

# Introduction to Working Group 4: “Other New Physics Signatures”

**Convenors:** Albert De Roeck, Tao Han,  
JoAnne Hewett, and Sabine Riemann

**CERN TH Institute:** From LHC to Future Colliders  
(CERN, Feb. 9, 2009)

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Other New Physics Signatures:



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- Leptonic and other s-channel resonances
- multi-gauge-boson signals
- measurement of mass and spin, quantum numbers
- leptoquark-type signatures
- flavour physics
- fourth generation-type signatures, exotic quarks
- TeV scale gravity-type signatures
- other possible signatures of new physics

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Interpretations of results for  $10 \text{ fb}^{-1}$  at LHC

$\longleftrightarrow$  Implications of future collider scenarios.

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Broad range of theoretical ideas!

## Observational Aspects:

(Almost) Any 2-body combinations are predicted!

	$e/\mu$	$\tau$	$\nu$	$j$	$b$	$t$	$\gamma$	$W/Z$	$h$
$e/\mu$	$Z'_{KK}$ $G_{KK}$	LFV $\tilde{\nu}, H^{\pm\pm}$	$W'_{KK}$	LQ	LQ	LQ	$e^*, \mu^*$	$L^\pm, N^0$ $\ell^*, \nu^*$	$L^\pm$ $\ell^*$
$\tau$		$Z'_{KK}$ $G_{KK}$	$W'$ ...	LQ	LQ	LQ	$\tau^*$	$\tau', \mu'$	
$\nu$				LQ	LQ	LQ	$\nu^*$	$\nu^*, \nu'$	
$j$				$Z', G_{KK}$ $\rho_{TC}$	RPV	RPV			
$b$					$Z', G_{KK}$ $\rho_{TC}$		$b^*$	$T$	$b'$
$t$						$Z', G_{KK}$ $\rho_{TC}$	$t^*$	$T$	$T$
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All kinds of observables: spin (final state, angular)  
couplings (asymmetries, angular distributions), mass (bumps) ...

Anticipating early discoveries (and pop up champagne)!

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Vast body of literature exists in these topics:  
Both theoretical and experimental.

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Searches at the Tevatron:

# Current Status

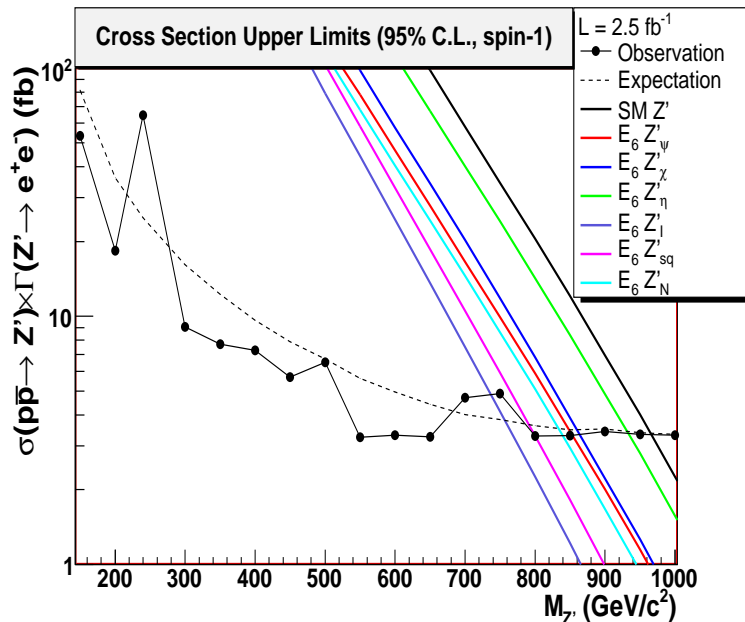
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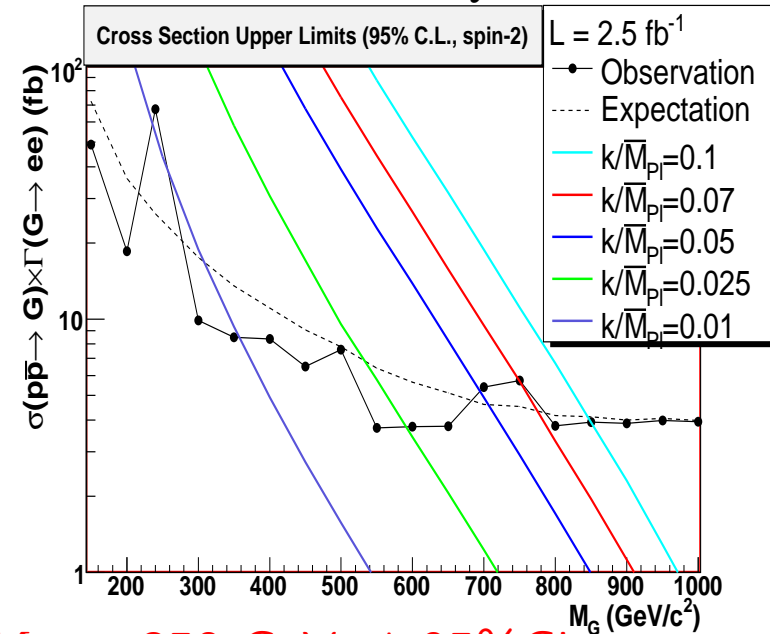
## Searches at the Tevatron:

- $Z', G_{KK} \rightarrow e^+e^-$  at the Tevatron:

CDF Run II Preliminary



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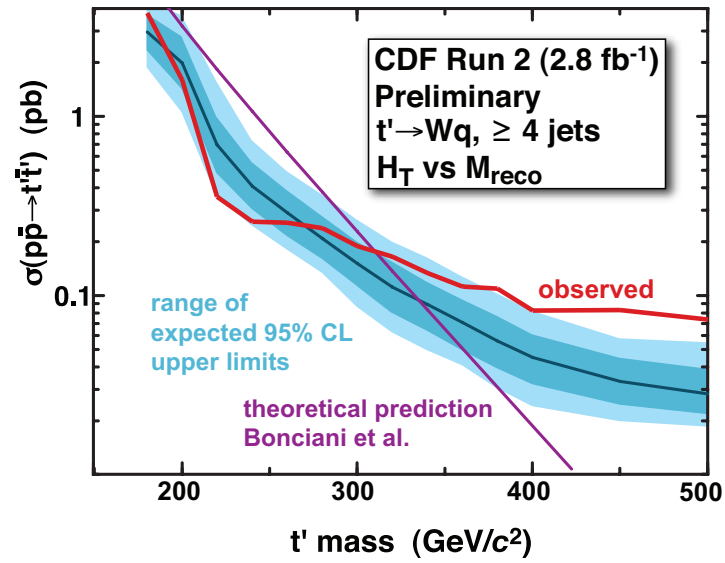
For  $ee$ :  $M_{Z'} > 966 \text{ GeV}$ ,  $M_{G_{kk}} > 850 \text{ GeV}$  at 95%CL.

For  $\mu\mu$ :  $M_{Z'} > 1030 \text{ GeV}$ ,  $M_{G_{kk}} > 921 \text{ GeV}$  at 95%CL.



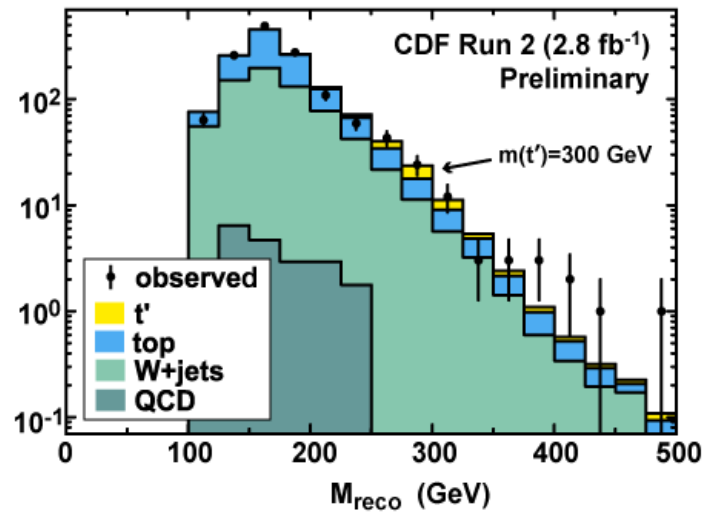
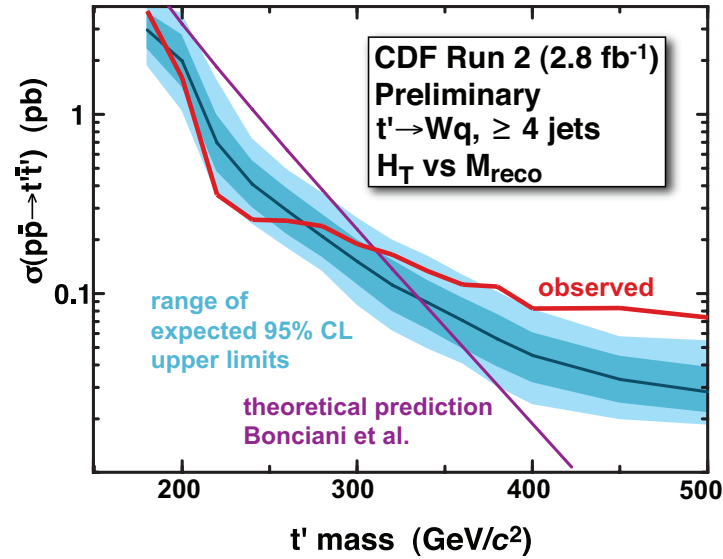
- $p\bar{p} \rightarrow t'\bar{t}' \rightarrow W^+ j, W^- j$  at CDF: (0810.3349)

$M_{t'} > 311$  GeV:



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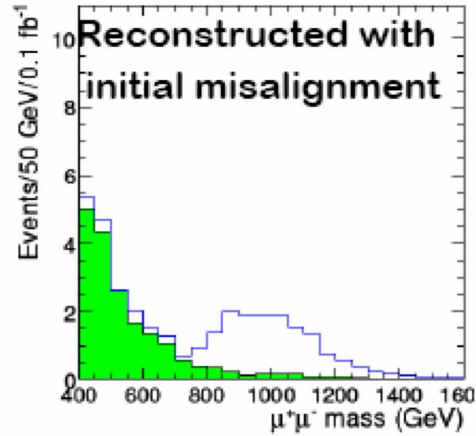
There are 7 events in 375–500 GeV (excess!) ...

# Searches at the LHC:

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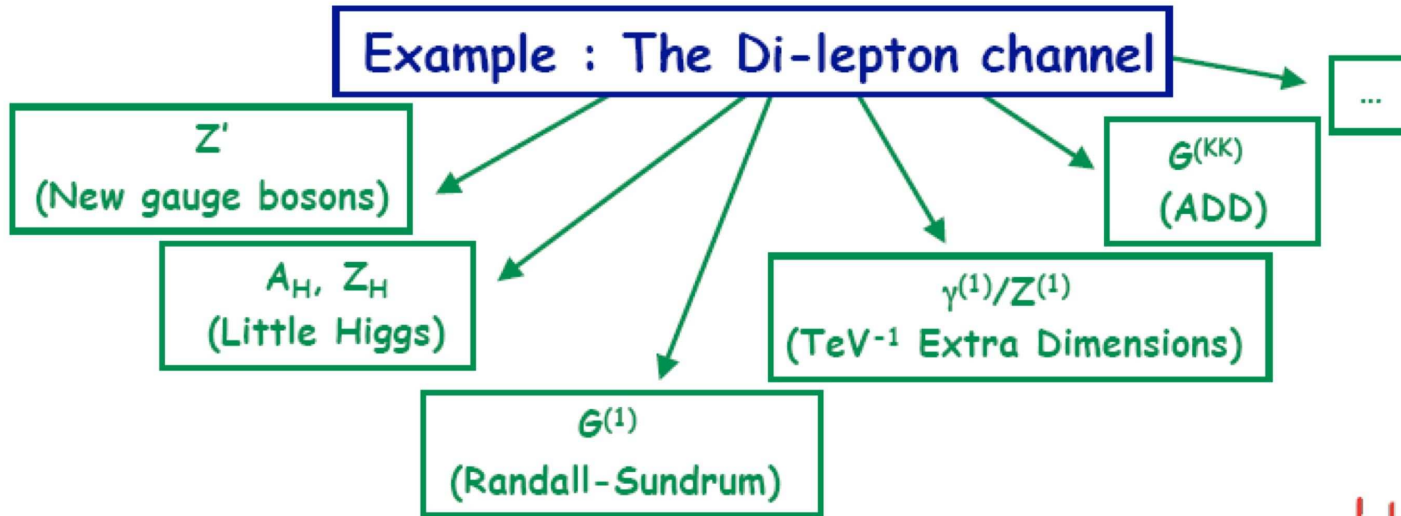
## Early discoveries? E.g. Di-lepton Resonance

