e^+e^- results from BABAR and implications for the muon g-2

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- the BABAR ISR program and the muon g-2
- the dominant $\pi^+\pi^-(\gamma)$ channel
- results on $K^+K^-(\gamma)$
- results on $\pi^+\pi^-\pi^+\pi^-$, $K^+K^-\pi\pi$, $K_S\,K_L$ channels
- BABAR data impact on the g-2 prediction
- preliminary result: K form factor at large Q^2

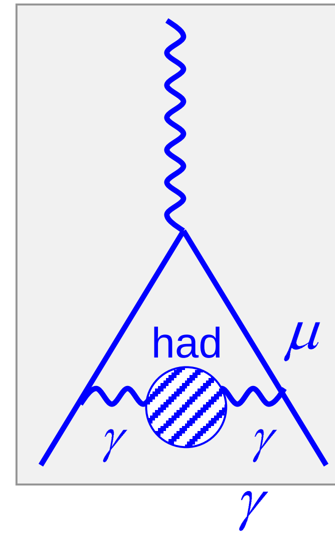
Hadronic Vacuum Polarization and Muon $(g-2)_\mu$

Dominant uncertainty in g-2 Standard Model prediction from lowest-order HVP piece

Cannot be calculated from QCD (low mass scale), but one can use experimental data on e+e−→hadrons cross section (Bouchiat-Michel 1961)

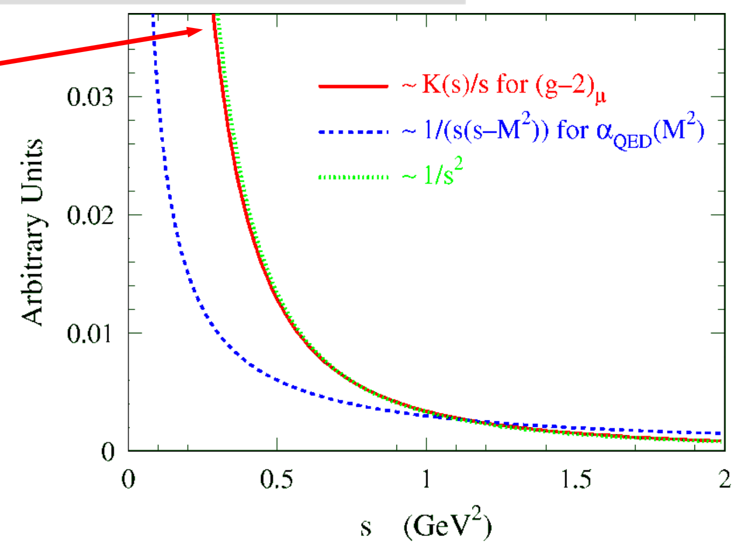
Born: $\sigma^{(0)}(s) = \sigma(s)\ \alpha/\alpha(s)\ ^{2}$

$$12\pi\,\mathrm{Im}\Pi_\gamma(s) = \frac{\sigma^0[e^+e^- \to \mathrm{hadrons}\,(\gamma)]}{\sigma_{pt}} \equiv R(s)$$

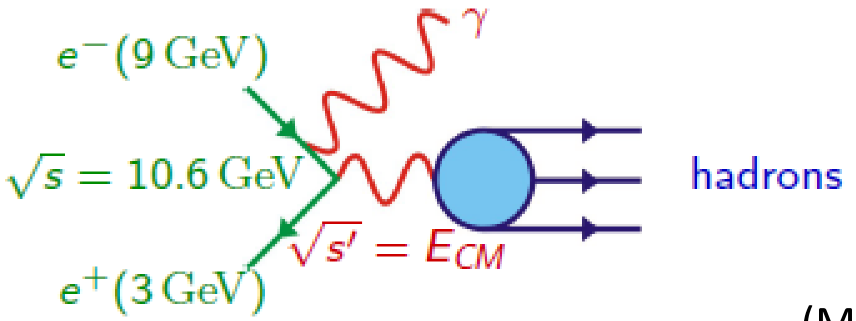


$$a_\mu^{had} = \frac{\alpha^2}{3\pi^2}\int_{4m_\pi^2}^{\infty} ds\,\frac{K(s)}{s}\,R(s)$$

Dispersion relation



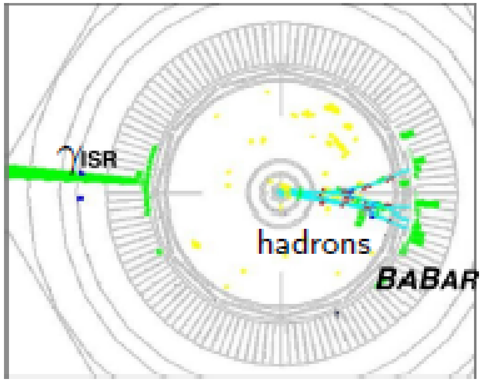
The ISR method at BABAR



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

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

($M^2_{hadrons}$)



- High energy (E^*_γ >3 GeV) detected at large angle
  → defines √s' = E_{CM} and provides strong background rejection
- Event topology: ISR photon back-to-back to hadrons
- → high acceptance, strong boost to hadrons (measurements from threshold and easier PID)
- Final state can be hadronic or leptonic (QED)
  → $\mu^+\mu^-\gamma(\gamma)$ events used to get ISR luminosity
- Kinematic fit including ISR photon
  → removes multihadronic background; improves mass resolution (a few MeV)
- Continuous measurement from threshold to 3-5 GeV
  →reduces systematic uncertainties compared to multiple data sets with different colliders and detectors

The BaBar ISR program

- almost complete set of exclusive hadronic e^+e^- annihilation channels up to 2 GeV

- published:

$\pi^+\pi^-$	PRL 2009; PRD 2012
$K^+ K^-$	PRD 2013
$\pi^+\pi^-\pi^0$	PRD 2004
$2(\pi^+\pi^-)$, $K^+K^-\pi^+\pi^-$, $K^+K^- 2\pi^0$, $2(K^+K^-)$	PRD 2007; PRD 2012; PRD 2012
$K^0_S K^{+-}\pi^{-+}$, $K^+K^-\pi^0$, $K^+K^-\eta$	PRD 2005; PRD 2008
$2(\pi^+\pi^-)\pi^0$, $2(\pi^+\pi^-)\eta$, $K^+K^-\pi^+\pi^-\pi^0$, $K^+K^-\pi^+\pi^-\eta$	PRD 2007
$3(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, $2(\pi^+\pi^-) K^+K^-$	PRD 2006
$\Phi\ f^0(980)$	PRD 2006; PRD 2007
$p\bar{p}$	PRD 2006, PRD 2012
$\Lambda\bar{\Lambda}$, $\Lambda\bar{\Sigma}^0$, $\Sigma^0\bar{\Sigma}^0$	PRD 2007
$K^0_S K^0_L$, $K^0_S K^0_L \pi^+\pi^-$, $K^0_S K^0_S \pi^+\pi^-$	PRD 2014

- preliminary: K^+K^- large Q^2

- in progress: $\pi^+\pi^- 2\pi^0$, $\pi^+\pi^- 3\pi^0$, $K^0_S K^{+-}\pi^{-+}\pi^0$, $K^0_S K^{+-}\pi^{-+}\eta$

- not covered: $\pi^+\pi^- 4\pi^0$, $K^0_S K^0_L \pi^0\pi^0$

The BaBar ISR method for μμγ(γ), ππγ(γ),KKγ(γ)

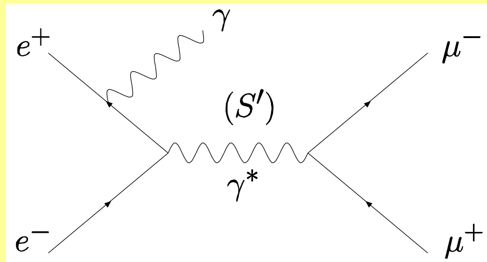
$e^+ e^- \rightarrow \mu^+ \mu^- \gamma\ (\gamma)$ and $\pi^+ \pi^- \gamma\ (\gamma)$, $K^+K^-\ \gamma(\gamma)$ measured simultaneously
Kinematic fits with additional ISR or FSR photon

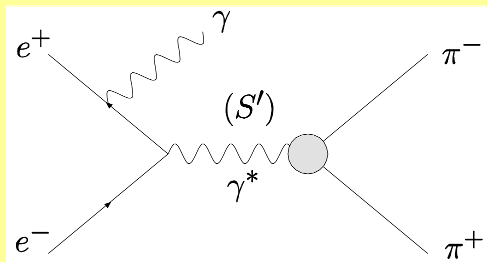
$$x = 2E^*_\gamma/\sqrt{s}$$

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

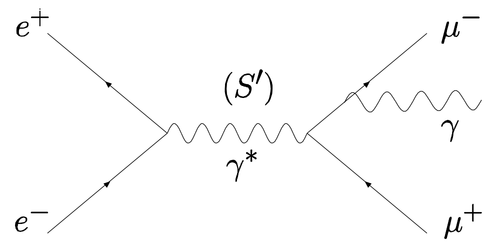
measure ratios
ππ/μμ KK/μμ
ISR lumi drops out

ISR



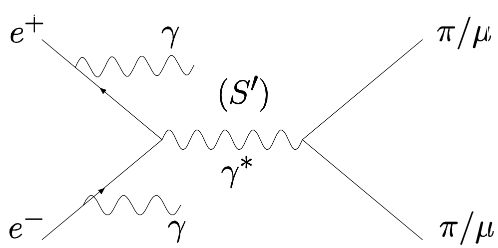


FSR

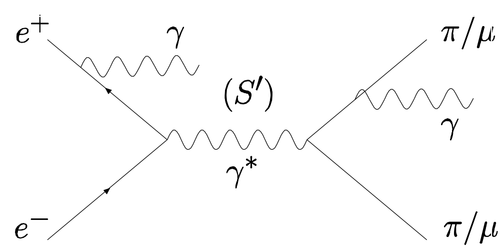


LO FSR negligible for ππ at s~(10.6 GeV)^2, but see talk by Liangliang Wang

ISR + add. ISR



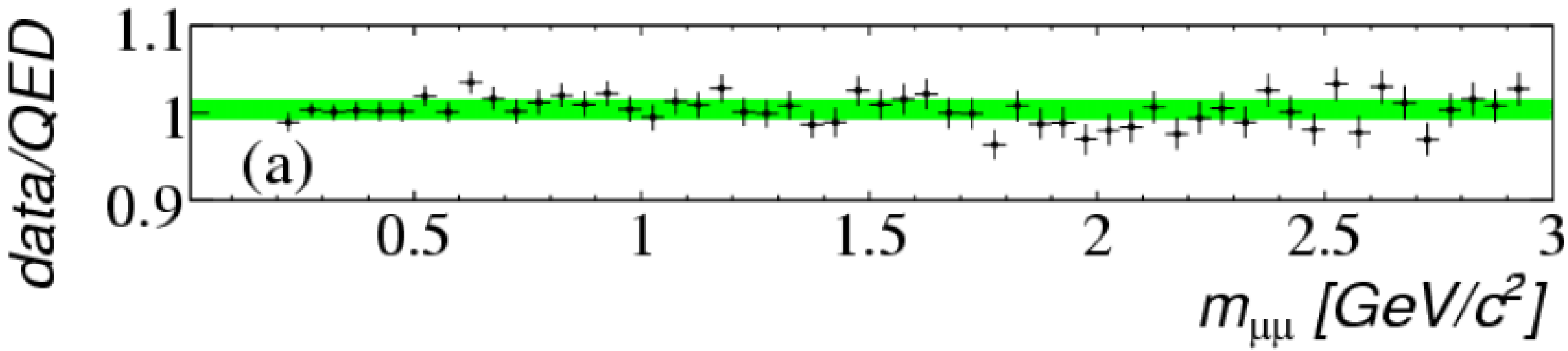
ISR + add. FSR



QED Test with $\mu\mu\gamma$ sample

- absolute comparison of $\mu\mu$ mass spectra in data and in simulation (AfkQed based on EVA)
- simulation corrected for data/MC efficiencies
- AfkQed corrected for incomplete NLO using Phokhara
- strong test (ISR probability drops out for $\pi\pi$)

BaBar



$$\frac{\sigma^{data}_{\mu\mu\gamma(\gamma)}}{\sigma^{NLO\ QED}_{\mu\mu\gamma(\gamma)}} = 1 + (4.0 \pm 1.9 \pm 5.5 \pm 9.4)\ 10^{-3}$$

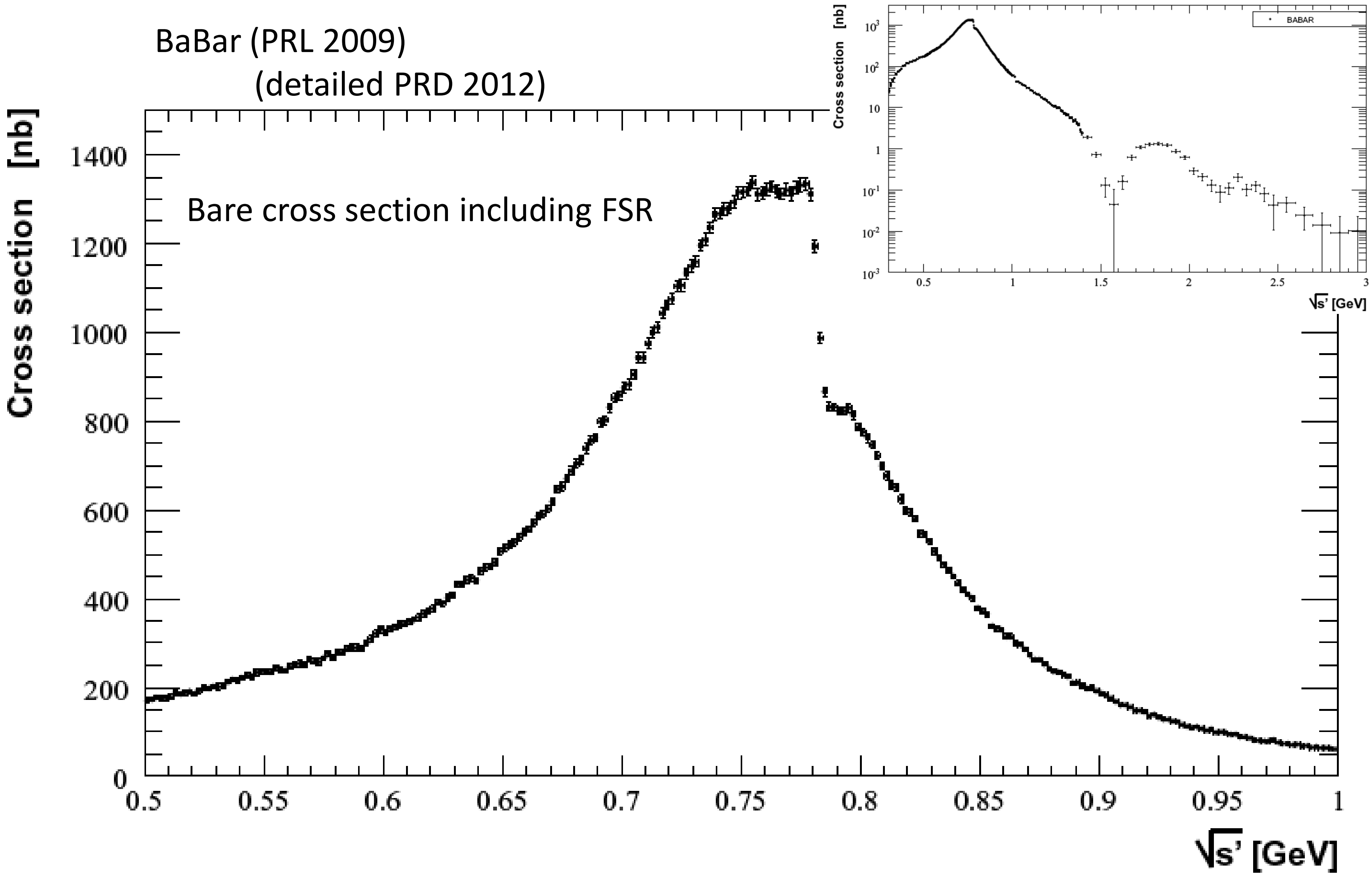
(0.2 – 3 GeV)

