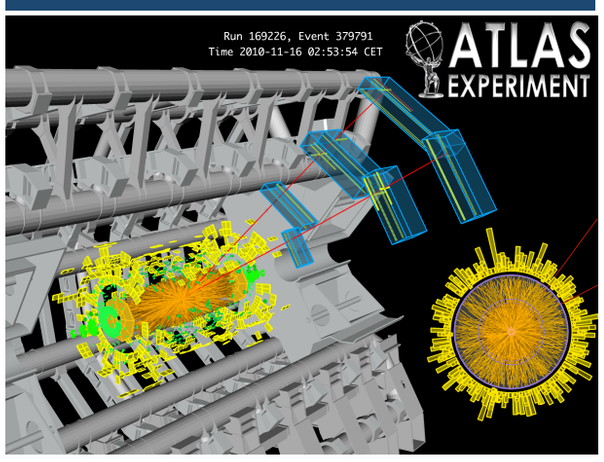
LHCC Poster Session - CERN, 23 March 2011

J/ψ Suppression and Z Boson Production in $\sqrt{s_{NN}}$ = 2.76 TeV Pb-Pb Collisions

Why Study J/ψ in Heavy Ions Collisions?

- Suppression of J/ψ yield is expected in **highly central events** in HI collisions
- The suppression is of interest because:
  - gives experimental sensitivity to medium temperature
  - could be due to quark-gluon plasma production
- A suppression was already observed in past experiments:
  - NA50 at CERN SPS in Pb-Pb collisions at $\sqrt{s_N}$ = 17.3 GeV
  - PHENIX at RHIC in Au-Au collisions at $\sqrt{s_N}$ = 200 GeV
- Then why study J/ψ yield at the Large Hadron Collider (LHC)?
  - suppression mechanisms not fully understood, new effects might be there
  - proposal of J/ψ enhancement at high energies from charm quark recombination
  - at the LHC the first Z measurement in Pb-Pb is possible
  - Z measurement is interesting as no suppression is expected in this case

J/ψ Candidate in a Heavy Ions Collisions Event



J/ψ Analysis Selection

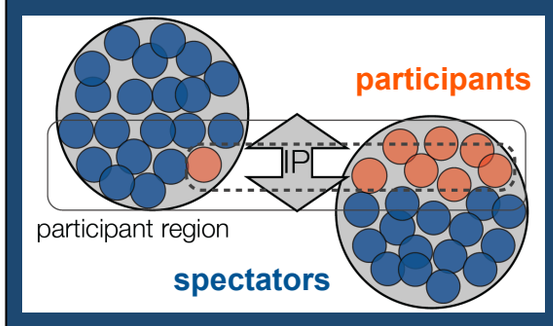
- Using almost all Pb-Pb integrated luminosity ~ 6.7 pb^{-1}
- Trigger selection, **~100% efficient**:
  - ATLAS Minimum Bias Trigger Scintillators (MBTS)
  - the two MBTS in the ATLAS endcaps must have triggered in coincidence, with $|\Delta t^{A-C}| < 5$ ns
- Requested one vertex with three pointing tracks per event
- Track reconstruction in Pb-Pb collisions is difficult due to high occupancy (especially for central events) → tighter selection than in p-p
- **J/ψ candidates selection:**
  - reconstruction requires 9 silicon hits per track
  - $p_T^{\mu1,\mu2} > 3$ GeV
  - both muons must have an inner detector track associated to a full track in the muon spectrometer (combined muons)

Goal of this Analysis

$$R_c = \frac{N_c^{corr}(J/\Psi \to \mu^+\mu^-)}{N_{40-80\%}^{corr}(J/\Psi \to \mu^+\mu^-) \cdot R_{coll}}$$

- R_c is the ratio defined as the J/ψ yield in centrality bin c divided by its yield in the most peripheral bin
- c subscript indicates that the given quantity is related to the c-th centrality bin
- $N_c^{corr} = N_c^{measured}/(\varepsilon_c^{J/\psi} \times w_c)$ where $\varepsilon_c^{J/\psi}$ is the reconstruction efficiency in the centrality bin, and w_c is the centrality bin width
- R_{coll} is the normalized mean number of binary collisions, $R_{coll} = N_{coll,c}/N_{coll,40\text{-}80}$
- Normalization on the most peripheral bin simplifies the measurement → only centrality-dependent effects should be considered in the efficiency computation and in the systematics assessment

