# Searches for a Dark Matter Candidate in Particle Physics Experiments at the Fermilab Tevatron

**Paul Geffert**, Max Goncharov, Eunsin Lee, Rishi Patel*, David Toback, Peter Wagner, and Slava Krutelyov**

**for the CDF Collaboration**

**Texas A&M University**

*New York University**

*University of California at Santa Barbara***

# Outline

- Dark matter
- Supersymmetry and a dark matter candidate
- Photon timing
- The analysis and results
- Future Improvements and Prospects
- Conclusion

Analysis Published in

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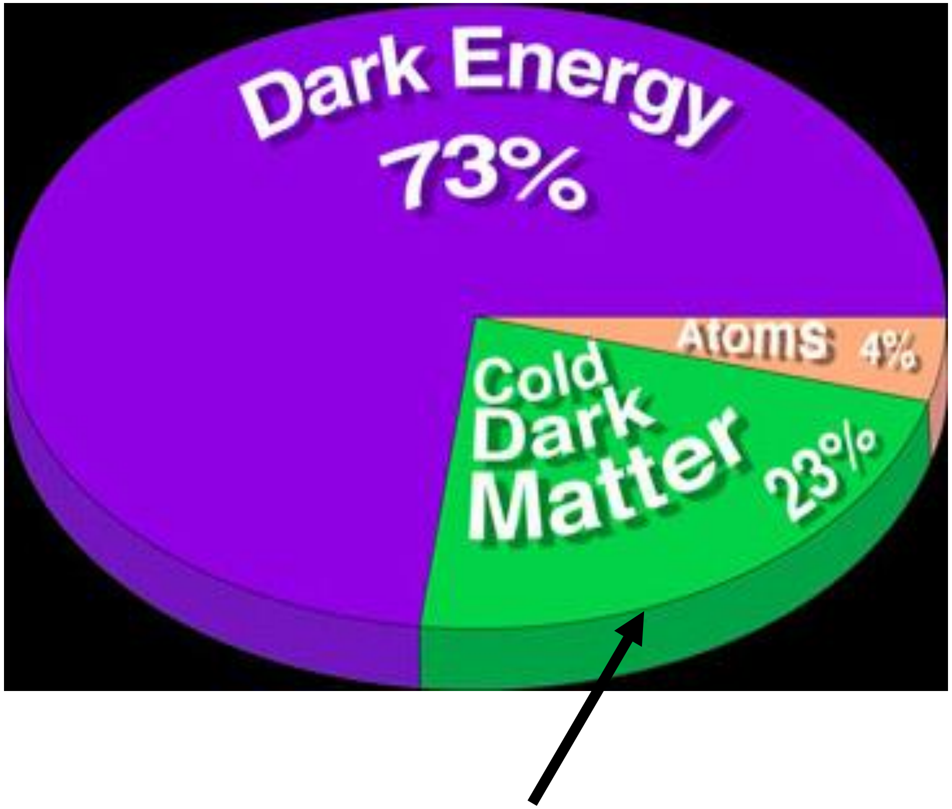
# Dark Matter

- What is dark matter?
  - Does not interact with photons (**dark**)
  - Has mass and interacts gravitationally
  - Could be an undiscovered particle

