Royal Holloway
University of London

Preliminary Measurement of the BF($\tau^- \rightarrow K^- \pi^0 \nu_\tau$) using the BABAR Detector

Fabrizio Salvatore

Royal Holloway University of London

for the BABAR Collaboration

International workshop on Tau Lepton Physics

Nara new public hall, Nara, Japan September 14-17, 2004

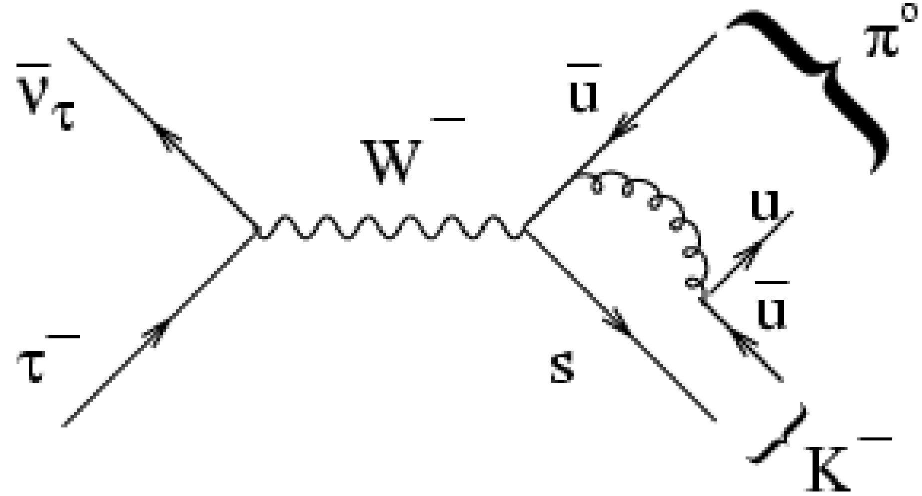
Outline

- Motivation
- PEP-II and the BABAR Experiment
- Event Selection:
  - $K^{-}\pi^{0}$ selection and efficiency
  - Systematic errors
- Preliminary Result
- Conclusions and Outlook

Motivation

- Hadronic τ decays provide a clean laboratory for studying the hadronic weak current

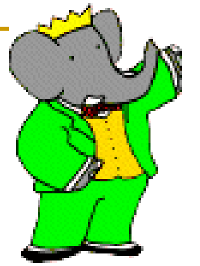
- For decays with overall net strangeness, $SU(3)_f$ symmetry breaking can be used to determine the absolute value of the CKM matrix element V_{us}, the strong coupling constant α_s and m_s



- The uncertainty in the extraction of $|V_{us}|$ and m_s is dominated by the experimental measurement uncertainties

- The high luminosity provided by PEP-II, coupled with $\sigma_{\tau\tau}$=0.89 nb at BABAR energies, provides a high statistics sample to study $\tau^- \rightarrow K^- \pi^0 \nu_\tau$ decays

