Summary of the Tau-2010 Workshop

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1990 → 2010

LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

MANCHESTER
1824
The University of Manchester

General remarks

- 20-year anniversary of original Tau workshop

- in this period: fantastic progress in τ physics through LEP, CLEO, B-factories, BES, and neutrino experiments

- early meetings: consolidation of τ as a standard lepton with universal couplings (precision experiments)

- but also, use of the τ to study EW and QCD physics

  ex. τ polarization at LEP and hadronic decays

- recently, τ used more and more as tool to investigate New Physics, in particular with hadron colliders (for more than 25 years τ only detected and studied at e^+e^- machines)

The Tau-2010 Programme

- Tau-2010 in Manchester has been an exciting meeting

- quite diversified programme with a large emphasis on τ as a tool to search for New Physics (NP)

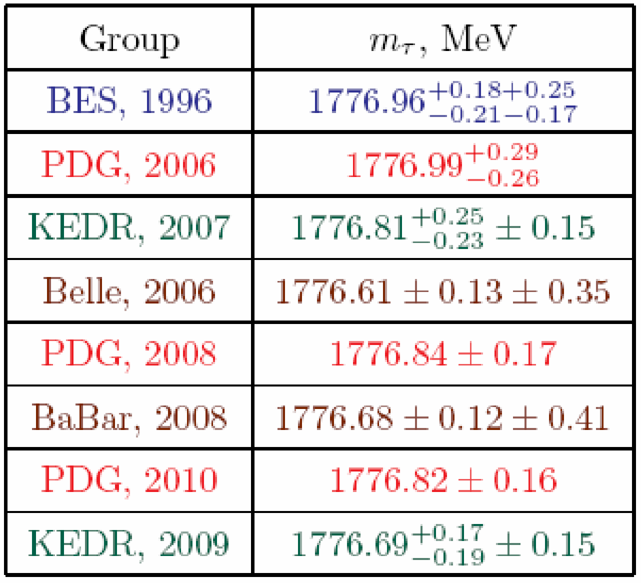
		# talks
τ properties		10
τ for NP	B-factories	12
	hadron colliders	8
τ for QCD		6
CVC / g–2 / $\alpha(M_Z)$		11
neutrinos		6
future and related topics		8

- theory / experiment: 17 / 43

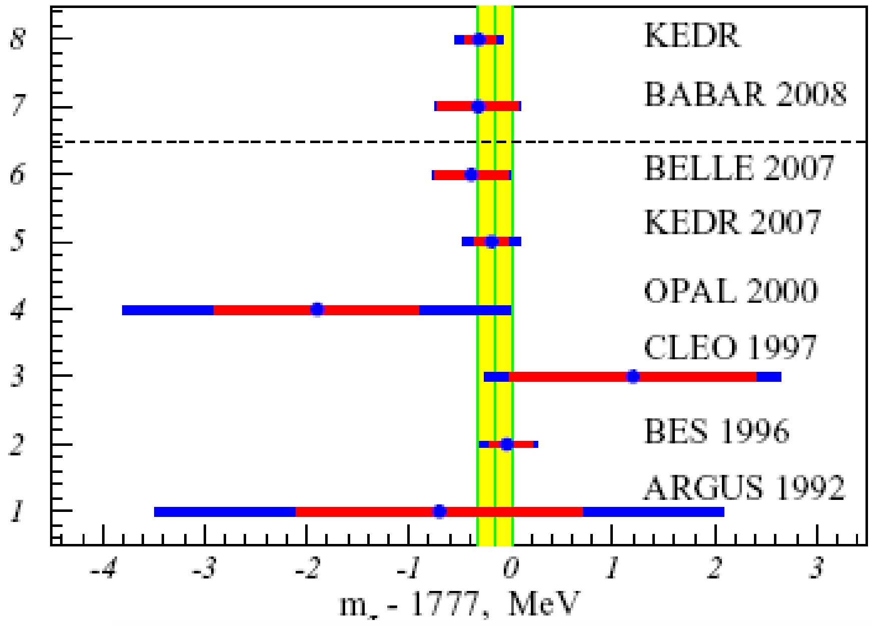
τ Mass and Lifetime

S. Eidelman

Latest direct τ mass measurement from KEDR: good agreement with !996 BES and with pseudomass method at BABAR and Belle



Group	m_τ, MeV
BES, 1996	$1776.96^{+0.18+0.25}_{-0.21-0.17}$
PDG, 2006	$1776.99^{+0.29}_{-0.26}$
KEDR, 2007	$1776.81^{+0.25}_{-0.23} \pm 0.15$
Belle, 2006	$1776.61 \pm 0.13 \pm 0.35$
PDG, 2008	1776.84 ± 0.17
BaBar, 2008	$1776.68 \pm 0.12 \pm 0.41$
PDG, 2010	1776.82 ± 0.16
KEDR, 2009	$1776.69^{+0.17}_{-0.19} \pm 0.15$



Red error bars - systematics, blue - total error

No new result on lifetime: promise of precise result from BABAR and Belle

τ Leptonic Charged Current Coupling

$$\left(\frac{g_\tau}{g_\mu}\right)^2 = \frac{\tau_\mu}{\tau_\tau}\left(\frac{m_\mu}{m_\tau}\right)^5 B_e \frac{f\left(\frac{m_e^2}{m_\mu^2}\right)}{f\left(\frac{m_e^2}{m_\tau^2}\right)} \Delta_W \Delta_\gamma$$

	τ_τ (fs)	B_e (%)	m_τ (MeV)	
1.0034	290.6 ± 1.0	17.85 ± 0.05	1776.82 ± 0.16	PDG, 2010
± 0.0045	± 0.0034	± 0.0028	± 0.0004	$+0.76\sigma$

$$\left(\frac{g_\tau}{g_\mu}\right)^2 = \frac{B_\pi}{B_{\pi\to\mu\bar{\nu}_\mu}} \frac{\tau_\pi}{\tau_\tau} \frac{2 m_\pi m_\mu^2}{m_\tau^3} \left(\frac{1-\frac{m_\mu^2}{m_\pi^2}}{1-\frac{m_\pi^2}{m_\tau^2}}\right)^2 \frac{1}{\delta_{\tau/\pi}}$$

ALEPH	0.9924 ±0.0104	τ→πν
BABAR	0.9856 ± 0.0057	τ→πν
	0.9827 ± 0.0086	τ→Kν

R. Sobie

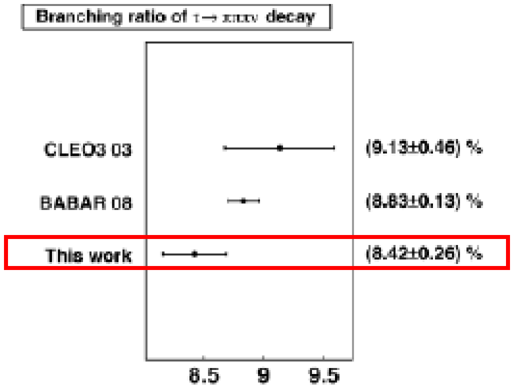
BABAR results low, but no discrepancy claimed

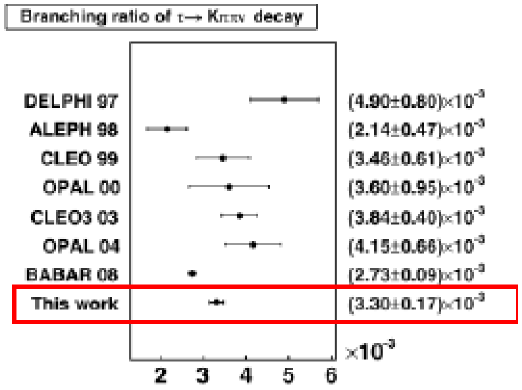
New hadronic decay measurements (1)

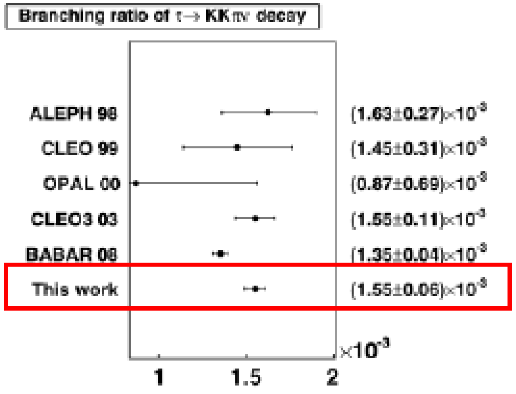
- $\tau \to (\pi\pi\pi, K\pi\pi, KK\pi, KKK)\nu$ Belle — MJ Lee
- $\tau \to (K^0\pi, K^0\pi\pi^0)\nu$ BABAR — A. Adametz
- problems!

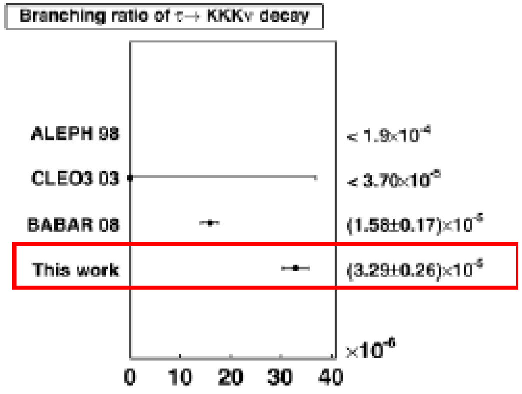
  large inconsistencies between BABAR and Belle

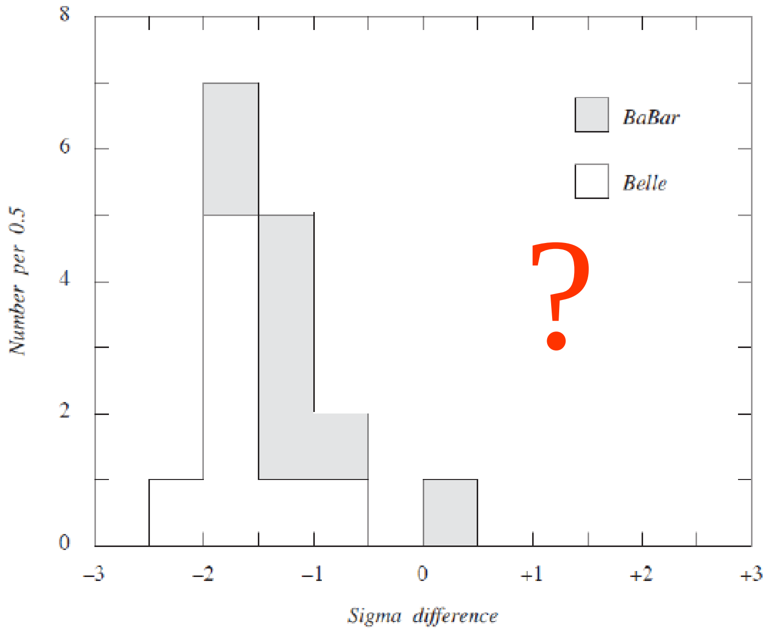
  continued trend of BR smaller than previous determinations











PDG 2010

New hadronic decay measurements (2)

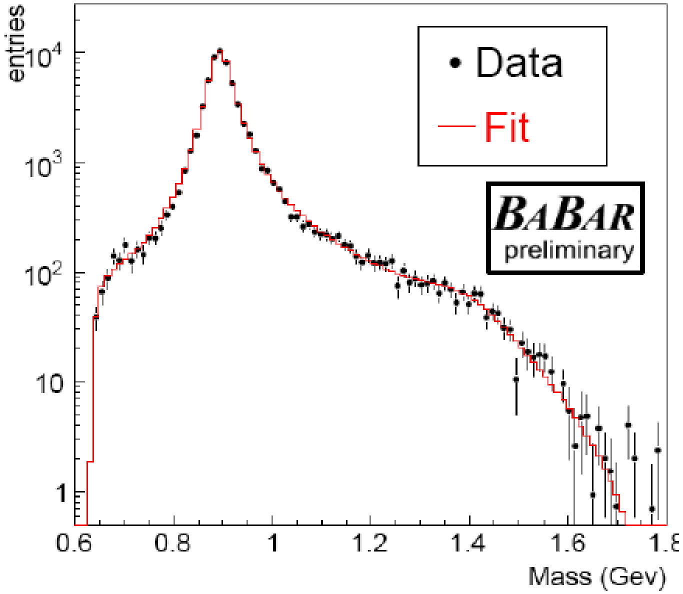
- $\tau \to (K^0\pi, K^0\pi\pi^0)\nu$ BABAR
- fit of the Belle mass spectrum

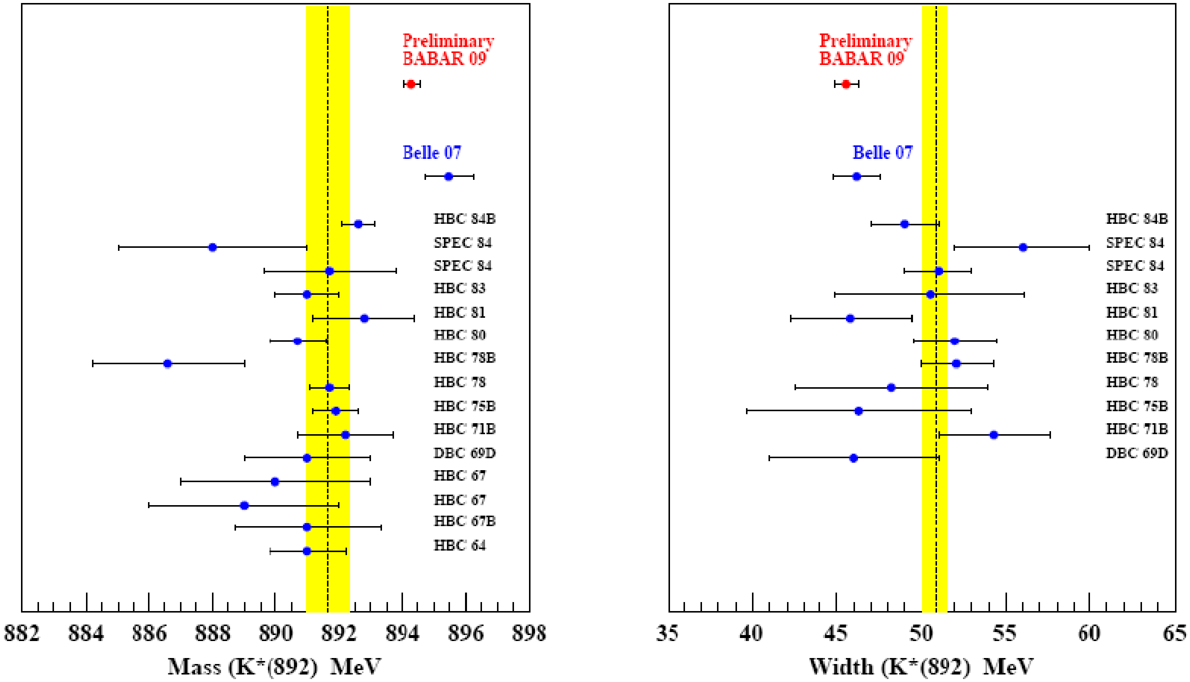
A. Adametz

E. Passemar

K*(892) + K*(1410) + K*(800)

K*(892) parameters consistent with Belle, but much different from hadron experiments





- still no evidence for second-class currents

$BF(\tau \to \eta\pi\nu_\tau) < 9.9\times10^{-5}$ @ 95% CL (preliminary)

CLEO limit: $BF(\tau \to \eta\pi\nu_\tau) < 1.4\times10^{-4}$ @ 95% CL

K. Alwyn

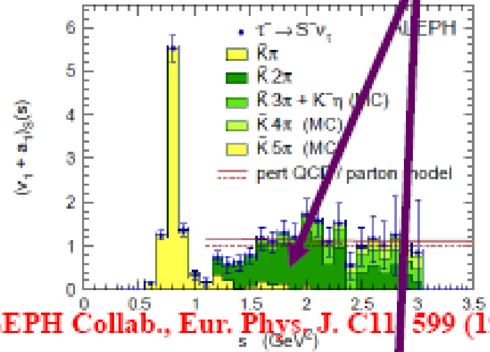
Toward a precise strange spectral function

