Search for Neutralino and Smuon

Haijun Yang Keith Riles

University of Michigan, Ann Arbor

American Linear Collider Workshop

University of Texas, Arlington

January 10, 2003

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, PYTHIA V3.1

  → ISR and Beamstrahlung
  → NLC Beam Energy Spread (1%)
  → Smuon width ∼ 1 GeV
  → 80% Right Polarized electron
  ⇒ Thanks to Michael E. Peskin, Masako Iwasaki.

- Analysis Platform: JAVA Analysis Studio V2.2.5

  ⇒ Thanks to Tony Johnson, Mike Ronan, Wolfgang Walkowiak.

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

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

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

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

- 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, $sign(\mu)$

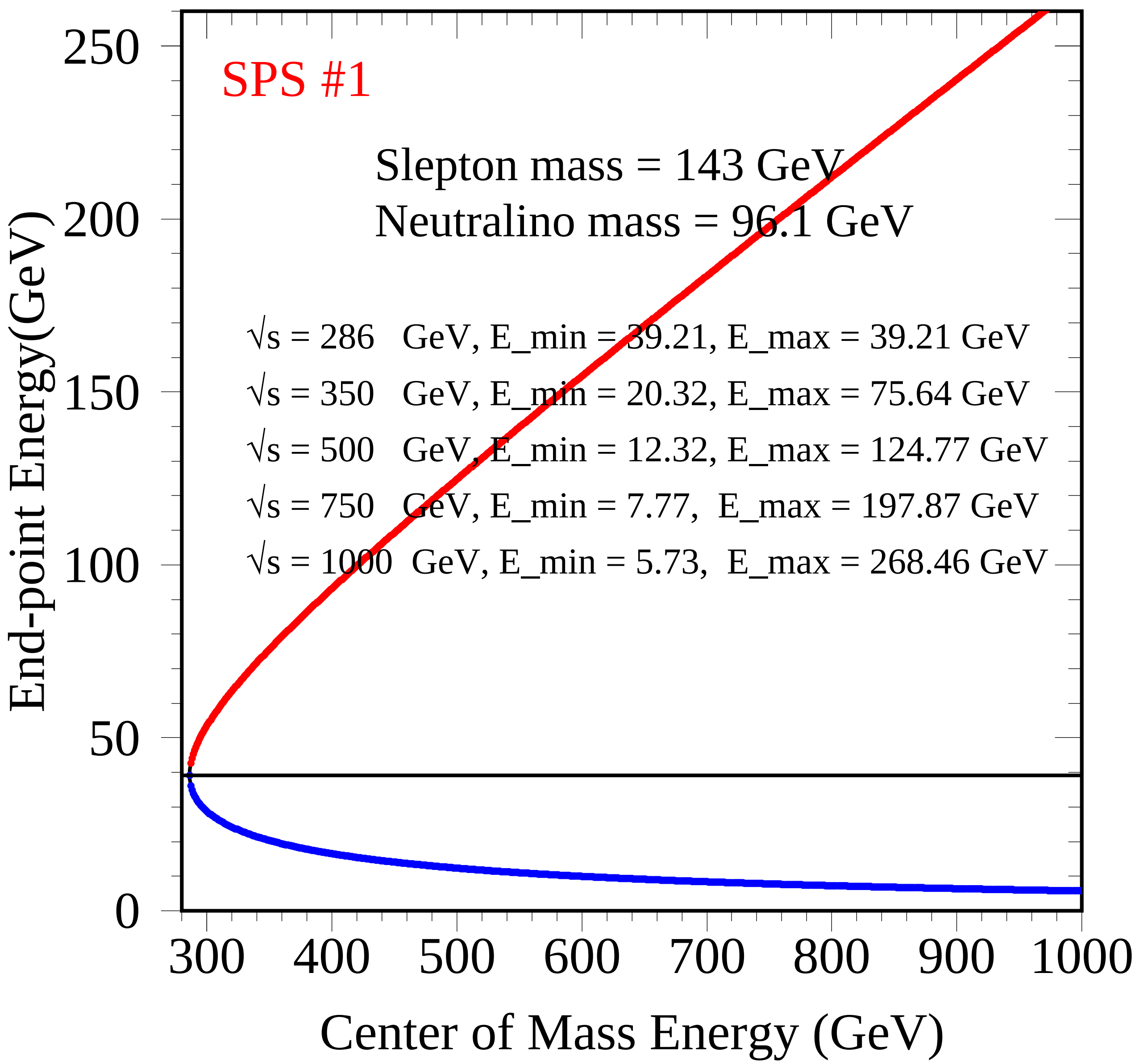
- Three parameter sets examined

  $\Rightarrow M_{\tilde{\mu}_R^\pm}$ = 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.

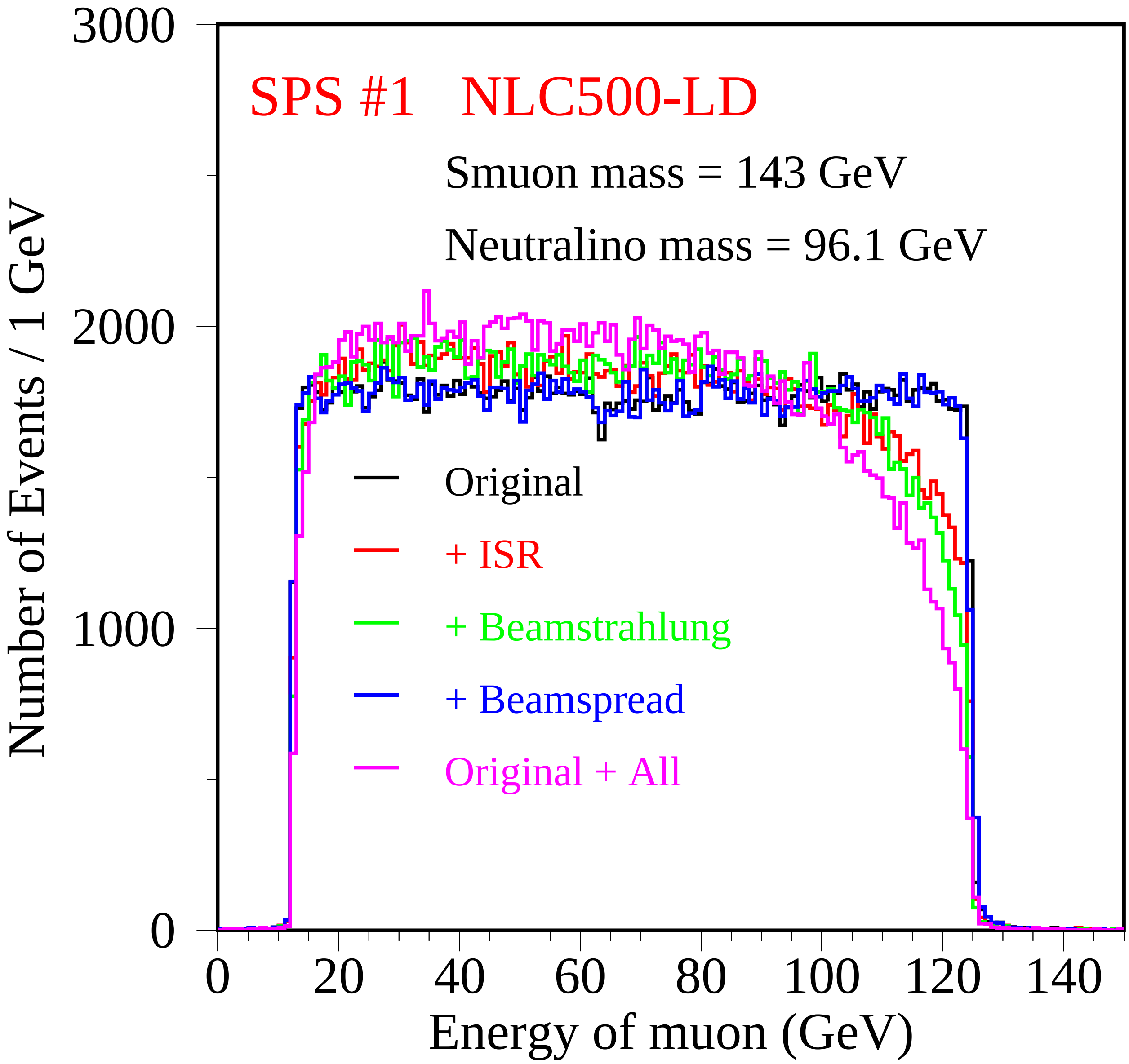
$$M^2_{\tilde{\mu}_R^\pm} = E^2_{cm} \bullet \frac{E_{min} \times E_{max}}{(E_{min} + E_{max})^2} \quad (1)$$

