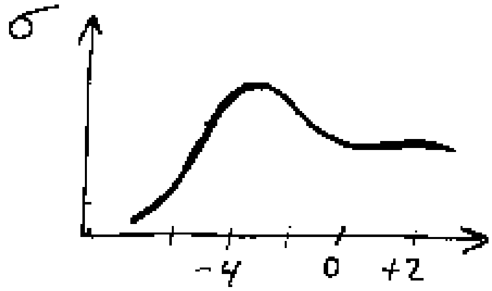
$t\bar{t}$ Threshold

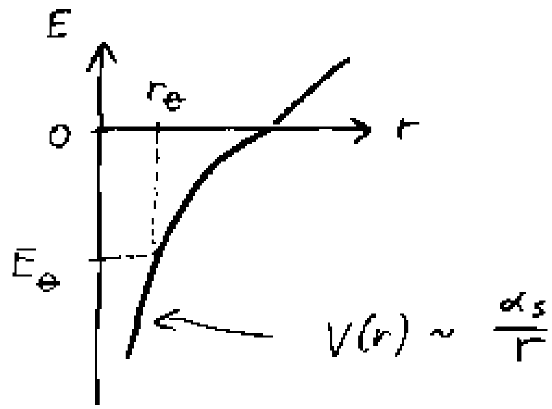
R. Frey
Oregon



$E = \sqrt{s} - 2m_t$
(GeV)

$\sigma(E)$ depends on
$m_t, \Gamma_t, \alpha_s(m_Z), m_H, \lambda_t$

λ_t: tH Yukawa coupling



Short-lived Coulombic
$t\bar{t}$ atom, ⊖ ($\Gamma_\theta \approx 2\Gamma_t$
Large $\Gamma_t \Rightarrow$ no long-dist...
effects

i.e. Clean study of short-distance QCD potential

$\Rightarrow$ only 1S clearly visib...

$r_\theta \propto 1/\alpha_s$

$\Rightarrow$ larger $\alpha_s \Rightarrow$ larger E_θ

$\therefore \alpha_s, m_t$ measurements strongly correlated in σ

$\frac{d\sigma}{dp_t}$: "top Fermi motion"
Reconstruct top momentum

$\rightarrow$ different α_s, m_t correlation

$t\bar{t}$ Threshold Curve

a – "Theory" $V_{QCD}(r) \sim C_F \frac{\alpha_s(\mu)}{r}$ $\mu \sim \alpha_s m_t \sim$ [Bohr radius]

$C_F = 4/3$

r cutoff by Γ_t^{-1}

⇒ short distance only

Fadin & Khoze (87)
Peskin & Strassler (91)
Jezabek, Kuhn, & Teubner (92)
Sumino, et al. (93)

b – + ISR $\beta = \frac{2\alpha}{\pi}[\ln(s/m_e^2) - 1] \approx 1/8$

e.g. Kuraev & Fadin (85)

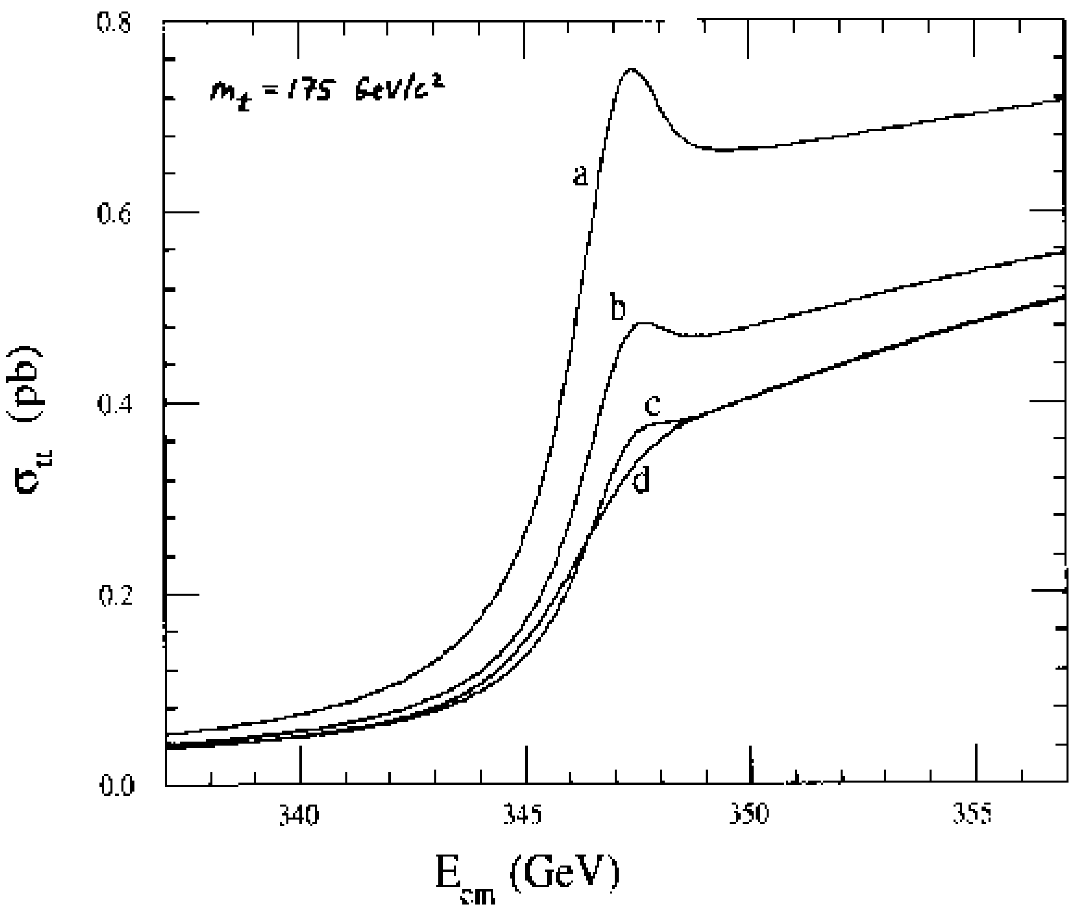
c – + beamstrahlung

← δ(1) ~ 50%

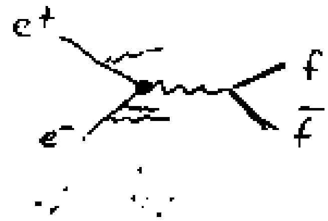
P. Chen (92)

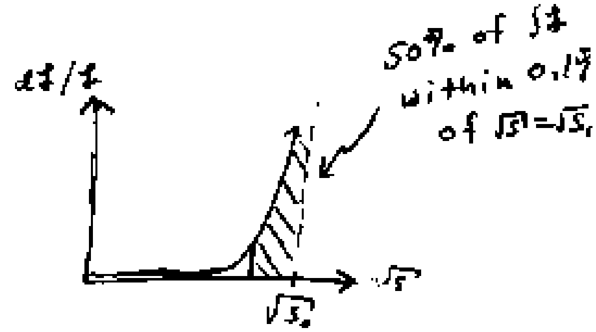
d – + $\Delta E/E)_{LINAC}$

NLC ZDR, Ch. 12 (96)

