Dr. Umberto De Sanctis

New Phenomena at the TeV Scale With Top Quarks

NPTEV-TQP2020
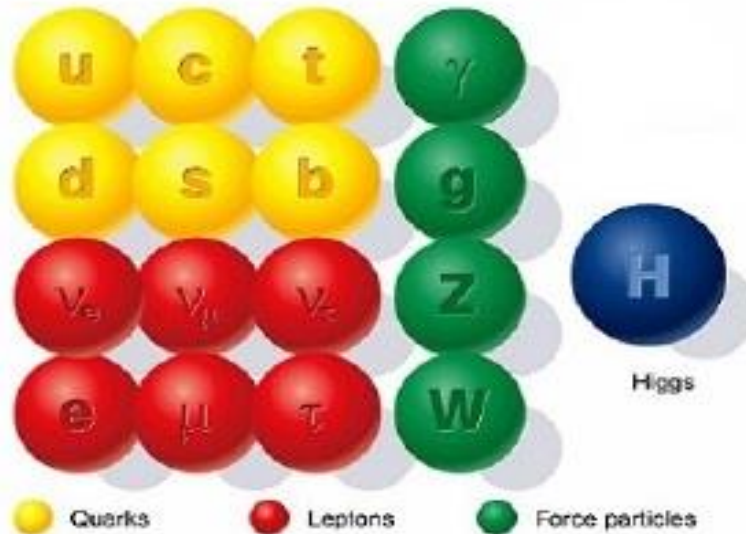
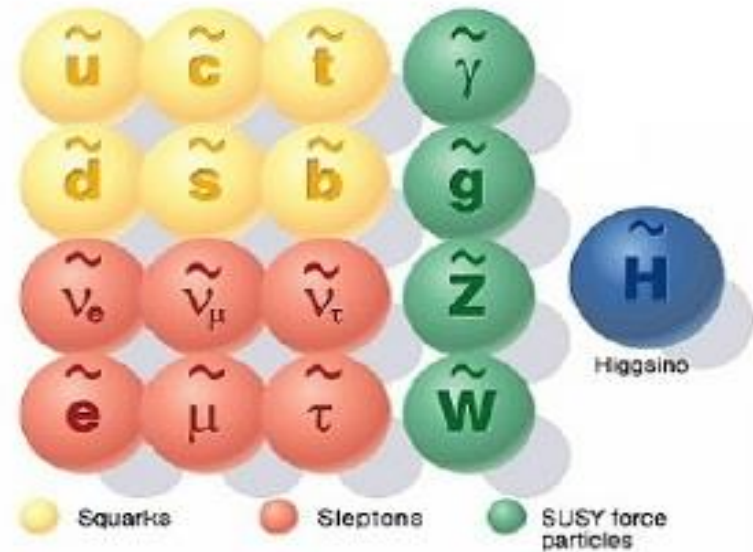16/12/2016 Roma Tor Vergata

- ➢ Spent the whole career in the **ATLAS Experiment**
- ➢ Supersymmetry (SUSY)
  - ➢ Searches in the dilepton channel
- ➢ Top Physics
  - ➢ tt cross-section measurement in single lepton channel
  - ➢ W+jets background estimation
  - ➢ Top charge asymmetry measurement
- ➢ B-physics
  - ➢ Bs → μμ BR measurement
  - ➢ Topological trigger studies
- ➢ ATLAS upgrade activities for HL-LHC
  - ➢ L1 Track project
- ➢ NPTEV-2020 Project

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SUPERSYMMETRY

Standard particles	SUSY particles
u c t	ũ c̃ t̃
d s b	d̃ s̃ b̃
γ g Z W	γ̃ g̃ Z̃ W̃
νe νμ ντ	ν̃e ν̃μ ν̃τ
e μ τ	ẽ μ̃ τ̃
H (Higgs)	H̃ (Higgsino)

