Search for Neutralino and Smuon

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Physics Goals and Backgrounds

Physics Goals:

- To determine the slepton and neutralino mass precision at NLC in $e^+e^- \to \tilde{\ell}_R^+\tilde{\ell}_R^- \to \ell^+\ell^-\tilde{\chi}_1^0\tilde{\chi}_1^0$
- To evaluate the impact of tracking performance on their mass determinations

Backgrounds:

- Benefitted from series of studies of SUSY particles by Colorado group (U. Nauenberg *et al.*) [http://hep-www.colorado.edu/SUSY/grpwk.html]
- Focused here on Tracking performance requirements
- Right-handed smuon channel considered in the first study

- MC Generator: PANDORA V2.2, PYTHIAV3.1
  - $\rightarrow$ ISR and Beamstrahlung
  - $\rightarrow$ NLC Beam Energy Spread (1%)
  - $\rightarrow$ Smuon width $\sim$ 1 GeV
  - $\rightarrow$ 80% Right Polarized electron
  - $\Rightarrow$ Thanks to Michael E. Peskin, Masako Iwasaki.

- Analysis Platform: JAVA Analysis Studio V2.2.5
  - $\Rightarrow$ Thanks to Tony Johnson, Mike Ronan, Wolfgang Walkowiak.

- Detectors: LDMAR01(LD), SDMAR01(SD)

- NLC is operated at $\sqrt{S} = 500$ GeV

- $e^+e^- \rightarrow \tilde{\mu}_R^+\tilde{\mu}_R^-$, $\tilde{\mu}_R^\pm \rightarrow \mu^\pm\tilde{\chi}_1^0$

- The fi rst analysis based on Fast MC sample, only signal and random background are considered.

SUSY parameters

- SUSY parameters (mSUGRA)
  1. the Universal Scale mass, m_0
  2. the Universal gaugino mass, M
  3. the trilinear coupling in higgs sector , A_0
  4. the Ratio of two VEV, $tan\beta$
  5. the Higgsino Mixing parameter, $sign(\mu)$

- Three parameter sets examined

$\Rightarrow M_{\tilde{\mu}_R^\pm}$ = 143 GeV, $M_{\tilde{\chi}_1^0}$ = 96.1 GeV(88 fb - SPS1)

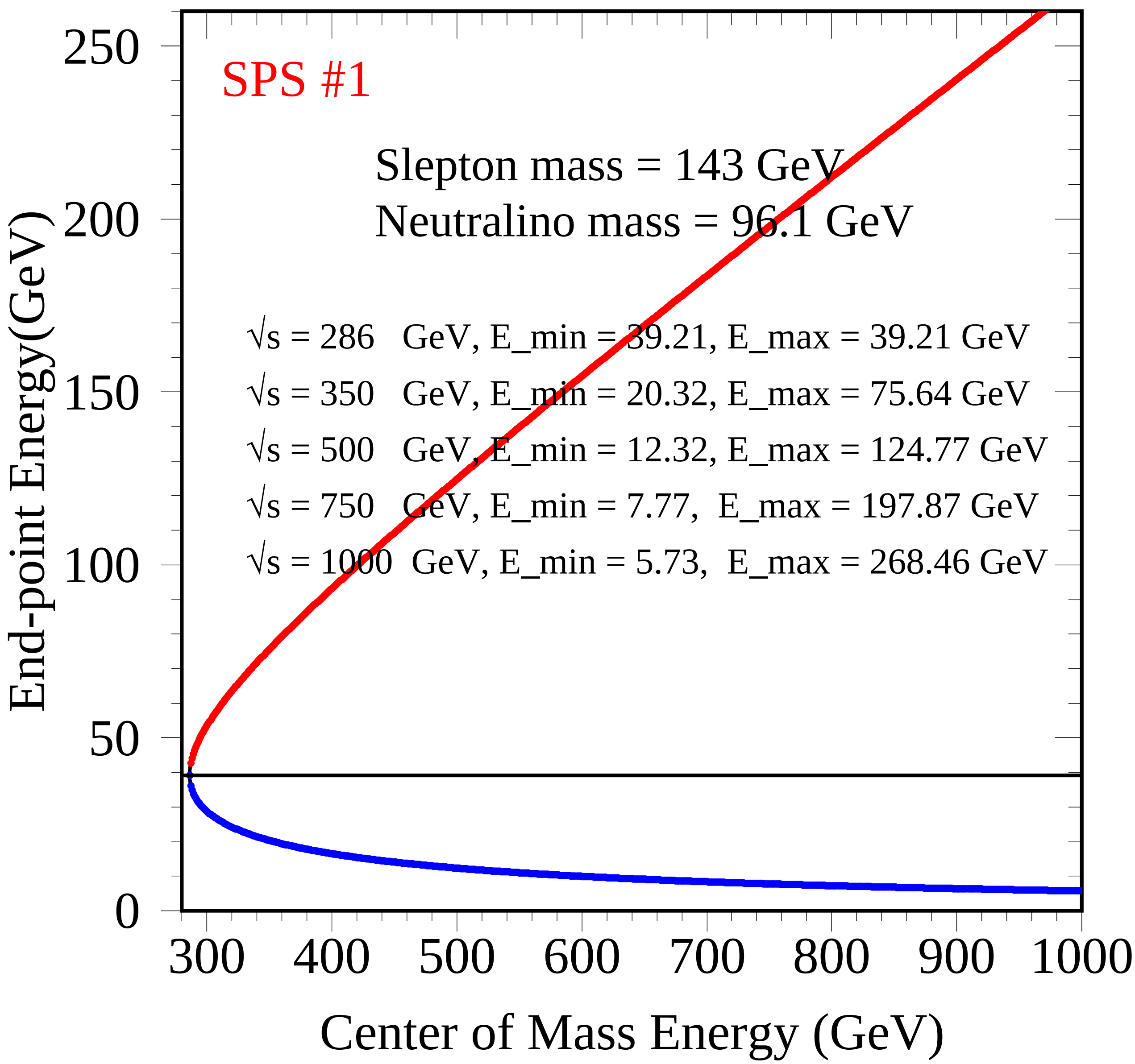
$\Rightarrow M_{\tilde{\mu}_R^\pm}$ = 156.95 GeV, $M_{\tilde{\chi}_1^0}$ = 128.7 GeV(75 fb)

$\Rightarrow M_{\tilde{\mu}_R^\pm}$ = 86.0 GeV, $M_{\tilde{\chi}_1^0}$ = 80.0 GeV

- Smuon and Neutralino masses can be determined by measuring endpoints of muon energy spectra.

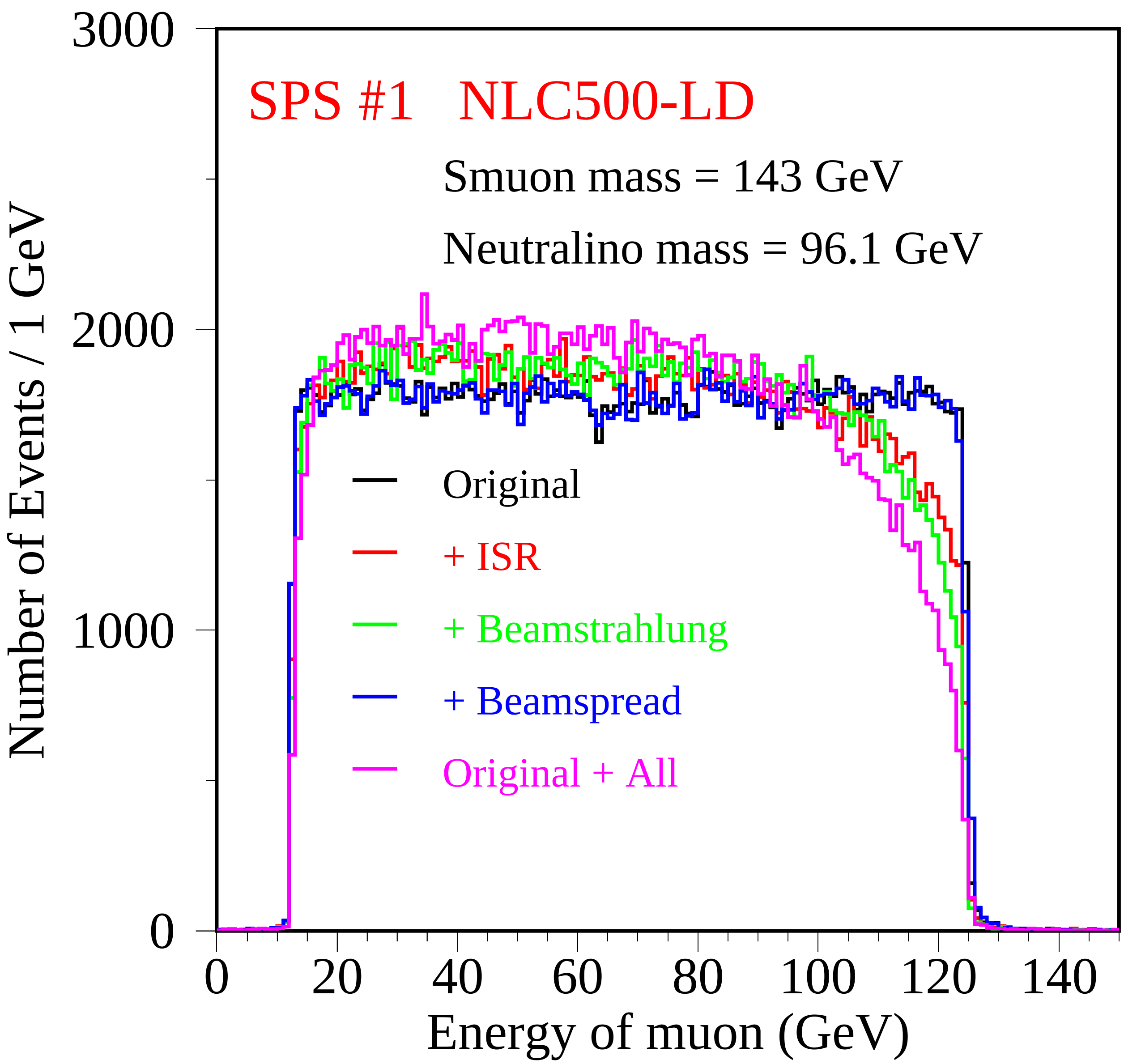
$$M^2_{\tilde{\mu}_R^\pm} = E^2_{cm} \bullet \frac{E_{min} \times E_{max}}{(E_{min} + E_{max})^2} \quad (1)$$

$$M^2_{\tilde{\chi}_1^0} = M^2_{\tilde{\mu}_R^\pm} \bullet \{1 - 2\frac{E_{min} + E_{max}}{E_{cm}}\} \quad (2)$$