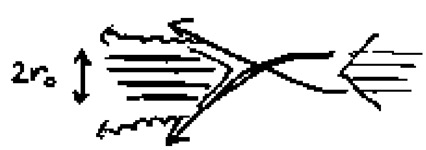


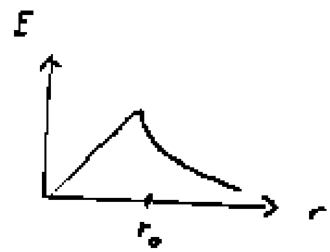
Initial-state radiation (ISR)





Beamstrahlung





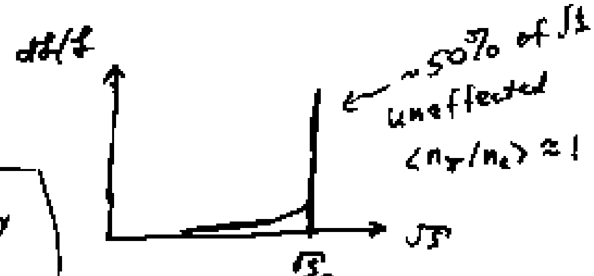
$$\Upsilon = \frac{\gamma B_b}{B_c} \approx 0.08 \text{ for NLC } \sqrt{s} = 500 \text{ GeV}$$

$\Rightarrow$ classical

$\gamma = \sqrt{s}/m_e$

B_b : beam field

$B_c = m_e^2 c^3/e\hbar = 4 \times 10^9$ T

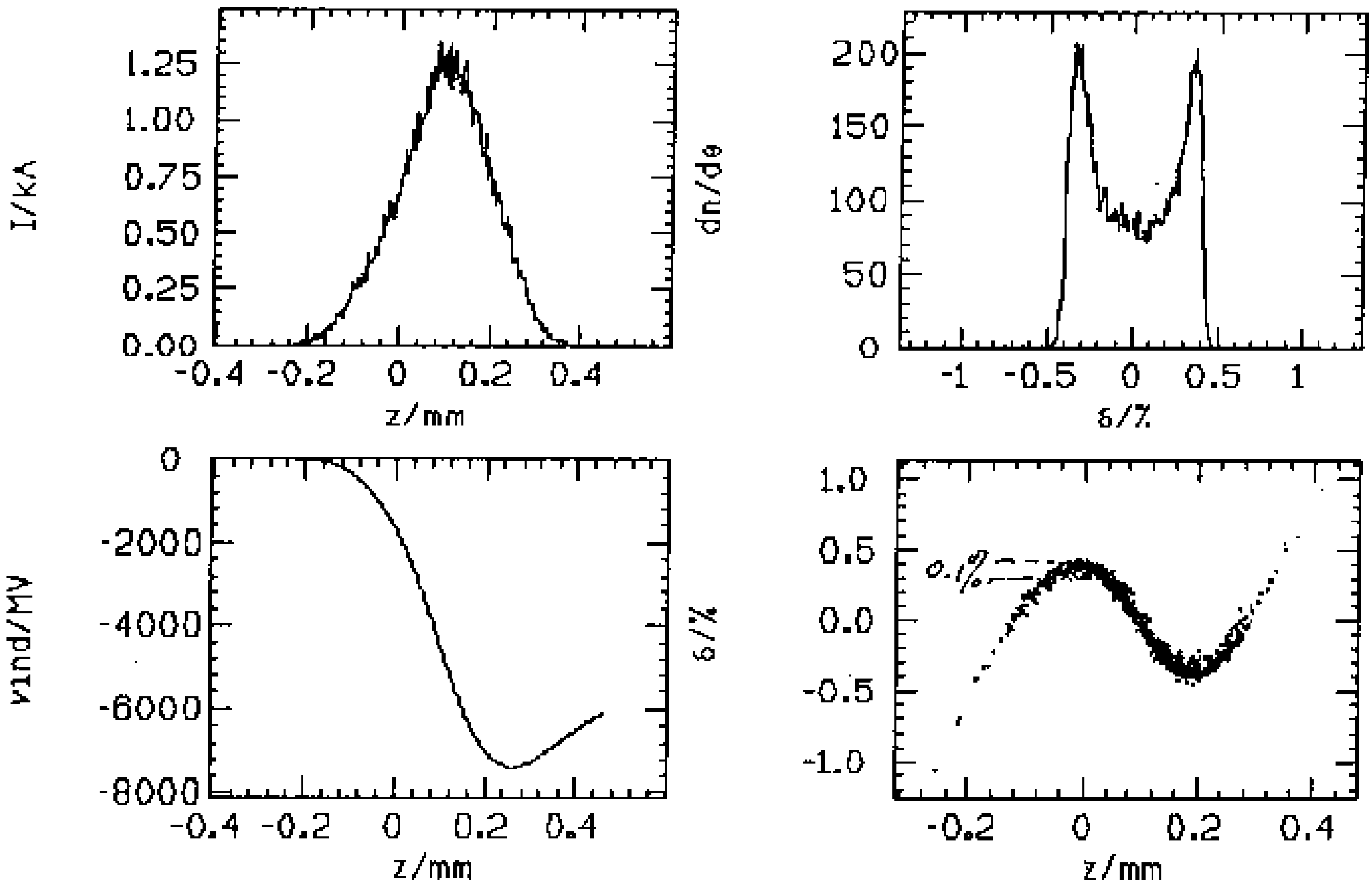


Main effect: Effective luminosity loss in tails; some smearing due to $\Delta E \gtrsim \Gamma_t$

Zimmermann
(ZDR)

