11th International Workshop on Meson Production, Properties and Interaction

Kaonic helium measurements in the SIDDHARTA experiment

Diana Laura Sirghi

INFN-LNF

on behalf of SIDDHARTA collaboration

10 - 15 June 2010
Krakow, Poland

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**

EU Fundings: JRA10 – FP6 - I3HP
Network WP9 – LEANNIS – FP7- I3HP2

The scientific aim

the determination of the ***isospin dependent*** $\bar{K}N$ ***scattering lengths*** through a

~ eV measurement of the shift

and *of the width*

of the K_α line of **kaonic hydrogen** and

the *first (similar) measurement* of **kaonic deuterium**

See talk of A. Romero Vidal

Kaonic Helium measurements SIDDHARTA experiment

In the framework of the SIDDHARTA experiment we have performed the **Kaonic helium transition to the 2p level (L-lines)** measurements:

- **for first time in a gaseous target for ^{4}He**
- **for the first time ever for K^{3}He**

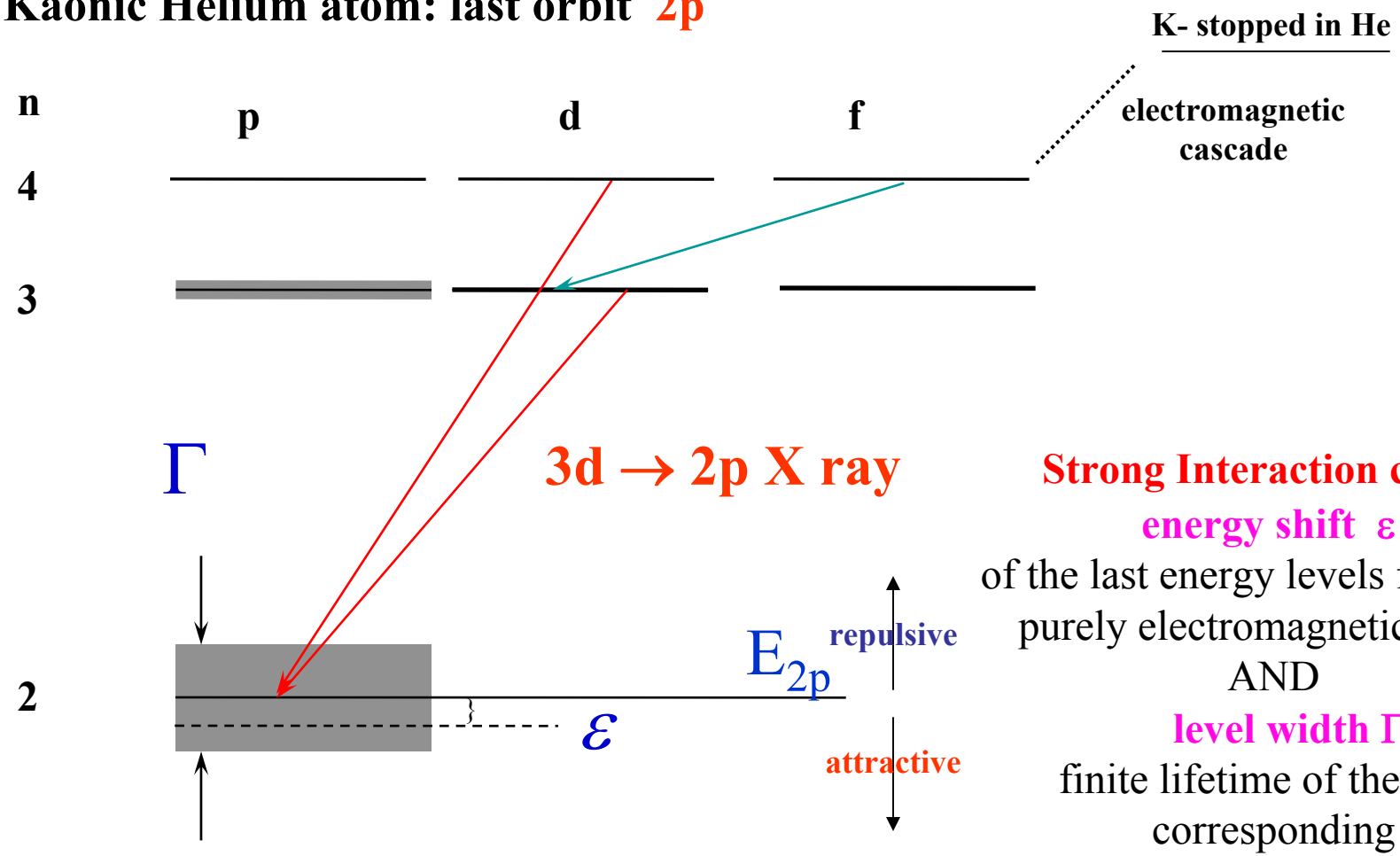
The interest for such type of measurement was rather high due to:

so-called "kaonic helium puzzle"

some theoretical predictions of possible high energy shift

Kaonic Helium atoms

Kaonic Helium atom: last orbit 2p



Strong Interaction causes:

energy shift ε

of the last energy levels form their purely electromagnetic values

AND

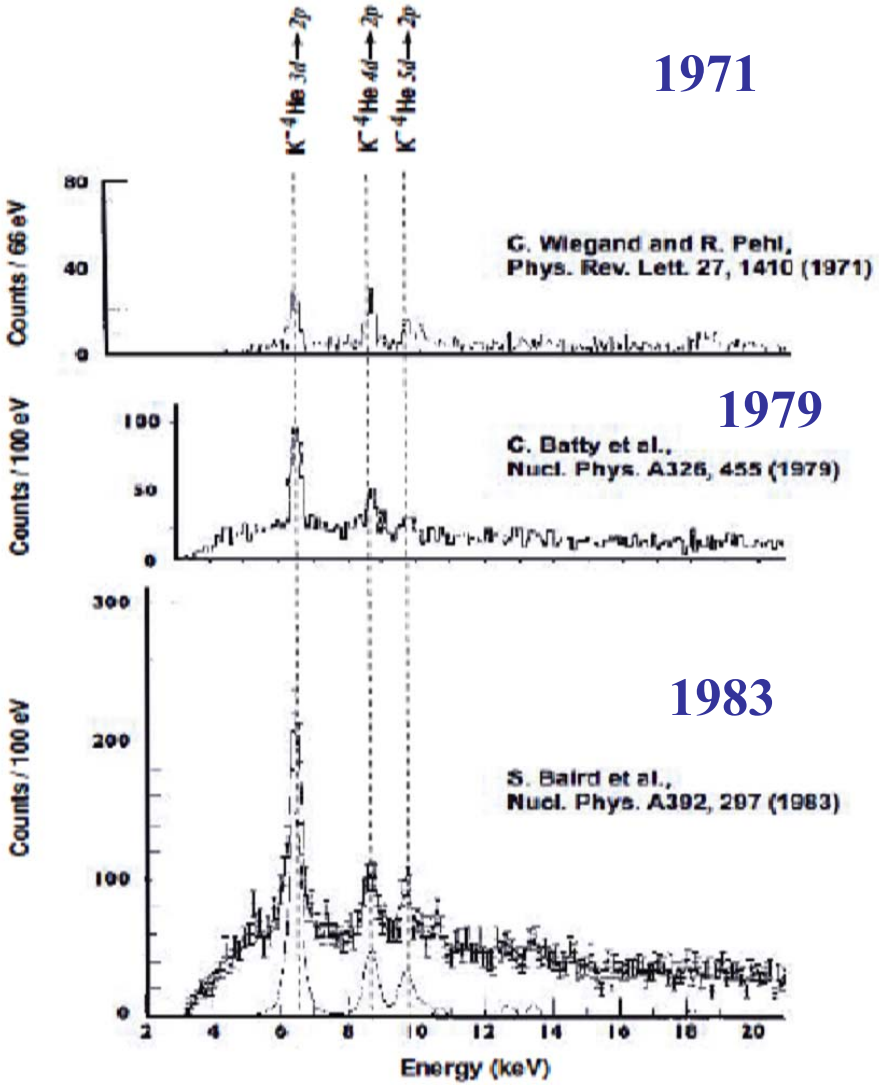
level width Γ

finite lifetime of the state corresponding

to an increase in the observed level width

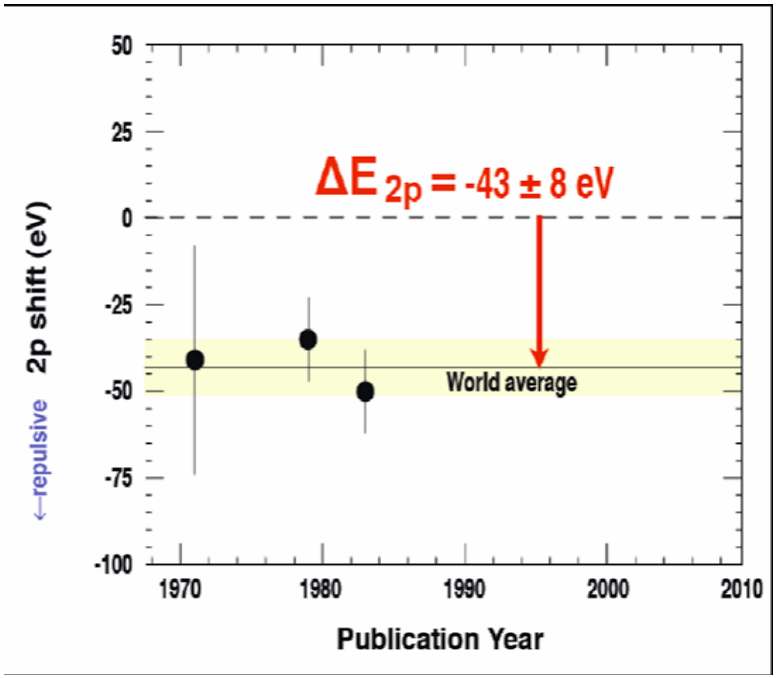
$$\varepsilon = E_{3d \to 2p}(\text{exp}) - E_{3d \to 2p}(\text{e.m.})$$

Kaonic helium atom data (Z=2)



Average of above

ΔE_{2p}(eV)	Γ_{2p} (eV)
-41±33	-
-35±12	30±30
-50±12	100±40
-43±8	55±34



Kaonic helium atoms theoretical values

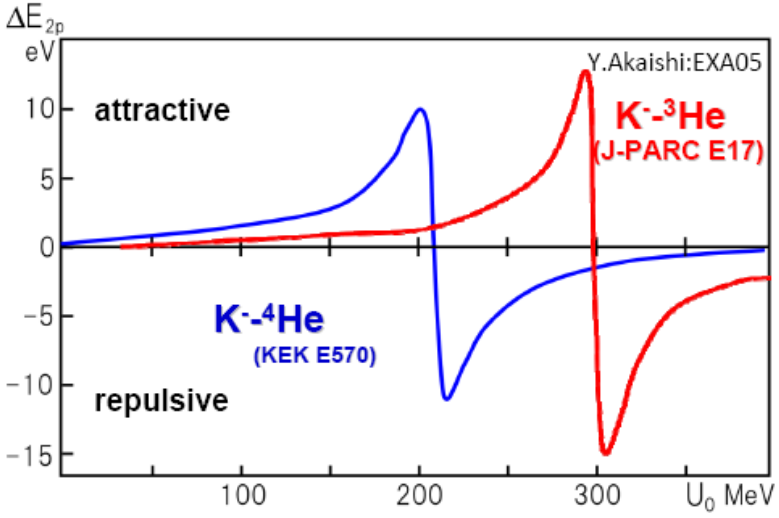
There are two types of theories compared to the experimental results:

Optical-potential model

Shift (eV)	Ref.
-0.13±0.02	Batty, NPA508 (1990) 89c
-0.14±0.02	Batty, NPA508 (1990) 89c
-1.5	Akaishi, Porc. EXA05

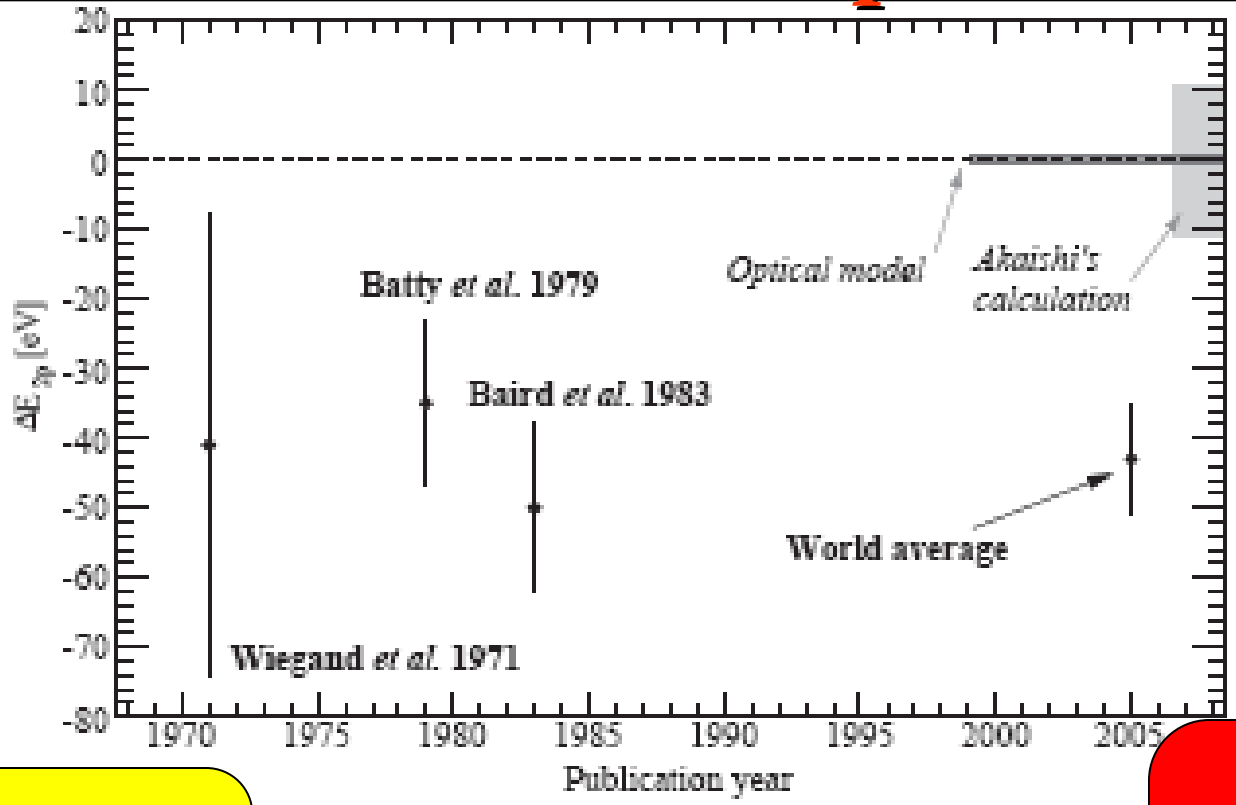
Tiny shift ($\Delta E_{2p} \approx 0$ eV)

Akaishi-Yamazaki model of deeply-bound kaon-nucleus states



Predicts a possible maximum shift: ΔE_{2p} of ± 10 eV

What is Kaonic helium puzzle?