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



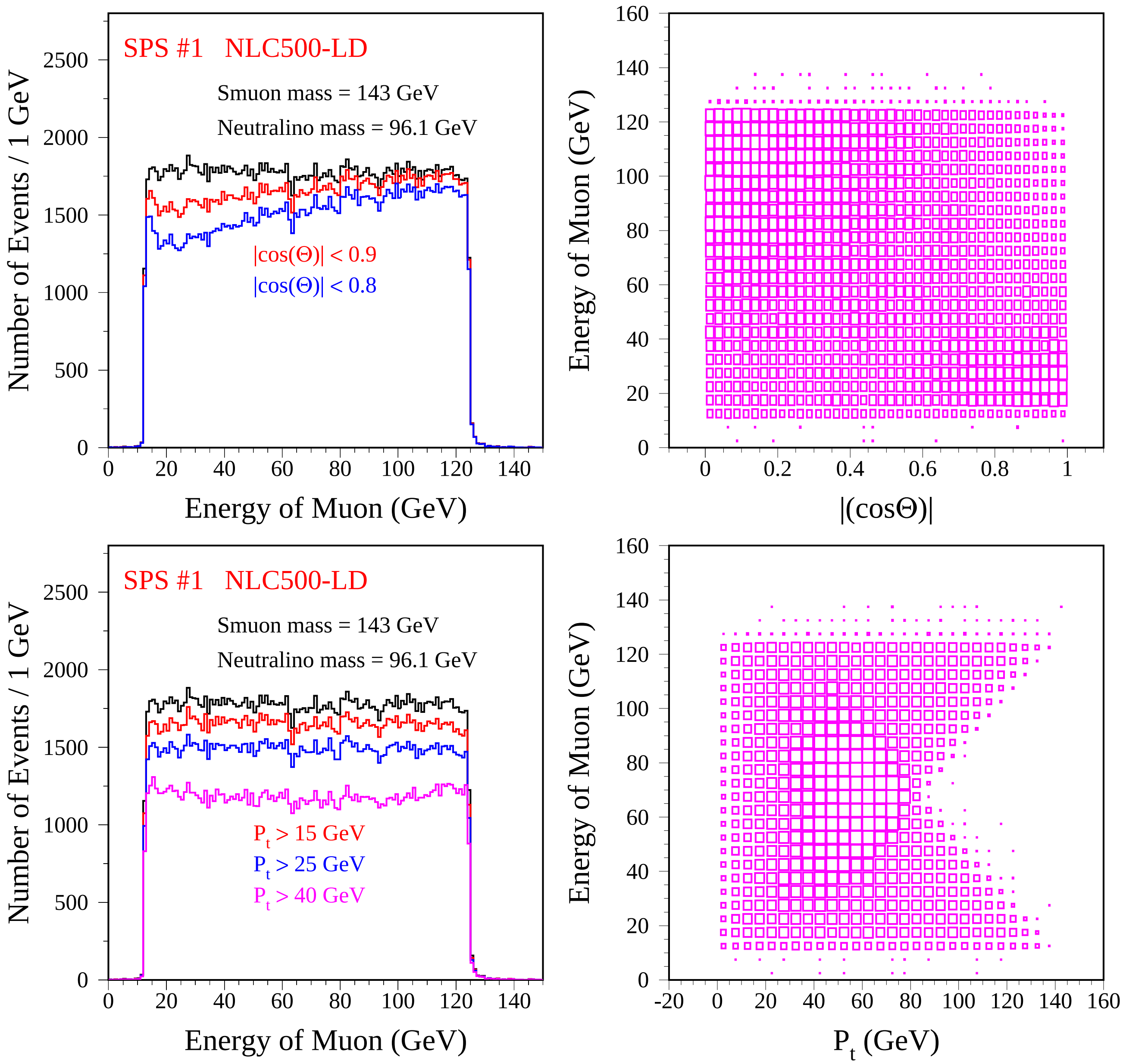
- Min/Max muon energy as a function of center of mass energy.

Muon Energy Distribution

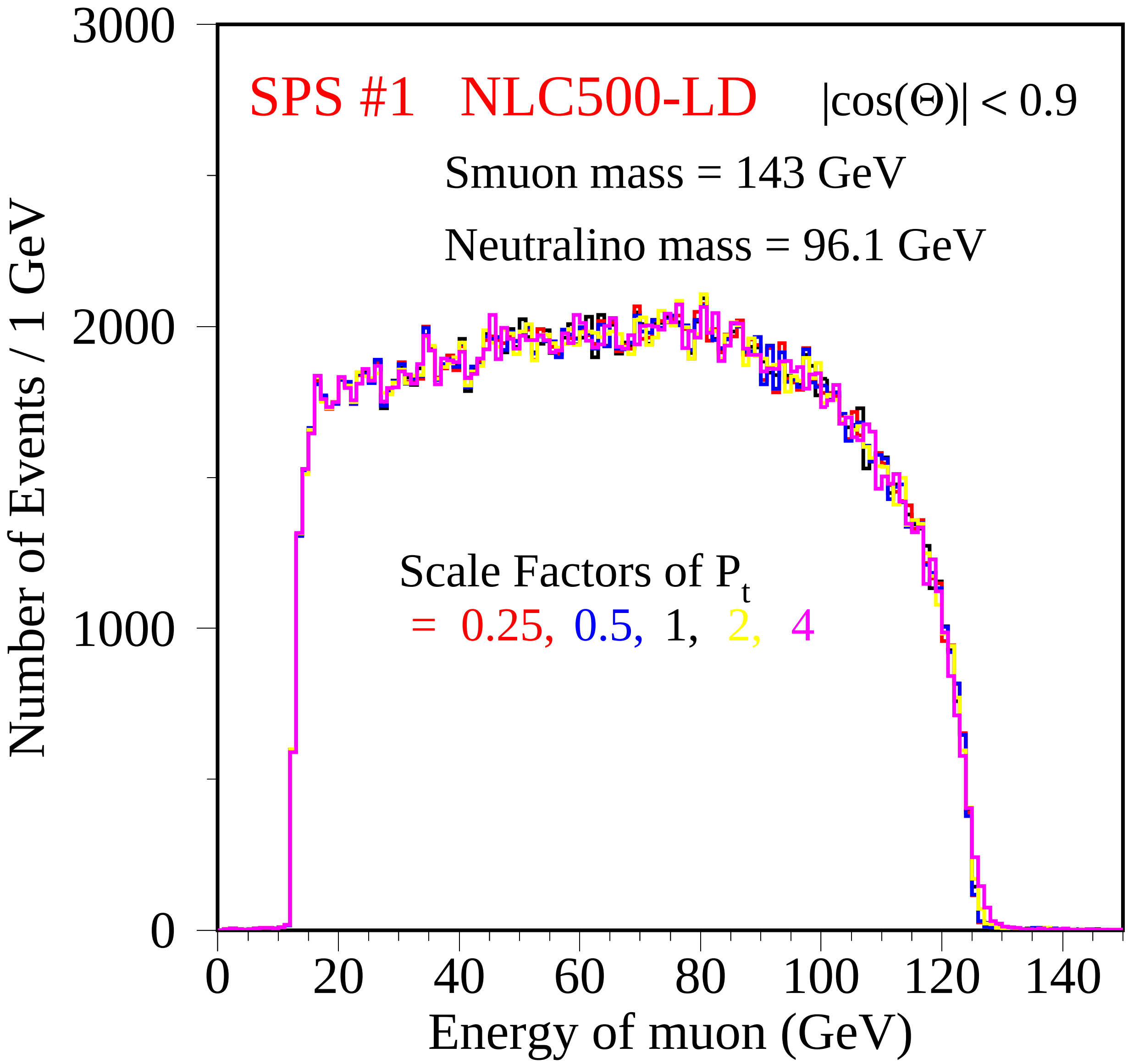


• Comparison of muon energies for various effects, ISR, beamstrahlung and beam energy spread.

Muon Energy Distribution



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



- 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.

- **Monte Carlo Interpolation Technique**

400K Fast MC signal events are produced. The fitted parameters are E_{min} and E_{max}, the goodness of fit is defined by a binned χ^2. Another fit method - maximum likelihood is used for a cross check, the results are consistent.

