A New Approach To Evaluate The Leading Hadronic Corrections To Muon g-2

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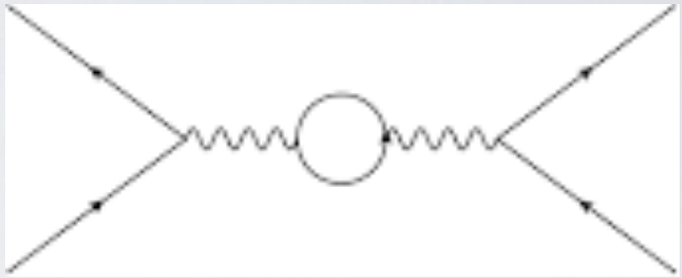
Vacuum Polarization makes α_{em} running assuming a well defined "effective" value at any scale



vacuum polarization and the "effective charge" are defined by:

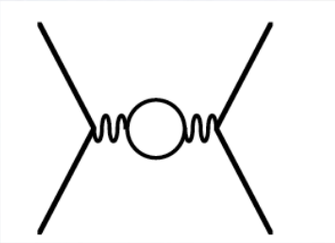
$$e^2 \rightarrow e^2(q^2) = \frac{e^2}{1+(\Pi(q^2)-\Pi(0))} \qquad \alpha(q^2) = \frac{\alpha(0)}{1-\Delta\alpha}; \quad \Delta\alpha = -\Re e\left(\Pi(q^2)-\Pi(0)\right)$$

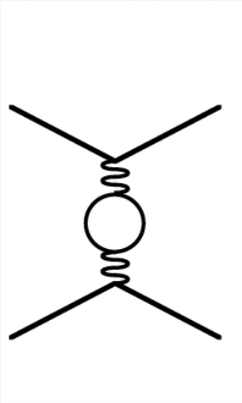
$\Delta\alpha$ takes contributions from leptonic and hadronic and gauge bosons elementary states

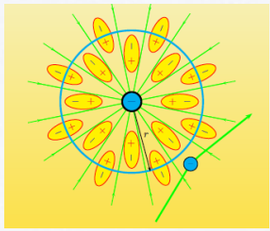
Among these the non-perturbative $\Delta\alpha_{had}$

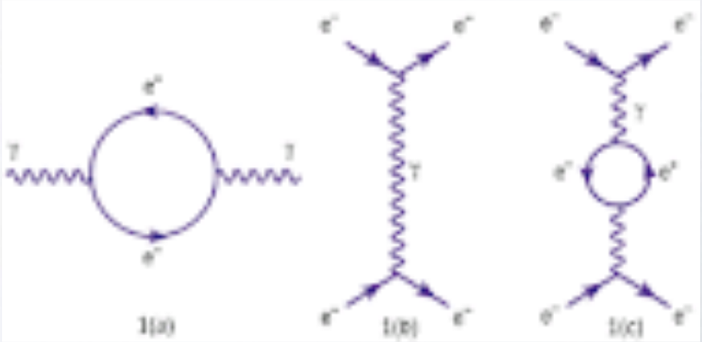
$$\Delta\alpha = \Delta\alpha_{leptonic} + \Delta\alpha_{gb} + \Delta\alpha_{had} + \Delta\alpha_{top}$$

α









The numerical prediction of electroweak observables involves the knowledge of $\alpha(q^2)$ usually for $q^2 \neq 0$

for example the knowledge of $\alpha(m_Z^2)$ is relevant to the evaluation of quantities measured by the LEP experiments.

This is achieved by evolving from $q^2 = 0$ to the Z mass.

The evolution is expressed by the quantity $\Delta\alpha(q^2)$ receives contributions from leptons, hadrons and the gauge bosons.

The hadronic contribution to the vacuum polarization, which cannot be calculated from first principles, is estimated with the help of a dispersion integral and evaluated by using total cross section measurements of e+e− → hadrons at low energies.

Therefore, any evolved value of $\Delta\alpha(q^2)$ and particularly for $q^2 \geq m_\pi^2$ is affected by uncertainties originating from hadronic contributions.

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M. Davier and A. Hoecker: Phys. Lett. B435 (1998) 427;
M. Davier, S. Eidelman, A. Hoecker and Z. Zhang: Eur. Phys. J. C27 (2003) 497
D. Karlen and H. Burkhardt: Eur. Phys. J. C22 (2001) 39; hep-ex/0105065 (2001)
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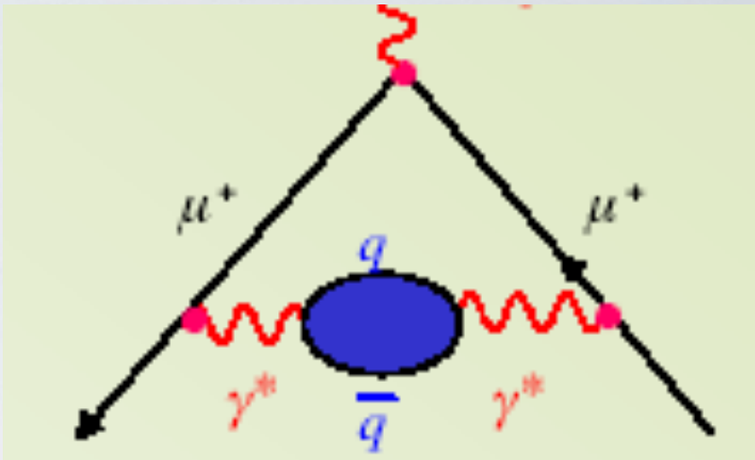
a_μ^{HLO} calculation, traditional way: time-like data



$$\boxed{a_\mu^{HLO} = \frac{1}{4\pi^3}\int_{4m_\pi^2}^{\infty} \sigma_{e^+e^-\to hadr}(s)K(s)\,ds}$$

$$a_\mu = \frac{g-2}{2}$$

$$a_\mu^{HLO.} = \frac{\alpha}{\pi^2}\int_0^\infty \frac{ds}{s} K(s)\,\mathrm{Im}\,\Pi_{had}(s)$$

$$K(s) = \int_0^1 dx \frac{x^2(1-x)}{x^2 + (1-x)(s/m^2)} \sim \frac{1}{s}$$

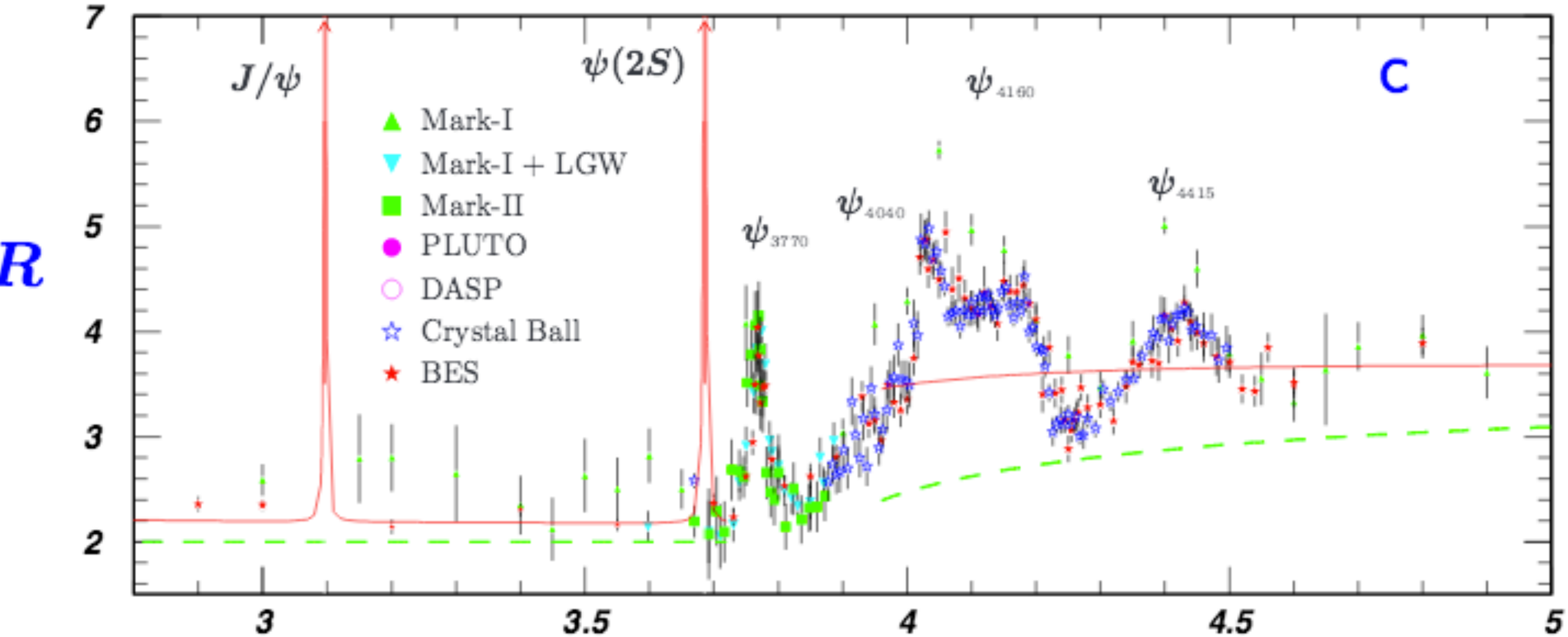
$$\sigma_{e^+e^-\to hadr}(s) = \frac{4\pi}{s}\mathrm{Im}\,\Pi_{had}(s)$$

Old way : based on precise experimental (time-like) data:

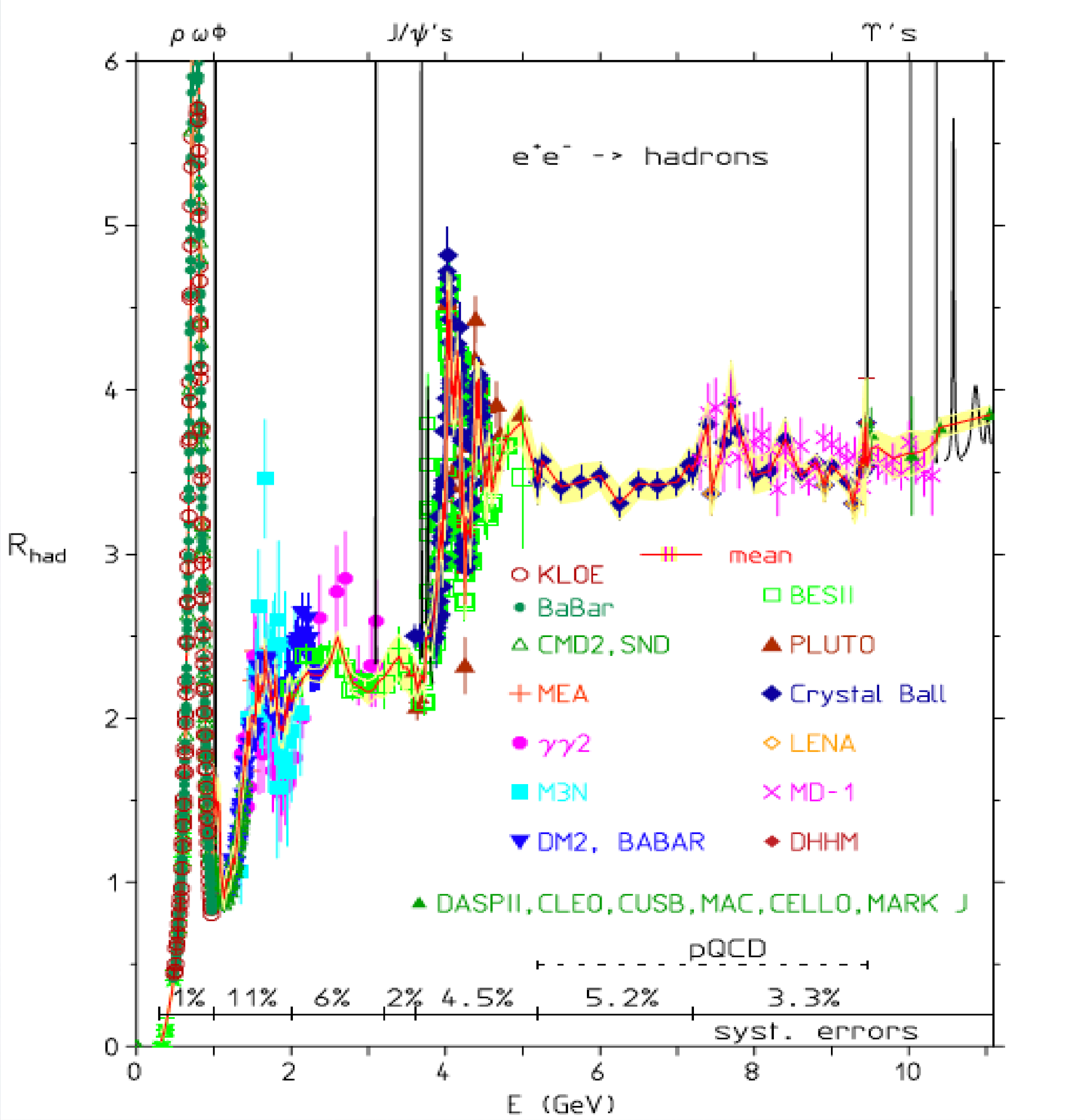
$$a_\mu^{had} = (689.7 \pm 4.4)\cdot 10^{-10}$$ The main contribution is in the low energy region

δa_μ^{exp} 1.5 10^{-10} = 0.2 % on a_μ^{HLO}
(from the 0.7 % of the present accuracy)

New measurements at
FNAL and JPARC


R
7
6
5
4
3
2
3
3.5
4
4.5
5
J/ψ
ψ(2S)
ψ3770
ψ4040
ψ4160
ψ4415
C
Mark-I
Mark-I + LGW
Mark-II
PLUTO
DASP
Crystal Ball
BES

with a more detailed plot….


