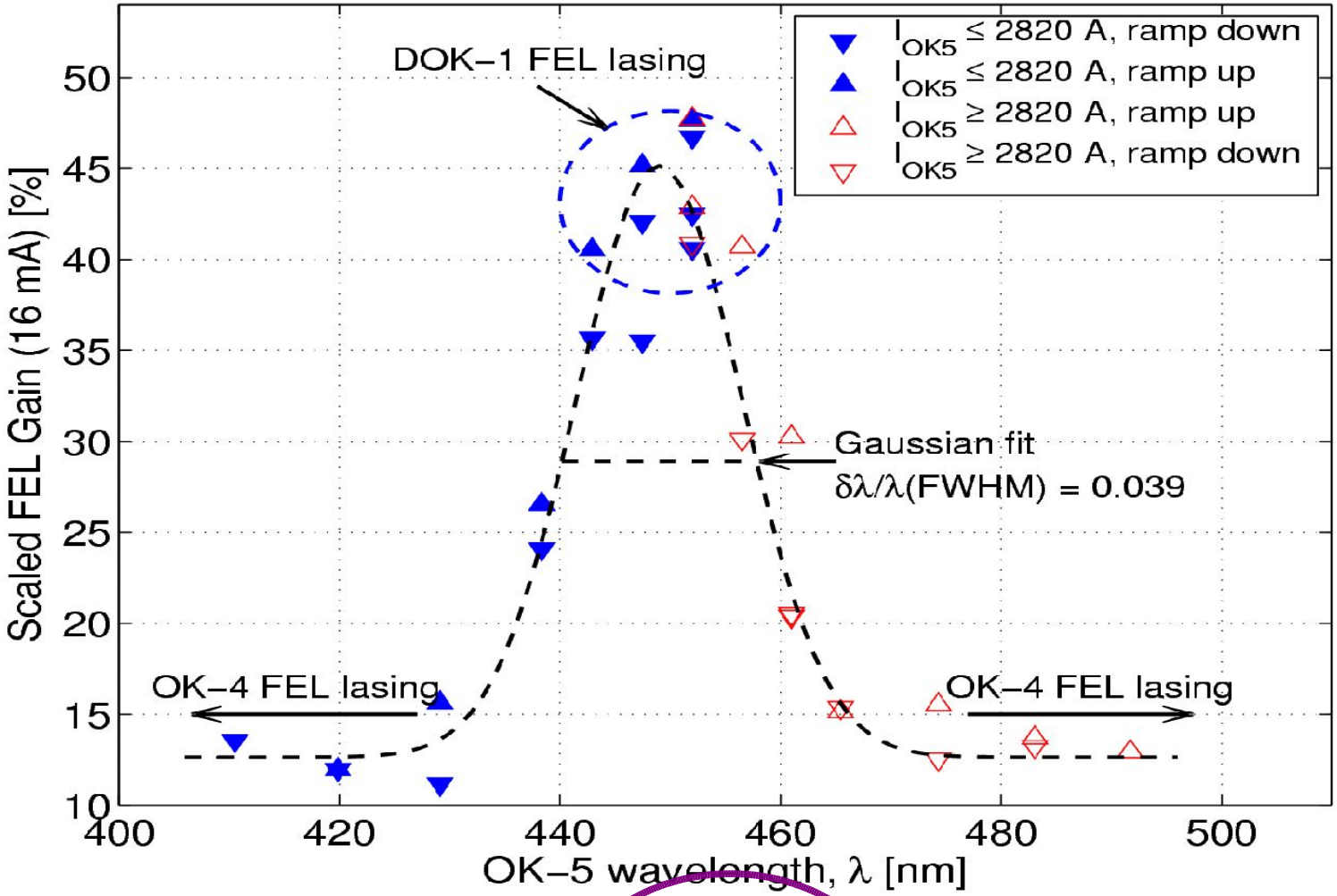
Peak current: ~29 A
Energy spread (σ_E/E): ~1.4e-3