If we are lucky:  
a signal could be seen very early on

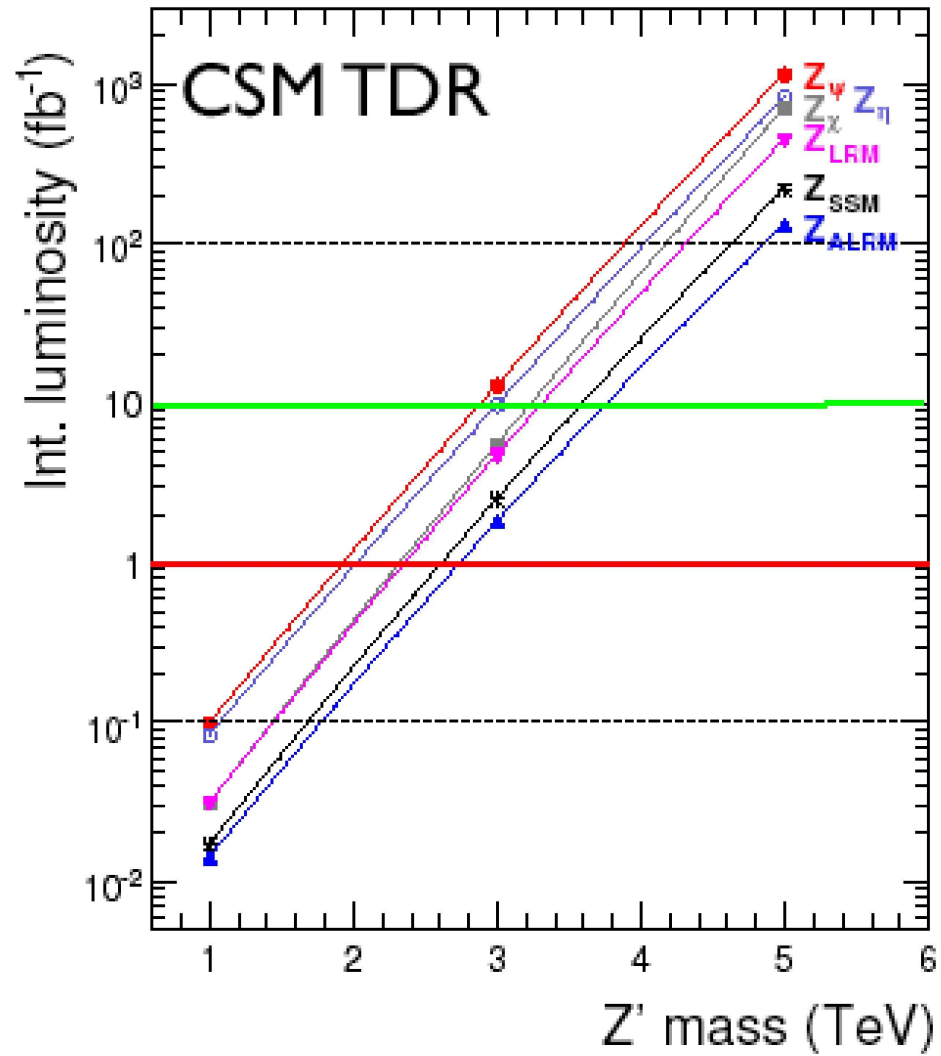


First months of operation

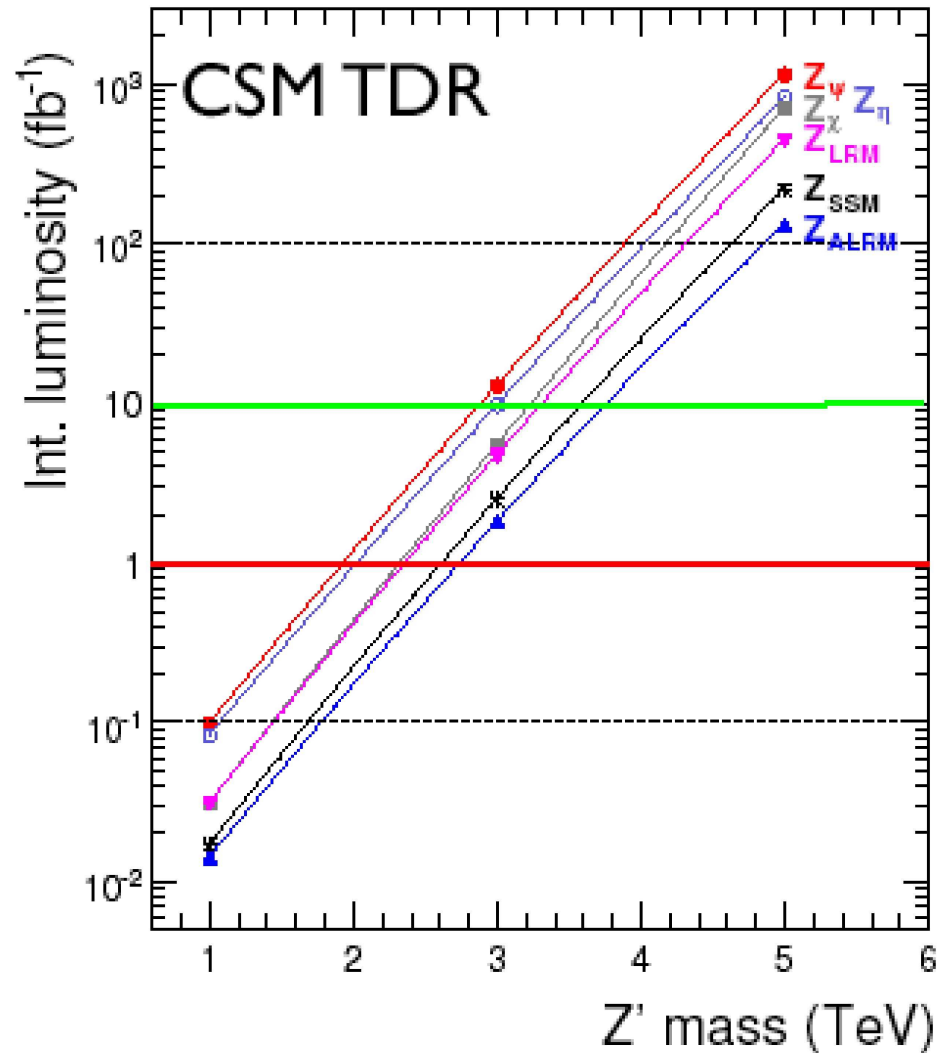
CMS PTDR



# $Z'$ Search at the LHC:



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