- **Relative Mass Uncertainty (%)**

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

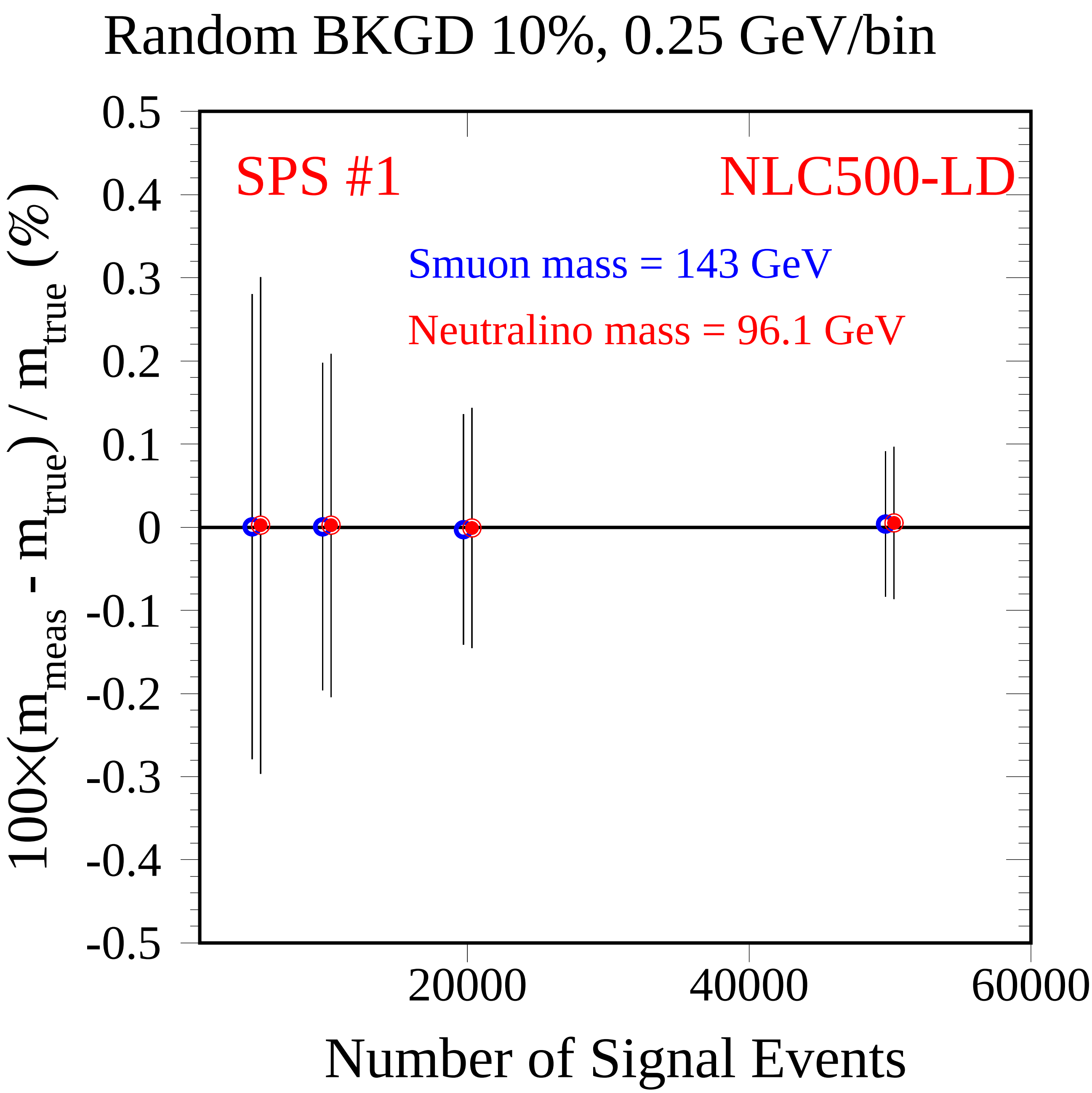
- **Mass Error comes from errors of E_{min} and E_{max}**

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

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

where,

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

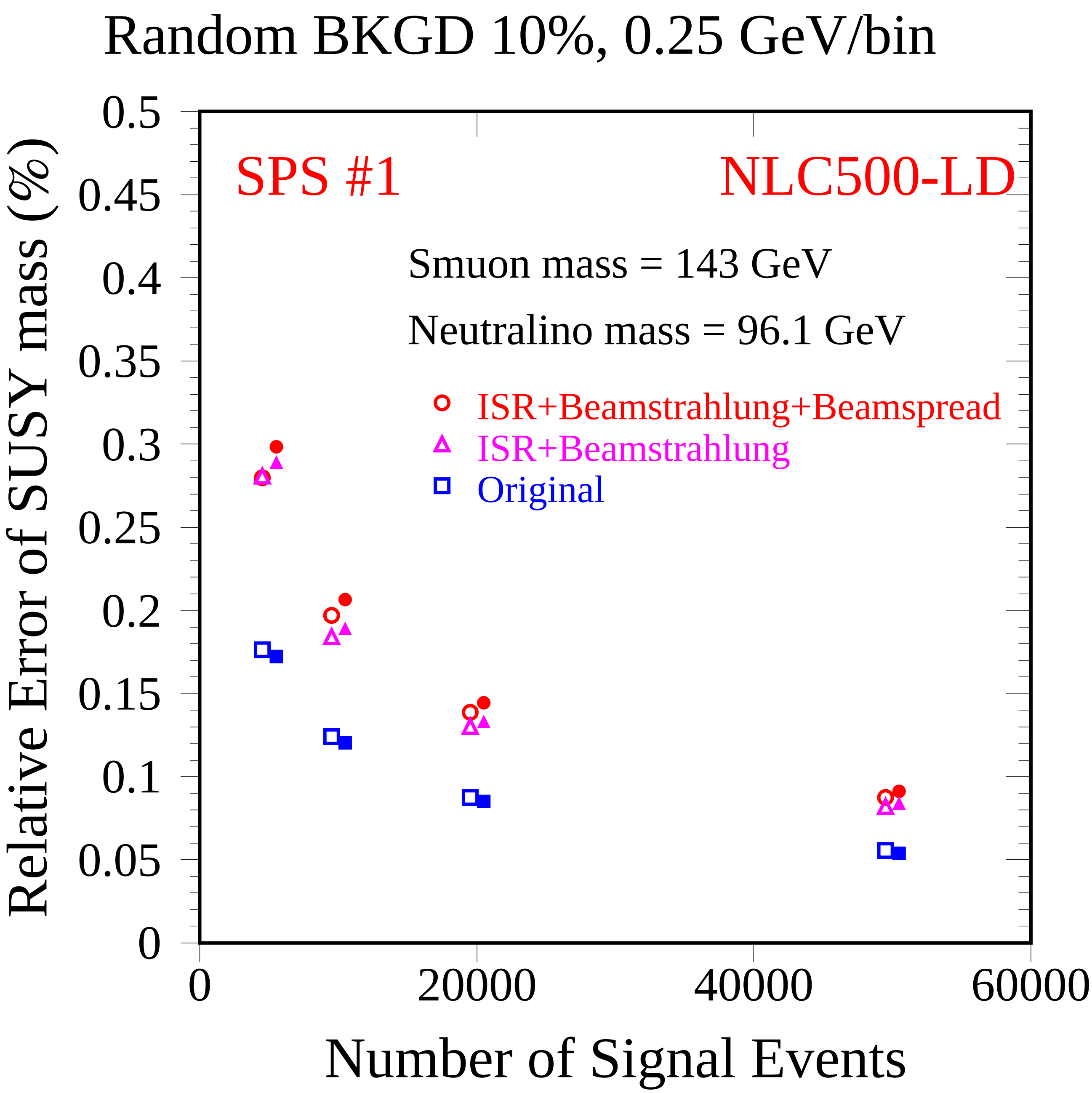


- 5000 Signal events is equivalent to $\sim 100\ fb^{-1}$ Data

  (3-4 months run at design luminosity)

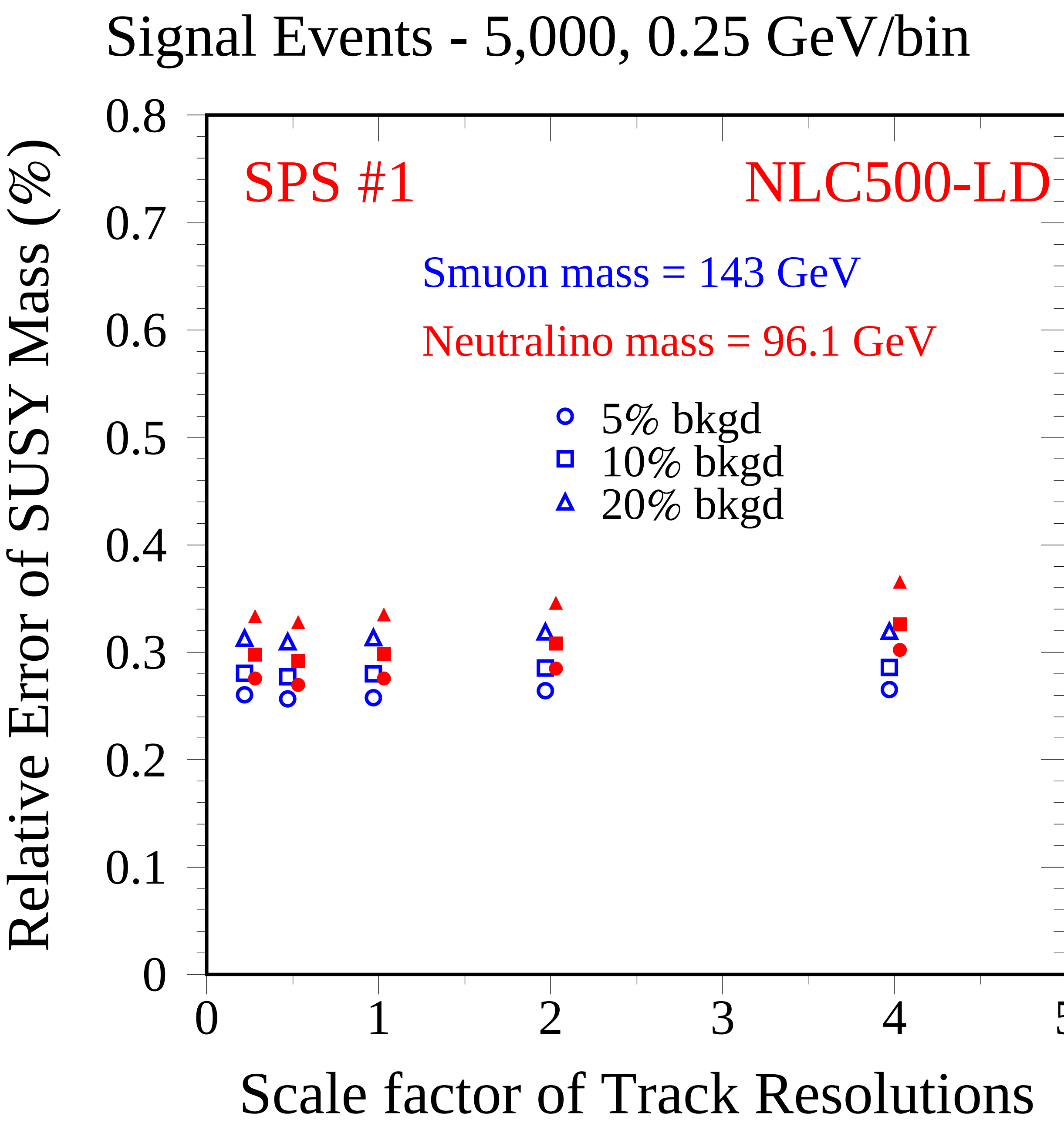
⇒ Extracted mass consistent with statistical uncertainty.

