ODR Imaging of ILC Lepton Beams

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OUTLINE

- Introduction
- Optical Diffraction Radiation (ODR) as a nonintercepting (NI) beam-size monitor.
- Optical Diffraction Radiation Experimental Results
- Potential applications of ODR to ILC-TA and ILC
- Summary

Strategy (We can extend this to ODR.)

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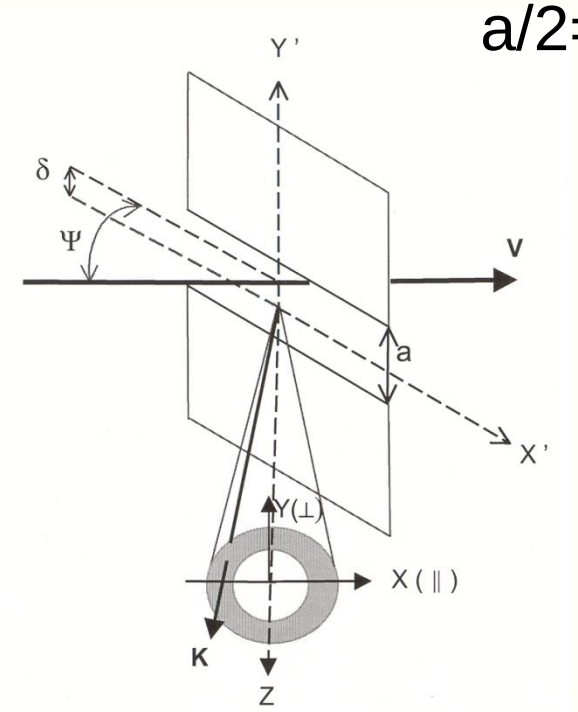
Convert particle-beam information to optical radiation and take advantage of imaging technology, video digitizers, and image processing programs. Some reasons for using OTR/ODR are listed below:

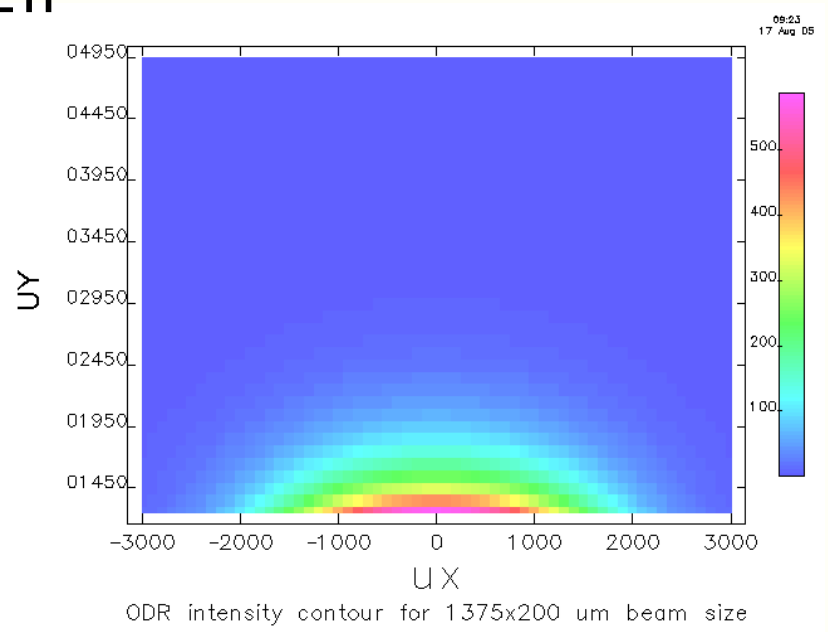
- The charged-particle beam will transit/pass nearby thin metal foils to minimize/eliminate beam scattering and Bremsstrahlung production.
- These techniques provide information on
  - Transverse position
  - Transverse profile
  - Divergence and beam trajectory angle

ODR is a Potential Nonintercepting Diagnostic for GeV Lepton Beams and TeV Hadron Beams

- At left, schematic of ODR generated from two vertical planes (based on Fig.1 of Fiorito and Rule, NIM B173, 67 (2001). We started with a single plane.
- At right, calculation of the ODR light generated by a 7-GeV electron beam for *d* =1.25 mm in the optical near field based on a new model (Rule and Lumpkin).

