Strangeness Nuclear Physics at DAΦNE: Status and Future Strategy

Catalina Curceanu

LNF – INFN, Frascati

What Next @ LNF-INFN, 10-11 Nov. 2014

The low-energy kaon-nucleon/nuclei interaction studies are fundamental for understanding the QCD in the Strangeness sector in the non-perturbative regime:

- **Explicit and spontaneous chiral symmetry breaking (mass of nucleons)**
- **Dense and cold baryonic matter ?**
- **Role of strangness in Neutron stars (EOS)**
- **Many other topics (Λ(1405), Kmass….)**

Role of Strangeness in the Universe from particle and nuclear physics to astrophysics

DAFNE

$e^- e^+$ collider

- **$\Phi \rightarrow K^- K^+$** (49.1%)
- **Monochromatic low-energy K^-** (~127MeV/c)
- **Less hadronic background due to the beam**

(compared to hadron beam line : e.g. KEK /JPARC)

<u>Ideal for low-energy kaon physics:</u>

Kaonic atoms

Kaon-nucleons/nuclei interaction studies

Hypernuclear physics

What was done at DAΦNE
Past experiments

Kaonic atoms

Hypernuclei

Low-energy Kaon-nuclei processes

DEAR
SIDDHARTA

FINUDA

FINUDA
AMADEUS – step 0

What Next @ DAΦNE

- Kaonic atoms
  - SIDDHARTA-2
    TES (Okada talk)
    Other?
  - Kaon mass
- Hypernuclei
  - AMADEUS?
- Low-energy Kaon-nuclei (deeply bound)
  - AMADEUS

Low-energy nuclear physics at DAΦNE

Status & Strategy

Curceanu
contributions from
A. Filippi & S. Piano

Feasibility (technical)

Zmeskal
Okada

Interest for - Strangeness physics (at low energy): a series of Workshops organized at ECT* - Trento (since 2006) – the last ones:

1) Strangeness in Nuclei, 4-8 October 2010

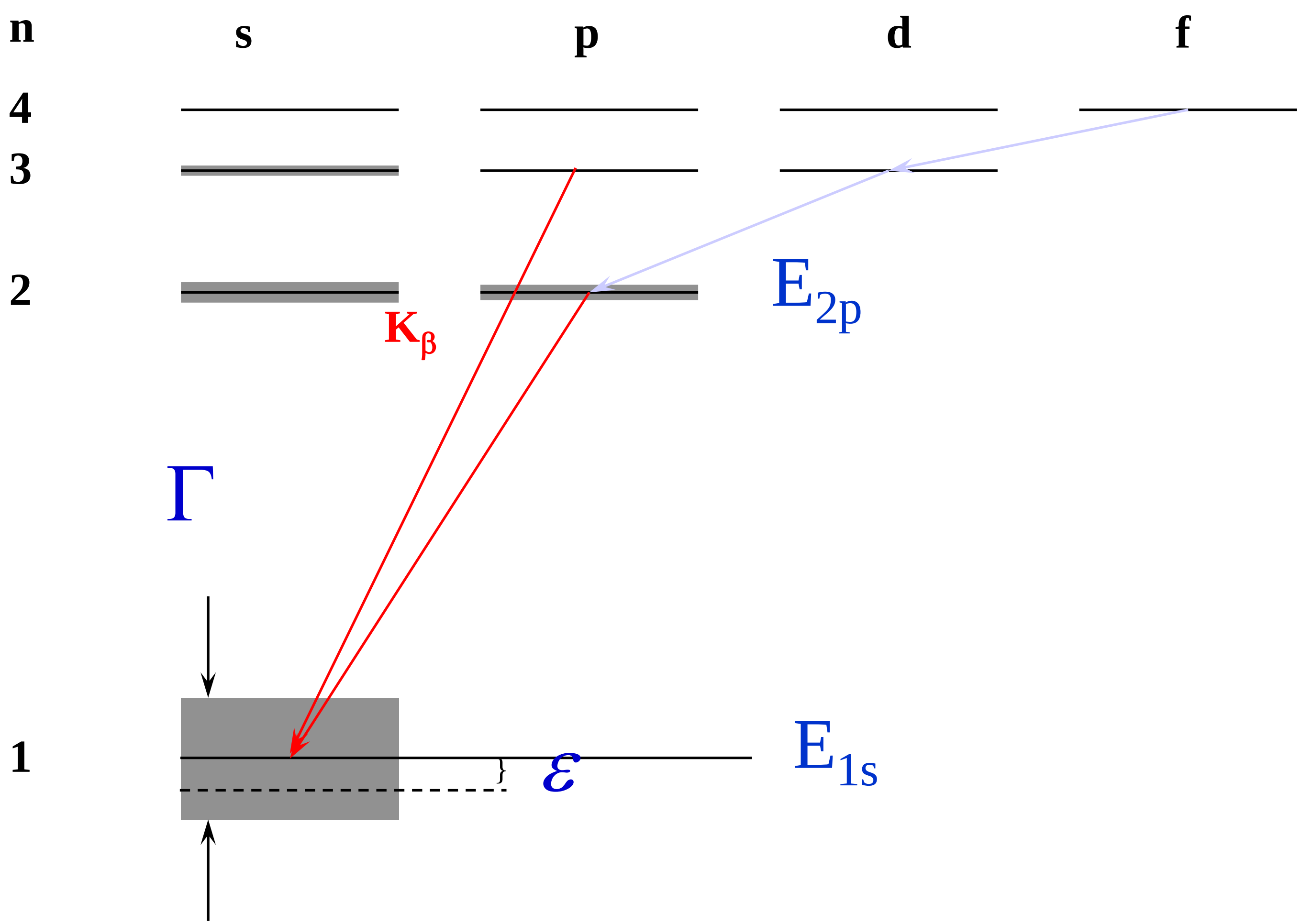
1) New trends in the low-energy QCD in the strangeness sector: experimental and theoretical aspects, 15-19 October 2012

3) Strangeness in the Universe?
Theoretical and experimental progress and challenges in the antikaon nuclear physics, ECT* 21-25 October 2013

Achievements and Perspectives in Low-Energy QCD with Strangeness
ECT*, Trento, 27-31 October 2014

Exotic Atoms Studies

Kaonic atoms cascade and the strong interaction



DEAR and SIDDHARTA

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

- **LNF- INFN, Frascati, Italy**
- **SMI- ÖAW, Vienna, Austria**
- **IFIN – HH, Bucharest, Romania**
- **Politecnico, Milano, Italy**
- **MPE, Garching, Germany**
- **PNSensors, Munich, Germany**
- **RIKEN, Japan**
- **Univ. Tokyo, Japan**
- **Victoria Univ., Canada**

SIDDHARTA - main results:

- Kaonic Hydrogen: 400pb^{-1}, most precise measurement ever, Phys. Lett. B 704 (2011) 113, Nucl. Phys. A881 (2012) 88; Ph D 78 citations

- Kaonic deuterium: 100 pb^{-1}, as an exploratory first measurement ever, Nucl. Phys. A907 (2013) 69; Ph D

- Kaonic helium 4 – first measurement ever in gaseous target; published in Phys. Lett. B 681 (2009) 310; NIM A628 (2011) 264 and Phys. Lett. B 697 (2011); PhD 51 citations

- Kaonic helium 3 – 10 pb^{-1}, first measurement in the world, published in Phys. Lett. B 697 (2011) 199; Ph D

- Widths and yields of KHe3 and KHe4 - Phys. Lett. B714 (2012) 40;; kaonic kapton yields

DEAR & SIDDHARTA – important TRAINING for young researchers - 8 Ph Ds

EXOTIC ATOMS

Kaonic hydrogen casts new light on strong dynamics

Hadronic bound systems with strange quarks, such as kaonic hydrogen, are well suited for testing chiral dynamics, especially in view of the interplay between spontaneous and explicit symmetry breaking. Effective field theories with coupled channels based on chiral meson–baryon Lagrangians have become well established as a framework for describing $\bar{K}$–nucleon interactions at threshold, including much disputed Λ(1405) resonances and deeply bound antikaonic nuclear clusters lying just below the respective thresholds.

A recent precision measurement at the Laboratori Nazionali di Frascati of the strong-interaction-induced shift and width of the 1s level in kaonic hydrogen sheds new light on these basic problems in strong-interaction binding and dynamics. Kaonic hydrogen, in which a K^- replaces the electron, is produced by the capture of

The SIDDHARTA collaboration with the apparatus. (Image credit: C Curceanu.)

stopped K^- from the decay of ϕ mesons in hydrogen gas. The ϕ mesons are generated nearly at rest at the DAΦNE e^+e^- collider, operating in a new, high-luminosity collision mode.

