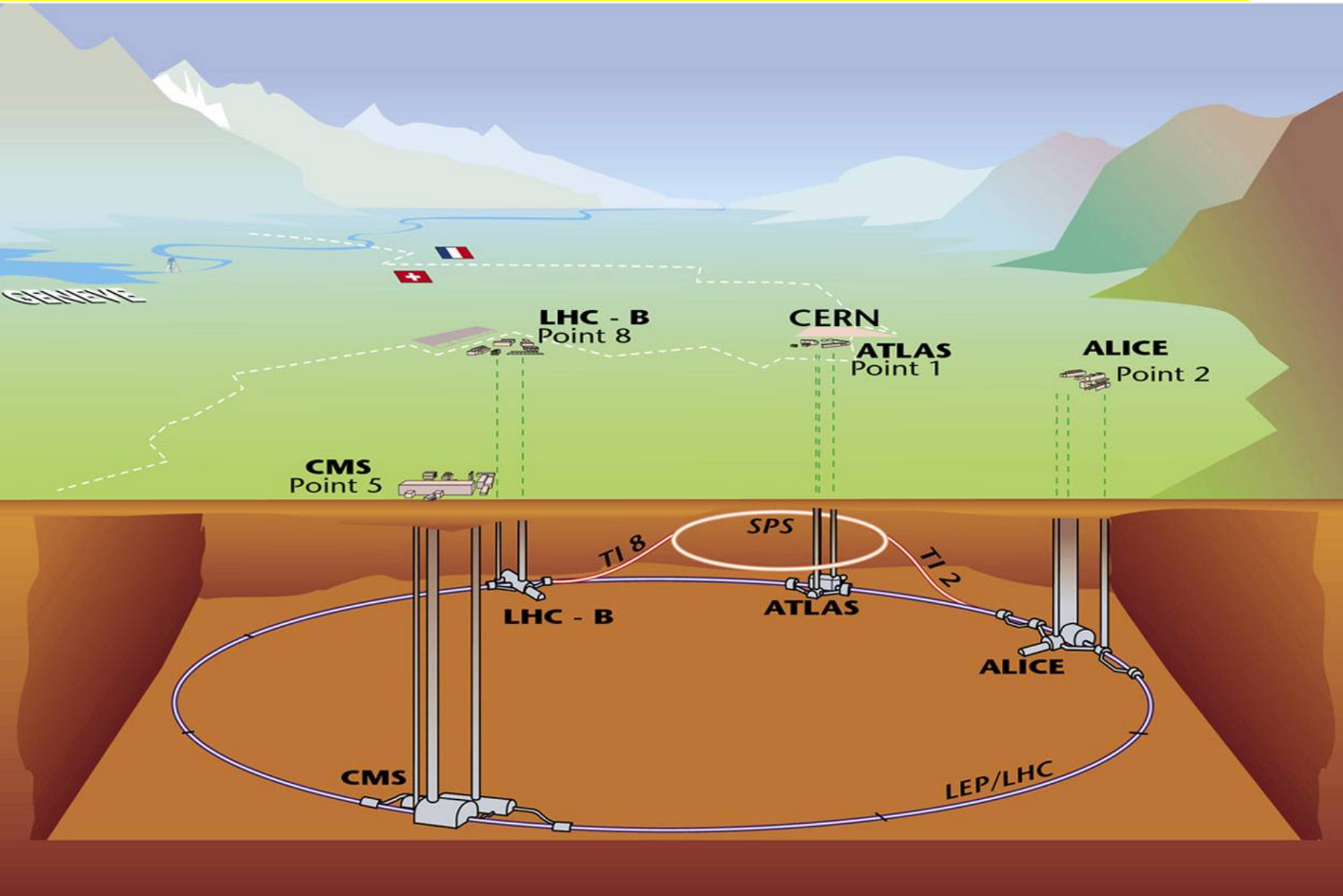
ATLAS @ UVic

- Physics
  - Very brief overview of the motivation for the LHC and ATLAS
- The Large Hadron Collider
  - Status, Timelines, Turn-on plans
- The ATLAS Detector
  - Status, Timelines
- UVic ATLAS Group
  - Group composition, roles in ATLAS
- UVic ATLAS Activities
  - Liquid argon electronics feedthroughs: the end-game
  - Detector commissioning work
  - Detector calibration
  - Computing
  - Progress to first physics

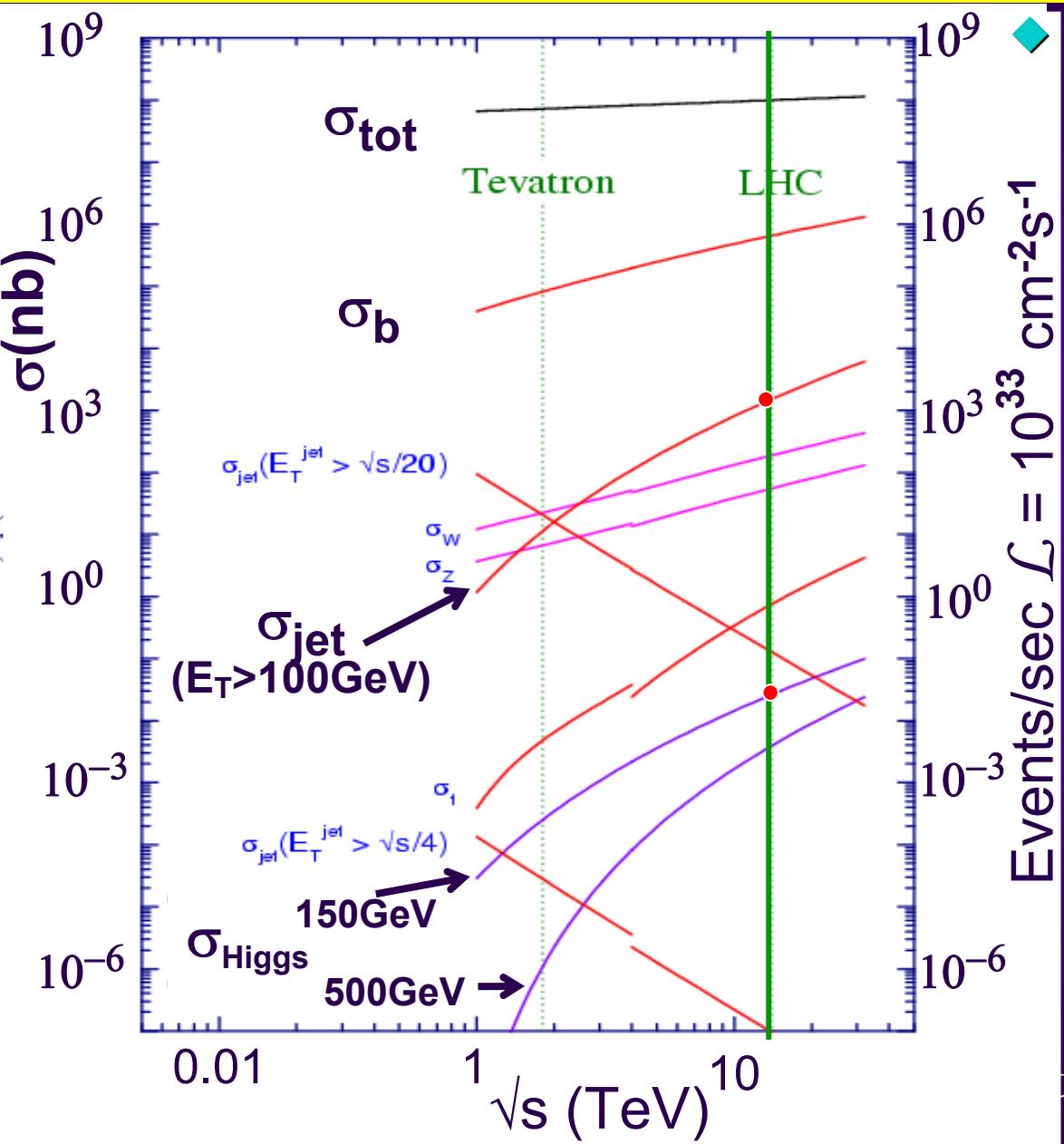
Rob McPherson UVic/IPP

GSC-19 Site Visit to UVic 13 October 2006

Large Hadron Collider: p-p @ 14 TeV

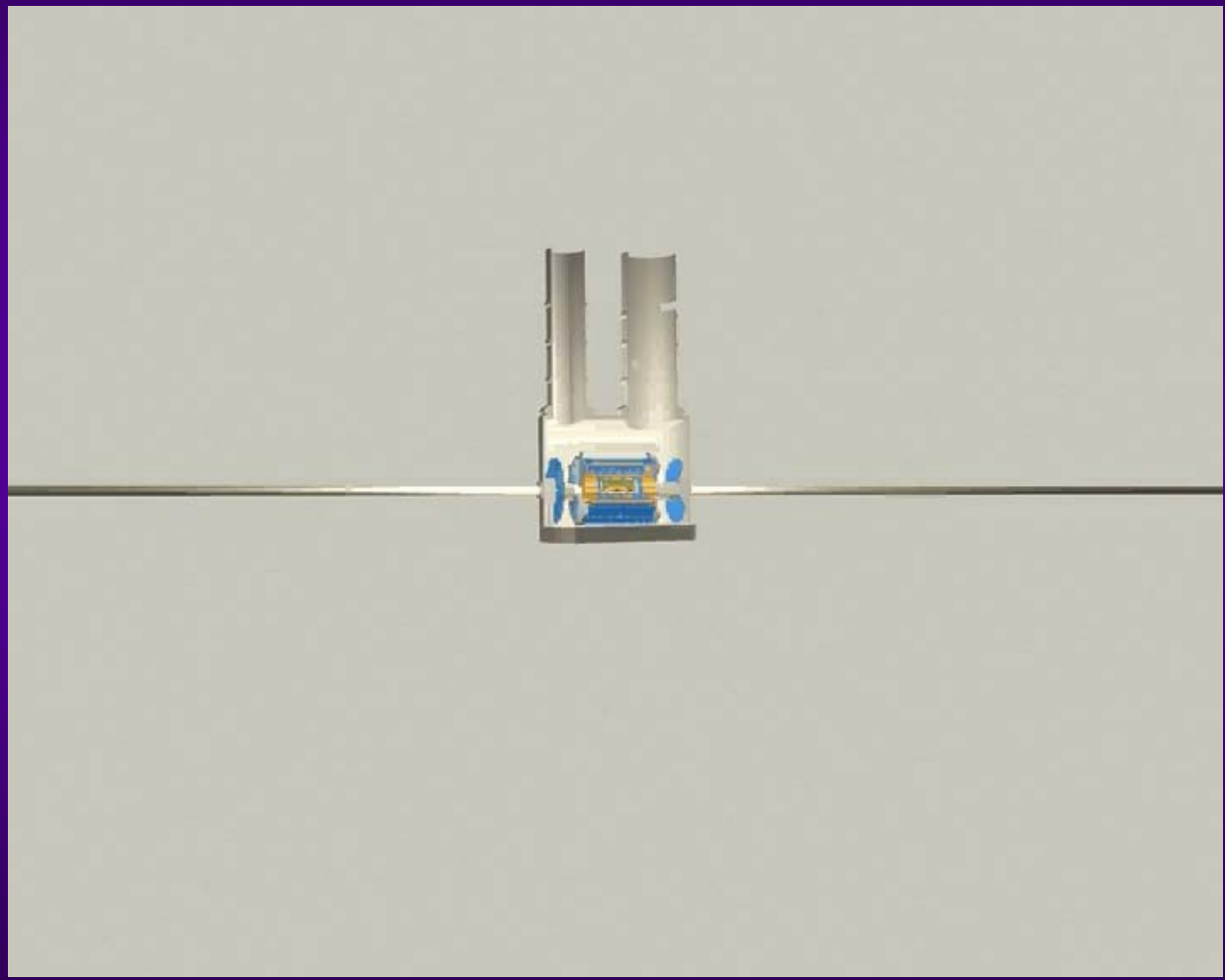


p-$\bar{p}$ or p-p: cross-sections



- LHC:
  - Large SM Higgs rates
    - O(1 Hz) for lightest allowed Higgs at nominal luminosity
  - Also: QCD, top, bottom, W, Z factory
    - Precision measurements of cross-sections, couplings, branching ratios
    - QCD at highest scales
  - Real goal: find physics beyond the Standard Model
    - SUSY, heavy quarks, heavy leptons, extra dimensions, new gauge bosons, compositeness …

ATLAS Detector



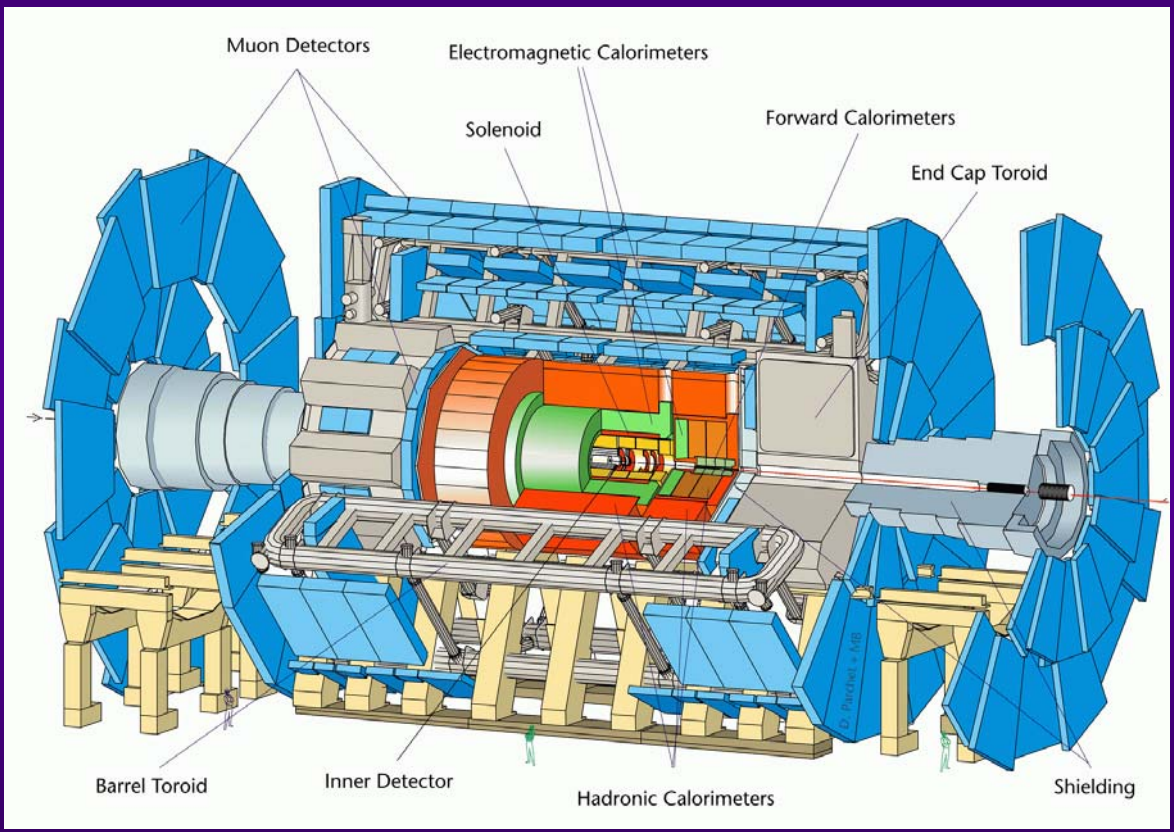
The ATLAS Experiment & ATLAS-Canada

Alberta, Carleton, McGill, Montréal, Regina, SFU, Toronto, TRIUMF, UBC, Victoria, York