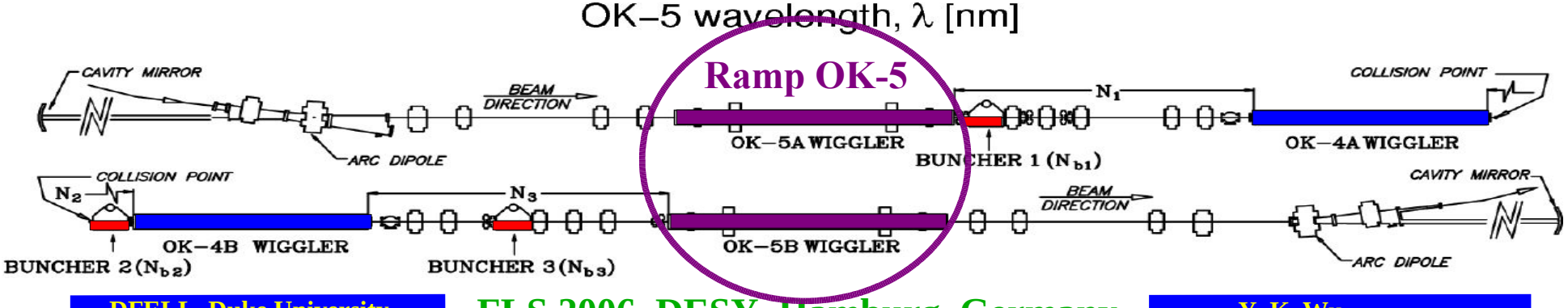
OK-4, OK-5, DOK-1 FEL Gain vs Current



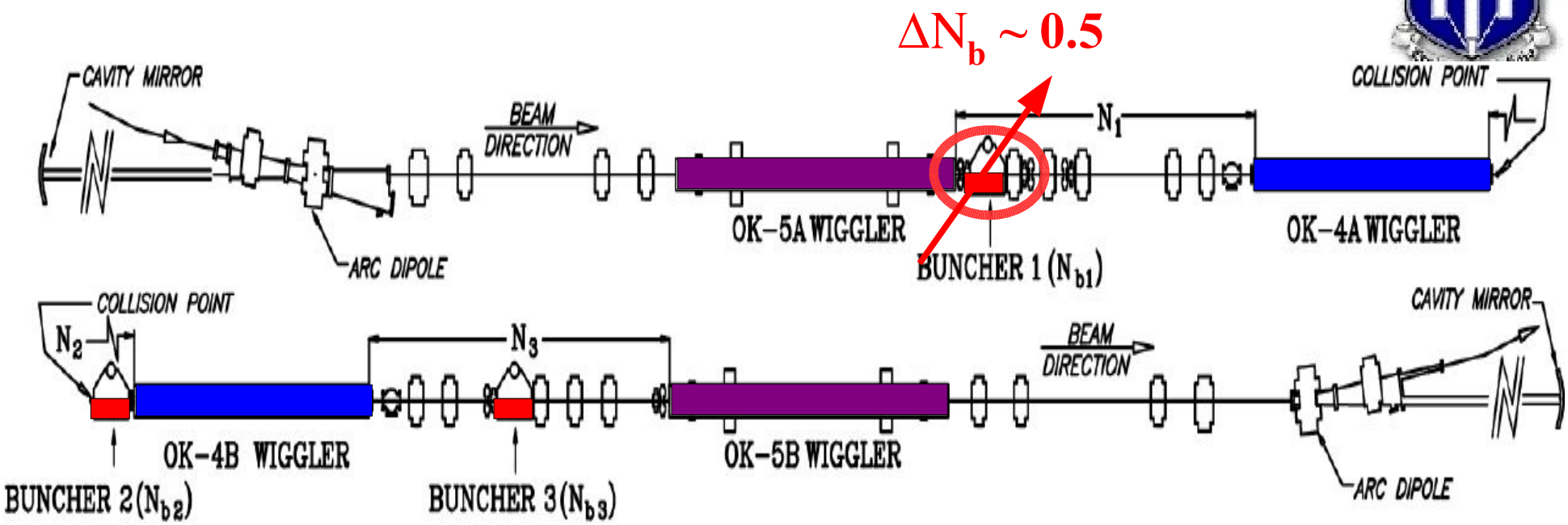
- **Microwave instability region: Gain ~ $I_b^{2/3}$**
- **DOK-1 gain ~2.2-2.3 times OK-4 gian + OK-5 gain**

