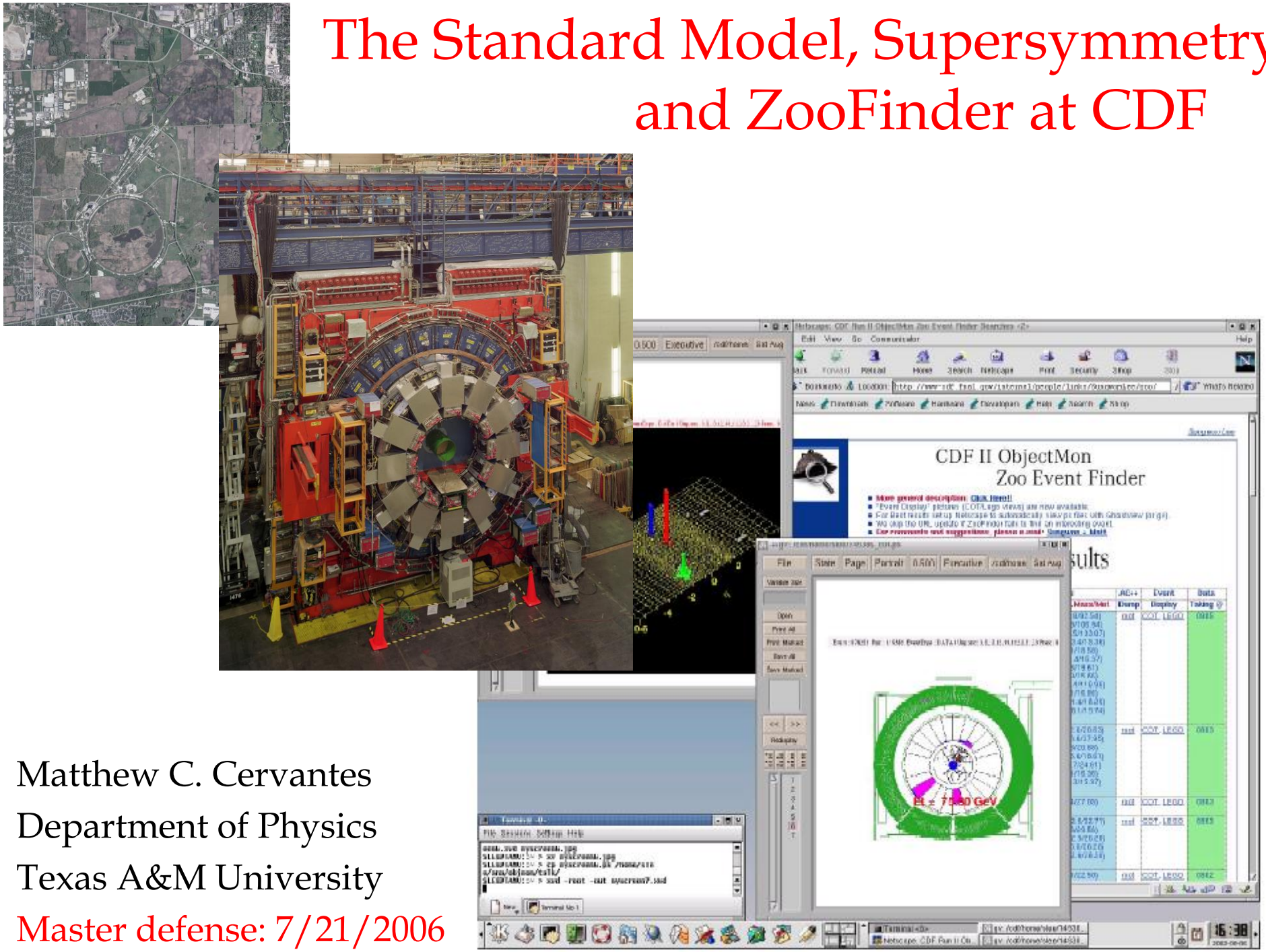
The Standard Model, Supersymmetry and ZooFinder at CDF



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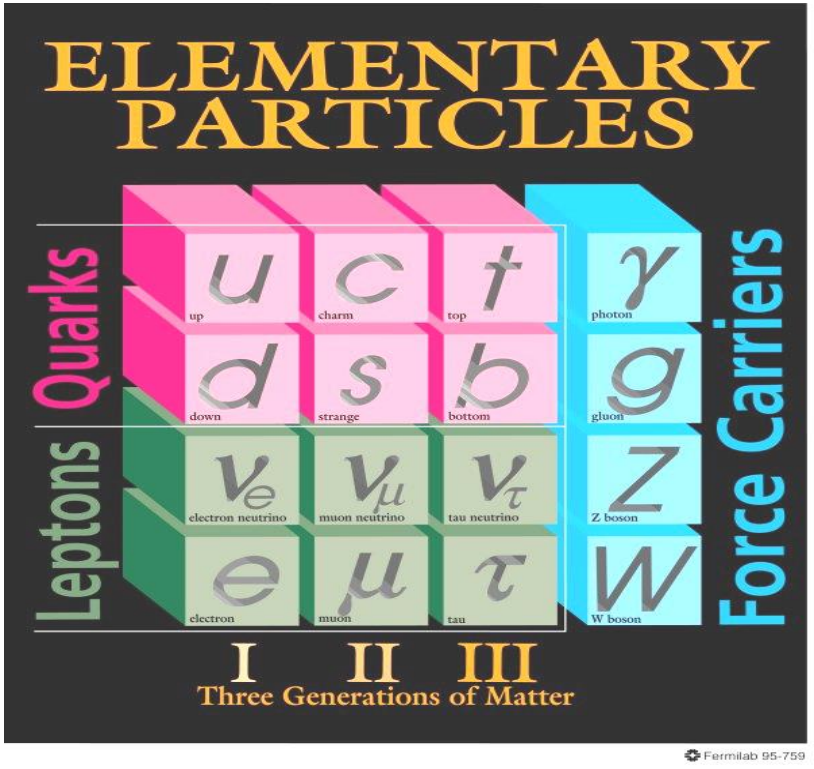
Outline

