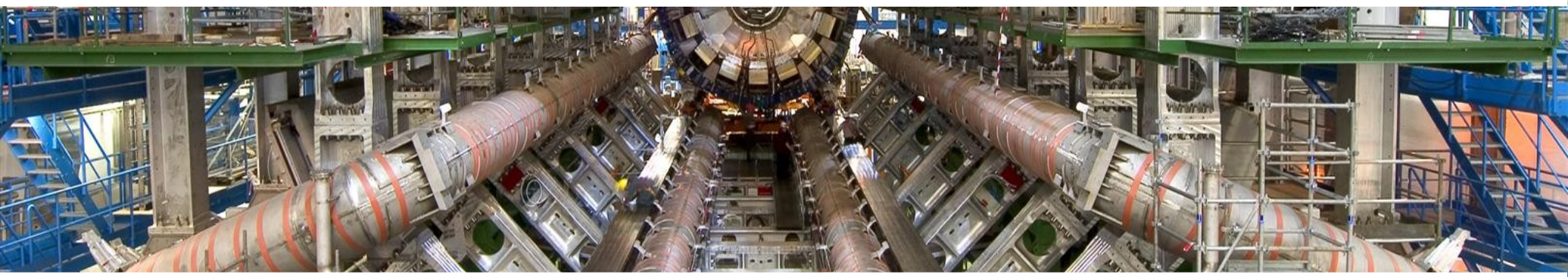
ATLAS electroweak measurements with early data



On behalf of the ATLAS collaboration

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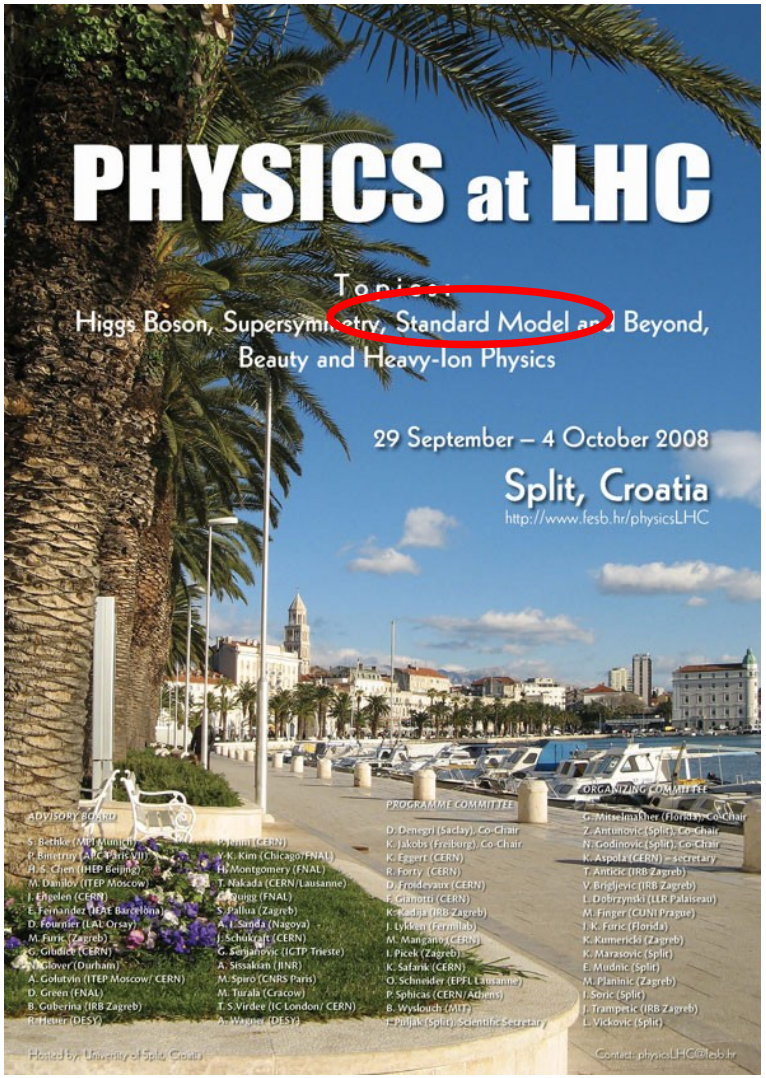
Outline



- **Electroweak (EWK) Physics at ATLAS**
  - ***W and Z cross sections***
  - ***W and Z ratios***
  - ***W and Z asymmetries***
- **Performance of the ATLAS detector**
  - ***Lepton trigger, ID, charge efficiencies***
  - ***E^{T}_{Miss} and lepton energy scale***
  - ***QCD backgrounds from data***

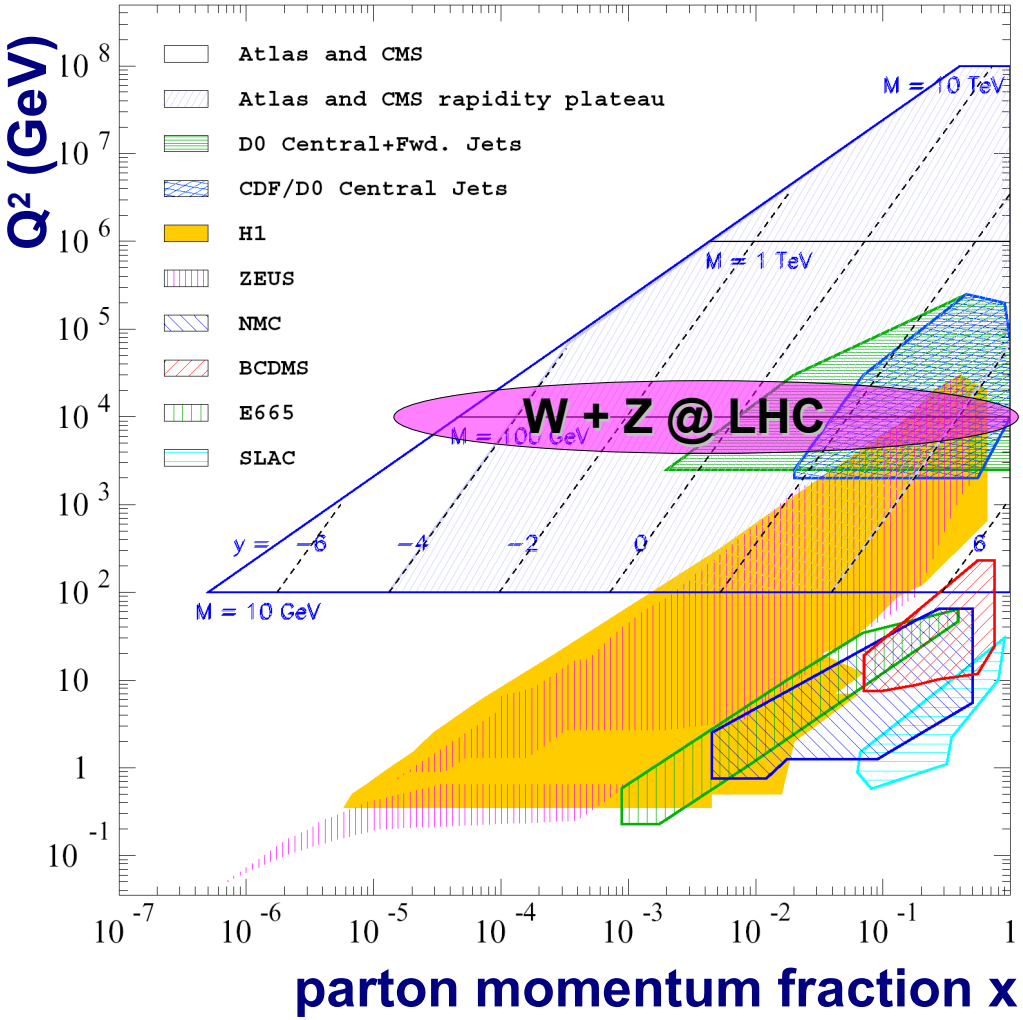
What can we learn from EWK measurements?