DOK-1 FEL Detuning

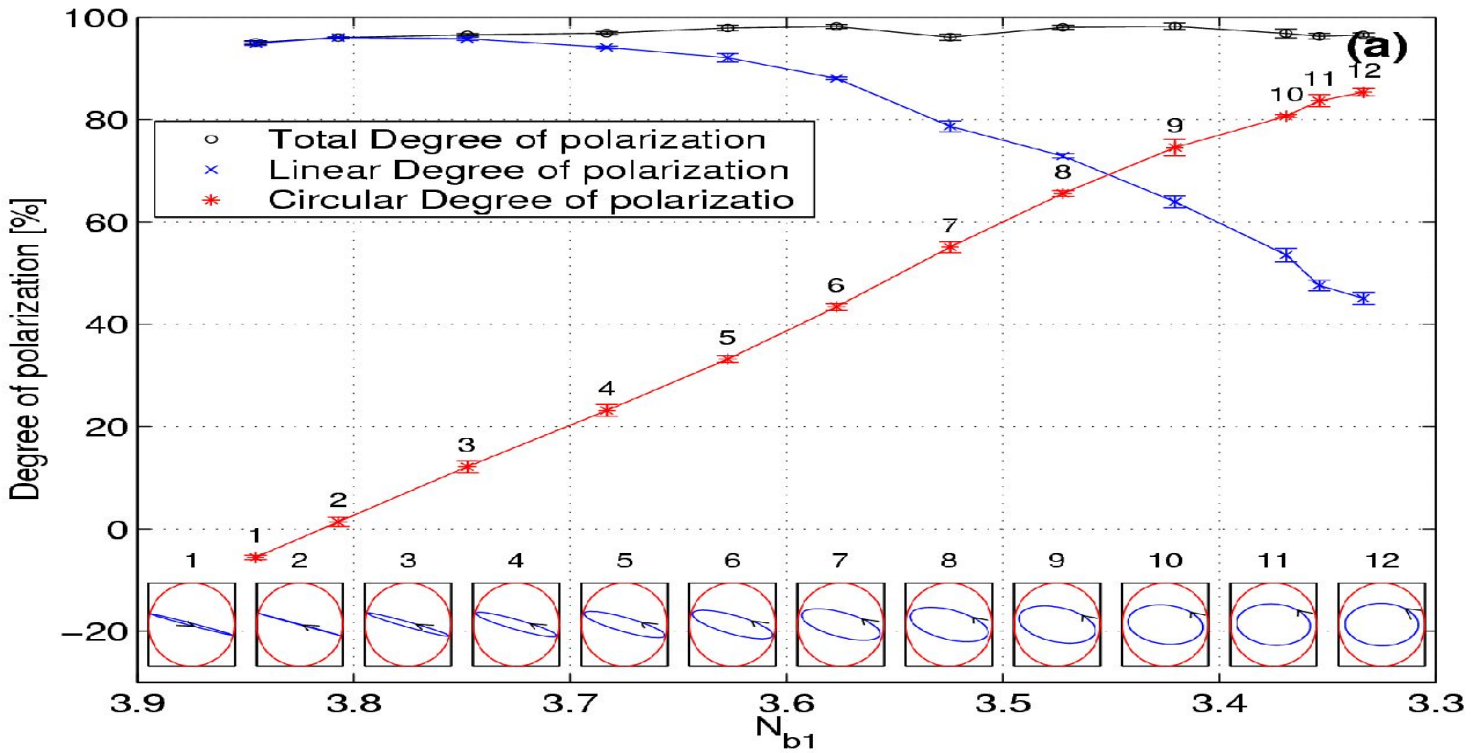




Switching FEL Polarization (One-Buncher Knob)

