# Looking for Technicolor in ATLAS


Louis Helary

LAPP, Université de Savoie, CNRS/IN2P3,
Annecy-le-Vieux, France


On the behalf of the ATLAS Collaboration.

# Outline

- Theoretical introduction.
- Current experimental limits.
- LHC & ATLAS.
- Technicolor studies conducted in ATLAS.

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# Technicolor

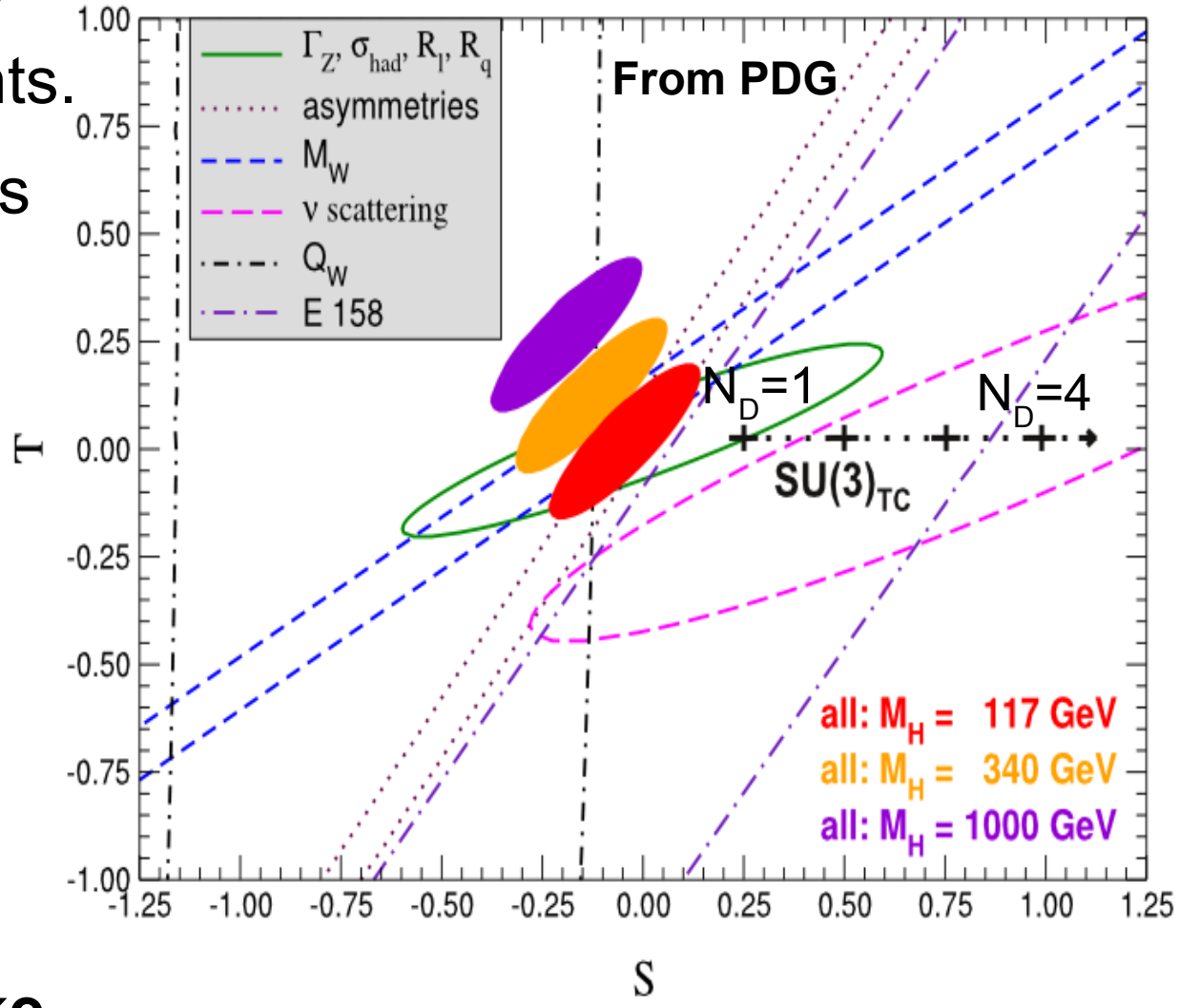
- Developed in late 70's by S. Weinberg & L. Susskind.
- Introduce a new strong interaction to generate masses of W and Z.

↳No Higgs Boson.

- Interaction invariant under a $\mathbf{SU(N_{TC})_{TC}}$ gauge group.
  - $\mathbf{N_{TC}} \geq 3$.
  - If $\mathbf{N_{TC}=3}$ **QCD-like model**. Spectrum is scaled-up QCD.
- Introduce $\mathbf{N_D}$ doublets of Technifermions.
- Search the light bound states, mostly Technimesons.

# EW Constraints

- QCD-like TC ruled out by precise EW measurements.
- Peskin-Takeuchi variables (S, T, U). Parameterize contributions of new physics to EW radiative corrections.
- **$S_{Exp}$=-0.10 ± 0.10** (PDG 2008)
- **$S_{TC}$≈ 0.25 $N_D$ ($N_{TC}$/3)** ( Phys. Rev. D 46, 381)
- So **$S_{TC}$≈ 0.25** for **QCD-like TC and $N_D$=1**



# Low Scale Technicolor

- Walking gauge coupling.

↳Feature introduced to cure Flavor-Changing Neutral Current problem.

↳Also avoids S parameter discrepancy.

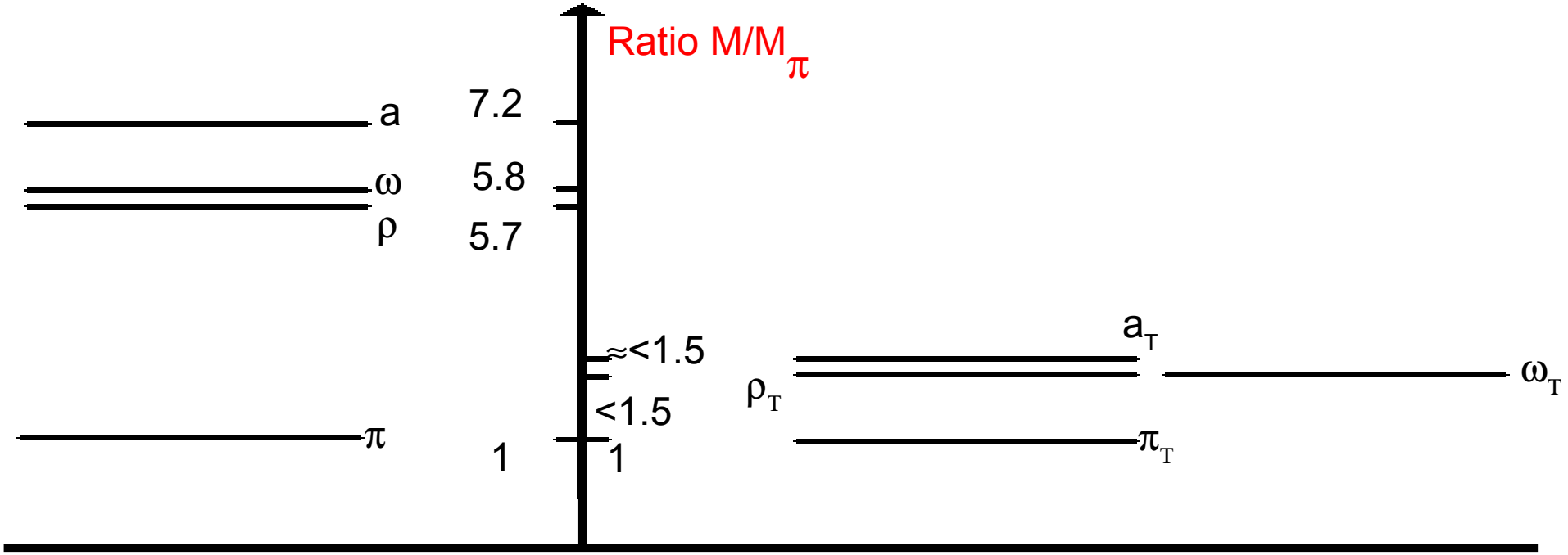
- Requires large number of Technifermion doublets:

↳$\Lambda_{TC} \approx 246 \text{ GeV}/\sqrt{N_D} < 100 \text{ GeV}$

↳$N_D \approx 10$

# Phenomenological consequences

- Walking impose : $M_{\omega T}$ , $M_{\rho T}$ & $M_{aT}$ <$2M_{\pi T}$




- So $\omega_T$,$\rho_T$,$a_T$ decay mostly weakly, in 2 gauge bosons($\gamma$,$Z^0$,$W^{\pm}$).

↳ Narrow resonances expected: $\Gamma$~1GeV.

- All studies shown are done wrt: LSTC strawman in PYTHIA.

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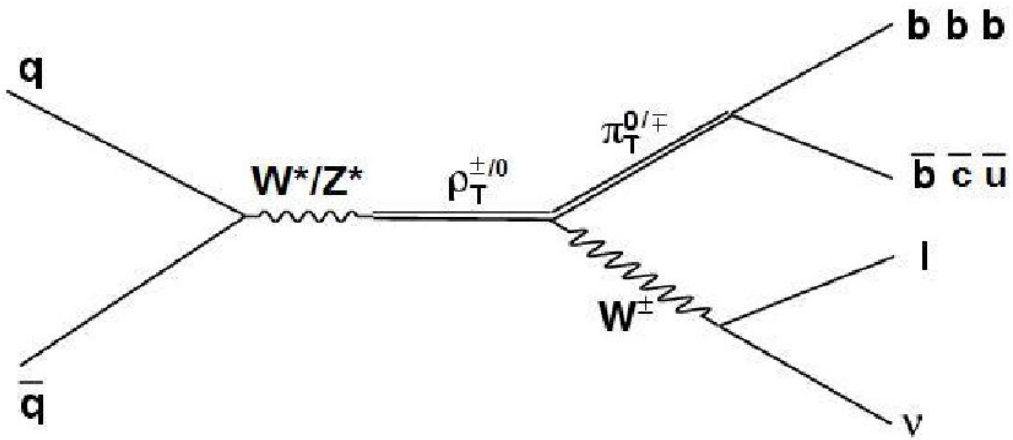
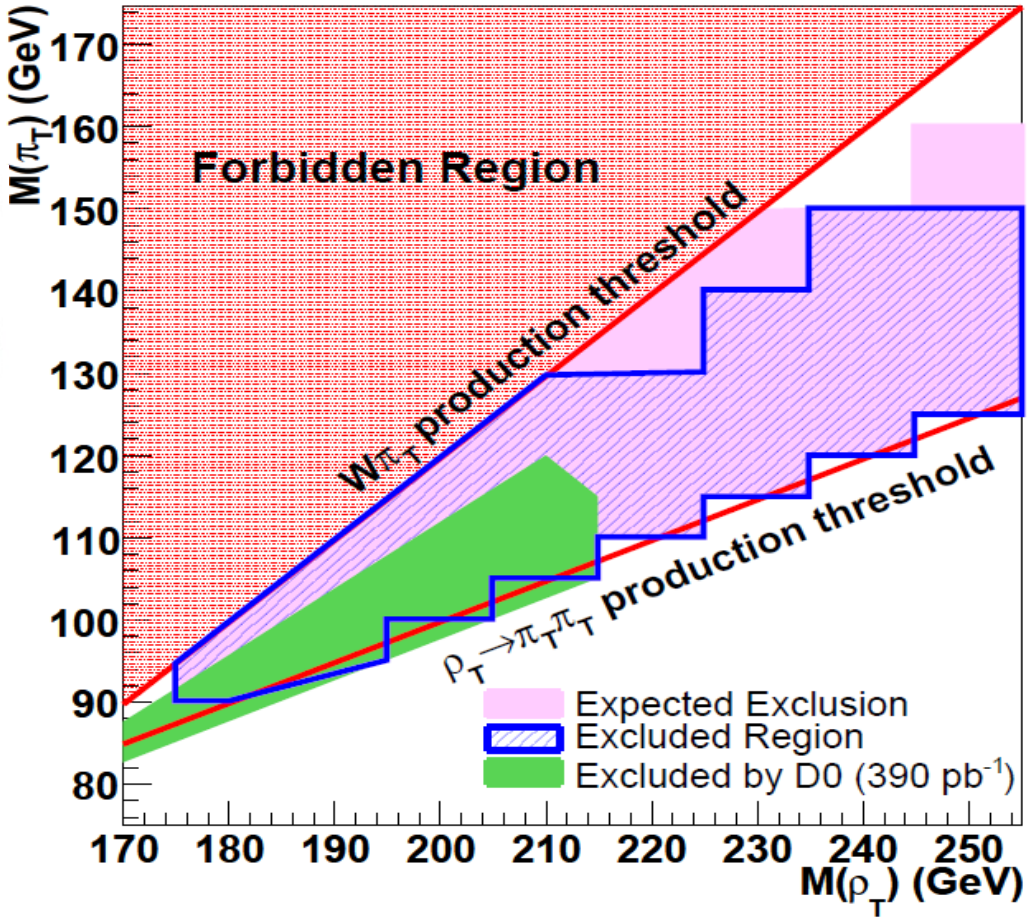
# Semi-leptonic searches

