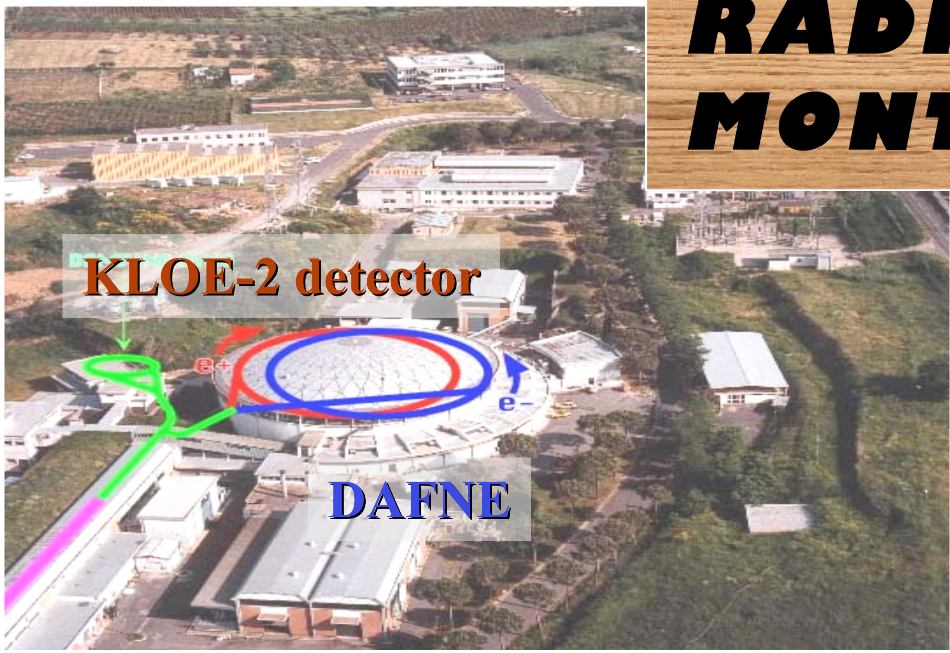
The KLOE-2 High Energy Program and the need for MC generators

RADIO MONTECARLOW



Graziano Venanzoni

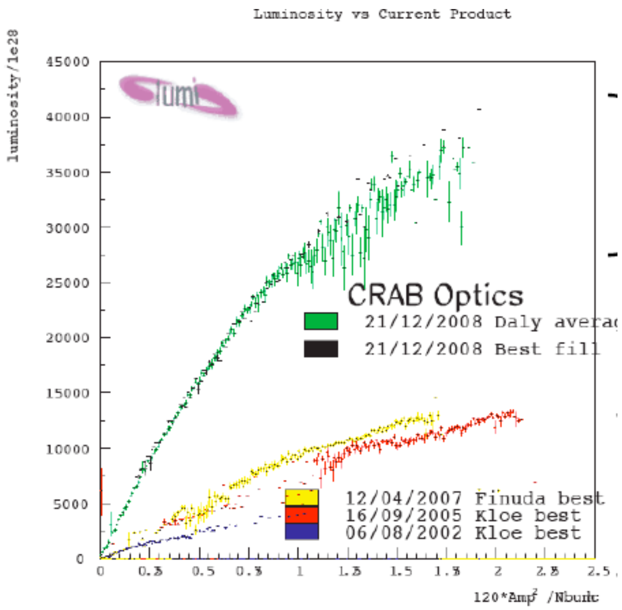
Laboratori Nazionali di Frascati

8th RMCWG meeting, Liverpool, 18/9/10

KLOE-2 at upgraded DAΦNE

Crabbed waist scheme at DAΦNE (P. Raimondi)

- increase L by a factor *O*(5)
- requires minor modifications
- relatively low cost



KLOE-2:

Extended KLOE physics program at DAFNE upgraded both in **luminosity** O(20 fb^{-1}) and **energy** ($2m_{\pi}<\sqrt{s}<2.4$ GeV)

Physics issues:

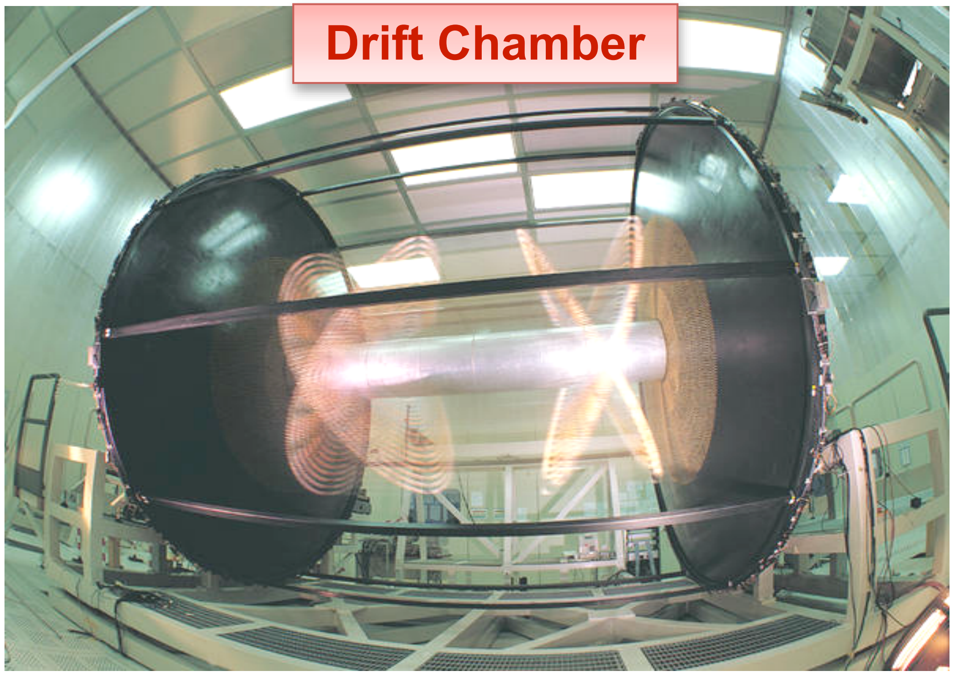
- Neutral kaon interferometry, CPT symmetry & QM tests
- Kaon physics, CKM, LFV, rare K_S decays
- $\gamma\gamma$ physics
- η,η', light scalar physics
- Search for new physics at O(1 GeV)
- Hadronic cross section at low energy

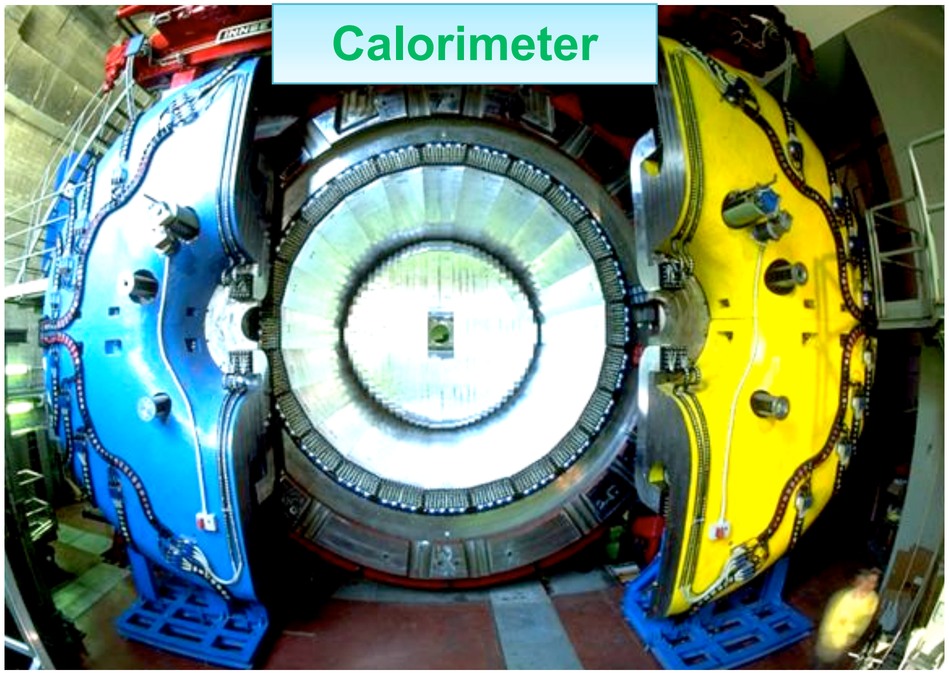
Detector upgrades:

- $\gamma\gamma$ tagging system (already funded)
- Inner tracker (partially funded)
- Calorimeters in forward directions (partially funded)
- Computing and networking upgrades

Already approved the first 3 years at ϕ peak (data taking will start soon)

From KLOE…





Multi-purpose detector optimized for K_L physics

- Huge, transparent Drift Chamber in 5.2 kGauss field of a SC coil
- Carbon fiber walls, 55000 stereo wires, 2 m radius, 4 m long, He/CO_2 gas mixture
- Momentum resolution: $\sigma(p_T)/p_T \sim 0.4\%$

- Pb-Scintillating Fiber Calorimeter with excellent timing performance
- 24 barrel modules, 4 m long and C-shaped End-Caps for 98% solid angle coverage
- Time resolution: $\sigma_T = 54\ \text{ps} / \sqrt{E(\text{GeV})} \oplus 50\ \text{ps}$
- Energy resolution: $\sigma_E/E = 5.7\% / \sqrt{E(\text{GeV})}$

…to KLOE-2…

Minimal detector upgrades:

- Tagger for γγ physics: to detect off-momentum $e^{\pm}$ from
  $$e^+e^- \rightarrow e^+e^-\gamma^*\gamma^* \rightarrow e^+e^-X$$

