Effect of Beamstrahlung in Higgs Measurement

Ikuo Ueda
(ICEPP, University of Tokyo, Japan)

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- Introduction
- Effect on $\sqrt{s}$
- Effect on Recoil Mass
- Effect on Selection Efficiency
- Summary & Conclusion

Introduction

Beam focalization at the IP

– increases luminosity significantly.

– increases charge density of the beams.

$\Downarrow$

Significant "beamstrahlung".

broadening energy spectrum

Beamstrahlung reduces energy of electrons and positrons in the beams independently.

- $\sqrt{s}$ will decrease from the nominal value.
  $\Rightarrow$ Wrong energy constraint in the analysis.
  $\Rightarrow$ Increase of apparent recoil mass.
- Lab. system $\neq$ CM system
  $\Rightarrow$ Boost of produced Z and H bosons.
  $\Rightarrow$ Effect on Selection Efficiencies.

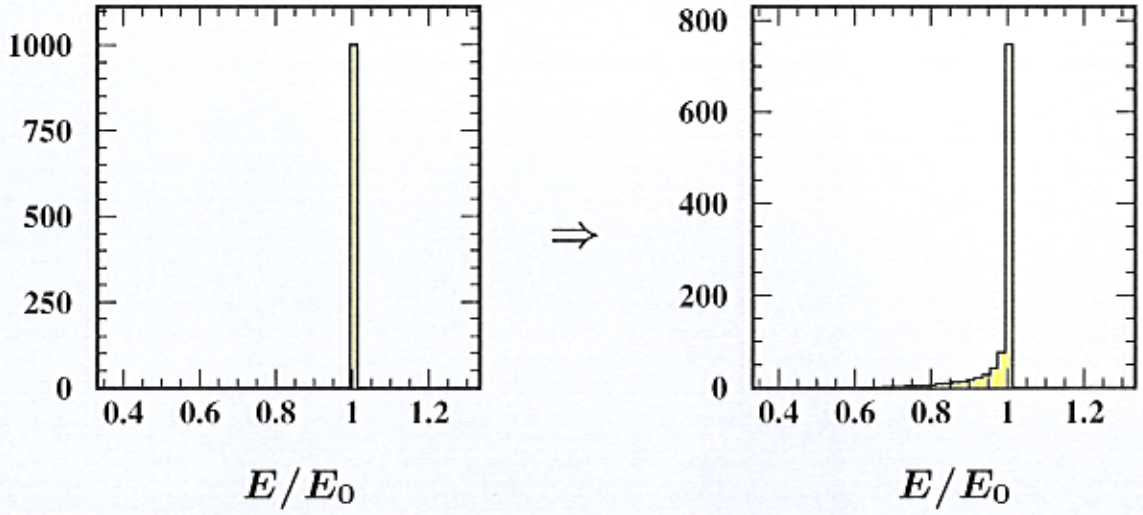
Beamstrahlung

Beamstrahlung:

The particles of one beam produce the synchrotron radiation in the electromagnetic field of on-coming beam and lose their energy.

The beam energy spectrum broadened by beamstrahlung can be parametrised using;

$$\frac{N_b}{\sigma_x^* + \sigma_y^*}, \quad \frac{E_0}{\sigma_z}$$

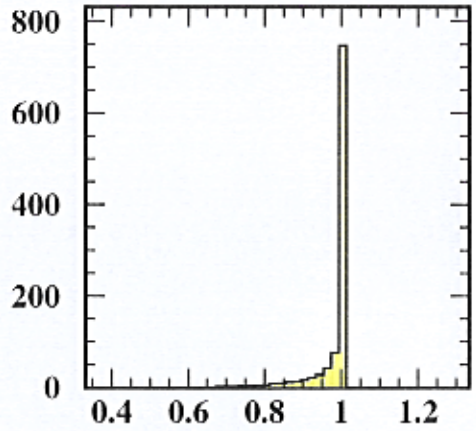


(Energy spectrum is calculated using the function written by N.Toomi)

