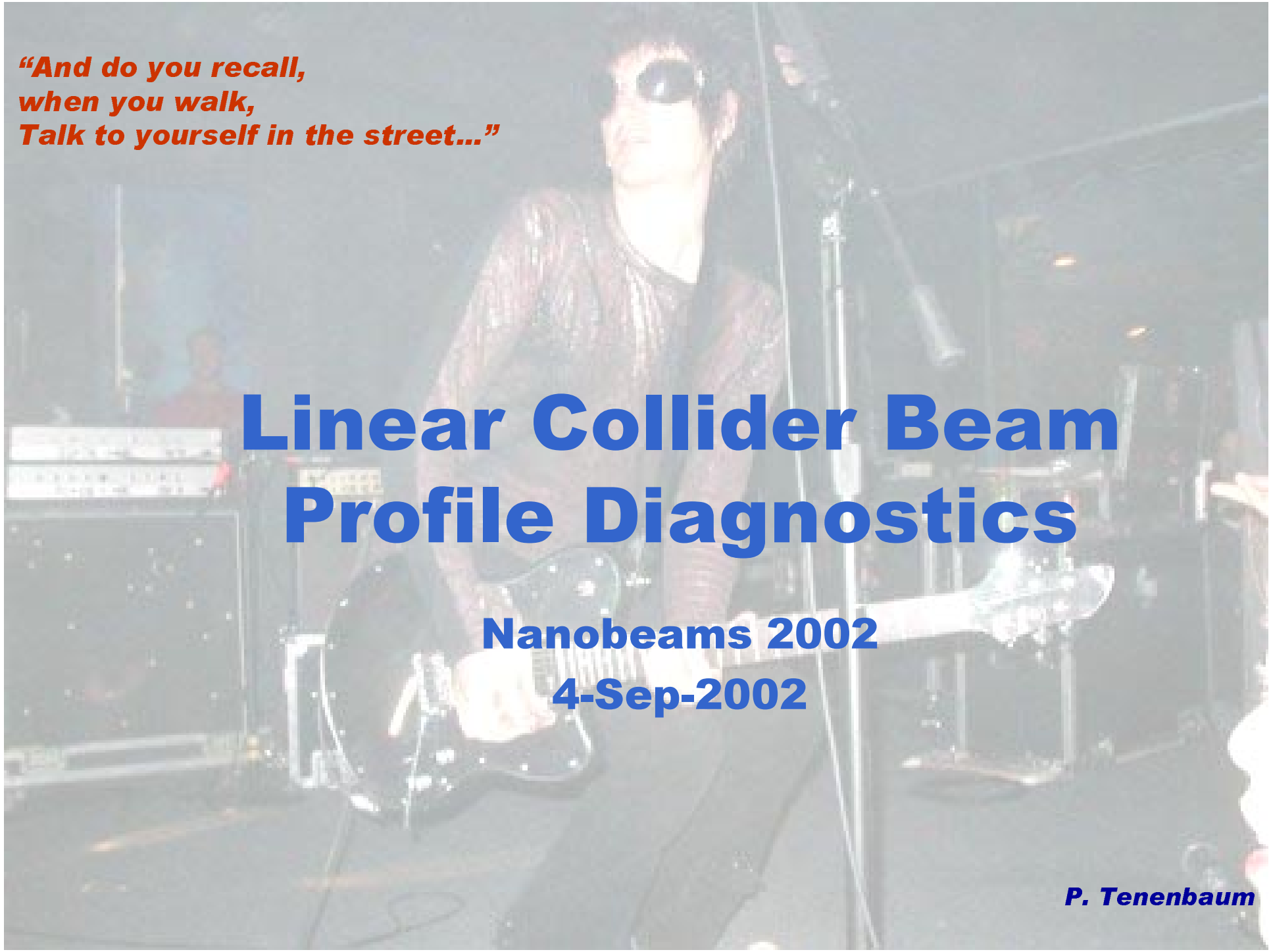


"And do you recall,
when you walk,
Talk to yourself in the street..."

