14th International Masterclasses 2018

Hands on particle physics

Georgians (HEPI TSU) in the ATLAS experiment

Tamar Djobava

On behalf of the High Energy Physics Institute of Iv. Javakhishvili Tbilisi State University (HEPI TSU)

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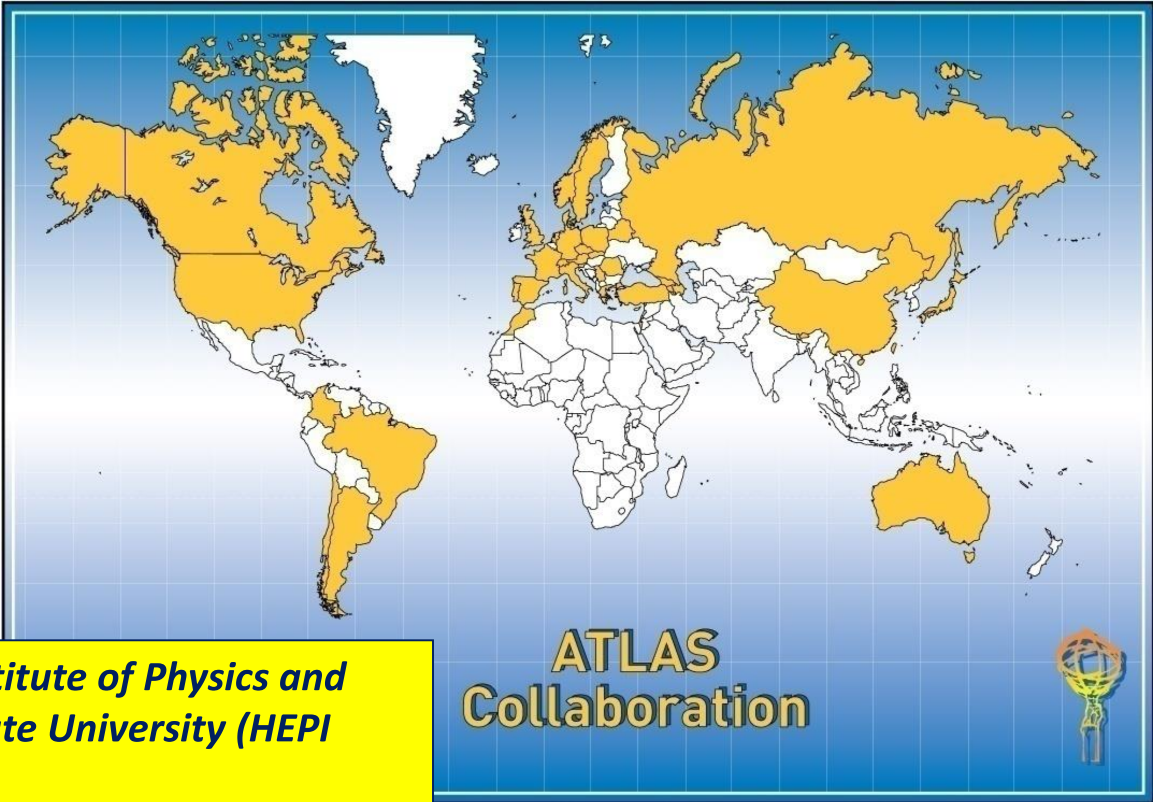
6 March, 2018, Tbilisi, Georgia

The Large Hadron Collider Project:
A dream became reality…

ATLAS Collaboration

38 Countries
182 Institutions
3000 Scientific participants total
(1200 Students)



The joint team from E.Andronikashvili Institute of Physics and* High Energy Physics Institute of *Tbilisi State University (HEPI TSU) became ATLAS member since 1994

Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, Birmingham, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Brasil Cluster, Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Regina, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

Georgians in the ATLAS collaboration

E.Andronikashvili Institute of Physics of TSU → **Detector tasks/Physics Analysis**

HEPI TSU → **Detector tasks/Physics Analysis**

Georgian Technical University → **Detector Software Development**

Tile Calorimeter

- Operation shifts
- Maintenance and consolidation works
- Analysis of ATLAS Tile Calorimeter (TileCal) behavior and stability using Detector Control System (DCS) data.

Upgrade of ATLAS TileCal for High luminosity LHC.

- Investigation of the performance of ATLAS TileCal Demonstrator prototype based on the testbeam data
- Study of TileCal performance with new cell granularity.

Physics Analysis

- Search for Flavor Changing Neutral Current (FCNC) top quark decays $t \to Zq$ (q=u,c quarks) in ATLAS Run 2 and HL-LHC conditions
- Measurement of the differential cross-sections of prompt and non-prompt production of J/ψ and $\psi(2S)$ in pp collisions at $\sqrt{s}$=13 TeV
- Associated production of a top-antitop pair with a quarkonium state (J/ψ)

