Semileptonic branching fractions of b and c hadrons at OPAL

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Outline

- Brief overview on semileptonic branching ratios
- A new method to extract $\mathrm{BR}(\mathrm{b} \to \ell \mathrm{X})$
- A first measurement for $\mathrm{BR}(\mathrm{c} \to \ell \mathrm{X})$ at OPAL
- Outlook

Current situation for $\mathrm{BR}(\mathrm{b} \to \ell \mathrm{X})$

- Theory can now accommodate experimental values for $\mathrm{BR}(\mathrm{b} \to \ell \mathrm{X})$ and n_c simultaneously
- But experimental results obtained at Z^0 and $\Upsilon(4S)$ for $\mathrm{BR}(\mathrm{b} \to \mu \mathrm{X})$ differ by 2.3 σ

$$\Upsilon(4S) : \mathrm{BR}(\mathrm{B} \to \ell \mathrm{X}) = (10.45 \pm 0.21)\%$$
$$\mathrm{Z}^0 \quad : \ \mathrm{BR}(\mathrm{b} \to \ell \mathrm{X}) \ = (11.12 \pm 0.20)\%$$

- b hadrons at the Z^0: $\mathrm{B}^0, \mathrm{B}^{\pm}, \Lambda_\mathrm{b}, \mathrm{B}_\mathrm{s}$
- b hadrons at the $\Upsilon(4S)$: B^0 and $\mathrm{B}^{\pm}$ only

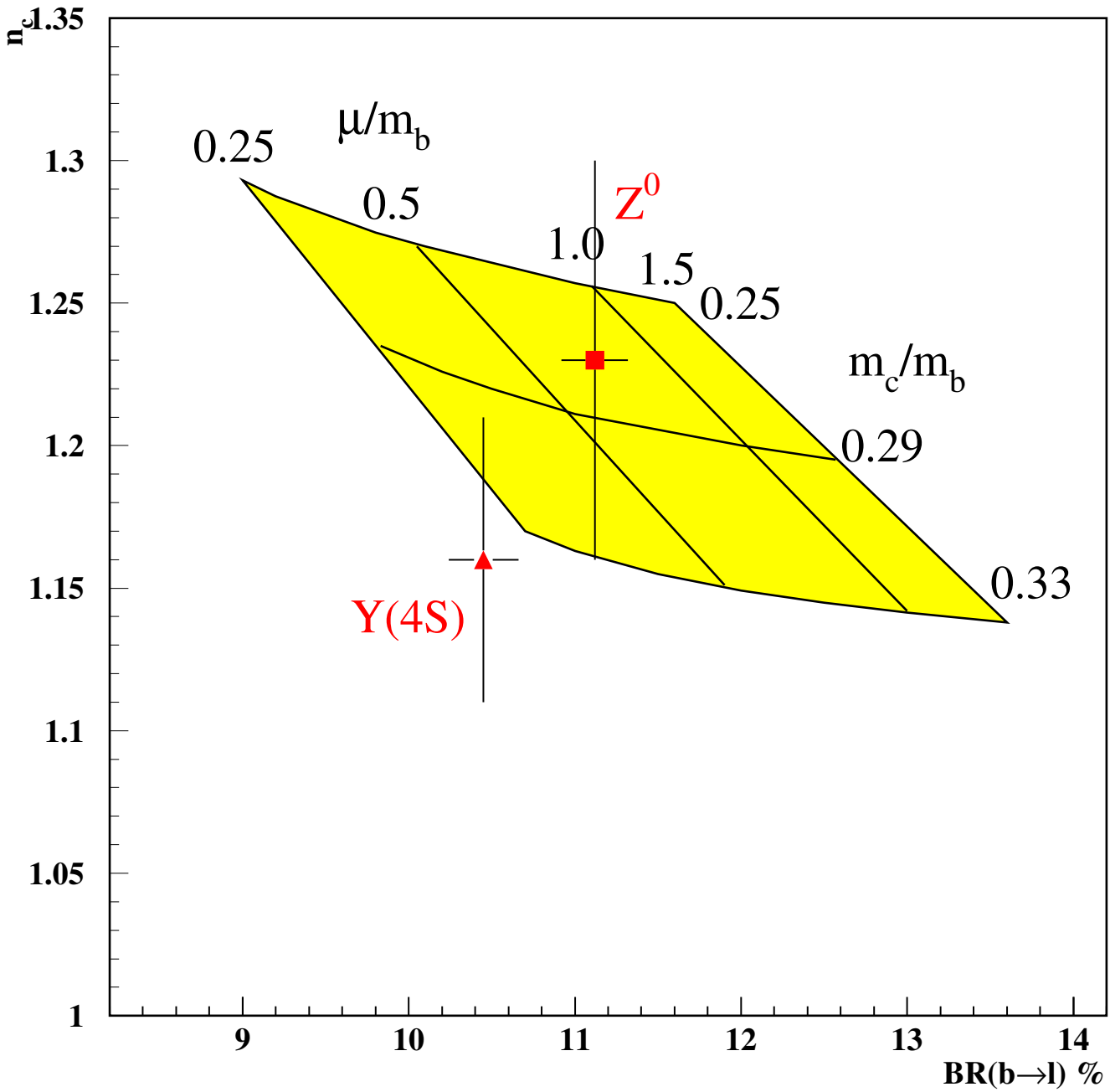
$$\mathrm{Assume}\ \Gamma^b_{\mathrm{sl}} \approx \Gamma^{\mathrm{B}}_{\mathrm{sl}} \Rightarrow \mathrm{BR}^{\mathrm{B}}_{\mathrm{sl}} \approx \frac{\tau_{\mathrm{B}}}{\tau_{\mathrm{b}}} \cdot \mathrm{BR}^{\mathrm{b}}_{\mathrm{sl}}$$
$$\Downarrow$$

Correction increases discrepancy:

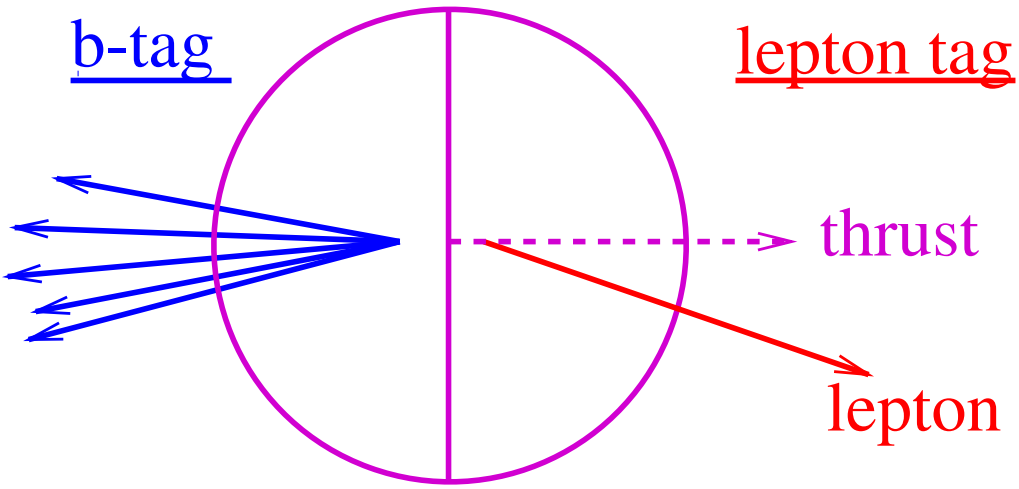
$$\Rightarrow (10.45 \pm 0.21)\% \neq (11.32 \pm 0.32)\% \Leftarrow$$

$BR(b \to \ell X)$ versus n_c

n_c: number of charm hadrons per b hadron decay



New method to extract $\mathrm{BR}(\mathrm{b} \to \ell \mathrm{X})$

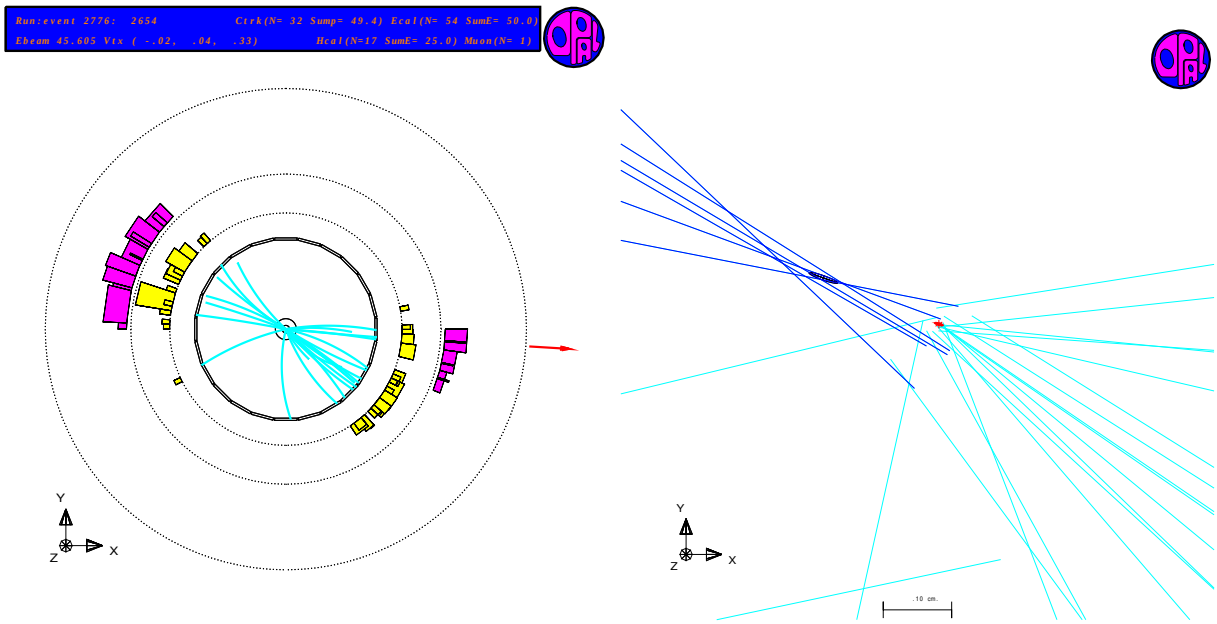


- Select $\mathrm{b\bar{b}}$ events using a lifetime b-tagging technique
  $\to$ Extract b purity from data $(93.24 \pm 0.70)\%$
- Search all hemispheres opposite a b-tagged hemisphere for prompt leptons
- Use a neural network to separate $(\mathrm{b} \to \mu)$ from $(\mathrm{b} \to \mathrm{c} \to \mu)$ events (use info from p, p_t and jet shape)
- Use shape of NN output variable to fit for the fractions of $(\mathrm{b} \to \mu)$, $(\mathrm{b} \to \mathrm{c} \to \mu)$ and other backgrounds.

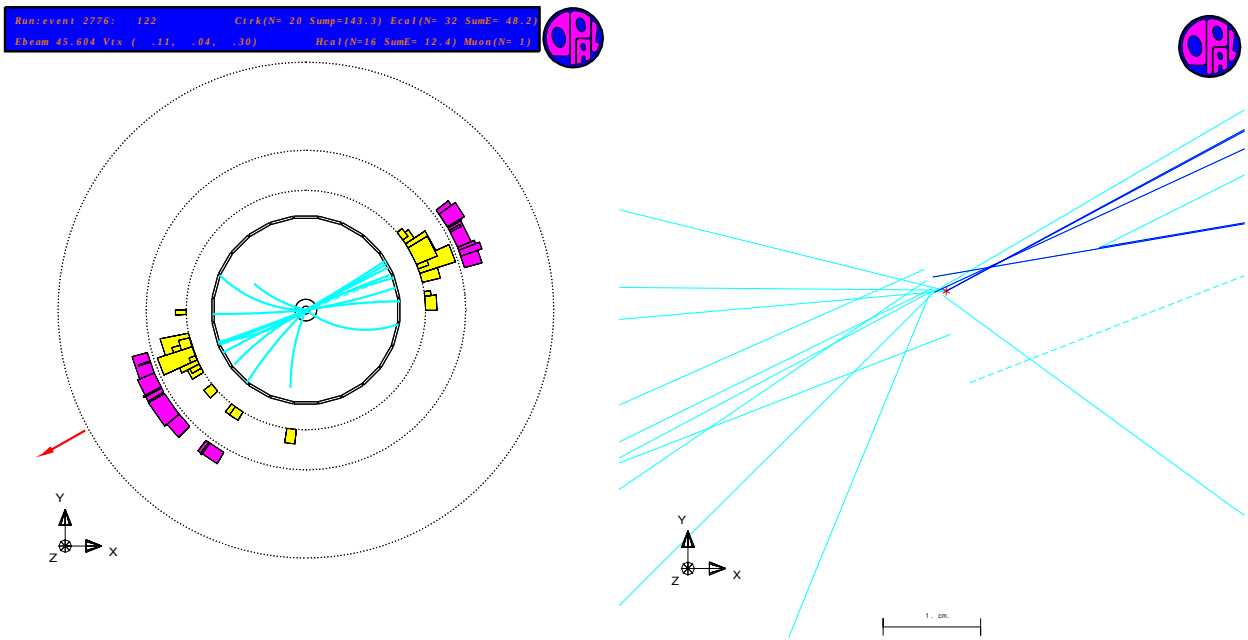
$\Rightarrow$ Preliminary result with muons only