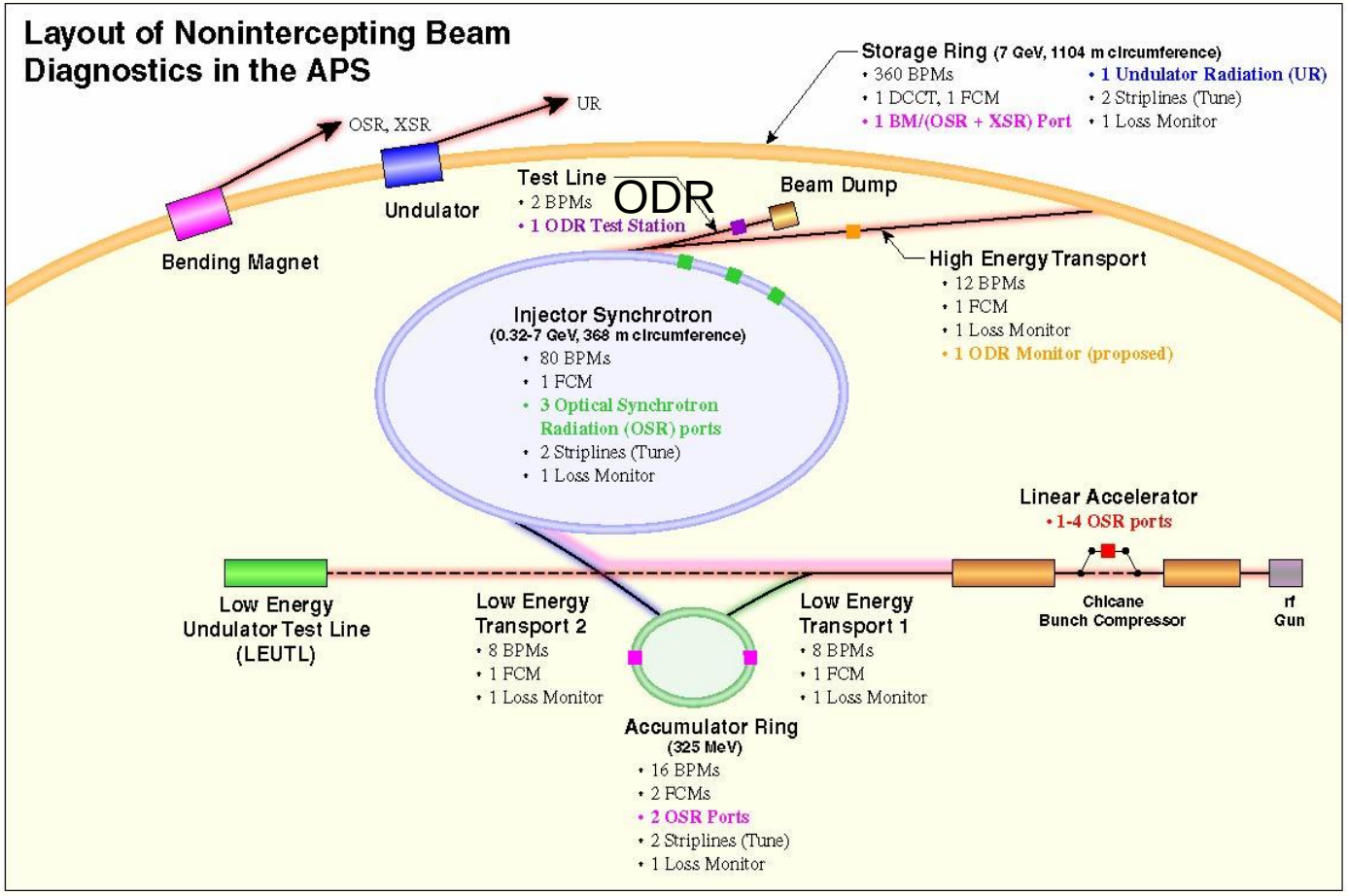
$$a/2=d\sim\gamma\lambda/2\pi$$





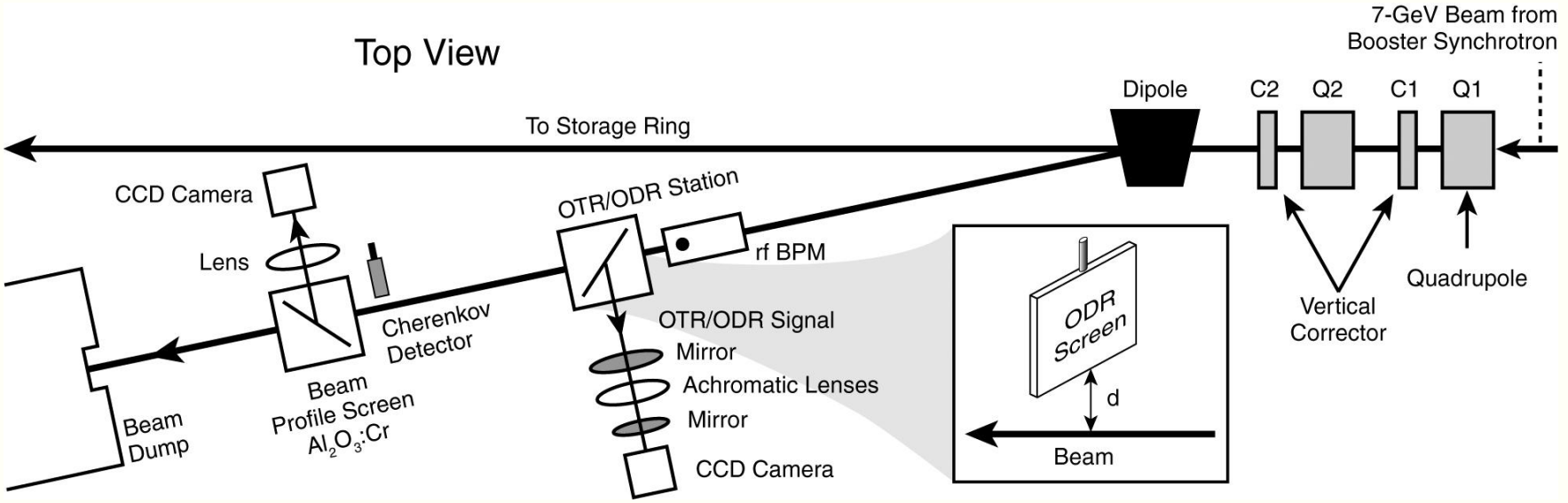
The APS Facility Has Provided Sources for Developing Time-Resolved, NI Diagnostics

