Study of Neutralino Production using Tau Identification

Blanka Sobloher, Klaus Desch, Thorsten Kuhl
DESY, University of Hamburg

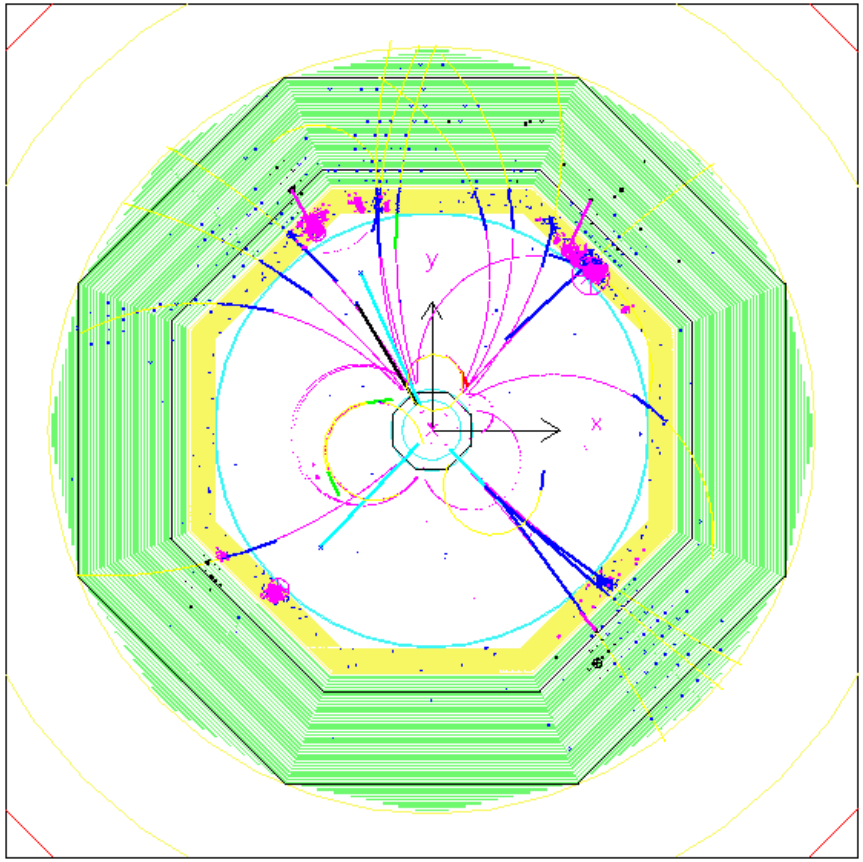
LCWS 2004, Paris, 21 April 2004

- Motivation for tau identification
- Tau identification: strategy and definition
- Application to Neutralino production: first look
- Outlook

Experimental environment

- TESLA parameters
  - $\sqrt{s}$ = 500 GeV
  - $\int L\, dt \approx 500\ fb^{-1}$ in 1-2 years

- Simulation tools
  - SUSY spectrum: SPheno 2.2 with interface to Pythia 6.303 via SLHA
  - Eventgeneration: Pythia 6.303 for both SM and SUSY processes
  - Parametrised detector simulation: Simdet 4.1



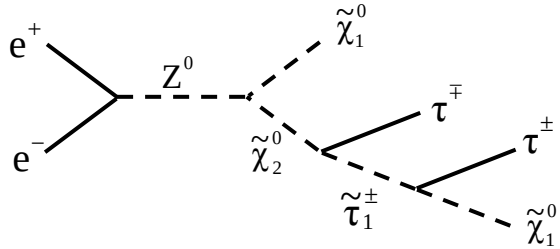
Motivation for Tau Identification

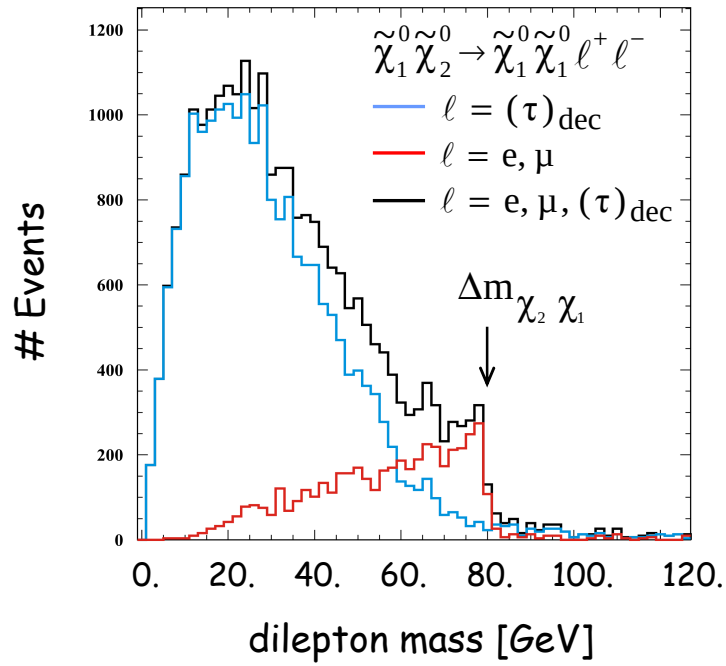
- SUSY scenarios with high tan β
  - Sparticles tend to decay dominantly into tau leptons
  - Many SUSY processes contribute together

