A Study of the ATLAS Tile Calorimeter LASER Calibration System Dynamic and Spin Studies at the LHC

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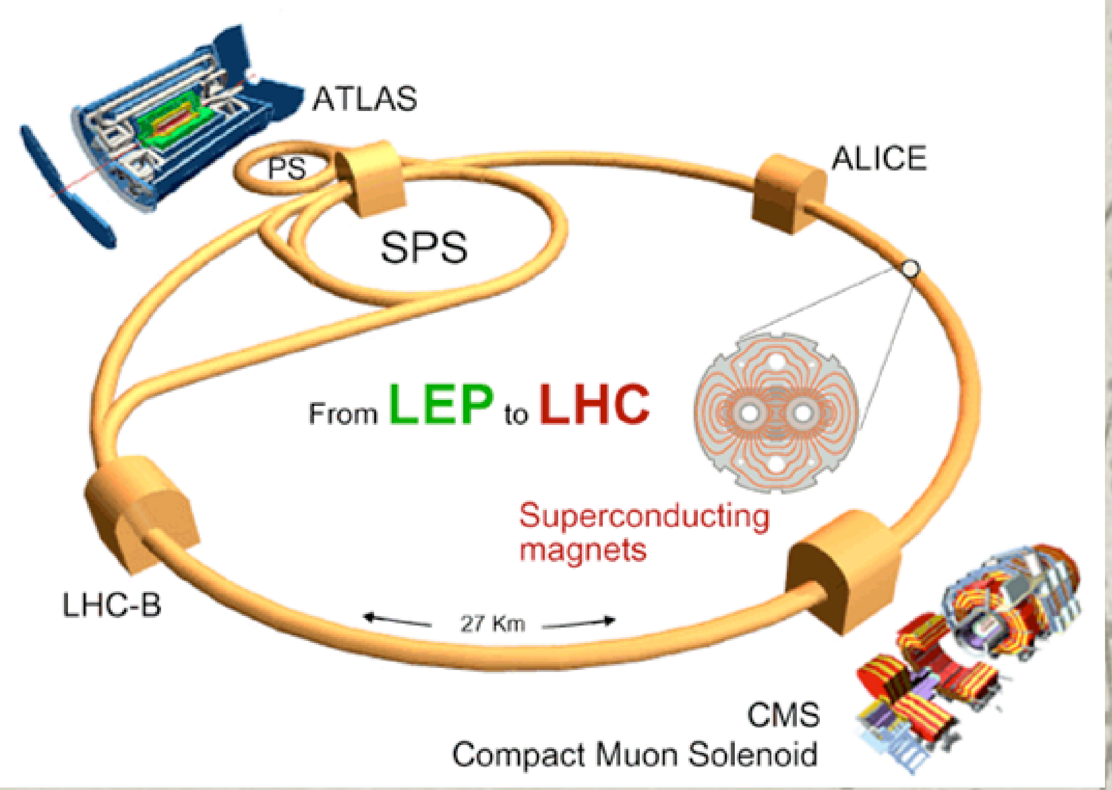
Overview

- Study of the ATLAS Tile Calorimeter LASER Calibration System Dynamic
  - The ATLAS experiment
  - Tile Cal
  - The LASER system
  - Intrinsic dynamic of the LASER system
  - Measurement of the wheel filters
  - Problems observed
  - Conclusions
- Spin Studies At the LHC:
  - Spin Background
  - Planned LHC studies
    - Higgs
    - Testing the standard model
    - Beyond the standard model
  - UMich Λ_b study at ATLAS
  - Conclusions

The ATLAS Experiment

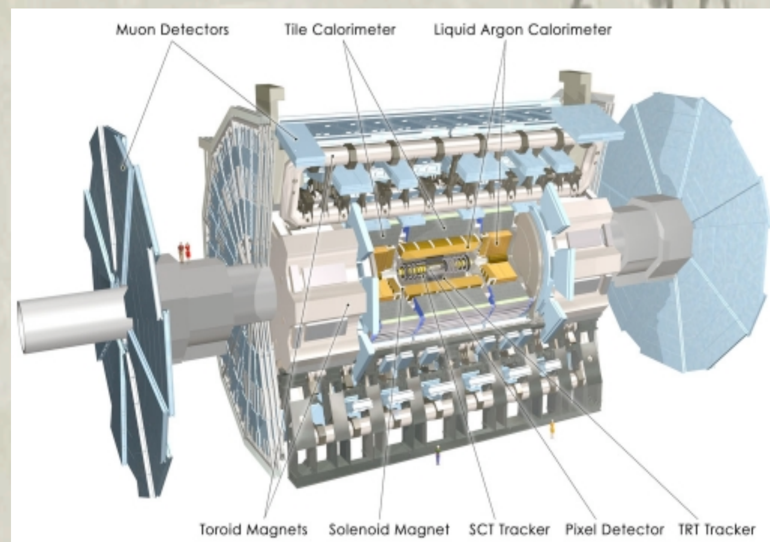
- 3 major components:
  - Inner tracker: precise momentum measurement
  - Calorimeter: particle energy
  - Muon spectrometer: muon momenta



