Minijet Production in Future e^+e^- Linear Colliders

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Introduction

Collision between Beamstrahlung and Bremsstrahlung photons at Interaction Point

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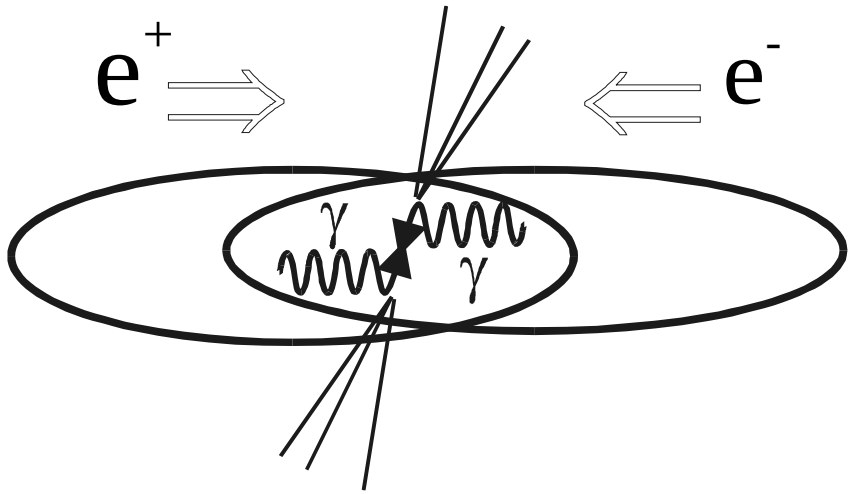
Are Minijets serious backgrounds in future e+e- linear collider?

- P.Chen et al. Phys.Rev.D49 (1994)
- R.Engel et al. Phys.Rev.D54 (1996)



Minijets in a 5 TeV Linear Collider

JLC / NLC IP Parameters

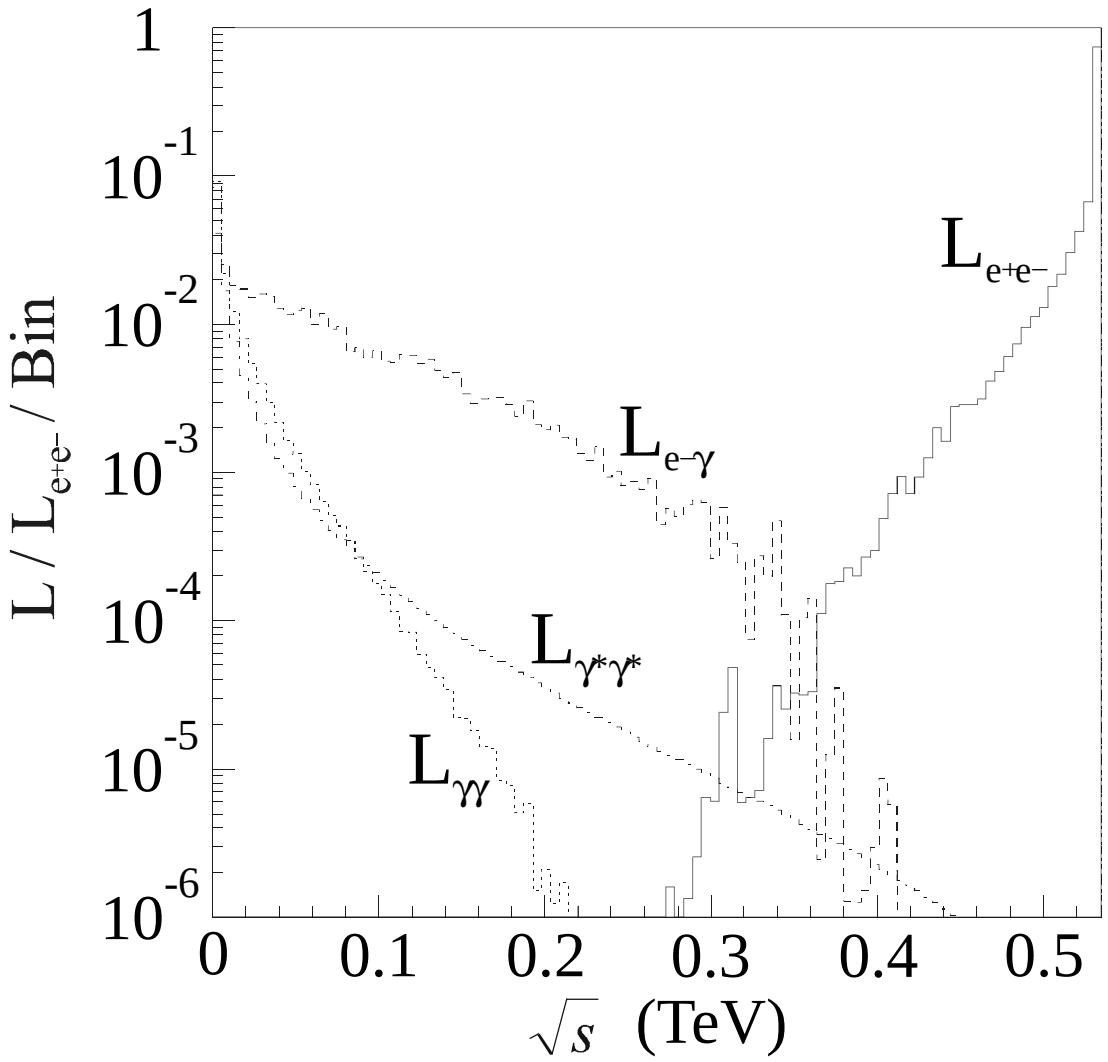
The IP parameters are calculated using the program lcopt, written by K. Yokoya, and verified with GuineaPig and analytic expressions. Parameters are listed for repetition rates of both 120 Hz and 100 Hz with the latter in parentheses.

Preliminary!! IP Parameters for the JLC /NLC (8/8/98)

	500 GeV			1 TeV		
	A	B	C	A	B	C
CMS Energy (GeV)	535	515	500	1046	1008	978
Luminosity (10**33)	7.7 (6.4)	7.0 (5.8)	6.0 (5.0)	15 (12.5)	13 (10.9)	11.6 (9.7)
Repetition Rate (Hz)	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)	120 (100)
Bunch Charge (10**10)	0.75	0.95	1.1	0.75	0.95	1.1
Bunches/RF Pulse	95	95	95	95	95	95
Bunch Separation (ns)	2.8	2.8	2.8	2.8	2.8	2.8
Injected $\gamma\varepsilon x/\gamma\varepsilon y$ (10**-8)	300/3	300/3	300/3	300/3	300/3	300/3
$\gamma\varepsilon x$ at IP (10**-8)	400	450	500	400	450	500
$\gamma\varepsilon y$ at IP (10**-8)	6	10	14	6	10	14
$\beta x/\beta y$ at IP (mm)	10/0.1	12/0.12	13/0.2	10/0.125	12/0.15	13/0.2
$\sigma x/\sigma y$ at IP (nm)	277/3.4	330/4.9	365/7.6	197/2.4	235/3.9	260/5.4
σz at IP (um)	90	120	145	90	120	145
Υave	0.14	0.11	0.09	0.38	0.3	0.25
Pinch Enhancement	1.41	1.36	1.5	1.41	1.46	1.5
Beamstrahlung δB (%)	4.5	4.0	3.6	10.9	10.3	9.7
Photons per e+/e-	1	1.1	1.17	1.3	1.43	1.51

