

CERN – Pakistan Cooperation

Hafeez R. Hoorani

National Centre for Physics
Quaid-I-Azam University

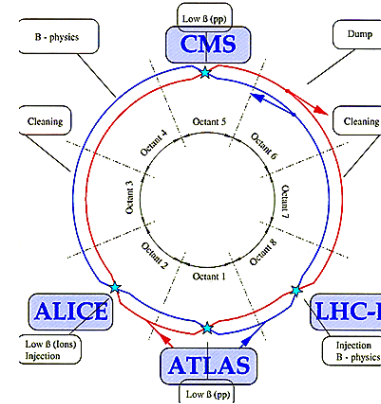
Outline

- **CERN, LHC, CMS & Abdus Salam**
- **Pakistan – CERN Relationship**
- **NCP – CERN Interaction**
- **Benefits for Pakistan**

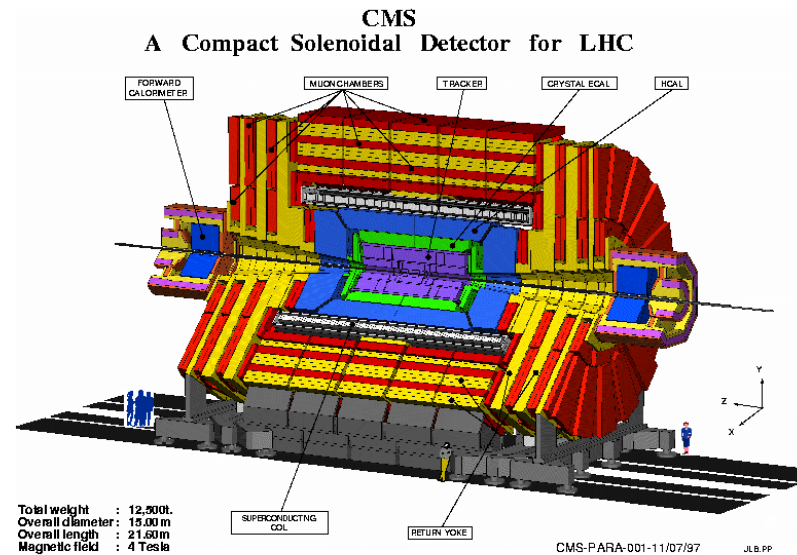
What and Where is CERN, LHC, CMS?



European
Center for
Nuclear
Research
(CERN)



Large
Hadron
Collider
(LHC)



Compact Muon Solenoid
(CMS)



17/11/14

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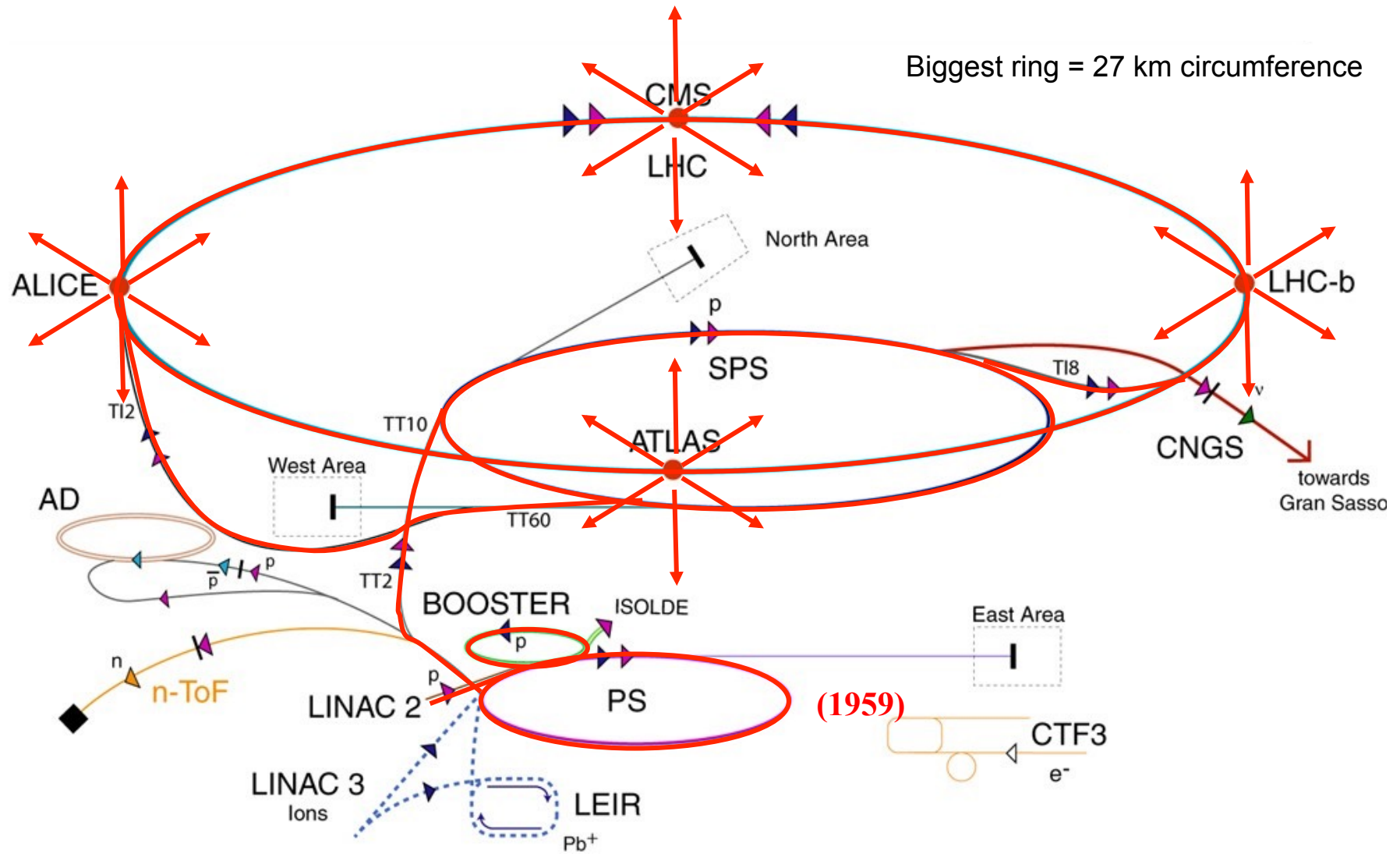
CERN: The Laboratory

- **C**entre **E**uropeenne pour la **R**echerche **N**ucleaire
CERN or **E**uropean **O**rganization for **N**uclear
Research
- Established in 1954.
- Funded by 21 Member States.
- More than half of the high-energy physicists in the world are working at CERN.
- Annual Budget is around US \$ 1.25 billion.
- One of the current active project is the **L**arge
Hadron **C**ollider (**LHC**).
- **Goal is pure research in basic science, in particular High-Energy Physics.**

CERN Accelerators

- Intersecting Storage Ring **ISR**
- Proton Synchrotron **PS**
- Super-Proton Synchrotron **SPS**
- Large Electron Positron **LEP**
- Large Hadron Collider **LHC**
 - **Lepton and Hadron Colliders**
 - **Precision Measurements of Standard Model**
 - **Discovery and explore physics beyond SM**

Accelerator complex



- ▶ protons
- ▶ ions
- ▶ neutrons

- ▷ antiprotons
- ▷ electrons
- ▷ neutrinos

- AD Antiproton Decelerator
- PS Proton Synchrotron
- SPS Super Proton Synchrotron

- LHC Large Hadron Collider
- n-ToF Neutron Time of Flight
- CNGS CERN Neutrinos Gran Sasso

CTF3 CLIC Test Facility 3

Why LHC?