- **The Standard Model of Particle Physics**
- **Supersymmetry and the Tevatron**
- **ZooFinder at CDF**

The Standard Model

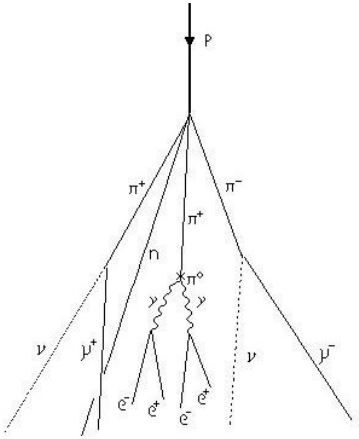
- Currently our best model for understanding the elementary particles and fundamental interactions
- Light quarks (u,d,s)
- Heavy quarks (c,b,t)
- All (anti)matter made up of spin = ½ fermions
- All force mediators are spin = 1 gauge bosons



- Mass progenitor: Higgs Boson spin = 0 (not seen yet)

The Standard Model forces

- A force is the means of interaction between an object with another object
- There exist fo *mer*



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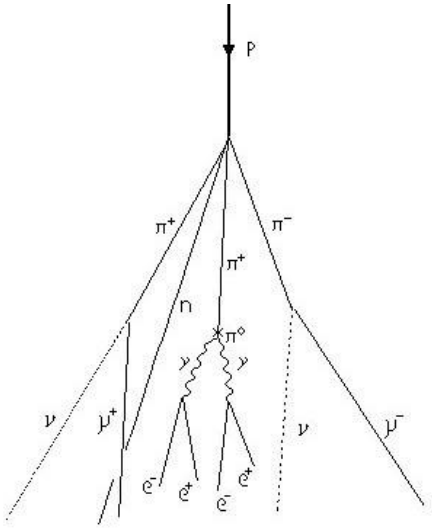
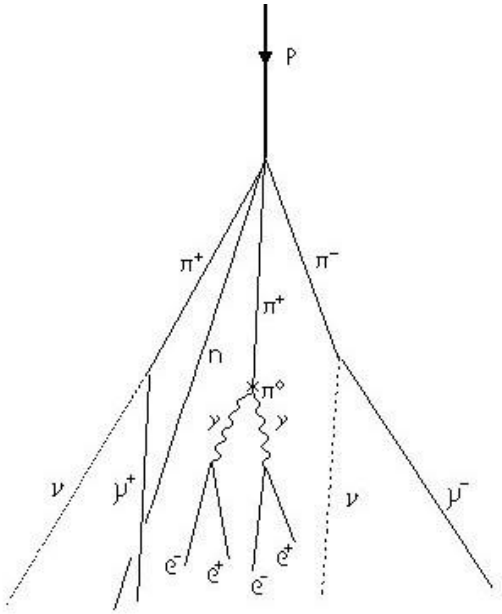
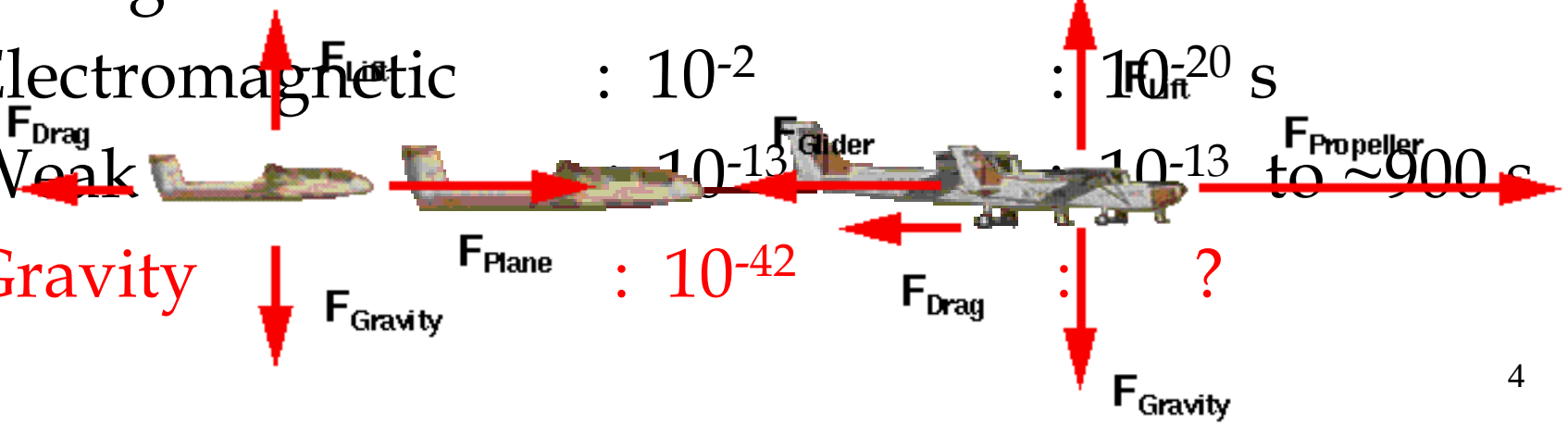




I **Ty** **e**

Strong	: 10	: 10 s
Electromagnetic	: 10^{-2}	: 10^{-20} s
Weak	: 10^{-13}	: 10^{-13} to ~900 s
Gravity	: 10^{-42}	: ?



Quantizing the fundamental forces

- In particle physics we probe distance scales which require quantum mechanical theories… each force has a specific quantized force mediator (carrier)!

Interaction	Carrier
QED ("electric charge")	massless photon
GWS ("weak charge" quarks & leptons)	massive W, Z
QCD ("color charge" quarks & gluons)	massless gluon
General Relativity (objects with mass)	graviton ?