Created: 07/05/98 by Tor Raubenheimer
Modified: 08/08/98 by Tor Raubenheimer

Luminosity Distribution of a 500 GeV Linear Collider

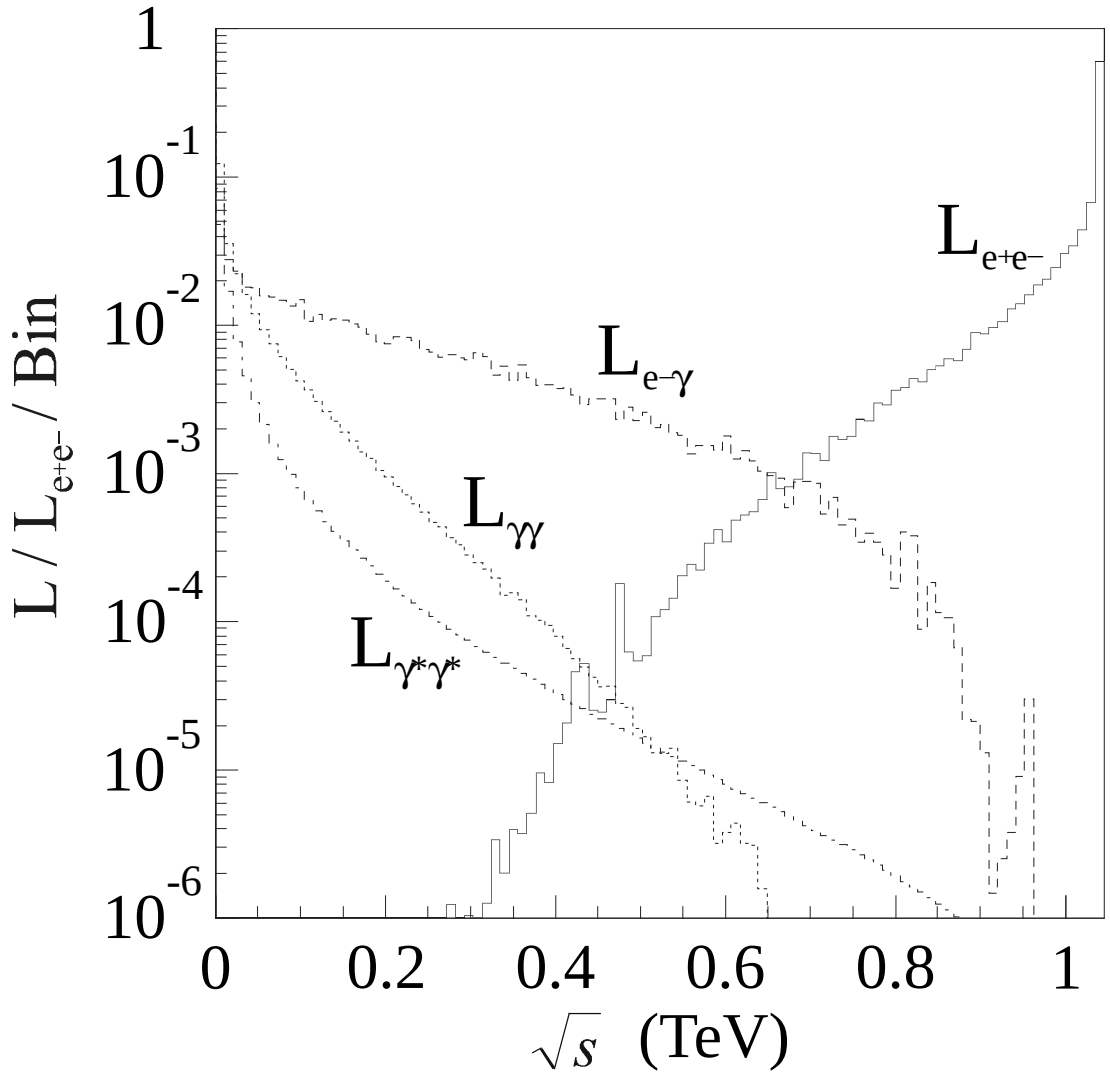


Total Luminosity (0.5 TeVA)

$$L_{ee} = 6.72 \times 10^{33} (cm^{-2} s^{-1})$$
$$L_{e\gamma} = 2.44 \times 10^{33} (cm^{-2} s^{-1})$$
$$L_{\gamma\gamma} = 1.05 \times 10^{33} (cm^{-2} s^{-1})$$
$$L_{\gamma^*\gamma^*} = 8.59 \times 10^{32} (cm^{-2} s^{-1})$$

$L_{e\gamma^*}$, $L_{\gamma\gamma^*}$, $L_{\gamma^*\gamma}$ Geometrical Reduction

Luminosity Distribution of a 1 TeV Linear Collider



Total Luminosity (1 TeV A)

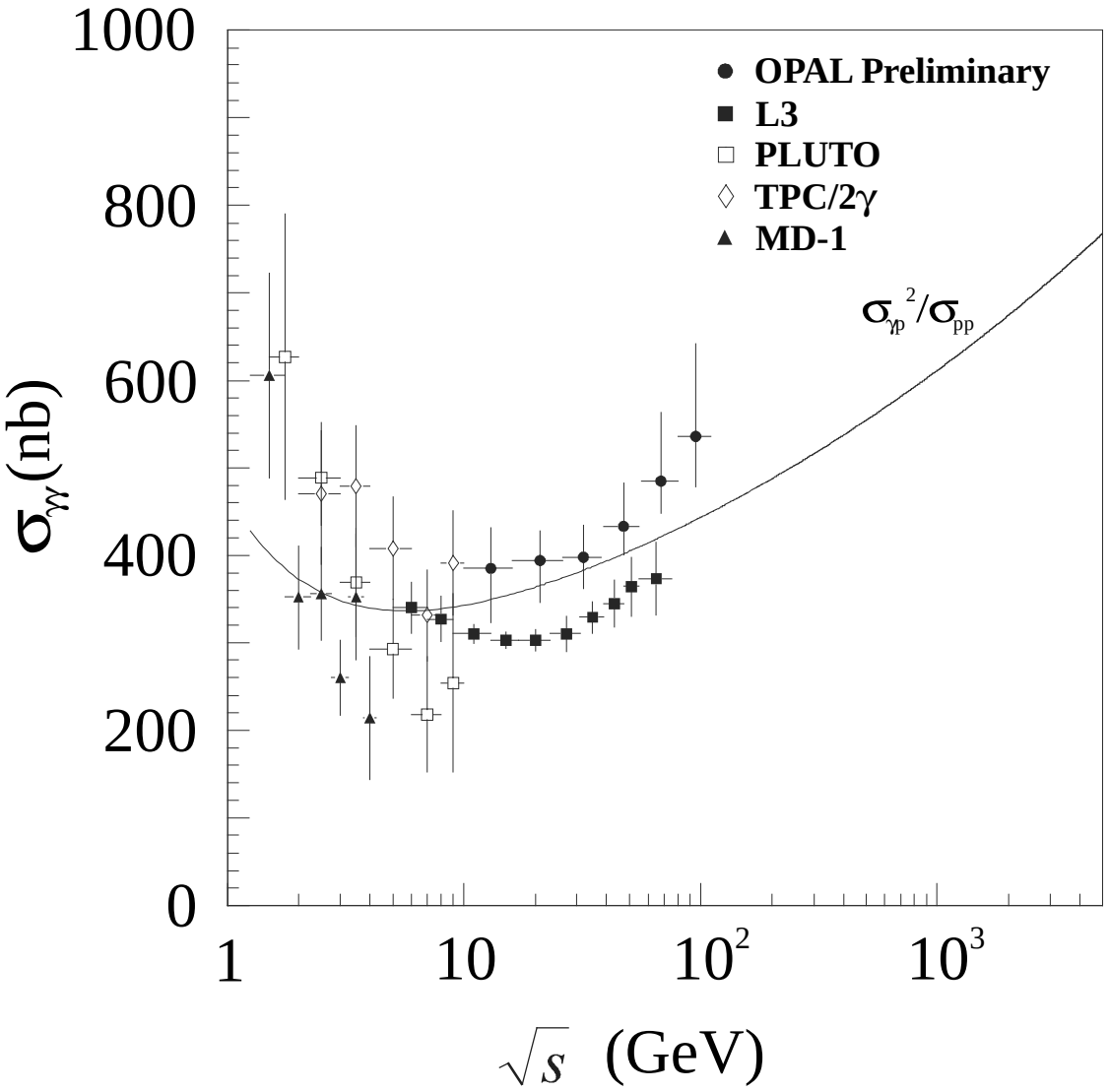
$$L_{ee} = 1.28 \times 10^{34} (cm^{-2} s^{-1})$$