Relative Mass Error



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

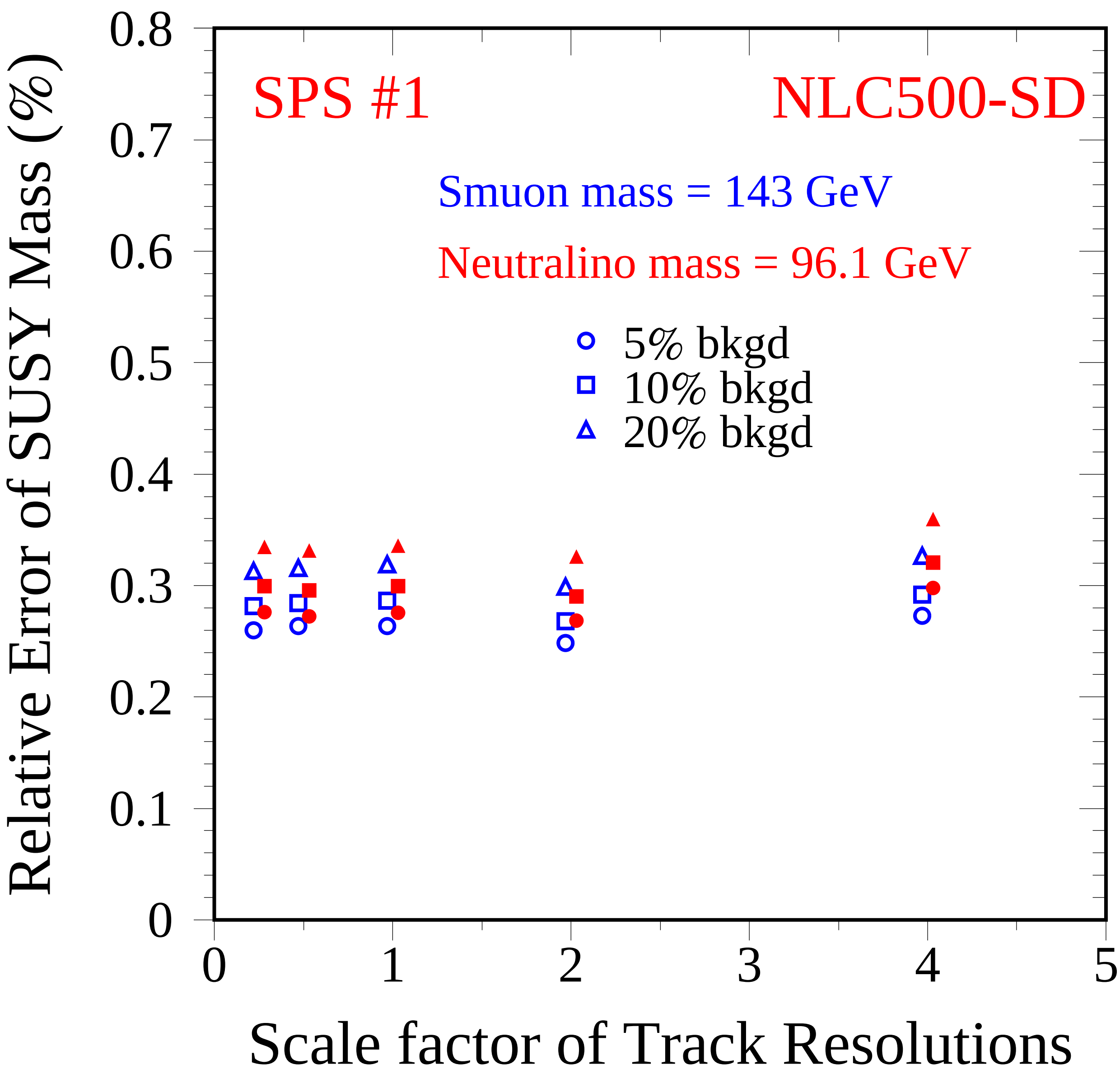
Relative Mass Error



⇒ Mass error is insensitive to track resolutions.

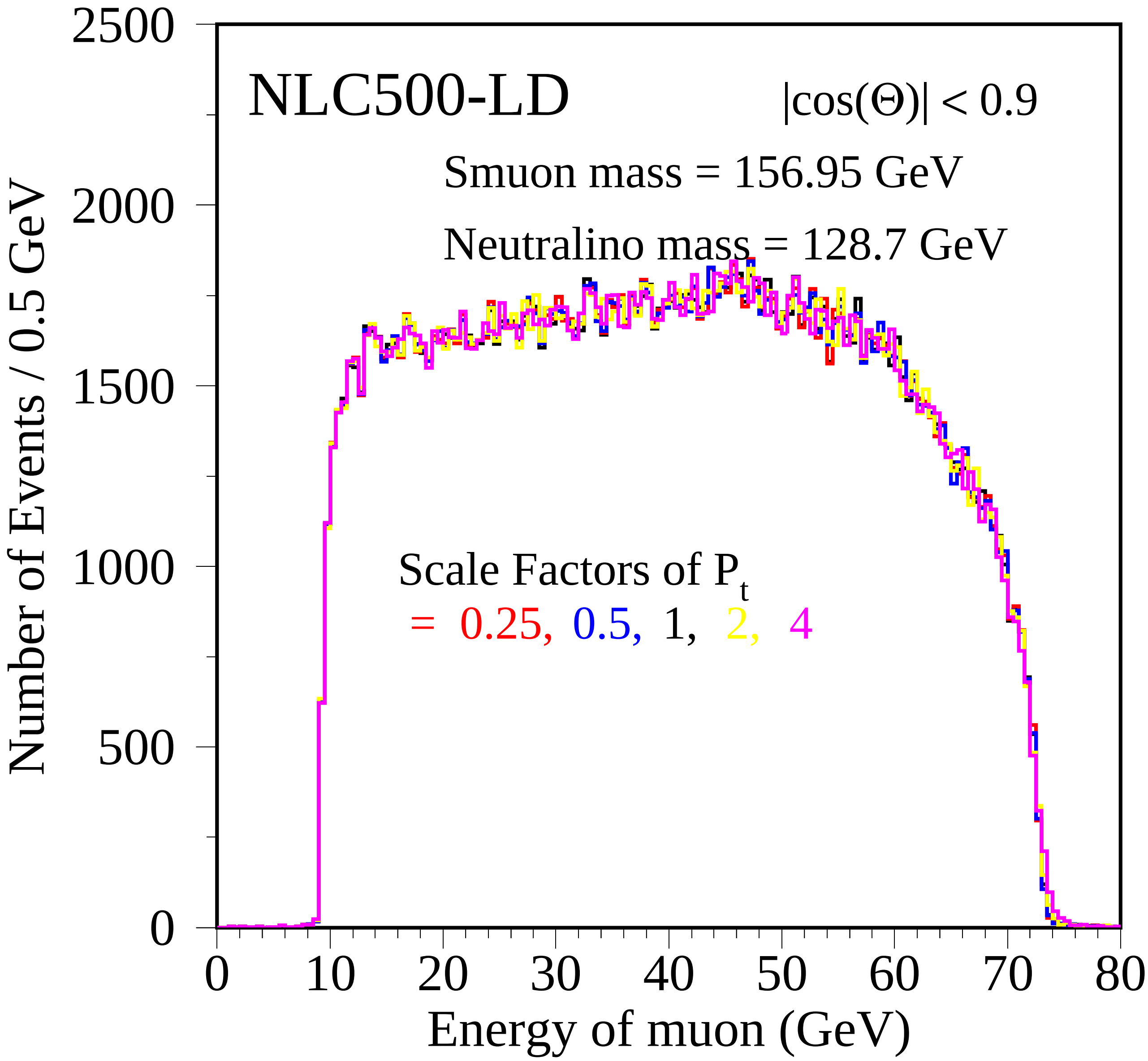
⇒ Relative error is ~ 0.3% for 5K signal events.

