BSM Part One (Theory)

Joseph Lykken
Fermilab

Physics at TeV Colliders, 3 May 05

Physics at TeV Colliders
"New Physics" working group home page

http://allanach.home.cern.ch/allanach/lesHouches/susy.html

Topics

* Flavour Physics and BSM: there will be a discussion session and talks on May 16
* Alternative Models for Higgs and Electroweak Symmetry Breaking:
  - o SUSY models with a heavy Higgs
  - o Higgs as a Goldstone Boson
  - o Higgs as gauge fields
  - o Higgsless models
  - o Invisible Higgs and CP violation in the Higgs sector
* Signature of SUSY breaking scenarii:
  - o SUSY Higgs
  - o What can be seen and at which scale
  - o Discriminating between models
  - o Precision measurements and new techniques for parameter extraction
  - o Spin measurements
  - o Physics with gravitinos?
  - o LHC/ILC connection (may contribute to all of above topics...)
  - o Reconstruction of cascade decays (may contribute to all of above topics...)
  - o Split SUSY

* SUSY les Houches Accord and SPS-like Studies:
  - o Interfacing with NLO cross sections
  - o tg beta and effective couplings
  - o New ingredients: RPV
* Extra-dimensions:
  - o Model independent constraints on new gauge bosons
  - o Universal Extra Dimensions
* Collider Physics and Cosmology:
  - o NMSSM DM and colliders
  - o Requirements on LHC and LC data to match precision data on dark matter
  - o Non standard cosmology and colliders
  - o Baryogenesis and the TeV colliders
* MC and New Tools for the New Physics:
  - o SM backgrounds to SUSY searches
  - o BSM tools - review and discussion day

Theory Conveners: B. Allanach , C. Grojean and J. Lykken
Atlas Contacts: T. Lari and S. Ferrag
CMS Contact: L.Pape and F. Moortgat
Tevatron Contacts: S. Rolli (CDF) and S. Muanza (D0)
Linear Collider Experimental Contact: K. Desch
Monte-Carlo Contact: P.Skands


UX15 Jura Mon May 2 09:00:04 2005
LHC is coming

status of BSM theory

- there are too many models
- none of them are any good

an outsider's view of the Les Houches workshops

- there seem to be two prevailing strategies for what BSM people work on and write up for Les Houches workshops:

strategy #1

- study the phenomenology of models which are sufficiently new, bizarre, or baroque that nobody has looked at them yet

- "collider signals of neutrino-mediated SUSY with breaking of R-parity, T-parity, G-parity, P-parity, CP, CPT, Lorentz-invariance, and unitarity."

strategy #2

- study increasingly obscure phenomenological details of well-developed models (i.e. sugra), preferably those which will only be accessible to colliders or collider upgrades that will never happen

modified strategies

- focus on the main gaps in our readiness for BSM analysis at LHC

- focus on BSM areas which are both underdeveloped ***and*** robust

modified strategies

- focus on the main gaps in our readiness for BSM analysis at LHC
- question from Luc Pape: what are the most physically sensible, best-motivated ways to go from minimal sugra to a more robust class of MSSM models?
- we must have a good answer to this before July 2007!

beyond msugra

- beyond msugra does not just mean mgmsb, mamsb, and R-parity violation
- "sugra" does not mean gravity-mediation, it means mediation of hidden sector SUSY breaking via Planck suppressed operators
- there are a lot of possible Planck suppressed operators (see string theory)
- SUSY@LHC may (probably!) have direct sensitivity to Planck scale physics

beyond msugra

- thus, discriminating between msugra and "variations" of msugra is likely to be the most important and exciting physics that happens in our lifetimes
- need to develop a well-thought-out, well-motivated framework for extending msugra

beyond msugra

- a straightforward approach is to start with your favorite msugra benchmark
- now look at some more general MSSM points close to the benchmark, and look at what happens to your LHC signatures as you vary
- combine this with theory input to get improved model lines and eventually new benchmarks
- this is a good thing to do for Les Houches