Canadian activities focused on LAr calorimetry

4 large projects funded by a Major Installation Grant:

- Endcap Hadronic Calorimeter
- Forward Hadronic Calorimeter
- Front-End-Board Electronics
- Endcap Signal Feedthroughs



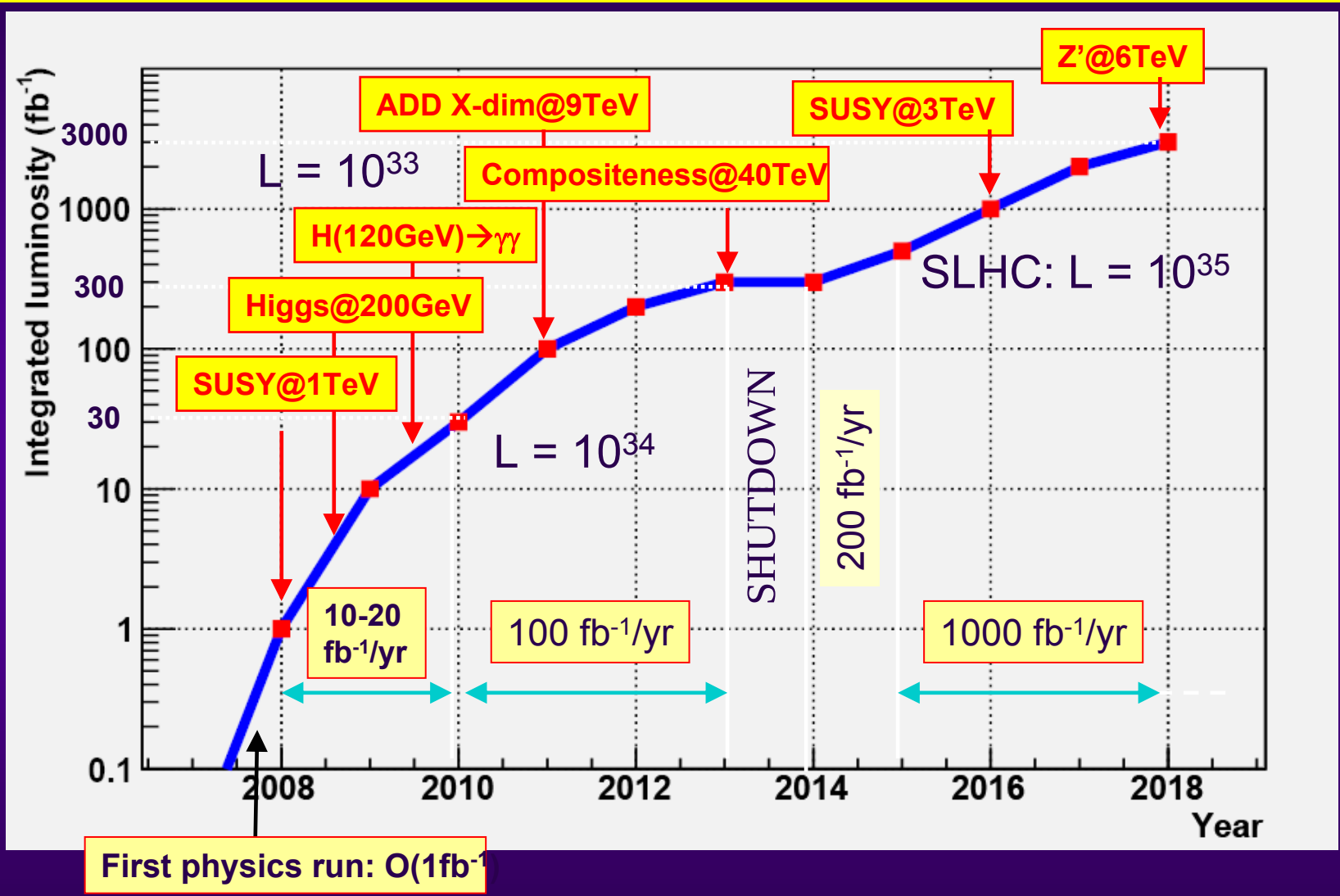
diameter	25 m
barrel toroid length	26 m
total weight	7000 tons

LAr cryostat and calorimeters construction and installation completed

Detector commissioning well underway

Focus shifting to robust calibration and reconstruction, computing, physics analysis

LHC Luminosity Profile



LHC: Status and Plans

- Almost all hardware construction finished, including pre-installation testing
  - Magnets, power converters, control systems, ...
- Installation proceeding
- All magnets in place by ~ March 2007
- Machine closed August 2007, start commissioning
- Operations 1 November 2007 $\Rightarrow$ collisions at 450 GeV x 450 GeV by end of 2007
  - Use 450 GeV for commissioning safety / quenching systems, beam dumps
- Shutdown for final installation (eg, last collimators, ...)
- High energy operations start $\approx$ 1 April 2008
  - Pessimist: 100 pb^{-1} with $\sqrt{s}$=14 TeV in 2008
  - Optimist: few fb^{-1} with $\sqrt{s}$=14 TeV in 2008

1000th (/1746) Dipole Installed (5 Sept 2006)

ATLAS: Status and Plans

- Calorimeters are all mechanically in place
  - Electronics installation + commissioning ongoing
  - Remaining worry: Rad hard LV + HV power supply delivery
    - In principle OK, but watching carefully
  - Taking cosmic ray data regularly with Calo barrel
  - Electronics pulser runs with endcap calos (not cold until early 07)
- Inner detector (silicon + straw tubes + pixels)
  - SCT+TRT Barrel in place, cabling ongoing
  - Endcaps installed after barrel commissioning (spring 07)
  - Pixels: cable delivery a worry. May install un-cabled detector in 07.
- Muon system
  - Barrel chamber installation almost done. Cabling until end 06
  - Endcap "wheel" assembly started
- Magnets
  - Solenoid tests and maps completed (up to 8 kA with 7.73 kA needed)
  - Barrel toroid system tests ongoing now (full field ~ mid November)
  - Endcap toroids installed Spring 2006
- Aim: completed detector summer 2007

ATLAS Detector Under construction
November 2005

UVic ATLAS Group

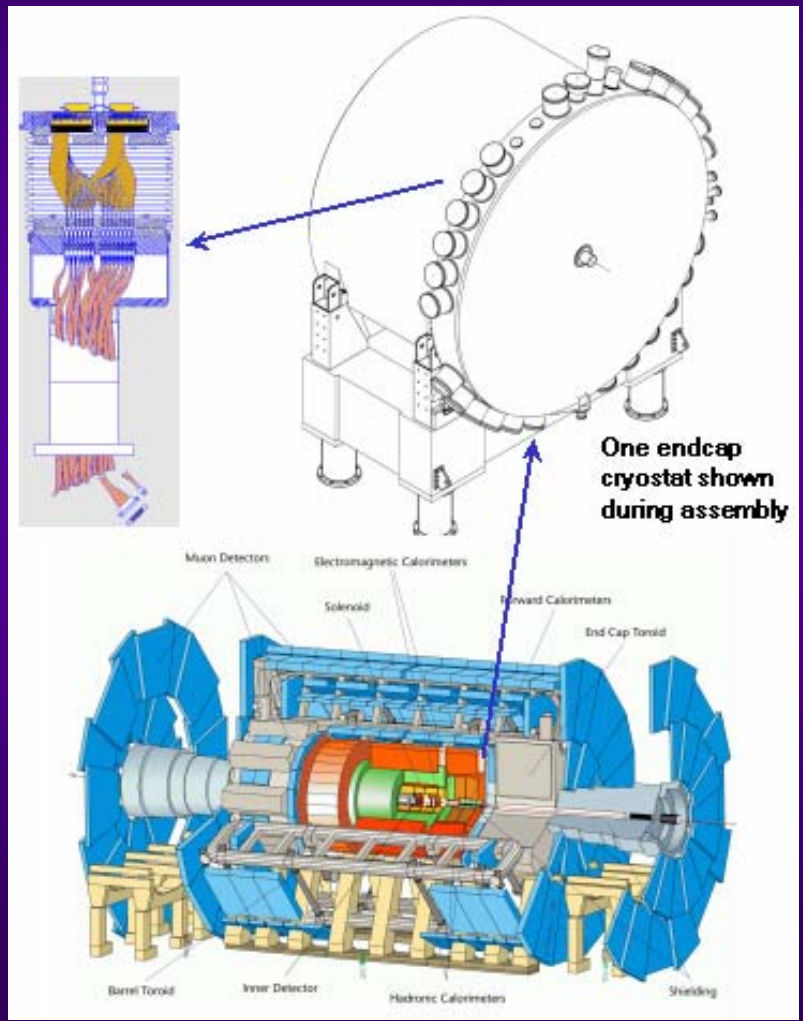
- Faculty
  - Albert (started Sep 06), Astbury (retired), Keeler, Kowalewski, Lefebvre (PI 92-03), McPherson (PI 03-), Sobie
- Onsite TRIUMF Staff
  - Birney, Charron, Dowling, Langstaff, Lenckowski
- Postdoctoral Research Associates
  - Fincke-Keeler, Lelas (CERN, started Aug 06), Seuster, Voss (finished May 06), Wielers (finished September 04)
- Onsite staff supported by MFA/MRS
  - Agarwal (Computing Applications), Poffenberger (Detector Physicist)
- Current Graduate Students
  - Berghaus (Ph.D. Lefebvre), Edmonds (M.Sc. Lefebvre/McPherson), Ince (Ph.D., Keeler), Vanderster (Ph.D. Sobie+comp sci)
  - + one or more of Courneyea, Lessard, Taylor
- Degrees Awarded
  - 7 M.Sc. (Bishop, Fortin, Hughes, Ince, Robertson, Shaw, White)
  - 2 Ph.D. (Dobbs, O'Neil)
- Undergraduate Students
  - typically 3 per year

UVic ATLAS Group: Leadership

- Founding Spokesperson of ATLAS-Canada (Lefebvre, 1992-94)
- Hadronic Endcap Calorimeter Chief Engineer (Hodges, 1996-00)
- LAr HEC Beam Test Software Coordinator (Lefebvre, 1997-02)
- LAr Cryostat and Cryogenics Steering Committee (Hodges, 1997-00; Lefebvre, 1997-03)
- Endcap Signal Feedthrough Project Leader (Lefebvre, 1997-)
- Advisory Committee to the Collaboration Board (Lefebvre, 1998-99)
- ATLAS-Canada Co-Spokesperson (Keeler, 1998-99; McPherson 2004-)
- Rep on the International Computing Board (Sobie, 1999-2004)
- LAr Database Coordinator (Sobie, 2000-02)
- LAr Detector Control System Coordinator (McPherson, 2002-2005)
- LAr Beam Test Software Coordinator (McPherson, 2002-)
- ATLAS Offline Commissioning Coordinator (McPherson, 2004-)
- ATLAS Data Quality Coordinator (McPherson, 2006-)

LAr Endcap Signal Feedthrough Project I

Project Leader: Lefebvre
Chief Engineer: Hodges



- ATLAS LAr calorimetry has over 180k signal channels which must come through the cryostats
- Each feedthrough unit carries 1920 electrical channels
- Feedthrough units: 64 in barrel, 50 in endcap
- The endcap signal feedthrough project is an ATLAS common fund contribution from Canada. Over $4M from NSERC MIG.
  - This was Canada's major construction common fund contribution to ATLAS, completed on time and under budget
- All endcap feedthough units built at UVic
- Onsite TRIUMF staff crucial to the success of the project
- Onsite MFA supported personnel still critical

