# Top Quark at ATLAS

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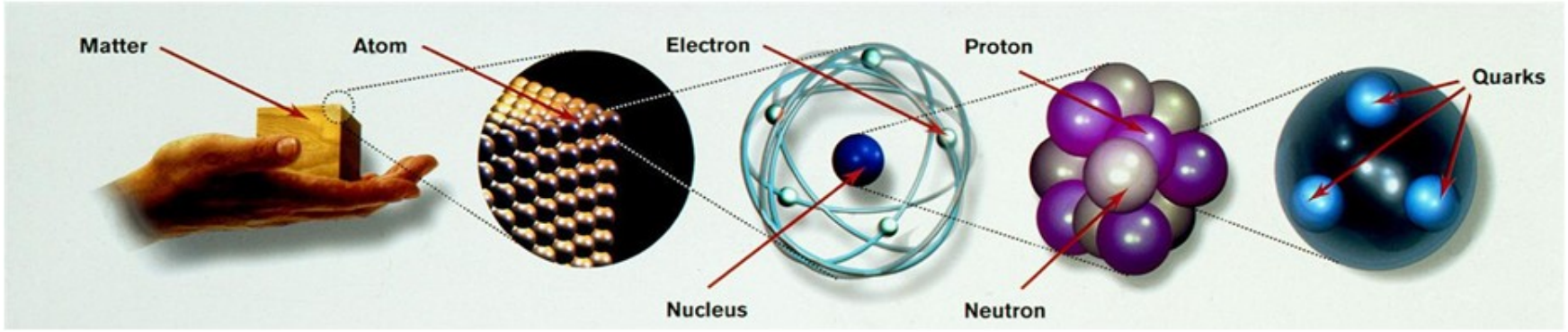
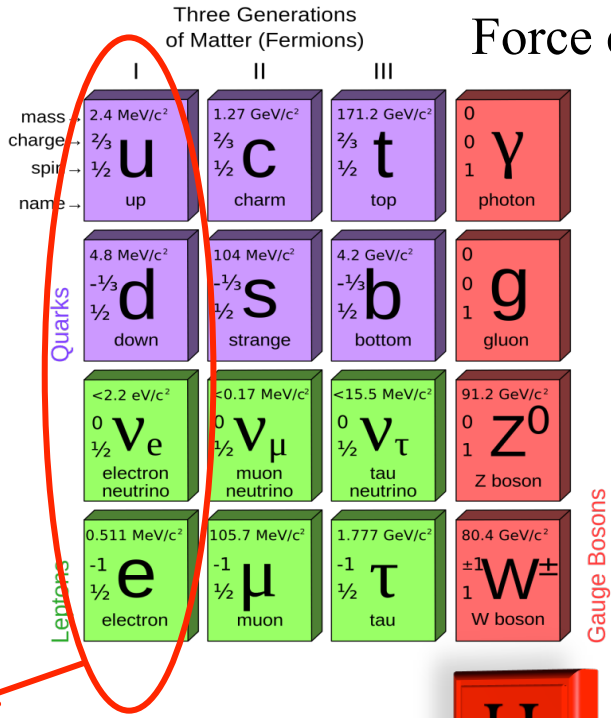
06.10.2015

# The Standard Model



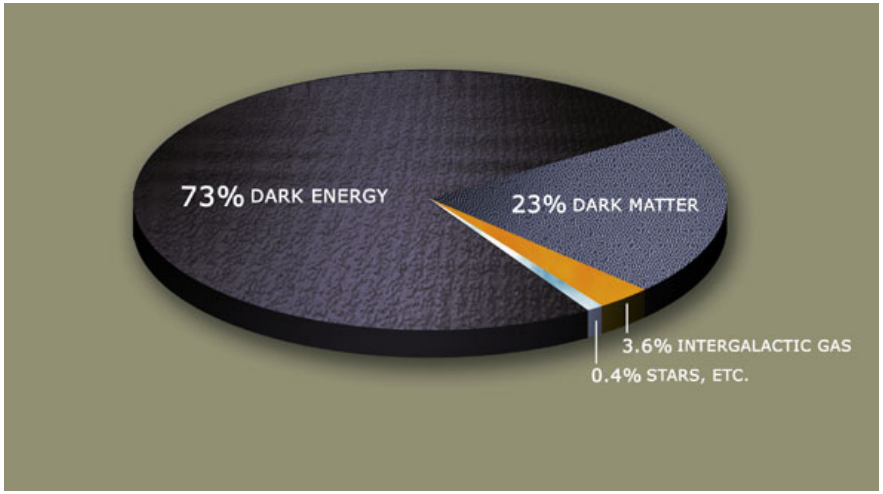

Spin-1/2 particles called fermions:

- Quarks
  - electric charge 2/3e or -1/3e
  - three colours
- Leptons:
  - neutrinos, electrically neutral
  - charged leptons



# Open Questions

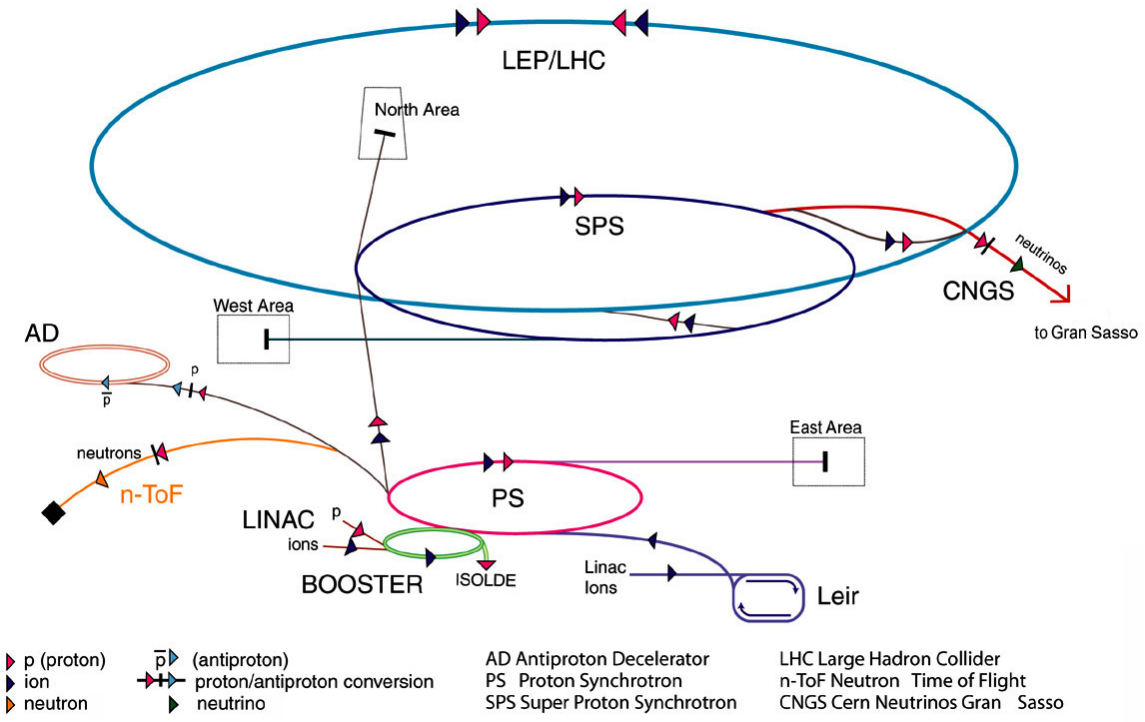
- Three particle generations?
- Neutrino mass
- Mass hierarchy, eV scale to ~173 GeV.
- Matter antimatter asymmetry?
- Gravity
- Dark matter and dark energy