ρ ω φ
J/ψ's
ϒ's
e⁺e⁻ -> hadrons
R_had
E (GeV)
mean
KLOE
BaBar
CMD2, SND
MEA
γγ2
M3N
DM2, BABAR
BESII
PLUTO
Crystal Ball
LENA
MD-1
DHHM
DASPII, CLEO, CUSB, MAC, CELLO, MARK J
pQCD
1%
11%
6%
2%
4.5%
5.2%
3.3%
syst. errors

Measurement of the running of α_{em}

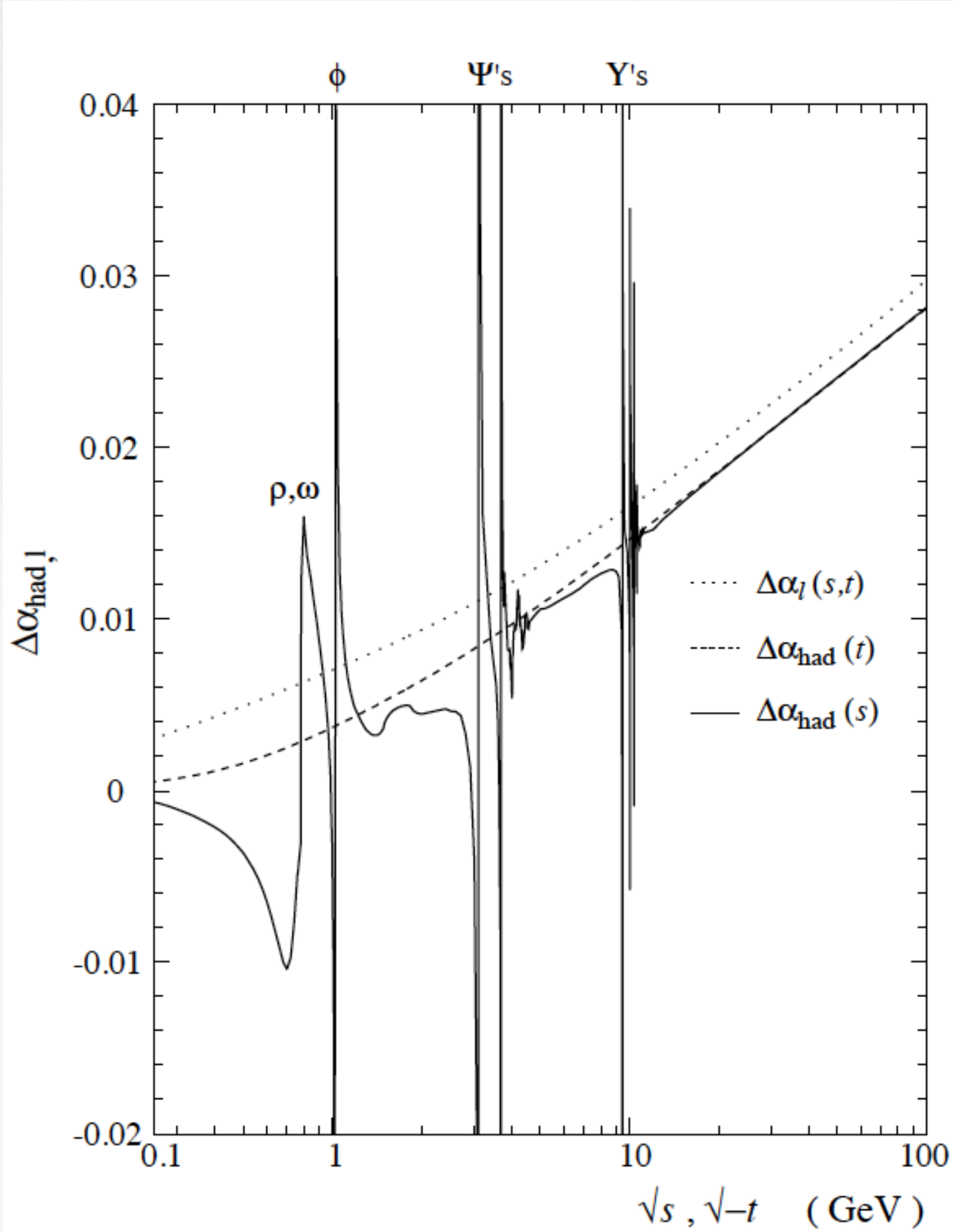
A direct measurement of $\alpha_{em}(s/t)$ in space/time-like regions can show the running of $\alpha_{em}(s/t)$

It can provide a test of "duality" (fare way from resonances)

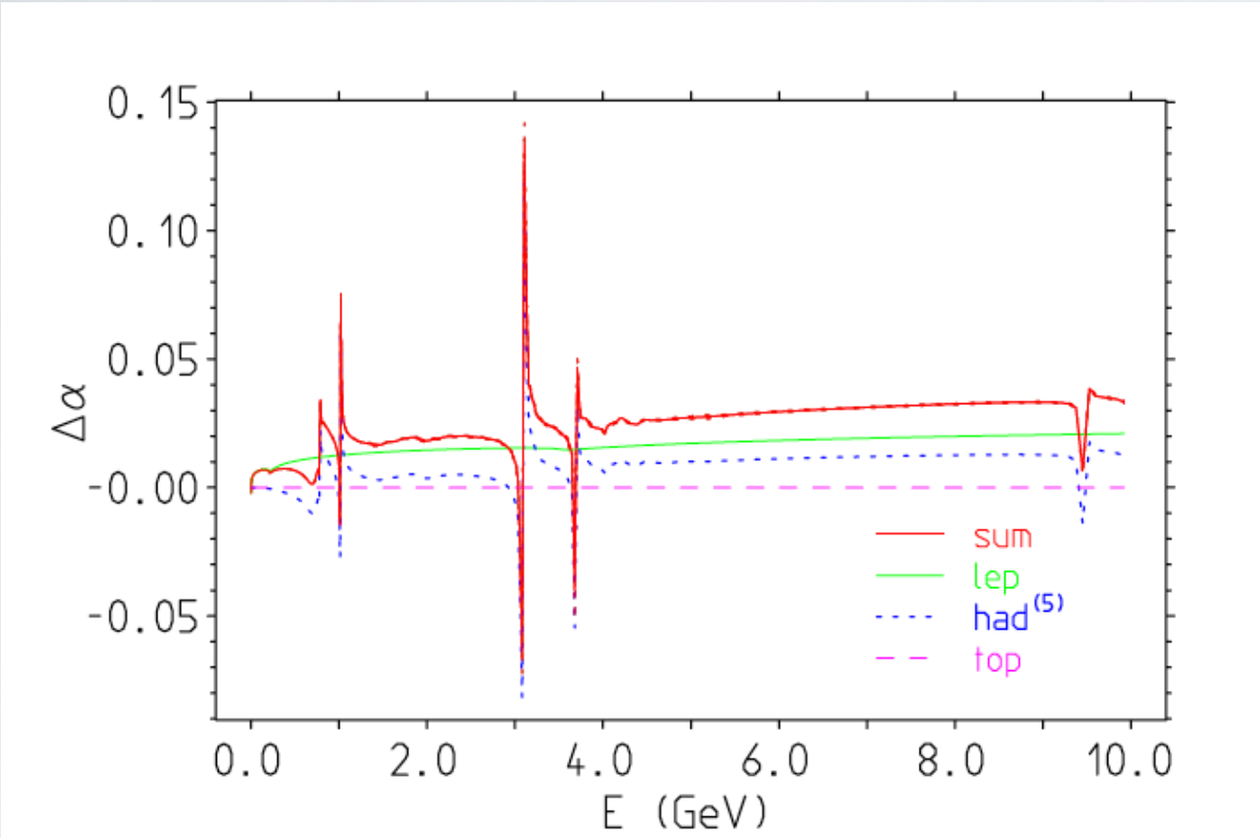
It has been done in past by few experiments at e^+e^- colliders by comparing a "well-known" QED process with some reference (obtained from data or MC)

$$\left(\frac{\alpha(q^2)}{\alpha(q_0^2)}\right)^2 \sim \frac{N_{signal}(q^2)}{N_{norm}(q_0^2)}$$

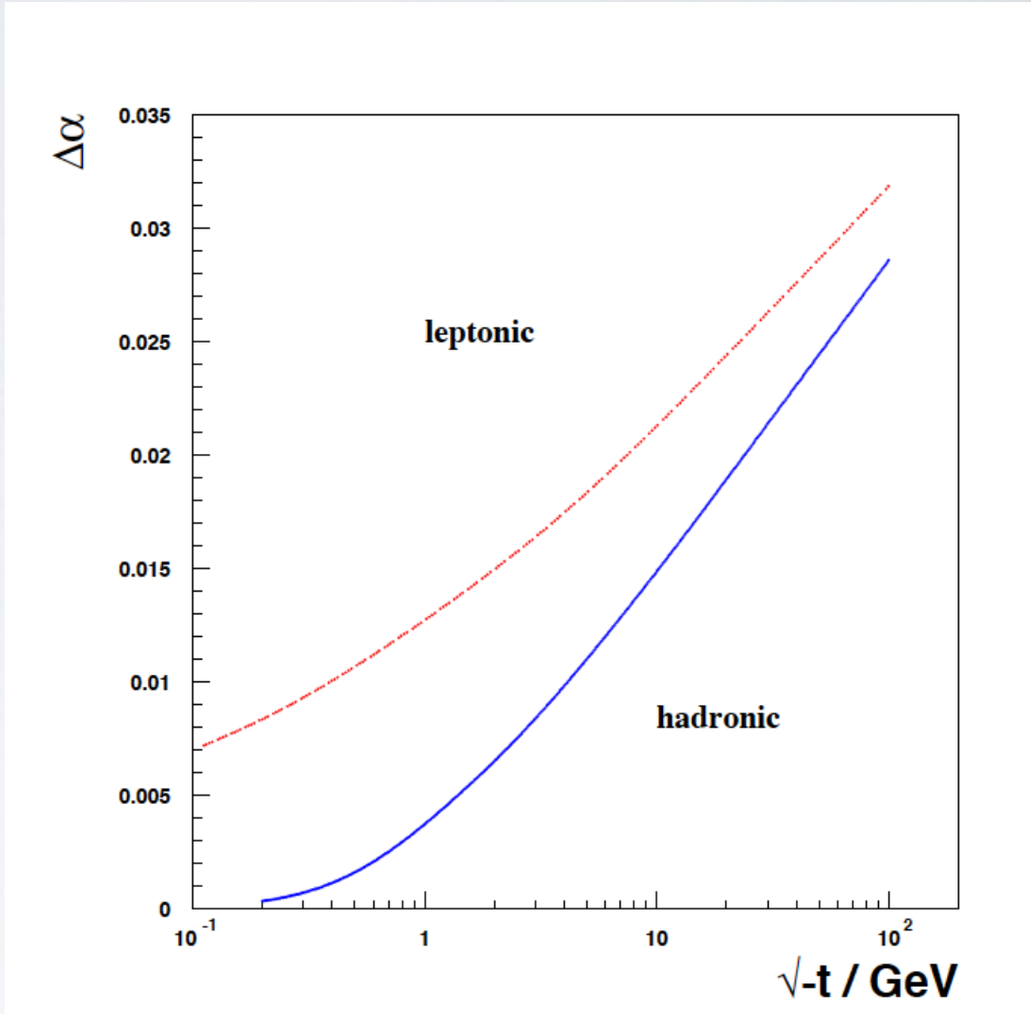
N_{signal} can be any QED process, muon pairs, etc…
N_{norm} can be Bhabha process, pure QED as $\gamma\gamma$ pair production, a well as theory, or any other reference process.

