



# International Masterclasses 2019

## Hands on particle physics

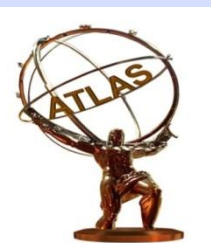
# Georgians (HEPI TSU) in the ATLAS experiment

**Tamar Djobava**

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

[Tamar.Djobava@cern.ch](mailto:Tamar.Djobava@cern.ch)

14 March, 2019, Tbilisi, Georgia



# CERN: founded in 1954: 12 European States Today: 22 Member States

~ 3700 staff or paid personnel  
~ 12300 scientific users  
Budget (2016) ~1000 MCHF

**Member States:** Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Israel, Italy, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland and United Kingdom

**Associate Member States:** India, Lithuania, Pakistan, Turkey and Ukraine

**Associate Member States in the pre-stage to Membership:**  
Cyprus, Serbia, Slovenia

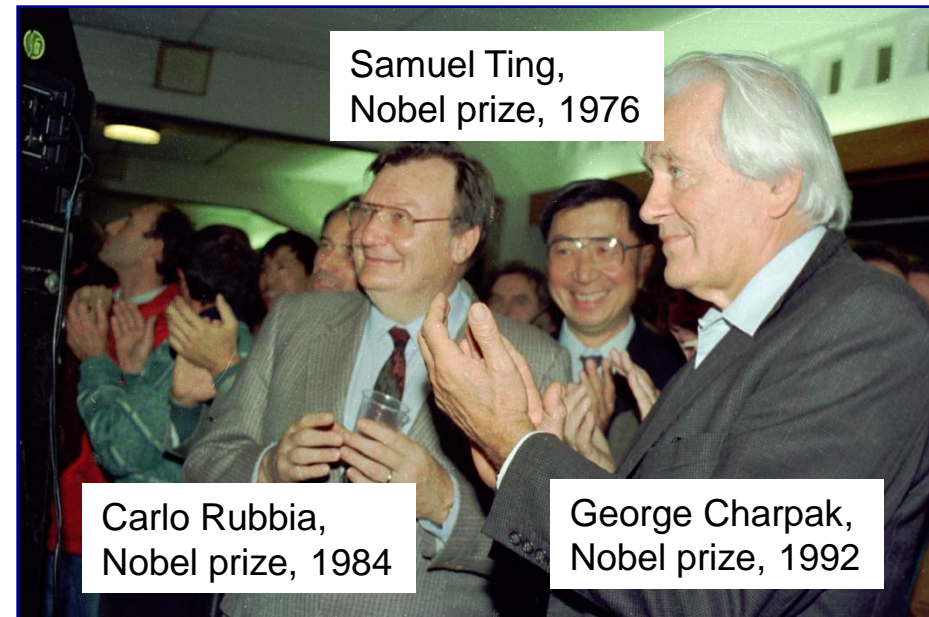
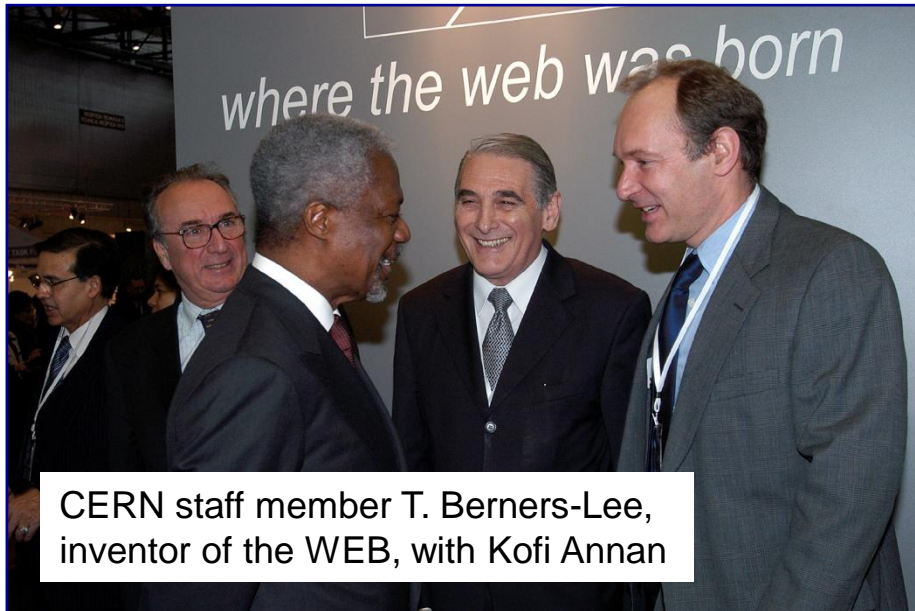
**Applications for Membership or Associate Membership:**  
Brazil, Croatia, Ireland, Russia,

**Observers to Council:** The European Union, Japan, JINR, the Russian Federation, UNESCO and the United States of America

# CERN: the largest particle physics laboratory in the world

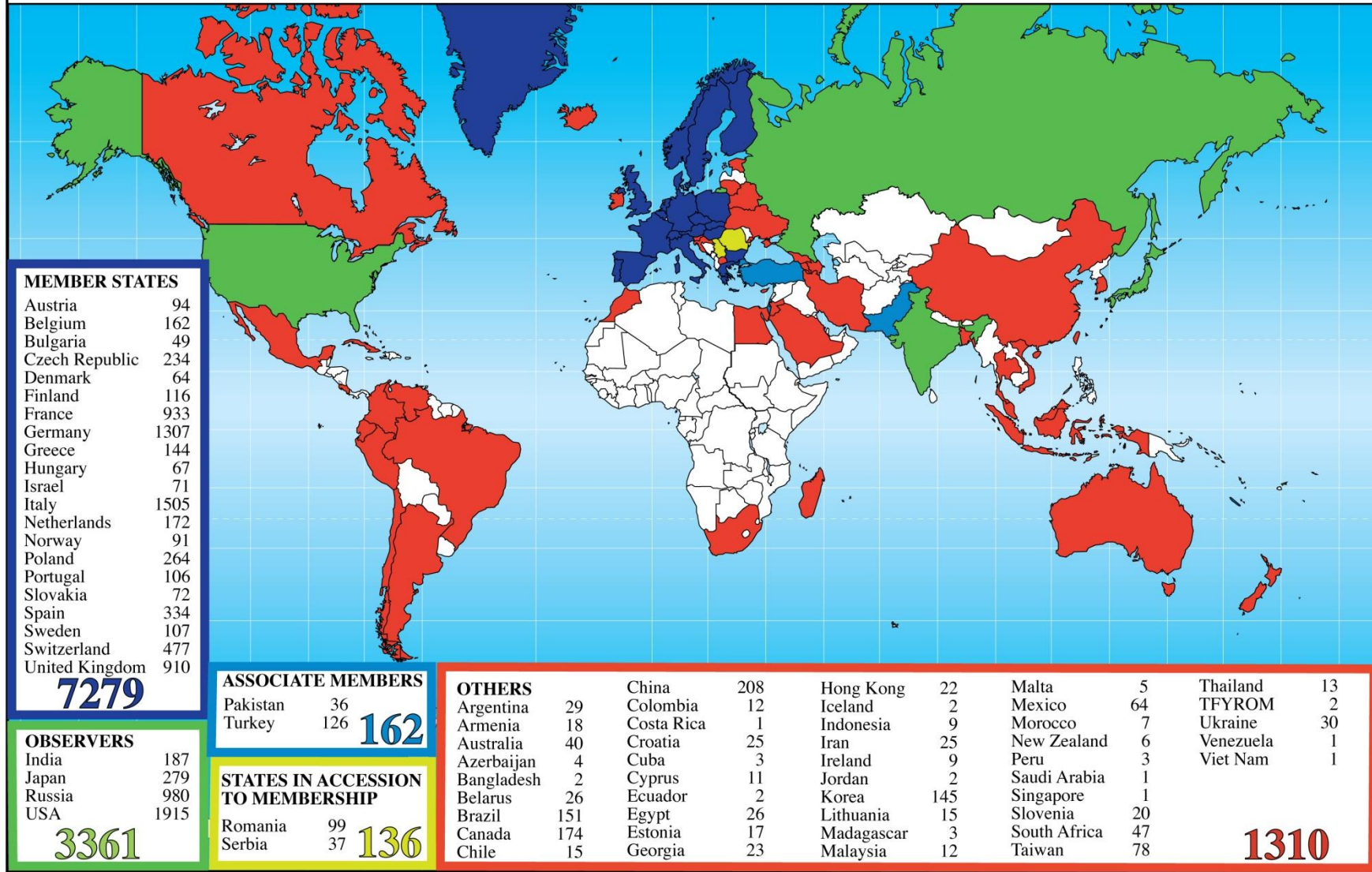
## Mission:

- ❑ science: fundamental research in particle physics
- ❑ technology and innovation → transferred to society (e.g. the World Wide Web)
- ❑ training and education
- ❑ bringing the world together: > 12000 scientists, > 110 nationalities