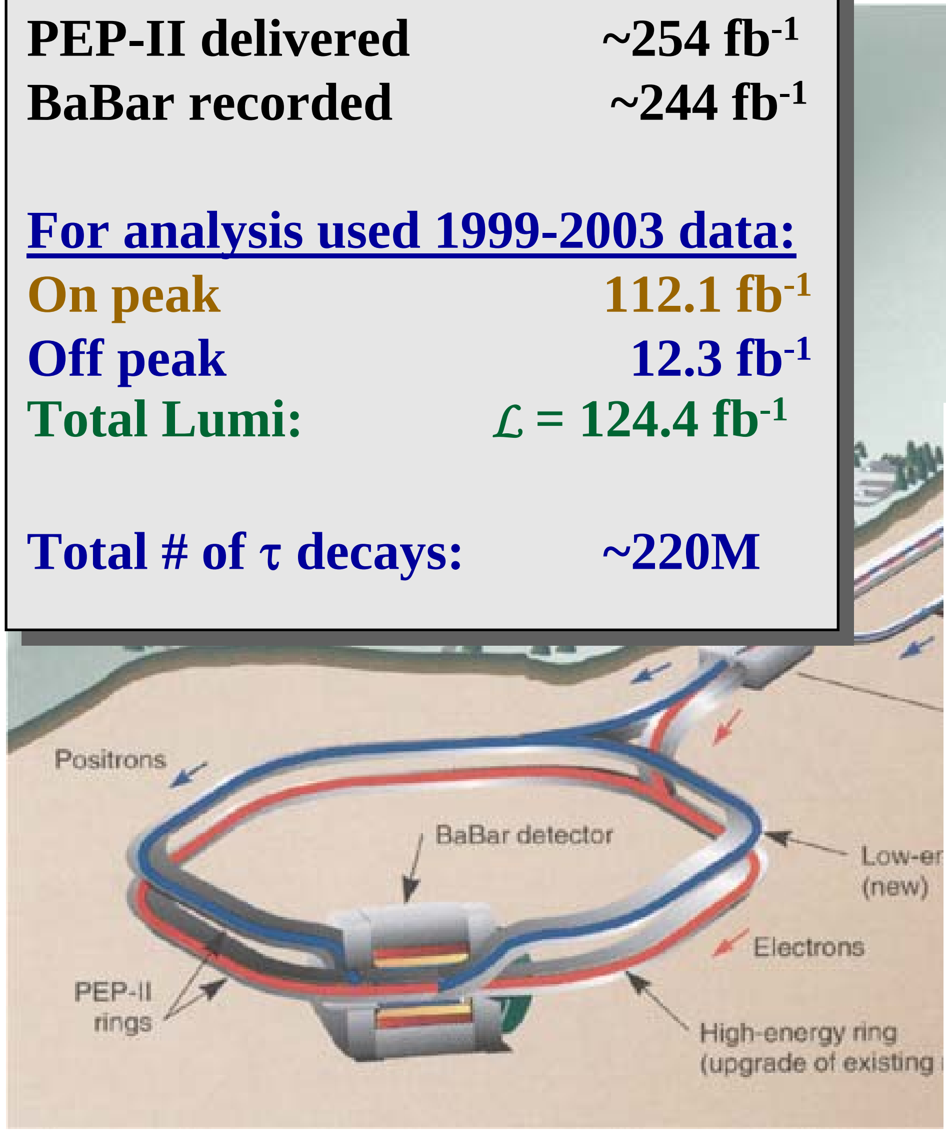
PEP-II Performance

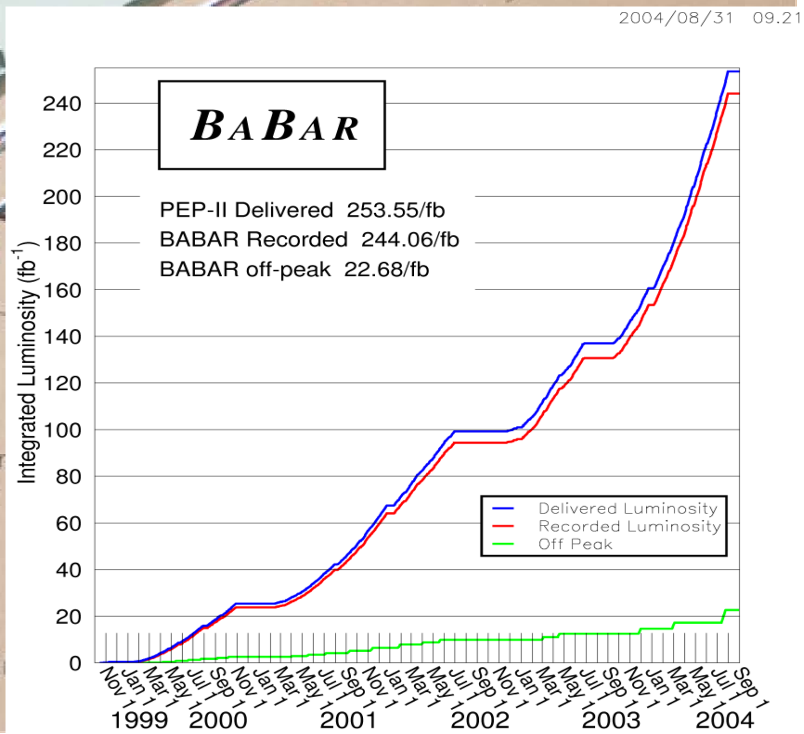


PEP-II delivered ~254 fb^{-1}
BaBar recorded ~244 fb^{-1}