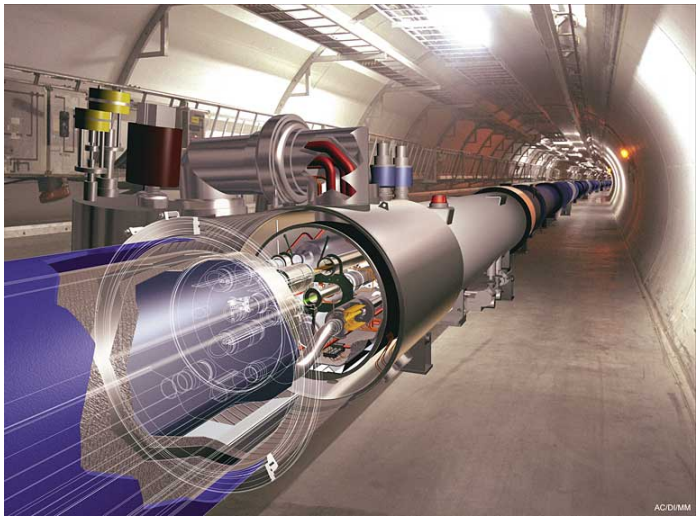



Extensions to SM try to answer one or more of these questions by:

- New particles
- New symmetries
- Extra dimensions
- String theory

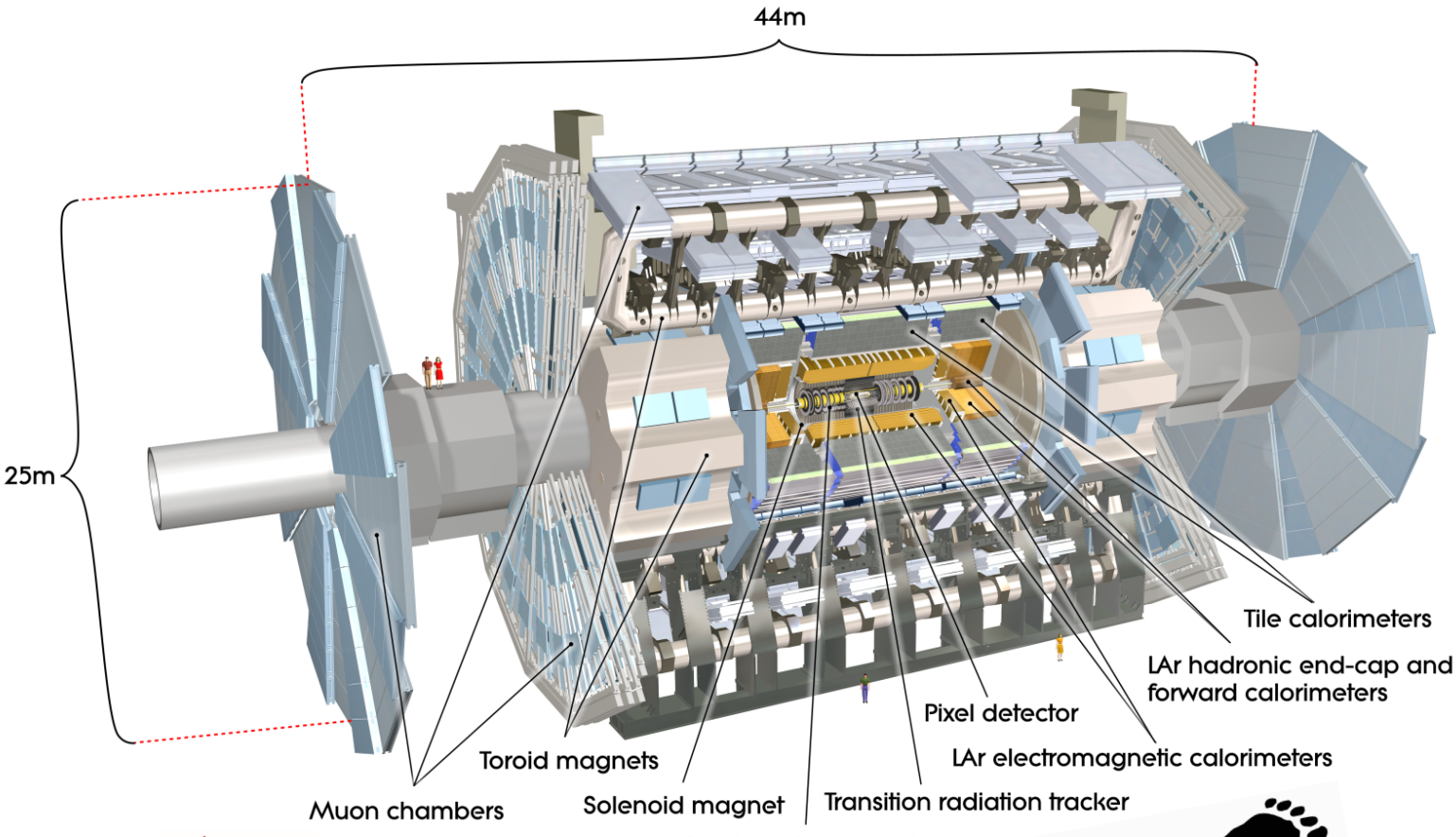
# The Large Hadron Collider

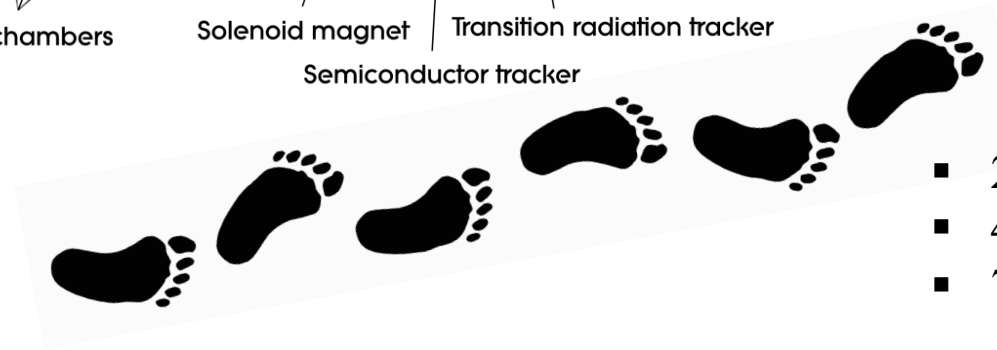


- 27 km circumference
- **Proton-proton** collider
- Operational since 2010
  - in 2011 $\sqrt{s} = 7$ TeV
  - in 2012 $\sqrt{s} = 8$ TeV
  - in 2015 $\sqrt{s} = 13$ TeV

