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

26 March, 2019, Tbilisi, Georgia

CERN: founded in 1954: 12 European States
Today: 23 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, Net herlands, Norway, Poland, Portugal, Romania, Serbia, 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

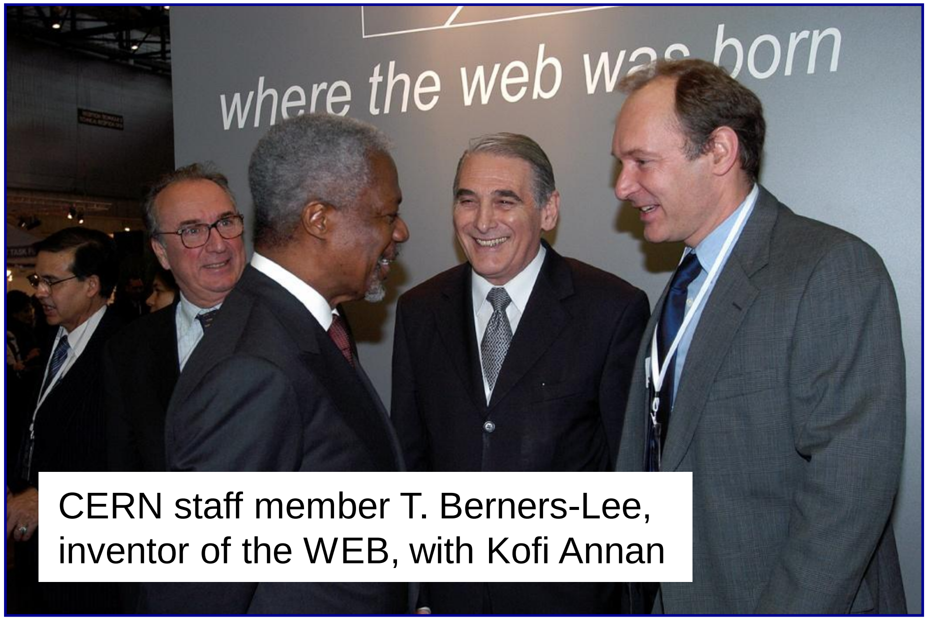
Applications for Membership or Associate Membership:
Brazil, Croatia, Ireland, Russia,

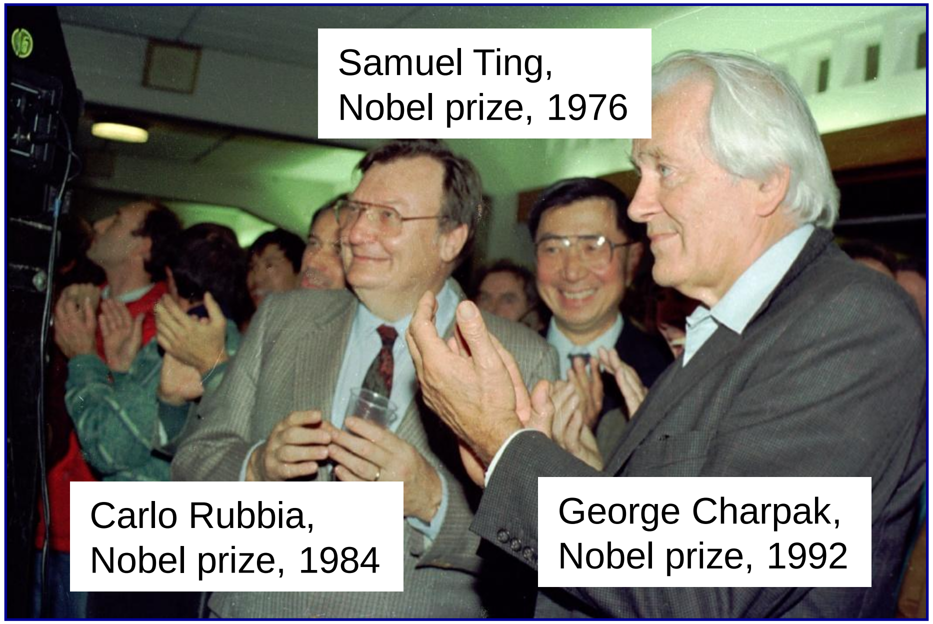
Observers to Council: The European Union, Japan, JINR, the Russian Federation, UNESCO and the United States of America

CERN: the largest particle physics laboratory in the world

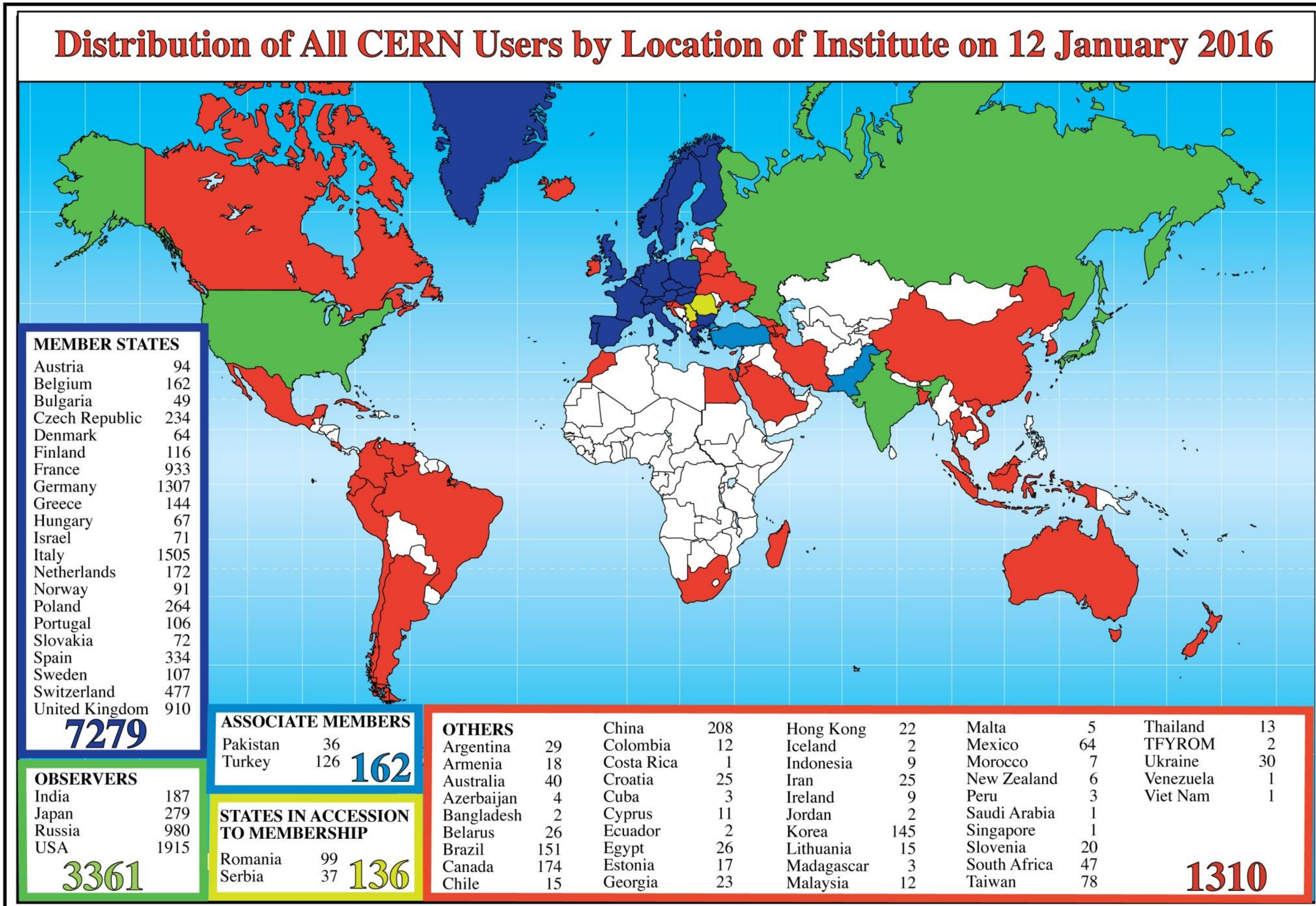
Mission:

- 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



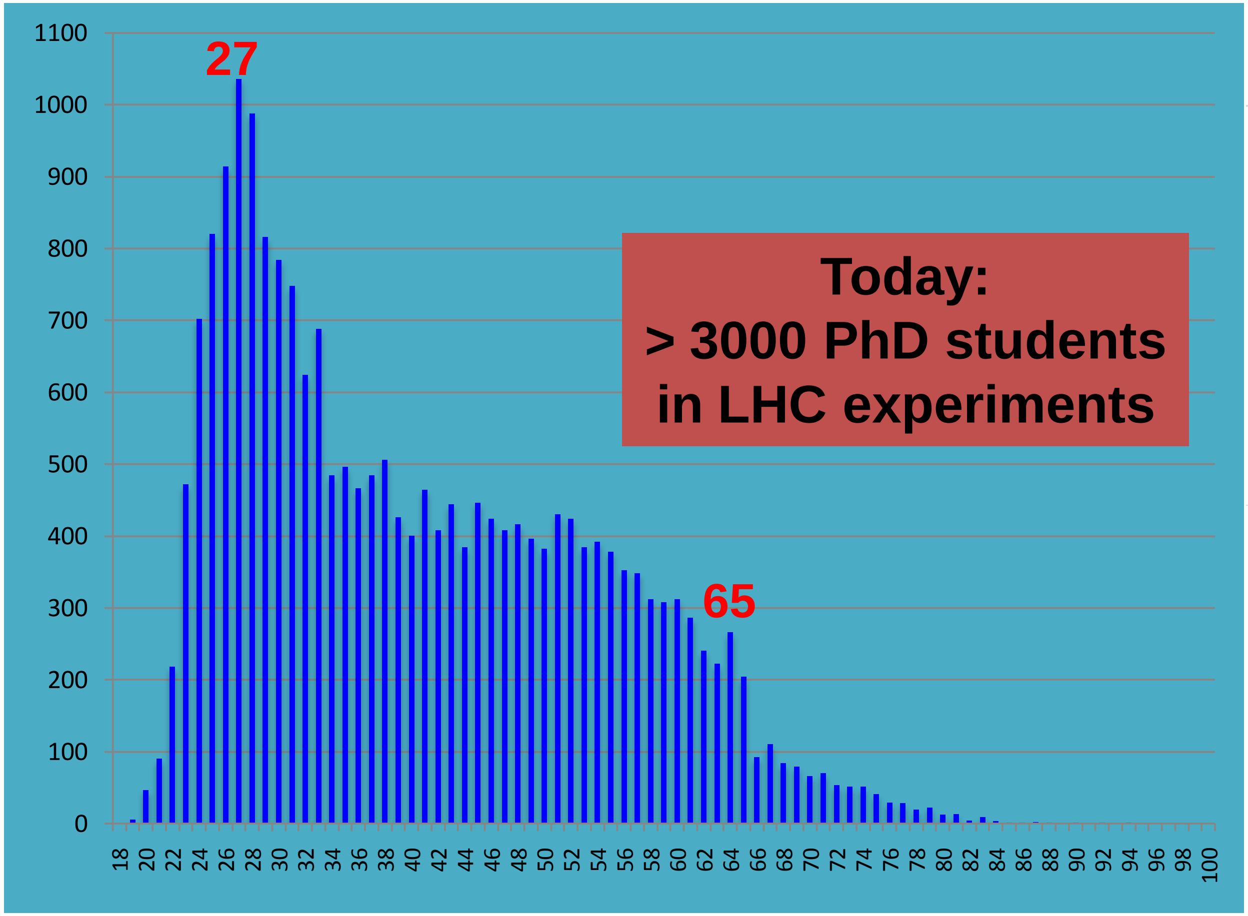


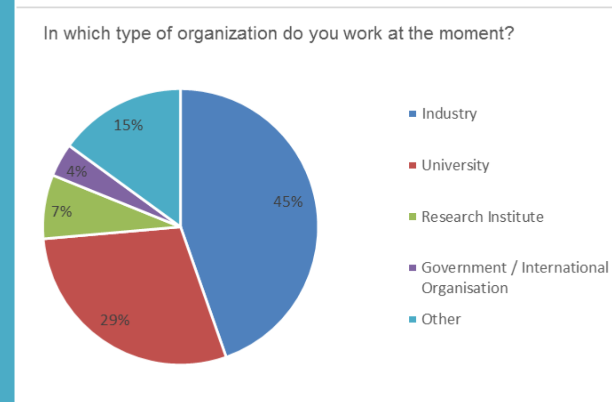
More than 12000 scientists from all over the world

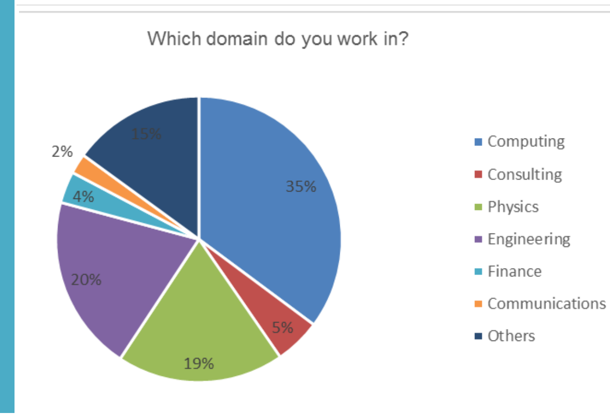


Age Distribution of Scientists

- and where they go afterwards







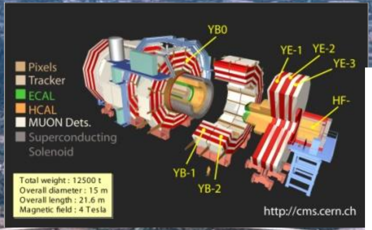
They do not all stay: where do they go?

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

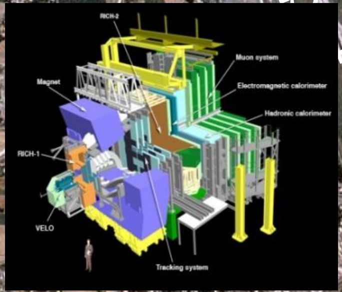
CMS



CMS
2900 Physicists
184 Institutions
38 countries
550 MCHF

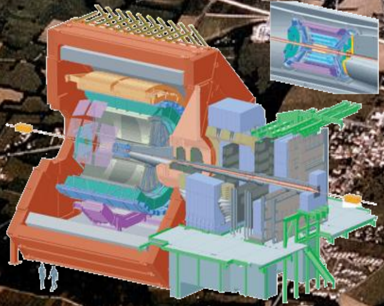
LHCb
700 Physicists
52 Institutions
15 countries
75 MCHF

