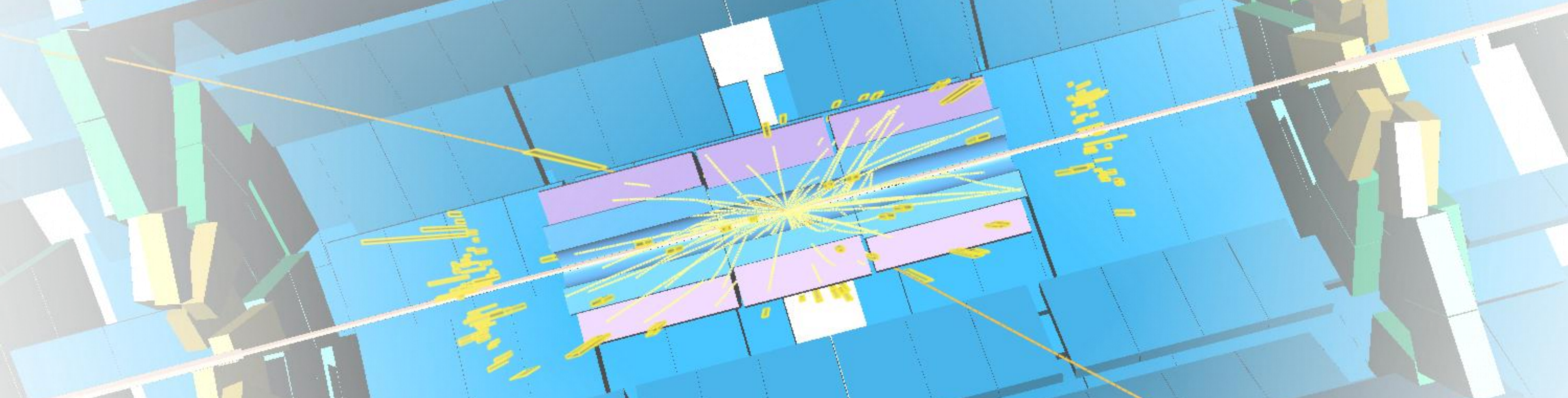
Measurement of Z → μμ cross section in LHC



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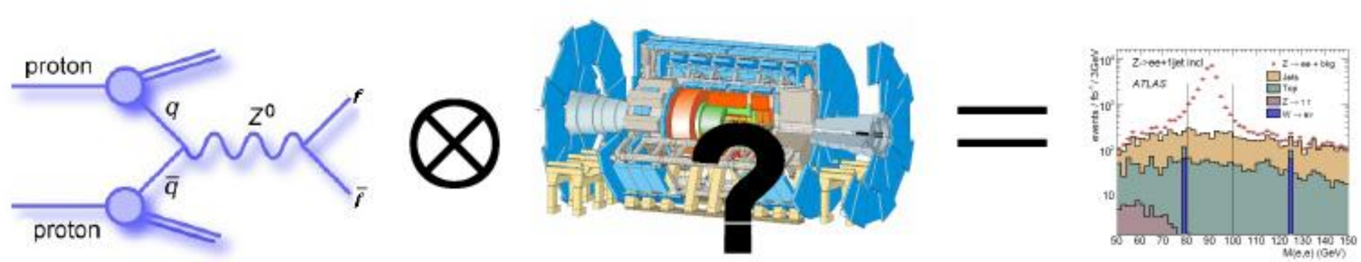
XIV LNF Spring School "Bruno Touschek" – 11-15 May 2009

Overview

The "re-discovery" of the Standard Model with the analysis of W and Z production crucial for ATLAS and others LHC experiments:

1. **Alignment of tracking detector (i.e. the ATLAS Muon Spectrometer) and calibration**
2. **Monte Carlo tuning and detector understanding**
3. **Setting new PDF constraints**



