DAΦNE-2004

HIGHLIGHTS
and
CONCLUDING REMARKS

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Kaons
B-mesons
C-mesons
Hypernuclei
Rare decays
Theory predictions
Experimental and theoretical errors
Closing experiments
Running experiments
New experiments
New accelerators

76 talks ....!
2000 slides.......................

Flavour dynamics
old and new physics

dangerous

comments

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50 (rejection factor 40)

On which axes to project the contents
in an understandable way?

New results
Recent results
A glance to the future

The choise of the axis:

1) the 1's : Vus
2) the 0's : CKM, rare decays,
   P-T-CP violations,
   several new observations of rare decay
3) kaonic "atoms" and Hypernuclei
4) thanks……
5) good lunch!

Determination of $|V_{us}|$ in Semileptonic K_L Decays

KTeV

$$f_+(t) = f_+(0)\left(1 + \lambda'_+ \frac{t}{M_\pi^2} + \frac{1}{2}\lambda''_+ \frac{t^2}{M_\pi^4}\right)$$

$$f_0(t) = f_+(0)\left(1 + \lambda_0 \frac{t}{M_\pi^2}\right),$$

where $t = (P_K - P_\pi)^2 = (P_\ell + P_\nu)^2$

KTeV measures $B(K_L \to \pi e \nu)$ and $B(K_L \to \pi \mu \nu)$

KTeV measures form factors needed to calculate phase space integrals

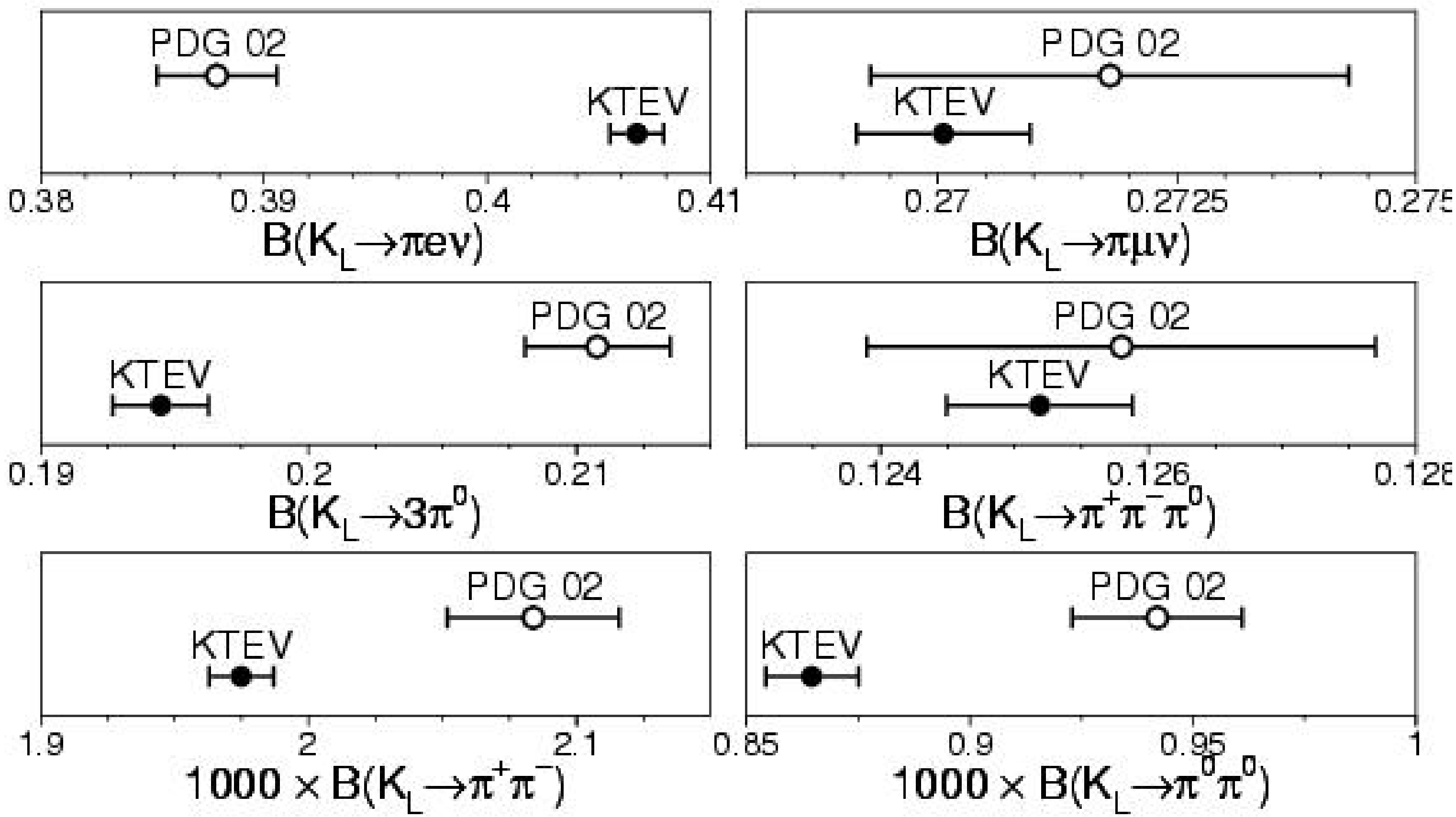
$$\Gamma_{K\ell 3} = \frac{G_F^2 M_K^5}{192\pi^3} S_{EW}(1+\delta_K^\ell)\left|V_{us}\right|^2 f_+^2(0) I_K^\ell$$

Rad. Corrections (theory)

Form factor at t=0 (theory)

…. an earthquake in the KL system…..

Comparison of KTeV and PDG Branching Fractions



An earthquake in the B.R……..

Nice work….well done

Branching Fraction and Partial Width Results

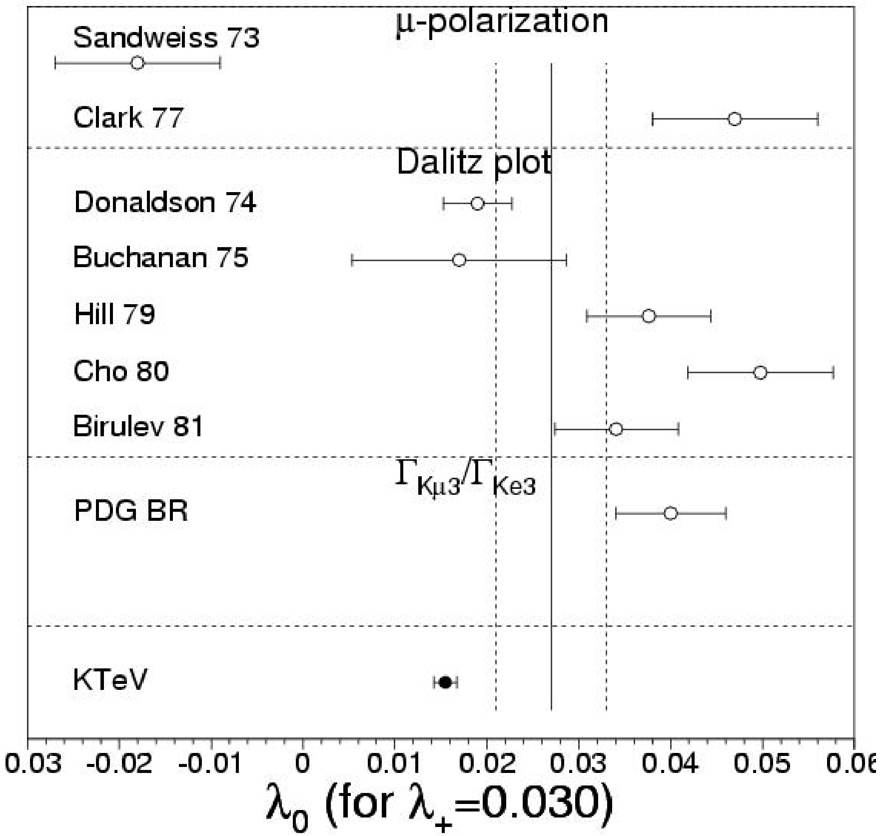
Decay Mode	Branching Fraction	$\Gamma_i\ (10^7\ s^{-1})$
$K_L \to \pi e \nu$	0.4067 ± 0.0011	0.7897 ± 0.0065
$K_L \to \pi \mu \nu$	0.2701 ± 0.0009	0.5244 ± 0.0044
$K_L \to \pi^+ \pi^- \pi^0$	0.1252 ± 0.0007	0.2431 ± 0.0023
$K_L \to \pi^0 \pi^0 \pi^0$	0.1945 ± 0.0018	0.3777 ± 0.0045
$K_L \to \pi^+ \pi^-$	$(1.975 \pm 0.012) \times 10^{-3}$	$(3.835 \pm 0.038) \times 10^{-3}$
$K_L \to \pi^0 \pi^0$	$(0.865 \pm 0.010) \times 10^{-3}$	$(1.679 \pm 0.024) \times 10^{-3}$

Partial widths use K_L lifetime of $\tau_L = (5.15 \pm 0.04) \times 10^{-8}$ sec.

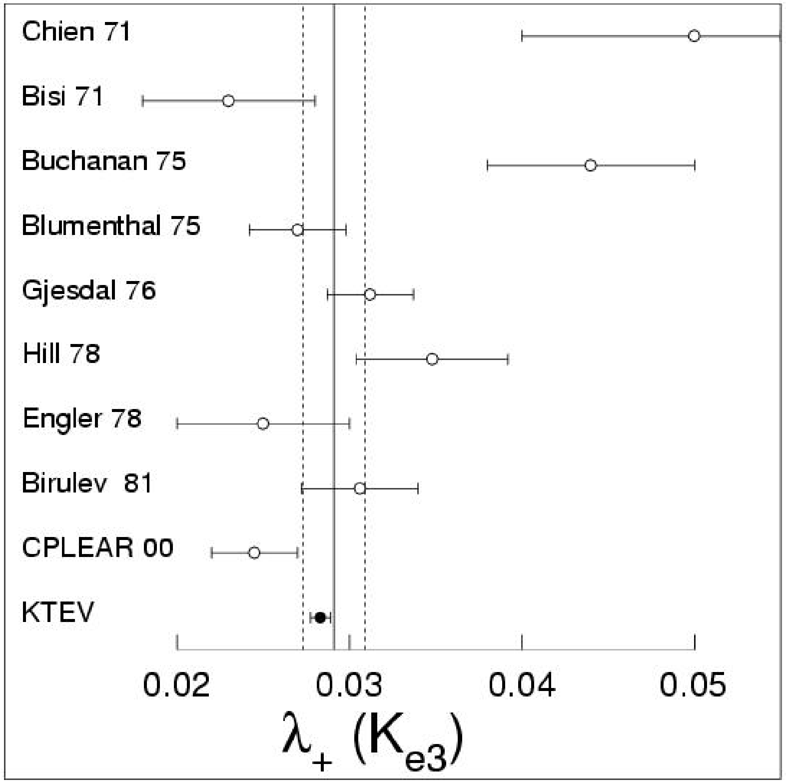
NA48 preliminary ….Ke3 B.R 39.5 +-0.3 +-0.3

Semileptonic Form Factors:

×5 more precise than PDG



×3 more precise than PDG



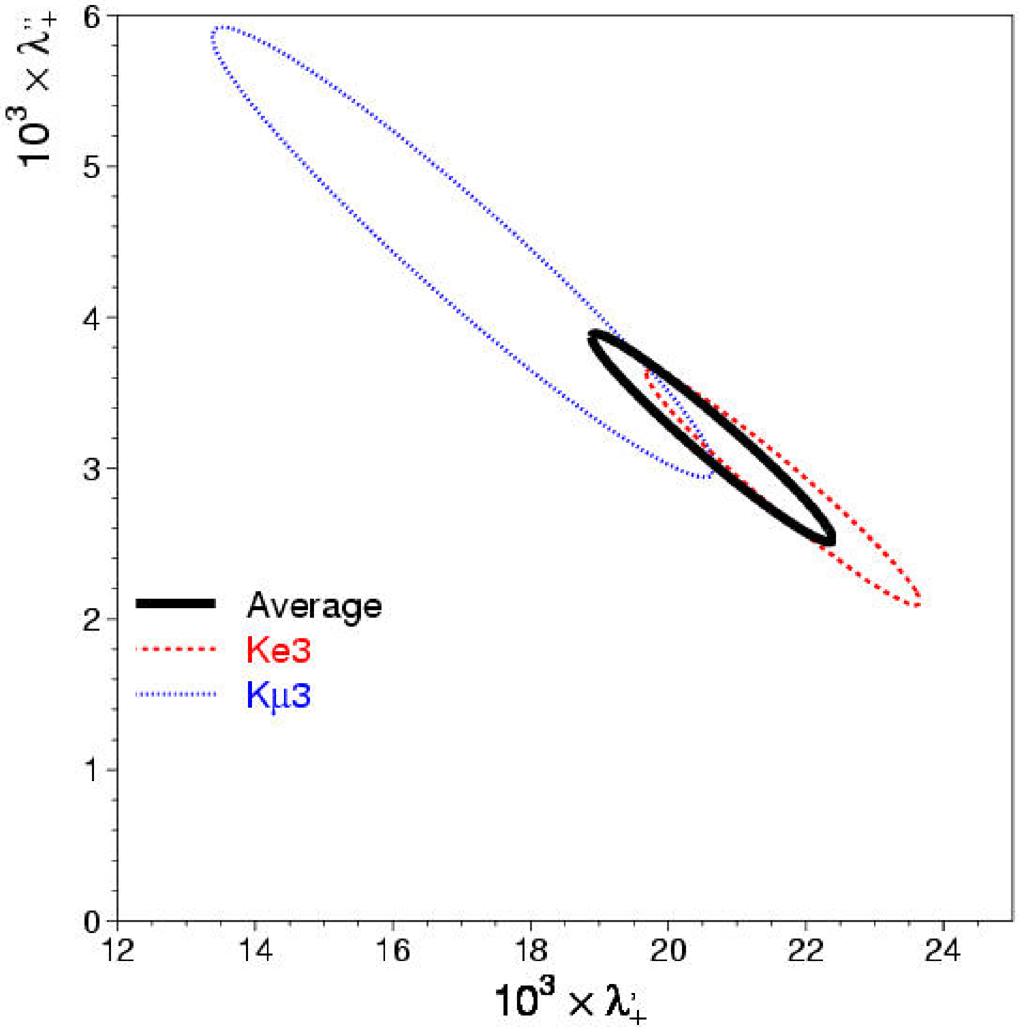
$$f_+(t) = f_+(0)\left(1+\lambda'_+\frac{t}{M_\pi^2}+\frac{1}{2}\lambda''_+\frac{t^2}{M_\pi^4}\right)$$

$$f_0(t) = f_+(0)\left(1+\lambda_0\frac{t}{M_\pi^2}\right),$$

where $t=(P_K-P_\pi)^2=(P_\ell+P_\nu)^2$

Form Factor Results

Parameter	Value ($\times 10^{-3}$)
λ_+'	20.64 ± 1.75
λ_+''	3.20 ± 0.69
λ_0	13.72 ± 1.31



Consistency of Branching Fraction and Form Factor Results with Lepton Universality

Compare $\Gamma_{K\ell 3} = \dfrac{G_F^2 M_K^5}{192\pi^3} S_{EW} (1+\delta_K^\ell) |V_{us}|^2 f_+^2(0) I_K^\ell$ for K_{e3} and $K_{\mu 3}$

$$\left[\frac{\Gamma_{K\mu 3}}{\Gamma_{Ke3}}\right]_{PRED} = \left(\frac{1+\delta_K^\mu}{1+\delta_K^e}\right)\left(\frac{I_K^\mu}{I_K^e}\right)$$

1.0058(10) from Andre

0.6622(18) from KTeV

$$\left[\frac{\Gamma_{K\mu 3}}{\Gamma_{Ke3}}\right]_{MEAS} \Big/ \left[\frac{\Gamma_{K\mu 3}}{\Gamma_{Ke3}}\right]_{PRED} = 0.9969 \pm 0.0048 = \left(\frac{G_F^\mu}{G_F^e}\right)^2$$

Same test with PDG widths and FF gives 1.0270±0.0182

$K_S \rightarrow \pi e \nu$

Preliminary results

Branching ratios

$BR(K_S \rightarrow \pi^- e^+ \nu) = (3.54 \pm 0.05_{stat} \pm 0.05_{syst})\ 10^{-4}$

$BR(K_S \rightarrow \pi^+ e^- \nu) = (3.54 \pm 0.05_{stat} \pm 0.04_{syst})\ 10^{-4}$

$\mathbf{BR(K_S \rightarrow \pi e \nu) = (7.09 \pm 0.07_{stat} \pm 0.08_{syst})\ 10^{-4}}$

Charge asymmetry

$\mathbf{A_S = (-2 \pm 9_{stat} \pm 6_{syst})\ 10^{-3}}$

$A_L = (3.322 \pm 0.058 \pm 0.047)\ 10^{-3}$ [KTeV 2002]

$A_L = (3.317 \pm 0.070 \pm 0.072)\ 10^{-3}$ [NA48 2003]

Test of the rule $\Delta S = \Delta Q$

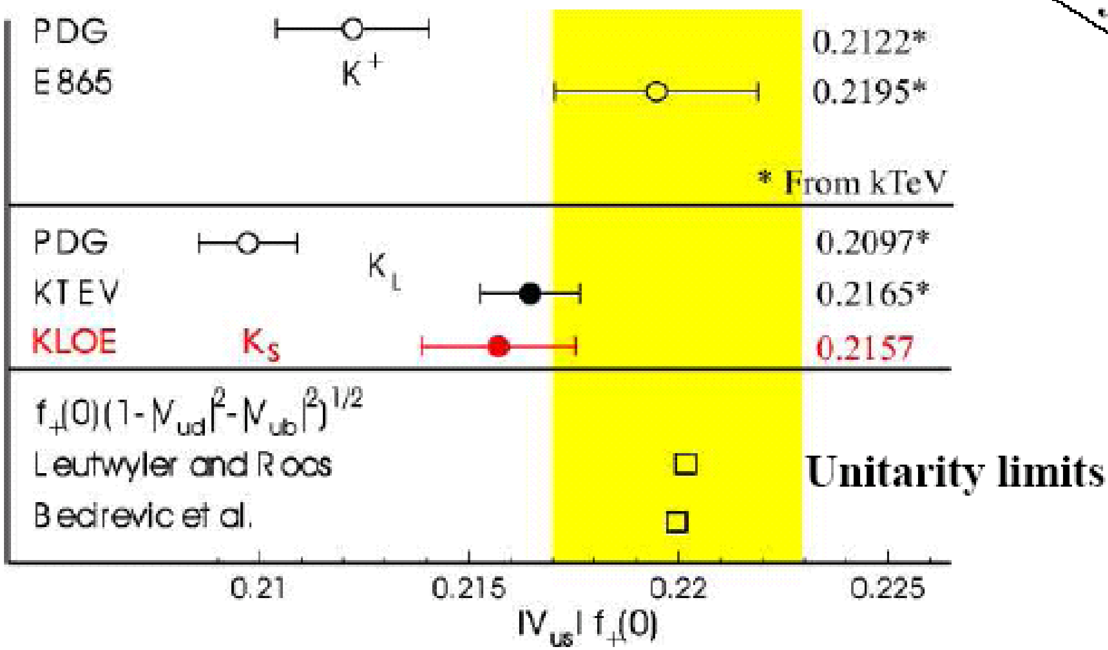
$Re(x_+) = (-0.0018 \pm 0.0041_{stat} \pm 0.0045_{syst})$ CPLEAR

$\mathbf{Re(x_+) = (0.0136 \pm 0.0031_{stat} \pm 0.0029_{syst})}$ **with PDG** $\mathbf{BR(K_L \rightarrow \pi e \nu)}$

$\mathbf{Re(x_+) = (0.0017 \pm 0.0029_{stat} \pm 0.0029_{syst})}$ **with KTeV** $\mathbf{BR(K_L \rightarrow \pi e \nu)}$

$K_S \to \pi e \nu : V_{us}$

Preliminary results



$$V_{us}(K_{S,e3}) \cdot f^{K0}{}_{+}(0) = (0.2157 \pm 0.0018)$$

KLOE

$|V_{us}|$ Results

For $K_L \to \pi e \nu$: $|V_{us}| = 0.2253 \pm 0.0023$

For $K_L \to \pi \mu \nu$: $|V_{us}| = 0.2250 \pm 0.0023$

$$|V_{us}| = 0.2252 \pm 0.0008_{KTeV} \pm 0.0021_{ext}$$

KTeV error: branching fractions, form factors

Ext error: $f_+(0)$, K_L lifetime, radiative corrections

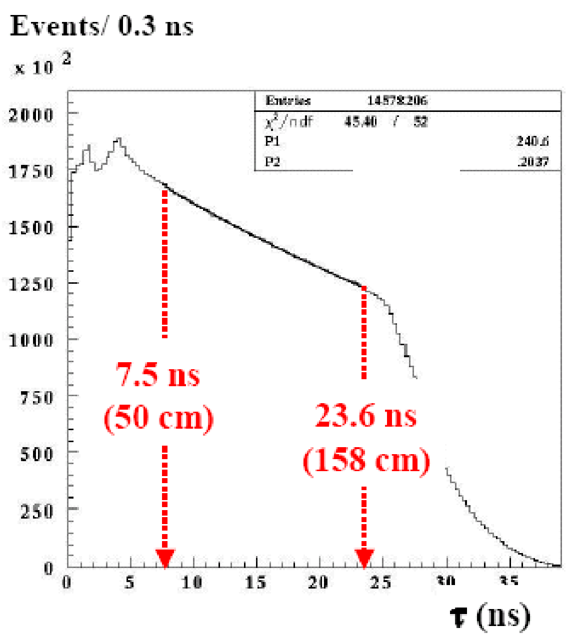
$$1 - \left(|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2\right) = 0.0018 \pm 0.0019$$

KLOE and NA48 will follow?...................

.....1st big news.......

K_L lifetime

14.5 10^6 $K_L \to \pi^0 \pi^0 \pi^0$ events



$\tau(K_L) = (\ldots \pm 0.20_{stat})$ ns

τ (PDG) (fit) = (51.7 ± 0.4) ns

PRD 6 (1972), 1834

The study of the systematic error must be completed.
It includes

- the estimate of the background
- the photon detection efficiency
- the time-scale calibration data and MC comparison.

Systematics < 0.6% at present limited by MC statistics.

- K_L decays: measuring all BRs. Statistical accuracy at 0.1%. **(..as in KTeV..)** Systematics affects mainly absolute BRs.
- $K^\pm$ semileptonic: statistical accuracy at 0.5% , but dominated by MC statistics. Systematics under study.

V_{us} coupling constant

$$|\mathbf{V_{us}}| = \sqrt{\frac{128\pi^3\Gamma(\mathrm{K^0_{e3}})}{\mathrm{G_F^2 M^5_{K^0} S_{EW} I_{K^0}}}}\frac{1}{\mathrm{f_+(0)}} \tag{18}$$

$$S_{EW} = 1.0232, \quad I_{K^0} = 0.10339 \pm 0.00063$$

Radiative correction acc. to Cirigliano

$$\frac{\text{Number of } K_{e3(\gamma)} \text{ events inside Dalitz plot}}{\text{Number of all } K_{e3(\gamma)} \text{ events}} = 0.99423 \tag{19}$$

$f_+(0) = 0.981 \pm 0.010$	ChPT, Cirigliano et al
$f_+(0) = 0.965 \pm 0.009$	Lattice
$f_+(0) = 0.973 \pm 0.010$	theoretical average

Decay rate

$\Gamma(K_{e3}) = B(e3)/\tau(\mathrm{K_L}) = (7.67 \pm 0.10) \cdot 10^6 s^{-1}$ (preliminary)

V_{us} coupling constant

$$|\mathrm{V_{us}}| = 0.219 \pm 0.0015(\mathrm{exp}) \pm 0.0022(\mathrm{theor}) \qquad (20)$$

$$= 0.219 \pm 0.0027 \quad \text{(preliminary)}$$

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.9963 \pm 0.00155 \quad (2.4\,\sigma \text{ from } 1)$$

NA48

New ideas

τ decay (V_{us}) Jamin et al.

m_s from sum rules or LQCD as input, may become competitive with B-factory results. At present δV_{us}~0.0045, low values

Hyperon decays (V_{us})

Cabibbo et al. have revisited the subject focussing on vector form fact.
δV_{us}~0.0027 (exp) but O(1%) or more SU(3) breaking effects NOT included, lattice?