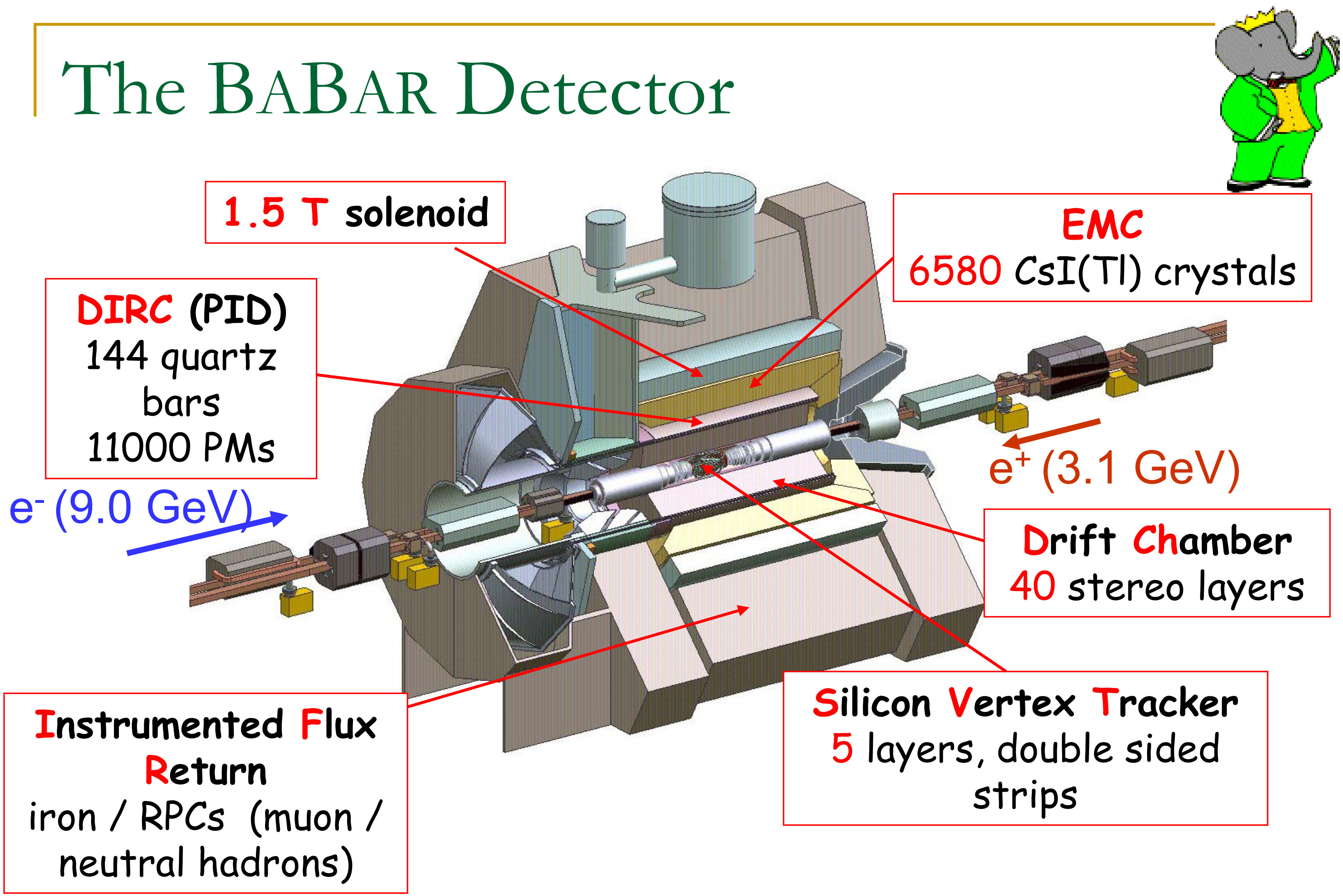
For analysis used 1999-2003 data:
On peak 112.1 fb^{-1}
Off peak 12.3 fb^{-1}
Total Lumi: $\mathcal{L}$ = 124.4 fb^{-1}