Signal Events - 5,000, 0.25 GeV/bin



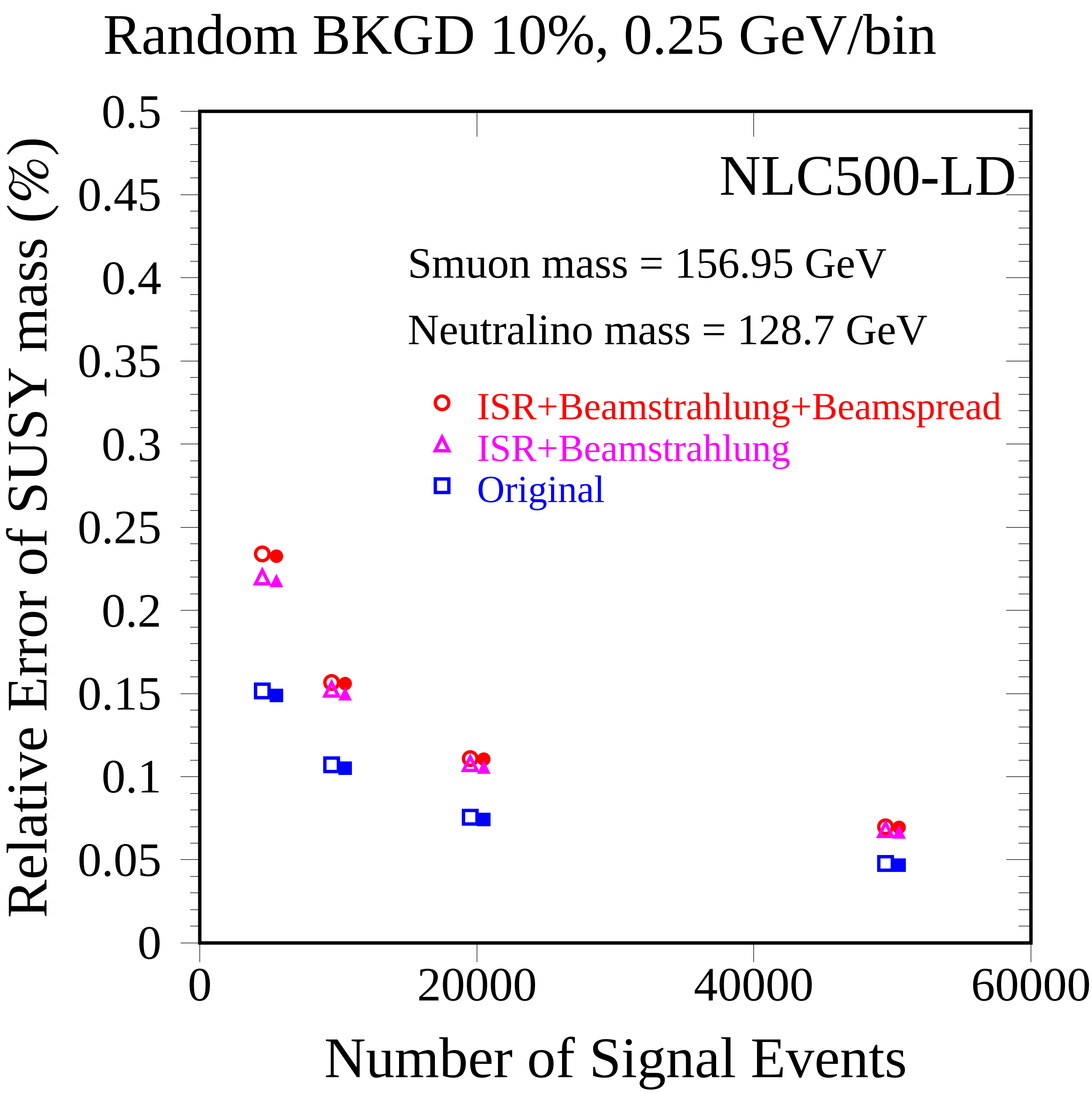
⇒ Mass error is insensitive to track resolutions.

⇒ Relative error is ∼ 0.3% for 5K signal events.



- 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.

