

# Hadron Collider Physics



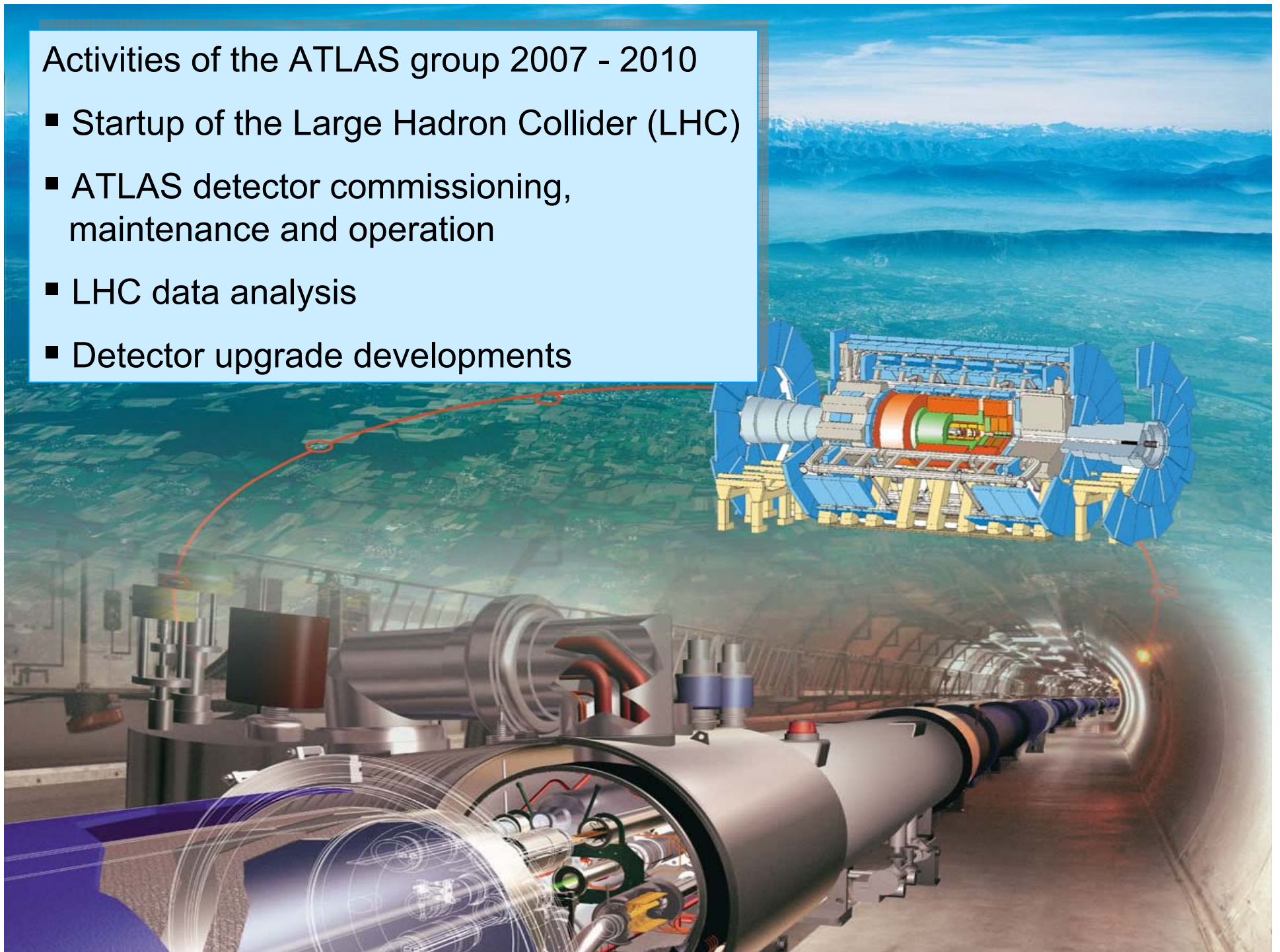
<http://atlas.ch>

Hubert Kroha  
for the ATLAS Group  
Advisory Board  
27.10.2010



## Activities of the ATLAS group 2007 - 2010

- Startup of the Large Hadron Collider (LHC)
- ATLAS detector commissioning, maintenance and operation
- LHC data analysis
- Detector upgrade developments



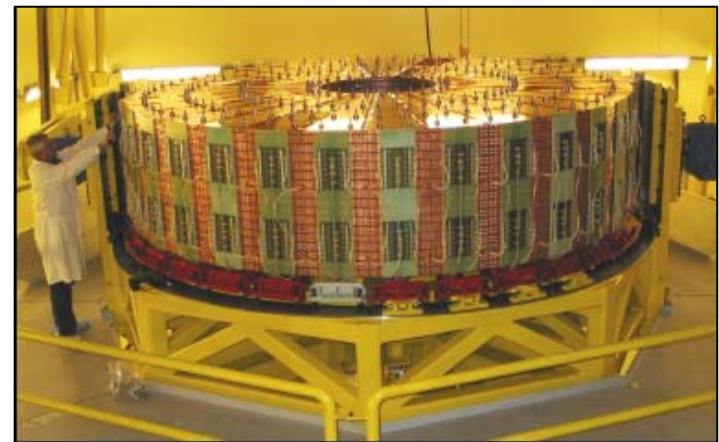
## History

- MPP founding member of ATLAS
- Detector design 1992 – 1997
- Detector construction 1999 – 2006
- Detector installation 2005 – 2007
- ATLAS commissioning 2007 – 2009
- Data taking and analysis 2009 ...

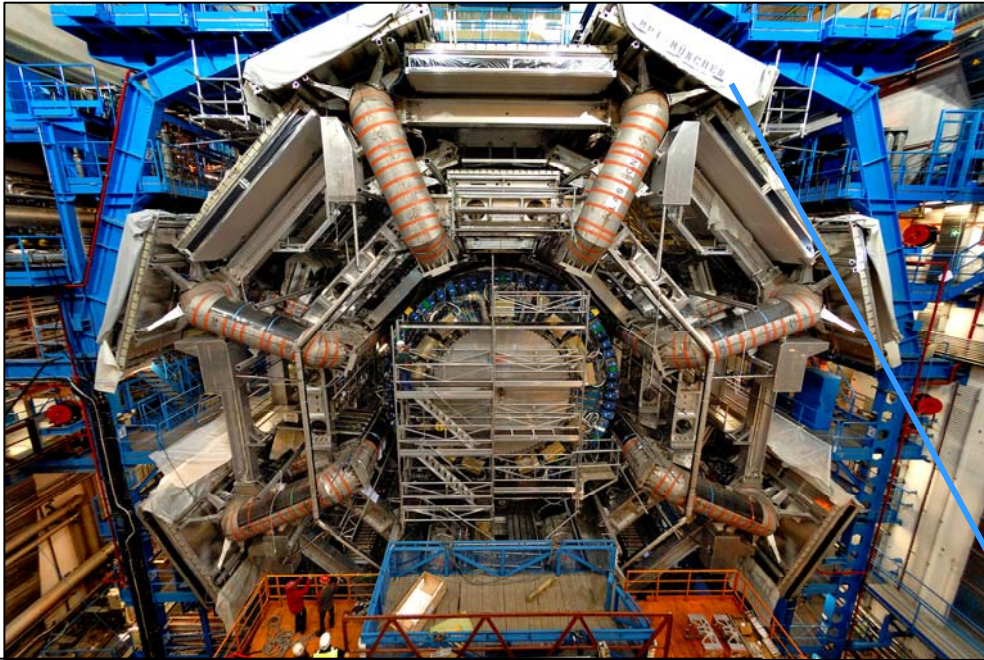


## ATLAS detector **design and construction:**

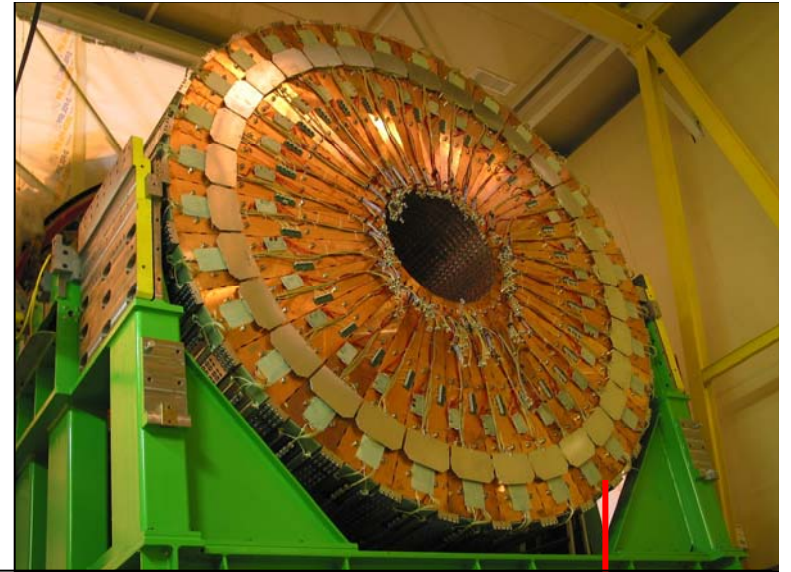
- 15% of precision drift-tube chambers for the Muon Spectrometer, optical alignment monitoring system.
- 25% of the liquid-argon Hadron Endcap Calorimeter, “cold” readout electronics.
- 10% of the silicon strip detector modules for the Semiconductor Central Tracker.



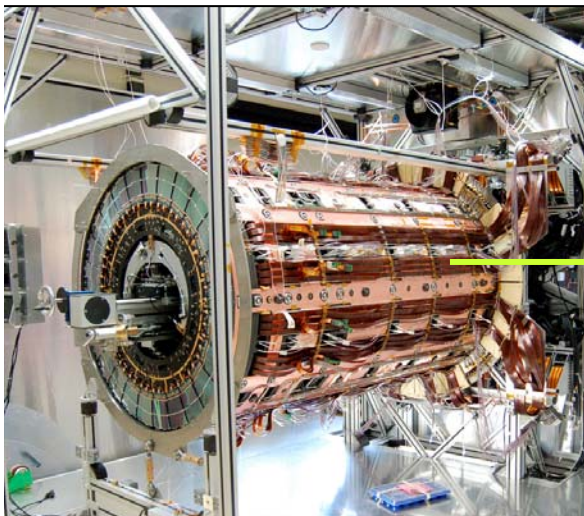




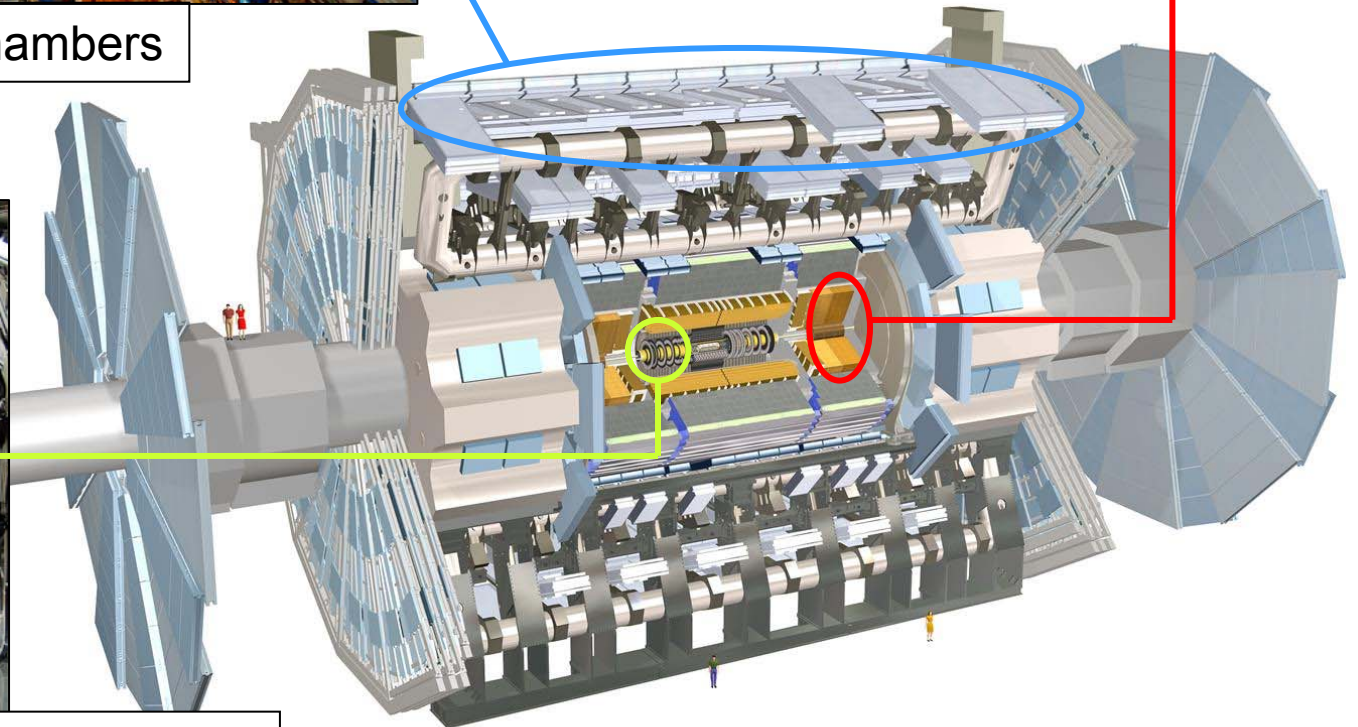
Muon Drift Tube (MDT) chambers



Hadron Endcap Calorimeter (HEC)



Semiconductor Central Tracker (SCT)



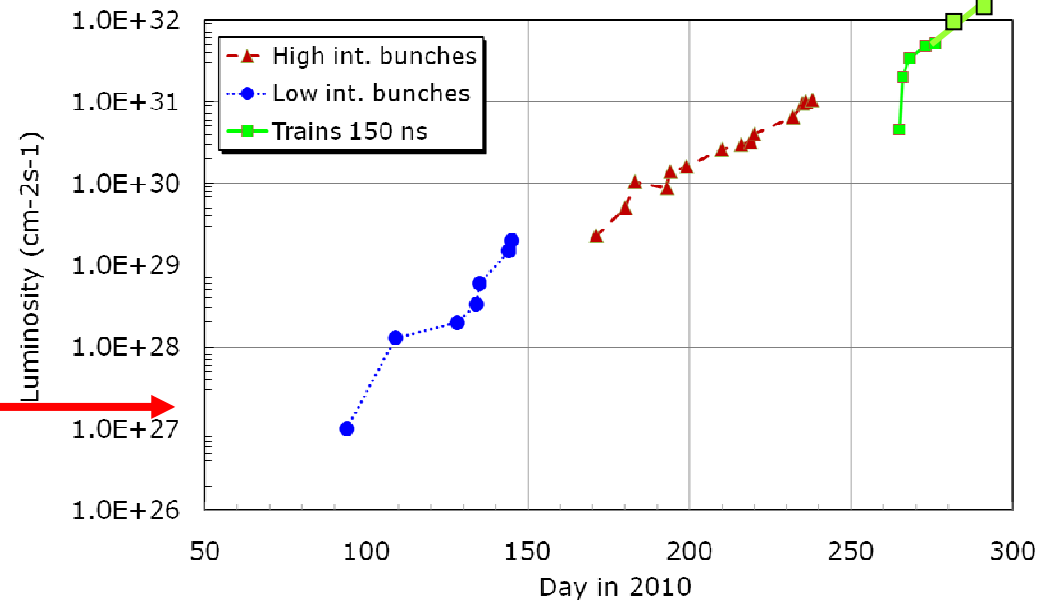
# LHC Startup and Luminosity Evolution

First proton-proton collisions:  
20 November 2009 at 0.9 TeV  
11 December 2009 at 2.36 TeV  
**30 March 2010 at 7.0 TeV**  
centre-of-mass energy

**Peak inst. luminosity**  $2 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$

with 368 proton bunches/ beam  
in trains with 150 ns bunch spacing and  
 $10^{11}$  protons/ bunch  
20 MJoule stored beam energy

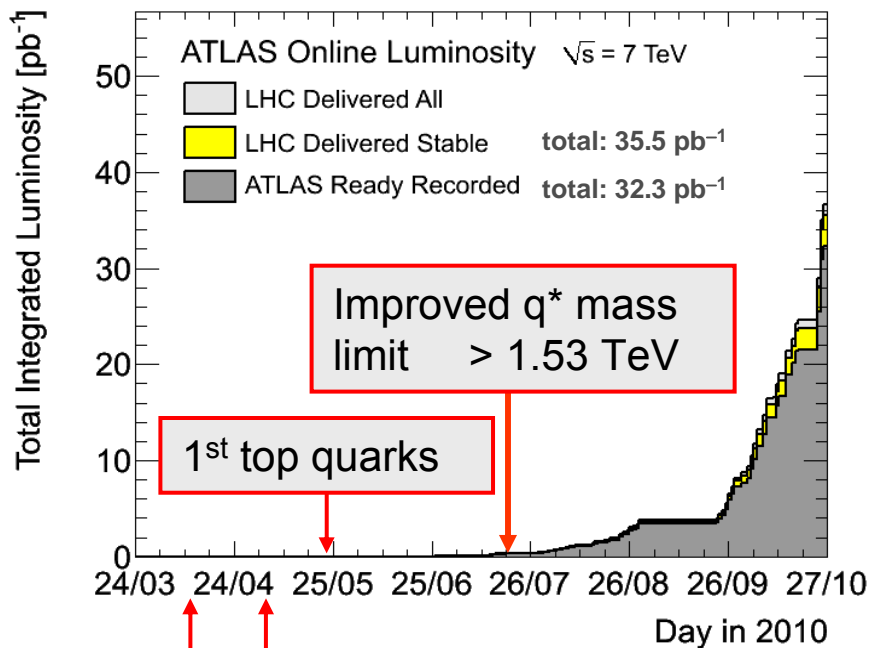
LHC run 2010



LHC design luminosity  $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$

with 2835 proton bunches/ beam  
and 25 ns bunch spacing,  
 $10^{11}$  protons/ bunch  
335 MJoule stored beam energy





26/10/2010, 8:30 CET:

Integrated luminosity 2010:  $35.5 \text{ pb}^{-1}$   
 $2.5 \times 10^{12}$  pp collisions at 7 TeV

Goal 2010:  $50 \text{ pb}^{-1}$

ATLAS data taking efficiency:  $\sim 92\%$

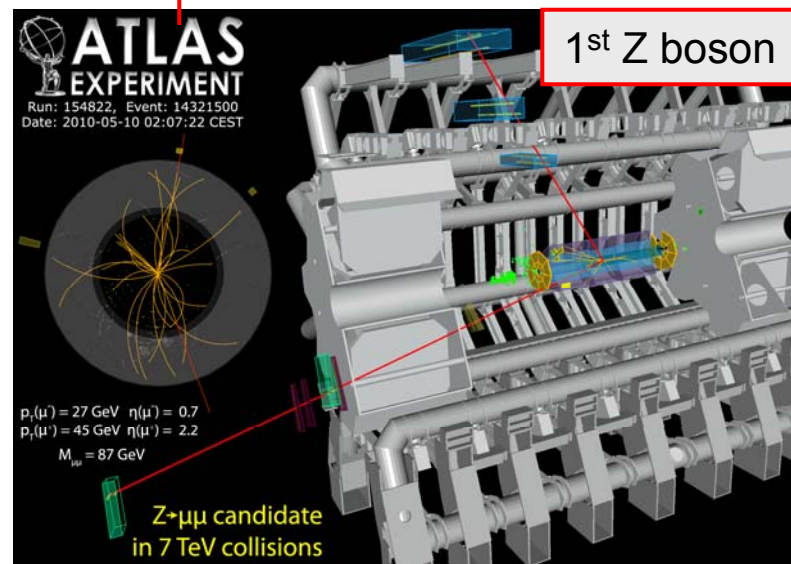
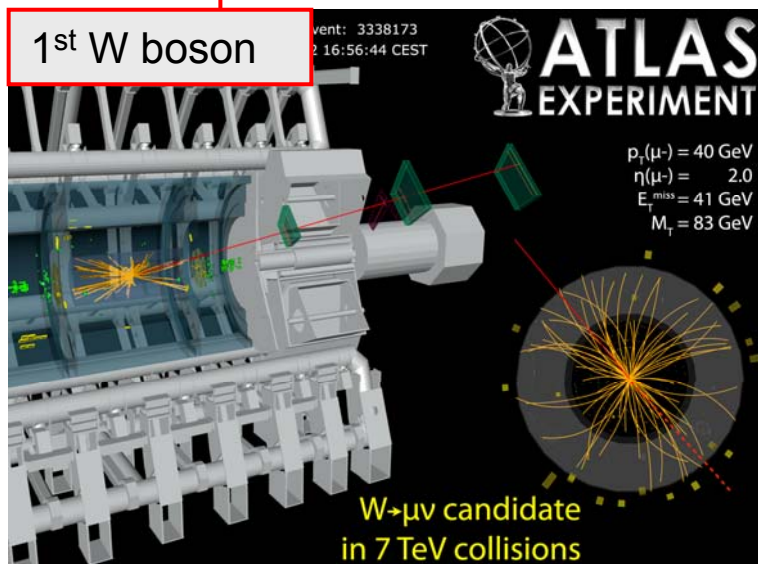
Next steps:

Nov. 2010: Heavy ion run

2011:  $1 \text{ fb}^{-1}$  pp

2012/13: LHC improvements

From 2013:  $10 \text{ fb}^{-1}$ / year at 14 TeV



## ATLAS Project

Director: S. Bethke

**Project Leaders:** S.Kluth (Computing)  
H.Kroha (Muon Spectrometer)  
S.Menke (Calorimeter)  
R.Nisius (Silicon Tracker)

**Independent Research Group Leader (Minerva program):** S.Kortner

**Senior Physicists:** T.Barillari, A.Kiryunin, O.Kortner, H.-G.Moser (HLL), D.Salihagic, H.von der Schmitt (H.Oberlack, R.Richter, P.Schacht)

**Postdocs:** G.Cortiana, J.Dubbert, M.Flowerdew, C.delle Fratte (RZG), P.Haefner, S.Kotov, A.Macchiolo, M.Nagel, I.Potrap, G.Pospelov, R.Seuster, V.Zhuravlov

**PhD Students:** M.Beimforde, B.Bittner, J.Bronner, D.Capriotti, Th.Ehrich, P.Giovannini, A.Jantsch, St.Kaiser, J.von Loeben, S.Stern, M.Vanadia, Ph.Weigell

**Diploma Students:** M.Goblirsch, M.Kilgenstein, Ph.Schwegler

### **Positions:**

12 Staff positions (7 permanent )  
2 Service (CERN, HLL, IT)  
1 MPG Minerva position  
4 MPG central funding  
4.5 Temporary employment fund  
( 3 Retired )  
12 PhD positions

# ATLAS Commissioning and Operation

## Muon Spectrometer

- Muon detector maintenance and data quality monitoring  
**ATLAS coordinator: J.Dubbert**
- Calibration of the drift tube chambers  
**ATLAS coordinator: O.Kortner**
- Alignment of the muon spectrometer with muon tracks
- Muon identification performance

## Calorimeter

- Hadronic endcap calorimeter maintenance and data quality monitoring
- Energy cluster reconstruction algorithm  
**S.Menke**
- Hadronic shower calibration  
**ATLAS coordinators: P.Schacht, S.Menke**

## Tracking Detector

- Silicon tracker data quality monitoring
- Alignment of the inner tracker with tracks  
**ATLAS coordinator: J.Schieck**

## Computing

- Operation of ATLAS Tier-2 computing center in Garching (RZG)
- ATLAS central computing and software tasks  
**Various coord. tasks: H.v.d.Schmitt**

Efficiency of the detectors 98–99% since March 2010

Contributions to detector installation and operation:  
**Diploma thesis: B.Bittner (2008)**  
**PhD theses: E.Rauter (2009), M.Groh (2009),  
J.von Loeben (2010), Th.Ehrich (2010)**

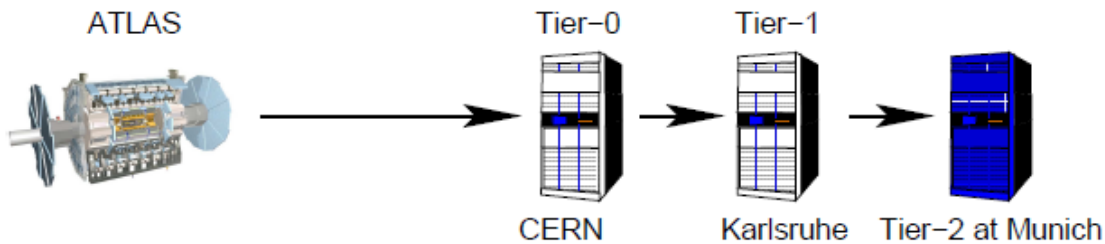


## Management Tasks in the ATLAS Collaboration

- |  |                      |
|--|----------------------|
| ▪ LAr Calorimeter Project Leader (2002–08)           | Horst Oberlack       |
| ▪ Physics Analysis Tools Coordinator (2007–09)       | Sven Menke           |
| ▪ Computing Coordinator (2010–12)                    | Hans von der Schmitt |
| ▪ Higgs Physics Coordinator (2010–12)                | Sandra Kortner       |
| ▪ Muon Identification Coordinator (2007–08, 2010–12) | Oliver Kortner       |
| ▪ Publications Committee Member (2007–2009)          | Sven Menke           |
| ▪ Speakers Committee Member (2009–12)                | Hubert Kroha         |

# Operation of a ATLAS Tier-2 Computing Center

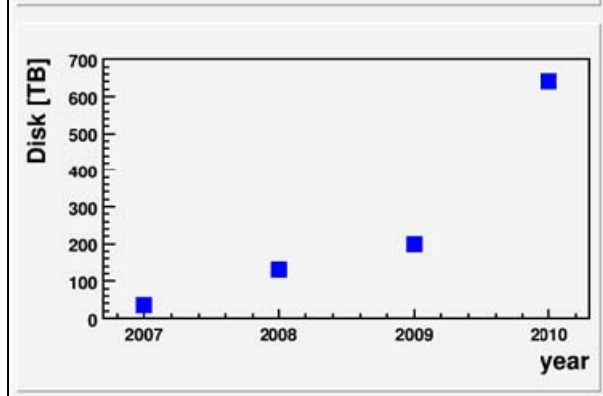
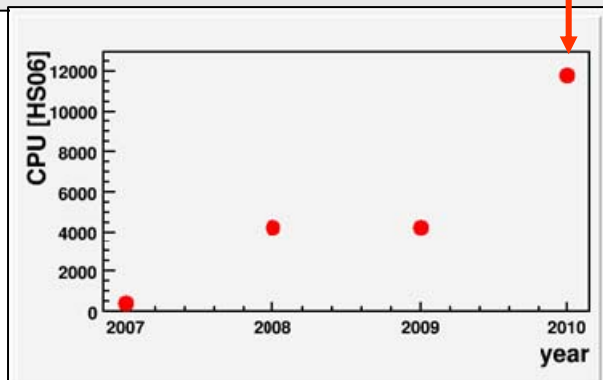
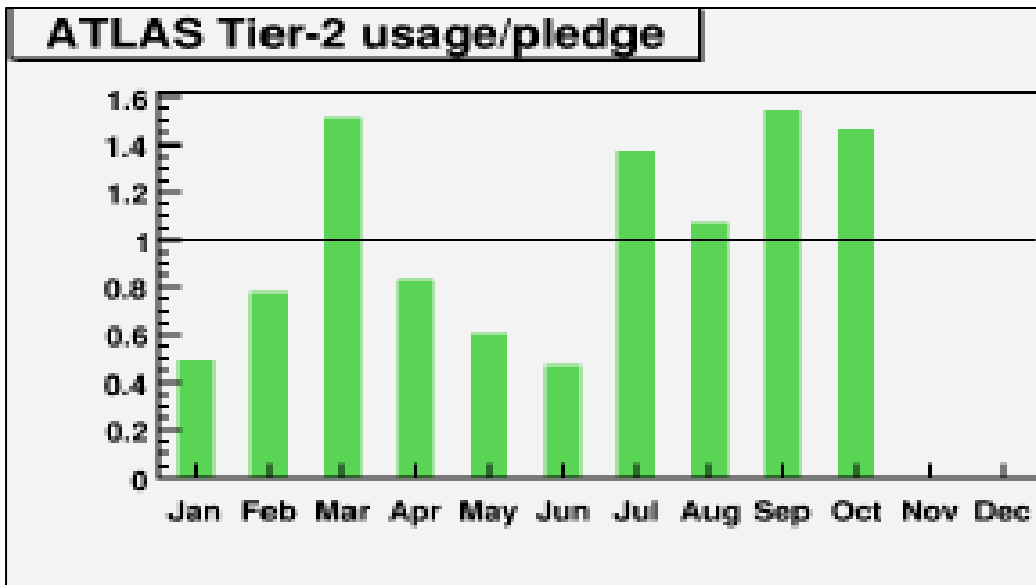
Sharing with Ludwig-Maximilians University Munich



Disk: 650 Tbyte data storage space  
 CPU: 12000 HEP-SPEC06 = 800 cores

Includes:

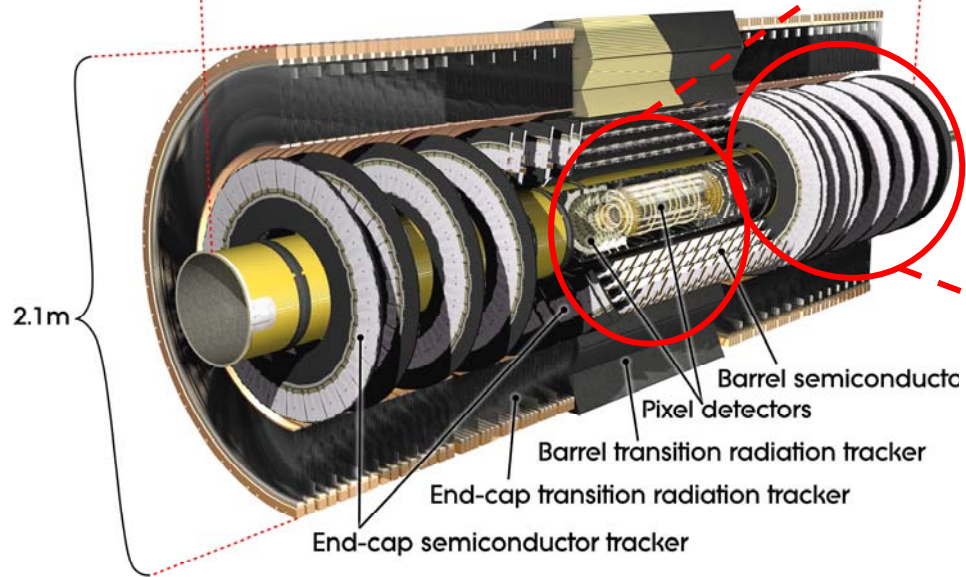
- 3% of ATLAS Tier-2 capacity
- Local data analysis (Tier-3)
- Muon Calibration & Alignment Center



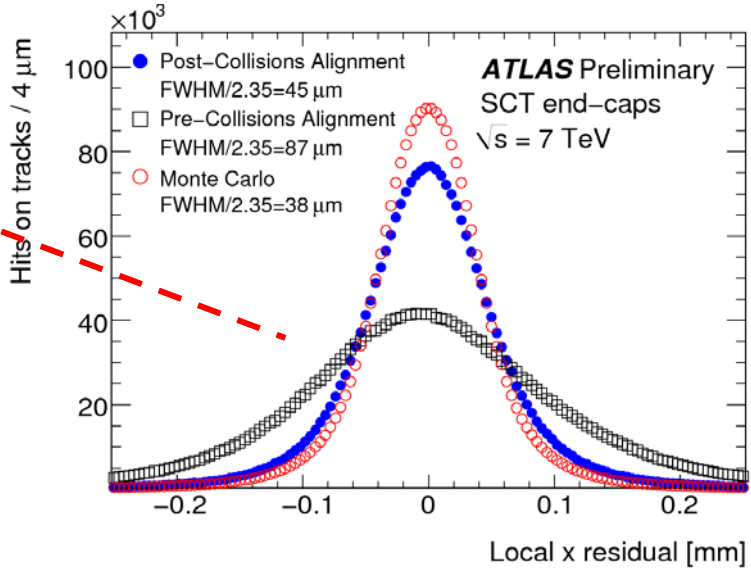
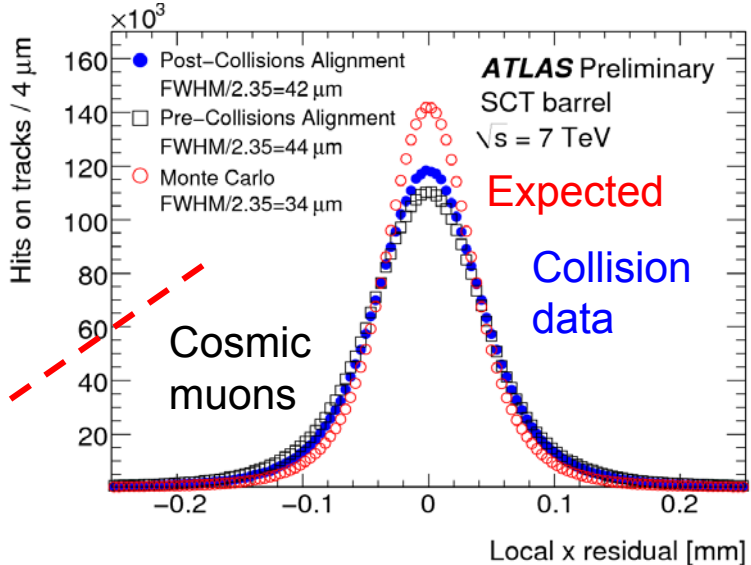


# Inner Tracker Alignment

- Iterative algorithm to measure the relative positions of **5800** silicon strip and pixel detector modules with particle tracks with  **$\sim 10 \mu\text{m}$**  accuracy developed at MPP.
- Applied to alignment with cosmic muon tracks during ATLAS commissioning.
- Algorithm used in parallel with other methods for continuous alignment with tracks from pp collisions.



Alignment accuracy:  
deviations from nominal positions



Diploma theses: M.Kayl (2007)  
PhD theses: S.Patarraia (2009), R.Härtel (2009), T.Göttfert (2010)

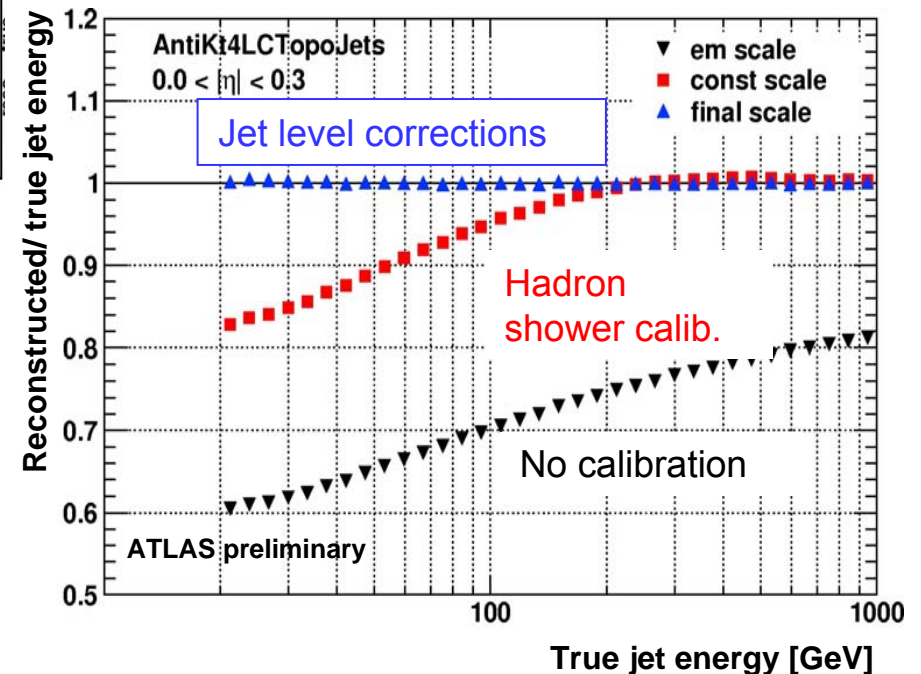
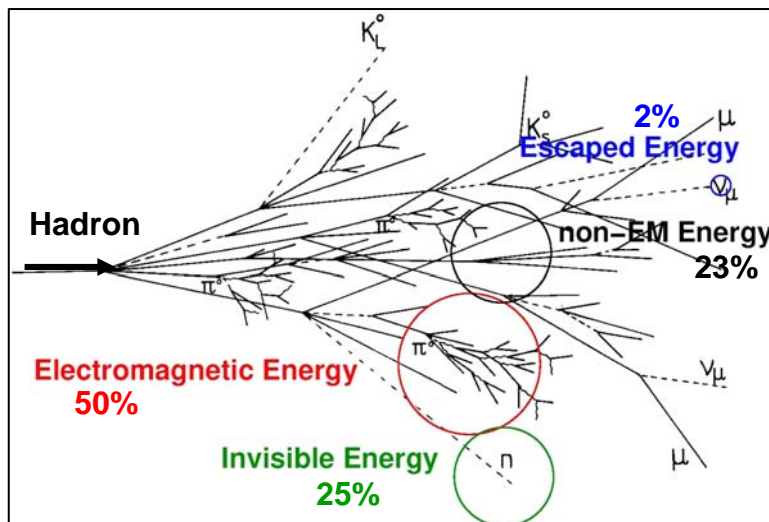
# Hadronic Shower and Jet Calibration

- Long-term program initiated and lead by MPP:
  - Corrections for
    - different calorimeter response to electromagnetic and hadronic energy depositions,
    - inactive calorimeter regions,
    - particles lost from jets.
- Validated with extensive testbeam measurements and with collision data.
- Ultimate jet calibration independent of the physics process, now available and maintained for ATLAS.

Diploma thesis: J.Erdmann (2008)

PhD theses:

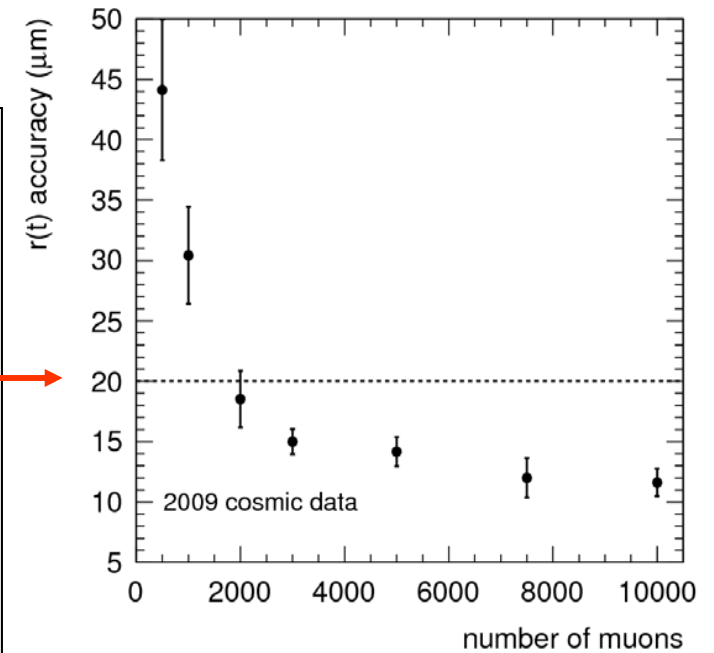
A.Jantsch (2010), P.Giovannini (2011)



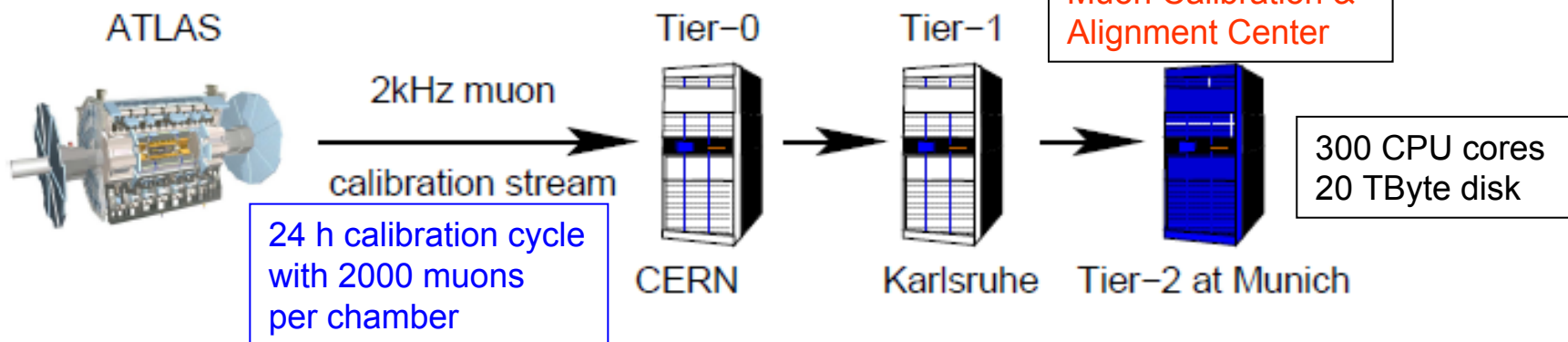


# Muon Chamber Calibration

- Muon precision drift tube chambers provide spatial resolution of **35  $\mu\text{m}$**  to achieve 10% momentum resolution at 1 TeV.
- Algorithm for robust calibration of the space-drift time  $r(t)$  relationships of **1170 chambers** with **20  $\mu\text{m}$**  accuracy developed at MPP. →
- Corrections for magnetic field non-uniformity validated with testbeam measurements.
- **Muon Calibration & Alignment Computing Center**, in operation since 2008, located at the Munich ATLAS Tier-2 center.



