Luminosity Measurements And Standard Model Results from ATLAS

UNIVERSITY OF ALBERTA

Nitesh Soni

University of Alberta

(based at CERN)

ATLAS EXPERIMENT

at

Centre de Physique des Particules de Marseille

CPPM

1st March, 2012

Luminosity Measurements And Standard Model Results from ATLAS

Séminaires

Luminosity Measurements and Standard Model Results from ATLAS

by Nitesh Soni

jeudi 1 mars 2012 from **14:00** to **15:00** (Europe/Paris)
at CPPM (Amphithéâtre)

Description The last couple of years are very fascinating for LHC and the ATLAS experiment. With the data collected more than 5fb-1, the ATLAS is in a very exciting phase to firm or crackdown the Standard Model by analyzing the various physics topics. My talk will cover the production and the measurements of W and Z vector bosons properties which are extremely important to understand before making any discovery. The Luminosity plays a very crucial role in many of the cross-section measurements at ATLAS, so precise determination of luminosity is very important. In ATLAS, the absolute calibration of luminosity is provided by performing the van der Meer scan. I will discuss the method and the detectors e.g. Luminosity detector (LUCID). In addition I will also show briefly the latest about the searches for low mass higgs.

LHC and the ATLAS experiment

Measurements of W and Z vector bosons properties

Determination of luminosity

Latest about the searches for low mass higgs

Menu for Today's Seminar

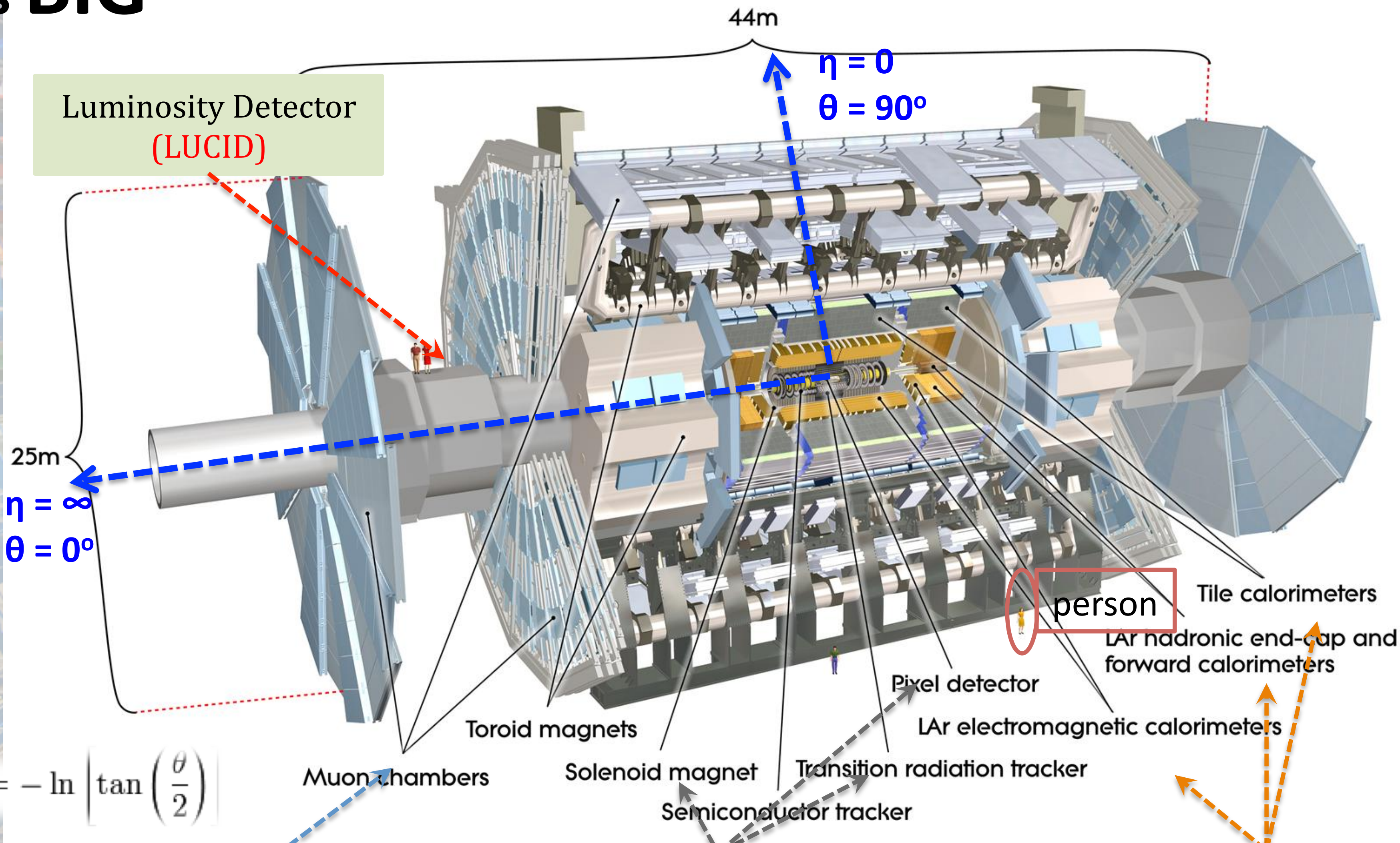
- Detector and its operations in 2011
- Luminosity Measurements
  - ATLAS Strategy
  - van der Meer Scans at ATLAS
  - Luminosity results and prospects for 2012
- Physics Topics
  - Results from Electroweak Bosons (W and Z)
    - Total and differential Cross-section measurement
    - Lepton Charge Asymmetries in W→lν
    - W-polarization studies
  - Diboson Final States
    - W/Z+γ, WW, WZ and ZZ production
  - Higgs Searches: Latest update
- Summary


LARGE HADRON COLLIDER (LHC)
▪ Proton Collisions (pp) at CM = 7TeV (in 2010/11)
▪ Heavy Ion Collisions (PbPb) at CM = 2.76TeV/u (in late 2010-11 run)
LHCb
Geneva Lake
LHCb
(B-physics)
p
7TeV
p
ATLAS
(general purpose)
▪ 27 km Long Collider Ring
▪ Located 330 feet under ground
▪ Collisions per second : 660 million
▪ Design Luminosity (L) : 10^34 cm^-2 s^-1
(Achieved luminosity in 2011~3.65 X 10^33 cm^-2 s^-1)
CMS
(general purpose)
ALICE
(Heavy ION)
CMS

A TOROIDAL LHC APPARATUS (ATLAS)

weighs: 7700 tons, 44 X 25 X 20m, 100 million channels

is BIG



$$\eta = -\ln\left|\tan\left(\frac{\theta}{2}\right)\right|$$

Muon System

Inner Detector (tracking)

Calorimeters

DETECTOR OPERATIONS IN 2011

DETECTOR HARDWARE

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	96.4%
SCT Silicon Strips	6.3 M	99.2%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.8%
Tile calorimeter	9800	96.2%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	99.9%
LVL1 Muon RPC trigger	370 k	99.0%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	97.7%
RPC Barrel Muon Chambers	370 k	97.0%
TGC Endcap Muon Chambers	320 k	97.9%
Total	**88 M**	**> 96 %**

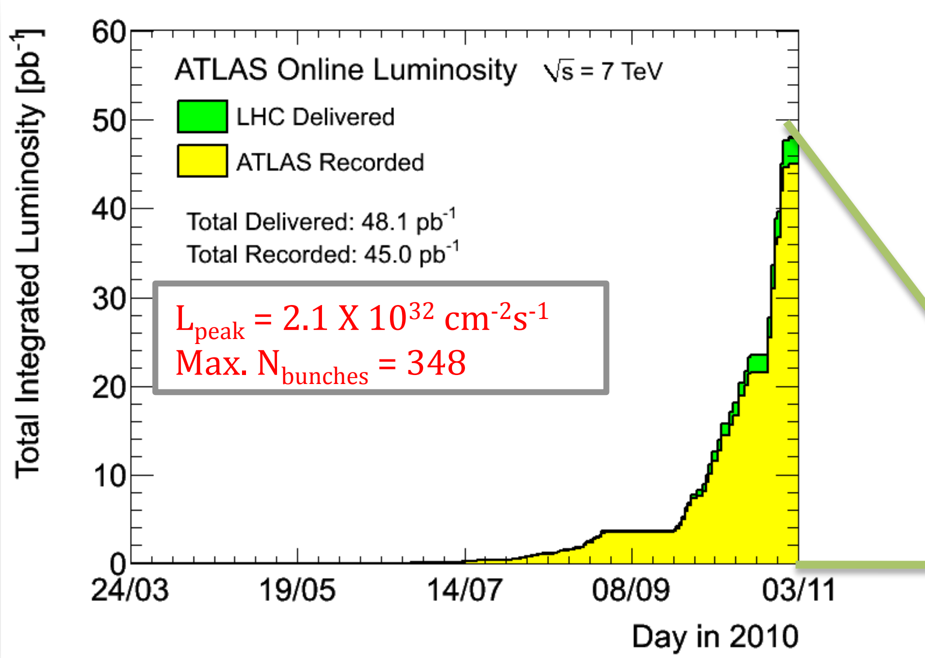
Expect to repair most of the failed channel during the technical shutdown
(in 2010 was able to restore the detector > 99%)

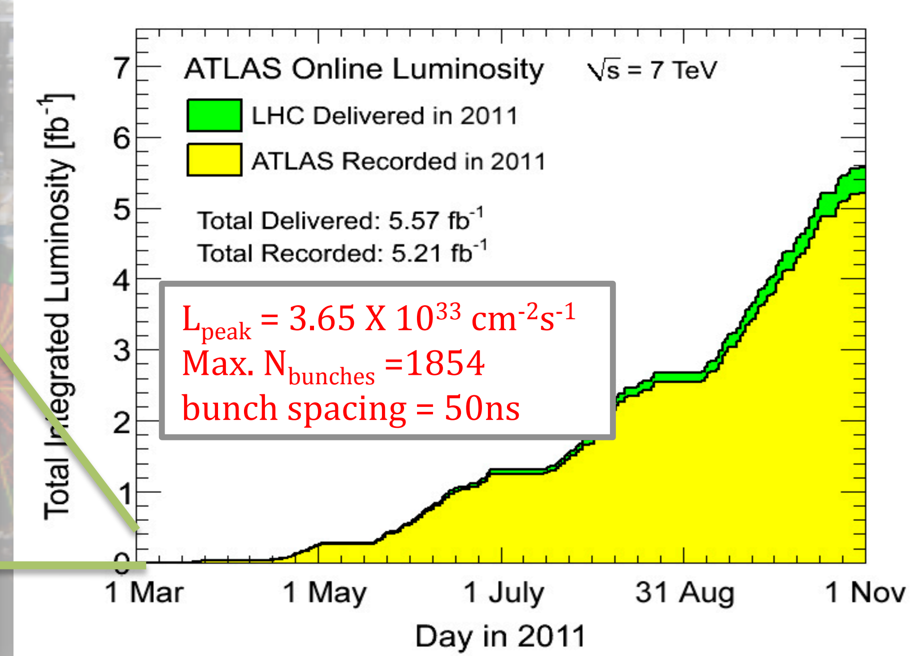
Operational Fractions in 2011

ATLAS DATA TAKING 2010-11

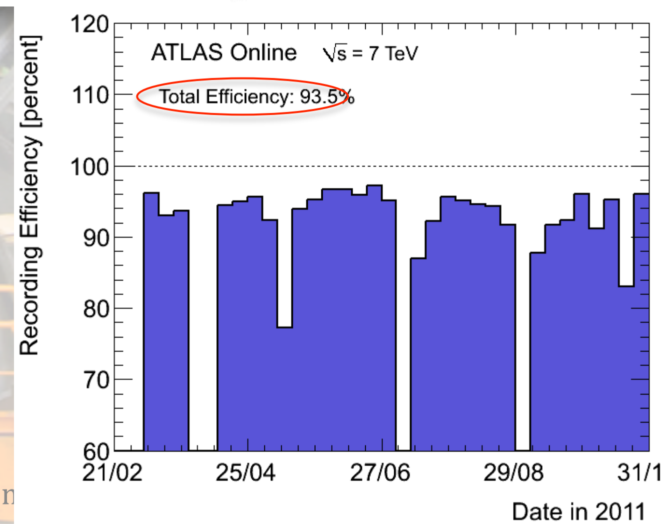
At $\sqrt{s}$ = 7TeV, first collisions on 30th March, **2010**

5.21fb^{-1} in **2011** at $\sqrt{s}$ = 7TeV



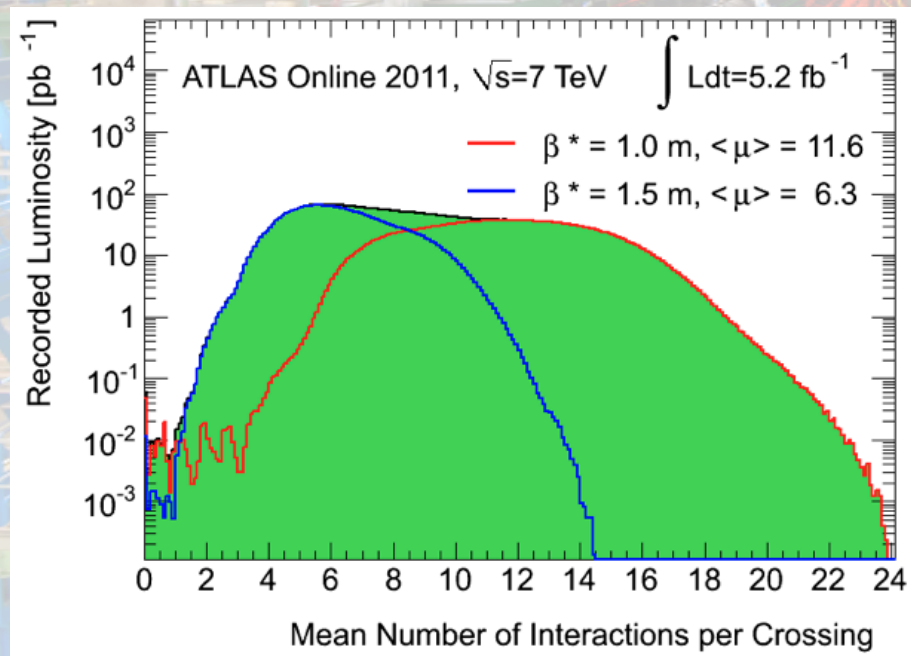


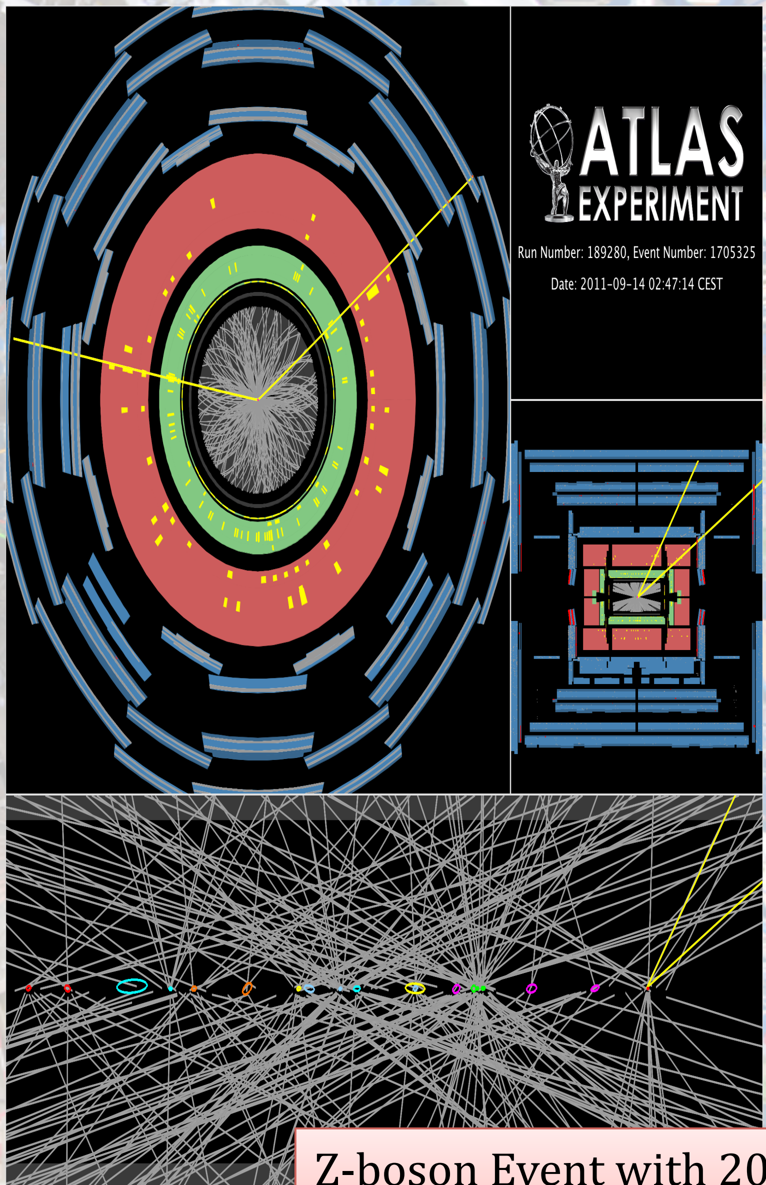
- Spectacular Performance of LHC
- Peak Luminosity = 3.65×10^{33} cm^{-2}s^{-1}
- Max. Data recorded/day 135pb^{-1} (*~3 times more than 2010*)
- 93.5 % of data taking efficiency



Major Challenges in 2011

•Deal with pile-up is great challenge in high luminosity running scenario (tracking, vertexing, lepton isolation, jet energy scale, reconstruction CPU time etc.)
•In 2011: Average number of interactions/ BX (<μ>) = 12 (max. interactions ~ 34)
•In 2010: <μ> ~ 1.3





Z-boson Event with 20 reconstructed vertices

MENU FOR TODAY'S SEMINAR

- Detector and its operations in 2011
- Luminosity Measurements
    - ATLAS Strategy
    - van der Meer Scans at ATLAS
    - Luminosity results and prospects for 2012
- Physics Topics
    - Results from Electroweak Bosons (W and Z)
        - Total and differential Cross-section measurement
        - Lepton Charge Asymmetries in $W \rightarrow l\nu$
        - W-polarization studies
    - Diboson Final States
        - $W/Z+\gamma$,WW,WZ and ZZ production
    - Higgs Searches: Latest update
- Summary