- Quarks
- Leptons
- Force particles

- Squarks
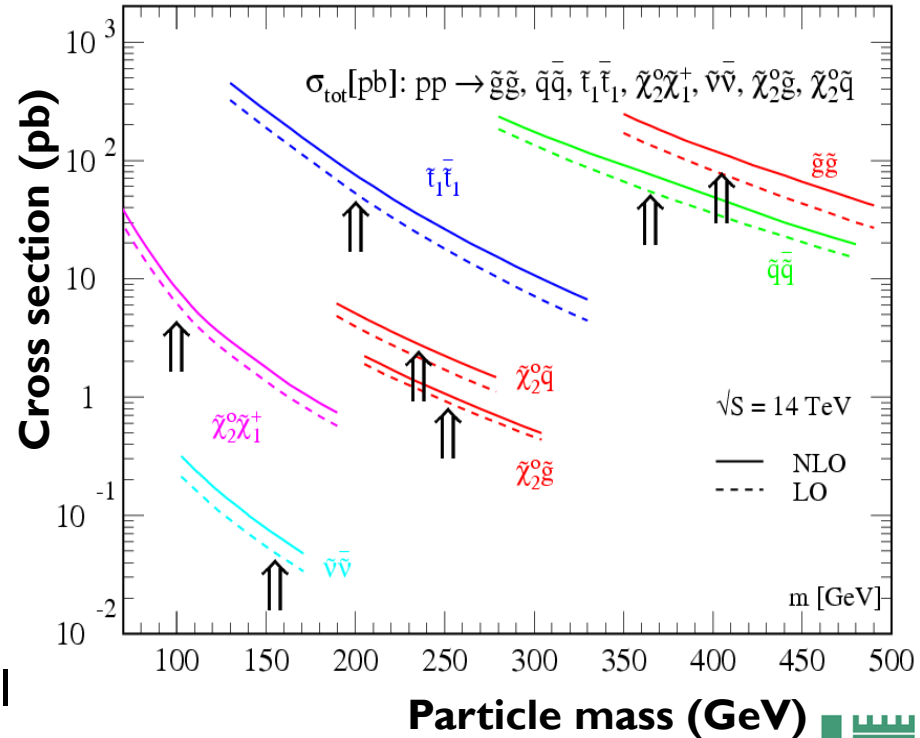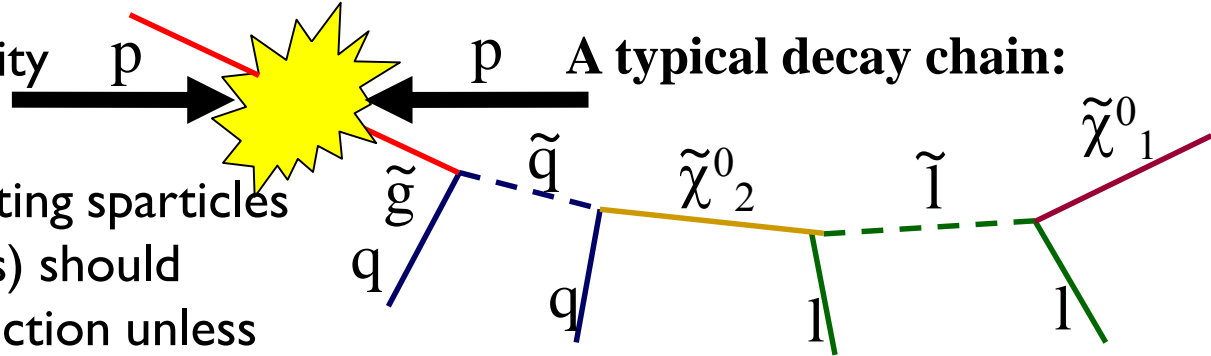- Sleptons
- SUSY force particles

Standard particles   **SUSY particles**

➢ New symmetry that associates to every SM particle a partner with different spin

➢ Solution to the "naturalness/hierarchy/fine-tuning" problem

➢ Candidate for Dark Matter (called LSP) if R-parity conservation holds

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- Assuming R-parity conservation

- Strongly interacting sparticles (squarks, gluinos) should dominate production unless very heavy.

- Cascade decays to the stable, weakly interacting lightest neutralino follows.

- Event topology:

    - high p_T jets (from squark/gluino decay)

    - Large E_T^{miss} signature (from LSP)

    - High p_T leptons, b-jets, τ, jets (depending on model parameters).

A typical decay chain:

- ➤ 2005-2008: Master and PhD theses at Milano University
- ➤ Inclusive and exclusive searches in final states with:
  - ➤ 2 Opposite Sign Same Flavour (OSSF) high-P_T leptons (e, μ)
  - ➤ High-P_T jets + High missing transverse energy E^T_{MISS}
- ➤ Sensitive to SUSY scenarios with:
  - ➤ R-Parity conservation
  - ➤ Gluinos decay chains
  - ➤ Interpreted within mSUGRA framework
- ➤ New method to estimate tt backgorund for these searches (dominant one)
- ➤ Results with 1 fb^{-1} at √s=14 TeV:
  - ➤ Significantly extend the **discovery potential** of the inclusive searches
  - ➤ Reconstruct SUSY particles **kinematic properties (e.g. mass differences)** with a precision < 2%

