Forward-Backward asymmetry measurement in $pp \rightarrow Z/\gamma^* + X \rightarrow \mu^+\mu^- + X$ events at the ATLAS experiment

Incontri di Fisica delle Alte Energie

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G. Cattani

University of Rome "Tor Vergata" & INFN Roma 2

$Z \rightarrow \mu\mu$ forward-backward asymmetry

- The presence of both axial and vector coupling of the quarks and leptons to the γ^*/Z boson gives rise to an asymmetry in the polar emission of muons.
  - Allow measurement of the weak mixing (Weinberg) angle

$$J_\mu^{NC} = J_\mu^3 - \sin^2\theta_W J_\mu^{em}$$

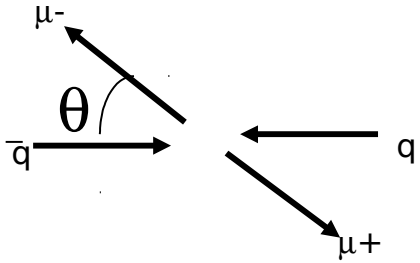
- The F/B asymmetry measurement can be extended to higher invariant masses in Drell-Yan spectrum
  - Possible observation of new physics scenarios: extra dimensions, new gauge bosons, etc.

- Definition of forward-backward asymmetry:
  - **A_{FB}= (F-B)/(F+B)**

    F = number of events with $\cos(\theta^*)>0$

    B = number of events with $\cos(\theta^*)<0$
    - θ^* defined in Collins-Soper reference frame
- θ dependence of the x-section
  - angle between incoming particle (quark) and outgoing particle (lepton)

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\theta} = \frac{3}{8}N_c[1+\frac{4}{3}A_{FB}\cos\theta+\cos^2\theta]$$



G.Cattani – giordano.cattani@cern.ch
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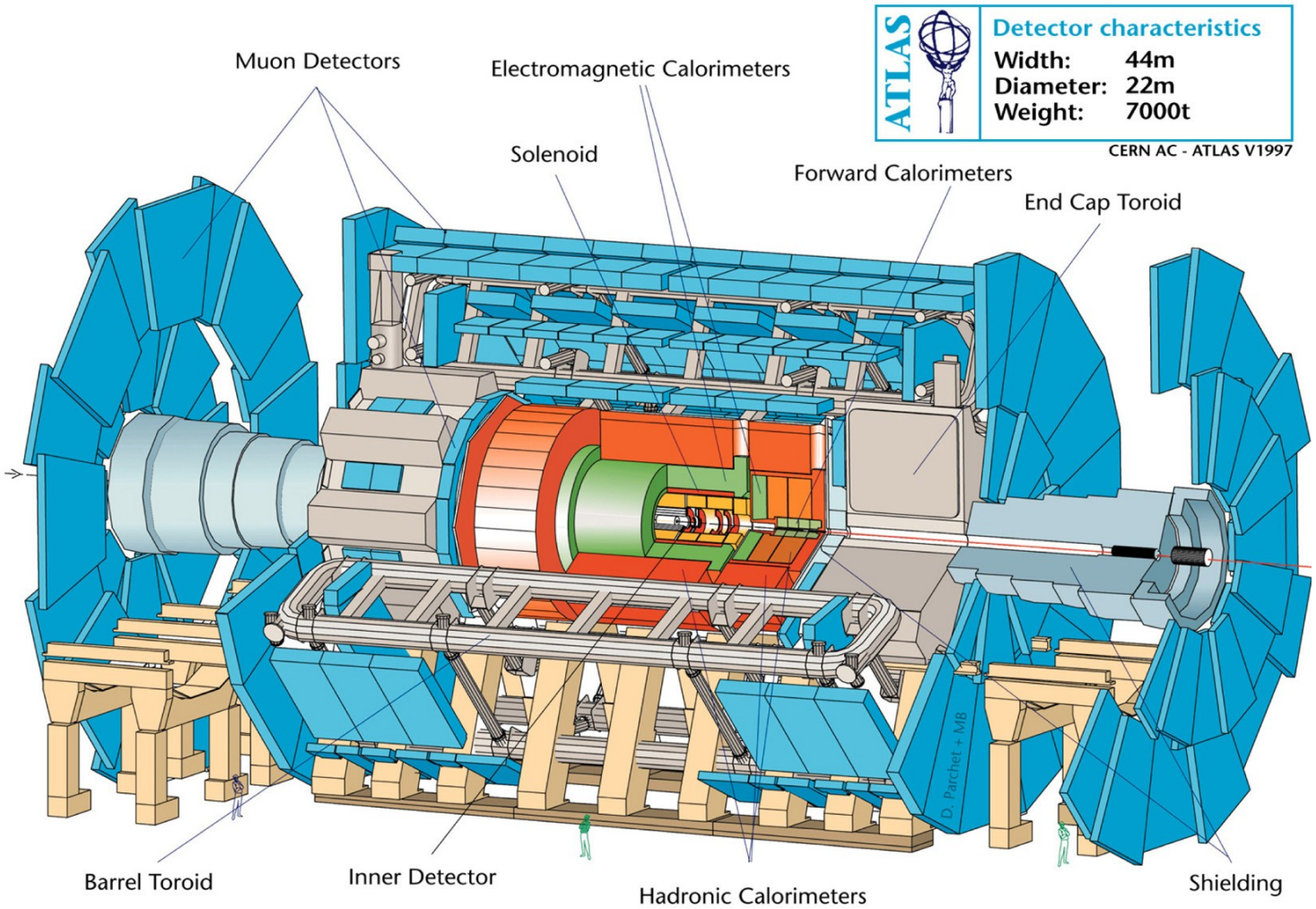
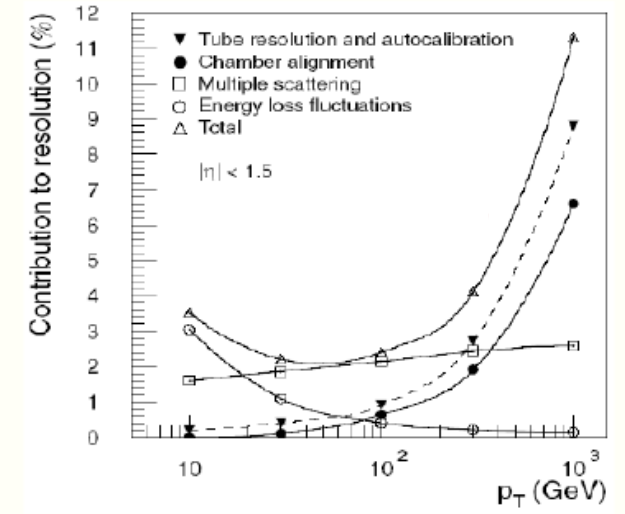
The ATLAS experiment



