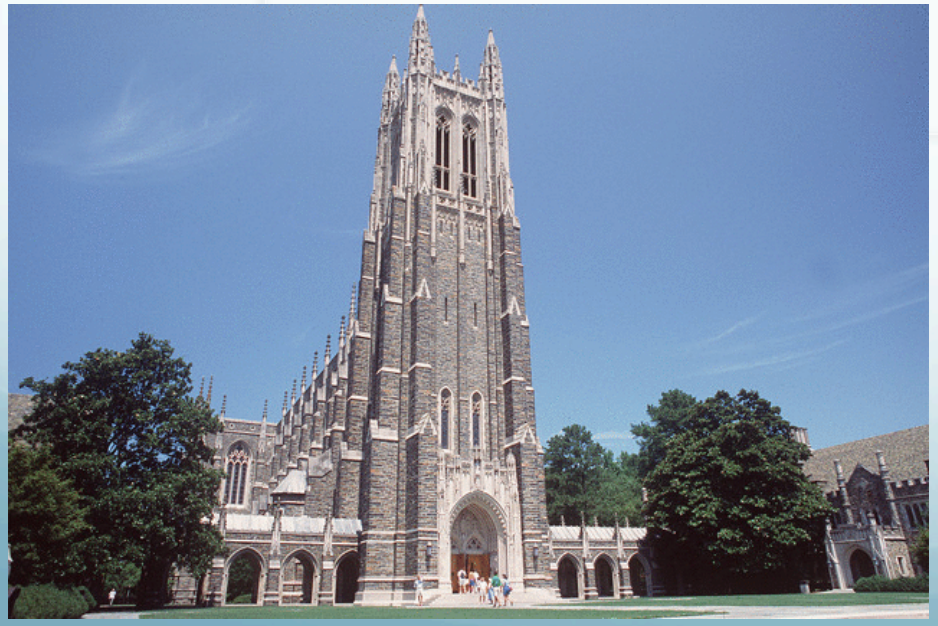
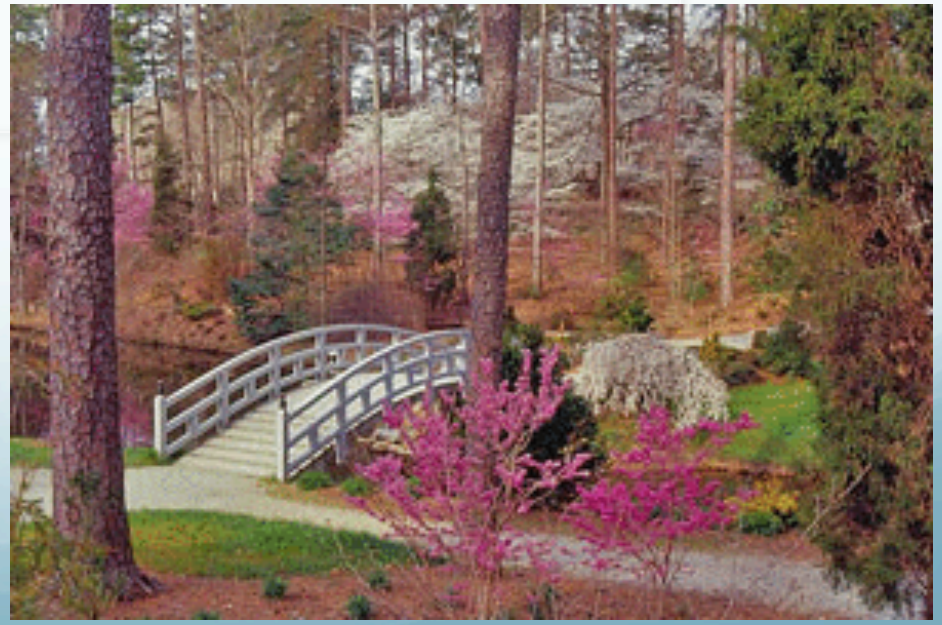
Duke / CoEPP activites: Global dilepton analyses, Silicon Strip Upgrade (ITk)

Mark Kruse

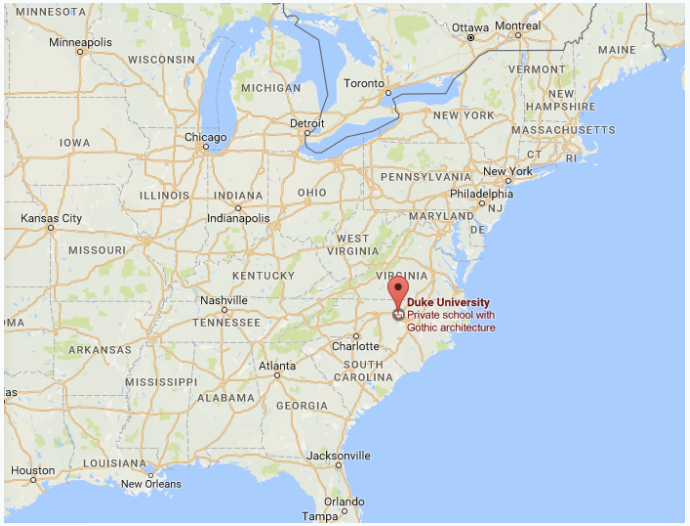
Duke
UNIVERSITY

CoEPP workshop, Adelaide
February, 2017





Duke University



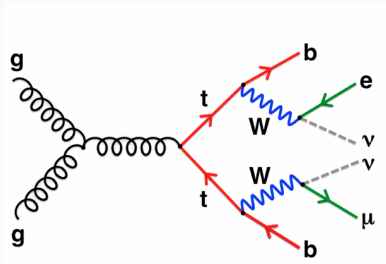
- Located in Durham, North Carolina
- Private university of ~7000 undergrad and ~7000 graduate students
- Physics Department ~30 faculty
  - HEP group (7 faculty, 6 postdocs, 10 PhD students):
    - **ATLAS**: Ayana Arce, Al Goshaw, Ashutosh Kotwal, Mark Kruse
    - **Neutrinos** (K2K, COHERENT, DUNE): Kate Scholberg, Chris Walter
    - **Mu2e** (Fermilab): Seog Oh