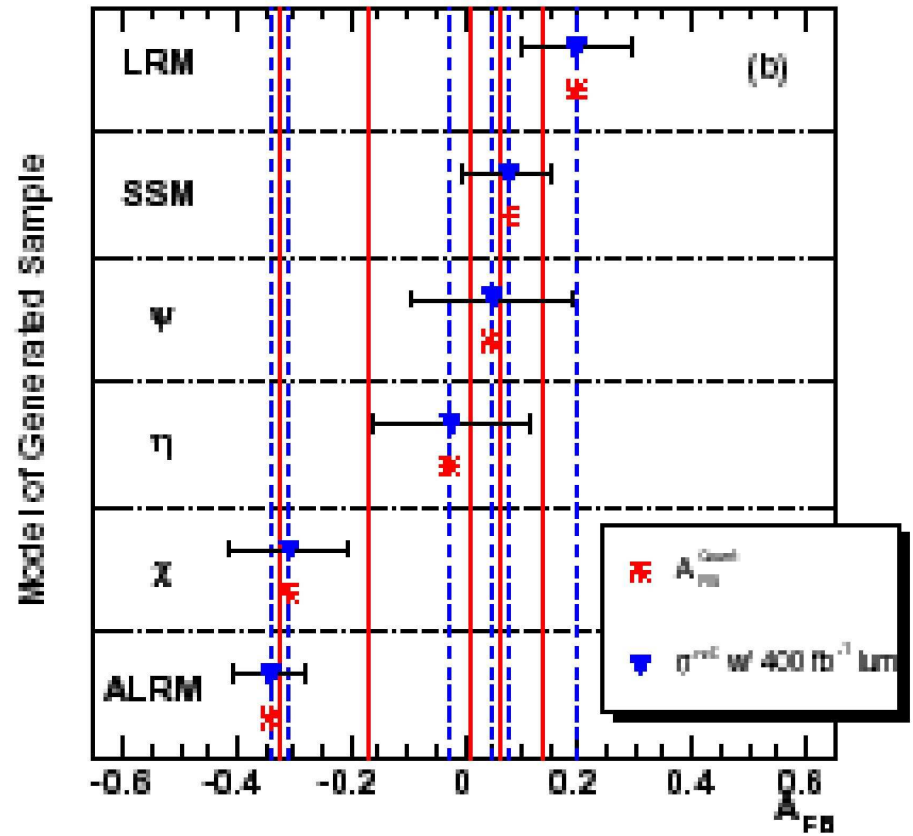
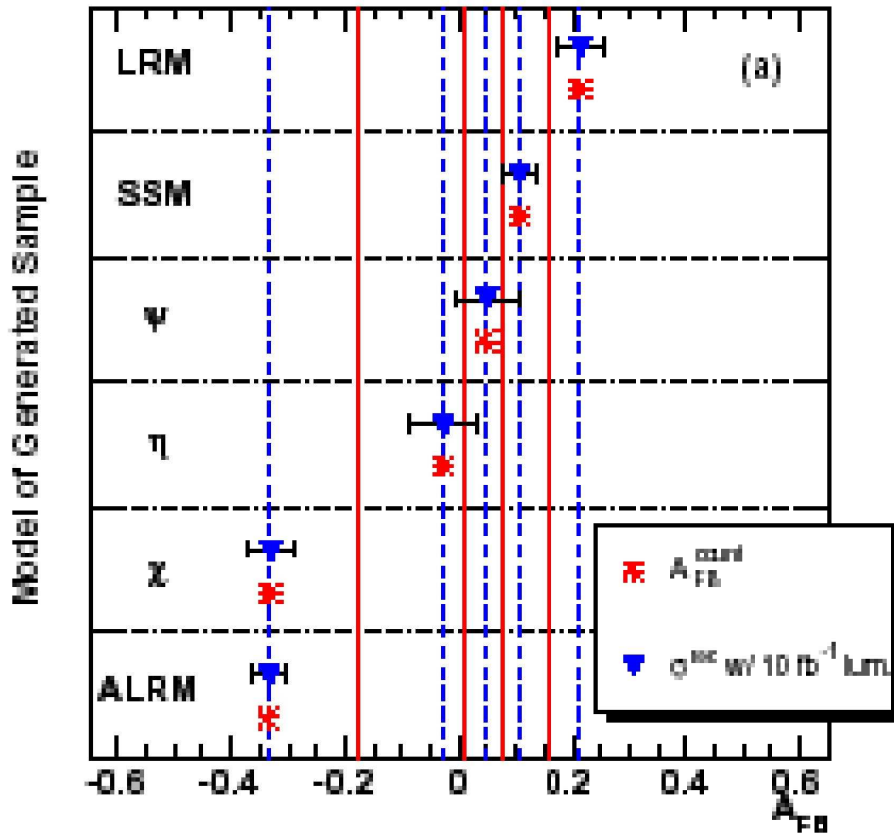


With  $10 \text{ fb}^{-1}$ , one can reach  $M_{Z'} = 3 - 4 \text{ TeV}$ .  
Even for  $200 \text{ pb}^{-1}$ , one can reach  $M_{Z'} = 1.4 - 2.2 \text{ TeV}$ .

