BILEPTON SEARCHES

Ilkay Türk Çakır
Turkish Atomic Energy Authority

with the contributions from O. Cakir, Z. Kırca, U. Erkarslan

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OUTLINE

- Motivation
- Bilepton properties
- Effective Lagrangian with Bileptons
- Signal and Background
- Angular Distributions
- Detector Simulation
- Conclusion

MOTIVATION

- **STANDARD MODEL (SM)-**

  In Standard Model the lepton and baryon numbers are conserved.

  The SM gives a good description of the known fundamental particles using the SU(3)xSU(2)xU(1) gauge group to describe their colour and electroweak interactions. There are still unanswered questions within the SM. There are expectations for the new physics beyond the SM at large energy scales.

- **BEYOND THE STANDARD MODEL – (BSM)**

  MSSM - Scalar spartners carry the same baryon or lepton number as their associated fermions

  L-R Symmetric Models, 3-3-1 Models, Technicolour, GUT, Compositeness scenarios:

  - predict the existence of light lepto-quarks, diquarks, bileptons
  - New scalar and vector bosons can have lepton/baryon number or both of them

BILEPTONS

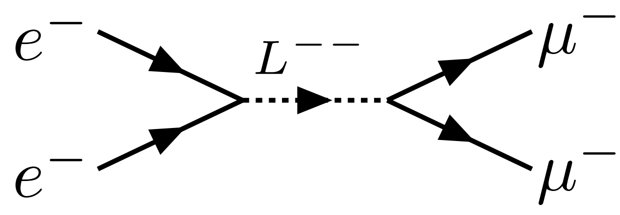
- A bilepton is a boson which couples minimally to two SM leptons, but not to quarks
- Bileptons can carry charges and also couple to electroweak gauge bosons
- They don't carry colour quantum number
- If bilepton has lepton number L=0 - (very similar properties to the SM bosons)
- If bilepton has L=2 – new particles – (scalar and vector)
- Expected masses are in the TeV range

DOUBLY CHARGED BILEPTONS

- The s-channel resonant production of doubly charged bileptons at e^-e^- collider dominates over their t-channel in direct production at e^-e^+ colliders.

Collider Parameters	CLIC–I	CLIC –II
	500 GeV	3000 GeV
$\sigma_{x+y}(nm)$	204.5	45.09
$\sigma_z(mm)$	0.072	0.044
N	6.8×10^9	3.72×10^9
$L_{int}(fb^{-1})$	210	200

$$e^- e^- \rightarrow \mu^-, \mu^-$$



INTERACTION WITH LEPTONS

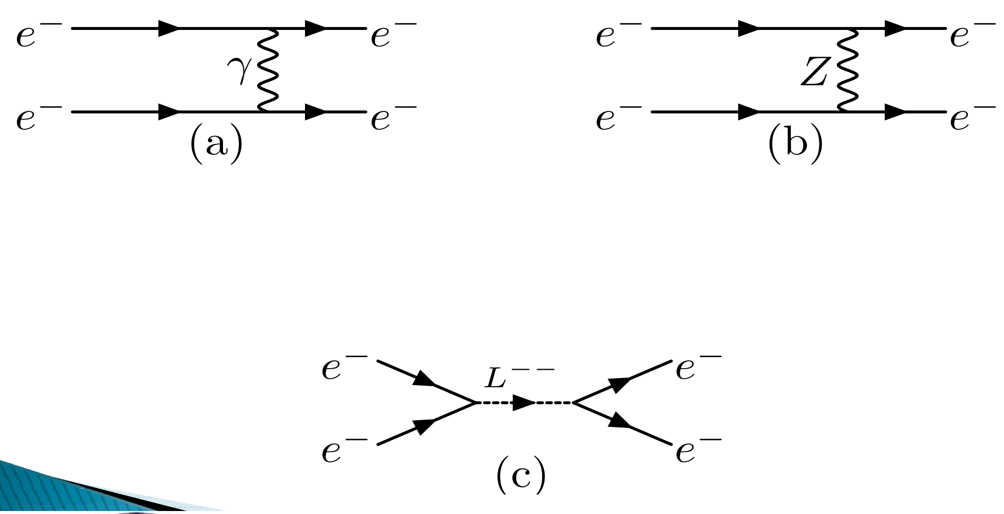
$$L = \tilde{\lambda}\,\overline{e}_i^{\,c} P_R e_j \tilde{L}_1^{--} + \lambda_2^{ij}\,\overline{e}_i^{\,c}\gamma^{\mu} P_R e_j L_{2\mu}^{--} + \sqrt{2}\,\lambda_3^{ij}\,\overline{e}_i^{\,c} P_L e_j L_3^{--} + h.c.$$

Scalar bilepton

Vector bilepton

Scalar bilepton

$$e^- e^- \rightarrow e^-, e^-$$



Projection Operators

$$P_L = (1 - \gamma_5)/2$$

$$P_R = (1 + \gamma_5)/2$$

DECAY WIDTHS

$$\Gamma_{\tilde{L}_1^{--}} = \frac{m_L}{8\pi}\sum_{i,j}\lambda_{ij}^2$$

$$\Gamma_{L_2^{--}} = \frac{m_L}{24\pi}\sum_{i,j}\lambda_{ij}^2$$

$$\Gamma_{L_3^{--}} = \frac{m_L}{4\pi}\sum_{i,j}\lambda_{ij}^2$$

Mass (GeV)	$\tilde{L}_1^{--}$	L_2^{--}	L_3^{--}
200	0.24	0.08	0.48
300	0.36	0.12	0.72
400	0.48	0.16	0.95
500	0.59	0.19	1.19
1000	1.19	0.39	2.38
1500	1.79	0.59	3.58
2000	2.38	0.79	4.77
2500	2.98	0.99	5.96
3000	3.58	1.19	7.16

DIFFERENTIAL CROSS SECTIONS- I

$$\frac{d\sigma(e^-e^- \to e^-e^-, \tilde{L}_1^{--})}{dt} = \frac{2\pi\alpha^2}{s^2}$$

$$\left\{ [RR]\left[\sum_i R_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right) + 2\frac{\lambda^2}{e^2}\frac{s}{s-m_L^2}\right]^2 \right.$$

$$+ [LL]\left[\sum_i L_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right)\right]^2$$

$$\left. + [LR]\left[\left(\sum_i L_i R_i \frac{t}{u-m_i^2}\right)^2 + \left(\sum_i L_i R_i \frac{u}{t-m_i^2}\right)^2\right] \right\}$$

DIFFERENTIAL CROSS SECTIONS- II

$$\frac{d\sigma(e^-e^- \to e^-e^-, L_3^{--})}{dt} = \frac{2\pi\alpha^2}{s^2}$$

$$\left\{ [RR]\left[\sum_i R_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right)\right]^2 \right.$$

$$+[LL]\left[\sum_i L_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right) + 4\frac{\lambda^2}{e^2}\frac{s}{s-m_L^2}\right]^2$$

$$\left. +[LR]\left[\left(\sum_i L_i R_i \frac{t}{u-m_i^2}\right)^2 + \left(\sum_i L_i R_i \frac{u}{t-m_i^2}\right)^2\right] \right\}$$

