LC Beam Instrumentation Tests Using SLAC's End Station A

Colloque international sur les collisionneurs linéaires
LCWS04 19-23 Avril, 2004 Paris, France

Luminosity, Energy and Polarization (LC-LEP) Measurements

SLAC A-Line and End Station A

LC-LEP Beam Tests at SLAC

M. Woods (SLAC)

Beam Instrumentation Tests for the Linear Collider using the SLAC A-Line and End Station A

SLAC-LOI-2003.2

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http://www.slac.stanford.edu/grp/rd/epac/LOI/LOI-2003.2.pdf

LCRD and UCLC

FY04 R&D Proposals to DOE and NSF

Luminosity

Fast Gas Cherenkov Calorimeter (*Iowa St.*)
Parallel Plate Avalanche, Secondary Emission Detectors (*Iowa*)
Large Angle Beamsstrahlung Monitor (*Wayne St.*)
3d Si Detector for Pair Monitor (*Hawaii*)

Energy

Synchrotron Stripe Spectrometer (*Oregon, UMass*)
rf BPM Spectrometer (*Notre Dame*, *UC Berkeley*)

Polarization

Quartz Fiber Calorimeter; W-pair asymmetry (*Iowa*)
Background study (*Tufts*)
Quartz Fiber Detector; transverse polarization (*Tennessee*)

General Comments

Risks to LC luminosity and LC physics capabilities

- Any beam or detector instrumentation that cannot be commissioned until the LC is built have very high risk factors.

  ⇨ Do beam tests early!

Beam-beam effects

- much greater than in previous machines
- backgrounds
- large disruption and deflection angles