- The first three interactions account for the observed production of matter and anti-matter during a *high energy particle collision*…as described by the SM_5!

Conservation laws

- **Emmy Noether** (1917): *Symmetry* ←→ *Conservation*

- All the force interactions conserve electric charge:

Conservation of charge ←→ Shift in quantum mechanical phase

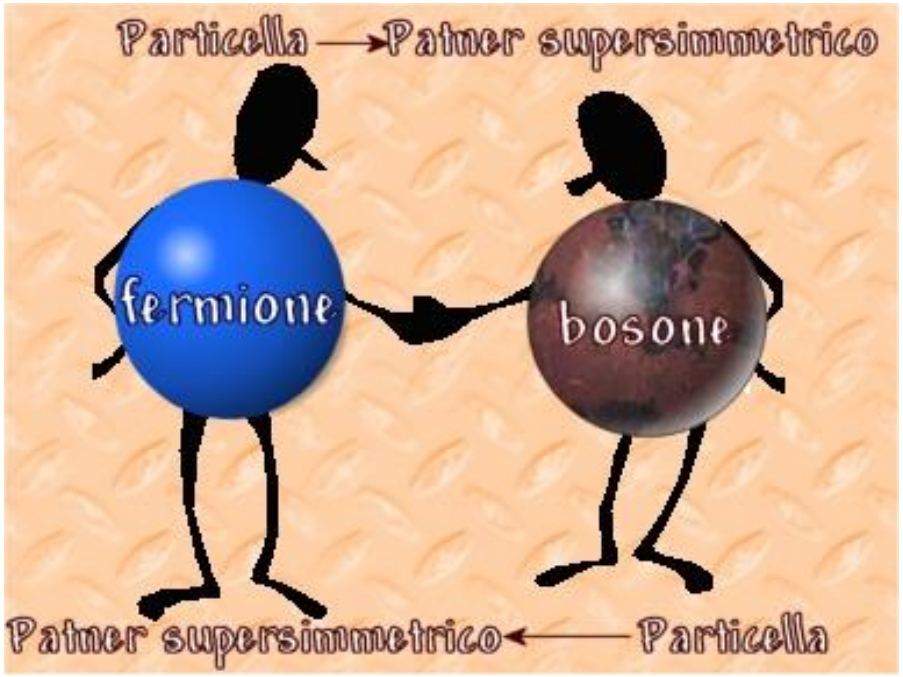
Symmetry	Conservation law
Translation in time	Energy
Translation in space	Momentum
Rotation	Angular momentum

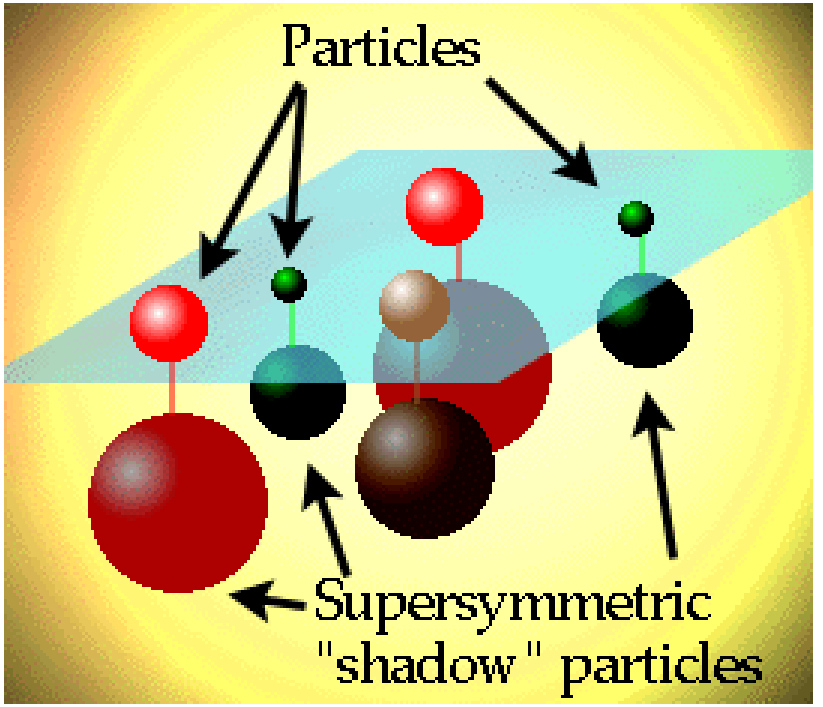
- Conservation of lepton number and baryon number

- Any other symmetries for our Standard Model particles?

Supersymmetry

- Postulates a Fermion-Boson symmetry: **Every fermion (boson) has a boson (fermion) "super-partner"**
- Double the particle spectrum (recall QED did this with the introduction of the positron) and work out a supersymmetric theory