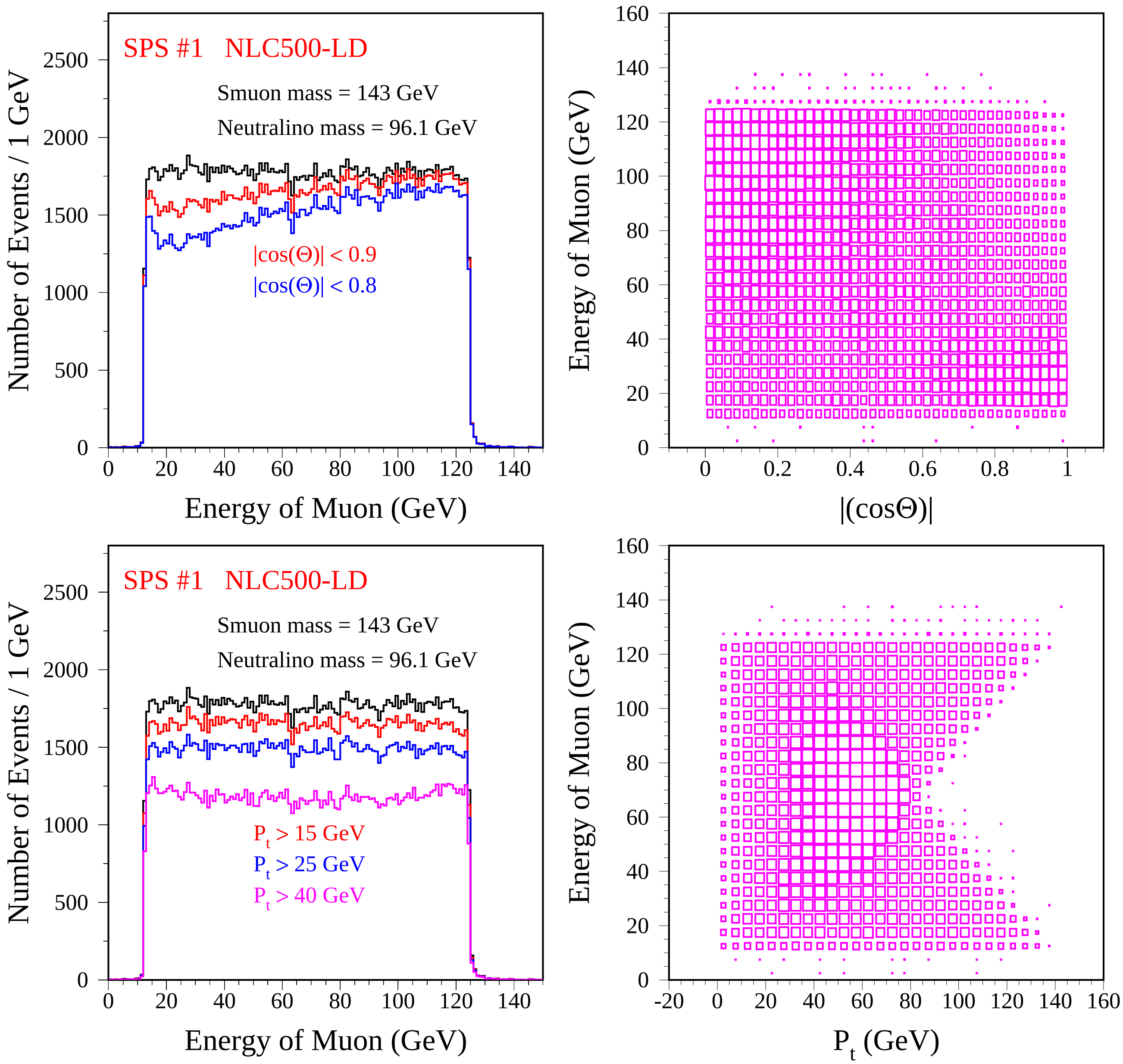
- Min/Max muon energy as a function of center of mass energy

Muon Energy Distribution



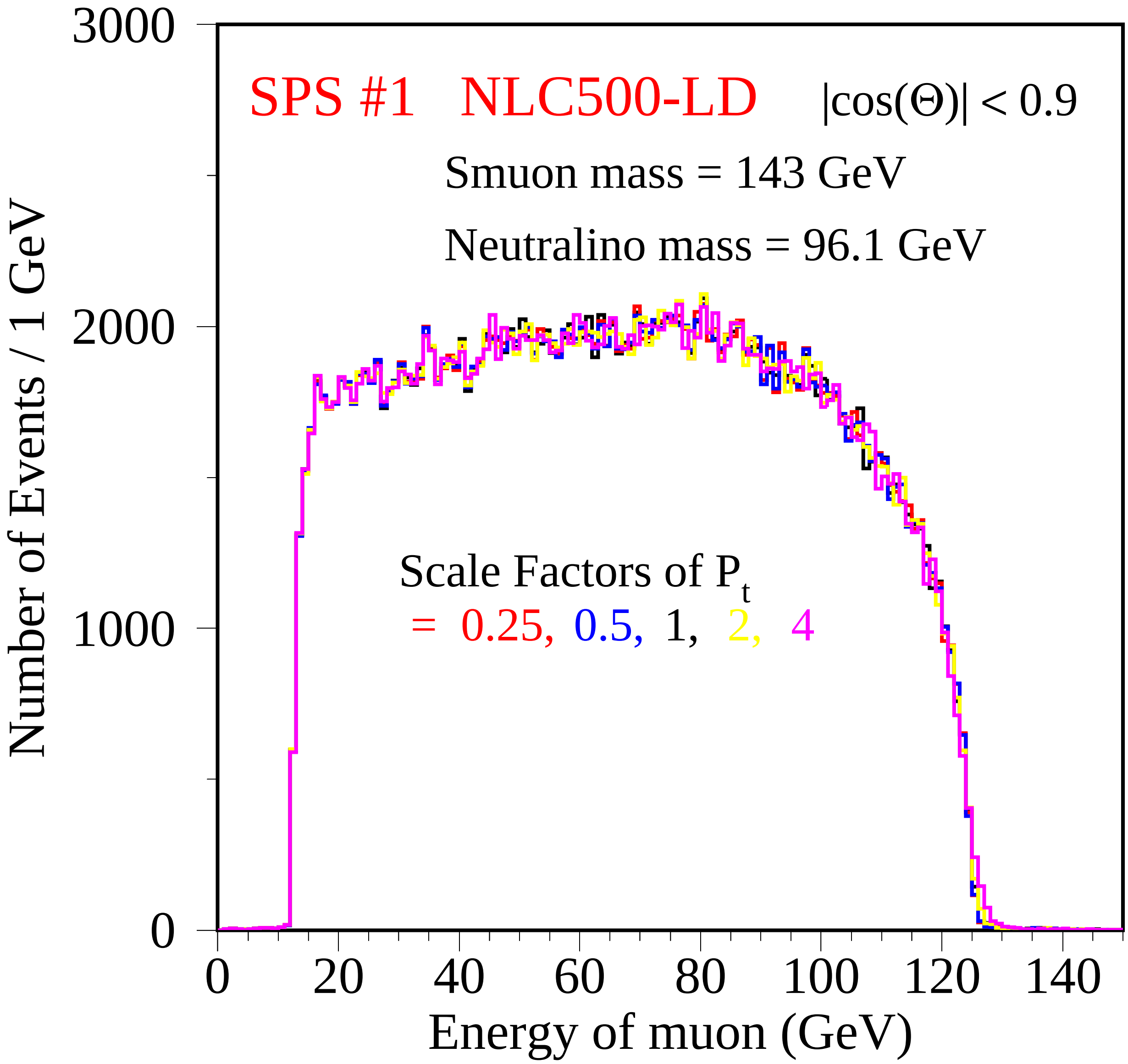
- Comparison of muon energies for various effects, ISR, beamstrahlung and beam energy spread.

Muon Energy Distribution



• Muon energy endpoints are well maintained after muon polar angle and P_t total cuts.

Muon Energy Distribution



- SPS#1 Scenario ($\Delta M = 47$ GeV).
- Track momentum resolution $\Delta(\frac{1}{P_t})$ is re-scaled by factors = 0.25, 0.5, 1.0, 2.0, 4.0.

Mass Determination

- Monte Carlo Interpolation Technique

400K Fast MC signal events are produced, one half sample is treated as 'data', another half as 'MC'. The fitted parameters are E_{min} and E_{max}, the goodness of fit is defined by a binned χ^2.