  ⇨ Mimick some beam-beam effects in a fixed target beam test

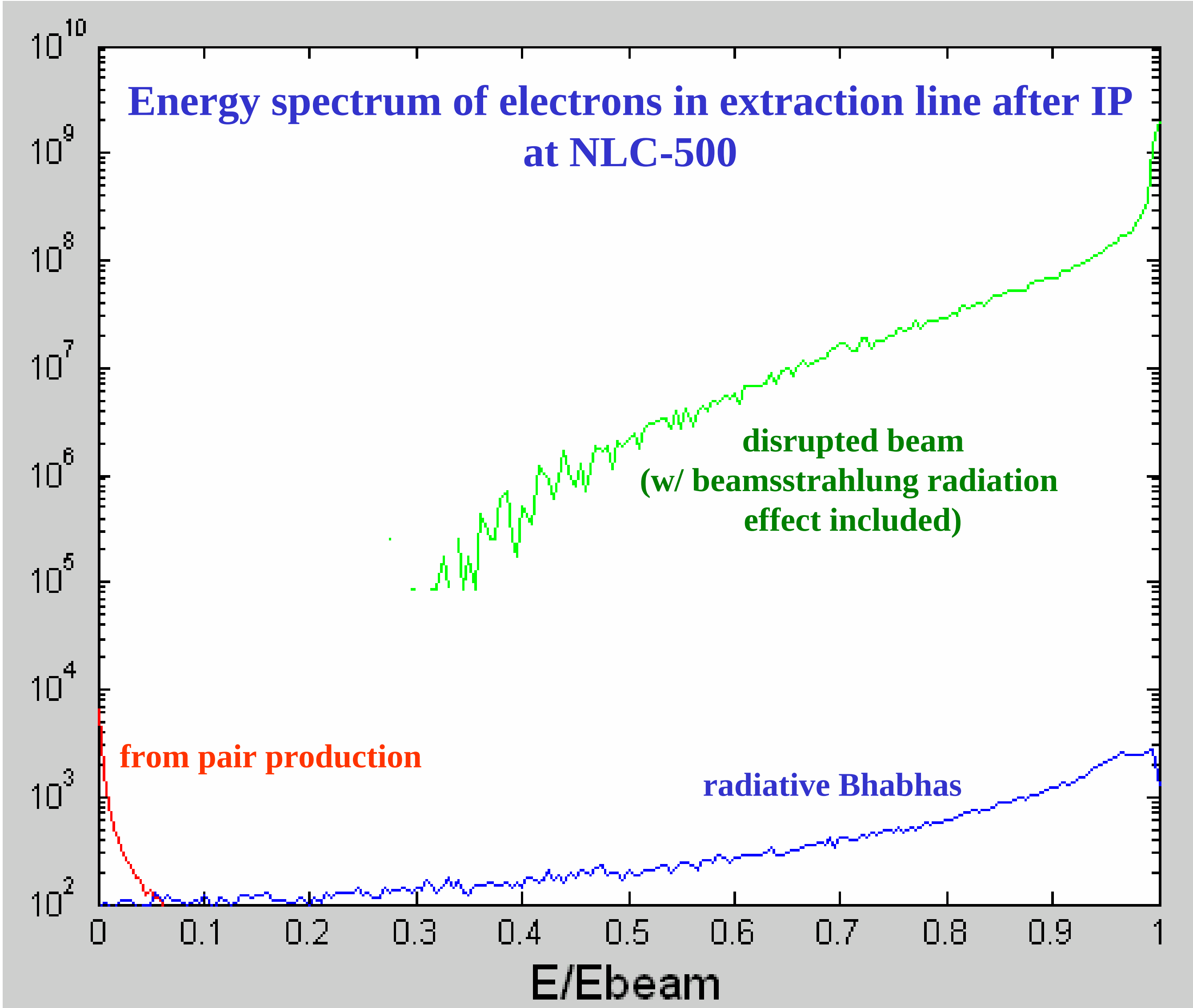
Precision Measurements

- Challenging requirements for luminosity, energy and polarization measurements

  ⇨ Instrumentation requires beam tests

Beamsstrahlung at the Linear Collider

~5 % of the beam energy gets radiated into photons due to beamsstrahlung (at SLC this was 0.1%)



LC-LEP Measurement Goals

Luminosity, Luminosity Spectrum

• Total cross sections:	absolute $\delta L/L$ to ~0.1%
• Z-pole calibration scan for Giga-Z:	relative $\delta L/L$ to ~0.02%
• threshold scans (ex. top mass):	relative $\delta L/L$ to 1%
	+L(E) spectrum: core width to <0.1% and tail population to <1%

Energy

• Top mass:	200 ppm (35 MeV)
• Higgs mass:	200 ppm (25 MeV for 120 GeV Higgs)
• W mass:	50 ppm (4 MeV) ??
• 'Giga'-Z A_{LR}:	200 ppm (20 MeV) (comparable to ~0.25% polarimetry)
	50 ppm (5 MeV) (for sub-0.1% polarimetry with e+ pol) ??

Polarization

• Standard Model asymmetries:	< 0.5%
• 'Giga'-Z A_{LR}:	< 0.25%

Instrumentation for Luminosity, Luminosity Spectra and Luminosity Tuning

Luminosity

Bhabha LuMon detector from 40-120 mrad

Luminosity Spectrum

Bhabha acolinearity measurements using forward tracking
and calorimetry from 120-400 mrad
+ additional input from beam energy, energy spread and energy spectrum
measurements

Luminosity Tuning

Pair LuMon detector from 5-40 mrad
Beamstrahlung detector from 1-2 mrad (further downstream)
IP BPMs

Instrumentation for Energy, Energy Spread and disrupted Energy Spectrum

Energy

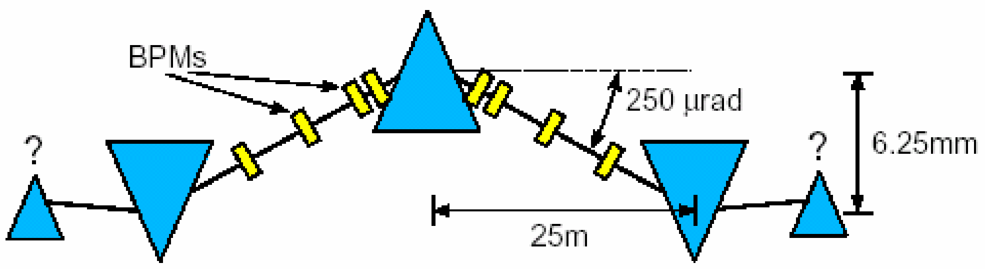
BPM spectrometer (upstream of IP)
Synchrotron Stripe spectrometer (in extraction line)

Energy Spread

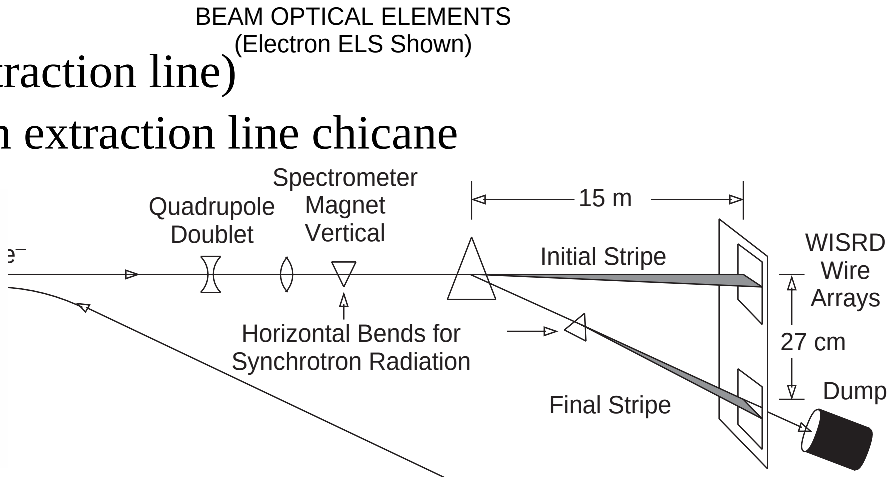
Synchrotron Stripe spectrometer (in extraction line)
Wire scanner at high dispersion point in extraction line chicane