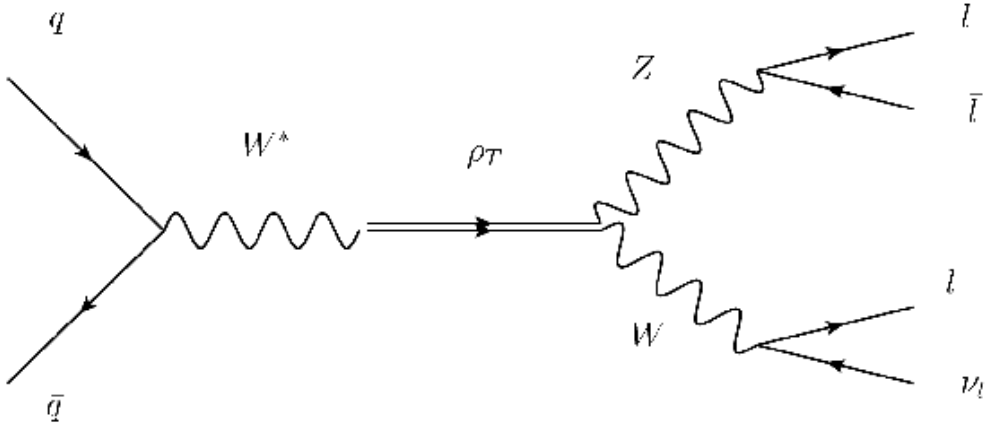


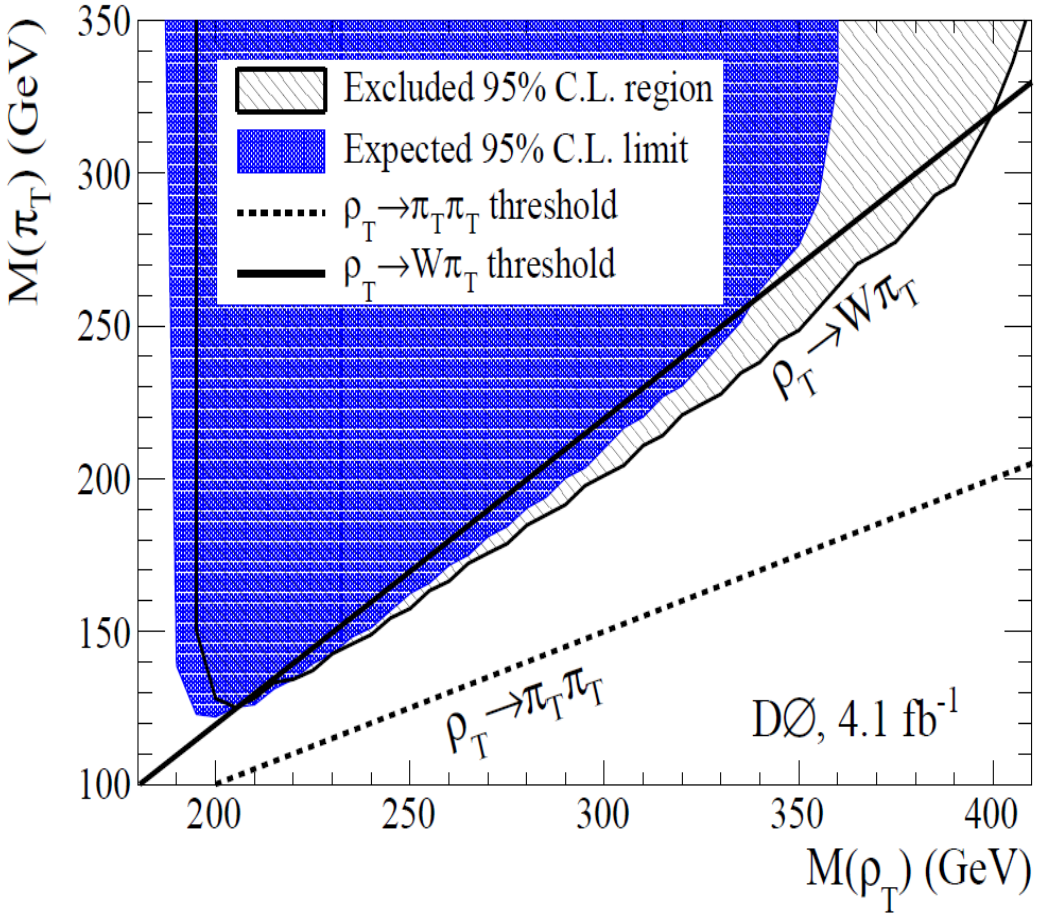




Search in lνbq channel.
CDF 1.9 fb$^{-1}$
D0 390 pb$^{-1}$

**From CDF pub. Note 9302 & ArXiv 0912.2059**

# Leptonic searches




Search in lllυ channel.
D0 4.1fb$^{-1}$

**From ArXiv 0912.0715**

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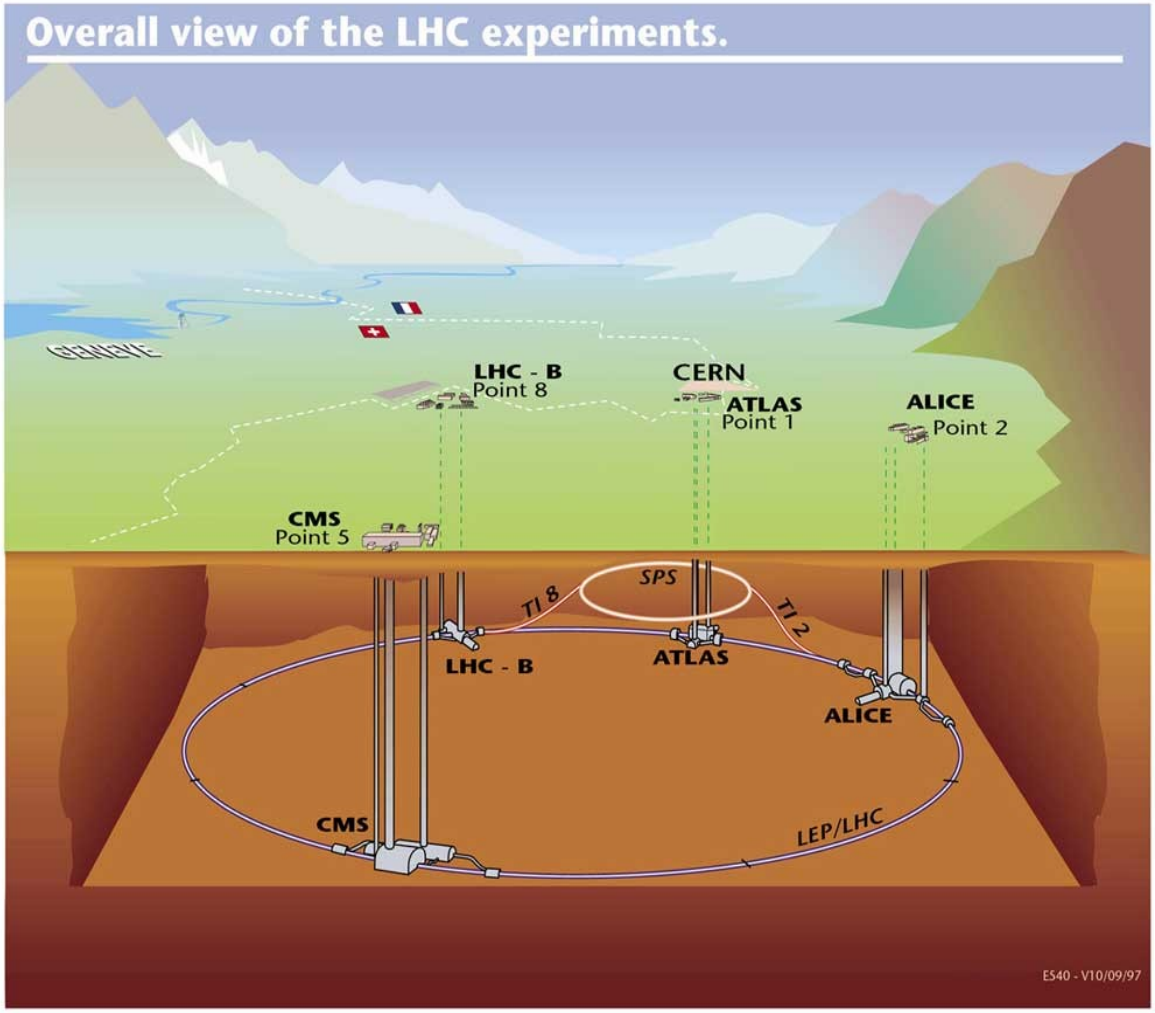
# LHC: Large Hadron Collider