→ GOAL: all combined SUSY analysis

SPS1a	BR
$\tilde{\tau}_1^+ \to \tilde{\chi}_1^0 \tau^+$	100%
$\tilde{\chi}_1^+ \to \tilde{\chi}_1^0 \tau^+ \nu_\tau$	90.4%
$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tau^+ \tau^-$	86.0%
$\tilde{e}_L^- \to \tilde{\chi}_1^- \nu_e$	32.8%
$\to \tilde{\chi}_2^0 e^-$	18.3%
$\tilde{\mu}_L^- \to \tilde{\chi}_1^- \nu_\mu$	30.9%
$\to \tilde{\chi}_2^0 \mu^-$	16.4%
$\tilde{\tau}_2^- \to \tilde{\chi}_1^- \nu_\tau$	30.5%
$\to \tilde{\chi}_2^0 \tau^-$	17.2%

$$\tilde{\chi}_1^0 \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \tilde{\chi}_1^0 \tau^+ \tau^-$$



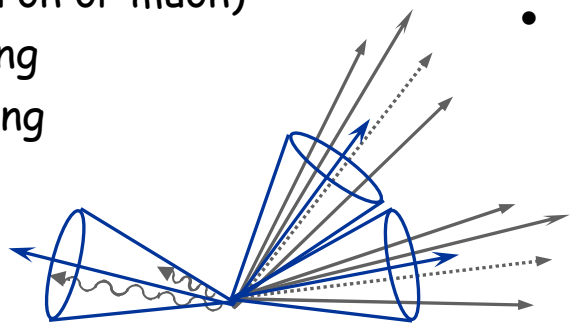


Tau Identification: Requirements

GOAL: Find a variable number of isolated and collimated jets of low multiplicity

Requirements:

- 1-prong (85%) and 3-prong (15%) taus
- Independent of actual decay channel
- Independent of actual final state
- Best possible association of tracks and calorimeter clusters to a tau candidate
- Classification of tau candidates as
  - Leptonic (electron or muon)
  - Hadronic 1-prong
  - Hadronic 3-prong



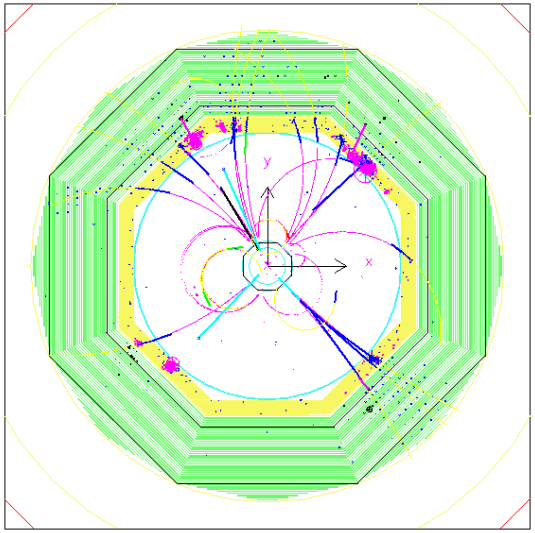
Make use of a

cone jet algorithm

Relevant parameters:

- Threshold of starting particles (0.5 – 1.0 GeV)
- Minimal cone energy (≈ Threshold)
- Cone width (half angle) (θ_{cone} ~ 0.2 - 0.25 (10° - 15°))

Association of Cones with Taus

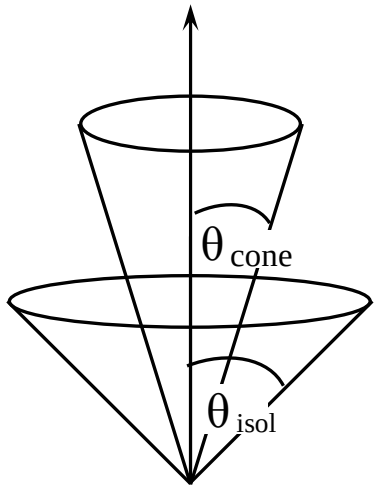


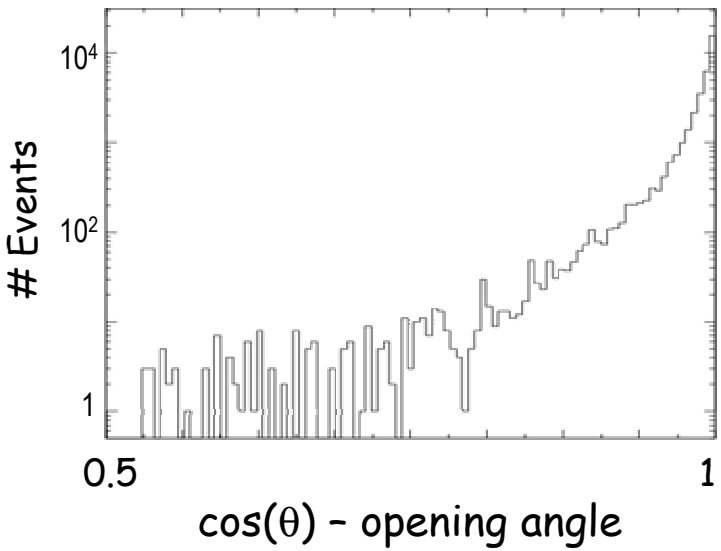
- Allocation:
  - One tau correct in a single cone : > 90%
  - Mixing of taus (or something else): < 4%
  - Splitting of taus onto several cones: < 4%