Linear Collider Beam Profile Diagnostics

Nanobeams 2002
4-Sep-2002

P. Tenenbaum

Profile Measurements

- Emittance – beam phase space in (xx') or (yy')
- xy coupling
- beam shape (tails)
- Energy spread
- IP Angular Divergence
- Bunch Length
  - you're not hallucinating, you read that right!

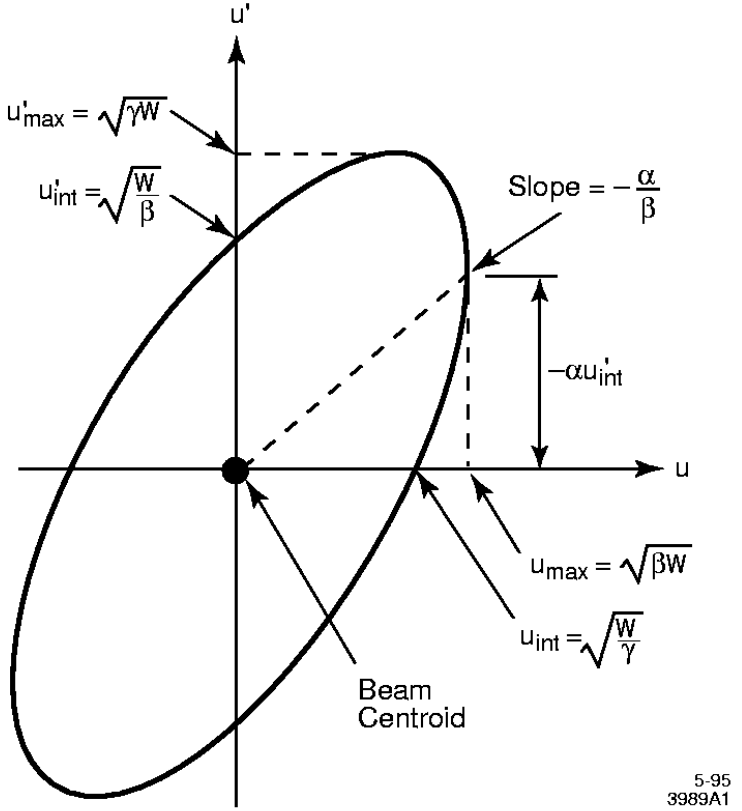
Emittance

Under "ordinary" conditions, beam in (xx') or (yy') phase space is an *ellipse*, characterized by 3 parameters:

"Area" parameter (ε)

"Aspect Ratio" parameter (β)

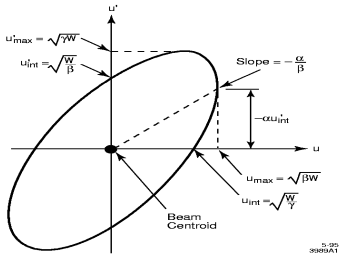
"Orientation" parameter (α)



$$\sigma_y = (\varepsilon\,\beta)^{1/2},\ \sigma_{y'} = [\varepsilon(1+\alpha^2)/\,\beta]^{1/2}$$

Generally, this is the parameter we can measure...

Emittance (2)



If you can only measure σ_y, how do you get the emittance?

Storage Ring: measure β by other means

Make use of the ring recirculation – well-defined β which is "machine parameter" – any beam stored in ring will get to $\sigma_y = (\varepsilon\,\beta)^{1/2}$, where β is defined by lattice only