Georgians in the ATLAS collaboration

The Team Leader Dr. I.Minashvili

J.Khubua

I.Minashvili

E.Tskhadadze

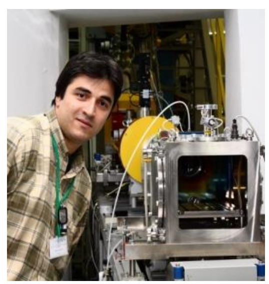
T.Djobava

M.Mosidze

N.Mosulishvili

G.Devidze

A.Durglishvili



J.Jejelava

T. Zakareishvili

B. Chargeishvili

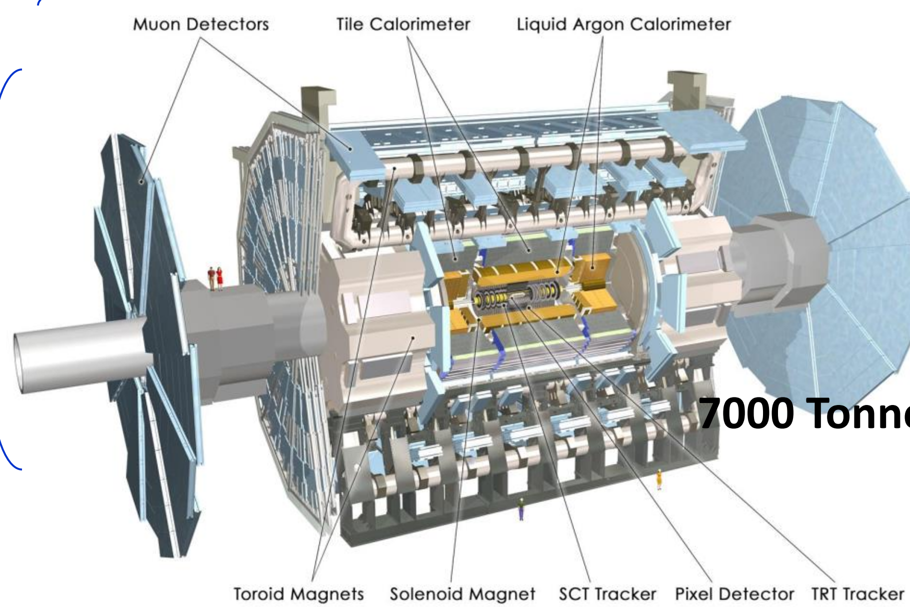
V.Kartvelishvili

ATLAS Detector

ATLAS superimposed to the 5 floors of building 40

45 m

24 m

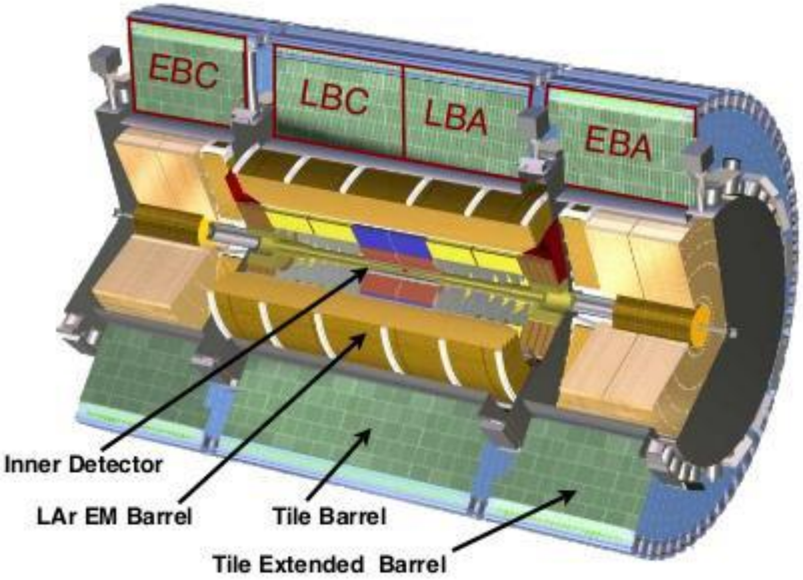


7000 Tonnes

The detector is a cylinder with a total length of 45 m and a radius of 12 m and weights apptoximately 7000 tonnes.

ATLAS HadronicTile Calorimeter

ATLAS Tile Calorimeter



- Diameter: 8.5 m
- Length= 12 m
- Weight: 2900 T
- Total thickness of 7.4λ_{int} at η=0

Design goals:

- large dynamic range (detect low signal from muons up to high signals from jets at TeV scale)
- energy linearity ~2% for high p_T jets up to few TeV

- 3 cylinders with coverage: $|\eta| < 1.7$
- Sampling calorimeter: Fe/scintillator: 4:1
- Double PMT readout via WLS fibers (5000 cells->10k channels)
- Aim for jet energy resolution: $\Delta E/E = 50\%/\sqrt{E} \oplus 3\,\%$

ATLAS Tile Calorimeter

Scientists from HEPI TSU under leadership of Prof. J.Khubua were and are now heavily involved in all phases of the Hadronic Tile Calorimeter, from its design, prototype tests, construction, installation, calibration, commissioning (refurbishment of super drawers-central and extended barrels), operation to the physics performance (J.Khubua, I.Minashvili, N.Mosulihvili)

- **energy scale and simulation**
- **maintenance and consolidation (LS1..)**
- **operation (shifts, data quality)**
- **online and DAQ**
- **Upgrade**
- **Test beam data analysis**

