Alternative New Physics at the LHC

Andrew Askew
for ATLAS and CMS

Alternative New Physics at the LHC (not SUSY)

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- Many, MANY new models: MSSM, mSUGRA, NUHM, Split SUSY, GMSB, AMSB, ADD-ED, RS-ED, UED, E6 GUTs, Little Higgs, Hidden Valley, …
- I will attempt to cover the general sensitivity of ATLAS and CMS to certain (non-SUSY) signatures:
- A play in three acts:

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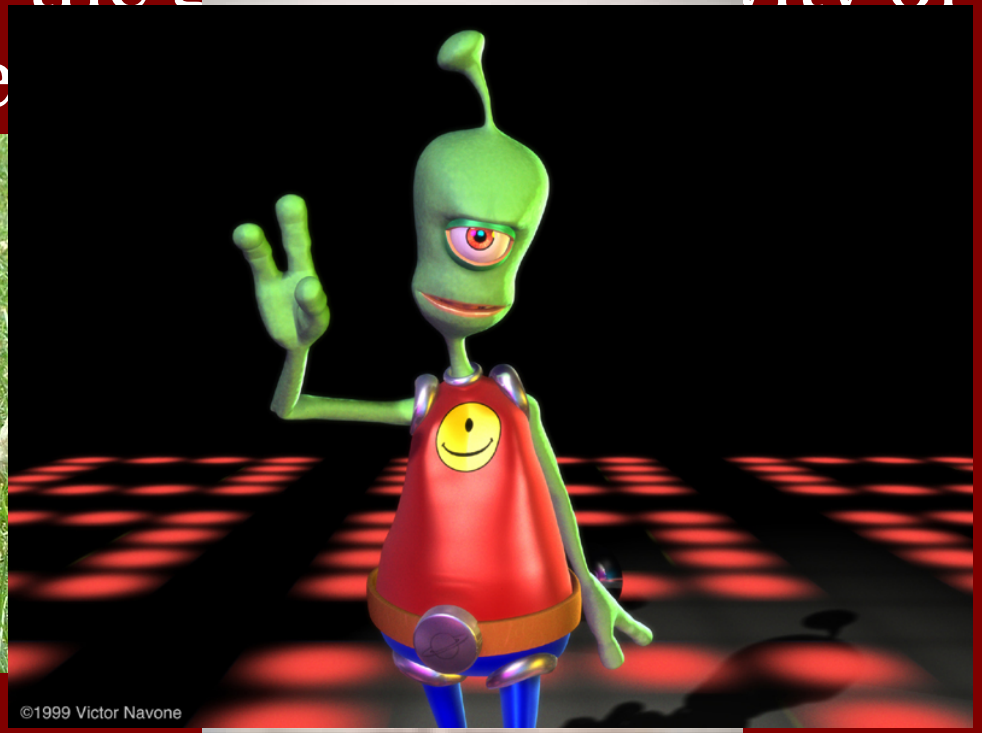
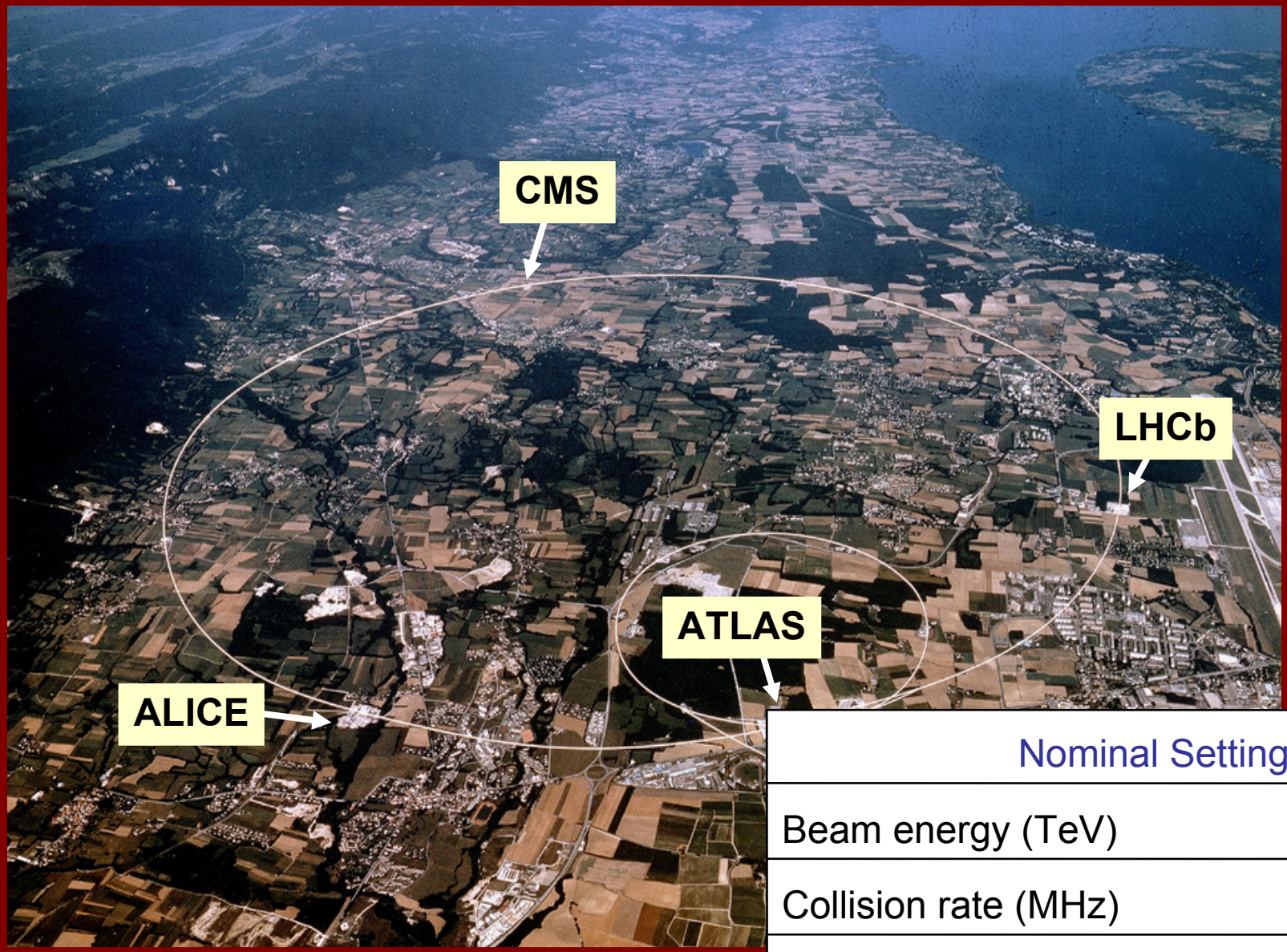
- A play in three acts:
  - The Conventional
  - The UnConventional
  - The UnExpected?



Outline:

- Conventional:
  - Leptons + mE_T, Dileptons, Trileptons, Lepton + jets. Traditional collider search signatures.
- UnConventional:
  - Heavy Stable Charged particles.
  - High activity events.
- Unexplored:
  - Hm…

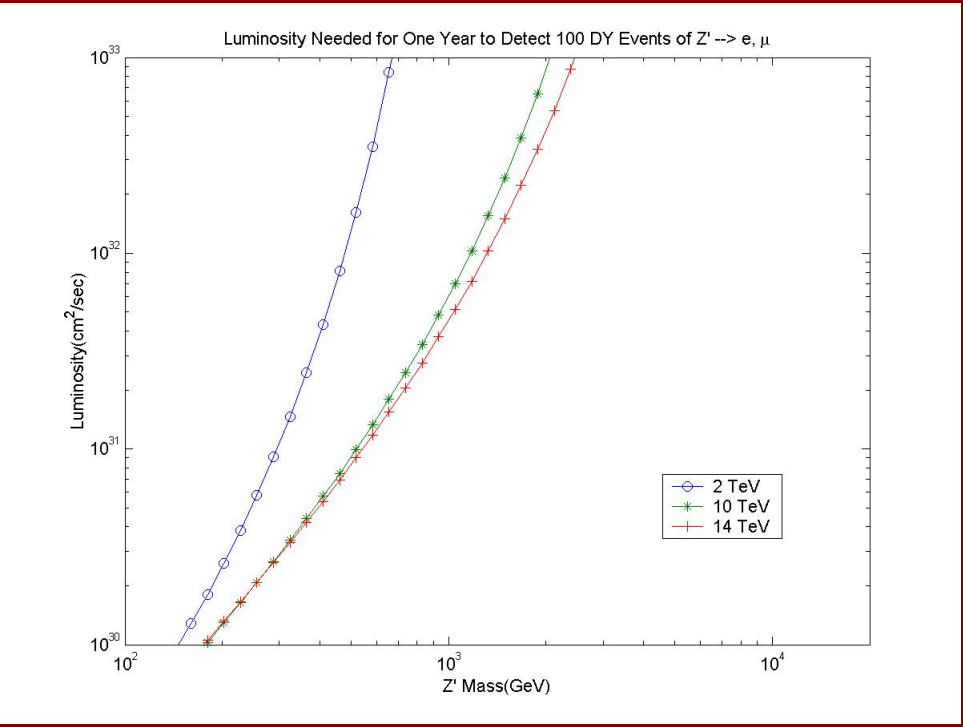


Nominal Settings	
Beam energy (TeV)	7
Collision rate (MHz)	40
# particles per bunch	1.15×10^{11}
Luminosity ($cm^{-2}\ s^{-1}$)	10^{34}
Stored energy per beam (MJ)	362

Got a more full review on LHC status on Monday from Leandro

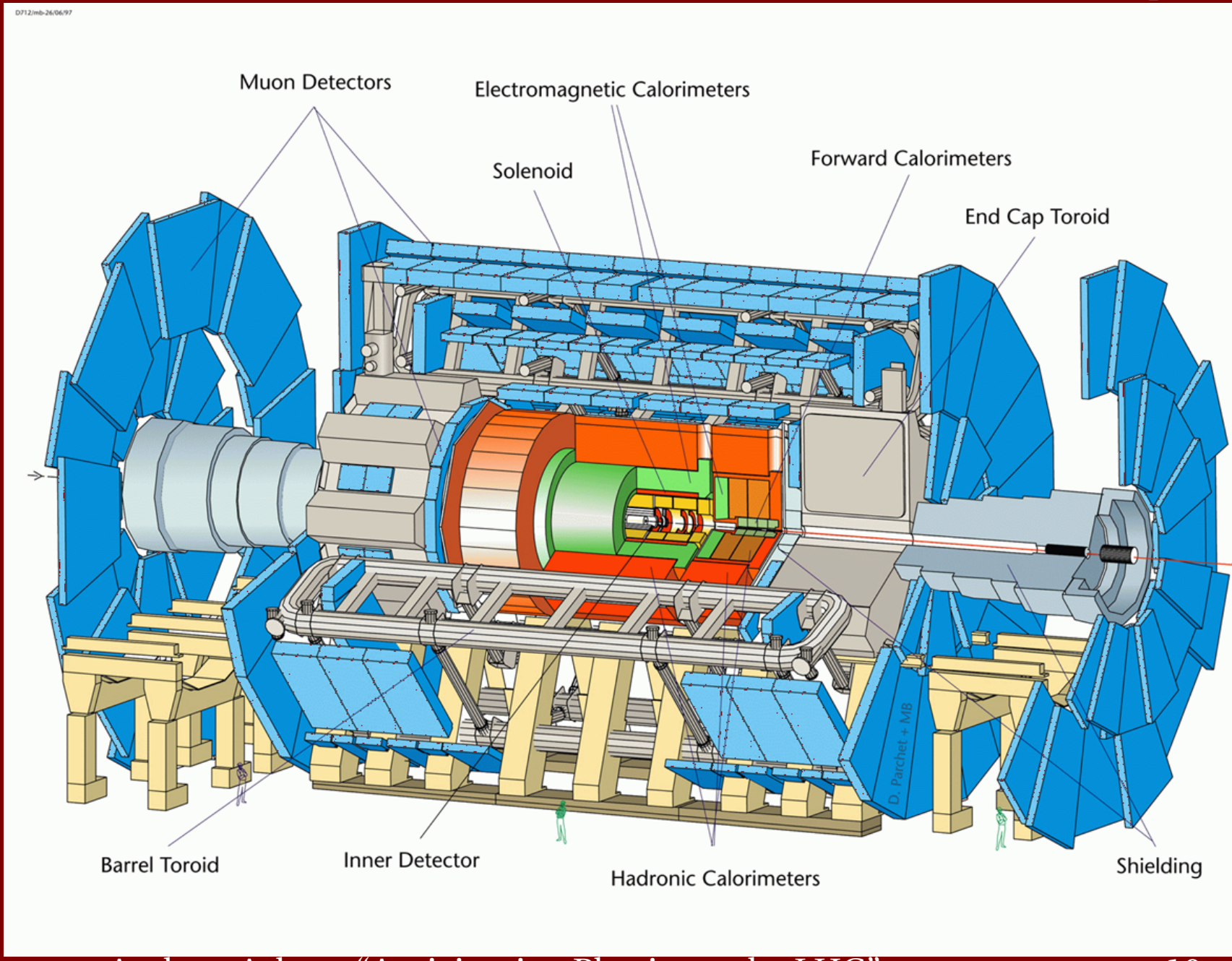
Caveats:

- Should begin running THIS year:
  - Center of mass energy 10 TeV.
  - Estimated integrated luminosity 40 pb^{-1}.
  - Studies I will show highlight both large integrated luminosity, (almost) perfected detectors and early start-up scenarios, to give a flavor of early and final sensitivity.



Detectors: ATLAS

No experimentalist talk is complete without the apparatus!