DIFFERENTIAL CROSS SECTIONS- III

$$\frac{d\sigma(e^-e^- \to e^-e^-, L_{2\mu}^{--})}{dt} = \frac{2\pi\alpha^2}{s^2}$$

$$\Bigg\{ [RR]\left[\sum_i R_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right)\right]^2$$

$$+[LL]\left[\sum_i L_i^2 \left(\frac{s}{t-m_i^2} + \frac{s}{u-m_i^2}\right)\right]^2$$

$$+[LR]\Bigg[\left(\sum_i L_i R_i \frac{t}{u-m_i^2} - \frac{\lambda^2}{e^2}\frac{t}{s-m_L^2}\right)^2$$

$$+\left(\sum_i L_i R_i \frac{u}{t-m_i^2} - \frac{\lambda^2}{e^2}\frac{u}{s-m_L^2}\right)^2\Bigg]\Bigg\}$$

BACKGROUND CROSS SECTIONS

cut	$\sqrt{s}=500$	$\sqrt{s}=1000$	$\sqrt{s}=3000$
10	3002.2	2997.6	2989.7
50	126.5	124.8	123.5
100	33.5	33.1	32.3
200	6.5	8.8	8.5
400	X	1.7	2.2
1000	X	X	0.3

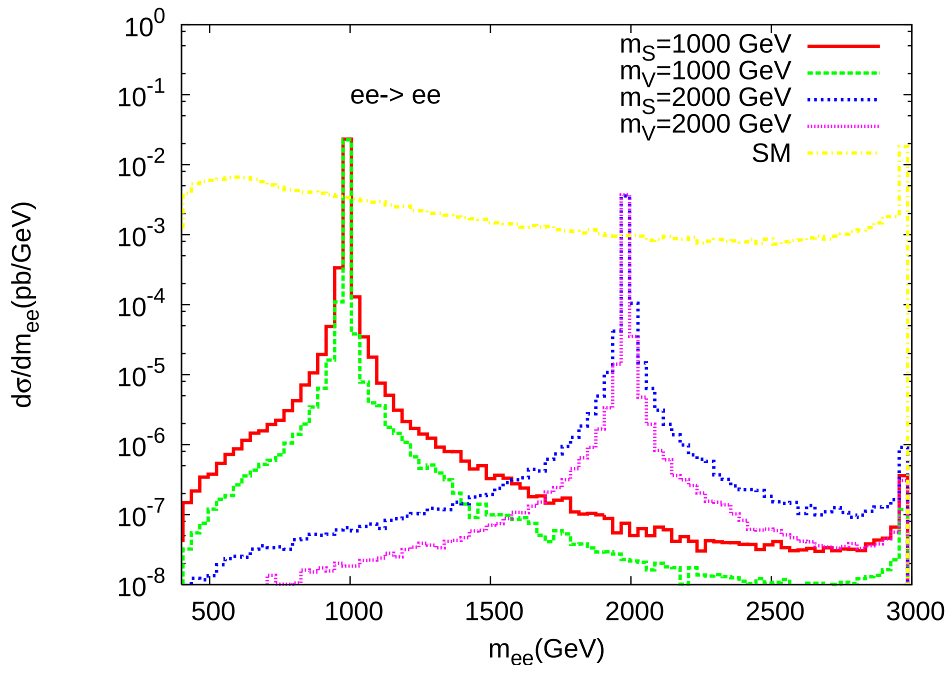
Cross sections of the background $e^-e^- \to e^-e^-$ depending on transverse momentum cut at different center of mass energies.

RESONANCE CASE

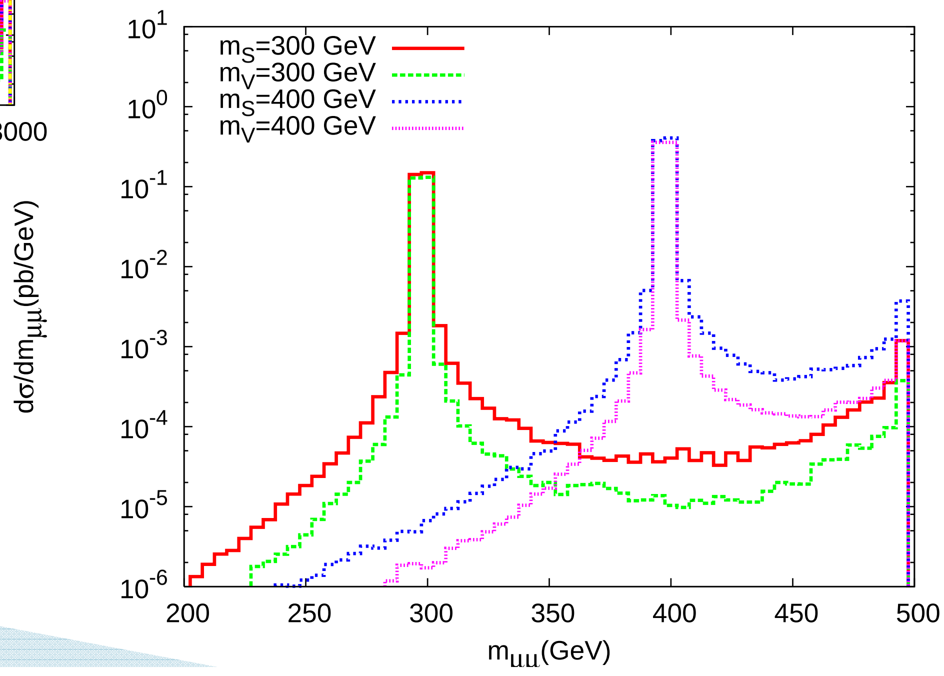
Resonance case	σ (pb)	σ (pb)
500	2448.6	6995.2
1000	594.3	1691.2
3000	62.9	178.5
5000	22.2	62.7

