KLOE-2 Experiment at DAΦNE

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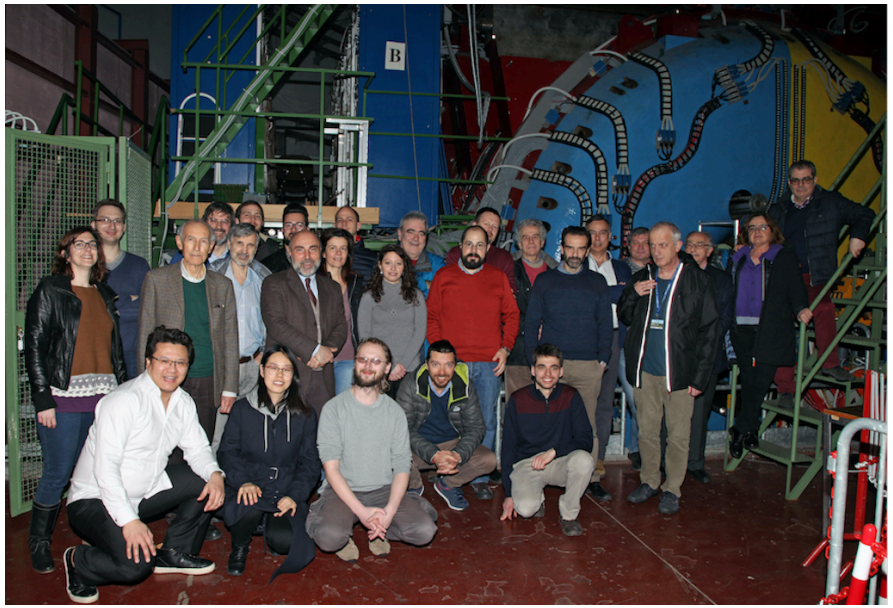
On behalf of KLOE-2 Collaboration