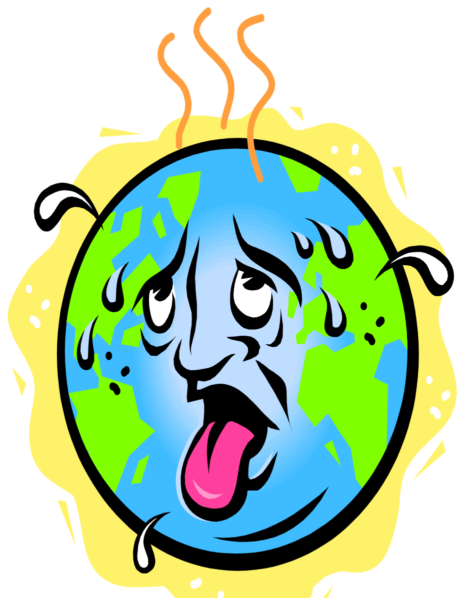



Large fraction of the energy in the universe

# "Cold" Dark Matter vs. "Warm" Dark Matter

Cold
"Large Mass"
~100 GeV

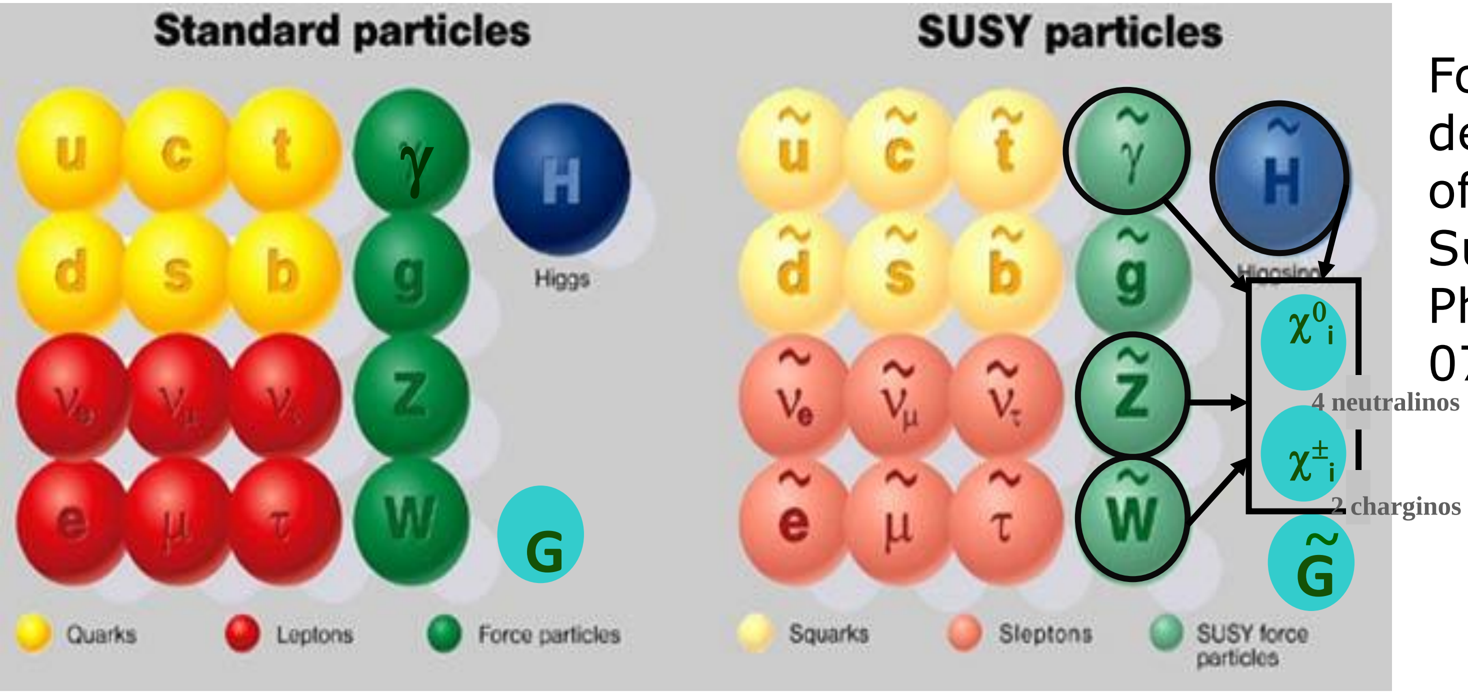
- Cold Dark Matter is favored for large scale galaxy formation
- Warm Dark Matter is favored for subgalactic scale formation
- Most searches focus on Cold Dark Matter, but we search for Warm Dark Matter because we have a powerful new search technique



Warm
"Small Mass"
~1 keV

# Supersymmetry

- Supersymmetry is a model of particle physics that predicts new particles
- If this theory is correct, one of these new particles could be the dark matter
- Our warm dark matter candidate is a light gravitino, $\tilde{G}$ , the supersymmetric partner of the as yet undiscovered graviton