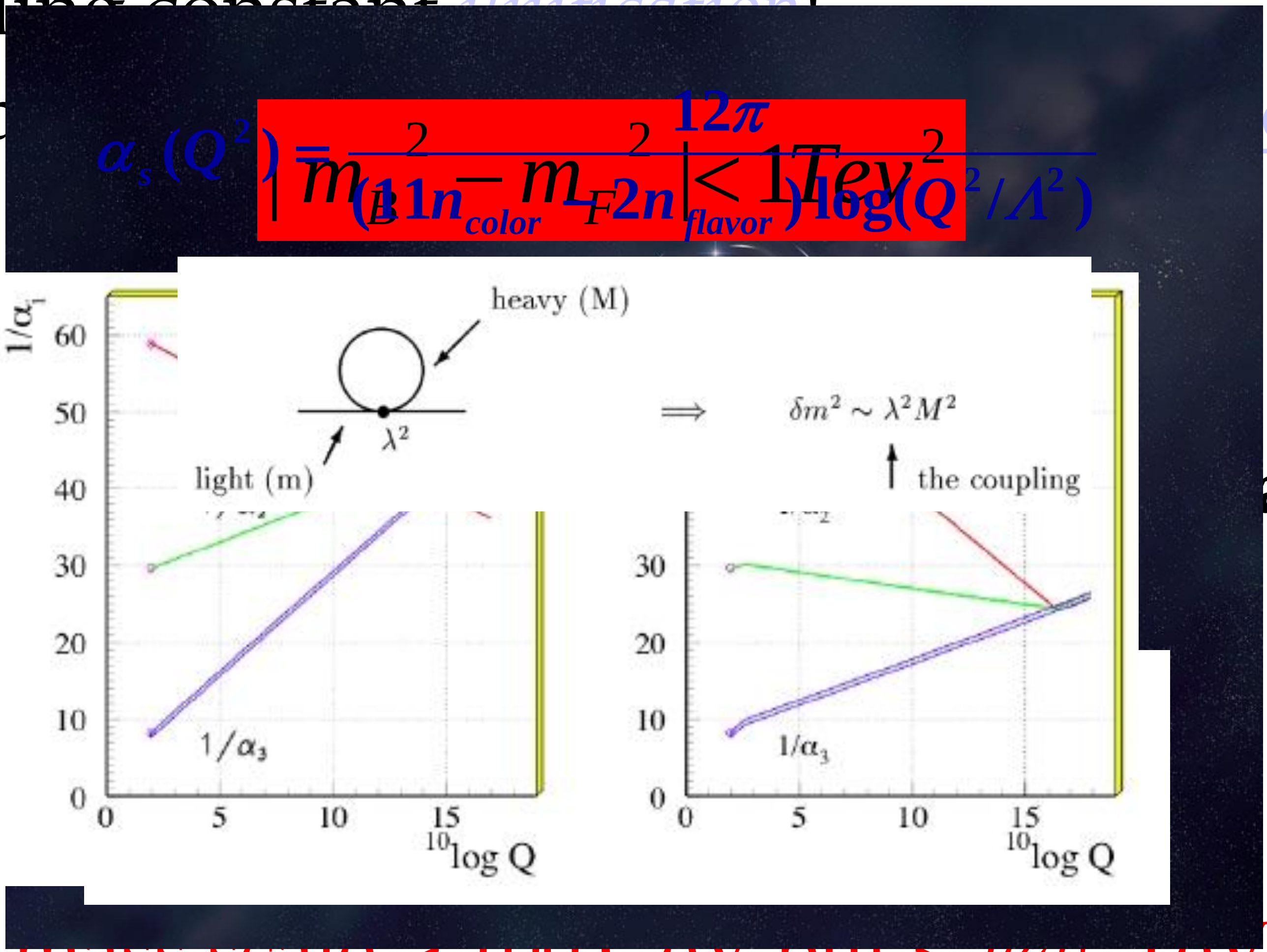


Why do we need Supersymmetry?

- Incorporate gravity into a quantum framework!
- Possible solution of the *Mass Hierarchy* problem!
- Coupling constant *unification*!
- Possib… …ment!

$$\alpha_s(Q^2) = \frac{12\pi}{(11 n_{color} - 2 n_{flavor}) \log(Q^2/\Lambda^2)}$$

$$|m_B^2 - m_F^2| < 1 TeV^2$$



- **What… …able?**

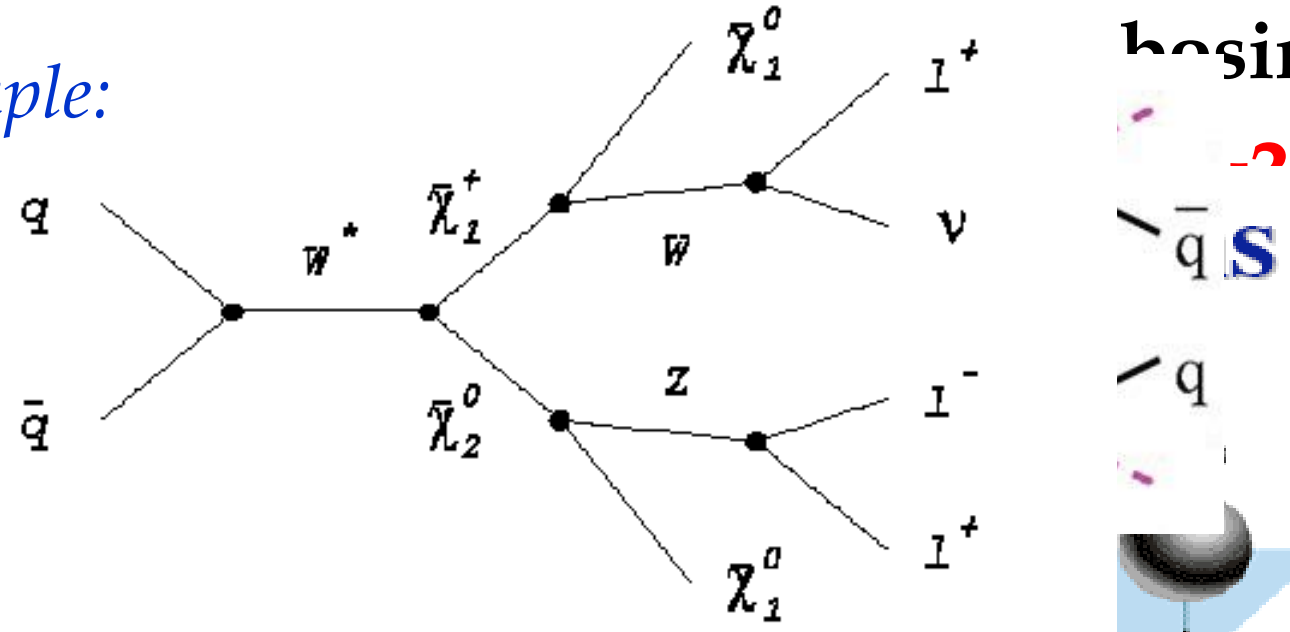
- SUSY mass scale > 100 GeV but < *few* TeV