INVARIANT MASS

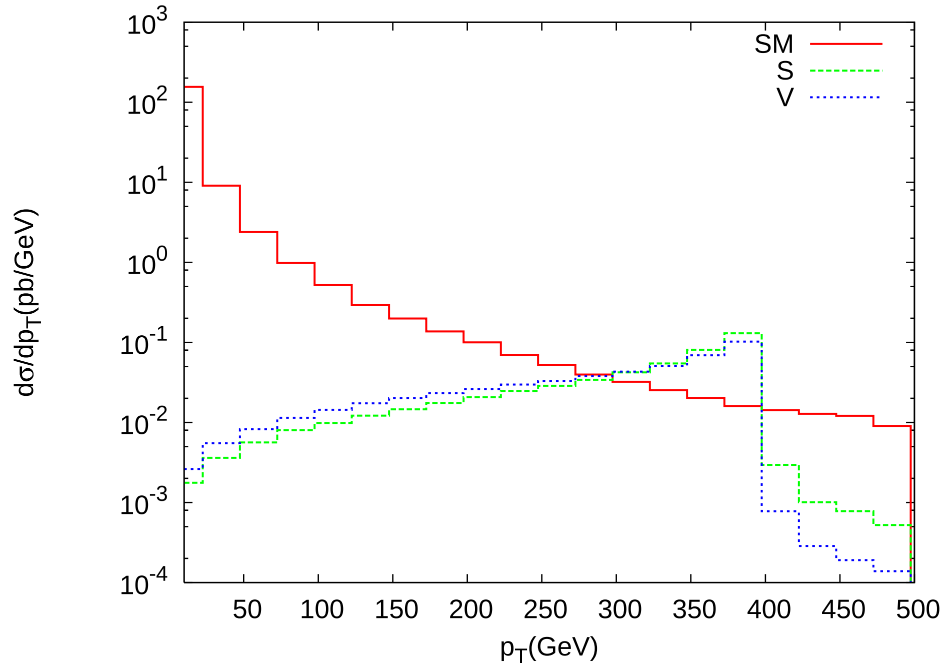
$$e^- e^- \rightarrow e^-, e^-$$



$$e^- e^- \rightarrow \mu^-, \mu^-$$

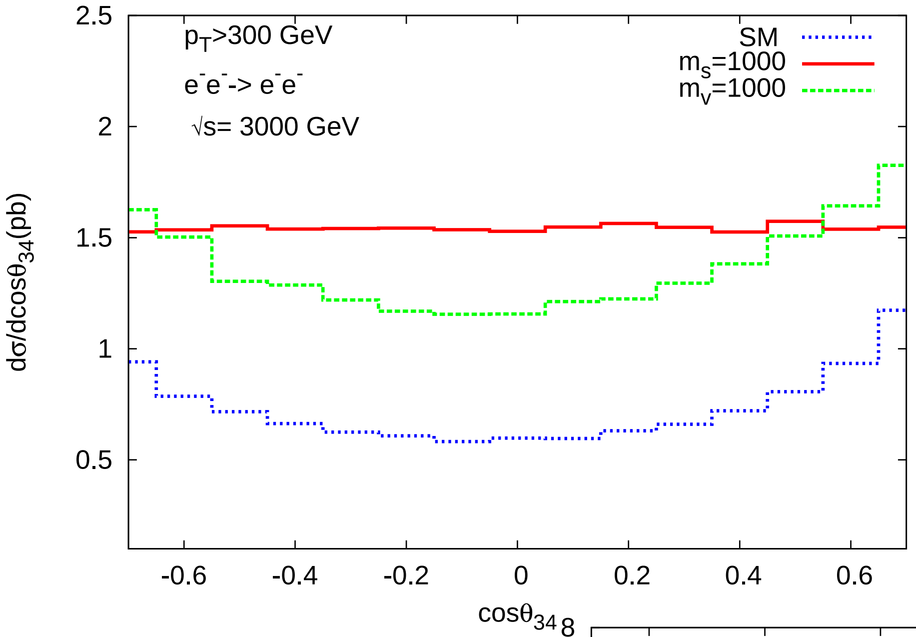


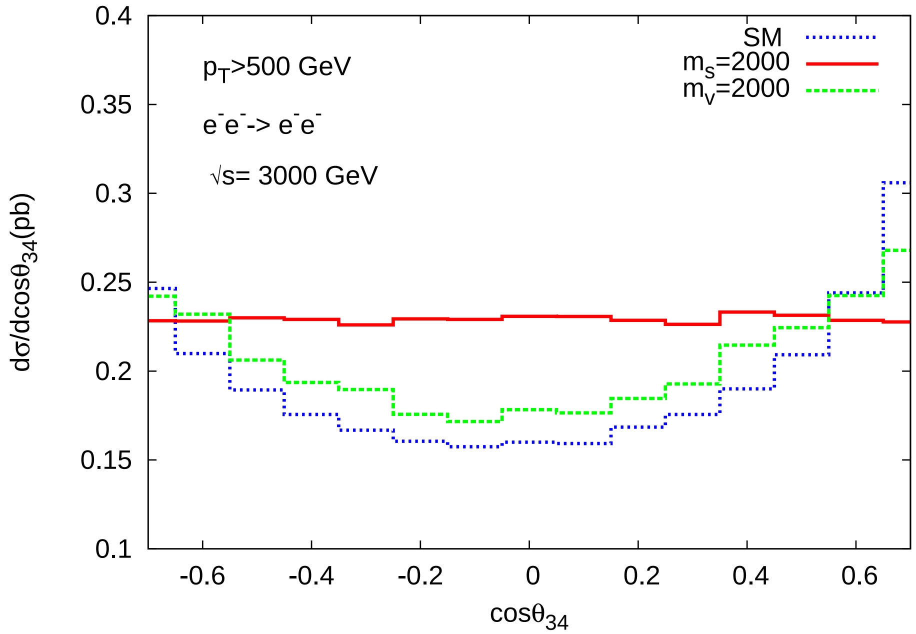
TRANSVERSE MOMENTUM

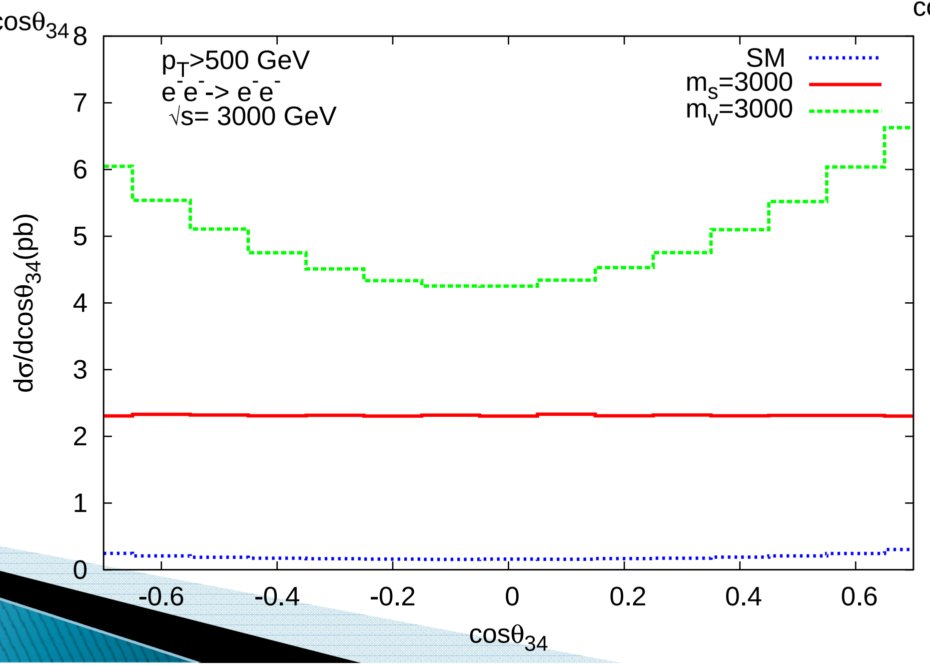


P_T distributions at $\sqrt{s} = 1000 GeV$

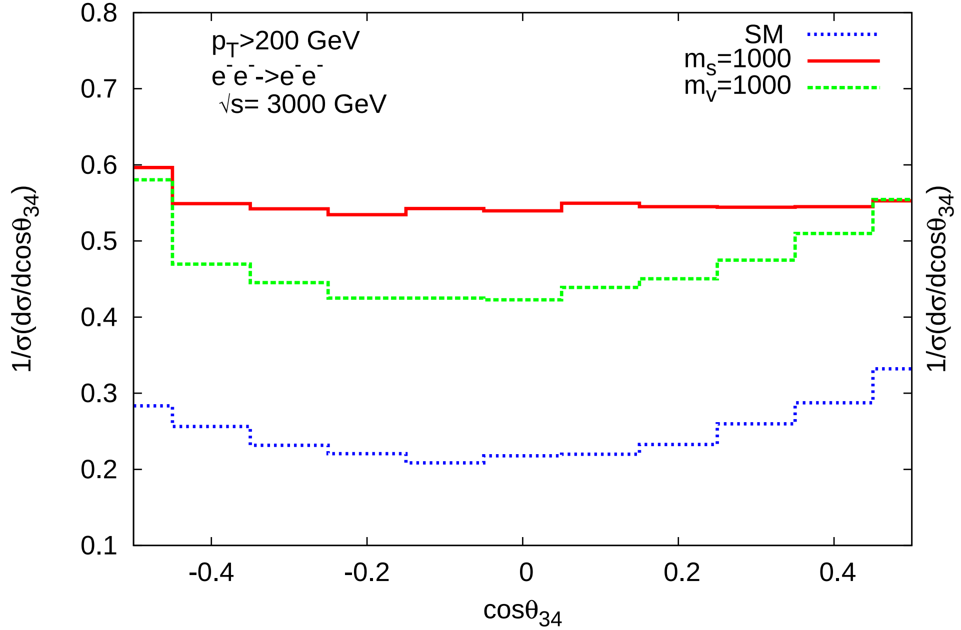
ANGULAR DISTRIBUTIONS (SCALAR AND VECTOR BILEPTONS)

