Thoughts about first physics at LHC

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Outline

- Less than 3 years from Data.
- New energy regime
- Expect to find rich new physics menu.
- Before trying to sell a Higgs boson or SUSY, better look at Standard Model
  - A short tour of increasing luminosity
  - Physics that we might get and what we need to get it

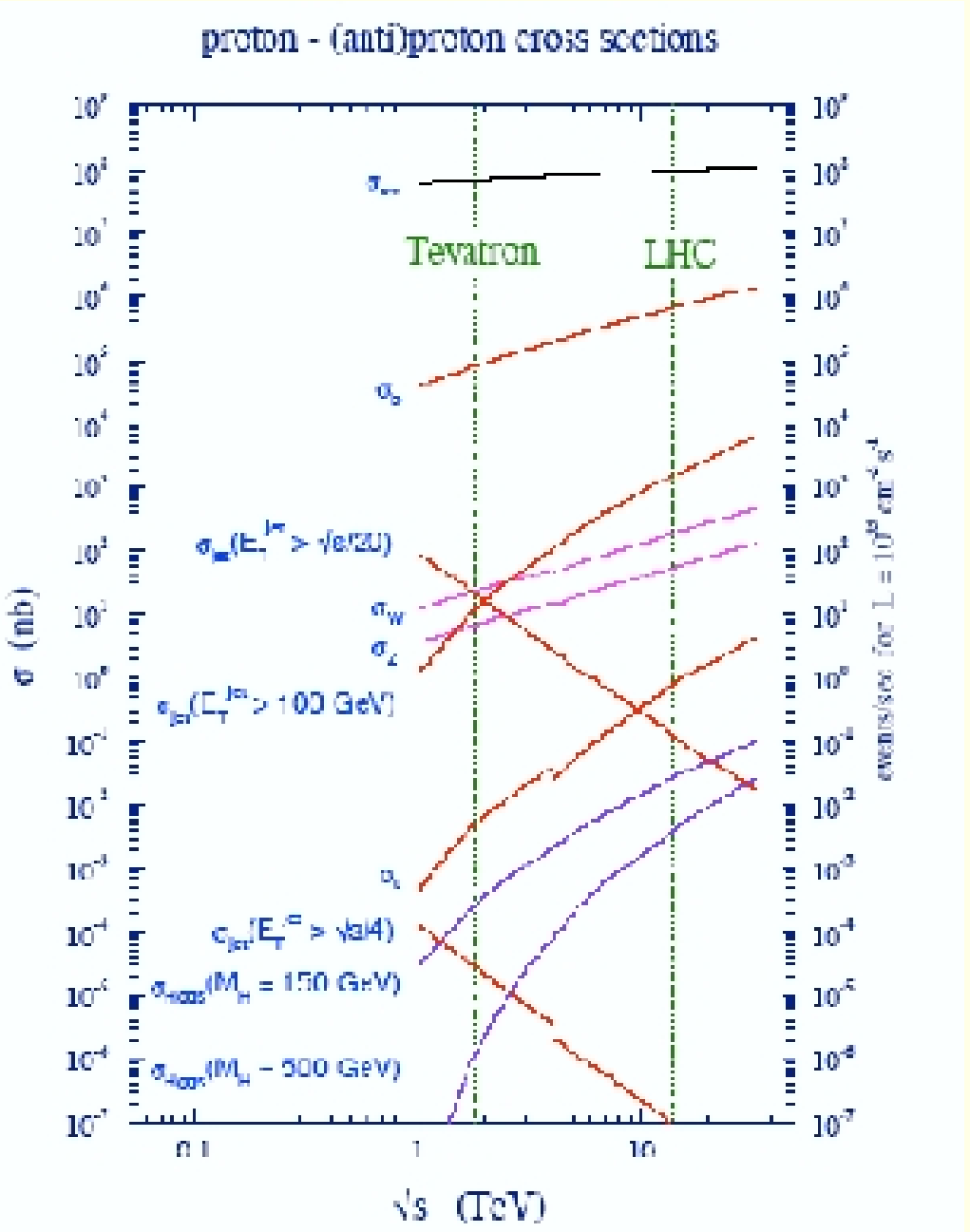
Its a 15 year program
How many experiments will be taking data in 2010, 2015, 2020?

Huge range of rates

We expect to measure all (but one) of these

We expect to calculate them

Can claim to understand detector and physics modeling when this is done



Backgrounds – Measuring and Calculating

At present, we rely on MC for signal and background estimates

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A concern: underlying and min-bias events

Affects process that need forward jet tagging $e.g.$ $WW - scattering$ or central jet veto $e.g.$ extraction of objects produced by EW interaction