Disrupted Energy Spectrum

Synchrotron Stripe spectrometer (in extraction line)
Wire scanner at high dispersion point in extraction line chicane



Proposed BPM spectrometer at NLC



Synchrotron Stripe Spectrometer at SLC

SLAC A-Line and End Station A Facility

- Beam Characteristics and Comparison with NLC Beam
- Beam Diagnostics

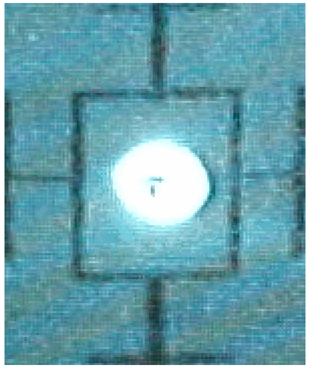
Beam Parameters at SLAC ESA and NLC-500

Parameter	SLAC ESA	NLC-500
Charge/Train	5×10^{11}	14.4×10^{11}
Repetition Rate	10-30 Hz	120 Hz
Energy	25 GeV	250 GeV
e^- Polarization	85%	80%
Train Length	270ns	267ns
Microbunch spacing	0.3ns	1.4ns
Energy Spread	0.15%	0.3%

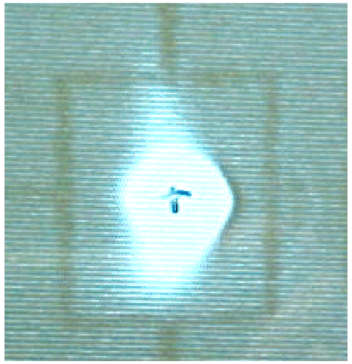
Beam Parameters at SLAC ESA and TESLA-500

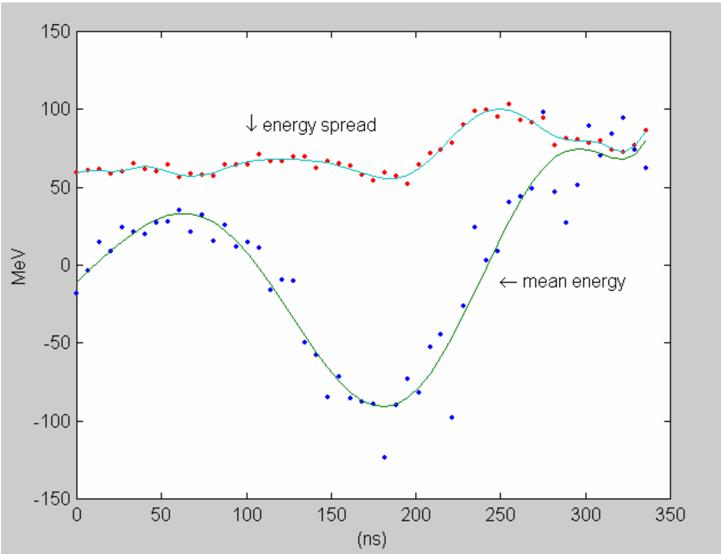
Parameter	**SLAC ESA**	**TESLA-500**
Repetition Rate	10-30 Hz	5 Hz
Energy	25 GeV	250 GeV
e^- Polarization	85%	80%
Train Length	340 ns	1 ms
Microbunch spacing	340 ns	337 ns
Bunches per train	2	2820
Bunch Charge	2.0×10^{10}	2.0×10^{10}
Energy Spread	0.15%	0.1%

Can provide clean beams (little halo or beam tails)

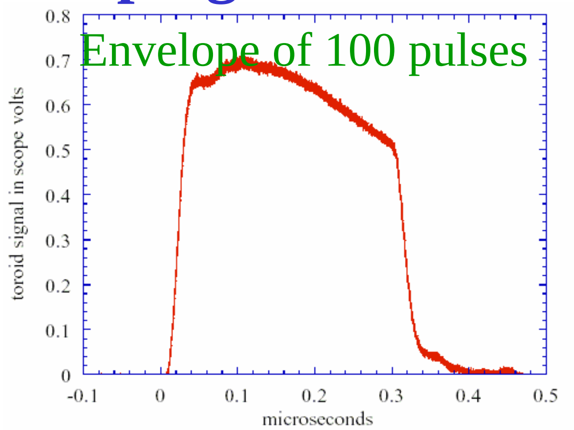


Can provide beams with tails!