— LET: Low Energy Tagger (130-230 MeV)

calorimeters, LYSO + SiPM

— HET: High Energy Tagger (E > 400 MeV)

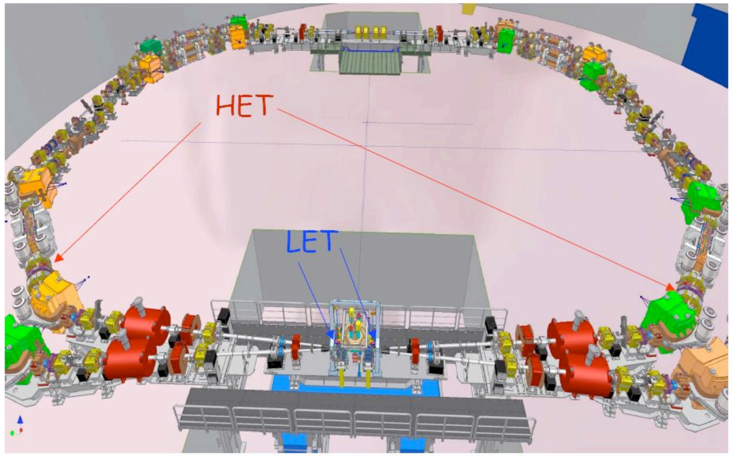
position sensitive detectors

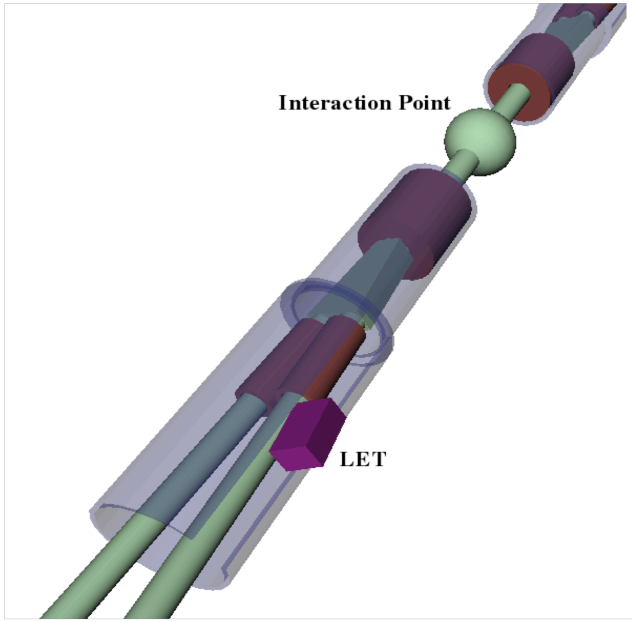
(strong energy-position correlation

⇒ use the DAΦNE magnets as $e^{\pm}$ spectrometer)

- Already funded by INFN

Approved ⇒ “roll-in”: Summer 2010





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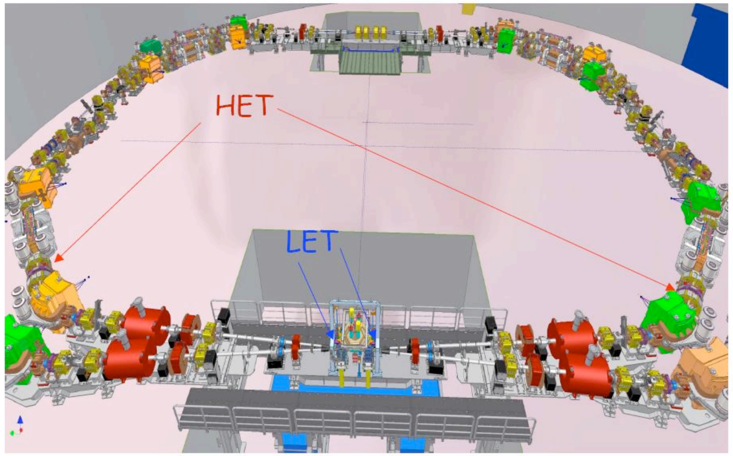
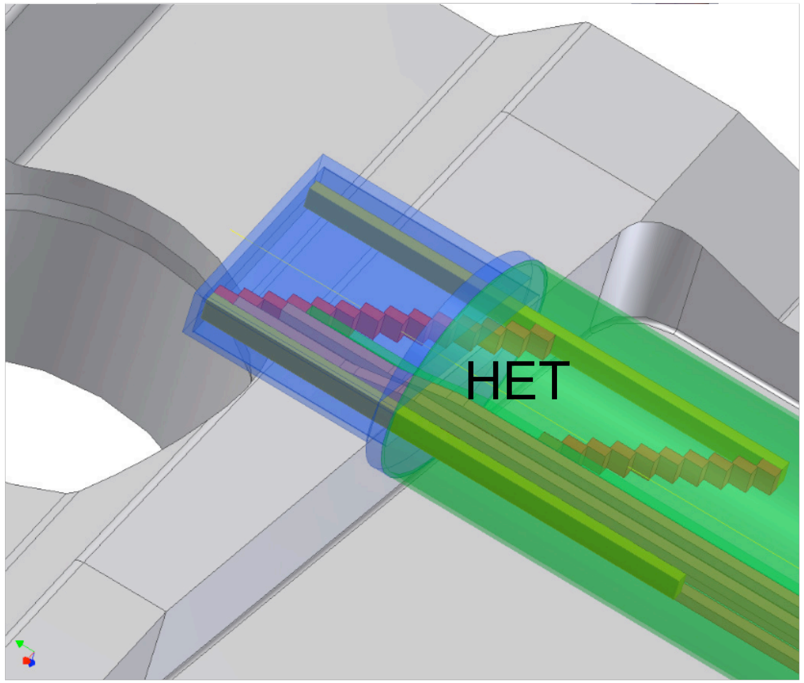




…to KLOE-2…

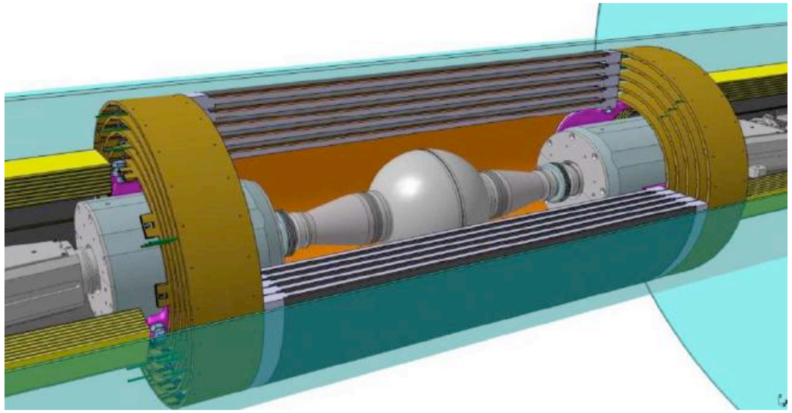
Major detector upgrade

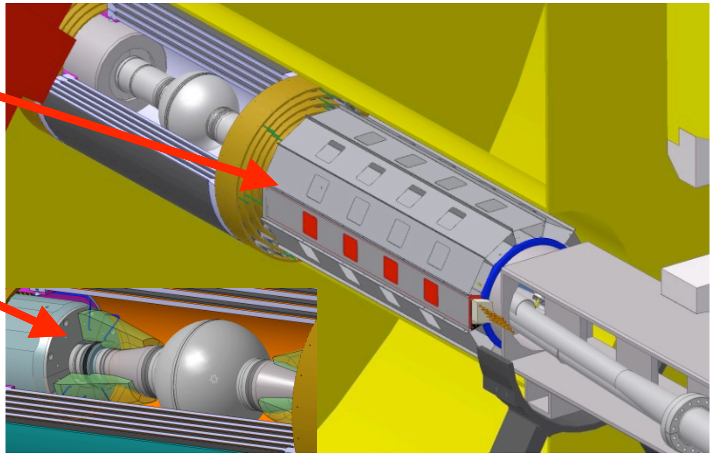
- Inner tracker (between the beam pipe and the DC): 4 layers of cylindrical triple GEM:

— improve vertex reconstruction near the IP

- QCALT: W + scint. tiles

  readout by SiPM via WLS fibers





- CCAL: LYSO crystals + APD; close to IP to increase acceptance for photons coming from the IP (min. angle: 21°→ 9°)

- Partially funded

  Time scale: installation in late 2011

Inner Tracker: the C-GEM project (novel technology developed at LNF)

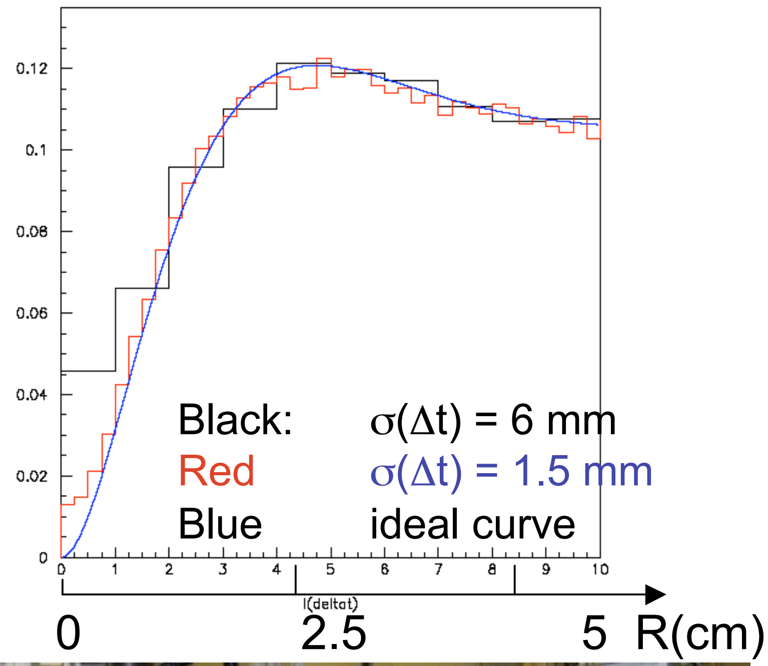
- Improve vertex reconstruction (of a factor 3 for $K_S \rightarrow \pi\,\pi$ from (present 6mm))
- Improve acceptance for low-Pt tracks
- Light material in order to minimize m.s. and γ absorbition

