New Scalar Top Study Using SIMDET

Alex Finch, André Sopczak

Lancaster University

Hanna Nowak

DESY Zeuthen

Amsterdam, April 2003

Outline

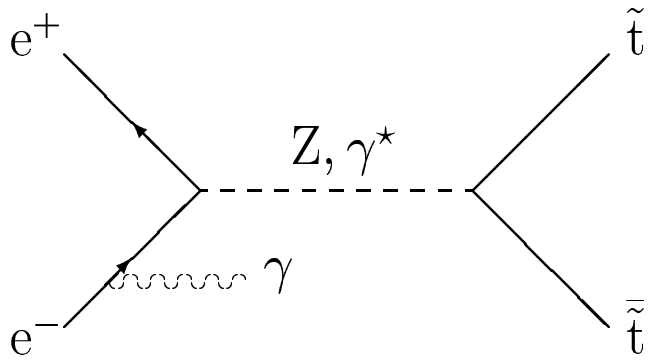
- **Scalar Top Quark Production**
- **Previous Results:**
  - **Neutralino Decay Mode**
  - **Chargino Decay Mode**
  - **SPS-5 Interpretation**
- **SIMDET Event Generation**
- **Selection Optimization**
- **Efficiency and Background**
- **c-Quark Tagging**
- **Conclusions**

Scalar Quarks

- **SUSY partners of the quark helicity states.**
- **mixing proportional to the quark mass large mixing, large mass splitting for the third generation.**

$$\tilde{t}_1 = \tilde{t}_L \cos\theta_{LR} + \tilde{t}_R \sin\theta_{LR}$$

Production:



Production via s-channel Z, γ exchange
Free parameters : mass and $\cos\theta_{LR}$
Minimum cross section for vanishing Z coupling

Scalar Quarks

Decay:

- **Two-body decays:** $\tilde{t}_1 \to c\tilde{\chi}_1^0$ **,** $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm}$
- **three-body decays:** $\tilde{t}_1 \to bl\tilde{\nu}_l$

Detailed study for the two-body decay mode:

- **2 jets +** E_{miss} **with b and with c-tagging**

$\Delta m = m_{\tilde{t}_1} - m_{\tilde{\chi}^0}$

Main background depends on Δm

- **low** Δm **(5...10 GeV) : 2 photon processes**
- **medium** Δm **(20 ...40 GeV): 2f processes**
- **high** Δm **(50 ... 70 GeV): 4f processes (WW, ZZ)**

Assumptions

Case Studies

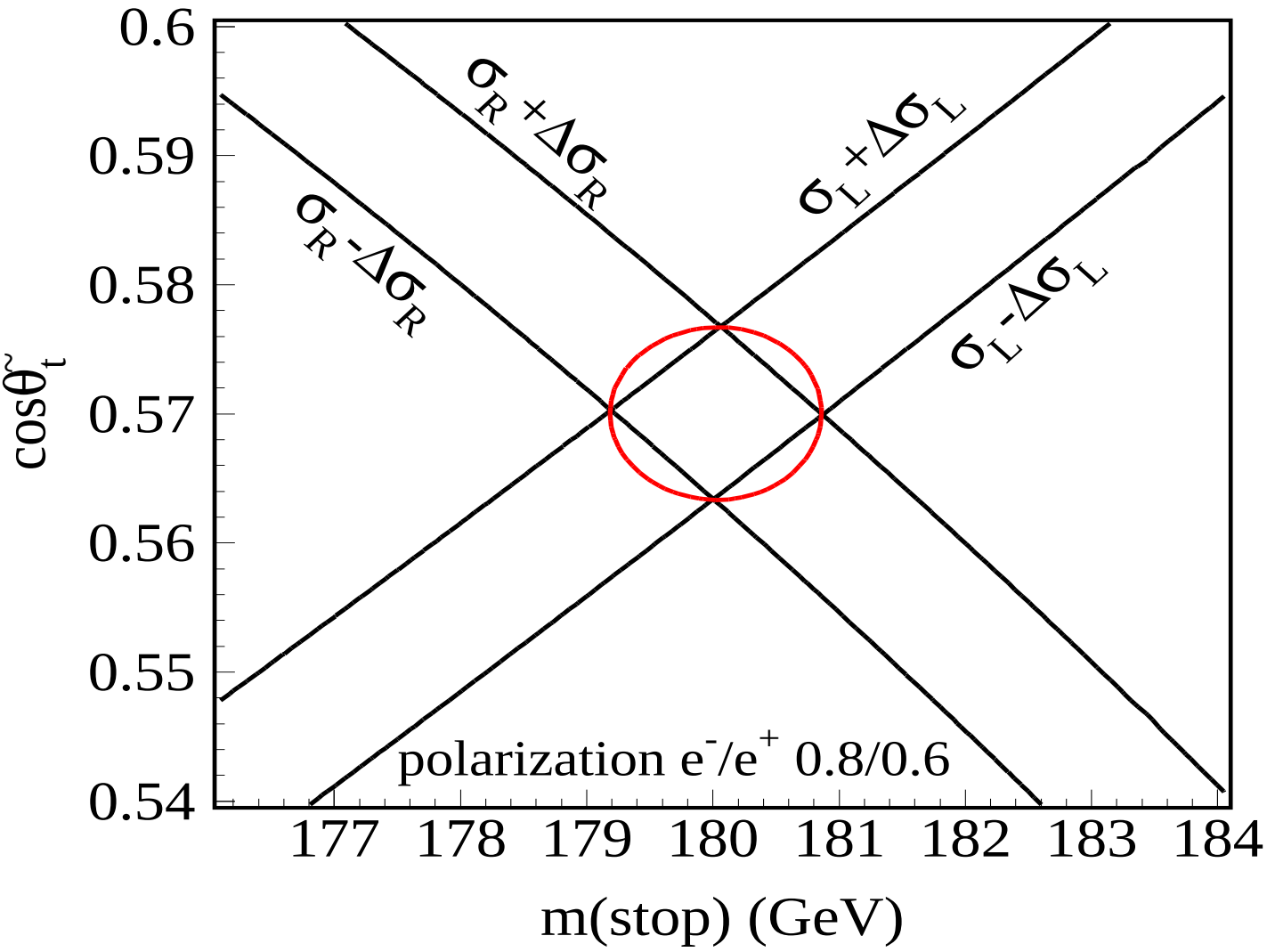
- **180 GeV $\tilde{t}_1$**
- **A: 100 GeV $\tilde{\chi}_1^0$**
- **B: 150 GeV $\tilde{\chi}_1^\pm$ and 60 GeV $\tilde{\chi}_1^0$**
- **Energy 500 GeV**
- **Luminosity 500 fb^{-1} for each polarization state**
- **Branching ratio 100 %**

Goal :
How well can we determine
$m_{\tilde{t}_1}$ and $\cos\theta_{LR}$?