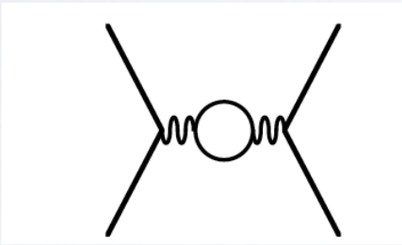


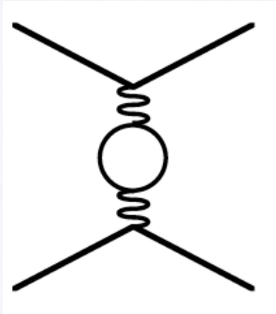
Running of α_{em}



time-like







space-like

$$\Delta\alpha_{had}^{(5)}(M_Z^2) = -\frac{\alpha M_Z^2}{3\pi}\mathrm{Re}\int_{4m_\pi^2}^{\infty} ds\,\frac{R(s)}{s(s-M_Z^2-i\varepsilon)}$$

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A new approach to evaluate the leading hadronic corrections to the muon g-2

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2. Theoretical framework

The leading-order hadronic contribution to t
given by the well-known formula [4,15]

$$a_\mu^{\mathrm{HLO}} = \frac{\alpha}{\pi^2} \int_0^\infty \frac{ds}{s} K(s)\, \mathrm{Im}\Pi_{\mathrm{had}}(s + i\epsilon),$$

where $\Pi_{\mathrm{had}}(s)$ is the hadronic part of the photon vacuum polarization, $\epsilon > 0$,

$$K(s) = \int_0^1 dx \frac{x^2(1-x)}{x^2 + (1-x)(s/m_\mu^2)} \tag{2}$$

is a positive kernel function, and m_μ is the muon mass. As the total cross section for hadron production in low-energy e^+e^- annihilations is related to the imaginary part of $\Pi_{\mathrm{had}}(s)$ via the optical theorem, the dispersion integral in Eq. (1) is computed integrating experimental time-like ($s > 0$) data up to a certain value of s [2,18,19]. The high-energy tail of the integral is calculated using perturbative QCD [20].

Alternatively, if we exchange the x and s integrations in Eq. (1) we obtain [21]

$$a_\mu^{\mathrm{HLO}} = \frac{\alpha}{\pi} \int_0^1 dx\, (x-1)\, \overline{\Pi}_{\mathrm{had}}[t(x)], \tag{3}$$

where $\overline{\Pi}_{\mathrm{had}}(t) = \Pi_{\mathrm{had}}(t) - \Pi_{\mathrm{had}}(0)$ and

$$t(x) = \frac{x^2 m_\mu^2}{x-1} < 0 \tag{4}$$

is a space-like squared four-momentum. If we invert Eq. (4), we get $x = (1-\beta)\,(t/2m_\mu^2)$, with $\beta = (1-4m_\mu^2/t)^{1/2}$, and from Eq. (3) we obtain

$$a_\mu^{\mathrm{HLO}} = \frac{\alpha}{\pi} \int_{-\infty}^{0} \overline{\Pi}_{\mathrm{had}}(t) \left(\frac{\beta-1}{\beta+1}\right)^2 \frac{dt}{t\beta}. \tag{5}$$

Eq. (5) has been used for lattice QCD calculations of a_μ^{HLO} [22]; while the results are not yet competitive with those obtained with the dispersive approach via time-like data, their errors are expected to decrease significantly in the next few years [23].

The effective fine-structure constant at squared momentum transfer q^2 can be defined by

$$\alpha(q^2) = \frac{\alpha}{1-\Delta\alpha(q^2)}, \tag{6}$$

To summarize

$$a_\mu^{HLO} = -\frac{\alpha}{\pi}\int_0^1 (1-x)\Pi_{had}(-\frac{x^2}{1-x}m_\mu^2)dx$$

a_μ=(g-2)/2

$$t = \frac{x^2 m_\mu^2}{x-1} \quad 0 \le -t < +\infty$$

$$x = \frac{t}{2m_\mu^2}(1-\sqrt{1-\frac{4m_\mu^2}{t}}); \quad 0 \le x < 1;$$

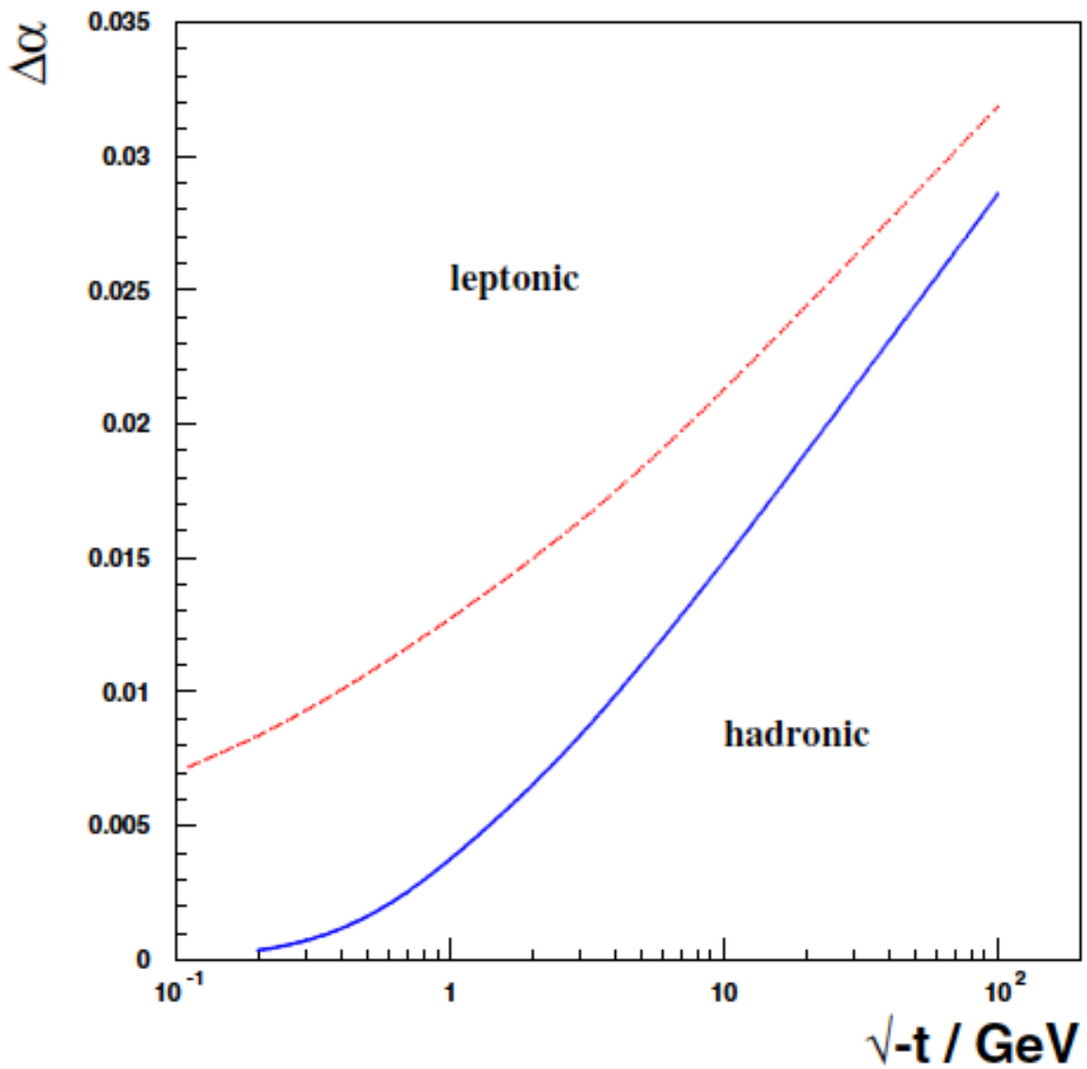
$$t = -s\sin^2(\frac{\vartheta}{2})$$

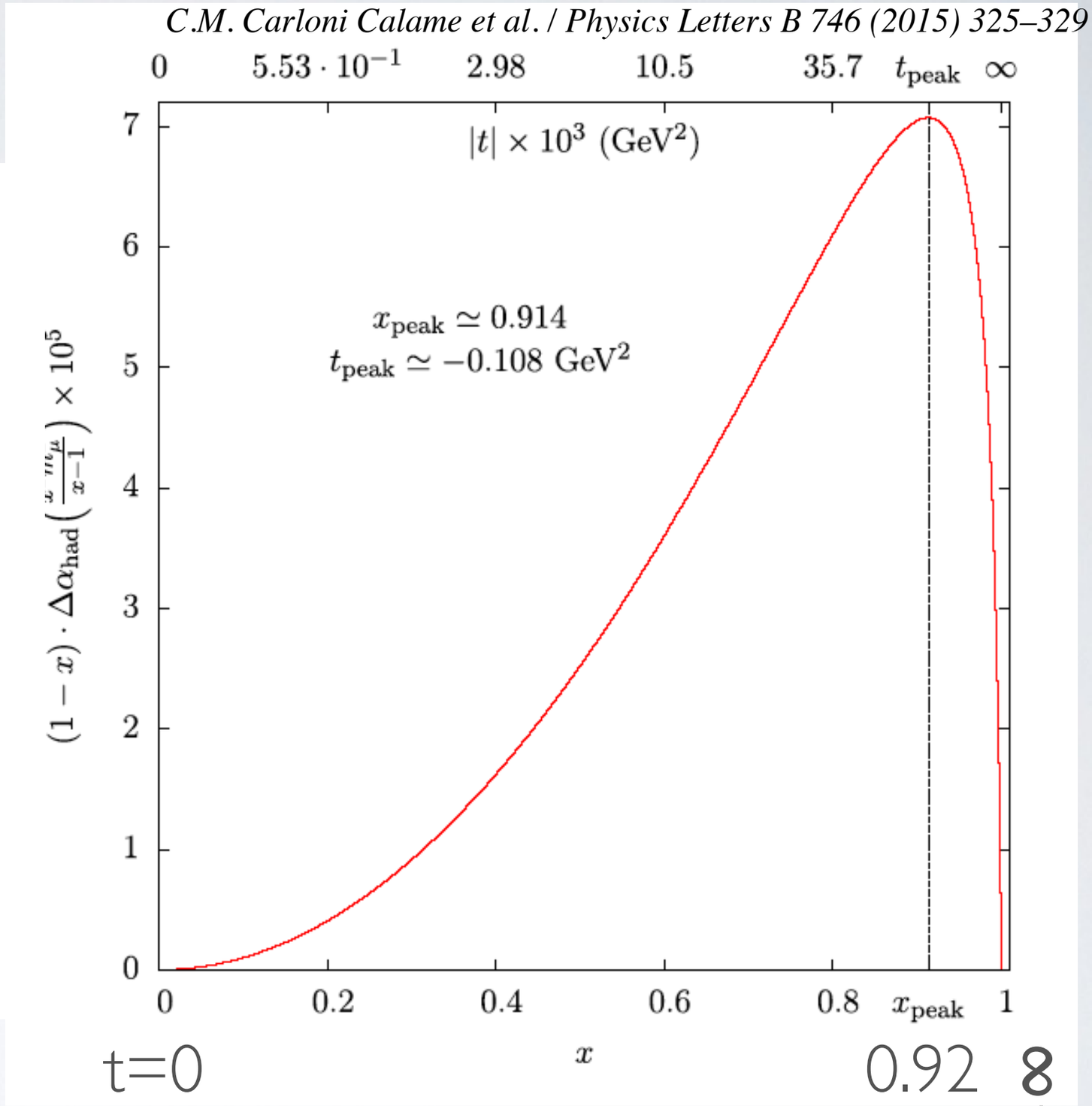
$$\Delta\alpha_{had}(t) = -\Pi_{had}(t) \quad for\ t < 0$$

with the "t" kernel

$$a_\mu^{HLO} = -\frac{\alpha}{\pi}\int_0^1 (1-x)\Delta\alpha_{had}(-\frac{x^2}{1-x}m_\mu^2)dx$$

functional form of the kernel





t=0 0.92 8

$\Delta\alpha$ is dominated at low t by the leptonic contribution

large t-values are depressed by x-1 denominator

The integrand is peaked at ~x=0.92
t=-0.11 GeV^2 (~330 MeV) for which
$\Delta\alpha_{had}(0.92) \sim 10^{-3}$

A. Arbuzov, D.Haidt, C.Matteuzzi,M.Paganoni, L.T. Eur. Phys. J. C 34 (2004) 267

arXiv:hep-ph/0402211v1 19 Feb 2004

The running of the electromagnetic coupling α in small-angle Bhabha scattering

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Abstract

A method to determine the running of α from a measurement of small-angle Bhabha scattering is proposed and worked out. The method is suited to high statistics experiments at e^+e^-colliders, which are equipped with luminometers in the appropriate angular region. A new simulation code predicting small-angle Bhabha scattering is also presented.

