Undergraduate Research at Argonne National Laboratory

Jimmy Proudfoot
Argonne Distinguished Fellow
Group leader of the ATLAS (LHC) Group in the High Energy Physics Division at Argonne National Laboratory

First A few words about me and my research

Thesis research: Muon-proton scattering at Fermilab – missed finding evidence for intrinsic charm in the proton as we only had a 2.8 sigma effect!

Postdoc at DESY (Hamburg): e^+e^- scattering - quark hadronization, QCD, search for top, gluon spin

Joined Argonne and CDF: ppbar collisions at 1.8TeV - electroweak physics, top search and discovery

Moved from CDF to ATLAS: pp collisions at 7-8TeV - electroweak physics, boosted bosons, Higgs discovery

Along the way:
Lots of software: low and high level assembler, Fortran, C, C++, database and calibration systems, software trigger, and many performance studies and optimization (electromagnetic shower shapes, signal reconstruction, jet energy measurement)

Lead the design of a calorimeter for the (cancelled) SSC
One of the leaders in the team that built the ATLAS Tile Calorimeter

Science Undergraduate Laboratory Internships (SULI): http://science.energy.gov/wdts/suli/

The Science Undergraduate Laboratory Internship (SULI) program encourages undergraduate students to pursue science, technology, engineering, and mathematics (STEM) careers by providing research experiences at the Department of Energy (DOE) laboratories. Selected students participate as interns appointed at one of 16 participating DOE laboratories. ***They perform research, under the guidance of laboratory staff scientists or engineers, on projects supporting the DOE mission.***

The U.S. Department of Energy (DOE), Office of Science provides the funding for this program.

Why is the DOE involved in education?
For over 60 years the Department of Energy has supported the education and training of scientists, engineers, and technology specialists to maintain the scientific and technical workforce needed to address the Department's and Nation's complex challenges in energy, national security, the environment, and discovery science.

Eligibility: Main Criteria – check http://science.energy.gov/wdts/suli/ for more details

Must be currently enrolled as a full-time undergraduate student at an accredited institution, and also have completed at least one year as a matriculating undergraduate student at the time of applying. Special criteria for Graduating Seniors.

Must have an undergraduate cumulative minimum Grade Point Average (GPA) of 3.0 on a 4.0 scale for all completed courses as a matriculating student. (2.95 is OK, 2.94 isn't)

Must be 18 years or older at the time the internship begins.

Must be a United States Citizen or Permanent Resident Alien at the time of applying.

Must have earned a high school diploma or General Education Development (GED) equivalent at the time of applying.

Additional Eligibility requirements:

Applicants are limited to participation in the SULI program to no more than two internships.

Applicants can apply to the SULI program a maximum of three times.

SULI Program: application details {see http://science.energy.gov/wdts/suli/}

Applications for the SULI program are solicited annually for three separate internship terms. ***Internship appointments are 10 weeks in duration for the Summer Term (May through August)*** or 16 weeks in duration for the Fall (August through December) and Spring (January through May) Terms. Each DOE laboratory offers different research opportunities; not all DOE laboratories offer internships during the Fall and Spring Terms. ***{although we - i.e. ANL - consider applications to all terms, my focus today is however on the summer term}***

Follow the application instructions precisely

Respect the application deadlines - in 2013 these were:

At the submission deadline (shown in red) the application system will close, and no materials will be accepted after the submission deadline has passed. **The Application System closes at 5:00 PM Eastern Time.**

SULI Internship Term:	Spring 2014	Summer 2014*	Fall 2013
On-line Application Opens	August 6, 2013	October 18, 2013	May 1, 2013
Applications Due	October, 1, 2013 5:00 PM ET	**January 10, 2014** **5:00 PM ET**	June 12, 2013 5:00 PM ET
Offer Notification Period Begins on or around	October, 15, 2013	January 20, 2014	June 24, 2013
All DOE Offers and Notifications Complete	November 29, 2013	April 1, 2014	August 1, 2013

SULI Program: What is expected from you

1) **Oral or Poster Presentation**:

All participants are required to deliver either an oral or a poster presentation before an appropriate peer group, based upon the participant's internship research project activities.

2) **One-page peer review:**

All participants must provide a one-page written peer review of another SULI intern's talk or poster.

3) Abstract for General Audience:

All participants are required to complete and submit an abstract (300 word limit) summarizing their research experience at a level appropriate for a general audience.

4) Research Report Paper:

All participants must complete and submit a 1500 – 3000 word research report paper describing their project related internship activities, submission of the research report paper must be made prior to the end of your appointment.

SULI Program: How to find interesting projects & opportunities

Selecting a Host DOE Laboratory and Research Project
Applicants must **identify their first and second choice laboratories** indicating where they would like to do their research internship.
Applicants must also **select a research area(s) of interest matching one of those listed for a particular laboratory's ongoing research programs**. This choice is made at the sole discretion of the applicant.

