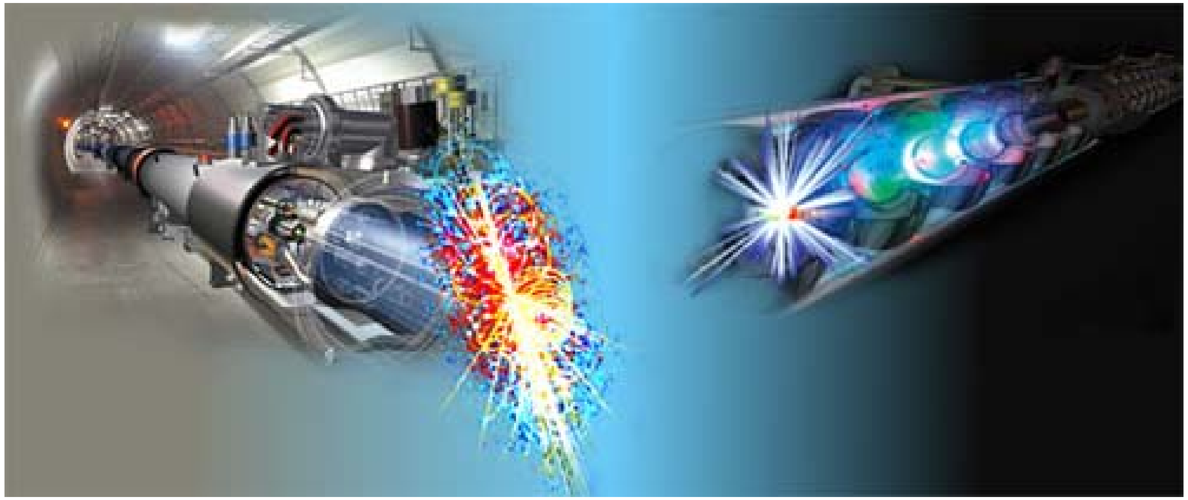
Beyond the SM signals at the LHC
The LHC Early Phase for the ILC
FNAL 12-14 April

Albert De Roeck
CERN
and University of Antwerp
and the IPPP Durham



Reminder: Mass Reach

Ellis, Gianotti, ADR
hep-ex/0112004+ few updates

Units are TeV (except $W_L W_L$ reach)
$\int L dt$ correspond to 1 year of running at nominal luminosity for 1 experiment

PROCESS	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}	VLHC 40 TeV 100 fb^{-1}	VLHC 200 TeV 100 fb^{-1}	LC 0.8 TeV 500 fb^{-1}	LC 5 TeV 1000 fb^{-1}
Squarks	2.5	3	4	5	20	0.4	2.5
$W_L W_L$	2σ	4σ	4.5σ	7σ	18σ	6σ	90σ
Z'	5	6	8	11	35	8†	30†
Extra-dim (δ=2)	9	12	15	25	65	5-8.5†	30-55†
q*	6.5	7.5	9.5	13	75	0.8	5
Λcompositeness	30	40	40	50	100	100	400
TGC (λ_γ)	0.0014	0.0006	0.0008		0.0003	0.0004	0.00008

† indirect reach
(from precision measurements)

LHC: High energy: direct mass coverage into the TeV range
LC: Precision: large indirect mass reach

What for 1-10 fb^{-1}?

This talk

- My mission statement

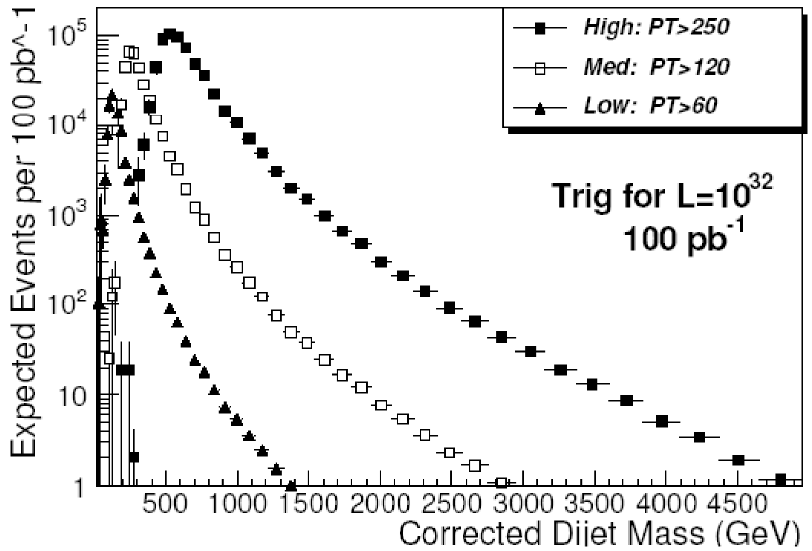
  How much one will know with 1 - 10 fb^{-1} of data in different scenarios, i.e. how much will one know about new observed states and how much scope will there be for other new physics to hide in 1 - 10 fb^{-1} of LHC data.

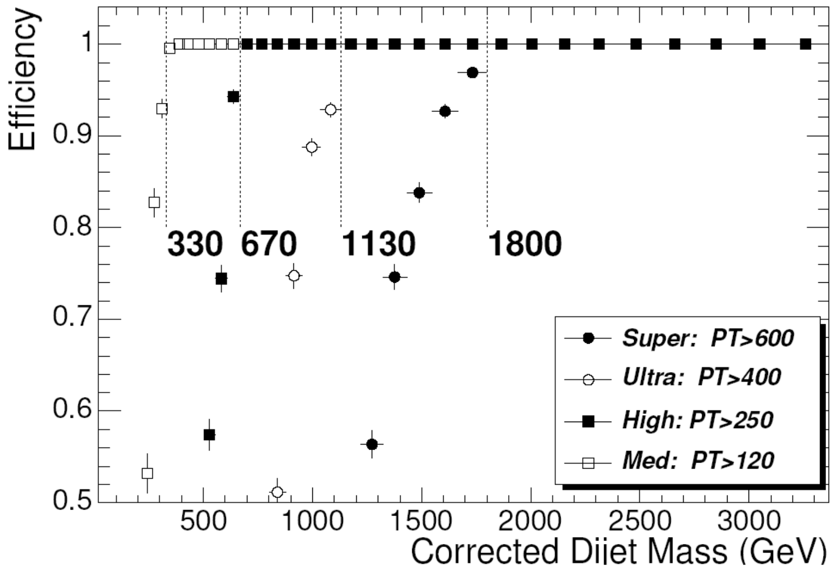
  The scenario that we would like you to consider is the observation of new states of physics beyond the SM. We would like you to cover all possible scenarios of BSM physics *except* missing energy, leptonic resonances and multi gauge bosons

- So what is left?
  - Jets, Photons, (b/τ), top quarks, combined signatures, special signatures, eg heavy stable charged particles, r-hadrons
- Hence: in this talk ⇒
  - New physics with (di)jets
  - New physics with top quark
  - RPV SUSY, Technicolor (jets + leptons, leptons)
  - ED with photons and (non-resonant) leptons
  - Spherical events/Black holes
  - Other exotics (excited quarks & leptons,...)
  - Special signatures, weird scenarios

Initial Dijet studies

- Jets : Iterative cone algorithm with R = 0.5 in (η,ϕ)
- Triggers with different tresholds to cover full dijet mass range
  Adjust dynamically during luminosity ramp-up of the LHC

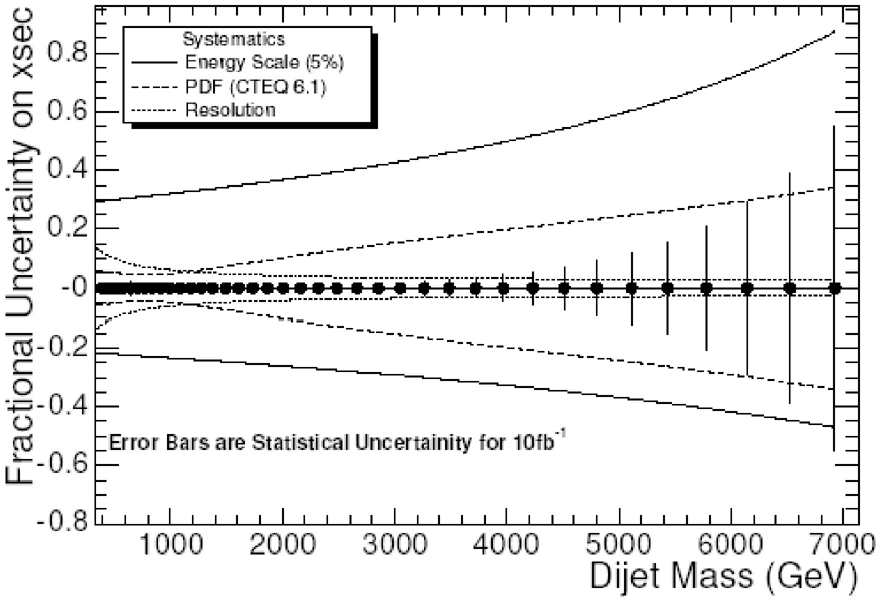


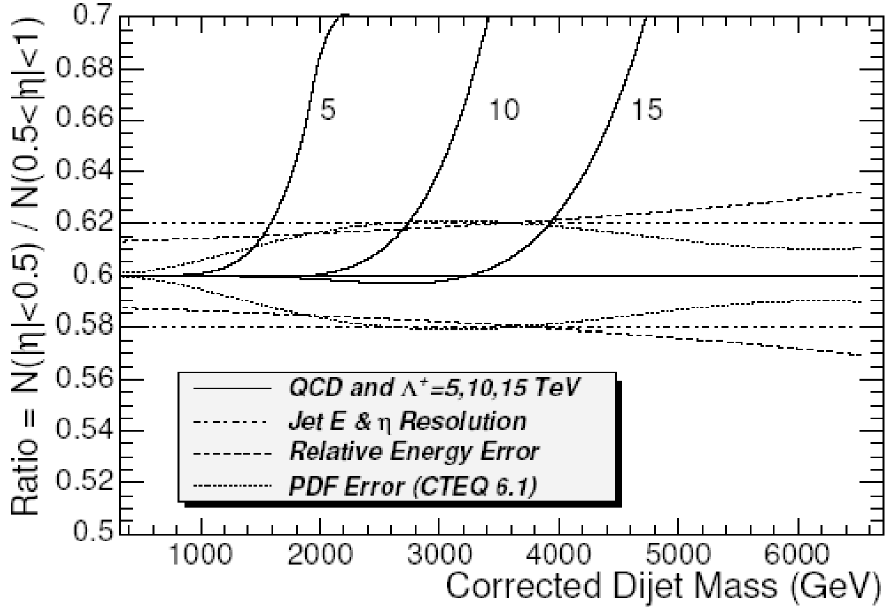


Access to high masses already for low eg 100 pb^{-1}

Dijets: Ratios

Dijet ratio: $N(|\eta| < 0.5)/N(0.5 < |\eta| < 1.0)$



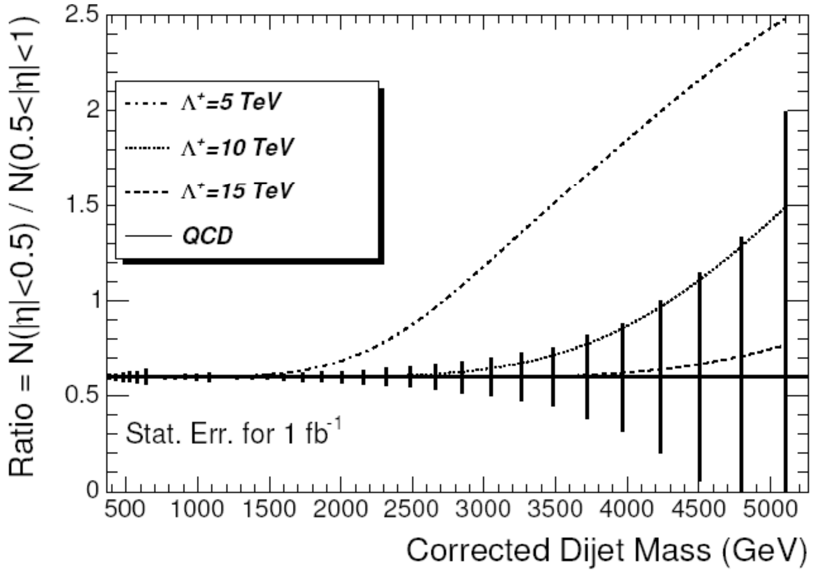


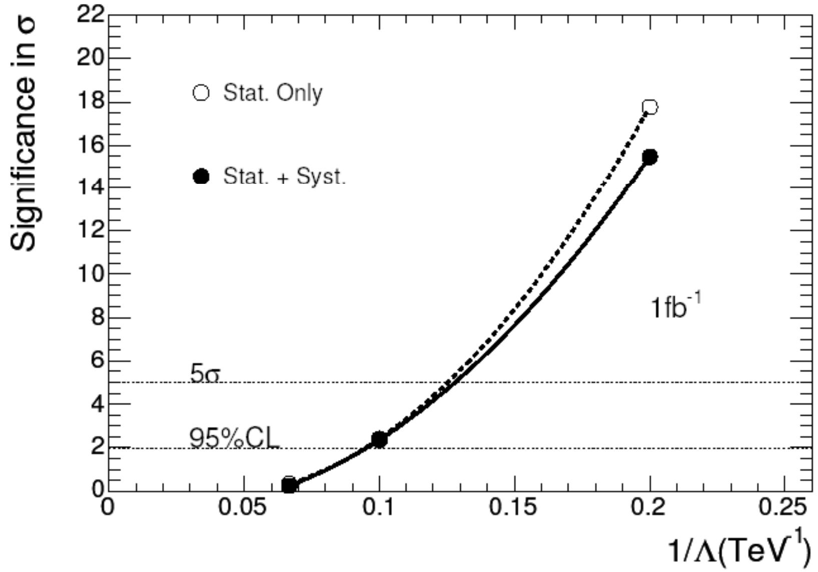
Systematics
Energy scale (5%)
PDFs (CTEQ6.1 series)
Energy smearing (resolution)

Sensitivity to contact interactions for 3 CI scales

Dijets: Contact Interactions

Dijet ratio: $N(|\eta| < 0.5)/N(0.5 < |\eta| < 1.0)$





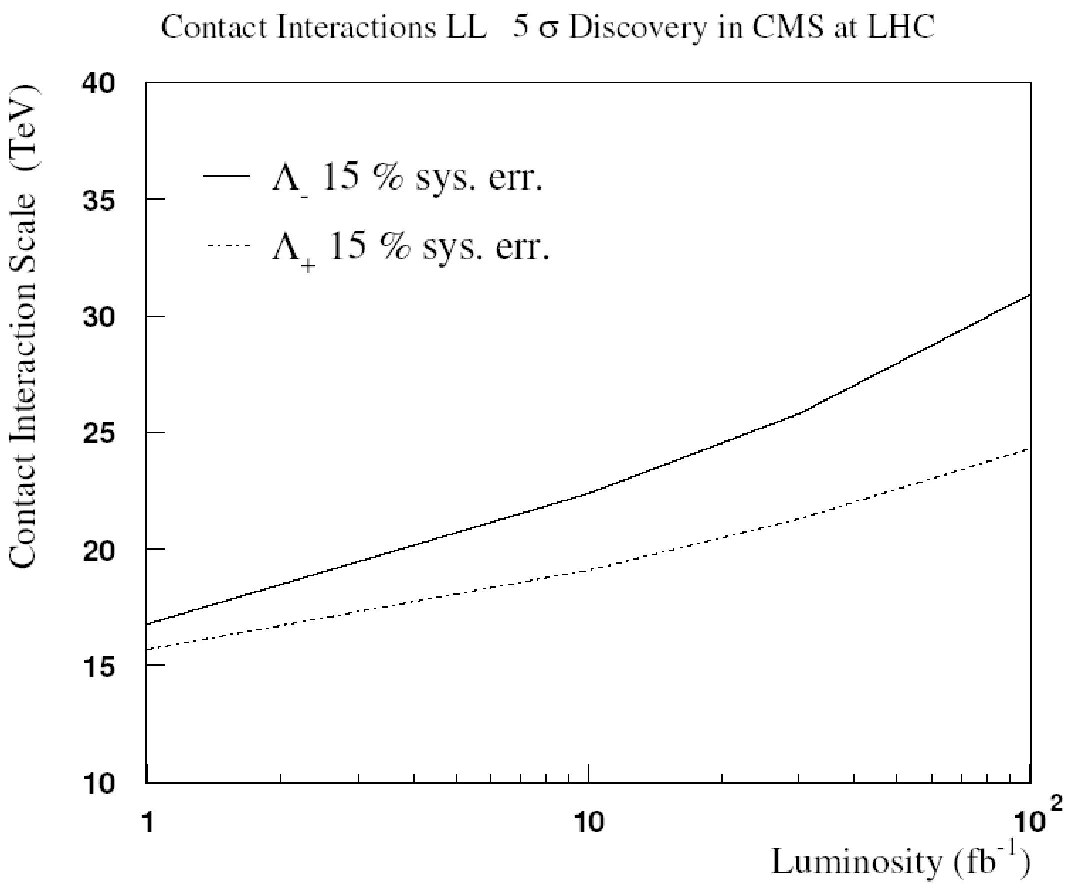
Reach versus start up luminosities

Luminosity	95% CL Excluded Scale			5σ Discovered Scale		
	100 pb^{-1}	1 fb^{-1}	10 fb^{-1}	100 pb^{-1}	1 fb^{-1}	10 fb^{-1}
Λ^+(TeV)	<6.2	<10.4	<14.8	<4.7	<7.8	<12.0

$\Rightarrow$ Reach ~ 12-15 TeV with 10 fb^{-1}

Drell Yan muons

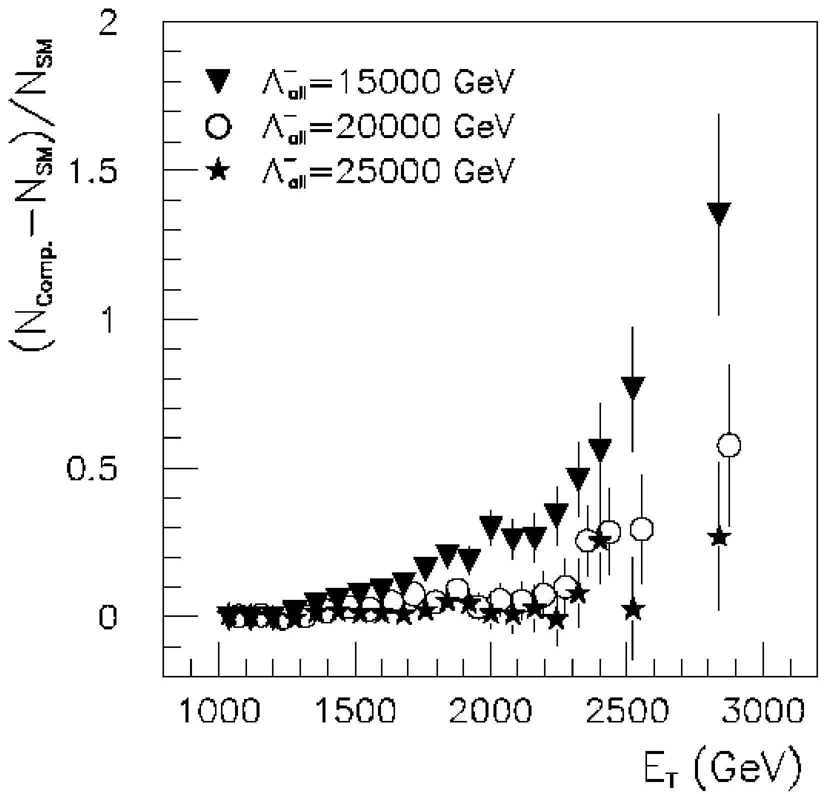
Contact Interactions in the lepton final state channel