$$L_{e\gamma} = 6.15 \times 10^{33} (cm^{-2} s^{-1})$$

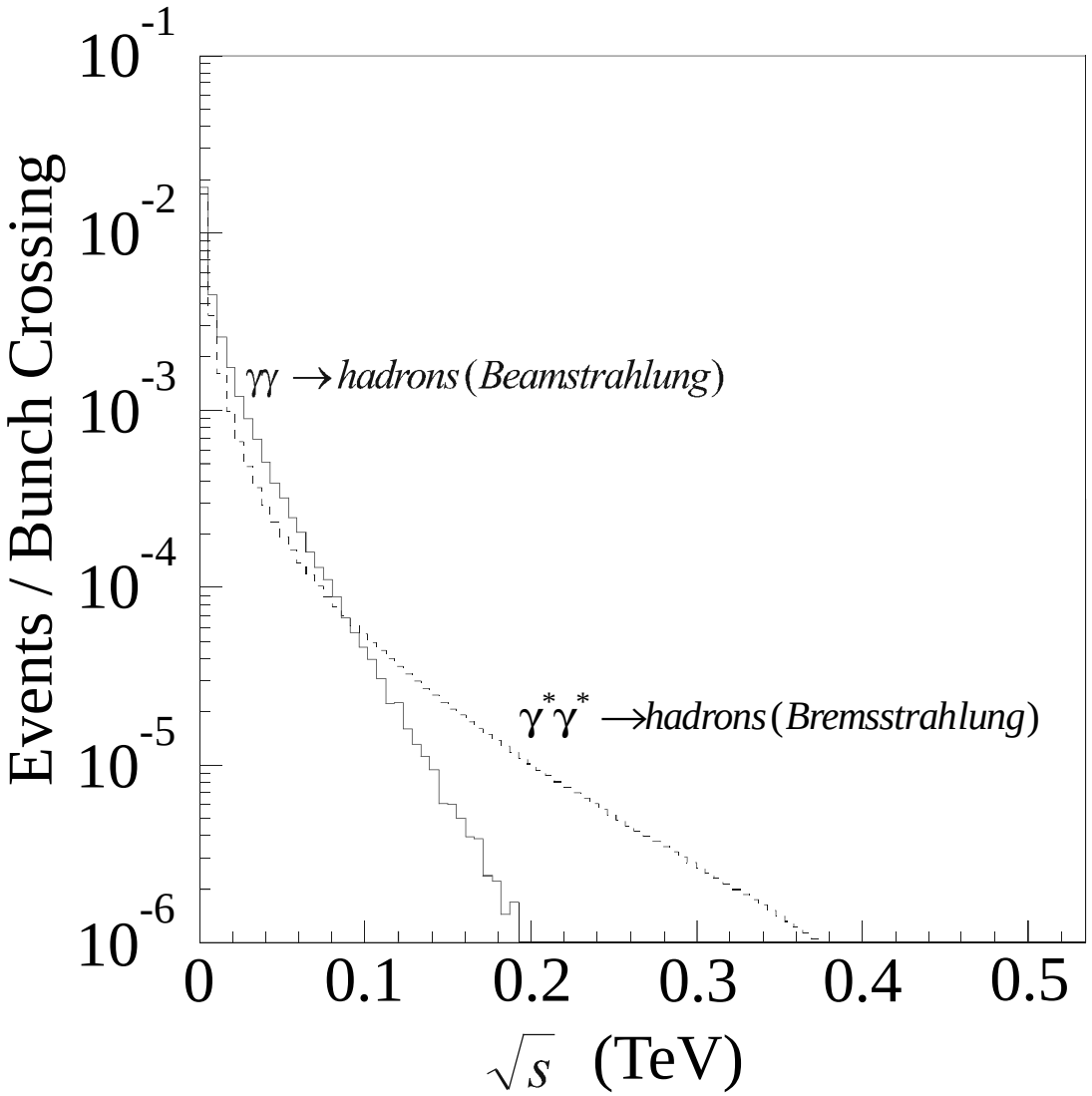
$$L_{\gamma\gamma} = 3.44 \times 10^{33} (cm^{-2} s^{-1})$$