# The ATLAS Detector



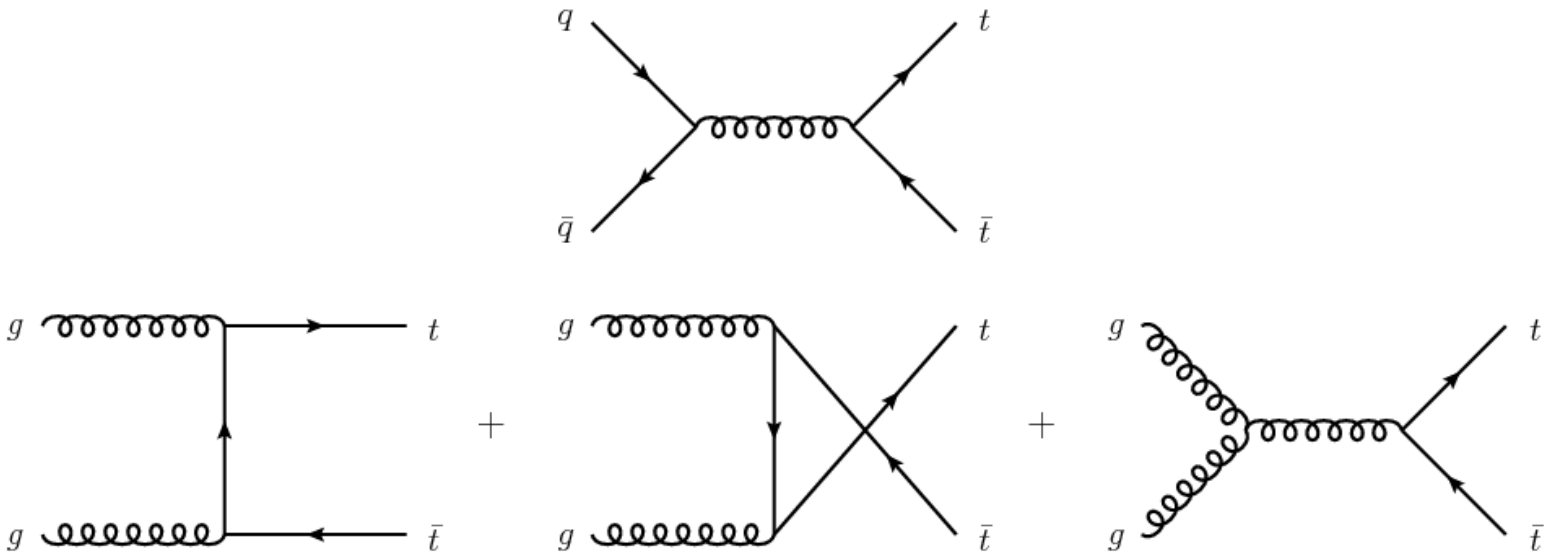



- 22 m height
- 44 m length
- 7000 tons weight

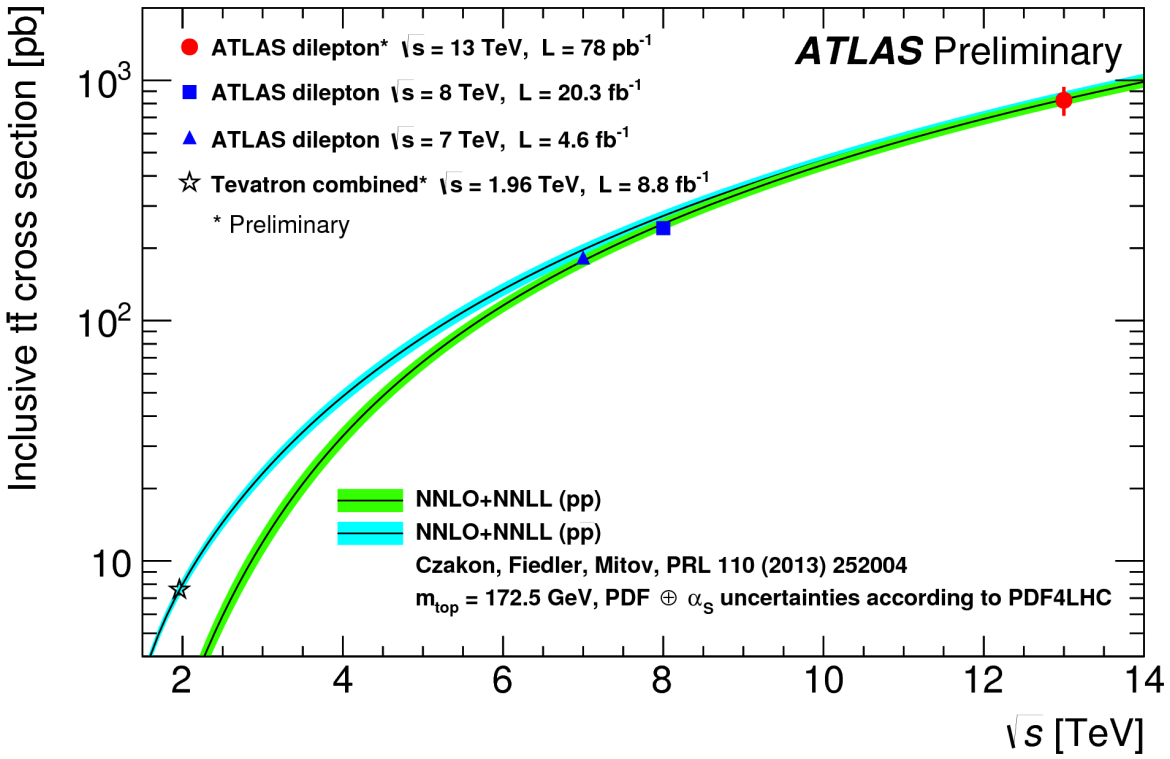
# Top-quark production at LHC

- The heaviest fundamental particle
- It decays very fast before it hadronize
- Top quark can be produced in SM:
  - in pairs through strong interaction
  - singly associated to other particles through weak interaction

- ❖ $M_{top} = 173.3 \pm 0.9$ GeV
- ❖ Life-time ~ $10^{-25}$ s
- ❖ Decays to bW ~100%



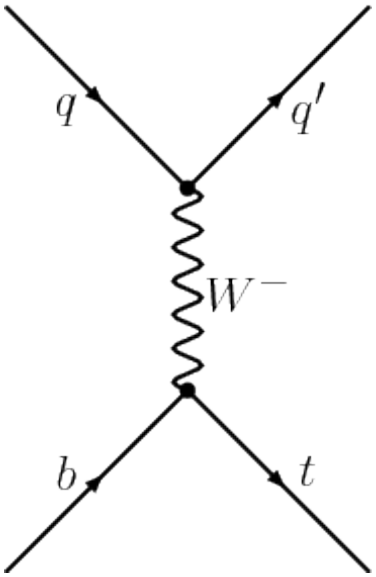
# Top Anti-Top Quark Cross Section



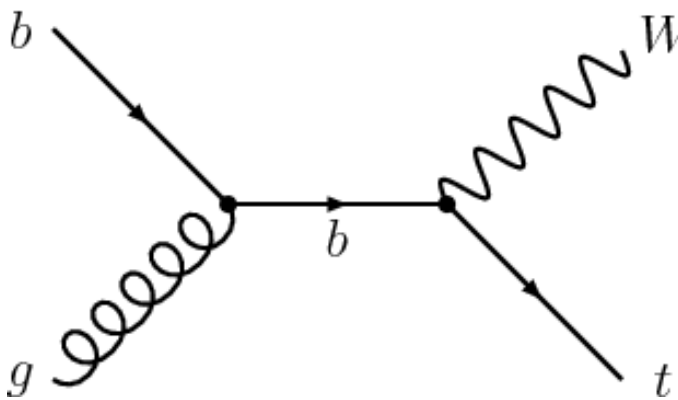

- Cross section goes up with energy?!
- At low energy proton anti-proton produce more top quarks!
- Many things we should get right before we have an agreement between theory and experiment