MJ Lee

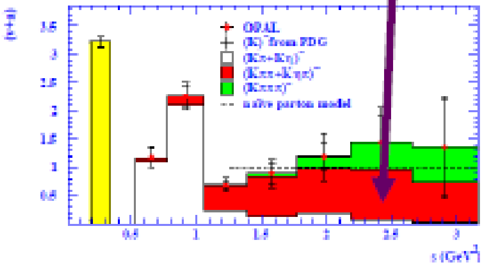
LEP

Belle

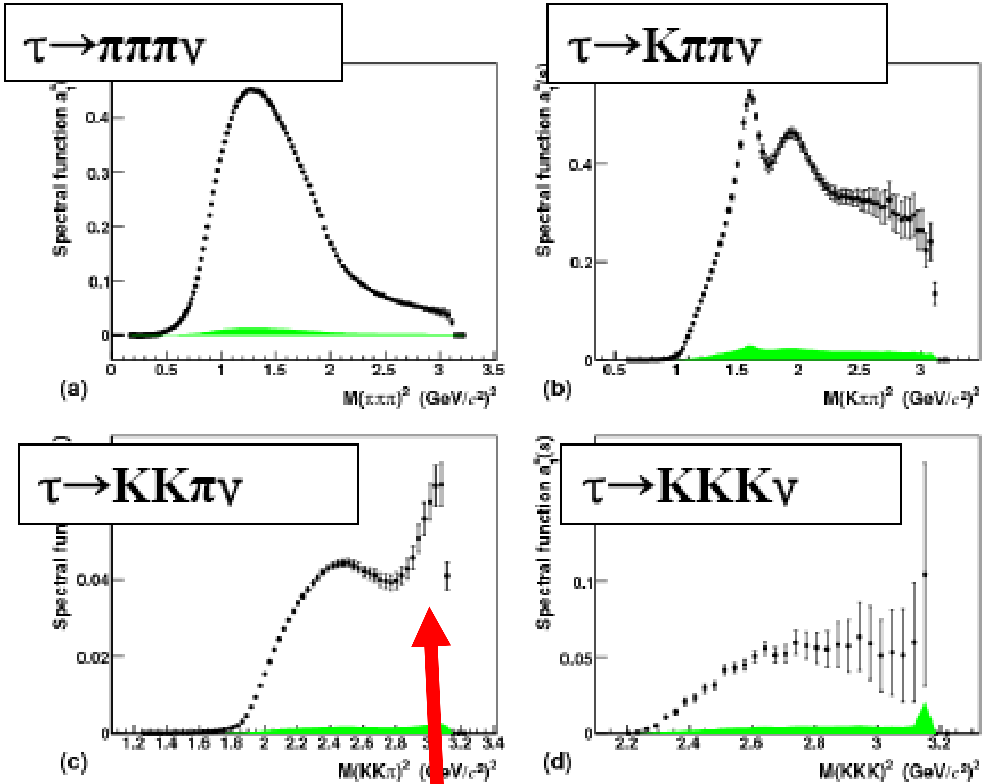
Large contribution from τ→Kππν



ALEPH Collab., Eur. Phys. J. C11, 599 (1999).



OPAL Collab., Eur. Phys. J. C35, 437 (2004).

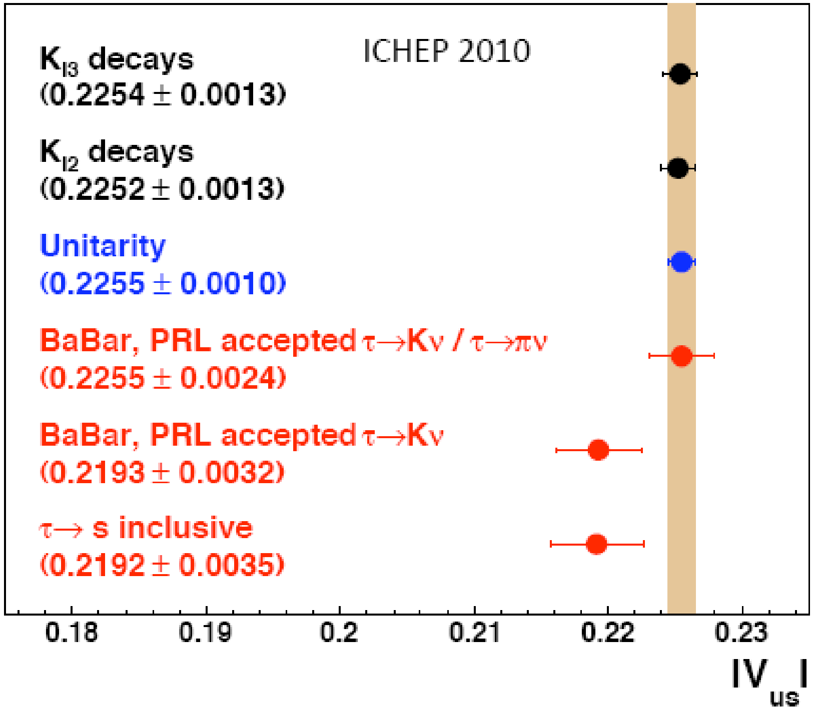


Black : spectral function, Err. from mass spectrum

Green : Error from other sys. source

?

V_{us} from strange decays



R. Sobie

$$B(\tau^- \to K^-\nu_\tau) = \frac{G_F^2 f_K^2 |V_{us}|^2 m_\tau^3 \tau_\tau}{16\pi\hbar}\left(1-\frac{m_K^2}{m_\tau^2}\right)^2 S_{EW}$$

$$\frac{B(\tau^- \to K^-\nu_\tau)}{B(\tau^- \to \pi^-\nu_\tau)} = \frac{f_K^2}{f_\pi^2}\frac{|V_{us}|^2}{|V_{ud}|^2}\frac{(1-m_K^2/m_\tau^2)}{(1-m_\pi^2/m_\tau^2)}(1+\delta_{LD})$$

$$f_K / f_\pi = 1.189 \pm 0.007$$

$$\delta_{LD} = (0.03 \pm 0.44)\%$$

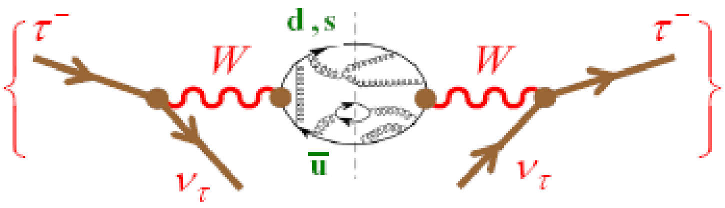
- most precise BABAR determination is from the Kν / πν ratio, agrees well with results from K_{l3} and V_{ud}+unitarity
- the inclusive analysis depends on a (possibly) incomplete sum of decays and the validity of the perturbative QCD prediction. Should wait for a more precise spectral function from BABAR/Belle.

HFAG-tau A. Pich K. Maltman

τ hadronic decays: a QCD laboratory

A. Pich

$\Gamma_{\tau\to\nu_\tau+\mathrm{had}} \sim \mathrm{Im}\,\{$



$\}$

$$R_\tau \equiv \frac{\Gamma(\tau^-\to\nu_\tau+\mathrm{had})}{\Gamma(\tau^-\to\nu_\tau e^-\bar{\nu}_e)} = 12\pi\int_0^{m_\tau^2} dx\left(1-\frac{s}{m_\tau^2}\right)^2\left[\left(1+2\frac{s}{m_\tau^2}\right)\mathrm{Im}\,\Pi^{(1)}(s)+\mathrm{Im}\,\Pi^{(0)}(s)\right]$$

hadrons from the QCD vacuum

$$R_\tau = N_C\, S_{\mathrm{EW}}\,(1+\delta_{\mathrm{P}}+\delta_{\mathrm{NP}}) = R_{\tau,V}+R_{\tau,A}+R_{\tau,S}$$

$S_{\mathrm{EW}} = 1.0201\ (3)$; $\delta_{\mathrm{NP}} = -0.0059 \pm 0.0014$

Marciano-Sirlin, Braaten-Li, Erler

Fitted from data (Davier et al)

$\delta_{\mathrm{P}} = a_\tau + 5.20\, a_\tau^2 + 26\, a_\tau^3 + \ldots \approx 20\%$; $a_\tau \equiv \alpha_s(m_\tau)/\pi$

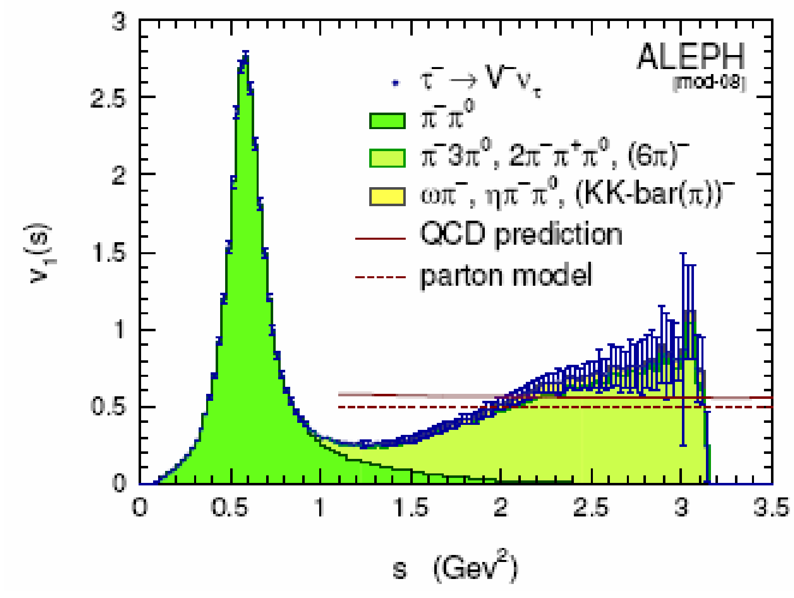
$$R_\tau = \frac{1-B_e-B_\mu}{B_e} = 3.640 \pm 0.010$$

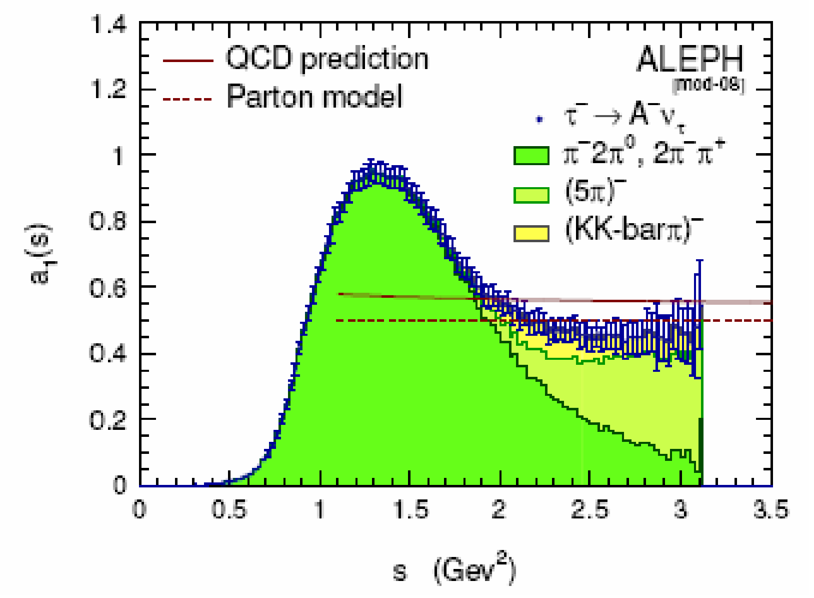
Experimental spectral function given by the normalized mass spectrum×BR×kinematic factor

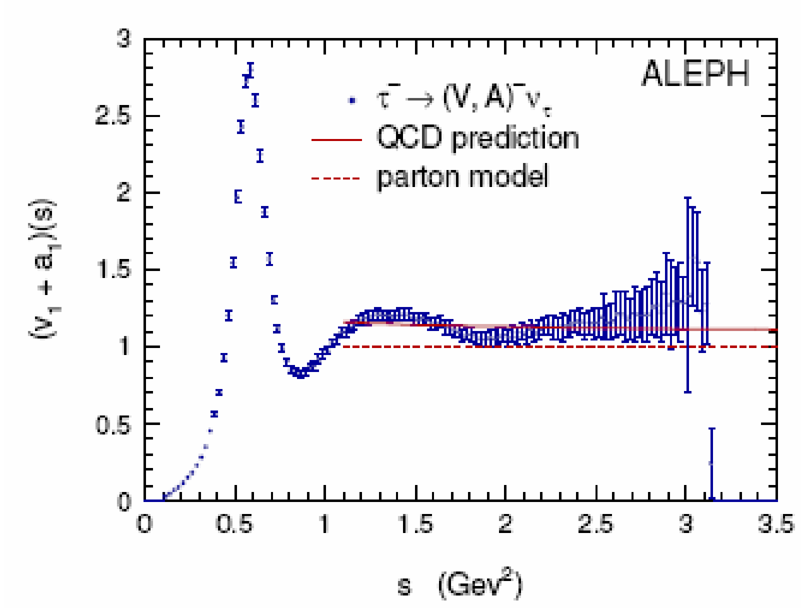
τ spectral functions from LEP

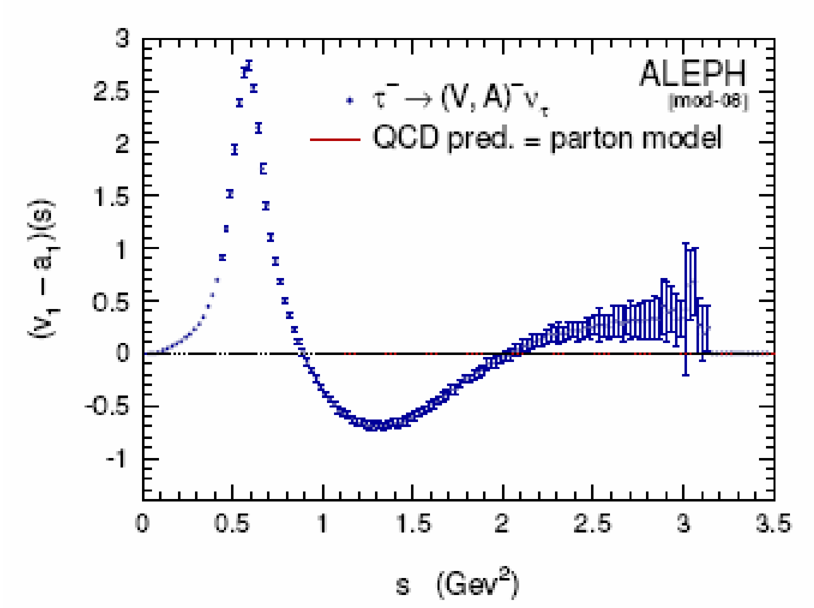
- strong advantage of LEP for τ physics: $Z\rightarrow\tau\tau$ provided a sample with large (uniform) efficiency and very small background
- disadvantage: relatively low statistics (4×10^5 τ's) and large boost
- thus calorimeter granularity was essential (ALEPH)
- QCD analyses from ALEPH, OPAL, and CLEO
- most accurate spectral functions from ALEPH
- used in dozens of phenomenological papers by theorists
- shortcomings: statistical limitations at large mass and possibly small residual detector effects from particle/photon overlaps