Prior to selecting a host laboratory and research area, applicants should read carefully the research areas available at each DOE laboratory by reading the brief information provided below AND reviewing the research information on the laboratory website.
See: http://science.energy.gov/wdts/suli/how-to-apply/selecting-a-host-doe-laboratory/

Information on the Argonne summer internship can be obtained from the following link:
http://www.dep.anl.gov/p_undergrad/summer.htm
A key link from this page is the Research Participation Catalog.

How are applications judged?

Applications will be assessed based upon the applicant's:

performance in completed academic coursework, and especially coursework in science, technology, engineering, or mathematics (STEM);

strength of recommendation letters;

expressed scientific interests;

and the applicant's background, experience, accomplishments, and interests as they relate to the research programs at the host laboratories.

More on this below

Educational programs at Argonne National Laboratory:

All temporary educational appointments for students and faculty at the pre-college through university levels must be made through Educational Programs. SULI is only one program. The summer intern program is described at http://www.dep.anl.gov/p_undergrad/summer.htm check for others at http://www.dep.anl.gov/

Appointments within educational categories are primarily designed for the educational benefit of students and faculty from educational institutions from the United States and abroad. Must have:

Realistic and achievable research goals

Balance between structure (directed work) and independence (self-directed work)

Designated Mentor (key element in program) to help intern work out what she/he should get from the internship experience

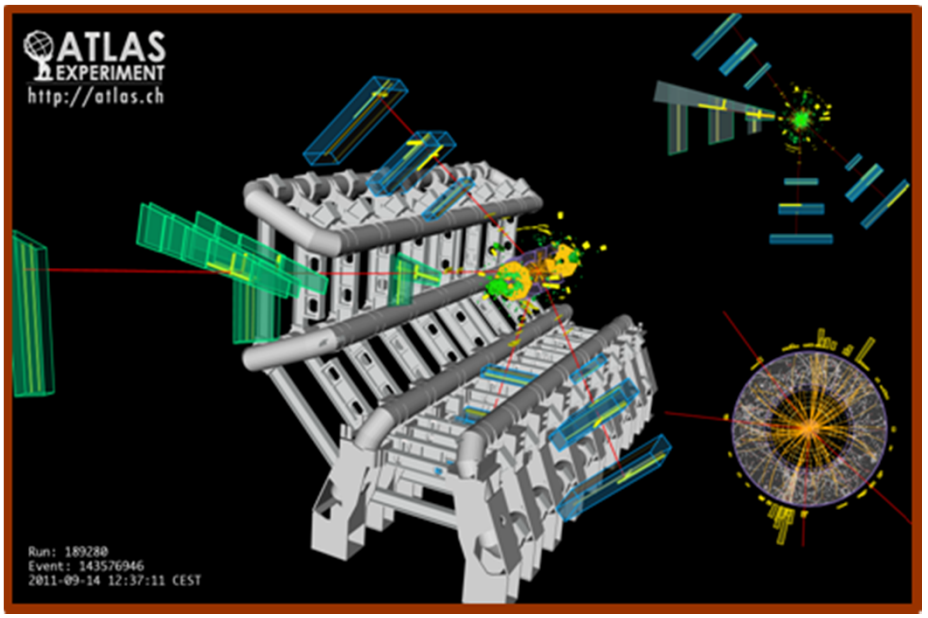
A key resource - The Research Participation Catalog: http://www.dep.anl.gov/p_undergrad/summer.htm

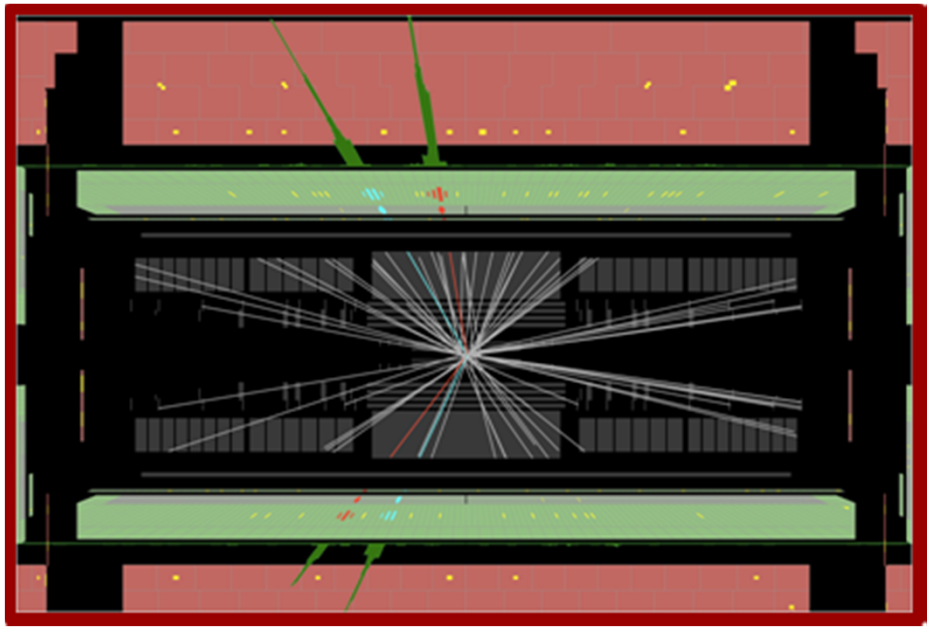
Example: Extract from ANL Research Participation Catalog - search within High Energy Physics, and then down to the ATLAS experiment (i.e. the one I work on)