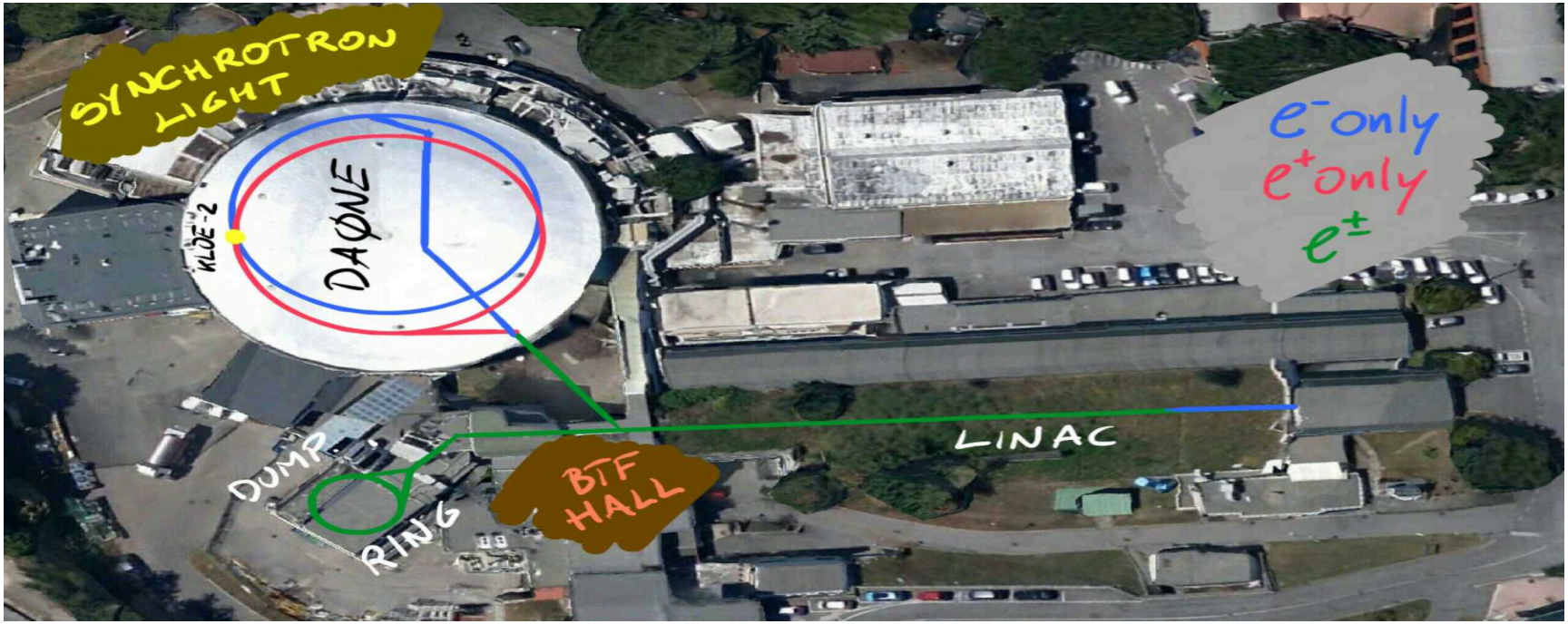


The 6th Young Researchers Workshop

Outline

- KLOE/KLOE-2 detectors@ DAFNE collider
- KLOE/KLOE-2 Physics
  - Ks semileptonic decays
  - Measurement of the running QED coupling constant $\alpha(s)$
- Summary

DAΦNE φ-factory



- Double rings e^+e^- collider @ $\sqrt{s}=M_\phi=1020$ MeV
- 105 bunches in each ring with a time interval of 2.7 ns
- Updated DAΦNE is working in Crab-Waist interaction scheme with the beam crossing angle 2×12.5 mrad

The KLOE detector

Drift Chamber:

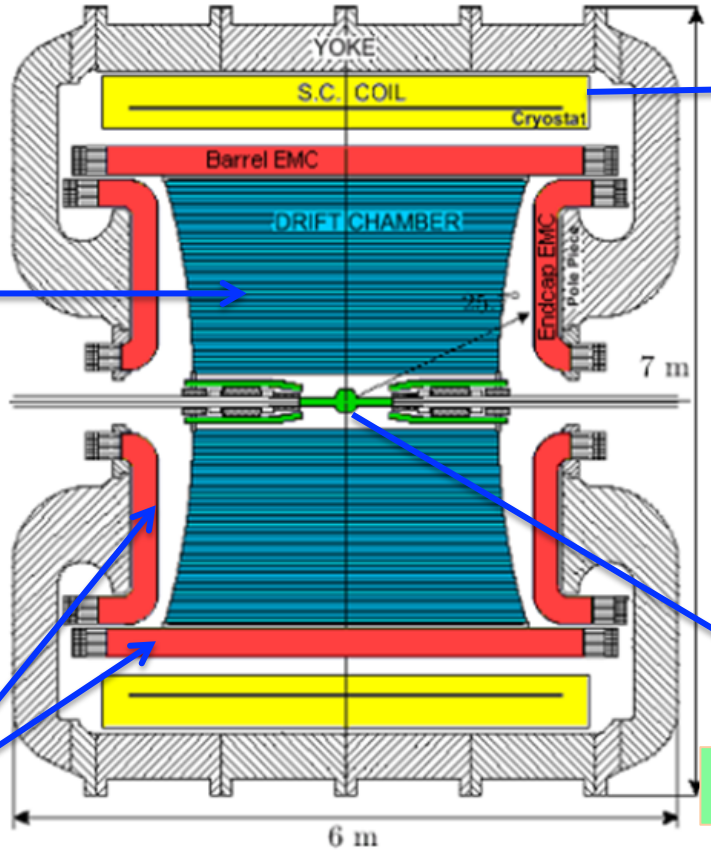
- **12582 sense cells**
- **4 m diameter, 3.3 m long**
- **Gas mixture: 90% Helium-10% isobutane**
- **$\delta p_T/p_T < 0.4\%$ ($\theta > 45^0$)**
- **$\sigma_{xy} \approx 150$ mm, $\sigma_z \approx 2$ mm**

