Future plans at DAΦNE
Fundamental Physics at the strangeness frontier:

Proposal for a 3-years period (post-SIDDHARTA-2)

High Precision Kaonic Atoms Measurements on DAΦNE:

The strangeness Mendeleev table

Catalina Curceanu, INFN-LNF

62nd LNF Scientific Committee Meeting

November 8, 2021

Based on: https://arxiv.org/pdf/2104.06076.pdf

SELECTED PROPOSED MEASUREMENTS:
scientific interest, feasibility, community…

Fundamental physics at the strangeness frontier at DAΦNE.
Outline of a proposal for future measurements.

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arXiv:2104.06076v1 [nucl-ex] 13 Apr 2021

The DAΦNE collider at INFN-LNF is a unique source of low-energy kaons, which was used by the DEAR, SIDDHARTA and AMADEUS collaborations for unique measurements of kaonic atoms and kaon-nuclei interactions. Presently, the SIDDHARTA-2 collaboration is underway to measure the kaonic deuterium exotic atom. With this document we outline a proposal for fundamental physics at the strangeness frontier for future measurements of kaonic atoms and kaon-nuclei interactions at DAΦNE, which is intended to stimulate discussions within the broad scientific community performing research directly or indirectly related to this field.

SciCom:

The proponents of the kaonic physics proposal are invited to elaborate an updated scheme with a reduced but realistic scope, in particular in terms of the required integrated luminosity that can realistically be delivered within the upcoming 3-5 years.

Part. and Nuclear physics
QCD @ low-energy (Ph1)

Astrophysics
EOS Neutron Stars (Ph2)

Kaonic atoms high precision measurements

Dark Matter studies (Ph3)

Fundamental physics
New Physics (Ph4)

Theoreticians support from (but not only):

(Ph1) (Ph2) STRONG-2020 EU, i.e. THEIA WP Strange Hadrons and the Equation-of-State of Compact Stars; ISNEUMAT-INFN,…
(Ph3) Merafina, Yamazaki, Akaishi…
(Ph4) Pospelov; Pohl, Indelicato…

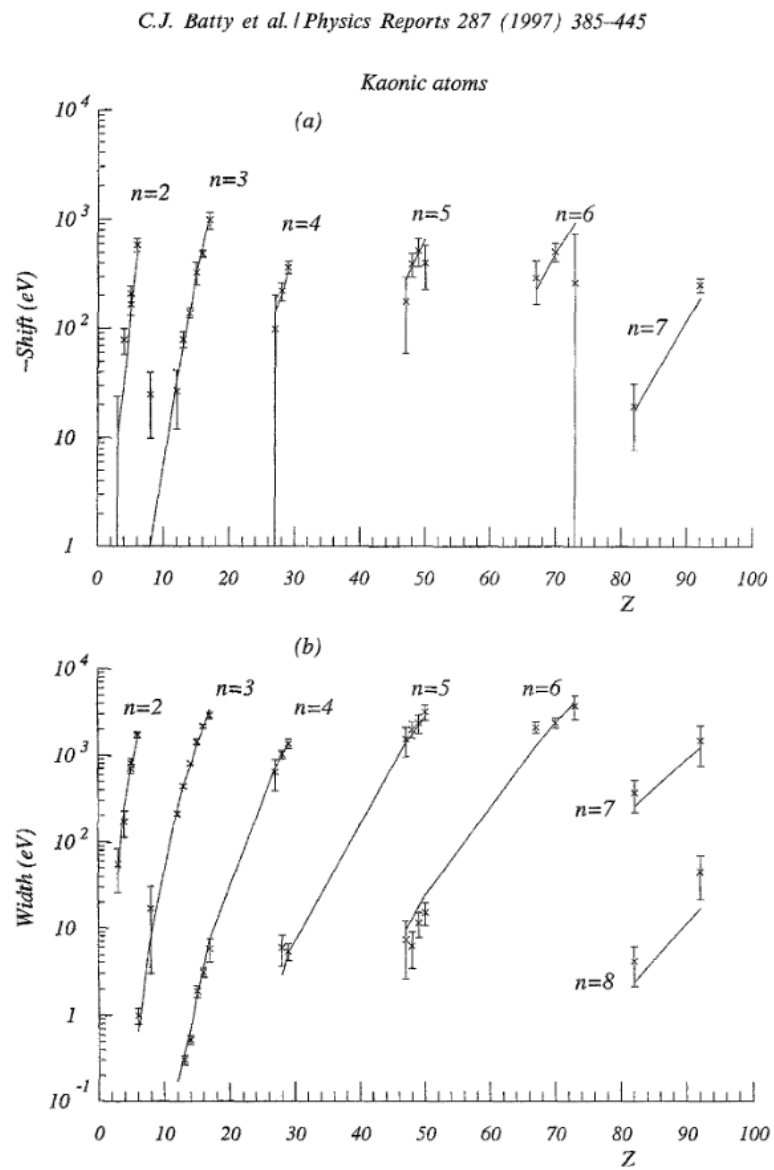
Strangeness precision frontier at DAΦNE: a unique opportunity for measurements of kaonic atoms along the periodic table: **will represent a reference in physics with strangeness**