Will be measured once data exists and MC will be tuned to agree... But

Speech

Getting Started: QCD

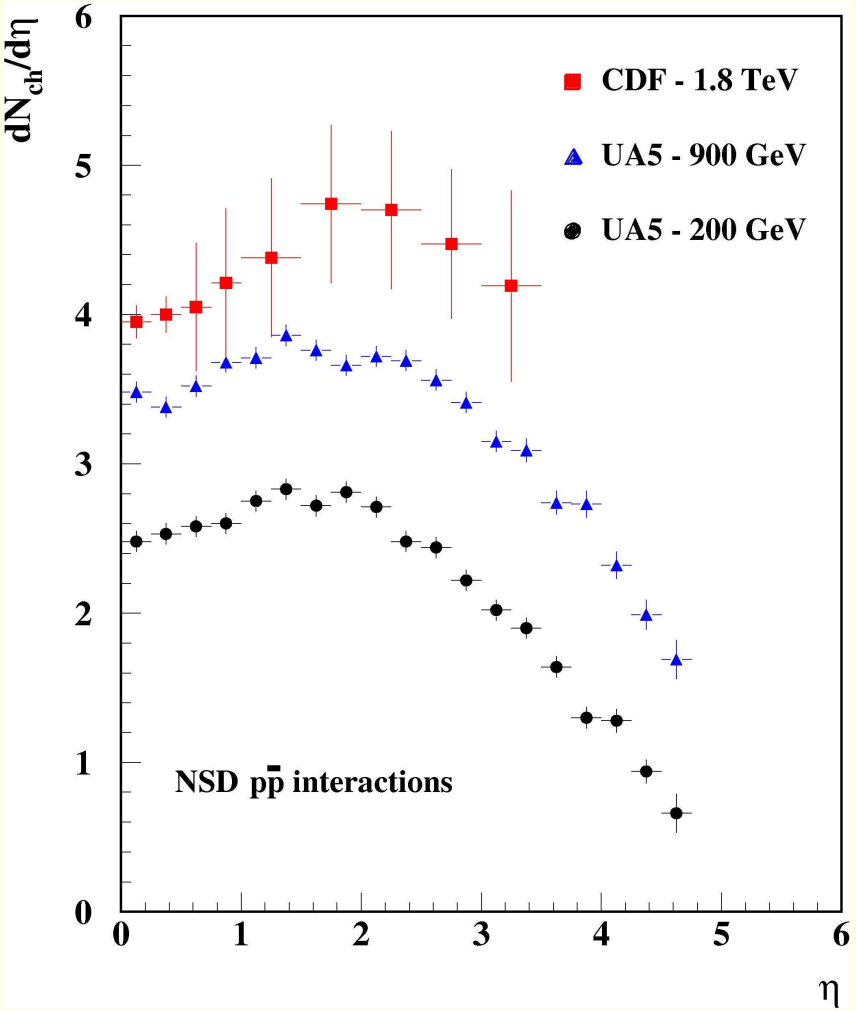
New energy regime so all data is important.

Measure $dN/d\eta$ and dn/dp_T for min bias: Theory predictions now please

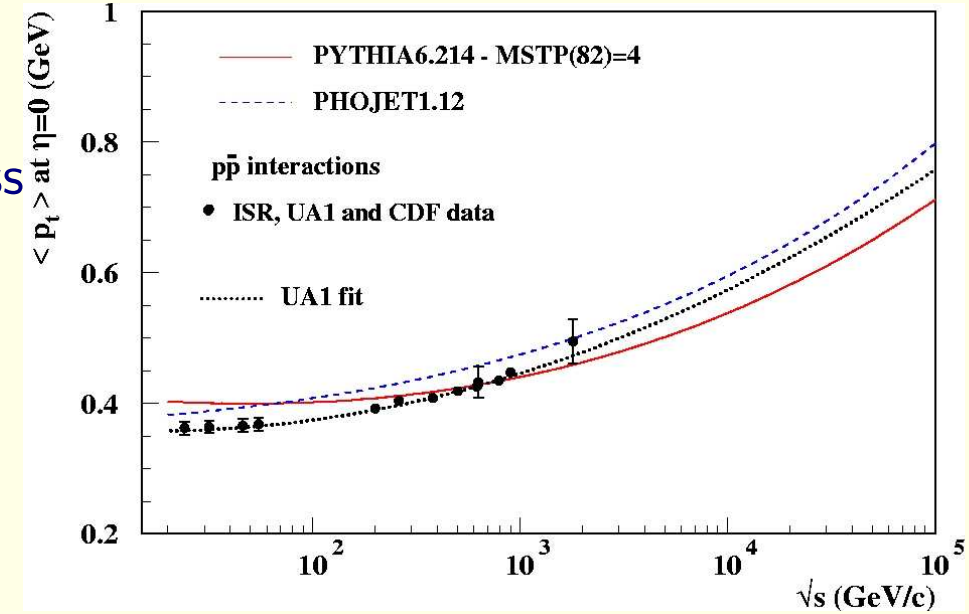
$1mb^{-1}$ needed!!