Beamstrahlung

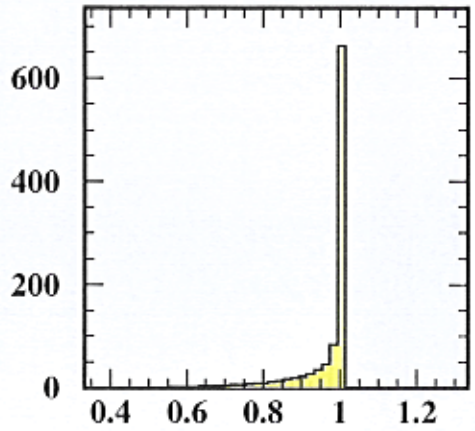
The average energy loss induced by beamstrahlung:

$$\delta_{BS} = \delta_{BS}\left(\frac{N_b^2}{(\sigma_x^* + \sigma_y^*)^2}, \frac{E_0}{\sigma_z}\right)$$



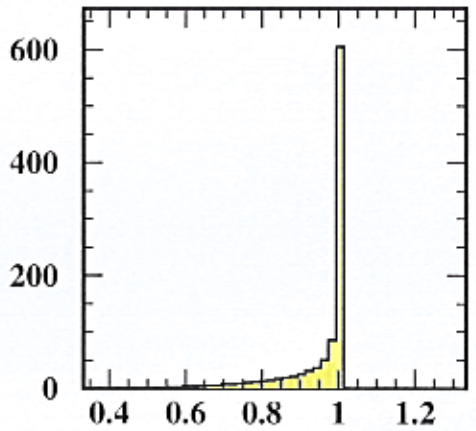
$E_0 = 150\text{GeV}$
$N_b = 0.63 \times 10^{10}$
$\sigma_x^* = 260\text{nm}$
$\sigma_y^* = 3\text{nm}$
$\sigma_z = 90\mu\text{nm}$

$\left(\frac{N_b/0.63\times10^{10}}{\sigma_x^*/260\text{nm}}\right)^2$ [1.0]



$E_0 = 150\text{GeV}$
$N_b = 1.26 \times 10^{10}$
$\sigma_x^* = 368\text{nm}$
$\sigma_y^* = 3\text{nm}$
$\sigma_z = 90\mu\text{nm}$

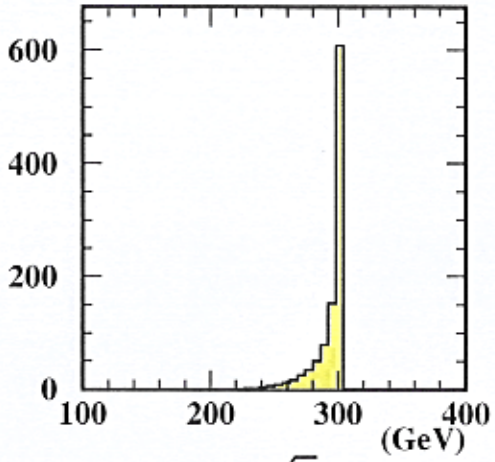
[2.0]



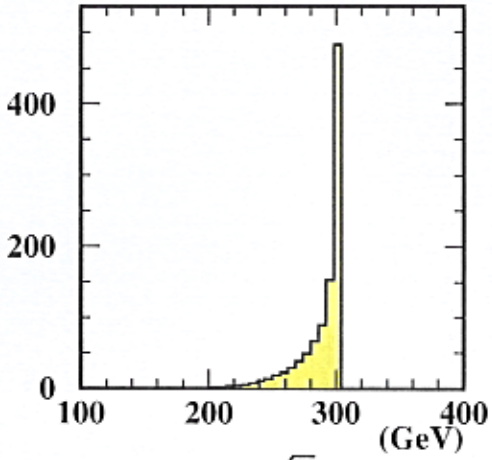
$E_0 = 150\text{GeV}$
$N_b = 1.89 \times 10^{10}$
$\sigma_x^* = 450\text{nm}$
$\sigma_y^* = 3\text{nm}$
$\sigma_z = 90\mu\text{nm}$

[3.0]