A. Arbuzov, D. Haidt, C. Matteuzzi, M. Paganoni and L.T.
A. Eur. Phys. J. C 34 (2004) 267

The method to measure the running of α exploits the fact that the cross section for the process $e^+e^- \to e^+e^-$ can be conveniently decomposed into three factors :

$$\frac{d\sigma}{dt} = \frac{d\sigma^0}{dt}\left(\frac{\alpha(t)}{\alpha(0)}\right)^2 (1+\Delta r(t)) \tag{3}$$

each one of them known with an accuracy of at least 0.1%

1st factor

$$\frac{d\sigma^0}{dt} = \frac{d\sigma^B}{dt}\left(\frac{\alpha(0)}{\alpha(t)}\right)^2 .$$

Born cross section contains all the soft and virtual corrections

Bhabha is a pure QED processes
quarks enter only in loops

$$\frac{d\sigma^B}{dt} = \frac{\pi\alpha_0^2}{2s^2}\mathrm{Re}\{B_t + B_s + B_i\},$$

$$\begin{aligned}
B_t &= \left(\frac{s}{t}\right)^2\left\{\frac{5+2c+c^2}{(1-\Pi(t))^2} + \xi\frac{2(g_v^2+g_a^2)(5+2c+c^2)}{(1-\Pi(t))}\right. \\
&+ \left.\xi^2\left(4(g_v^2+g_a^2)^2 + (1+c)^2(g_v^4+g_a^4+6g_v^2g_a^2)\right)\right\} \\
B_s &= \frac{2(1+c^2)}{|1-\Pi(s)|^2} + 2\chi\frac{(1-c)^2(g_v^2-g_a^2)+(1+c)^2(g_v^2+g_a^2)}{1-\Pi(s)} \\
&+ \chi^2\left[(1-c)^2(g_v^2-g_a^2)^2 + (1+c)^2(g_v^4+g_a^4+6g_v^2g_a^2)\right] \\
B_i &= 2\frac{s}{t}(1+c)^2\left\{\frac{1}{(1-\Pi(t))(1-\Pi(s))}\right. \\
&+ (g_v^2+g_a^2)\left(\frac{\xi}{1-\Pi(s)} + \frac{\chi}{1-\Pi(t)}\right) \\
&+ \left.(g_v^4+6g_v^2g_a^2+g_a^4)\xi\chi\right\}
\end{aligned}$$

2nd factor

$$\left(\frac{\alpha(t)}{\alpha(0)}\right)^2$$

Vacuum polarization effects contains the running of alpha

3rd factor

$$(1+\Delta r(t))$$

contains all the real and virtual effects not incorporated in the running of alpha

$$\alpha(q^2) = \frac{\alpha(0)}{1 - \Delta\alpha(q^2)},$$

$\alpha(0)$ is the Sommerfeld fine structure constant measured with a precision of $O(10^{-9})$

$\Delta\alpha(q^2)$ from loop contributions to the photon propagator

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN-PH-EP/2005-014
21 February 2005
Revised 28 June 2005

Measurement of the running of the QED coupling in small-angle Bhabha scattering at LEP

OPAL Collaboration

Abstract

Using the OPAL detector at LEP, the running of the effective QED coupling $\alpha(t)$ is measured for space-like momentum transfer from the angular distribution of small-angle Bhabha scattering. In an almost ideal QED framework, with very favourable experimental conditions, we obtain:

$$\Delta\alpha(-6.07\,\mathrm{GeV}^2) - \Delta\alpha(-1.81\,\mathrm{GeV}^2) = (440 \pm 58 \pm 43 \pm 30) \times 10^{-5}\,,$$

where the first error is statistical, the second is the experimental systematic and the third is the theoretical uncertainty. This agrees with current evaluations of $\alpha(t)$. The null hypothesis that α remains constant within the above interval of $-t$ is excluded with a significance above $5\,\sigma$. Similarly, our results are inconsistent at the level of $3\,\sigma$ with the hypothesis that only leptonic loops contribute to the running. This is currently the most significant direct measurement where the running $\alpha(t)$ is probed differentially within the measured t range.

All this has been made possible by a very accurate determination of the Luminosity by the OPAL collaboration ….

A measurement of the Luminosity at 10^{-4} at LEP

Giovanni Abbiendi

INFN - Bologna

Eur. Phys. J. C 45, 1–21 (2006)
Digital Object Identifier (DOI) 10.1140/epjc/s2005-02389-3

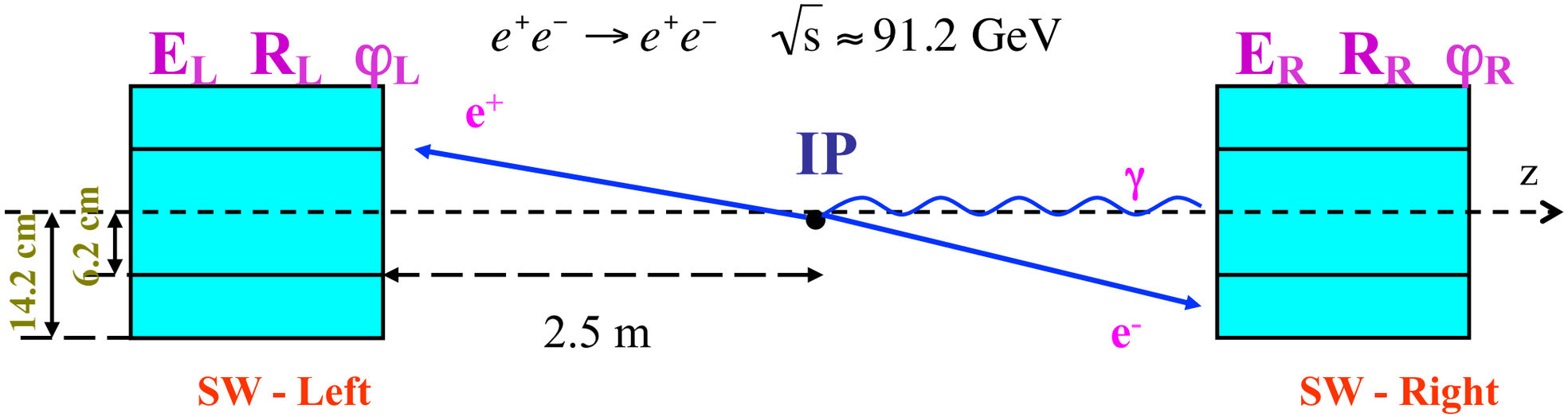
THE EUROPEAN PHYSICAL JOURNAL C

Measurement of the running of the QED coupling in small-angle Bhabha scattering at LEP

The OPAL Collaboration

G. Abbiendi[2], C. Ainsley[5], P.F. Åkesson[3,y], G. Alexander[22], G. Anagnostou[1], K.J. Anderson[9], S. Asai[23], D. Axen[27], I. Bailey[26], E. Barberio[8,p], T. Barillari[32], R.J. Barlow[16], R.J. Batley[5], P. Bechtle[25], T. Behnke[25], K.W. Bell[20], P.J. Bell[1], G. Bella[22], A. Bellerive[6], G. Benelli[4], S. Bethke[32], O. Biebel[31], O. Boeriu[10], P. Bock[11], M. Boutemeur[31], S. Braibant[2], R.M. Brown[20], H.J. Burckhart[8], S. Campana[4], P. Capiluppi[2], R.K. Carnegie[6], A.A. Carter[13], J.R. Carter[5], C.Y. Chang[17], D.G. Charlton[1], C. Ciocca[2], A. Csilling[29], M. Cuffiani[2], S. Dado[21], G.M. Dallavalle[2], A. De Roeck[8], E.A. De Wolf[8,s], K. Desch[25], B. Dienes[30], J. Dubbert[31], E. Duchovni[24], G. Duckeck[31], I.P. Duerdoth[16], E. Etzion[22], F. Fabbri[2], P. Ferrari[8], F. Fiedler[31], I. Fleck[10], M. Ford[16], A. Frey[8], P. Gagnon[12], J.W. Gary[4], C. Geich-Gimbel[3], G. Giacomelli[2], P. Giacomelli[2], R. Giacomelli[2], M. Giunta[4], J. Goldberg[21], E. Gross[24], J. Grunhaus[22], M. Gruwé[8], P.O. Günther[3], A. Gupta[9], C. Hajdu[29], M. Hamann[25], G.G. Hanson[4], A. Harel[21], M. Hauschild[8], C.M. Hawkes[1], R. Hawkings[8], R.J. Hemingway[6], G. Herten[10], R.D. Heuer[25], J.C. Hill[5], D. Horváth[29,c], P. Igo-Kemenes[11], K. Ishii[23], H. Jeremie[18], P. Jovanovic[1], T.R. Junk[6,i], J. Kanzaki[23,u], D. Karlen[26], K. Kawagoe[23], T. Kawamoto[23], R.K. Keeler[26], R.G. Kellogg[17], B.W. Kennedy[20], S. Kluth[32], T. Kobayashi[23], M. Kobel[3], S. Komamiya[23], T. Krämer[25], P. Krieger[6,l], J. von Krogh[11], T. Kuhl[25], M. Kupper[24], G.D. Lafferty[16], H. Landsman[21], D. Lanske[14], D. Lellouch[24], J. Letts[o], L. Levinson[24], J. Lillich[10], S.L. Lloyd[13], F.K. Loebinger[16], J. Lu[27,w], A. Ludwig[3], J. Ludwig[10], W. Mader[3,b], S. Marcellini[2], A.J. Martin[13], T. Mashimo[23], P. Mättig[m], J. McKenna[27], R.A. McPherson[26], F. Meijers[8], W. Menges[25], F.S. Merritt[9], H. Mes[6,a], N. Meyer[25], A. Michelini[2], S. Mihara[23], G. Mikenberg[24], D.J. Miller[15], W. Mohr[10], T. Mori[23], A. Mutter[10], K. Nagai[13], I. Nakamura[23,v], H. Nanjo[23], H.A. Neal[33], R. Nisius[32], S.W. O'Neale[1,*], A. Oh[8], M.J. Oreglia[9], S. Orito[23,*], C. Pahl[32], G. Pásztor[4,g], J.R. Pater[16], J.E. Pilcher[9], J. Pinfold[28], D.E. Plane[8], O. Pooth[14], M. Przybycień[8,n], A. Quadt[3], K. Rabbertz[8,r], C. Rembser[8], P. Renkel[24], J.M. Roney[26], A.M. Rossi[2], Y. Rozen[21], K. Runge[10], K. Sachs[6], T. Saeki[23], E.K.G. Sarkisyan[8,j], A.D. Schaile[31], O. Schaile[31], P. Scharff-Hansen[8], J. Schieck[32], T. Schörner-Sadenius[8,z], M. Schröder[8], M. Schumacher[3], R. Seuster[14,f], T.G. Shears[8,h], B.C. Shen[4], P. Sherwood[15], A. Skuja[17], A.M. Smith[8], R. Sobie[26], S. Söldner-Rembold[16], F. Spano[9], A. Stahl[3,x], D. Strom[19], R. Ströhmer[31], S. Tarem[21], M. Tasevsky[8,s], R. Teuscher[9], M.A. Thomson[5], E. Torrence[19], D. Toya[23], P. Tran[4], I. Trigger[8], Z. Trócsányi[30,e], E. Tsur[22], M.F. Turner-Watson[1], I. Ueda[23], B. Ujvári[30,e], C.F. Vollmer[31], P. Vannerem[10], R. Vértesi[30,e], M. Verzocchi[17], H. Voss[8,q], J. Vossebeld[8,h], C.P. Ward[5], D.R. Ward[5], P.M. Watkins[1], A.T. Watson[1], N.K. Watson[1], P.S. Wells[8], T. Wengler[8], N. Wermes[3], G.W. Wilson[16,k], J.A. Wilson[1], G. Wolf[24], T.R. Wyatt[16], S. Yamashita[23], D. Zer-Zion[4], L. Zivkovic[24]

Small-angle Bhabha scattering in OPAL



2 cylindrical calorimeters encircling the beam pipe at ± 2.5 m from the Interaction Point