- Relative Mass Uncertainty (%)

$$= 100 \times \frac{M_{meas.} - M_{true}}{M_{true}} \quad (3)$$

- Mass Error comes from errors of E_{min} and E_{max}

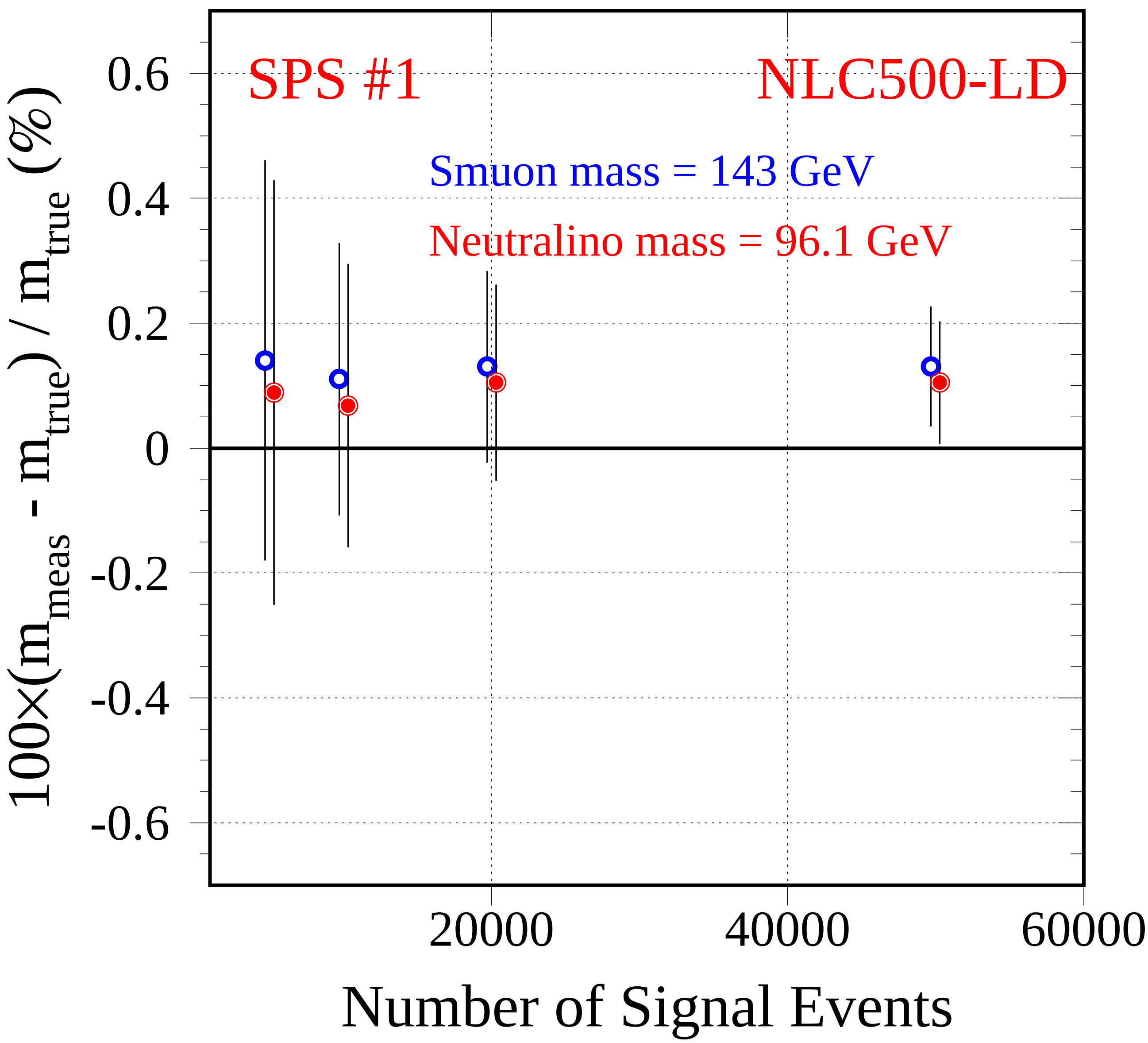
$$\frac{\Delta M_{\tilde{\mu}_R^\pm}}{M_{\tilde{\mu}_R^\pm}} = A \bullet \sqrt{[\frac{\Delta E_{min}}{E_{min}}]^2 + [\frac{\Delta E_{max}}{E_{max}}]^2} \quad (4)$$

$$\frac{\Delta M_{\tilde{\chi}_1^0}}{M_{\tilde{\chi}_1^0}} = \frac{M^2_{\tilde{\mu}_R^\pm}}{M^2_{\tilde{\chi}_1^0}} \bullet \sqrt{(\frac{C}{E_{min}} - \frac{1}{E_{cm}})^2 \Delta E^2_{min} + (\frac{C}{E_{max}} - \frac{1}{E_{cm}})^2 \Delta E^2_{max}} \quad (5)$$

where,

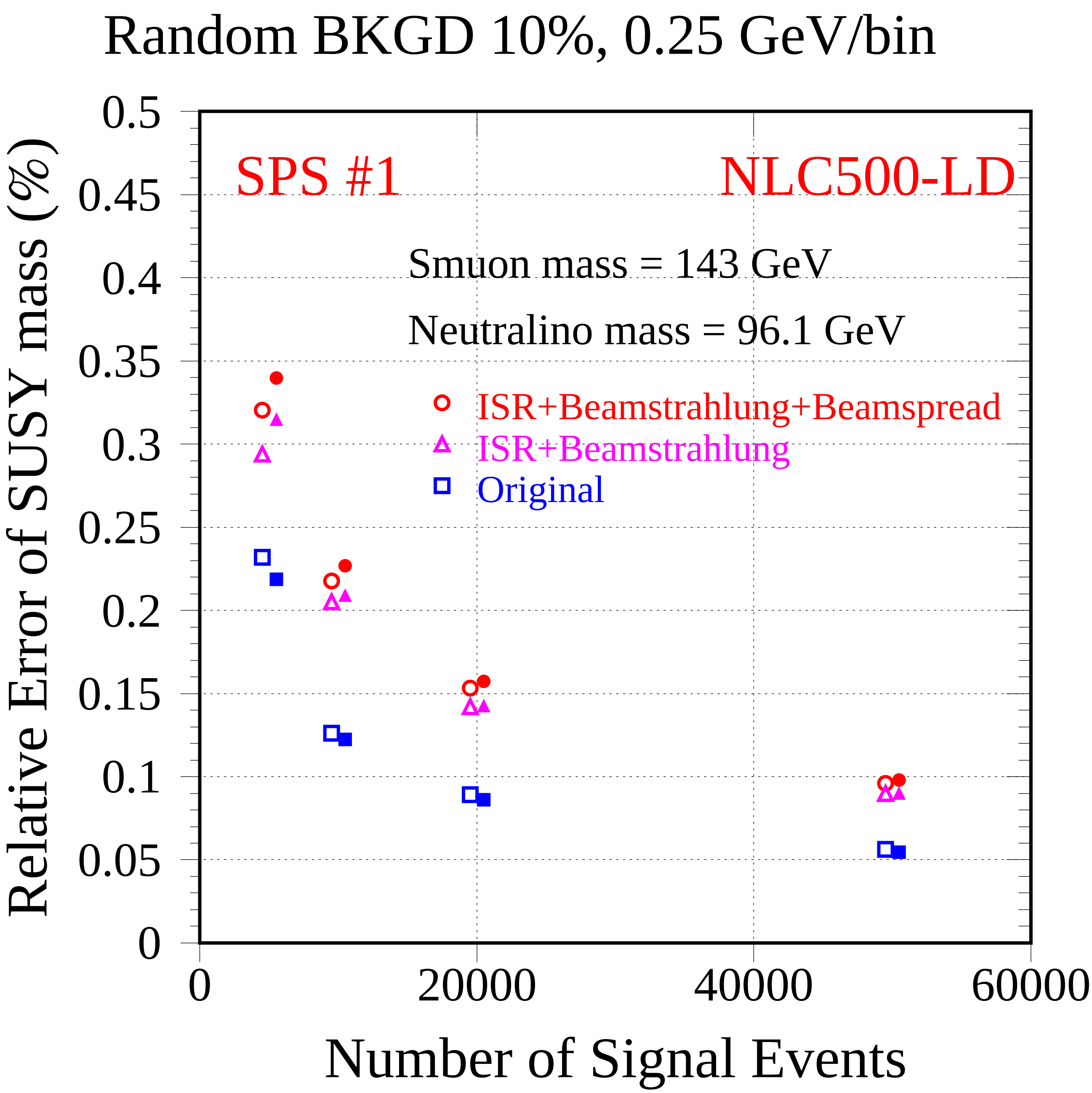
$$A = \frac{E_{max} - E_{min}}{2(E_{max} + E_{min})}, \quad B = \frac{E_{max} + E_{min}}{E_{cm}}, \quad C = A(1 - 2B)$$