More than 12000 scientists from all over the world

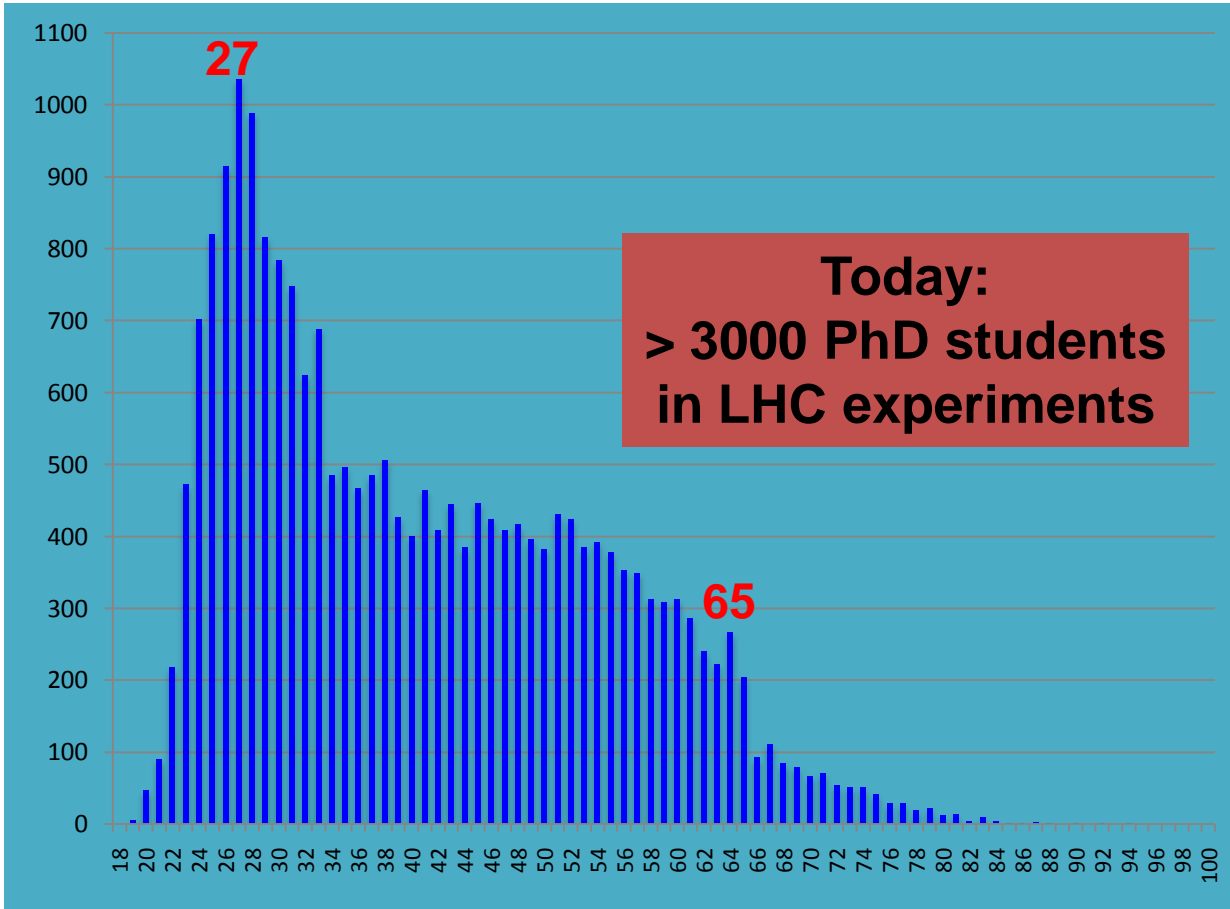
## Distribution of All CERN Users by Location of Institute on 12 January 2016



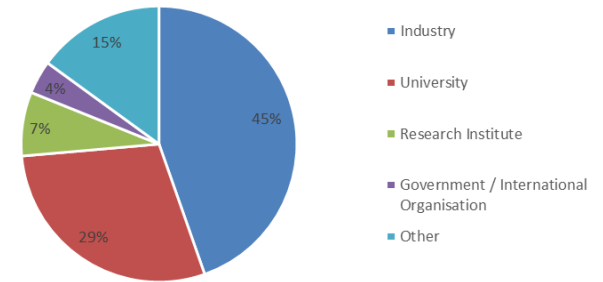


# Age Distribution of Scientists

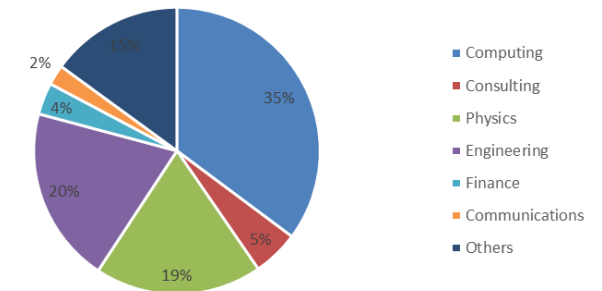
- and where they go afterwards



In which type of organization do you work at the moment?



Which domain do you work in?

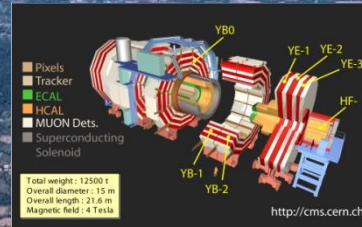


**They do not all stay: where do they go?**

# Large Hadron Collider (LHC)

**Collider is a 27 km long collider ring housed in a tunnel about 100 m underground near Geneva**

Lake of Geneva

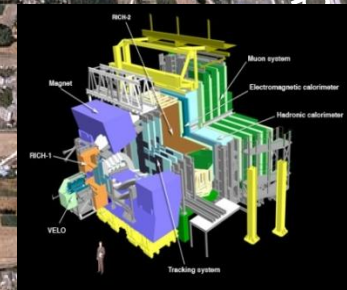


CMS

**CMS**  
 2900 Physicists  
 184 Institutions  
 38 countries  
 550 MCHF

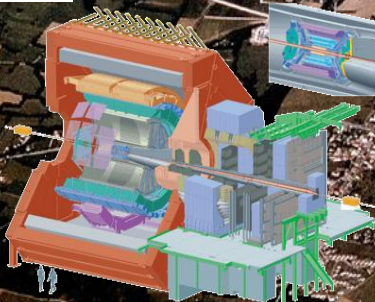
**LHCb**  
 700 Physicists  
 52 Institutions  
 15 countries  
 75 MCHF