# Z' Studies at the LHC:

On-peak  $A_{FB}^{\text{count}}$  and  $\sigma^{\text{inc}}$ , 1 TeV

On-peak  $A_{FB}^{\text{count}}$  and  $\sigma^{\text{inc}}$ , 3 TeV



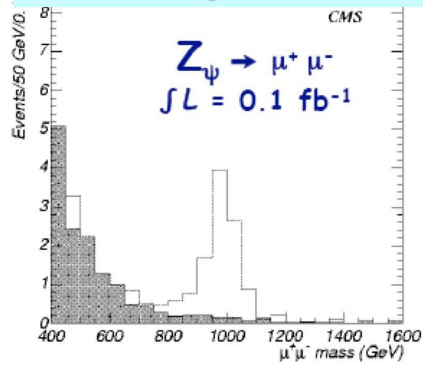
for  $M_{Z'} = 1$  (3) TeV with  $10$  ( $400$ )  $\text{fb}^{-1}$ .

# More searches at the LHC:

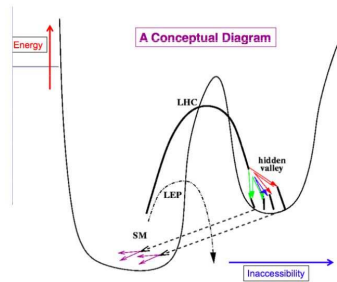
- Rich physics to search for:

## BSM Physics at the LHC

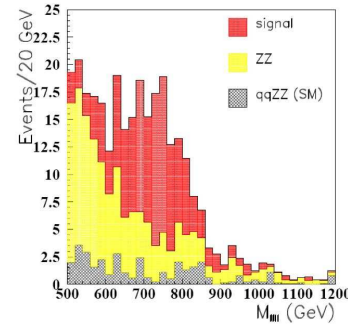
### New Gauge Bosons?



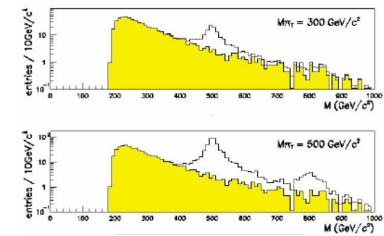
### Hidden Valleys?



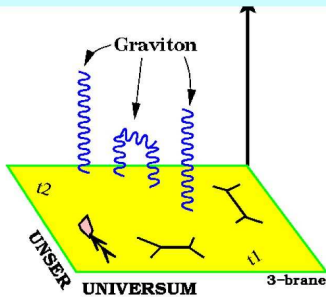
### ZZ/WW resonances?



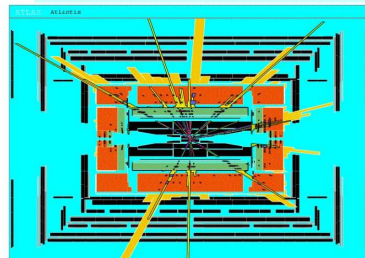
### Technicolor?



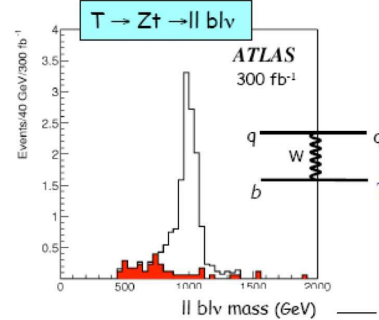
### Extra Dimensions?



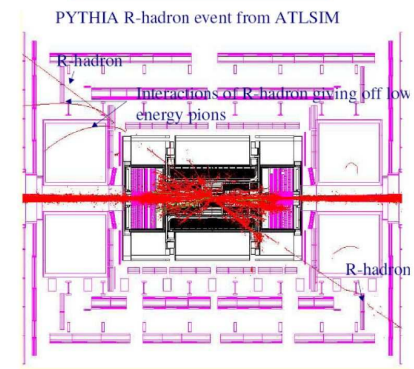
### Black Holes???



### Little Higgs?



### Split Susy?



We do not know what is out there for us...



## Going to Future Colliders

New frontiers for high energy and precision physics.

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- Muon Colliders: Precision physics and energy frontier.