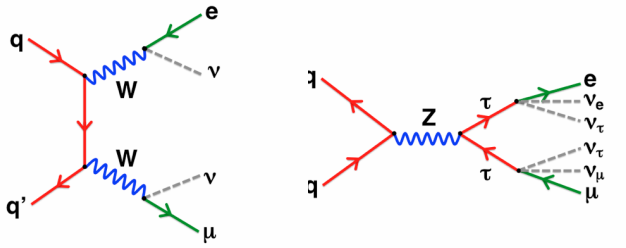
Introduction

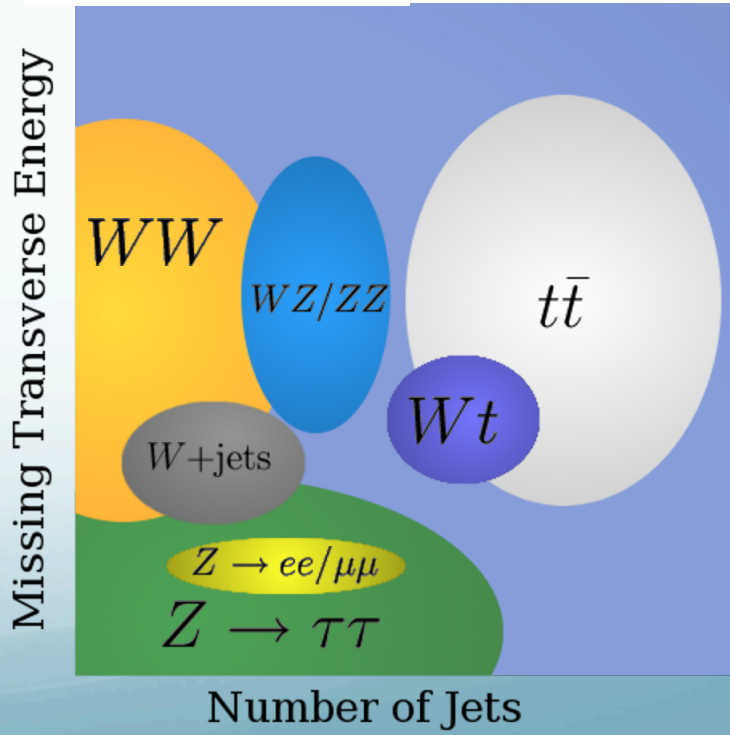
- Duke and CoEPP have enjoyed a very productive collaboration over several years, primarily through analysis of dilepton events at ATLAS
- CoEPP (Sydney) and Duke developed for ATLAS Run 1 a novel technique for simultaneously measuring cross-sections of processes with dilepton final states (coined AIDA – An Inclusive Dilepton Analysis)
  - Developed (and extended from the original CDF idea), and successfully implemented by Sydney/Duke – Duke thesis of Kevin Finelli
    - Published: **Phys.Rev. D91 (2015) 052005**
  - Adapted technique and infrastructure for ttW/ttZ analysis → discovery of ttW using same-sign dilepton events – Duke PhD thesis of Chen Zhou
    - Published: **JHEP 1511 (2015) 172**
  - Pursuing several Run 2 directions
- Duke grad students (past and present) who have worked, or are working, with CoEPP:
  - Kevin Finelli graduated 2014 (now at Sydney)
  - Chen Zhou graduated May 2016 (now postdoc with Wisconsin/ATLAS)
  - Three 3rd year PhD students (to graduate 2018/2019): Doug Davis, Kevin Holway, Ping Zhao

Simultaneous measurements of SM processes using dilepton final states (AIDA)

- Duke/CoEPP(Sydney) effort (Finelli, Kruse, Limosani, Saavedra, Suster, Varvell)
- Published: **Phys.Rev. D91 (2015) 052005**
- Basic idea:
  - Main SM processes well separated in MET vs N_{jets} phase space
  - Rather than perform series of cuts to reject background for a chosen signal (as in standard cross section measurements), perform simultaneous fit to all main processes
  - Worked very well for ATLAS Run 1 measurements
- Advantages of AIDA include a full understanding of the entire parameter space, more global test of SM, ability to study cross-section correlations





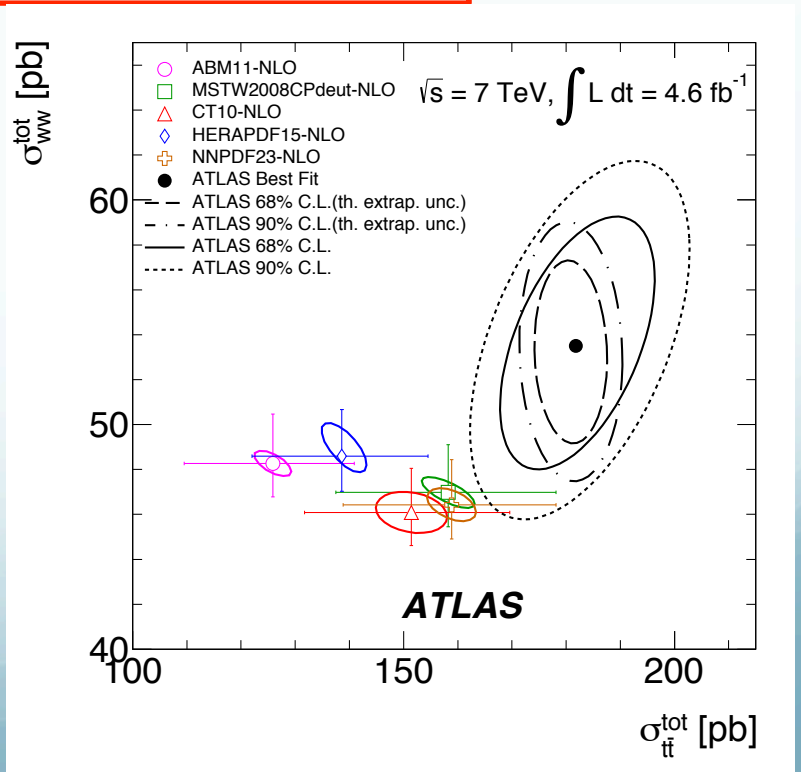


AIDA results in Run 1

- Production cross sections for pp@7TeV simultaneously extracted from the AIDA phase space:

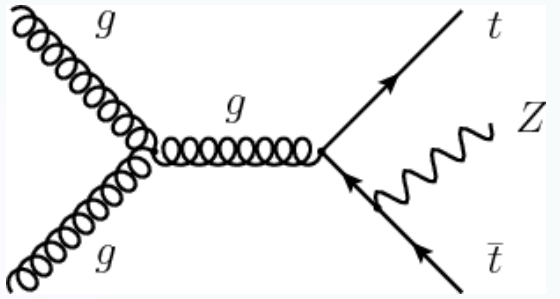
$$\sigma(t\bar{t}) = 181.2 \pm 2.8(stat.)\ ^{+9.7}_{-9.5}(syst.)\ \pm 3.3(lum.)\ \text{pb}$$
$$\sigma(WW) = 53.3 \pm 2.7(stat.)\ ^{+7.3}_{-8.0}(syst.)\ \pm 1.0(lum.)\ \text{pb}$$
$$\sigma(Z \to \tau\tau) = 1174 \pm 24(stat.)\ ^{+72}_{-87}(syst.)\ \pm 21(lum.)\ \text{pb}$$

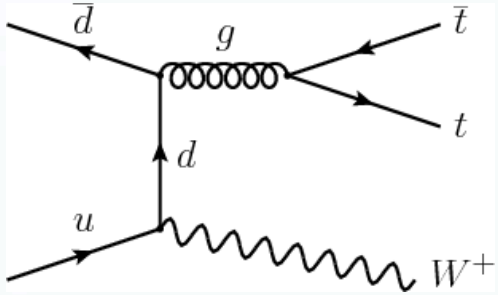
- Also produced for the first time underlying correlations in the predicted and measured cross sections
  - Constrain PDFs

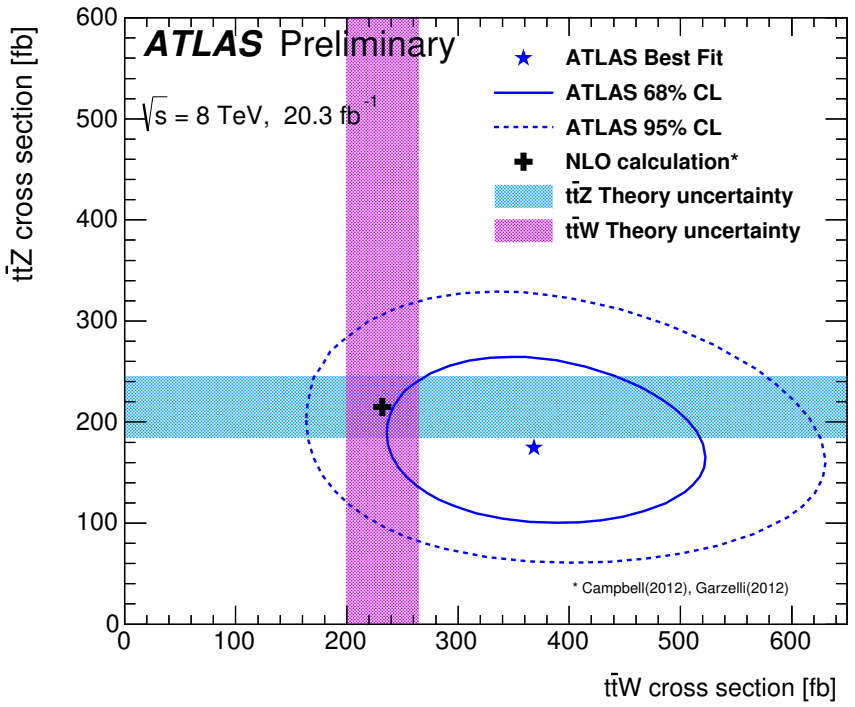


Run 1 search for ttW/ttZ

- Duke/Sydney (thesis of Duke grad student Chen Zhou)
- Published: **JHEP 1511 (2015) 172**
- Various search channels
  - Most sensitive are SS dilepton (dominates ttW) and 3-lepton (dominates ttZ)
- AIDA technique can simultaneously extract ttW and ttZ usiing SS dilepton and 3-lepton events
- Produced first 5.0σ measurement of ttW







Anomaly seen in our Run 1 ttW SS analysis: excess of 3-tag SS eμ events

- Observe 7 events (some with striking characteristics) – expect about 1.5 (mostly from ttW)

	P_T(e)	P_T(μ)	b-jet1, bjet2, bjet3	MET	Non-tagged
1	50	39	125, 101, 51	151	83, 35, 27
2	87	49	168, 71, 32	96	127, 39
3	212	92	188, 141, 50	149	203
4	61	95	712, 350, 222	240	
5	46	45	61, 49, 33	128	80
6	112	38	131, 98, 58	227	265, 41
7	153	157	117, 62, 43	132	67, 58, 44, 40