# Single Top Quark Production

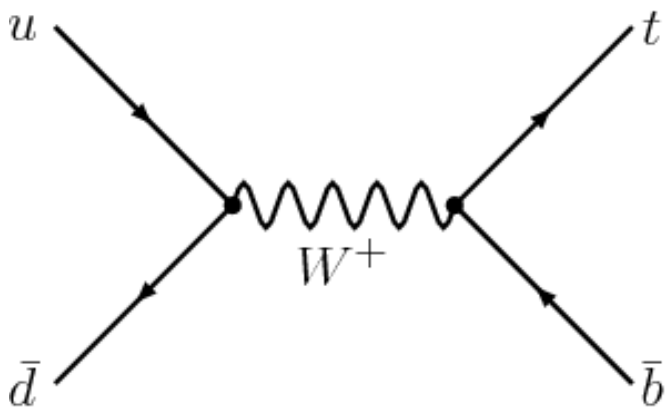
- Three production channels:




t-channel:

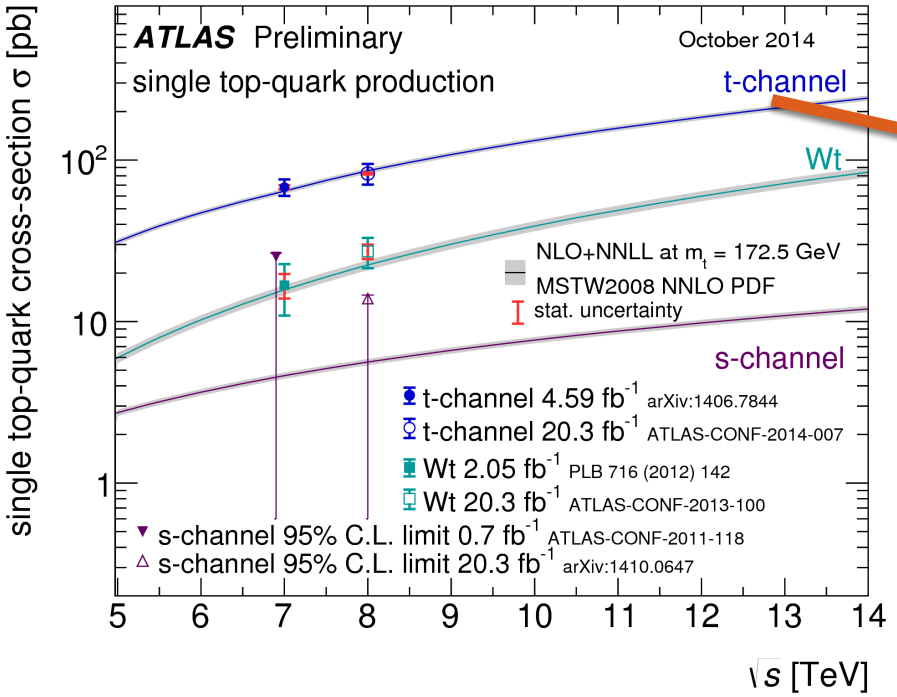


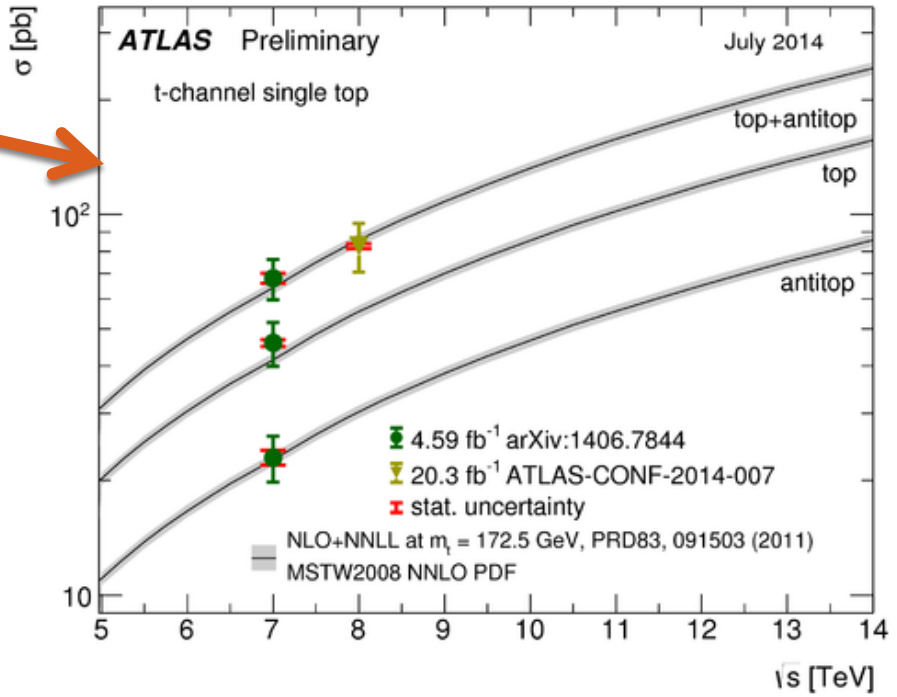

Wt-channel:



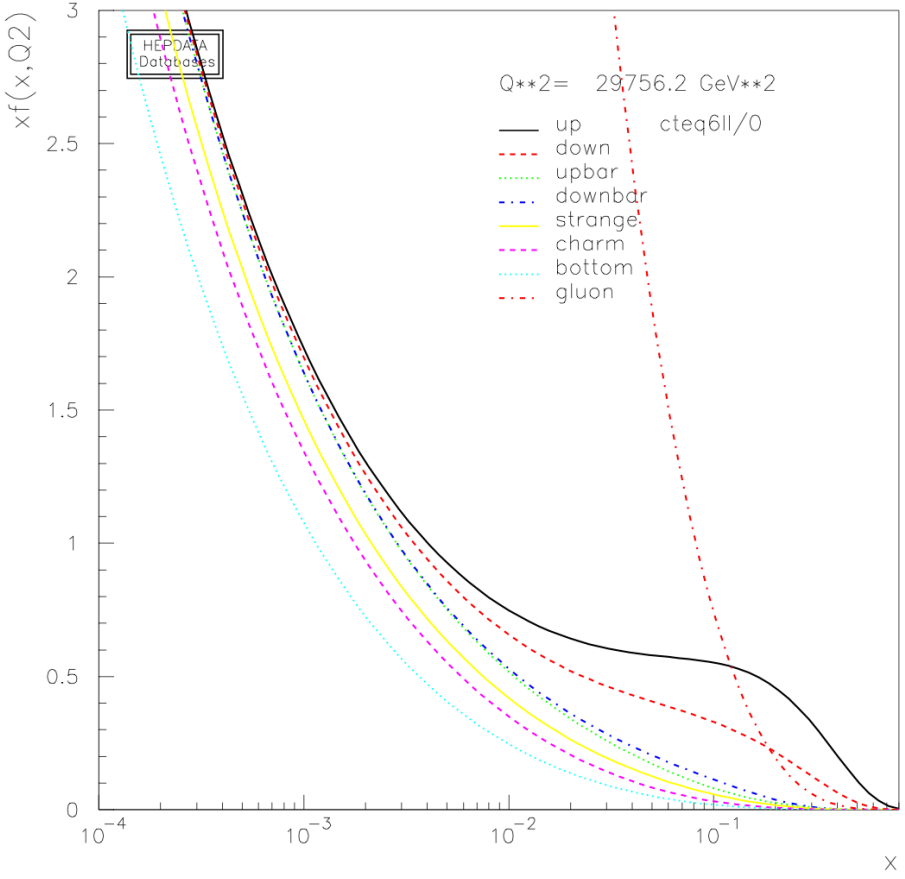

s-channel:

# Single Top Quark Cross Section



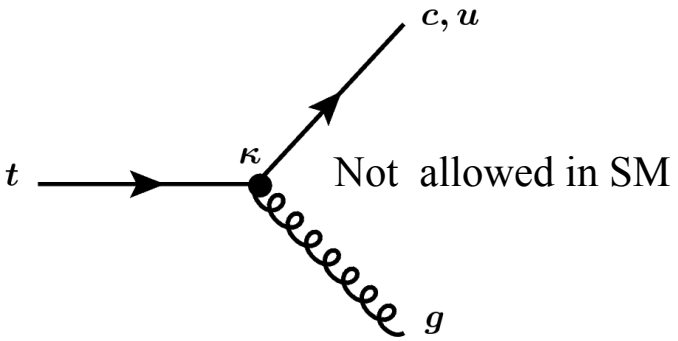
# Parton Distribution Function



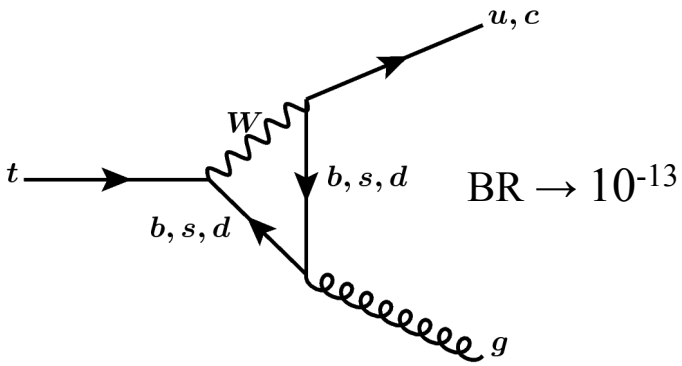

$$x_1 x_2 . s = M^2$$

$$\sqrt{s} = 7, 8, 13, 14 \text{ TeV}$$

# Rare Top Quark Production Processes: FCNC in strong sector




Not allowed in SM

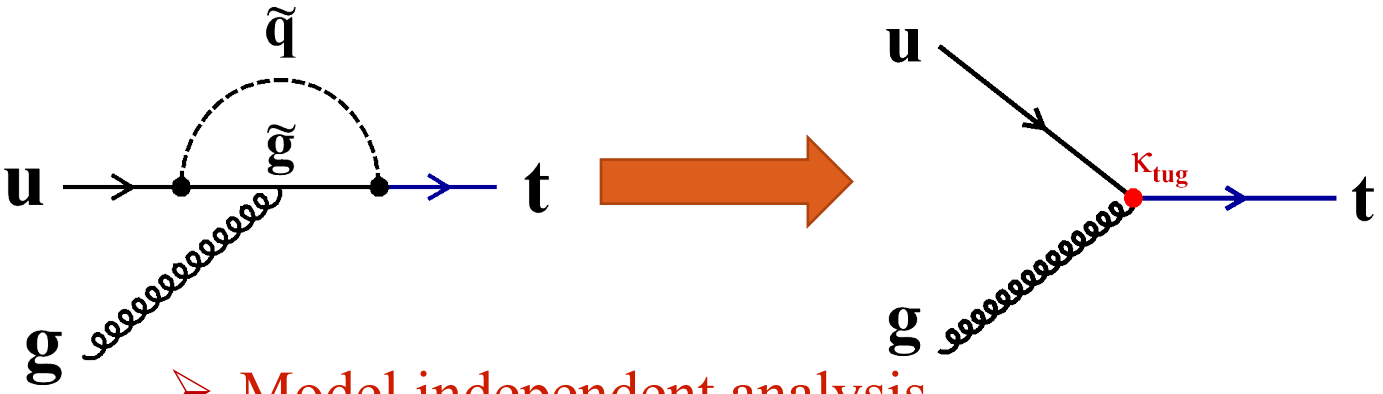



BR → $10^{-13}$

- Motivation:
  - Experimental
  - Theoretical (predicted excess depends highly on model; 5-8 orders)?

# Example of FCNC processes

Probe the coupling between the top quark and light quarks+gluon




➢ Model independent analysis

Searching for FCNC in top quark **decay** is challenging:

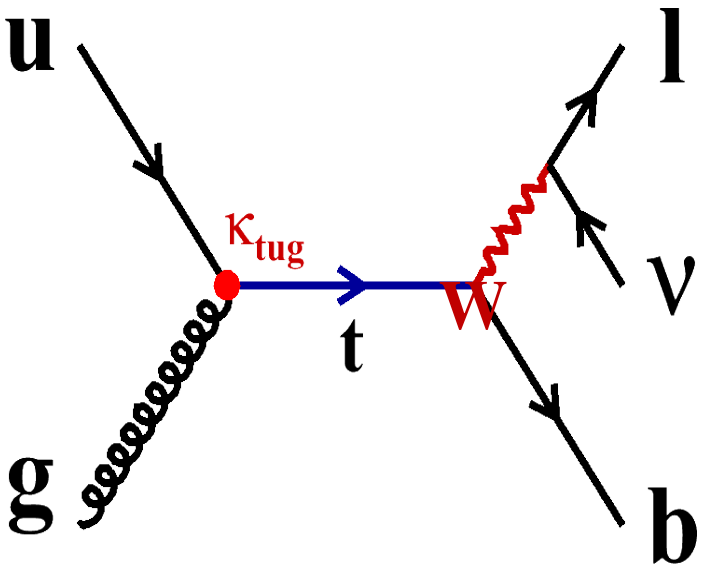
- limited by tt production cross-section and low branching fraction
- very difficult to separate from the multijet background

Top quark **production** via FCNC:

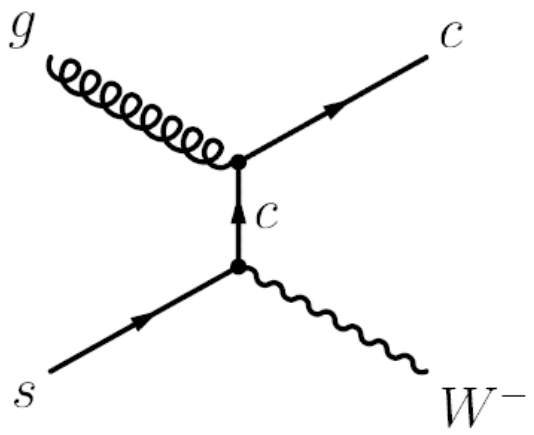
- higher cross-section
- no associated production
  - the top quark has very low $P_T$ compared with SM top quarks

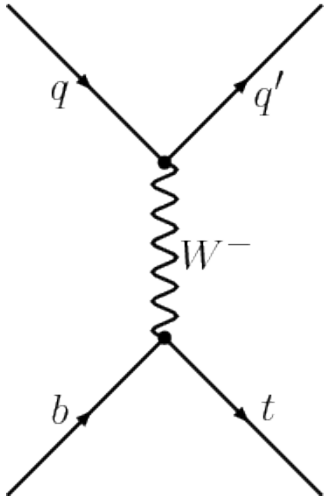
# Event selection

- Lepton selection (electron / muon):
- Missing transverse momentum
- One Jets (identified as a b-jet)