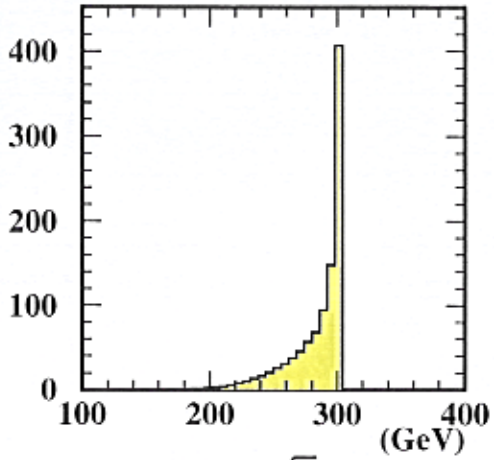
Effect on Center of Mass Energy



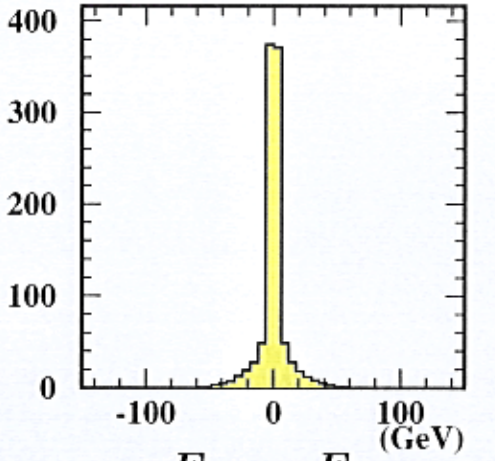
$\sqrt{s}$ [1.0]



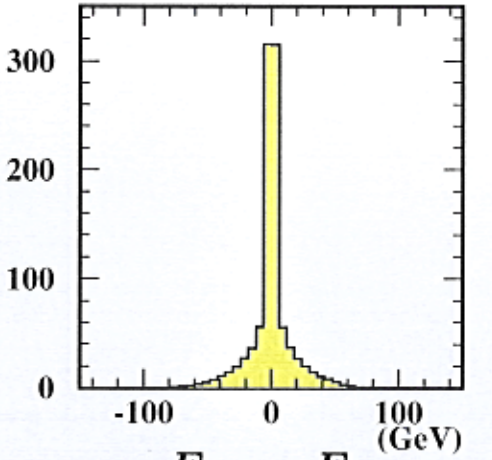
$\sqrt{s}$ [2.0]



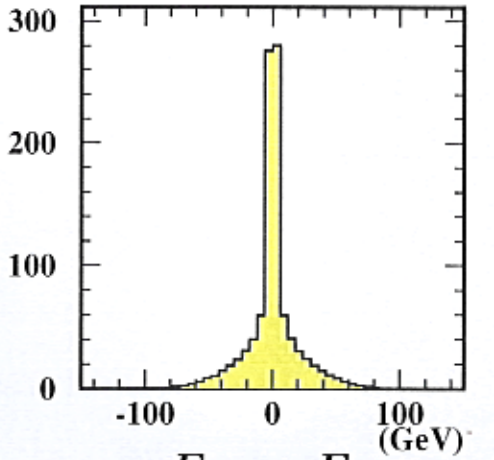
$\sqrt{s}$ [3.0]



$E_{e-} - E_{e+}$ [1.0]



$E_{e-} - E_{e+}$ [2.0]



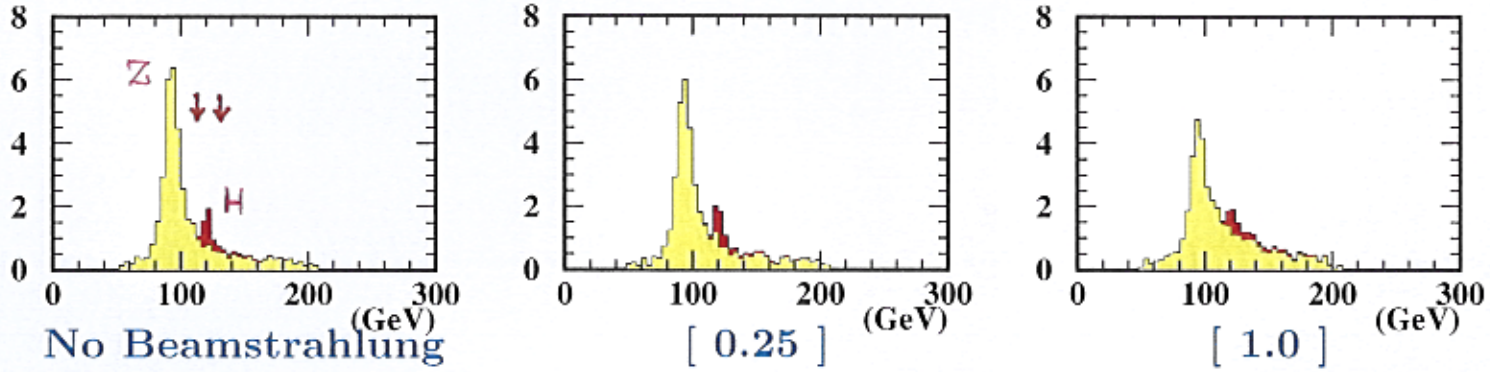
$E_{e-} - E_{e+}$ [3.0]