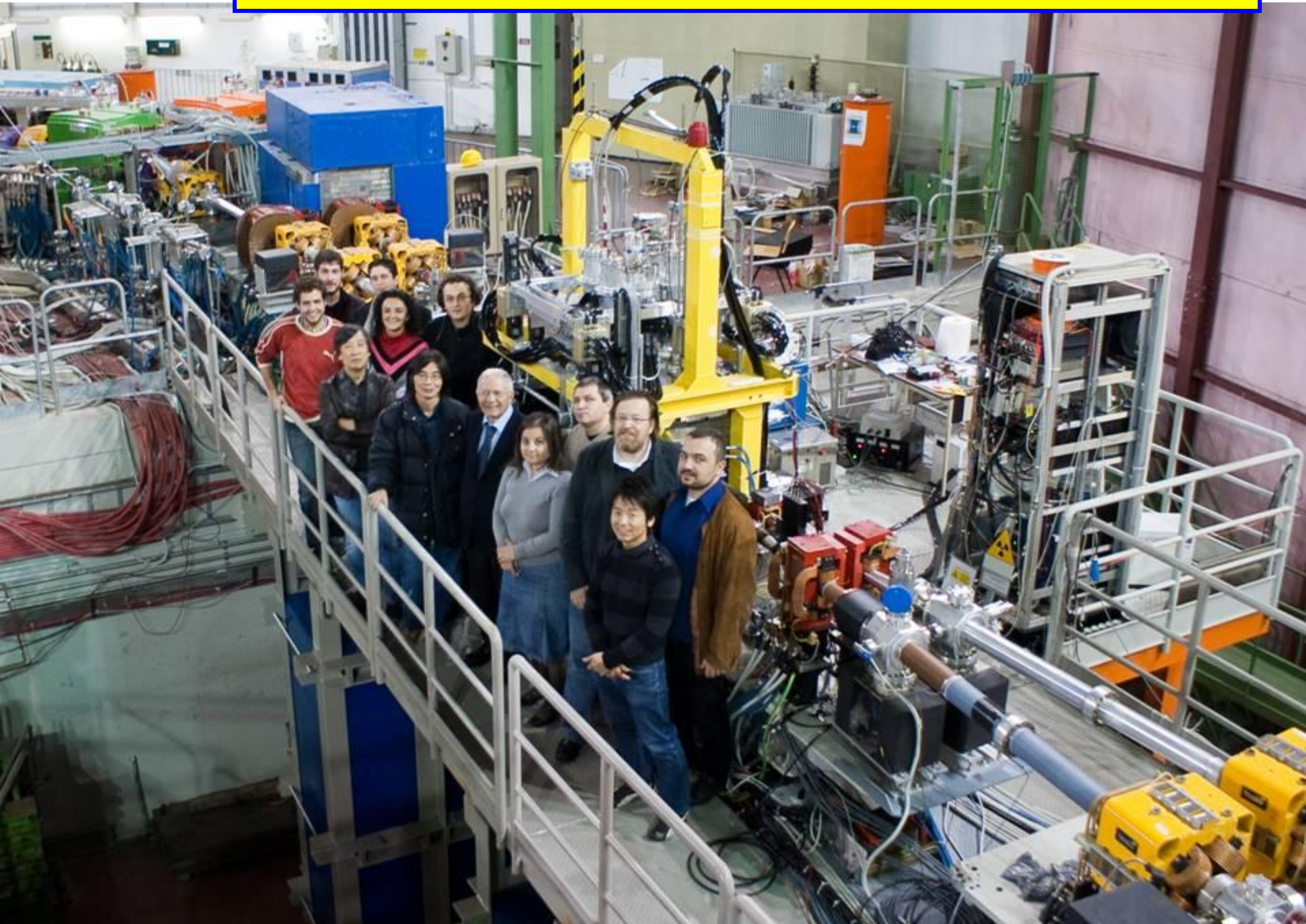
The shift and width of the kaonic 1s state is deduced from precision X-ray spectroscopy of the K-series transitions in the kaonic hydrogen. The emitted K-series X-rays, with energies of 6–9 keV, were detected by the recently developed Silicon Drift Detector for Hadronic Atom Research by Timing Application (SIDDHARTA) experiment, which performs X-ray–kaon coincidence spectroscopy using microsecond timing and the excellent energy resolution of about 180 eV FWHM at 6 keV of 144 large-area (1 cm^2) silicon drift detectors that surround the hydrogen target cell. This method reduces the large X-ray background from beam losses by orders of magnitude. It has led to the most precise values for the 1s level shift, $\varepsilon_{1s} = -283 \pm 36\,(\text{stat.}) \pm 6\,(\text{syst.})$ eV, and width $\Gamma_{1s} = 541 \pm 89\,(\text{stat.}) \pm 22\,(\text{syst.})$ eV for kaonic hydrogen (Bazzi *et al.* 2011).

A recent study using next-to-leading-order chiral dynamics calculations of the shift and the width has shown excellent agreement with these measurements (Ikeda *et al.* 2011). Further measurements with similar accuracy are planned for the K-series X-rays from kaonic deuterium, using an improved SIDDHARTA-2 set-up to disentangle the isoscalar and isovector scattering lengths.

• Further reading

M Bazzi *et al.* *Phys. Lett.* **B704** (2011) 113.
Y Ikeda, T Hyodo and W Weise 2011 arXiv:1109.3005[nucl-th].

November 2009 – end of SIDDHARTA



HYP2012

Concluding Remarks

Tomofumi NAGAE,

Kyoto University

HIGHLIGHTS

HYP2012

Exotic Atoms:
Future Perspectives

Bonus) Kaonic hydrogen at precision better than 10 eV (calib. For Kd) -<u>100 pb^{-1}</u>

1) Kaonic deuterium measurement : <u>800 pb^{-1} (500 pb^{-1})</u>

2) Kaonic helium 3 and 4 transitions to the 1s level and 2p level <u>400 pb^{-1}</u>

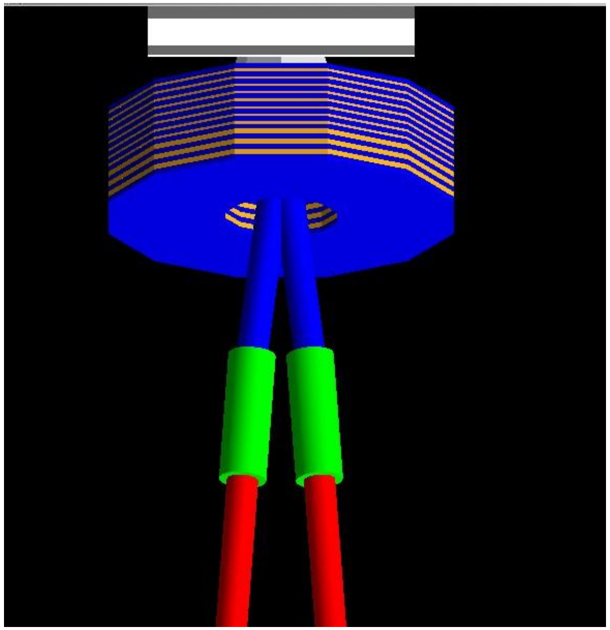
3) Other kaonic atoms (KC, KSi, KNi, KSn, KPb…) – <u>200 pb^{-1}/each</u> (could be done in parallel)

4) Kaon mass precision measurement at the level of <10 keV

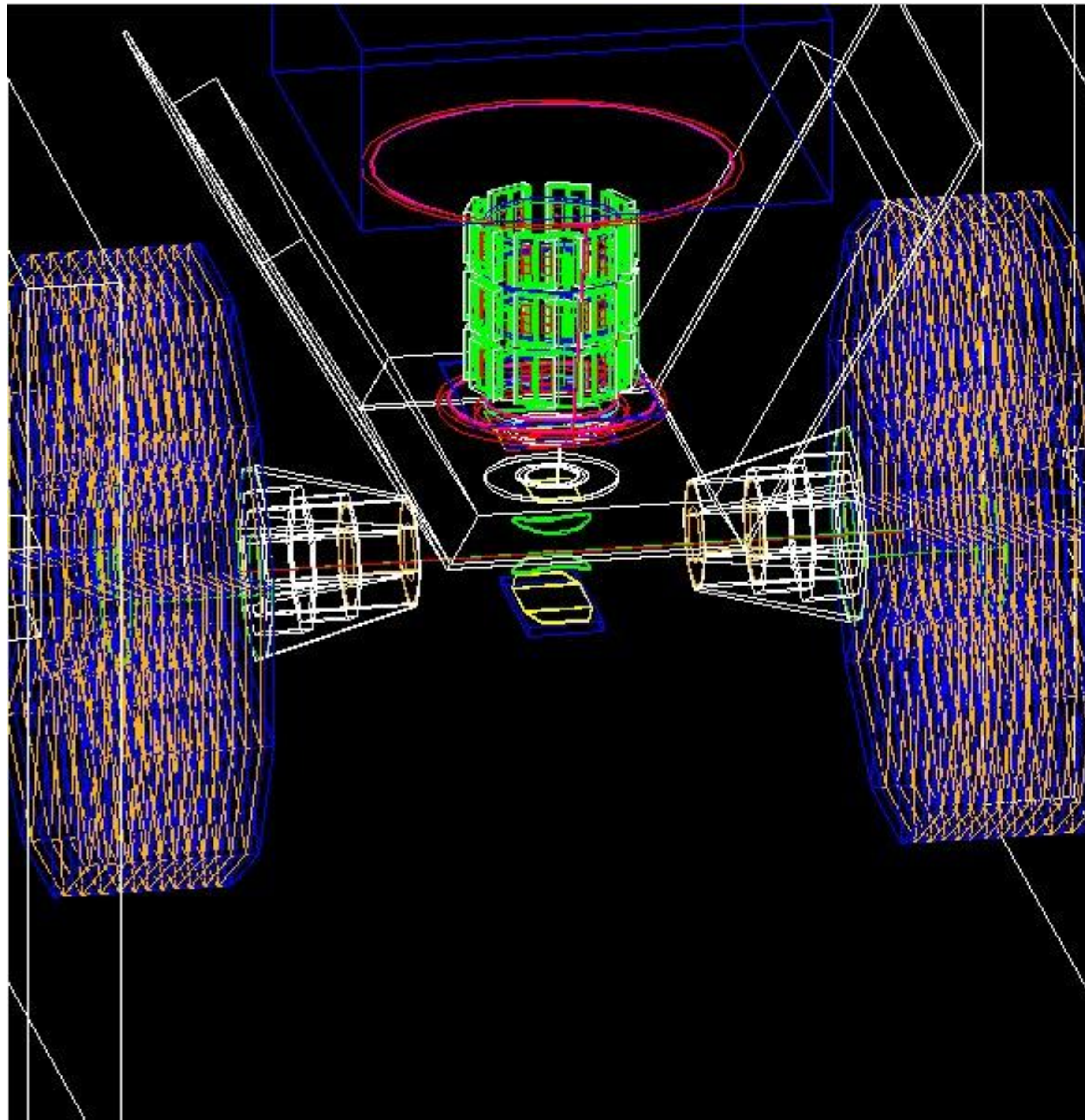
5) Investigate the possibility of the measurement of other types of hadronic exotic atoms (sigmonic hydrogen ?)