Random BKGD 10%, 0.25 GeV/bin



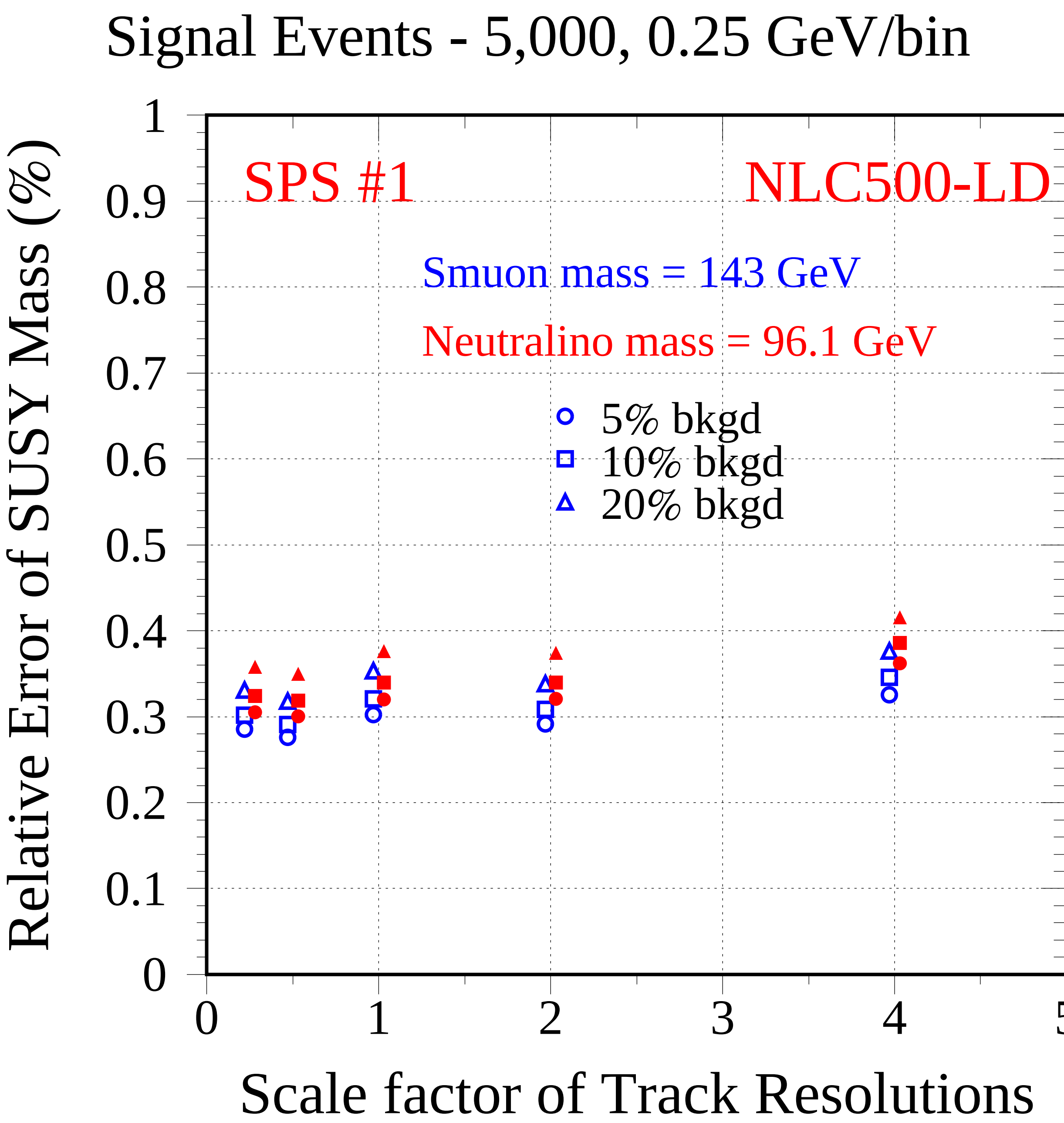
- 5000 Signal events is equivalent to $\sim$ 100 fb^{-1} Data
  (3-4 months run at design luminosity)

$\Rightarrow$ Extracted mass consistent with statistical uncertainty.



⇒ Relative mass error is affected by ISR, beamstrahlung and beam energy spread.

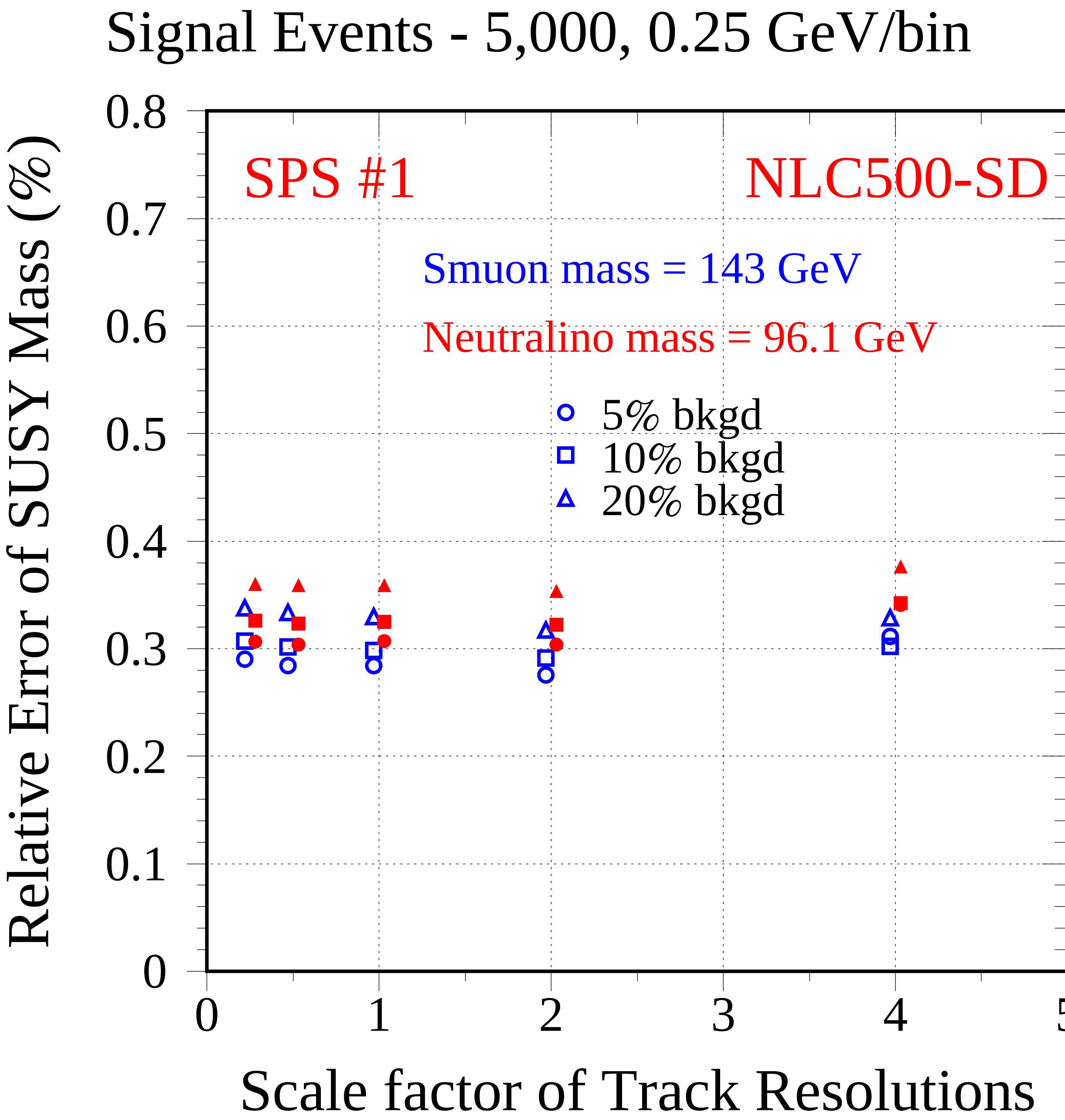
Relative Mass Error



⇒ Mass error is insensitive to track resolutions.

⇒ Relative error is ~ 0.35% for 5K signal events.