LAr Endcap Signal Feedthrough Project II

- Installation and tests at CERN
  - Supervision: Poffenberger
  - Contributions from
    - Birney, Chekulaev, Langstaff, undergraduate students
- During installation in pit, some delicate uncabling / modifications, recabling needed (ongoing)
  - Critical to have continuity of Poffenberger's availability
    - Possible because of his MFA support at UVic

electrical tests at CERN

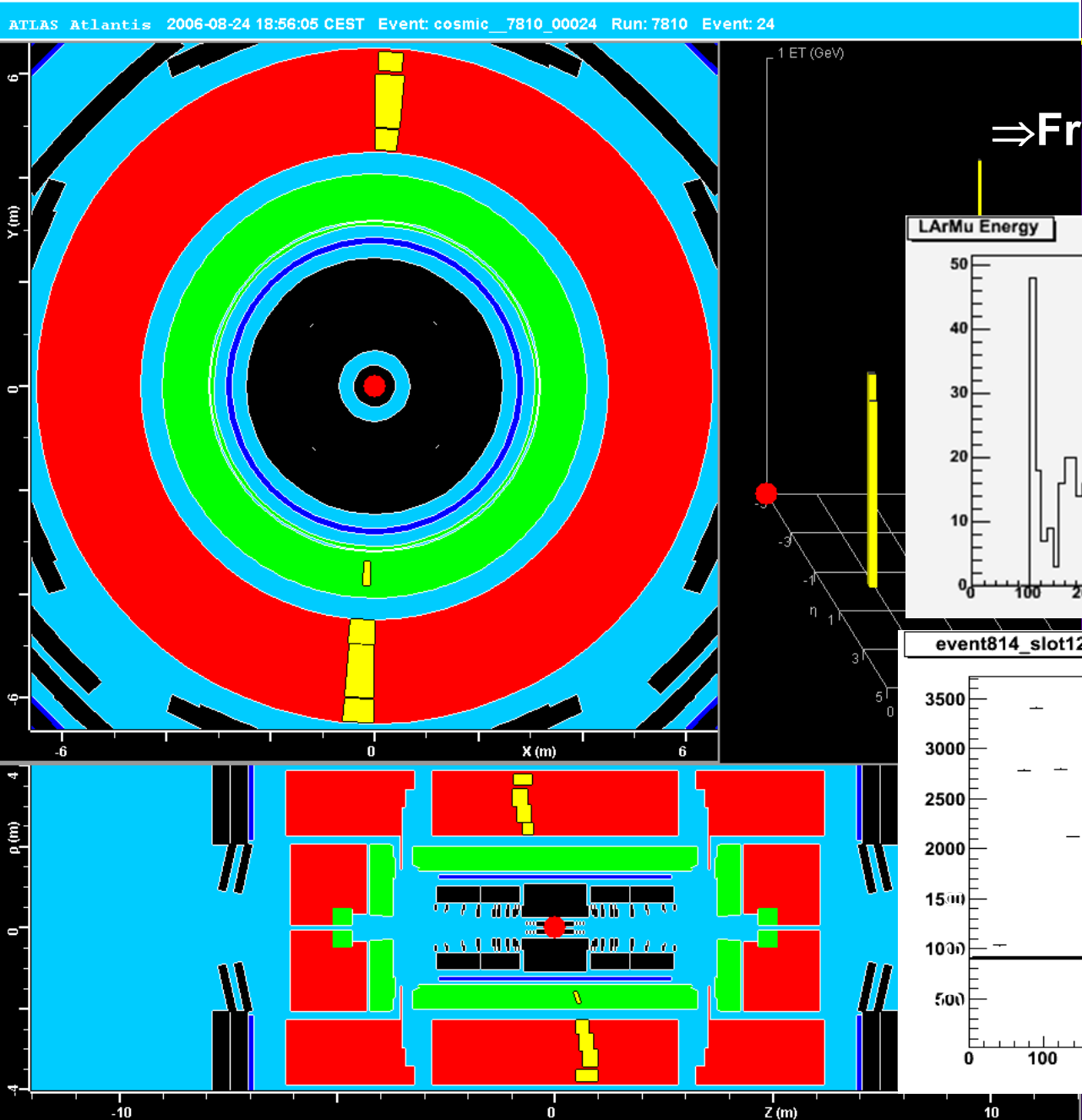
last feedthrough produced at UVic, 25 Oct 2002

installation at CERN

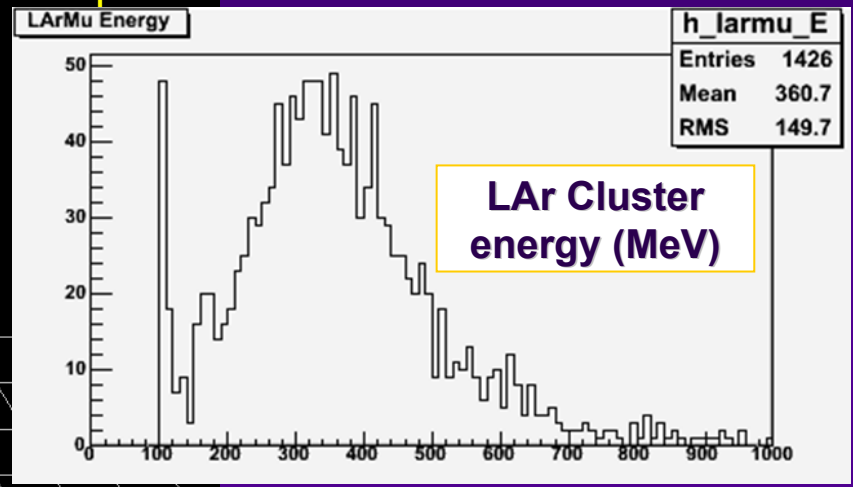
Calorimeter Commissioning

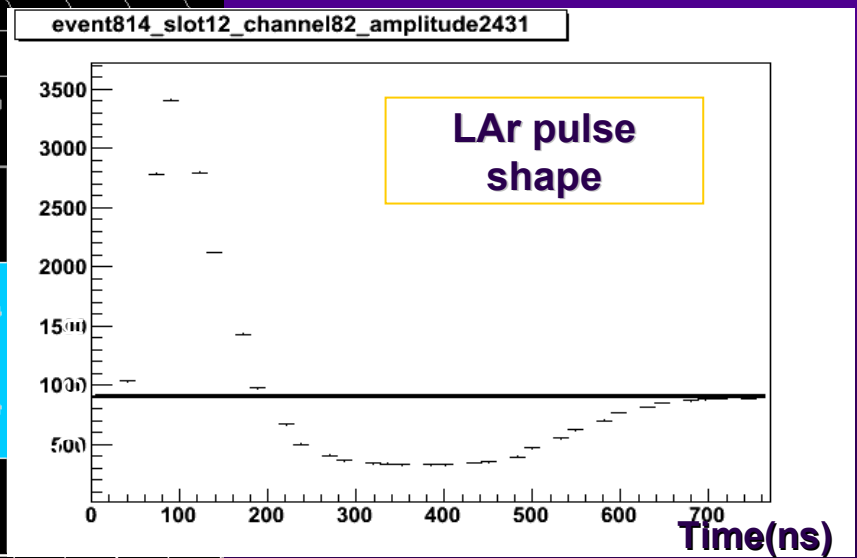
- Experience from testbeam carrying over into commissioning LAr calorimeters
- Several commissioning "expert weeks" in 2006
- UVic developed
  - Complete monitoring and reconstruction framework (Lefebvre, McPherson, Seuster, Voss)
  - Interactive browsing and analysis environment (Ince)
  - Tutorials and documentation for entire Calorimeter community for commissioning and analysis use
  - Many early and critical monitoring and debugging analysis tools (Lefebvre, McPherson, Seuster)
    - ⇒ UVic framework used for virtually all LAr commissioning analysis, and now being adopted for other systems, including likely the basis of overall ATLAS data quality monitoring

Cosmics in barrel calorimeters



⇒From our monitoring tools



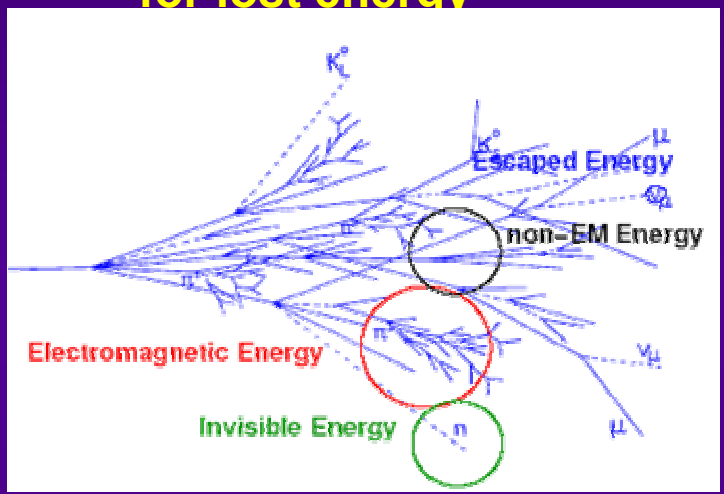


Calorimeter Calibration I

- UVic started on calibration in testbeam context
  - HEC TB up to 2001, EMEC+HEC 2002, EMEC+HEC+FCAL 2004
- Carrying work through into ATLAS context
  - Using TB for reconstruction + DB development, MC validation
  - And developing techniques for in situ calibration in ATLAS
- 2002 EMEC+HEC Testbeam
  - Data converted to final ATLAS data format for future analysis (Seuster)
    - This will likely be adopted by other systems as well
  - Continuing effort to port simulation into final ATLAS framework, in particular "calibration hits" or MC truth (Fincke)
    - ⇒ These two efforts together gives us access to the 2002 EMEC+HEC testbeam data as a critical MC validation tool

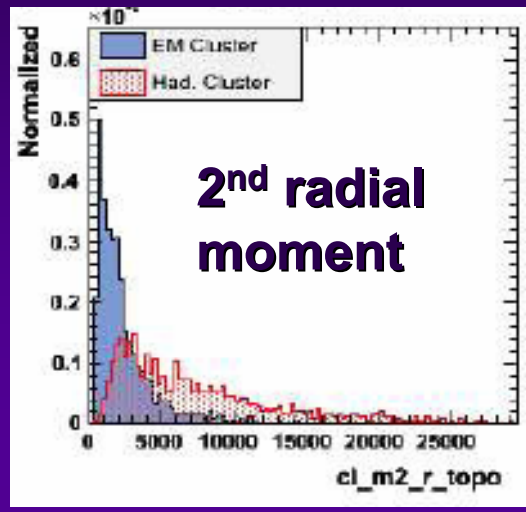
Calorimeter Calibration II

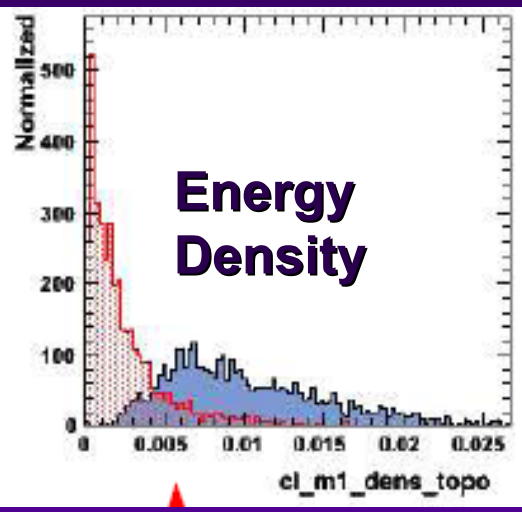
- **Cluster Classification**
  - **EM ⇒ do nothing**
  - **Hadronic ⇒ compensate for lost energy**

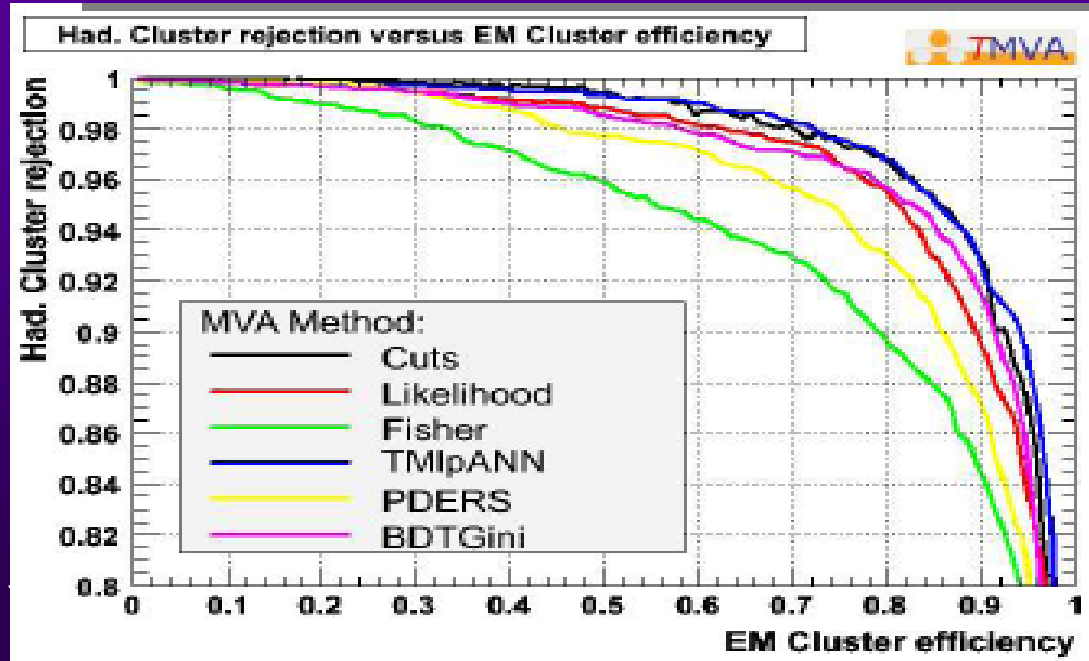


- **Kai Voss**
  - **Developed multivariate analysis tool for cluster classification**
  - **Offshoot: "TMVA" analysis package (being integrated into root!)**

