Measurement of Tau Spectral Functions from ALEPH

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Outline

- Introduction
- Measured mass spectrum
- Comparison data/MC of charged hadron and neutral pions
- Unfolding
- Results

Tau Spectral Functions

The spectral function is the normalised mass spectrum scaled with other kinematic factors

$$v_{\pi\pi^0}(s) = \frac{m_\tau^2}{6|V_{ud}|^2 S_{\rm EW}} \frac{B(\tau^- \to \pi^-\pi^0\nu_\tau)}{B(\tau^- \to e^-\bar{\nu}_e\nu_\tau)} \frac{dN_{\pi\pi^0}}{N_{\pi\pi^0}ds} \left[\left(1-\frac{s}{m_\tau^2}\right)^2\left(1+\frac{2s}{m_\tau^2}\right)\right]^{-1}$$

The mass spectrum of the $\pi\pi^0$ final state is obtained by

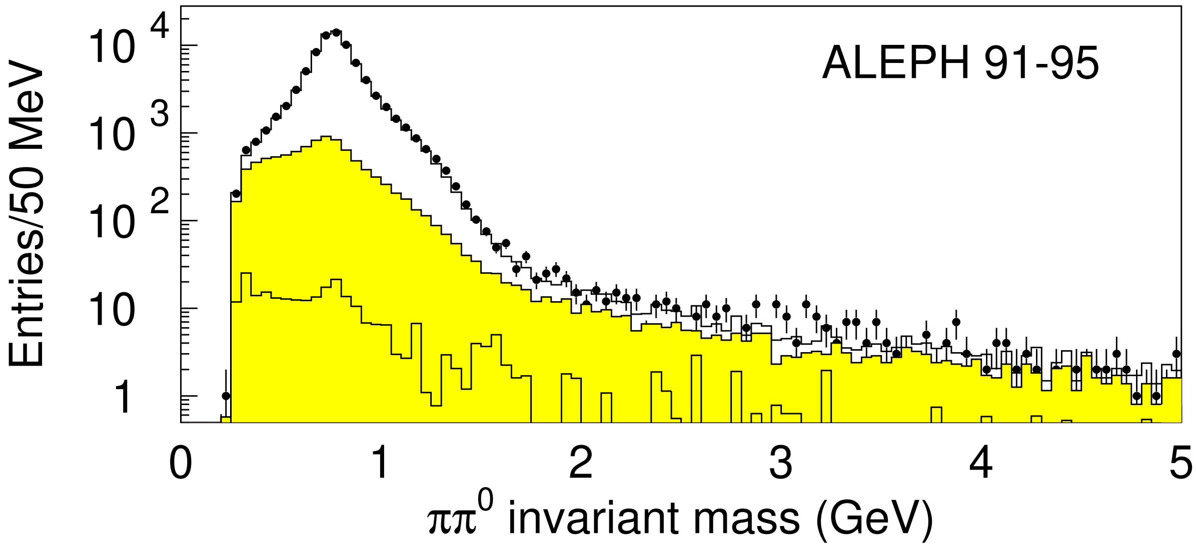
- subtracting non-tau (small) and tau cross-feed background
- correcting migration and detector resolution effects by an unfolding