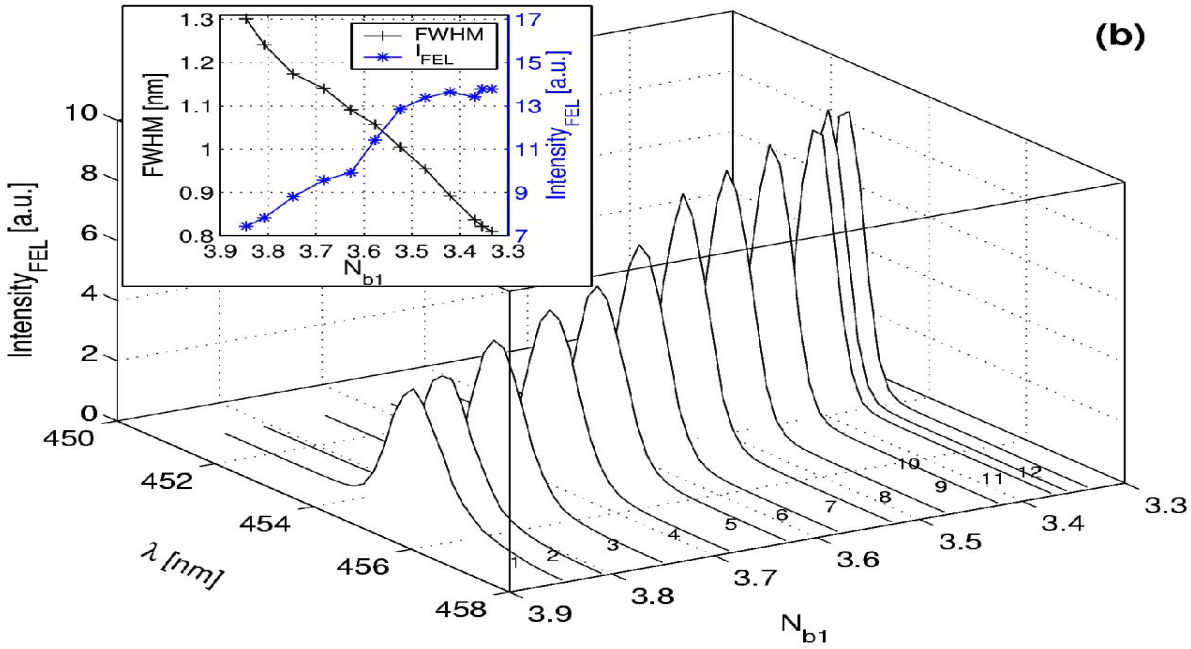


DOK-1 FEL Polarization Switch



- N_{b1} changes by 0.52 (from 3.85 to 3.33)

- Linear Pol: 95% to 45%
- Circular Pol: -6% to 85%
- Wavelength, λ, 455 to 453 nm
- Δλ, 1.30 nm to 0.81 nm
- Power increased by a factor of two



Kwang-Je Kim, *Circular polarization with crossed-planar undulators in high-gain FELs*, NIMA 445, 2000

Summary

- **Challenges for Duke FELs**
  - Dynamics degradation due to OK-5 wigglers (reduced lifetime)
  - Full control of multiple collision points for gamma production
  - Mirror damages due to radiation
  - Improving the FEL power for user operation
- **Key thrusts for DOK FELs in the near future**
  - VUV operation between 150 and 200 nm

(For DOK1 FEL, 20-30% gain expected for 150 nm with I_b =40-50 mA)

  - Fast polarization switches

Horizontal + Vertical -> Circular; Left + Right -> Linear

  - Multi-color operation: coherent harmonics in EUV