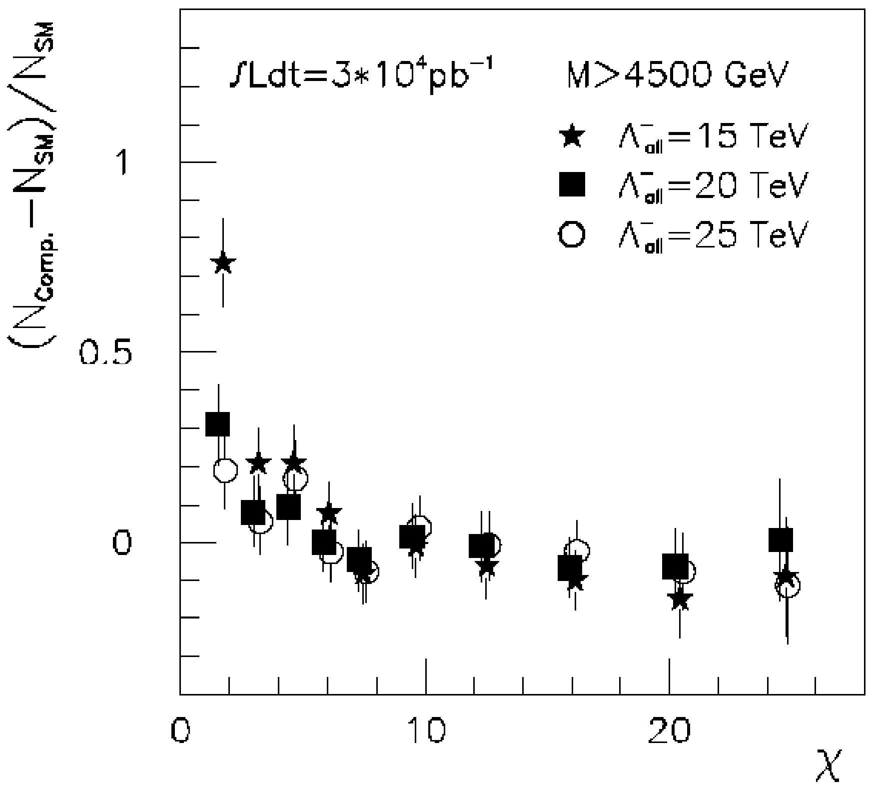


Reach ~ 20 TeV with 10 fb^{-1}

Dijets

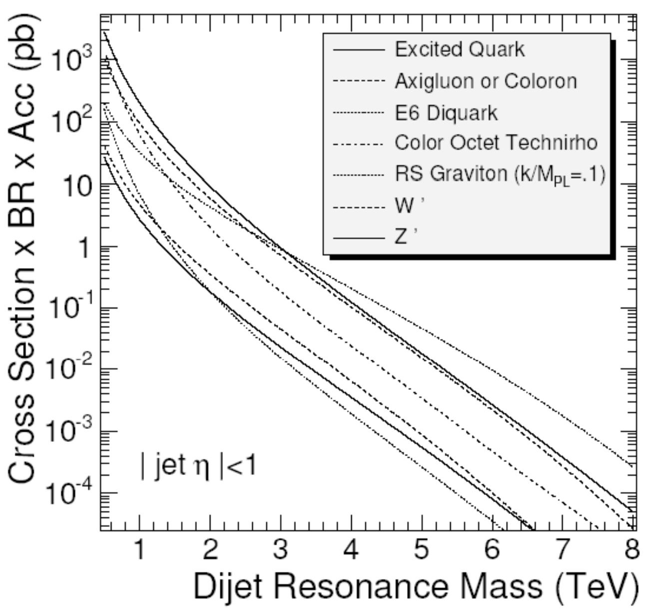
Ultimately, with the highest luminosities:

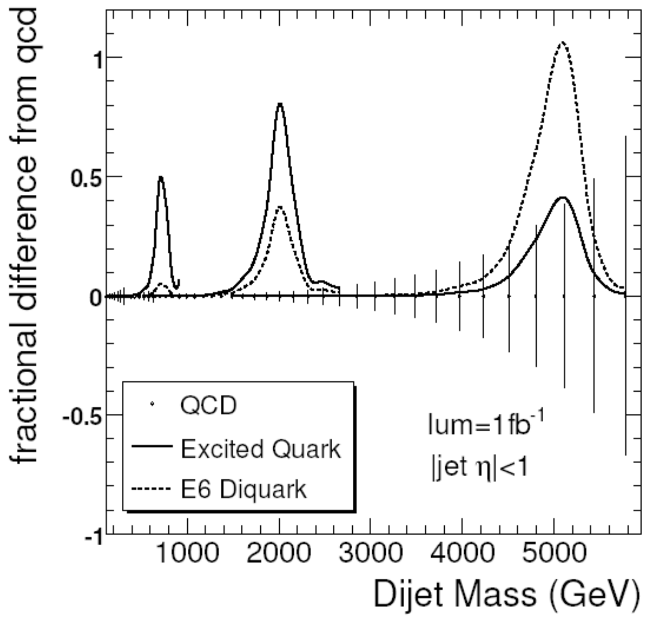




Scenario	14 TeV 300 fb^{-1}	14 TeV 3000 fb^{-1}	28 TeV 300 fb^{-1}	28 TeV 3000 fb^{-1}
Λ(TeV)	40	60	60	85

Dijets: New Physics Reach Summary

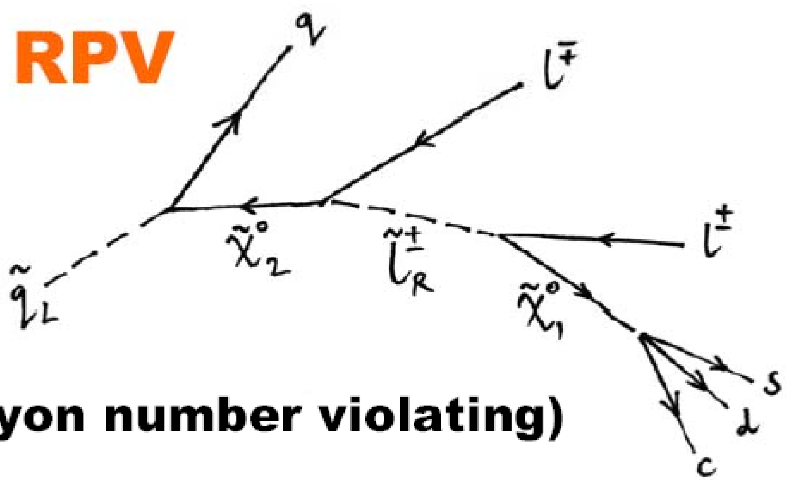




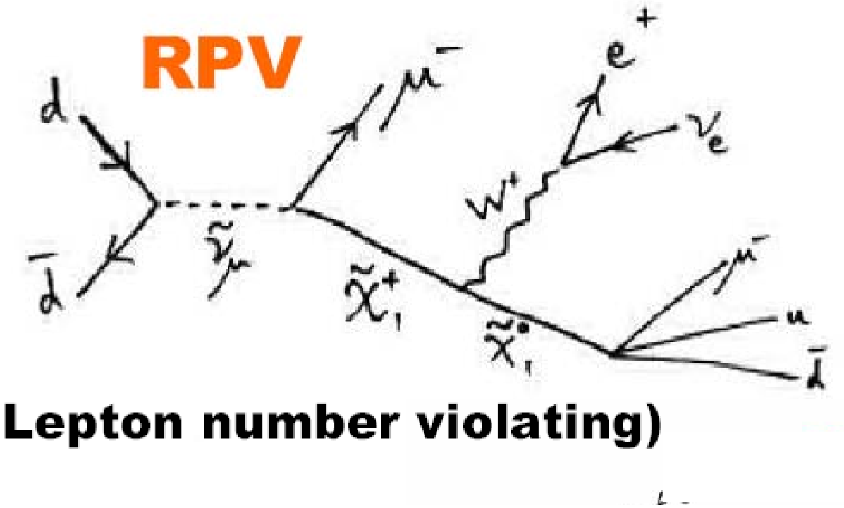
Resonance Model	95% CL Excluded Mass (TeV/c^2)			5σ Discovered Mass (TeV/c^2)		
	100 pb^{-1}	1 fb^{-1}	10 fb^{-1}	100 pb^{-1}	1 fb^{-1}	10 fb^{-1}
Excited Quark	0.7 - 3.6	0.7 - 4.6	0.7 - 5.4	0.7 - 2.5	0.7 - 3.4	0.7 - 4.4
Axigluon or Colouron	0.7 - 3.5	0.7 - 4.5	0.7 - 5.3	0.7 - 2.2	0.7 - 3.3	0.7 - 4.3
E_6 diquarks	0.7 - 4.0	0.7 - 5.4	0.7 - 6.1	0.8 - 2.0	0.8 - 3.7	0.8 - 5.1
Colour Octet Technirho	0.7 - 2.4	0.7 - 3.3	0.7 - 4.3	0.7 - 1.5	0.7 - 2.2	0.7 - 3.1
Randall-Sundrum Graviton	0.7 - 1.1	0.7 - 1.1 1.3 - 1.6	0.7 - 1.1 1.3 - 1.6 2.1 - 2.3	N/A	N/A	N/A
W'	0.8 - 0.9	0.8 - 0.9 1.3 - 2.0	0.8 - 1.0 1.3 - 3.2	N/A	N/A	N/A
Z'	N/A	N/A	2.1 - 2.5	N/A	N/A	N/A

R-Parity violating Susy

	How stable is the lightest SUSY particle (L.S.P.) ?	Large missing energy?	Event can be reconstructed fully?	Sparticle production
RPC	Stable	Yes	Usually not	Only in pairs
RPV	Unstable (decays to leptons or jets)	No	Yes	Either singly, or in pairs



(Baryon number violating)

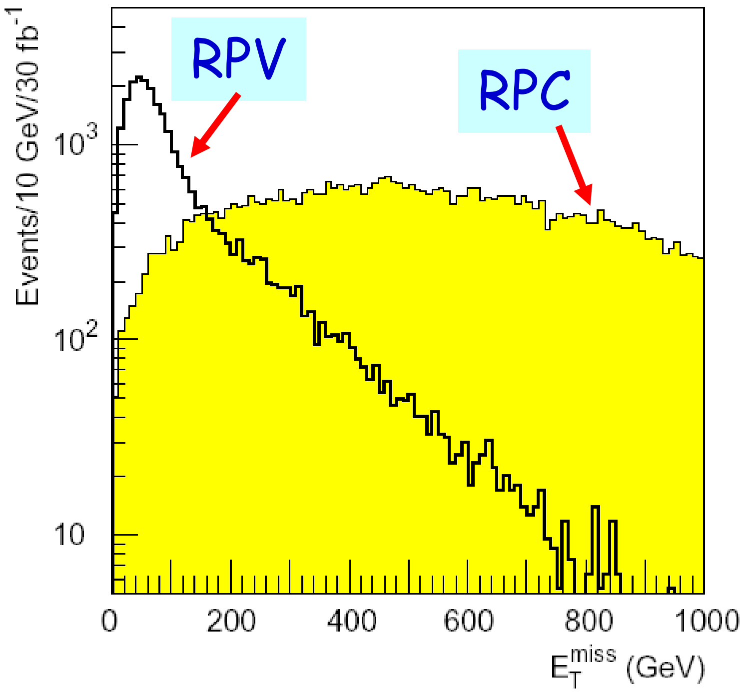


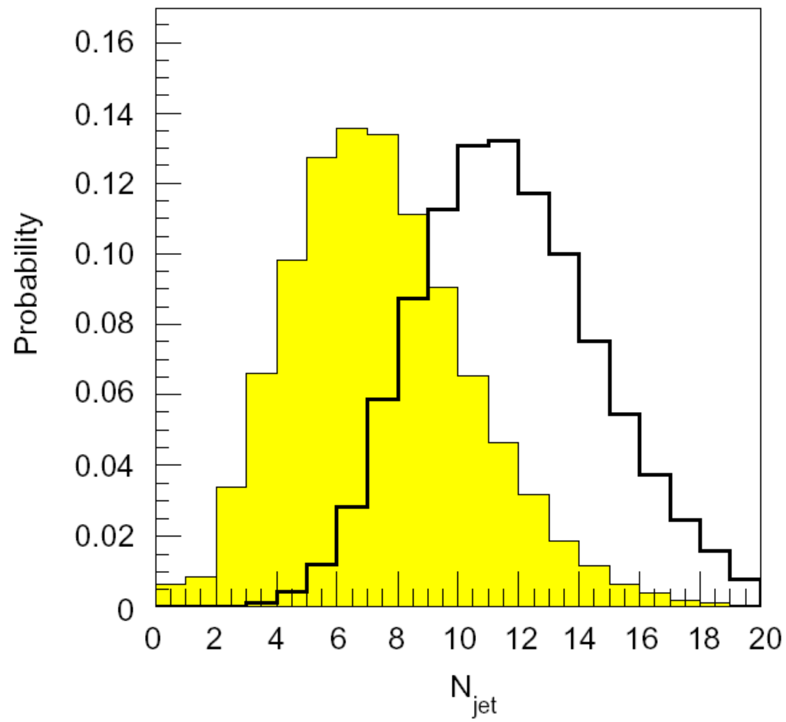
(Lepton number violating)

Multijets + lepton events + relatively small missing E_T

R-parity violation

M_0=100 GeV $m_{1/2}$=300 GeV A=300 GeV tanβ=2.1 μ>0





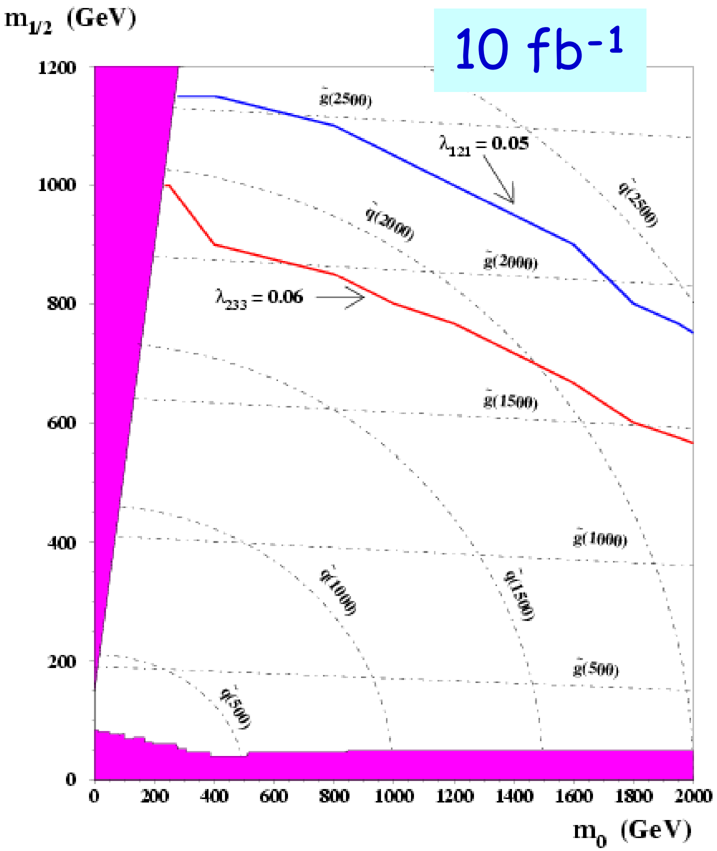
Less missing E_T More Jets and/or Leptons than RPC SUSY

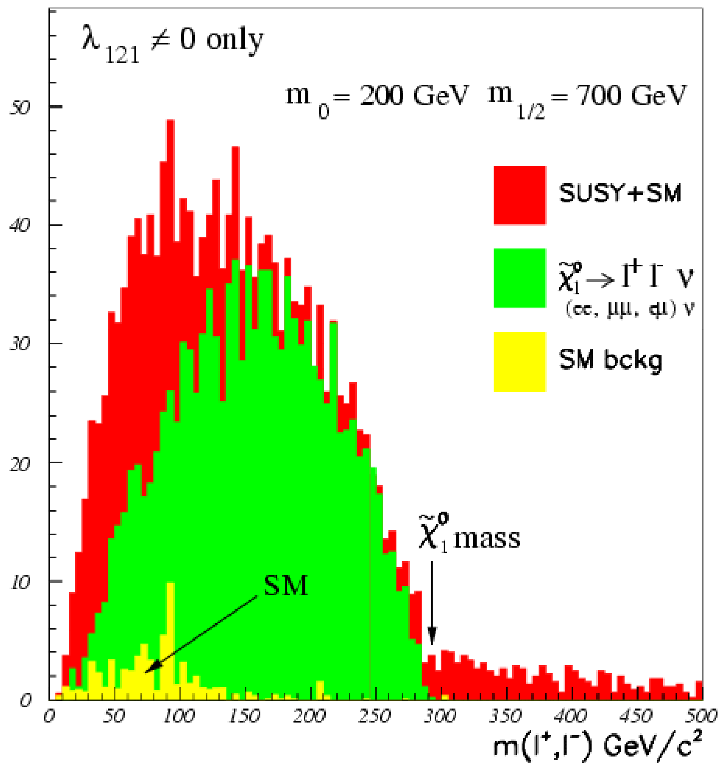
R-Parity Violating SuSY

Example! No real recent experimental studies

Selection of 3 isolated leptons + 2 jets

10 fb^{-1}





⇒ Discovery of squark/sleptons up to ~ 2 TeV with 10 fb^{-1}

Early Top-quark events

Can we observe an early top signal with limited detector performance ?
And use it to understand detector and physics ?

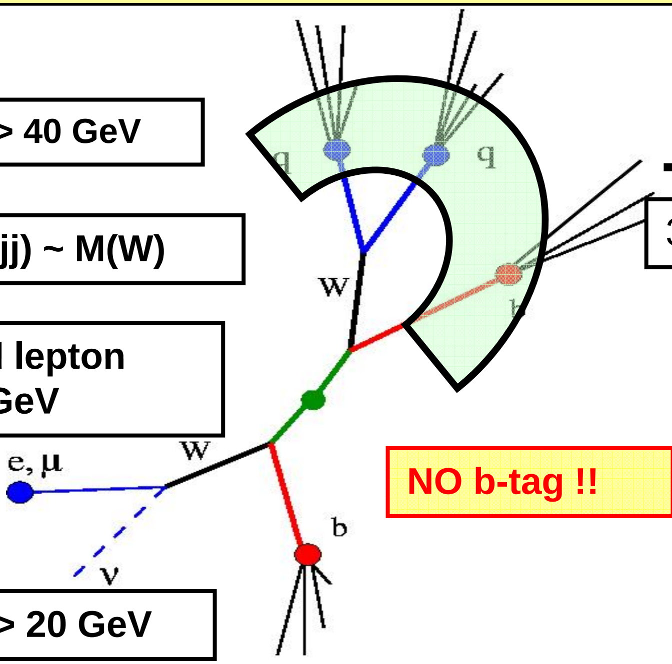
$\sigma_{tt} \approx 250$ pb for $tt \rightarrow bW\, bW \rightarrow bl\nu\, bjj$

4 jets p_T> 40 GeV

2 jets M(jj) ~ M(W)

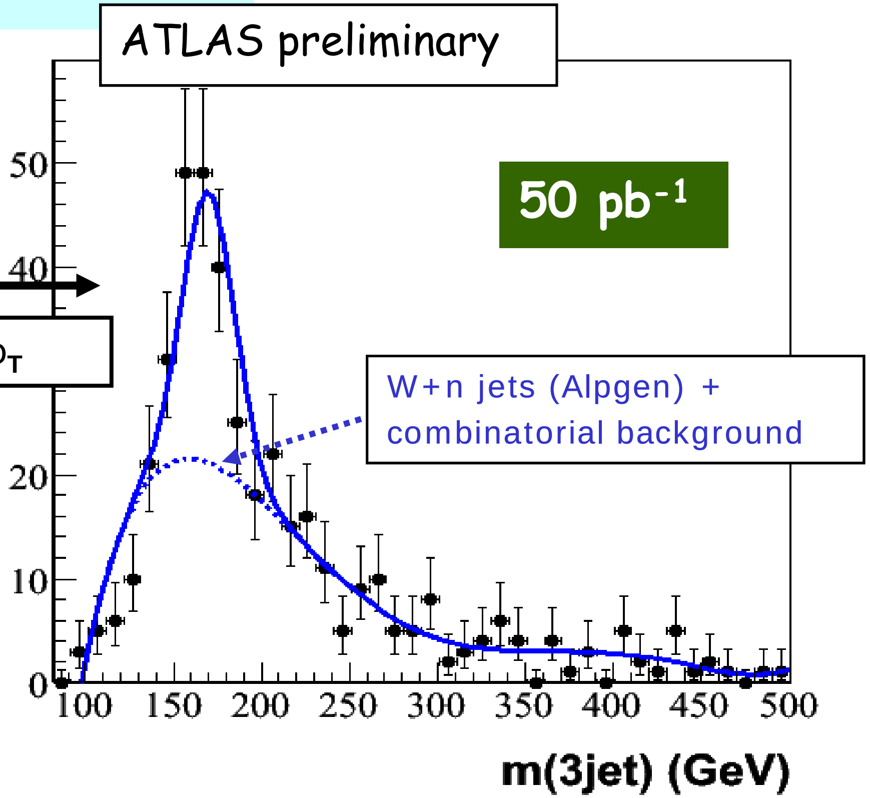
Isolated lepton
p_T> 20 GeV

E_T^{miss} > 20 GeV



3 jets with largest $\sum p_T$

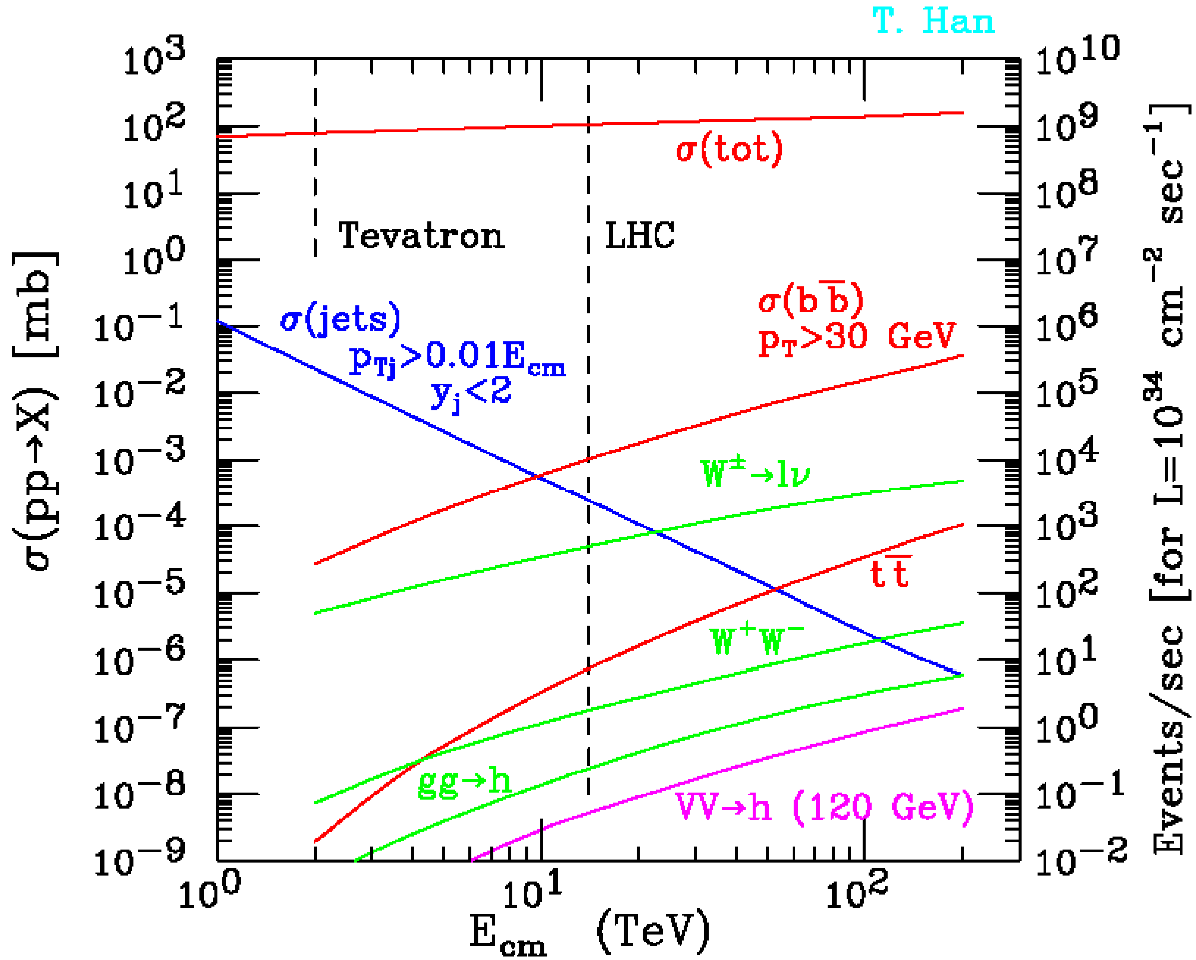
NO b-tag !!