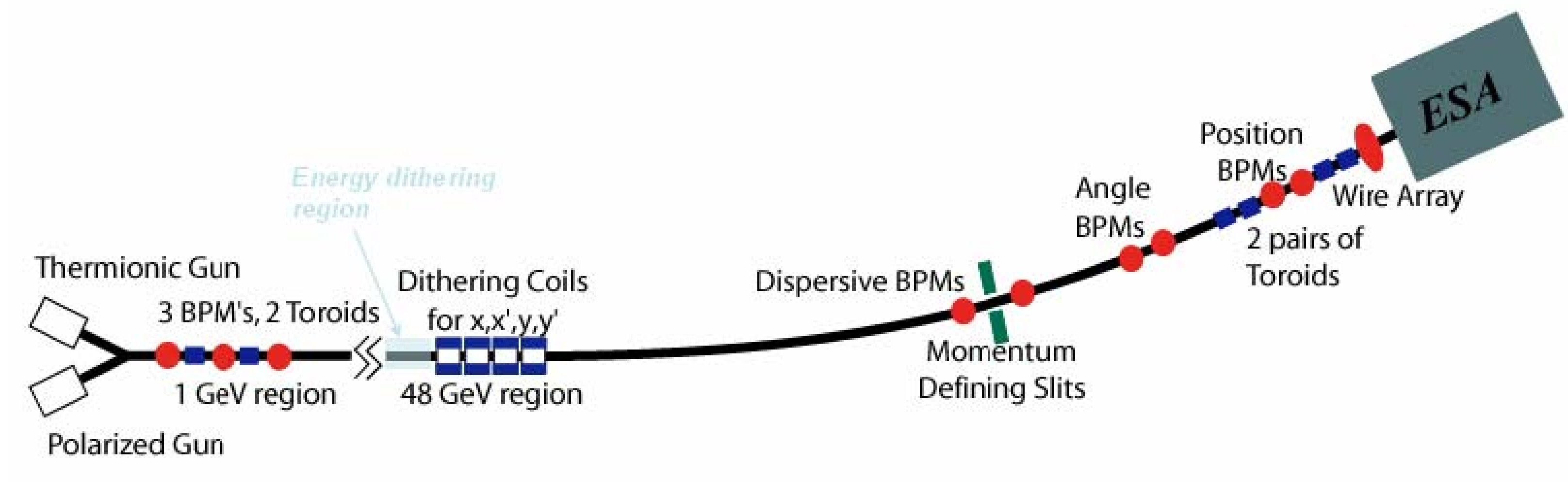


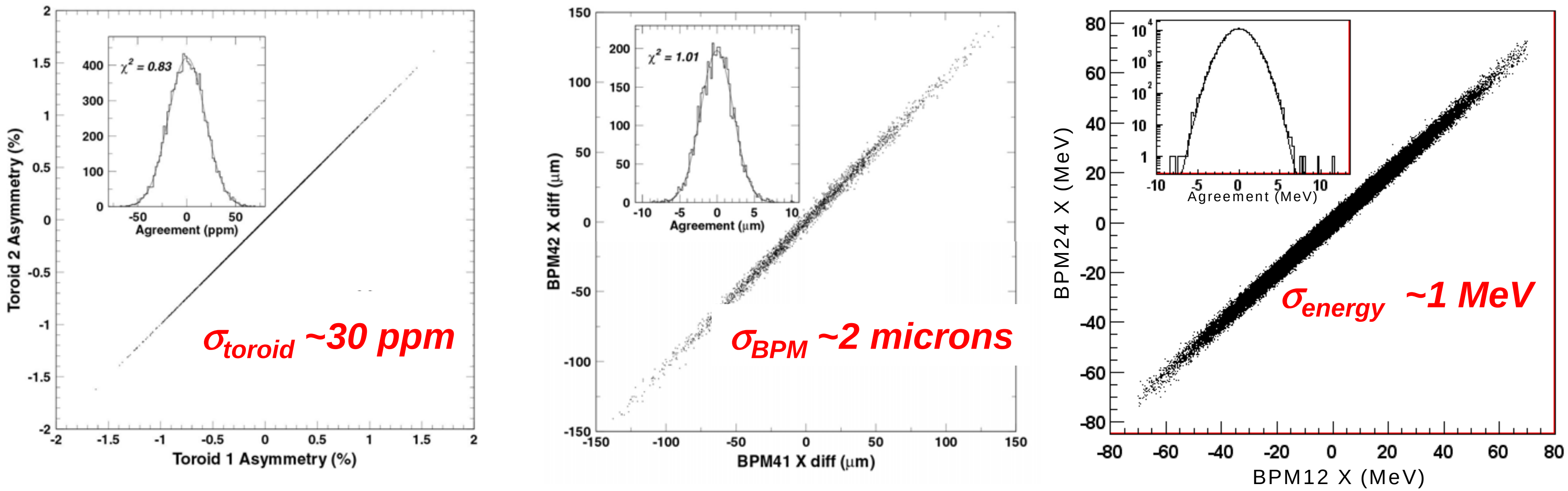
Can provide "banana" beams in energy by pulse shaping source laser intensity