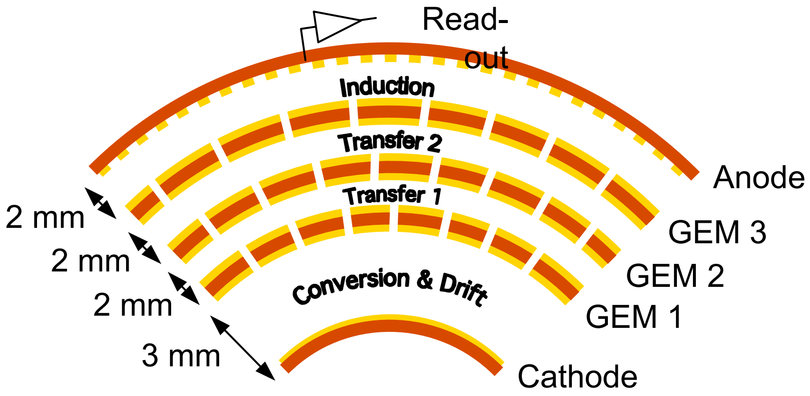
$\rightarrow$Cylindrical triple GEM

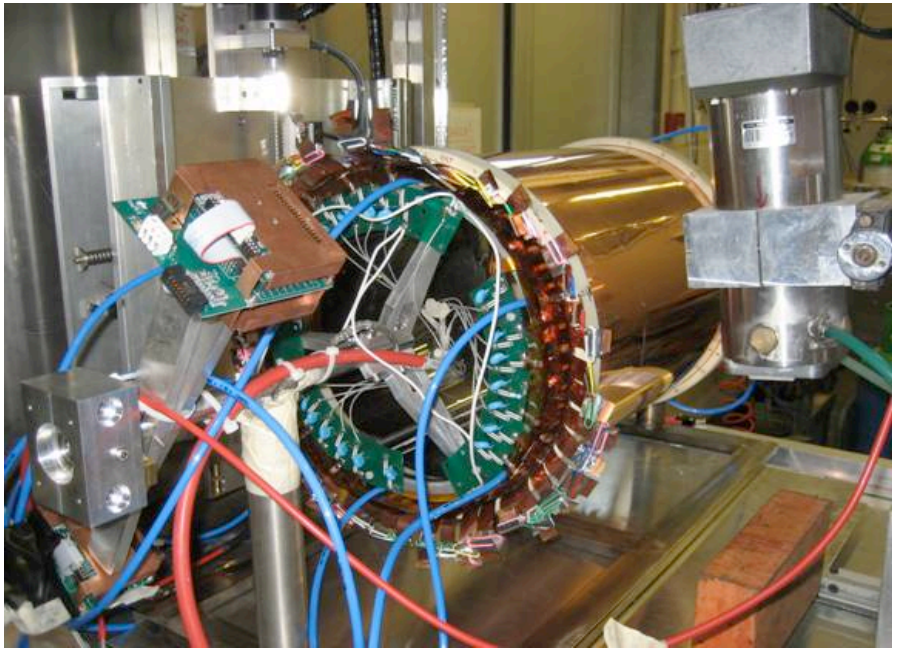
(G.Bencivenni et al.)

$\sigma(r\phi)$ = 200 μm

$\sigma(z)$ = 500 μm







Very important also for multihadronic cross section!

KLOE-2 High Energy program:

- running DAFNE up to 2.-2.5 GeV (and possibly below 1 GeV), with a luminosity ~10^{32} cm^{-2}s^{-1} (~5 pb^{-1} per day$\Leftrightarrow$1 fb^{-1}/year, assuming 50% duty cycle).

Main Motivation:

Measurement of the (multi)hadronic cross section in the region 1-2 GeV at 1-2% (now 3-15%)$\Rightarrow$ Dramatic impact in the precision tests of the SM via $(g-2)_\mu$ and $\alpha_{em}(M_Z)$

Other motivations:

$\gamma\gamma$ physics above the ϕ, spectroscopy, exotics (light bosons), Baryon FF, etc…

References:

- KLOE-2 LoI: www.lnf.infn.it/lnfadmin/direzione/roadmap/LoIKLOE.pdf
- F.Ambrosino et al., EPJC50(2007)729
- Physics with KLOE2 experiment at the ϕ-factory, arXiv:1003.3868
- **D. Babusci et al. "Proposal for taking data with the KLOE-2 detector at the DAFNE Collider upgraded in energy", LNF NOTE 10/17(P), arXiv:1007.521**

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Proposal for taking data with the KLOE-2 Detector at the DAΦNE collider upgraded in energy

arXiv:1007.521

LNF Note 10/17(P)
June 2010

Abstract

This document reviews the physics program of the KLOE-2 detector at DAΦNE upgraded in energy and provides a simple solution to run the collider above the ϕ-peak (up to $\sim$ 2, possibly 2.5 GeV). It is shown how a precise measurement of the multihadronic cross section in the energy region up to 2 (possibly 2.5) GeV will have a major impact on the tests of the Standard Model through a precise determination of the anomalous magnetic moment of the muon and the effective fine-structure constant at the M_Z scale. With a luminosity of $\sim 10^{32}\mathrm{cm}^{-2}\mathrm{s}^{-1}$, DAΦNE upgraded in energy can perform a scan in the region from 1 to 2.5 GeV in one year, by collecting an integrated luminosity of 20 pb^{-1} for single point (corresponding to few days of data taking), assuming an energy step of 25 MeV. A few years of data taking in this region would provide important tests of QCD and effective theories by $\gamma\gamma$ physics with open thresholds for pseudo-scalar (like the η'), scalar (f_0, f_0', etc...) and axial-vector (a_1, etc...) mesons; vector-mesons spectroscopy and baryon form factors, tests of CVC, and searches for exotics. In the final part of the document a technical solution for the energy upgrade of DAΦNE is proposed.

Proposal supported by LNF (Research and Accelerator Division) together with national and foreign institutes

Presented at LNF on June 11 2010 and (informally) to LNF SC on 24 June

From LNF SC report (June 2010)

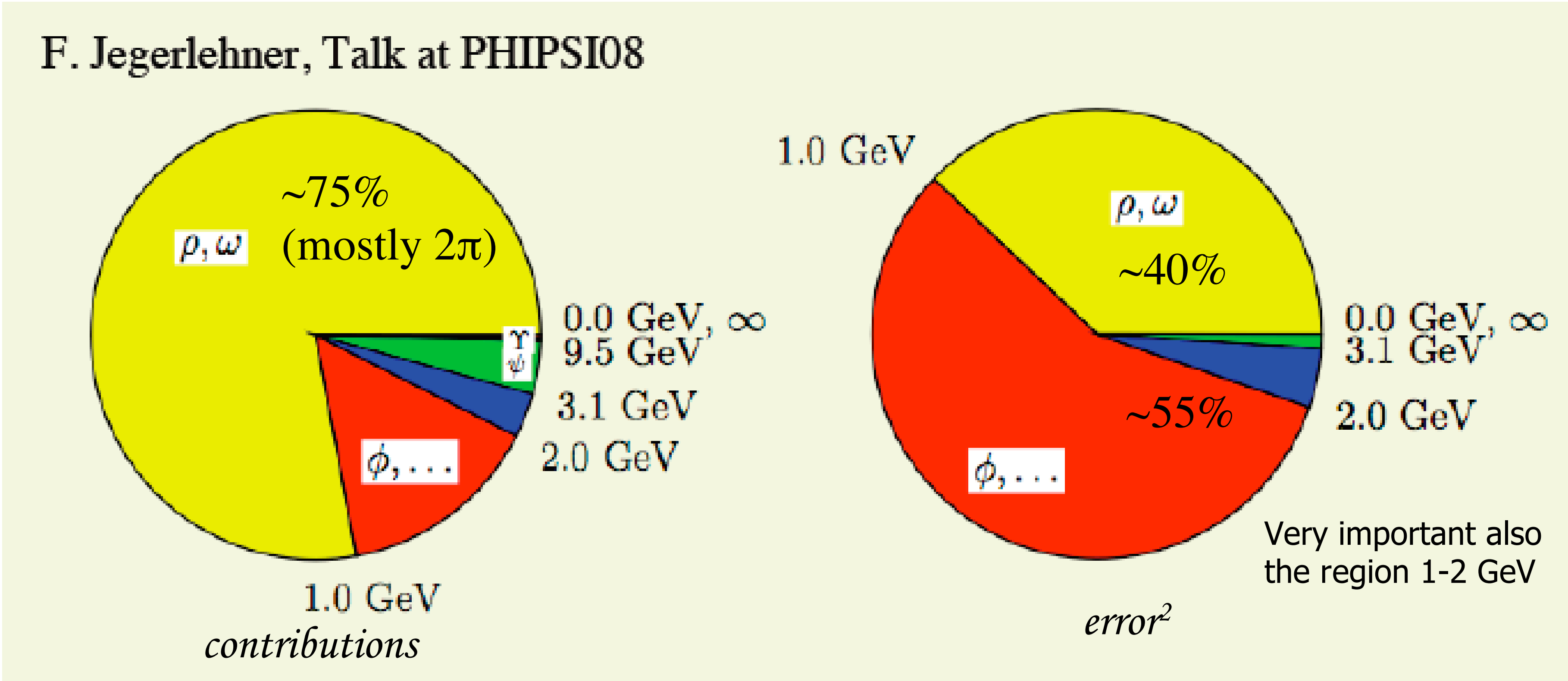
A meeting to discuss future Laboratory projects was held on June 11 (www.lnf.infn.it/11giugno). A study for an energy upgrade of DAΦNE – to at least 2 GeV in the c.m.s. – was presented. This possibility drew broad support from physicists both inside and out of the laboratory. In order to firm up the energy and the cost estimate, currently in the range of 10 M€, a prototype of a superconducting main dipole must be developed.