ALEPH τ spectral functions









The need for updated spectral functions

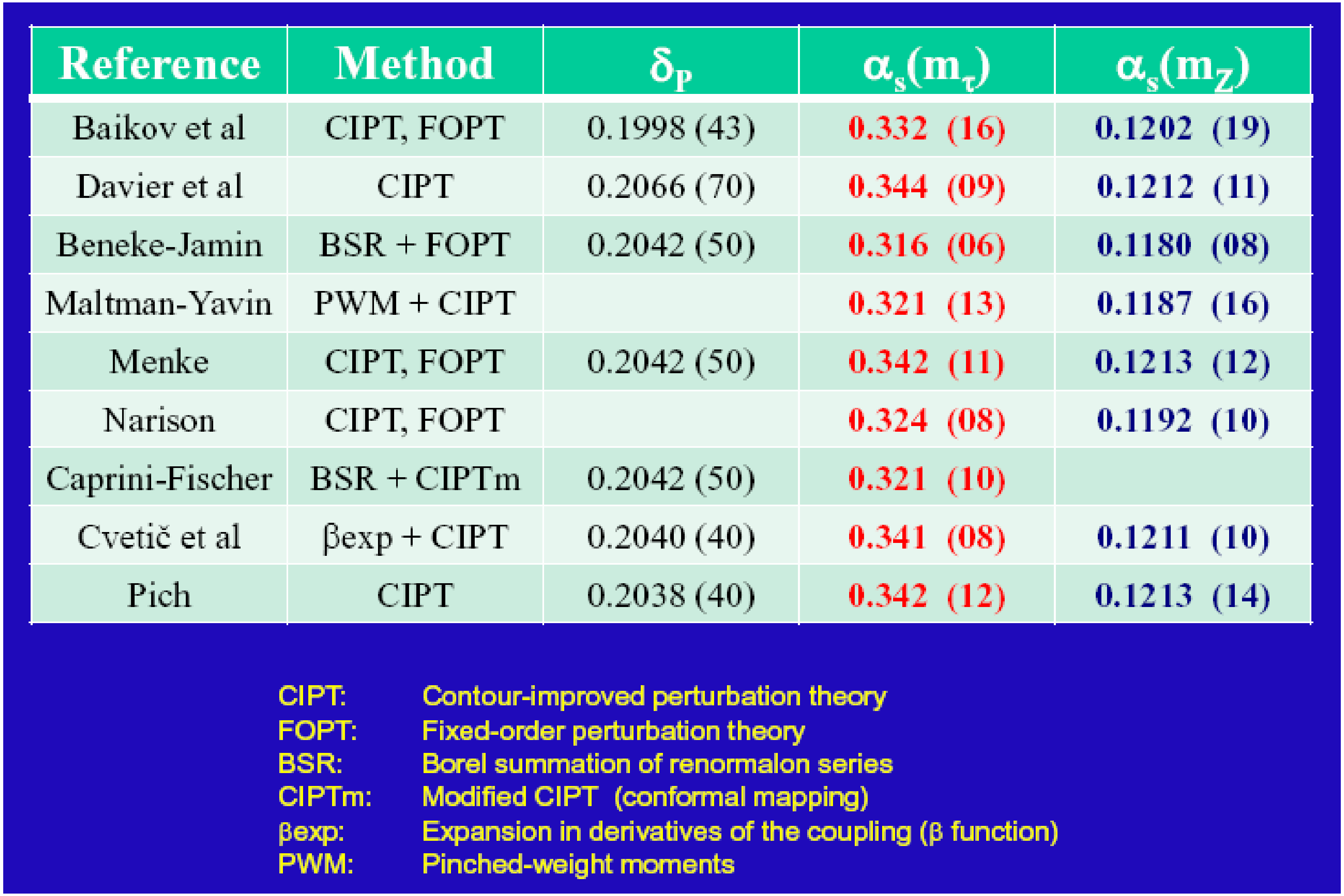
- QCD analyses are based on $R_\tau = \Gamma(\tau \to \nu \text{ hadrons}) / \Gamma(\tau \to \nu\nu e)$ (branching ratios) and spectral moments (weight(s)×SF)
- fits ⇒ precise value of $\alpha_s(m_\tau)$ and non-perturbative components
- however SF's are poorly determined at large mass
- BABAR and Belle have in store ×500 more data / LEP
- it is a duty to provide information on such fundamental physical quantities
- it will allow a better determination of the QCD parameters and detailed checks which are beyond the present status (such as a study of possible duality violations (OPE problems)
- the vector spectral functions are also needed for improved vacuum polarization contributions to $\alpha(M_Z)$ and g-2
- however, improving the normalization of the spectral functions is beyond the reach of the B-factories

QCD analyses: the theoretical side

- the QCD description is on a very good footing, thanks to (miraculous) conditions rendering the non-perturbative term very small, despite the low mass scale
- the perturbative expansion is known up to O(α_s^4)
- but problems still remain from the series truncation
- ongoing discussion on CIPT A. Pich
  vs. FOPT M. Jamin
- the arguments for preferring FOPT challenged
- other CIPT options have appeared recently C. Valenzuela, I. Caprini
- should one worry about duality violations? D. Boito
- discussion will certainly continue: a conservative approach should be to add an additional uncertainty covering the difference between ‘reasonable’ approaches, for instance CIPT–CIPT with conformal mapping, i.e. $\Delta\alpha_s(m_\tau) = \pm 0.01$
- still the result would remain the most precise determination from experiment

Recent $\alpha_s(m_\tau)$ analyses

A. Pich



Reference	Method	δ_P	$\alpha_s(m_\tau)$	$\alpha_s(m_Z)$
Baikov et al	CIPT, FOPT	0.1998 (43)	0.332 (16)	0.1202 (19)
Davier et al	CIPT	0.2066 (70)	0.344 (09)	0.1212 (11)
Beneke-Jamin	BSR + FOPT	0.2042 (50)	0.316 (06)	0.1180 (08)
Maltman-Yavin	PWM + CIPT		0.321 (13)	0.1187 (16)
Menke	CIPT, FOPT	0.2042 (50)	0.342 (11)	0.1213 (12)
Narison	CIPT, FOPT		0.324 (08)	0.1192 (10)
Caprini-Fischer	BSR + CIPTm	0.2042 (50)	0.321 (10)	
Cvetič et al	βexp + CIPT	0.2040 (40)	0.341 (08)	0.1211 (10)
Pich	CIPT	0.2038 (40)	0.342 (12)	0.1213 (14)

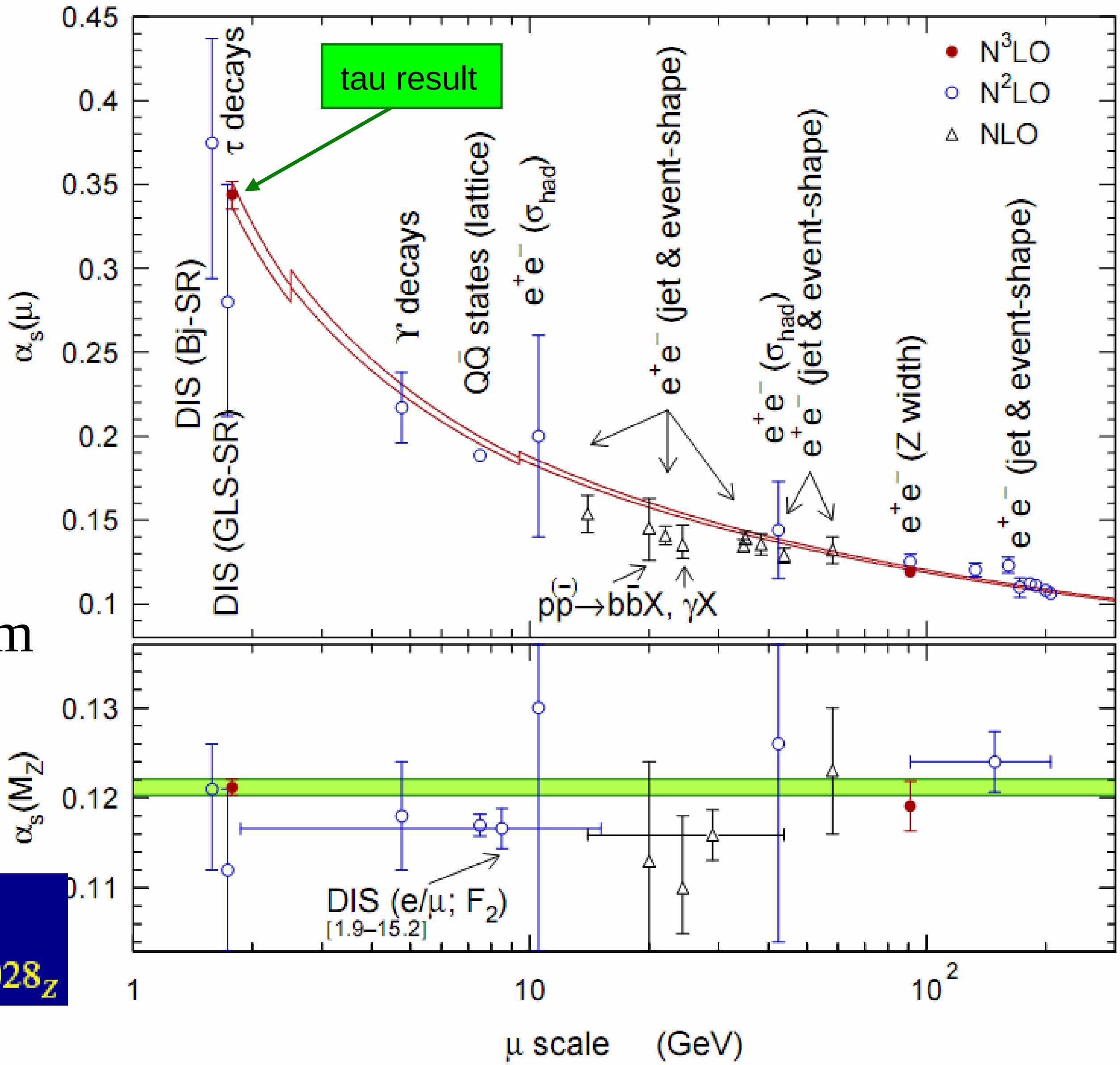
CIPT:	Contour-improved perturbation theory
FOPT:	Fixed-order perturbation theory
BSR:	Borel summation of renormalon series
CIPTm:	Modified CIPT (conformal mapping)
βexp:	Expansion in derivatives of the coupling (β function)
PWM:	Pinched-weight moments

Precise test of QCD running constant

evolve $\alpha_s(m_\tau)$ to M_Z using RGE

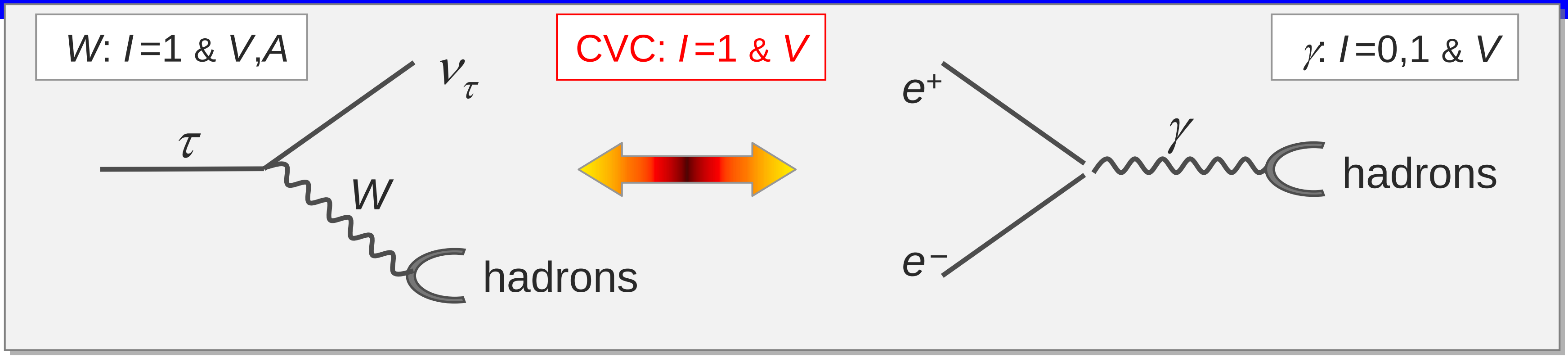
good agreement with $\alpha_s(M_Z)$ from EW fit

best test of asymptotic freedom



$$\alpha_s^\tau(M_Z^2) - \alpha_s^Z(M_Z^2) = 0.0019 \pm 0.0011_\tau \pm 0.0028_Z$$

τ hadronic decays and e+e–→ hadrons: the CVC connection



Hadronic physics factorizes in Spectral Functions

Isospin symmetry connects *I* =1 *e+e–* cross section (neutral) to τ vector spectral functions (charged):

$$\sigma^{(I=1)}\left[e^+e^-\to\pi^+\pi^-\right]=\frac{4\pi\alpha^2}{s}\upsilon\left[\tau^-\to\pi^-\pi^0\nu_\tau\right]$$

τ decays: analogous to ISR for e^+e^- ⇒ get spectral function from threshold to m_τ

$$\upsilon\left[\tau^-\to\pi^-\pi^0\nu_\tau\right]\propto\frac{\mathrm{BR}\left[\tau^-\to\pi^-\pi^0\nu_\tau\right]}{\mathrm{BR}\left[\tau^-\to e^-\bar{\nu}_e\nu_\tau\right]}\;\frac{1}{N_{\pi\pi^0}}\frac{dN_{\pi\pi^0}}{ds}\;\frac{m_\tau^2}{\left(1-s/m_\tau^2\right)^2\left(1+s/m_\tau^2\right)}\;\frac{R_{IB}(s)}{S_{EW}}$$

Branching fractions

Mass spectrum

Kinematic factor (PS)

Isospin correction

Tests of CVC

- CVC is violated by small isospin breaking (IB) effects of EM origin
- most precise test with the 2π spectral functions
- a discrepancy appeared in 2003 with more precise ee data (CMD-2)
- progress in IB corrections with more complete theoretical work
  G. Lopez Castro et al.
- new ee data (KLOE, BABAR) introduce more confusion, as discrepancies (as large as ee/τ) show up within ee data
- KLOE result with ππ / μμ not yet available
- situation re-evaluated at this meeting with all available data
  MD, A. Hoecker, B. Malaescu, Z. Zhang (DHMZ) A. Hoecker

KLOE and BABAR

G. Venanzoni B. Malaescu

- KLOE and BABAR use the novel ISR method
- but with major differences

  s'/s range

  BABAR measures ππ/μμ ratio at NLO

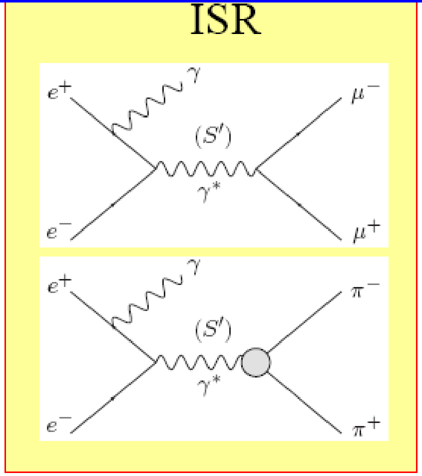
  KLOE gets ISR radiator from Phokhara

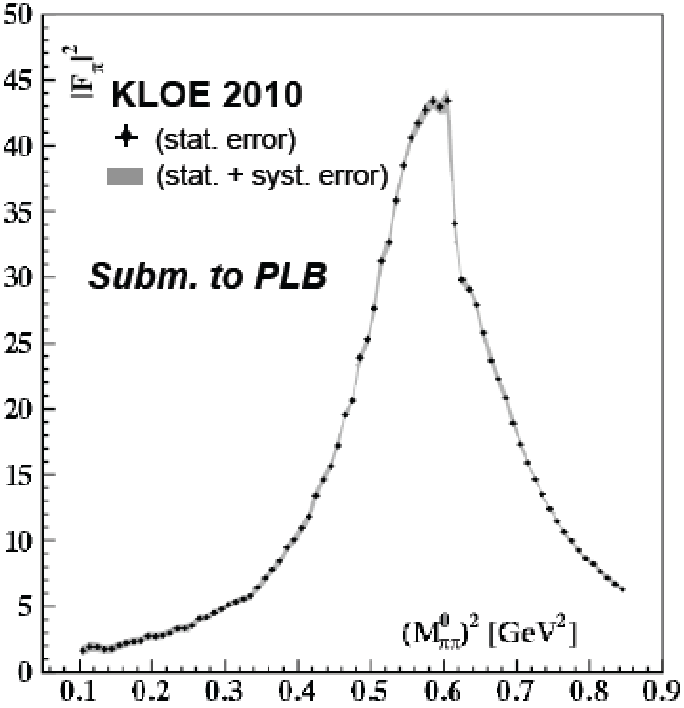
- small systematic uncertainties 0.6-0.5 %