Top signal observable in early days with no b-tagging and simple analysis
(100 ± 20 evts for 50 pb^{-1}) → measure σ_{tt} to 20%, m to 10 GeV with ~100 pb^{-1} ?
- commission b-tagging, set jet E-scale using W → jj peak
- understand detector performance for e, μ, jets, b-jets, missing E_T, …
- understand / constrain theory and MC generators using e.g. p_T spectra

Top Quarks at the LHC

The LHC is a top factory: 1 Hz at startup luminosity
Cross section rises factor 10 faster than W/Z



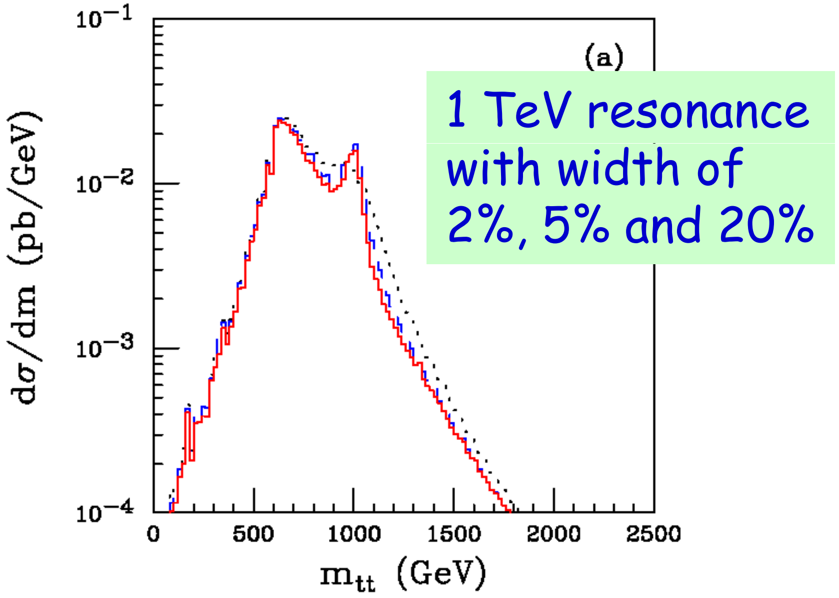
Top: a window to new physics

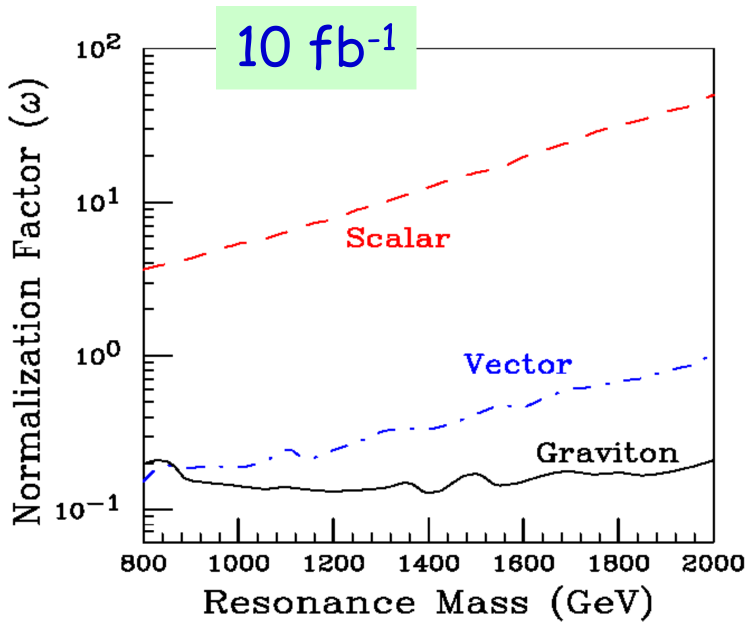
- Largest Yukawa coupling (proportional to $m_t, \cot\beta$):
  $H,\ A \to t\bar{t}$.
- Strong Dynamics (TC, Topcolor/Top See-Saw, Little Higgs):
  $\rho_{TC},\ \eta_{TC},\ \pi_{TC},\ Z_L \to t\bar{t}$.
- Extra-dimensions (warped and universal):
  $g_{KK},\ G_{KK} \to t\bar{t}$.
- Supersymmetry ($\tilde{t}$ often the lightest squark):
  $\tilde{t}_R \to t\tilde{\chi}^0$.
- LH with T-parity (theories with naturalness argument):
  $T \to tA^0$.
- ... ...
- Representative features:

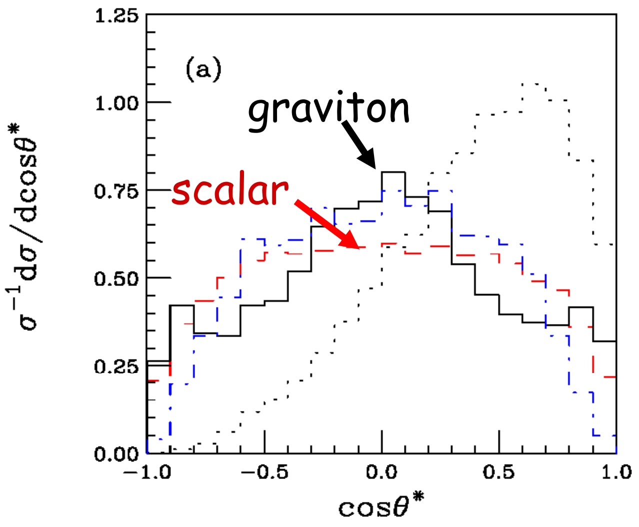
Model Class	Spin-0	Spin-1	Spin-2
Technicolor/Topcolor/RS	× (nrw/brd)	× (nrw/brd)	× (narrow)
MSSM	× (narrow)		
Little Higgs	× (narrow)	× (narrow)	

T. Han
Princeton

t-tbar Resonances





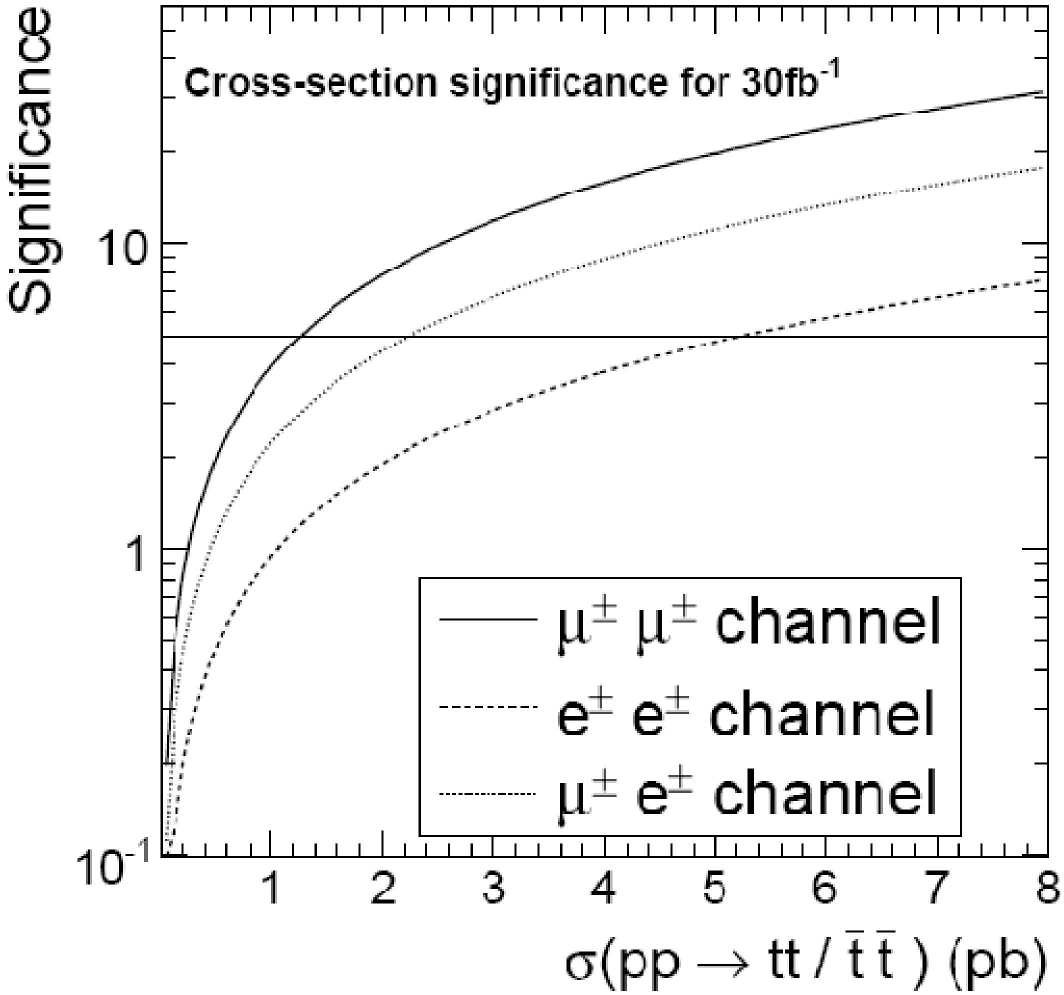


- Largest Yukawa coupling (proportional to $m_t, \cot\beta$): $H,\ A \to t\bar{t}$.
- Strong Dynamics (TC, Topcolor/Top See-Saw, Little Higgs): $\rho_{TC},\ \eta_{TC},\ \pi_{TC},\ Z_L \to t\bar{t}$.
- Extra-dimensions (warped and universal): $g_{KK},\ G_{KK} \to t\bar{t}$.

Spin analysis from polar angular distributions of the top quark in the resonance c.m. frame

Barger, Han, Walker
Hep-ph/0612016

Same sign top search



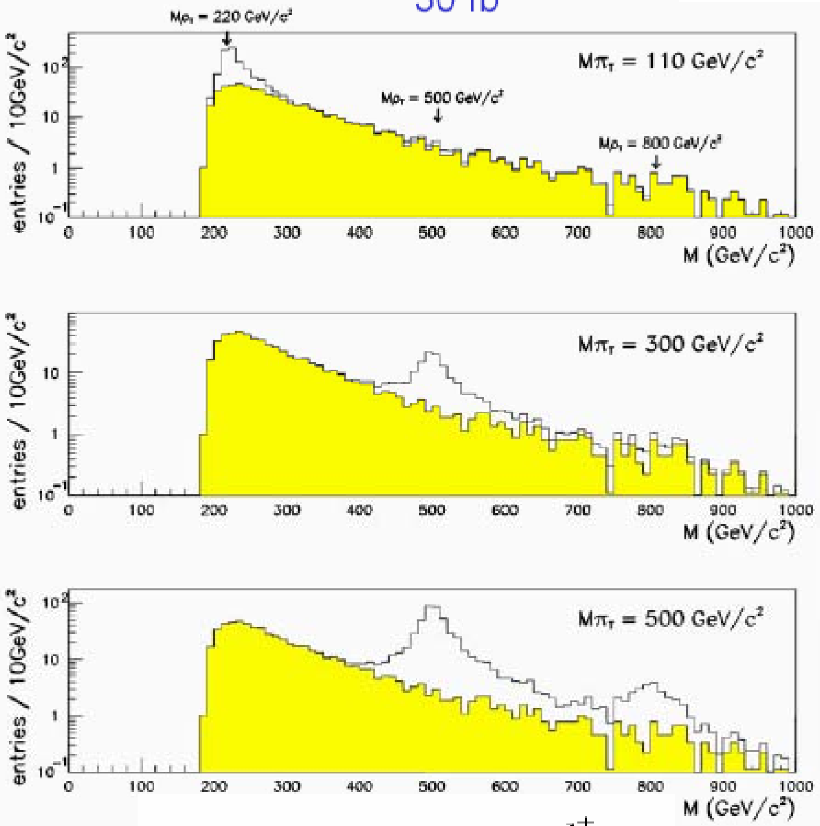
Significance of a same sign top excess over SM background as function of the cross section

Technicolor

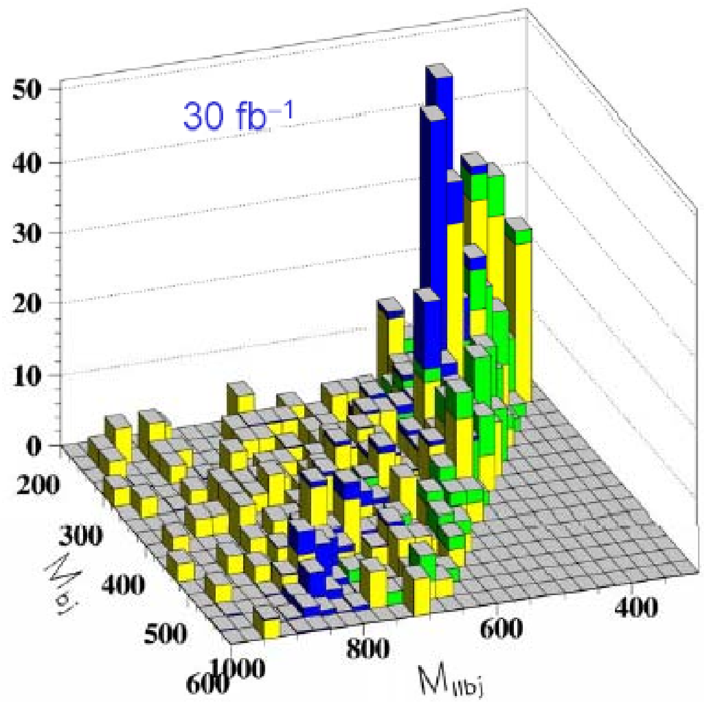
Technicolor: leptons or leptons +jets

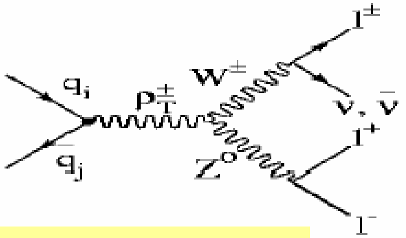
ATL-PHYS-99-020

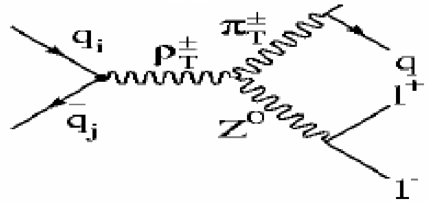
30 fb^{-1}



results depend on parameters







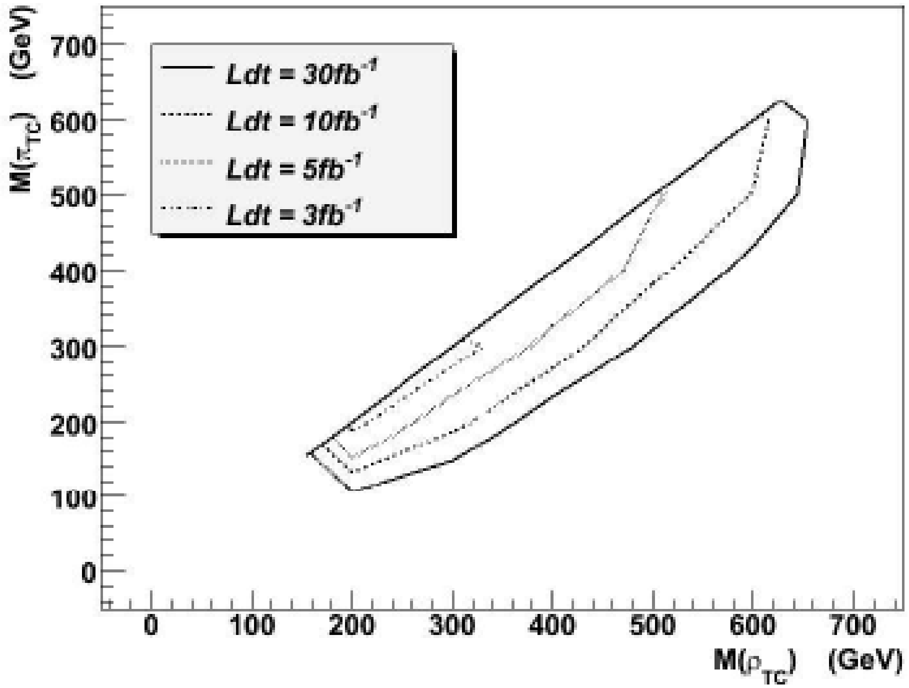
3-lepton channel

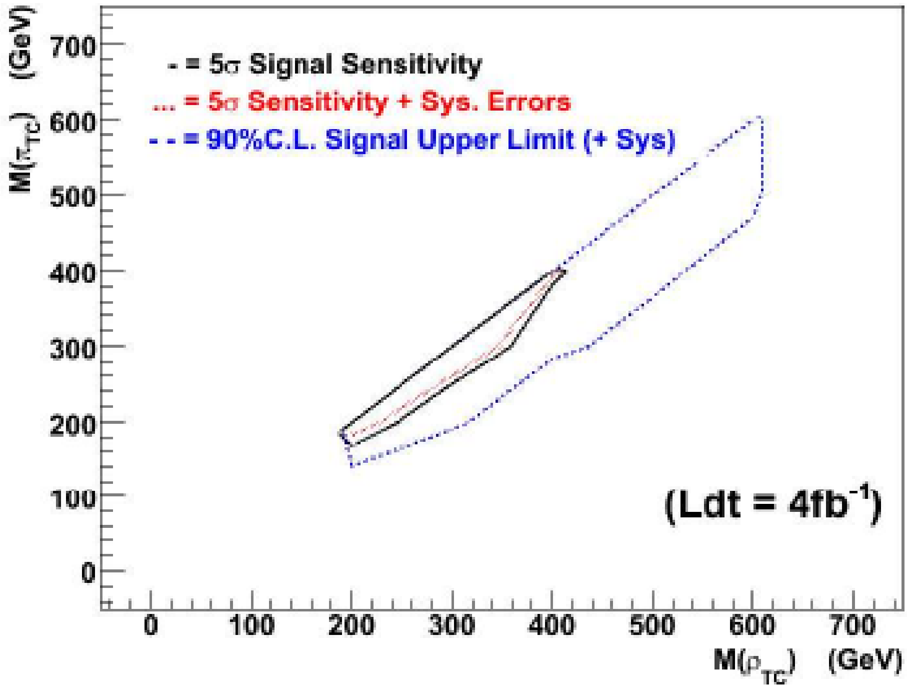
2 leptons+2jets channel

Technicolor

5σ sensitivity curves for $\rho_{TC} \rightarrow W+Z \rightarrow$ leptons channel