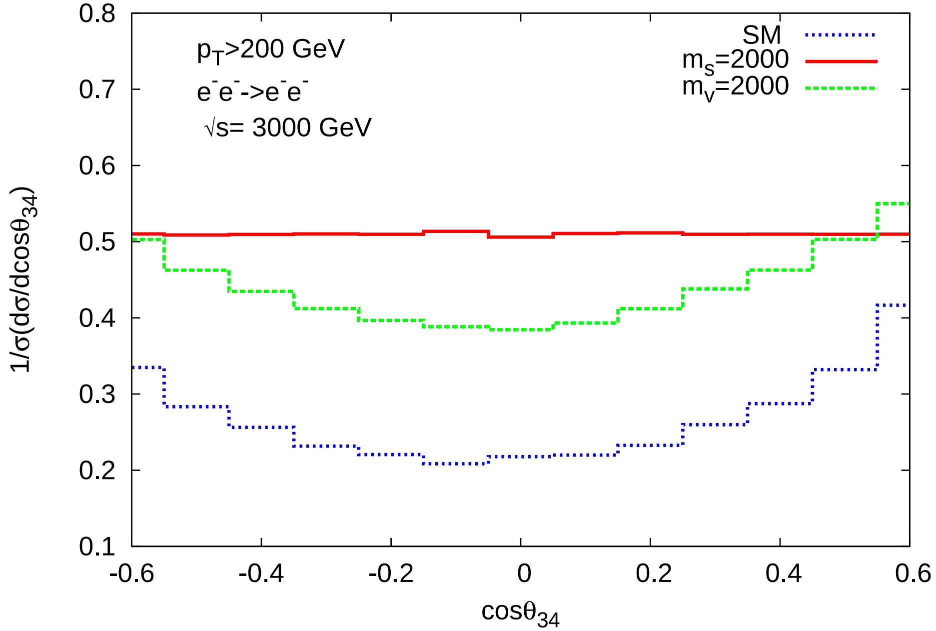


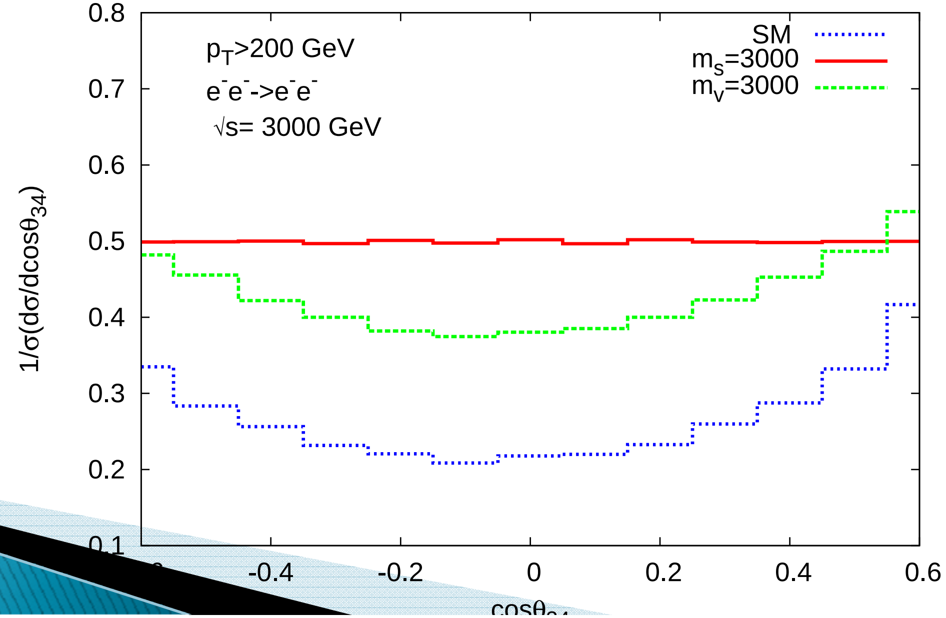




NORMALIZED ANGULAR DISTRIBUTIONS -I



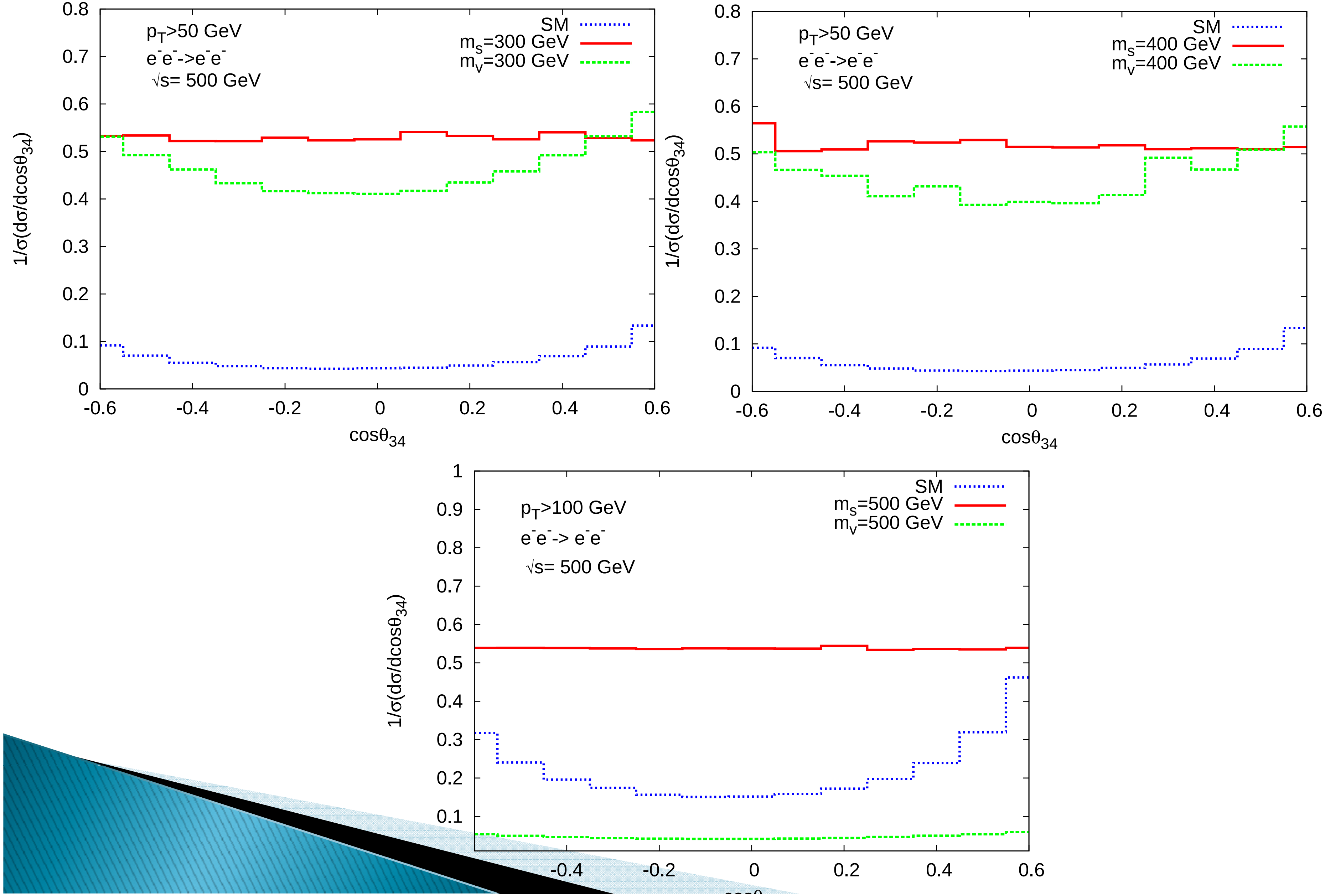




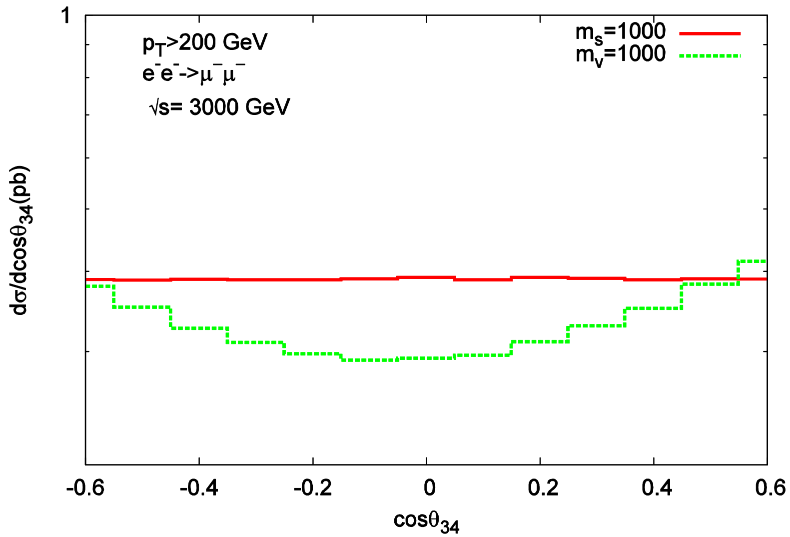
$cos\theta_{34}$

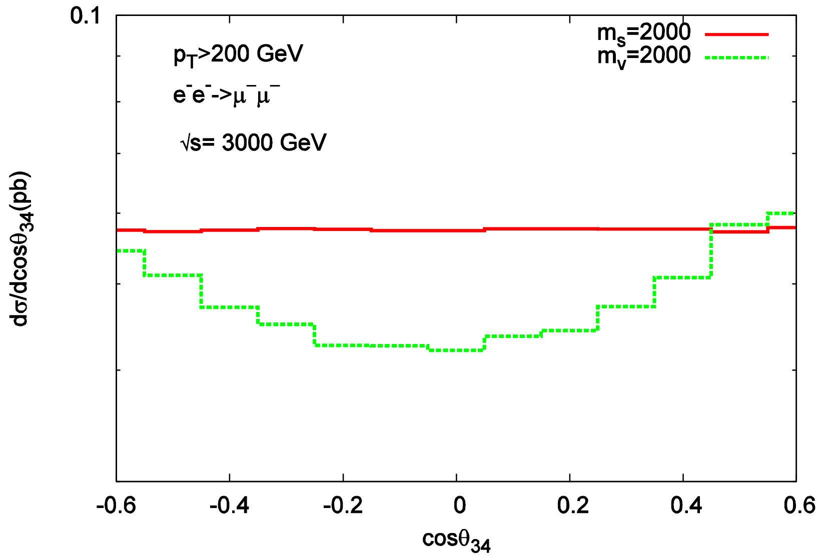