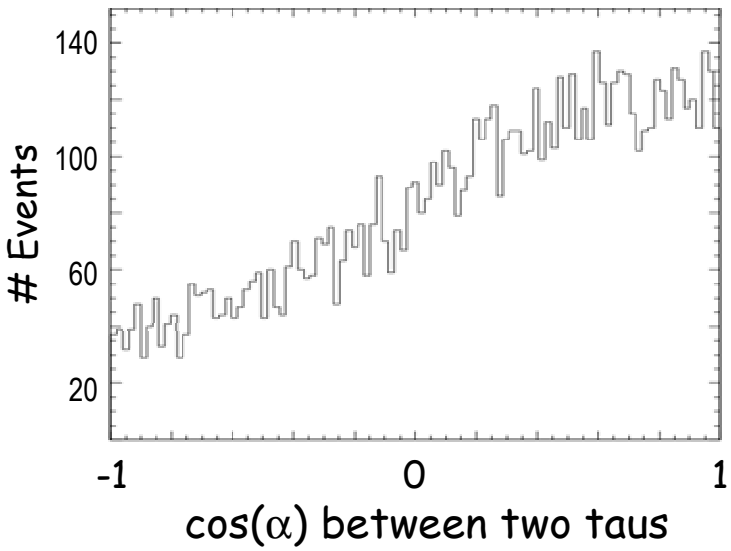
Allocation class	$\tilde{\chi}_1^0\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\tau^+\tau^-$	$\tilde{\chi}_2^0\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tau^+\tau^- \; \tilde{\chi}_1^0\tau^+\tau^-$
all correct	89.9%	81.3%
tau + gamma	0.7%	1.8%
splitted tau	3.9%	6.4%
splitted + gamma	0.1%	0.3%
mixed taus	3.1%	6.6%
mixed + gamma	< 0.1%	< 0.1%
missing tau	1.1%	0.1%
other	1.2%	2.3%

Tau Identification: Definition

- Tau candidate:
  - One cone of 10° with 1 or 3 tracks
  - Correct charge sum: ±1
  - Invariant mass < 2 GeV
  - No further tracks in a 15° isolation cone
  - Whole cone lies well in the detector: $|\eta| < 2$ (≈15 °)
- Selection of a tau pair:
  - Two candidates with opposite charge: $Q_1 \cdot Q_2 < 0$







Tau Identification: Classification

- Classification:
  - 1-prong
    - Electron (e): track + full energy in ECAL
    - Muon (μ): MIP (track + sparse Energy in ECAL and HCAL)
    - Hadronic (1pr)
  - 3-prong (3pr)

Single efficiency:
- e: ~ 80%
- μ: ~ 80%
- 1pr: ~ 87%
- 3pr: ~ 72%

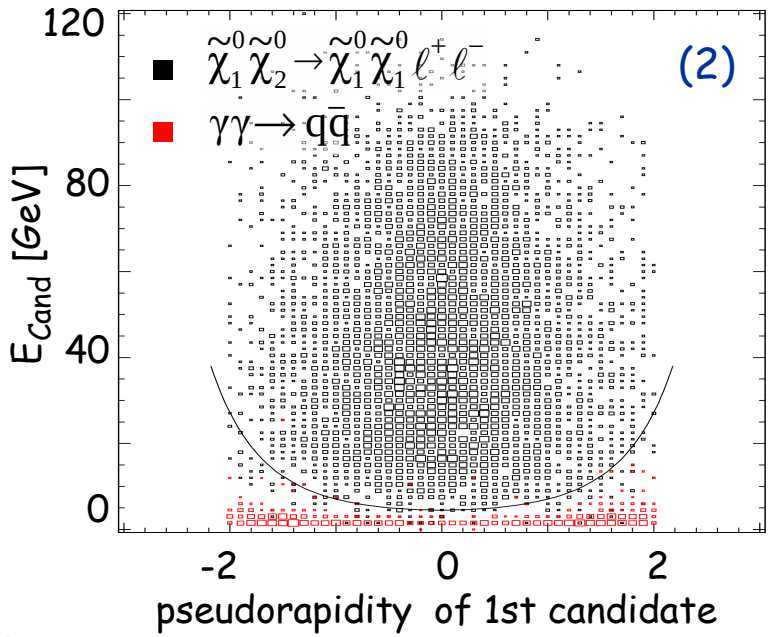
Detector Classification (2 taus from $\tilde{\chi}_1^0\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\tau^+\tau^-$)

Generator Level	e/e	e/μ	μ/μ	e/1pr	μ/1pr	1pr/1pr	e/3pr	μ/3pr	1pr/3pr	3pr/3pr	total
e/e	64%			17%		1%					81%
e/μ		63%		9%	9%	1%					82%
μ/μ			64%		18%	2%					84%
e/1pr	2%	0.2%		70%		10%					82%
μ/1pr		3%	0.2%	0.3%	70%	10%					83%
1pr/1pr	0.1%			6%	0.3%	75%					80%
e/3pr	0.1%			2%		0.2%	58%		8%		68%
μ/3pr		0.1%			2%	0.1%		58%	9%		69%
1pr/3pr				0.1%		2%	2%	0.1%	64%		68%
3pr/3pr									4%	52%	56%

Selection of $\tilde{\chi}_1^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\tilde{\chi}_1^0\ell^+\ell^-$ and $\tilde{\chi}_2^0\tilde{\chi}_2^0 \to \tilde{\chi}_1^0\ell^+\ell^-\ \tilde{\chi}_1^0\ell^+\ell^-$

- 1st step: common for 2 and 4 leptons
  - (1) $2 \le N_{cand} \le 6$,

    max 1 additional charged cone
  - (2) $E_{cand1} > 4.5 \cdot \exp(0.45 \cdot \eta^2)$ GeV
  - (3) $E_{neutral} < 150$ GeV
  - (4) $\cos(\alpha_{r\varphi}) > -0.9$
  - (5) $P_{tvis} < 20$ GeV, $|\cos(\theta_{miss})| < 0.85$