λ using f_π/f_K from lattice Marciano (2004):

$$\frac{\Gamma(K \to \mu\bar{\nu}_\mu(\gamma))}{\Gamma(\pi \to \mu\bar{\nu}_\mu(\gamma))} = \frac{|V_{us}|^2 f_K^2 m_K \left(1 - \frac{m_\mu^2}{m_K^2}\right)^2}{|V_{ud}|^2 f_\pi^2 m_\pi \left(1 - \frac{m_\mu^2}{m_\pi^2}\right)^2} \underbrace{0.9930(35)}_{\text{R.C.}}$$

Use LQCD for f_π/f_K. Present MILC result 1.201(8)(15)
Staggered fermions, partially unquenched. From there we get

λ= 0.2238 ± 0.0003(exp) ± 0.0004(rc) ± 0.0030(lattice)

Compatible with other determinations. MILC error debated.

Great potential for improvement

CONCLUSIONS

- We presented a quenched lattice study of the $K \rightarrow \pi$ vector form factor at zero momentum transfer

- The calculation is the first one obtained by using a non-perturbative method based only on QCD, except for the quenched approximation

- Our final result, $f_+(0) = 0.960 \pm 0.005_{stat} \pm 0.007_{syst}$ is in good agreement with the estimate made by Leutwyler and Roos and quoted by the PDG

- In order to increase the accuracy of the theoretical prediction the most important step is to remove the quenched approximation

Lubicz

THE 0’s

Conclusions from NA48- rare decay

- **First observations of the $K_S \to \pi^0 e^+ e^-$ and $K_S \to \pi^0 \mu^+ \mu^-$ decays:**

$$BR(K_S \to \pi^0 e^+ e^-) = (5.8^{+2.8}_{-2.3}\Big|_{stat} \pm 0.8_{syst}) \text{ x } 10^{-9}$$ [PLB576 (2003)]

$$BR(K_S \to \pi^0 \mu^+ \mu^-) = (2.9^{+1.4}_{-1.2}\Big|_{stat} \pm 0.2_{syst}) \text{ x } 10^{-9}$$

- **Branching Ratio measured for $K_L \to e^+ e^- e^+ e^-$**

$$BR(K_L \to e^+ e^- e^+ e^-) = (3.30 \pm 0.24_{stat} \pm 0.14_{syst} \pm 0.10_{norm}) \times 10^{-8}$$

Upper Limit determination

- We derive from our analysis:

$$BR(K_S \to 3\pi^0) = \frac{N_{3\pi}/\varepsilon_{3\pi}^{TOT}}{N_{2\pi}/\varepsilon_{2\pi}^{TOT}} BR(K_S \to 2\pi^0) = \frac{5.76/0.23}{38.2\times10^6} \times 0.314 \leq 2.1\times10^{-7} \ @\,90\%\ CL$$

This improves of a factor ~70 the previous limit.

- Using this upper limit we can calculate some parameters directly related to CP and CPT test.

Using PDG values and our limit:

$$|\eta_{000}| = \frac{A(K_S \to 3\pi^0)}{A(K_L \to 3\pi^0)} = \sqrt{\frac{\tau_L}{\tau_S}\frac{BR(K_S \to 3\pi^0)}{BR(K_L \to 3\pi^0)}} \leq 0.024 \ @\,90\%\ CL$$

- This limit makes completely negligible the contribution of this decay on Im(δ) reducing of a factor ~2.5 the uncertainty on Im(δ)

Branching ratio & Confidence level

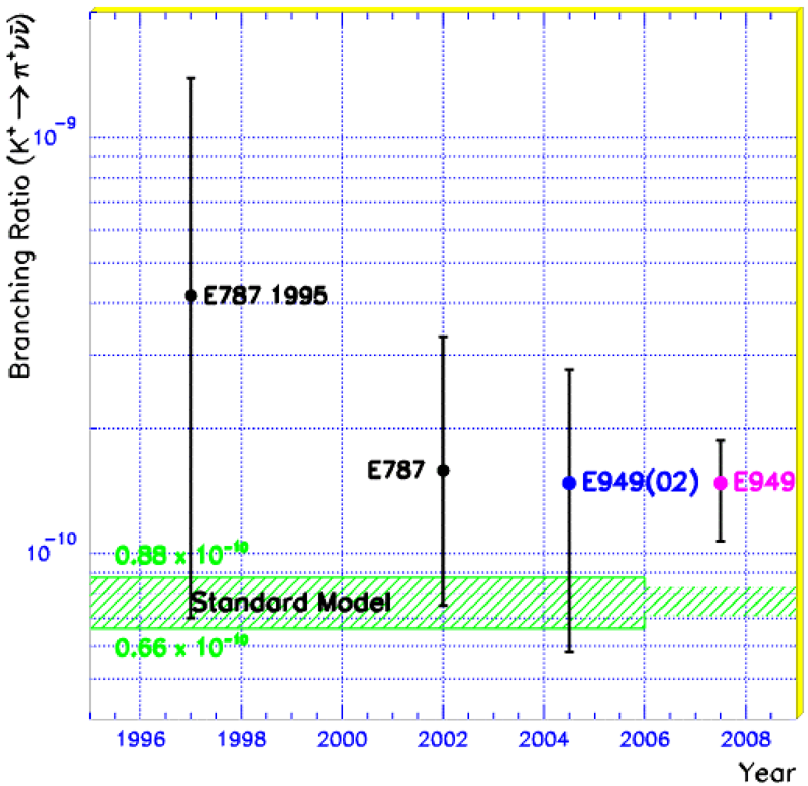
- E949 result alone:
  $Br(K^+ \to \pi^+ \nu\bar{\nu}) = 0.96^{+4.09}_{-0.47} \times 10^{-10}$ (68% CL)
- Combine E787 and E949 results
  $\to$ increase statistics

$$Br(K^+ \to \pi^+ \nu\bar{\nu}) = 1.47^{+1.30}_{-0.89} \times 10^{-10}$$

(68% CL)

	E787		E949
N_K (10^{12})	5.9		1.8
Candidate	E787A	E787C	E949A
S_i/b_i	50	7	0.9
W_i	0.98	0.88	0.48

$\left(W_i \equiv S_i/(S_i + b_i)\right.$: signal contribution to $\left.Br(K^+ \to \pi^+ \nu\bar{\nu})\right)$



E949(02) = combined E787&E949.

E949 projection with full running period.

(~60 weeks)

from  to 

Future Kaon program at KEK/J-PARC

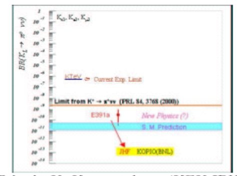
Takeshi K. Komatsubara (KEK-IPNS)

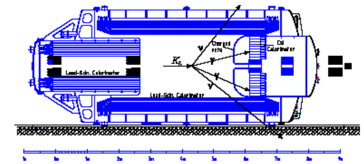
9 June 2004 $DA\Phi NE$2004: Physics at Meson Factories

E391a http://www-ps.kek.jp/e391/ at E-Hall

the first experiment dedicated to $K_L^0 \to \pi^0 \nu\bar{\nu}$

- Japan: KEK, Saga, Yamagata, RCNP, Osaka, NDA, Kyoto
- Russia: JINR
- USA: Chicago
- Taiwan: TNU
- Korea: Pusan



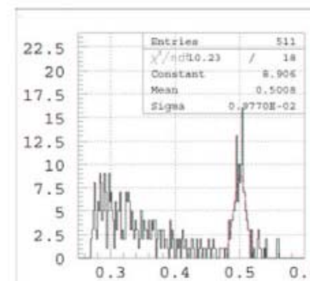


The KL $\pi^0\nu\bar{\nu}$ quest….. has started…….

KOPIO …….

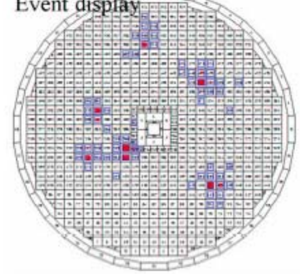
E391a Data Taking (from 18 Feb 2004)

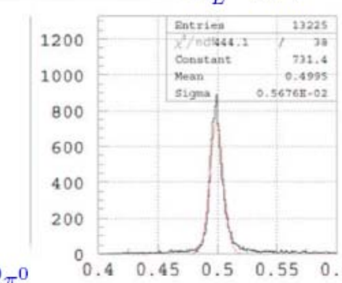
		E391a
Ev size	Bytes	6K
		ADCs
Tr rate	Hz	500
Data flow	B/spill	6M
	B/Day	120G



$K_L^0 \to \pi^0\pi^0$

Event display





$K_L^0 \to \pi^0\pi^0\pi^0$

0’s or very small…..

T- KEK E246
P- Hyper CP FNAL
CP-

Result of T-violating Muon Polarization Measurement in the $K^+ \rightarrow \pi^0 \mu^+ \nu$

C. Rangacharyulu
Saskatoon, SK

- Stopped K^+ experiment with a SC toroidal spectrometer
- Measurement of all decay kinematics directions
  - Double ratio measurement with small systematic errors

History

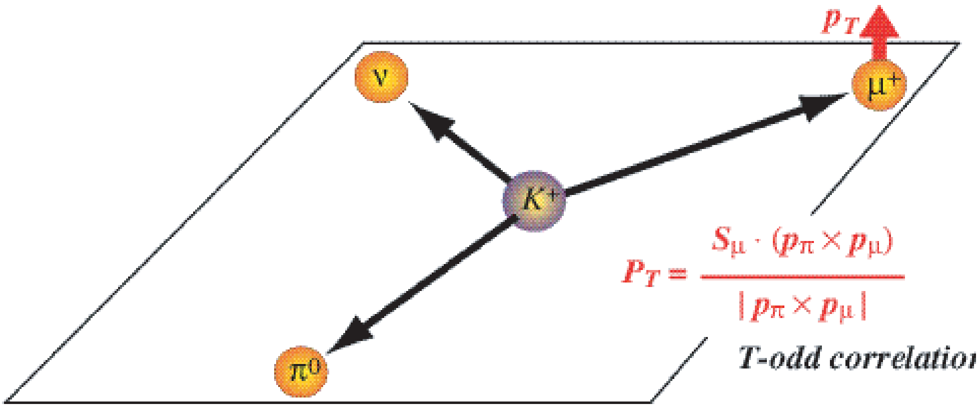
- **1992-1995 : detector construction**
- **1996-2000 : data taking**
- **1999 : first result published with 1/4 of data**
  $\mathrm{Im}\xi$ = -0.023 ± 0.007(stat) ± 0.003(syst)
  [M.Abe *et al.*, Phys.Rev.Lett. 83(1999) 4253]
- **2001-2003 : analysis**
- **2004 (this conference) : report of the final result**

By products:

- $K^+ \rightarrow \mu^+ \nu \gamma$: P_T **= -0.0064 ± 0.0185(stat) ± 0.0010(syst)**
  [V.Anisimovsky et al., Phys.Lett. B562 (2003) 166]
- K_{e3}, $K_{\pi 2\gamma}$, K_{e4}, ...

KEK E246 experiment

Transverse Muon Polarization in $K^+ \longrightarrow \pi^0 \mu^+ \nu$



$P_T^{spurious}$ *(Final State Interaction)* = very small

$P_T \neq 0 \rightarrow$ T-violation

$K_{\mu 3}$ decay form factors and T violation

$$M \propto f_+(q^2)\,[2\,\tilde{p}_K^\lambda\,\bar{u}_\mu \gamma_\lambda (1-\gamma_5) u_\nu + (\xi(q^2) - 1) m_\mu \bar{u}_\mu (1-\gamma_5) u_\nu]$$

$$\xi(q^2) = f_-(q^2) / f_+(q^2)$$

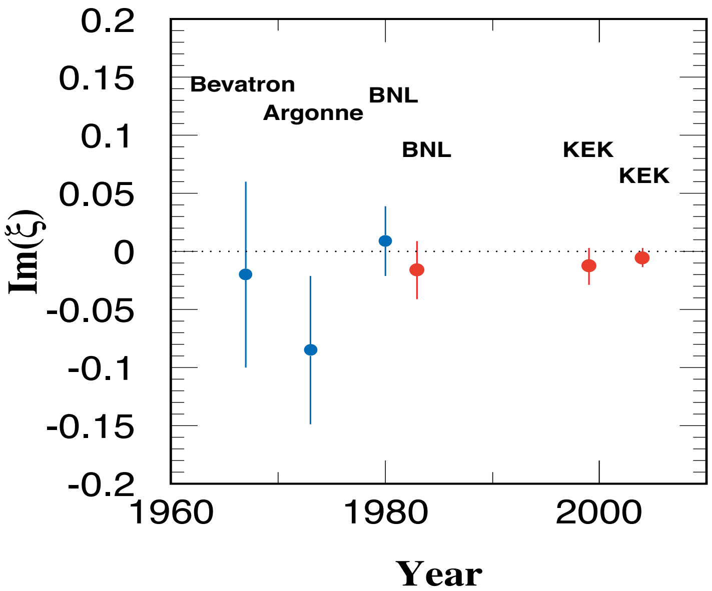
$$P_T \sim \mathrm{Im}(\xi)\,\frac{m_\mu}{m_K}\,\frac{|p_\mu|}{E_\mu + |p_\mu|\, n_\mu \cdot n_\nu - m_\mu^2 / m_K}$$

$\mathrm{Im}(\xi) \neq 0 \longleftrightarrow$ T-violation

History of $K_{\mu 3}$ transverse polarization experiments

- $K_L \rightarrow \pi^- \mu^+ \nu$ Bevatron 1967 $\mathrm{Im}\xi = -0.02 \pm 0.08$
- $K_L \rightarrow \pi^- \mu^+ \nu$ Argonne 1973 $\mathrm{Im}\xi = -0.085 \pm 0.064$
- $K_L \rightarrow \pi^- \mu^+ \nu$ BNL-AGS 1980 $\mathrm{Im}\xi = 0.009 \pm 0.030$
- $K^+ \rightarrow \pi^0 \mu^+ \nu$ BNL-AGS 1983 $\mathrm{Im}\xi = -0.016 \pm 0.025$

Final Result



P_T = - 0.0017 ± 0.0023(stat) ± 0.0011(syst)
($|P_T| < 0.0050$: 90% C.L.)

Imξ = - 0.0053± 0.0071(stat) ± 0.0036(syst)
($|\mathrm{Im}\xi| < 0.016$: 90% C.L.)

- This limit constrains the parameters of some non-standard CP violation models with high sensitivity.
- We are going to propose a next generation P_T experiment at the high intensity accelerator J-PARC.

Problem: Producing Λ's of Known Polarization

$\Lambda/\overline{\Lambda}$'s of known polarization can be produced through the decay of **unpolarized** $\Xi^-/\overline{\Xi}^+$'s:

$$\Xi^- \rightarrow \Lambda\pi^- \qquad \overline{\Xi}^+ \rightarrow \overline{\Lambda}\pi^+$$

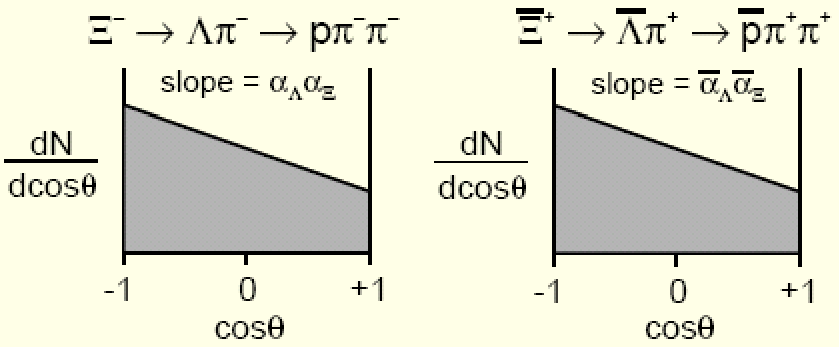
If the Ξ is produced unpolarized — which can simply be done by targeting at 0 degrees — then the Λ is found in a helicity state:

$$\vec{P}_\Lambda = \alpha_\Xi \hat{p}_\Lambda \qquad \vec{P}_{\overline{\Lambda}} = \overline{\alpha}_\Xi \hat{p}_{\overline{\Lambda}}$$

$$\frac{dN(\mathrm{p})}{d\cos\theta} = \frac{N_0}{2}(1 + \alpha_\Lambda \alpha_\Xi \cos\theta) \qquad \frac{dN(\bar{\mathrm{p}})}{d\cos\theta} = \frac{N_0}{2}(1 + \overline{\alpha}_\Lambda \overline{\alpha}_\Xi \cos\theta)$$

If CP is good, the slopes of the proton and antiproton $\cos\theta$ distributions are identical, and:

$$\alpha_\Xi \alpha_\Lambda = \overline{\alpha}_\Xi \overline{\alpha}_\Lambda$$



Results from *CP* Violation Search

Weighting Technique:

- ∼10% total data sample
- selected from end of 1999 run
- 118.6 million Ξ^-
- 41.9 million $\overline{\Xi}^+$
- no acceptance or efficiency corrections

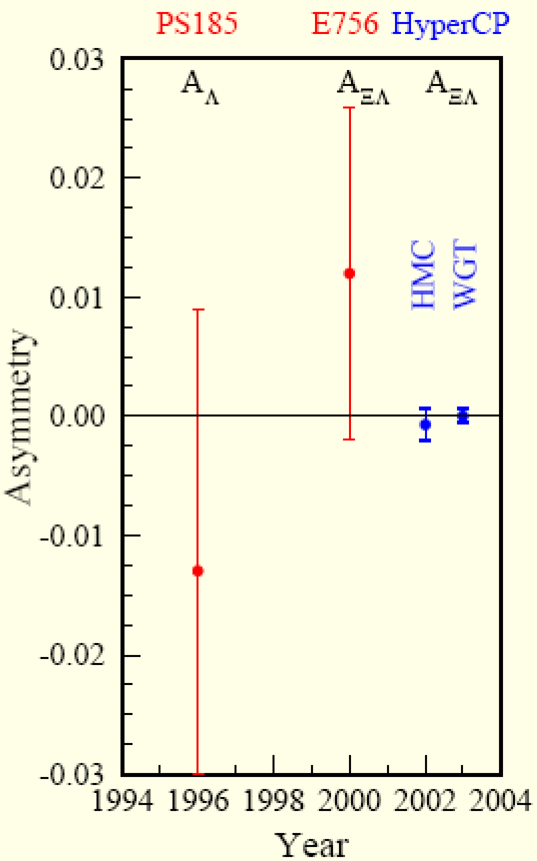
$$A_{\Xi\Lambda} = [0.0 \pm 5.1(\text{stat}) \pm 4.2(\text{syst})] \times 10^{-4}$$

Check with HMC Technique:

- ∼ 5% of the total data sample
- prescaled selection of 1997 and 1999
- 15 million Ξ^-
- 30 million $\overline{\Xi}^+$

$$A_{\Xi\Lambda} = [-7 \pm 12(\text{stat}) \pm 6.2(\text{syst})] \times 10^{-4}$$

⇒20× improvement on previous result.



Search for Parity Violation in $\Omega^- \to \Lambda K^-$ Decays

$$\Omega^- \to \Lambda K^- \qquad \Lambda \to p\pi^-$$

- Although spin-3/2, $\Omega^- \to \Lambda K^-$ decay goes much like the other hyperon two-body decays:

$$\frac{dP}{d\cos\theta} = \frac{1}{2}(1 + \alpha_\Omega P_\Omega \cos\theta)$$

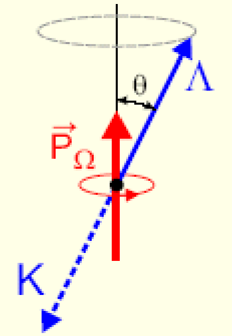
- Here:

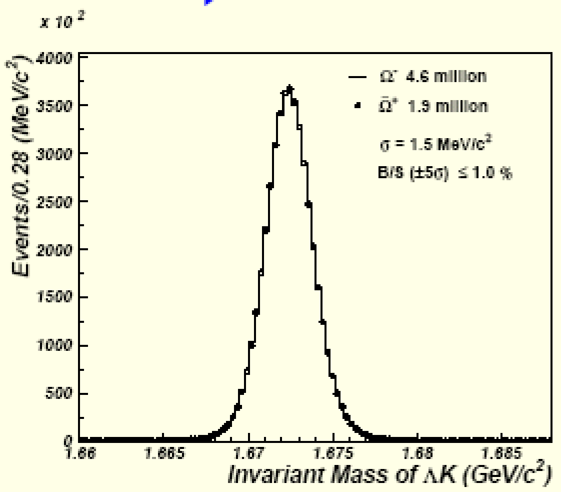
$$\alpha_\Omega = \frac{2\mathrm{Re}(P^* D)}{|P|^2 + |D|^2}$$

- A non-zero α_Ω indicates parity violation.
- All other hyperons have non-zero α parameters; only the Ω^- has resisted efforts to find an asymmetrical decay distribution.
- *HyperCP* is measuring α_Ω using unpolarized Ω^-'s through the polarization given to the daughter Λ, which is α_Ω:

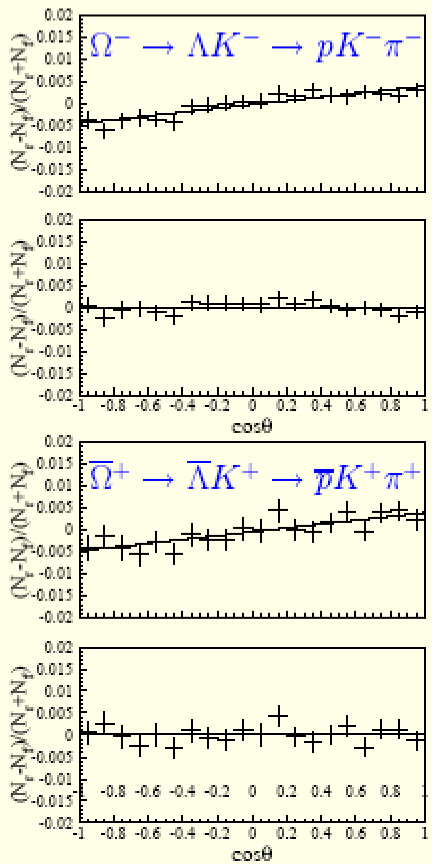
$$\frac{dP}{d\cos\theta} = \frac{1}{2}(1 + \alpha_\Omega \alpha_\Lambda \cos\theta)$$

- Large data sample, little background.



