Photon-based Signatures from GMSB SUSY and Extra Dimensions

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with slides stolen from R. Culbertson, S. Eno and G. Landsberg

Outline

- Photon Identification
  - Tevatron and extrapolation to LHC
- Extra Dimensions
- GMSB SUSY
- How Tevatron will / should influence LHC
- Summary

Photon ID

- There are two principal backgrounds: jets and electrons
- CDF and DØ have conceptually mature algorithms
  - clusters with small had. fraction:
    - CDF: had/EM < 0.055 + 0.00045·E^{γ}
    - DØ: EM/(EM+had) > 0.9
  - isolation in calorimeter and tracker
    - can be absolute or relative to photon energy
    - CDF's track isolation: $\Sigma|p_T| < 2$ GeV + 0.005·E_T^{γ}
    - DØ calorimeter isolation: EM(0.2) / (EM(0.4)+had(0.4)) < 0.15
  - shower shape consistent with EM object
    - CDF: use shower max. chamber information
    - DØ: use fine segmentation of calorimeter (both longitudinal and transverse)
  - no charged track pointing to the cluster
    - various definitions of "pointing"
    - DØ also has hit counts in roads to pick lost electron tracks (not generally used in analyses yet)
- "Typical" CDF's selections are probably tighter than DØ's

Photon ID Challenges

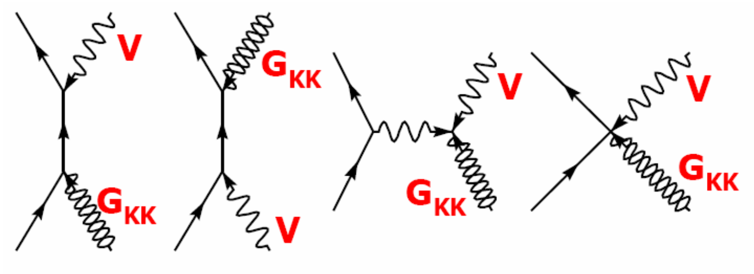
- No clean sample of photons in situ
  - have to tune MC to electrons and then use it for photons
  - unlike e^+e^- machines, at hadron collider there is no such thing as single isolated electron: underlying event + pile-up
- Tuning MC is hard. Biggest problem seems to be in the material before the calorimeter (tracker & infrastructure)
  - mechanical drafts are slow to propagate to GEANT
  - as-built detector is not the same as as-drafted
- Conversions
  - hard to determine probability of
    - correct material budget
    - reconstruction of two tracks very close in space
  - probabilities to reconstruct tracks from conversion seem to be correlated
  - but the probability is relatively small
    - with LHC detectors the problem is going to be worse

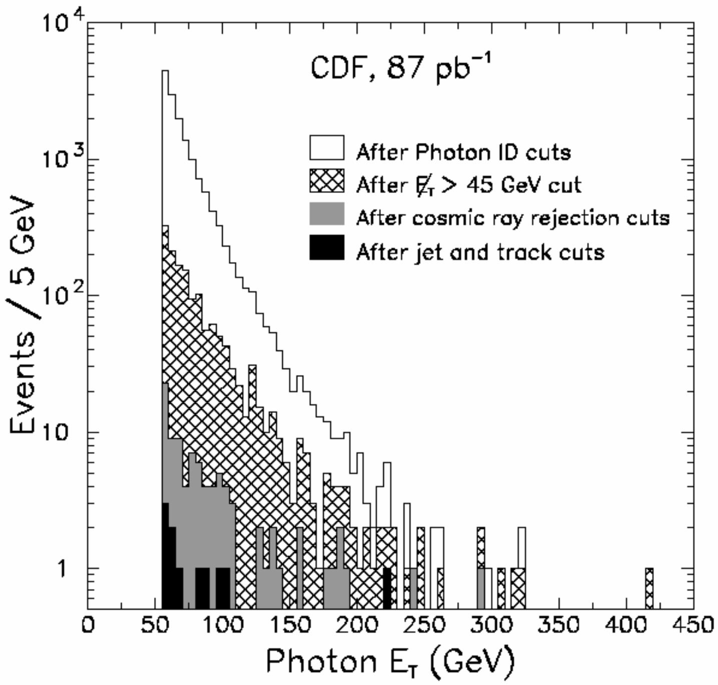
Are Existing Algorithms Adequate for LHC?

- Conceptually – yes
- Biggest challenge will be tracker material
- Smarter algorithms (NN, etc.)
  - definitely will give improvement (expect to see them employed at Tevatron before LHC turn-on)
  - but, NNs are only as good as the samples they were trained on
    - no clean photon signal in data

Extra Dimensions

- photon + MET
  - Graviton escapes into the extra dimension
  - CDF has done the search in Run I





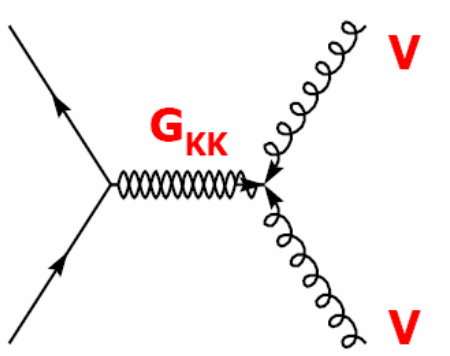
somewhat lower sensitivity than a mono-jet search