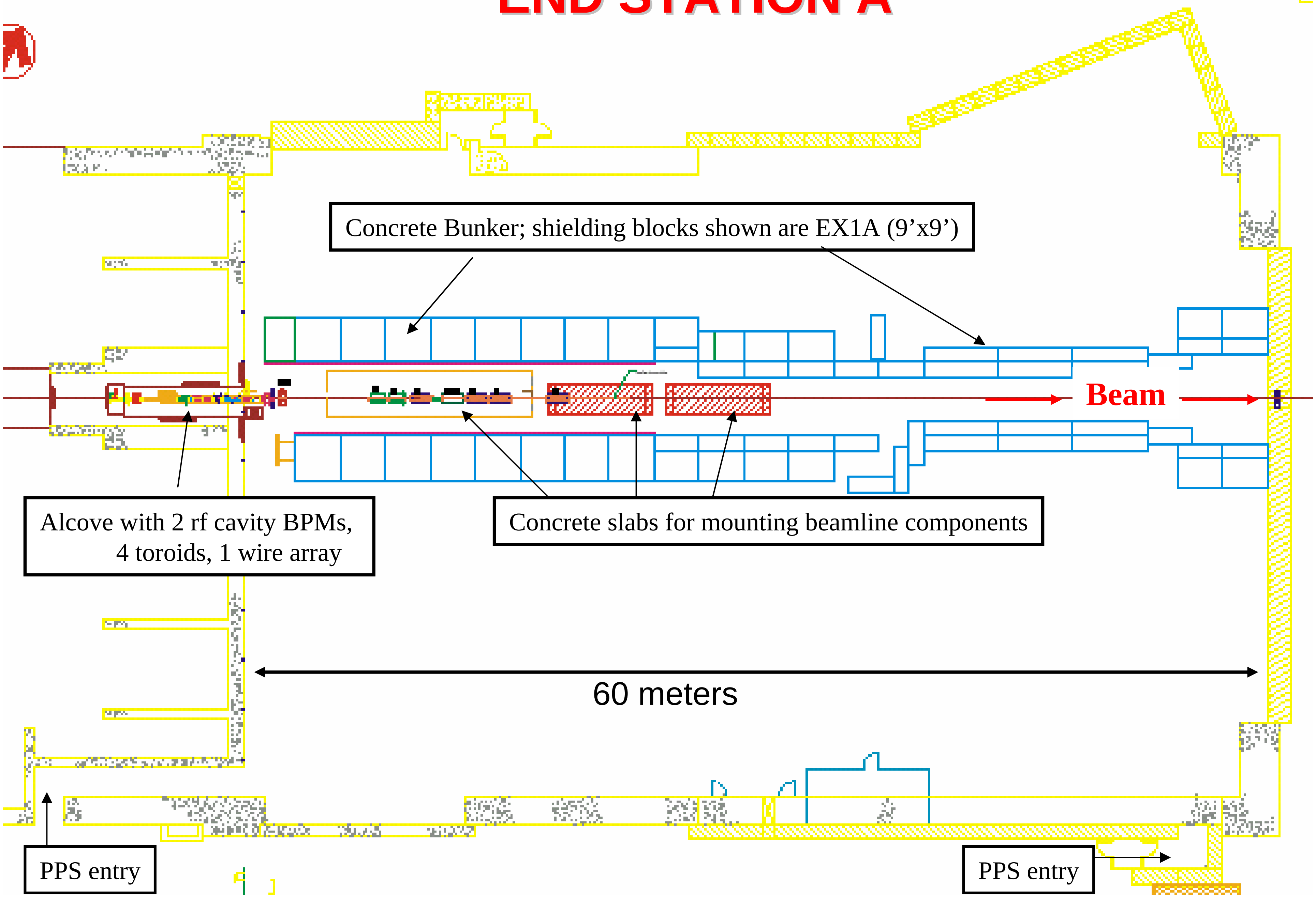
Can translate banana energy distribution to banana spatial distribution by introducing dispersion