modified strategies

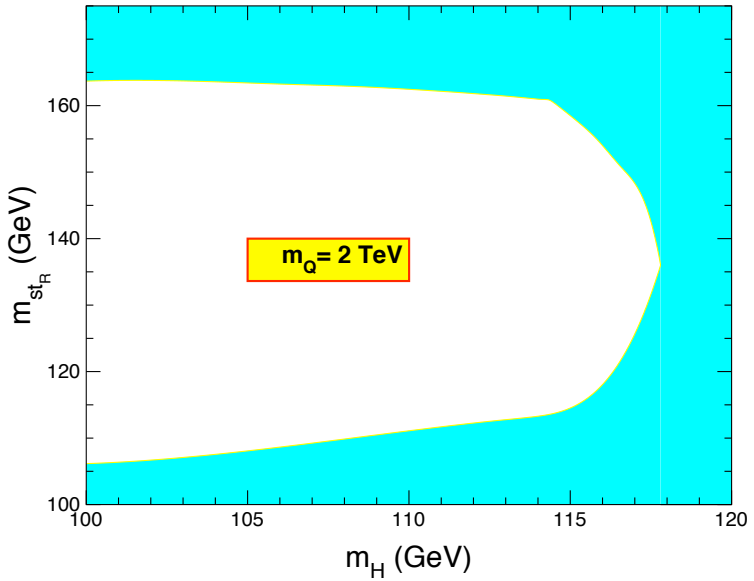
- focus on BSM areas which are both underdeveloped ***and*** robust
- example #1:
  non-minimal SUSY Higgs
- example #2 (related):
  CP violation in Higgs/SUSY sectors

CP violation

- we have not yet discovered the CP violating physics responsible for the matter excess in our universe
- it could be in the neutrino sector
- it is equally likely to be in the Higgs/ SUSY sector
- but electroweak baryogenesis is very constraining on SUSY

Light Stop

Motivation: sufficiently strong first order phase transition to preserve generated baryon asymmetry



$m_h \lesssim 120$ GeV

$m_{\tilde{t}_1} \lesssim 165$ GeV

moderate $\tan\beta \sim 5$

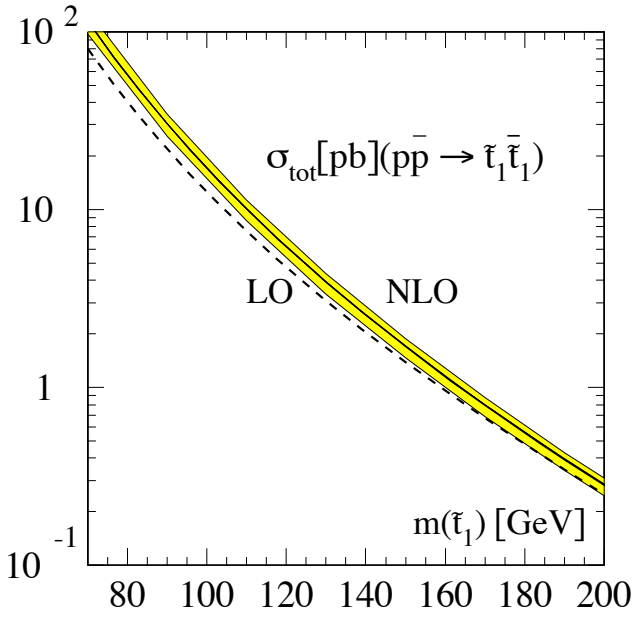
[Carena, Quiros, Wagner, 1998]

NB: Right Ωh^2 from $\tilde{\chi}_1^0 \tilde{t}_1$ coannihilation: $m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0} \sim 30$ GeV. Otherwise other contributions from e.g. light sleptons needed.