Relative Mass Error



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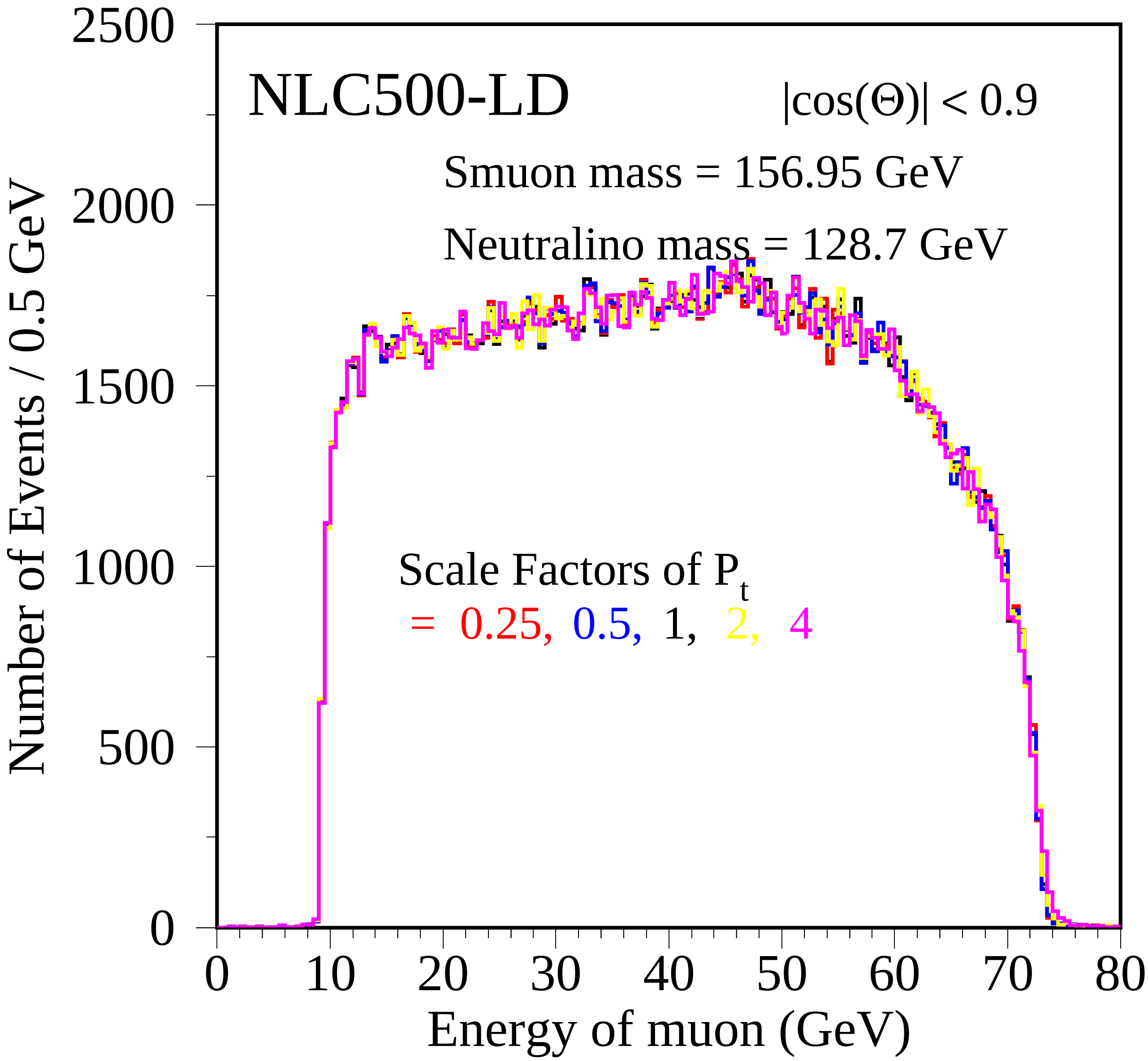
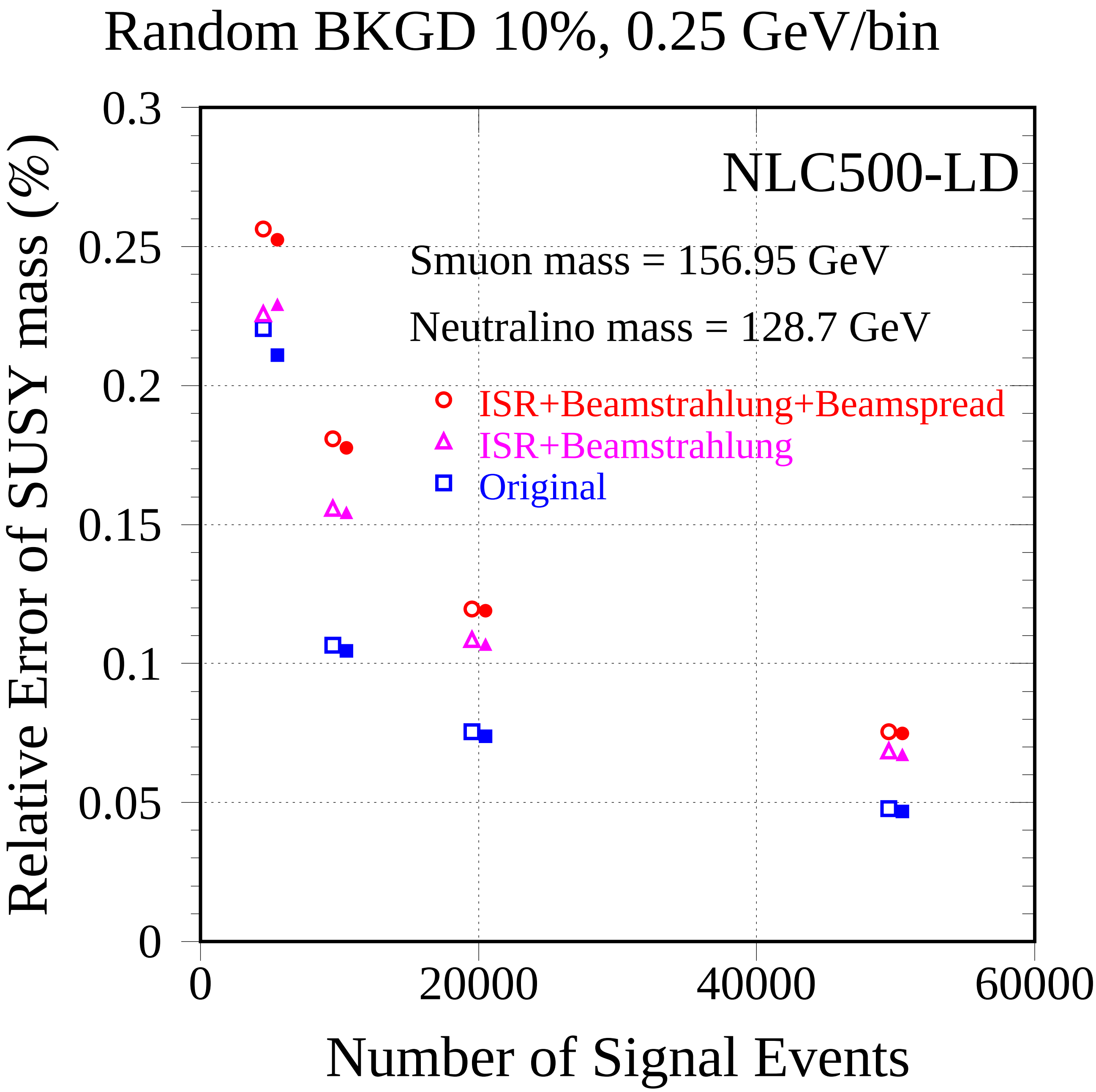


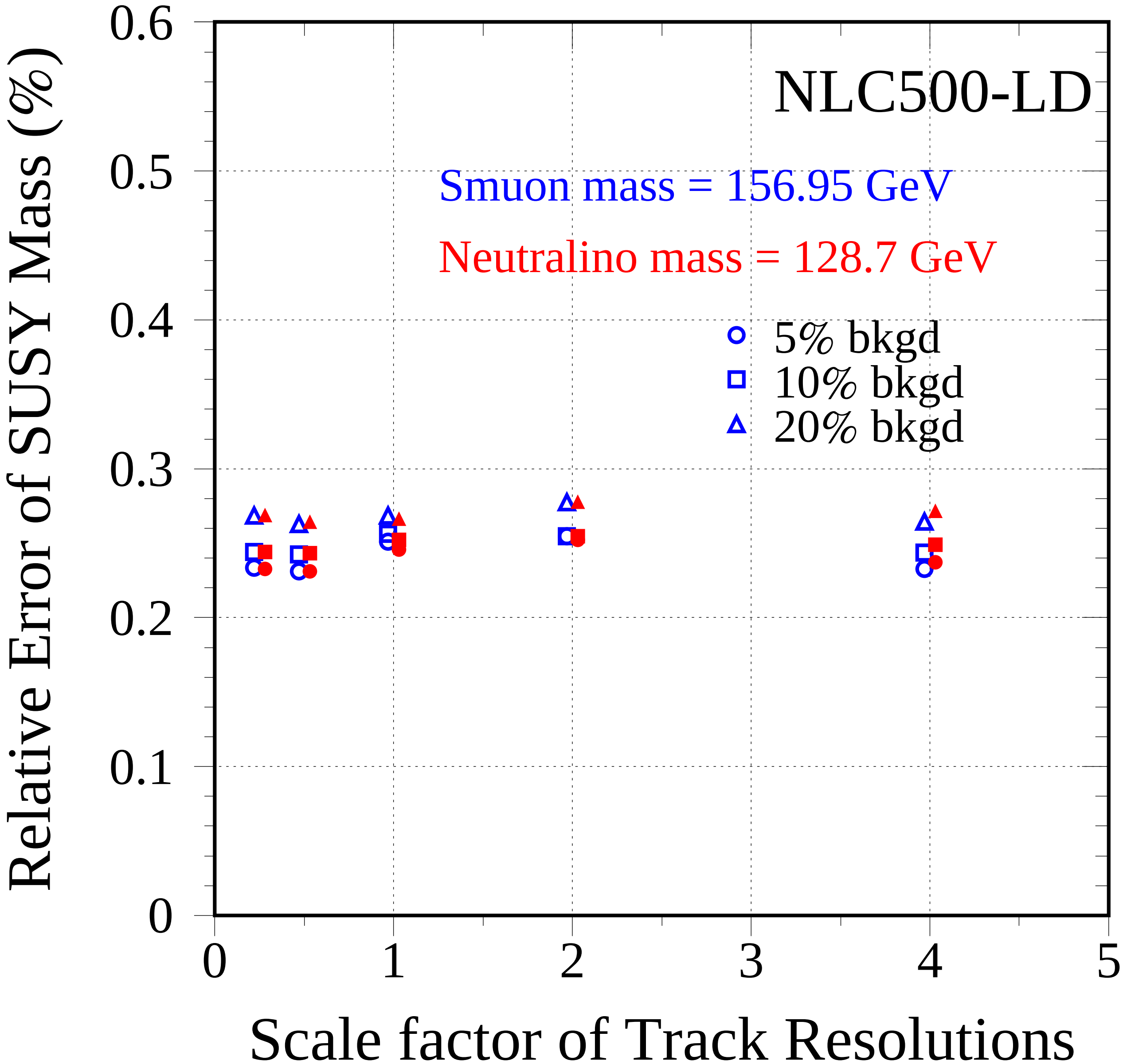
- Another mass combination ($\Delta M = 28$ GeV).
- Track momentum resolution $\Delta(\frac{1}{P_t})$ is re-scaled by factors = 0.25, 0.5, 1.0, 2.0, 4.0.