LUMINOSITY DETERMINATION AT ATLAS

WHY

- **Accurate measurement of delivered *Luminosity* (*L*)** needed for
  - Cross-section measurements of ***Standard Model Processes*** (because for most of them the largest uncertainty comes from luminosity)
  - Searches for ***New Physics*** to evaluate the background levels and determine the sensitivity to new physics signatures
- Needed for ***monitoring the performance*** of LHC, and ATLAS

BASIC STRATEGY TO DETERMINE THE LUMINOSITY

precision

- Using *machine parameters* e.g. using ***vdM scans*** (*Currently used*), targeted precision < 3%
- Using any *physics processes* e.g. using ***W and Z counting*** method (*only used for cross-check at the moment but in future can be used*): targeted precision 1 – 2%
- Using a *detector* which provides the absolute value of the Luminosity: e.g. using ***ALFA detector*** (Absolute Luminosity For ATLAS) (*detector in operation this year but requires special conditions of beam to provide the precision*): Targeted Precision < 1%

Luminosity Determination at ATLAS

USING MACHINE PARAMETERS

$$\mathcal{L} = \frac{\mu n_b f_r}{\sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\varepsilon \sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\sigma_{\text{vis}}}$$

μ = Number of inelastic collisions per bunch crossing
n_b = Number of bunch pairs colliding (1,…. 2808)
f_r = LHC revolution frequency (11245.5Hz)
σ_{inel} = total inelastic pp-cross section (Pythia 6: 71.5mb)

μ^{vis} = Number of detected events per bunch crossing

ε = Acceptance X efficiency of Luminosity Detector

σ_{vis} = visible cross-section = Lumi. Calibration Constant

$\mu_{vis} = \varepsilon\mu$ *: measured from the* ***detector rates (e.g. LUCID)***
$\sigma_{vis} = \varepsilon\sigma$ *: measured from the* ***van Der Meer Scan*** *(or beam separation scans)*

Luminosity Determination at ATLAS

Using machine parameters

$$\mathcal{L} = \frac{\mu n_b f_r}{\sigma_{\mathrm{inel}}} = \frac{\mu^{\mathrm{vis}} n_b f_r}{\varepsilon \sigma_{\mathrm{inel}}} = \frac{\mu^{\mathrm{vis}} n_b f_r}{\sigma_{\mathrm{vis}}}$$

μ = Number of inelastic collisions per bunch crossing
n_b = Number of bunch pairs colliding (1,.... 2808)
f_r = LHC revolution frequency (11245.5Hz)
σ_{inel} = total inelastic pp-cross section (Pythia 6: 71.5mb)

μ^{vis} = Number of detected events per bunch crossing
ε = Acceptance X efficiency of Luminosity Detector
σ_{vis} = visible cross-section = Lumi. Calibration Constant

$\boldsymbol{\mu_{vis} = \varepsilon\mu}$: *measured from the* ***detector rates (e.g. LUCID)***
$\boldsymbol{\sigma_{vis} = \varepsilon\sigma}$: *measured from the* ***van Der Meer Scan*** *(or beam separation scans)*

Using physics processes

$$L = \frac{N^{Obs}_{W/Z} - N^{Bkg}_{W/Z}}{C_{W/Z} \cdot A_{W/Z} \cdot \sigma_{th.}}$$

# of W/Z events

# of background events expected (small)

Total Eff. to record the event which falls within acceptance

Acceptance of W/Z events Given by the fraction of events satisfying the geometrical and kinematical cuts in the event selection

theoretical cross-section uncertainty ~2-3%

main reason *NOT* to use the prime method

Luminosity Determination at ATLAS

USING MACHINE PARAMETERS

$$\mathcal{L} = \frac{\mu n_b f_r}{\sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\varepsilon \sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\sigma_{\text{vis}}}$$

Luminosity Measurement using this method

- μ = Number of inelastic collisions per bunch crossing
- n_b = Number of bunch pairs colliding (1,…,2808)
- f_r = LHC revolution frequency (11245.5Hz)
- σ_{inel} = total inelastic pp-cross section (Pythia 6: 71.5mb)

- μ^{vis} = Number of detected events per bunch crossing
- ε = Acceptance X efficiency of Luminosity Detector
- σ_{vis} = visible cross-section = Lumi. Calibration Constant

μ_{vis} = εμ** : measured from the **detector rates (e.g. LUCID)

***σ_{vis} = εσ** : measured from the **van Der Meer Scan** (or beam separation scans)*

USING PHYSICS PROCESSES

$$L = \frac{N^{Obs}_{W/Z} - N^{Bkg}_{W/Z}}{C_{W/Z} . A_{W/Z} . \sigma_{th.}}$$

- $N^{Obs}_{W/Z}$: # of W/Z events
- $N^{Bkg}_{W/Z}$: # of background events expected (small)
- $C_{W/Z}$: Total Eff. to record the event which falls within acceptance
- $A_{W/Z}$: Acceptance of W/Z events Given by the fraction of events satisfying the geometrical and kinematical cuts in the event selection
- $\sigma_{th.}$: theoretical cross-section uncertainty ~2-3%

main reason *NOT* to use the prime method

ATLAS Strategy for Luminosity

*** Bunch-by-Bunch**

BCM

- EventOR , EventAND
- Separate measurements from H/V

LUCID

- EventOR, EventAND
-HitOR, HitAND

Vtx Method

- vertex based Event Counting
- vertex counting

ZDC (HI)

- Evt. Inclusive A or C

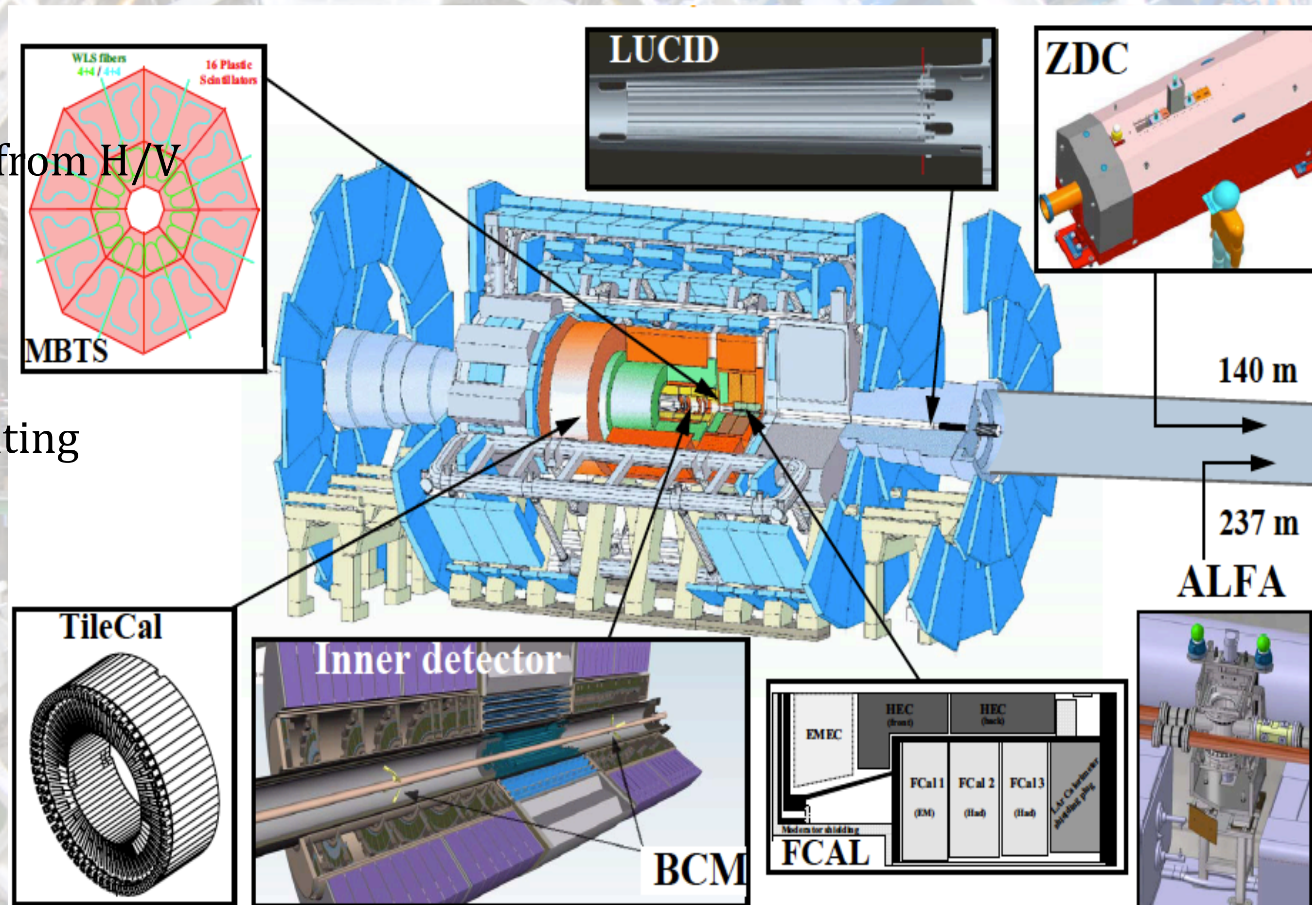
*** BCID blind**

FCAL

- Gap currents

Tile Cal

- PMT Currents

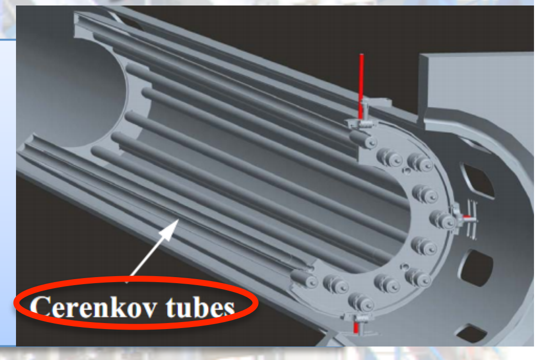


ATLAS Strategy: Several sub-detectors and multiple algorithms for redundancy/ consistency (All autonomous)
in 2010: LUCID was preferred (EventOR) *and* ***in 2011 BCM is preferred (EventOR)***

Luminosity measurement Using Cherenkov Integrating Detector (LUCID)

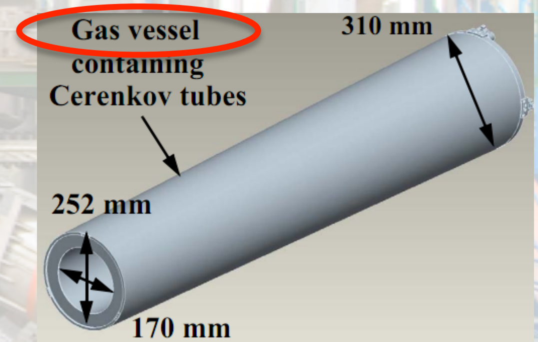
PRIMARY PURPOSE

- Dedicated to provide the ***bunch by bunch*** luminosity in ATLAS (***Relative***)
- Official ATLAS ***Online Luminosity Monitor***
- It has the Interaction ***Trigger Capability*** at low luminosity ~ 10^{33} cm^{-2} s^{-1}
- After calibration it provides the ***Absolute Luminosity***
- Sensitive to charged particles pointing to the primary pp-collisions
- ***LUCID Phase-I*** design for $L \sim 10^{27}$ cm^{-2} s^{-1} to $4 X 10^{33}$ $cm^{-2}s^{-1}$

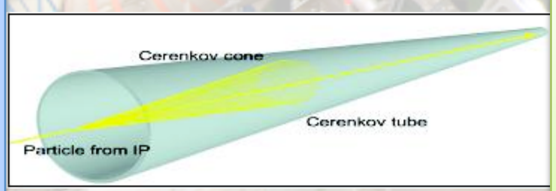


DETECTORS

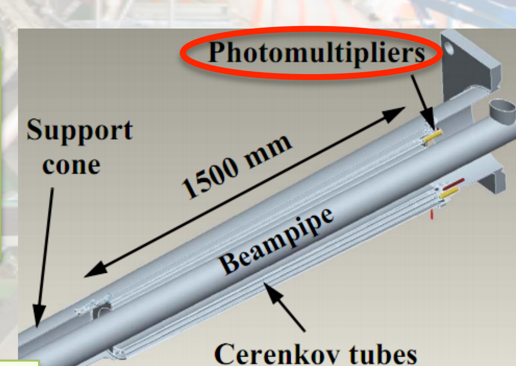
- Two modules at ± 17m from Interaction Point
- 5.6 < |η| < 5.9 : placed in the forward direction
- 20 *reflected Aluminum Tube/Module*
- Filled with C_4H_{10} gas



PRINCIPLE



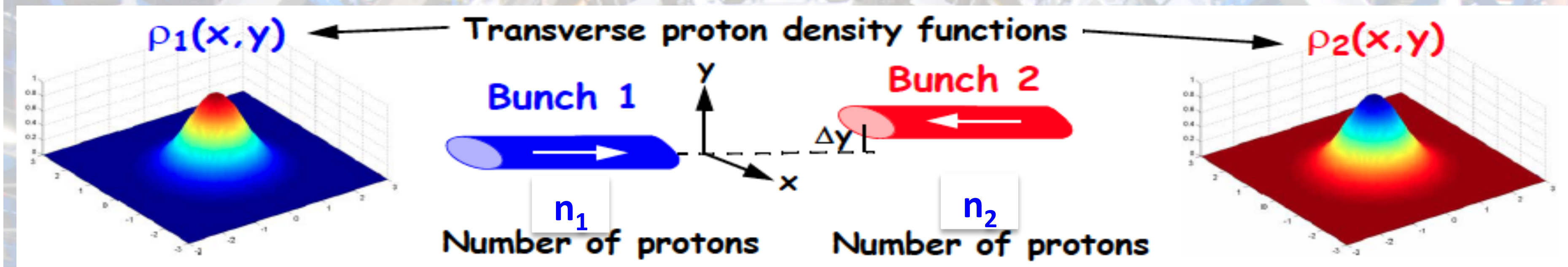
- Photons are emitted at 3°
- Typically, *3 reflections* inside the tube
- Photons are readout by *Photomultiplier tubes* (PMT)



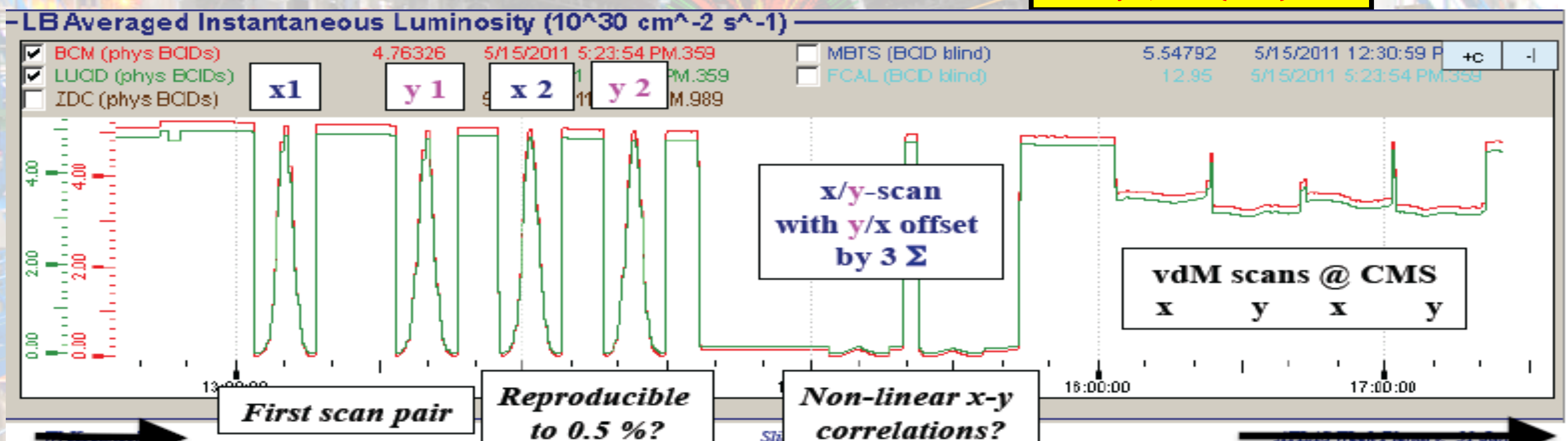
Note: *After 2011 technical shutdown LUCID was also run without gas*

JINST 3 S08003 (2008)

VAN DER MEER SCANS (ABSOLUTE *L* CALIBRATION)



ISR-PO/68-31, 1968 (CERN)
Eur. Phys. J. C 71(2011) 1630



Most Standard Scan Sequence

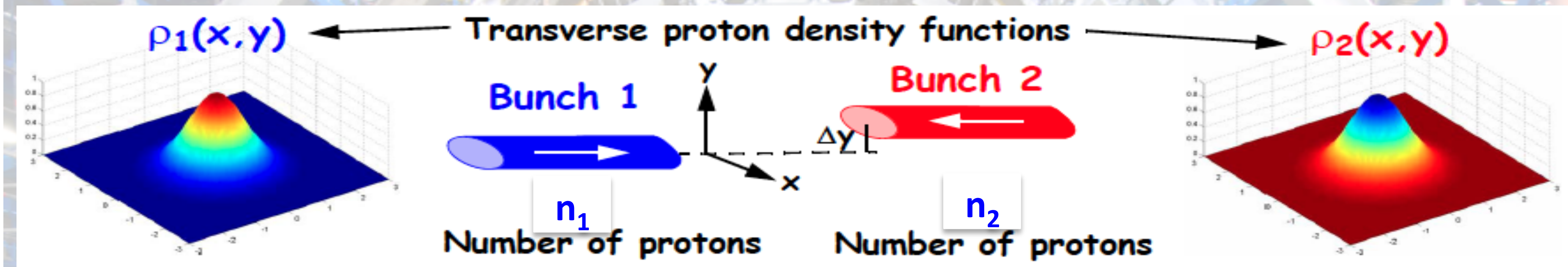
- Initial horizontal scan followed by vertical

(recentering of beams if required)

- Second horizontal scan followed by vertical scan

(check on reproducibility issues on key elements of luminosity)

VAN DER MEER SCANS (ABSOLUTE $\mathcal{L}$ CALIBRATION)



ISR-PO/68-31, 1968 (CERN)
Eur. Phys. J. C 71(2011) 1630

$$\mathcal{L} = n_b f_r n_1 n_2 \int \hat{\rho}_1(x,y)\hat{\rho}_2(x,y)\,dx\,dy$$