SIDDHARTA 2 (GEANT4 MC, M. Iliescu & C. Berucci)

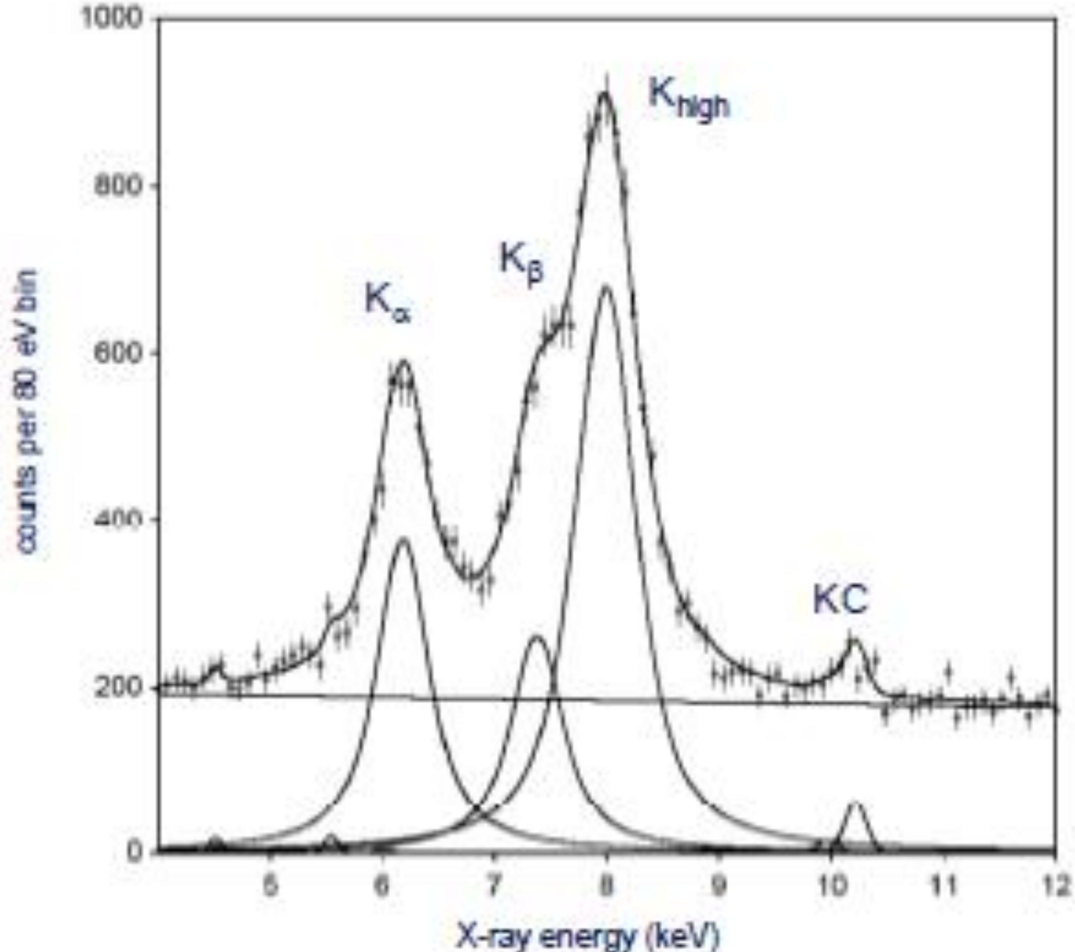
Detail of the beam pipes outside IR



Setup detail



Kaonic hydrogen $L=100\ pb^{-1}$



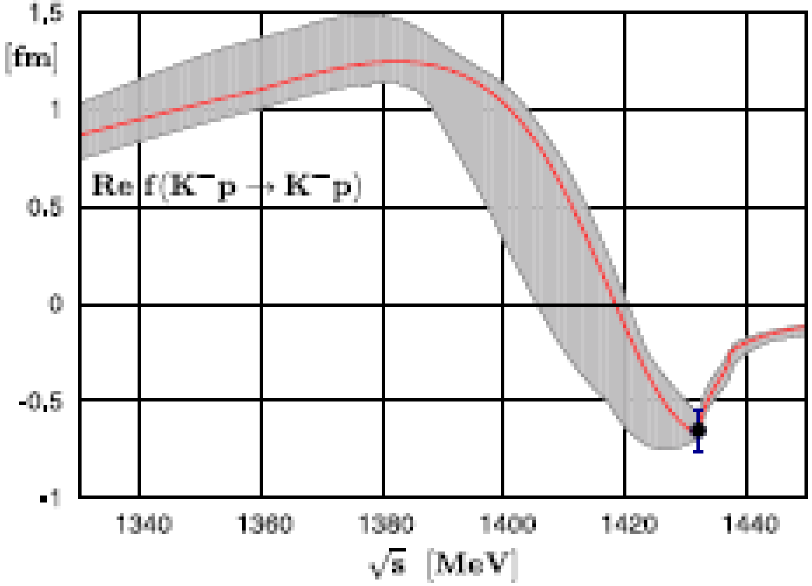
Factor 3-4 better than SIDDHARTA:

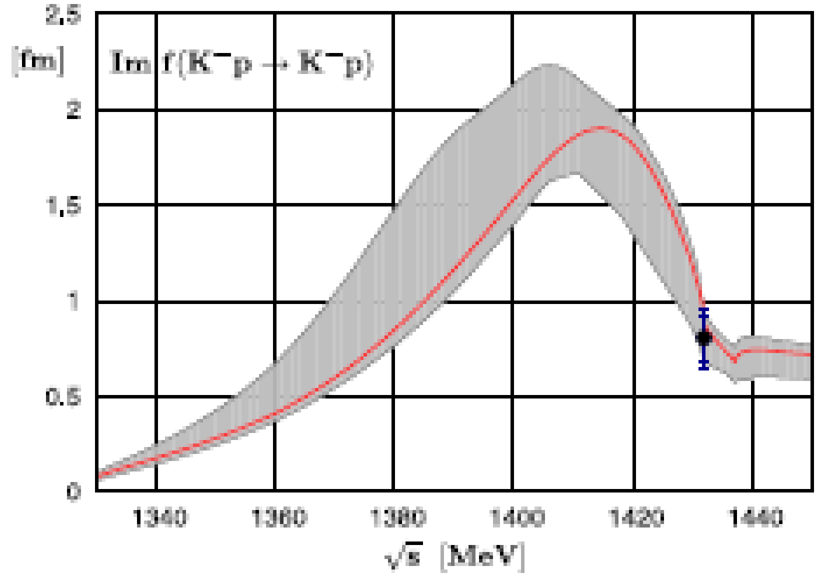
SIDDHARTA-2 with 246 cm² new SDDs from FBK

S/B= 10:3 = sum(K_α) / sum(bg in FWHM of signal)
precision: σ(shift) ~ 10 eV, σ(width) ~ 21 eV

M. Cargnelli

$K^- p$ scattering amplitude from NLO chiral SU(3) dynamics

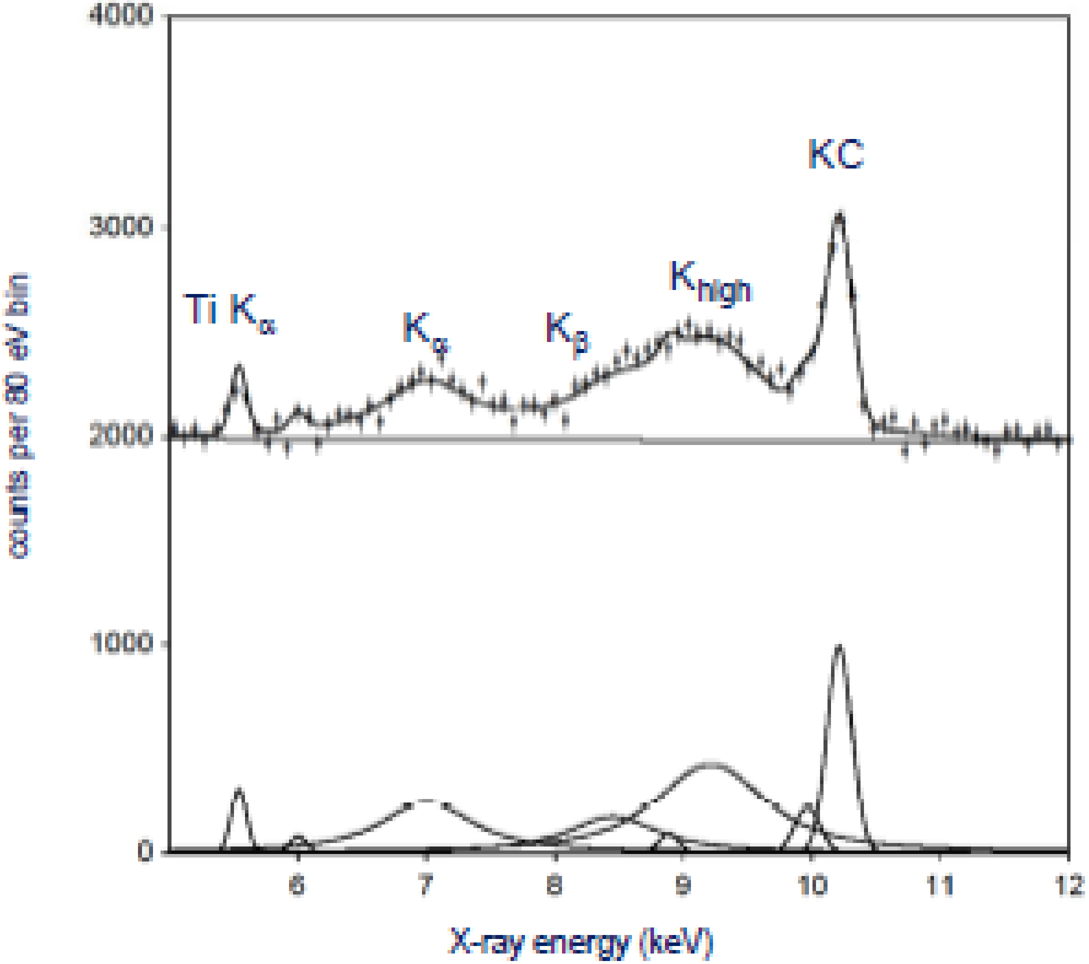




Y. Ikeda, T. Hyodo, W. Weise (IHW), PLB **706** (2011) 63; NPA **881** (2012) 98

Threshold f(K^-p) given by SIDDHARTA K^-H experiment

Kaonic deuterium L=800 pb^{-1}



SIDDHARTA-2 with 246 cm^2 new SDDs from FBK
yield(K_α) = 0.001, K_{series} yield pattern as in Kp
shift = 800 eV, width = 800 eV

S/B= 1:3 = sum(K_α) / sum(bg in FWHM of signal)
precision: σ(shift) ~ 34 eV, σ(width) ~ 79 eV

M. Cargnelli

The kaonic atoms 'puzzle': what next?

E. Friedman [(a)]

Other kaonic atoms: Gal, Okada

[(a)] Racah Institute of Physics, the Hebrew University, Jerusalem, Israel

The expression 'kaonic atoms puzzle' refers to an apparent conflict between phenomenological optical potentials obtained from fits to kaonic atom data and the corresponding potentials constructed from more fundamental approaches [1,2]. Whereas the best-fit phenomenological potentials have for the real part typical depths of 180 MeV at nuclear-matter densities, best-fit $t\rho$ potentials are less than half that deep. Moreover, the corresponding depths of chiral-motivated potentials [3] are typically only 30-40 MeV. This topic attracted attention since the mid-1990s because of its implications for neutron stars. Extrapolating the deep potentials to 3-4 times the normal nuclear density, condensation of K^- mesons could take place, which has non-negligible effects on the equation-of-state, see [4] for a recent reference. Condensation at these densities is not possible with the shallow potentials. The depth of the antikaon-nucleus potential is relevant also to recent theoretical speculations and experimental indications [5] for the existence of bound states of antikaons in light nuclei with binding energies of the order of 100 MeV. If confirmed, that will clearly exclude the shallow potentials.