Muon Spectrometer

Pseudorapiity coverage
up to $|\eta| < 2.7$

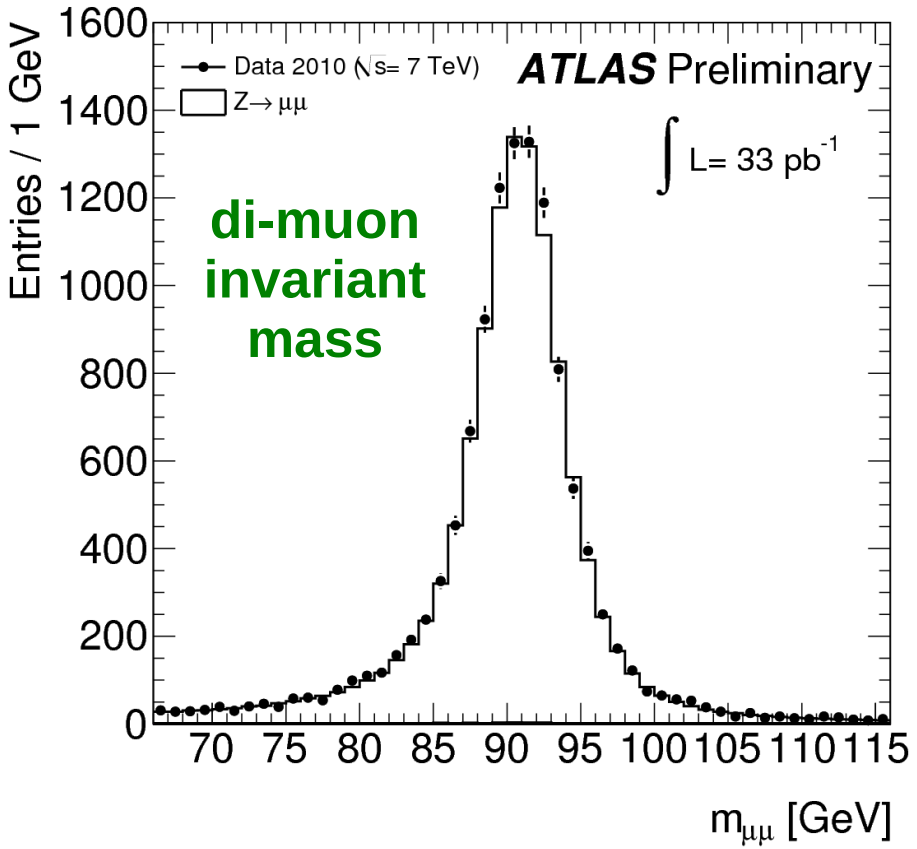
σ/p_T up to ~10% @ 1 TeV



$Z \rightarrow \mu\mu$ candidate event selection

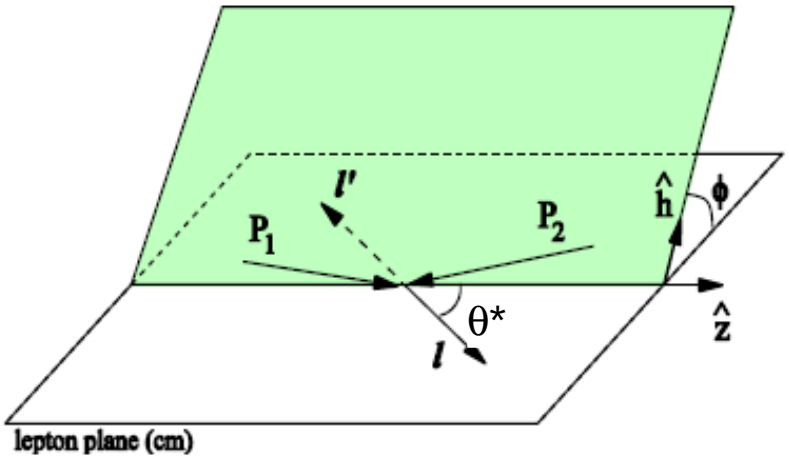
- Event selection:
  - GRL + bcid
  - Trigger: according to run
  - $N_{VTX} > 1$ and $N_{tracks} >= 3$ and $|Z_{VTX}| < 200$ mm
  - At least 2 combined muons with
    - $p_T > 20$ GeV
    - $|\eta| < 2.4$
    - $|z_0| < 10$ mm for both tracks (wrt to same "good" vertex)
  - Muon quality as Muon Combined Performance Group recommendations
  - Isolation: $\sum p_T/p_T < 0.2$ for both muon tracks
  - Charge: $c_1 * c_2 < 0$
  - Mass window: $66 < M_{\mu\mu} < 116$ GeV

- 2010 data sample (~ 34 pb^{-1})

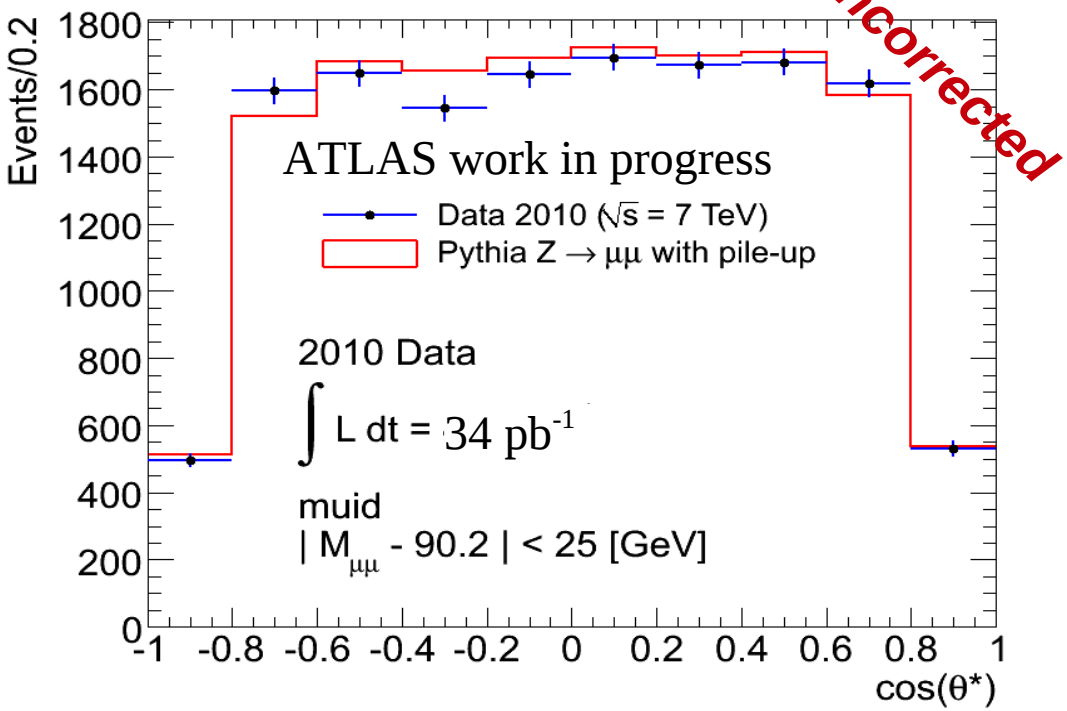


"Raw" $A_{F/B}$ measurement

- Asymmetry evaluated with counting method:
  - A_{FB}=(F-B)/(F+B)
    F = number of events with cos(θ*)>0
    B = number of events with cos(θ*)<0
- Only statistical error



cos(θ*) distribution



$A_{F/B}$(%)		
	All Y_z	$\|Y_z\|>1$
MC	1.3 ± 0.3	4.9 ± 1.3
Data	1.9 ± 0.8	2.2 ± 0.4