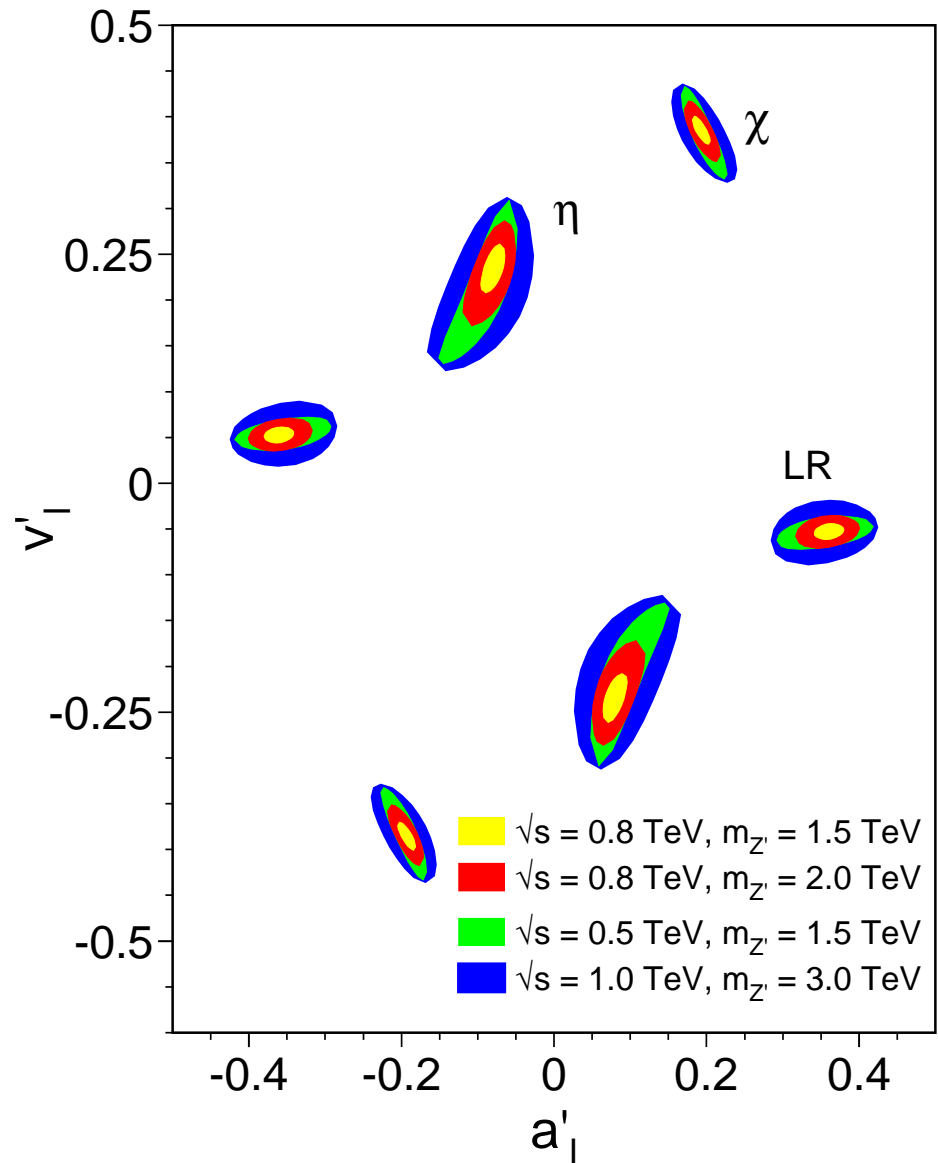
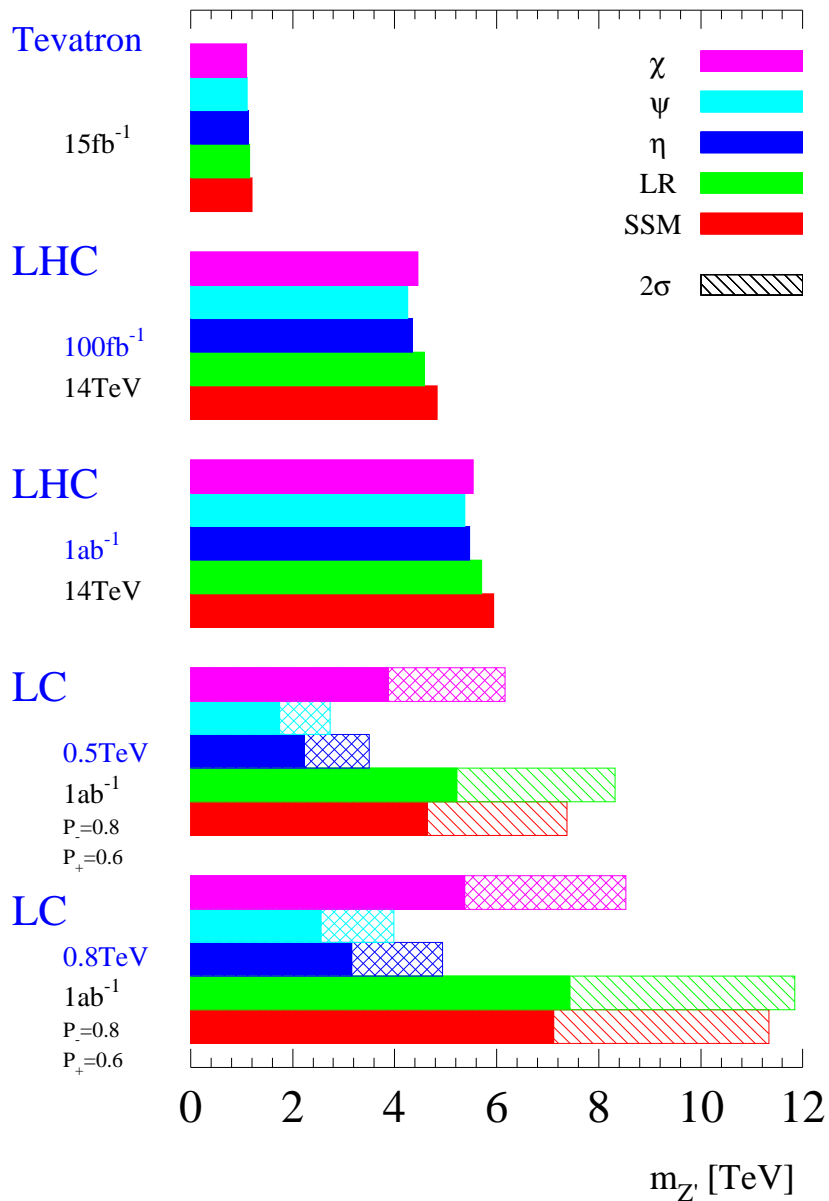
## Going to Future Colliders

New frontiers for high energy and precision physics.

- SLHC: Luminosity frontier.
- DLHC, VLHC: Energy frontier.
- ILC: Precision physics.
- CLIC: Energy frontier and precision physics
- Muon Colliders: Precision physics and energy frontier.

Depending upon LHC discoveries, make optimal choice.