- **Topology A: 2 c-jets + E_{miss}**
- **Topology B: 2 b-jets + 4 quark-jets + E_{miss}**

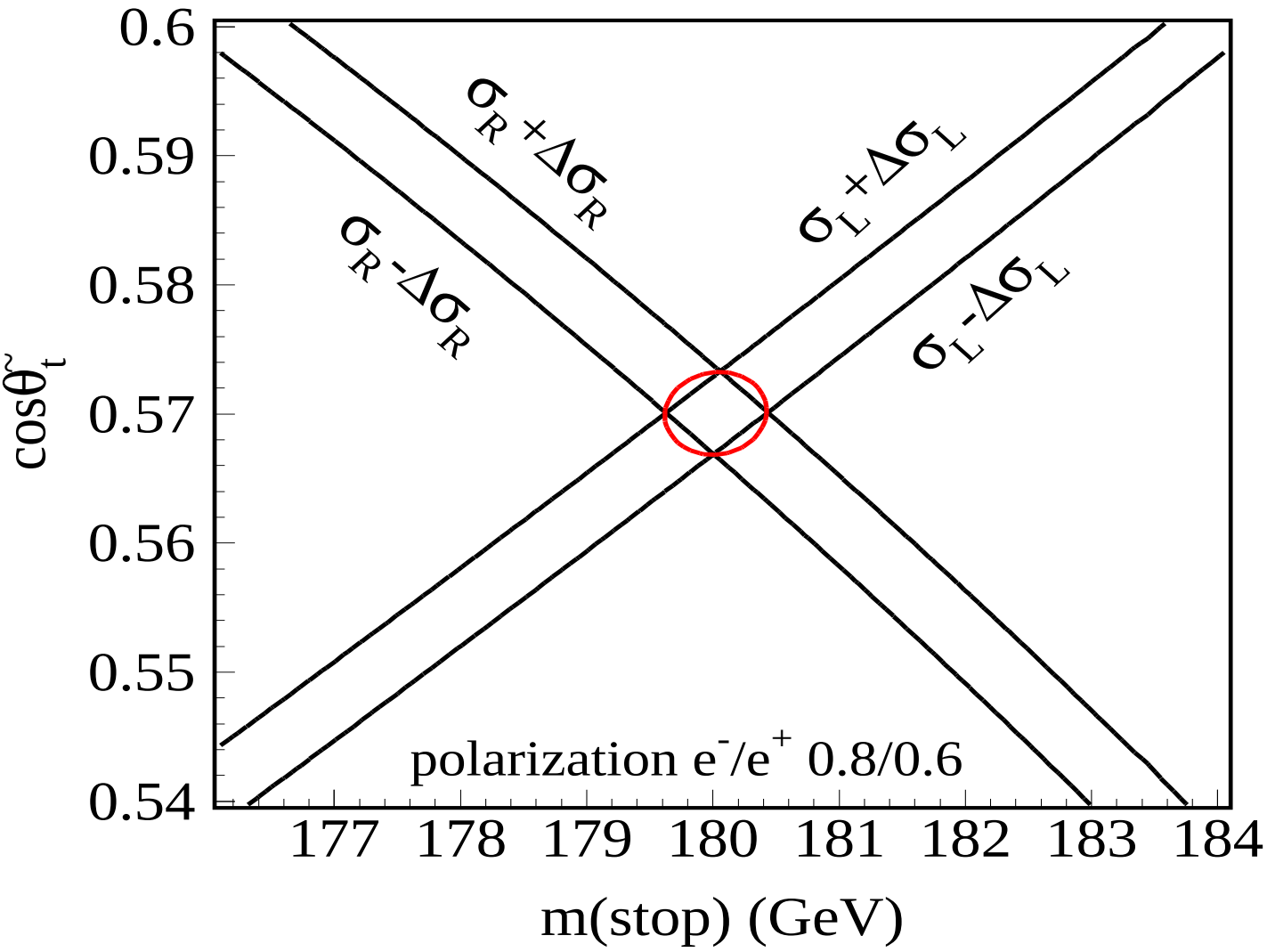
SGV Results

Neutralino Decay mode



L (fb^{-1})	e^- Pol.	e^+ Pol.	Δm	$\Delta \cos\Theta$
10	**0.8**	**0.0**	**7.0**	**0.06**
500	**0.9**	**0.0**	**1.0**	**0.009**
500	**0.8**	**0.6**	**0.8**	**0.008**

Chargino Decay mode



L (fb^{-1})	e^- Pol.	e^+ Pol.	Δm	$\Delta \cos\Theta$
10	**0.8**	**0.0**	**7.0**	**0.06**
500	**0.9**	**0.0**	**0.5**	**0.004**
500	**0.8**	**0.6**	**0.4**	**0.003**