$\Rightarrow$ Electrons will be included in upcoming final publication

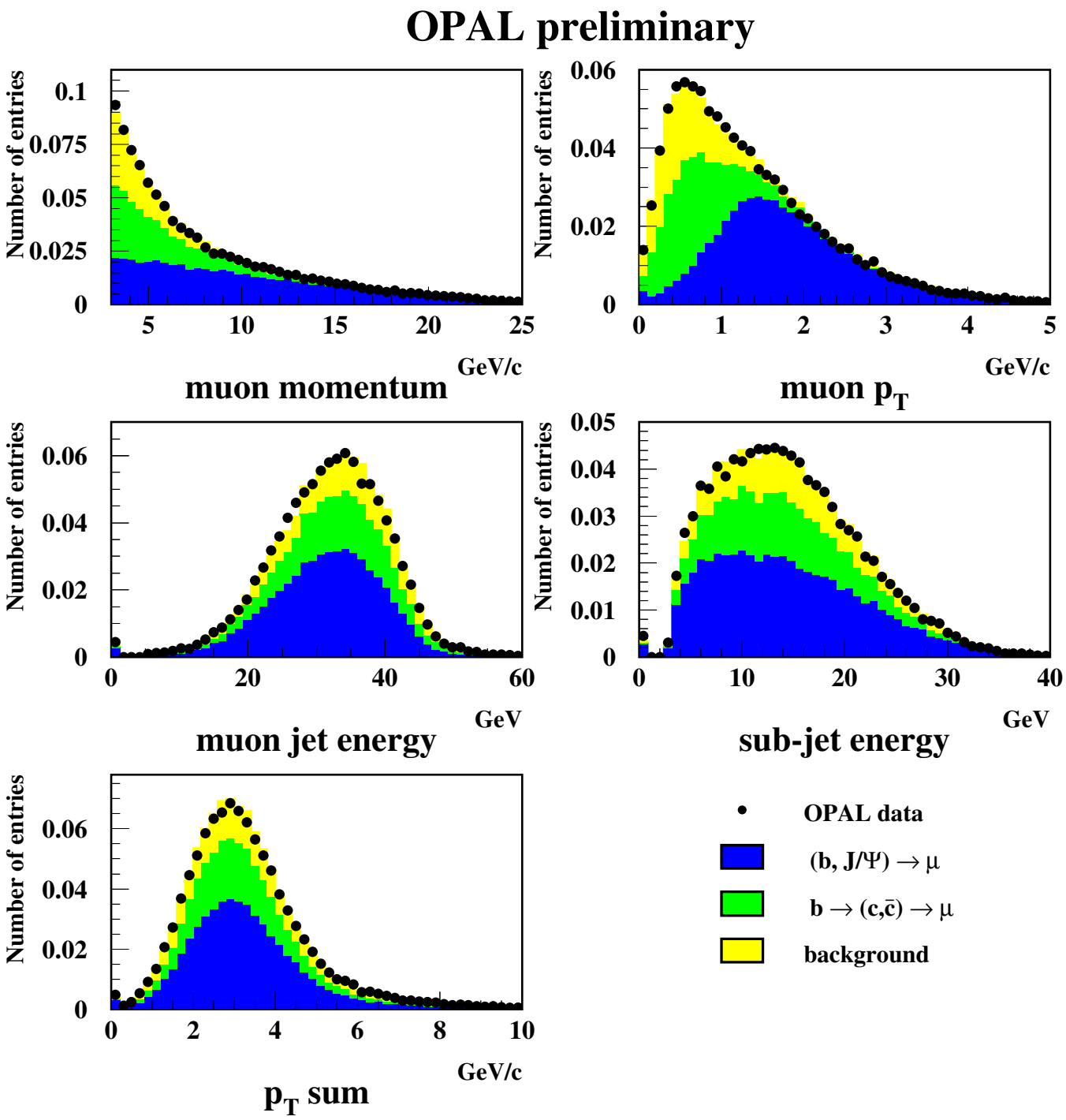
Typical $(b \rightarrow \mu)$ MC event



Typical $(b \rightarrow c \rightarrow \mu)$ MC event



Neural network input variables



NN output: data vs MC

- Use binned χ^2 to fit the data against the shape of NN output for the three Monte Carlo samples
- Fit has 2 free parameters: $f([\mathrm{b},\ \mathrm{J}/\Psi] \to \mu)$ and $f(\mathrm{b} \to [\mathrm{c}, \bar{\mathrm{c}}] \to \mu)$
- Monte Carlo statistics are included in the fit