TileCal

How it works:

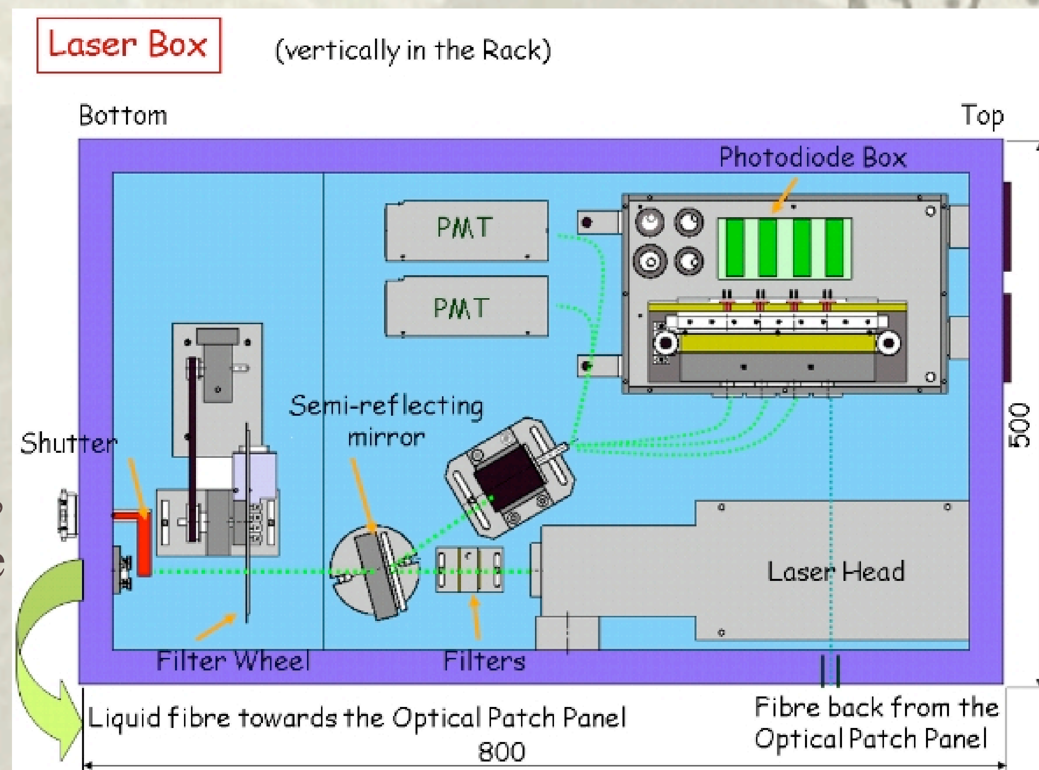
1. Hadronic showers ionize the iron plates and illuminate the scintillating plastic tiles.
2. Light is collected and transmitted via optical fibers to the PMTs.
3. The charge collected by the photomultipliers is digitized and sent to ATLAS readout.
4. Information is reconstructed and summed in order to find the initial particle energy.



- Calibration: Reduce and understand the difference between the energy of the particle and the energy reconstructed.

The LASER System

- The LASER system serves a variety of functions:
    1. a fast, on-line control of the behavior of the PMTs and the associated front-end electronics of TileCal,
    2. a measurement of the time drift of the relative gains,
    3. a measurement of the linearity of each PMT, and
    4. a measurement of the number of photo-electrons received by each PMT.



The wheel filter: each filter applies a specific attenuation factor to the light

Goal:

- Analyze data generated by the LASER system in order to measure the attenuation factor and therefore the dynamic of the LASER system

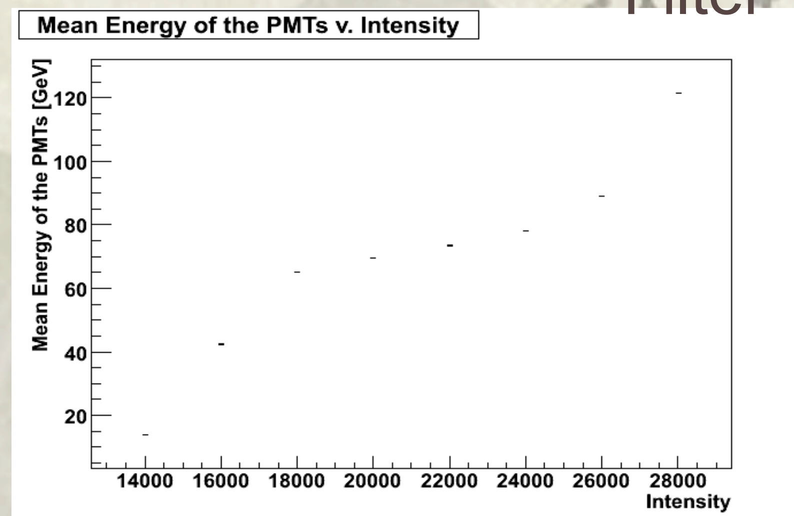
Data Samples

- Two modes: Standalone and TDaq
- Standalone: All Filters
- TDaq: Filters 1, 4, 8
- LASER intensities 14000, 16000, 18000, 20000, 22000, 24000, 26000, 28000, 30000 (arbitrary units)
- ~ 5000 events

