Beam Energy Measurement:

SLC-style Energy Spectrometer

(WISRD in extraction line)

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IP Beam Instrumentation Study
SLAC, 26 June 2002

WISRD information from
LCWS 2000, Fermilab, 26 October 2000

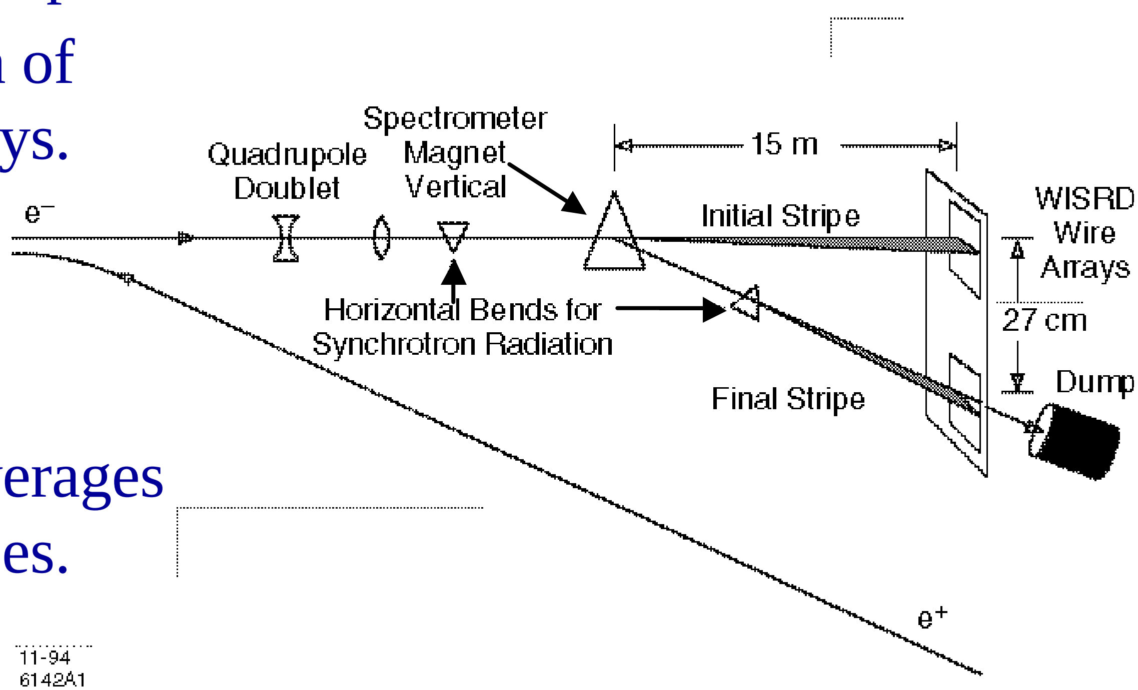
Not here...

Marc Ross,
SLAC

SLC/SLD Energy Spectrometer
(ca 1986-1990 technology)

- Energy spectrometer in extraction line, just before beam dump.
- Horizontal bends create synchrotron radiation stripes.
- Vertical spectrometer magnet separates stripes.
- Measure separation of stripes on wire arrays.
- Measurements at 120 Hz beam rate.
- Large single-pulse electronic noise, averages out over many pulses.

THE EXTRACTION LINE SPECTROMETER
BEAM OPTICAL ELEMENTS
(Electron ELS Shown)



SLC Spectrometer Systematic Errors

Spectrometer Error Budget

Magnet	100 ppm
(measure & monitor)	
Survey (detector wires)	90 ppm
Survey (magnet roll)	170 ppm
Subtotal	217 ppm
Calculations:	
Numerical approx.	85 ppm
Energy loss from IP	105 ppm
Subtotal	135 ppm
Total	**255 ppm**

Total for avg. of many beam pulses.
(~ 400 ppm single-pulse noise)

- Some improvement available in magnet measurement & monitoring.
- Detector technology would change.
- Relative roll of stripe magnets dominates 170 ppm, can fix this.
- Numerical approximations made due to limited CPU speed.
- Energy loss
  - due to SR between IP and spectrometer calculated,
  - due to beam-beam interaction taken as 50% of the measured energy loss; beams colliding vs not colliding. (check w/ Guinea Pig)