LHC line on this plot

It needs working tracking or EM calorimeter: Precision not needed

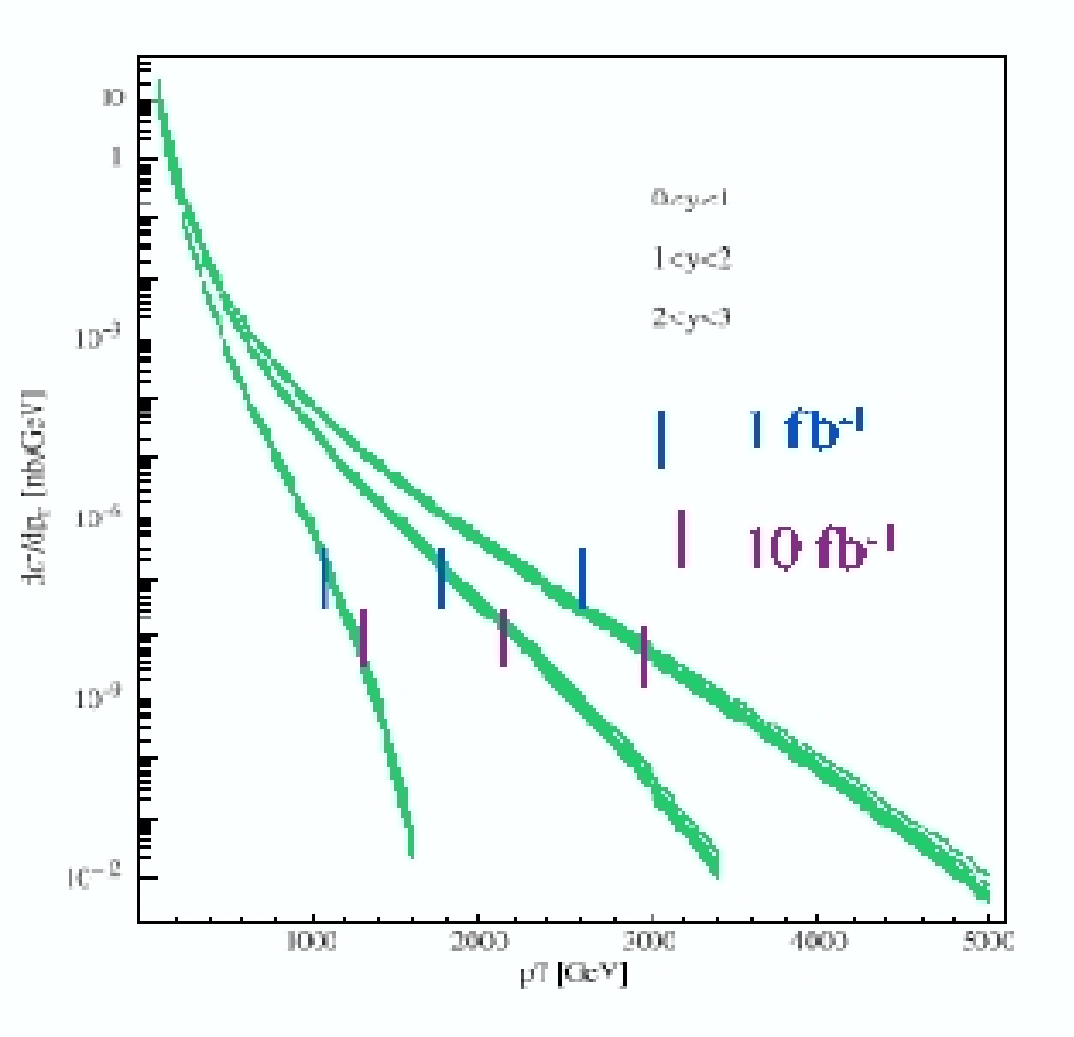


Little data is also needed to do total cross section
This is much harder.
may never be done
But it's less uncertain

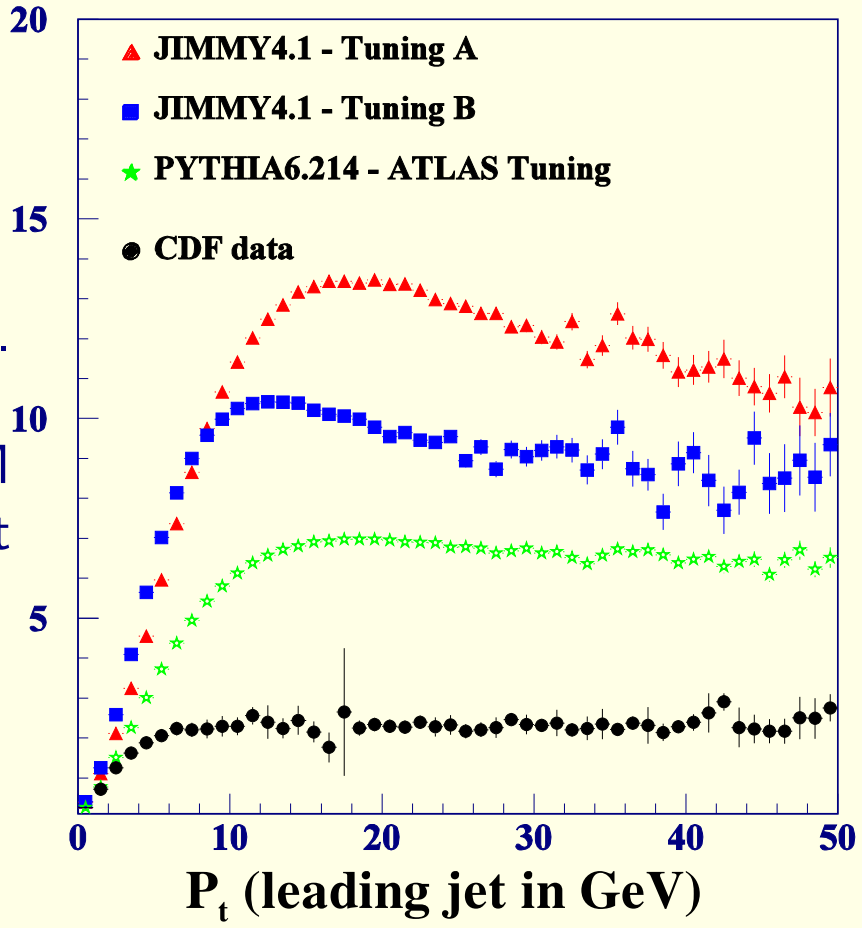


Next comes high p_T QCD

This starts immediately and never ends
Don't expect any new physics at the bottom end
Biggest exptl. uncertainty comes from Jet energy scale (later)
500 GeV jets with $100nb^{-1}$
50 GeV Jets with $100\mu b^{-1}$
Initially tune up MC
Eventually measure α_s