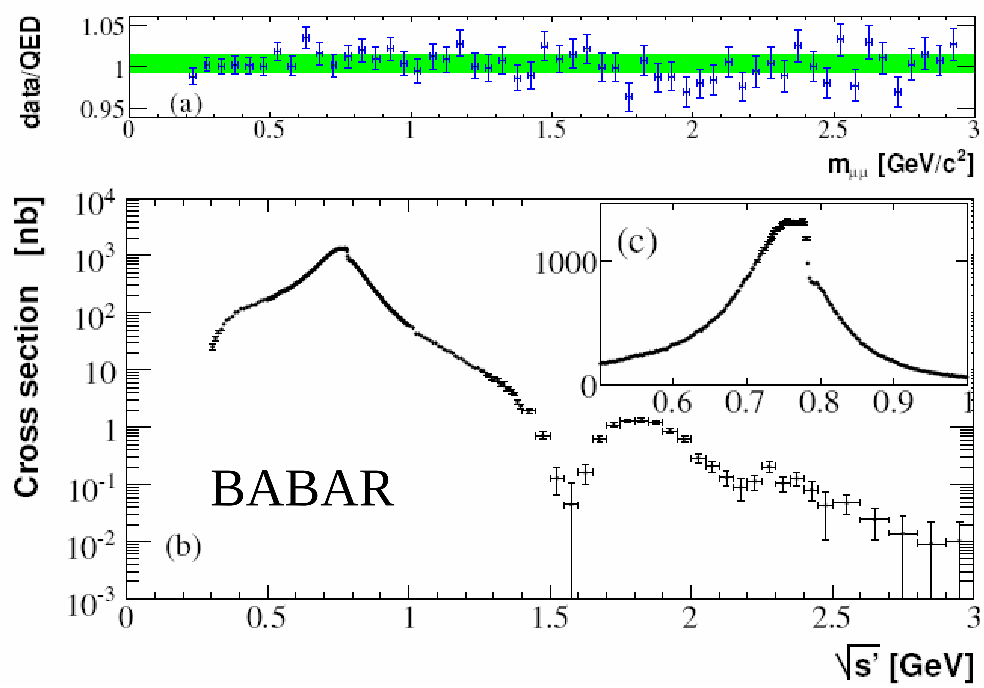
$$x = 2E^*_\gamma/\sqrt{s}$$

$$s' = s(1-x)$$

H. Czyz

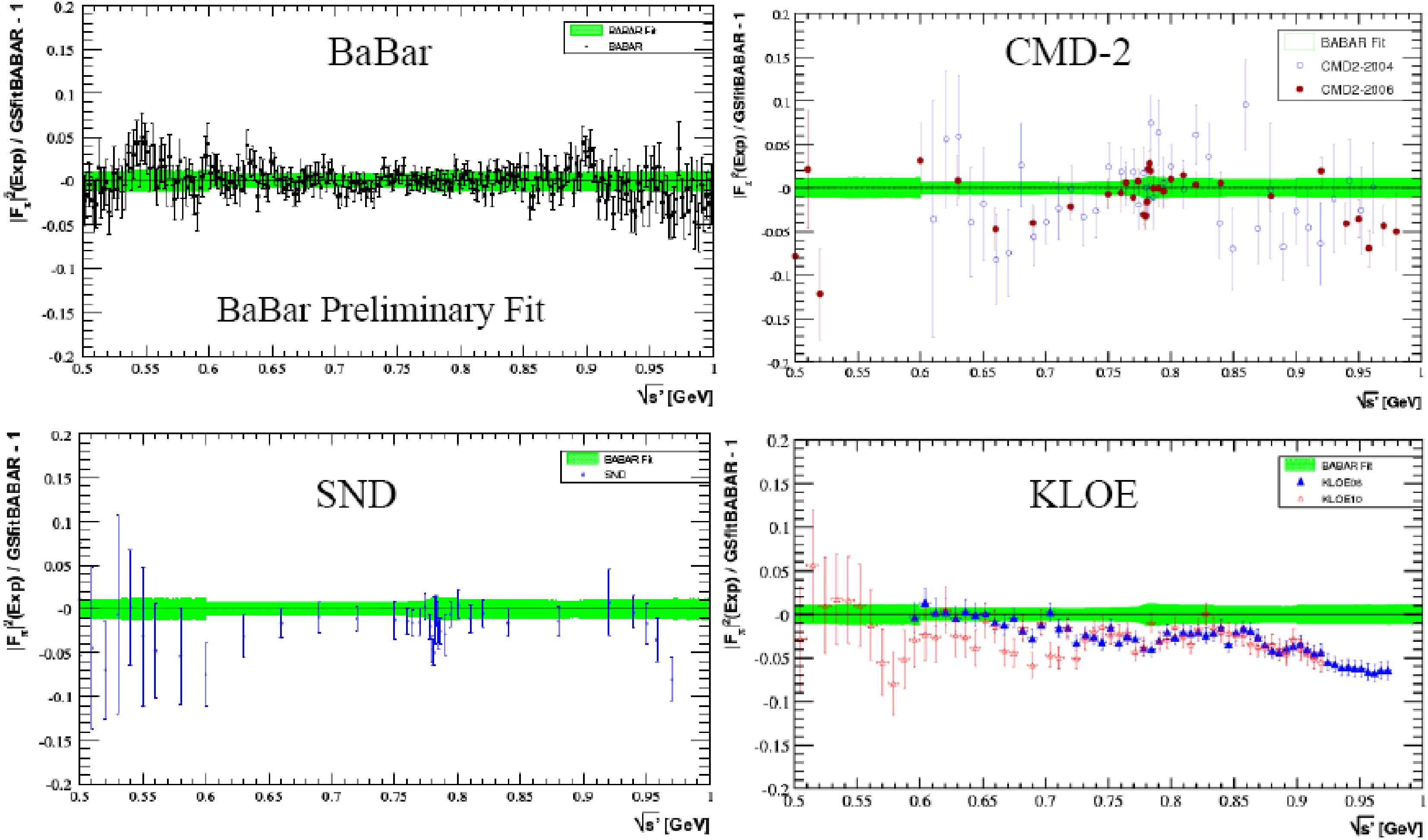






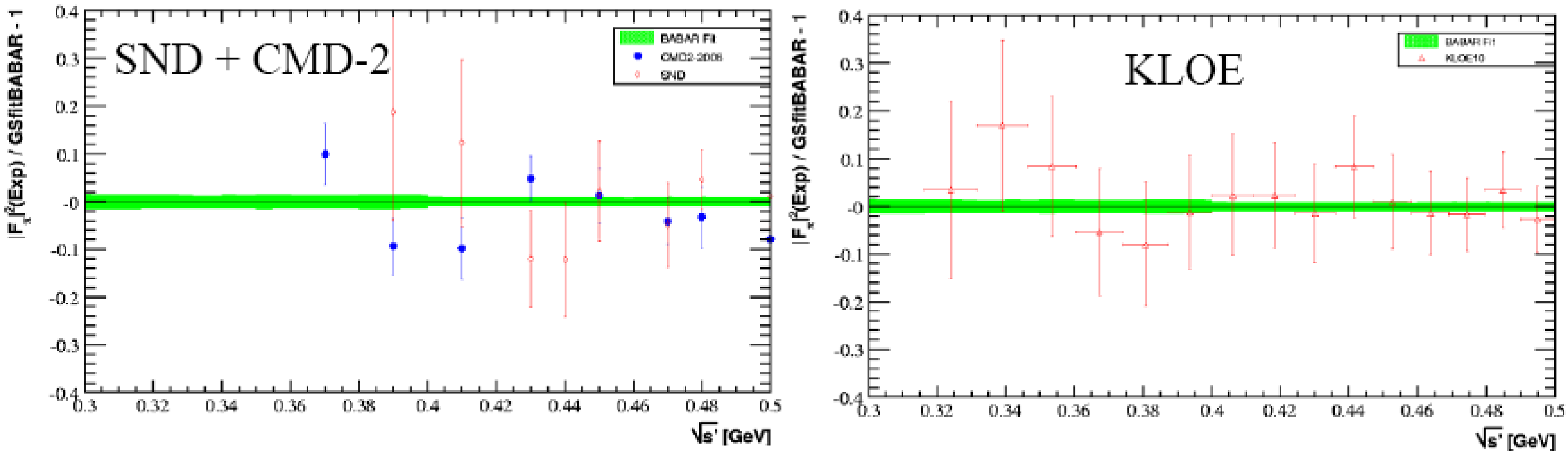
Comparison of input ee→ππ BABAR/other exp.

direct relative comparison of cross sections with BaBar fit (stat + syst errors included)
(green band)

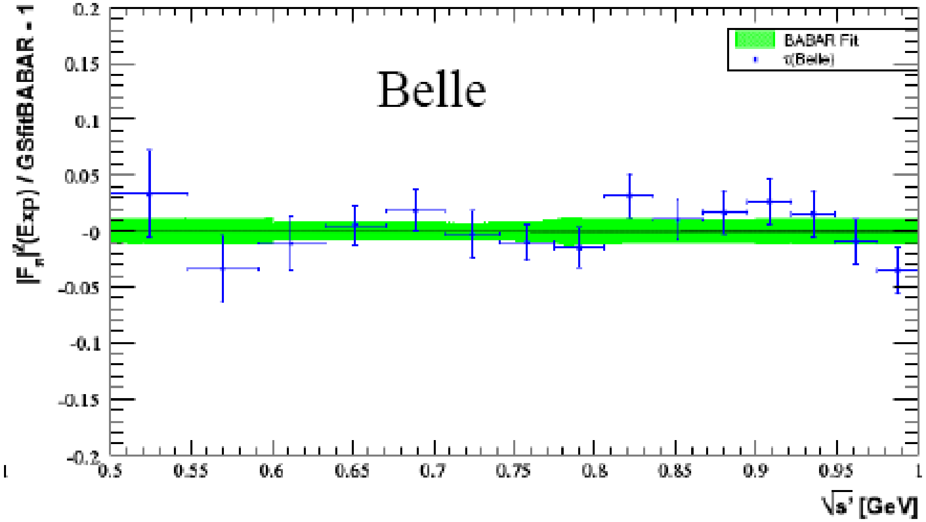


Comparison of input ee→ππ BABAR/other exp.

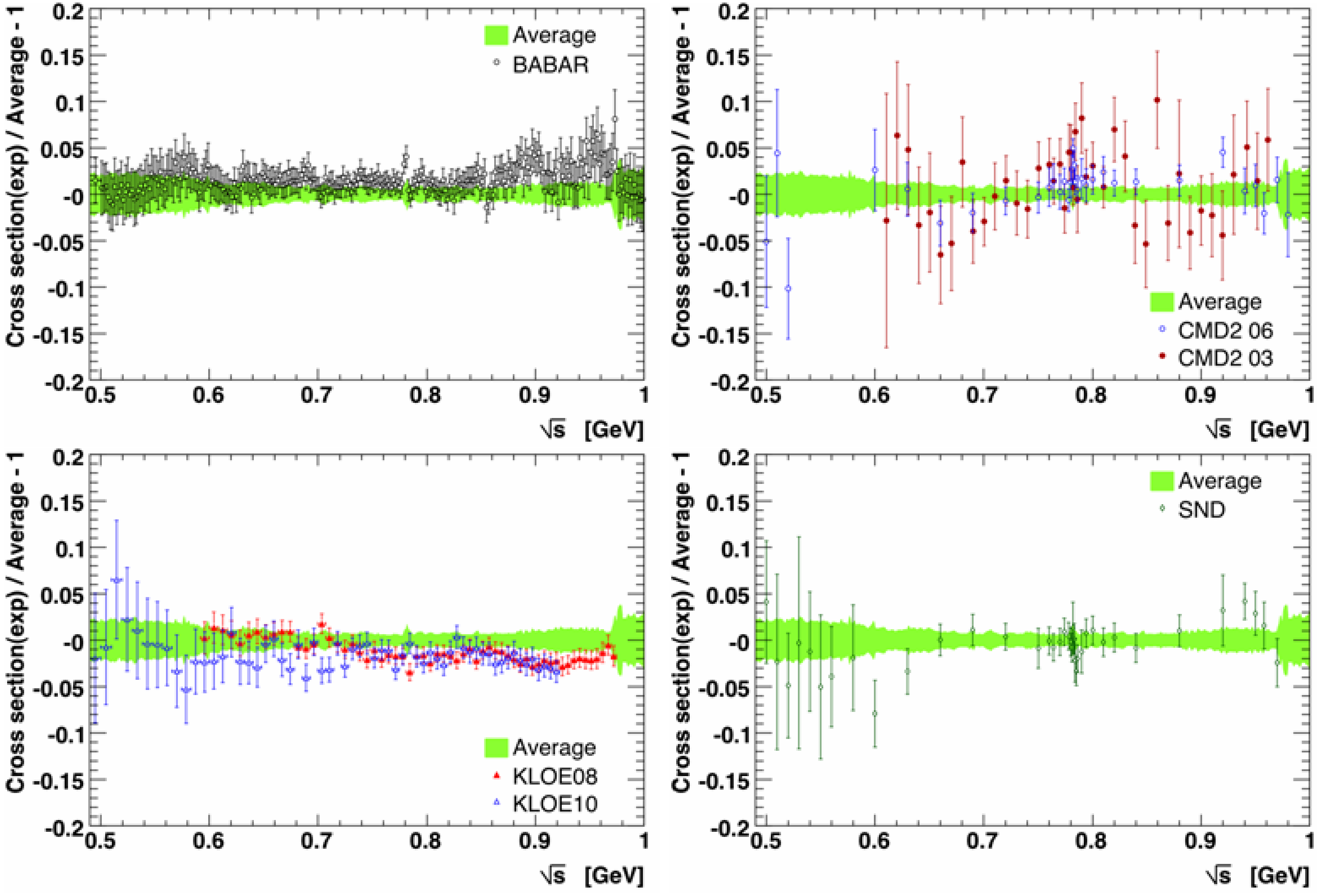
Comparison at low energy: good agreement, but other exp. not as precise