G.Cattani – giordano.cattani@cern.ch
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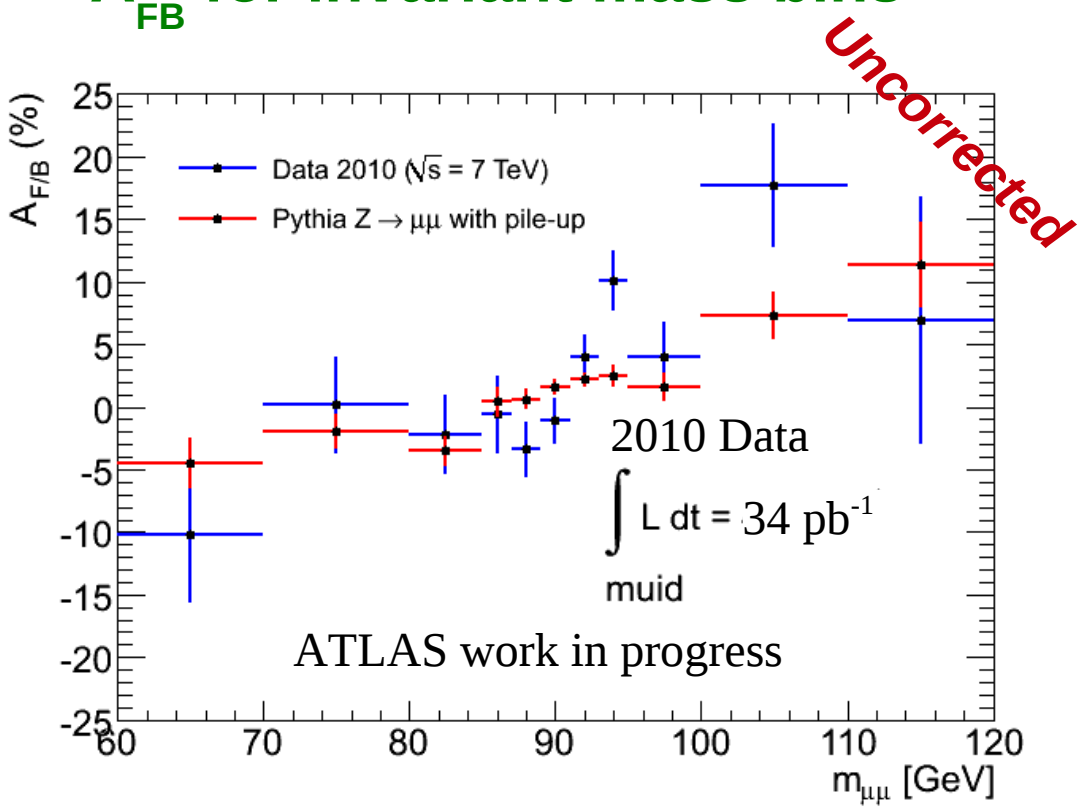
A_{FB} vs di-muon invariant mass

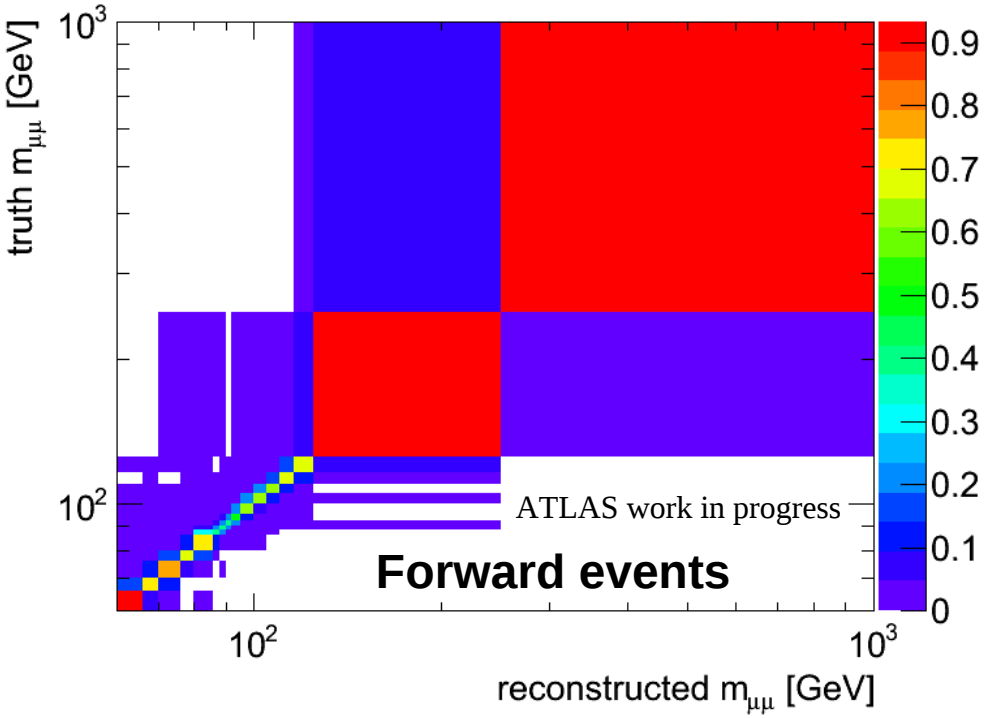
A_{FB} for invariant mass bins



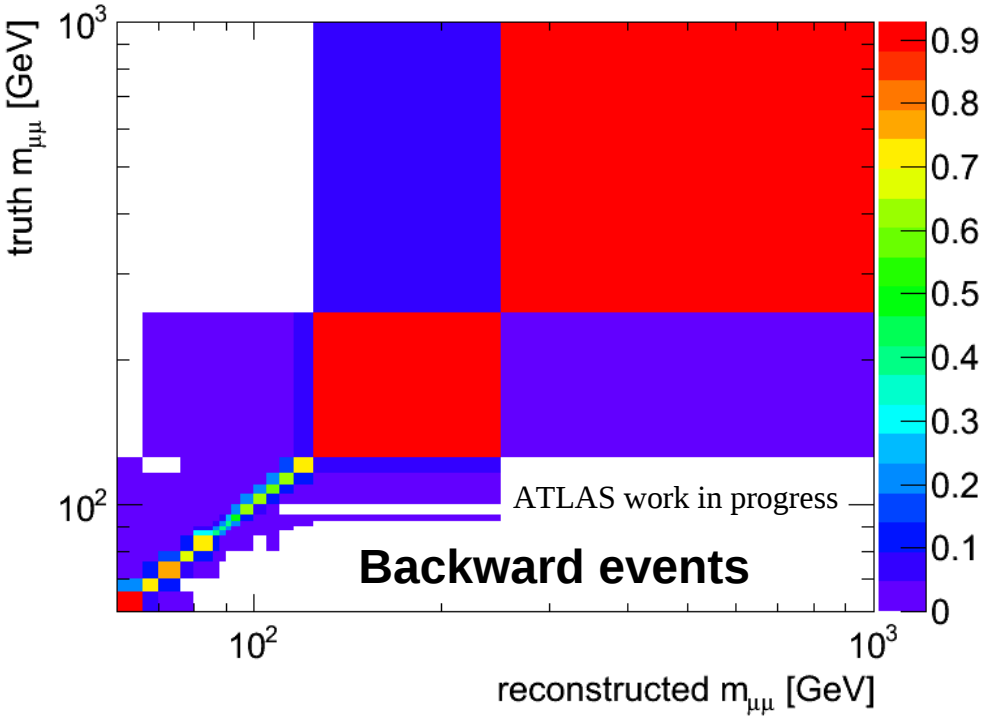
- "Raw" distributions should be corrected using MC based response matrices to take into account for:
  - detector resolution and FSR (mass bin migration correction)
  - incorrect quark direction: the direction of the quark and anti-quark is not known in proton-proton experiments and leads to a dilution in the asymmetry