For experts, a detailed discussion of GMSB Supersymmetry is Phys. Rev. D 58, 075005 (1998)

# Supersymmetry and Dark Matter

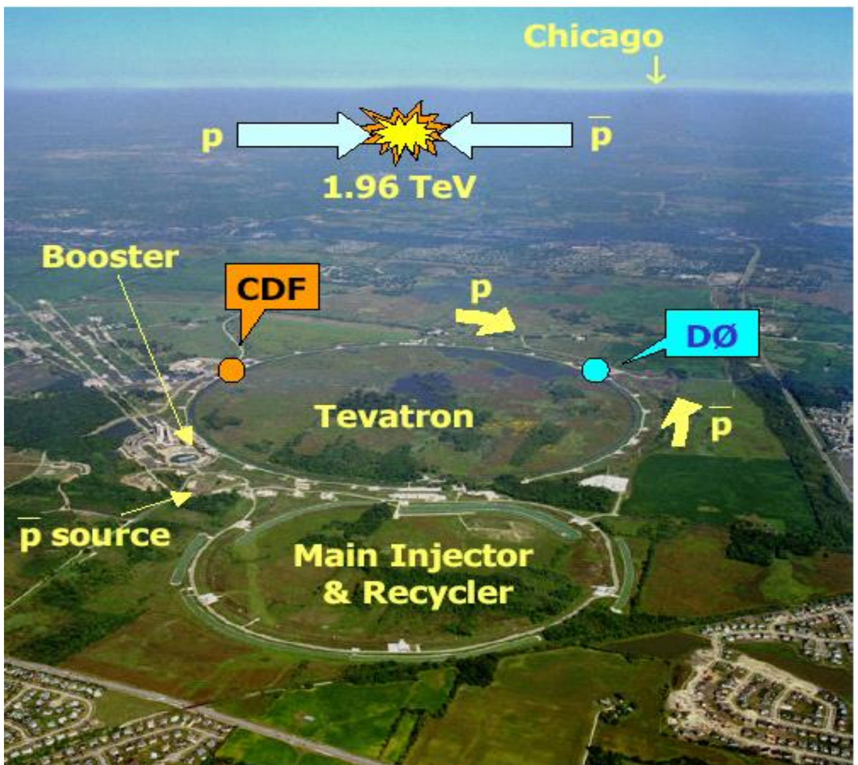
- In our model all supersymmetric particles decay into the lightest neutralino, $\tilde{\chi}_1^0$, in the very early universe
- The $\tilde{\chi}_1^0$ is long-lived (nanoseconds) and thus stable on the time scale of Inflation. At later times it decays via $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$
- The $\tilde{G}$ is the lightest supersymmetric particle and will not decay and thus could be dark matter
- If it has a mass in the keV range, it is a good warm dark matter candidate

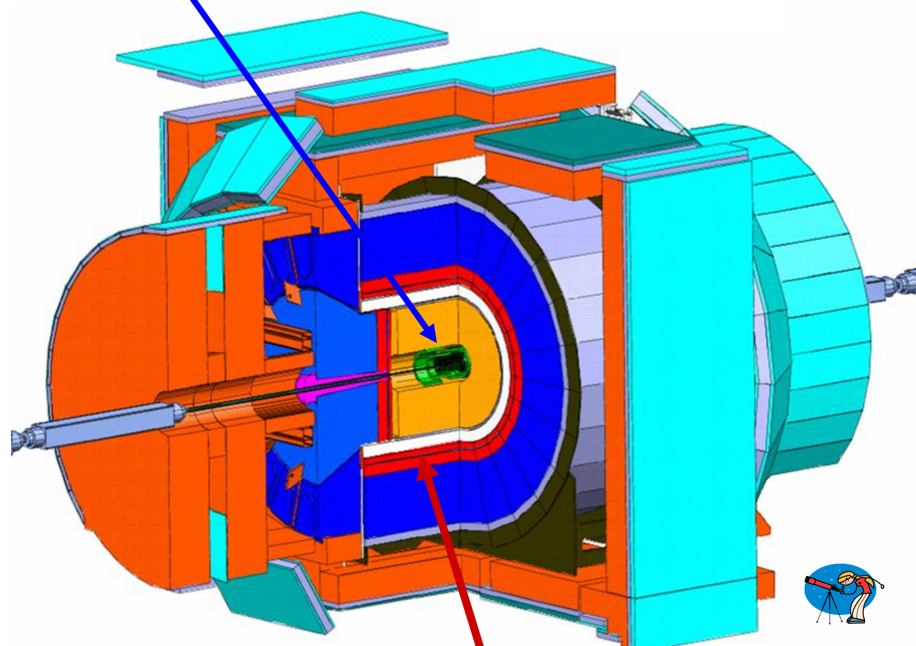
# Tevatron at Fermilab :
## Collider Detector at Fermilab **(CDF)**