Calorimeter:

98% coverage of 4π

$\sigma_E/E = 5.7\%/\sqrt{E(\text{GeV})}$

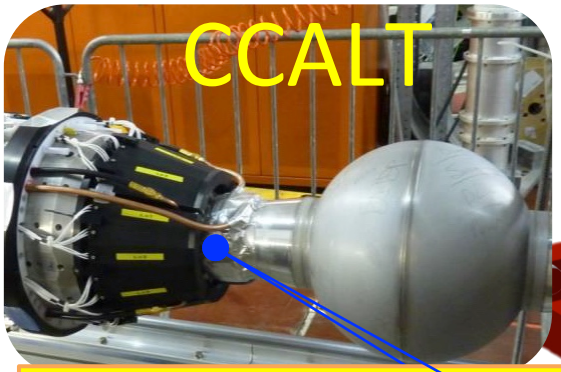
$\sigma_t = 55$ ps$/\sqrt{E(\text{GeV})} \oplus 140$ ps



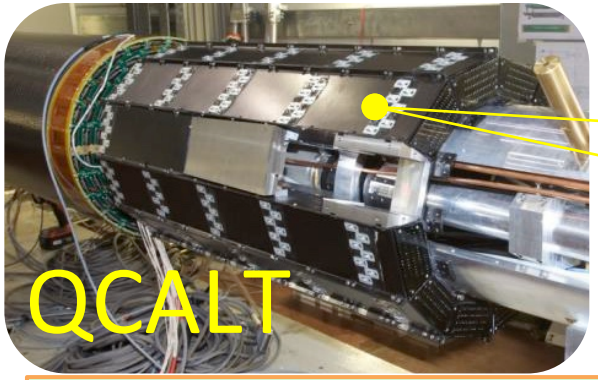
SC Magnet: B = 0.52 T

Interaction point (IP)