$$L_{\gamma^*\gamma^*} = 1.64 \times 10^{33} (cm^{-2} s^{-1})$$

Experimental Data of $\gamma\gamma$ Total Cross Section



JLC/NLC 500 GeV A



$\gamma\gamma$ hadronic events

Beamstrahlung
Effective Cross Section 54.5 nb

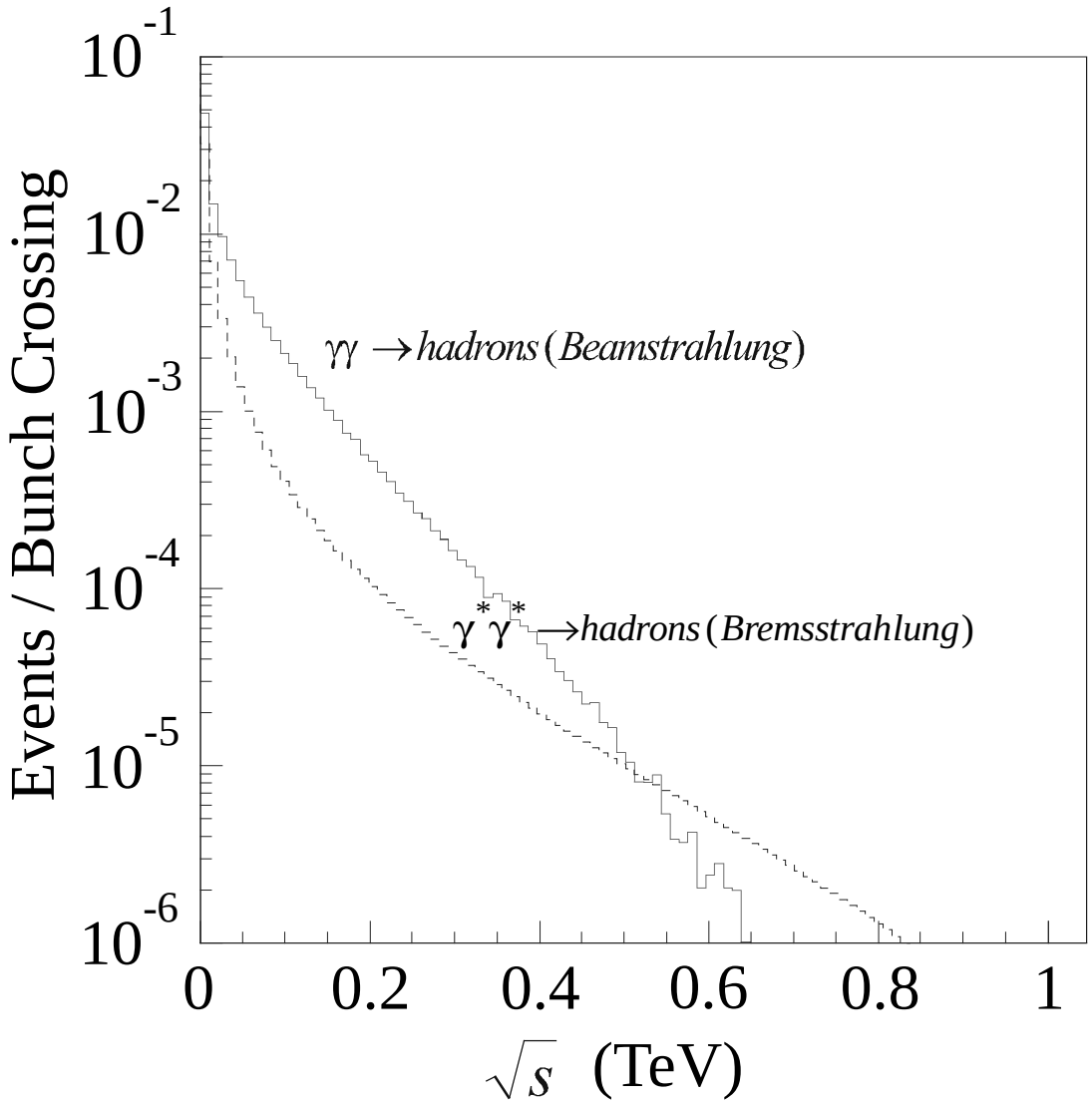
Events per bunch	**3.21×10^{-2}**
Events per 100ns	**1.16**
Events per pulse	**3.06**

Bremsstrahlung
Effective Cross Section 44.5 nb

Events per bunch	**2.62×10^{-2}**
Events per 100ns	**0.944**
Events per pulse	**2.49**

Problem
Signal + Minijets within the time resolution of the detector

JLC/NLC 1 TeV A



$\gamma\gamma$ hadronic events

Beamstrahlung
Effective Cross Section 102 nb

Events per bunch	**1.14×10^{-1}**
Events per 100ns	**4.12**
Events per pulse	**10.9**

Bremsstrahlung
Effective Cross Section 46.3 nb

Events per bunch	**5.22×10^{-2}**
Events per 100ns	**1.88**
Events per pulse	**4.95**