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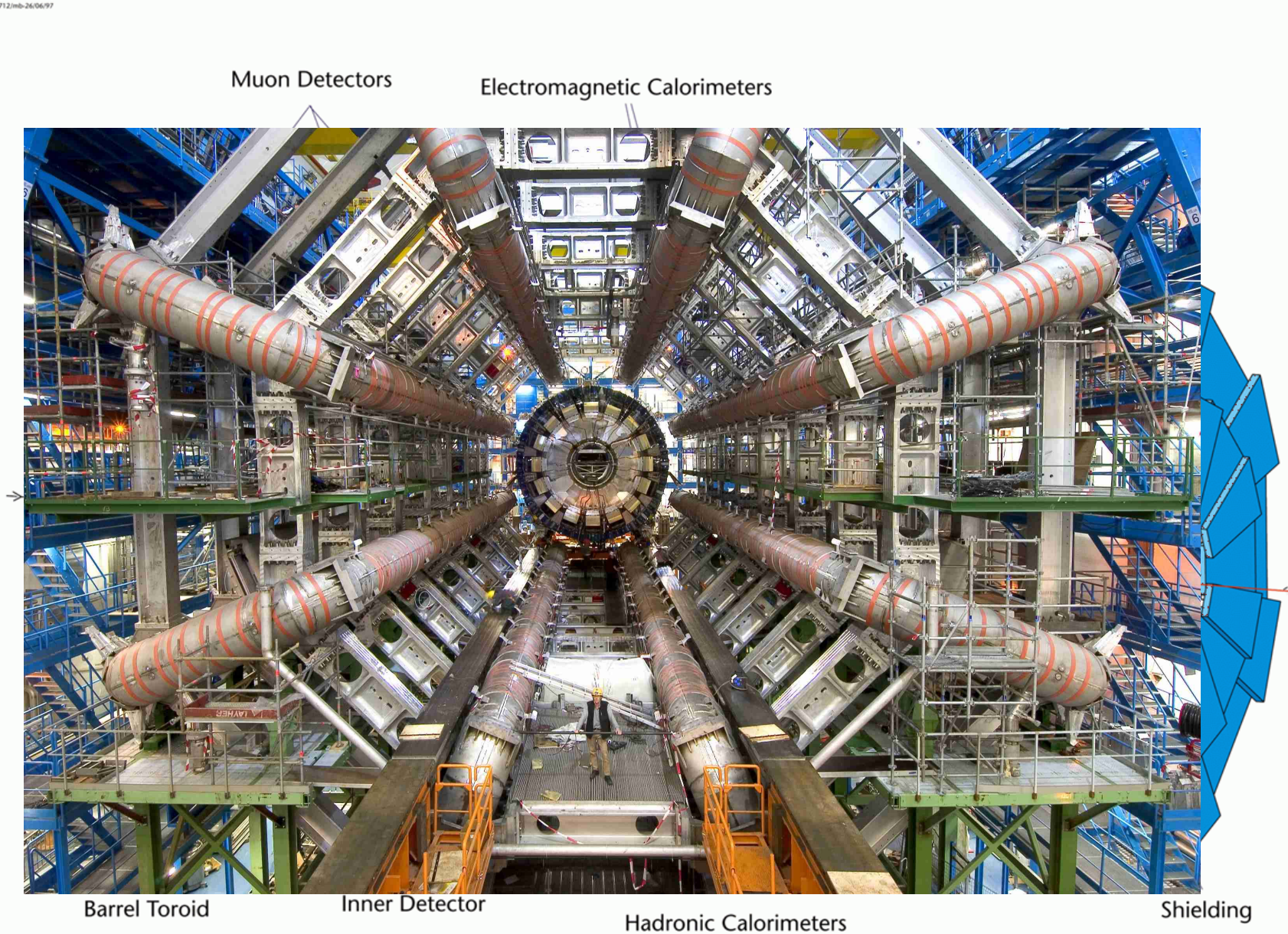

Detectors: CMS

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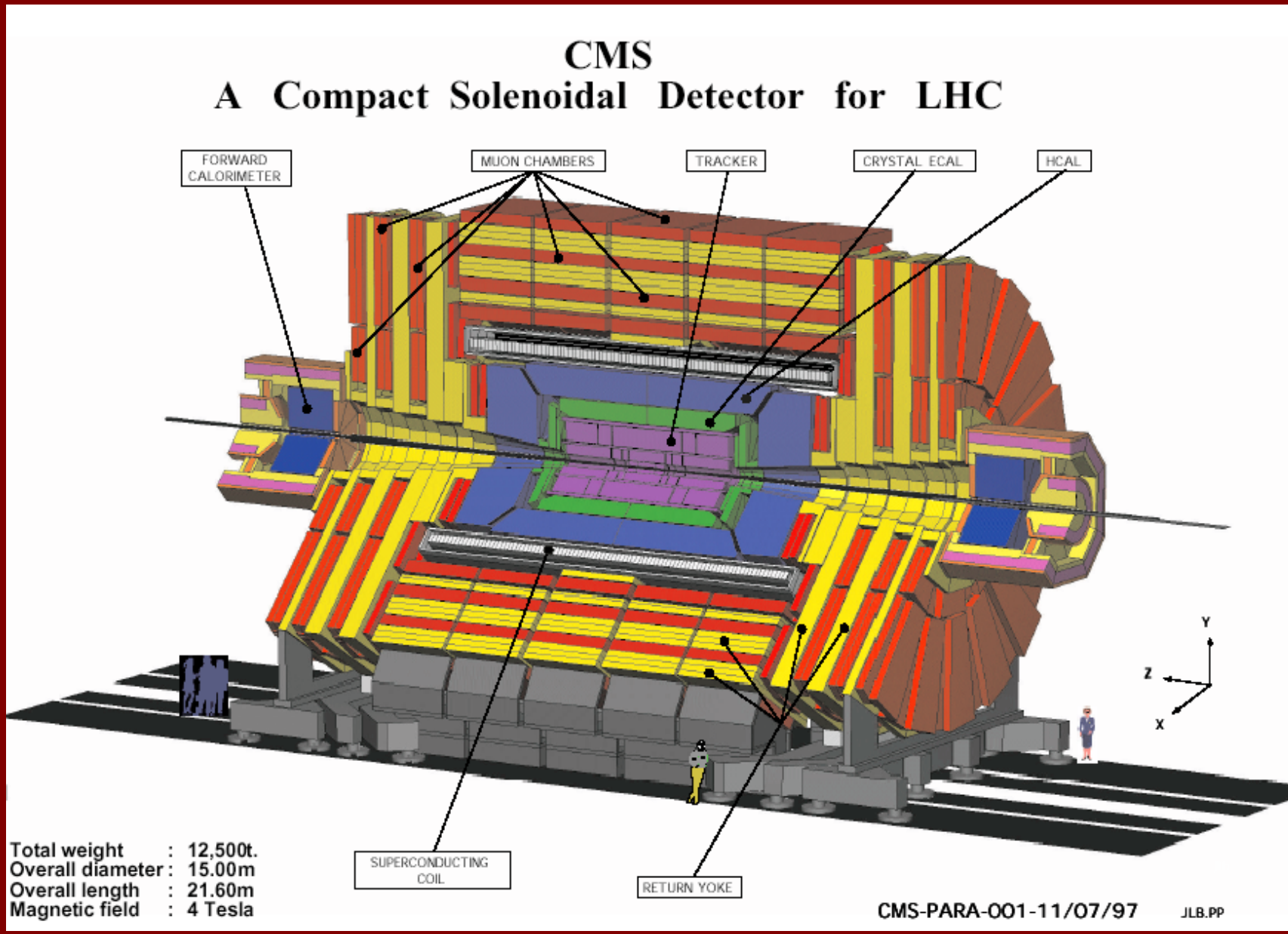

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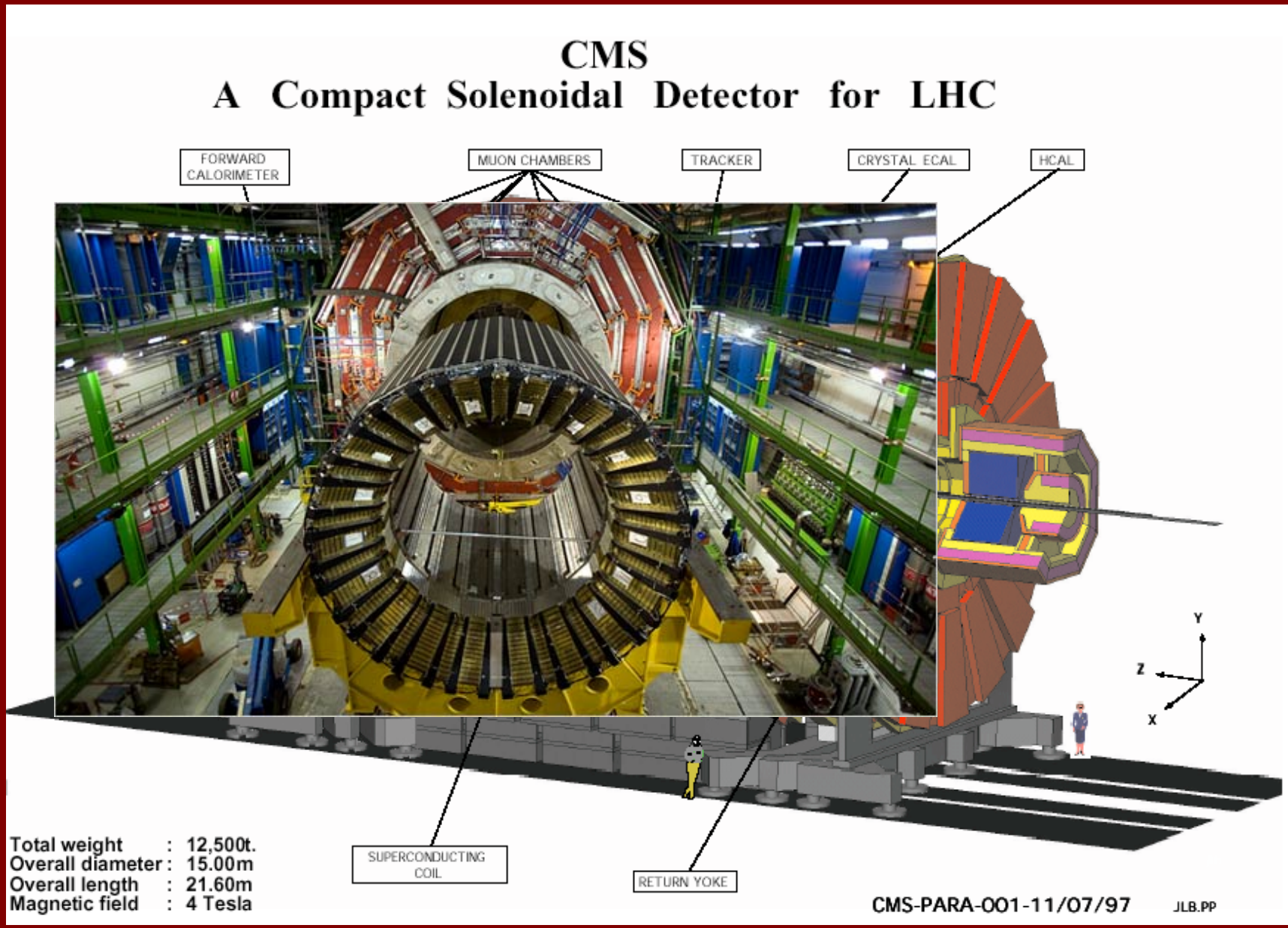

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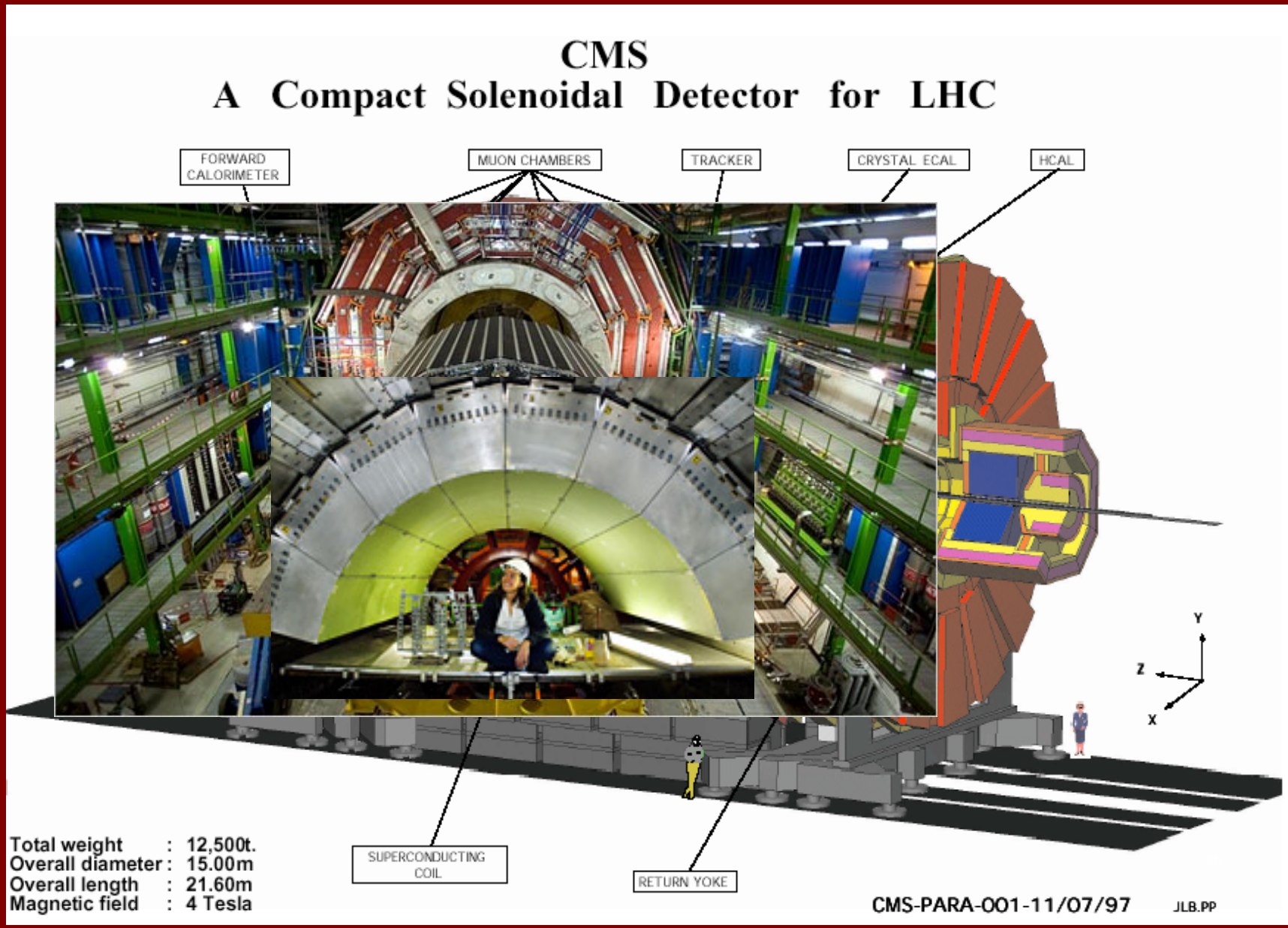