Total # of τ decays: ~220M

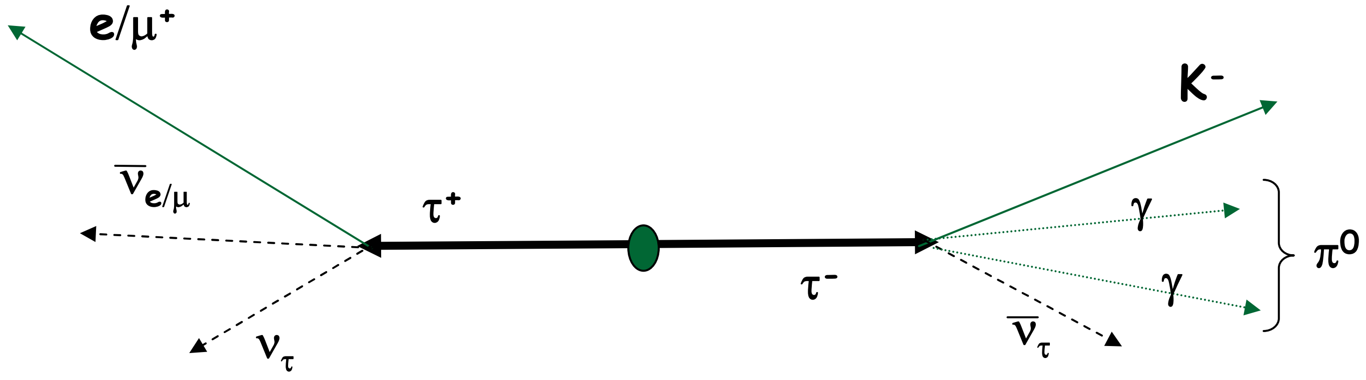




The BABAR Detector

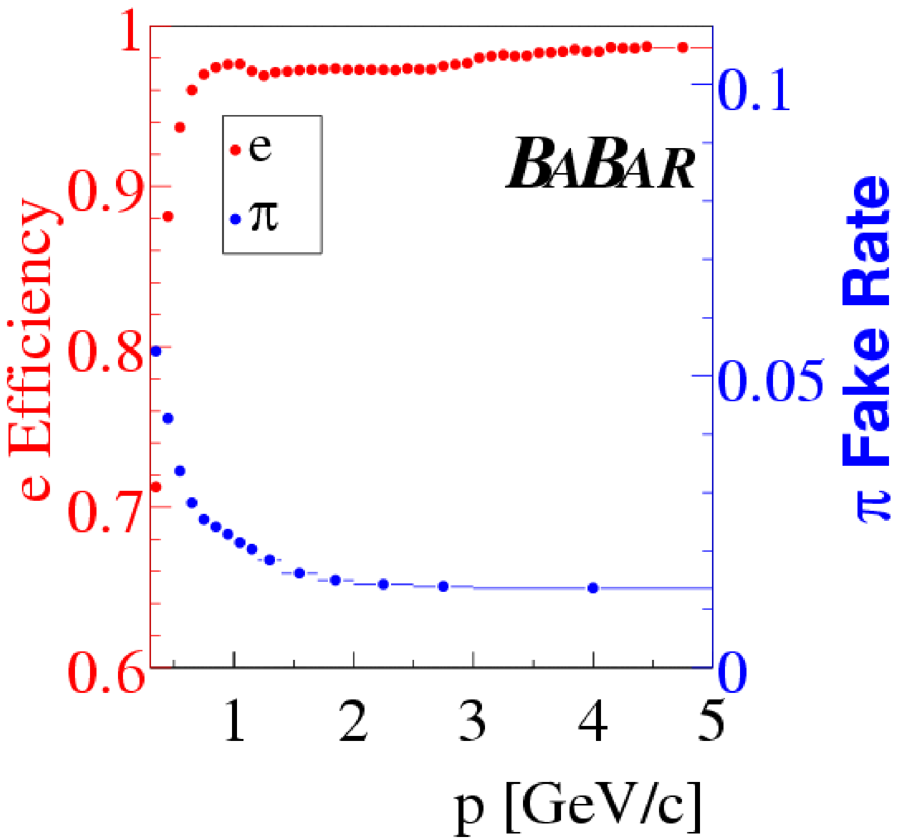


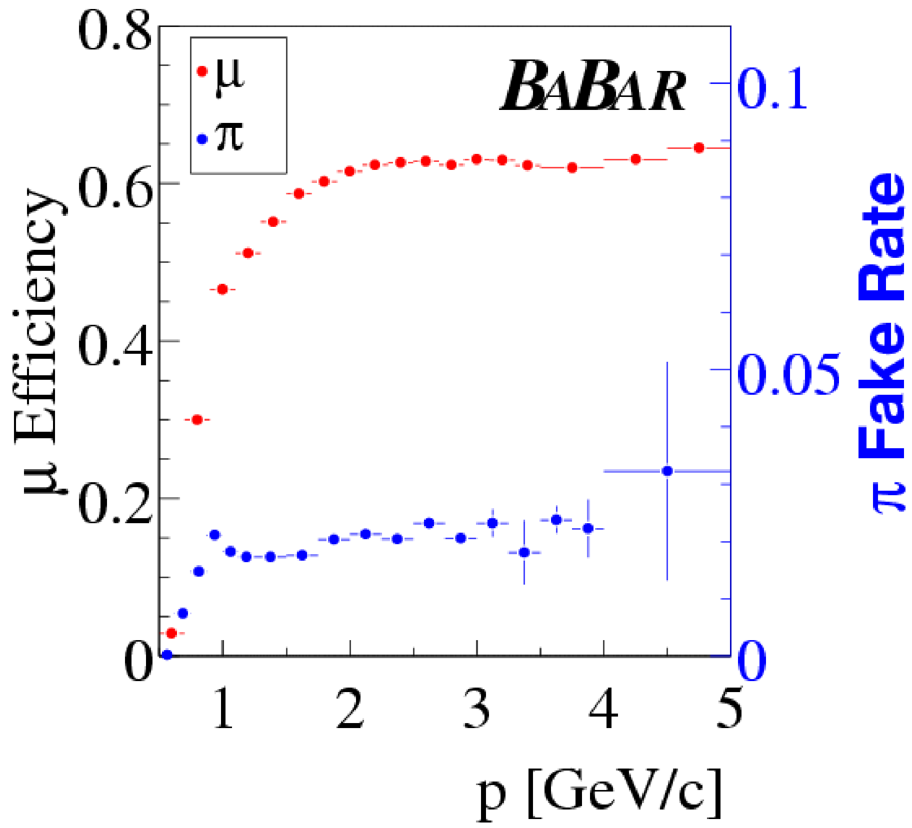
Event topology



- Event divided in two hemispheres defined by the plane perpendicular to the thrust vector
- Only events with one charged track in each hemisphere are selected:
  - "Signal" hemisphere: track identified as Kaon
  - "Tag" hemisphere: track identified as electron or muon