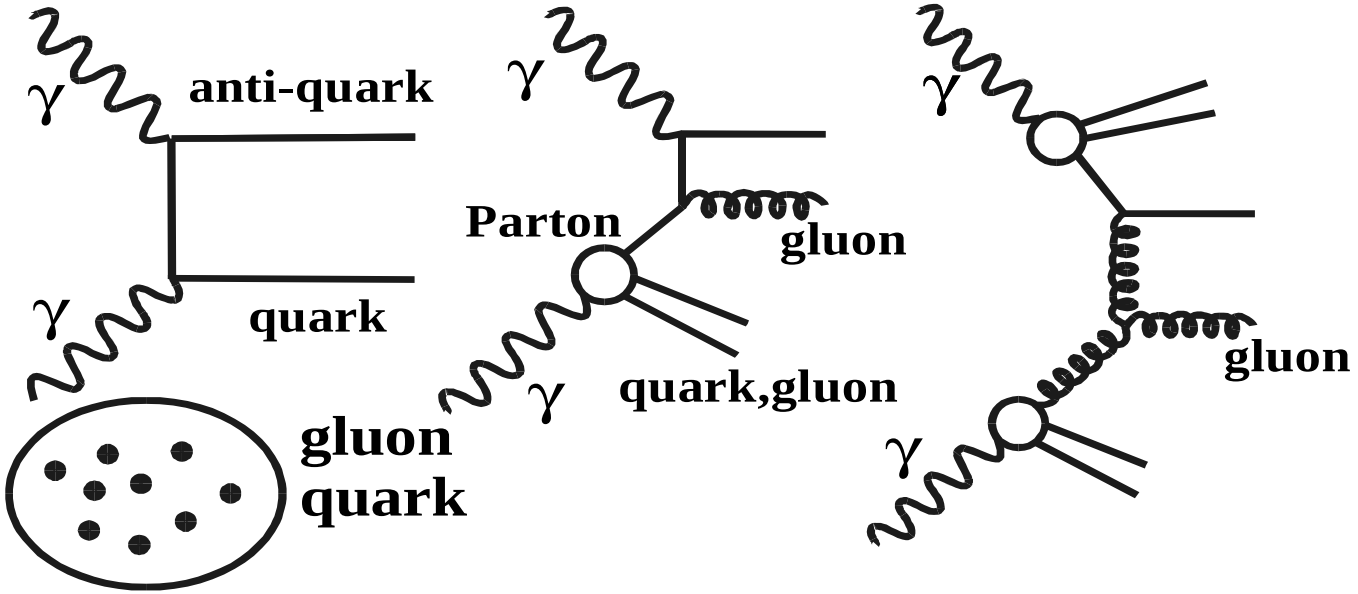
$\gamma\gamma$ Minijets Cross Section

$e^+e^- \rightarrow e^+e^-\gamma\gamma \rightarrow$ *Minijets* $+ e^+e^-$

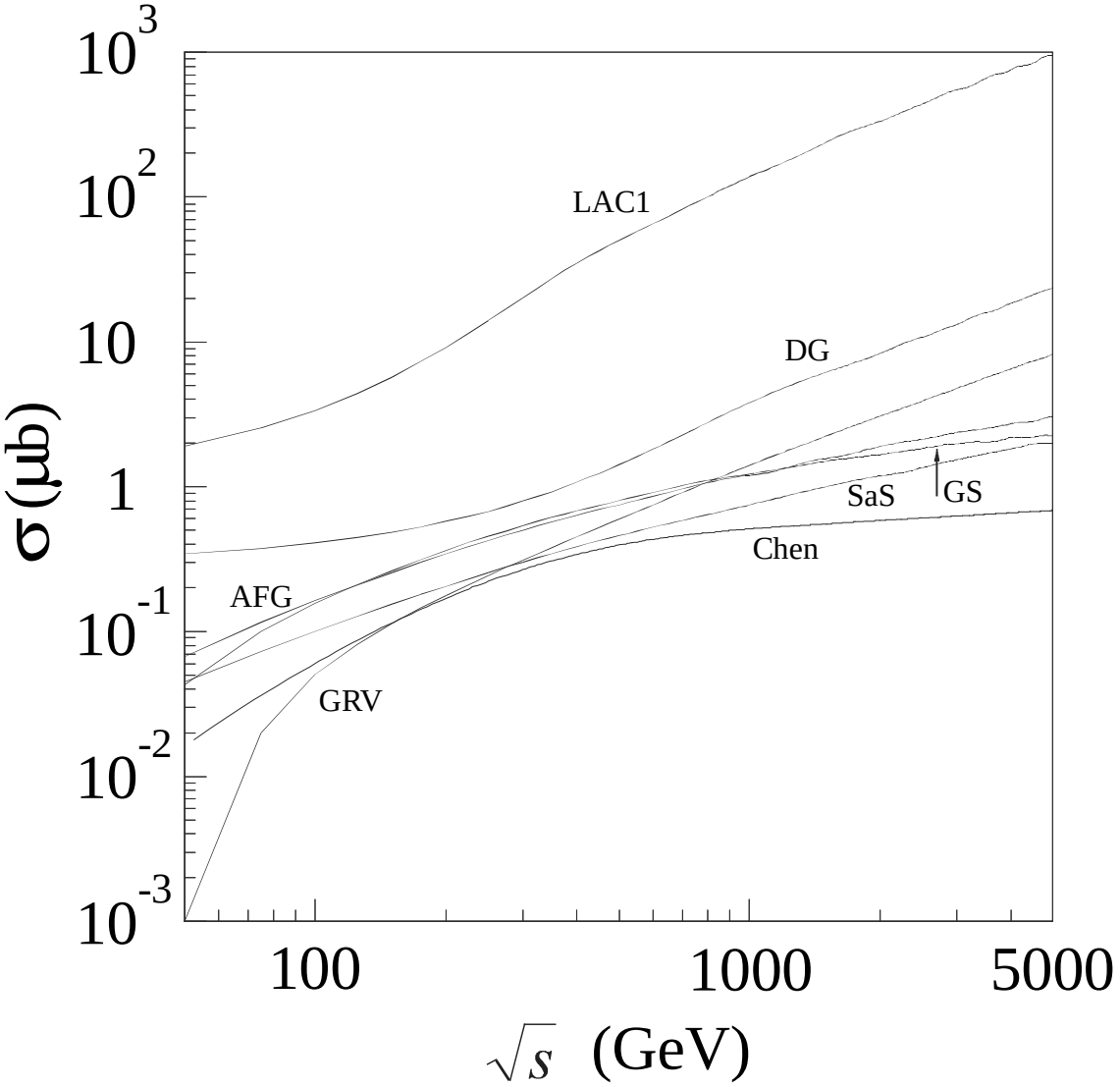
$e^+e^- \rightarrow e^+e^-\gamma\gamma$ (Beams. and Brems. photons)

$\gamma\gamma \rightarrow$ *Minijets*

$$\frac{d^3\sigma(\gamma\gamma \rightarrow j_1 j_2 X)}{dp_t d\eta_1 d\eta_2} = 2 p_t x_1 x_2 \sum_{i,j,k,l} f_{i|\gamma}(x_1) f_{j|\gamma}(x_2) \frac{d\hat{\sigma}_{ij \rightarrow kl}(\hat{s},\hat{t},\hat{u})}{d\hat{t}}$$

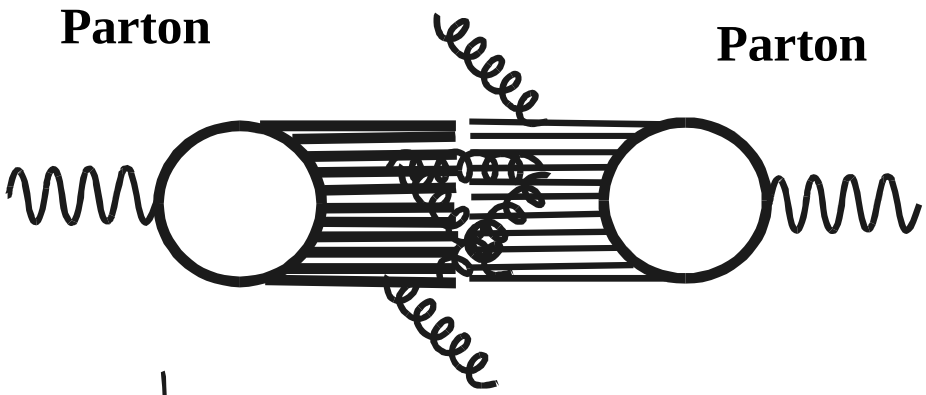


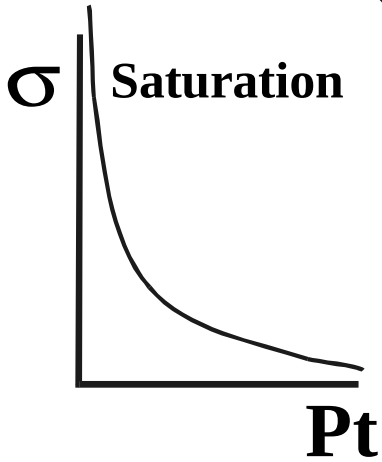
$\gamma\gamma$ Minijets Cross Section



Large Uncertainty of Total Cross Section of Minijets

- **Experimental Data: Low energy $\gamma\gamma$ collisions**
  –> Parton Density Function
- **Problem of Parton Saturation at high energy > 1 TeV**





Experimental Data :
γp,pp collisions

$$\sigma_{\text{Total}} = \sigma_{\gamma p}{}^{2} / \sigma_{pp}$$

$$\sigma_{\text{Total}} = \sigma_{\text{VMD}} + \sigma_{\text{Minijets}}$$

Ignore σ_{VMD} $(\sigma_{\text{VMD}} << \sigma_{\text{Minijets}})$

Differential Cross Section of Minijets

$$\sigma_{\textbf{Minijets}}(p_{t,\min}(\sqrt{s})) = \sigma_{\gamma p}{}^{2} / \sigma_{pp}$$