# At the ILC: (Virtual) $Z'$ Reach





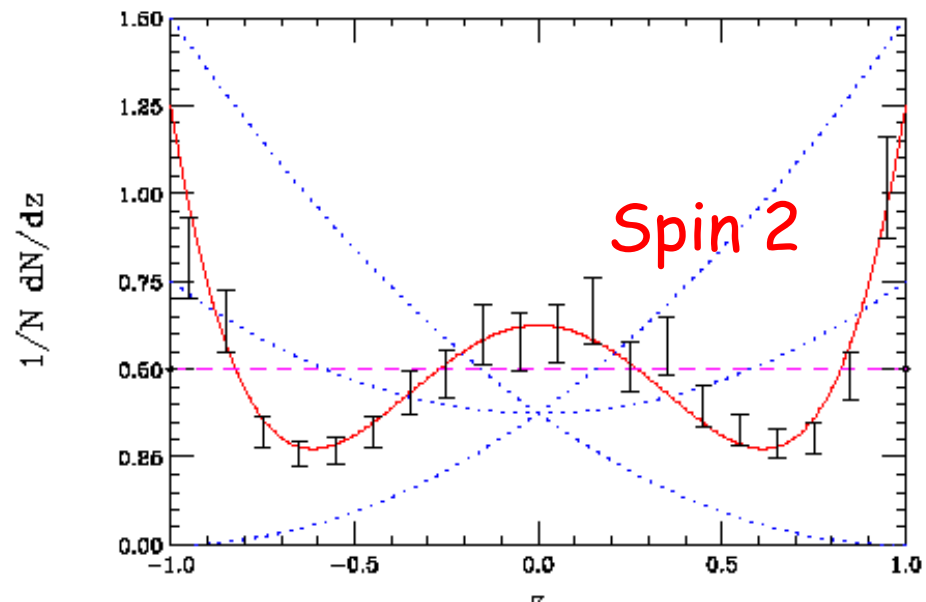
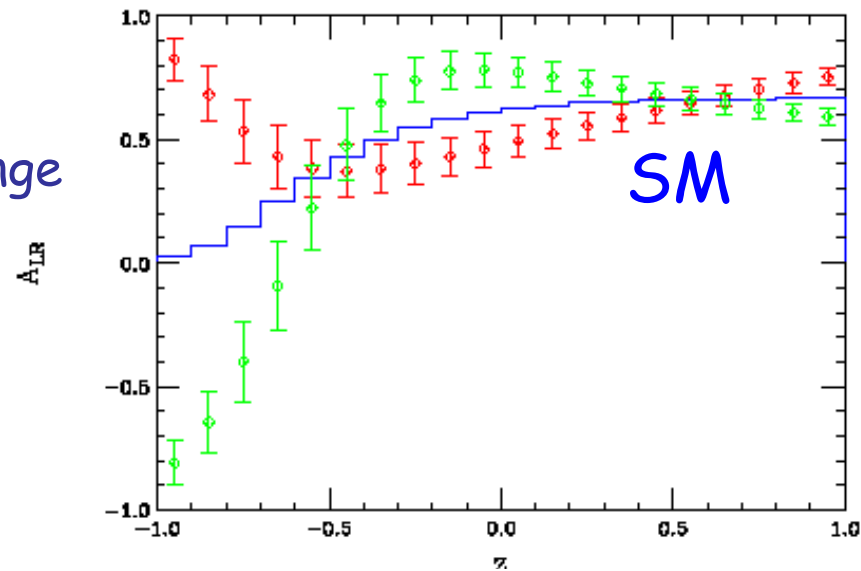
# At the ILC: Angular distributions for spin

$$A_{LR}(e^+e^- \rightarrow b\bar{b})$$

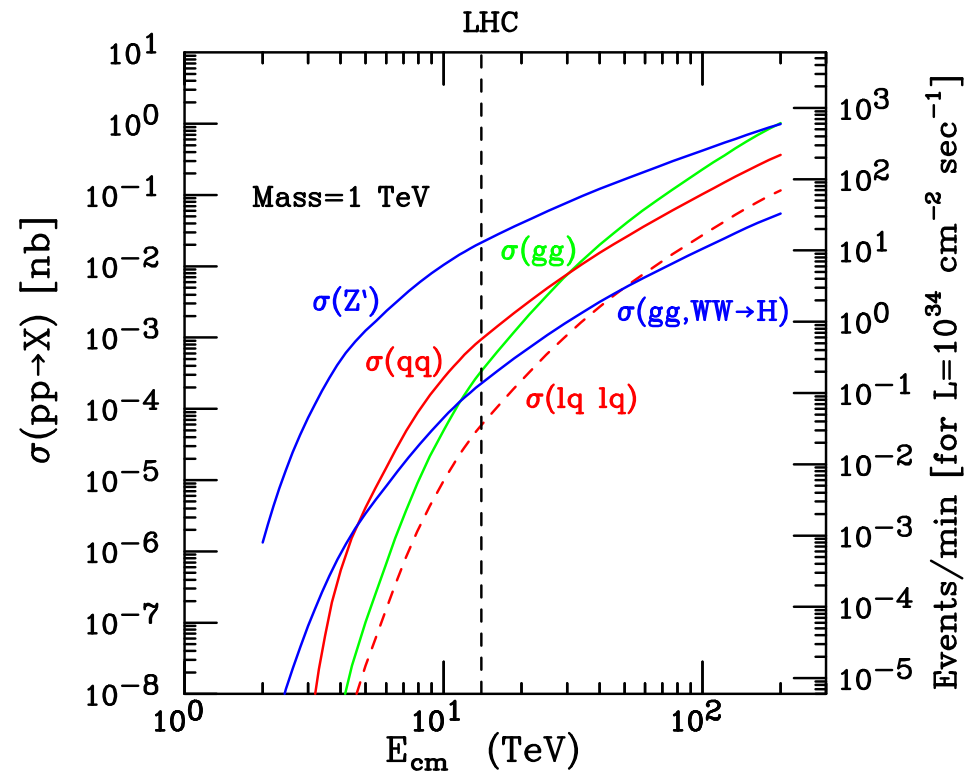
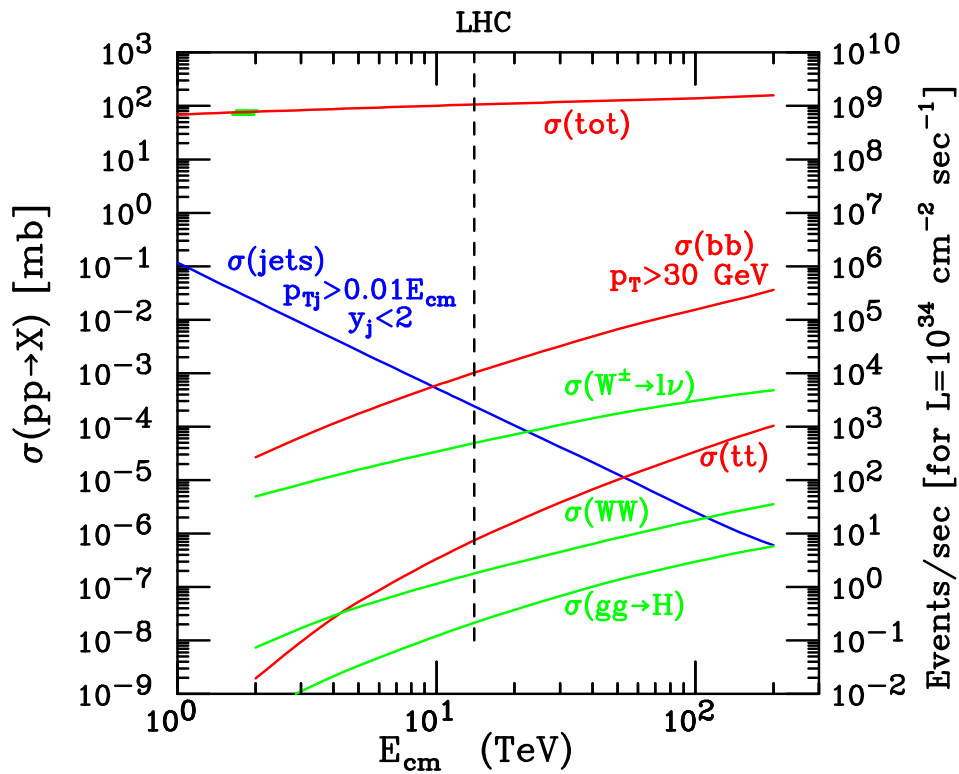
Eg.  $A_{LR}$