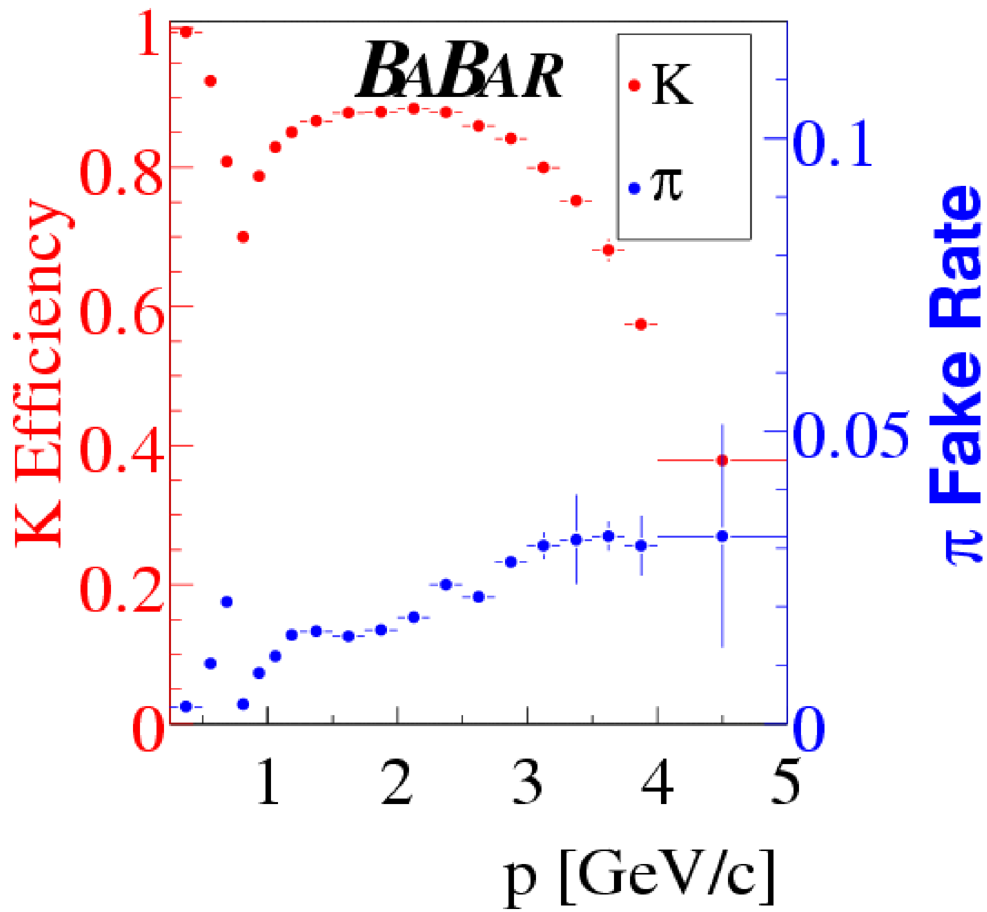
Lepton identification and π mis-ID



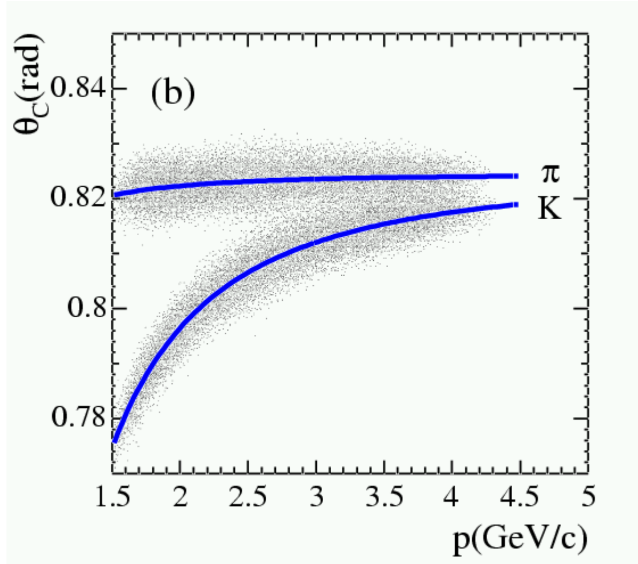


- Efficiency and mis-id measured from data:
  - efficiency: $e^+e^-\gamma$ and $\mu^+\mu^-\gamma$ sample
  - π mis-ID: $D^{*+}\to D^0\pi^+$, $D^0\to K^+\pi^-$

Kaon efficiency and π mis-ID



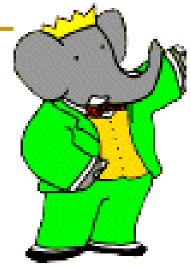
Good K/π separation using the information from the DIRC



Efficiency and mis-ID computed using $D^{*+} \to D^0\pi^+$ data sample

$\hookrightarrow K^+\pi^-$

Event selection



- Thrust ≥ 0.9
- R_2 = $2^{nd}/0^{th}$ Fox-Wolfram moment ≥ 0.5

reject $q\bar{q}$ background

- Missing momentum ≥ 0.5 GeV/c
- Events where both charged tracks are identified as electron are rejected