Careful re-analyses of the world's data on kaonic atoms could not suggest an explanation to the puzzle. Removing from the data base the nuclear species which contribute most to the increased χ^2 for the shallow potentials, (130 for 65 data points for the $t\rho$ potential against 85 for the deep potential), we still get the two (deep and shallow) solutions from the χ^2 fits. Repeating some of the 30-40 years old experiments seems the only way to proceed but it is unrealistic to repeat measurements on more than 20 targets. We therefore studied the possibility of selecting a small sub-group of targets that will be representative of the full

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Five targets have been selected that cover the whole range of the periodic table, where the width of the 'lower' level is between 0.5 and 3 keV and the yield of the 'upper' level is at least $\approx 10\%$. These are C, Si, Ni, Sn and Pb. For the last two the separated isotopes of ^{120}Sn and ^{208}Pb are highly recommended. It is found that with any 4 of the 5 targets it is possible to observe all the features of the potentials found in global fits.

[1]E. Friedman, A. Gal and C.J. Batty, Nucl. Phys. A **579** (1994) 518.

[2]E. Friedman and A. Gal, Phys. Reports **452**, (2007) 89.

[3]A. Ramos and E. Oset, Nucl. Phys. A **671** (2000) 481.

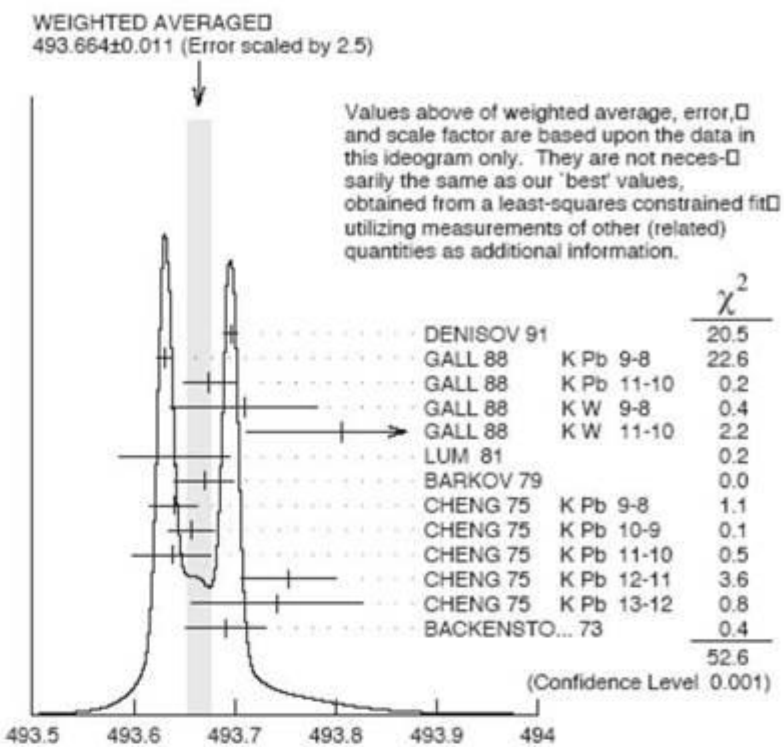
Proposal to solve the Kaon mass ambiguity with SIDDHARTA2

Catalina Curceanu

The present value of the charged kaon mass

$$m_{K^\pm} = 493.677 \pm 0.013 \ \text{MeV} \ (\text{S} = 2.4)$$

as reported in PDG with a Scaling factor of 2.4 has already a long (more than 20 years) history and is biased by ambiguity. The ambiguity – generating the scaling factor, is coming from the fact that the two most precise measurements on Kmass do not agree, as can be easily seen in the figure below:



Negatively Charged Kaon Mass

See Okada talk too

TABLE II. Experimental mass measurements from each transition in megaelectronvolts. If the χ^2 per degree of freedom was greater than 1.0, the error listed with the weighted average is the statistical error scaled up by a factor of $(\chi^2/\nu)^{1/2}$.

Transition	M_{K^-}	Transition	M_{Σ^-}
K^-Pb$(11 \to 10)$	493.675 ± 0.026	Σ^-Pb$(14 \to 13)$	1197.731 ± 0.192
K^-Pb$(9 \to 8)$	493.631 ± 0.007	Σ^-Pb$(13 \to 12)$	1197.492 ± 0.098
K^-W$(11 \to 10)$	493.806 ± 0.095	Σ^-Pb$(12 \to 11)$	1197.412 ± 0.186
K^-W$(9 \to 8)$	493.709 ± 0.073	Σ^-W$(14 \to 13)$	1197.397 ± 0.396
		Σ^-W$(13 \to 12)$	1197.388 ± 0.127
		Σ^-W$(12 \to 11)$	1197.677 ± 0.109
Average	493.636 ± 0.011 $\chi^2/\nu = 2.31$	Average	1197.532 ± 0.057 $\chi^2/\nu = 0.968$

In conclusion, there is in GALL paper the possibility that some bias interfered with the data, especially in the most precise line measured, i.e. the 9 to 8 transition in KPb.
This is a pending mistery and till no other measurement is going to be done there is no solution to this problem.

From where it comes:

What can we do in SIDDHARTA2?

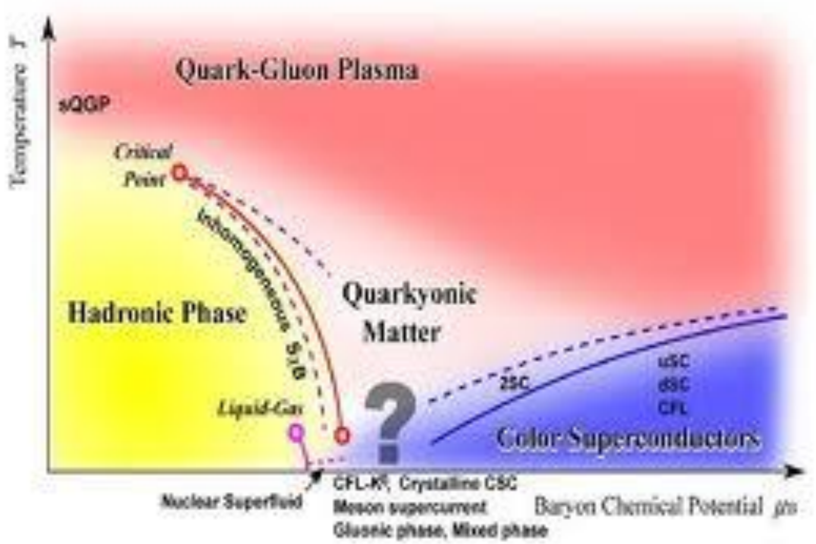
REMEASURE K-Pb transitions!!!

K mass at 5-7 keV with some 10^2 pb^{-1} (Pb or other target)

Mass of K^+ and K^- independently

- CPT requires that the mass of the K^+ be the same as K^-.
- Direct measurement of K^+ and K^- mass separately is a direct test of CPT.
- **Gives a systematic error for kaonic atoms transitions energies**

Low-energy kaon-nuclei Interactions studies



AMADEUS

Antikaon Matter At DAΦNE: Experiments with Unraveling Spectroscopy

AMADEUS collaboration
116 scientists from 14 Countries and 34 Institutes

lnf.infn.it/esperimenti/siddharta
and
LNF-07/24(IR) Report on lnf.infn.it web-page (Library)

AMADEUS started in 2005 and was presented and discussed in all the LNF Scientific Committees

EU Fundings FP7 – I3HP2 and HP3:
Network WP9 – LEANNIS;
WP24 (SiPM JRA);
WP28 (GEM JRA)

HadronPhysics2
Study of Strongly Interacting Matter

HadronPhysics I3
Study of Strongly Interacting Matter

Experimental program of AMADEUS

Unprecedented studies of the low-energy charged kaons interactions in nuclear matter: solid and gaseous targets (d, ^3He, ^4He) in order to obtain unique quality information about:

- Nature of the controversial **Λ(1405)**
- Possible existence of **kaonic nuclear clusters** (deeply bound kaonic nuclear states)
- Interaction of K^- with **one** and **two nucleons.**
- Low-energy charged kaon **cross sections** for momenta lower than 100 MeV/c (missing today)
- Many other processes of interest in the low-energy QCD in strangeness sector -> implications from particle and nuclear physics to astrophysics (dense baryonic matter in **neutron stars**)

AMADEUS status

- Analyses of the **2002-2005 KLOE data**:
- Dedicated **2012** run with pure **Carbon target** inside KLOE
    - **Λp** from 1NA or 2NA (single or multi-nucleon absorption)
    - **Λd** and **Λt** channels
    - Λ (1405) -> $\Sigma^0\pi^0$
    - Λ (1405) -> $\Sigma^+\pi^-$
    - ΣN/ΛN internal conversion rates
- R&D for more refined setup
- Future possible scenario

Produced 2 PhDs

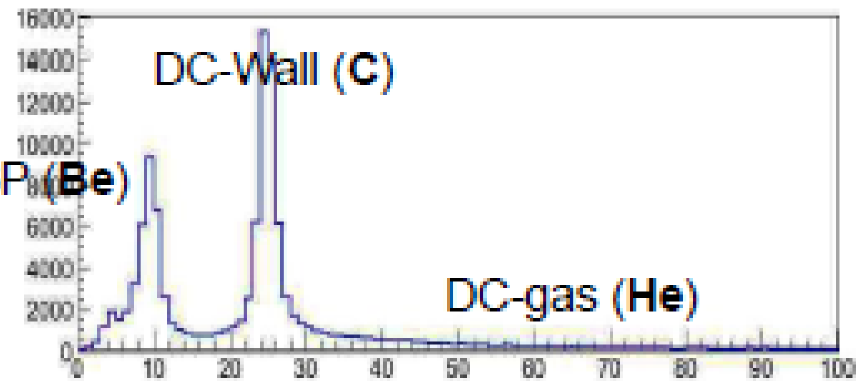
KLOE data on K⁻ nuclear absorption

Use of two different data samples:

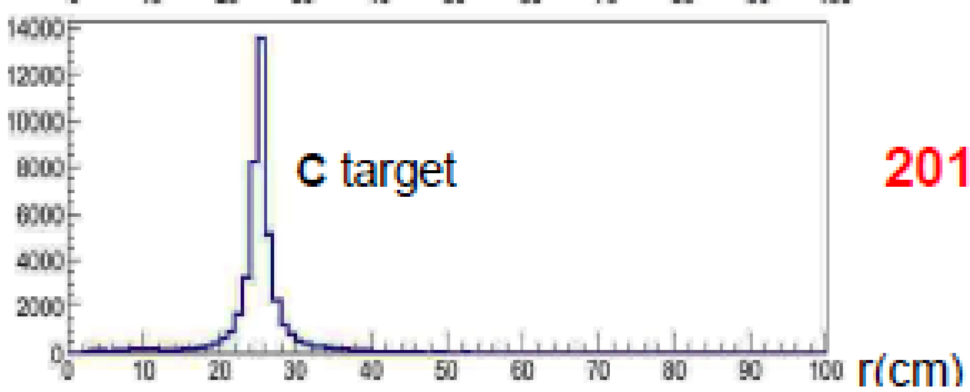
- KLOE data from 2004/**2005** (2.2 fb^{-1} total, 1.5fb^{-1} analyzed)

- Dedicated run in november/december **2012** with a **Carbon target** of 4/6 mm of thickness (~90 pb^{-1}; analyzed 37 pb^{-1}, x1.5 statistics)

<u>Position of the K^- hadronic interaction inside KLOE:</u>

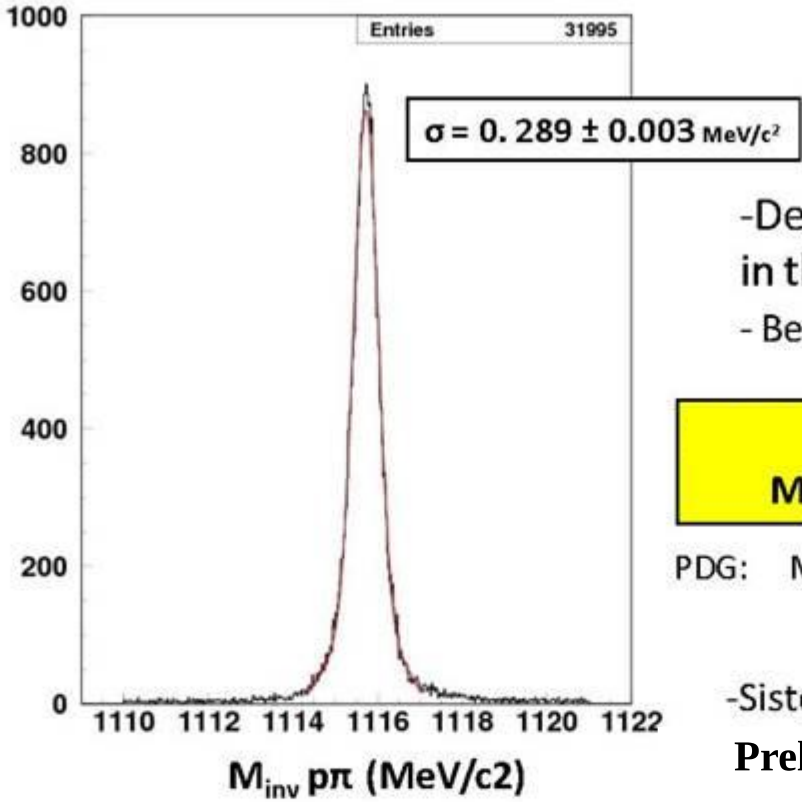


2005 data



2012 with Carbon target

Lambda invariant mass



$\Lambda \rightarrow p + \pi^-$

-Dedicated event selection to avoid **Energy loss** in the DC wall

- Best $\chi 2$ tracks and vertices

M_{inv} = **1115,723 ± 0. 003 stat** (MeV/c²)

PDG: M_Λ = 1115,683 ± 0.006 stat ± 0.006 syst (MeV/c²)

-Sistematics dependent of momentum calibration

Preliminary evaluation with 2-body decay

$K^\pm \rightarrow \mu^\pm \nu$

$K^\pm \rightarrow \pi^\pm \pi^0$

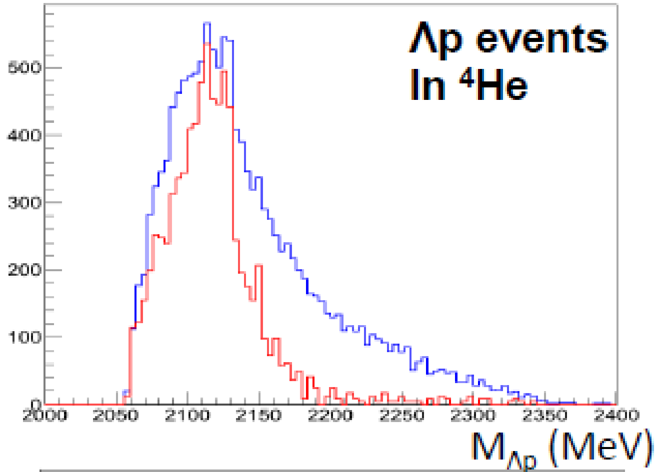
Λp analysis

-Competing processes:

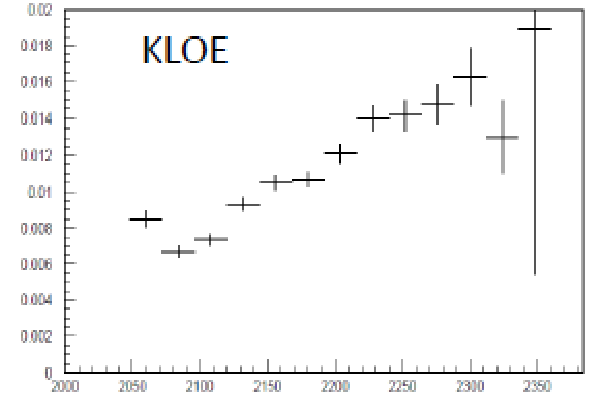
1NA: $K^-N \rightarrow \Lambda\pi^-$ (N from residual nucleus)

2NA: $K^-NN \rightarrow \Lambda N$ (pionless)

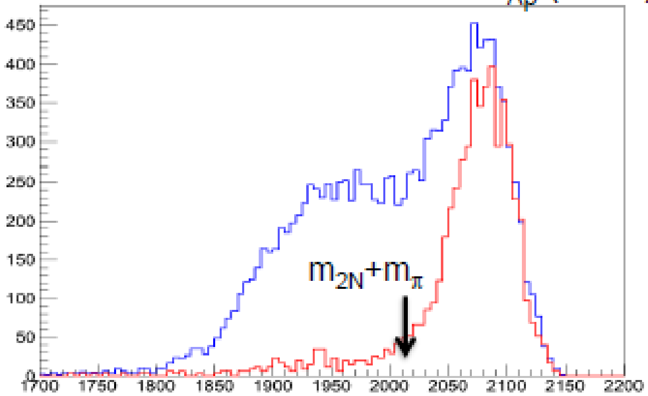
A perfect disentanglement between single and multi-nucleon absorption can be achieved thanks to the **nice acceptance:**



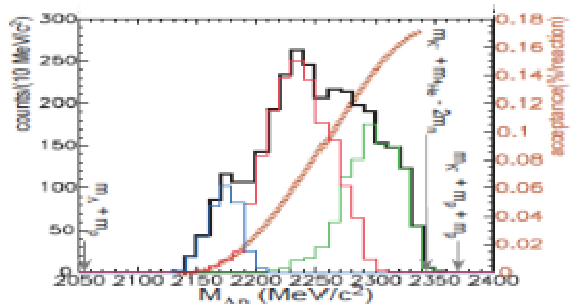
Λp all events
$\Lambda\pi^-$(p) events
(arbitrary normalization)



Acceptance in $M_{\Lambda p}$ (MeV)
(arbitrary normalization)



The Λp missing mass for the $\Lambda\pi^-$(p) events lies exactly In the 2N+π^- mass region



KEK-E549
Mod.Phys.Lett.A23, 2520 (2008)