- Why is the Z boson massive while the related photon is massless? What is the “origin” of mass? - **HIGGS**
- Can we obtain experimental evidence to support the hypothesis of Grand Unification of all fundamental forces? - **GUT**
- Is the “dark matter” in the universe due to supersymmetric particles: neutralinos? - **LSP**
- Can we account for the matter – antimatter asymmetry in our universe? – **CP violation**

Why LHC?

- Are there only 3 families of quarks and leptons?
- Do the elementary particles of today have sub-structure?
- Does a new form of matter exist e.g. Quark-Gluon Plasma?

?

LHC can answer or shed considerable light on these fundamental questions.



Experimental Particle Physics in Pakistan

- ❑ **Dr. R M Chaudhry** at GC, Lahore (the alma mater of young **Abdus Salam**) got the Cockcroft-Walton accelerator in 1954.
- ❑ Professor Salam played a major role in establishing the scientific infrastructure in the country.
- ❑ **Experimental Setups:**
 - 10 MeV Pelletron at NCP, Islamabad.
 - 1.2 MeV Cockcroft-Walton Accelerator at CASP, GCU, Lahore.
 - 2 MeV Pelletron Tandem Accelerator at CASP, GCU, Lahore.
- ❑ A 250 keV, locally developed, electrostatic charged particle accelerator at PINSTECH, Islamabad.
- ❑ PINSTECH has initiated a program to develop a **RF Linear Accelerator (LINAC)** for radiotherapy and research.

Salam: The leader of Pakistani Science

- Prof. Salam was one of the first few in late fifties who realized that **gauge symmetry** should be related to all forces and unification
 - Like EM force which satisfy U(1) gauge symmetry, Prof. Salam proposed that SU(2) gauge symmetry should be related to weak force
- Prof. Salam and Weinberg independently used Higgs mechanism to generate masses for the W^\pm and Z bosons in their Nobel-Prize winning papers
 - These particles were later discovered at CERN
 - Hence the first interaction of Pakistani theorist with CERN and SLAC
- The first interaction with BNL occurred in fifties when Prof. Salam proposed his “Two-components neutrino theory”
 - Explained that left-right asymmetry(or parity violation) is connected with zero mass of neutrino
 - According to his theory right handed neutrinos don't exist in nature
 - Parity violation was validated by experiments at BNL

Unification of Electromagnetic and Weak forces

=>Electroweak theory was developed by Salam, Weinberg and Glashow (Nobel prize 1979)



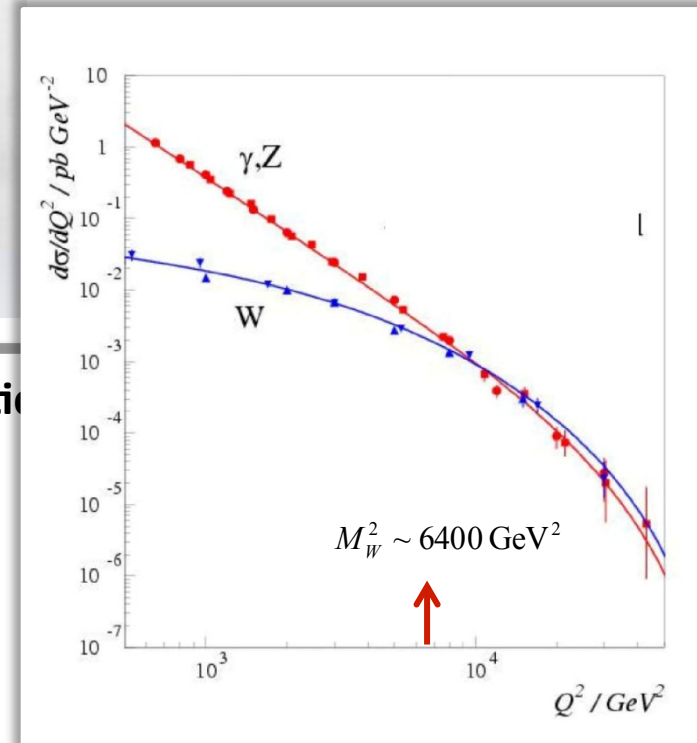
Sheldon Lee Glashow



Abdus Salam



Steven Weinberg



❑ Experimental evidence of Weak and Electromagnetic force unification

- Data from the HERA electron-proton collider
- W/Z bosons were discovered at CERN
- ✓ **First interaction of Pakistani theorists with CERN and SLAC**
- ✓ **Prof. Salam did pioneering work in the development of Standard Model of particle physics**

Salam impact on Pakistani HEP

- Many of his brilliant students continued the legacy
- Prof. Riazuddin (one of Prof. Salam student) was a great particle physicist
- He published about two hundred papers
 - Some of his papers have 500+ citations
- Wrote many well known HEP books (used as text books around the world):
 - *A Modern Introduction to Particle Physics*, 3rd edition published by World Scientific in 2012 (first edition was published in 1992)
 - *Quantum Mechanics* by Prof. Riazuddin and Prof. Fayyazuddin, published by World Scientific, Singapore
 - *Theory of Weak Interaction in Particle Physics* by Prof. Riazuddin and Prof. Marshak, published by John Wiley, New York

Pakistan-CERN Relationship

Pak-CERN Relation Milestones

- ❑ 1994 – CERN-Pakistan cooperation agreement signed
- ❑ 1994 to 1997 – Informal mutual visits exploring areas of cooperation
- ❑ 1997 – Formal protocol signed for the CMS magnet barrel yoke support structure
- ❑ 1999 – NCP becomes a full member of CMS Collaboration
- ❑ 2003 – Joint CERN Pakistan Committee (JCPC) established
- ❑ 2006 – President of Pakistan initiative increases the collaboration
- ❑ 2012 – LHC consolidation Protocol signed
- ❑ 2012 – Cooperation extended to LINAC-4, CLIC and Magnet group
- ❑ 2013 – **Pakistan files application for Associate membership**
- ❑ 2014 – Collaboration for CESSAMag project started