ISR γ efficiency 3.4 syst.
trigger/tracking/PID 4.0

BaBar ee luminosity

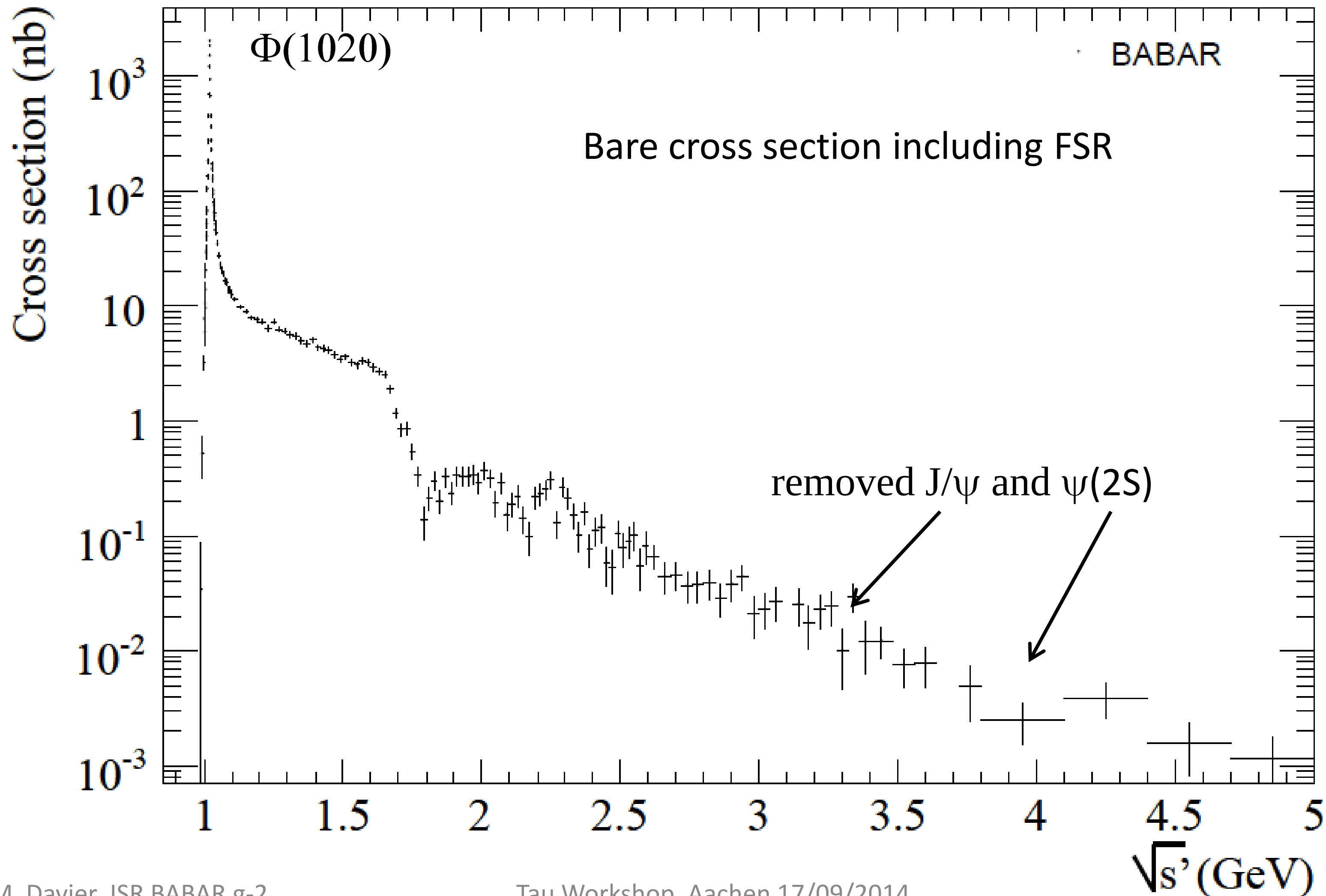
Results on $e^+e^- \to \pi^+\pi^-(\gamma)$

BaBar (PRL 2009)
(detailed PRD 2012)

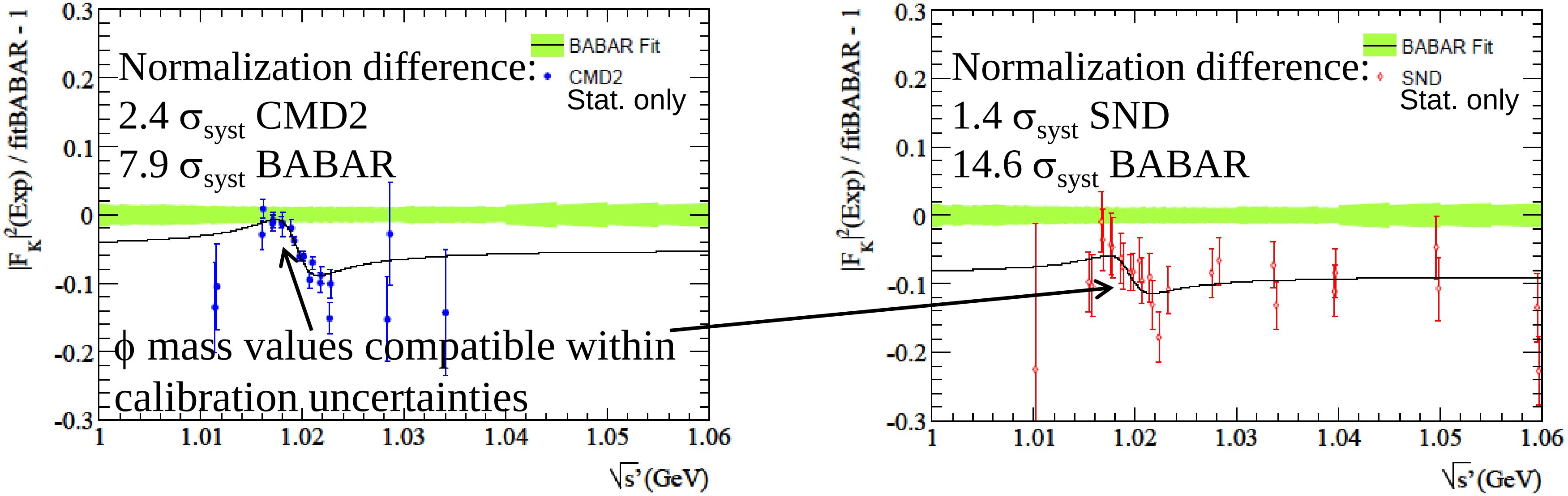


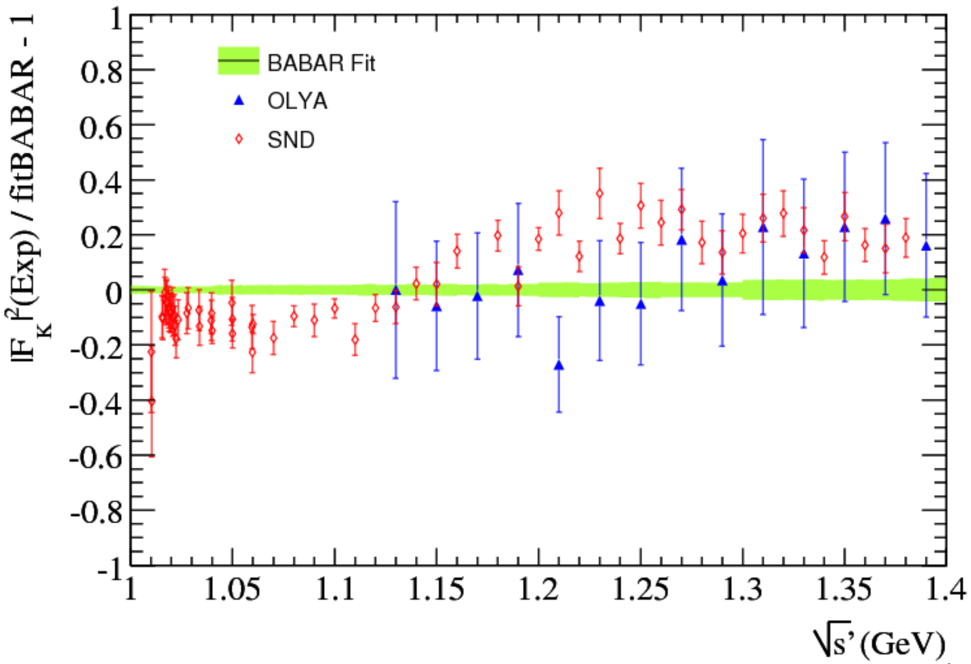
Results on the $e^+e^- \rightarrow K^+K^- (\gamma)$ bare cross section

- effective ISR luminosity obtained with μμ sample as for ππ cross section
- FSR measured and included

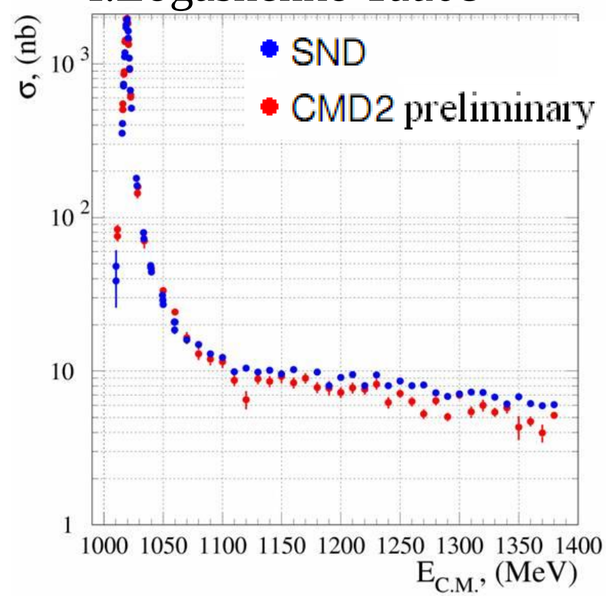


Comparison to previous experiments





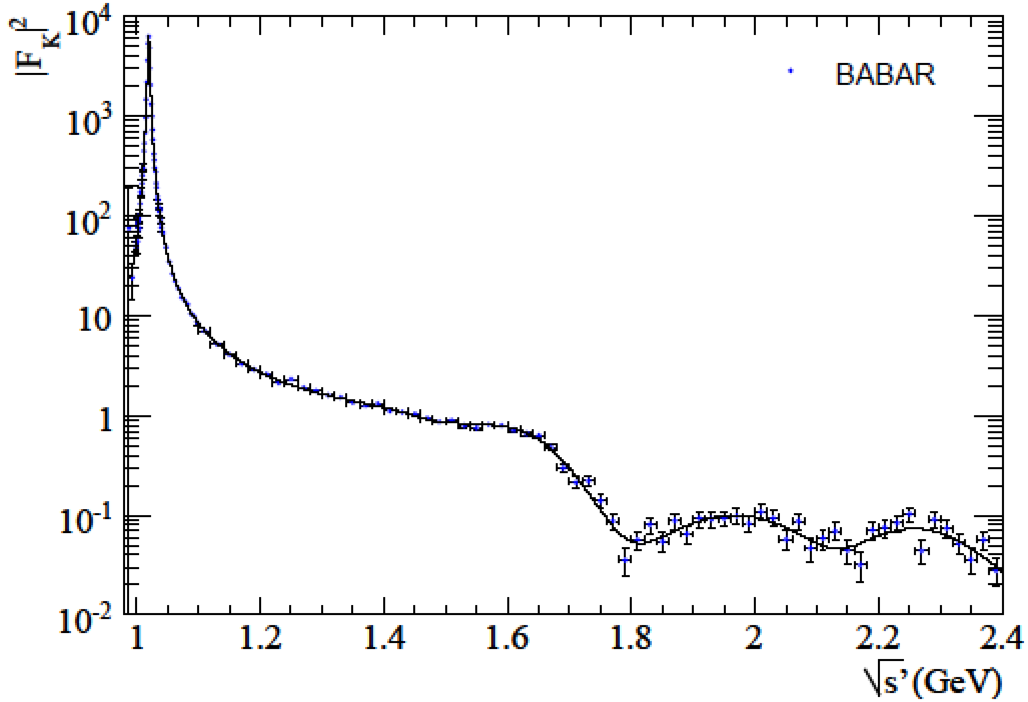
I.Logashenko Tau08



The ϕ parameters

m_ϕ, Γ_ϕ, and ϕ cross section obtained from a VDM fit of the form factor (Kuehn et al.)