Sabine Kraml, TeV4LHC workshop

$\tilde{t}_1$ rates and signatures

- Large rate of $p\bar{p} \to \tilde{t}_1\bar{\tilde{t}}_1$
- Decay $\tilde{t}_1 \to c\tilde{\chi}_1^0 \rightsquigarrow 2j + \not{E}_T$
- Other modes: $\tilde{t}_1 \to b\tilde{\chi}_1^{\pm},\ bW\tilde{\chi}_1^0,\ bl\tilde{\nu}$
- If gluino mass ∼300–400 GeV:
  $p\bar{p} \to \tilde{g}\tilde{g} \to tt\,\tilde{t}_1\tilde{t}_1$
  ca. 50% of SUSY cross section

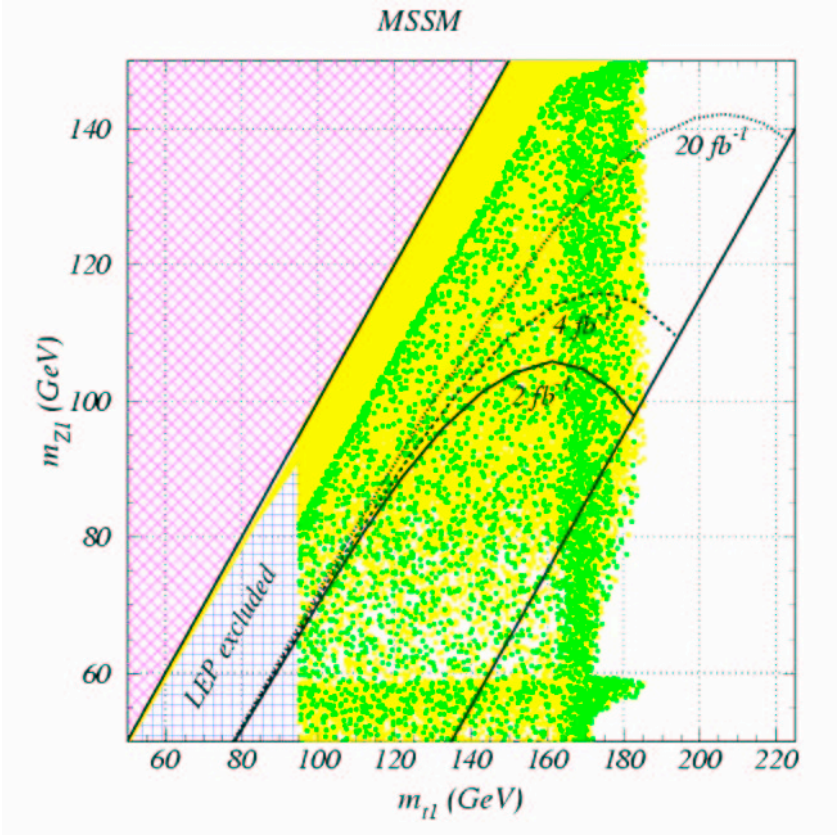


[Plehn, Spira]

- Possible discovery channel at Tevatron
- At LHC: $pp \to \tilde{g}\tilde{g} \to tt\,\tilde{t}_1\tilde{t}_1$, $pp \to \tilde{g}\tilde{b} \to tW\tilde{t}_1\tilde{t}_1$, ...
  VERY difficult if stop is light

Sabine Kraml, TeV4LHC workshop

Tevatron reach for $\tilde{t}_1 \longrightarrow c\tilde{\chi}_1^0$



Demina, Lykken, Matchev, Nomerotski hep-ph/9910275

[Balazs, Carena, Wagner, hep-ph/0403224]

Sabine Kraml, TeV4LHC workshop

Same-sign top pairs?

R. Demina, J. Lykken, K. Matchev, A. Nomerotski
hep-ph/9910275

We now turn to discuss the possibility of producing stops in SUSY cascades. Among the remaining SUSY particles, gluinos have the largest production cross section, and they can decay to $t\bar{t}$ pairs.