$100\mu b^{-1}$: Measure $dN/d\eta$ and dN/dp_T for low p_T jets:



Start QCD study of underlying event. Some predictions
It needs working tracking or EM calorimeter and jet finding: Precision not needed

These parts of QCD are least well understood: they are irrelevant in e^+e^-: Speech

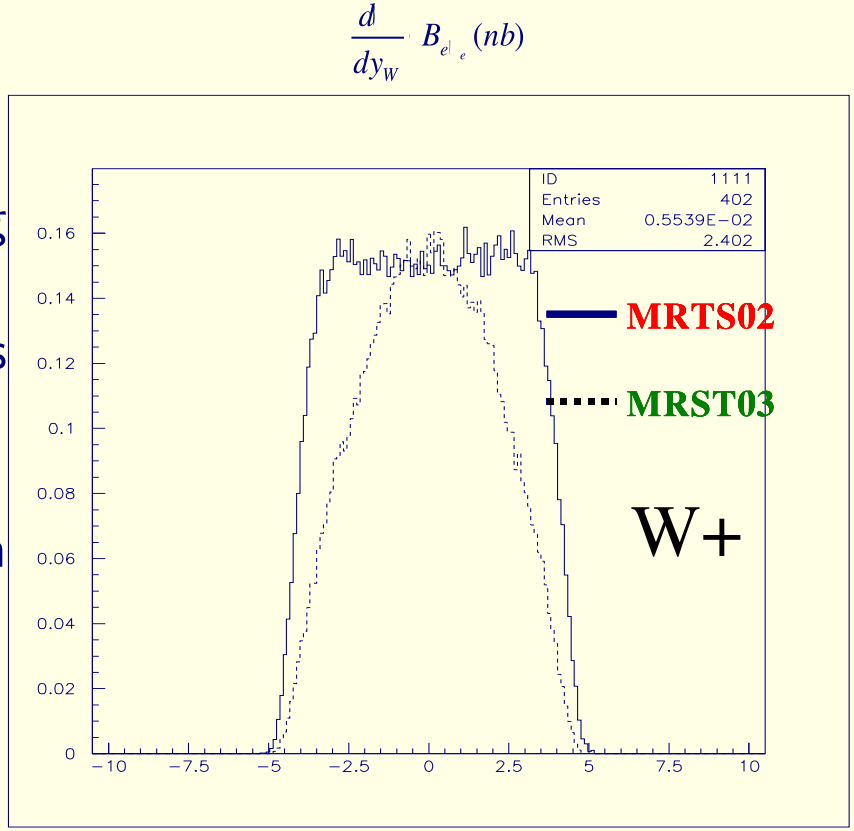
Now go and re-evaluate the jet tagging and vetoing, that you expect to use in Higgs searches

$10pb^{-1}$: 100 jets beyond the Tevatron kinematic limit:

Electro-weak

$\sigma(W) \times BR(W \rightarrow e^{+}\nu) \sim 15nb$
High statistics starts with $1pb^{-1}$

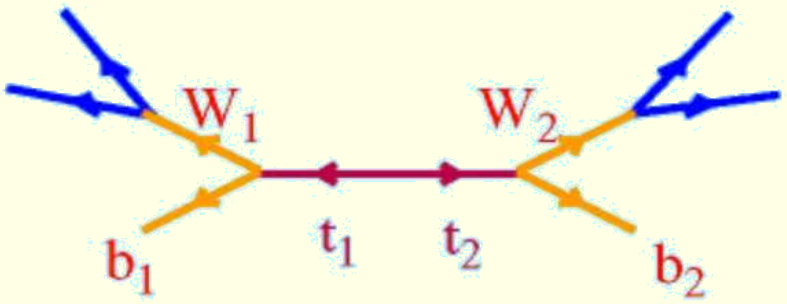
Used to calibrate EM calorimeters, missing E_T, understand e/μ behavior
Physics measurements of cross-sections and structure functions
Note big uncertainty in forward region
A long term goal will be precision measurement of W mass:



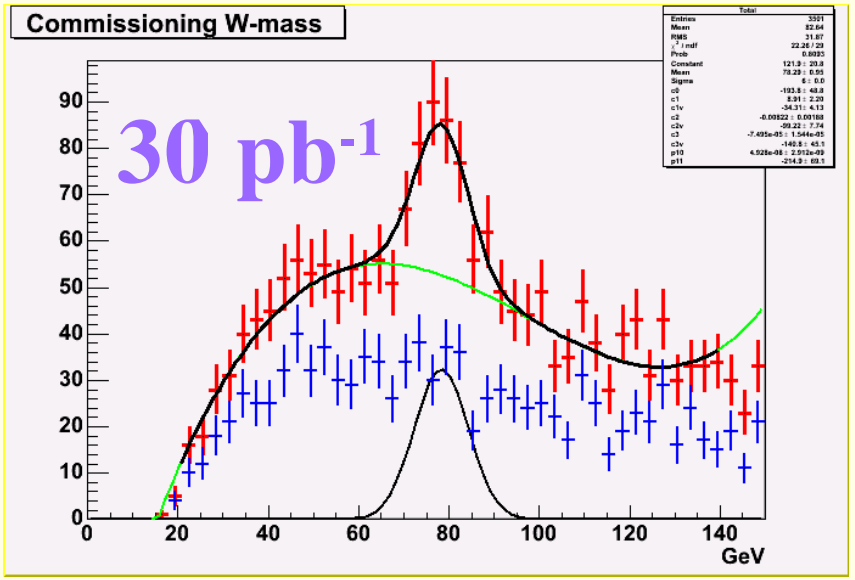
Top

- $10pb^{-1}$ (1 day at 1/100 of design luminosity) gives 8000 $t\bar{t}$
- S/B better than Tevatron
- Ultimate Gaol is precise measurement of top mass
- Initially, Calibrate the detector, measure cross-section

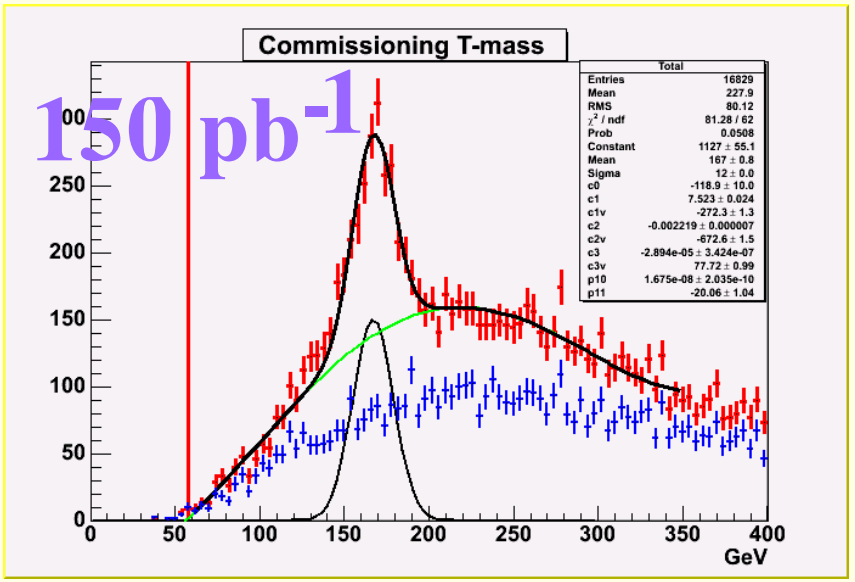
Use the semileptonic decay
Clean and plenty of rate
No b-tagging is needed It needs working tracking or EM calorimeter and jet finding



Use these to calibrate jets from W



assume b-jet scale is same (approx)
reconstruct top peak
measure cross section



Now have sample of events with two b's for measuring the b-tagging.

Many more

- B production rates
- Drell-Yan
- ψ and Υ
- WW, ZZ, $W\gamma$ at low p_T where SM should be OK

30 days with luminosity 10^{31} does most of this program:
Don't believe any claims of new physics until the above has been done!!

How long to wait before new physics??

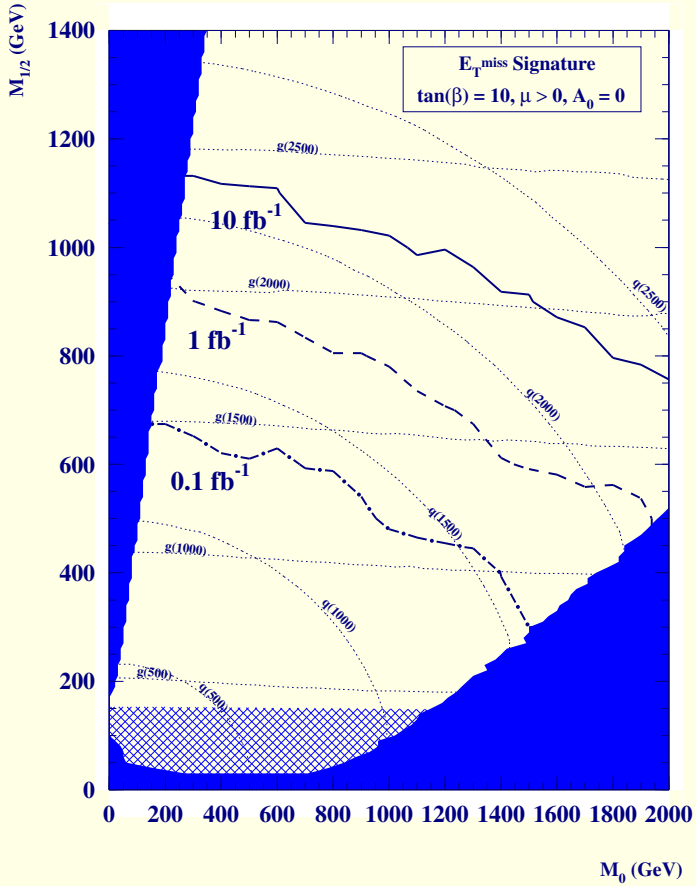
- Must be be beyond existing limits
- Rates must be less than something
- Single production of something $e.g.$ Z'
- Pair production of something

Things with QCD coupling will show up first

Best defined example is SUSY

How fast can SUSY be found?