J.Khubua

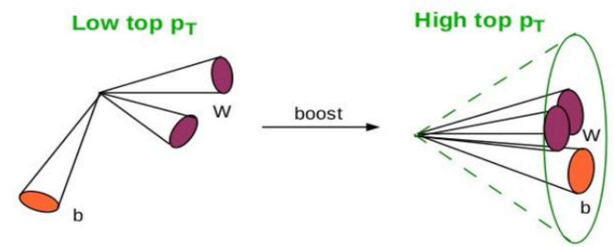
I.Minashvili

N.Mosulishvili

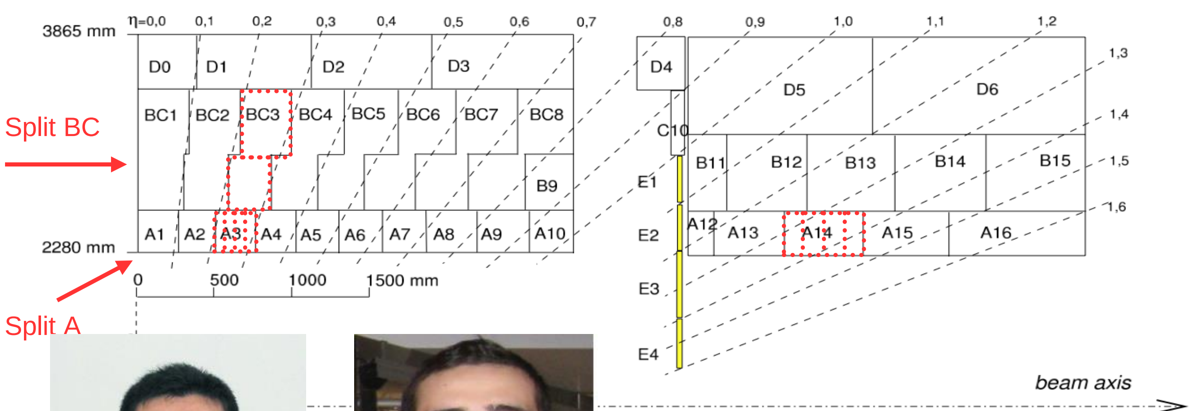
High Granularity TileCal study

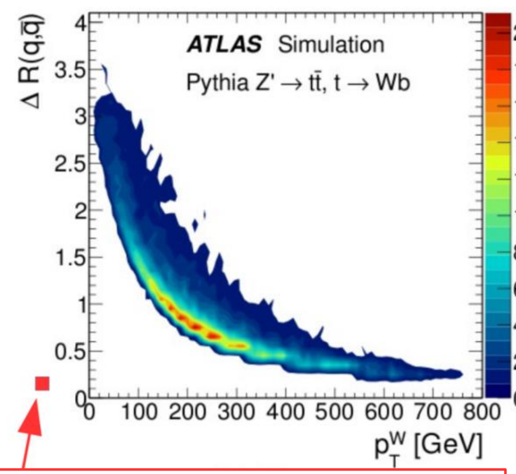
TileCal phase 2 upgrade geometry

- Improve granularity using multianode PMTs (8x8 channel matrix)
  - **Split BC cells (x2) → 3 → 4 longitudinal layers in LB**
  - **Split A cells (x4) → eta granularity = 0.1 → 0.025**
- Not changing the detector (only PMTs and optical guide)
- This is an upgrade idea being studied in TileCal (not yet the baseline)



- Higgs, W, Z, top (p_T > 2 TeV) decay to narrow jets with jet radius smaller than 0.4 in φ x η
- Such narrow jets have substructure (2 or 3 subjets)





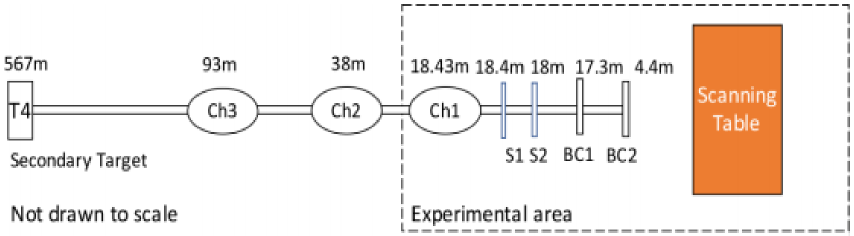
TileCal cell size (0.1x0.1) becomes comparable with a typical separation between 2 quarks from W decays

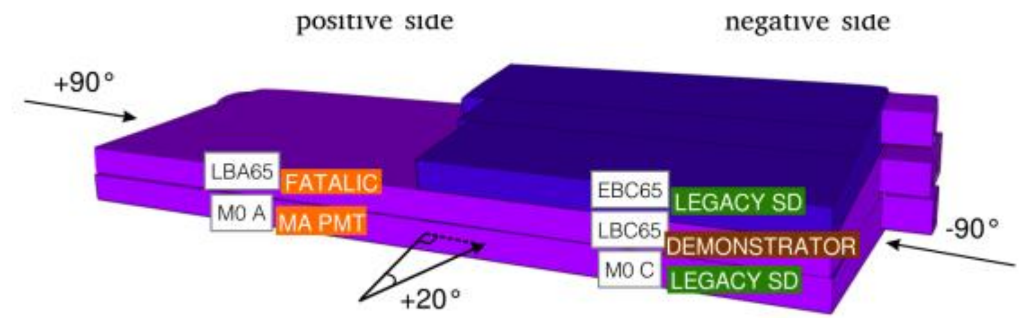
A. Durglishvili

B. Chargeishvili

Tile Calorimeter Demonstrator Test Beam data -2015-2017

Tile Calorimeter Demonstrator Test Beam data analysis –Muon data 2017





- The high-energy muons traverse the entire TileCal modules for any angle of incidence, thereby allowing a study of the module response in great detail through their entire volume.
- The interaction of muons with matter is well understood. The dominant energy loss process is ionization and the energy lost is essentially proportional to the muon track path length.
- Muon data allows us to:
  - **verify the new electronics performance by checking the equalization of the cell response of the demonstrator drawer.**

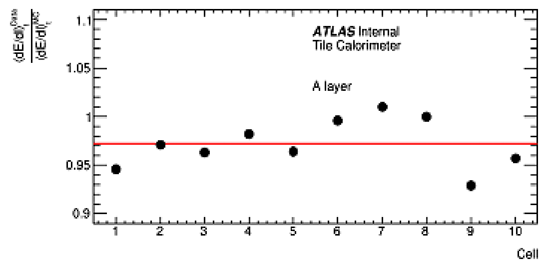
The response of the detector has been studied determining the ratio between the energy deposited in a calorimeter cell (dE) and the track path-length in the cell (dl) using 165 GeV muons at an incident angle of -90°.

