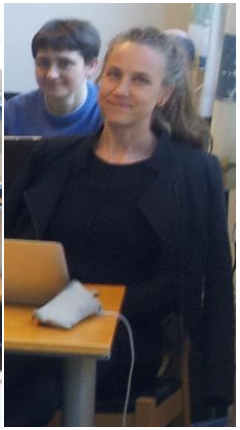
High Energy Particle Physics

Emphasis on ATLAS experiment

RECFA visiting Norway

Farid Ould-Saada et al.

Oslo, 2.10.2015



UNIVERSITAS BERGENSIS

The Research Council of Norway

UiO : Universitetet i Oslo

ATLAS

HEPP as part of CERN-related program of the Research Council Norway (RCN)

- Mainly ATLAS experiment at LHC and particle physics theory
- Partners: Bergen (UiB), Oslo (UiO), Gjøvik (HiG)
- Funding scheme
  - 50% RCN: hardware, operations, computing, researchers
  - 50% Universities: Staff, PhD students
- Previous program 2006 – 2011
    - RCN Funding: ~6 MNOK/year (excluding detector R&D) AND Grid computing funds for Tier-1
- Current approved program 2012–2019 → 2 periods
  - Current project period 2012 – 2015
    - RCN Funding: ~10 MNOK/year, including detector R&D and 50% Grid computing
  - New project period: 2016 – 2019
    - RCN funding sought: 13-14 MNOK/year, excluding core ATLAS phase II upgrade
    - Increase mainly due to NOK depreciation, … 1 CHF~6 a few years ago, it is ~8.6 today
- ATLAS upgrade core and related development must be from Infrastructure application : 2014/15 → failed : Resubmission in 2016

HEPP Activities & Talk Outline

- Manpower situation
  - briefly
- Detector & Upgrade → Gerald Eigen
  - Brief summary
- ATLAS Operations
  - briefly
- Software and Computing → Jon Nilsen
  - ATLAS software: briefly
  - distributed computing and data management, ARC middleware, Tier-1
- ATLAS Physics
  - Main part of my talk
- Related theory → Torsten Bringmann
- Education & Outreach → Eirik Gramstad
  - Educational material, dissemination, masterclasses

MANPOWER

- Manpower – currently involved in ATLAS
  - → see details in following (hidden) slides:
  - 6 professors mainly in ATLAS (3 UiO, 3 UiB) + 1 (HiG)
  - 6 researchers / post-docs funded by RCN
  - 6 researchers funded by ATLAS (2) and NeIC (2), UiO (1), UiB (1)
  - 2 engineers/technicians
  - ~6 active PhD students and ~6 active master students
- Collaboration / Cooperation
  - ATLAS, NorduGrid, Nordic eInfrastructure Collaboration (NeIC), Uninett Sigma2, USIT, Technology providers, Sintef …
  - Particle physics Theory is part of HEPP

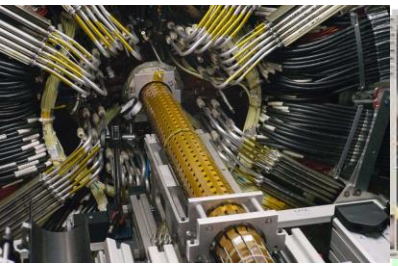
ATLAS PhD & Master Student defences

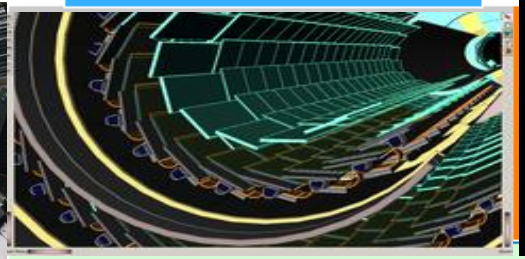
- 2012-2015 (4y) compared to previous period 2006-2011 (6y)
  - Decrease of masters/year: 3.7 → 1.75
  - Number of PhDs/year stable: 2 → 2
    - despite high quality data and other opportunities offered by LHC program
    - Limitation is funding

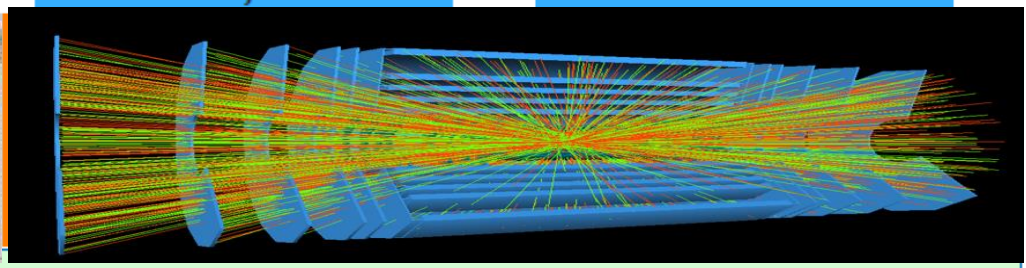
Students	06-11	2012	2013	2014	2015	12-15
Master	22	3	1	1	2	7
PhD	12	1	3	2	2	8

ATLAS detector consolidation & upgrades

PHASE 0 - LS1 | **PHASE 1, 2 - LS2** | **PHASE 2 - LS3**

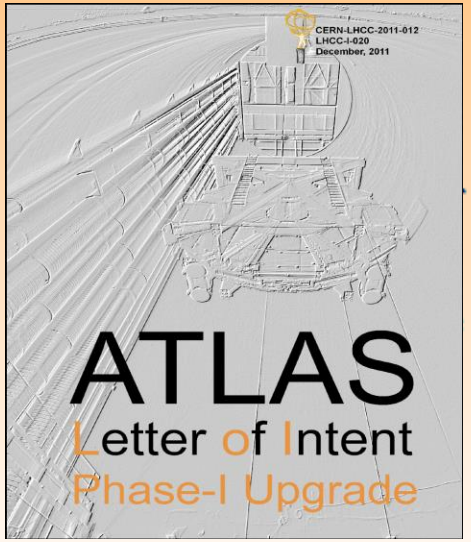






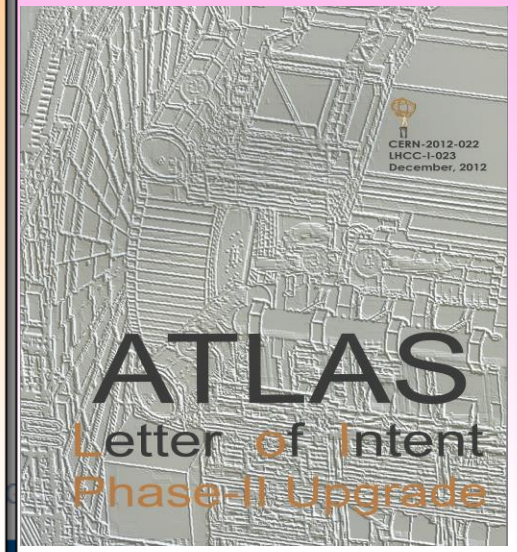
ATLAS has devised a 3 stages program to optimise the physics reach at each Phase

- New Insertable pixel b-layer (IBL)



- New forward diffractive physics detectors (AFP)

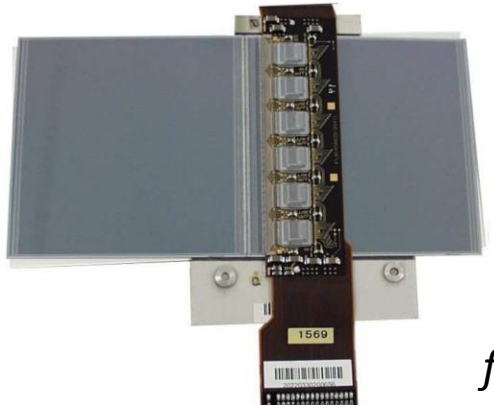
- All new Tracking Detector



ATLAS detector, operations & upgrade

Past ATLAS detector activities:

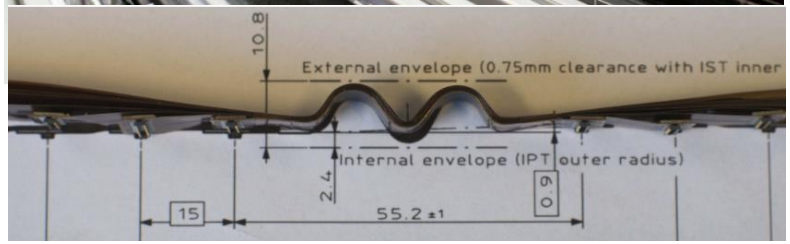
- ***SCT module construction***, commiss. and operation
- ***Inner B-Layer*** (CORE 73 kCHF, in total 227 kCHF)
  - 3D Pixels R&D with SINTEF
  - Intermediate FLEX R&D and deliverable
  - ERC ITN TALENT



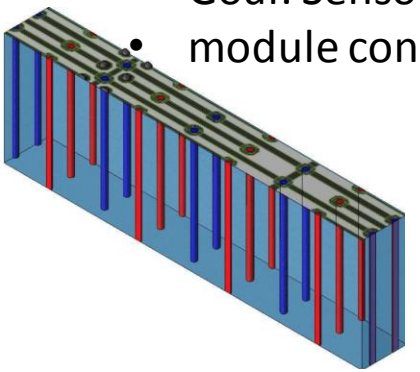
SCT modules from Oslo

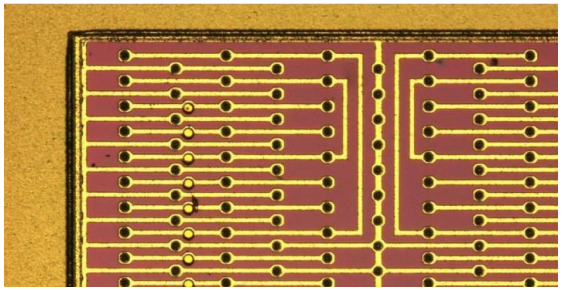
Ongoing ATLAS detector activities (see Eigen's talk):

- ***ATLAS Forward Protons*** (AFP) (1% core)
  - FLEX R&D and baseboards (UiO)
  - Mechanical holder (UiB)
- ***HL-LHC ATLAS Inner Tracker*** (ITk)
  - 3D Pixel R&D with SINTEF
  - Testbeam activities (run 3)
  - Goal: Sensors for the innermost pixel layer
  - module construction (Strips or Pixel)



IBL flexes from Oslo





3D sensor R&D

ATLAS upgrade activities - People

Master-students

Mohammad Inam (Stugu) – 3D testbeam analysis

Kristine Helle (STUGU) – 3D testbeam analysis

Yassin Munir (Read/Røhne) -

Anders Heggelund (Stugu) – ATLAS ITk, 3D testbeam analysis

PhD-students

Håvard Gjersdal (Strandlie/Stapnes/Røhne) – 3D testbeam, tracking algorithms

Beatrice Mandelli (CERN, Stapnes/Røhne) - IBL Staves QA, WB corrosion

Laura Franconi (EU/MC/TALENT - Read/Røhne) – IBL Bytestream, SINTEF 3D sensor evaluation

Simon Feigl (EU/MC/TALENT - Stapnes/Røhne) - IBL Thermal mock-up, HV-CMOS pixels

Steffen Mæland (UiB - Stugu/Eigen) – IBL Bytestream

Postdocs (0.5 FTE)