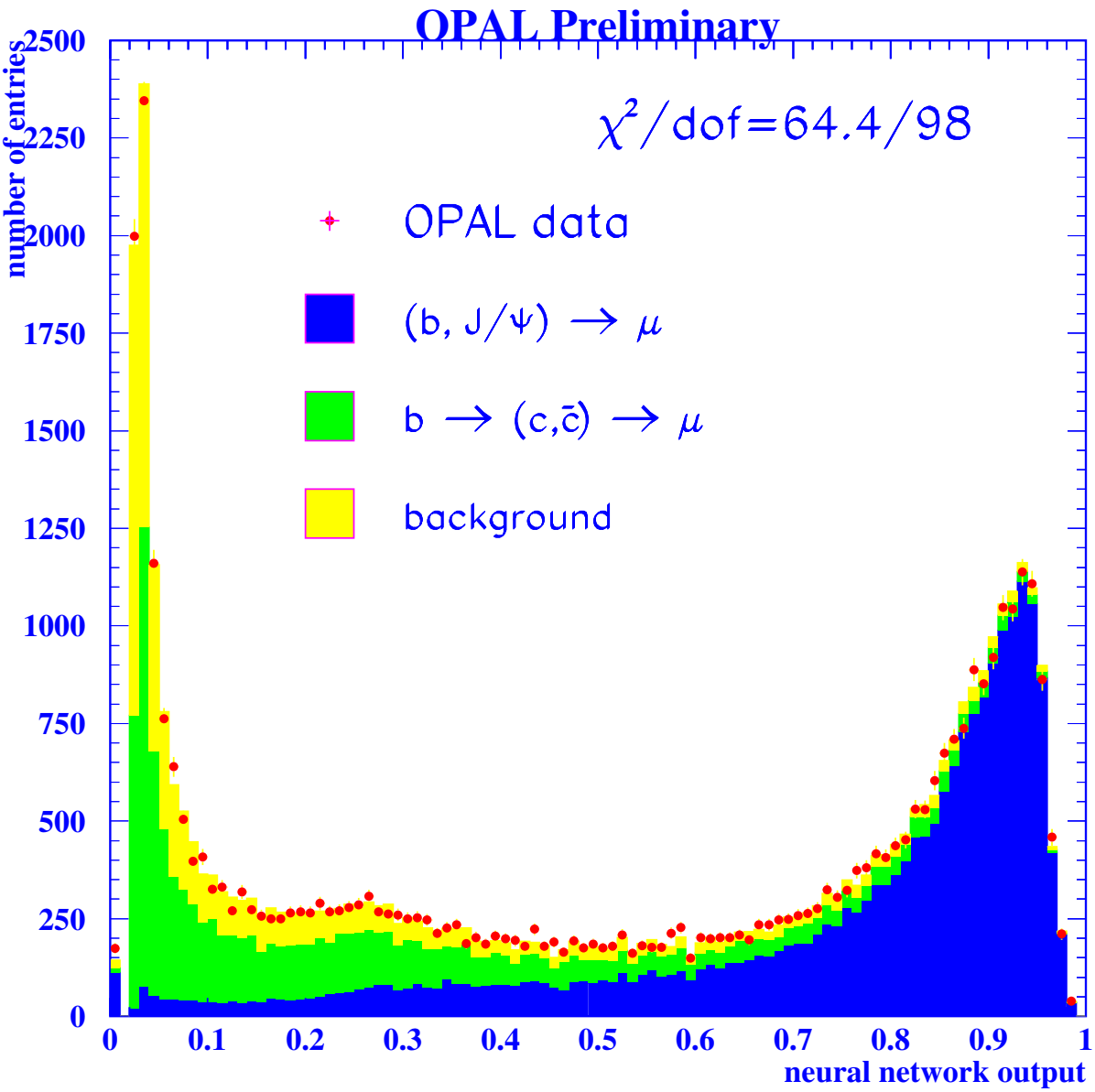
From the fit to $38\,617$ muons from $1992 - 1995$:

$$f([\mathrm{b},\ \mathrm{J}/\Psi] \to \mu) = 0.5311 \pm 0.0025\ (\mathrm{stat.})$$
$$f(\mathrm{b} \to [\mathrm{c}, \bar{\mathrm{c}}] \to \mu) = 0.2745 \pm 0.0080\ (\mathrm{stat.})$$

Correlation coefficient = -0.40.

Using these fractions, we can check data against MC

Agreement between data and MC



Calculating $(\mathrm{b} \to \mu)$

$$\mathrm{BR}(\mathrm{b} \to \mu\mathrm{X}) = \frac{N_{(\mathrm{b}\to\mu)}}{N_{\mathrm{b}}}$$

$N_{(\mathrm{b}\to\mu)}$= # of b events decaying semileptonically

N_{b} = # of (b $\to$ X) events

$$\mathrm{BR}(\mathrm{b} \to \mu\mathrm{X}) = \frac{N_{\mu} \cdot f_{\mathrm{b}}}{\epsilon_{\mathrm{b}\to\mu}} \cdot \frac{1}{N_{\mathrm{b-tags}} P_{\mathrm{b}}}$$

N_{μ}= # muons found opposite a b-tagged hemisphere $(38\,617)$

f_{b}= signal fraction determined by the fit

$f(\mathrm{b} \to \mu) \ = 0.5311 \pm 0.0025)\%$

$\epsilon_{\mathrm{b}\to\mu}$= muon finding efficiency from MC: $(62.44 \pm 0.89)\%$

$N_{\mathrm{b-tags}}$= all b-tagged hemispheres $(319\,013)$

P_{b}= b-flavour purity extracted from data $(93.24 \pm 0.70)\%$

$$\Downarrow$$

$$\mathrm{BR}(\mathrm{b} \to \mu\mathrm{X}) =$$

$$(10.86 \pm 0.08\ (\mathrm{stat.}) \pm 0.22\ (\mathrm{syst.})^{+0.46}_{-0.31}\ (\mathrm{model}))\%$$