**The Tevatron (accelerator) :**
**to produce high energy $p\bar{p}$ collisions**

**Surround the collision point with a huge detector**

**CDF :**
**To study the collisions**

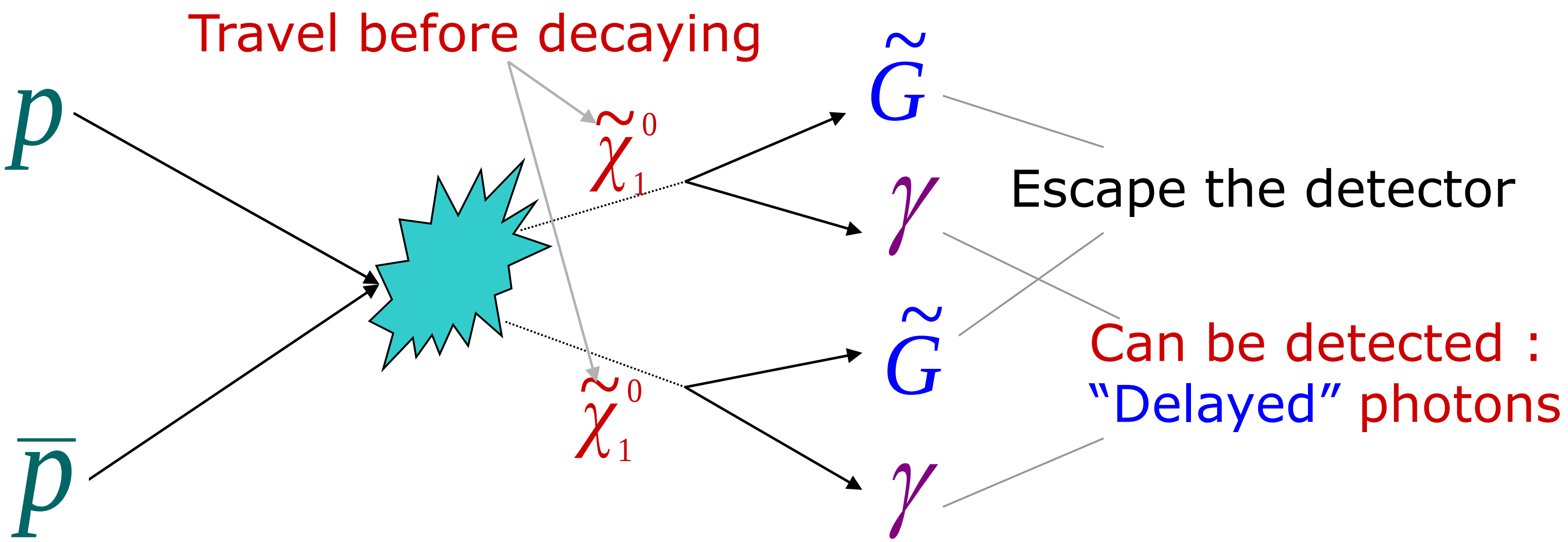


EM Calorimeter:
Photon timing +
4-momentum