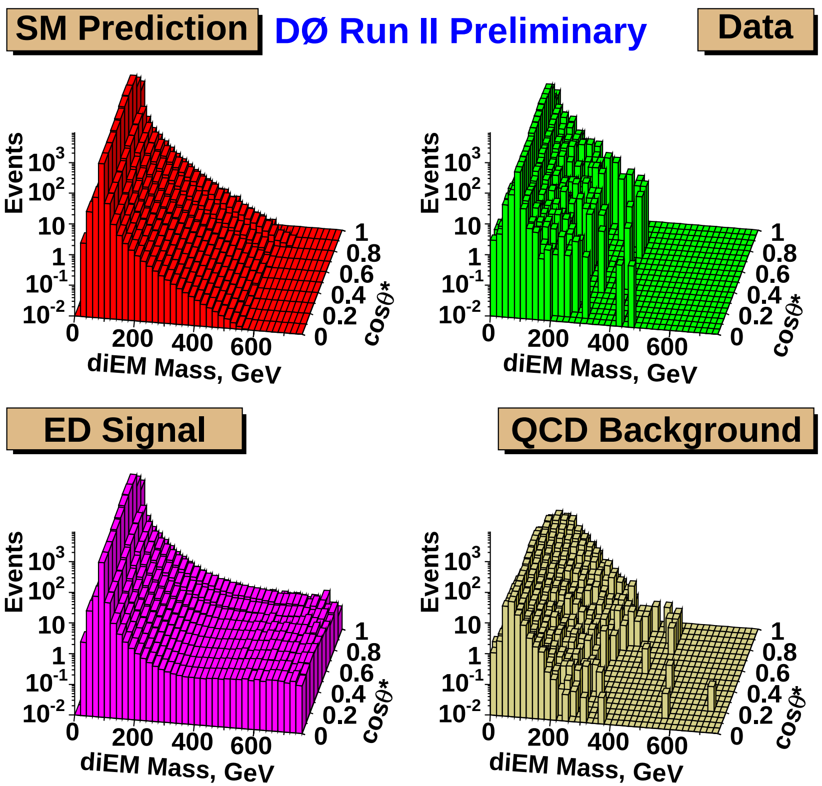
	N=4	N=6
γ + MET	0.54	0.58
Jet + MET	0.77	0.71

M_S limits in GRW formalism from CDF in Run I – still best limits in these channels

Extra Dimensions

- di-photon cross-section at high mass
  - production is modified by virtual graviton exchange – best channel, sensitivity is a lot better than in dileptons





Run II DØ Search (200 pb^{-1})

Analysis similar to Run I.

Does not separate photons and electrons

In GRW formalism M_S > 1.36 TeV

Combined with Run I measurement –

M_S > 1.43 TeV

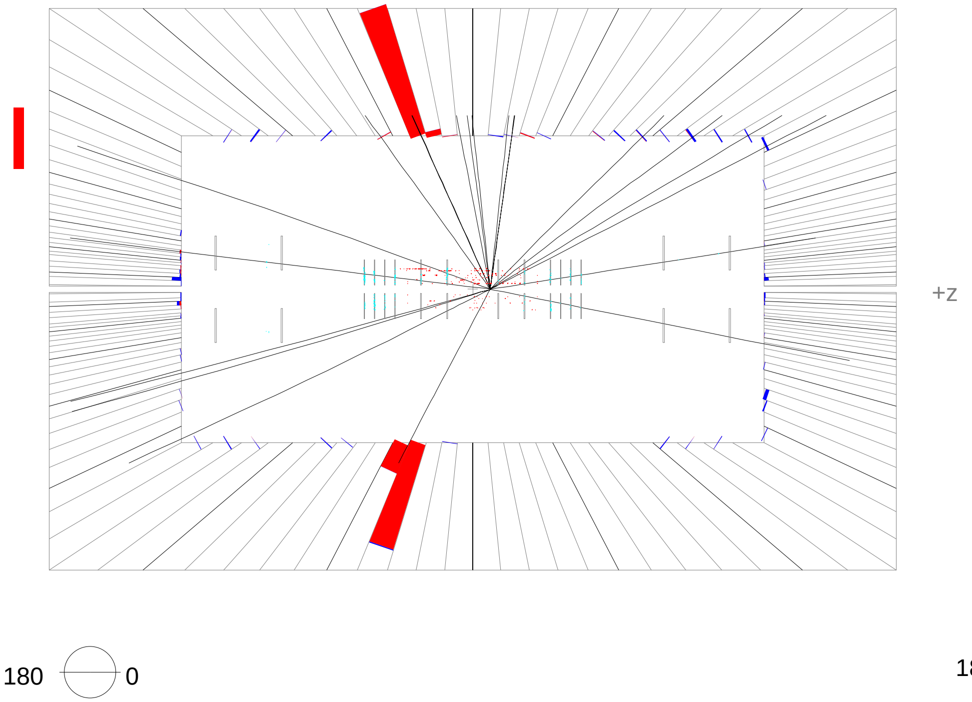
– best limits on LED today

Extra Dimensions

- di-photon cross-section at high mass
- interesting event candidates:

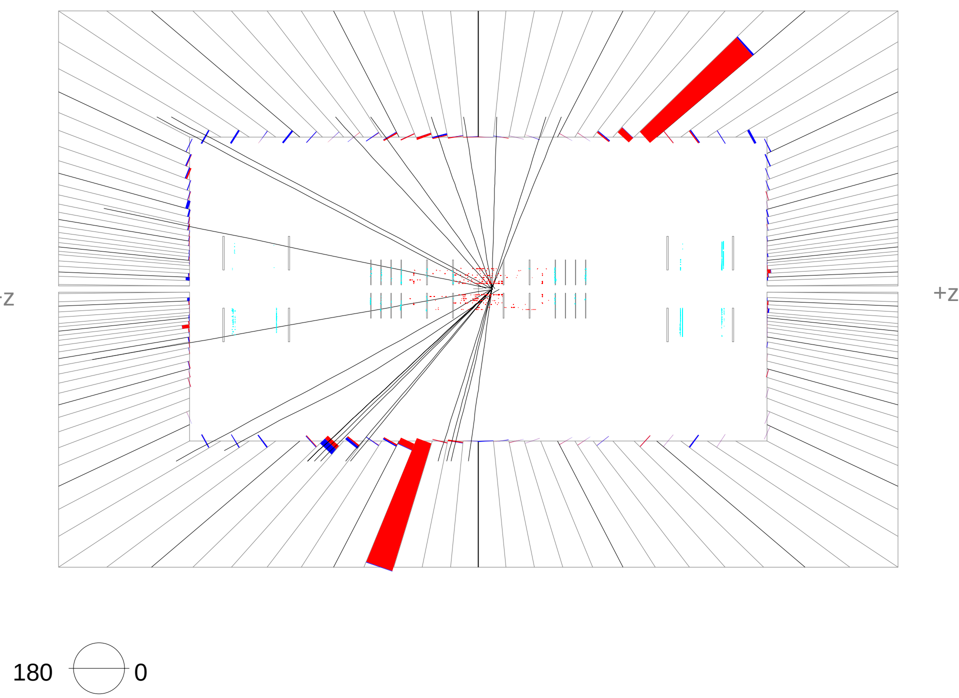
Event Callas

m(ee) = 475 GeV $\cos(\theta^*)$ = 0.01



Di-photon event

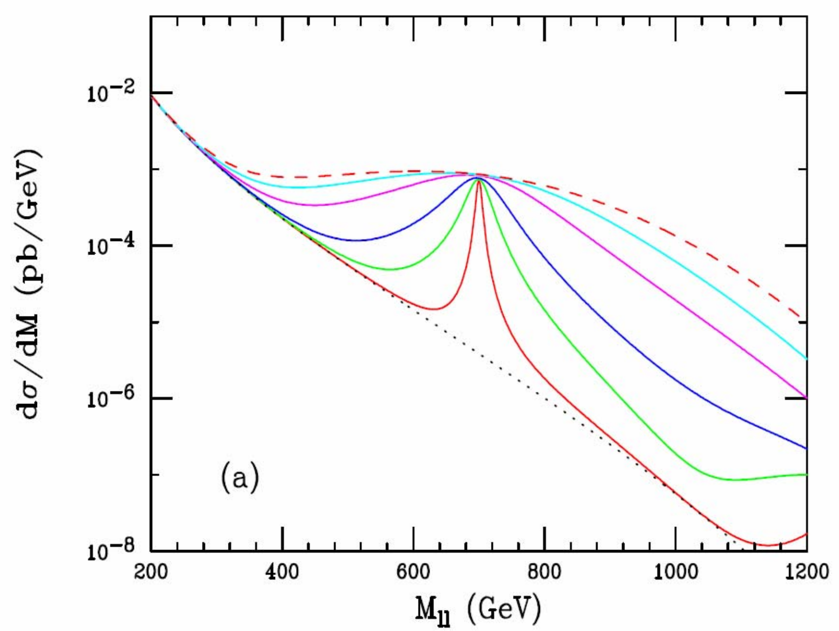
m(ee) = 436 GeV $\cos(\theta^*)$ = 0.01



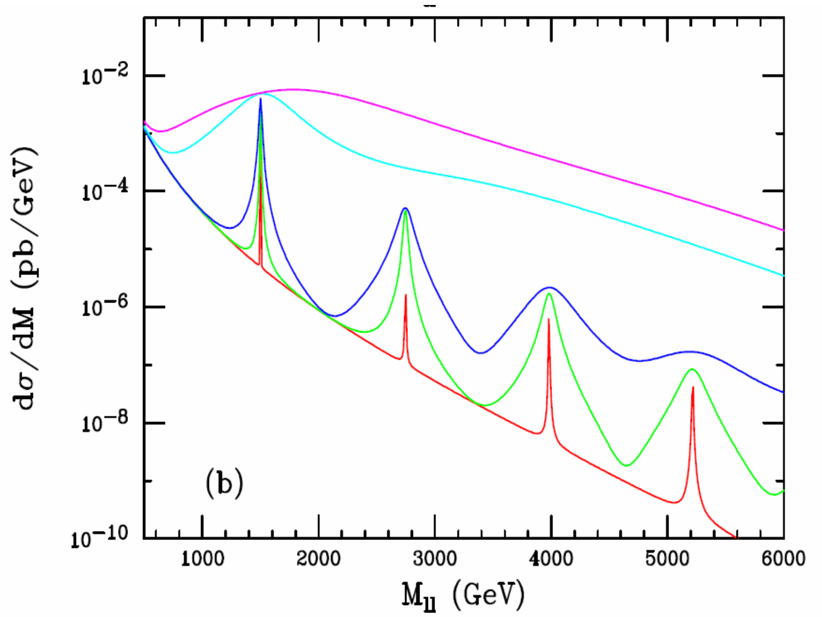
Extra Dimensions

- di-photon mass peaks – RS gravitons
  - best channel branching into photons is two times larger than into leptons
  - depending on k/M_{Pl} can be quite narrow