Zongchang Yang – ATLAS ITk, 3D testbeam analysis

Staff (~2 FTE)

Ole Dorholt (UiO/FI/ELAB) – IBL, 3D R&D, AFP ATLAS ITk

Attiq Ur Rehman (UiB) – ATLAS ITk (Intermediate flex), 3D R&D

Ole Røhne (UiO/FI/HEP) – IBL (Staves WG, Intermediate flex), 3D R&D, AFP, ATLAS ITk

Bjarne Stugu (UiB) - IBL, 3D R&D, AFP ATLAS ITk

Heidi Sandaker (UiO/FI/HEP) – IBL, 3D R&D, AFP ATLAS ITk

Alex Read (UiO/FI/HEP)

Farid Ould-Saada (UiO/FI/HEP)

Manpower is an issue

ATLAS upgrade activities – Recent publications

Experience on 3D Silicon Sensors for ATLAS IBL, ATLAS Collaboration (G. Darbo (INFN, Genoa) for the collaboration). Nov 25, 2014. 9 pp. **JINST 10 (2015) 05, C05001**

Status of the AFP project in the ATLAS experiment ATLAS Collaboration (Marek Taševský (Prague, Inst. Phys.) for the collaboration). 2015. **AIP Conf.Proc. 1654 (2015) 090001**

ATLAS pixel IBL modules construction experience and developments for future upgradATLAS Collaboration (A. Gaudiello (Genoa U. & INFN, Genoa) for the collaboration). 2015. 4 pp. **Nucl.Instrum.Meth. A796 (2015) 56-59**

Overview of the ATLAS Insertable B-Layer (IBL) ProjectATLAS Collaboration (M.A. Kagan (SLAC) for the collaboration). 2014. 5 pp. Conference: C13-09-23.3, p.484-488 Proceedings

The upgrade of the ATLAS Inner DetectorATLAS Collaboration (D. Ferrère (Geneva U.) for the collaboration). 2013. 9 pp. **Nucl.Instrum.Meth. A718 (2013) 30-38**

Beam test results of 3D silicon pixel sensors for future upgradesATLAS IBL Collaboration (C. Nellist (Manchester U.) *et al.). 2013. 5 pp.* **Nucl.Instrum.Meth. A732 (2013) 141-145**

Overview of the ATLAS Insertable B-Layer (IBL) Project ATLAS IBL Collaboration (O. Røhne (Oslo U.) for the collaboration). 2013. 7 pp. **Nucl.Instrum.Meth. A731 (2013) 18-24**

The ATLAS Insertable B-Layer (IBL) project
ATLAS Collaboration (J. Bilbao De Mendizabal (Geneva U.) for the collaboration). 2013. 6 pp. **Nucl.Instrum.Meth. A730 (2013) 220-225**

Involvements & Responsibilities

- Committees, Editorial boards, …
- Combined performance
  - Muons – *(W. Liebig)*
  - Taus – Tau energy scale calibration for early Run-2 analyses *(B. Martin)*
- Inner detector tracking data quality coordination; Inner detector online monitoring *(A. Kastanas)*
- Tier-1, Distributed Computing, Data Management
  - 4 FTEs service work ➔ J. Nilsen's talk
- Software framework
  - 1.5 FTEs ➔ next slide

Derivation framework software and production, Event Data Model & Format

- Design and implementation of the derivation framework, CPU profiling, throughput improvements, output monitoring *(J. Catmore)*
- Liaison with physics groups and commissioning of the framework in production *(J. Catmore, E. Gramstad)*.
- Derivation production *(E. Gramstad)*. ATLAS Train Coordination team. Implementation in the new ATLAS production system (prodsys2) and overlooking and monitoring.

  References
  - *A New Petabyte-scale Data Derivation Framework for ATLAS, Procs CHEP2015*
  - *Implementation of the ATLAS Run 2 event data model, Procs CHEP2015*
  - *Original analysis model review report, https://cds.cern.ch/record/1543445,*

- Monte Carlo Truth *(J. Catmore)*. Design, implementation and maintenance of the xAOD truth structure and the truth DxAODs used for analysis.
  - Near-term: contribute to rationalisation of MC truth in the simulation work-flow

- **Future**
  - **Longer-term: contribute to implementation of multi-threaded applications in the new software framework**

Qualification Tasks

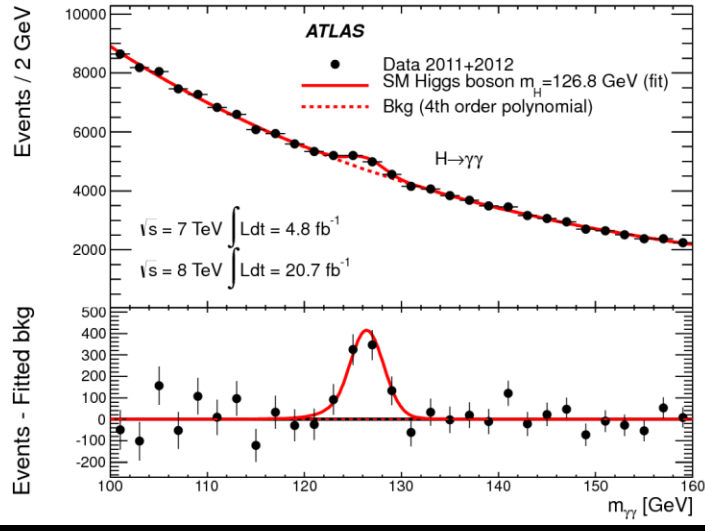
- Cover online activities, detector operation, software, computing
- A selection
  - Semi Conductor Tracker & pixel noise studies, monitoring, …, *(Ø. Dale , J. Lindroos, E. Gramstad, M. Pedersen)*
  - Constructing the IBL cabling map and decoding the bytestream from the new IBL front-end chips FE-I4 *(L. Franconi)*
  - Encoding of data for Insertable B-Layer pixel detector. Major updates of bytestream converter *(S. Mæland)*
  - Configuration editor for pixel Data Acquisition system *(Z. Yang)*
  - New features for multi-leg/NLO generator Alpgen - Showering with Herwig++, Interface within Athena, physics validation *(M. bugge)*
  - Use of Alpgen on supercomputer resources – splitting of input into smaller bunches and showering, physics validation *(V. Morisbak)*
  - Access to Chinese HPCs, new Python backend *(S. Raddum)*

PHYSICS EXPLOITATION

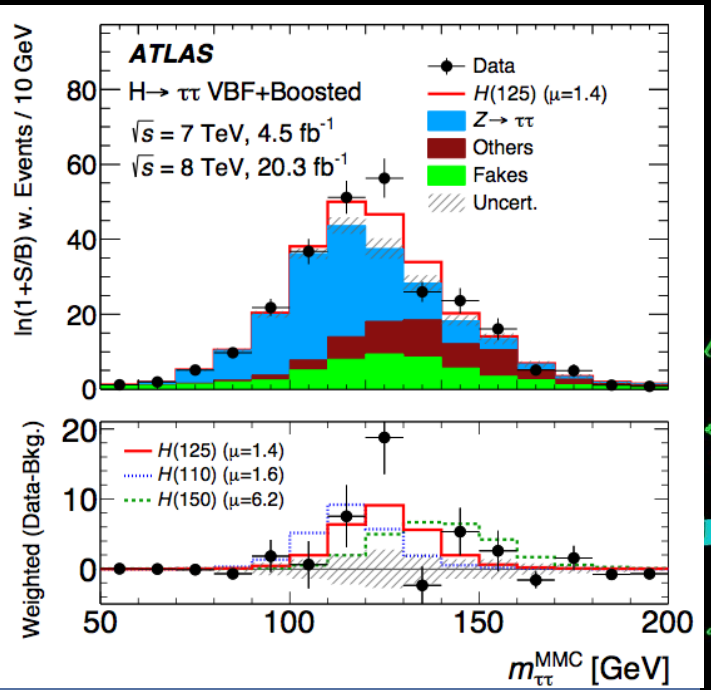
- Standard Model, flavour and Higgs precision measurements.
  - *Higgs decays to di-photons*
  - *Higgs decays to tau-pairs*
  - *Higgs decays to 4 leptons through ZZ**
  - B-meson properties and CKM fits
- Searches for new physics with lepton final states
  - Supersymmetry
  - Dark Matter
  - Exotics
  - Model independent searches

A particle consistent with the Higgs Boson observed with the ATLAS Detector at the Large Hadron Collider, Science 338 (2012) 1576.

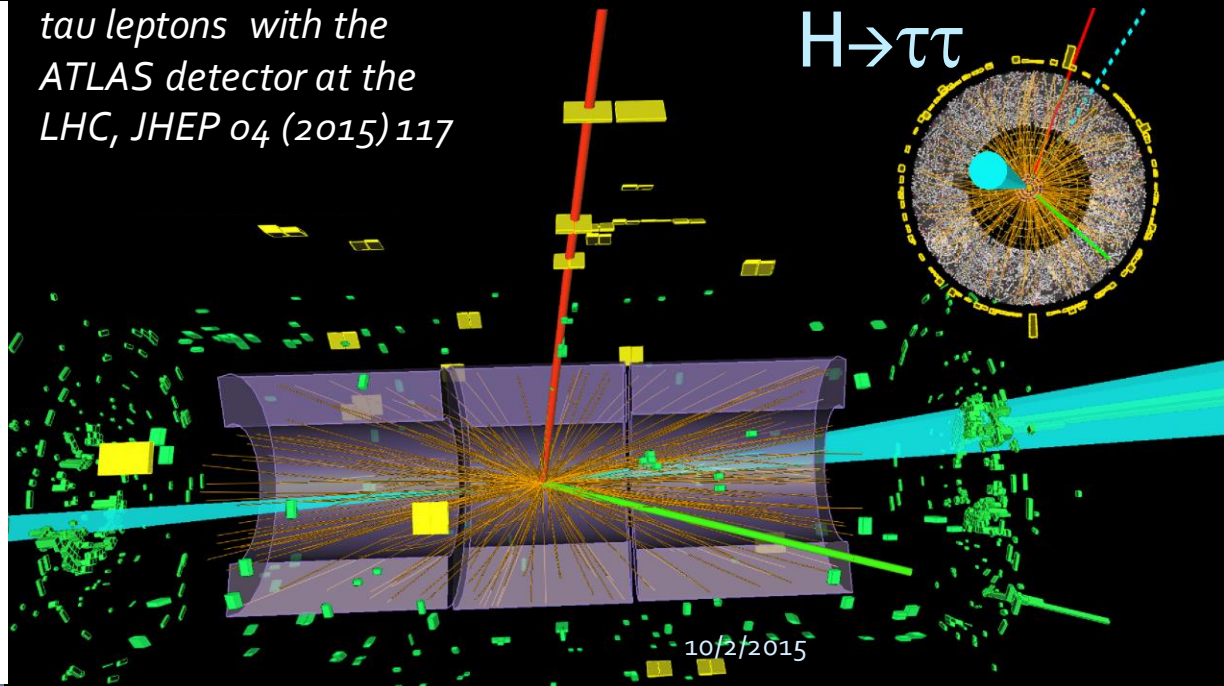
H→γγ



Evidence for the Higgs-boson Yukawa coupling to tau leptons with the ATLAS detector at the LHC, JHEP 04 (2015) 117

