Complementarity of Slepton Studies at the LHC and LC

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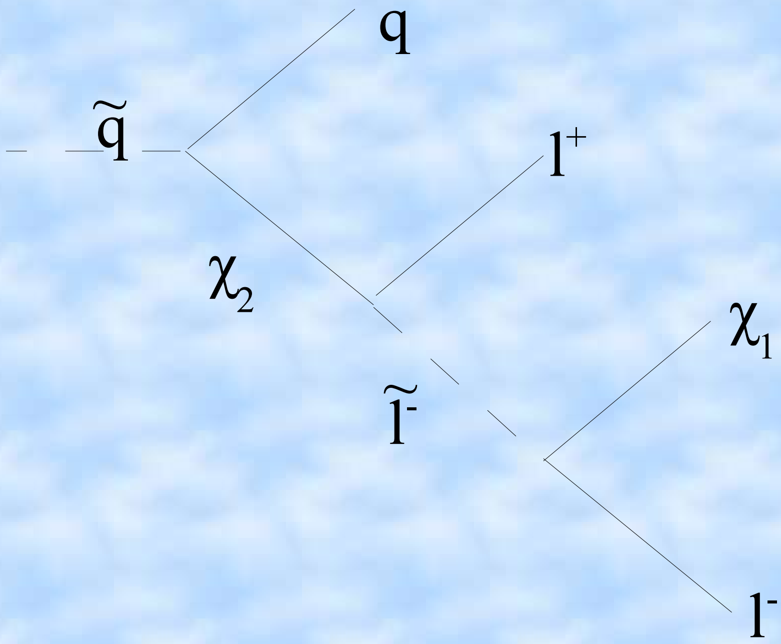
Outline of talk

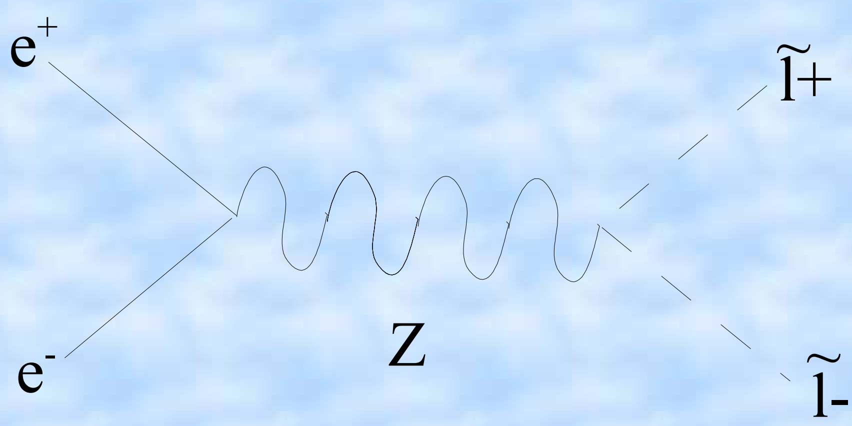
- Sleptons at the LHC and LC
- Getting a handle on slepton masses at the LHC through χ_2 decay.
- Kolmogorov-Smirnov test
- Testing our approach in mSUGRA
- Conclusions

Sleptons at the LHC and LC

- LHC – We'll mainly make squarks and gluinos. Sleptons will be made through cascade decays mostly.

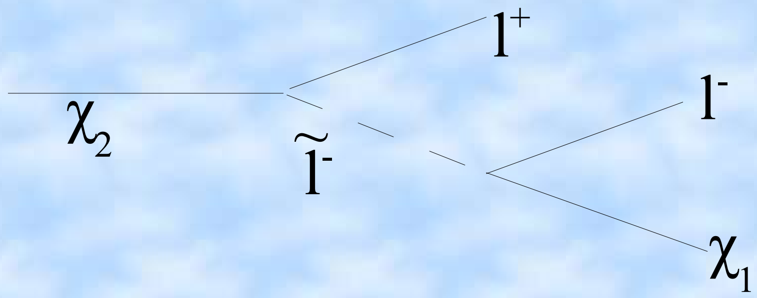


- LC – Sleptons can be made directly!



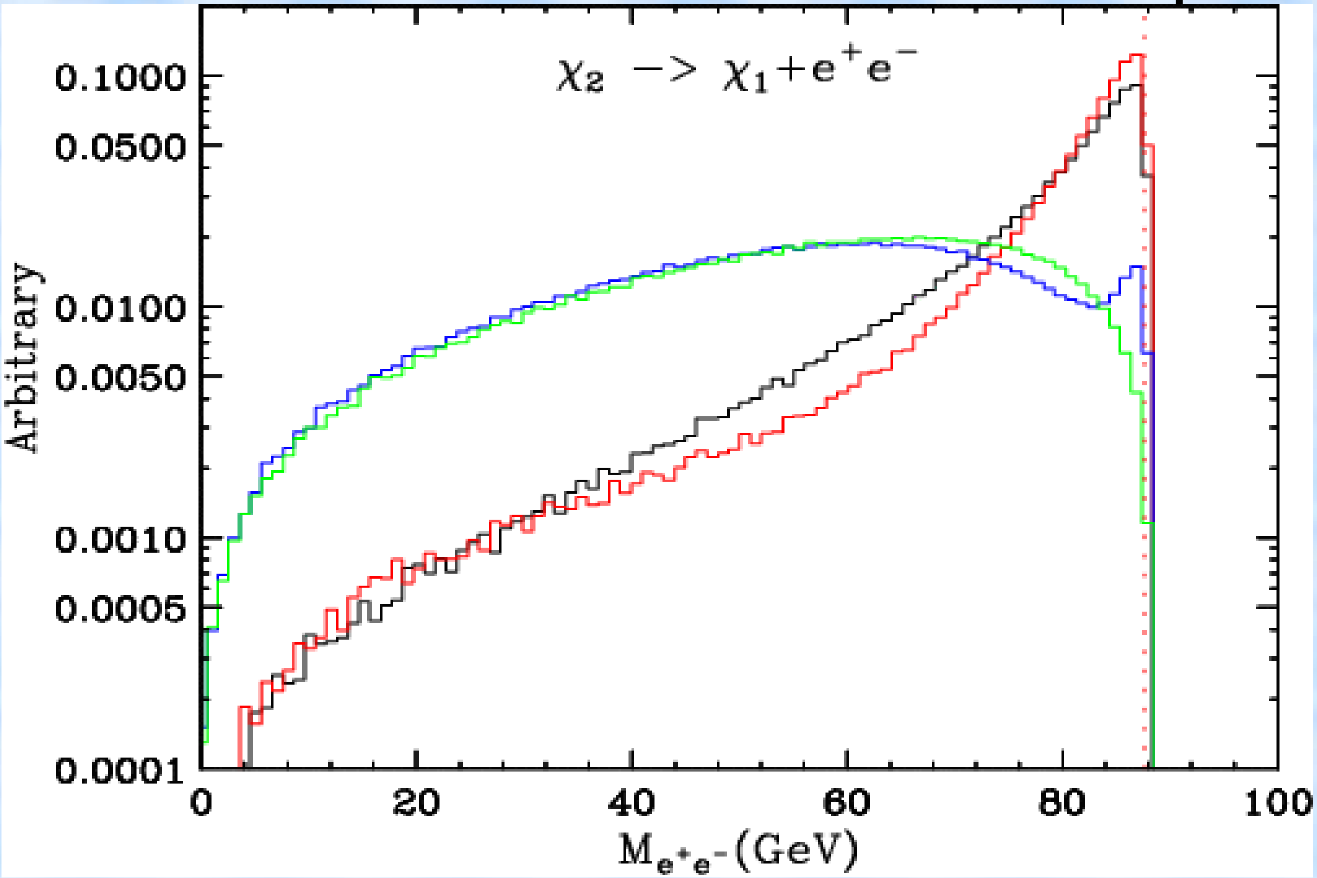
- Measuring slepton masses at the LHC
  - Direct production?
    - not obviously possible (large WW and tt backgrounds).
  - Indirect production?
    - Can be faked with virtual sleptons.
- If we *could* measure slepton masses at the LHC:
  - we would **know** the slepton masses!
  - could help us justify the funding of a linear collider
  - could help us with appropriate design parameters (center of mass energy, etc.) for a linear collider