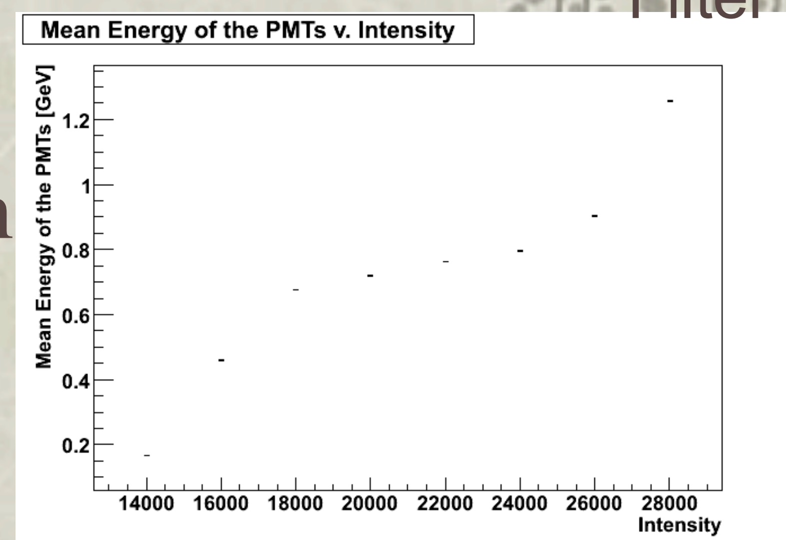
Intrinsic Dynamic of the LASER System

- Mean energy of the PMTs of TileCal as a function of LASER intensity.
- Intrinsic dynamic is of order 10.
- Dynamic does not seem to depend on filter.