BC1, Pre-acc, and BC2 - wakefield compensated with T566

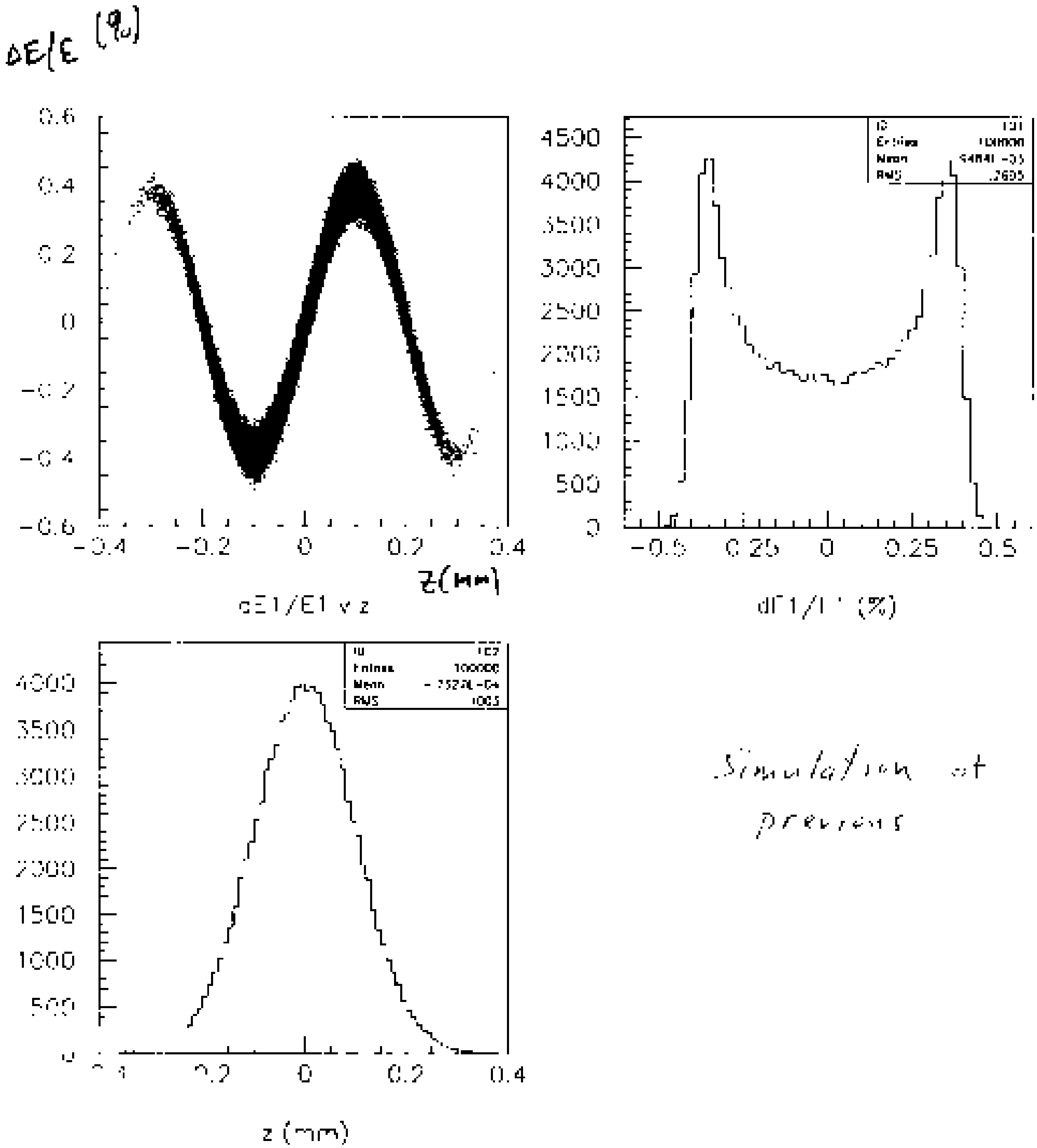
ITNOW - 8	ZOFFB/DE- 0.000	ZBAR/MM - 0.0950	EBAR/GEV-267.2497
N/1.E10 - 0.650	PHASP/DE- -15.70	SIGZ/MM - 0.1007	SIGE/E/%- 0.2709
NP - 49980	LWAK - T	ZFWH/MM - 0.2208	EFWH/E/%- 0.7995
NBIN - 280	SWAK/M - 8130.00	DZBN/MM - 0.0025	de/dz /%- -0.17
V/1.E6 -270323.0	R56/M - -0.0360	IHNN/KA - 0.6401	YNN - 0.72



LUMPXLN 20AUG95 18:03:20

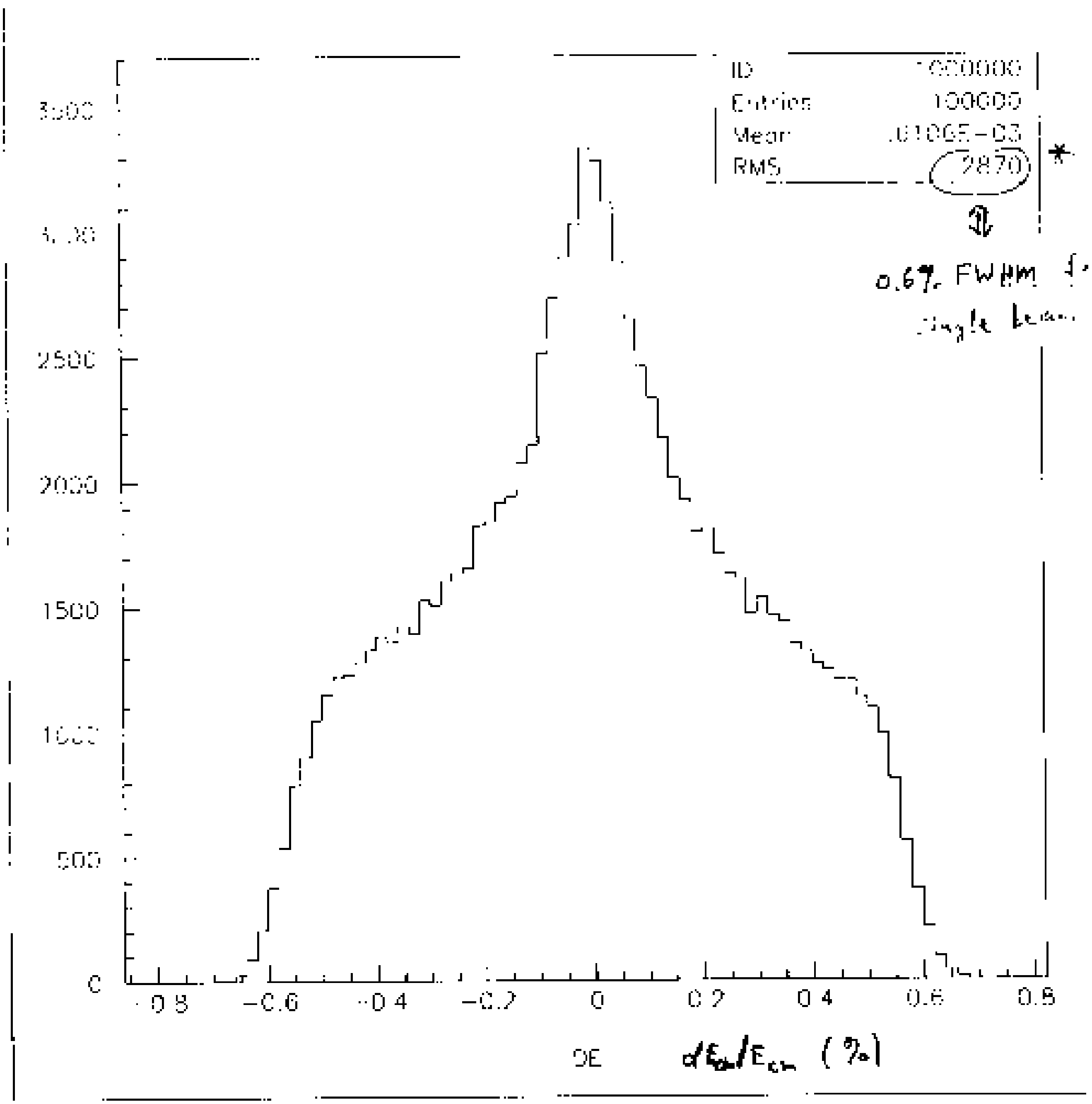
Also 0.2% bunch-to-bunch energy spread - FZ