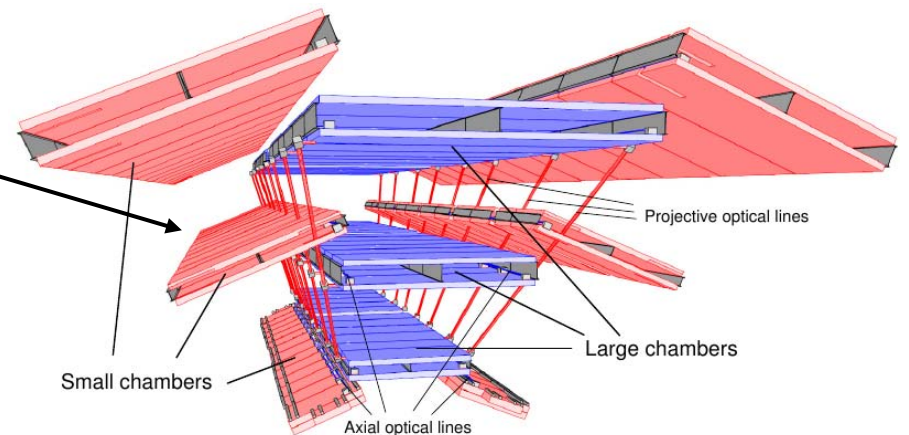
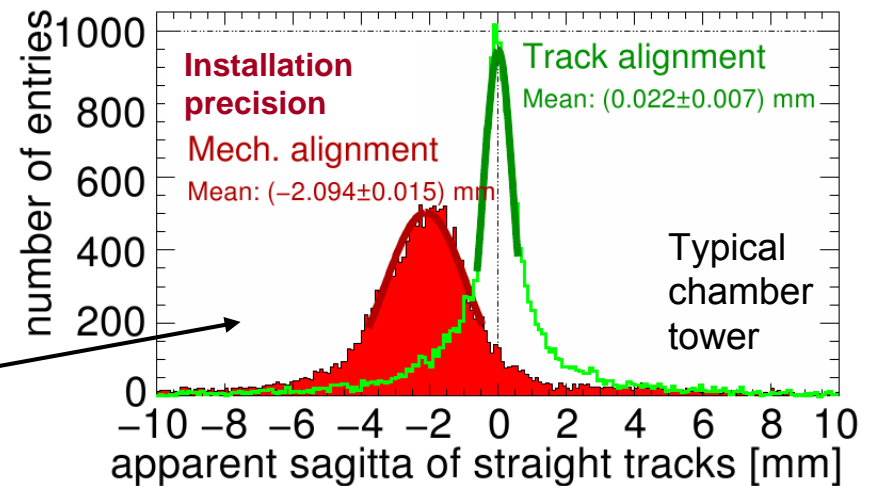
PhD thesis:  
J.von Loeben (2010)



# Muon Spectrometer Alignment

- Alignment of the muon chambers with  $50\ \mu\text{m}$  accuracy on track sagitta required for aim of **10% momentum resolution at 1 TeV**, crucial for  $A \rightarrow \mu\mu$  and  $Z' \rightarrow \mu\mu$  search.
- **Initial alignment** with cosmic muon tracks by MPP with  $100\ \mu\text{m}$  sagitta resolution at 1 TeV as required for the first data taking (bench mark:  $Z \rightarrow \mu\mu$  mass resolution).  
Final alignment accuracy with straight muon tracks from collision data (magnetic field off).
- **Laser alignment system** (concept developed at MPP) then monitors chamber movements over time with  $\sim 10\ \mu\text{m}$  precision.

- Alignment algorithms for chambers w/o optical sensors and for initial alignment with straight muon tracks developed at MPP.
- Alignment with muon tracks performed in 24h cycles using the muon calibration data stream at the **Munich Calibration & Alignment Center**.



Diploma theses: J.Schmaler (2007), B.Bittner (2008)  
PhD theses: St.Kaiser (2010), J.Bronner,  
M.Vanadia



# Muon Reconstruction Performance

First measurements of

- muon momentum resolution with cosmic rays and collision data
- muon detection efficiency and fake probability
- muon energy loss in the calorimeters
- di-muon mass resolution

Leading role of the MPP group

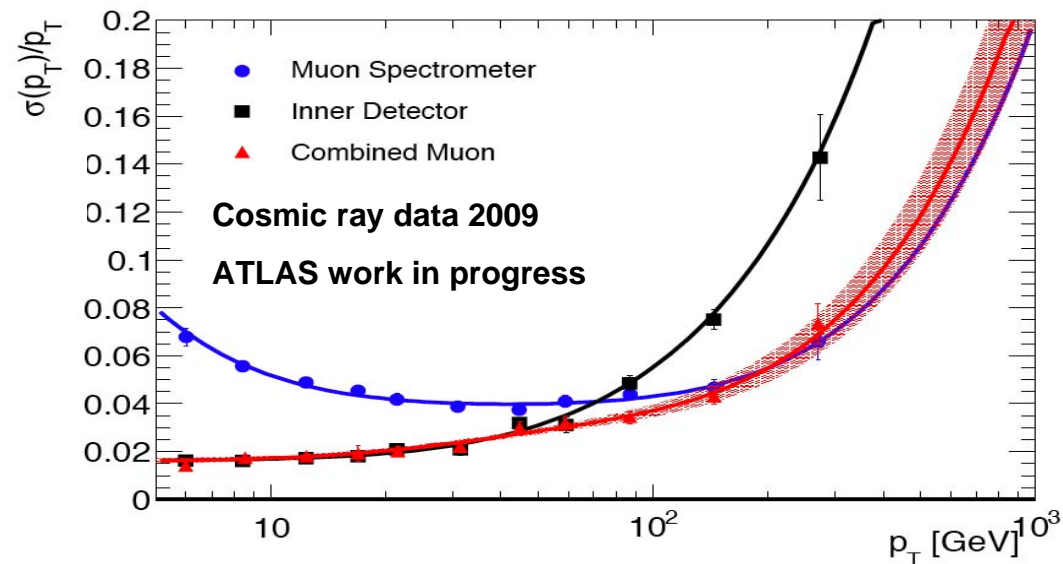
Oliver Kortner:

ATLAS Muon Performance coordinator,  
editor of muon conference papers

ATLAS-CONF-2010-036

ATLAS-CONF-2010-064

PhD theses: D.Capriotti, S.Stern, M.Vanadia



- ATLAS Expected Performance, CERN-OPEN-2008-020
- Muon Spectrometer Commissioning, arXiv:1006.4384v2 (2010), accepted by EPJC

# ATLAS Physics Program

- Precision **top quark** measurements (top mass, cross section, rare decays).
- Search for the **Higgs boson** in the Standard Model and beyond.
- Search for **supersymmetry** and for beyond Standard Model physics (**currently Z'**).

Based on expertise in operation and performance of the major subdetectors.

**Standard Model physics (electroweak, QCD)** in the early data taking phase in conjunction with data-driven background studies for new physics searches.

## Standard Model Physics

**O.Kortner, H.Kroha, S.Menke**

T.Barillari, M.Flowerdew, S.Kortner, R.Seuster,  
J.Bronner, D.Capriotti, P.Giovannini, S.Stern,  
M.Vanadia

## Top Quark Physics

**S.Menke, R.Nisius**

T.Barillari, G.Cortiana, P.Haefner, S.Kluth,  
M.Nagel, G.Pospelov,  
P.Giovannini, A.Jantsch

## Higgs Boson Searches

**S.Kortner, H.Kroha**

O.Kortner, S.Kotov, S.Stonjek,  
J.Bronner, Th.Ehrich, St.Kaiser, S.Stern

## SUSY & Beyond SM Searches

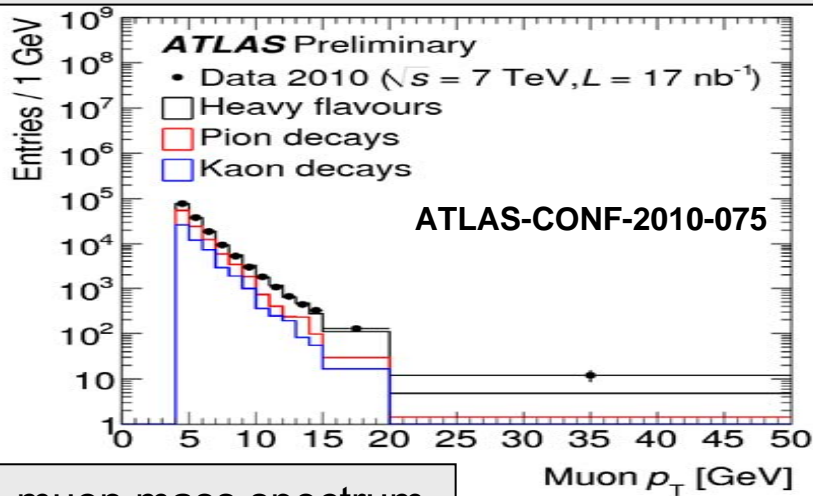
**V.Zhuravlov, H.Kroha**

M.Flowerdew, O.Kortner, I.Potrap,  
J.von Loeben

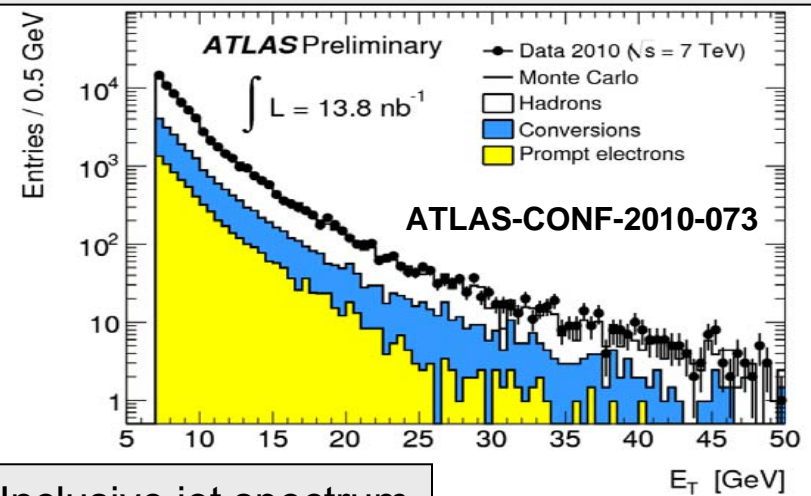
# Standard Model Physics

## Observation of inclusive lepton and jet production

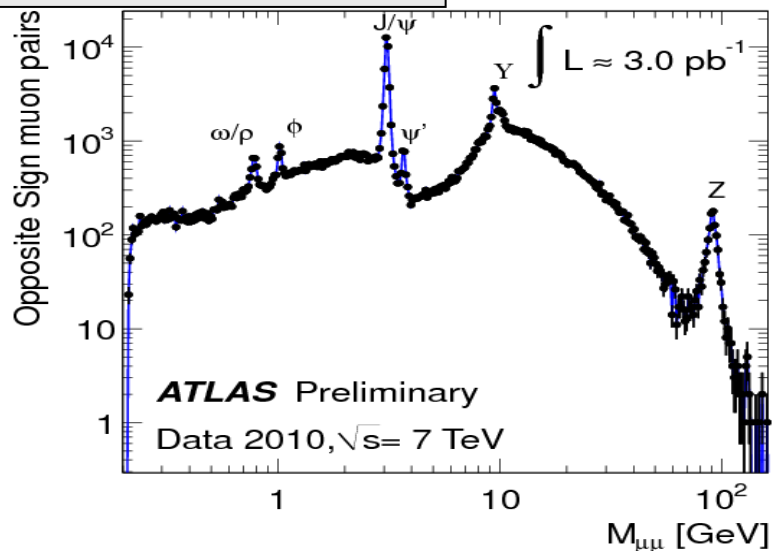
Inclusive muon transverse mom. spectrum



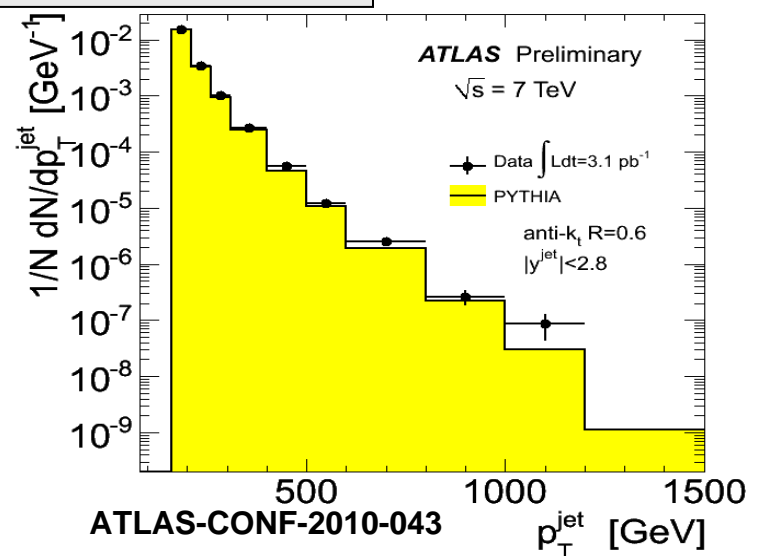
Inclusive electron transverse energy spectrum



Di-muon mass spectrum



Inclusive jet spectrum

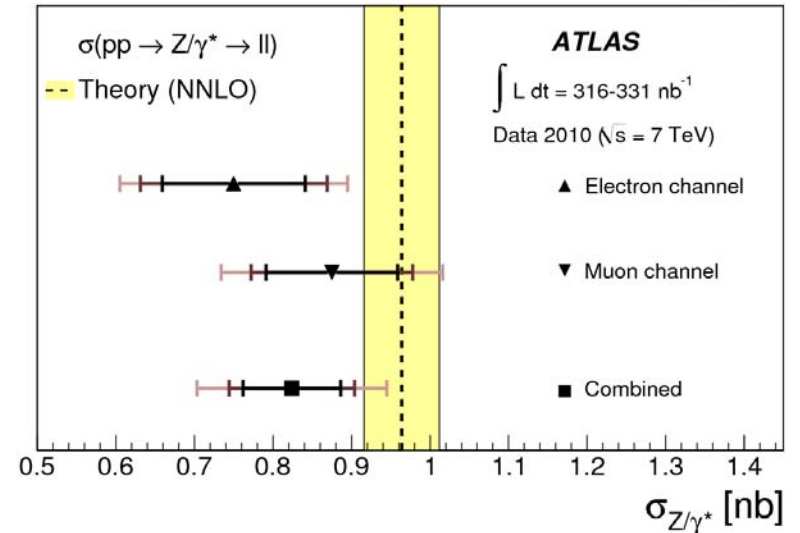
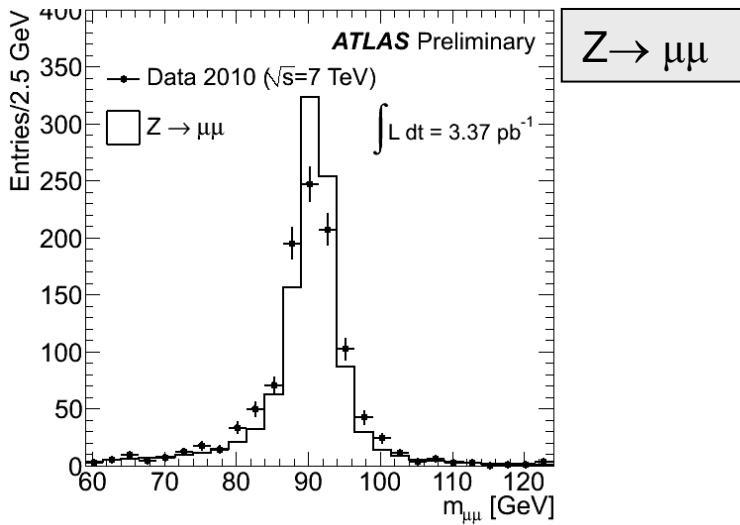
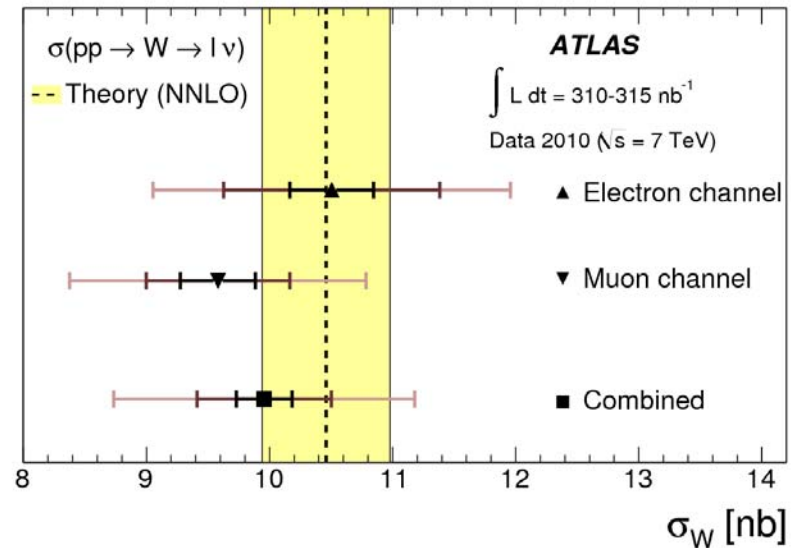
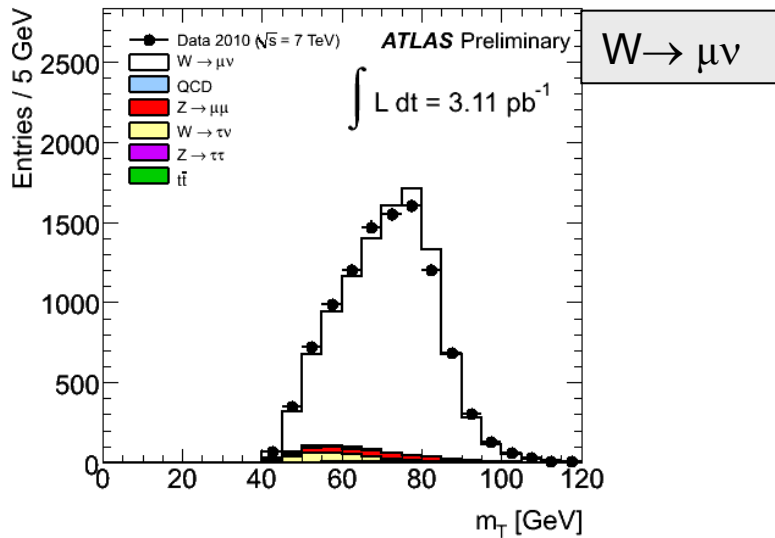




# Standard Model Physics

W/ Z Production Cross section, arXiv:1010.2130 (2010), submitted to JHEP

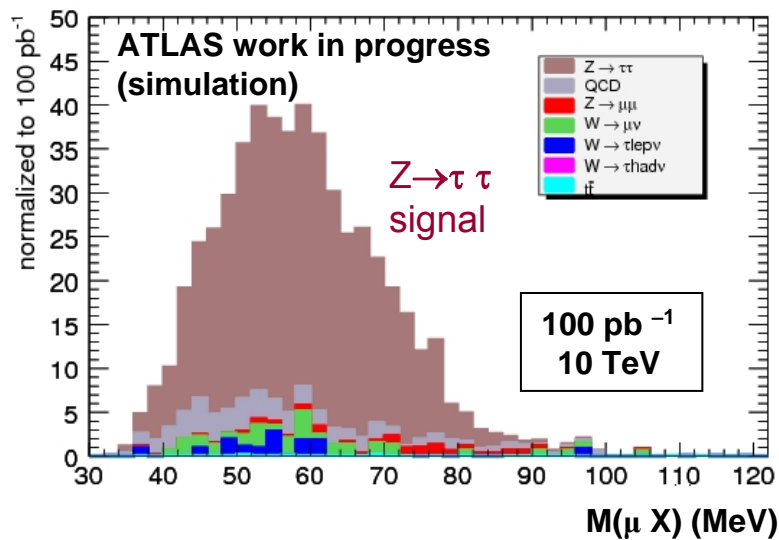
Observation of electroweak gauge boson W and Z production, cross section in good agreement with the prediction



# Standard Model Physics

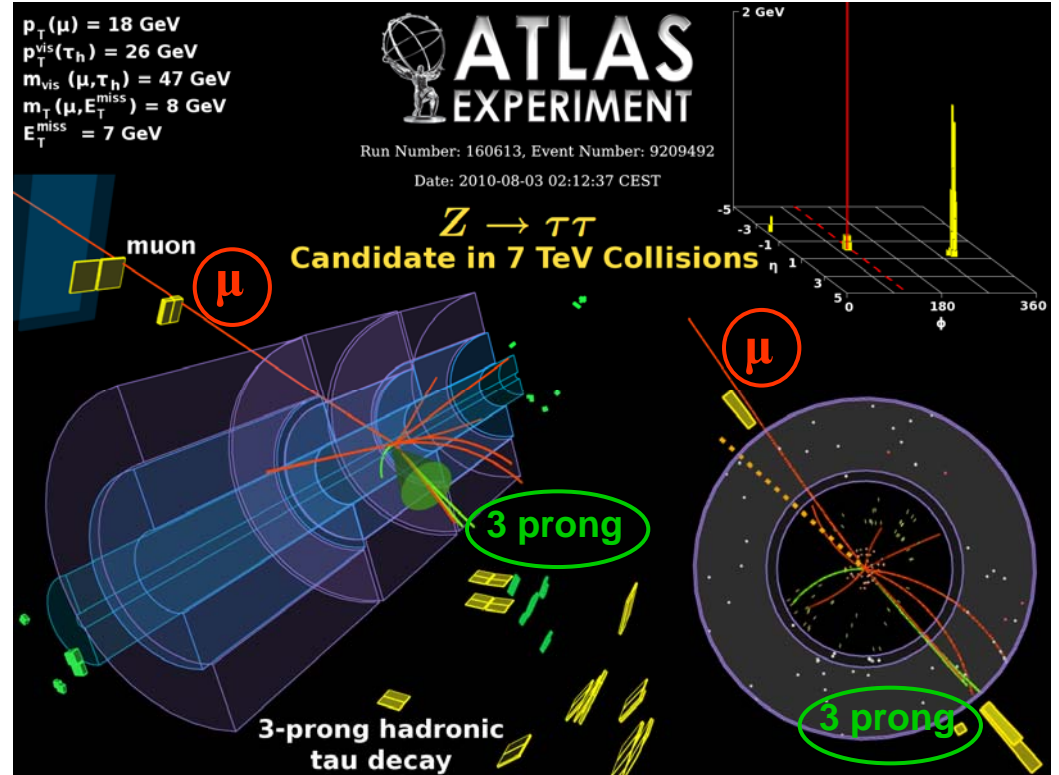
## Search for $Z \rightarrow \tau \tau$ decays

Simulation study of  $Z \rightarrow \tau \tau \rightarrow (\mu \nu \nu) (\text{hadrons } (X) + \nu)$  decays:



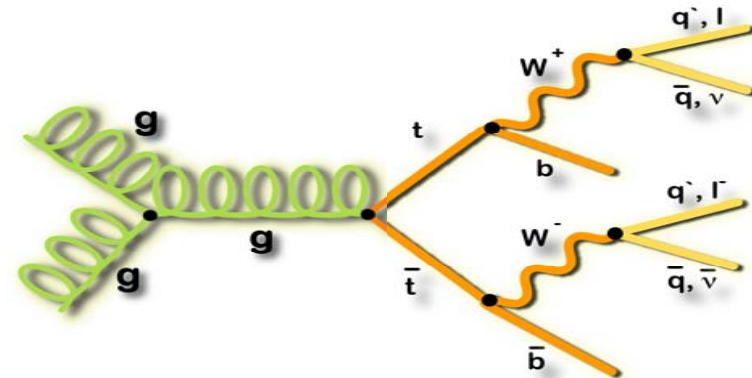
PhD thesis: D.Capriotti

- Standard Model test.
- Validation of  $\tau$  identification for Higgs and SUSY searches.
- Background for Higgs  $\rightarrow \tau \tau$  signals.
- First candidate events.