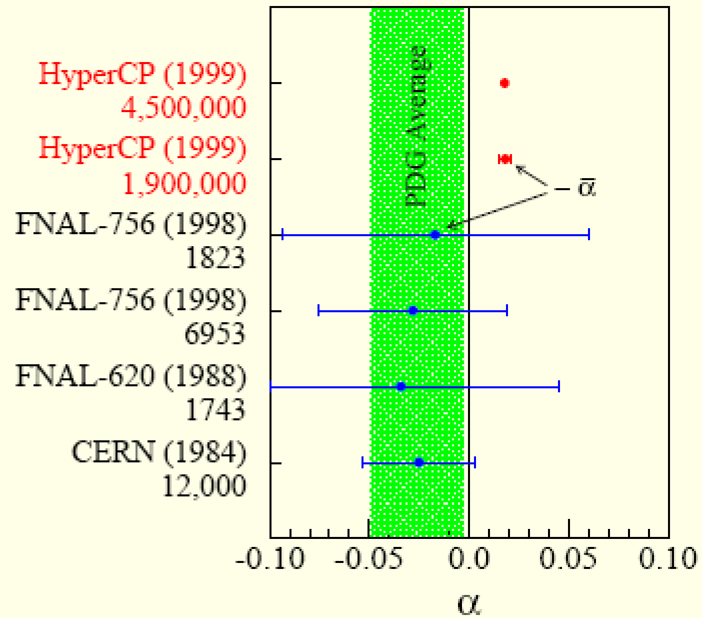


Preliminary Measurement of α_Ω and $\overline{\alpha}_\Omega$ in $\Omega^- \rightarrow \Lambda K^-$ Decays



1999 : $\alpha_\Omega = [\ \ 1.78 \pm 0.19(\text{stat}) \pm 0.10(\text{syst})] \times 10^{-2}$

1999 : $\overline{\alpha}_\Omega = [-1.81 \pm 0.28(\text{stat})] \times 10^{-2}$



- First evidence of parity violation in Ω^- decays.
- Can search for CP violation in $\Omega^- / \overline{\Omega}^+$ decays.

good!

0’s in the complex plane

TRIANGLES:
Vcb
Vub
angles

Inclusive $|V_{cb}|$ measurement strategy

$$|V_{cb}| = \frac{Br(B \to X_c \ell \nu)}{\tau_B} \times f_\Gamma^\ell(m_b, m_c, \mu_G^2, \mu_\pi^2, \rho_{LS}^3, \rho_D^3)$$

$$Br(B \to X_c \ell \nu) = Br(B \to X_c \ell \nu, E_\ell > E_0) \times f_0^\ell(E_0, m_b, m_c, \mu_G^2, \mu_\pi^2, \rho_{LS}^3, \rho_D^3)$$

- f_Γ, f_0 : heavy quark expansion (HQE) formulae*
- m_b and m_c : running quark masses (at μ = 1 GeV)
- μ_G, μ_π, ρ_{LS}, ρ_D : non-perturbative QCD parameters

*Gambino & Uraltsev
hep-ph/0401063
hep-ph/0403166

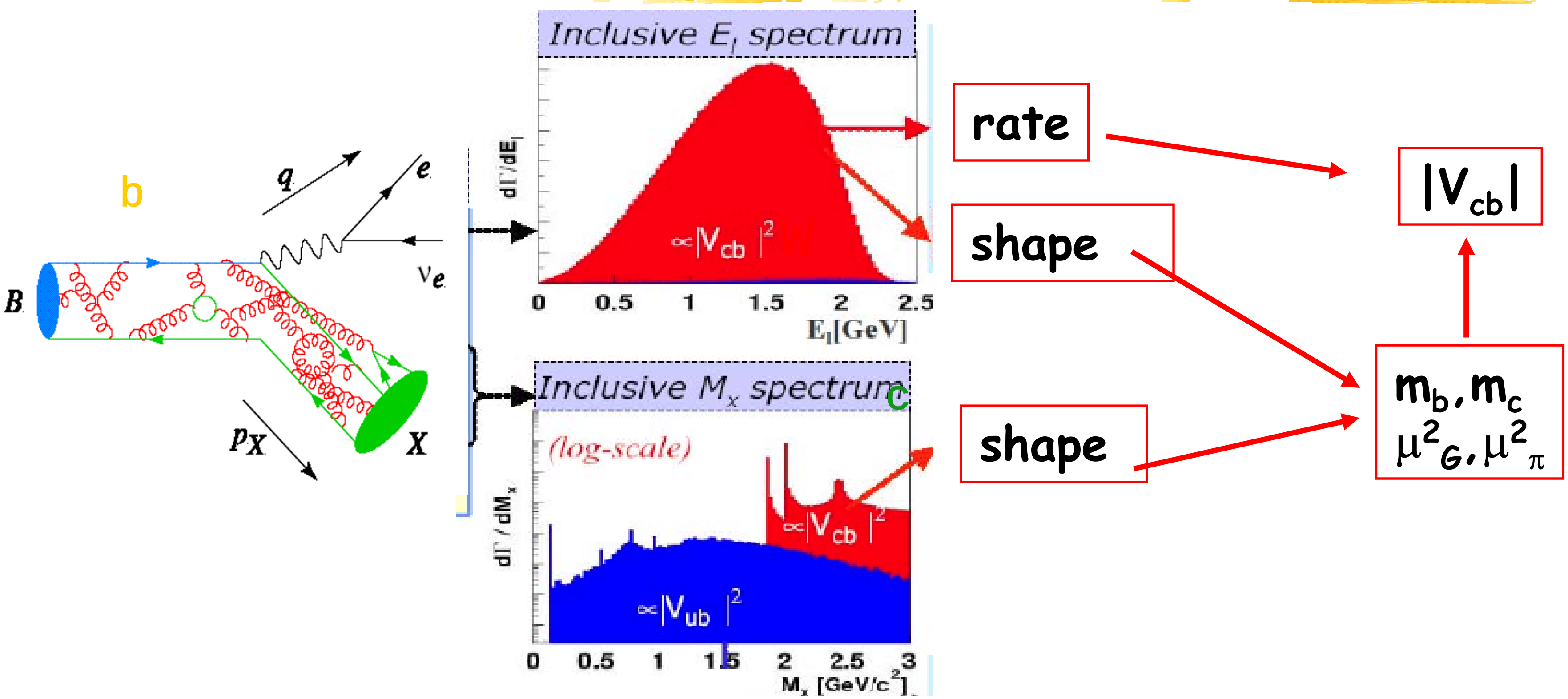
Problem: large uncertainties in m_b, m_c, μ's and ρ's

Solution: Measuring m_b, m_c, μ_G, μ_π, ρ_{LS}, ρ_D, simultaneously to $Br(B \to X_c e \nu)$ and $|V_{cb}|$ using HQE's predictions of E_l and M_{Xc} moments.

$$M_i^\ell(E_\ell, E_\ell > E_0) = f_i^\ell(E_0, m_b, m_c, \mu_G^2, \mu_\pi^2, \rho_{LS}^3, \rho_D^3) \quad i=1..3$$

$$M_i^{Xc}(M_{Xc}, E_\ell > E_0) = f_i^{Xc}(E_0, m_b, m_c, \mu_G^2, \mu_\pi^2, \rho_{LS}^3, \rho_D^3) \quad i=1..4$$

inclusive Vcb



from the shape get non-perturbative parameters though the 'moments'

$$M_n(O) = \left(\frac{m_b}{2}\right)^n \left(\varphi_n(r) + a_n(r)\frac{\alpha_s}{\pi} + b_n(r)\frac{\mu_\pi^2}{m_b^2} + c_n(r)\frac{\mu_G^2}{m_b^2} + d_n(r)\frac{\rho_D^3}{m_b^3} + s_n(r)\frac{\rho_{LS}^3}{m_b^3} + \dots \right)$$

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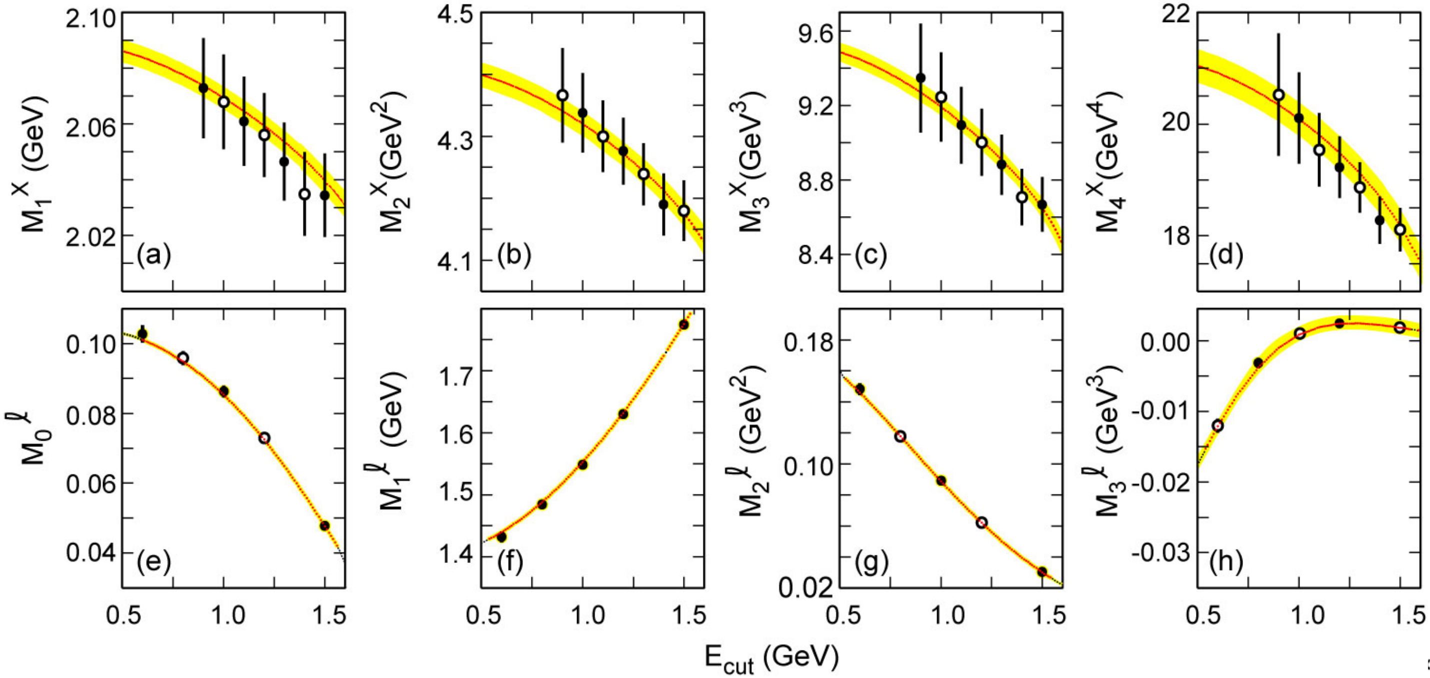
Fit results

Accepted by
Phys. Rev. Lett.
hep-ex/0404017

M_{Xc} and E_l moments as a function of minimum E_l cut

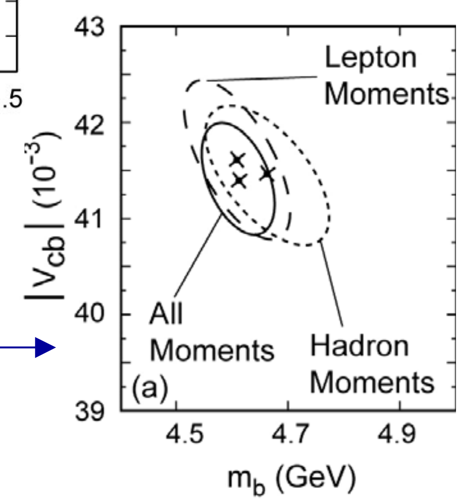


$\chi^2 = 15$
$N_{dof} = 20$

- ● used in global fit
- ○ not used in global fit

➢ Excellent agreement between data and HQE predictions!

➢ Excellent agreement between lepton and hadron moments! →

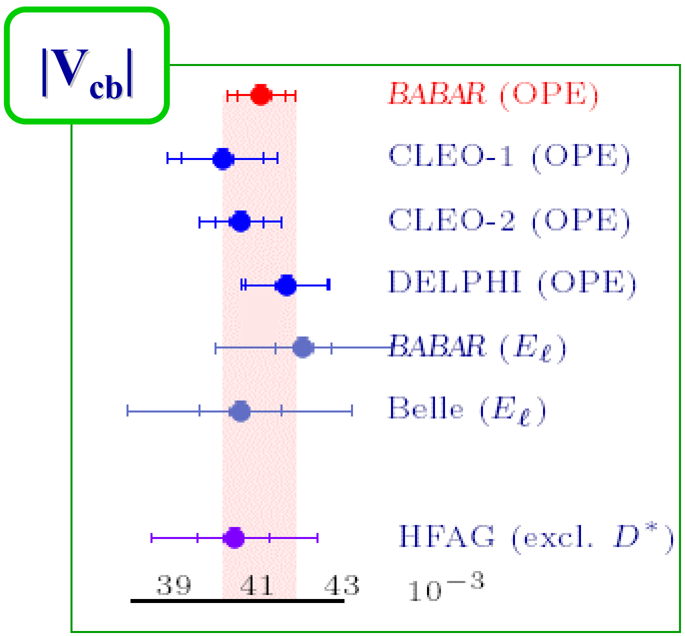


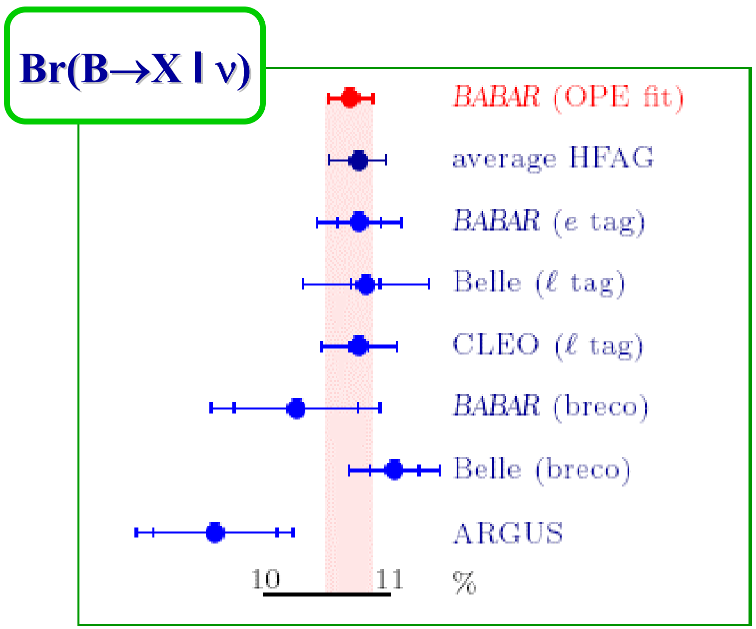
$|V_{cb}|$: result and comparison

$$|V_{cb}| = (41.4 \pm 0.4_{\text{exp}} \pm 0.4_{\text{HQE}} \pm 0.2_{\alpha_s} \pm 0.6_{\Gamma_{\text{SL}}}) \times 10^{-3}$$

$$Br(B \to X_c e \nu) = (10.61 \pm 0.16_{\text{exp}} \pm 0.06_{\text{HQE}})\%$$

- 2% error on $|V_{cb}|$!





Fit Results

$$|V_{cb}| = (41.4 \pm 0.4_{\exp} \pm 0.4_{\mathrm{HQE}} \pm 0.2_{\alpha_s} \pm 0.6_{\Gamma_{\mathrm{SL}}}) \times 10^{-3}$$
$$Br(B \to X_c e \nu) = (10.61 \pm 0.16_{\exp} \pm 0.06_{\mathrm{HQE}})\%$$
$$m_b(1\,GeV) = (4.61 \pm 0.05_{\exp} \pm 0.04_{\mathrm{HQE}} \pm 0.02_{\alpha_s})\,GeV$$
$$m_c(1\,GeV) = (1.18 \pm 0.07_{\exp} \pm 0.06_{\mathrm{HQE}} \pm 0.02_{\alpha_s})\,GeV$$

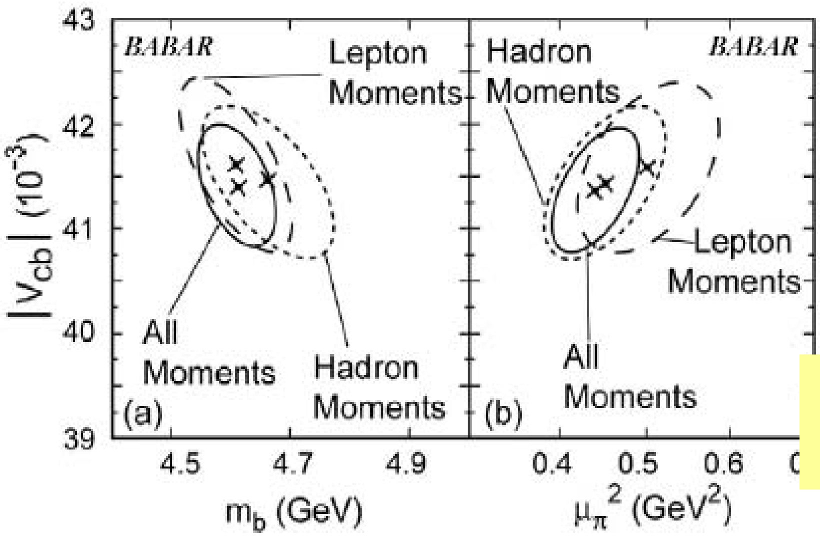
Kinetic scheme:
Small pert corrections
Minimal set of parmts
No $1/m_c$ expansion
Uraltsev & PG

kinetic mass scheme

$$\mu_\pi^2 = (0.45 \pm 0.04_{\exp} \pm 0.04_{\mathrm{HQE}} \pm 0.01_{\alpha_s})\,GeV^2$$
$$\mu_G^2 = (0.27 \pm 0.06_{\exp} \pm 0.03_{\mathrm{HQE}} \pm 0.02_{\alpha_s})\,GeV^2$$
$$\rho_D^3 = (0.20 \pm 0.02_{\exp} \pm 0.02_{\mathrm{HQE}} \pm 0.00_{\alpha_s})\,GeV^3$$
$$\rho_{LS}^3 = (-0.09 \pm 0.04_{\exp} \pm 0.07_{\mathrm{HQE}} \pm 0.01_{\alpha_s})\,GeV^3$$

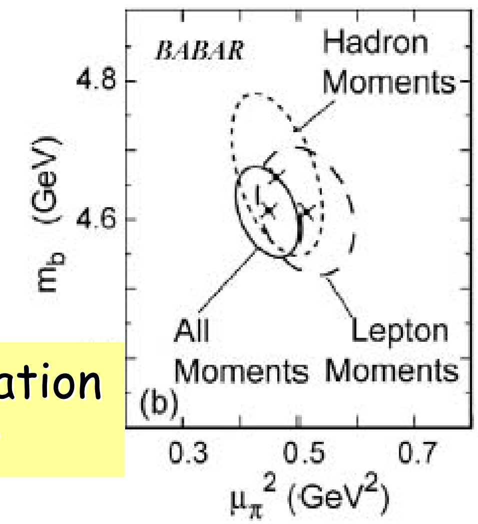
Strong correlation between m_b and m_c:

$$m_b(1\,\mathrm{GeV}) - m_c(1\,\mathrm{GeV}) = (3.44 \pm 0.03_{\exp} \pm 0.02_{\mathrm{HQE}} \pm 0.01_{\alpha_S})\,\mathrm{GeV}$$



2D projections of the fit result:

$\Delta\chi^2 = 1$ ellipses



No sign of deterioration for higher cuts

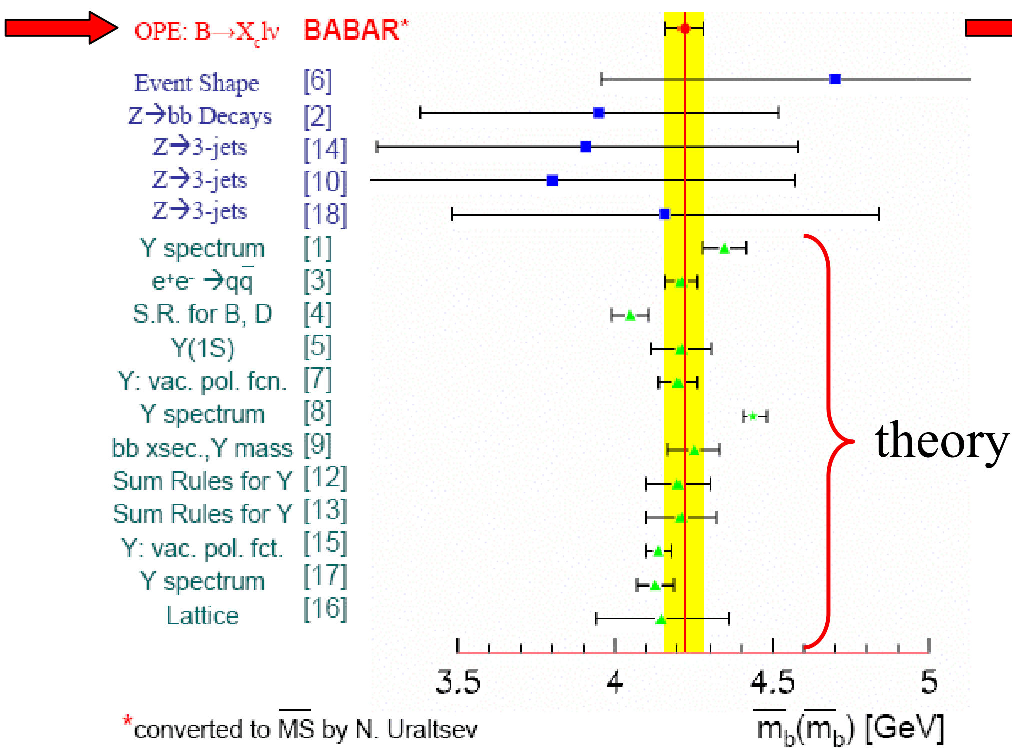
m_b, m_c: result and comparison

kinetic mass scheme

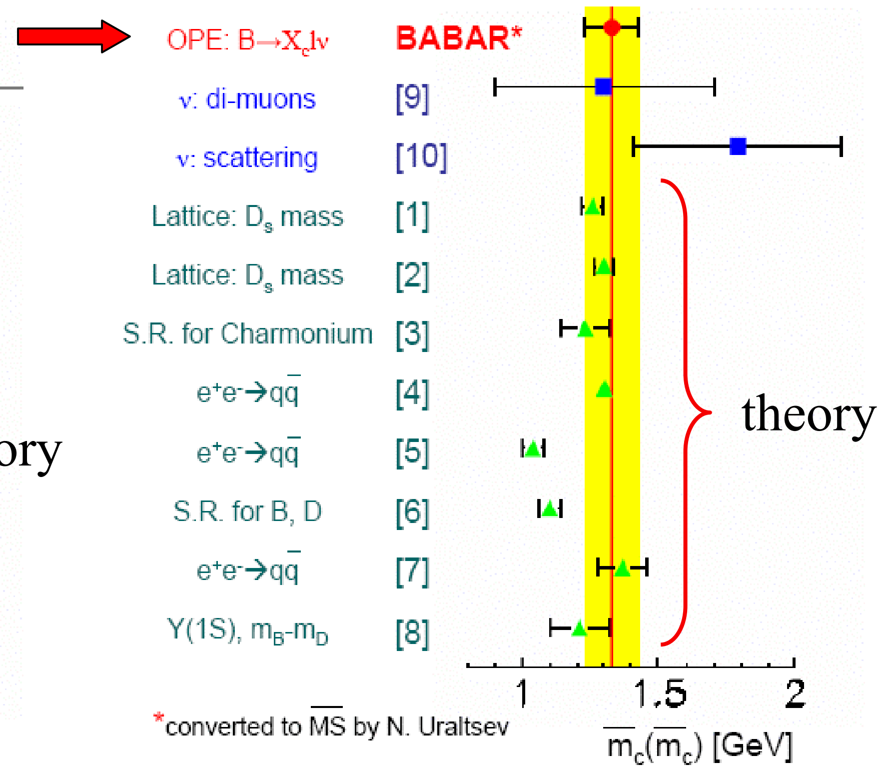
$$m_b(1\ GeV) = (4.61 \pm 0.05_{\rm exp} \pm 0.04_{\rm HQE} \pm 0.02_{\alpha_s})\ GeV$$

$$m_c(1\ GeV) = (1.18 \pm 0.07_{\rm exp} \pm 0.06_{\rm HQE} \pm 0.02_{\alpha_s})\ GeV$$