SPS-5 – mSUGRA

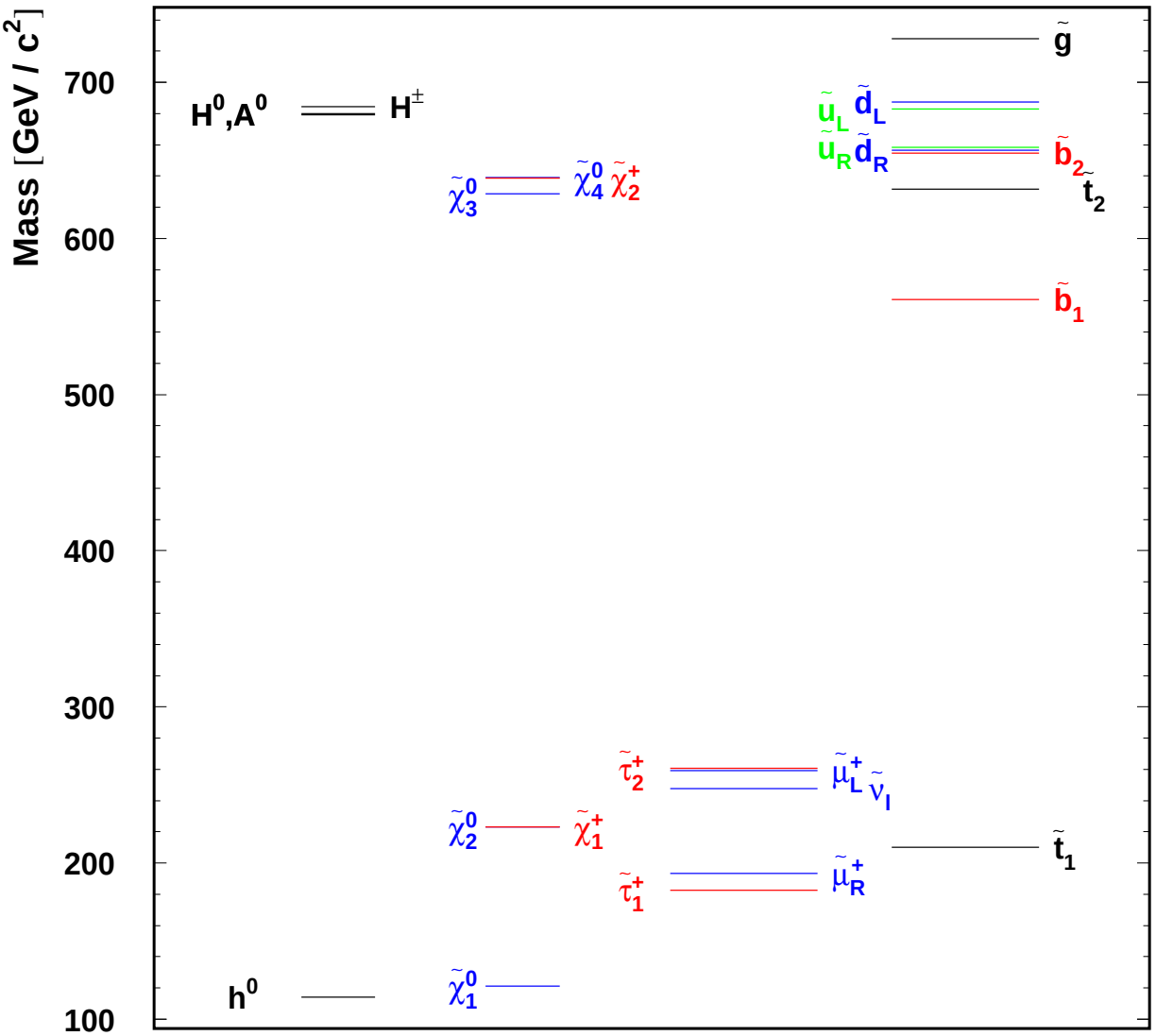
Interpretation in a detailed scenario

m_0	150	GeV
$m_{1/2}$	300	GeV
A_0	-1000	GeV
$\tan\beta$	5	
sign μ	$+$	

Light SUSY particles:

Particle	Mass (GeV)
scalar top 1	**210**
chargino 1	**223**
neutralino 2	**223**
neutralino 1	**121**
Higgs bosons h	**114**

SPS-5 – mSUGRA


Mass [GeV / c^2]
700
600
500
400
300
200
100
H^0,A^0
H$^\pm$
h^0
$\tilde{\chi}_3^0$
$\tilde{\chi}_4^0$ $\tilde{\chi}_2^+$
$\tilde{\chi}_2^0$
$\tilde{\chi}_1^+$
$\tilde{\chi}_1^0$
$\tilde{\tau}_2^+$
$\tilde{\tau}_1^+$
$\tilde{\mu}_L^+$ $\tilde{\nu}_l$
$\tilde{\mu}_R^+$
$\tilde{u}_L$ $\tilde{d}_L$
$\tilde{u}_R$ $\tilde{d}_R$
$\tilde{g}$
$\tilde{b}_2$
$\tilde{t}_2$
$\tilde{b}_1$
$\tilde{t}_1$

Possible SUSY background reactions

n=neutralino

ch=chargino

(1)	**n2n1**	$\rightarrow$	**Z n1 n1**
(1a)		$\rightarrow$	**$q\bar{q}$ n1 n1**
(1b)		$\rightarrow$	**ll n1 n1**
(2)	**n2n2**	$\rightarrow$	**Z n1 Z n1**
(2a)		$\rightarrow$	**$q\bar{q}$ n1 $q\bar{q}$ n1**
(2b)		$\rightarrow$	**$q\bar{q}$ n1 ll n1**
(3)	**chch**	$\rightarrow$	**W n1 W n1**
(3a)		$\rightarrow$	**$q\bar{q}$ n1 $q\bar{q}$ n1**
(3b)		$\rightarrow$	**$q\bar{q}$ n1 lν n1**