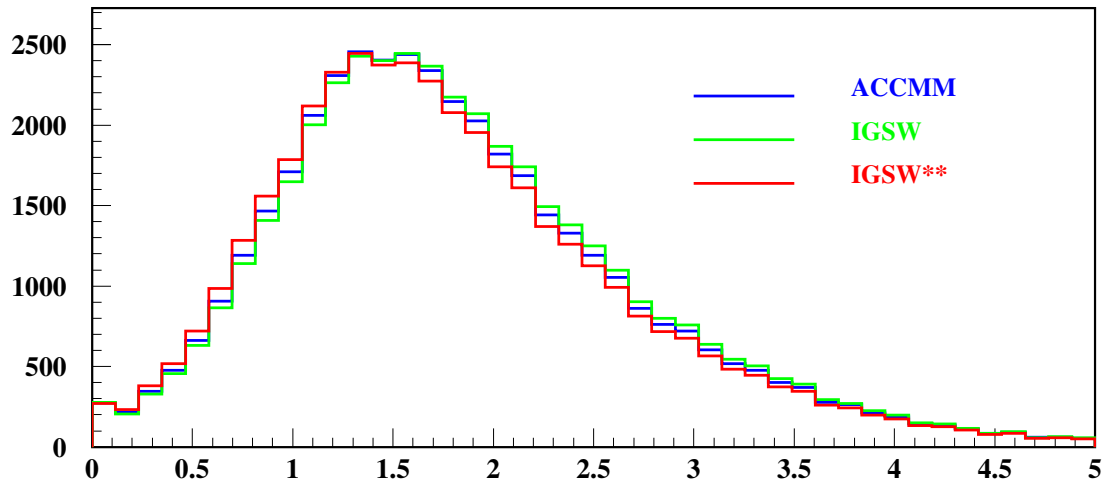
Model-dependent uncertainties

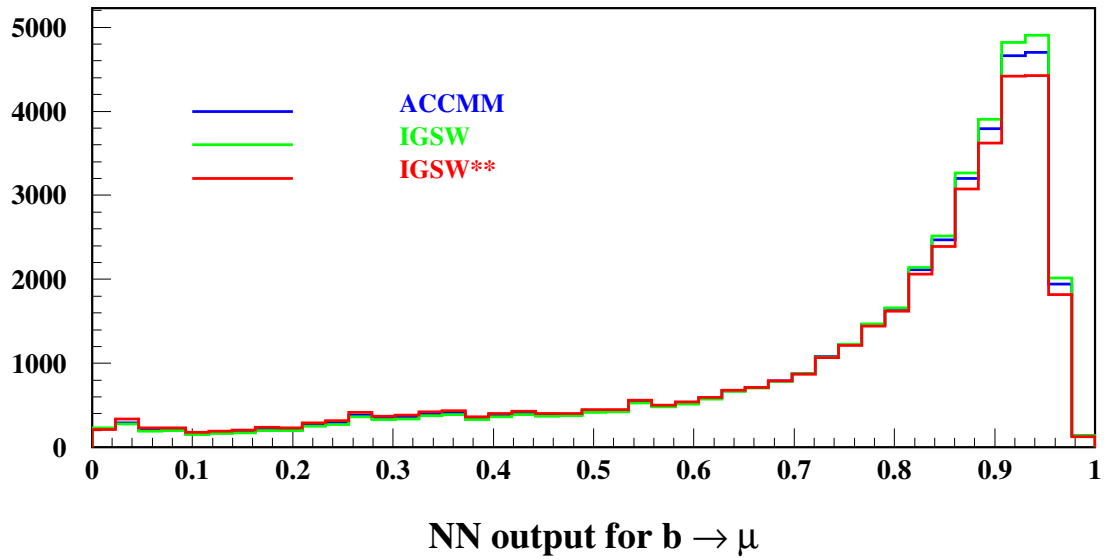
- Lepton decay models: ACCMM model for central value

  IGSW for $+1\sigma \rightarrow \Delta = -2\%$ (worse χ^2/dof)

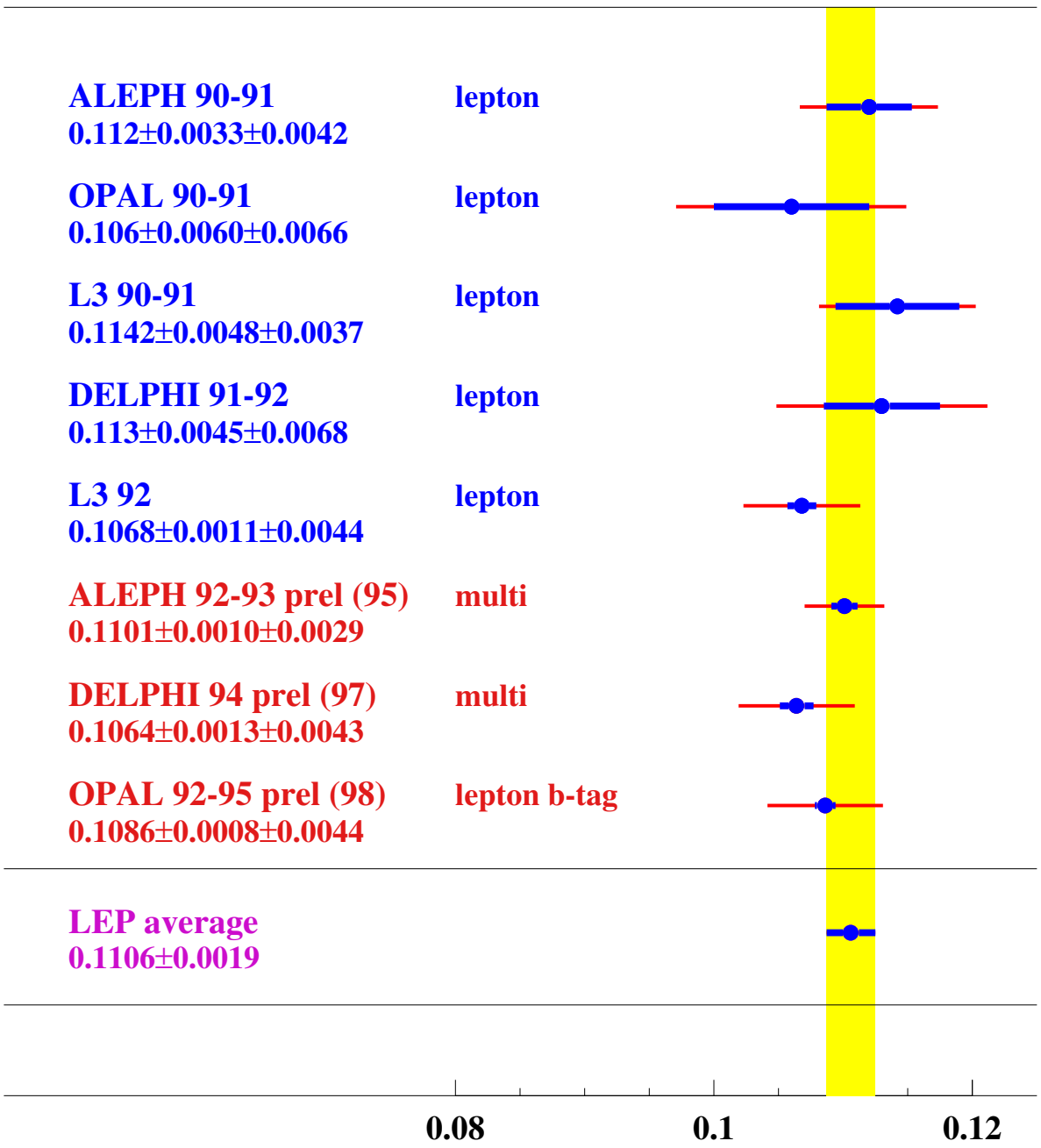
  IGSW** for $-1\sigma \rightarrow \Delta = +4\%$