LHCb

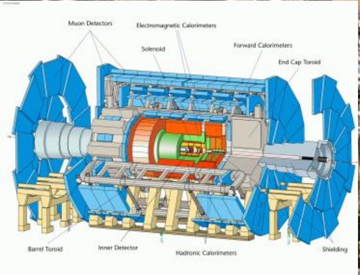


ALICE
1000 Physicists
105 Institutions
30 countries
150 MCHF

ALICE



ATLAS

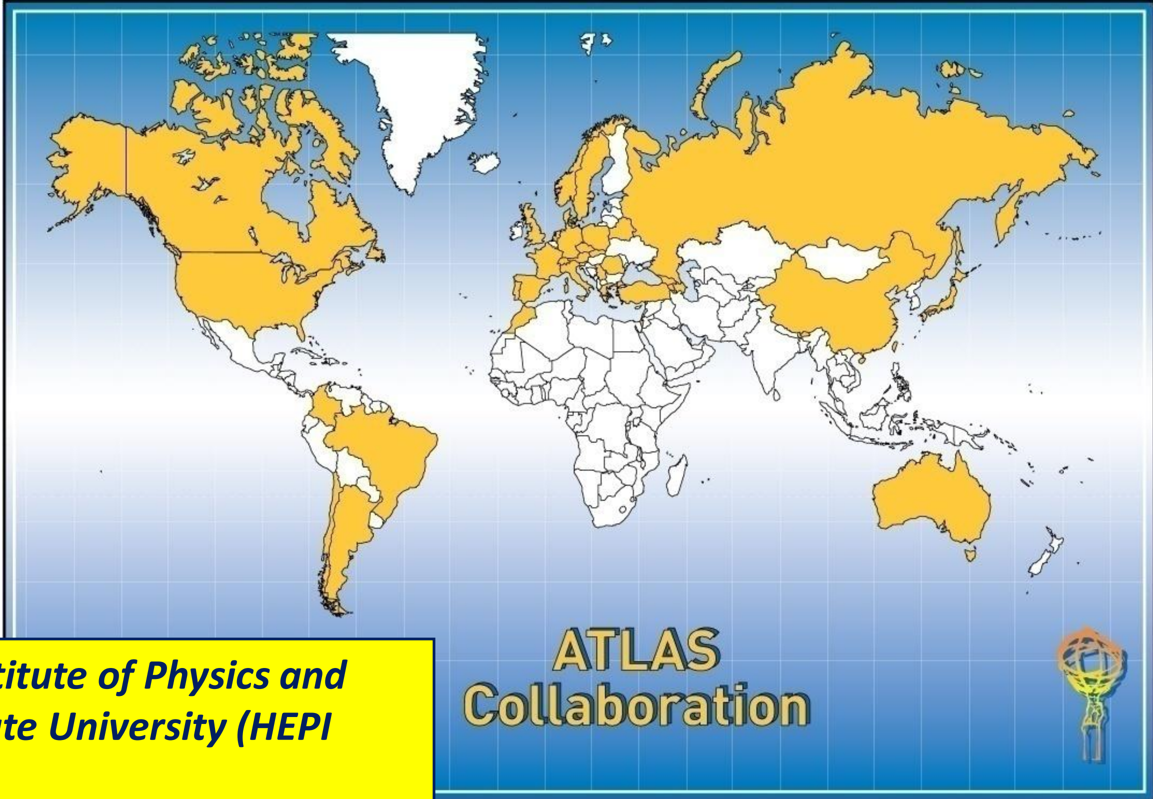


ATLAS
3000 Physicists
182 Institutions
38 countries
550 MCHF

The Large Hadron Collider Project:
A dream became reality…

ATLAS Collaboration

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



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

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

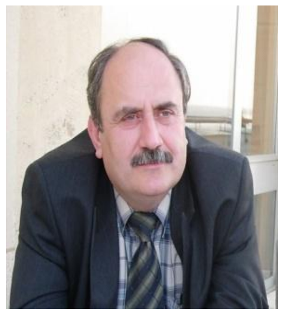
- Search for Flavor Changing Neutral Current (FCNC) top quark decays $t \rightarrow Zq$ (q=u,c quarks) in ATLAS Run 2 and HL-LHC conditions
- Measurement of the differential cross-sections of prompt and non-prompt production of J/ψ and ψ(2S) in pp collisions at $\sqrt{s}$=13 TeV
- Associated production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

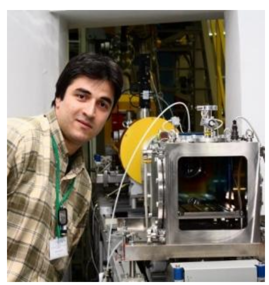

T.Djobava


M.Mosidze


N.Mosulishvili


G.Devidze


A.Durglishvili


J.Jejelava


T. Zakareishvili


B. Chargeishvili

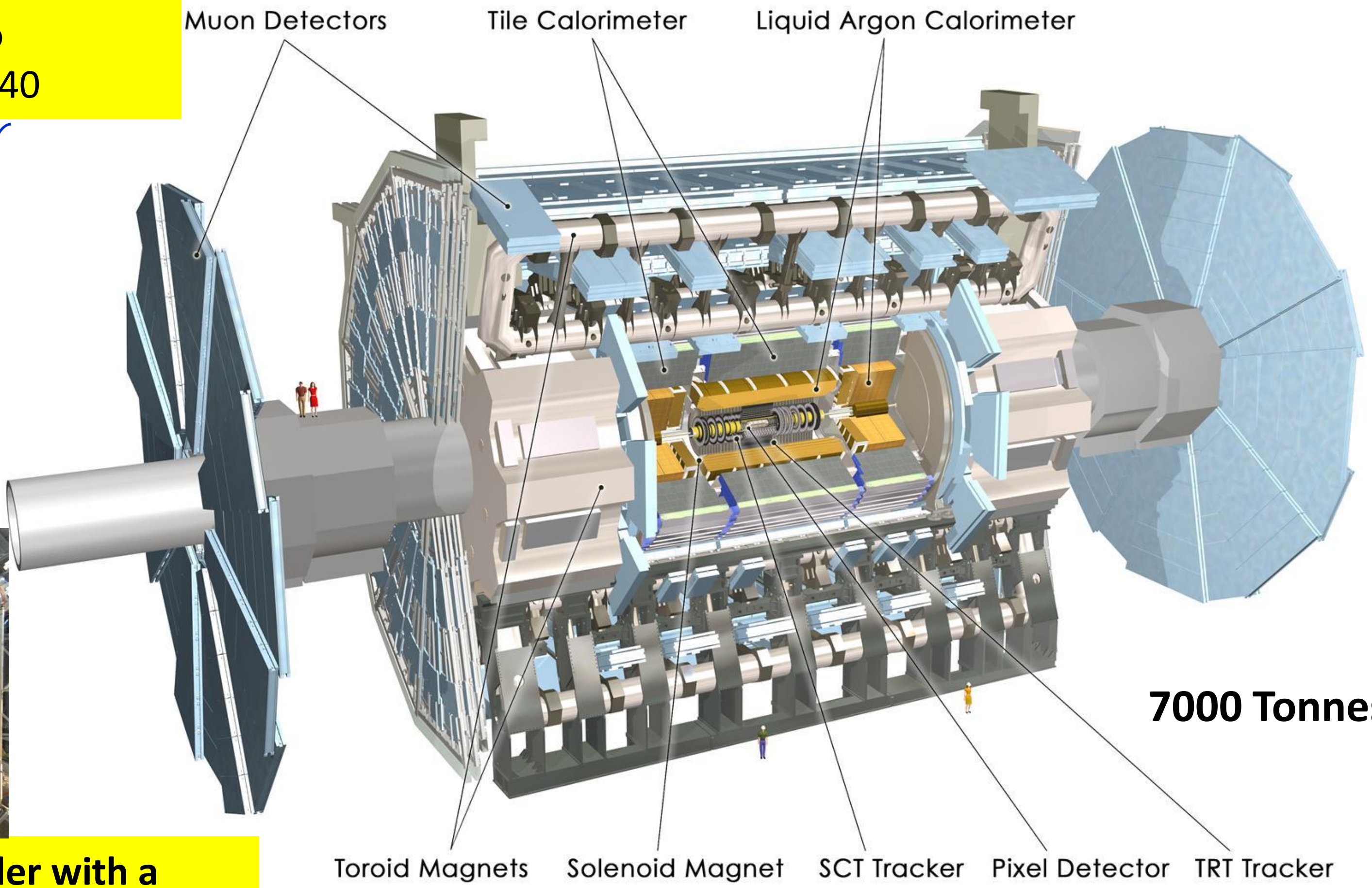

V.Kartvelishvili

ATLAS Detector

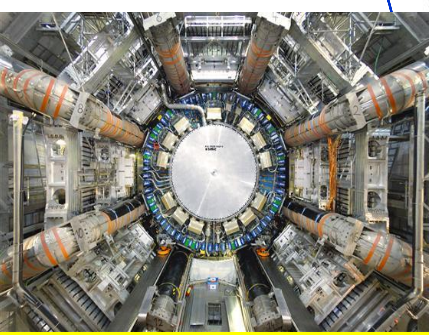
ATLAS superimposed to the 5 floors of building 40