early data:

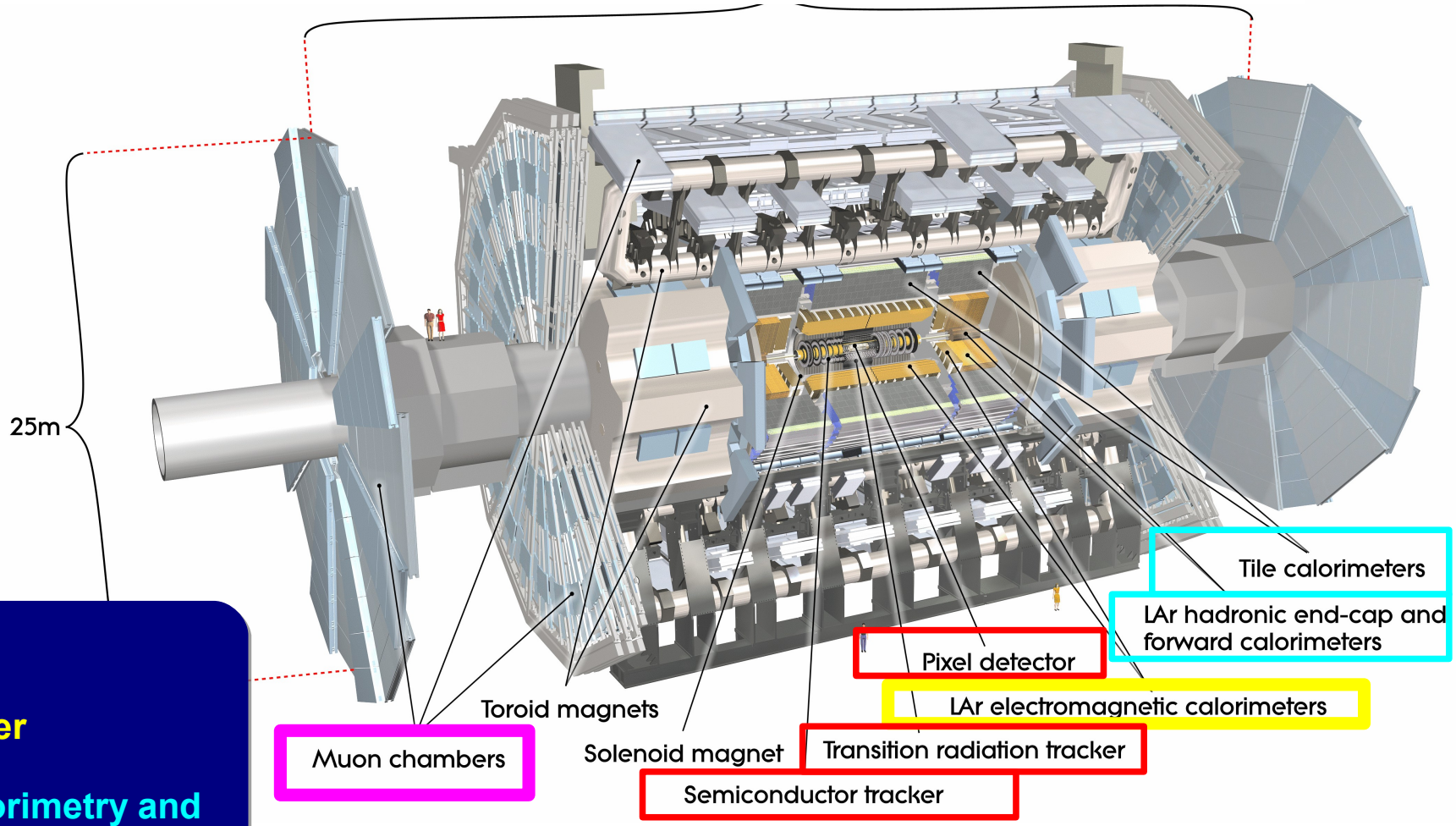
- **Theoretical calculations**
  NNLO QCD, EW effects
- **Electroweak parameters**
  Γ_W, V_{cs}
- **Knowledge of PDFs**
  u/d, sea quarks

in future:

- **Future backgrounds**
  σ(W) >> σ(H), σ(X)
- **Precision tests of SM, m_W**

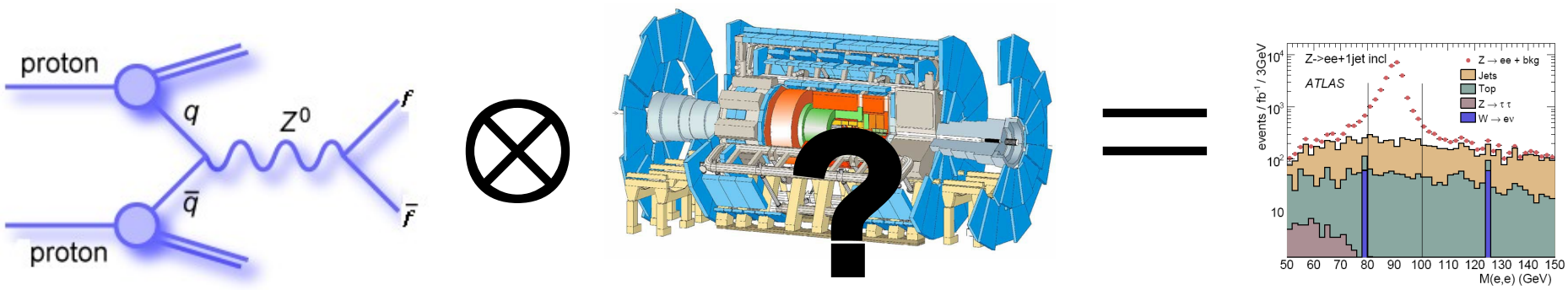


EWK tools to understand the detector



- **Tracking**
- **EM calorimeter**
- **Hadronic calorimetry and E^{t}_{miss} reconstruction**
- **Muon chambers**
- **Trigger**

Detector performance with EWK physics



Detector Performance

- **Selection and reconstruction**
  - Trigger efficiencies
  - ID performance
  - Tracking efficiencies
- **Resolutions and Scales**
  - Lepton energy scales and resolutions
  - E^{T}_{miss} scale and resolutions

To study EWK with early data is crucial!