- Fragmentation models: Peterson, Kartvelishvili, Collins & Spiller: vary each model by $< x_E > \pm 1\sigma \rightarrow \Delta = \pm 2\%$

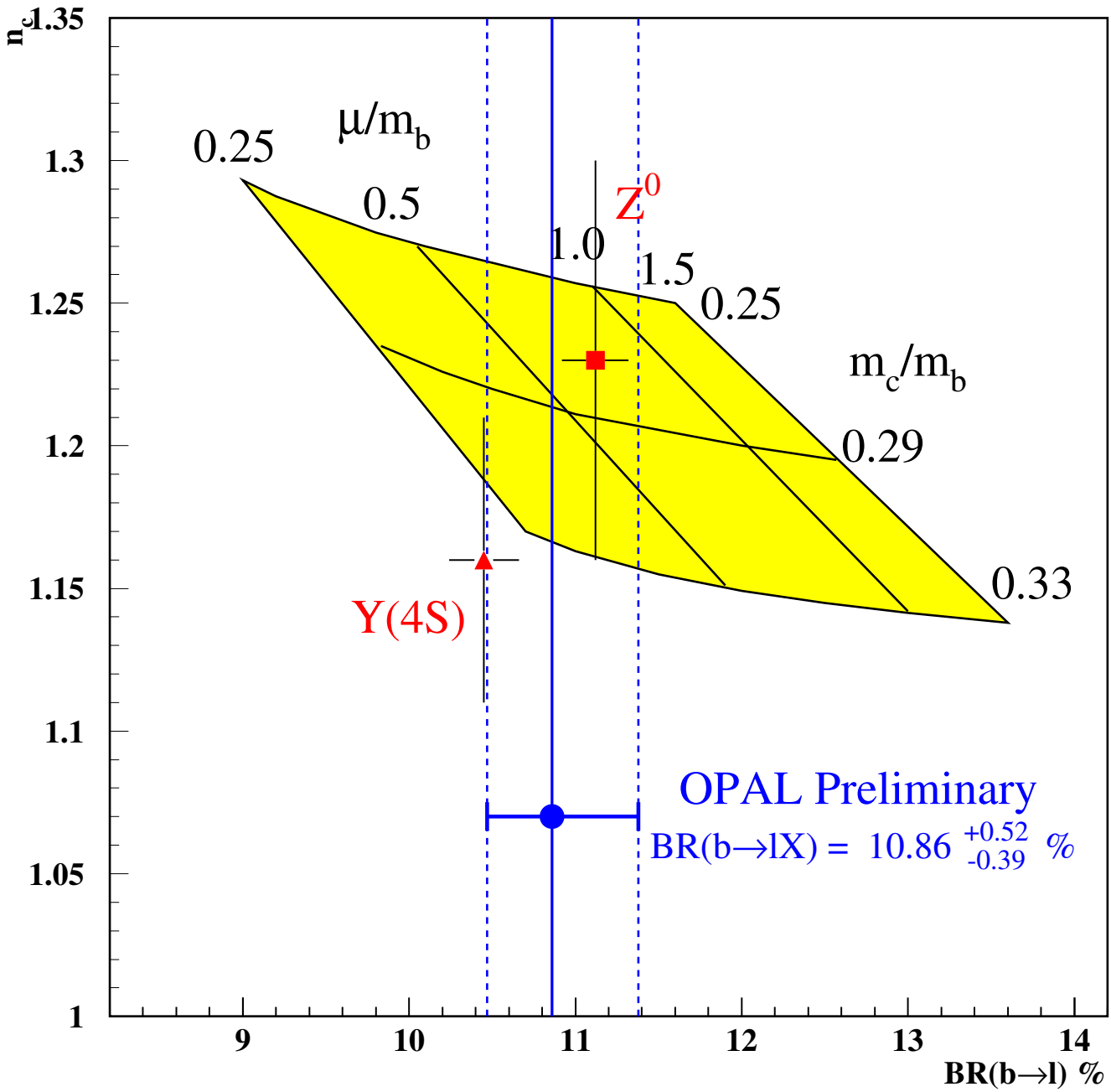




Comparison with other results



New situation for $(b \to \ell)$

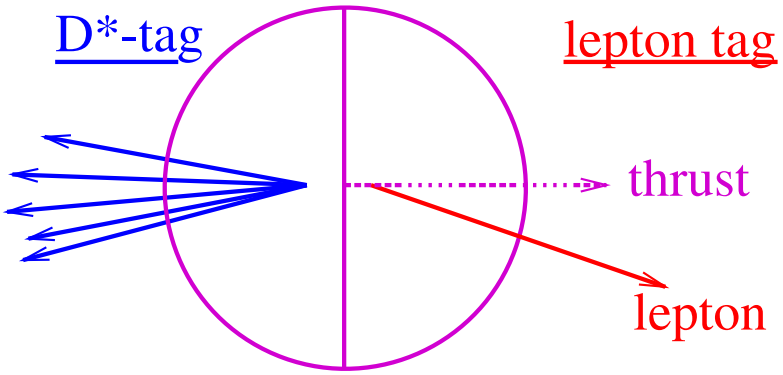


Previous average: $\mathrm{BR}(\mathrm{b} \to \ell\mathrm{X}) = (11.12 \pm 0.20)\%$