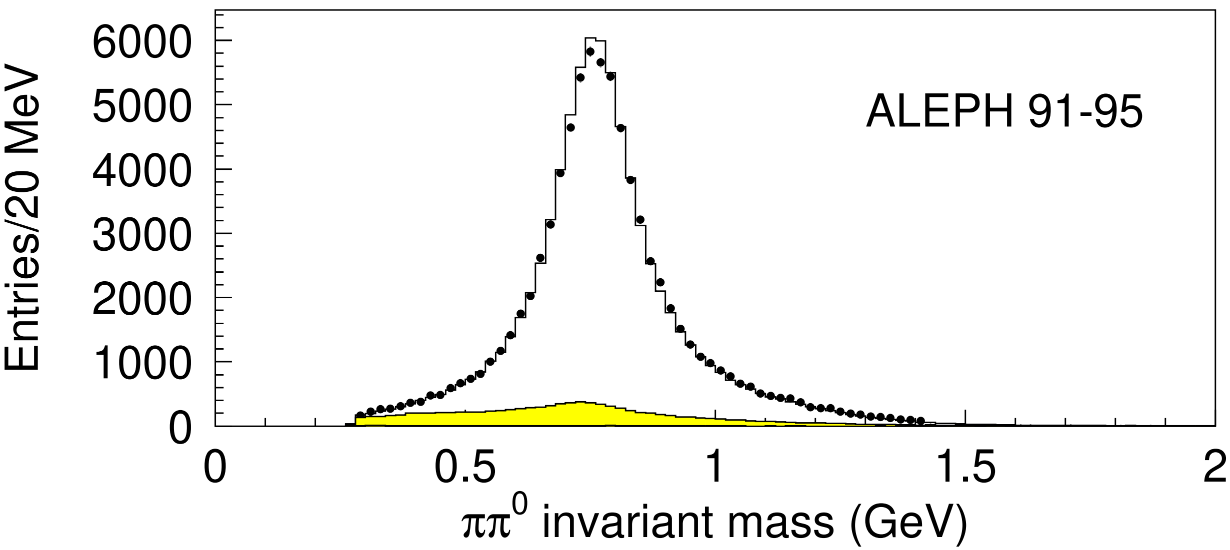
➔ Experimentally, the two key components of the spectral function are

- branching fraction of the decay mode (see the talk by Michel)
- the shape of the mass spectrum