700 GeV KK at Tevatron



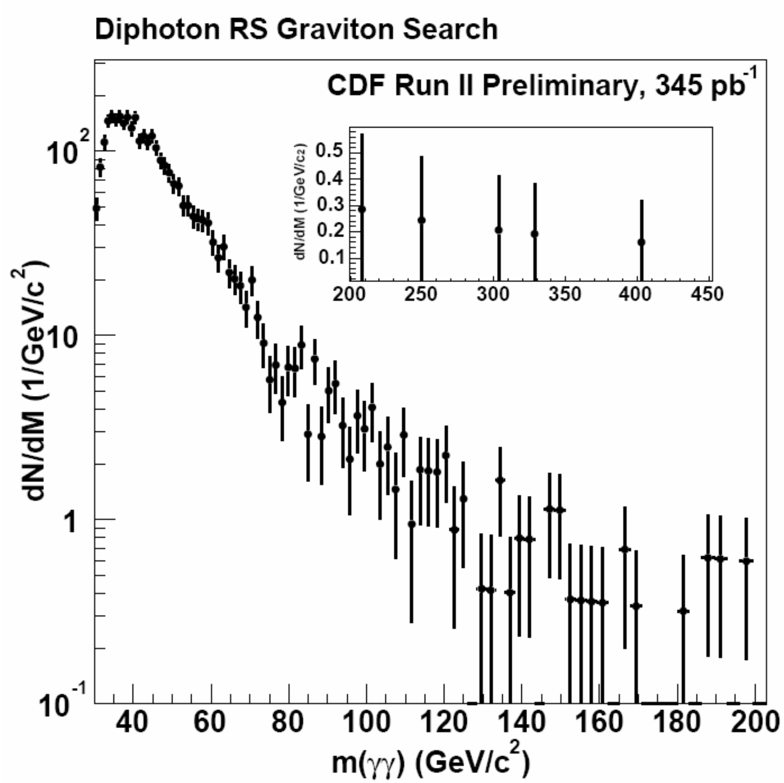
1500 GeV KK at LHC

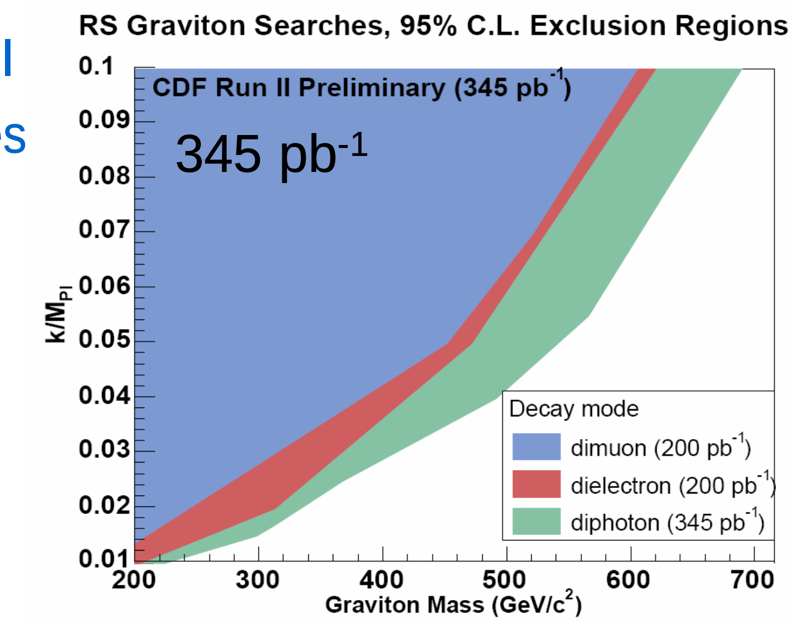


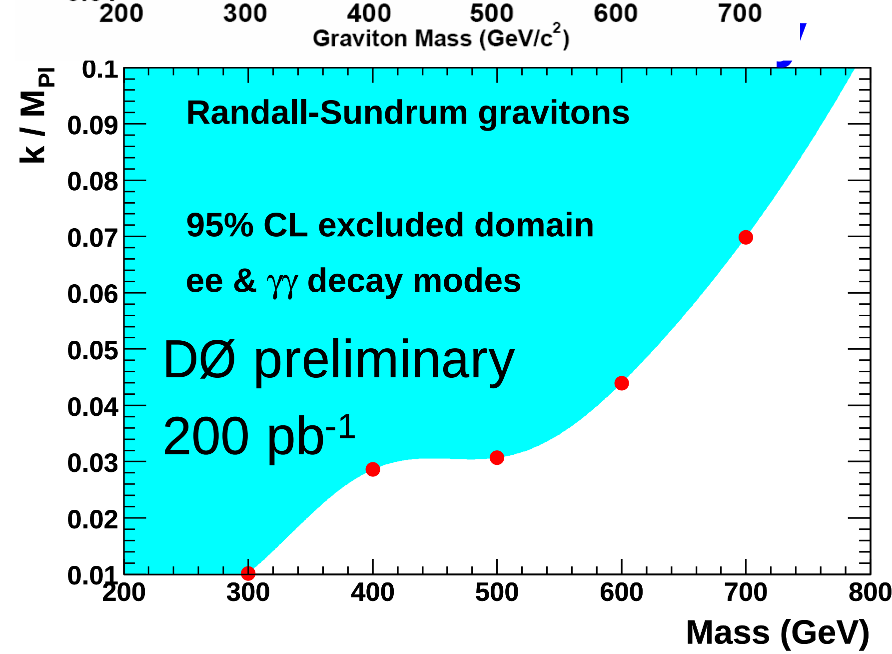
H. Davoudiasl, J.L. Hewett, T.G. Rizzo, PRD 63 (2001)

RS Gravitons

- CDF searched for RS gravitons in Run I
- Both CDF and DØ have Run II searches







For $k/M_{Pl} = 0.1$ limits are

690 GeV (CDF)   790 GeV (DØ)

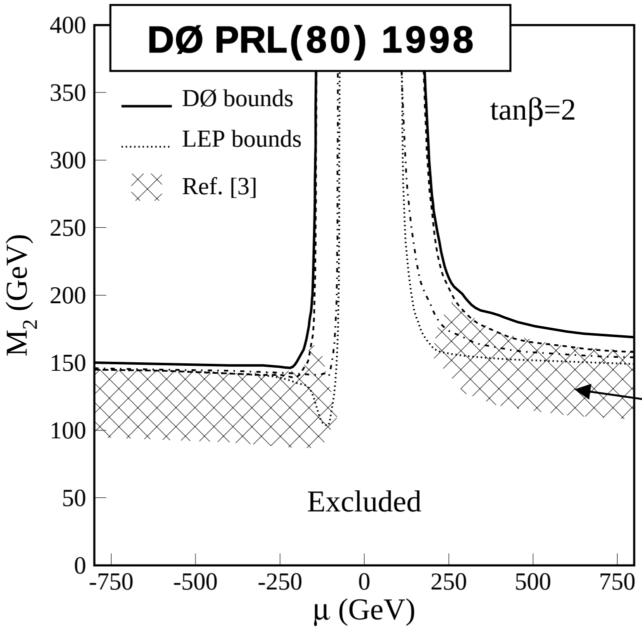
Universal Extra Dimensions

- Generally UED give "SUGRA-like" signatures that are harder than typical SUGRA – small splitting between KK excitations
- Some models consider KK number violation with lightest KK decays to photon and KK graviton