Slepton masses at the LHC through χ_2 decay.



- Sleptons - cascade decays at the LHC
- Useful information - from the m_{ll} distribution of χ_2 decay(see, for example, I. Hinchliffe and F. Paige, PRD 61:095011, 2001):
  - 3-body decays (virtual slepton/Z): kinematic endpoint of m_{ll} gives $(m_{\chi 2} – m_{\chi 1})$
  - 2-body decays: kinematic endpoint of m_{ll} gives: $((m_{\chi 2}^{\ 2} – m_{slep}^{\ 2})(m_{slep}^{\ 2} - m_{\chi 1}^{\ 2})/m_{slep}^{\ 2})^{1/2}$
- Just the endpoints? What about the shape of the distribution? Can that tell us anything?
  - Yes, can discriminate between 3-body and 2-body decay.
  - Can even measure slepton masses!

Invariant Mass Distributions and the Slepton Mass



Slepton mass values: black - infinite, red – 1 TeV,
blue – 500 GeV, green – 300 GeV

Aha! The shapes are quite different, even for the same endpoint value!

The distributions look different to the eye, but how would we tell them apart from experimental data?

The Kolmogorov-Smirnov (KS) test can do this:

- Calculates maximum cumulative deviation between two normalized data samples.
- Null hypothesis: the two samples came from the same underlying distribution
- Calculates the confidence level with which that null hypothesis can be falsified.

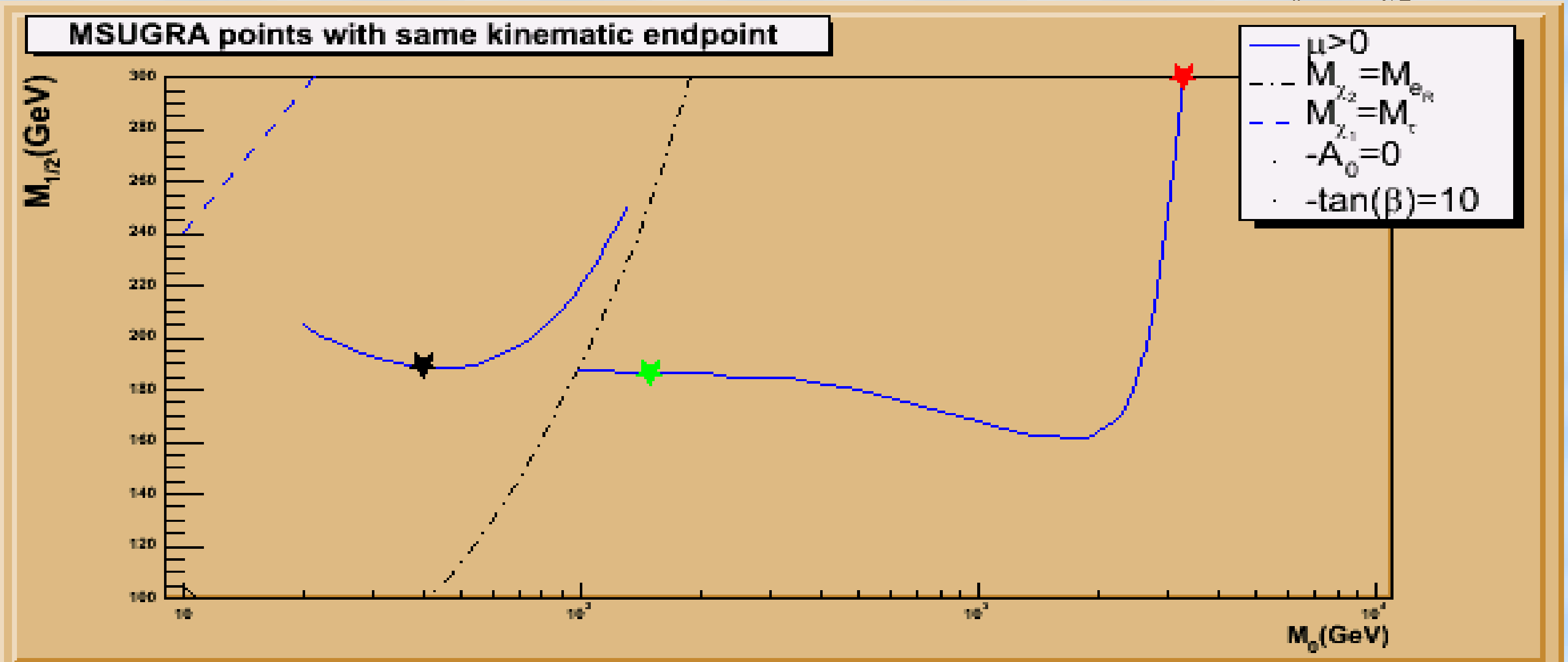
- Compare experimental distributions with template distributions having identical kinematic endpoints but varying slepton masses.
- KS test allows us to rule out ranges of slepton masses as inconsistent with the experimental distribution.