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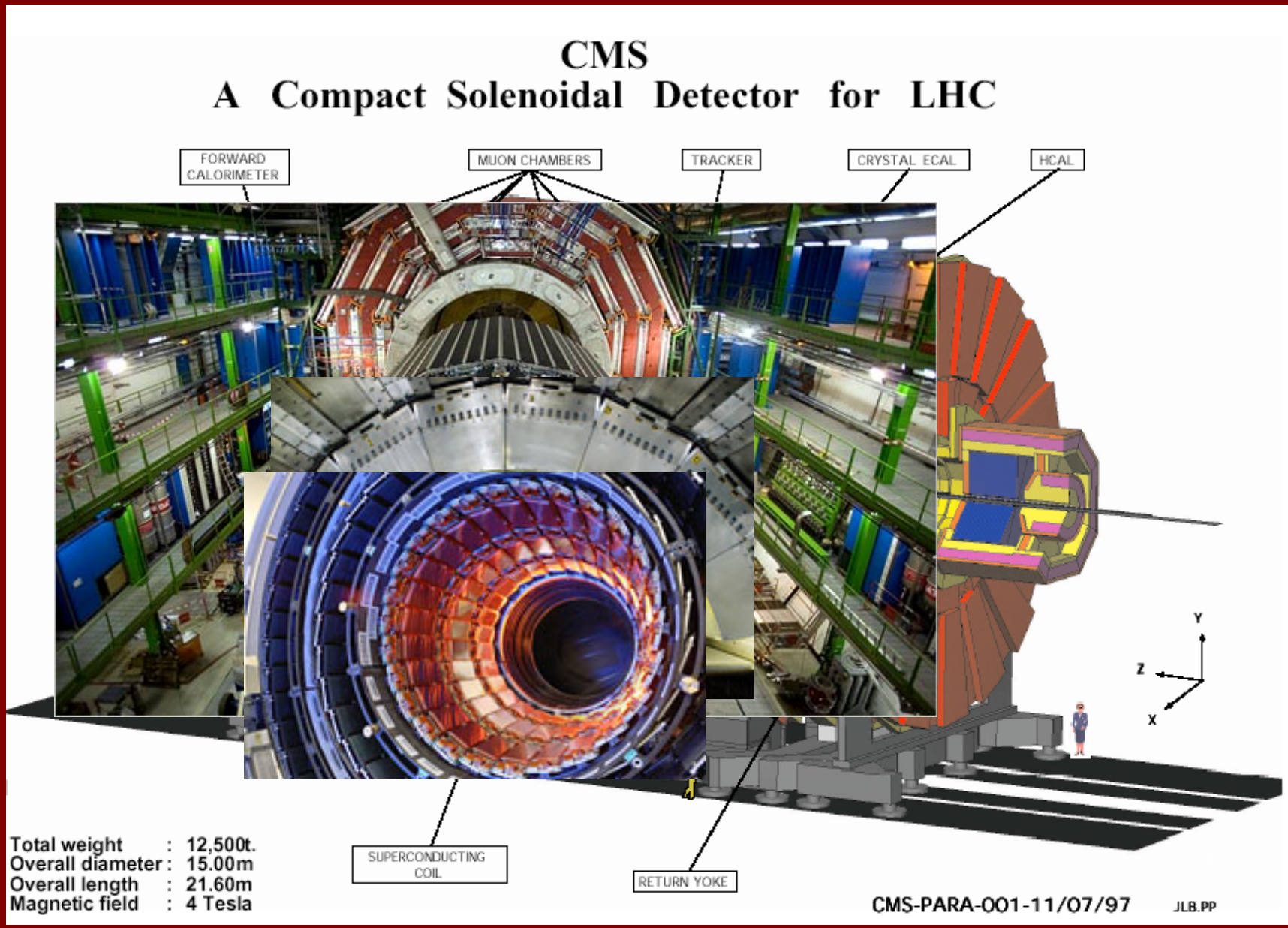


The Conventional: Leptons

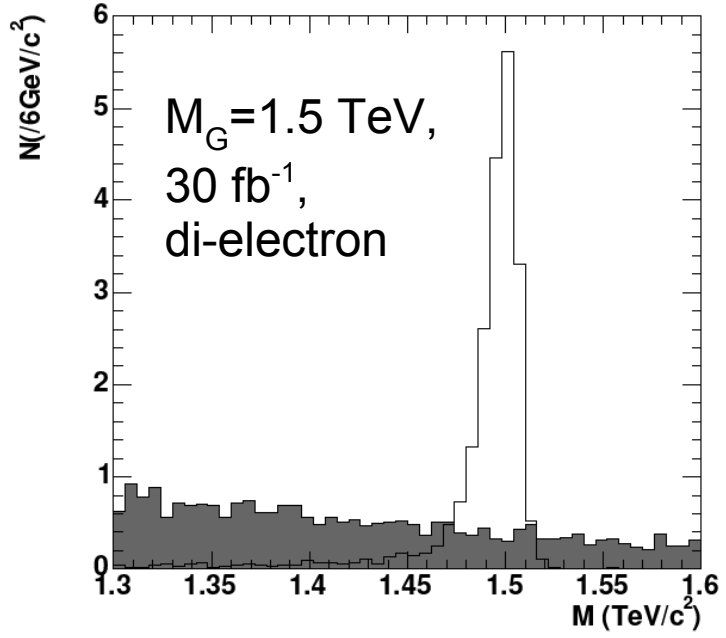
- Cleanest signatures at a hadron collider, and luckily, many new physics models contain 'conventional' signals :
  - Dileptons/Diphotons: Z primes, Gravitons, Unparticles
  - Lepton + missing E_T: W prime
  - Trileptons: TechniColor, other W prime models.
  - Leptons + Jets: W_R, Leptoquarks.

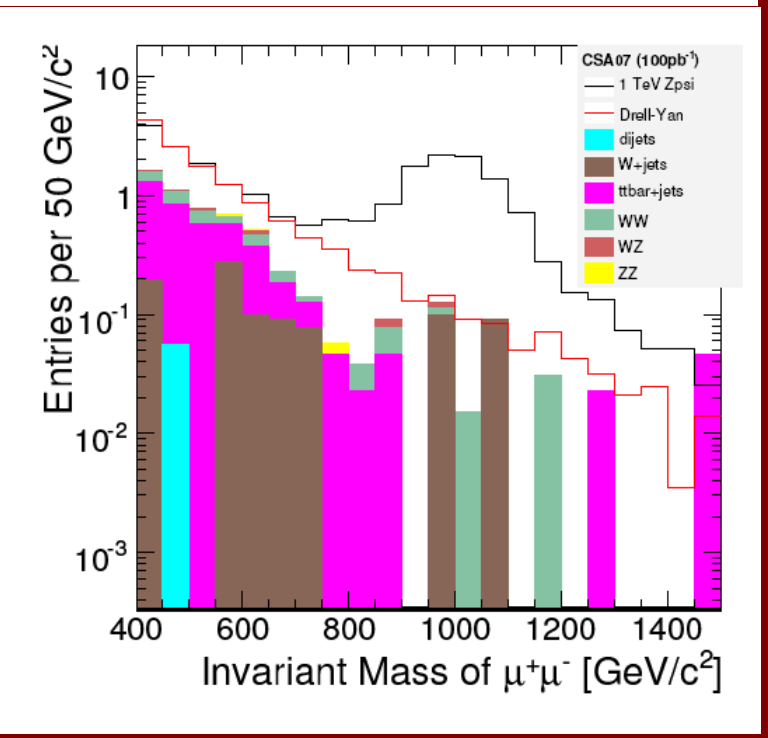
Dileptons:

- Checklist:
  - Sequential Standard Model (same couplings as Z^0), Left-Right, Alternative Left-Right (different couplings).
  - GUTs : E6 → SO(10)xU(1)$_\psi$ → SU(5) x U(1)$_\chi$ x U(1)$_\psi$: Z_ψ, Z_χ
  - G_{RS}: Gravitons yielding high mass decays.
  - G_{ADD}: Indirect sensitivity, change kinematics.
  - UnResonanaces: not really a resonance, but starkly alters spectrum (hep-ph:0706.3025).
  - Technicolor.
- My apologies, I can't cover ALL of these, but I'll try to give you a sense.

Dileptons (CMS):

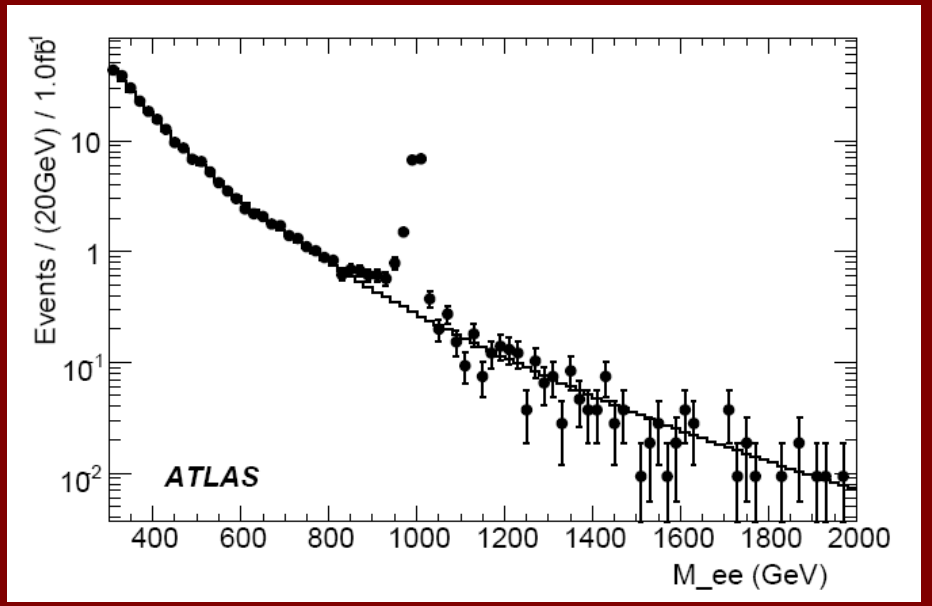
- Top plot: 1.5 TeV (RS) Graviton decay to dielectrons in fairly 'ideal' case, with 30 fb^{-1} .
- Bottom plot: Early running scenario, Z_ψ with M=1 TeV decay to dimuons, with early (poor) alignment and 100 pb^{-1}.

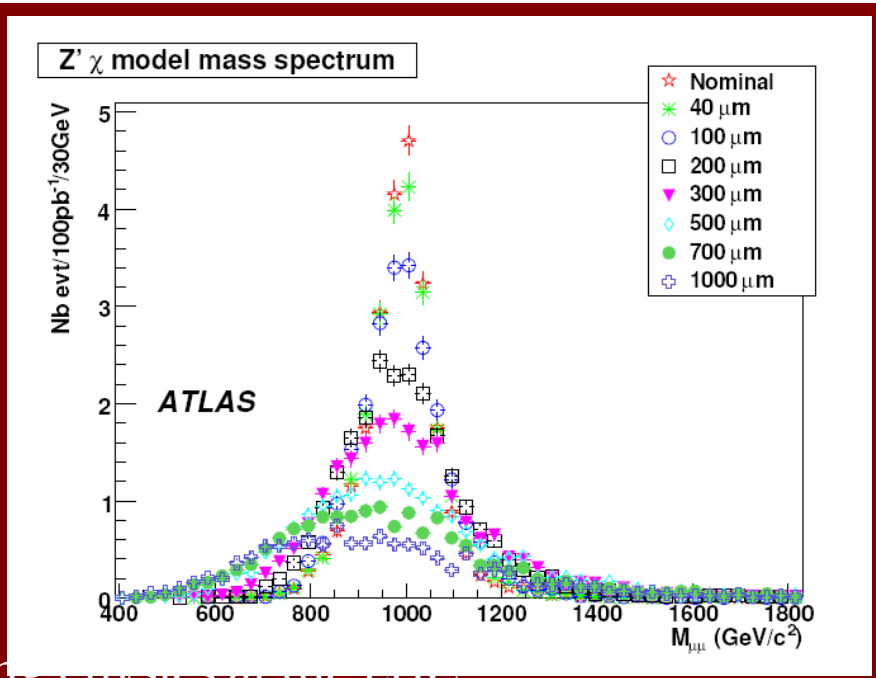




Dileptons (ATLAS):

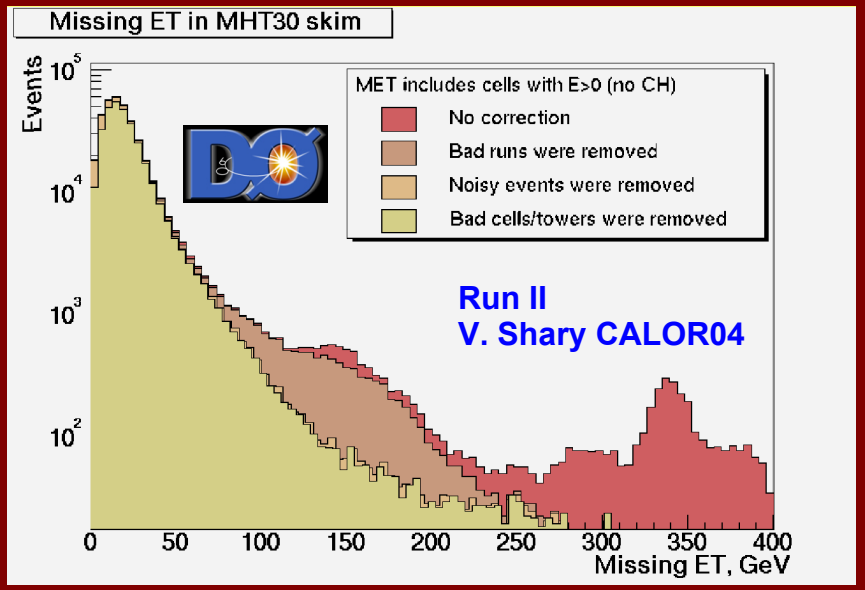
- Top: (RS) Graviton of mass 1 TeV, decay to dielectrons, 100 fb^{-1}.
- Bottom, Z_χ decay to dimuons, several different qualities of early alignment, 100 pb^{-1}.