$\delta = \Delta E_{beam} / E$

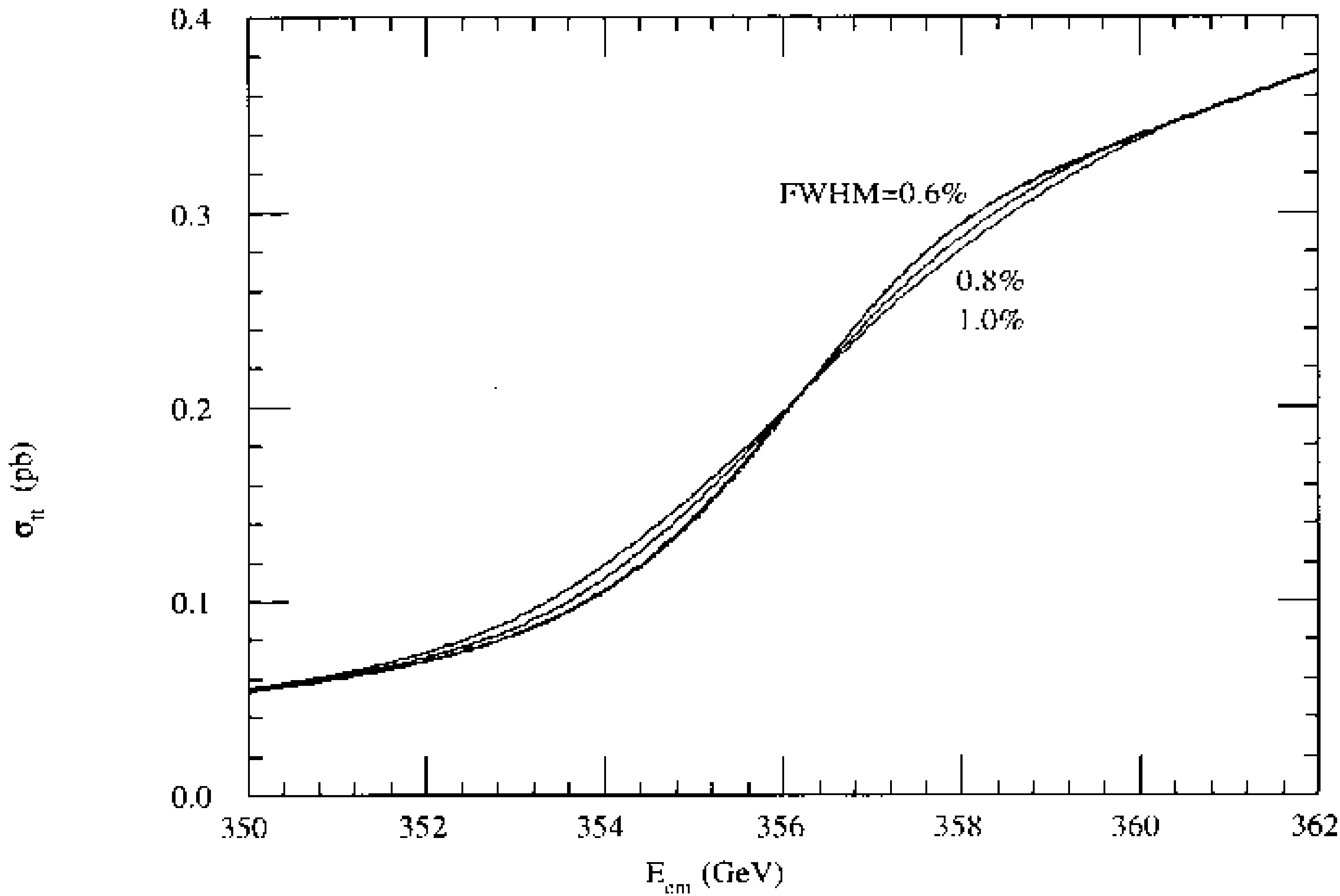


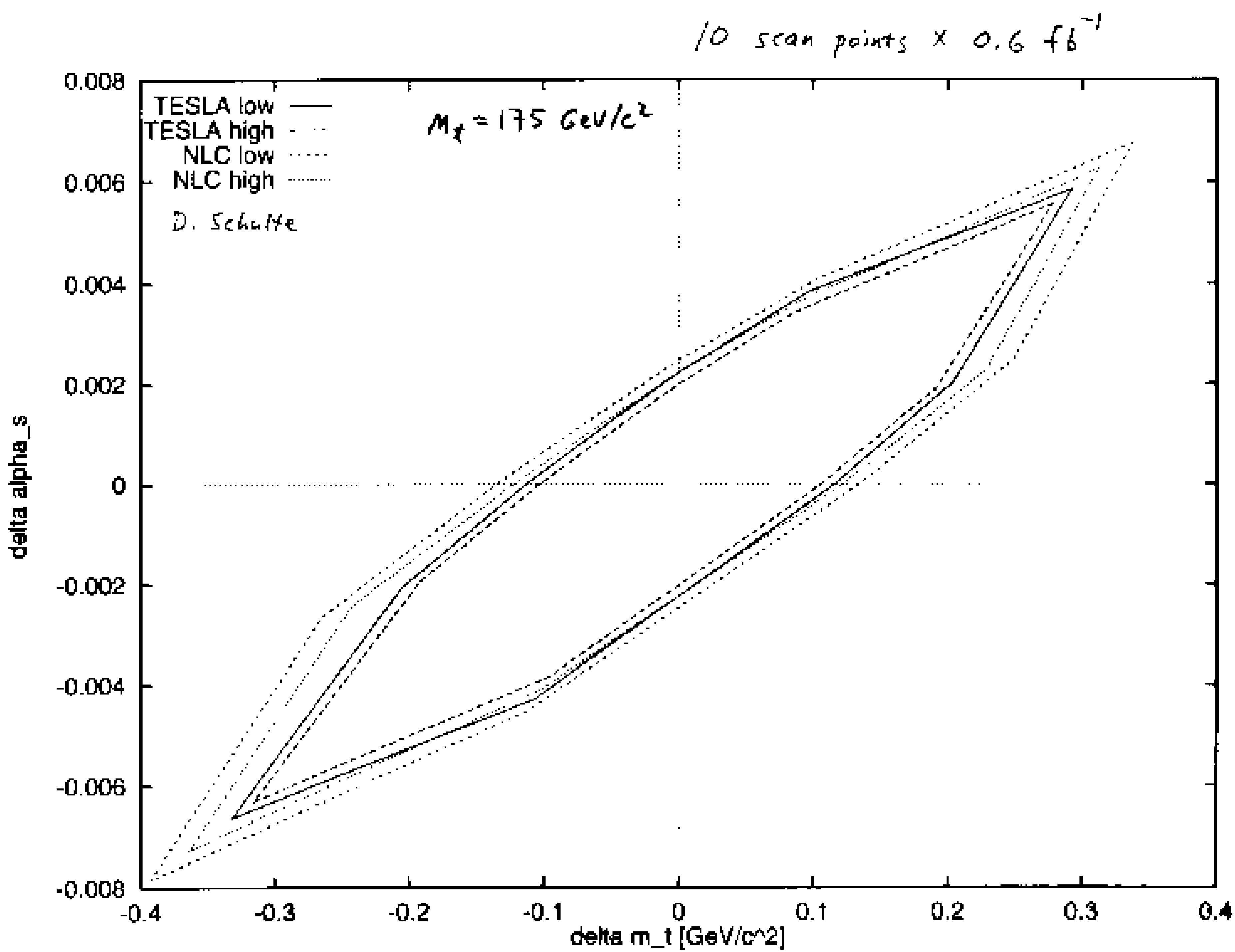
Simulation of previous

Linac $\Delta E/E|_{e^-} \otimes \Delta E/E|_{e^+}$ at IP



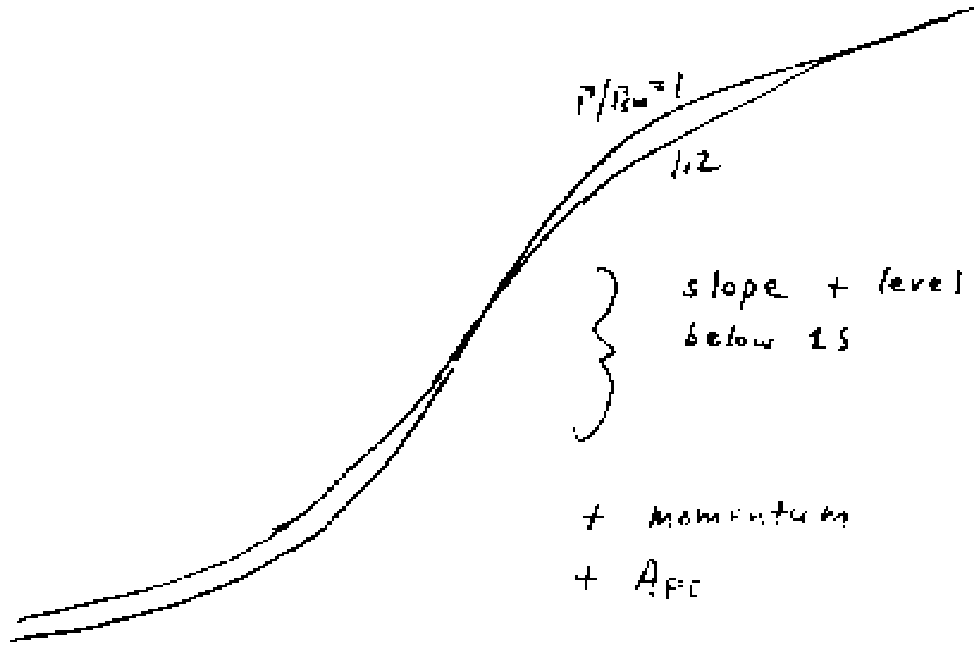
* Can use gaussian with same RMS


0.4
0.3
0.2
0.1
0.0
350
352
354
356
358
360
362
σtt (pb)
Ecm (GeV)
FWHM=0.6%
0.8%
1.0%



10 scan points x 0.6 fb^-1
M_t = 175 GeV/c^2
TESLA low
TESLA high
NLC low
NLC high
D. Schulte
delta alpha_s
delta m_t [GeV/c^2]
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4