The SC welcomed the fact that the study for the DAΦNE upgrade is jointly authored by the DA and by the KLOE community. Of course, more technical work is needed for an in-depth discussion. The SC encourages the Laboratory to continue this study and in particular to develop the superconducting dipole prototype In general, the laboratory's projects should not be paralyzed by the absence of a decision on the SuperB project; on the contrary, good strategic thinking requires preparing for more than one outcome. The SC would like to be shown a more detailed proposal for a DAΦNE upgrade at its next meeting.

In summary, the SC congratulates the KLOE collaboration on the excellent work on this important subject supports the KLOE 2 program to improve the measurements of the hadronic cross section with an energy scan above the ϕ peak.

Dispersion Integral: $a_\mu^{HLO} = \int_{4m_\pi^2}^{\infty} \sigma_{had}(s) K(s) ds$ K(s)~1/s

Contribution of different energy regions to the dispersion integral and the error to a_μ^{HLO}



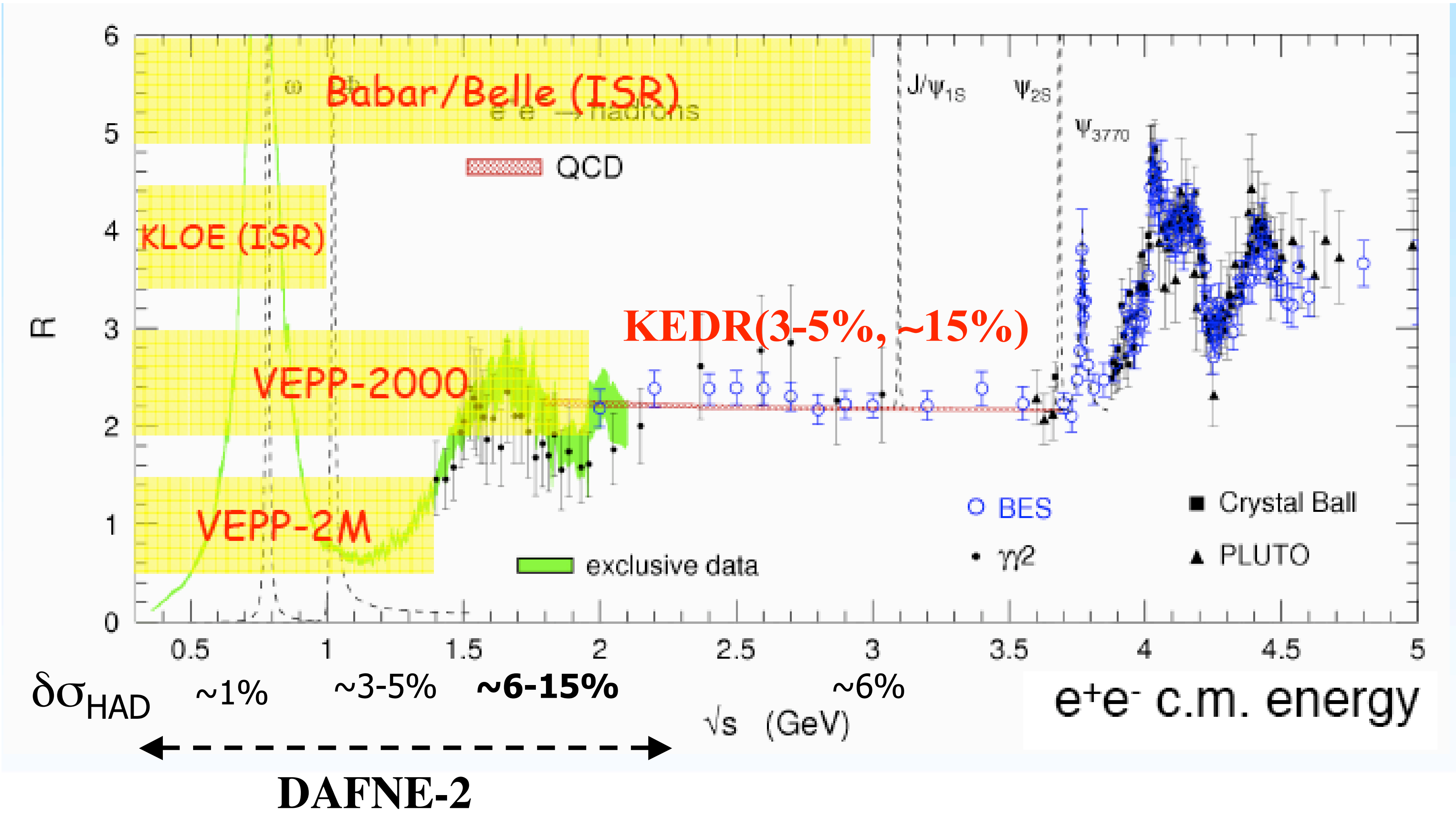
Experimental errors on σ^{had} translate into theoretical uncertainty of a_μ^{had}!

→ Needs precision measurements!

$\delta a_\mu^{exp} \rightarrow 1.5\ 10^{-10} = 0.2\%$ on a_μ^{HLO}

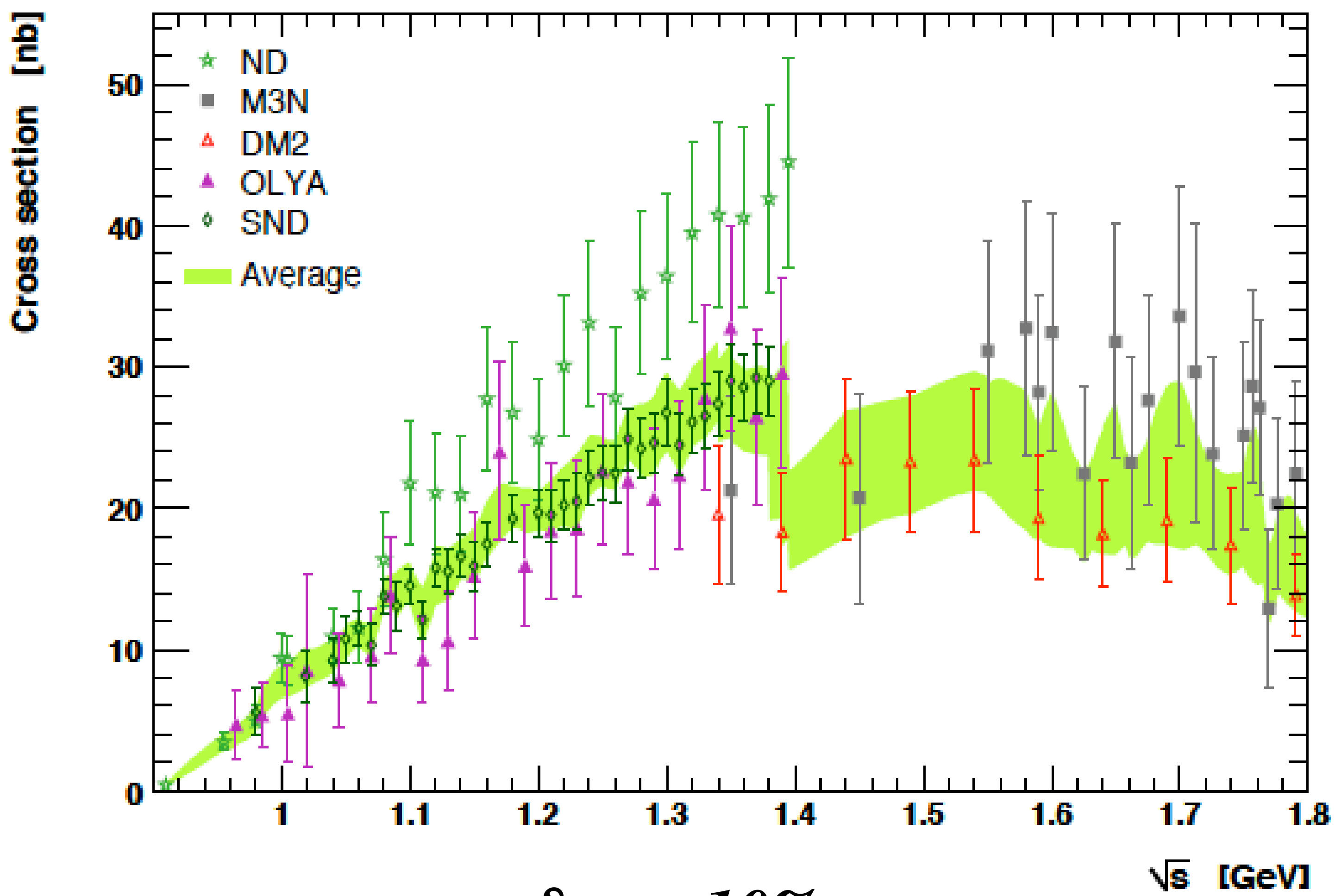
New g-2 exp.

e⁺e⁻ data: current and future/activities



Above 1 GeV

Example: $\sigma(e^+e^- \to \pi^+\pi^- 2\pi^o)$



$\delta\sigma_{sys}$~10%

DAFNE-2 can well improve this situation ($\rightarrow \delta\sigma_{HAD}$ ~ 2%)