LHCb

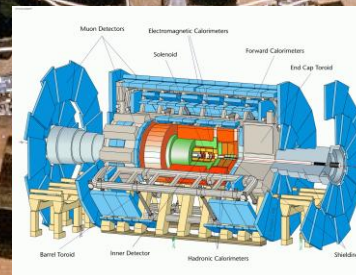


**ALICE**  
 1000 Physicists  
 105 Institutions  
 30 countries  
 150 MCHF

ALICE



ATLAS



**ATLAS**  
 3000 Physicists  
 182 Institutions  
 38 countries  
 550 MCHF

**The Large Hadron Collider Project:  
*A dream became reality...***



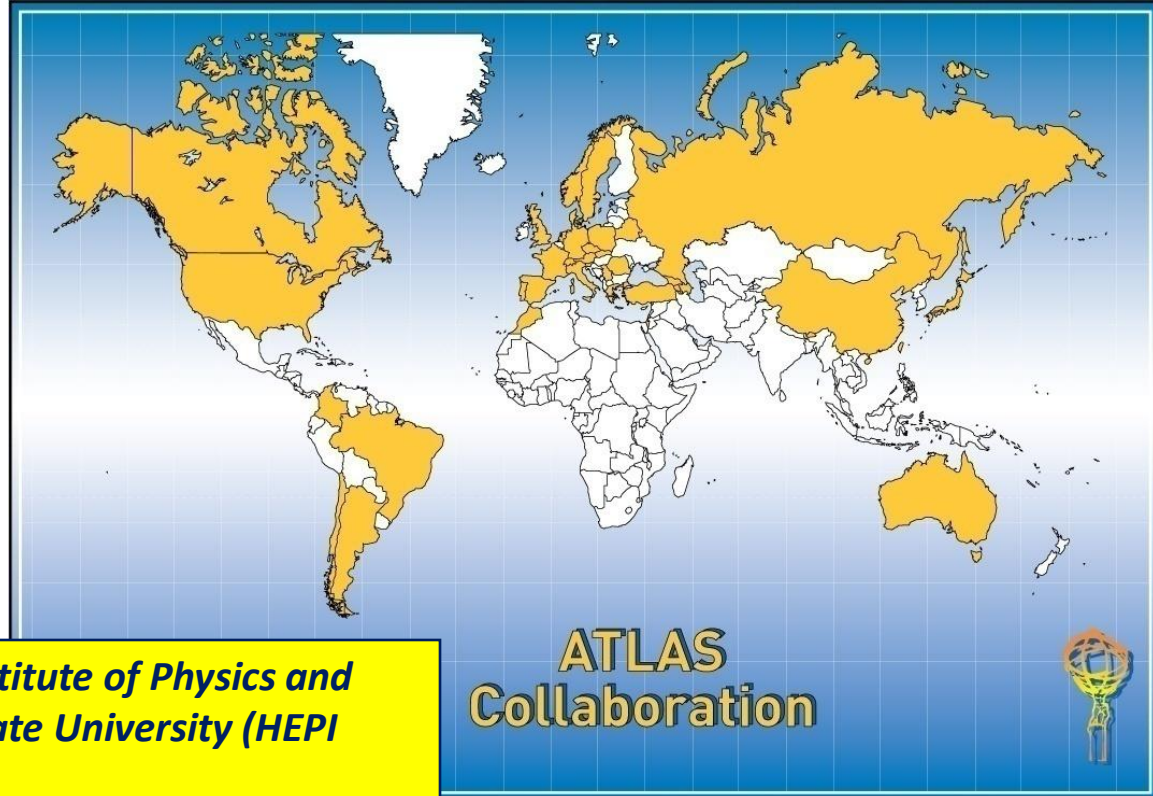


# ATLAS Collaboration

38 Countries

182 Institutions

3000 Scientific participants total  
(1200 Students)



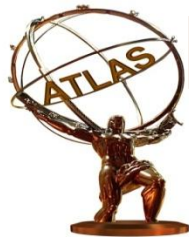
ATLAS  
Collaboration



*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 Ancey, 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**

**HEPI TSU**

**Georgian Technical**  
**University**

**Detector**  
**tasks/Physics**  
**Analysis**

**Detector**  
**tasks/Physics**  
**Analysis**

**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  $t \rightarrow Zq$  ( $q=u,c$  quarks) in ATLAS Run 2 and HL-LHC conditions
- Measurement of the differential cross-sections of prompt and non-prompt production of  $J/\psi$  and  $\psi(2S)$  in pp collisions at  $\sqrt{s}=13$  TeV
- Associated production of a top-antitop pair with a quarkonium state ( $J/\psi$ )



# Georgians in the ATLAS collaboration



## The Team Leader Dr. I.Minashvili



J.Khubua



I.Minashvili



E.Tskhadadze



T.Djobava



M.Mosidze



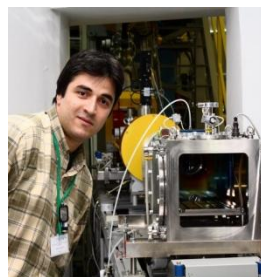
N.Mosulishvili



G.Devidze



A.Durglishvili



J.Jejelava



T. Zakareishvili



B. Chargeishvili



V.Kartvelishvili

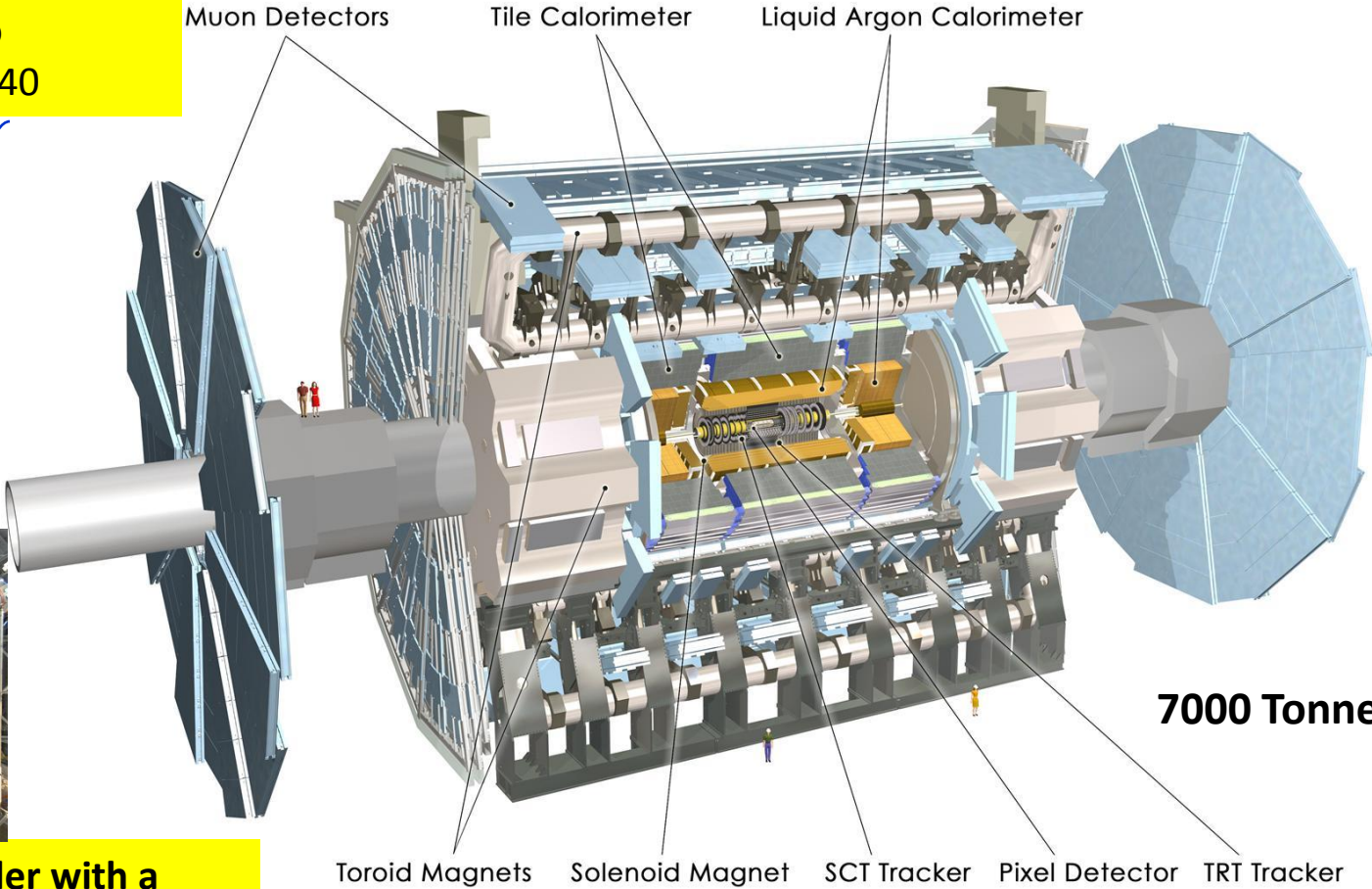
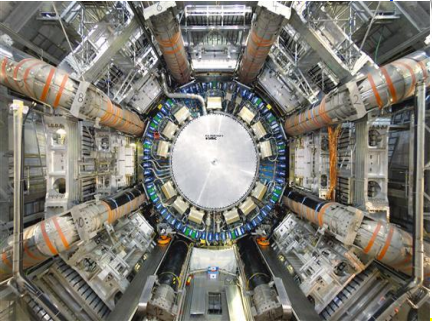
# ATLAS Detector



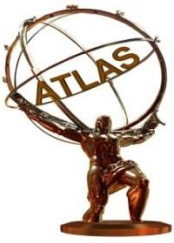
ATLAS superimposed to the 5 floors of building 40