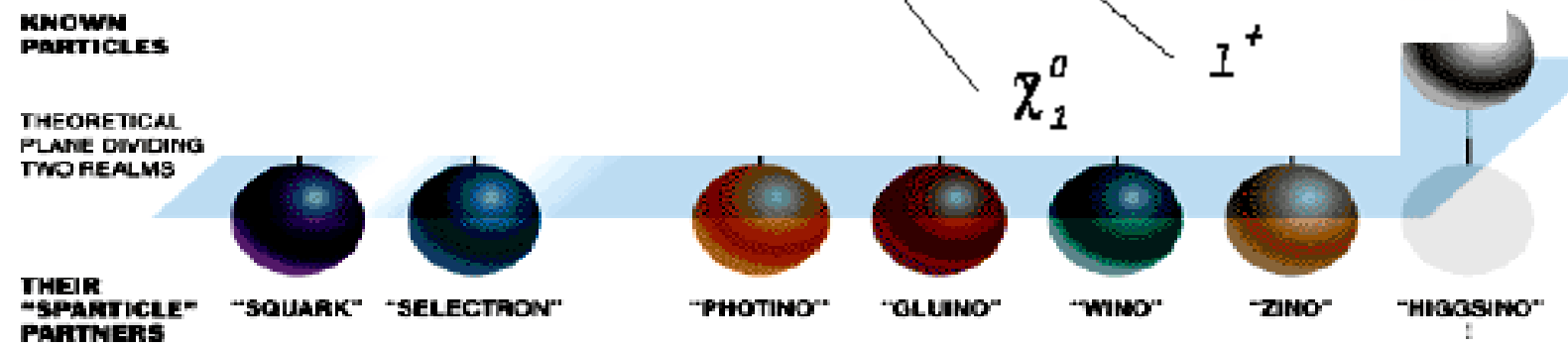
Minimal Supersymmetric Standard Model (MSSM)

- In analogy to the SM we try to construct an elementary supersymmetric "sparticle" table:

fermion **bosinos**

Simple example:



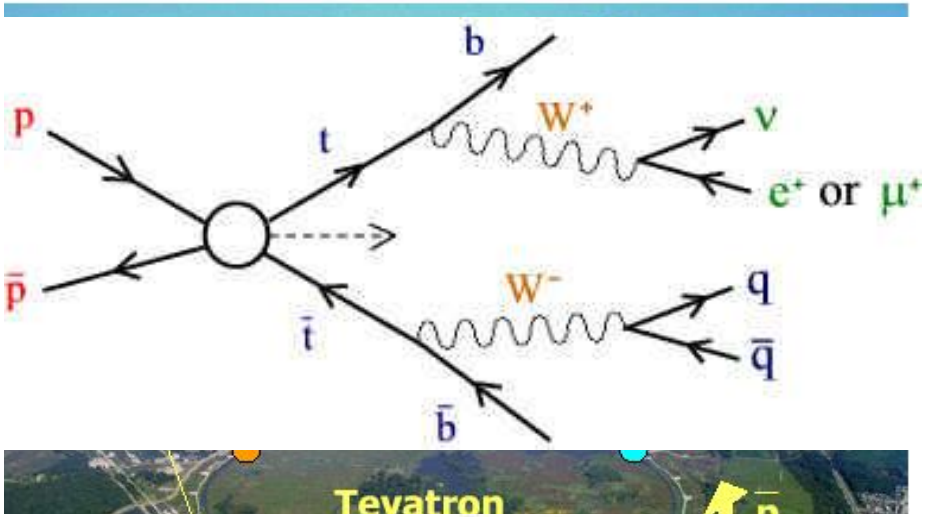


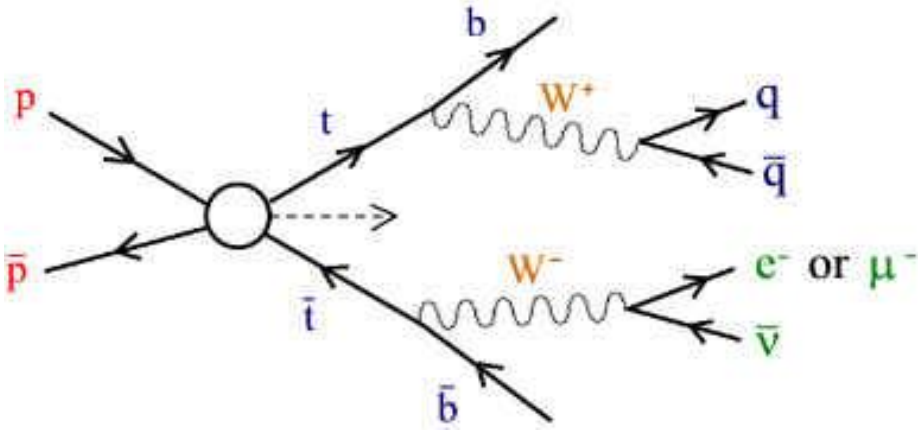
Photino, Zino and Neutral Higgsino: Neutralinos