Filter 1

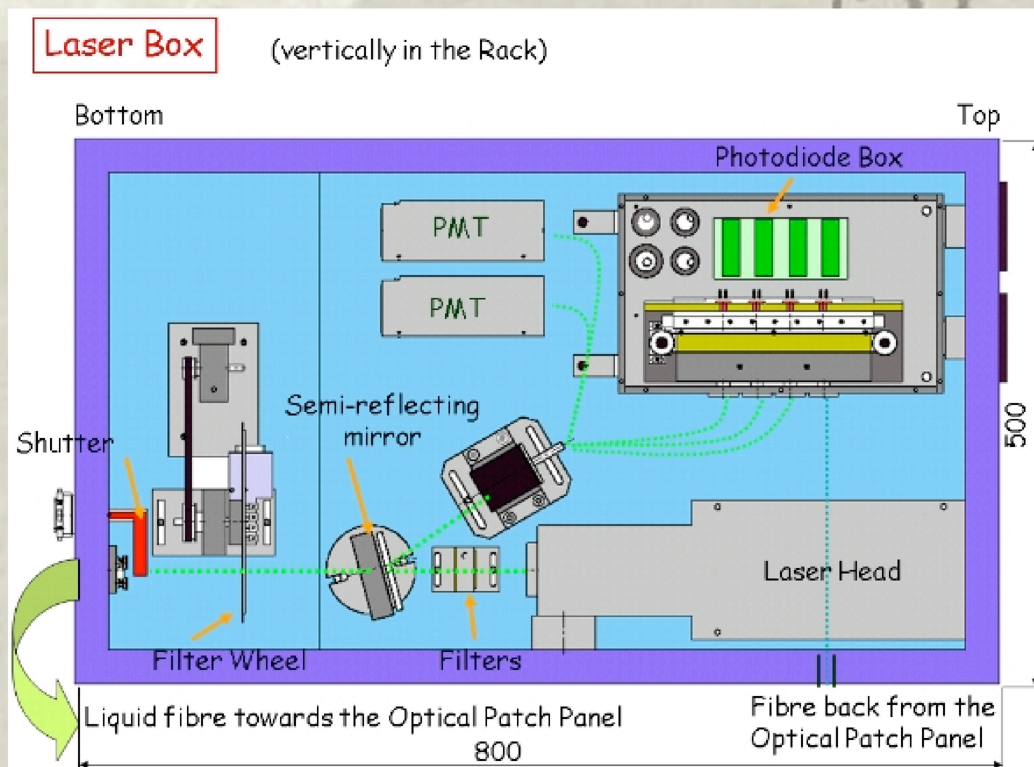


Filter 4



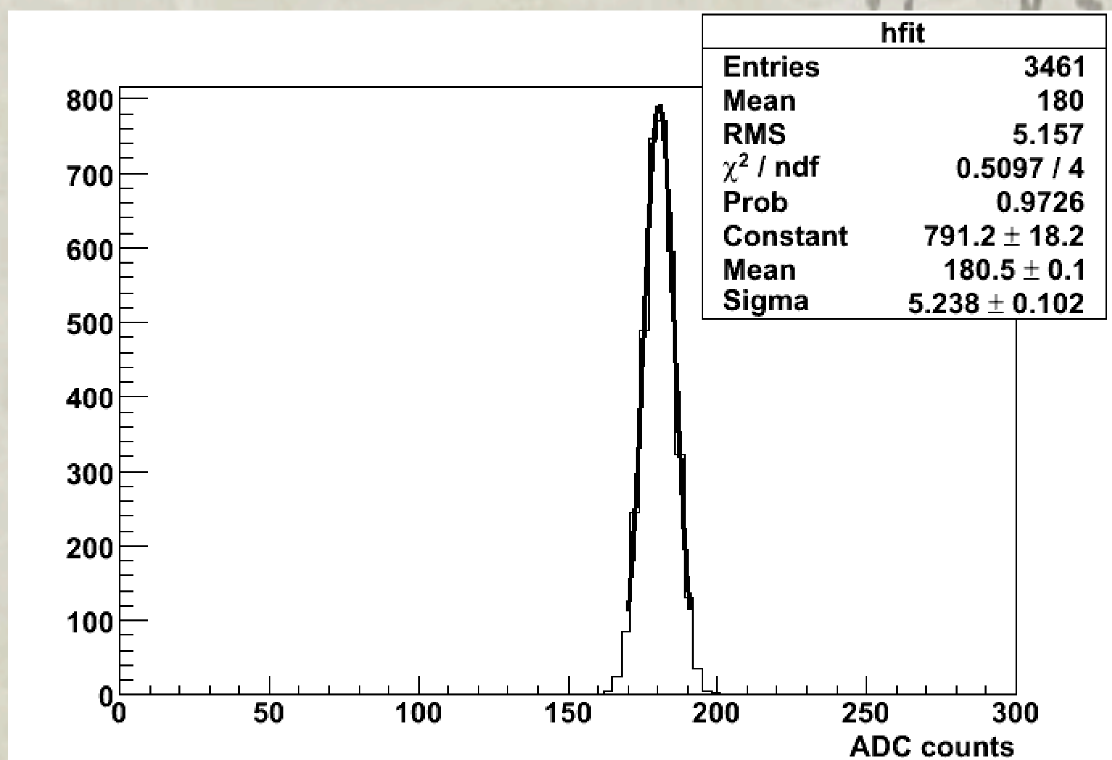
Measurement of the Wheel Filters

- Diode 4 sees the light that has gone through the filter



Measurement of the Wheel Filters

- Pedestal value: comes from electronic noise



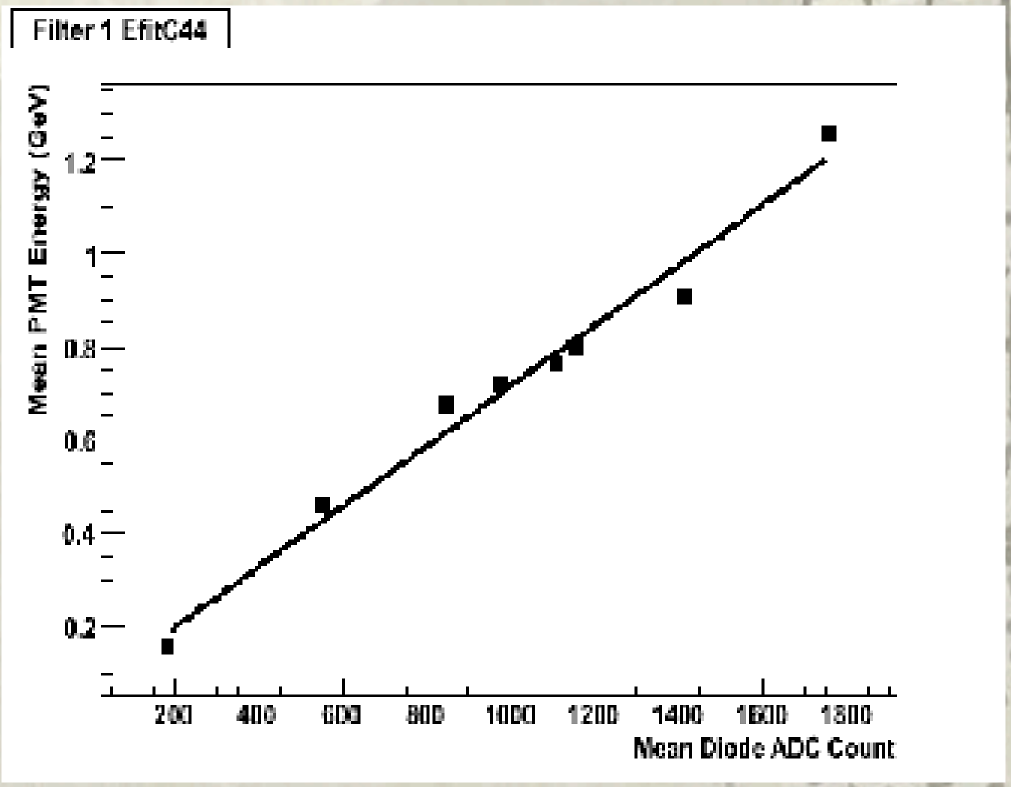
Calculation of the Attenuation Factor

- ADC_diode4/MeanADC_diodes1,2,3

Name	Filter8/ filter1	Filter2/ Filter8	Filter7/ Filter8	Filter7/ Filter2	Filter3/ Filter2	Filter4/ Filter3
Attenuation from Data	0.339 ± 0.002	0.261 ± 0.005	2.434 ± 0.058	9.325 ± 0.155	0.293 ± 0.007	0.317 ± 0.002