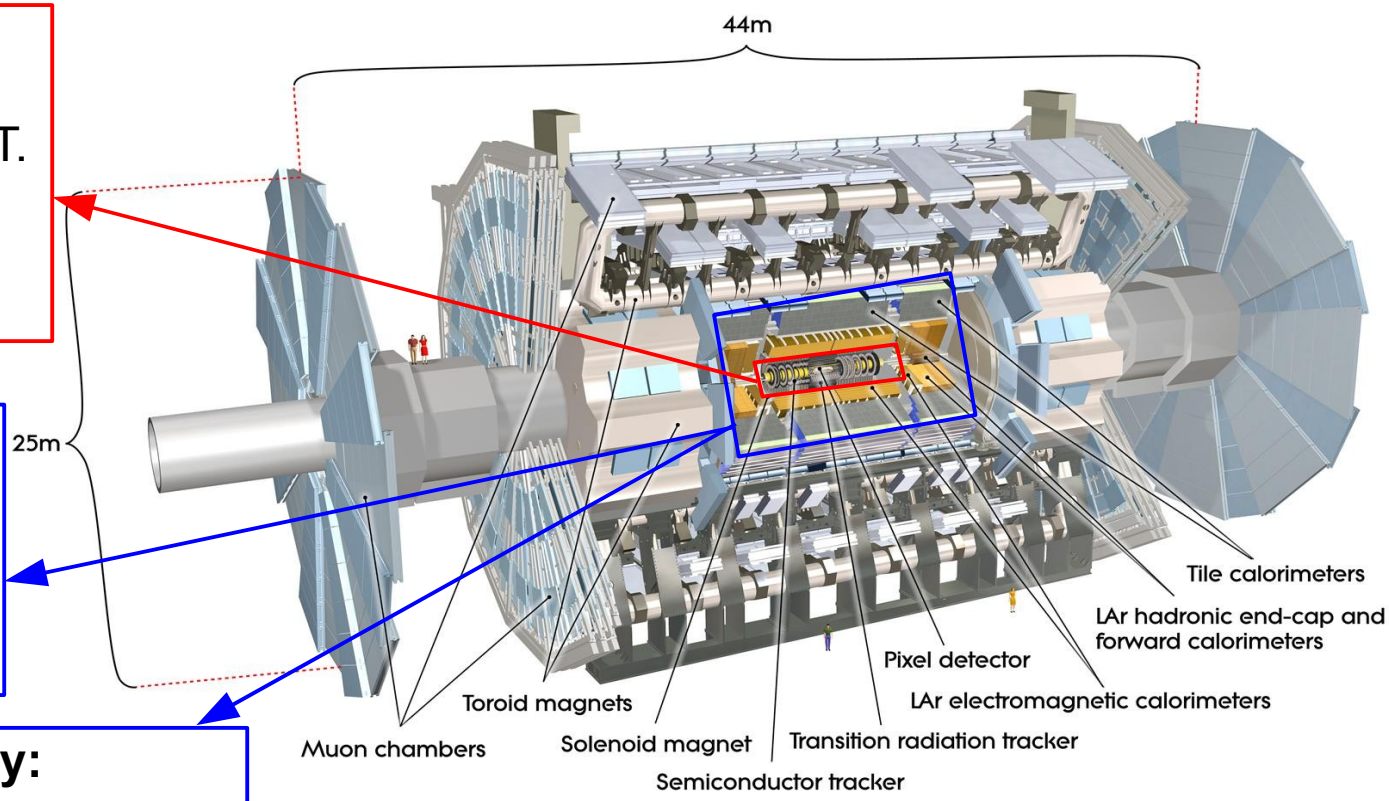

- **Nominal CM Energy:**
  14 TeV
- **Integrated Lumi / year:**
  Low: 10 $fb^{-1}$
  High: 100 $fb^{-1}$
- **Start in 2009.**
- **Run 2010-2011:**
  Expect:
  7TeV to 10 TeV
  ~100 $pb^{-1}$ to 1$fb^{-1}$

# ATLAS: A Toroidal LHC ApparatuS

- **Tracking:**
  - 2T Solenoid field.
  - Silicon(pixel+SCT) & TRT.
  - Coverage $-2.5 \leq \eta \leq 2.5$
  - $\sigma_{PT}/P_T = 0.05\% P_T \oplus 1\%$

- **EM Calorimetry:**
  - Accordion shape Lead LAr
  - Coverage: $-3.2 \leq \eta \leq 3.2$
  - $\sigma_E/E = 10\%/\sqrt{E} \oplus 0.7\%$

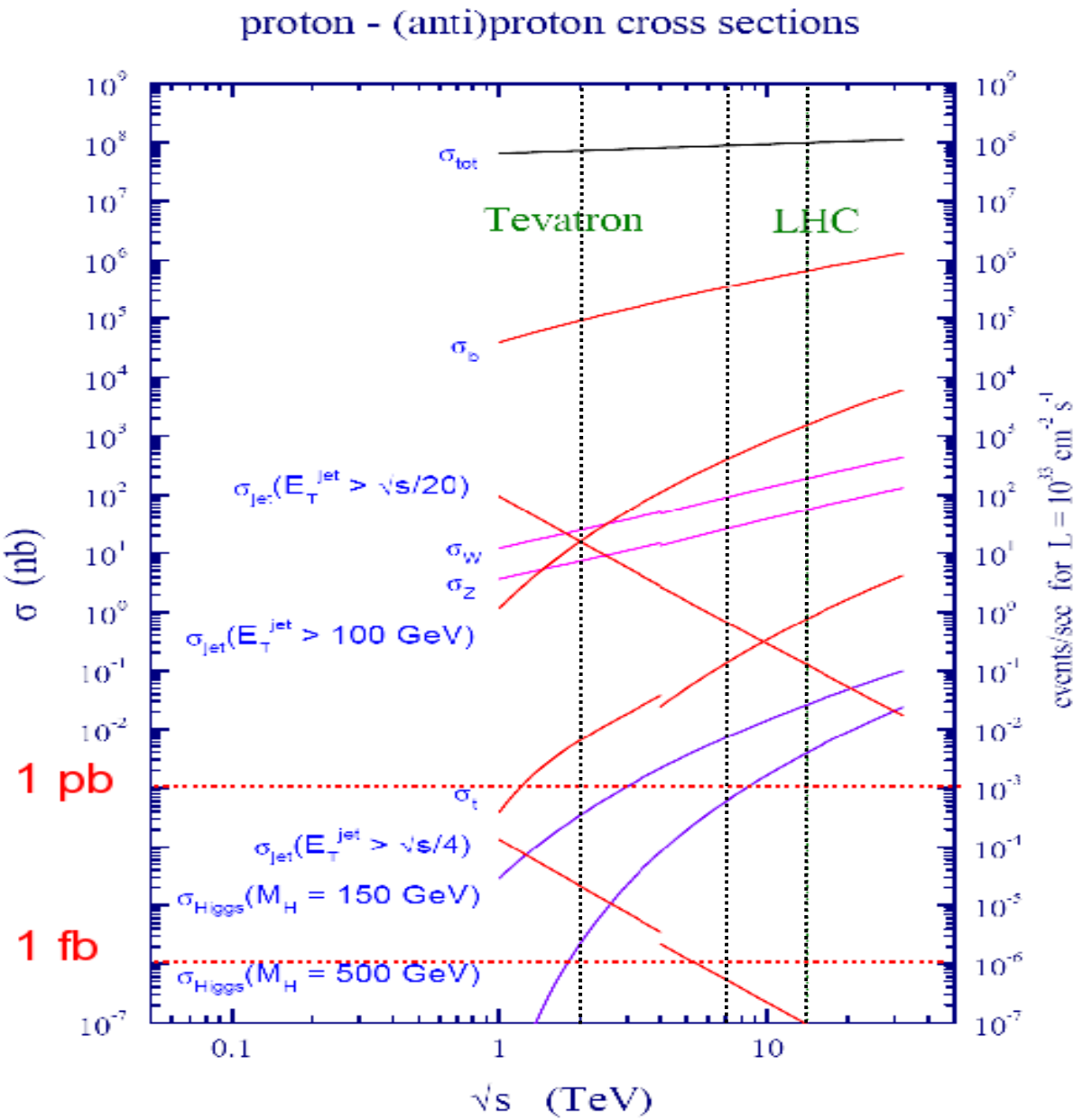
- **Hadronic Calorimetry:**
  - **Barrel & EndCap:**
    - Coverage: $-3.2 \leq \eta \leq 3.2$
    - $\sigma_E/E = 50\%/\sqrt{E} \oplus 3\%$
  - **Forward:**
    - Coverage: $3.1 \leq |\eta| \leq 4.9$
    - $\sigma_E/E = 100\%/\sqrt{E} \oplus 10\%$