The ATLAS experiment is investigating the behavior of matter, energy, space and time and the smallest distance scales ever probed. Located at the Large Hadron Collider at CERN, the European Organization for Nuclear Physics, near Geneva, Switzerland, ATLAS will observe the highest energy proton-proton collisions ever achieved: 14 TeV. ……. …… Argonne physicists' lines of investigation include studying Quantum Chromodynamics (the behavior of quarks and gluons), electroweak symmetry breaking and the question of why some particles have mass and others do not, … and searches for new physics in boosted systems …. the contributions of Argonne to the detectors systems can be found at:
http://atlaswww.hep.anl.gov/group/
We provide opportunities for students and faculty to get involved with computer simulation of physics processes, detector operations and monitoring associated with the Tile Calorimeter and Region of Interest Builder, upgrade R&D for new front-end calorimeter readout electronics and data link, and physics data analysis at what, with the discovery of what may be the missing piece in the puzzle of the Standard Model, is a unique point in time in the history of high energy physics.

i.e. the discovery of the Higgs Boson

Summer Interns in the ATLAS Group in the HEP Division





Past SULI Summer Interns in the ATLAS Group

2012
- Joshua Loyal (Duke)
- Lucas Mastalli-Kelly (Harvey Mudd)
- Zack Schut (Valparaiso)
- ***Jack Weinstein (Illinois) {Research Aid}***

2011
- Michael Erickson (College of New Jersey)
- Linus Marchetti (Carnegie-Mellon)
- Jack Weinstein (**Illinois**)

2010
- Zach Epstein (Duke)
- Andrew Johnson (Carnegie Mellon)
- Craig Levy (Northeastern)

2009
- Nathan Gardner (Lawrence Tech)
- Jason Boomsma (Anderson)

2013
- Stephanie Lona (**UIUC**)
- Kenny Umethum (**UIUC**)
- Kyle Strand (Winona State University)
- Andrea Clark (Beloit College)

This year we have offered SULI positions to 4 students:
1 in software and computing;
3 in physics research

How do we select the students?

We actually start by compiling a list of possible research topics

An example from last year:

I think I have a good idea for a summer-length project that could be interesting to the student, an analysis I am working on, and to the ATLAS collaboration as well.

Right now I am working on a ZGamma(gamma) analysis and one potentially non-trivial background to this process is a double parton interaction (DPI), where we would produce a Z boson in one interaction and two photons in another interaction. The cross section of the DPI is about 10% of the signal process of Zgg, so this background might not be negligible.

The project idea would be to investigate the yield of this process, and then to see if we can use vertex information from the two electrons and the pair of photons and see if we can possibly reject some of this background.

I thought it seemed neat,
Ben

Key issues in selection of topics are:

- **Feasibility**
- **Potential Accomplishments**
- **Potential Impact**

We also consider variations around the theme – this is RESEARCH and sometimes projects change and outcomes are not guaranteed

The list of possible topics this year – I

We take the DOE goals for the SULI program very seriously:
".. perform research, under the guidance of laboratory staff scientists or engineers, on projects supporting the DOE mission…"

New physics could manifest itself in the form of anomalous electroweak couplings. We are looking at two-photon production of pairs of W bosons…. All the datasets are analyzed with the Root/C++ framework.

In the next LHC running period the expected number of interactions per bunch crossing is expected to be on order 50…. This project would involve running the ATLAS beam spot software with different configurations and **determining the settings that give the best measurement resolution**.

The public ATLAS Higgs to gamma gamma dataset could be re-interpreted as a limit on the Higgs to b-quark coupling… work on a sensitivity study to determine if an analysis looking for a Higgs radiating off a b-quark in the initial state proton would be competitive with the current ATLAS limits….

Work on ROOT I/O improvements - Enhancements to ATLAS event persistence to allow navigation via ROOT TTreeIndex…. DataHeader optimization

Investigation of TileCal cell occupancies for very high-pT jets. Estimation of frequency of events in which TileCal modules contain >1 TeV energy from QCD SM processes. Look at different TileCal layers.

The list of possible topics this year -II

TileCal: To **understand the impact of non-uniform distribution of jet energies in TileCal modules**. This requires a calculation of correction factors (or weights) as a function of Eta and Phi, and calculation of resolution functions before and after such corrections.