45 m

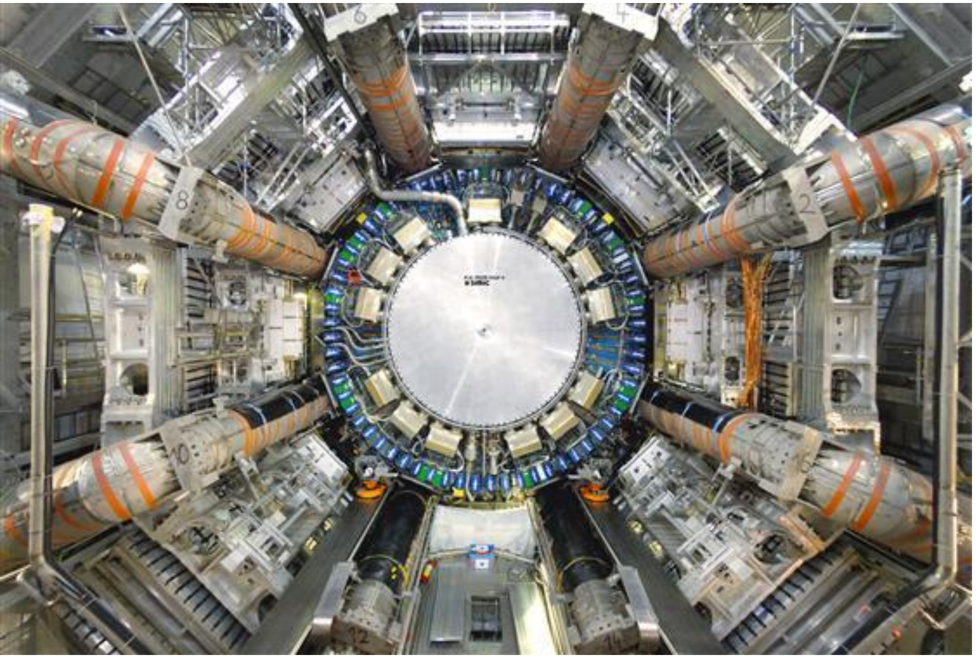
24 m



7000 Tonnes

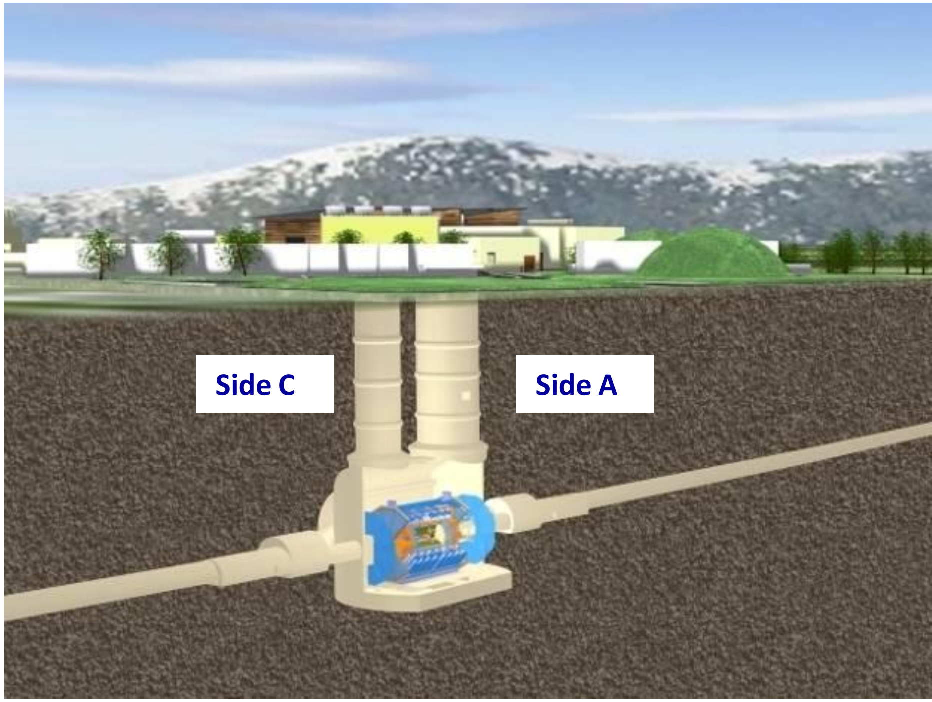


The detector is a cylinder with a total length of 45 m and a radius of 12 m and weights apptoximately 7000 tonnes.



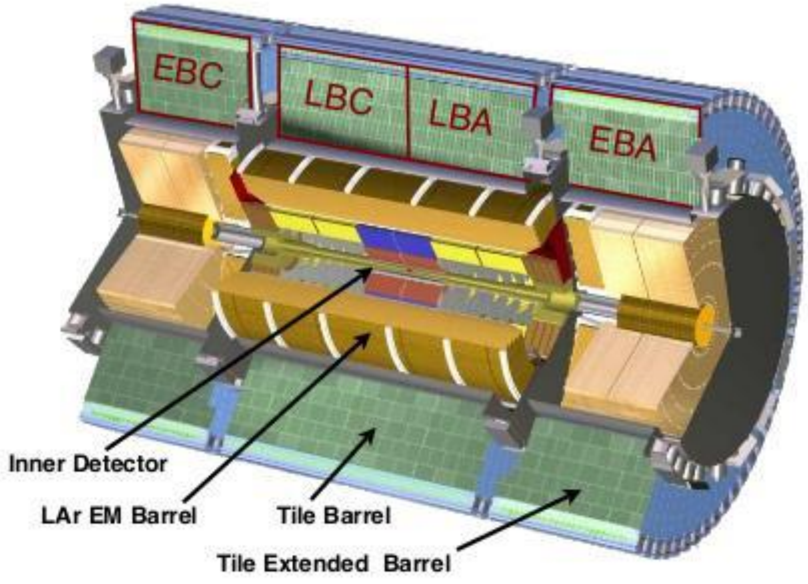
The Underground Cavern at Point-1 for the ATLAS Detector

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



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: $\Delta E/E = 50\%/\sqrt{E} \oplus 3\ \%$