- **Muon Spectrometer:**
  - Up to 1T Toroid field.
  - Coverage $-2.7 \leq \eta \leq 2.7$
  - $\sigma_{PT}/P_T = 10\%$ at $P_T = 1$TeV

# Backgrounds

- At LHC much larger hadronic backgrounds, all studies will be focused on (semi-)leptonic final states.



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  - Search in final states with weak bosons
  - Search in di-lepton final State

# Search in final states with weak bosons

From:

•**arXiv:0802.3715**
"LSTC at the LHC"
G.Azuelos & all

| Case | $M_{\rho_T} = M_{\omega_T}$ | $M_{a_T}$ | $M_{\pi_T}$ | $M_{\pi_T^{0\prime}}$ | $\sigma(W^{\pm}Z^0)$ | $\sigma(\gamma W^{\pm})$ | $\sigma(\gamma Z^0)$ | $\sigma(Z^0\pi_T^{\pm})$ |
|---|---|---|---|---|---|---|---|---|
| A | 300 | 330 | 200 | 400 | 110 | 168 | 19.2 | 158 |
| B | 400 | 440 | 275 | 500 | 36.2 | 64.7 | 6.2 | 88.6 |
| C | 500 | 550 | 350 | 600 | 16.0 | 30.7 | 2.8 | 45.4 |

Masses are in GeV, Cross Sections are in fb.

•**ATL-PHYS-CONF-2008-03**
G.Azuelos, J. Ferland, K. Lane & A. Martin.

| Background | Cross section (fb) |
|---|---|
| $WZ \to 3\ell + \nu$ | 430 |
| $ZZ \to 4\ell$ | 52 |
| $Z + \bar{b}b \to \ell^+\ell^- \bar{b}b$ | 7600 |
| $\bar{t}t \to 2\ell\, 2\nu\, \bar{b}b$ | 22,800 |
| $W\gamma \to \ell\nu\gamma$ | 2560 |
| $W$ jet $\to \ell\nu\gamma$ (fake) | 3180 |
| $Z\gamma \to \ell^+\ell^-\gamma$ | 700 |
| $Z$ jet $\to \ell^+\ell^-\gamma$ (fake) | 315 |

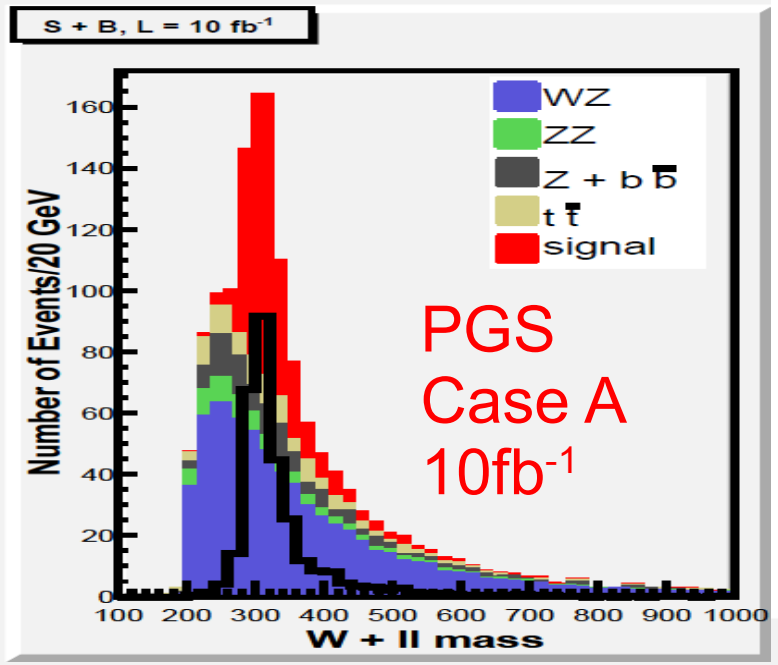
•**ATL-PHYS-CONF-2008-004**
K. Black

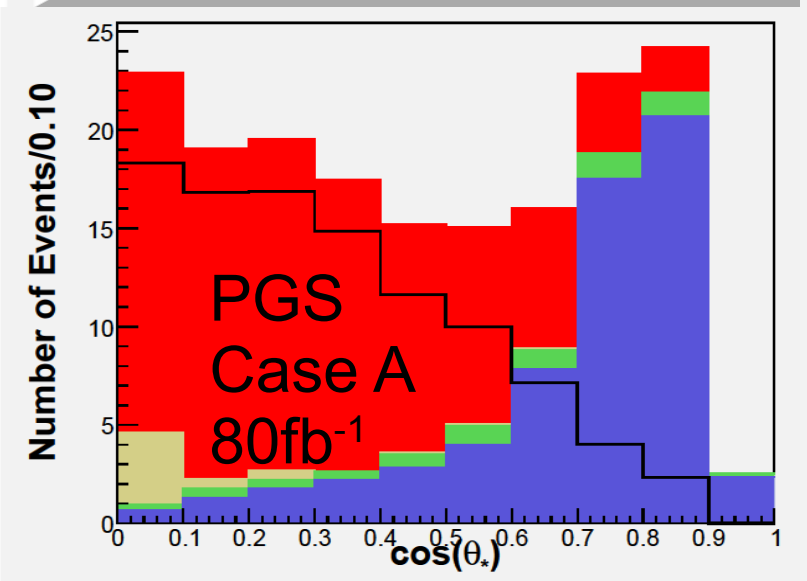
•Studies made @14 TeV, with:
- ATLAS fast simulation.
- Parameterized simulation (PGS)

•W and Z decay into electrons and muons.