45 m

24 m

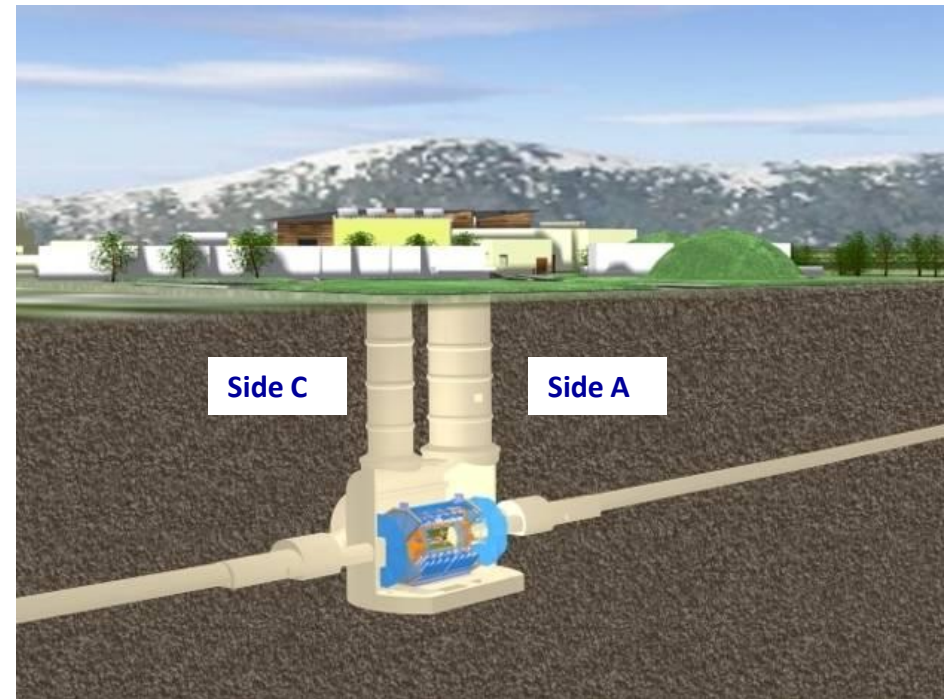
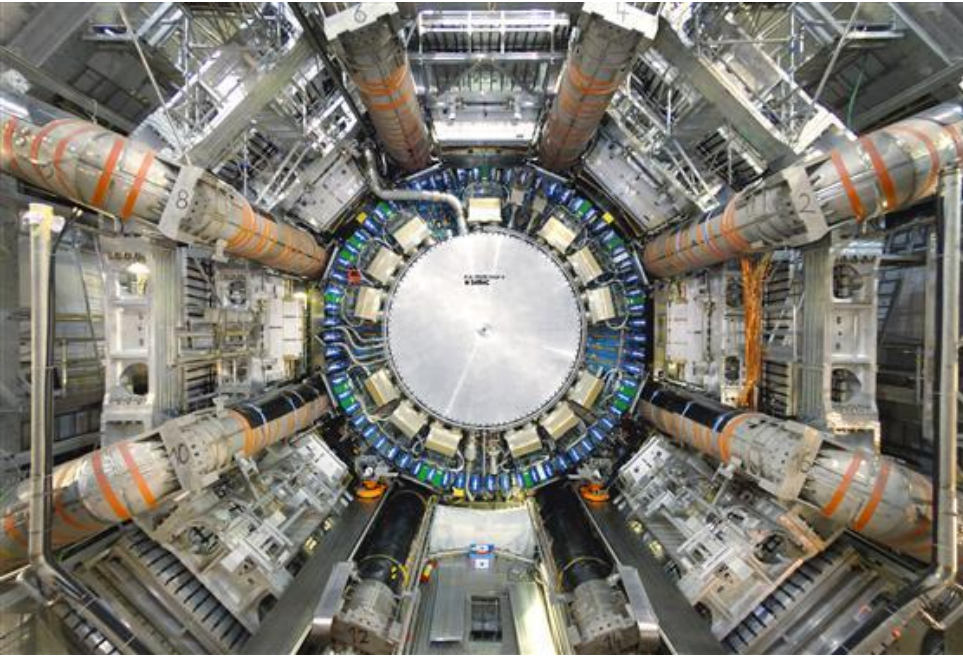


The detector is a cylinder with a total length of 45 m and a radius of 12 m and weights approximately 7000 tonnes.



## The Underground Cavern at Point-1 for the ATLAS Detector

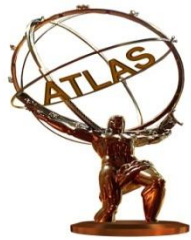
Length = 55 m  
Width = 32 m  
Height = 35 m



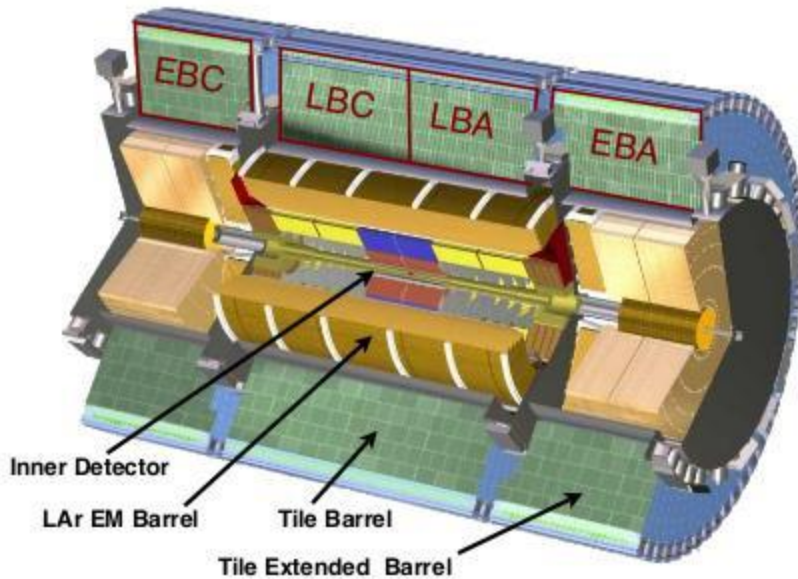


# ATLAS Hadronic Tile Calorimeter





# ATLAS Tile Calorimeter



- Diameter: 8.5 m
- Length= 12 m
- Weight: 2900 T
- Total thickness of  $7.4\lambda_{\text{int}}$  at  $\eta=0$

## Design goals:

- large dynamic range (detect low signal from muons up to high signals from jets at TeV scale)
- energy linearity  $\sim 2\%$  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  $\rightarrow$  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.Mosulishvili**)

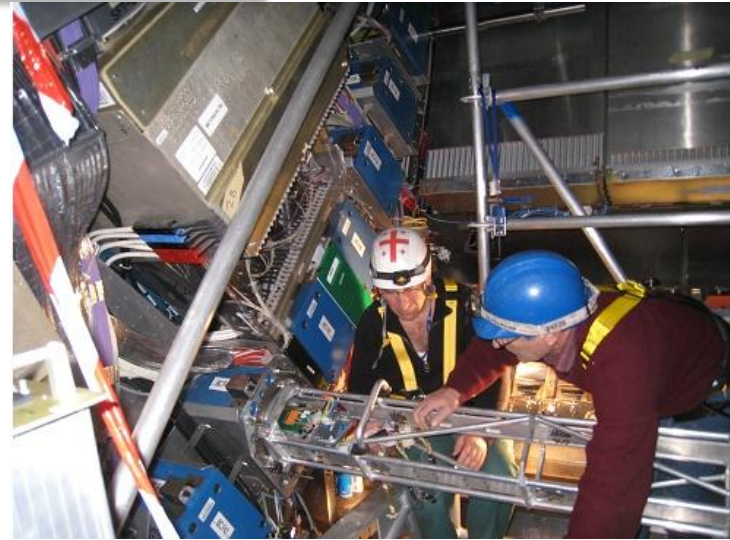
- energy scale and simulation
- maintenance and consolidation (**LS1..**)
- operation (shifts, data quality)
- online and DAQ
- Upgrade
- Test beam data analysis



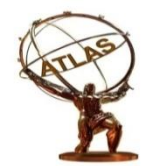
**J.Khubua**



**I.Minashvili**



**N.Mosulishvili**

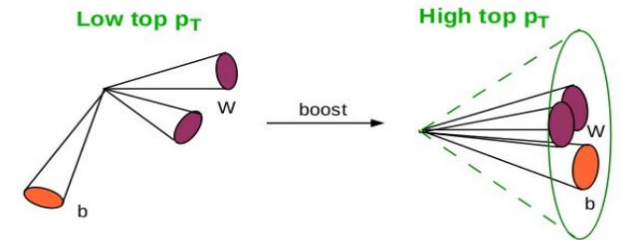


# High Granularity TileCal study

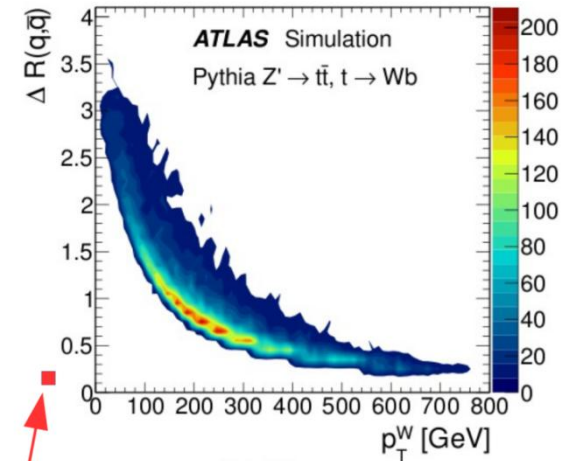
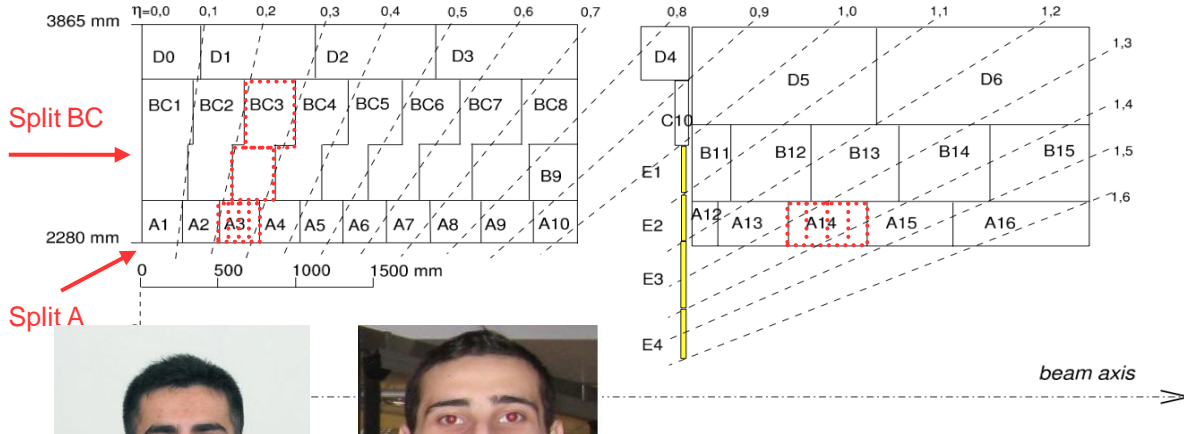