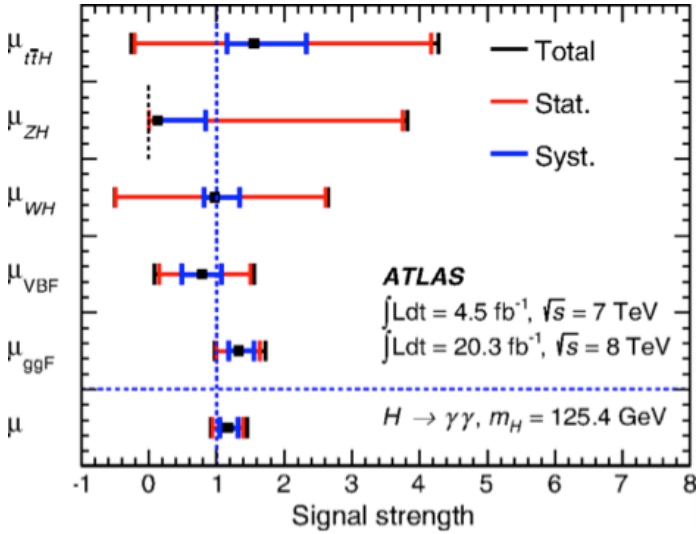


H→ττ



Higgs boson properties: H to diphotons

- Measurement of Higgs production in di-photon decay channel H→γγ
  - *Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, PL B 716 (2012) 1*
  - *PhD thesis: Lillian Smestad, "The Search for the Standard Model Higgs Boson in H → γγ Decays with the ATLAS Detector in 4.9 fb−1 of 2011 Data at √s = 7 TeV", main supervisor A. Read, 2013*
  - *Measurement of Higgs boson production in the diphoton decay channel, PR D90 (2014) 112015, …, A. Read et al.*



- Run 2 plans
  - Precision measurements of Higgs decays to di-photons at higher energies and luminosity, and search for deviations from SM.
  - *Read, Msc's A. Bielefeld and A-M. Hovda, PhD student.*

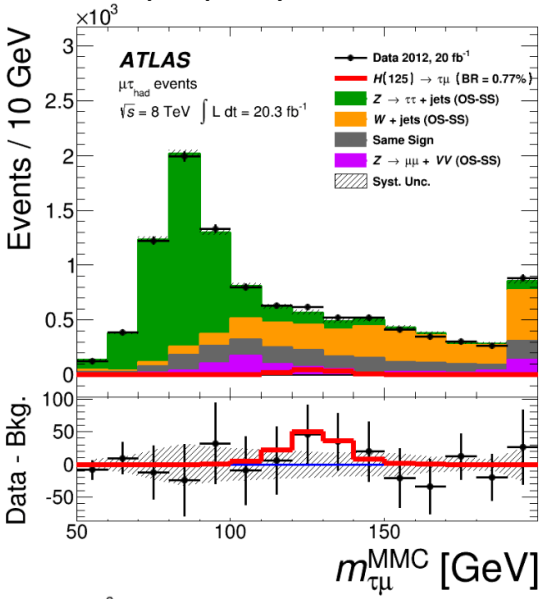
Higgs boson properties: H to taus

- Run 1 - H→ττ
  - *PhD thesis: Peter Rosendahl, "Searching for the Higgs Boson in Pairs of tau Leptons in Data from the ATLAS Experiment", supervisor B. Stugu, October 2013.*
  - *Method to Estimate the Boson Mass and Optimise Sensitivity to Helicity correlations of $\tau^+\tau^-$ final states, P. Rosendahl, T. Burgess, B. Stugu, JHEP01(2012)43*

Run 2 plans

- Higgs CP-analysis H→ττ – S. Mæland (PhD), B. Stugu
  - Measure scalar-pseudoscalar Higgs mixing angle in H→ττ via angular distributions of the tau pair
  - In H rest frame: angle between tau decay planes depend on CP property

- Lepton Flavour Violation in H→τμ
  - S. Hellesund (MSc), B. Stugu. Optimize mass peak reconstruction in Higgs boson rest frame. Search for resonance over a large mass range.
  - ***Excess observed by both ATLAS and CMS***



Charged Higgs

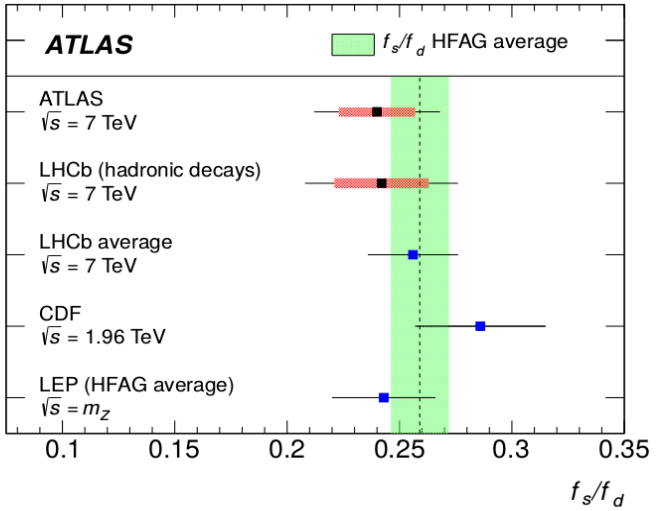
- Search for a charged Higgs boson in the transition region m_{H+} around m_t in the $\tau\nu_\tau$ channel.
- PhD thesis S. Raddum, main supervisor A. Read
  - A reliable description of charged Higgs production in the transition region is provided by the MATCHIG algorithm implemented in PYTHIA
  - Using Atlfast II simulated events with m_{H+} = 170 GeV and ATLAS 8-TeV data, this analysis attempts to close the gap at $m_{H+} \sim m_t$.
  - The analysis focuses on the $\tau\nu_\tau$ decay channel, which is the most promising and cleanest channel.
  - **Analysis based on Run 1 with possibility to include first look at 13 TeV**
- No further plans beyond Silje's thesis.

Improving H→4l coupling measurements

- Goal: to improve statistical sensitivity for different Higgs production modes
  - (*G. Eigen, Z. Yang, J. Zalieckas)*
- Investigating different multivariate techniques:
  - Use 2 Boost Decision Tree (BDT) outputs in profiled-likelihood fit
    - allows to use larger statistics in fit.
    - better statistical sensitivity wrt Run 1 final results:
  - Make use of neural network multi-classifier to separate production mechanism specific events
    - Performs better than BDT (binary classifier)
    - Novel approach, work in progress

B physics

- Branching fractions
- Fragmentation fractions essential for *b*-hadron cross sections and branching ratios.
  - Particularly relevant for rare decays ($B_s^0 \rightarrow \mu\mu$).
  - *Determination of the ratio of b-quark fragmentation fractions **fs/fd** in pp collisions at √s=7 TeV with the ATLAS detector (2015),* …, G. Eigen, Z. Zalieckas et al., arXiv:1507.08925, sub. To PRL

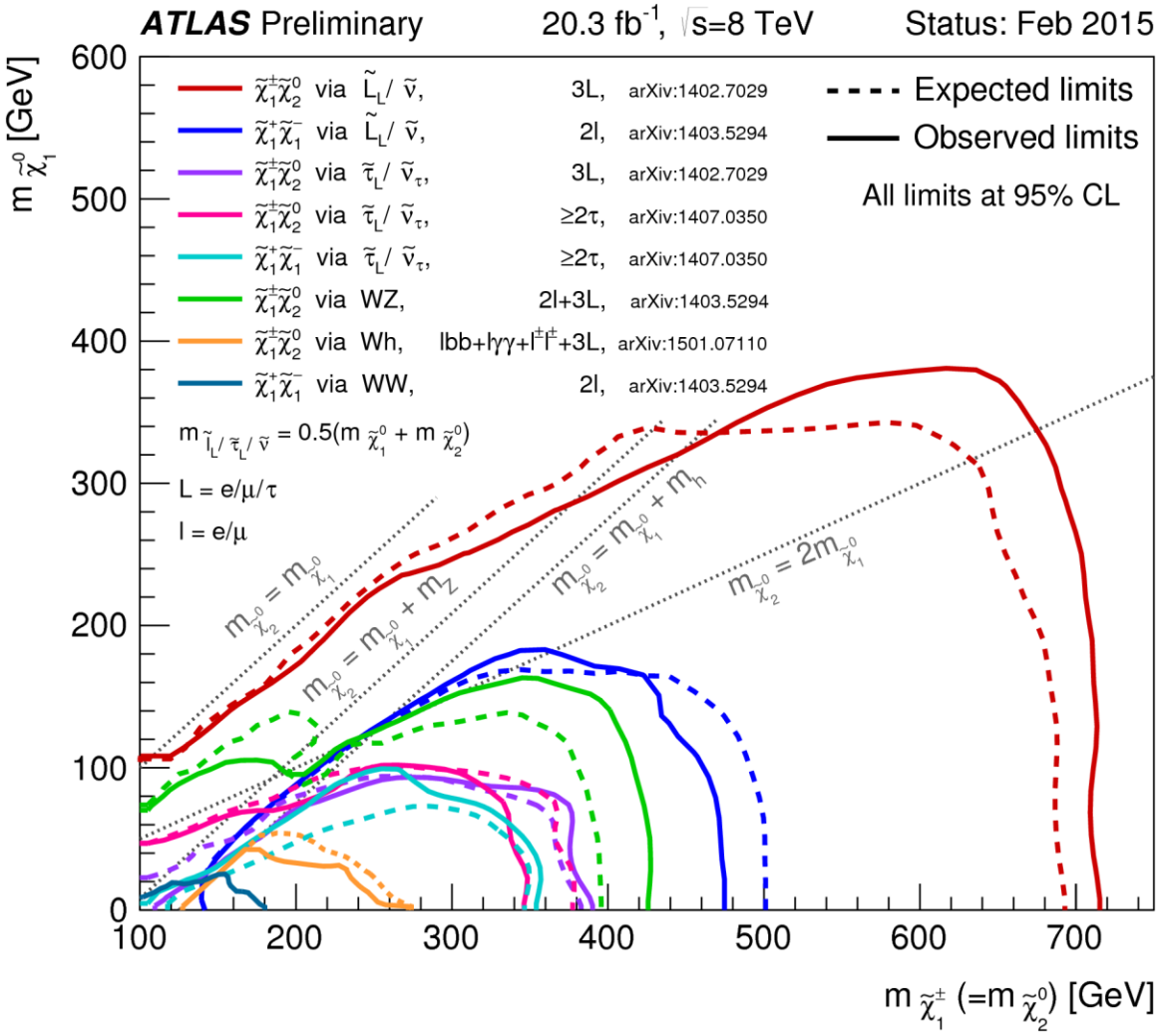


- $B_c^{\pm}$ meson properties (A. S. Træet's Master thesis)
  - Measure ratio of branching fractions BR($J/\psi\ \pi^+\pi^+\pi^-$) / BR($J/\psi\ \pi^+$).