# $a_T^{\pm}/\rho_T^{\pm} \rightarrow W^{\pm}Z \rightarrow lll\upsilon$

- Reconstruct:
  - 4 momenta of Z with 2 most energetic leptons.
  - 4 momenta of W with remaining lepton and $ME_T$. Use W mass constraint.
  - 4 momenta of $\rho_T$ with W and Z.
- Main Backgrounds: WZ,ZZ,Zbb,tt.
- Once a clear peak seen, need to check the $|\cos(\theta^*)|$, to establish the underlying theory origin of the resonance.

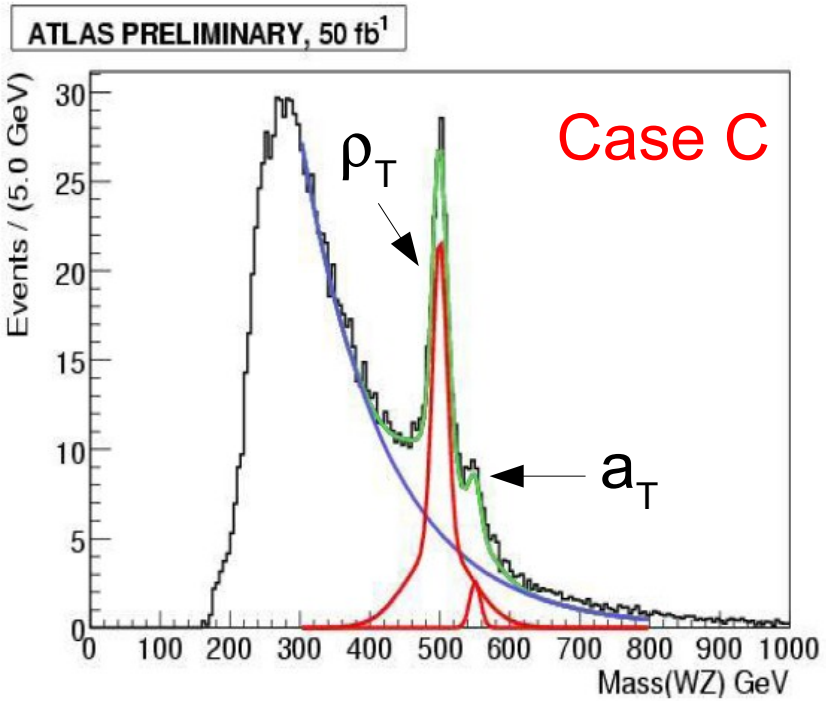


# Results

- Then see if we can distinguish $\rho_T^{\pm}$ and $a_T^{\pm}$.

- Finally compute the luminosity to get a 5σ discovery.



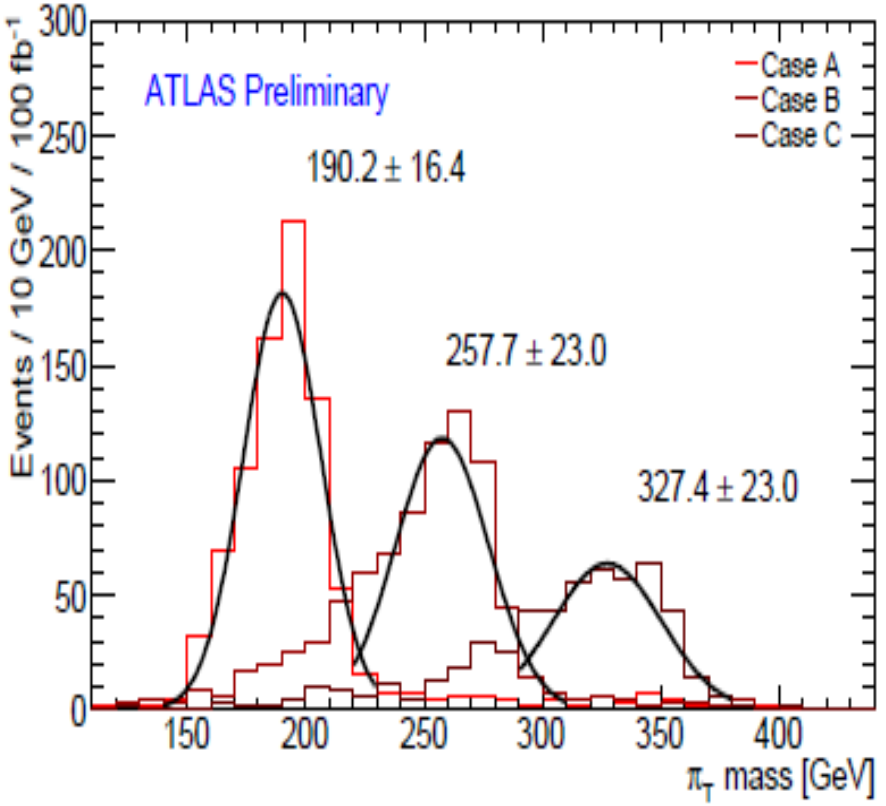

**Luminosity required to get a 5σ discovery**

| $WZ$ | $M_{\text{peak}}$ (GeV) | $\sigma$ (GeV) | $\mathcal{L}_{\text{min}}$ ($\text{fb}^{-1}$) | $p_T$ cut |
|---|---|---|---|---|
| A | 311 | 25.6 | 2.4 | $p_T(W,Z) > 50$ GeV |
| B | 414 | 34.5 | 7.2 | $p_T(W,Z) > 75$ GeV |
| C | 515 | 41.0 | 14.7 | $p_T(W,Z) > 75$ GeV |

# $a_T^{\pm}/\rho_T^{\pm} \rightarrow Z\pi^{\pm}_T \rightarrow llbq$

- Consider here the possibility to observe a $\pi_T$ at the LHC.

- Main Backgrounds:
  tt, Zjj, Zbj, Zbb.