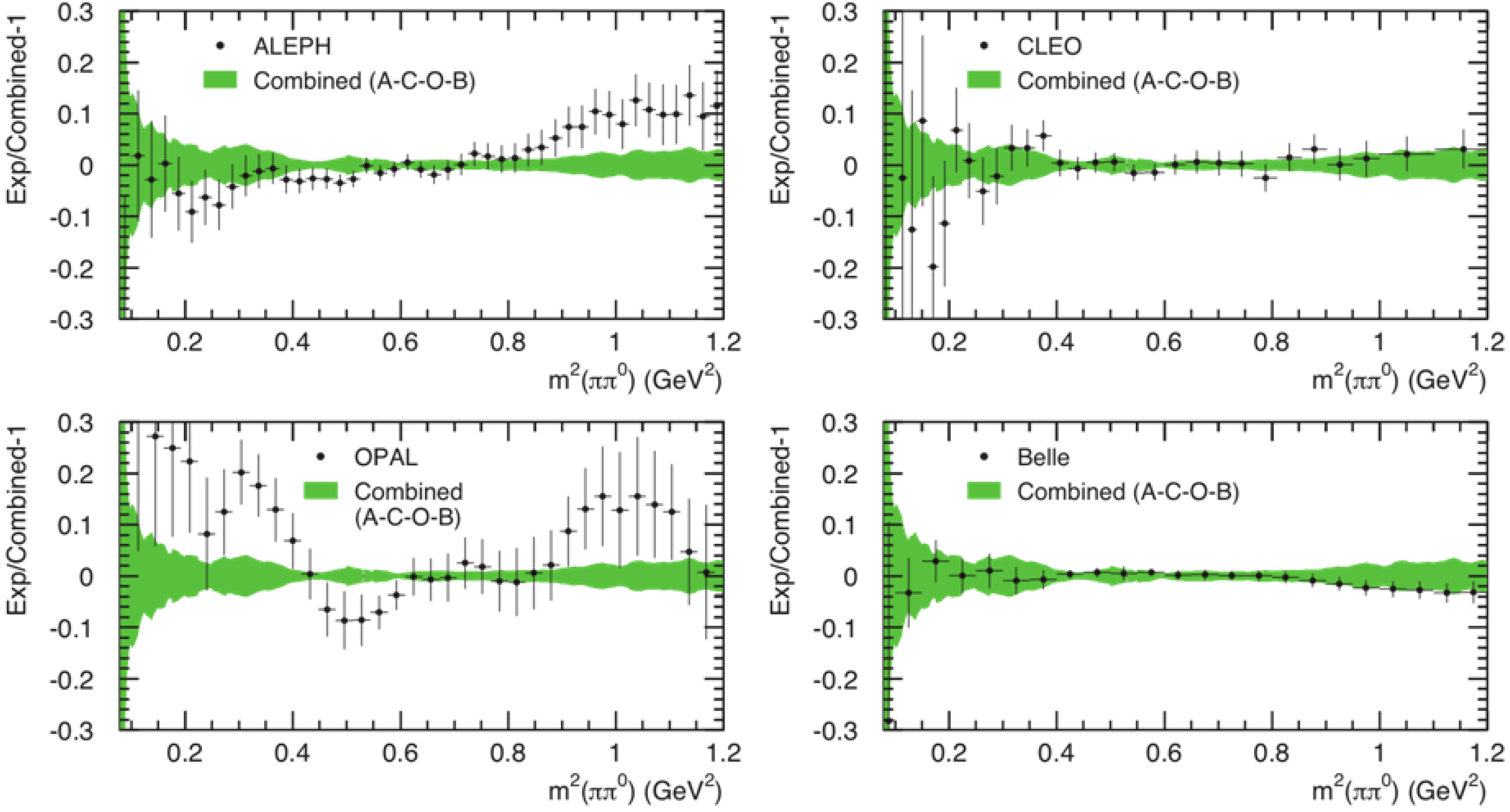
Comparison BABAR / Belle



Comparison of input ee→ππ data



Comparison of input $\tau\to\pi\pi^0\nu$ data



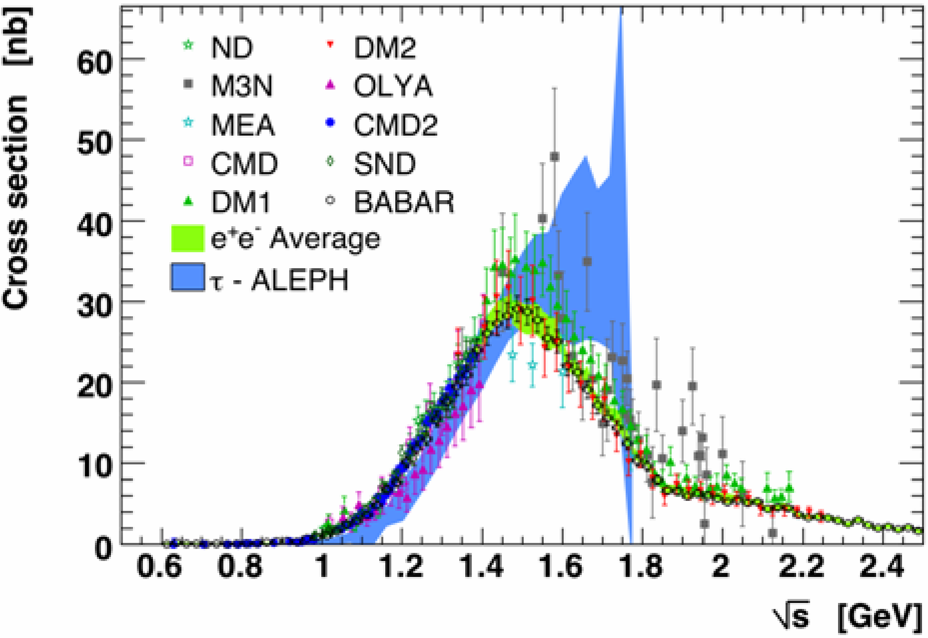
Comparison of $\tau\to4\pi\nu$ and $ee\to4\pi$ data

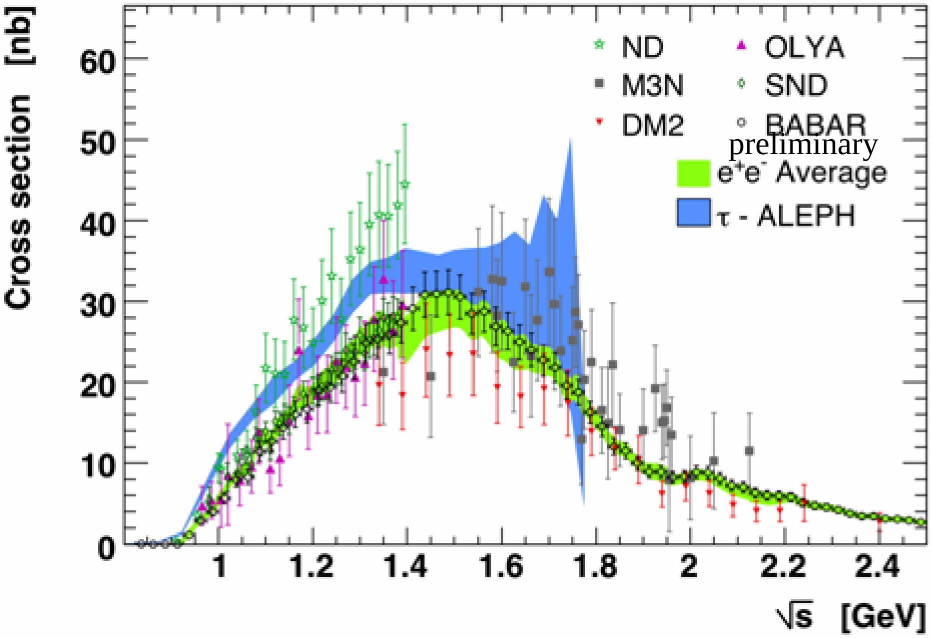
DHMZ

- two isospin relations

$$\sigma^{(I=1)}_{2\pi^+2\pi^-} = 2\cdot\frac{4\pi\alpha^2}{s}\upsilon_{\pi^-3\pi^0\nu_\tau}$$

$$\sigma^{(I=1)}_{\pi^+\pi^-2\pi^0} = \frac{4\pi\alpha^2}{s}\left(\upsilon_{2\pi^-\pi^+\pi^0\nu_\tau} - \upsilon_{\pi^-3\pi^0\nu_\tau}\right)$$

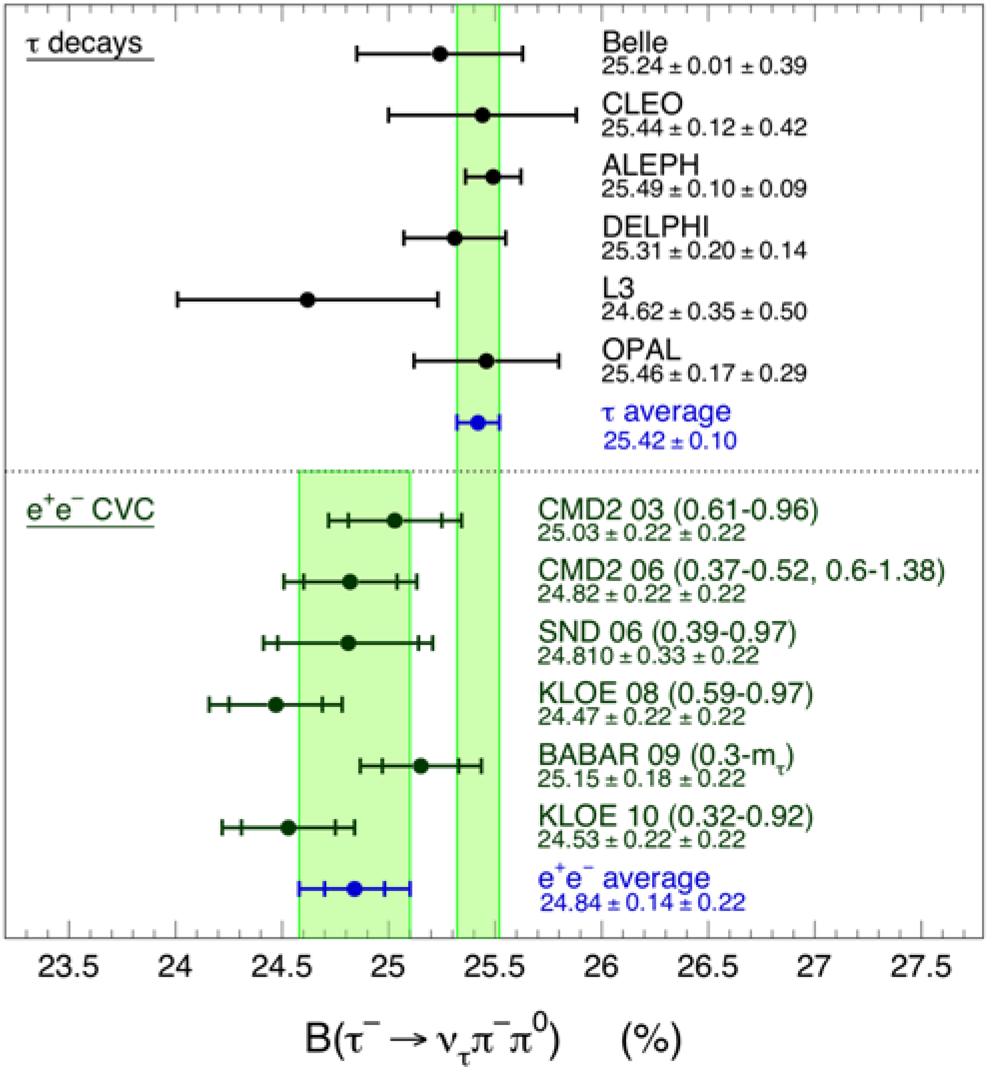




Can Belle and BABAR get the 4π τ spectral functions and BR’s ?

CVC predictions for τ branching ratios

DHMZ



$$\mathrm{BR}^{\mathrm{CVC}}_{\tau^- \to \pi^- \pi^0 \nu_\tau} \propto \int_0^{m_\tau^2} ds\ \mathrm{kin}(s) \cdot \sigma^{\text{IB-corrected}}_{e^+e^- \to \pi^+\pi^-}(s)$$

IB corrections of +0.69 ± 0.22 applied for $\pi^+\pi^0$

Difference: BR[τ] – BR[e^+e^- (CVC)]:

Mode	$\Delta(\tau - e^+e^-)$	"Sigma"
$\tau^- \to \pi^- \pi^0 \nu_\tau$	+ 0.58 ± 0.28	2.1
$\tau^- \to \pi^- 3\pi^0 \nu_\tau$	– 0.03 ± 0.09	0.3
$\tau^- \to 2\pi^- \pi^+ \pi^0 \nu_\tau$	+ 0.69 ± 0.22	3.2

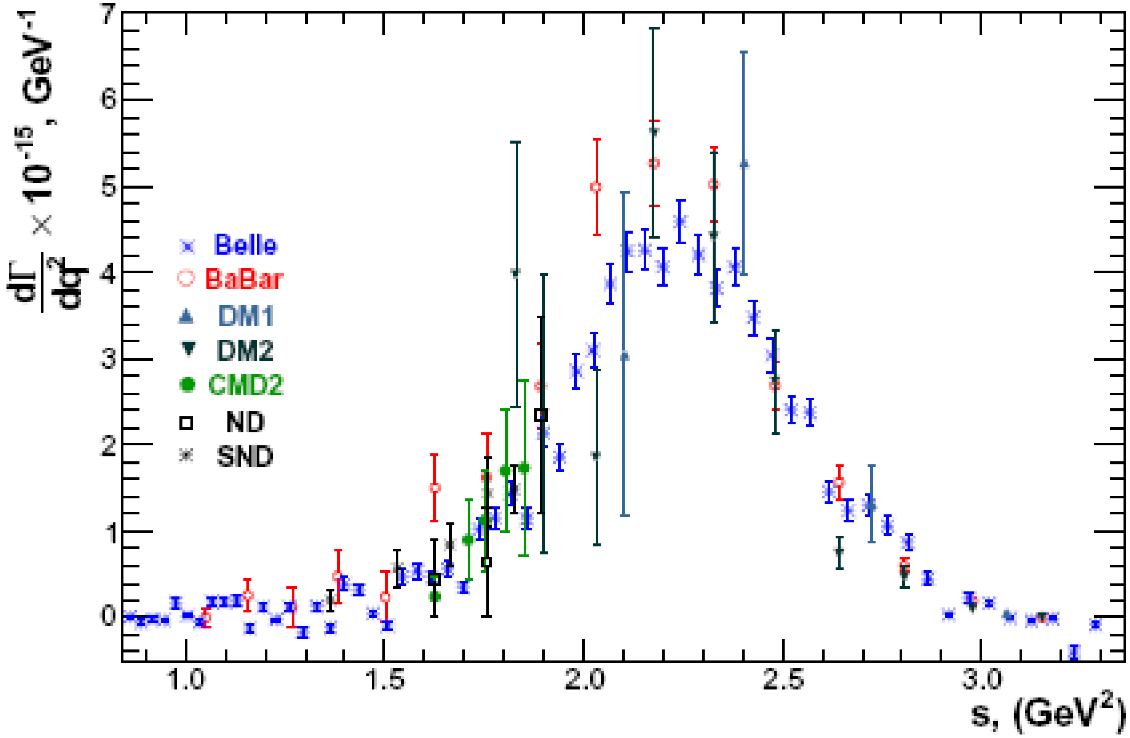
CVC predictions of $\pi^+\pi^-$ much improved with BABAR data and re-evaluated IB corrections (4.5σ previously) !

Tests of CVC in ηππ and η'ππ modes

S. Eidelman

Using precise data from BABAR on ee→ηππ and Belle on $\tau \to \eta\pi\pi^0\nu$

$\mathcal{B}_{\mathrm{CVC}} = (0.153 \pm 0.018)\%$ is consistent with $\mathcal{B}_{\mathrm{PDG}} = (0.139 \pm 0.010)\%$

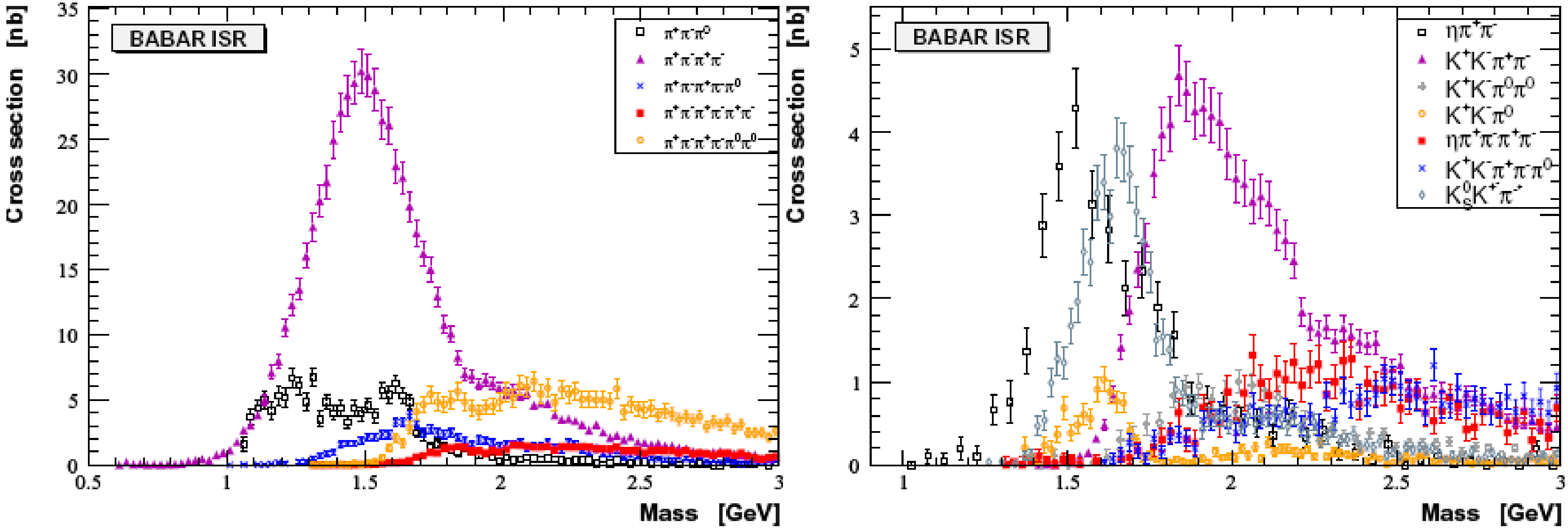


New evaluations of muon g–2

- HLMNT: include KLOE 2010 T. Teubner
- DHMZ: include KLOE 2010 A. Hoecker

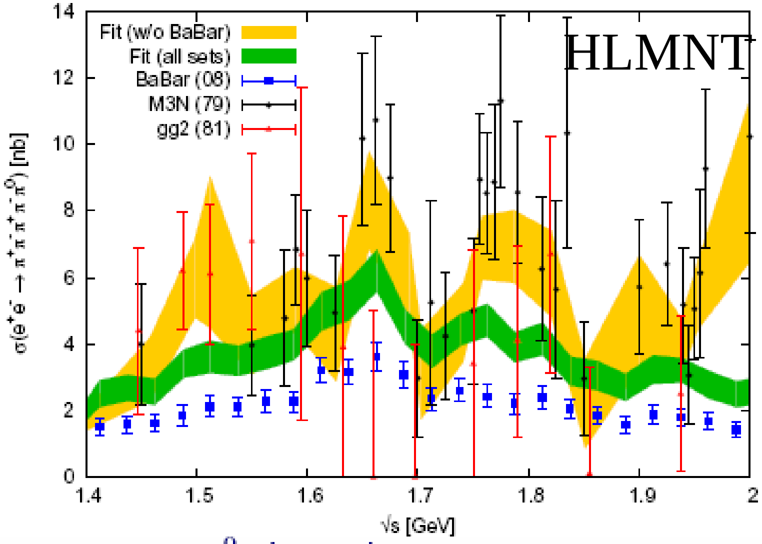
complete re-evaluation of multi-hadronic contributions
using all BABAR data ⇒ more reliable estimate of missing channels (isospin+dynamics)
include correlations between experiments and channels

