Physics opportunities with an "energy upgrade" of DaΦne

[flexible c.o.m energy to run both below and above the Φ peak]

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- Introduction
- The hadronic contribution to $(g-2)_\mu$
- The hadronic contribution to α_{em}
- Spectroscopy and $\gamma\gamma$ physics
- Exotics
- Conclusions

Introduction

The *high-intensity frontier* in the LHC era:

- Study of rare & forbidden processes

  Full complementarity with the LHC for the identification of nature of physics beyond the SM

- Precision measurements of fundamental SM couplings

  Several SM parameters, which are likely to play a fundamental role in the identification of the underlying theory, can only be measured at low energies.

- Deeper studies of QCD

  There are still interesting aspects of non-perturbative QCD which are not fully understood and need to be investigated further.

Introduction

The *high-intensity frontier* in the LHC era:

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- Precision measurements of fundamental SM couplings [α_{em} ,...]

  Several SM parameters, which are likely to play a fundamental role in the identification of the underlying theory, can only be measured at low energies.

- Deeper studies of QCD [$\gamma\gamma \to \pi, \eta, \sigma$, ...]

  There are still interesting aspects of non-perturbative QCD which are not fully understood and need to be investigated further.

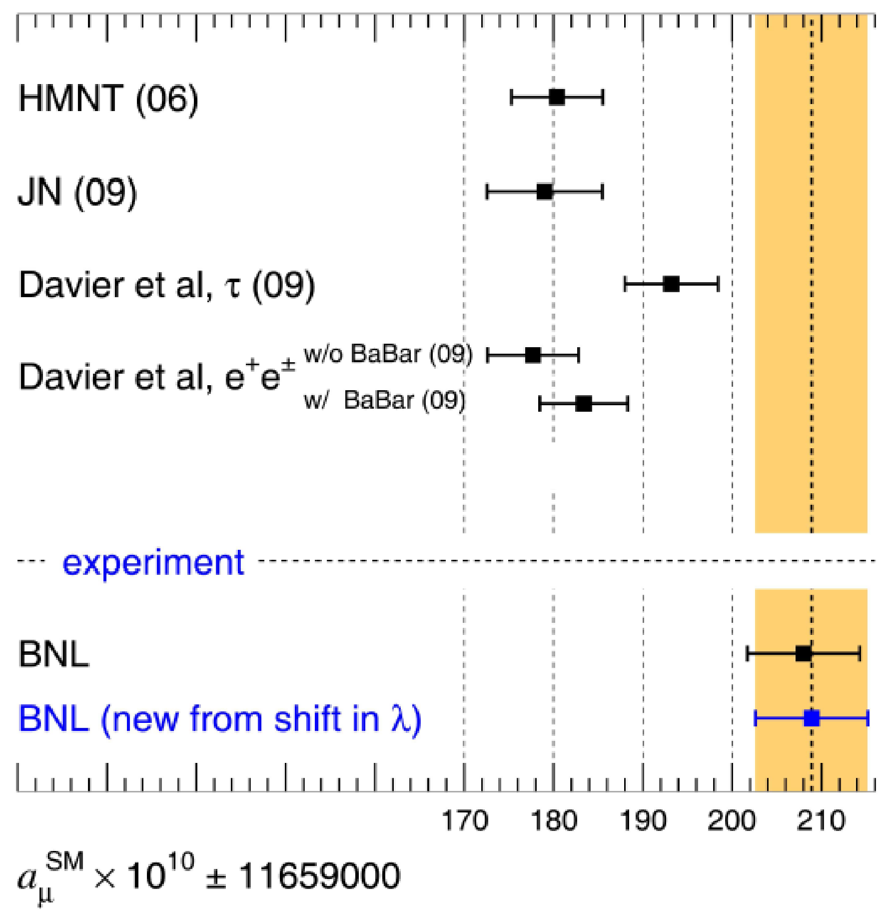
A DAΦNE upgrade with *flexible c.o.m. energy* [~ (0.5–2.5) GeV] could allow to perform *significant measurements* in all these 3 categories

The hadronic contribution to $(g\text{-}2)_\mu$

The anomalous magnetic moment of the muon is one of the most (if not *the most*) significant low-energy constraint on a wide class of new-physics models

$$\Delta a_\mu^{exp} = a_\mu^{exp} - a_\mu^{SM} = (25 \pm 8)10^{-10}$$

- In the last few years the result for a_μ^{SM} has become more reliable and the size of the discrepancy has (slightly) increased
- The discrepancy is large compared to $a_\mu^{ew\text{-}SM}$ ($a_\mu^{ew\text{-}SM} \sim 15\times10^{-10}$)



The hadronic contribution to $(g-2)_\mu$

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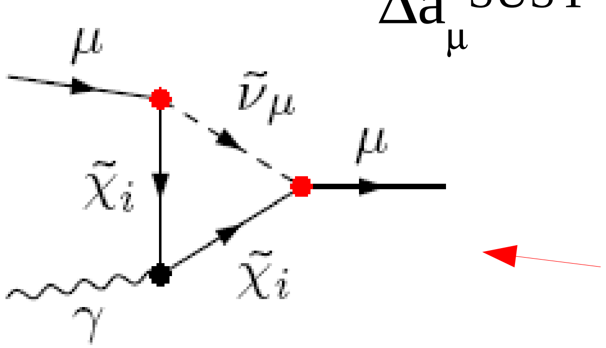
Unique example of helicity suppressed observable sensitive to electroweak physics

$$\mathscr{L}_{\rm eff} = \frac{c_{eff}}{\Lambda^2}\, \bar{\mu}_R \sigma^{\mu\nu} \mu_L \phi F_{\mu\nu}$$