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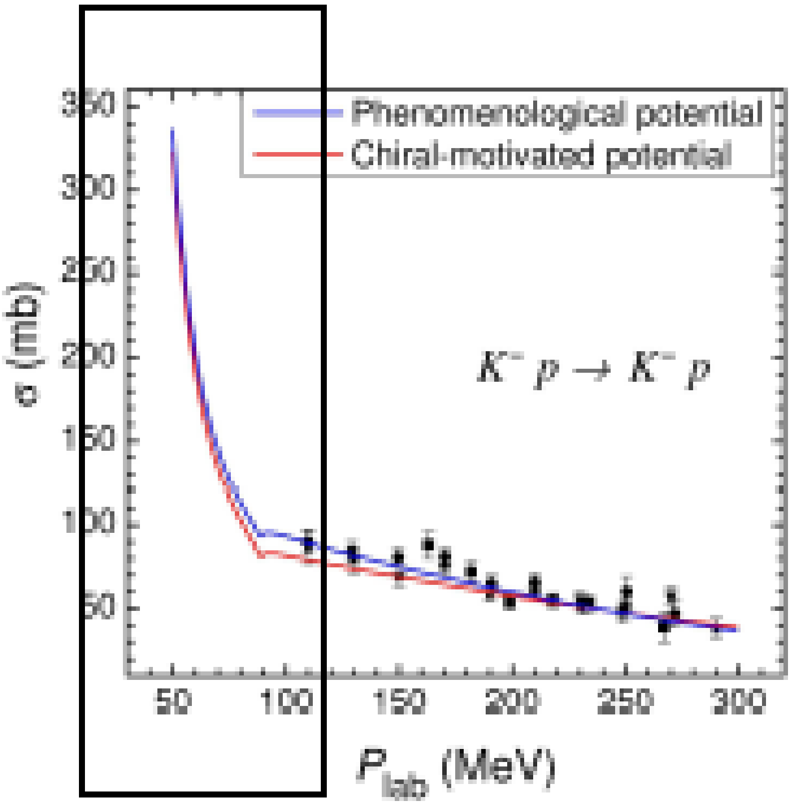
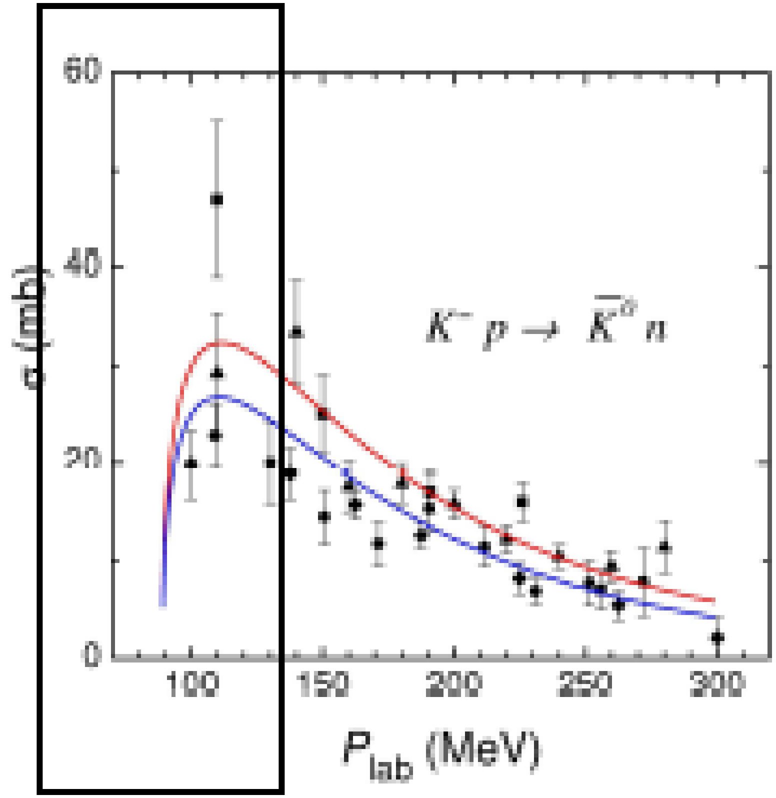
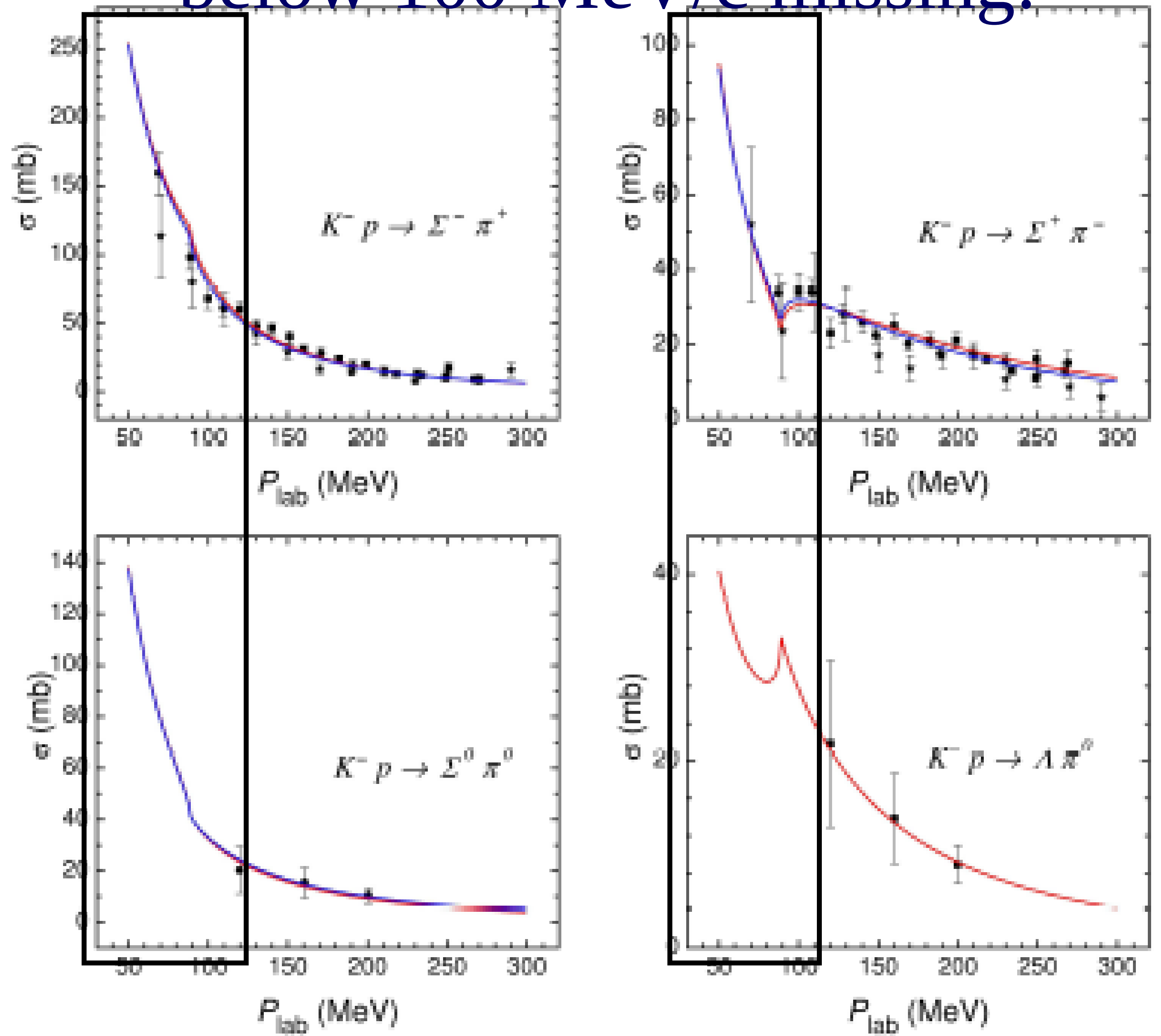
Low-energy kaon scattering below 100 MeV/c missing:





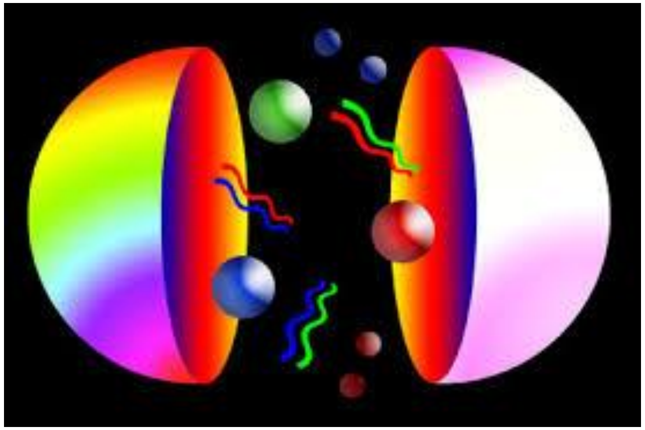
Low-energy kaon processes below 100 MeV/c missing:



AMADEUS

- **AMADEUS has an enomous potential to perform complete measurements of low-energy kaon-nuclei interactions in various targets (Zmeskal's talk)**
- Use of various dedicated targets: H, d, He3 He4….(active target config. - > Zmeskal's talk) – 300 pb-1/target

Hypernuclear physics



Study of hyperHelium ${}^{4}_{\Lambda}He$, ${}^{5}_{\Lambda}He$ production and decays (1)

Production of light hyperfragments

- Sparse old bubble chamber/emulsions observations
- First studies by FINUDA from ^{6}Li, ^{7}Li and heavier targets: π^- spectroscopy (NP **A835** 439 (2010))
  - **${}^{4}_{\Lambda}He$: $K^- + {}^{A}Z \rightarrow {}^{4}_{\Lambda}He + X + \pi^-$** ($\pi^-$ momentum: 255 MeV/c)
    - ~ 120 events observed overall by FINUDA
  - **${}^{5}_{\Lambda}He$: $K^- + {}^{A}Z \rightarrow {}^{5}_{\Lambda}He + X' + \pi^-$** ($\pi^-$ momentum: 275.15 MeV/c)
    - first exploratory studies in ^{6}Li, ^{7}Li with (p,d) coincidences
- **Neutral π spectroscopy**: thorough open field!

S. Piano, A. Filippi

Study of hyperHelium ${}^{4}_{\Lambda}$He, ${}^{5}_{\Lambda}$He production and decays (2)

Studies of Non-Mesonic decays

- Disfavored decay channels for light Hypernuclei
- Two body rare decays: **rare** mode, ~ 1.5% of total NM decay rate (Rayet, Nuovo Cim. 42B (1968), 238)
- **Very clean experimental signatures: monochromatic signals, exclusive events**
  - **${}^{4}_{\Lambda}\mathrm{He} \rightarrow {}^{3}\mathrm{He}\ n$**
    - a few events observed in bubble chamber (Block 1959 + Corenmans 1968)
  - **${}^{4}_{\Lambda}\mathrm{He} \rightarrow dd$**
    - d momentum: 570 MeV/c
    - One event observed in bubble chamber (Block 1970) + events by FINUDA (16 exclusive + 43 inclusive)
  - **${}^{4}_{\Lambda}\mathrm{He} \rightarrow pt$**
    - p momentum: 508 MeV/c
    - No events ever observed (no tritons observed by FINUDA, < momentum threshold)
  - **${}^{5}_{\Lambda}\mathrm{He} \rightarrow dt$**
    - d momentum: 597 MeV/c
    - Never observed

S. Piano, A. Filippi

Neutron rich Λ hypernuclei by K^-_{stop} in ^{6}Li and ^{7}Li (1)

large isospin hypernuclei: important to understand the properties of $\Lambda N \rightarrow \Sigma N$ mixing and glue role of Λ around the nuclear drip lines

Charged pion spectroscopy

(K^-, π^+) elementary reaction: DCX, 2 steps

$K^-_{stop}\, p \rightarrow \Sigma^- \pi^+$; $\Sigma^- p \rightarrow \Lambda n$

$K^-_{stop}\, p \rightarrow \Lambda \pi^0$; $\pi^0 p \rightarrow n\, \pi^+$

Yield: 10^{-5}-10^{-6}/K^-_{stop}

- **$K^-_{stop}\, {}^6Li \rightarrow {}^6_\Lambda H\, \pi^+$**
  - *3 evts only seen at DAΦNE with FINUDA*
    Phys. Rev. ***C86,*** *05730 (2012)*
  - *Not confirmed at JPARC with* E10 in π induced reaction*:* **^{6}Li(π^-, K^+)** @ p_π = 1.2 GeV/c
    Phys. *Lett.* ***B729****, 39 (2014)*
- **$K^-_{stop}\, {}^7Li \rightarrow {}^7_\Lambda H\, \pi^+$**
  - *Never observed so far*

S. Piano, A. Filippi

Neutron rich Λ hypernuclei by K^-_{stop} in ^6Li and ^7Li

large isospin hypernuclei: important to understand the properties of $\Lambda N \rightarrow \Sigma N$ mixing and glue role of Λ around the nuclear drip lines

Neutral pion spectroscopy (KLOE calorimeter)