Input: Different cluster moment

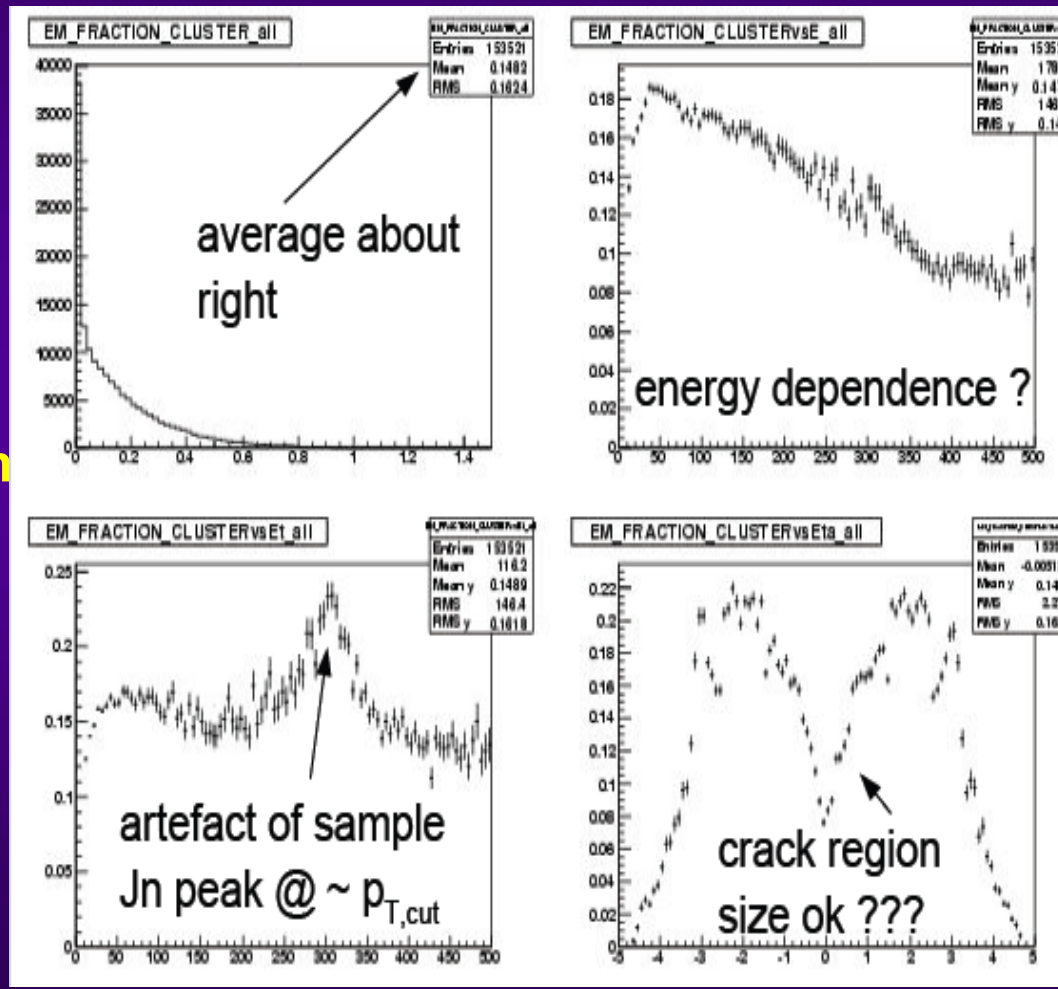




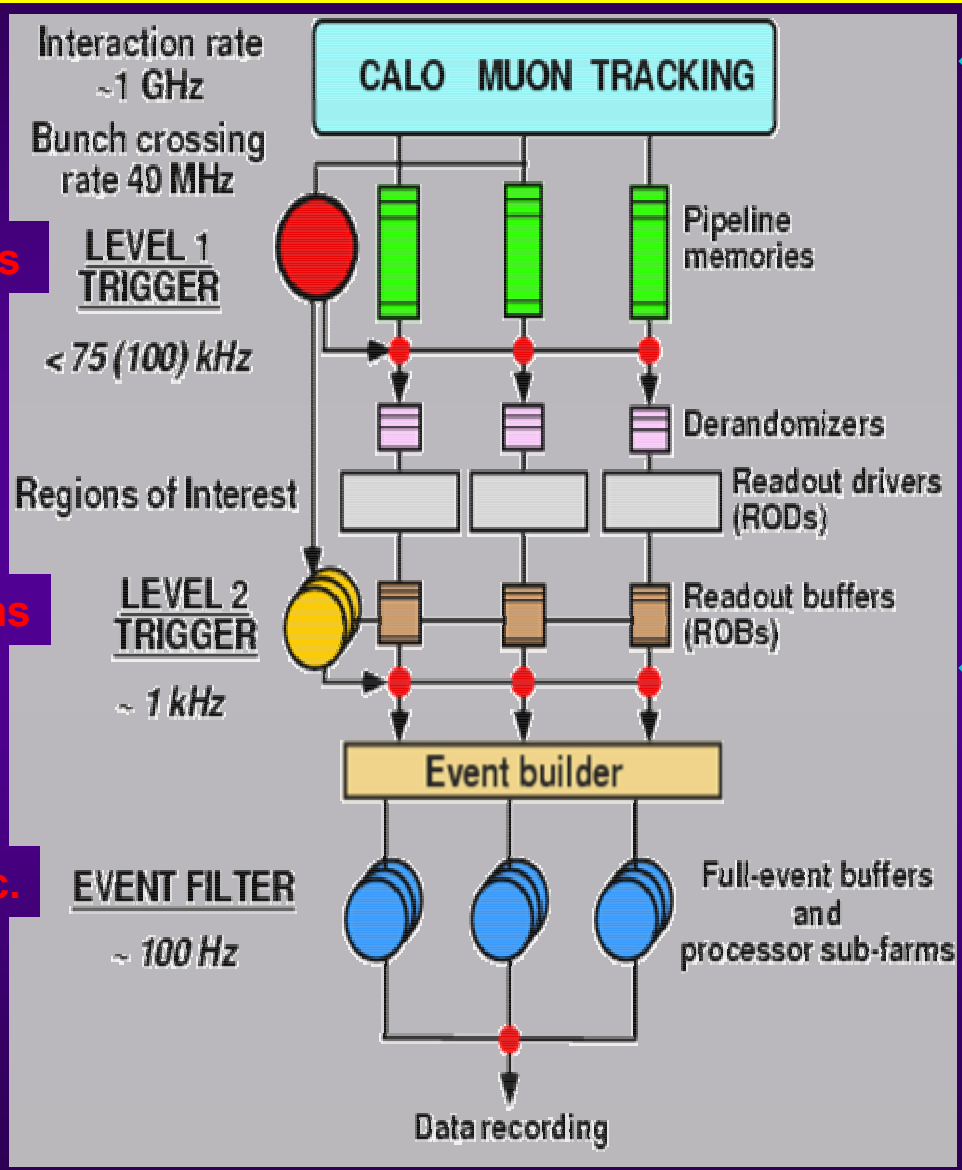


Calorimeter Calibration III

- Recent work to prepare for in situ jet calibration
  - Seuster, Ince, Lefebvre, McPherson
- Defining a set of "jet moments" to diagnose possible jet reconstruction problems
  - CALIBHIT: EM fraction from MC truth
  - TRUTH: energy fraction carried by photons in jets
  - CLUSTER: energy fraction classified as EM
  - TRACK: energy from aligned tracks
- CLUSTER moments for all jets, or vs. E, ET, eta



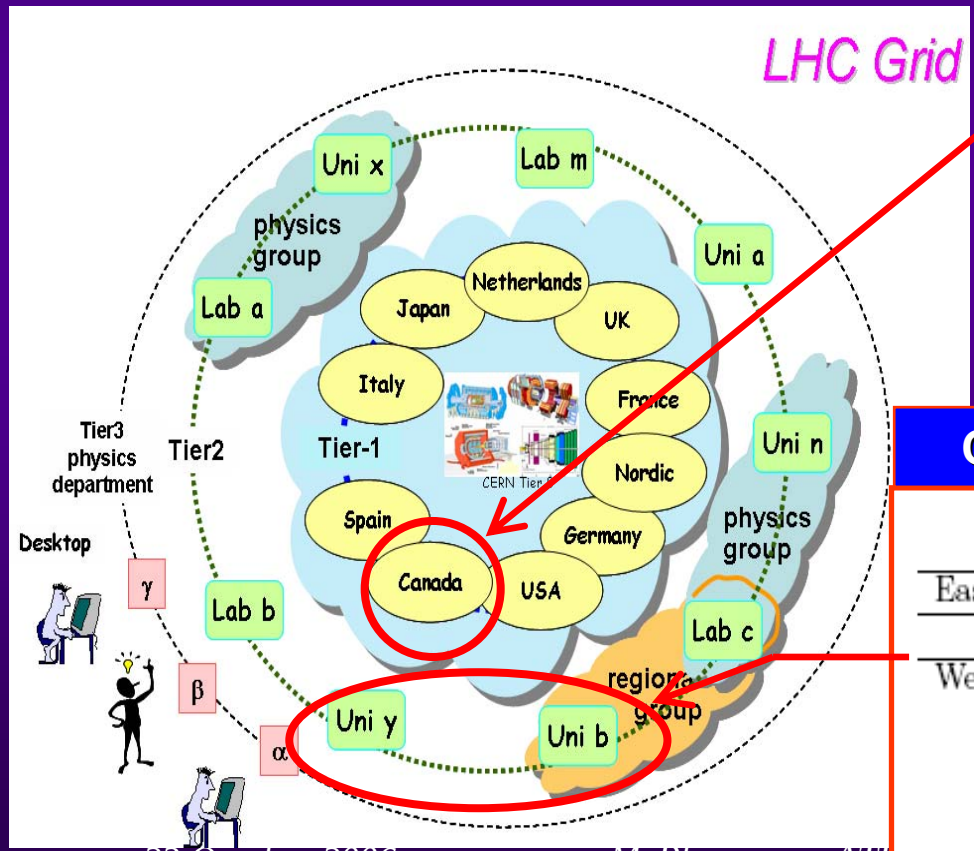
High Level Trigger (Kowalewski)



- Resurgence of HLT in Canada
  - McGill, Montréal, Alberta
  - UVic joining, with this as main focus of Kowalewski's ATLAS efforts
- Critical issues
  - Making offline code, calibrations, DBs, run robustly
  - Robust triggers
  - Include trigger modeling in analysis

Computing & Analysis I

- UVic had a pioneering role in computing for ATLAS in Canada (Sobie with Agarwal, Vanderster, and many coop students)
  - Including GridX1, used for both a standalone computational grid and interface to LHC computing grid (LCG), with execution tools fed-back into LCG



TRIUMF Tier-1 (CFI-EOF)

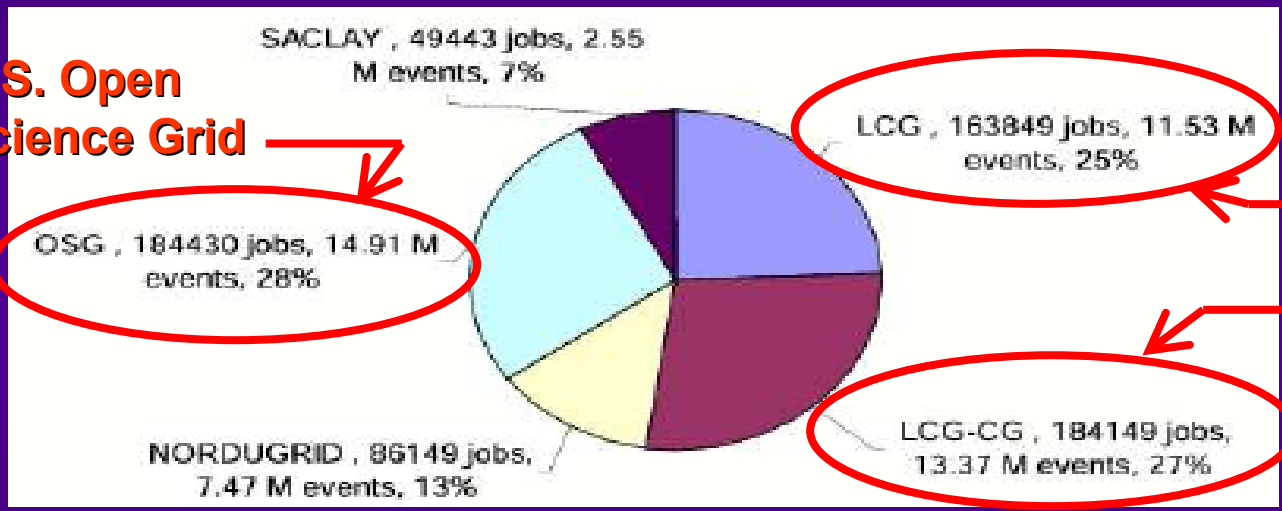
UNIVERSITY Tier-2 (proposed in CFI-NPF)

Canadian proposed Tier-2 Breakdown

			CPU (kSI2k)	Disk (TB)
East Tier-2:	SciNet	(Toronto)	2,500	1,500
	CLUMEQ	(McGill)	1,650	500
West Tier-2:	WestGrid		2,500	1,500
		(Alberta)	800	100
		(Simon Fraser)	850	700
		(Victoria)	850	700

Computing & Analysis II

- Critical issues for computing and analysis for ATLAS and ATLAS-Can.
  - Production systems: real progress being made
    - Both for Monte Carlo production and Data reconstruction
  - Development of the CondorG executor for GridX1 adopted for wide LCG production
    - CondorG: one person do the work of ~ a dozen on the old EDG executor



U.S. Open Science Grid

LCG –default executor

LCG - CondorG

  - Distributed grid-aware analysis is still in its infancy
  - Foresee need for physics application specialists at different sites
    - System administrators will support clusters
    - Postdocs will support code validation
    - Application specialists connect the two
      - Currently at UVic we have Agarwal, supported 50% by MFA, but need will grow as we enter data-taking mode

Physics ...

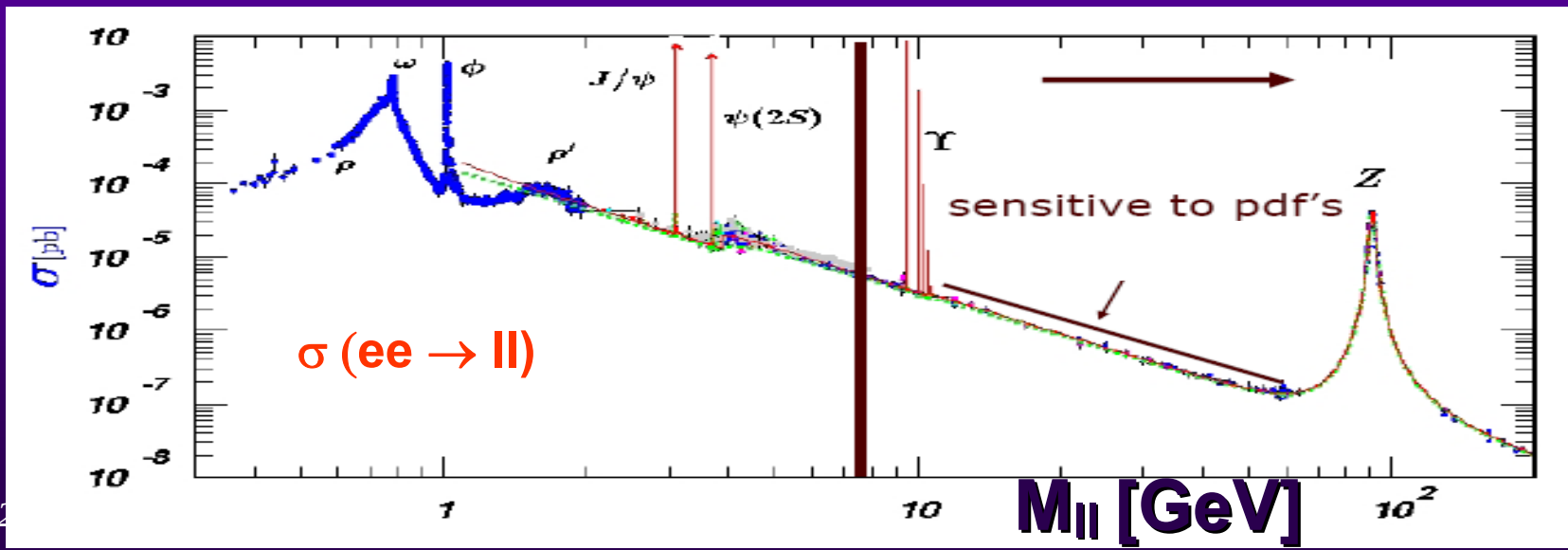
- Positioning ourselves for first physics in ATLAS
  - Believe strongly that working through detector reconstruction, calibration, commissioning puts us in position for best early physics in ATLAS
    - And from past experience, best early physics carries on to best final physics
  - From recent ATLAS-Canada grant request:

Topic	Institute
QCD di-jets	Victoria
SM top physics	Carleton
Hadronic top pair decays	Victoria
Anomalous top production	Victoria
Inclusive SUSY; fake / instrumental $\not\!\!E_T$	TRIUMF, Victoria, ~~Toronto~~
SUSY end-point search	Carleton
Higgs in SUSY decays	Victoria
Two-electron finder for Drell-Yan, Z′	Victoria
Z′ or strong interaction resonance in τ channel	Montréal
Black holes	Alberta
ADD extra dimensions	Toronto
Randall-Sundrum graviton search	Regina, Toronto
Trigger-aware charged Higgs	McGill
Lepton identification and fake rate studies	Toronto

Table 5: Analyses in Canada for early ATLAS physics

Early Physics: Low mass Drell Yan ee I (Ince Ph.D., Keeler with Lelas)

- Drell-Yan (di-lepton production) is a golden LHC search channel
  - High mass Z', ...
- Ince did electron reconstruction in 2002 EMEC-HEC testbeam for M.Sc. thesis, and Lelas developed current e-γ clustering for ATLAS
  - $\Rightarrow$ developing analysis of low-mass Drell-Yan events for early data
    - Demonstrate modeling of low-mass region and then extend search to high-mass region ...
- Current studies
  - Low Pt di-electron reconstruction using only calorimeter information
    - Around M_{ll} = 60 +/- 5 GeV: expect 60/day at 10^{32}
    - Around M_{ll} = 10 GeV: expect 1200/day at 10^{32}



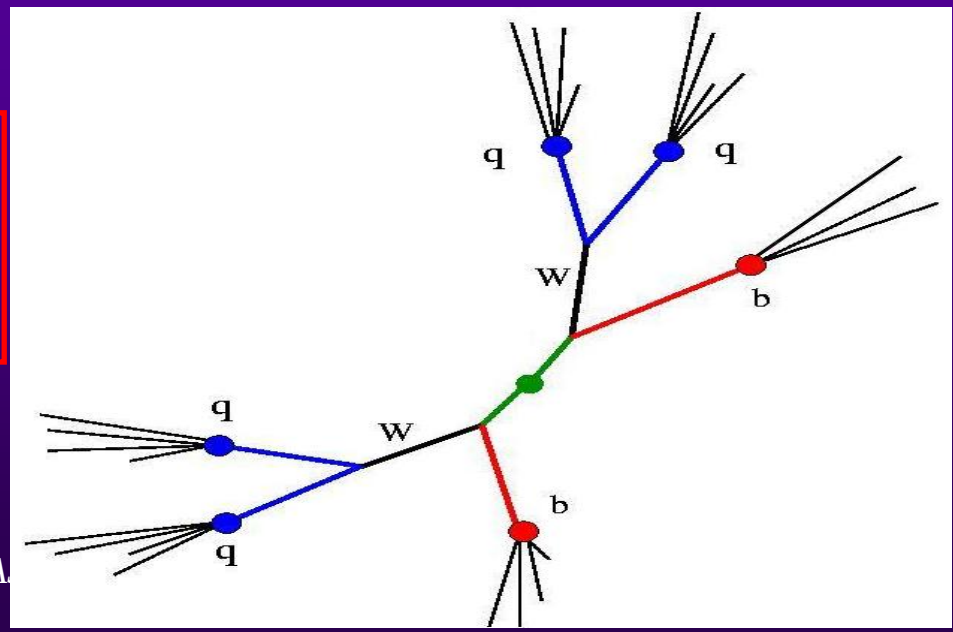
Fully Hadronic Top Pairs

(Edmonds M.Sc., Lefebvre, McPherson with Seuster)

- Fully hadronic top pair production not previously studied in detail in ATLAS
- QCD background large. Current effort: validating 6 hard parton QCD simul.
- But many kinematic constraints exist allowing signal selection (especially for boosted tops)
- Goals
  - Develop fully hadronic top quark selection, including trigger
  - Study kinematic properties of events
    - Add to mass measurement
    - But also look for anomalous top production (eg: SUSY or other new physics)

tt final states

- 44% Full hadronic : 6 jets
- 30% Semileptonic : l + ν + 4jets
- 5% Dileptonic : 2l + 2ν + 2jets



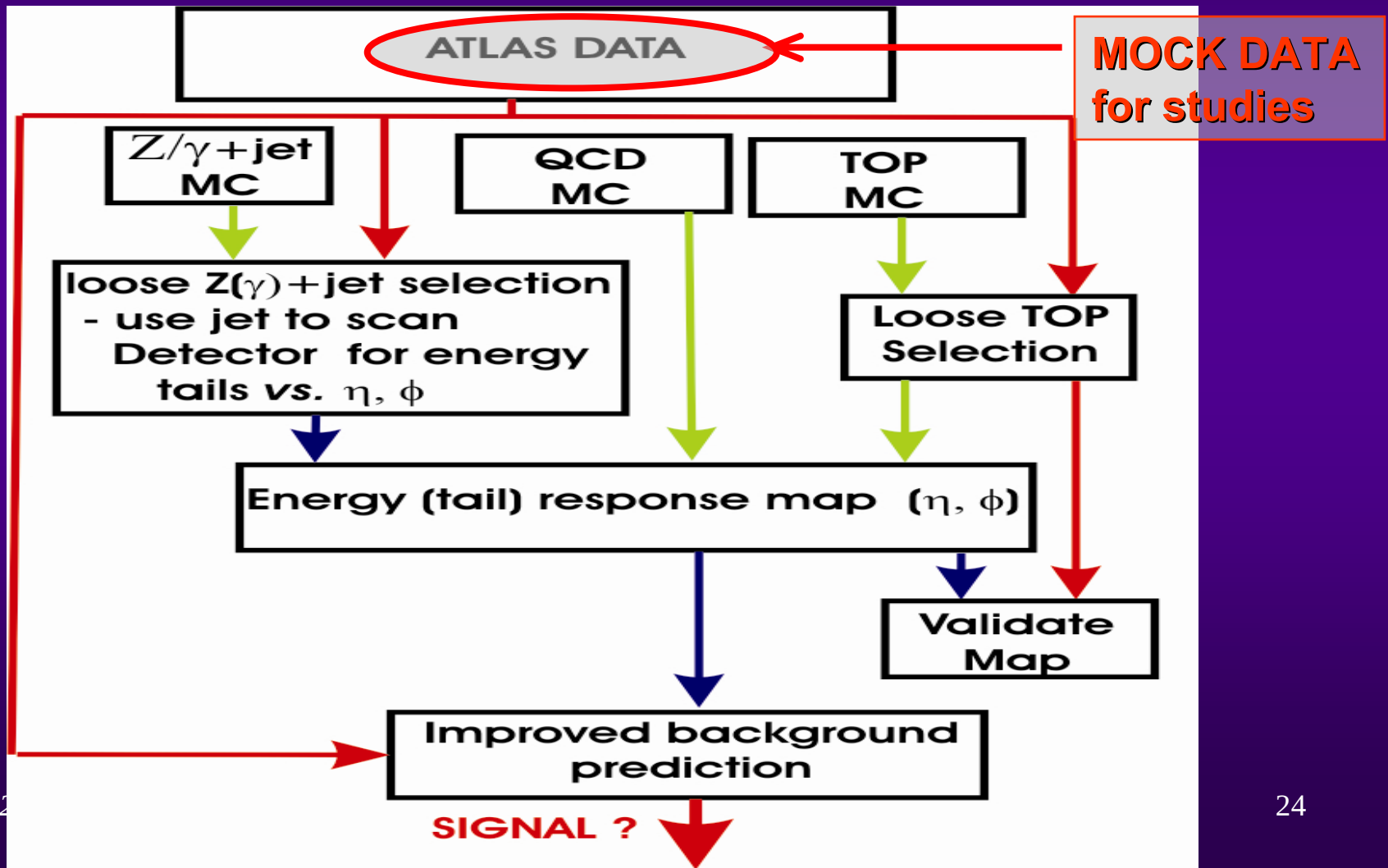
Fully Hadronic Channel:

NLO σ = 369pb

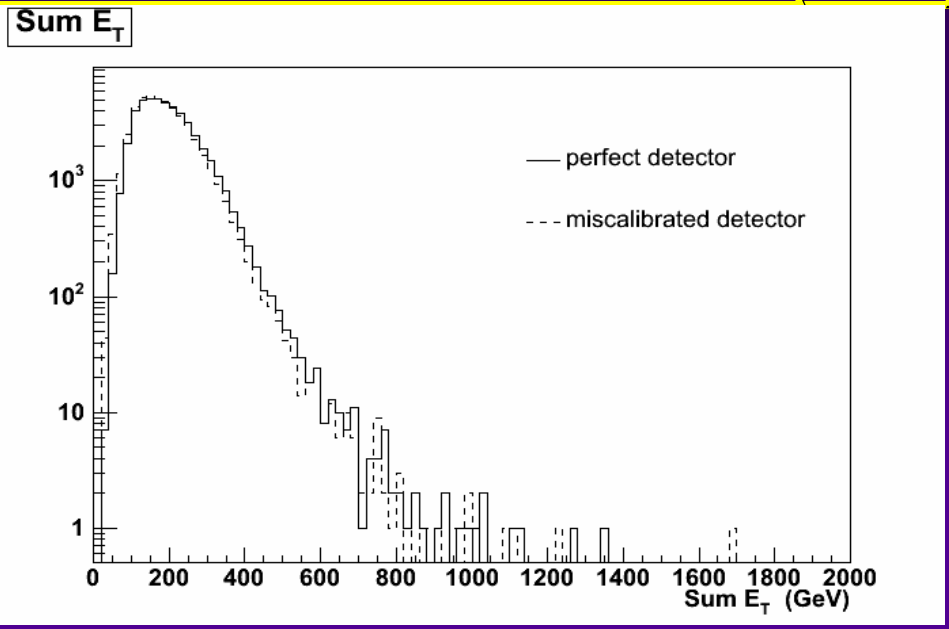
(370 kEvents in 1 fb^{-1})

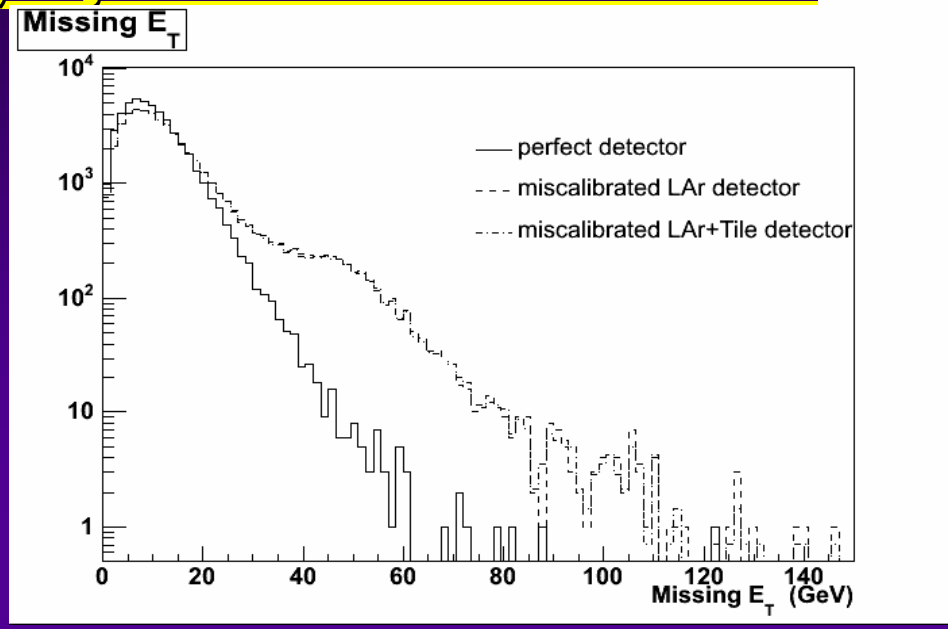
ETmiss analysis: tails from data? I
(McPherson, Trigger, possible Courneyea MSc project)

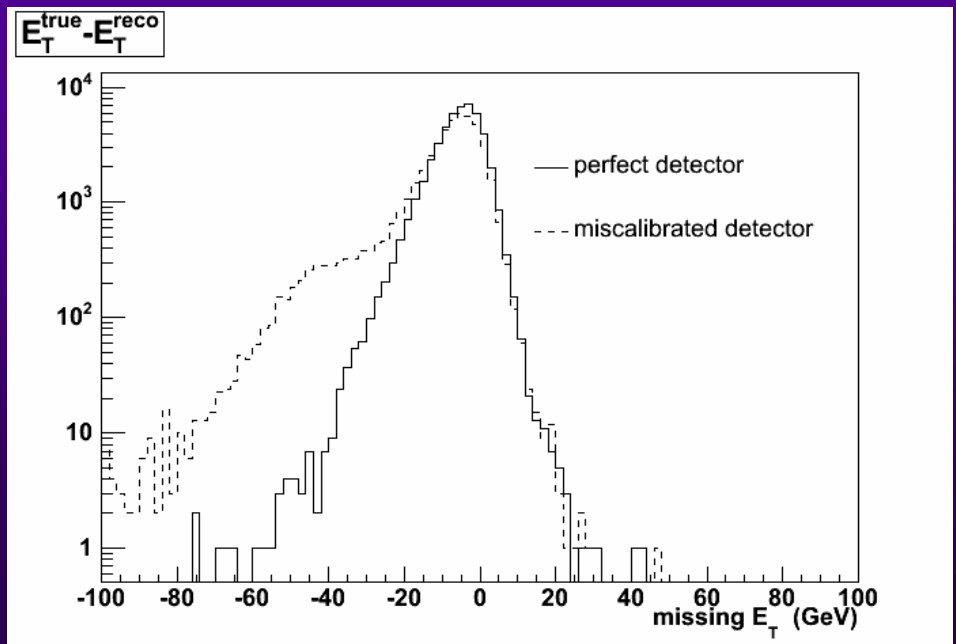
- SUSY, Extra dimensions, more ...
  - Modeling missing transverse energy critical ⇒ notoriously difficult!
    - Extract from Data??