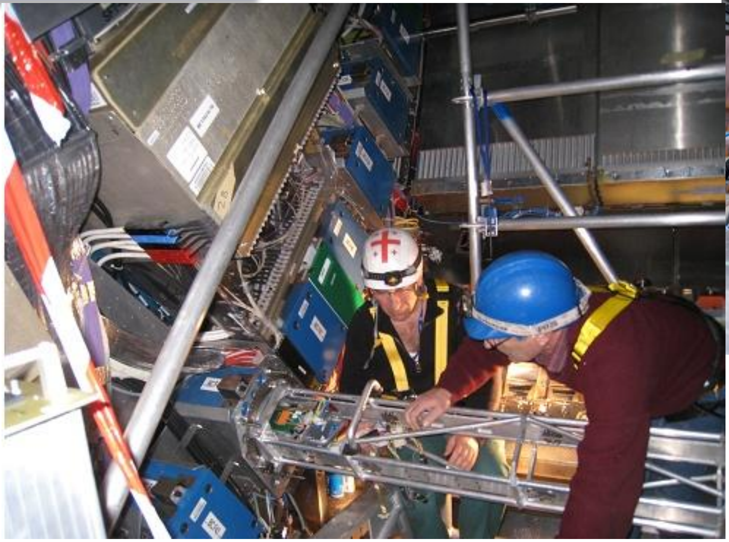
ATLAS Tile Calorimeter

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

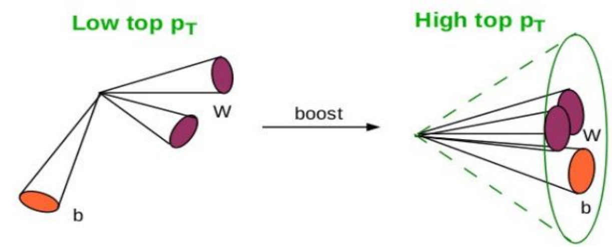


N.Mosulishvili

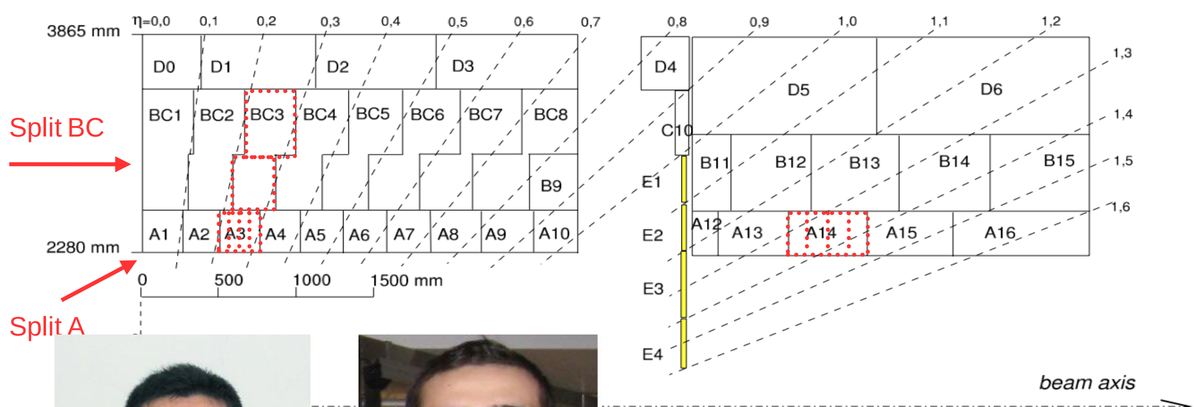
High Granularity TileCal study

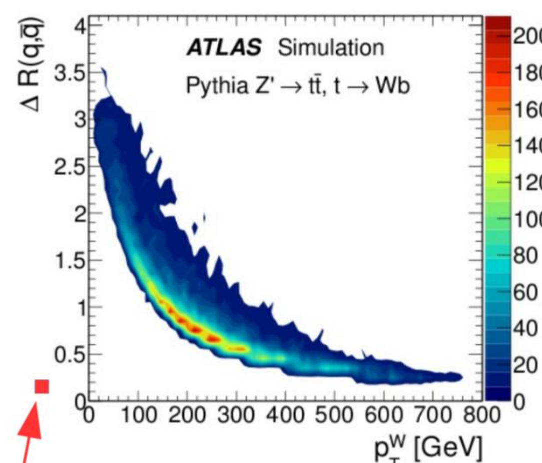
TileCal phase 2 upgrade geometry

- 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)





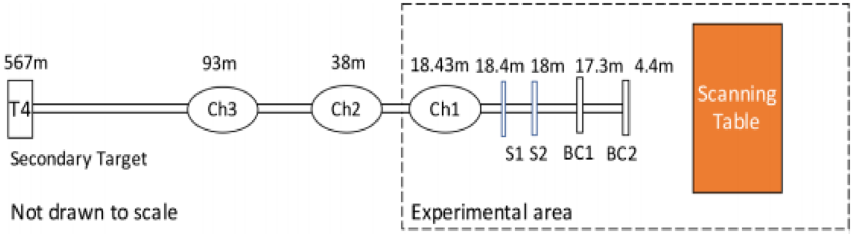
A. Durglishvili

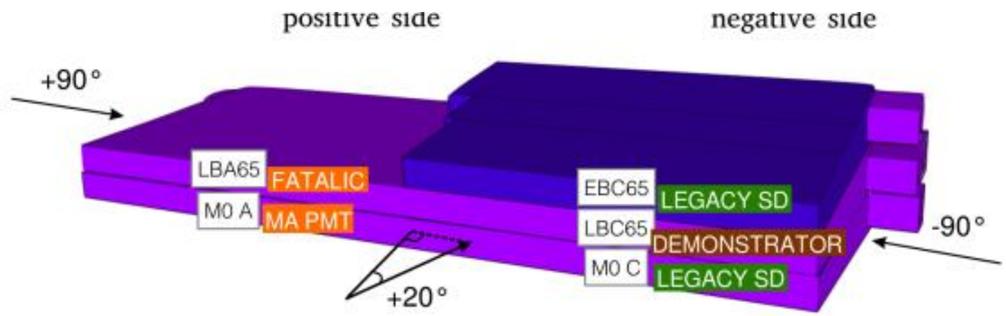
B. Chargeishvili

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

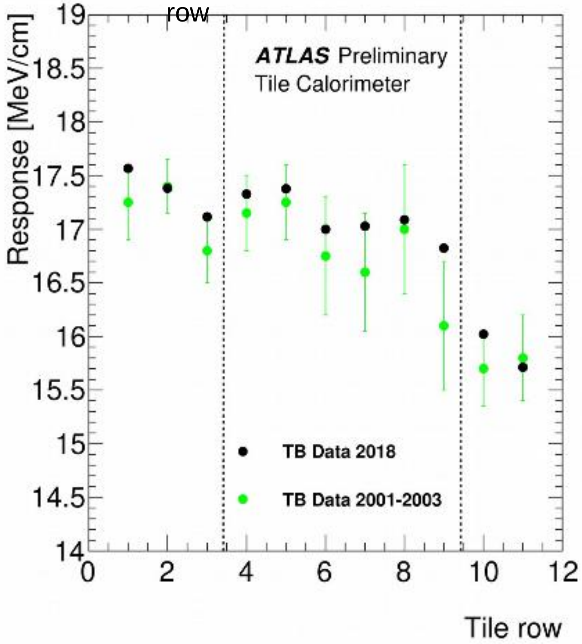
Tile Calorimeter Demonstrator Test Beam data -2015-2017

Tile Calorimeter Demonstrator Test Beam data analysis –Muon data 2018





Muon results: E vs Tile row



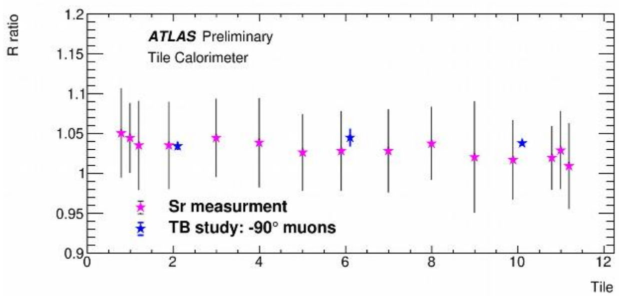
The signal per unit path length produced by -90° muons incident on individual tile-row's center.