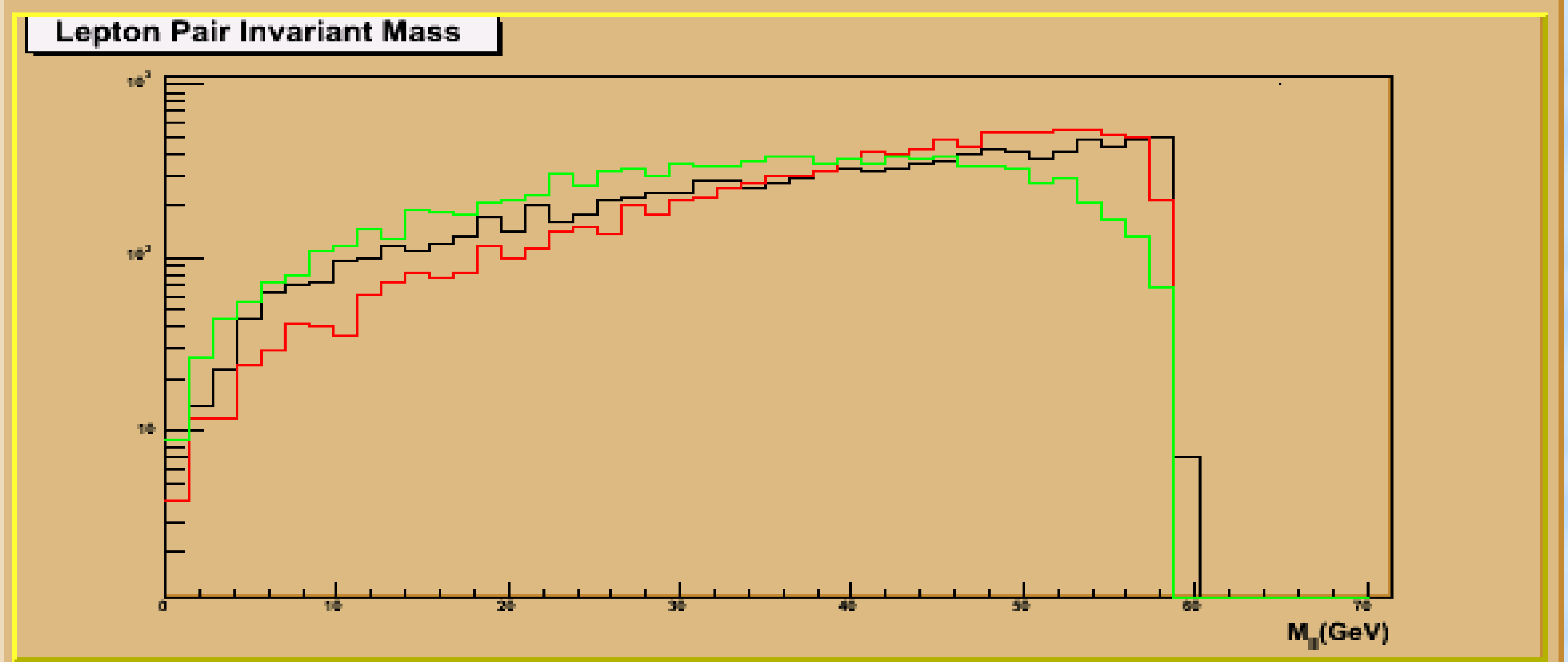
Some caveats before more plots start rolling in...

- These plots are all for 1000 signal events at the LHC, using Isajet
  - These plots do not include any cuts or background, so they are preliminary, proof-of-technique plots
- We have only considered portions of mSUGRA parameter space
  - we have consistently taken $\tan\beta = 10$ and $A_0 = 0$.