Present status: old and very old measurements with low precisison (some even wrong: kaonic helium puzzle)

We propose to do precision measurements along the periodic table at DAΦNE for:

- Selected light kaonic atoms
- Selected intermediate mass kaonic atoms
- Selected heavy kaonic atoms

charting the periodic table



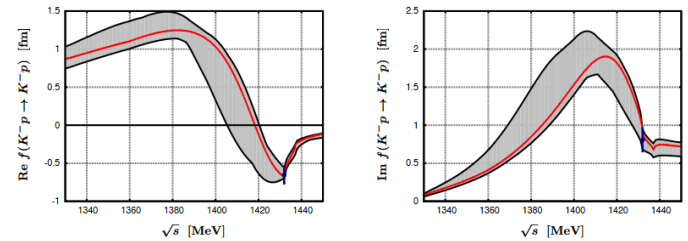
Participating Institutes: (> 50 proponents all experimentalists)

1) INFN-LNF, Italy: Curceanu, Bazzi, Clozza, Guaraldo, Iliescu, Miliucci, Scordo, D. Sirghi, F. Sirghi, Vazquez Doce; De Paolis, Napolitano, Sgaramella,
2) Politecnico and INFN Milano, Italy: Fiorini, Carminati, Deda
3) CNR-IMEM, Parma, Italy: Zappettini, Betteli
4) INFN Trieste: S. Piano, P. Camerini
5) INFN Torino: A. Filippi
6) SMI – OeAW, Vienna, Austria: Amsler, Zmeskal, Shi, Tuechler
7) RIKEN, Japan: Asano, Itahashi, Iwasaki, Ma, Murayama, Outa, Sakuma, Yamaga
8) RCNP, Japan: Inoue, Kawasaki, Noumi, Shirotori
9) ELPH, Japan: Ohnishi, Sada, Yoshida
10) JAEA, Japan: Hashimoto
11) Osaka University, Japan: Akaishi
12) Chubu University, Japan: Okada
13) Univ. Zagreb, Croatia: Bosnar, Friscic, Makek, Zugec
14) Jagiellonian Univ.,Poland: Moskal, Khreptak, Niedźwiecki, Skurzok
15) TUM Munich,Germany: Fabbietti
16) Univ, Mainz: Pochodzalla, Achenbach
17) IFIN-HH, Bucharest, Romania: M. Bragadireanu
18) Sorbonne Université,Campus Pierre et Marie Curie, France: Indelicato
19) CNRS, Institut des NanoSciences de Paris, France: Trassinelli
20) Santiago de Compostela, Spain: Romero Vidal
21) The George Washington University, USA: Strakovsky
22) Old Dominion University, USA: Moskov
Plus contacts with other potential participants