Using our program for general searches of new physics in invariant mass distributions, process 2012 data. Last time we ran it in 2010 (and found boosted Z). We need to slim COMMON ntuple, fill electrons, muons, jet etc, and process the 2012 data. We can also improve it using ProMC file format and Michel Ericsson's new algorithm to identify peaks.

Convert the existing analysis (for example, inclusive direct photons) from ROOT Tree **to the ProMC format and benchmark data storage** (should see ~30% file size reduction). Benchamk the processing speed speed and investigate a parallel processing on a multiple cores

+ several others

The different projects require different skills and skill levels – we adjust them as necessary and only go forward with those that meet the requirements on **Feasibility; Potential Accomplishments; and Potential Impact**
The abbreviated project description is what you will see on an offer

What do you need on your application:

Essential:

Specify desire to work in our area of research, by:

- What you write on your form as requested research area (for example, it HAS to have High Energy Physics before someone in HEP will look at it)
- What you write in your essay
- What you write as your research interests

Good GPA and a record of appropriate math and science classes

Strong letters of support

Willingness to learn and work through problems which may not be clearly specified and will take some thinking

Highly Desirable:

Computing skills such as familiarity with a scripting language such as Python, C++, C, Java, LaTex… => we filter candidates on these skills,

- => but we are only looking for initial knowledge and do provide training to use the tools needed to perform the analyses

Familiarity with document processing and presentation tools such as PowerPoint, MSword and their equivalents in LibreOffice/Open Office/

Awards, broader areas of participation, prior research experience

What we (the group) provide includes:

Designated Mentor – will usually be the member of the group proposing the project

Project description, goal

Software tools as needed to perform the analysis

Help and training to perform the analysis (such as with the software tools and interpretation of the analysis variables, understanding how the detector works)

Group with whom to discuss problems and details, present results… laugh, drink coffee …..

Representative project from 2013: picked because in this case I was one of the co-mentors

The Project Goal: Understand the impact on Tile Calorimeter performance from parts of the detector which were off due to power supply problems and for which a correction algorithm had been implemented in software

The Approach: study energy density in events with large energy depositions in the Tile Calorimeter

Begin by defining type of plots to make and processing experimental data

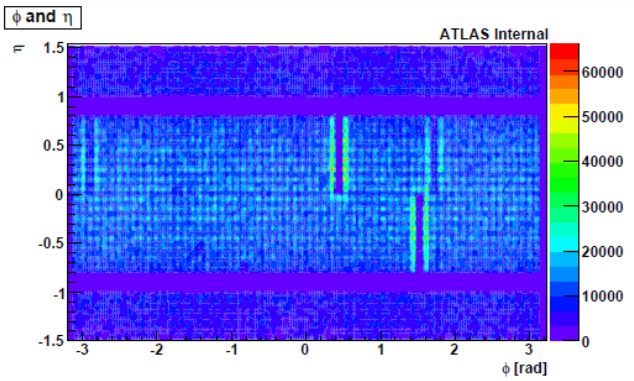
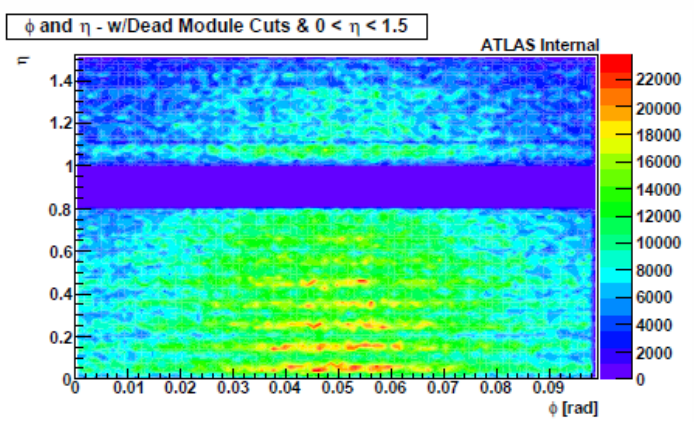


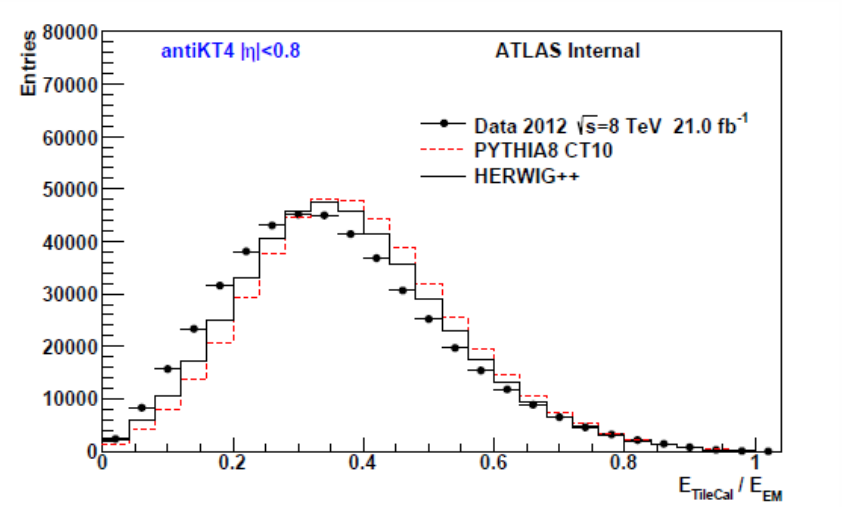
Figure 12: ϕ - η distribution for the total jet energy (in GeV) measured in TileCal. The distribution was obtained by summing up all TileCal energies of jets for all events in 2012 data. The number of bins in $\phi(\eta)$ is 192 (90).