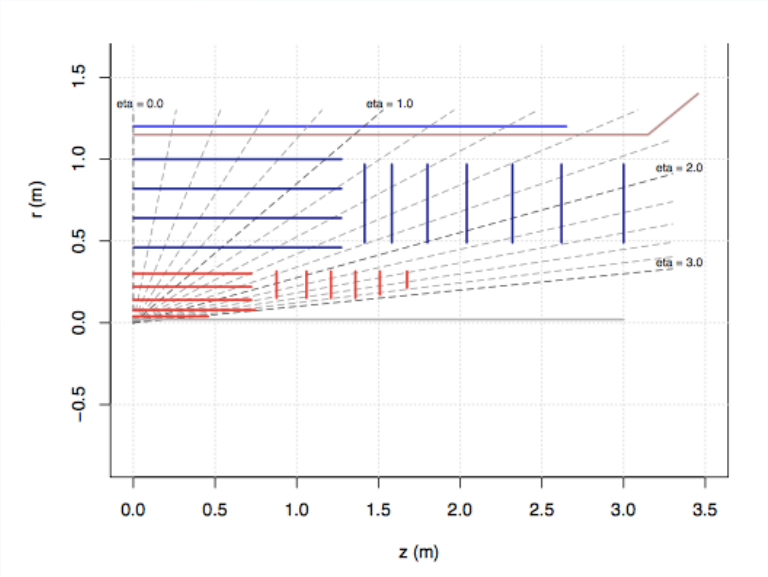
- Following up in Run 2 (Ping Zhou as part of SUSY analysis)

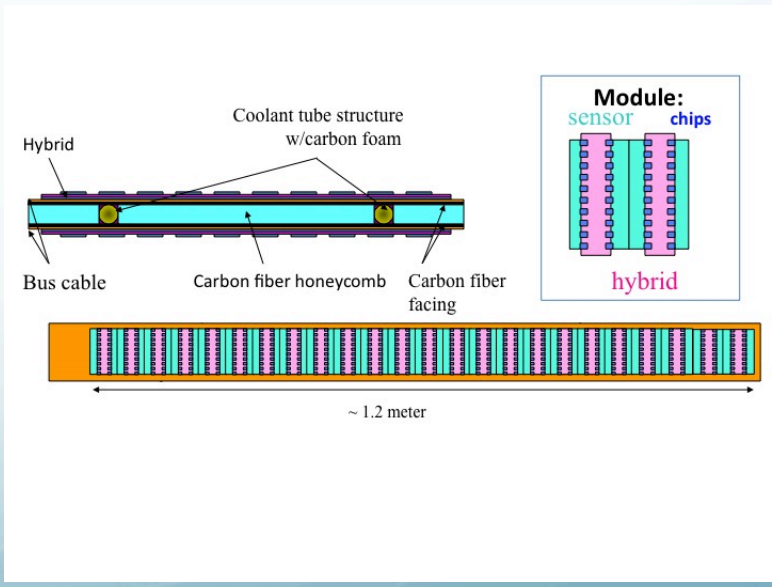
AIDA: Run 2 plans

- Building on our AIDA investment and expertise from Run 1, Run 2 plans include
  - Inclusion of single top (Sydney: **Bunting, Cheema**, Finelli, **Suster**, Wang, Varvell)
    - **Inclusive and differential Wt measurements** (Carl's and Kevin F's talks for details)
  - Extension of simultaneous $\sigma_{tt}/\sigma_{WW}/\sigma_{Z \to \tau\tau}$ and correlation measurements for 13 TeV, including quantitative measure of SM consistency in our AIDA parameter space.
  - ttW/ttV cross-section measurements at 13 TeV
    - Using SS dileptons – we weren't involved in first Run2 measurement but possibilities exist for future iterations
    - Can include other SS signatures (e.g. tribosons) for extended simultaneous fit, and new physics searches
  - Precision top-Z coupling measurement (longer term)
    - Important step toward top-Higgs coupling measurement
  - Dark Matter searches (Kevin Holway investigating possibilities)
  - Involvement in SUSY searches (follow up on SS $e\mu$) ?
- We have restarted our biweekly AIDA meetings to focus on a coordinated Run 2 effort

ITk activities at Duke

- The current ATLAS ID will be replaced by an all-silicon tracker (ITk) for phase 2
- Currently, **Phase 2 (2026-2030)**: instantaneous luminosity ~1 x 10^{35}, $\langle \mu \rangle$~200, integrate 3000 fb^{-1}
- LOI (2012) layout: (4 barrel + 6 disc) pixel + (5.2 barrel + 7disc) strips
- ITk now a project within US-ATLAS
- We (at Duke) have designed and developed module testing infrastructure that will be replicated at other institutions
- US ATLAS model is to train grad students and postdocs locally for them to participate in pre-production and production activities at national labs (mostly BNL) starting 2018
- Institutions (such as Duke) will also be active in module stress tests and firmware (FPGA) code development (Ping Zhao's qualification task)





Current Duke ITk personnel

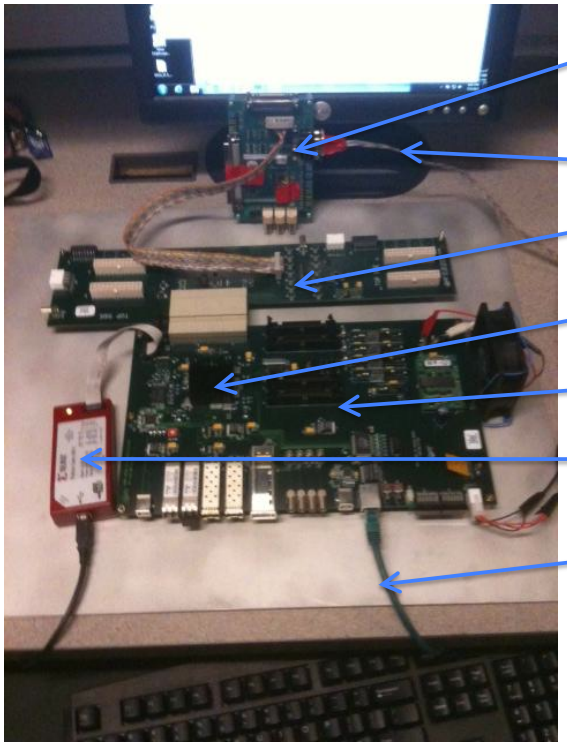
- **Faculty**: Ayana Arce, Mark Kruse
- **Technical support:** Brogan Thomas
- **Postdoc:** TBD
- **Grad students:**
  - Ping Zhao (current qualification task working on DAQ firmware)
  - Chen Zhou (qualified on ITk, graduated May 2016)
- Plus many talented Duke undergrads