→ direct probe of Yukawa interactions

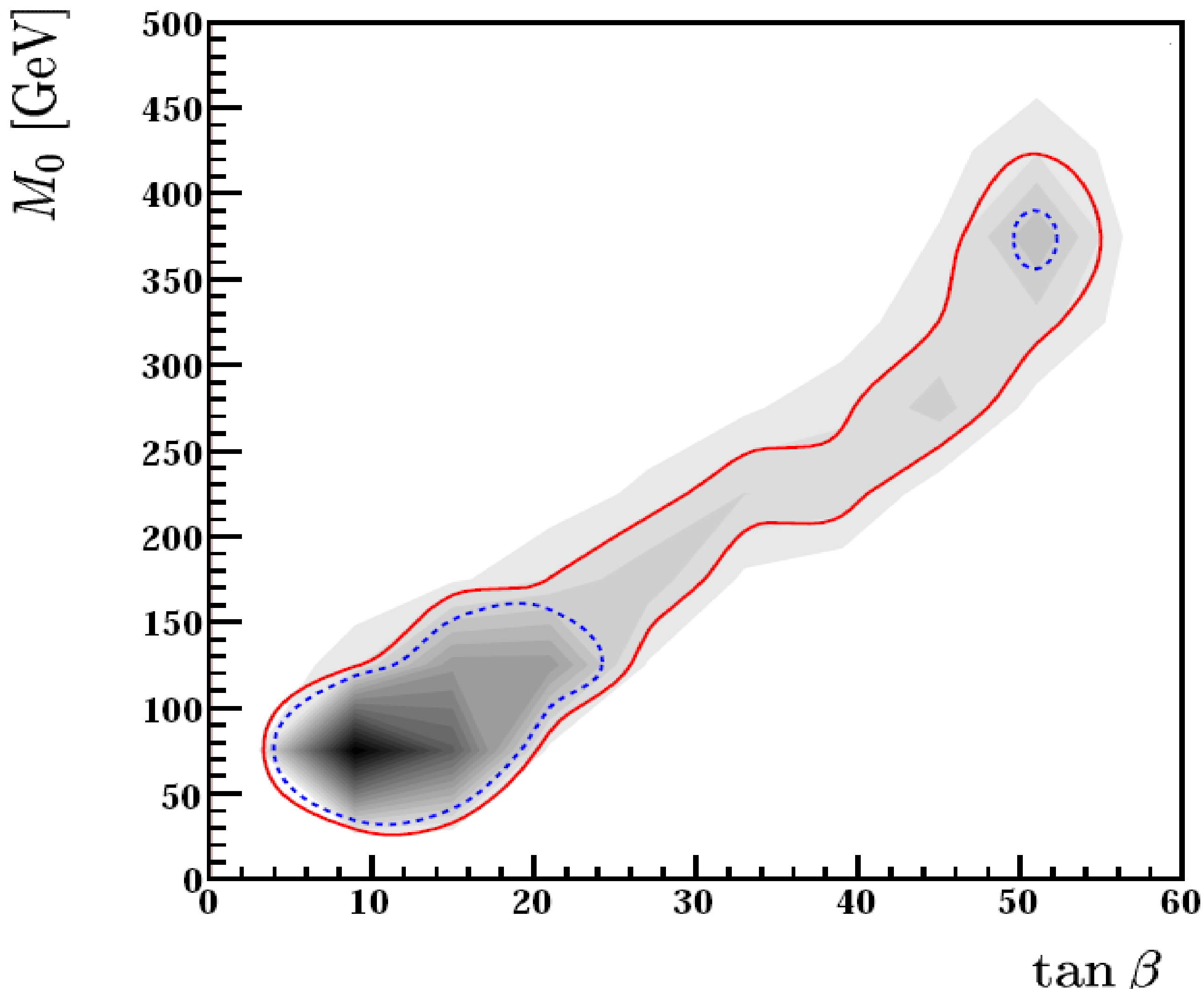
$$\Delta a_\mu^{\rm SUSY} \sim \tan\beta \times (m_W/M_{\rm SUSY})^2 \times (a_\mu^{\rm ew\text{-}SM}) \times {\rm sgn}(\mu)$$



Couplings proportional to the muon Yukawa and not to its mass !!

▶ *The hadronic contribution to* $(g\text{-}2)_\mu$

E.g.: Role of indirect constraints in a global fit of the CMSSM:



Key role played by $(g\text{-}2)_\mu$ & $B \to X_s\, \gamma$

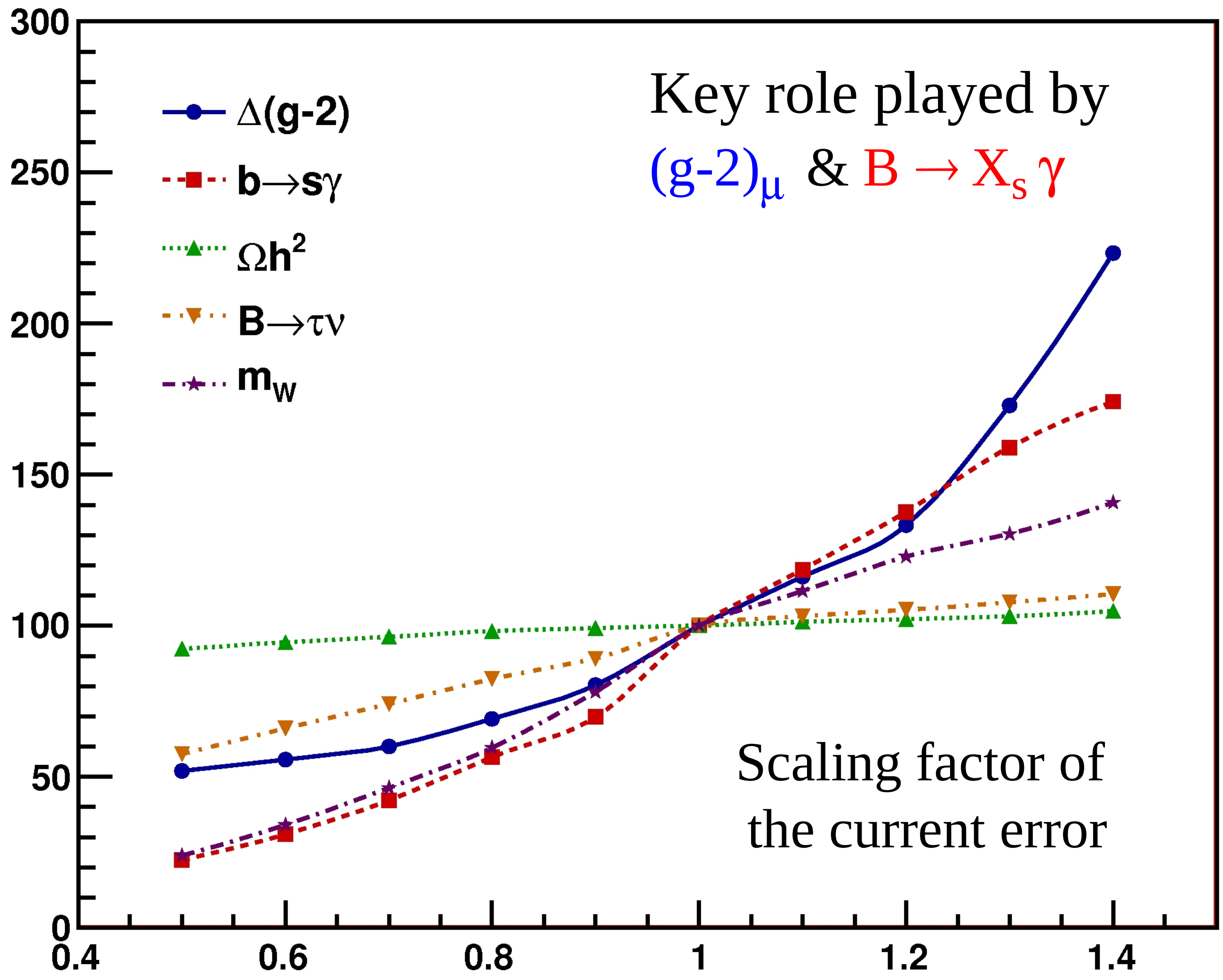
N.B.: at LHC we hope to measure well M_0 (and other mass param.) but we don't expect a good sensitivity to $\tan\beta$

Buchmuller et al. *arXiv:* 0707:3447 [hep-ph]

The hadronic contribution to $(g\text{-}2)_\mu$

E.g.: Role of indirect constraints in a global fit of the CMSSM:

% change of the preferred area

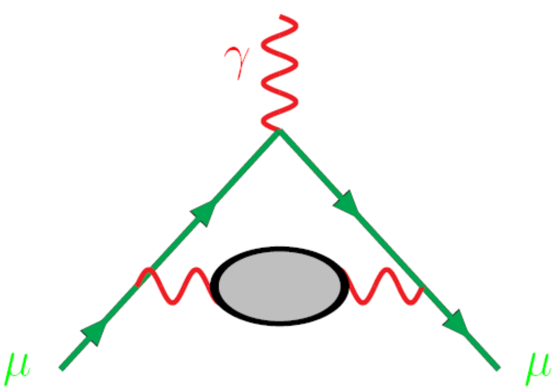


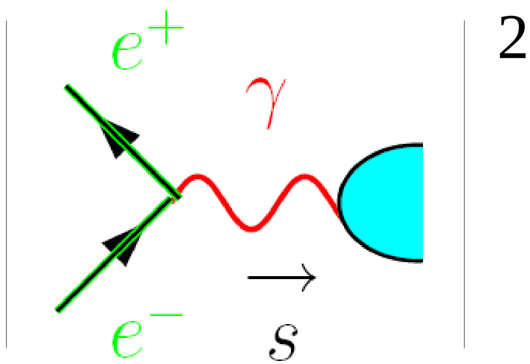
Buchmuller et al. *arXiv:* 0808.4128 [hep-ph]

The hadronic contribution to $(g\text{-}2)_\mu$

$$\Delta a_\mu^{exp} = a_\mu^{exp} - a_\mu^{SM} = \begin{cases} (27.7 \pm 8.4)\ 10^{-10} & \text{Eidelman TAU08} \\ (24.6 \pm 8.0)\ 10^{-10} & \text{Davier } et\ al.\ arXiv\text{: 0908.4128} \end{cases}$$

$$8.4 \approx 5_{HLO} \oplus 3_{LBL} \oplus 6_{BNL}$$





$\sigma(e^+e^- \rightarrow \text{hadr.})$

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$$8.4 \approx 5_{HLO} \oplus 3_{LBL} \oplus 6_{BNL}$$

$$\downarrow \quad \downarrow \quad \downarrow$$

$$4 \approx 2.5 \oplus 2.5_{LBL} \oplus 1.6$$

new $e^+e^- \to$ hadr. (→ 2.5) ; new g-2 (→ 1.6)

A substantial reduction of the present error is not a dream !

Venanzoni, MCW '09

$\delta a_\mu^{HLO} = 5.29 = 3.0(\sqrt{s}<1\text{GeV}) \oplus 3.9(1< \sqrt{s}<2\text{GeV})$

$\delta a_\mu^{HLO} \to 3 = 2.5\ (\sqrt{s}<1\text{GeV}) \oplus 1.5\ (\sqrt{s}<1\text{GeV})$

This means:

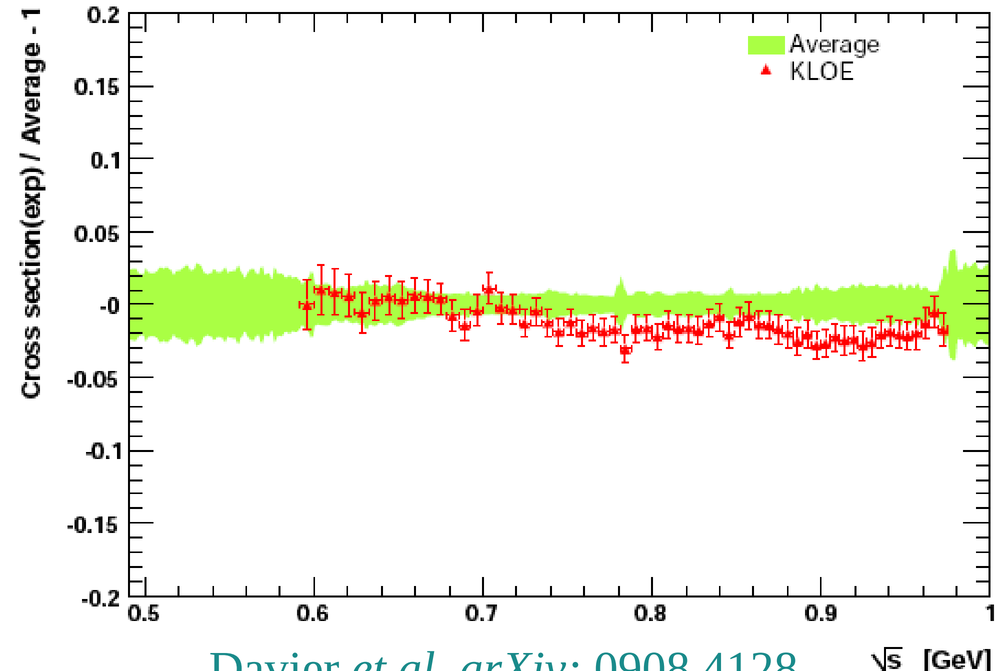
$\delta\sigma_{HAD} \sim 0.4\%$ $\sqrt{s}<1$GeV (instead of 0.7% as now)

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

But we need better data on $\sigma(e^+e^- \to \text{hadr.})$ both below and above 1 GeV

The improvement in the 1-2 GeV region clearly requires an energy upgrade [useful also for α_{em}]

But an energy scan in the 600-900 MeV region is also the only way to get a *convincing* error ($\delta\sigma$<0.5%) in dominant low-energy region



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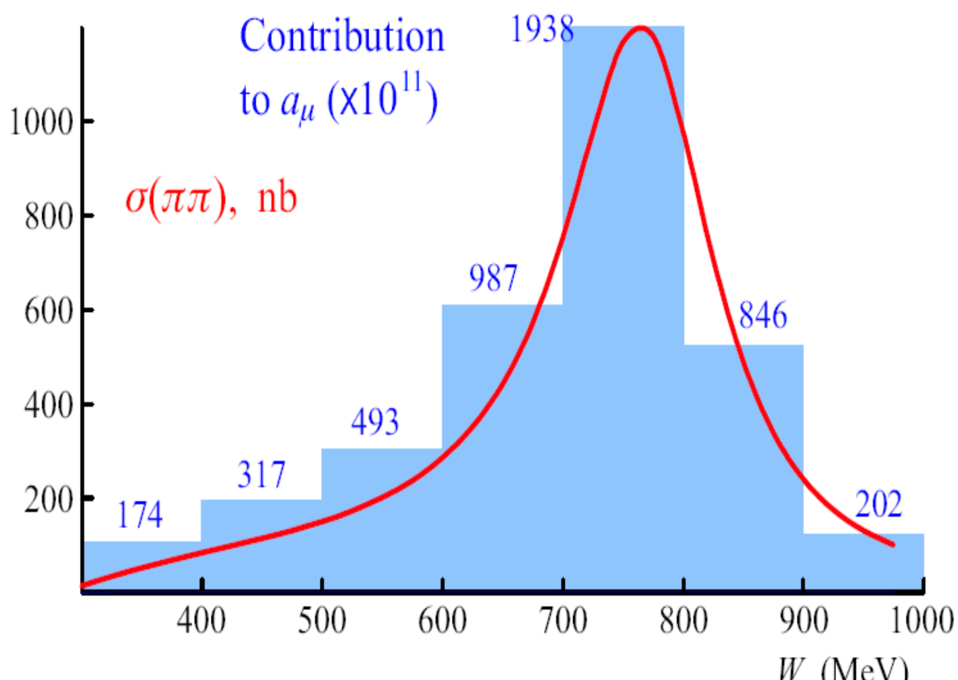
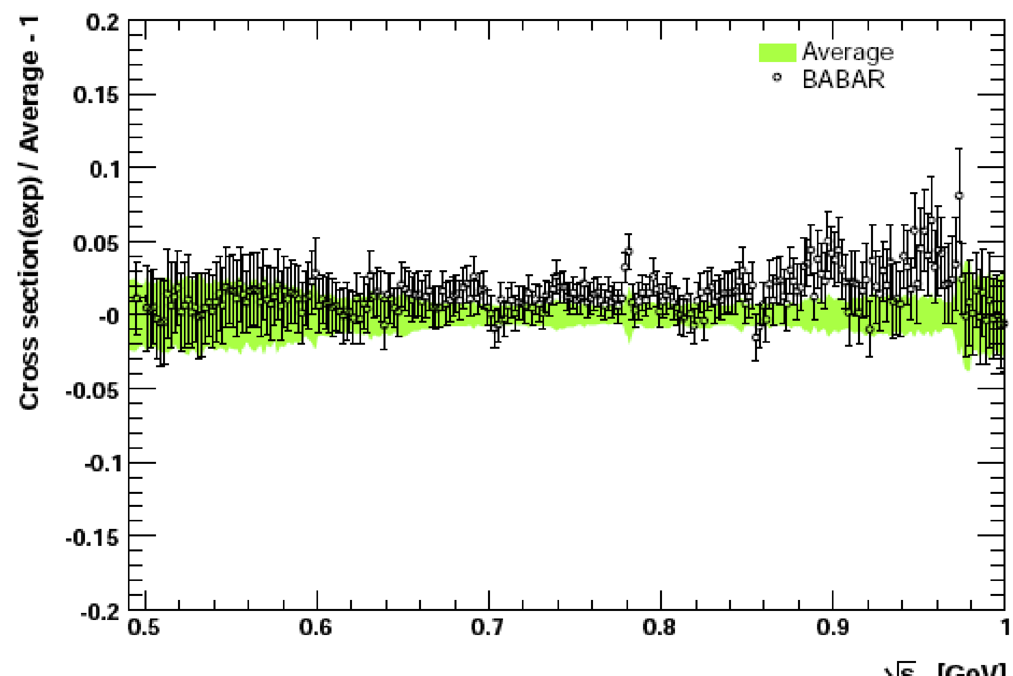