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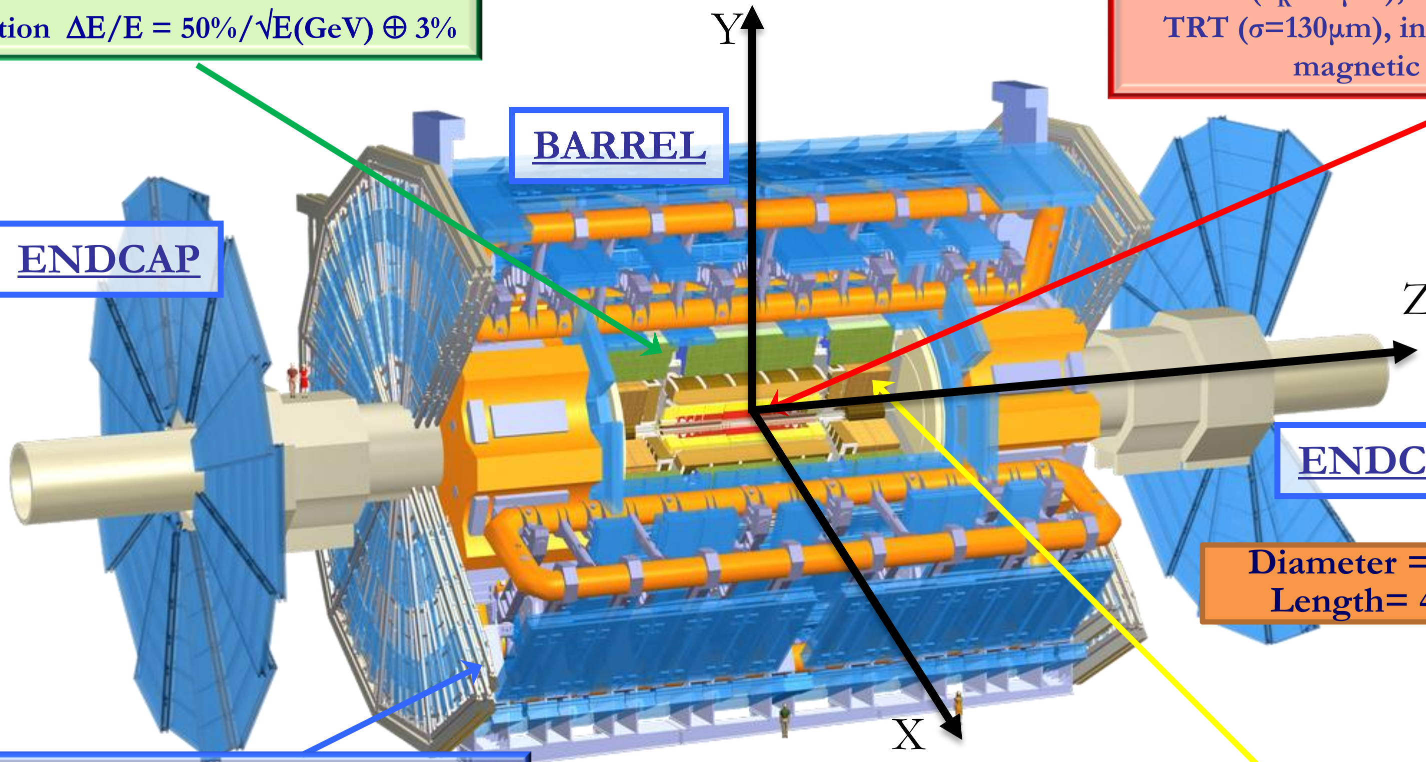
The ATLAS Experiment

ADRONIC CALORIMETER:
Iron -scintillator Tiles
Resolution $\Delta E/E = 50\%/\sqrt{E(GeV)} \oplus 3\%$

INNER TRACKER:
PIXEL (σ_R=10μm), SCT (σ_R=17μm), TRT (σ=130μm), in 2T soleinodal magnetic field



Diameter = 22 m
Length= 46 m

MUON SPECTROMETER:
3 Toroidal magnetic fiield(1 barrel,2 endcap)
MDT, RPC barrel
MDT, TGC , CSC endcap

EM CALORIMETER:
Alternate layers Pb-LAr
Resolution $\Delta E/E = 10\%/\sqrt{E(GeV)} \oplus$
$\oplus 0.5\%/E\ (GeV) \oplus 0.7\%$

