Low-energy $e^+e^- \to$ hadrons cross sections and g-2 of the muon

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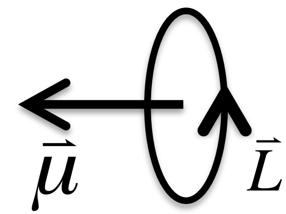
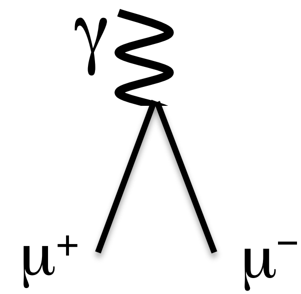
g_μ - 2 in the standard model

- Gyromagnetic ratio g: $\vec{\mu} = g\frac{e}{2mc}\vec{s}$



→ The relationship between angular momentum L (or s) and magnetic moment μ



- Dirac (tree-level) result for a charged lepton l: $g_l = 2$ (exactly)
- Radiative corrections alter the prediction: $g_l = 2\,(1 + a_l)$, introducing sensitivity to new physics through loops
- The "anomalous" moment $a_l = \frac{g_l - 2}{2}$

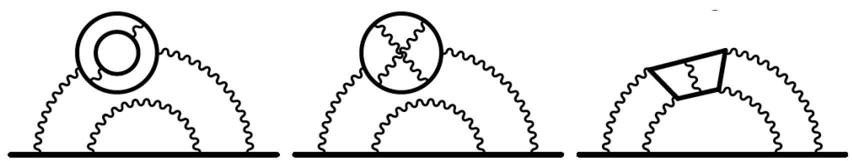
The muon anomaly a_μ is much more sensitive to virtual heavy particle production in loops than the electron anomaly a_e: the relative virtual terms scale like $(m_\mu/m_e)^2 \approx 43{,}000$

g_μ - 2 in the standard model

In the standard model, $a_\mu = a_\mu^{QED} + a_\mu^{EW} + a_\mu^{hadronic}$

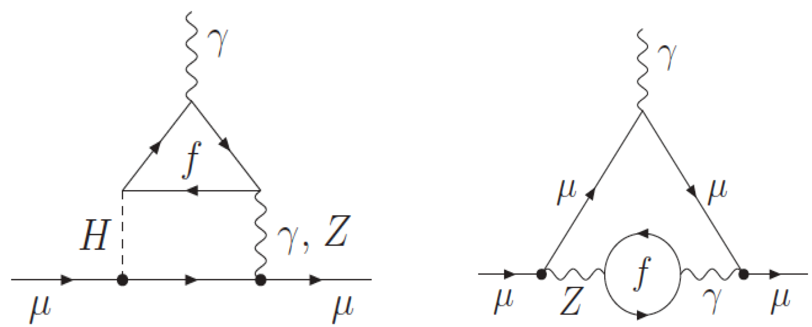
$$a_\mu^{QED} = 116\,584\,718.951 \pm 0.080 \times 10^{-11}$$

Aoyama, Hayakawa, Kinoshita, Nio;
PRL 109 (2012) 111808



Calculations up to 10th order in α_{QED}

$$a_\mu^{EW} = 153.6 \pm 1.0 \times 10^{-11}$$

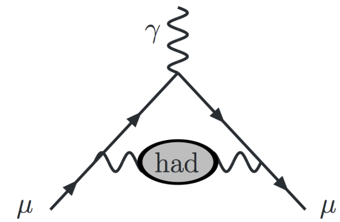


Gnendiger et al., PRD88 (2013) 053005

g_μ - 2 in the standard model

$$a_\mu^{hadronic} = a_\mu^{had,LO-VP} + a_\mu^{had,NLO-VP} + a_\mu^{had,LbLS}$$

Leading-order hadronic vacuum polarization



$$a_\mu^{had,LO-VP} = 6923 \pm 42 \times 10^{-11}$$

Davier et al., EPJC71 (2011) 1515

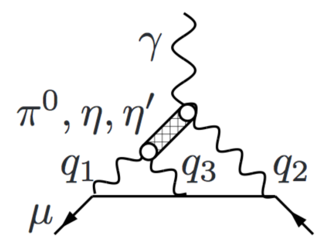
[$6949 \pm 43 \times 10^{-11}$: Hagiwara et al., J. Phys. G38 (2011) 085003]

Higher-order hadronic vacuum polarization

$$a_\mu^{had,HO-VP} = -98.4 \pm 0.7 \times 10^{-11}$$

Hagiwara et al., J. Phys. G38 (2011) 085003

Light-by-light scattering



$$a_\mu^{had,LbLS} = 105 \pm 26$$

Prades et al., arXiv:0901.0306 (2009)

Diagrams from Jegerlehner and Nyffeler, Phys. Rept. 477 (2009) 1

g_μ - 2 in the standard model

Summary: individual SM contributions:

a_μ^{QED}	116584718.951 ± 0.080
a_μ^{EW}	153.6 ± 1.0
$a_\mu^{had,LO-VP}$	6923 ± 42
$a_\mu^{had,HO-VP}$	-98.4 ± 0.7
$a_\mu^{had,LbLs}$	105 ± 26

all in units of 10^{-11}

Total SM prediction compared to measurement

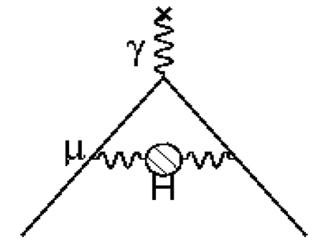
$a_\mu^{total-SM}$	116591802 ± 49
$a_\mu^{BNL-E821}$	116592089 ± 63
Data - SM	287 ± 80

Davier et al., EPJC71 (2011) 1515

- 3.6 σ difference between data and SM prediction (3.3 σ with Hagiwara et al. result for $a_\mu^{had,LO-VP}$)
- Uncertainty in the SM prediction dominated by LO-VP term

LO hadronic vacuum polarization term $a_\mu^{had,LO-VP}$

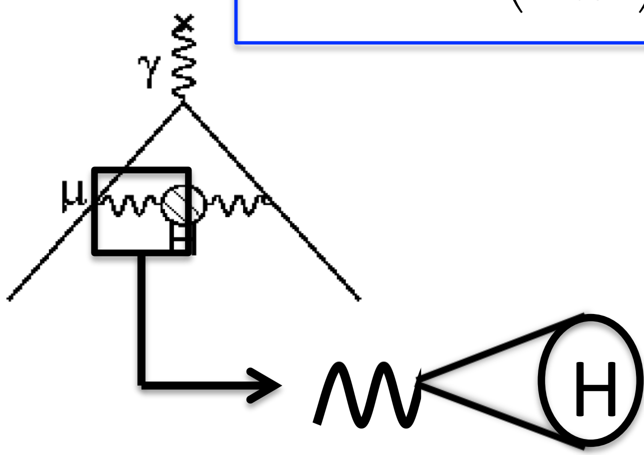
- Energy scale too low for perturbative calculations
- Lattice calculations not yet adequately precise
  [M Della Morte et al., JHEP 1203 (2012) 055]
- The most precise result for $a_\mu^{had,LO-VP}$ obtained from low-energy $e^+e^- \rightarrow$ *hadrons* data and an integral over a dispersion relation



$$a_\mu^{had,LO-VP} = \left(\frac{\alpha m_\mu}{3\pi}\right)^2 \int_{m_\pi^2}^{\infty} \frac{K(s)R_{had}}{s^2}\,ds \qquad R_{had} = \frac{\sigma(e^+e^- \rightarrow hadrons)}{\sigma(e^+e^- \rightarrow \mu^+\mu^-)}$$

$$K(s) = \text{kinematic factor}$$

see Phys. Rep. 477 (2009) 1



$e^+e^- \rightarrow$ hadrons production through a photon coupling

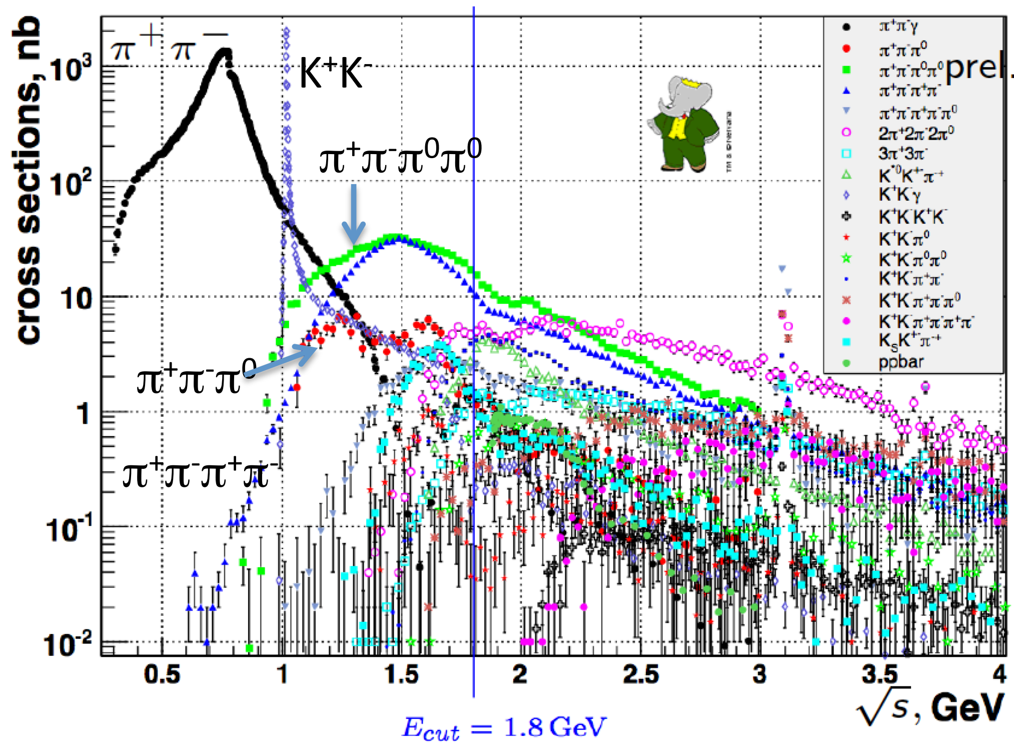
- $1/s^2$ term → low-energy contributions dominate
- Need precise measurements of R_{had} at low $\sqrt{s}$
- Use sum of exclusive channels for E < 2 GeV: background to inclusive channel from $e^+e^- \rightarrow e^+e^-$ and $e^+e^- \rightarrow \mu^+\mu^-$ events very large & inclusive detection efficiency not precise below 2 GeV [generic MC (Jetset) doesn't work]
- Perturbative calculation or inclusive $\sigma(e^+e^- \rightarrow$ *hadrons*) data used for E > 2 GeV