- **Beam Energies from 50 MeV to 7 GeV are available for tests.**



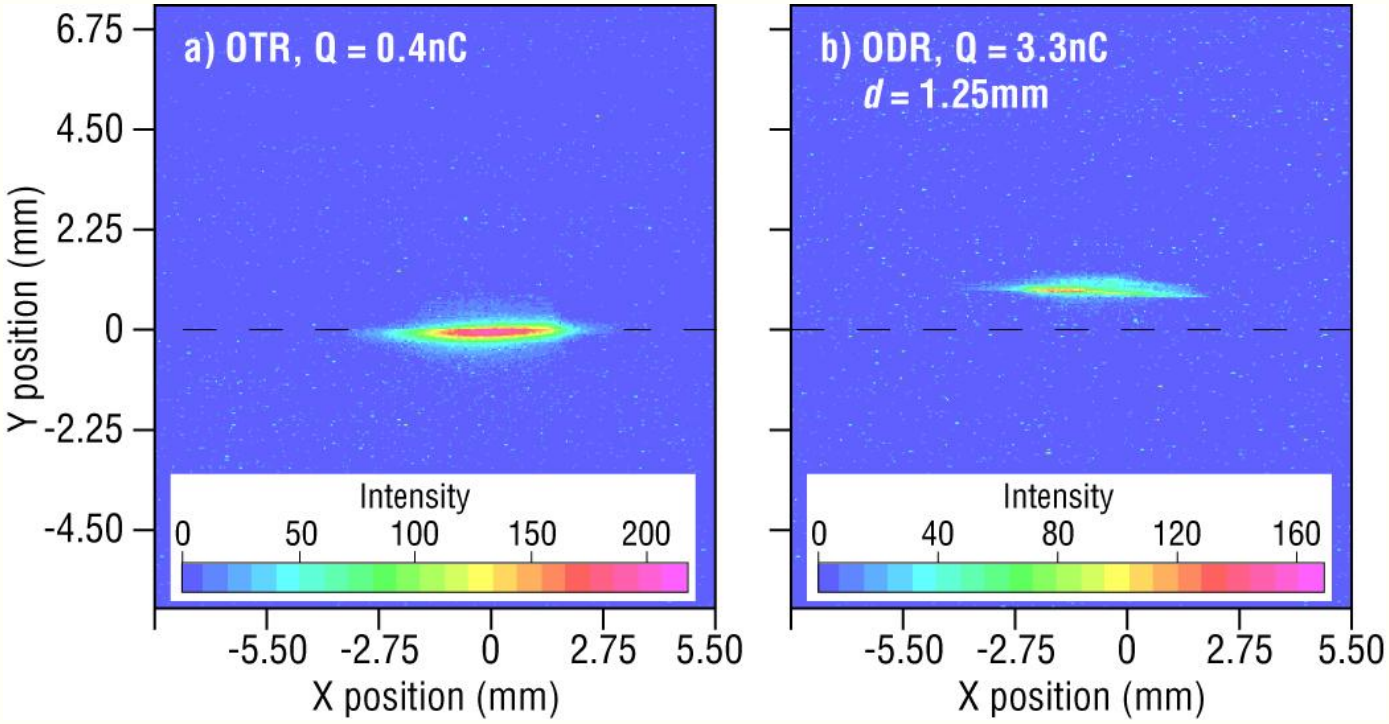
Schematic of the OTR/ODR Test Station on BTX Line at APS

- **Test station includes the rf BPM, metal blade with stepper motor control, imaging system, Cherenkov Detector, and downstream beam profile screen. The dipole is 5.8 m upstream of the ODR converter screen.**



Investigations of Optical Diffraction Radiation on 7-GeV Beams at APS are Relevant to CEBAF Beams