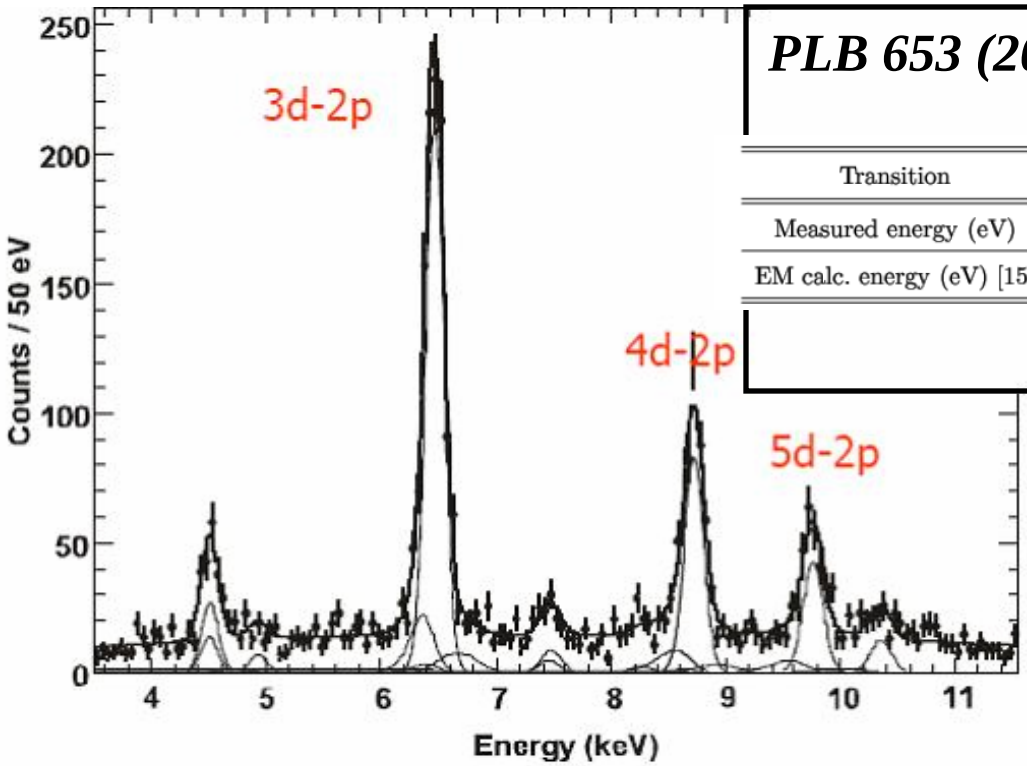


Experiment:
Large shift
(ΔE2p ≈ 40 eV)

Theory:
ΔE2p ≈ 0 eV
or
< ± 10 eV

Need a new K-^{4}He X-ray measurement!

New K^4He results by KEK PS E570



PLB 653 (2007) 387

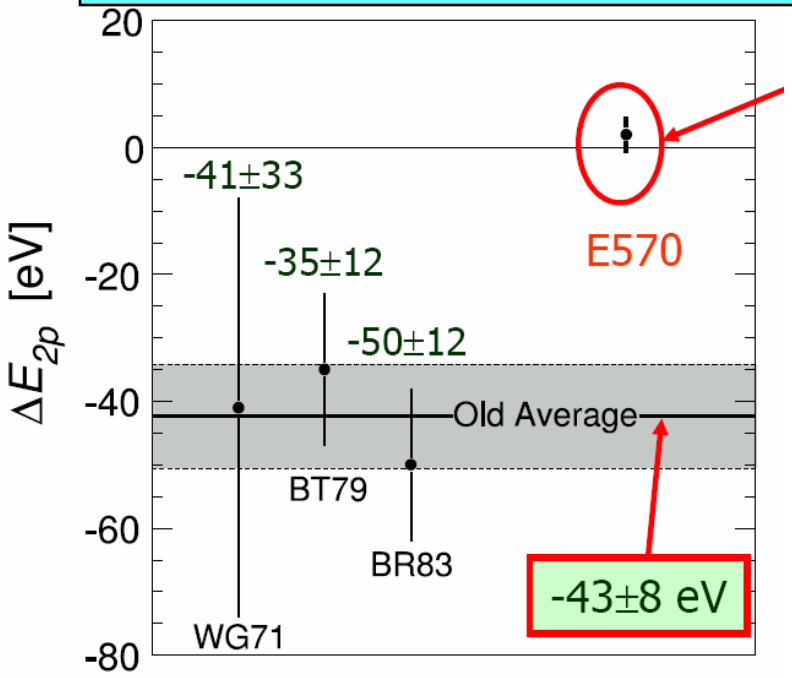
Transition	$3d \rightarrow 2p$	$4d \rightarrow 2p$	$5d \rightarrow 2p$
Measured energy (eV)	6466.7 ± 2.5	8723.3 ± 4.6	9760.1 ± 7.7
EM calc. energy (eV) [15]	6463.5	8721.7	9766.8

K^4He 3d→2p: 1500 events

3x higher statistics
2x better Energy resolution
6x better S/N

$$\Delta E_{2p} = 2 \pm 2(\text{stat.}) \pm 2(\text{syst.})\ \text{eV}$$

Solving the kaonic helium puzzle



Theory:
ΔE2p ≈ 0 eV
or
< ± 10 eV

Old experiments:
Large shift
(-43±8 eV)

Difference between the new and the old experiments

E570 experiment:
Small shift
(+2±2±2 eV)

Experimental confirmation need!
SIDDHARTA experiment

SIDDHARTA experiment

$$e^+ + e^- \rightarrow \phi \rightarrow K^+ + K^-$$

Monochromatic, low-momentum kaon beam from DAFNE (127 MeV/c)

No hadronic background due to the beam line (compare with hadron beam line :e.g with KEK line)

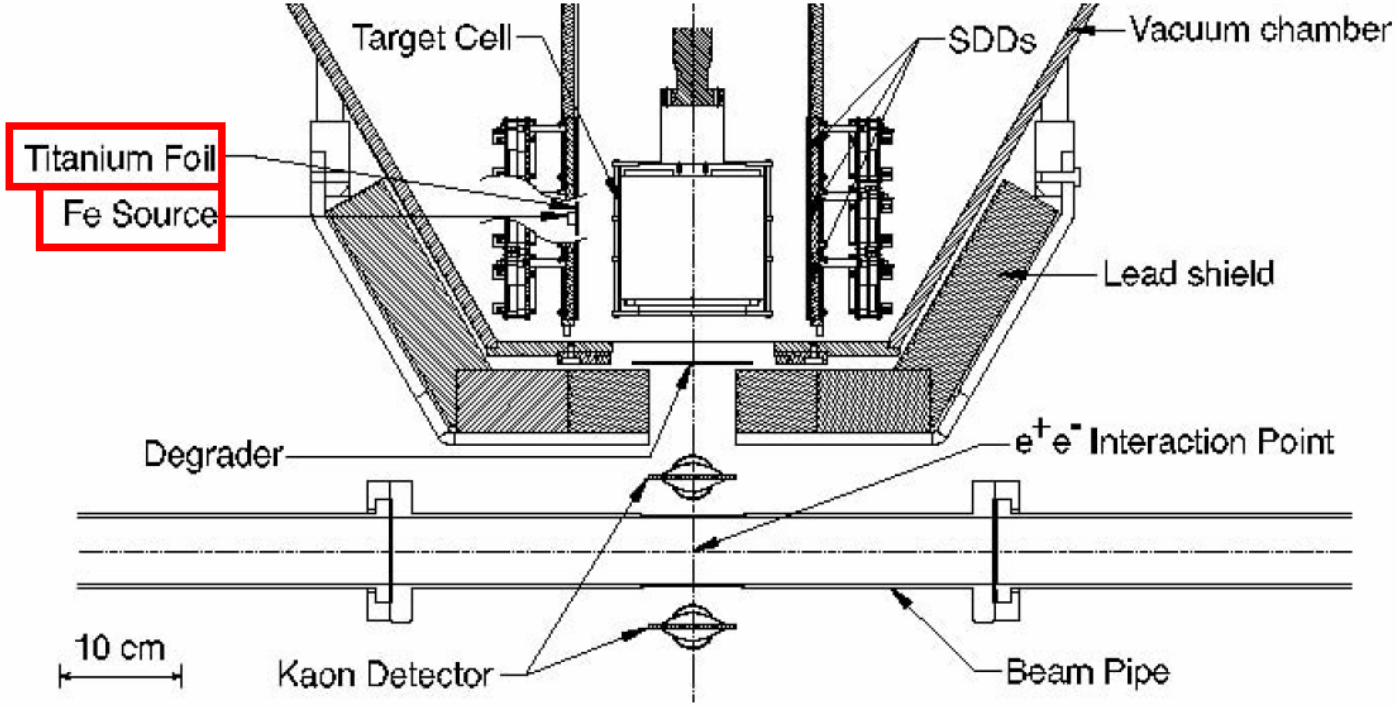
SIDDHARTA experiment:

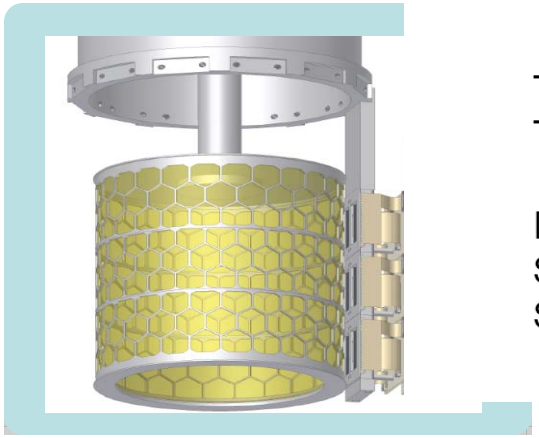
• gas target with an efficient kaon stopping power (negligible Compton scattering in helium)

•K+K- pair detection

•Silicon Drift Detector (SDDs) as detector

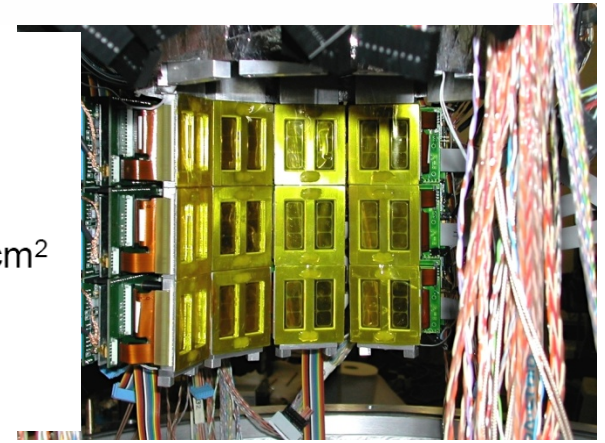
The experimental setup

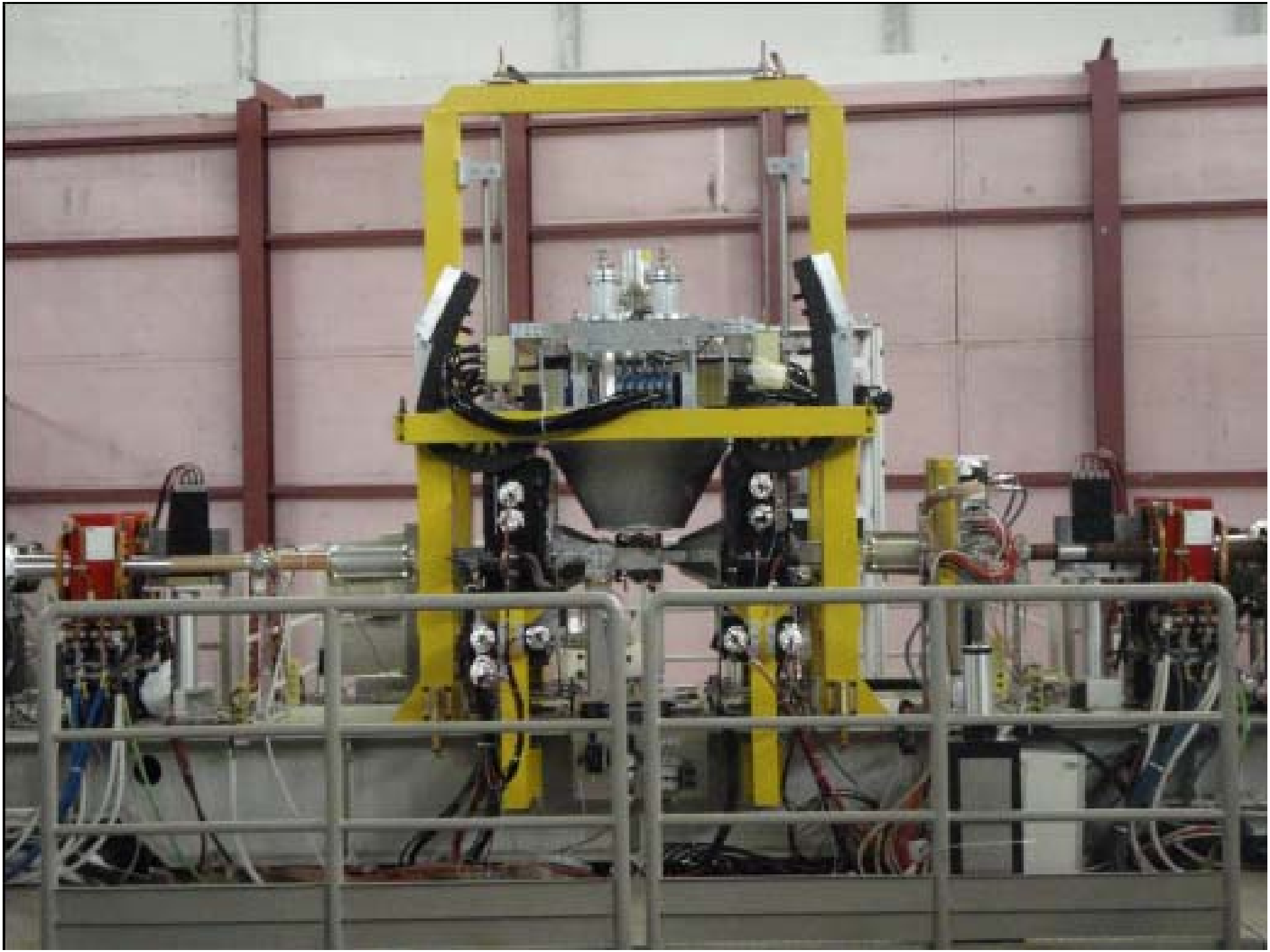




Target size: r=6cm, h=12 cm
Target density:27 K, 0.95 bar = 10 bar at NTP

Installed SDD:144 cm^2, Used in Analysis: 60 cm^2
SDD operation temp. :170 K,
SDD Energy resolution: ~150 eV (at 6 keV)