cosine in the rest-frame of particles

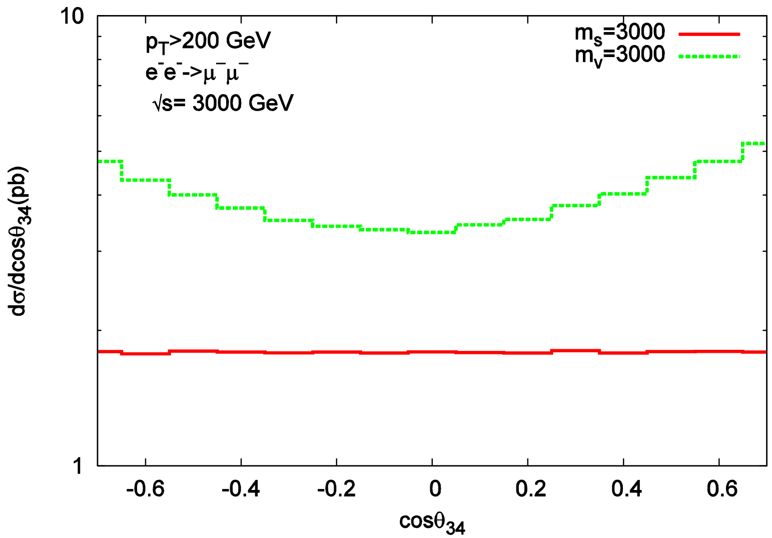
NORMALIZED ANGULAR DISTRIBUTIONS -II



ANGULAR DISTRIBUTIONS (SCALAR AND VECTOR BILEPTONS)







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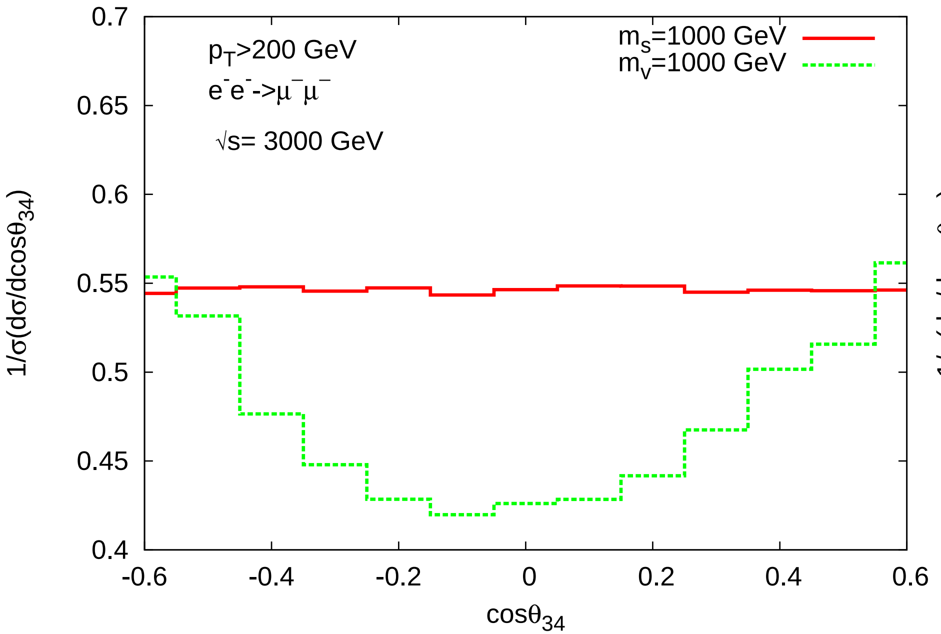