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

The Determination of C_μ:

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

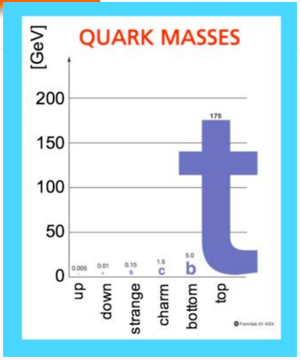
1. 2017, 24-27 January, Barcelona, Spain, 5th Beam Telescopes and Test Beams Workshop 2017
"Muon Signals at a Low Signal-to-Noise Ratio Environment", T. Zakareishvili; Session: Data Analysis and Test Beam Results; https://indico.desy.de/indico/event/16161/contributions

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

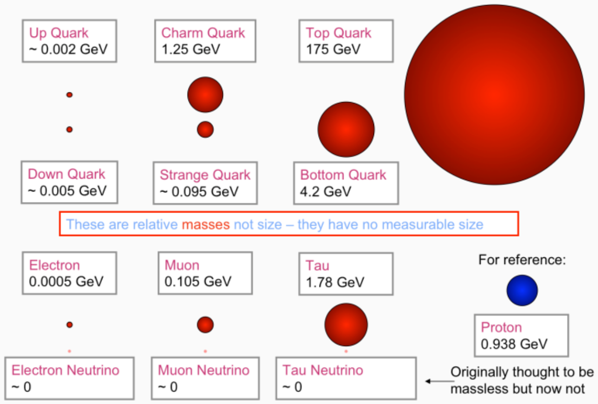
3. 2019, 14-18 January, Geneva, CERN, Switzerland, 7th Beam Telescopes and Test Beams Workshop 2019
Studies of the response of the ATLAS Tile Calorimeter to beams of particles at the CERN test beams facility
T. Zakareishvili; Session: Analyis - Fibres & Calorimeters.
https://indico.cern.ch/event/731649/sessions/295254/#20190117

Motivations for Top Quark Physics Studies

- The top quark was first observed in 1995 at the Fermilab $p\bar{p}$ 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 l e l ; 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 ...

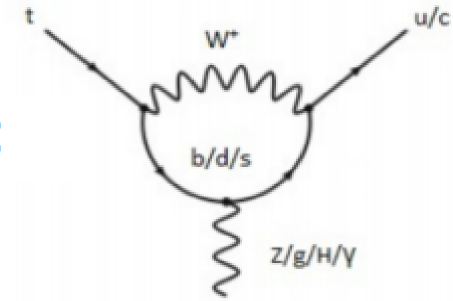
- *Experiment:* Top quark useful to calibrate the detector
- *Beyond Top:* Top quarks are major source of background for almost every search for physics beyond the SM – New Physics

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}

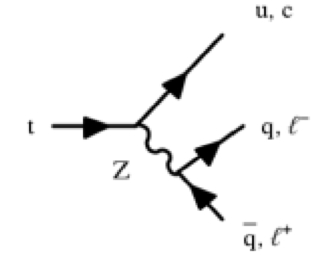
SM:



Strongly suppressed by GIM mechanism in SM

→ Powerful probe for new physics

BSM:



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

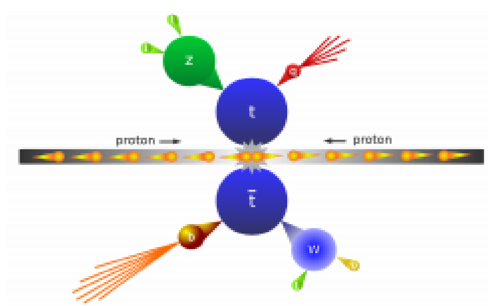
- One top decays through FCNC (t→qZ) and other through SM dominant mode (t→bW)
- Leptonic decays of W and Z bosons

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

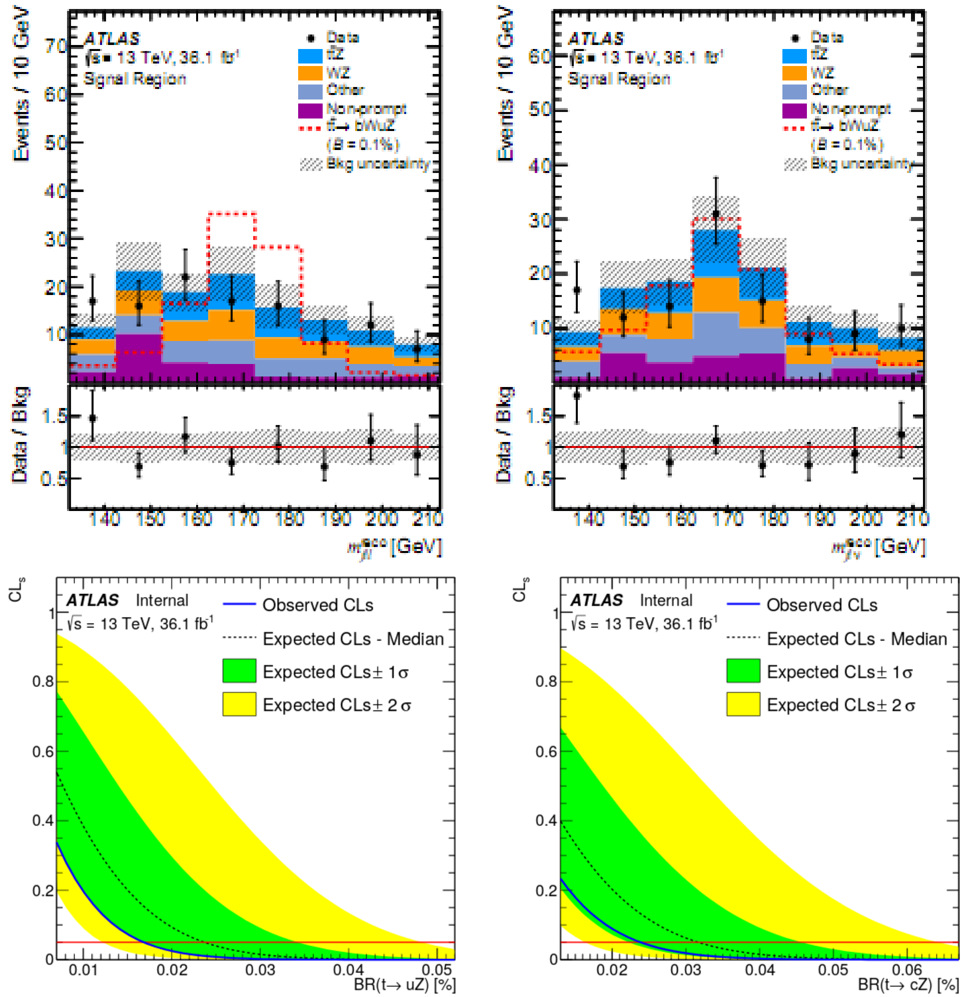


Analysis Team: J.Araque, N.Castro, B.Galhardo, F.Veloso, (LIP, Portugal)
A.Durglishvili, T.Djobava, M.Mosidze (HEPI TSU, Georgia)
S.Hellman, S.Molander (Stockholm University, Sweden)

Results of $t\rightarrow qZ$ FCNC search

- 36 fb^{-1} 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	1.7×10^{-4}	2.4×10^{-4}
Expected	2.4×10^{-4}	3.2×10^{-4}
Expected -1σ	1.7×10^{-4}	2.2×10^{-4}
Expected +1σ	3.4×10^{-4}	4.6×10^{-4}