only (1a) has a similar signature

$\sigma(\mathrm{n1n2}) = 0.037$**pb**

$\mathrm{BR}(\mathrm{n2} \rightarrow \mathrm{Z\ n1}) = 0.012$

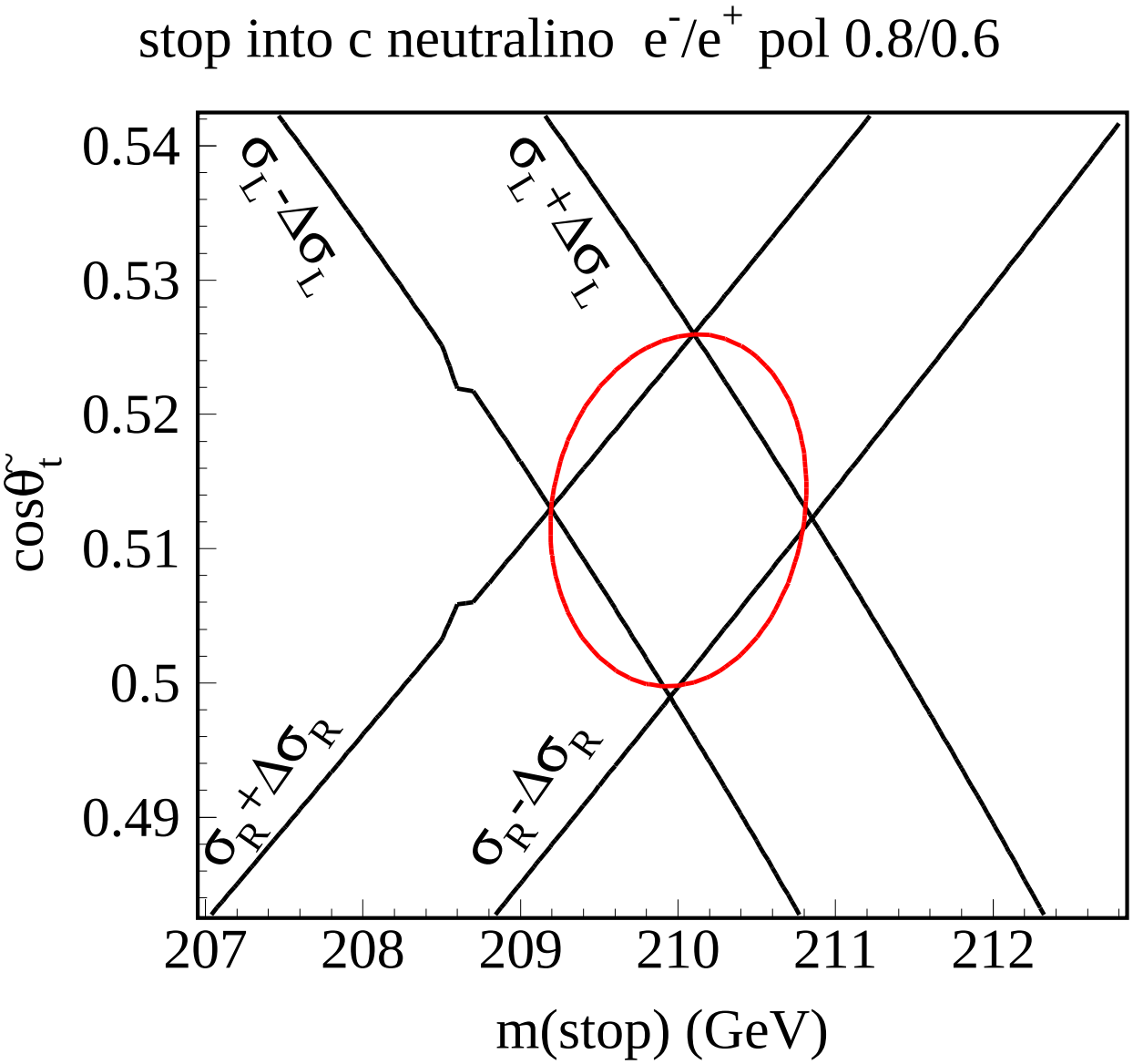
$\mathrm{BR}(\mathrm{Z} \rightarrow \mathrm{qq}) = 0.70$

Thus, $\sigma(\mathrm{n1n2} \rightarrow \mathrm{qq\ n1\ n1}) = 0.31$**fb**

$<< \sigma(\mathrm{signal})$

No significant background from Supersymmetric processes.

SPS-5 – mSUGRA



L (fb^{-1})	e^- Pol.	e^+ Pol.	Δm	$\Delta \cos\Theta$
500	0.8	0.6	1.0	0.013

SIMDET Signal and Background

$\tilde{t}_1$ into c $\tilde{\chi}_1^0$ and 1000 fb $^{-1}$ SM backgrounds

Channel	Generated	Presel.	Presel. 500 fb^{-1}	prev. SGV
$c\tilde{\chi}_1^0$	50 k	48%	48%	47%
$q\bar{q}$	12169 k	131325	64963	46788
$t\bar{t}$	620 k	70798	32715	43759
Ze^+e^-	5740 k	47574	24864	4069
$Z\ Z$	560 k	5787	3100	4027
$We\nu$	4859 k	440114	252367	252189
$W^+\ W^-$	6800 k	212142	122621	115243

SIMDET Signal and Background

Total background 500631 cf. SGV: 466075

After additional preselection cuts:

evis/ecms < 0.52

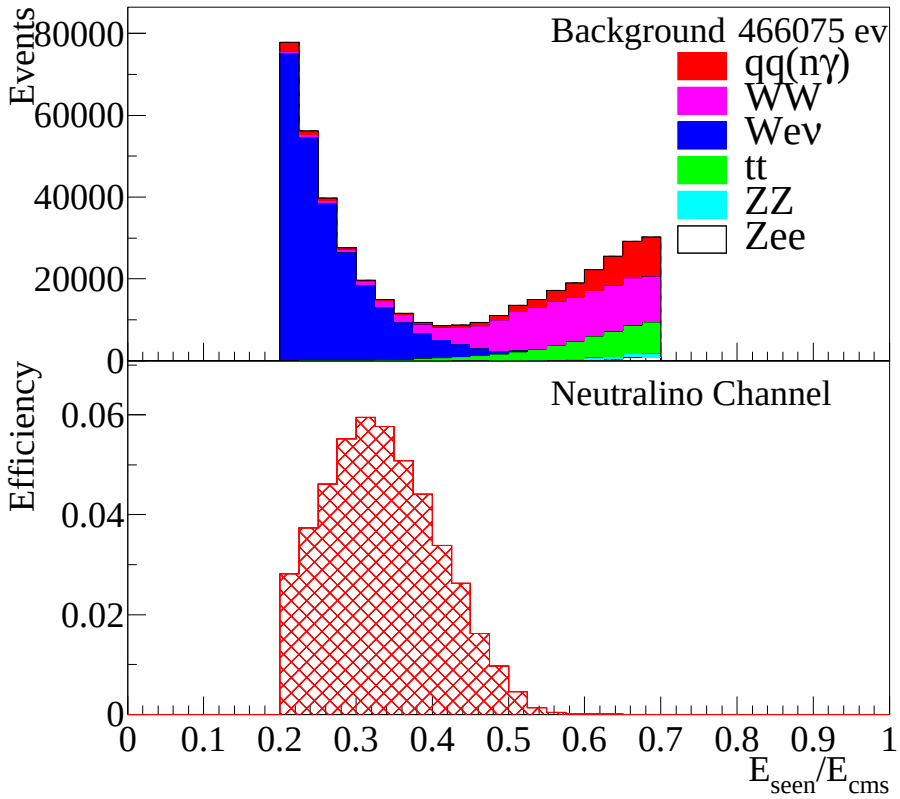
ptmiss/evis > 0.05 **(new cut for SIMDET only)**