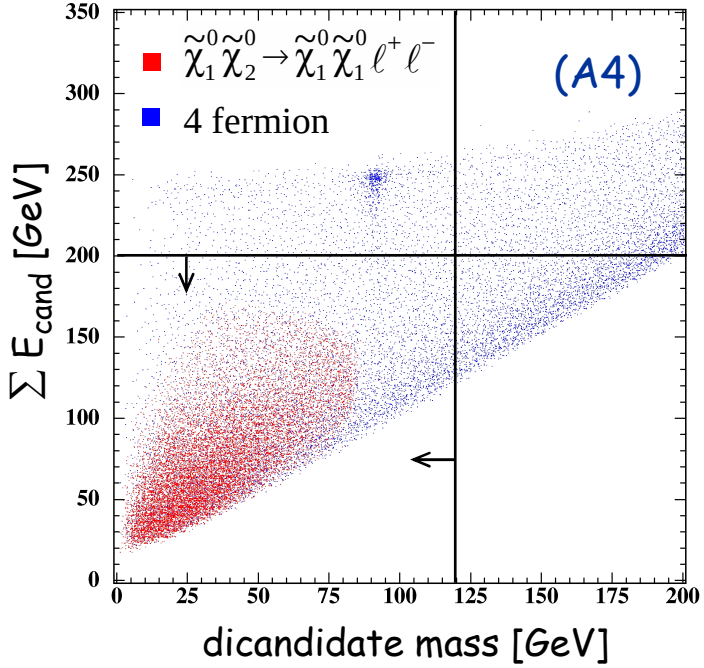


	Signal 2ℓ	Signal 4ℓ	SUSY	2 fermion	4 fermion	2 photon
	32.1 k	29.5 k	357 k	8.7 M	18.2 M	9.8 G
(1)	24.5 k	27.9 k	297 k	1.3 M	1.4 M	830 M
(2)	24.2 k	27.8 k	295 k	1.1 M	1.0 M	26.3 M
(3)	24.2 k	27.8 k	294 k	851 k	719 k	20.7 M
(4)	22.5 k	27.4 k	246 k	80.3 k	480 k	1.7 M
(5)	18.0 k	21.1 k	198 k	4.5 k	148 k	964

$500 fb^{-1}$ @500GeV

Selection of $\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$

- Step 2a: specific for 2 leptons
  - (A1) $N_{cand} = 2$
  - (A2) opposite charge: $Q_1 \cdot Q_2 < 0$
  - (A3) no additional charged cones, $E_{neutral} < 20$ GeV
  - (A4) Veto 4 fermion: $\sum E_{cand} < 200$ GeV, dicandidate mass < 120 GeV



	Signal 2ℓ	Signal 4ℓ	SUSY	2 fermion	4 fermion	2 photon
After (5)	18.0 k	21.1 k	198 k	4.5 k	148 k	964
(A1)	14.4 k	1.2 k	124 k	15	72.6 k	138
(A2)	14.3 k	1.0 k	122 k	13	68.1 k	138
(A3)	14.3 k	65	120 k	1	62.8 k	0
(A4)	14.3 k	65	94.7 k	1	17.3 k	0