Since the stops are invisible, the signature is similar to the leptonic channels of top pair production. The crucial difference from $t\bar{t}$ production is that because of the Majorana nature of the gluino, half of the time the top quarks will have the same sign.

Such an analysis is also in preparation for Run II.

Search For Gluino Pair Production Using Like-Sign Top Dilepton Events

Chadd Smith

A dissertation submitted to the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy.

We present the results of a search for supersymmetry via gluino pair production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. The data sample represents the full 106.1 pb^{-1} of integrated luminosity collected by the Collider Detector at Fermilab (CDF) during Run I of the Tevatron. The gluino, a supersymmetric partner of the gluon, is expected to be strongly produced at the Tevatron. The scalar top, superpartner of the top quark, is believed to be the lightest squark and the only squark less massive than the gluino. In the region of parameter spaced defined by $(m_t + m_{\tilde{t}}) < m_{\tilde{g}} < (m_q + m_{\tilde{q}})$, $(\tilde{g} \longrightarrow t\ \tilde{t})$ is the preferred decay channel. The Majorana nature of the gluino gives rise to like-sign top quarks from $\tilde{g}\tilde{g}$ events. We use the top dilepton analysis to search for this unique signature in the like-sign dilepton channel, and we set upper limits on the cross section for gluino-gluino production. Despite a low expected background contribution of $0.67 \pm^{1.54}_{0.24}$ events, we observe two like-sign $e\mu$ events and one trilepton event. This experimental result, and the difficulty of probing gluino masses close to the top mass due to the systematics surrounding a light stop, prevents the establishment of a mass limit on the gluino. Whether the observed excess in the data is simply a statistical fluctuation or a hint of "new physics" will be a subject of interest at the Tevatron during Run II.

Cross sections, event numbers: SM processes

	tb	tqb	$\bar{t}b$	$\bar{t}qb$	ZZ	ZW	WW	$t\bar{t}$	$Zb\bar{b}$	All
σ, pb	0.212*	5.17*	0.129*	3.03*	18(NLO)	26.2	70.2	886(NLO)	232(NLO)*	
N1	2,120	51,700	1,290	30,300	180,000	262,000	702,000	8,860,000	2,320,000	
N2	112	1,798	71	1,067	256	727	39.7	142,691	12,924	160,000

▷ Other process

▷ generated with CompHEP

main contribution into background

	WWW	ZWW	ZZW	ZZZ	$WWWW$	$ZWWW$	$ZZWW$	$ZZZW$	$ZZZZ$
σ, pb	0.129	0.0979	0.0305	0.00994	0.000574	0.000706	0.000442	0.000572	0.0000161
N1	1,290	979	305	99.4					
N2	<15	<10	<3	<1					

	$t\bar{t}W$	$t\bar{t}Z$	$t\bar{t}WW$	$t\bar{t}ZW$	$t\bar{t}ZZ$
σ, pb	0.556	0.65	neg.	neg.	neg.
N1	5,560	6,500			
N2	<200	<200			