Pak-CERN Protocols and Agreements

S #	Signing	Title
1	Nov 1994	Cooperation agreement concerning: The development of scientific and technical cooperation in the research projects of CERN.
2	Nov 1997	Protocol for the supply of steel supports for the four outer rings of the Compact Muon Solenoid (CMS) magnet barrel yoke
3	June 1998	Memorandum of Understanding (MoU): For collaboration in the construction of the CMS detector
4	June 1999	Protocol to the cooperation agreement 1994 between National Center for Physics (NCP) and CERN concerning: Further collaboration between CERN and the NCP.
5	May 2000	Amendment to the MoU of June 1998: For collaboration in the construction of the CMS detector (CMS Collaboration)
6	June 2001	Protocol to the cooperation agreement 1994 concerning: The development and procurement of special components and of services for the CMS detector.
7	July 2003	Protocol to the cooperation agreement 1994 concerning: A special contribution by Pakistan towards the construction of the LHC.
8	May 2004	Addendum A1 to the protocol 2003 concerning: A special contribution by Pakistan towards the construction of the LHC. It is for the execution of R & D, design, production and/or testing tasks and/or supply of ATLAS detector components.
9	Jan 2006	Memorandum of Understanding (MoU): For collaboration in the development and exploitation of the Worldwide LHC computing Grid
10	Jan 2006	Addendum P066//M1 to the protocol 2003 concerning: A special contribution by Pakistan towards the construction of the LHC. It is for the supply of steel shielding.
11	Sept. 2006	Extension to the protocol 2003 concerning: A special contribution by Pakistan towards the construction of the LHC.

Pak-CERN Protocols and Agreements

12	Dec 2006	Protocol to the cooperation agreement 1994 concerning: The allocation of an additional grant of 5 M CHF by the Government of the Islamic Republic of Pakistan for CERN-Pakistan collaboration.
13	Oct. 2008	Amendment A1 to the protocol 2006 concerning: Definitive technical contents of the contribution to the Linac4/SPL projects (Annex VIIa).
14	Sept. 2010	Addendum No.1 to the protocol 2006 concerning: The CMS Resistive Plate Chambers Layer Number 4 (RPC4) Detector.
15	Sept. 2010	Addendum No.2 to the protocol 2006 concerning: The CMS YE4 Shielding Wall.
16	June 2011	Joint Statement of Intent concerning: The participation of Pakistan in the large Hadron Collider (LHC) consolidation project.
17	June 2011	Extension to the protocol 2003 concerning: A special contribution by Pakistan towards the construction of the LHC
18	Sept. 2012	Addendum P066/LHC/A2 to the protocol 2003 concerning: Mechanical works for the consolidation of the LHC splices.
19	Oct, 2013	Addendum No. P066/LHC/A3 to the protocol 2003 concerning: Scientific and technical contribution of Pakistan in the CLIC study
20	Jan, 2014	Addendum No. P066/LHC/A4 to the protocol 2003 concerning: Scientific and technical contribution of Pakistan in the Linac4 Project
21	Jan. 2014	Protocol to the cooperation agreement 1994 concerning: A contribution by Pakistan to CERN in the framework of the CESSAMag Project.

The CERN effect

❑ Particle Detectors:

- R&D on particle detectors, such as RPCs, Gas Electron Multipliers (GEM) at NCP and PINSTECH.

❑ Grid Computing:

- The Worldwide LHC Computing Grid (WLCG) nodes at NCP and COMSATS in collaboration with CMS and ALICE.
- Early computing efforts at NUST.

❑ Accelerator Technology:

- Design and manufacture of NSC magnets.
- Sending people in RF acceleration groups like CLIC and LINAC4.
- Recently 5 LEP cavities from CERN have just arrived.

❑ Laser Alignment system for CMS CT

Pakistan-CERN Collaboration



Dr. Ashfaq Ahmad Chairman PAEC and Prof. Luciano Maiani DG CERN (7th May 1999)



Pervez Musharaf Pakistani President, Pervez Butt Chairman PAEC and Robert Aymar DG CERN (25th Jan 2006)



Dr. Badar Suleman Member Science PAEC and Prof. Joseph Incandela CERN Spokesperson (11th May 2012)



Dr. Atta ur Rehman Minister of Science and Technology Pakistan and Prof. Hafeez Hoorani visiting CMS exhibition hall (15th Sept.2000)

Pakistan-CERN Collaboration Status



DG CERN and Chairman PAEC (July 2011, Islamabad)

Collaboration with CERN

- Collaboration with CERN started when MoU was signed in 1994
- Collaboration was further strengthened when Pakistan Atomic Energy Commission signed MoU with CERN in Islamabad on 16 May 2000
 - The MoU increased Pakistani contribution to CMS from 1 MCHF to 2.5 MCHF
- Since then collaboration expanded in different area's
- Pakistani institutes are now actively involved in CMS and ALICE experiments
- Contributed to ATLAS experiments both in hardware and computing area's
- Contribute to LHC consolidation

CERN COURIER



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Microscopy



Nanopositioning



Hexapods

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CERN COURIER

Jun 28, 2000

CERN and Pakistan strengthen agreement

Signed in Islamabad in May was an addendum to the Memorandum of Understanding between CERN and Pakistan, covering increased Pakistani involvement in the CMS experiment for CERN's LHC collider.

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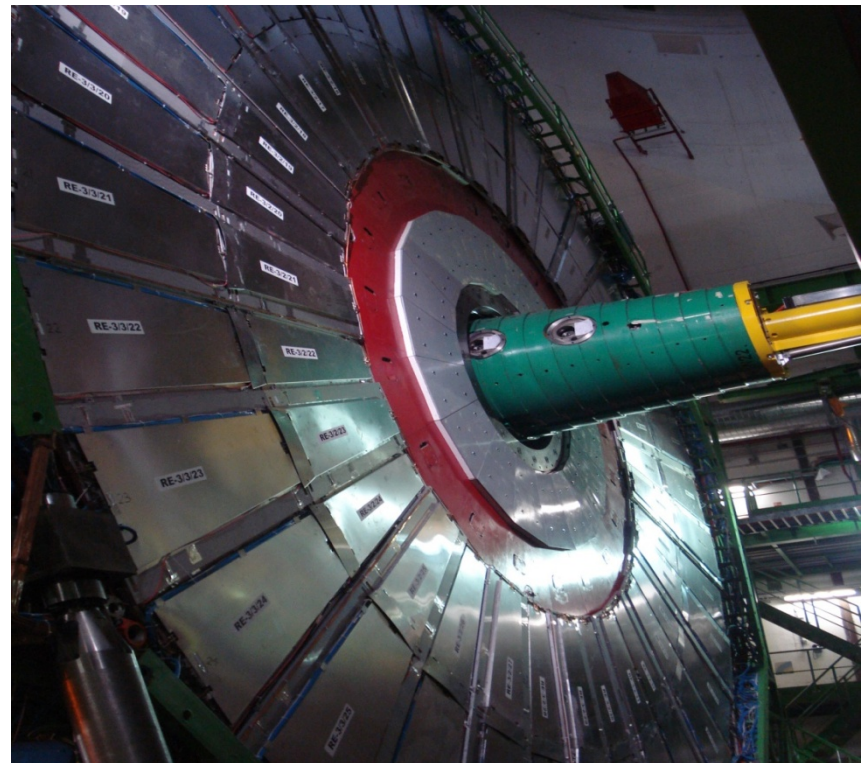
Pakistan is supplying six giant 25 ton support feet for the main