Measurements and Predictions of the b-Quark Mass ($\overline{\rm MS}$ scheme) PDG2003



Measurements and Predictions of the c-Quark Mass ($\overline{\rm MS}$ scheme) PDG2003



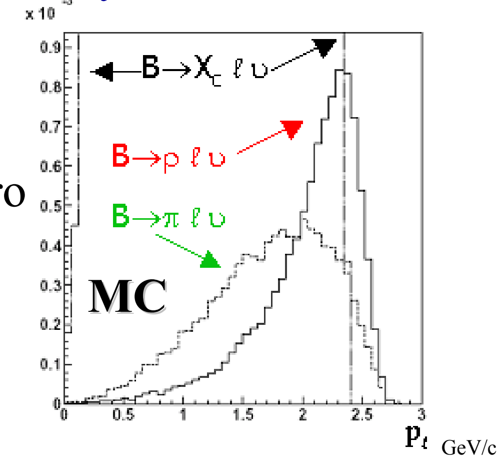
Conversion of m_b and m_c from kinetic mass to $\overline{\rm MS}$ scheme by N. Uraltsev (hep-ph/9708372, hep-ph/0302262 , hep-ph/0304132)

Phys. Rev. Lett. 90:181801,2003

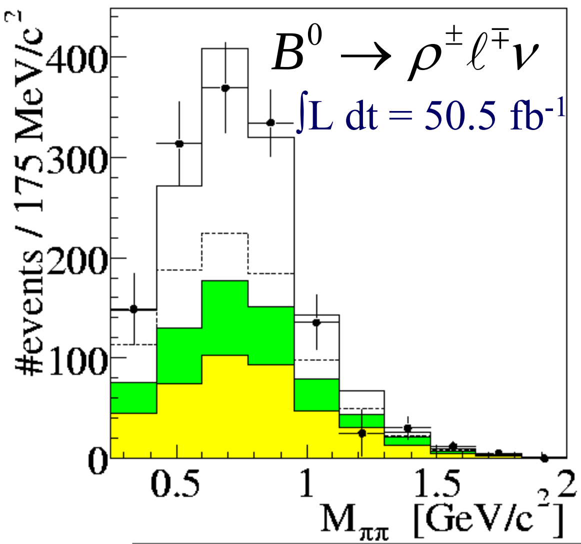
Exclusive $|V_{ub}|$

- Strategy: untagged identification of $B \to \rho e \nu$ decays with "ν reconstruction"
- Signal extracted by requiring:
  - very high momentum electron
  - $\Delta E = E_{beam} - E_\rho - E_l - E_{miss}$ compatible with zero
  - $M_{\pi\pi}$ compatible with ρ mass

exclusive analysis advantage



- Rather high theoretical uncertainties (~15%)
- Relatively high yield: 834 ± 102 events (only electrons and 50.5 fb^{-1})



$$|V_{ub}| = \left(3.64 \pm 0.22(stat) \pm 0.25(syst)^{+0.39}_{-0.56}(theo)\right) \times 10^{-3}$$

$$Br\left(B^0 \to \rho^- e^+ \nu\right) = \left(3.29 \pm 0.42(stat) \pm 0.47(syst) \pm 0.60(theo)\right) \times 10^{-4}$$

- Much more to be expected soon:
  - larger dataset
  - additional decay modes
  - reduced theoretical uncertainties
  - form factor(s) measurement
  - new recoil techniques

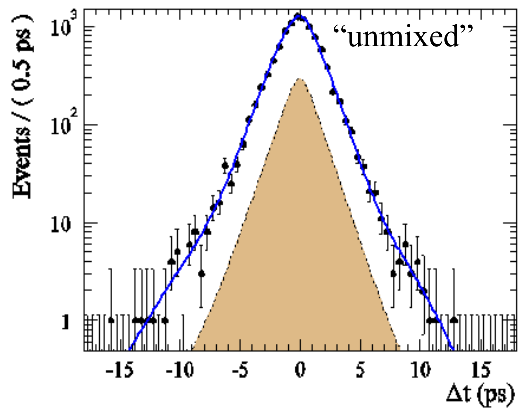
« classic » B^0 - $\overline{B}^0$ mixing

(1) Phys.Rev.Lett.88:221802,2002
(2) Phys.Rev.Lett.88:221803,2002
(3) Phys.Rev.Lett.89:011802,2002
(4) Phys.Rev.D66:032003,2002
(5) Phys.Rev.D67:072002,2003

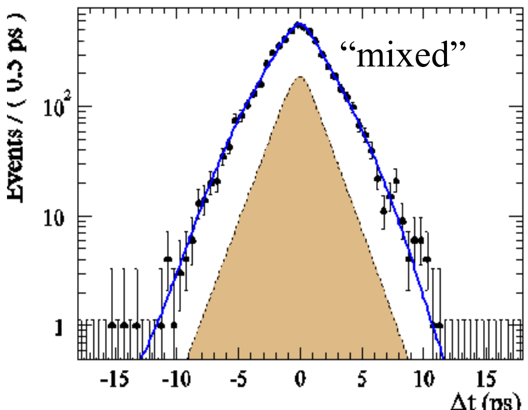
- The B^0 - $\overline{B}^0$ mixing technique is well-known and well-documented:

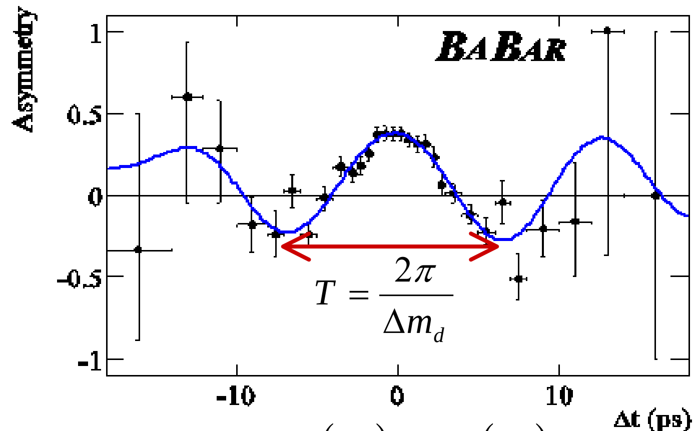
1. Determination of vertex and flavor of the two B's
2. "Δt" between the two B's estimated from distance between vertices

$B^0\overline{B}^0 \to B^0\overline{B}^0$



$B^0\overline{B}^0 \to B^0B^0 / \overline{B}^0\overline{B}^0$





$$N_\pm(\Delta t;\Delta m_d) = \frac{e^{-|\Delta t|/\tau}}{4\tau}(1 \pm \cos\Delta m_d \Delta t)$$

$$Asymmetry(\Delta t) = \frac{N_+(\Delta t) - N_-(\Delta t)}{N_+(\Delta t) + N_-(\Delta t)} = \cos(\Delta m_d \Delta t)$$

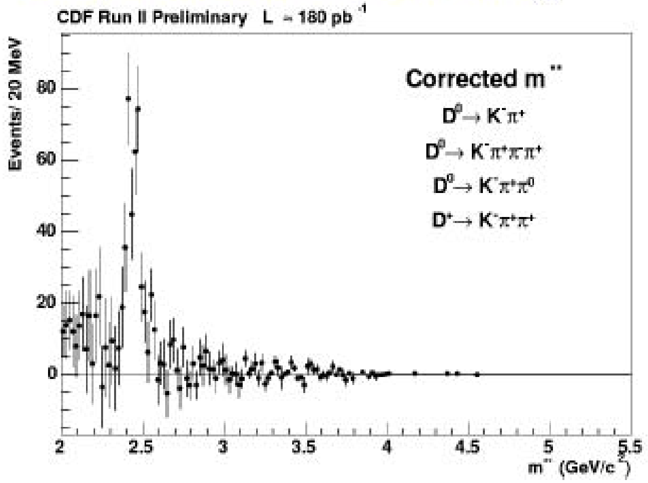
Results (23×10^6 $B\overline{B}$):

$$\Delta m_d = 0.500 \pm 0.008 \pm 0.006 \quad ps^{-1}$$
(averaged 1,2,5)

$$\tau_{B^0} = 1.529 \pm 0.012 \pm 0.029 \quad ps$$ (3)

Hadronic Mass Moments

- Most precise determination of V_{cb} based on inclusive semileptonic decays
  $B \to X_c\, l\, \nu$ ($X_c = D^+/D^0/D^*/D^{**}$)
- Basic idea: OPE applied to HQET relates experimental width to V_{cb}:
  $\Gamma(B \to X_c l \nu) = |V_{cb}|^2 f(\Lambda, \lambda_1, \lambda_{2,\ldots})$ ['form factors' in expansion in powers of m_B)
  $\Lambda, \lambda_1, \lambda_2, \ldots$ OPE parameters related to hadronic mass moments of $M^2(X_c)$ mass distribution in semi-leptonic decays
- Measurement of mass moments provides useful constraints on $\Lambda, \lambda_1, \lambda_2, \ldots$ & improves determination of V_{cb}



- Challenge: Reconstruct $B \to D^{**} l X$, with $D^{**} \to D^+/D^0/D^*\, X$
- Need to understand all possible reflections/cross-talks between various modes

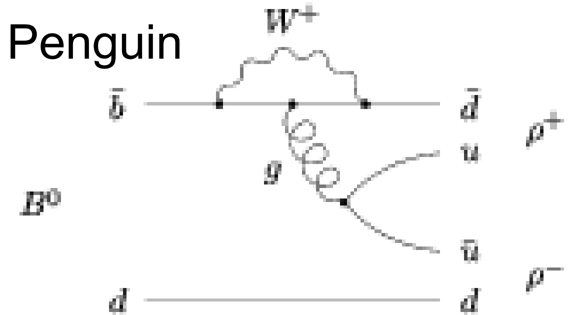
Doable at hadron collider!
Preliminary analysis at CDF!

CDF and D0 are coming……with a lot of statistics

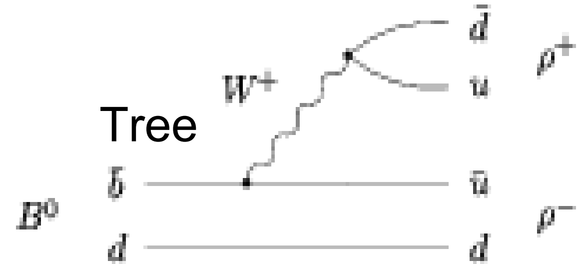
ALFA or Φ2

Prospects of α from B→ρρ

Penguin



Tree



Both tree and penguin amplitudes contribute.

If no penguins:

$$C = 0$$

$$S = \sin(2\alpha)$$

With penguin contributions:

$$C \propto \sin(\delta)$$

$$S = \sqrt{1-C^2}\sin(2\alpha_{eff})$$

Using the Grossman-Quinn bound to limit $\Delta\alpha = |\alpha - \alpha_{eff}|$

$$\sin^2(\Delta\alpha) \leq \frac{BR(B^0 \to \rho^0\rho^0)_{Long.}}{BR(B^+ \to \rho^+\rho^0)_{Long.}}$$

Decay is penguin dominated.

$B^0\to\rho^0\rho^0$ branching ratio is small compared to $B^+\to\rho^+\rho^0$!

$$BR(B^0 \to \rho^0\rho^0) = (0.63^{+0.72}_{-0.60} \pm 0.12)\times 10^{-6}$$
$$BR(B^+ \to \rho^+\rho^0) = (26.4^{+6.1}_{-6.4})\times 10^{-6}$$

$$|\alpha_{eff} - \alpha| \leq 14.7^\circ \quad (90\%CL)$$
$$|\alpha_{eff} - \alpha| \leq 12.9^\circ \quad (68\%CL)$$

The B→ρρ decay

$B^0 \to \rho^+ \rho^-$ is a VV-decay ➔The decay can proceed through 3 partial waves:

S (L=0, CP even), P (L=1, CP odd), D(L=2, CP even)

3 helicity amplitudes:

$\lambda=0$ → longitudinal polarization. Pure CP even eigenstate.

$\lambda=\pm1$ → transverse polarization. Mix of CP even and odd eigenstates.

The decay $B^0 \to \rho^+ \rho^-$ has been observed at BaBar and its BR and polarization measured: (PRD 69, 031102 (2004) and hep-ex/0404029, submitted to PRL)

$$BR = (30 \pm 4 \pm 5) \times 10^{-6} \quad , \quad f_{long} = 0.99 \pm 0.03 \pm 0.03$$

$B^0 \to \rho^+ \rho^-$ is an excellent candidate for measuring α:

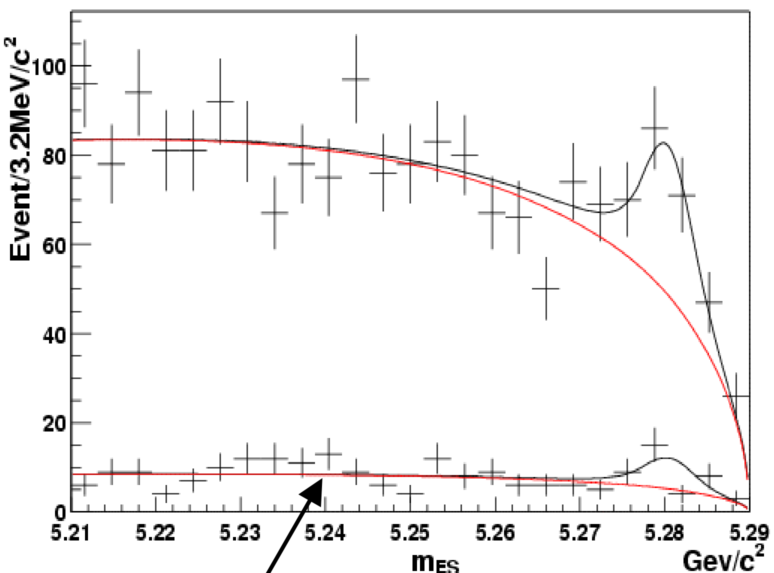
- Longitudinally saturated
- Relatively large BR
- Small penguin pollution
- Two charged tracks in the decay for vertexing

B→ρρ Signal Selection

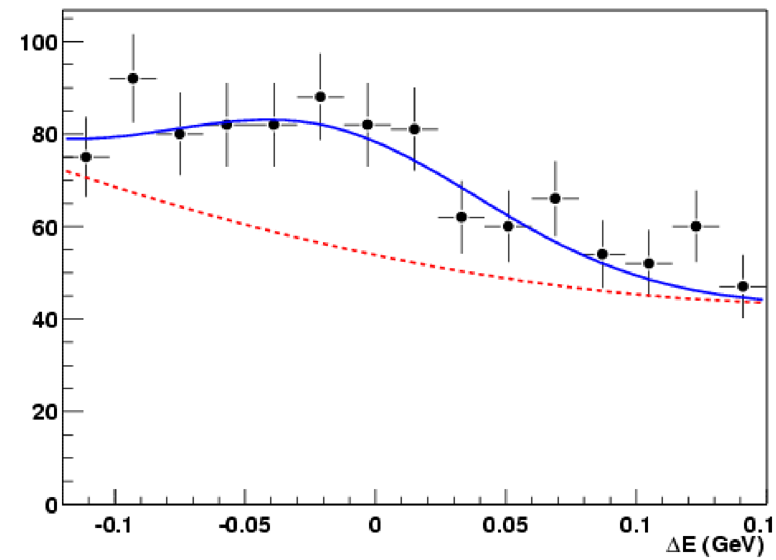
Also use the ρ-mass and ρ-decay angle (helicity) to distinguish signal from background.

B-mass: $m_{\mathrm{ES}} = \sqrt{E^{*2}_{\mathrm{beam}} - p^{*2}_{B}}$

Missing energy: $\Delta E = E^{*}_{B} - E^{*}_{\mathrm{beam}}$



Events with clean tags.



Full likelihood
Background
Data

Summary

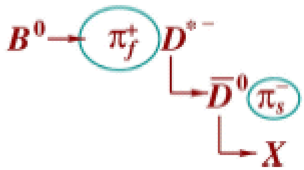
- No significant constraint on α from $B\rightarrow\pi\pi$
  - Non optimal $B^0\rightarrow\pi^0\pi^0$ BR (large penguins).
- $B\rightarrow\rho\pi$ quasi-2-body analysis performed but no model-independent constraints on α
  - Non-CP eigenstate and penguins not under control.
- $B\rightarrow\rho\rho$ provides the most stringent constraint on α. This analysis has been carried out at BaBar, and the result is (with some simple assumptions):

$$\alpha = 96^\circ \pm 10^\circ_{stat} \pm 4^\circ_{syst} \pm 13^\circ_{penguin}$$

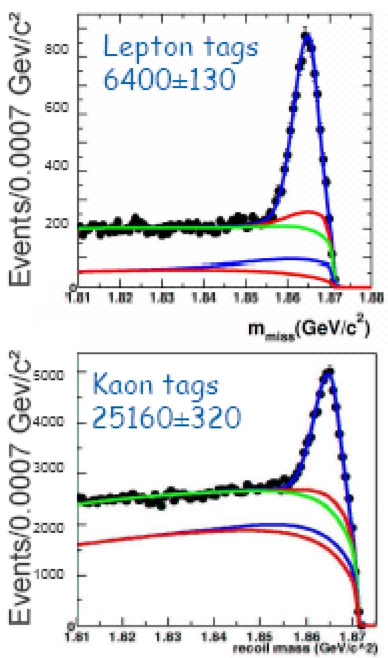
GAMMA or $\Phi 3$

Partial reconstruction of $B^0 \to D^*\pi$

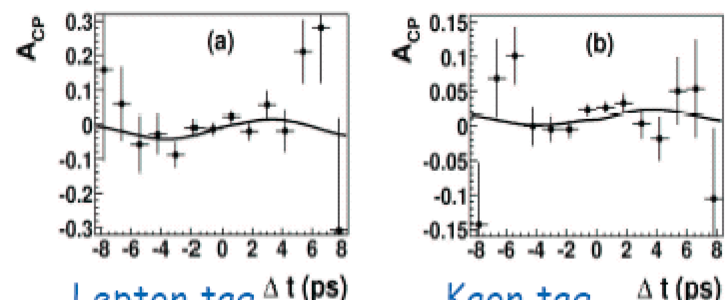
76 fb^{-1}



- no attempt to reconstruct D^0
- more events but more background



$$A_{CP}^{rec} = \frac{N(B^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t) - N(\bar{B}^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t)}{N(B^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t) + N(\bar{B}^0_{tag}, B^0 \to D^{*\pm}\pi^{\mp})(t)}$$



Lepton tag

Kaon tag

$$a^* = 2r\sin(2\beta+\gamma)\cos(\delta^*) = -0.063 \pm 0.024 \pm 0.014$$

Deviates from 0 at 2.3 σ

(Hep-ex/0310037, accepted by PRL)

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Conclusion and prospects

- First steps to extract γ are promising :
  - $D^{(*)}\pi$ analysis well established :
    $|\sin(2\beta+\gamma)| > 0.58$ at 95 % CL
  - GLW and ADS : need more statistics
  - The presented analysis will be updated with more data
- Other channels to measure γ :
  - $D^{(*)}\rho$ for $\sin(2\beta+\gamma)$
  - GLW with D^0 decays into CP-odd
  - ADS with other final states
  - D^*K, D^*K^* decays…

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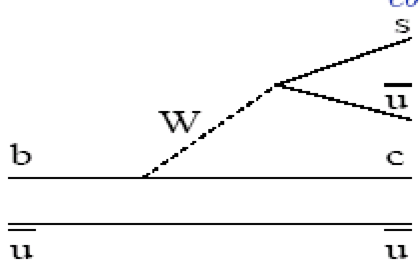
- Can access ϕ_3 via interference between $B^- \to D^0 K^-$ & $B^- \to \bar{D}^0 K^-$
- Reconstruct D in final states accessible to both D^0 and $\bar{D}^0$

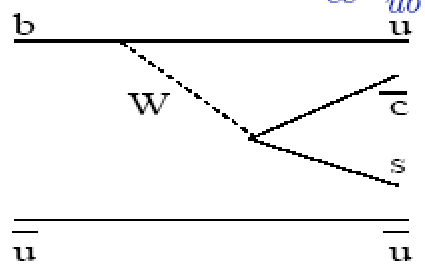
  eg. $D_{CP} K^-$ (Gronau, London, Wyler method)
- Can use multibody final states, *eg.* $K_S \pi^+ \pi^-$ (first noted by Atwood, Dunietz, Soni)

$B^- \to D^0 K^- \sim V_{us} V_{cb}^*$



COLOUR ALLOWED

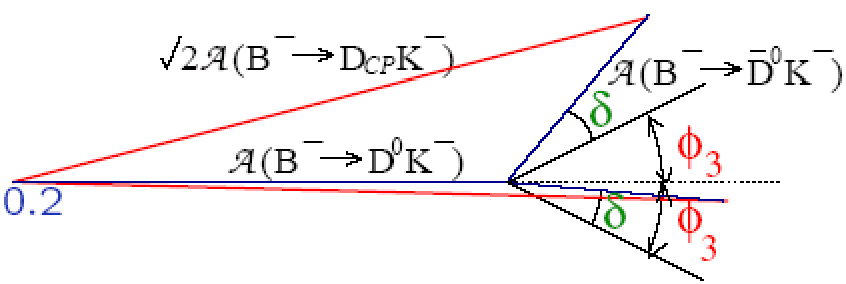
$B^- \to \bar{D}^0 K^- \sim V_{cs} V_{ub}^*$



COLOUR SUPPRESSED

$\mathcal{A}$ — amplitude

$r = \mathcal{A}_{\text{SUPPRESSED}} / \mathcal{A}_{\text{FAVOURED}} \sim 0.1 - 0.2$



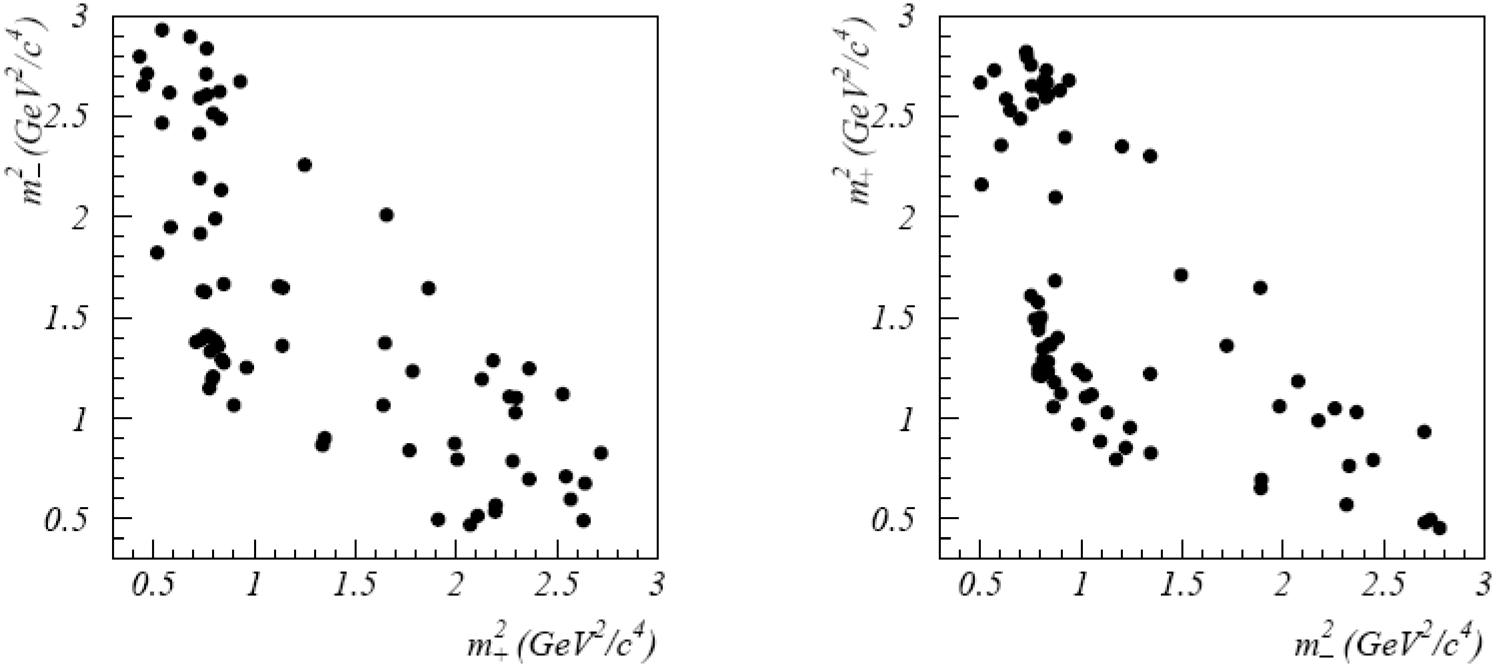
Principle of the Multi-Body Analysis

- Consider $\bar{D}^0 \to K_S\pi^+\pi^-$
  $\to$ define amplitude at each Dalitz plot point as $f(m_+^2, m_-^2)$
  where $m_+ = m_{K_S\pi^+}$, $m_- = m_{K_S\pi^-}$
- Consider $D^0 \to K_S\pi^+\pi^-$
  $\to$ amplitude at each Dalitz plot point is $f(m_-^2, m_+^2)$
- $\left|f(m_+^2, m_-^2)\right|$ can be measured using flavour tagged D mesons