KLOE-2

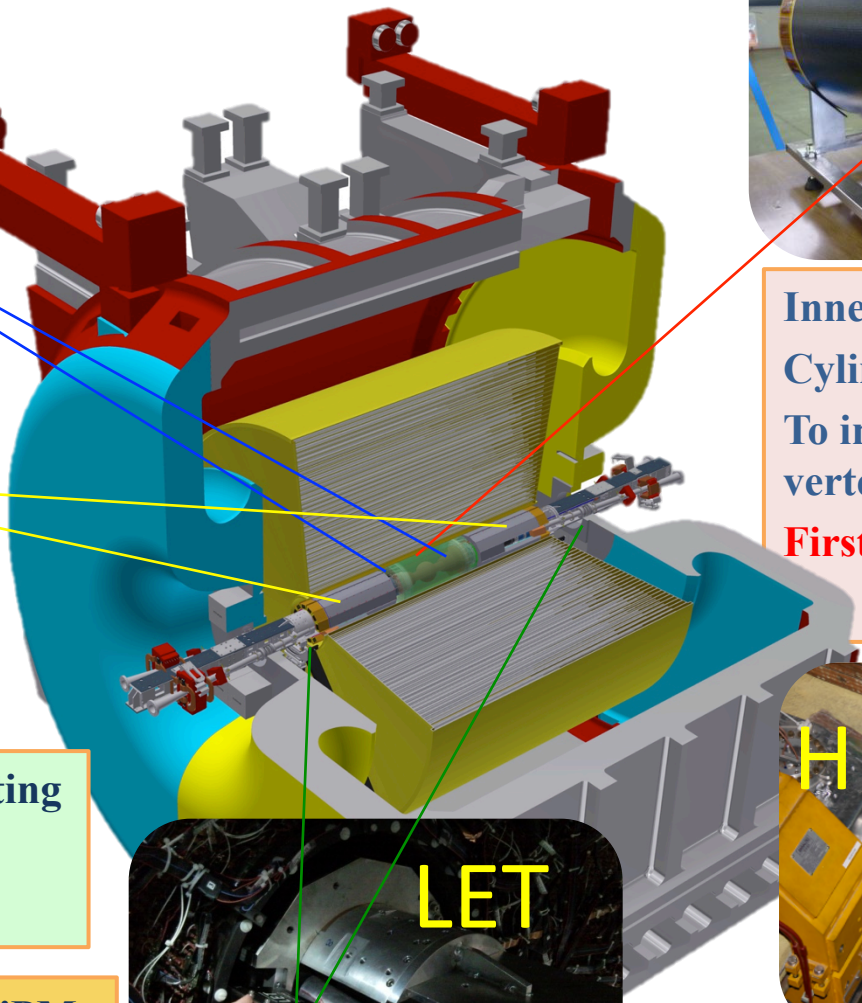


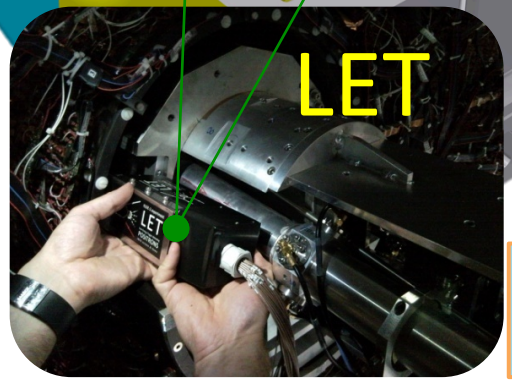
CCALT – LYSO Crystal
w SiPM - Low polar angle γ

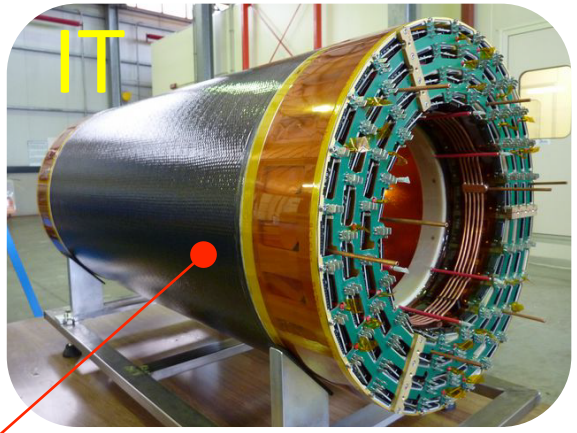


QCALT – Tungsten / Scintillating
Tiles w SiPM - K_L decays
Quadrupole Instrumentation

LET: 2 calorimeters LYSO + SiPMs
@ ~ 1 m from IP
e^+e^- taggers for γγ physics (HET)