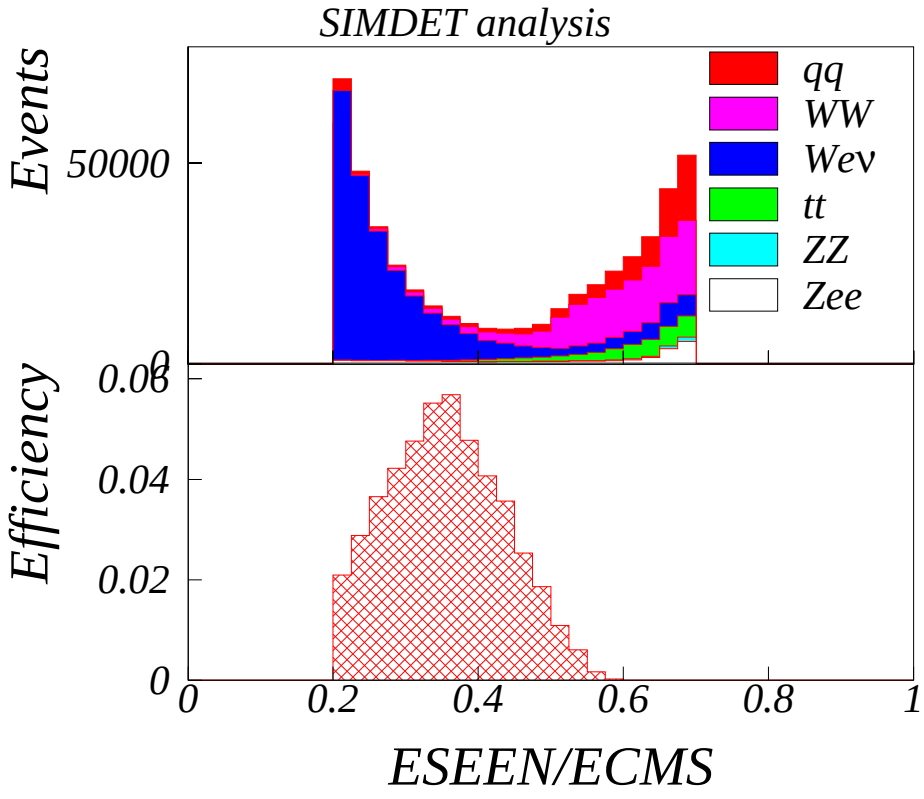
Channel	qq	WW	eWv	tt	ZZ	eeZ
	6801	23278	226070	5267	125	2147

Total background after preselection:

263691 cf. SGV 278377 events

SIMDET Signal and Background





IDA

IDA = Iterative Discriminant Analysis

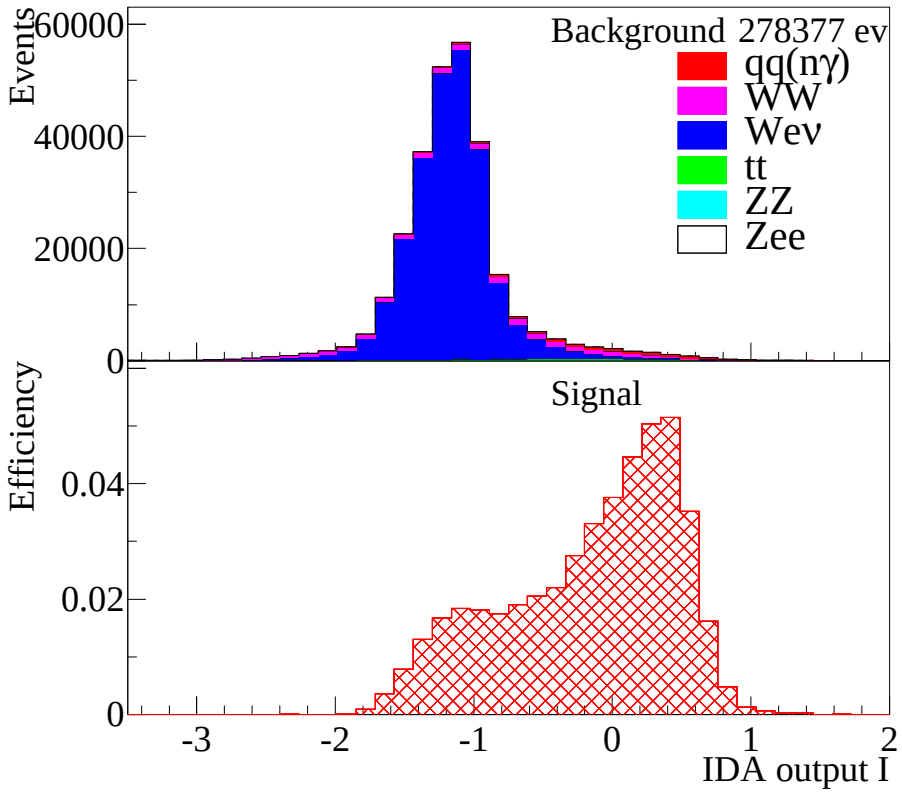
- **First MC half-sample used for training**
- **Second part for analysis after a more tight preselection.**