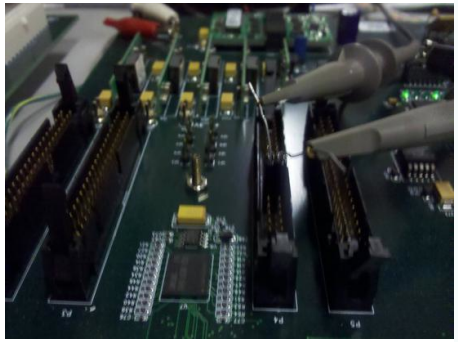
- Main ITk role: develop standardised module testing infrastructure, DAQ procedures (FPGA firmware, software). Will be conducting various module stress tests during (pre)production.

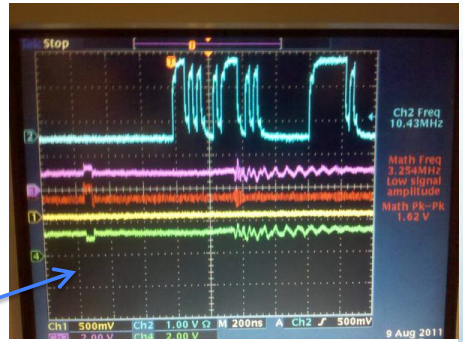
History: started with HSIO system

- started with HSIO test setup (with ABCn250 1-chip board)

The ATLAS silicon upgrade HSIO setup at Duke







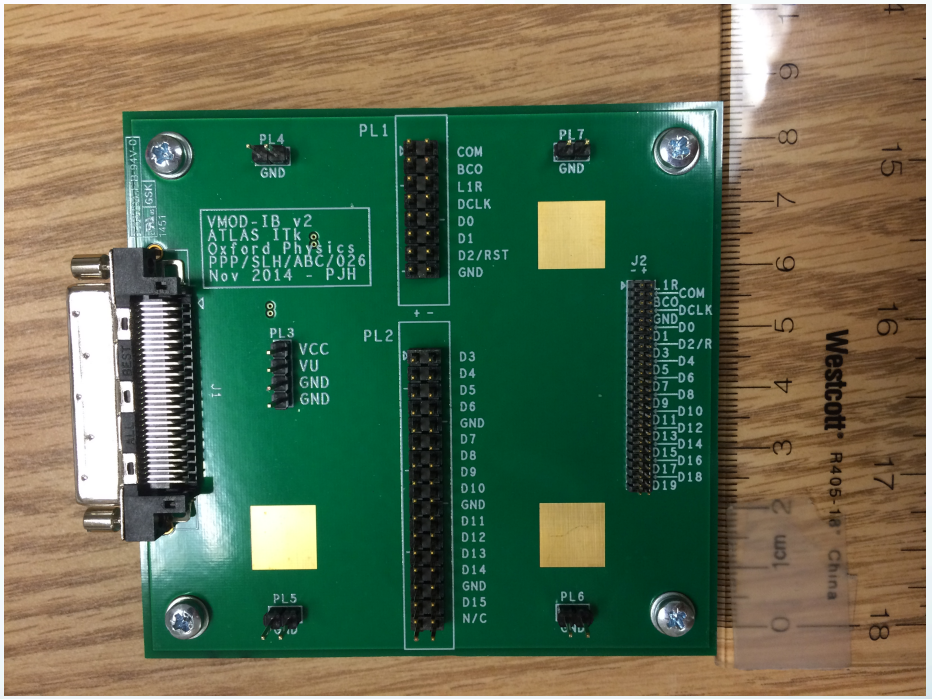
Signals shown on a scope being sent to the ABCn chip

Current activities at Duke

- Developing Atlys/Nexus setups
- Developing module testing infrastructure (cooling, power, support, etc.)
- Developing interlock system
- Working on simulations (for module testing, and separately in overall ITk simulation group)
- Coordinating SR1@CERN setups

HSIO → Atlys

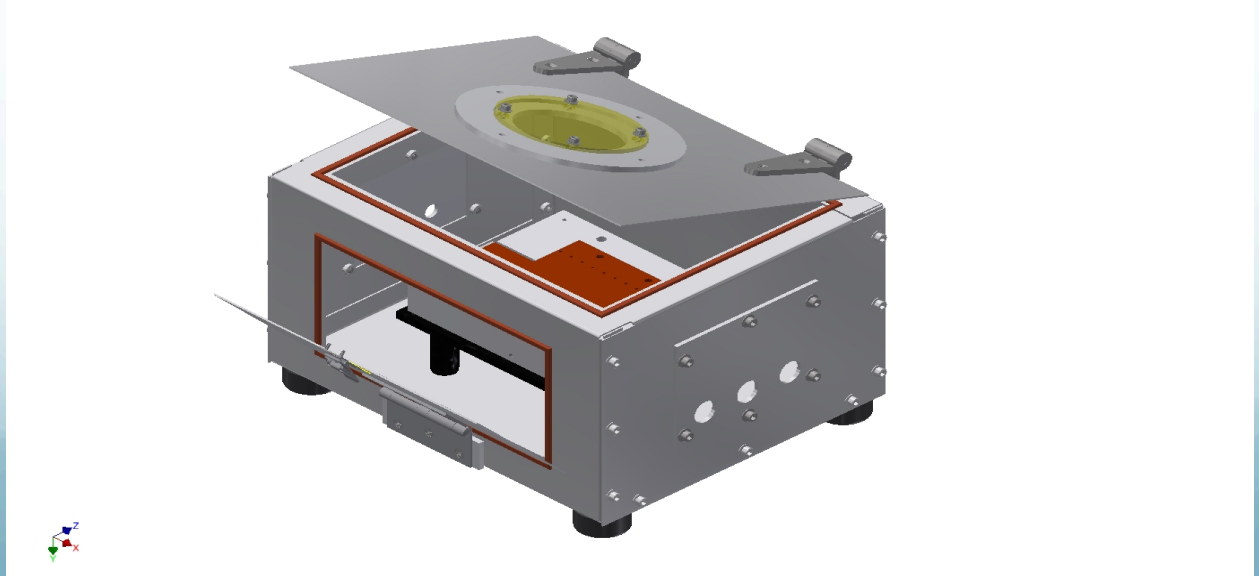
- Ping Zhao (Duke grad student) is working with UK (mostly Peter Phillips, Matt Warren)