J. Franzini '03



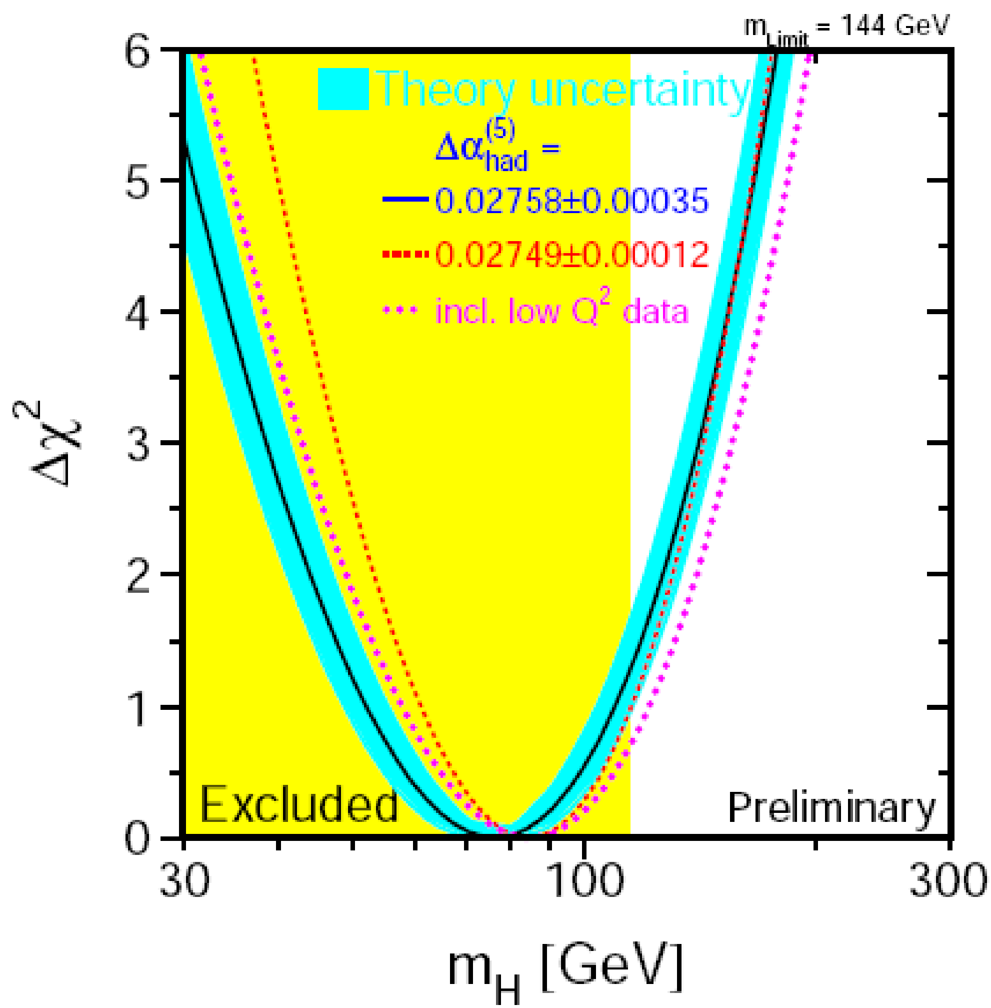
The hadronic contribution to α_{em}

While $\alpha_{em}(m_e)$ is known with an incredible precision [$\sim 3\times10^{-9}$!], the error on $\alpha_{em}(M_Z)$ -the effective coupling relevant at the electroweak scale- is much larger because of hadronic uncertainties:

$$\frac{\Delta\alpha_{em}(M_Z)}{\alpha_{em}(M_Z)} \sim (1\text{-}4)\times10^{-4}$$

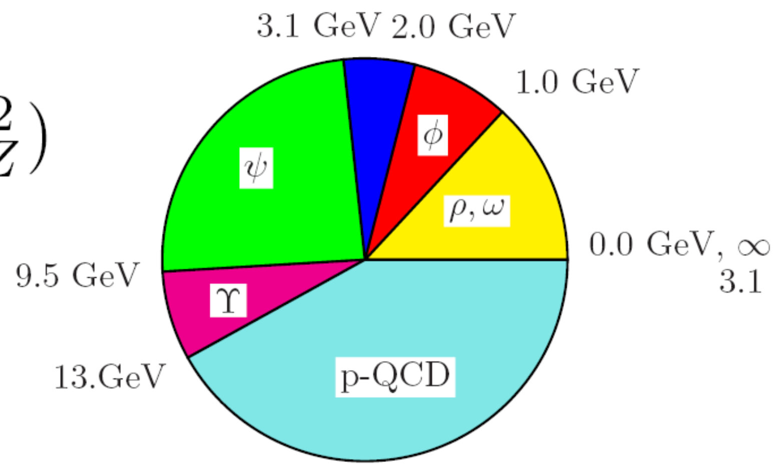
Significant source of uncertainty →
(*given the precision reached on other e.w. fundamental couplings*)

$$\frac{\delta G_\mu}{G_\mu} \sim 8.6\times10^{-6}$$
$$\frac{\delta M_Z}{M_Z} \sim 2.4\times10^{-5}$$