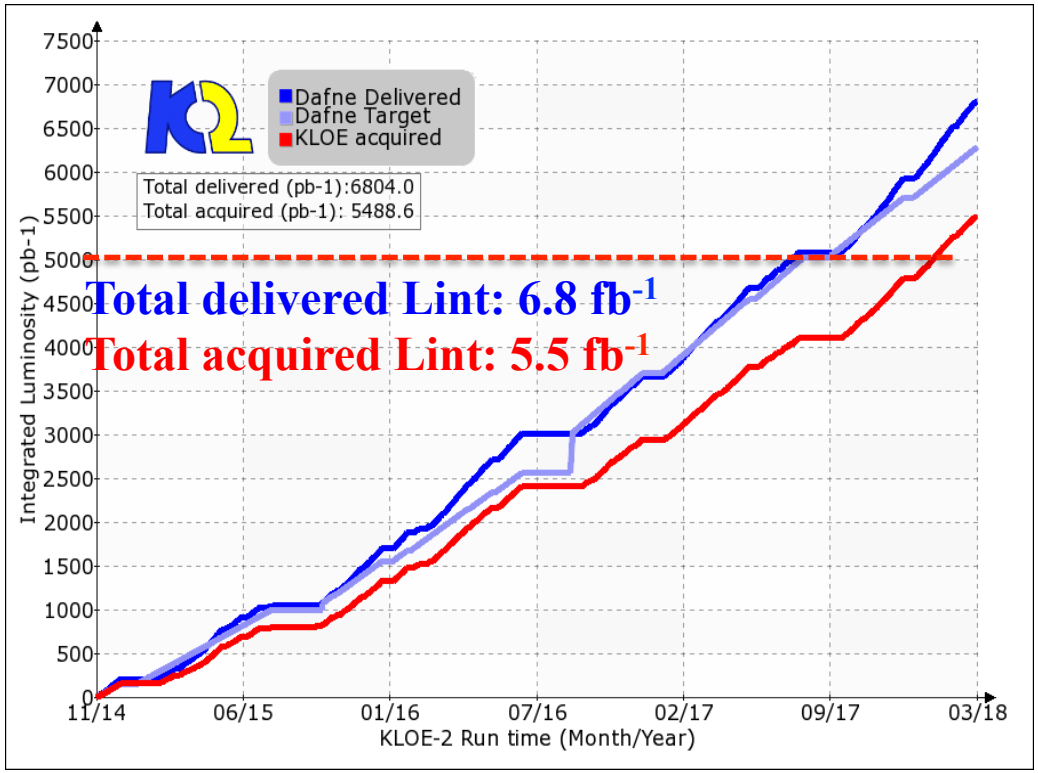


Inner Tracker – 4 layers of
Cylindrical GEM detectors
To improve the track and
vertex reconstruction
First time CGEM in high
energy experiment

HET: Scintillator hodoscope +PMTs
pitch:5 mm; placed at 11 m from IP

KLOE-2 Run

- KLOE-2 data-taking campaign started on Nov. 2014, and finished in the end of Mar. 2018
- Collected Luminosity ≈ 5.5 fb^{-1}
- Best performance:
  - Peak L ~ $2.38 \times 10^{32} cm^{-2} s^{-1}$
  - Lint delivered ~ 14.3 pb^{-1}/day
  - Lint collected ~ 11.9 pb^{-1}/day



KLOE+KLOE-2 Lint=8 fb^{-1} → **2.4×10^{10} ϕ decays** → **Unique data sample for typology and statistical relevance**

Physics @ KLOE-2

Workshop on e^+e^- physics @ 1GeV https://agenda.infn.it/conferenceDisplay.py?confId=11722

Eur. Phys. J. C 68 (2010) 619

A wide physics program

- Kaon Physics:
  8.2×10^9 K_S and K_L events
- $\gamma\gamma$ physics $e^+e^-\rightarrow e^+e^-\gamma^*\gamma^*\rightarrow e^+e^-X$
- Light meson spectroscopy
  3.1×10^8 η events
  1.48×10^8 η' events
  4.0×10^6 ω events
- Hadron physics below 1 GeV
- Dark sector searches

• Discrete symmetries test • CKM test • High precision tests of CPT and QM • Rare kaon decays
• $X=\pi\pi \Rightarrow$ study of $f_0(500)$ • $X=\pi^0/\eta \Rightarrow \Gamma(\pi^0\rightarrow\gamma\gamma)$, space-like TFF
• Properties of scalar/vector mesons • η/η' physics • Rare η decays
• ISR studies with 3π, 4π final states • Measurement of α_μ^{HLO} in the space-like region

Refer to E. Perez del Rio's talk

Ks semileptonic charge asymmetries

The charge asymmetries of K_S and K_L:

$$A_{S,L} = \frac{\Gamma(K_{S,L} \to \pi^- e^+ \nu) - \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})}{\Gamma(K_{S,L} \to \pi^- e^+ \nu) + \Gamma(K_{S,L} \to \pi^+ e^- \bar{\nu})} = 2[\mathrm{Re}(\varepsilon_K) \pm \mathrm{Re}(\delta_K) - \mathrm{Re}(y) \pm \mathrm{Re}(x_-)]$$