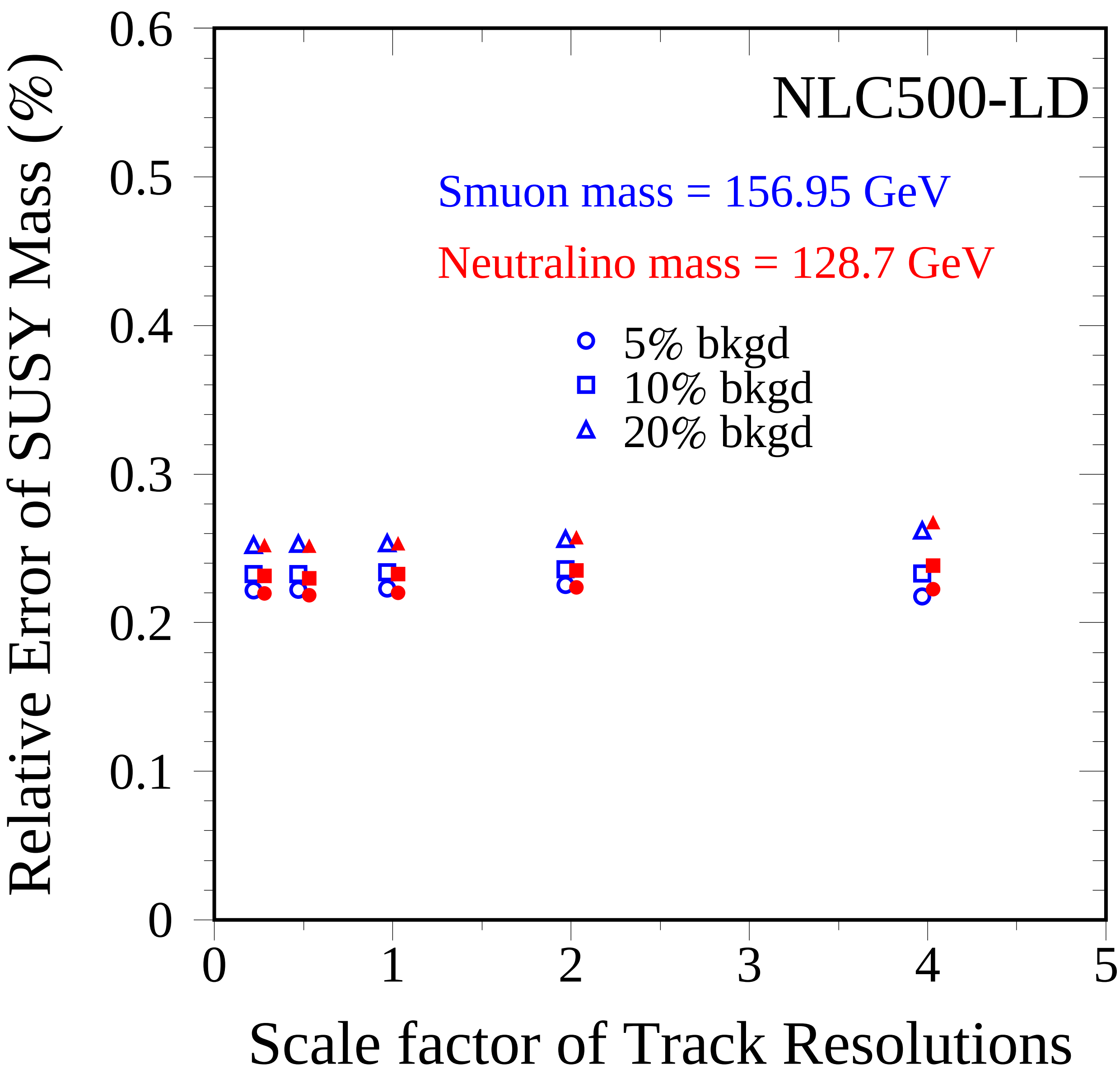
Relative Mass Error



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

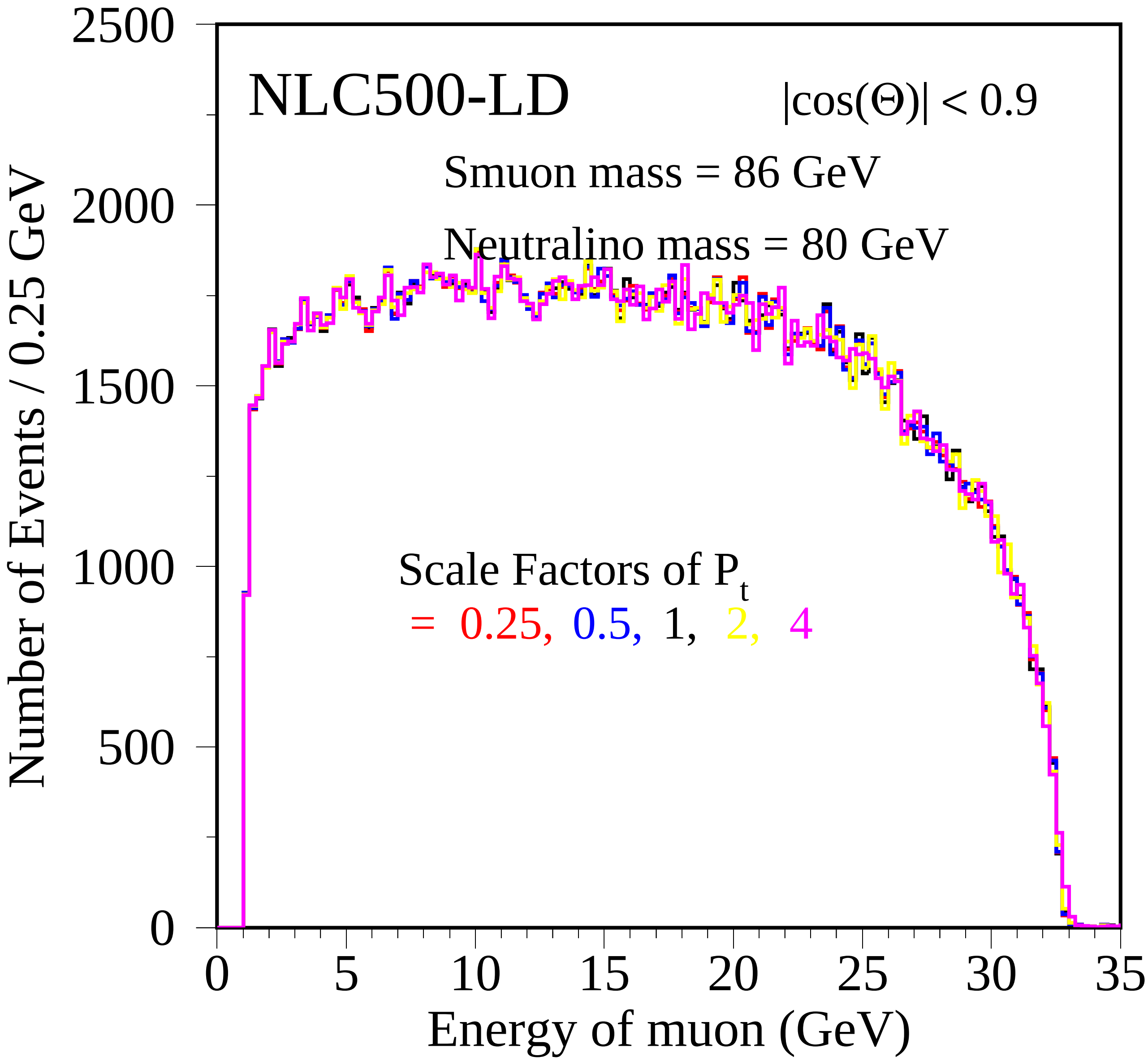
Relative Mass Error

Signal Events - 5,000, 0.25 GeV/bin



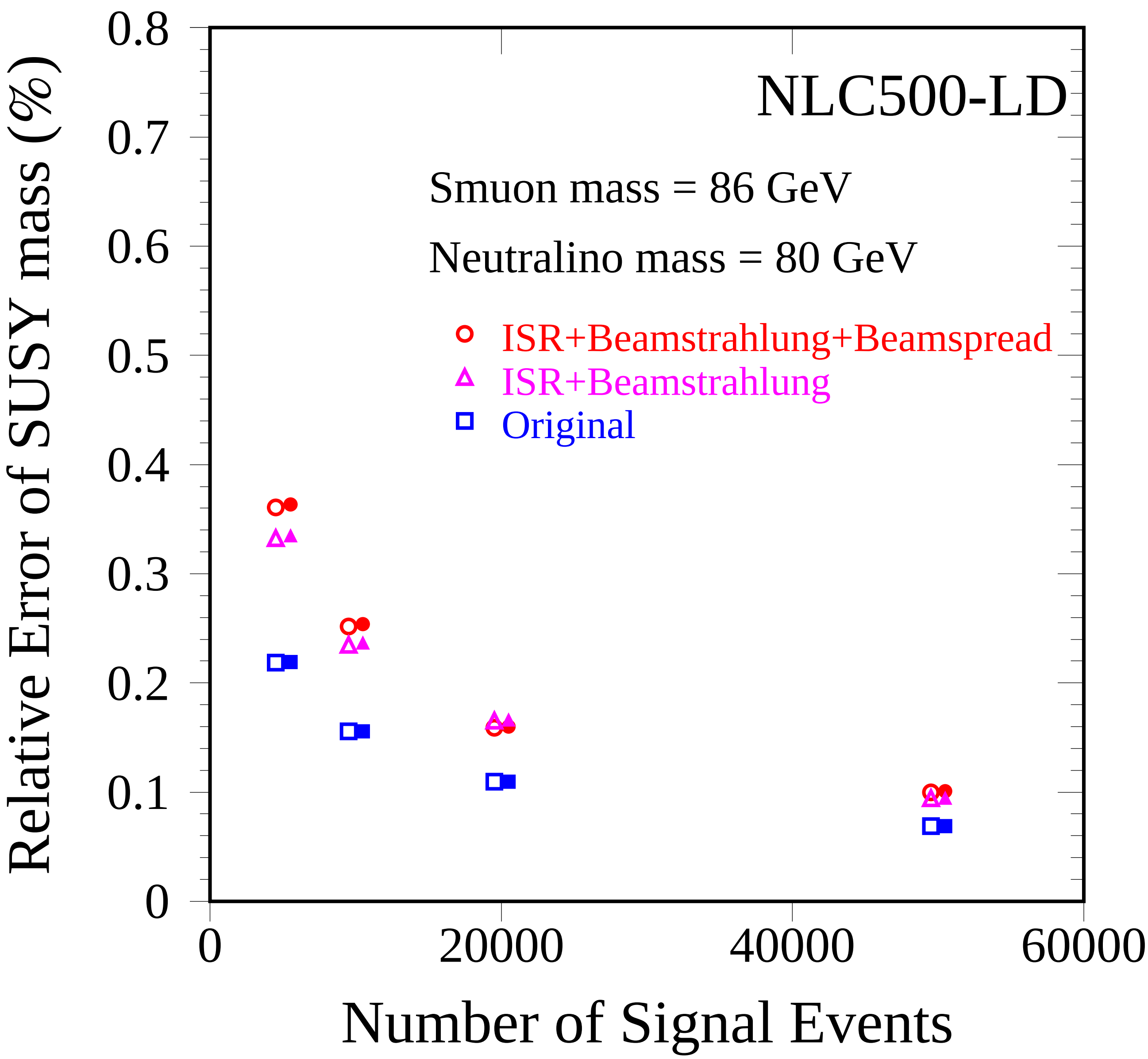
⇒ Mass error is insensitive to track resolutions.