Distribution Shapes in mSUGRA

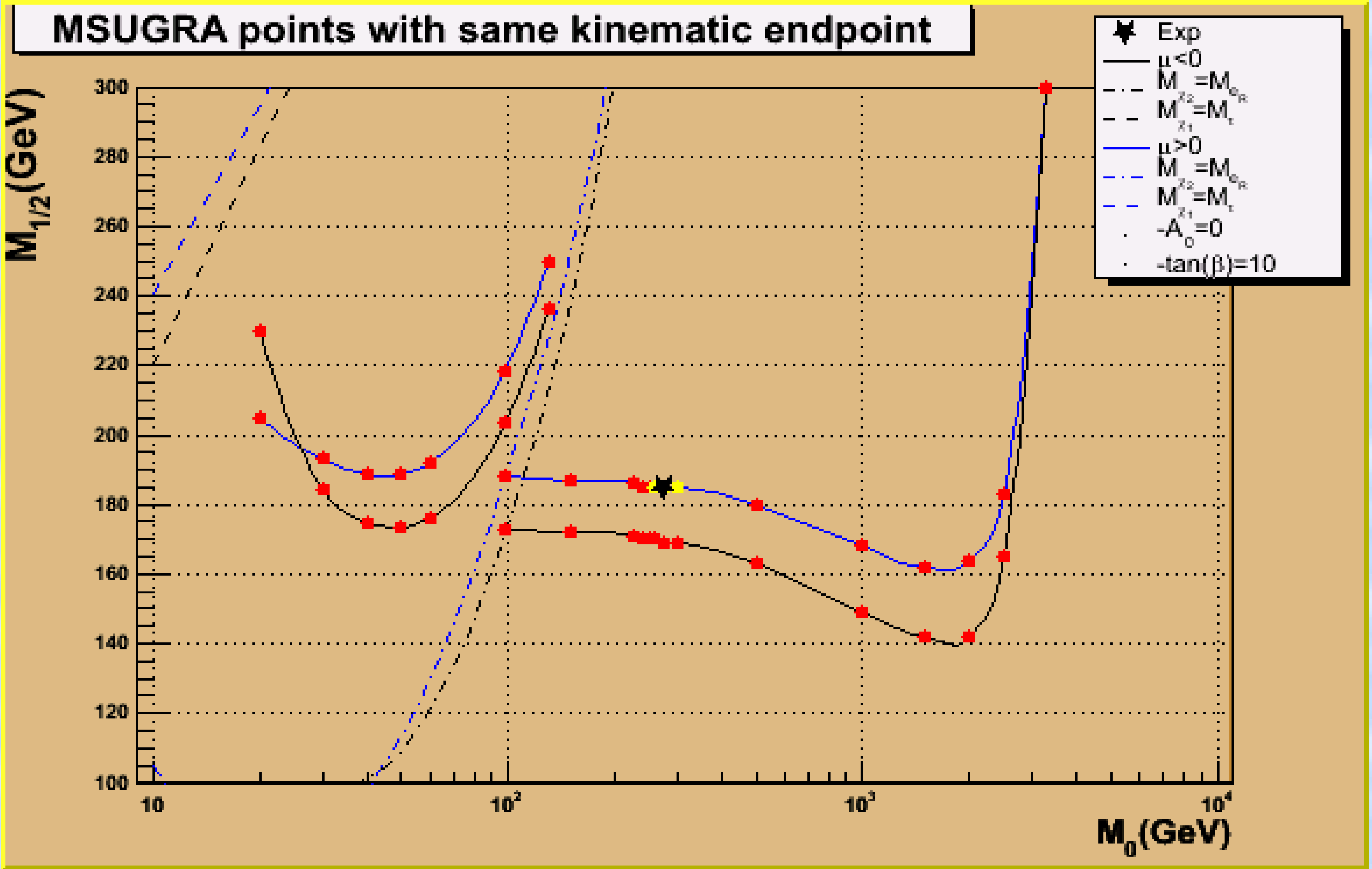
- For a fixed endpoint value of 59 GeV, we get line segments in the $(m_0, m_{1/2})$ plane:



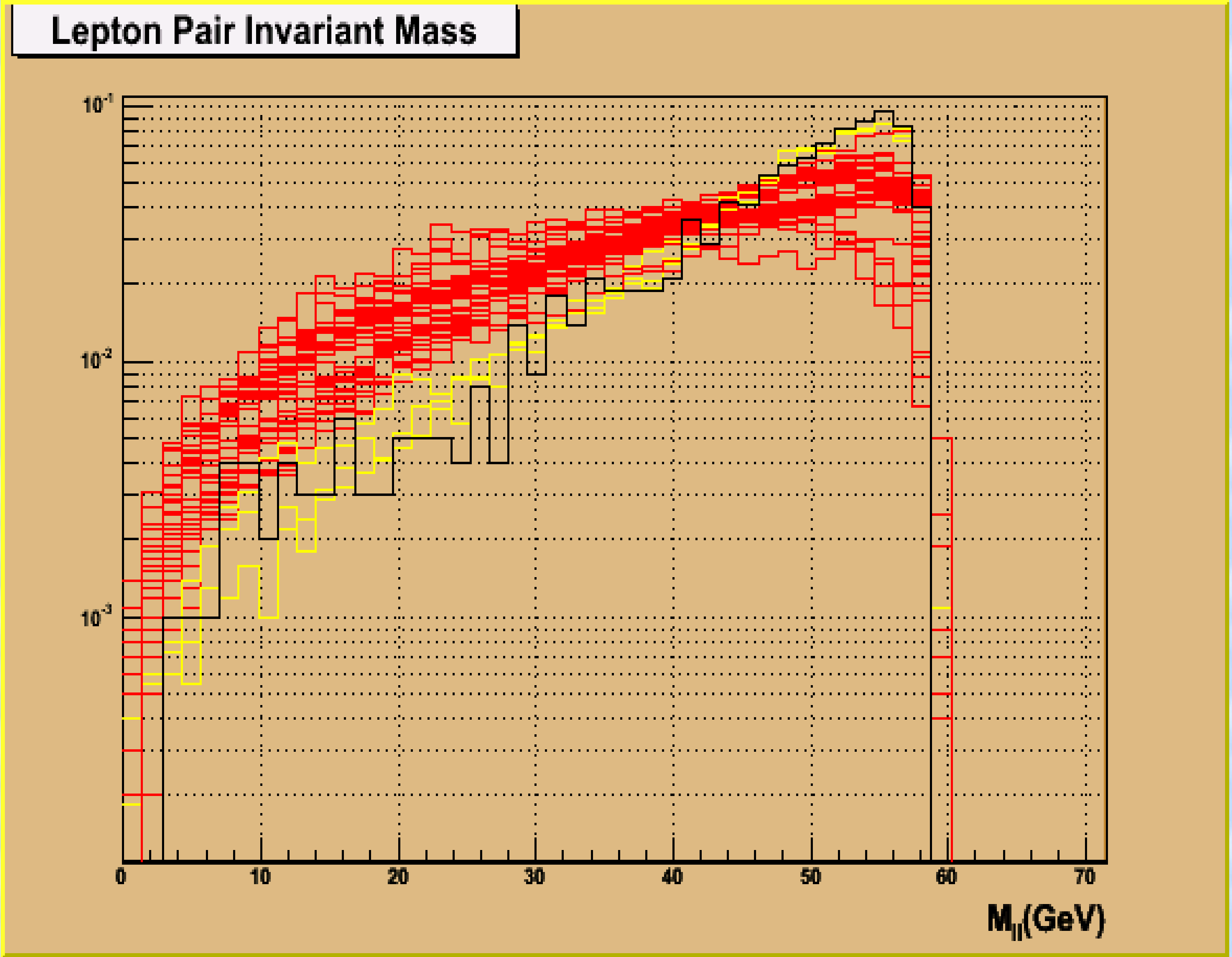


Kolmogorov-Smirnov in mSUGRA (point with $m_0 \sim 300$ GeV)

- Black star – taken to be experimental result.
- Red dot – templates that can be ruled out at the 95% confidence level.
- Yellow dot – templates that can't be ruled out at the 95% confidence level.