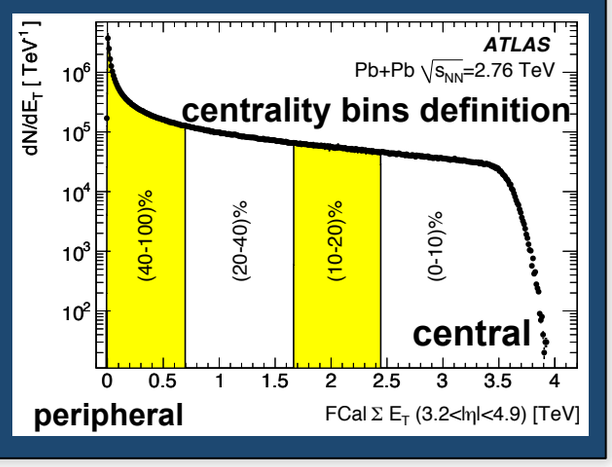
Heavy ions Collisions are not Point-Like: R_{coll} Definition



- In each ion-ion collision we have N_{coll} binary collisions between nucleons
- Hence any yield measurement must be normalized to N_{coll}
- N_{coll} is estimated using Glauber Monte Carlo simulation
- **N_{coll} depends on the Impact Parameter** (IP) between the two ions

How do we Measure the IP in Real Life?

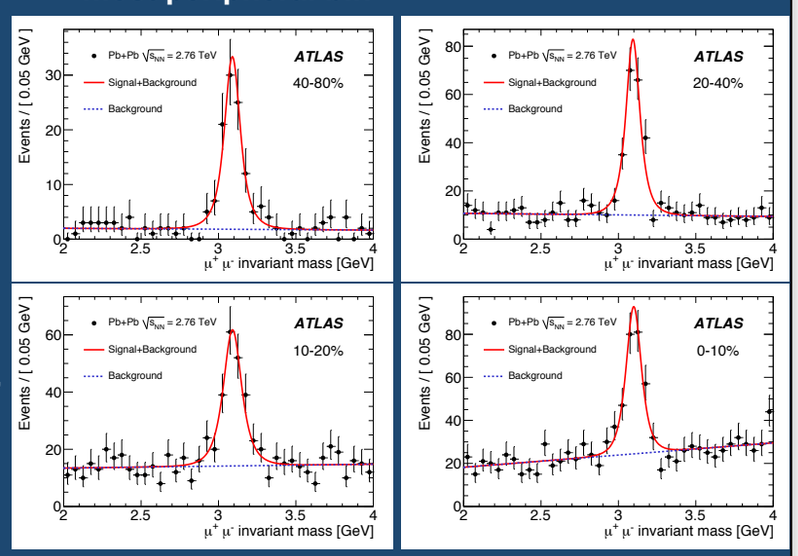
- We cannot measure the IP directly but...
- We can use the observation that the event track multiplicity increases when the IP decreases
- Using the transverse energy deposited in the ATLAS forward calorimeters (3.2 < |η| < 4.9) we define centrality, where:
  - central event → big IP
  - peripheral event → small IP
- We only use peripheral events up to 80% to reduce systematic on R_{coll}



J/ψ Yield Extraction

- 613 candidates selected
- **Two alternative methods** used
- Sideband subtraction method:
  - assuming linear background
  - signal region: $m_{inv} \in [2.95, 3.25]$ GeV
  - sidebands: $m_{inv} \in [2.4, 2.8] \cup [3.4, 3.8]$ GeV
- Unbinned maximum likelihood invariant mass fit with per-candidate uncertainty