LO hadronic vacuum polarization term $a_\mu^{had,LO-VP}$

Channels contributing the largest <u>uncertainty</u> in $a_\mu^{had,LO-VP}$: $\Delta a_\mu^{had,LO-VP}$

	Channel	$\Delta a_\mu^{had,LO-VP}$ ($\times 10^{-11}$)
*	$\pi^+\pi^-$	28
*	$\pi^+\pi^-\pi^0$	15
	$\pi^+\pi^-\pi^0\pi^0$	12
*	K^+K^-	7
	$\pi^+\pi^-\pi^+\pi^-$	5
*	$KK\pi\pi$	4
*	K_SK_L	4

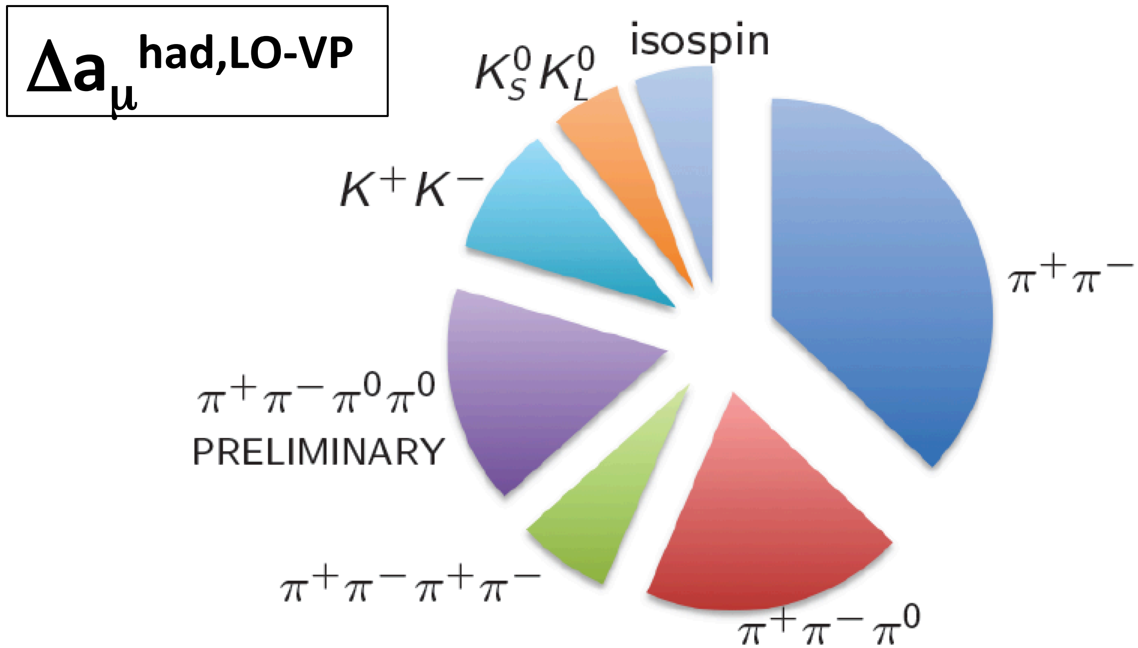
[Davier et al., EPJC71 (2011) 1515]



- Contribution of the $\pi^+\pi^-$ state to the dispersion integral: 75%
- The 3π, 4π, and KK channels the next most important
- Final states with kaons important above the ϕ mass

* New results shown below (but not yet accounted for in $a_\mu^{had,LO-VP}$)

Relative contributions of different channels to the uncertainty in $a_\mu^{had,LO-VP}$



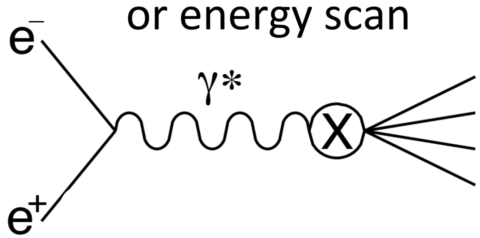
"Isospin" refers to unmeasured processes, with cross sections estimated using isospin relations: largest contributions are $KK\pi$ and $KK\pi\pi$

From Andreas Hafner (Moriond 2015), using results from Davier et al., EPJC71 (2011) 1515

Partial list of experiments: R_{had} at $\sqrt{s} < 2$ GeV

Experiment	Collider	Location	Energy range
KLOE	DAϕNE	Frascati	1.02 GeV
DM1. DM2	DCI	Orsay	1.35-2.4 GeV
CMD2, SND	VEPP-2M	Novosibirsk	0.4-1.4 GeV
CMD3, SND	VEPP-2000	Novosibirsk	0.3-2 GeV
BESIII	BEPC-II	IHEP, Beijing	2-4.6 GeV
CLEO-c	CESR	Cornell	3.67-4.17 GeV
Babar	PEP-II	SLAC	10.6 GeV

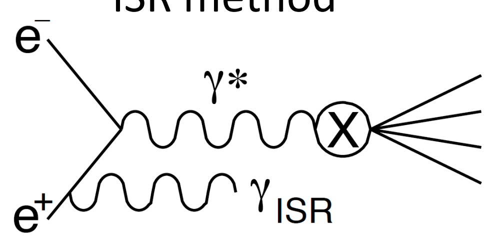
Single fixed energy
or energy scan



CMD3, SND, BESIII

or

ISR method

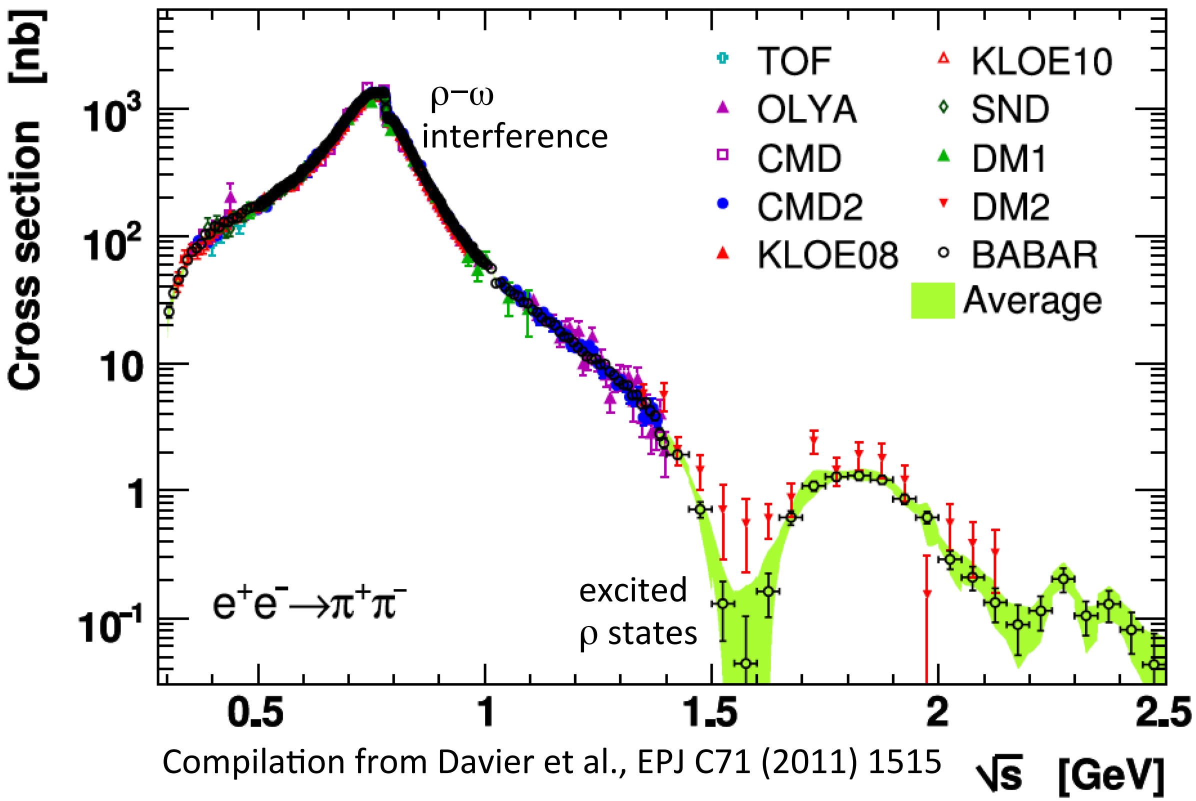


KLOE, BESIII, Babar

Measure σ ($e^+e^- \to X$)
versus $m_{\gamma*} = m_X = \sqrt{s'}$

Current status of published results: $e^+e^- \rightarrow \pi^+\pi^-$

Most precise published $e^+e^- \rightarrow \pi^+\pi^-$ measurements: Babar & KLOE



Compilation from Davier et al., EPJ C71 (2011) 1515

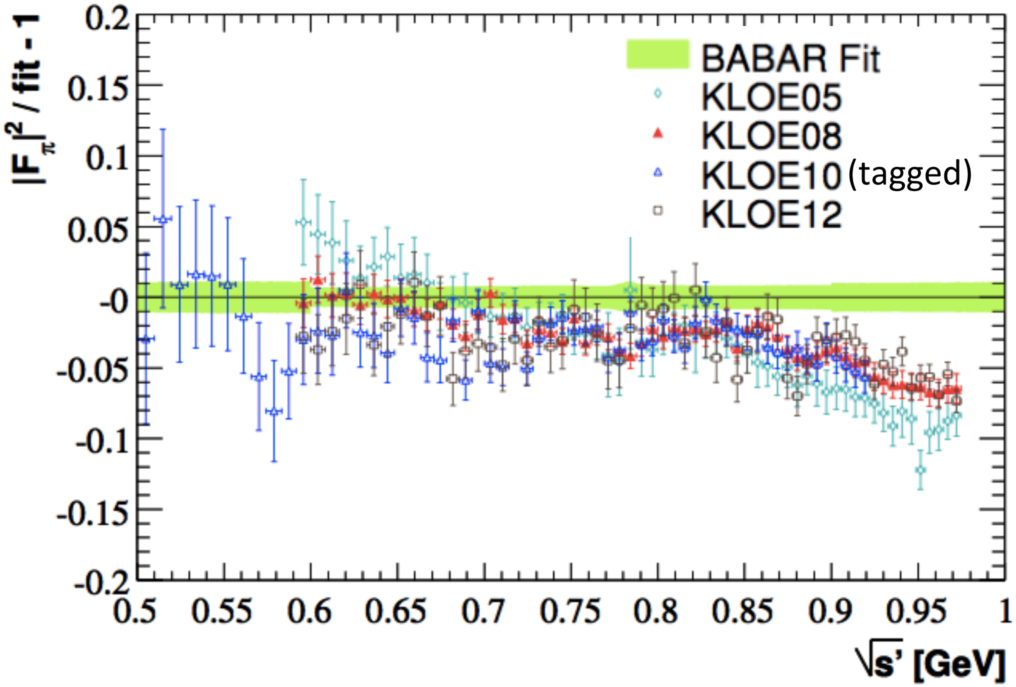
Babar:
PRL 103 (2009) 231801
PRD 86 (2012) 032013
large angle ISR = tagged