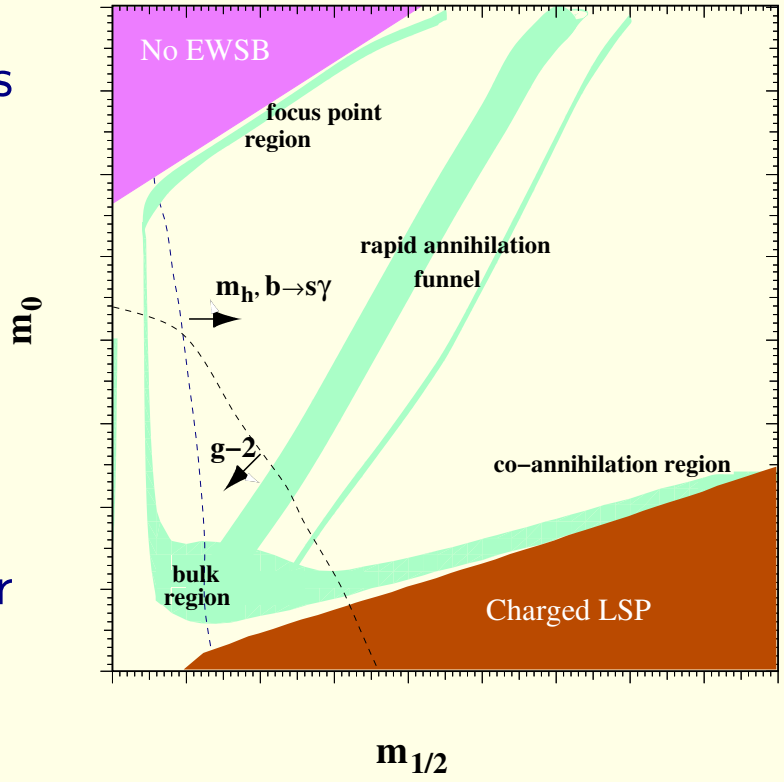
Plot shows reach in SUSY model space
Solid region is not allowed
Hatched region is already ruled out by LEP
Contours label squark and gluino masses and luminosity
Example – $0.1 fb^{-1}$ discovers gluino of mass 1 TeV
This is 1 year at 1/1000 of design luminosity!



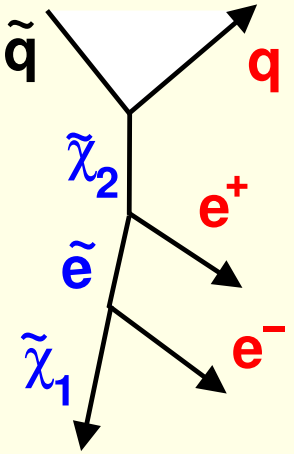
Should not have to wait too long

Fine tuning arguments indicate SUSY is "late"
If SUSY is Dark matter

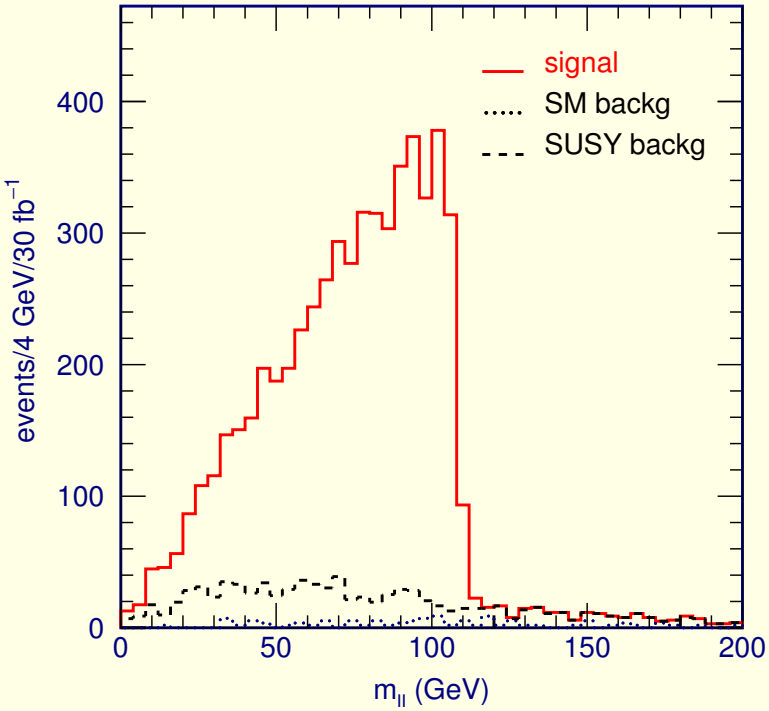
- Smaller masses preferred
- Larger masses implies degeneracies or enhanced couplings