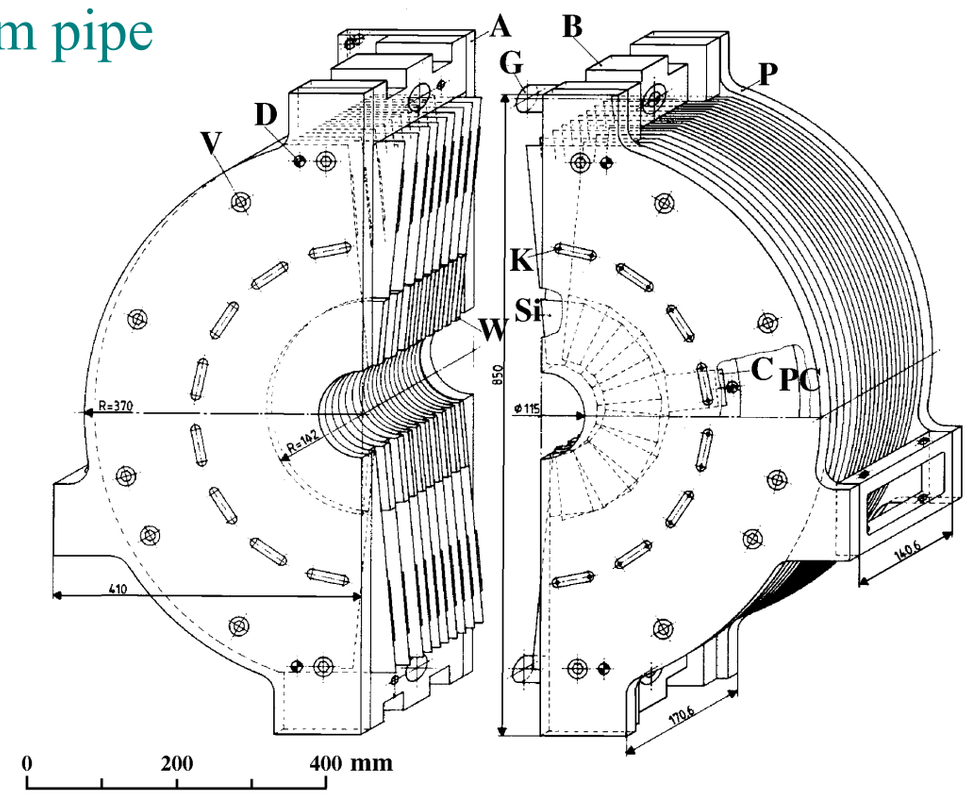
19 Silicon layers

18 Tungsten layers

Total Depth 22 X_0 (14 cm)

Each detector layer divided into 16 overlapping wedges

Sensitive radius: **6.2 – 14.2 cm**, corresponding to **scattering angle** of **25 – 58 mrad** from the beam line



Final Error on Luminosity

After all the effort on Radial reconstruction the dominant systematic error is related to Energy (mostly tail in the E response and nonlinearity)
Quantitatively: (OPAL Collaboration, Eur.Phys.J. C14 (2000) 373)

	Systematic Error ($\times 10^{-4}$)
Energy	1.8
Inner Anchor	1.4
Radial Metrology	1.4

Total Experimental Systematic Error : 3.4×10^{-4}

Theoretical Error on Bhabha cross section: 5.4×10^{-4}

The Methos used follows the above parametrization/factorization of the Bhabha cross-section

$$\frac{d\sigma}{dt} = \frac{d\sigma^{(0)}}{dt}\left(\frac{\alpha(t)}{\alpha_0}\right)^2 (1+\epsilon)\,(1+\delta_\gamma) + \delta_Z$$

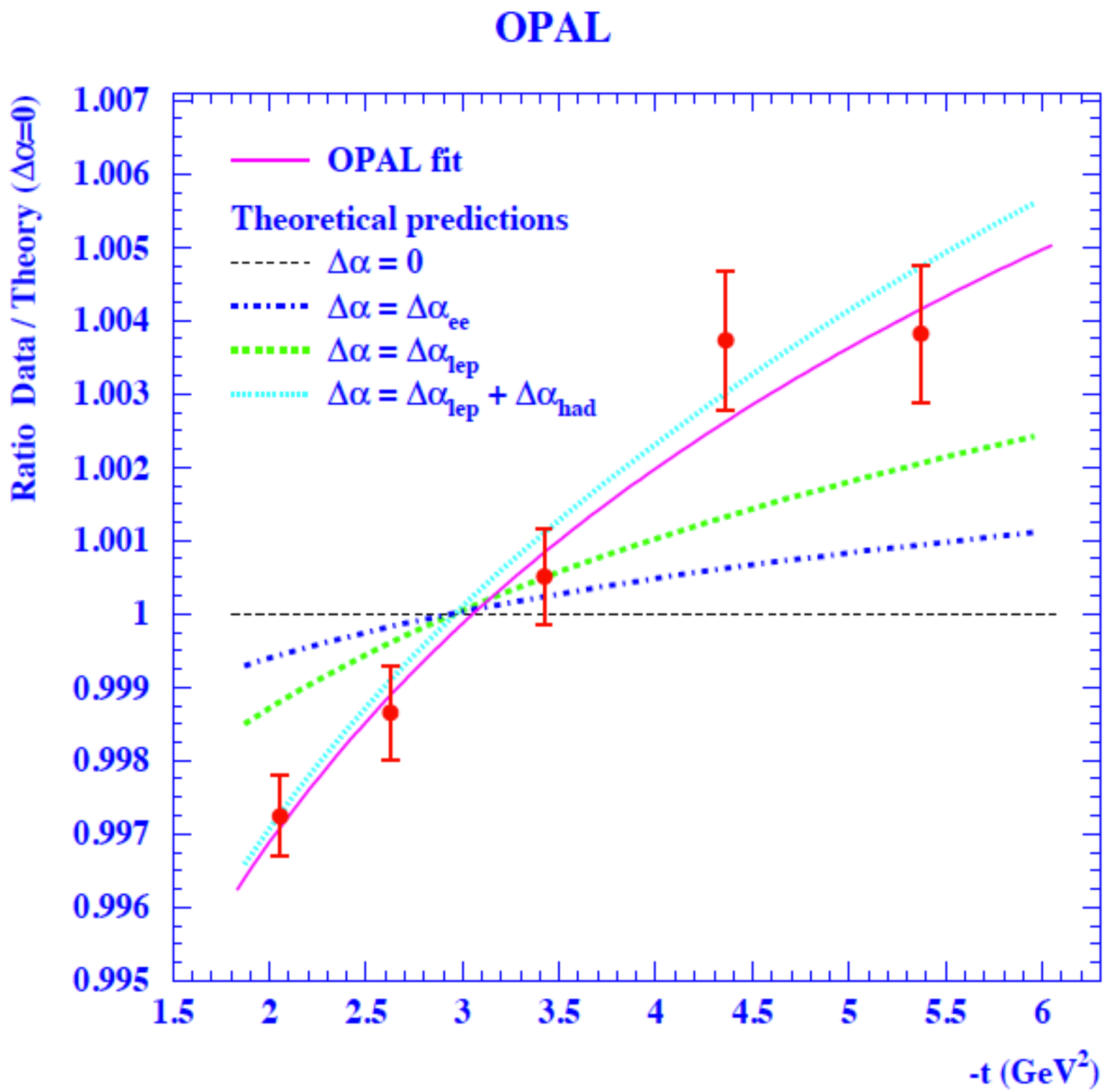
$$\frac{d\sigma^{(0)}}{dt} = \frac{4\pi\alpha_0^2}{t^2}$$

We determined the effective slope of the Bhabha momentum transfer distribution which is simply related to the average derivative of $\Delta\alpha$ as a function of $\ln t$ in the range $2\ \mathrm{GeV}^2 \leq -t \leq 6\ \mathrm{GeV}^2$. The observed t-spectrum is in good agreement with Standard Model predictions. We find:

$$\Delta\alpha(-6.07\,\mathrm{GeV}^2) - \Delta\alpha(-1.81\,\mathrm{GeV}^2) = (440 \pm 58 \pm 43 \pm 30) \times 10^{-5}\,,$$

where the first error is statistical, the second is the experimental systematic and the third is the theoretical uncertainty.

This measurement is one of only a very few experimental tests of the running of $\alpha(t)$ in the space-like region, where $\Delta\alpha$ has a smooth behaviour. We obtain the strongest direct evidence for the running of the QED coupling ever achieved differentially in a single experiment, with a significance above $5\,\sigma$. Moreover we report clear experimental evidence for the hadronic contribution to the running in the space-like region, with a significance of $3\,\sigma$.


OPAL
OPAL fit
Theoretical predictions
Δα = 0
Δα = Δα_ee
Δα = Δα_lep
Δα = Δα_lep + Δα_had
Ratio Data / Theory (Δα=0)
1.007
1.006
1.005
1.004
1.003
1.002
1.001
1
0.999
0.998
0.997
0.996
0.995
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
-t (GeV²)

Our proposal therefore has to deal with some experimental issues….

Experimental Issues

Using Bhabha at small angle (to emphasize t-channel contribution) to extract $\Delta\alpha$:

$$\left(\frac{\alpha(t)}{\alpha(0)}\right)^2 \sim \frac{d\sigma_{ee\to ee}(t)}{d\sigma^0_{MC}(t)}$$

Where $d\sigma^0_{MC}$ is the MC prediction for Bhabha process with $\alpha(t) = \alpha(0)$ and there are corrections due to RC…

$$\Delta\alpha_{had}(t) = 1 - \left(\frac{\alpha(t)}{\alpha(0)}\right)^{-1} - \Delta\alpha_{lept}(t)$$

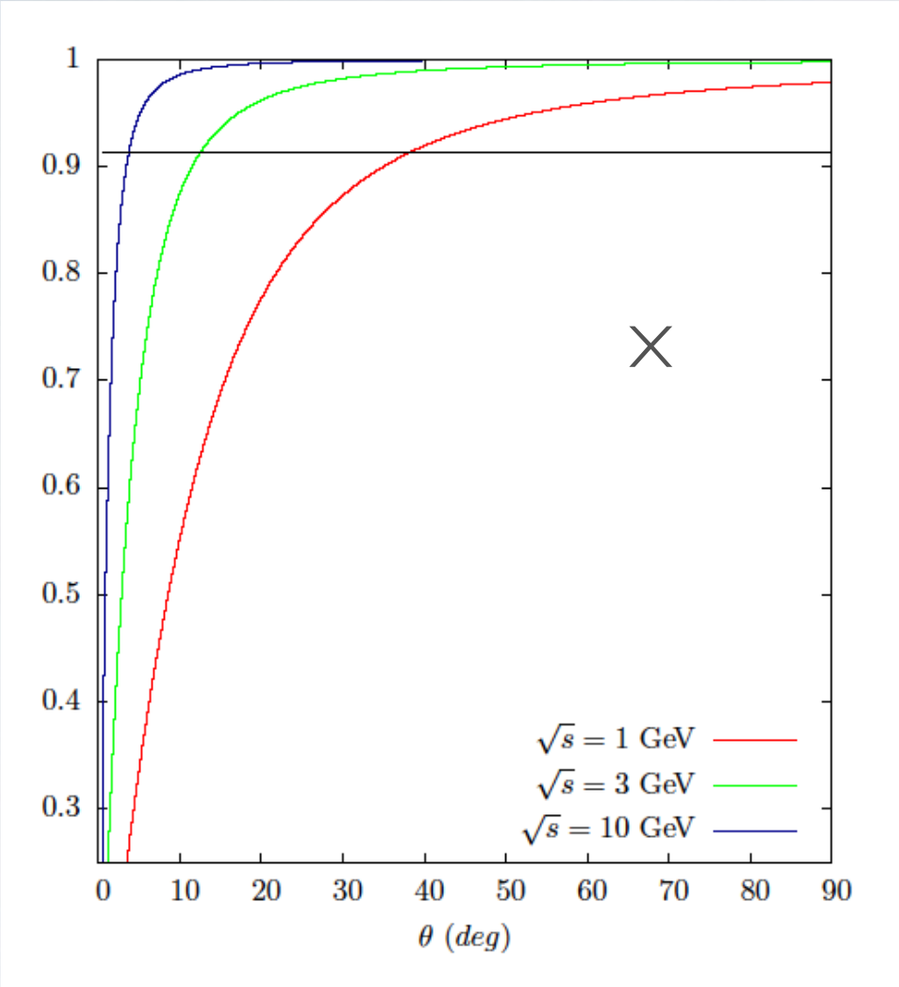
since $\Delta\alpha_{lep}(t)$ is theoretically well known

Which experimental accuracy we are aiming at ?
$\delta\Delta\alpha_{had} \simeq$ 1/2 fractional accuracy on $d\sigma(t)/d\sigma^0_{MC}(t)$.