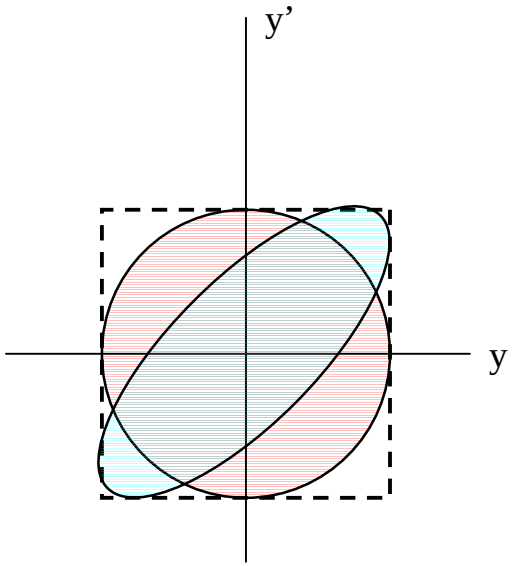
Linear Machine:

No recirculation, so β is function of lattice and initial beam conditions, well-defined "matched" β may not exist!

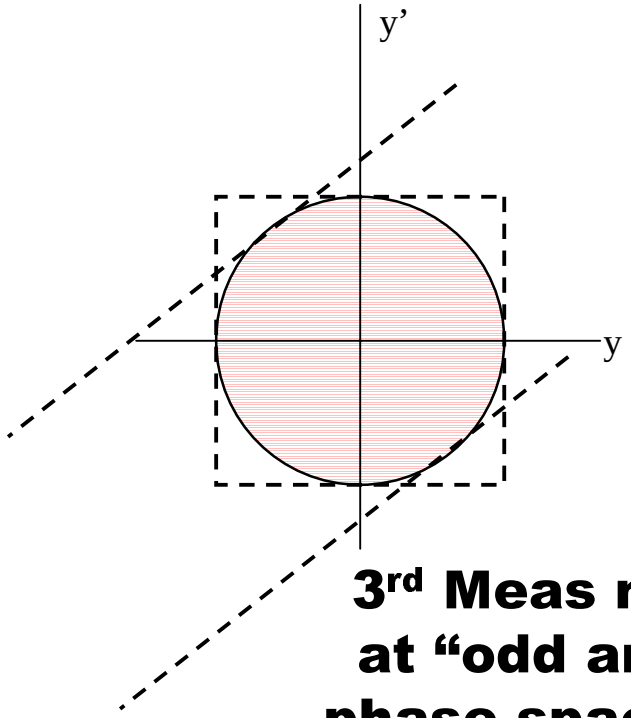
3 parameters, so need to make ≥ 3 linearly independent measurements!

Emittance (3)

Linear Machine: Make use of the fact that focusing lattice transforms angles at one location to positions at another



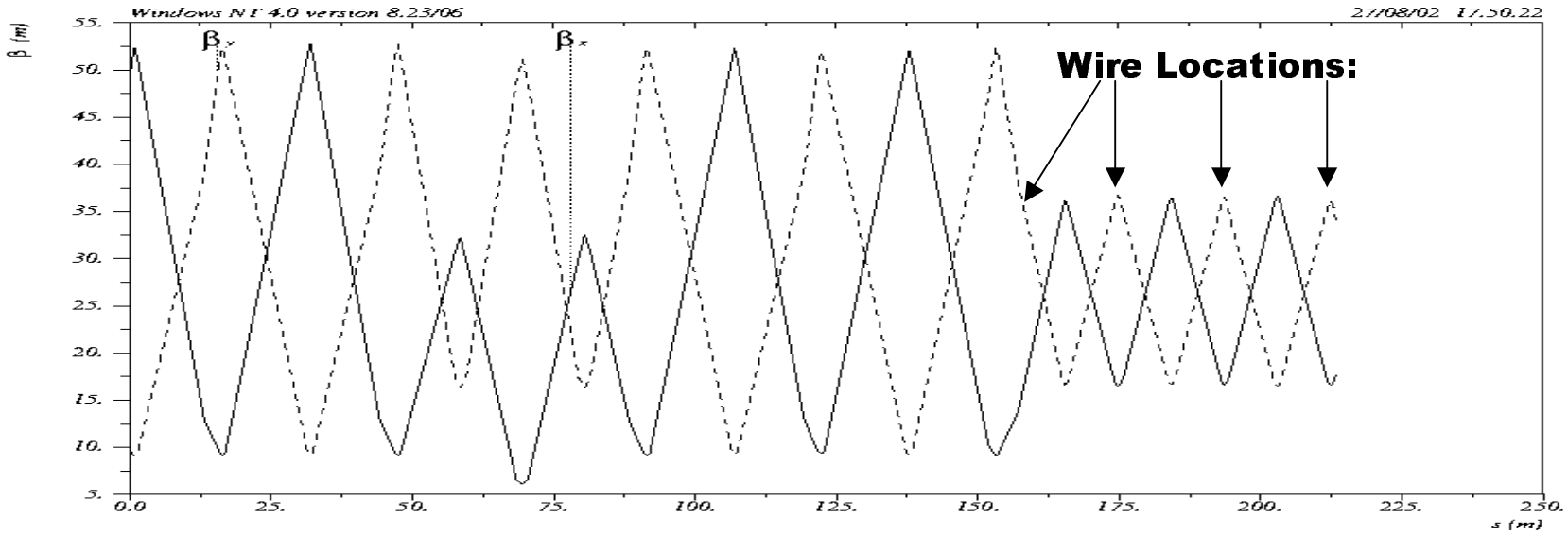
2 Measurements don't constrain beam ellipse…