Additional Note on the Dominant Systematic Error

- The **dominant systematic error** of 170 ppm is actually the uncertainty in the **relative orientation of the magnetic fields** in the stripe magnets.
  - If the fields are not parallel, the SR stripes are not parallel, and the measured energy depends on the portion of the stripe used.
  - This error **cannot** be controlled by geometric survey.
- In order to control this systematic error one must:
  - Monitor the relative stripe orientations with the spectrometer.
  - Measure and control the portion of the stripe used for measurement.
  - Correct the energy measurement for this effect.
- In order to minimize the systematic error, the capability to do the above must be in the initial spectrometer design.

SLC Energy Spectrometer Accuracy
(truth in advertising)

- The 255 ppm uncertainty Þ σ(Ebeam) = 12 MeV
- Calculation errors correlated, *i.e.*, E+ & E- Þ σ(Ecm) = <u>20</u> MeV

- Only able to perform Z-peak scan in 1997-98; last SLD run.
- Using all available information from the peak scan, the spectrometer Ecm was low by 46 ± 25 MeV (w.r.t. Mz).
- Combined with the acolinearity of muon pairs recorded during the peak scan, the best estimate is:
  - electron spectrometer offset = 0 ± 27 MeV
  - positron spectrometer offset = –46 ± 27 MeV

- A detailed study has not identified the cause of the offset.

Lessons Learned (?)

- The SLC spectrometer was an add-on ...
  - Positron spectrometer magnet has significant field distortion; inadequate orbit control could be the cause of the large energy offset found.
  - Difficulty in surveying magnets; no provision for monitoring magnet roll.
  - No real provision for monitoring absolute calibration over 10+ years.
  - SLC energy measurements in accelerator have better short-term stability than spectrometer energy measurements, and resolution of 20-40 ppm.

⇒ Integrate energy measurement into accelerator design & operation.

- Stability and resolution degraded at highest SLC luminosity, presumably due to beam disruption effects.

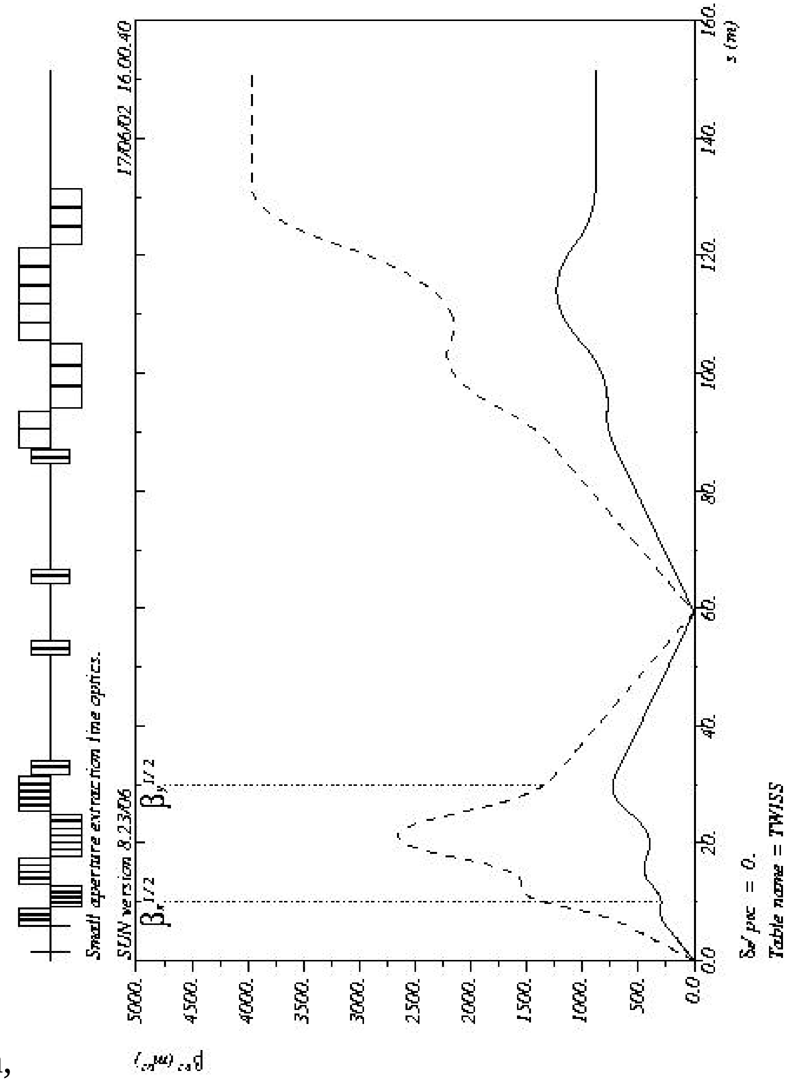
⇒ Extraction line spectrometer may not be optimal for precise measurement of colliding beam energies … think carefully.