Measured Mass Spectrum

ALEPH 2005

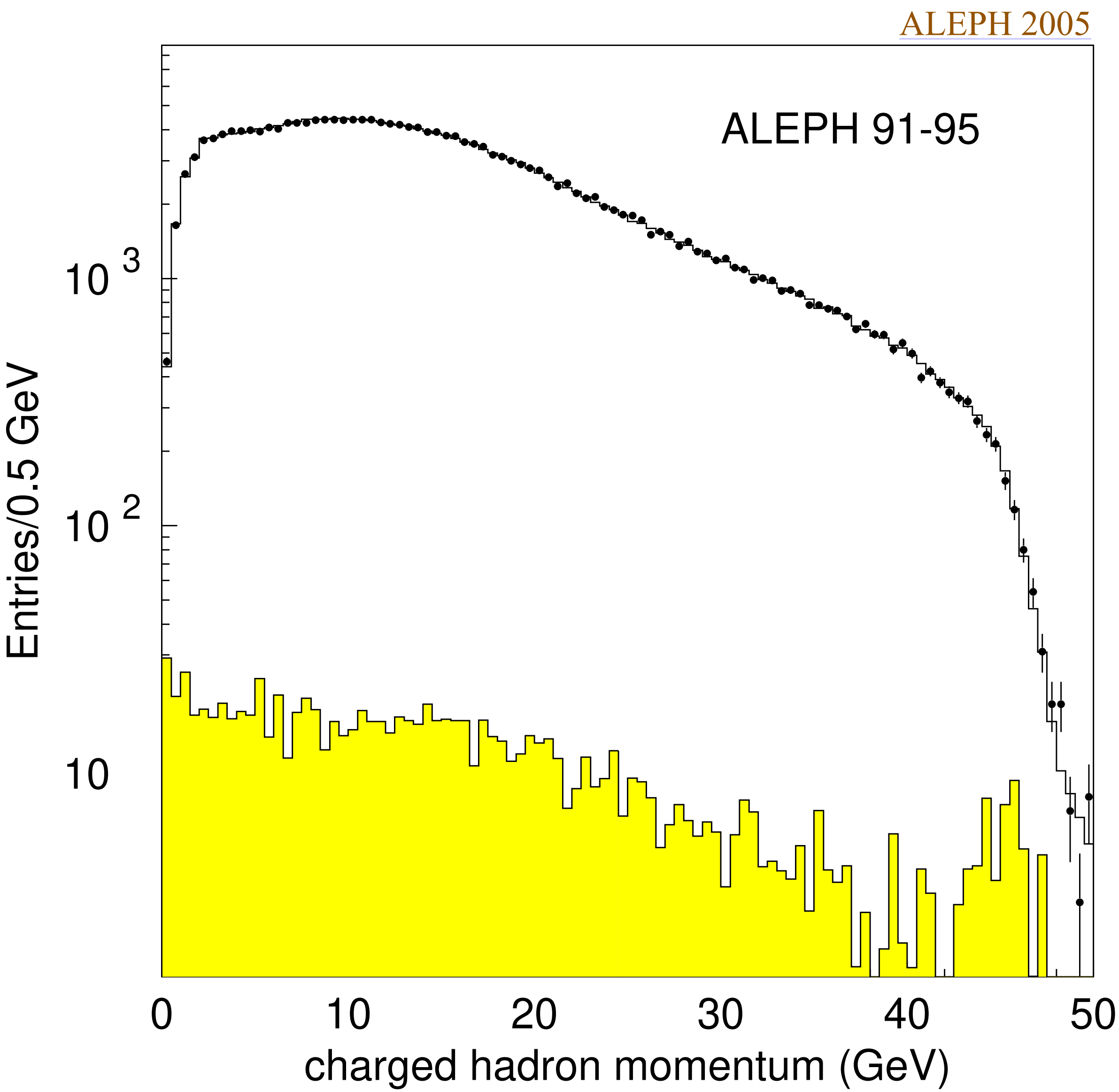




Non-tau background at per-mille level

Tau cross-feed at percent level under the rho peak

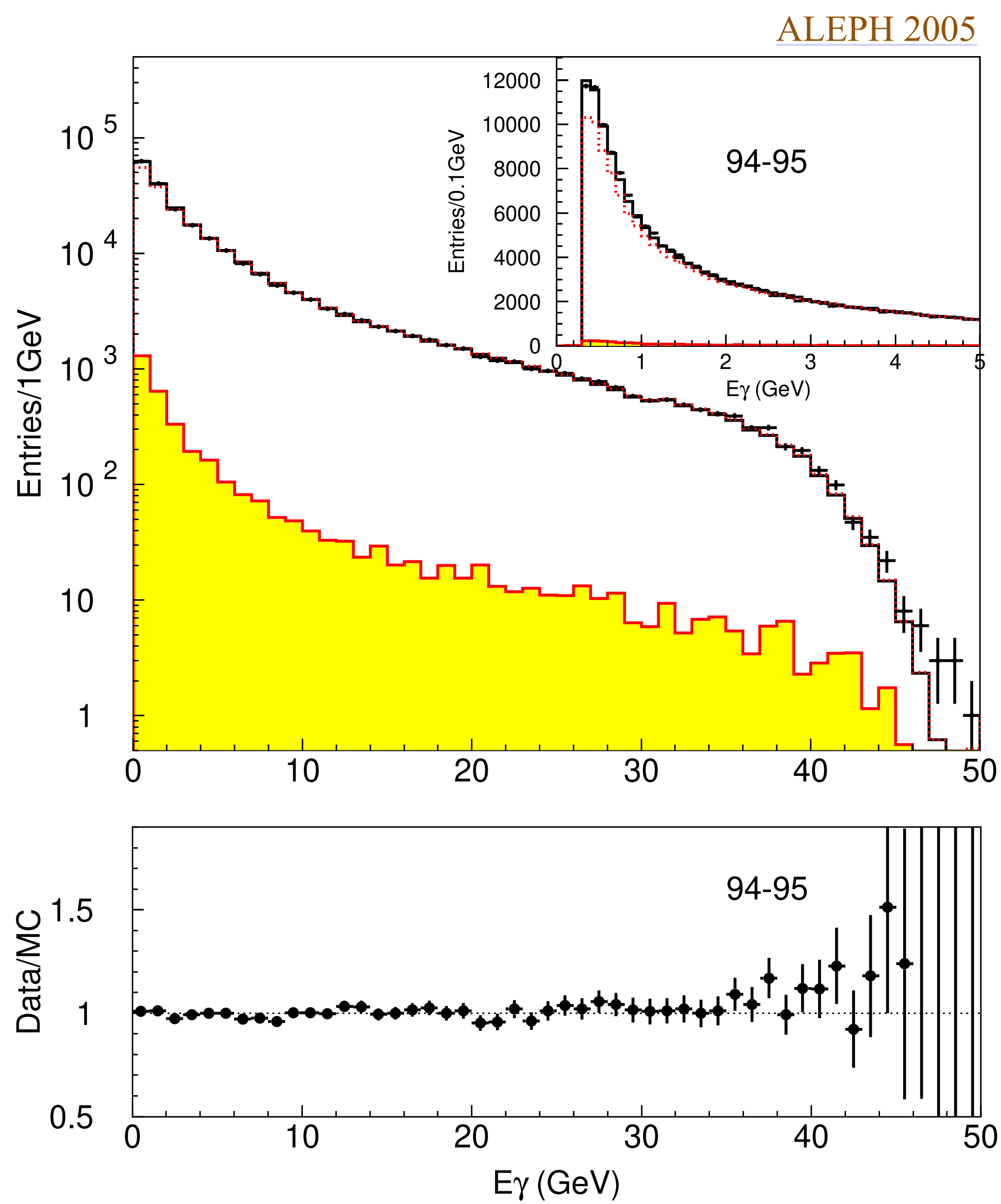
Charged Hadron Momentum Spectrum



Non-tau background at per-mille level