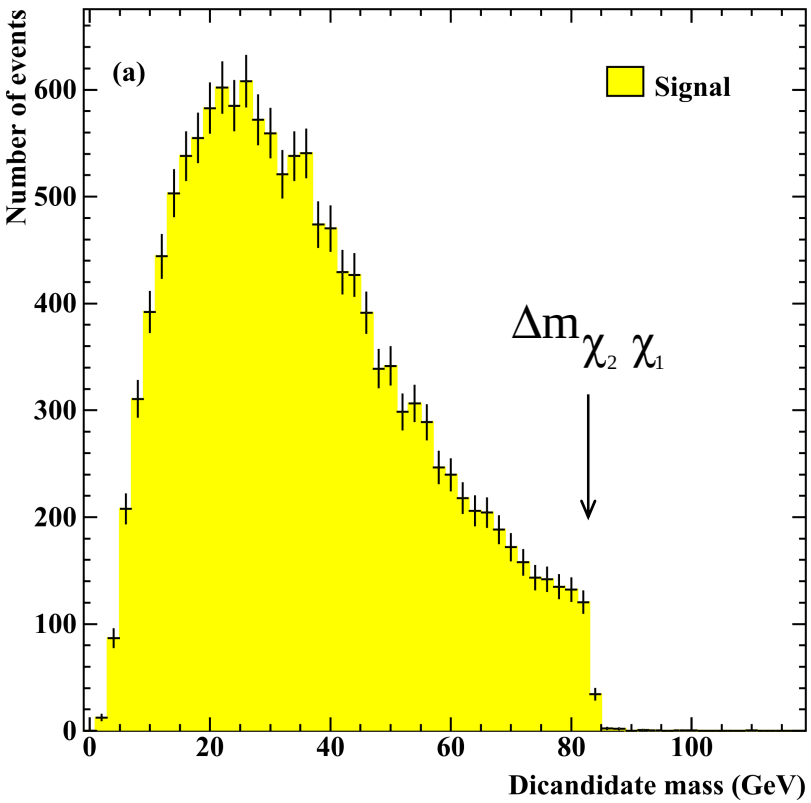
$\varepsilon_{Sig} \approx 45\%$

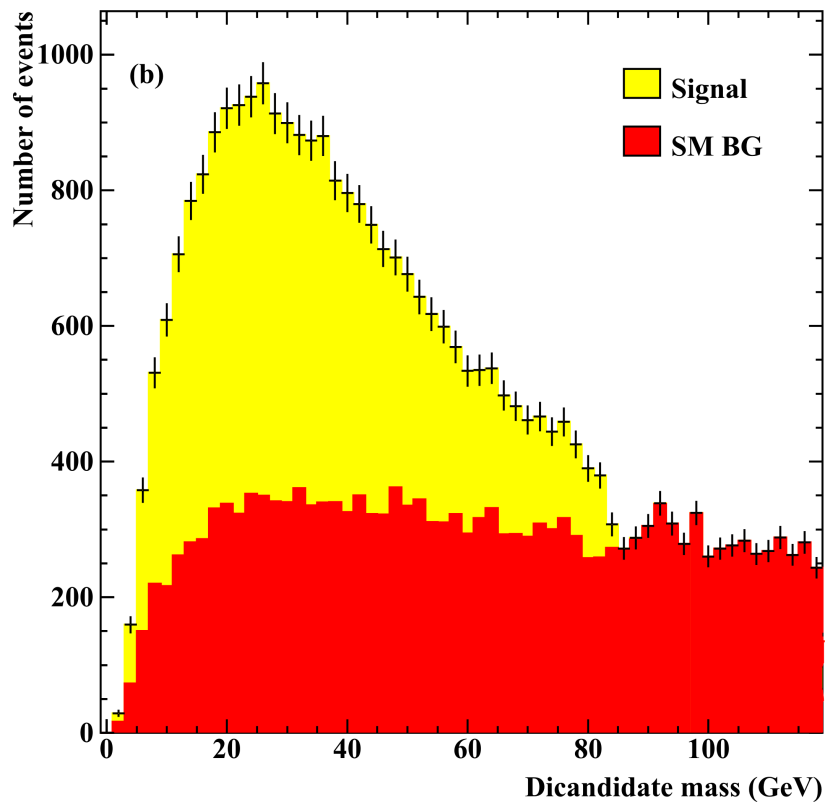
$N_{Sig}/N_{SM} \approx 1$

SUSY contributions!

Invariant mass for $\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$

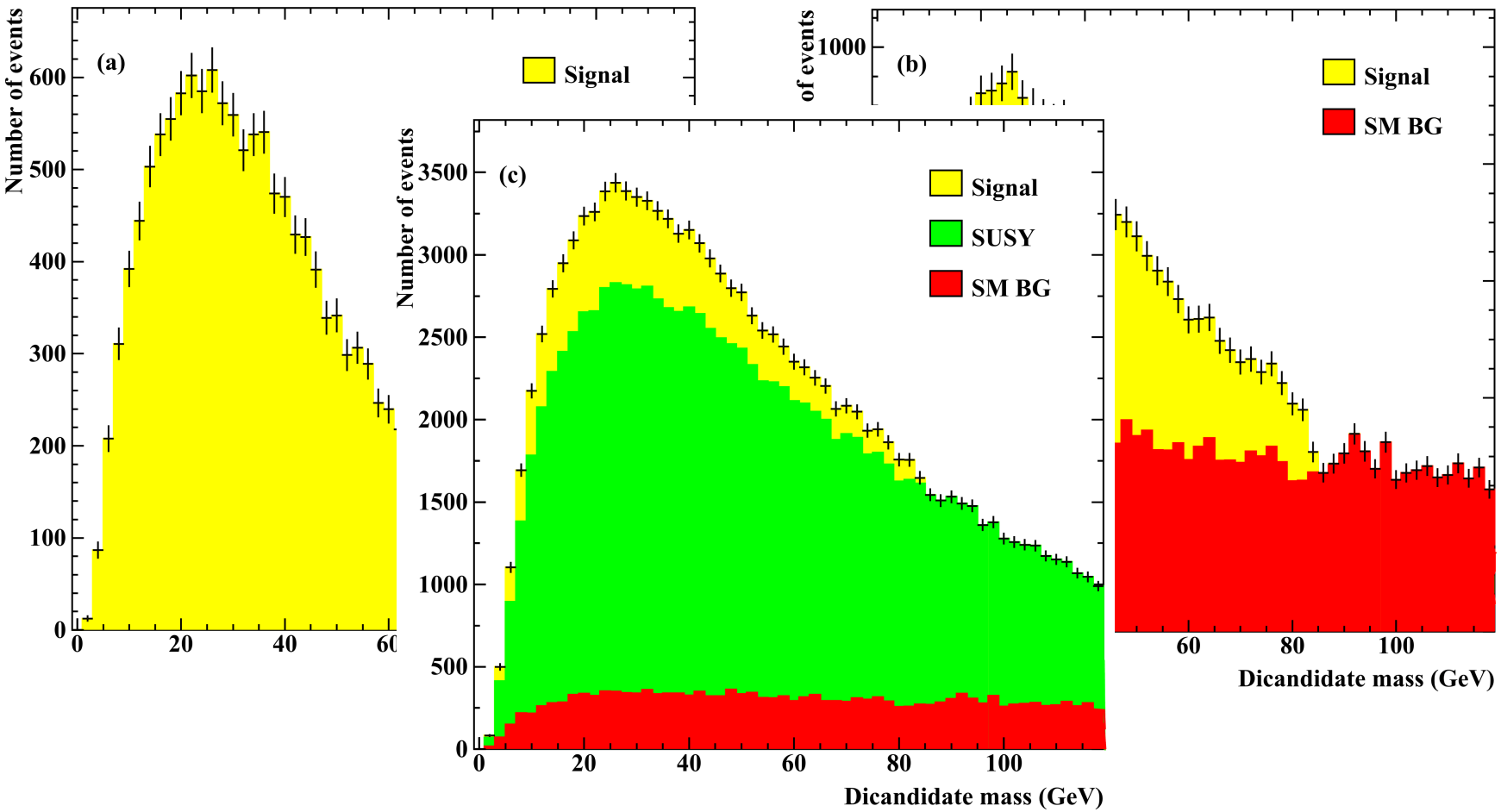
- After all cuts





Invariant mass for $\tilde{\chi}_1^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0 \ell^+ \ell^-$

- After all cuts



Selection of $\tilde{\chi}_2^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^- \; \tilde{\chi}_1^0 \ell^+ \ell^-$

- Step 2b: specific for 4 leptons
  - (B1) $N_{cand} = 4$
  - (B2) two pairs of opposite charge
  - (B3) no additional charged cones,