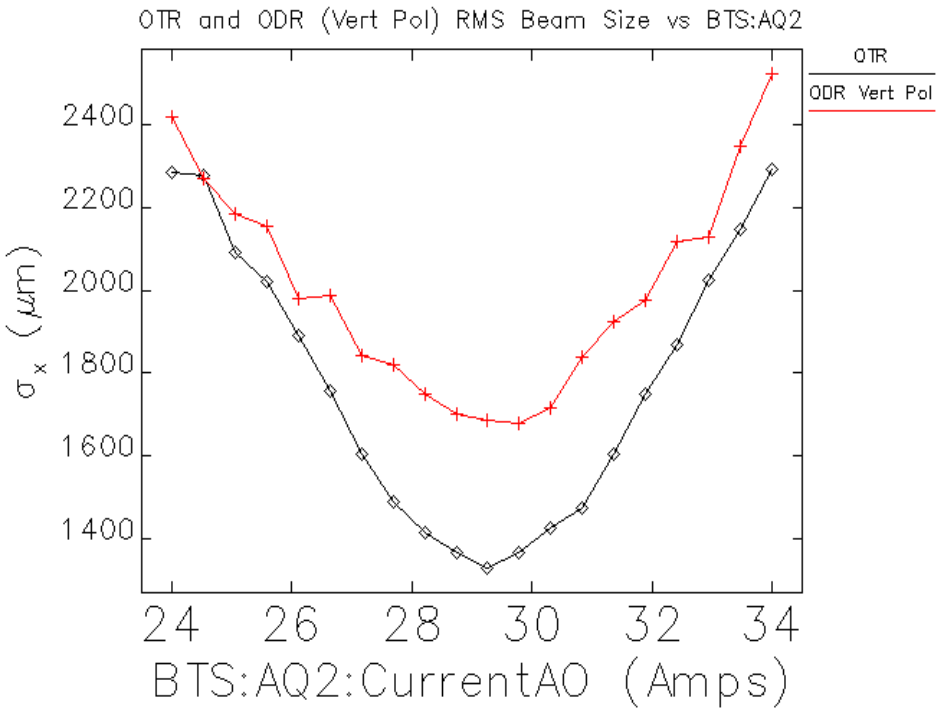
- **ODR offers the potential for nonintercepting, relative beam-size monitoring with near-field imaging. This is an alternate paradigm to far-field work at KEK.**

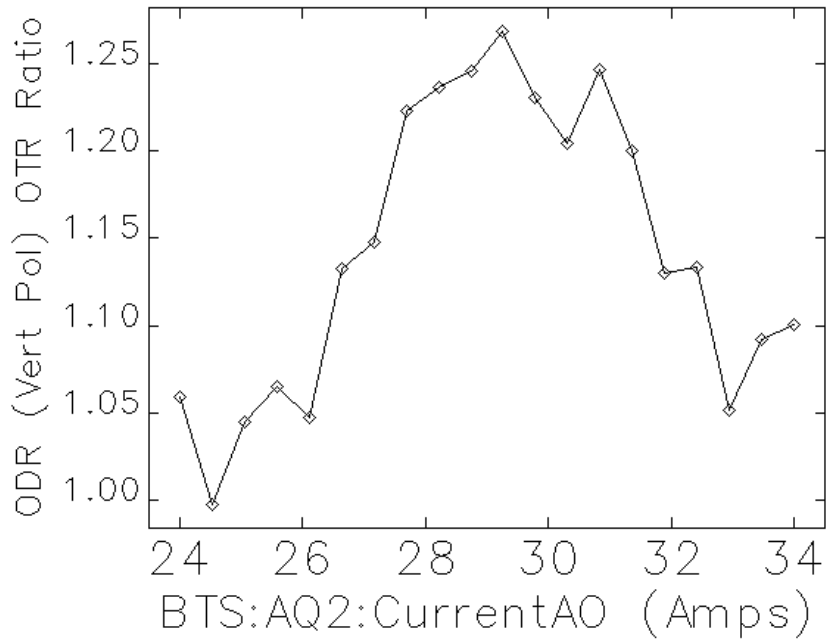


Lumpkin et al., Phys. Rev. ST-AB, Feb. 2007

Perpendicular ODR Polarization Component Gives More Direct Representation of Beam Size.