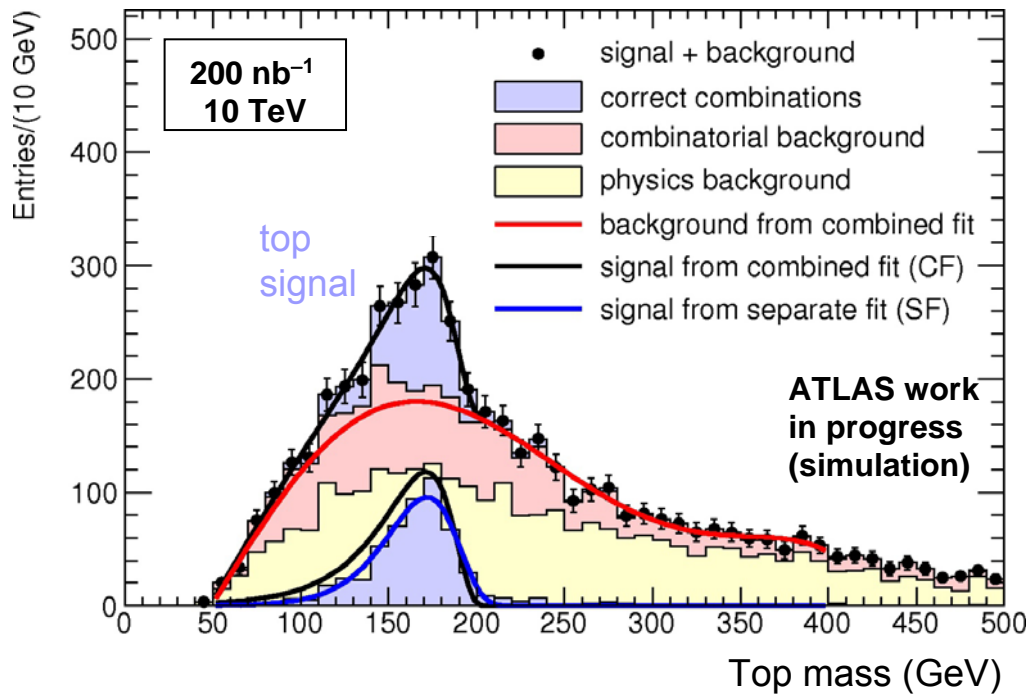


# Top Quark Physics

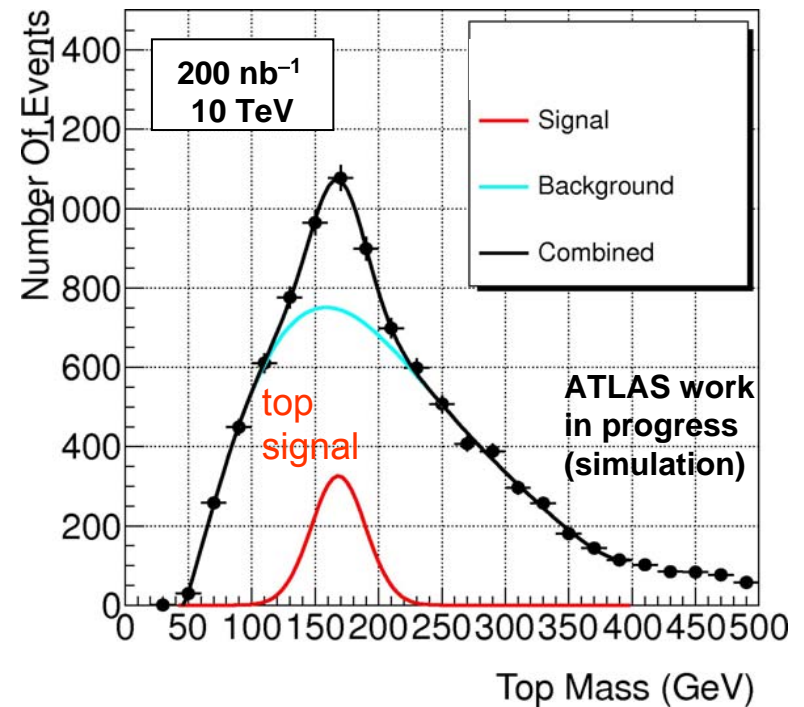
Study of  $t\bar{t}$  event reconstruction in semi-leptonic and fully hadronic final states



One semi-leptonic + one hadronic top decay



Both top decays hadronic



Analysis driven by MPP group

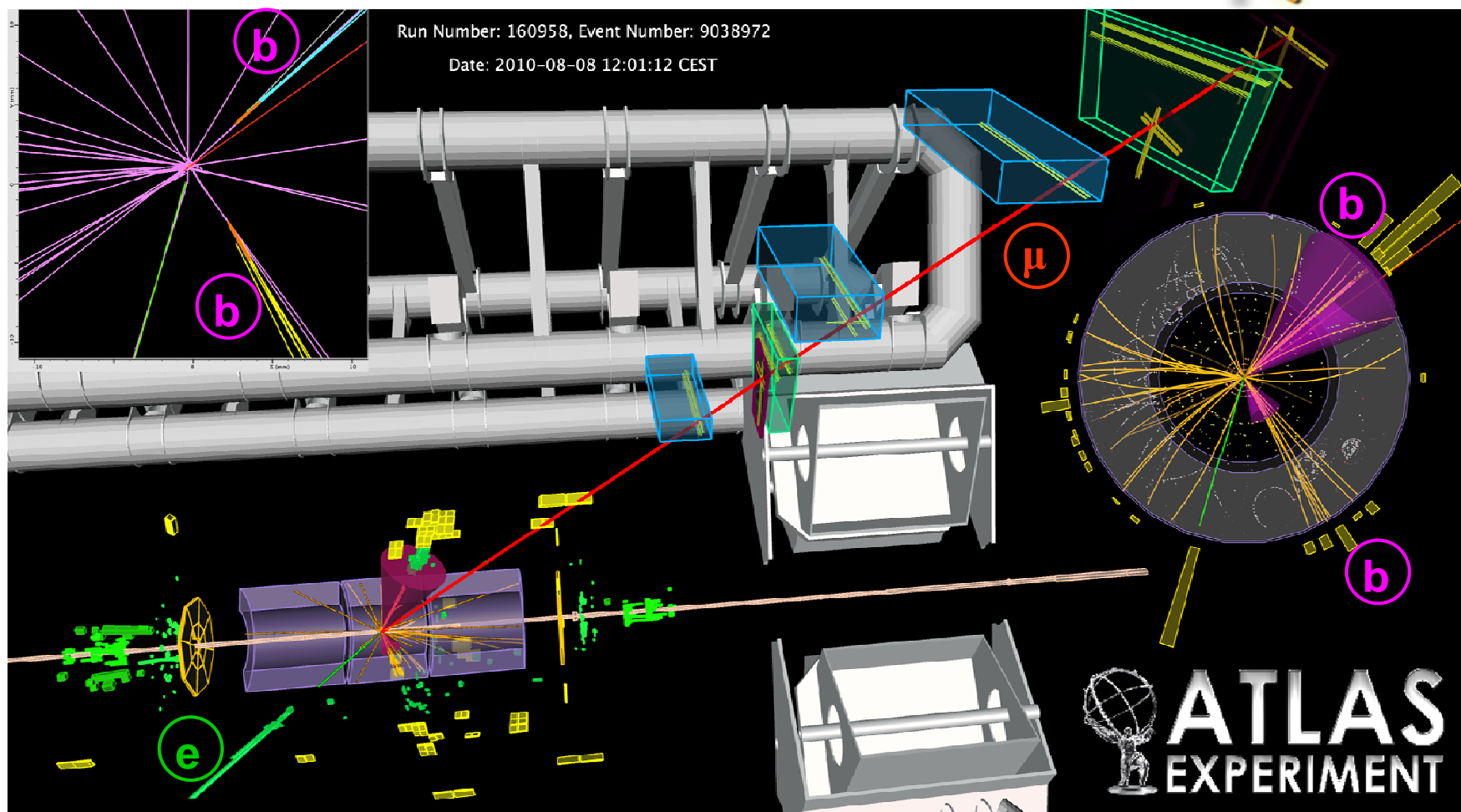
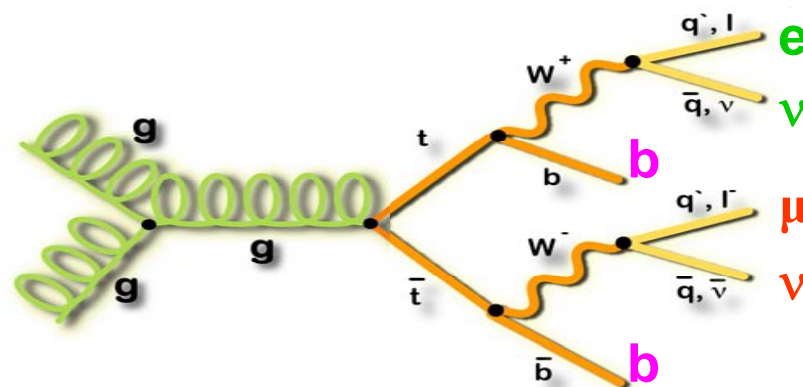
Diploma thesis: Ph.Weigell (2010)

PhD theses: E.Rauter (2009), R.Härtel (2009), T.Goettfert (2010),  
S.Pataraiia (2009), A.Jantsch (2010), P.Giovannini (2011)



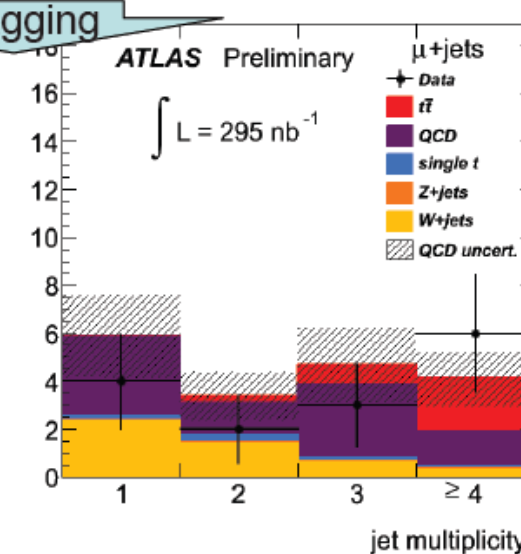
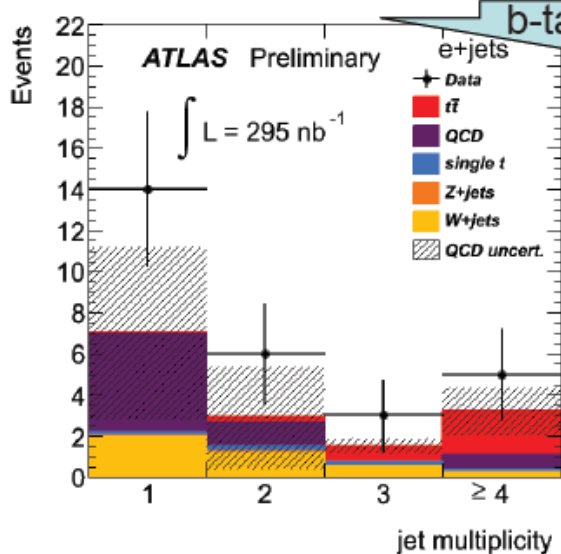
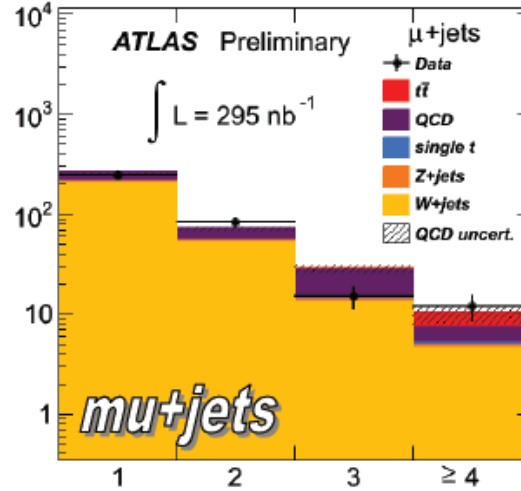
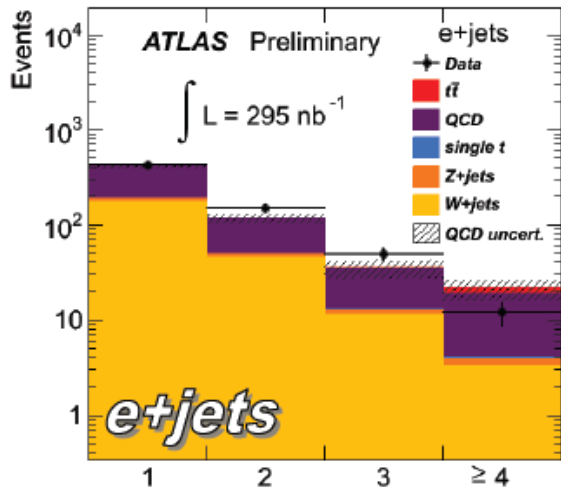
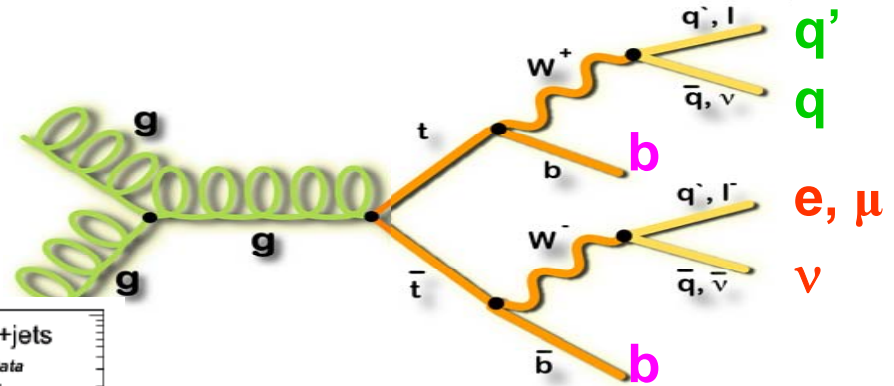
# Top Quark Physics

First top quark pair candidate events end of May



# Top Quark Physics

Search for  $t\bar{t}$  events in lepton + jets final states



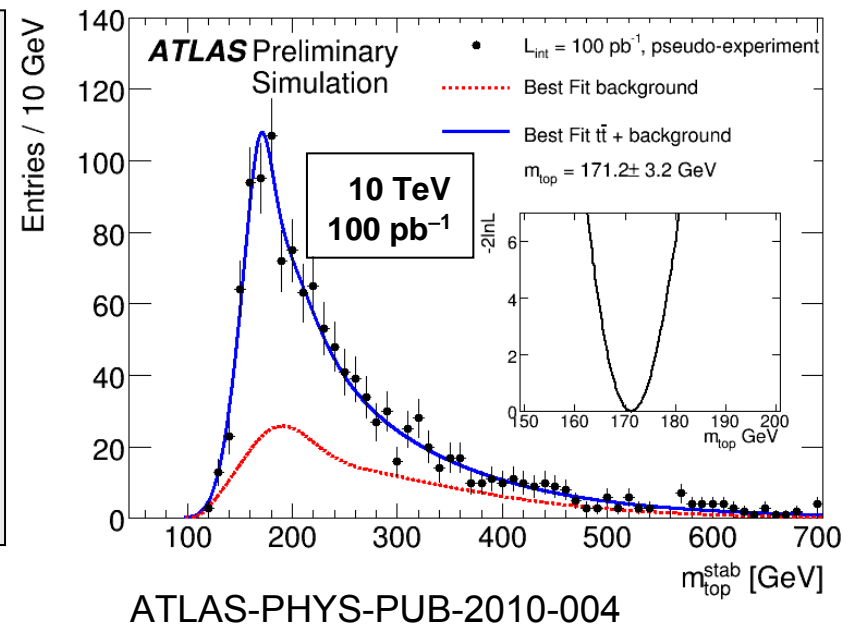
- Good agreement between data and Monte Carlo prediction.
- QCD background estimated from data (meas. of fake lepton rate in multi-jet events).
- **After b-jet tagging:** excess of events with  $\geq 4$  jets starts to show up above the backgrounds.
- **Top quark observation at LHC soon.**

ATLAS-CONF-2010-087

# Top Quark Physics

## Prospects for top mass measurement

- Lepton + jets final states.
- **Top mass reconstruction with template method:** fit to expected event properties depending on the top mass (templates).
- Expected top mass uncertainty at 10 TeV (~50% larger at 7 TeV)
  - with  $100 \text{ pb}^{-1}$ :  $\pm 2.0 \text{ GeV (stat.)} \pm 3.8 \text{ GeV (syst.)}$
  - with  $1 \text{ fb}^{-1}$ :  $\pm 0.6 \text{ GeV (stat.)} \pm 2.0 \text{ GeV (syst.)}$



Giorgio Cortiana:

ATLAS top mass coordinator



# Higgs Boson Searches

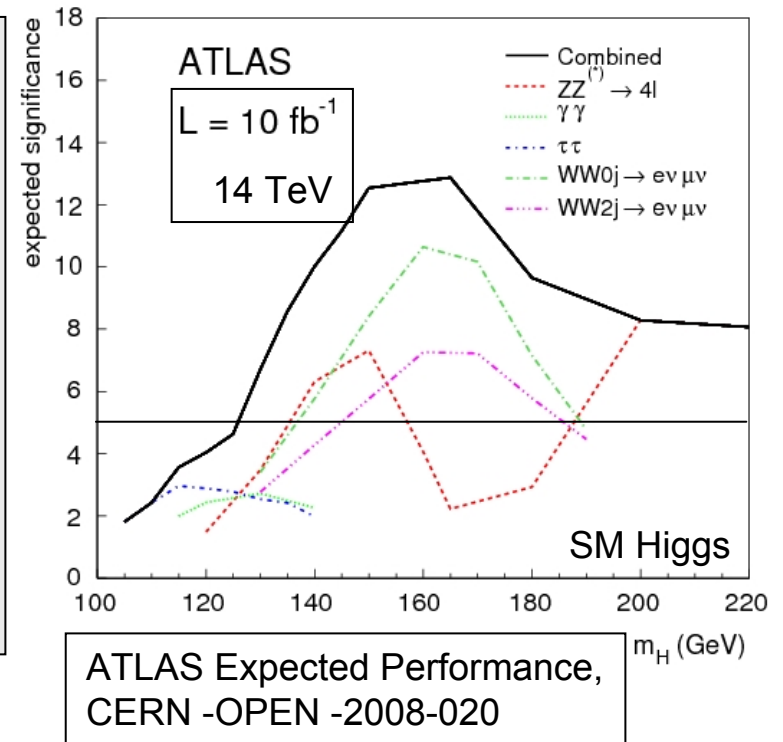
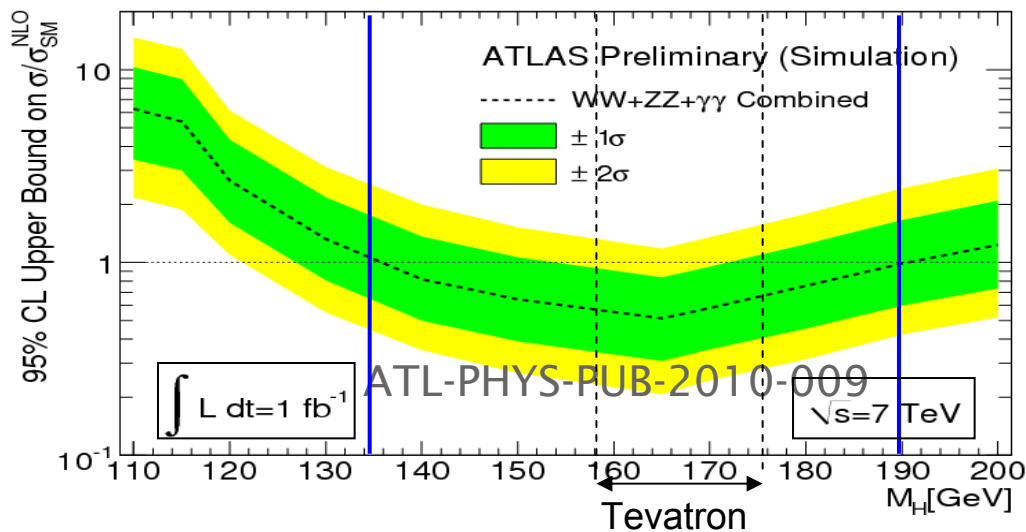
Sensitivity studies for the discovery decay modes in the Standard Model (SM):

- $H \rightarrow WW$  (main focus for 2010/11 data)
- $H \rightarrow ZZ \rightarrow 4 \text{ leptons}$
- $H \rightarrow \tau\tau, bb$

and in the minimal supersymmetric extension (MSSM):

- Neutral Higgs  
 $A/H/h \rightarrow \mu\mu, \tau\tau$  (main focus for 2010/11 data)
- Charged Higgs  $H^\pm \rightarrow \tau\nu$

Expectations for Standard Model Higgs boson at 7 TeV:

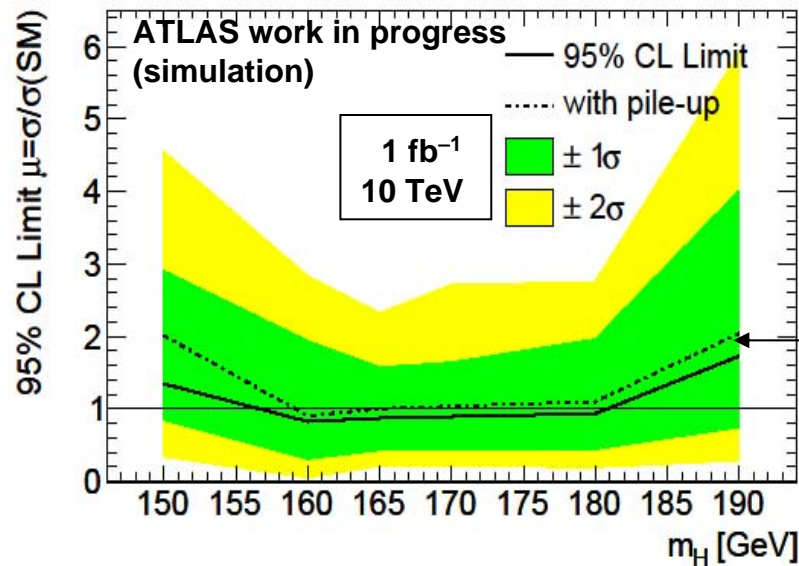


Sandra Kortner:

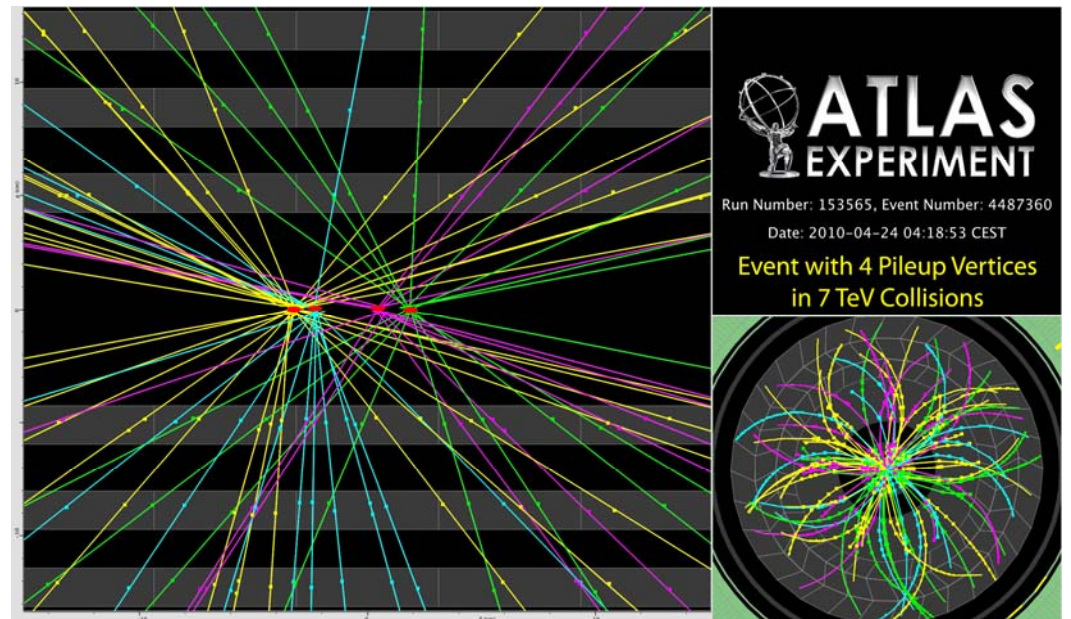
ATLAS Higgs physics coordinator

# SM Higgs Boson Searches

Sensitivity study for  $pp \rightarrow qq H, H \rightarrow WW$  (gauge boson-fusion production)



First study of the effect of multiple (4x) pp interactions (event pile-up)



ATL-PHYS-PUB-2009-056

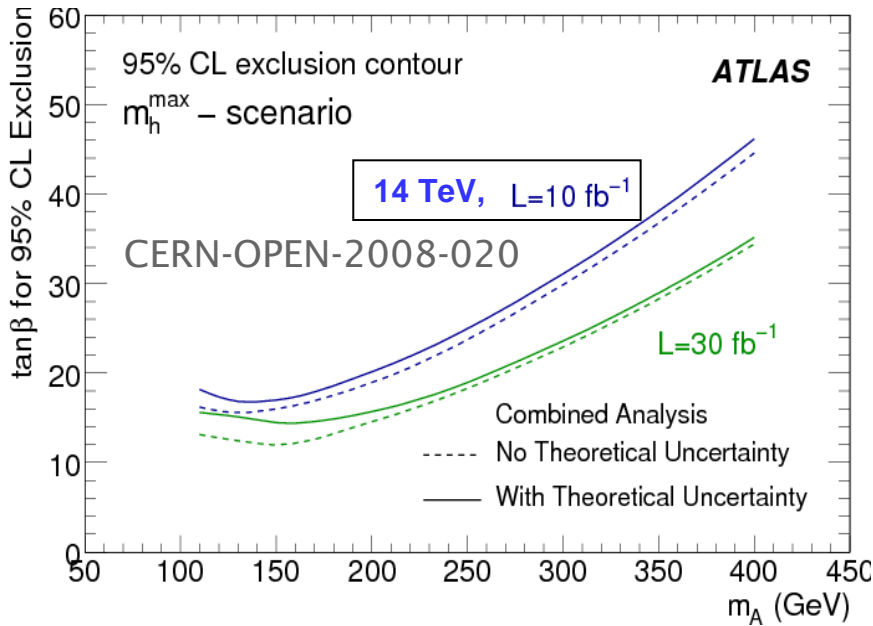
ATL-PHYS-INT-2010-072

PhD thesis: St.Kaiser (2009)

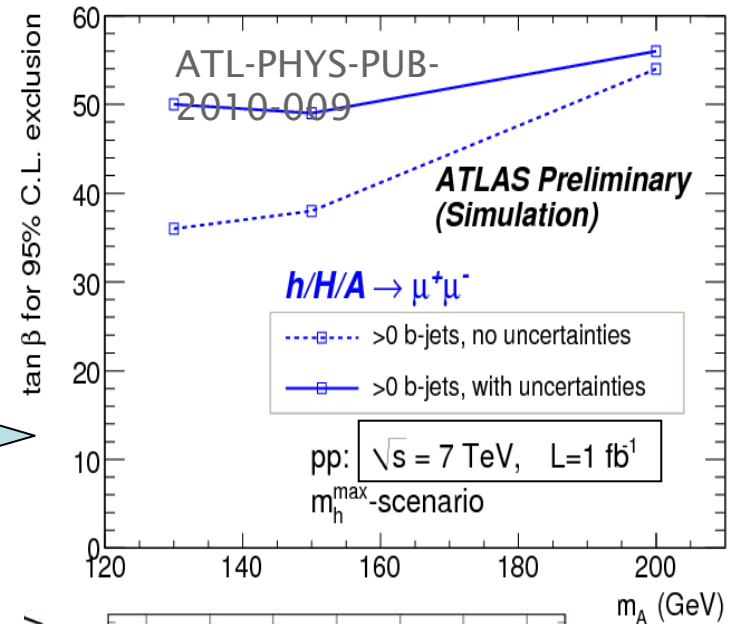
# MSSM Higgs Boson Searches

Sensitivity studies for  $A/H/h \rightarrow \mu\mu$

Analysis driven and coordinated by MPP group



update

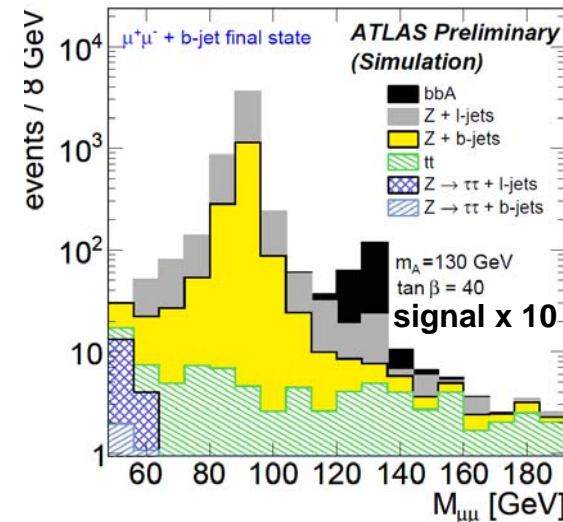


Essential:  
Estimation of  $Z \rightarrow \mu\mu$  and  $t\bar{t}$  background  
from data (di-electron events).

Method developed at MPP

ATL-PHYS-INT-2010-058

Diploma thesis: S.Stern (2009)  
PhD theses: G.Dedes (2008), S.Stern



10 TeV  
1 fb<sup>-1</sup>

# MSSM Higgs Boson Searches

## Sensitivity studies for charged Higgs bosons

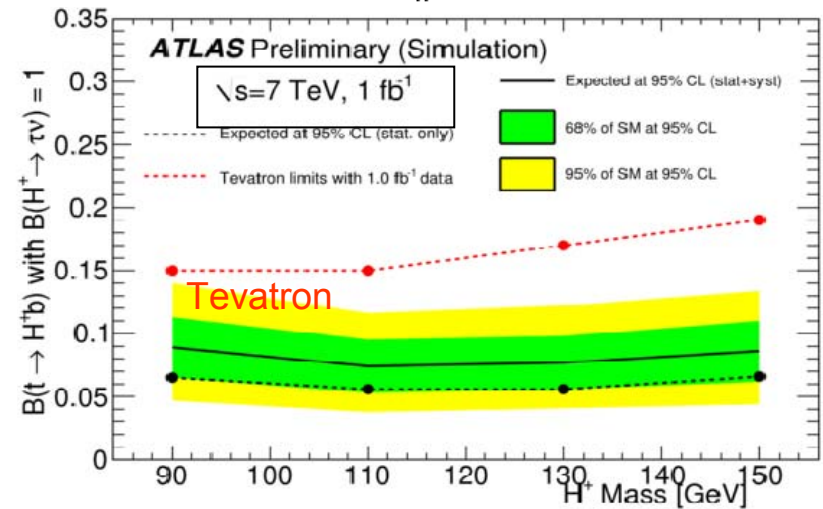
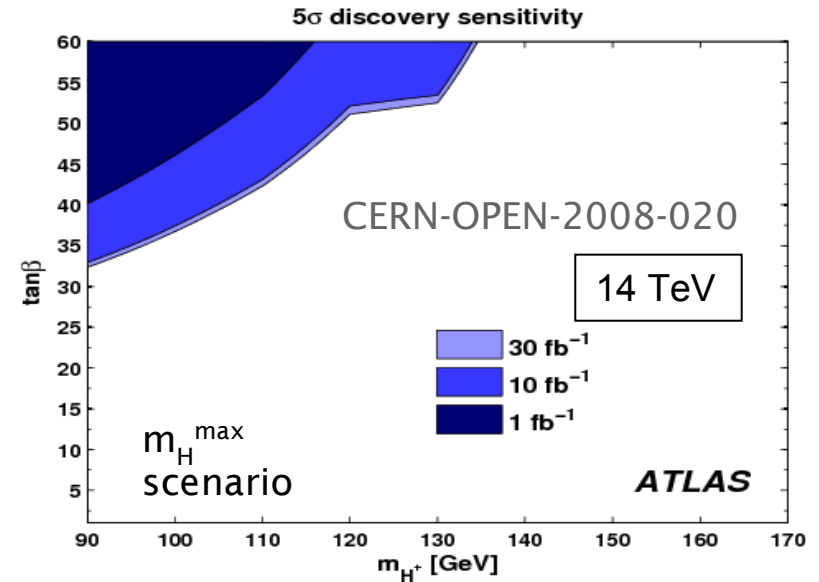
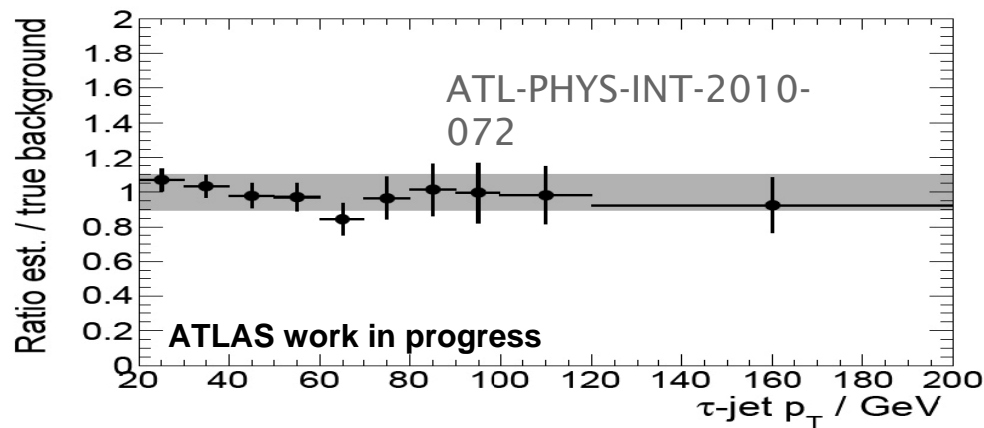
for  $m_H < m_t$ :  
 production in top decays  $t \rightarrow bH^\pm$  with  $H^\pm \rightarrow \tau^\pm \nu$   
 (semilept. decay of 2<sup>nd</sup> top)

Essential:

Estimation of  $t\bar{t}$  background from data:

- Due to **fake  $\tau$  leptons**: from QCD di-jet and Z+jet events.
- Due to **real  $\tau$  leptons**: simulated  $\tau$  decays embedded in reconstructed  $t\bar{t}$  events.

Methods developed at MPP.



ATLAS-PHYS-PUB-2010-009

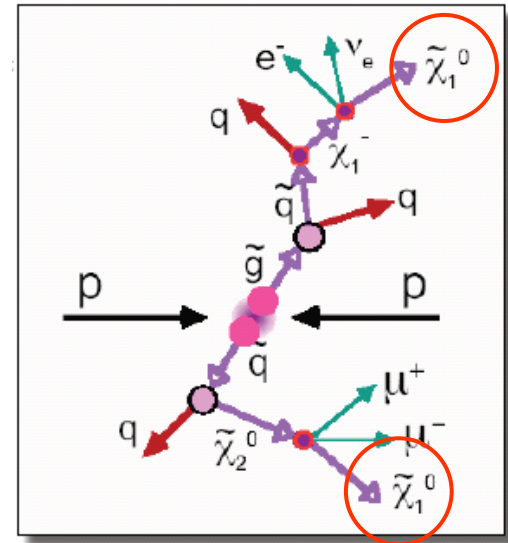
Analysis driven by MPP group

PhD thesis: Th.Ehrich (2010)

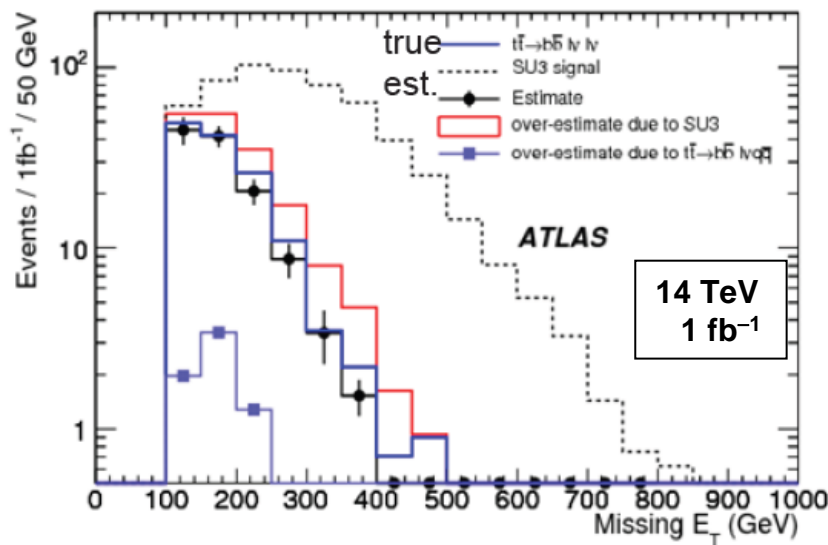


# Searches for Supersymmetric Particles

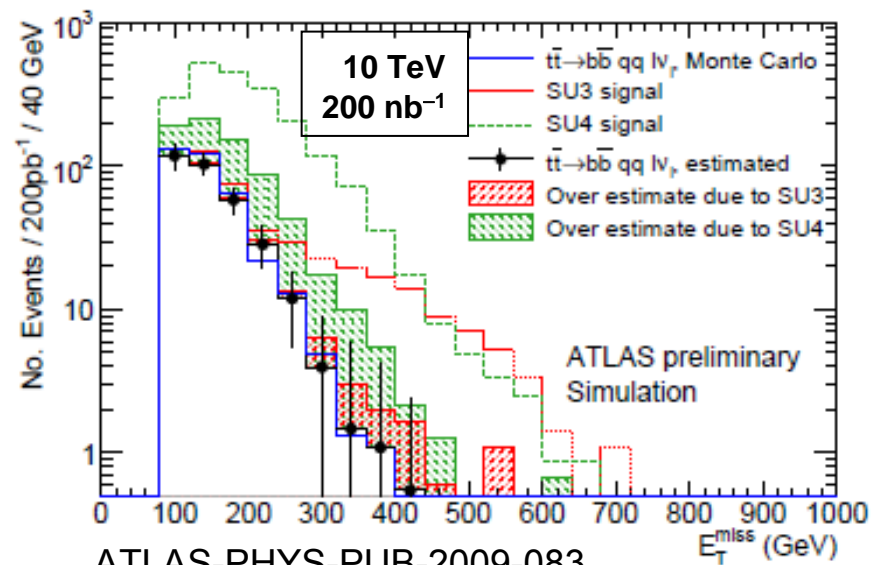
- Emphasis on inclusive searches with early data.  
Signatures: multiple jets, leptons and missing energy  $E_T^{\text{miss}}$  (due to escaping lightest SUSY particles  $\tilde{\chi}_1^0$ ).
- Estimation of Standard Model  $t\bar{t}$ , W and Z background from data control samples (generalized “side bands”) essential.
- Several methods developed at MPP.