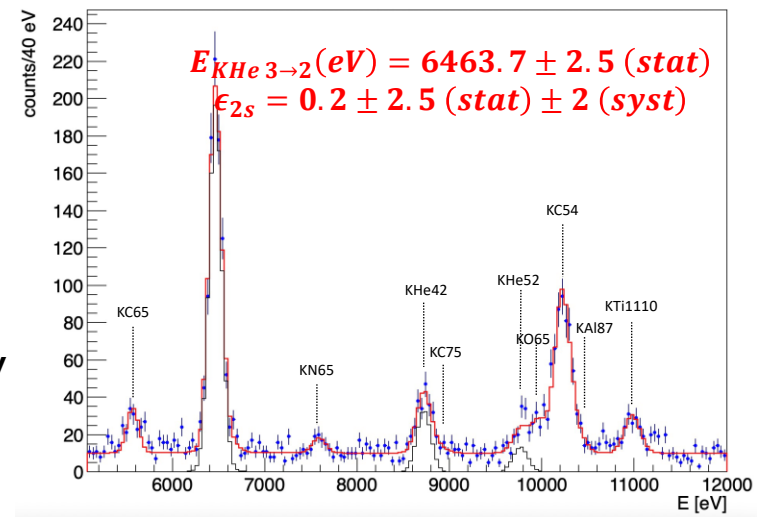
Support from about 50 theoreticians not listed above

Light and Heavy Kaonic Atoms measurements: LHKA

1) **KH** *Kaonic Hydrogen*: **200 pb^{-1}** – with SIDDHARTA-2 setup – to get a precision < 10 eV (present precision about 40 eV shift and 90 eV width) very important for theory (QCD at threshold with strangeness – physic below threshold) – as soon as possible! (Weise, Nucl Phya A 2021)
Ph1, Ph2



2) Setup with 1 mm SDD detectors:
Kaonic Li; Be; B; He in the energy region 10-40 keV (see talk Sgaramella for Li case) – precision < 2-3 eV
SDDs are financed and ordered (FBK)
Ph1, Ph2, Ph4
Will be ready within 2022!

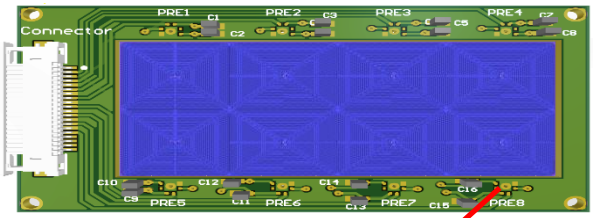


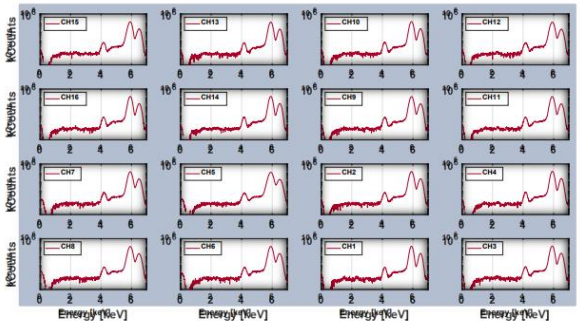
2) **Setup with 2 HPGe detectors**
Heavy kaonic atoms: transitions above 70 keV
Kaonic Pb, W – precision at the level of 3-10 eV
Ph2, Ph4
HPGe available (Zagreb) and ready for use