Then we discuss results, and what else would be interesting to plot

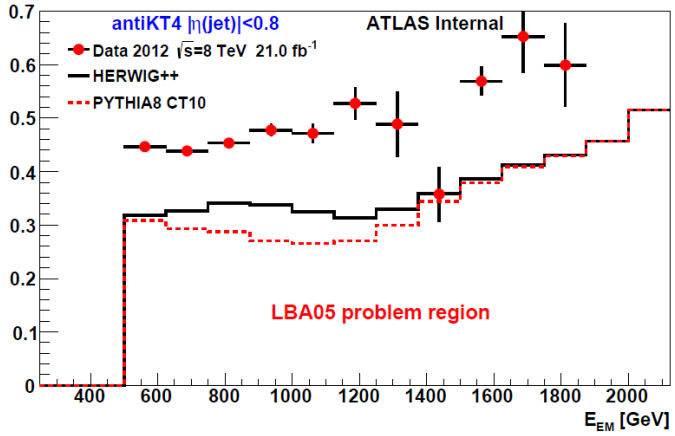


Representative Project – Continued I

Compare to Monte Carlo



EM-scale jet energy fraction in TileCal for jets with corrected $p_T(jet) > 650$ GeV and $|\eta| <$



(a) For known bad region

Study problem region(s) in more detail to better understand the impact

Representative Project – Continued II

Interpret results, present to collaboration and document work

Note in this example the collaboration includes physicists from Europe and Russia – THIS IS TYPICAL

Map of TileCal energies using high-p_T jets in 2012 data

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[b]*HEP Division, Argonne National Laboratory, 9700 S. Cass,Argonne, IL 60439, USA*
[c]*European Laboratory for Particle Physics (CERN), CH-1211 Geneva 23, Switzerland*
[d]*Institute for High Energy Physics, 142281, Protvino, Russia*

Abstract

This note describes an examination of jet energies in the Tile calorimeter (TileCal) using data collected in 2012. The data are compared with the Monte Carlo (MC) simulations, HERWIG++ and PYTHIA8, for jets with $p_T\,(jet) > 650$ GeV. There are three major aspects of these studies that can help to understand the underlying problems with TileCal during 2012 pp collisions. The first aspect of importance is that the energy densities are dependent on both η and ϕ where cylindrical symmetry was expected. The energy deposited in the Tile calorimeter is overestimated in data and MC by about 30% in the modules nearby the regions where the TileCal modules were switched off, an effect resulting from the algorithm used to recover the energy lost in these modules. In addition, it was seen that the MC simulations overestimate the fraction of jet energies seen in the TileCal barrel region. Lastly, from studying the beginning and end of each run, it was observed that the TileCal energy distributions for the beginning of runs show small differences from those for the end of runs, with discrepancies at the level of 1%.

Accomplishments and Impact I *{in other words what you can write on your resumé}*

Jason Boomsma is co-author on the ATLAS internal note:
General Particle Searches, J. Boomsma, S. Chekanov, ATL-COM-PHYS-2009-619

Craig Levy is co-author on the paper:
New approach for jet-shape identification of TeV-scale particles at the LHC, S.Chekanov, C.Levy, J.Proudfoot, R.Yoshida, Phys. Rev. D 82, 094029 (2010)

Andrew Johnson is co-author on the ATLAS paper:
Measurement of the production cross section for W-bosons in association with jets in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector, Phys.Lett.B698:325-345,2011

Linus Marchetti is co-author on the ATLAS internal note:
Estimation of dijet backgrounds to Z→μμ decay with the matrix method and in situ determination of muon identification efficiency and jet to muon fake rate, L. Marchetti, A. Paramonov, ATL-COM-PHYS-2011-1031

Jack Weinstein, is co-author on a conference paper (ACAT) on his 2011 work:
An Exploration of SciDB in the Context of Emerging Technologies for Data Stores in Particle Physics and Cosmology, J. Phys.: Conf. Ser. 368 (2012) 012021