Pakistan is supplying six giant 25 ton support feet for the main "barrel" magnet of the CMS detector, as well as material for the magnet itself. Under the new agreement the National Centre for Physics at Quaid-i-Azam University, Islamabad, will also supply 432 resistive plate chambers (RPCs) for the CMS forward muon system as part of a collaboration that also involves China, Italy, Korea and the US. In addition the front-

NCP-CERN Interaction

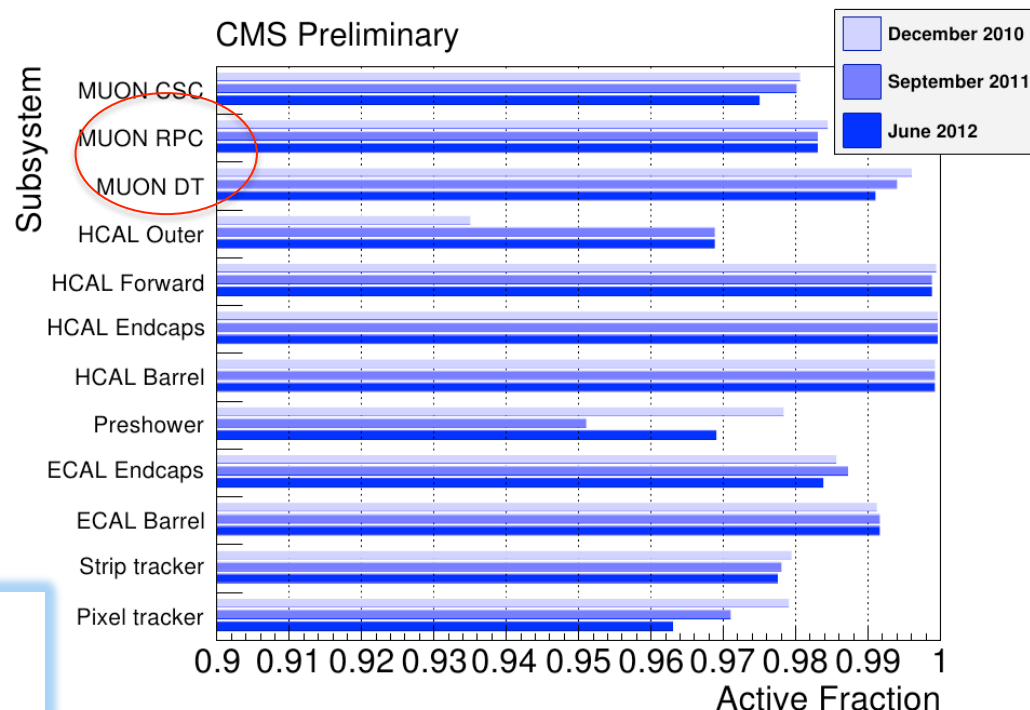
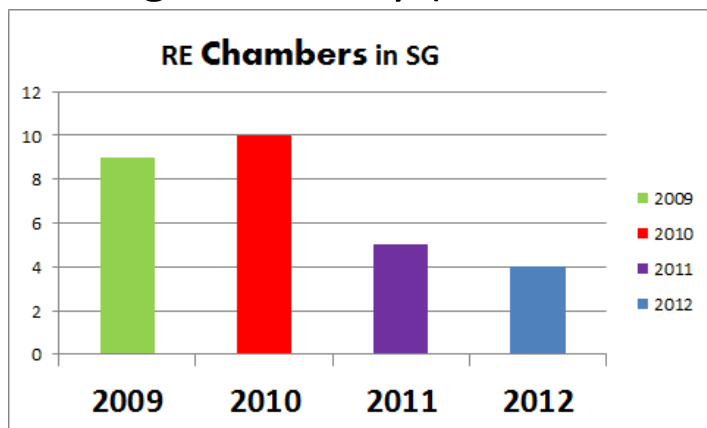
CMS RPC's project

- Built, tested, installed and commissioned (288 + 10% contingency) RPCs
 - Makes 66% of Endcap RPC system of CMS detector at CERN
 - Responsible for the operation and maintenance of Endcap RPC's
- People power involved ~ 40 people including Physicists, Engineers, Software Developer, Students, Technicians
- Performance Requirement for RPC's
 - Time Resolution < 3 ns
 - Efficiency > 95 %
 - Cluster Size < 3
- Installation, cabling
 - Signal cables
 - High Voltage
 - Low Voltage
 - Detector Control System cables
 - Temperature cables