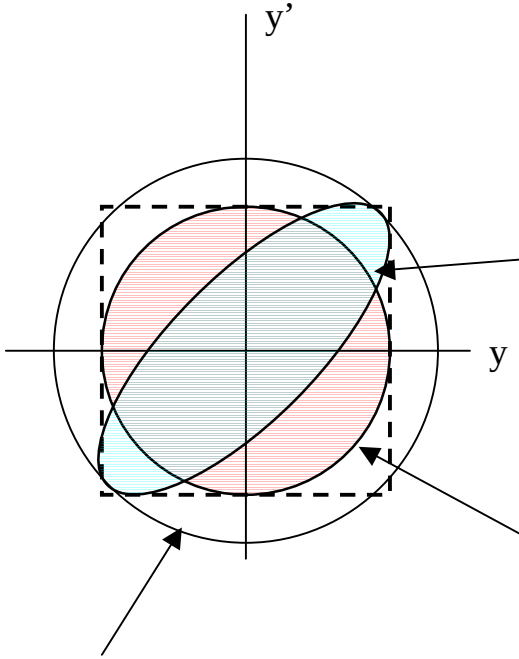
3rd Meas must be at "odd angle" in phase space (not 0 or 90 degrees)

NLC Emittance Station

- Uses 4 wires
- At vertically-focusing quads
  - y emittance smaller, need location where y beam size naturally bigger
- Optics have optimal transport properties for emittance measurement
  - Properly matched beam gives same size readout at each wire



"Matched Beam Size?"