Example: Searches requiring 1 lepton in the event



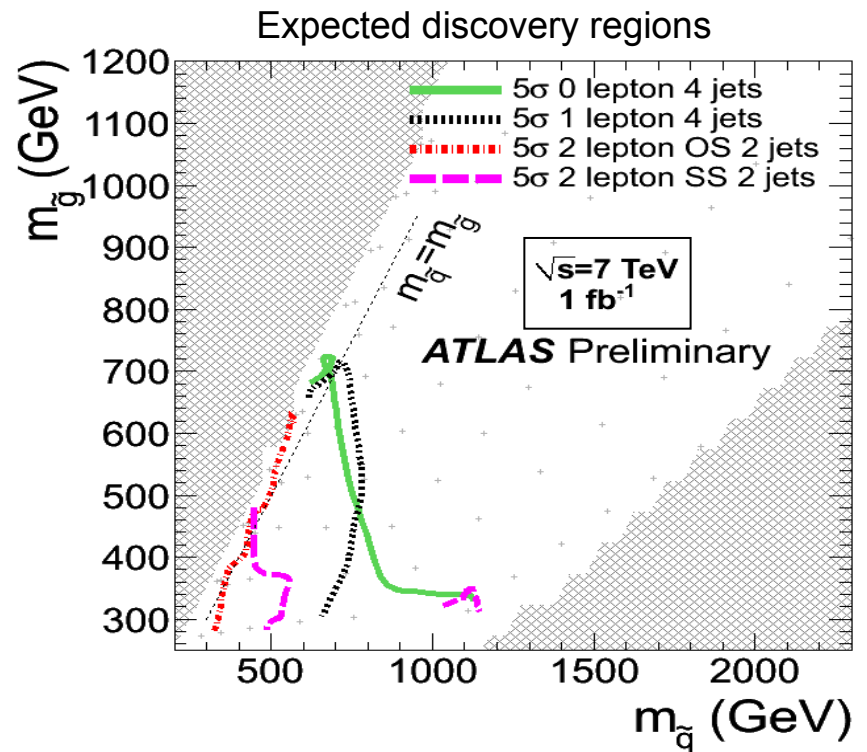
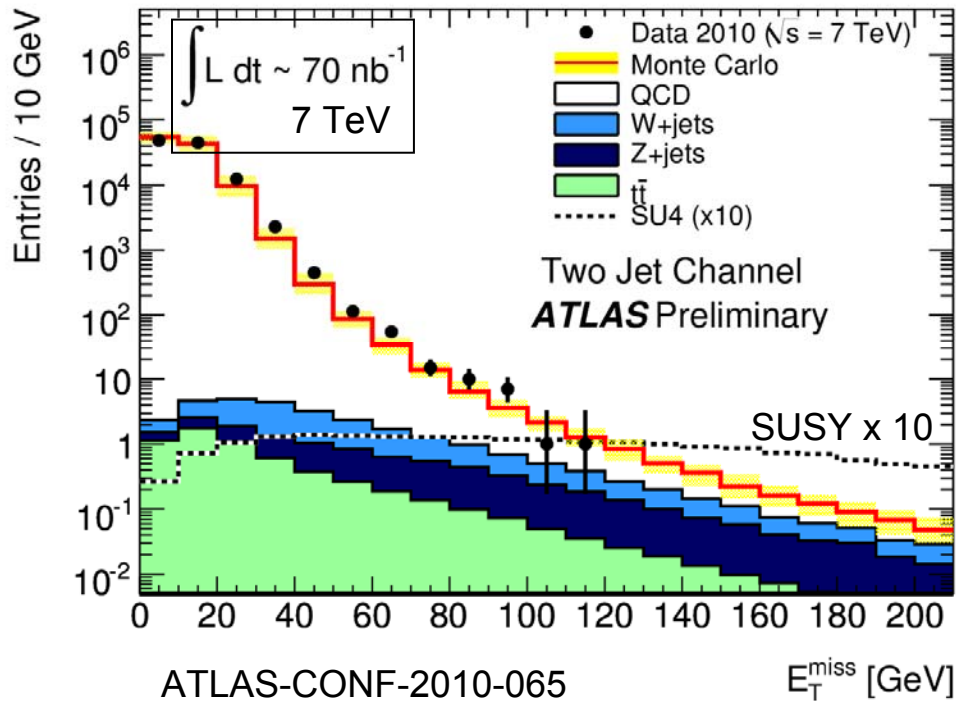
CERN-OPEN-2008-020



ATLAS-PHYS-PUB-2009-083

# Searches for Supersymmetric Particles

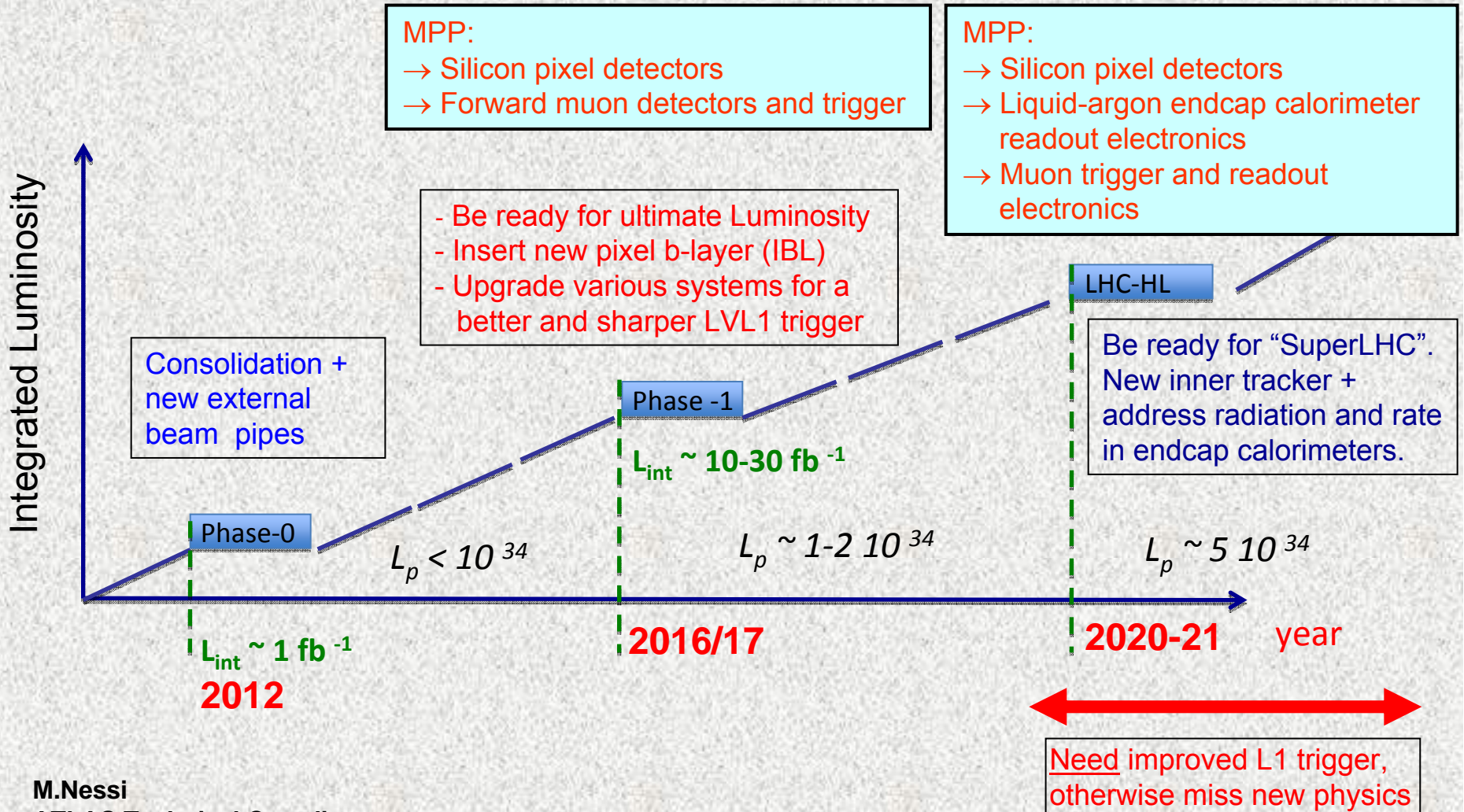
- So far the Standard Model predictions match the data well.
- With  $1 \text{ fb}^{-1}$  at 7 TeV, squarks and gluinos with masses up to  $\sim 700 \text{ GeV}$  can be discovered.



ATLAS-PHYS-PUB-2010-010

# ATLAS Upgrade Program

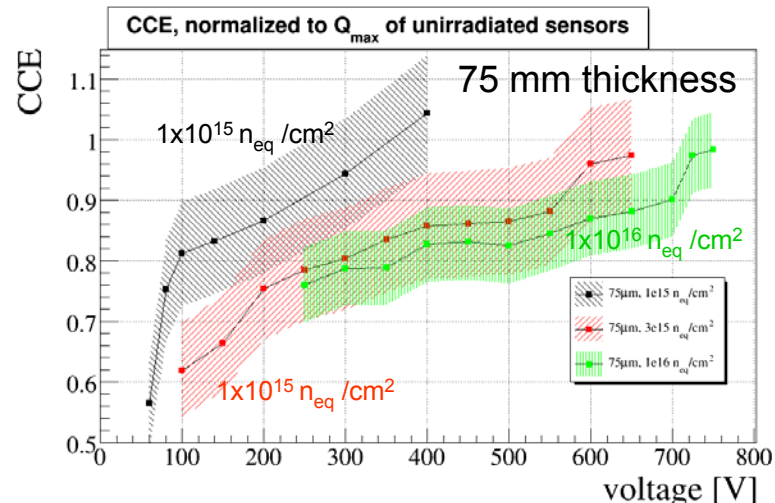
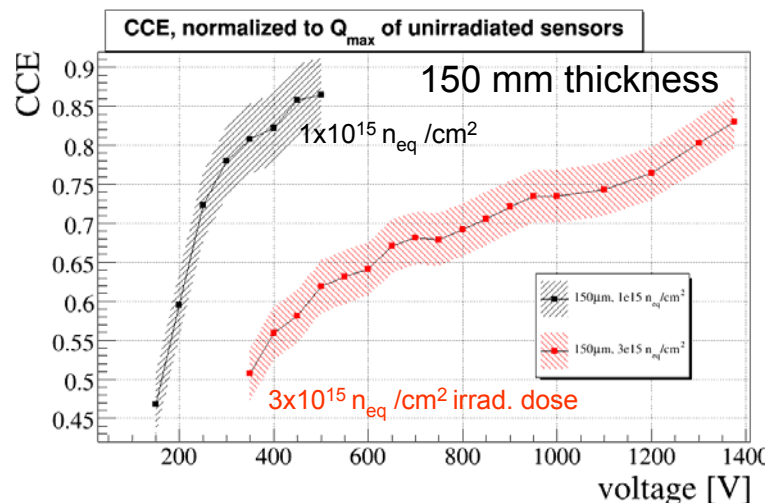
## LHC Upgrade/Shutdown Schedule



M.Nessi  
 ATLAS Technical Coordinator

# Silicon Pixel Detector Development

- Silicon sensors for the ATLAS pixel vertex detector designed at the MPP/MPE Semiconductor Lab (HLL).
- Silicon sensor thinning technology developed at the HLL: reduction of scattering material in the silicon pixel tracking detector.
- n-in-p pixel sensors with 75  $\mu\text{m}$  and 150  $\mu\text{m}$  thickness produced and tested.
- Charge collection efficiency (CCE) after high irradiation doses is higher for thinner sensors due to higher intrinsic electric field.
- 150  $\mu\text{m}$  thick sensors produced for qualification for new pixel detector layer (IBL) to be installed in 2016/17 shutdown. **Decision on sensor technology end of 2011.**
- Contribution to **2016/17 pixel detector upgrade** depending on technology choice.

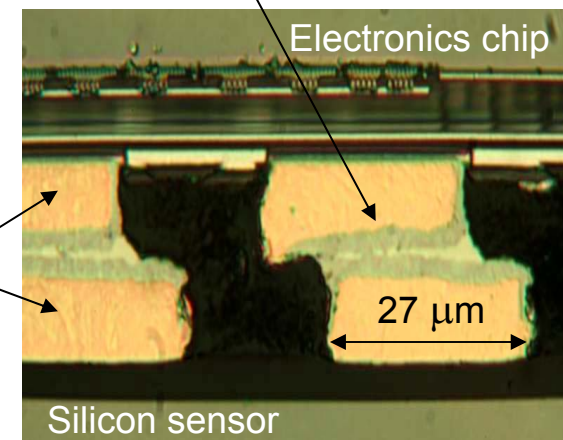
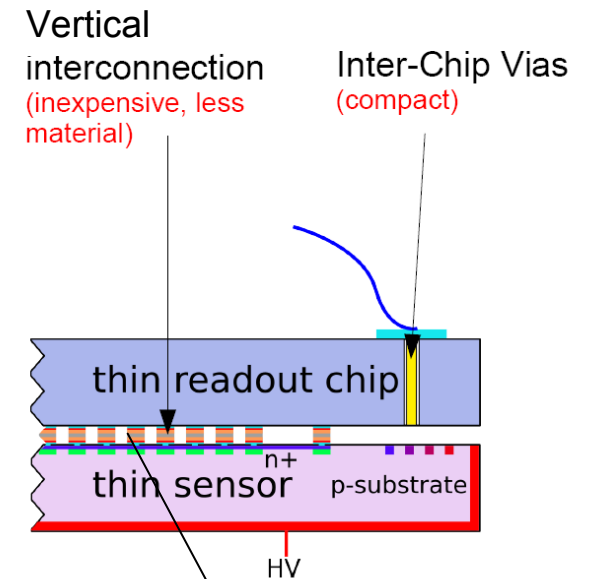


PhD theses: M.Beimforde (2010), Ph.Weigell



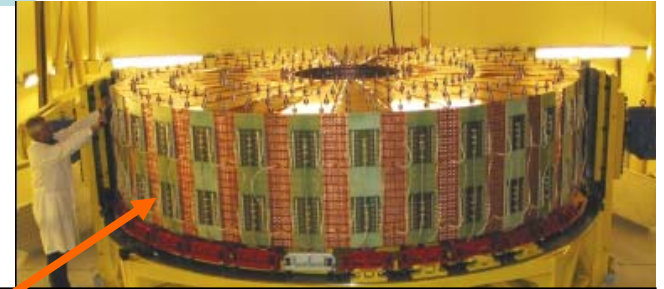
# Silicon Pixel Detector Development

- Long-term project for “vertical” integration of pixel sensors and readout electronics.
- Industry driven process.  
International HEP collaboration, H.-G.Moser (HLL) convenor.
- Possibly more robust alternative to bump-bonding.
- Potential for higher granularity, reduced inactive sensor area, less scattering material.
- Test with thin pixel sensors (HLL) and ATLAS pixel readout electronics in progress with Fraunhofer Institute EMFT.
- Development of pixel sensor modules for new ATLAS silicon tracker planned for 2020/21 shutdown.

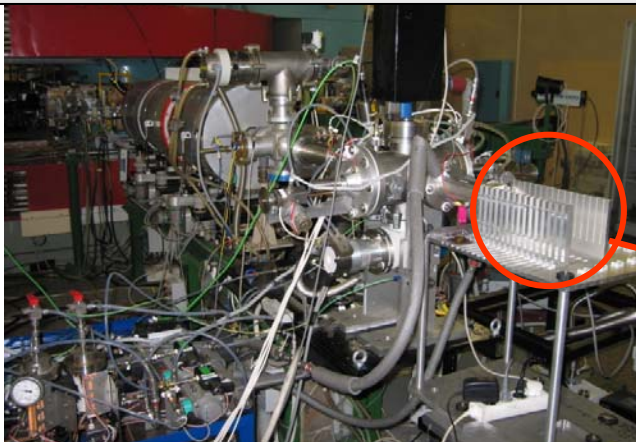


PhD theses: M.Beimforde (2010), Ph.Weigell

# Hadron Endcap Calorimeter Electronics

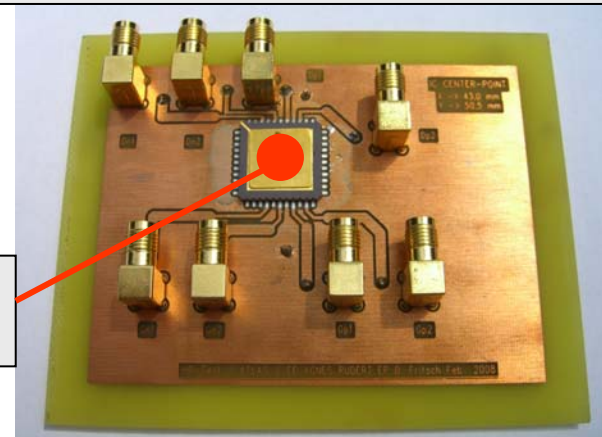


- “Cold” Hadron Endcap Calorimeter electronics (preamplifiers), operated in the liquid argon, developed and produced at MPP.
- Radiation tolerance corresponding to 10 years of LHC operation with safety factor of 10.
- Operation at SuperLHC luminosity may nevertheless require replacement of cold electronics in 2020/21 shutdown depending on radiation levels observed in ATLAS until end of 2011.
- Development of new radiation hard readout chips (only) at MPP.
- Radiation tolerance of preamplifier structures produced in modern chip technologies by different foundries very good. Tests and simulation of behavior at liquid argon temperature ongoing.



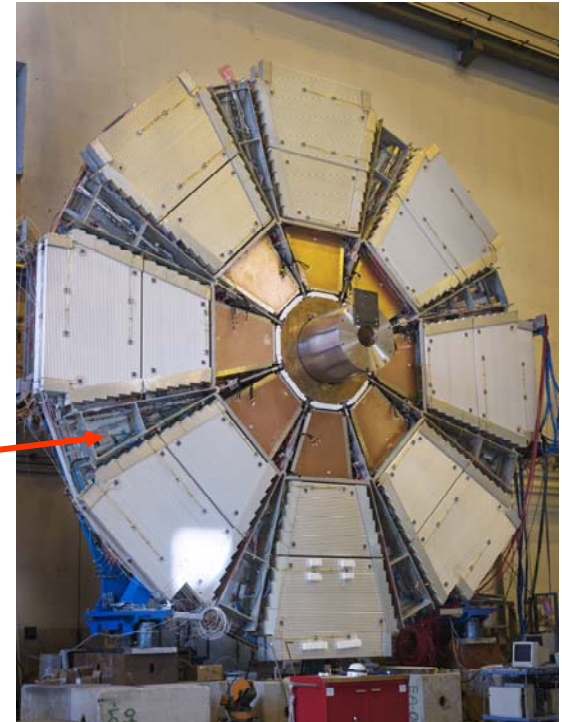
Irradiation test setup near Prague

Irradiated samples



# Muon Drift-Tube Detectors for High Irradiation Rates

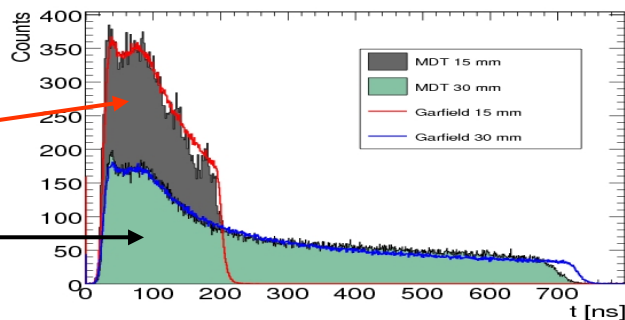
- ATLAS muon chambers have to cope with high counting rates **up to 200 kHz/ tube** in the forward detector regions due to neutron and  $\gamma$  radiation induced by the proton collisions.
- Counting rates may **increase by up to factor of 5** at SuperLHC luminosities with drift-tube occupancies reaching 100%.
- High-rate behavior of the chambers studied by the MPP group.
- Upgrade proposal of the forward muon spectrometer for high LHC luminosities by the MPP group: replacement of the inner endcap layers **in the 2016/17 shutdown**.
- Technical Design Report and chamber technology decision **end of 2011. Jörg Dubbert Technical Coordinator**.



- Fast muon drift-tube detectors with **half the tube diameter** developed at MPP which can cope with increased irradiation rates **with 7 x smaller occupancy**.