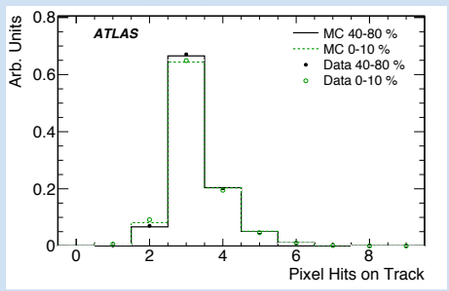
most peripheral bin

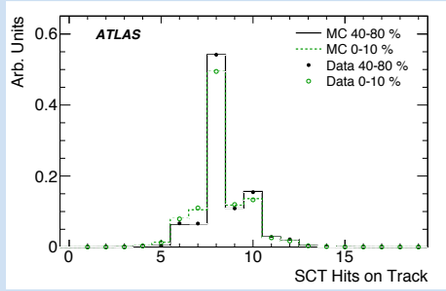


most central bin

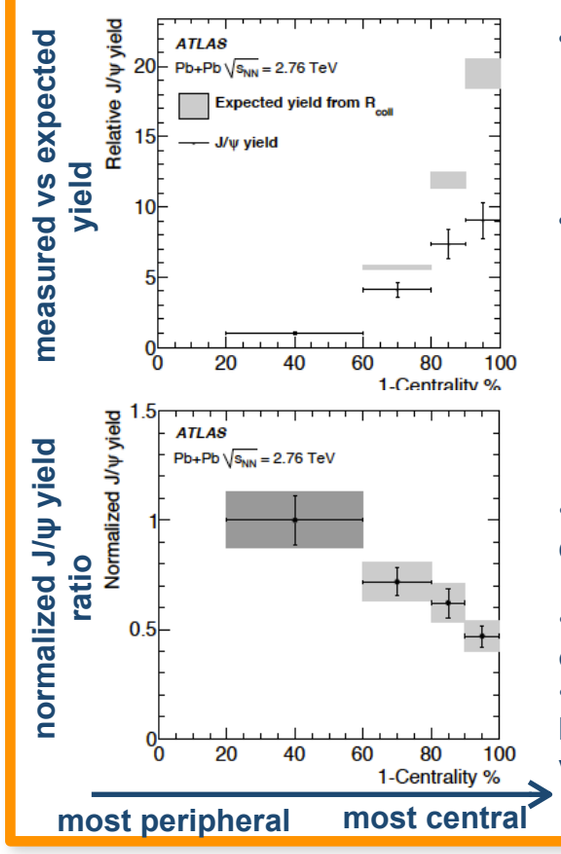
Efficiency Extraction and Monte Carlo Reliability

- We need to assess muon reconstruction efficiency dependence on centrality
- Not enough statistics for data-driven method
- Using Monte Carlo (MC) sample with Pythia p-p J/ψ candidates overlaid to Hijing simulated heavy ions events
- MC has been validated comparing basic tracks properties with the data sample → **very good agreement was found**
- Very small efficiency dependence found on centrality: drop of ~3% for most central events wrt most peripheral ones





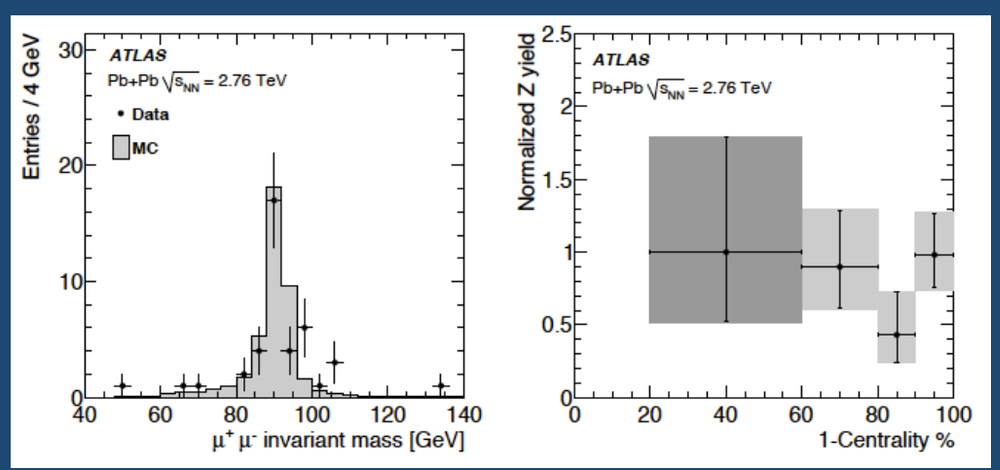
First Observation of J/ψ Yield Suppression at LHC



- **Upper plot:**
  - Grey boxes: expected yield from R_{coll} with systematic uncertainty
  - Black points: J/ψ measured yield with statistical uncertainty
- **Lower plot:**
  - Ratio of measured over expected yield
  - Black error bars: statistical uncertainty
  - Grey bands: statistical and systematic uncertainties summed in quadrature
  - Main systematics: reconstruction efficiency ~2.3-6.8%, signal extraction ~5.2-6.8%, R_{coll} estimate ~3.2-5.3%
- Data points in the ratio plot are not consistent with their average:

  $P(\chi^2, NDoF=3) = 0.11\%$
- **A significant decrease of the ratio is observed as a function of centrality**
- Qualitatively the same effect as observed by the NA50 and PHENIX experiments at very different center-of-mass energies

First Observation of Z Boson in Pb-Pb Collisions



- 38 Z boson candidates found
- Left plot: Z invariant mass peak in data (black points) compared to what expected in Monte Carlo simulation (grey histogram)
- Right plot: normalized Z yield ratio, black bars for statistical uncertainty, grey bands for systematic and statistical uncertainties summed in quadrature
- Systematics conservatively the same as for J/ψ measurement
- **No trend observed: not enough statistics but still useful check**

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Bibliography
- Phys Lett. B697 (2011) 294-312
- Phys. Rev. Lett. 105, 252303

ATLAS EXPERIMENT