**Dominant backgrounds:**



# Event yields

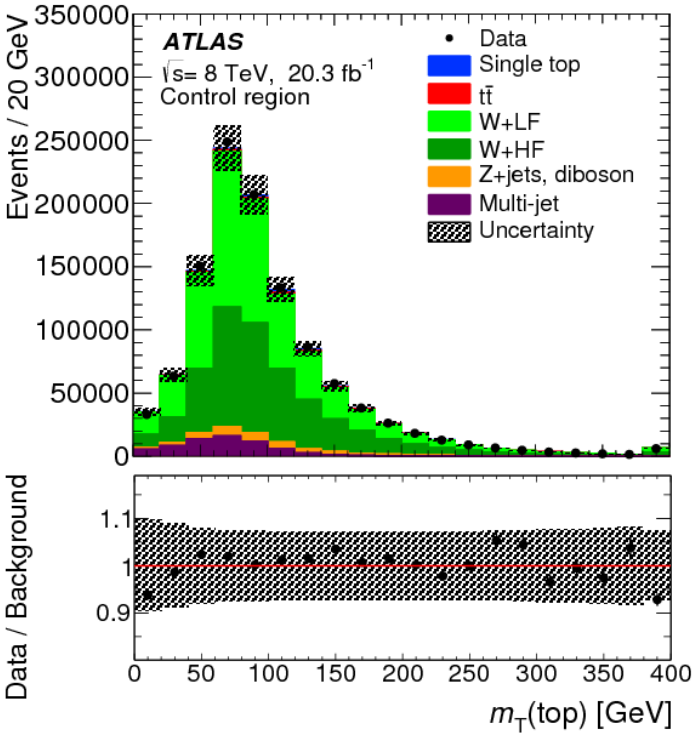
arXiv:1509.00294

| Process | Control region | Signal region |
|---|---|---|
| Single top | 7 930 ± 250 | 8 580 ± 260 |
| $t\bar{t}$ | 6 290 ± 170 | 6 870 ± 180 |
| $W$+LF | 410 100 ± 8 200 | 4 100 ± 1 100 |
| $W$+HF | 340 800 ± 4 700 | 38 000 ± 1 600 |
| $Z$+jets | 38 800 ± 1 500 | 3 570 ± 280 |
| Multi-jet | 32 100 ± 5 500 | 4 970 ± 840 |
| Total expected | 836 000 ± 11 000 | 66 100 ± 2 200 |
| Data | 826 517 | 66 305 |