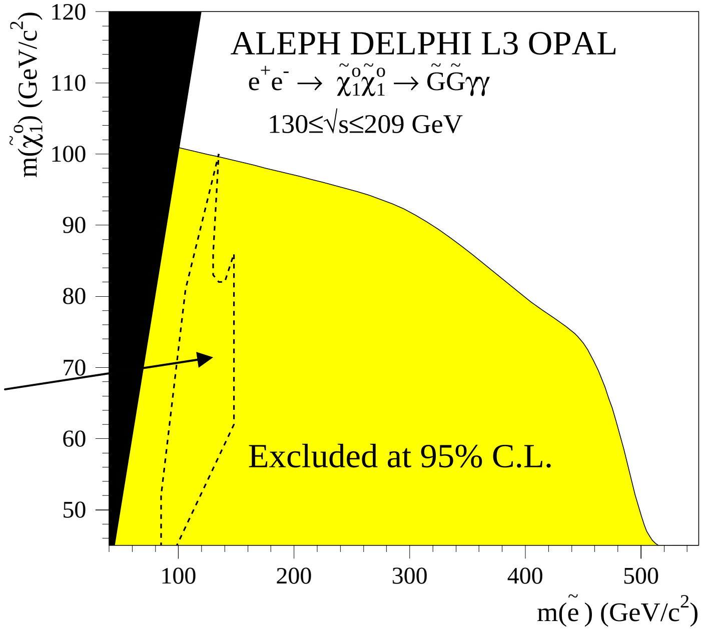
  C. Macesanu, C.D. McMullen, S. Nandi PL B546 (2002)
- This kind of model would produce final states with two photons and missing ET
  - very similar to GMSB SUSY
  - no experimental limits yet

GMSB SUSY

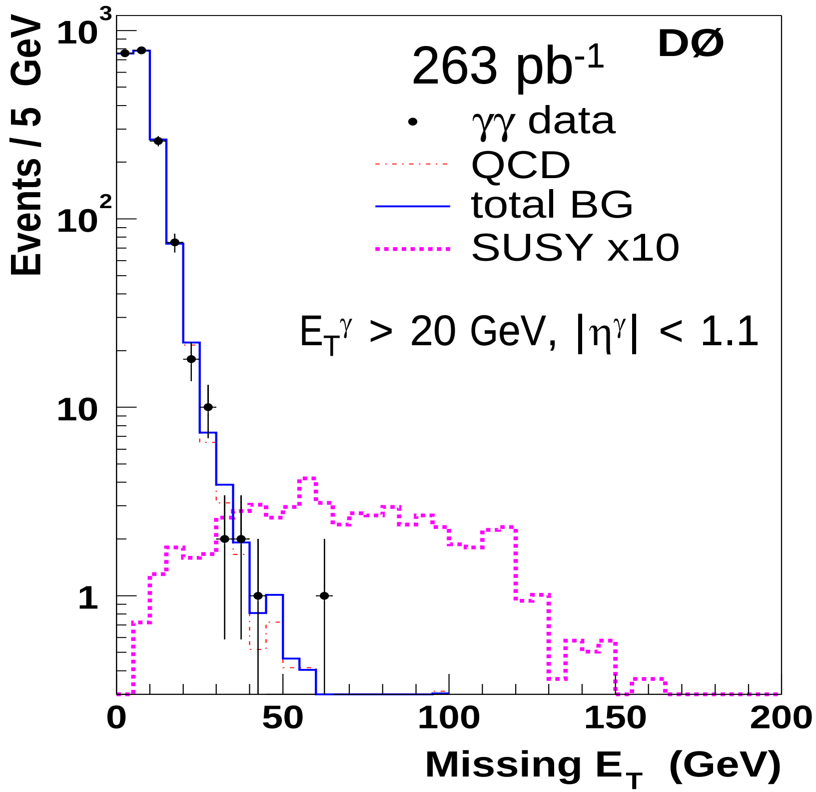
- CDF has found an interesting event $\gamma\gamma ee\ E_T$
- DØ found no high MET diphoton events and set lower limit on neutralino mass at $M(\chi_1^0) > 77$ GeV
- In GMSB framework CDF set lower limit on neutralino mass at $M(\chi_1^0) > 65$ GeV
- LEP2 limit is about $M(\chi_1^0) > 100$ GeV

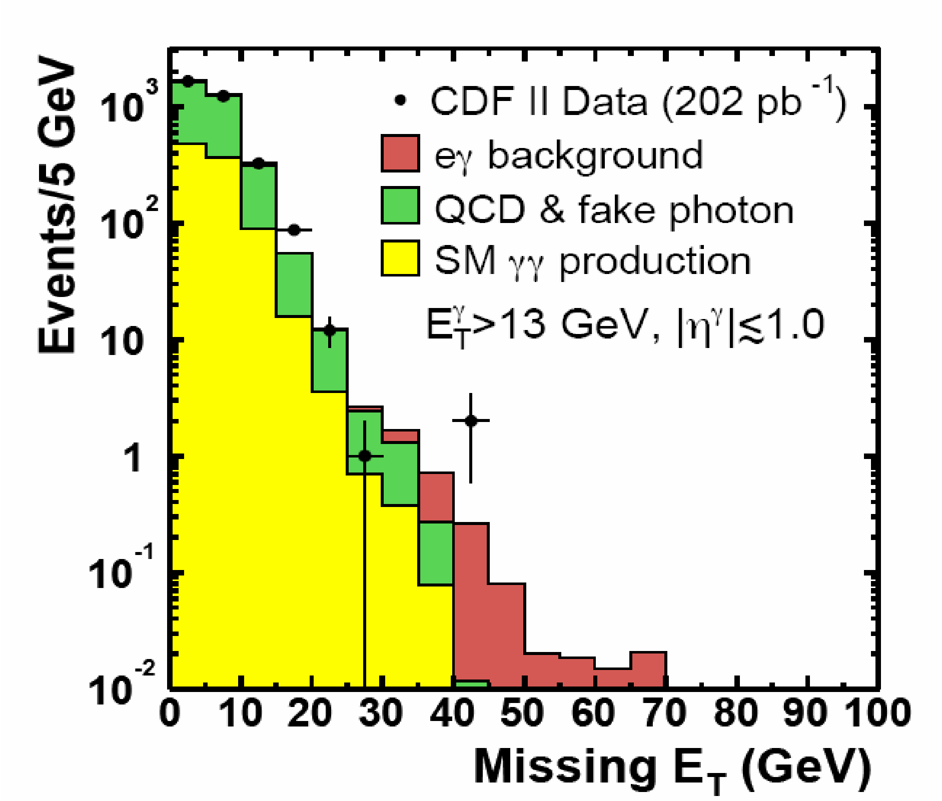


Both GMSB chargino and selectron interpretation of the CDF event are excluded at 95% CL