- **Quadrupole current scan provides beam-size scan.**

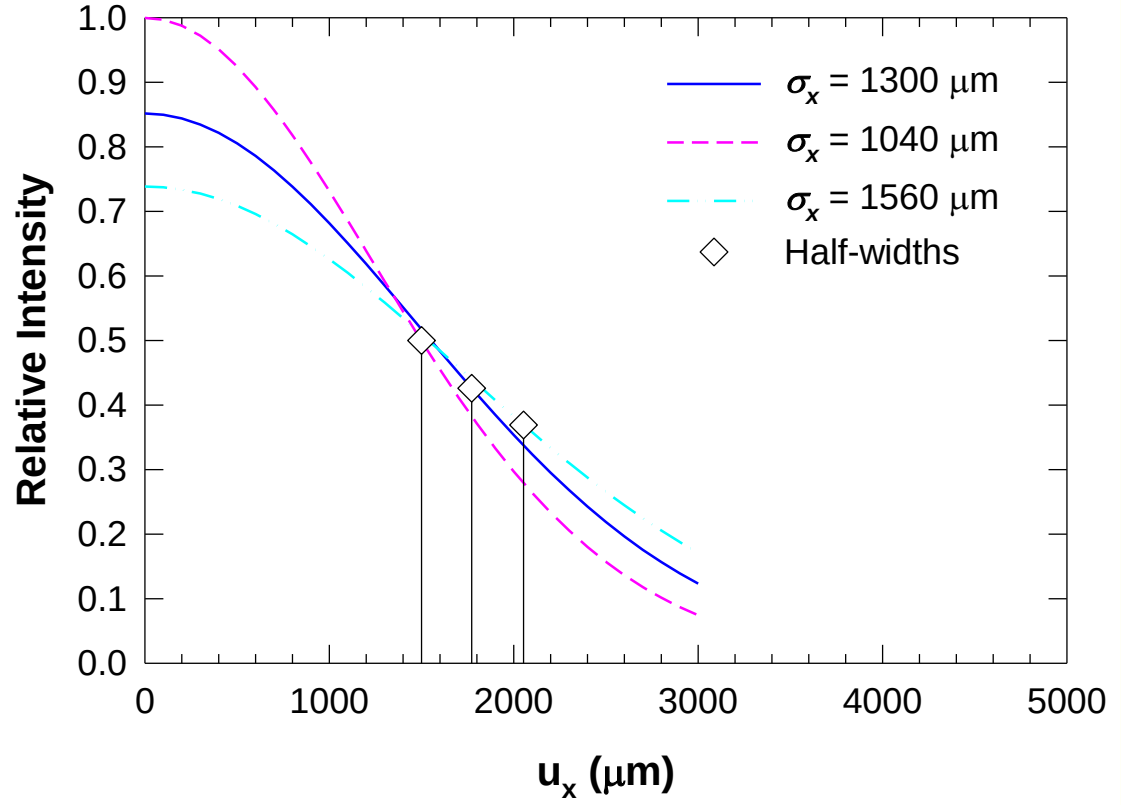




Lumpkin et al., Phys. Rev. ST-AB, Feb. 2007

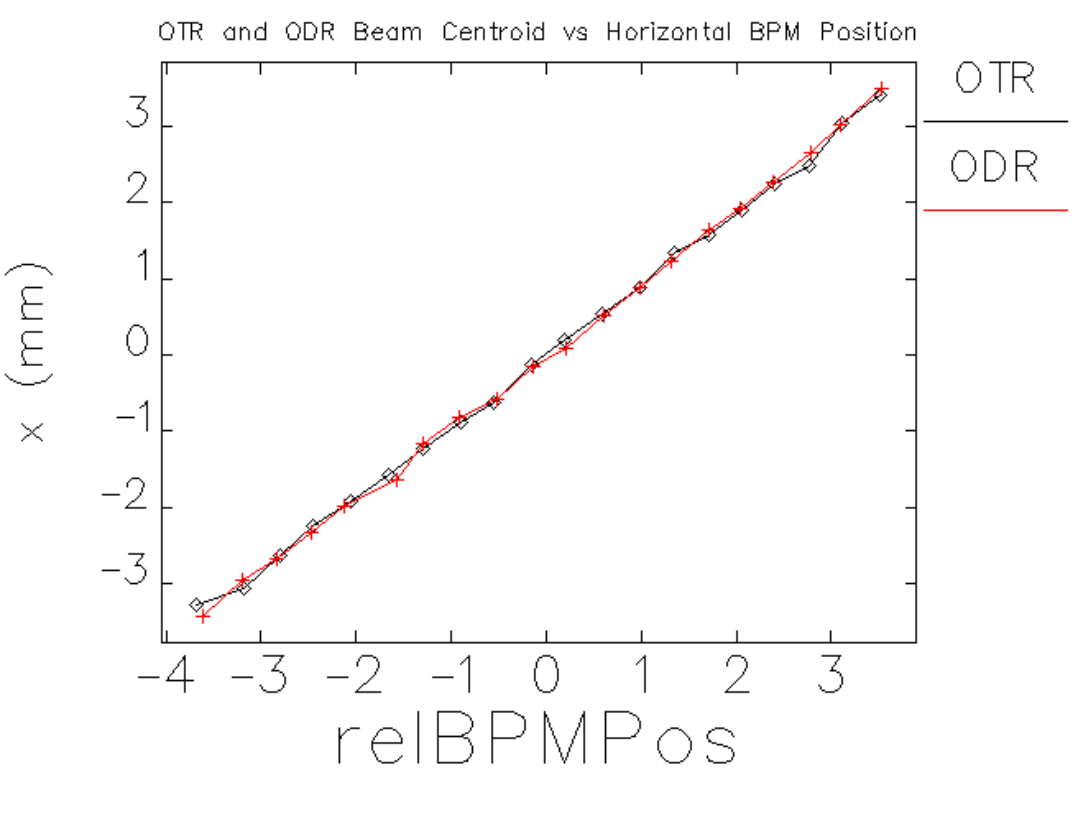
Analytical Model Indicates Beam-size Sensitivity on x Axis (Parallel to Edge)

- **Beam size varied +- 20% around 1300-μm value to show change in ODR profile detectable with *d*=1000 μm and σ_y=200 μm.**