1

$$\mathcal{L} = \frac{n_b f_r n_1 n_2}{2\pi \Sigma_x \Sigma_y}$$

where

$$\Sigma_x = \frac{1}{\sqrt{2\pi}} \frac{\int R_x(x)dx}{R_x(0)}$$

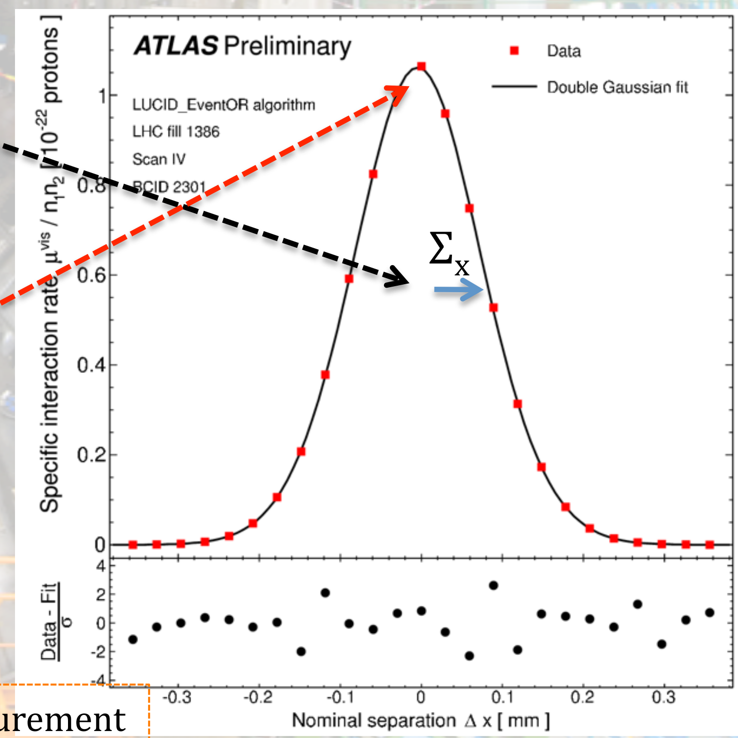
2

$$\mathcal{L} = \frac{\mu n_b f_r}{\sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\varepsilon \sigma_{\text{inel}}} = \frac{\mu^{\text{vis}} n_b f_r}{\sigma_{\text{vis}}}$$

Comparing 1 and 2

$$\sigma_{vis} = 2\pi \frac{\mu_{vis} \Sigma_X \Sigma_Y}{n_1 n_2}$$

from current measurement



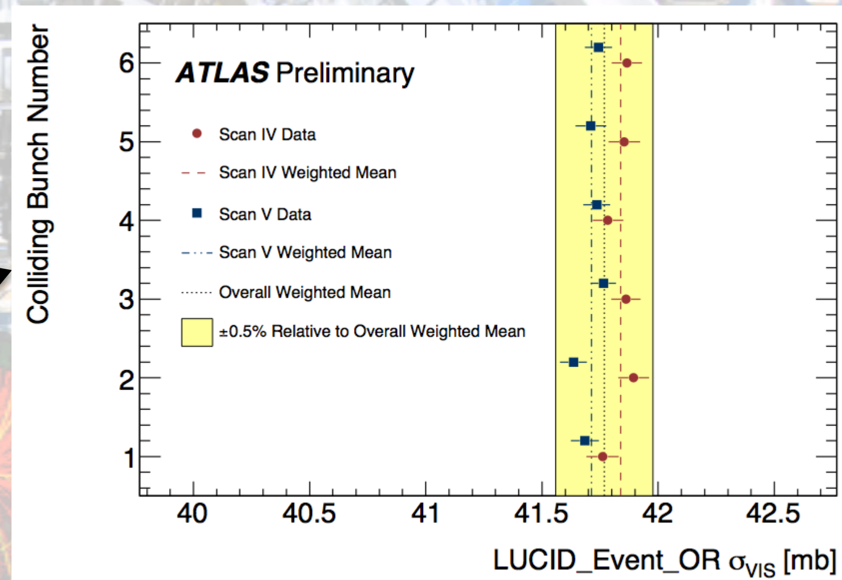
Eur. Phys. J. C 71 (2011), 1630

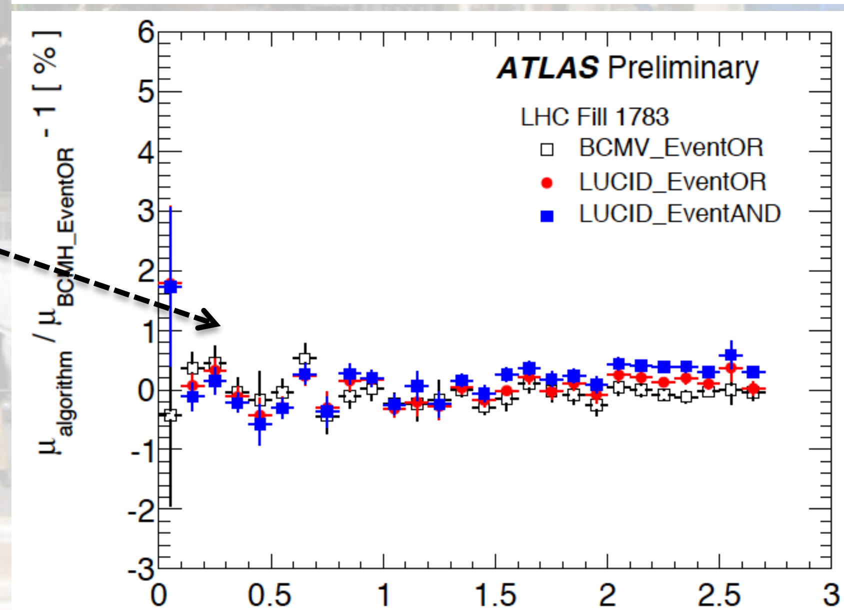
SYSTEMATIC ERRORS ON L

Source	Uncertainty
Beam centering	0.1%
Emittance Growth	0.5%
Beam Position Jitter	0.3%
σ_{vis} consistency	0.5%
Length Scale Calibration	0.3%
Fit model	0.8%
Absolute ID length scale	0.3%
Transverse correlations	0.9%
μ-dependence	0.5%
Bunch Charge Product	3.1%
Detector stability	0.7%
Total	3.4%

σ_{vis} = 41.75±1.30mb

Dominant systematic Errors



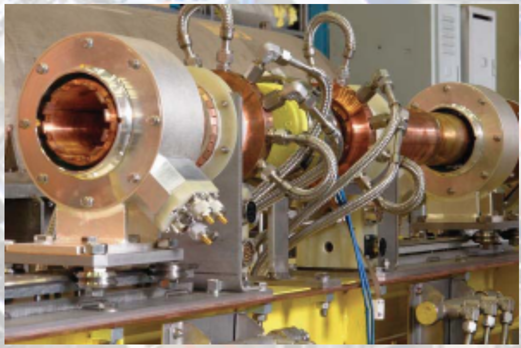


Eur. Phys. J. C 71 (2011), 1630

ATLAS-CONF-2011-116

Current Measurements from LHC

NOTE: Information provided by LHC Luminosity Team



Direct-Current Current Transformer (DCCT)
(measure the total current)

Fast Bunch-Current Transformer (FBCT)
(Measure the fraction of the current in each bunches)

# of protons in bunch j

Calibrated Scale Factor

baseline offset from DCCT

$$n_j = (\alpha N^{DCCT} - N_{baseline} - N_{Ghostcharge}) \frac{N_j^{FBCT}}{\sum_j N^{FBCT}}$$

Systematic Errors on $n_1 n_2$

2.7% $\oplus$ <0.1% $\oplus$ negligible $\oplus$ 1.6% = 3.1%

Total Calibration Errors = Error Scan $\oplus$ Error Current = 1.3% $\oplus$ 3.1% = 3.4%

CERN-ATS-Note-2011-004 PERF,2011

Eur. Phys. J. C 71 (2011), 1630

PROSPECTS FOR 2012

- For latest update for Luminosity update please see the ATLAS talk on LHC Lumi-days workshop today
  - https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=162948
- There is drastic improvement in current measurements and errors will go down to less than 2% (although these numbers are still preliminary, beam current measurement 3.1 %→0.35%)

- The machine running scenario would be different in 2012, and some detector needs to re-calibrate, MC needs to tune for 8TeV

- Luminosity calibration might affect from long term stability, mu-dependence issues, Detector reproducibility/internal consistency issues (change over the shutdown e.g. LUCID modules etc.)

Menu for Today's Seminar

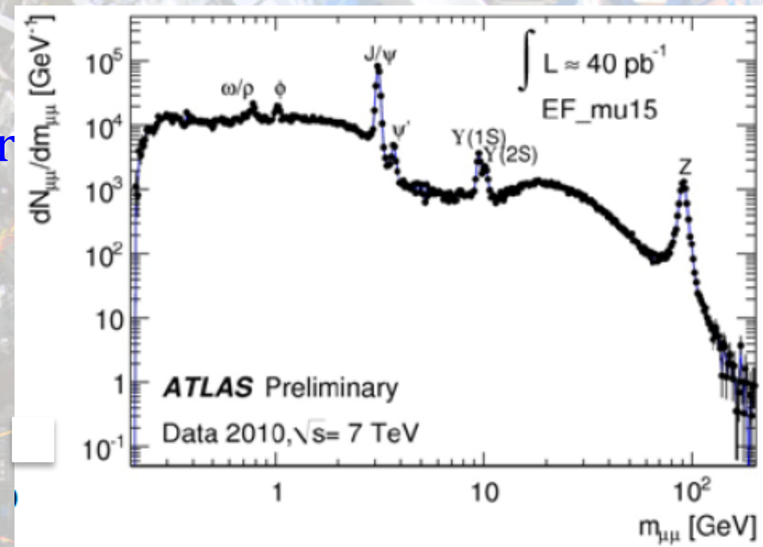
- Detector and its operations in 2011
- Luminosity Measurements
  - ATLAS Strategy
  - van der Meer Scans at ATLAS
  - Luminosity results and prospects for 2012
- Physics Topics
  - Results from Electroweak Bosons (W and Z)
    - Total and differential Cross-section measurement
    - Lepton Charge Asymmetries in W→lν
    - W-polarization studies
  - Diboson Final States
    - W/Z+γ,WW,WZ,ZZ production
  - Higgs Searches: Latest update
- Summary

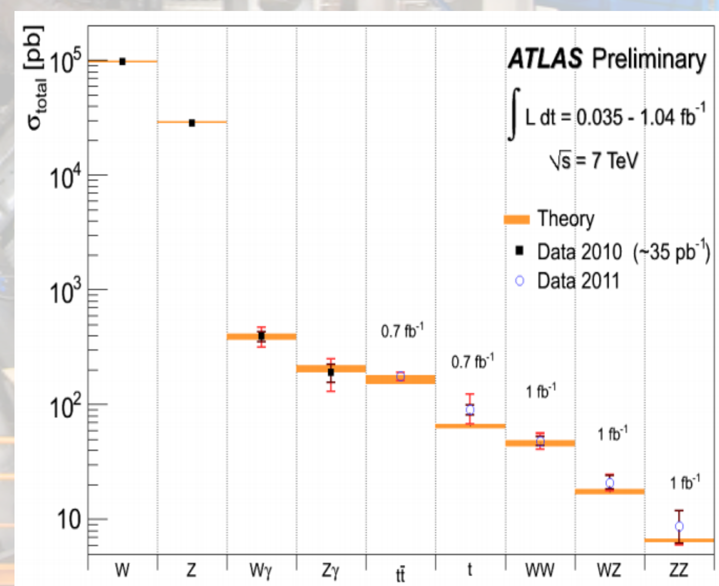
Strategy to reach the Physics Goals

- 2010 (data set ~ $34pb^{-1}$)
  - Understand and to Calibrate the detector
  - Rediscover the Standard Model

- 2011 (data set ~ $5fb^{-1}$)
  - Precise Understanding of SM at high Energies
    - Distribution of extra jets in SM processes
    - Background to searches
  - New Physics
    - Discover, if lucky
    - Else restricted the allowed regions

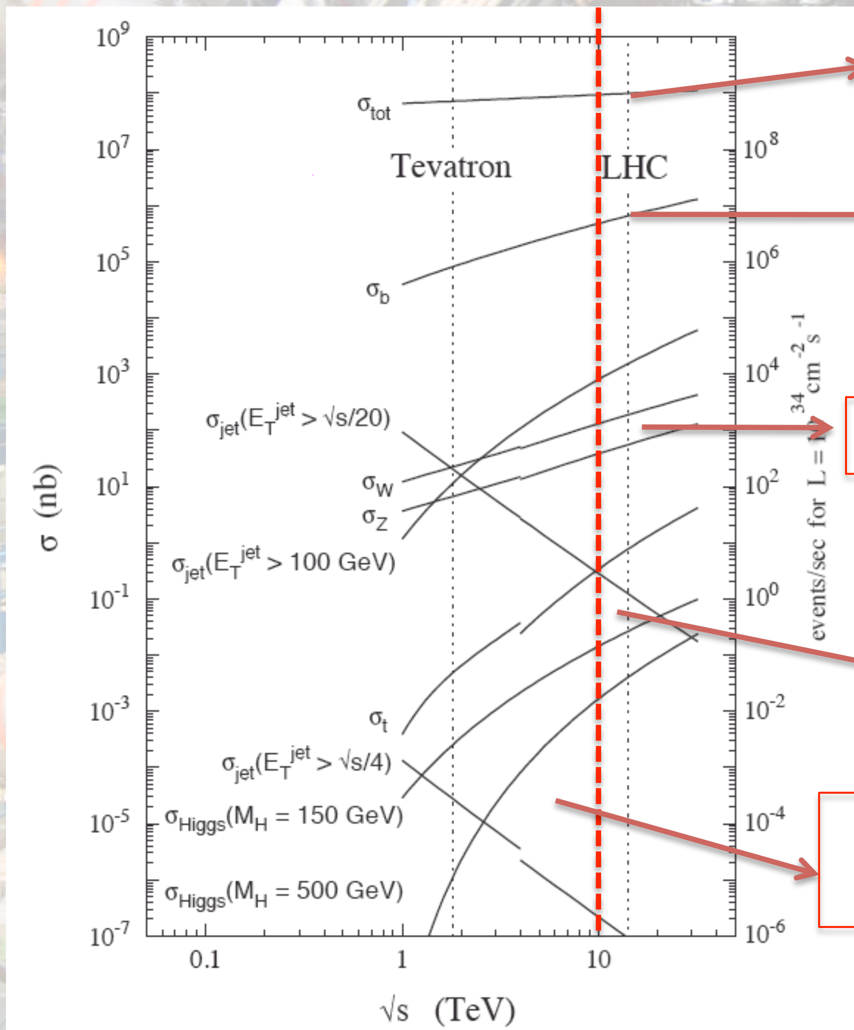
- 2012 +.. (~10-$15fb^{-1}$)
  - Close on Mass mechanisms (higgs?)
  - ... and may be more





PRODUCTION CROSS-SECTION AT LHC

LHC @ 7TeV



Total inelastic pp-Cross-sections ~70mb

expect huge statistics for B-physics

Copious amount of W's and Z's production

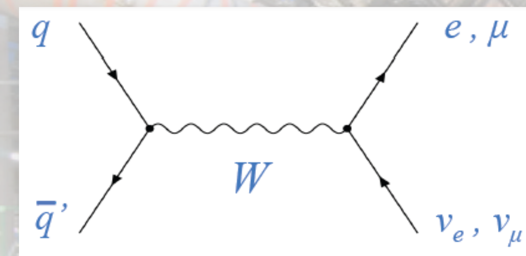
in the following slides

top-quark production

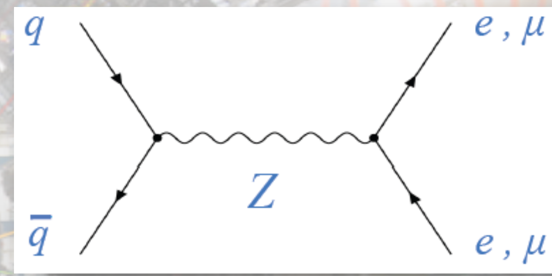
Higgs production, more events produced compare to any previous collider

Production of W and Z-boson

- W and Z discovered in 1983 by UA1 and UA2 collaborations
  m_W = 80.398 ± 0.023 GeV; m_Z = 91.188 ± 0.0021 GeV



$W \rightarrow l\nu$; $l = e$ or μ



$Z \rightarrow ll$; $l = e$ or μ

W/Z important, why?

- Fundamental milestones in the “rediscovery" of the Standard Model
- Powerful tools to constrain PDFs and test perturbative QCD
- Z leptonic decay is gold-plated process to calibrate the detector to the ultimate precision (very clean)
- *Dominant backgrounds* in searches for New Physics e.g. *Higgs, SUSY* etc.