GMSB SUSY



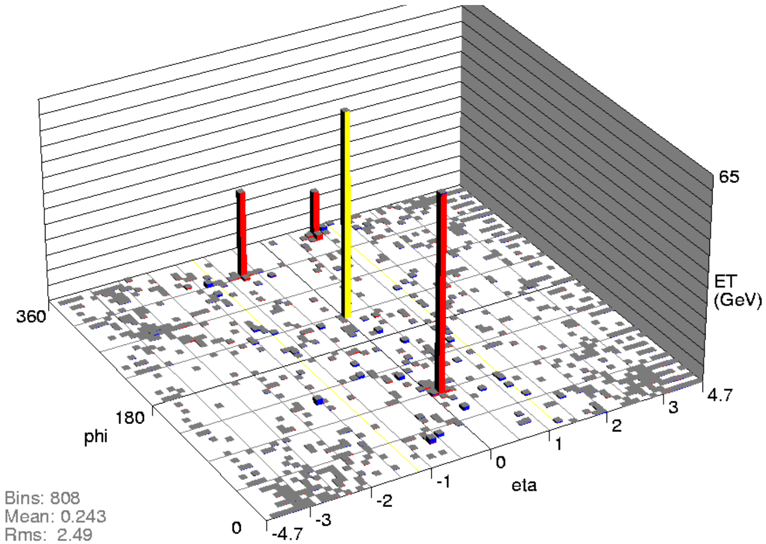


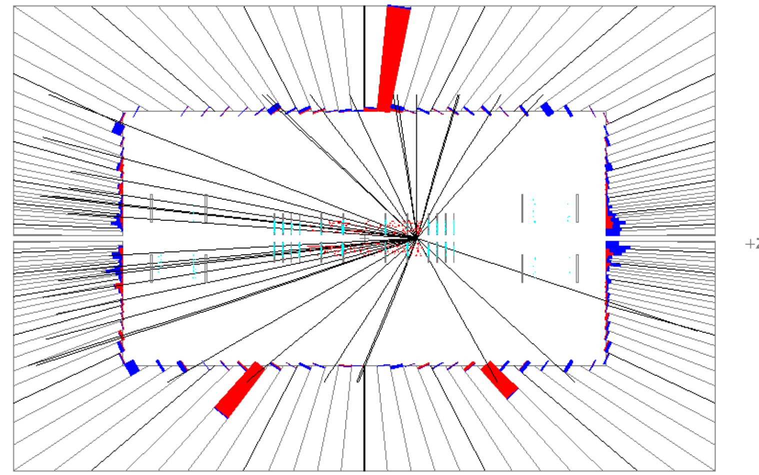
MET cut at 40 GeV
expected: 3.7±0.6
observed: 2
C1 > 195 GeV
N1 > 108 GeV

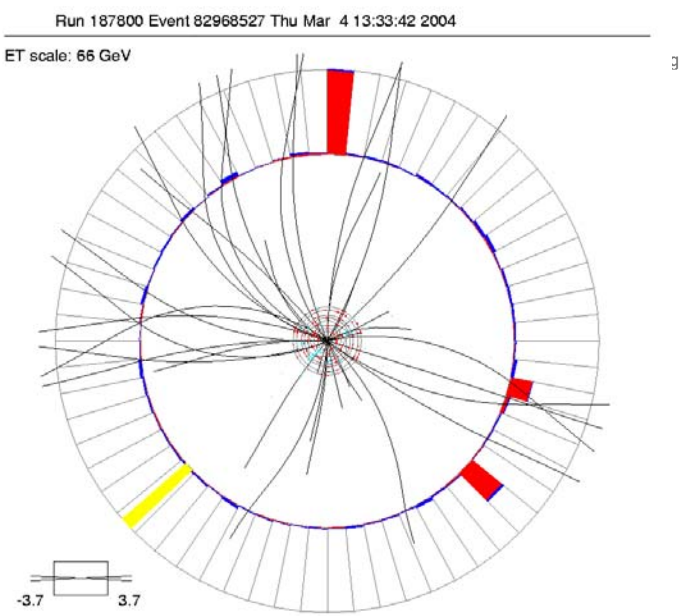
best limit on promptly decaying neutralino

MET cut at 45 GeV
expected: 0.27±0.12
observed: 0
C1 > 167 GeV
N1 > 93 GeV

Highest MET Event: Lennox







cousin of Run I CDF event?!

	pT						
1	69.4						
2	27						
3	23.9		track pT = 15.4				
	m(12) = 86.5		mT(1) = 121.2			Z(vtx) = 31.2	
	m(13) = 71.0		mT(2) = 61.4				
	m(23) = 45.1		mT(3) = 68.5			MET = 63.0	
	m(123) = 120.7						
	pT(12) = 55						
			M_cluster(e,g2,MET) = 112 GeV				
			Definition from Baur *et al* **PRD 48** (1993)				