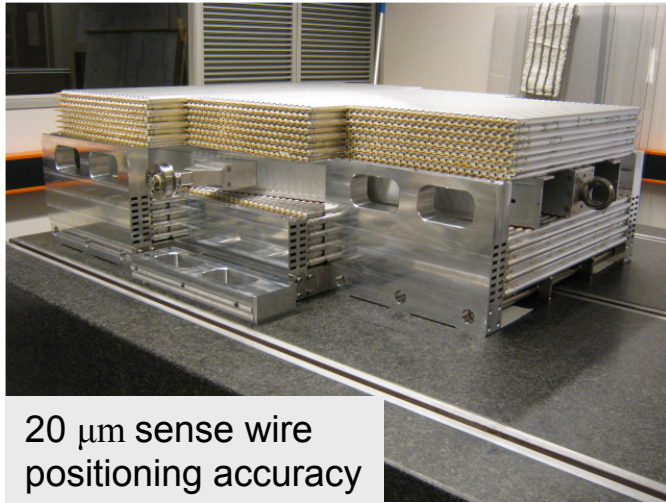
3.5 x shorter drift-time spectrum of **15 mm  $\varnothing$  tubes** compared to present 30 mm  $\varnothing$  tubes



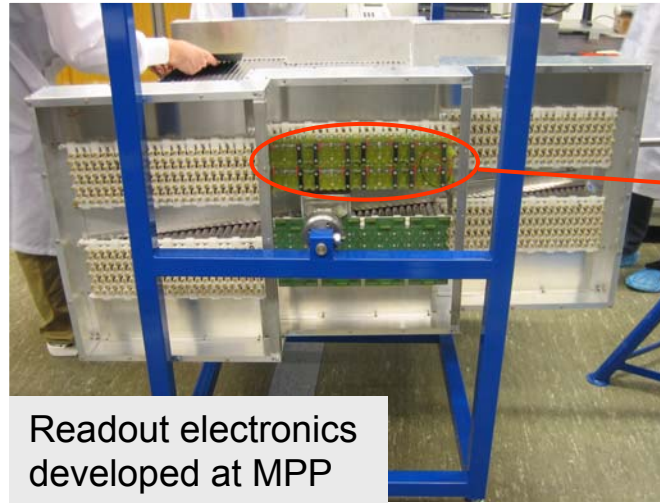


# Muon Drift-Tube Detectors for High Irradiation Rates

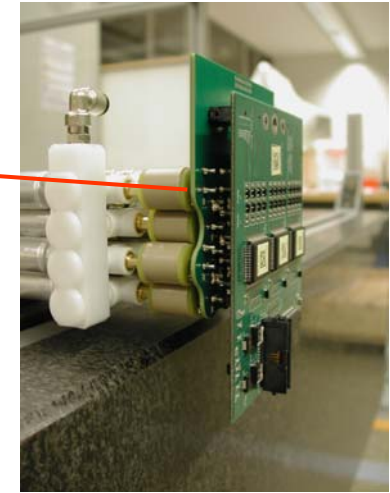
Construction of a full-scale prototype chamber 2010



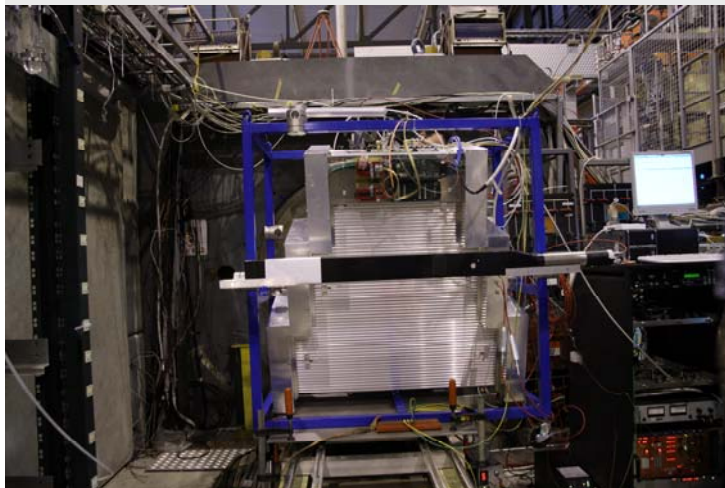
20  $\mu\text{m}$  sense wire positioning accuracy



Readout electronics developed at MPP



Operation in testbeam and Gamma Irradiation Facility at CERN



Design ready for construction of chambers to fill acceptance gaps in barrel muon spectrometer in **2012 shutdown**.

Most advanced detector development, including new readout electronics, for **2016/17 inner endcap layer upgrade**.

**Major contribution and further leadership of MPP group expected.**

Diploma theses: Ph.Schwegler (2010), M.Kilgenstein (2010)  
PhD thesis: B.Bittner



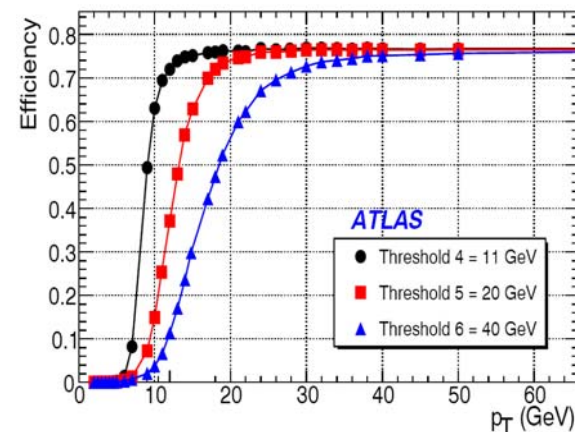
# Muon Trigger Upgrade Development

- Upgrade of level-1 muon trigger mandatory for SuperLHC operation of ATLAS: **sharpening of the threshold as function of transverse momentum.**
- Concept developed by MPP group making use of the **high spatial resolution of the muon drift-tube chambers.**
- To be integrated into new radiation hard muon detector readout electronics for
  - **2016/17 endcap muon spectrometer upgrade** and
  - replacement of the barrel muon detector readout electronics **in 2020/21 shutdown.**
- Test board under development at MPP.
- New radiation hard readout chip designed at MPP** in IBM 130 nm CMOS technology supported by CERN shows excellent performance.

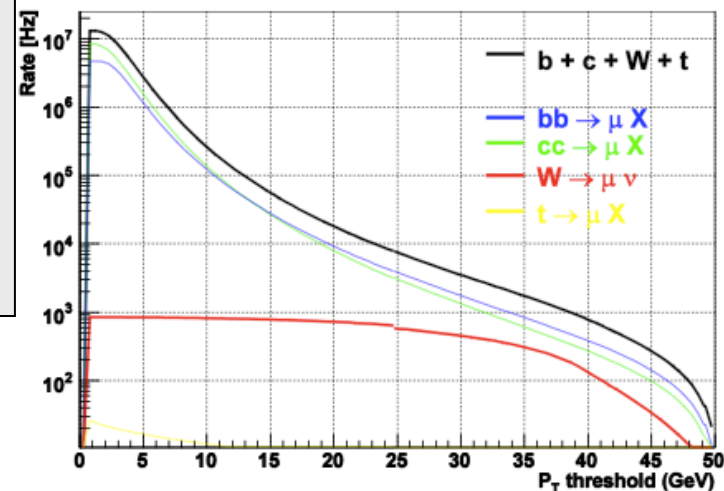
Independent Research Group  
of Sandra Kortner



ATLAS muon trigger efficiency



Muon rate at SuperLHC  
( $L = 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ )



## Summary

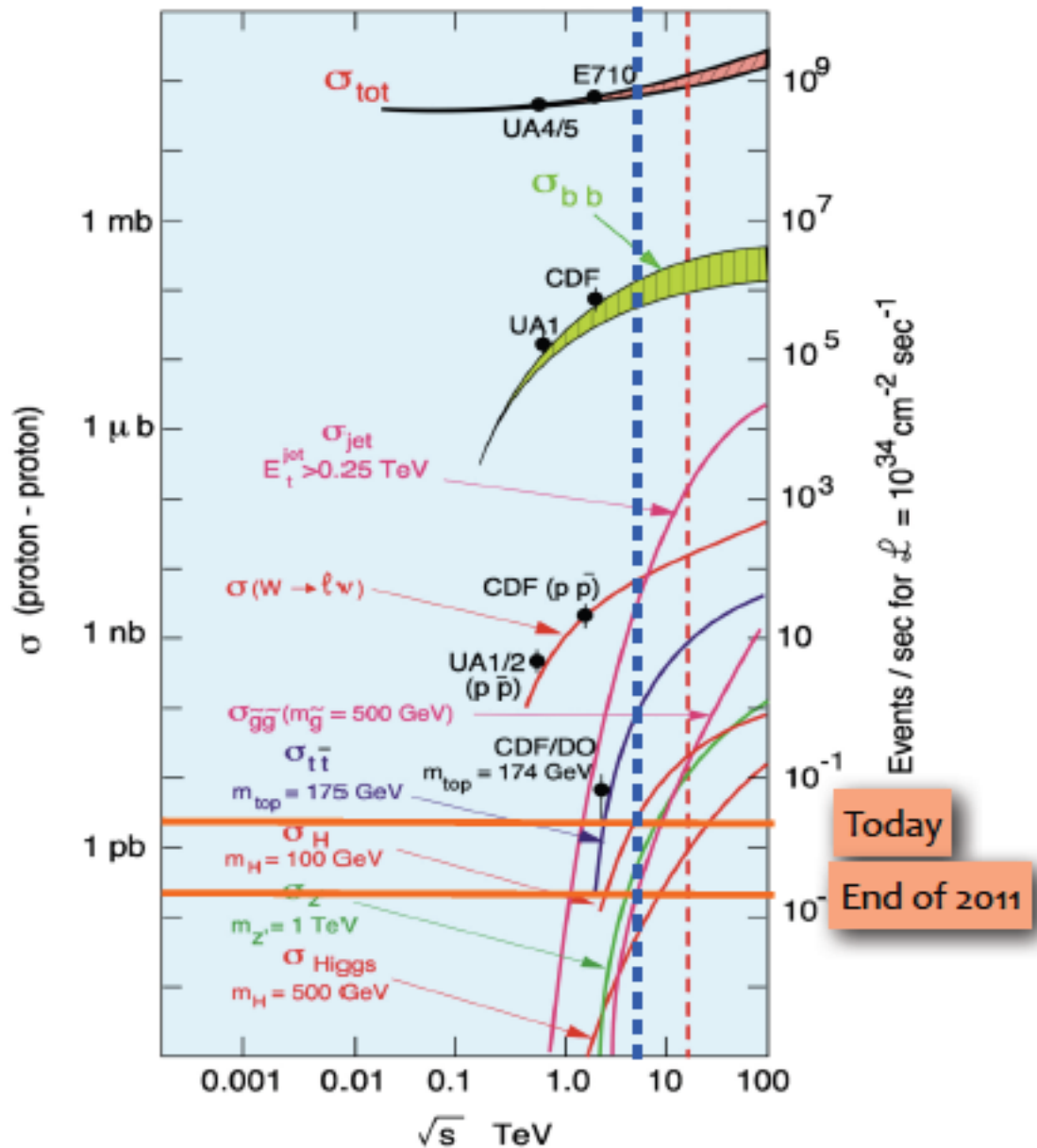
- Major contributions of MPP to construction, commissioning and operation of the ATLAS experiment.
- Successful transition from construction to data analysis era:  
MPP contributions to
  - 2 of 6 submitted/ published ATLAS collision data papers
  - 4 of 7 ATLAS pre-data taking papers
  - 17 of 96 collision data conference papers

34 ATLAS talks in 2007-2010, 14 about physics results  
(2.6% of all talks for 1% of authors, 2<sup>nd</sup> best talks/authors ratio in ATLAS)
- Physics program covers the main questions to be answered at the LHC.
- Major contributions to detector upgrades expected from us. Very successful and advanced R&D work, often only possible with the expertise and resources available at MPP.
- Important to continue the support of the MPG for the operation of the ATLAS experiment is continued.

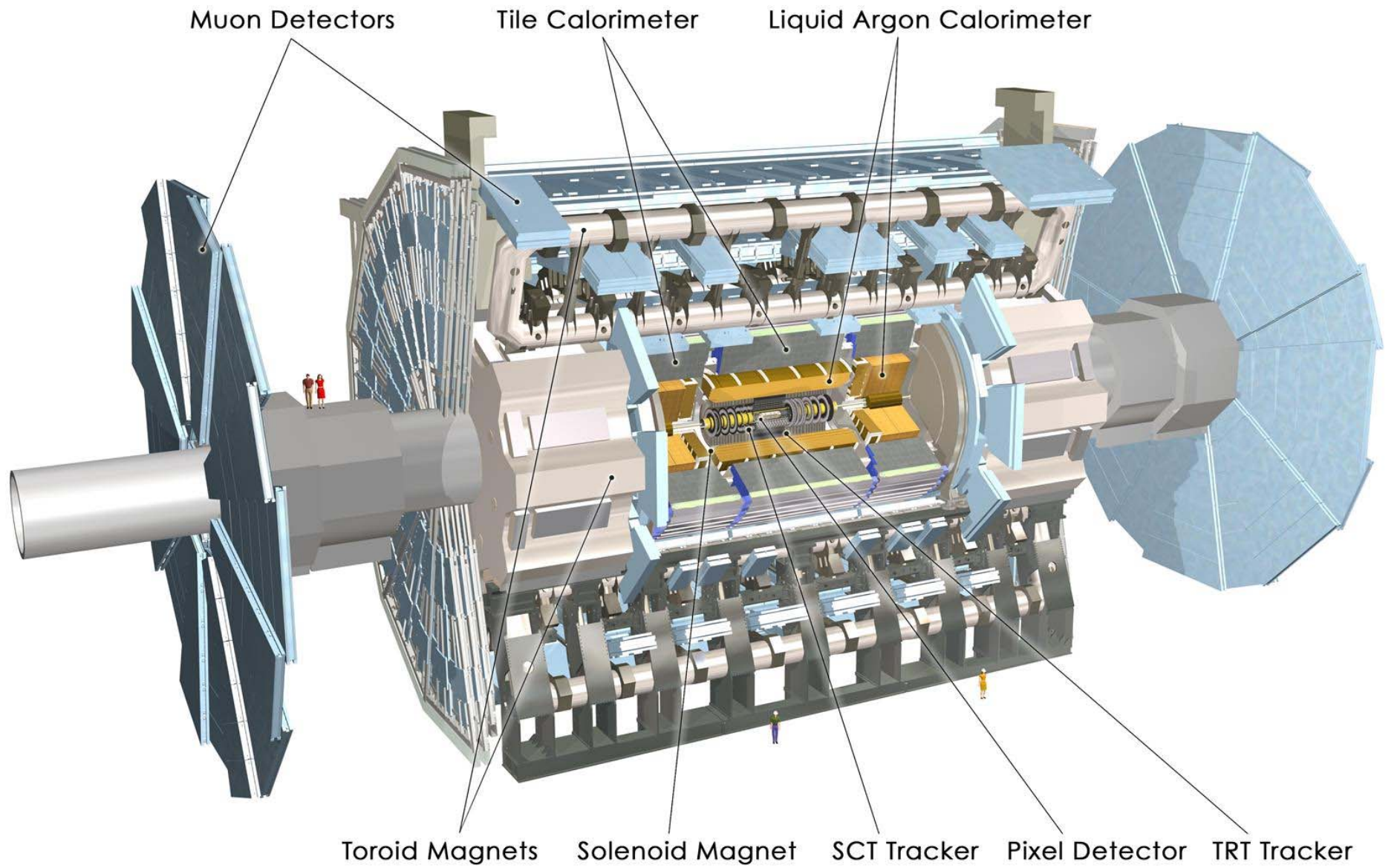
# Backup

Rates for  $L=10^{32} \text{ cm}^2\text{s}^{-1}$  @ 7 TeV

inelastic pp collision	$10^7 \text{ Hz}$
b-quark pair production	$10^4 \text{ Hz}$
jet production, $E_T > 250 \text{ GeV}$	$1 \text{ Hz}$
$W \rightarrow l\nu$	$1 \text{ Hz}$
t-quark pair production	$10^{-2} \text{ Hz}$
$Z'$ ( $m_{Z'} = 1 \text{ TeV}$ )	$10^{-4} \text{ Hz}$
Higgs ( $m_H = 500 \text{ GeV}$ )	$10^{-5} \text{ Hz}$





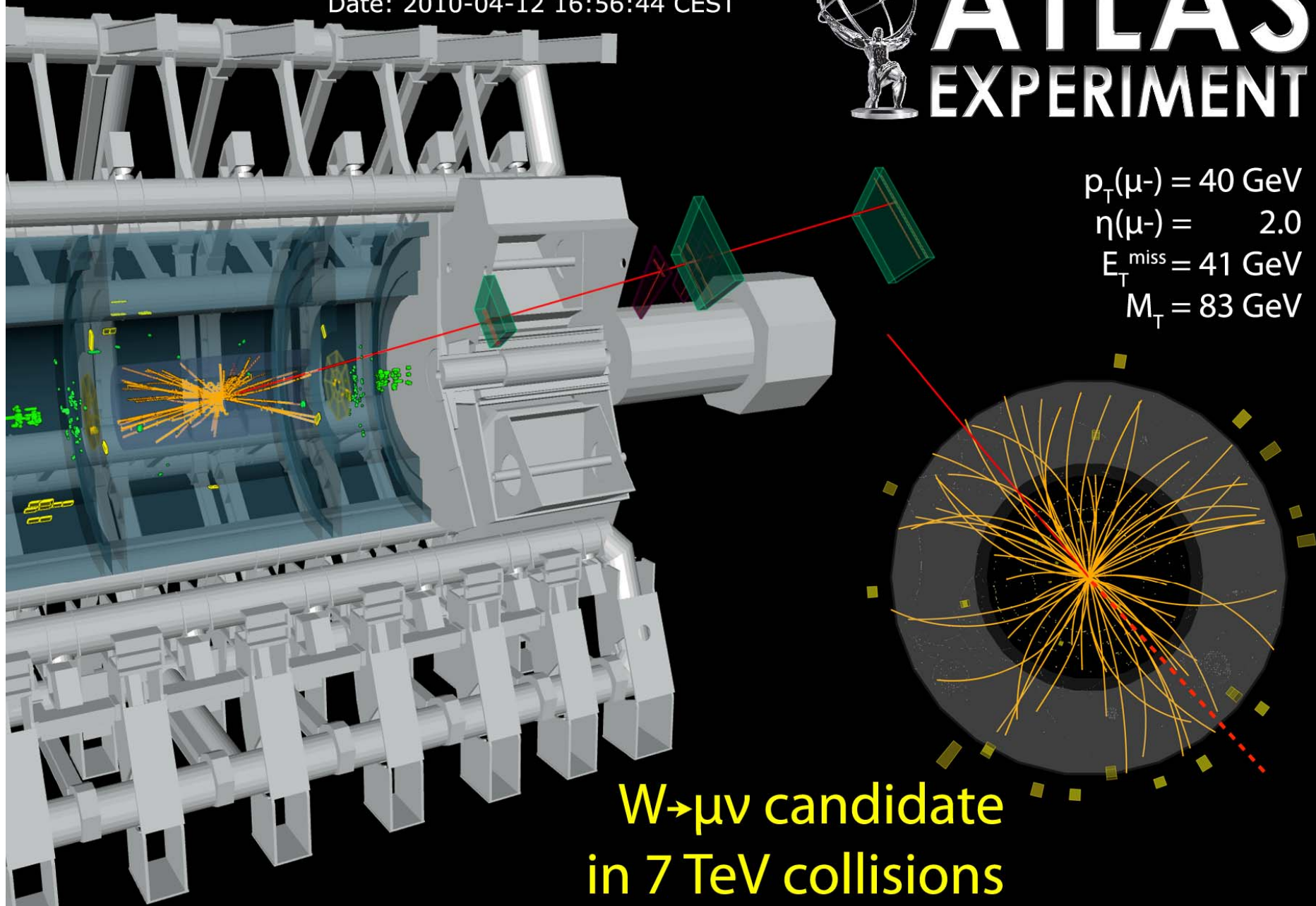


Run: 152845, Event: 3338173  
Date: 2010-04-12 16:56:44 CEST



# ATLAS EXPERIMENT

$p_T(\mu^-) = 40 \text{ GeV}$   
 $\eta(\mu^-) = 2.0$   
 $E_T^{\text{miss}} = 41 \text{ GeV}$   
 $M_T = 83 \text{ GeV}$



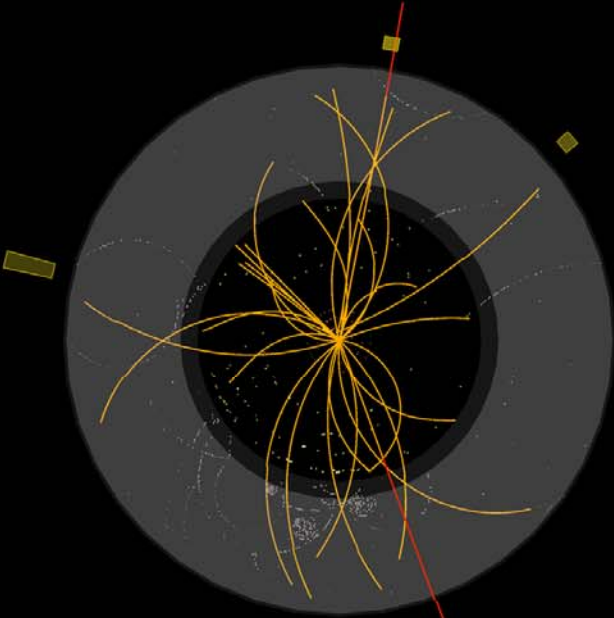
**$W \rightarrow \mu\nu$  candidate  
in 7 TeV collisions**