- ➢ 2014-2016: Postdoc at University of Sussex: B-physics

- ➢ **Rare but clean** decay suppressed by FCNC in the SM
  - ➢ BR(Bs→μμ) = $(3.65 \pm 0.23) \times 10^{-9}$
  - ➢ BR(Bd→μμ) = $(1.06 \pm 0.09) \times 10^{-10}$

- ➢ **Sensitive to New Physics** contributions through loops
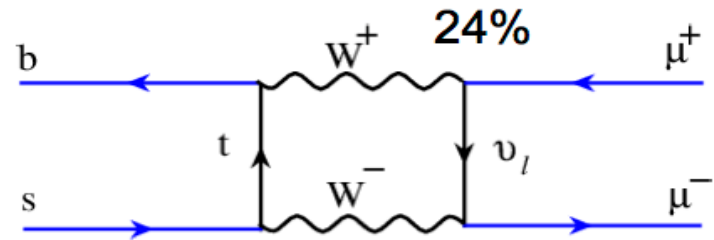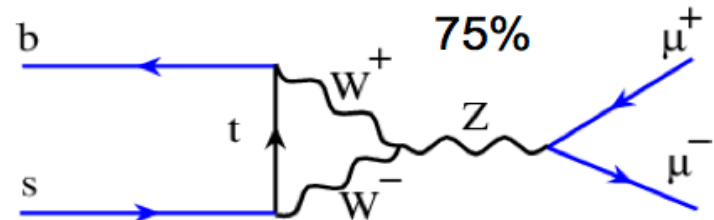
- ➢ Measurements by CMS and LHCb:

  - ➢ BR(Bs→μμ) = $\left(3.9^{+1.6}_{-1.4} \right) \times 10^{-9}$
  - ➢ BR(Bd→μμ) = $\left(2.8^{+0.7}_{-0.6} \right) \times 10^{-10}$
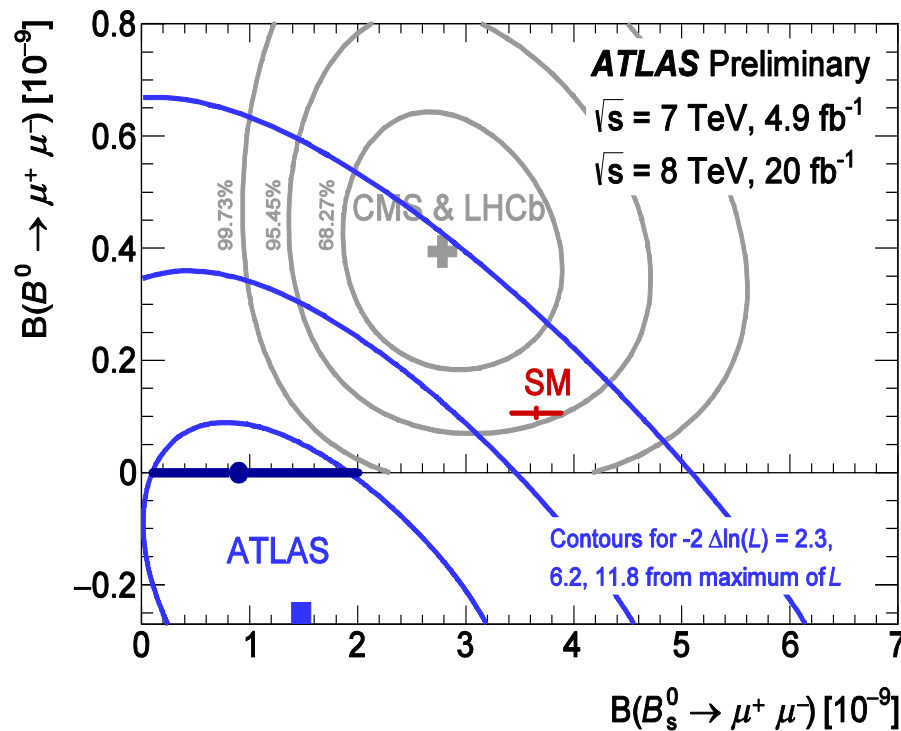
- ➢ Analysis strategy:
  - ➢ BR extracted w.r.t to a well know high statistics reference channel ($B^{\pm} \to J/\psi K^{\pm}$) → reduce systematics
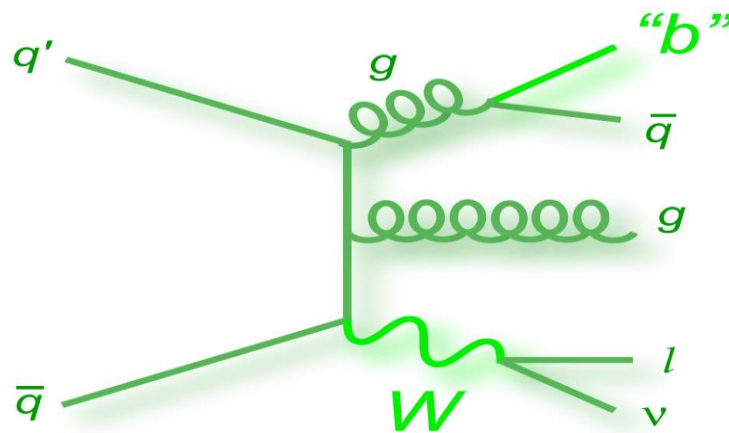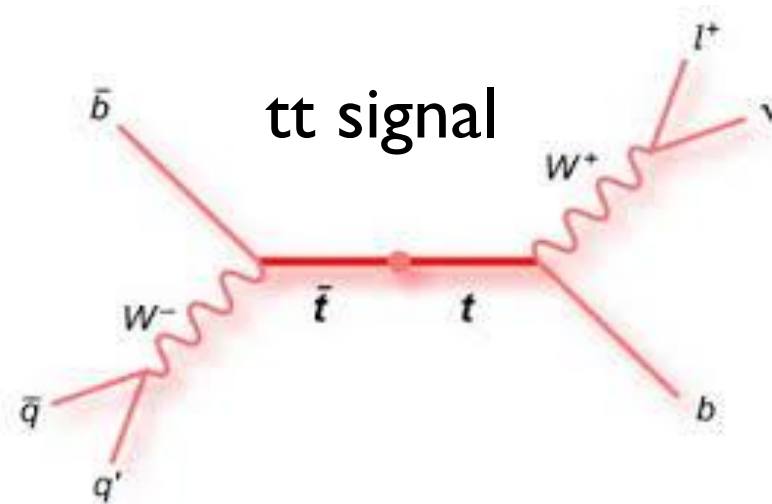 - ➢ Blind analysis; High reduction/control of the backgrounds