KLOE:
PLB606 (2005) 12 [2001 data]
PLB 670 (2009) 285 [2002 data]
PLB 720 (2013) 336 [2002 data]
small angle ISR = untagged

PLB 700 (2011) 102
large angle ISR [2006 data]

Signal MC (Babar): AfkQed [based on Czyż & Kühn, EPJ C18 (2001) 497]
(KLOE 2013): Phokhara [Czyż, Grzelinska, Kühn, & Rodrigo, EPJ C39 (2005) 411

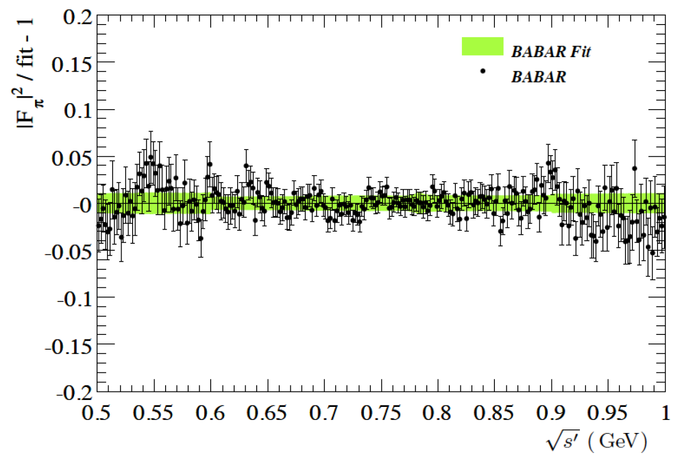
Current status of published results: $e^+e^- \to \pi^+\pi^-$



π^+ form factor:

$$|F_\pi|^2(s') = \frac{3s'}{\pi\alpha^2(0)\beta_\pi^3}\,\sigma_{\pi\pi}(s')$$

β_π = pion speed



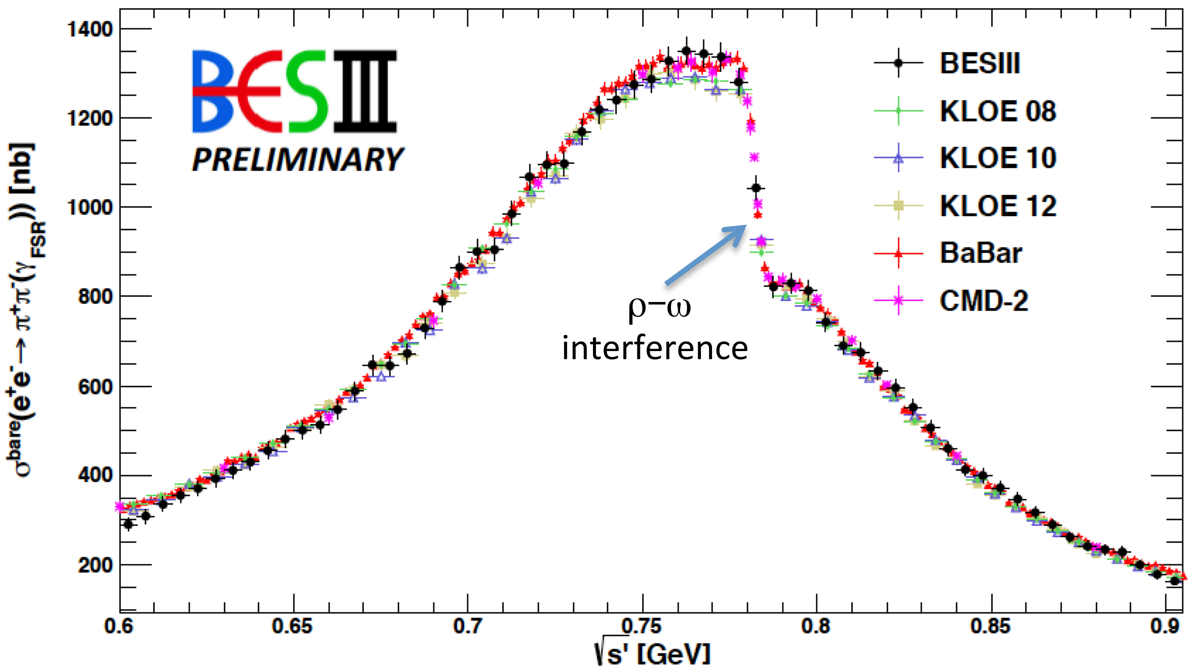
The Babar and KLOE measurements are consistent below the ρ resonance, but differ by up to ~6% at for √s' > m_ρ

→ An important source of remaining uncertainty for $e^+e^- \to \pi^+\pi^-$ and thus for the SM prediction of $a_\mu^{had,LO-VP}$

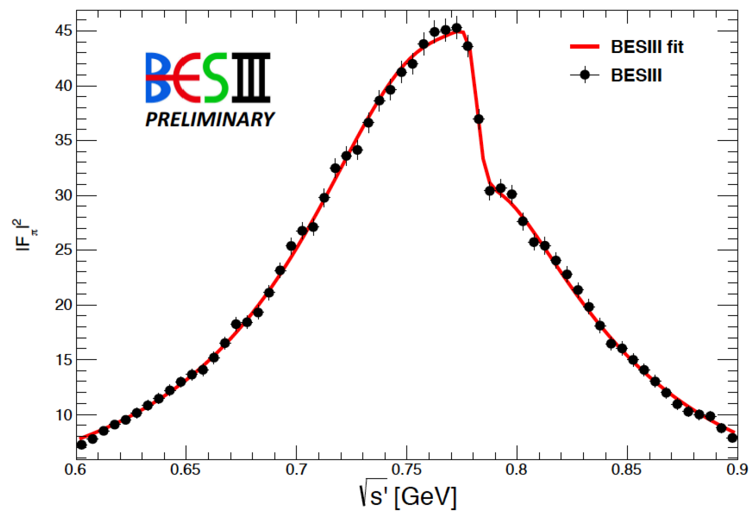
→ Need new precise data to resolve the discrepancy

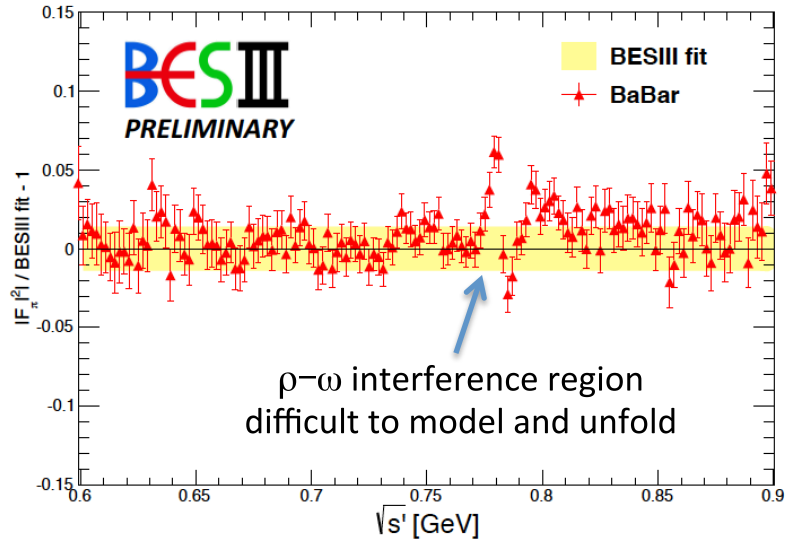
BESIII: $e^+e^- \to \pi^+\pi^-$

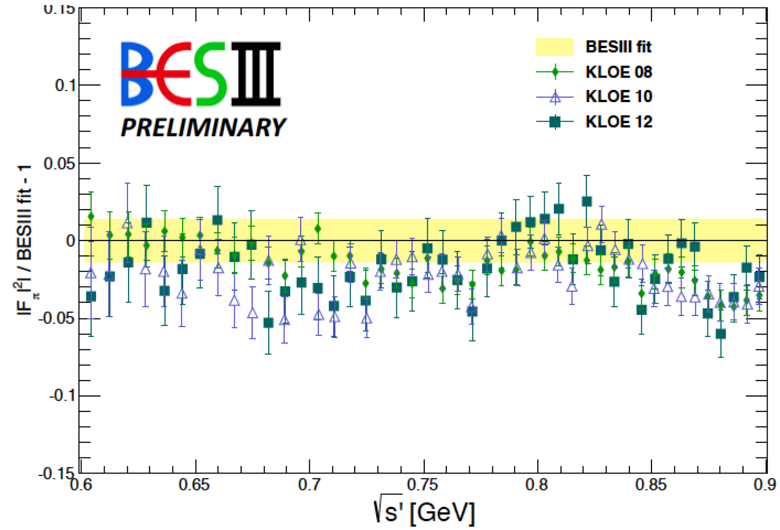
- New results from BESIII ! (preliminary)
- $e^+e^- \to \pi^+\pi^-\gamma_{ISR}$ data at $\sqrt{s'}$ = 0.6 - 0.9 GeV collected at the $\psi(3770)$ resonance with the ISR technique (tagged ISR photons)
- Ldt = 2.9 fb^{-1} (of around 9 fb^{-1} collected between 2.1 and 4.6 GeV)