Total required integrated luminosity: 200 + 400 (200) pb^{-1}

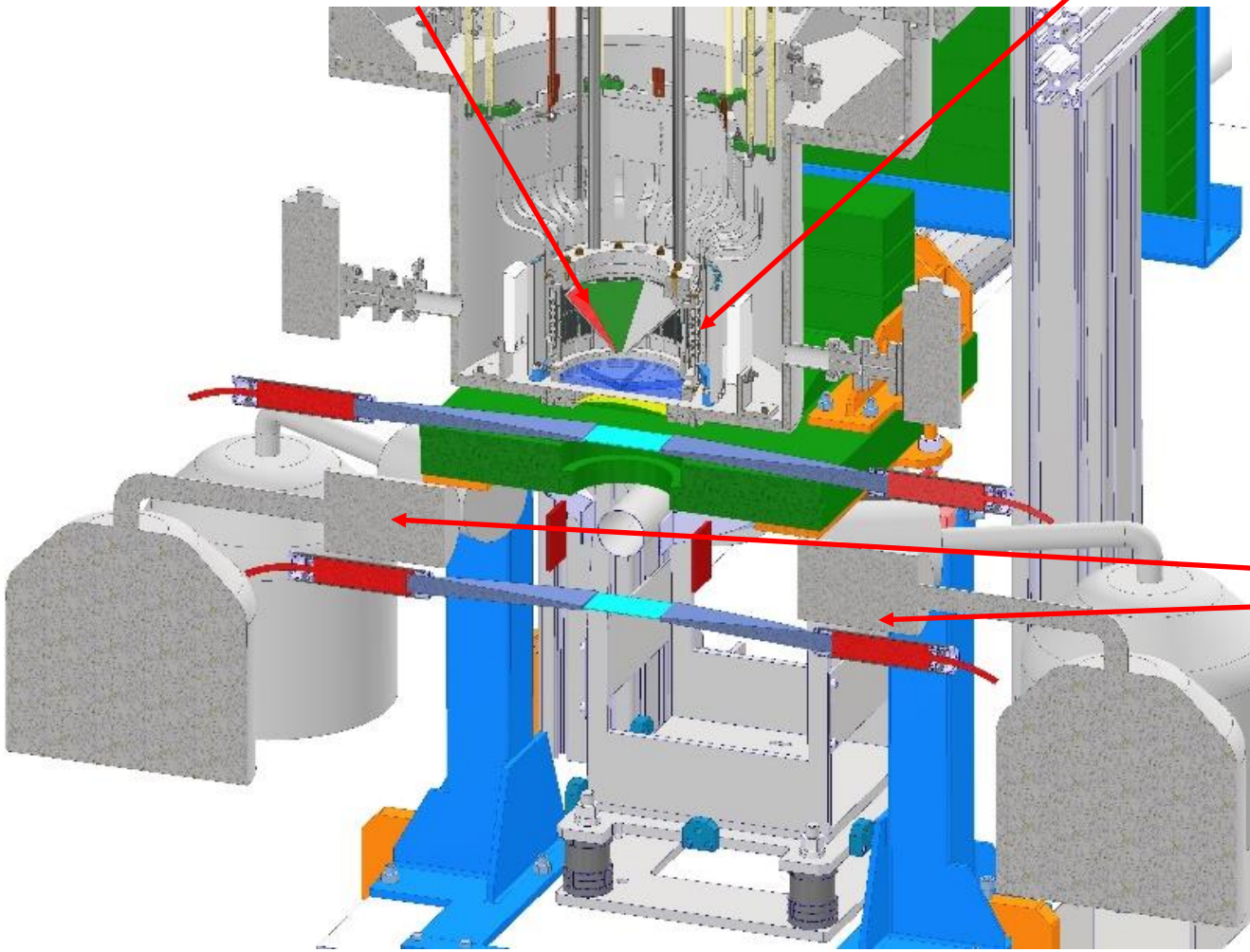
Light and heavy kaonic atoms measurements: LHKA setup

Li, Be, B targets





16 spectra acquired with an ^{55}Fe source with a 1000 μm thick SDD array (peaking time of the filter was set to 3 μs)



Intermediate and Heavy Kaonic Atoms measurements IHKA

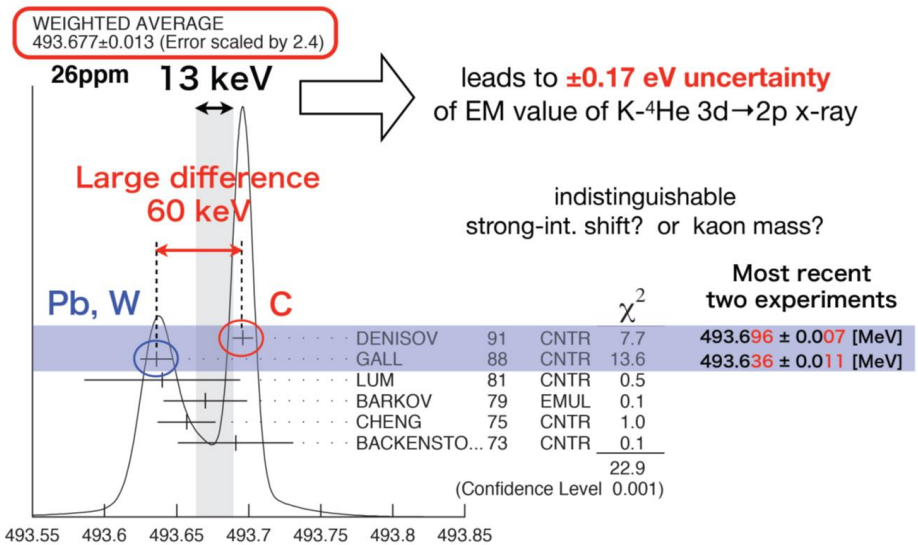
1) Setup with CdZnTe detectors:

Kaonic Ti, V, Zr, Ag, between 40 and 200 keV keV – precision 3-5 eV

CdZnTe are developed within ASTRA STRONG-2020 project

Will be ready within 2023

Ph1, Ph2, Ph3



Uncertainty in electron screening. Gamma-ray contamination(Pb,W).

→ **new measurement with low-Z gas targets**

3) **Setup with 2 HPGe detectors continued**

Heavy kaonic atoms: transitions above 70/100 keV

Kaonic Co, Au, Pt – precision at the level of 5-10 eV (depending on energy of transition)

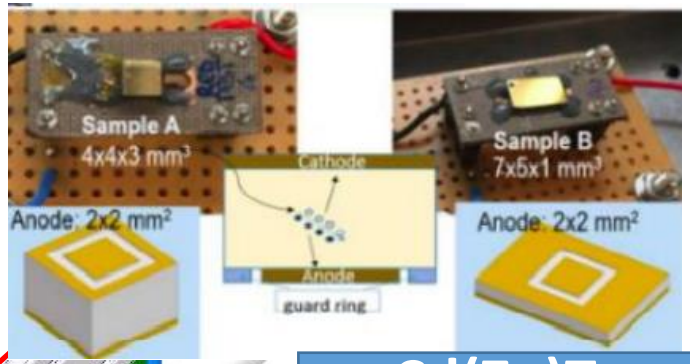
HPGe available and ready for use (Zagreb Univ. plus Mainz – additional HPGe)