Interference of exchange  
of virtual graviton KK  
States with SM  
amplitudes

Hewett, hep-ph/9811356



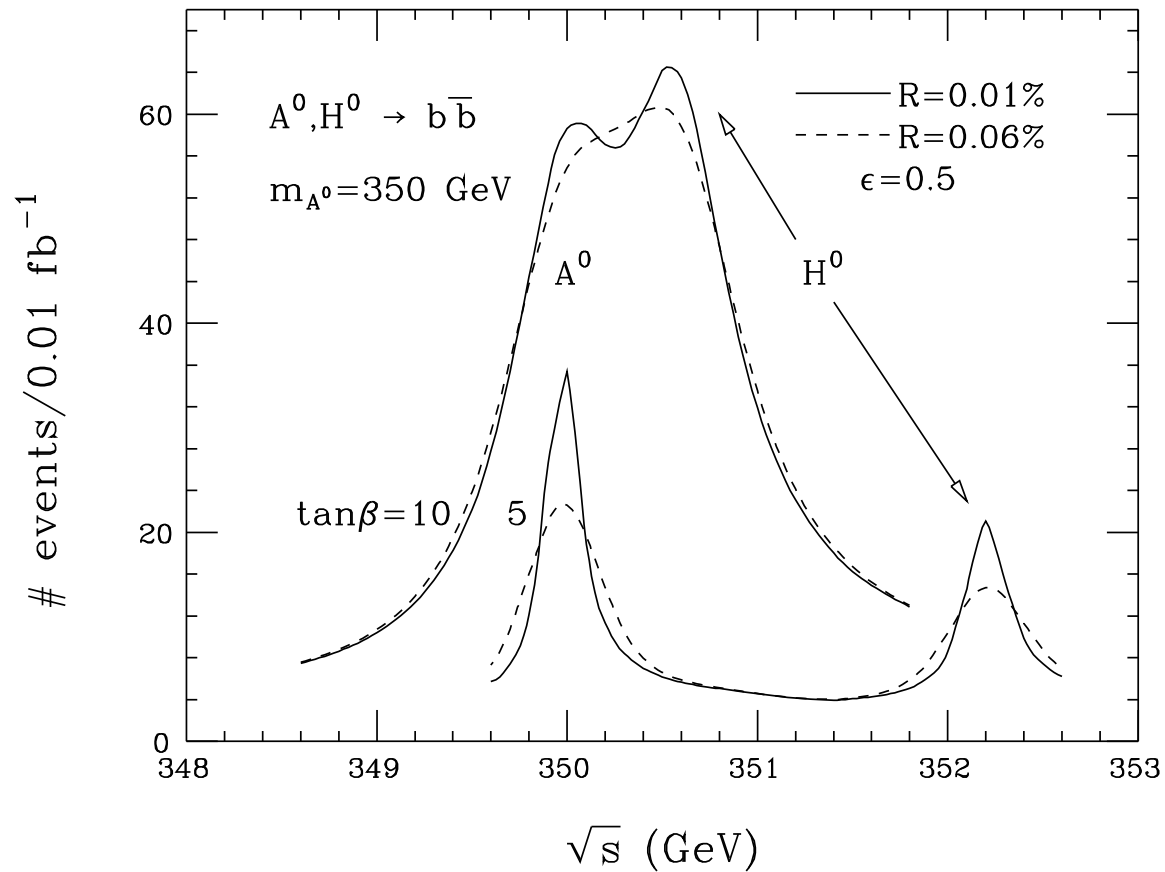
# At the VLHC:



Higher threshold, higher luminosity:  
for heavier or colored particles.

# Precision scalar mass determination at a muon collider:

Separation of  $A^0$  &  $H^0$  by Scanning



High beam-energy resolution, high luminosity:  
A Higgs factory.

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- Multi-jet resonance?

## The Program and WG4 Activities

Updated at the site:

<http://sites.google.com/site/lhc2fcwg4/>