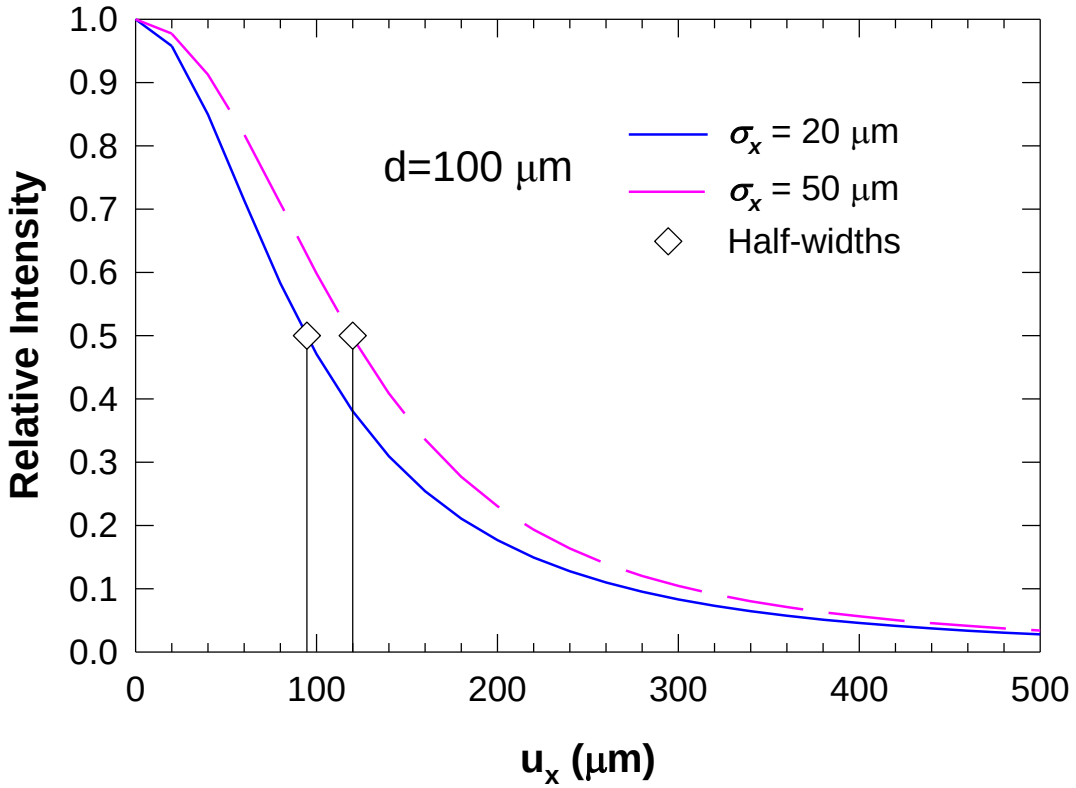
ODR Also Has Good NI Beam-Position Sensitivity Using Orthogonal Polarization Component

- **OTR and ODR Image Centroid versus Horizontal rf BPM values are linear.**



Analytical Model Indicates Beam-size Effect in New Regime at 20-50 μm for 7-GeV Beam (XFEL,ERL,ILC)

- Model shows new regime possible even without polarization selection for fixed σ_y = 20 μm.



ODR Techniques for ILC

- **Most anticipated beam sizes addressed. Smallest beam sizes need studies.**

Energy (GeV)	X Beam size (μm)	Y Beam size (μm)
1	650	35
5	300	15
15	150	8
250	30	2

Multi-GeV values per M. Ross talk, July 27, 2007

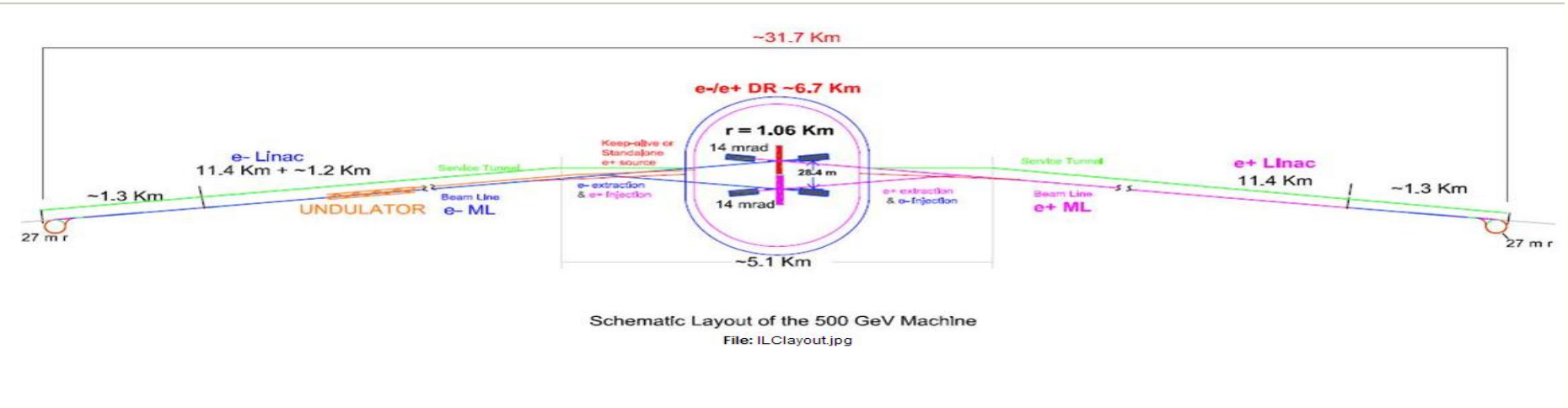
ILC-TA Beam Offers Extended Parameter Space To Test and ODR Offers an NI Beam-size Monitor for Operations.