BESIII: $e^+e^- \rightarrow \pi^+\pi^-$



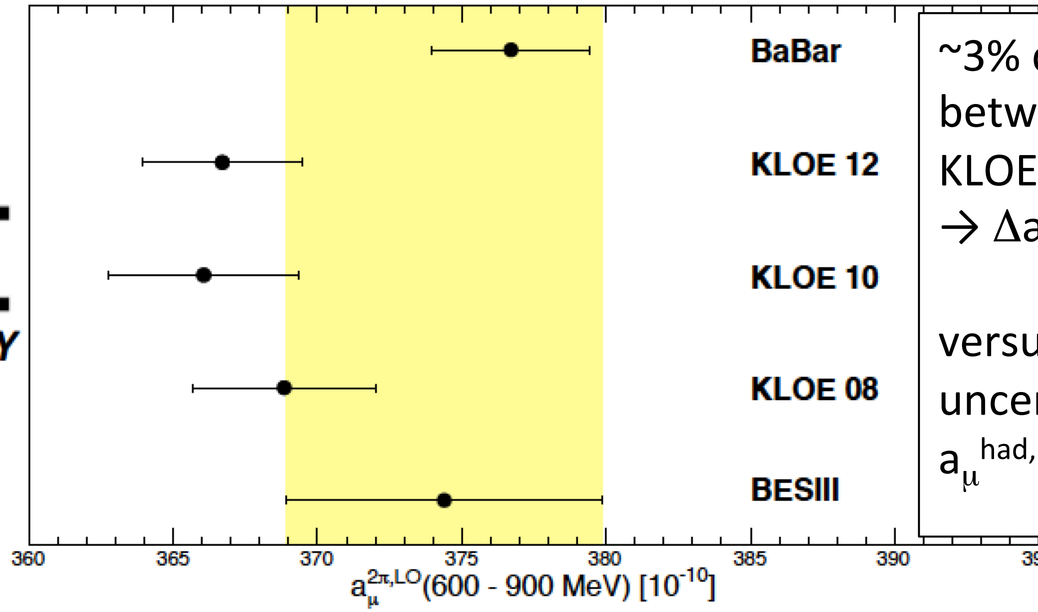




- BESIII data agree well with Babar below the ρ peak; lie slightly below Babar above m_ρ
- BESIII data lie above the KLOE data over the full energy range by about one standard deviation

BESIII: $e^+e^- \rightarrow \pi^+\pi^-$

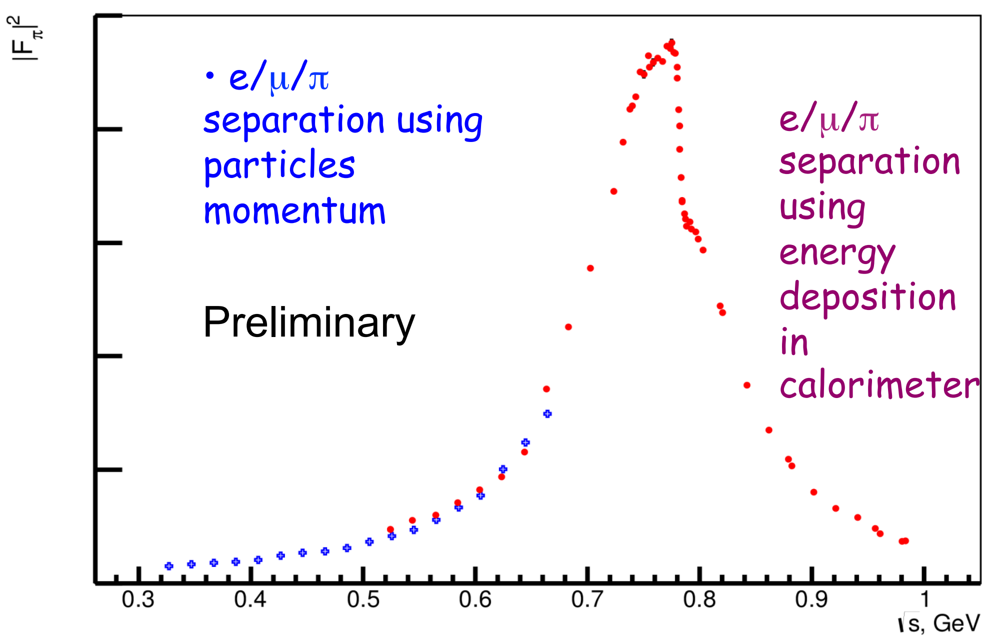
PRELIMINARY



~3% difference between Babar and KLOE
$\rightarrow \Delta a_\mu^{\pi+\pi-,LO-VP} \approx 10 \times 10^{-11}$
versus total uncertainty in $a_\mu^{had,LO-VP}$ of 42×10^{-11}

- BESIII preliminary result for $a_\mu^{\pi+\pi-,LO-VP}$ between KLOE and Babar but closer to Babar
- BESIII plans to publish this summer with reduced uncertainty as the luminosity determination is improved
- Measurements of $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ and $\pi^+\pi^-\pi^0\pi^0$ also planned (the two channels with next largest contributions to the current uncertainty in $a_\mu^{had,LO-VP}$)
- Will measure inclusive $\sigma(e^+e^- \rightarrow$ hadrons) in 2-3 GeV region with ~3% precision, bettering world's best result (BESII) by factor of 2 ; test perturbative result

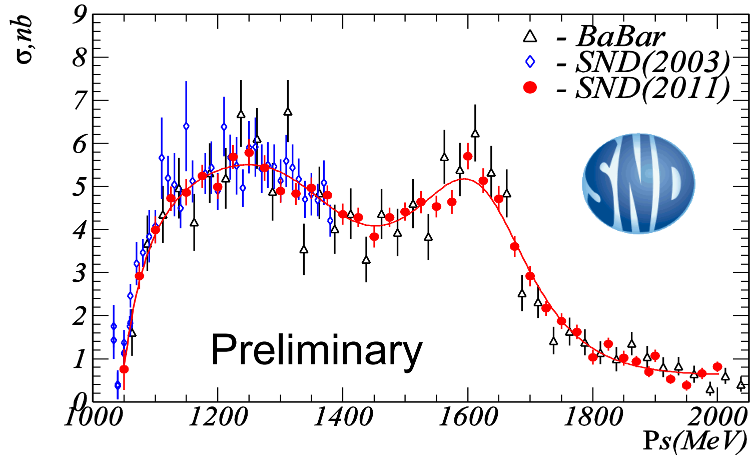
CMD3: $e^+e^- \to \pi^+\pi^-$



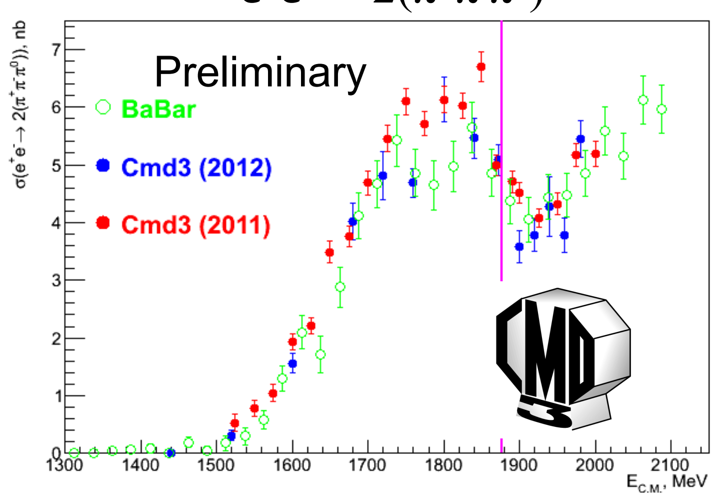
- VEPP-2000 delivered ~60 pb^{-1} from 2010-2013 in a scan (0.32 – 2.00 GeV)
- Most CMD3/SND results still preliminary; expect 2-3 years before publications
- Machine being upgraded (positron injector): hope to restart end-2015 or beginning-2016 and collect ~1 fb^{-1} in next 5-10 years
- Goal is to measure $a_\mu^{\pi+\pi-,LO\text{-}VP}$ with a precision of 0.35%, compared to 0.7% for Babar and 0.8% for KLOE

VEPP-2000: examples of other final states

$e^+e^- \to \pi^+\pi^-\pi^0$

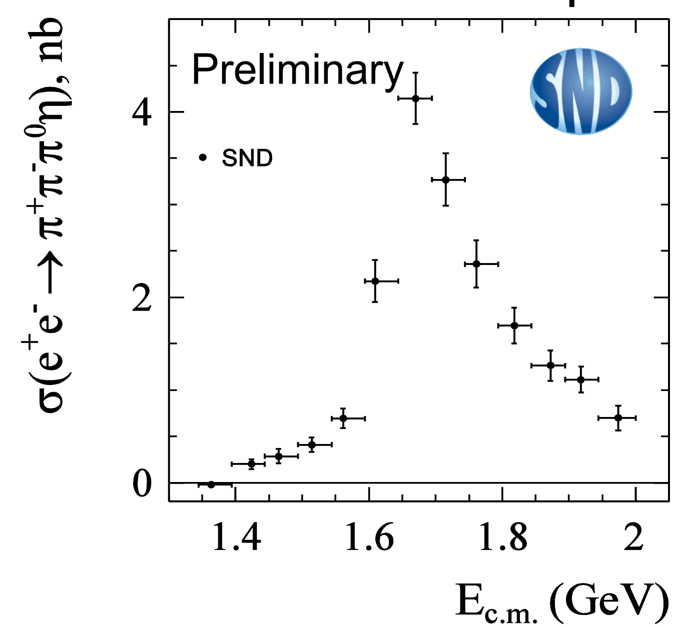


$e^+e^- \to 2(\pi^+\pi^-\pi^0)$



- Significant improvements and cross checks in some channels, potentially leading to shifts in cross section results
- First measurements in others, replacing isospin-based estimates

$e^+e^- \to \pi^+\pi^-\pi^0\eta$

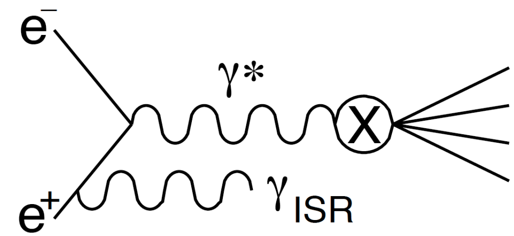


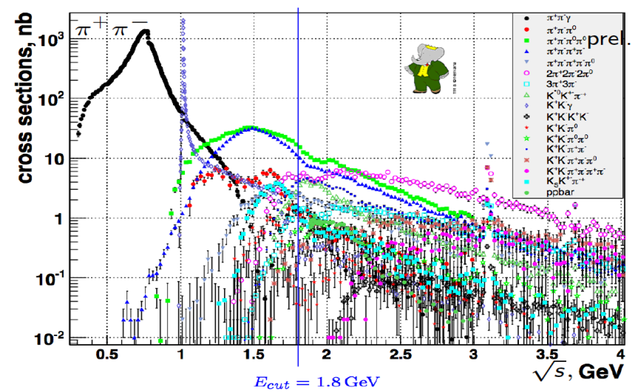
The Babar ISR $e^+e^- \rightarrow$ hadrons program