$m_\phi = (1019.51 \pm 0.02 \pm 0.05)$ MeV
$\Gamma_\phi = (4.29 \pm 0.04 \pm 0.07)$ MeV



Good agreement with PDG:
$m_\phi = 1019.455 \pm 0.020$ MeV
$\Gamma_\phi = 4.26 \pm 0.04$ MeV

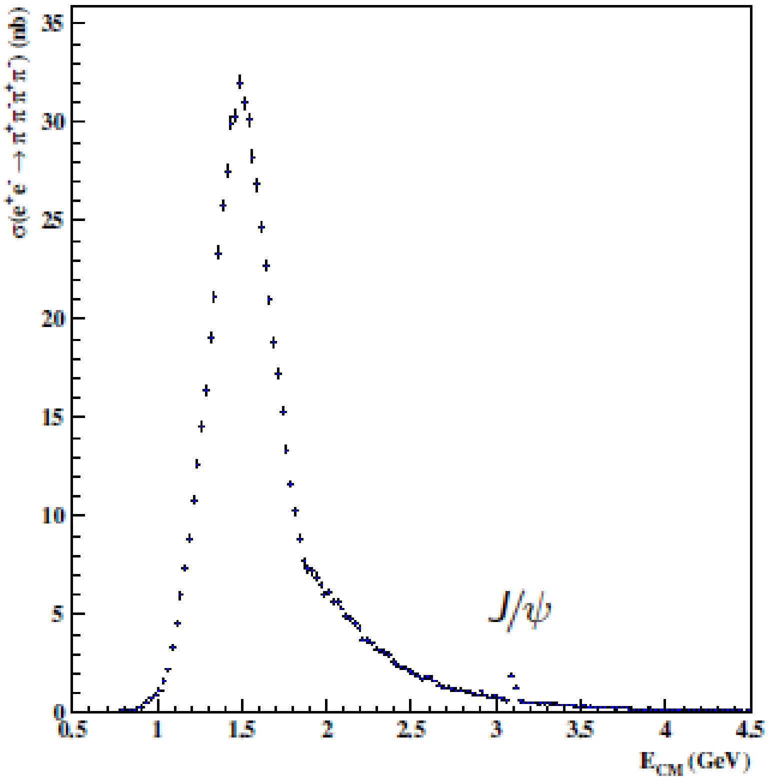
From integrated ϕ peak:

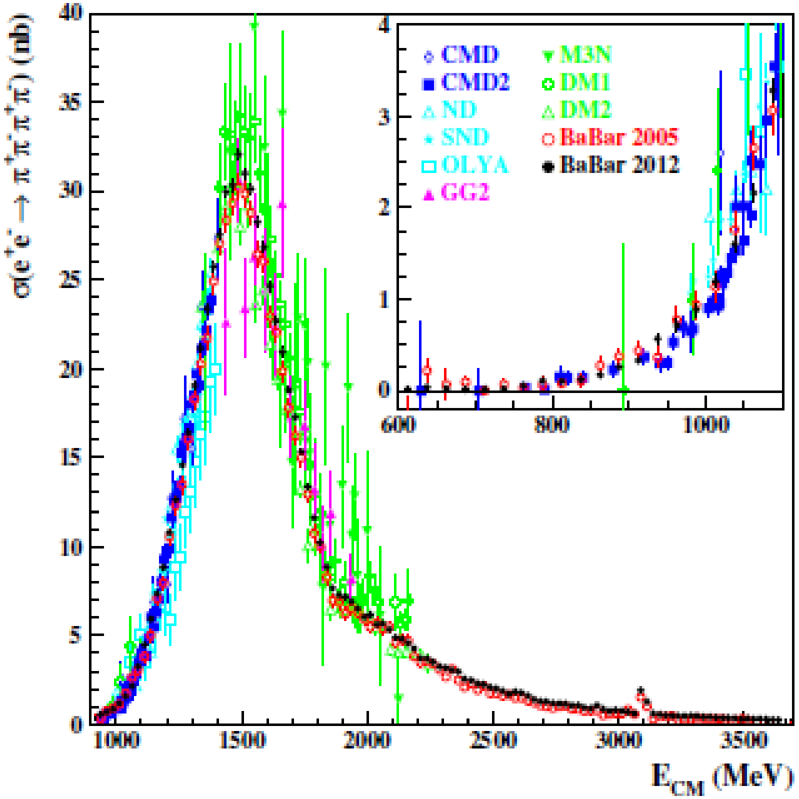
$\Gamma^\phi_{ee} \times B(\phi \to K^+K^-) = (0.6344 \pm 0.0059_{exp} \pm 0.0033_{fit} \pm 0.0015_{cal})$ keV (1.1%)

[CMD2: $(0.605 \pm 0.021 \pm 0.013)$ keV (4.1%)]

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

published in 2012, based on 454 fb^{-1} (earlier publication on 89 fb^{-1})



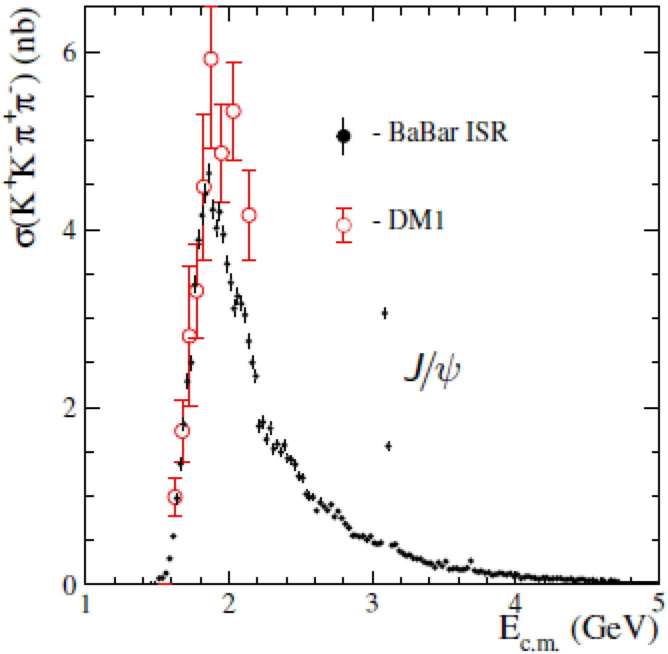


- **Systematic uncertainties**
  2.4% in peak region (1.1-2.8 GeV)
  11% (0.6-1.1 GeV)
  4% (2.8-4.0 GeV)
- J/ψ visible

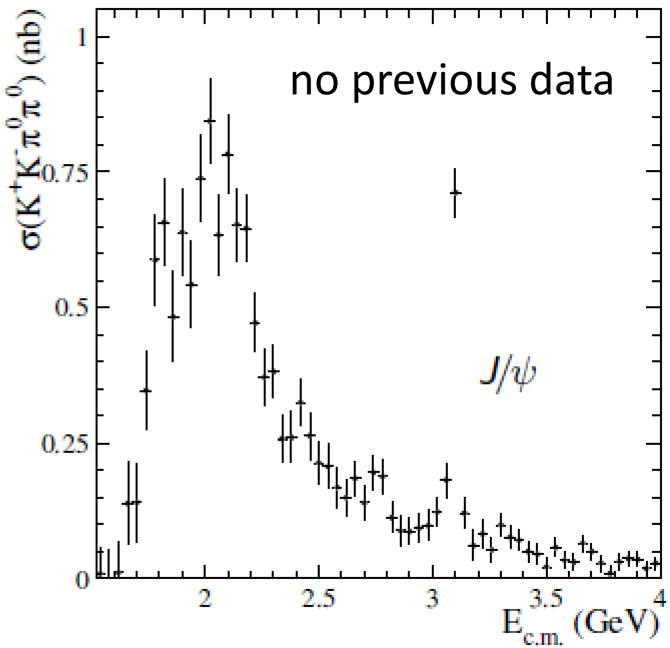
- < 1.4 GeV: agreement with previous *BABAR* results, SND and CMD-2 data
- > 1.4 GeV: highest precision (DM2, 20%)

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

published in 2012 based on the full BABAR statistics (454 fb^{-1})
→ huge improvement compared to existing data



- syst. uncertainty: 4 - 11%
- resolution: 4.2 - 5.5 MeV
- J/ψ clearly visible



- syst. uncertainty: 7 - 16%
- resolution: 8.8 - 11.2 MeV
- J/ψ clearly visible

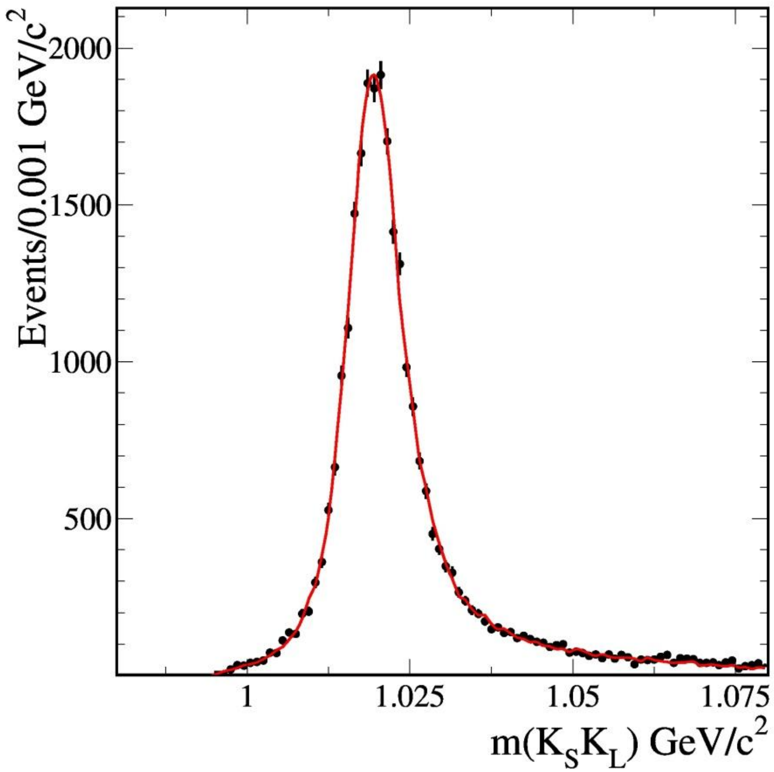
below 2 GeV $K^*(890)\,K\pi$ dominant, also smaller $\phi\,\pi\pi$ and $\rho\,KK$

New results on $e^+e^- \to K_S K_L$: ϕ

published in 2014 based on the full BABAR statistics (454 fb^{-1})

- K_S reconstructed $\pi^+\pi^-$
- K_L direction measured in EM calorimeter
- K_L efficiencies measured using kinematically constrained $\phi \to K_S$ (K_L)

$$\Gamma^{\phi}_{ee} \times B(\phi \to K_S K_L) = (0.4200 \pm 0.0033_{stat} \pm 0.0122_{syst} \pm 0.0019_{fit}) \text{ keV} \quad (3.0\%)$$



$$m_\phi = (1019.46 \pm 0.04 \pm 0.06) \text{ MeV}$$
$$\Gamma_\phi = (4.21 \pm 0.10 \pm 0.07) \text{ MeV}$$

$$\frac{B(\phi \to K_S K_L)}{B(\phi \to K^+ K^-)} = 0.662 \pm 0.021 \quad \text{BABAR}$$

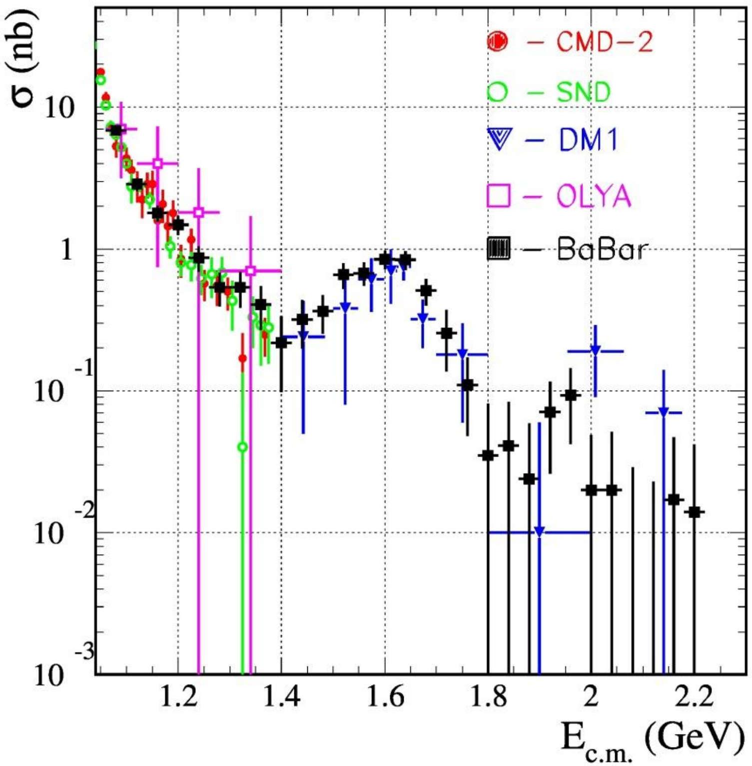
[0.68 ± 0.03 CMD-2]

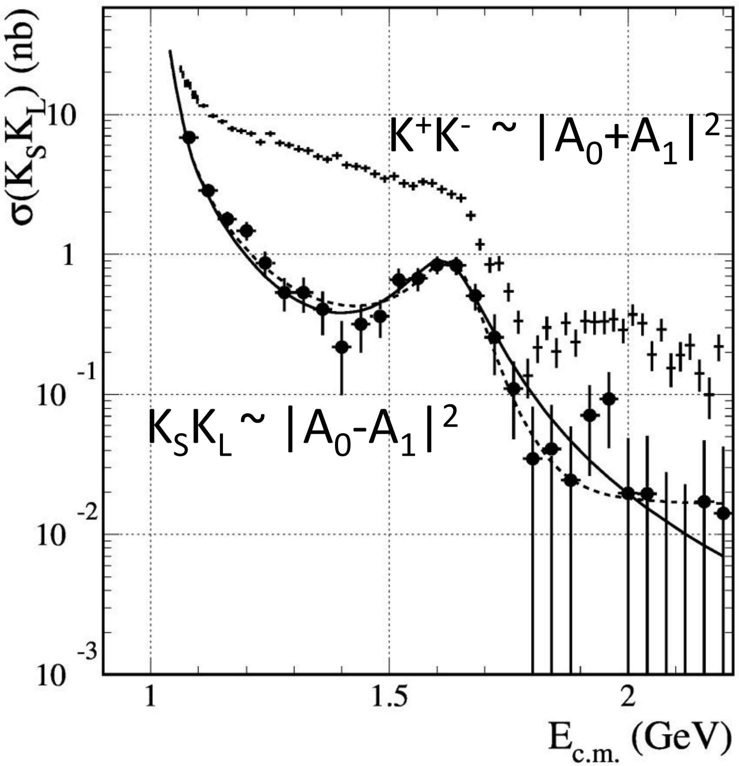
[0.671 ± 0.023 PDG BR av]

[0.740 ± 0.014 PDG fit]

tension between $K\bar{K}$ and other modes

New results on $e^+e^- \to K_S K_L$: large Q^2



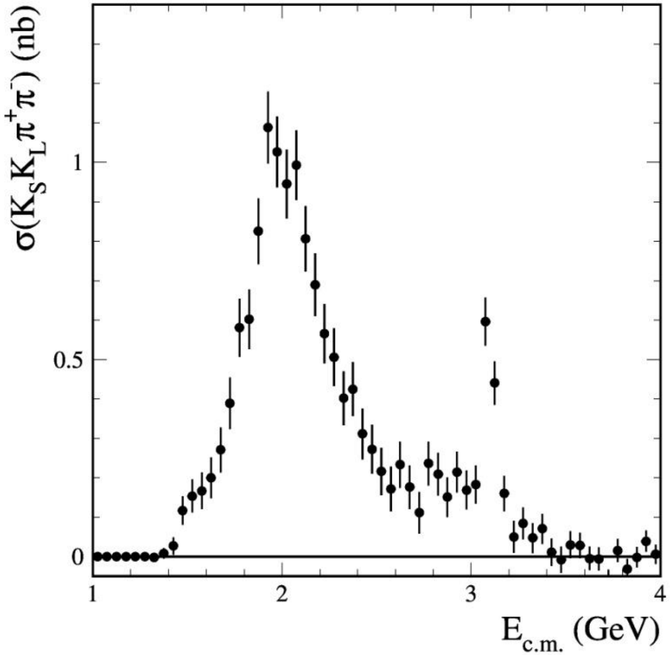


large effect suggestive of $\phi(1680)$

but large interference with isovector part

New results on $e^+e^- \to K_S K_L \pi^+\pi^-$, $K_S K_S \pi^+\pi^-$

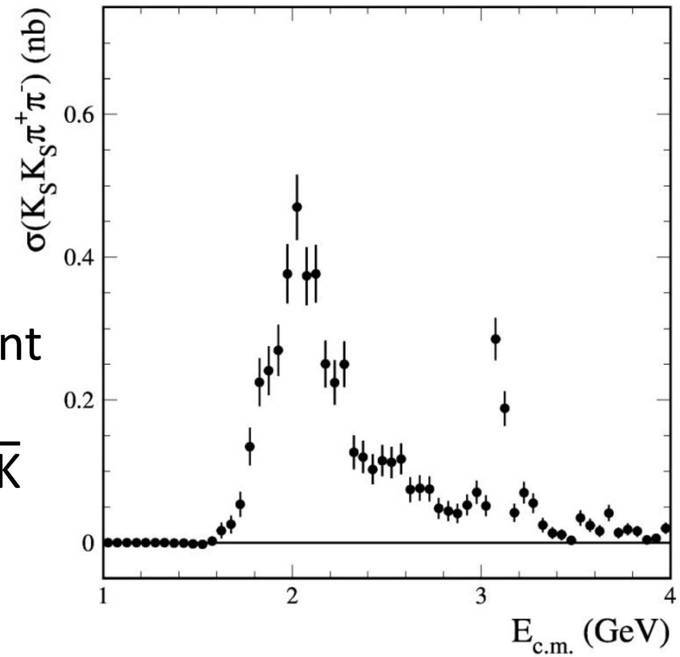
published in 2014 based on the full BABAR statistics (454 fb^{-1})