Effect on Recoil Mass

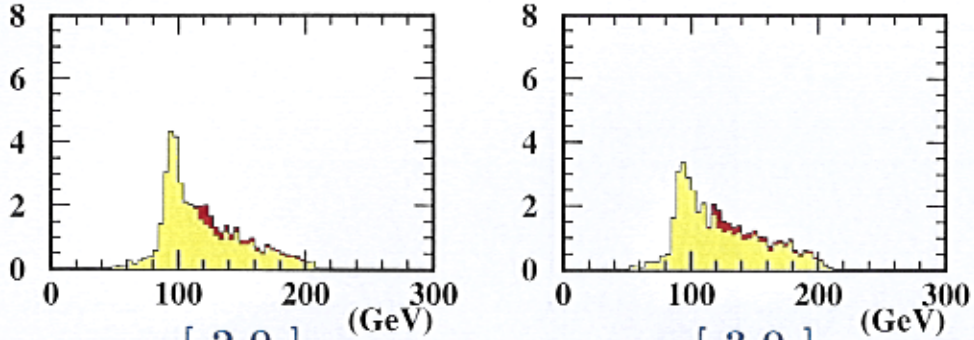
For leptonic channel,

$$m_{\ell\ell} \sim m_Z$$

$$m_{\rm recoil} = ((\sqrt{s} - E_{\ell\ell})^2 - p_{\ell\ell}^2)^{1/2}$$



No Beamstrahlung [0.25] [1.0]

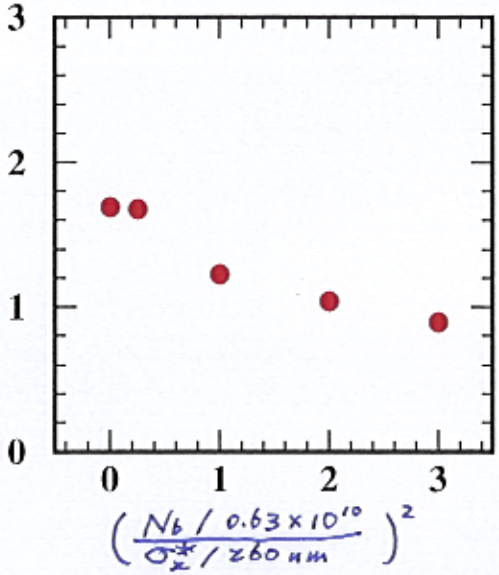


[2.0] [3.0]

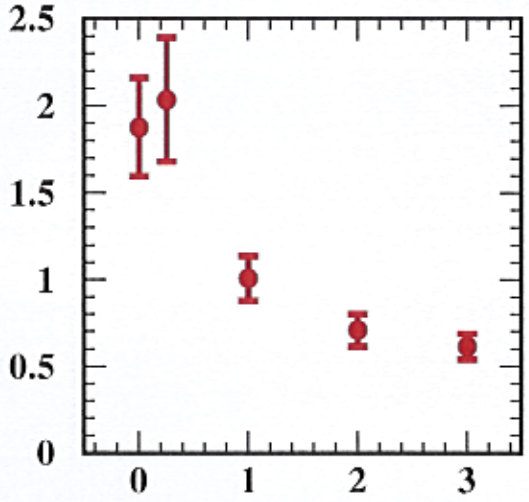
Effect on Recoil Mass

after the selection (I. Nakamura's talk)

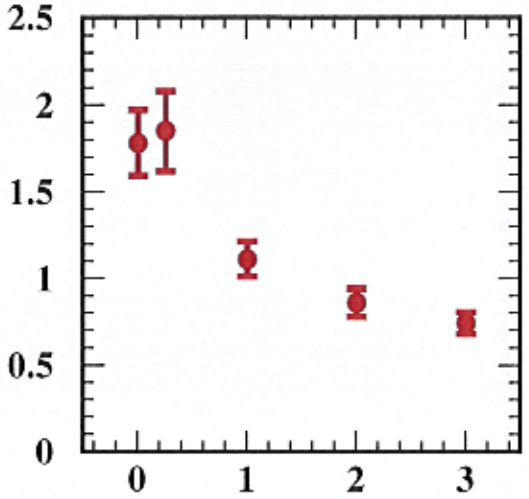
# of sig. evts / fb^{-1}



S/N



$S/\sqrt{N}$ at $1\mathrm{fb}^{-1}$



x-axis	E_{CM}(GeV)	N_b	σ_x^*(nm)	σ_y^*(nm)	σ_z(μm)
0.0	300	No Beamstrahlung			
0.25	300	0.32×10^{10}	260	3	90
1.0	300	0.63×10^{10}	260	3	90
2.0	300	1.26×10^{10}	368	3	90
3.0	300	1.89×10^{10}	450	3	90