# Neutralino Decays

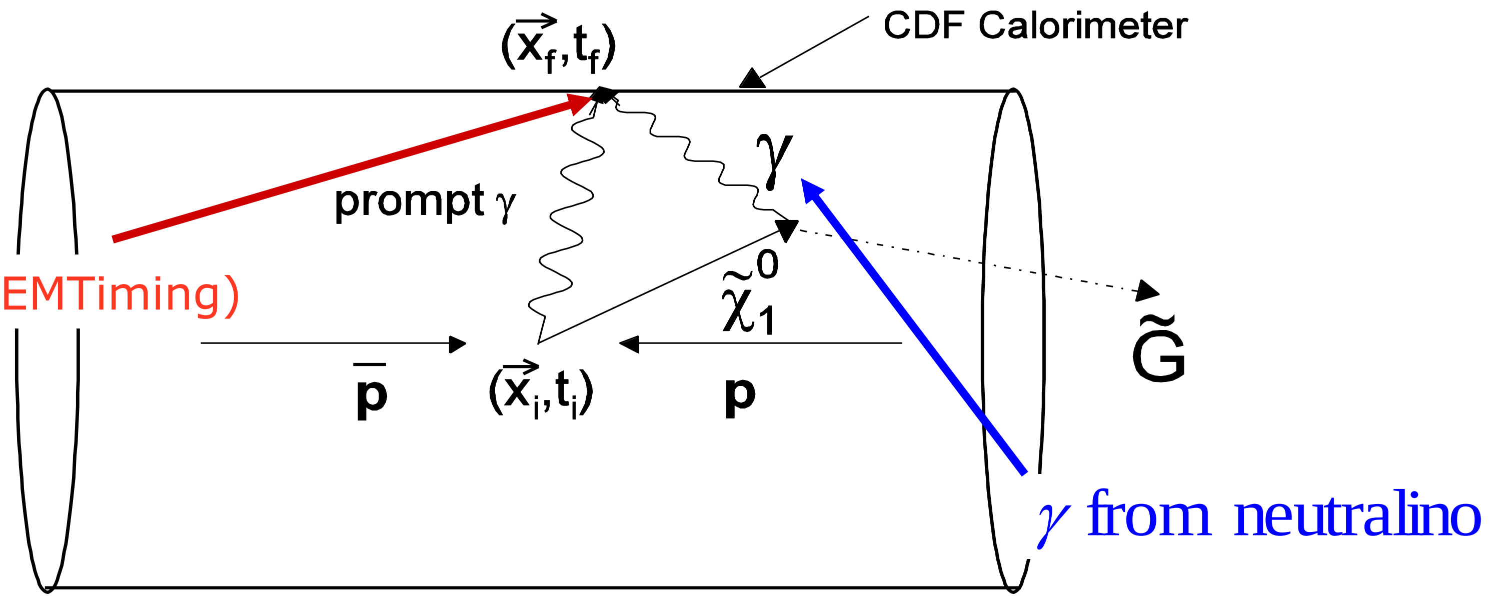
- Neutralinos can be produced in pairs in the Tevatron and decay(~100%) via $\tilde{\chi}_1^0 \rightarrow \gamma\,\tilde{G}$
- Nanosecond lifetime (long-lived) $\tilde{\chi}_1^0$'s would travel macroscopic distances in the detector before decaying