Mass bin migration correction

- Reconstructed invariant mass is not equal to truth mass
  - Need to correct for invariant mass migration
- Calculate the probability of a reconstructed mass to be a different mass

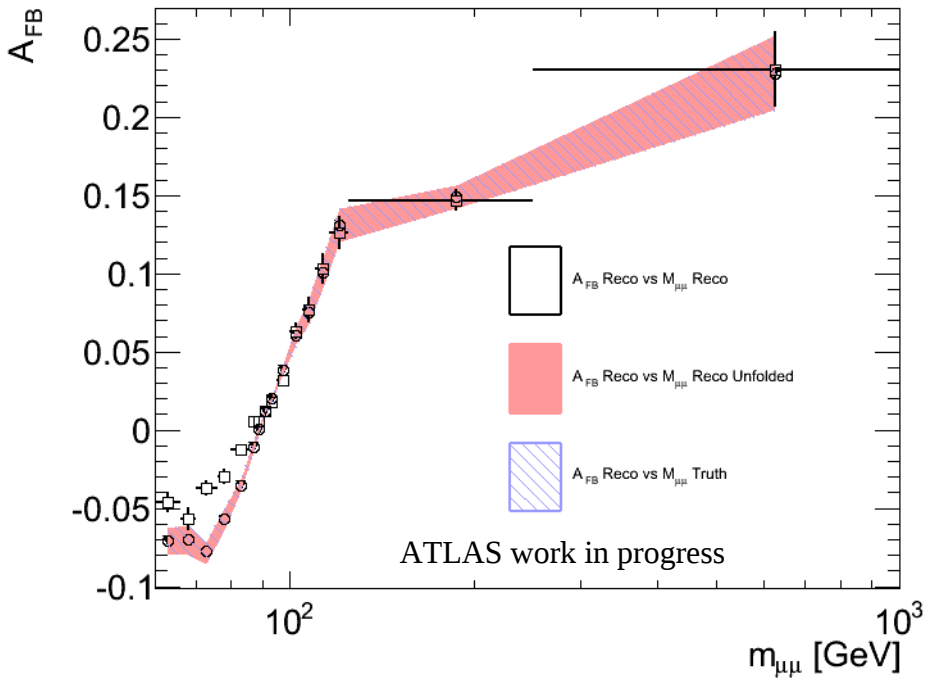


Mass Migration response matrices



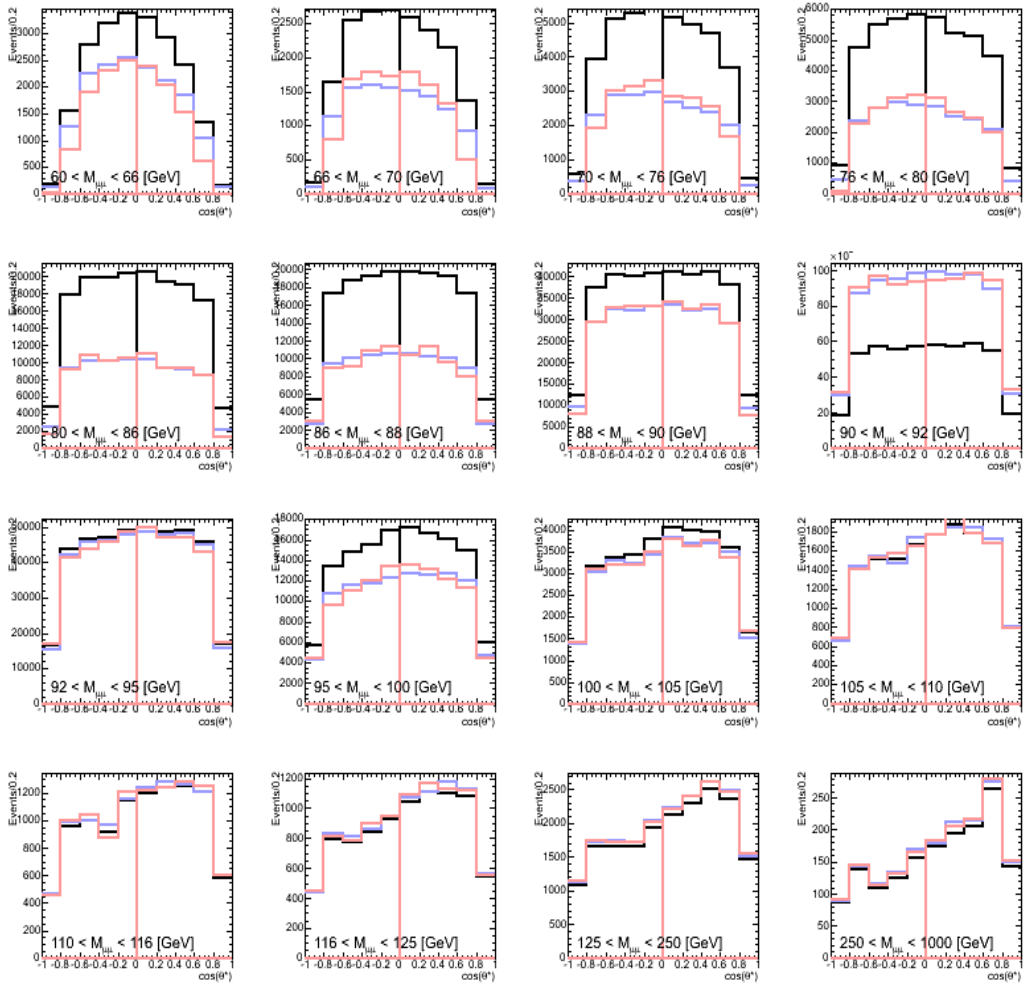
Mass migration closure test on MC

- Closure test on MC
- Compare:
  - **Reco asymmetry vs uncorrected mass**
  - **Reco asymmetry vs corrected mass**
  - **Reco asymmetry vs true mass**
- Correction brings back the mass distribution to its true value, up to the point that the two curves are indistinguishable