RPC's Performance during data taking

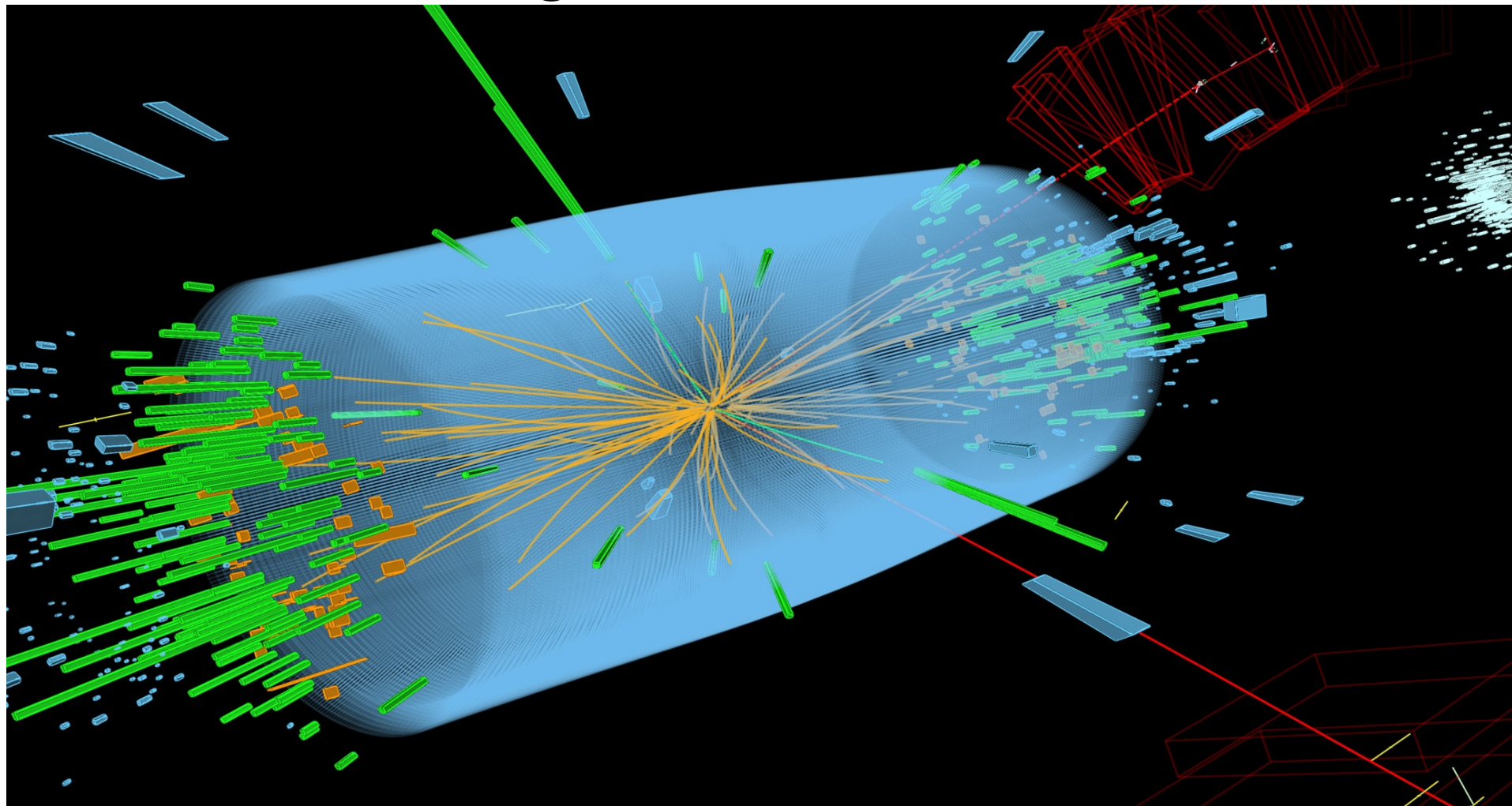
- Detectors are performing very well
 - CMS reported that RE detectors are operational 99.8 % of the time with very high efficiency (more than 98%, comparable to any other sub-detector)



- Other requirements within specification

- covers $0 < |\eta| < 1.6$
- **Double gaps gas chamber:** 2 mm gas width
- **Bakelite** bulk resistivity: $\rho = 2-5 \times 10^{10} \Omega\text{cm}$
- **Gas mixture:** $\text{C}_2\text{H}_2\text{F}_4 + \text{iso-C}_4\text{H}_{10} + \text{SF}_6$
 96.2% 3.5% 0.3%
- Operated in **avalanche mode**

Decay products of Higgs boson candidate passing through Pakistani Detectors



17/11/14

Higgs candidate detected with RPCs built with contributions from Pakistan.

Presented to Dr Ansar Parvez, The Pakistan Atomic Energy Commission.
CMS Experiment at the LHC, CERN, 25.09.2012

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Some other contributions

- Our group developed Detector Control System (DCS) for RPC
 - Now being used at P5
- Also developed RPC Construction DB
- The GUI for configuration database is also developed by our group
 - Deployed at P5 in 2011 and has been used successfully since then
- Testing of Data Quality & Monitoring (DQM) module is responsibility of our group
- Contributed to the development of LHC data Logging System & LHC Common Console Manger (CCM) from October 2006 to December 2007

Grid Node to access LHC data

- Processing of huge amount of LHC/CMS data needs a lot of computational power, hence resources
- First Pakistani Tier2 was deployed in June 2004 (operational 24/7 even during severe blackout in Pakistan)
- Immediate access to wealth of LHC data with up-to-date CMS software releases

Year	CPU	HEPSPEC06	Storage	Network Connectivity
Jan-08	14	67.2	3.2 TB	2 Mbps (Shared)
April-08	36	172.8	3.2 TB	2 Mbps (Shared)
Sep-08	74	355.2	3.2 TB	10 Mbps (dedicated)
Feb-10	160	1600	3.2 TB	10 Mbps (dedicated)
Jun-10	240	2400	69 TB	155 Mbps (dedicated)
Dec-10	524	6364	87 TB	155 Mbps (dedicated)
June-11	524	6364	175 TB	155 Mbps (dedicated)
May-12	524	6364	260 TB	155 Mbps (dedicated)