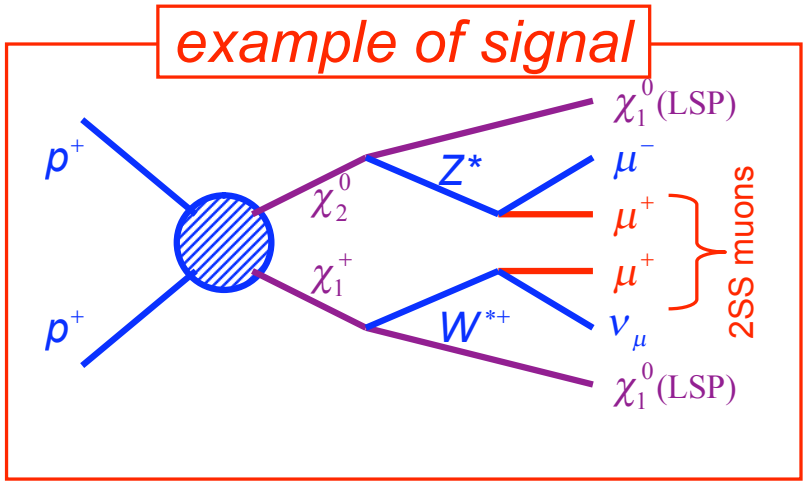
- negligible contribution

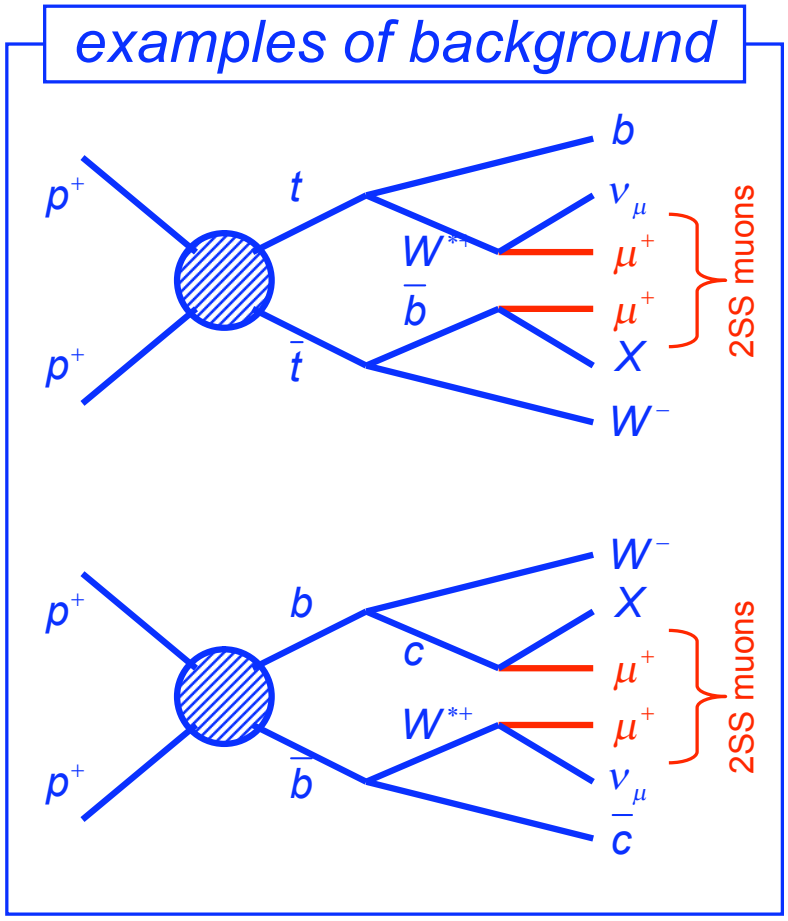
▷ Notations:

all but $t\bar{t}W$, $t\bar{t}Z$ are negligible

- ▷ N1 – total number of expected events for integral luminosity of $10fb^{-1}$
- ▷ N2 – number of events after pre-selection (two same sign muons, P_T>10 GeV)

Same-sign dimuons signal + backgrounds





- Handles for separation:
  - dimuons with same signs
  - isolation
  - cut on vertices
  - $\not{E}_t$
  - number of jets
- CDF and DØ successfully killed considered backgrounds

generator-level muons, pt >10 GeV, letal < 2.4
from Pythia t-tbar production
numbers = LHC 10 fb-1= 8,860,000 t-tbar pairs

single muon	OS dimuons	SS dimuons	tri-muons	4 muons
2,339,000	228,400	117,300	24,900	500