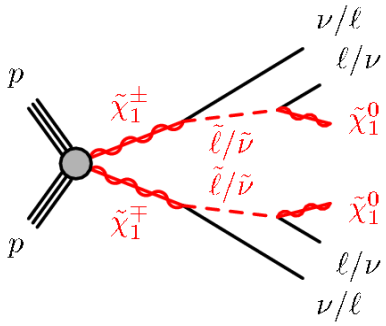
Searches for new physics with leptons

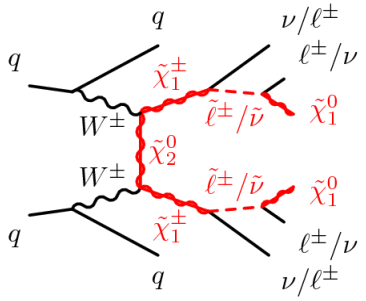
- This was our substantial physics analysis activity in Run 1 resulting in 6 PhD theses (*more to come in the future*) and direct contribution to more than 20 ATLAS published papers
  - Supersymmetry, Dark matter, Exotic phenomena
- PhD theses - 50% women
  - F. Ould-Saada – main supervisor
    - ***Katarina Pajchel***, *"Searches for Supersymmetry in multi-lepton final states with the ATLAS detector and related challenges"*, 2011
    - ***Eirik Gramstad***, *"Searches for Supersymmetry in di-lepton final states with the ATLAS detector at 7 TeV", 2013*
    - ***Maiken Pedersen***, *"Direct gaugino and slepton search in di-lepton final states and ATLAS discovery for education", 2014*
    - **Magnar Bugge**, *"Search for new charged bosons and dark matter in final states with one lepton and missing transverse energy with the ATLAS detector at the LHC"*, 2015
  - A. Lipniacka – main supervisor
    - ***Therese Sjursen***, *"Search for supersymmetry with tau leptons in the ATLAS experiment at the LHC", June 2014.*
    - ***Alex Kastanas***, *"Monitoring and Measurements with the ATLAS Inner Detector and Search for Supersymmetry using ATLAS data", October 2014*

SUSY searches with leptons – e, μ, τ



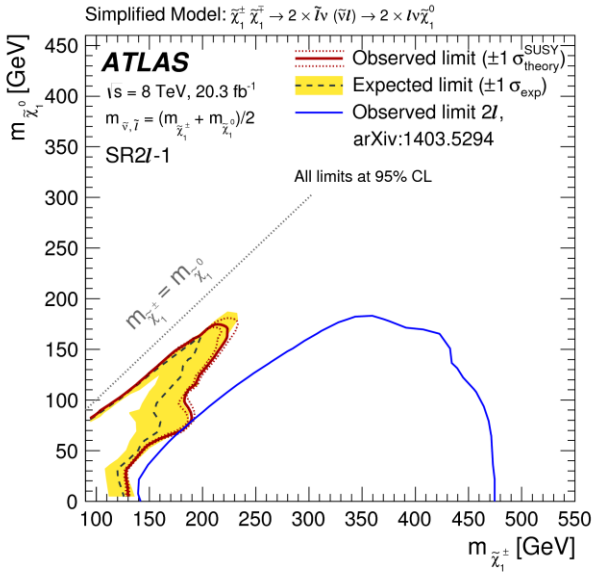
- Weak production of charginos, neutralinos, sleptons: 2/3 e/μ
  - Oslo
- Strong production with tau final states 1/2 τ
  - Bergen
- Phenomenological studies and DM interpretation

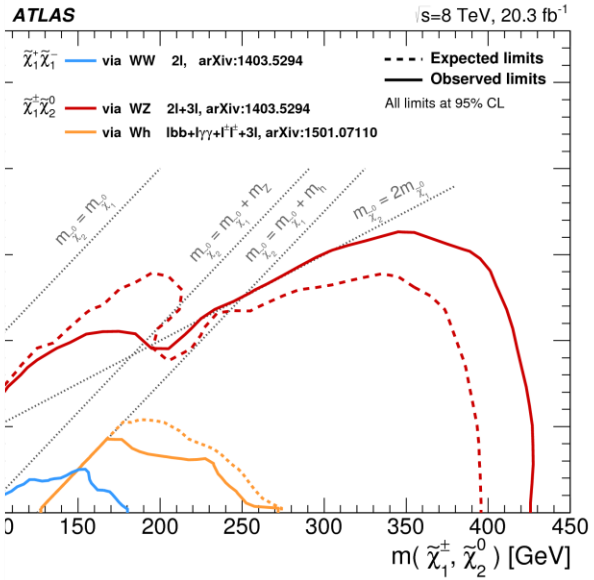


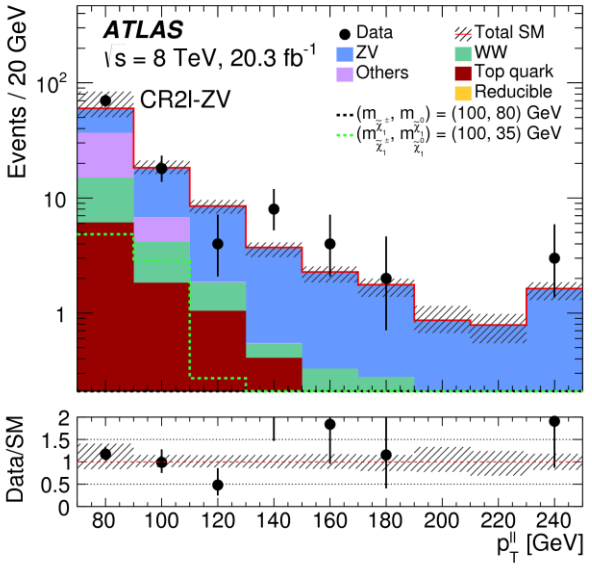


SUSY Electroweak production

- Weak production of charginos, neutralinos, sleptons: 2/3/.. e/μ
  - Phenomenological studies, pMSSM scan
  - Data-driven QCD and converted-photon background
  - Analysis and interpretation in terms of gauginos, sleptons, DM
- UiO team:
  - *B. Gjelsten, E. Gramstad, F. Ould-Saada, K. Pajchel, M. Pedersen*
- Run2
  - *+ H. Sandaker, PhD H. Oppen, PhD K. Vadla, …*







Recent publications
SUSY electroweak production with e,μ

- *Summary of the ATLAS experiment's sensitivity to supersymmetry after LHC Run 1 - interpreted in the phenomenological MSSM, arXiv:1508.06608 (2015)*
- *Search for the electroweak production of supersymmetric particles in √s =8 TeV pp collisions with the ATLAS detector, arxiv:1509.07152 (2015)*
- *Search for direct production of charginos, neutralinos and sleptons in final states with two leptons and missing transverse momentum in pp collisions at √s =8 TeV with the ATLAS detector, JHEP 05 (2014) 071*
- *Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in √s =8 TeV pp collisions with the ATLAS detector, JHEP 04 (2014) 169*
- *Search for supersymmetry at √s =8 TeV in final states with jets and two same-sign leptons or three leptons with the ATLAS detector, JHEP 06 (2014) 035*
- *Search for direct slepton and gaugino production in final states with two leptons and missing transverse momentum with the ATLAS detector in pp collisions at √s =7 TeV, PL B718 (2013) 879*
- *Search for direct production of charginos and neutralinos in events with three leptons and missing transverse momentum in √s =7 TeV pp collisions with the ATLAS detector, PL B718 (2013) 841*

SUSY strong production with taus and DM interpretation in pMSSM

- UiB Team:
  - *A. Lipniacka, T. Buanes, T. Burgess, Ø. Dale, A. Kastanas, B. Martin dit Latour, W. Liebig, J. Lindroos, H. Sandaker, T. Sjursen, L. Smestad*

- SUSY search with taus
- Summary of searches for squarks and gluinos
- Scan of phenomenological MSSM
- Search for $stop_1 \rightarrow stau_1$

- Follow-up the current activity in Run 2 at 13 TeV
  - Search for strongly-produced SUSY with taus
    - Explore SUSY parameter space using simplified and general models, …
    - Run-1 sensitivity expected to be exceeded with 2015 data

Recent publications
SUSY strong production with taus and DM interpretation in pMSSM

- *Summary of the ATLAS experiment's sensitivity to supersymmetry after LHC Run 1 - interpreted in the phenomenological MSSM* (2015), arXiv:1508.06608 [hep-ex]
- *Search for direct scalar top pair production in final states with two tau leptons in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector* (2015), arXiv:1509.04976 [hep-ex]
- *Summary of the searches for squarks and gluinos using $\sqrt{s}$ = 8 TeV pp collisions with the ATLAS experiment at the LHC* (2015), arXiv:1507.05525 [hep-ex]
- *Search for supersymmetry in events with large missing transverse momentum, jets, and at least one tau lepton in 20 fb^{-1} of $\sqrt{s}$ = 8 TeV proton-proton collision data with the ATLAS detector*, JHEP 09 (2014) 103, arXiv:1407.0603 [hep-ex]

Search for SUSY with jets + MET + taus

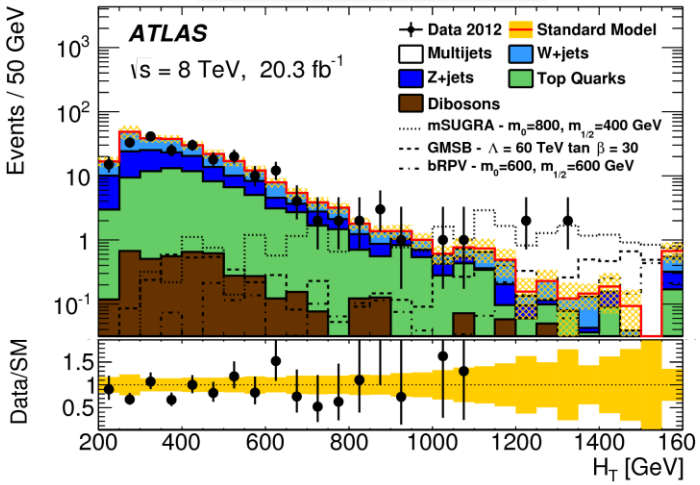
Search for strongly-produced SUSY with τ in final state.

Scenarios: GMSB, mSUGRA, nGM, bilinear-RPV.

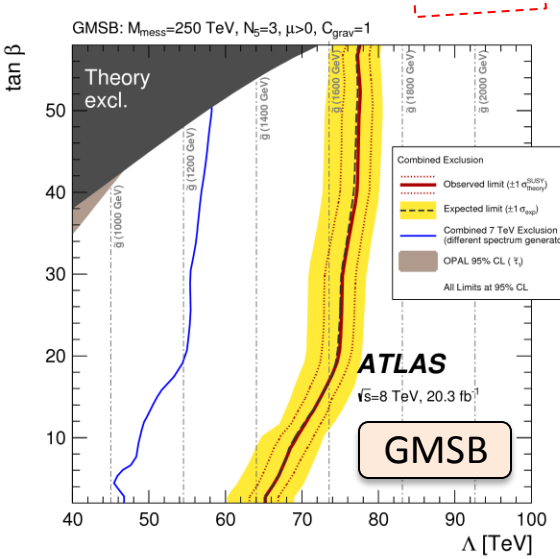
4 channels: 1τ, 2τ, μτ, eτ.

Responsible for 1τ channel since beginning of Run-1.