## TileCal phase 2 upgrade geometry

- Improve granularity using multianode PMTs (8x8 channel matrix)
  - Split BC cells (x2)  $\rightarrow$  3  $\rightarrow$  4 longitudinal layers in LB
  - Split A cells (x4)  $\rightarrow$  eta granularity = 0.1  $\rightarrow$  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  $\phi \times \eta$
- 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



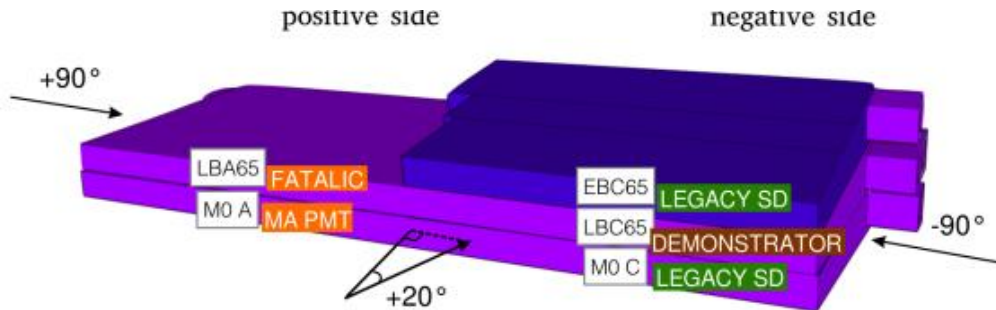
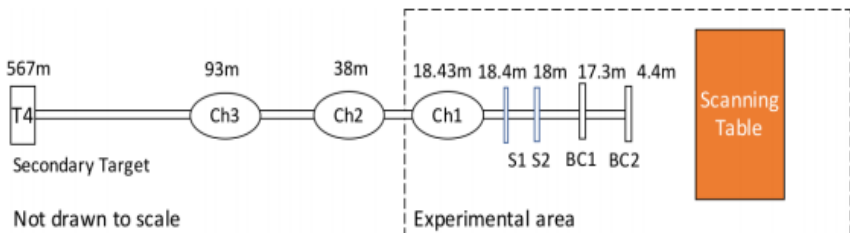


# Tile Calorimeter Demonstrator Test Beam data -2015-2017

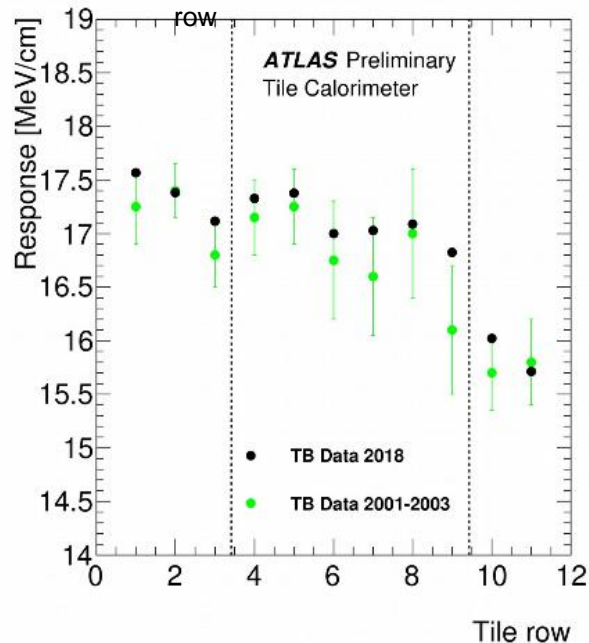




# Tile Calorimeter Demonstrator Test Beam data analysis – Muon data 2018



Muon results: E vs Tile



The signal per unit path length produced by  $-90^\circ$  muons incident on individual tile-row's center.

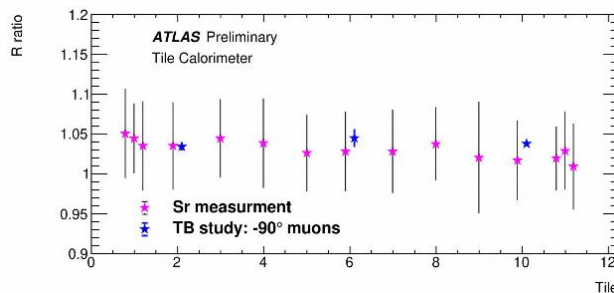
After Cs equalization is performed, the correction for the cell dimension in the reconstruction of the energy ( $C_\mu$ ) is obtained using the response of 300 GeV muons hitting at  $-90^\circ$  in the middle of the cells tile rows.

The Determination of  $C_\mu$  :

Layer	Corr. Factor (TB 2001-2003)	Corr. Factor (TB 2018)
A	1.000	1.000
BC	$1.025 \pm 0.002$	$1.014 \pm 0.008$
D	$1.088 \pm 0.005$	$1.094 \pm 0.010$



T. Zakareishvili



R ratio - the ratio of the central region average response over the full region average response of the tile is tile size independent.

- Violet stars: Sr measurements of individual tiles.
- Blue stars: is new measurements at the test beam, average behavior of many tiles in a module.
- Error bars: RMS values.



# Conferences and workshops



1. 2017, 24-27 January, Barcelona, Spain, 5<sup>th</sup> 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, 6<sup>th</sup> Beam Telescopes and Test Beams Workshop 2018  
“**Studies of the ATLAS hadronic Calorimeter response to different particles at Test Beams**”, T. Zakareishvili; Session: **Analysis, Scintillating Fibres & Calorimeters**.  
<https://indico.desy.de/indico/event/18050/session/8/contribution/34/material/slides/0.pdf>
3. 2019, 14-18 January, Geneva, CERN, Switzerland, 7<sup>th</sup> Beam Telescopes and Test Beams Workshop 2019  
**Studies of the response of the ATLAS Tile Calorimeter to beams of particles at the CERN test beams facility**  
T. Zakareishvili; Session: **Analysis - Fibres & Calorimeters**.  
<https://indico.cern.ch/event/731649/sessions/295254/#20190117>

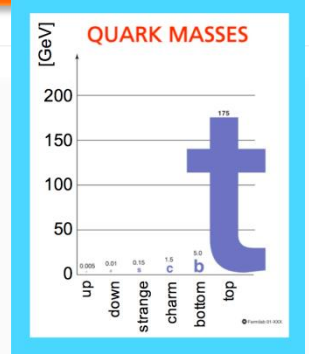




# Motivations for Top Quark Physics Studies

The top quark was first observed in 1995 at the Fermilab pp̄ Tevatron collider by CDF and DO experiments:

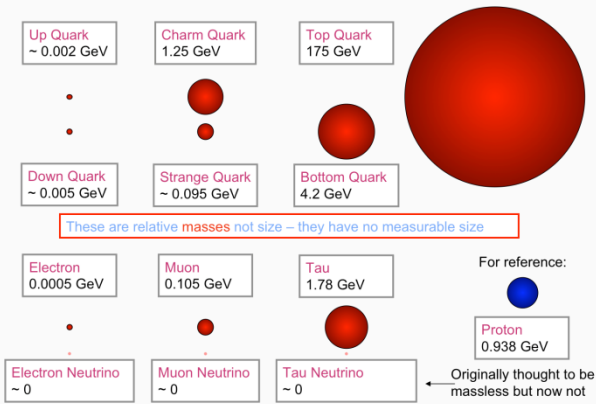
- $M_t = 174.3 \pm 3.2$  (stat)  $\pm 4.0$  (syst)
- $\sigma_{t\bar{t}} = (\text{CDF } M_t = 175 \text{ GeV}) = 6.5 \pm_{1.4}^{1.7} \text{ pb}$
- $\sigma_{t\bar{t}} = (\text{Do } M_t = 172 \text{ GeV}) = 5.9 \pm 1.7 \text{ pb}$
- $Q_{em}^e = 2/3 |e|$ ; Weak isospin partner of b quark:
- $T_3 = 1/2$ ; Color triplet, spin 1/2;



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**.