Conferences and workshops

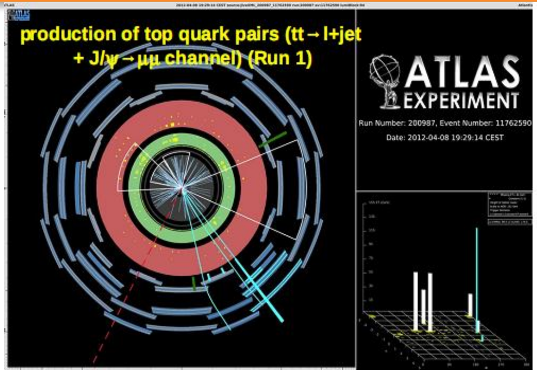
1. 2017, 17-22 September, Braga, Portugal, Top2017 - 10th International Workshop on Top Quark Physics , (http://top2017.lip.pt/) "Search for tZ Flavor Changing Neutral Currents in top quark decays with ATLAS at 13 TeV", A.Durglishvili, Poster session; https://indico.cern.ch/event/659310/

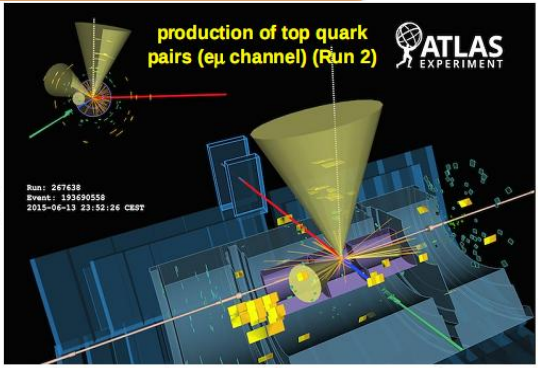
2.The 2018 European School of High Energy Physics, Maratea, Italy, 20 June-3 July, 2018 "Search for flavour-changing neutral current top-quark decays t→qZ in proton-proton collisions at √s=13 TeV with the ATLAS Detector".
A.Durglishvili, Poster session;
http://physicschool.web.cern.ch/PhysicSchool/ESHEP/ESHEP2018/

J/ψ production with top pair

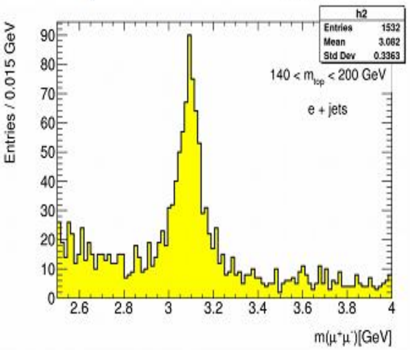
Analysis Team:
V.Kartvelishvili, J.Walder (Lancaster University (GB);
B.Chargeishvili, T.Djobava, T. Zakareishvili (HEPI TSU)

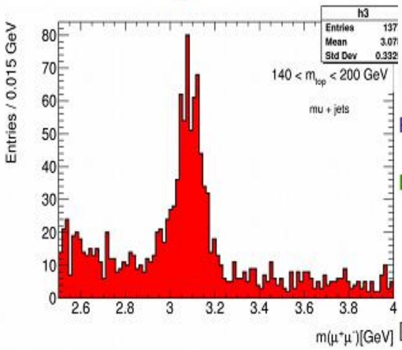
Prof.V.Kartvelishvili





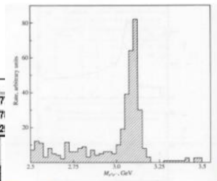
Selection: lepton + 4jets + dimuon(s) (cut on top mass: $140 < m_t < 200$ GeV).





11/1/17

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 ⇒

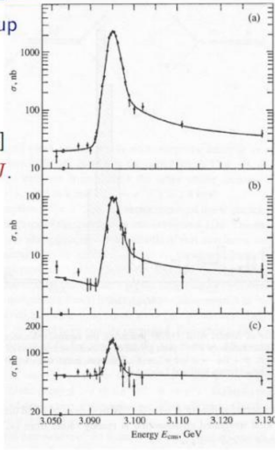
(a) $e^+e^- \to$ hadrons

(b) $e^+e^- \to \mu^+\mu^-$

(c) $e^+e^- \to e^+e^-$

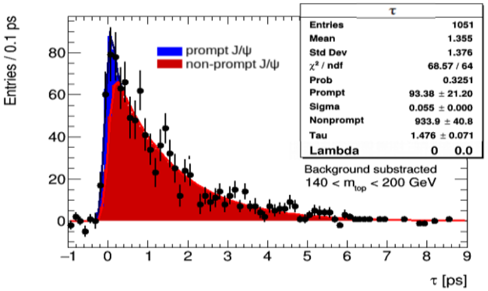
[Augustin et al., PRL, 7/11/1974]

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



Lifetime of J/ψ candidates in top events

|Δη| and |sin(Δφ)| cuts applied.

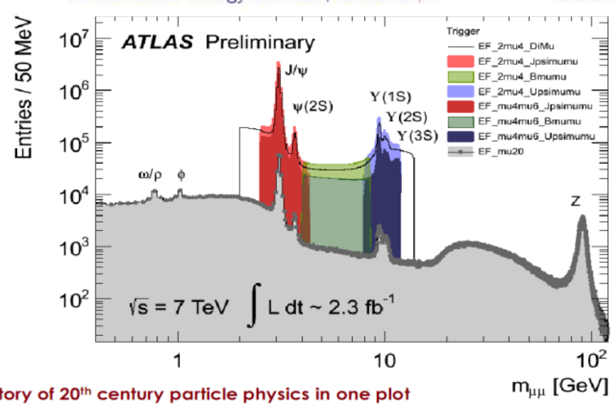


Fit function:
pdf={ε*δ(τ)+(1-ε)*exp(τ)} ⊗ Resolution

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!