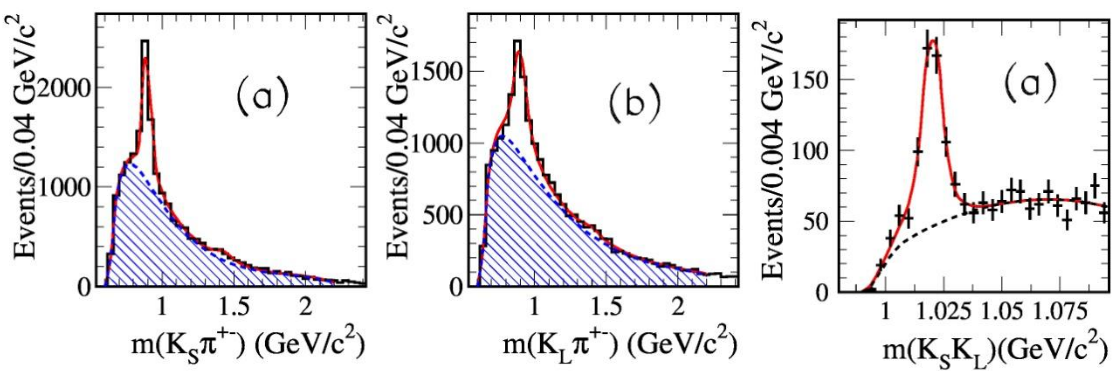


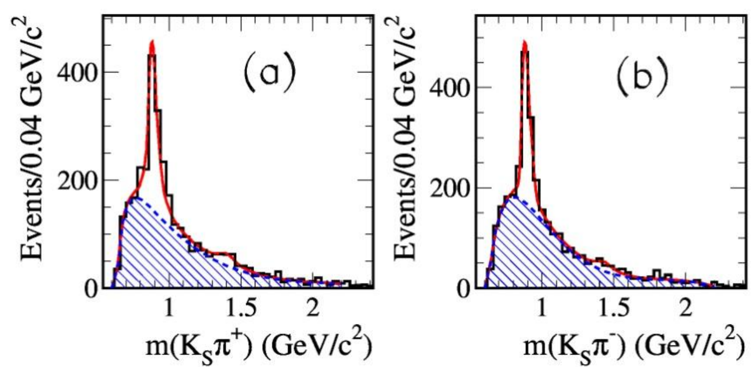
unmeasured before

K*(890) K π dominant

also ϕ $\pi\pi$ $\rho K \bar{K}$

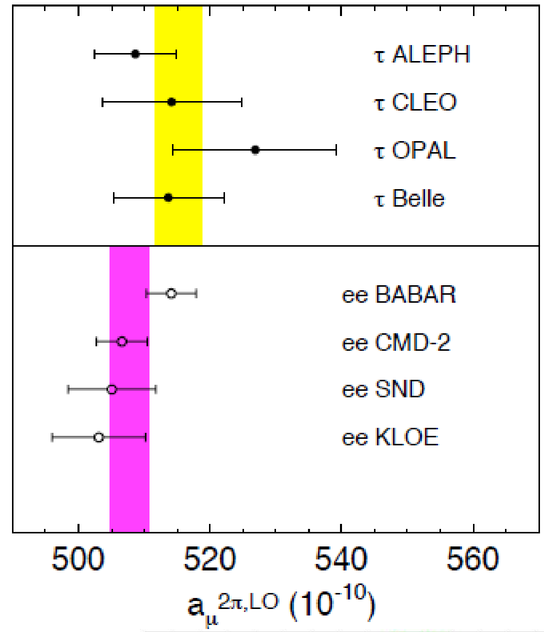






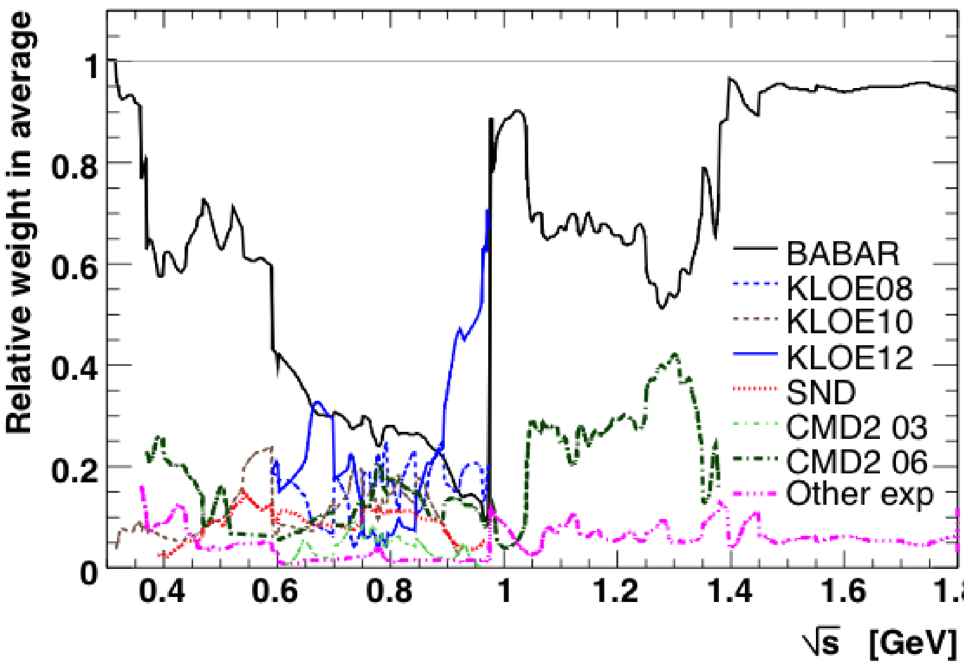
Impact of BABAR data for g-2: $\pi^+\pi^-$

Integral from threshold to 1.8 GeV: BABAR most precise (with CMD-2), reduces tension between e^+e^- and τ

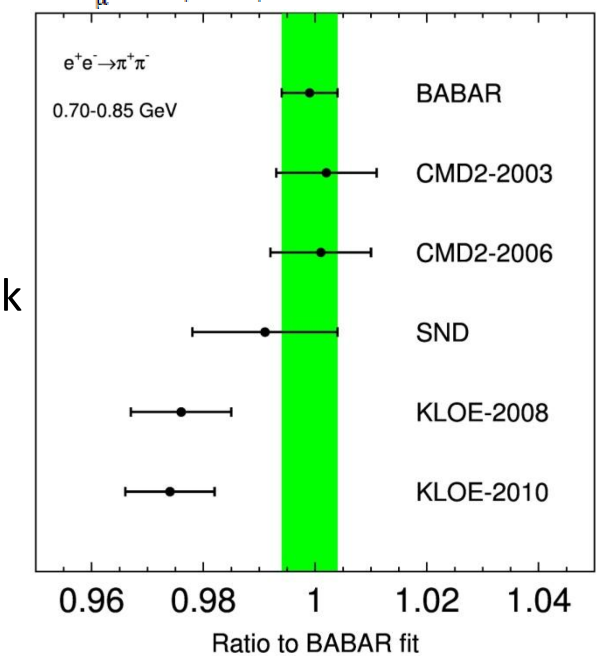


Weights of different experiments in combining their results (DHMZ 2010)

BABAR dominates everywhere, except between 0.8 and 0.93 GeV where KLOE is the most precise



Discrepancy on the ρ peak



Impact of BABAR data for g-2: K^+K^- and $2(\pi^+\pi^-)$

$a_\mu^{KK,\,LO}$ [0.98;1.800] GeV = (22.95 ± 0.14 (stat) ± 0.22 (syst)) 10^{-10} (1.1%)

DHMZ 2011: update of all results before BABAR:
$a_\mu^{KK,\,LO}$[0.98;1.8]GeV = (21.63 ± 0.27 (stat) ± 0.68 (syst))10^{-10} (3.4%)

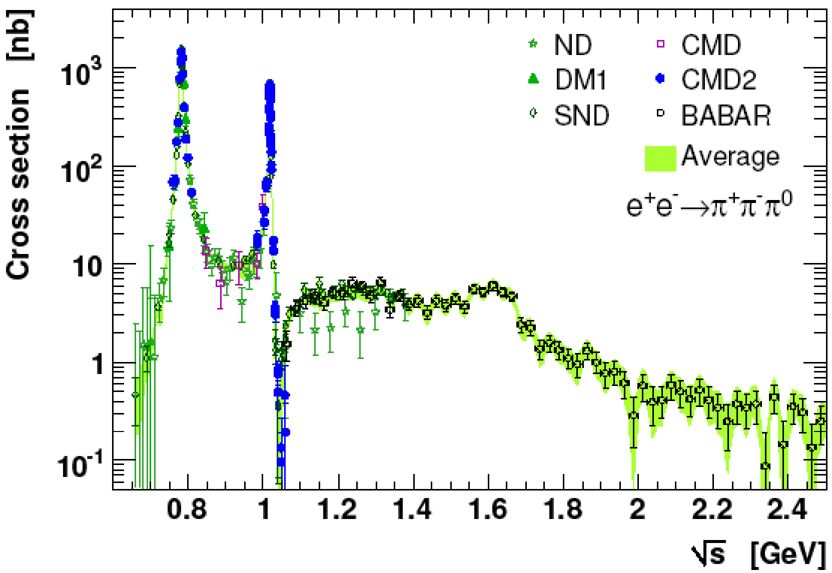
BABAR more precise than previous world average by a factor of 3

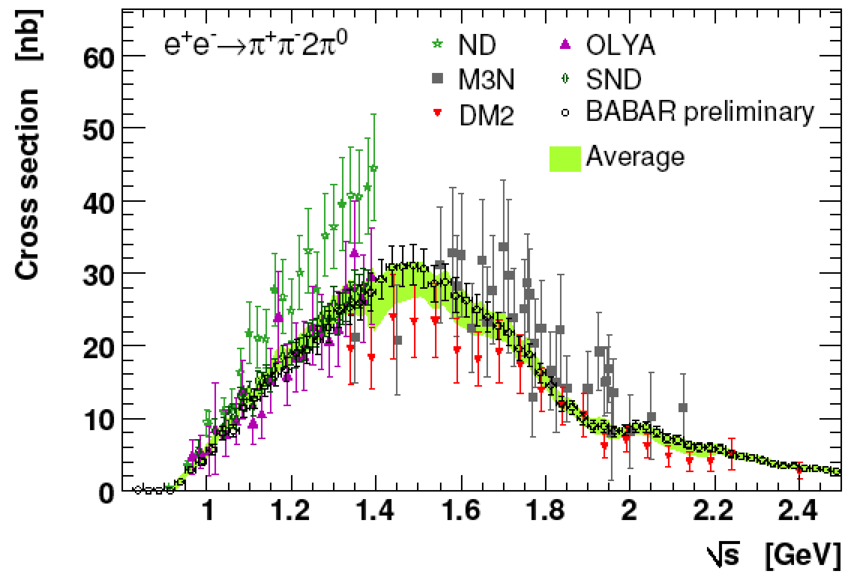
$a_\mu^{4\pi,\,LO}$ [0.98;1.800] GeV = (13.64 ± 0.03 (stat) ± 0.36 (syst)) 10^{-10} (2.6%)

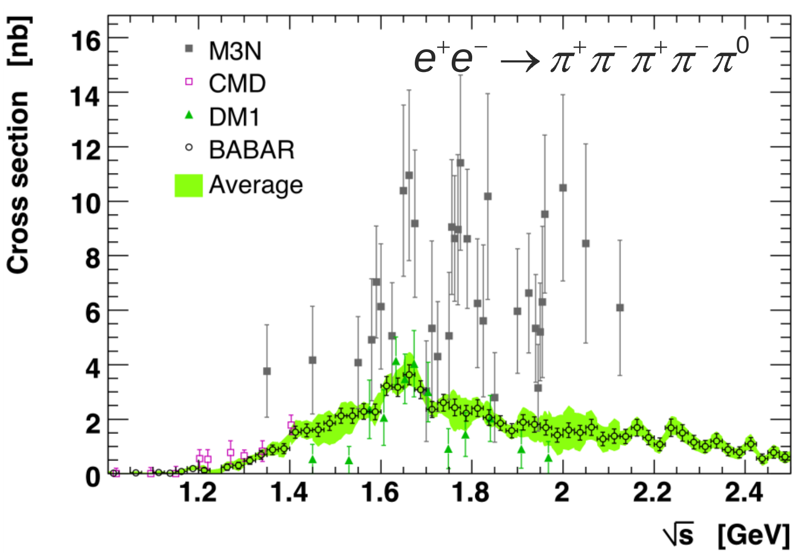
DEHZ 2003: all results but BABAR 2007:
$a_\mu^{4\pi,\,LO}$[0.98;1.8]GeV = (13.95± 0.90 (exp) ± 0.23(rad))10^{-10} (6.7%)

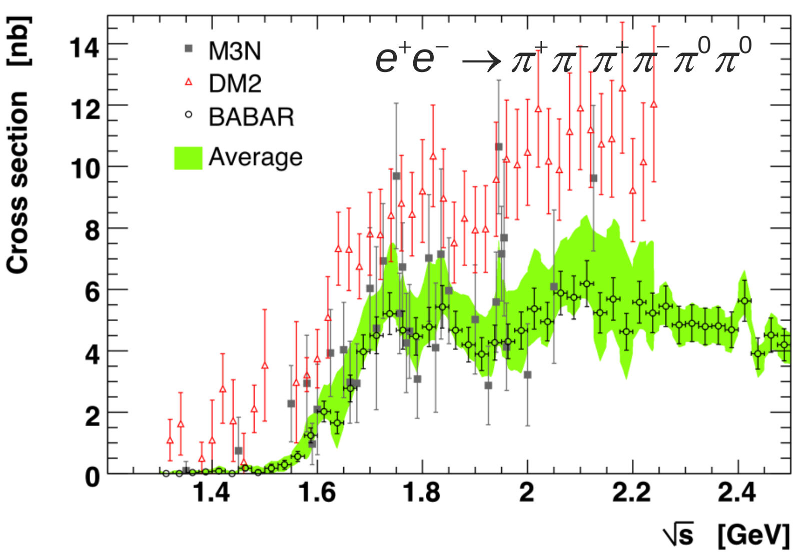
BABAR more precise than previous world average by a factor of 2.6

