Ajay Kumar

Ph. D. in experimental High Energy Physics (University of Delhi)

✉ a.kumar@cern.ch ☎ +1-765-607-3988 http://home.fnal.gov/ ajay/AboutMe.html

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Career Objective

To make the most of my potential and discover new horizons in the field of research. To utilize my perfect blend of training in data analysis, experimental particle physics and collaboration work. Possess the ability and experience of working in large collaborations and have good organizational and communication skills. My long term career objective is to become a good teacher.

Education

- **University of Delhi** Delhi, India
  Ph.D. in Experimental High Energy Physics *Oct 2010 - May 2015 (Thesis Submitted).*
  - Thesis Topic: **"Search for the SM Higgs boson in the H → WW → lνjj & Probe of WW Production in Vector Boson Fusion Topology in the CMS Experiment at the LHC"**
  - Thesis Supervisor: **Dr. Kirti Ranjan**, Associate Professor, University of Delhi
  - Written courses: Particle Physics, Advanced Numerical Techniques, Accelerator physics, Scattering Theory.
  - Research Scholar at University of Delhi, India (Since Oct 2010 till date.)
  - Research Intern. at LPC, Fermilab, USA (One and half year, Academic session: 2012-2013, 2013-2014
  - Visiting PhD student as User at CERN (One year, 2012, 2013, 2014)
- **University of Delhi** Delhi, India
  M.Sc. Physics, Specialization in Electronics *2008 - 2010*
  - Secured first division in Master of Science in physics.
  - Successfully conceptualized, assembled and demonstrated a Project on "Micro-controller based fire security system".
- **University of Delhi** Delhi, India
  B.Sc.(Hons.) Physics *2005 - 2008*
  - Awarded certificate of merit on topping the college in Bachelor of Science (Hons.) in physics.
  - Written courses: Quantum Physics, Classical physics, Mathematical physics, Statistical physics, Electromagnetic theory, Semiconductor Physics, Electronics.

Research Experience

- **Physics Analysis:**
  - **Search for the SM Higgs boson**: Since 2011 in collaboration with LPC lnujj group, I have worked on various aspects of the search for the SM Higgs boson decaying to WW semileptonically ($H \to WW \to \ell\nu jj$), where one W boson decays leptonically and hence allows for triggering of events, while other W boson decays hadronically making this final state to possess second highest production cross-section times branching ratio over whole high mass range of the Higgs boson. The presence of two jets brings in large background contributions from W+jets process and thus makes this analysis challenging at the LHC. This analysis have evolved over years in terms of sophistication of techniques, understanding of signal and physics outreach.
    - Worked in collaboration with experts from Fermilab and CERN and helped with simulation of signal and backgrounds, objects selections, data-processing, multivariate optimization (likelihood method), data-driven background estimation through unbinned maximum likelihood fit to data, limit extraction and systematic studies.
    - Did feasibility study of Higgs at 125 GeV in this final state.
    - Lead to approval of this analysis with full RUN 1 data through talk in Higgs working group meeting. This analysis recently got submitted to Journal of High Energy Physics in combination with other High mass Higgs analysis.
  - **WW+WZ cross-section measurement and aTGC study**: The gauge symmetry of the Standard Model (SM) fixes the triple gauge boson couplings that determine the self-interactions of electroweak gauge vector bosons V (=W,Z). The pair production of vector gauge bosons allows a direct test of the electroweak sector of the SM. Observation of anomalous triple gauge boson couplings would be an indication of physics beyond the SM. The measurement of WW+WZ diboson production cross section in $p-p$ collisions at $\sqrt{s} = 8\ TeV$ in the semileptonic final state at the Large Hadron Collider (LHC), where one W boson decays leptonically while the other vector boson V decays hadronically, giving rise to either two energetic jets (jj) or a merged jet (J) in the final state is being performed.
    - Worked in collaboration with experts from Fermilab on its various aspects such as MC simulation, data processing, systematics study, data driven background estimations etc.
    - Lead to pre-approval through talk in SMP General meeting at CERN, and pushing for publication.
  - **Vector boson scattering**: One extremely important process of the SM, which is related intimately to EW symmetry breaking, is that the gauge bosons (γ, W and Z) interaction with each other through quartic interactions. At the LHC, the $WWWW$ interactions can be studied through the radiation of W bosons from quarks, which is a rare process. The final state of this analysis is characterised by two forward jets with large pseudorapidity gap, coming from opposite hemisphere and have large dijet invariant mass. A special jet selection technique is developed with emphasis on having

higher signal efficiency. This work is performed for the first time in the CMS in semileptonic decay mode.