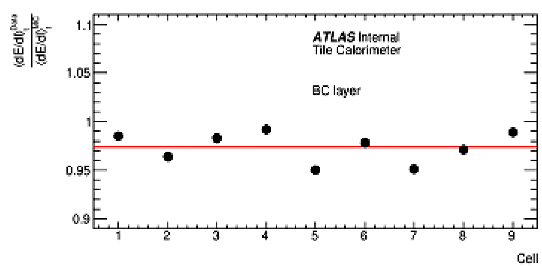
● The ratio of experimental and simulated dE/dl values was defined for each calorimeter cell:

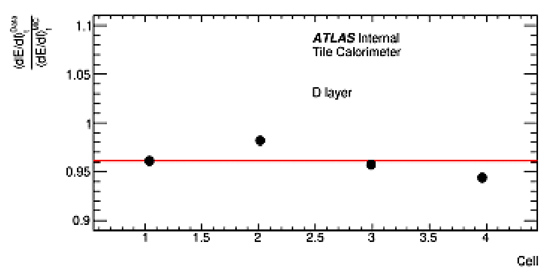
$$R = \frac{\langle dE/dl \rangle_t}{\langle dE/dl \rangle_t^{MC}}$$

● The red horizontal lines – the mean values of dE/dl for each layer.

● The data show a layer uniformity at 1%. An offset of max 4% is observed for Data/MC.







T.Zakareishvili

Conferences and workshops

1. 2017, 24-27 January, Barcelona, Spain, 5th Beam Telescopes and Test Beams Workshop 2017

"Muon Signals at a Low Signal-to-Noise Ratio Environment", T. Zakareishvili; Session: Data Analysis and Test Beam Results https://indico.desy.de/indico/event/16161/contributions

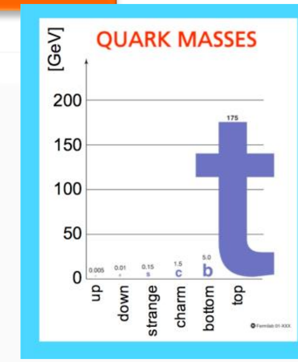
2.2018, 16-19 January, Zurich, Switzerland, 6th Beam Telescopes and Test Beams Workshop 2018

"[Studies of the ATLAS hadronic Calorimeter response to different particles at Test Beams](#)", T. Zakareishvili; Session: Analyis, Scintillating Fibres & Calorimeters.

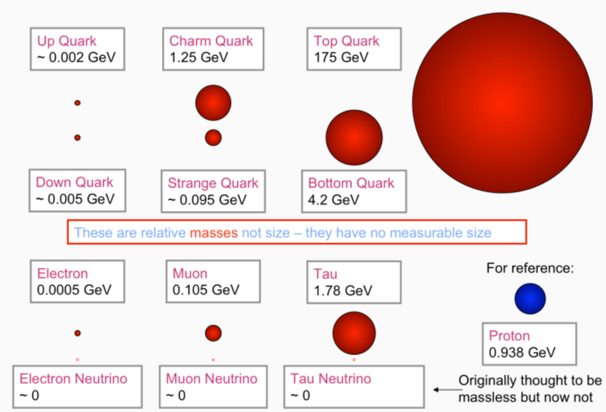
https://indico.desy.de/indico/event/18050/session/8/contribution/34/material/slides/0.pdf

Motivations for Top Quark Physics Studies

- **The top quark was first observed in 1995 at the Fermilab $p\bar{p}$ Tevatron collider by CDF and DO experiments:**
- **M_t = 174.3±3.2 (stat) ±4.0 (syst)**
- **$\sigma_{t\bar{t}}$ = (CDF M_t = 175 GeV) = 6.5 $\pm_{1.4}^{1.7}$ pb**
- **$\sigma_{t\bar{t}}$ = (Do M_t = 172 GeV) = 5.9 ± 1.7 pb**
- **Q^e_{em}=2/3 I e I ; Weak isospin partner of b quark:**
  T^t_3 =1/2; Color triplet, spin ½;



- **The top quark is the heaviest elementary particle yet discovered. Its mass, of the same orders the electroweak scale, is about twice that of the W and Z bosons and about 35 times larger than its isospin partner, the b quark and slightly less than the mass of the gold nucleus.**
- **Large value of top mass and short lifetime ($\tau_t \sim 5\times10^{-25}$ sec) make top quark unique:**
  - **Decays before hadronization**
  - **Sensitive window for New Physics**
    - **Many new heavy particles produce top quarks**
    - **Detailed properties of top probe SM & beyond**



- And in addition ...

- ***Experiment:* Top quark useful to calibrate the detector**
- ***Beyond Top:* Top quarks are major source of background for almost every search for physics beyond the SM – New Physics**

Search for FCNC

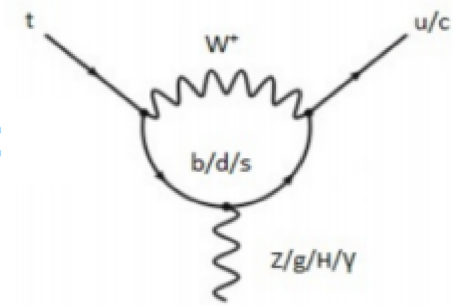
Top-quark FCNC decay branching ratio:

Model:	SM	QS	2HDM	FC 2HDM	MSSM	$\not{R}$ SUSY	RS	Mirror Model
$BR(t \to qZ)$:	10^{-14}	10^{-4}	10^{-6}	10^{-10}	10^{-7}	10^{-6}	10^{-5}	10^{-6}

A search for top quark **F**lavor **C**hanging **N**eutral **C**urrent decay in $t\bar{t}$ production:

- One top decays through FCNC (t→qZ) and other through SM dominant mode (t→bW)
- Leptonic decays of W and Z bosons

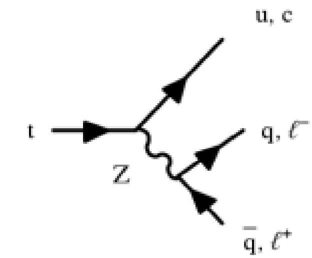
SM:



Strongly suppressed by GIM mechanism in SM

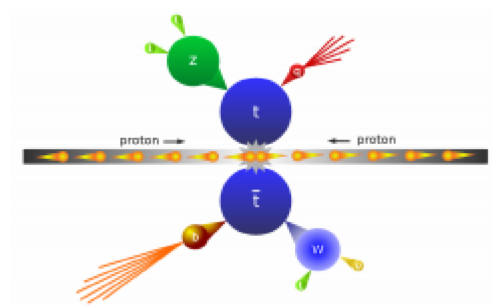
→ Powerful probe for new physics

BSM:



Signal sample

- Separate samples for t→uZ and t→cZ
- $t\bar{t}$ production and decay processes are done by **MadGraph5_aMC@NLO** at NLO in QCD
- Top-quark FCNC decay is done by TopFCNC model:
  https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/TopPropertiesFCNCMCRunII
- Parton shower with **Pythia8** and the A14 tune



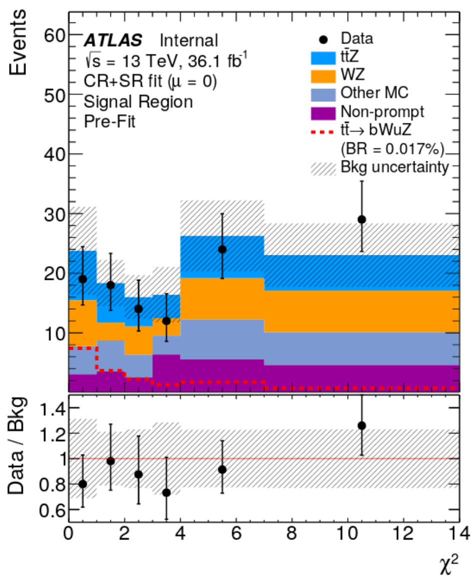
Event topology

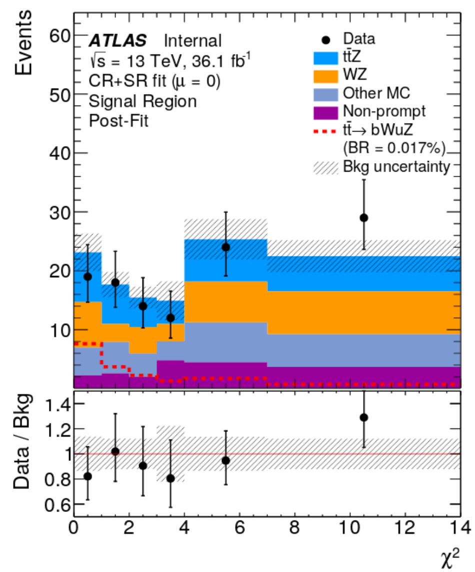
3 isolated leptons, at least two jets, with only one being b-tagged and missing transverse energy from the undetected neutrino

Analysis Team: J.Araque, N.Castro, B.Galhardo, F.Veloso, (LIP, Portugal)
A.Durglishvili, T.Djobava, M.Mosidze (HEPI TSU, Georgia)
S.Hellman, S.Molander (Stockholm University, Sweden)

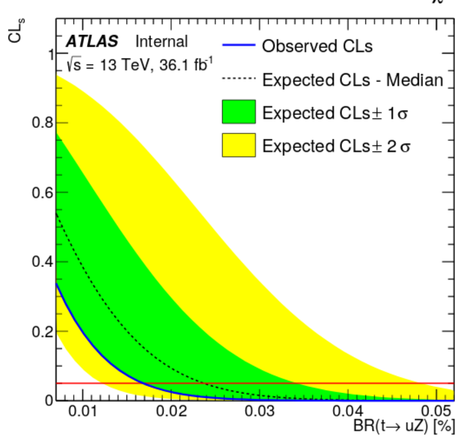
Results of $t \to qZ$ FCNC search

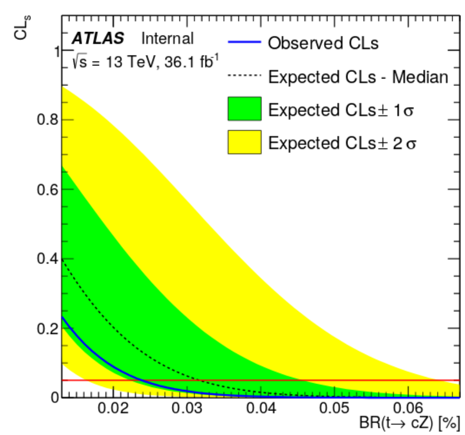
- 36 fb^{-1} of 13 TeV data analysed
- Observed data agree well with the SM background expectations
- No evidence of signal is found
- 95% CL upper limits are set on the branching ratios of $t \to uZ$ and $t \to cZ$





	Observed	-1σ	Expected	$+1\sigma$
$\mathcal{B}(t \to uZ)$ [%]	0.017	0.017	0.024	0.035
$\mathcal{B}(t \to cZ)$ [%]	0.023	0.022	0.032	0.046





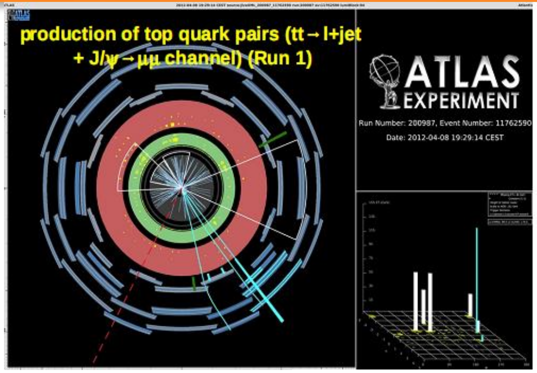
Conferences and workshops

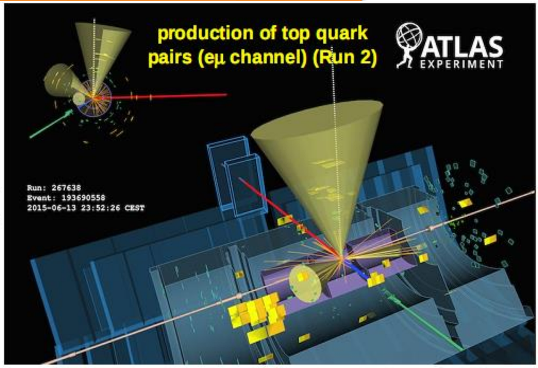
2017, 17-22 September, Braga, Portugal, Top2017 - 10th International Workshop on Top Quark Physics , (http://top2017.lip.pt/) "Search for tZ Flavor Changing Neutral Currents in top quark decays with ATLAS at 13 TeV", A.Durglishvili, Poster session; https://indico.cern.ch/event/659310/