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



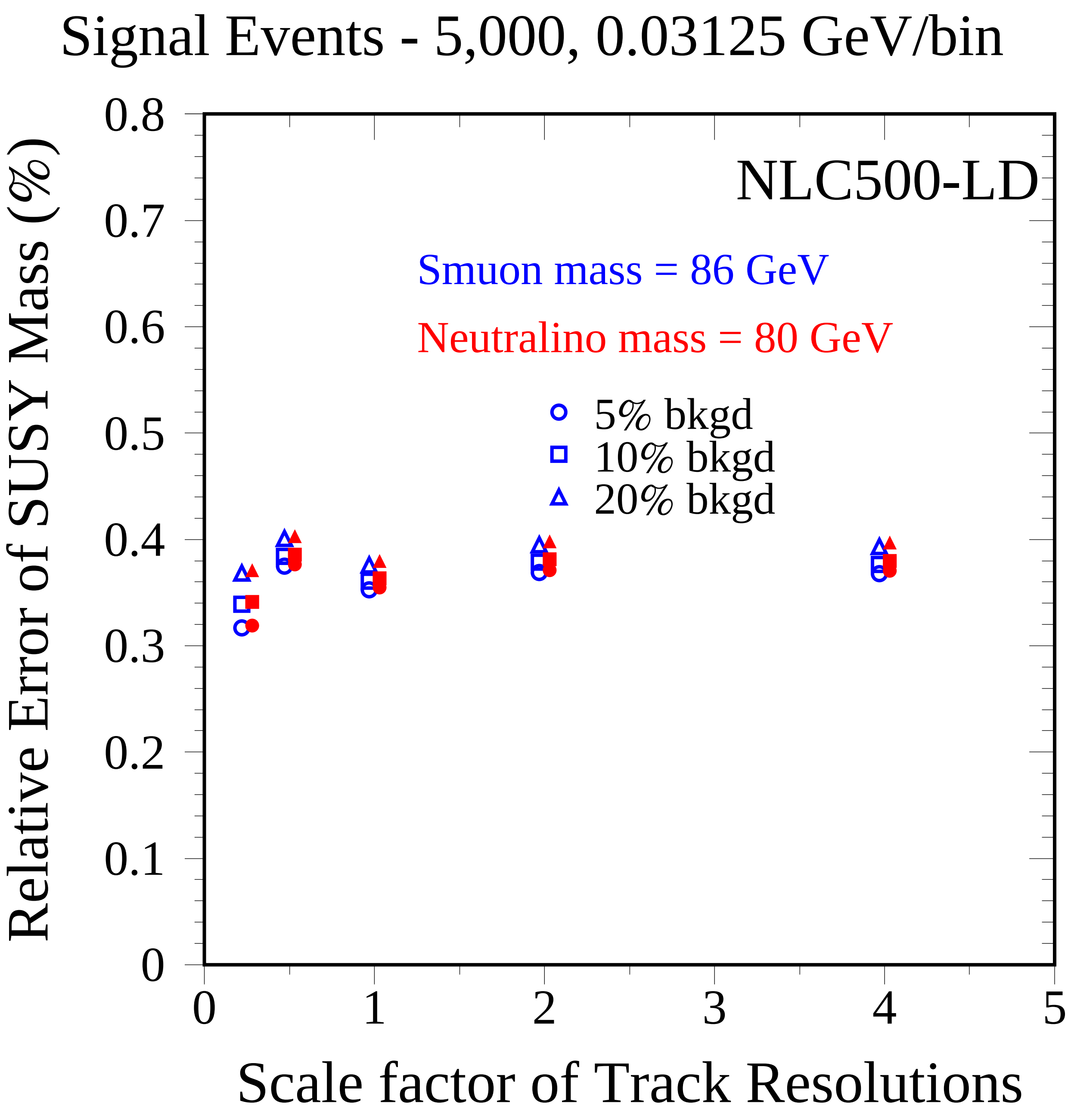
- Another mass combination ($\Delta M = 6$ GeV).
- Track momentum resolution $\Delta(\frac{1}{P_t})$ is re-scaled by factors = 0.25, 0.5, 1.0, 2.0, 4.0.

Random BKGD 10%, 0.03125 GeV/bin



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

Relative Mass Error

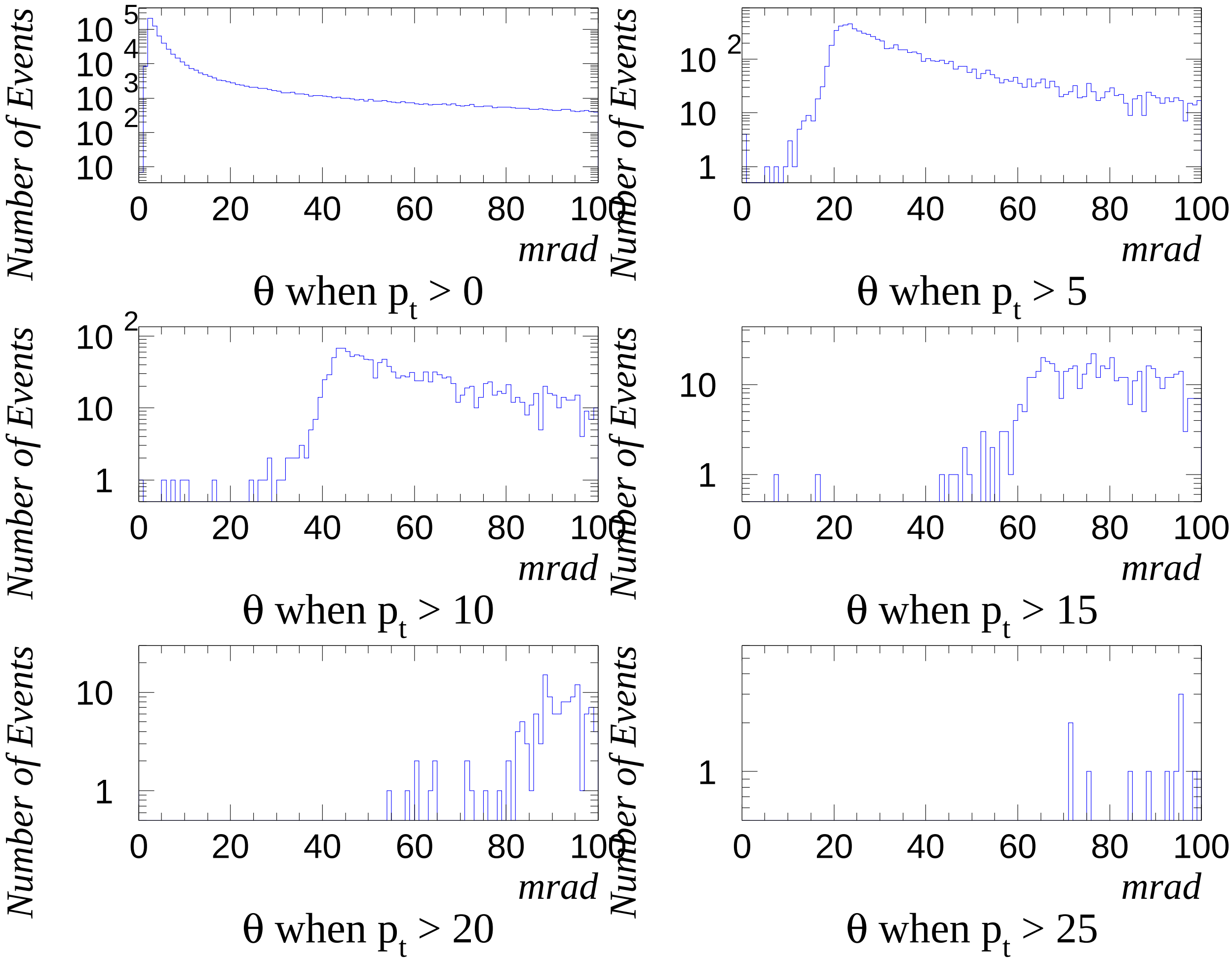


⇒ Mass error is insensitive to track resolutions.