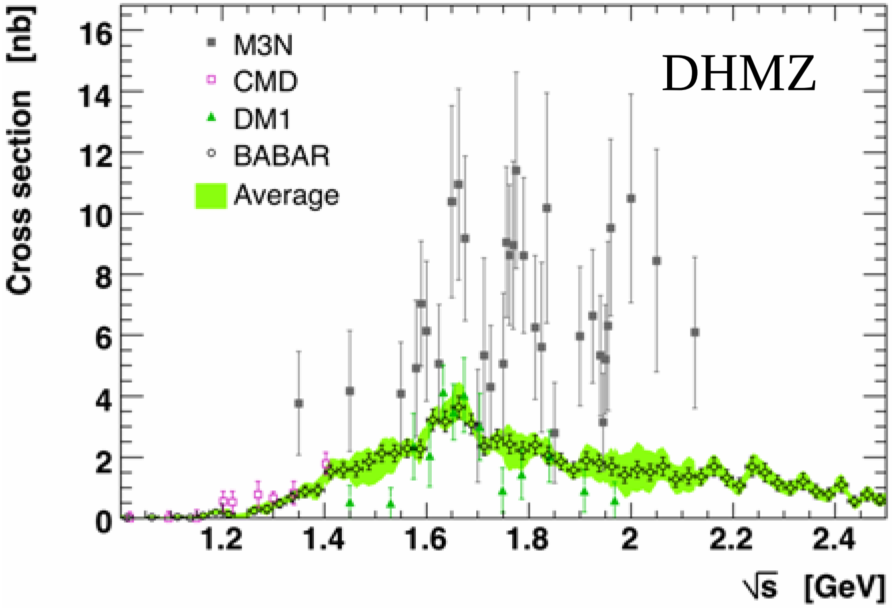
Statistical + systematic errors B. Malaescu



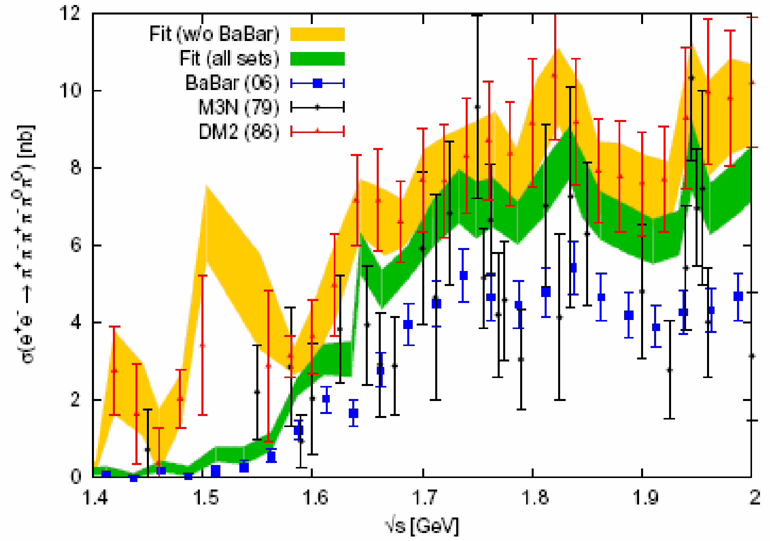
Some systematic differences in HLMNT/DHMZ

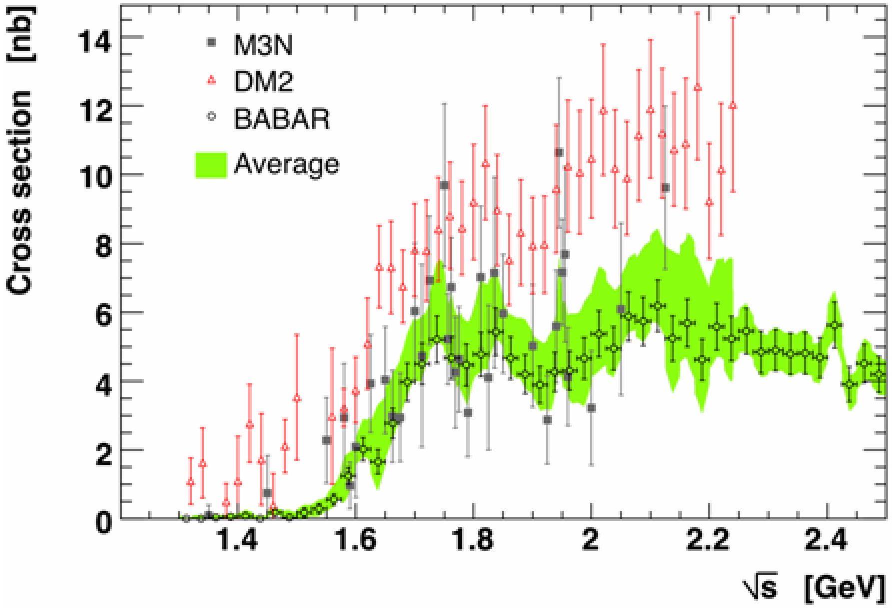
$2\pi^+2\pi^-\pi^0$ channel





$2\pi^-2\pi^-2\pi^0$ channel





New results for g–2

PRELIMINARY

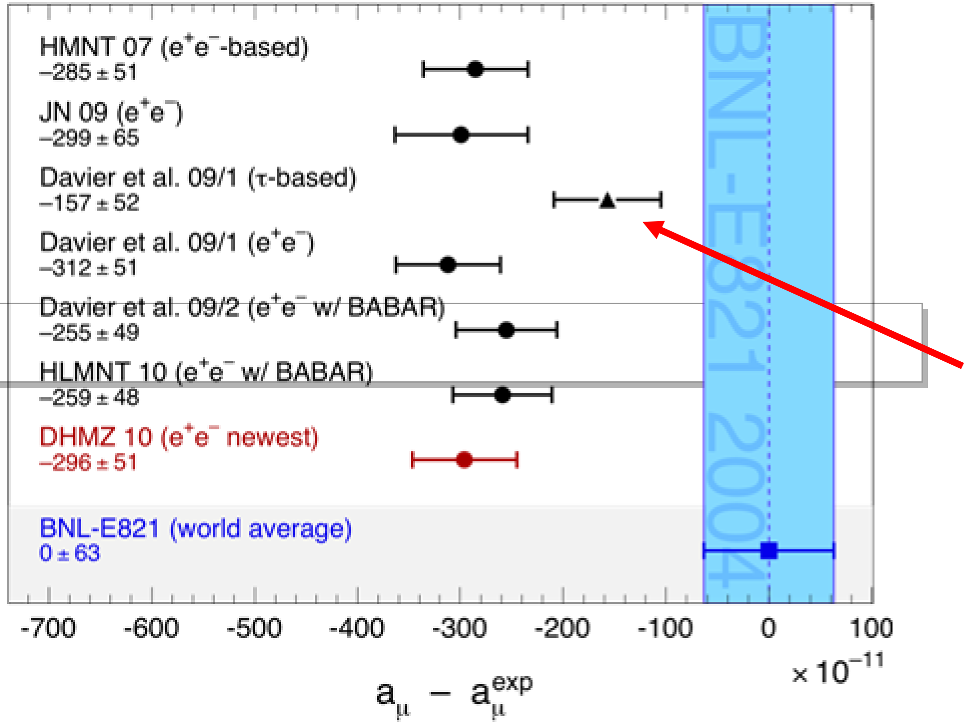
$$a_\mu^{SM}[e^+e^-] = (11\,659\,179.3 \pm 4.4_{\text{had,LO}} \pm 2.6_{\text{NLO}} \pm 0.2_{\text{QED+weak}}) \times 10^{-10}$$

DHMZ, Tau 2010

$$a_\mu^{SM}[e^+e^-] = (11\,659\,183.0 \pm 4.5_{\text{had,LO}} \pm 2.6_{\text{NLO}} \pm 0.2_{\text{QED+weak}}) \times 10^{-10}$$

HLMNT Tau 2010

Status: Tau2010, preliminary



Observed Difference with Experiment:

$$a_\mu^{\,exp} - a_\mu^{\,SM} = (29.6 \pm 8.1) \times 10^{-10}$$

➡ 3.6 ”standard deviations“

DHMZ, Tau 2010

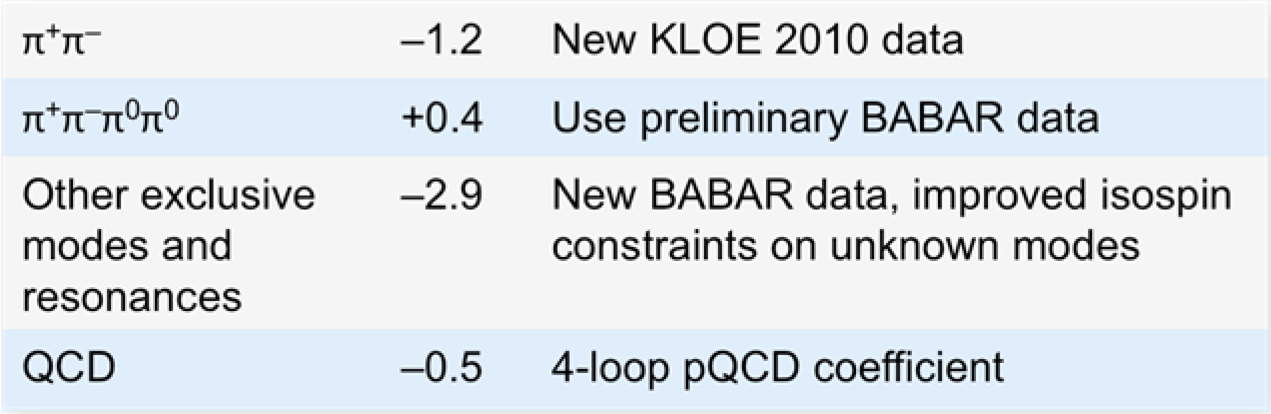
Note that the re-evaluated tau result would follow large part of shift (though not that due to KLOE …)

… →

Discussion

The Tau-2010 DHMZ result is – 4.1×10^{-10} smaller than that of 2009
(the latter of which is compatible with that of HLMNT 2010)

Origins of main changes:



$\pi^+\pi^-$	–1.2	New KLOE 2010 data
$\pi^+\pi^-\pi^0\pi^0$	+0.4	Use preliminary BABAR data
Other exclusive modes and resonances	–2.9	New BABAR data, improved isospin constraints on unknown modes
QCD	–0.5	4-loop pQCD coefficient

Many modes also have been computed for the first time with HVPTools
featuring a more precise interpolation, and better error propagation than our previous software

- The deviation prediction/experiment has grown stronger (3.6 σ)
- τ and ee estimates much closer (still $2\pi\ 2\pi^0$ to be understood)
- remaining discrepancies KLOE/BABAR-BELLE to be resolved

New results for $\Delta\alpha_{had}(M_Z)$

Also the hadronic contribution to $\alpha_{QED}(M_Z)$ has been re-evaluated:

$$\Delta\alpha_{had}^{(5)}(M_Z^2) = (274.23 \pm 0.17_{stat} \pm 0.87_{syst} \pm 0.54_{QCD}\ [1.0_{tot}]) \times 10^{-4}$$

DHMZ, Tau 2010

$$\Delta\alpha_{had}^{(5)}(M_Z^2) = (275.9 \pm 1.5_{tot}) \times 10^{-4}$$

HLMNT, Tau 2010

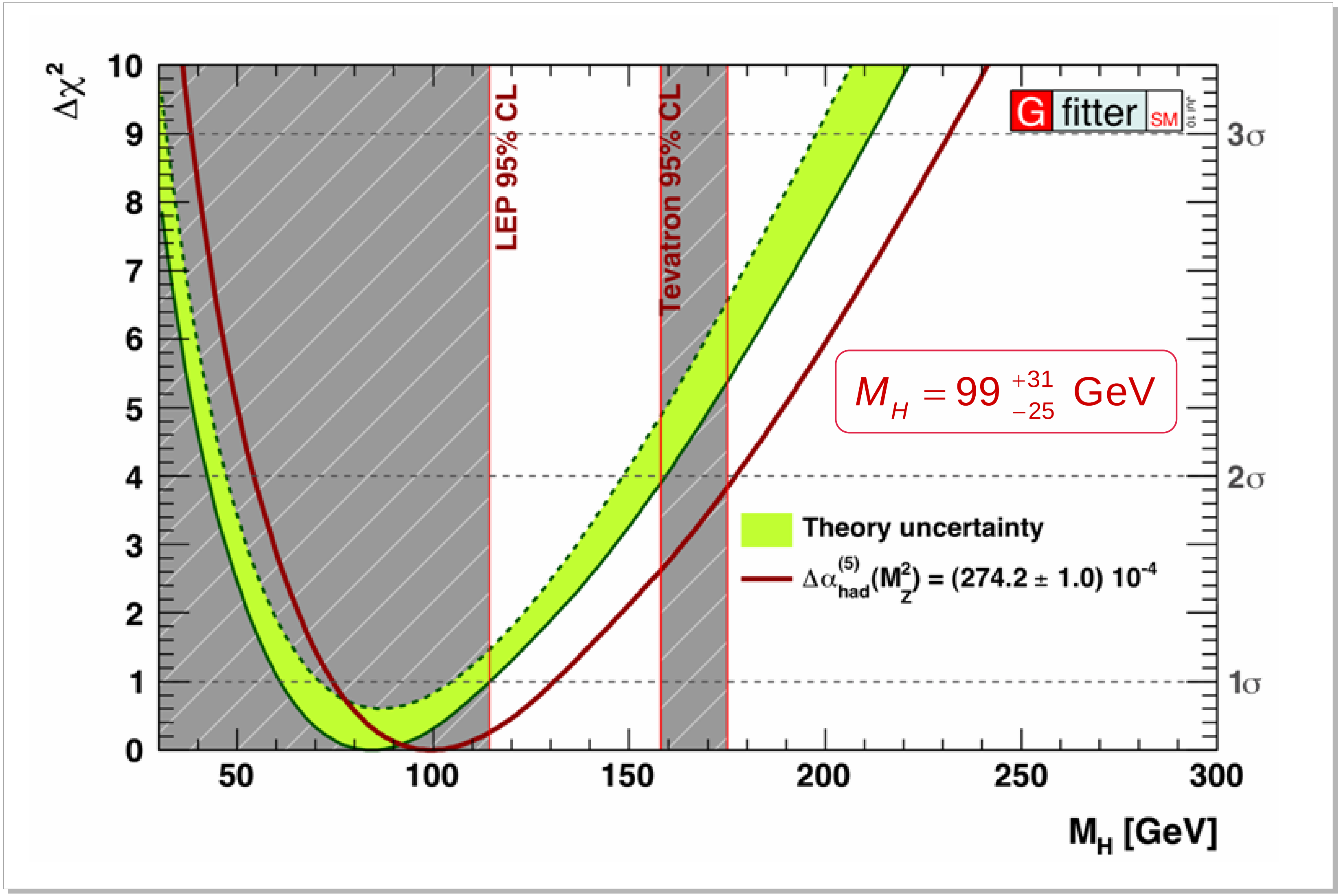
The better precision of the DHMZ value with respect to HLMNT is because of the use of QCD instead of BES data between 1.8 and 3.7 GeV

(HLMNT employs QCD central values, but with BES errors)

Due to the –40% correlation between $\Delta\alpha_{had}(M_Z)$ and M_H in the global electroweak fit, the change in the central value should increase M_H and reduce tension between fit and direct searches !