Showing the effect of mass bin correction on cos(θ*) distribution

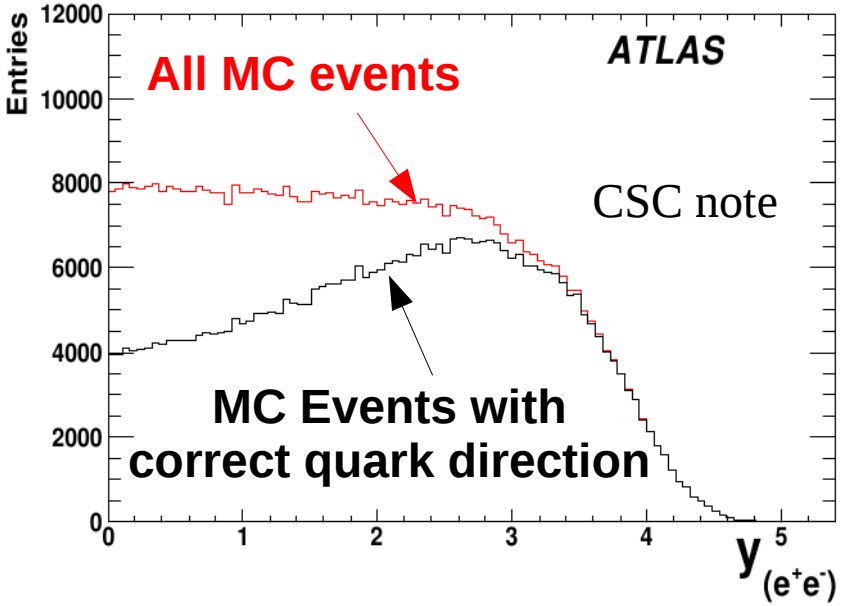
ATLAS work in progress

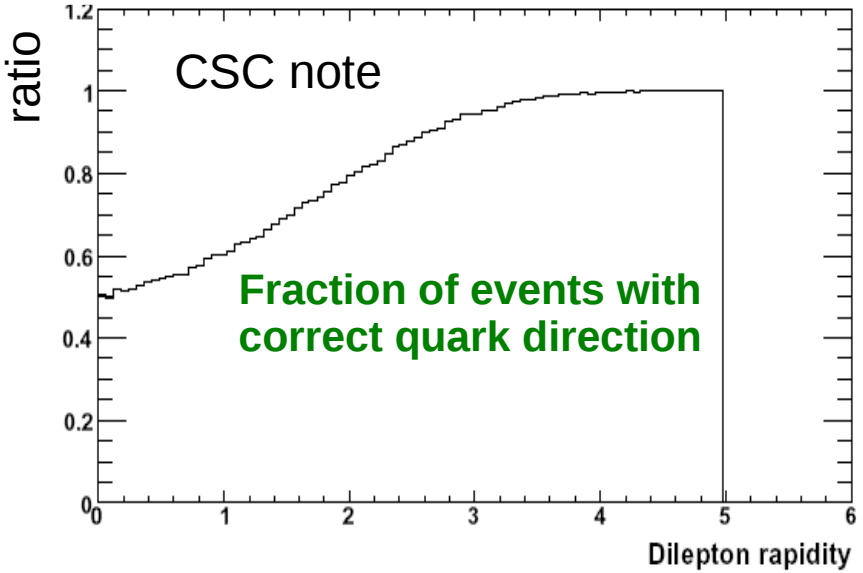


Quark direction: dilution

- At central di-lepton rapidity the probability that the valence quark direction and the di-lepton boost coincide is lower due the smallness of the valence quark distribution
  - This reduces the forward-backward asymmetry: **dilution**