Excellent agreement data/MC over the full momentum spectrum

Photon Energy Spectrum



Dotted histo indicates the size of the fake photon corrections (at low energies)

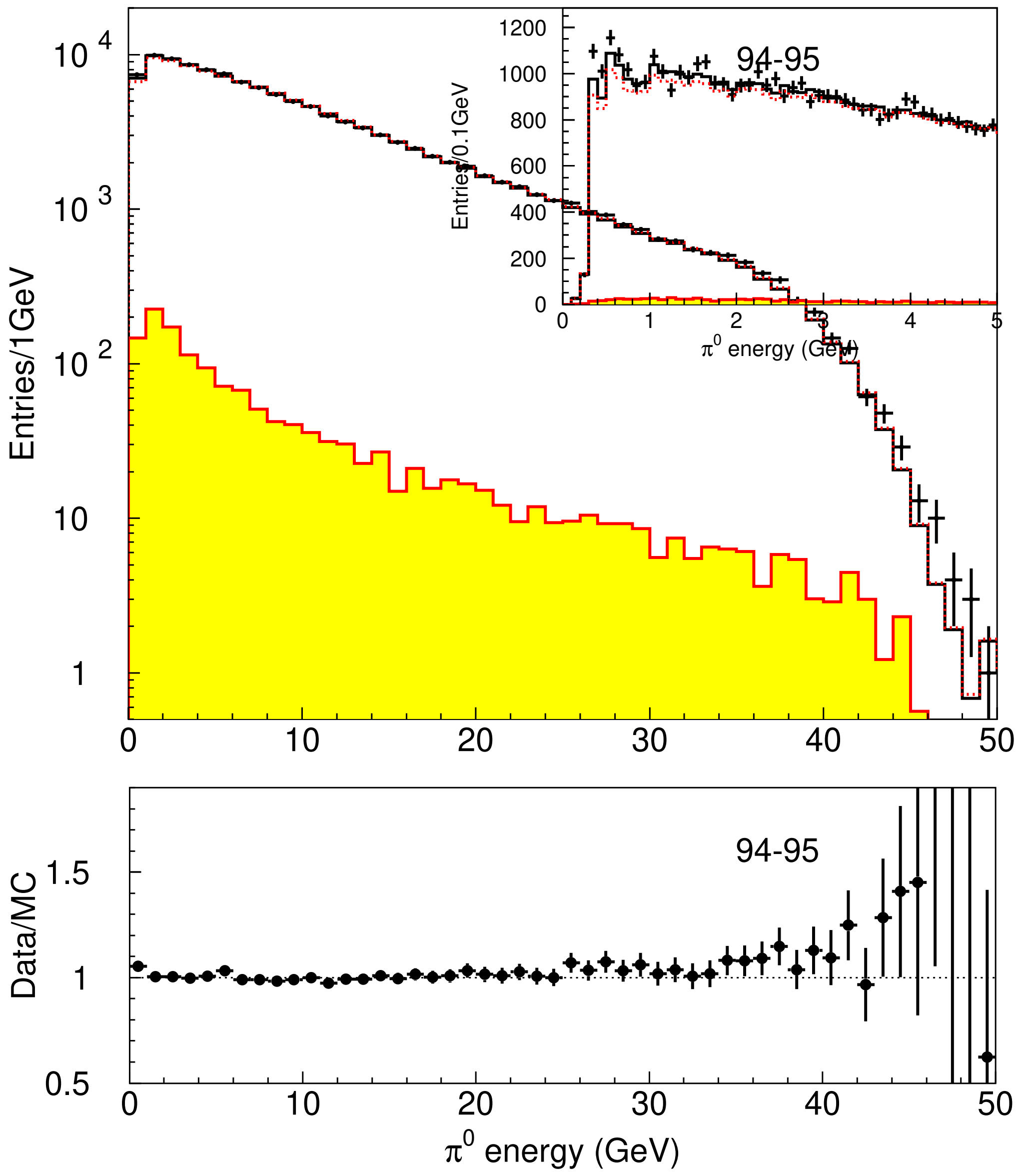
Good agreement data/MC except at the high energy tail (understood)