ETmiss analysis: tails from data? III
Z (→ee) + jets



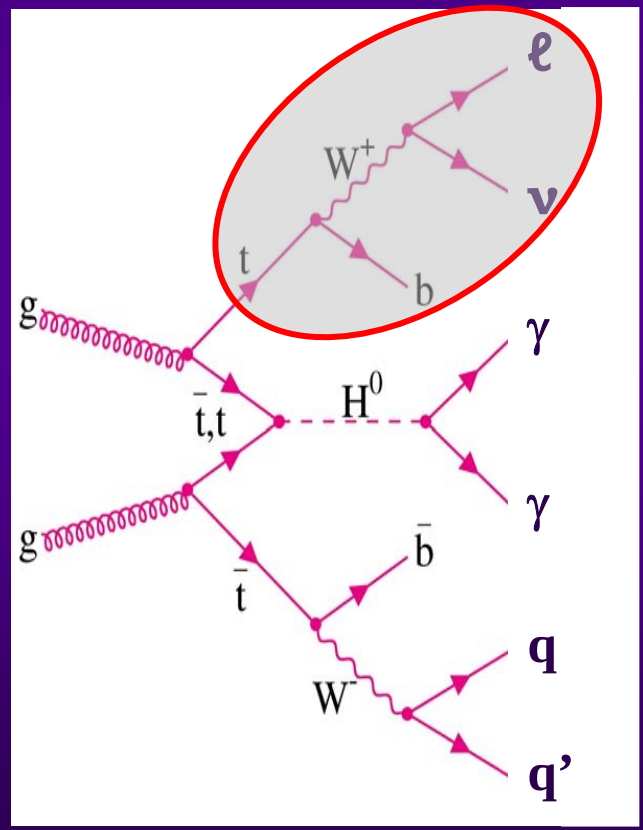




- Under development
  - Demonstration that we can measure tails in Z+jet and quantify them in other channels
  - Build corrections directly into analysis
- Carry into other hadronic analyses too ...

More data ... Higgs properties with t(t)H - I (Albert)

- ATLAS sees a Higgs-like object:
  - Question: is it H^0_{SM} ??
    - Spin = 0
    - CP-even
  - Other models gives alternatives
    - MSSM: h,H CP-even but A CP-odd
    - General 2HDM
      - h1,h2,h3 ⇒ mixed CP
    - ... host of other models
  - Using ttH
    - Can determine top-quark couplings and object CP
    - With enough data, spin can be extracted too
- Technique:
  - Partial Event reconstruction
    - Increases efficiency O(10x)
  - Similar to H→γγ selection



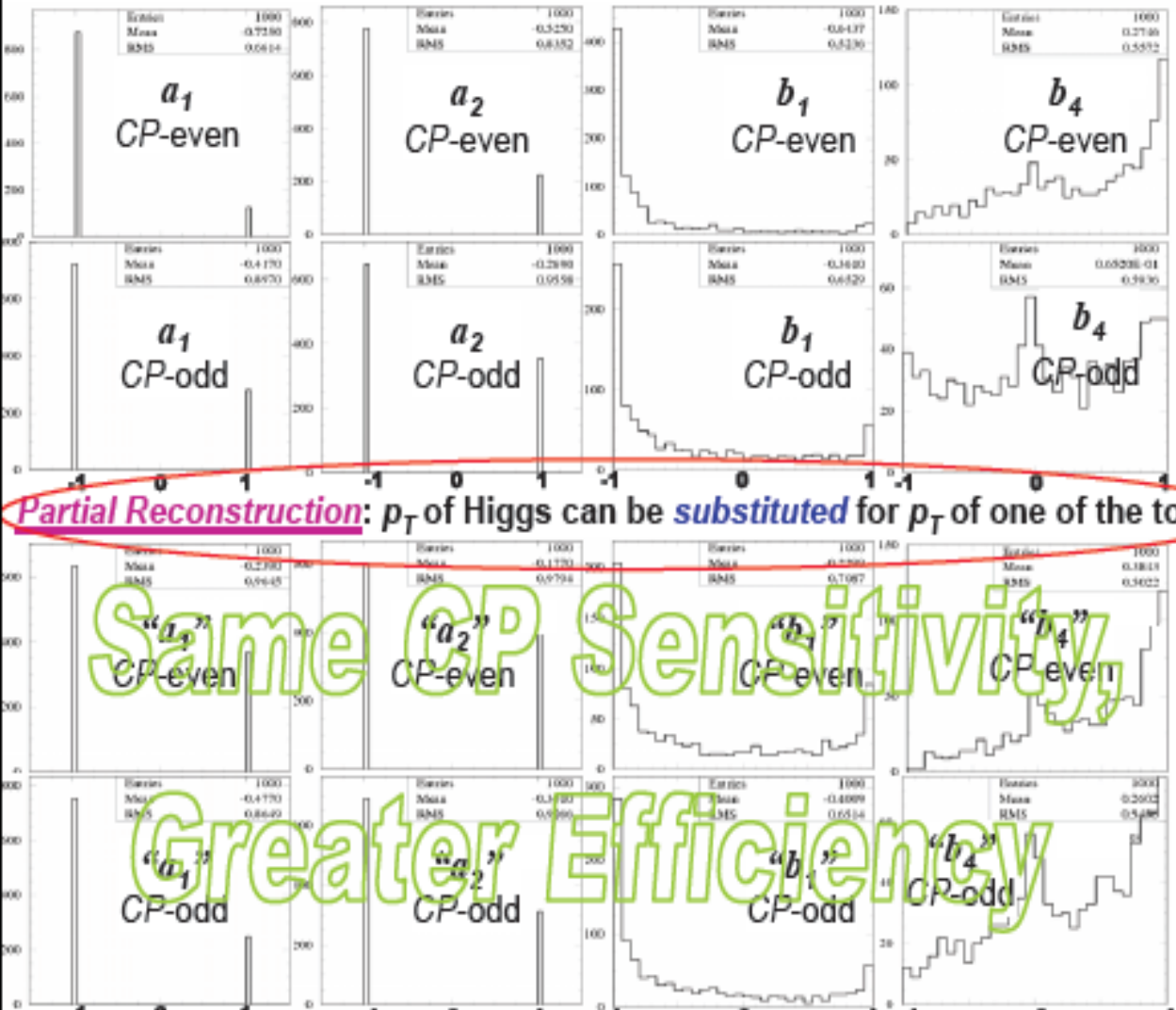
More data ... Higgs properties with t(t)H - II

CP-sensitive variables:

(Gunion & He, PRL 76, 4468 (1996))

$$a_1 = \frac{(\vec{p}_t \times \hat{n})\cdot(\vec{p}_{\bar{t}} \times \hat{n})}{|(\vec{p}_t \times \hat{n})\cdot(\vec{p}_{\bar{t}} \times \hat{n})|} \qquad b_1 = \frac{(\vec{p}_t \times \hat{n})\cdot(\vec{p}_{\bar{t}} \times \hat{n})}{p_t^T p_{\bar{t}}^T} \qquad b_2 = \frac{(\vec{p}_t \times \hat{n})\cdot(\vec{p}_{\bar{t}} \times \hat{n})}{|\vec{p}_t||\vec{p}_{\bar{t}}|}$$

$$a_2 = \frac{p_t^x p_{\bar{t}}^x}{|p_t^x p_{\bar{t}}^x|} \qquad b_3 = \frac{p_t^x p_{\bar{t}}^x}{p_t^T p_{\bar{t}}^T} \qquad b_4 = \frac{p_t^z p_{\bar{t}}^z}{|\vec{p}_t||\vec{p}_{\bar{t}}|}$$

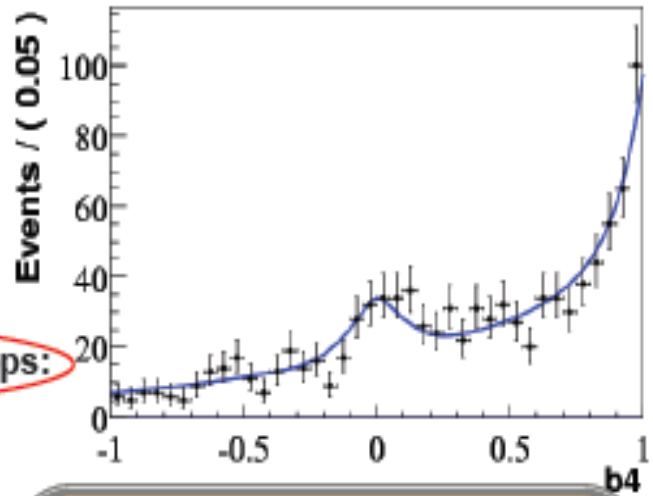


Partial Reconstruction: p_T of Higgs can be substituted for p_T of one of the tops:

Same CP Sensitivity,

Greater Efficiency

Combined maximum likelihood ***CP* fit** using all 6 variables (CP_{even} signal projection onto b_4)



CP Sensitivity Estimates

(0 = CP-even Higgs, 1 = CP-odd)

40 fb^{-1}	±0.5
80 fb^{-1}	±0.3
800 fb^{-1}	±0.1

NOTES: 120 GeV SM coupling Higgs, from *t(t)H* only, adding other channels improves sensitivity.

UVic ATLAS Operations Model

- Largest effort is UVic based
  - Currently 2 postdocs
  - Most student activity
  - Analysis based at Victoria
- CERN presence critical for commissioning, operations, collaborative interactions
  - 1 postdoc (requesting to move to two postdocs @ CERN)
  - Requesting funds to allow ~ 1 year at CERN per PhD student
  - Significant commuting to CERN for physics and detector weeks
    - Typically ~ 4 trips per year minimum
    - Longer stays for commissioning work, future data-taking, or personnel with central core roles
- Collaboration within Canada also critical
  - We share personnel, computing resources across Canada
  - Have 3 ATLAS-Canada physics meetings per year rotating through country
  - Plus workshops including Canada and U.S. ATLAS members for specific topics, physics analysis tutorials
  - Locally have weekly Western Canada (Alberta, Regina, TRIUMF, UBC, UVic,) ATLAS phone meetings discussing a variety of commissioning, calibration and physics topics
    - Grew out of weekly UVic ATLAS meetings and still UVic organized

ATLAS @ UVic: (near) future

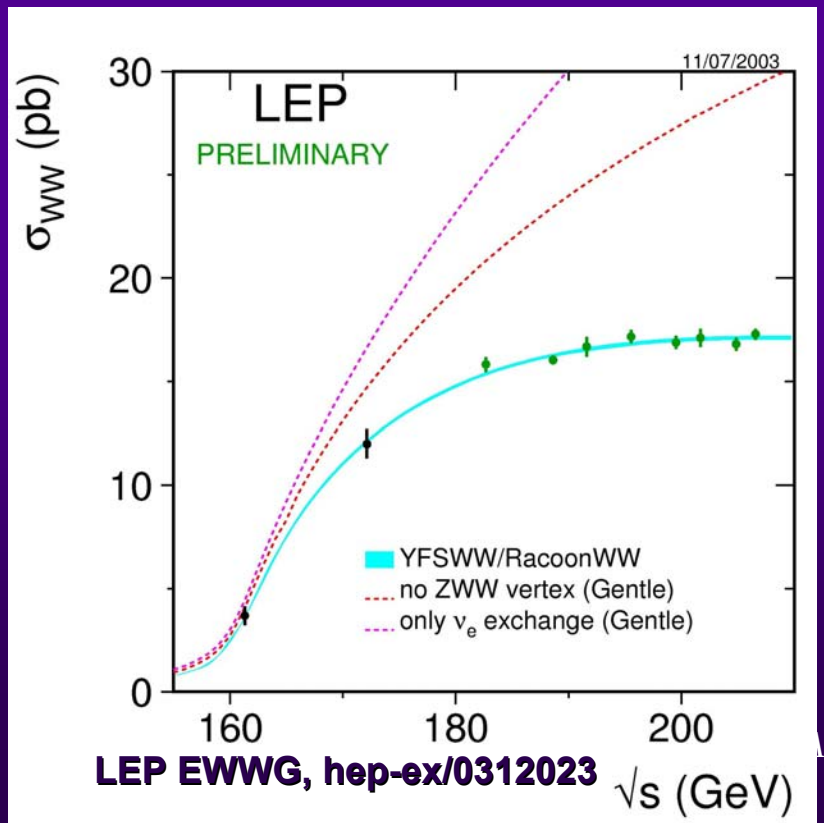
- Foresee continued group expansion
  - Many new, very good, students interested
  - And faculty shifting to ATLAS
- Clearly need to expand our presence at CERN
  - Detector operations
  - And also experience for students
- And UVic-based analysis
  - Physics analysis
  - Also detector calibration work done remotely
- Entering a new epoch in particle physics
  - Will be an exciting few years ...