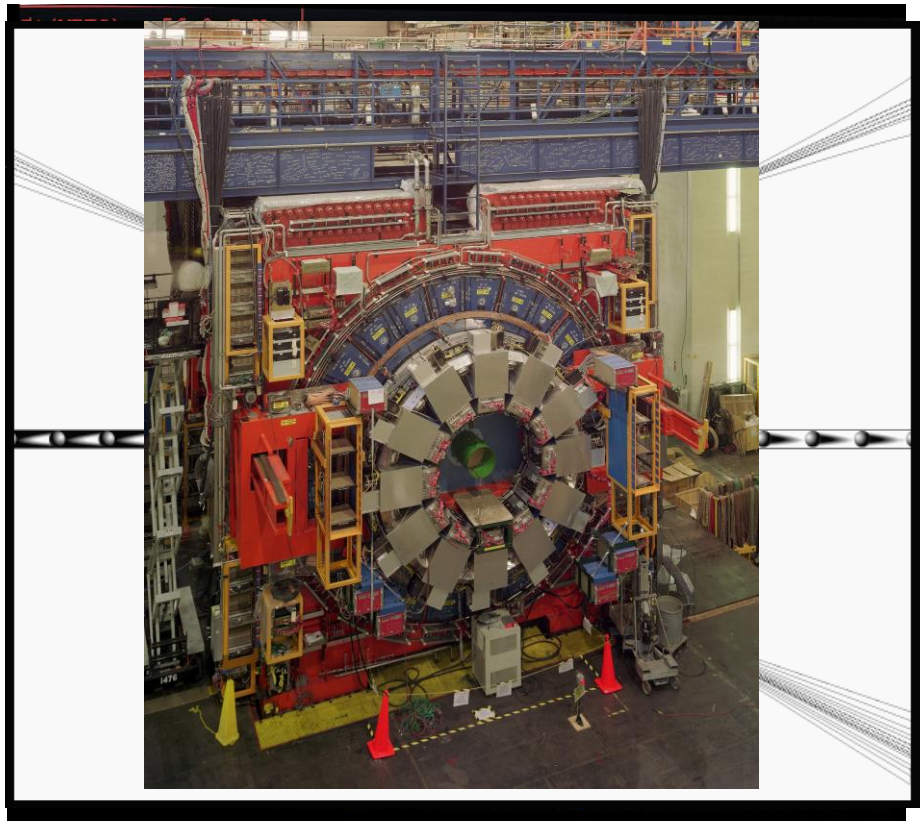
Charged Wino, charged Higgsino: Charginos

Fermilab Tevatron Collider

- World's highest energy particle collider until LHC
- Proton anti-proton collisions at a center of mass energy ~ 2 TeV







Two detectors: CDF and D-Zero took data during 1992 - 1996 (RunI) → Top quark discovery!

Run II of the Fermilab Tevatron

Proton anti-proton collisions at a center of mass energy ~ 2 TeV

Run II : CDF II more sophisticated!

e.g. TAMU added *EM timing*

to CDF II to determine if any

"unusual" events contain these

"direct photons" or if they are

from an indirect interaction.

- Run II of the Fermilab Tevatron is currently taking data:
  ~ 1 fb^{-1} (~50 trillion proton anti-proton collisions) on tape !

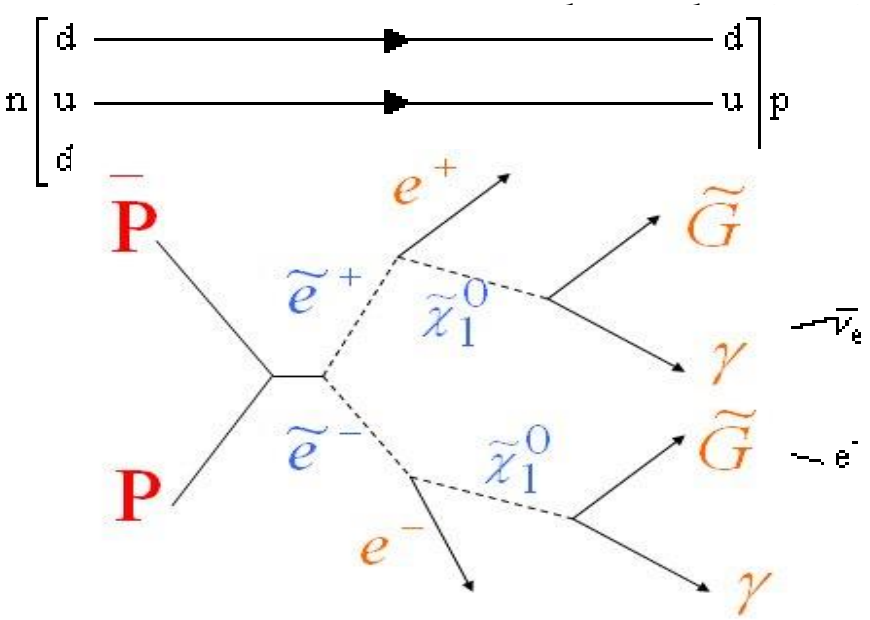
Many things can potentially can go wrong *during* data taking!

Murphy's Law : If things can go wrong, they will go wrong!

Supersymmetry Signatures

- Missing momentum led to postulating existence of a ***neutrino***; in analogy a ***neutralino*** might possibly show up as an "unusual object" that is missing transverse momentum!

- In a more pro models have to say about the



- Is it possible that these ghostly undetected particles are the missing transverse energy events?
- Note that the SUSY partner of the spin = 2 graviton (recall its exclusion from the SM), the spin = 3/2 gravitino, now enters the game *supersymetrically*!