- Consider $B^+ \to \left(K_S\pi^+\pi^-\right)_D K^+$
  $\to$ amplitude is $f(m_+^2, m_-^2) + re^{i(\delta+\phi_3)}f(m_-^2, m_+^2)$
- Consider $B^- \to \left(K_S\pi^+\pi^-\right)_D K^-$
  $\to$ amplitude is $f(m_-^2, m_+^2) + re^{i(\delta-\phi_3)}f(m_+^2, m_-^2)$
- Can extract (r, δ, ϕ_3) from B^+ & B^- data

$B^{\pm} \to (K_S \pi^+ \pi^-)_D K^{\pm}$ Dalitz Plot Distributions

$M_+ = f(m_+^2, m_-^2) + re^{i(\delta+\phi_3)} f(m_-^2, m_+^2)$ $\qquad$ $M_- = f(m_-^2, m_+^2) + re^{i(\delta-\phi_3)} f(m_+^2, m_-^2)$

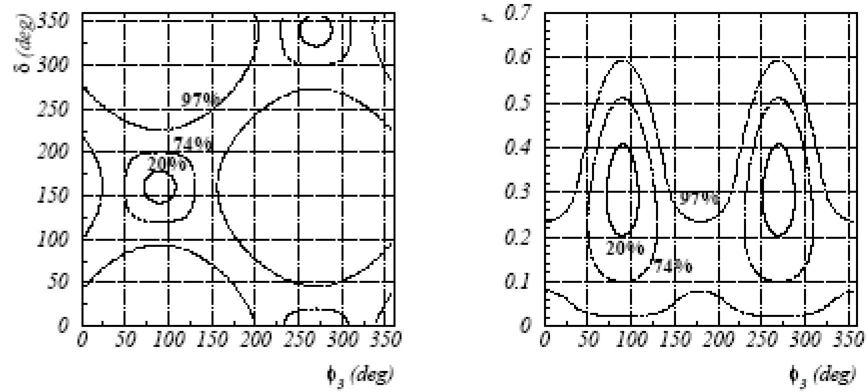


Extraction of ϕ_3

Avoid using fit likelihood errors $\rightarrow$ construct PDF for $(r, \phi_3, \delta)_{\text{true}}$ using Toy MC

$B^\pm \rightarrow \left(K_S\pi^+\pi^-\right)_D K^\pm$

$\phi_3 > 0$ with $> 94\%$ probability



PRELIMINARY

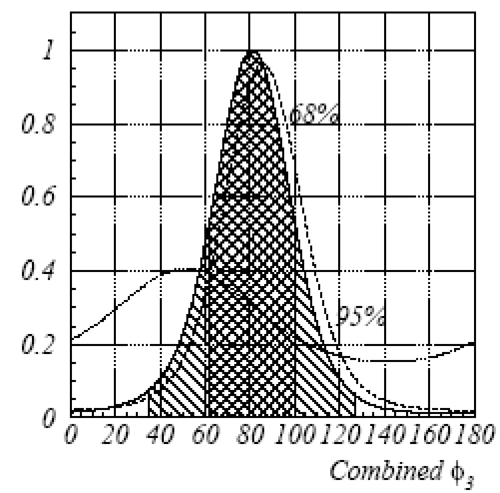
$B^\pm \rightarrow \left(K_S\pi^+\pi^-\right)_D K^\pm$: $\phi_3 = 86^\circ \pm 20^\circ (49^\circ)$

$B^\pm \rightarrow \left(\left(K_S\pi^+\pi^-\right)_D \pi^0\right)_{D^*} K^\pm$: $\phi_3 = 51^\circ \pm 47^\circ (82^\circ)$

Combined:

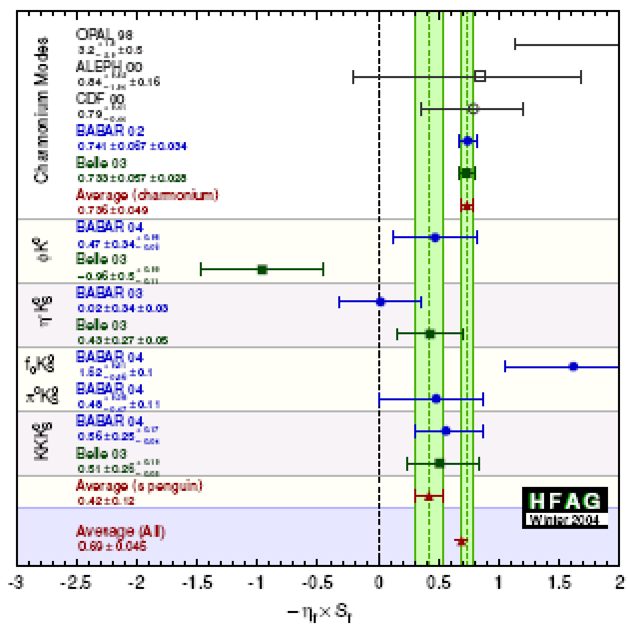
$\phi_3 = 81^\circ \pm 19^\circ (46^\circ)_{\text{stat}} \pm 13^\circ_{\text{sys}} \pm 11^\circ_{\text{model}}$

Errors are 68% (95%) confidence limits



$\mathcal{B}$ and CPV in $B^0 \rightarrow K^+K^-K^0_S$ and $B^+ \rightarrow K^+K^0_SK^0_S$

$-\eta_f \times S_f$	ϕK^0	KKK^0_S
BABAR	$0.47 \pm 0.34^{+0.08}_{-0.06}$	$0.56 \pm 0.25 \pm 0.04^{+0.17}_{-0.00}$
Belle	$-0.96 \pm 0.50^{+0.09}_{-0.11}$	$0.51 \pm 0.26 \pm 0.05^{+0.18}_{-0.00}$
Average	0.02 ± 0.29 (0.28 stat only)	$0.54 \pm 0.18^{+0.17}_{-0.00}$ (0.18 stat only)



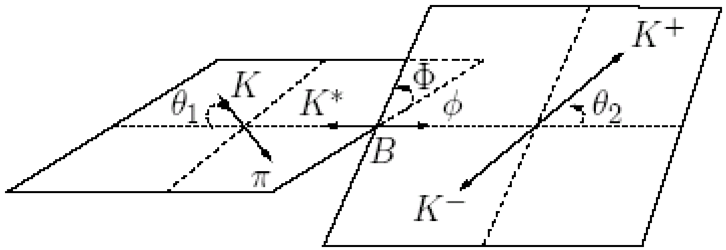
Disagreement between

b → s penguin dominated and

charmonium modes of $\sim 2.4\,\sigma$

Full angular analysis $B \to \phi K^*$

- Angular distribution of $B \to VV$ unknown *a priori*



$$\frac{1}{\Gamma}\frac{d^3\Gamma}{d\cos\theta_1 d\cos\theta_2 d\Phi} = \frac{9}{8\pi}\frac{1}{|A_0|^2+|A_{+1}|^2+|A_{-1}|^2}\times$$

$$\left\{\frac{1}{4}\sin^2\theta_1\sin^2\theta_2\left(|A_{+1}|^2+|A_{-1}|^2\right)+\cos^2\theta_1\cos^2\theta_2|A_0|^2+\right.$$

$$\frac{1}{2}\sin^2\theta_1\sin^2\theta_2\left[\cos 2\Phi \mathrm{Re}(A_{+1}A^*_{-1})-\sin 2\Phi \mathrm{Im}(A_{+1}A^*_{-1})\right]-$$

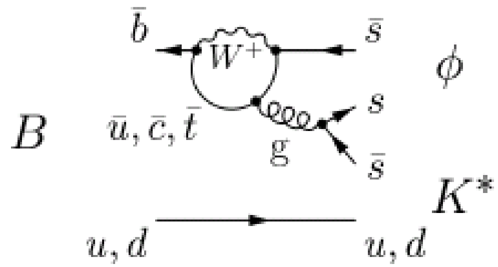
$$\left.\frac{1}{4}\sin 2\theta_1\sin 2\theta_2\left[\cos\Phi \mathrm{Re}\left(A_{+1}A^*_0+A_{-1}A^*_0\right)-\sin\Phi \mathrm{Im}\left(A_{+1}A^*_0-A_{-1}A^*_0\right)\right]\right\}$$

$A_{\parallel} = \frac{A_{+1}+A_{-1}}{\sqrt{2}}$, CP-even

$A_{\perp} = \frac{A_{+1}-A_{-1}}{\sqrt{2}}$, CP-odd

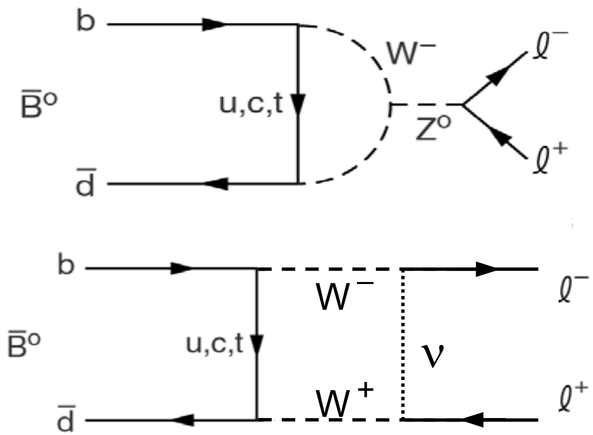
Full angular analysis $B \longrightarrow \phi K^*$

- Decays to two vector mesons reveal fundamental dynamics
  - Successes: $\sin 2\alpha$ from $B \to \rho\rho$
  - Surprises: Longitudinal polarization in $B \to \phi K^*$ smaller than SM prediction
- Hint of new physics?
  - $B \to \phi K^*$ is a pure penguin loop

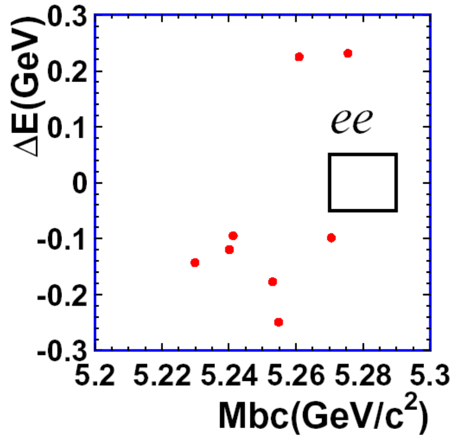


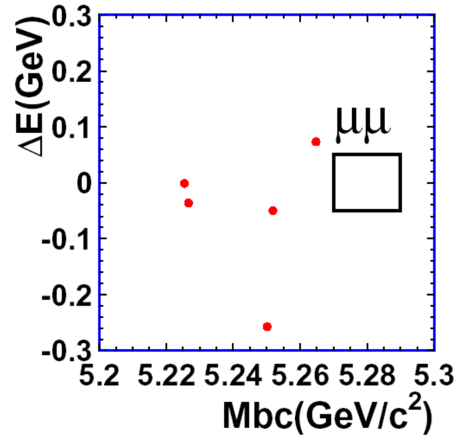
  - Perform full angular analysis

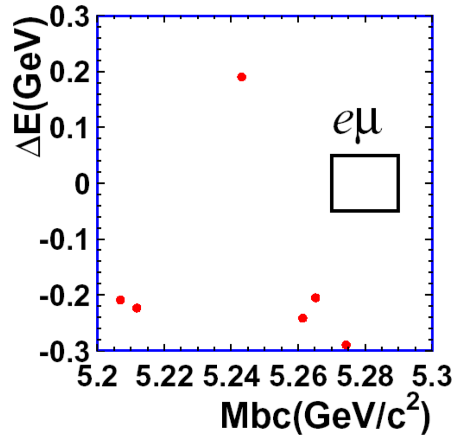
$B^0 \to l^+ l^-$



Belle







Very small in Standard Model

- $B(B^0 \to \tau^+\tau^-) \approx 3 \times 10^{-8}$
- μ and e modes helicity suppressed
- possible large enhancement from non-SM scalar currents (e.g., MSSM)
- important window for New Physics

Best published Limit:
Belle (78 fb^{-1}) PRD 68,111101(2003)

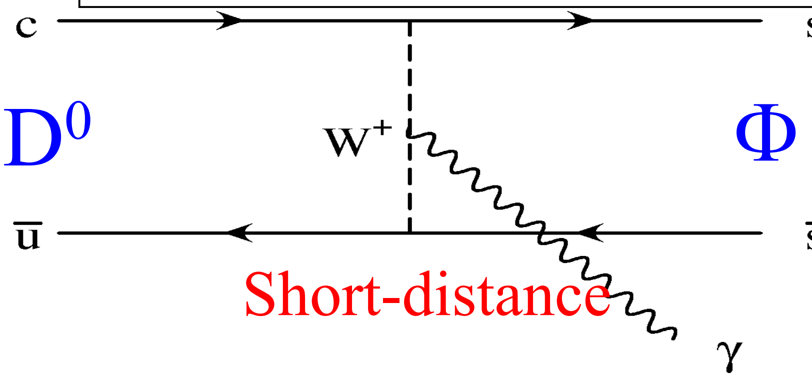
$$B(B^0 \to \mu^+\mu^-) < 1.6 \times 10^{-7}\ (90\%\ \mathrm{CL})$$
$$B(B^0 \to e^+ e^-) < 1.9 \times 10^{-7}\ (90\%\ \mathrm{CL})$$
$$B(B^0 \to \mu\, e\,) < 1.7 \times 10^{-7}\ (90\%\ \mathrm{CL})$$

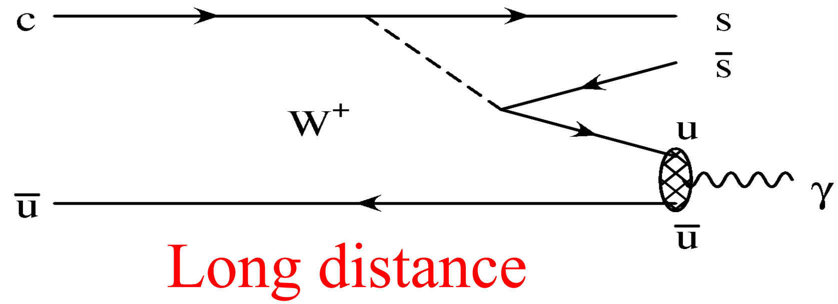
CDF preliminary

171 pb^{-1} (hep-ex/0403032)

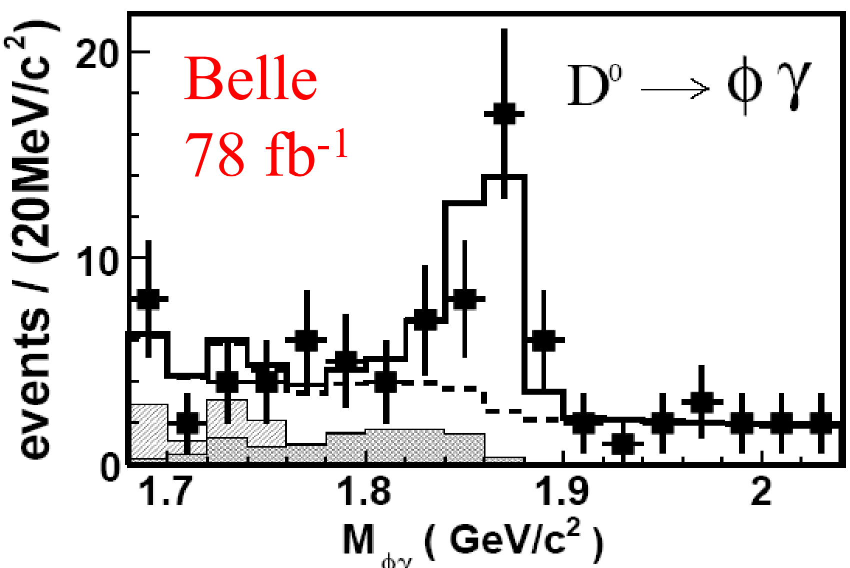
$$B(B^0 \to \mu^+\mu^-) < 1.5 \times 10^{-7}\ (90\%\ \mathrm{CL})$$

First Observation of $D^0 \to \varphi\gamma$





- In SM, short distance contribution negligible (< 10^{-8})
- Long-distance contribution due to vector meson dominant [Burdman95, Fajfer97]
- Rate predicted in range [$(0.04\text{-}3.4)\times 10^{-5}$], 90% CL limit from CLEO $<1.9 \times 10^{-4}$
- Reality check when considering long-distance effects in $b\to d\gamma$ for determing V_{td}



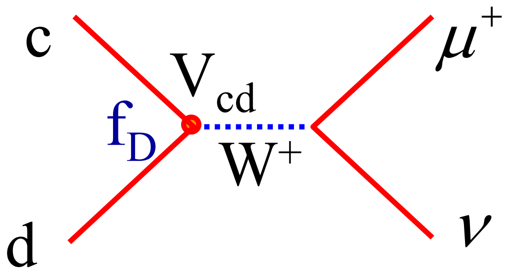
Observe $27.6^{+7.4}_{-6.5}(stat)^{+0.5}_{-1.0}(syst)$ events

Significance is 5.4σ !

$$B(D^0 \to \Phi\gamma) = [2.60^{+0.70}_{-0.61}\ (stat)\ ^{+0.15}_{-0.17}]\times 10^{-5}$$

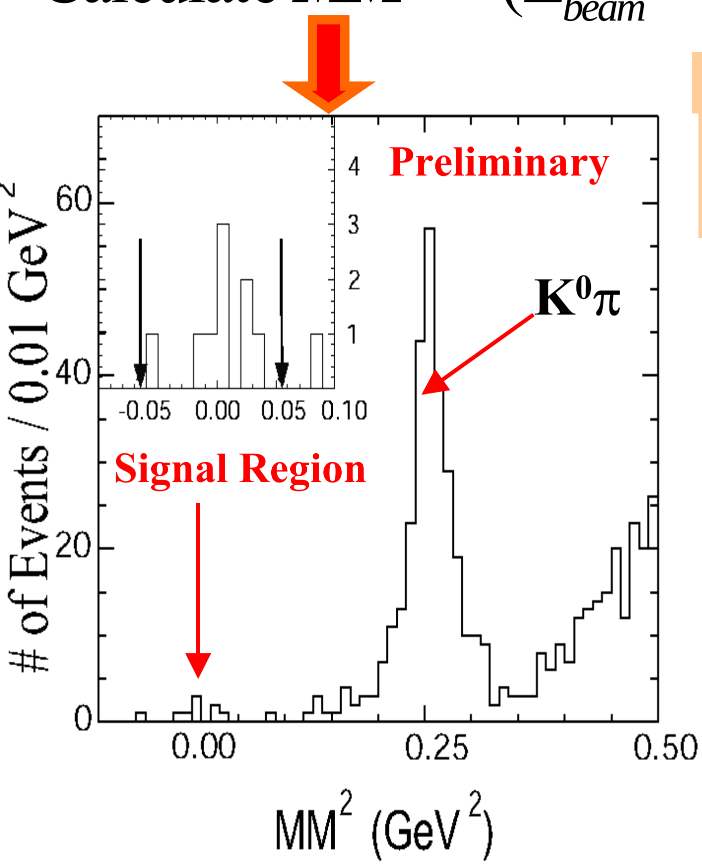
" An anchor for future development of non-perturbative QCD" **Belle**

Observation of $D^+ \to \mu^+ \upsilon_\mu$ (CLEO-c)



$$\Gamma(M \to l\nu) = \frac{1}{8\pi} G_F^2 f_M^2 m_l^2 M_M \left(1 - \frac{m_l^2}{M_M^2}\right)^2 |V_{qq'}|^2$$

Calculate $MM^2 = (E_{beam} - E_\mu)^2 - (-\overrightarrow{P_{D^+}} - \overrightarrow{P_\mu})^2$ recoiling against recoed D



9 events in 2σ window ($-0.056 < MM^2 < 0.056$ GeV^2), 0.67 ±0.24 estimated background

$B(D^+ \to \mu^+ \nu_\mu) = (4.57 \pm 1.66 \pm 0.41) \times 10^{-4}$

$\Rightarrow f_{D^+} = (230 \pm 42 \pm 10) MeV$ [Prelim]

This is just the begining

Expect $\times 60$ data at $\psi(3770)$ soon

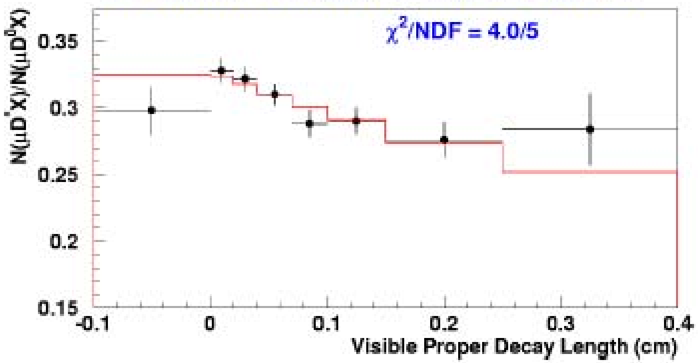
New era in charm physics is here !