reject Bhabha events

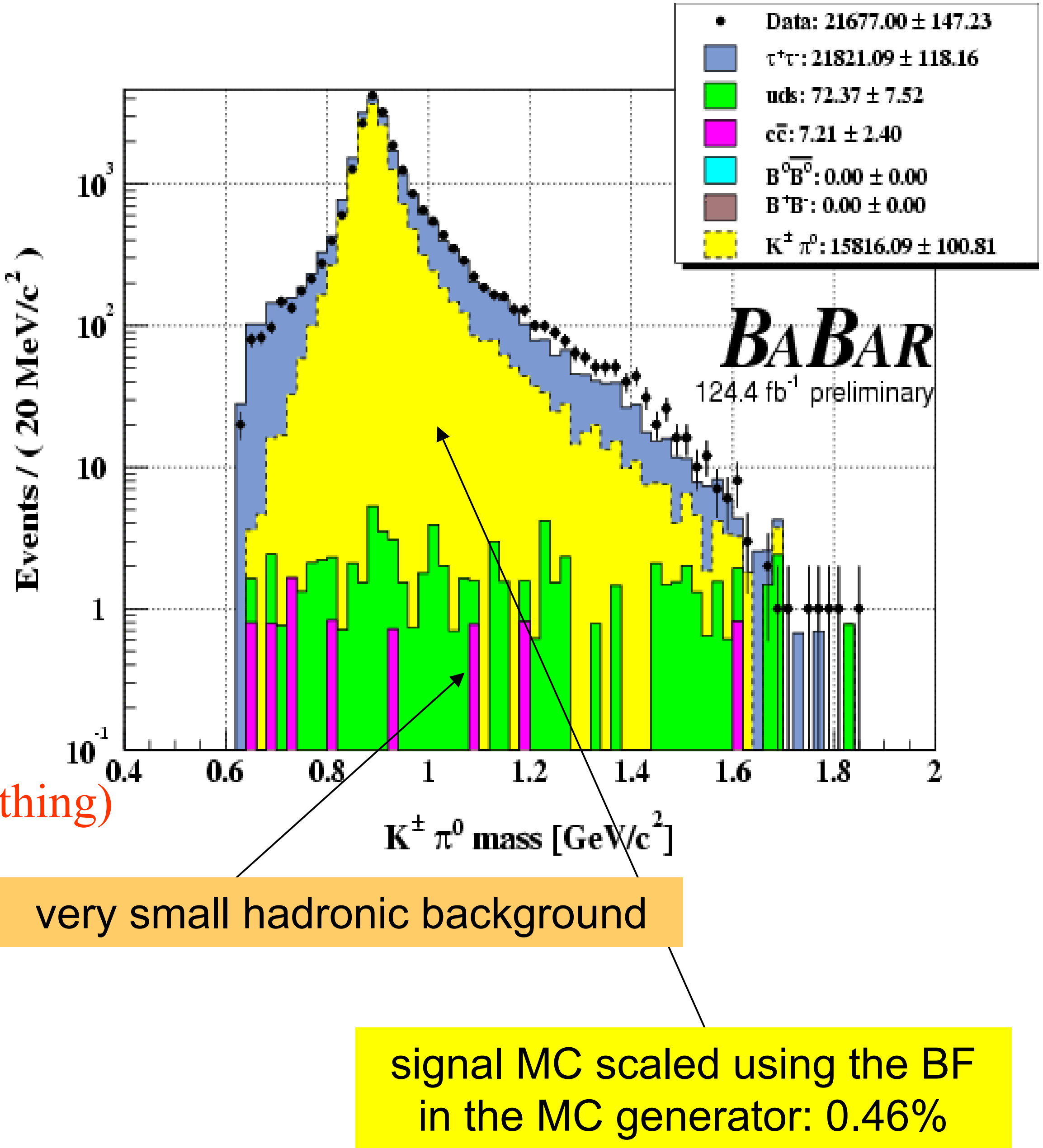
- Only 1 π^0 in the event
  - Only π^0s from two separated EMC energy deposits with $E_\gamma > 50$ MeV;
  - $100 < m_{\pi^0} < 160$ MeV/c^2
- Angle between K and π^0 candidates $\theta_{K\pi^0} < 1.0$ rad
- Energy in the "signal" hemisphere not associated with the charged track or π^0 candidate ≤ 50 MeV

Selected events

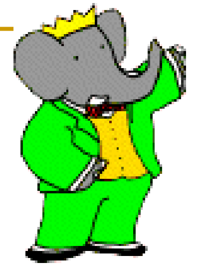
- After all cuts and selections:
  - 21678 events selected in 124.4 fb^{-1} of data
    - 12377 with e-tag
    - 9301 with μ-tag
- Signal Efficiency:

$$\varepsilon_{sig} = \frac{N_{sel}}{N_{gen}}(\tau_1 \rightarrow K\pi^0\nu_\tau; \tau_2 \rightarrow \text{anything})$$

  - (1.61±0.01) %
    - (0.92±0.01) % e-tag
    - (0.69±0.01) % μ-tag

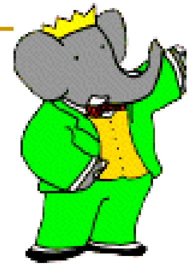


Background evaluation



- Background evaluated using MC events
  - generic τ, Bhabha, μ+μ-, qq and BB samples
- Main contribution comes from non-signal τ decays
  - for $m_{K\pi^0} \leq 0.8$ GeV/c^2 mainly $KK^0\pi^0$, $K^0\pi^-$ and $K\pi^0\pi^0$
    - In particular, BF has large measurement uncertainty for:
      $\sigma_{BF}/BF(\tau \to KK^0\pi^0)$ ~ 13%
      $\sigma_{BF}/BF(\tau \to K\pi^0\pi^0)$ ~ 40%
  - for $m_{K\pi^0} \geq 1.0$ GeV/c^2 mainly $\pi\pi^0$ (σ_{BF}/BF ~ 0.5%)
- Total background:
  - 6086 events (e+μ tag)
    - 3524 in the e-tagged sample
    - 2562 in the μ-tagged sample