Global EW fit with $\Delta\alpha_{had}(M_Z)_{DHMZ}$

Most probable value for M_H moves from 84 to 99 GeV



Further progress

- ππ / μμ KLOE analysis
- completion of BABAR ISR programme
- VEPP-2000 data B. Shwartz
- DAFNE 2 ? G. Venanzoni
- superB-factory(ies ?) H. Hayashii, A. Lusiani

- on the theory side: more work on hadronic LBL contribution
- continued development of accurate MC generators H. Czyz, Z. Was

- need for more precise direct measurement: present exp. error (6.3) larger than theory error (5.1) which will improve

  2 projects: FermiLab B.L. Roberts

  JPARC T. Mibe

- g–2 brings complementary information to LHC direct searches for New Physics

Searching for New Physics in τ decays: CPT, CP

- long shots: tests of CPT (BABAR) H. Choi

$$\frac{M(\tau^+)-M(\tau^-)}{M_{Average}} = (-3.4 \pm 1.3[stat] \pm 0.3[syst]) \times 10^{-4}$$

- looking for CP violation

BABAR

$$A_Q = \frac{\Gamma\left(\tau^+ \to \pi^+ K_S^0\, \overline{\nu}_\tau\right) - \Gamma\left(\tau^- \to \pi^- K_S^0\, \nu_\tau\right)}{\Gamma\left(\tau^+ \to \pi^+ K_S^0\, \overline{\nu}_\tau\right) + \Gamma\left(\tau^- \to \pi^- K_S^0\, \nu_\tau\right)}$$

$$(-0.10 \pm 0.21[stat] \pm 0.22[syst])\%$$

Belle same channel M. Bischofberger

differential asymmetry (decay angles)

as function of mass

$$\boxed{\Delta \equiv \left(\frac{d\Gamma(\tau^-)}{d\Pi} - \frac{d\Gamma(\tau^+)}{d\Pi}\right) = \mathrm{Im}(\eta_S) \times C'(Q^2) \times \frac{\mathrm{Im}(F F_H^*)}{m_\tau} \times \cos\beta \cos\psi}$$

($H^\pm$)

$$(d\Pi = dQ^2 d\cos\theta\, d\cos\beta)$$

Limits $|\mathrm{Im}(\eta_S)|$ **< 0.13 – 0.27 at 90% c. l.**

(Belle preliminary)

~15× better than previous limits

(CLEO: $|\mathrm{Im}(\eta_S)| < 4.1$)

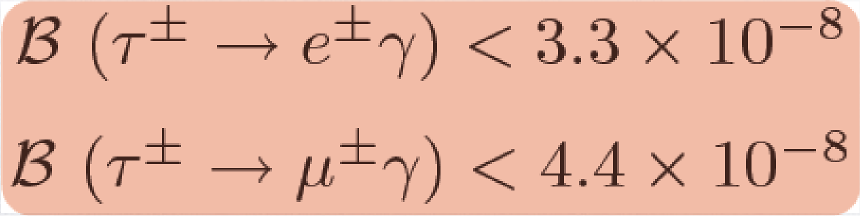
Searching for New Physics in τ decays: LFV (1)

- strong motivation to look for LFV decays as proof of NP
- SM expectation completely negligible
- SUSY is a leading candidate

A. Pilaftsis, T. Morozumi
A. Ilakovac, A. Texeira

- strong B-factory potential: limits so far, but reaching a few $\times 10^{-8}$

BABAR



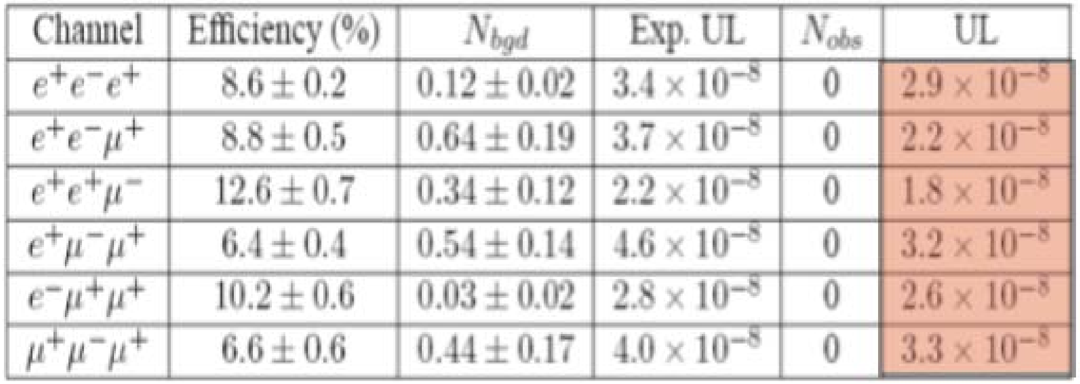
$$\mathcal{B}\left(\tau^{\pm} \to e^{\pm}\gamma\right) < 3.3 \times 10^{-8}$$

$$\mathcal{B}\left(\tau^{\pm} \to \mu^{\pm}\gamma\right) < 4.4 \times 10^{-8}$$

1.2×10^{-7}

4.5×10^{-8}

Belle



Channel	Efficiency (%)	N_{bgd}	Exp. UL	N_{obs}	UL
$e^+e^-e^+$	8.6 ± 0.2	0.12 ± 0.02	3.4×10^{-8}	0	2.9×10^{-8}
$e^+e^-\mu^+$	8.8 ± 0.5	0.64 ± 0.19	3.7×10^{-8}	0	2.2×10^{-8}
$e^+e^+\mu^-$	12.6 ± 0.7	0.34 ± 0.12	2.2×10^{-8}	0	1.8×10^{-8}
$e^+\mu^-\mu^+$	6.4 ± 0.4	0.54 ± 0.14	4.6×10^{-8}	0	3.2×10^{-8}
$e^-\mu^+\mu^+$	10.2 ± 0.6	0.03 ± 0.02	2.8×10^{-8}	0	2.6×10^{-8}
$\mu^+\mu^-\mu^+$	6.6 ± 0.6	0.44 ± 0.17	4.0×10^{-8}	0	3.3×10^{-8}

A. Cervelli
M. Lewczuk
K. Inami

Belle will update to the full sample of 1 ab^{-1}

Searching for New Physics in τ decays: LFV (2)

More limits…

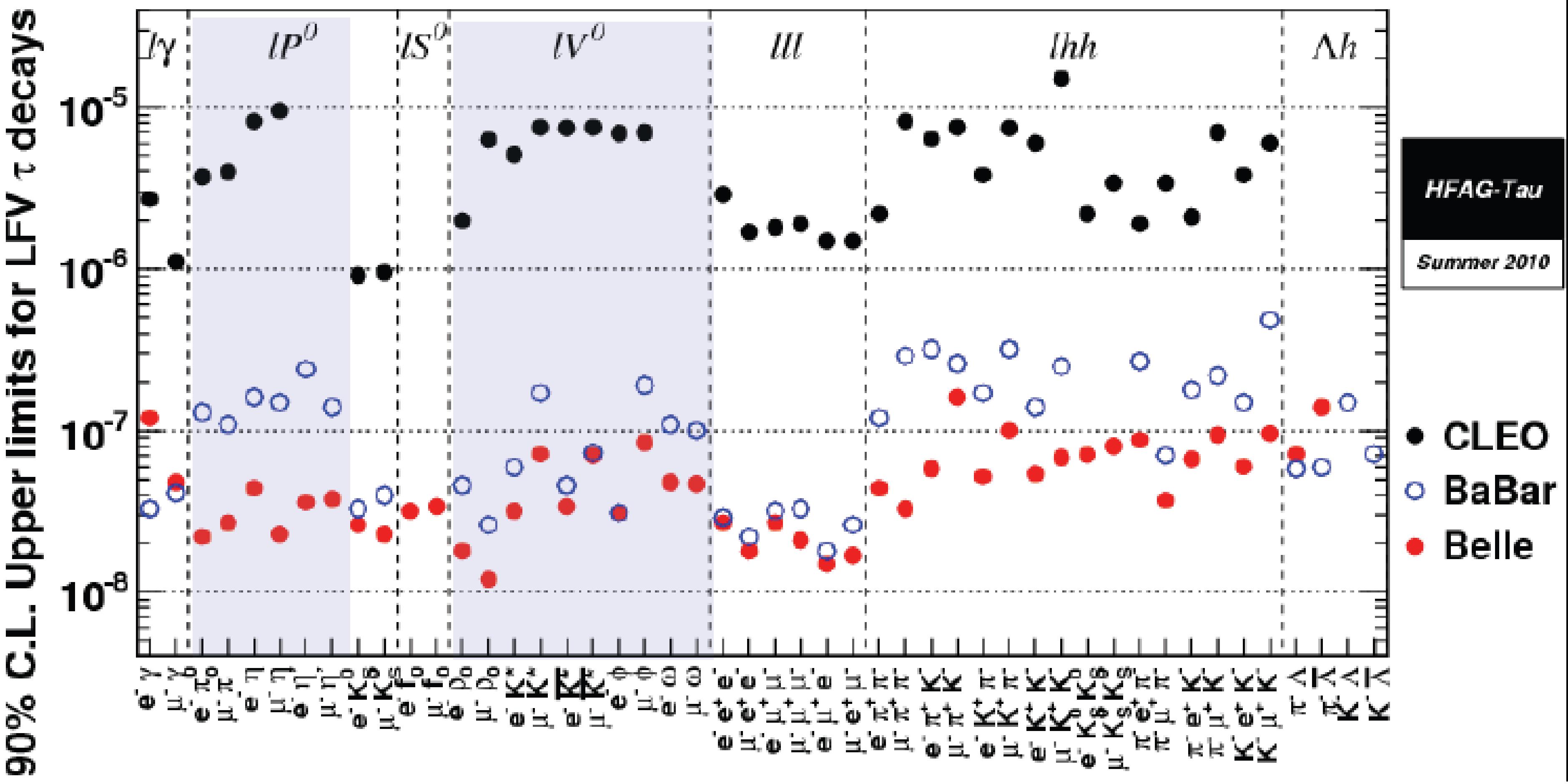
$\tau\to$	Eff. %	N_{BG}^{exp}	$N_{obs.}$	UL x10^{-8}
$\mu\eta(\to\gamma\gamma)$	8.2	0.63±0.37	0	3.6
$\mu\eta(\to\pi\pi\pi^0)$	6.9	0.23±0.23	0	8.6
$\mu\eta$(comb.)				2.3
$e\eta(\to\gamma\gamma)$	7.0	0.66±0.38	1	8.2
$e\eta(\to\pi\pi\pi^0)$	6.3	0.69±0.40	0	8.1
$e\eta$(comb.)				4.4
$\mu\eta'(\to\pi\pi\eta)$	8.1%	$0.00^{+0.16}_{-0.00}$	0	10.0
$\mu\eta'(\to\rho^0\gamma)$	6.2%	0.59±0.41	0	6.6
$\mu\eta'$ (comb.)				3.8
$e\eta'(\to\pi\pi\eta)$	7.3%	0.63±0.45	0	9.4
$e\eta'(\to\rho^0\gamma)$	7.5%	0.29±0.29	0	6.8
$e\eta'$ (comb.)				3.6
$\mu\pi^0(\to\gamma\gamma)$	4.2%	0.64±0.32	0	2.7
$e\pi^0(\to\gamma\gamma)$	4.7%	0.89±0.40	0	2.2

$\tau\to$	Eff.	N_{BG}^{exp}	$N_{obs.}$	UL x10^{-8}
e-ρ^0	7.6%	0.29±0.15	0	1.8
μ-ρ^0	7.1%	1.48±0.35	0	1.2
e-ϕ	4.2%	0.47±0.19	0	3.1
μ-ϕ	3.2%	0.06±0.06	1	8.4
e-ω	2.9%	0.30±0.14	0	4.8

$\tau\to$	Eff.	N_{BG}^{exp}	$N_{obs.}$	UL x10^{-8}
e-K^{*0}	4.4%	0.39±0.14	0	3.2
μ-K^{*0}	3.4%	0.53±0.20	1	7.2
e-$\overline{K^{*0}}$	4.4%	0.08±0.08	0	3.4
μ-$\overline{K^{*0}}$	3.6%	0.45±0.17	1	7.0
μ-ω	2.4%	0.72±0.18	0	4.7

Searching for New Physics in τ decays: LFV (3)

Very impressive achievement!



LFV using muons

- most sensitive experiment on $\mu \to e\,\gamma$: MEG B. Golden

  first 2-month run analyzed: a few candidates?
  sensitivity 6×10^{-12}
  upper limit 1.5×10^{-11}

  3 years to reach a few $\times 10^{-13}$ sensitivity

- ambitious projects for $\mu \to e$ conversion on a nucleus

  present best limit SINDRUM II: 7×10^{-13}

COMET (JPARC)	10^{-16}	A. Kurup
Mu2e (Fermilab)	10^{-16}	C. Dukes
PRISM/PRIME	10^{-18}	R. Barlow

Search for NP in decays involving τ: B-factories

- Lepton universality could be broken in Υ(nS) decays as a result of New Physics, such as a pseudoscalar light Higgs decaying to ττ (narrow window!) M-A Sanchis-Lozano

- New search form BABAR: no evidence E. Guido

$R_{\tau\mu}(\Upsilon(1S))$: 1.005 ± 0.013 (stat.) ± 0.022 (syst.)