Relative Mass Error



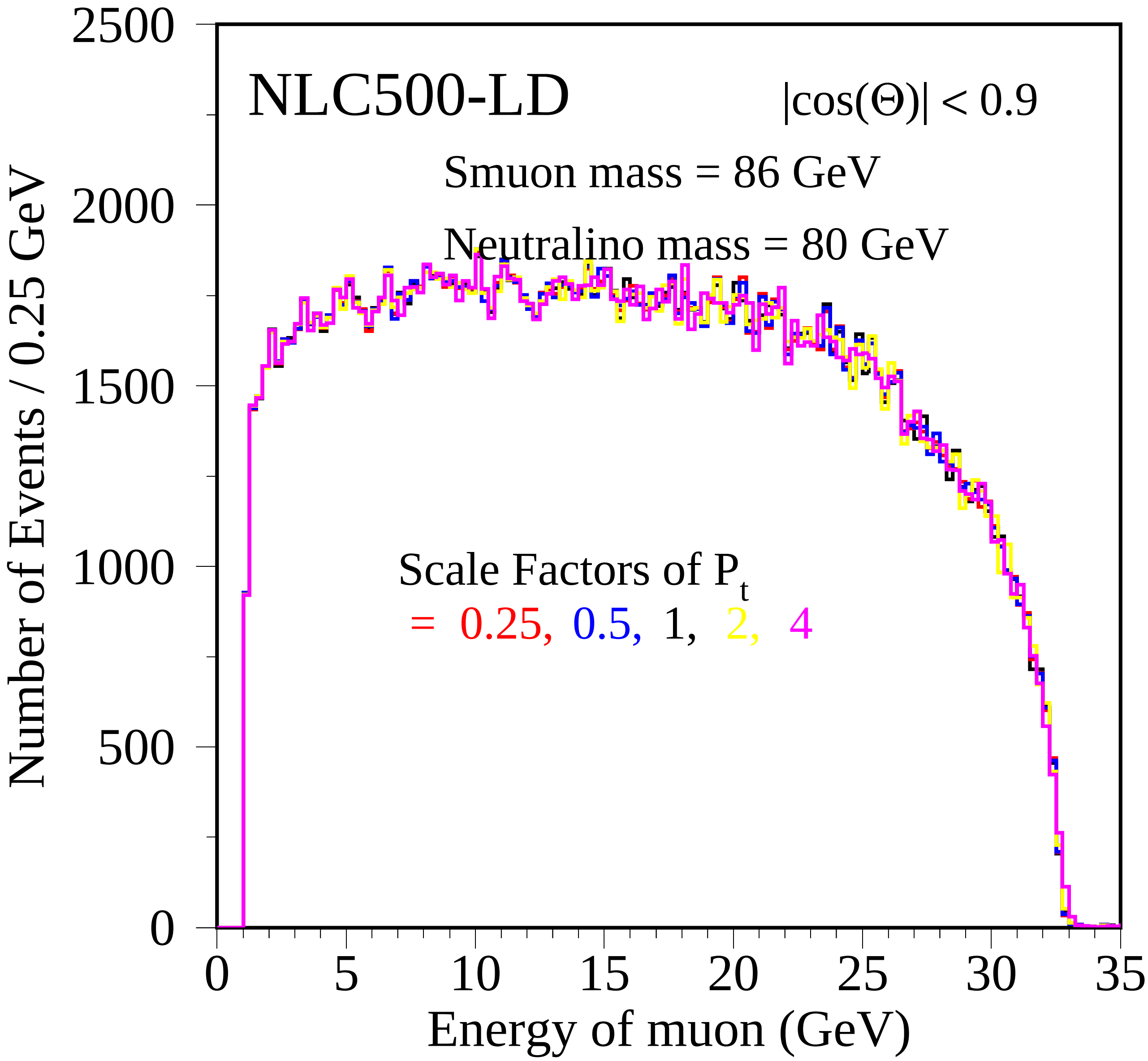
⇒ Relative mass error is affected by ISR, beam-strahlung and beam energy spread.

Signal Events - 5,000, 0.25 GeV/bin



⇒ Mass error is insensitive to track resolutions.

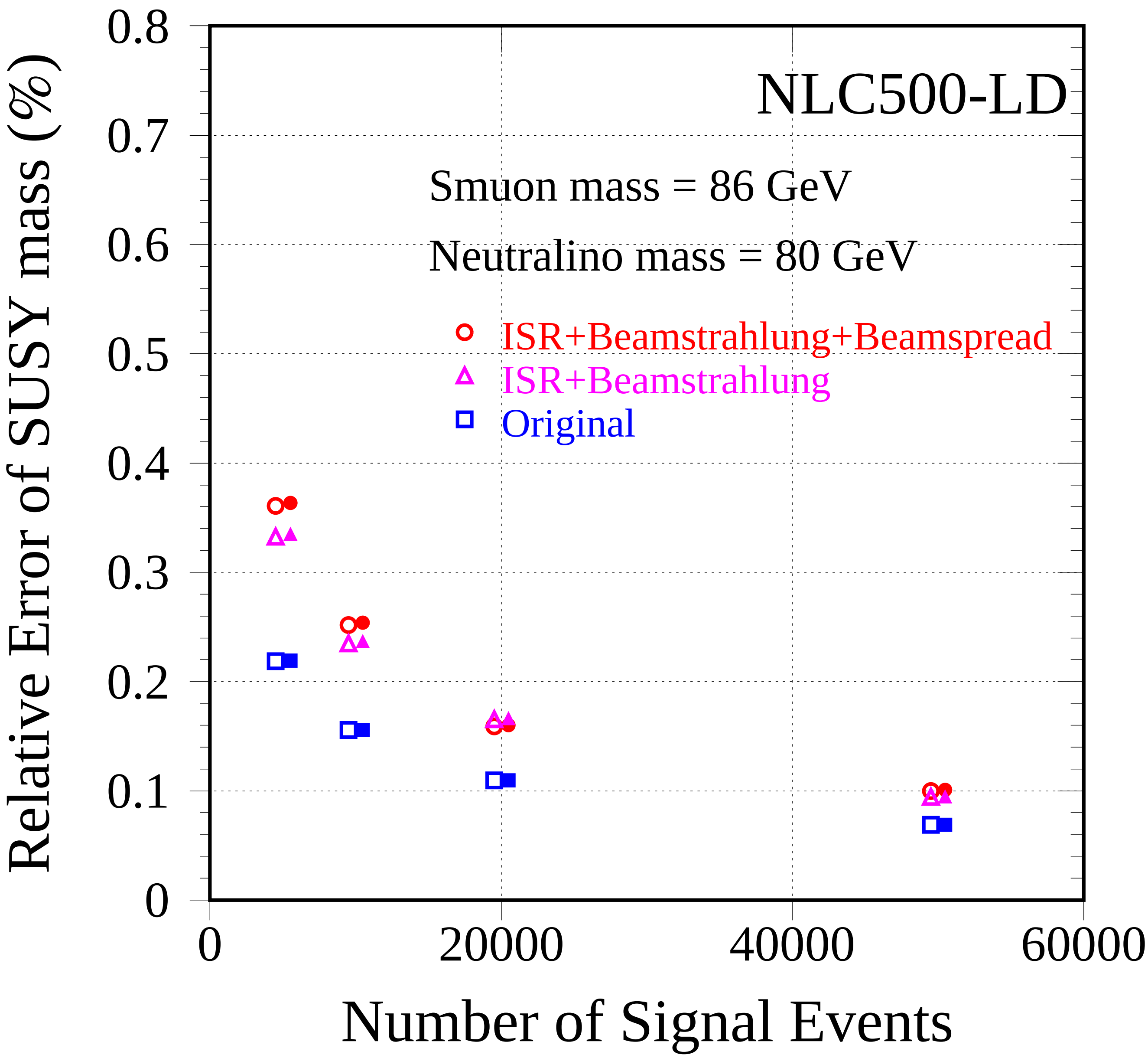
⇒ Relative error is ∼ 0.25% for 5K signal events.



- Another mass combination ($\Delta M = 6$ GeV).
- Track momentum resolution $\Delta(\frac{1}{P_t})$ is re-scaled by factors = 0.25, 0.5, 1.0, 2.0, 4.0.