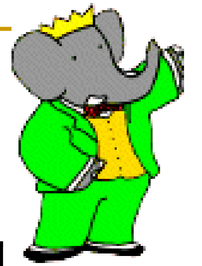
Systematic uncertainties



Systematic	e-tag [%]	μ-tag [%]	Combined [%]
Trk. eff.	1.40	1.40	1.40
π^0 eff.	3.26	3.26	3.26
Particle ID	2.20	3.50	2.40
$\mathcal{L} * \sigma_{\tau\tau}$	2.30	2.30	2.30
MC signal stat.	0.87	1.00	0.63
MC bkgnd stat.	0.83	0.97	0.63
τ Bkgnds	0.90	0.90	0.90
Total	5.0	5.7	5.0

All numbers are preliminary

Branching fraction result



Data	e-tag	μ-tag	Combined
Real	12377±111	9301± 94	21678 ± 147
$\tau^+\tau^-$	3494 ± 59	2512 ± 50	6006 ± 78
uds	25 ± 5	48 ± 6	73 ± 8
ccbar	5 ± 2	2 ± 1	7 ± 2
BBbar	-	-	-
ε_{sig}	0.92±0.01 %	0.69±0.01 %	1.61±0.01 %

$$\mathcal{B}(\tau \to K^- \pi^0 \upsilon_\tau) = \frac{1}{2N_{\tau\tau}} \frac{N_{data} - N_{bkg}}{\varepsilon_{sig}}$$

$$N_{\tau\tau} = \sigma_{\tau\tau} \mathcal{L}_{data} = 111 \times 10^6$$

Preliminary

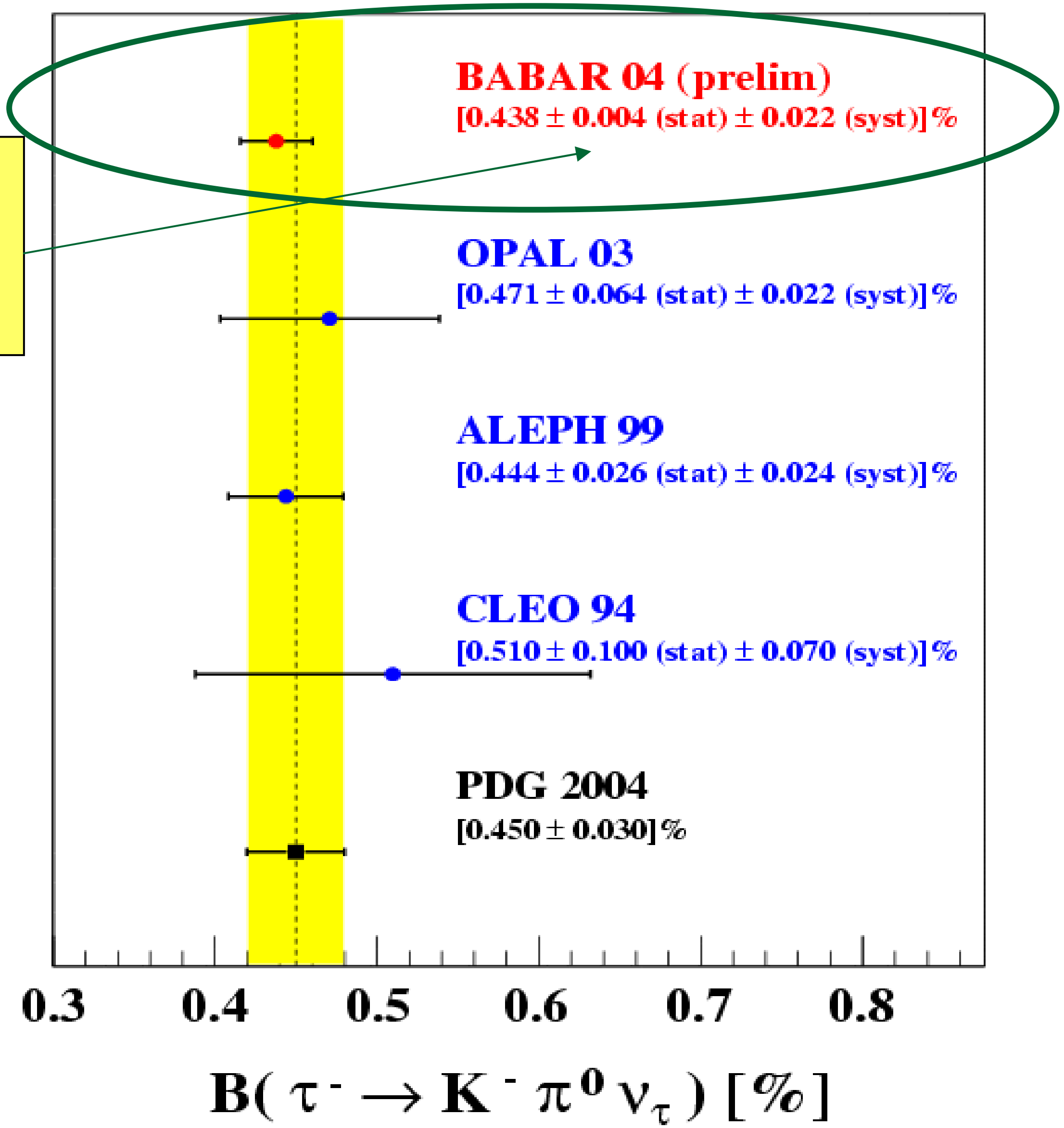
Sample	$\mathcal{B}(\tau^- \to K^- \pi^0 \nu_\tau)$ [%]
e-tag	0.436±0.005(stat)±0.022(syst)
μ-tag	0.442±0.006(stat)±0.025(syst)
Combined	0.438±0.004(stat)±0.022(syst)