J/ψ production with top pair

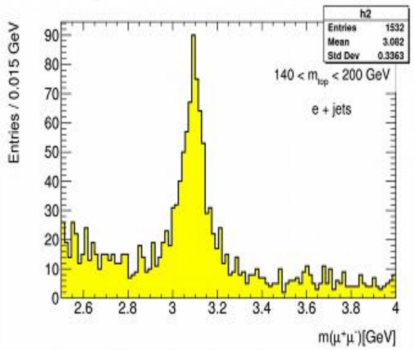
Prof.V.Kartvelishvili

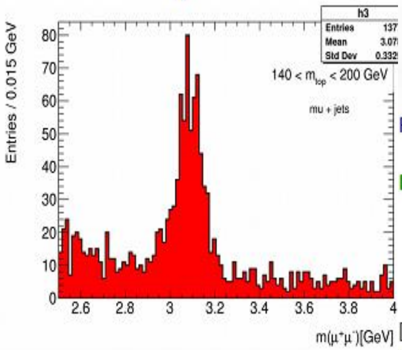
Analysis Team:
V.Kartvelishvili, J.Walder (Lancaster University (GB);
B.Chargeishvili, T.Djobava, T. Zakareishvili (HEPI TSU)



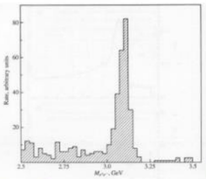


Selection: lepton + 4jets + dimuon(s) (cut on top mass: $140 < m_t < 200$ GeV).





The Beginning: J/ψ



⇐ Discovery 1: Ting's group

$pN \to e^+e^-X$

at $P_{lab} = 30$ GeV/c

[Aubert et al., PRL, 6/11/1974]

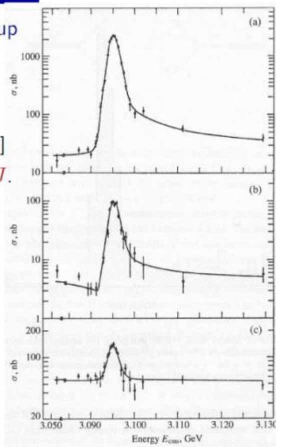
Found a peak in e^+e^- inv.mass at 3.1 GeV, called it J.

Discovery 2: Richter's group ⇒

(a) $e^+e^- \to$ hadrons
(b) $e^+e^- \to \mu^+\mu^-$
(c) $e^+e^- \to e^+e^-$

[Augustin et al., PRL, 7/11/1974]

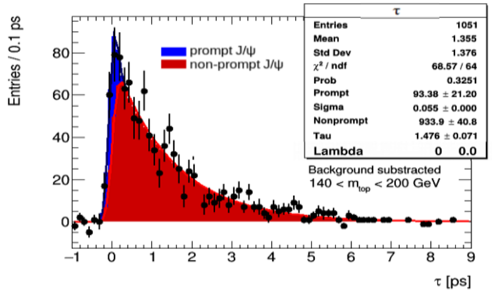
Found a peak in all these three cross-sections, at the c.m.s. energy 3.1 GeV; called it ψ.



11/1/17

Lifetime of J/ψ candidates in top events

|Δη| and |sin(Δφ)| cuts applied.

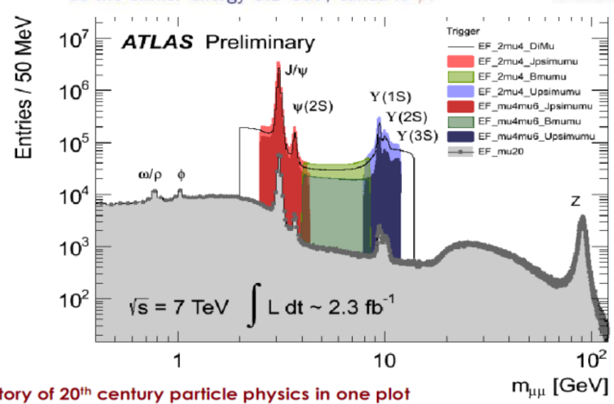


Fit function:
pdf={ε*δ(τ)+(1-ε)*exp(τ)} ⊗ Resolution

Resolution=λ*g(σ)+(1-λ)*g(2*σ)

Fit parameter Prompt – number of prompt J/ψ
Fit parameter Nonprompt – number of non-prompt J/ψ
σ is fixed, σ = 0.055 ps
λ is fixed to 0 - effectively sigma is 0.11, in-line with expectations.

Fit shows that we have 93 ± 21 prompt J/ψ - s!