Jets + MET + 1τ

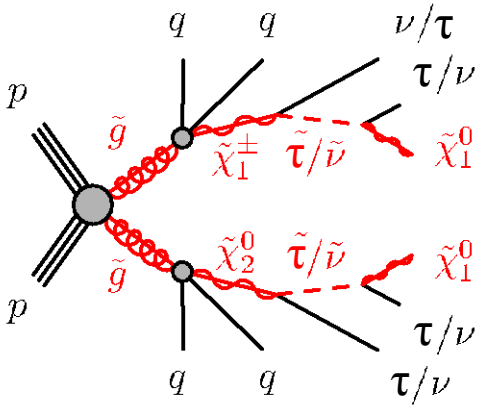


JHEP

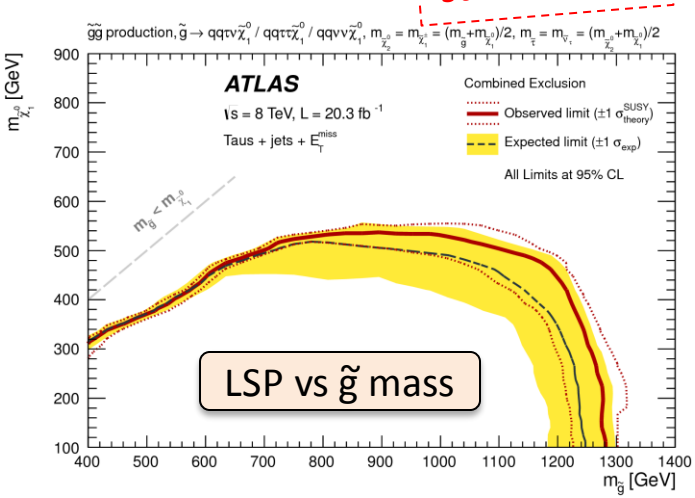


Re-interpretation within simplified model of gluino and squark pair production, with tau-rich cascade decay.

Assumptions on decay modes and SUSY mass spectrum.



sub. to JHEP



Scan of phenomenological MSSM

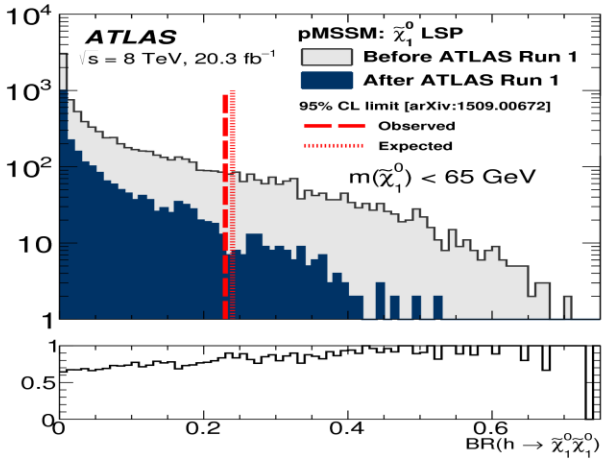
Scan of 19-D parameter space using Run-1 SUSY searches.

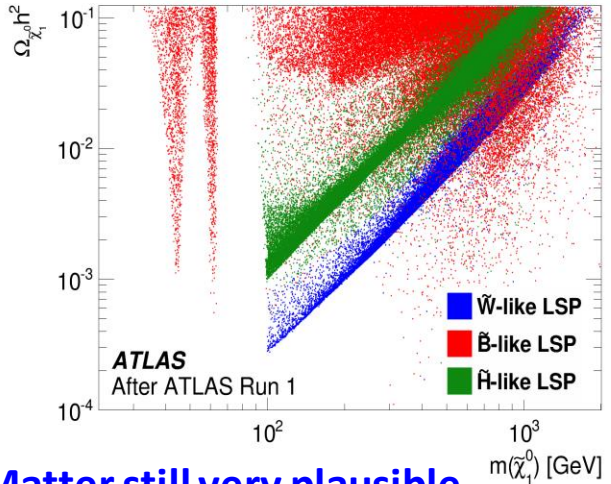
~300k sampling points for A×ε evaluation. Fraction of models run through ATLAS simulation for actual exclusion.

Leading role in Dark Matter interpretation (impact of ATLAS)

8 out of 50 editors funded by the HEPP project!

JHEP



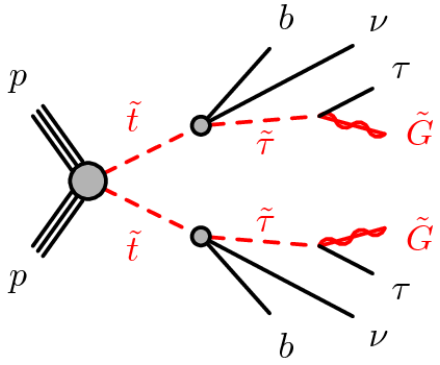


SUSY Dark Matter still very plausible

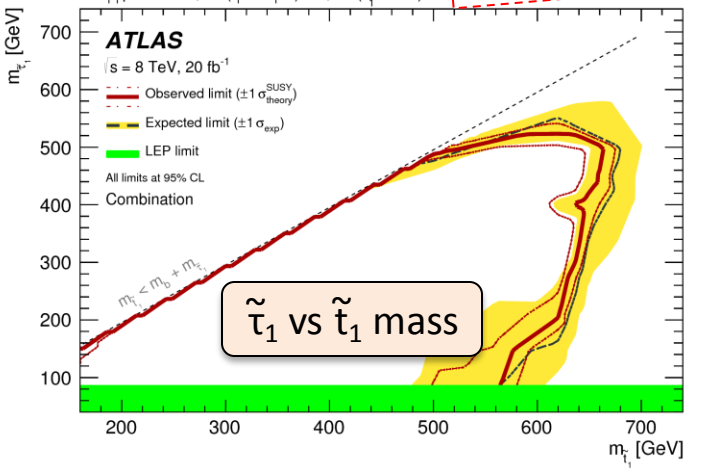
Search for $\tilde{t}_1$ -> $\tilde{\tau}_1$

First search at hadron collider for 3-body decay of stop into stau.
Final states: ττ, τe, τμ + di-lepton.

Contributed through data-driven estimate of multi-jet background.

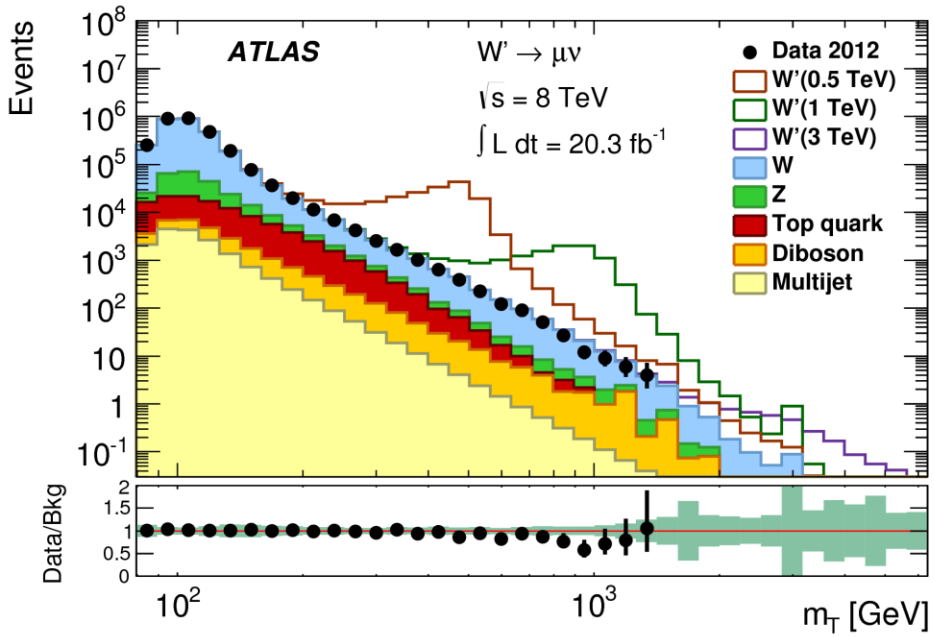


sub. to EPJC



Exotic searches – new gauge bosons, graviton, dark matter, …

- di-leptons (ll, l E_T^{miss})
  - New (gauge) bosons $W'^{(*)}$,$Z'^{(*)}$, …
  - Graviton, Contact interaction
  - Data-driven QCD background estimation
  - Discovery prospects and limit settings
- WIMP DM interpretation



New charged (gauge) boson $W'^{(*)} \rightarrow l\nu$ ➔

$M_{W'}$>3.24TeV M_{W^*}>3.21TeV

- *Search for new particles in events with one lepton and missing transverse momentum at √s= 8 TeV, …, M. Bugge, F. Ould-Saada et al., JHEP 09 (2014) 37; EPJ C 72 (2012) (7 TeV), …*

- *Search for new charged bosons and dark matter in final states with one lepton and missing transverse energy, **M. Bugge** (sup. F. Ould-Saada), PhD thesis, 2015*

Search for Di-lepton resonances (ee, μμ)

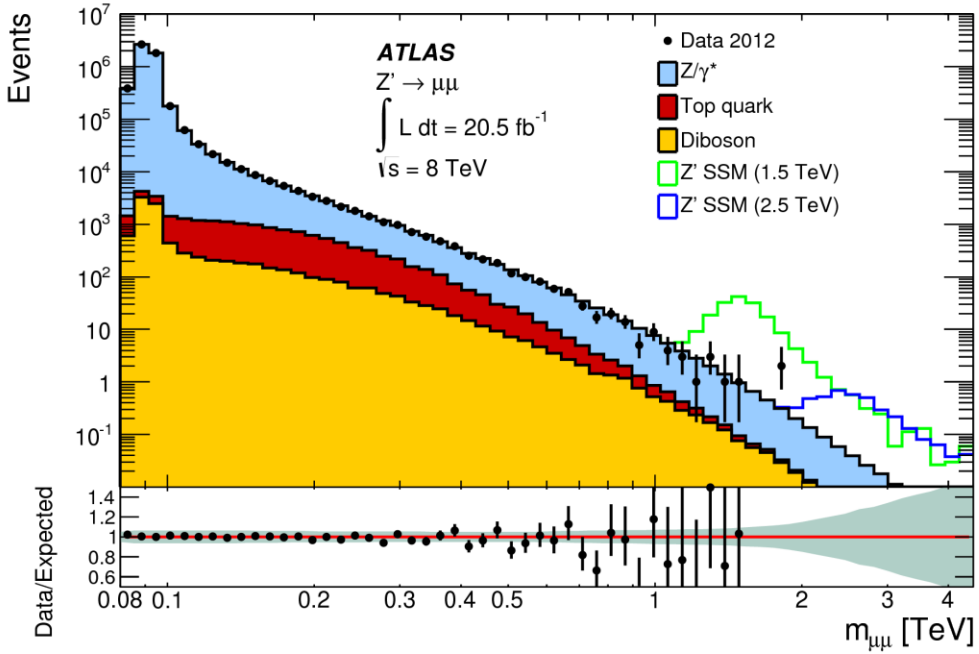
– New (gauge) bosons $Z'^{(*)}$, Graviton G^*