T **CPT violation in K^0-K^0bar mixing**

CPT violation in ΔS=ΔQ **ΔS≠ΔQ amplitudes**

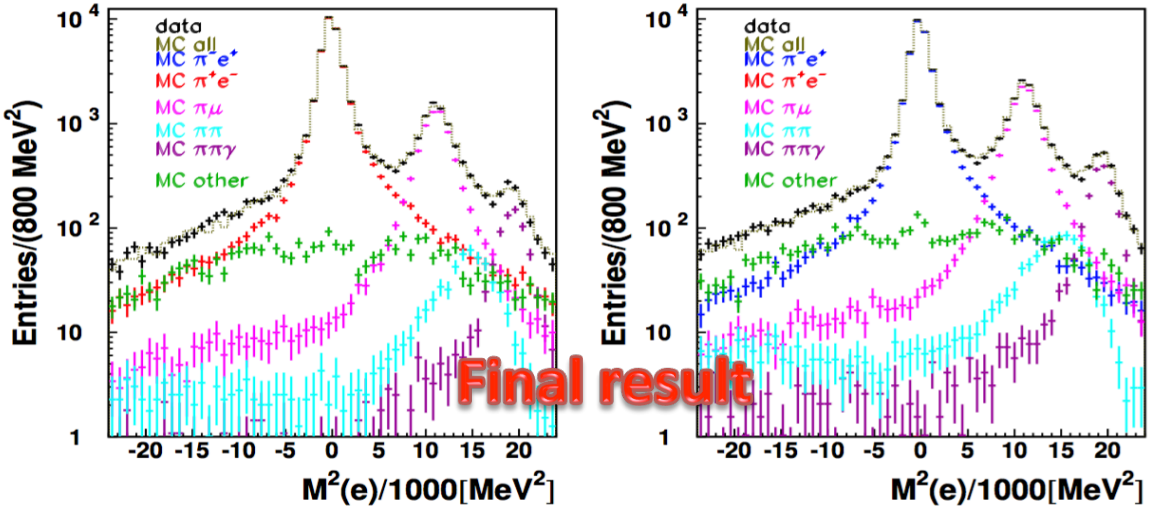
- $A_{S,L} \neq 0$ implies CP violation
- Assuming CPT invariance: $A_S = A_L = 2\mathrm{Re}(\varepsilon)$ expected to be around 3×10^{-3}, accounting for the CP impurity in the mixing in the physical state
- Any difference between A_S and A_L is of particular importance as a test of the CPT symmetry
- **$A_L = (3.322 \pm 0.058 \pm 0.047) \times 10^{-3}$ KTeV PRL 88 (2002) 181601**
- **$A_S = (1.5 \pm 9.6 \pm 2.9) \times 10^{-3}$ KLOE PLB 636 (2006) 173 (Lint = 410 pb^{-1})**

Ks semileptonic charge asymmetries

Paper in preparation

- The new KLOE A_S analysis has been finalized with 1.7 fb^{-1} data sample
- Combined with the previous KLOE analysis

$$A_S = (-3.7 \pm 5.0_{stat} \pm 2.6_{syst}) \times 10^{-3}.$$ **Final result**



$K_S \rightarrow \pi^+ e^- \nu bar$ $K_S \rightarrow \pi^- e^+ \nu$

Using the A_L, $Re(\delta_K)$ and $Re(\varepsilon_K)$ from other experiments as input, the CPT-violating parameter are extracted as:

$$Re(x_-) = (-2.0 \pm 1.4) \times 10^{-3},$$
$$Re(y) = (1.7 \pm 1.4) \times 10^{-3}.$$