Including this result: $\mathrm{BR}(\mathrm{b} \to \ell\mathrm{X}) = (11.06 \pm 0.19)\%$

Extracting $\mathrm{BR}(\mathrm{c} \to \ell \mathrm{X})$ at LEP

$$\mathrm{D}^{*+} \to \mathrm{D}^0 \pi^+$$
$$\hookrightarrow \mathrm{K}^- \pi^+$$
$$\hookrightarrow \mathrm{K}^- \mathrm{e}^+ \nu_e$$
$$\hookrightarrow \mathrm{K}^- \mu^+ \nu_\mu$$
$$\hookrightarrow \mathrm{K}^- \pi^+ \pi^0$$
$$\hookrightarrow \mathrm{K}^- \pi^+ \pi^- \pi^+$$



- Select D^{*+} in one hemisphere

  $\to$ find fraction of D^{*+} events from $\mathrm{b\bar{b}}$ and $\mathrm{c\bar{c}}$ events using lifetime, jet shape and charge info:

  $$f_c^{D^{*+}} = 0.774 \pm 0.008 \pm 0.022$$

- Search all hemispheres opposite a D^{*+} for leptons:

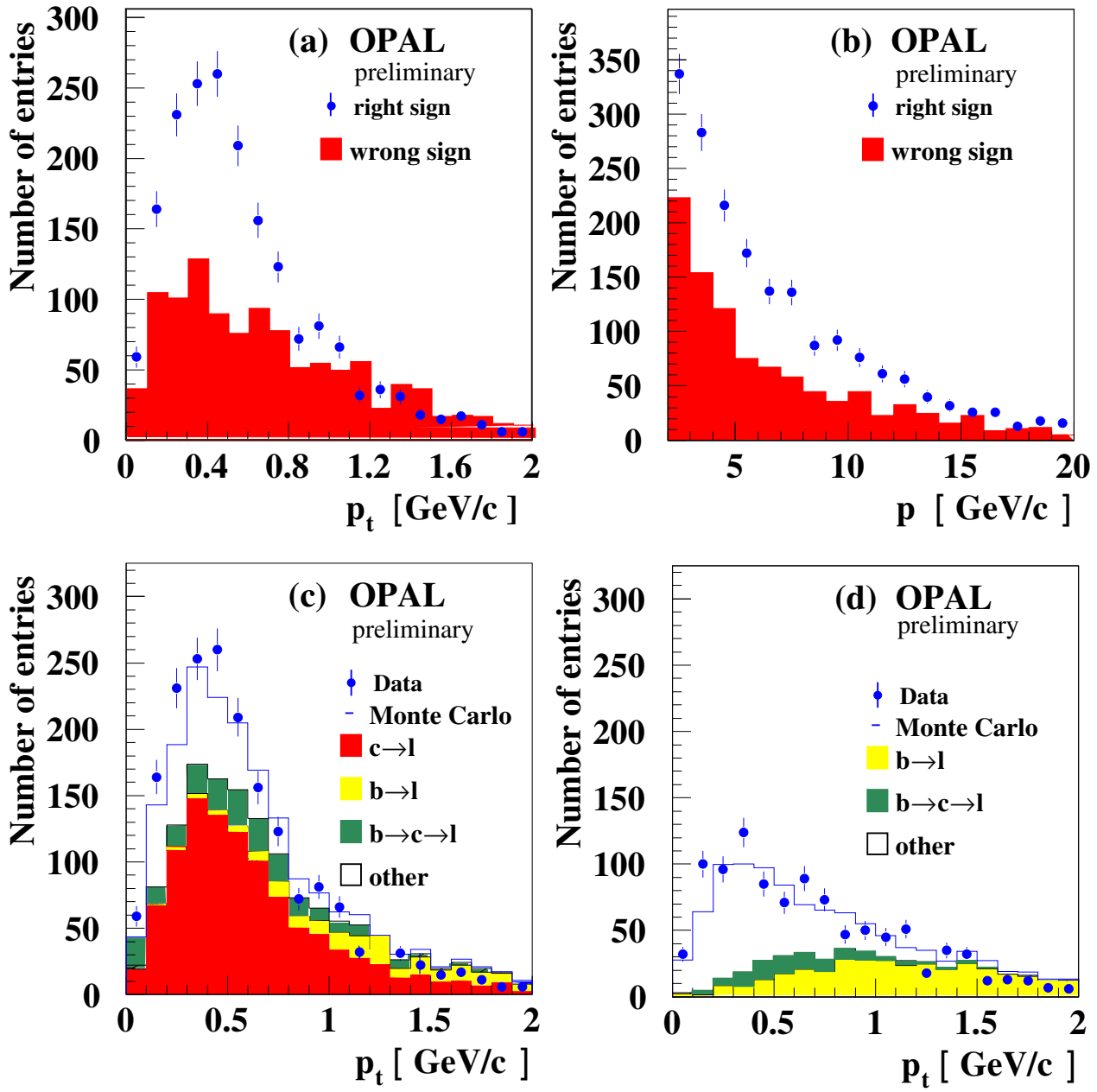
  $\mathrm{D}^{*+}\ell^- \Rightarrow$ Right-sign sample (RS)

  $\mathrm{D}^{*+}\ell^+ \Rightarrow$ Wrong-sign sample (WS)