- **W and Z boson well understood**

  - differential NNLO calculations
  - < 2% theor. uncertainty on acceptance

- **Clean signatures, high statistics**

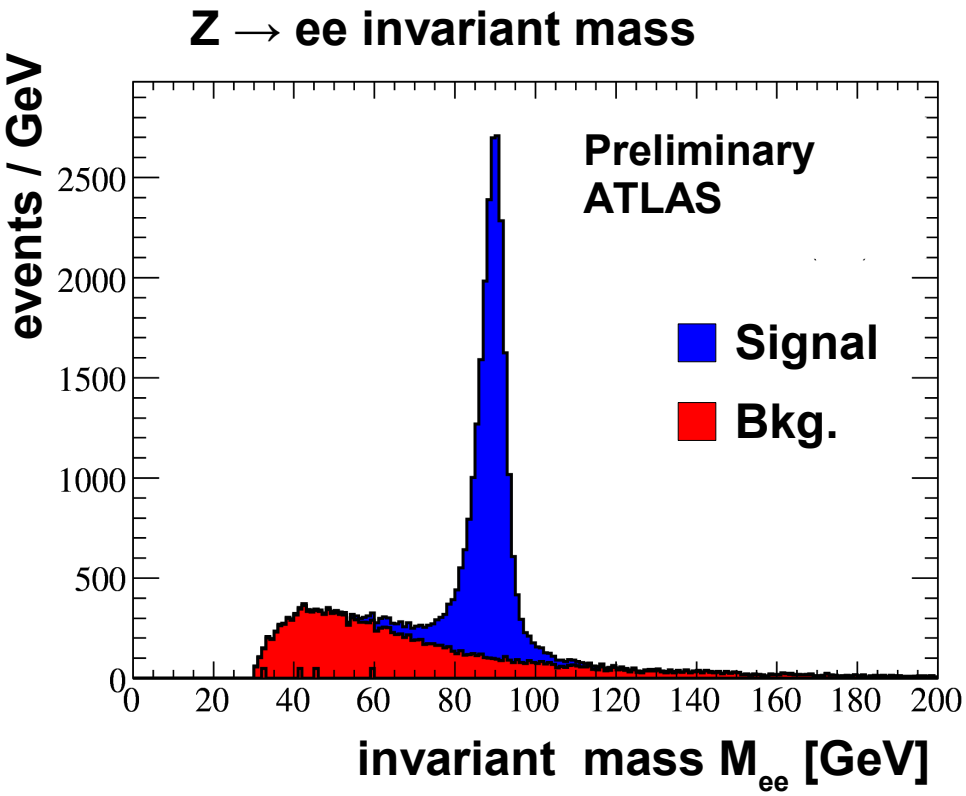
  - $\sigma(W \rightarrow l\nu)$: ~ 20 nb
  - $\sigma(Z \rightarrow ll)$: ~ 2 nb

all following results can be found in:
ATLAS Collaboration
"Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics"
CERN-OPEN-2008-020

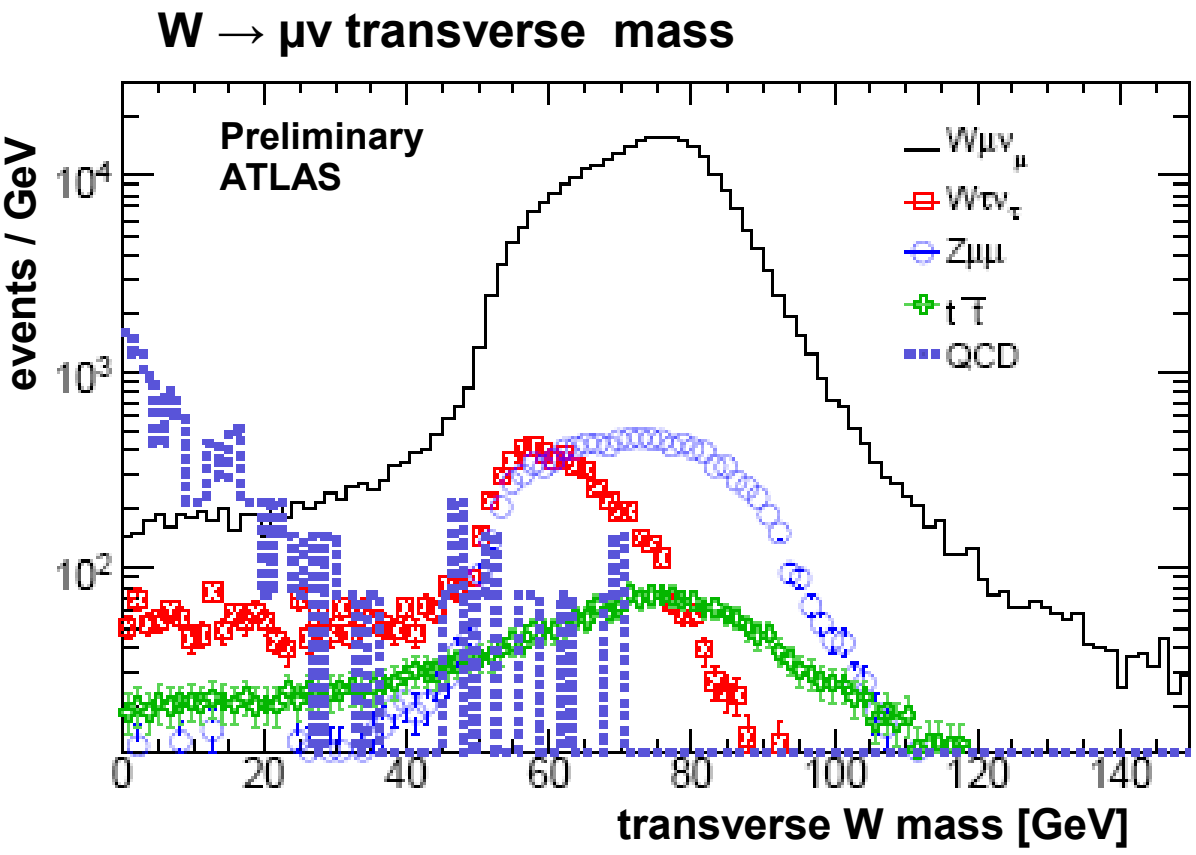
Event Selection for Z Bosons

$Z \rightarrow ee$ Selection cuts
robust early data selection

- $P_T > 15$ GeV
- $|\eta| < 2.5$
- $80 < M_Z < 100$ GeV
- Isolation
- Electron ID
- Single lepton trigger



Event Selection for W Bosons



W → μν Selection cuts
robust early data selection

- **P_T > 25 GeV**
- **|η| < 2.5**
- **E^T_{miss} > 25 GeV**
- **M_T > 40 GeV**
- **Isolation**
- **Electron ID**
- **Single lepton trigger**

W / Z cross section ratio

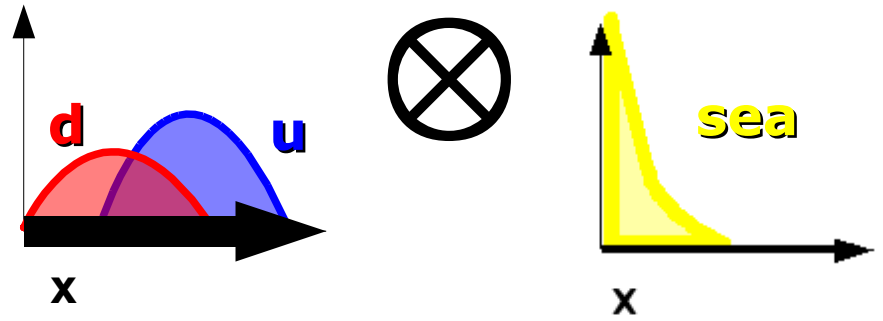
$$\mathrm{R} = \frac{\sigma_{\mathrm{W}} \times \mathcal{BR}(\mathrm{W} \to \mathrm{l}\nu)}{\sigma_{\mathrm{Z}} \times \mathcal{BR}(\mathrm{Z} \to \mathrm{ll})} = \frac{\sigma_{\mathrm{W}} \Gamma_{\mathrm{Z}} \Gamma_{\mathrm{W} \to \mathrm{l}\nu}}{\sigma_{\mathrm{Z}} \Gamma_{\mathrm{W}} \Gamma_{\mathrm{Z} \to \mathrm{ll}}}$$