- One could steal pulses out of collision, but at the cost of luminosity.

NLC Extraction Line Lattice Functions

Apologies for figure orientation!

- Extraction line lattice includes a chicane (vertical or horizontal) with a secondary focus.
- Chicane is natural location for beam monitoring instrumentation.
- In particular, this seems a natural location for a WISRD style spectrometer.



NLC Extraction Line Wire Scanner Study

- Y. Nosochkov & T.O. Raubenheimer, SLAC-PUB-8871, June 2001
- Simulated wire scanner at secondary focus in extraction line vertical chicane.
- See below: 1-σ ellipses in x-y for narrow energy slices.

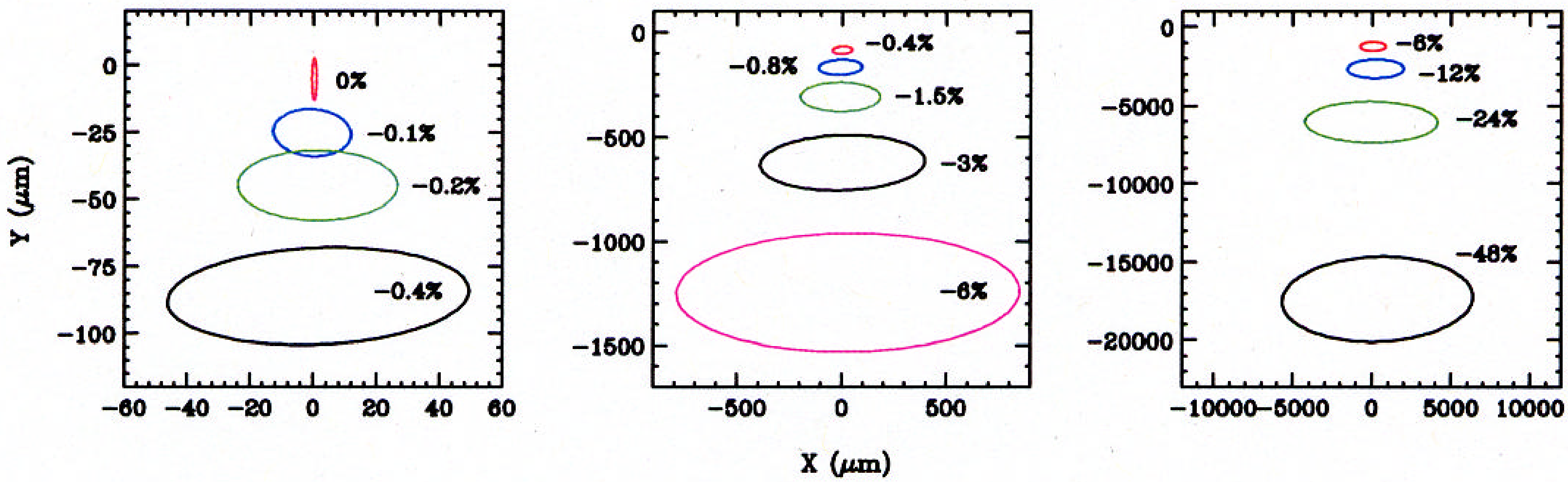


Figure 5: Monoenergetic ellipses at the secondary focus with $\eta_y = 2$ cm.