117300+24900+500 = 142,700, compare to 142,691 in the CMS study

generator-level muons, pt >10 GeV, letal < 2.4
from Pythia t-tbar production
numbers = LHC 10 fb-1= 8,860,000 t-tbar pairs

single muon	OS dimuons	SS dimuons	tri-muons	4 muons
2,339,000	228,400	117,300	24,900	500

now apply isolation cut:
remove muons within 30 degs of any >15 GeV “jet object”

generator-level muons, pt >10 GeV, letal < 2.4
from Pythia t-tbar production
numbers = LHC 10 fb-1= 8,860,000 t-tbar pairs

single muon	OS dimuons	SS dimuons	tri-muons	4 muons
2,339,000	228,400	117,300	24,900	500

now apply isolation cut:
remove muons within 30 degs of any >15 GeV “jet object”

single muon	OS dimuons	SS dimuons	tri-muons	4 muons
1,030,300	45,000	2,000	300	~0

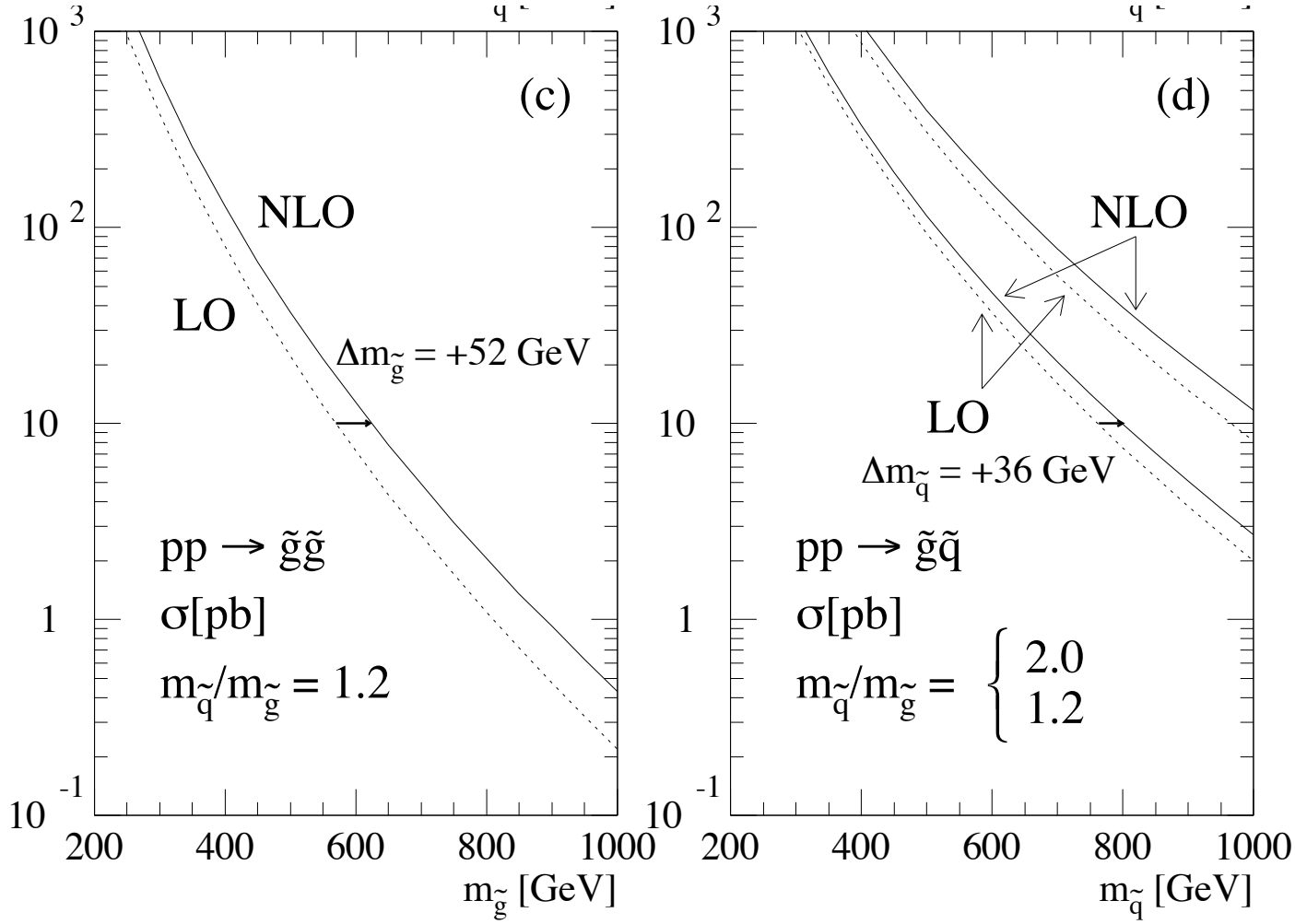


Figure 22: The total cross-section for the LHC ($\sqrt{S} = 14$ TeV). NLO (solid) compared with LO (dotted). Parton densities: GRV94, with scale $Q = m$.