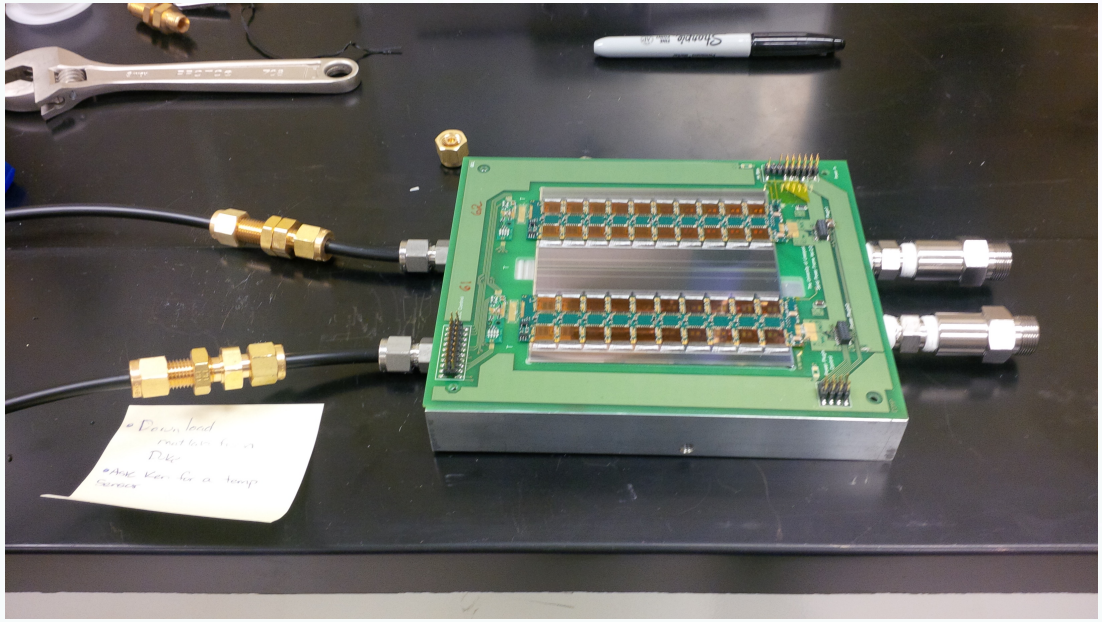
- We have successfully gotten this to work with a ABCn250 chip (Ping becoming VHDL expert)
- Will soon be getting a ABCn130 chip board / module