  - I am leading this analysis. I have been rigorously working on setting up the software, finalizing with selections, backgrounds estimation methods etc. I did simulation and generator level study to understand the signal, developed a special jet selection technique, set-up Roofit based fitting procedure for MC modelling, background estimation, signal extraction and systematic study.
  - Also, explored possibility of reconstructing quark-gluon likelihood tagger, another likelihood discriminator to separate between signal and backgrounds.
  - Finished with feasibility study of this analysis at 8 TeV. I hope to continue with this analysis at 13 TeV. The machinery is ready to analyse 13/14 TeV data for this study. Currently I am advising a PhD student who is working on this analysis at 13 TeV data.

- **Search for heavy vector like top quark partner in single lepton final state**: This is my new current project. The SM comprises of three generations of chiral quarks. Many theoretical extensions of physics BSM posit the existence of vector-like quarks. Such quarks occur in models like the Little Higgs, extra dimensions or the minimally supersymmetric standard model. These quarks have the same left and right quantum numbers. They could be an SU(2) singlet or a doublet with the same left and right couplings. This condition on the couplings makes the interactions of these quarks purely vector-like. We look at a minimal extension of the SM by introducing a vector-like top-like (of charge 2/3) heavy quark that couples to the third generation. The model we consider has only two parameters: the mass of the new heavy quark and the mixing with the third generation, parametrized as an angle. Such vector-like fermions in the Little Higgs model are introduced to cancel the Higgs mass quadratic divergence which results from the interaction of Higgs with the top quark. We consider decays of the this heavy vector-like quark T into three possible decay modes: $T \to bW$, $T \to tH$ and $T \to Zt$. My focus on for this analysis is to set up multivariate (Boosted Decision Treee based) shape based analysis chain using all the sofisticated technique of jet-substructure for boosted top, W and H tagging.
- **Detector Work:**
  - **Alignment parameter error (APE) estimation:** This method is based on minimization of residual width to Ideal/Design value.
    - This method helps in devising an APE value for optimal performance of tracker.
    - It can be also used to validate any improved alignments by comparing given geometry with ideal geometry.
    - I was the **main contact expert** for the CMS since 2011 till April 2015. I worked on its development and maintenance since 2011.
  - **Tracker Validation:** Worked on data-driven track based offline validation of tracker, monitoring of cosmic rates, primary vertex validations. Took weekly shift role in 2012 CMS running for tracker validation.
  - **CMS Operation:** Worked on operation of CMS running, data recoding and validation by taking DQM offline shifts, tracker offline shifts in 2012.

- **Communication and collaboration:**

- Strong communication/presentation skills: presented data clearly and confidently to both small and large groups, at home or abroad.
- Collaborated and communicated at all professional levels, and with people from diverse origins and cultures. Can work both independently and in team settings.

Publications

1. Publication list enclosed.

Participation in Workshops, Schools and Conferences

- **LHCP14** Columbia University, New York City, USA
  Large Hadron Collider Physics Conference *June 2-7, 2014*
- **FNAL Software School** LPC Fermilab, USA
  Programming Reconstruction Software for Large Computing Projects Course *August 4-8, 2014*
- **HCPSS2012** Fermilab, Batavia (United States)
  7th Fermilab-CERN Hadron Collider Physics Summer School *August 6-17, 2012*
- **Lepton-Photon 2011** TIFR, Mumbai
  The XXV International Symposium on LP Interactions at High Energies *August 22-27, 2011*
- 47^{th} **Fermilab user's meeting** LPC Fermilab, USA
  New Perspectives Conference *June 9-10, 2014*
- **SERC-EHEP 2011** VECC, Kolkata
  VIII SERC-EHEP School held at VECC campus *20th June to 10th July 2011*
- **XX DAE-BRNS** Santiniketan, Kolkata
  High Energy Symposium *January 13-18, 2013*
- **LPC Workshop** LPC Fermilab, USA
  JetMET at High Pile-up, Preparation for LHC Run II *January 27-29, 2014*
- **As a Co-facilitator of Jets exercise for CMSDAS14** LPC Fermilab, USA
  CMS Data Analysis School *January 8-12, 2014*
- **QCD Tools for LHC Physics** LPC Fermilab, USA
  From 8 to 14 TeV. What is needed and why? *November 14-16, 2014*
- **LPC Workshop** LPC Fermilab, USA
  Upgrade TP Performance Studies Group *May 8-10, 2014*
- **Various HATS@LPC** LPC Fermialb, USA
  covering wide range of topics on Software, Hardware and Upgrade August, 2013 - August 2014

Skills

- **Programming languages:** C/C++, Python, Shell, LaTeX, html, Fortran, Pascal etc.
- **Numerical and Statistical Analysis:** Machine Learning, Optimization, Hypothesis testing, RooFit, RooStats etc.
- **Event generator:** Using experience with Phantom, Madgraph, POWHEG, Pythia, VBF@NLO, MC@NLO.
- **Operating Systems :** Linux, UNIX, MacOS, Windows 7/8.
- **Applications:** CMSSW, ROOT, PyROOT, Gnu-plot, git, vim, LaTeX, Open Office, MS Office.
- I have learned excellent presentations and communications (verbal and written) skills, troubleshooting and debugging skills, teams skills.
- Adapted to living abroad, learned perseverance and self-motivation.