W. Beenakker[1*], R. Höpker[2], M. Spira[3] and P. M. Zerwas[2]

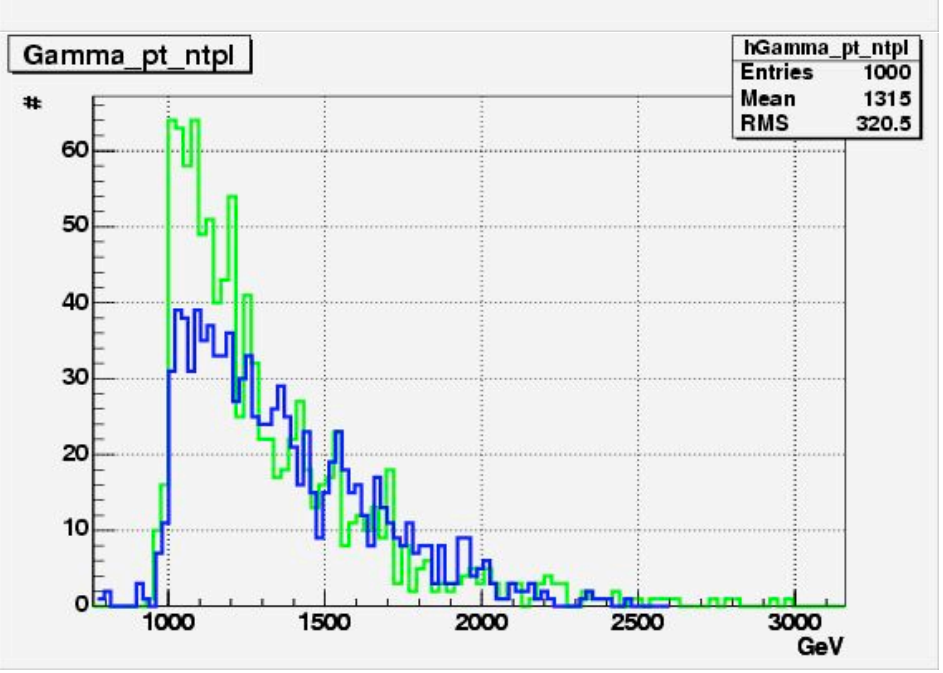
hep-ph/9610490

extra dimensions

- several models are serious enough that we can think about them for LHC
- this includes ADD, RS1, UED, and AED (a hybrid of UED and ADD)
- some simulation tools are now available
- what next?

extra dimensions

- validate and improve the simulation tools
- make the model descriptions more robust
- e.g. in ADD, worry about the high and low ends of the KK spectrum



CMS Phys.week @FNAL

Joanna Weng, Maria Spiropulu

- compare Sherpa 1.0.5 /Pythia(stagen) 6.2.7 (cross sections, kinematics)
- for M = 5000 GeV, n =2 Sherpa 0.025 fb/Pythia 0.035 fb
- for M = 5000 GeV, n =6 Sherpa CPU limit/Pythia 0.013 fb
- events simulated with OSCAR_3_9_0 (pre-release) and digitized with ORCA_8_8_0
- production request will be submitted very soon
- Comparisons with FAMOS and Tests Gflash shower parametrization in OSCAR


Fin