Attenuation from LASER Web Page	N/A	0.269 ± 0.003	N/A	N/A	0.304 ± 0.003	0.311 ± 0.024

Problems Observed

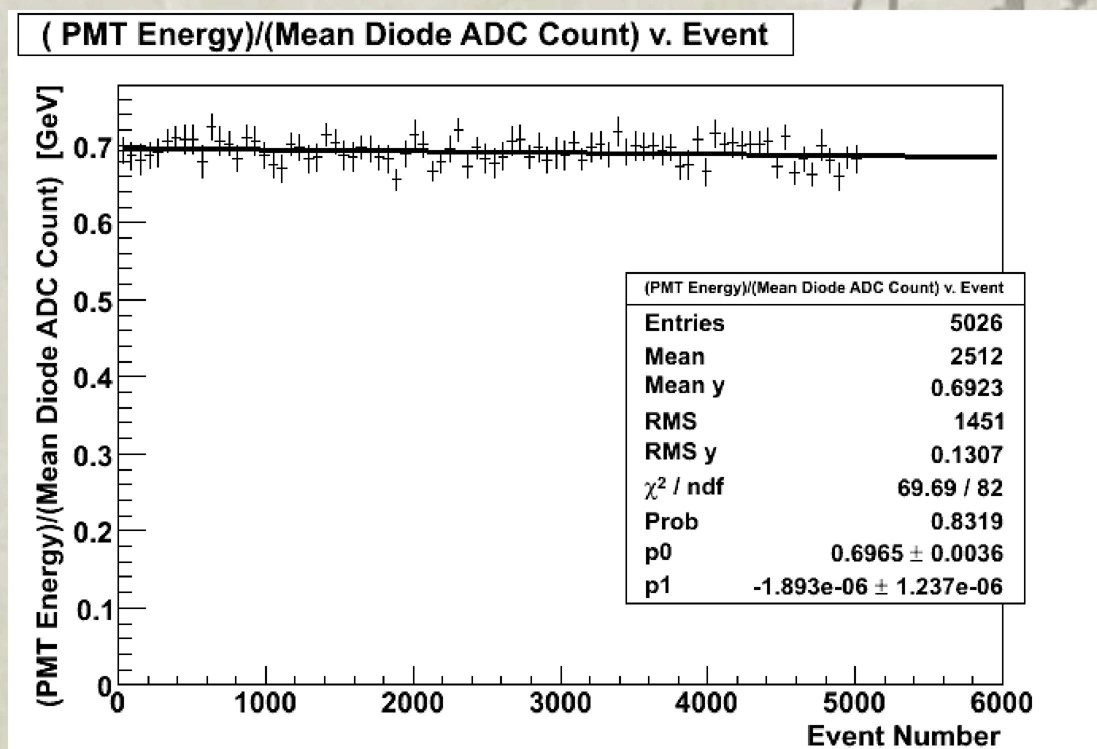
- Problem with diodes or PMT electronics?



Problems Observed

- Calibration constant =

  Energy_PMT/Mean diodeADCcount
- Significant slope



Conclusions: Study of the ATLAS Tile Calorimeter LASER Calibration System Dynamic

- Large dynamical range covered by wheel filters
- Intrinsic dynamic is of order 10 and does not depend on filter
- Attenuation factors within experimental uncertainties
- PMT energy as a function of mean diode ADC count demonstrated non-linearity
- Non-linearity is currently under investigation by the LASER group