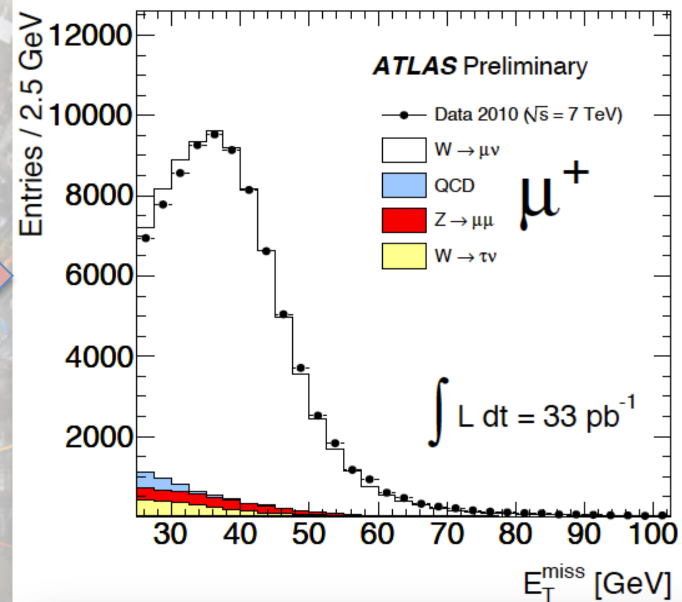
W and Z signature and selection

W Signature

- High p_T lepton + E_T^{miss}
- $E_T >$ 20GeV (for e) and $p_T >$ 13GeV (for μ)
- Sum $(p_T^{ID})/p_T < 0.2$ isolation for muon

W Selection

- $E_T^{miss} >$ 25GeV
- Trans. Mass of Lepton, $m_T >$ 40GeV
- 260000 W are found

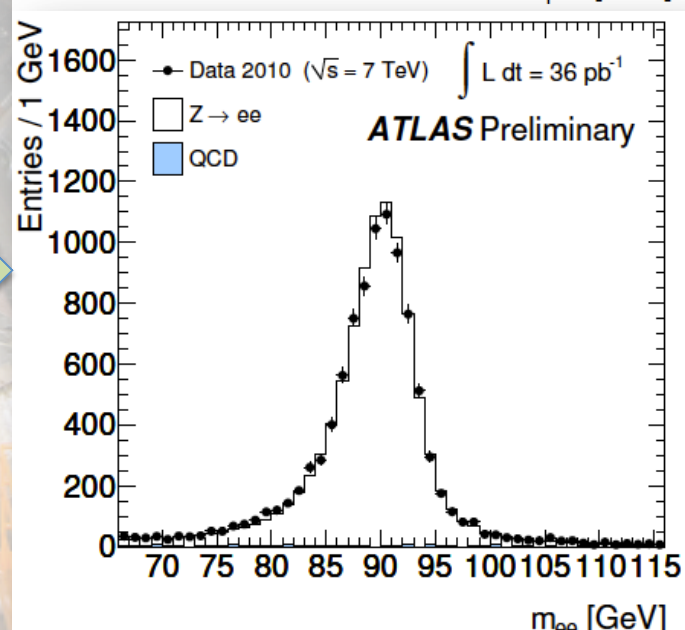


Z Signature

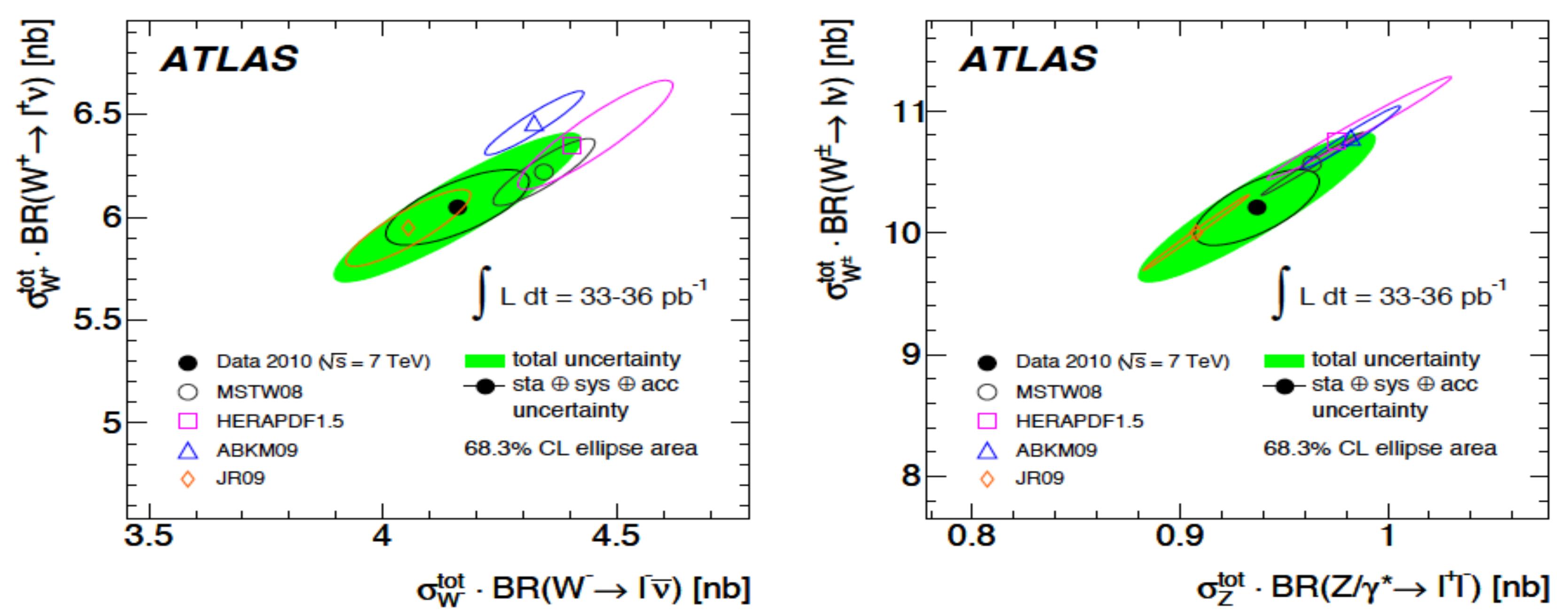
- Two high momentum leptons
- *$E_T >$ 20GeV (for e) and $p_T >$ 13GeV (for μ)*
- *Sum $(p_T^{ID})/p_T < 0.2$ isolation for muon*
- No Isolation for electron

Z Selection

- A pair of *oppositely charged* with p_T >20GeV
- Invariant mass *$66 < m_{ll} < 116$ GeV*
- *25000 Z* are found



Inclusive Cross-section Measurements



$\sigma^{tot}_W \cdot BR(W \to \ell\nu)$ [nb]				
	sta	sys	lum	acc
W^+	6.048 ± 0.016	± 0.072	± 0.206	± 0.096
W^-	4.160 ± 0.014	± 0.057	± 0.141	± 0.083
$W^\pm$	10.207 ± 0.021	± 0.121	± 0.347	± 0.164

$\sigma^{tot}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to \ell\ell)$ [nb] $66 < m_{\ell\ell} < 116$ GeV				
	sta	sys	lum	acc
Z/γ^*	0.937 ± 0.006	± 0.009	± 0.032	± 0.016

Systematic from Luminosity (3.2%)

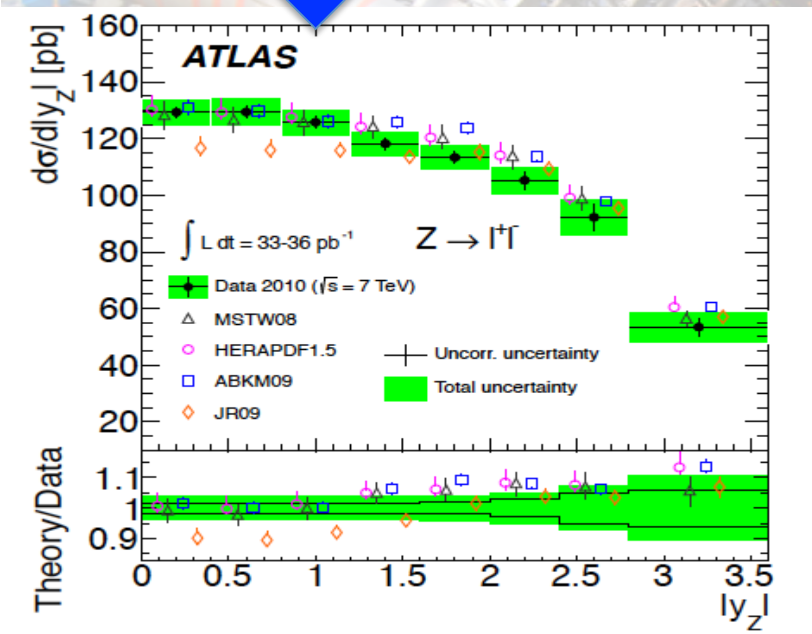
extrapolation Systematic

- $\sigma(W^+) > \sigma(W^-)$
- $\sigma(W) > \sigma(Z)$
- Best measurement so far
- Great input to various phenomenological models

arXiv:1109.5141v3[hep-ex]

More Interesting Results

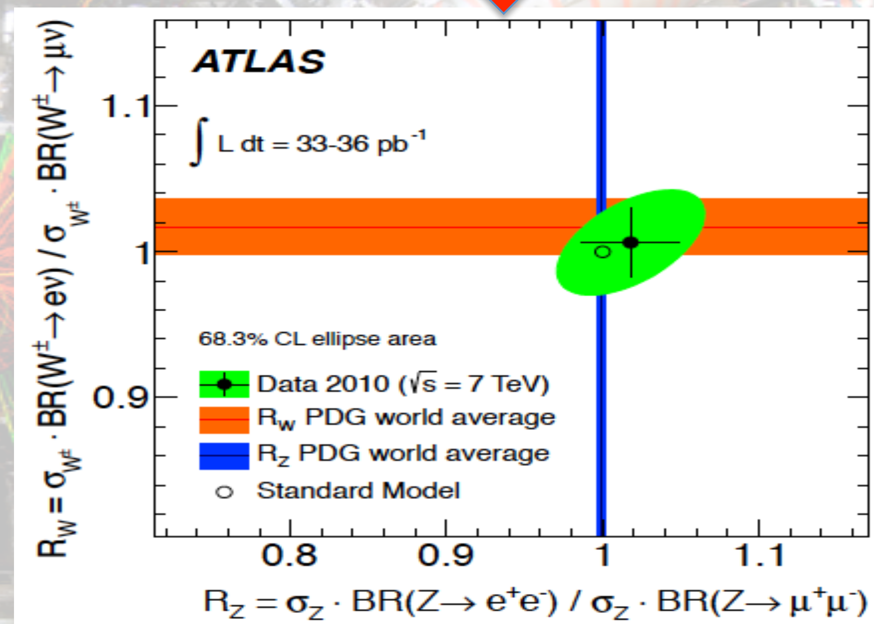
Differential cross-section measurements in the each bin



Tests for multiple aspects of QCD predictions

Important Ingredients for tuning simulations

Test of lepton-universality



$$R_W = \frac{\sigma_W^e}{\sigma_W^\mu} = \frac{Br(W \to e\nu)}{Br(W \to \mu\nu)} \qquad R_Z = \frac{\sigma_Z^e}{\sigma_Z^\mu} = \frac{Br(Z \to ee)}{Br(Z \to \mu\mu)}$$

comparable with PDG

arXiv:1109.5141v2[hep-ex]

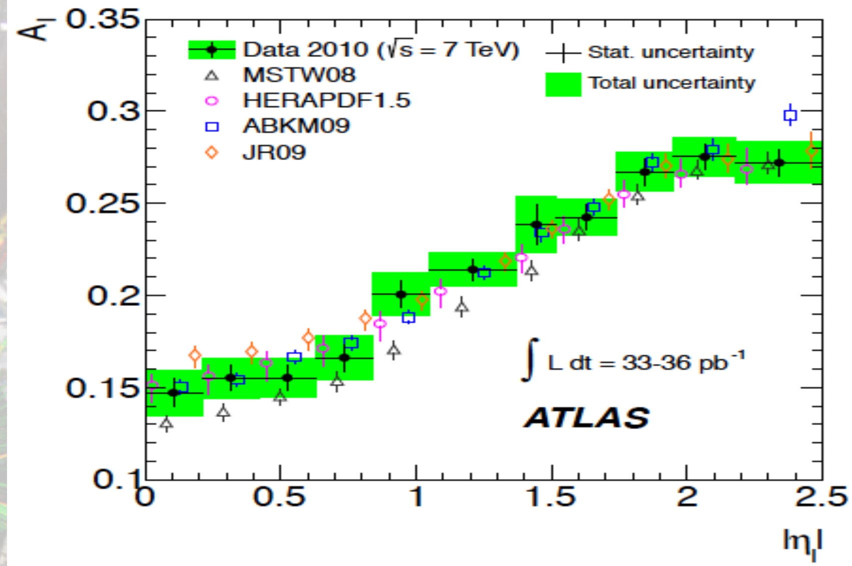
W-CHARGE ASYMMETRY

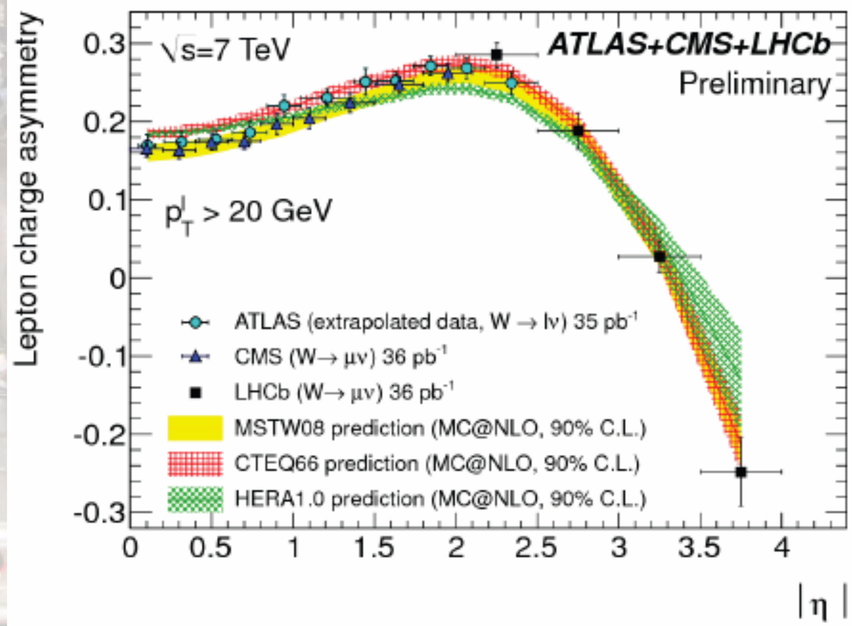
- Asymmetric W-production provides information about proton structure
  - *W-production (mostly) via valence-sea quark interaction*
  - *|y|-dependancy sensitive to differences between u and d parton distribution functions (PDFs)*
  - Difficult to reconstruct W-rapidity, use decay lepton rapidity

$$A_\mu = \frac{d\sigma_{W_{\mu^+}}/d\eta_\mu - d\sigma_{W_{\mu^-}}/d\eta_\mu}{d\sigma_{W_{\mu^+}}/d\eta_\mu + d\sigma_{W_{\mu^-}}/d\eta_\mu}$$

- Measurements compares well with predictions
  - ... however, measurement is input to PDF fits

- Common phase-space agreed by ATLAS, CMS and LHCb within LHC Electroweak working group





Phys. Lett. B 701 (2011) 31-49

W-POLARIZATION

- Use high-p_T W
  - *Sensitive to gluon content*
    - *ug→Wd, dg→Wu,ud→Wg*
- Analyze Angular Distribution of the decay products
  - Assume ϕ−Symmetry
- Replace W-decay angle with correlated Quantity
  - $cos\theta_{2D} = p_T^W.p_T^l/|p_T^W|*|P_T^l|$

for (θ,ϕ) the lepton (polar,azimuthal) angle in any W rest frame

$$\begin{aligned}\frac{1}{\sigma}\frac{d\sigma}{dcos\theta d\phi} &= \frac{3}{16\pi}\times[(1+cos^2\theta)\\ &+ \frac{1}{2}A_0(1-3cos^2\theta)+A_1 sin2\theta cos\phi\\ &+ \frac{1}{2}A_2 sin^2\theta cos2\phi + A_3 sin\theta cos\phi\\ &+ A_4 cos\theta + A_5 sin^2\theta sin2\phi\\ &+ A_6 sin2\theta sin\phi + A_7 sin\theta sin\phi]\end{aligned}$$

$\int d\phi$ in helicity frame

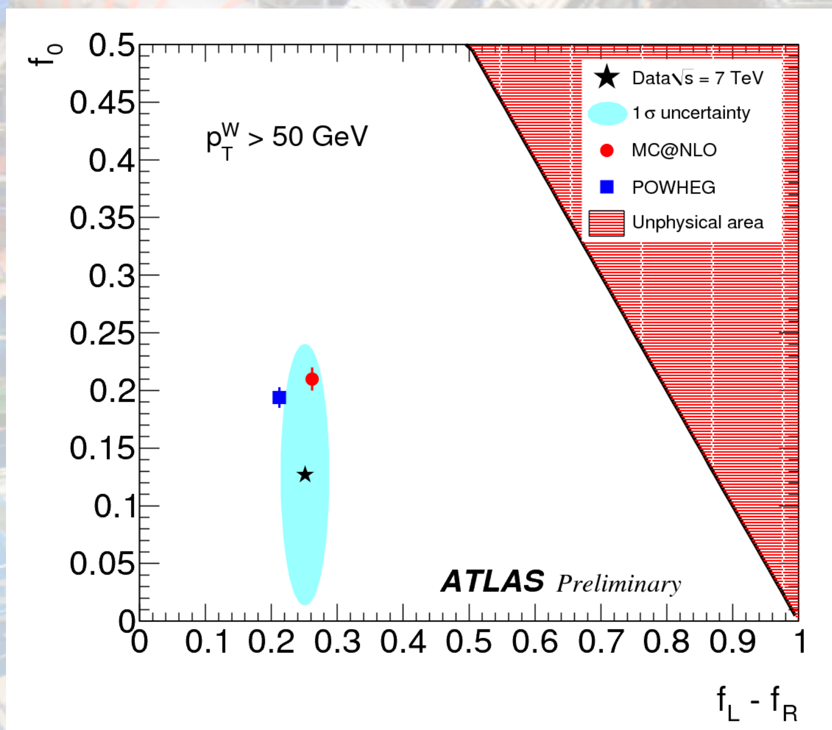
$$\begin{aligned}\frac{1}{\sigma}\frac{d\sigma}{dcos\theta} &= \frac{3}{8}f_L(1\mp cos\theta)^2\\ &+ \frac{3}{8}f_R(1\pm cos\theta)^2\\ &+ \frac{3}{4}f_0 sin^2\theta\end{aligned}$$