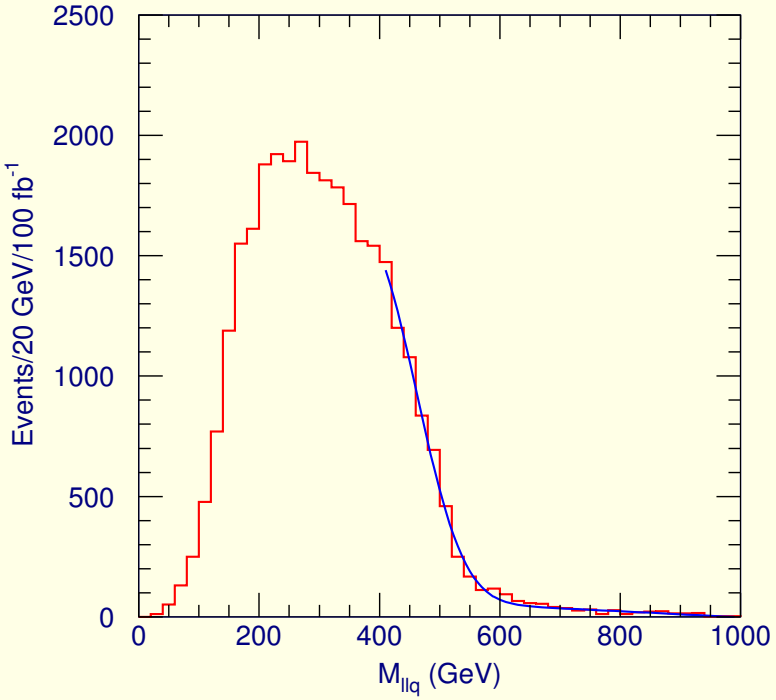
Decay $\tilde{q_L} \to q\tilde{\chi}_2^0 \to q\tilde{\ell}\ell \to q\ell\ell\tilde{\chi}_1^0$
Produces a pair of e^+e^- or $\mu^+\mu^-$ with an invariant mass in a restricted range.



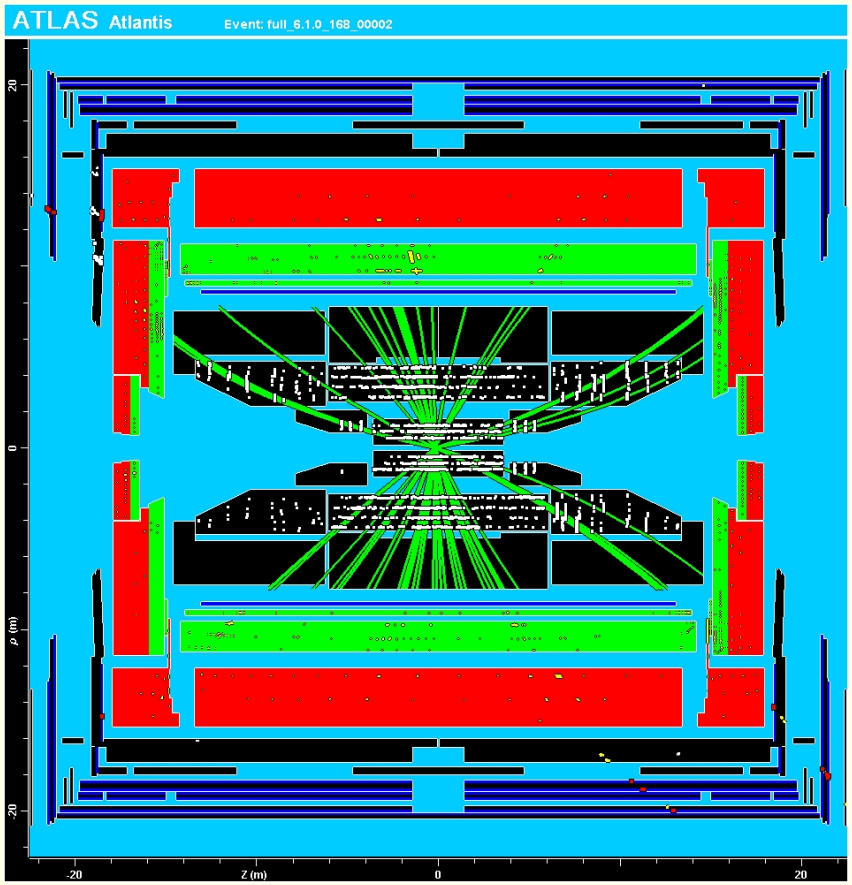
Plot shows invariant mass distribution of $\mu^+\mu^-$ and e^+e^-
This is $30fb^{-1}$ but
should be able to get a measurement with $300pb^{-1}$