Impact of BABAR data for g-2: other exemples









Impact of BABAR data for g-2: final-state dynamics

- R measurement by summing exclusive cross sections implies completeness of data
- Below 1.8 GeV hadron multiplicities up to 6 (all pions) and 4 ($K\overline{K}$ + pions) are adequate
- But some channels are very hard to measure: $\pi^+\pi^-4\pi^0$, $K_SK_L\pi^0$, $K_SK_L2\pi^0$
- Isospin symmetry can be used for estimating unmeasured modes:

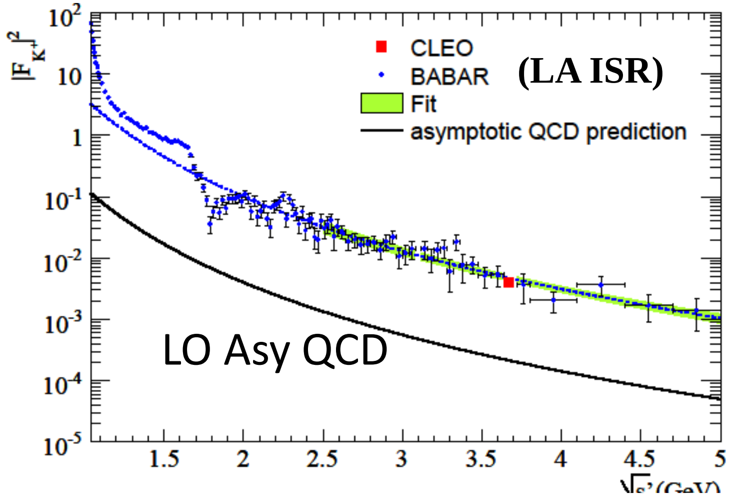
  Alemany-MD-Hoecker 1997, MD-Eidelman-Hoecker-Zhang 2003

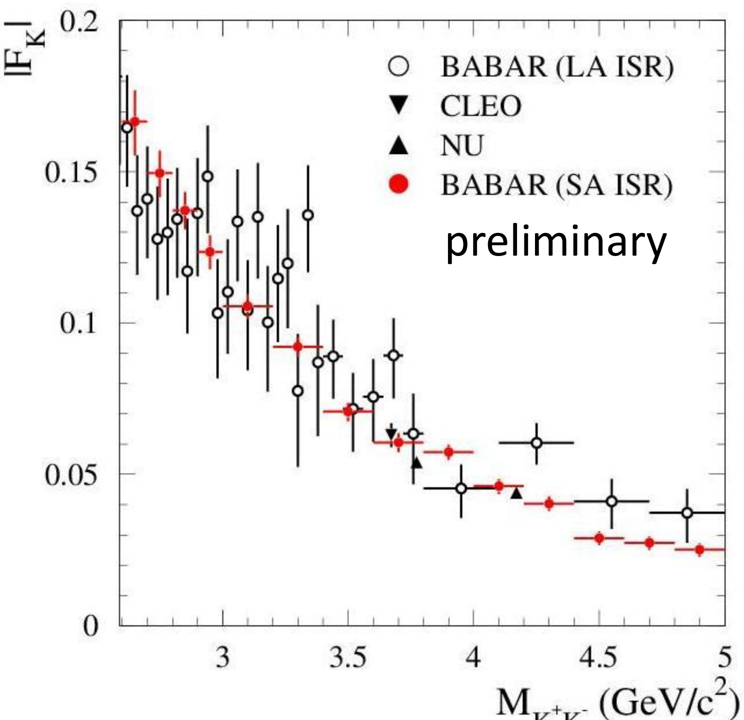
  but often only upper bounds are obtained
- Knowledge of final-state dynamics as available in BABAR analyses is essential to provide reliable estimates:

  MD-Hoecker-Malaescu-Zhang 2010
- example: $\overline{K}K\pi\pi$

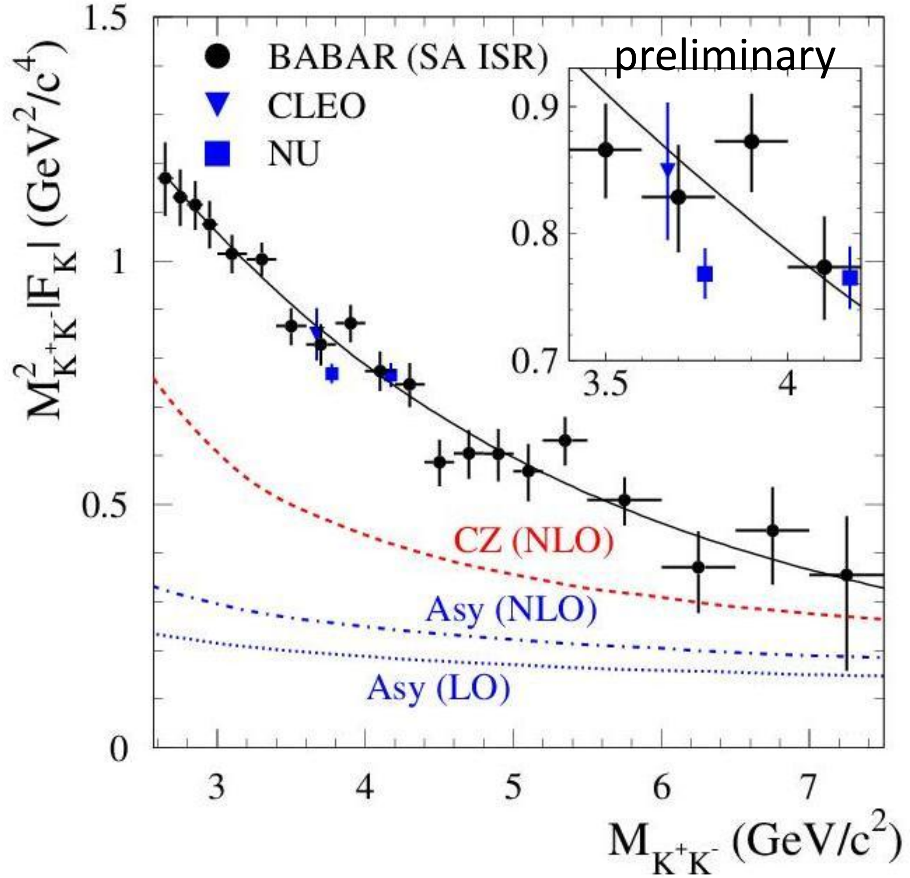
	contribution to a_μ ($\times 10^{-10}$)
2003: estimate	2.2 ± 1.0
2010: only $K^+K^-\pi^+\pi^-$ and $K^+K^-\pi^0\pi^0$ available with final states	1.35 ± 0.38
2014: $K_SK_L\pi^+\pi^-$ and $K_SK_S\pi^+\pi^-$ available with final states	in progress

Preliminary results on $e^+e^- \to K^+K^-$ at large Q^2





ISR with small-angle photon: much larger ISR luminosity, but efficiency only for large masses



slow approach to asymptotic QCD at NLO

$Q^2 \sim (10\ \mathrm{GeV})^2$ Chernyak- Zhitnitski 1984

Conclusions

- Through the ISR method BABAR could plan a complete and consistent program to measure precise cross sections for the dominant channels of $e^+e^- \to$ hadrons from threshold to ~2 GeV.
- This program has been carried out, just a few more channels in progress.

- New results presented: K^+K^-, $\pi^+\pi^-\pi^+\pi^-$, $K^+K^-\pi^+\pi^-$, $K^+K^-\pi^0\pi^0$, K_SK_L, $K_SK_L\pi^+\pi^-$ and $K_SK_S\pi^+\pi^-$.

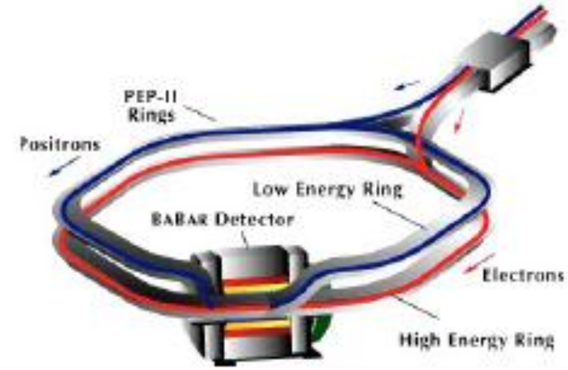
- BABAR results have a large impact on the hadronic vacuum polarization (HVP) contribution to the muon g-2; also, but lesser impact on $\alpha(M_Z^2)$.

- In addition to HVP there are other applications of these data in progress for QCD tests with finite energy sum rules, complementing similar studies done with hadronic τ decays.
- Also (not covered in this talk) BABAR ISR results provide input into hadron spectroscopy, resonance dynamics and measurement of baryon form factors.

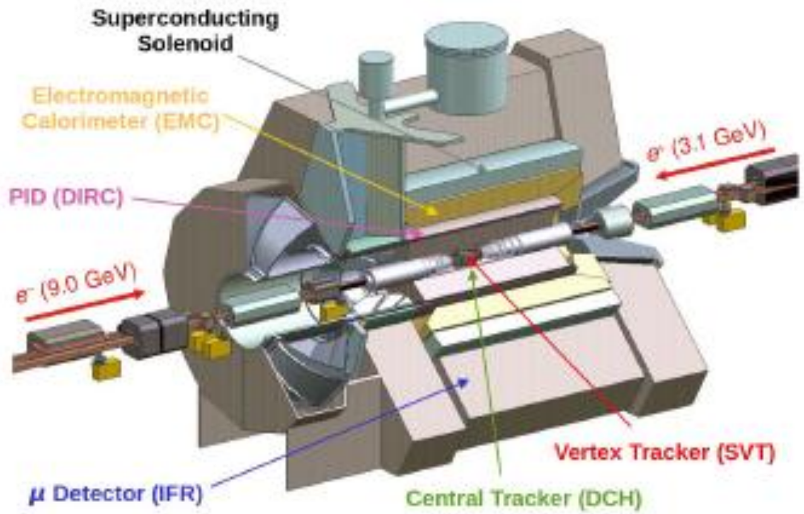
Backup slides

PEP-II and the *BABAR* detector at SLAC

- asymmetric e^+e^--collider: $9\,\mathrm{GeV}\ (e^-)$ and $3.1\,\mathrm{GeV}\ (e^+)$
- $\sqrt{s} = 10.58\,\mathrm{GeV} \Rightarrow \Upsilon(4S)$
  $\Rightarrow$ above $B\overline{B}$-threshold



- main purpose: B-physics
- multi purpose detector
- data taken from 1999 – 2008
- integrated luminosity: $531\,\mathrm{fb}^{-1}$
  on $\Upsilon(4S)$: $454\,\mathrm{fb}^{-1}$
  $\approx 600 \cdot 10^6\ B\overline{B}$-pairs



Analysis of $e^+e^- \to K^+K^-(\gamma)$

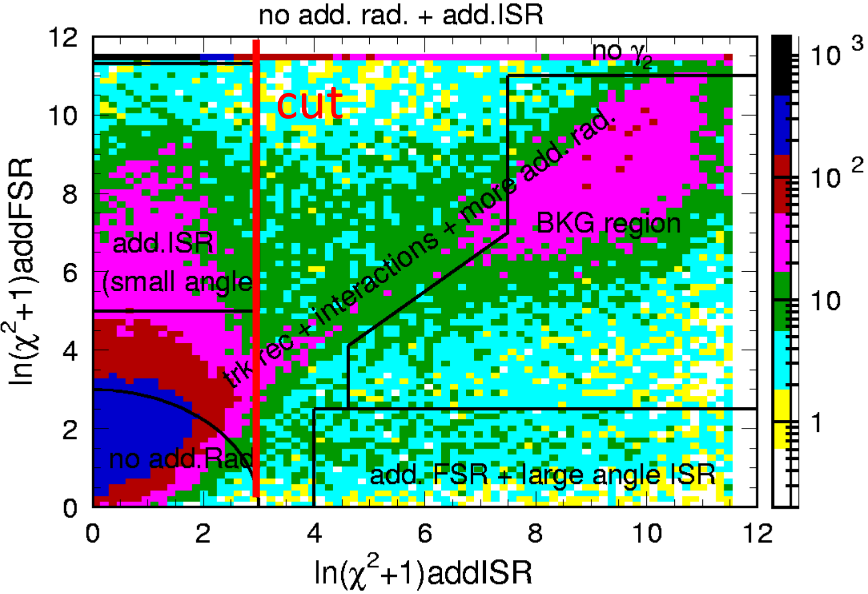
- procedures similar to $\pi\pi$ analysis
- luminosity 231 fb^{-1}

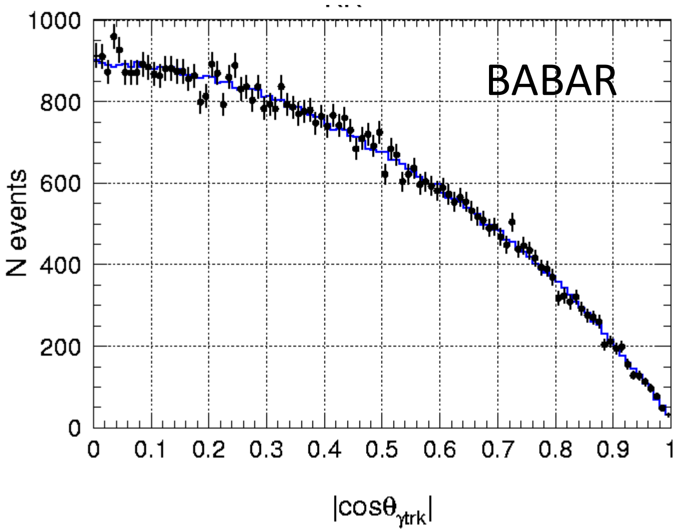
- efficiencies obtained from full simulation (AfkQed) and data/MC corrections
  trigger, tracking , K-ID and mis-ID efficiencies
- background studies, normalization using data, subtraction
- efficiency of the kinematical fit χ^2 cut
  → additional radiation ISR/FSR
  → studies with muons
  → differences between kaons and muons: secondary interactions,FSR
- unfolding background-subtracted and data/MC corrected mass spectra
- geometrical acceptance and second-order corrections using Phokhara
- ISR effective luminosity from $\mu\mu\gamma(\gamma)$: KK/$\mu\mu$ ratio
- mass-dependent systematic uncertainties, best in ϕ region (0.7%)