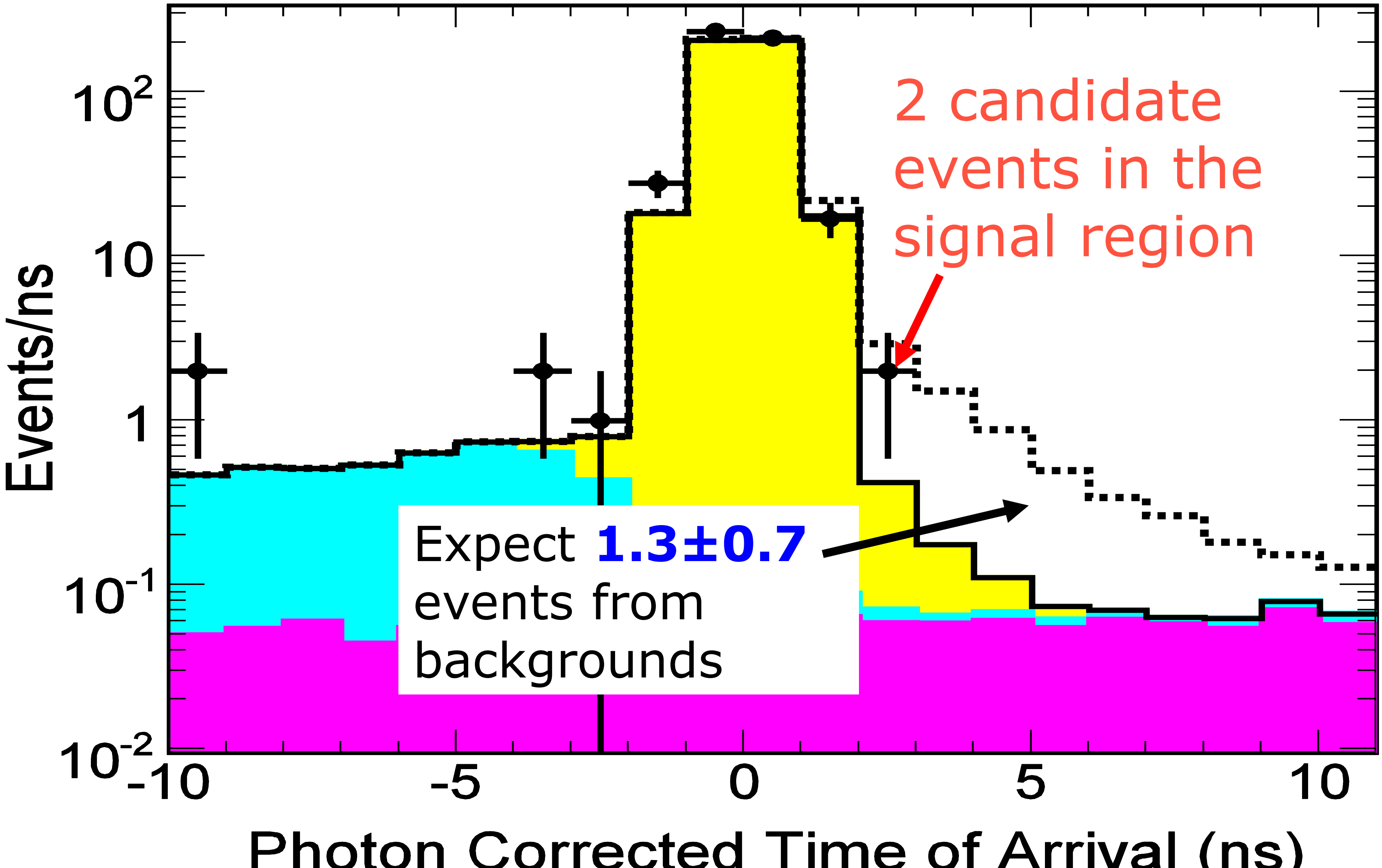
# Photons from Neutralino decays

- SM photons always travel directly from the collision point to the detector with speed *c*
- Neutralinos travel away from the collision point and then decay
  - The photon arrives at the detector later than expected, in other words "delayed"

Photon Timing (EMTiming)