Z production Cross Section

In this talk I will discuss the measurement of $Z\rightarrow\mu\mu$ cross - section with the first data with the ATLAS detector

$$\sigma_Z \cdot BR(Z \rightarrow \mu\mu) = \frac{N_Z^{obs} - N_B}{A \times \varepsilon_r \times \varepsilon_t \times \int L dt}$$

A: Fraction of events that passes kinematic and angular cuts

$\varepsilon_r \times \varepsilon_t$: Reconstruction and trigger efficiency (Tag & Probe method from data)

$\int L dt$: Sum on all data of Luminosity…

$$\int L(t)\, l(t)\, p(t)\, f(t)\, dt$$

Instant Luminosity, TDAQ lifetime, trigger prescale, failure and losses

Z production cross Section expected at LHC (NLO)

	√s [TeV]	σ·BR
Z→μμ	14	2.02 nb
	10	1.35 nb

Systematic contributions from experimental and theoretical sources need to be carefully taken in to account

$$\frac{\delta\sigma}{\sigma} = \frac{\delta N \oplus \delta B}{N - B} \oplus \frac{\delta\varepsilon}{\varepsilon} \oplus \frac{\delta A}{A} \oplus \frac{\delta L}{L}$$

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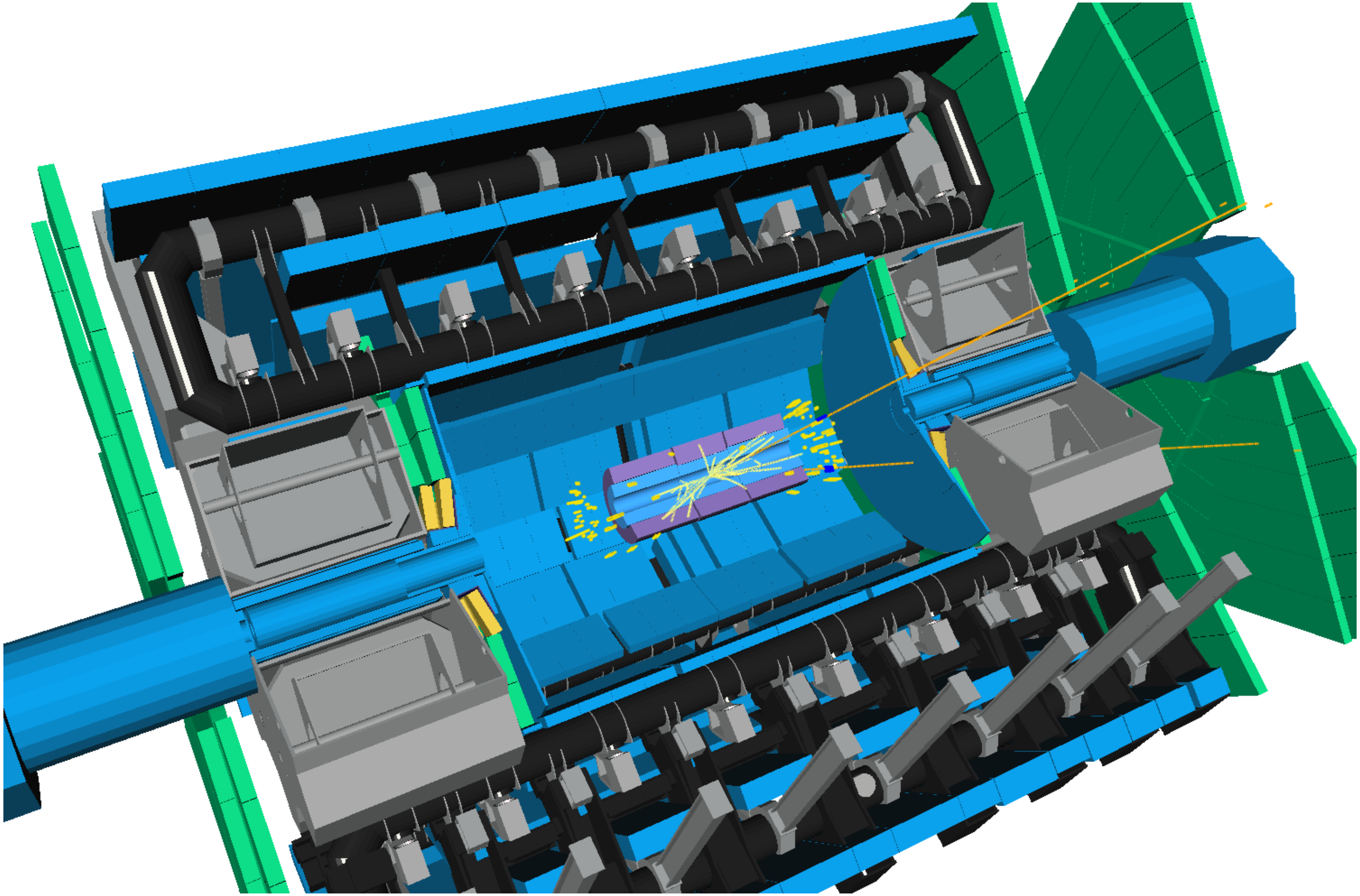
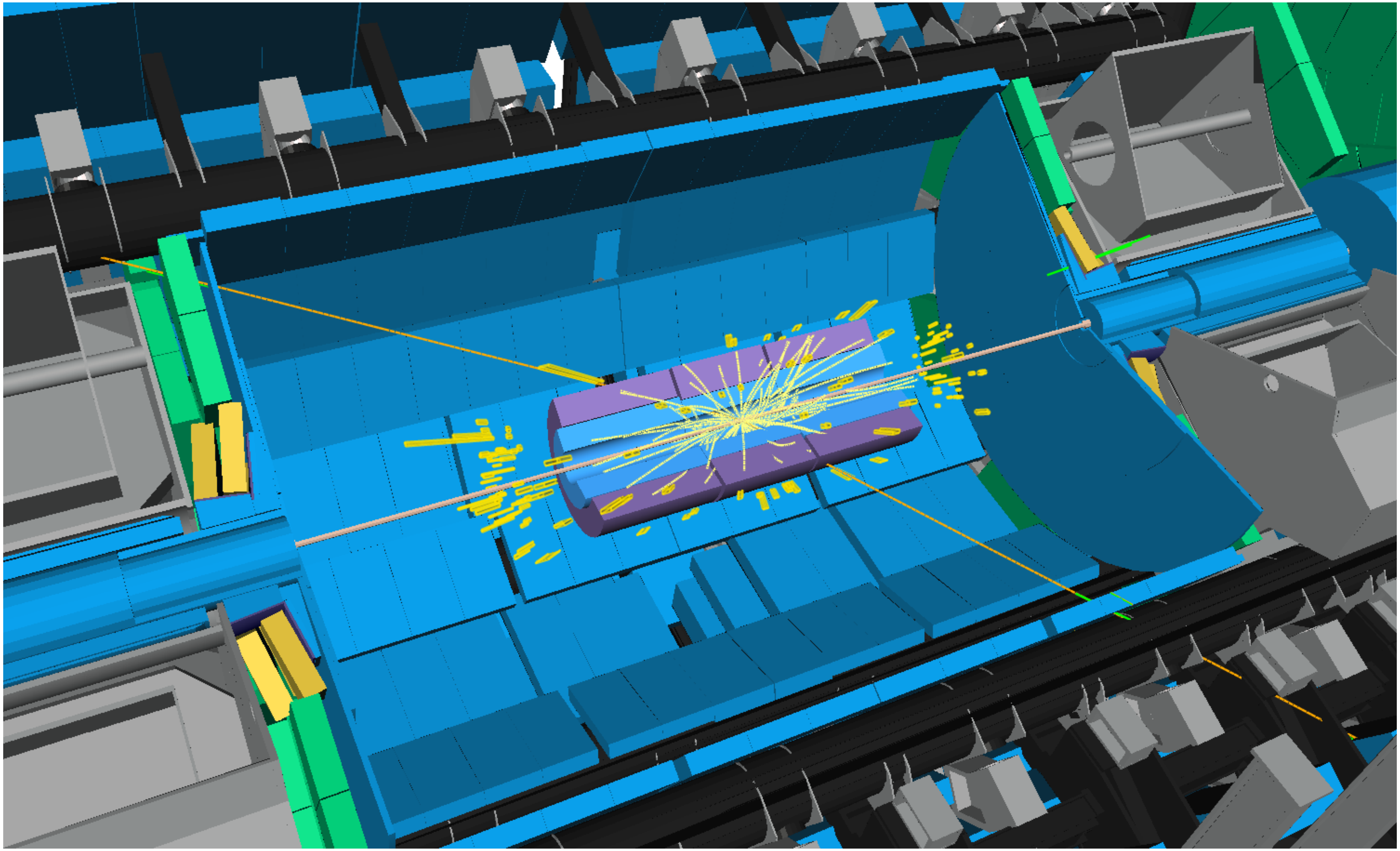
Event Gallery