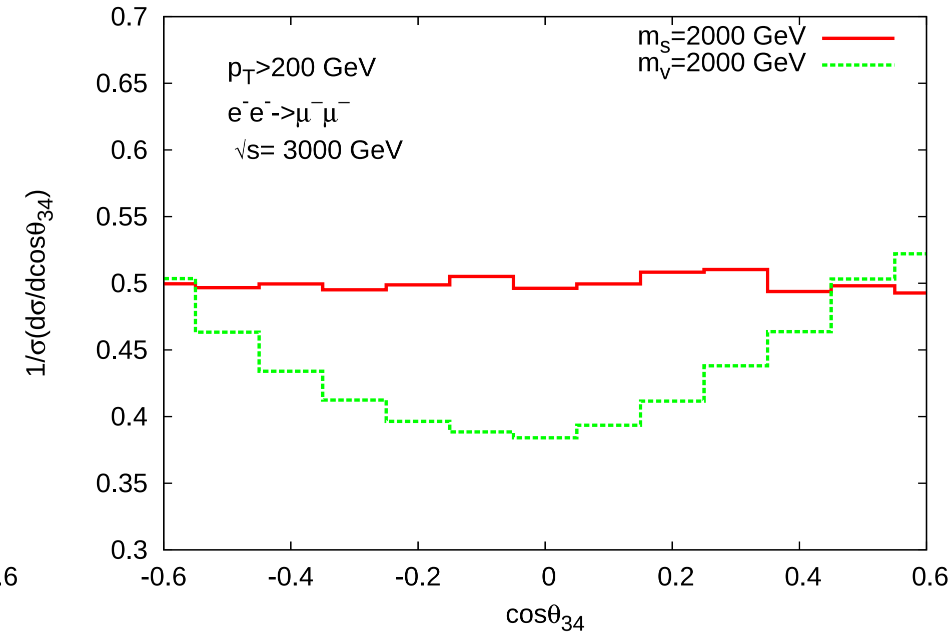

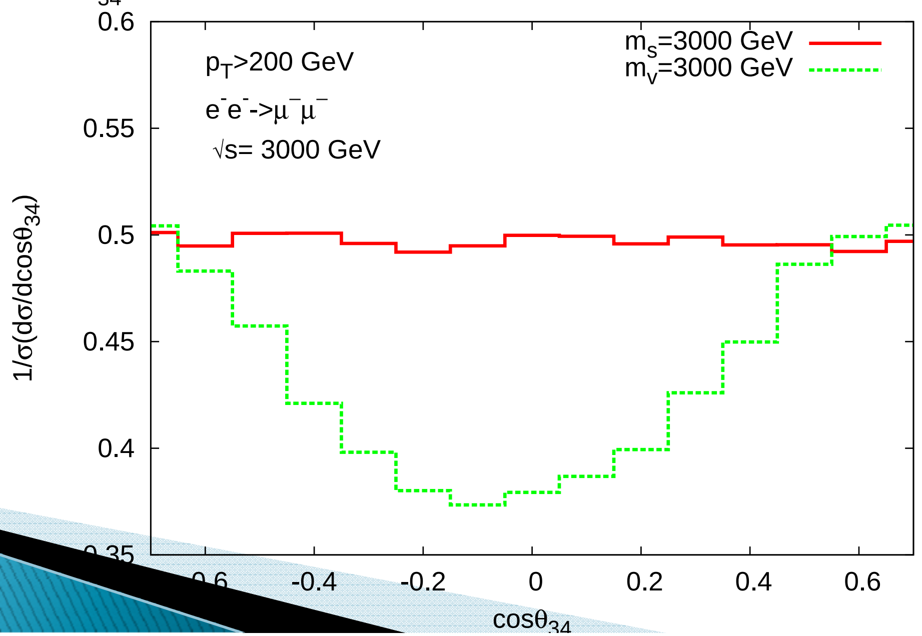

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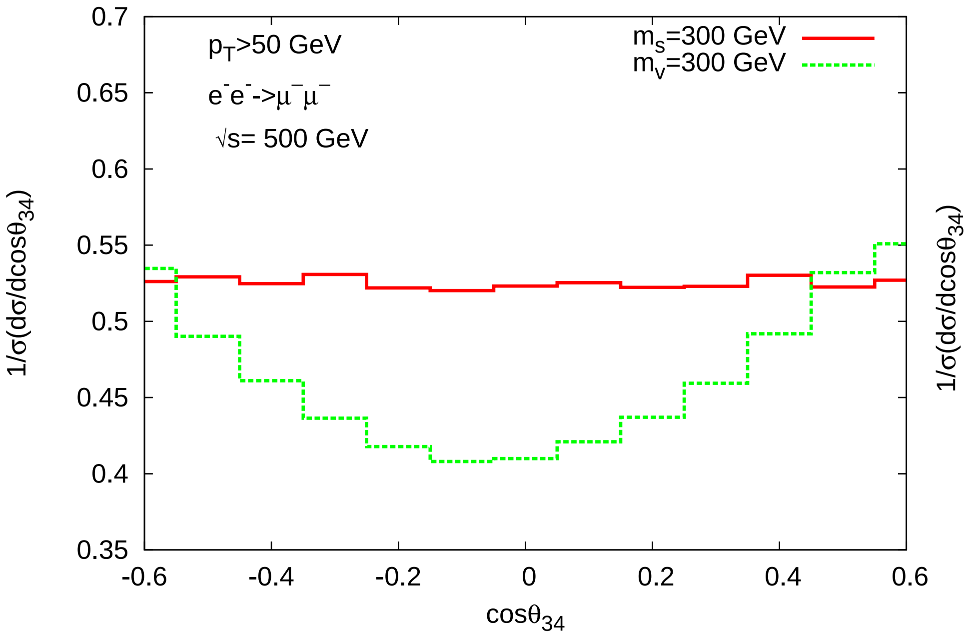
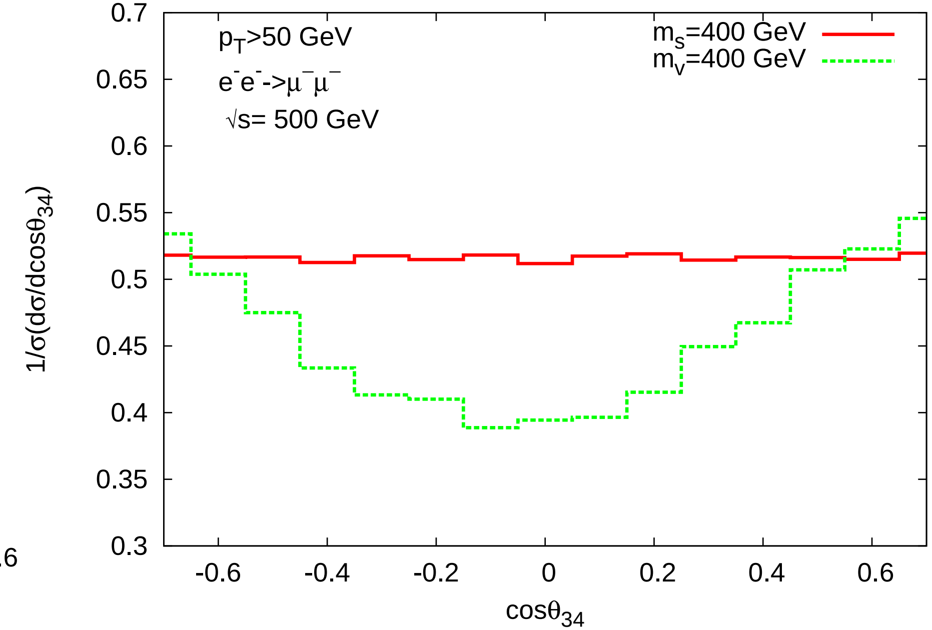
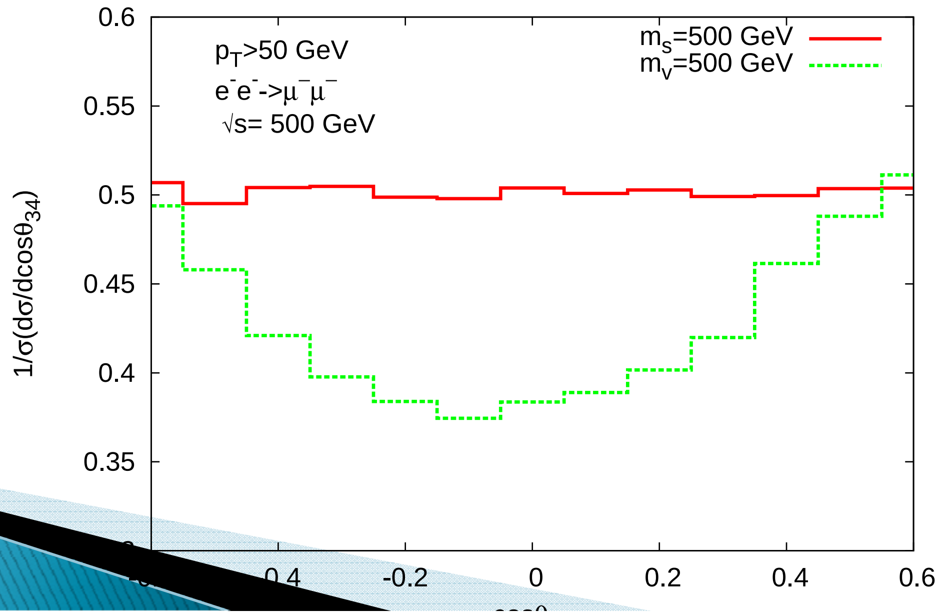
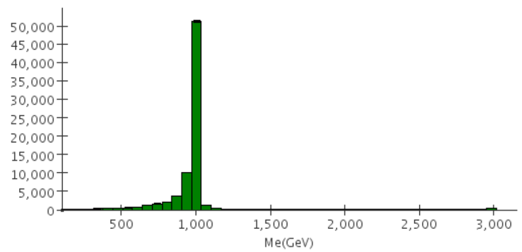