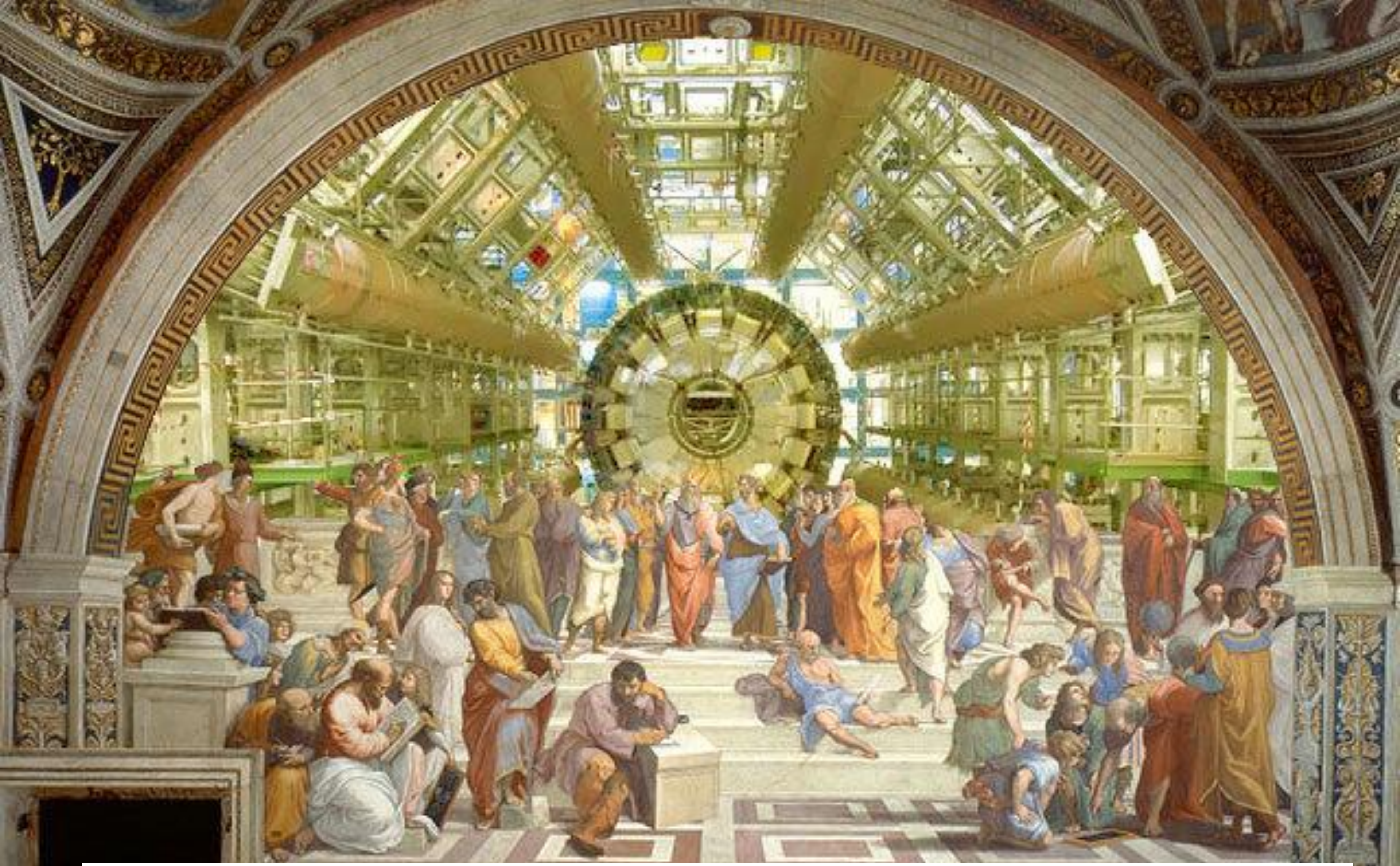


History of 20th century particle physics in one plot

Future

ATLAS Collaboration members at CERN (Bldg. 40)

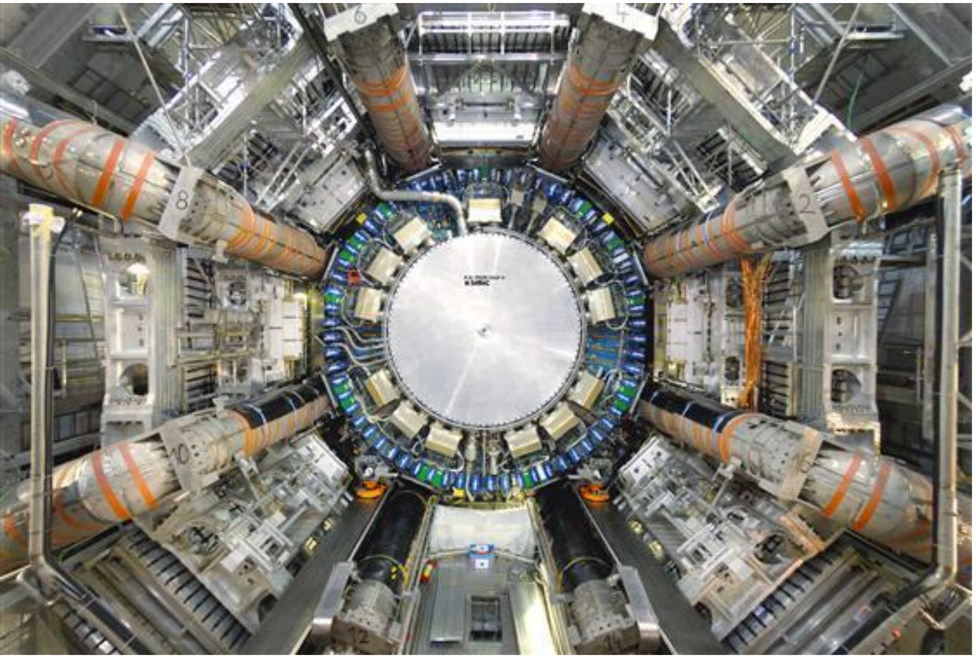
Attract and involve young scientists, PhD, Masters and Bachelor students in ATLAS



Thanks a lot !