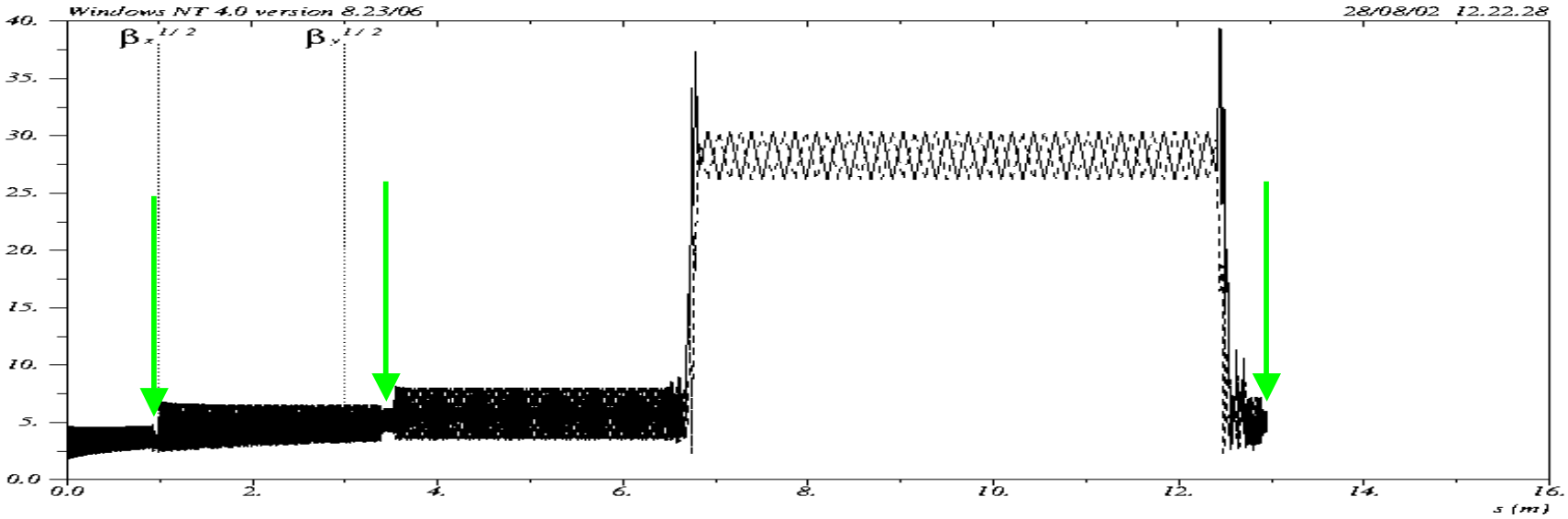
Define "Matched" ≡ "Has the parameters needed to give me the design value of β^* when transported to the IP"

Can define a "mismatch parameter" BMAG:

$$\sigma_y^* = (\beta_{design}^* \varepsilon \, BMAG)^{1/2}$$

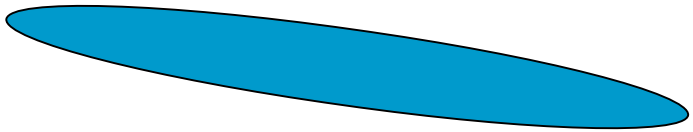
Emittance Stations

- Many 4-wire emittance stations in NLC design
  - 3 in main linac alone!
  - Improve localization of emittance problems
- Other designs (TESLA) have no emittance stations in main linac
  - can they do it all using the pre-BDS station?