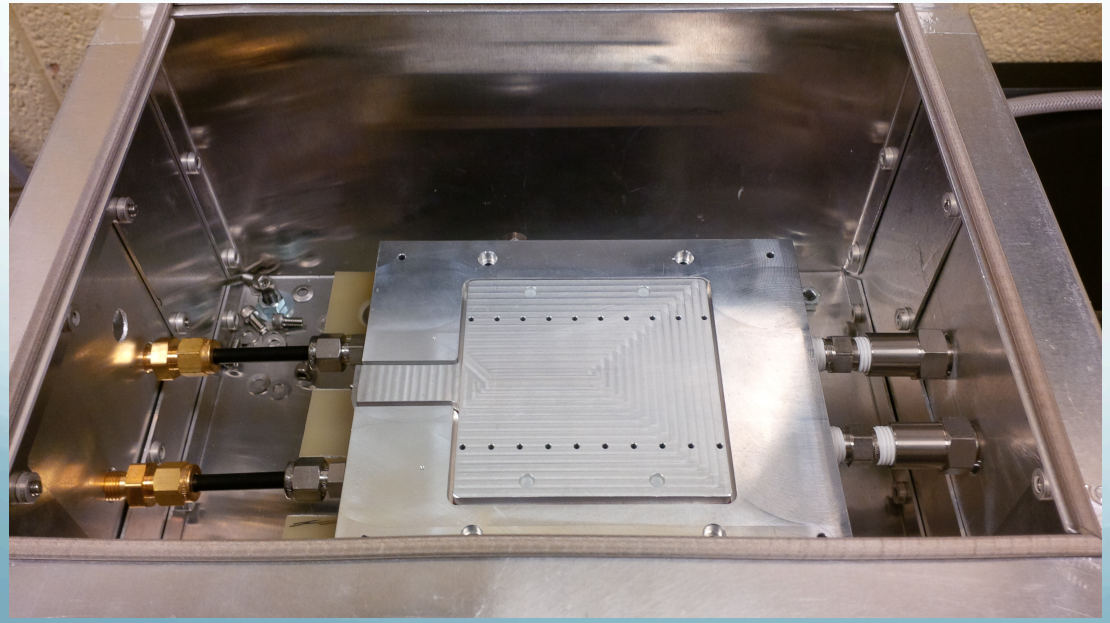
Module testing infrastructure

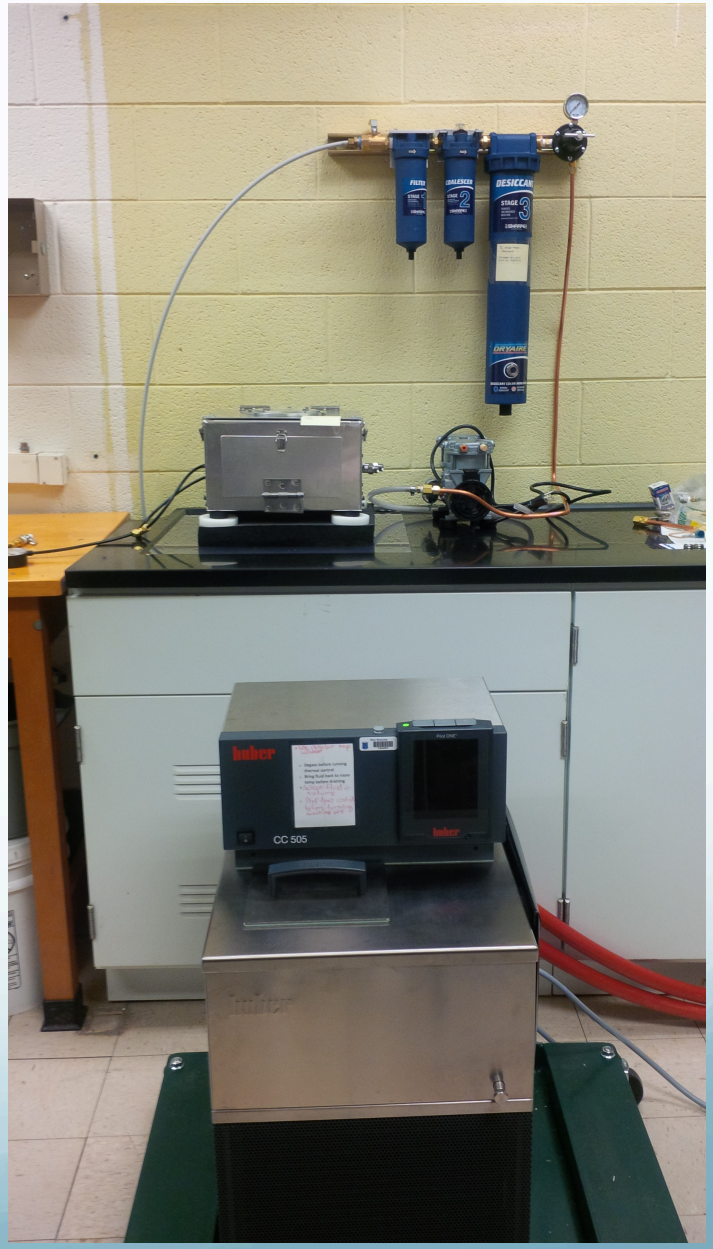
- We are developing a “standardized” module testing setup that will be easy to replicate elsewhere
  - Cooling system (want capability down to -40C): Huber CC-505 chiller best suits needs
  - Humidity control: installed dessicant air dryer
  - Developed interlock system to interlock on humidity and/or temperature
  - Cooling block support machined at Duke
  - Module enclosure designed and built at Duke



Module testing system at Duke

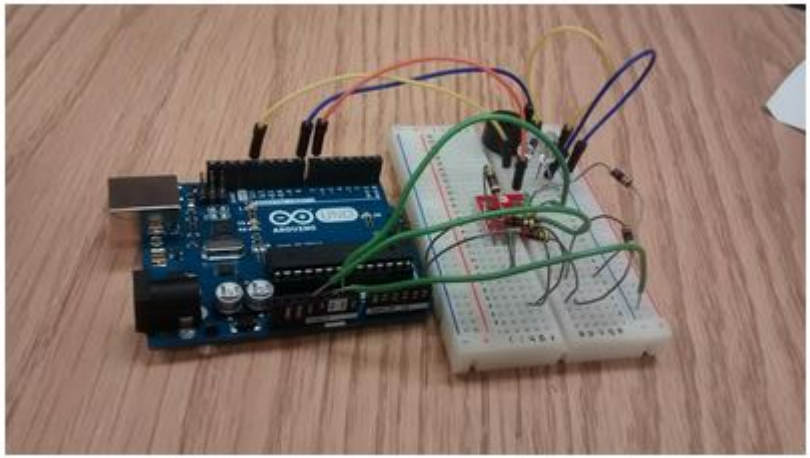






Module testing interlock system

- Modules are valuable – need to interlock on temp and perhaps humidity
- Design and fabrication of this system was a Duke undergrad project
- Employ simple Arduino based temperature and humidity monitoring system that can shut down power when preset thresholds reached
- PCBs made and installed



DAQ firmware development

- For module testing communication to ABCn readout chips done through programmable FPGA chips
- Expertise on this is rather limited (requires VHDL experience)
- Duke graduate student, Ping Zhao, working with Matt Warren on firmware development as his ATLAS qualification task
- Project has broader applicability than just for strip modules – coordinating with Adelaide group on similar setup

Conclusions

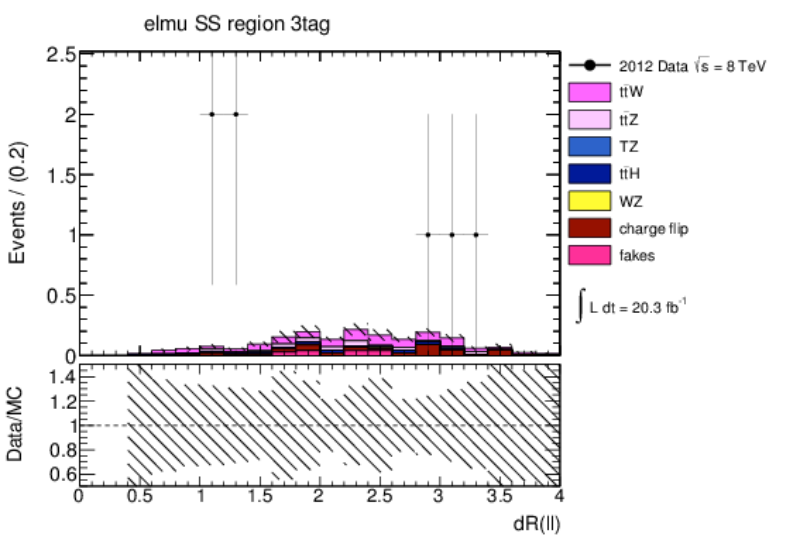
- Duke and CoEPP have enjoyed a productive collaboration on ATLAS analyses using (mostly) dilepton events
- We are continuing this effort in Run 2, and look forward to future mutually beneficial collaboration