# Searching for a “Delayed” Photon

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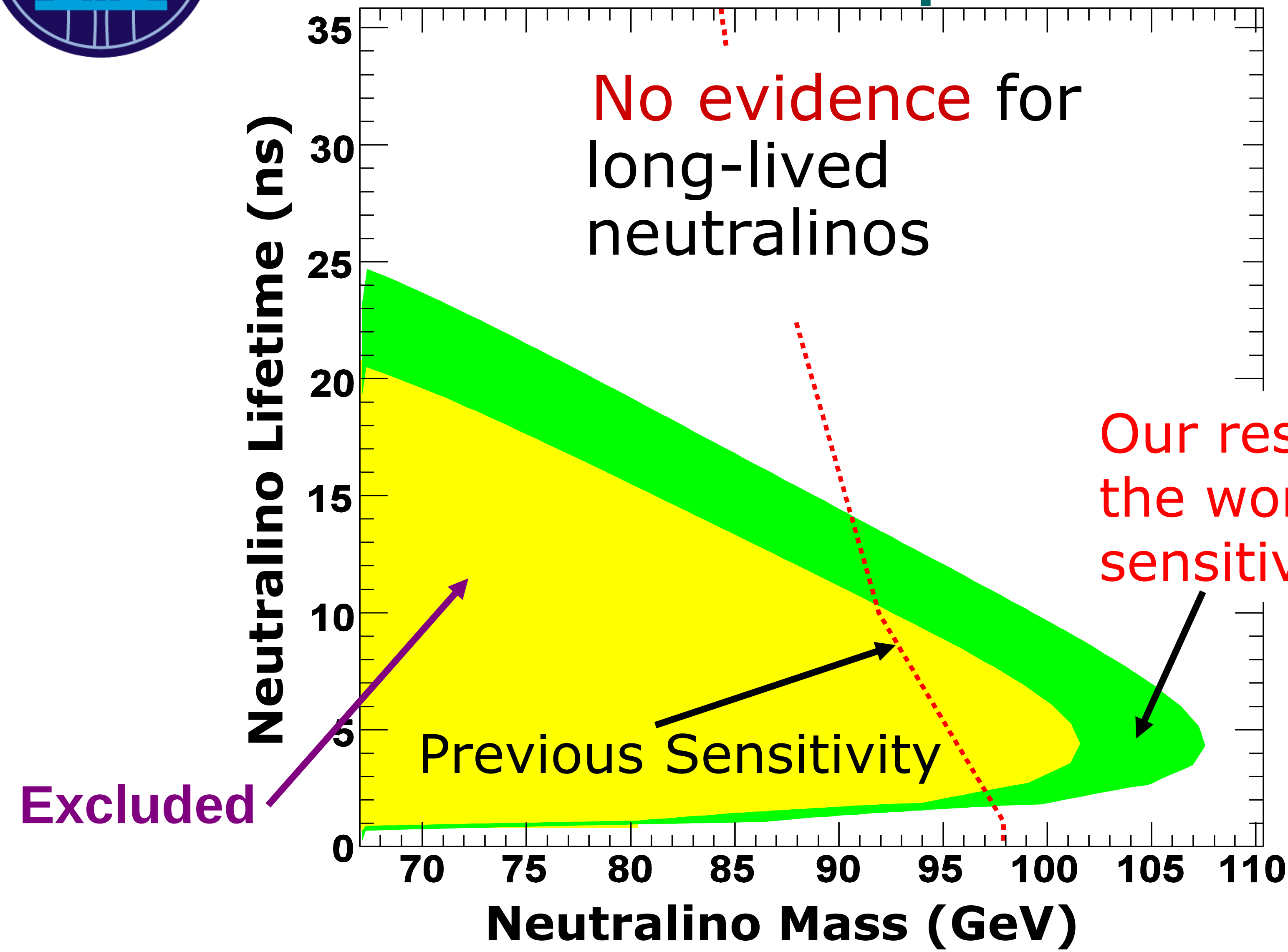
# Exclude Some of the Parameter Space