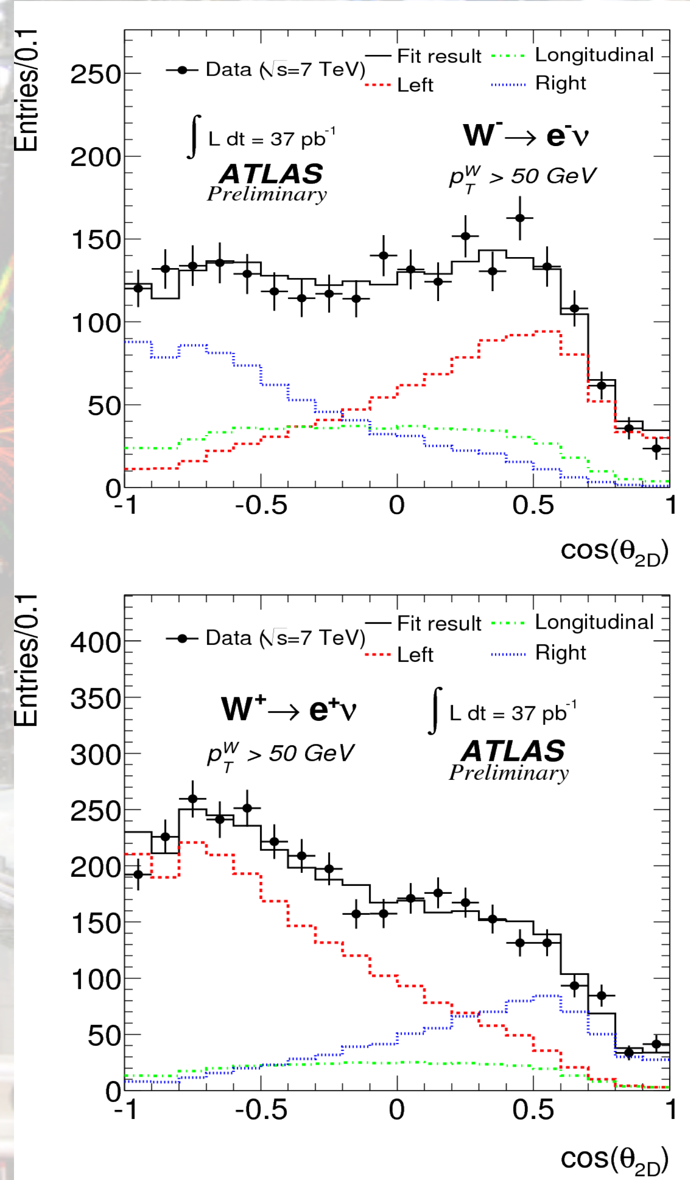
⚠ No p_z^ν measurement ⇔ two solutions, among which it is not possible to choose in an efficient way and so to get $\cos\theta_{3D}$ ⚠

Variable used: "Transverse helicity"

$\cos(\theta_{2D}) = \frac{\vec{p}^{\,*}_{T\ell}\cdot\vec{p}_{TW}}{|p^*_{T\ell}||p_{TW}|}$, where $\vec{p}^{\,*}_{T\ell}$ is the transverse momentum of the lepton in the W_T rest frame

W-POLARIZATION

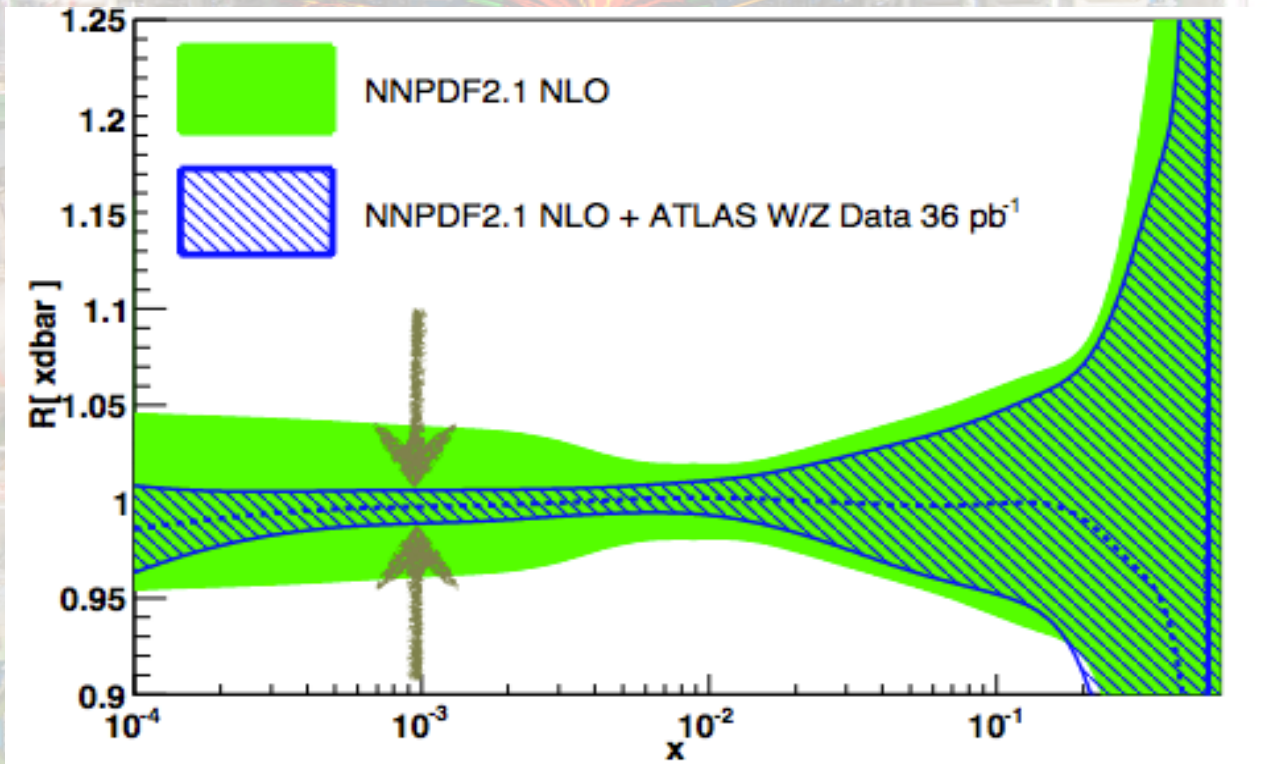




IMPACT ON PDFs

- W/Z results included NNPDF2.2
  - inclusive, differential cross-sections, asymmetry and W/Z+jets results
- Showing impact on W/Z inclusive cross-section and Asymmetry results
  - compete set of plots can be found at the PDF4LHC talk

https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=145744

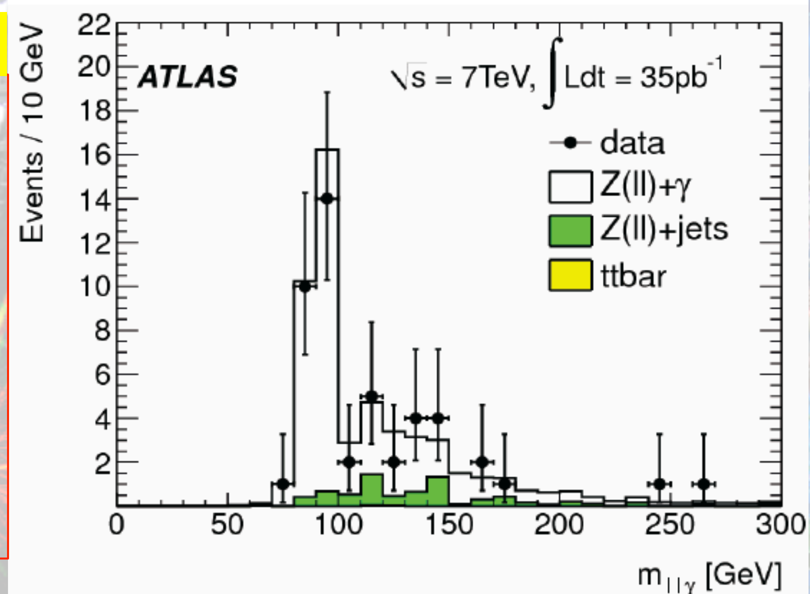


DI-BOSONS FINAL STATES

W/Z+γ Production

JHEP 1109 (2011) 072

- Highest cross-section diboson process
  - Probe anomalous TGC (ZZγ zero in SM), but new physics, could enhance the production rate
  - Background to searches (e.g. techni-rho, techni-omega, GMSB SUSY)
- High p_T, isolated lepton, Isolated photon
- 48 events Zγ and 192 events Wγ
- Compare well with NLO, uncertainty ~ 20%

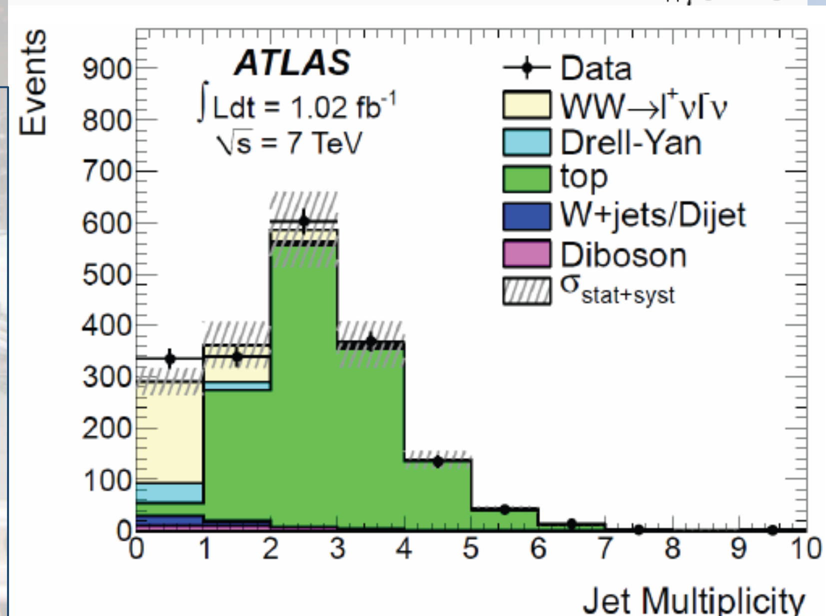


WW Production

ATLAS-CONF-2011-110

- W^+W^- production via qq(~97%) and gg (~3%)
  - Sensitive to TGC
  - Test of QCD, via gg→WW
  - irreducible background for H→WW
- Two High p_T leptons, Missing Transverse Energy
- Cut on jet multiplicity to remove top
- Cross-section

$$48.2 \pm 4.0(\text{stat}) \pm 6.4(\text{syst}) \pm 1.8(\text{lumi})\ \text{pb.}$$



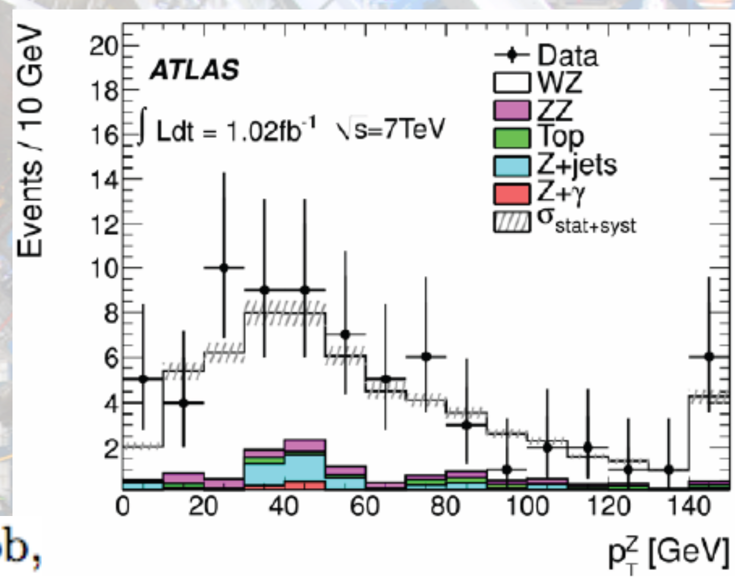
Di-bosons Final States

WZ Production

arXiv:1111.5570

- New particles decaying into WZ boson e.g. W', Anomalous TGCs
  - Different sensitivity compare than WW or W/Zγ production
- Cleaner than WW
  - S:B ~ 5:1
- Analysis uses the four channels with leptonic decays, 50 signal candidates

$$\sigma^{tot}_{WZ} = 20.5^{+3.1}_{-2.8}(\text{stat.})^{+1.4}_{-1.3}(\text{syst.})^{+0.9}_{-0.8}(\text{lumi.})\ \text{pb},$$

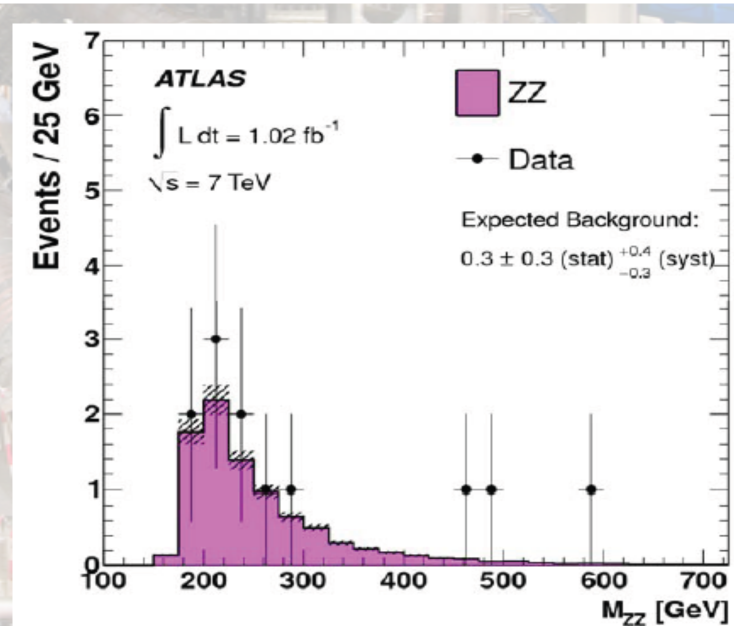


ZZ Production

Phys. Rev. Lett 108, 041804 (2012)

- Irreducible background for H→ZZ
- Four Isolated leptons
  - Not much backgrounds from SM processes
  - Multiple lepton combination is possible
- Small Cross section already accessible
  - Total Cross section: few pb
  - 1 fb^{-1} enough to make first, statistically

$$\sigma^{tot}_{ZZ} = 8.5^{+2.7}_{-2.3}(\text{stat})^{+0.4}_{-0.3}(\text{syst}) \pm 0.3(\text{lumi})\ \text{pb},$$



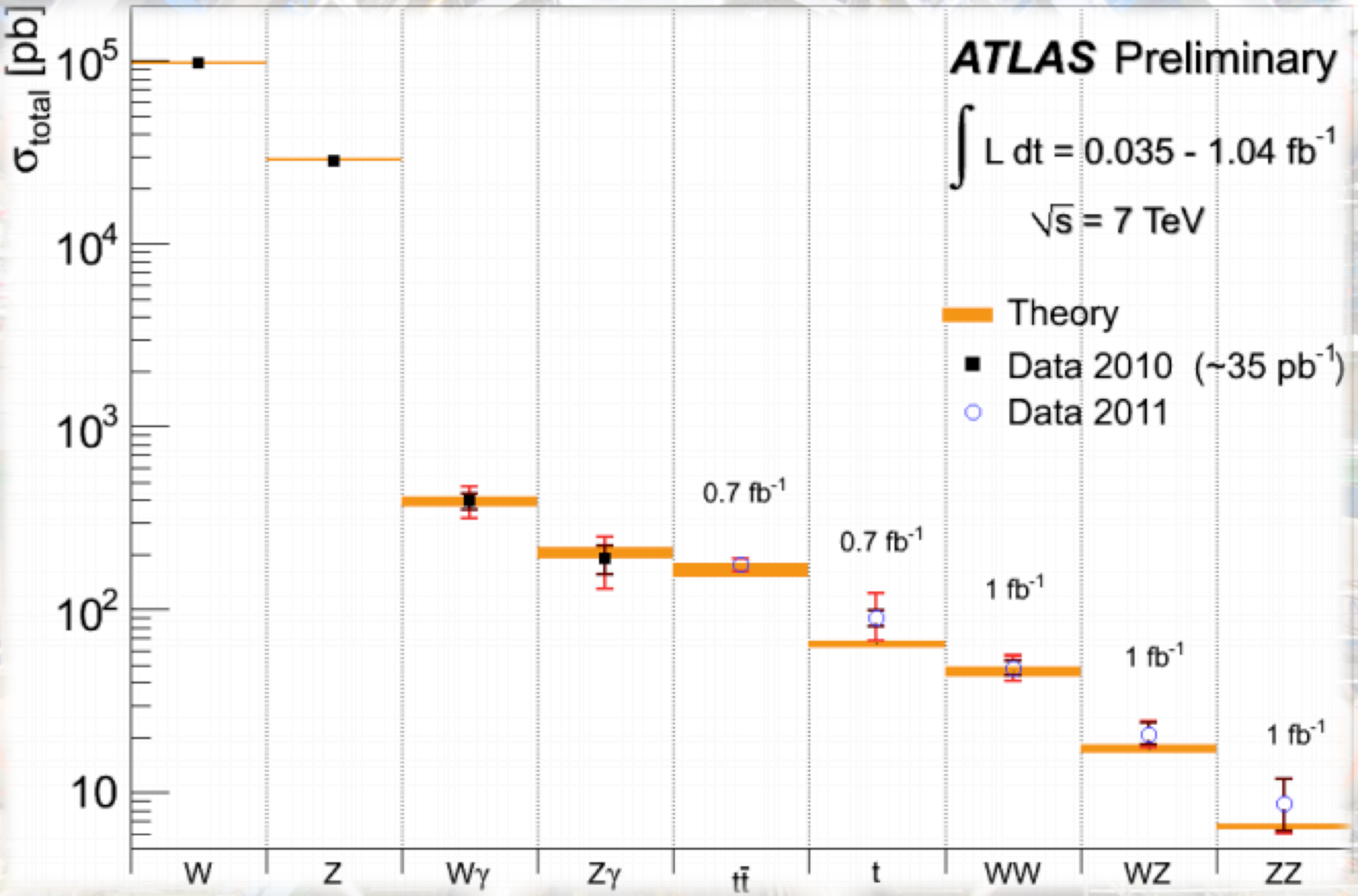
PRECISION OF SM CROSS-SECTION MEASUREMENTS

- ✓ Inclusive single bosons measurements are the most precise measurements , 1 – 2*%
- ✓ Inclusive di-bosons measurements follow the precision of the order of 5 - 7%
- ✓ W,Z+jets, Top pair cross-sections are still at the level of 8, >9% precision.

cross-section	n-lep	$\mathcal{L}$	Syst.	Syst. sources	Refs.
$\sigma_{t\bar{t}}$	2 lep	$35\,pb^{-1}$	$\sim 8\,\%$	b-tagging, MC	1108.3699
σ_{W+jets}	1 lep	$36\,pb^{-1}$	$\sim 9\,\%\ N_{jets} \geq 1$	JES, lep-id	1201.1276
			$\sim 35\,\%\ N_{jets} \geq 4$		
σ_{Z+jets}	2 lep	$36\,pb^{-1}$	$\sim 9\,\%\ N_{jets} \geq 1$	JES, lep-id	1111.2690
			$\sim 23\,\%\ N_{jets} \geq 4$		
σ_{WZ}	3 lep	$1.02\,fb^{-1}$	$\sim 7\,\%$	lep-id, $E_{\mathrm{T}}^{\mathrm{miss}}$	1111.5570
σ_{ZZ}	4 lep	$1.02\,fb^{-1}$	$\sim 4.6\,\%$	lep-id	1110.5016
σ_{W}	1 lep	$35\,pb^{-1}$	$\sim 1.2\,\%$ fid.	lep-id, $E_{\mathrm{T}}^{\mathrm{miss}}$, QCD	1109.5141
			$\sim 2.0\,\%$ tot.		
σ_{Z}	2 lep	$35\,pb^{-1}$	$\sim 1.0\,\%$ fid.	lep-id, isol, QCD	1109.5141
			$\sim 2.0\,\%$ tot.		