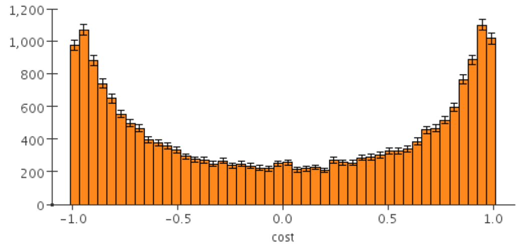


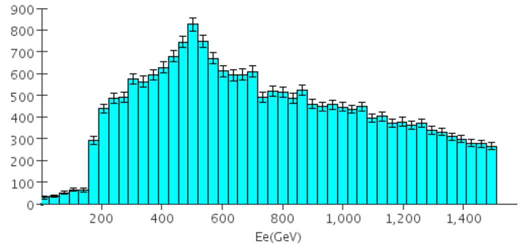


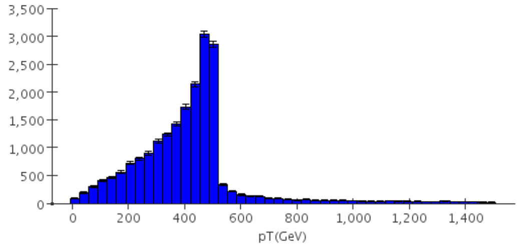
DETECTOR EFFECTS FOR SCALAR BILEPTONS

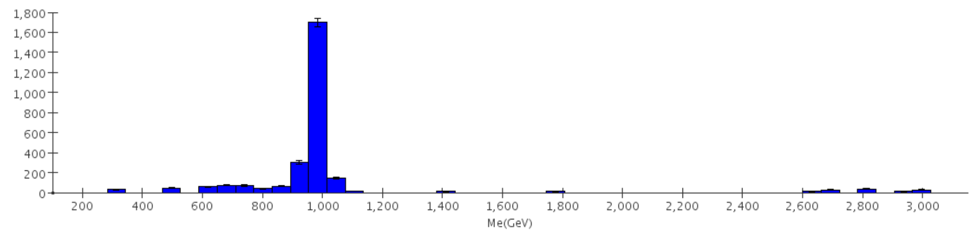
$$e^- e^- \rightarrow e^-, e^-$$ (JAS3)