Achievements and recognitions

- Primary author of 3+ and co-author of 109+ (h-index = 31) papers published in peer reviewed journals.
- Financial support by Department of Science and Technology (DST) to visit CERN for 6 months/year from 2011 till 2015.
- Financial support by Fermilab for LPC visit during 2013-2014 as "research Intern" and during 2012-2013 as visiting scientist.
- The Council of Scientific & Industrial Research (**CSIR**), National Eligibility Test NET,June 2010 & December 2010
- Graduate Aptitude Test in Engineering (**GATE**) 2010
- Joint Entrance Screening Test (**JEST**) 2010
- **First position** in BSc (H) physics in Acharya Narendra Dev College,University of Delhi
- Won fourth prize for meritorious performance in **Youth Parliament at National Level** in 1998-1999 for excellent oratory skills.
- Won several awards at Jawahar Novodaya Vidyalaya School, Rewar, Nawada in **Extempore, Quiz, debates etc.**

Projects

- Pre-Ph.D. Project under course work in **"Particle Physics"** on the topic **"Deep Inelastic Scattering"** under the able guidance of Prof. D. Choudhury and Dr. Kirti Ranjan
- Pre-Ph.D. Project under course work in **"Statistics & Computer Applications"** On the topic **"Study of Longitudinal beam dynamics in Acclector using Numerical Methods & Error Analysis"** under the able guidance of Dr. Awadhesh Prasad and Dr. Kirti Ranjan.
- M.Sc. Project: **"Microcontroller based Fire security system in petrochemical industries"** under the able guidence of Dr. Amithabh Mukharji, Dr. Vinay Gupta, Dr. K. Srinivashan at Electronics lab, Department of physics and Astrophysics, University of Delhi.
- BSc. Project: "Study effect of UV radiation on ZnO Thin films and fabrication of ZnO films using sputtering methods" under the able guidance of Prof. Vinay Gupta, at Department of physics and Astrophysics. University of Delhi.

Personal Information

- Language proficiency: Fluent in English and Hindi.
- Citizenship: India
- Marital status: Unmarried
- Gender: Male
- Date of Birth: 10th October 1985
- My codes developed through in recent years: https://github.com/ajaykumar649

List of Publications

Publication in Peer Reviewed Journals

Publications as Primary Author

1. "Search for a Higgs boson in the mass range from 145 to 1000 GeV decaying to a pair of W or Z bosons", **Ajay Kumar**, K. Ranjan et al, **JHEP 1510 (2015) 144**, CERN-PH-EP-2015-074 ; CMS-HIG-13-031. Corresponding to CMS PAS HIG-13-027 and CMS AN-2012/463
   Primary Authors: **Ajay Kumar**, Kirti Ranjan et al.

2. "Search for $WW\gamma$ and $WZ\gamma$ production and constraints on anomalous quartic gauge couplings in pp collisions at $\sqrt{s} = 8$ TeV "
   Published 25^{th}August 2014: **Phys. Rev. D 90, 032008**, CMS-SMP-13-009, CERN-PH-EP-2014-046
   Corresponding to CMS AN-2012/479
   Primary Authors: **Ajay Kumar**, Kirti Ranjan et al.

3. "Alignment of the CMS tracker with LHC and cosmic ray data "
   Published 6^{th}June 2014: **The CMS collaboration 2014 JINST 9 P06009**, Primary Authors: **Ajay Kumar**, Kirti Ranjan et al.

Total Number of Publications as of $4^{th}November$ 2015 **:** 1512.
(List can be found here: https://inspirehep.net/search?p=exactauthor%3AAjay.Kumar.1.

International conferences

Oral Presentation

- Probe of WW Production in vector boson fusion topology at APS2014, April Meeting of the American Physics Society, 5-8 April 2014, Savannah, GA (United States),

Poster Presentation

- Large Hadron Collider Physics Conference, Columbia University, New York City (United States), 2-7 June 2014, Poster Presentation on the 'Measurement of electroweak vector boson production in pp collision at CMS detector, LHC'.

Proceedings

- 'Measurement of Electroweak Vector Boson Pair Production in $p-p$ Collision with the CMS Detector at LHC', Ajay Kumar, arXiv:1409.3414 [hep-ex], Proceedings of the Second Annual LHCP, CMS-CR-2014/193, September 12, 2014.

National conferences

- Oral Presentation on "Measurement of electroweak vector boson pair productions in pp collision at CMS detector, LHC",New Perspectives Conference, June 9-10 2014, Fermi lab, Batavia (United States).