Event Gallery



Luminosity measurement

- Fundamental to pass from the rate of a process and it's relative cross section

- It's possible to estimate it taking into account the beam parameters:
  - Bunch cross frequency f
  - Number of colliding protons per bunch crossing N
  - Transversal beam size $\sigma_x \sigma_y$

$$L = f \frac{N^2}{4\pi\sigma_x\sigma_y}$$

- Beam size → biggest source of uncertainty
- Low luminosity phase → beam parameters will be used to measure the absolute luminosity
  - precision of about 20%
- Second phase → elastic pp collisions will be observed by Roman Pot detectors
  - more precise (<3%) measurement
- Relative luminosity will be measured by luminosity monitors (inelastic pp collisions)
  - Absolute measurement inferred from the relative one by means of calibration
- Well known processes (e.g.W/Z production itself) can also be used for luminosity measurement
  - Aim is to reach an accuracy of less than 5% during physics runs

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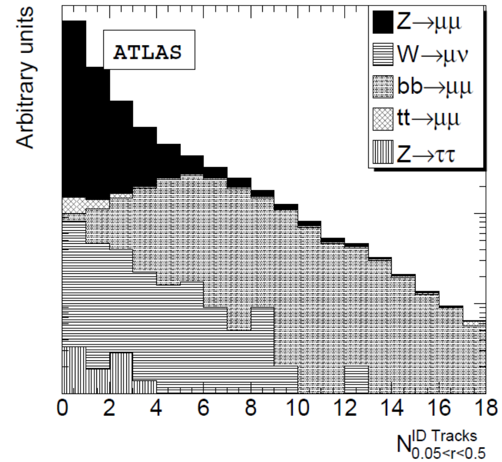
Z Event Selection

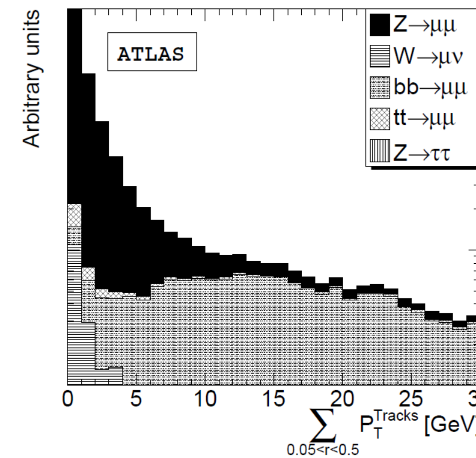
SELECTION CUTS

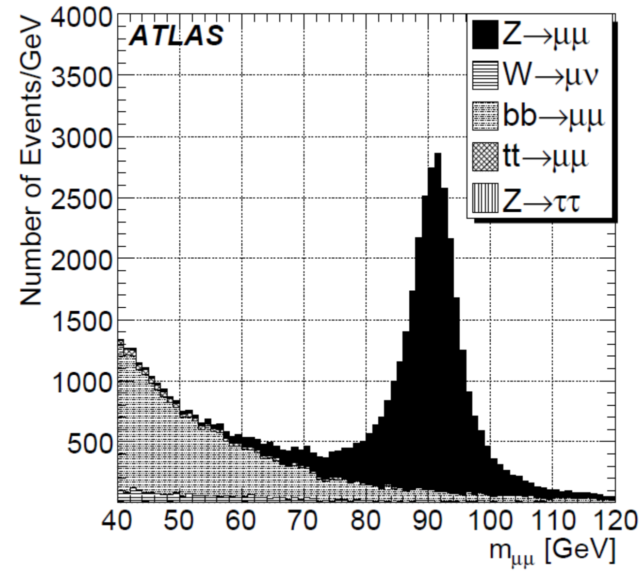
- **mu10 EF** trigger selection
- At least 2 muons with **pT>20GeV** and **|η|<2.5**
- Opposite charge & ID isolation within cone of 0.5 **(ΣpT<5GeV, Ntracks<6)**
- Invariant Mass **$|91.2\ \mathrm{GeV} - M_{\mu\mu}|<20\mathrm{GeV}$**