The analysis performed in two data taking periods 91-93, 94-95

Similar agreement for period 91-93

π^0 Energy Spectrum

ALEPH 2005



Similar agreement also seen for π^0 energy spectrum

Unfolding

To correct detector resolution effects, unfolding was initially performed with

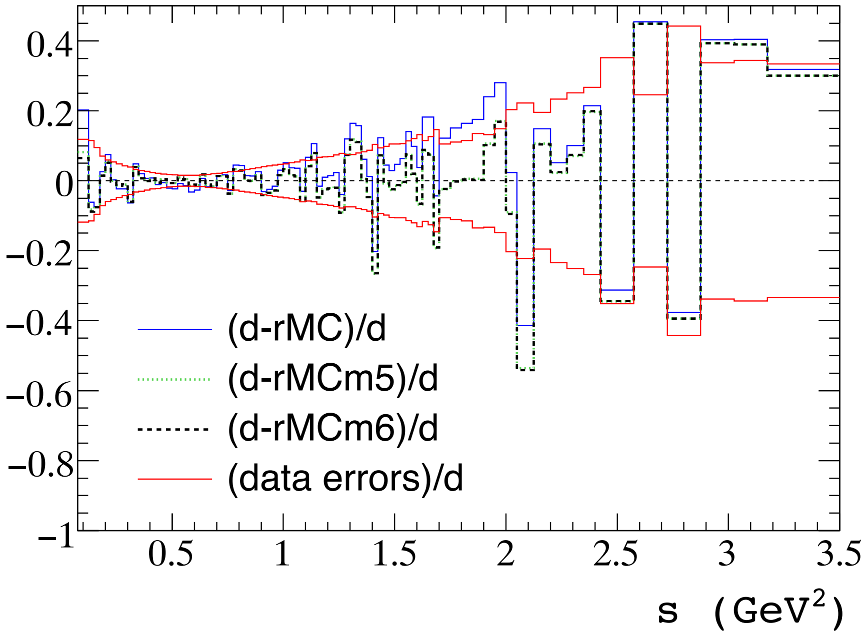
- SVD (singular value decomposition) technique [Hoecker-Vakhtang 1996]
- However there was an issue in the covariance matrix as pointed out by D. Boito