Less than 60% of events with correct quark direction at |Y| < 1

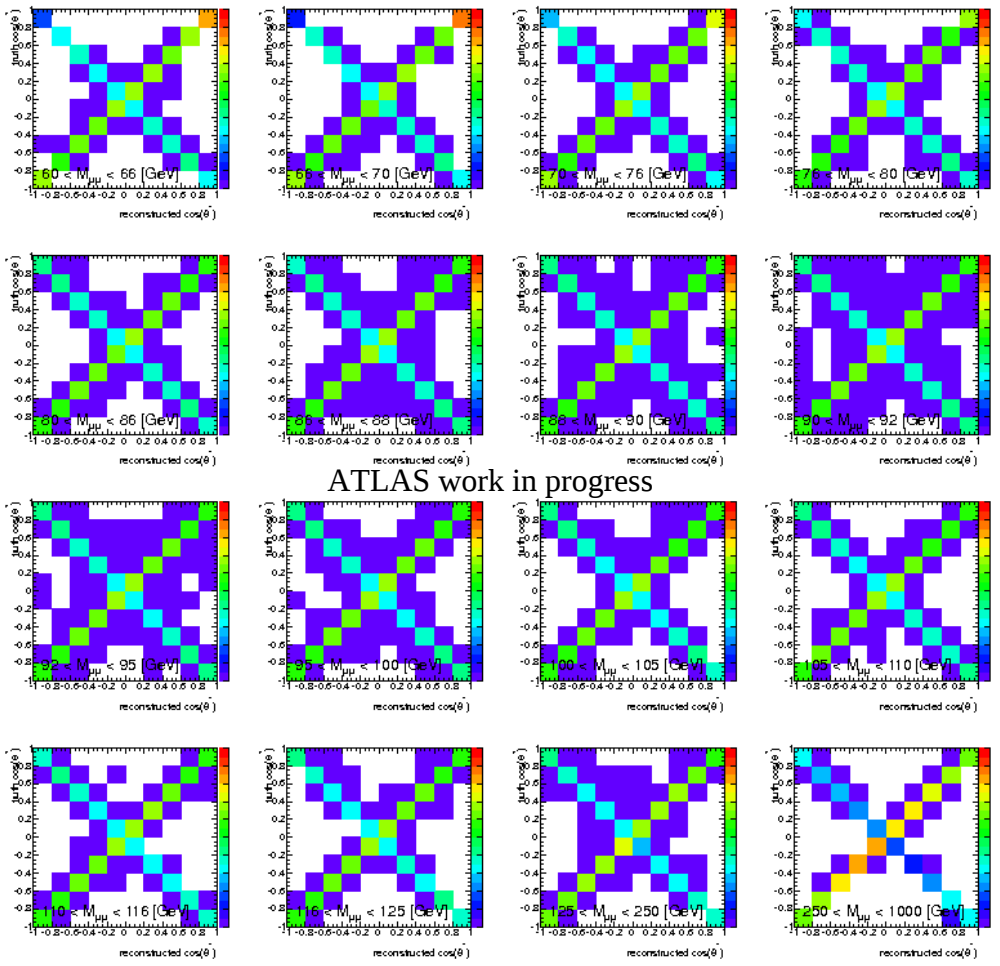




G.Cattani – giordano.cattani@cern.ch
University of Rome "Tor Vergata" & INFN Ro

Dilution unfolding correction

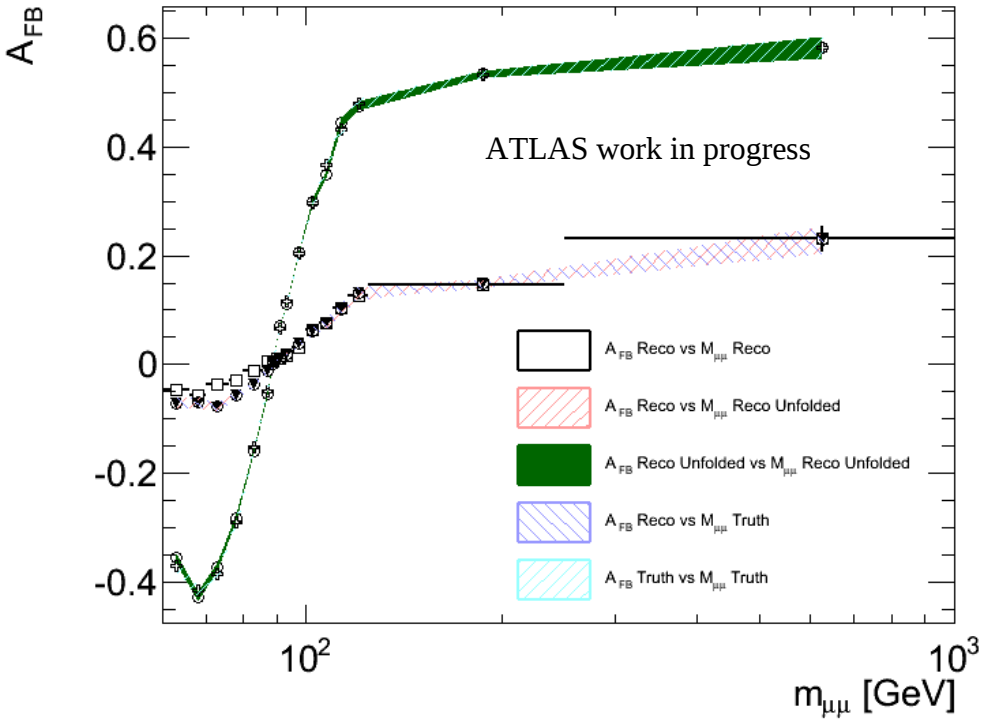
- Same approach as for mass bin migration correction
  - A response matrix for each true mass bin
  - True vs Reconstructed cos(θ*)



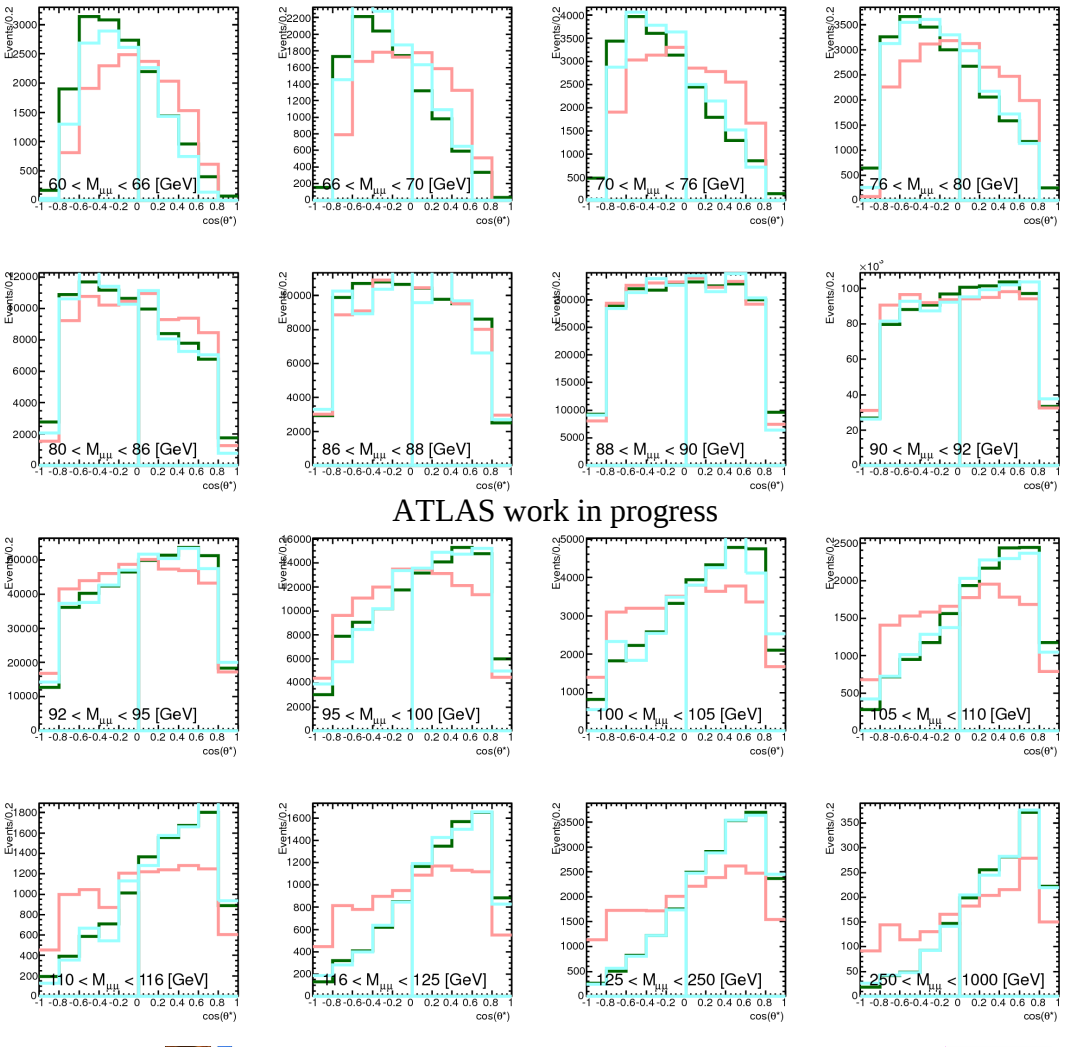
ATLAS work in progress

Final closure test on MC

True and Unfolded A_{FB} are perfectly superimposed!!