Pledges

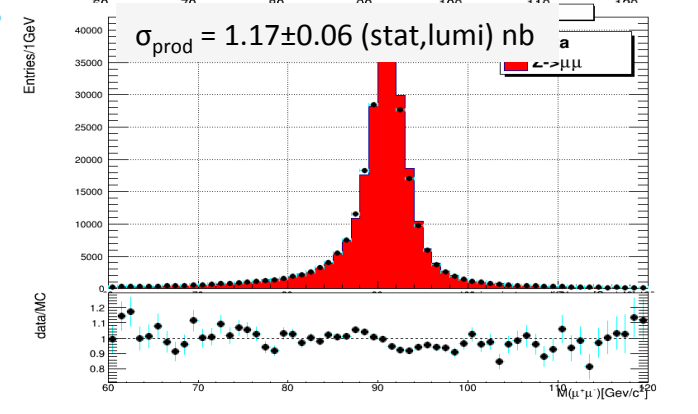
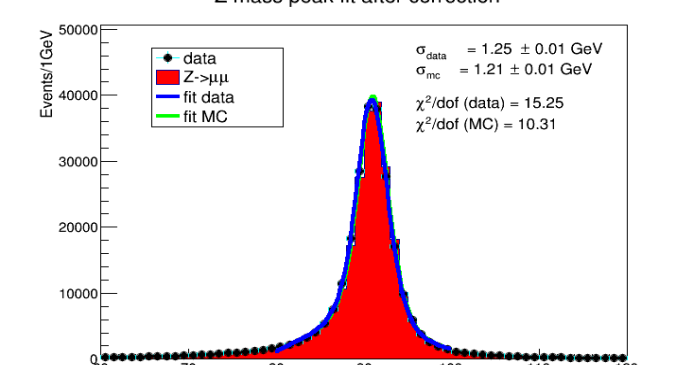
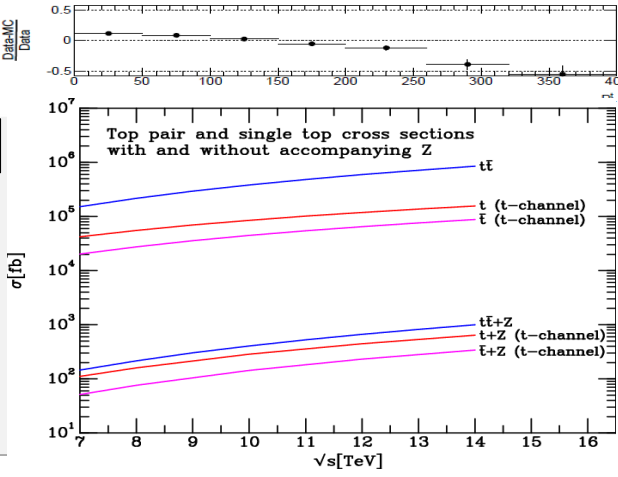
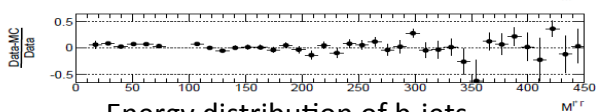
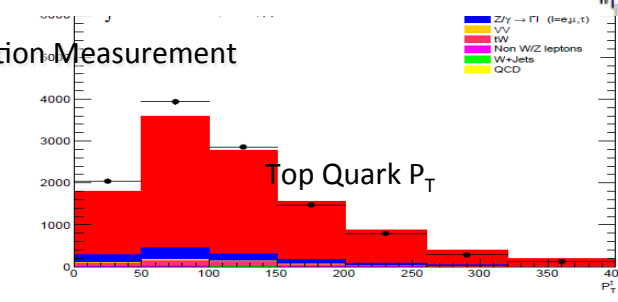
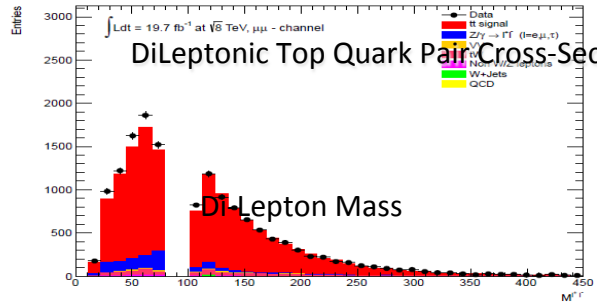
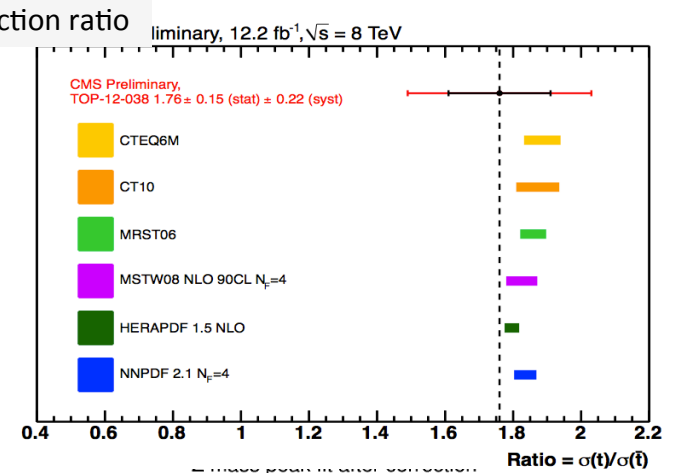
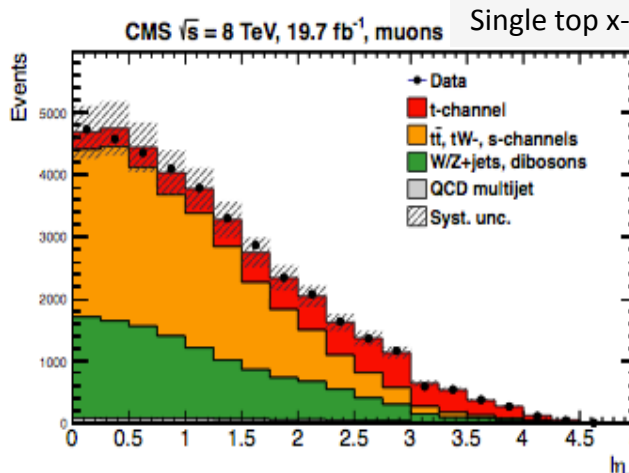
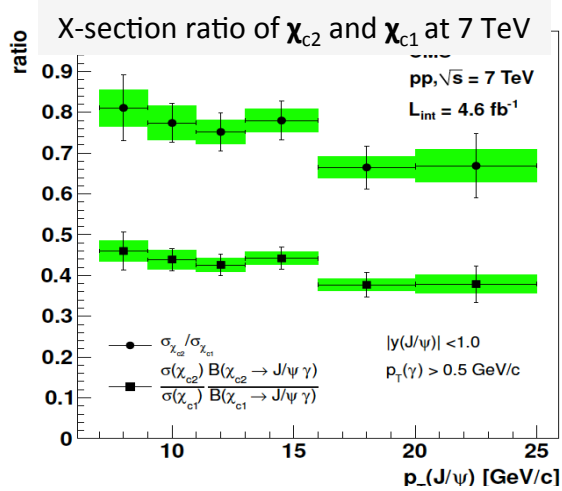
NCP-LCG2	2009	2010	2011	2012	2013
CPU (HEP-SPEC06)	3280	3480	4352	5440	6365
Disk (TB)	200	200	300	300	300
Network (Mbps)	42	42	53	66	-