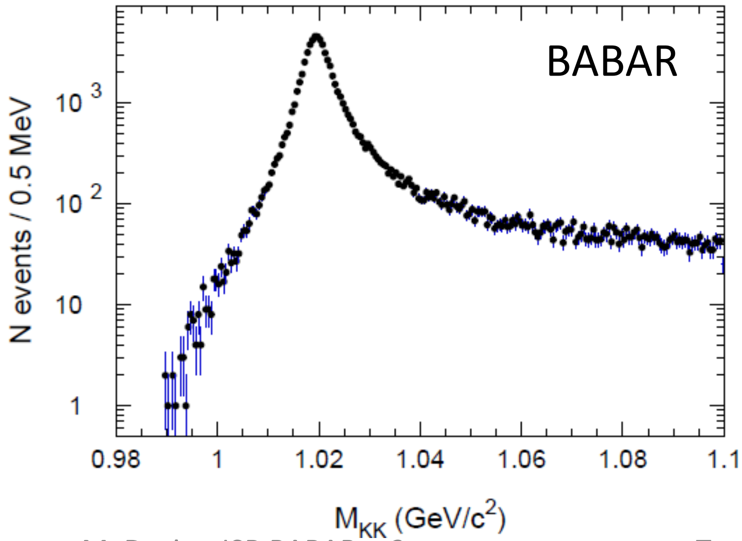
- cross section
- contribution to a_μ

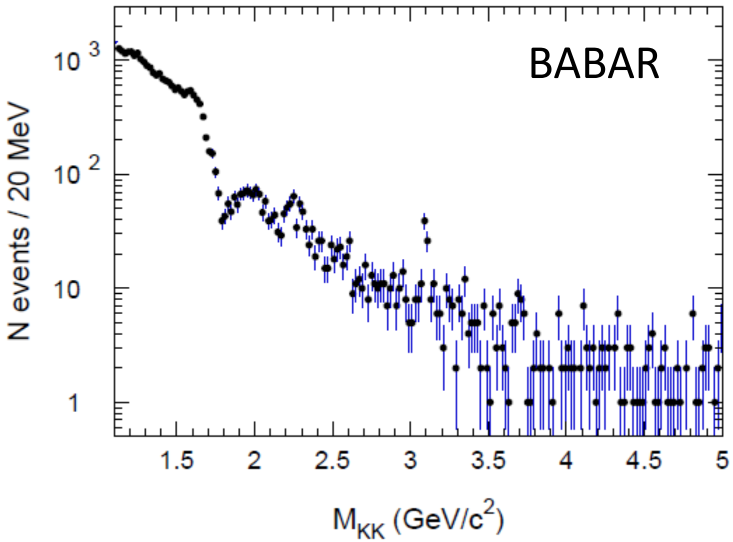
$e^+e^- \to K^+ K^-(\gamma)$ spectra

2 kinematic fits: ISR (add. photon collinear/beams), 'FSR' (add. detected photon at large angle)









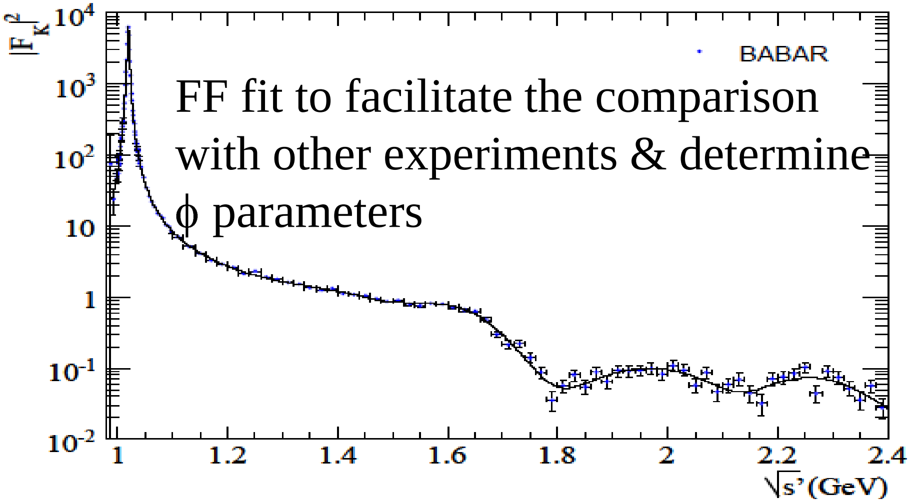
A phenomenological fit to the form factor

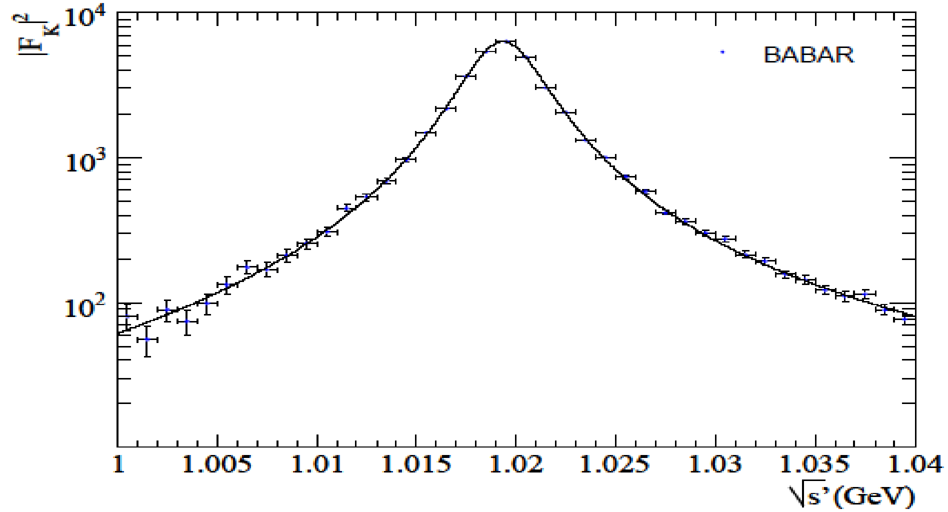
Kuehn et al.

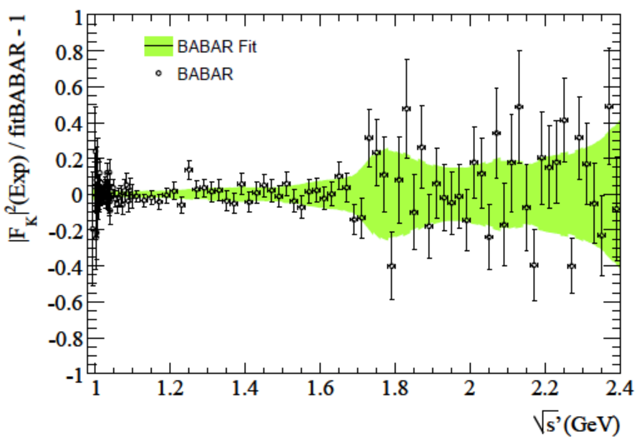
$$F_K(s) = (a_\phi\ BW_\phi + a_{\phi'}\ BW_{\phi'} + a_{\phi''}\ BW_{\phi''})/3$$
$$+\ (a_\rho\ BW_\rho + a_{\rho'}\ BW_{\rho'} + a_{\rho''}\ BW_{\rho''} + a_{\rho'''}\ BW_{\rho'''})/2$$
$$+\ (a_\omega\ BW_\omega + a_{\omega'}\ BW_{\omega'} + a_{\omega''}\ BW_{\omega''} + a_{\omega'''}\ BW_{\omega'''})/6$$

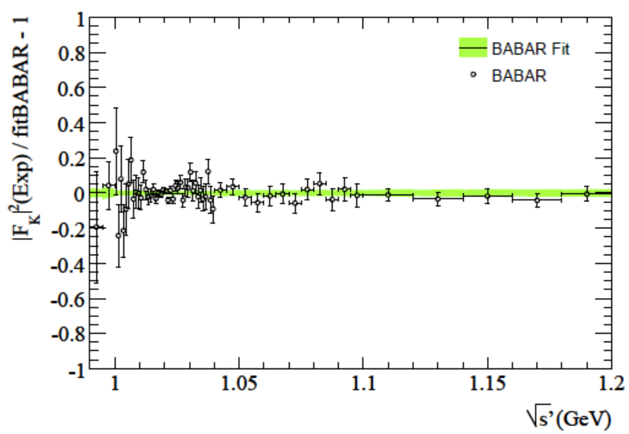
$$a_\phi + a_{\phi'} + a_{\phi''} = 1,$$
$$a_\rho + a_{\rho'} + a_{\rho''} + a_{\rho'''} = 1,$$
$$a_\omega + a_{\omega'} + a_{\omega''} + a_{\omega'''} = 1.$$

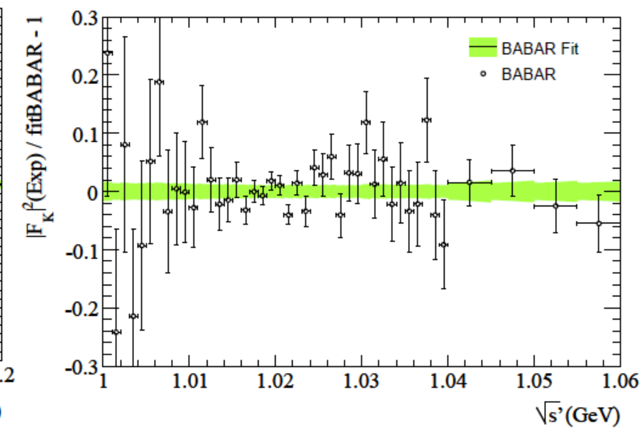
FF fit to facilitate the comparison with other experiments & determine ϕ parameters











Charged kaon form factor at large Q^2

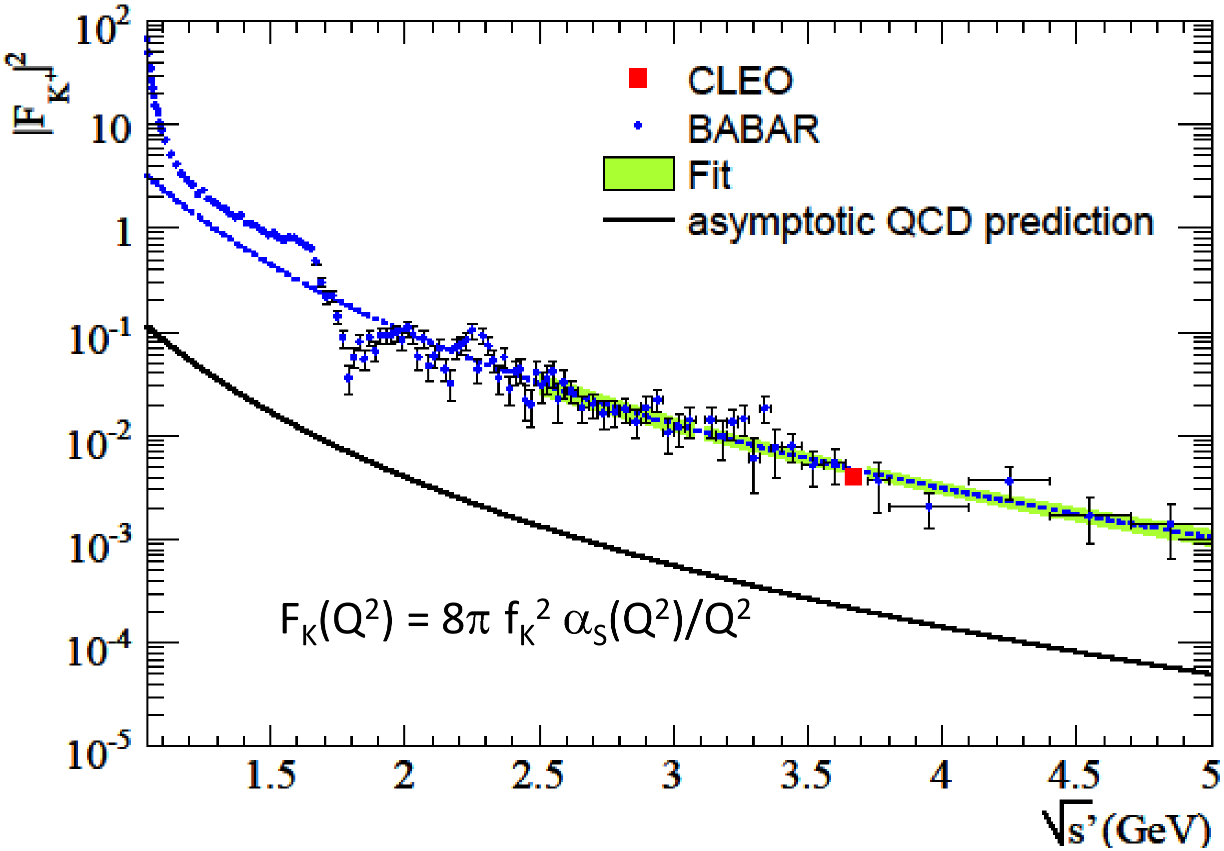
Predictions based on QCD in asymptotic regime (Chernyak, Brodsky-Lepage, Farrar-Jackson)

→ power law $F_K \sim \alpha_S(Q^2)\, Q^{-n}$ with n=2 in good agreement with data (2.5-5 GeV n=2.10 0.23)

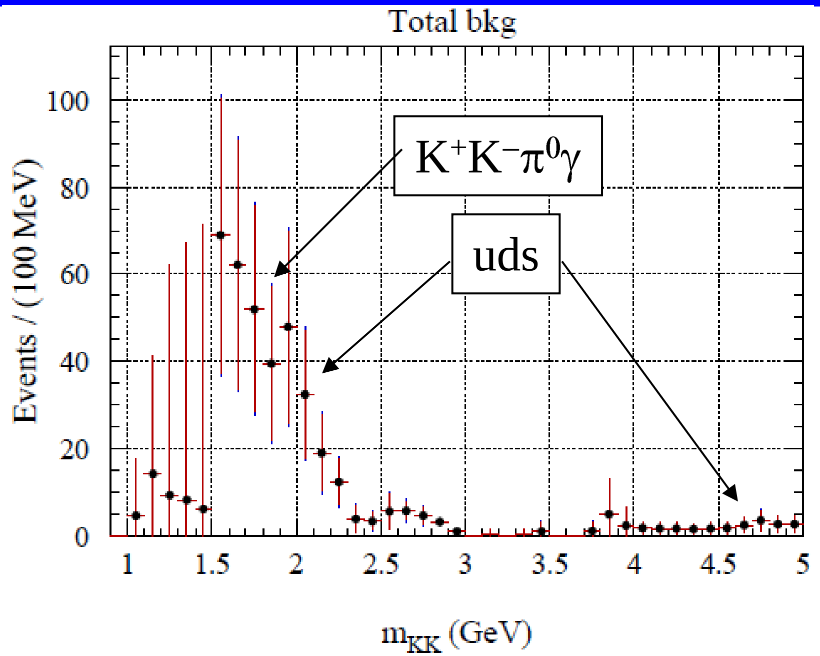
→ but data on $|F_K|^2$ a factor ~20 above prediction !