Additional Material

Standard Model: incomplete

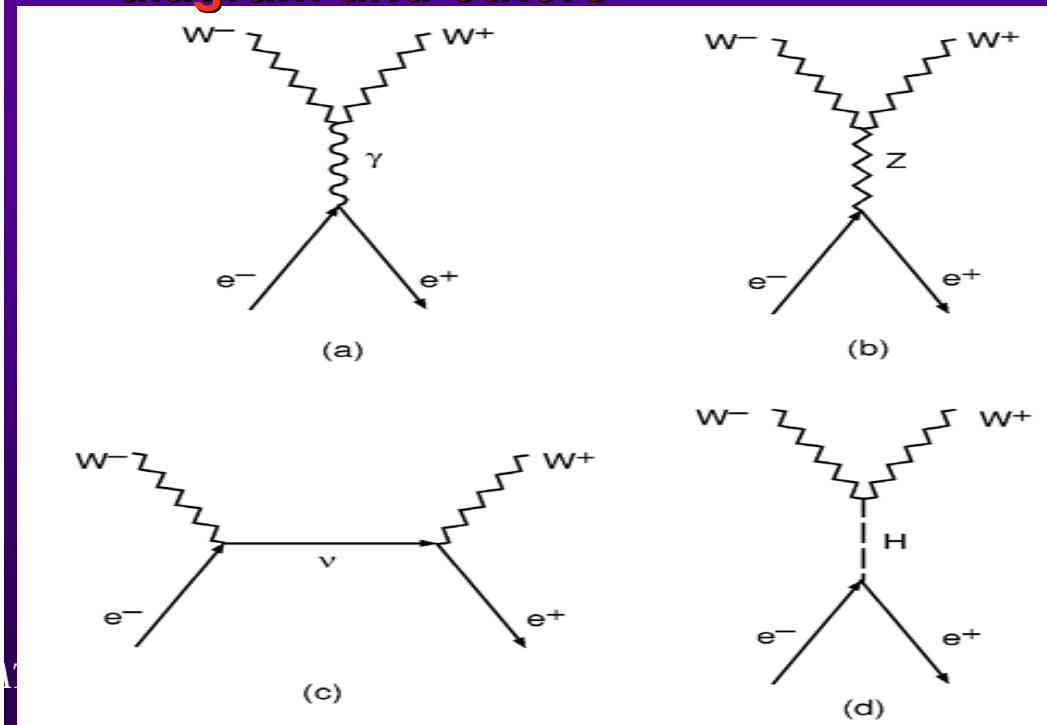
- Years of precision SM EW tests
- Still missing (but required): a Higgs
  - Gives mass to particles in a renormalizable way
  - Also enters into physics measurables in loops

$e^+e^- \rightarrow W^+W^-$



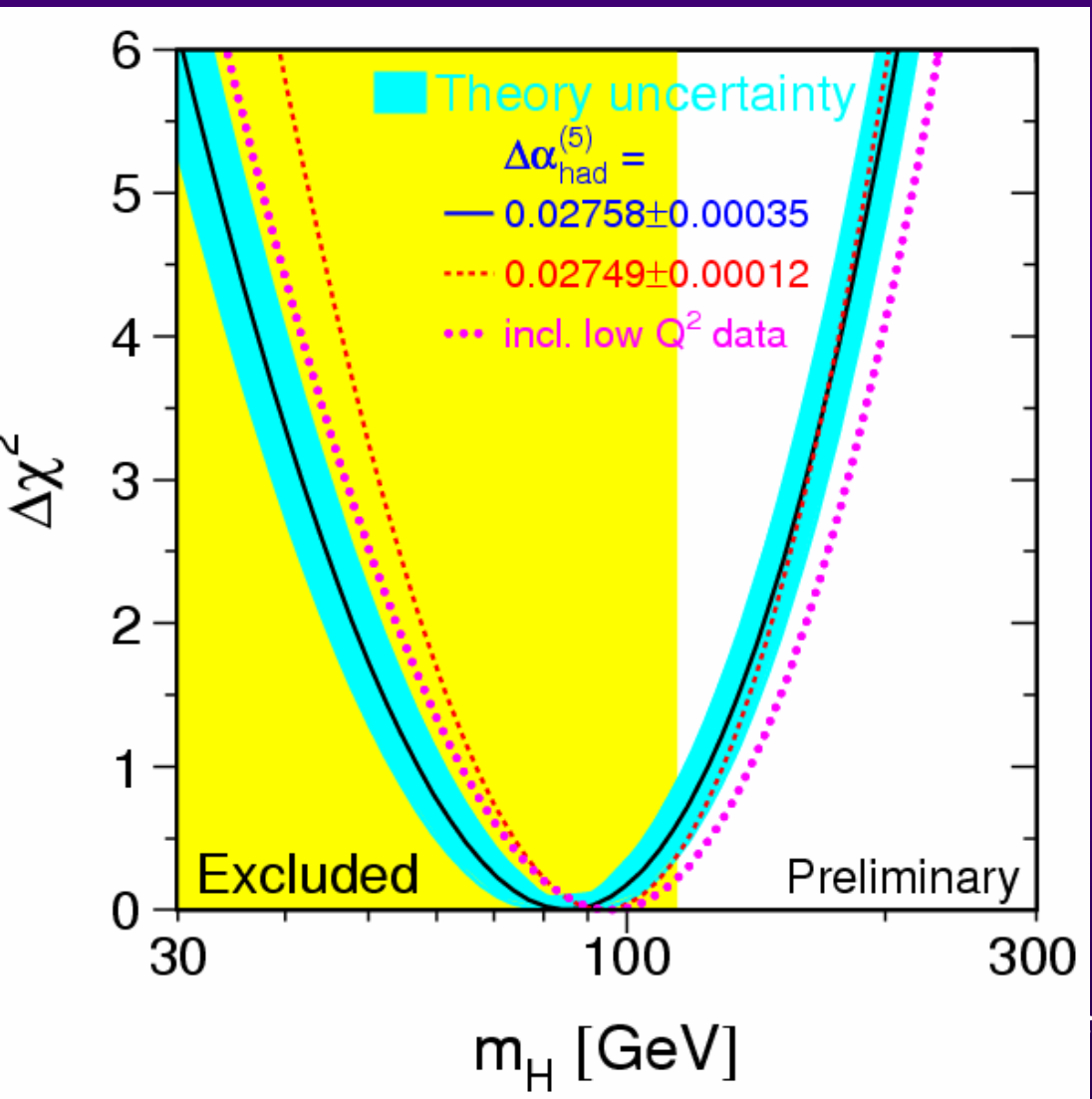
LEP EWWG, hep-ex/0312023

Contribution which grows like $m_e^2 s$ cancels between Higgs diagram and others



Constraints on Higgs boson H^0_{SM}

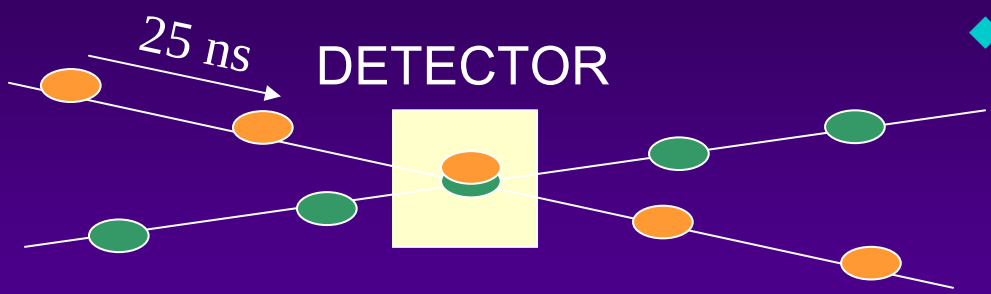
EW Fits: MH free Param.
Data from LEP, SLD, Tevatron



- **MH (summer 2006)**
  - **Most likely:**
    - 85 GeV
  - **Direct Search LEP:**
    - > 114 GeV @ 95% C.L.
  - **Indirect EW fit constraints:**
    - < 166 GeV @ 95% C.L.
  - **Including LEP direct search limit**
    - < 199 GeV @ 95% C.L.

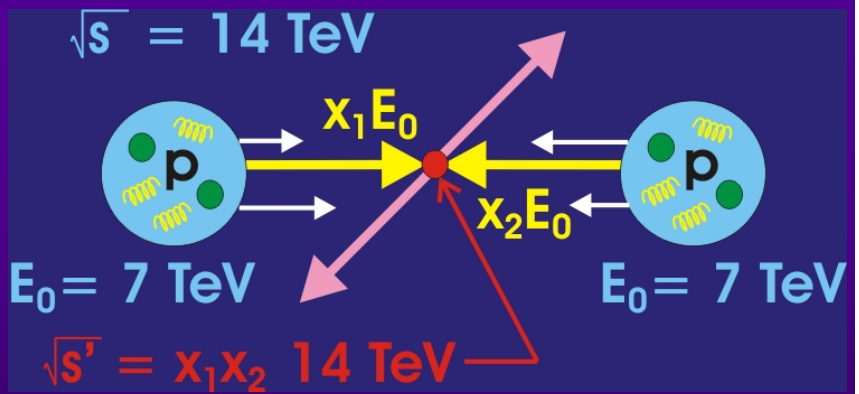
➢ **Complete the SM:**
  ➢ **Find H^0_{SM}?**
➢ **Look beyond the SM**
  ➢ **New symmetries, compositeness , …**

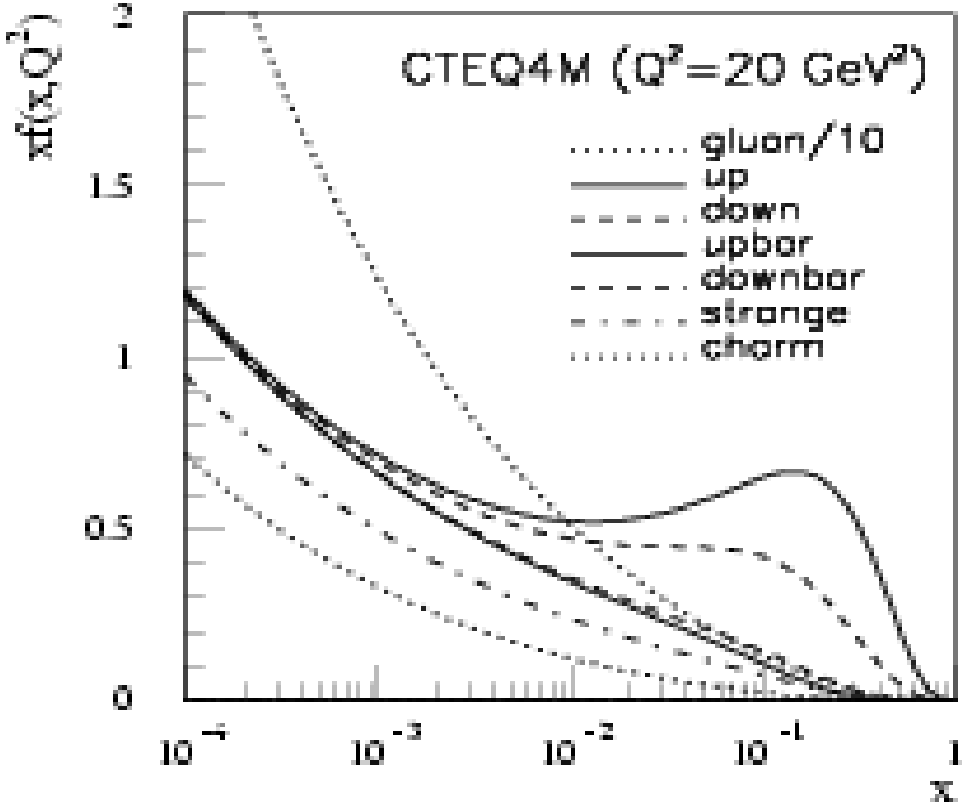
LHC interactions: p-p collisions



- Detector response ~ 20-50 ns
  - Integrate 1-2 crossings
    ⇒ pile-up ~ 25-50 min. bias
  - Detectors fast, highly granular

When protons collide:





$\sqrt{s'} \approx 100$ GeV $\Rightarrow x_1x_2 \sim 0.01$
$\sqrt{s'} \approx 5$ TeV $\Rightarrow x_1x_2 \sim 0.35$

Case for Physics "BSM"

- Quark/Lepton generations, masses
  - ⇒ Compositeness? Substructure? Strings?
  - ⇒ Common sub-elements quarks/leptons?
- Matter-Antimatter asymmetry
  - CPV in SM (K,B) + Big bang:
    - Not enough to explain observations
    - Neutrinos last "SM" hope (given ν mass≠0)
- Cosmological constant (dark energy ...)
  - Higgs energy density ≈ 10^{50} GeV/cm^3 (could finesse)
  - Observationally: < 10^{-4} GeV/cm^3
- Fine-Tuning of Higgs mass
  - Particle loop corrections to M_H ~ Λ^2
  - If theory cut-off Λ ~ O(M_P)
    - Fine tuning of corrections 1 : 10^{20} needed

➢ Case strong

➢ But related to mass?

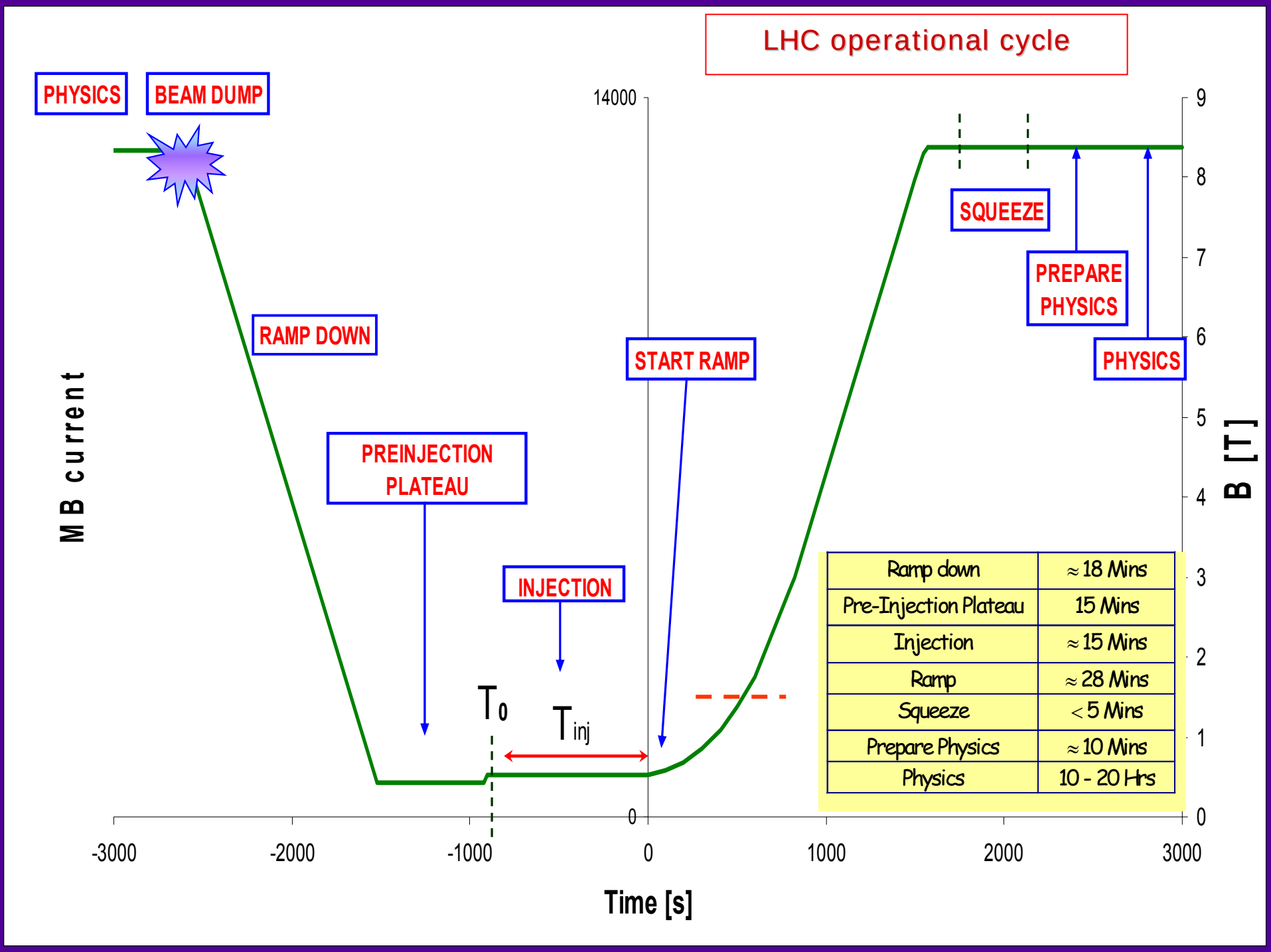
➢ Planck scale??