Impact of DAFNE-2 on $(g\text{-}2)_\mu$

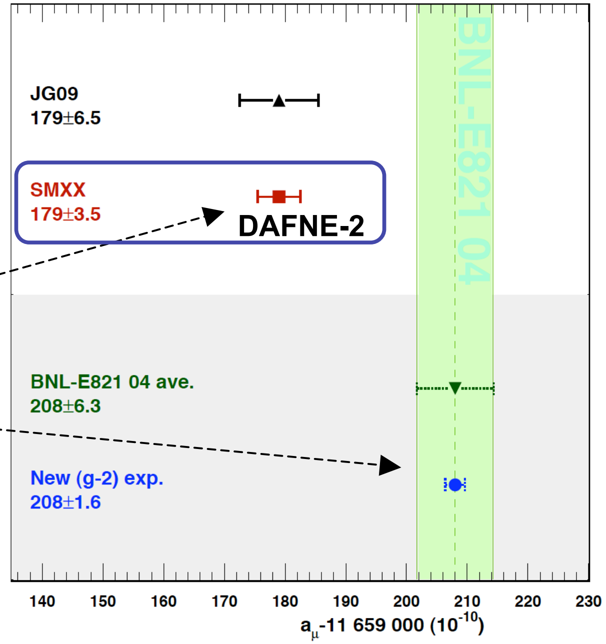
$a_\mu^{exp} - a_\mu^{theo,SM} = (27.7 \pm 8.4)10^{-10}$ (3.3σ) [Eidelman, TAU08]

$8.4 = \sim 5_{HLO} \oplus \sim 3_{HLbL} \oplus 6_{BNL}$

4 **$2.6_{DAFNE\text{-}2}$** 2.5 $1.6_{NEW\ G\text{-}2}$

$7\text{-}8\sigma$

(if 27.7 will remain the same)



$\delta a_\mu^{HLO} = 5.3 = 3.3(\sqrt{s}<1\text{GeV}) \oplus 3.9(1<\sqrt{s}<2\text{GeV}) \oplus 1.2(\sqrt{s}>2\text{GeV})$

$\delta a_\mu^{HLO} \rightarrow \mathbf{2.6} = 1.9\ (\sqrt{s}<1\text{GeV}) \oplus \mathbf{1.3\ (\sqrt{s}<1GeV)} \oplus 1.2(\sqrt{s}>2\text{GeV})$

This means:

$\delta\sigma_{HAD} \sim 0.4\%$ $\sqrt{s}<1$GeV (instead of 0.7% as now) *With ISR at 1 GeV*

$\delta\sigma_{HAD} \sim 2\%$ $1<\sqrt{s}<2$GeV (instead of 6% as now) *With Energy Scan 1-2 GeV*

Possible at DAFNE-2!

Precise measurement of σ_{HAD} at low energies very important also for $\alpha_{em}(M_Z)$ (necessary for ILC) !!!

Which contributions on $\alpha_{em}(M_Z)$ from DAFNE-2?

The running fine structure constant $\alpha(E)$ via the Adler function

F. Jegerlehner[a b * c †] **Nucl.Phys.Proc.Suppl.181-182:135-140 2008**

[a]H. Niewodniczanski Nuclear Physics Institute PAN, 31-342 Krakow, Poland

[b]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstrasse 15, D-12489 Berlin, Germany

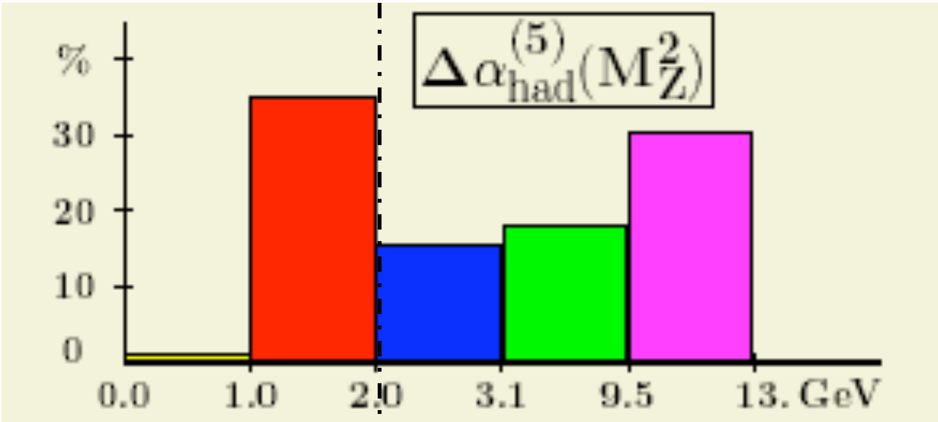
[c]Deutsches Elekronen-Synchrotron DESY, Platanenalle 6, D-15738 Zeuthen, Germany

We present an up-to-date analysis for a precise determination of the effective fine structure constant and discuss the prospects for future improvements. We advocate to use a determination monitored by the Adler function which allows us to exploit perturbative QCD in an optimal well controlled way. Together with a long term program of hadronic cross section measurements at energies up to a few GeV, a determination of $\alpha(M_Z)$ at a precision comparable to the one of the Z mass M_Z should be feasible. Presently $\alpha(E)$ at $E > 1$ GeV is the least precisely known of the fundamental parameters of the SM. Since, in spite of substantial progress due to new BaBar exclusive data, the region 1.4 to 2.4 GeV remains the most problematic one a major step in the reduction of the uncertainties are expected from VEPP-2000 [1] and from a possible "high-energy" option DAFNE-2 at Frascati [2]. The up-to-date evaluation reads $\Delta\alpha^{(5)}_{\rm had}(M_Z^2) = 0.027515 \pm 0.000149$ or $\alpha^{-1}(M_Z^2) = 128.957 \pm 0.020$.

" In any case as we see from Fig. 4 by far the largest improvement factor will come from precise cross–section measurements in the region from 1.4 to 2.4 GeV. A unique challenge and chance for VEPP-2000 and DAFNE-2. "

Comparison of error profiles for $\alpha_{em}(M_Z)$

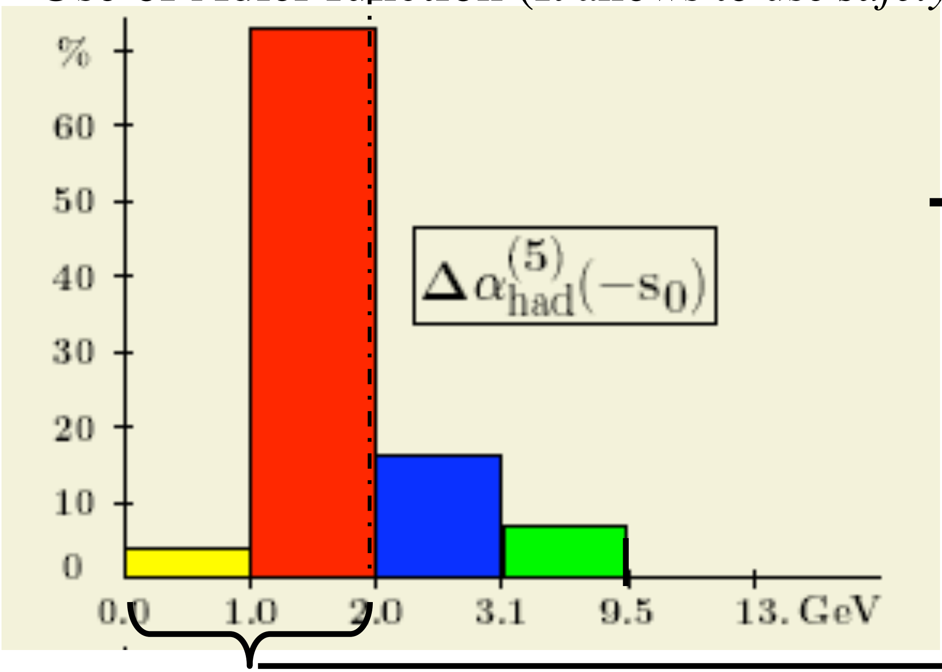
Direct integration of energy points



F. Jegerlehner, Nucl. Phys. B 181-182 (2008) 135

$\delta\sigma$ at 1% in the region **$\sqrt{s}$ < 10 GeV**
$\Rightarrow$ improvement of ~**3** in $\delta\alpha(M_Z)$