* excluding luminosity errors

SUMMARY OF W/Z BOSON RESULTS



✓Good agreement between data and SM expectations
✓Experimental precision starts to challenge the theory calculation

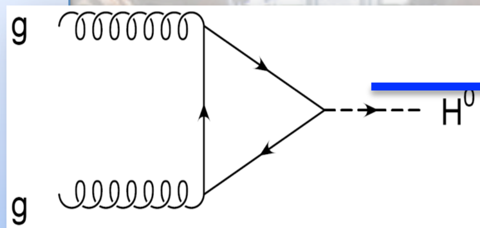
Menu for Today's Seminar

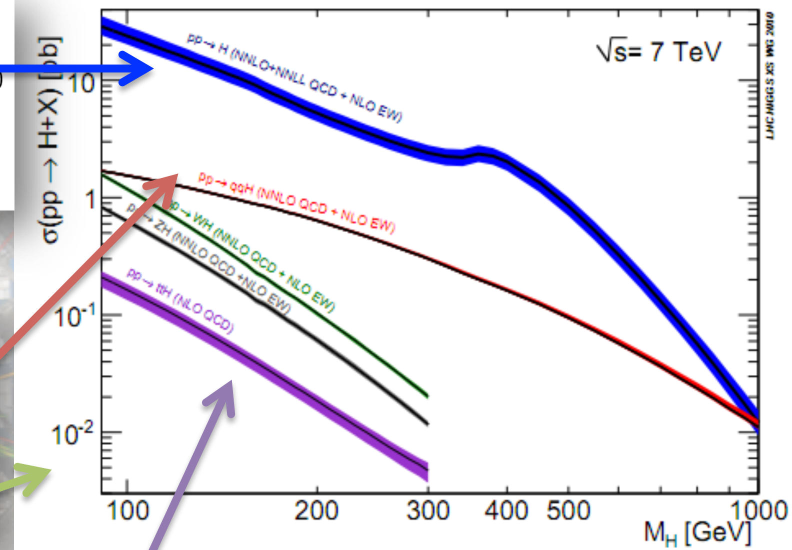
- Detector and its operations in 2011
- Luminosity Measurements
  - ATLAS Strategy
  - van der Meer Scans at ATLAS
  - Luminosity results and prospects for 2012
- Physics Topics
  - Results from Electroweak Bosons (W and Z)
    - Total and differential Cross-section measurement
    - Lepton Charge Asymmetries in $W \rightarrow l\nu$
    - W-polarization studies
  - Diboson Final States
    - $W/Z+\gamma$, WW, WZ, ZZ production
  - Higgs Searches: Latest update
- Summary

HIGGS PRODUCTION AT LHC

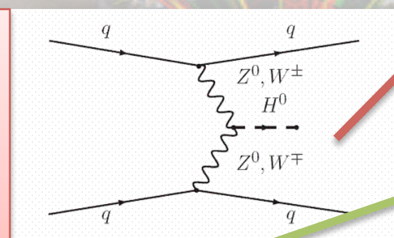
CERN-2011-002; arXiv:1101.0593

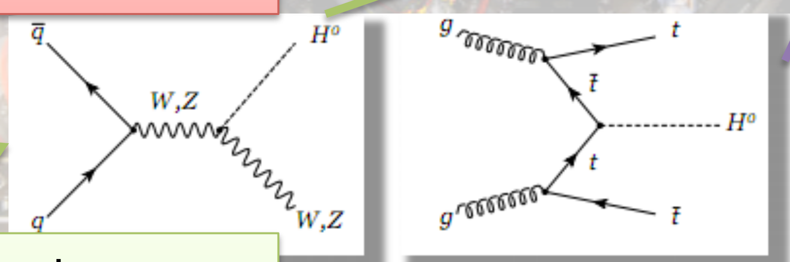
- Gluon fusion:
  - gg→H
  - dominant mechanism
  - channels:
    H→WW,ZZ,γγ



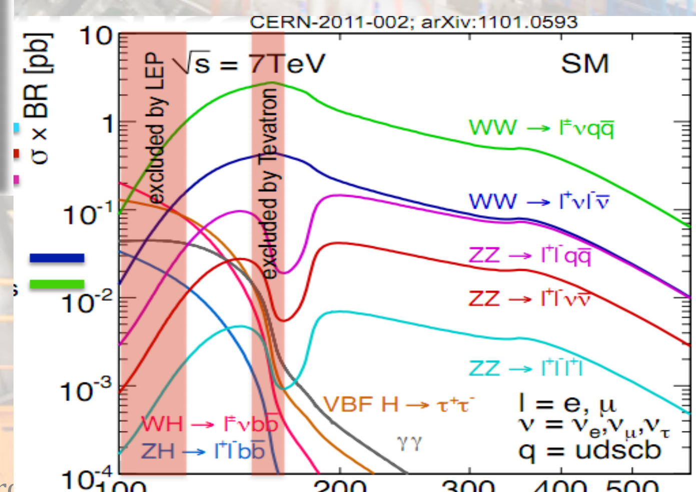


- Vector Boson Fusion (VBF):
  - qq→qqH
  - smaller but distinct
  - Channels
    H→ττ





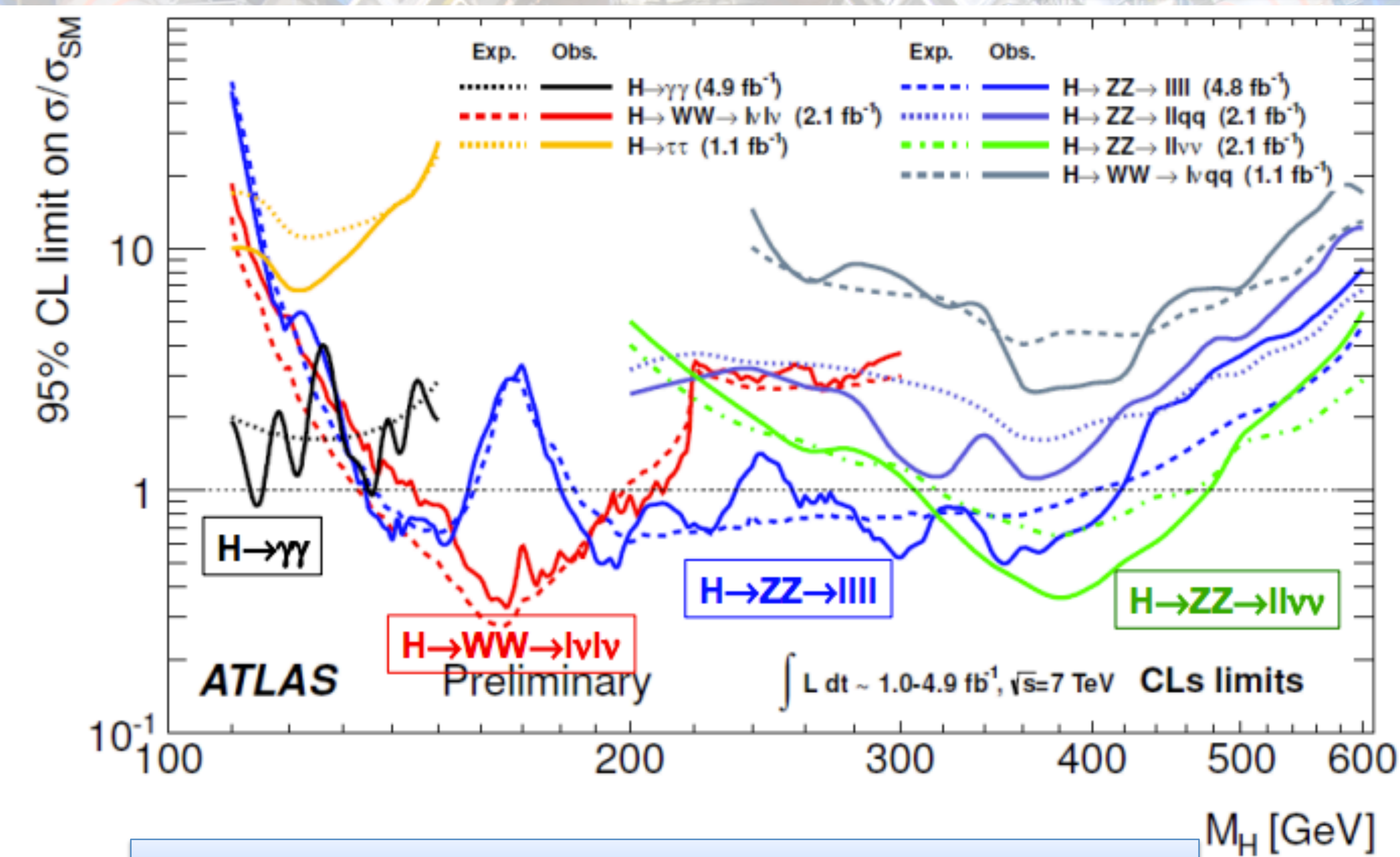
- Associated Production:
  - qq→WH, ZH, ttH
  - the smallest and difficult
  - Channels
    H→bb



HIGGS COMBINATION

Update after Dec. 13th Council meeting

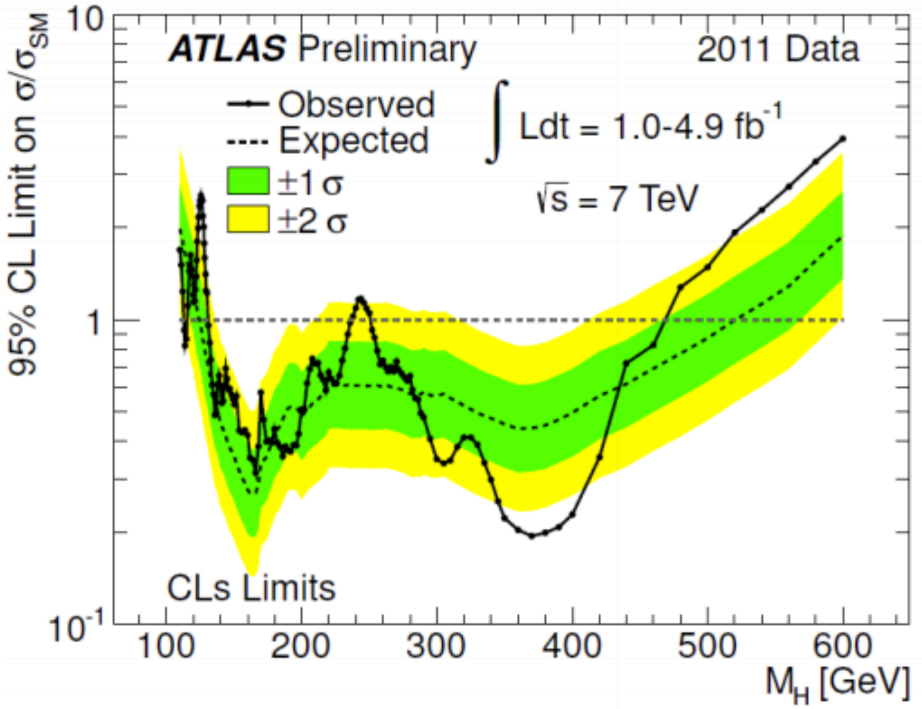
ATLAS-CONF-2011-163

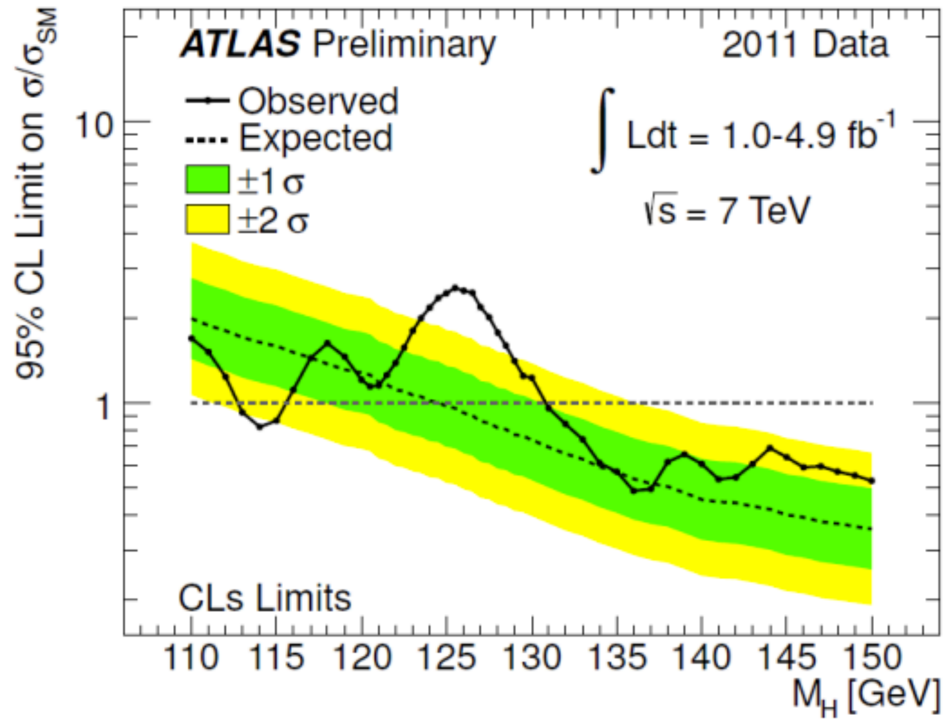


Expected (dashed lines) & Observed (Solid Lines) exclusions limits

HIGGS COMBINATION

Combined upper limits on Higgs Cross-sections





Observed Exclusions:
ATLAS: 112.7 – 115.6 GeV, 131 – 237 GeV, 251 – 468 GeV
CMS: 127 – 600 GeV
LEP: < 114.4GeV

- Full dataset update for most the channels for Moriond 2012 conference
- ATLAS+CMS combination??? may be after Moriond

LHC RUNNING @YEAR 2012

E_{beam} = 4 TeV/ beam

Bunch Spacing = 50ns

β^{*} = 0.6m

LHC Running @ 2012 (outcome from Chamonix workshop 2012)

L_{peak} = 6.8 X $10^{33}cm^{-2}s^{-1}$

Total Int. Lumi. = $15fb^{-1}$

$\langle\mu\rangle = 35$

Chamonix Workshop 2012 link at

https://indico.cern.ch/conferenceOtherViews.py?view=standard&confId=164089

Physics Shopping List at ATLAS

MEGA

- Higgs Searches
- SUSY Searches
- Extra dimensions
- Exotics
- B-Physics

The detail of all the latest results can be found at https://twiki.cern.ch/twiki/bin/view/AtlasPublic

ATLAS EXPERIMENT - Public Results

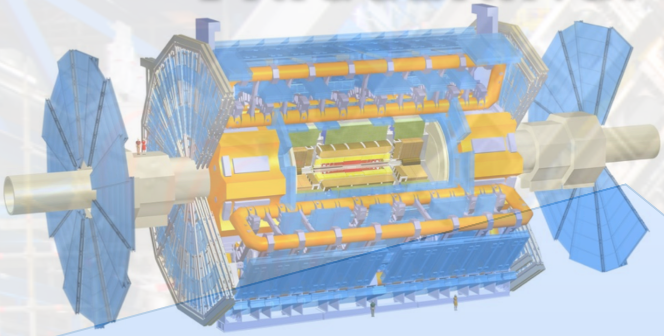
This is the central ATLAS results page. It is intended for physicists who are looking for documentation on ATLAS performance results. ATLAS results from LHC collision data are made available via three routes: publications, lis plots; and conference (CONF) notes, which describe preliminary results. Approved event displays are also availa plots and CONF notes are given in the tables below. In addition, public PUB notes may be available, these typica to collision data performance, or studies of the physics capabilities of ATLAS using simulation. PUB notes are us

SUMMARY

- Excellent year of LHC running and for ATLAS
- There are lots of efforts going on to measure the ATLAS luminosity with better precision
- No Surprises yet but many SM processes have been studied and have shown good agreement between data and MC
- Many SM precision measurements are underway with full available statistics (~ $5fb^{-1}$)
- ATLAS is covering almost every possible area of physics at LHC
- Looking forward to year 2012 with higher luminosity and higher beam energy

EXTRA SLIDES

TRIGGERING: REAL TIME EVENT SELECTION



Finding a Needle in a Million Haystacks

40 MHz (40 TB/s)

Level 1 – Special hardware processors

75 kHz (75 GB/s)

Level 2 – Embedded processors + PC Farms (Region of Interest)

1 kHz (1 GB/s)

Level 3 – PC Farms (several thousands PCs) (Full event)

100 Hz (100 MB/s)

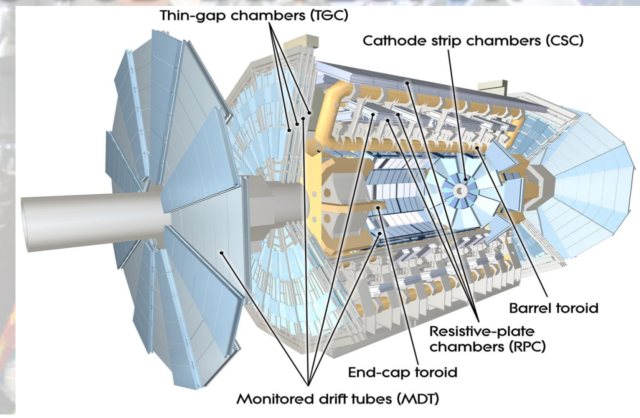
Data Recording and offline analysis

- Beam Collides every 50nSec
- Something happens every crossing
- Must select the "interesting ones"