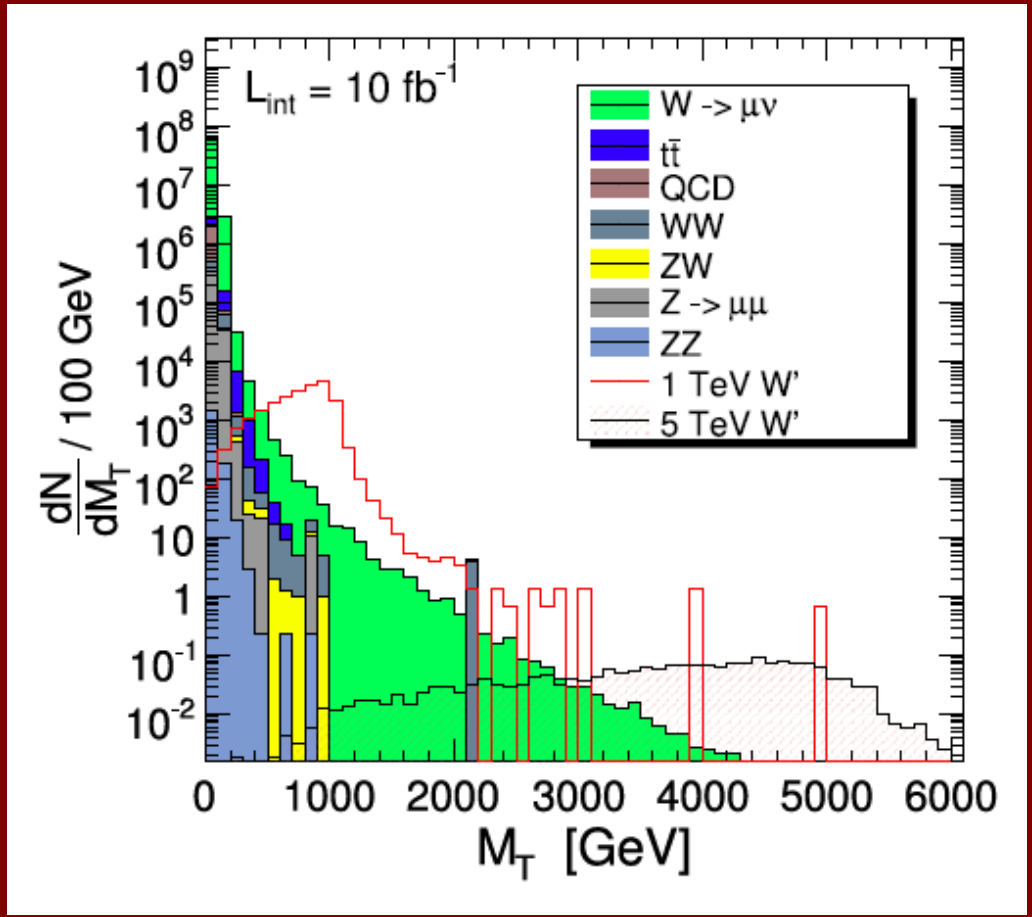
Lepton + mE_T

- Clear signals, of course with several buts:
  - Must be able to separate from the Standard Model W decays (which form the bulk of the background).
  - Must be able to understand the missing transverse energy in order to properly model.
  - Not trivial:



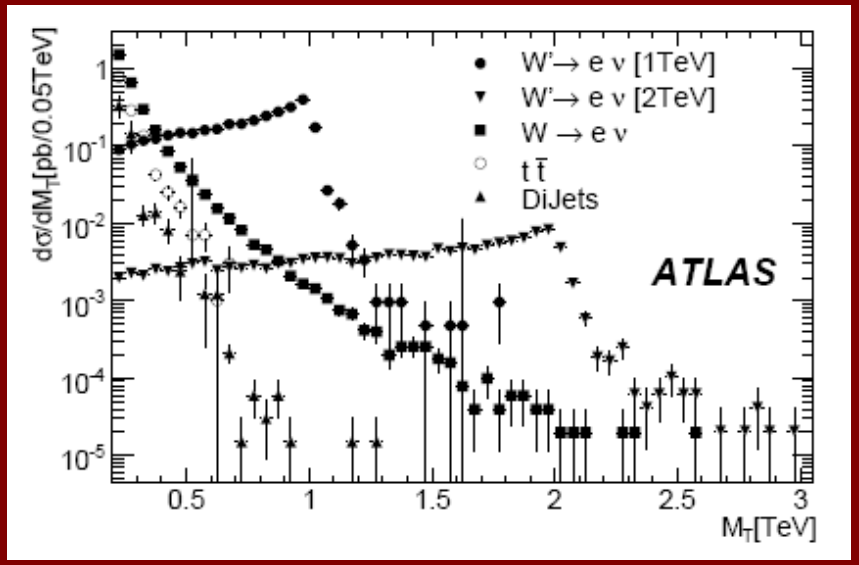
Lepton + mE_T (CMS):

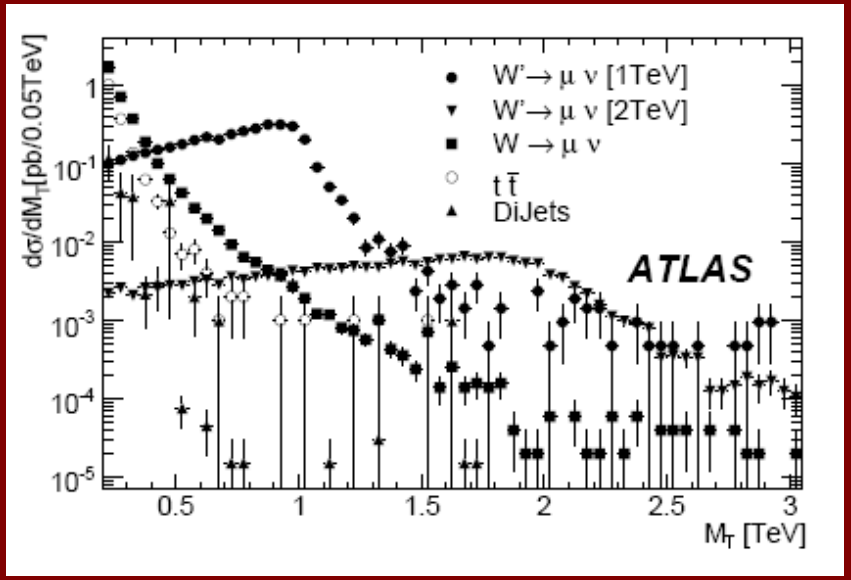
- Muon channel only here, actually HAS no cut on mE_T, simply strict isolation.
- Still relevant however to making this plot, though signal is very clear even scaling down the luminosity.



Lepton + mE_T (ATLAS):

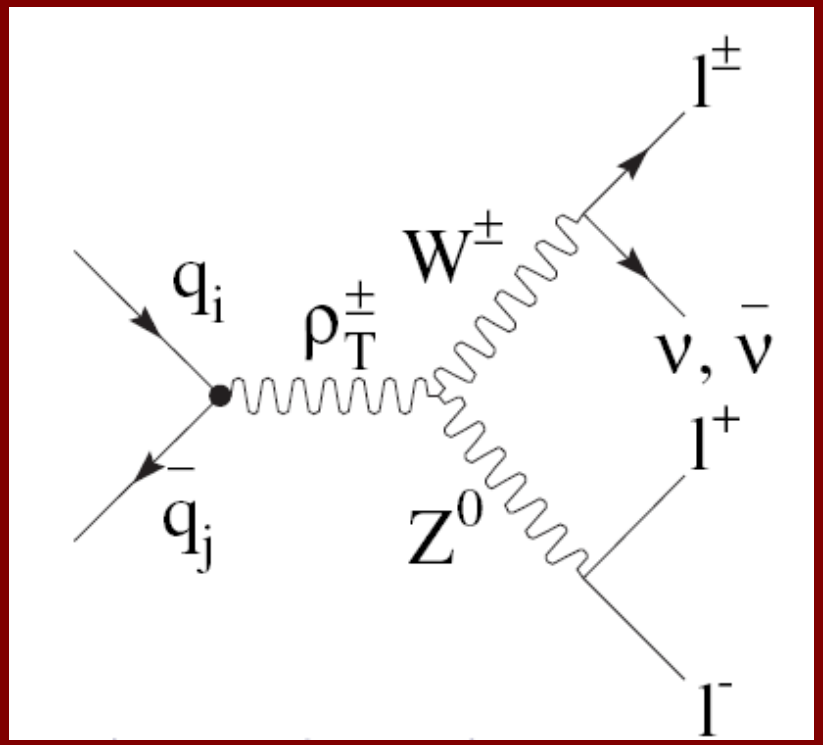
- Both of these plots are for two separate W prime masses, largest background (of course) is the SM W decay.
- Very clear signal: both of these plots are with only basic kinematic requirements (requires mE_T).





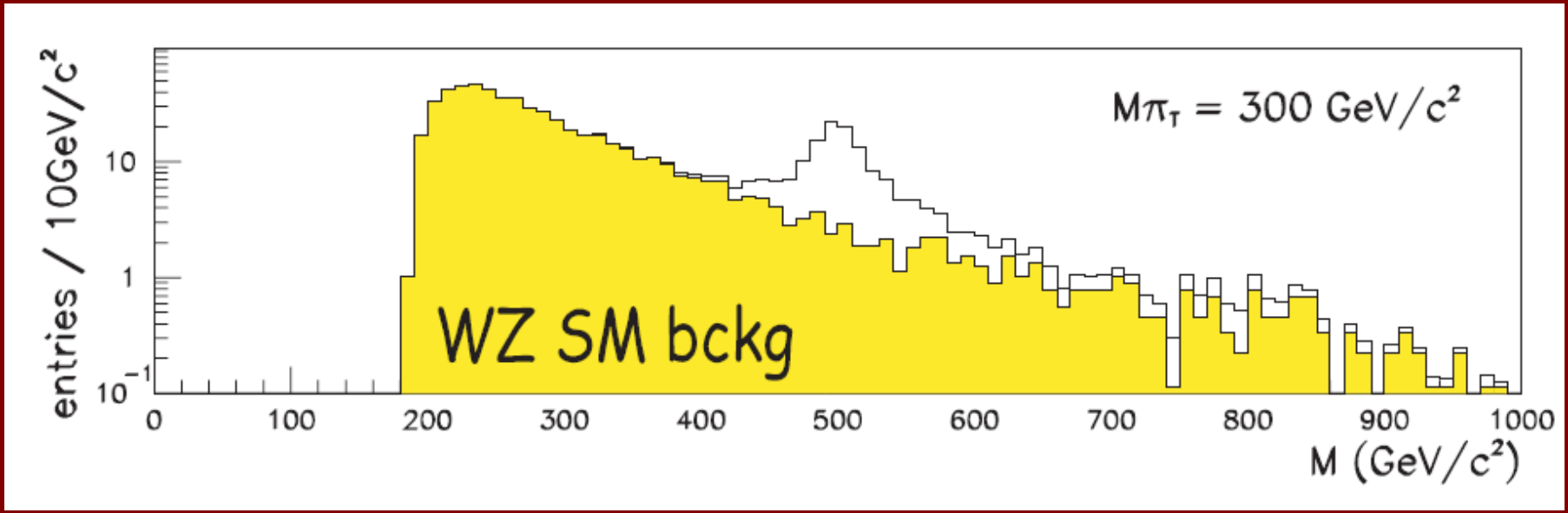
Trileptons:

- Extra clean signal, multiple leptons.
- Can be a sign of Technicolor, or W prime (substitute in diagram).
- All previous caveats apply:
  - Leptons understood early.
  - mE_T will take time.



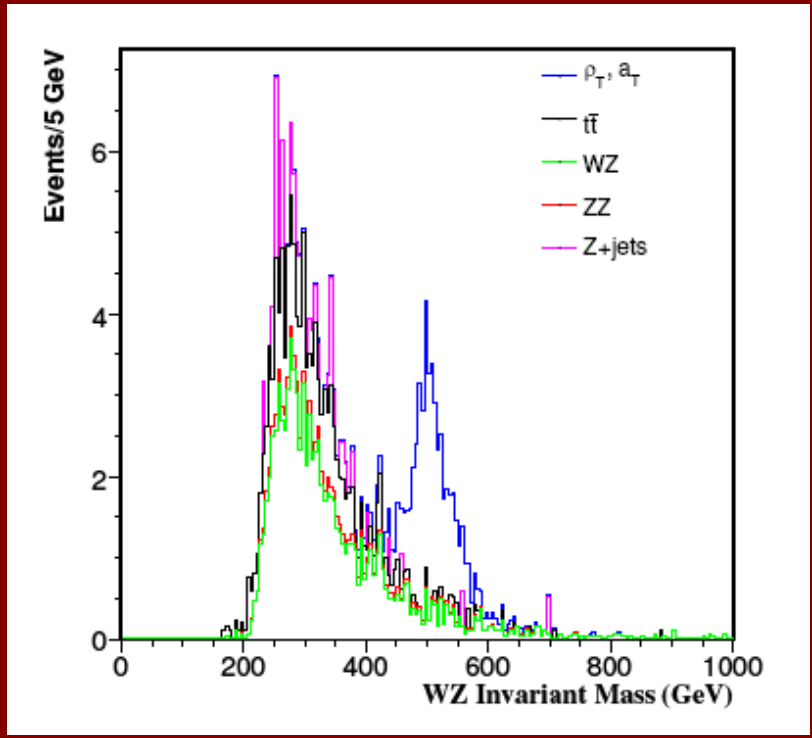
Trileptons (ATLAS):

- ATLAS, 30 fb^{-1}, decay of TechniPion to WZ.
  - Early study, only considered Standard Model WZ background (largest).
  - Clear even on continuum background.