Event Selection (w/o Beamstrahlung)

$\mathcal{L} = 100\text{fb}^{-1}1$

channel	$Z^0 \to q\bar{q}$		$Z^0 \to \nu\bar{\nu}$		$Z^0 \to e^+e^-$		$Z^0 \to \mu^+\mu^-$		Total	
signal	ε(%)	S	ε(%)	S	ε(%)	S	ε(%)	S	ε(%)	S
$e^+e^- \to Z^0h^0$	14.8	1,903	14.4	526	24.4	164	28.8	193	15.2	2,786
$h^0 \to b\bar{b}$	17.9	1,552	14.4	358	27.3	124	32.7	148	17.6	2,182
$h^0 \to c\bar{c}$	19.8	78.1	20.8	23.5	31.5	6.5	35.1	7.2	20.4	115
$h^0 \to gg$	17.4	155	29.0	74.9	33.5	15.8	37.5	17.7	20.4	263
$h^0 \to W^+W^-$	6.9	118	14.3	70.0	19.4	17.3	21.7	19.4	9.2	225
background		N		N		N		N		N
$e^+e^- \to q\bar{q}(\gamma)$		285		—		—		—		285
$e^+e^- \to WW$		497		314		—		—		811
$e^+e^- \to Z^0Z^0$		256		152		43.3		54.7		506
$e^+e^- \to e\nu W$		—		18		—		—		18
$e^+e^- \to e^+e^-Z^0$		—		—		—		—		—
Total Bkg		1,038		483		43		55		1,619
S/N		1.83		1.09		3.81		3.51		1.72
$S/\sqrt{N}$		59.1		23.9		25.0		26.0		69.2

(by I. Nakamura)

Effect on Selection Efficiency

Event Selection (w/ Beamstrahlung)

Beam Parameters @ JLC-500GeV except E_{cm} = 300 GeV

$\mathcal{L} = 100\text{fb}^{-1}$

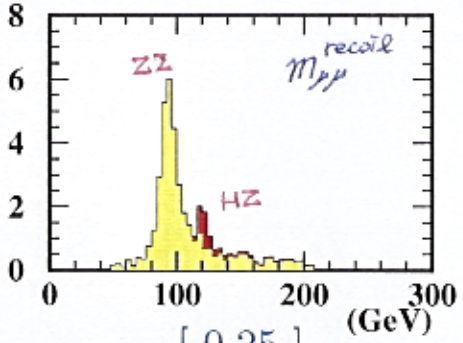
channel	$Z^0 \to q\bar{q}$		$Z^0 \to \nu\bar{\nu}$		$Z^0 \to e^+e^-$		$Z^0 \to \mu^+\mu^-$		Total	
signal	ε(%)	S	ε(%)	S	ε(%)	S	ε(%)	S	ε(%)	S
$e^+e^- \to Z^0h^0$	12.2	1,559	11.5	422	16.9	113	20.0	134	12.2	2,228
$h^0 \to b\bar{b}$	14.6	1,269	11.4	282	18.7	85.1	22.6	103	14.0	1,739
$h^0 \to c\bar{c}$	15.4	60.9	17.2	19.4	22.1	4.6	25.4	5.2	16.0	90.1
$h^0 \to gg$	14.2	128	24.0	61.9	24.4	11.5	26.4	12.4	16.6	214
$h^0 \to W^+W^-$	5.9	101	12.1	59.0	13.1	11.8	15.2	13.6	7.6	185
background		N		N		N		N		N
$e^+e^- \to q\bar{q}(\gamma)$		263		—		—		—		263
$e^+e^- \to WW$		661		511		—		—		1172
$e^+e^- \to Z^0Z^0$		239		137		63.6		71.3		511
$e^+e^- \to e\nu W$		—		26		—		—		26
$e^+e^- \to e^+e^-Z^0$		—		—		—		—		—
Total Bkg		1,163		674		64		71		1,972
S/N		1.34		0.63		1.77		1.88		1.12
$S/\sqrt{N}$		45.7		16.3		14.2		15.9		50.2

