

Danilo Domenici On behalf of the KLOE-2 Collaboration

STATUS OF KLOE-2

48th LNF Scientific Committee



• Status of physics analysis

- Tests of fundamental symmetries
- Precision Kaon and hadron measurements
- Search for dark U bosons

Status of detector

- Taggers (LET, HET)
- Calorimetries (EMC, QCALT, CCALT)
- Trackers (DC, IT)

Data-taking results and plan

Completed and Ongoing analysis

CPT test with $\varphi \to K_{\scriptscriptstyle S} K_{\scriptscriptstyle L} \to \pi^+ \pi^- \pi^+ \pi^-$	PLB 730 (2013) 89-94
Absolute BR of $K^+ \rightarrow \pi^+ \pi^- \pi^+ (\gamma)$	PLB 738 (2014) 128-133
BR and Transition Form Factor for $\phi \rightarrow \eta e^+e^- (\eta \rightarrow \pi^0 \pi^0 \pi^0)$	Submitted to PLB (arXiv:1409.4582)
U boson search in $e^+e^-\!\rightarrow U\gamma$, $U\rightarrow\mu^+\mu^-$	PLB 736 (2014) 459-464
U boson search in $e^+e^-\!\rightarrow U\gamma$, $U\rightarrow e^+e^-$	Preliminary presented at ICHEP14
U boson search in $e^+e^- \rightarrow Uh'$, $U \rightarrow \mu^+\mu^-$, $h' \rightarrow in\nu$.)	Draft paper
Dalitz plot analysis of $\eta \to \pi^+\pi^-\pi^0$	Check of systematics almost completed
T violation in $\varphi \to K_{\scriptscriptstyle S} K_{\scriptscriptstyle L} \to 3 \pi^0 \pi l \nu$	In progress
BR and charge asymmetry in $K_s \rightarrow \pi e \nu$	In progress
Measurement of K ⁺ mass	In progress

Interferometry studies

CPT and Lorentz invariance PLB 730 (2014) 89 Best sensitivity ever reached in the quark sector of the SM Extension

$$\begin{split} &\Delta a_{_0} = (-6.0 \pm 7.7_{_{stat}} \pm 3.1_{_{sys}}) \ 10^{-18} \ \text{GeV} \\ &\Delta a_{_X} = (\ 0.9 \pm 1.5_{_{stat}} \pm 0.6_{_{sys}}) \ 10^{-18} \ \text{GeV} \\ &\Delta a_{_Y} = (-2.0 \pm 1.5_{_{stat}} \pm 0.5_{_{sys}}) \ 10^{-18} \ \text{GeV} \\ &\Delta a_{_Z} = (\ 3.1 \pm 1.7_{_{stat}} \pm 0.6_{_{sys}}) \ 10^{-18} \ \text{GeV} \end{split}$$

The same analysis strategy can be used to improve the QM tests PLB 642 (2006) Example for the decoherence parameter ζ_{SL} with similar data set

 $I_{\pm}(\Delta \tau) \propto e^{-\Gamma |\Delta \tau|} \left[e^{\frac{\Delta \Gamma}{2} \Delta \tau} + e^{-\frac{\Delta \Gamma}{2} \Delta \tau} - 2(1 - \zeta_{SL}) \cos(\Delta m \Delta \tau) \right]$



Reduction of 30% on the error is expected

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Branching ratio of $K^+ \rightarrow \pi^+\pi^-\pi^+(\gamma)$

- Last KLOE measurement in Kaon sector: now all the six K[±] dominant BR and lifetime obtained with sub-percent precision
- Analysis strategy: the missing mass distribution from K⁺ (obtained from the tag side) and the two selected π is used for event counting



Average of the two results accounted for correlations

 $BR(K^+ \rightarrow \pi^+ \pi^- \pi^+ (\gamma)) = 0.05565 \pm 0.00031_{stat} \pm 0.00025_{syst}$

Δ BR/BR = 7.2 × 10⁻³ Factor of 5 better accuracy wrt best previous result

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Mass of K⁺ (with $\pi^+\pi^-\pi^+$)

 World average: 13 keV error with two measurements from kaonic atoms differing by 60keV (correspondig to 4.6σ)





Sample of $K^+ \rightarrow \pi^+\pi^-\pi^+$ is the best for mass resolution and low sensitivity to bias sources:

 $Q_{3\pi} = M_{K\pm} - 3 \times M_{\pi} = 75 \text{ MeV}$

 Expected mass accuracy with 4x10⁴ events is 5-7 keV

Transition FF in $\phi \rightarrow \eta e^+e^-$



Test of low energy QCD comparing Q² dependance predicted by pQCD models with data