- **Cancels important uncertainties**
  - **Luminosity (20-30% uncertainty expected)**
  - **Resummation, higher order effects cancel**
  - **Correlated uncertainties on the leptons**
- **Using precise LEP results contrains less known quantities**
  - **e.g. width Γ_w or mixing angle V_{cs}**

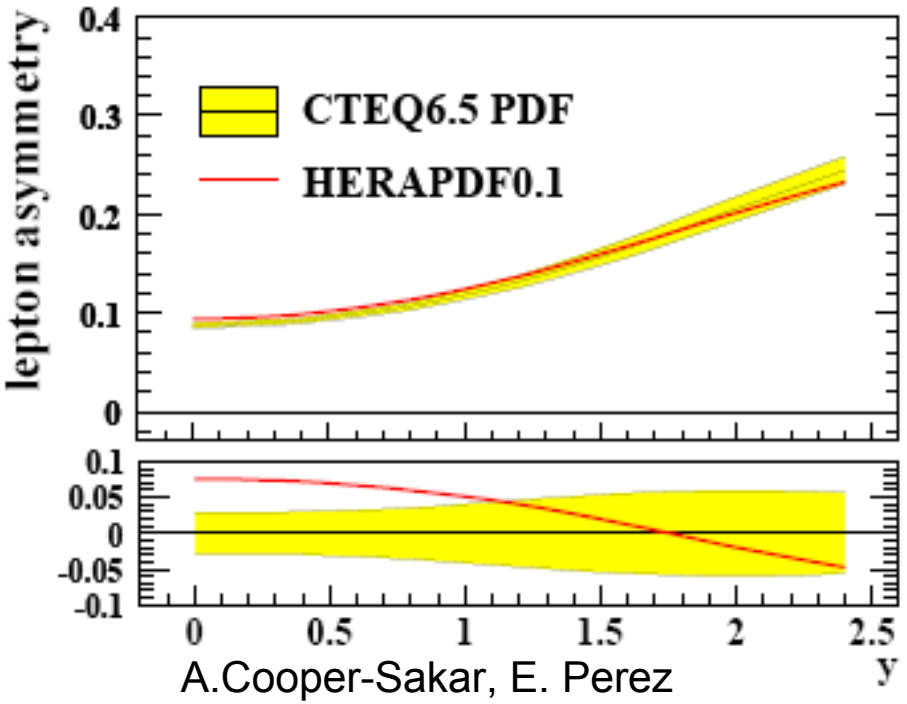
→ need to understand efficiencies and acceptances

W asymmetry – lepton asymmetry

$$A = \frac{d\sigma/d\eta_{e+} - d\sigma/d\eta_{e-}}{d\sigma/d\eta_{e+} + d\sigma/d\eta_{e-}}$$



- Different momenta for partons
- Higher Boost for W+ than W-
- Also for lepton (V-A weak decay)
- Gives handle to contrain PDFs
- Luminosity and efficiencies cancel
- Resummation cancels

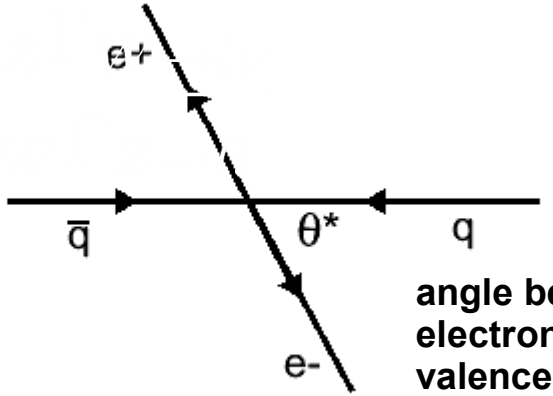


A.Cooper-Sakar, E. Perez

→ **need to understand background contribution**

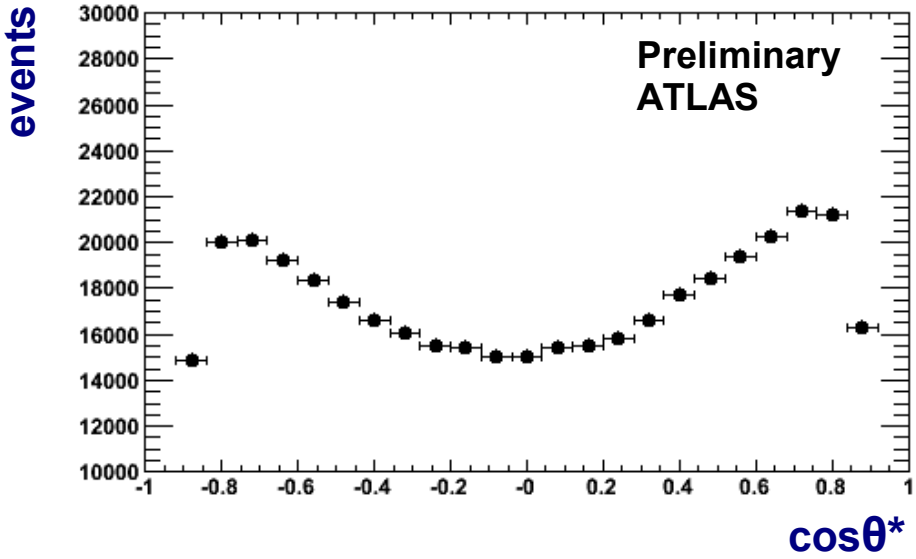
Z asymmetry

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B} = b(a - \sin^2 \theta_{eff}^{lept})$$



angle between electron and valence quark (Z-direction)

- $N_F = \cos\theta^* > 0$, $N_B = \cos\theta^* < 0$
- V-A: lepton in quark direction ($\cos\theta^* > 0$)
- A_{FB} gives fraction of weak force in Z
- Luminosity and efficiencies cancel
- First data: checks
- 100 fb^{-1}: precision in $\sin^2\theta$