Spin Studies at the LHC

–Spin Background

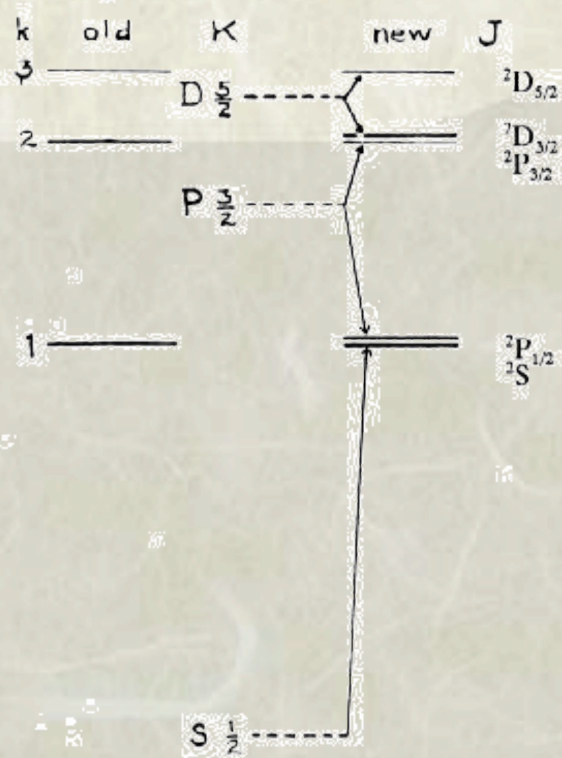
–Planned LHC studies

- Higgs
- Testing the standard model
- Beyond the standard model

–UMich Λ_b study at ATLAS

History: Electron Spin

Hydrogen n=3



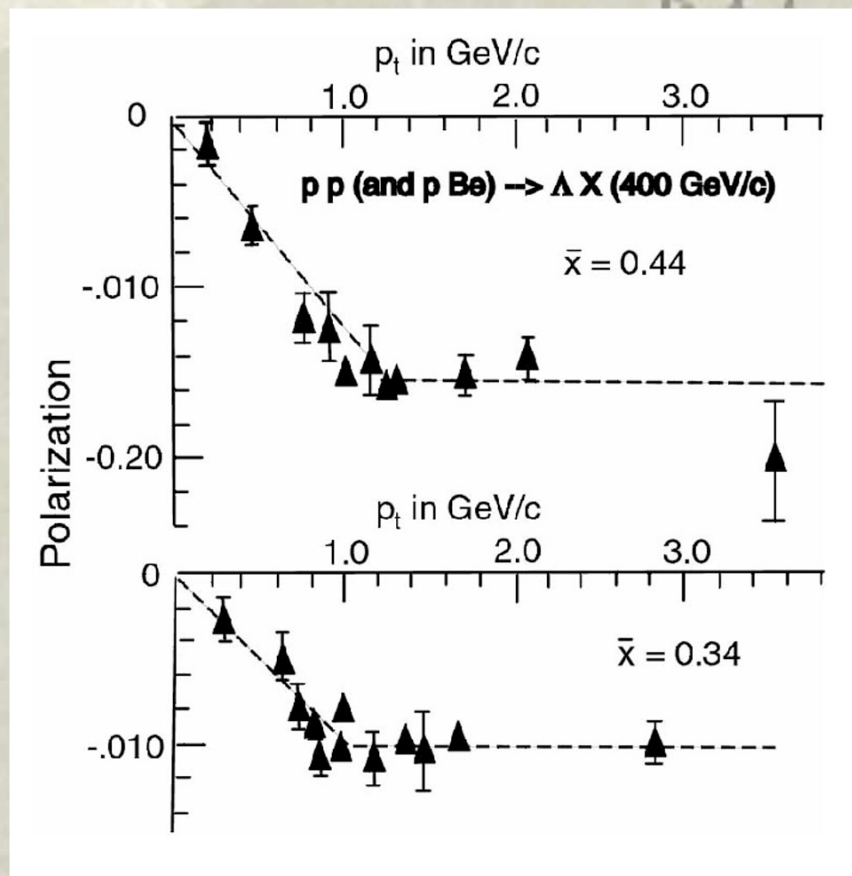
- Question: How can we explain the multiplicity of the spectral terms of the atom?
- Answer:
  - Landé: Ersatzmodell: multiplets result from core angular momentum. The property of the core changes when electrons are added to the core
  - Pauli: Multiplet is due to a characteristic of the electron. The quantum numbers n, k j, and m all belong to the electron.
  - R. de L. Kronig, **Uhlenbeck, Goudsmit**: electron is self-rotating.
  - **L.H. Thomas**: discrepancies between models and experiments due to an incorrect definition of the electron rest system -> Pauli withdraws reservations.
  - "Self-rotation" not spin.

History: Proton Spin

- Question: Is the proton a fermion or boson?
- Answer:
  - Hund: Fermions and bosons should exhibit different intensity ratios in their band spectrum. He finds the already-known experimental value of rotational specific heat of hydrogen assuming the proton is a boson.
  - Hori finds intensity ratio consistent with proton being a fermion with spin 1/2.
  - **Dennison**: A long time is required for a Hydrogen molecule to undergo even j to odd j transition. Hund's result should not agree with Hori because Hund assumed thermal equilibrium. Proton is spin 1/2 fermion.