PDG: (0.45±0.03)%

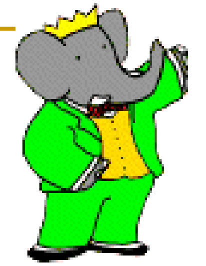
Comparison with other results

In agreement with PDG average

Improved uncertainty



What next?



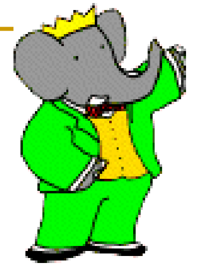
Measure the branching fraction of the $\tau^- \rightarrow K^0 \pi^- \nu_\tau$ decay and combine it with the presented result

$\Rightarrow$ $\tau^- \rightarrow (K\pi)^- \nu_\tau$ branching fraction

Study the mass spectrum of $\tau^- \rightarrow (K\pi)^- \nu_\tau$

Use $\tau^- \rightarrow (K\pi)^- \nu_\tau$ studies as input into the total strange spectral function

Conclusions



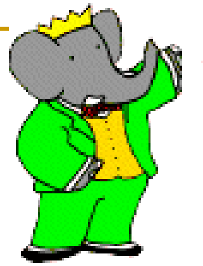
A preliminary measurement of the $\tau^- \rightarrow K^-\pi^0\nu_\tau$ branching fraction has been obtained using 124.4 fb^{-1} of data taken at BABAR:

$$B(\tau^- \rightarrow K^-\pi^0\nu_\tau) = (0.438 \pm 0.004(\text{stat}) \pm 0.022(\text{syst}))\%$$

Measurement consistent with world average (PDG 2004)

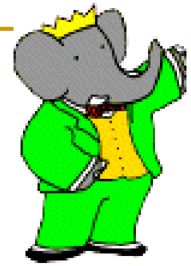
This analysis represents a significant improvement on previously published results

$\tau^- \rightarrow (K\pi)^-\nu_\tau$ is a clean laboratory for studying hadronic weak currents → more results to follow !



Backup Slides

τ background systematic



Decay Channel	$w/10^{-2}$	$\sigma(PDG)/\mathcal{B}(PDG)$ [%]
$\tau^- \to e^- \nu_e \nu_\tau$	0.159	0.34
$\tau^- \to \mu^- \nu_\mu \nu_\tau$	0.020	0.35
$\tau^- \to \pi^- \nu_\tau$	0.062	0.99
$\tau^- \to \pi^- \pi^0 \nu_\tau$	20.063	0.55
$\tau^- \to a_1^- \nu_\tau$	0.426	1.10
$\tau^- \to K^- \nu_\tau$	0.264	3.35
$\tau^- \to K^0 \pi^- \nu_\tau$	0.821	4.49
$\tau^- \to 2\pi^- \pi^+ \pi^0 \nu_\tau$	0.060	2.05
$\tau^- \to \pi^- 3\pi^0 \nu_\tau$	0.003	9.30
$\tau^- \to K^- K^+ \pi^- \nu_\tau$	0.009	9.14
$\tau^- \to K^- K^0 \pi^0 \nu_\tau$	4.456	12.90
$\tau^- \to K^- \pi^0 \pi^0 \nu_\tau$	0.791	39.70
$\tau^- \to K^- \pi^- \pi^+ \nu_\tau$	0.010	15.15
$\tau^- \to \pi^- \pi^0 K^0 \nu_\tau$	0.029	11.11
$\tau^- \to \eta \pi^- \pi^0 \nu_\tau$	0.003	13.79
$\tau^- \to K^- K^0 \nu_\tau$	0.338	10.38

Systematic error due to the uncertainty in the BF of τ background decays used in generated MC

$$\sigma_{\tau MC} = \sqrt{\sum_i \left(w_i \frac{\sigma_i^{PDG}}{\mathcal{B}_i^{PDG}}\right)^2}$$