- **CEBAF beam size is 10 times smaller and the charge is 1000 times greater than APS case. ILCTA beam sizes are nearly ILC prototypical.**

Parameter	APS	CEBAF	ILCTA	ILC
Energy (GeV)	7	1- 5	0.5-0.7	5, 250
Gamma (x1000)	14	2-10	1-1.4	10, 500
X Beam size (μm)	1300	50-80	200, 80	300, 30
Y Beam size (μm)	200	50-80	70, 30	15, 2
Current (nA)	6	100,000	50,000	50,000
Charge/ 33 ms (nC)	3	3,000	10,000	10,000

ILC Schematic Shows Potential Locations for NI Diagnostics

- **ODR possible beam size monitor at GeV energies.**



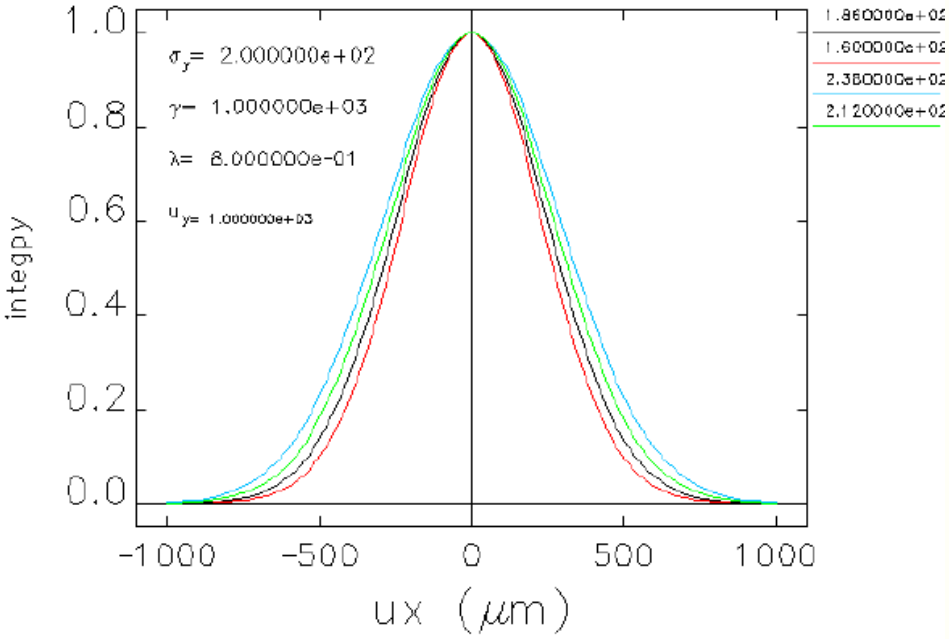
Schematic Layout of the 500 GeV Machine
File: ILClayout.jpg

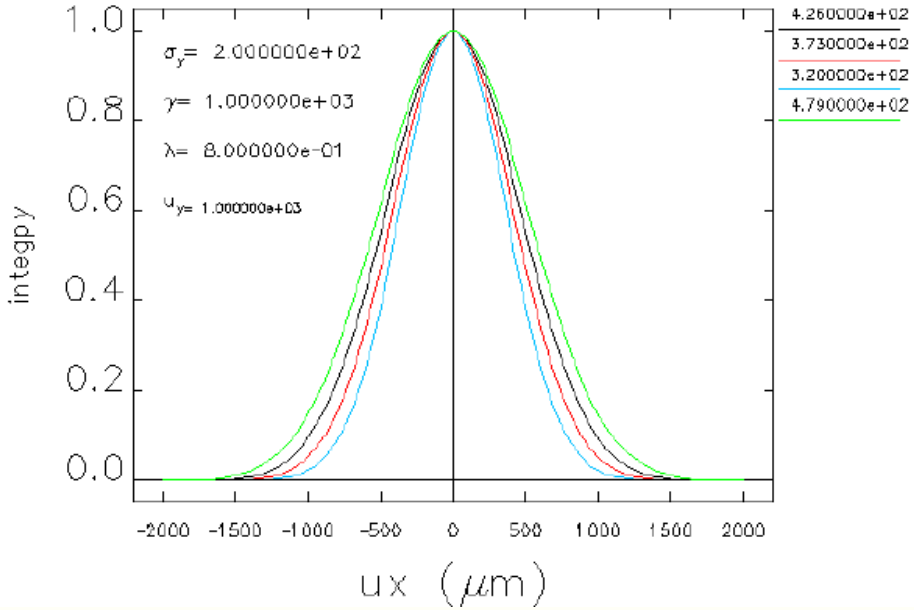
Further Studies Planned in FY08

- Planning of the ILCTA station at 550-750 MeV point.
- Baseline concept is to image at about 800 nm with a 16-bit camera and use the high charge of the macropulse to generate enough photons at this wavelength.
- Second concept is to image or detect in the MIR in the 3- to 10-μm regime, where there are more photons emitted. Possible detectors are pyroelectric arrays or cryo-cooled detectors (relevant to hadron issues).
- Collaboration with INFN on 900-MeV experiment at FLASH/ DESY. Studies possible in Jan.-Feb. 2008 with 16-bit camera.
- Collaboration at JLAB on CEBAF recirculating linac beam at location before nuclear physics target.