Several recent theory works on $V \rightarrow P\gamma^*$ to explain deviation of NA60 data from VMD expectations:

- Terschlusen and Leupold, Phys. Lett. B 691 191 (2009)
- Ivashyn, Prob. Atom. Sci. Tech. 2012N1 179 (2012)
- Schneider Kubis Nieking, Phys. Rev. D86 054013 (2012)

e⁺e⁻ mass after selections (data/MC)





U boson searches

 10^{-4}

 10^{-5}

 10^{-6}

 10^{-7}

1

3

KLOE ($\phi \rightarrow \eta e^+ e^-$

 $(g-2)_{\mu} 5\sigma$

 $(g-2)_{\mu} \pm 2\sigma$

favored

No evidence of dark force mediator in

- $φ → ηe^+e^-$ [PLB 720 (2013)]
- e⁺e⁻ → μ⁺μ⁻γ [PLB 736 (2014)]
- $e^+e^- \rightarrow e^+e^-\gamma$ [PRELIMINARY]

Exclusion plot at 90% C.L. in the coupling-mass plane





Combined result from on peak and off peak data

exclusion plots at 90% C.L. in the coupling-masses plane

Translates to a limit on $\alpha_D \epsilon^2$ from 10⁻⁹ to 10⁻⁸



300

400

500 m_h (MeV)

200

10

10

100

HAD

$\eta \rightarrow \pi^+\pi^-\pi^0$ Dalitz plot analysis

Isospin violating decay, sensitive to light quark mass difference From KLOE published result (450 pb⁻¹, 1.34×10⁶ events):

 $m_u = (2.02 \pm 0.14) MeV \ m_d = (4.91 \pm 0.11) MeV$

[Colangelo et al. PoS(EPS-HEP2011) 304]

 $m_u = (2.23 \pm 0.14) MeV$ $m_d = (4.63 \pm 0.14) MeV$ [Kampf et al., PRD84(2011)114015]

New analysis on an independent and larger (1.7 fb⁻¹) KLOE data set in progress, with new analysis scheme and improved MC simulation



DRELIMINARY					
PNLL	-a	b	d	f	g
KLOE08	1.090(5)(⁺⁸ - ₁₉)	0.124(6)(10)	0.057(6)(⁺⁷ - ₁₆)	0.14(1)(2)	-
KLOE new	1.095(3)	0.145(3)	0.081(3)	0.140(7)	-0.044(9)

Study of systematics is completed (still to be blessed by collaboration) Systematics on fit parameters at least a factor 2 best than 2008 measurement

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 $K_{c} \rightarrow \pi e v$

• Measurement of $BR(K_s \rightarrow \pi e \nu)$ and

$$AS = \frac{\Gamma(K_s \to \pi^- e^+ \nu) - \Gamma(K_s \to \pi^+ e^- \nu)}{\Gamma(K_s \to \pi^- e^+ \nu) + \Gamma(K_s \to \pi^+ e^- \nu)}$$

- $\sim 10^5 \text{ K}_s \rightarrow \pi \text{ev}$ decays reconstructed (1.7 fb⁻¹ sample)
- Cuts for selection based on fiducial volume, invariant mass and TOF



- $\Delta E(\pi, e) = E_{miss}(\pi, e) p_{miss}$ used as kinematic control variable
- Normalization MC to the data in progress 13.11.14 - LNE Scientific Committee

T symmetry test

- First approach to T symmetry test in the K system with a method successfully applied so far to B mesons
- Measurement of time dependent ratio of double decay amplitudes

$$R(\Delta t) \sim \frac{I(K_s \to \pi^{\pm} \ell^{\mp} \nu, K_L \to 3\pi^0; \Delta t)}{I(K_s \to \pi\pi, K_L \to \pi^{\mp} \ell^{\pm} \nu; \Delta t)}$$

• $R(\Delta t \gg \tau_S) \neq 1 \Rightarrow T \text{ violation}$



• Event selection strategy for the $K_s K_L \rightarrow 3\pi^0 \pi l \nu$ process in progress

Status of Drift Chamber





Bhabha scattering event in the DC event display: noise hits due to machine background

DC performance in agreement with previous KLOE run



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Status of EM Calorimeter





Online Bhabha and yy filtering had to be changed to accept events with high machine backgrounds (no events selected with 2005 filter)

Now we have enough statistics for calibration, but also a low energy tail, mostly on Endcaps. Work in progress

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Time-calibration with Bhabha and $e^+e^- \rightarrow \gamma\gamma$ events very close to 2005 Resolutions: 80/90 ps for Barrel/Endcaps