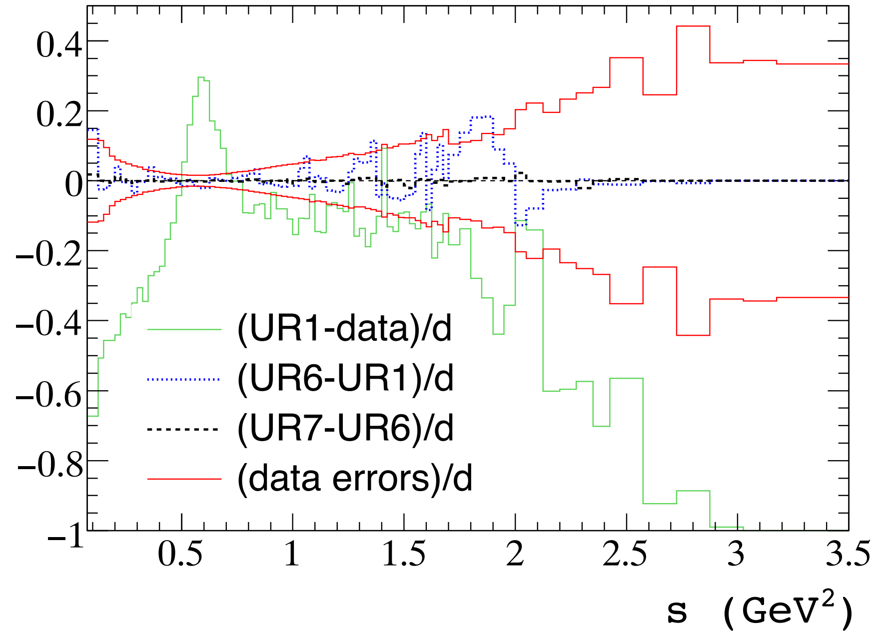
An Iterative Dynamically Stabilised (IDS) method [Malaescu 2011] used for update in 2013

The new unfolding method uses a weaker regularisation than the SVD approach
➔ The new method induces less smoothing and correlation between mass bins