Final result

With 5 fb^{-1} data at KLOE-2 accuracy is expected to be improve significantly

Measurement of the $\alpha(s)^{QED}$ below 1 GeV

PLB 767 (2017) 485

- α_{QED} is a running parameter due to vacuum polarization effect
- The vacuum polarization function can be absorbed by redefining the fine-structure constant as:

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

$$\Delta\alpha(s) = -4\pi\alpha(0)[\Pi(s) - \Pi(0)] = \Delta\alpha_{lep}(s) + \Delta\alpha^{(5)}_{had}(s) + \Delta\alpha_{top}(s)$$

vacuum polarization function

e, μ, τ contributions

hadronic contributions (from u, d, s, c, b quarks)

contribution of top quark (negligible at low energies)

Measurement of the $\alpha(s)^{QED}$ below 1 GeV

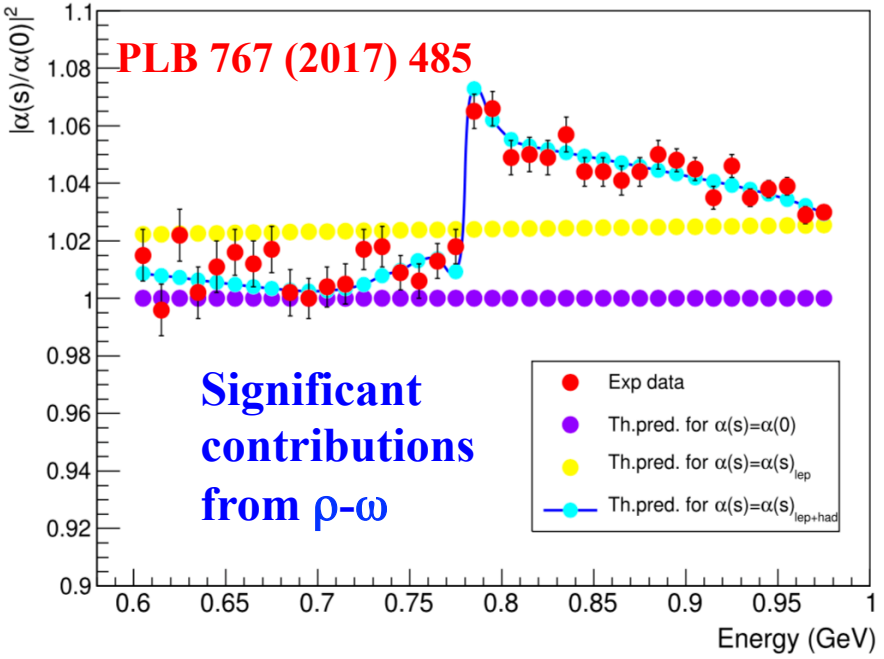
PLB 767 (2017) 485

- ISR process $e^+e^- \rightarrow \mu^+\mu^-\gamma$ with Lint = 1.7 fb^{-1}
- $\alpha(s)$ is extracted from the ratio of the differential cross section to the corresponding ones obtained from MC simulation with $\alpha(s) = \alpha(0)$ (constant)

$$\left|\frac{\alpha(s)}{\alpha(0)}\right|^2 = \frac{d\sigma_{data}(e^+e^- \rightarrow \mu^+\mu^-\gamma(\gamma))|_{ISR}/d\sqrt{s}}{d\sigma^0_{MC}(e^+e^- \rightarrow \mu^+\mu^-\gamma(\gamma))|_{ISR}/d\sqrt{s}}$$

- Different theoretical predictions are obtained from dispersion relations

  F. Jegerlehner, Nuovo Cimento C 034S1 (2011) 31
  - Constant coupling
  - Only contributions from lepton pairs
  - Full QED prediction with both lepton and quark pairs contributions