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

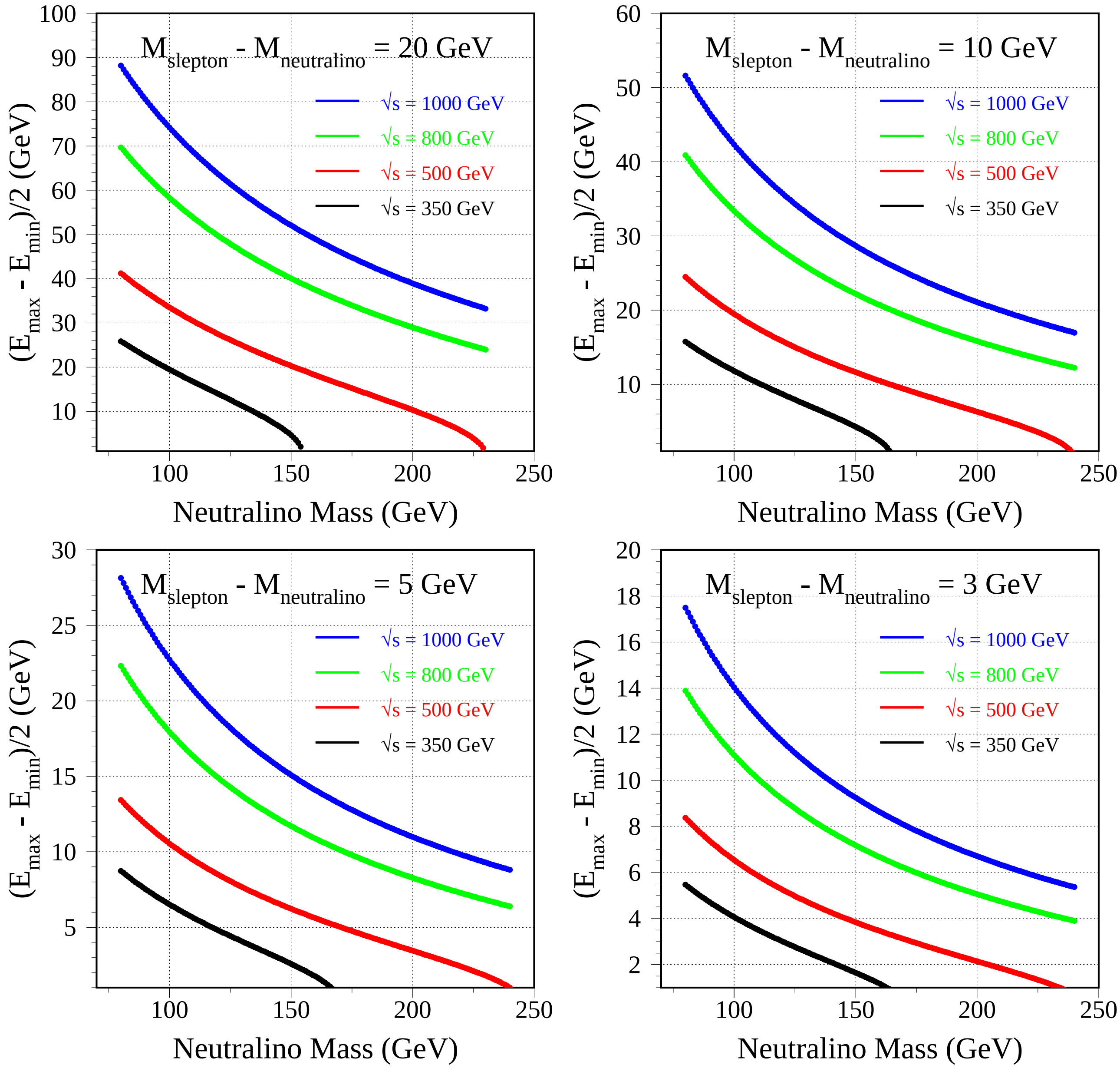
Accessible SUSY mass region at NLC

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



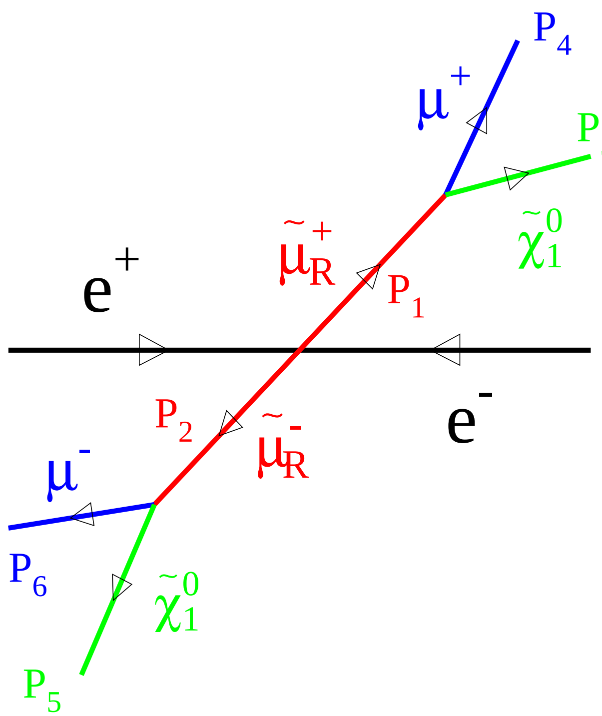
- Calorimeter acceptance of LD > 52 mrad.

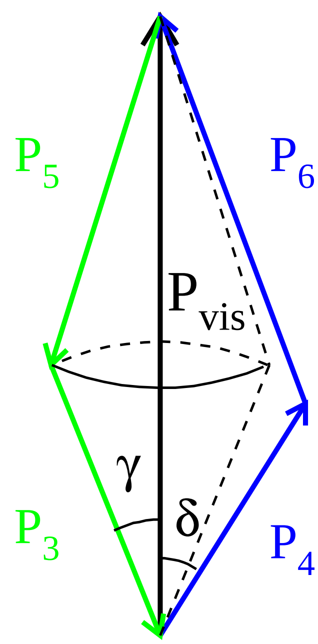
Accessible SUSY mass region at NLC



⇒ In order to measure SUSY masses precisely, higher $\sqrt{s}$ and lower e/γ veto angle are required for lower mass difference $\Delta M \equiv M_{\tilde{\mu}_R^\pm} - M_{\tilde{\chi}_1^0}$.

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



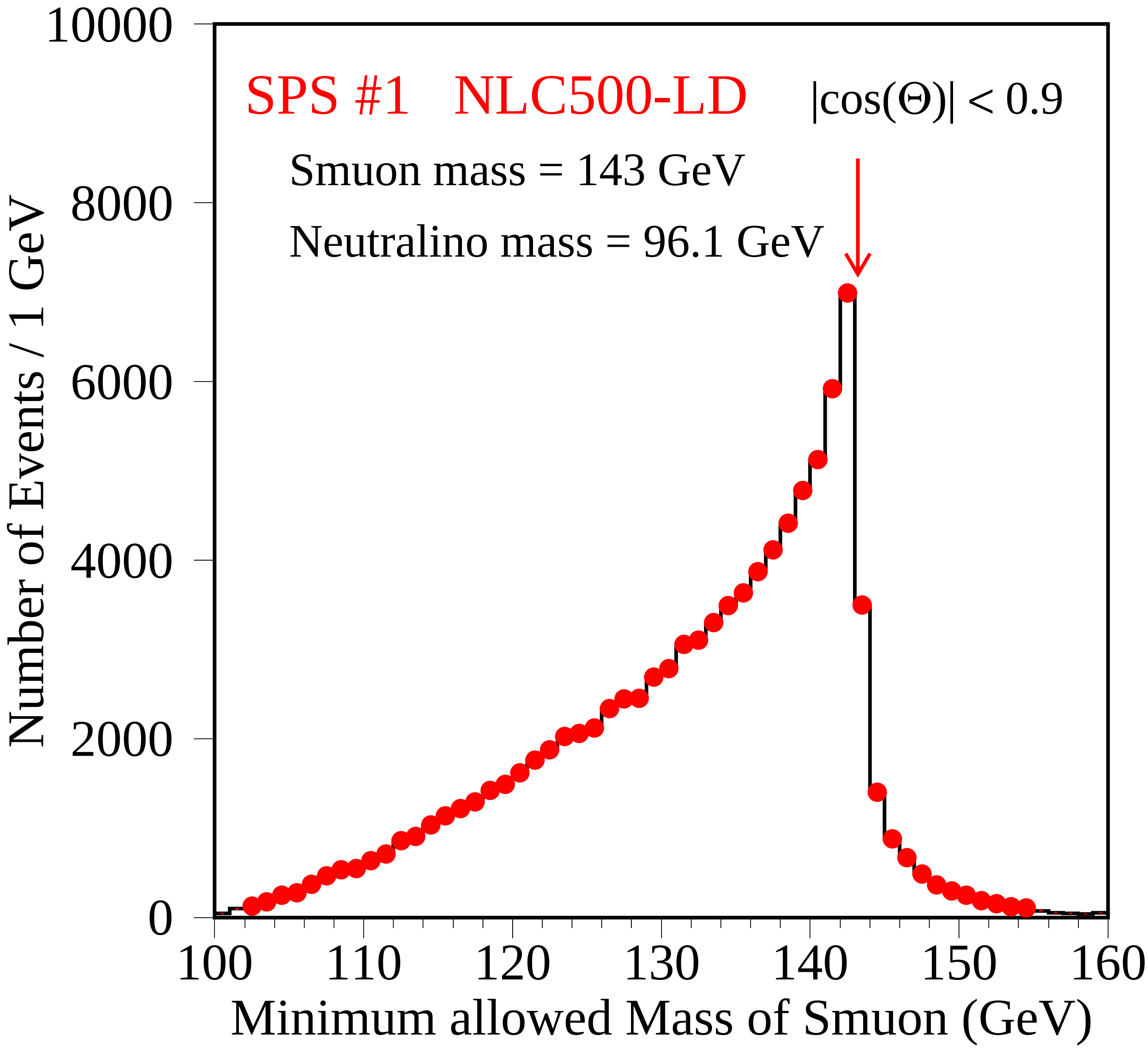


$$\mathbf{p_{vis}} = \mathbf{p_4} + \mathbf{p_6} = -(\mathbf{p_3} + \mathbf{p_5})$$

$$(\mathbf{M^{min}_{\tilde{\mu}^{\pm}_{R}}})^{\mathbf{2}} = E^2_{beam} - (p^{max}_1)^2 = E^2_{beam} - [p^2_3 + p^2_4 - 2p_3p_4cos(\gamma+\delta)] \quad (6)$$

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

$$cos(\delta) = \frac{p^2_4 + p^2_{vis} - p^2_6}{2p_4p_{vis}} \;\; ; \;\; cos(\gamma) = \frac{p^2_3 + p^2_{vis} - p^2_5}{2p_3p_{vis}}$$



⇒ 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

$\sim 0.3\%$ 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 $\sqrt{s}$ and lower e/γ veto angle are required for lower ΔM.