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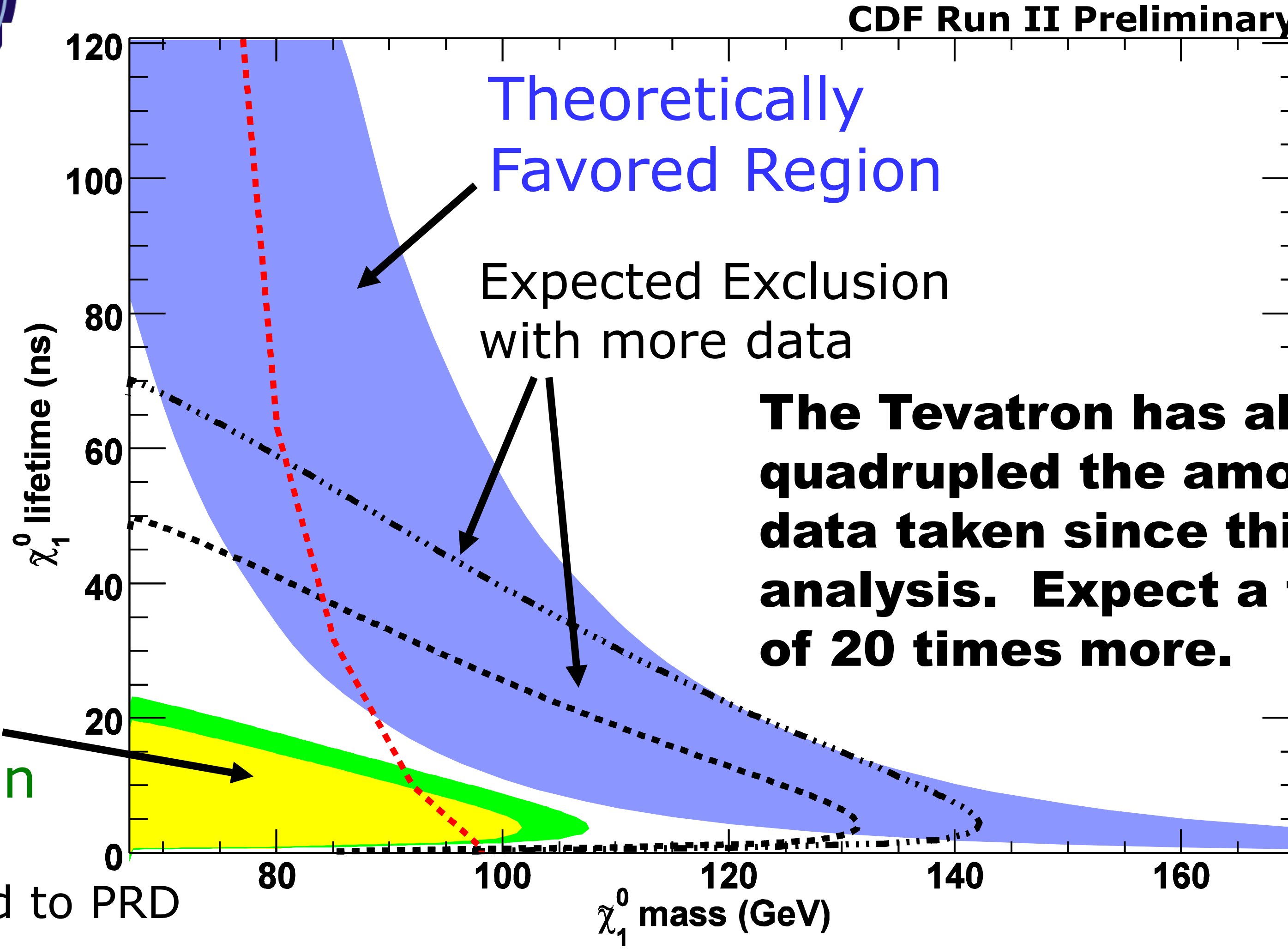
# Future Prospects




**The Tevatron has already quadrupled the amount of data taken since this analysis. Expect a total of 20 times more.**

Submitted to PRD

Will have sensitivity to the theoretically favored region!

# Improvements in Progress

- Add more data to the current analysis
  - New data already in hand!

- Improved analysis techniques
- Complementary searches
  - Look for decay photons from both neutralinos
  - More sensitive to the low lifetime region

# Conclusions

- We have performed the world's most sensitive search for long-lived particles that decay to a delayed photon and a dark matter candidate

- New analyses in progress make the prospects for discovery very promising

- With luck, we may be able to solve the cosmological mystery of dark matter