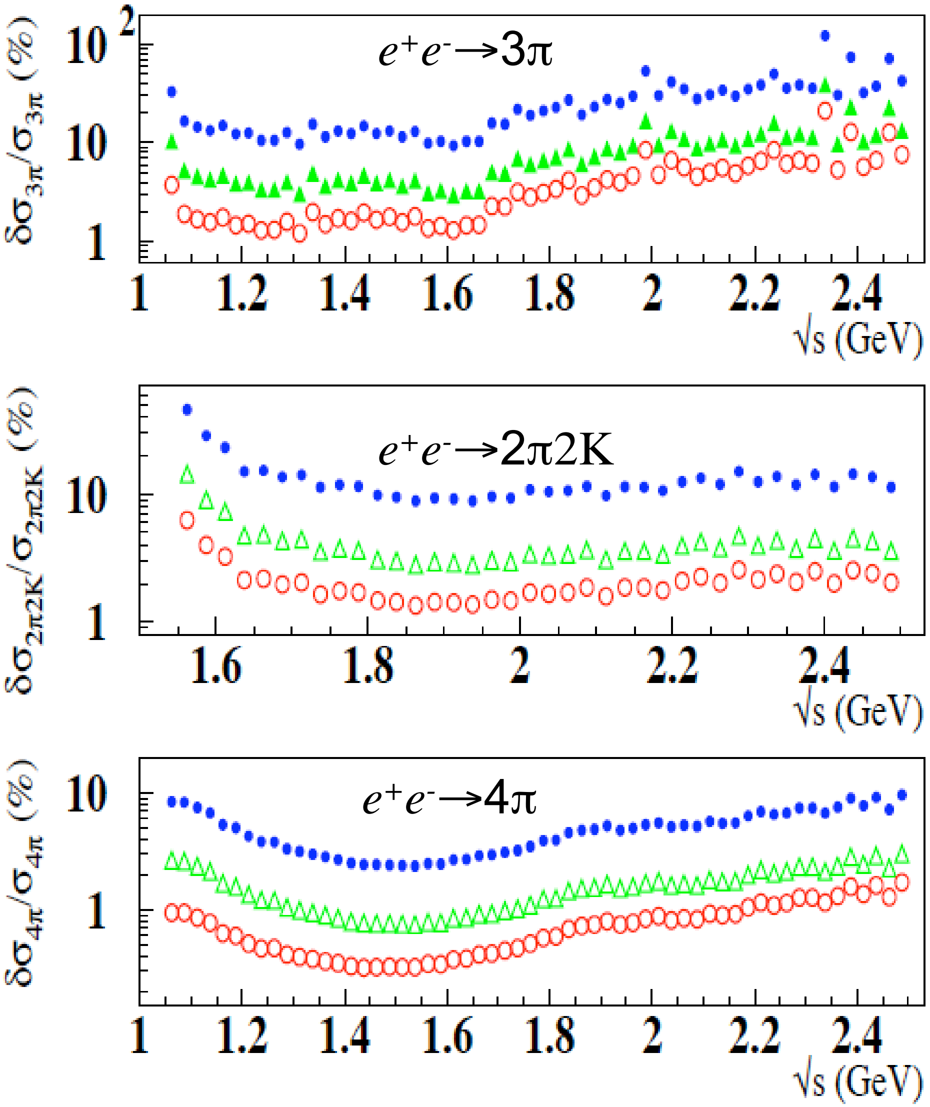
Use of Adler function (It allows to use *safely* pQCD down to 2.5 GeV)



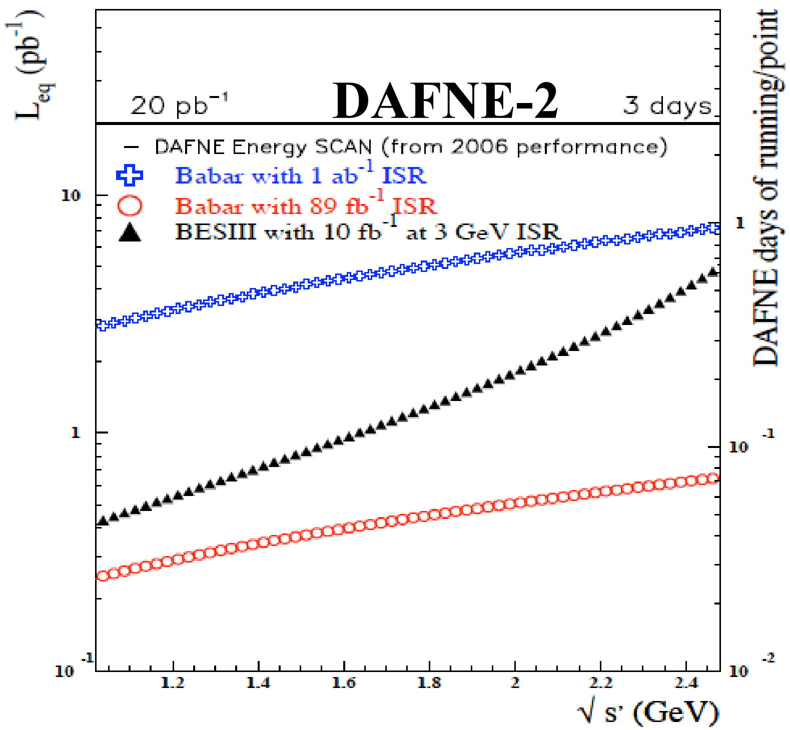
1% in the region 1<$\sqrt{s}$ < 2.5 GeV
$\Rightarrow$ improvement of ~5 on $\delta\alpha(M_Z)$

$2m_\pi$<$\sqrt{s}$ < 2 GeV
Extremely important:
- **80%** of $\delta\Delta\alpha^{(5)}_{had}$ (using Adler function)
- **95%** of δa_μ

Impact of DAFNE-2 on exclusive channels in the range [1-2.5] GeV with a scan (Statistics only)



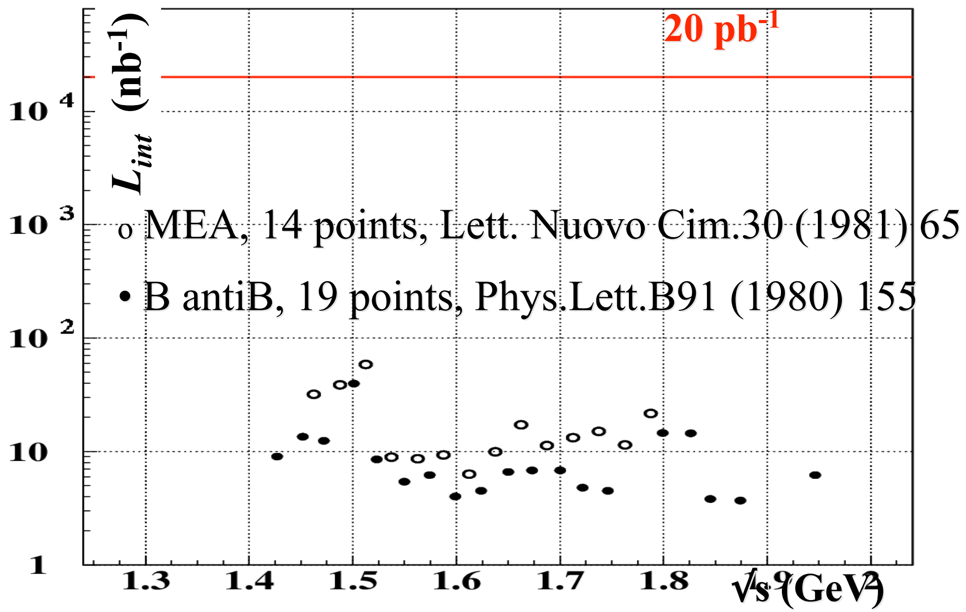
- **Published BaBar results: 89 fb^{-1} (ISR)**
- ▲ **"BaBar" × 10 (890 fb^{-1})**
- o **KLOE-2 energy scan: 20 pb^{-1}/point @ L= 10^{32} cm^{-2} s^{-1}, 25 MeV bin ⇒ 1 year data-taking**



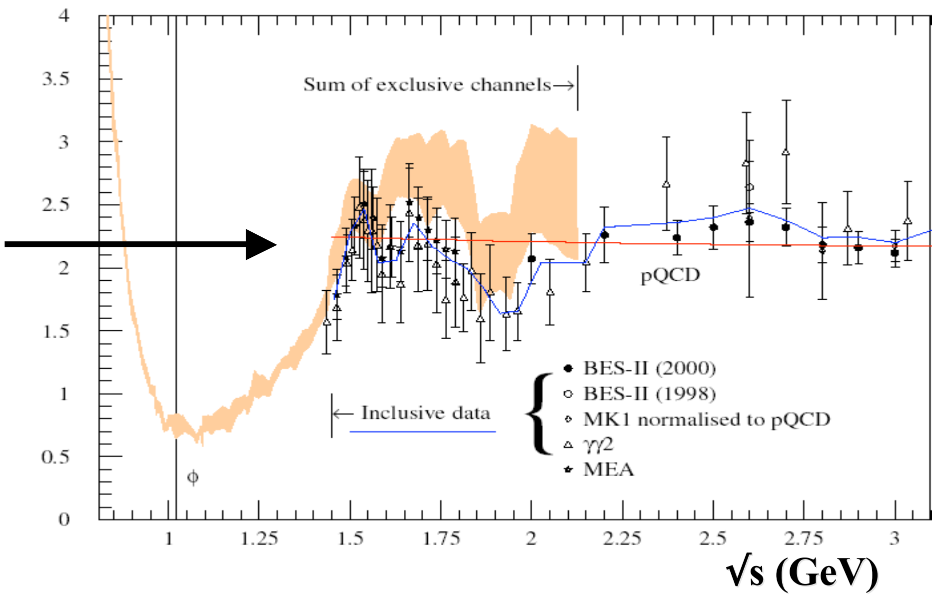
DAFNE-2 is **statistically** equivalent to 5÷10 ab^{-1} (Super)B-factory

Impact of DAFNE-2 on inclusive measurement

1) Most recent inclusive measurements: MEA and B antiB, with **total** integrated luminosity of **200 nb^{-1}** (one hour of data taking at 10^{32} cm^{-2} sec-1).**10% stat.+ 15% syst. Errors**