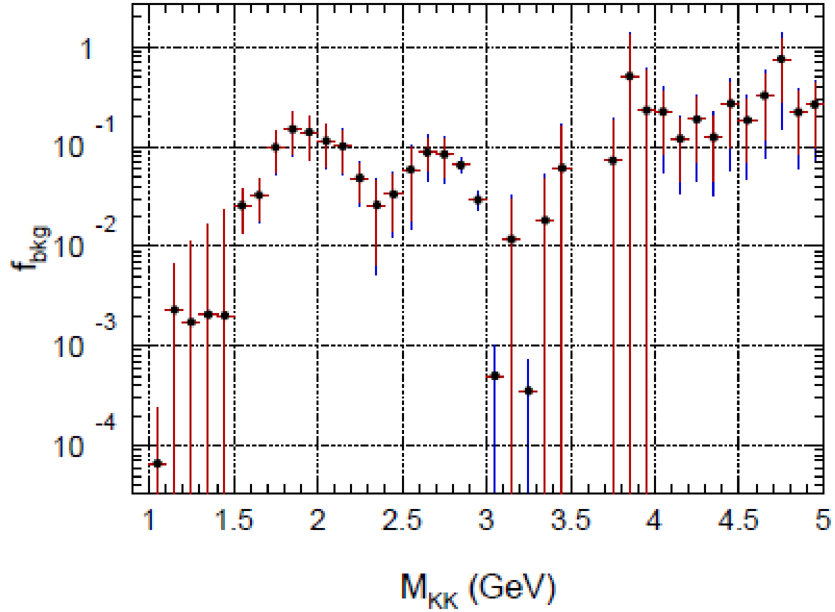
→ no trend in data up to 25 GeV^2 for approaching the asymptotic QCD prediction

→ similar trend observed with F_π



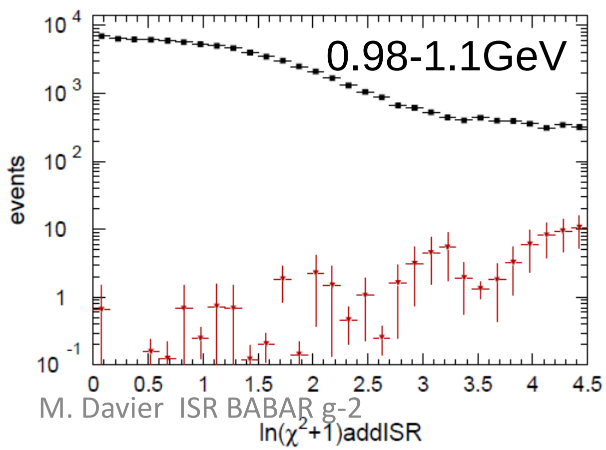
Background (MC, other than $\gamma\pi\pi$ and $\gamma\mu\mu$)

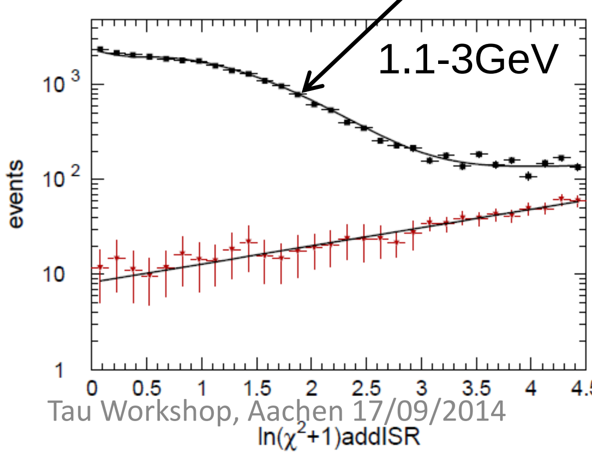


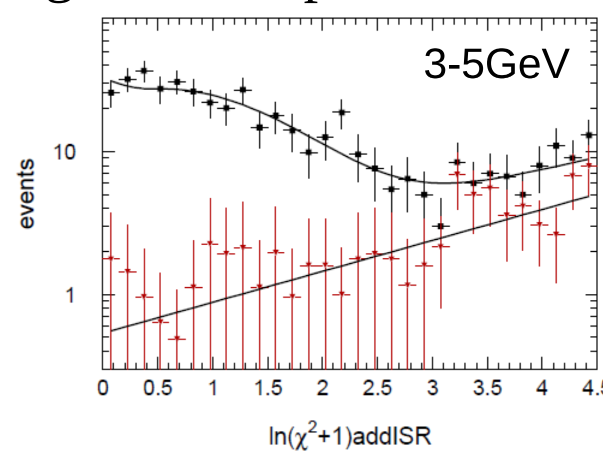


Cross-check of the background normalization

Signal shape from ϕ + background shape from MC







Geometrical Acceptance

→Used AfkQed to determine geometrical acceptance

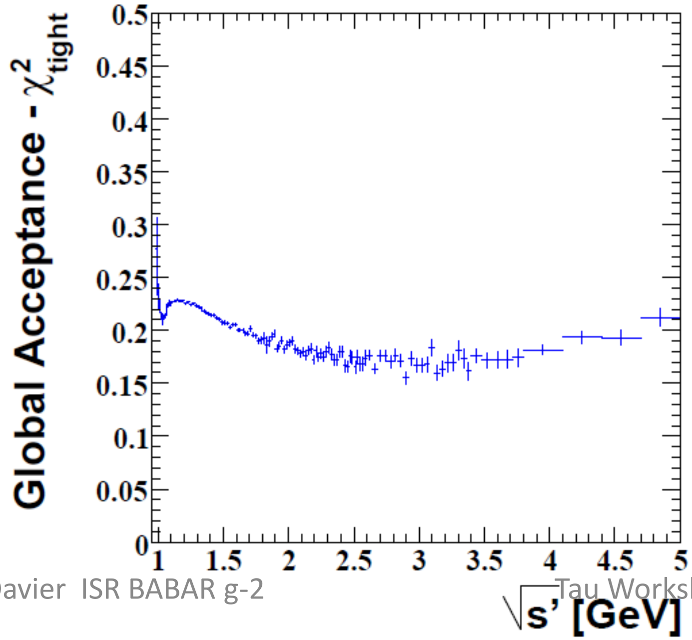
Main problems for AfkQed:

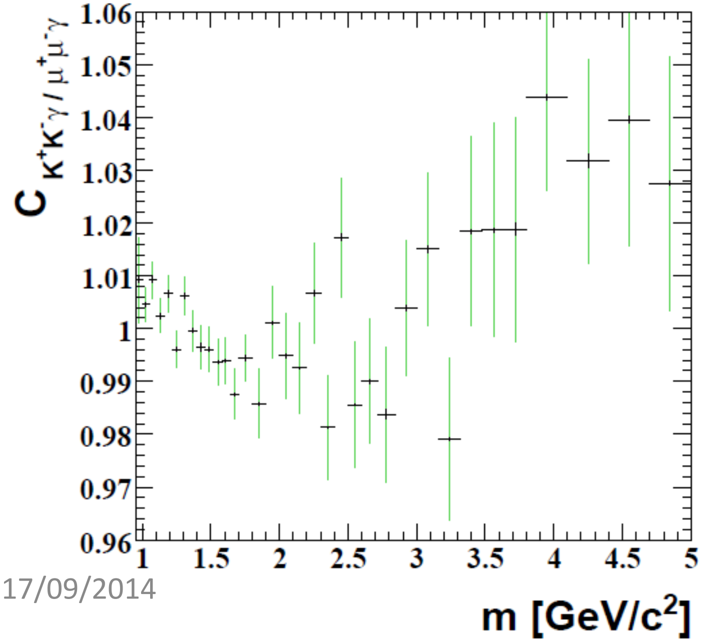
- assumption of collinear add. ISR
- lack of hard add. ISR because of the cut $m_{KK\gamma ISR(\gamma addFSR)} > 8$ GeV

→common to KK and μμ (first order, cancel in ratio)

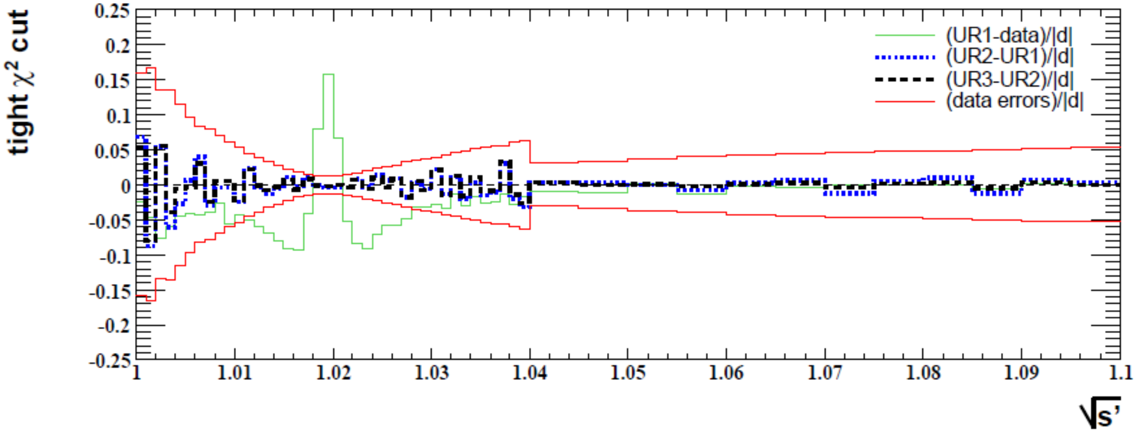
→second order effects studied with Phokhara (exact NLO QED for add. ISR)

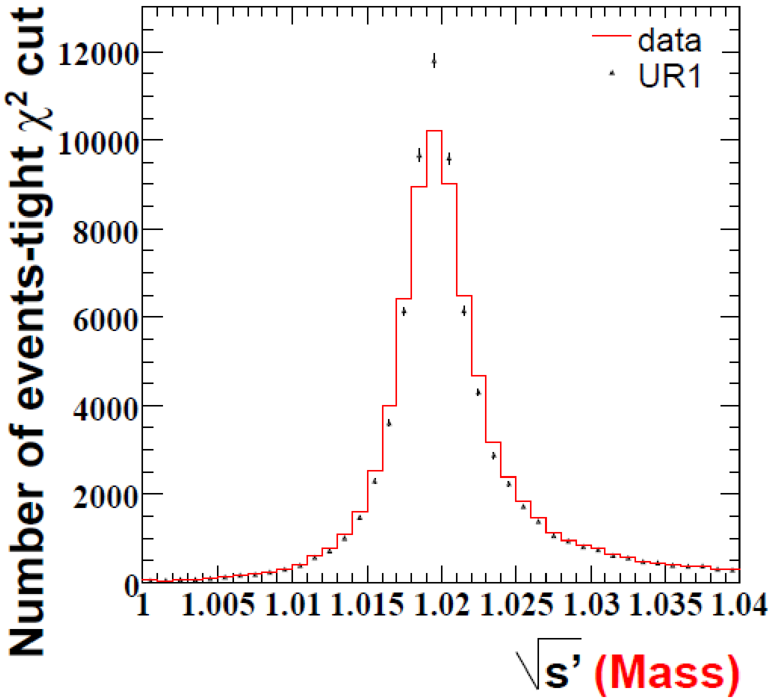
- also studied: effects of secondary interactions on the pre-selection cut (data/MC differences)

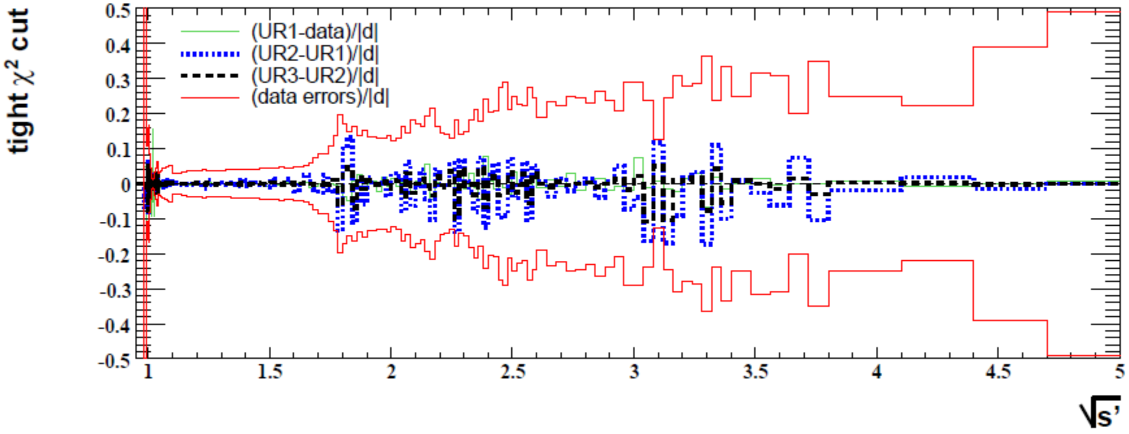




Effect of the unfolding







→result obtained after one iteration (UR2)

→procedure tested with toy models

Systematic uncertainties (x10^{-3}) for the $e^+e^- \rightarrow K^+K^- (\gamma)$ cross section

ϕ

sources	0.98-0.99	0.99-1	1-1.01	1.01-1.03	1.03-1.04	1.04-1.05	1.05-1.1
trigger/ filter	1.0	0.7	0.7	0.7	0.7	0.8	0.8
tracking	1.8	1.8	1.9	2.8	2.8	2.8	5.3
K-ID	10.6	8.8	5.4	4.1	6.5	12.7	12.8
background	157.2	20.9	1.6	0.1	0.3	0.6	1.1
acceptance	1.6	1.6	1.6	1.6	1.6	1.6	1.6
kinematic fit (χ^2)	2.0	2.0	2.0	2.0	2.0	3.3	3.2
ISR luminosity	3.7	3.7	3.7	3.7	3.7	3.7	3.7
unfolding	3.2	3.2	3.2	-	1.2	1.2	1.2
VP correction	-	-	0.4	2.5	0.5	-	-
sum (cross section)	157.7	23.4	8.2	7.2	8.5	14.1	14.9

sources	1.1-1.2	1.2-1.3	1.3-1.5	1.5-1.7	1.7-2.3	2.3-3	3-4	4-5
trigger/ filter	0.6	0.5	0.4	0.4	0.4	0.4	0.5	0.5
tracking	7.2	8.2	8.8	9.2	9.7	10.0	10.2	10.2
K-ID	13.0	16.3	26.3	33.1	41.1	51.4	52.1	54.4
background	4.9	11.8	18.5	13.6	56.0	24.3	67.6	243.5
acceptance	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
kinematic fit (χ^2)	2.3	2.5	2.6	3.5	4.5	5.6	14.6	23.4
ISR luminosity	3.7	3.7	3.7	3.7	3.7	3.7	12.7	22.3
unfolding	0.7	0.7	0.7	-	-	-	-	-
VP correction	-	-	-	-	-	-	-	-
sum (cross section)	16.4	22.3	33.7	37.3	70.4	58.1	88.1	251.8

The integrated ϕ contribution

$$\Gamma_{\phi}^{ee} \times B(\phi \to K^+K^-) = \frac{\alpha^2\beta^3(s,m_K)}{324}\,\frac{m_\phi^2}{\Gamma_\phi}\,a_\phi^2\,C_{FS}$$

a_ϕ obtained from the fit of the form factor

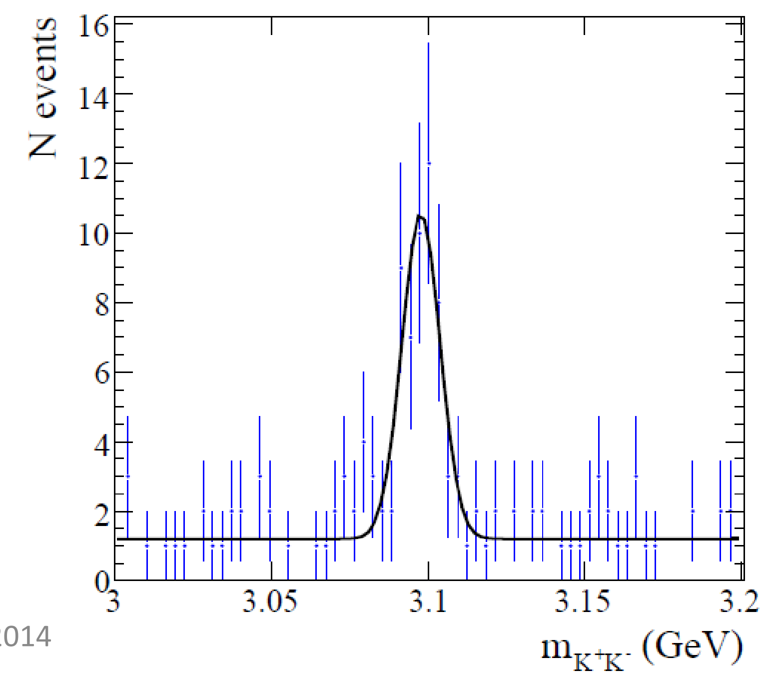
$$\Gamma_{\rm ee}^{\phi} \times B(\phi \to K^+K^-) = (0.6344 \pm 0.0059_{\rm exp} \pm 0.0028_{\rm fit} \pm 0.0015_{\rm cal})\,{\rm keV}$$ (1.1%)