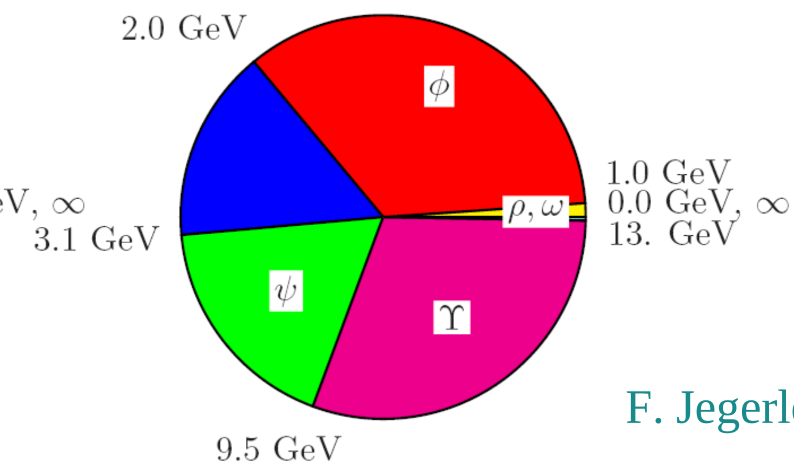


▶ *The hadronic contribution to* α_{em}

$$\Delta\alpha_{\rm had}(M_Z^2)$$

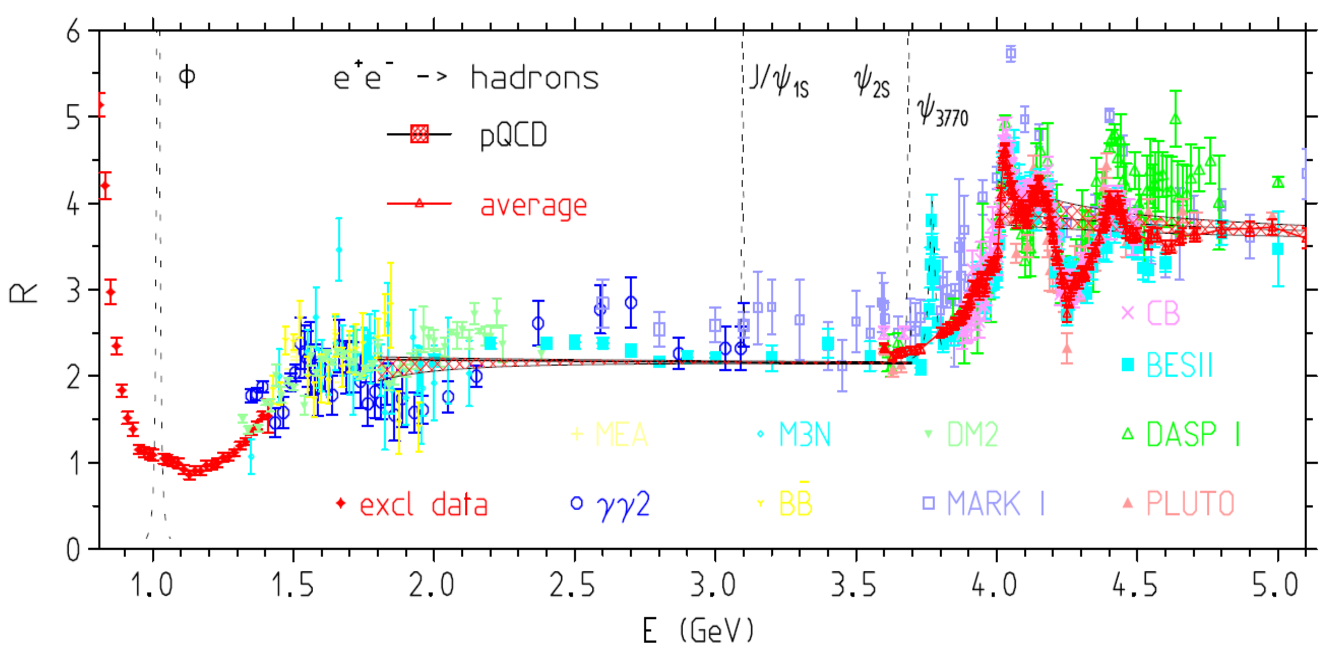


contribution



error

F. Jegerlenher '06

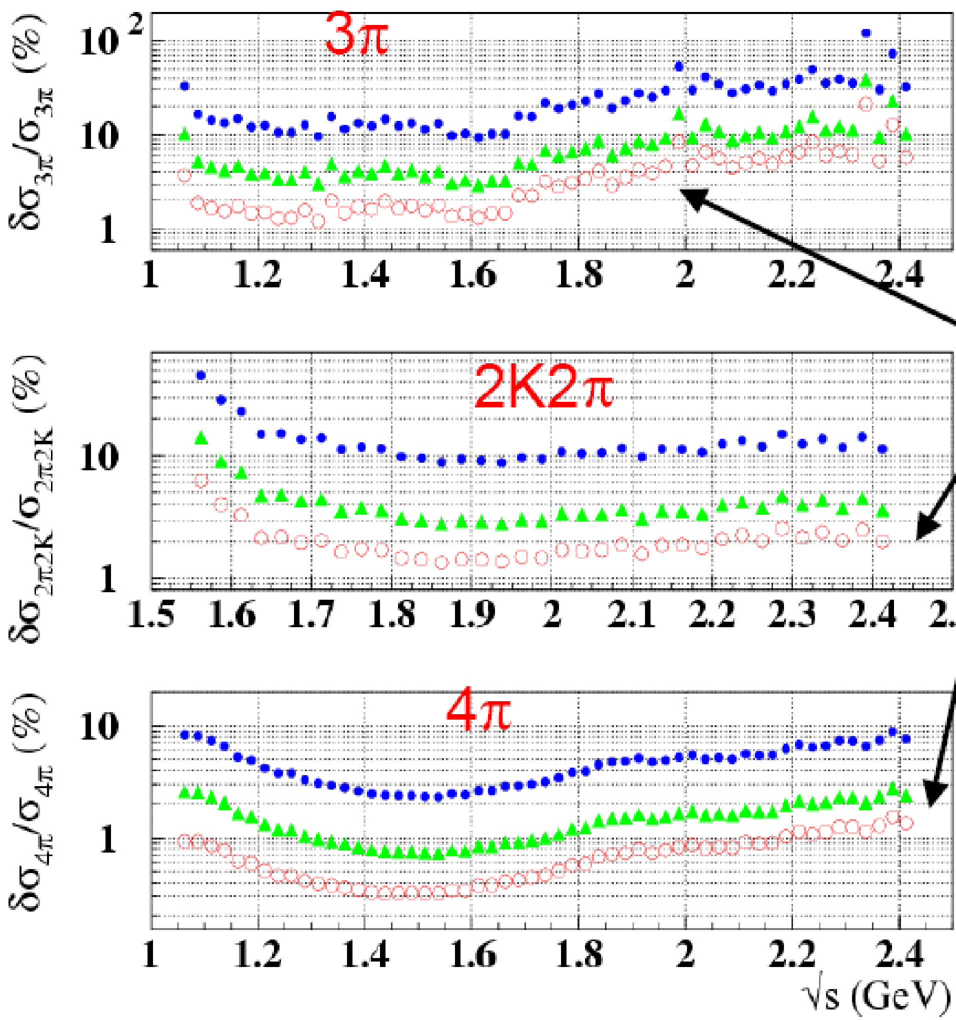


The high-energy range is not an issue: we can reduce the error using theory

The key problem is the <u>E < 2.5 GeV region</u>

▶ The hadronic contribution to α_{em}

Improving $\sigma(e^+e^- \to \text{hadr.})$ in the 1-2 GeV region is not an easy task (several channels), but an energy scan with KLOE (possibly with inner tracker) seems to be the best tool to achieve this important goal:

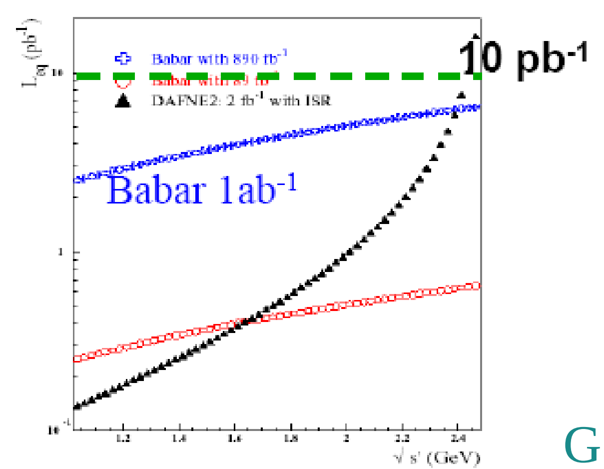