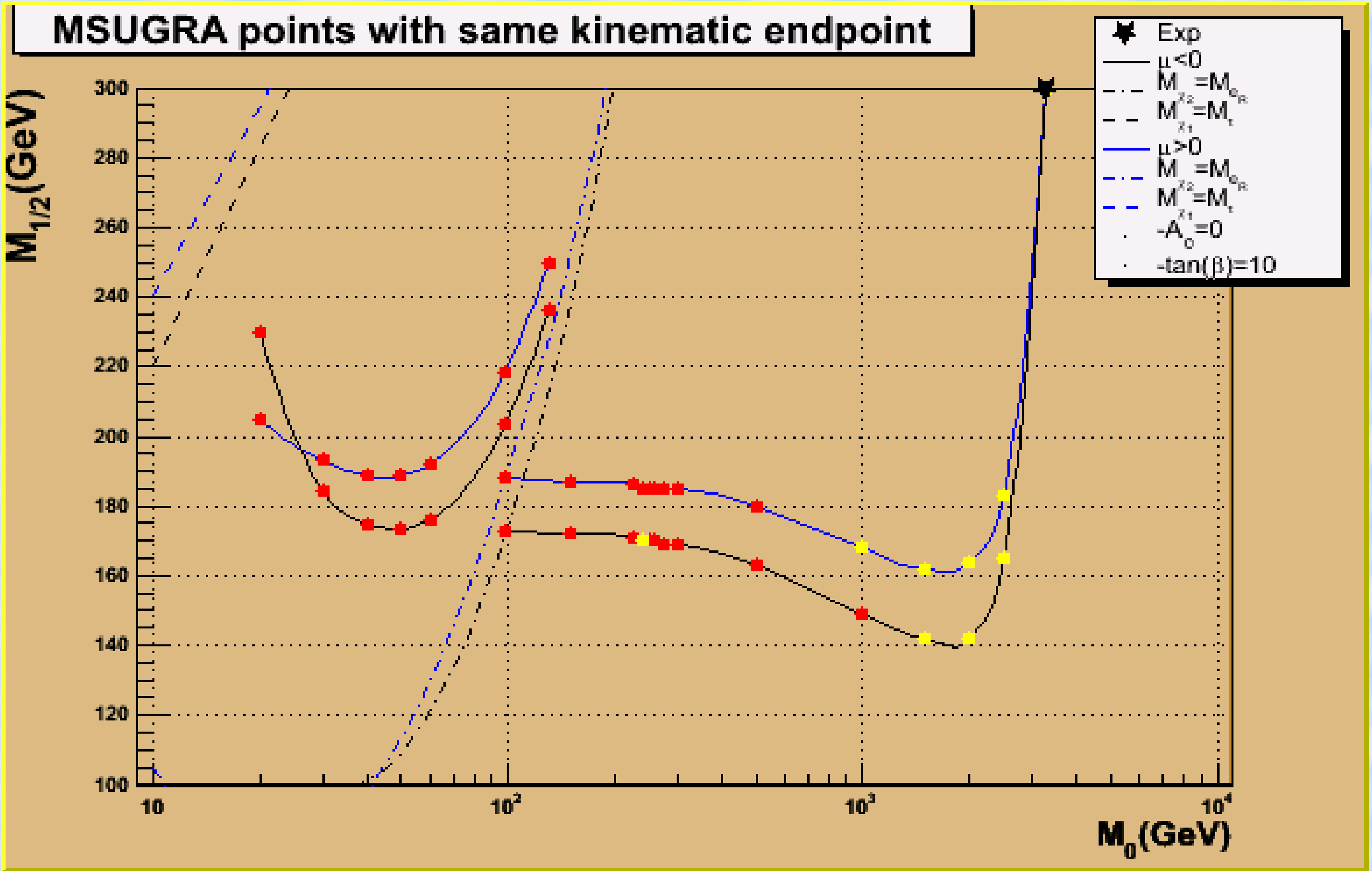


How does this look to the untrained eye?



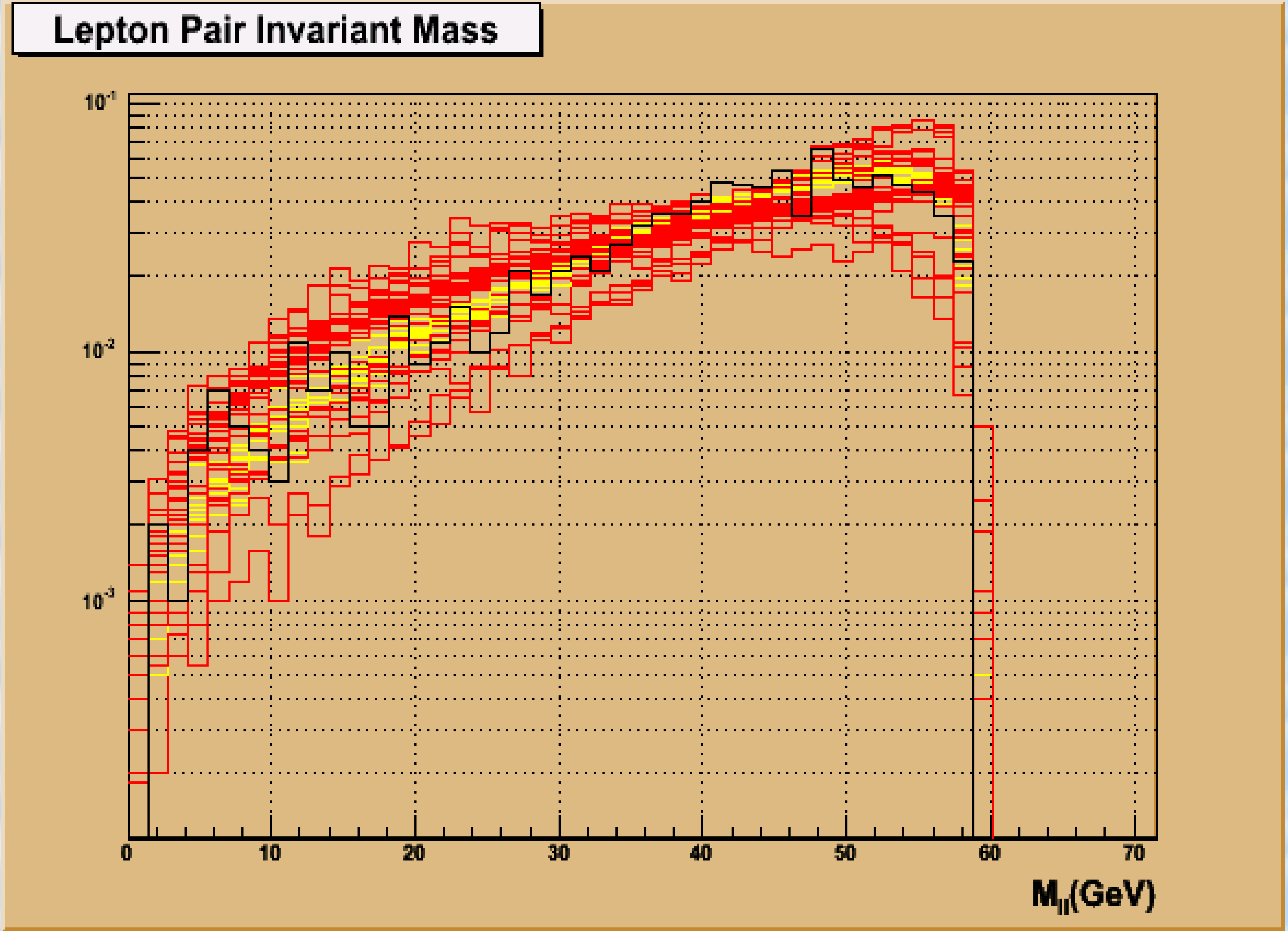
Kolmogorov-Smirnov in mSUGRA
(point with $m_0 \sim 3$ TeV)