Tevatron Results Will Influence Background Calculations for LHC

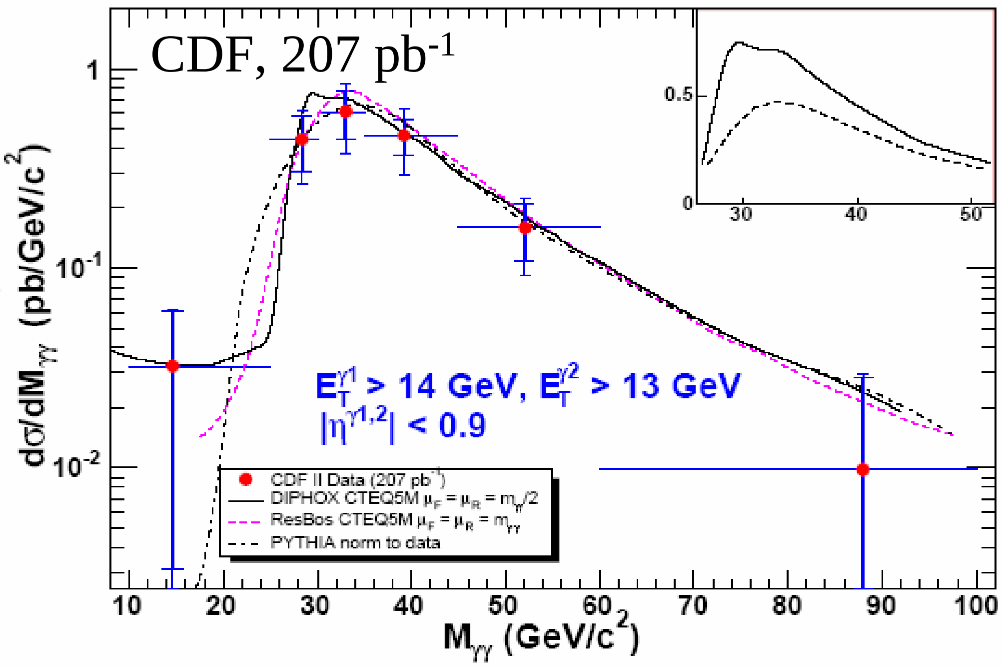
Diphoton Cross Section

Sample
- 207 pb-1
- Et>13,14 GeV, |η|<0.9
- Tight photon ID cuts
- 426±59 γγ in 889 events
- bg subtr. dominates uncertainty

Compare Pythia
- All LO + ISR model
- scaled ×2 for plots

Compare RESBOS
- LO + qq →γγ at NLO
- soft g ISR resummed

Compare Diphox
- All NLO but gg→γγ box
- gg→γγ NLO added by us



Balazs *et al.* Phys. Rev. D **57**, 6934 (1998)

Binoth *et al.* Eur. Phys. J. C **16**, 311 (2000)

Bern *et al.* *Nucl. Phys. Proc. SUppl.* ***116****, 178 (2003)*

Tevatron Results Will Influence Background Calculations for LHC

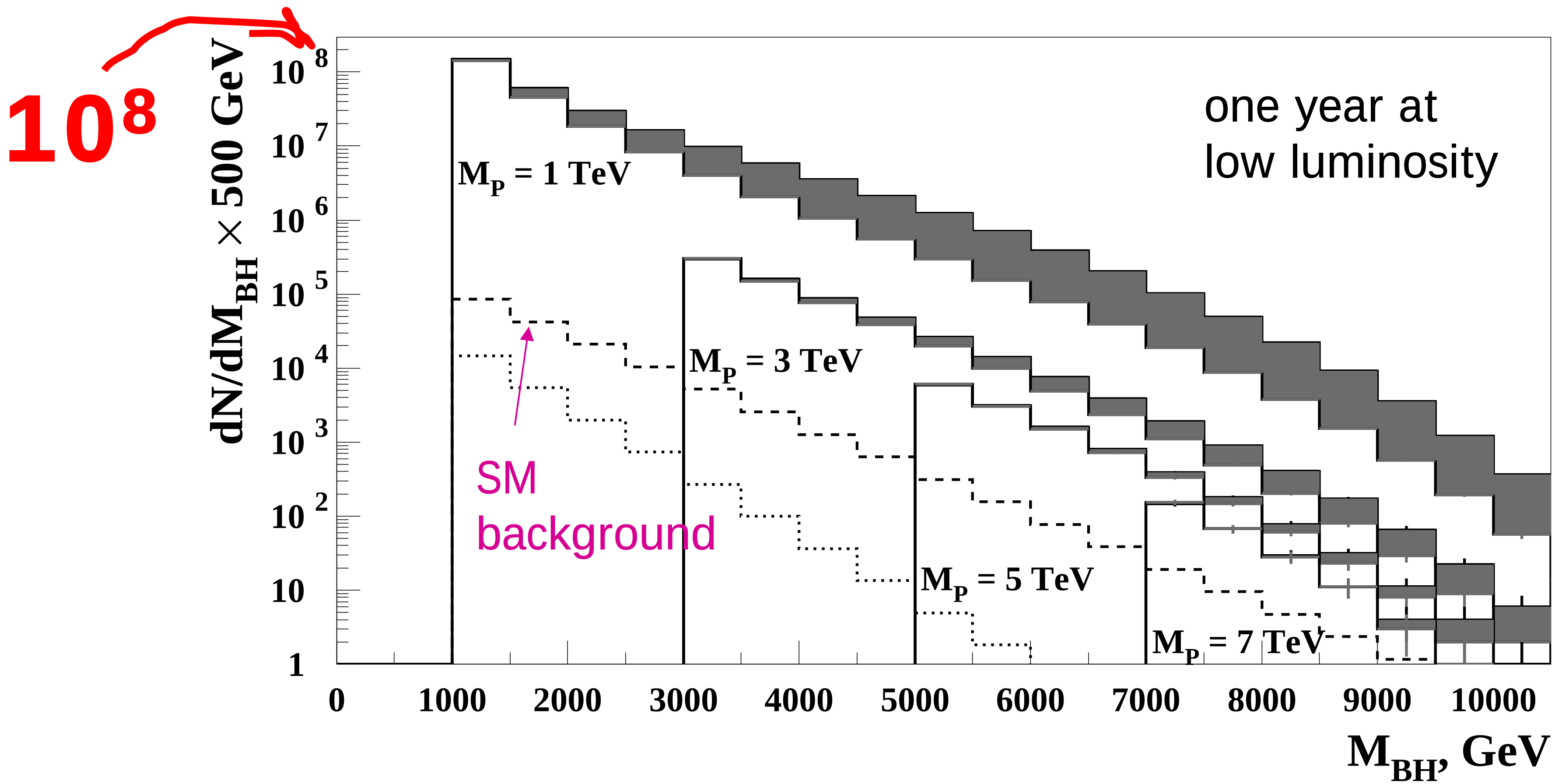
- Instrumental Backgrounds will likely not be described with the MC
- CDF and DØ has accumulated a lot of expertise on how to determine things from data
  - photon - jet fake rates
  - electron – photon misidentification