Beam Diagnostics for SLAC E-158



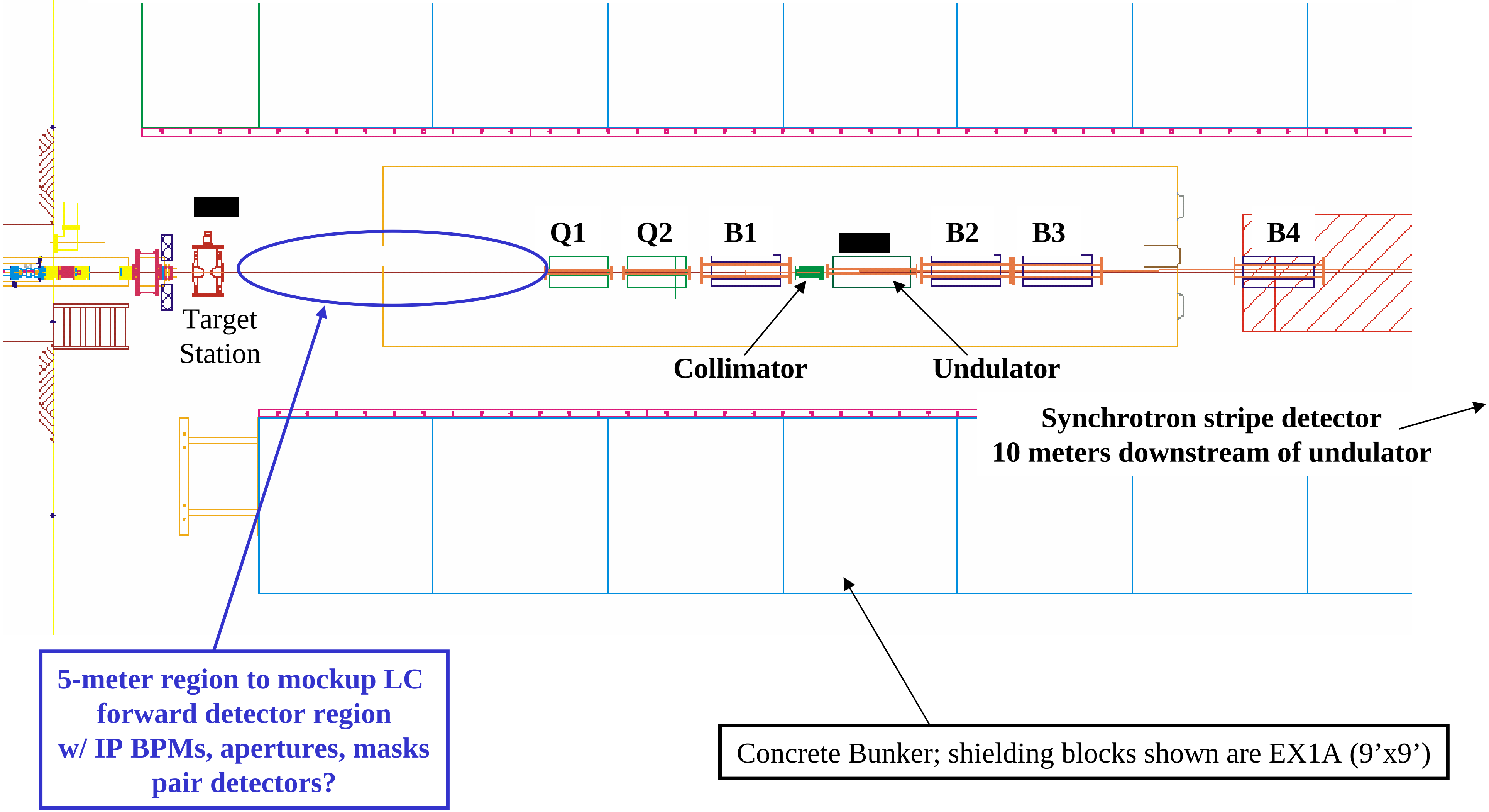


END STATION A

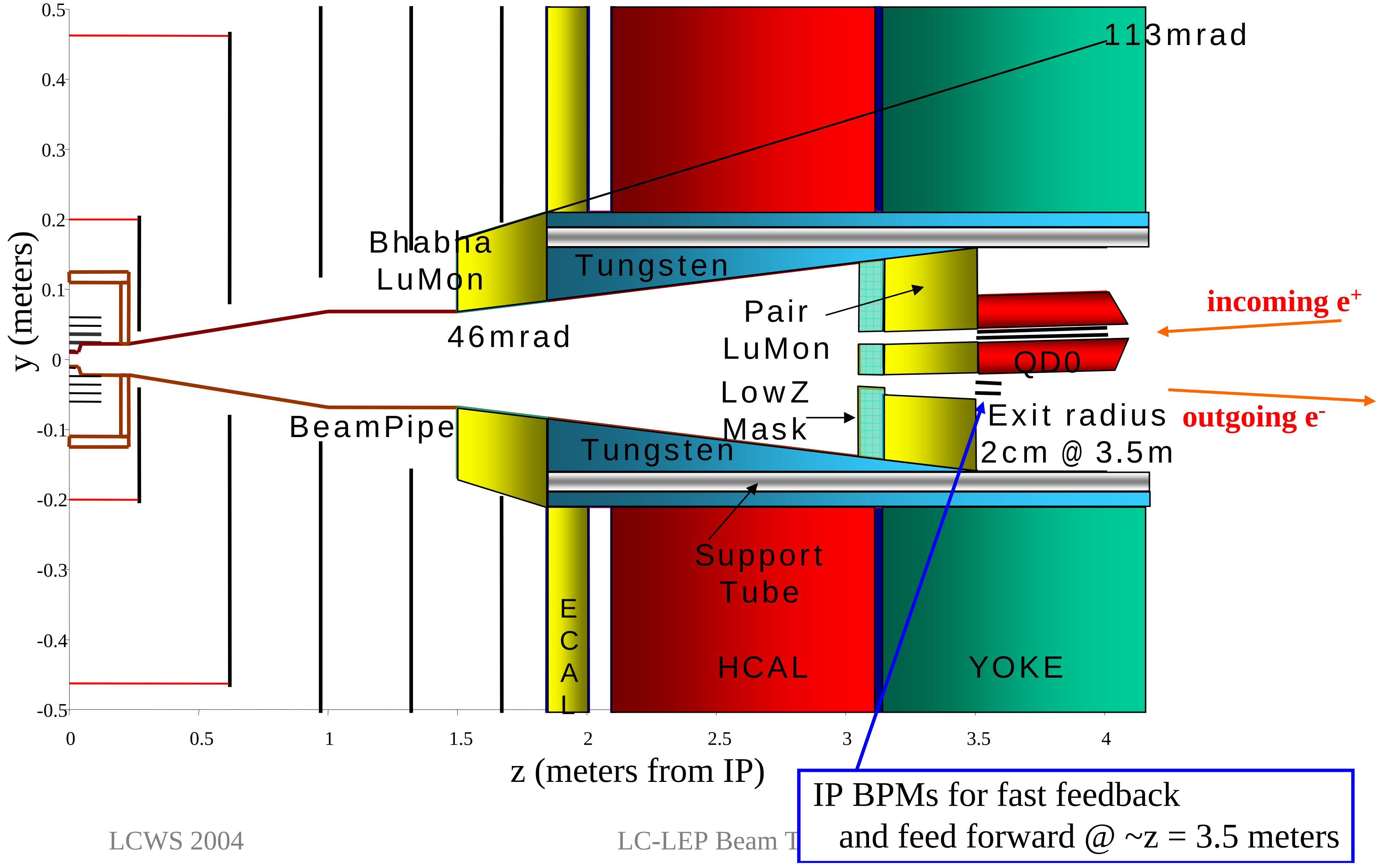


END STATION A (zooming in)

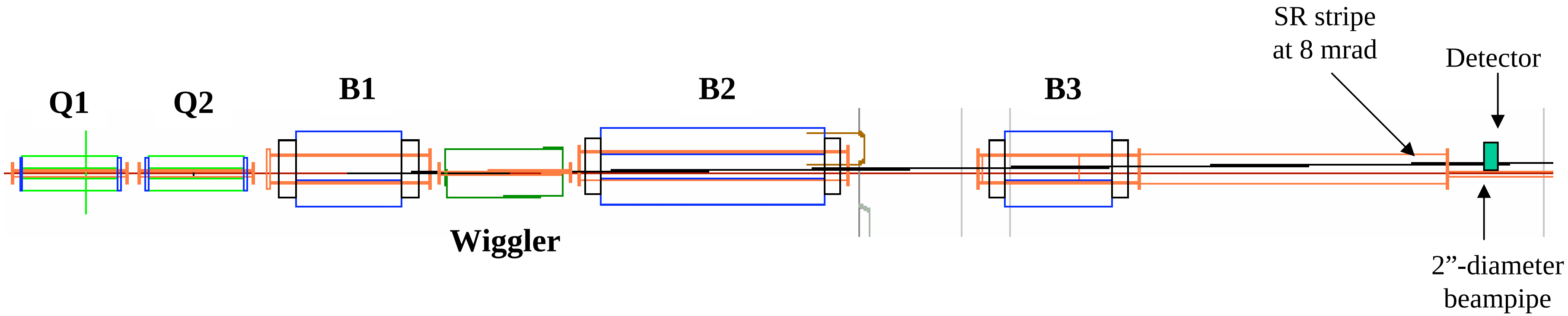
Ideas for LC BI Tests: 4-dipole chicane w/ undulator stripe magnet;
quad doublet to image target onto stripe detector plane
include “energy bpms” into chicane design?