Search search search and search some more…

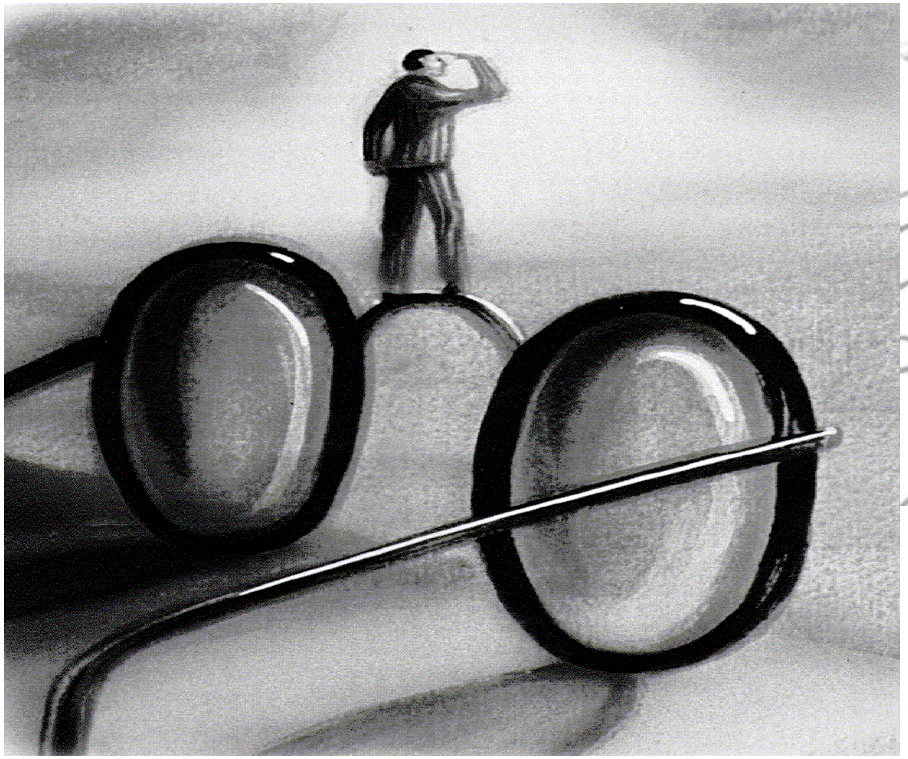
- If we wish to enhance our chances of finding new physics or even have a chance at discovering it, we should search for anything that cannot be explained by the SM. Anything unusual is interesting!

E.g. large invariant mass dilepton events

- It is also imperative that we keep an eye out for a malfunctioning detector.

- We need a real-time detector monitoring a system that searches for the unusual… enter ZooFinder!!!

ZooFinder at CDF



Matt Cervantes & Dr. SungWon Lee

[Prof. Dave Toback]

Upgraded version is now operating: P. Wagner of TAMU and C. Wolfe of Univ. of Chicago

Need extensive monitoring for CDF II

- **Detector performance *during data taking* is a necessity for purity of collected data.**
- **If unusual (bad) things in the detector are happening, *we need to know about them immediately.***
- **Unusual event(s) could imply detector malfunction(s).**

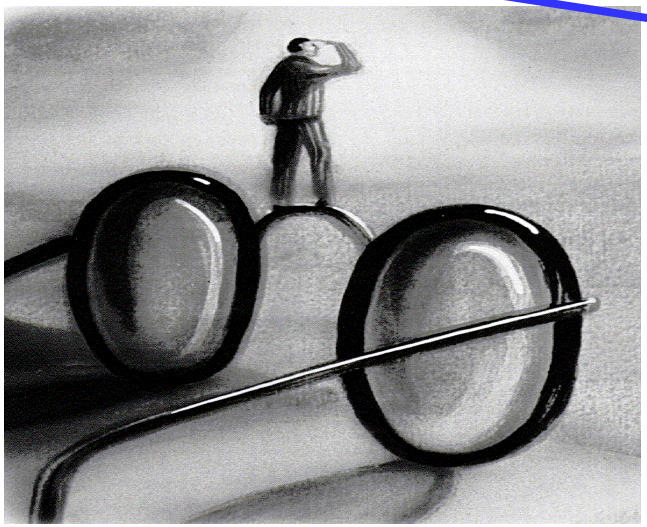
  e.g. Event with 6 muons at 1 Tev each.

  => Discovery of non-conservation of energy?
  => Likely a "broken" muon chamber… we need to monitor for such events.

A new monitoring system at CDF II

- **ZooFinder : Searches for "unusual" events (anomalous animals!). Finds, categorizes, then puts them into a "Zoo" to be studied.**
- **Identifies and classifies individual events as "unusual" by looking at the objects in the event.**
- **When does ZooFinder at CDF II monitor?**

  ZooFinder ran via a daemon program that samples high p_T data as it streams in!



object:
Electron
muon
tau
photon
MeT
etc.

Why monitor "unusual" events?

- **ZooFinder may also find unusual events in the *absence* of detector problems. (anomalous animals!)**

  => Hint of new physics?

  => Supersymmetry?

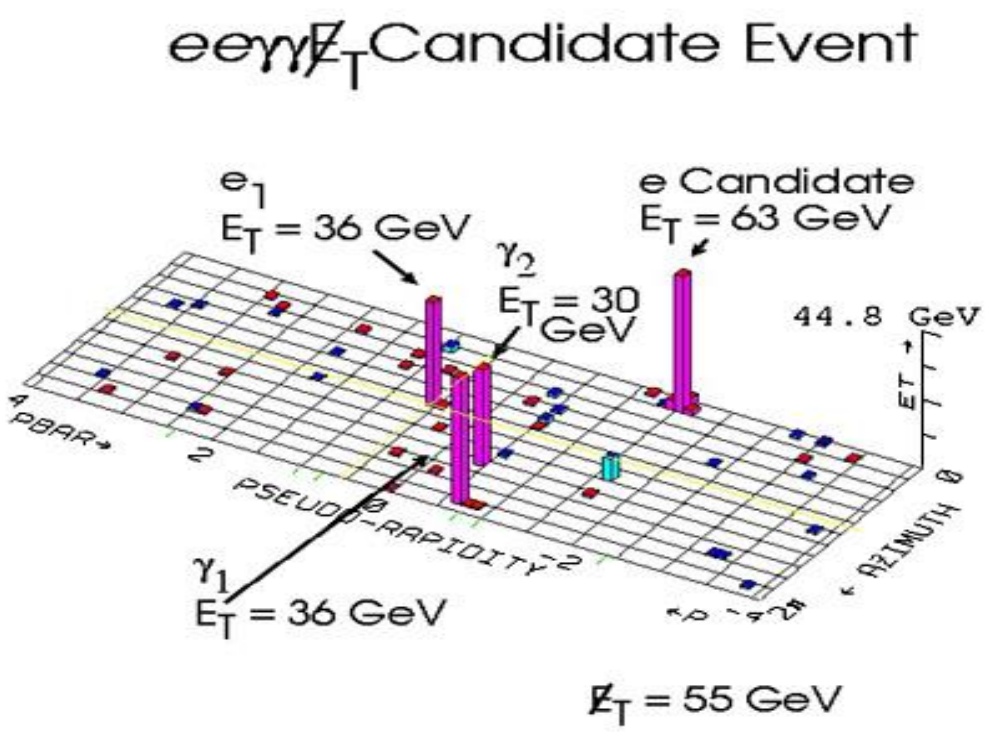
- **Want this type of information ASAP!**

Real-time monitoring of the detector for potential problems is crucial to aid in possible future discoveries at the 2 TeV Tevatron!