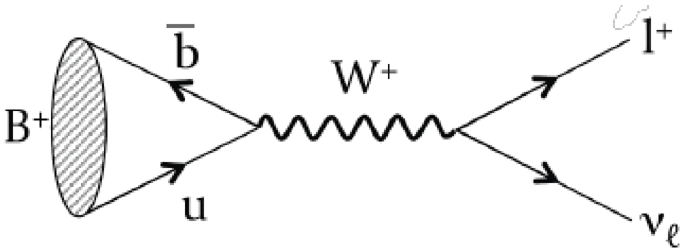
- LFV and FCNC looked for in D and B decays (Belle) M. Petric

  $<\sim 10^{-7}$ $<\sim 10^{-6}$

- B decays to τ

  B→Kττ B→τν BABAR M. Shramm
  B→τν Belle T. Iijima
  hot topic

Search for B→τ ν



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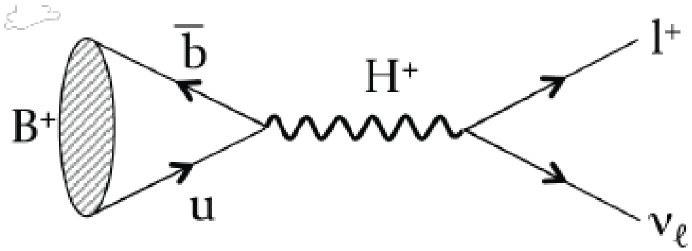
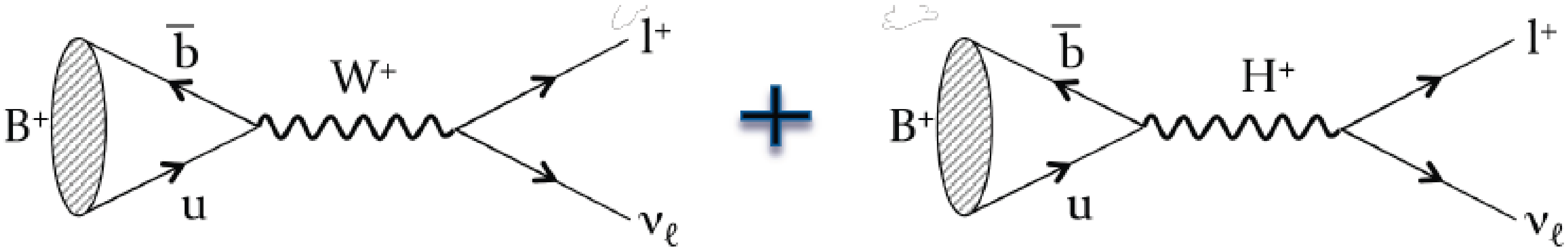


Search for B→τ ν



BABAR

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (1.80^{+0.57}_{-0.54} \pm 0.26) \times 10^{-4}$$

✦The combined Babar results is

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = (1.76 \pm 0.49) \times 10^{-4}$$

BELLE	hadronic tag	$Br(\tau\nu) = [1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)] \times 10^{-4}$
	leptonic tag	$Br(\tau\nu) = [1.54\ {}^{+0.38}_{-0.37}\ {}^{+0.29}_{-0.31}] \times 10^{-4}$
	combined	$Br(\tau\nu) = [1.68 \pm 0.31] \times 10^{-4}$

From CKM fit (w/o B→τν in the input)

➡ $Br_{CKM\ fit}(\tau\nu) = (0.763^{+0.113}_{-0.061}) \times 10^{-4}$ CKM fitter @ ICHEP2010

$Br_{CKM\ fit}(\tau\nu) = (0.805 \pm 0.071) \times 10^{-4}$ UT fit @ ICHEP2010

Tantalizing excess! Sensitive to H± masses at a few 100 GeV

Search for NP in decays involving τ: hadron colliders (1)

- TeVatron and LHC: hadron colliders enter a new era of searching for new physics involving τ in the final state
- very thorough work to develop efficient triggers and selection procedures

D0	R. Madar
ATLAS	S. Xella A. Kaczmarska
CMS	E. Friis

- first physics analyses

D0	T. Yang
ATLAS	D. Ludwig R. Goncalo
CMS	M. Bachtis

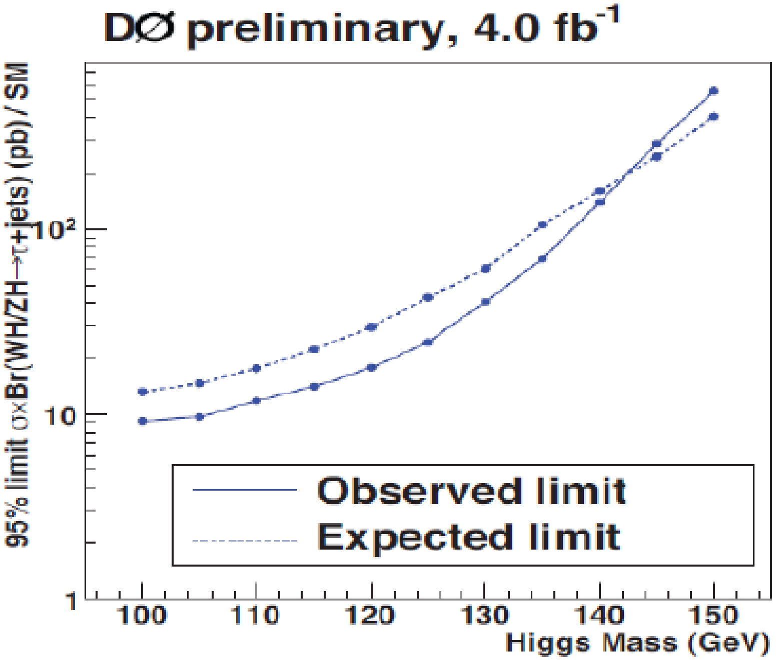
- most active discussion in the workshop
- expectations are high

Search for NP in decays involving τ: hadron colliders (2)

D0 SM Higgs search: τ detection increases sensitivity

$WH \to \tau\nu b\bar{b}$ (4.0 fb^{-1})

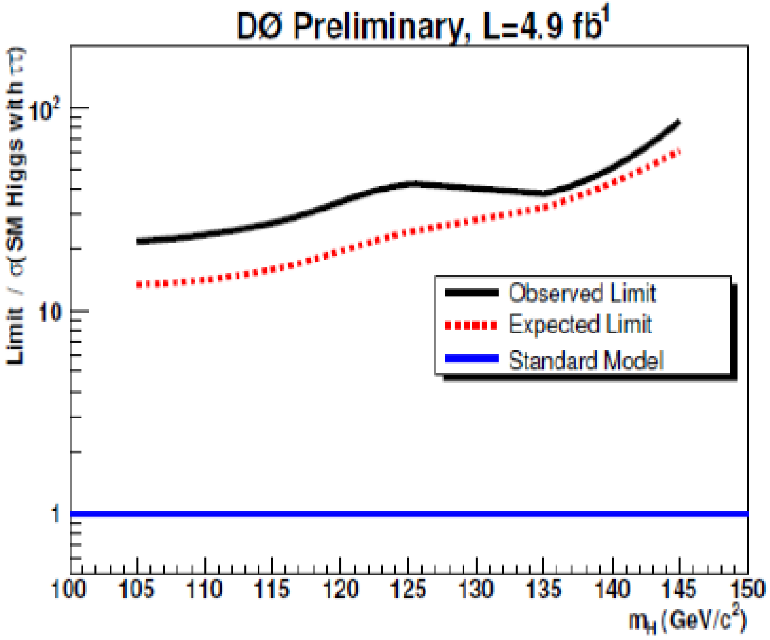
M_H=115 GeV: 14σ_{SM}



$HV \to \tau^+\tau^- q\bar{q}$ (4.9 fb^{-1})

M_H=115 GeV: 27σ_{SM}

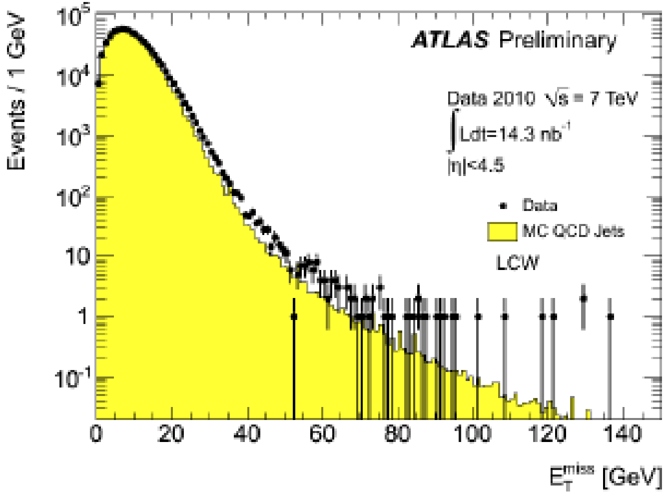
M_H=145 GeV: 86σ_{SM}

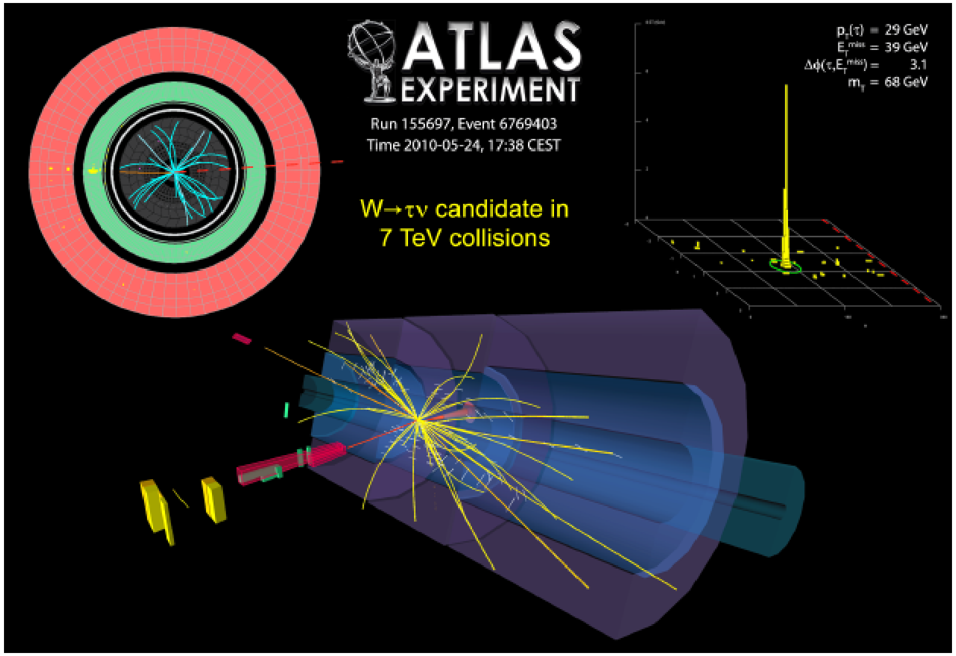


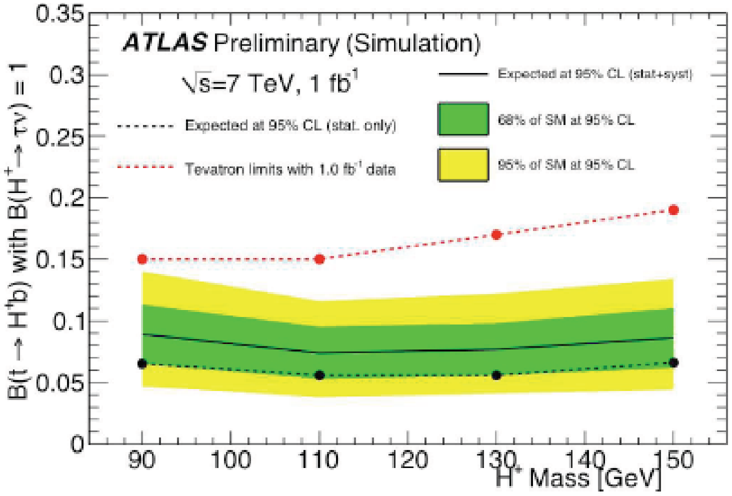
Search for NP in decays involving τ: hadron colliders (3)

ATLAS preparing for physics from first 2010-2011 run

E_T^{miss} crucial for SUSY searches

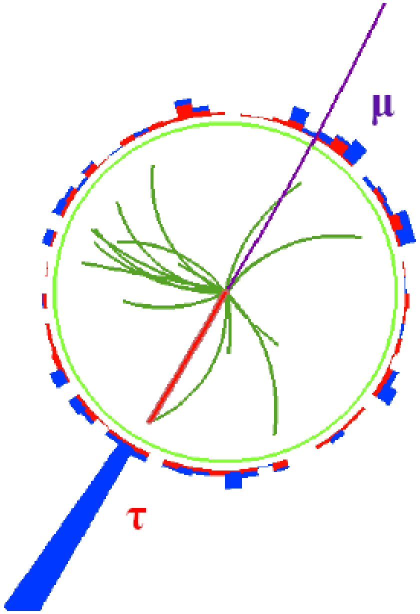






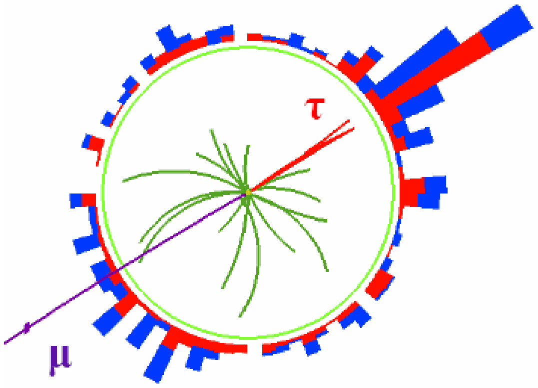
Search for NP in decays involving τ: hadron colliders (4)

CMS: first signal for Z→ττ
important validation step



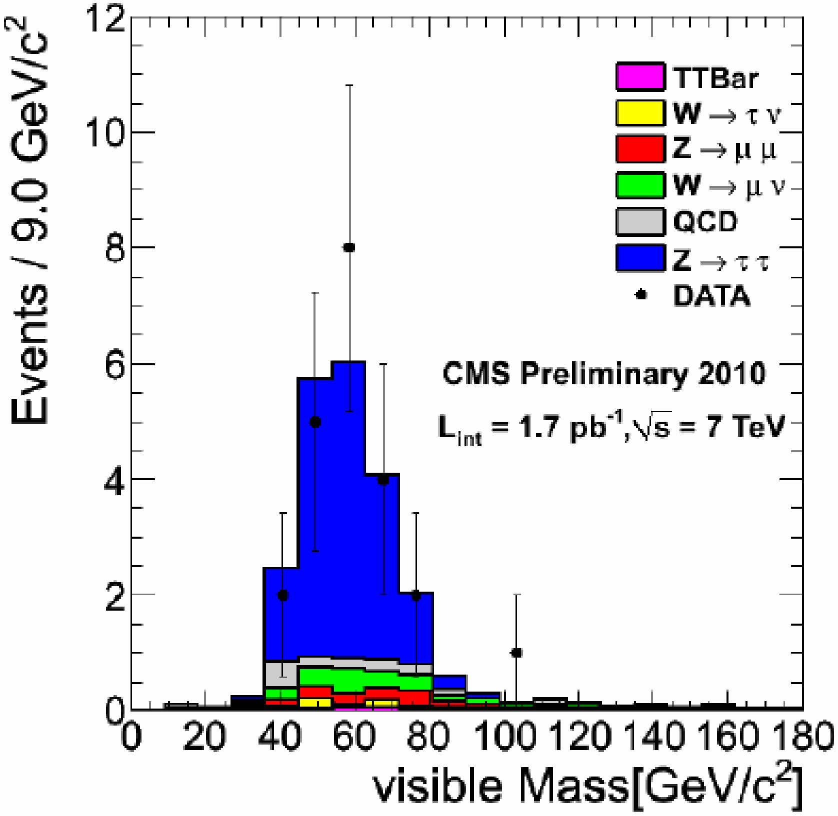
Vis. Mass= 73 GeV/c^2
M$_T$(μ,MET) =3.3 GeV

τ→μ τ→1-prong



Vis. Mass= 70 GeV/c^2
M$_T$(μ,MET) =4.1 GeV

τ→μ τ→3-prong



Clean Z → ττ signal observed

Neutrinos

- very important topic in general and in the context of τ physics
- apologies (last day!)
- importance of ν masses and mixing, CP violation in lepton sector, leptogenesis, baryon-antibaryon asymmetry W. Marciano
- OPERA: still one event for $\nu_\mu \rightarrow \nu_\tau$ oscillations Y. Gornushkin
- SuperK: search for ν_τ–induced events R. Wendell

Super-Kamiokande observes 134 ± 48 (stat) $^{+16.0}_{-27.2}$ (sys.) τ-like events

78 ±27 expected

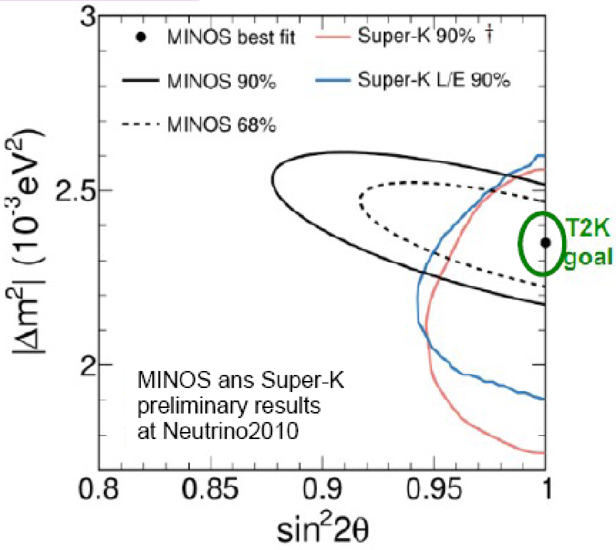
This result is consistent with the expectation from the oscillation hypothesis and in disagreement with no observation at **2.4 σ**

- T2K: 2010 results I. Danko

  continuing with improved source
- MINOS: 2010 results A. Habig

  ν_μ and $\overline{\nu}_\mu$ differ (?) at ~2σ

  ν_e appearance $\sin^2(2\theta_{13}) < 0.12$ (90% C.L.)
- UHE $\nu\tau$ search in IceCube SH Seo



Apologies and Thanks

Apologies to S. Banerjee, H. Hayashii, and A. Lusiani for not covering their contributions. Beyond my strength!

This has been a truly exciting workshop with first-class results

We should be thankful and congratulate George Lafferty and his team for a perfect organization and for putting together such a wonderful programme!