Energy-calibration with $e^+e^- \rightarrow \gamma\gamma$ events ~10% worse than 2005 Resolutions: 6/8 % @ 1 GeV for Barrel/Endcaps



Status of Low Energy Tagger

- LET calorimeters working since 2011
- Re-installed in the new IR in June 2013
- At present LETs are read-out with old KLOE electronics (EMC-TDC and DCH-ADC)
- New ADCs are in preparation to improve resolution and rate capability
- Reconstruction software, calibration with MIPs and slow control are ready
- MC simulation: IR geometry and detector response inserted in GEANFI





Positioning with comsics





Status of High Energy Tagger



- Noise level at few Hz after the threshold optimization
- TDC calibrated with beams: contiguous bunches are correctly identified (2.72 ns bunch crossing time fit)
- Collisions events needed to study correlations with KLOE EMC trigger







Status of QCALT



- First data reconstructed to check status of FE
- Occupancy plots show few dead channels, some SiPM with low HV and two FE boards (20 channels) to be fixed
- TDC under calibration



Status of CCALT

- All the 96 crystals have been tested with the LED embedded in the FE boards
- New Transition Boards installed
- DAQ boards 2 TDC (from EMC spares) and 2 ADC (from DC spares) installed
- 10 new custom general boards are being designed serving as ADC for CCALT and LET and TDC for EMC spares
- Timing with signals in progress





12+12 signals from the analog sum of4 crystals will be used as independentluminosity monitor for DAFNE



Status of Inner Tracker

- Monitoring Noisy/Dead channel
 Status & History
- Working point optimization: efficiency studies
- DC tracking with B=0: IT efficiency & Alignment/Calibration
- IT tracking with Kalman: IP position from Bhabha scattering events



Layer1 11000 8000 6000 4000 2000 0 15:03:27 15:05:27 15:07:27 15:09:27 15:11:27 15:13:27 15:16

Electron and positron injections as seen by the current monitor

Inner Tracker and Drift Chamber event display





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IT tracking with Kalman

IT and DC are two components of a unique tracking system intended to work together to achieve a vertex resolution of $c\tau_s/3 \approx 2 \text{ mm}$ for $K_s \rightarrow \pi^+\pi^-$ decay

Extrapolation from DC track parameters to IT is based on a Kalman filter



Presently testing the procedure with cosmic-rays and Bhabha events

DAFNE performance before Summer

$\begin{array}{l} \begin{array}{l} \begin{array}{l} 29 \text{ July - high lumi run} \\ \text{Current } e^{-} \max = 1500 \text{ mA} \\ \text{Current } e^{+} \max = 1000 \text{ mA} \\ \text{L}_{\text{peak}} = 1.69 \times 10^{32} \text{ cm}^{-2} \text{s}^{-1} \\ \text{L}_{\text{flh}} = 432 \text{ nb}^{-1} \xrightarrow{} \text{L}_{\text{fday}} > 10 \text{ pb}^{-1} \end{array}$



typical day in 2012

typical day in 2014



00:00-3

00:00-30

00:00-30

Time (hh:mm-day)

Time (hh:mm-day)

Time (hh:mm-dav)

DAFNE background vs currents

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DAFNE background vs luminosity

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KLOE-2 run on 2/7/14

EC rates kept <400 kHz

Still high T2 rate > 8 kHz

DC ON all the run (trips successfully recovered by Automatic RC) -

> Positron beam lost few times

1.5 x 10³² peak L

3.5 pb⁻¹ integrated in 20h (375 nb⁻¹/h)

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Plans for Data-taking

We just started regular 24h/7d data taking shifts

 Our goal is to integrate 1 fb⁻¹ of "physics-grade" data for June 2015 with at least 10 pb⁻¹/d x 4 consecutive days

 This result gives a reliable extrapolation to 5 fb⁻¹ within 2016



MC of new Interaction Region

Main differences in the new IR:

- 1. Increase of materials (new detectors)
 - 2. Increase of beam crossing angle



Definition of new materials in MC still to be calibrated with data

Running conditions in 2005

Usual Run1 Conditions: T2 rate ~ 4 kHz, Lumi ~ 10³², EndCap rates < 100 kHz



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Trigger Thresholds Studies

We tried to increase the Trigger thresholds of the EndCap Warm zone

Threshold	Lumi	T2 rate	Event size (EMC+DC)
Standard	7 x 10 ³¹	8 kHz	2 kB
warm +20%	7 x 10 ³¹	7 kHz (-12%)	2 kB
warm +30%	7 x 10 ³¹	6 kHz (-25%)	2 kB

- An appreciable decrease of T2 rate observed
- Hot zone to be done (here even higher improvement is expected)
- Impact on Physics to be carefully studied