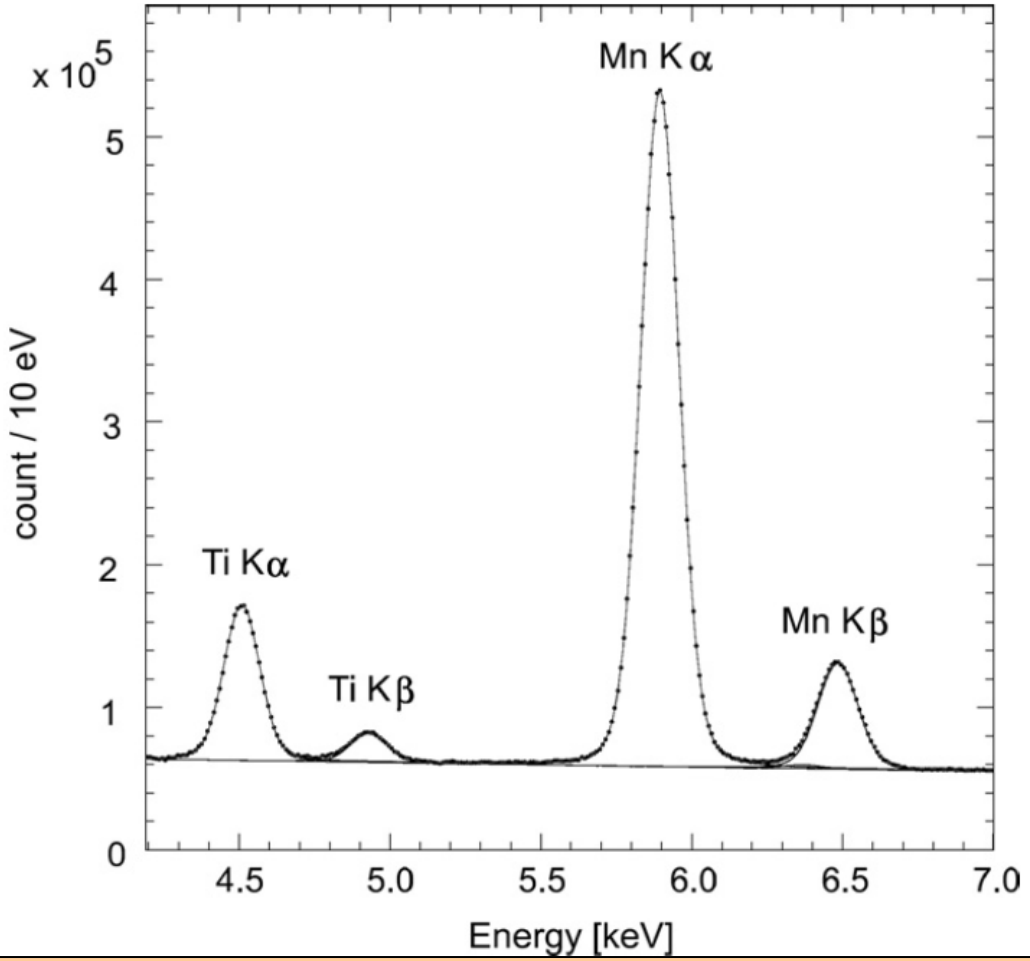
Kaonic ^{4}He data
SIDDHARTA experiment

The **Kaonic ^{4}He X-ray data** were taken for about **two weeks in January 2009**.

In this period, an **integrated luminosity of about 20pb^{-1}** was collected.

This corresponds to about **4.7 × 10^6 kaons** detected by the kaon detector.

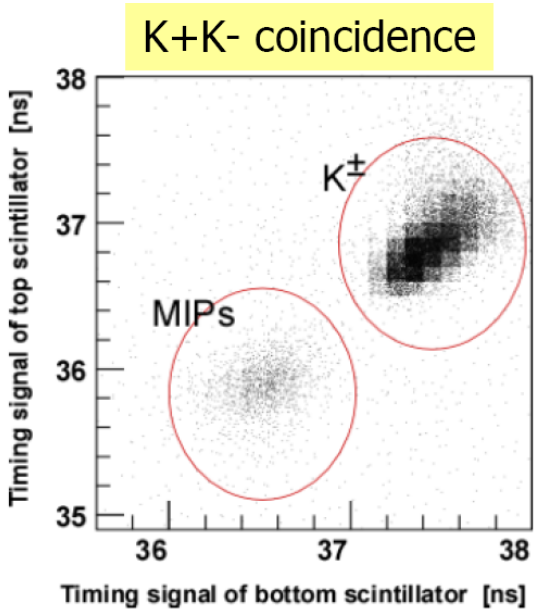
Energy calibration

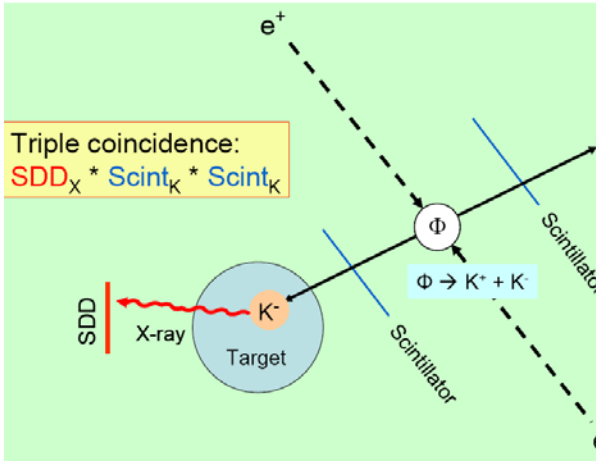


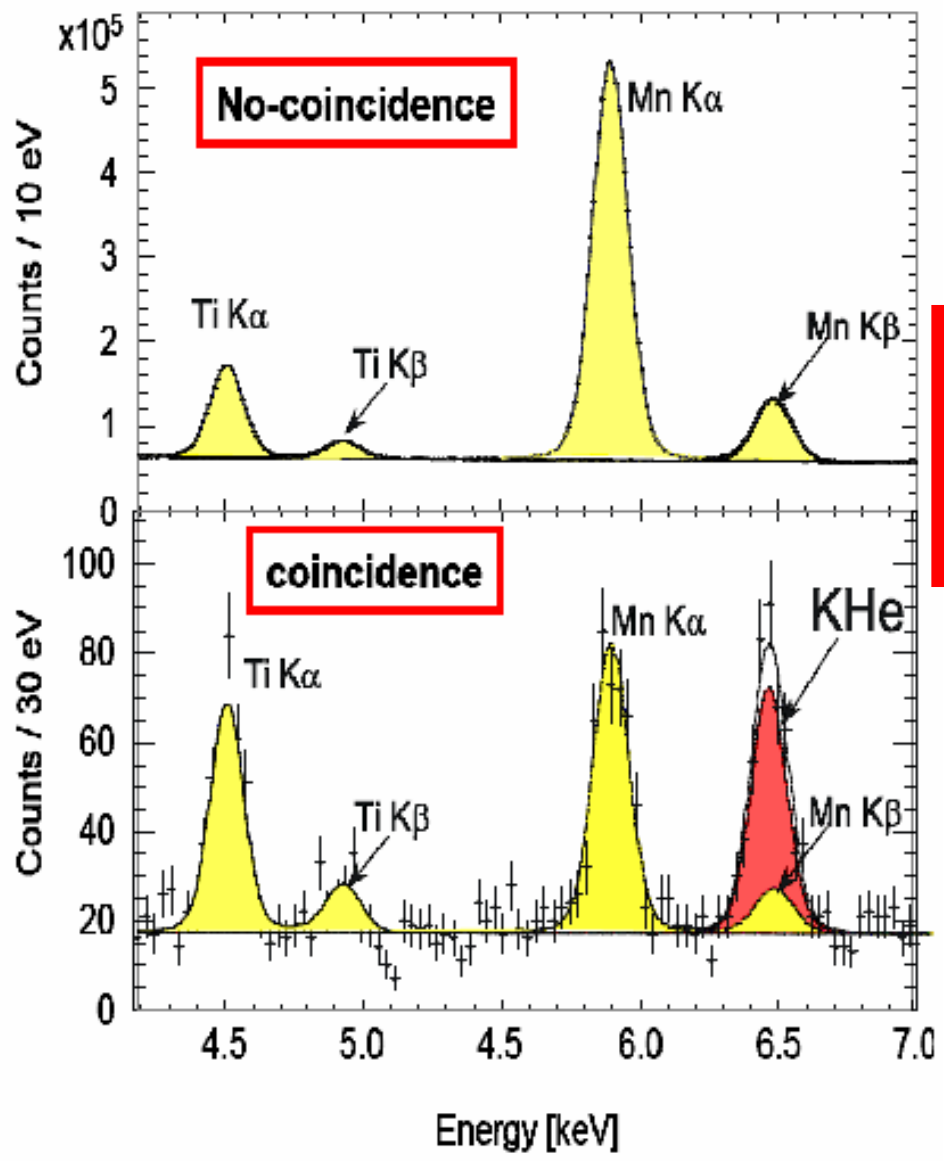
SDD spectrum of X-ray uncorrelated with kaon production.
Ti and Mn X-ray peaks are produced by the ^{55}Fe source in normal condition of beam