Accomplishments and Impact-II

Josh Loyal is co-author on the ATLAS internal note:
Measurement of Wgamma and Zgamma Productions and Searches for Technicolor in pp collisions at sqrt(s) = 7 TeV with the ATLAS Detector, ATL-COM-PHYS-2012-974

Kyle Strand is co-author on the ATLAS internal note:
Map of TileCal energies using high-pT jets in 2012 data, ATL-COM-TILECAL-2013-043

Michael Erickson – is co-author on the paper:
A non-parametric peak finder algorithm and its application in searches for new physics, S.Chekanov, M.Erickson, Advances in High Energy Physics", vol. 2013, Article ID 162986

Kyle Strand is co-author on a paper submitted to Com. Phys. Comm:
ProMC: Input-output data format for HEP applications using varint encoding, S.V. Chekanov, K. Strand, P. Van Gemmeren, CERN CDS: arXiv:1311.1229,ANL-HEP-PR-13-41

Stephanie Lona is co-author on the ATLAS internal note:
Measurement of the Zγ and Zγγ Production Cross Section in pp Collisions at √s = 8 TeV with the ATLAS Detector and limits on anomalous Triple and Quartic gauge couplings, ATL-COM-PHYS-2013-1573

But what if..

You consider the study of pp collisions at the highest energies manufactured on earth to be as dull as dishwater

After all the physicists working on this have spent the better part of 50 years hunting for a Higgs Boson (whatever that is?)

Then go to http://www.anl.gov/ check out the different research Divisions and then to http://www.dep.anl.gov/p_undergrad/summer.htm to find project areas which interest you

Then…

http://www.anl.gov/science

Checkout the other Research Divisions at Argonne:

Computing, Environment and Life Sciences
- BIO Biosciences
- EVS Environmental Science
- MCS Mathematics and Computer Science

Energy Engineering and Systems Analysis
- DIS Decision and Information Sciences
- ES Energy Systems
- NE Nuclear Engineering

Photon Sciences
- ASD Accelerator Systems
- AES APS Engineering Support
- XSD X-ray Science

Physical Sciences and Engineering
- CSE Chemical Sciences and Engineering
- HEP High Energy Physics
- MSD Materials Science
- NST Nanoscience and Technology
- PHY Physics

Energy Engineering & Systems Analysis (EESA)

EESA seeks to expand the frontiers of science through world-class applied research and development, create the tools that enable scientific and technological breakthroughs, and translate discoveries through engineering to the marketplace.

Photon Sciences (PS)

PS comprises three research and support divisions centered on the Advanced Photon Source (APS) at Argonne, which provides the brightest storage ring-generated x-ray beams in the Western Hemisphere to more than 5,000 scientists worldwide.

Physical Sciences & Engineering (PSE)

PSE's mission is to create new materials and chemistries, and advance accelerator physics. It operates and manages two sophisticated user facilities for the Department of Energy's Office of Science: the Center for Nanoscale Materials and the Electron Microscopy Center.

You can also see how a supercomputer sheds light on the universe!

Take a random example – battery research

Argonne NATIONAL LABORATORY

Center for Electrical Energy Storage

U.S. DEPARTMENT OF ENERGY

Focus Areas 3D Interface Architectures Dynamically Responsive Interfaces Control of Interfacial Processes Theory

Search Argonne ...

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Center for Electrical Energy Storage — an Energy Frontier Research Center

The Center for Electrical Energy Storage (CEES) tackles the scientific limitations of today's electrochemical energy storage technologies for transportation, residential, and commercial use. The prime mission of CEES is to acquire a fundamental understanding of electrode/electrolyte phenomena that control electrochemical processes and that will enable dramatic improvements in 1) the properties and performance of electrochemical energy storage devices and 2) the design of new materials and architectures. The research focuses predominantly on advancing lithium-ion battery science and technology, as these batteries offer the best opportunity for rapid technological enhancement. Through its university partners, CEES strives to mentor the next generation of scientists to meet the energy storage challenges of the future.

Energy storage devices have been available for many years, yet the atomic- and molecular-level processes that affect their operation and performance are not fully understood. With further knowledge of these processes, scientists can bridge gaps in current technologies and discover/invent new ways to meet future energy storage requirements. CEES is one of two Energy Frontier Research Centers (EFRCs) centered at Argonne. The other, the Institute for Atom-Efficient Chemical Transformations, focuses on advancing the science of catalysis for the efficient conversion of energy resources into usable forms for a variety of applications. Argonne also plays a prominent role in 10 other EFRCs (read the Argonne news release about the establishment of EFRCs at Argonne).

CEES Partners

Argonne is the lead laboratory for CEES, with Michael Thackeray, an Argonne Distinguished Fellow and Senior Scientist, as CEES Director. The Center's other members are Northwestern University and the University of Illinois at Urbana-Champaign. The Center receives $19 million of research funding over five years.