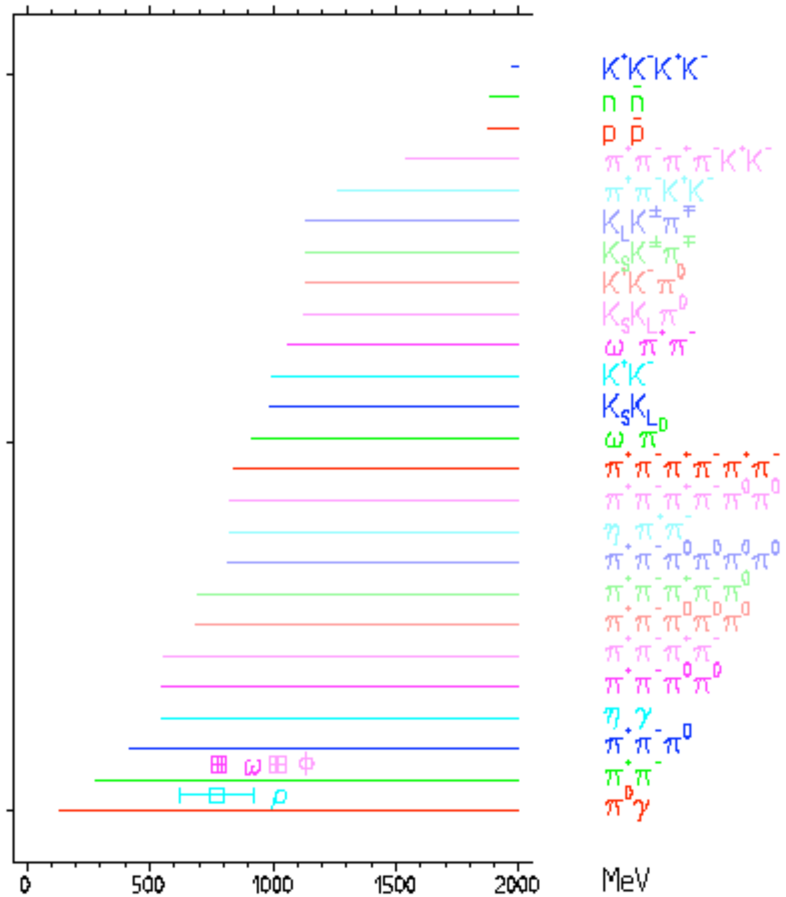


2) With 20 pb^{-1} per energy point (1year of data taking at 10^{32} cm^{-2} sec^{-1}) a **precise** comparison exclusive vs. inclusive can be carried out



Can KLOE-2 measure σ_{HAD} with 1% error in the region 1-2 GeV?

- Not easy task ⇒
- Statistics OK @ $10^{32}cm^{-2}\,sec^{-1}$ (scan)
- Systematics most likely under control, given the excellent performance of KLOE+inner tracker
- Precise determination of beam energy would help (using BS Compton)
- Exclusive vs inclusive?



KLOE-2 looks a perfect detector for these measurements, although a detailed **Monte Carlo** study must be done

$\gamma\gamma$ physics ($e^+e^- \rightarrow e^+e^- \gamma^*\gamma^* \rightarrow e^+e^- + X$) above ϕ

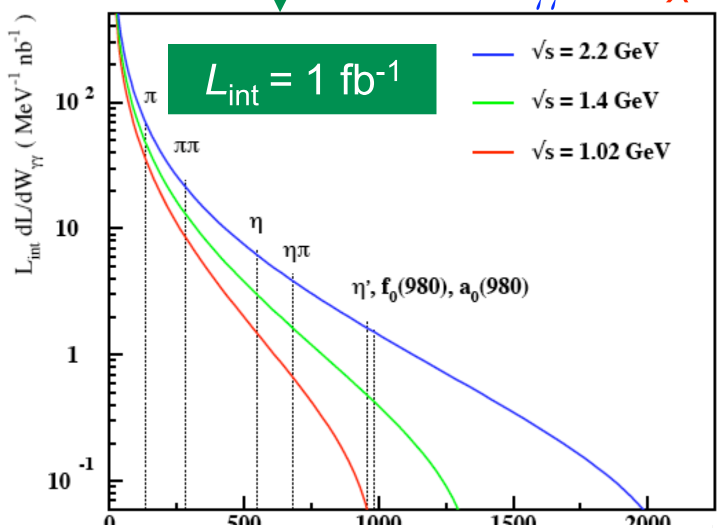
$$\frac{dN_X}{dW_{\gamma\gamma}} = \underbrace{L_{int} \frac{dL}{dW_{\gamma\gamma}}} \sigma(\gamma\gamma \rightarrow X) \qquad W_{\gamma\gamma} = M_X$$

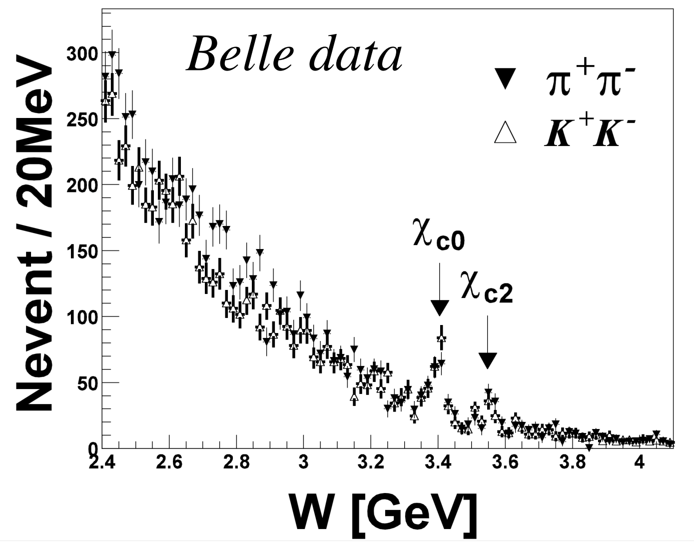
- Luminosity flux larger than at ϕ with lower background
- Open tresholds for η', f_0, a_0, KK
- Transitions Form Factors for axial-vectors (a_1, f_1, f_1')

Event yeld for L=1fb^{-1} ($\sqrt{s}$=1.4 GeV))

π^0	$\pi^0\pi^0$	η	η'
~5 10^5	10^4	~2 10^5	~ 10^5

- *Very rich physics, mostly complementary to other existing machines*
- *Impact on HLbL (via P(S),AV TFF)*





$\gamma\gamma \rightarrow K^+K^-$, $\pi^+\pi^-$ (2.4<W<4.1GeV)

Search for exotics below 2 GeV:

-Recent astrophysical puzzles [Pamela, Actic, Fermi, …] and the long-standing Dark Matter problem, have motivated the construction of various exotic extensions of the SM model characterized by:

- new light states [vectors and scalars with masses in the 0.1 - 1 GeV range]

- weakly coupled to photons, or directly coupled to muons and/or electrons

Precision differential measurements of $e^+e^- \to e^+e^- + \gamma$ and/or $e^+e^- \to \mu^-\mu^+ + \gamma$ and/or $e_+e_- \to E_{miss} + \gamma$, ... at low energies are the best way to constrain (or find evidences...) of such models [large parameter space is still unexplored !]

KLOE has already started this analysis at 1GeV

Needs of MC in the energy region below 2-2.5 GeV:

- σ_{HAD} and spectroscopy:
  - -Exclusive channels: which is the status of MC generators (see Eidelman's talk)? Are they sufficient precise (~1%)? Are they publically available?
  - -ISR: PHOKHARA has already a lot of channels (see Czyz's talk). What else?

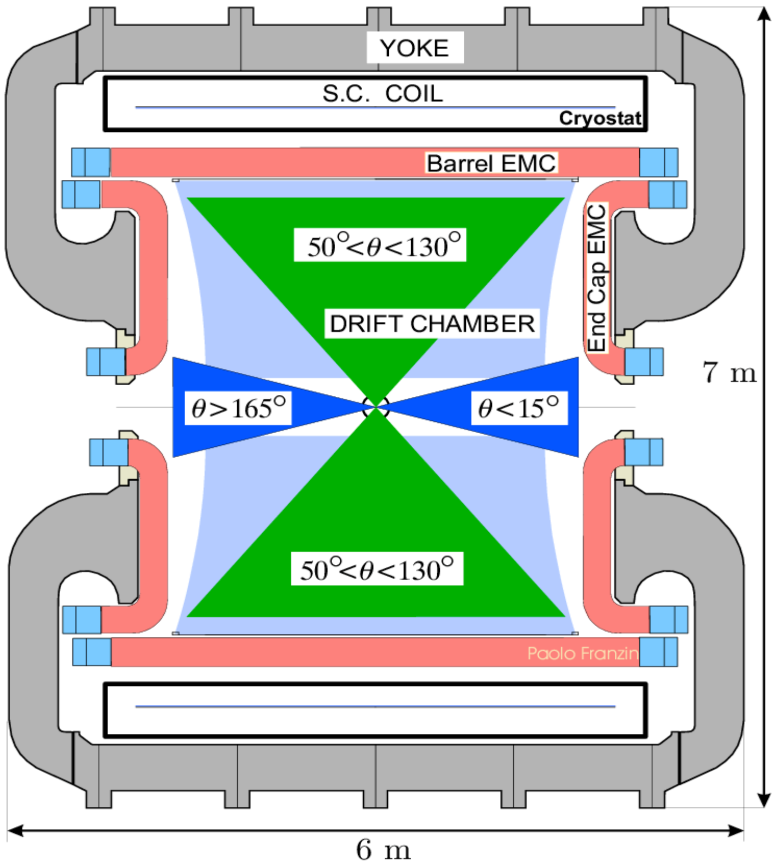
-Luminosity ?
  - see Montagna's talk

- gamma-gamma:
  - -Ekhara has been developed for single π^0,$\pi^+\pi^-$ (See Czyz's and Moricciani's talk). We have also a MC based on NPP model for $\pi^0\pi^0$. What about η,η' , scalars, axials?

- searches:
  - -Babayaga has been interfaced with "exotic" light states…(see Balossini's talk). Can be used also in the range above 1 GeV?

-Anything else?

Discussion is open…



SPARE SLIDES

DAFNE Energy upgrade scheme (P. Raimondi)

- Dafne injection scheme limits the beam energy to 540 MeV. An increase of this energy requires major changes, and seems not feasible.