(K^-, π^0) elementary reaction: direct production, 1 step

$K^-_{stop}\, p \rightarrow \Lambda\, \pi^0$

Yield :10^{-3}-10^{-4}/K^-_{stop}

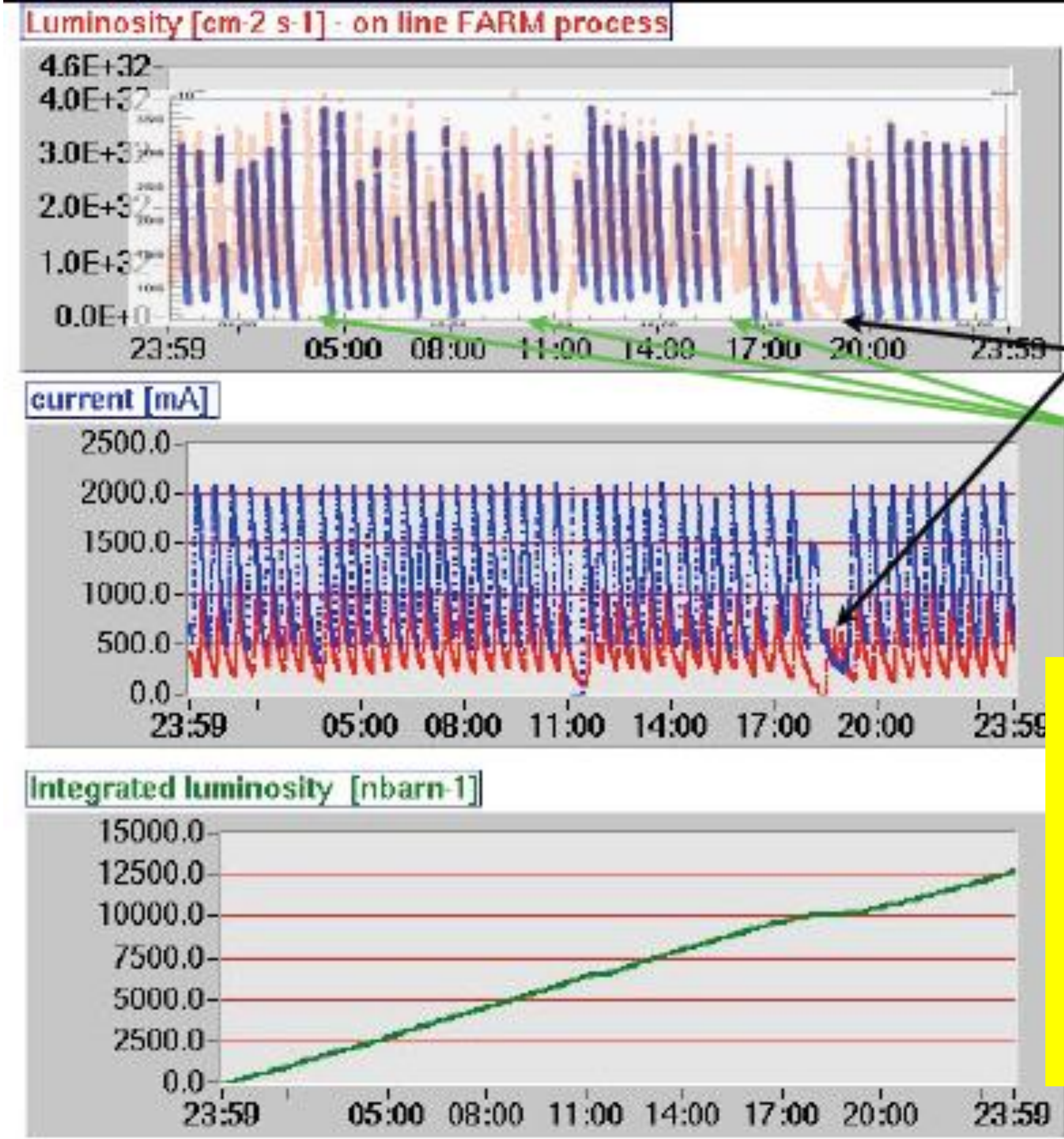
- **$K^-_{stop}\, {}^6Li \rightarrow {}^6_\Lambda He\, \pi^0$**
  - *Expected but never observed so far*
- **$K^-_{stop}\, {}^7Li \rightarrow {}^7_\Lambda He\, \pi^0$**
  - *Claimed at JLAB by* HKS (JLAB-E01-011): $e^-\, {}^7Li \rightarrow e'\, K^+\, {}^7_\Lambda He$

    Phys. Rev. Lett. ***110****, 12502 (2013)*

    $B_\Lambda = 5.68 \pm 0.03 \pm 0.25$ *MeV* $\Rightarrow \Delta p_{\pi 0} \sim 6$ MeV/c
  - *Further confirmations needed*

S. Piano, A. Filippi


STRATEGY
PLAN
THINK
MANAGE



2009/05/14

Injection prob.

Calibration runs

At least 6 pb^{-1}/day of good quality data

Plan for the Kaonic atoms measurements based on 150 pb^{-1} luminosity/month

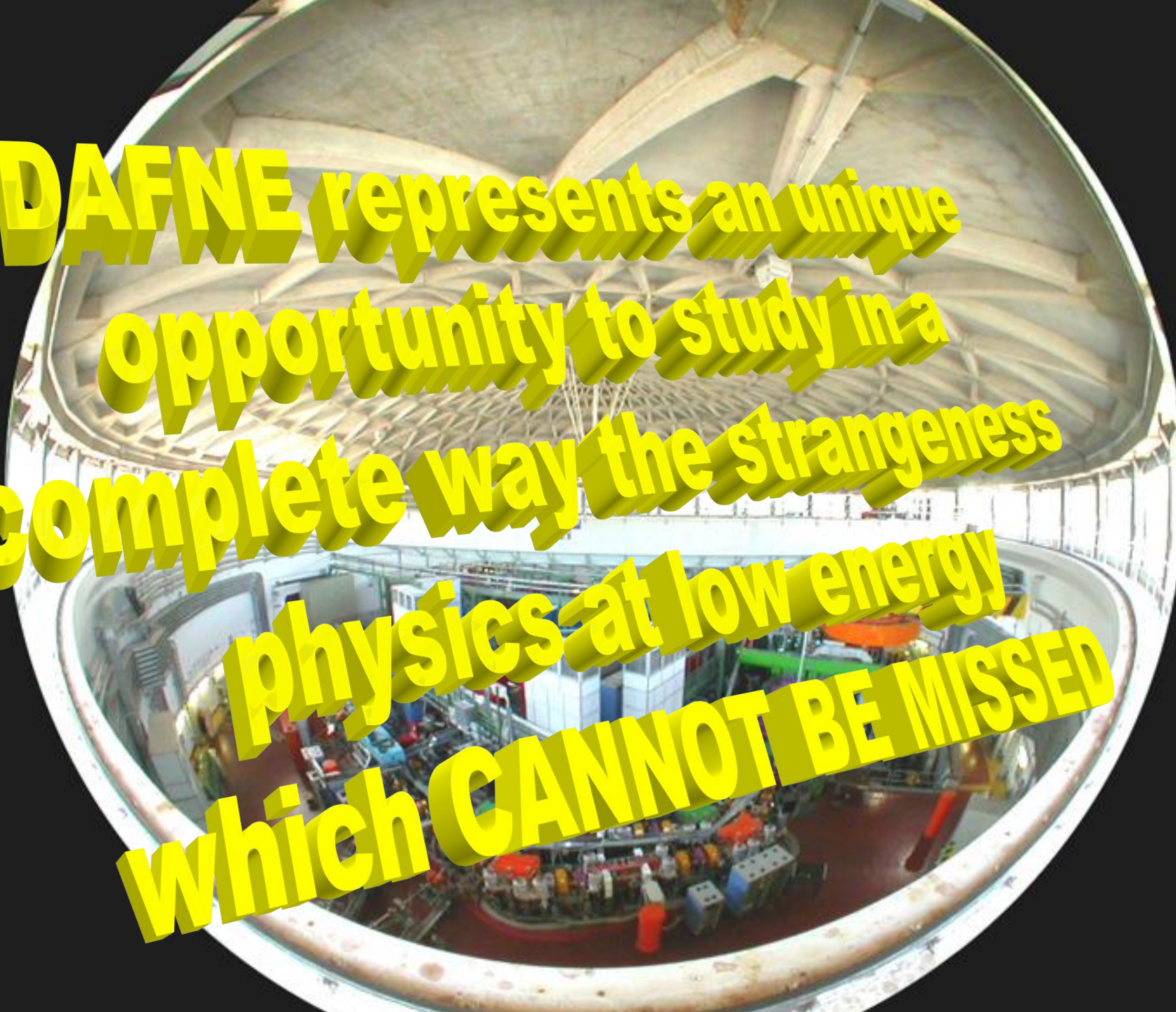
Measurement	Months	Lumin (pb^{-1})
Debug, calib. and KH (test degrader):	1-2	100 (KH)
Kaonic Deuterium:	3-7	800 (500)
KHe3 (1s, 2p)	8-10	400
KHe4	11-13	400
Solid targets (x 5)	14-18	5 targets
Kaon mass	19-24	800 (tbc)

Modular strategy with independent measurements – each one is SIGNIFICATIVE

Plan for the Kaon interactions with nuclei based on 150 pb^{-1} luminosity/month

Measurement	Months
Hydrogen target :	1-2
Deuterium target :	3-4
He3 target :	5-6
He4 target:	7-8
Solid targets (test for hypernuclear)	9-12
Active targets , hypernuclear	13-

Modular strategy with independent measurements – each one SIGNIFICATIVE



DAFNE represents an unique opportunity to study in a complete way the strangeness physics at low energy which CANNOT BE MISSED

What Next @ DAΦNE

3-4 years program – with modular strategy

Kaonic atoms

Hypernuclei

Low-energy Kaon-nuclei (deeply bound)

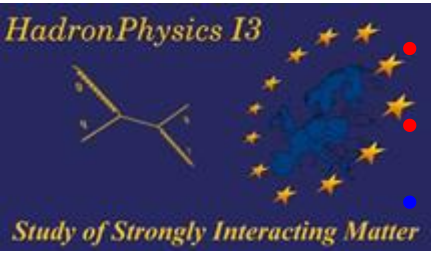
SIDDHARTA-2
TES
Other….

AMADEUS?