two step process : IDA 1 and IDA 2

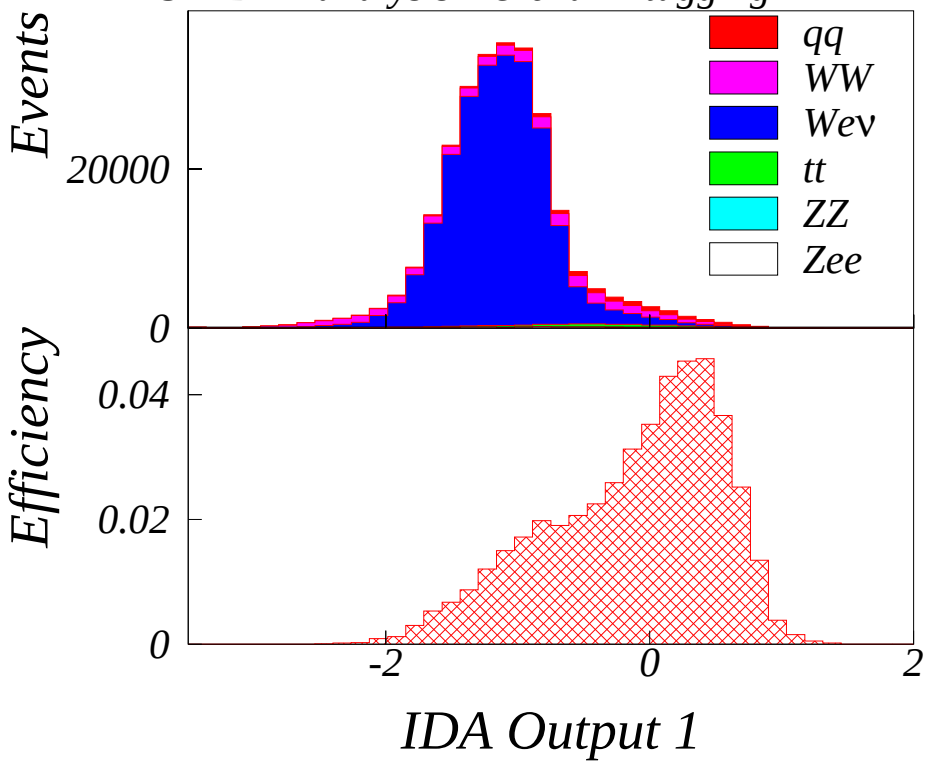
IDA 1: signal reduced to 50%

IDA 2: fine-tuning

IDA



SIMDET analysis NO charm tagging

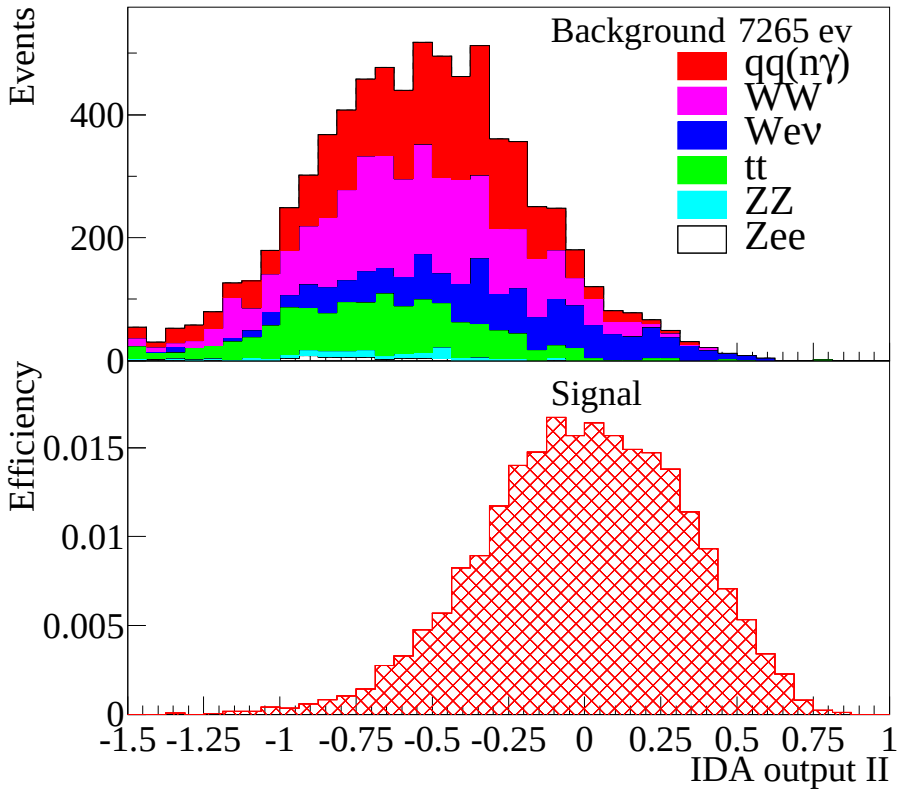


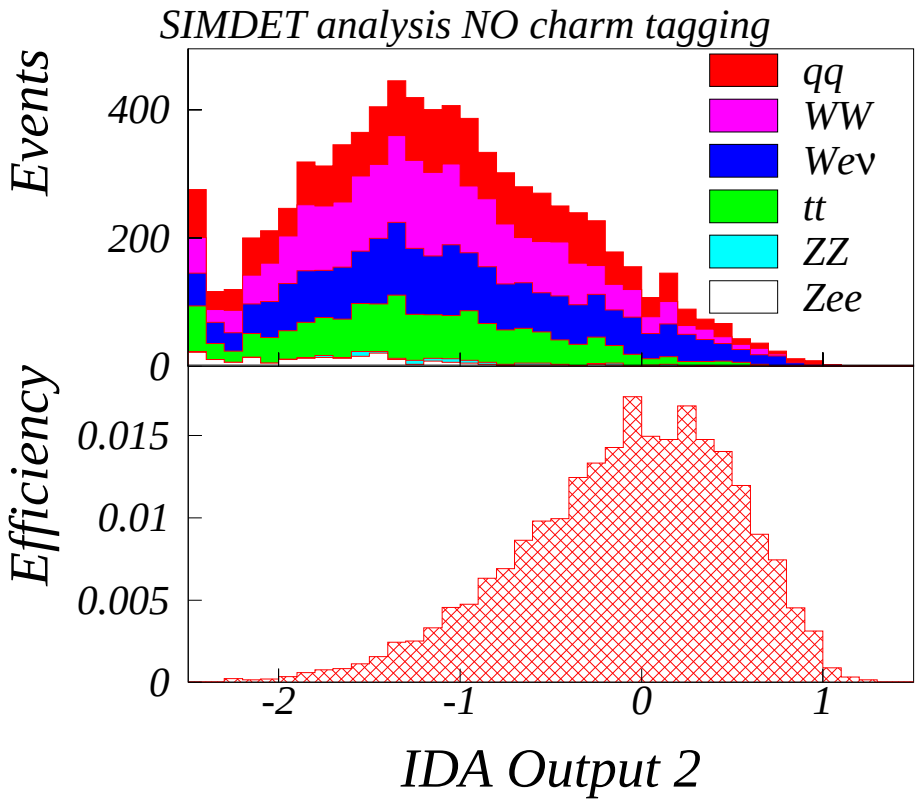
IDA

After first IDA step, remaining backgrounds without charm tag 7815 cf. SGV 7265 events.

With charm tag 3600 events.

IDA


Background 7265 ev
qq(nγ)
WW
Weν
tt
ZZ
Zee
Events
400
200
0
Signal
Efficiency
0.015
0.01
0.005
0
-1.5 -1.25 -1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1
IDA output II


SIMDET analysis NO charm tagging
qq
WW
Weν
tt
ZZ
Zee
Events
400
200
0
Efficiency
0.015
0.01
0.005
0
-2
-1
0
1
IDA Output 2

IDA