Ph1, Ph2, Ph3

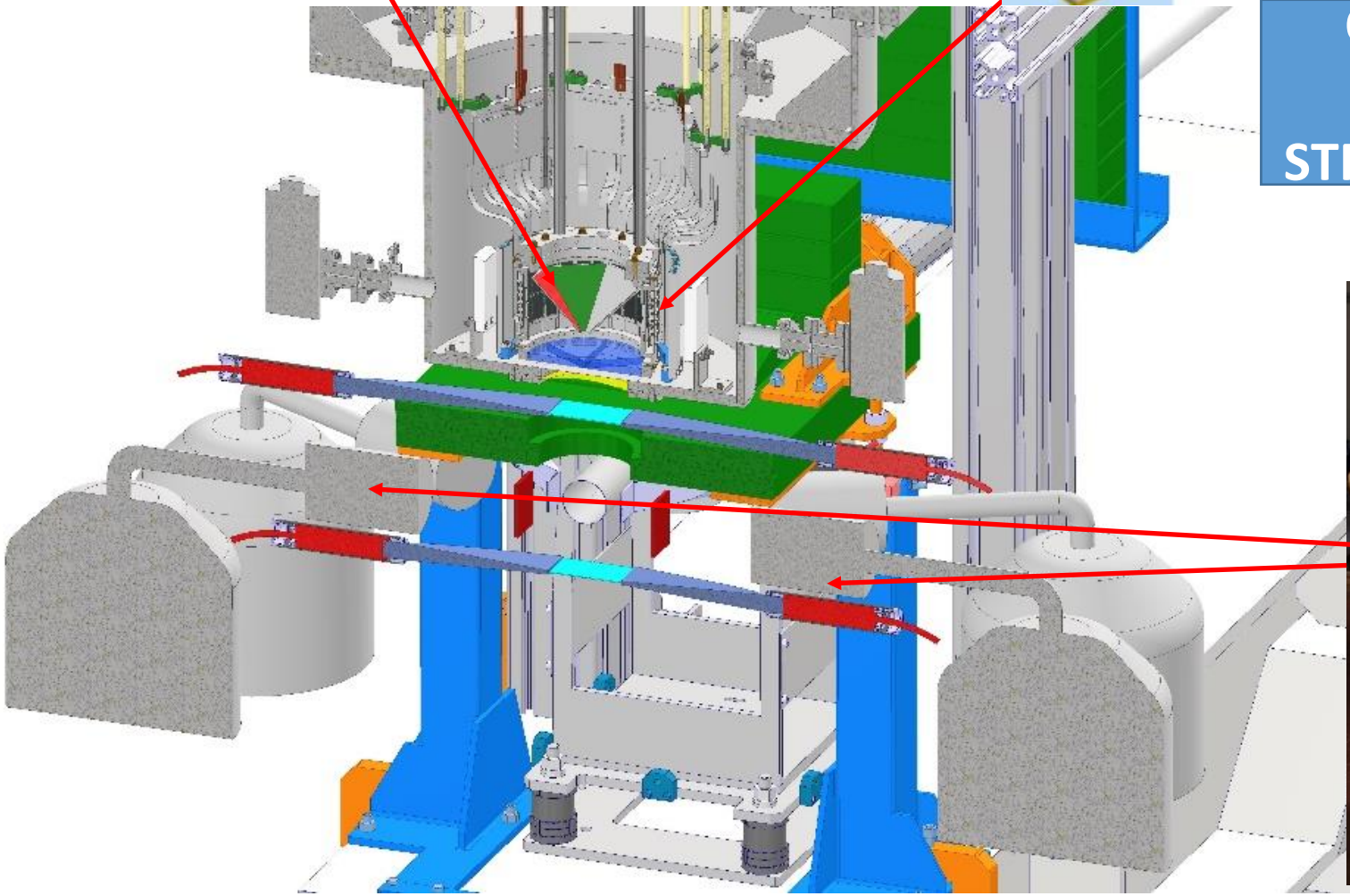
Total required integrated luminosity: 400 (200) pb^{-1}

Intermediate and heavy kaonic atoms measurements: IHKA

Ti, V, Zr, Ag targets



Cd(Zn)Te
ASTRA
STRONG-2020



Ultra-High precision measurements of Kaonic Atoms UHKA

1) Setup with 8 VOXES lines (crystal HAPG spectrometer):

Kaonic C, N, He: **precision < 0.5 eV**

VOXES detector developed; financing for building 8 lines required (possibility of external funding)

PHYSICAL REVIEW LETTERS **126,** 173001 (2021)

Will be ready within early 2025

Ph4, Ph1, Ph3, Ph2

Testing Quantum Electrodynamics with Exotic Atoms

Nancy Paul,[1,*] Guojie Bian,[1,2,†] Toshiyuki Azuma,[3,‡] Shinji Okada,[4,§] and Paul Indelicato[1,‖]

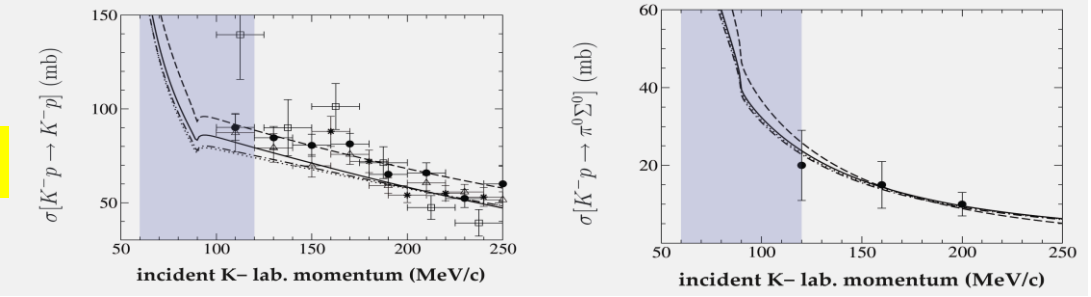
2) Feasibility test (measurements) for kaon-nuclei scattering exp.