Re Δα and Im Δα

- Re Δα(s) and Im Δα(s) are determined for the first time

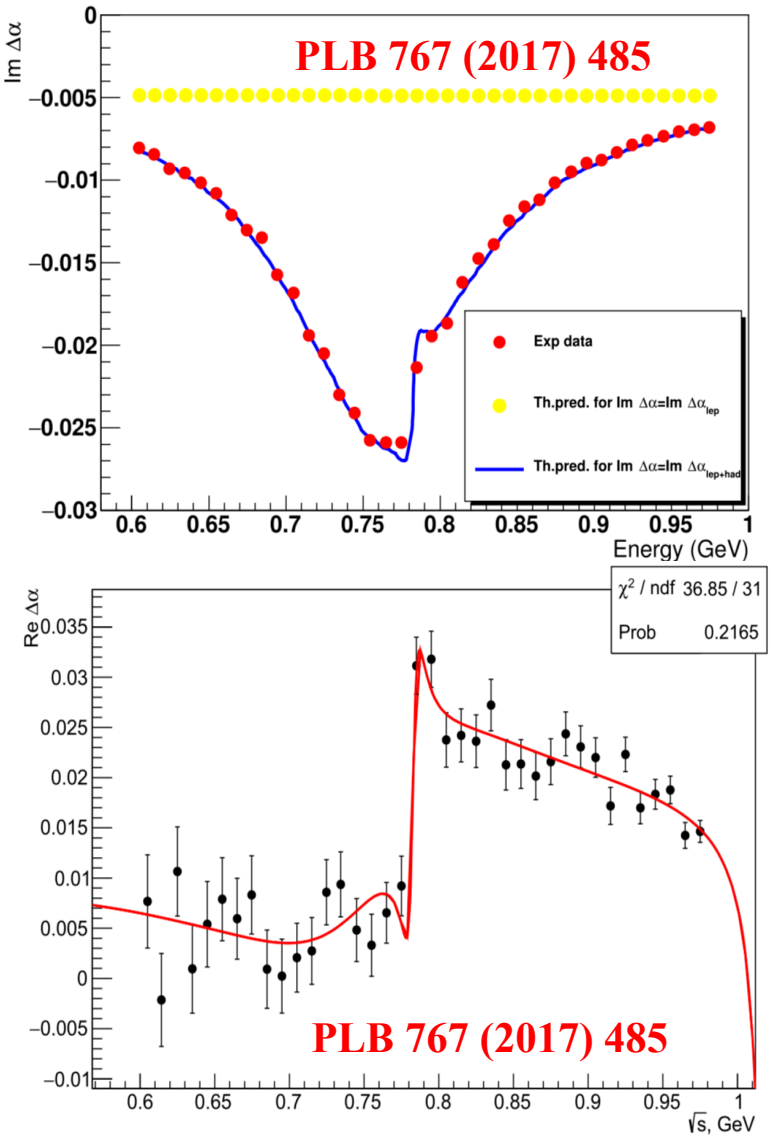
$$\mathrm{Im}\,\Delta\alpha = -\frac{\alpha}{3\pi}\frac{\sigma_{tot}(e^+e^- \to \gamma^* \to anything)}{4\pi\,|\alpha(s)|^2/3s}$$

$$\mathrm{Re}\,\Delta\alpha = 1 - \sqrt{|\alpha(s)/\alpha(0)|^2 - (\mathrm{Im}\,\Delta\alpha)^2}$$

- Fit to Re Δα(s): ρ(770) + ω(782) + ϕ(1020) + non resonant term

$$BR(\omega \to \mu^+\mu^-) = (6.6 \pm 1.4 \pm 1.7) \times 10^{-5}$$

PDG: (9.0 ± 3.1) × 10^{-5}



Perspectives and conclusions

- KLOE/KLOE-2 all together have completed their missions successfully and collected about 8 fb^{-1} data at ϕ peak

- KLOE is continuing to exploit the high statistics data samples to perform precision measurements

- Important to extend with KLOE-2 higher statistics
  - High precision
  - $\gamma\gamma$ analysis
  - Search for rare decays (improve the upper limits)
  - To improve C, P, T, CP, CPT tests
  - …

Thanks for your attention!!!