(by I. Nakamura)

Event Selection (w/ Beamstrahlung)

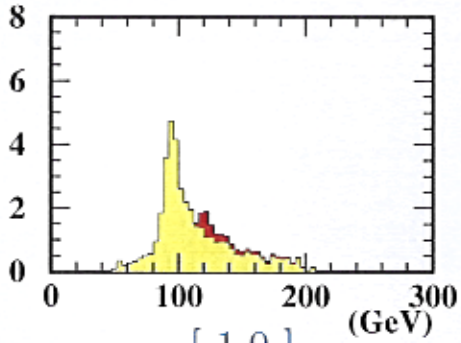
channel	$Z^0 \to q\bar{q}$	$Z^0 \to \nu\bar{\nu}$	$Z^0 \to e^+e^-$	$Z^0 \to \mu^+\mu^-$	Total
$e^+e^- \to Z^0h^0$	Efficiency (%)				
No BS	14.8	14.4	24.4	28.8	15.2
[1.0]	12.2	11.5	16.9	20.0	12.2
	−18%	−20%	−31%	−31%	−20%
background	Number of events @ $\mathcal{L} = 100\text{fb}^{-}1$				
No BS	1,038	483	43	55	1,619
[1.0]	1,163	674	64	71	1,972
	+12%	+40%	+49%	+29%	+22%
S/N					
No BS	1.83	1.09	3.81	3.51	1.72
[1.0]	1.34	0.63	1.77	1.88	1.12
	−27%	−42%	−54%	−46%	−35%
$S/\sqrt{N}$					
No BS	59.1	23.9	25.0	26.0	69.2
[1.0]	45.7	16.3	14.2	15.9	50.2
	−23%	−68%	−43%	−39%	−27%

Summary and Conclusion



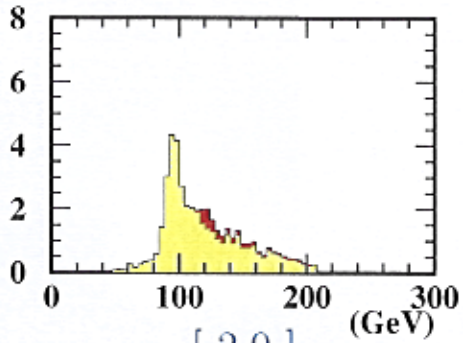
[0.25]

E_0 = 150GeV
N_b = ~~0.63~~ 0.315 $\times 10^{10}$
σ^*_x = 260nm
σ^*_y = 3nm
σ_z = 90μnm



[1.0]

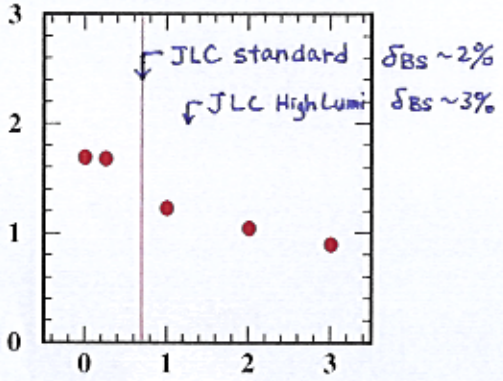
E_0 = 150GeV
N_b = 0.63 $\times 10^{10}$
σ^*_x = 260nm
σ^*_y = 3nm
σ_z = 90μnm



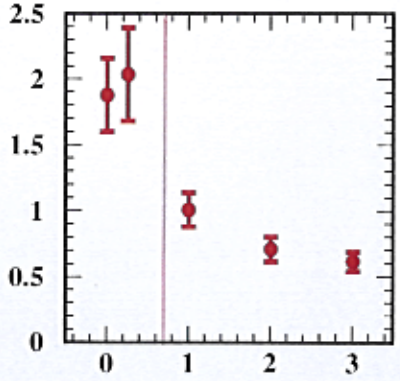
[2.0]

E_0 = 150GeV
N_b = ~~0.63~~ 1.26 $\times 10^{10}$
σ^*_x = ~~260~~ 368nm
σ^*_y = 3nm
σ_z = 90μnm

# of sig. evts / fb^{-1}



S/N



$S/\sqrt{N}$ at 1fb^{-1}