Isolation and pT cut chosen to **minimize** the statistical uncertainty on cross section measurement

~70% of the Z→μμ with muons in the acceptance are selected







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Z Event Selection

- Cut flow for signal and background (x10^4) for an integrated luminosity of 50pb^{-1}

Selection	$Z\to\mu\mu$	$b\bar{b}\to\mu\mu X$	$W\to\mu\nu$	$Z\to\tau\tau$	$t\bar{t}$
Trigger	3.76±0.01	10.08±0.04	36.7±0.1	0.09±0.01	0.69±0.01
2μ + Opp. charge	3.33±0.01	3.00±0.04	1.14±0.02	0.04±0.01	0.35±0.01
$M_{\mu\mu}$ cut	3.04±0.01	0.26±0.01	0.04±0.01	$(14\pm4)\times10^{-4}$	0.02±0.01
Pt cut	2.76±0.01	0.125±0.001	0.004±0.001	$(11\pm4)\times10^{-4}$	$(134\pm8)\times10^{-4}$
Isolation	2.57±0.02	$(18\pm5)\times10^{-4}$	$(9\pm5)\times10^{-4}$	$(11\pm4)\times10^{-4}$	$(66\pm4)\times10^{-4}$

- Dominant background from tt events
- Jet background expected to be smaller , but it's theoretically not well known → biggest uncertainty

Acceptance

- Calculated through MC simulation (MC@NLO) imposing kinematical cuts (p_T and η) on outgoing muons from Z
- In the first stage of data taking the uncertainties on luminosity and acceptance will dominate the Z cross section measurement
- Systematic error in acceptance calculation depends on:
  - the different PDF error sets that can be used
  - the Initial State Radiation
  - Intrinsic pT of incoming partons
  - QED corrections (computed with Photos tool)
  - Spin correlation between incoming partons and final leptons

Default settings for acceptance calculation: ISR on, Photos on, Intrinsic p_T=0 GeV, spin corr. on

$Z \rightarrow \mu\mu$ Acceptance **42.62 %**

Systematic error is of the order of 2%

Work in Progress

Reconstruction & trigger efficiency

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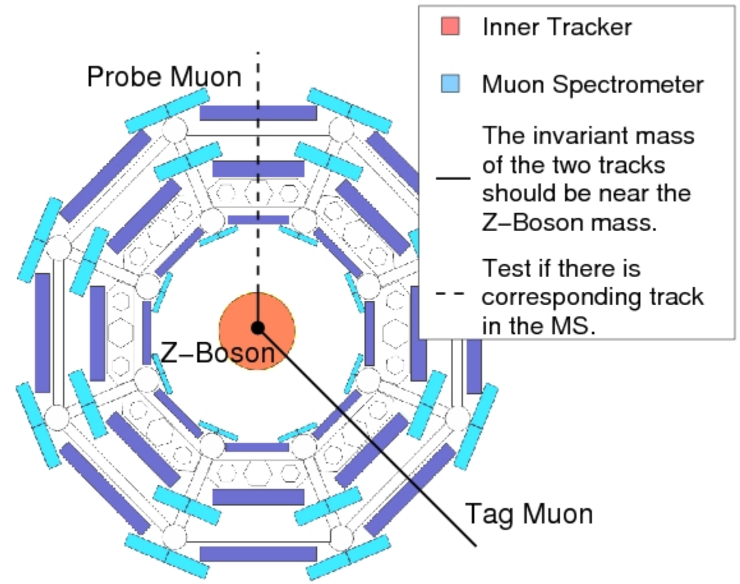
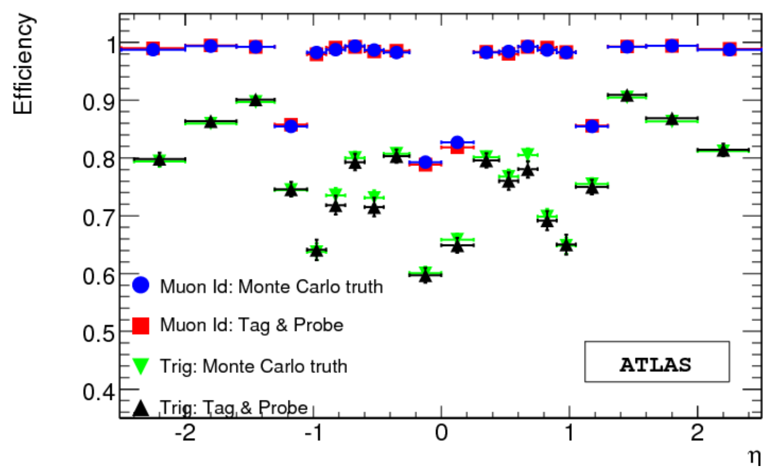
TAG & PROBE Method