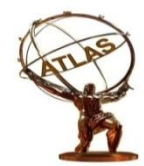
Large value of top mass and short lifetime ( $\tau_t \sim 5 \times 10^{-25}$  sec) make top quark unique:

- 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	$\tilde{R}$ SUSY	RS	Mirror Model
BR( $t \rightarrow qZ$ ):	$10^{-14}$	$10^{-4}$	$10^{-6}$	$10^{-10}$	$10^{-7}$	$10^{-6}$	$10^{-5}$	$10^{-6}$

A search for top quark Flavor Changing Neutral Current decay in  $t\bar{t}$  production:

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

## Signal sample

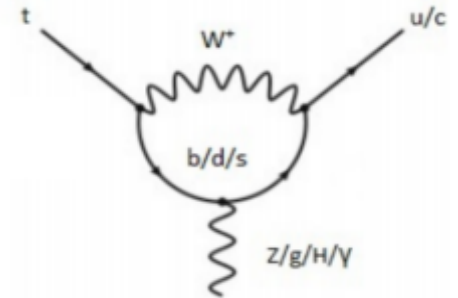
- Separate samples for  $t \rightarrow uZ$  and  $t \rightarrow cZ$
- $t\bar{t}$  production and decay processes are done by MadGraph5\_aMC@NLO at NLO in QCD
- Top-quark FCNC decay is done by TopFCNC model: <https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/TopPropertiesFCNCMCRunII>
- Parton shower 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)

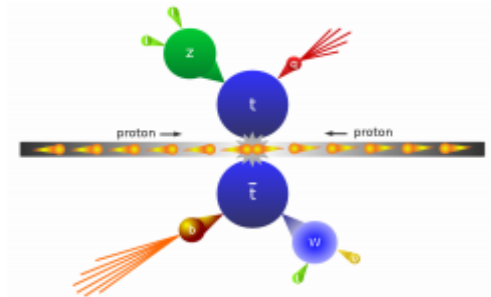
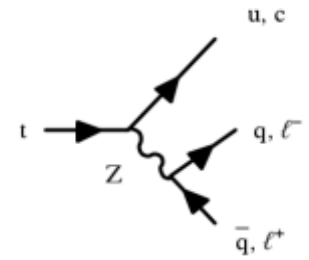
SM:

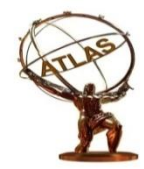


Strongly suppressed by GIM mechanism in SM

→ Powerful probe for new physics

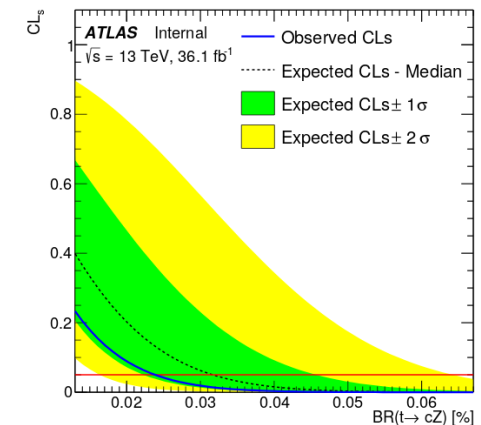
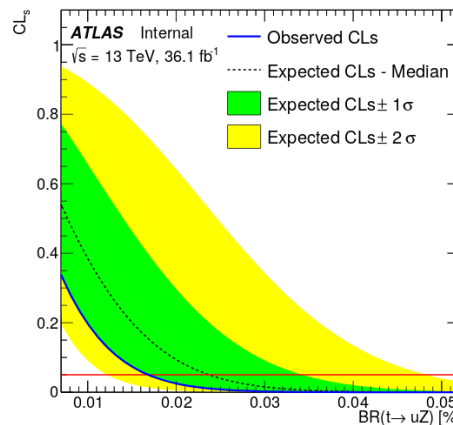
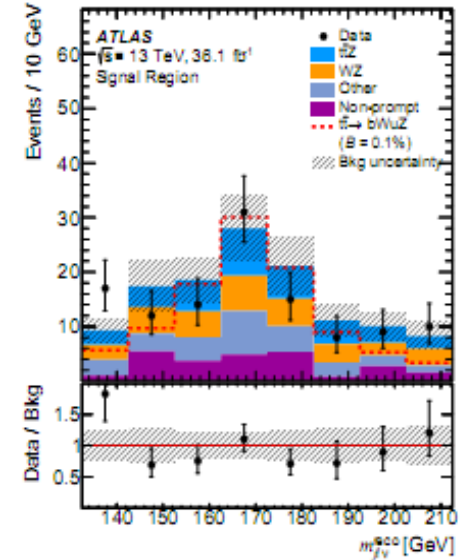
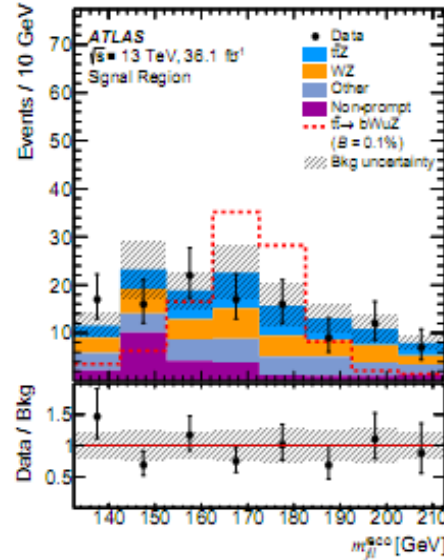
BSM:



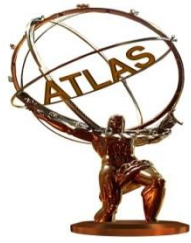


# Results of $t \rightarrow qZ$ FCNC search

- 36 fb<sup>-1</sup> of 13 TeV data ( $pp$  collisions) analysed (2015+2016 data)
- 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  $t \rightarrow uZ$  and  $t \rightarrow cZ$



	BR( $t \rightarrow uZ$ )	BR( $t \rightarrow cZ$ )
Observed	$1.7 \times 10^{-4}$	$2.4 \times 10^{-4}$
Expected	$2.4 \times 10^{-4}$	$3.2 \times 10^{-4}$
Expected $-1\sigma$	$1.7 \times 10^{-4}$	$2.2 \times 10^{-4}$
Expected $+1\sigma$	$3.4 \times 10^{-4}$	$4.6 \times 10^{-4}$



# Conferences and workshops



1. 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/>



2. The 2018 European School of High Energy Physics, Maratea, Italy, 20 June-3 July, 2018  
“Search for flavour-changing neutral current top-quark decays  $t \rightarrow qZ$  in proton-proton collisions at  $\sqrt{s}=13$  TeV with the ATLAS Detector”.  
A.Durglishvili, Poster session;  
<http://physicschool.web.cern.ch/PhysicSchool/ESHEP/ESHEP2018/>

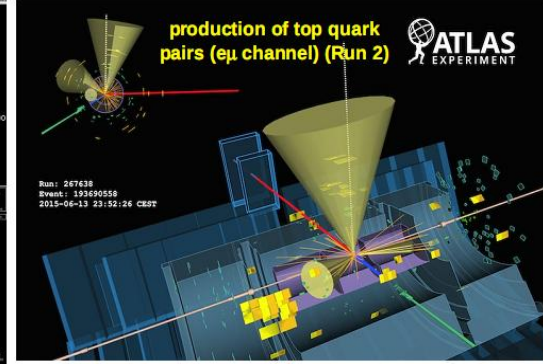
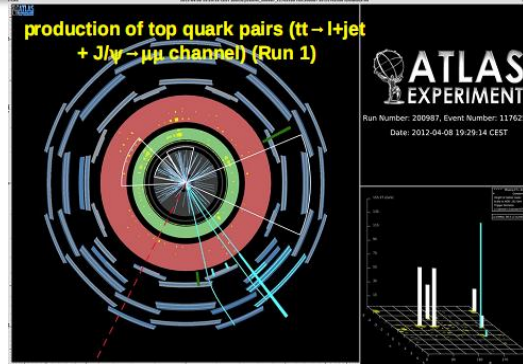


# J/ψ production with top pair



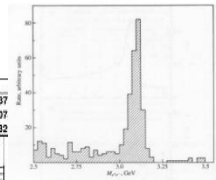
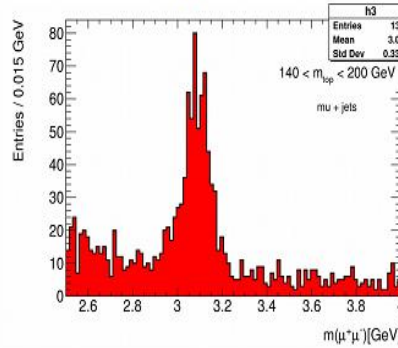
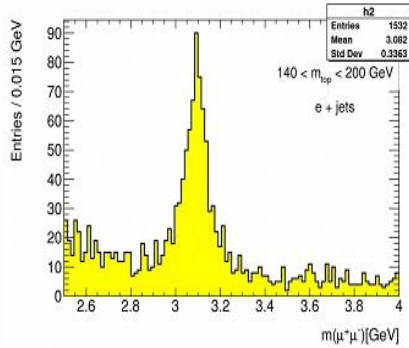
**Analysis Team:**  
**V.Kartvelishvili, J.Walder**  
 (Lancaster University  
 (GB);  
**B.Chargeishvili, T.Djobava,**  
**T. Zakareishvili** (HEPI TSU)