    $E_{neutral} < 20$ GeV

$\varepsilon_{Sig} \approx$ 35%

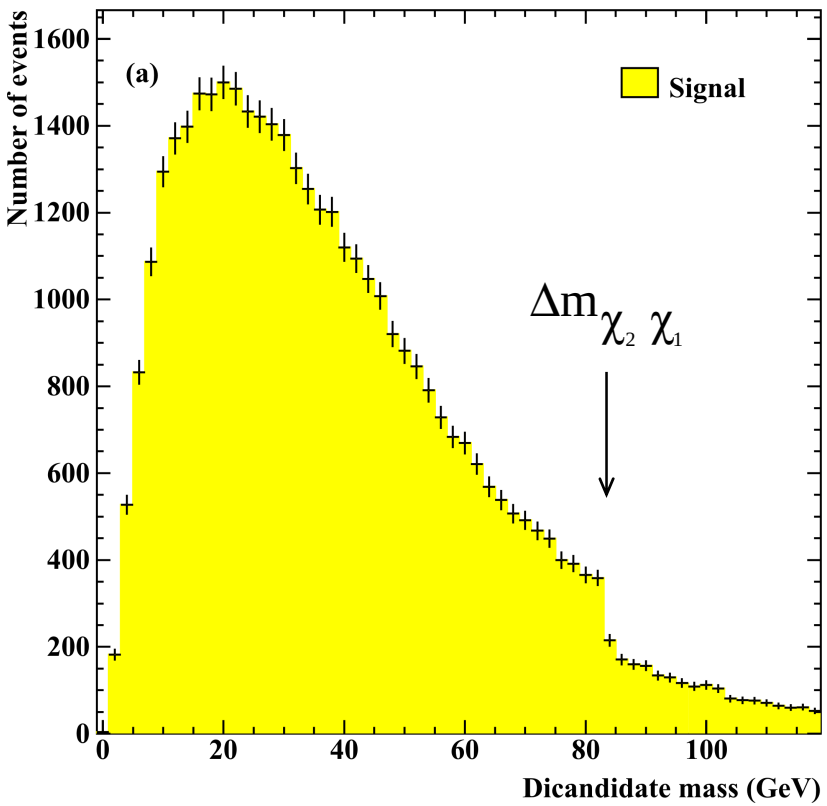
SM BG negligible

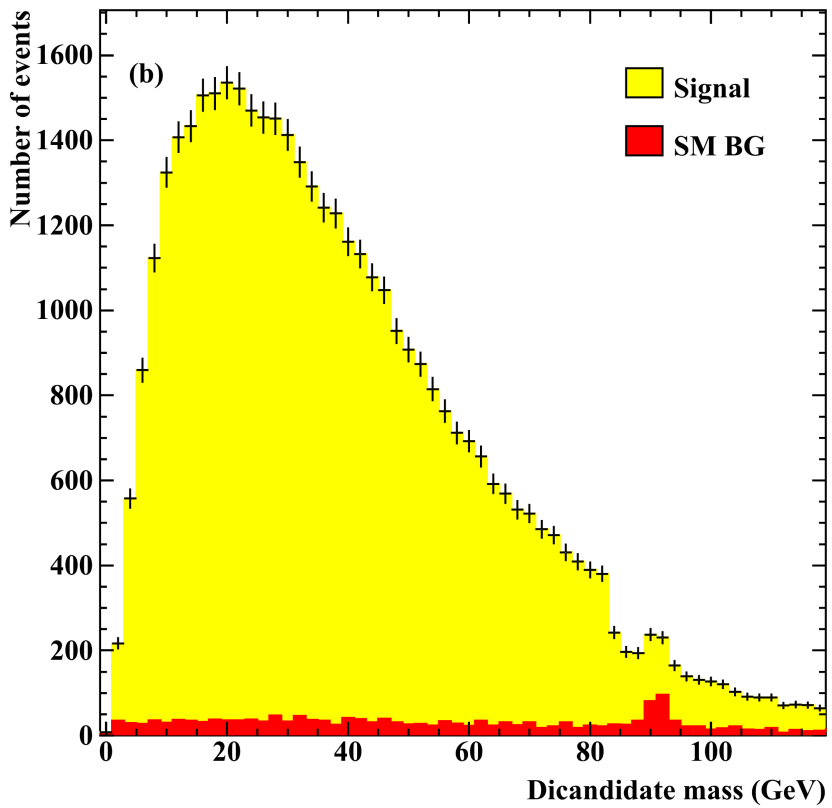
$N_{Sig}/N_{SUSY} \approx 1 / 2$

	Signal 2ℓ	Signal 4ℓ	SUSY	2 fermion	4 fermion	2 photon
After (5)	18.0 k	21.1 k	198 k	4.5 k	148 k	964
(B1)	394	12.1 k	30.5 k	860	15.3 k	0
(B2)	386	10.5 k	27.2 k	848	7.9 k	0
(B3)	0	10.1 k	23.1 k	1	614	0

Invariant mass for $\tilde{\chi}_2^0 \tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^- \; \tilde{\chi}_1^0 \ell^+ \ell^-$