B Lifetimes

$\tau(B^+)/\tau(B^0)$ Lifetime Ratio

Use binned χ^2 fit of event ratios to determine $\tau(B^+)/\tau(B^0)$

DØ RunII Preliminary, Luminosity = 250 pb^{-1}



D0 Preliminary result:
$\tau(B^+)/\tau(B^0) = 1.093 \pm 0.021 \pm 0.022$

Competitive with B factories

Lifetimes from excl. B -> J/ψ K

Use fully rec. B decays

$c\tau_{Bu}$ = 498.1±9.9(stat)±2.4(syst)

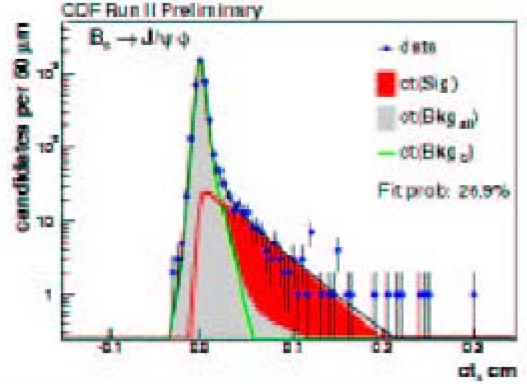
$c\tau_{Bd}$ = 461.3±15.4(stat)±2.4(syst)

$c\tau_{Bs}$ = 410.4±30.0(stat)+2.4-2.9(syst)

τ_{Bu}/τ_{Bd} = 1.080 ± 0.042

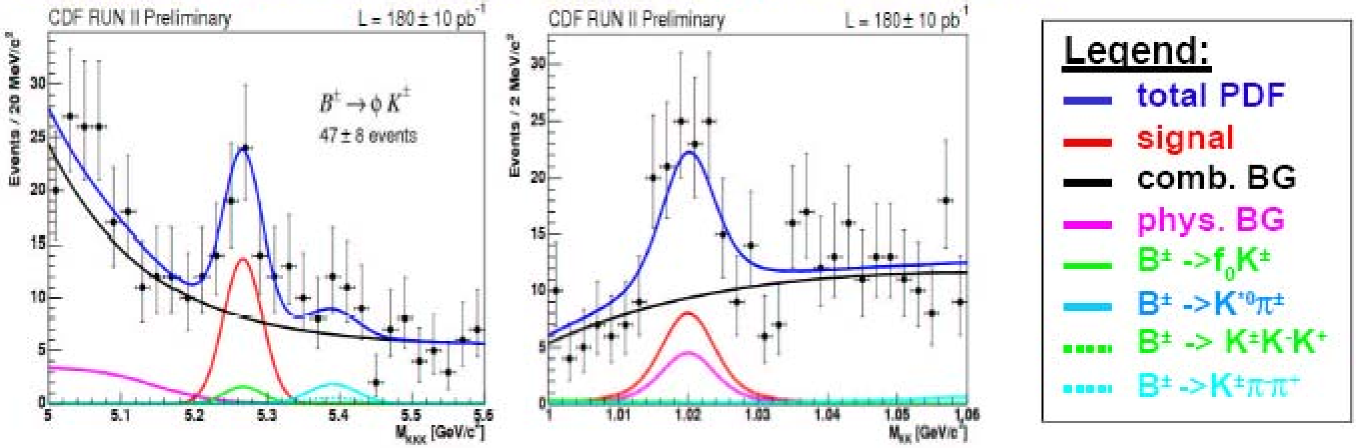
τ_{Bs}/τ_{Bd} = 0.890 ± 0.072

B_s->J/ψφ decay length



Observation of $B^{\pm} \to \phi K^{\pm}$

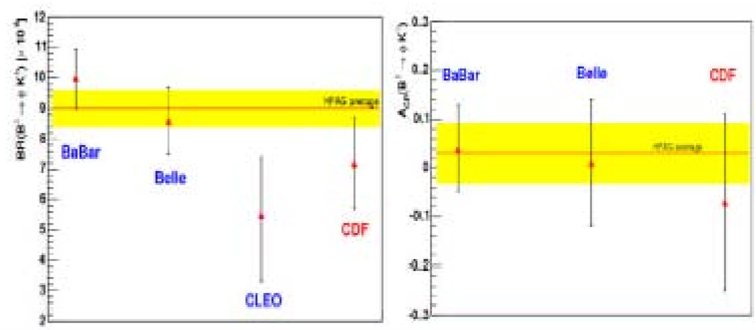
Updated BR measurement and first A_{CP} determination



- Fit result: N = 47±8 events
- Main background $B^{\pm} \to f_0 K^{\pm}$

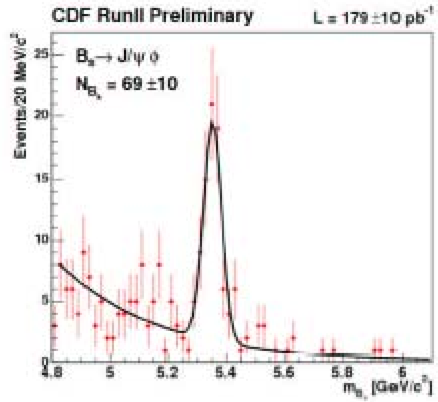
$BR = (7.2 \pm 1.3 \pm 0.7) \cdot 10^{-6}$

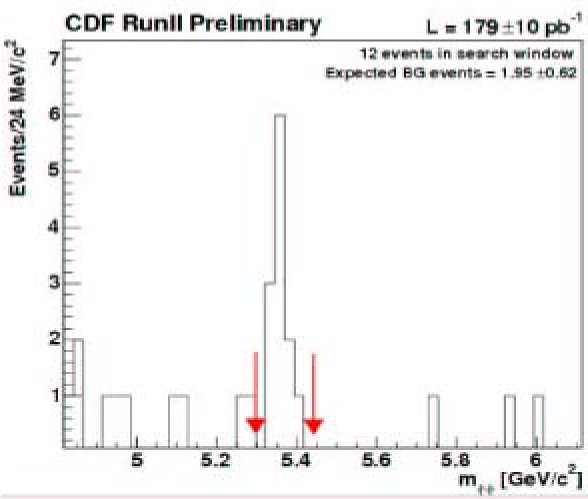
$A_{CP} = 0.07 \pm 0.17 \pm 0.06$



First Evidence for $B_s^0 \to \phi\phi$

- Search for $B_s^0 \to \phi\phi$: Perform blind analysis
- Use MC and high statistics 4-track modes for search optimization
- Normalize yield to $B_s \to J/\psi\phi$ decay (rel. eff.)
- Observe 12 events in search window





BR=(1.4 ± 0.6 ± 0.2 ± 0.5 (BR))·10^{-5}

(almost 5 sigma observation)

B_s Oscillations

Tevatron only place to observe B_s oscillations until LHC

Difficult measurement (give CDF prospects first):

Current conditions: Use fully rec. $Bs \to Ds\pi$

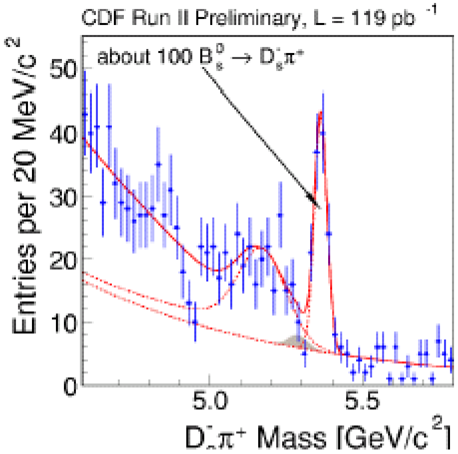
- $S = 1600$ events/fb^{-1}
- $S/B = 2/1$
- $\varepsilon D^2 = 4$ % (SLT+SST+JQT)
- σ_t=67 fs

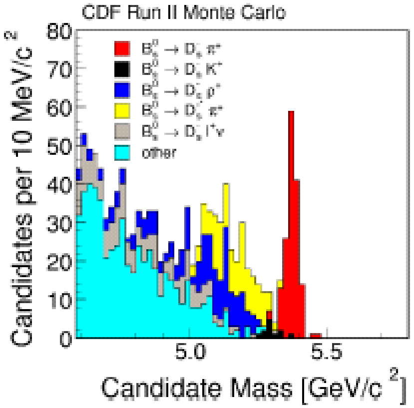
Short term: 500 pb^{-1} (no improvement up to 2005)

- 2σ (for $\Delta m_s = 15$ ps^{-1})
- Reach the current indirect limit.
- Cover the Standard Model favored range

Beyond SM favoured range (conserv. improvements)

- $5\,\sigma$ if $\Delta m_s = 18$ ps^{-1} with 1.8 fb^{-1}
- $5\,\sigma$ if $\Delta m_s = 24$ ps^{-1} with 3.2 fb^{-1}





CDF & D0 work towards B_s mixing with high priority

K with π

p

d

He

Λ with nuclei

50 years of Hypernuclear Physics

The 1st round

1953 Discovery of Λ hypernuclei
Emulsion detectors --- CERN PS, BNL AGS K^- beam

→ **Λ potential depth about 1/2**

The 2nd round

First Counter Experiments CERN & BNL
1973 Stopped (K^-,π^-) at CERN
1974 in-flight (K^-,π^-) at CERN PS and BNL AGS

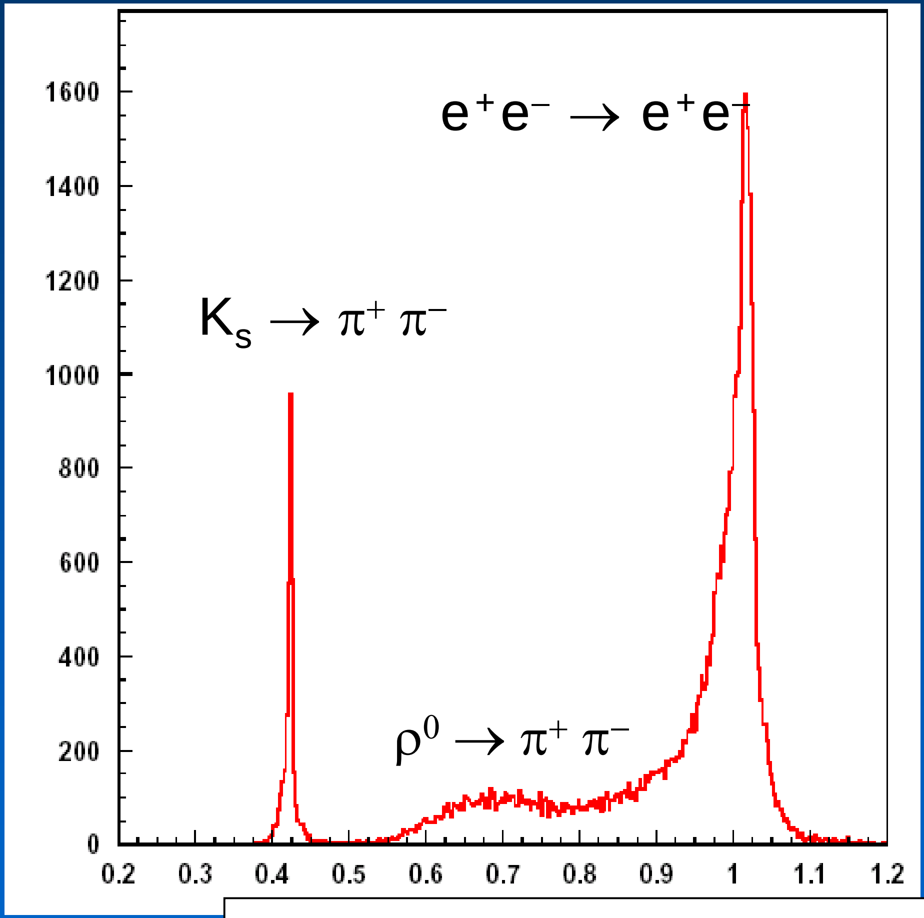
→ **very small spin-orbit splitting**

The 3rd round

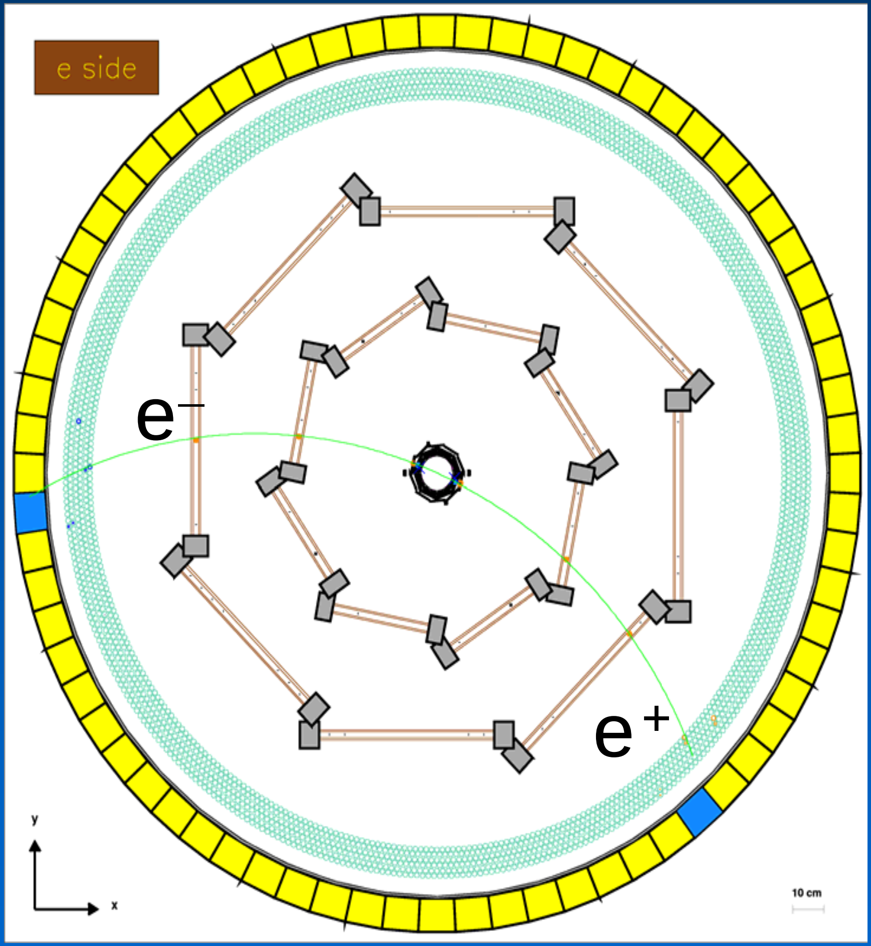
New reactions with New Detectors
1985 (π^+,K^+) started at AGS
1990 S=-2 searches at AGS and KEK (Emulsion-counter hybrid technique)
1993 S=-1 Λ Spectroscopy, Weak decay, SKS spectrometer
1998 γ ray spectroscopy (Hyperball)

→ **ΛN potential definition**
Γ_n/Γ_p puzzle in the non-mesonic decays ← **Solved!**

FINUDA performances: Bhabha event



e^+e^- invariant mass (GeV/c)



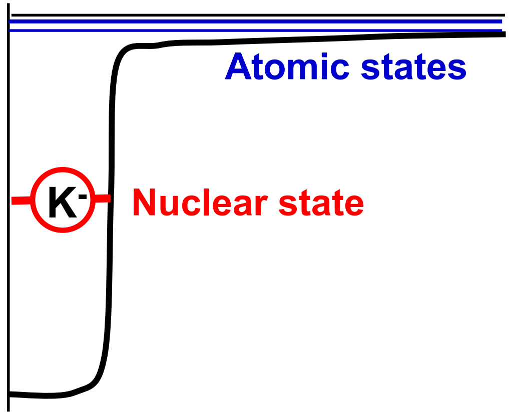
First results on hyper-nuclear spectroscopy from the FINUDA experiment at DAΦNE

Congratulations

DAΦNE04
June 8, 2004

Deeply-Bound $\bar{K}$-Nuclear States

A new paradigm in Nuclear Physics



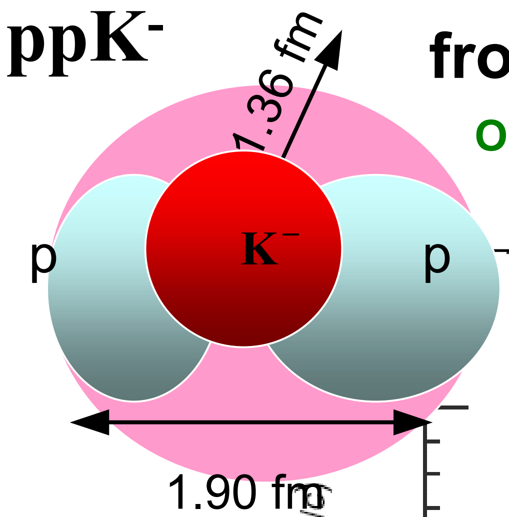
Yoshinori AKAISHI
Akinobu DOTE
Toshimitsu YAMAZAKI

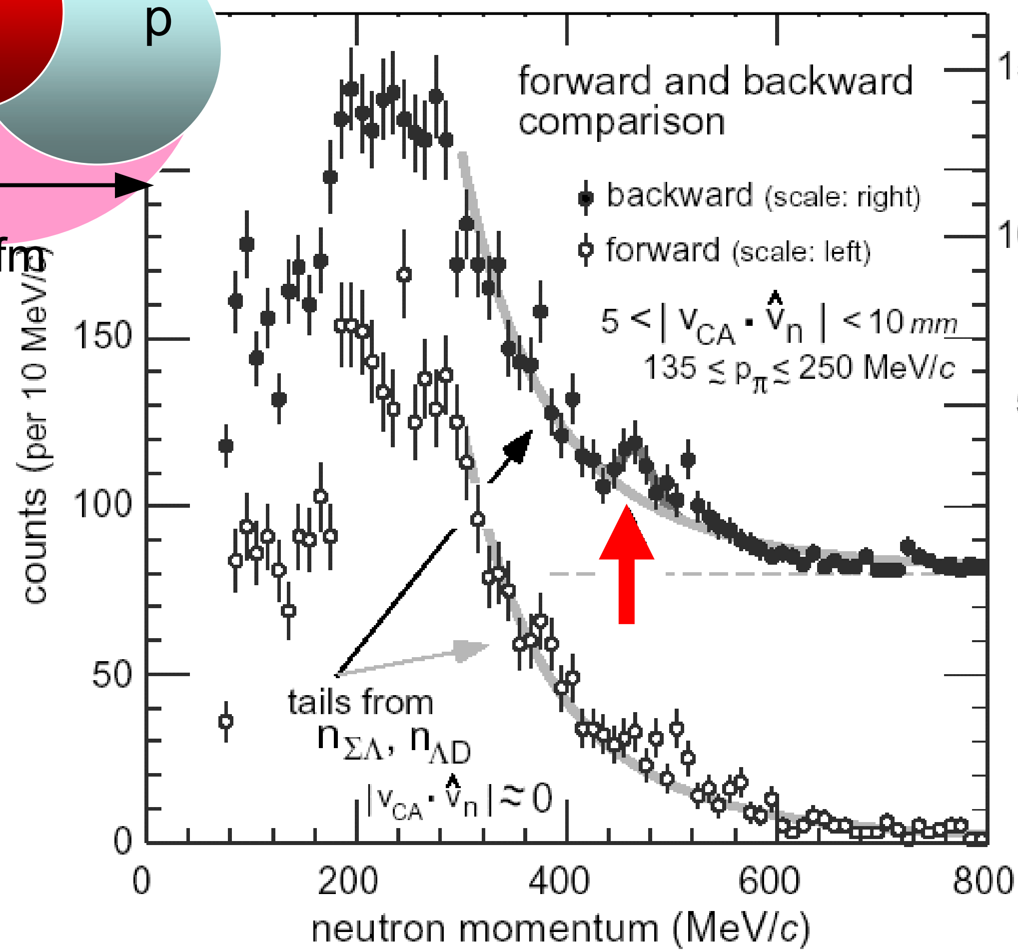
Evidence for K^-ppn

from ^4He(stopped K^-,n)

Oct.16, 2003 M. Iwasaki et al.

nucl-ex/0310018





M. Iwasaki
T. Suzuki
H. Bhang
G. Franklin
K. Gomikawa
R.S. Hayano
T. Hayashi
K. Ishikawa
S. Ishimoto
K. Itahashi
T. Katayama
Y. Kondo
Y. Matsuda
T. Nakamura
S. Okada
H. Outa
B. Quinn
M. Sato
M. Shindo
H. So
T. Sugimoto
P. Strasser
K. Suzuki
S. Suzuki
D. Tomono
A.M. Vinodkumar
E. Widmann
T. Yamazaki
T. Yoneyama

Concluding Remarks

Very interesting!

Nuclear $\bar{K}$ bound state

$\bar{K}$ behaves as a "contractor".

Mini strange matter

A new means to investigate
hadron dynamics in dense&cold matter

Formation/Decay-channel spectroscopies

Chiral restoration?
Color superconductivity?
Kaon condensation?
Strange hadronic/quark matter?

Few-body $\bar{K}$ nuclear systems would provide experimental data of fundamental importance for hadron physics with strangeness.

DAΦNE
SPring-8
J-Lab
GSI
J-PARC

Purpose

Weak decay mode of Λ hypernucleus

$$1/\tau_{HY} = \Gamma_{tot} \begin{cases} \Gamma_m \begin{cases} \Gamma_{\pi^-} \ (\Lambda \rightarrow p + \pi^-) \\ \Gamma_{\pi^0} \ (\Lambda \rightarrow n + \pi^0) \end{cases} \\ \Gamma_{nm} \begin{cases} \Gamma_p \ (\Lambda + p \rightarrow n + p) \\ \Gamma_n \ (\Lambda + n \rightarrow n + n) \\ \Gamma_{2N} \ (\Lambda NN \rightarrow NNN) \ ? \end{cases} \end{cases}$$

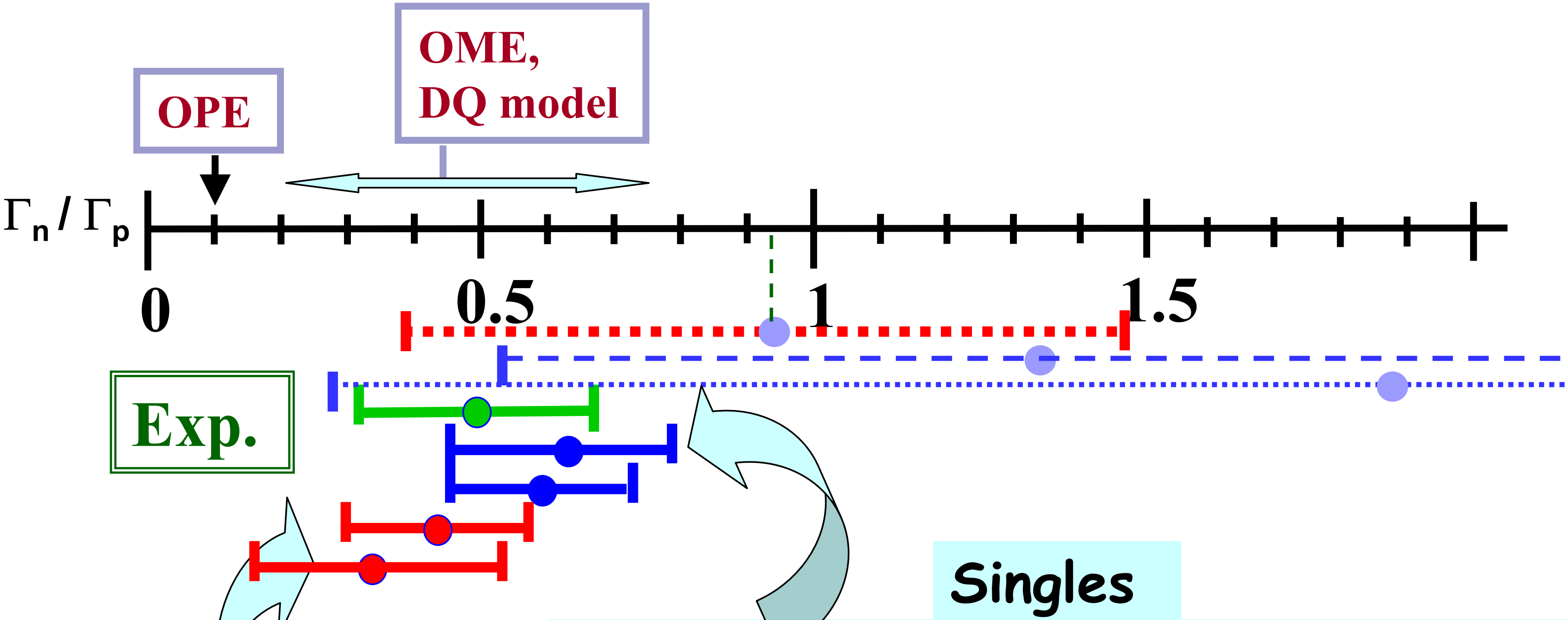
Mesonic
q ~ 100MeV/c

Non Mesonic(NMWD)
q ~ 400MeV/c

Direct determination of the Γ_n/Γ_p ratio !!!!