Technicolor Straw Man model



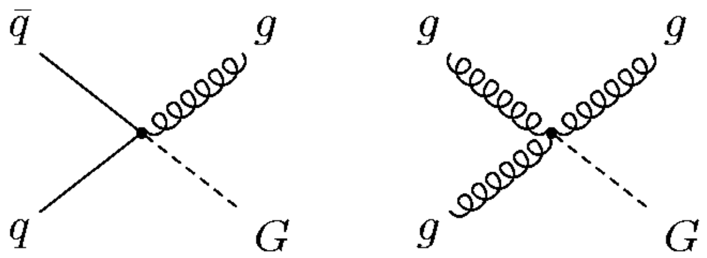


Sensitivity starting from a few fb^{-1} of data

CMS PTDR

Photon Signals: Eg. Extra Dimensions

ADD: Arkani –Ahmed, Dimopolous,Dvali

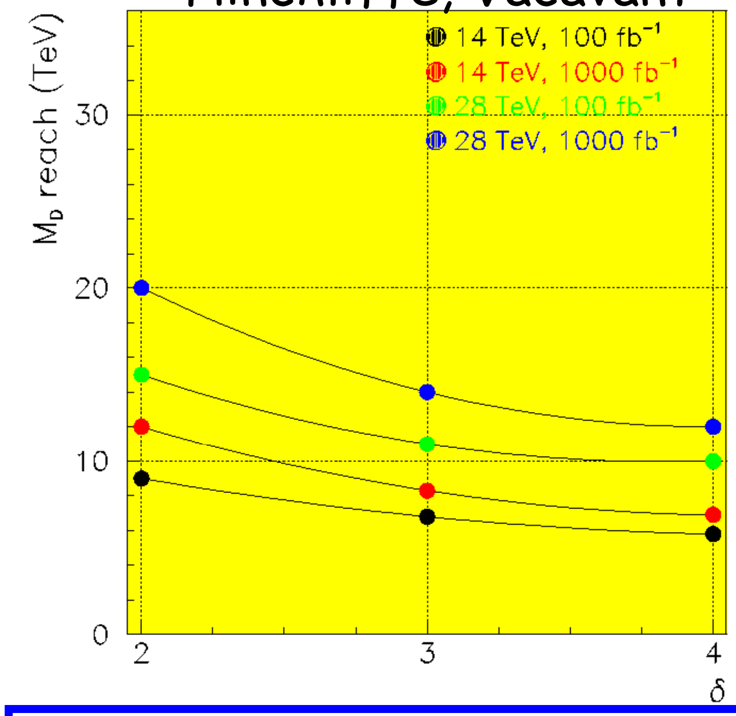


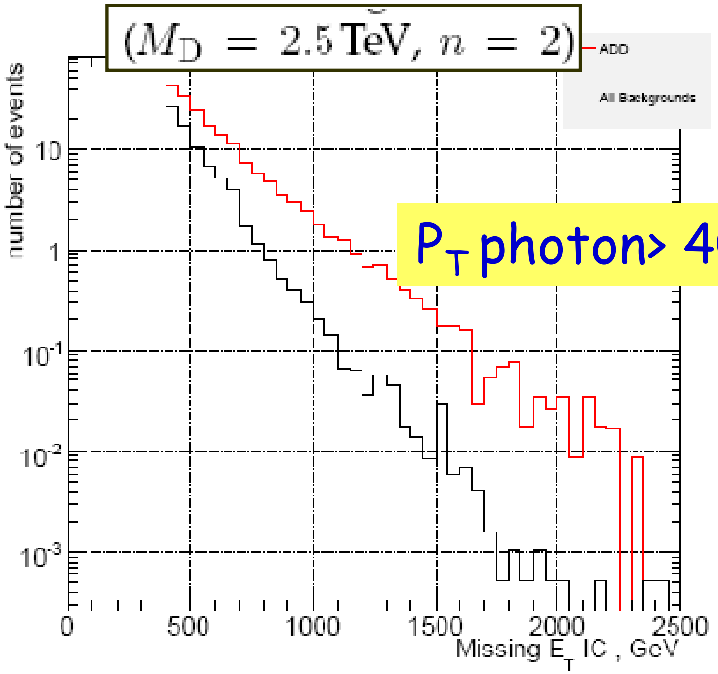
Graviton production!
Graviton escapes detection

Signal: single jet + large missing ET

Signal: single photon + large missing ET

Hinchliffe, Vacavant





30fb^{-1}

P_T photon> 400 GeV

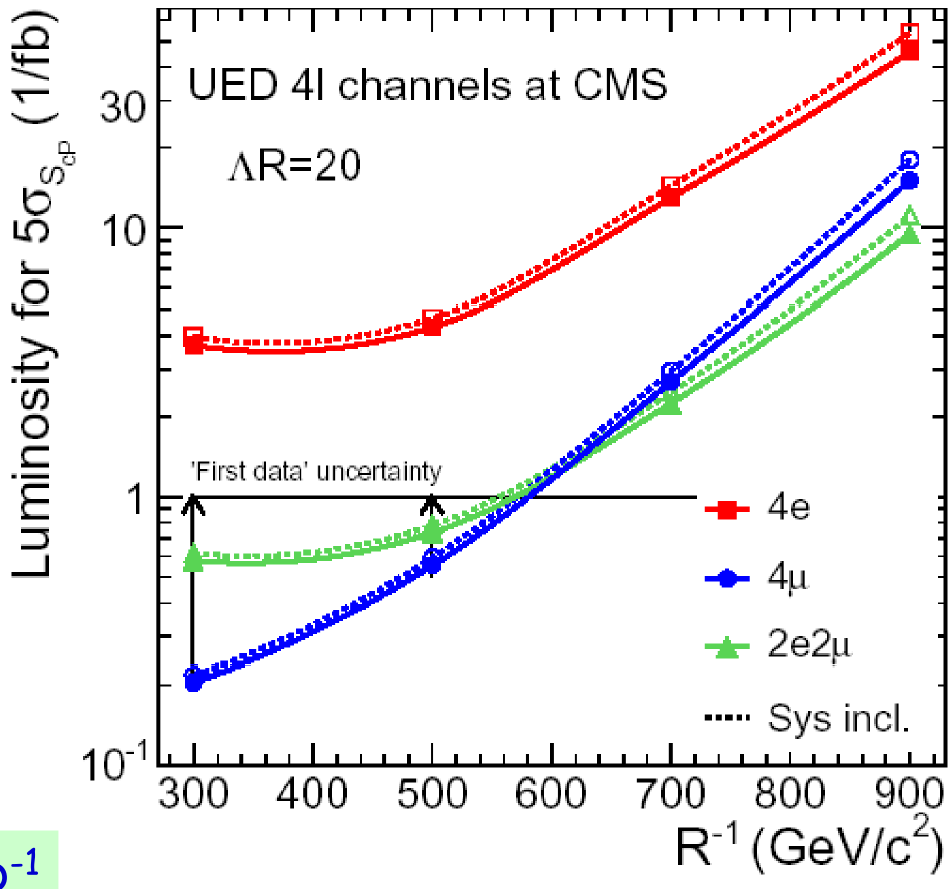
Test M_D to 7-9 TeV for 100 fb^{-1}

Test M_D to ~ 4 TeV for 100 fb^{-1}
~2.5 TeV for 10 fb^{-1}

Universal Extra Dimensions

4 lepton channel

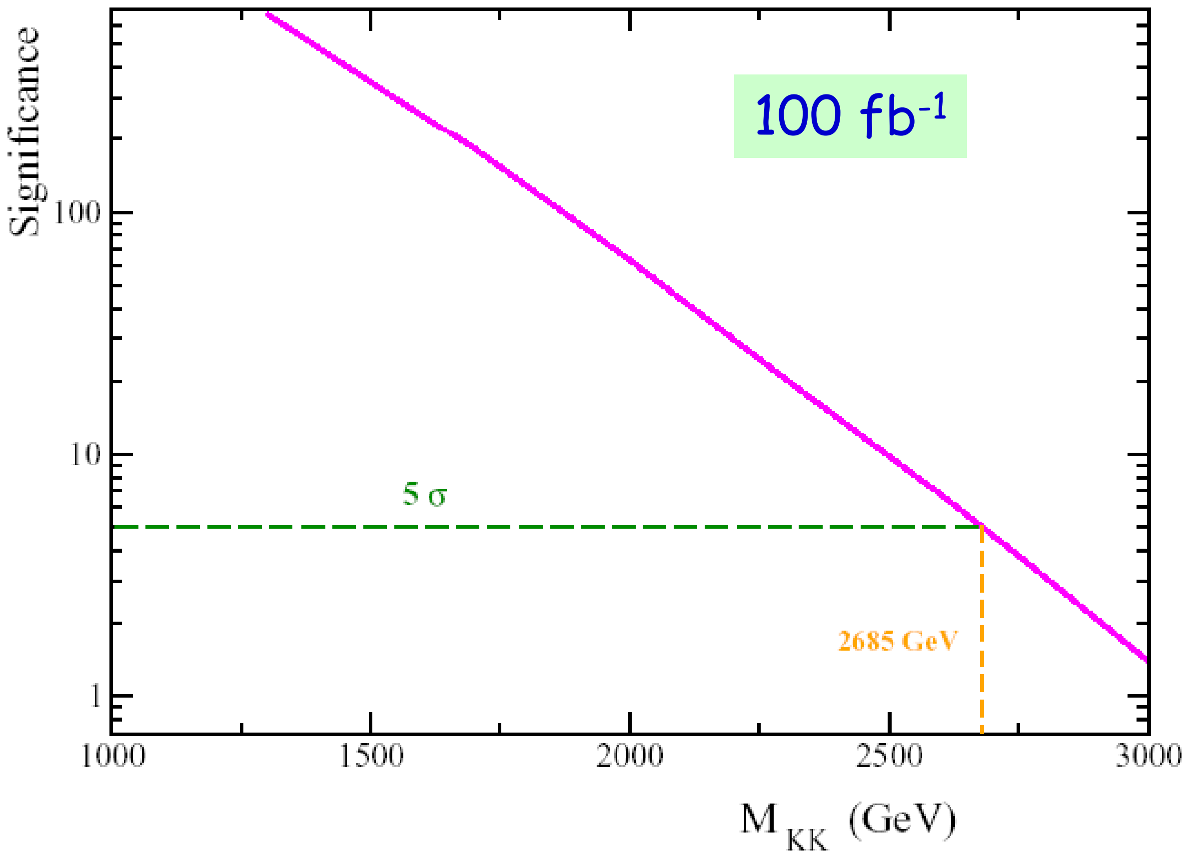
R^{-1}	σ_{Signal} (fb)	σ_B (fb)	N_{Signal} @30/fb	$N_{Background}$ @30/fb	S/B @30/fb	S_{12} @30/fb	$\mathcal{L}$ (1/fb) $S_{cP}=5\sigma$
4 electrons channel							
300	1.33E+0	6.75E-3	40	$1.10 \pm 0.22^{TH} \pm 0.06^{EXP}$	36	11	3.7 – 4.0
500	1.19E+0		35.7		32	10 – 9.8	4.3 – 4.6
700	5.13E-1		15.9		14	6.2 – 5.9 (7.7 – 7.3)*	13 – 14
900	2.23E-1		6.7		6.1	3.5 – 3.3 (4.0 – 3.7)*	46 – 54
4 muons channel							
300	1.72E+1	1.35E-1	517	$4.06 \pm 0.81^{TH} \pm 0.25^{EXP}$	126	42 – 41	< 1
500	7.79E+0		234		57	27 – 26	< 1
700	2.38E+0		71.4		17	13	2.7 – 3.0
900	7.28E-1		21.8		5.3	6.1 – 5.7 (7.1 – 6.5)*	15 – 18
2 electrons 2 muons channel							
300	7.86E+0	1.60E-1	236	$4.80 \pm 0.96^{TH} \pm 0.28^{EXP}$	49	27 – 26	< 1
500	6.53E+0		196		41	24 – 23	< 1
700	2.84E+0		85.1		18	15 – 14	2.2 – 2.5
900	1.04E+0		31.2		6.5	7.6 – 7.2	9.5 – 11



Reach ~900 GeV for R^{-1} with 10 fb^{-1}

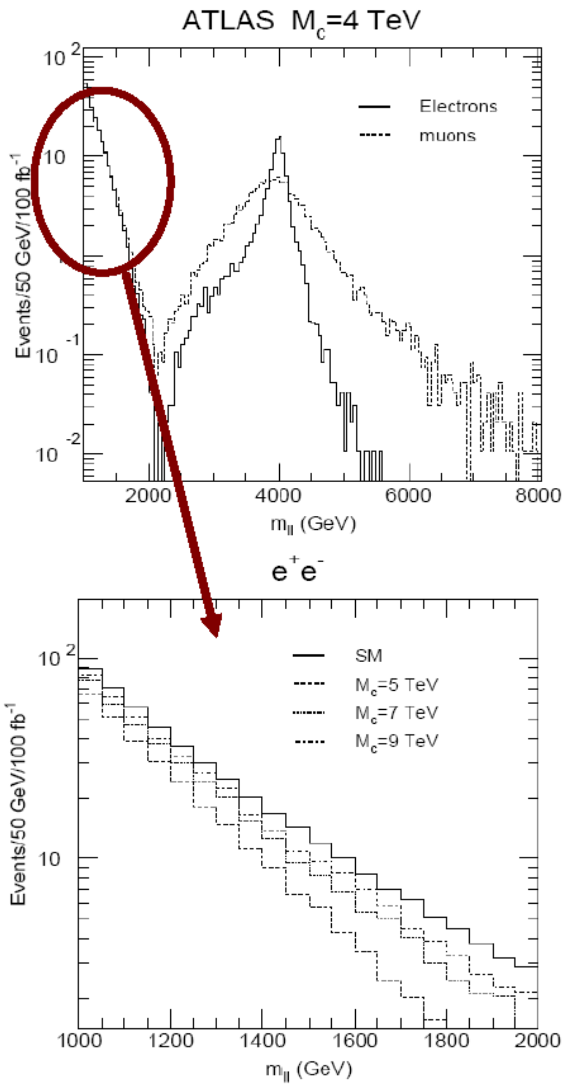
Universal Extra Dimensions

Dijet + Missing E_T final state



Sensitive to KK states with M ~ 2 TeV with 10 fb^{-1}

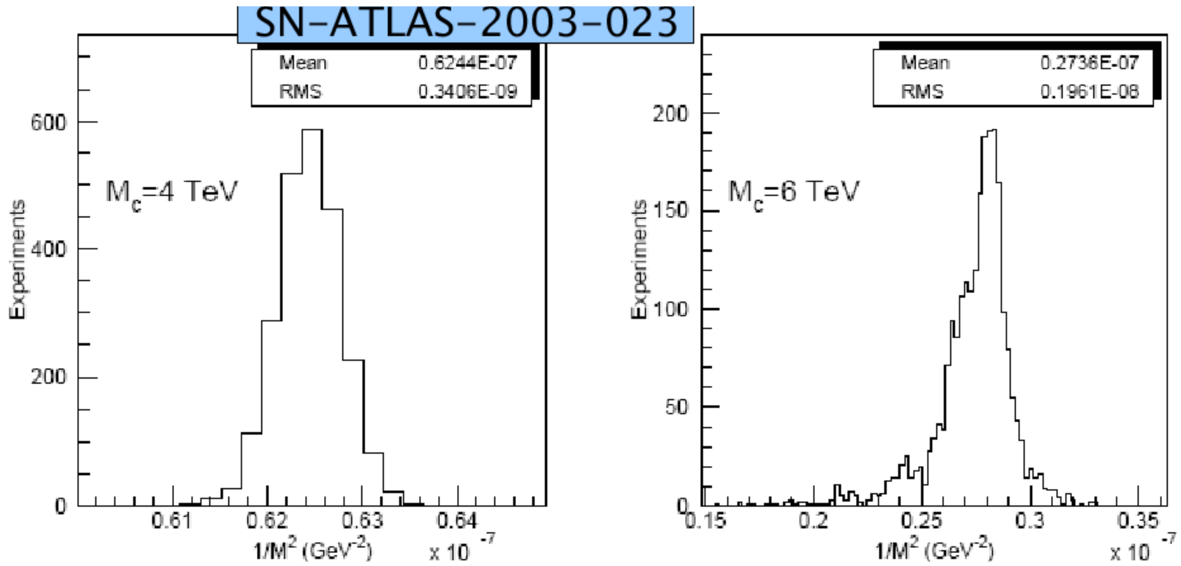
Indirect Search for Heavy Resonances



Tev^{-1} Extra Dimensions

Kaluza Klein excitations of a gauge boson
Interference with the DY SM process modifies the high mass di-lepton spectrum

Direct:	600 fb^{-1}	6 TeV
Interference :	600 fb^{-1}	16 TeV

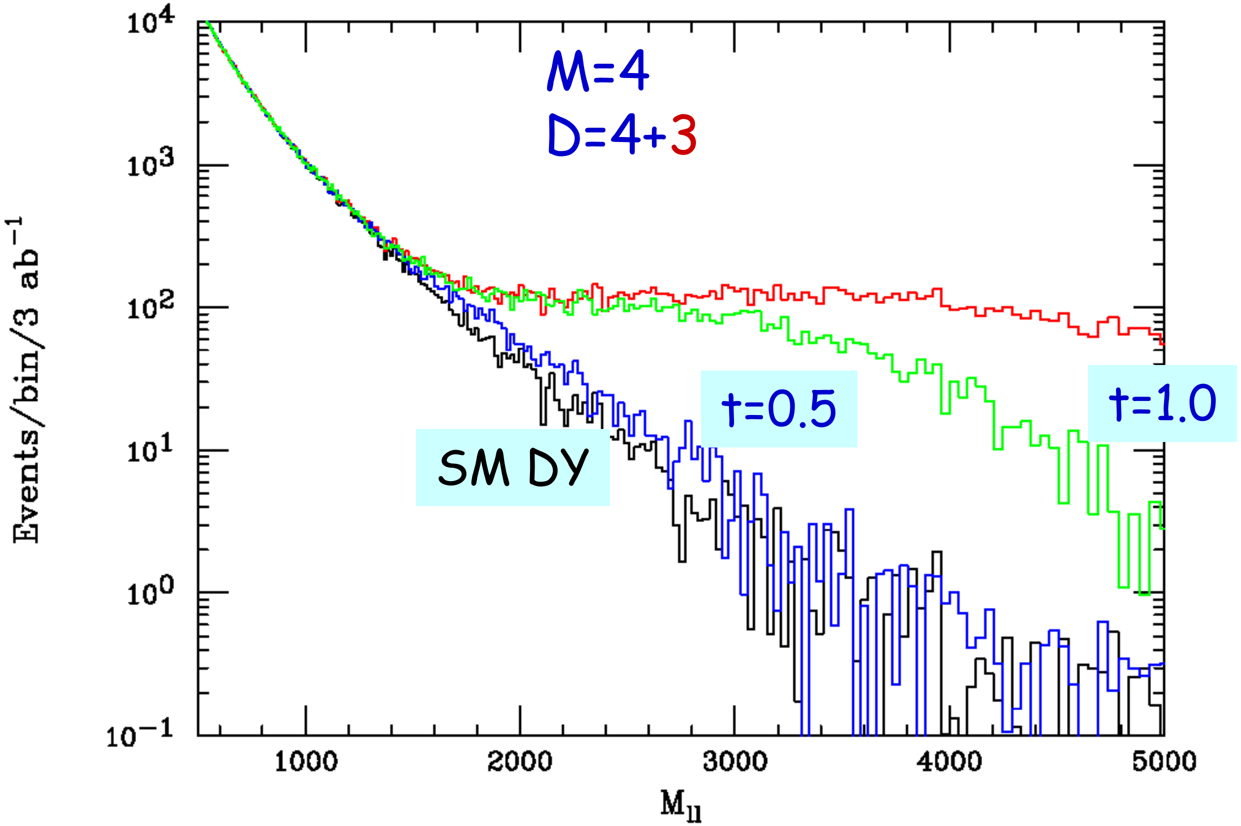


ADD with running gravitational couplings

New!