➢ Results for full Run1 dataset

➢ Simultaneous BR(Bs→μμ, Bd→μμ) extraction

➢ Comparable precision w.r.t. CMS and LHCb despite their better m(μμ) resolution

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➢ BR(Bs) = $0.9^{+1.1}_{-0.8}$ ×10⁻⁹ (stat. ± syst.)

    ➢ Compatibility with the SM: 2.0σ

➢ Upper limit on BR(Bd) placed at 4.2x10⁻¹⁰ (95% CLs)

tt signal

W+jets background

- ➤ Top quark is the heaviest particle in Nature
- ➤ Its lifetime is shorter than $1/\Lambda_{QCD}$ → It doesn't hadronise
- ➤ Possibility to study the properties of a bare quark!
- ➤ BR(t→Wb) ~ 99%
- ➤ Experimental signatures:
  - ➤ High-P_T jets with both light and heavy flavours HF (from b and c quark decays)
  - ➤ High-P_T isolated lepton (e,μ)
 - ➤ High missing transverse momentum E^T_{MISS}

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➢ 2009-2013: Postdoc at S.I.S.S.A. (Trieste): Top physics

➢ Phenomenological works on the spin determination for high-mass resonances and contact interactions in di-jet events

➢ Work in ATLAS:

  ➢ tt production cross-section measurement in the single lepton channel with and without b-tagging

    ➢ 36 pb^{-1} at $\sqrt{s}$ = 7 TeV → already systematics dominated

    ➢ Compatible with the SM predictions at NLO

  ➢ W+jets background estimation for tt analyses in the single lepton channel

    ➢ Developed a new **data-driven** method based on the W^+/W^- production charge asymmetry

    ➢ Determine both overall normalisation and flavour components ($Wb\bar{b}, Wc\bar{c}, Wc$ and W+ light jets)

    ➢ Most precise method → Adopted by all top analyses

➢ CDF reported a 3.4σ excess over SM → Started and led the activity for the two publication rounds

➢ Top charge asymmetry A_C is a small QCD NLO effect (1.2%) present in $q\bar{q}$/qg events. SM predicts that top and antitop have different rapidity widths $\Delta|y| \equiv |y_t| - |y_{\bar{t}}|$