Physics Analysis

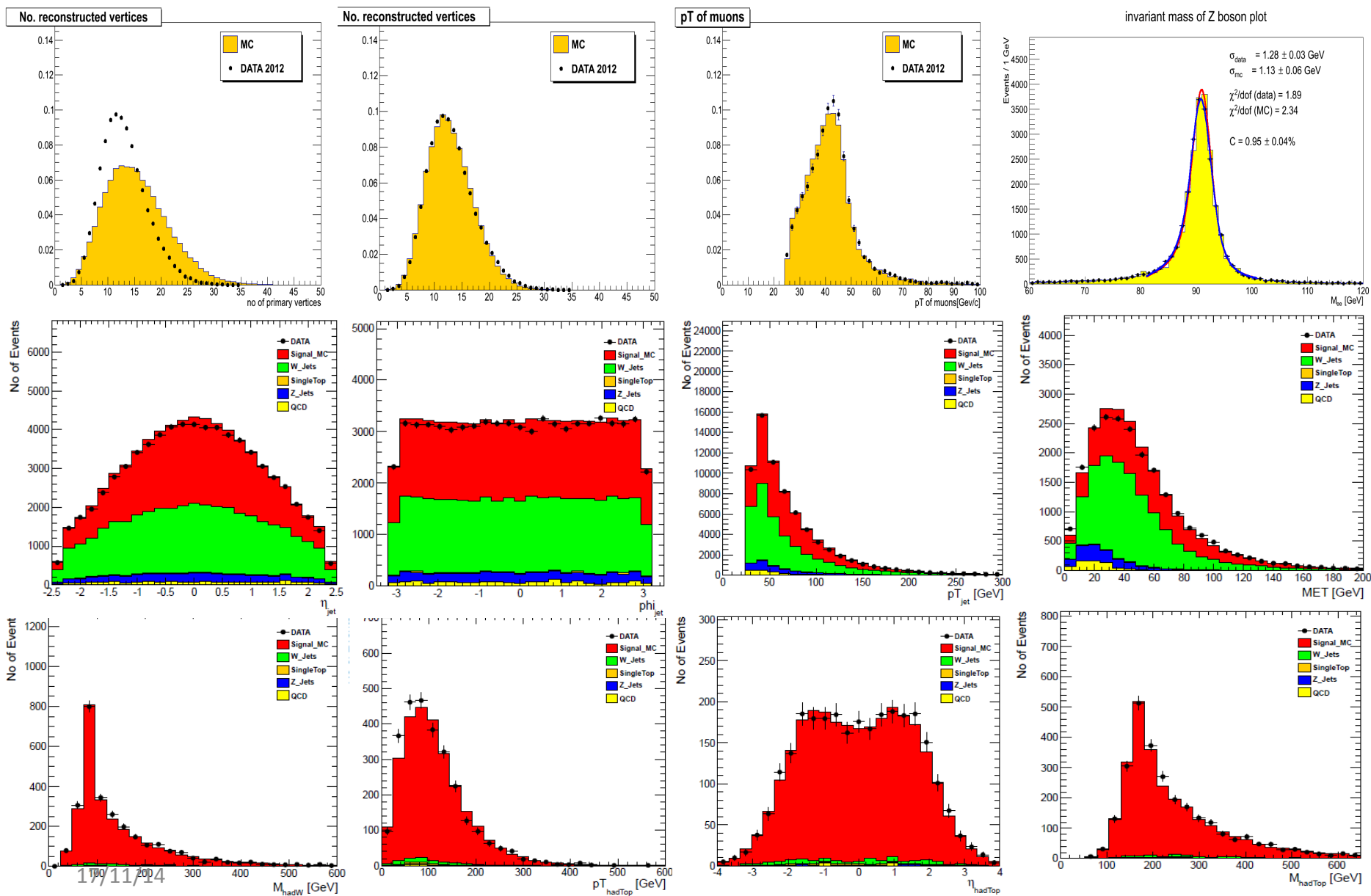
Some Physics Analyses covered at NCP

- Study of associated production of top quark and Z-boson using CMS data collected in 2012 at 8 TeV center-of-mass energy
- Z cross section measurement in muon channel
- Measurement of the single top t-channel charge asymmetry
- Study of χ_c states
- Energy peaks to calibrate particle masses
- DiLeptonic Top Quark Pair Cross-Section Measurement
- GEM Simulation: physics and performance studies
- Starting:
 - Work on SUSY and Beyond-the-Standard-Model (BSM) searches in multilepton final states
 - High pT muons Performance study
- Plan for SUSY searches on the basis of experience gain from top physics analysis

Highlights from different analysis



Highlights from different analysis



Output of CMS project at NCP

- **EHEP Staff:** 4 PhD, 4 Non-PhD, 3 Engineers
- **Students:** 7 PhD, 10 M.Phil
- **Total thesis on CMS project:**
 - Completed three PhD's and 27 M.Phil theses
 - both on hardware and physics analysis
 - Students were involved in commissioning of the RPC's as well as testbeam

Students Affiliation
Quaid-e-Azam University
Int. Islamic University
University of Karachi
Riphah University
Hazara University
Kohat University
Federal Urdu University

- Exp. Particle Physics is a diverse subject, students get experience of working are well equipped with physics concepts, hardware skill, analysis techniques and statistical methods, advance programming and computing skills, simulation and modeling, as well as experience of working in a large scientific collaboration
 - Hence successful in academic, research as well industrial environment

LHC Schools at NCP

NATIONAL CENTRE FOR PHYSICS
Islamabad

Physics@LHC

Announcement
FIRST SCHOOL ON LHC PHYSICS

12 - 30 October, 2009

The Experimental High Energy Physics Group of National Centre for Physics (NCP) is organizing the First School on Large Hadron Collider (LHC) Physics in collaboration with Pakistan Atomic Energy Commission. The main objective of this school is to prepare a group of trained young scientists who will analyze the data generated at LHC using CMS (Compact Muon Solenoid) and ALICE (A Large Ion Collider Experiment) Detectors. This will provide them an opportunity to carry out research in the fields of High Energy and Heavy Ion Physics. The first two weeks of this school will cover the Physics and Topics related to the CMS detector, whereas in the third week, the subject of the Heavy Ion Physics and ALICE detector will be discussed. At the end of the school, certificates of participation will be awarded to the participants.

Venue and Date
National Centre for Physics, QAU Campus, Shabdrata Valley Road, Islamabad
October 12th - 30th 2009 (Five days a week)

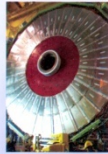
Registration
Registration Form: Available at NCP's website at the following link
<http://www.ncp.edu.pk/dsp.htm>
Registration Deadline: 20th September 2009

Participants
A total of 50 participants will be invited from all over the country to attend this school. All the interested students of M.Sc, MS, M.Phil or Ph.D who intend to participate in this school may apply.

Who can Participate
Students of M.Sc, MS, M.Phil or Ph.D
Scientists of academic and R&D organizations.