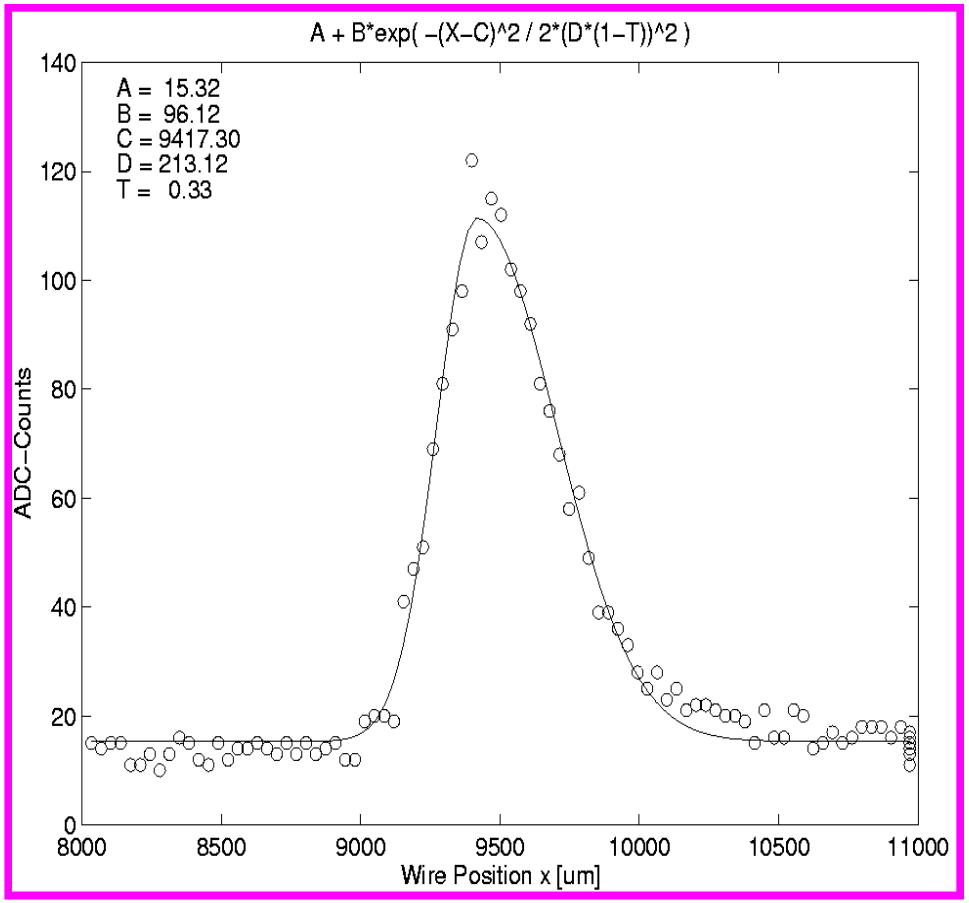
xy coupling

- x/y emittance ratio ~100
- small x-to-y coupling blows up y
- In principle: can measure by measuring tilt of beam at 4 locations
  - requires proper optics
  - x,y, and “odd-angle” wires
- In practice: problem is ill-conditioned for very flat beams…



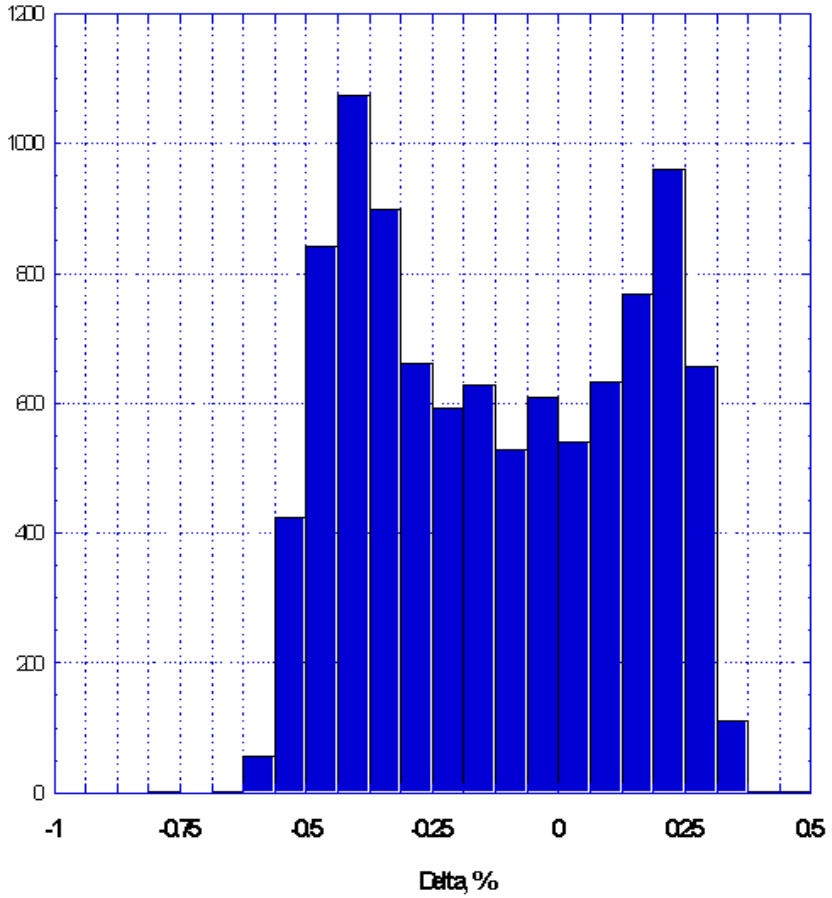
Beam Shape (Tails)