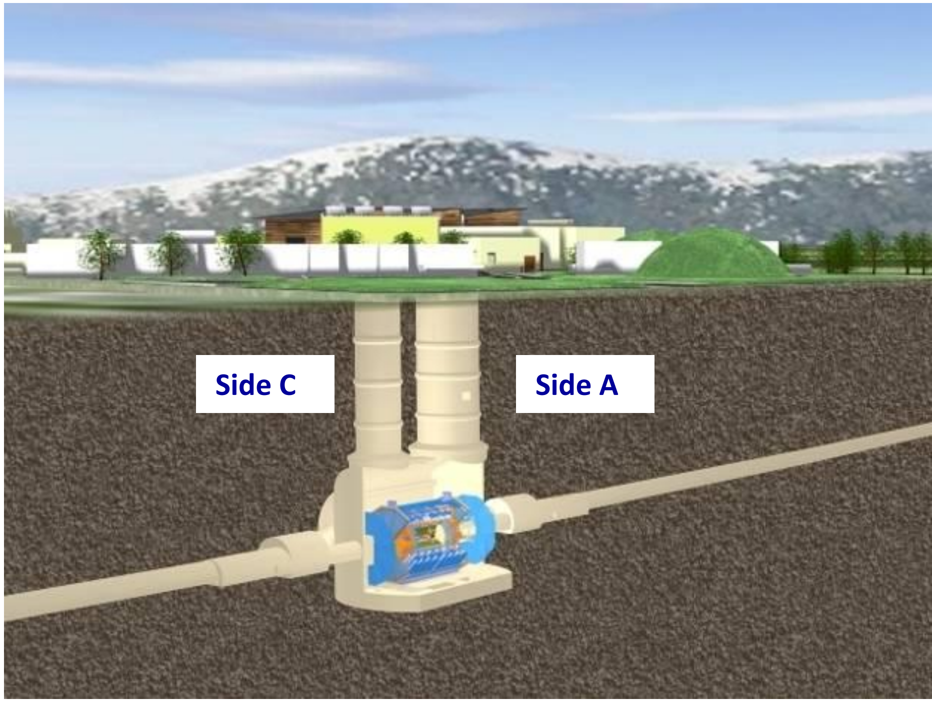
gmadlobT yuradRebisaTvis!

Back-ups

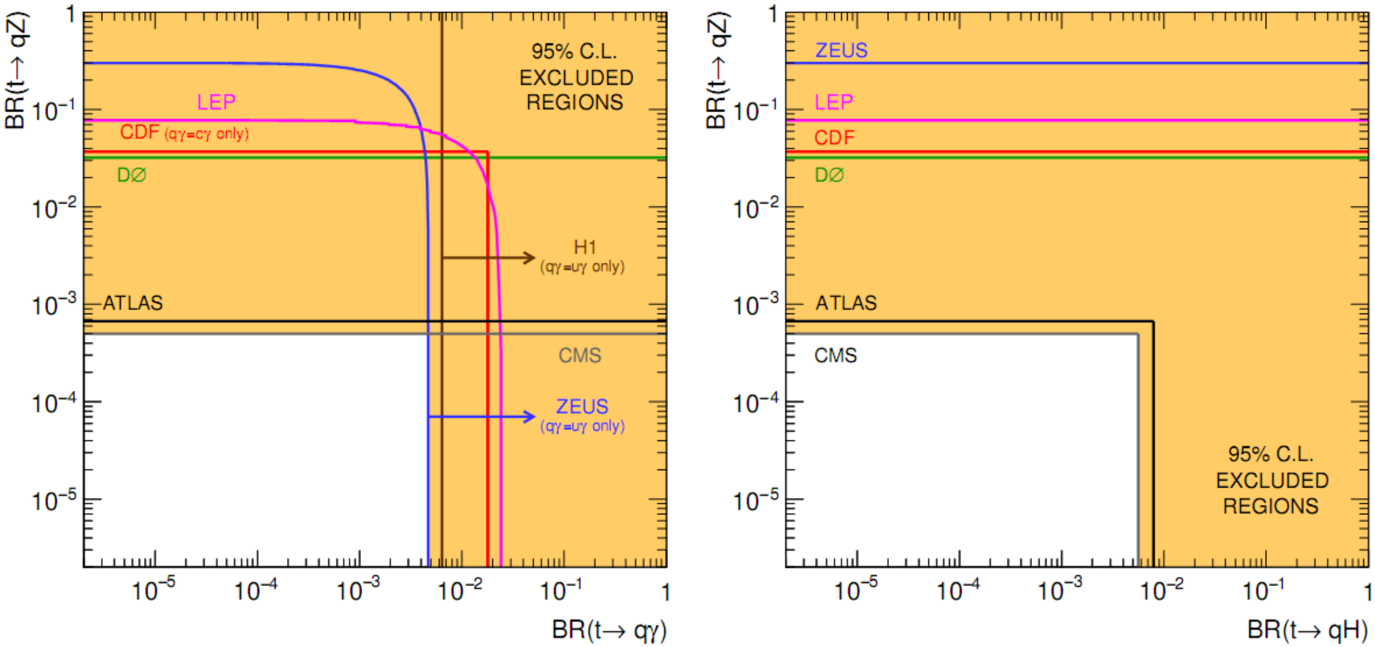


The Underground Cavern at Point-1 for the ATLAS Detector

Length	= 55 m
Width	= 32 m
Height	= 35 m



The current 95% CL observed limits on the BR(t→ qγ) vs BR(t → qZ) and BR(t → qH) vs BR(t → qZ)



(a) (b)

The current 95% CL observed limits on the (a) BR(t→ qγ) vs BR(t → qZ) and (b) BR(t → qH) vs BR(t → qZ) planes are shown. The full lines represent the results from the ATLAS, CDF, CMS, D0, H1, LEP (combined results of the ALEPH, DELPHI, L3 and OPAL Collaborations) and ZEUS collaboration. The ATLAS lines correspond to the limit on BR(t → qZ in trilepton channel.