➢ Case strong

➢ Not clear scale

➢ Here, case for EW scale new physics

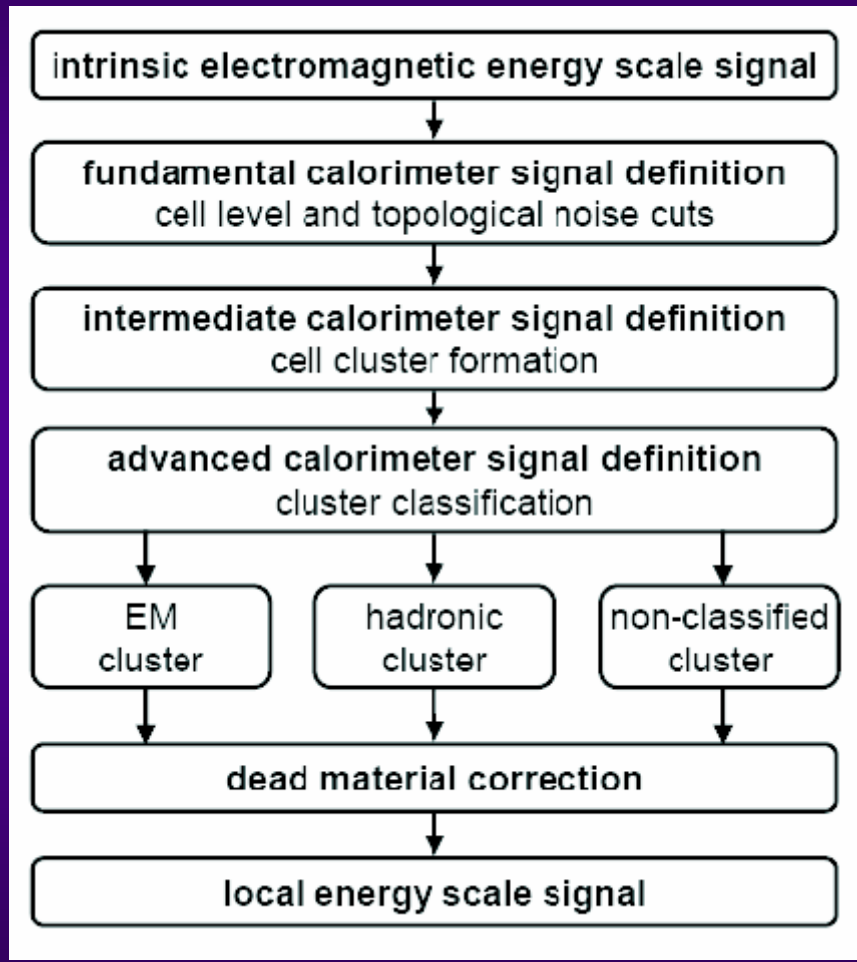
➢LHC


LHC operational cycle
PHYSICS
BEAM DUMP
RAMP DOWN
PREINJECTION PLATEAU
INJECTION
START RAMP
SQUEEZE
PREPARE PHYSICS
PHYSICS
MB current
B [T]
Time [s]
14000
0
-3000
-2000
-1000
0
1000
2000
3000
T0
Tinj
Ramp down ≈ 18 Mins
Pre-Injection Plateau 15 Mins
Injection ≈ 15 Mins
Ramp ≈ 28 Mins
Squeeze < 5 Mins
Prepare Physics ≈ 10 Mins
Physics 10 - 20 Hrs

Calorimeter Reconstruction

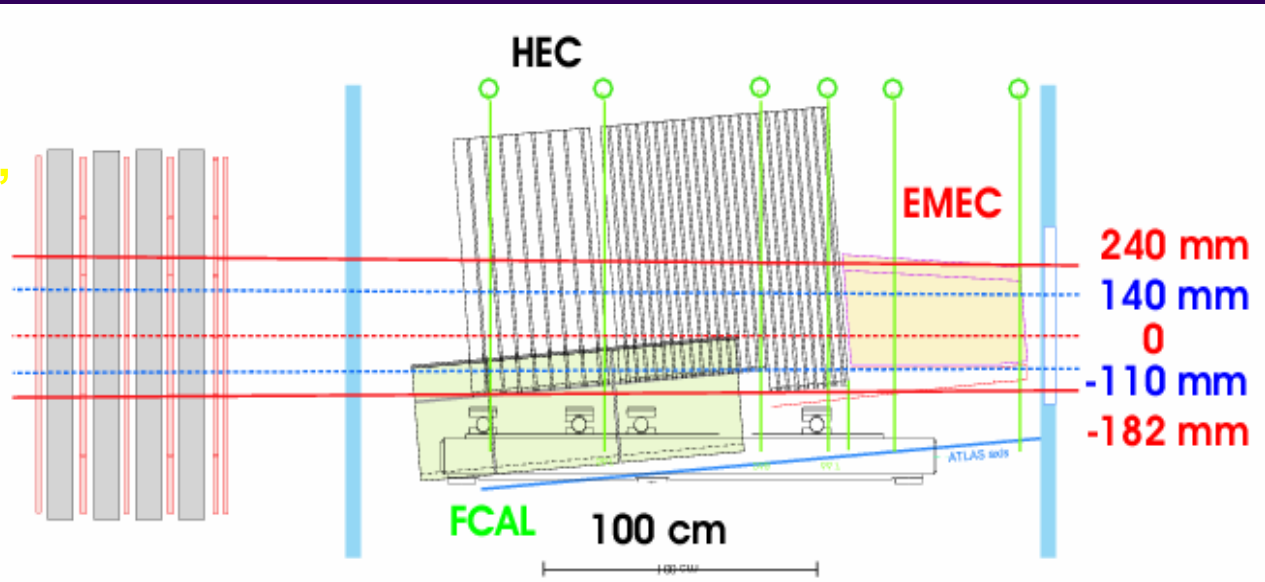
- UVic contributes to (almost) all parts of the calorimeter reconstruction and calibration chain
  - just snapshot of current projects today
- Focus on
  - Local hadronic calibration
  - jet reconstruction and calibration
  - New hire (Lelas) gives us in depth e/γ reconstruction expertise

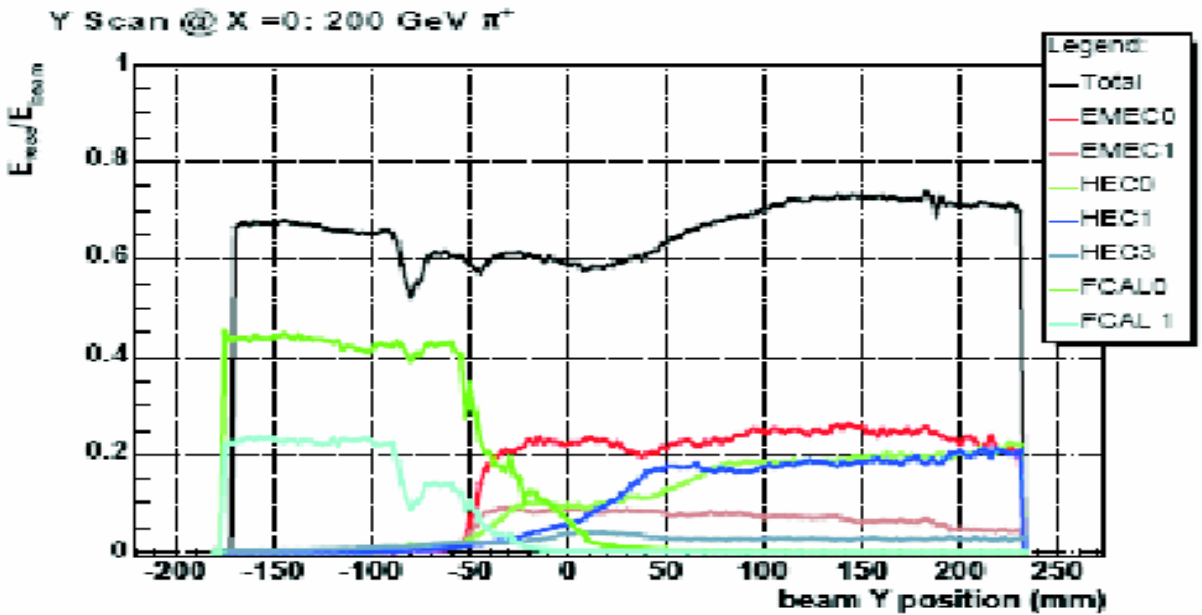
Local Hadronic Calibration



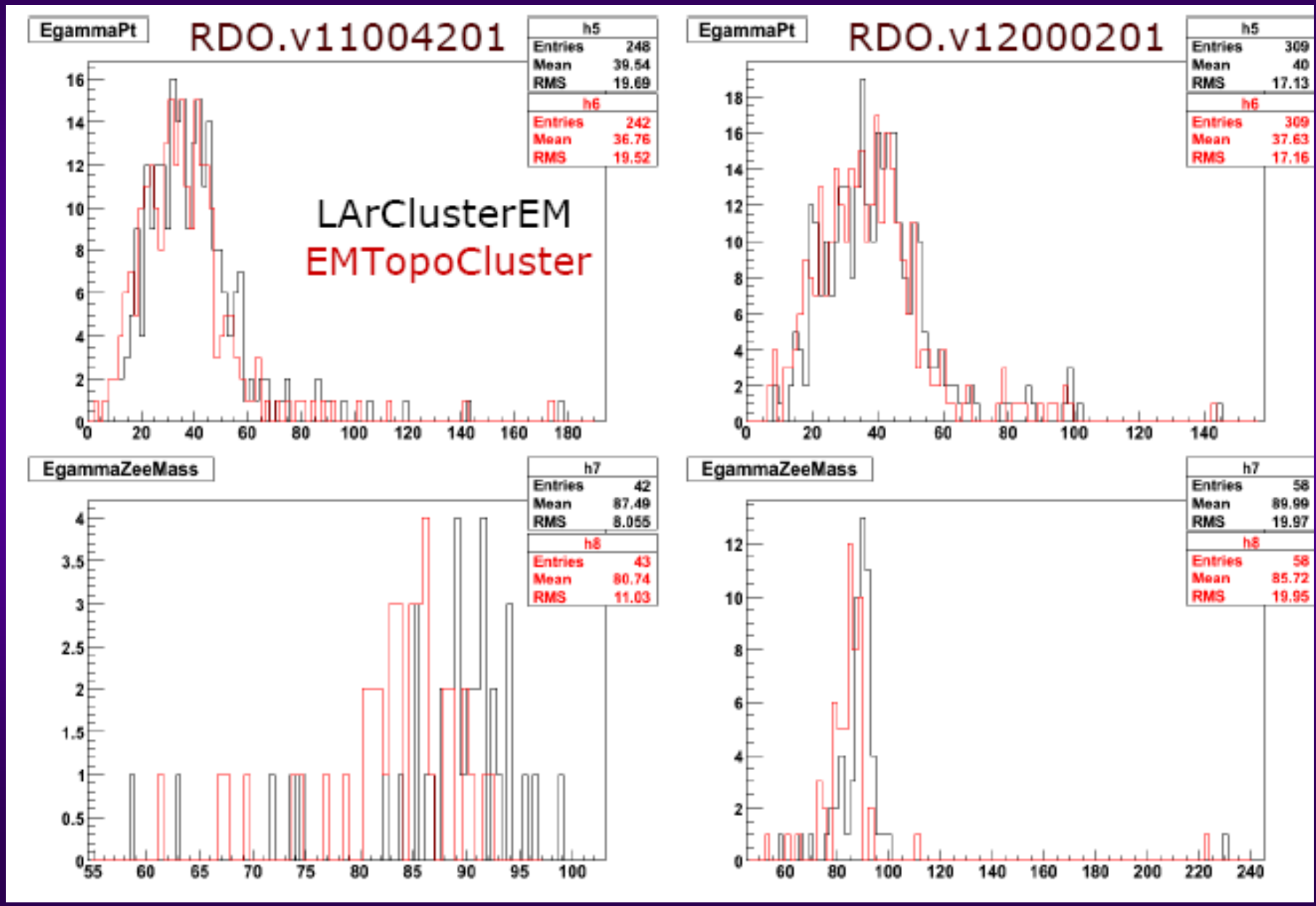
2004 EMEC-HEC-FCAL TB
(from Shaw's MSc Thesis -- Keeler, McPherson)

- 2004 TB designed to investigate energy sharing among EMEC, HEC and FCAL
- Particularly across significant dead-material in cryostat and supports
- In ATLAS, no tracking here, so difficult to calibration in situ
- UVic contributions:
  - Monitoring: Lefebvre, McPherson
  - Calibration: Shaw, Keeler, McPherson, Wielers
  - Analysis: Shaw, Keeler, McPherson





Early Physics: Low mass DrellYan ee II (early studies)



ETmiss analysis: tails from data? II

- Currently: produced large background sets with detector problems
  - 9 LAr HV lines: 224 cells @ 0, 9722 @ ½
  - 2 LAr FEC (1 EMB, 1 EC special): 7680 dead cells