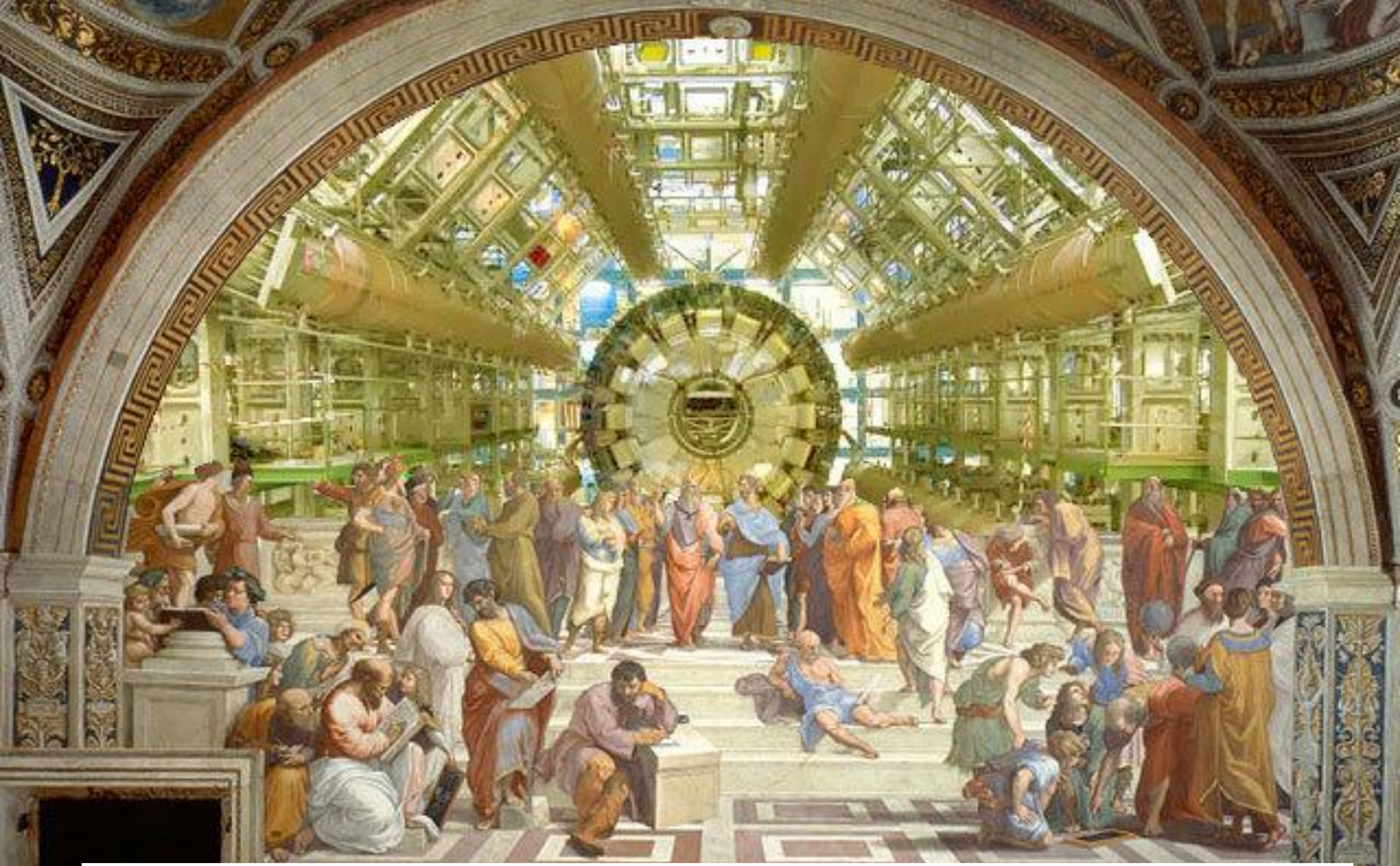


History of 20th century particle physics in one plot

Future

ATLAS Collaboration members at CERN (Bldg. 40)

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



Thanks a lot !

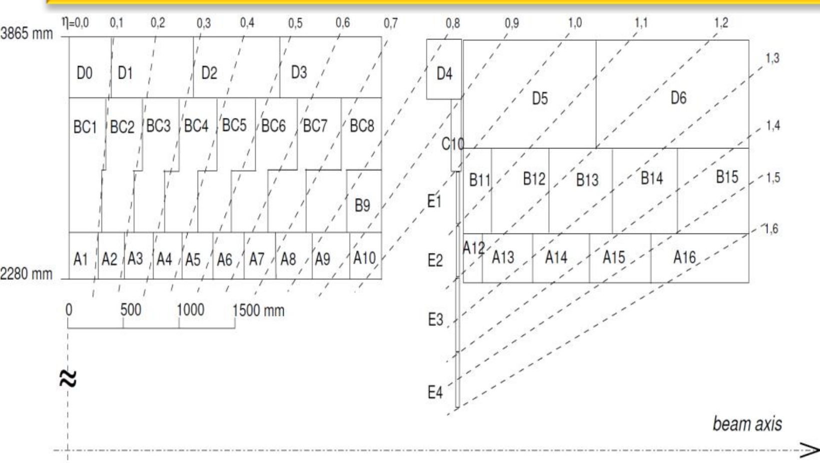
გმადლობთ ყურადღებისათვის!

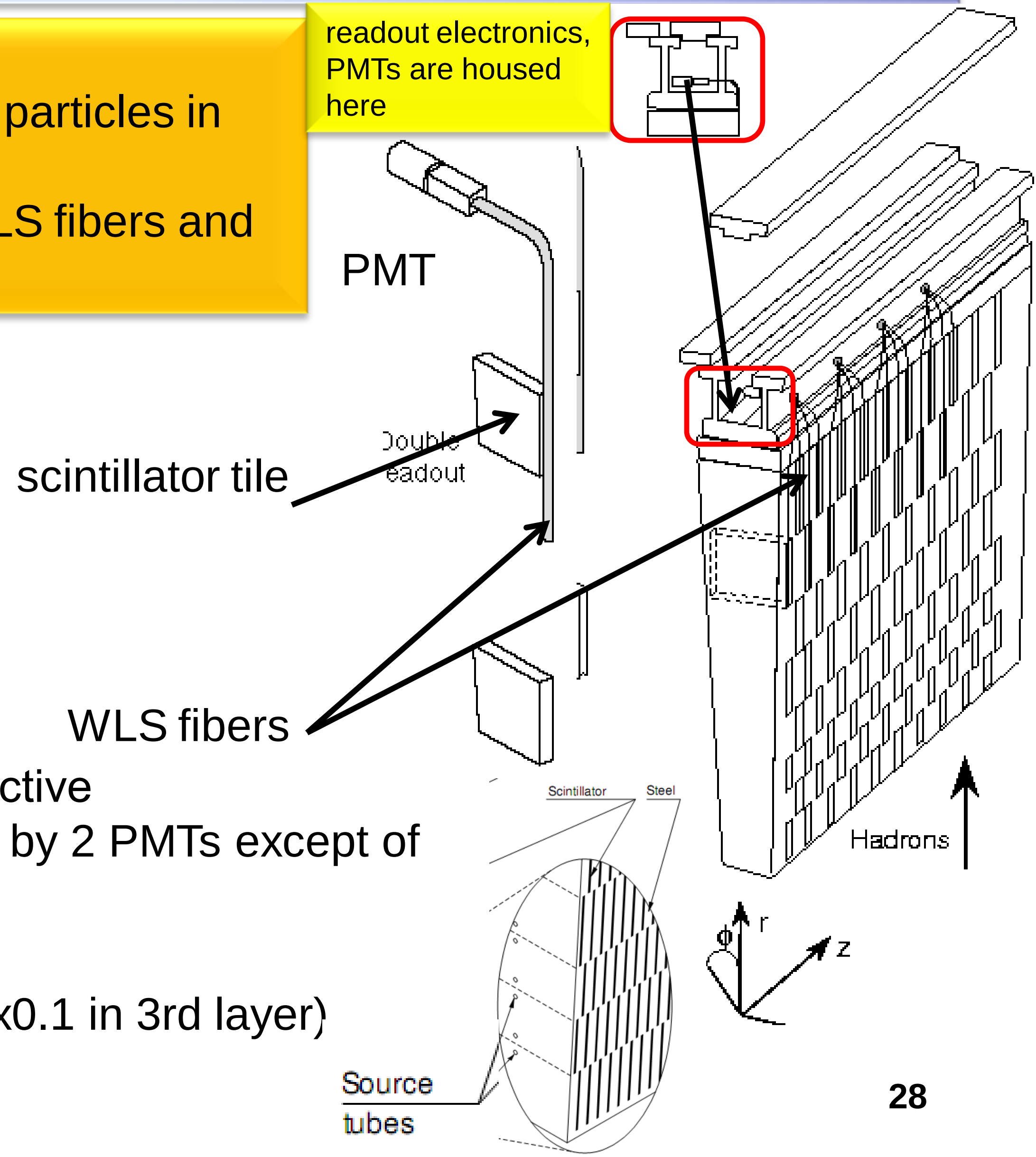
Back-ups

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





- Tile readout is grouped into projective geometry cells. each cell readout by 2 PMTs except of special cells
  - 3 longitudinal layers
  - Granularity $\Delta\eta x \Delta\varphi=0.1x0.1$ (0.2x0.1 in 3rd layer)