Sequential SM: $M_{Z'} > 2.9$ TeV

E_6-inspired models: $M_{Z'} > 2.5 – 2.6$ TeV

$M_{Z^*} > 2.8$ TeV

Randall-Sundrum Graviton (k/M~0.1):
$M_{G^*} > 2.7$ TeV



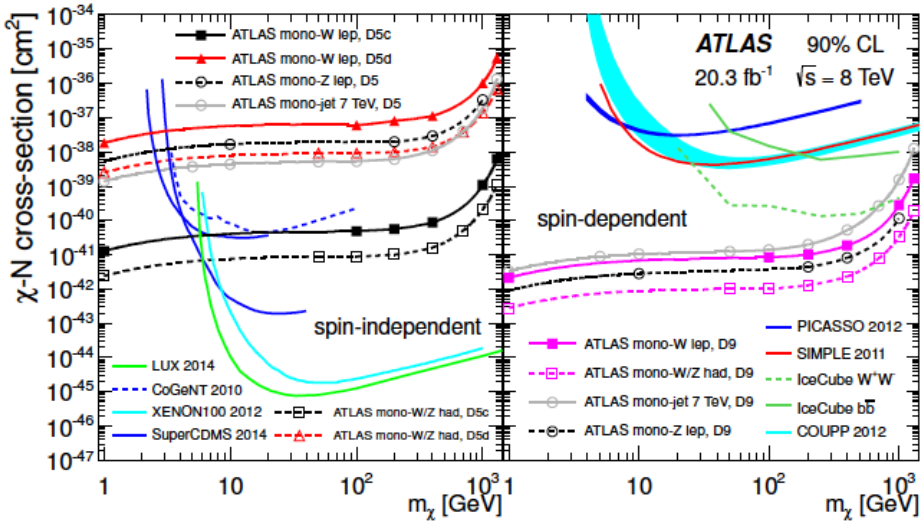
- *Search for High-Mass Dilepton Resonances at 8 TeV, G. Aad, V. Morisbak, F. Ould-Saada et al., Phys. Rev. D 90 (2014) 052005, JHEP 11 (2012) (at 7 TeV), …, PhD thesis, V. Morisbak (sup. Ould-Saada), 2017*

- *Search for di-muon resonances, K. Vadla (sup. Ould-Saada, J. Catmore), Master thesis 2015*

  - Validation of the new Event Data Model and data format (xAOD).
  - Analysis of 5 fb^{-1} of the 8 TeV data to search for additional gauge bosons Z'.
  - Feasibility studies of a search at 13 TeV.

Dark Matter interpretation

- **DM interpretation as mono-W: pp → W+χχ**
  - *…, Bugge, Ould-Saada et al., JHEP 09 (2014) 37*
  - Limits on the mass scale M_* of the unknown mediating interaction,



- Comparison with direct DM detection experiments
  - Better Sensitivity for spin-dependent interactions

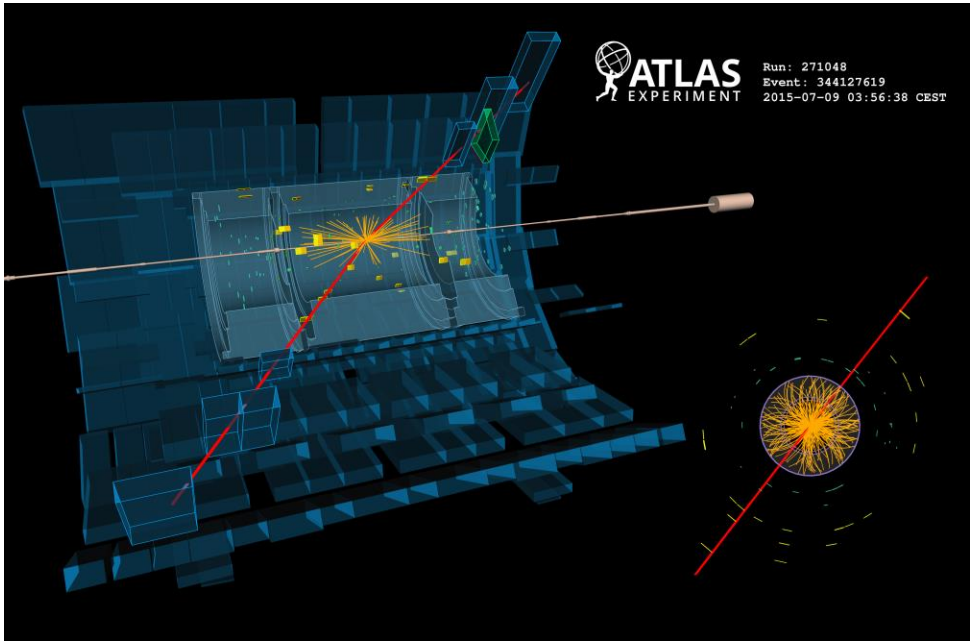
- **Dark matter search in mono-W and mono Z-events at 13 TeV – Run 2**
  - General DM investigations extending the search for SUSY DM.
  - "Simplified models" of DM production, including particles and interactions beyond the SM, provide an extension to the EFT approach.
  - PhD K. Vadla 2015 – 7.2019 (sup. Ould-Saada) in collaboration with PhD H. Oppen (sup. Sandaker), E. Gramstad, J. Catmore

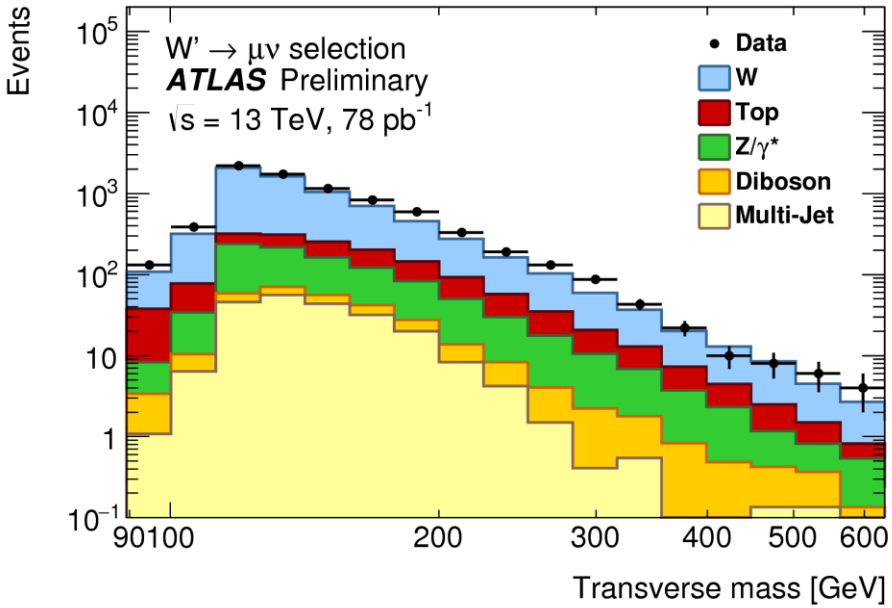
– **Collaboration with Bergen**

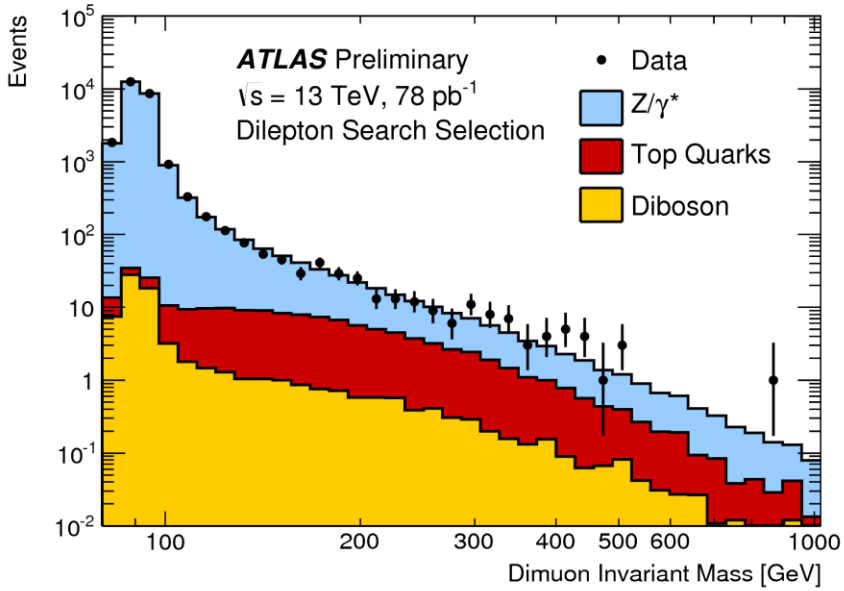
- **Model-independent search with leptons – Run 2**

Exotics searches

- First look at 13 TeV
  - Search for new particles in the charged lepton plus missing transverse energy final state, ATL-COM-PHYS-2015-254, *M. Bugge, F. Ould-Saada, J. Catmore* et al.
  - Search for resonant and non-resonant phenomena in the dilepton channel, ATL-COM-PHYS-2015-256, *V. Morisbak, F. Ould-Saada, J. Catmore, K. Vadla* et al.
  - EPS-HEP conference, 2015







WHAT NOW?

- READY for Run 2 & beyond
- There is one way to continue the good work …
  - Sustained funding at relevant level
  - Various detector upgrades are the door to high energies and luminosities … and to discoveries++
  - Computing infrastructure and software development required
  - Involvement of young scientists essential
- Funding of ATLAS upgrade and sustainability of the Computing Infrastructure are crucial
- NOT on the expense of the physics research program!
- ATLAS upgrade core and related development must be from Infrastructure application
  - 2014/15 → failed :
- Resubmission in 2016 – hopefully successful ☺

BACK-UP SLIDES

Determination of the ratio of *b*-quark fragmentation fractions f_s/f_d

sub. to PRL

Fragmentation fractions essential for ***b*-hadron cross sections and branching ratios**. **Particularly relevant for rare decays (B_s^0 -> μμ)**.

f_s/f_d extracted using B_d^0 and B_s^0 meson decays:

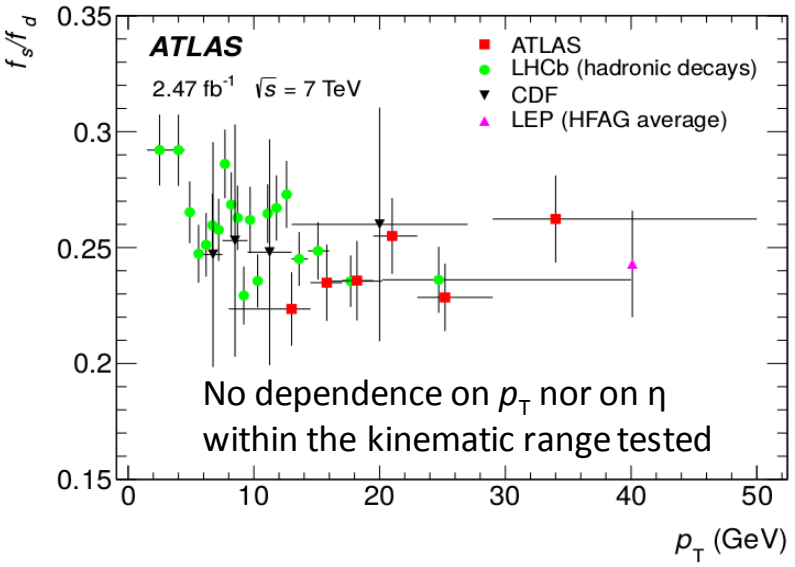
$$\frac{f_s}{f_d} = \frac{N_{B_s^0}}{N_{B_d^0}} \frac{\mathcal{B}(B_d^0 \to J/\psi K^{*0})}{\mathcal{B}(B_s^0 \to J/\psi \phi)} \frac{\mathcal{B}(K^{*0} \to K^+\pi^-)}{\mathcal{B}(\phi \to K^+K^-)} \mathcal{R}_{\mathrm{eff}}$$