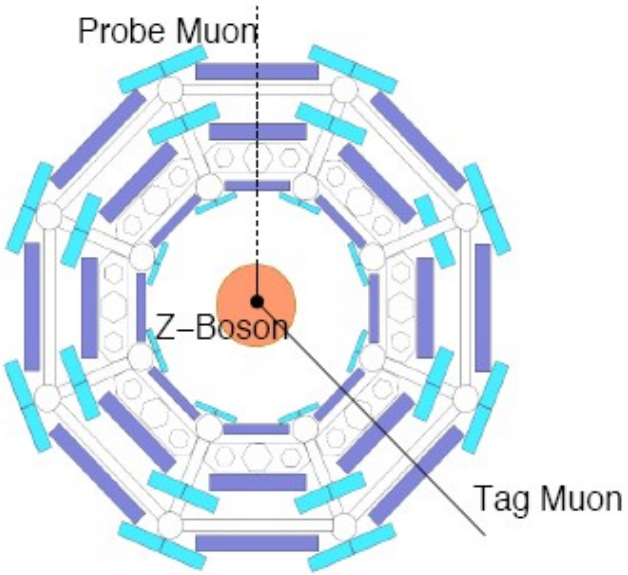


more details: **Thursday, 9 am**, **EWK physics @ LHC**, Lucia diCiaccio

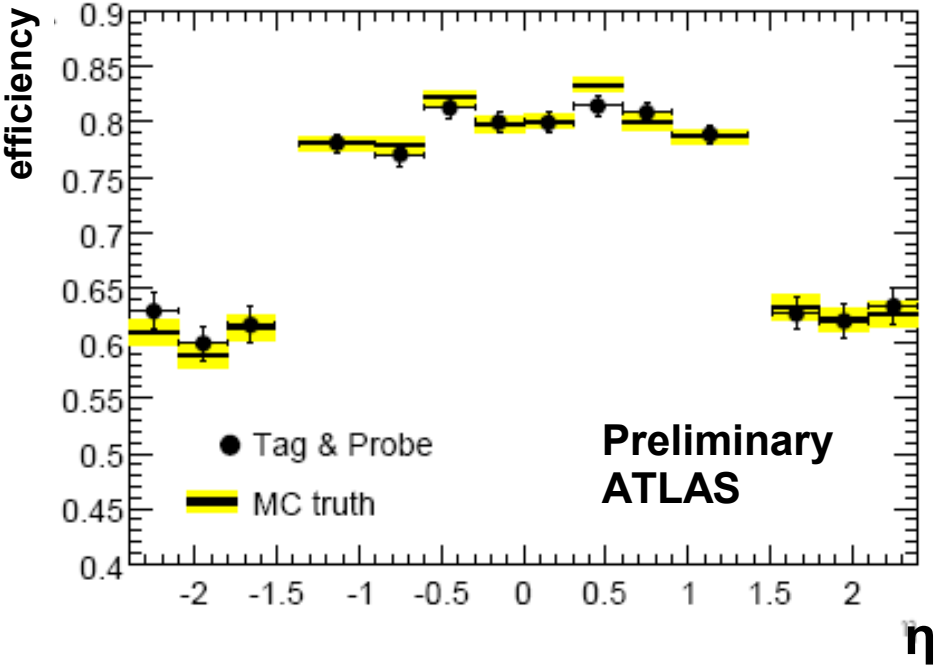
→ **need to understand tracking and charge ID**

Trigger, reconstruction and ID efficiencies

- Use Z → ll sample
- Well reconstructed lepton-*tag*
- measures *probe* lepton
- Trigger, reconstruction, ID, charge



Electron efficiency of trigger and identification



- Total efficiency:

  Systematical and statistical precision < 2% with 50 pb^{-1} for both muon and electron

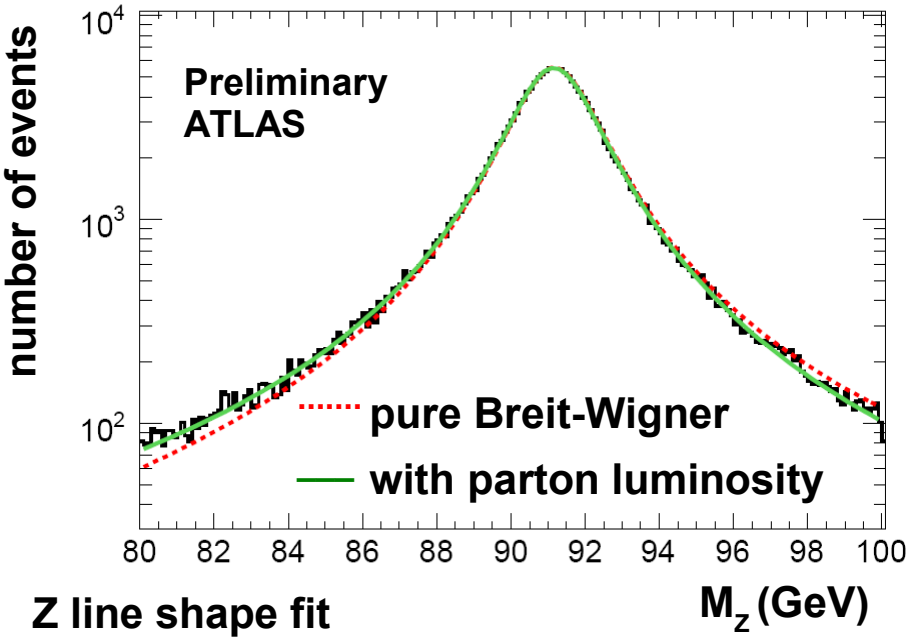
Energy scales and resolution

lepton energy scale and resolution

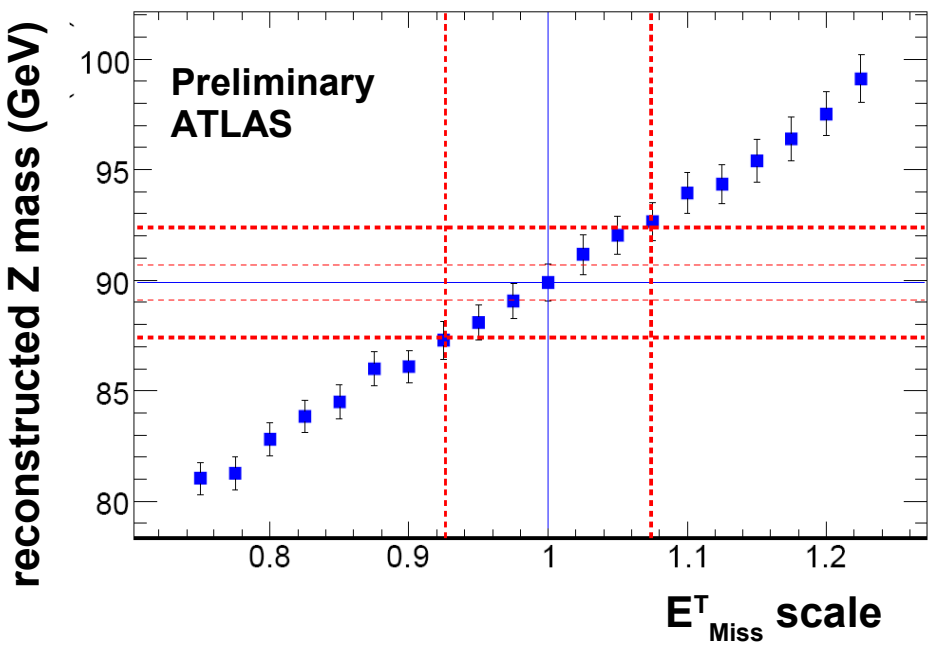
- Again: Use $Z \rightarrow ll$ sample
- Contraints from Z line shape
- Scale: < 0.5 % uncertainty
- Resolution < 0.5% uncertainty

E^T_{Miss} scale and resolution

- Semileptonic $Z \rightarrow \tau\tau$ sample
- Peak position yields E^T_{Miss} scale
- Scale: 8 % uncertainty (100 pb^{-1})
- Resolution: project E^T_{Miss} in $Z \rightarrow ll$