Signatures for a running gravitational coupling in ADD scenario of extra dimensions: virtual graviton exchange

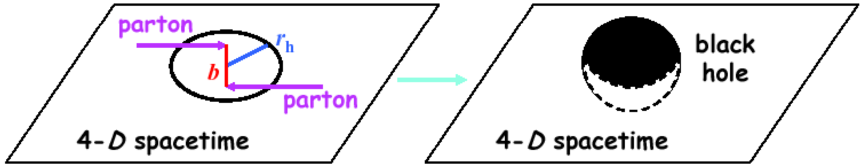
Put a form factor in the graviton KK coupling
$M^{D-2} \rightarrow M^{D-2}[1+q^2/t^2M^2]^{-1}$

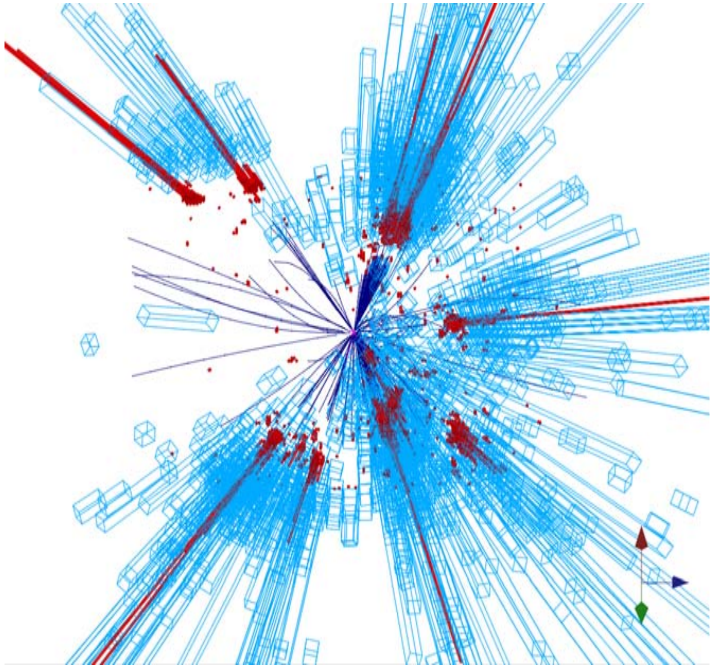


Hewett, Rizzo
to appear

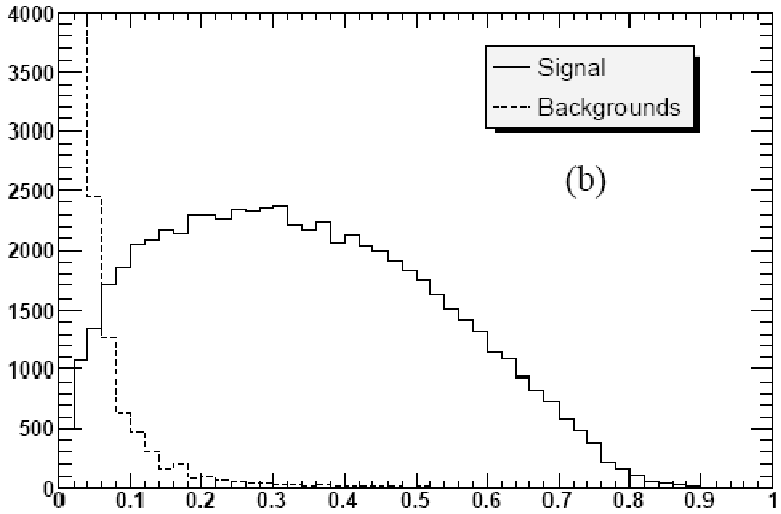
Black Holes Production

If the Planck scale in ~TeV region: can expect Black Hole production





Simulation of a black hole event with M_{BH} ~ 8 TeV in CMS

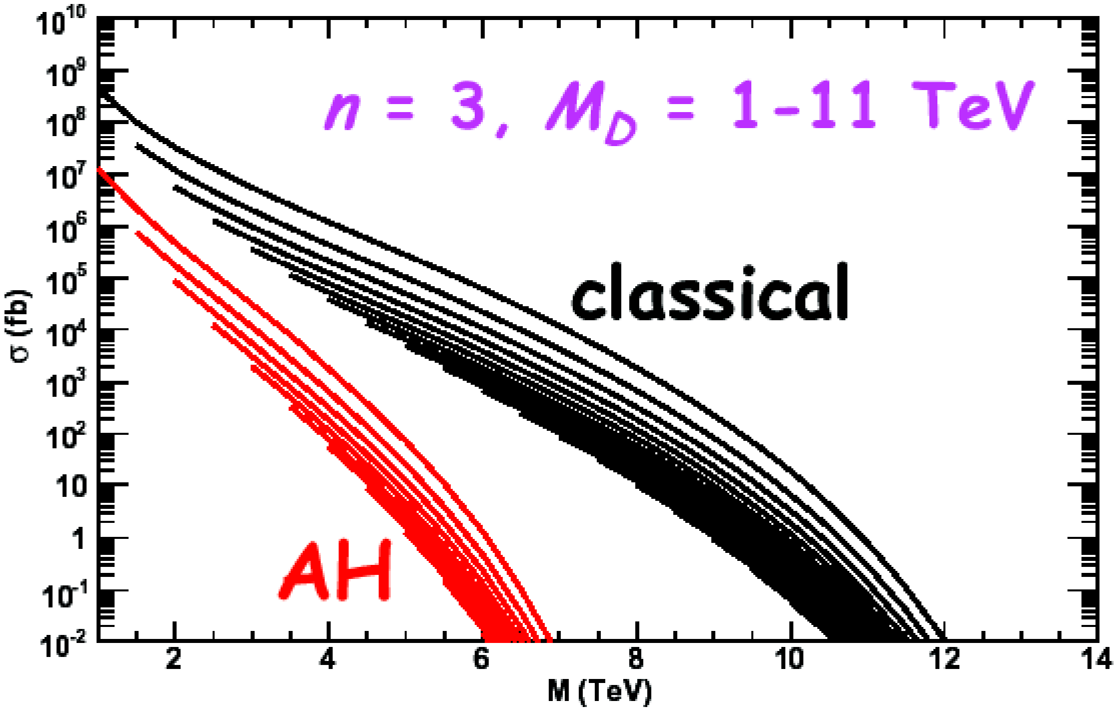


~ Spherical events: Many high energy jets leptons, photons etc.

Quantum Gravity in the lab?

Black Holes

Warning: cross section could be much less than optimistic estimates



$$\sigma_{BH} \sim \pi r_h^2$$

For 10 fb^{-1}

- Classical approximation to cross-section: large! Black Holes up to 8-10 TeV
- Apparent horizon (AH), not all energy trapped; see eg. hep-ph/0609055 Black holes up to 4-5 TeV

Heavy Leptons

C. Alexa

ATL-PHYS-2003-014

backgrounds:
ttbar, WW, WZ, ZZ

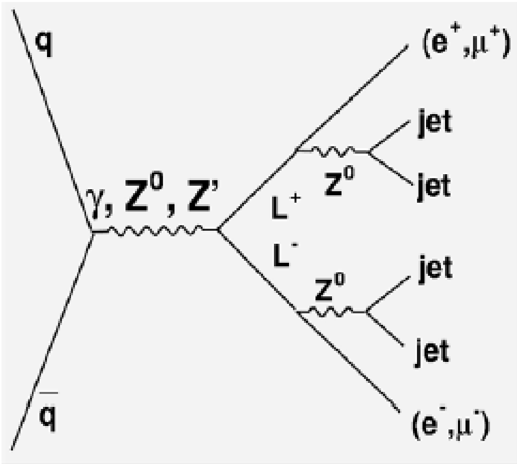
also:
6-lepton channel

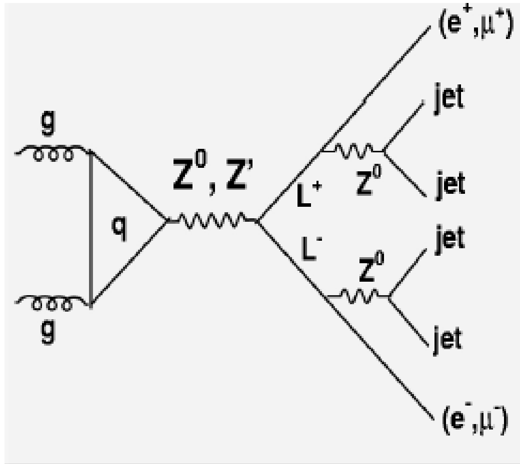
Experimental considerations:
- high energy leptons, jets

Systematics:
- large NLO corrections

conclusion:

ATLAS can discover sequential charged heavy leptons up to
M_L = 0.9 / 1.0 TeV
(low/high luminosity)





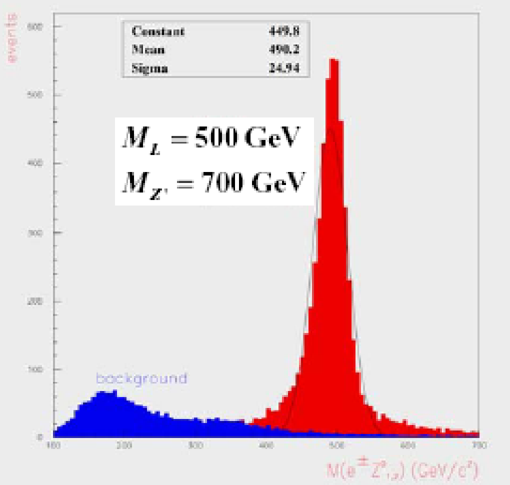
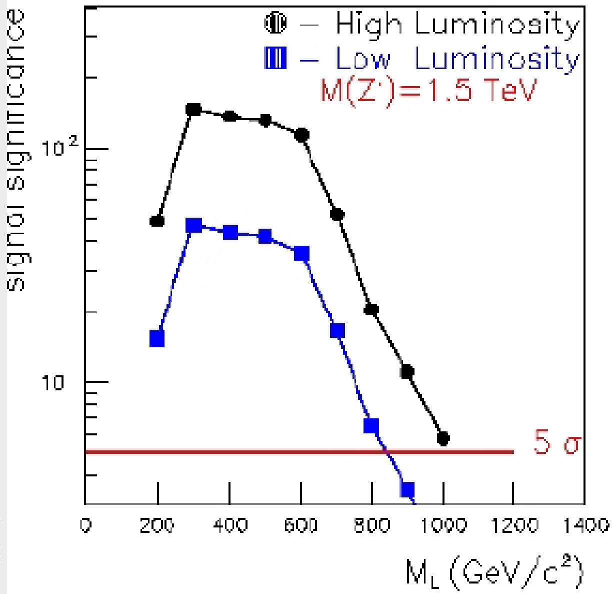
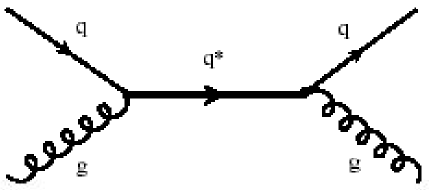


Figure 13: Signal to background comparison for $M_L = 0.5\ TeV/c^2$ and $M_{Z'} = 0.7\ TeV/c^2$, for $L \to e + Z^0$ channel.



G. Azuelos

Excited Quarks

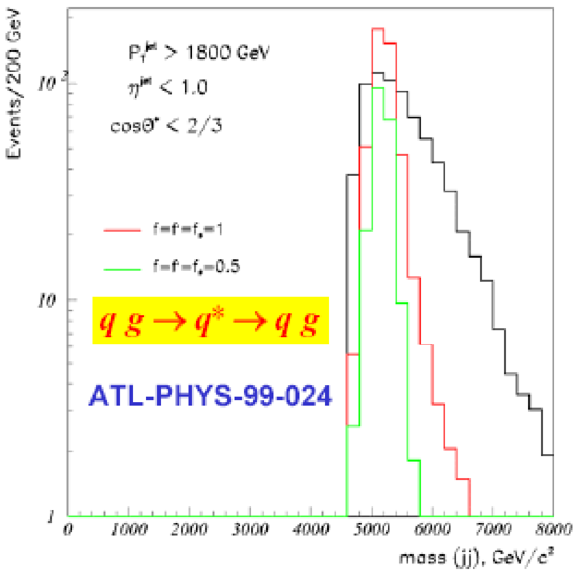


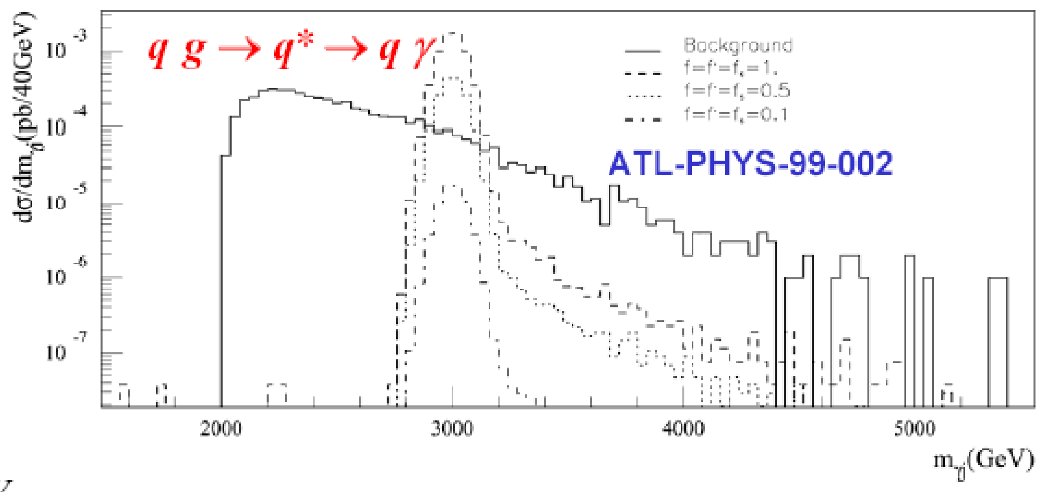
$$L = \frac{1}{2\Lambda}\bar{q}^*_R \sigma^{\mu\nu}\left(g_s f_s G^a_{\mu\nu} + g\, f \frac{\tau}{2} W_{\mu\nu} + g' f' \frac{Y}{2} B_{\mu\nu}\right) q_L + h.c.$$

take as reference : $\Lambda = m^*,\quad f_s = f = f' = 1$

O. Çakir, C. Leroy, R. Mehdiyev,
ATL-PHYS-2002-014

m^*(GeV)	Δm_{jj}(GeV)	S	B	S/B	$S/\sqrt{B}$
1000	170	12396806	16870000	0.73	3018
2000	320	858214	525000	1.63	1184
3000	445	37635	23500	1.60	245
5000	705	601	325	1.85	33
6000	880	75	60	1.25	9.6





Also : $q^* \to qZ;\quad q^* \to \bar{q}'W$

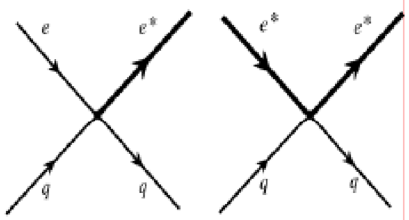
Reach ~ 3-5 TeV quarks with 10 fb^{-1}

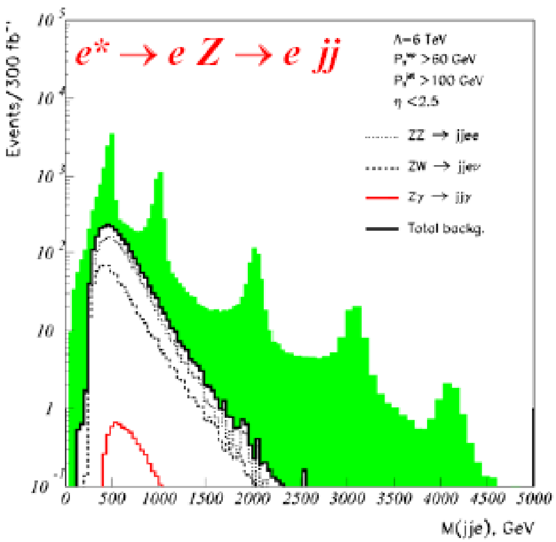
G. Azuelos

Excited leptons

G. Azuelos

contact interaction : $L_C = \frac{g_*^2}{2\Lambda^2} J_\mu J^\mu$

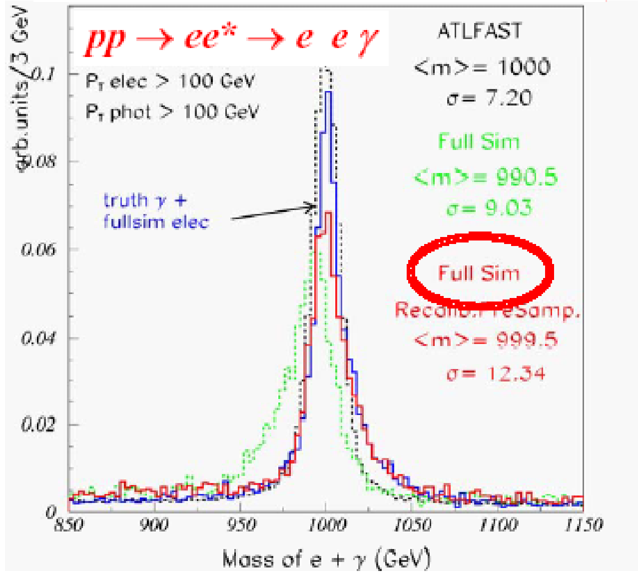




Experimental considerations:
- high energy e, γ
- $Z \to jj$, $W \to jj$

L = 300 fb^{-1}, Λ = 6 TeV

$m^* \to$	500	1 TeV	2 TeV	3 TeV	4 TeV
$q\bar{q} \to e^\star e \to Zee \to eeee$					
ΔM, GeV	20	38	63	84	
S	242	121	17	2	
S/B	25	76	283	333	
$S/\sqrt{B}$	77	96	69	26	
$q\bar{q} \to e^\star e \to Zee \to eejj$					
ΔM, GeV	40	60	106	180	200
S	4725	2388	358	54	6
S/B	3	16	48	67	-
$S/\sqrt{B}$	121	192	131	60	-



Reach ~ 2 TeV for 10 fb^{-1}

Recent Studies: New Signatures

Arkani-Hamed, Dimopoulos hep-th/0405159

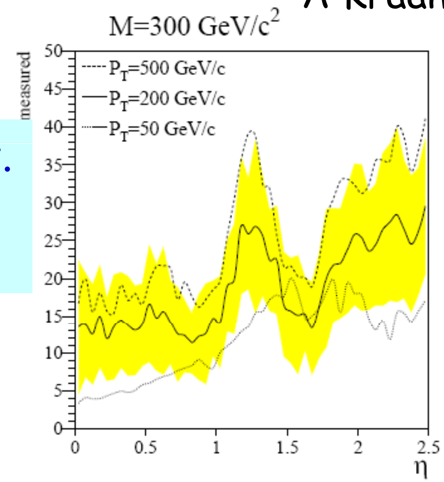
Split Supersymmetry

- Assumes nature is fine tuned and SUSY is broken at some high scale
- The only light particles are the Higgs and the gauginos
  - Gluino can live long: sec, min, years!
  - R-hadron formation: slow, heavy particles containing a heavy gluino.

  Unusual interactions with material

  eg. with the calorimeters of the experiments!

A Kraan

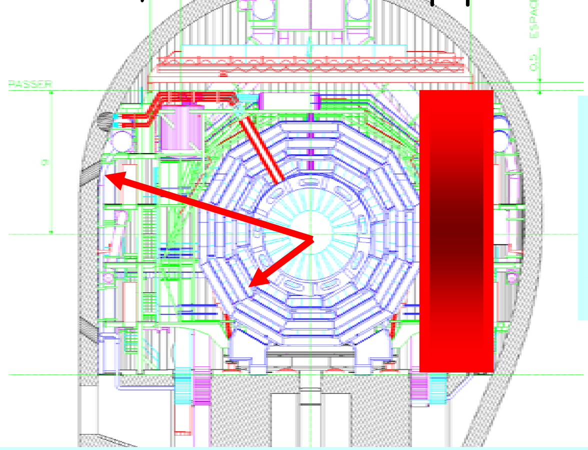


Energy fract. deposited in calorimeter

Gravitino Dark Matter and GMSB

- In some models/phase space the gravitino is the LSP
- Then the NLSP (neutralino, stau lepton) can live 'long'

K. Hamaguchi,M Nojiri,ADR hep-ph/0612060
ADR, J. Ellis et al. hep-ph/0508198



~ 1000 events per year

Sparticles stopped in the detector,walls of the cavern, or dense 'stopper' detector. They decay after hours---months…

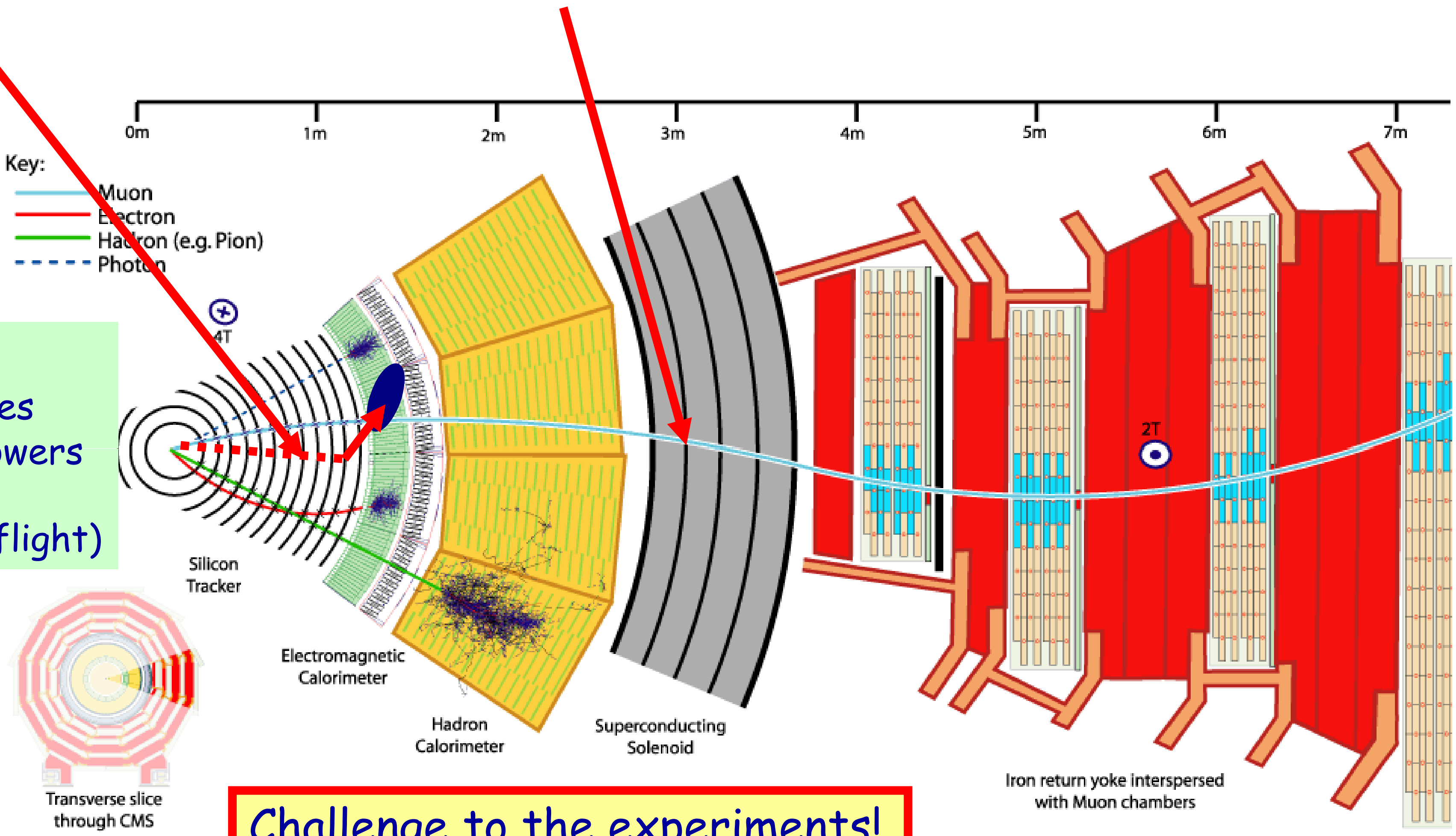
⇒Challenge to the experiments!