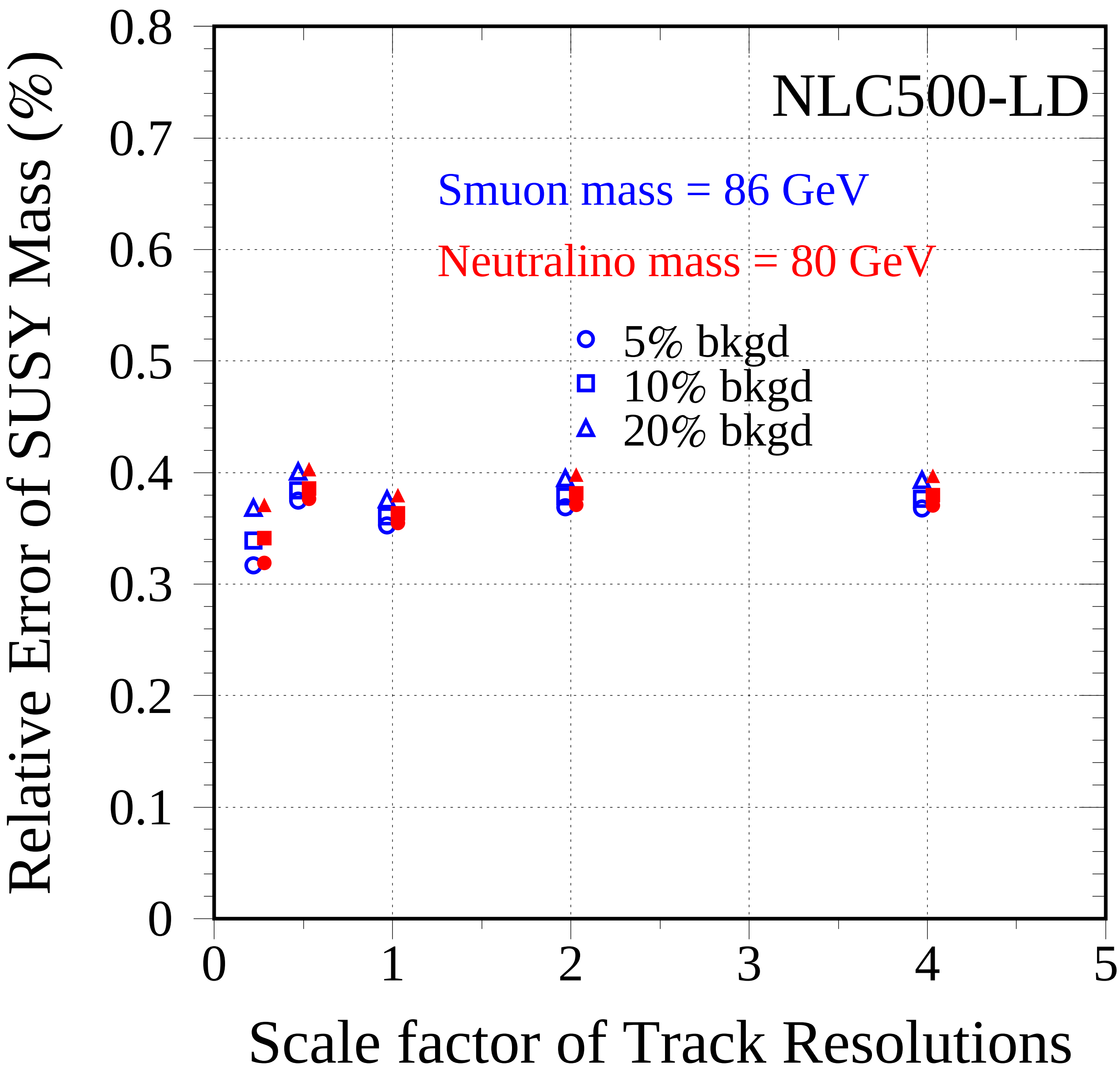
Relative Mass Error

Random BKGD 10%, 0.03125 GeV/bin



⇒ Relative mass error is affected by ISR, beam-strahlung and beam energy spread.

Signal Events - 5,000, 0.03125 GeV/bin

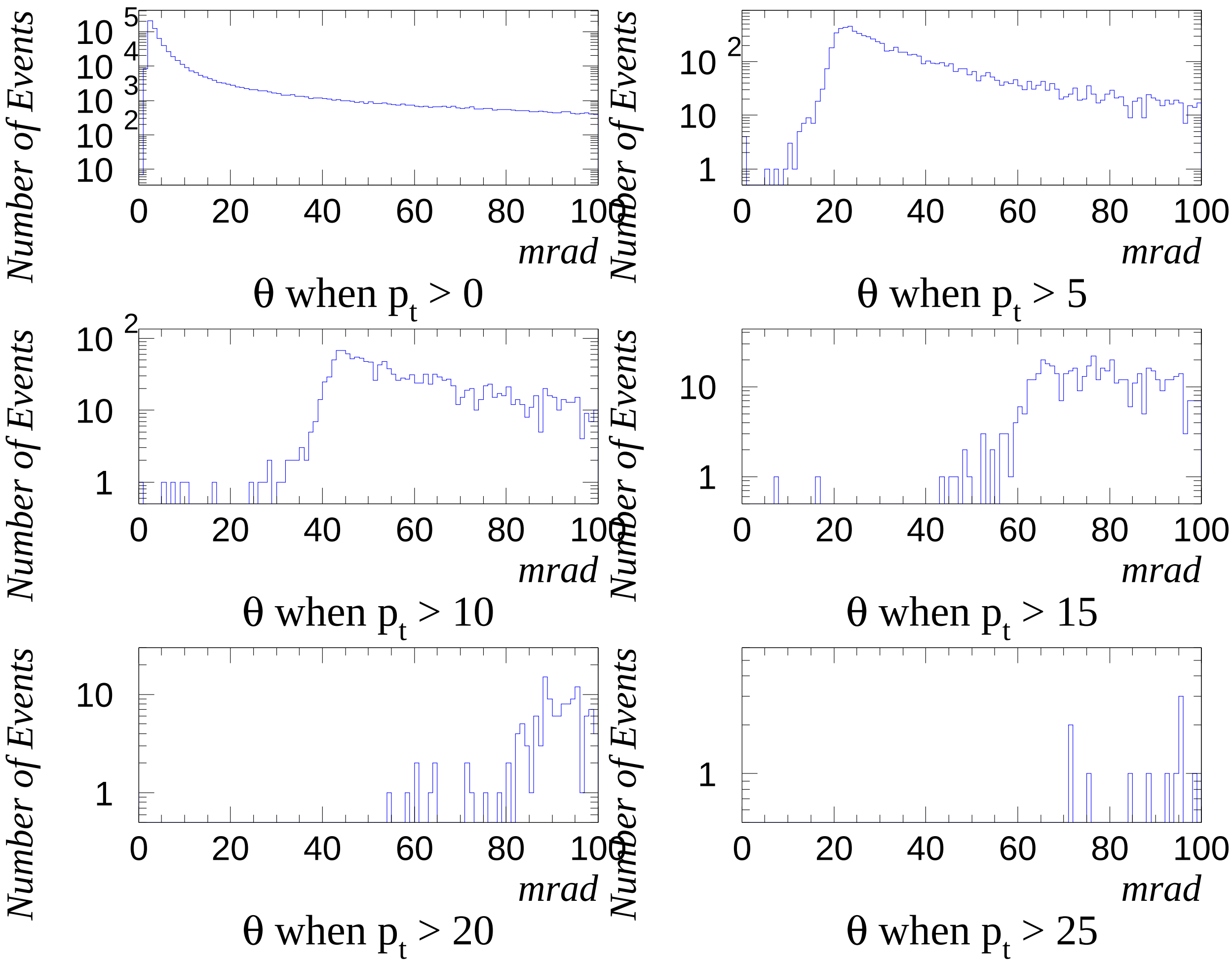


⇒ Mass error is insensitive to track resolutions.

⇒ Relative error is ~ 0.4% for 5K signal events.

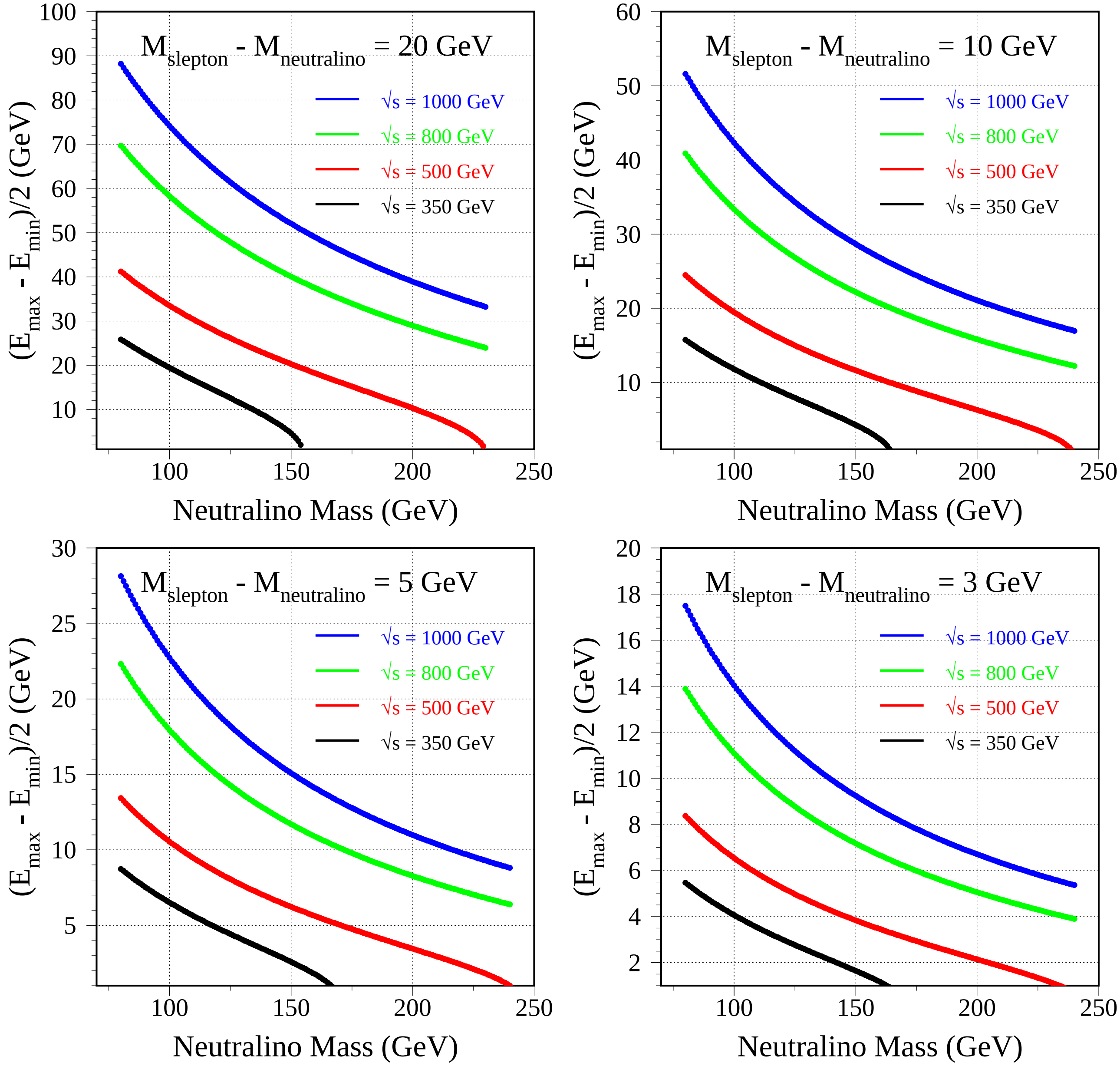
Accessible SUSY mass region at NLC

- According to analysis of U. Colorado group, P_t cut of about 15 GeV could eliminate most of the $\gamma^*\gamma^*$ background.