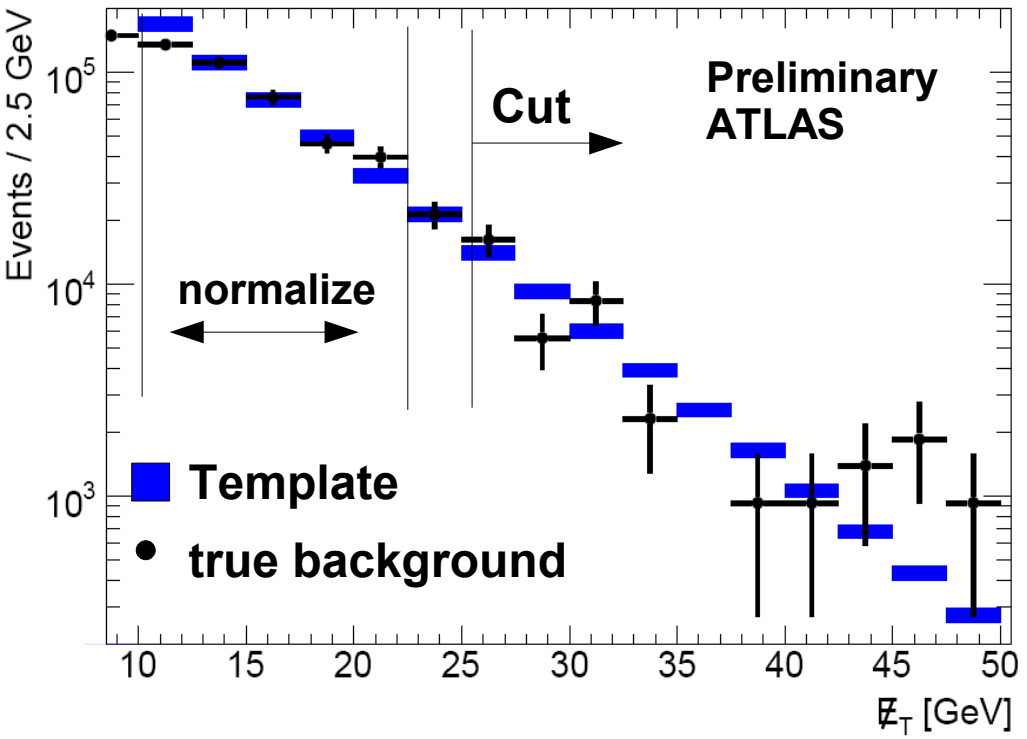


Z line shape fit



QCD Background for W production

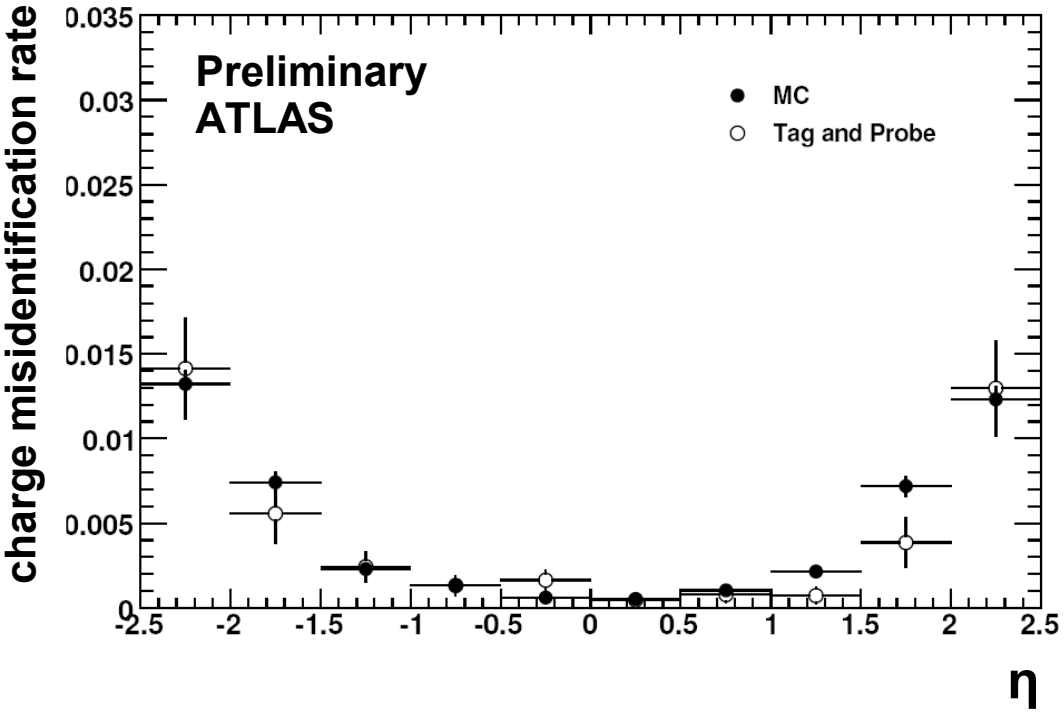
- Jets misidentified as electrons
- fake E^T_{miss}: hadronic energy not recovered
- Create pure background sample
  - same event selection
  - No track for EM object
  - jets faking photons
- E^T_{miss} shape same as faking electrons
- Fit distributions
- Normalize to 10-22.5 GeV E^T_{miss} in data
- Good description of background



Tracking performance: Charge-Misidentification

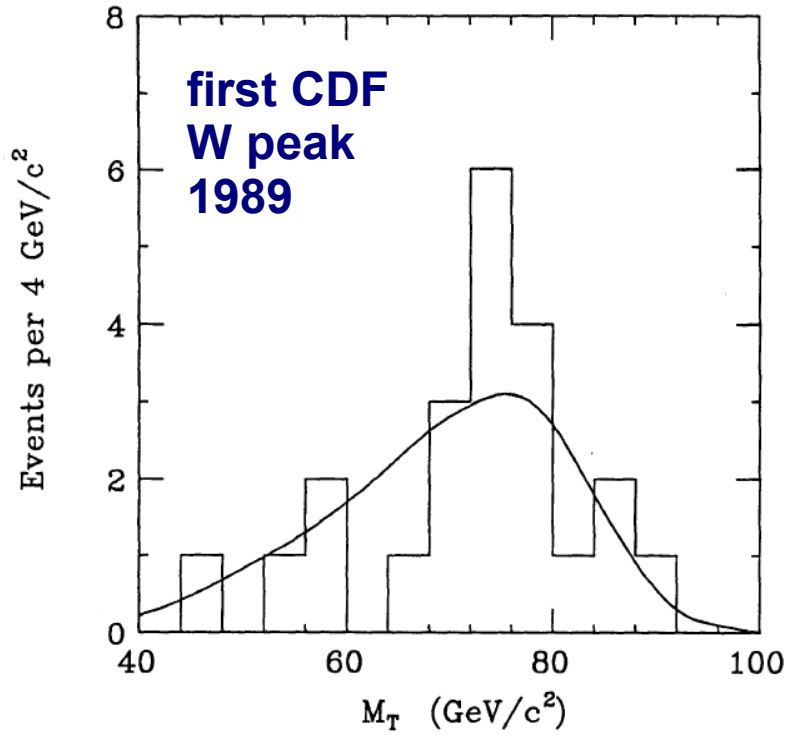
- Again using $Z \rightarrow ll$ events
- Tag and probe for charges
- Number of like-sign to all events
- e.g. electron misidentification rate:

$$f_{-} = \frac{e^{+}e^{+}}{e^{+}e^{+} + e^{+}e^{-}}$$



Outlook

1987	1989	1990			[...]	1992	1995
CDF	σ_W	Γ_Z, M_Z	σ_W/σ_Z	M_W	[...]	D0	WW search
engineering run	25.3 nb^{-1}	4.7pb^{-1}	4.4pb^{-1}	4.4/3.9pb^{-1}		Run I	14 pb^{-1}
$\Delta\sigma/\sigma$	19 %	33%, 0.4%	9 %	0.4 %			



σ uncertainties @ ATLAS
$Z \rightarrow \mu\mu$

Bkg: 2 %
ε_{tot} : 3 %
Theo. accept: 2 %

$\Delta\sigma/\sigma$
Systematic: < 5%
Luminosity: 20-30 %

2010 first electroweak physics publication?