Showing the effect of mass bin correction on cos(θ*) distribution



G.Cattani – giordano.cattani@cern.ch
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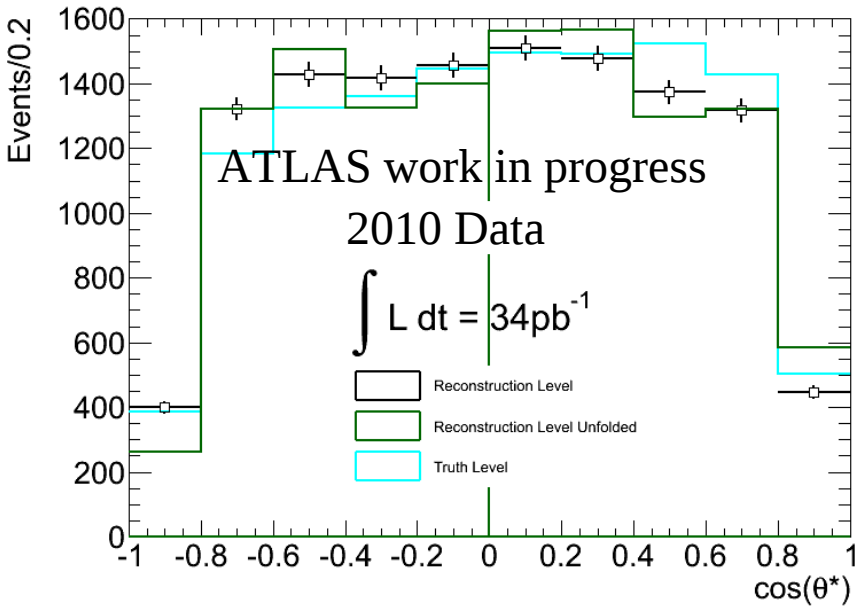
Results of the F-B asymmetry with the 2010 data

- MC based corrections applied to 2010 data
  - "Raw" distribution unfolded for incorrect quark direction
- To reduce impact of low statistics
  - No binning in $m_{\mu\mu}$ and $y_{\mu\mu}$



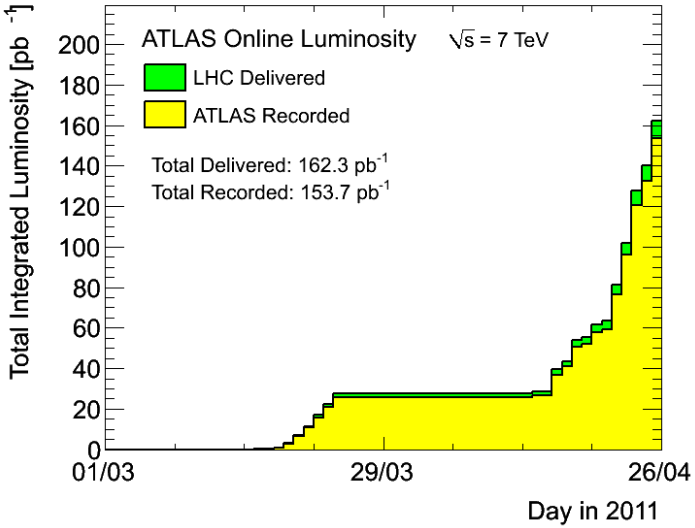
Waiting for 2011 data!

Dilution Unfolding

	$A_{F/B}$ (%)
Reconstruction Level	0.8
Reconstruction Level Unfolded	4.3
MC Truth Level	6.2

Summary and outlook

- A first measurement of the forward-backward asymmetry in $pp \rightarrow Z/\gamma^* + X \rightarrow \mu^+\mu^- + X$ with the ATLAS experiment has been performed
  - Preliminary results with an integrated luminosity of ~34pb^{-1} collected in 2010 have been presented
- MC based corrections for mass migration ad dilution studied
  - Closure test on MC succeded
  - When applied to 2010 data, results are encouraging even on the limited statistics available
- Ongoing work with 2011 data
  - Already collected ~150 pb^{-1} of wich ~120 pb^{-1} in the last 2 weeks!!



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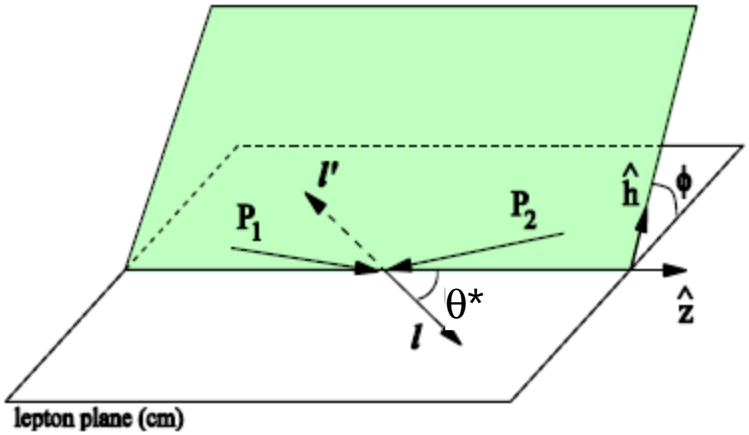
Backup slides

Collins-Soper reference frame

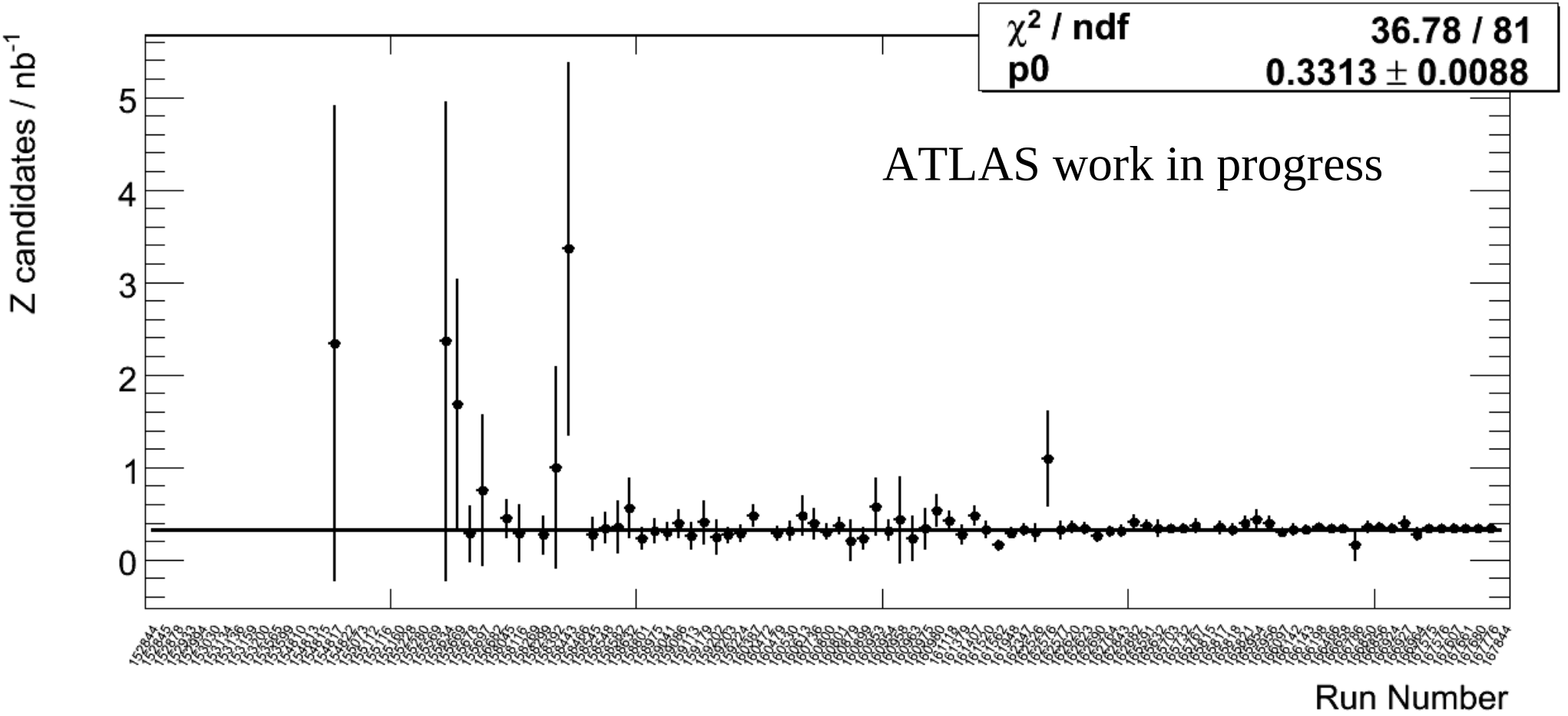
- Incoming quark direction not known at LHC
  - usually a valence quark annihilates with a sea anti-quark
  - in average the valence quark has more momentum than sea anti-quark
    - boosted system, quark same direction as Z/γ*
- Collins-Soper frame reduces uncertainty of transverse momentum of quarks