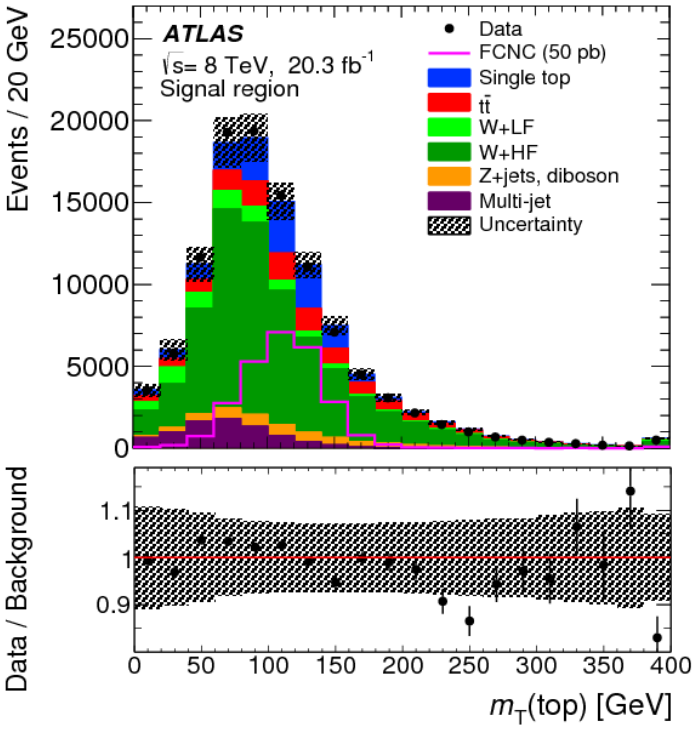
# Kinematic Variables

arXiv:1509.00294

Before requiring a b-jet

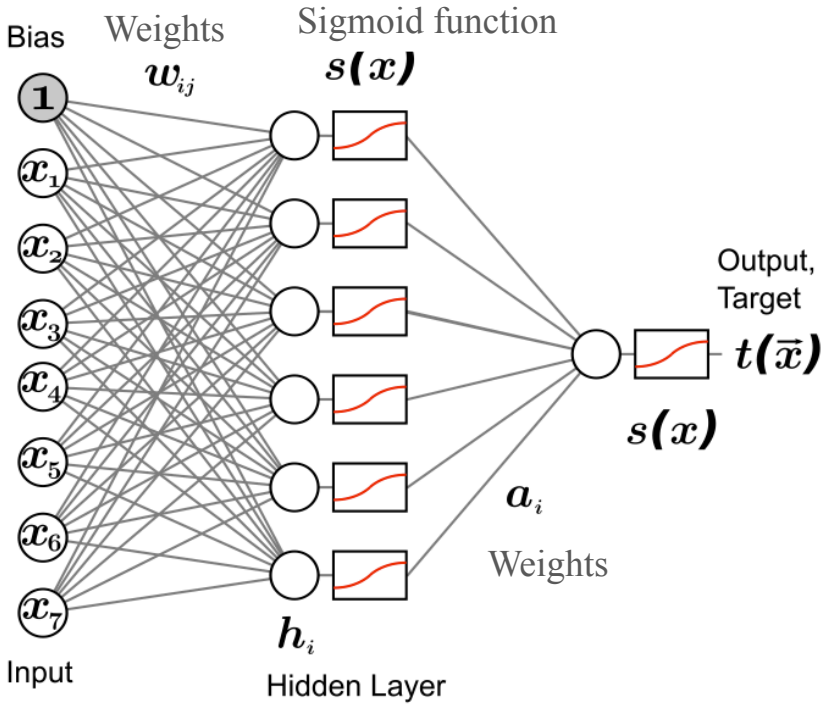


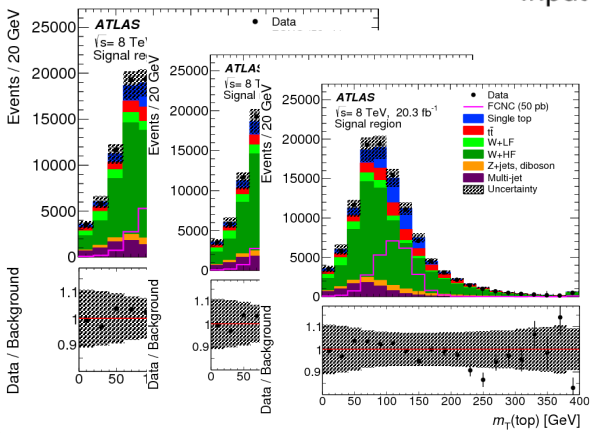

After requiring a b-jet

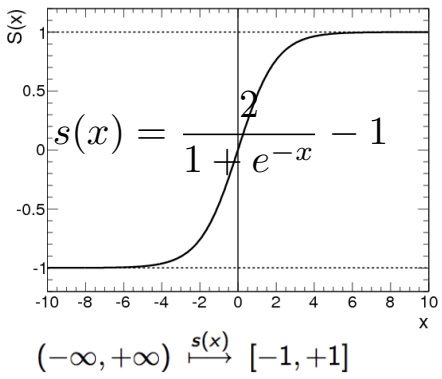



Pixel detector is very important in identify b quark jets

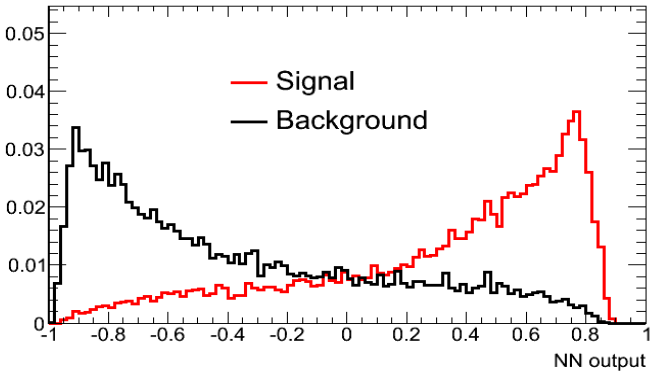
# Neural Network




$(-\infty, +\infty) \xrightarrow{s(x)} [-1, +1]$

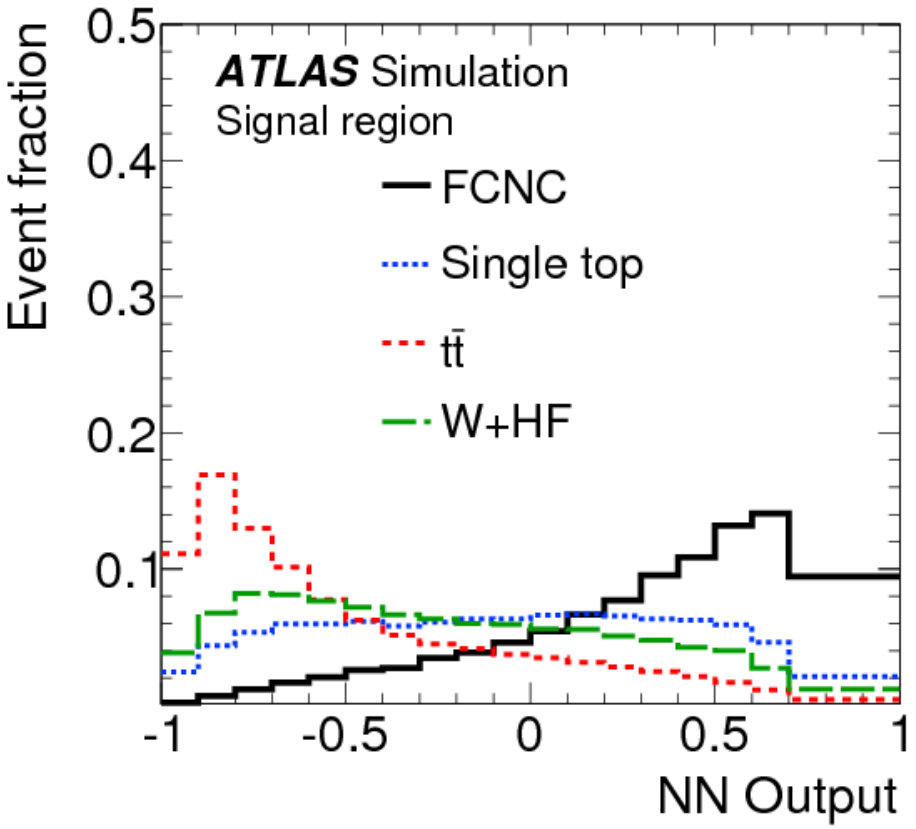


# Input variables

arXiv:1509.00294

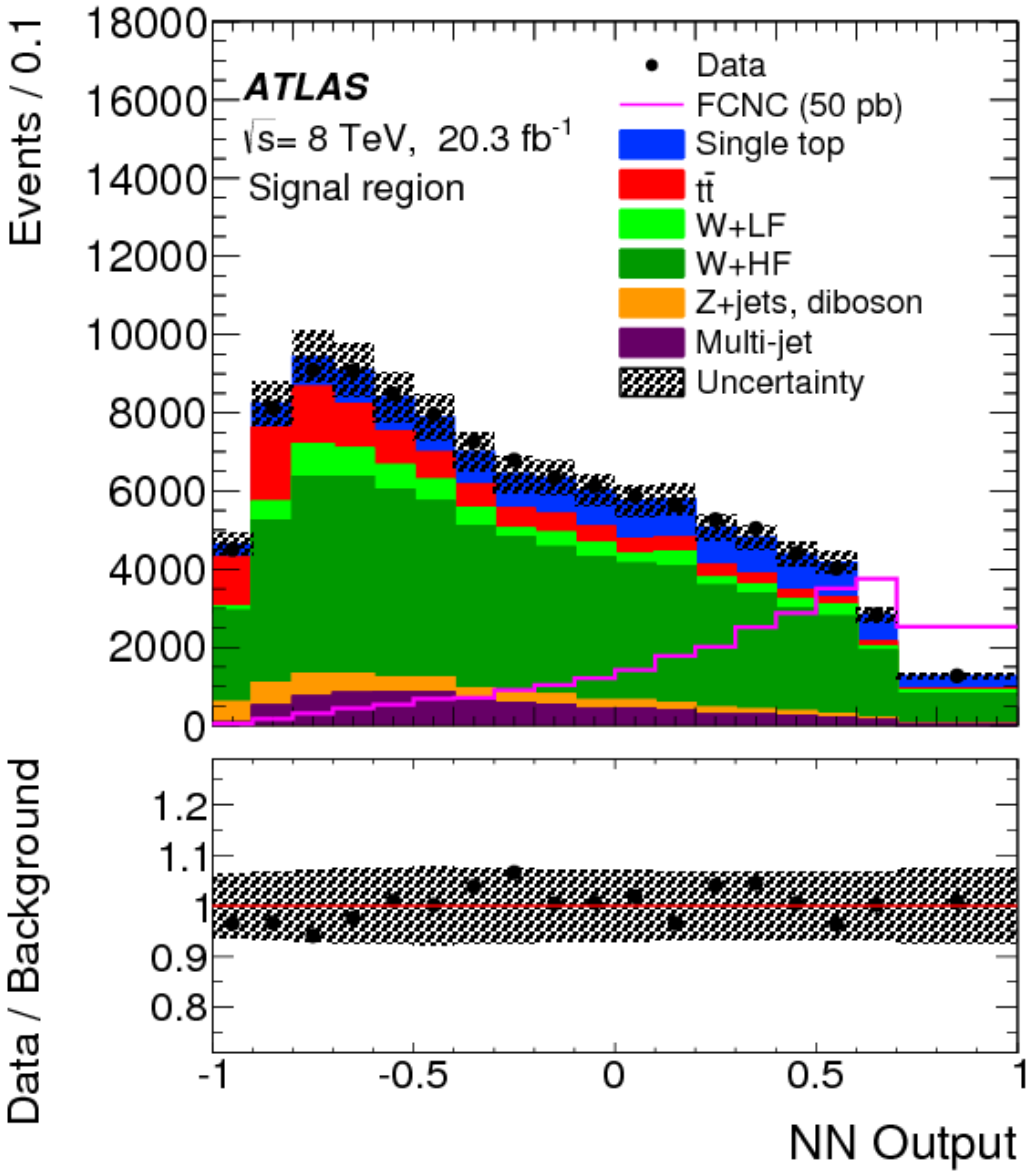
**Signal signature:**

- $P_T$ (top) ~ 0
  (W and b are back-to-back)
- P(W) is large
- More top than anti-top quarks