After second IDA step, remaining backgrounds

for 12% efficiency:

without charm tag 680 cf. SGV 400 events.

With charm tag 165 events.

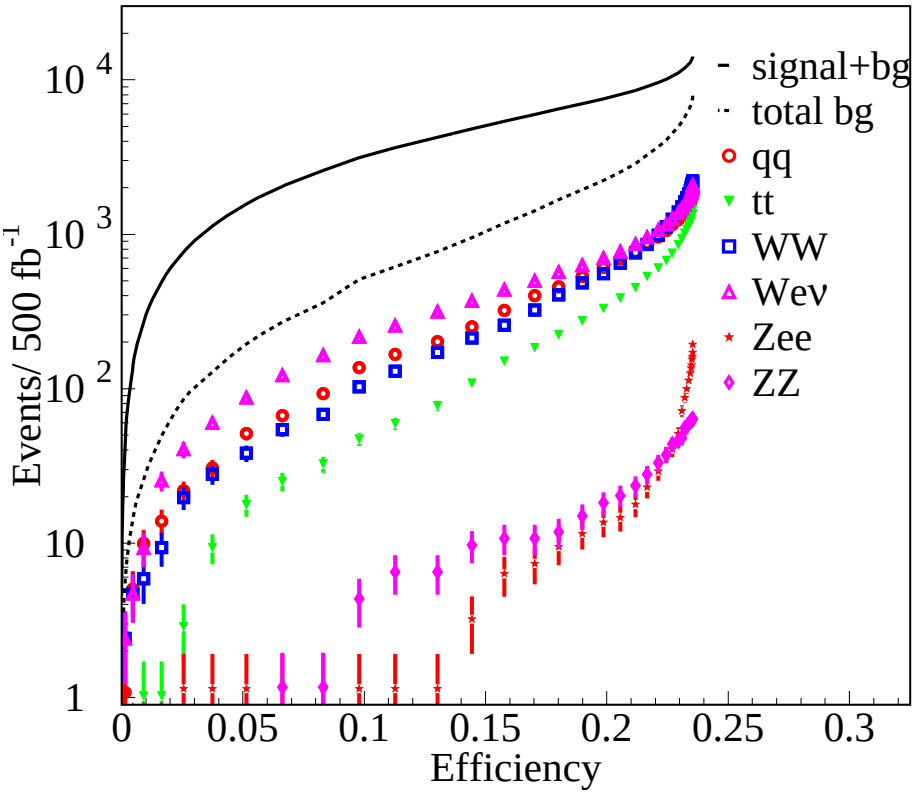
Polarization states:
e^-/e^+ –80/60 (left) versus 80/–60 (right)

Polarization	$\tilde{t}_1\bar{\tilde{t}}_1$	$We\nu$	WW	$q\bar{q}$	$t\bar{t}$	ZZ
e^-/e^+	**fb**	**pb**	**pb**	**pb**	**pb**	**pb**
$-0.8/0.6$	**81.81**	**10.72**	**22.64**	**21.49**	**1.113**	**0.909**
$-0.9/0$	**55.18**	**6.86**	**14.9**	**14.4**	**0.771**	**1.17**
$0/0$	**53.46**	**5.59**	**7.86**	**12.1**	**0.574**	**0.864**
$0.9/0$	**51.73**	**4.61**	**0.906**	**9.66**	**0.376**	**0.554**
$0.8/-0.6$	**76.41**	**1.780**	**0.786**	**13.99**	**0.542**	**0.464**