A long-term project nearing completion

Previously published results:

$\pi^+\pi^-$	PRL 103 (2009) 231801
$\pi^+\pi^-\pi^0$	PRD 70 (2004) 072004
$2(\pi^+\pi^-)$	PRD 85 (2012) 112009
$K^+K^-\pi^+\pi^-$, $K^+K^-\pi^0\pi^0$, $K^+K^-K^+K^-$	PRD 86 (2012) 012008
$2(\pi^+\pi^-)\pi^0$, $2(\pi^+\pi^-)\eta$, $K^+K^-\pi^+\pi^-\pi^0$, $K^+K^-\pi^+\pi^-\eta$	PRD 76 (2007) 092005
$3(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, $K^+K^-2(\pi^+\pi^-)$	PRD 73 (2006) 052003
$K^+K^-\eta$, $K^+K^-\pi^0$, $K_SK^+\pi^-$	PRD 77 (2008) 092002
$p\bar{p}$	PRD 87 (2013) 092005 PRD 88 (2013) 072009
$\Lambda\Lambda$, $\Lambda\Sigma^0$, $\Sigma^0\Sigma^0$	PRD 76 (2007) 092006





Recent results (discussed below):

K^+K^-, tagged ISR [PRD 88 (2013) 032013]

K^+K^-, untagged ISR [preliminary]

K_SK_L, $K_SK_{S/L}\pi^+\pi^-$, $K_SK_SK^+K^-$ [PRD 89 (2014) 092002]

$K_SK^+\pi^-\pi^0$, $K_SK^+\pi^-\eta$ [preliminary]

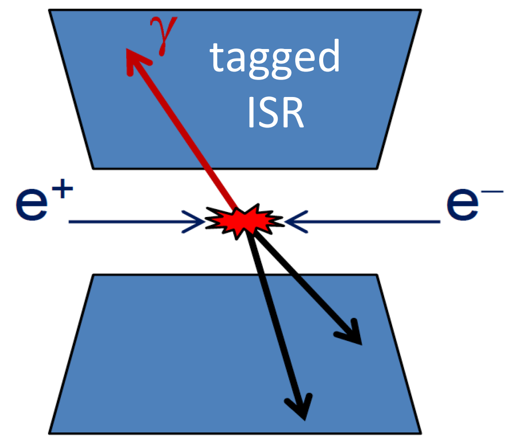
Ongoing studies:

$\pi^+\pi^-\pi^0\pi^0$, $\pi^+\pi^-\pi^0\pi^0\pi^0$, $K_SK_L\pi^0\pi^0$

Essentially the complete set of significant exclusive channels

Babar: $e^+e^- \rightarrow K^+K^-$ cross section (tagged ISR)

Babar PRD 88 (2013) 032013



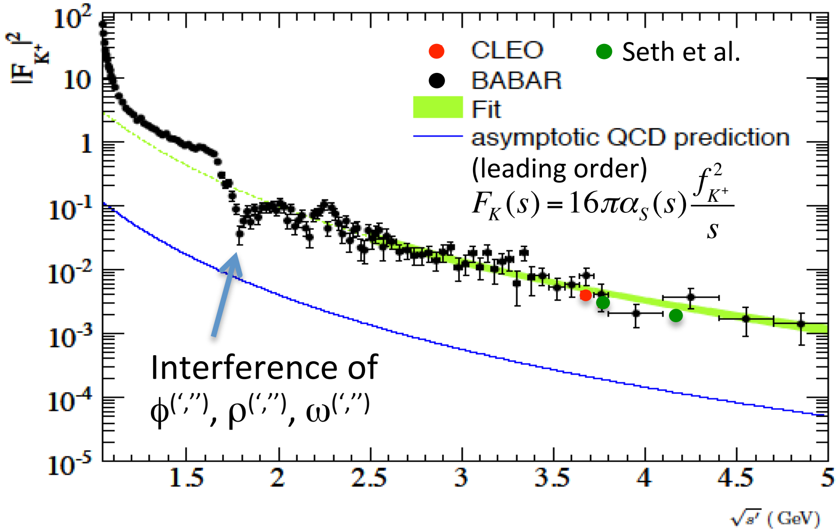
Tagged analyses provide high precision at low √s'

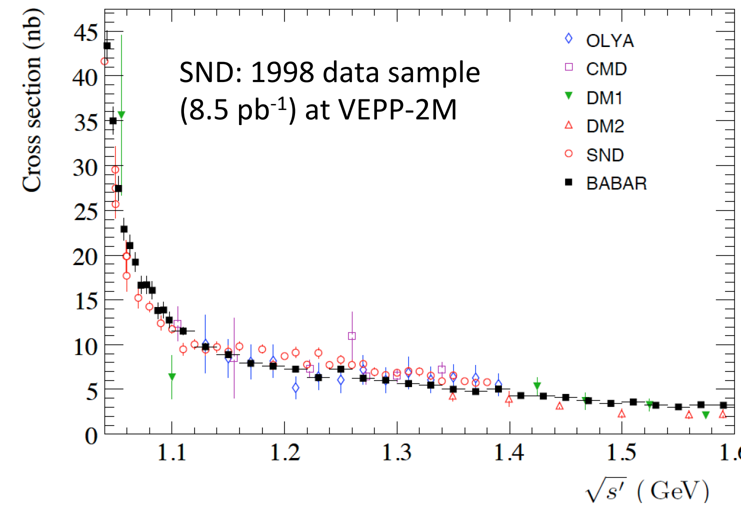
- Exactly 2 tracks, p > 1GeV, opposite charge, identified as kaons
- ≥ 1 photon with E* > 3 GeV
  (* = CM frame)
- ISR photon γ_{ISR} = photon with highest E*
- γ_{ISR} must lie within 0.3 radians of missing momentum formed from all other particles → strong suppression of non-ISR events
- Background ($\pi^+\pi^-\gamma$, $\mu^+\mu^-\gamma$, $\pi^+\pi^-\pi^0\gamma$, $\pi^+\pi^-2\pi^0\gamma$, $K^+K^-\pi^0\gamma$, $K^+K^-\eta\gamma$, $K_SK_L\gamma$, $pp\gamma$) subtracted using data-corrected simulation
- Cross section corrected for detector acceptance and resolution
  [AfkQed & Phokhara MC]

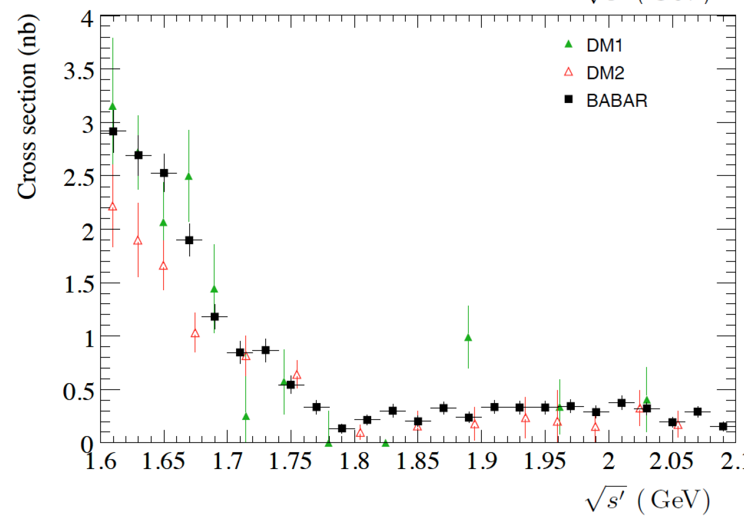
Babar: $e^+e^- \rightarrow K^+K^-$ cross section (tagged ISR)

Babar PRD 88 (2013) 032013

$$\sigma_{K^+K^-}(M_{K^+K^-}) = \frac{\pi\alpha^2\beta^3 C}{3M^2_{K^+K^-}}|F_K(M_{K^+K^-})|^2$$

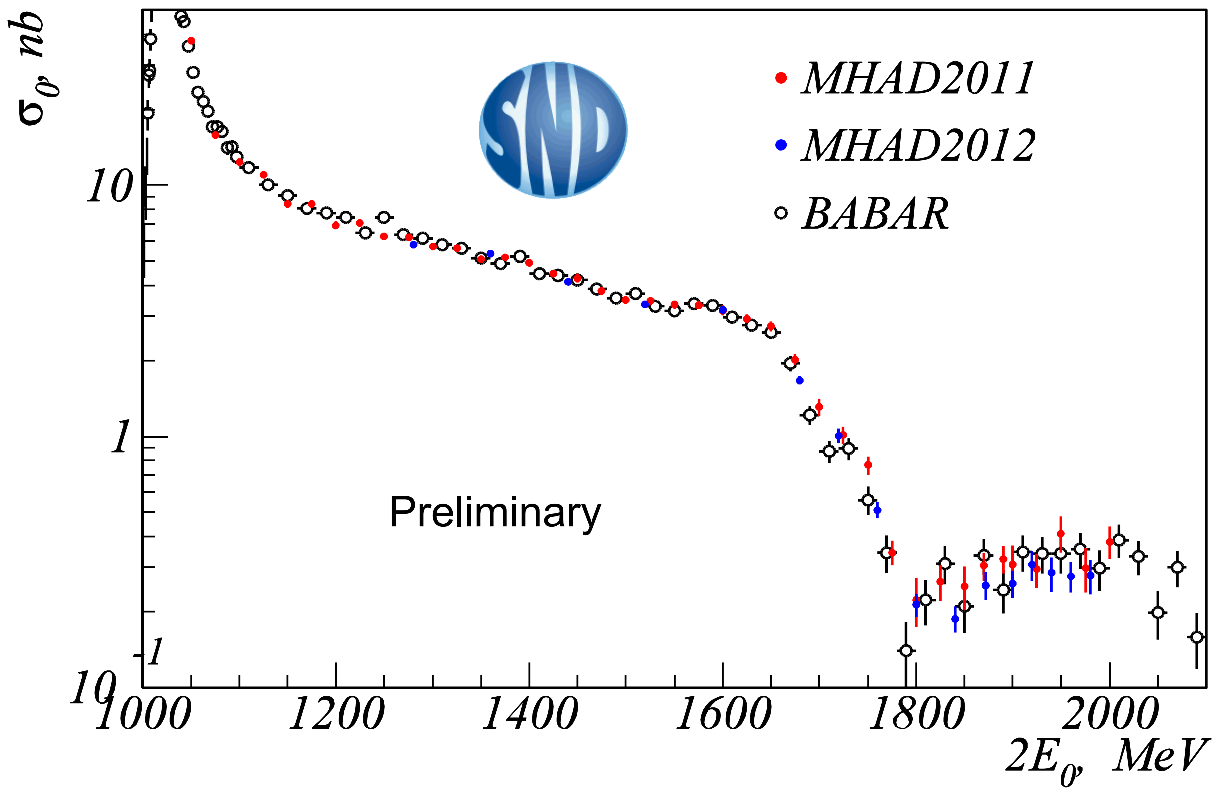






- Babars covers a larger energy range; results more precise than previous measurements
- $a_\mu^{K+K-,LO\text{-}VP}$ = 229.3 ± 1.8 (stat) ± 2.2 (syst) x 10^{-11}
  → 1.2% precision, versus precision of previous world average, with 3.3% precision
- Form factor F_K larger than leading order QCD asymptotic prediction by factor of ≈ 4 : need to test at higher √s'