Mockup forward region within 5 meters of IP, for masking, apertures, IP BPMs (NLC Silicon Detector shown)



SR Stripe Beam Tests:



All magnets are existing, from SPEAR

Magnet	Type	B-Field max	Vertical Gap	Horizontal Gap	Length
Q1, Q2			4.0"	4.0"	38"
B1, B3	10D45	9.85 kG	2.5"	10"	44"
B2	10D90	9.85 kG	2.5"	10"	89.5"
Wiggler	5 poles, 2 half-poles	17 kG	10.5"	1.75"	47"

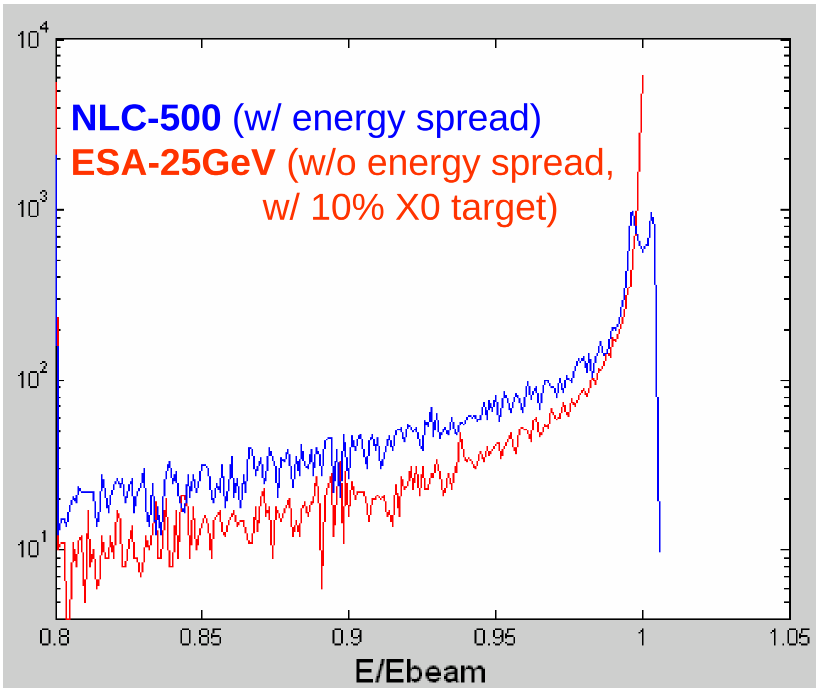
Beam Tests for Synchrotron Detectors

(for energy spectrometer, possibly for beamstrahlung detector)

Improve instrumentation for existing SLM in A-Line

Commission new synchrotron stripe detectors in ESA

- Mirrors and ccds for visible SR
- Quartz fibers w/ multi-anode PMT readout for ~MeV SR
- test capability for resolving beam energy spread and hard edge at $E = E_{beam}^{incoming}$



First Beam Tests

1. **IP BPMs (necessary for fast inter-train and intra-train feedbacks)**
   - Sensitivity to backgrounds, rf pickup
   - Mimic LC geometry, including fast signal processing (but no feedback)
   - Sample drive signal to kickers

2. **Energy BPMs**
   - Mechanical and electrical stability at 100-nm level
   - BPM triplet at z = 0, 2.5 and 5.0 meter spacing. BPMs 1 and 3 define straight line. Monitor BPM2 offset over time scales of minutes, hours
   - 2 adjacent BPMs to test electrical stability, separate from mechanical

3. **Synchrotron stripe diagnostics**
   - measure energy spread and the disrupted (brem) spectrum
   - characterize detector performance and capabilities

4. **Pair detectors**
   - mimic pair background with fixed target?
   - mimic pair background with diffuse primary beam of 4-GeV electrons
   - characterize detector response to pair background
   - use MonteCarlo to superimpose 250 GeV electron to determine electron id efficiency

Developing the Proposals

1. **Identify first users for the Beam Test Facility**
2. **Users develop full technical description of beam tests**
3. **Use beam test descriptions to determine beamline configuration**
4. **Formulate Run Plan for first beam tests**
    - Beam requirements
    - Time required
    - Common DAQ?
5. **Prepare SLAC Impact Report**
    - Budget
    - Resources provided by SLAC
    - Resources provided by users
6. **First beam tests possible in June 2005**

But,
- need well developed beam test proposals
- beam tests must be meaningful and cost-effective

Conclusions and Outlook

The long pulse polarized beam to End Station A reflects many of the beam characteristics for the NLC and TESLA beams at a 500-GeV collider.

LC-LEP beam tests can be carried out at SLAC's ESA to demonstrate the stringent requirements for the detectors and techniques to be employed at the Linear Collider. There is much work to do to carefully design meaningful and cost-effective beam tests. We can be ready for first beam tests in FY05.

The LOI received a very favorable response from the SLAC EPAC at its November meeting. We plan to submit beam test proposals to SLAC as they become available. SLAC will decide how to group the tests and schedule them.