How Tevatron Result Will Influence LHC Start-up Plan

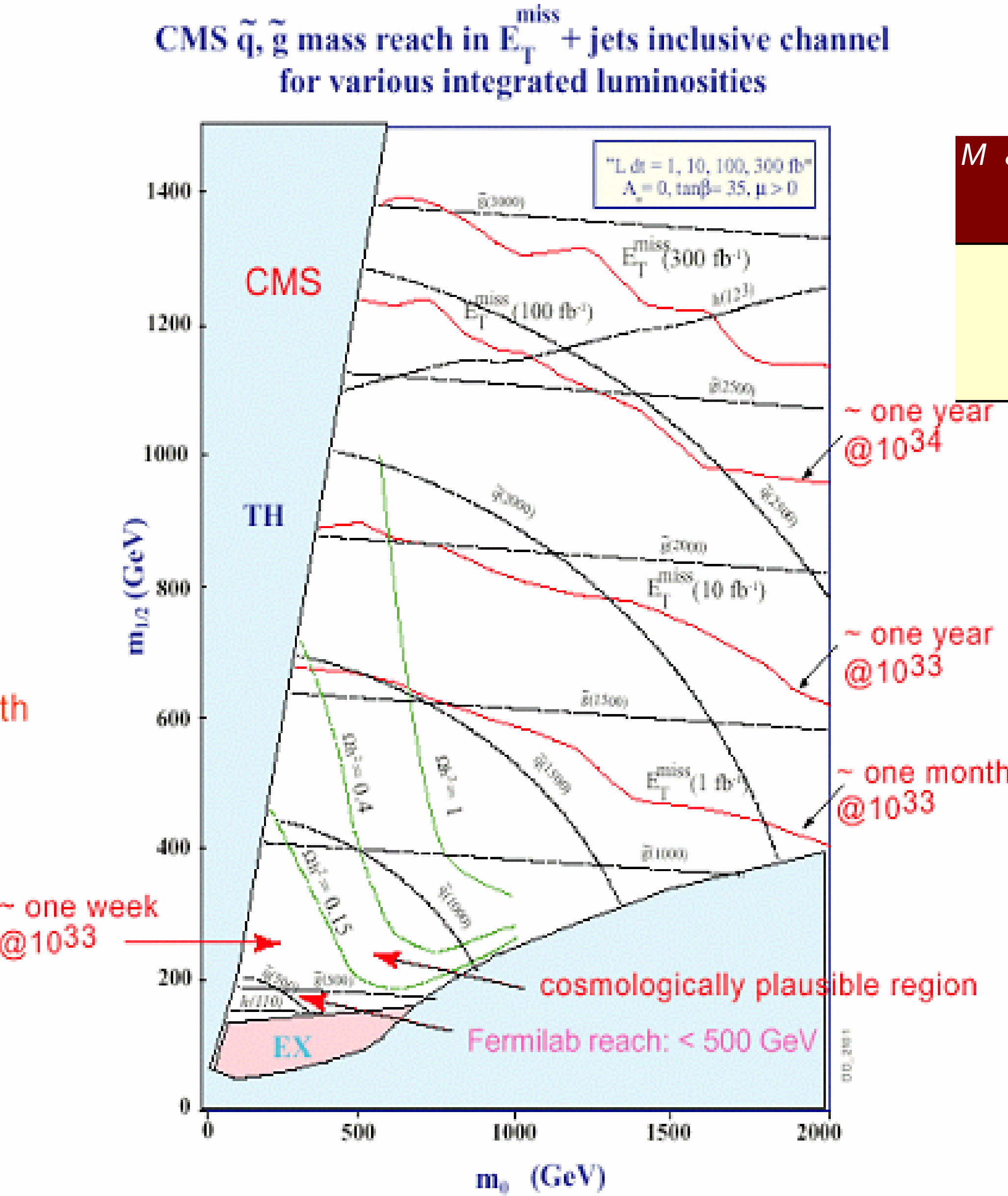
- Photon signatures involve high E_T central photons
  - it's unlikely that discovery at Tevatron would strongly influence trigger menu (for most of SUSY Jets+MET is the best way to trigger at LHC)
  - may be forward ECAL staging at CMS?
- LHC is an almost of order of magnitude jump in E_{CM}
  - chances are LHC would have enough data to see new physics soon after startup
  - if we see something at Tevatron, LHC would have data to see it very soon after startup

Black Holes?

- Dimopolous, Landsberg Phys.Rev.Lett. 87 (2001)
- Two high E_T photons or electrons in the final state



SUSY reach/ TimeScales



Mass(GeV)	σ (pb)	Evts/month Low lum - high lum
500	100	10^5-10^6
1000	1	10^3-10^4
2000	0.01	10^1-10^2

Cosmologically plausible region of parameter space covered within 1 year 1/10th design luminosity.
1 year of design luminosity covers all regions interesting for EWK symmetry breaking

Need to Be Ready

- Time to discovery will likely not be the time to accumulate data – it will be the time to understand detectors
- The discovery will be made not by the best detector, but by detector which is first understood
- MC will not describe the data (at least at the start)
- Calibration and alignment tools should be ready
  - Tried with test beam data?
- Data volume will be overwhelming
  - need <u>well thought trough </u>schemes for selection of datasets needed for calibration
  - Event sizes will be an issue – need reduced data sets
  - At DØ this selection was performed on a reduced data format which did not have all information needed for calibration, and the tools for locating RAW / DST events by run/event number were not convenient
- All the subsystems will try to debug/calibrate at the same time
  - Need convenient tools to propagate calibrations
- **Decision on content of data format is crucial**

Summary

- *(In case you have not heard)* Tevatron has broken 10^{32} $cm^{-2}s^{-1}$ barrier
- A lot of searches at the energy frontier
  - Extra dimensions – best sensitivity
  - GMSB SUSY – best sensitivity
- Lessons for LHC
  - tracker material influence on photon (and electron) ID and energy resolution
  - **Need to be ready at start-up!**