- Oral Presentation on "the Search for the Standard Model Higgs boson in $H \to WW \to \ell\nu qq$ decay mode in the CMS experiment", XX DAE-BRNS High Energy Physics Symposium, Visva-Bharati, Santiniketan, West Bangal (India).

CMS Public Documents

1. "Search for a Standard Model-like Higgs boson decaying into WW to $\ell\nu jj$ in $p-p$ collisions at $\sqrt{s} = 8TeV$", **Ajay Kumar**, Kirti Ranjan et al., **CMS-PAS-HIG-13-027**.

2. "Search for a Standard Model-like Higgs boson decaying into WW to $\ell\nu q\bar{q}$ in $p-p$ collisions at $\sqrt{s} = 8TeV$", **Ajay Kumar**, Kirti Ranjan et al., **CMS-PAS-HIG-13-008**.

3. "A Search for $WW\gamma$ and $WZ\gamma$ production in pp Collisions at $\sqrt{(s)} = 8TeV$", **Ajay Kumar**, Kirti Ranjan et al., **CMS-PAS-SMP-13-009**.

4. "Search for the Standard Model Higgs boson in the H to WW to $\ell\nu jj$ decay channel in pp collisions at the LHC", **Ajay Kumar**, Kirti Ranjan et al., **CMS PAS HIG-12-046**.

5. "Search for the Standard Model Higgs boson in the H to WW to $\ell\nu jj$ decay channel" **Ajay Kumar**, Kirti Ranjan et al., **CMS-PAS-HIG-12-021**.

CMS Internal Documents

1. "Measurement of $WW + WZ$ cross section and investigation of anomalous gauge boson couplings in semi-leptonic decays in pp collisions at s=8 TeV", **Ajay Kumar** et al., **CMS AN-2012/464**.

2. "Search for an SM-like Higgs boson in the $H \to WW \to \ell\nu jj$ decay with the full 2012 data", **Ajay Kumar** et al., **CMS AN-2012/463**.

3. "Measurement of $WW\gamma + WZ\gamma$ cross section and investigation of anomalous gauge boson couplings in semi-leptonic decays in pp collisions at ps = 8 TeV", **Ajay Kumar** et al. **CMS AN-12-479**.

4. "Searches for new physics in the $WW \to \ell\nu j$ nal state with merged W bosons", **Ajay Kumar** et al., **CMS AN AN-12-381**.

5. "Semi-leptonic decay of HWW at high mass in exclusive jet bins", **Ajay Kumar** et al., **CMS AN-2013/414**.

6. "Search for the Standard Model Higgs boson in the $H \to WW \to \ell\nu jj$ decay with 2012 HCP data", **Ajay Kumar** et al., **CMS AN-2012/368**.

7. "Search for the Standard Model Higgs boson in the $H \to WW \to \ell\nu jj$ decay with 2012 data",**Ajay Kumar** et al., **CMS AN-2012/193**.

8. "Search for high mass exotic resonances decaying to WW in the semi-leptonic channel", **Ajay Kumar** et al., **CMS AN-13-139**.

9. "Search for a Higgs Boson in $qqH \rightarrow W[lnu]W[jj]$ + 2 Tag Jets at s = 8 TeV", **Ajay Kumar** et al., **CMS AN-2012/465**.

10. " Measurement of WW+2-jet production at $\sqrt{s} = 8TeV$ and investigation of events with vector boson fusion topology", **Ajay Kumar** et al., **CMS AN-2012/466**.

11. "Search for a Higgs Boson in $qqH \rightarrow W[lnu]W[jj]$ + 2 Tag Jets", **Ajay Kumar** et al., **CMS AN-2012/139**.

12. "Search for Standard Model Higgs in $H \rightarrow WW$ semileptonic channel in low mass higgs region", **Ajay Kumar** et al., **CMS AN-2012/406**.

CMS Internal Presentations

1. CMS Internal talk: Oral talk on "Approval of $H \rightarrow WW\ell\nu jj$ Analysis" at Off-week Higgs meeting (Weekly) for ICHEP approvals, 17 July, 2014, CERN, Geneva (Switzerland).

2. CMS Internal talk: Oral talk on "Recent results on HWW and probing WW production in VBF topology, both with semileptonic final states" at LPC Physics Centre Topic of the Week Seminar, 31st July 2014, Fermilab, Batavia (United States).

3. CMS Internal Talk: Oral talk on "Pre-Approval of Measurement ofWW+WZ cross section in semi-leptonic decays in pp collisions at $\sqrt{s} = 8TeV$ and limits on anomalous TGCs", 10th February 2015, CERN, Geneva (Switzerland).

4. I have presented my work in CMS Collaboration via more that 160 Presentations, which can be found here: http://indico.cern.ch/