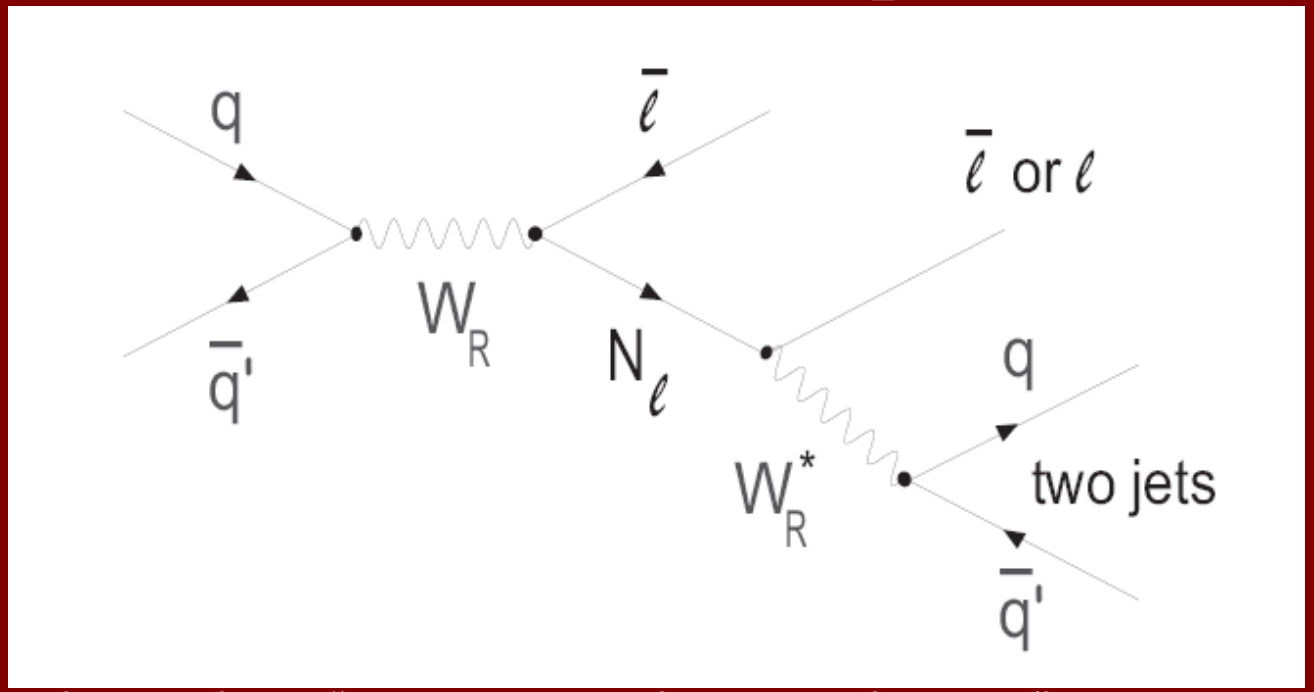
Trileptons (CMS):

- CMS four-body mass (three leptons + mE_T, make assumptions to solve for p_Z), for TechniColor ρ decay to WZ. 10 fb^{-1}.
- Backgrounds from ZZ, top included.



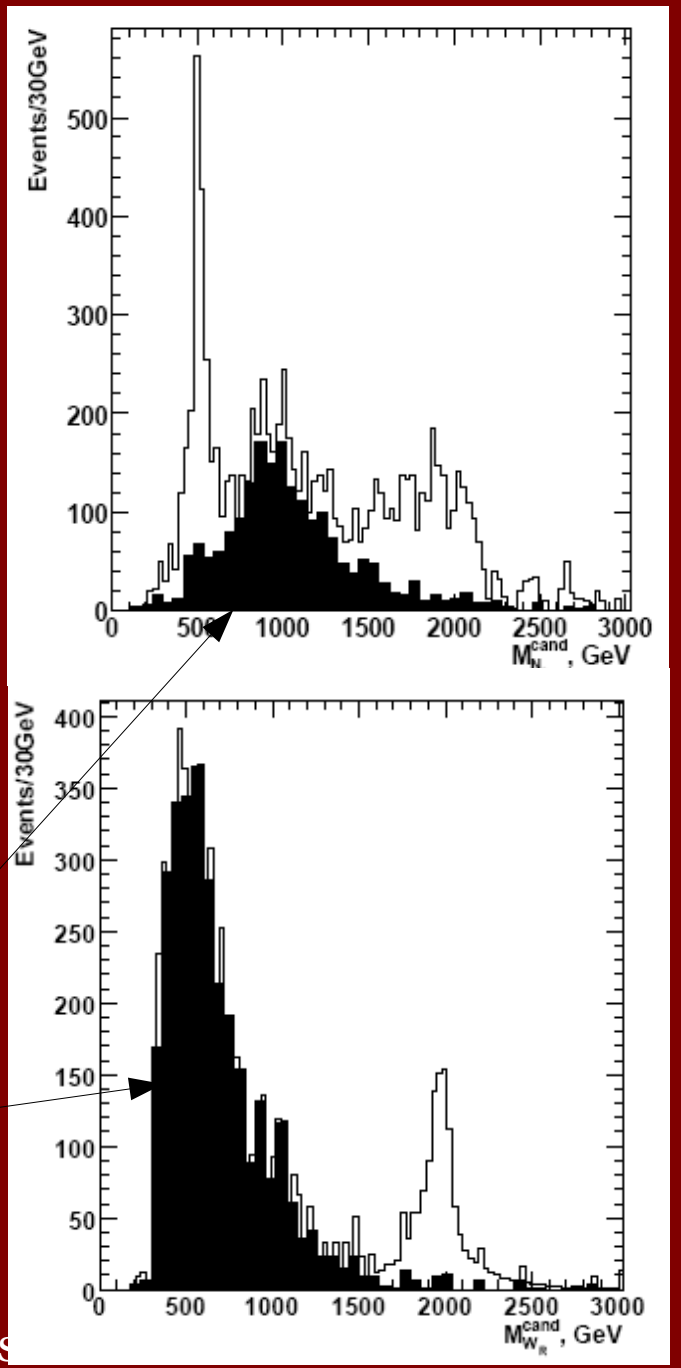
Leptons+Jets:

- In this case, two leptons, and two jets. Signal for both leptoquark production, as well as right handed W (W_R).
- Additional complication: Not mE_T, but the Jet energy scale and resolution complicate matters.



Leptons + Jets (CMS):

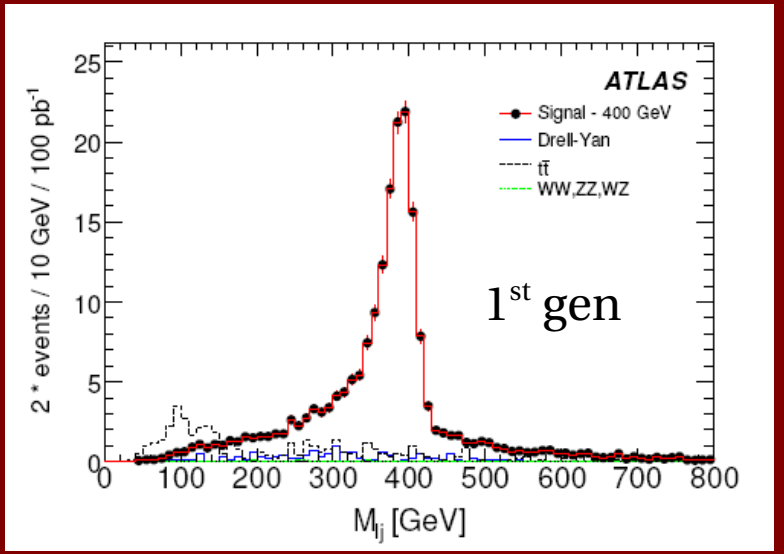
- Result for 2 TeV W_R:
  - Top plot is mass of associated heavy neutrino.
  - Bottom plot is the mass of all four objects.
- 30 fb^{-1}, well understood jet energy scale assumed.

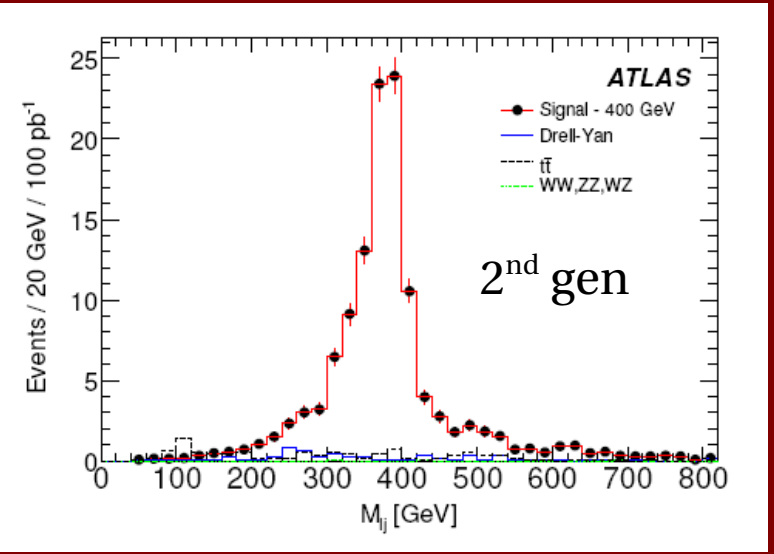


Standard Model background. Mainly Z+jets and top.

Leptons + Jets (ATLAS):

- Early result, leptoquarks pair produced, mass of 400 GeV
  - 100 pb^{-1}, though jet energy scale assumed to be well known.
  - Clear though, even if scale blurred considerably.





The UnConventional:

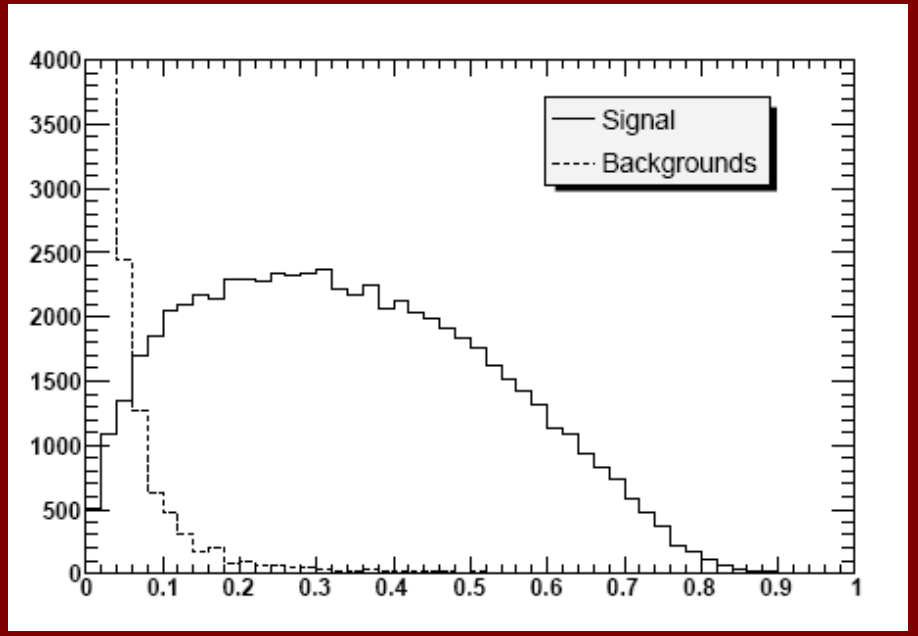
- Some signatures are 'unusual', but are receiving more attention:
  - Black Holes: High multiplicities of particles, ratios of leptons to jet, very different from 'conventional' particle measurements.
  - Heavy, Stable, Charged Particles (HSCP): Stable particles produced in collisions

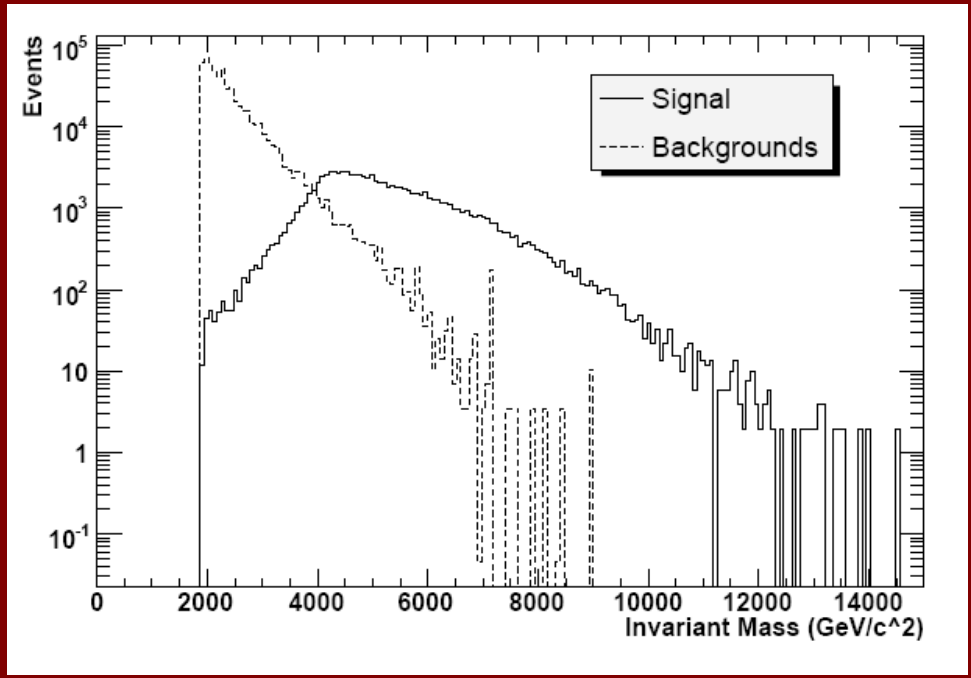
Black Holes:

- Create in collision, evaporate 'democratically' through Hawking radiation to all available SM particles.
- Handles:
  - Particle multiplicity (at a hadron collider, that doesn't mean much)
  - Ratio of leptons to jets
  - Event Sphericity
- LARGE Standard Model backgrounds.