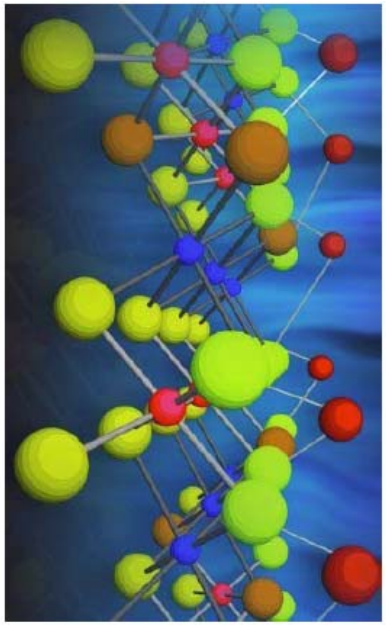
Related Items

Contact
Michael Thackeray
Director, Center for Electrical Energy Storage
630.252.9184

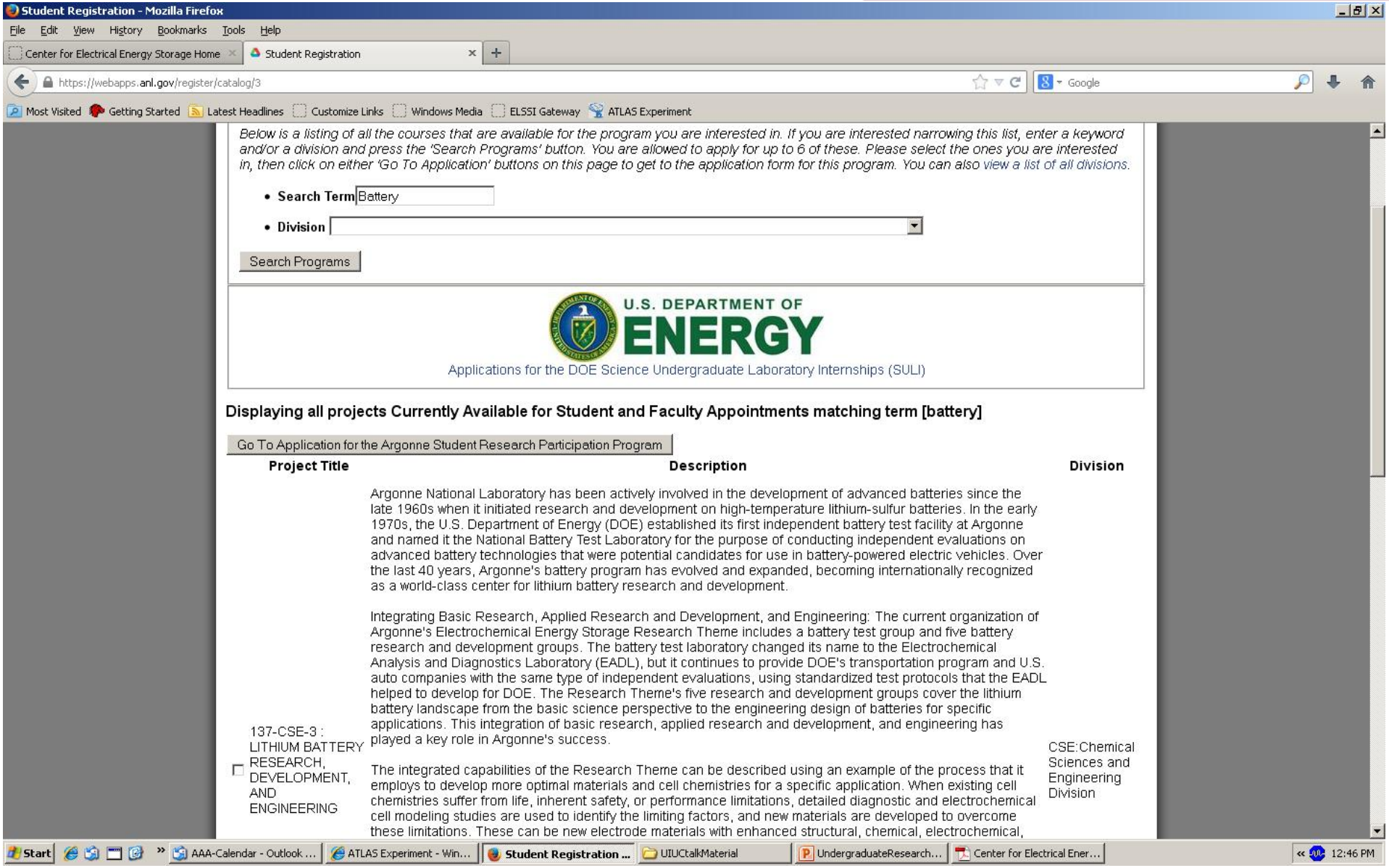
CEES Fact Sheet
(PDF, 187 kb)

Research Highlights Poster
(PDF, 1.8 MB)

U.S. Department of Energy, Basic Energy Sciences Workshop Report
Basic Research Needs for Electrical Energy Storage
(PDF 8.3 MB)