ATLAS: Zoom in to sub-detector

- Muon Spectrometer
  - ○Air-core toroids with thin gap muon chambers

|η| < 2.47, Muon Trigger, momentum resolution < 10% upto $p_T \sim$ 1TeV



- Calorimeters
  - ○LAr Calorimeter (EM)

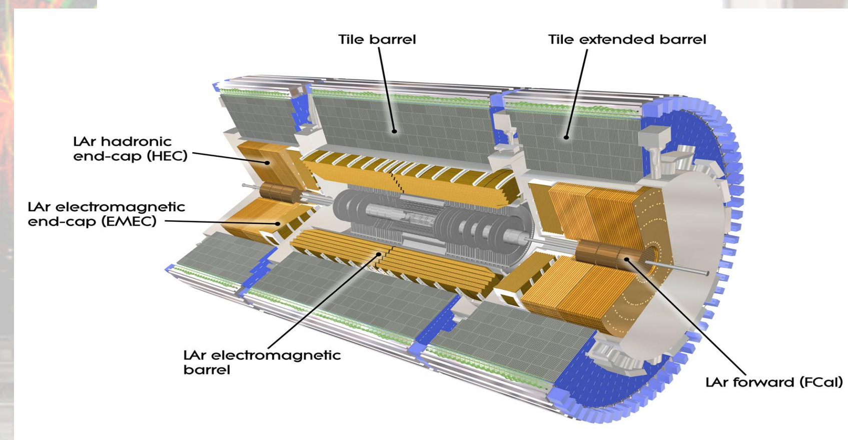
|η| < 3.2, Energy Res. 10%/sqrt(E)

  - ○Tile Calorimeter (Hadronic)

|η| < 5.0, Energy Res. 50%/sqrt(E) + 0.03

e/photon identification & meas.

jets and Missing Energy measurement

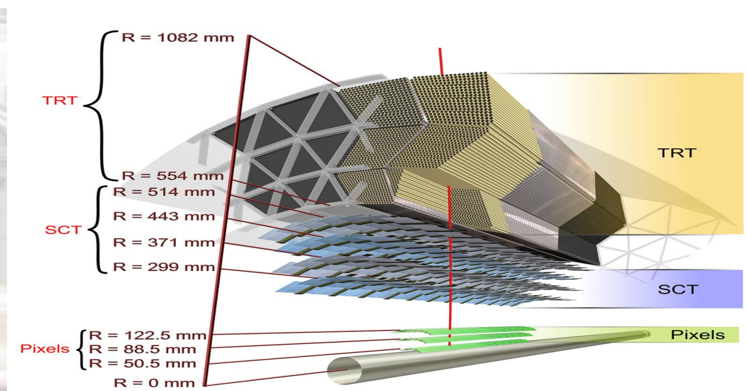


- Inner Detector (tracking)
  - ○Si Pixel Layers
  - ○Semiconductor Tracker
  - ○Transition Radiation Tracker

(|η| < 2.5, B=2T)

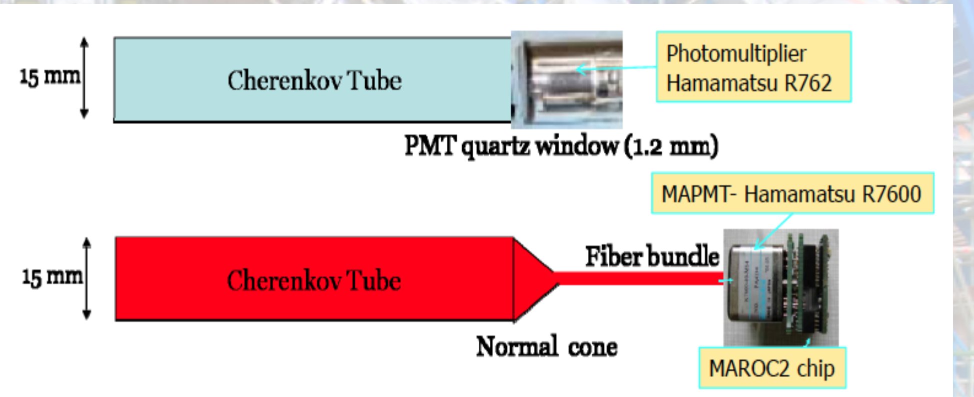
σ/pT < 4% for p_T ~100 GeV

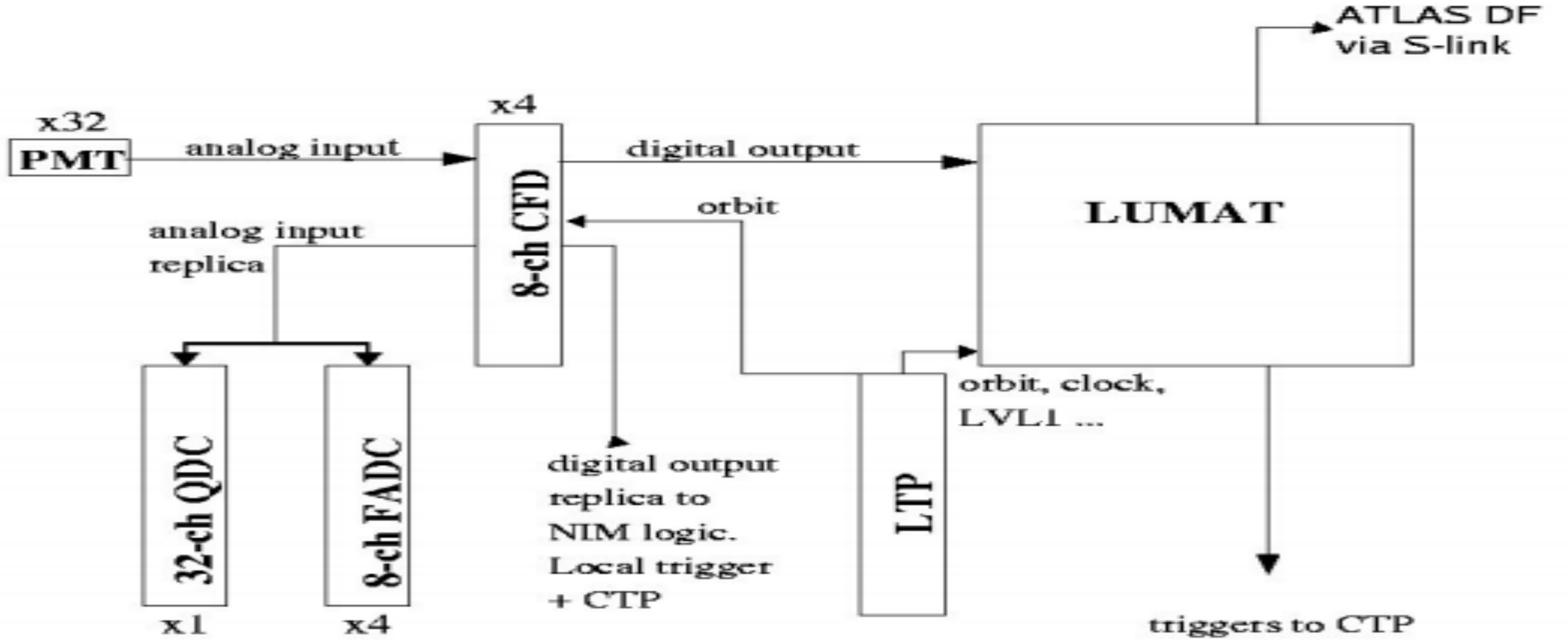
Good e/pi separation



LUMINOSITY MEASUREMENT USING CHERENKOV INTEGRATING DETECTOR (LUCID)

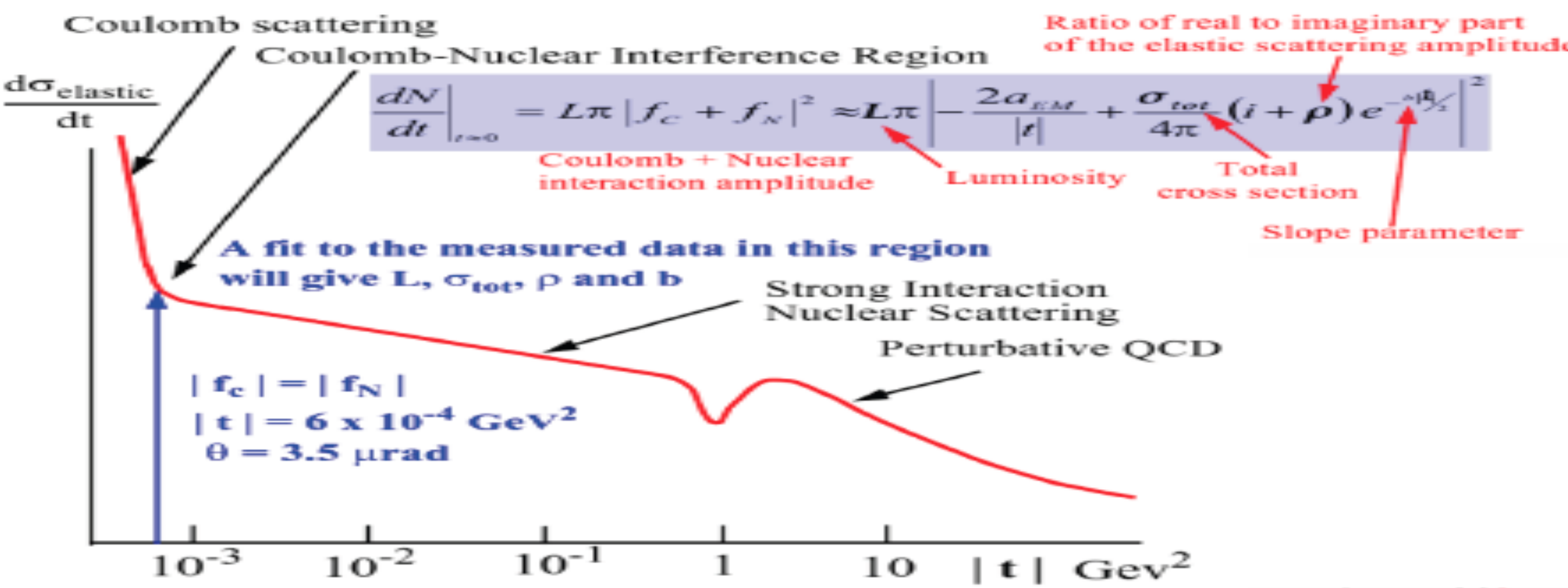
- The LUCID electronics is de-coupled from DAQ so that it can provide the luminosity determination even if no global ATLAS run is in progress





ALFA DETECTOR PRINCIPLE

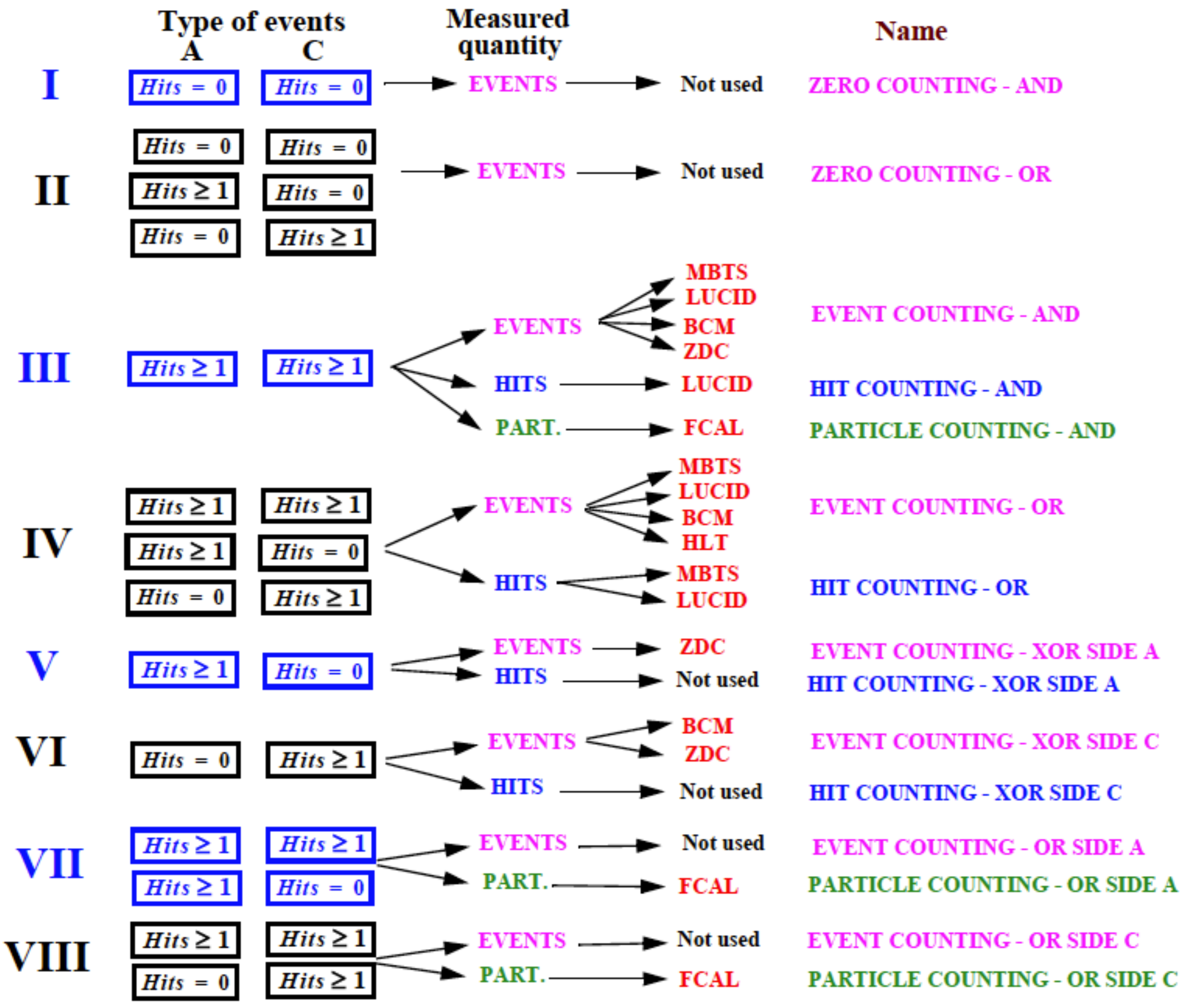
- … Coulomb interference (ALFA)
  - Measure at such small *t* - values that σ_{el} becomes sensitive to the Coulomb amplitude



$$\left.\frac{dN}{dt}\right|_{t\to 0} = L\pi\,|f_C + f_N|^2 \approx L\pi \left| -\frac{2a_{EM}}{|t|} + \frac{\sigma_{tot}}{4\pi}(i+\rho)e^{-b|t|/2} \right|^2$$

- effectively a normalization of $\mathcal{L}$ to the exactly calculable QED amplitude
- no total-rate measurement → no add'tl detectors needed to cover $\eta > 5$
- used by UA4: $\mathcal{L}$ to 2-3 %

DEFINITION OF LUMINOSITY ALGORITHMS



Systematic Errors on Luminosity

	ATLAS-CONF- 2011-116 (~ 2 fb^{-1}) %	%	Updated 2011 (5 fb^{-1}, projected) %	%
DCCT calibration	2.73		0.23	
FBCT bunch-by-bunch fractions	1.30		0.20	
Ghost charge correction	0.18		0.18	
Subtotal, bunch-charge product		*3.03*		*0.35*
Beam centering	0.10		0.10	
Emittance growth & other non-reproducibility	0.40		1.20	
Beam position jitter	0.30		0.30	
Bunch-to-bunch σ_{vis} consistency	0.40		0.40	
Fit model	0.80		0.40	
Background subtraction			0.20	
Dynamic beta			0.80	
Non-linear transverse correlations	0.50		0.50	
Reference $\mathcal{L}_{sp}$			0.30	
μ-dependence during vdM scan	0.50		0.50	
Length scale calibration	0.30		0.30	
ID lengh scale	0.30		0.30	
BCM H/V calibration inconsistency	0.70		0.70	
Subtotal, calibration-scan systematics		*1.49*		*1.95*
Total systematic uncertainty on σ_{vis}		***3.4***		***2.0***

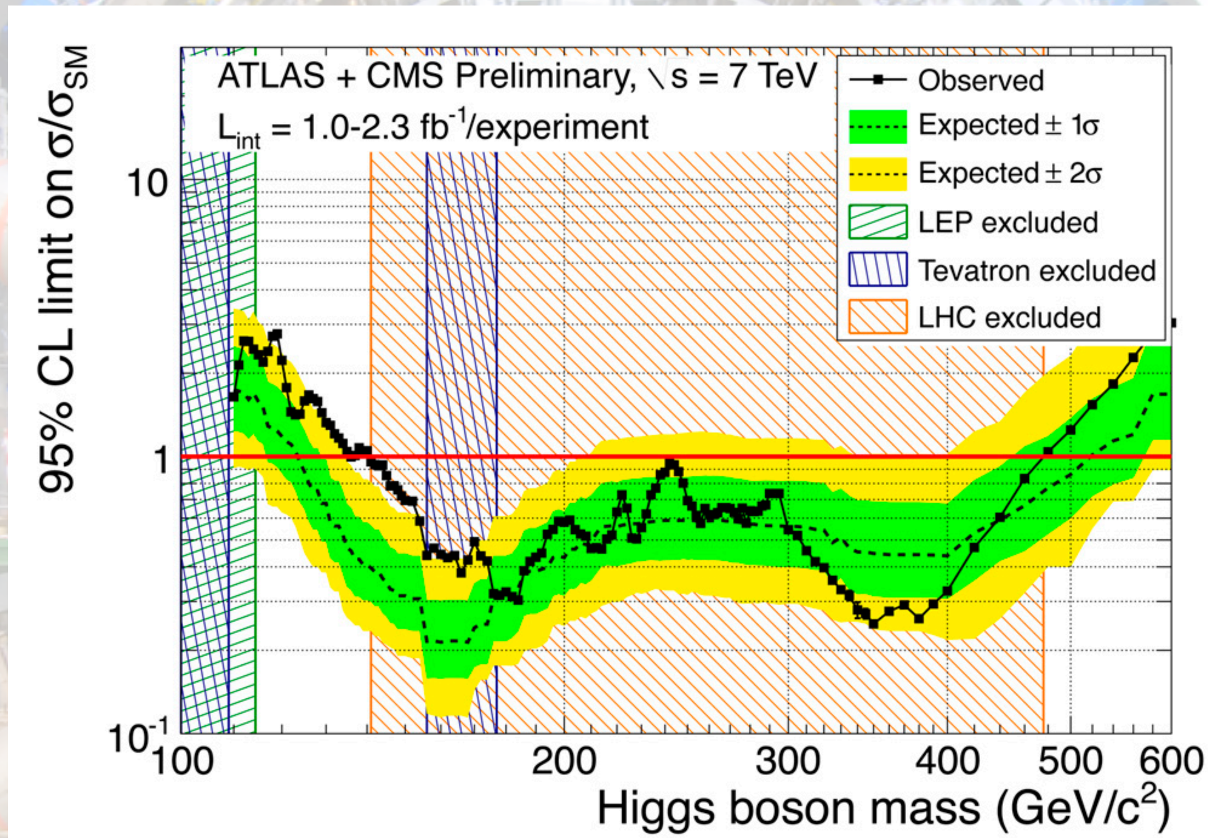
Some of these still in flux

2010 vs 2011

	vdM Scan IV–V (1 October, 2010)	*vdM* Scan VII–VIII (15 May, 2011)
LHC Fill Number	1386	1783
Scan Directions	2 sets of horizontal plus vertical scans	
Total Scan Steps per Plane	25 ($\pm 6\sigma_b$)	25 ($\pm 6\sigma_b$)
Scan Duration per Step	20 s	20 s
Number of bunches colliding in ATLAS & CMS	6	14
Total number of bunches per beam	19	38
Number of protons per bunch	$\sim 0.9 \cdot 10^{11}$	$\sim 0.8 \cdot 10^{11}$
β-function at IP [$\beta^\star$] (m)	~ 3.5	~ 1.5
Transverse single beam size σ_b (μm)	~ 60	~ 40
Half crossing angle (μrad)	± 100	± 120
Typical luminosity/bunch ($\mu b^{-1}/s$)	0.22	0.38
μ (interactions/crossing)	1.3	2.3

Reason for another scans: Because of change in Lumi. detector read out etc.