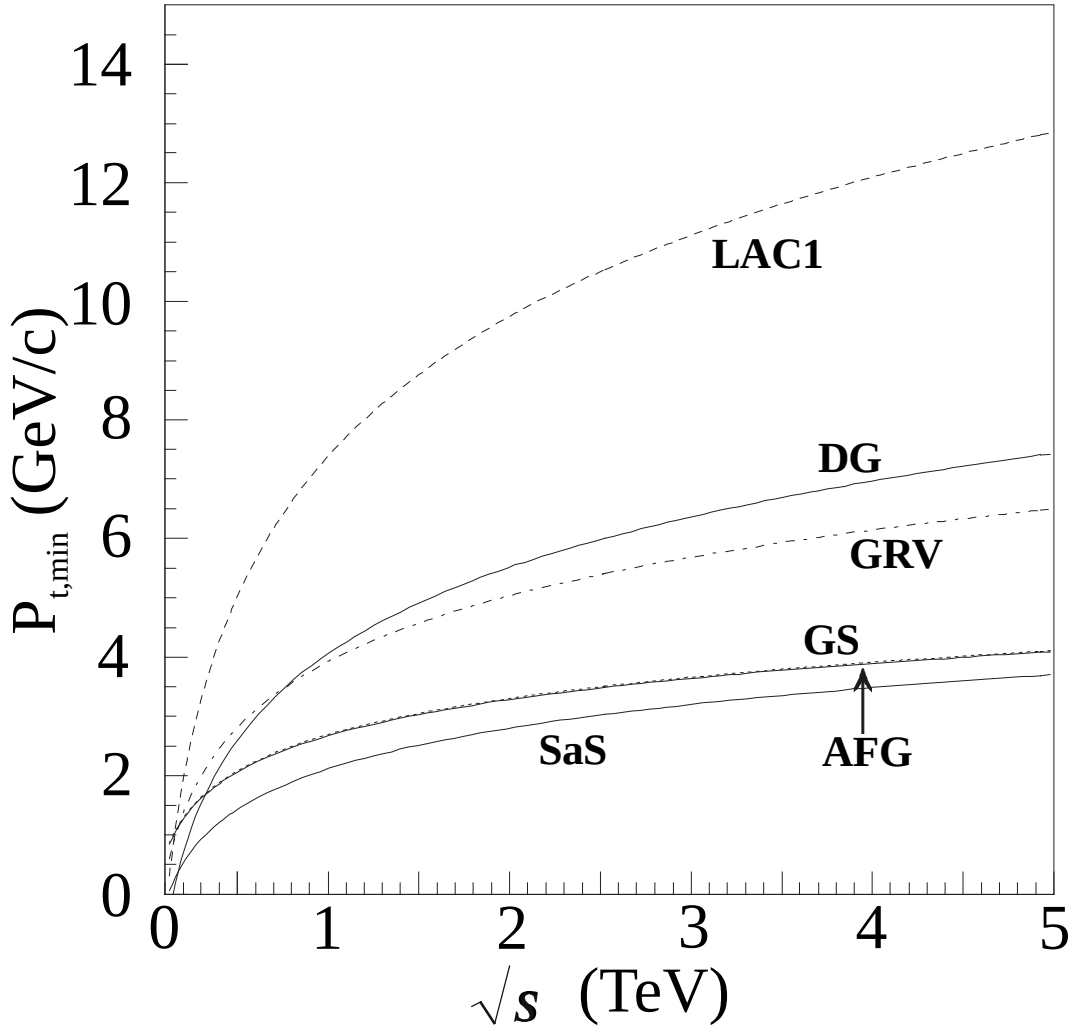
Parton Density Functions

DG-G Set1	**LO**	$P_{t,\min} = 2.1\mathrm{Log}\sqrt{s/21000}$
LAC-G Set1	**LO**	$P_{t,\min} = 3.4\mathrm{Log}\sqrt{s/13000}$
GS-G-96 HO	**NLL**	$P_{t,\min} = 0.88\mathrm{Log}\sqrt{s/2200}$
GRV-G	**LO**	$P_{t,\min} = 1.6\mathrm{Log}\sqrt{s/7400}$
AFG-G Set HO	**NLL**	$P_{t,\min} = 0.88\mathrm{Log}\sqrt{s/2300}$
SaS-G 2M	**LO**	$P_{t,\min} = 0.99\mathrm{Log}\sqrt{s/14000}$

Chen's model

$$\sigma_{\textbf{Chen}} = \sigma_{\gamma\gamma\to hadrons}\left(1-\exp\left[-\sigma_{\textbf{Minijets}} / \sigma_{\gamma\gamma\to hadrons}\right]\right)$$

$P_{t,min}$ of Photon Parton Density Functions



Detector Simulation

CAIN Beam-Beam Interaction (*Beamstrahlung*)
2-D Luminosity of $\gamma\gamma$ collision (z,η)

PYTHIA5.7 Parton Distribution Function
Dress and Grassie model
$\gamma\gamma$ Minijets production

$$\mathbf{P_{t,min} = 2.1 Log\sqrt{s/21000}\ (\sqrt{s} > 375\,GeV)}$$

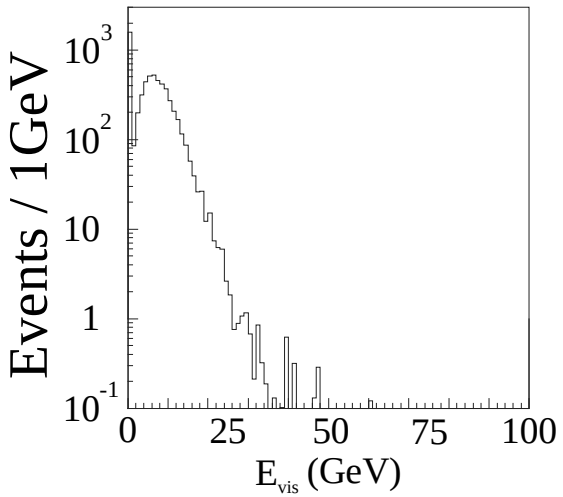
$$\mathbf{2.0\ (\sqrt{s} \leq 375\,GeV)}$$

LUND Fragmentation

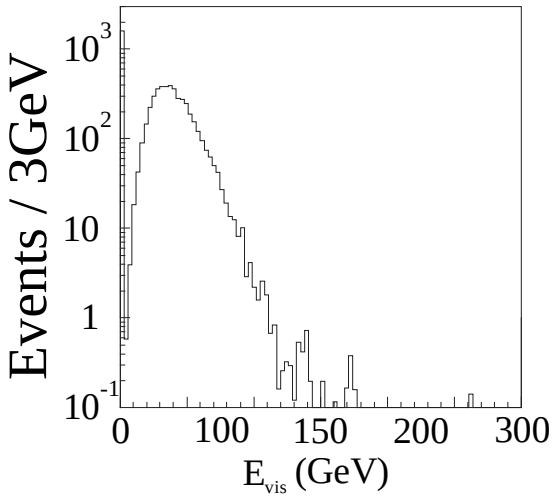
Detector Simulator
Detector JLC-I, $|\cos\theta|<0.95$
CDC,CAL

JLC/NLC 500 GeV A

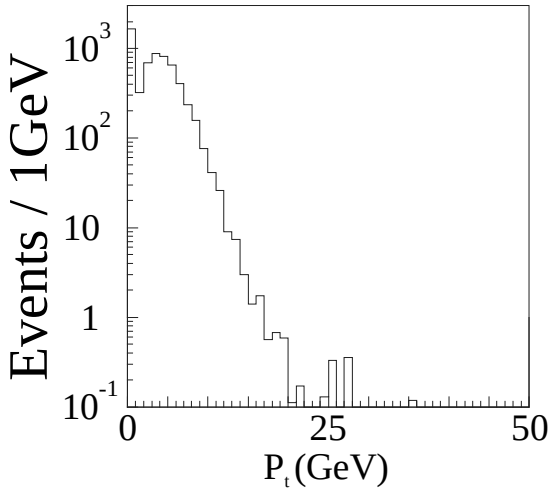
Tracking Detector



Calorimeters



Tracking Detector



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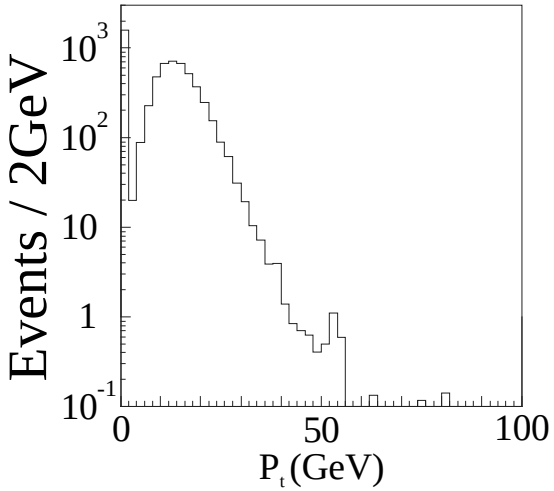