Γ_t



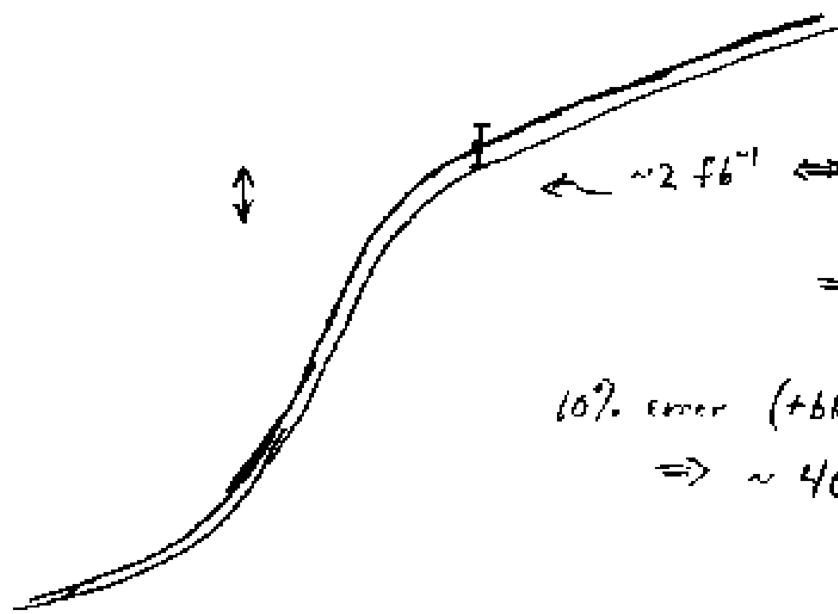
slope + level below 1S

+ momentum

+ A_{FB}

$\Rightarrow \delta\Gamma/\Gamma \approx 5-10\%$; ~ 40 fb^{-1}

λ_t

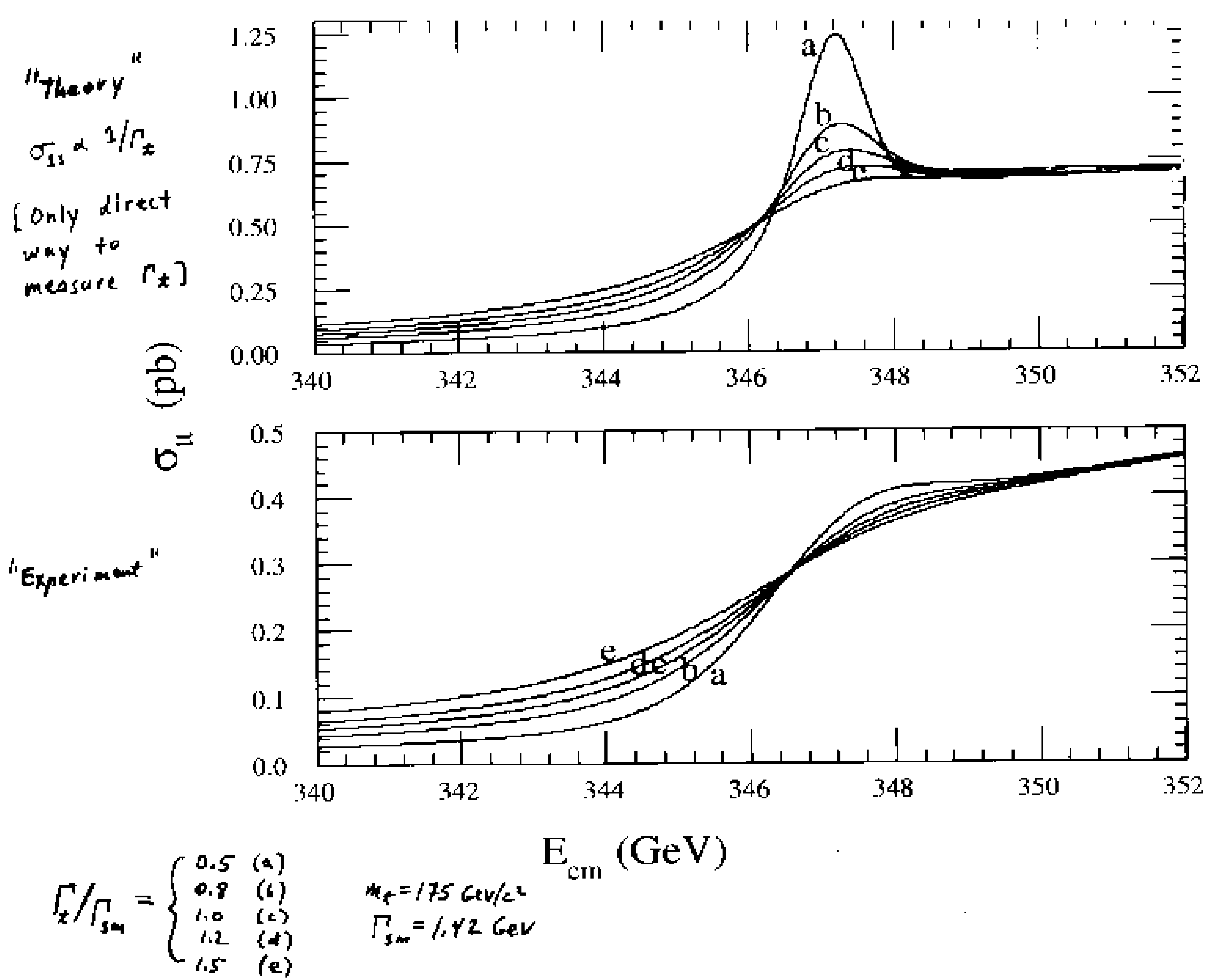


← ~2 fb^{-1} ⟺ 5% (M_H = 60 – 150 GeV/c^2)

$\Rightarrow \frac{\delta\lambda_t}{\lambda_t} \simeq 30\%$

10% error (+ bkgd. measurement)

$\Rightarrow$ ~ 40 fb^{-1}


"Theory"
$\sigma_{tt} \propto 1/\Gamma_t$
[Only direct way to measure Γ_t]
"Experiment"
σ_{tt} (pb)
1.25
1.00
0.75
0.50
0.25
0.00
0.5
0.4
0.3
0.2
0.1
0.0
340
342
344
346
348
350
352
a
b
c
d
e
E_{cm} (GeV)
Γ_t/Γ_{SM} = 0.5 (a), 0.8 (b), 1.0 (c), 1.2 (d), 1.5 (e)
$m_t = 175$ GeV/c^2
$\Gamma_{SM} = 1.42$ GeV

tH Yukawa coupling at threshold

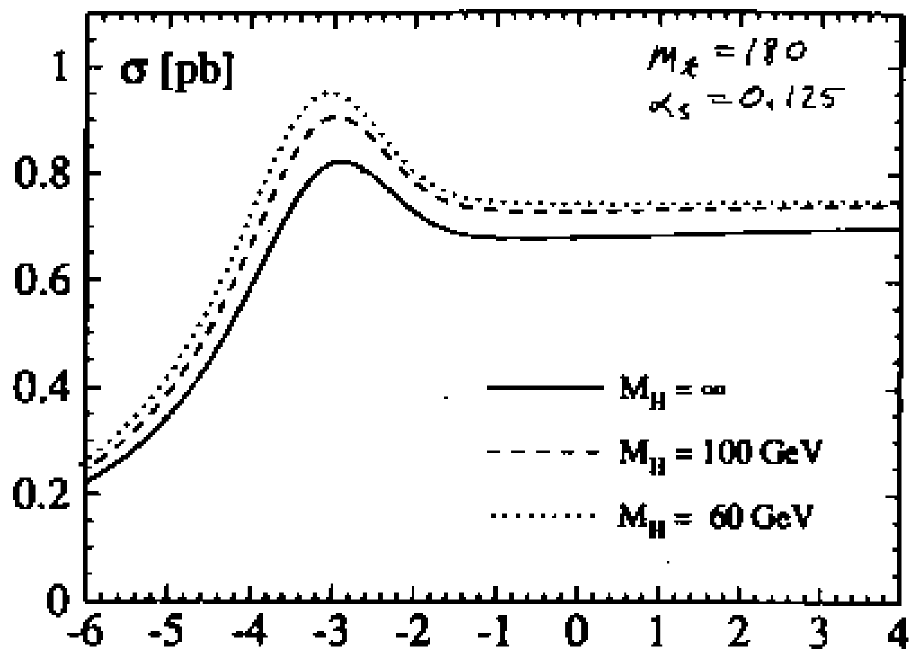
$$V(r) = V_{QCD} + V_Y \ , \quad V_Y = -\frac{\lambda^2}{4\pi}\frac{e^{-m_H r}}{r} \ ,$$

$$\lambda^2 = \sqrt{2}\, G_F\, m_t^2 \cdot \beta_H^2$$

$(\beta_H = 1 \ , \ \text{MSM}$

- very short range rel. to QCD
  $\Rightarrow$ no effect on m_θ
- does effect $|\psi(0)|^2 \Rightarrow \sigma$ enhanced