If we assume to measure $\delta\Delta\alpha_{had}$ at 5% at the peak of the integrand ($\Delta\alpha_{had}$ ~10^{-3} at x=0.92) fractional accuracy on

$$d\sigma(t)/d\sigma^0_{MC}(t) \sim 10^{-4}$$

Very challenging measurement (one order of magnitude improvement respect to date) due to the systematics



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Most of the region (up to x~0.98) can be covered with low energy machines as Dafne/VEPP-2000 or tau/charm-B-factories

Covering up to 60^0 at $\sqrt{s}$=1 GeV can arrive at x= 0.95

A different situation can be obtained at tau/charm/ B-factories (and at future ILC/TLEP machines) where smaller below 20° are needed

Statistics

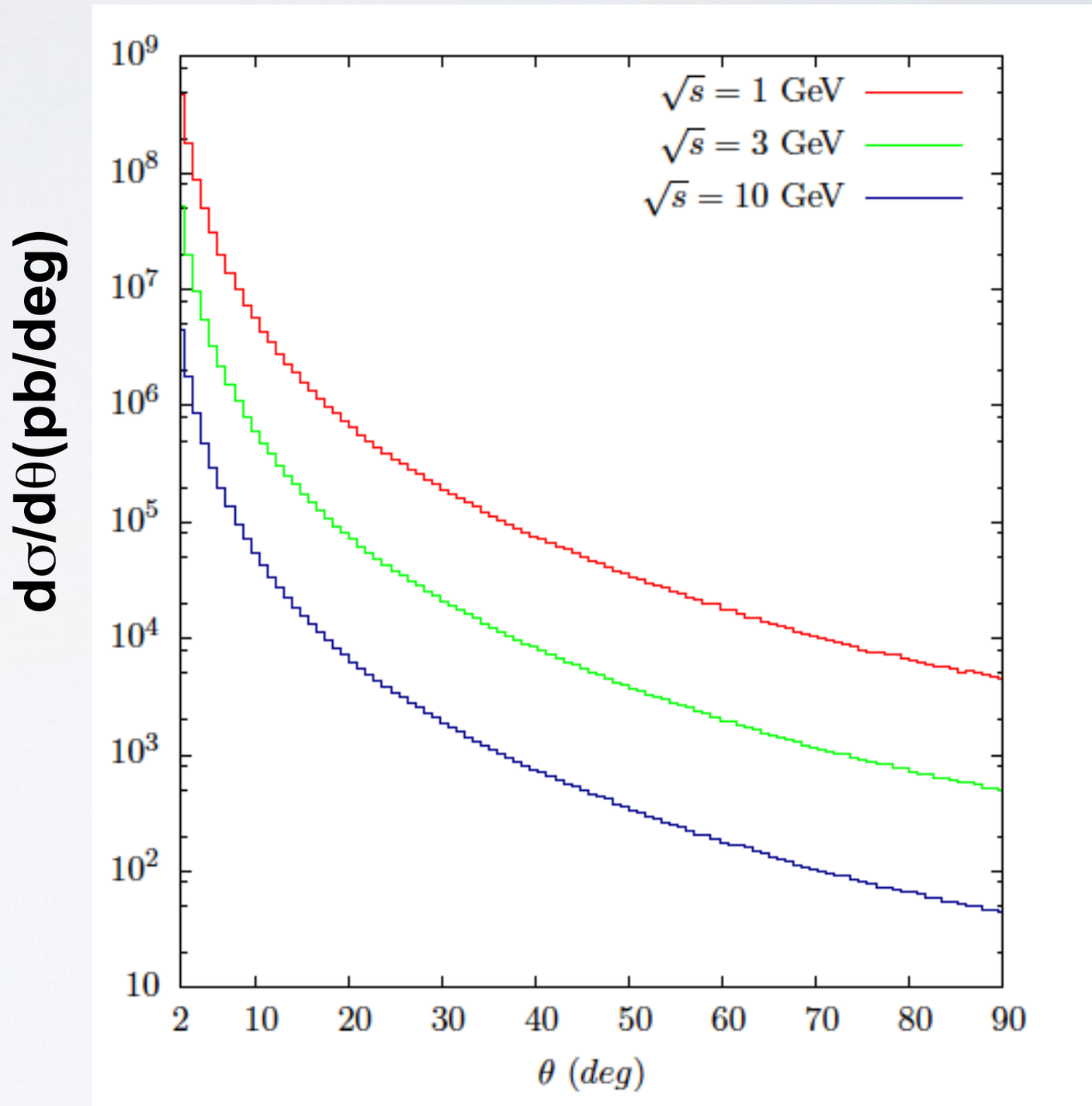
O(10^{-4}) accuracies on Bhabha cross section require at least 10^8 events which at 20° mean:

O(1) fb^{-1} @ 1 GeV

O(10) fb^{-1} @ 3 GeV

O(100) fb^{-1} @ 10 GeV

All these luminosities are realistic estimates at flavour factories



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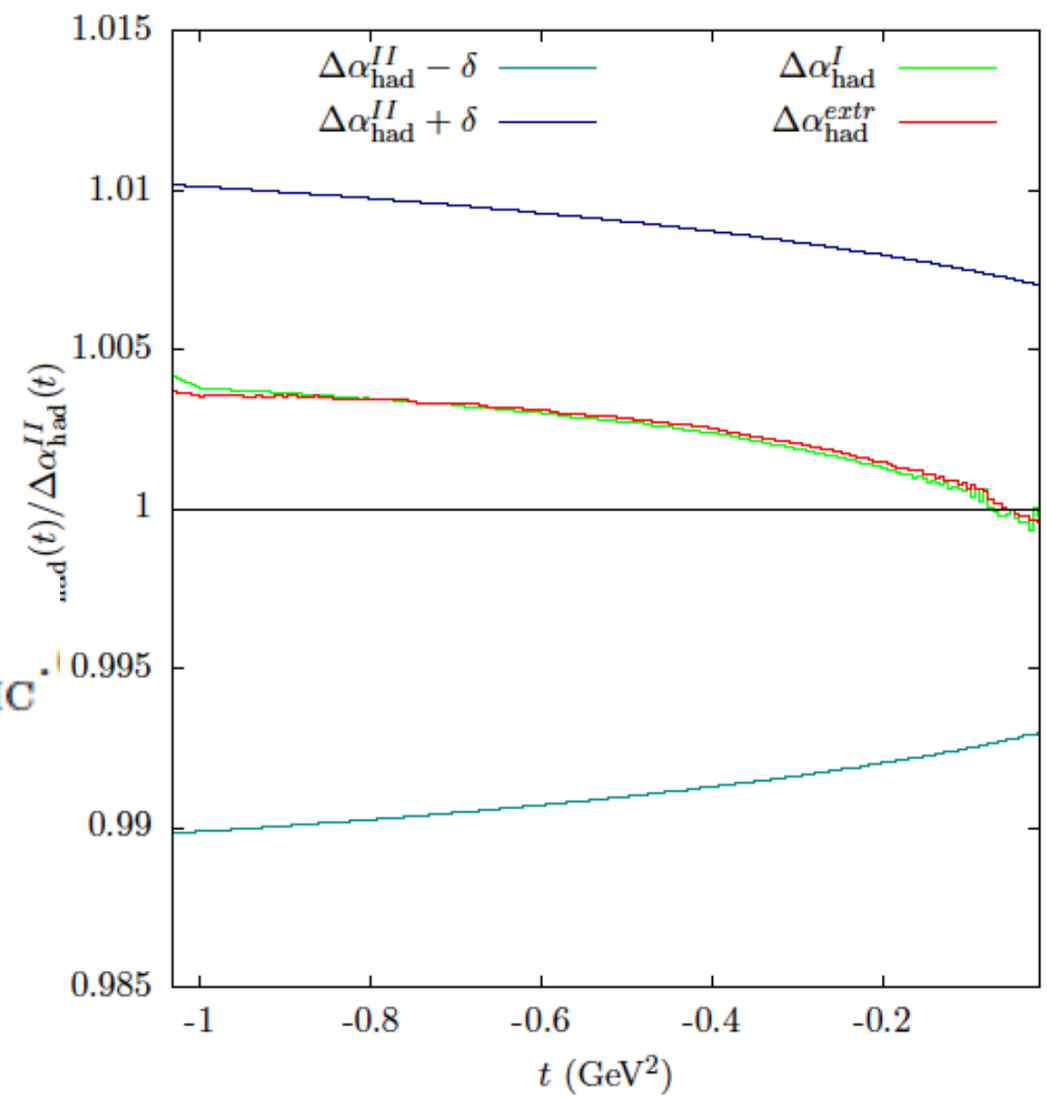
Additional considerations: Rad. Corr.

A Monte Carlo procedure has been developed to check if $\Delta\alpha_{had}(t)$ can be obtained by a minimization procedure with a different $\Delta\alpha_{had}(t)$' inside

$$\left.\frac{d\sigma}{dt}\right|_{\text{data}} = \left.\frac{d\sigma}{dt}\Big(\alpha(t),\alpha(s)\Big)\right|_{\text{MC}},$$

→

$$\left.\frac{d\sigma}{dt}\right|_{j,\text{data}} = \left.\frac{d\sigma}{dt}\Big(\bar{\alpha}(t)+\frac{i_j}{N}\delta(t),\alpha(s)\Big)\right|_{j,\text{MC}}.$$



$\Delta\alpha_{had}(t)$ is obtained with<10^{-4} error !

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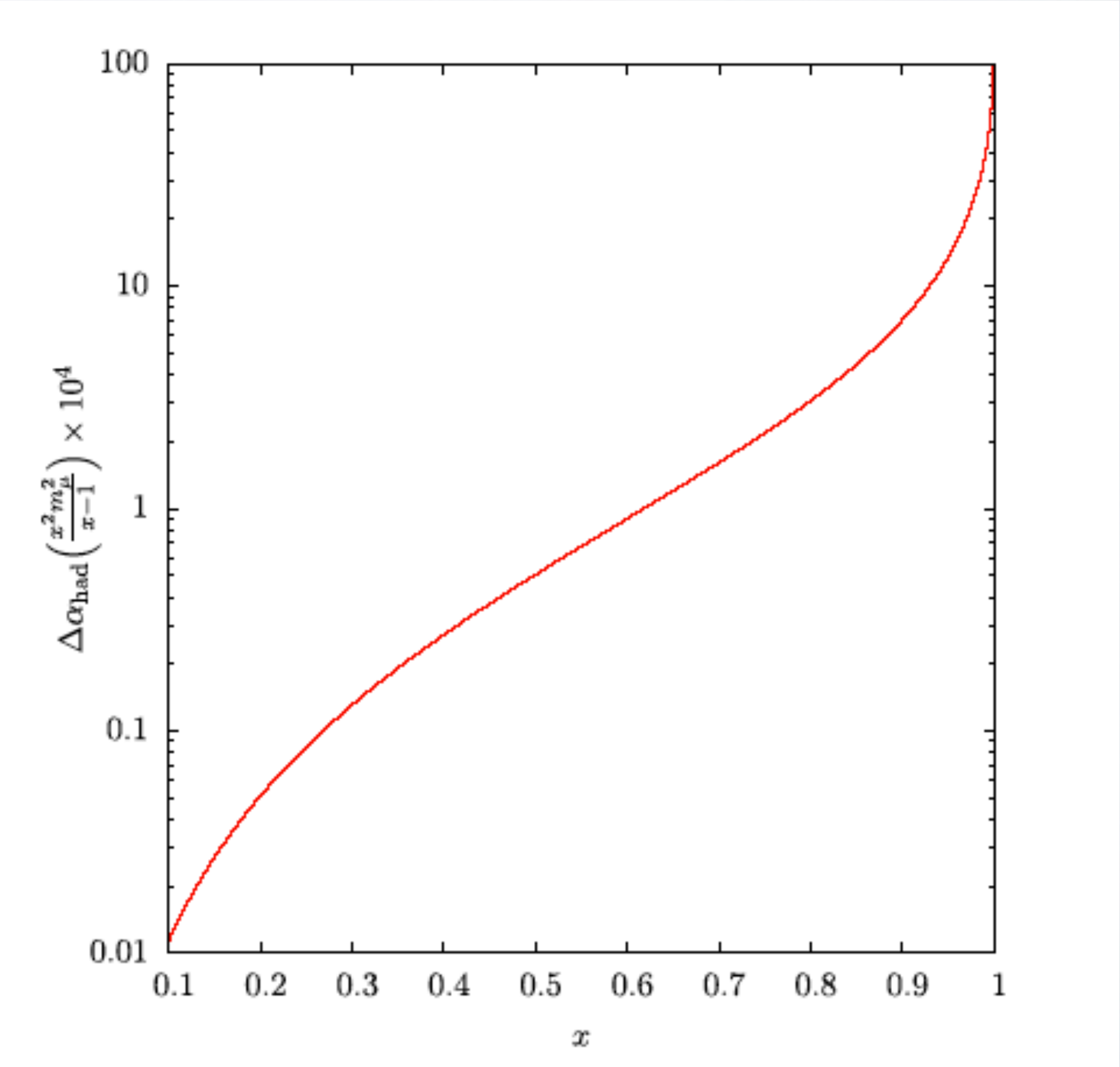
Normalization

- Bhabha as a normalization: i.e. the data sample at very
- small angles $\Delta\alpha_{had} \simeq 10^{-5}$

Use a hadron-free process as $e^+e^- \to \gamma\gamma$



Measurement of DAFNE Luminosity with KLOE/KLOE-2 at 10^{-4}?