Why Spin Matters

- Spin is still a mystery!
  - How does this intrinsic property work?
  - What is it in interactions that knows how the particle is spinning?
- An observable that can distinguish standard model particles from particles in physics beyond the standard model (SUSY, LED, Technicolor, etc.)



Higgs Studies

Detector	What	Why	How
Not specified	$H^{-} \rightarrow \tau^{-}_{R} \bar{\nu}_{R}$ with τ polarization = $+1$ τ-jet signal	Look for the charged Higgs boson $H^{\pm}$ in the MSSM.	Use τ polarization cut to enhance signal/background ratio in $H^{\pm}$ search
ATLAS and CMS	$H \rightarrow ZZ \rightarrow 4l$	Determine the spin of the Higgs boson to discriminate between SM and non SM Higgs.	Look at the spin-dependent angular distributions of the decay leptons.

Testing the Standard Model

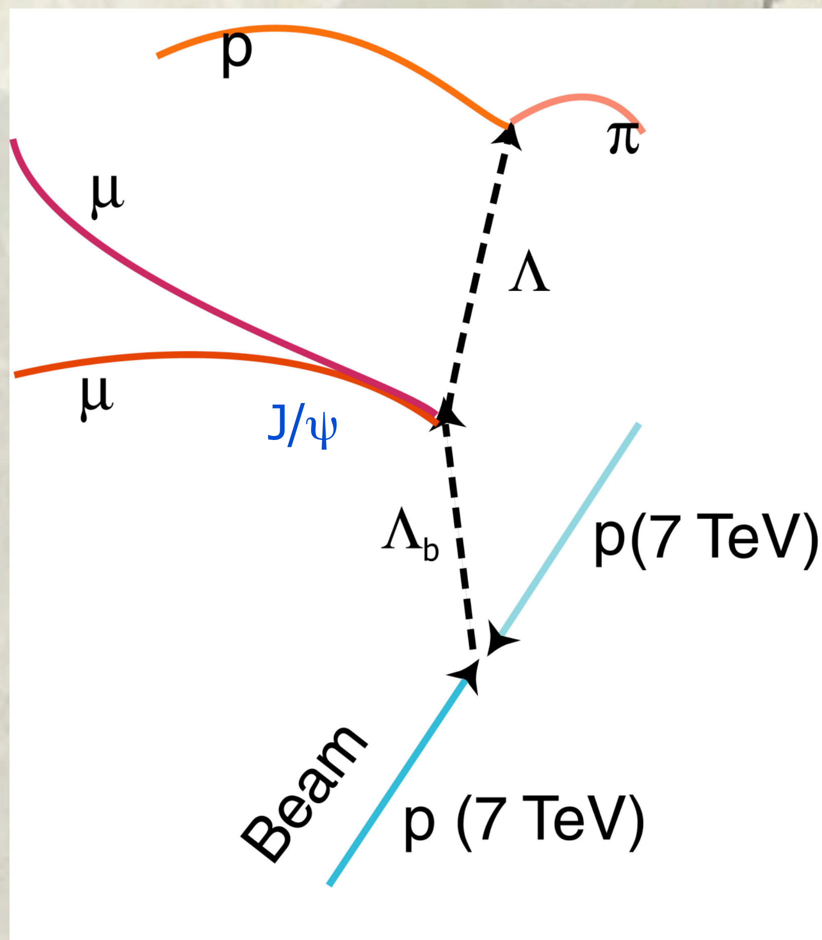
Detector	**What**	**Why**	**How**
ATLAS	Measuring the spin density element of the Z boson.	Test the precise prediction in the SM for Z polarization and its dependence on mass energy in ZZ production.	Use $q\bar{q} \rightarrow ZZ \rightarrow 4l$ and reconstruct the decay angle of the decay leptons in the Z rest frame.
ATLAS	W Polarization in top decays	Test SM	Use W polarization to deduce sensitivity to tWb anomalous couplings.
CMS	Top quark pair production in semi-leptonic final state	To determine the top quark spin and search for possible deviations from SM coupling.	Measure the correlation between spins of the top and anti-top quarks produced at the LHC for semi-leptonic decay of top quark pair.
ALICE	$pp \rightarrow \left(\Lambda^t jet\right) jetX$ where Λ is part of one of the observed jets.	Test the possible color flow dependence of single spin asymmetries and the (non)universality of transverse momentum dependent functions.	Study the new Λ polarization observable that arrises from the Sivers effect in the fragmentation process.