AMADEUS

Kaon mass

Participating Institutions
Strong International Collaboration(s)



- **LNF- INFN, Frascati, Italy**
- **other INFN sections**
- **SMI- ÖAW, Vienna, Austria**
- **IFIN – HH, Bucharest, Romania**
- **Politecnico, Milano, Italy**
- **La Sapienza, Roma, Italy**
- **CNR – IMEM, Parma Italy**
- **Univ. Heidelberg, Germany**
- **Jagellonian Univ., Krakow, Poland**
- **Inst. Experim. Physics, Warsaw, Poland**
- **TUM, Muenchen, Germany**
- **Univ. Zagreab, Croatia**
- **RIKEN, Japan**
- **Univ. Tokyo, Japan**
- **Victoria Univ., Canada**
- **Others will join (GSI related…)**

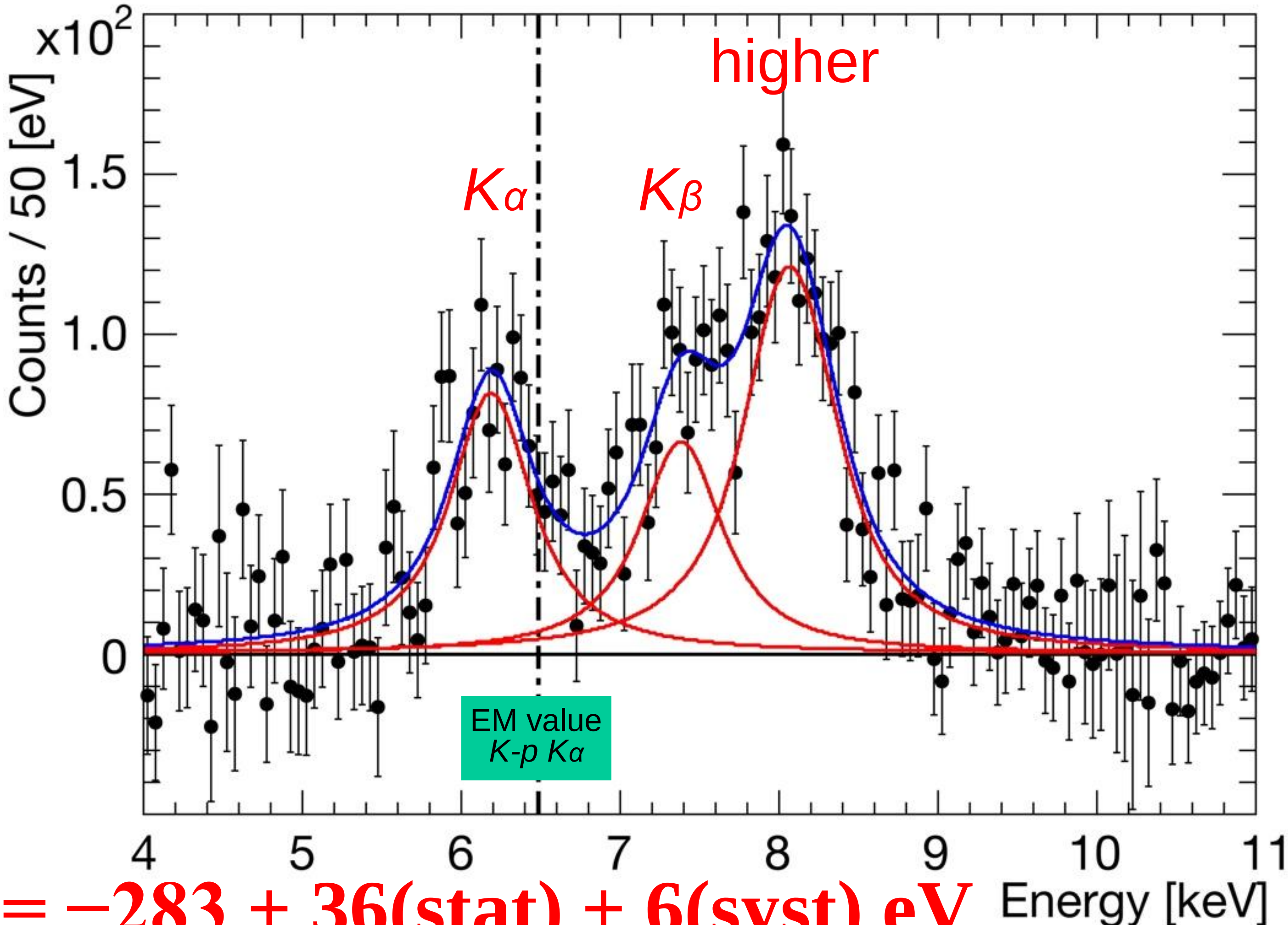
Opportunity to participate to HORIZON 2020 calls

(as HadronPhysicsHorizon;

Marie Curie IF;

Marie Curie RICE....)

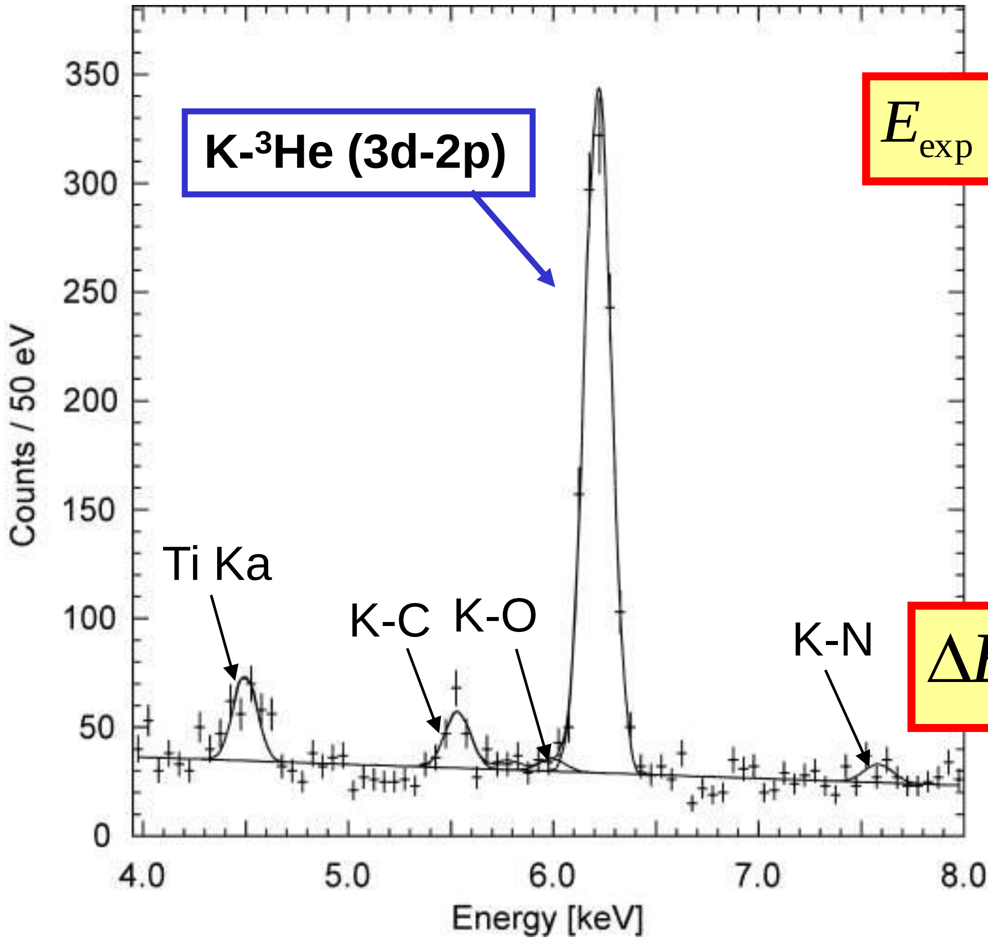
Residuals of K-p x-ray spectrum after subtraction of fitted background



$\varepsilon_{1S} = -283 \pm 36(\mathrm{stat}) \pm 6(\mathrm{syst})$ eV

$\Gamma_{1S} = 541 \pm 89(\mathrm{stat}) \pm 22(\mathrm{syst})$ eV

Kaonic Helium-3 energy spectrum – 3 days DAQ



X-ray energy of K-3He 3d-2p

$$E_{\text{exp}} = 6223.0 \pm 2.4(sta) \pm 3.5(sys)\ \text{eV}$$

QED value: $E_{e.m.} = 6224.6\ \text{eV}$

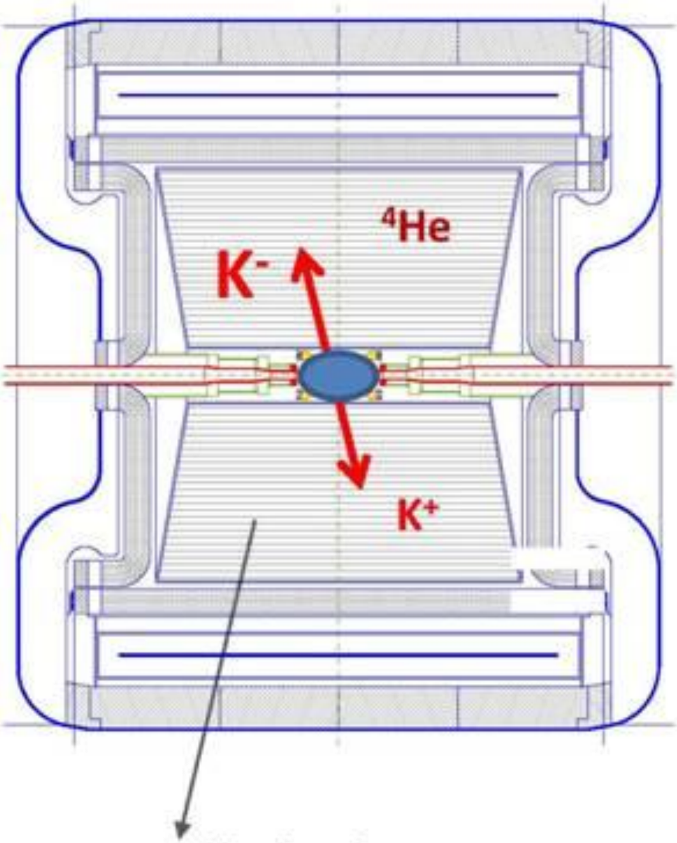
$$\Delta E_{2p} = E_{\text{exp}} - E_{e.m.}$$

$$\Delta E_{2p} = -2 \pm 2(sta) \pm 4(sys)\ \text{eV}$$

World First !
Observation of K-^{3}He X-rays
Determination of strong-interaction shift

arXiv:1010.4631v1 [nucl-ex], PLB697(2011)199

Hadronic interactions of K^- in KLOE



KLOE Drift Chamber

- The Drift Chambers of KLOE contain mailny **^{4}He**
- From analysis of KLOE data and Monte Carlo:
  0.1 % of K^- from daΦne should **stop in the DC volume**
- This would lead to hundreds of possible kaonic clusters produced in the 2 fb^{-1} of KLOE data.