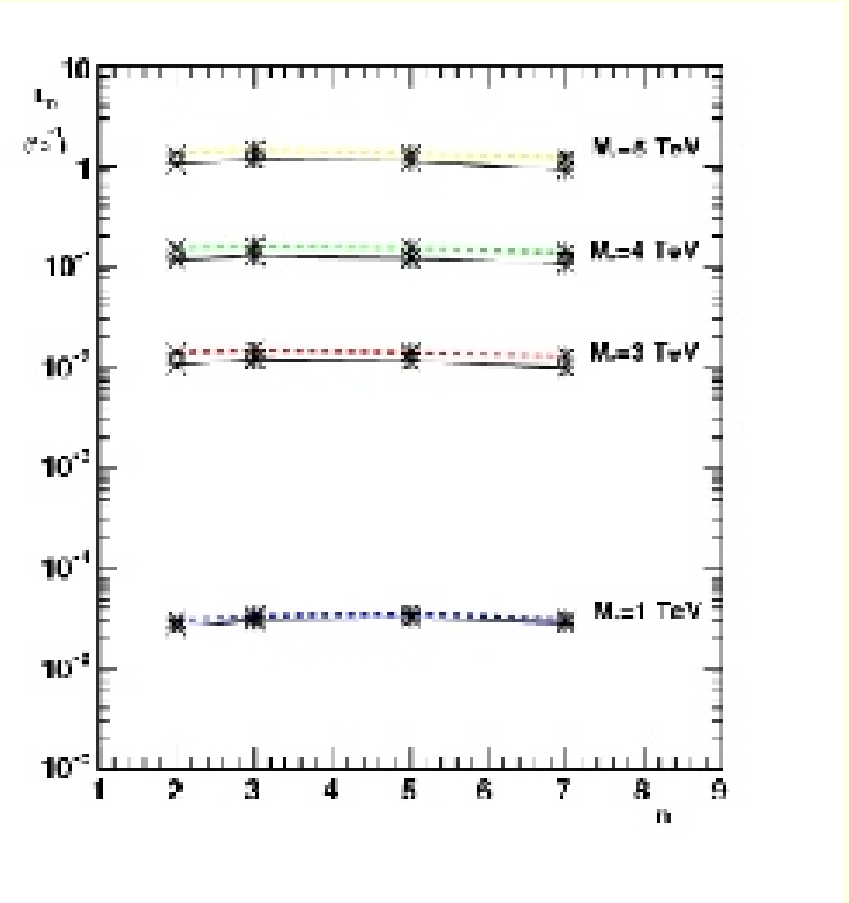
More complicated topologies can be reconstructed starting here and adding jets.



Less well defined – Mini black holes



very clear signal
Boltzmann distribution



Large rate (uncertain)
May not need much luminosity
$10pb^{-1}$ reaches 3 TeV

A Bit further ahead: Higgs

Higgs is not a "typical" LHC discovery as it demands much luminosity

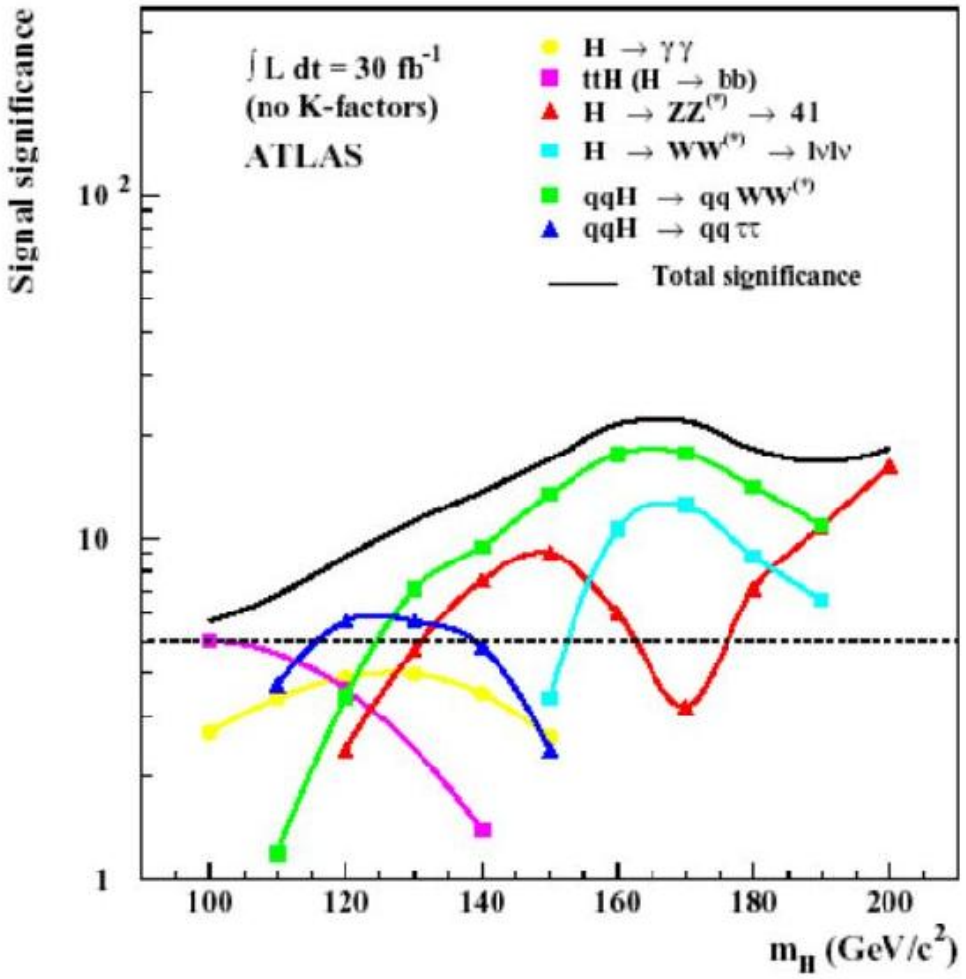
Plot shows statistical significance after $30 fb^{-1}$

Easiest channel depends on mass

The black curve shows the combined result

Might get lucky/clever but

Plenty to do while waiting



Conclusions/Messages

- Accelerator and Detectors approaching completion
- Theorists with new models: Focus on LHC not LC if you expect to be tested soon
- QCD is not boring!!
- LHC is first new energy frontier in a generation
  "Our field may be toast if we fail to fully exploit it"