- Polar axis is defined as the bisector of the two proton beams
- θ* angle between polar axis and lepton

Stability studies of $Z \rightarrow \mu\mu$ candidates

- Yield per nb^{-1}

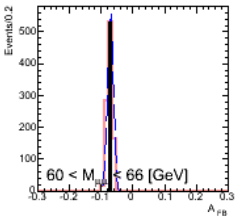


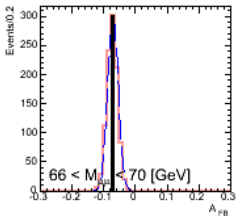
More on mass correction and dilution

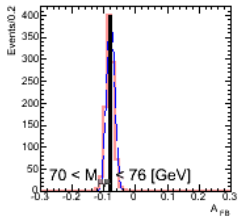
- Study effect of limited MC statistics (~ 2M reconstructed Z $\rightarrow \mu\mu$) on response matrices
- ToyMC:
  - Fluctuate matrix bins within statistical errors
  - For each matrix, calculate corrected mass[cos(θ^*)] distributions, calculate asymmetry value
  - Next slide show the distribution of the asymmetry values in the various mass bins
    - Black line is value obtained with “nominal” (=non fluctuated) matrix
    - Dashed blue line: gaussian fit $\rightarrow$ mean and σ
    - As expected, bins where correction is larger have larger dependence on statistical precision of matrix (see also previous slides)

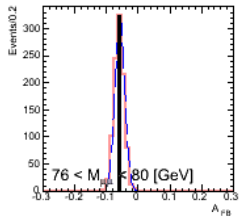
A_{FB} vs mass bin

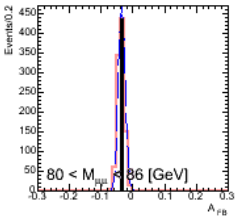
Mass bin migration

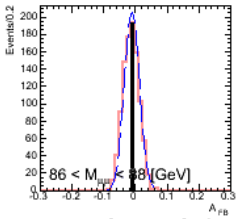


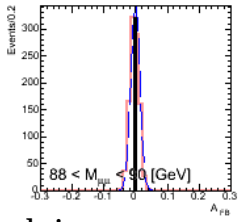


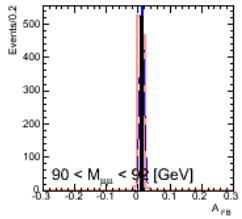


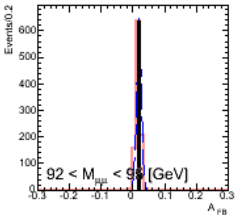


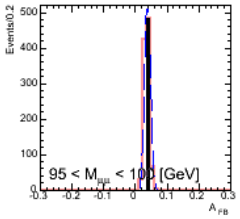


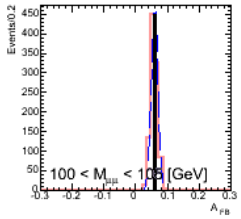


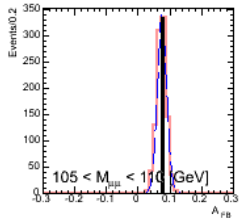


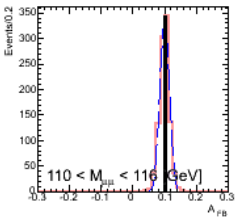


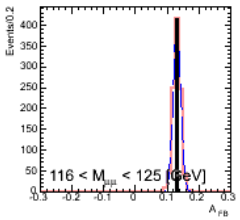


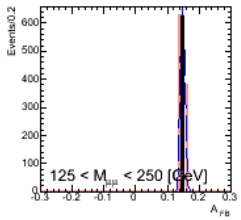


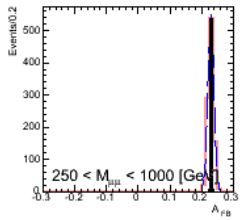






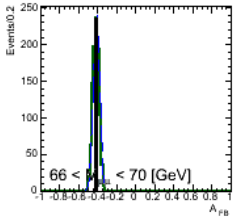


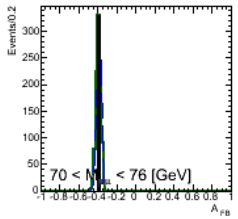


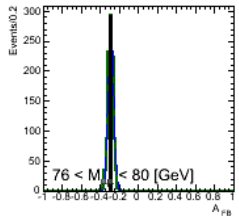


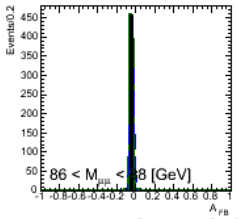
ATLAS work in progress

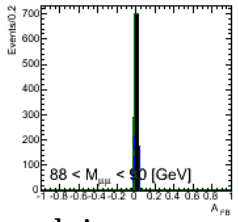
Dilution

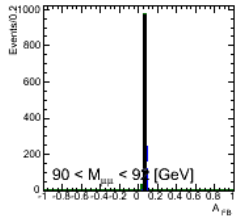


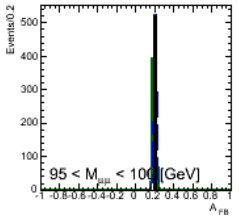


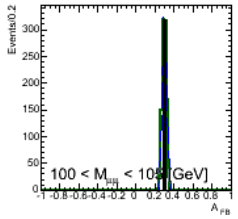


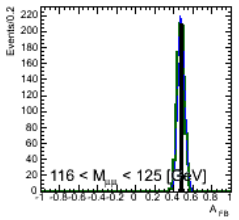


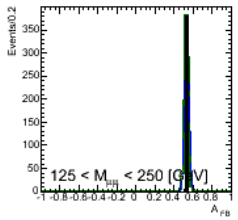


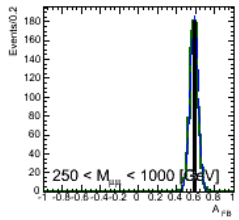


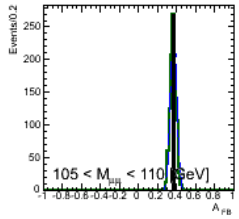












ATLAS work in progress