Recent Studies: Special signatures

Eg. $\chi \rightarrow \gamma$+ gravitino   or heavy (slow) stau slepton

GMSB or
GDM models

Signatures
- Displaced vertices
- Non-pointing showers
- Long lived 'heavy muons' (time of flight)



Challenge to the experiments!

Stable Massive Particles

SMP	LSP	Scenario	Conditions
$\tilde{\tau}_1$	$\tilde{\chi}_1^0$	MSSM	$\tilde{\tau}_1$ mass (determined by $m^2_{\tilde{\tau}_{L,R}}$, μ, $\tan\beta$, and A_τ) close to $\tilde{\chi}_1^0$ mass.
	$\tilde{G}$	GMSB	Large N, small M, and/or large $\tan\beta$.
		$\tilde{g}$MSB	No detailed phenomenology studies, see [23].
		SUGRA	Supergravity with a gravitino LSP, see [24].
	$\tilde{\tau}_1$	MSSM	Small $m_{\tilde{\tau}_{L,R}}$ and/or large $\tan\beta$ and/or very large A_τ.
		AMSB	Small m_0, large $\tan\beta$.
		$\tilde{g}$MSB	Generic in minimal models.
$\tilde{\ell}_{i1}$	$\tilde{G}$	GMSB	$\tilde{\tau}_1$ NLSP (see above). $\tilde{e}_1$ and $\tilde{\mu}_1$ co-NLSP and also SMP for small $\tan\beta$ and μ.
	$\tilde{\tau}_1$	$\tilde{g}$MSB	$\tilde{e}_1$ and $\tilde{\mu}_1$ co-LSP and also SMP when stau mixing small.
$\tilde{\chi}_1^+$	$\tilde{\chi}_1^0$	MSSM	$m_{\tilde{\chi}_1^+} - m_{\tilde{\chi}_1^0} \lesssim m_{\pi^+}$. Very large $M_{1,2} \gtrsim 2$ TeV $\gg |\mu|$ (Higgsino region) or non-universal gaugino masses $M_1 \gtrsim 4M_2$, with the latter condition relaxed to $M_1 \gtrsim M_2$ for $M_2 \ll |\mu|$. Natural in O-II models, where simultaneously also the $\tilde{g}$ can be long-lived near $\delta_{GS} = -3$.
		AMSB	$M_1 > M_2$ natural. m_0 not too small. See MSSM above.
$\tilde{g}$	$\tilde{\chi}_1^0$	MSSM	Very large $m^2_{\tilde{q}} \gg M_3$, e.g. split SUSY.
	$\tilde{G}$	GMSB	SUSY GUT extensions [25–27].
	$\tilde{g}$	MSSM	Very small $M_3 \ll M_{1,2}$, O-II models near $\delta_{GS} = -3$.
		GMSB	SUSY GUT extensions [25–29].
$\tilde{t}_1$	$\tilde{\chi}_1^0$	MSSM	Non-universal squark and gaugino masses. Small $m^2_{\tilde{q}}$ and M_3, small $\tan\beta$, large A_t.
$\tilde{b}_1$			Small $m^2_{\tilde{q}}$ and M_3, large $\tan\beta$ and/or large $A_b \gg A_t$.

Q_{em}	C_{QCD}	S	Model(s)
0	**8**	1	Universal Extra Dimensions (KK gluon)
± 1	**1**	$\frac{1}{2}$	Universal Extra Dimensions (KK lepton)
			Fat Higgs with a fat top (ψ fermions)
			4th generation (chiral) fermions
			Mirror and/or vector-like fermions
		0	Fat Higgs with a fat top (ψ scalars)
$\pm\frac{4}{3}$	**3**	$\frac{1}{2}$	Warped Extra Dimensions with GUT parity (XY gaugino)
		0	5D Dynamical SUSY-breaking (xyon)
$-\frac{1}{3},\frac{2}{3}$	**3**	$\frac{1}{2}$	Universal Extra Dimensions (KK down, KK up)
			4th generation (chiral) fermions
			Mirror and/or vector-like fermions
			Warped Extra Dimensions with GUT parity (XY gaugino)
$\epsilon < 1$	**1**	$\frac{1}{2}$	GUT with $U(1) - U(1)'$ mixing
			Extra singlets with hypercharge $Y = 2\epsilon$
			Millicharged neutrinos
?	?	$0/\frac{1}{2}/1$	"Technibaryons"

hep-ph/06110402

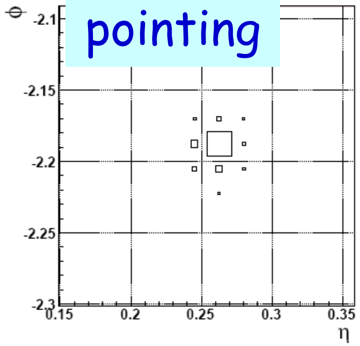
Stable Massive Particles are not a rarity at all (it seems)…

Recent analyses

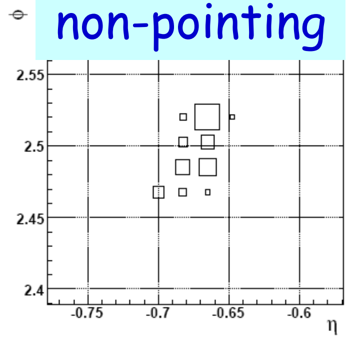
• GMSB: Non-pointing photons

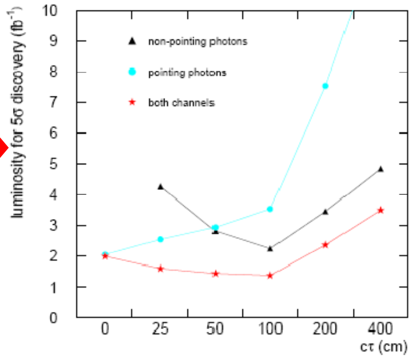
GMSB parameters $N = 1 \quad \tan\beta = 1 \quad \mathrm{sgn}\,\mu = 1 \quad M_m = 2\Lambda$

pointing



non-pointing

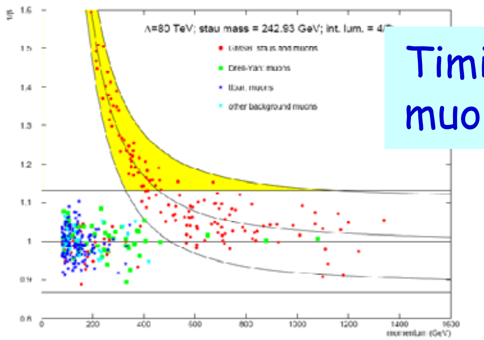




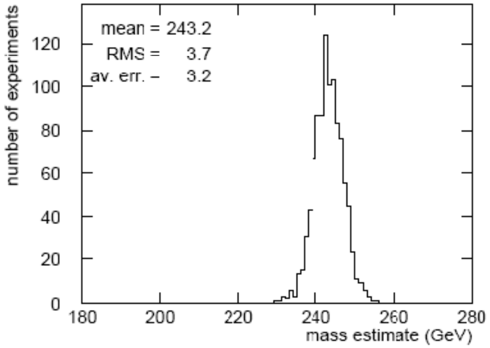
χ ct lifetime extraction with ~20% precision

• GMSB: long living staus

GMSB parameters $N = 3 \quad \tan\beta = 3 \quad \mathrm{sgn}\,\mu = 1 \quad M_m = 2\Lambda$



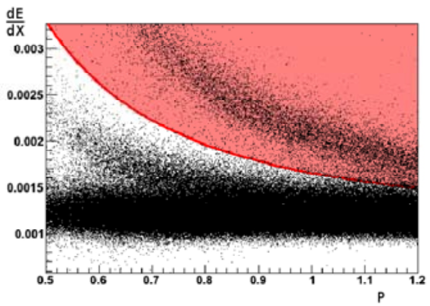
Timing (β) in muon detectors



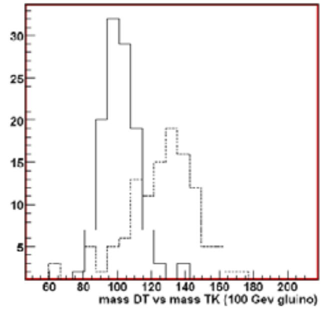
stau mass extraction with a few % precision

• R-hadrons

trigger/mass meas. for region β > 0.6



de/dx in the tracker



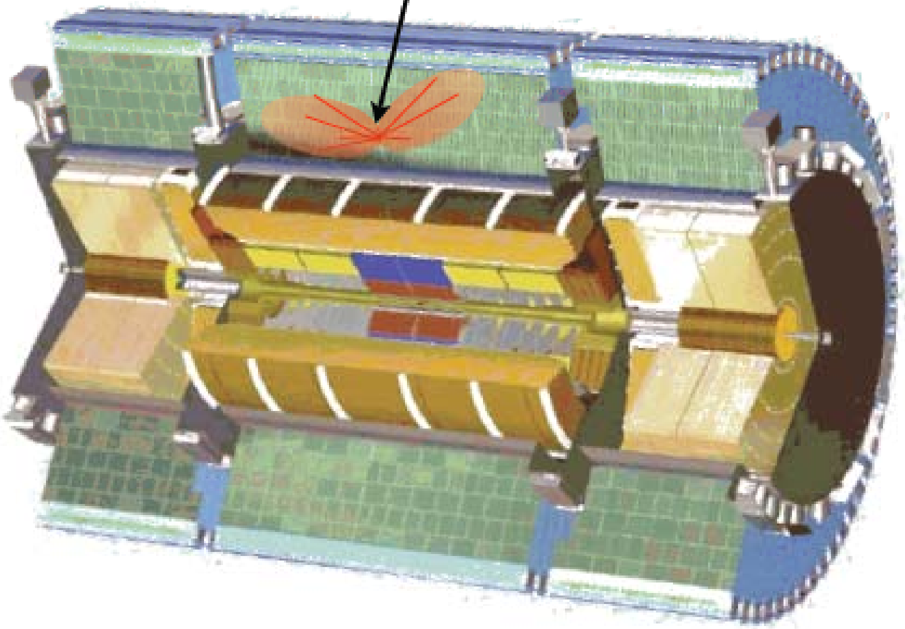
β-tracker ≠β muons

Long Lived Gluinos

$$\tau_{\tilde{g}} > 100 \text{ ns}$$

looking for stopped gluinos that later decay

100s GeV Unbalanced $= \not{E}_T$



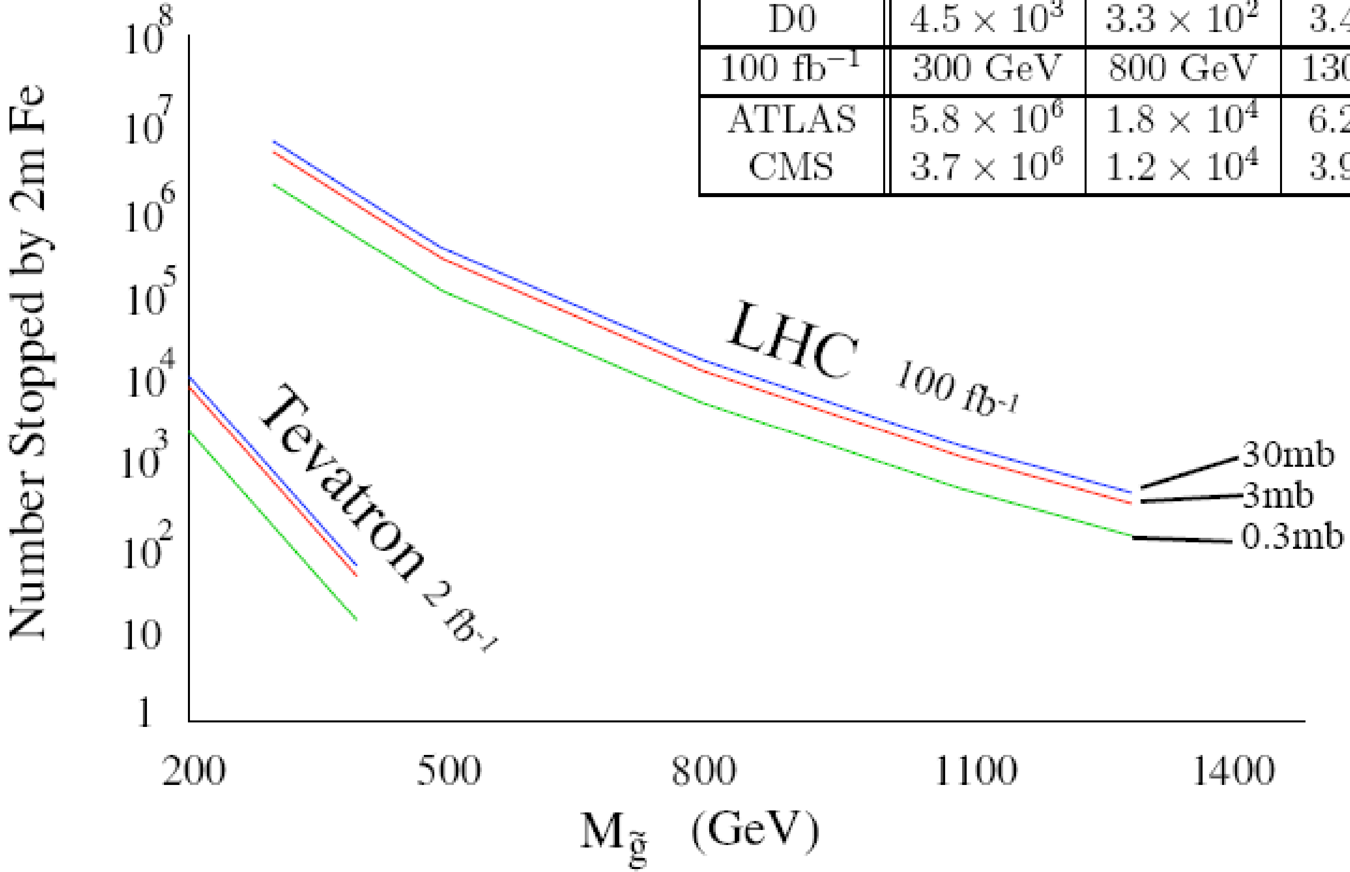
Uncorrelated with any beam crossing
No tracks going to or from activity

Split Susy

Total Number of Stopped Gluinos

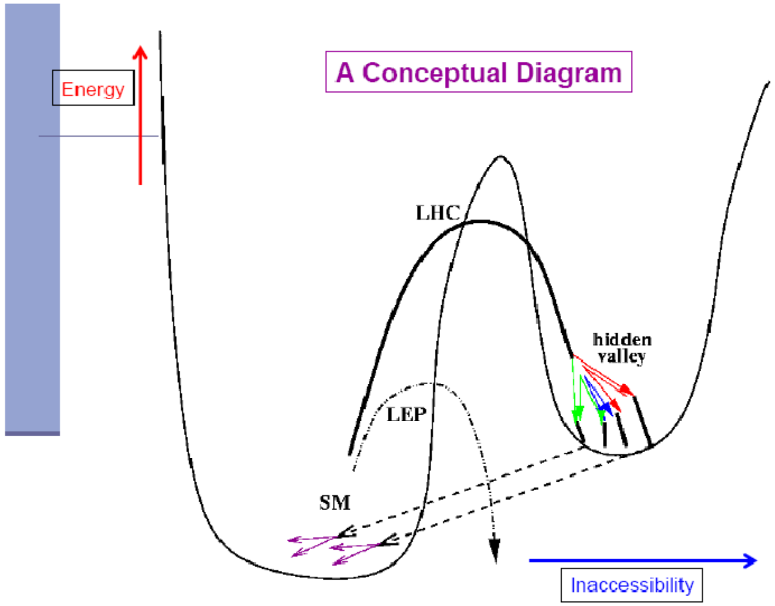
Arvanitaki, Dimopoulos, Pierce, Rajendran, JW hep-ph/0506242

$2\ \text{fb}^{-1}$	200 GeV	300 GeV	400 GeV
CDF	4.1×10^3	3.1×10^2	3.3×10^1
D0	4.5×10^3	3.3×10^2	3.4×10^1
$100\ \text{fb}^{-1}$	300 GeV	800 GeV	1300 GeV
ATLAS	5.8×10^6	1.8×10^4	6.2×10^2
CMS	3.7×10^6	1.2×10^4	3.9×10^2



J. Wacker

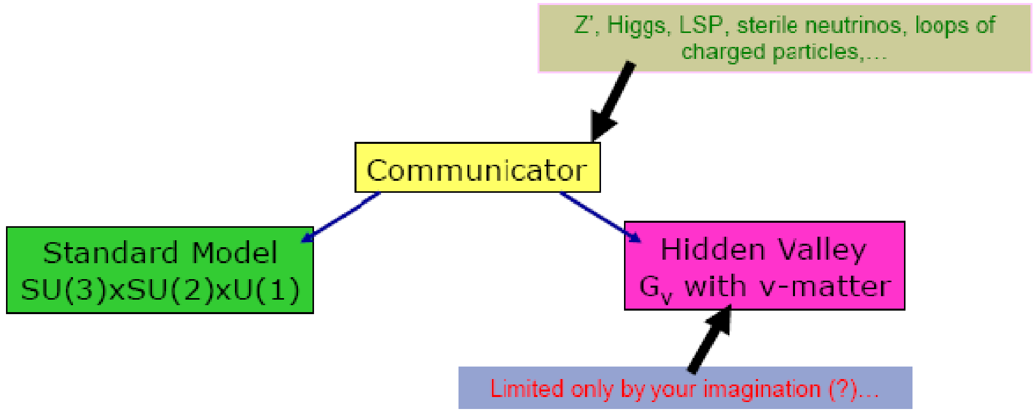
Hidden Valley Physics?