CMD2: 0.605   0.020   0.013 keV (3.9%)

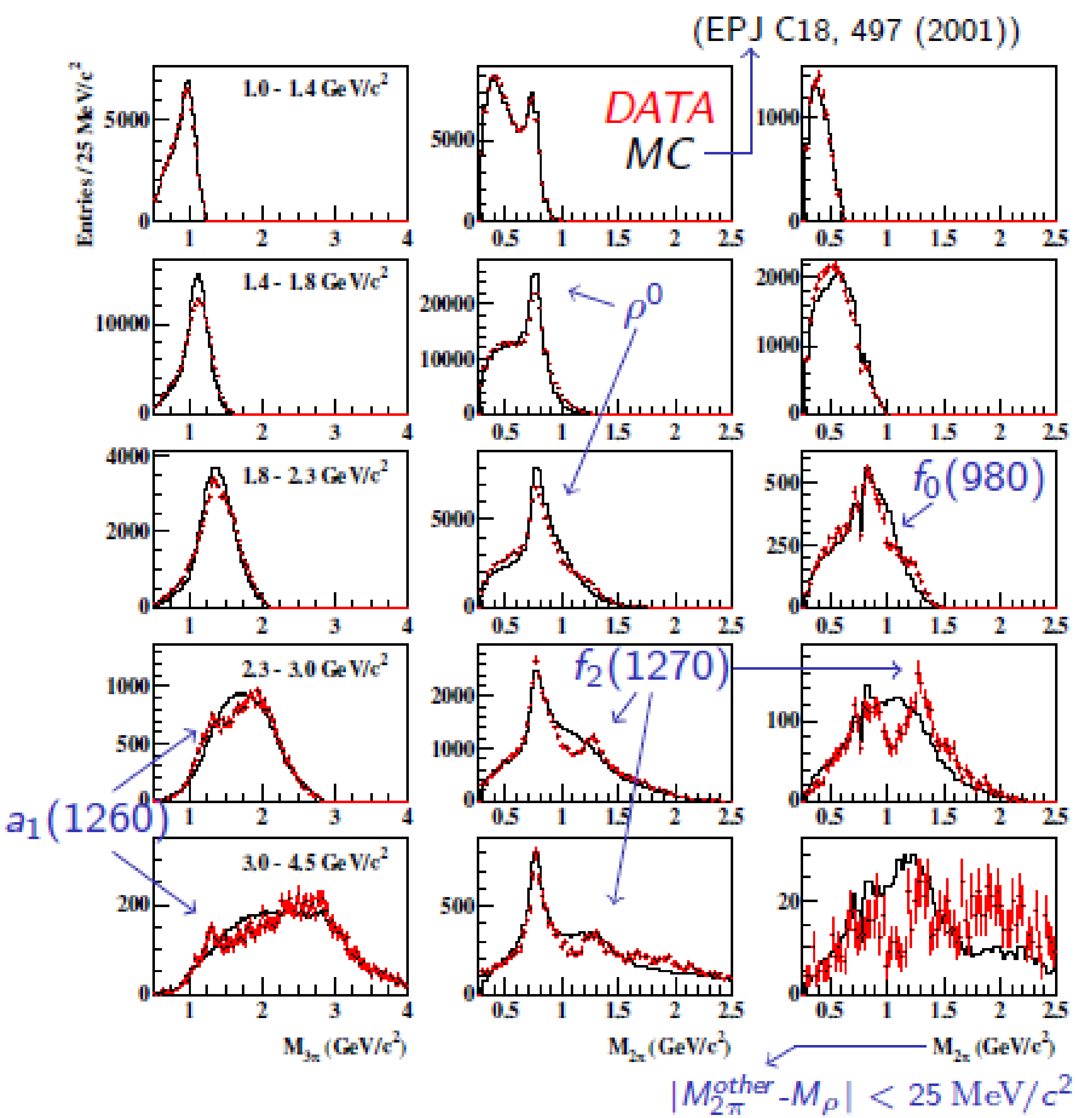
The branching fraction of J/ψ to K^+K^-

$B(J/\psi \to K^+K^-) = (4.16 \quad 0.86_{exp} \quad 0.10\ _{\Gamma ee})*10^{-4}$

World average: $(2.37 \quad 0.31\ )*10^{-4}$ (~Mark III)



Internal structure in various E_{CM} energy slices   e+e-→2π+2π−



First column (4 entries/event):

$a_1(1260)$

Second column (4 entries/event):

strong ρ^0 contribution
e.g. for $M_{4\pi} > 1.4\,\mathrm{GeV}/c^2$:
1/4*th* of entries in ρ^0 peak
$\rho^0\rho^0$ is forbidden
→ ρ^0 in each event!

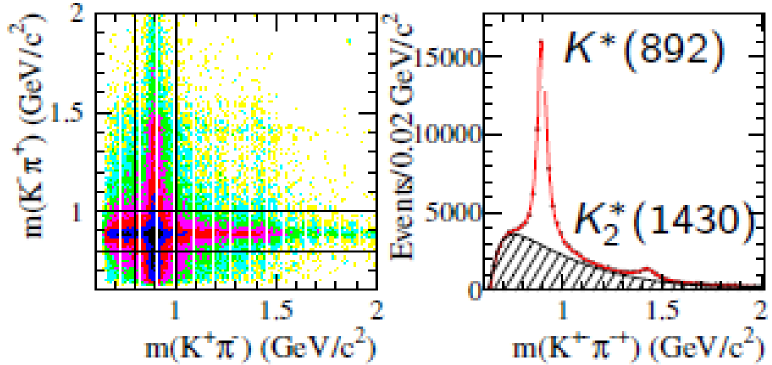
Third column (1 entry/event):

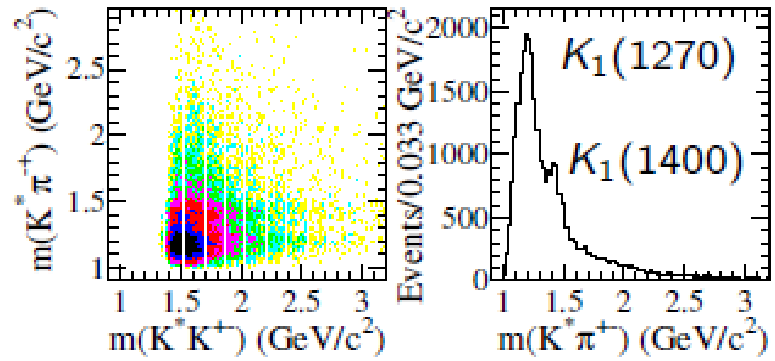
2π lie within ρ^0 mass
→ other $\pi^+\pi^-$'s mass plotted

$f_2(1270)$, $a_1(1260)$, $f_0(980)$ . . . ?
→ Partial Wave Analysis needed

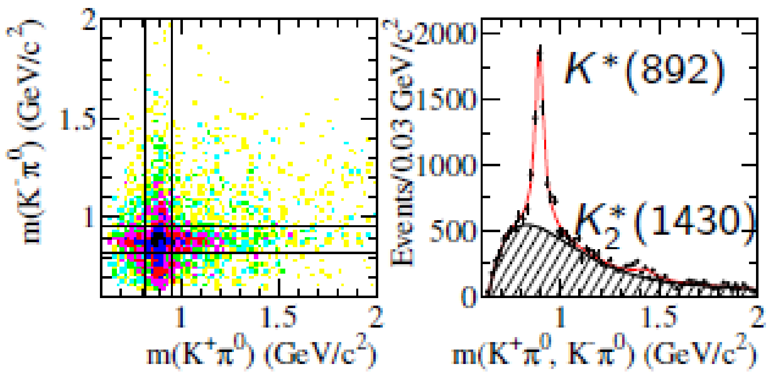
Intermediate Resonances of $e^+e^- \to K^+K^-\pi^+\pi^-$

$K^+K^-\pi^+\pi^-$



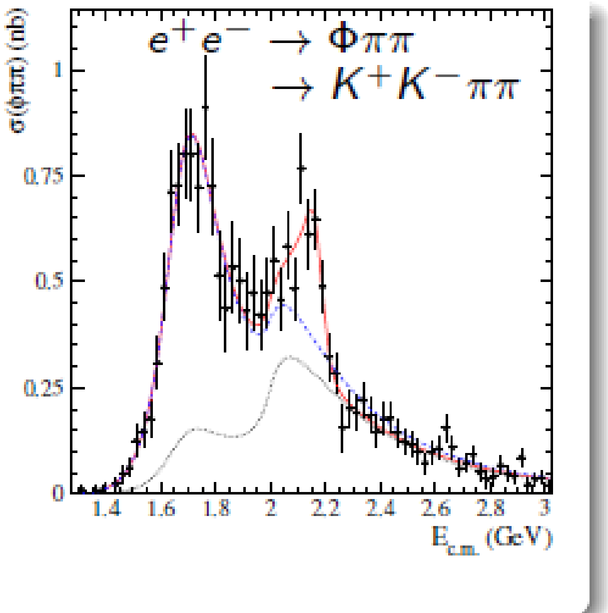


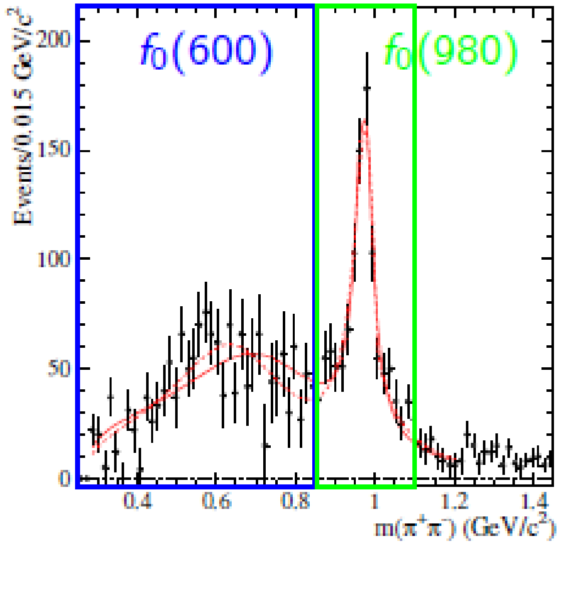
$K^+K^-\pi^0\pi^0$

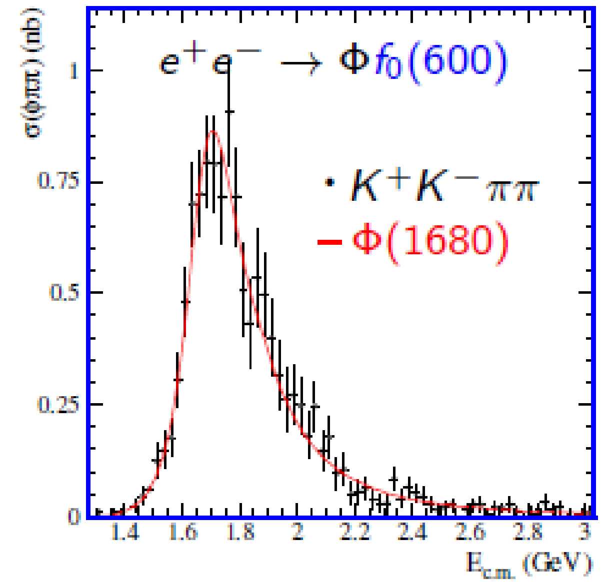


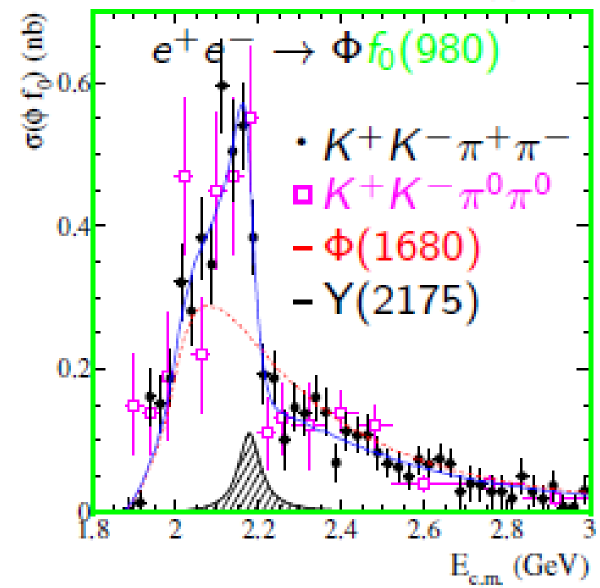
cross section dominated by
$K^*(892)K^\pm\pi^\mp$ final state
$K_1(1270, 1400) \to K^*(892)\pi$ and
$K_1(1270) \to K\rho(770)$ are seen

$e^+e^- \to \phi\pi\pi \to K^+K^-\pi\pi$









- Requirement: $\phi \to K^+K^-$
- Fit assumes two resonances
- Y(2175) confirmed: $J^{PC} = 1^{--}$
  M=$2176 \pm 14 \pm 4\,\mathrm{MeV}/c^2$; $\Gamma = 90 \pm 22 \pm 10\,\mathrm{MeV}$
- Might not be a radial excitation: width too small & should also decay into $\phi f_0(600)$ as for $\phi(1680)$
- Strangeness partner of Y(4260)? Hybrid-candidate?

Impact of BABAR data for g-2: K^+K^-

BABAR results:

$a_\mu^{KK,\,LO}$ [0.98;1.800] GeV = (22.95 0.14 (stat) ± 0.22 (syst)) 10^{-10} (1.1%)

$a_\mu^{KK,\,LO}$ [1.000;1.055] GeV = (18.49 0.13 (stat) ± 0.13 (syst)) 10^{-10}

$a_\mu^{KK,\,LO}$ [1.055;1.800] GeV = (4.44 0.04 (stat) ± 0.10 (syst)) 10^{-10}

$a_\mu^{KK,\,LO}$ [1.800;3.000] GeV = (0.121 0.003 (stat) ± 0.008 (syst)) 10^{-10}

DHMZ 2011: update of all results before BABAR:

$a_\mu^{KK,\,LO}$[0.98;1.8]GeV = (21.63 ± 0.27 (stat) ± 0.68 (syst))10^{-10} (3.4%)

BABAR more precise than previous world average by a factor of 3