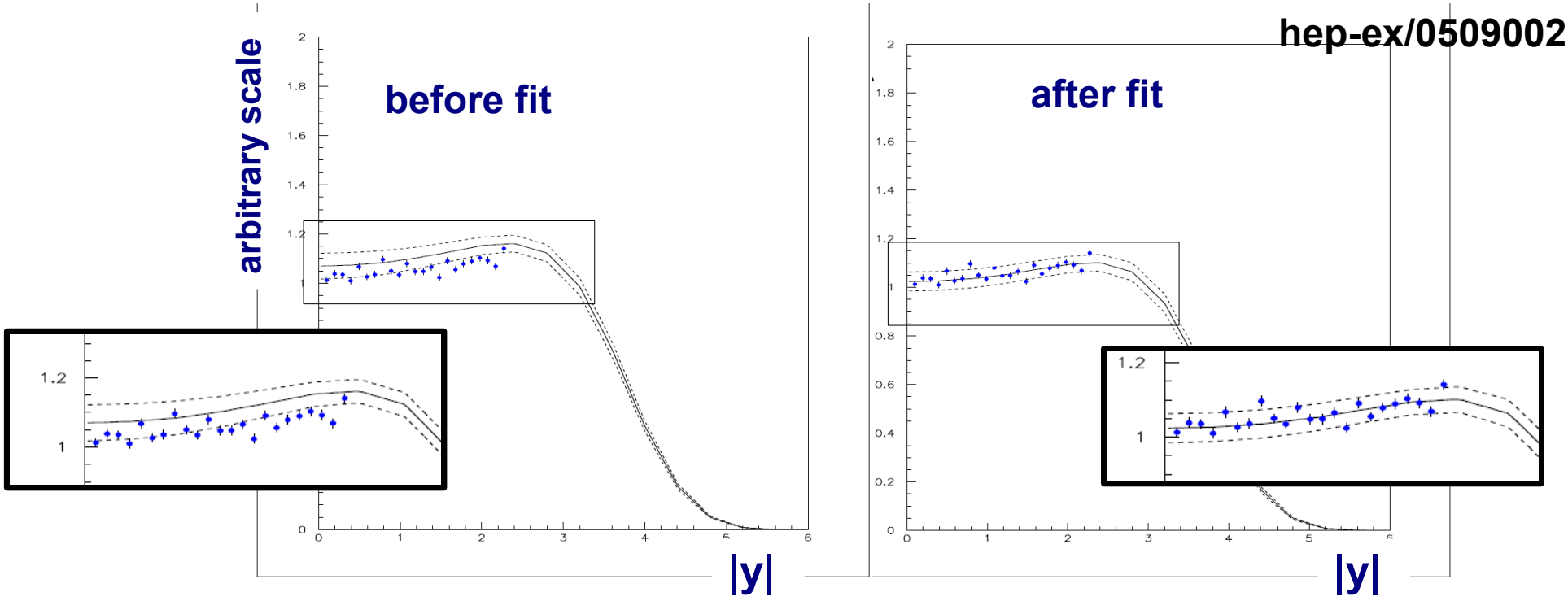
ATLAS electroweak measurements - Conclusions -

- **Methods to determine systematics in place:**
  - ***Tag & probe: reconstruction, trigger, ID, charge***
  - ***QCD backgrounds from data***
  - ***E^{T}_{Miss} and lepton energy scale***
- **Various analysis planned**
  - ***W, Z: cross sections, ratios, asymmetries***

NOW: waiting for early data

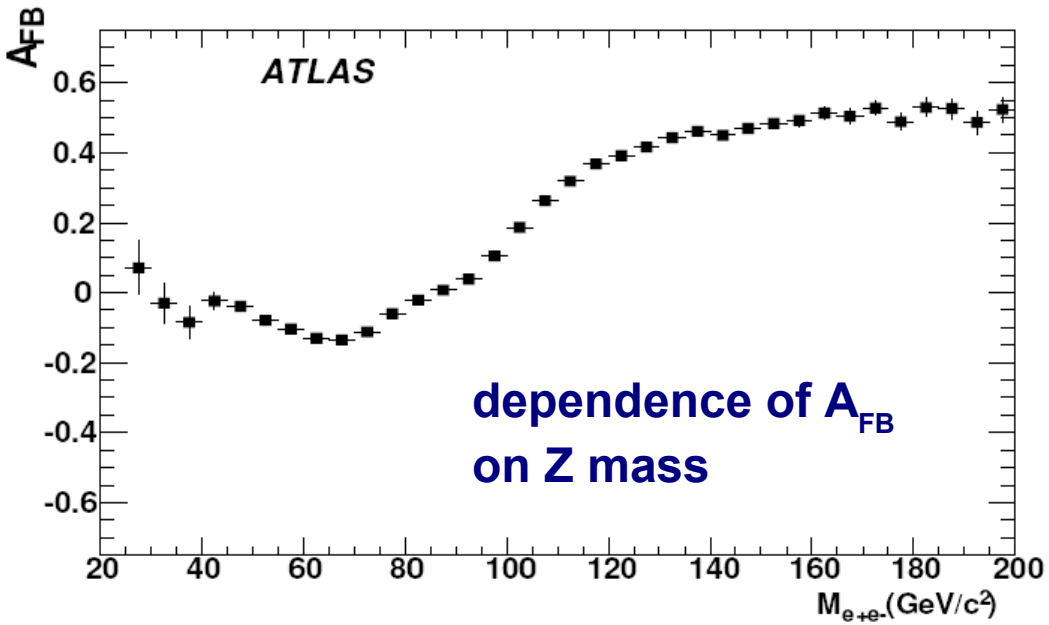
'Hvala lijepo' to the organizers!

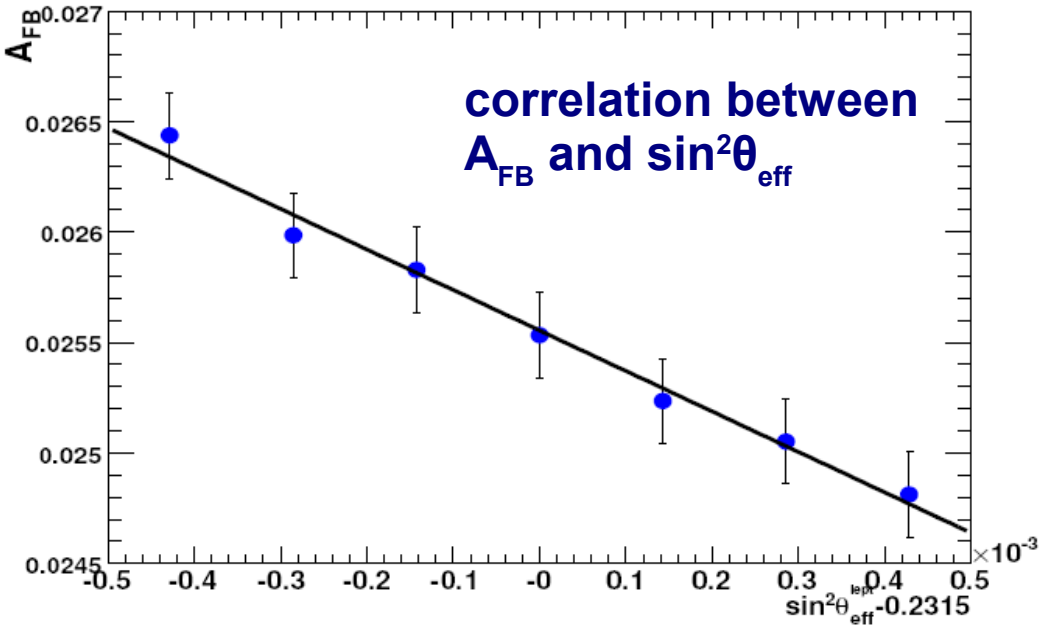
W rapidity – lepton rapidity: Proof of principle