- **Wakefields and other problems can cause beam to have non-gaussian shape**
  - **“asymmetric Gaussian”**
- **Helpful to measure directly**
  - **can tune to minimize asym parameter**



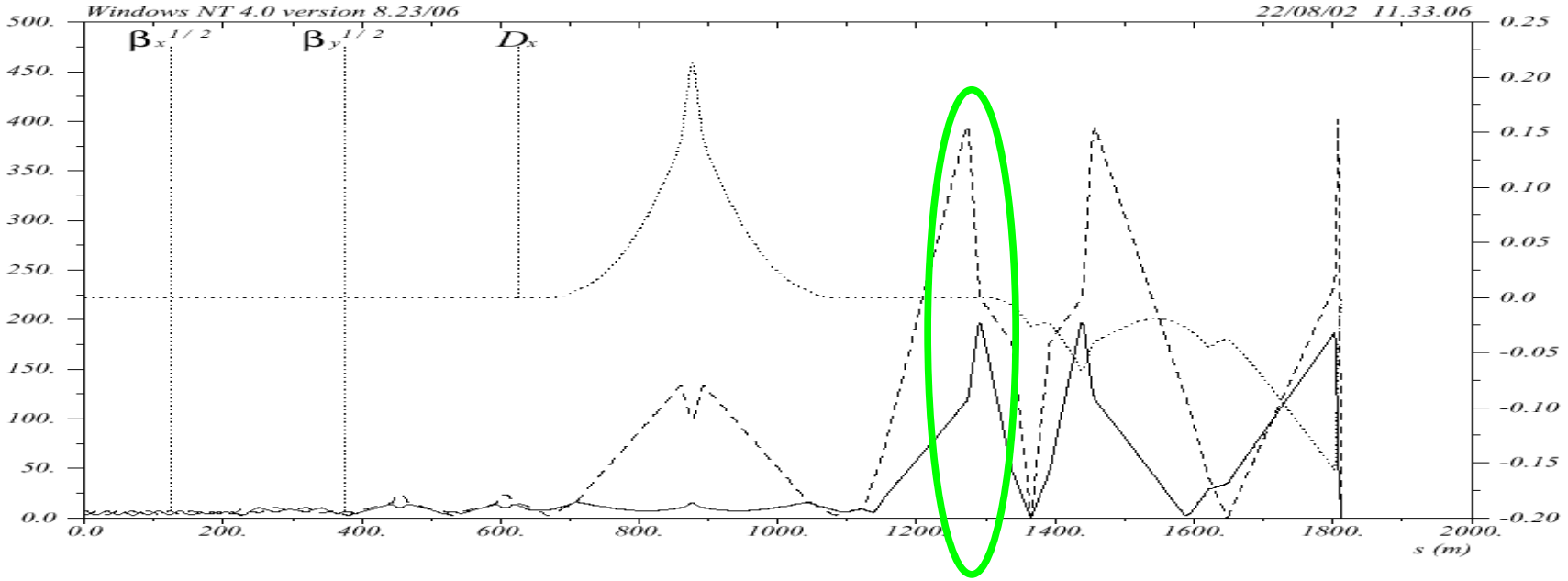
Energy Spread

- NLC, CLIC have large energy spread at end main linac
  - ~0.25%
  - odd shape ("batman" distribution)
- Measure with wire at point with high η_x and small β_x
  - size dominated by $\eta_x\sigma_\delta$ term