Harlander, Jazabek, & Kühn '95



→ Sensitive to m_H with $10\ fb^{-1}$

→ (Need m_t, α_s Known) ←

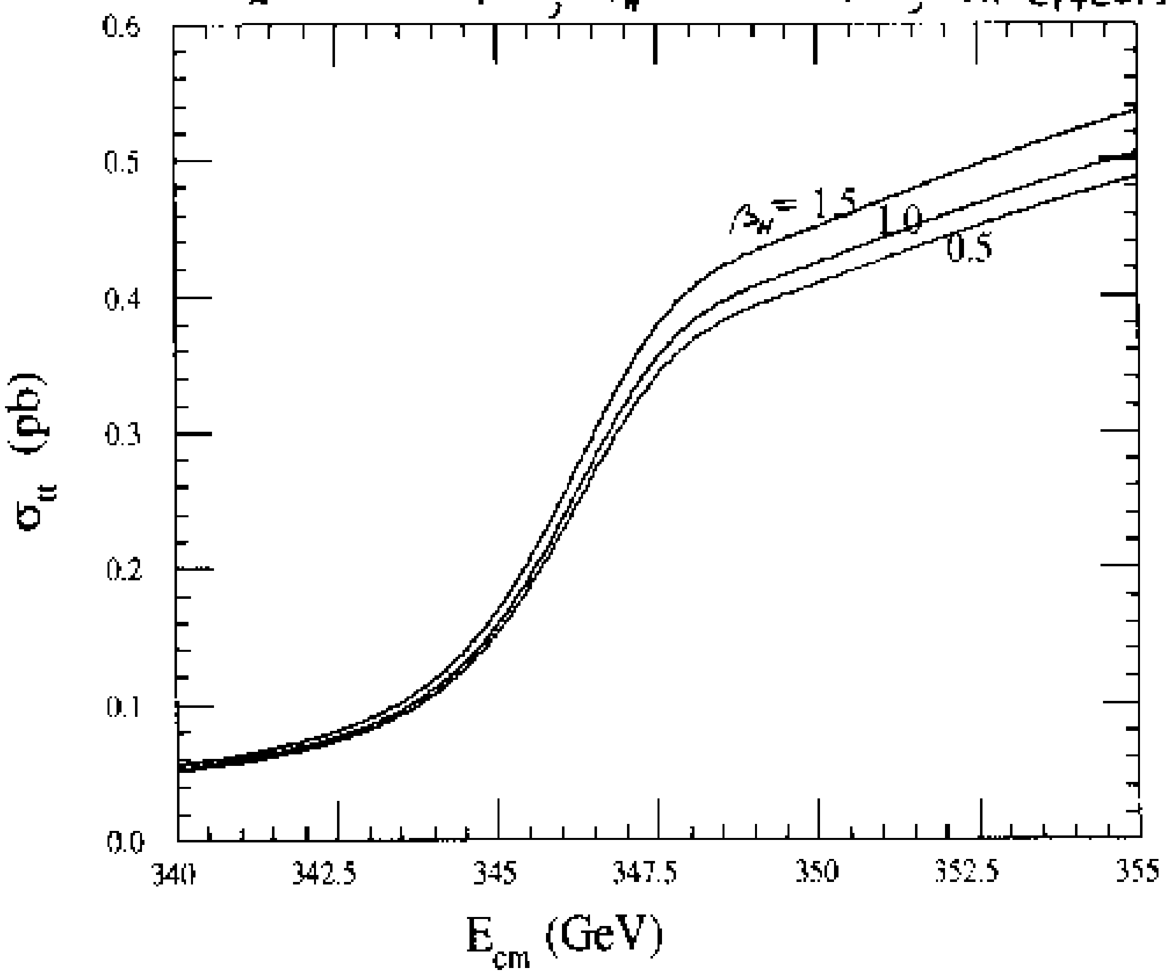
$$V(r) = V_{QCD} + V_Y ,$$

$$V_Y = -\frac{\lambda_t^2}{4\pi}\frac{e^{-m_H r}}{r}$$

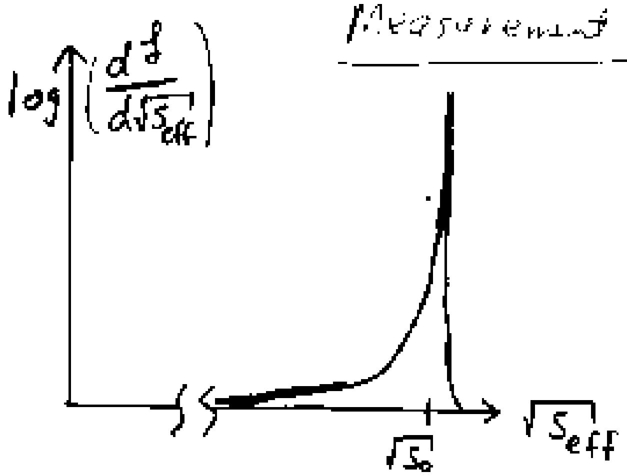
$$\lambda_t = \left[\sqrt{2}\,G_F\right]^{1/2} \beta_H m_t = \beta_H m_t / v_H$$

$$\beta_H = \begin{cases} 1 , & \text{MSM} \\ a/\sin\beta + b/\tan\beta , & \text{2HDM (SUSY)}, \tan\beta = v_2/v_1 \\ \text{etc.} & \end{cases}$$

$m_t = 175$ GeV/c^2 , $m_H = 300$ GeV/c^2 ; all effects



Measurement of Lum. Spectrum



Need to determine $\frac{d\mathcal{L}(\sqrt{s_0})}{d\sqrt{s_{eff}}}$ to convert data at scan point $\sqrt{s_0}$ to σ.

Method outlined by Frary & Miller [DESY-92-123A]:

- Measure p_+^0, p_-^0 $\rightarrow$ $\sqrt{s_0} = 2\sqrt{p_+^0 p_-^0}$ using SLC-like beam spectrometers.

  SLC $\rightsquigarrow$ $\frac{25\text{ MeV}}{90\text{ GeV}} = \frac{100\text{ MeV}}{360\text{ GeV}}$ $\leftarrow$ NLC

- Measure Bhabha acollinearity distribution

  $$\theta_A \simeq \left(\frac{p_+ - p_-}{p}\right)\sin\theta$$

  > rate = 100 R, $30 \leq \theta < 80$ mrad

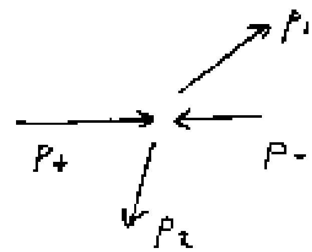
  > Si-W cal., e.g.

- model ISR ⊕ BS ⟺ $dN/d\theta_A$
  ⊕ $\Delta E_{cm}/E_{cm}$

* chromatic effects for beam energy measurement?

* BS spectrum depends on beam parameters (changeable) and beams offset (changeable).

Measuring a final-state acollinearity process.