- Calorimeter acceptance of LD $>$ 52 mrad.

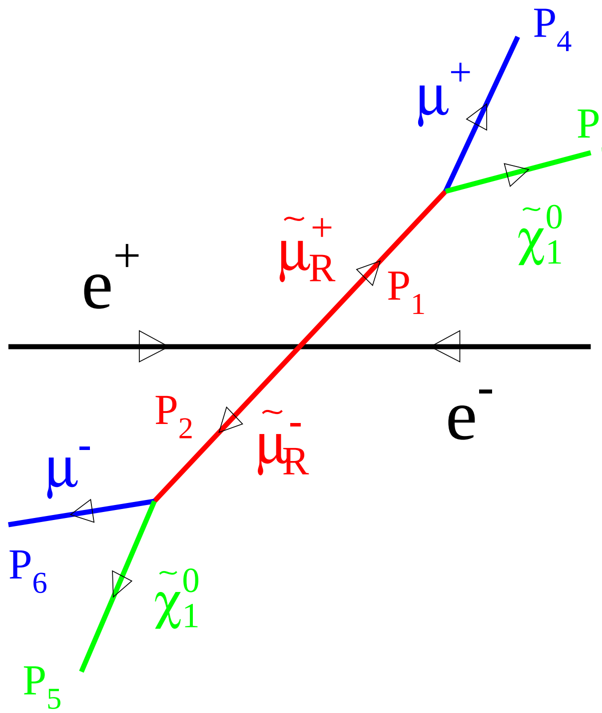
Accessible SUSY mass region at NLC

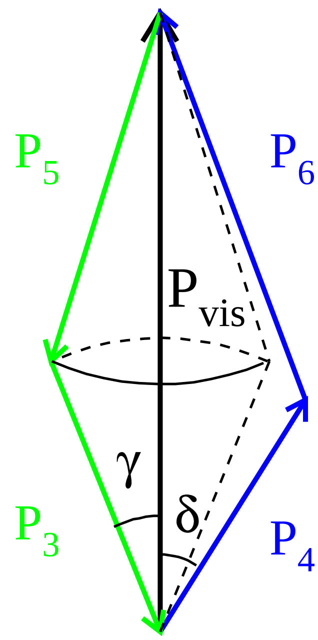


⇒ In order to measure SUSY masses precisely,

higher $\sqrt{s}$ is required for lower $\Delta M \equiv M_{\tilde{\mu}_R^{\pm}} - M_{\tilde{\chi}_1^0}$.

- If the lightest neutralino mass is known, then ...



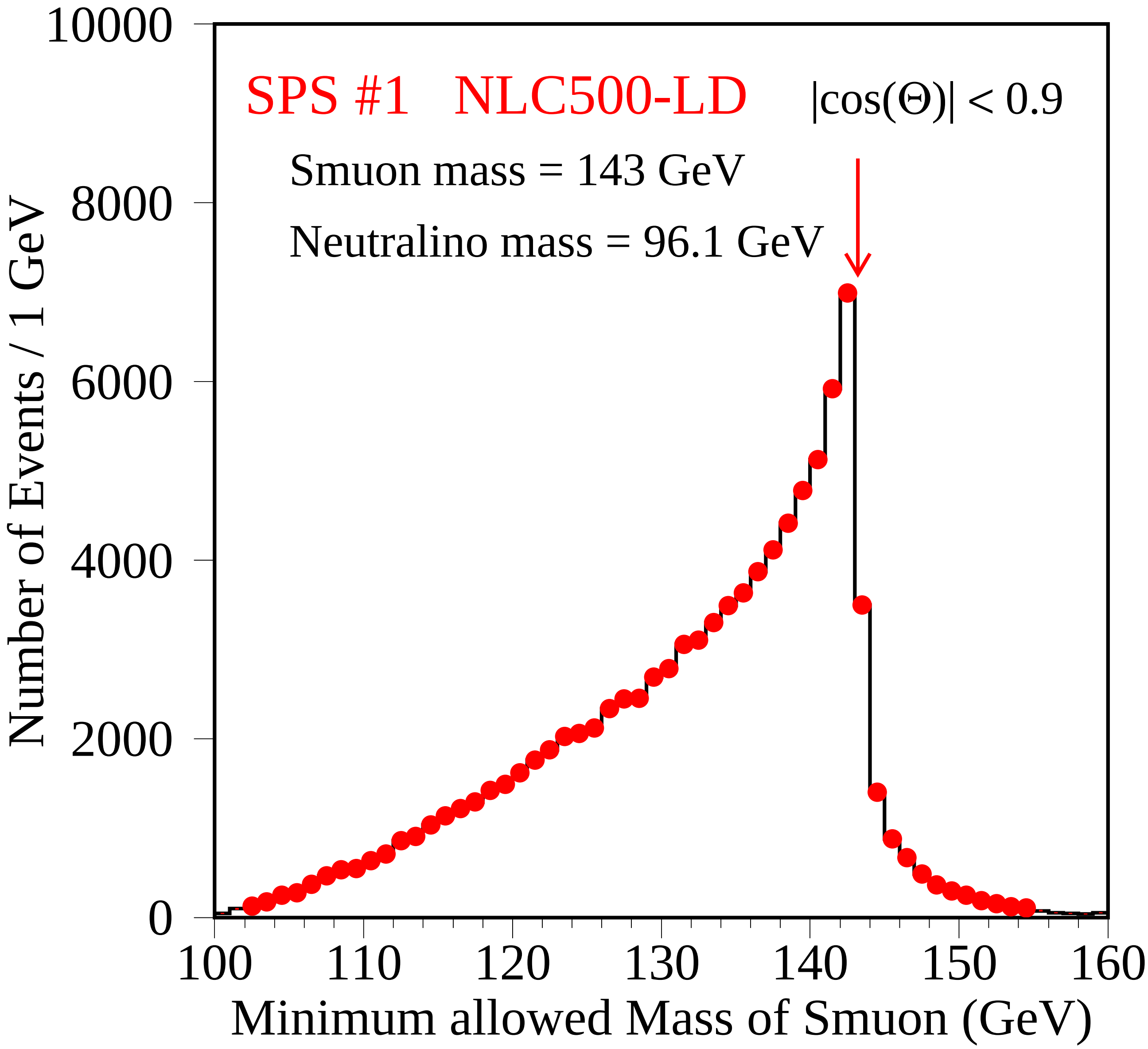


$$\mathbf{p_{vis}} = \mathbf{p_4} + \mathbf{p_6} = -(\mathbf{p_3} + \mathbf{p_5})$$

$$(\mathbf{M^{min}_{\tilde{\mu}^{\pm}_R}})^2 = E^2_{beam} - (p_1^{max})^2 = E^2_{beam} - [p_3^2 + p_4^2 - 2p_3p_4cos(\gamma+\delta)] \quad (6)$$

$$p_3 = \sqrt{(E_{beam} - E_4)^2 - M^2_{\tilde{\chi}^0_1}} \;\; ; \;\; p_5 = \sqrt{(E_{beam} - E_6)^2 - M^2_{\tilde{\chi}^0_1}}$$

$$cos(\delta) = \frac{p_4^2 + p_{vis}^2 - p_6^2}{2p_4p_{vis}} \;\; ; \;\; cos(\gamma) = \frac{p_3^2 + p_{vis}^2 - p_5^2}{2p_3p_{vis}}$$



⇒ mass error is improved by factor of ∼ 3

But, $M_{\tilde{\mu}_R^\pm}$ strongly depends on $M_{\tilde{\chi}_1^0}$ precision.

Very Preliminary Conclusions

- Three mass pairs are investigated at NLC500,

  $M_{\tilde{\mu}_R^\pm} = 143$ GeV, $M_{\tilde{\chi}_1^0} = 96.1$ GeV,
  $E_{min} = 12.32$ GeV, $E_{max} = 124.77$ GeV;

  $M_{\tilde{\mu}_R^\pm} = 156.95$ GeV, $M_{\tilde{\chi}_1^0} = 128.7$ GeV,
  $E_{min} = 9.07$ GeV, $E_{max} = 72.82$ GeV;

  $M_{\tilde{\mu}_R^\pm} = 86$ GeV, $M_{\tilde{\chi}_1^0} = 80$ GeV,
  $E_{min} = 1.027$ GeV, $E_{max} = 32.64$ GeV;

$\Rightarrow$ Smuon and neutralino masses are
insensitive to track momentum resolution.

$\Rightarrow$ Relative mass errors of 5K signal events are

$\sim$ 0.35% for high $\Delta M = 47$ GeV, $E_{min} \sim 12$ GeV

$\sim$ 0.25% for medium $\Delta M = 28$ GeV, $E_{min} \sim 10$ GeV

$\sim$ 0.40% for low $\Delta M = 6$ GeV, $E_{min} \sim 1$ GeV

$\Rightarrow$ Higher $\sqrt{s}$ is required for lower ΔM.