**Prof.V.Kartvelishvili**



**The Beginning:  $J/\psi$**

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



← **Discovery 1: Ting's group**

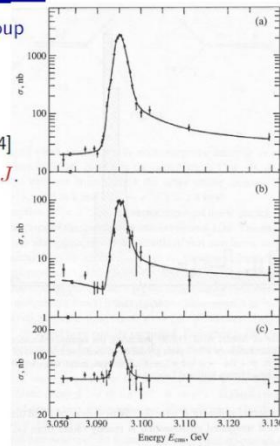
$$pN \rightarrow e^+e^- X$$

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

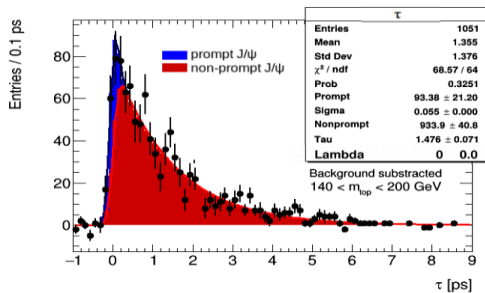


Found a peak in all these three cross-sections, at the c.m.s. energy 3.1 GeV; called it  $\psi$ .

11/1/17

## Lifetime of $J/\psi$ candidates in top events

$|\Delta\eta|$  and  $|\sin(\Delta\phi)|$  cuts applied.

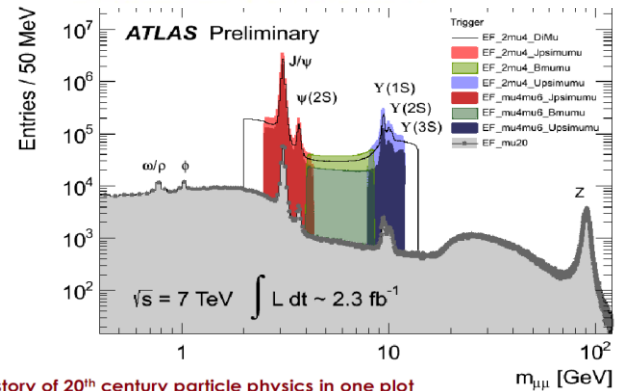


Fit function:  
 $pdf = \{ \epsilon * \delta(\tau) + (1-\epsilon) * \exp(\tau) \} \otimes \text{Resolution}$

Resolution =  $\lambda * g(\sigma) + (1-\lambda) * g(2 * \sigma)$

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

Fit shows that we have  $93 \pm 21$  prompt  $J/\psi$  - s!



History of 20<sup>th</sup> century particle physics in one plot

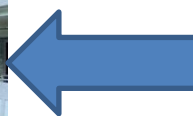




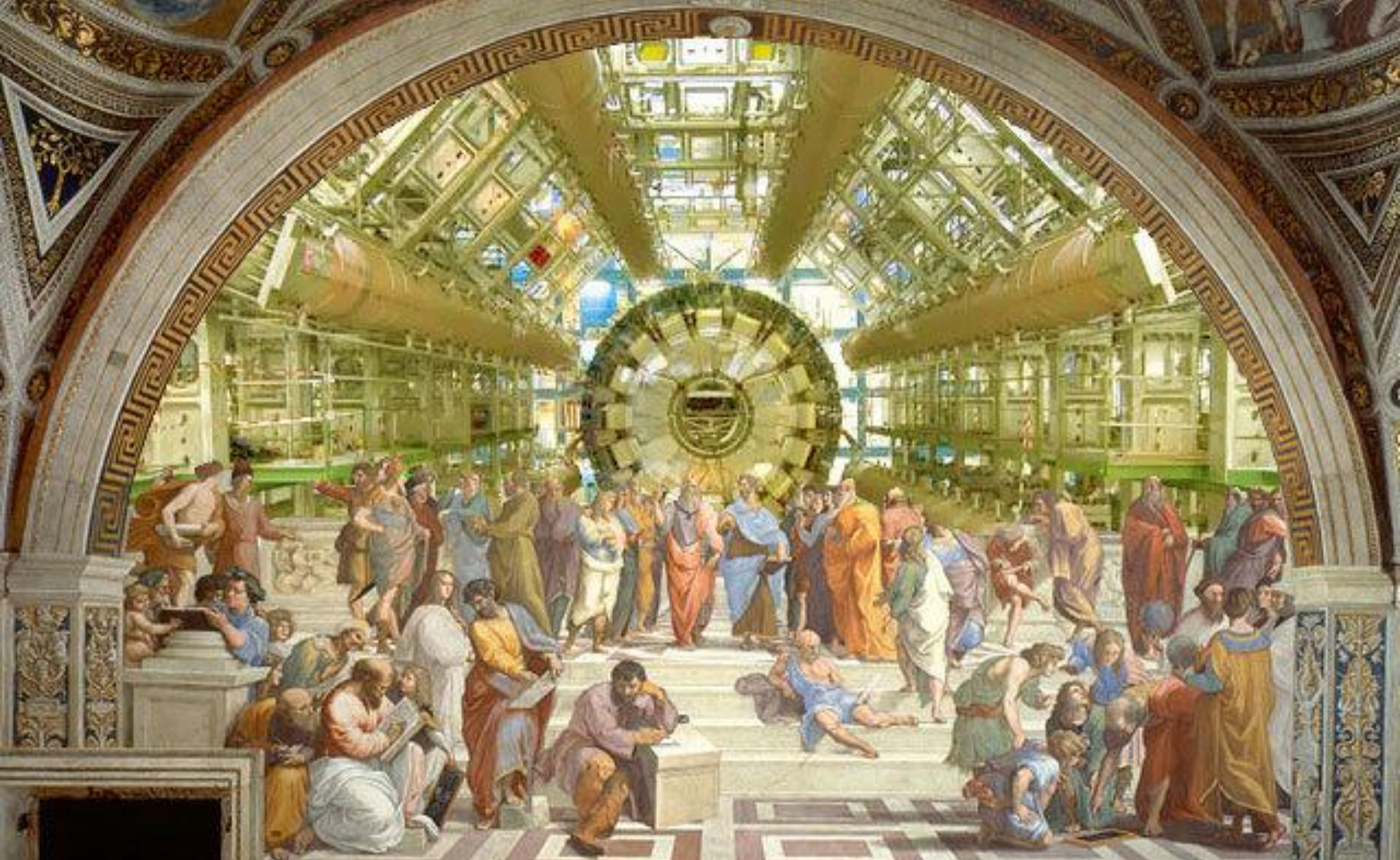
# Future



**ATLAS Collaboration members at CERN (Bldg. 40)**



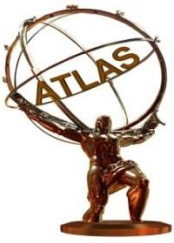
**Attract and involve young scientists, PhD, Masters and Bachelor students in ATLAS**