SND: $e^+e^- \to K^+K^-$

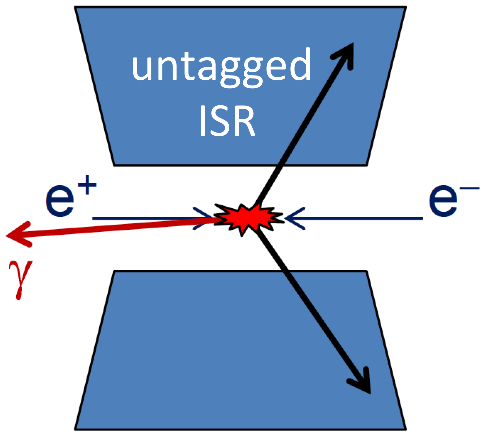


Upgraded SND detector at VEPP-2000:

- 2011 and 2012 data samples (60 pb^{-1})
- Agreement with Babar much improved

Babar: $e^+e^- \to K^+K^-$ (untagged ISR)

Preliminary



- Above 3 GeV, statistical precision greatly improved using untagged events
- allows access to higher Ecm = √s' = m_{KK}
  - → better satisfies the asymptotic condition $m_{KK} \to \infty$
  - → provides a more valid test of the QCD perturbative calculation
- As in tagged analysis, require events to have exactly two charged tracks, with opposite charge, identified as kaons

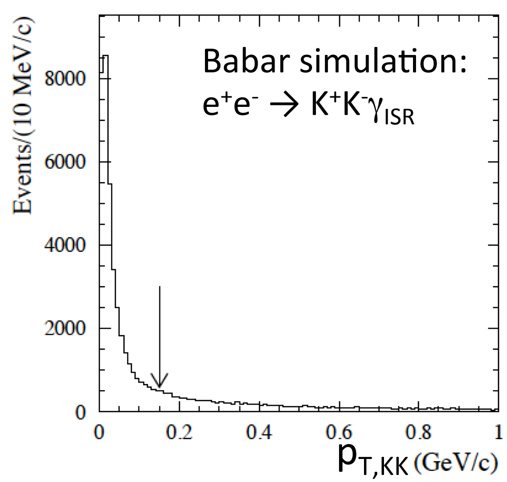
Require events to be consistent with an ISR photon along the beam axes:

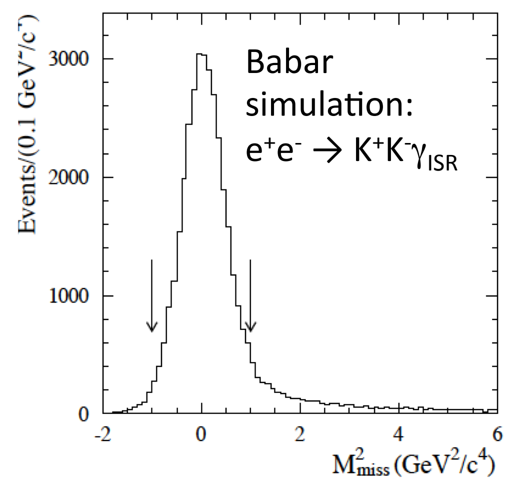
$p_{T,KK} < 0.15$ GeV

$|M_{miss}|^2 = |(p_{e+} + p_{e-} - p_{KK})^2|$

< 1.0 GeV

≈ 0 for signal events



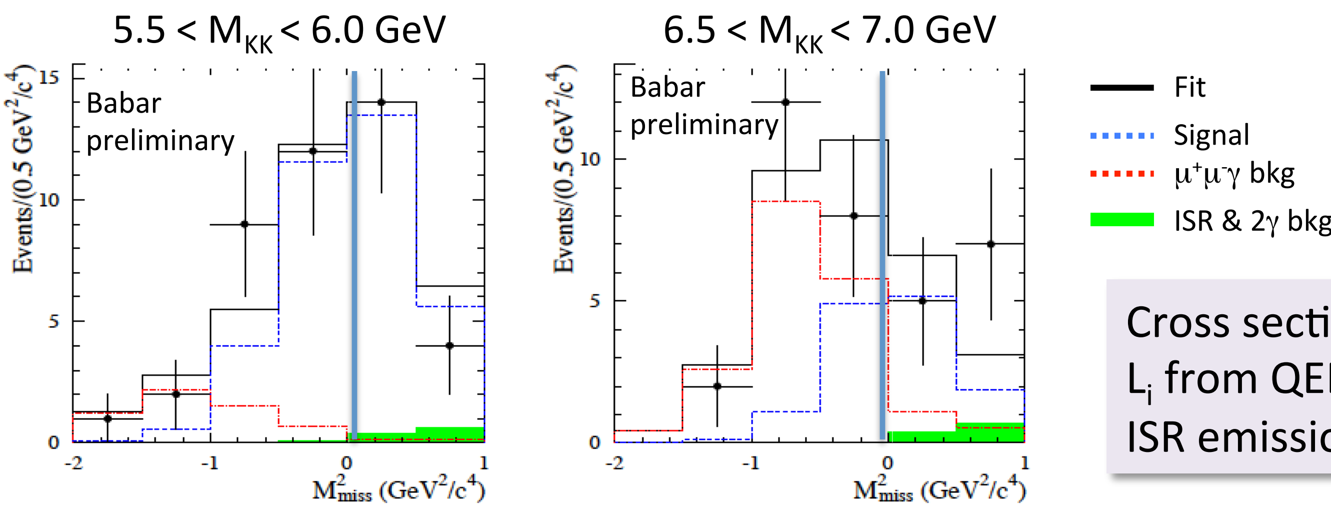


Babar: $e^+e^- \to K^+K^-$ (untagged ISR)

Main background for $m_{KK} > 5.5$ GeV: $\mu^+\mu^-\gamma$ background

→ maximum-likelihood fit of M_{miss}^2 distribution in bins of M_{KK}

- PDF for $\mu^+\mu^-\gamma$ from data with ≥ 1 identified muon
- PDF for signal events $K^+K^-\gamma$ from simulation [Phokhara]

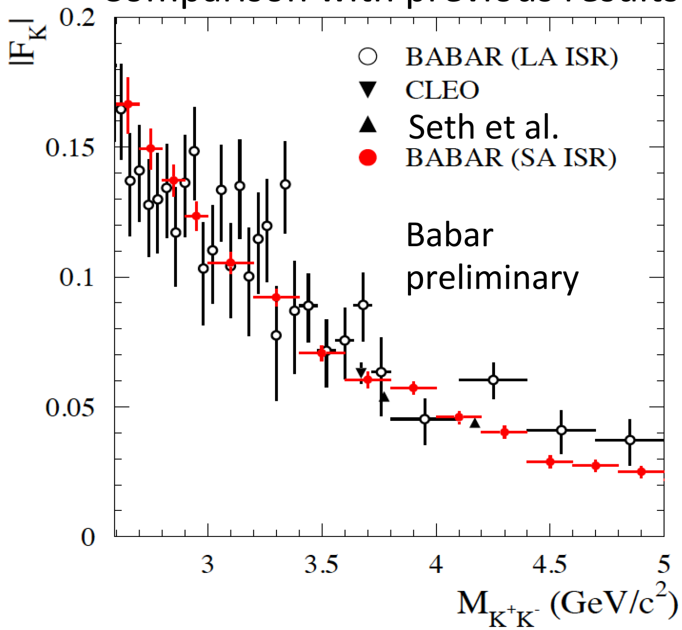


Cross section: $\sigma_i = N_{sig} / (\varepsilon_i L_i)$; L_i from QED calculations for ISR emission (0.5% accuracy)

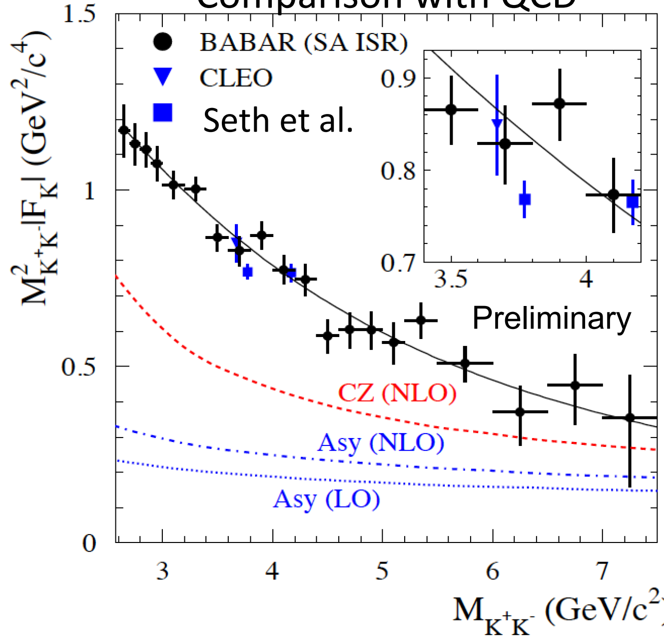
$M_{K^+K^-}$ (GeV/c^2)	N_{data}	N_{sig}	$N_{\mu\mu\gamma}$	N_{ISR}	$N_{\gamma\gamma}$
5.5–6.0	42	$35.3 \pm 6.7 \pm 0.6$	6.0 ± 3.7	0.7 ± 0.4	0.4 ± 0.3
6.0–6.5	25	$10.8 \pm 4.6 \pm 1.2$	11.4 ± 4.3	2.2 ± 0.8	0.3 ± 0.2
6.5–7.0	34	$13.2 \pm 5.6 \pm 1.2$	18.9 ± 5.7	1.1 ± 0.5	< 0.3
7.0–7.5	44	$7.0 \pm 5.4 \pm 1.6$	33.4 ± 7.0	3.8 ± 1.3	< 0.5
7.5–8.0	91	$0.0 \pm 6.0 \pm 1.7$	86.9 ± 9.7	4.5 ± 1.6	< 0.5