Number of mesons from invariant mass fit

pQCD prediction

PDG

A × ε ratio from MC

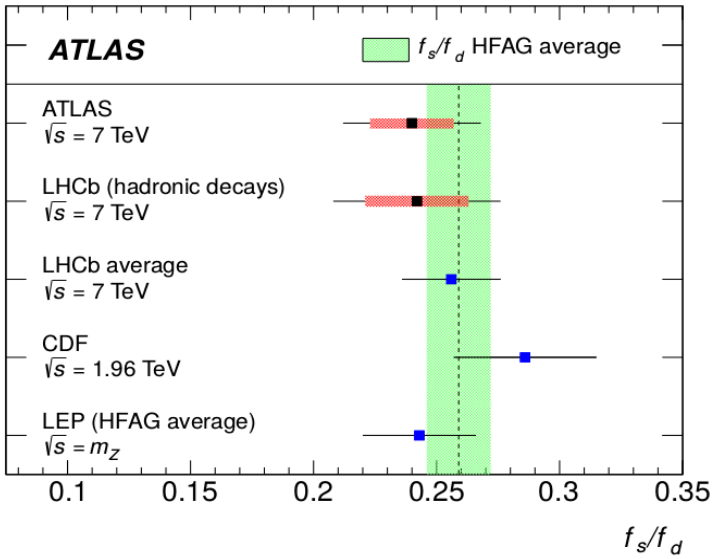


From data yields, one gets:

$$\frac{f_s}{f_d} \frac{\mathcal{B}(B_s^0 \to J/\psi \phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.199 \pm 0.004(\mathrm{stat}) \pm 0.008(\mathrm{sys})$$

Final measurement:

$$\frac{f_s}{f_d} = 0.240 \pm 0.004(\mathrm{stat}) \pm 0.010(\mathrm{sys}) \pm 0.017(\mathrm{th})$$



Higgs *CP* analysis in decays to τ τ

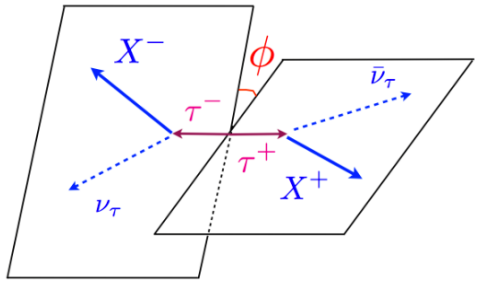
S. Mæland
B. Stugu

H->ττ involvement initiated with P. Rosendahl's thesis (supervised by B. Stugu) on 2011 ATLAS data, as part of the Higgs -> ττ discovery (evidence) effort.

Lead to publication: P. L. Rosendahl, T. Burgess and B. Stugu, "A method to estimate the boson mass and to optimise sensitivity to helicity correlations of tau+tau- final states", JHEP (2012) 043, arXiv:1105.6003 [hep-ex]

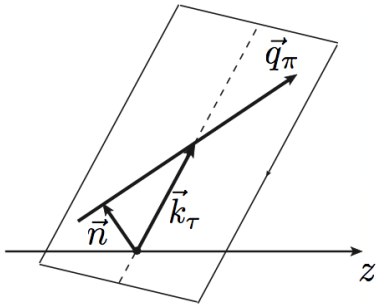
Measure scalar-pseudoscalar Higgs mixing angle in Htautau decays by analysing angular distributions of the tau pair

In H rest frame: angle between tau decay planes depend on CP property



Without neutrino momentum, two methods can be used to reconstruct acoplanarity:

✻ Impact vector method:

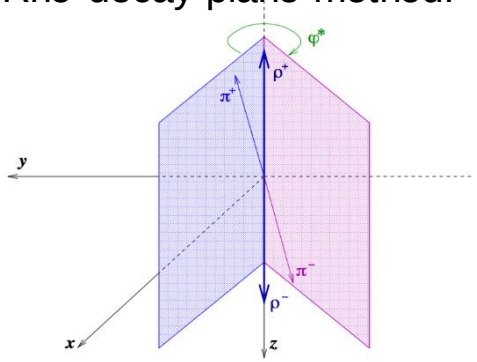


$$\varphi^*_{CP} = \begin{cases} \varphi^* & \text{if } \mathcal{O}^*_{CP} \geq 0 \\ 2\pi - \varphi^* & \text{if } \mathcal{O}^*_{CP} < 0 \end{cases}$$

where

$$\varphi^* = \arccos(\hat{\mathbf{n}}^{*+}_\perp \cdot \hat{\mathbf{n}}^{*-}_\perp),$$
$$\mathcal{O}^*_{CP} = \hat{\mathbf{p}}^*_- \cdot (\hat{\mathbf{n}}^{*+}_\perp \times \hat{\mathbf{n}}^{*-}_\perp)$$

✻ Rho decay plane method:



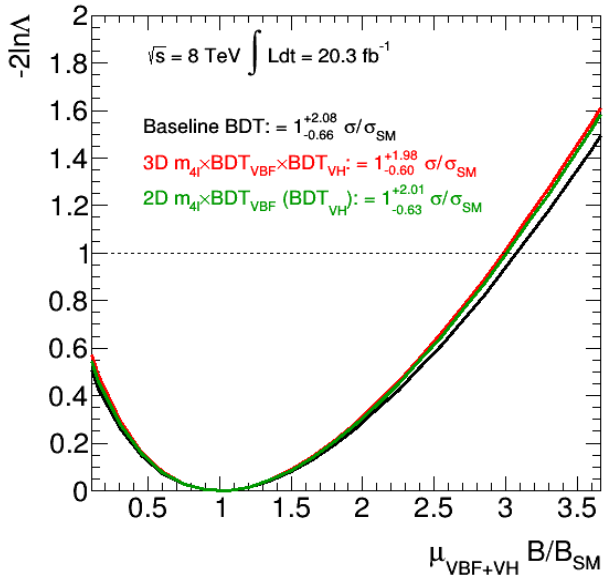
Improving Higgs couplings measurements for H->4l

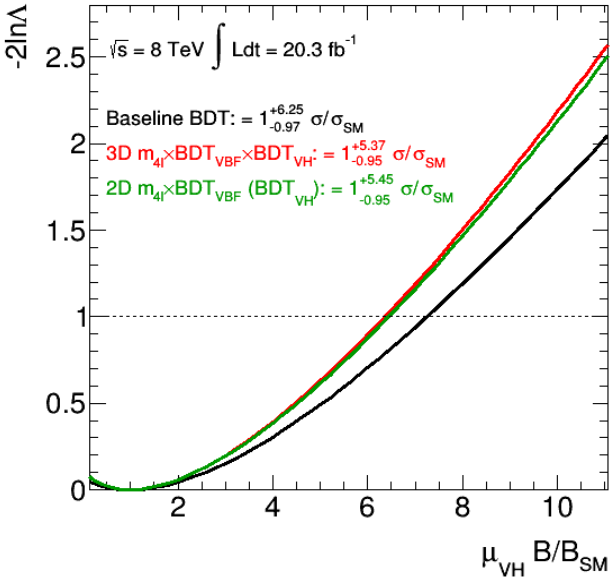
G. Eigen
Z. Yang
J. Zalieckas

- Goal: to improve statistical sensitivity for different Higgs production modes.
- Investigating different multivariate techniques:
- Method a) use 2 Boost Decision Tree (BDT) outputs in profiled-likelihood fit.
  - It allows to use larger statistics in fit.
  - Better statistical sensitivity wrt Run 1 final results:

$$\Delta\mu^{stat}_{VBF+VH} \approx 4.6\% \text{ and } \Delta\mu^{stat}_{VH} \approx 14.1\%$$

- Method b) employs neural network multi-classifier to separate production mechanism specific events.
  - Performs better than BDT (binary classifier)
  - Novel approach, work in progress





IBL bytestream converter

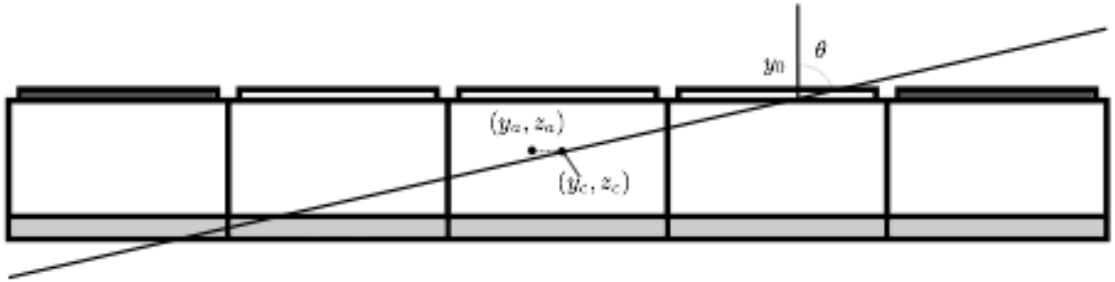
S. Mæland

- Major update to the bytestream converter code in august to prepare for 25ns runs
  - FE-I4 hit discriminator settings now read from database, updated by DAQ prior to each run
- Full FE-I4 service code treatment was implemented before the summer
- Run-2 pixel cabling map now stable for five months
- Bytestream encoder updated to reflect current IBL ROD firmware, meaning IBL hits are ordered identically in simulations and data (hit ordeling is non-trivial)
  - Essential for FTk studies

Pixel depletion depth measurement

S. Mæland
B. Stugu

- Size of the depleted region in the pixel sensors can be measured by correlating charge deposited in a cluster to the parameters of its associated track
  - Based on method described by André Schorlemmer, fall 2014 (CERN-THESIS-2014-185)
  - Irradiation causes hit efficiency to drop. Efficiency can be recovered by adjusting bias voltage, but need to know the current depletion depth
  - Note under preparation

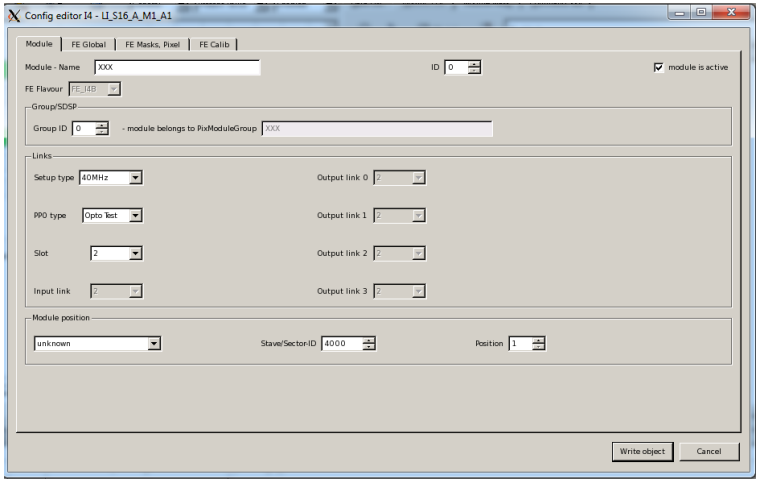


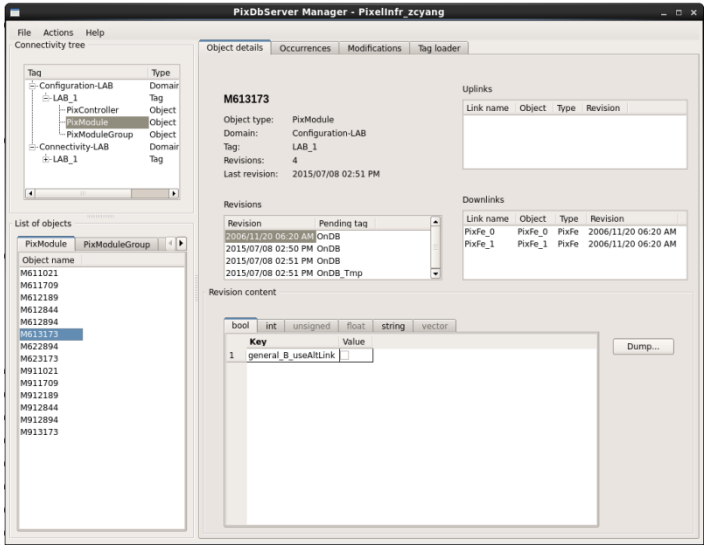
Configuration Editor in Pixel DAQ system