String Theory inspired (M. Strassler)

Eg. Strassler & Zurek hep-ph/0604261

- Basic minimal structure

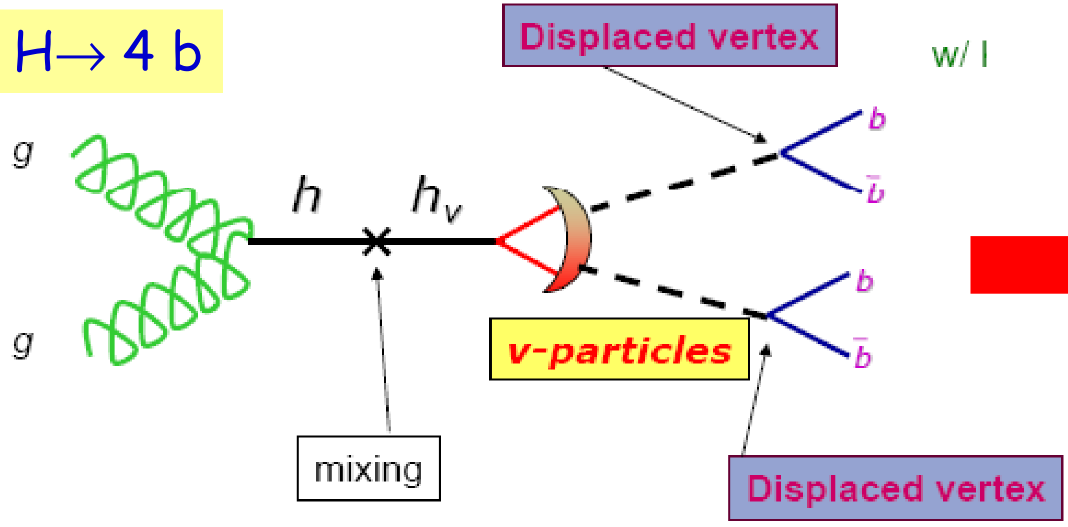


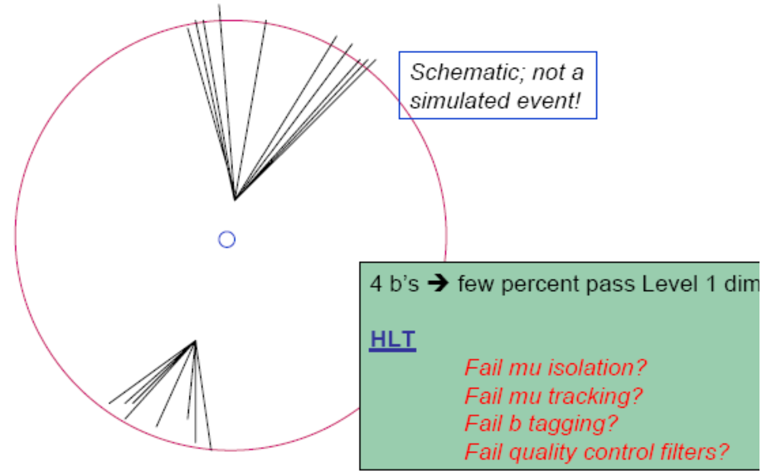
New possible phenomena that could occur in these models

- Higgs decays to two [or more] long-lived particles
  - ***Aside*** *on classes of possible decays of new particles*
- Z' decays to the v-sector:
  - *Final state with many particles, possibly long-lived*
- LSP decays to the v-sector
  - *Degradation of MET signal*
  - *Wide array of complex final states*

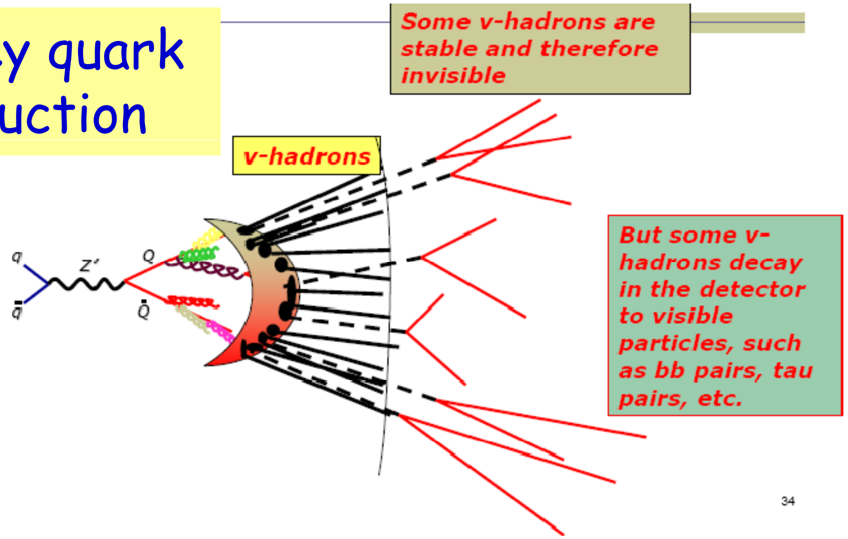
Some Hidden Valley Signals

H→ 4 b

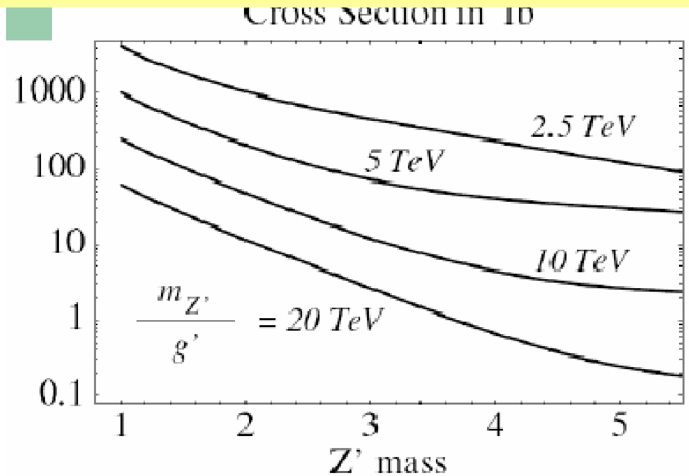




Valley quark production



Production rates for v-hadrons



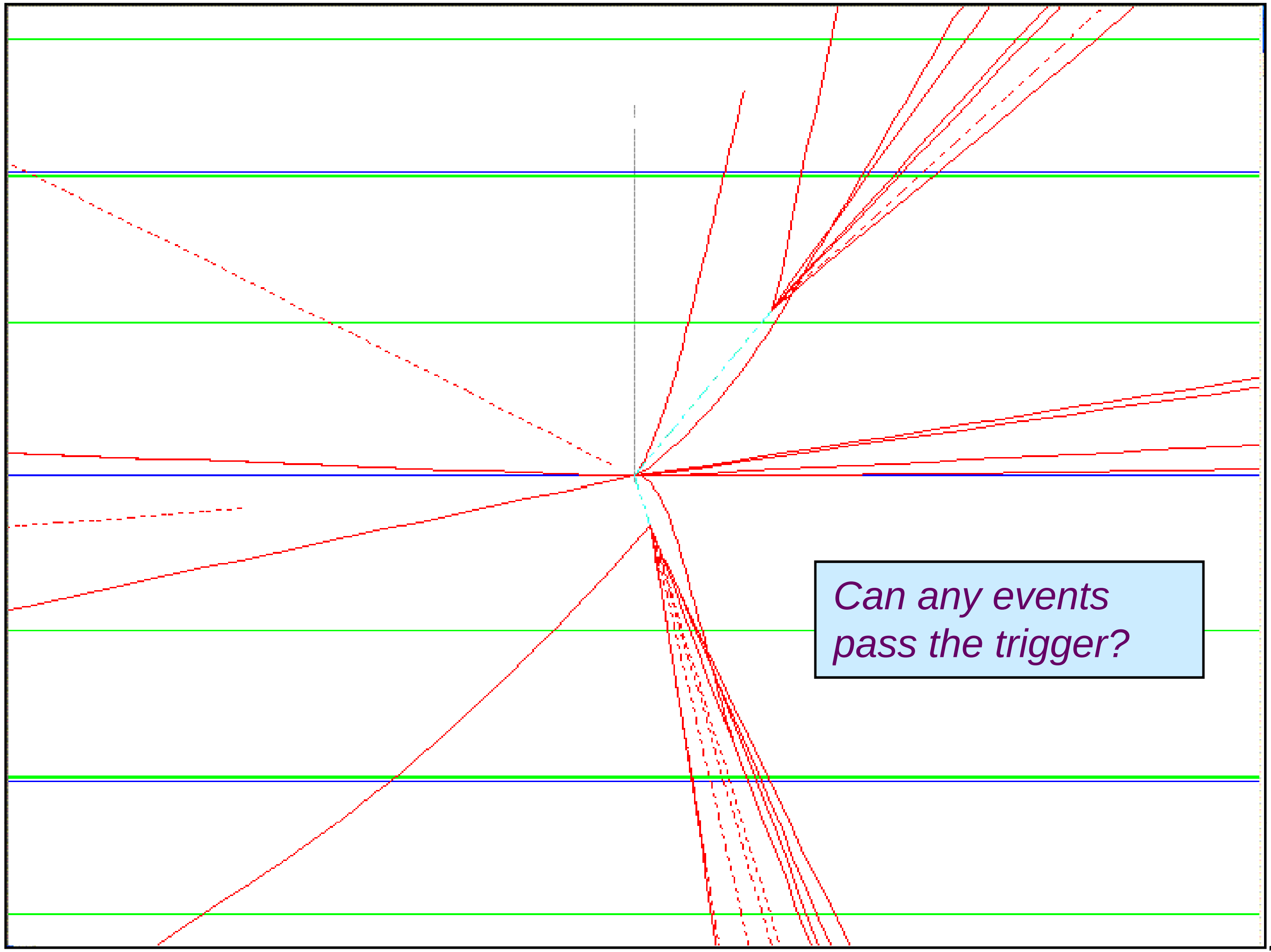
The Fear Factor: A real challenge for the triggers at the LHC

New Discovery Mode for the Higgs?

M. Strassler & K. Zurek   5/2006

Higgs Decays to Long-Lived Particles

ATLAS Rome-Seattle working group:

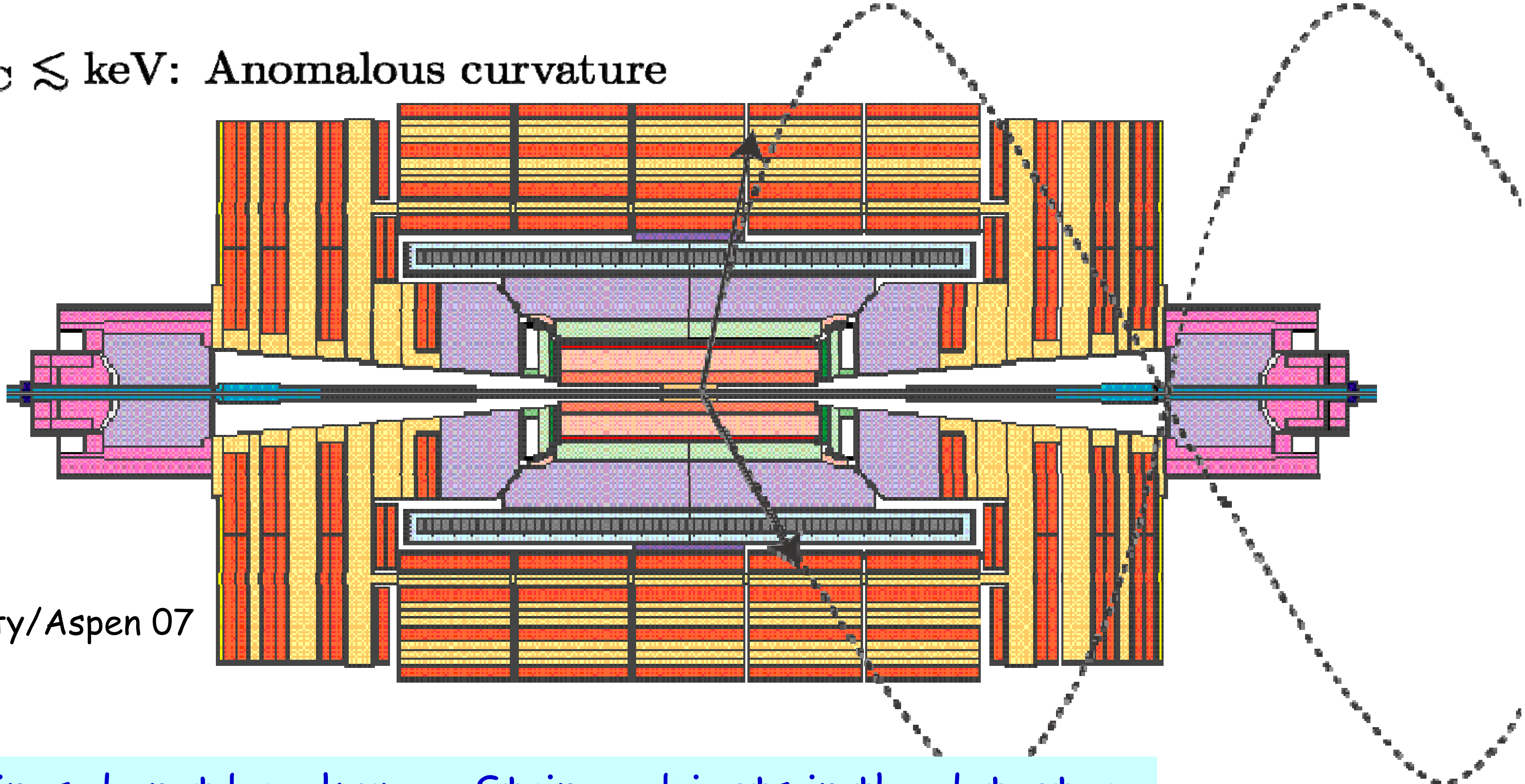


Can any events pass the trigger?

New: (Colour) Strings at the LHC

Macro-strings: new strong interactions & new quarks m_Q> several hundered GeV

$\Lambda_{IC} \lesssim$ keV: Anomalous curvature



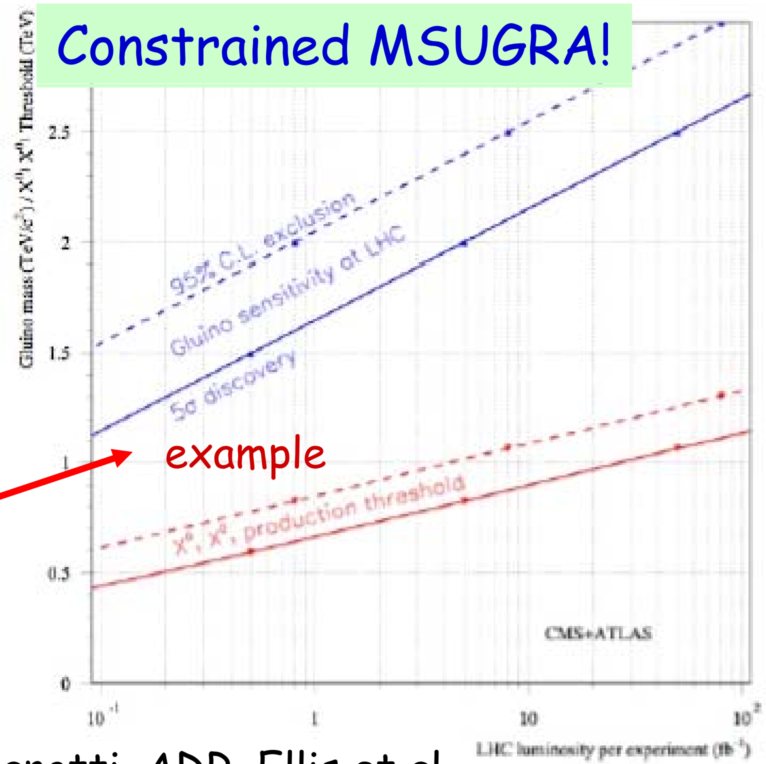
Markus Luty/Aspen 07

- Strings do not break up ⇒ Stringy objects in the detector.
- End points are massive quarks (quirks)
- The strings can oscillate⇒ strange signature in detectors

Summary

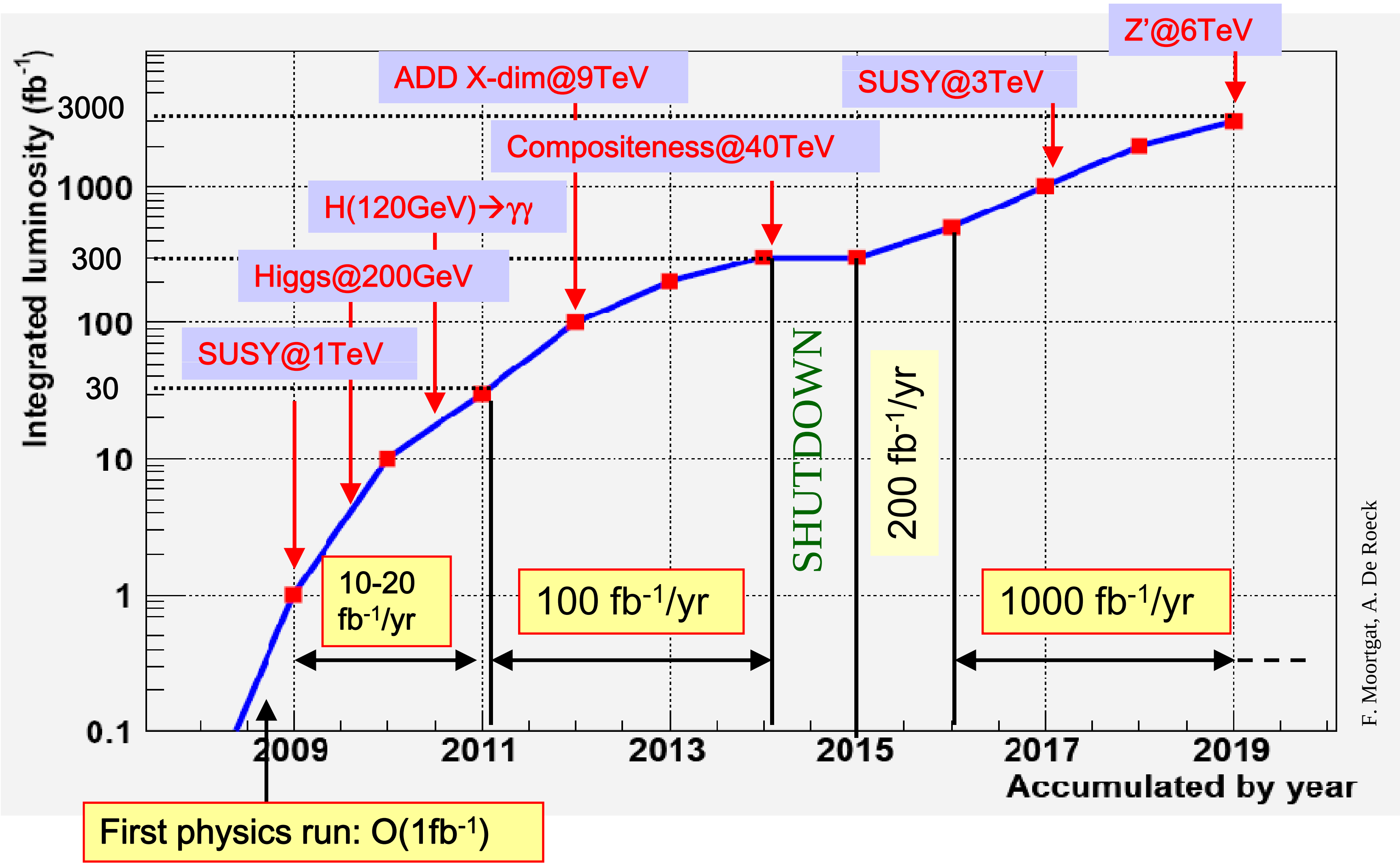
- LHC: prepared for searches for many new scenarios
- Already with 10 fb^{-1} the region covered will be for massive particles with mass more than 1 TeV (several TeV in most cases)
  - Both for discovery or exclusion.
- Note that new experiments are new ⇒ Ramping up will take time

  Be patient!
- Early findings obviously very relevant for the ILC
  - may set initial energy for a LC
  - may affect detector choices
- For this workshop:
  - What do we learn from the (non) observation of new particles?



Gianotti, ADR, Ellis et al

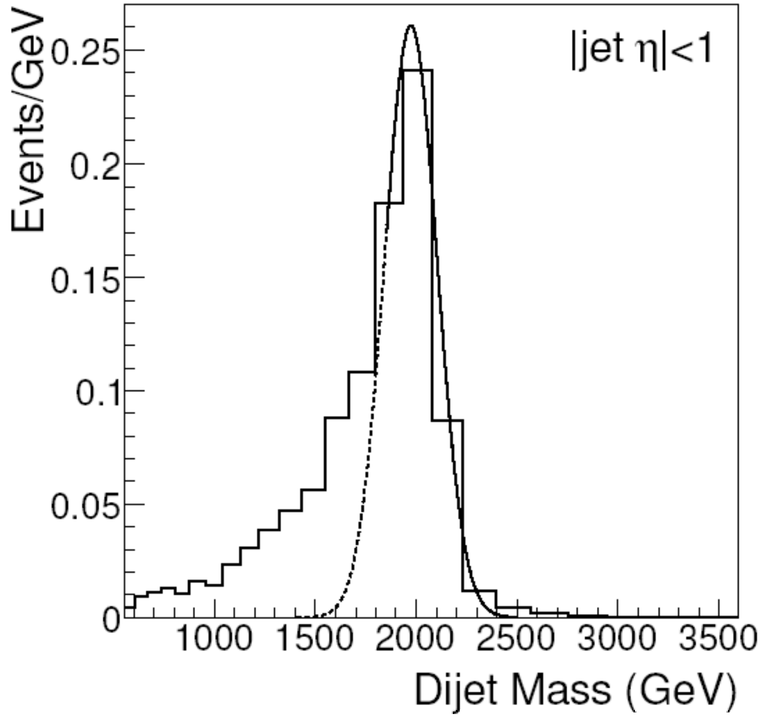
Discovery/Luminosity Roadmap?