Energy resolution: FWHM (@6.4 keV): 151 ± 2 eV

Triple coincidences

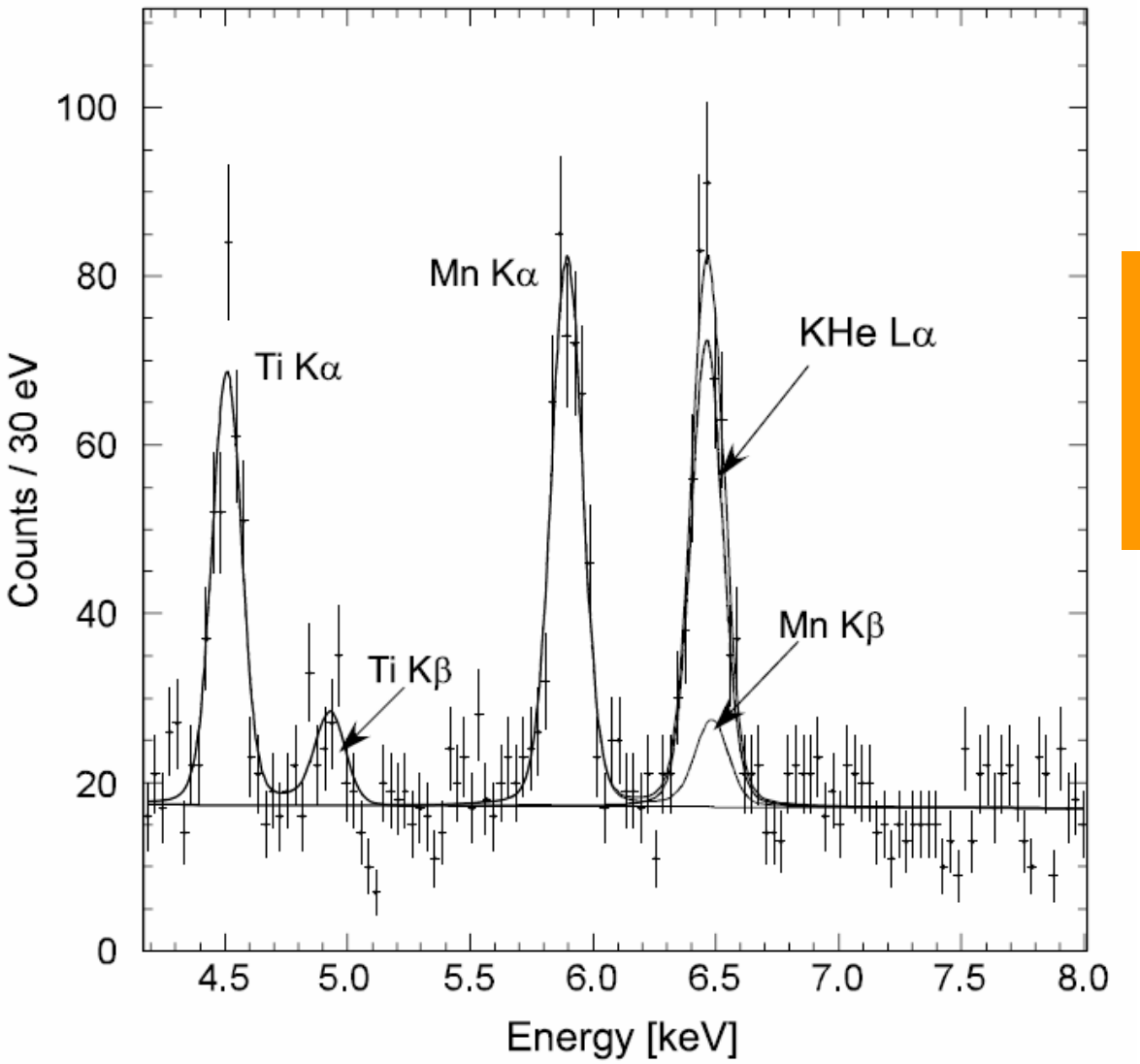






Background suppression more than 10^4

Energy spectrum of K-^{4}He X-rays



Energy of K^{4}He L_α (3d→2p) line:

E_{exp} = 6463.6±5.8 eV

New results of K-^{4}He 2p level shift

E_{exp} = 6463.6±5.8 eV

$E_{e.m.}$ = 6463.5±0.2 eV

$\Delta E = E_{exp} - E_{e.m.} = 0 \pm 6(stat) \pm 2(syst)$ eV

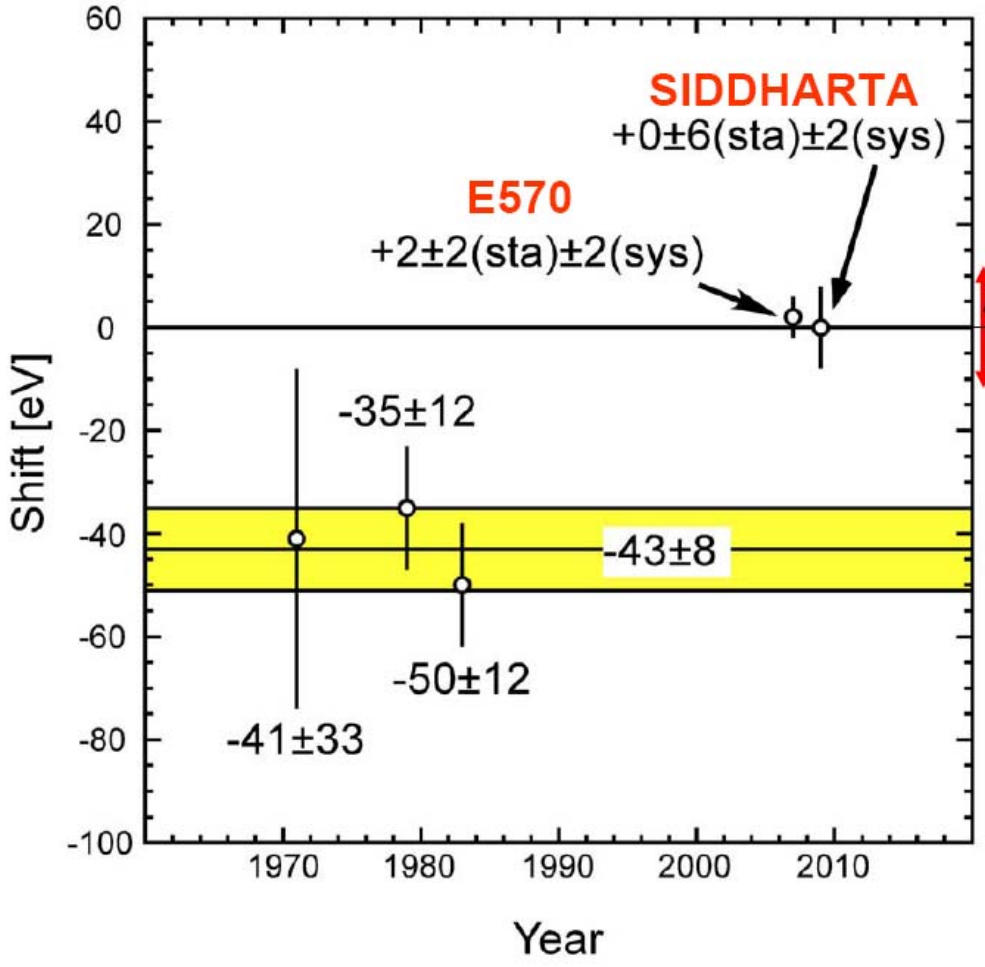
Published in PLB 681(2009) 310-314

ΔE (eV)	Ref.
-41 ± 33	Wiegand *et al.* [5]
-35 ± 12	Batty *et al.* [6]
-50 ± 12	Baird *et al.* [7]
-43 ± 8	Average of above [1,7]
$+2 \pm 2$ (stat) ± 2 (syst)	Okada *et al.* [10]
0 ± 6 (stat) ± 2 (syst)	This work