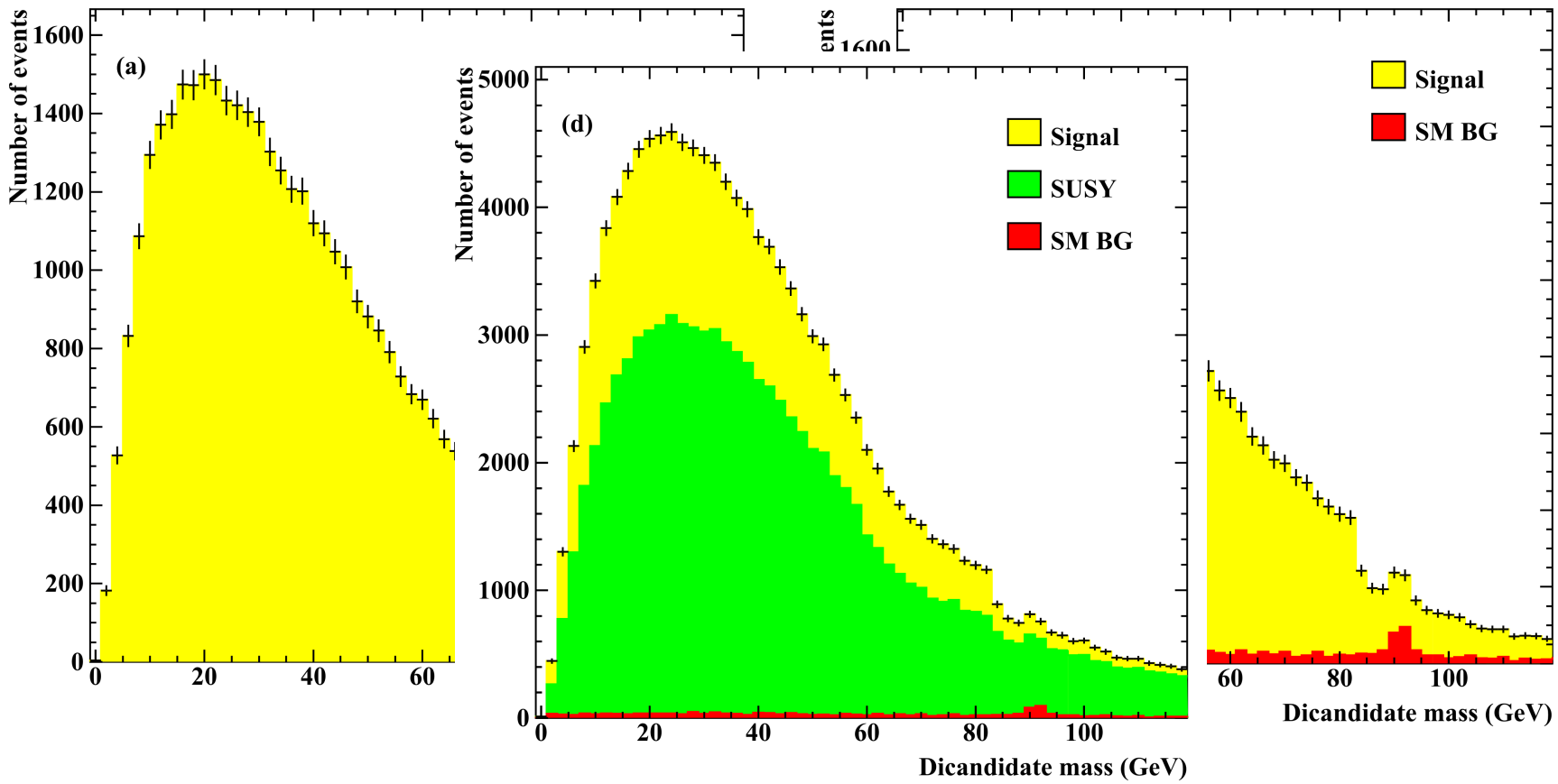
- After all cuts
- No special pairing, take both combinations (4 pairs per event)



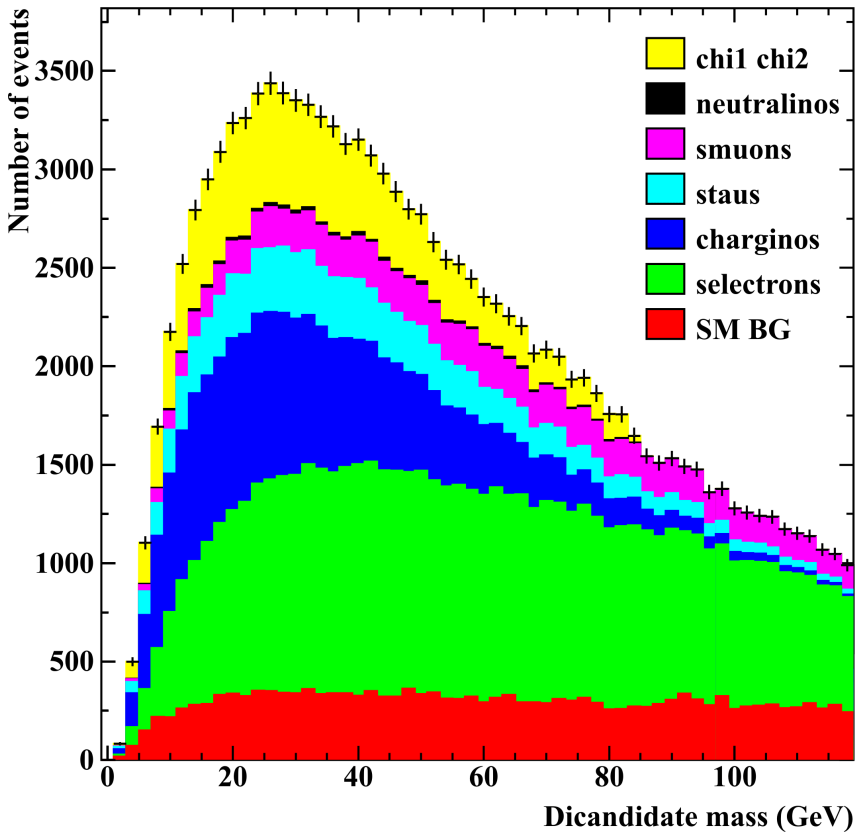


Invariant mass for $\tilde{\chi}_2^0\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \ell^+\ell^- \; \tilde{\chi}_1^0 \ell^+\ell^-$