Physics Beyond the Standard Model

Detector	What	Why	How
Not Specified	$\tilde{q} \to q\tilde{x}_2^0 \to ql^\pm \tilde{l}^\mp \to ql^\pm l^\mp \tilde{x}_1^0$	Provide information on the chirality structure of sfermion-fermion-neutralino interaction	Observe the $\tilde{x}_2^0$ polarization due to the chirality structue of squark-quark-neutralino coupling via its effects on the angular distribution of the slepton in neutralino decay.
ATLAS	$J/\Psi \to \mu^+\mu^-$	$J/\Psi \to \mu^+\mu^-$ is a main source of background for Quarkonia -> di muons, the main channel of analysis to measure quarkonium production.	Measure J/Ψ polarization to reconstruct background.
Not Specified	$d_R \bar{d}_R \to t_L \bar{t}_L$	Look for R-parity violating interactions that can happen in the MSSM.	R-parity violating interactions induce anomalous top pair productions and cause top quark polarization. Use the polarization as an observable for probing interactions.
LHCb	$\Lambda_b \to \Lambda(X)\gamma$	Look for physics beyond the SM by probing whether there is a right-handed component to the photon	Observe the angular asymmetry between the Λ_b spin and photon momentum. Combine this with Λ(1115)->pπ or Λ(1115)->pK decay polarization to test the structure of standard model.
Not Specified	$pp \to \tilde{b}\tilde{b}^* \to b\bar{b}\not{p}_T$	Distinguish a universal extra dimensional interpretation with a fermionic heavy bottom quark from supersymmetry with a bosonic bottom.	Use the angular correlations to probe the sbottom spin.
CMS	di-muon channel	Understand a new LED resonance state, which may be observed at CMS.	Use the spin-dependent measurement of the cosine of the polar angle of the muon center of mass system and the di-muon pair. They should differ between Z' or RSI graviton.
ATLAS	SUSY spin measurements	Measure spins of new particles to demonstrate they are the predicted super partners.	Measure charge asymmetry from left squark cascade decay or measure the angular distributions from direct slepton productions.

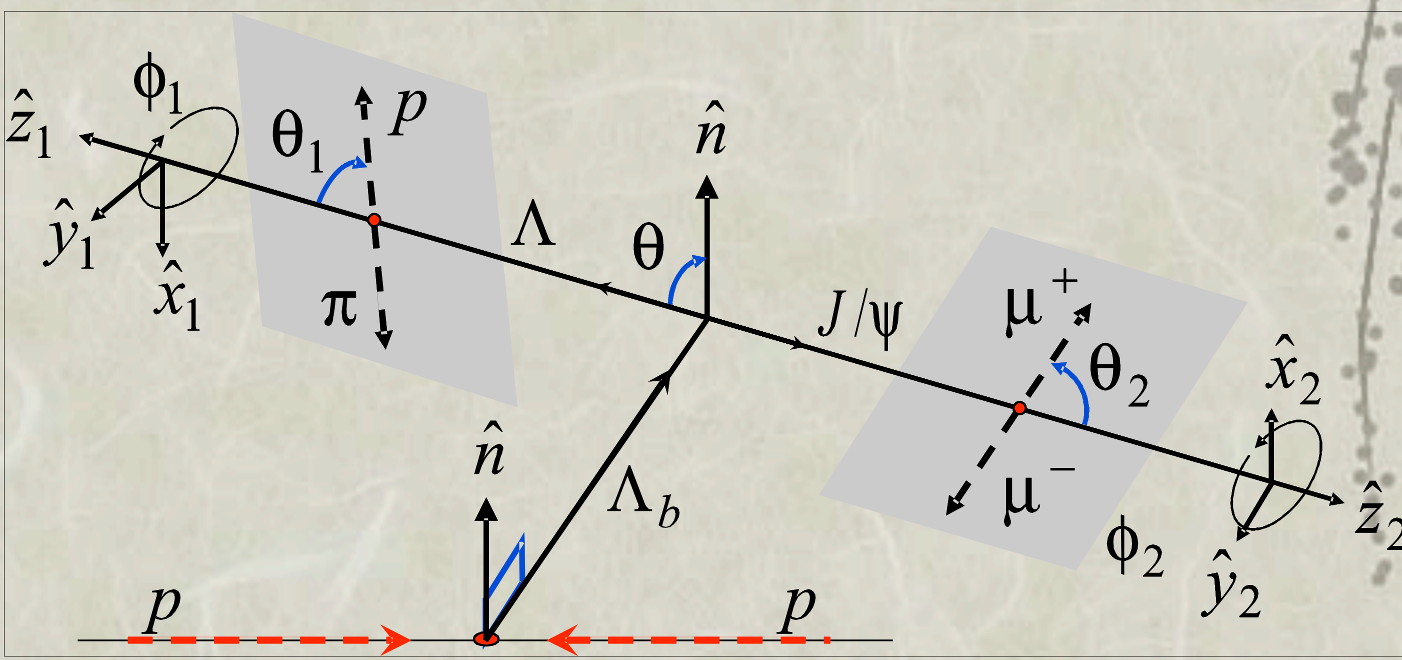
Studying the Λ_b

- UMich and ATLAS
- Λ_b will have much more polarization than Λ^0
- A better understanding of spin



Measuring Spin

- Select the decay
- Angular distributions



Conclusions: Spin Studies at the LHC

- The LHC has the potential to provide valuable insight into the mystery that is spin.
  - Why is there a plateau?
  - What is it in interactions that knows how a particle is spinning?
- Might find some new physics along the way

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