Performance

ALEPH update 2013

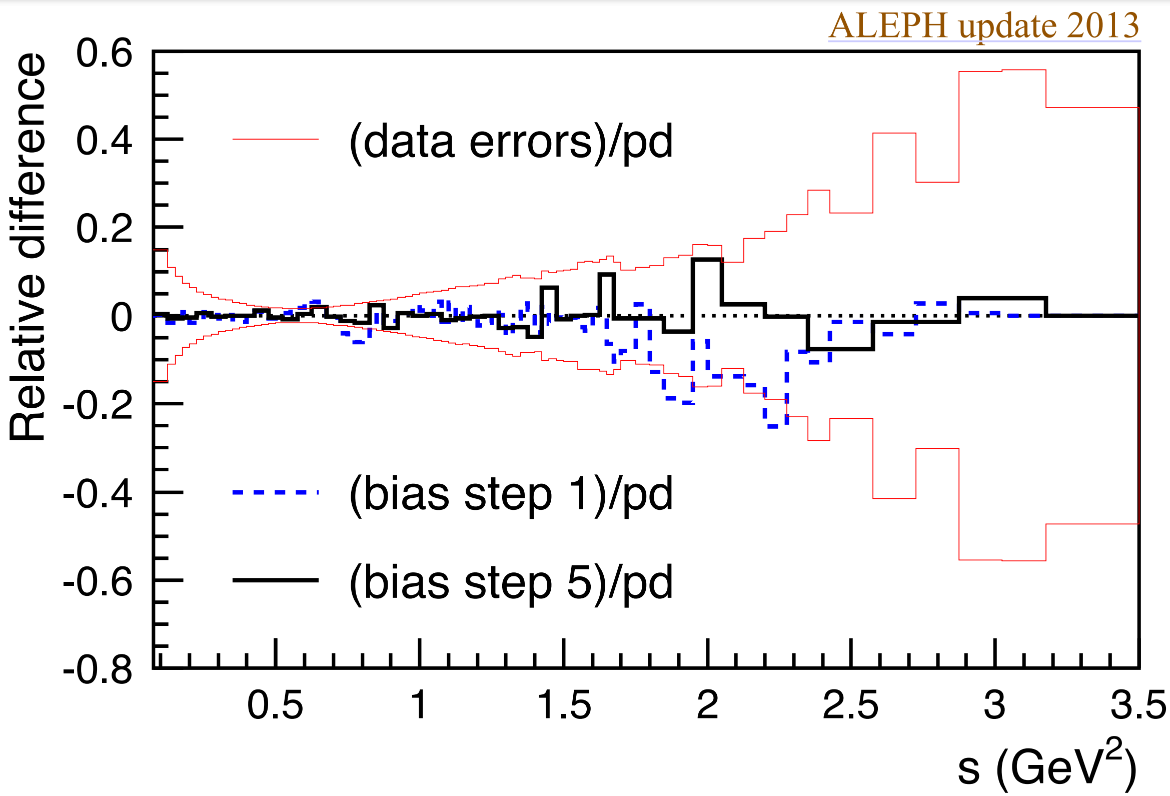




Comparison data (d) and reconstructed MC (rMC) for different numbers of iterations
➔ Agreement improves after each iteration

Relative correction to the measured spectrum resulting from the unfolding
➔ Most of the correction is applied in the first iteration

Unfolding Bias



Closure test using pseudodata (pd) — reweighed MC spectrum having similar shape on reconstruction level as the data

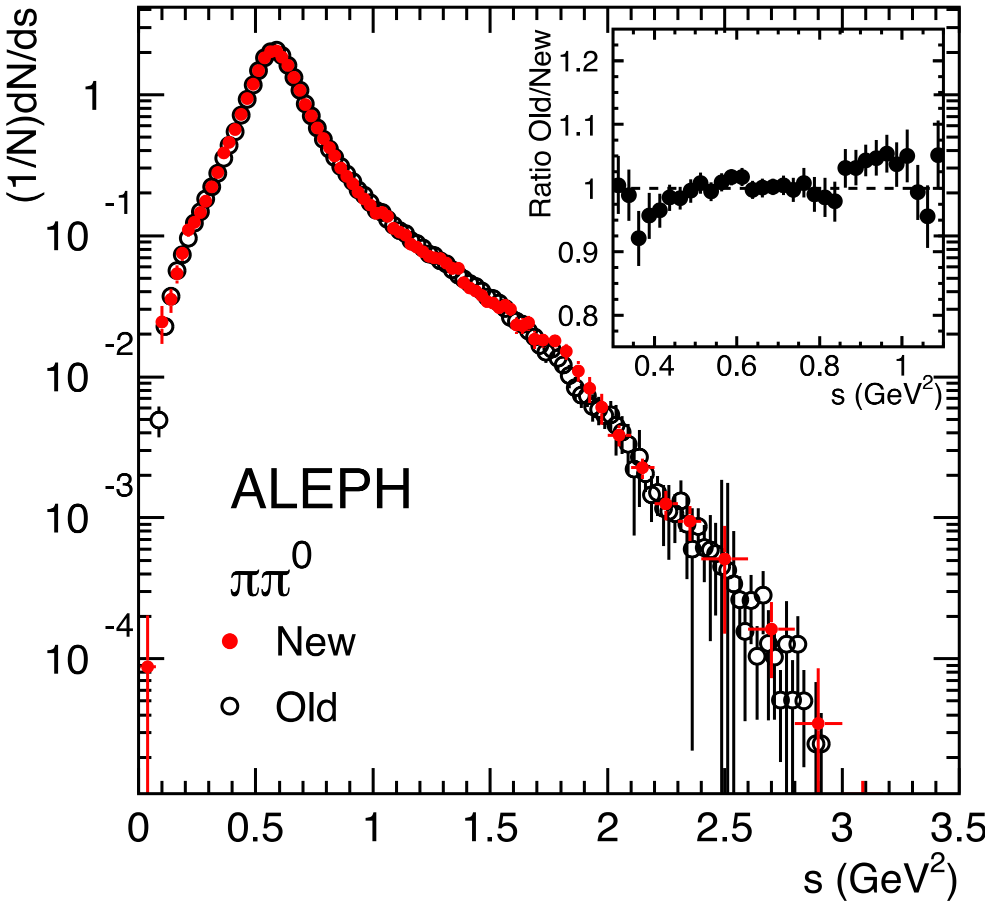
Bias = difference between the true pd spectrum and the unfolded one

The fluctuations in the unfolded spectrum after 5 iterations are of mainly stat origin