Categorizing Unusual Events

- **Unusual event *"captured"* during Run I:**
  Famous eeγγ + Missing Energy candidate
  (10^{-6} background predicted, unexpected!)

- **vards unusual**
  vith high
  eγ, etc.
  , etc.
  c.
  etc …



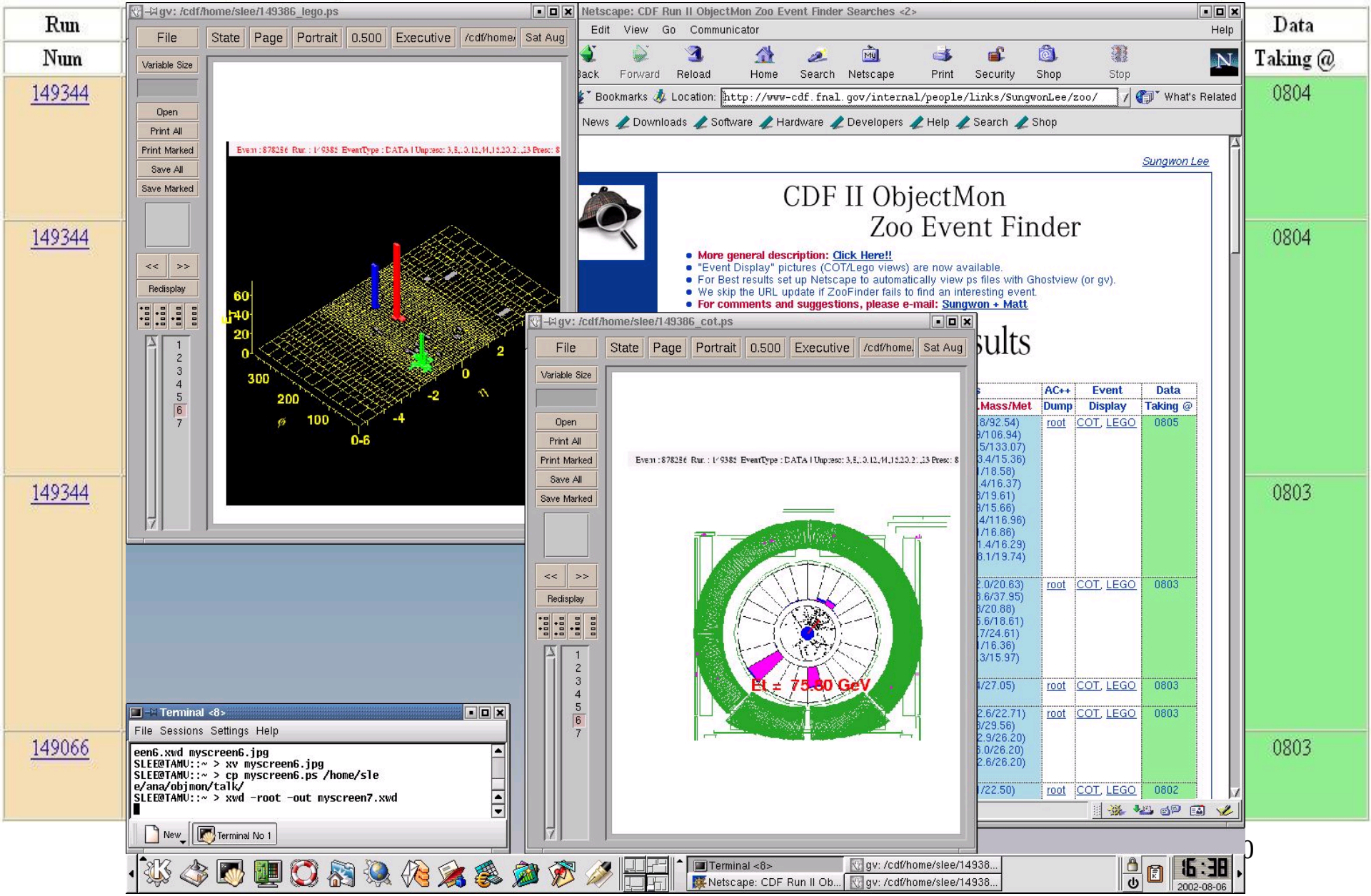
First reported by PhysMon, the predecessor of ZooFinder!

Detained Information on the Unusual

If an *unusual event* is found, ZooFinder quickly sends email to experts and post it to a web page which provides easy access to the "Zoo" events

- **Run Number and Event Number(s)**
- **Event Type : "eμγ"**
- **Event Kinematics**
- **Event Display: "snapshots" → easy, quick inspection of unusual events by eye**

ZooFinder Web Page



Summary

- **The Standard Model is a very encompassing theory of elementary particle physics, but it is incomplete.**
- **Supersymmetry is a potentially promising route towards the extension of our current SM.**
- **The Fermilab Tevatron collider and CDF II detector are great tools to be used in our searches for Supersymmetry**
- **ZooFinder is a monitoring system for the CDF detector at the Fermilab Tevatron which works to identify *unusual* events in real time.**
- **It provides a powerful tool which helps ensure robust detector operation, which is imperative for an experiment at the high energy frontier.**

- **Last but not least… a special thanks to**

D. Toback

S. W. Lee

T. Kamon