- Uses the independent muon measurement given by Inner Detector and Muon Spectrometer
- Requires two reconstructed track in ID and at least 1 in Muon Spectrometer. Invariant mass of two ID tracks close to Z mass. ID tracks isolated
- ID track + associated MS track
  $\rightarrow$tag muon
- The second track in the ID correspond to a probe muon
  $\rightarrow$ same role of the generated muon in the determination of efficiency with simulated data





Momentum scale and resolution

The muon momentum measurement will be affected by:

- limited knowledge of the magnetic field
- uncertainty in the energy loss of the muons
- alignment of the muon spectrometer

} pT scale and resolution

ENERGY LOSS

Muons with pT<100 GeV lose on average ~3 GeV on their passage through the calorimeters almost independently of their energy.

- 5% uncertainty in material traversed correspond to a ±150 MeV uncertainty in energy loss.
- Using Z → μμ events, one computes the tower-dependent corrections which minimize:

$$\chi^2 = \sum_{\mu\mu \ pairs \ k} \frac{\left[\left(p_{corr,+,k} + p_{corr,-,k}\right)^2 - M_Z^2\right]^2}{\sigma_k^2}$$

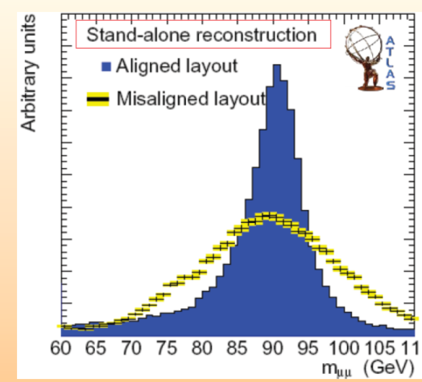
MS MISALIGNMENT

Accounted by computing scale factors to correct the observed Z shape.

- pT scale → impact on measured mean value
- pT resolution → impact on Z width

Iterative procedure changes the MC pT resolution function in width and scale

- Recalculate the Z mass distribution
- Procedure stops if the new MC distribution agree with the measured distribution



Conclusions

Expected results for the $\sigma_Z \cdot BR(Z \rightarrow \mu\mu)$ measurement 50pb^{-1} @ 14TeV

Process	N(x10^4)	B(x10^4)	A×ε	δA/A	δε/ε	σ(pb)
$Z \rightarrow \mu\mu$	2.57±0.02	0.010±0.002	0.254	0.023	0.03	2016±16± 76

The first collisions at $\sqrt{s}$ = 10 TeV are hopefully coming soon:

- First collisions expected in late 2009. The plan is to run continuously for almost an year without the winter shutdown . The goal is to integrate 100-300 pb^{-1} .
- With the first few tens of pb^{-1} it will be possible get the first SM physics measurements, that represents the background for the new physics signals at LHC.
- The $Z \rightarrow \mu\mu$ mass and cross-section measurements will be used first to understand the detector: align and calibrate the muon spectrometer and to measure the muon reconstruction and trigger efficiency.
  - A lot of work ongoing today to study the physics measurement at 10 TeV

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