Simulated Wire Scan Energy Spectrum

- Simulation uses GUINEA-PIG and DIMAD.
- Spectrum falls of at dp/p~-85%, but simulation limited to dp/p=-55%.
- Energy spectrum is reconstructed reasonably well with vertical chicane.

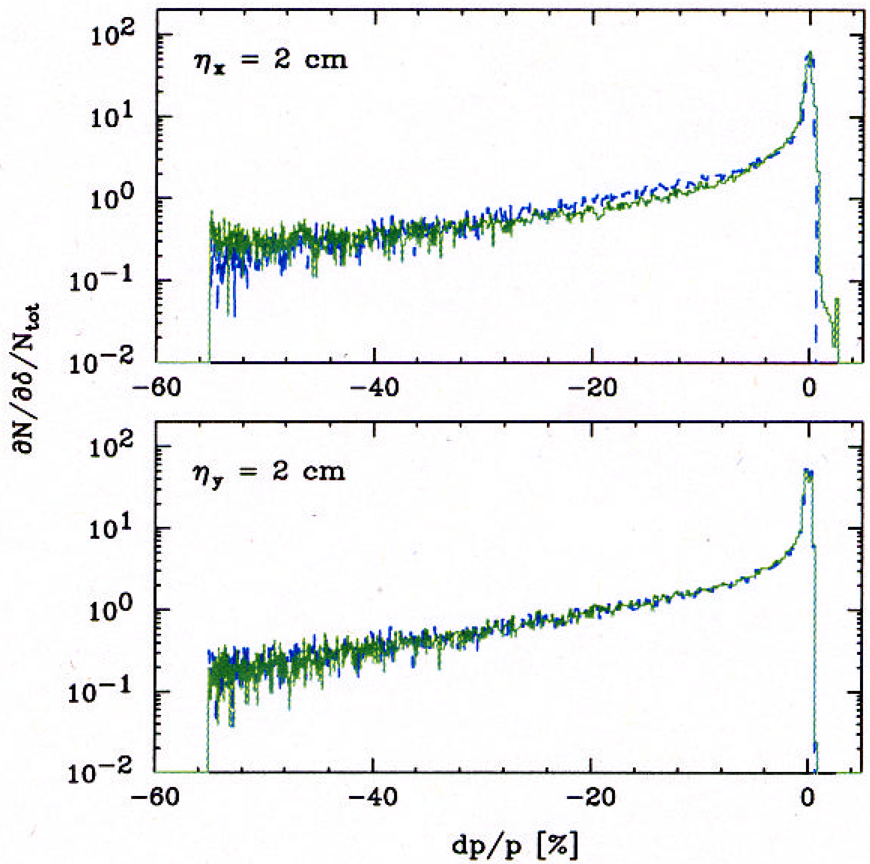


Figure 6: Original (blue, darker shade) and measured (green) energy spectrum $\frac{1}{N_{tot}}\frac{dN}{d\delta}$ for x and y chicane.

What's Next?

- Must integrate diagnostics into accelerator design & operation.
- Wire scanner probably not useable while running, so …
- To understand feasibility of SLC-style spectrometer we will need complete simulations:
  - Basic resolution, as for wire scanner study.
  - Beam optics issues for energy measurement and for energy spectrum.
  - Effect of backgrounds; depends on detector technology.
- If an SLC-style spectrometer is desired, we must think carefully about the detector. (*e.g.*, Mike Woods suggests mirror to transport SR light to a remote detector, perhaps CCDs.)
- New detector ideas might require other R&D. (*e.g.*, Mike Woods asks if the mirror would survive.)

Additional Comments

- Is it better to measure the energy in the accelerator, rather than the extraction line? Do we need/want both?
  (absolute calibration with beam position monitors?)
- There are additional questions for low energy physics; need to understand the extent to which Z-pole and W physics can use Ecm calibration w.r.t. Mz. (stability issues? energy range?)
- Because the luminosity spectrum is important to all physics for which the energy is critical, the use of Bhabas or other physics processes is an integral part of energy measurement. This needs consideration across physics working groups.