① 2 → 2 process

② precise θ_A measurement

$$\delta E \simeq \frac{p_{beam}}{\sin\theta} \delta\theta_A$$

$\Rightarrow \delta\theta_A \lesssim 1$ mrad

inner pt $\delta x \sim 50\mu m$ (tracker)
outer pt $\delta x \sim 500\mu m$ (Si-W cal.?)

③ rate

Frary and Miller

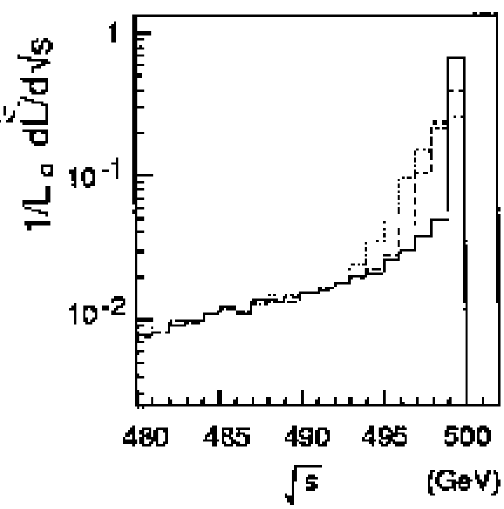
Table 3: Approximate rates for possible luminosity and signal processes

Process	Rate	Comment
Bhabha 180-300 mr.	223R	Endcap. Best statistics, adequate precision.
Bhabha 300-800 mr.	104R	Intermediate
Bhabha 800-2341 mr	8R	Barrel. Lower statistics, good precision.
$\mu^+\mu^-$	R	Low statistics, good precision.
$Z^0\gamma$	30R	Reasonable statistics. Should study further.
W^+W^-	12R	Reasonable statistics. Poor precision.
Two real γ	2R	Low statistics, reasonable precision.
$t-\bar{t}$	$\sim R$	Signal.

$$\left[\ R = \sigma/\sigma_{pt}\ ,\ \sigma_{pt} = 0.087\,pb/s(TeV^2) \approx 1\,pb\ \right]$$

JLC Lum. Spectrum Study

$10\, fb^{-1}$



MC WAB sample used to reconstruct $d\mathcal{L}/d\sqrt{s}$ for various θ_A resolutions

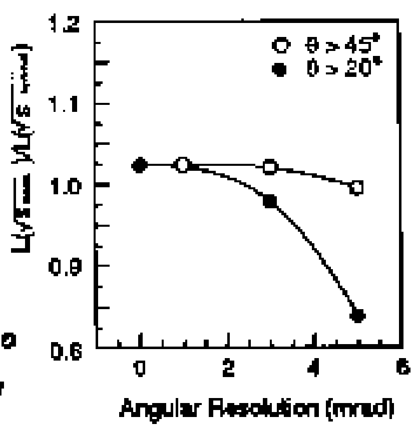
——— perfect

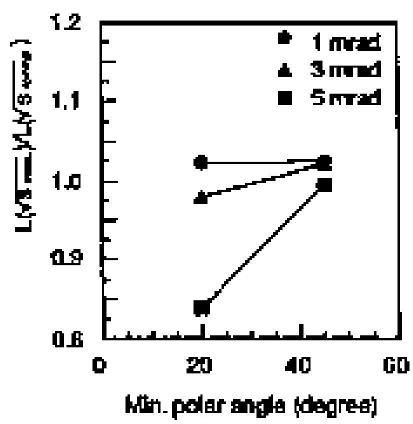
– – – $\delta\theta_A = 3$ mrad

······ $\delta\theta_A = 5$ mrad

$\dfrac{L_{meas}}{L_{nom}}$

for $495 < \sqrt{s} < 500$ GeV

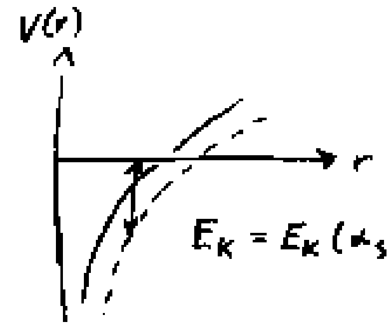


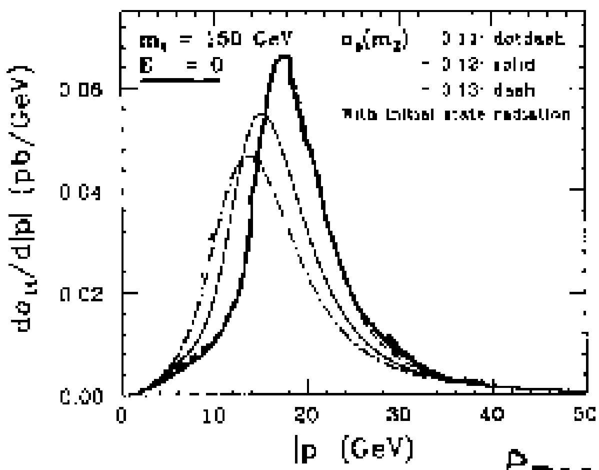


For physics, especially $t\bar{t}$ threshold, want to preserve "δ-function" at $\sqrt{s} = \sqrt{s_0}$

$$\Rightarrow \begin{cases} \delta\theta_A \lesssim 2 \text{ mrad in barrel} \\ \delta\theta_A \lesssim 1 \text{ mrad in endcap} \end{cases}$$

Top Momentum Distribution





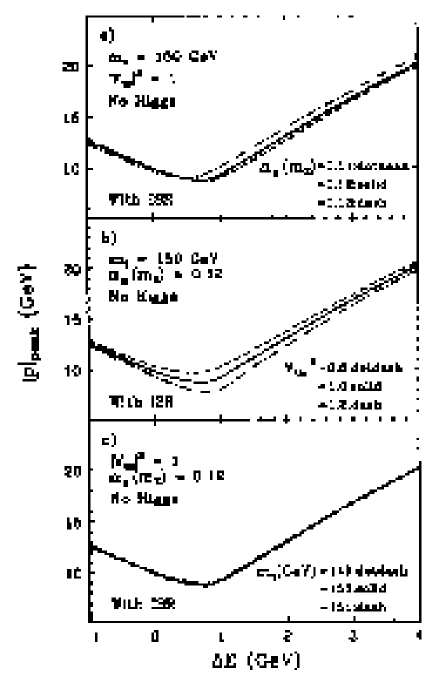
p_{Top}

$\alpha_s(m_Z^2) = 0.12$

$\alpha_s(m_Z^2) = 0.13$

parameterize by p_0, the mom. at peak of distrib

p_0



α_s

V_{tb} (or Γ_t)

m_t

Fujii, Matsui, & Sumino (94)

$\Delta E = \sqrt{s} - \sqrt{s_{th}}$