  ⇒ The most reasonable solution is to inject in Dafne at the "nominal" energy of about 510MeV and then ramp the energy up to desired one

  The Quad's around the interaction region must be replaced by superconductive ones (now they are permanent)

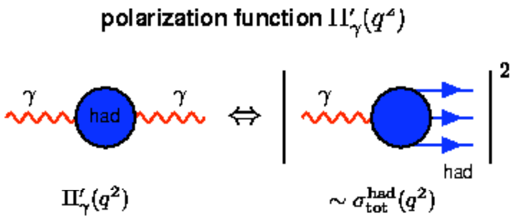
  ⇒ In this way 1.4 GeV can be reached.
- In order to achieve higher energy (2 GeV) the dipoles in the main rings must be replaced.
- Assuming $L \sim 10^{32}\ cm^{-2}\ s^{-1}$ and 50% duty cicle (due to ramping time) $\rightarrow 5 pb^{-1}$/day can be reached ($1 fb^{-1}$/year).
- Cost estimate: ~10 Meur (up to ~2 GeV)

Needs a detailed work

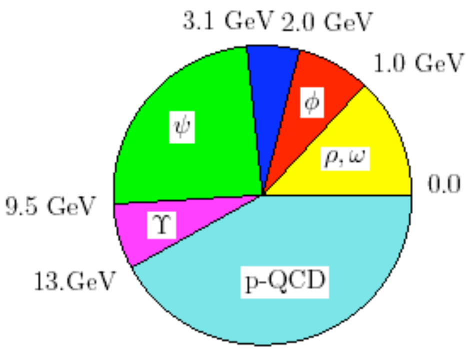
Effective fine structure constant $\alpha_{em}(M_Z)$

$$\alpha(M_Z) = \frac{\alpha(0)}{1-\Delta\alpha(M_Z)}$$

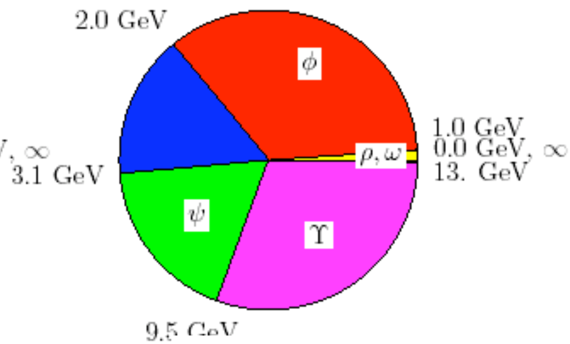
$\Delta\alpha = \Delta\alpha_l + \Delta\alpha^{(5)}_{had} + \Delta\alpha_{top}$



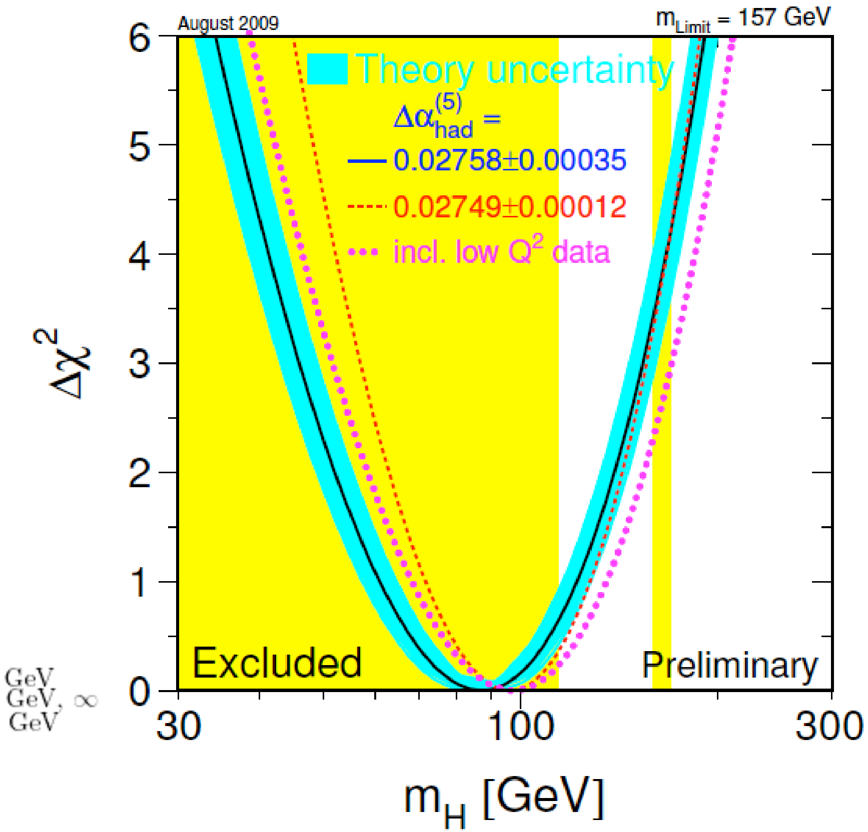
$$\Delta\alpha^{(5)}_{had}(M_Z^2) = -\frac{\alpha M_Z^2}{3\pi}\mathrm{Re}\int_{4m_\pi^2}^{\infty} ds \frac{R(s)}{s(s-M_Z^2-i\varepsilon)}$$



$\Delta\alpha^{(5)}_{\mathrm{had}}(M_Z^2)$



$\delta^2\Delta\alpha^{(5)}_{\mathrm{had}}(M_Z^2)$



$$\Delta\alpha^{(5)}_{had}(M_Z^2) = 0.027607 \pm 0.000225$$

$$\alpha^{-1}(M_Z^2) = 128.947 \pm 0.035$$

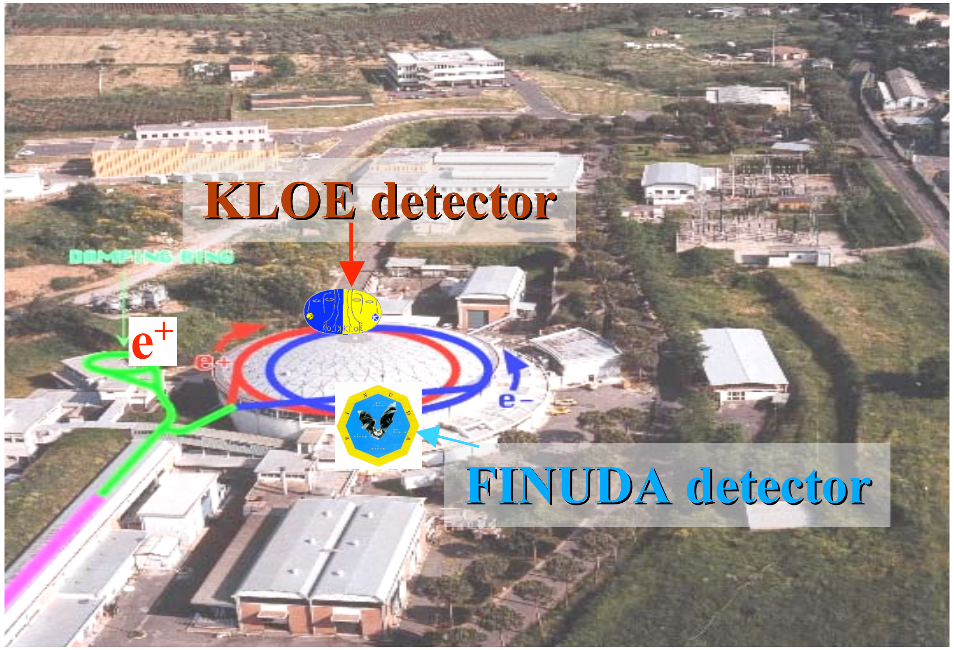
FJ08

$\delta\alpha(M_Z)/\alpha(M_Z) \sim 2 \div 7\times10^{-4} \rightarrow 5\times10^{-5}$

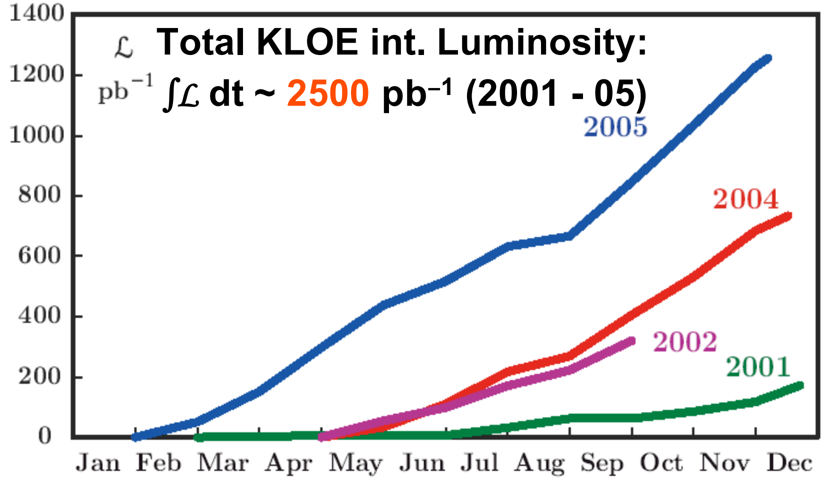
Requirement from ILC (6x improvement)

DAΦNE: A Φ-Factory

e^+e^- - collider with $\sqrt{s}=m_\Phi \approx 1.0195$ GeV



Integrated Luminosity



Peak Luminosity $L_{peak} = 1.5 \cdot 10^{32} cm^{-2}s^{-1}$

KLOE05 measurement (PLB606(2005)12) was based on $140pb^{-1}$ of 2001 data!

2006:

- **Energy scan (4 points around m_Φ-peak)**
- **240 pb^{-1} at $\sqrt{s}$ = 1000 MeV (off-peak data)**

KLOE08 measurement (PLB670(2009)285) was based on $240pb^{-1}$ from 2002 data!

*The **new** measurement (KLOE10) is based on 233 pb^{-1} of **2006** data (different event selection)*