- Black star – taken to be experimental result.
- Red dot – templates that can be ruled out at the 95% confidence level.
- Yellow dot – templates that can't be ruled out at the 95% confidence level.



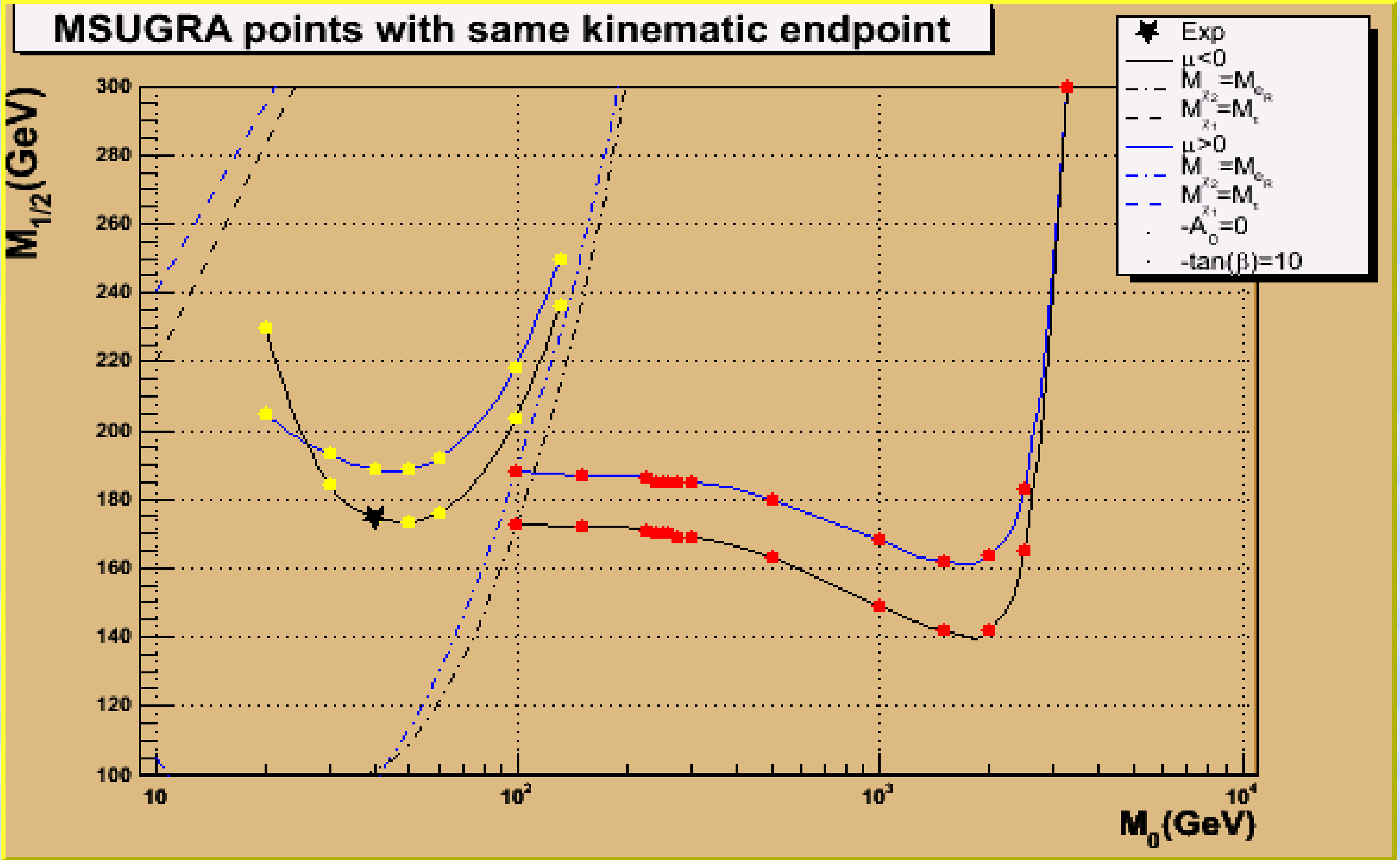
How does this look to the untrained eye?

- Kolmogorov-Smirnov certainly has better vision than me!



Kolmogorov-Smirnov in mSUGRA
(point with $m_0 \sim 50$ GeV, slepton is real)

- Black star – taken to be experimental result.
- Red dot – templates that are ruled out at the 95% confidence level.
- Yellow dot – templates that can't be ruled out at the 95% confidence level.