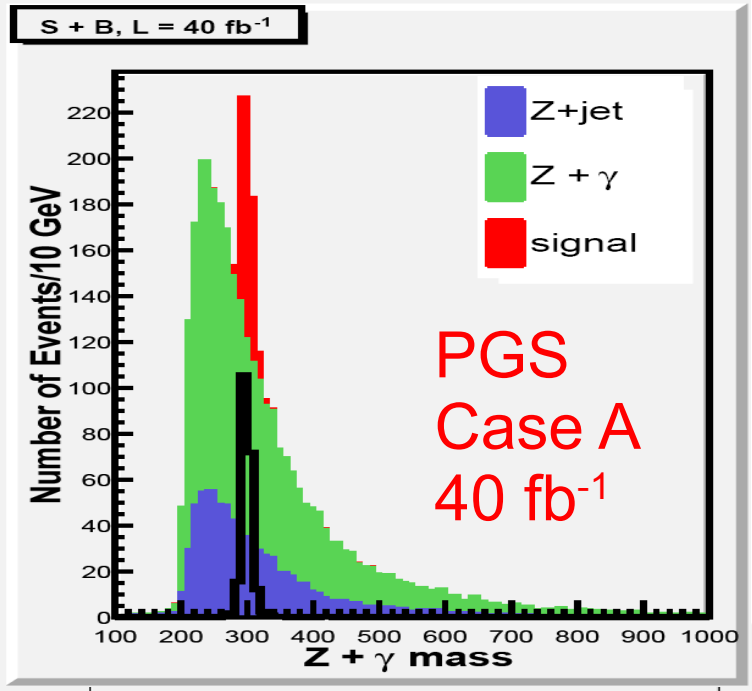

**Reconstructed $\pi_T$ mass.**

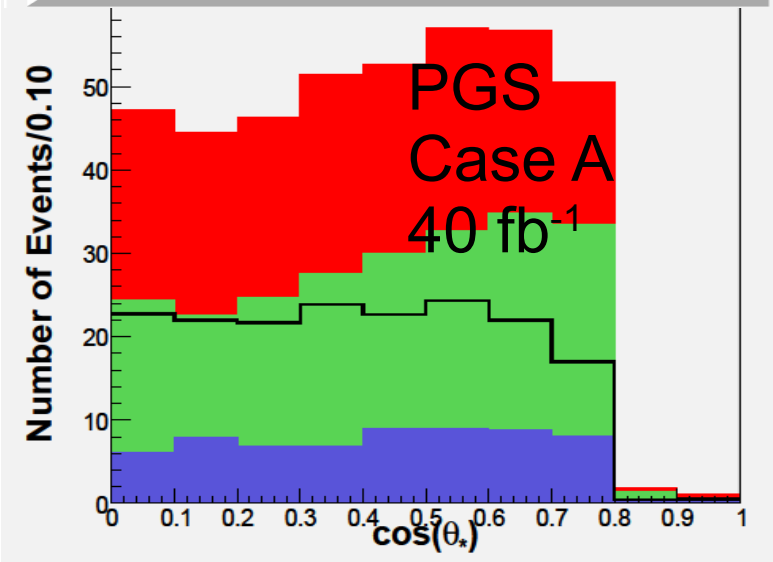
**Luminosity required to get a 5σ discovery**

| Sample | peak | A | B | C |
|---|---|---|---|---|
| Luminosity [fb$^{-1}$] | $\rho_T^{\pm}$ | 8.3 | 15.1 | 14.8 |
| | $a_T^{\pm}$ | 47.5 | 106 | 390 |

# $\omega_T \rightarrow Z\gamma \rightarrow ll\gamma$

- Very clear signature.
- But lower cross section × BR.
- Main Backgrounds: $Z\gamma$, Z jets
- Needs more data.



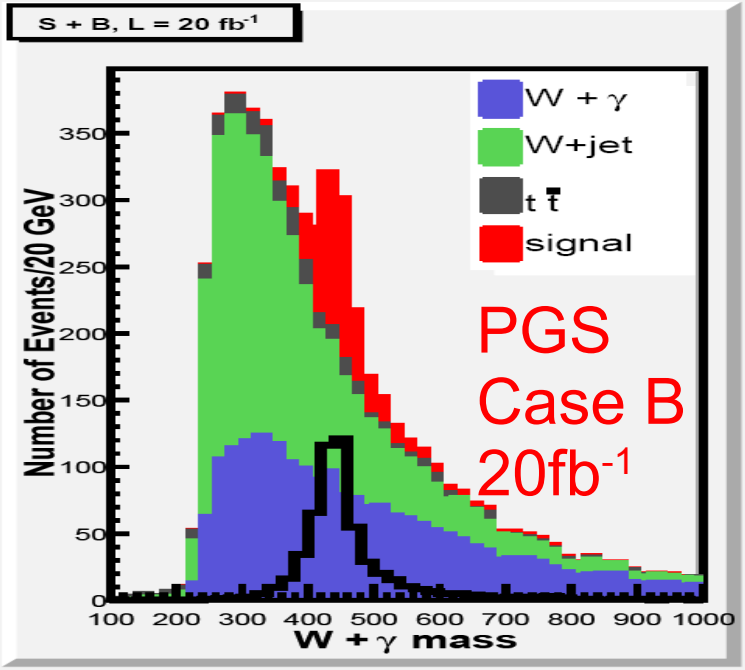



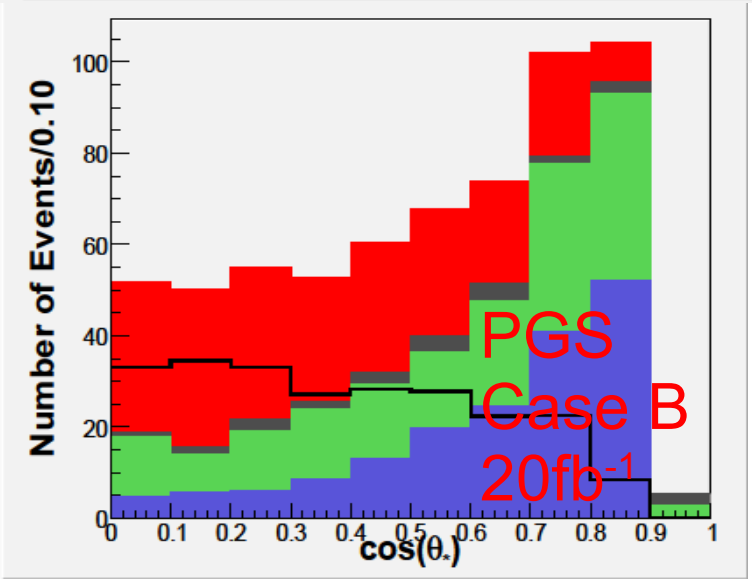

**Luminosity required to get a 5σ discovery**

| $\gamma Z$ | $M_{\text{peak}}$ (GeV) | $\sigma$ (GeV) | $\mathcal{L}_{\text{min}}$ ($\text{fb}^{-1}$) | $p_T$ cut |
|---|---|---|---|---|
| A | 299 | 7.3 | 16.8 | $p_T(\gamma, Z) > 80$ GeV |
| B | 398 | 9.4 | 45.5 | $p_T(\gamma, Z) > 110$ GeV |
| C | 498 | 12.0 | 97.2 | $p_T(\gamma, Z) > 150$ GeV |

# $a_T^{\pm} \rightarrow W^{\pm}\gamma \rightarrow l\upsilon\gamma$

- Wider peak, but higher cross section.
- Main Backgrounds: Wγ,W jets,tt
- Very good channel to discover and study LSTC at LHC.