Babar: $e^+e^- \rightarrow K^+K^-$ (untagged ISR)

Comparison with previous results



Comparison with QCD



- Asy NLO and CZ NLO: leading-twist NLO calculations [Melic et al., PRD60, 074004 (1999)]
- ASY NLO: asymptotic distribution amplitude (DA) [Brodsky & Lepage: PLB87 (1979) 359]
  → How the meson momentum is shared between the quarks
- CZ NLO: Chernyak & Zhitnitsky QCD sum rule DA [Phys. Rep. 112, 173 (1984)]
- At the higher scales probed in this analysis, the QCD prediction is in much better agreement with the data

Babar: $e^+e^- \to K_S K_L$ (tagged ISR)

Babar PRD 89 (2014) 092002

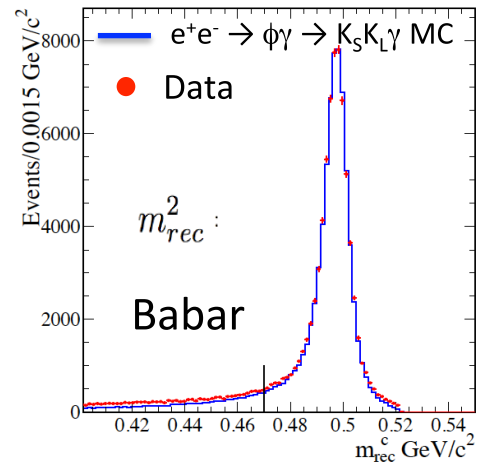
- ISR photon = highest energy γ with $E_\gamma^* > 3$ GeV
- Exactly one $K_S \to \pi^+\pi^-$ candidate consistent with interaction point (IP)
- No charged tracks consistent with IP

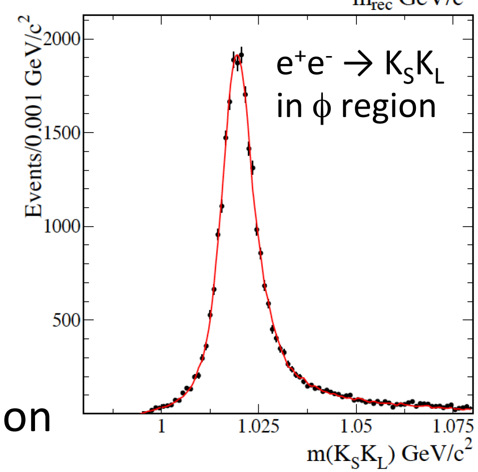
K_L detection efficiency measured from data:

- Plot recoil mass against the $K_S\gamma_{ISR}$ system

$$m_{rec}^2 = (E^+ + E^- - E_\gamma - E_{K_S^0})^2 - (\bar{p}^+ + \bar{p}^- - \bar{p}_\gamma - \bar{p}_{K_S^0})^2$$

- Clean K_L peak observed, from the dominant $e^+e^- \to \phi\gamma \to K_S K_L \gamma$ resonant channel
- Apply K_L selection to this sample:
  - → require an isolated EM cluster with
    - < 0.5 radians from expected K_L direction
    - E > 0.2 GeV





K_L detection efficiency ≈ 48% (2% lower than simulation)

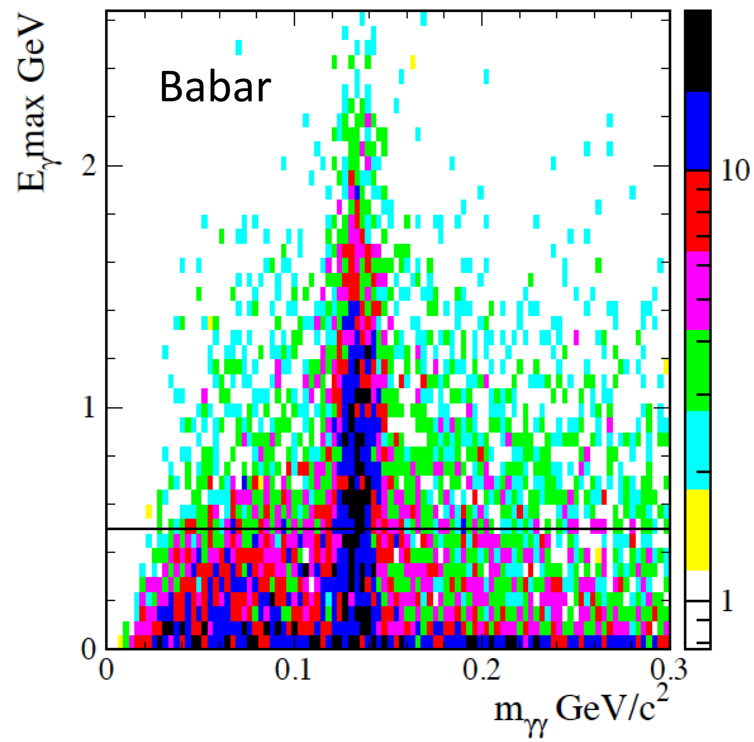
→ determined as function of the K_L energy and direction

Babar: $e^+e^- \rightarrow K_S K_L$ (tagged ISR)

$e^+e^- \rightarrow K_S K_L$ nonresonant channel [$m_{KSKL} = \sqrt{s'} > 1.06$ GeV]

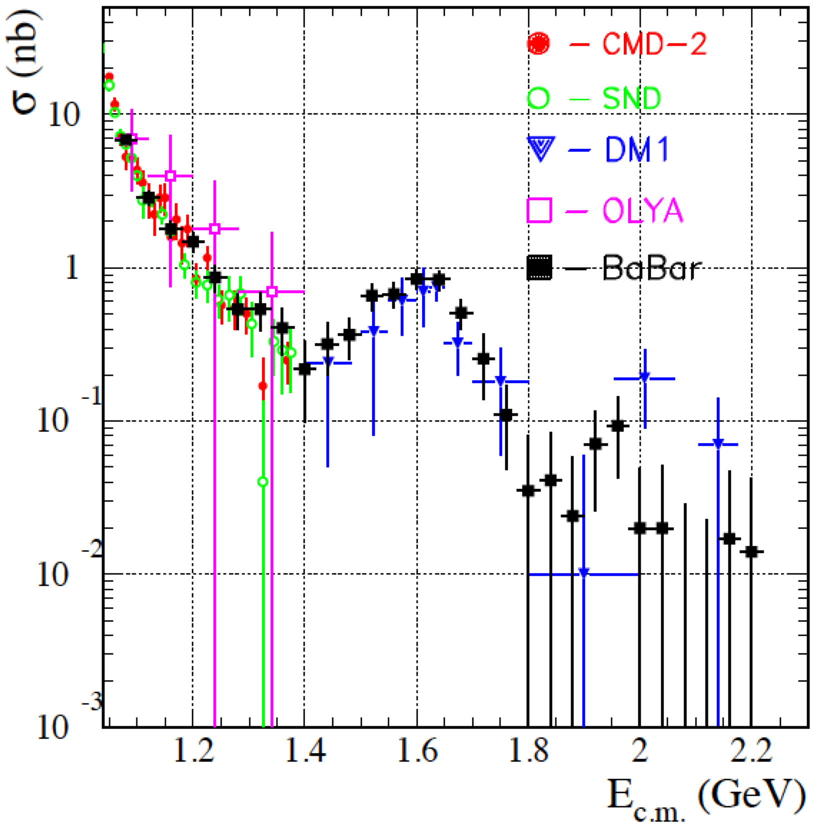
$\rightarrow$ significant background from $e^+e^- \rightarrow K_S K_L (n\pi^0)$

- Examine all EM clusters except those assigned to the K_L and γ_{ISR} ; assume they are photons
- Plot $E_{\gamma,max}$ versus $m_{\gamma\gamma}$ for all $\gamma\gamma$ pairs (the larger of the 2 γ energies in the pair)
- Require $E_{\gamma,max} < 0.5$ GeV to reduce $n\pi^0$ background
- Data sidebands used to evaluate residual background



Babar: $e^+e^- \to K_SK_L$ (tagged ISR)

$e^+e^- \to K_SK_L$ cross section above the ϕ



Babar data

- cover a larger energy range
- are more precise

than previous experiments

Clear evidence for resonant structures

- $\omega(1420)$, $\omega(1650)$, $\phi(1680)$, $\rho(1450)$ contributions ?
- about 1000 events in this region
- only 58 events in this region for the only previous result [DM1 (Orsay); PLB 99 {1981) 261]

Babar: first measurements of the $e^+e^- \to K_S K_L \pi^+\pi^-$, $K_S K_S \pi^+\pi^-$, $K_S K_S K^+K^-$ cross sections