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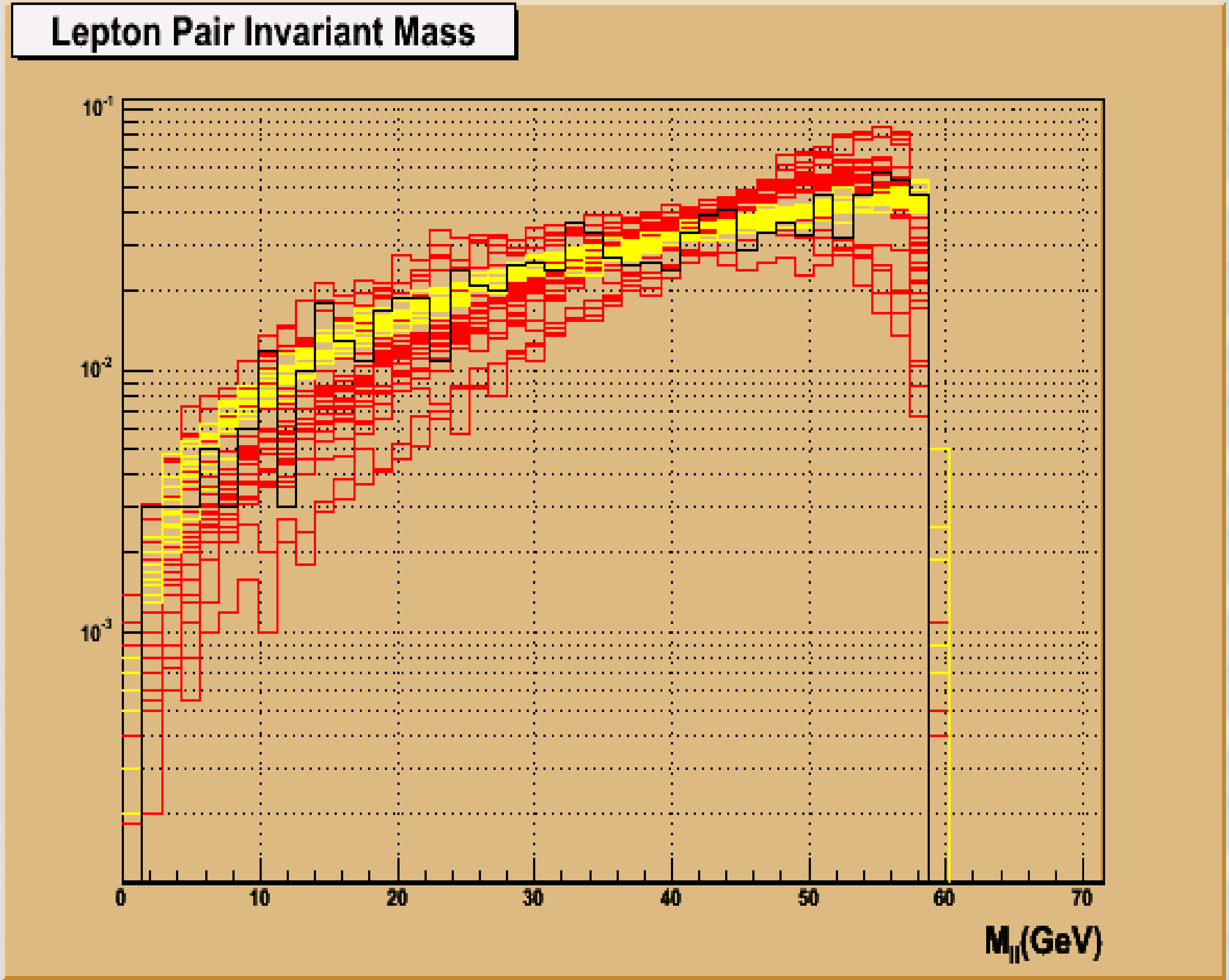
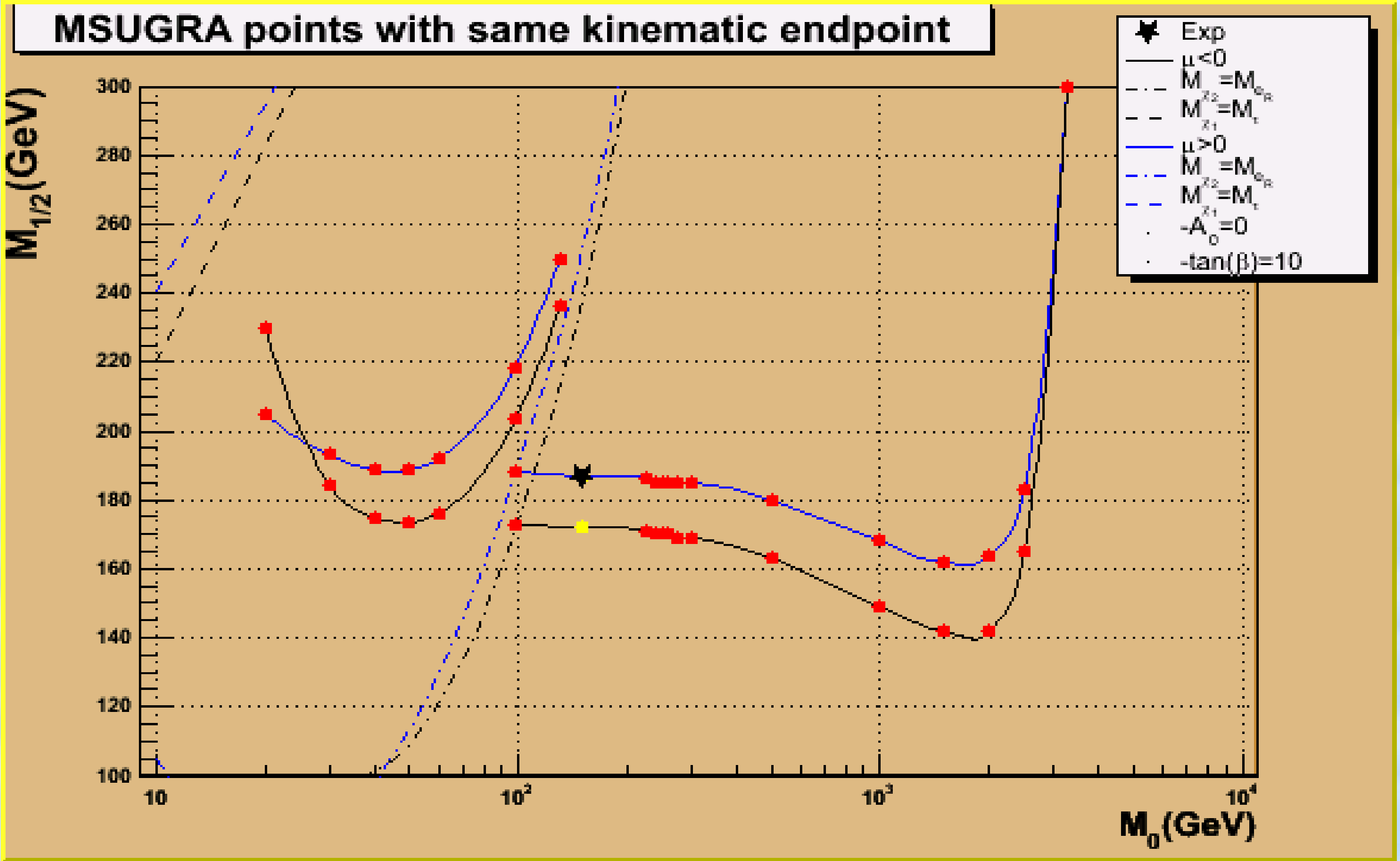