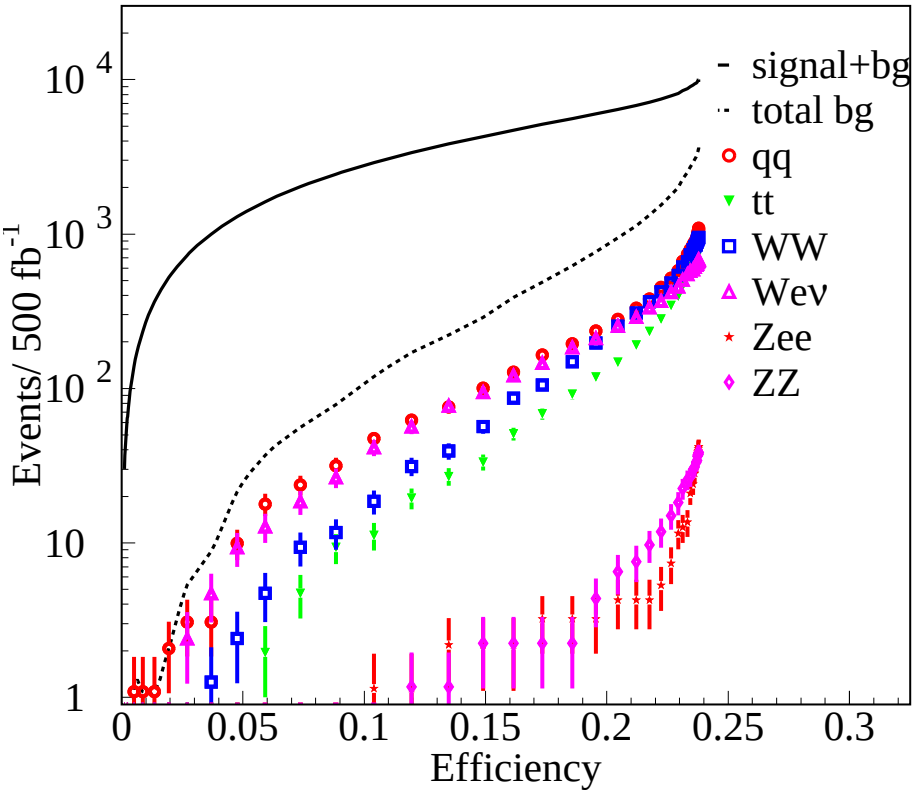
minimum signal cross-section:
cos$\theta_{LR} = 0.57$ — no Z-exchange

c-Quark Tagging

SIMDET analysis NO charm tagging



SIMDET analysis - charm tagging IS used

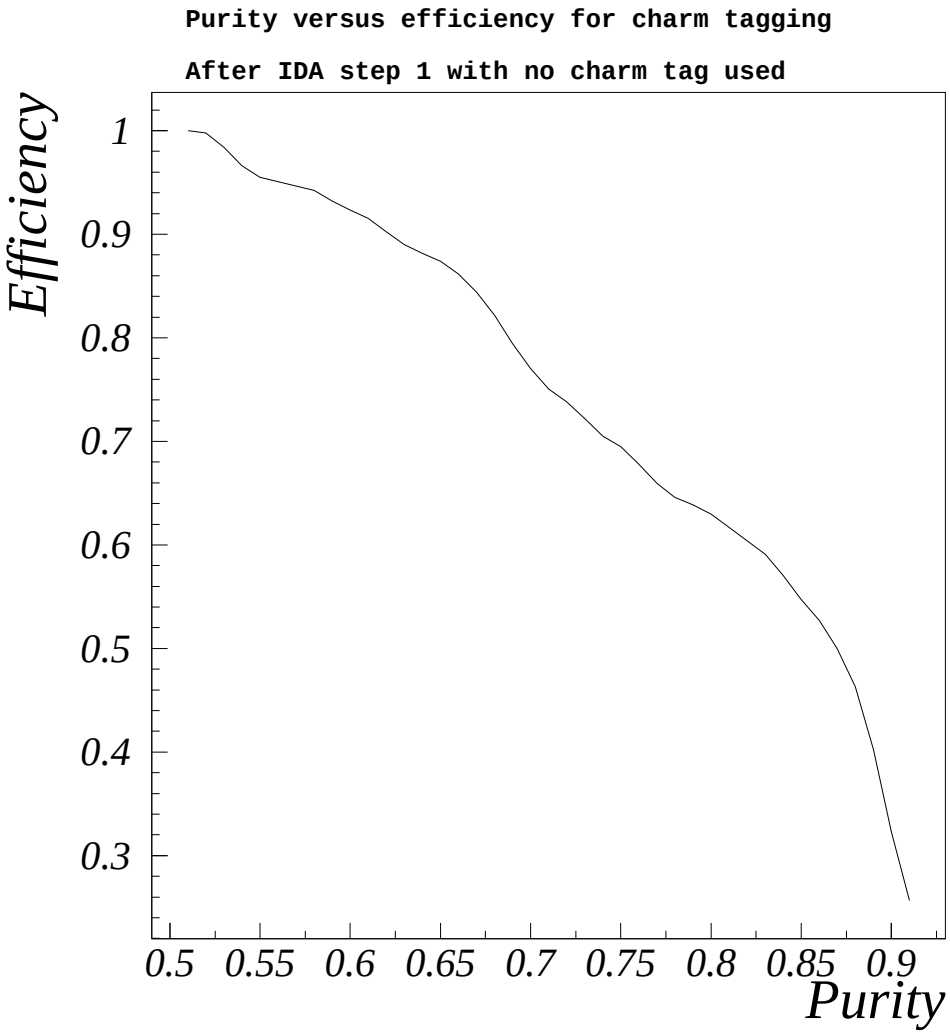


SIMDET-4 and c-Quark Tagging

New simulation with SIMDET-4 (J. Schreiber et.al.)
Including CCD vertex detector (LCFI Collaboration, C. Damerell et.al.)
Preliminary performance of c-quark tagging with ZVTOP (T.Kuhl et.al.):

$\tilde{\chi}^0 c \bar{\tilde{\chi}}^0 \bar{c}$ **signal efficicency vs. purity**

for all background after IDA step-1.



Conclusions

- **After first discovery at Tevatron or LHC, difficult detailed understanding of Supersymmetric processes.**
- **Precision measurements are essential to establish Supersymmetry as they were crucial for the SM.**
- **A high luminosity collider will provide details of the Supersymmetric particle spectrum.**
- **Polarization of e^+ and e^- are particularly important for the determination of the scalar top properties.**
- **Precise determination of couplings and mixing angles.**
- **Investigation of a Supersymmetry model scenario $\Rightarrow$ complementarity studies for the Tevetron and LHC.**
- **New SIMDET simulation for 1000 fb^{-1} at 500 GeV.**
- **30.748 million events simulated.**
- **SGV distributions largely agree with SIMDET.**
- **c-tagging in the $\tilde{\chi}^0\mathrm{c}\bar{\tilde{\chi}}^0\bar{\mathrm{c}}$ decay channel with a CCD LCFI detector.**
- **FUTURE plans:**
- **Higher sensitivity for mass and mixing angle.**
- **Dedicated SPS-5 simulation.**
- **Endpoint method for mass determination.**
- **c-tagging optimization.**
- **LCFI detector design study.**