Average of E_{vis} & P_t		
	Track	Cal
E_{vis}	5.9 GeV	30 GeV
P_t	3.5 GeV	11 GeV

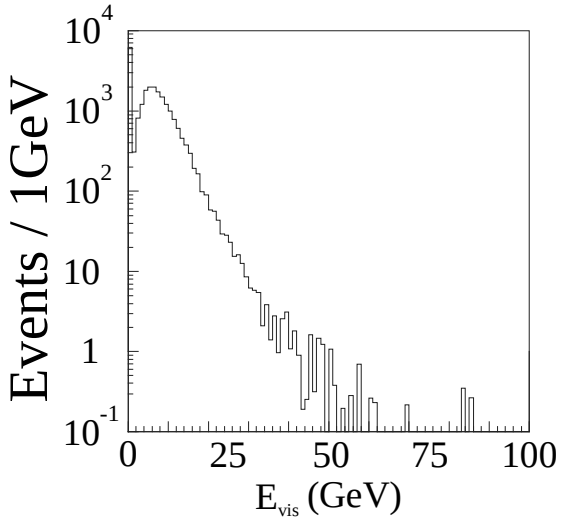
Ratio of No hitting event
24%

$L_{e+e-}=0.5pb^{-1}$

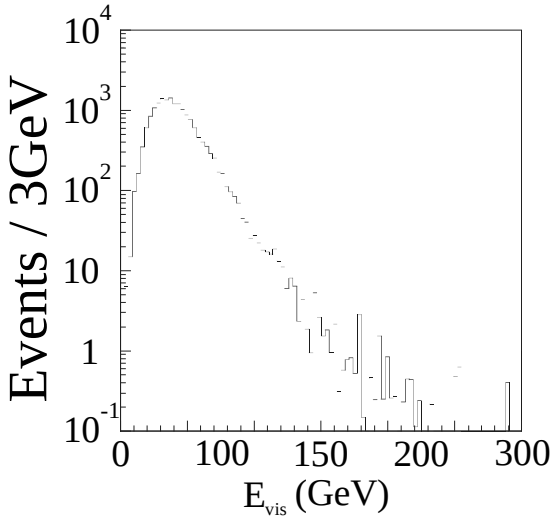
$\sqrt{s_{\gamma\gamma}} > 20\,\mathrm{GeV}$

JLC/NLC 1 TeV A

Tracking Detector



Calorimeters



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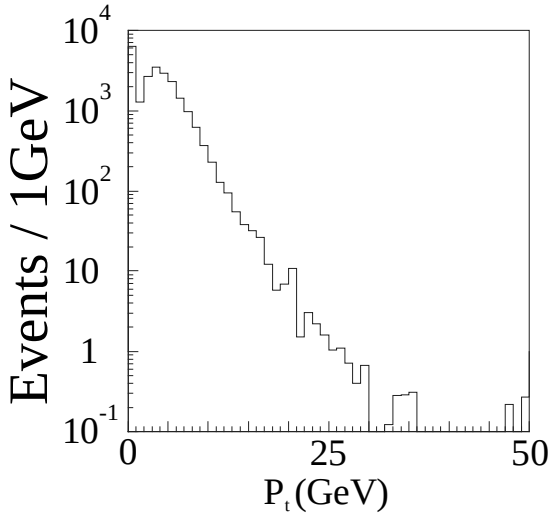
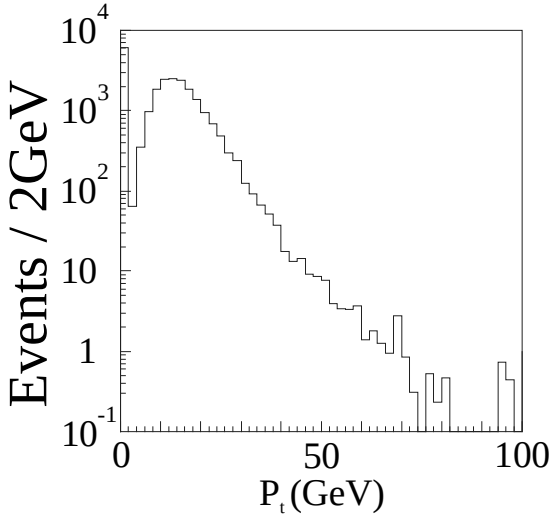


Calorimeters



Average of E_{vis} & P_t

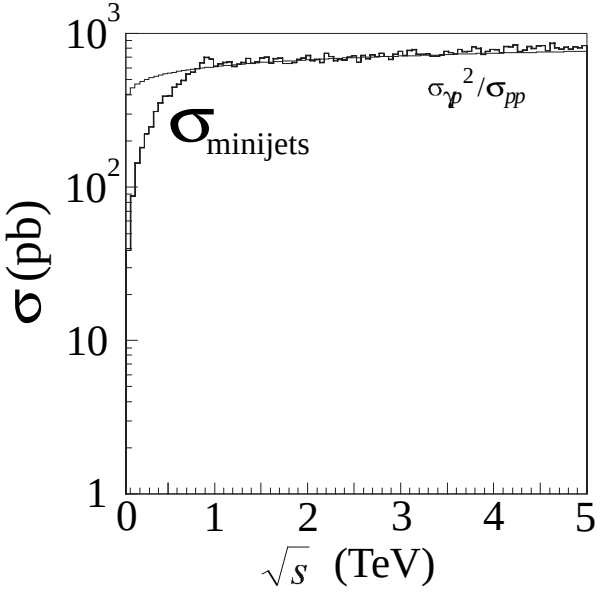
	Track	Cal
E_{vis}	6.1 GeV	31 GeV
P_t	3.6 GeV	11 GeV