Rebinning to broader bins reveals a negligible syst bias

Comparison of Unfolded Spectra

ALEPH update 2013

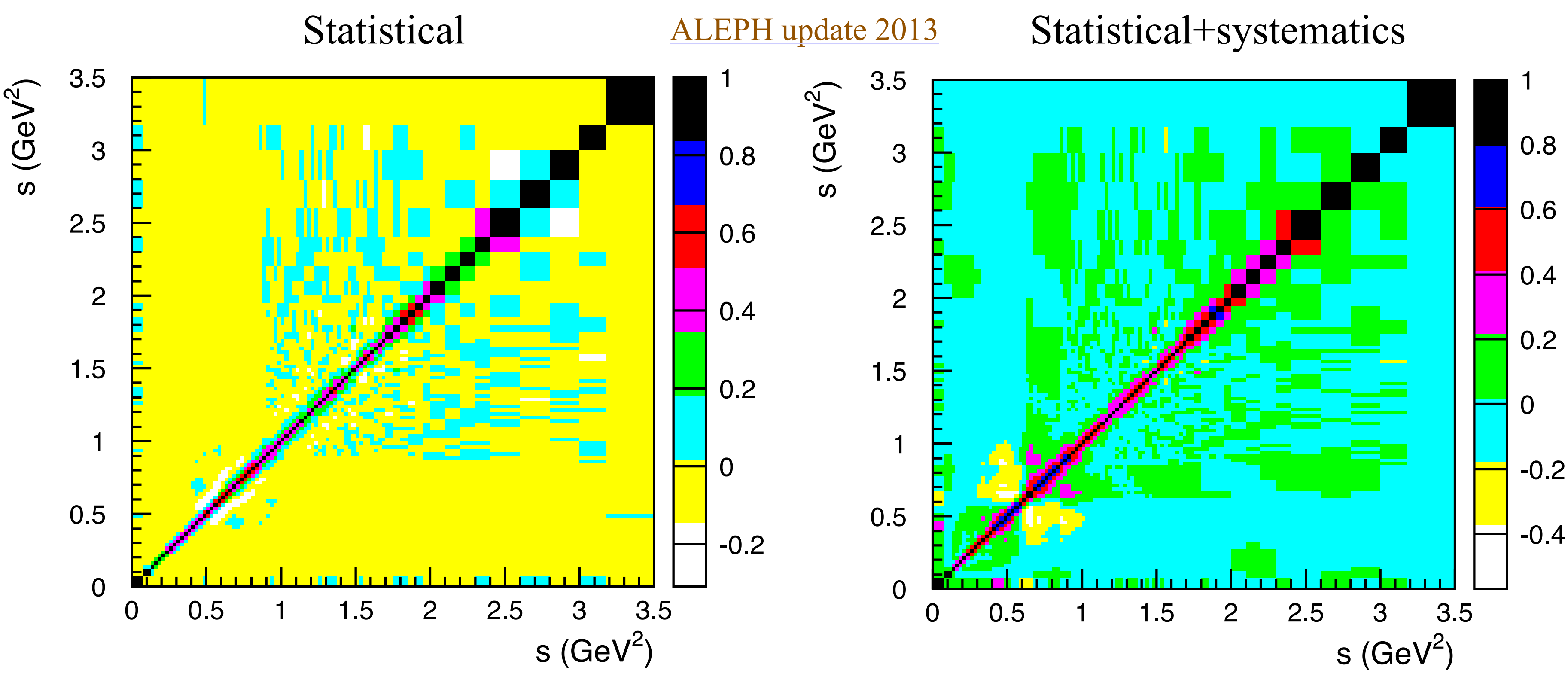


The new spectrum

- is less smooth
- uses coarser bins at the tails

An example of Correlation Matrices for Vector Spectral Function

ALEPH update 2013



They have been carefully checked using pseudodata

Online Availability

- ➢ Numerical spectral function files and their covariance matrices are available online at this web page:
  http://aleph.web.lal.in2p3.fr/tau/specfun13.html

- ➢ They have been used in many phenomenological studies (see e.g. DHZ 2005)