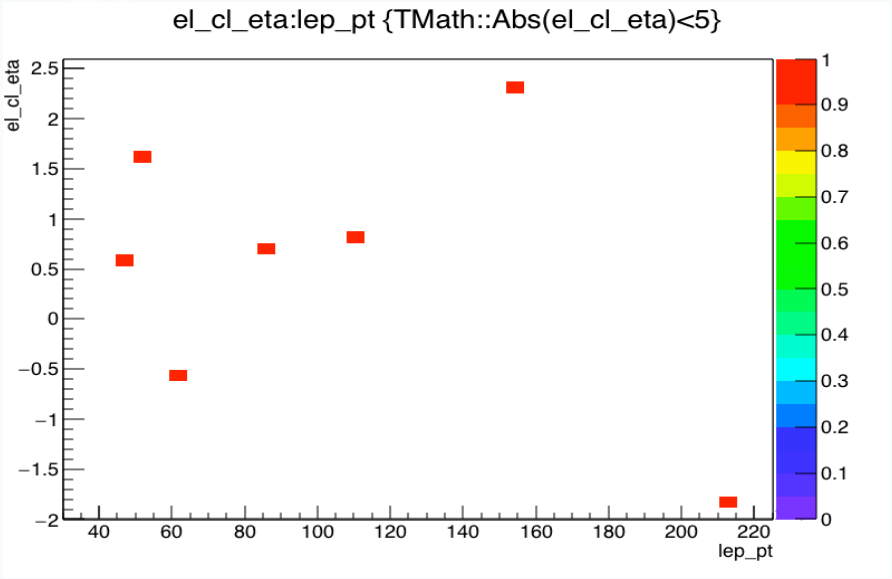
Backup

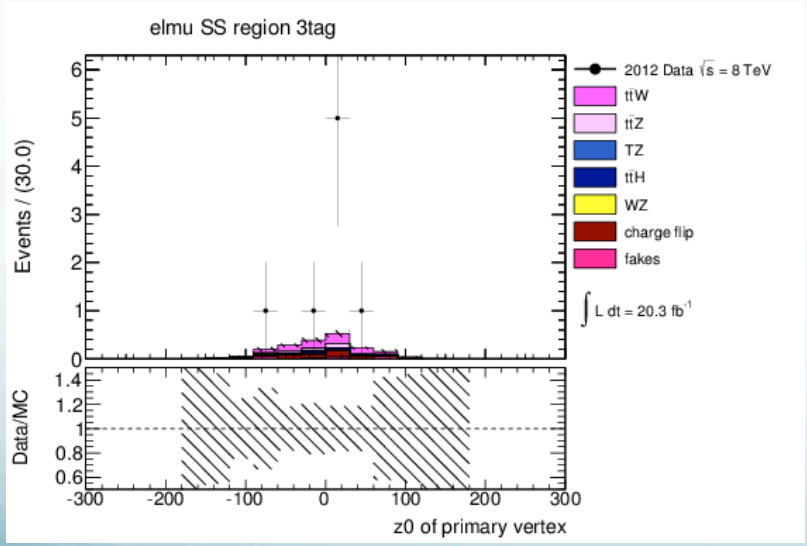
Outreach – a few thoughts from a US perspective

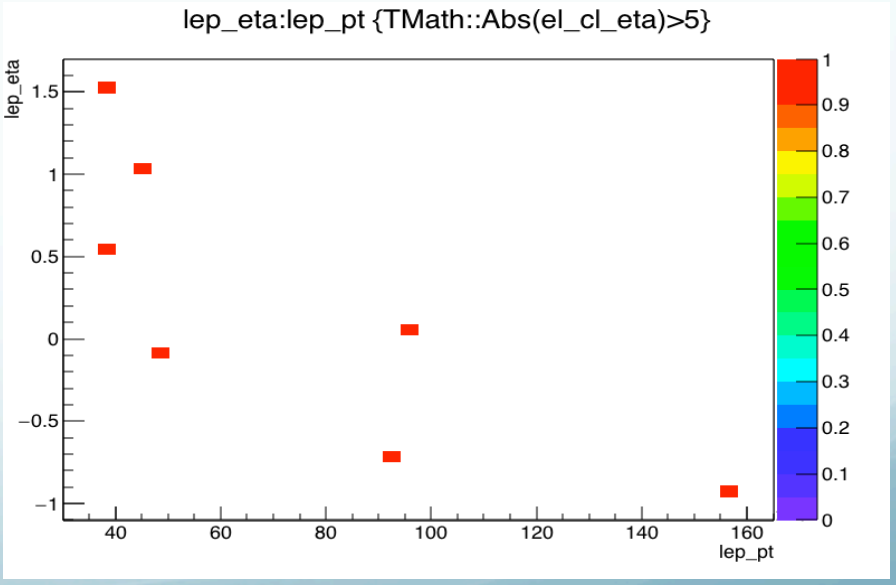
- An important ingredient in any program, both for the image of the science being done, and connections made with a broader audience
- We need to do more to address the question of what benefit we are providing to society and taxpayers with the science we do
- Increasingly, programs are being expected to have an outreach component, not just for doing, but developing, outreach activities
  - Has always been true for NSF funded programs in the US, but now also gaining importance for DOE programs
- We might think about CoEPP collaborations on outreach developments?
  - One possibility: LHC series of events at selected festivals – recent examples, WOMAD (UK), Moogfest (US)

Numerous studies done to understand excess









- Nothing conclusive: will be following up in Run 2