How to solve a puzzle

Γ_n/Γ_p Status



Singles

$^{5}_{\Lambda}He$: 0.61±0.081±0.082 (E462)

$^{12}_{\Lambda}C$: 0.58±0.06±0.08 (E508)

: (0.45~0.51)±0.15 (E307/E369)

Coincidence

$^{5}_{\Lambda}He$: 0.43 ±0.12 ±0.044±(E462)

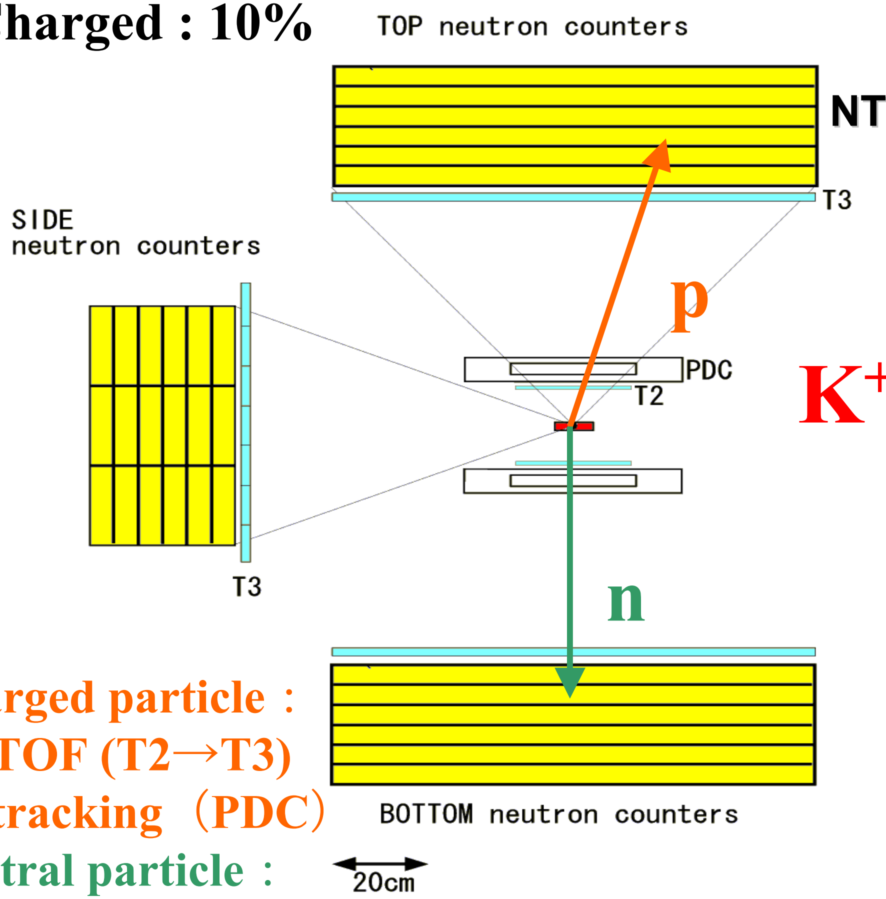
$^{12}_{\Lambda}C$: 0.34 ±0.13 ±0.05 (E508)

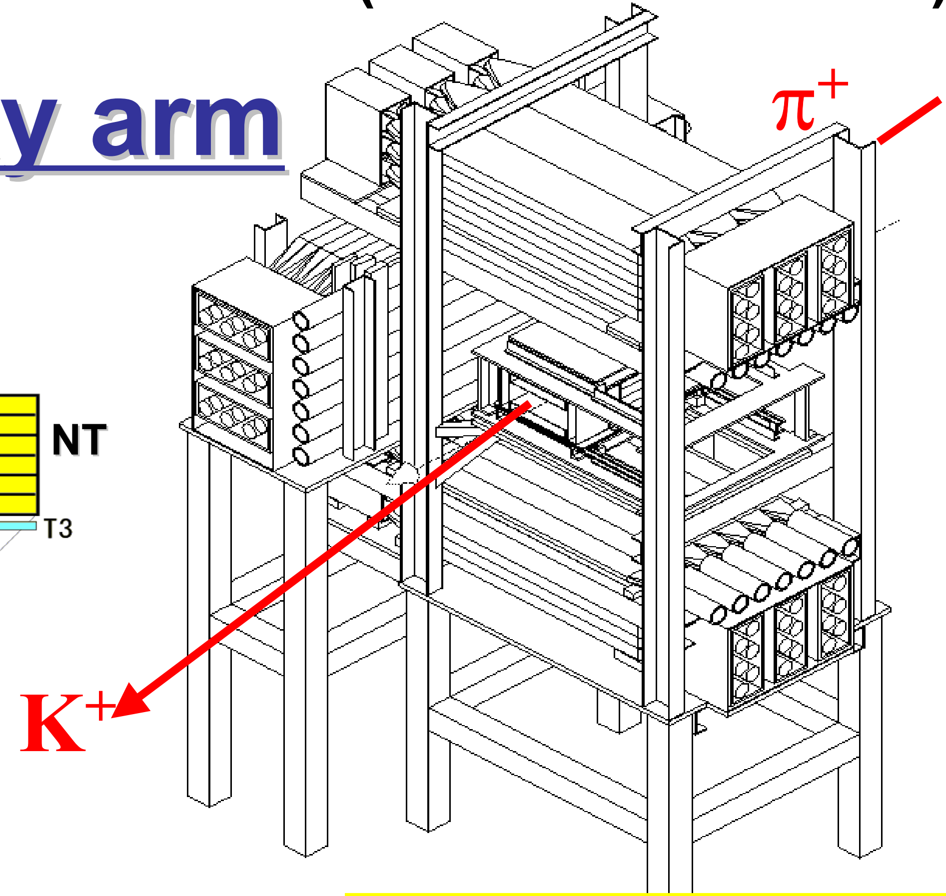
SETUP

Decay arm

(KEK-PS K6 & SKS)

Solid angle
Neutral: 26.5%
Charged : 10%





Charged particle：
- TOF (T2→T3)
- tracking（PDC）

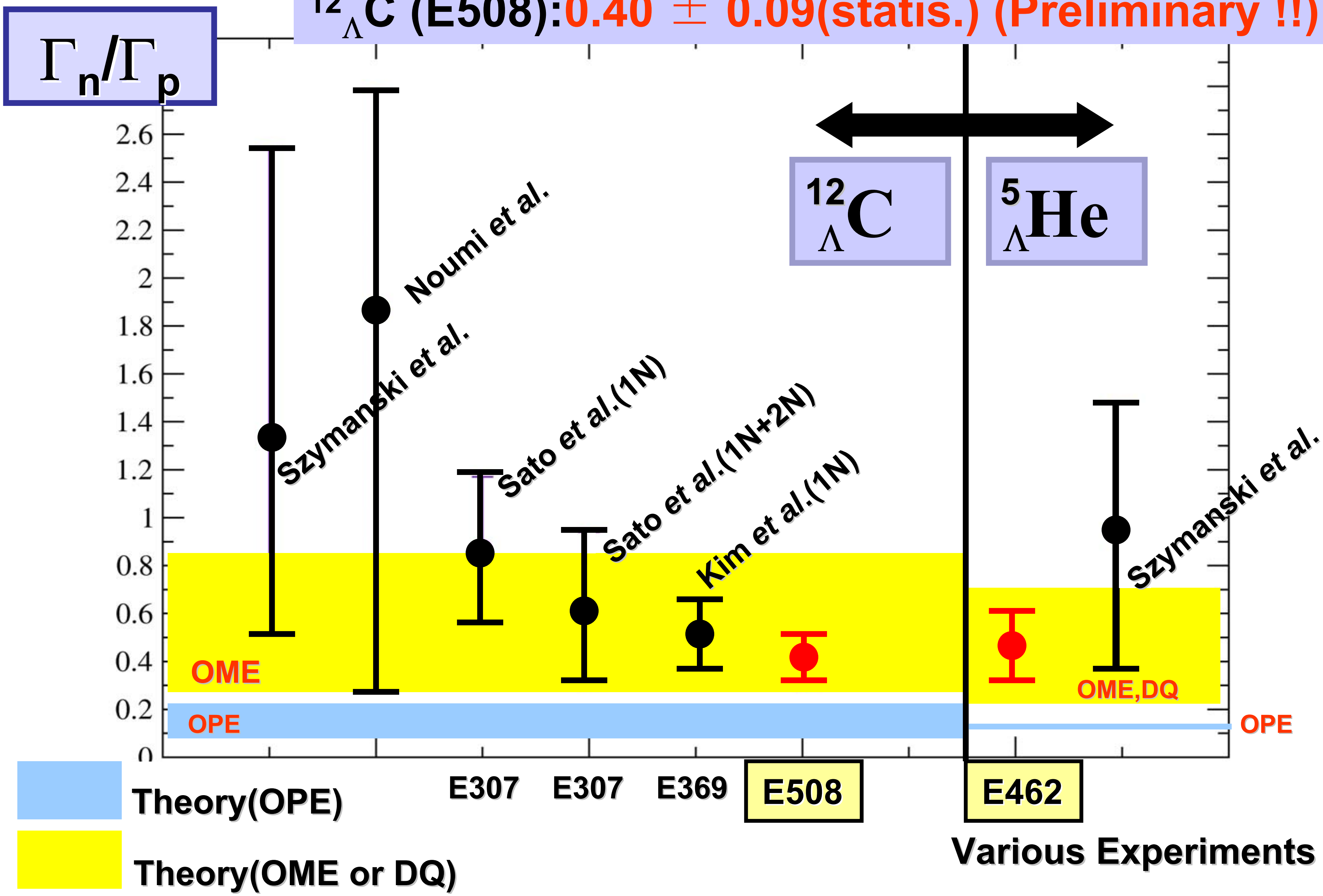
Neutral particle：
- TOF (target→NT)
- T3 VETO

NT: 20cm×100cm×5cm
T3: 10cm×100cm×2cm
T2: 4cm×16cm×0.6cm

Results

$^{5}_{\Lambda}$He (E462): 0.45 ± 0.11 ± 0.04 (Final !!)

$^{12}_{\Lambda}$C (E508): 0.40 ± 0.09(statis.) (Preliminary !!)



Chiral PT and scattering lenght

We wish to confront high precision, low energy QCD predictions with data

Example: $\pi\pi$ scattering lengths

Theory [1]

$a_0 = 0.220 \pm 0.005$

$a_0 - a_2 = 0.265 \pm 0.004$

Experiment ?

K_{e4}	E865 [2]

$a_0 = 0.216 \pm 0.013 \pm 0.002 \pm 0.002$

Pionium	DIRAC [3]
$K_{e4}, K \to 3\pi$	NA48, in progress [4]

---

[1] Colangelo, Gasser, Leutwyler 2000; [2] E865, Brookhaven, 2002,2003; [3] Tauscher, this afternoon; [4] NA48 Workshop 2004; Cabibbo, this conference

1. πK atom DIRAC

   clean case, atom fully understood

   connection with

   - ChPT
   - vacuum properties of QCD

   Theory of $K\pi$ scattering not yet fully worked out [1]. Data lacking

2. Kaonic hydrogen DEAR

   $$\boxed{\Lambda^*}$$

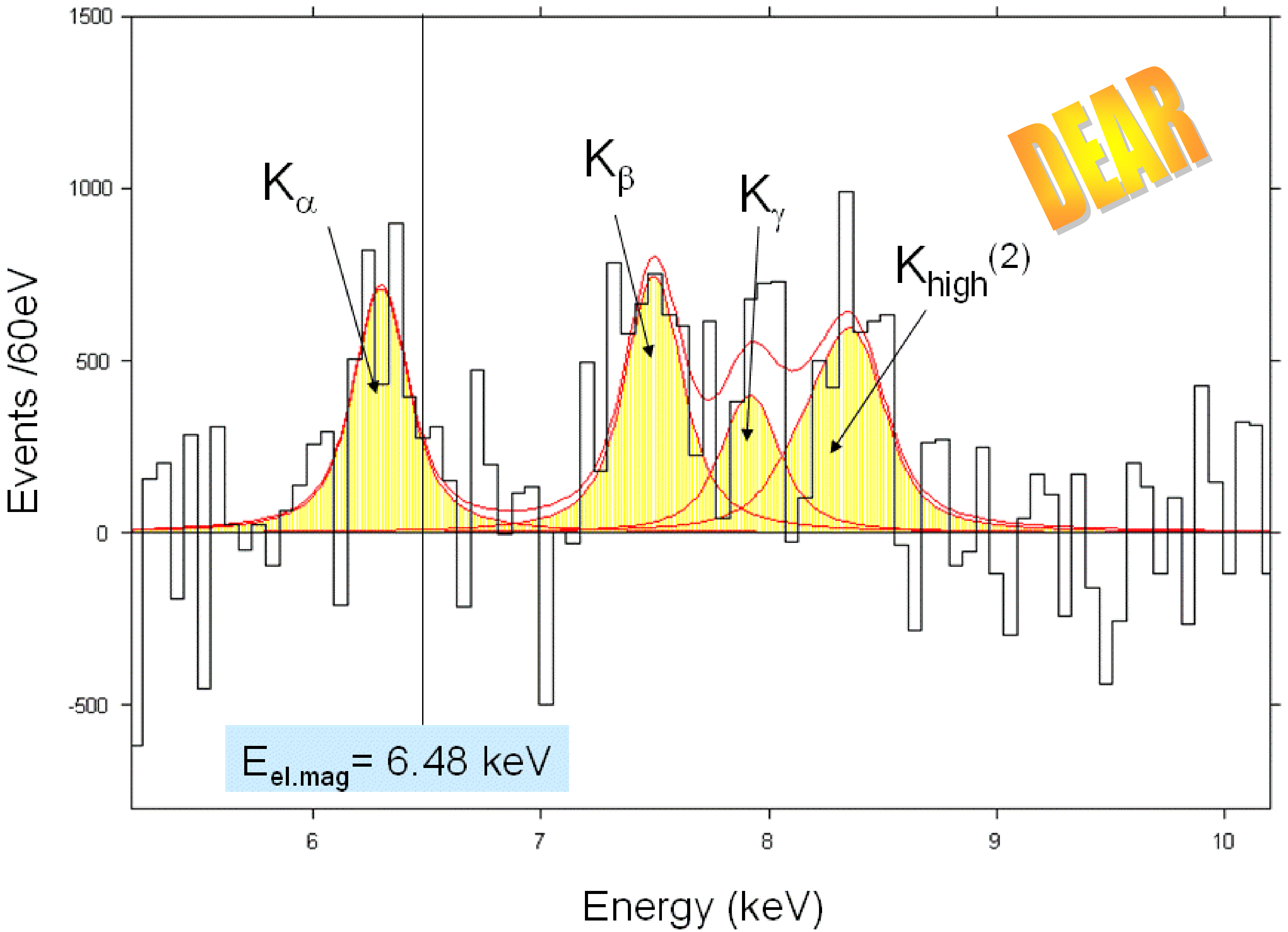
   data available, atom understood. Error analysis in calculation of scattering lengths is missing

   More precise data will reveal whether theory is able to describe the complex situation properly

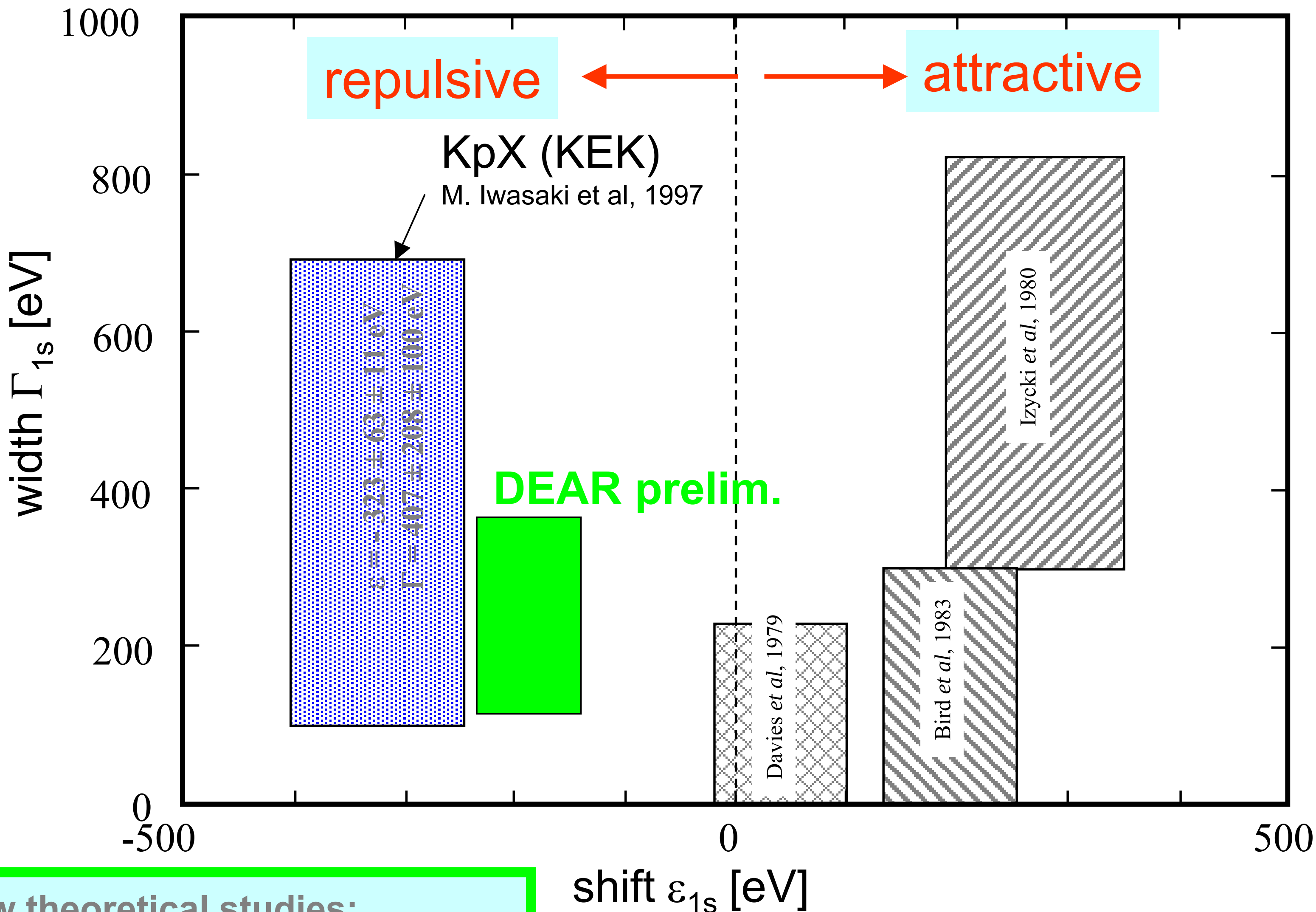
---

[1] Bijnens and Talavera 2004

Resulting K^-p Spectrum
(all background fit-components subtracted)



DEAR Results (preliminary)



New theoretical studies:
Ivanov *et al.* 2003 / 2004
Meißner, Raha, Rusetsky 2004

Results on the Shift and Width

2 independent analyses starting from the raw data
giving consistant results

Combined results => preliminary DEAR average
to be published in Phys.Rev.Lett.

Shift: ε_{1s} = - 194 ± 37 (stat.) ± 6 (syst.) eV

Width: Γ_{1s} = 249 ± 111 (stat.) ± 30 (syst.) eV

→ a_{K^-p} =..

Higher statistic with a better detector

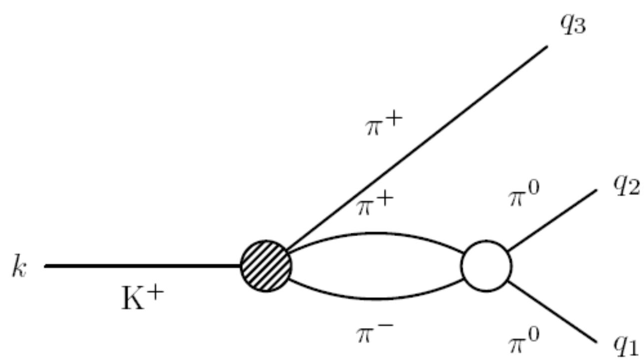
Congratulations !

The $a_0 - a_2$ pion scattering length from $K^+ \to \pi^+\pi^0\pi^0$ decay

Nicola Cabibbo

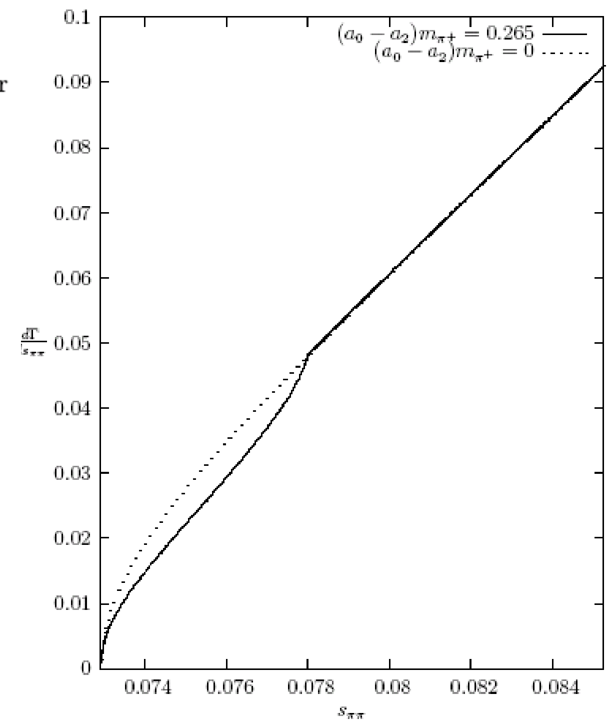
How to measure $a_0 - a_2$ in $K^+ \to \pi^+\pi^0\pi^0$

This is based on the effects of $\pi^+\pi^- \to \pi^0\pi^0$ re-scattering from $K^+ \to \pi^+\pi^+\pi^-$ near the threshold for that reaction.



The method is based on two fundamental properties of the S-matrix:

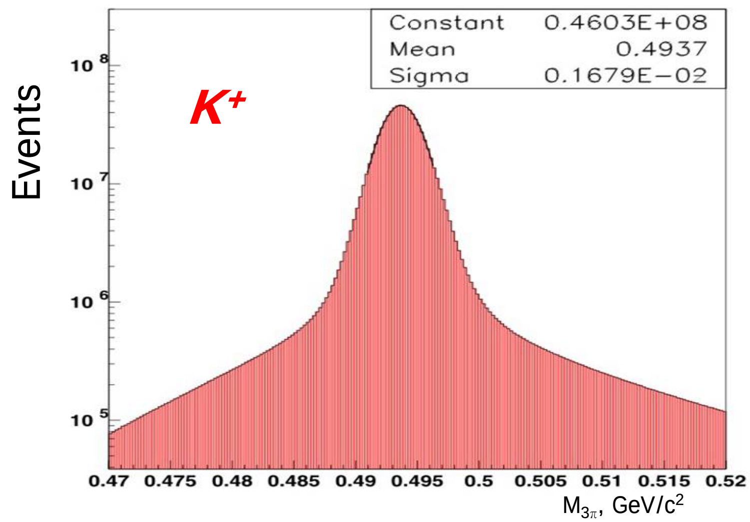
1. Unitarity: $S^\dagger S = 1$
2. Analyticity of the S-matrix elements as a function of the external momenta.