**Luminosity required to get a 5σ discovery**

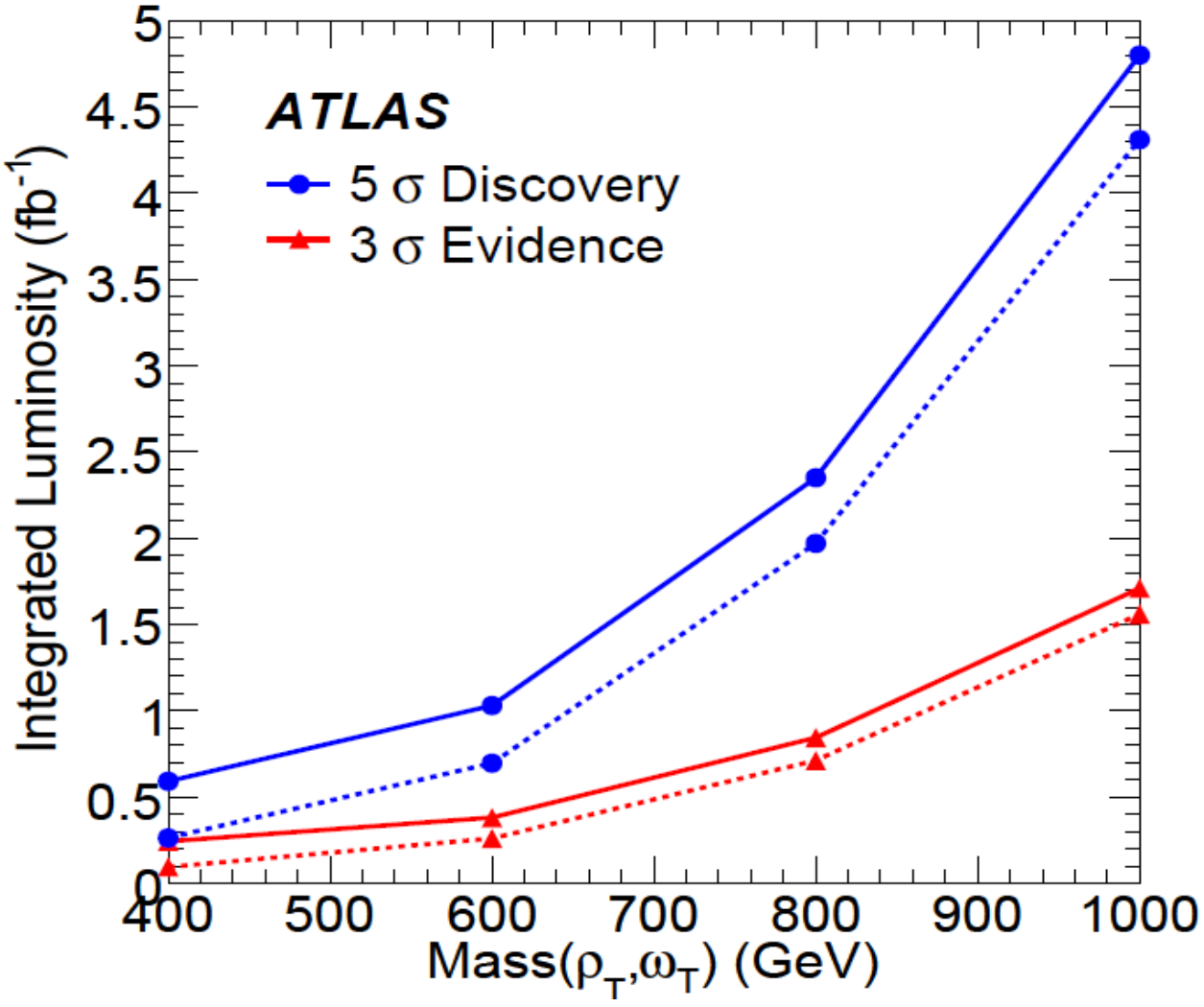
| $\gamma W$ | $M_{\text{peak}}$ (GeV) | $\sigma$ (GeV) | $\mathcal{L}_{\text{min}}$ ($\text{fb}^{-1}$) | $p_T$ cut |
|---|---|---|---|---|
| A | 328 | 31.2 | 2.3 | $p_T(\gamma, W) > 75$ GeV |
| B | 439 | 39.1 | 4.5 | $p_T(\gamma, W) > 100$ GeV |
| C | 547 | 39.3 | 7.8 | $p_T(\gamma, W) > 125$ GeV |

# Search in di-lepton final State

- Study conducted with ATLAS full simulation @ 14 TeV.
- Background considered: Drell-Yan processes.
- Look only at the di-muon final state.
- From CERN-OPEN-2008-020 : “Expected Performance of the ATLAS Experiment” The ATLAS Collaboration.

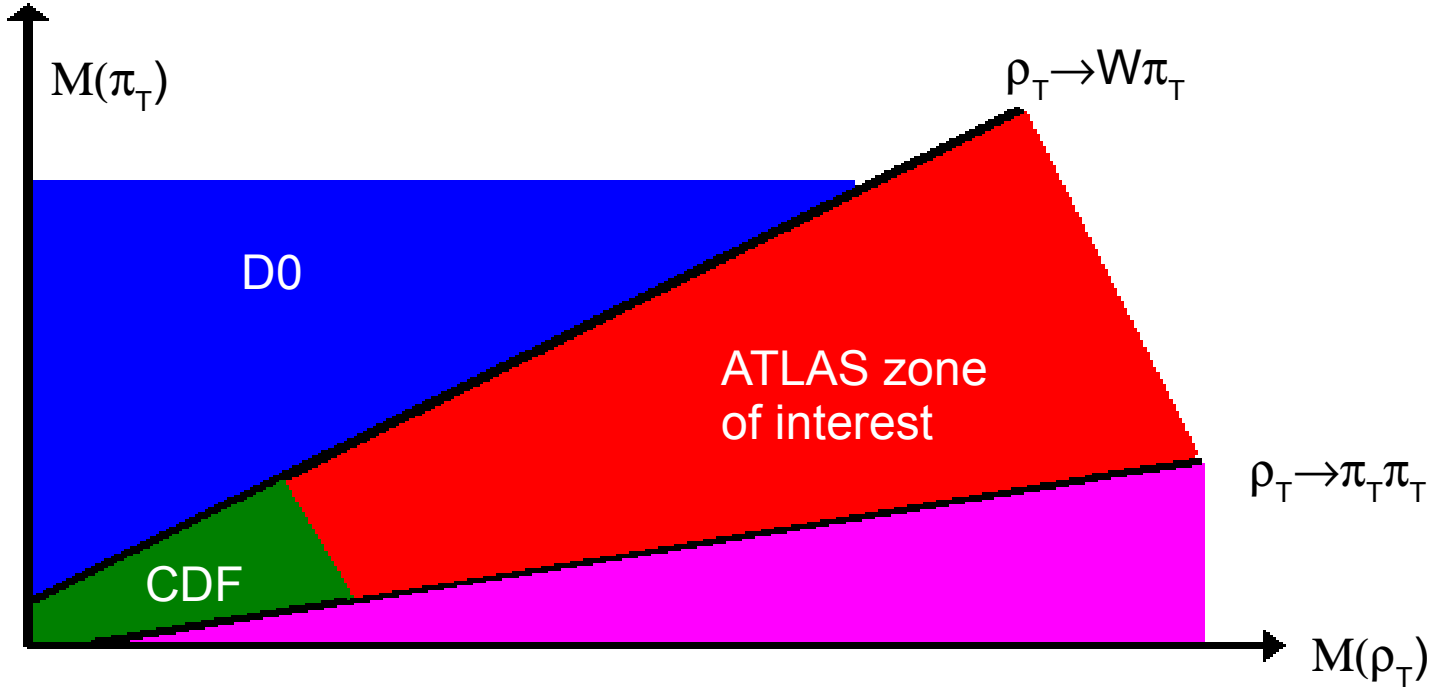
# $\rho_T/\omega_T \rightarrow \mu^+\mu^-$

- Discovery potential for $\rho_T/\omega_T \rightarrow \mu^+\mu^-$ .
- Dashed line statistical uncertainty only.
- Solid line takes into account statistical and systematic uncertainties.
- Could be the best channel to discover LSTC at LHC!



# Conclusions

- Technicolor interesting alternative to Higgs Mechanism.
- Most of the studies presented here are currently being done or redone with ATLAS full simulation, at lower center of mass energy.




- Thank you for your attention!