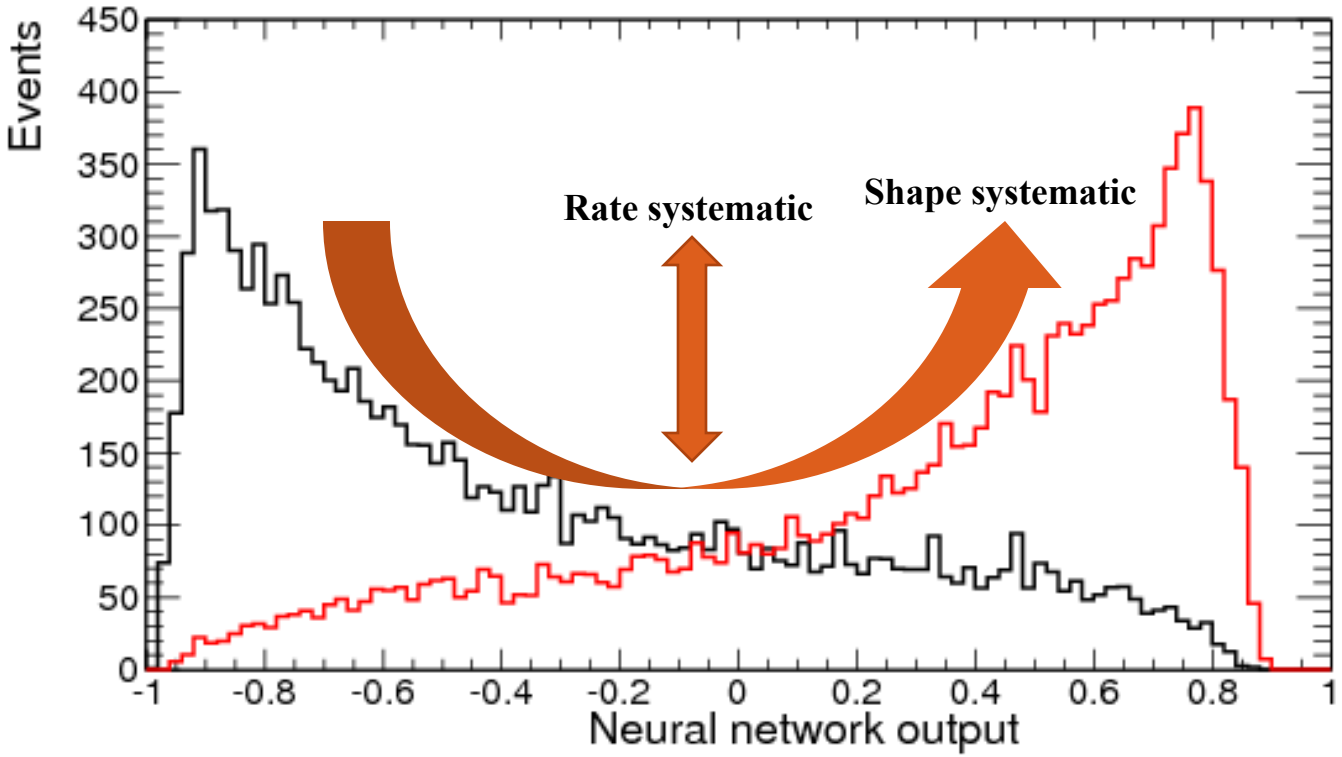
# NN Output

arXiv:1509.00294



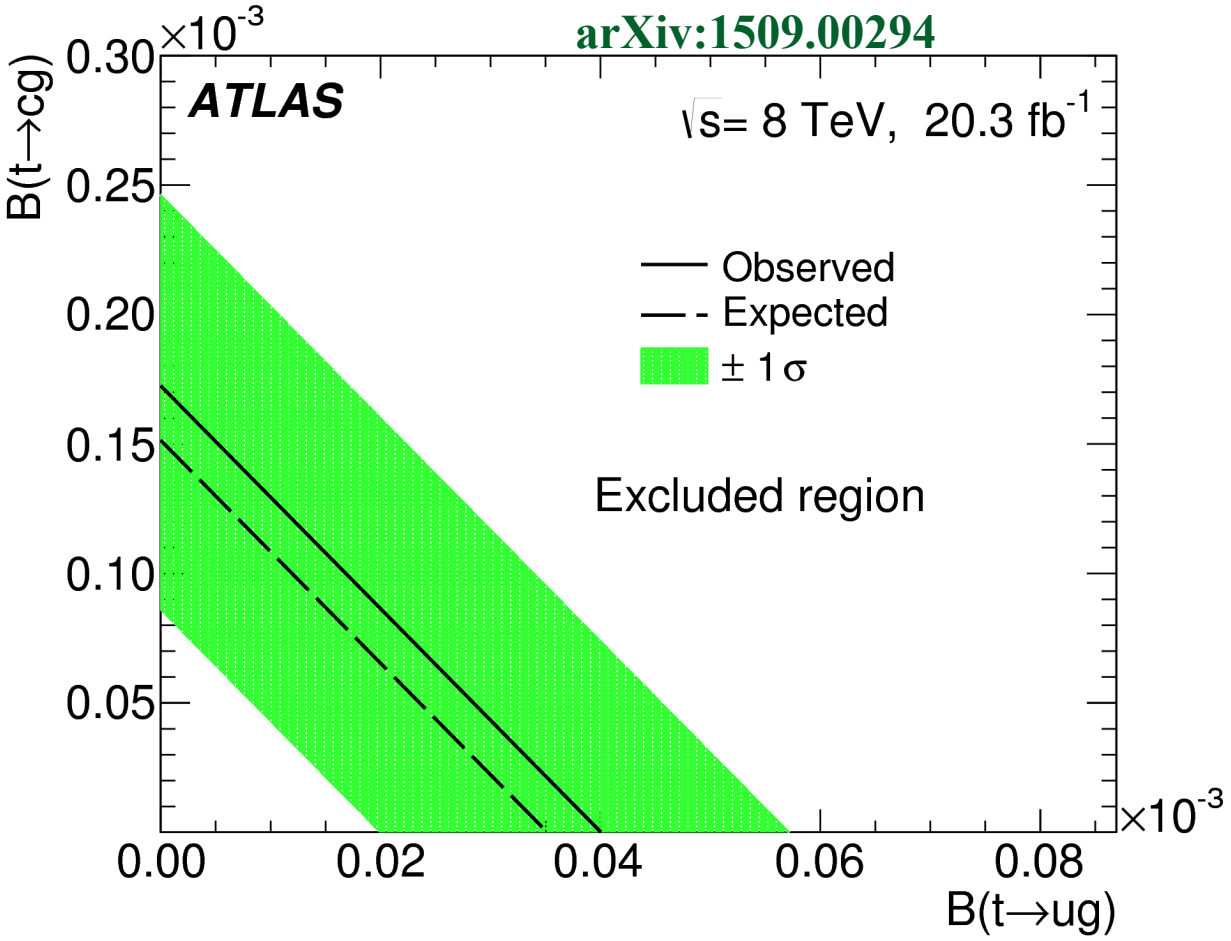
# Systematic uncertainties

- Type of systematic uncertainties:
  - rate  systematic uncertainties of each background processes
  - shape systematics which affects  the signal and background templates



# Results from collision data

- No signal is observed and an upper limit at 95% C.L. is calculated



# Summary

- Top quark play an important rule in search for new physics
- Understanding the proton structure plays a key rule in measuring the cross section
- The ATLAS inner detector is critical in identifying the short lived particles
- Do not forget the importance of the detector and physics **Simulations!**