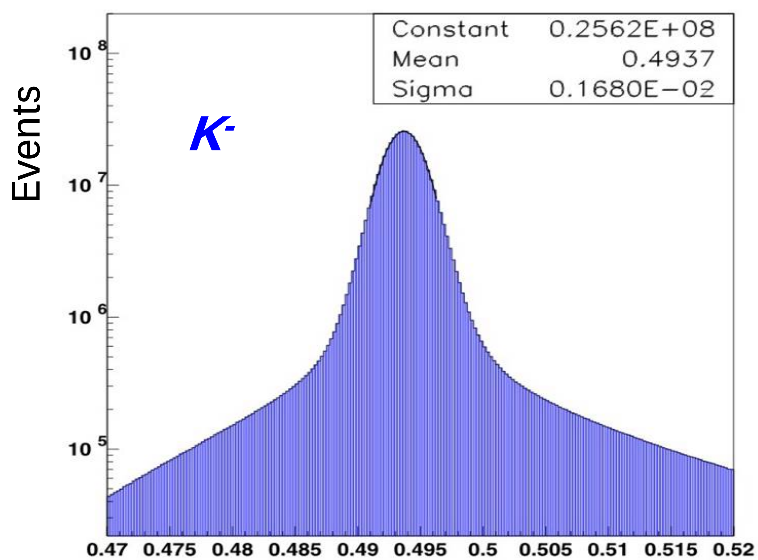


The $s_{\pi\pi}$ invariant mass distribution with/without the re-scattering correction, in arbitrary units.

Kaon spectra and Statistics

$K^{\pm} \Rightarrow \pi^{\pm}\pi^{+}\pi^{-}$





Mass Resolution: *1.7 MeV*

Events per supersample (in 10^6)

	K+	K-	ALL
SS1	310	170	480
SS2	290	160	450
SS3	120	70	190
ALL	720	400	1120

Prospects and space for improvement

- Experimental fit to terms $O(\delta^3)$ in differential rate.
- Compute these terms in Chiral Perturbation Theory
- Compute radiative corrections

The theoretical error can be made very small.
The experimental error can be made very small

In NA48: $>10^8\ K^+ \to \pi^+\pi^0\pi^0$ events,

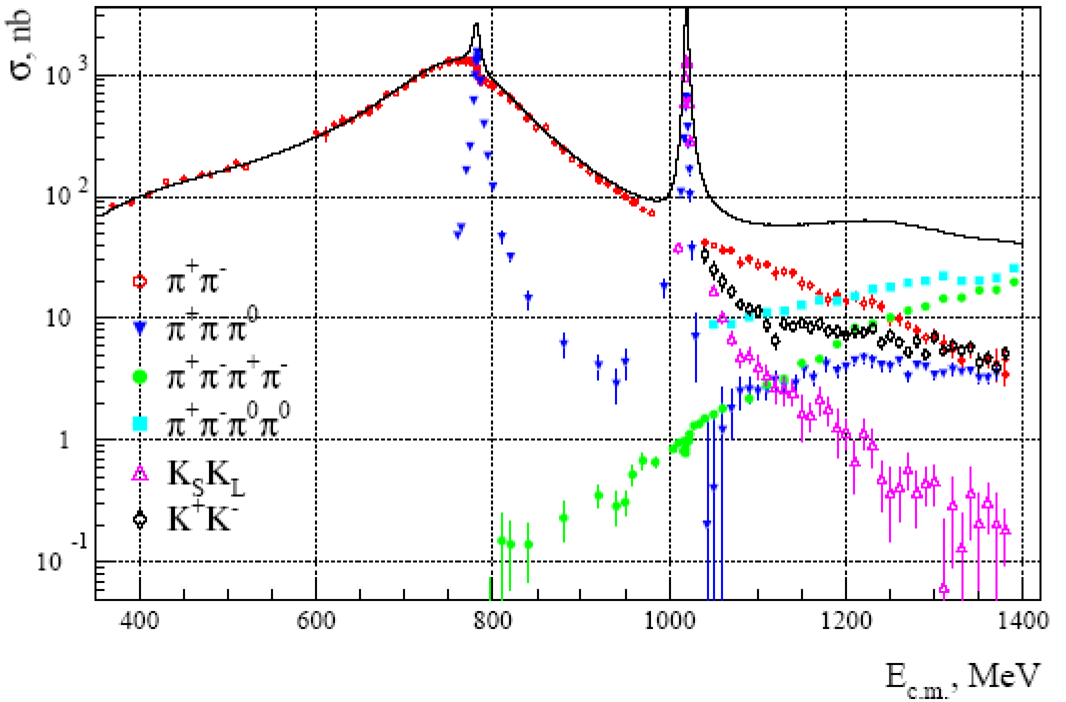
of which 3%, $(> 3 \times 10^6)$ below the $\pi^+\pi^-$ threshold.

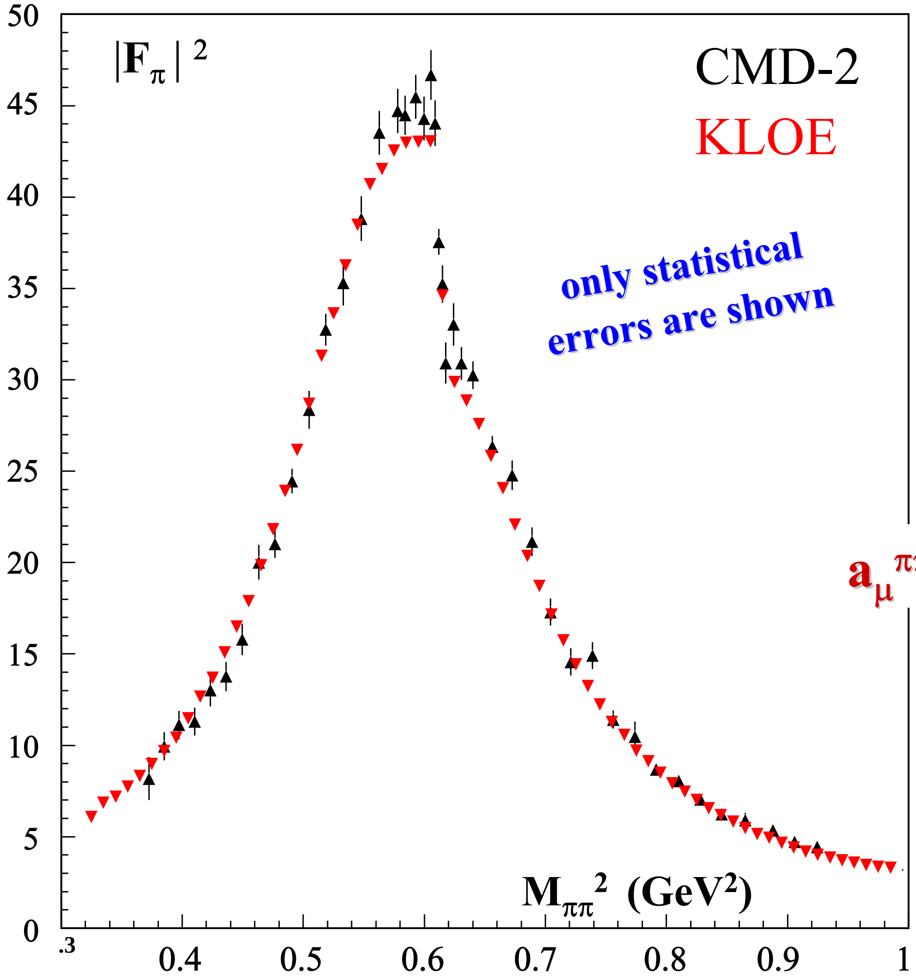
The statistical error on the effect should result $< 1\%$.

..so..be careful…. **Cabibbo has joined NA48…..**
NA48 are striking again!

g-2

Hadronic Cross Sections at CMD-2





Comparison with CMD-2

we have evaluated the
dispersion integral for the ππ channel
in the range $0.35\ GeV^2 < M_{\pi\pi}^2 < 0.95\ GeV^2$

$$a_\mu^{\pi\pi} = (\ 388.7 \pm 0.8_{stat} \pm 3.5_{syst} \pm 3.5_{theo}\ ) \times 10^{-10}$$

KLOE PRELIMINARY

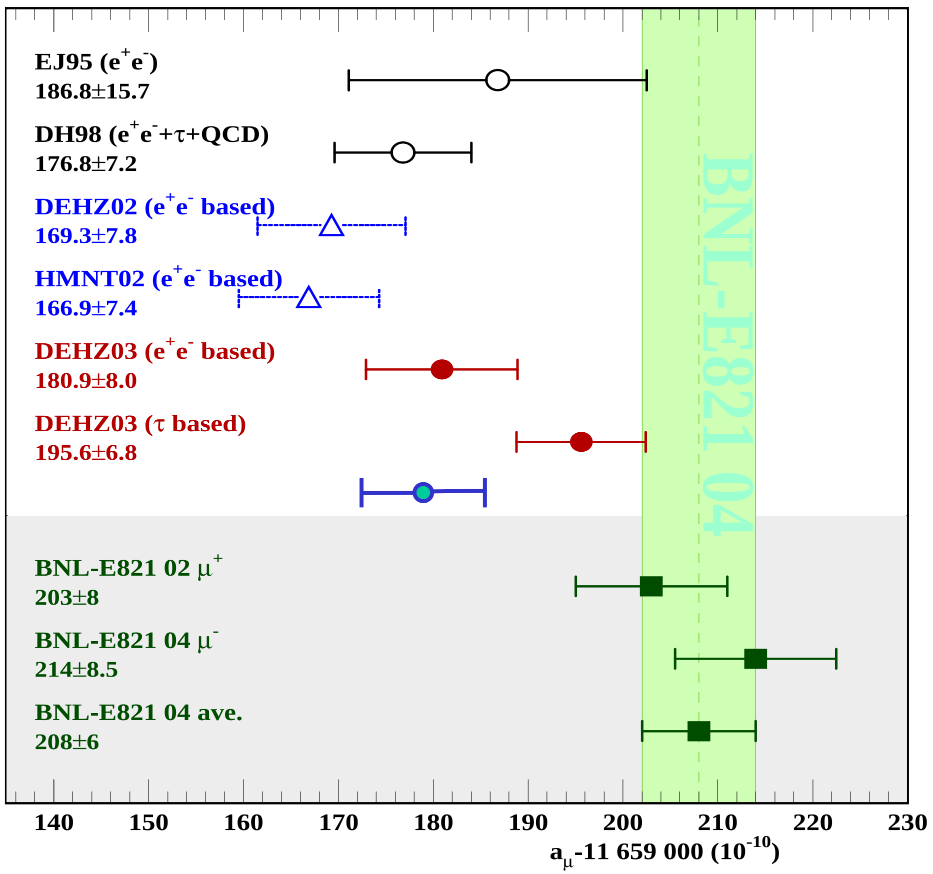
comparison with CMD-2 in the range
$0.37\ GeV^2 < M_{\pi\pi}^2 < 0.93\ GeV^2$

KLOE $a_\mu^{\pi\pi} = (375.6 \pm 0.8_{stat} \pm 4.9_{syst+theo}) \times 10^{-10}$ 1.3% *Error*

CMD-2 $a_\mu^{\pi\pi} = (378.6 \pm 2.7_{stat} \pm 2.3_{syst+theo}) \times 10^{-10}$ 0.9% *Error*

How the plot from M. Davier et al. (2003) modifies…

…including KLOE result



Theory vs Experiment (January 2004)

Contribution	$a_\mu, 10^{-10}$
Experiment	11659208 ± 6
QED	11658470.6 ± 0.3
Electroweak	$15.4 \pm 0.1 \pm 0.2$
Hadronic	694.9 ± 7.9
Theory	11659180.9 ± 8.0
Exp.–Theory	$27.1 \pm 10.0\ (2.7\sigma)$

Recent theory progress: $a_\mu^{\rm exp} - a_\mu^{\rm th} = (20.8 \pm 9.7) \cdot 10^{-10}\ (2.1\sigma)$

How can the theoretical error be improved?

BNL, Muon g-2 Collaboration, 2004
Positive and negative muons combined

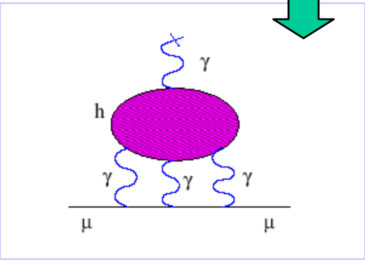
$$a_\mu^{\rm exp} = 11\ 659\ 208(6) \times 10^{-10}\ (0.5\ \text{ppm}).$$

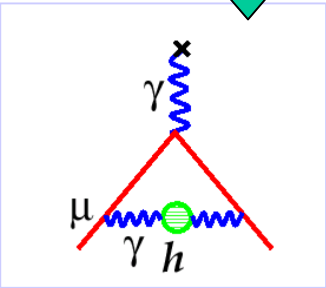
$$\delta^{\rm QED} a_\mu = 11\ 658\ 470.35 \pm 0.28 \times 10^{-10}$$

Electroweak: $(15.4 \pm 0.2) \times 10^{-10}$

Hadron (CMD2 +KLOE): $\delta^{\rm VP}_{\rm had} a_\mu = [(692.4 \pm 6.4)_{\rm lo} - (9.79 \pm 0.095)_{\rm nlo}] \times 10^{-10}$

Light-by-light: $\delta^{\rm lbl}_{\rm had} a_\mu = (8 \pm 4) \times 10^{-10}$





Without electroweak

Ex-theory=37 +- 10

Many new results

A very active field

A very long future

Very clever and dedicated people

Let me have your comments……in a polite way….

..and thanks to the organising committee!

EXOTIC SPECTROSCOPY

Pentaquarks

Five quark state: 4 quarks + 1 anti-quark

flavour (anti-quark) $\neq$ flavour(quarks)

Predicted by Diakonov, Petrov, Polyakov (1997)

States observed so far:

$\Theta^+ : |u\,u\,d\,d\,\bar{s}\rangle$

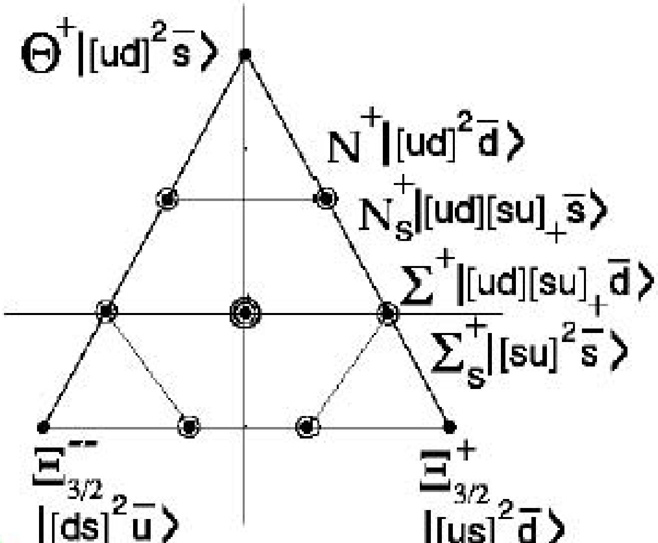
$\Xi^{--} : |s\,s\,d\,d\,\bar{u}\rangle$ $\Xi^0 : |\bar{s}\,\bar{s}\,\bar{d}\,d\,\bar{u}\rangle$

$\Theta_c^0 : |u\,u\,d\,d\,\bar{c}\rangle$

Discuss first: Θ^+

mass ~ 1530 MeV, width < 15 MeV

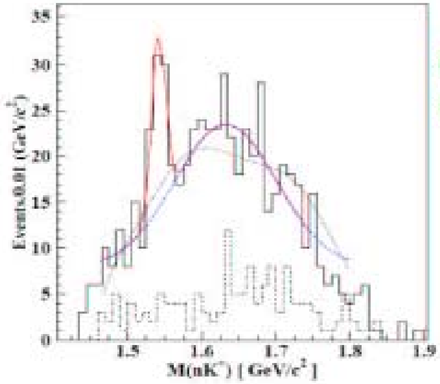
Decays equally to nK^+ and pK^0



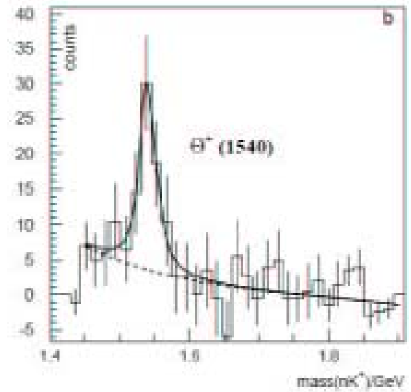
(Jaffe, Wilczek
PRL 91, 232003)

Pentaquarks

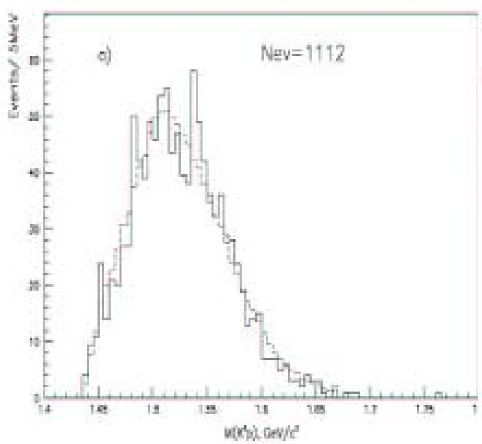
Θ^+: Reported evidence in nK^+



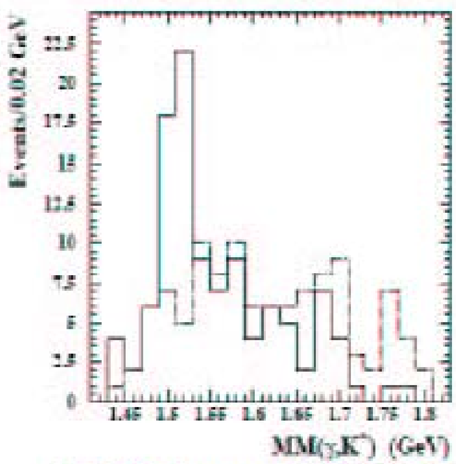
CLAS
hep-ex0307018



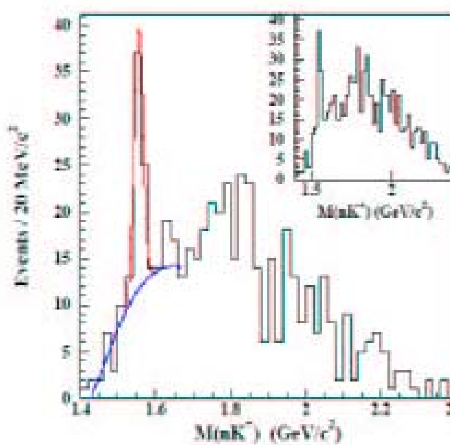
SAPHIR
hep-ex0307083



DIANA hep-ex0304040



LEPS hep-ex0402005

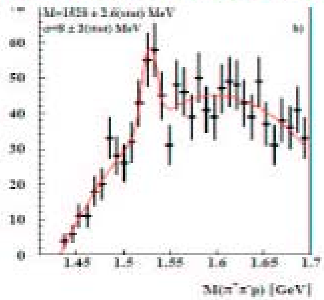


CLAS-2 hep-ex0402005

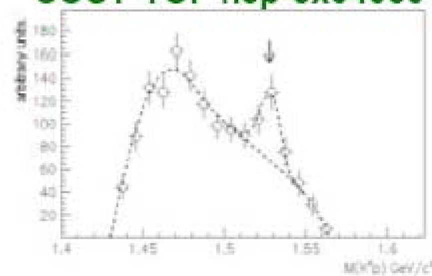
Pentaquarks

Θ^+: Reported evidence in pK^0

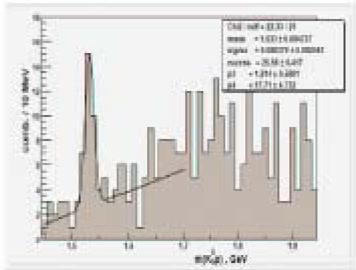
HERMES hep-ex0312044

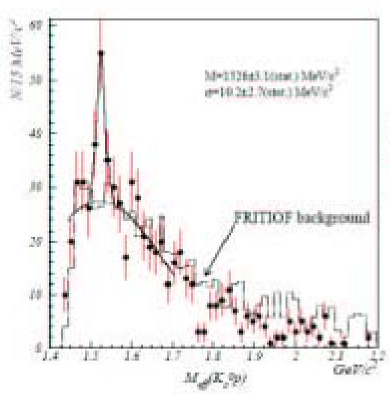


COSY-TOF hep-ex0403011

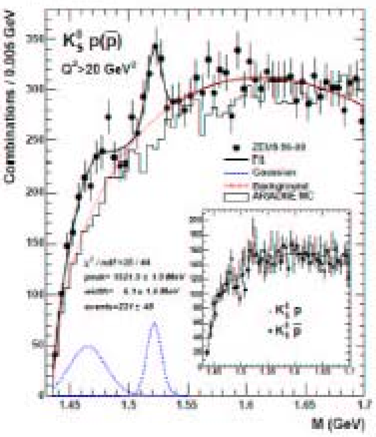


Asratyan et al.hep-ex0309042





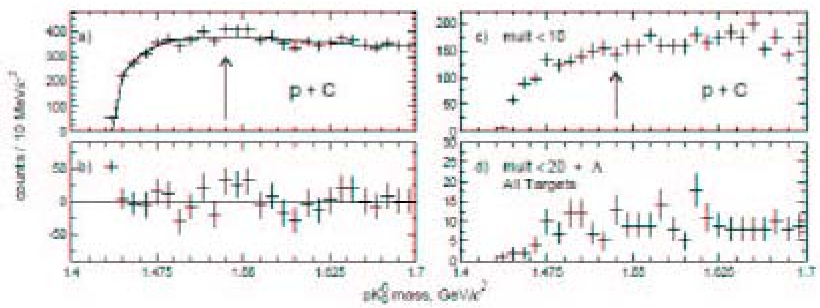
SVD
hep-ex0401024



ZEUS
hep-ex0403051

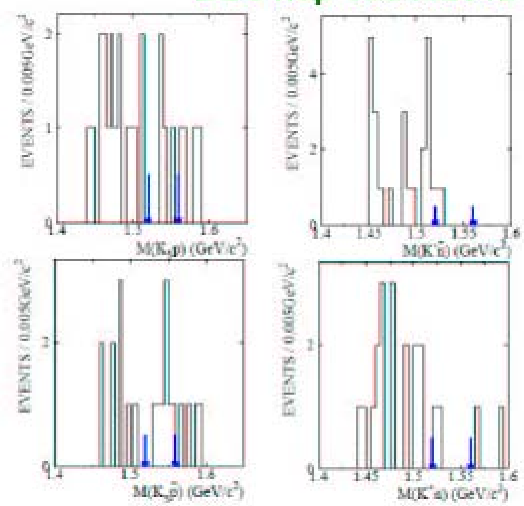
Pentaquarks

Θ^+: Reported negative evidence

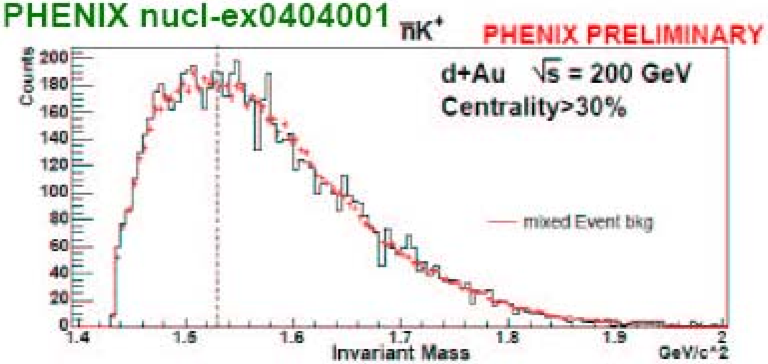


HERA-B hep-ex0403020

BES hep-ex0402012



PHENIX nucl-ex0404001



BaBar at APS (prelim.)