Black Holes (CMS):

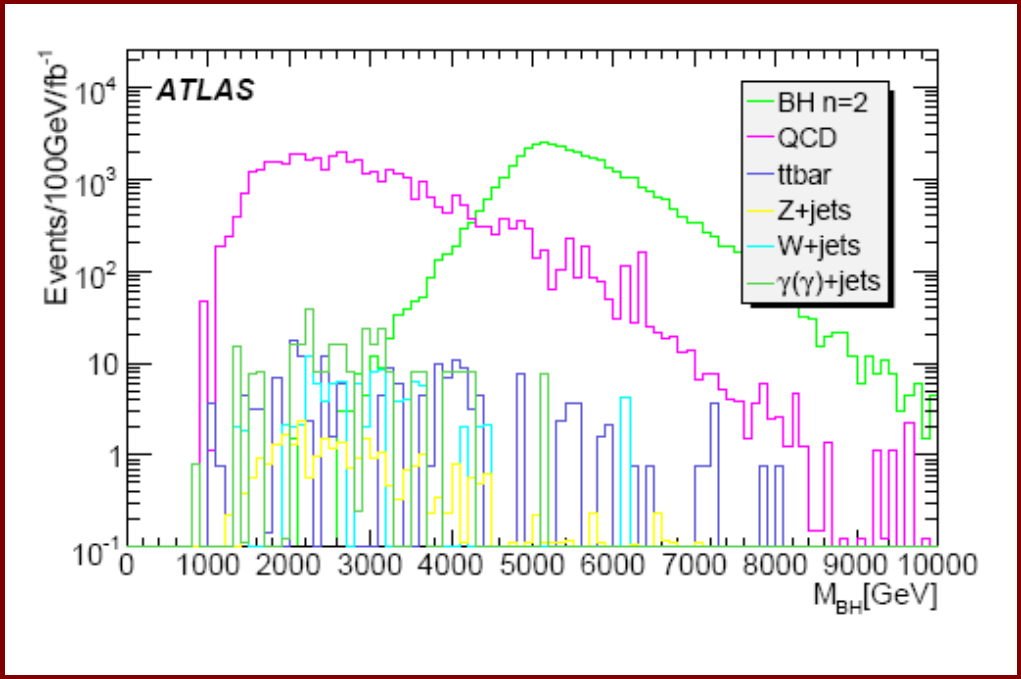
- Depend heavily on:
  - Evaporation giving more spherical events than continuum QCD.
  - Black hole being very massive (M>4 TeV)

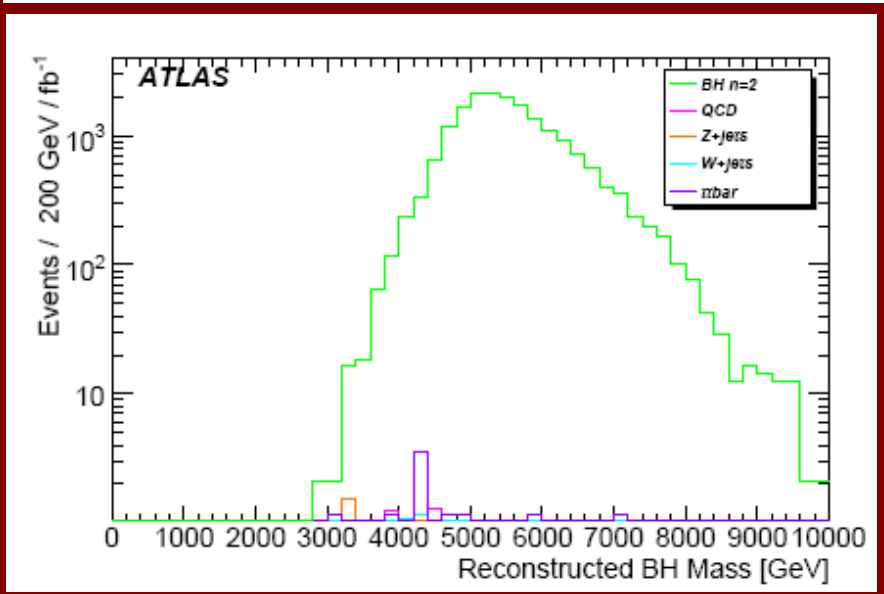




Black Holes (ATLAS):

- Top plot: invariant mass of Black Hole decay products (M>5 TeV).
- Bottom: Same, but requiring a high E_T lepton.



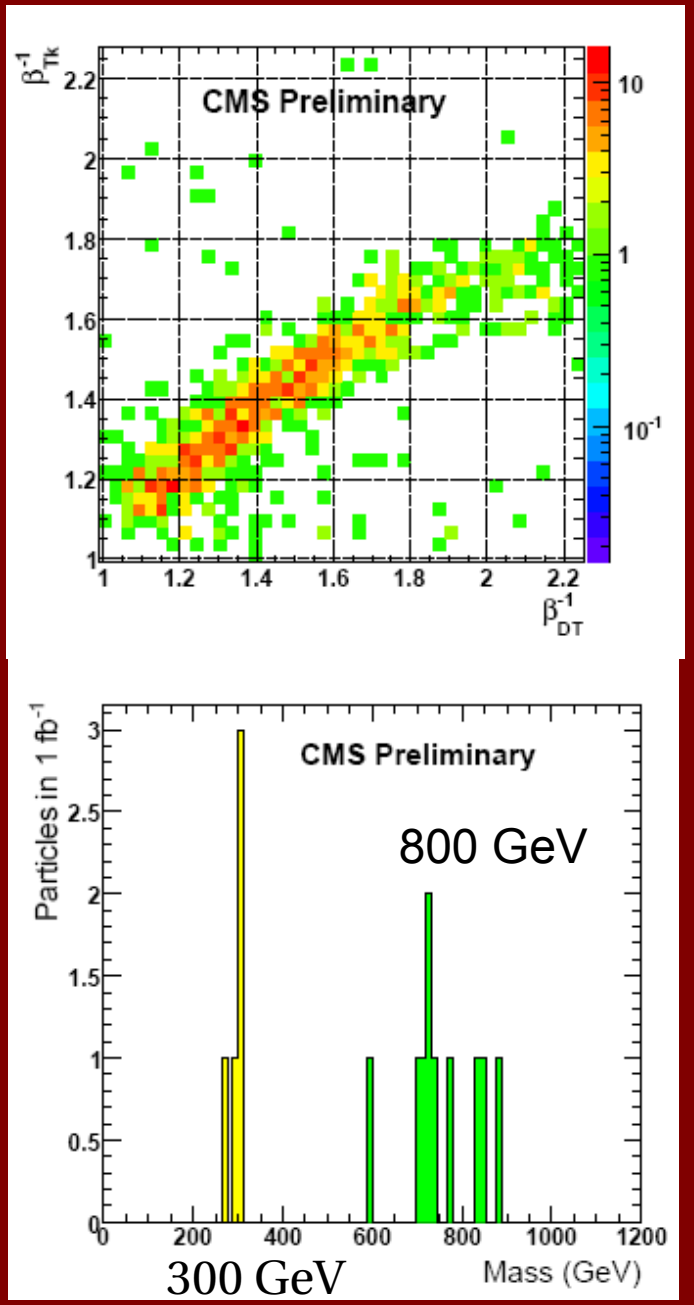


HSCP:

- For Universal Extra Dimensions, SM particles have KK partners, which can be pair produced.
- There are also GMSB/Split SUSY, but those aren't 'alternative' enough for this talk.
- A heavy, stable particle, with charge propagating through the detector will appear somewhat like a muon, depending on the mass (too slow=out of time=not triggered).

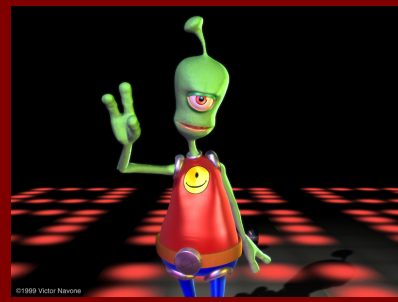
HSCP (CMS):

- CMS tracker can measure dE/dx for the particle passage, and thus measure β.
  - Can also correlate this to measurement from muon drift tubes.
  - Effectively leads to no background.



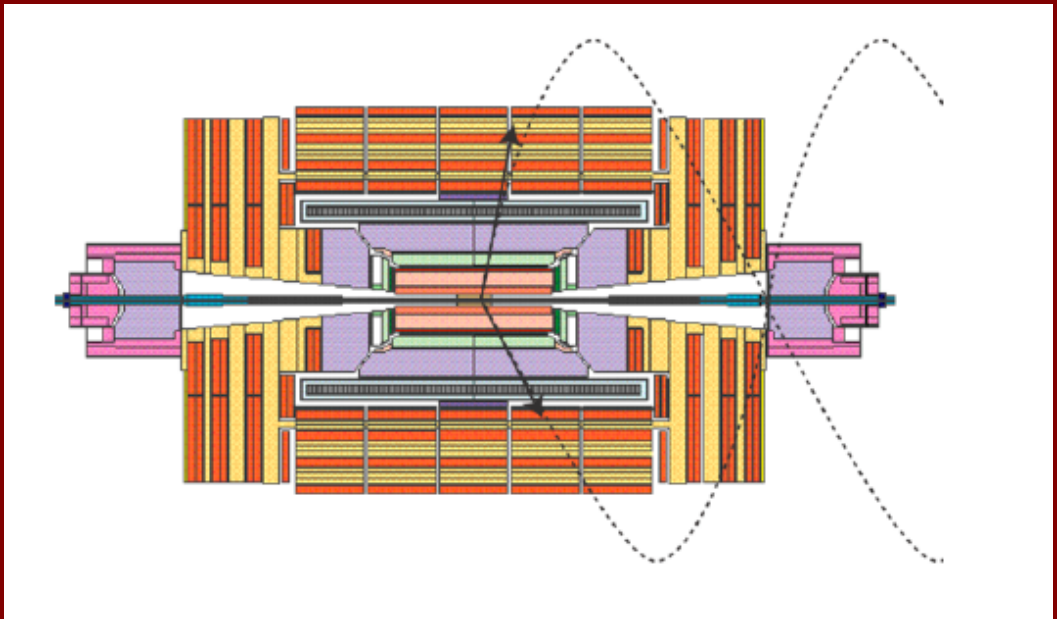
The UnExpected?

- A sad truism is that we can only find something if we're looking in the right place.
  - Searching the wrong haystack means you never find the needle!
  - We're starting to consider models (like Hidden Valley, quirks) that give us signatures that aren't well…even unconventional. They're weird.
  - What else could we be missing? Due to the enormous data volume, unless these events are identified (and triggered) and selected, they will be lost!



Quickly the Quirk Query!

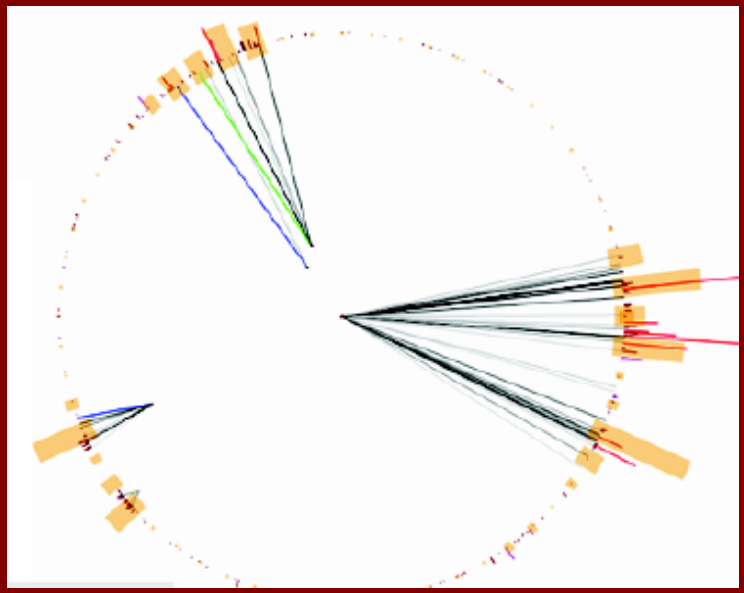
- Not, in fact, Lewis Carrol.
- This is a nice idea, for $\Lambda \sim 100$ eV, quirks enter detector, tracks bend differently:
  - Like monopoles, would need different tracking.



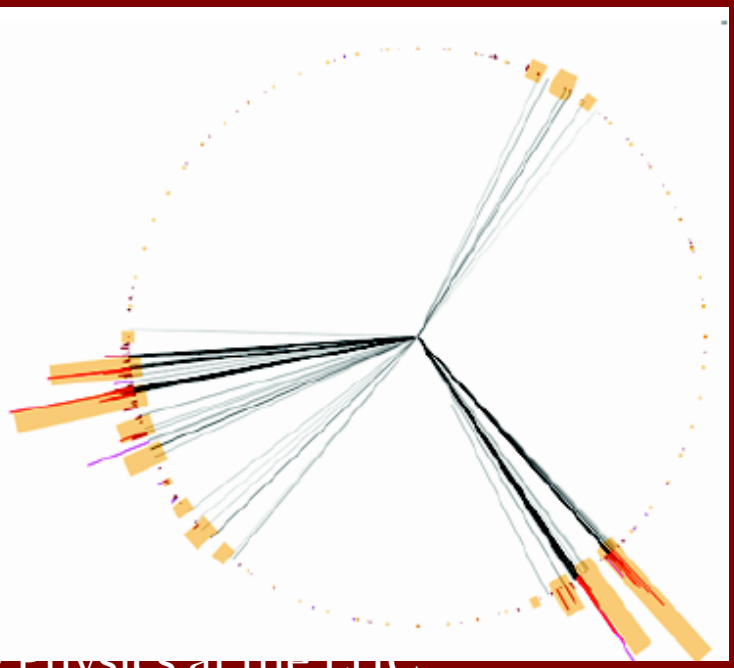
Stolen from Z. Chacko

Hidden Valley (I):

- All different shapes and sizes:
  - Requires algorithm changes to efficiently observe (if possible)!
  - Some handles, but require specific study.