- After all cuts
- No special pairing, take both combinations (4 pairs per event)



Conclusion and Outlook

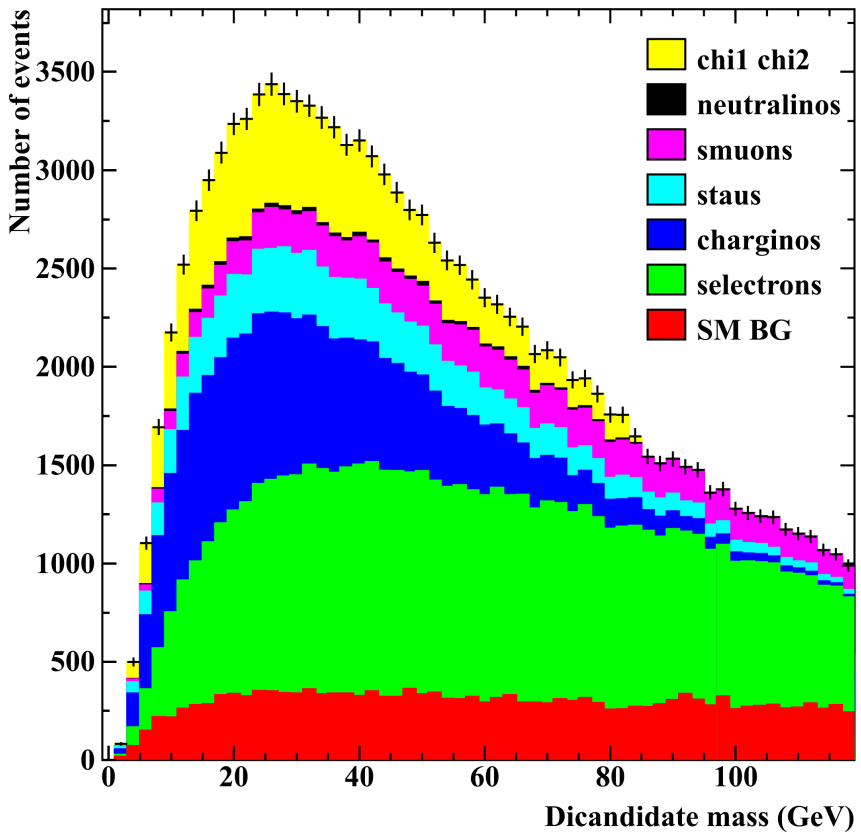


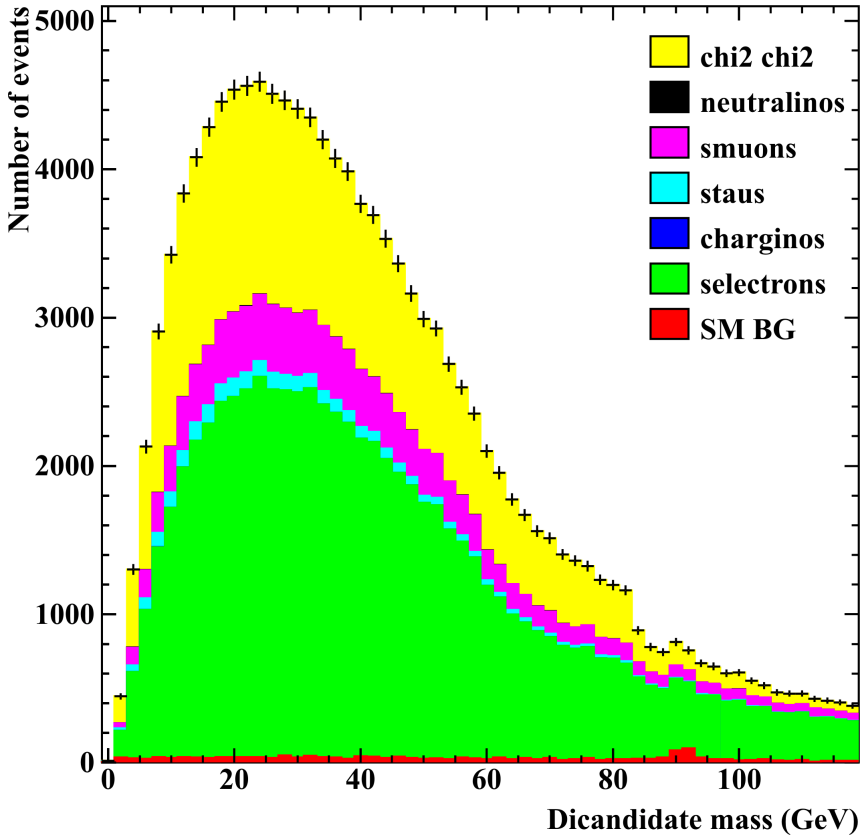
- Good lepton identification
  - High efficiency
  - Searches for multi lepton final states, i.e. 2 and 4 e/mu/tau
  - SM BG not negligible but acceptable
  - Big contributions from other SUSY processes

- A lot of improvements possible
  - Optimization
  - Include lepton classification
  - Include polarisation and full SM MC (thanks to Tim Barklow@SLAC)

    → Disentangle and fit all contributing SUSY final states

→ Give precisions on cross sections, BR's and masses not only in Neutralino production but in many SUSY processes


Number of events
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Dicandidate mass (GeV)
chi1 chi2
neutralinos
smuons
staus
charginos
selectrons
SM BG


Number of events
5000
4000
3000
2000
1000
0
0
20
40
60
80
100
Dicandidate mass (GeV)
chi2 chi2
neutralinos
smuons
staus
charginos
selectrons
SM BG