**Thanks a lot !**

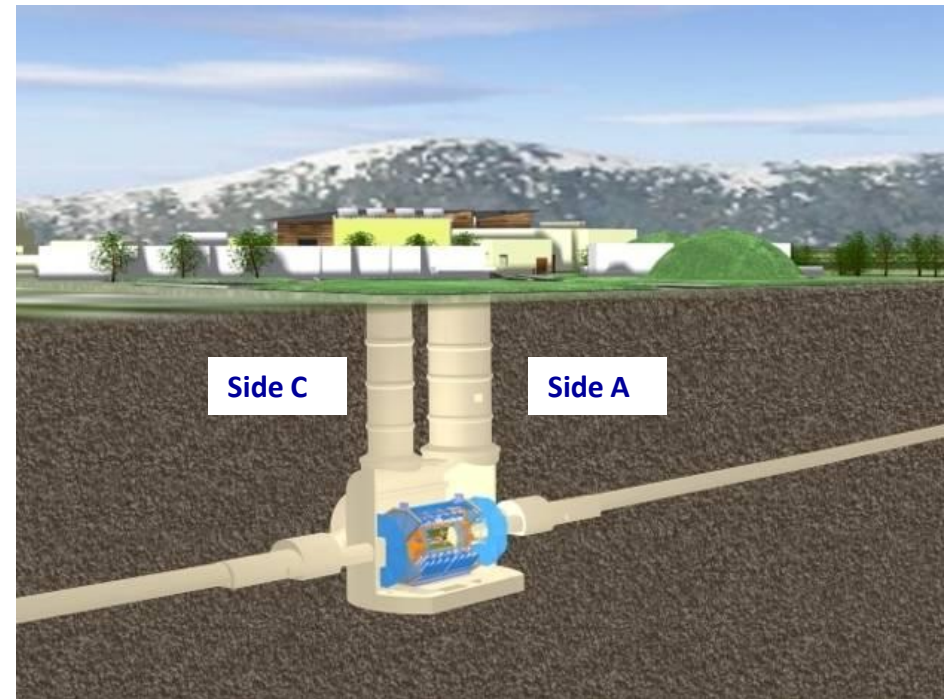
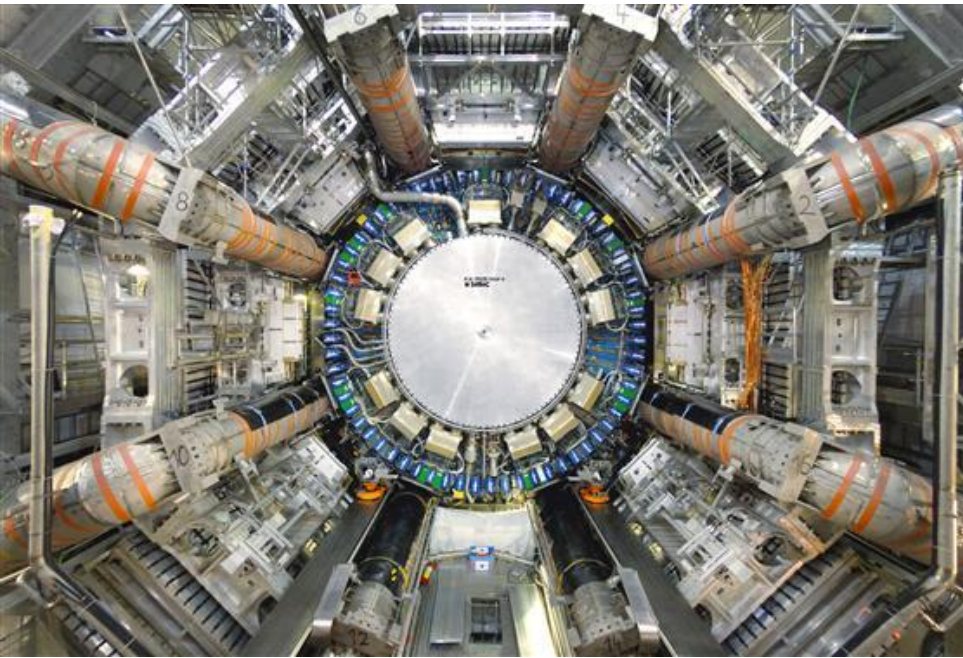
**გმადლობთ ყურადღებისათვის!**

# Back-ups



## The Underground Cavern at Point-1 for the ATLAS Detector

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



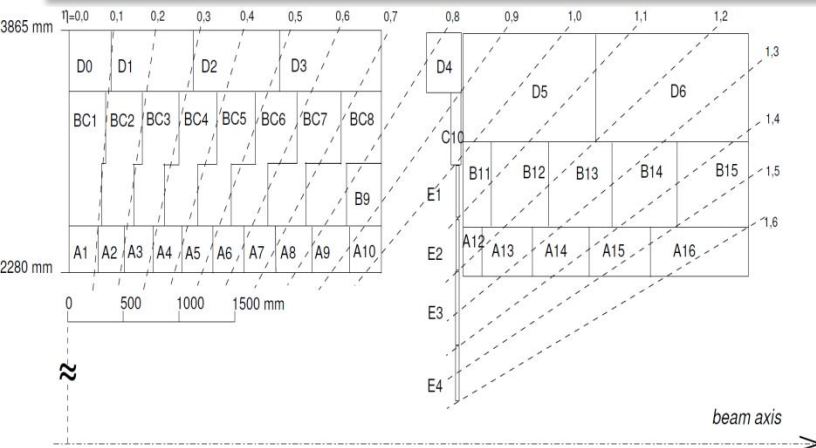
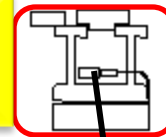


# ATLAS Tile Calorimeter

## Principle of TileCal:

Measure light produced by charged particles in plastic scintillator.  
 scint. light from tiles collected by WLS fibers and delivered to photomultipliers (PMTs)

readout electronics, PMTs are housed here



scintillator tile

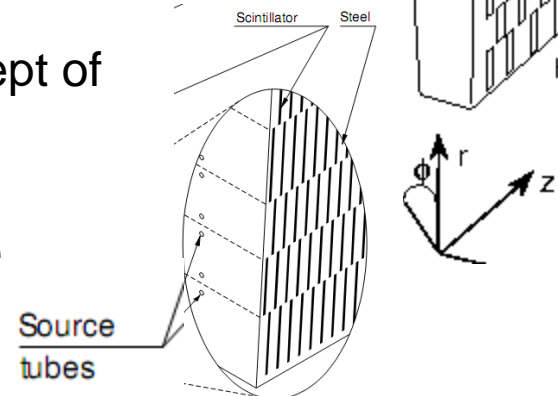
WLS fibers

PMT

Double readout

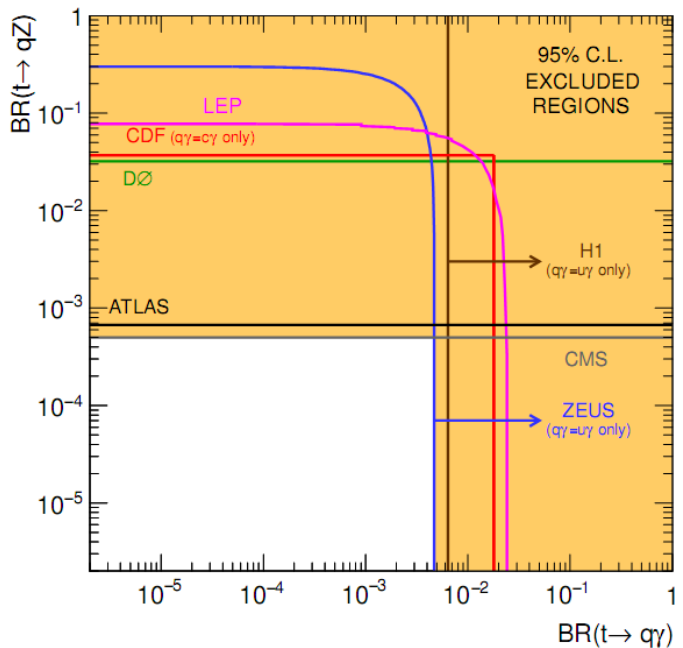
Hadrons

- Tile readout is grouped into projective geometry cells. each cell readout by 2 PMTs except of special cells
- 3 longitudinal layers
- Granularity  $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$  ( $0.2 \times 0.1$  in 3rd layer)

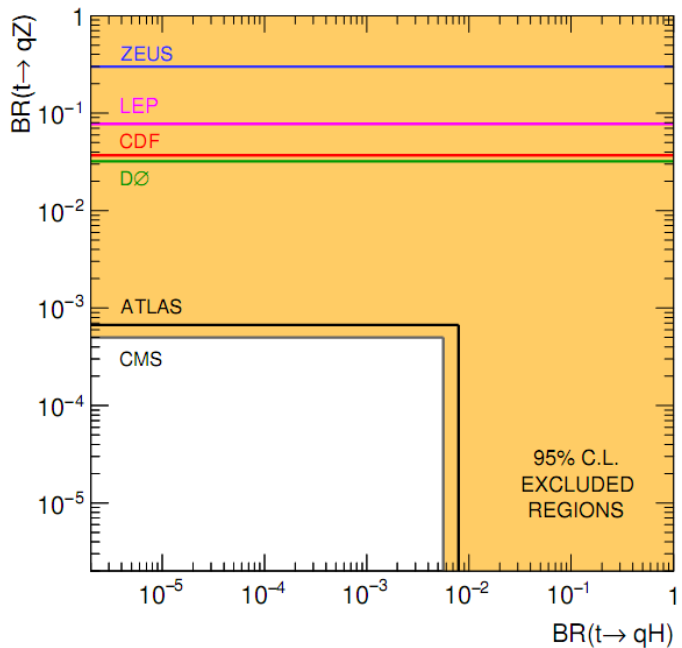




**The current 95% CL observed limits on the  $BR(t \rightarrow q\gamma)$  vs  $BR(t \rightarrow qZ)$  and  $BR(t \rightarrow qH)$  vs  $BR(t \rightarrow qZ)$**



(a)



(b)

The current 95% CL observed limits on the (a)  $BR(t \rightarrow q\gamma)$  vs  $BR(t \rightarrow qZ)$  and (b)  $BR(t \rightarrow qH)$  vs  $BR(t \rightarrow qZ)$  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  $BR(t \rightarrow qZ)$  in trilepton channel.