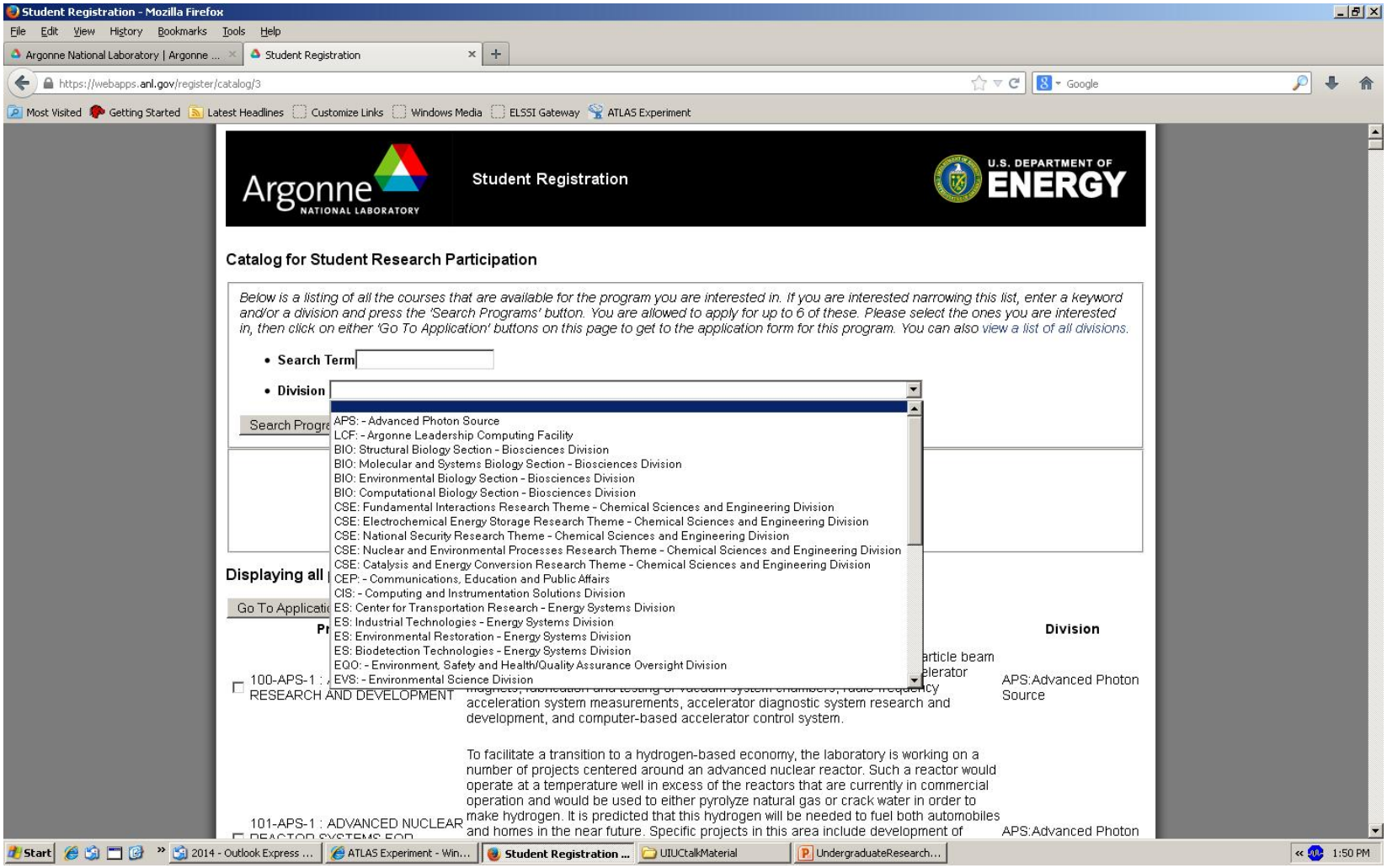
Above: An artistic rendition showing a metal-fluoride stabilized surface structure at a lithium cobalt oxide electrode/electrolyte interface (Li – light red; Co – blue; O – yellow; F – orange; metal cations capping the oxy-fluoride surface – dark red; electrolyte: wavy blue background).



Not just battery development - you can also find a project on vehicle systems testing

Another way to get ideas: Search the Research Participation Catalog: http://www.dep.anl.gov/p_undergrad/summer.htm

Browse by Division (or key word search)



And Remember

The goal of this program is to introduce you to the research environment

–

but it should also be fun

Acknowledgements

Many ATLAS Group members have been key to the success of the SULI program in the group and helped me prepare this presentation (and apologies if I have missed someone – I hope I haven't):

Sergei Chekanov
Jeremy Love
Ben Auerbach
Peter van Gemmeren
David Malon
Duong Nguyen
Lily Asquith
Sasha Paramonov
Rik Yoshida

Thank You for your attention