F. Ambrosino et al [KLOE] Eur. Phys. J. C 47, 589–596 (2006)

Table 2. Summary of the corrections and systematic errors in the measurement of the luminosity

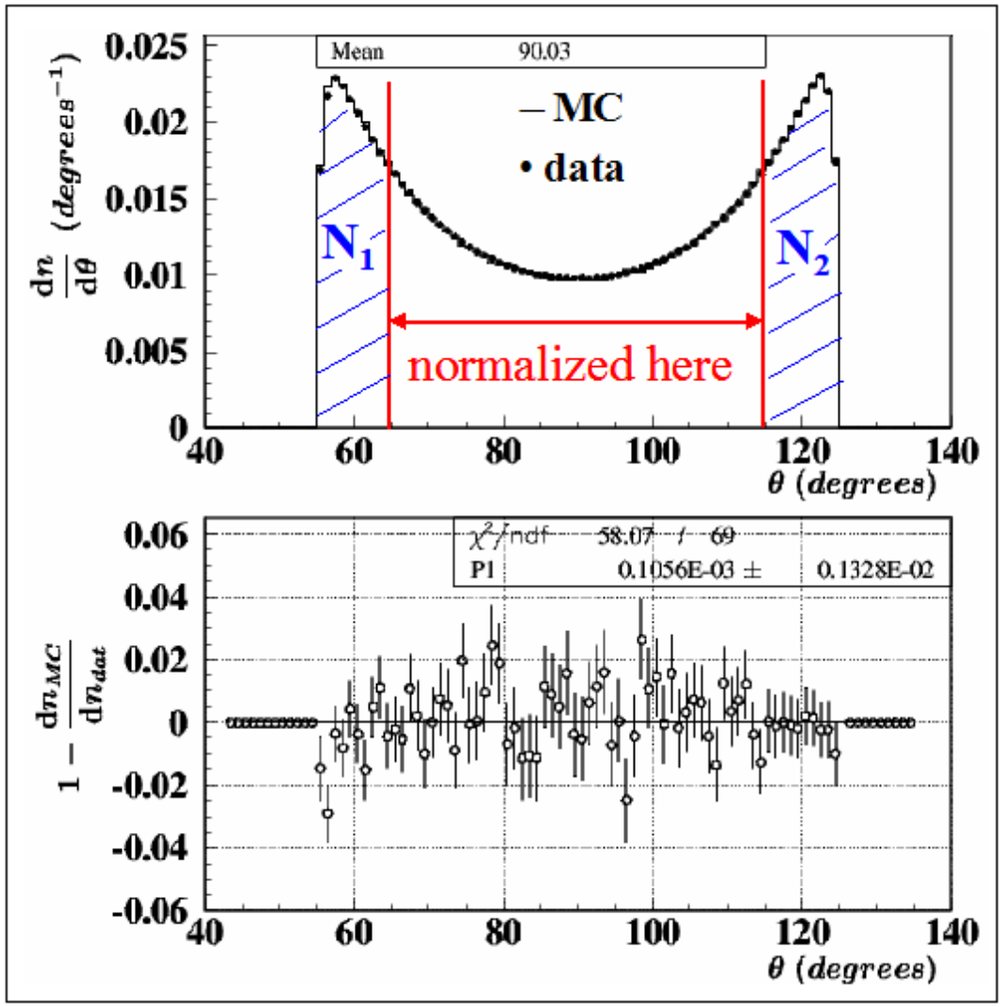
	correction (%)	systematic error (%)
angular acceptance	+0.25	0.25
tracking	–	0.06
clustering	+0.14	0.11
background	−0.62	0.13
cosmic veto	+0.40	–
energy calibration	–	0.10
center of mass energy	+0.10	0.10
	+0.34	0.32

Adding in quadrature: 0.3 %

(can be improved by a factor 10?)

From F. Nguyen 2006

Polar angle systematics



✓ global agreement is very good

but the cut occurs in a steep region of the distributions

⇒ estimate of border mismatches

✓ after normalizing MC to make it coincide with data in the region $65^o < \theta < 115^o$, we estimate as a systematic error:

$$\frac{N^{dat}_{[55:65]+[115:125]} - N^{MC}_{[55:65]+[115:125]}}{N^{dat}_{TOT}} \sim 0.25\%$$

Can be improved at 10^{-4}?

G. Venanzoni, Seminar at LNF, Frascati, 20 May 2015

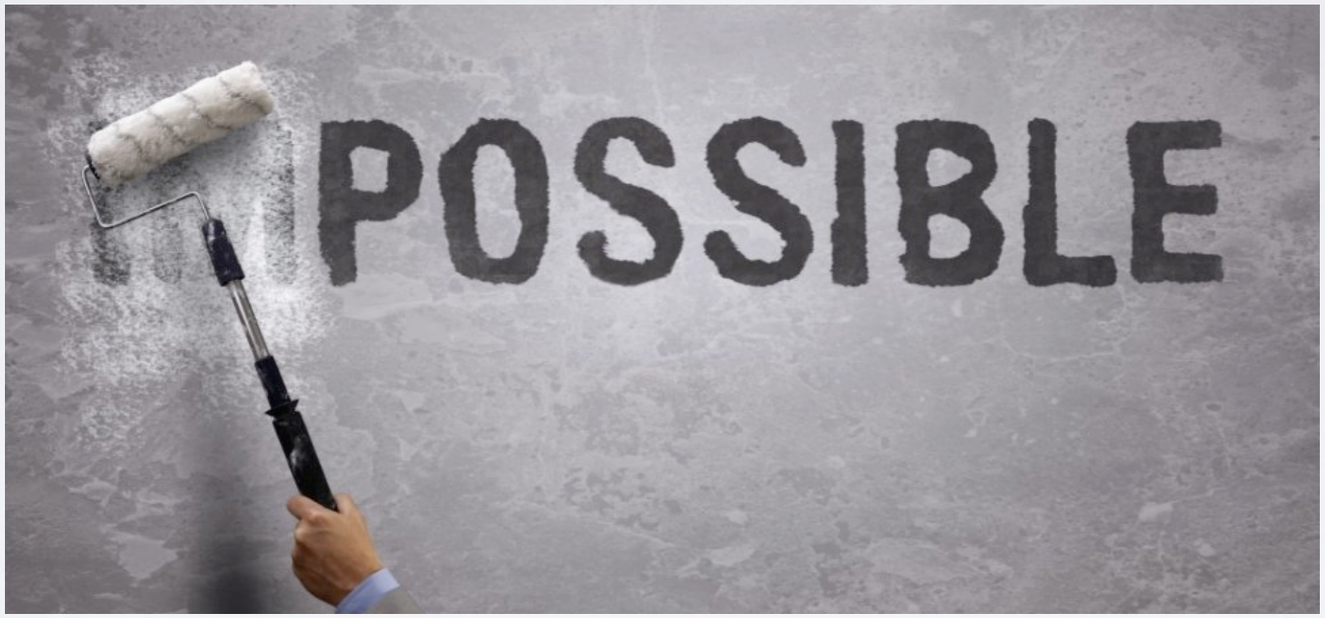
Measuring α_{em} running in space like region appears to be feasible and potentially comparable to the present time like way.

We propose an alternative formula for a_μ^{HLO} in spacelike region.
at low values of t (<1 GeV^2) and can be explored at low energy e+e- machines (VEPP2000/DAFNE, τ/charm, B-factories) as well as at high energies ILC/TLEP.

This may be achieved by measuring the Bhabha cross section in a new, poorly explored, region of relatively small angles at accuracy at least of $O(10^{-4})$

Both experimental and theoretical improvements, tests, calculations, ….have to come out…..

and hopefully……


POSSIBLE

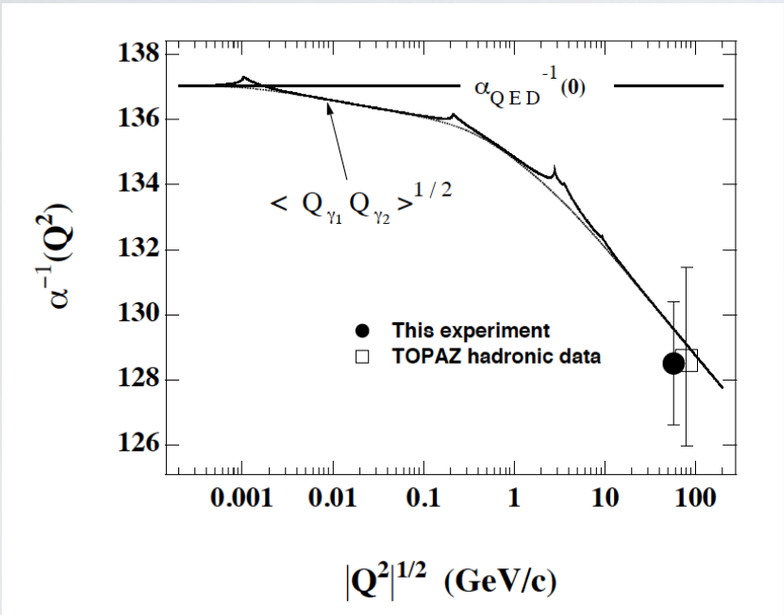
FINIS


MISSION:
POSSIBLE

?