SIDDHARTA's results is consistent with the results obtained by E570 experiment

"kaonic helium puzzle" solved

Summary of the K-^{4}He shifts



Akaishi Prediction
-10~ +10 eV

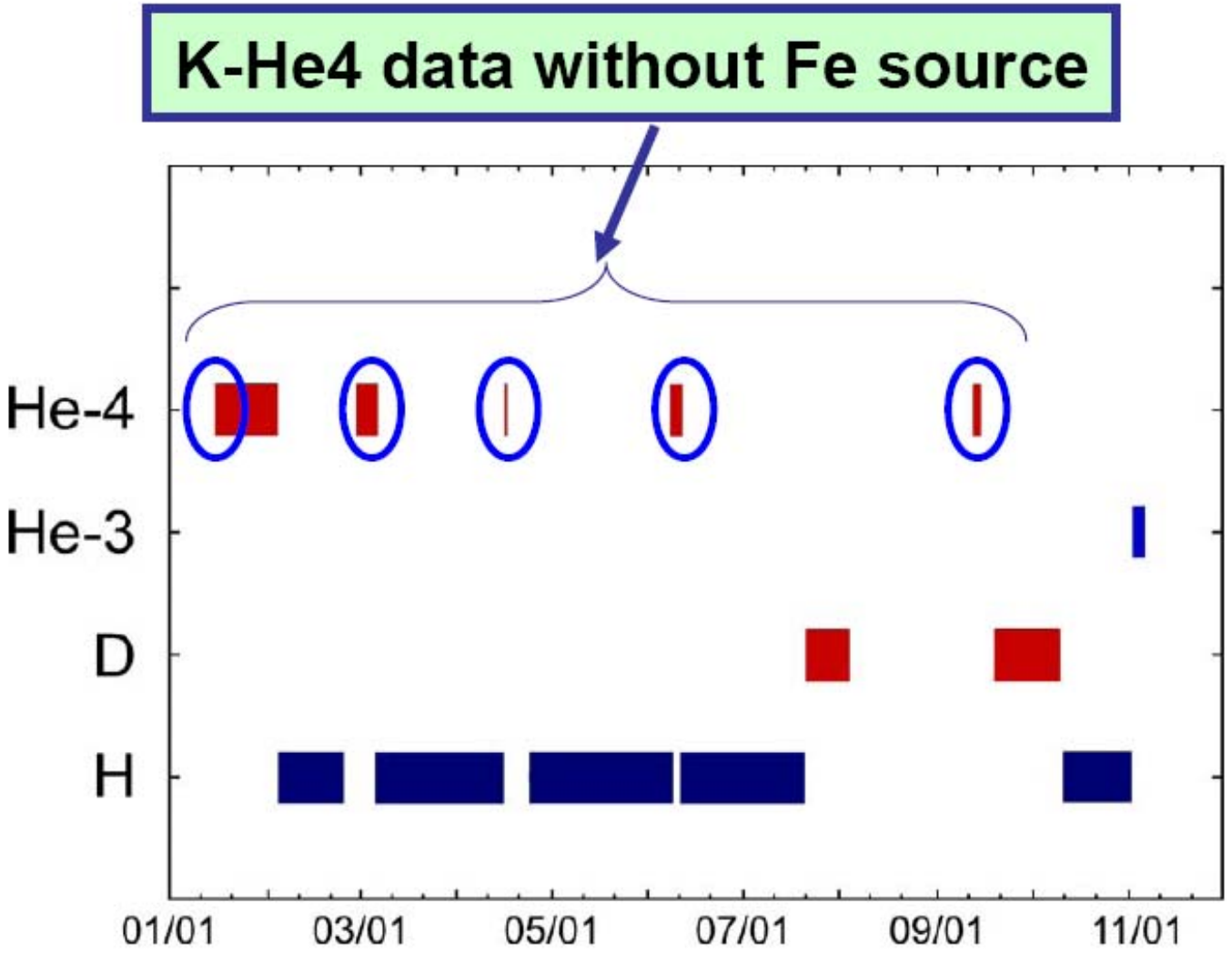
Optical model
~0eV

Optical model
Tiny (~ 0eV)

K-nucl model
Small (<±10 eV)

K-He4 exp
Large (-40 eV)

Data taking periods of SIDDHARTA in 2009



Very preliminary K-^{4}He spectrum

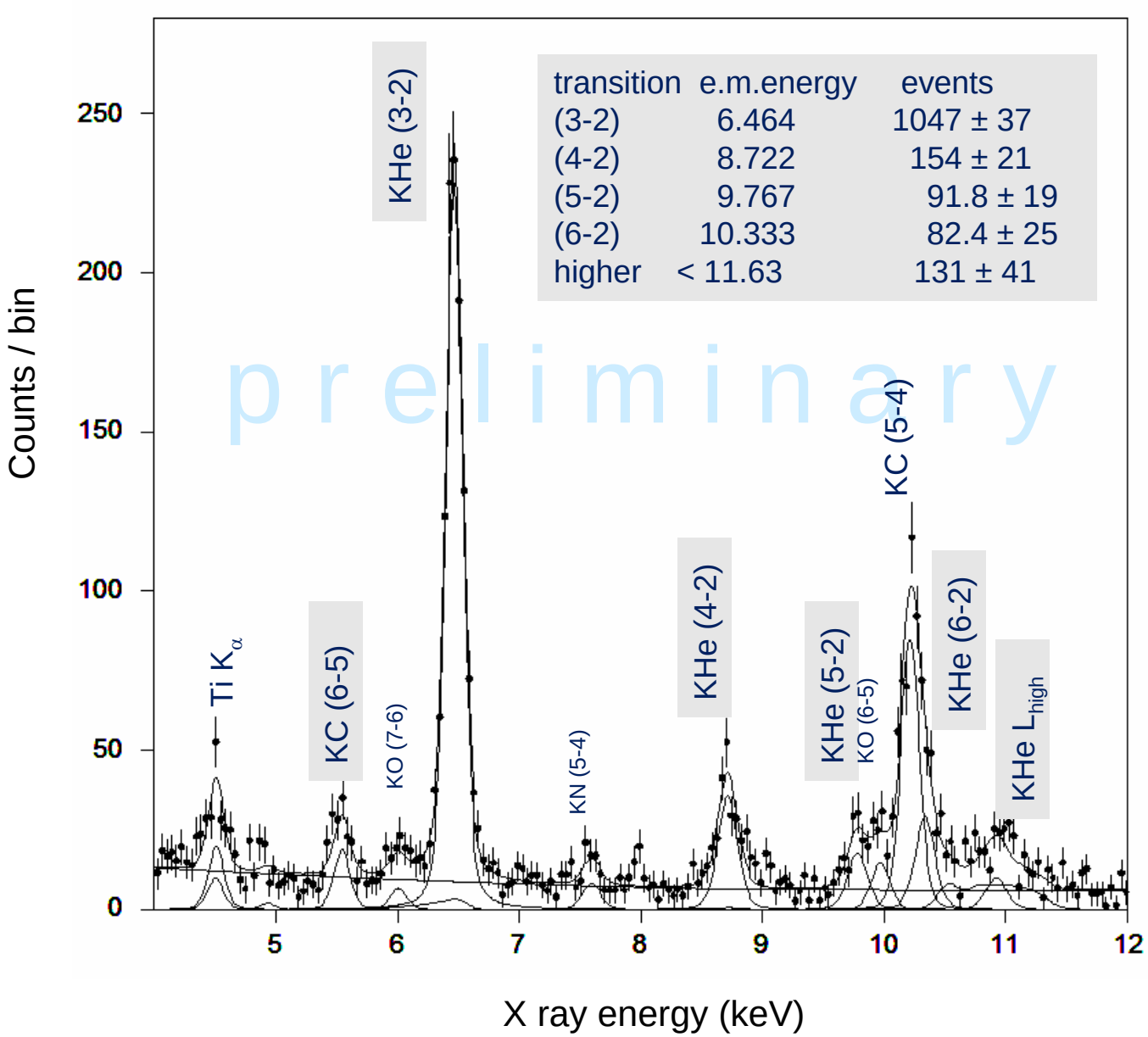
KHe used for **gasstop optimization** + physics interest[1])

data from setup 2 (no Fe55 source)

Higher statistics of the K-^{4}He L lines (L_α, L_β, L_γ)

Smaller statistics in shift, determination of width

X-ray yield information in gas (for the first time)



[1]) compare KEK E570 KHe L lines in liquid He, consistent result, first measurement in gas

The Kaonic-^{3}He case

There are NOT previous experiments done for the X-ray measurements for Kaonic- ^{3}He

Planned experiments: SIDDHARTA (done);

E17 (to be done)