Kolmogorov-Smirnov in mSUGRA
(point with $m_0 \sim 100$ GeV, slepton is virtual)

- Black star – taken to be experimental result.
- Red dot – templates that are ruled out at the 95% confidence level.
- Yellow dot – templates that can't be ruled out at the 95% confidence level.



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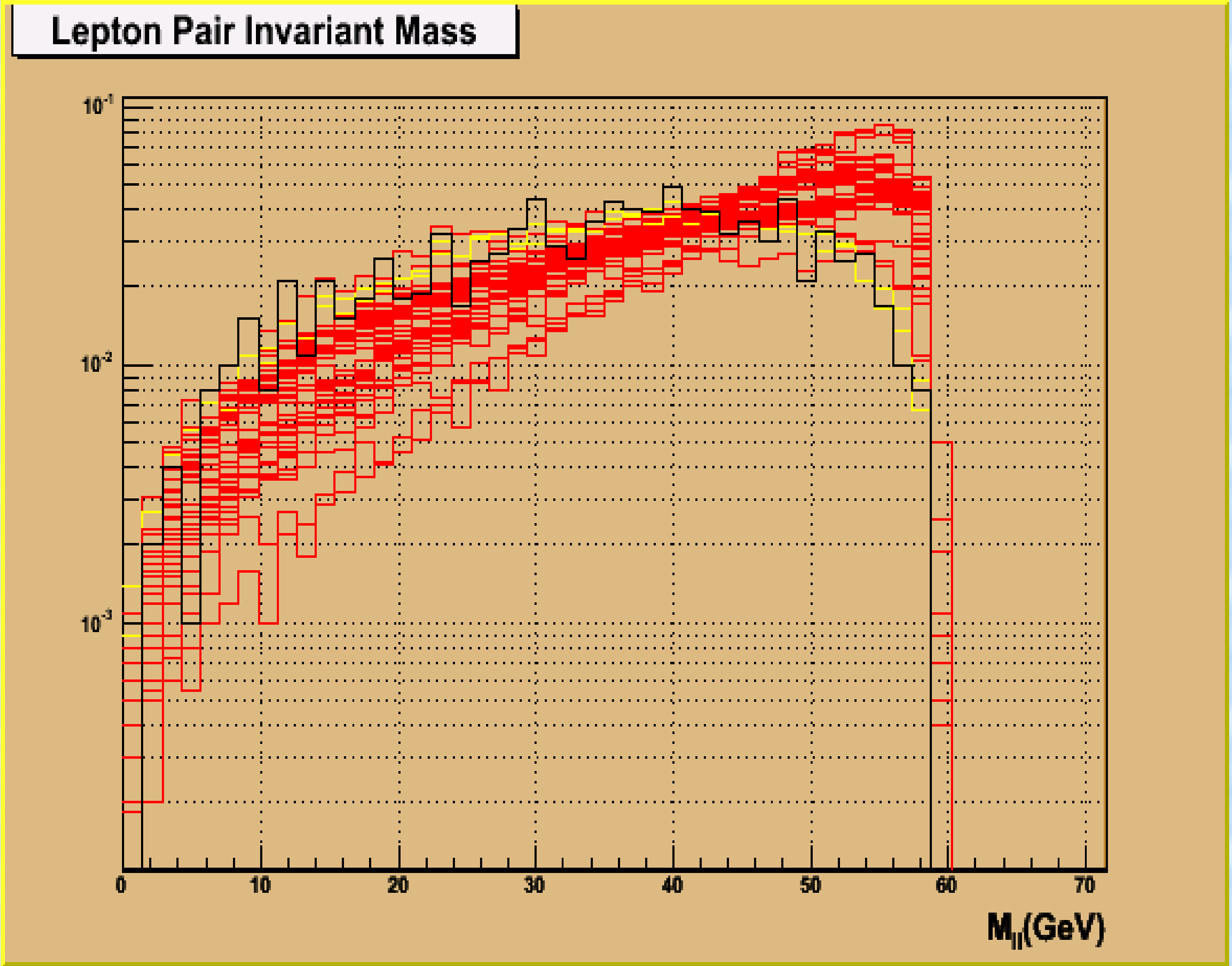

What have we learned from this?

- High-mass points ($m_0 > 1$ TeV) can often be distinguished from low-mass points, and a lower limit on the value of m_0 can be determined.
- For low-mass 3-body decay points, the m_0 value can be bracketed (sometimes quite nicely), but the sign of μ is not always clear.
- For 2-body decay points (with a real slepton), the value of m_0 can be bracketed, and they can be clearly distinguished from 3-body decay points.

Conclusions

- Slepton mass determinations are possible at the LHC through neutralino decays, even for virtual sleptons.
- The Kolmogorov-Smirnov test can be used to discriminate between neutralino decay distributions that result from different SUSY parameters.
  - This shape analysis can be used to constrain the underlying SUSY parameters, we've illustrated this explicitly for mSUGRA.

Outlook

- This study in mSUGRA still needs realistic backgrounds and cuts.
- Once the mSUGRA study is understood, it will then be expanded to the MSSM.
- These shape analyses will also undoubtably be useful in making measurements at a future linear collider.