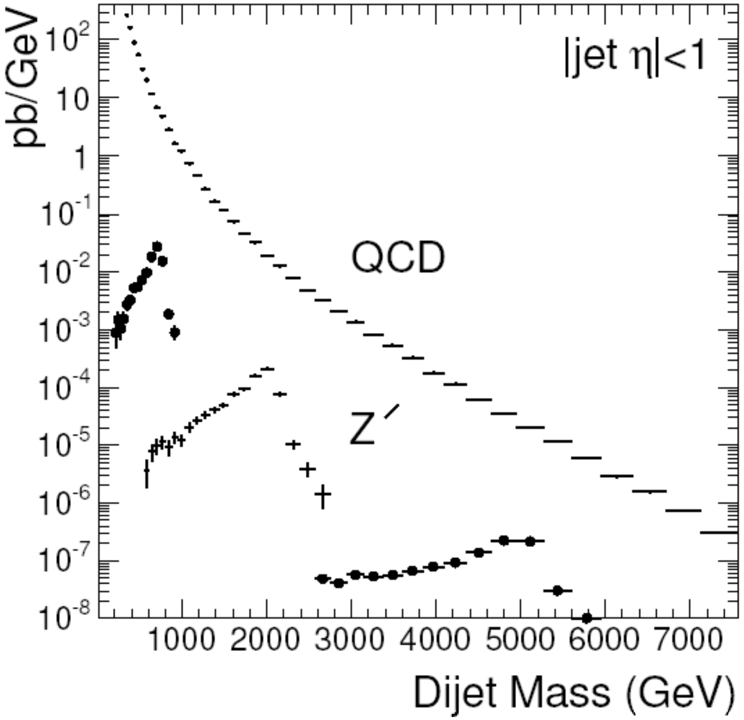
Backup slides

Dijets: Z' resonances

With the CMS detector



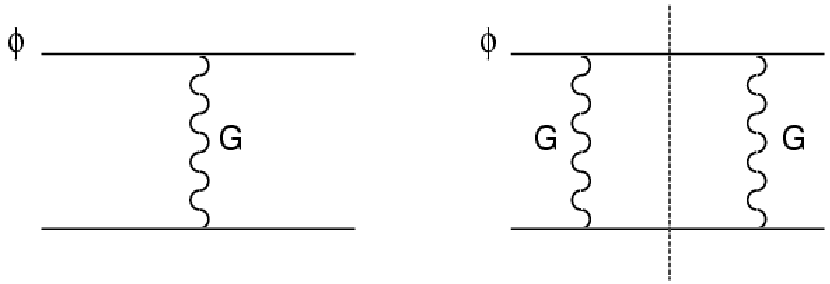
Mass distribution 2 TeV Z'



QCD background (PYTHIA)
+ 0.7, 2 and 5 TeV Z'

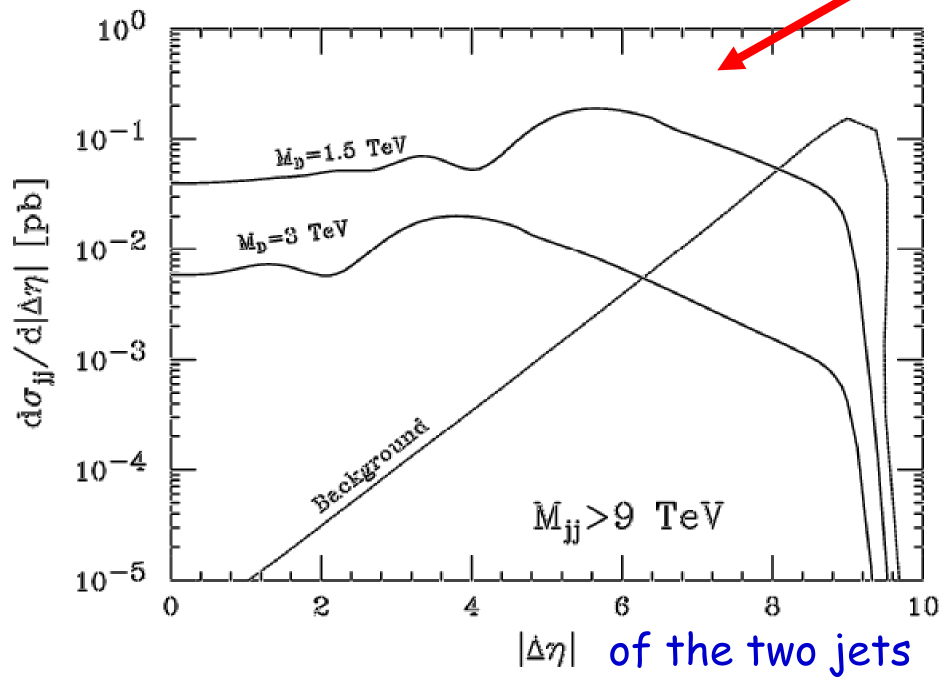
Transplanckian effects

Once you pass the Planck scale $\sqrt{s} \gg M_D$…

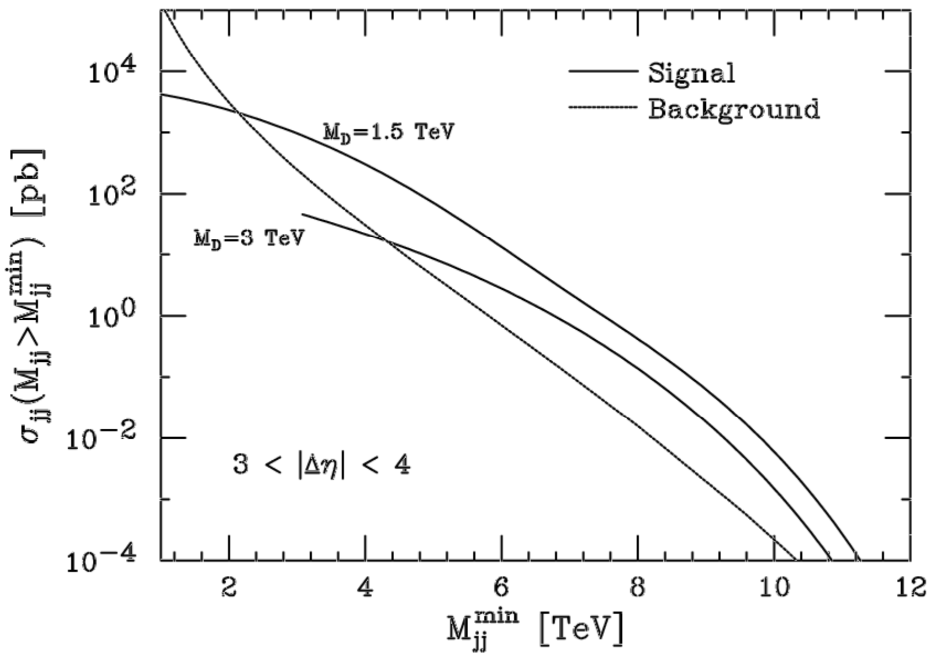


Processes with small momentum transfer e.g. :
Elastic transplanckian collisions:
Study gravity propagation in ED's
Signal: dijets with large M_{jj}

Guidice, Rattazzi, Wells

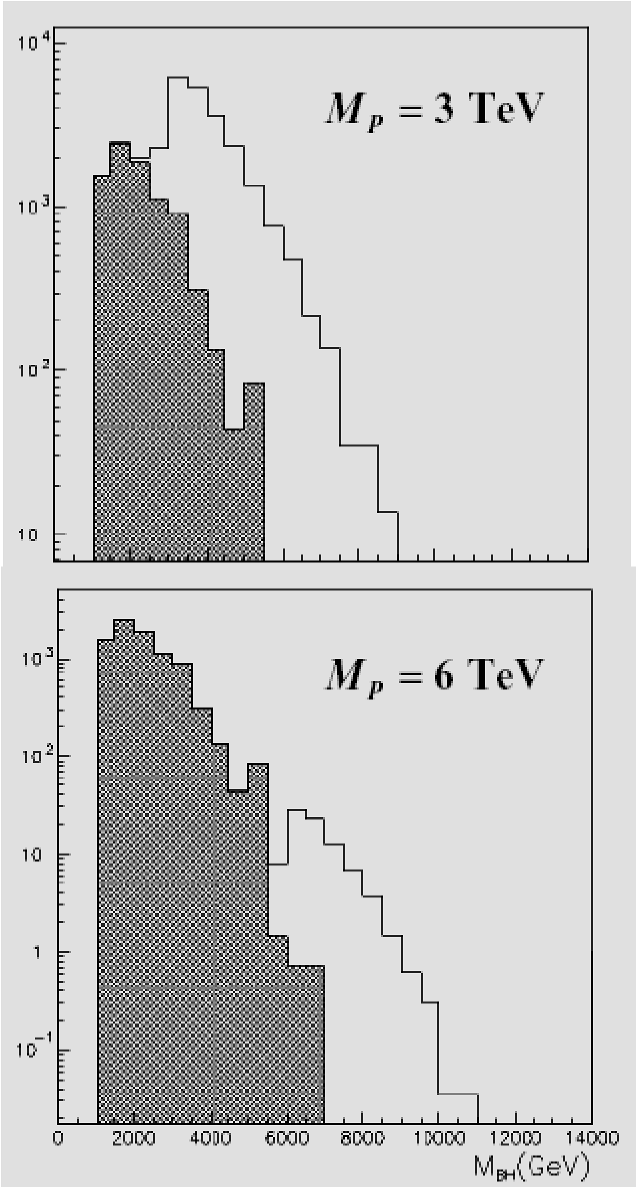


of the two jets



Full experimental study still missing

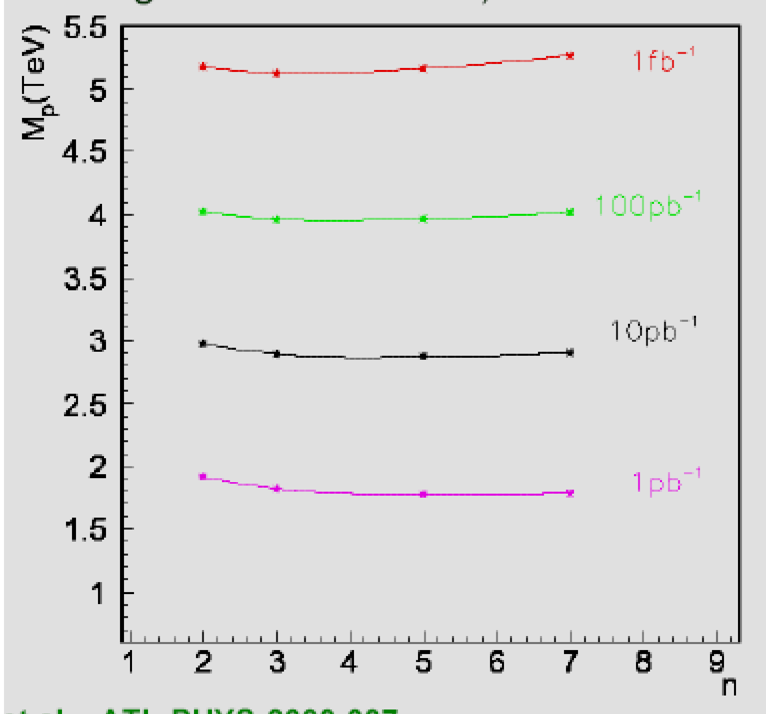
Black Holes



simulation in ATLAS

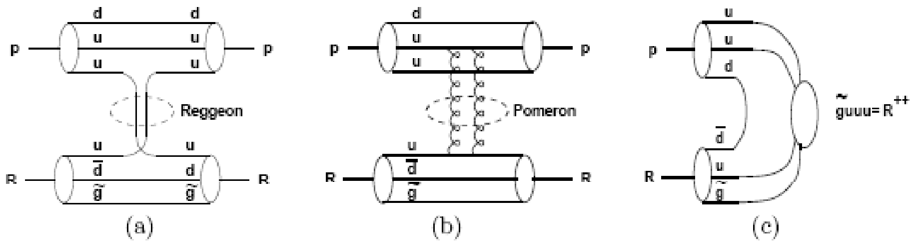
- selection of spherical events
- **M_{BH}** reconstructed for each event
- reconstruction of **M_P** from the cross section **ds/dM_{BH}**
- given the energy distribution for M_{BH} $\Rightarrow$ **T_H**

n deduced from T_H, M_{BH} and M_P
(Hawking radiation formula)



J. Tanaka et al., ATL-PHYS-2003-037

How do these R-hadrons interact with matter?



R-Hadrons

(e.g. A Kraan hep-ph/0404001)

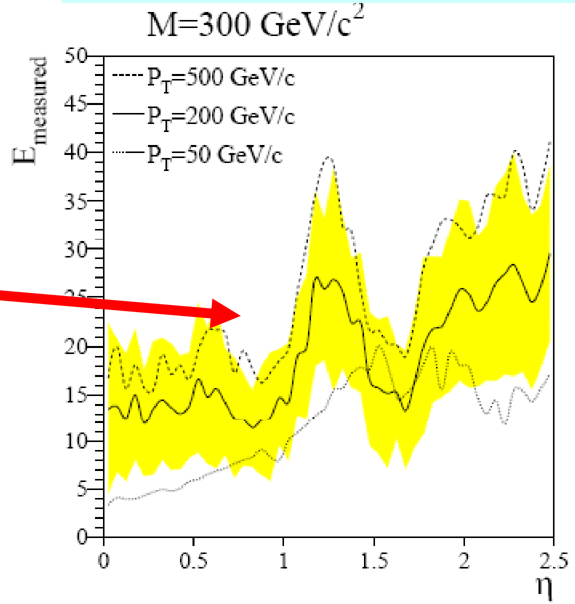
- Gluino interactions suppressed as $1/M^2$
- u,d quarks interact but with a kinetic energy of order 1 GeV

$\Rightarrow$ deposite only 10-15% of energy while passing through ATLAS/CMS calorimeters

This will be a remarkable signature

Also: charge flip while passing through matter

Need to modify the detector simulation toolkit (Geant4)



Understanding of travel of heavy particles through matter good enough?

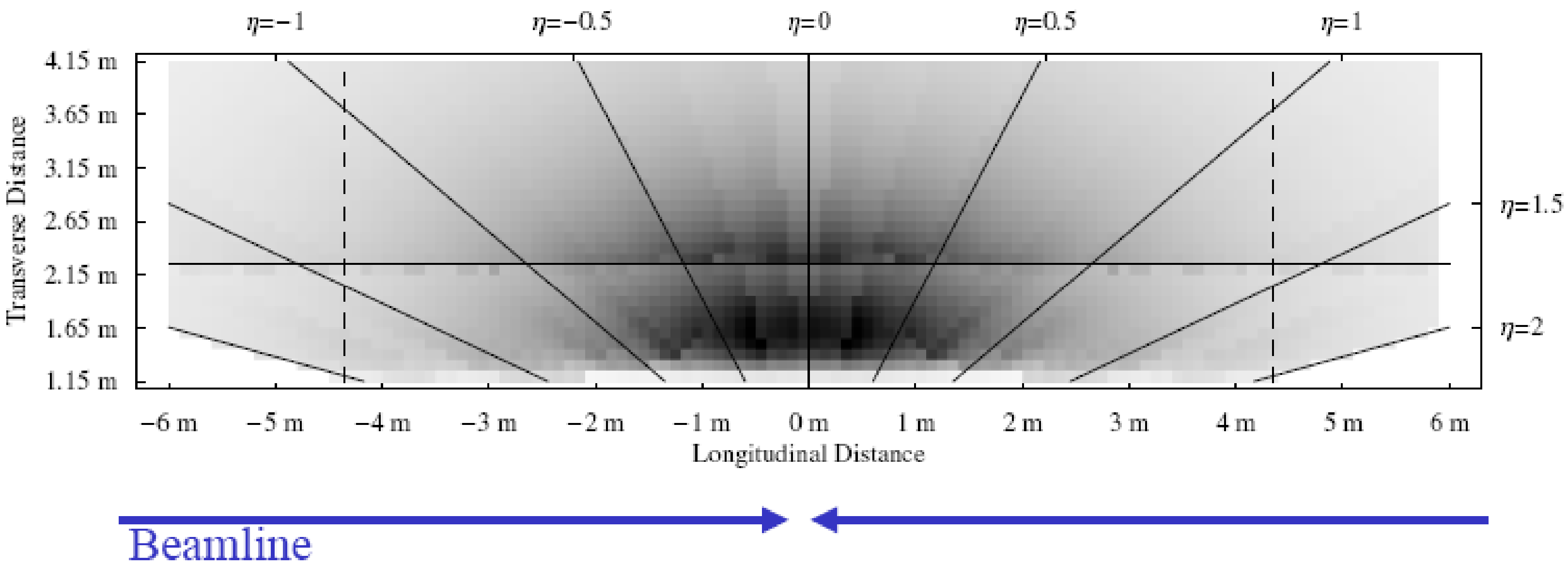
Further: anomalous de/dx, time-of-flight measurements. Trigger is a challenge

Split Susy

Density of Stopped Gluinos

300 GeV gluino

Atlas Detector



Not uniformly distributed in detector

No tracks going into or out of calorimeter

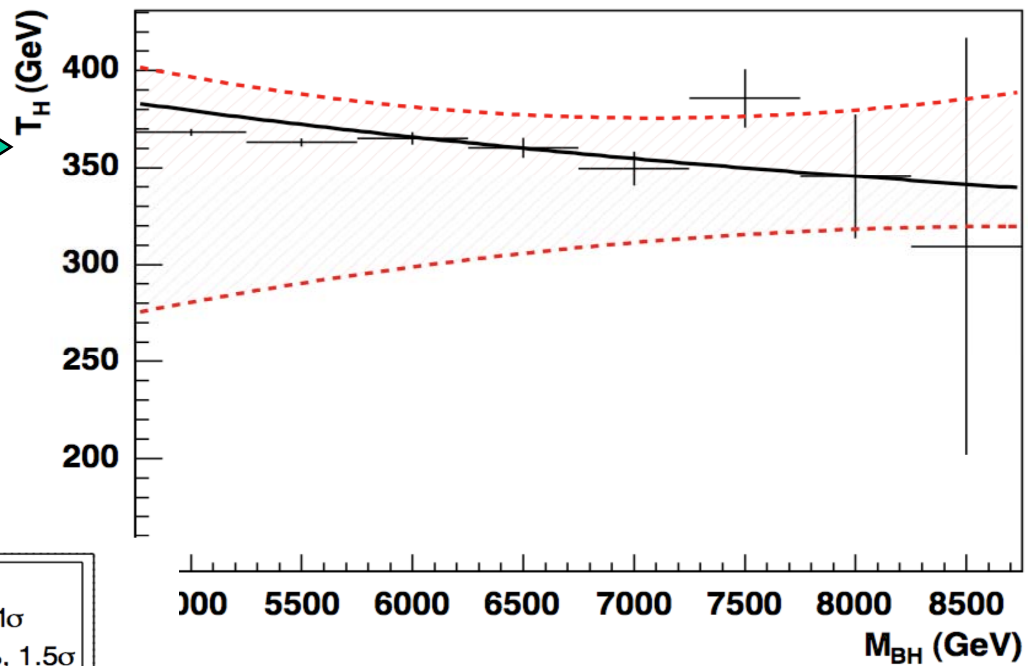
Arvanitaki, Dimopoulos, Pierce, Rajendran, JW hep-ph/0506242

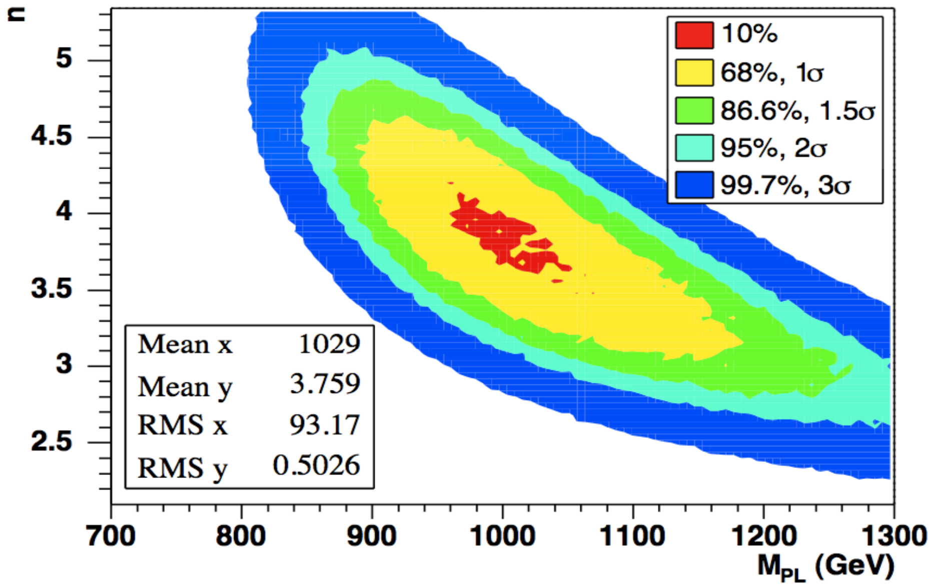
Black Hole Searches

Can measure characteristic T at average mass

-> combine this with cross section data to extract n.

Assume 20% error on σ





Area of interest for **Alberta Group!**

Extra dimensions

Hypothesize that there are extra space dimensions

Volume of bulk space >> volume of 3-D space

Hypothesize that gravity operates throughout the bulk

SM fields confined to 3-D

Then unified field will have "diluted" gravity, as seen in 3-D

With n-D gravity mass scale=weak mass scale -> no hierarchy problem!

Can experimentally access quantum gravity!

Missing energy signatures

Black hole production

But extra dimension is different length scale from "normal" ones

-> new scale to explain