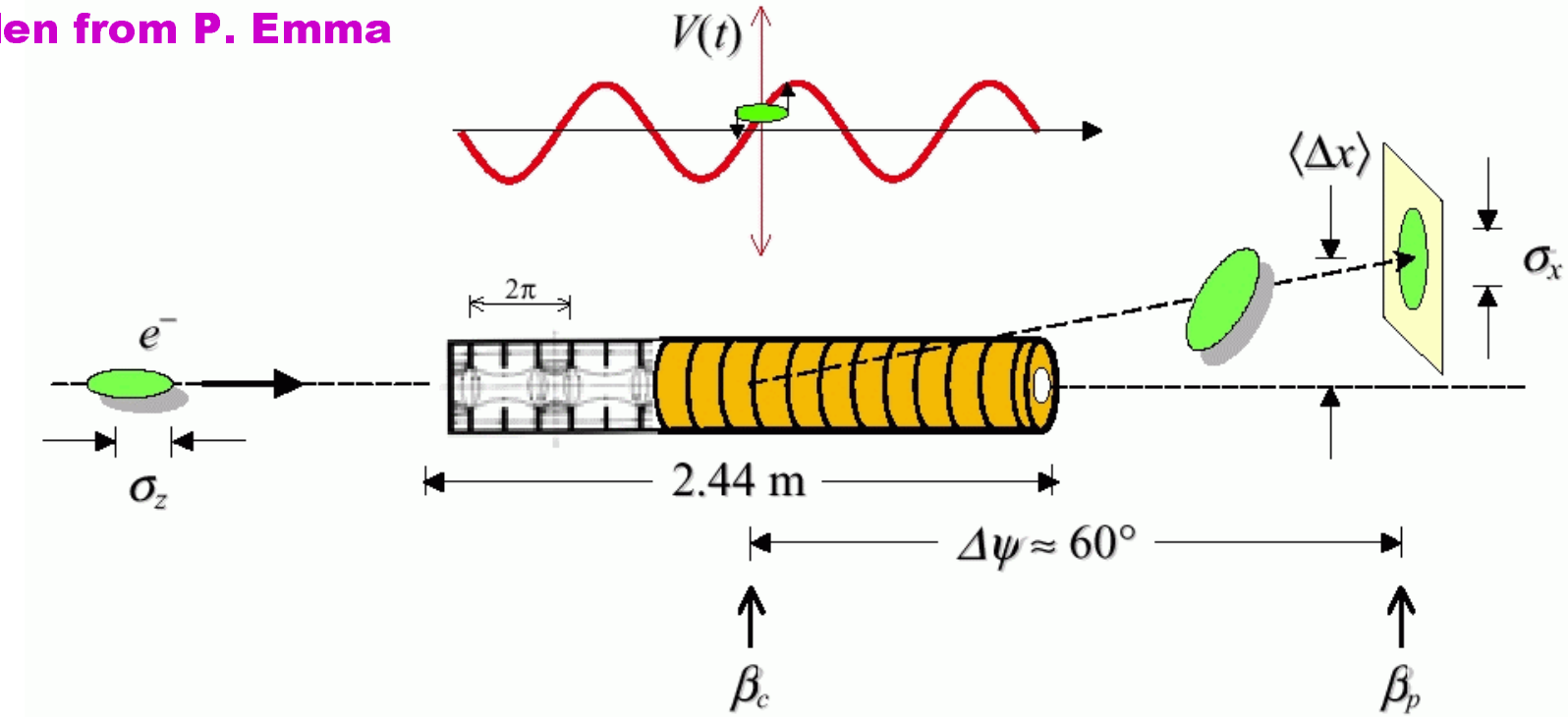
IP Angular Divergence

- How do you know you have set β^* correctly?
  - IP beam size? Too easy to mess up
    - Beam size at final doublet? $\beta^* = \varepsilon R_{34}^2 / \sigma_{wire}^2$
    - Big beam size at doublet easier to measure
    - use metal wire or laser wire?
    - beware of backgrounds from intercepting beam!



Bunch Length

Image stolen from P. Emma



RF deflector creates x'z correlation

Measure x size on downstream profile monitor

For NLC, requires indestructible monitor…

Conclusions

- **Linear Colliders require a wide variety of profile measurements**
- **Virtually all profile measurements must be non-invasive**
- **Virtually all profile monitors must be indestructible and able to resolve um-size bunch sizes**
- **Buy futures in Nd:YAG**