- 250 pb^{-1} of W events generated with CTEQ6.1
- Fast detector simulation, corrected back with Zeus-PDF
- Use as input for Zeus PDF fit
- 40% reduction on uncertainty on gluon parameter in ZEUS parametrisation
- No luminosity needed, only slope important

Z asymmetry

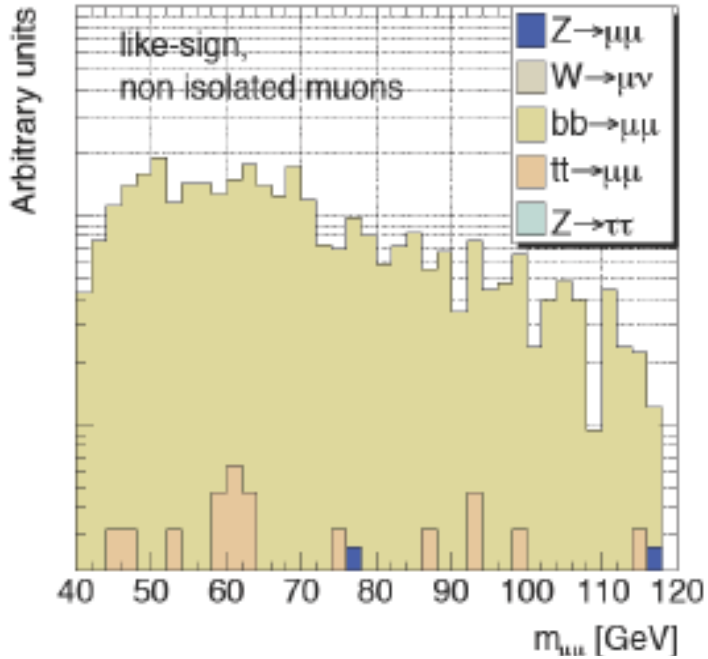

A_FB
ATLAS
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
20
40
60
80
100
120
140
160
180
200
M_e+e-(GeV/c²)
dependence of A_FB
on Z mass


A_FB
0.027
0.0265
0.026
0.0255
0.025
0.0245
-0.5
-0.4
-0.3
-0.2
-0.1
-0
0.1
0.2
0.3
0.4
0.5
×10⁻³
sin²θ_eff^lept-0.2315
correlation between
A_FB and sin²θ_eff

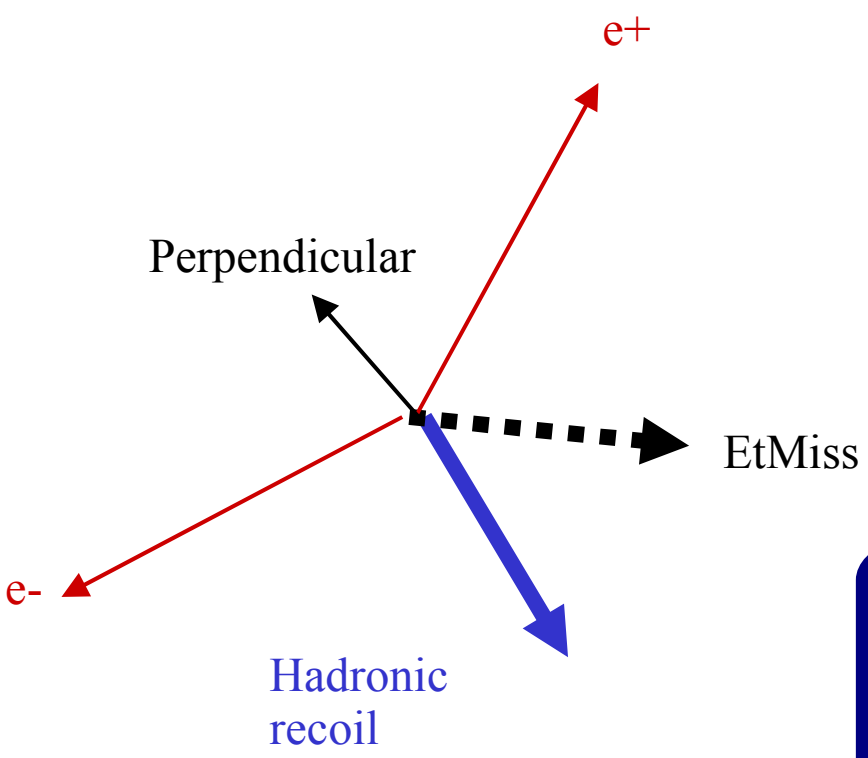
QCD Backgrounds

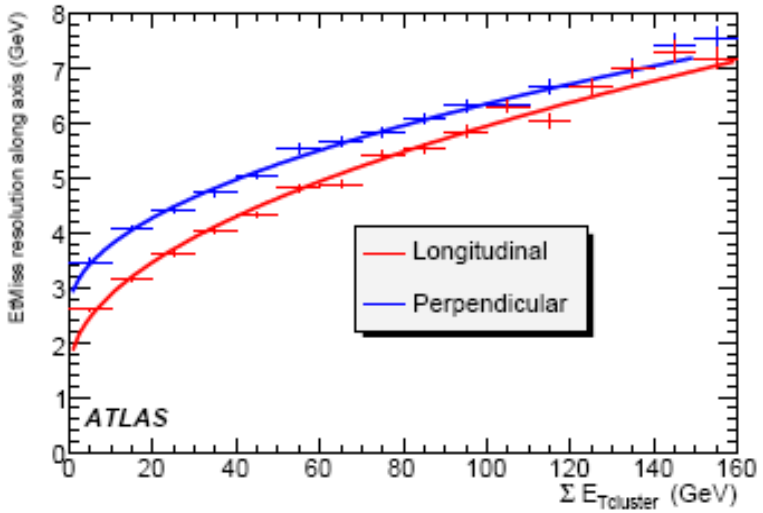
muon channels

- **Apply all cuts apart from Isolation**
  - background enriched sample
- **determine $N_{likesign}$ / $N_{opposite}$**
- **ratio of like sign events and opposide signs are ~equal in signal sample**



E^{t}_{miss} Projection in Z events





- **Project E^{T}_{Miss} in direction perpendicular / parallel to ee**
- **Projection in bins of E^{T} sum (hadronic recoil) gives resolution**
- **smear E^{T}_{Miss} with these to study W boson acceptance**

Calorimeter calibration using Z events

full description:
ATL-LARG-2004-008

$$E_i^{\text{reco}} = E_i^{\text{true}}(1+\alpha_i)$$

resonctructed energy

$$M_{ij}^{\text{reco}} \simeq M_{ij}^{\text{true}}\left(1+\frac{\alpha_i+\alpha_j}{2}\right) = M_{ij}^{\text{true}}\left(1+\frac{\beta_{ij}}{2}\right)$$

i, j regions in the calorimeter
M = Z mass

$$-\ln L_{\text{tot}} = \sum_{k=1}^{N_{ij}} -\ln L\left(M_k \Big/ \left(1+\frac{\beta_{ij}}{2}\right), \sigma_{M,k}\right)$$

minimize and extract β_{ij} for each event *k*

$$L(M,\sigma_M) = \int_{-\infty}^{+\infty} \text{BW}(M-u)\mathcal{L}(M-u)\frac{e^{-u^2/2\sigma_M^2}}{\sqrt{2\pi}\sigma_M}du$$

using Z line shape