BaBar, with the published L_{int} per point (90 fb^{-1})

BaBar, with 10 × (the present L_{int})

DAFNE-2, with 20 pb^{-1} per point [20 MeV bins]

- DAFNE-2 is **statistically** better than O(1ab^{-1}) B-factories
- Improvement on systematics come as well



G. Venanzoni '06

Spectroscopy and $\gamma\gamma$ *physics*

There are still several interesting open issues in low-energy spectroscopy (4q states, glueballs, etc...) which would strongly benefit from high-precision measurements of $e^+e^- \to X$ and $e^+e^- \to X + e^+e^-$ at $\sqrt{s}$ above 1 GeV

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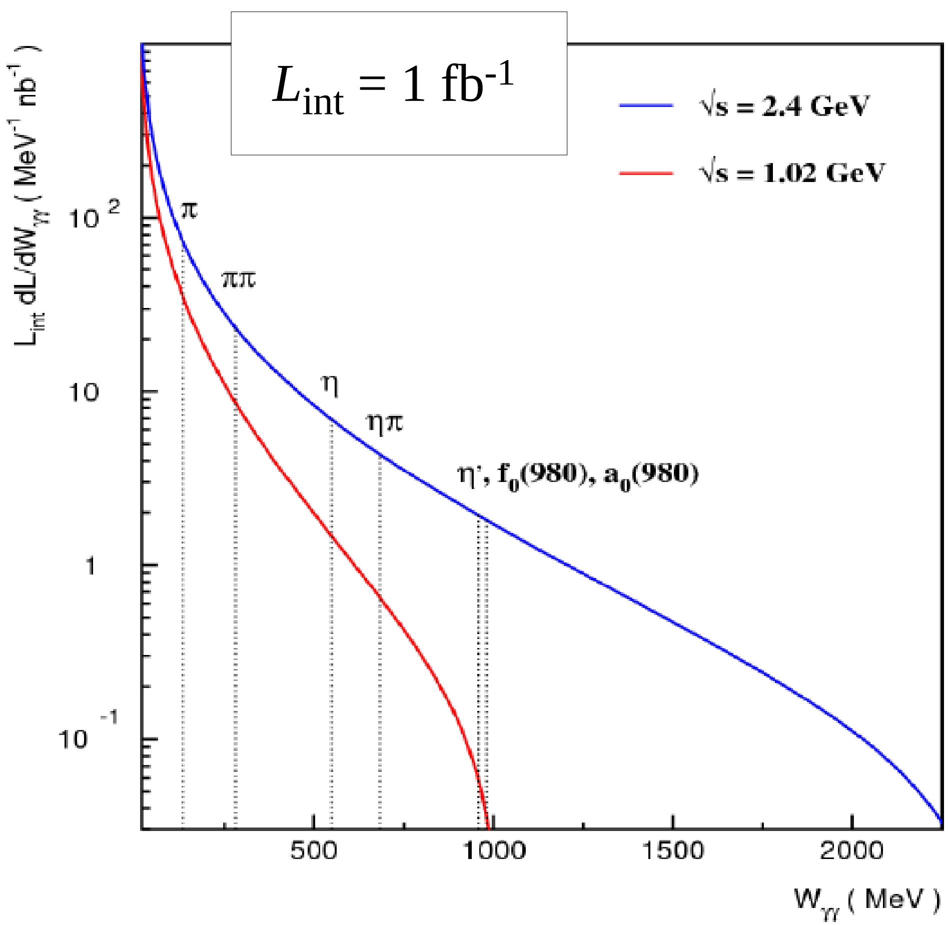
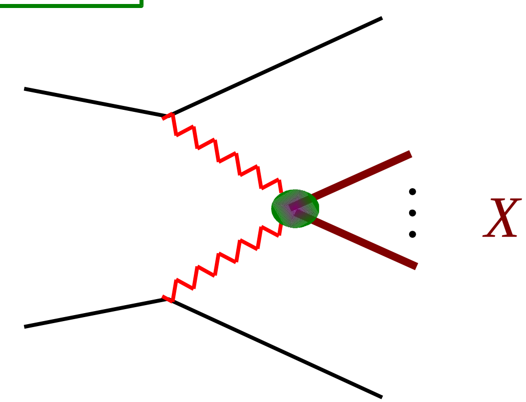