  $\to$ subtract WS events from RS events

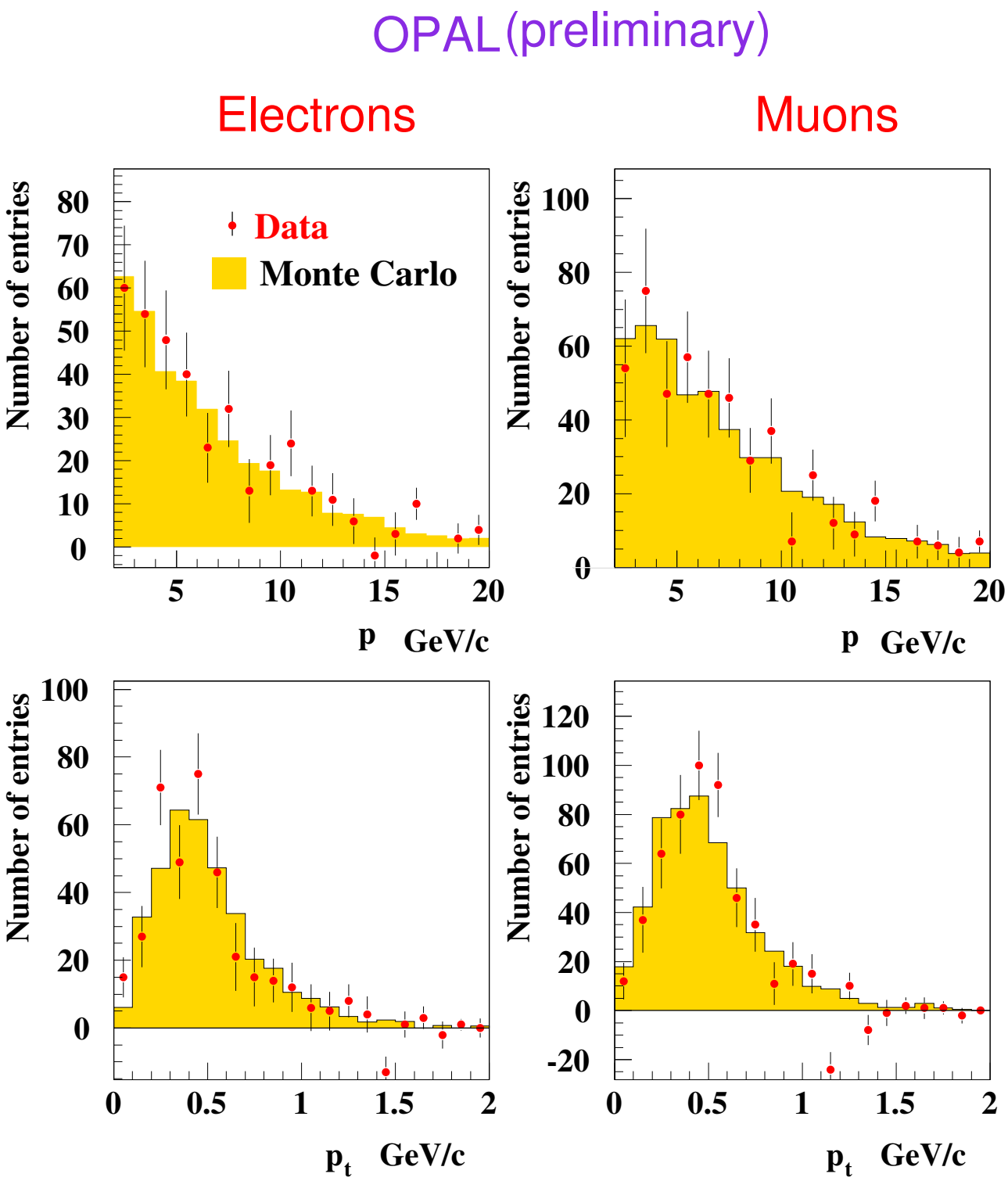
  $\to$ correct for mixing and combinatorial background differences in RS and WS samples

Spectra for leptons opposite a D^{*+}



Lepton spectra after background subtraction

OPAL (preliminary)



Residual contributions from $b\bar{b}$ and combinatorial background are still included both for data and Monte Carlo plots.

Results for $\mathrm{BR}(\mathrm{c} \to \ell \mathrm{X})$

OPAL (preliminary)

Sample	D^{*+} e	$\mathrm{D}^{*+}\,\mu$	$\mathrm{D}^{*+}\,\ell$
Right-sign	661	1045	1706
Wrong-sign	305	558	863
$N^{c}_{\mathrm{D}^{*+}\ell^{-}}$	378 ± 31	476 ± 40	854 ± 51

$$\mathrm{BR}(\mathrm{c} \to e\mathrm{X}) = (10.2 \pm 0.9^{+0.8}_{-0.7})\%$$
$$\mathrm{BR}(\mathrm{c} \to \mu\mathrm{X}) = (\ 8.9 \pm 0.7^{+0.7}_{-0.6})\%$$

Assuming fully correlated systematic errors (except for lepton identification and MC statistics):

$\mathrm{BR}(\mathrm{c} \to \ell \mathrm{X})$ measurements	
OPAL (prel.)	$(\ 9.5 \pm 0.6^{+0.7}_{-0.6})\%$
DELPHI (prel. 97)	$(\ 9.7 \pm 0.8 \pm 0.4)\%$
ARGUS (most recent)	$(\ 9.6 \pm 0.4 \pm 1.1)\%$
ARGUS, PEP, PETRA	$(\ 9.8 \pm 0.5)\%$

$\Downarrow$

No discrepancy found between Z^0 and $\Upsilon(4S)$ results for $\mathrm{BR}(\mathrm{c} \to \ell \mathrm{X})$

Conclusion and outlook

- This $\mathrm{BR}(\mathrm{b} \to \ell \mathrm{X})$ measurement slightly reduces the $\mathrm{BR}_{\mathrm{sl}}^{\mathrm{Z}^0}$ average but still greater than $\mathrm{BR}_{\mathrm{sl}}^{\Upsilon(4\mathrm{S})}$

  $\to$ New updated measurements by ALEPH and DELPHI should soon supersede old, preliminary results

- This new technique still needs improvement mostly to reduce model-dependence

  - add information on jet charge in the NN

  - fit simultaneously for the fragmentation parameter

  - add electrons mostly to provide a cross-check

  - reduce the minimum lepton momentum cut

  $\to$ final result expected later this year

...meanwhile the $\mathrm{BR}_{\mathrm{sl}}^{\Upsilon(4\mathrm{S})} \neq \mathrm{BR}_{\mathrm{sl}}^{\mathrm{Z}^0}$ problem is still there for b hadrons no discrepancy found for c hadrons

preliminary papers available after July 22nd.

`http://www.cern.ch/Opal/pubs/results_public.html`