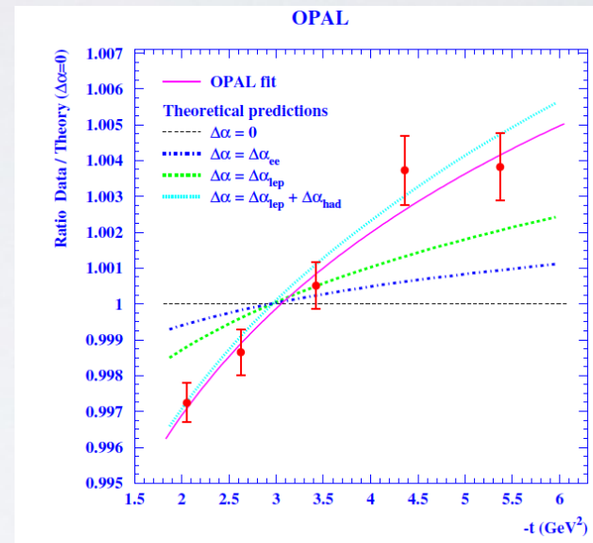
time-like

N sqrt(s)=57.8GeV



$$\frac{e^+e^- \to \mu^+\mu^-}{e^+e^- \to e^+e^-\mu^+\mu^-}$$

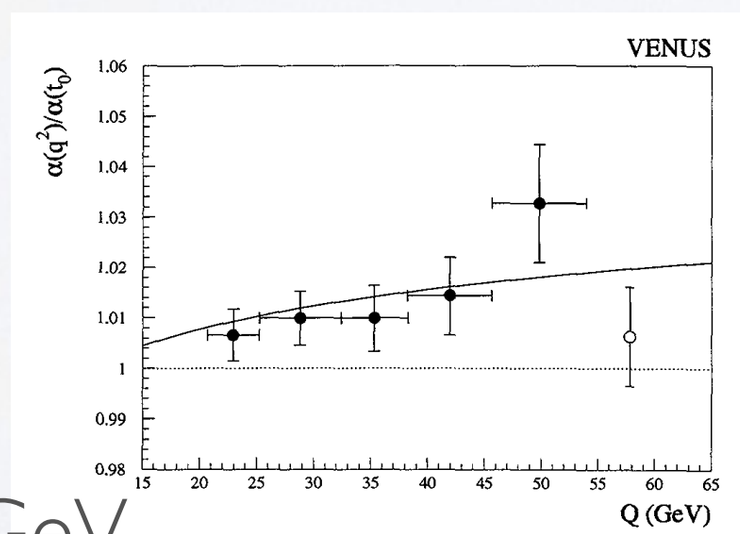
sqrt (s) = 189 GeV

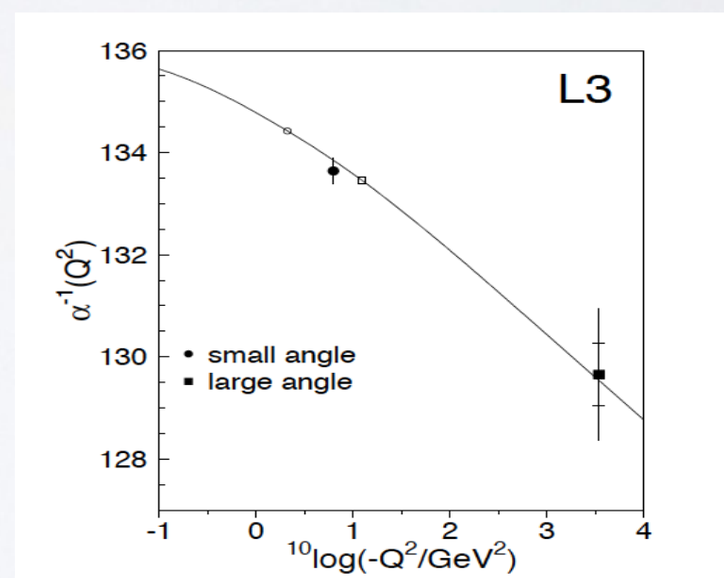


1.3<√-t<2.5 GeV

space-like

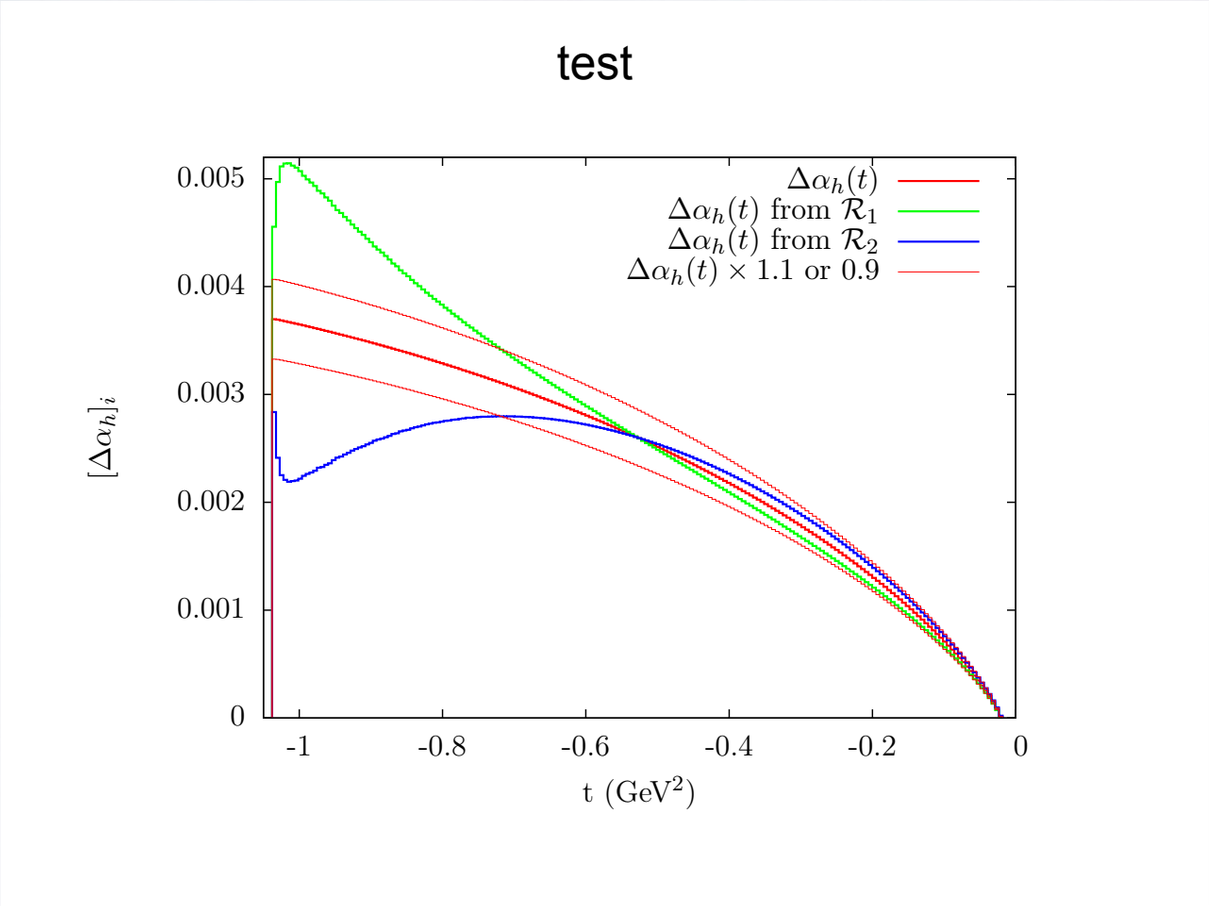
$$\frac{e^+e^- \to e^+e^-}{e^+e^- \to \mu^+\mu^-}$$



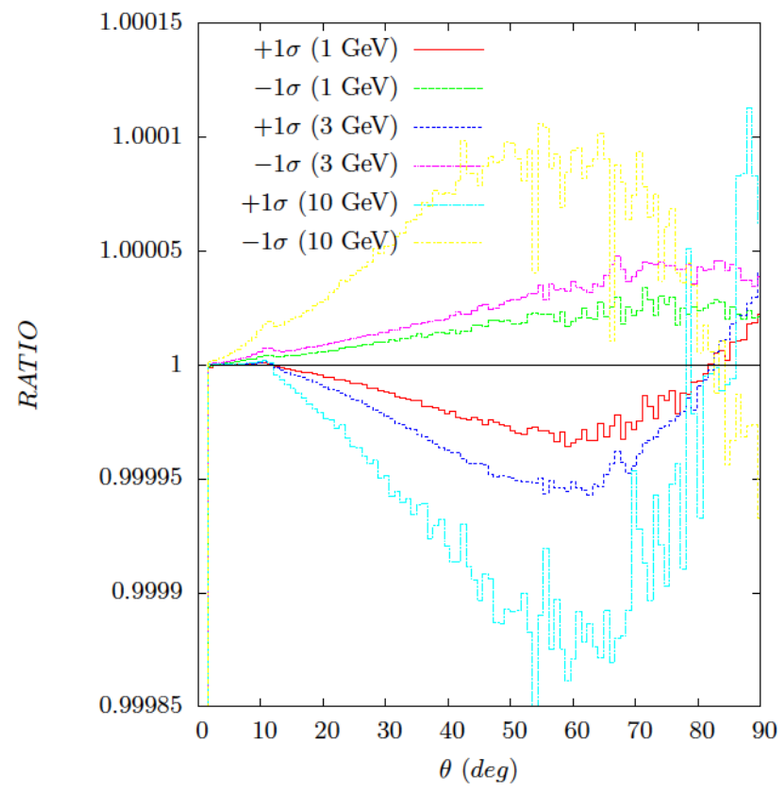


10< sqrt(-t)<54GeV

1.5<√-t<2.5 GeV
3.5<√-t<58 GeV


test
$\Delta\alpha_h(t)$
$\Delta\alpha_h(t)$ from $\mathcal{R}_1$
$\Delta\alpha_h(t)$ from $\mathcal{R}_2$
$\Delta\alpha_h(t) \times 1.1$ or 0.9
$[\Delta\alpha_h]_i$
0.005
0.004
0.003
0.002
0.001
0
-1
-0.8
-0.6
-0.4
-0.2
0
t (GeV^2)

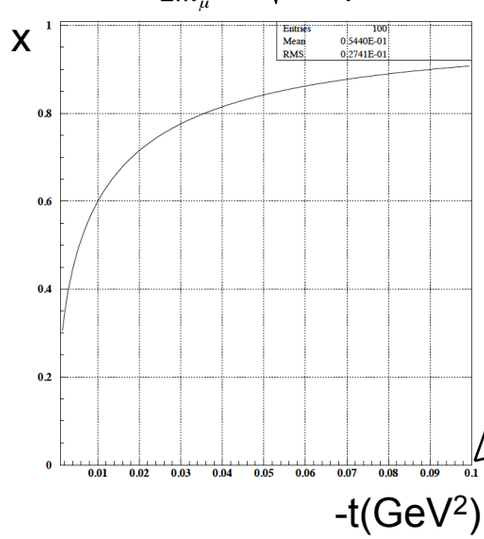
$\Delta\alpha_{em}^{HAD}(s)$ dependence



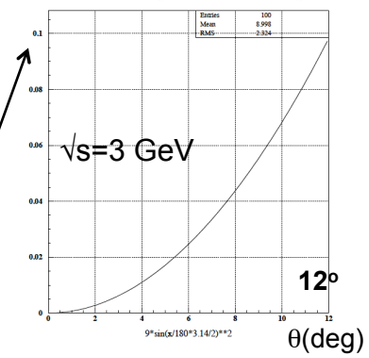
Which is the best energy/angle configuration?

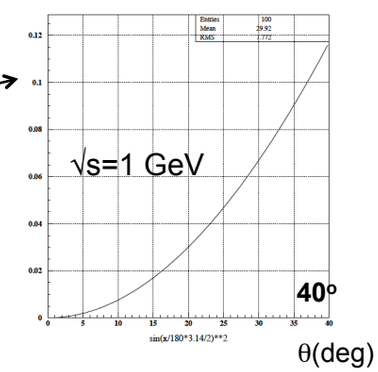
$$x = \frac{t}{2m_\mu^2}\left(1-\sqrt{1-\frac{4m^2}{t}}\right)$$

2013/06/24 00.37

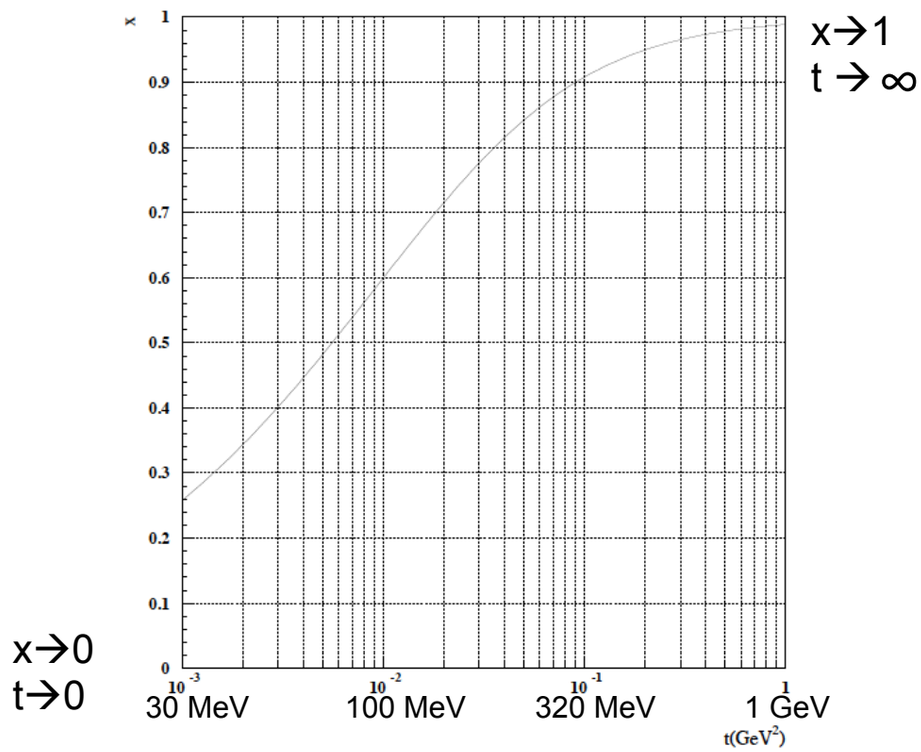


-t = 9(1-cosθ)/2





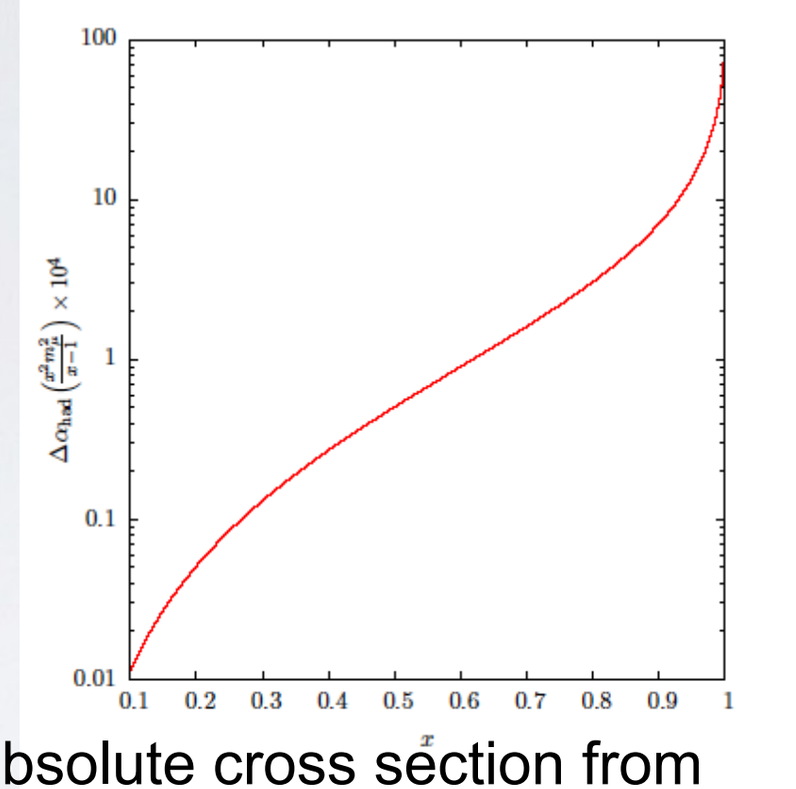
x vs t behaviour



x→1
t → ∞

x→0
t→0

Additional consideration: Normalization



To compare Bhabha absolute cross section from data with MC we need Luminosity of the machine. Two possibilities:

1) Use Bhabha at very small angle where the uncertainty on $\Delta\alpha_{had}$ can be neglected (for example at E_{beam}=1 GeV and θ=5°, $\Delta\alpha_{had}$ ~10^{-5}).

2) Use a process with $\Delta\alpha_{had}$=0, like e+e- $\gamma\gamma$. However very difficult to determine it at 10^{-4} accuracy.

Option 1) looks better to us as some of the common systematics cancel in the measurement !