Z. Yang

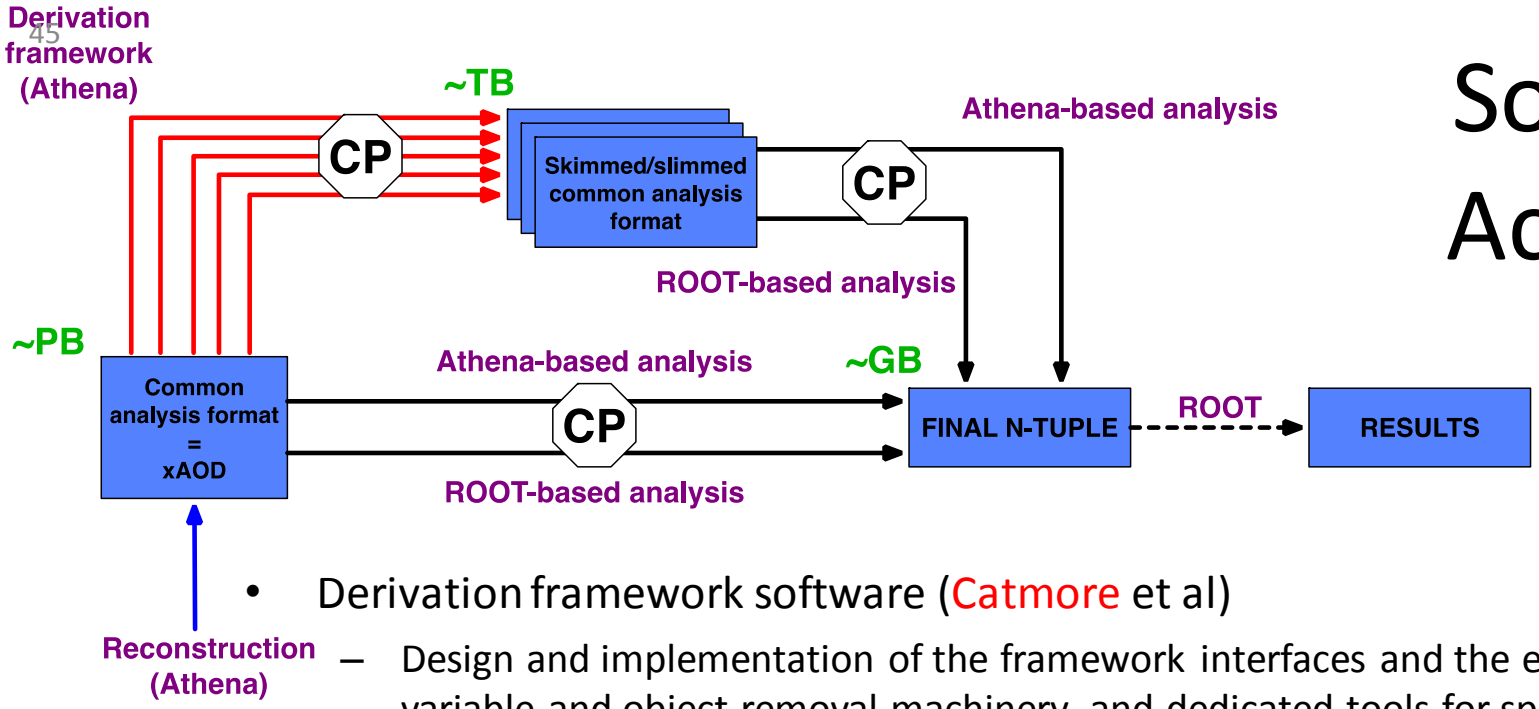
- Implementation of configuration editors in the main user interface of the ATLAS Pixel/IBL/DBM DAQ system:

1. Add configuration editors in the calibration console.
2. Can edit the configuration for different modules.
3. Can save and write the changes into database server.
4. Keep track of modification history.





Software Activities

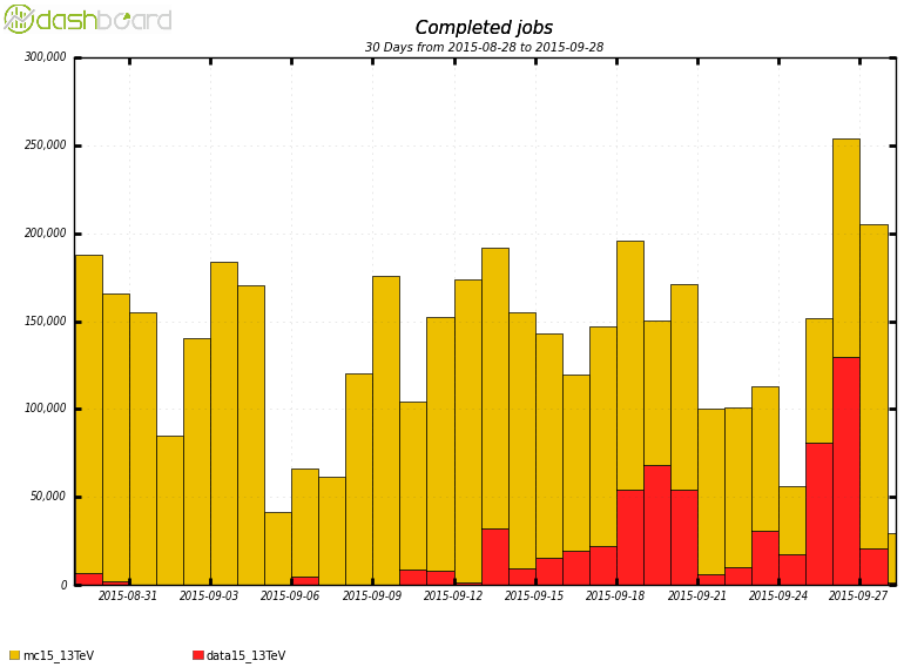


- Derivation framework software (Catmore et al)
  - Design and implementation of the framework interfaces and the event selection, variable and object removal machinery, and dedicated tools for specific tasks
  - CPU profiling, throughput improvements, output size/overlap monitoring
  - Liaison with physics groups and commissioning of the framework in production. Catmore, Gramstad.

- Monte Carlo Truth (Catmore)
  - Design, implementation and maintenance of the xAOD truth structure and the truth DxAODs used for analysis
- Future
  - Near-term: contribute to rationalisation of MC truth in the simulation work-flow
  - Longer-term: contribute to implementation of multi-threaded applications in the new software framework

Software Activities

- Derivation production – Gramstad et al.
  - ATLAS Train Coordination team
  - Implementation in the new ATLAS production system (prodsys2)
  - follow up production requests from physics and performance groups
  - Main responsible for overlooking and monitoring derivation production
    - monitoring the job status, reporting on failures and suggestions for improvements to Atlas Distributed Computing Team (ADC) and prodsys2 developers
    - monitoring derivation jobs in terms of CPU usage, overlaps, sizes, obsolescence, …



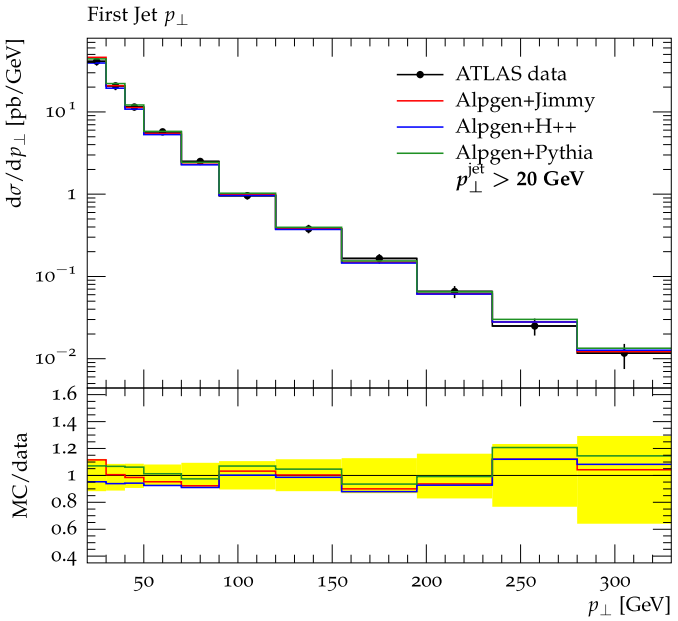
➔ Derivation production has evolved from being based mainly on manual operations to a much more automated and fail-safe system

References

- *A New Petabyte-scale Data Derivation Framework for ATLAS,, Procs CHEP2015*
- *Implementation of the ATLAS Run 2 event data model, Procs CHEP2015*
- *Original analysis model review report, https://cds.cern.ch/record/1543445,*

Software – student qualification

- Software development, support and validation of implementations of new multi-leg/NLO generator features for ATLAS. Magnar Bugge.
  - Showering of Alpgen events with Herwig++
  - Interface within Athena, physics validation, compare Alpgen+Herwig++ to existing alternatives
- Implementing & validating modifications to the ATLAS simulation framework and use on supercomputer resources. Vanja Morisbak.



  - Scrips to split Alpgen large input files into smaller bunches before showering.
  - Validation with Z MC: Compare HPC-produced Alpgen Z MC showered in Pythia6 to two official ATLAS MC samples using Rivet.
  - Check whether observed discrepancy in TTbar Alpgen+Pythia6 (PDF CTEQ5l) and TTbar Alpgen+fHerwig (PDF CTEQ6L1) is due to PDF difference

PhD & Master Students
HEPP Project

- 2012-2015 (4y) compared to 2006-2011 (6y)
  - Decrease of masters/year:
    - 5 -> 3 (all) ; 3.7 -> 1.75 (experiment)
  - Increase of PhDs in theory, experiment stable
    - 2.5 ->3.25 (all); 2 -> 2 (experiment)

Students	06-11	2012	2013	2014	2015	12-15
Master	30	6	1	1	4	12
Experiment	22	3	1	1	2	7
Theory	8	3	0	0	2	5
PhD	15	1	4	4	4	13
Experiment	12	1	3	2	2	8
Theory	3	0	1	2	2	5