$$\frac{dN_X}{dW_{\gamma\gamma}} = L_{int}\,\frac{dL}{dW_{\gamma\gamma}}\,\sigma(\gamma\gamma \to X)$$

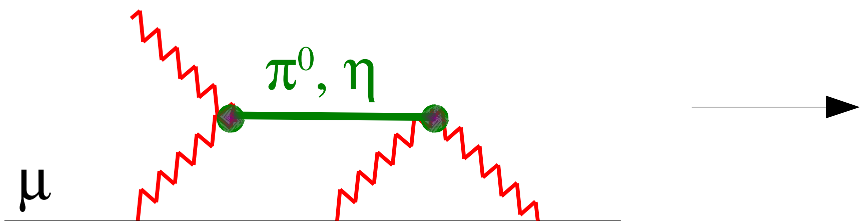


The high-energy requirement is particularly relevant for $\gamma\,\gamma$ physics

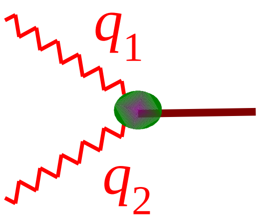
Spectroscopy and γ γ *physics*

One specific aspect worth to be recalled: the possibility to improve the error on the LBL contribution to $(g\text{-}2)_\mu$

Largely dominant LBL contrib.:



Uncertainty due to our ignorance about $\pi(\eta)\gamma^*\gamma^*$ form factors $F(q_1^2, q_2^2)$



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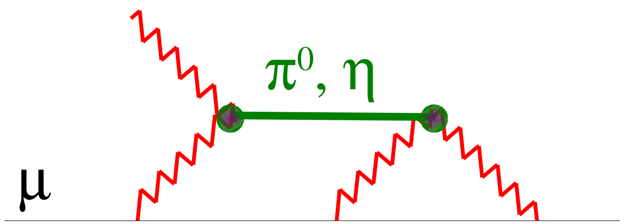
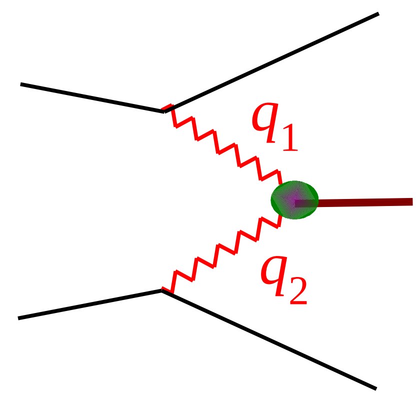


→ Uncertainty due to our ignorance about $\pi(\eta)\gamma^*\gamma^*$ form factors $F(\,q_1^2,\,q_2^2\,)$

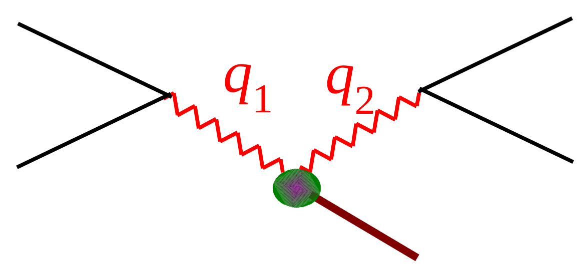


Not easy, but definitely worth to be further investigated

Some infos on these f.f. are obtained from
-radiative Dalitz decays [$dF(\,0,\,q^2\,)/dq^2$]
-leptonic decays [weighted integral of the f.f.]

What we really miss is $d^2 F(q_1^2,\,q_2^2\,)/dq_1^2\,dq_2^2$ which could possibly extracted from

$\gamma^*\gamma^* \to$ P at large angle and/or $\gamma^* \to$ P γ^*, both at large energy [Bijnens, Persson, '01]



Exotics

Recent astrophysical puzzles [Pamela, 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 !]

F. Bossi

Probably a lot can be done already at $\sqrt{s}$ =1 GeV; however, going to lower energies could possibly help [further investigation needed]

Conclusions

There is a rich physics program both below and above 1 GeV:

- The low-energy program (0.6–1.4 GeV) is really unique (no competition from other facilities), quite interesting, and apparently not too expensive ⇒ worth to consider it even in parallel to SuperB (shorter time scale, already part of the KLOE2-LOI), provided there is no competition for the site

- The high-energy option (1.4–2.5 GeV) is more expensive and would not make sense if the SuperB project will go on. However, it is certainly an interesting mide-term low-cost alternative for the Lab, if the SuperB project will not be approved (if we want to have it ready as a relatisitc "plan-B", it need to be further investigated now: the project is particularly interesting if it can be realised soon)

Conclusions

Final (partially-related) comment:

- If the SuperB will be approved, it would be wise to consider the possibility of a machine with “flexible c.o.m. energy” (*is it feasible without compromising peak luminosity, and with a “fast” energy-tune?*) able to run down to lower energies (e.g. from the Υ to the ψ):
  - On the physics side, this could allow to cover part of the program I just discussed (+ much more ...)
  - On a more stratigical point of view, this could allow to avoid a “duplicate” of the Japanese machine