Topics to be Covered
First two weeks (October 12th - 19th 2009):

- Introduction to LHC Project
 - LHC Machine
 - CMS Detector
 - RPC Detector
 - Grid Computing
- Physics potentials of LHC:
 - Standard Model
 - Heavy Flavor
 - Higgs Searches
 - New Physics (Supersymmetry, Extra-dimensions)



ANNOUNCEMENT
SECOND SCHOOL ON THE LHC PHYSICS
April 25th - May 4th 2011
National Centre for Physics, Islamabad

Experimental High Energy Physics Group of National Centre for Physics is organizing the Second School on Large Hadron Collider (LHC) Physics. The main objective of this school is to prepare a group of trained young scientists who will analyze the data generated at LHC using CMS (Compact Muon Solenoid) Detector. This will provide them an opportunity to carry out research in the field of Experimental High Energy Physics. The school will cover the Physics and data analysis techniques related to the CMS detector. At the end of the school, certificates of participation will be awarded to the participants.

Participants
Students of M.Sc, MS, M.Phil, Ph.D and Scientist of Academic and R&D organizations can apply. A total of 50 participants will be invited all over the country to attend this school.

Topics to be Covered


- Introduction to Standard Model of Particle Physics
- Introduction to LHC Project
- Introduction to CMS Detector
- Analysis Tools for Data
 - Linux, C++
 - Event Generator, Pythia
 - CMSW
 - Python
 - ROOT
 - Grid Computing

Speakers
Riazuddin
Hafeez Hoorani
Shamona Fawad
Muhammad Irfan Asghar
Tamoor Khushid
Muhammad Ahmad
Wajid Ali Khan

Organizers
Shamona Fawad
Muhammad Asif
Wajid Ali Khan
Muhammad Ahmad
Tamoor Khushid
Muhammad Irfan Asghar

Contact Person
Shamona Fawad
National Centre for Physics
Quaid-i-Azam University Campus,
Shabdrata Valley Road, Islamabad
Contact: 051-3027337
E-mail: fh-course@ncp.edu.pk

Registration Form
Registration Form Available at NCP website
<http://www.ncp.edu.pk/apply.htm>
Registration Deadline
20 March, 2011



- ❑ EHEP Group of NCP organize Schools on LHC Physics every year
- ❑ Main objective of these Schools is to prepare a group of trained young scientists who could analyze LHC
- ❑ We are organizing “**First ICTP-NCP International School on LHC Physics**” from 25 August to 05 September, 2014

First School on LHC Physics

ANNOUNCEMENT
3rd SCHOOL ON THE LHC PHYSICS
08 - 19, October 2012
National Centre for Physics, Islamabad

Large Hadron Collider (LHC) has performed very well and beyond expectations. LHC has delivered 5 fb⁻¹ of data in 2011, which is much more than the expected value of 1 fb⁻¹ in 2011. Today LHC is running at higher energy and at higher luminosity than ever achieved in history. The current goal of LHC is to achieve 15 fb⁻¹ or more data in 2012.

Experimental High Energy Physics Group (EHEP) of National Centre for Physics is organizing the Third School on Large Hadron Collider (LHC) Physics. This will provide young scientists an opportunity to understand the tools required to carry out research in the field of EHEP. The school will cover the Physics and data analysis techniques related to the CMS detector. At the end, certificates of participation will be awarded to the participants.

Participants
Students of M.Sc, MS, M.Phil, Ph.D and Scientist of Academic and R&D organizations can apply. A total of 50 participants will be invited from all over the country to attend this school.

Topics to be Covered

- Standard Model of Particle Physics
- Introduction to LHC Project
- Introduction to CMS Detector
- Data Analysis Tools
 - Linux, C++
 - Event Generator, Pythia
 - CMSW
 - Python
 - ROOT
 - Grid Computing

Invited Speakers
John Ellis
Rolf Heuer
Jae In Im
Gigi Ridolfi
Roberto Tenchini



Organizers
Ashfaq Ahmad
Muhammad Irfan Asghar
Muhammad Irfan Shah
Jamina Bahir Butt
Shamona Fawad
Muhammad Gul
Qamar ul-Hassan
Wajid Ali Khan
Ishar Sagheer

Chair of the School
Roberto Tenchini
University of Pavia, Italy
Email: roberto.tenchini@cern.ch

Hafeez R. Hoorani
National Centre for Physics
Email: hafeez.hoorani@ncp.edu.pk

Registration Form
Registration Form Available at NCP website
<http://www.ncp.edu.pk/first-school-on-the-lhc-physics.php>
Registration Deadline
10 September 2012

Contact Person
Muhammad Irfan Asghar
Contact: 051-3077300 ext 488
Email: irfan.asghar@ncp.edu.pk
fh-course@ncp.edu.pk

Third School on LHC Physics

Second School on LHC Physics

The Abdus Salam International Centre for Theoretical Physics (ICTP)

ANNOUNCEMENT
FIRST ICTP-NCP INTERNATIONAL SCHOOL ON LHC PHYSICS
25 August - 05 September 2014
Islamabad, Pakistan

The Abdus Salam International Centre for Theoretical Physics (ICTP, Italy) in collaboration with the National Centre for Physics (NCP) Pakistan is jointly organizing the First ICTP-NCP International School on LHC Physics to be held in Islamabad from 25th August to 05th September, 2014. The school will cover pedagogical introduction and research activities for the training and intellectual advancement of young researchers and students.

TOPICS TO BE COVERED IN THE COLLEGE INCLUDE

- Introduction to Standard Model of Particle Physics
- Introduction to LHC Project
- Introduction to CMS Detector
- Physics Beyond the Standard Model
- Physics Analysis at CMS Experiments
- Data Analysis Tutorial

PARTICIPATION
Scientists and students from all countries, that are members of the United Nations, UNESCO or IAEA, may attend the activities. As a regional activity, priority will be given to graduate students, post-doctoral researchers, faculty and research scientists from Asia. Participants from developed countries are also welcome to attend. All activities will be conducted in English.

As a rule, travel and subsistence expenses of the participants should be borne by their home institutes. The candidates should make every effort to secure support for travel (or at least half-price). However, limited funds are available for participants (less than 45 years of age) from developing countries who are also working in a developing country. Such support is available for only those who will attend the entire activity.

There is no registration fee.

HOW TO APPLY
The application form can be accessed at:
<http://agenda.ictp.int/en.php?2632>
Once in the website, comprehensive instructions will guide you step-by-step, on how to fill out and submit the online application form no later than 15 April 2014. Recommendation letters are encouraged for students and younger researchers.

**Activity Secretariat: e-mail: fh-course@ncp.edu.pk
Ph: +92-51-3077300
Course web page: <http://agenda.ictp.int/en.php?2632>
ICTP Home Page: <http://www.ictp.acad.edu>**

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Application deadline
19 April 2014



First ICTP-NCP International School on LHC Physics

1- First School on LHC Physics:

Date: 12th to 30th October 2009

No of Participants. 60

2- Second School on LHC Physics:

Date: 25th April – 14th May 2011

No of Participants. 45

3- Third School on LHC Physics:

Date: 08-19 November 2012

No of Participants. 50