➢ At LHC: less visible effect but much higher statistics

➢ A_C measured after unfolding for detector/acceptance effects
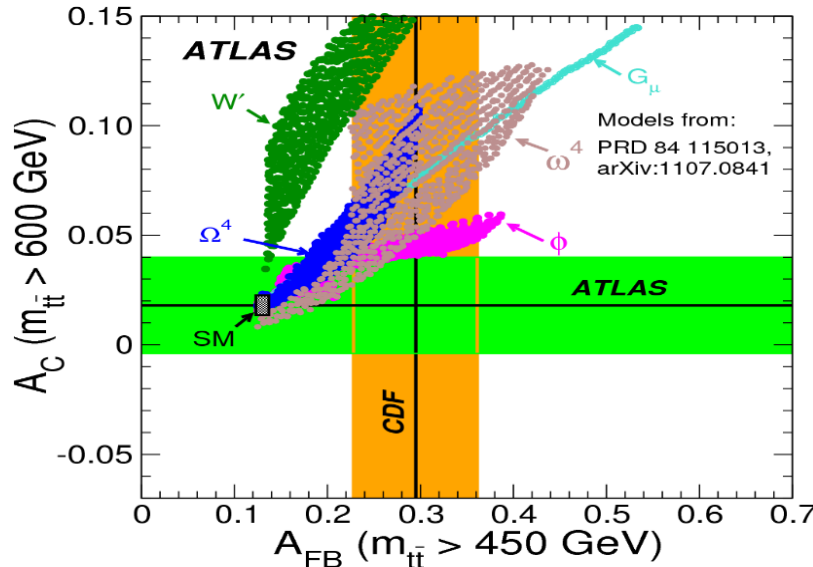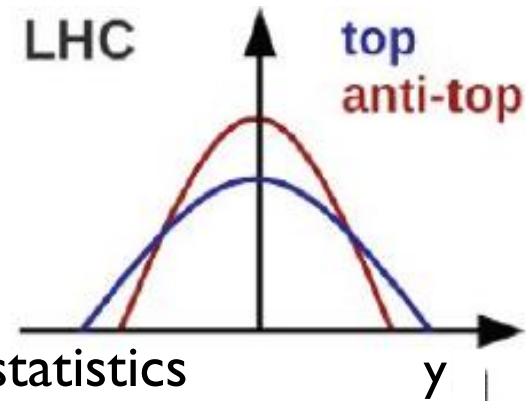
➢ Most precise LHC measurement

➢ Inclusive and differential ATLAS measurements compatible with SM

➢ Comparison between ATLAS and CDF → Some model disfavoured

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➢ Level-1 Topological trigger
  ➢ Optimised, supervising a PhD student, Run-2 trigger strategies for B-physics using Level-1 muon topological info
  ➢ x3 rejection improvement → Vital for B-physics in Run2!

➢ Level-1 Track Project for HL-LHC
  ➢ Goal: make a Level-1 trigger decision using ID info
    ➢ Low latency trigger (few μs)
    ➢ Pattern recognition and track fitting using Associative Memory and FPGA (à-la FTK)
  ➢ Add flexibility to the trigger system for HL-LHC
  ➢ Development of the track fitting algorithm based on Principal Component Analysis and tracking performance studies

➢ NPTEV-2020 project: find New Physics in top events

➢ Tool: **Soft Muon Tagging**

 ➢ Identify the muon from the semileptonic decays of the b quark (e.g. $b \to c\mu\nu$) in $t \to W(\to \mu\nu)b$ decay

➢ Several measurements foreseen. One of them is to look for **CP violation** in b-semileptonic decays

➢ 2 muons: one from W, one from the b-cascade

➢ Count the number of same-charge/opposite-charge muons N^{++}, N^{--}, N^{+-}, N^{-+}

➢ Build asymmetries sensible to CP violation both in B^0-$\overline{B}^0$ mixing and direct b/c semileptonic decays

$$A^{ss} = \frac{P(b \to l^+) - P(\bar{b} \to l^-)}{P(b \to l^+) + P(\bar{b} \to l^-)} = \frac{\left(\frac{N^{++}}{N^+}\right) - \left(\frac{N^{--}}{N^-}\right)}{\left(\frac{N^{++}}{N^+}\right) + \left(\frac{N^{--}}{N^-}\right)}$$

$$A^{os} = \frac{P(b \to l^-) - P(\bar{b} \to l^+)}{P(b \to l^-) + P(\bar{b} \to l^+)} = \frac{\left(\frac{N^{+-}}{N^+}\right) - \left(\frac{N^{-+}}{N^-}\right)}{\left(\frac{N^{+-}}{N^+}\right) + \left(\frac{N^{-+}}{N^-}\right)}$$

➢ **All asymmetries consistent with SM**
➢ **First limit on direct CPV in b→cX decay**
➢ Analysis on 13TeV data just started