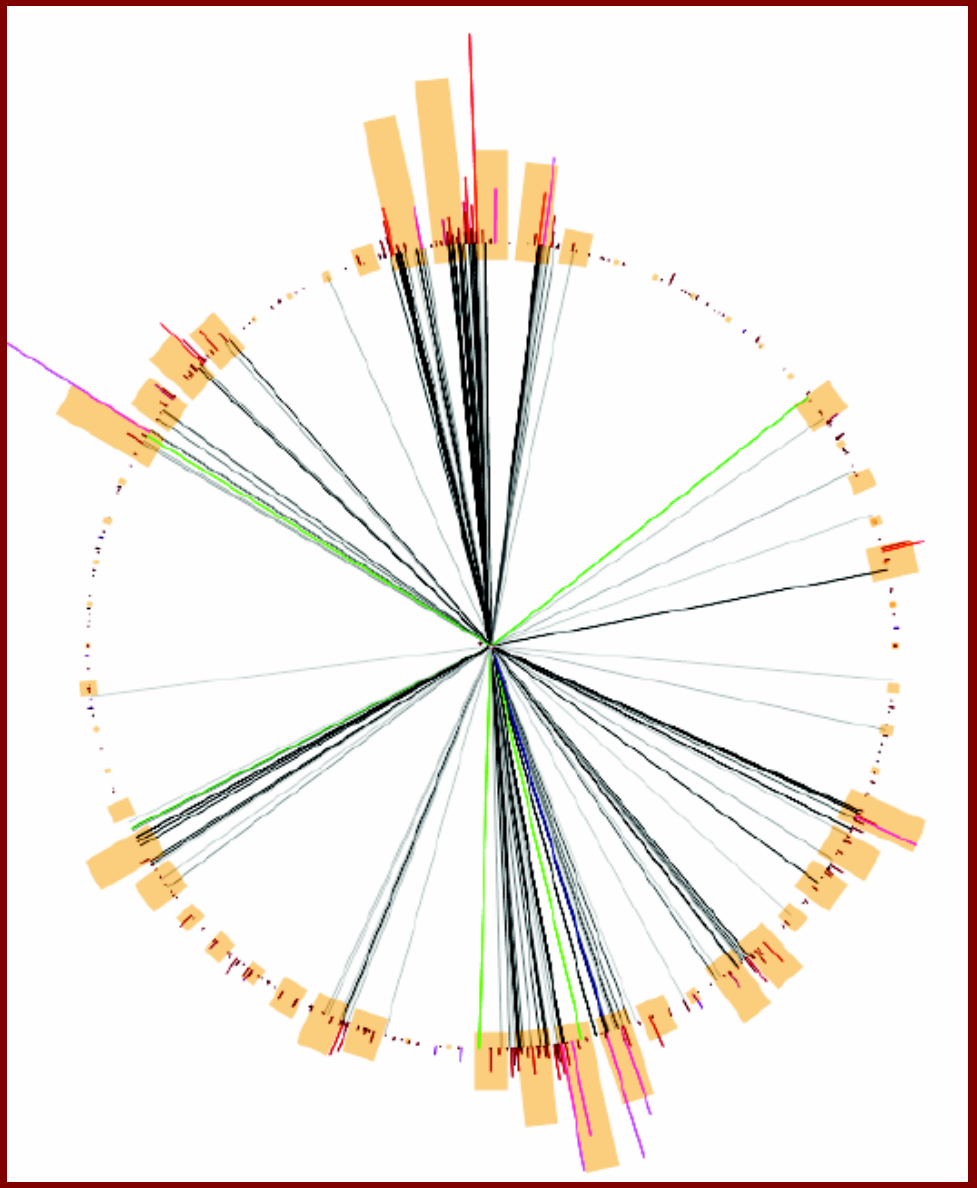


These were stolen from M. Strassler



Hidden Valley (II):

- High multiplicity, multiple jets/leptons, some high ET, some low…would be triggered.
- But not something we're going to just STUMBLE over.



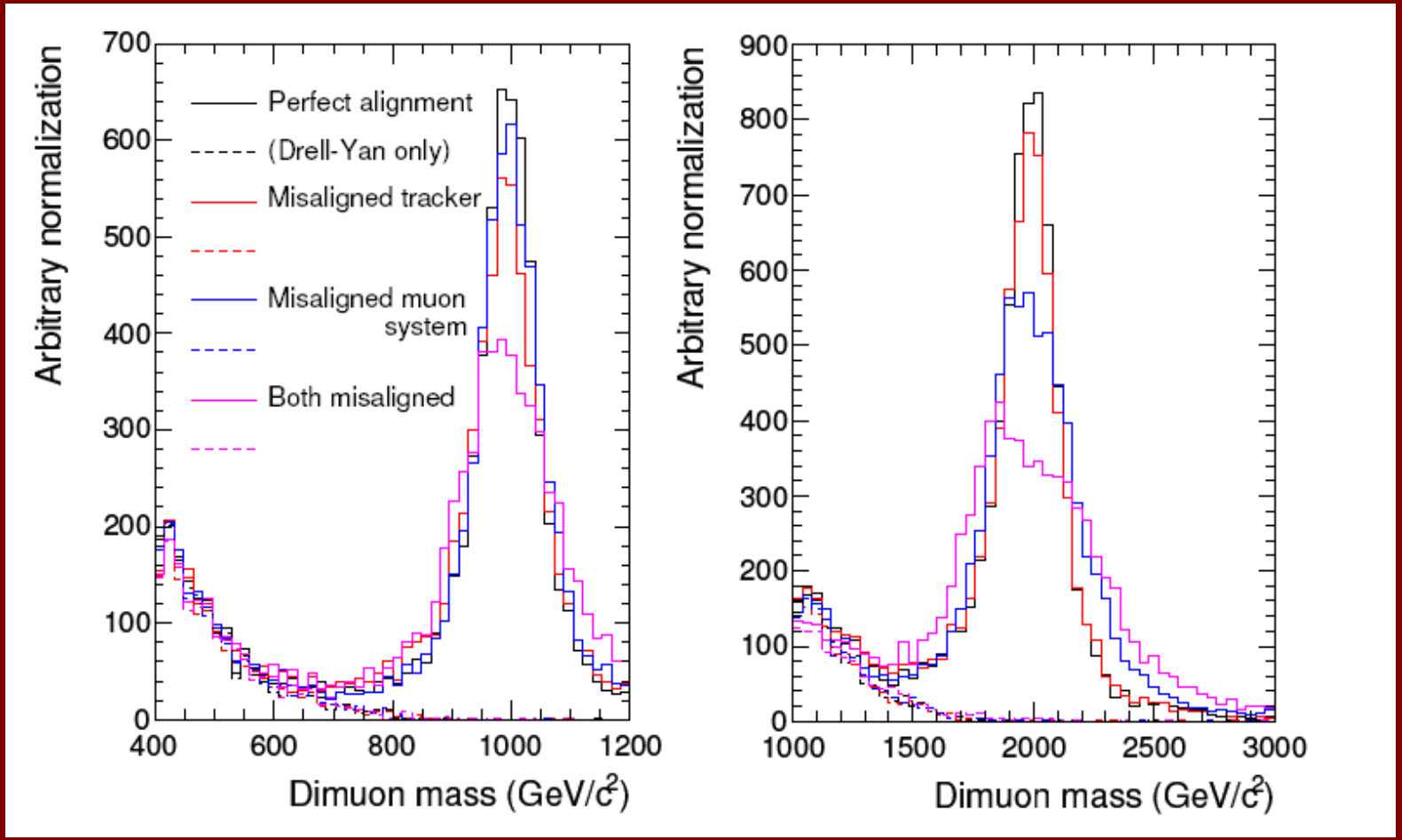
Conclusions:

- Detectors are nearing completion (no design changes at this point folks).
- Tuned up on a lot of physics, ready to launch the real searches.
- But still time to change triggers/reconstruction so that we can capture MORE physics.
- Your input can help!

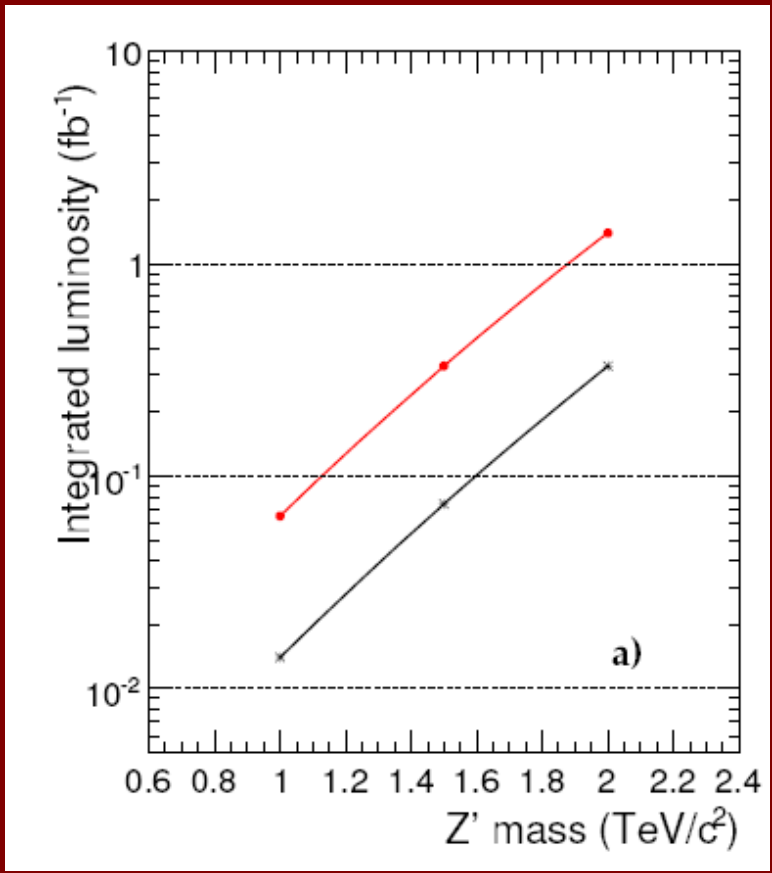
Backups:

for your entertainment

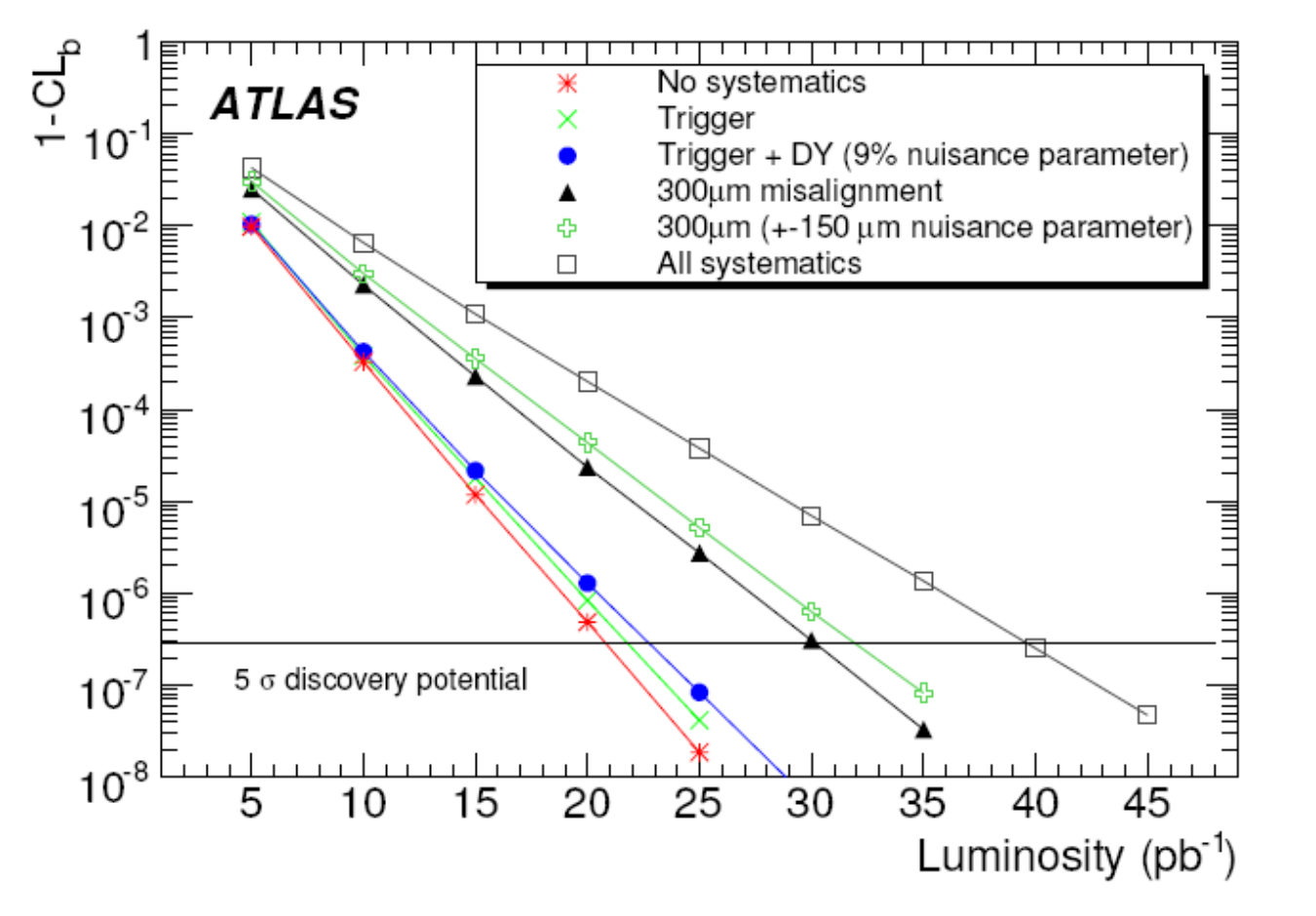
CMS: Dimuon early alignment scenarios



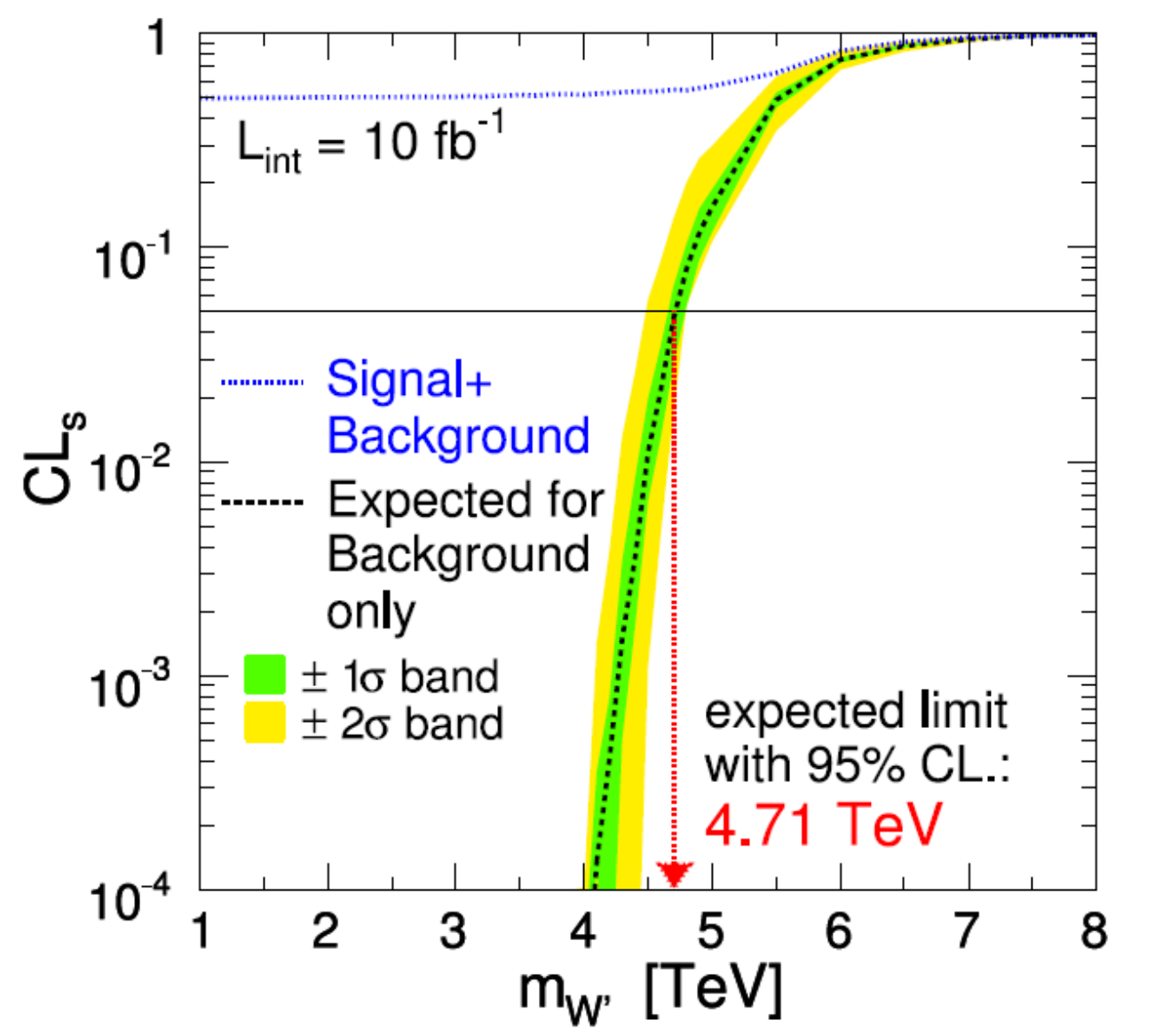
CMS Z_φ ->μμ



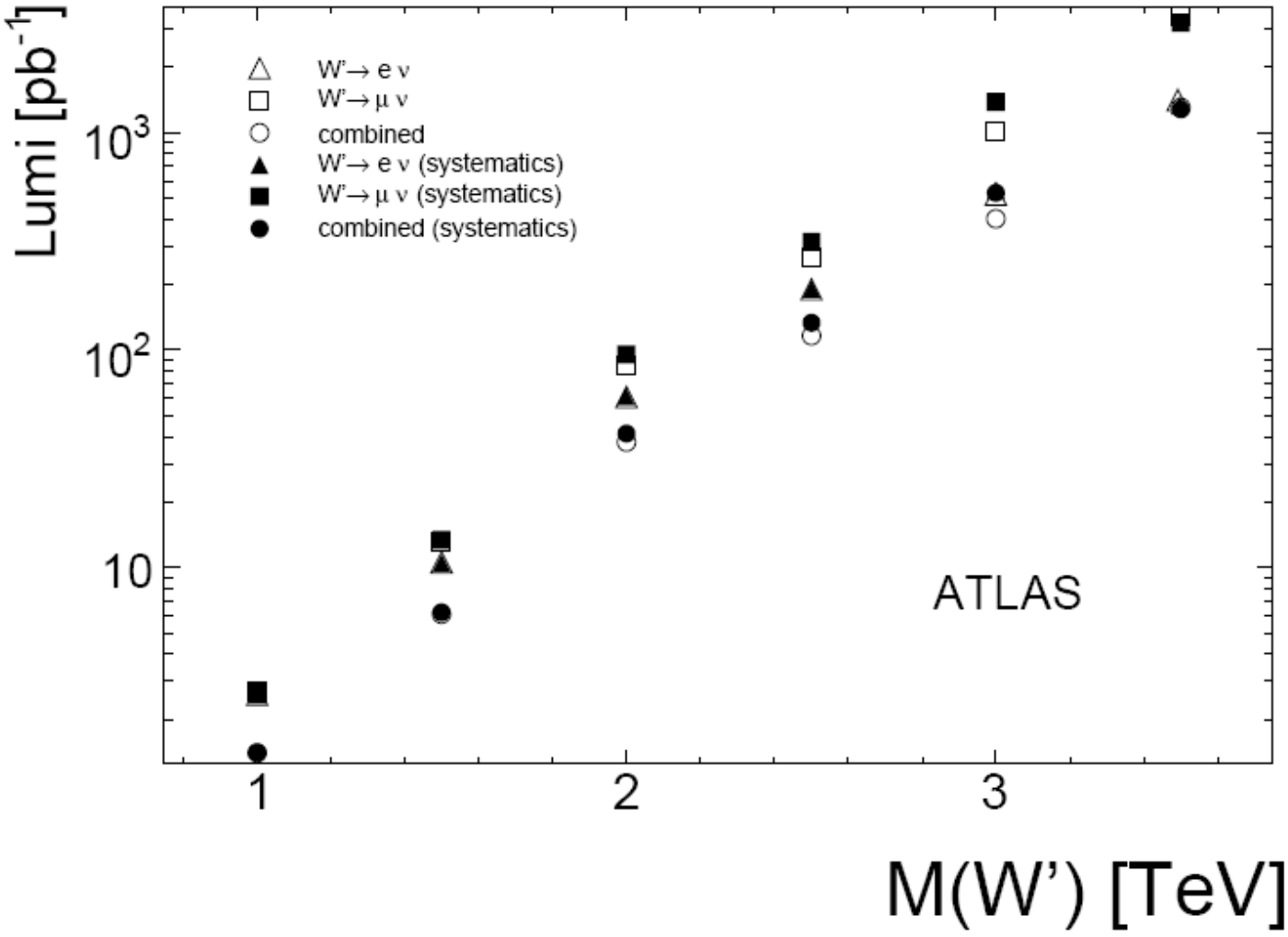
ATLAS Z_χ ->μμ



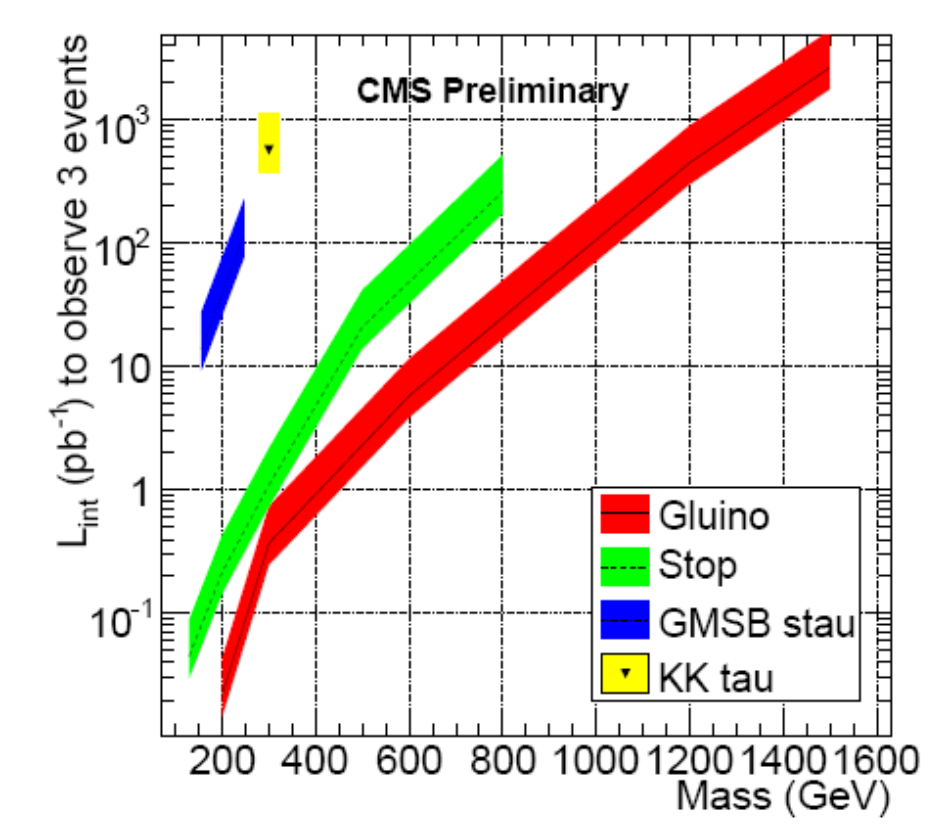
CMS W'->μν


L_{int} = 10 fb^{-1}
Signal+ Background
Expected for Background only
± 1σ band
± 2σ band
expected limit with 95% CL.:
4.71 TeV
CL_s
$m_{W'}$ [TeV]
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
1 2 3 4 5 6 7 8

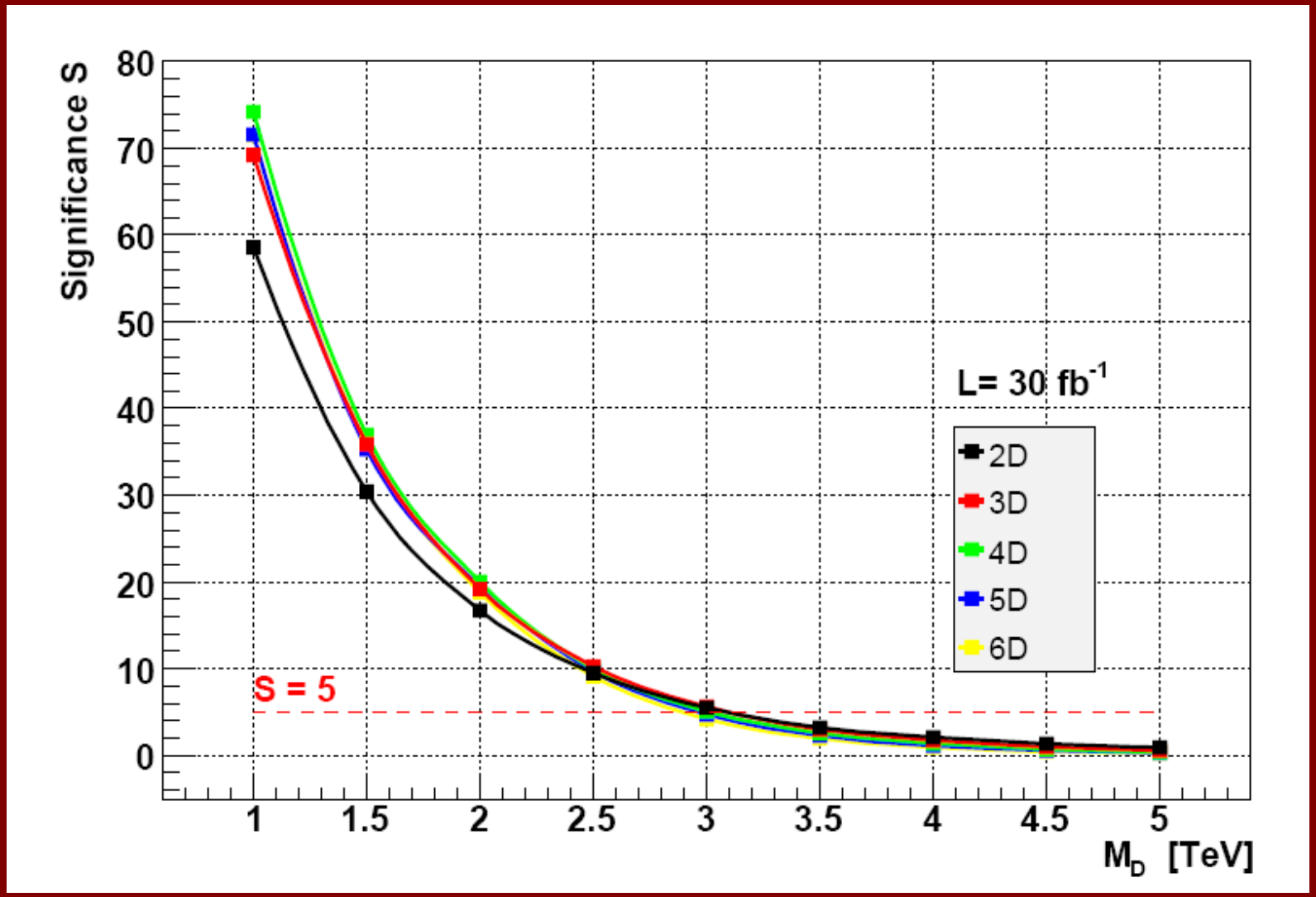
ATLAS W' ->μν


Lumi [pb^{-1}]
10^3
10^2
10
1
2
3
M(W') [TeV]
W'→ e ν
W'→ μ ν
combined
W'→ e ν (systematics)
W'→ μ ν (systematics)
combined (systematics)
ATLAS

CMS HSCP:


CMS Preliminary
L_{int} (pb^{-1}) to observe 3 events
10^3
10^2
10
1
10^{-1}
200 400 600 800 1000 1200 1400 1600
Mass (GeV)
Gluino
Stop
GMSB stau
KK tau

CMS Black Holes:



ATLAS Black Holes (with lepton)