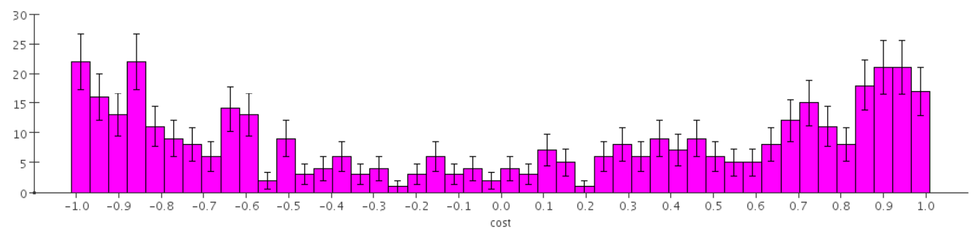


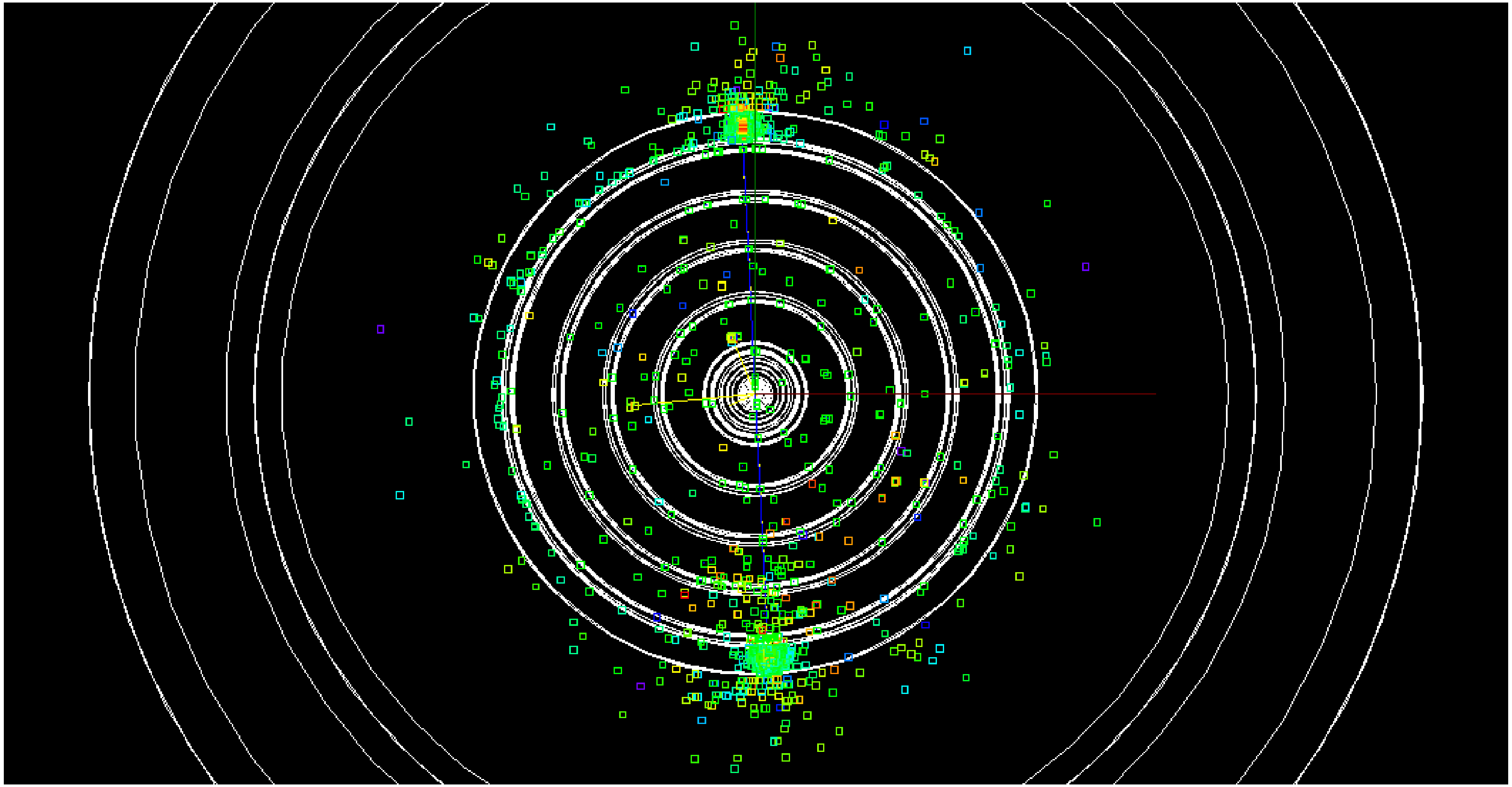




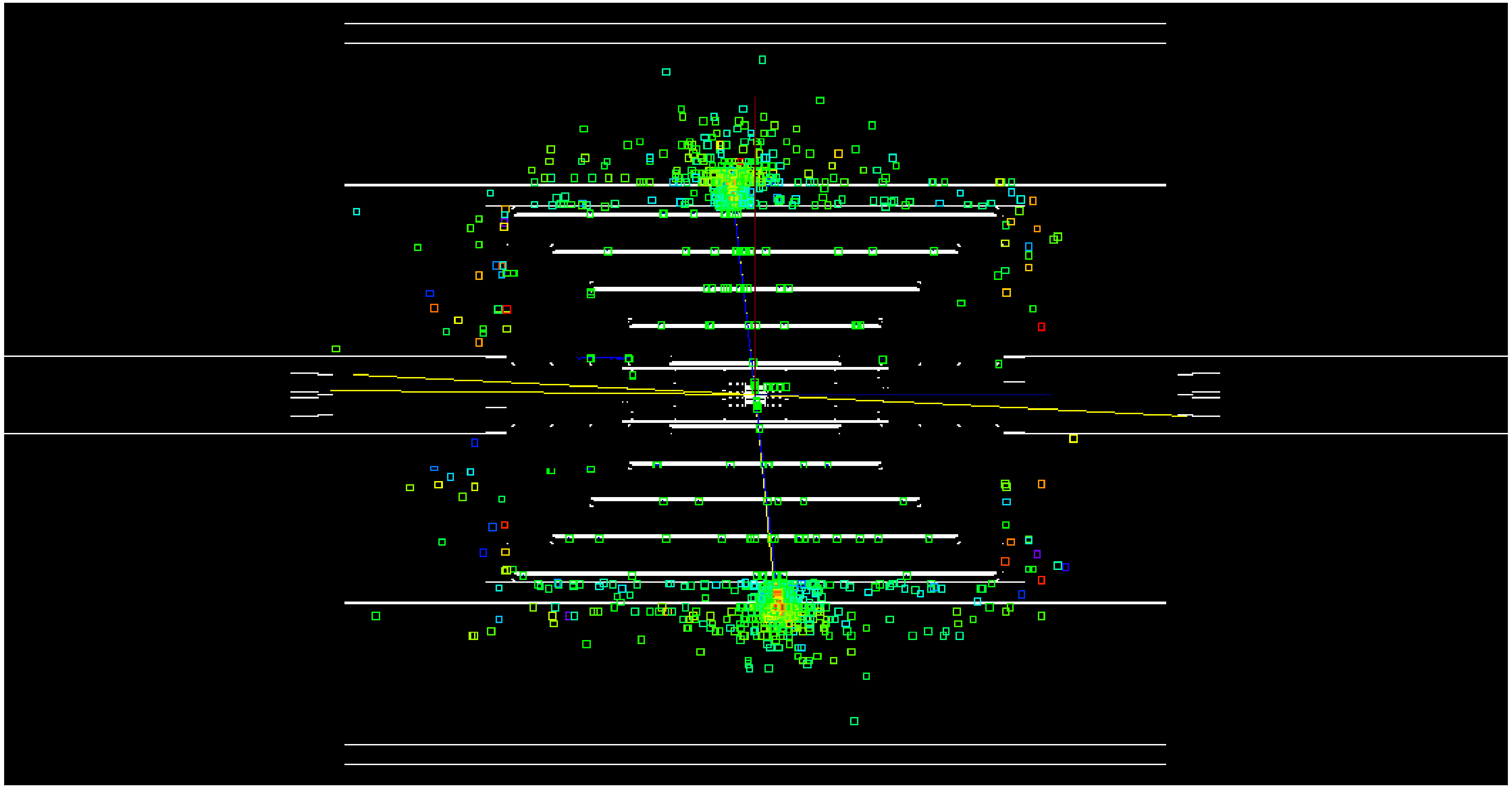








Bilepton decay event seen in CLIC000 det.



Bilepton decay event seen in CLIC000 det.

SIGNAL SIGNIFICANCE

Signal significance for the process $e^- e^- \to e^* e^-$ at the center of mass energy $\sqrt{s}$=3 TeV taking integrated luminosity $L = 200\ fb^{-1}$

Mass (GeV)	Δm(GeV)	$S/\sqrt{B}$ (λ=0.07)
500	20	6.3
1000	30	5.4
2000	40	3.9

CONCLUSION

- We have presented the angular distribution of the same sign leptons in the final state.

- For scalar bileptons the differential cross section remains smooth (isotropic) while for vector bileptons it is peaked in both forward and backward directions.

- The resonant production of doubly charged scalars and vectors have also advantage when highly polarized electrons in the initial state are used.

- An e−e− collider could be used as a factory for bileptons, doubly charged Higgs bosons, where their masses, total decay widths and couplings could be measured precisely.

- Our calculations show that signal significance $S/\sqrt{B} \sim \sqrt{L}$ can be rescaled for an initial luminosity in case of a limited time of e−e− running mode of ILC and CLIC.