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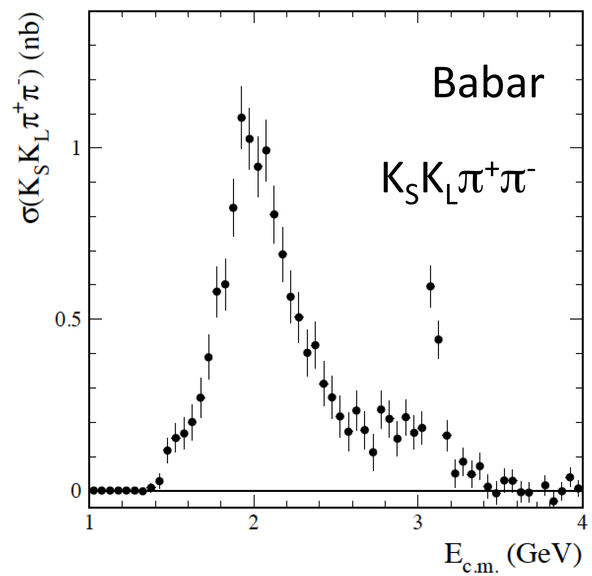
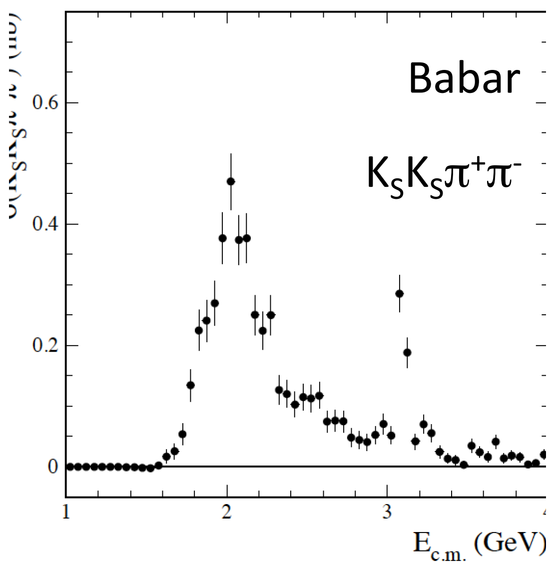
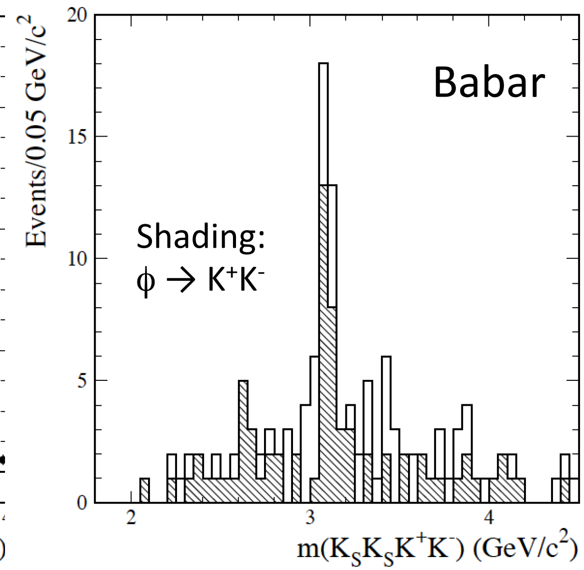






First measurements of

$J/\psi \to K_S K_L \pi^+\pi^-$

$\to K_S K_S \pi^+\pi^-$

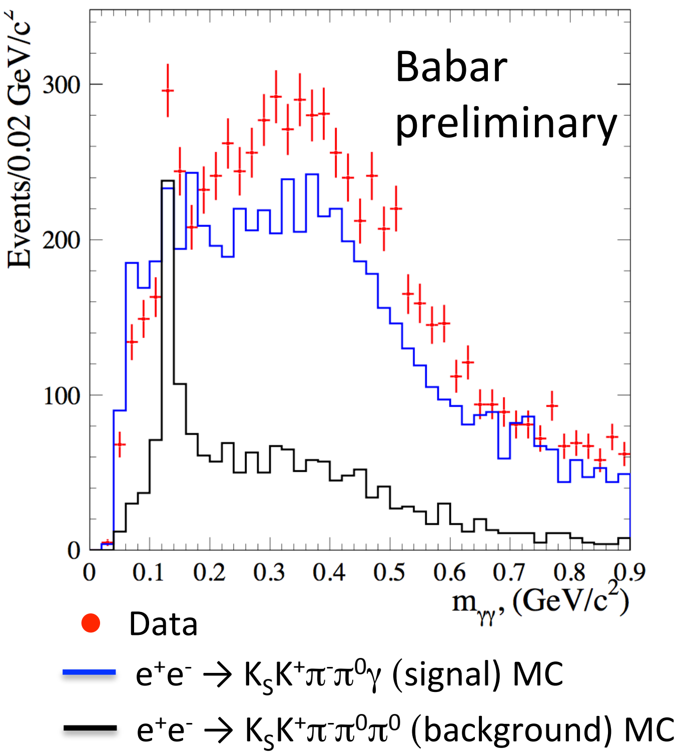
$\to K_S K_S K^+K^-$

	J/ψ Branching Fraction (10^{-3}) This work	PDG2012
$\mathcal{B}_{J/\psi \to K^0_S K^0_L \pi^+\pi^-}$	$3.7 \pm 0.6 \pm 0.4$	no entry
$\mathcal{B}_{J/\psi \to K^0_S K^0_S \pi^+\pi^-}$	$1.68 \pm 0.16 \pm 0.08$	no entry
$\mathcal{B}_{J/\psi \to K^0_S K^0_S K^+K^-}$	$0.42 \pm 0.08 \pm 0.02$	no entry

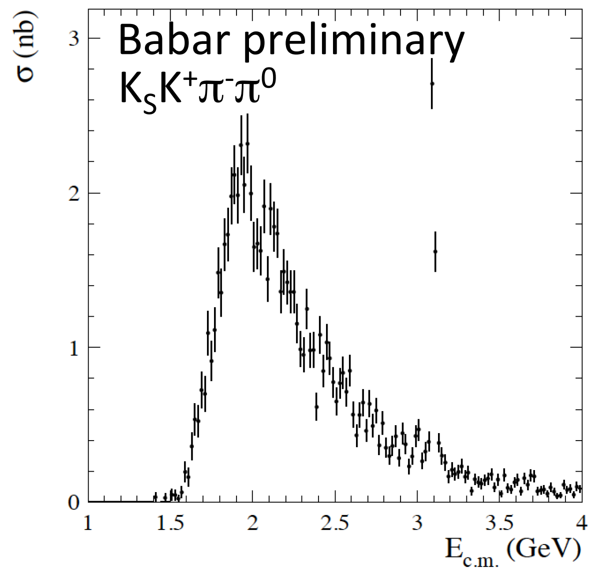
Babar: first measurements of the $e^+e^- \to K_S K^+\pi^-\pi^0$ and $K_S K^+\pi^-\eta$ cross sections (tagged ISR)

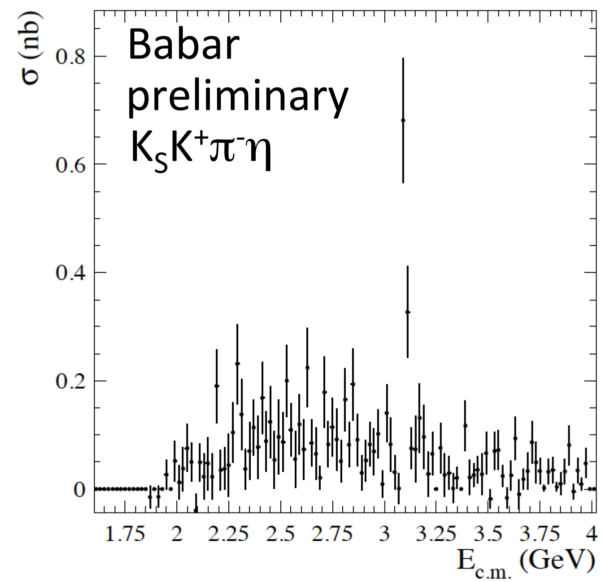
Preliminary

- ISR photon = highest energy γ with $E_\gamma^* > 3$ GeV
- At least one $K_S \to \pi^+\pi^-$ candidate consistent with interaction point
- At least two additional photons, with $m_{\gamma\gamma}$ consistent with m_{π^0} or m_η
- Two oppositely charged tracks, one identified as a pion & one as a kaon
- Background from non-ISR $e^+e^- \to K_S K^+\pi^-\pi^0\pi^0$ and $K_S K^+\pi^-\eta\pi^0$ events evaluated from simulation normalized to data using the additional π^0 mass peak
- Background from ISR $e^+e^- \to K_S K^+\pi^-$ and $K_S K^+\pi^-\pi^0\pi^0$ or $K_S K^+\pi^-\eta\pi^0$ [one more or one less π^0] events evaluated from data sidebands



Babar: first measurements of the $e^+e^- \to K_S K^+ \pi^- \pi^0$ and $K_S K^+ \pi^- \eta$ cross sections (tagged ISR)





$$\mathcal{B}^{J/\psi}_{K^0_S K^\pm \pi^\mp \pi^0} = (5.7 \pm 0.3 \pm 0.4) \cdot 10^{-3}$$

$$\mathcal{B}^{J/\psi}_{K^0_S K^\pm \pi^\mp \eta} = (1.30 \pm 0.25 \pm 0.07) \cdot 10^{-3}$$

First measurement

- BES result: (2.2 ± 0.4) x10^{-3}
  [PRD 77 (2008) 032005]
  (Babar result around 2σ lower)

Measurement of $e^+e^- \to K_S K_L \pi^0 \pi^0$ underway: will complete the measurement of the $e^+e^- \to KK\pi\pi$ cross section (~25% of the total hadronic cross section at √s=2 GeV)

Summary

- Precise low-energy e^+e^- hadronic cross section data needed to obtain an accurate SM prediction for $a_\mu^{had,LO-VP}$
- Babar and KLOE results for $a_\mu^{\pi+\pi-,LO-VP}$ differ by ~3%; the new data from BESIII and CMD3/SND will help to resolve the discrepancy
- New precise data on $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ expected from BESIII and CMD/SND
- New results on $e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0$ expected from Babar, BESIII, and CMD3/SND
- With the new data, hope to reduce the uncertainty in $a_\mu^{had,LO-VP}$ by around 50% in the next few years [Blum et al., arXiv:1311.2198 (2013)]
- Babar ISR program about finished, but we have new results on final states with $K^\pm$, K_S, and K_L mesons that provide new information, tests of QCD, and first observations of cross sections and J/ψ branching fractions

Thanks to Achim Denig and Sergey Serednyakov for providing information about the BES and SND/CMD3 programs !

EXTRA

The Babar ISR $e^+e^- \rightarrow$ hadrons program

Babar tagged ISR analyses

- ISR at 10.6 GeV
- ≥ 1 photon identified in the detector with E* > 3 GeV (* = CM frame)
- ISR photon γ_{ISR} = photon with highest E*
- Boost of the recoil system yields good efficiency for "soft" particles, allowing measurements of cross sections down to the production threshold
- Can access a wide range of energy in a single experiment: from threshold to 4-5 GeV