Transition	Kaonic-^{3}He e.m. (eV)(*)
3d->2p	6224
4d->2p	8399
5d->2p	9406

(*)Zeitschrift fur Physik D 15 (1990) 321

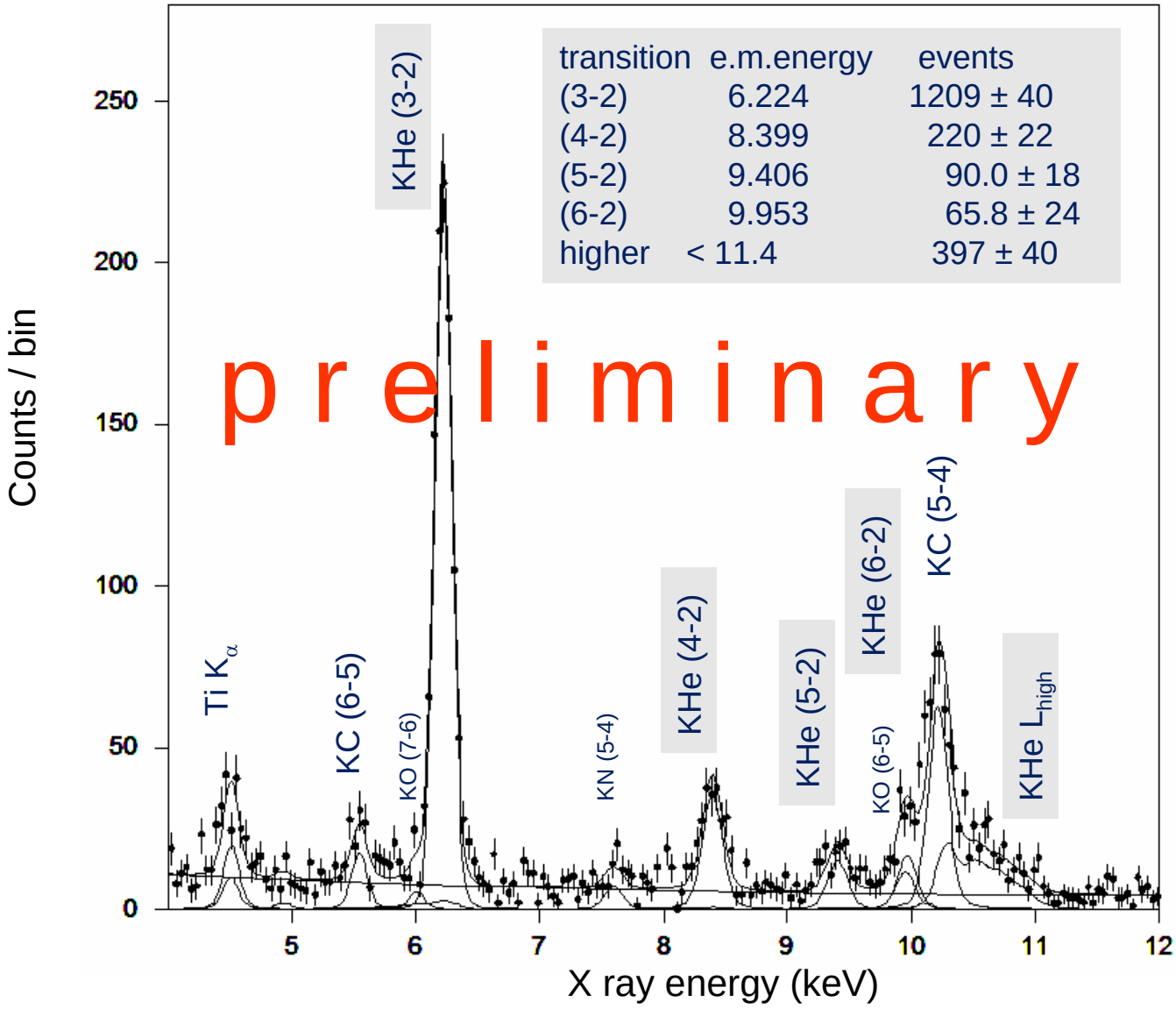
Kaonic ^{3}Helium data SIDDHARTA experiment

The **Kaonic- ^{3}He X-ray data** were taken for about **3 days in November 2009**.

In this period, an **integrated luminosity of about 16 pb^{-1}** was collected.

Very preliminary K-^{3}He spectrum

KHe3
never measured
before !



The statistical error for the transition 3d→2p in K ^{3}He is less than 3 eV.

Conclusions (1)

DAFNE proves to be a **real and "ideal" kaonic atom "factory"**

SIDDHARTA experiment **measured the kaonic helium transitions 3d→2p transitions**:

- for **the first time** in a **gaseous target for ^{4}He**
- for the **first time ever for ^{3}He**

A new value of the 2p level shift for Kaonic ^{4}Helium was obtained: **$\Delta E = 0 \pm 6(stat) \pm 2(syst)$ eV**

Conclusions (2)

Confirmed the small shift obtained by recent experiment E570 for **Kaonic ^{4}Helium**

The **"kaonic helium puzzle"** for **Kaonic ^{4}Helium** is now **solved**

The preliminary analysis of the **3d→2p transitions for Kaonic ^{3}Helium**, indicate that the **statistic error shift is less than 3 eV.**

Future plans

The upgrade of the SIDDHARTA experimental setup

DAFNE 2012

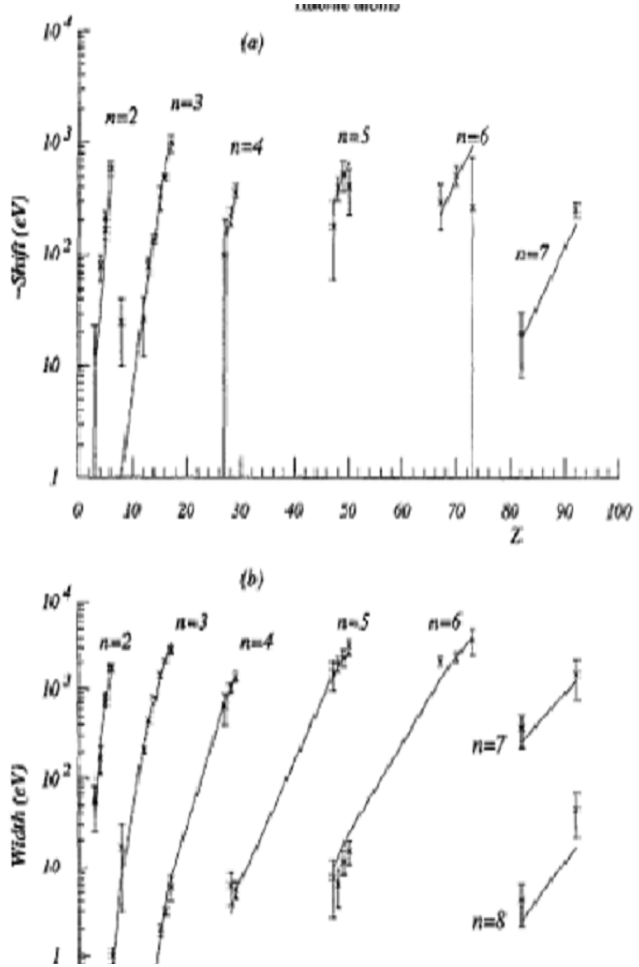
Precise measurements for the X-ray transitions for kaonic hydrogen and kaonic deuterium

Measuring, with higher precision, the X-ray transitions for Kaonic ^{4}He and Kaonic ^{3}He to the 2p level and the first tentative to the 1s level

Kaonic atoms data (Z>3)

The shift and widths of kaonic atom X-ray energy have been measured using targets with atomic numbers from Z=1 to Z-92, which provide very important quantities for understanding the antiKN strong interaction.

C.J. Batty et al., Physics Reports 287(1997) 385-445



The shifts and widths for kaonic atoms with Z≥3 are systematically well understood;

The optical model expressing the kaonic atom data have been used for calculation of the antiKaonN interaction.

There are discrepancies for:

Kaonic Hydrogen (Z=1)

Kaonic Helium (Z=2)

See talk of A. Romero Vidal