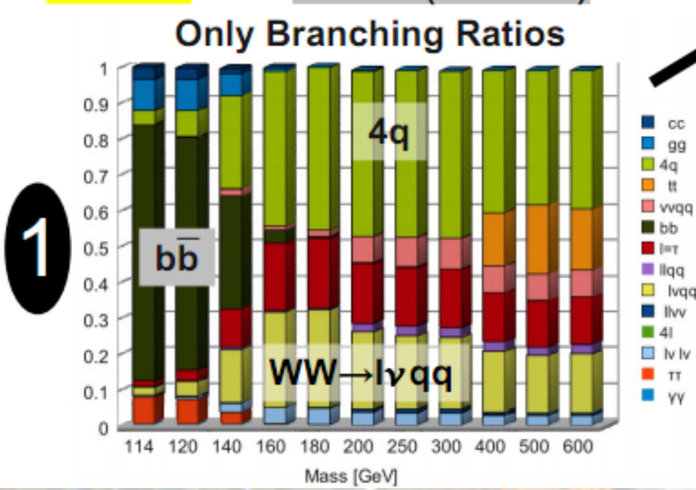
ATLAS and CMS combined Higgs Searches

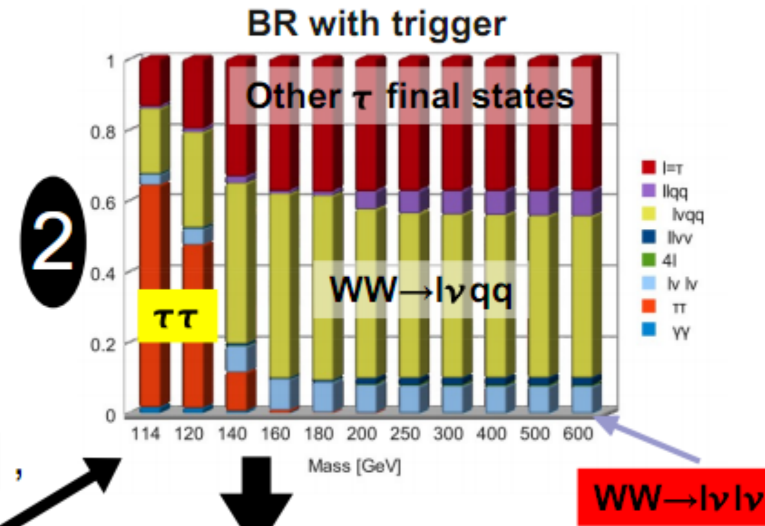


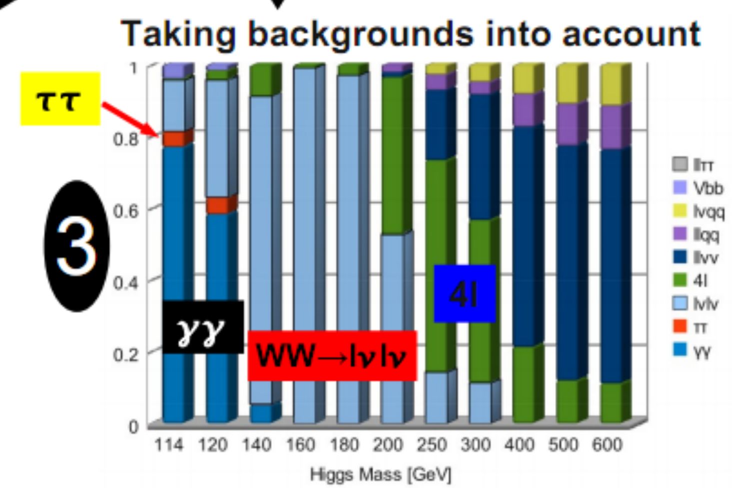
- Idea is to include or exclude the Standard Model Higgs

Low Mass Higgs Searches

- So far, the integrated luminosity allows mainly for a Higgs search in gg→H production
- Viable channels need:
  (1) High branching ratio
  (2) Good trigger
  (3) Low background level
- Channels remaining in the end:
  $H \to WW \to l\nu l\nu$, $H \to ZZ \to 4l$, $H \to \gamma\gamma$,
  $H \to \tau\tau$ and $W/ZH(H \to b\bar{b})$



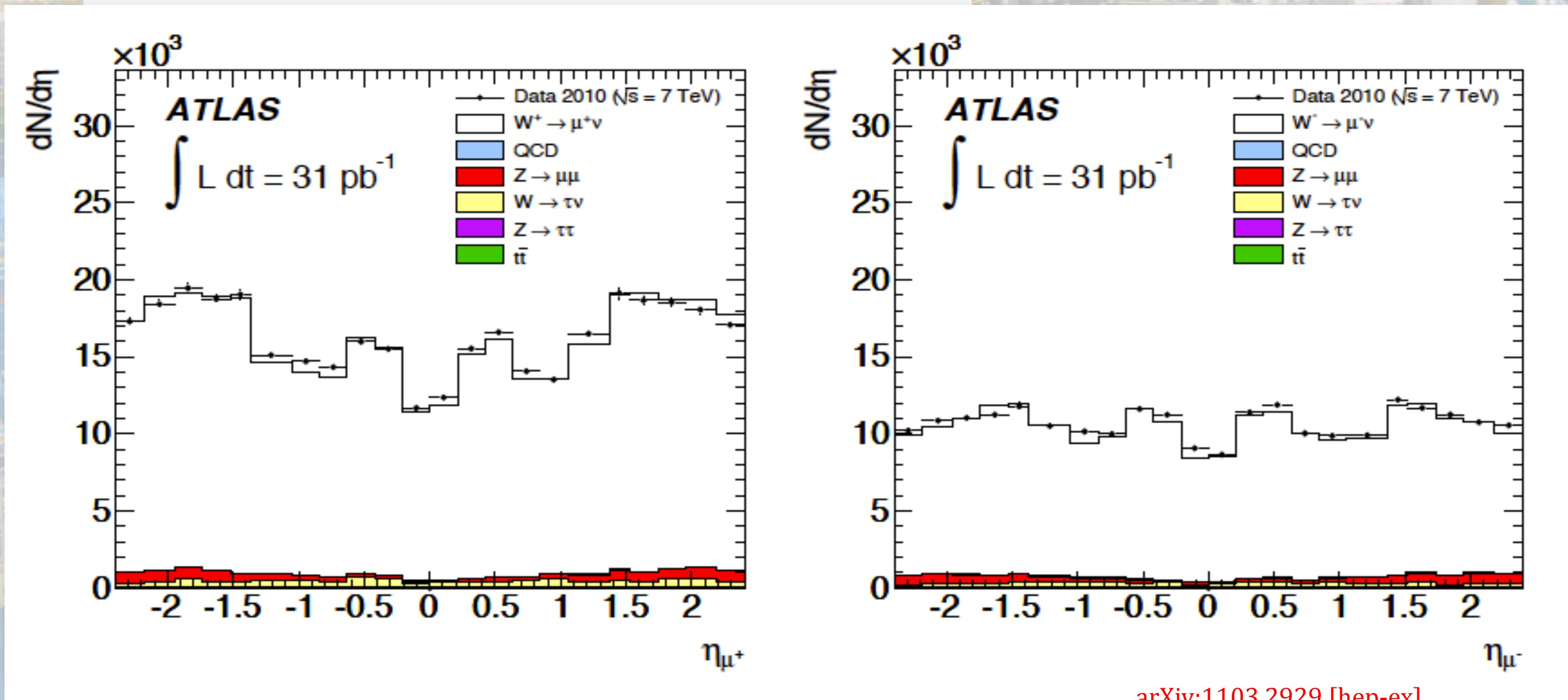




Lepton Charge Asymmetry in W-boson

- Provides important information about the proton structure as described by the parton distribution function
- Parton Momentum Fraction Range (x) $10^{-3} < x < 10^{-1}$

$$A_\mu = \frac{d\sigma_{W\mu^+}/d\eta_\mu - d\sigma_{W\mu^-}/d\eta_\mu}{d\sigma_{W\mu^+}/d\eta_\mu + d\sigma_{W\mu^-}/d\eta_\mu}$$



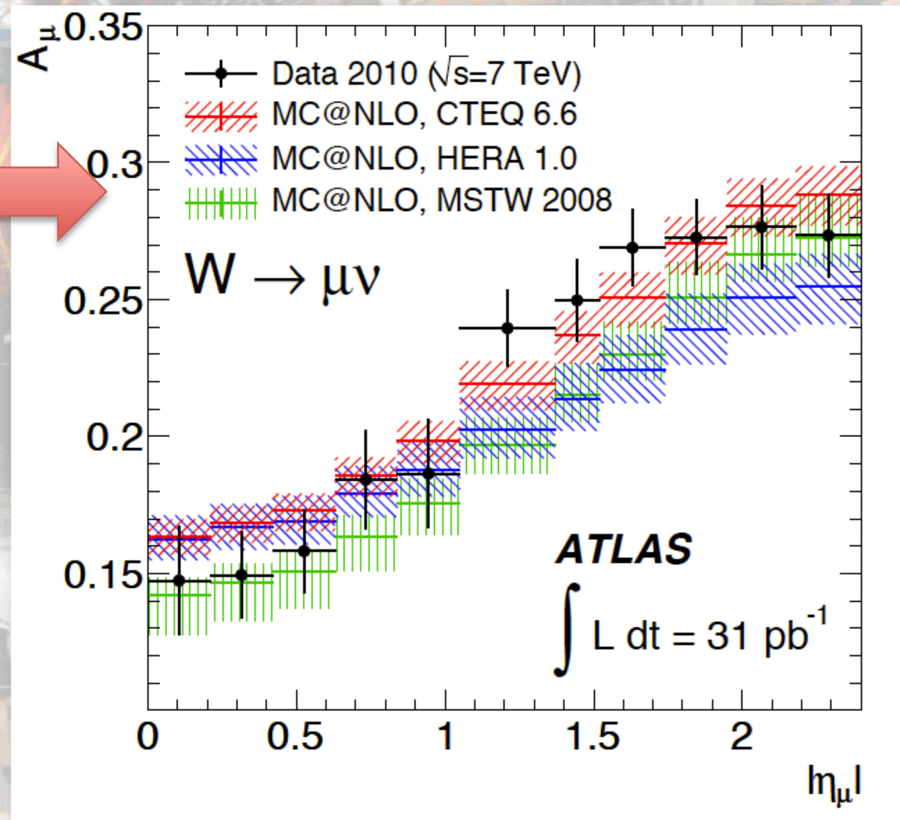
arXiv:1103.2929 [hep-ex]
submitted to Phy. Lett. B

Lepton Charge Asymmetry in W-boson

- Systematic uncertainities calculated in each bin of η
- Dominant systematic uncertainties comes from the trigger and reconstruction efficiencies

All predictions are presented with 90% confidence level error bands

Data is ~ compatible with all the predictions with different PDF's sets



arXiv:1103.2929 [hep-ex]
submitted to Phy. Lett. B

Higgs Searches In Different Channels

Table 1: Summary of the individual channels contributing to the combination. The central number in the three-part mass ranges indicates the transition from a low-m_H optimized to high-m_H optimised event selections.

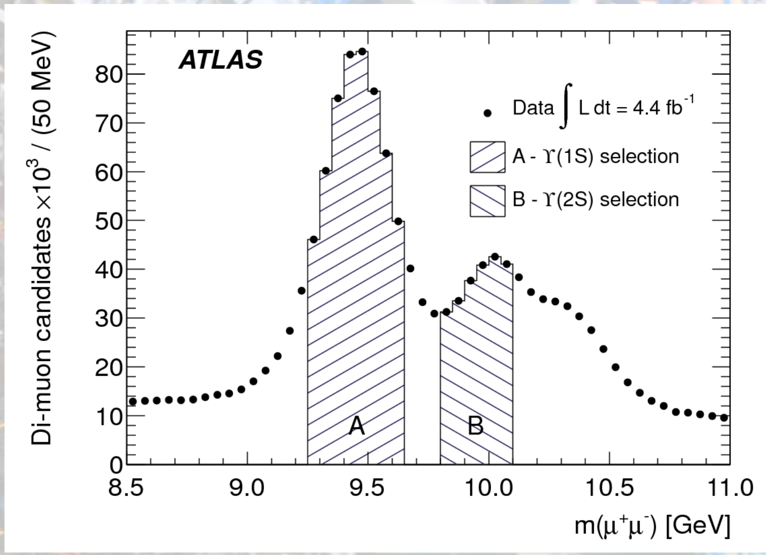
Higgs Decay	Subsequent Decay	Additional Sub-Channels	m_H Range	L [fb^{-1}]
$H \to \gamma\gamma$	–	9 sub-channels ($p_T^{\text{thrust}} \otimes \eta_\gamma \otimes$ conversion)	110-150	4.9
$H \to ZZ$	$\ell\ell\ell'\ell'$	$\{4e, 2e2\mu, 2\mu2e, 4\mu\}$	110-600	4.8
	$\ell\ell\nu\bar{\nu}$	$\{ee, \mu\mu\} \otimes$ {low pile-up, high pile-up}	200-280-600	4.7
	$\ell\ell q\bar{q}$	$\{ee, \mu\mu\} \otimes$ {b-tagged, untagged}	200-300-600	4.7
$H \to WW$	$\ell\nu\ell\nu$	$\{ee, e\mu, \mu\mu\} \otimes$ {0-jet, 1-jet, VBF}	110-300-600	4.7
	$\ell\nu jj$	$\{e, \mu\} \otimes$ {0-jet, 1-jet}	300-600	4.7
$H \to \tau\tau$	$\ell\ell 4\nu$	0-jet $\oplus$ {1-jet, VBF, VH}	110-150	4.7
	$\ell\tau_{\text{had}}3\nu$	$\{e, \mu\} \otimes$ {0-jet} $\otimes$ $\{E_T^{\text{miss}} \gtrsim 20$ GeV$\}$ $\oplus$ $\{e, \mu\} \otimes$ {1-jet} $\oplus$ {VBF}	110-150	4.7
	$\tau_{\text{had}}\tau_{\text{had}}2\nu$	{1-jet}	110-150	4.7
$VH \to bb$	$Z \to \nu\nu$	$E_T^{\text{miss}} \in \{[120, 160), [160, 200), \geq 200$ GeV$\}$	110-130	4.6
	$W \to \ell\nu$	$p_T^V \in \{< 50, [50, 100), [100, 200), \geq 200$ GeV$\}$	110-130	4.7
	$Z \to \ell\ell$	$p_T^V \in \{< 50, [50, 100), [100, 200), \geq 200$ GeV$\}$	110-130	4.7

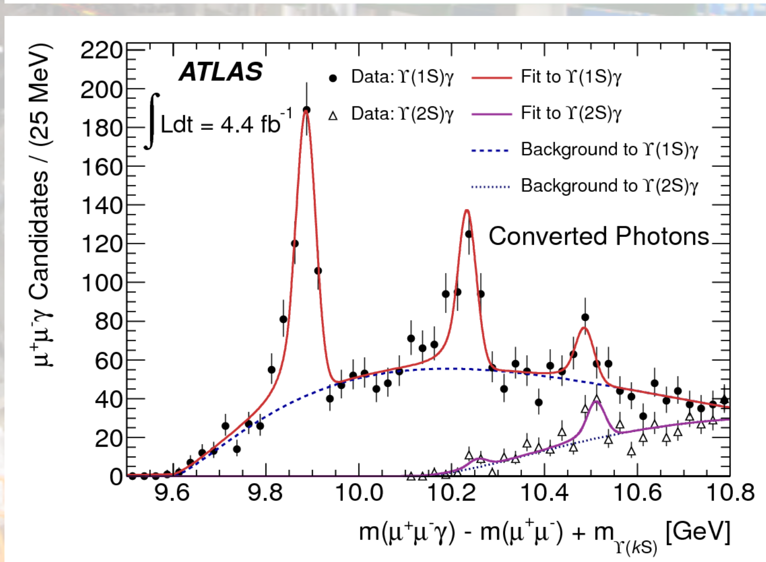
Observation of New χ_b state

- Measurement of $\chi_b(nP)$ properties provide a unique insight into QCD close to the $b\bar{b}$ threshold
- Reconstruction via radiative decays

$\chi_b(nP) \rightarrow \Upsilon(1S)\gamma$ and $\chi_b(nP) \rightarrow \Upsilon(2S)\gamma$
where $\Upsilon(1S,2S) \rightarrow \mu^+\mu^-$

- $\chi(3P)$ with M=10.530±0.005 (stat.)±0.009(syst.)GeV
- First Observation, predicted with M~10.52GeV
- Hyperfine splitting between triplet states J=0, 1, 2 of similar size as mass resolution





arXiv:112.5154