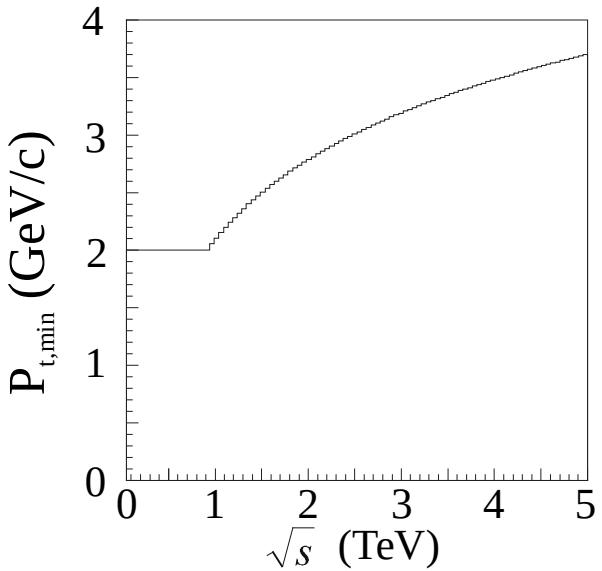
Ratio of No hitting event
26%

$L_{e+e-}=0.5pb^{-1}$

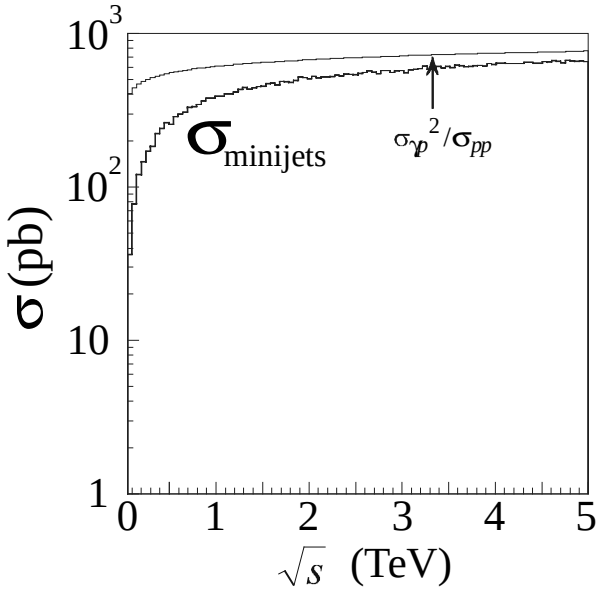
$\sqrt{s_{\gamma\gamma}} > 30\,\mathrm{GeV}$

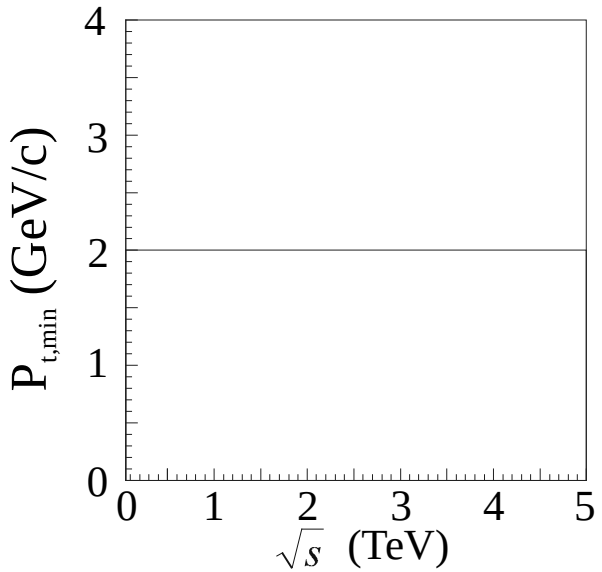
Our model





Chen's model





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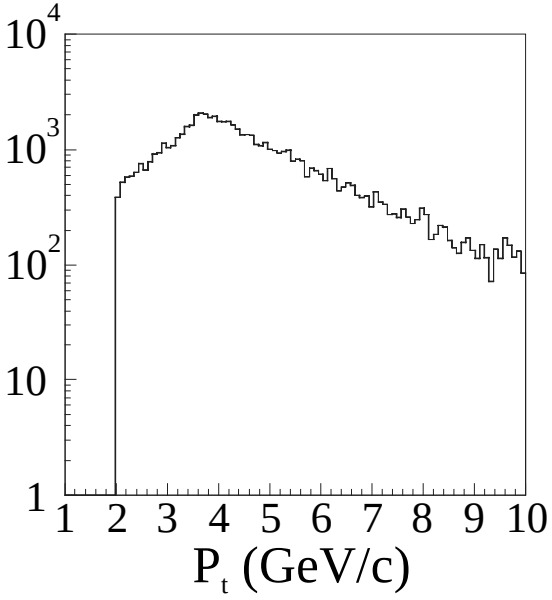
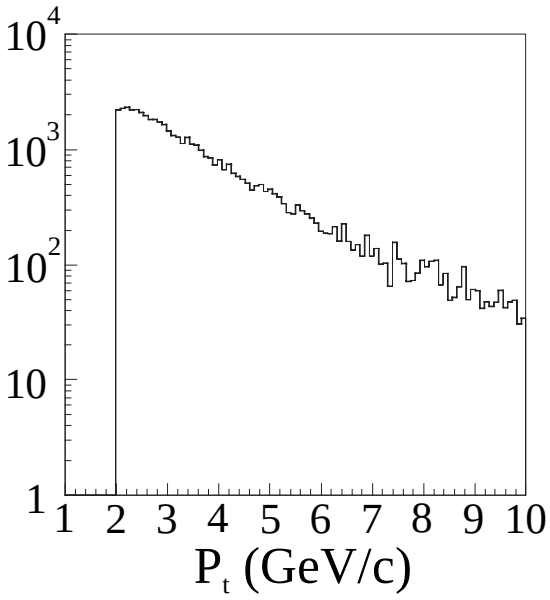
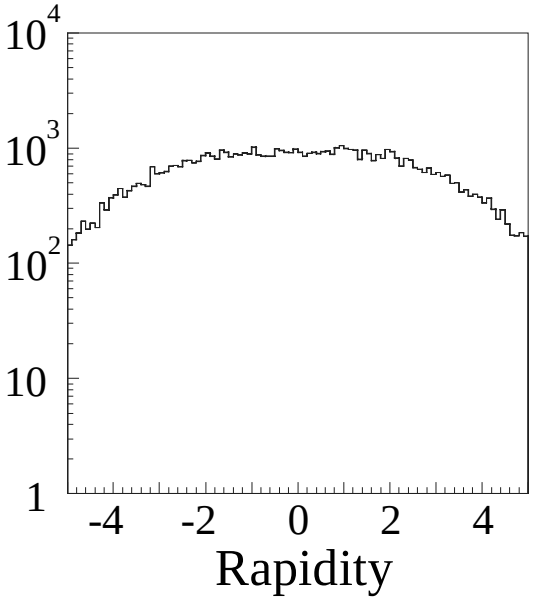
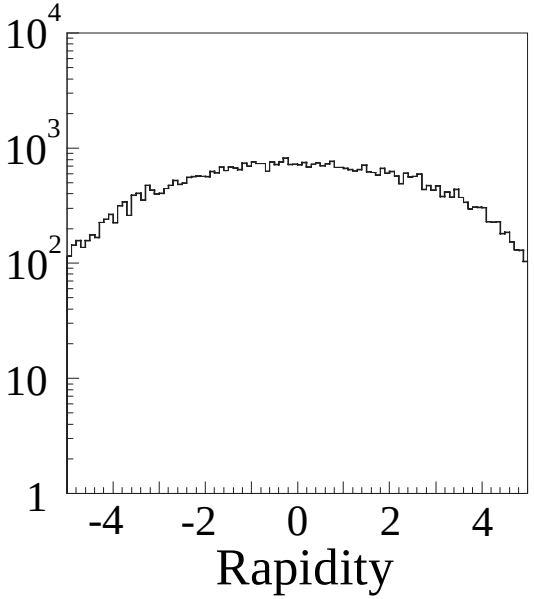


Chen's model







Conclusion

- We have estimated Minijets backgrounds by using the total cross section $\sigma_{\gamma p}{}^{2} / \sigma_{pp}$ in future linear colliders.

- Minijet backgrounds are small per bunch crossing.

- We have calculated the functions $P_{t,min}(\sqrt{s})$ of the photon parton distributions.

- We have performed the detector simulation and the results show that the energy deposit per event is smaller than the collision energy of the initial electron and positron beams.