ODR Model Shows Beam-size Effects

- **ILC-TA examples for beam-size monitor for σ_x=200 μm and 400 +- 20% μm with σ_y=200 μm, d = 5 σ_y, and γ=1000.**

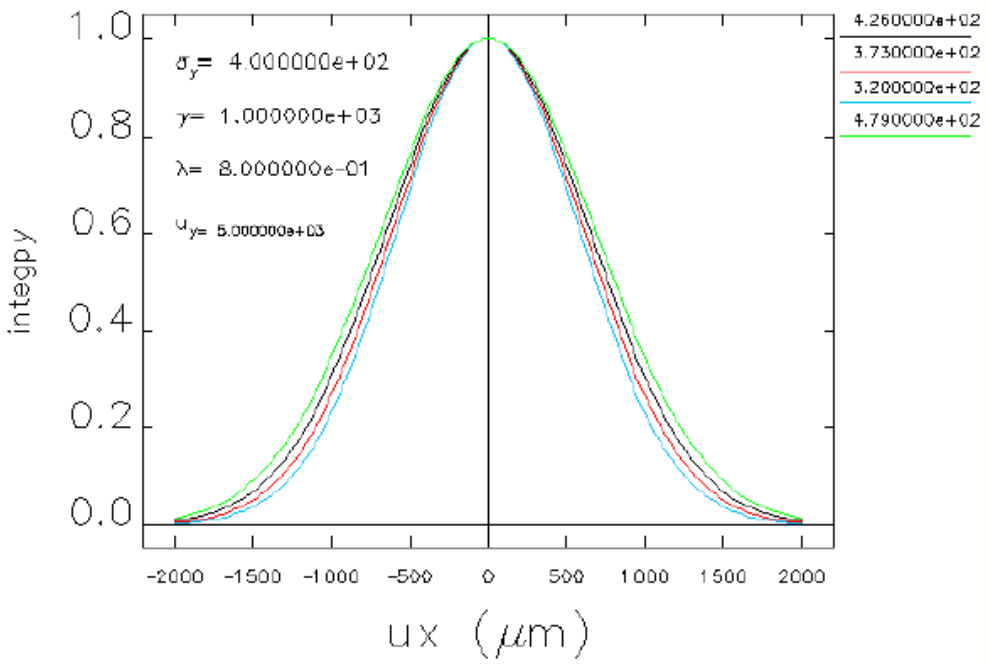


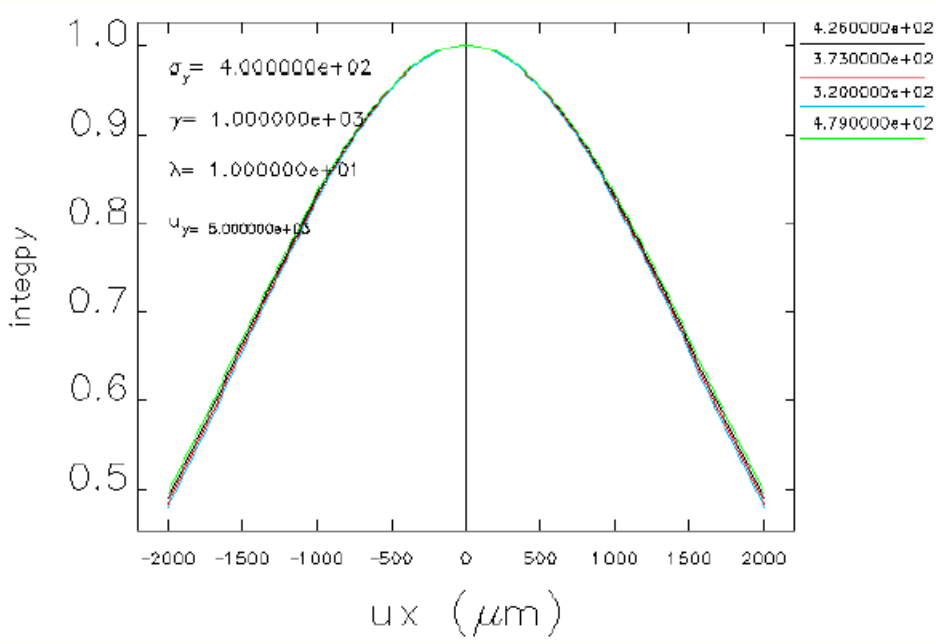


Courtesy of C.-Y. Yao, ANL

ODR Model Shows Wavelength Effect

- **ILC-TA examples for beam-size monitor for σ_x=400 +- 20% μm with σ_y=400 μm, $d = 12\,\sigma_y$, and γ=1000.**





Courtesy of C.-Y. Yao , ANL

SUMMARY

- *A new NI relative beam size monitor based on ODR has been proposed to support APS top-up operations.*
- *The ODR near-field imaging techniques also have relevance to x-ray FELs, ERLs, APS upgrade, and emerging LWFAs.*
- *The ODR techniques also appear applicable to NI monitoring of the CEBAF 5-GeV beam at 100 μA before the experimental hall.*
- *The ODR techniques appear applicable to ILCTA for sub-GeV beam with high average current.*
- *The ODR techniques appear applicable to ILC at multi-GeV energies.*