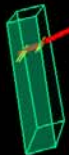


# ATLAS EXPERIMENT

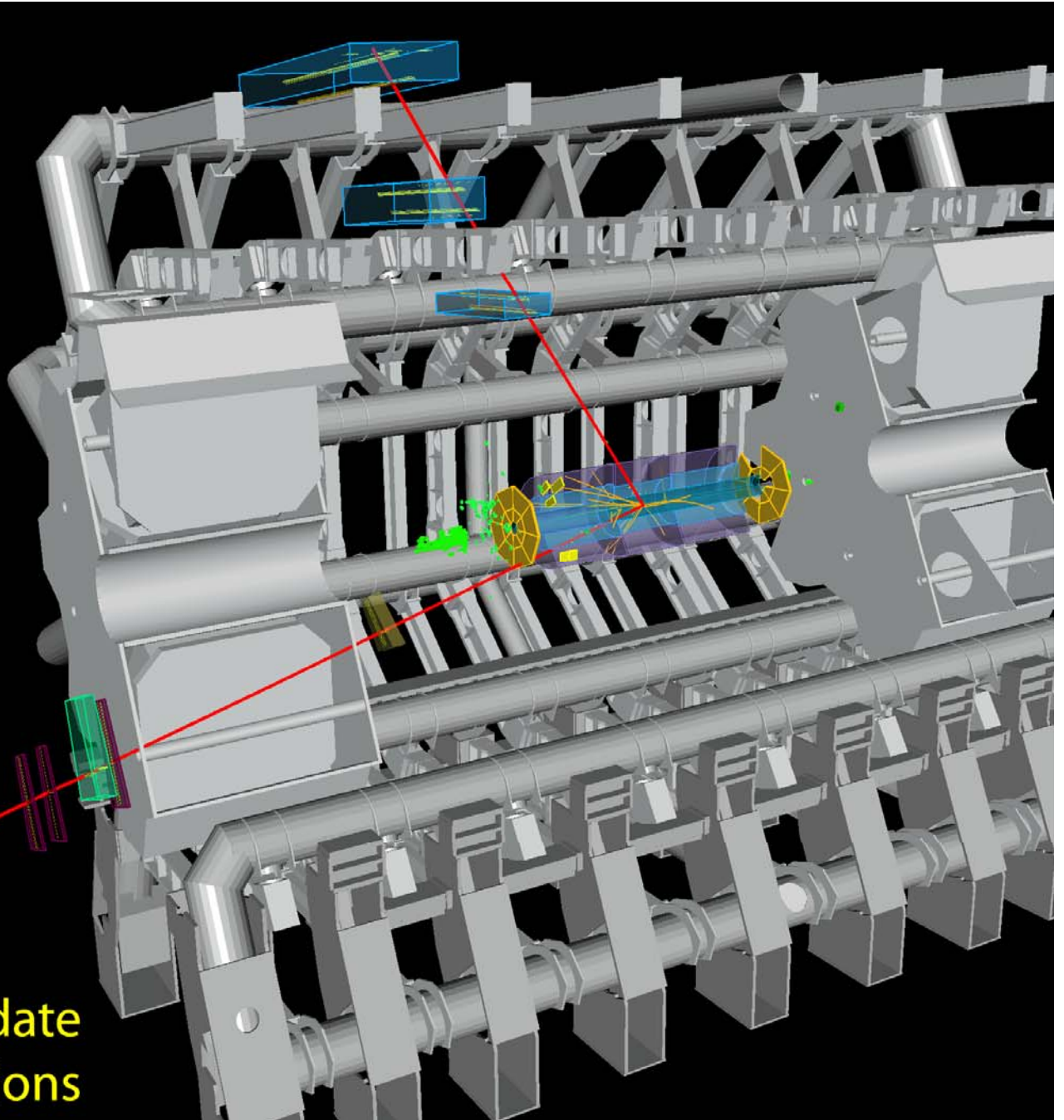
Run: 154822, Event: 14321500  
Date: 2010-05-10 02:07:22 CEST



$p_T(\mu^-) = 27 \text{ GeV}$   $\eta(\mu^-) = 0.7$   
 $p_T(\mu^+) = 45 \text{ GeV}$   $\eta(\mu^+) = 2.2$   
 $M_{\mu\mu} = 87 \text{ GeV}$



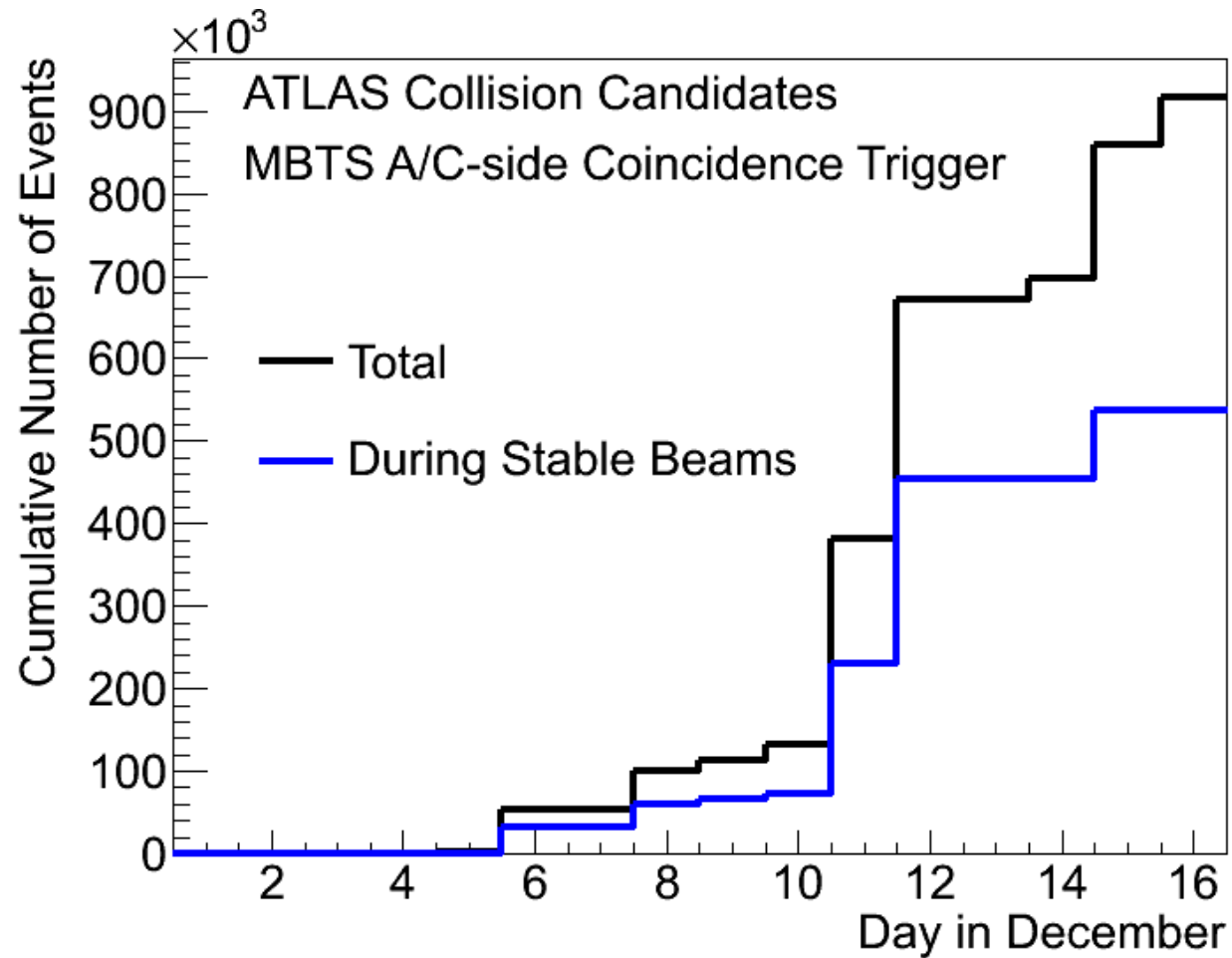
**Z $\rightarrow\mu\mu$  candidate  
in 7 TeV collisions**



Luminosity 2009 at 0.9 TeV:

Peak:  $7 \times 10^{26} \text{ cm}^{-2} \text{ s}^{-1}$

Integrated:  $12 \mu\text{b}^{-1}$



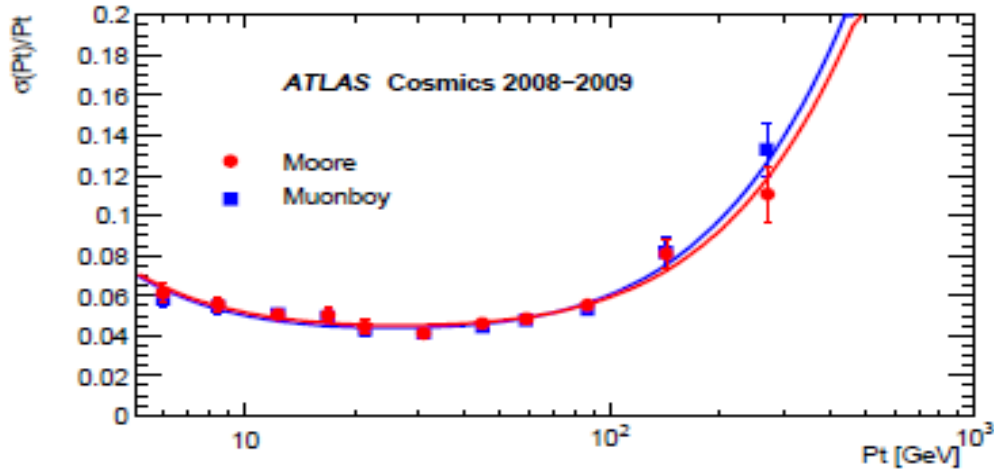


# Muon Reconstruction Performance

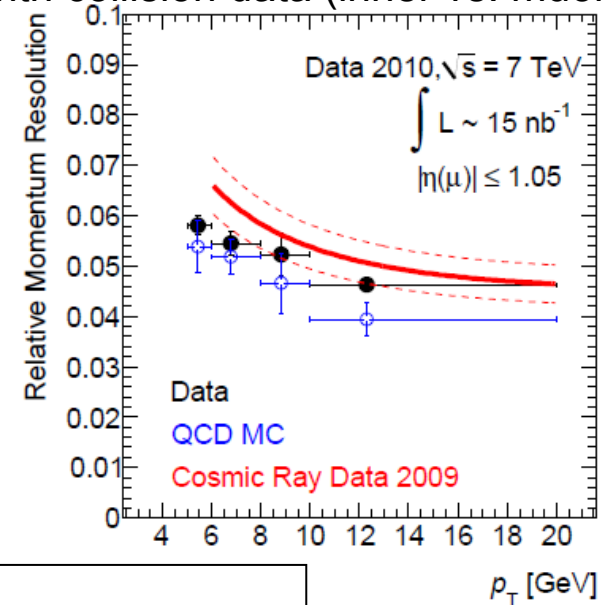
Leading role of the MPP group, ATLAS coordinator: Oliver Kortner

## Muon spectrometer momentum resolution

with cosmic muons (upper vs. lower half of detector)



with collision data (inner vs. muon det.)

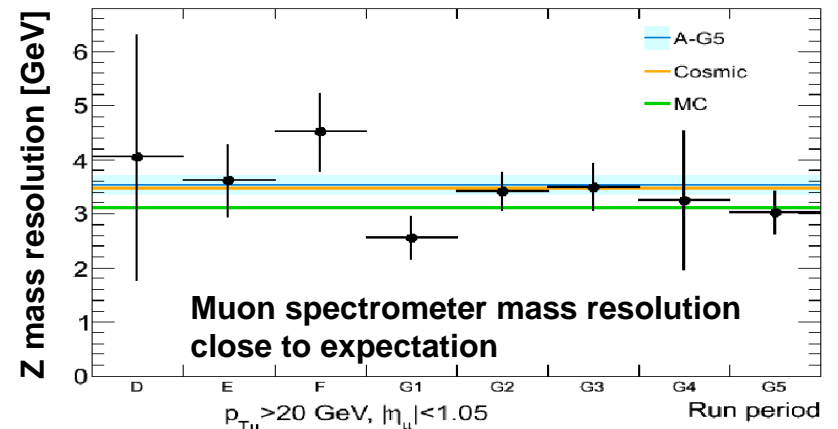


- ATLAS Expected Performance, CERN-OPEN-2008-020
- Muon Spectrometer Commissioning, arXiv:1006.4384v2 (2010), accepted by EPJC

## Di-muon mass resolution

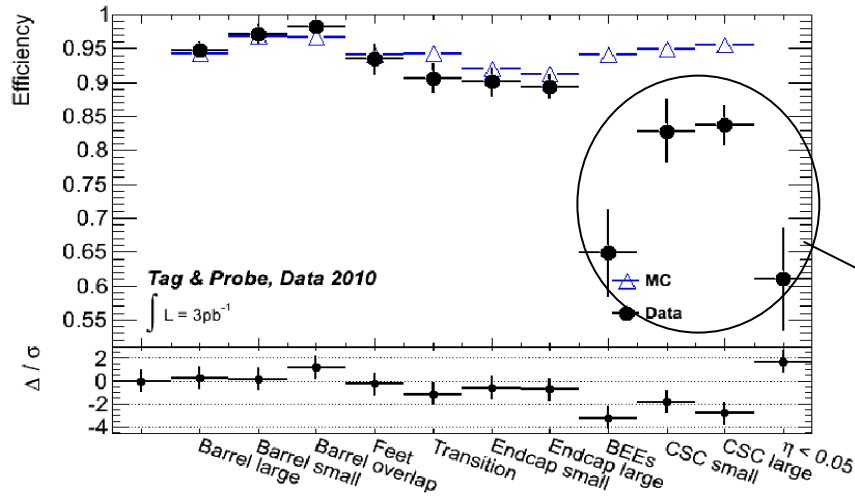
Detector alignment crucial for good mass resolution of heavy di-muon resonances:

- $Z \rightarrow \mu\mu$  (calibration channel)
- $A \rightarrow \mu\mu$  search
- $Z' \rightarrow \mu\mu$  search



# Muon Reconstruction Performance

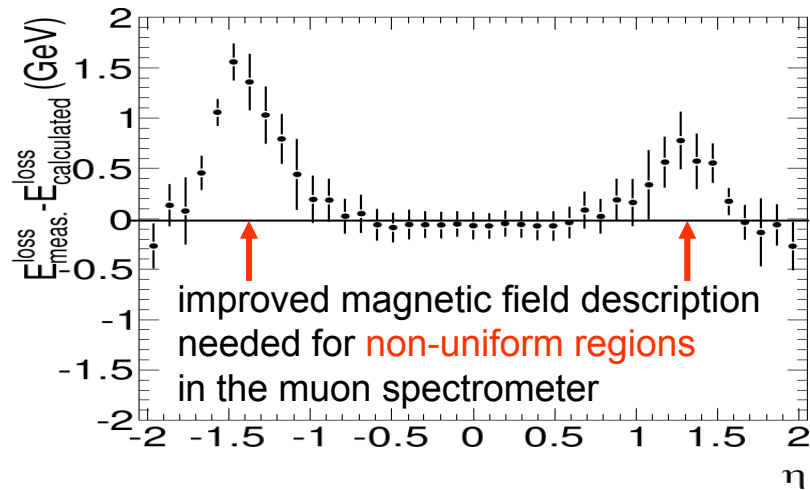
## Muon identification efficiency



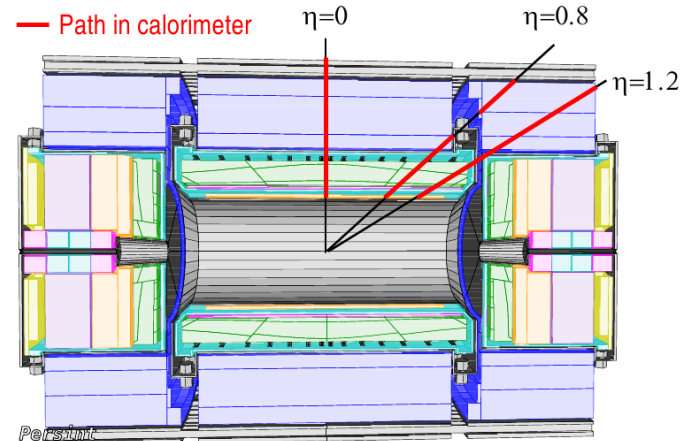
First muon efficiency measurement for different detector regions with  $Z \rightarrow \mu\mu$  tag-and-probe method

Alignment problems

## Muon energy loss in the calorimeters



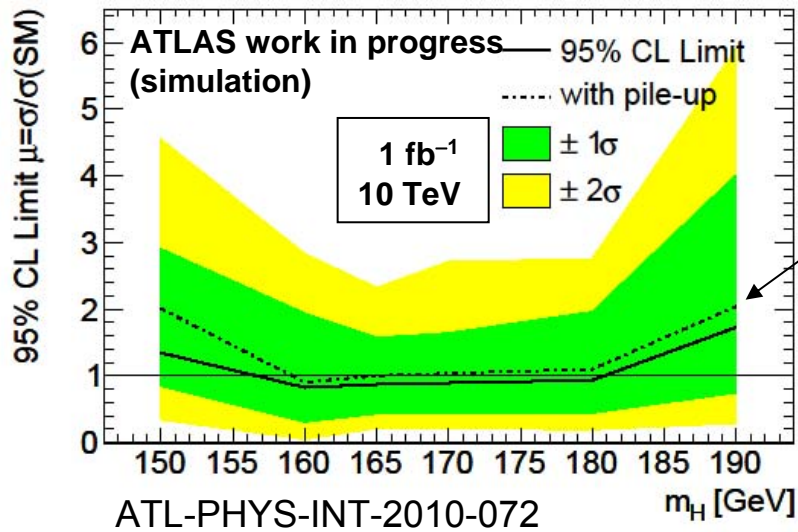
$E_{\text{meas.}}^{\text{loss}} \propto \text{path length in calorimeter material}$



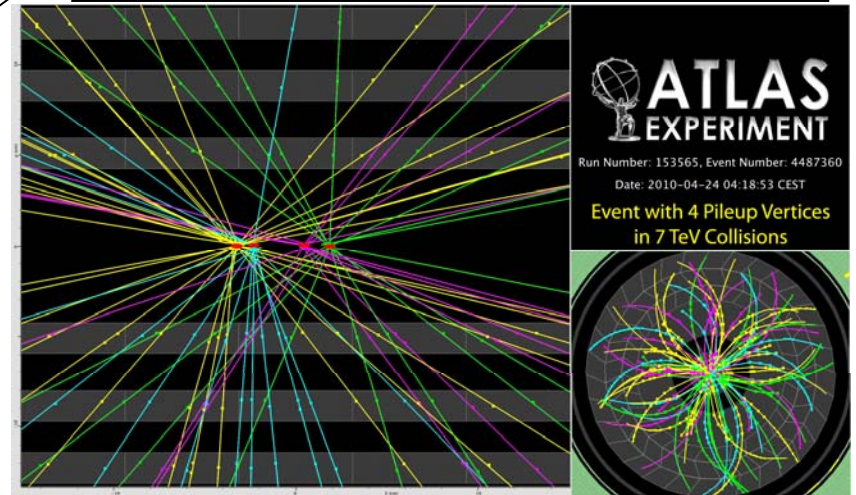
PhD theses: D.Capriotti, M.Vanadia, J.Bronner, S.Stern

# SM Higgs Boson Searches

Sensitivity study for  $pp \rightarrow qq H, H \rightarrow WW$  (gauge boson-fusion production)

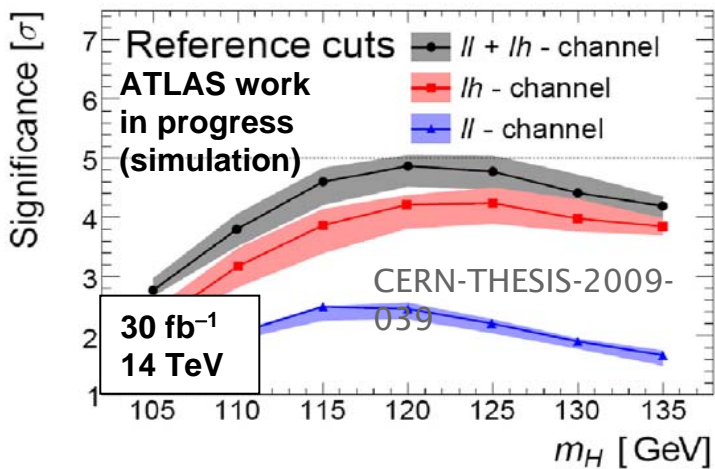


First study of the influence of multiple (4x) pp interactions (event pile-up)



PhD thesis: St.Kaiser (2009)

Sensitivity improvement for  $pp \rightarrow qq H, H \rightarrow \tau\tau$



Employing multi-variate analysis methods for event selection



PhD thesis: M.Groh (2009)