With TPG detector

TPC developed by Sendai ELPH Japan, SMI-Vienna and LNF-INFN (HP2, HP3 EU)

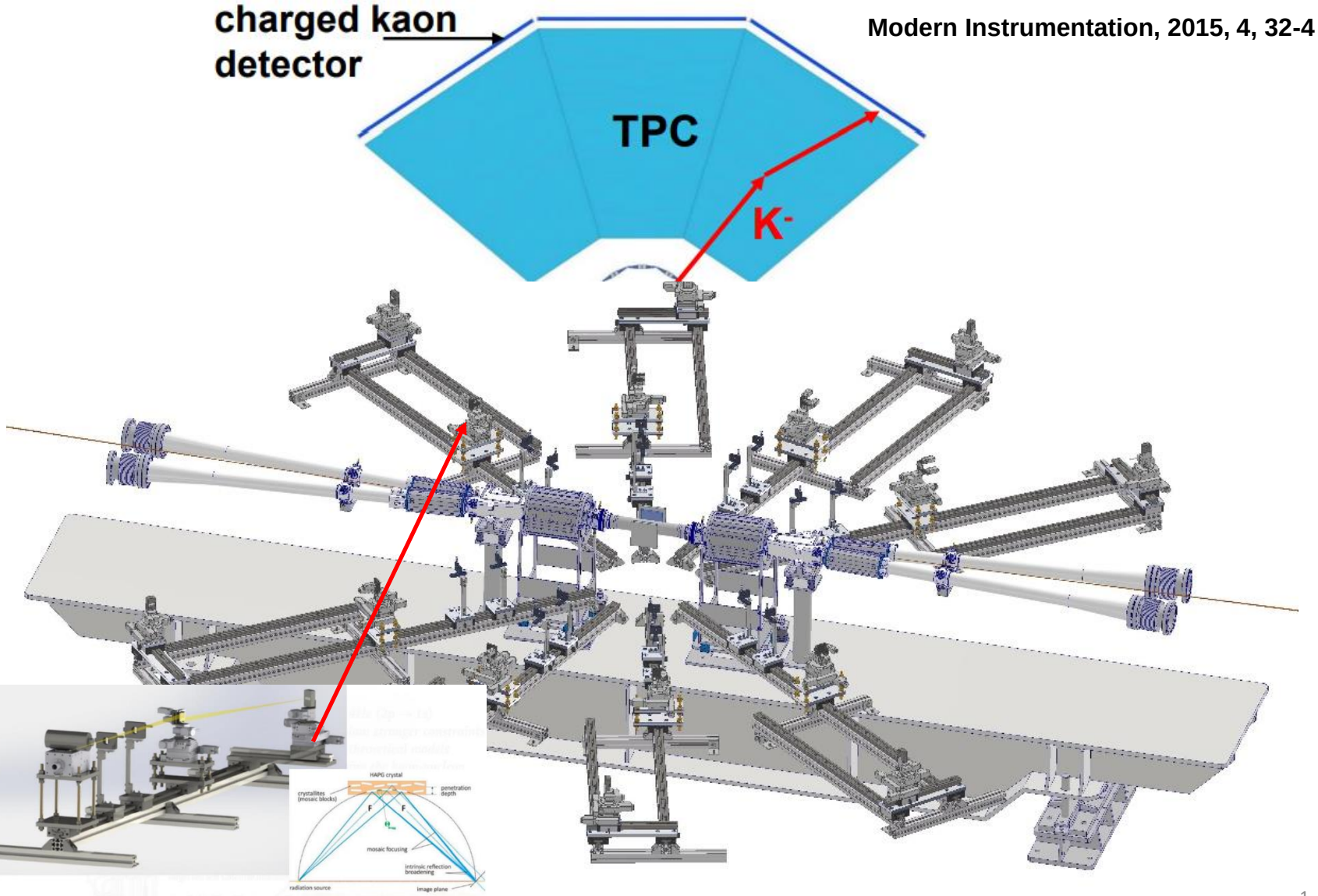
KP nuclear scattering – feasibility for FUTURE MEASUREMETS (2 years after KA)

Total required integrated luminosity: 400 pb^{-1}



Ultra-high precision measurements of kaonic atoms UHKA

Modern Instrumentation, 2015, 4, 32-4

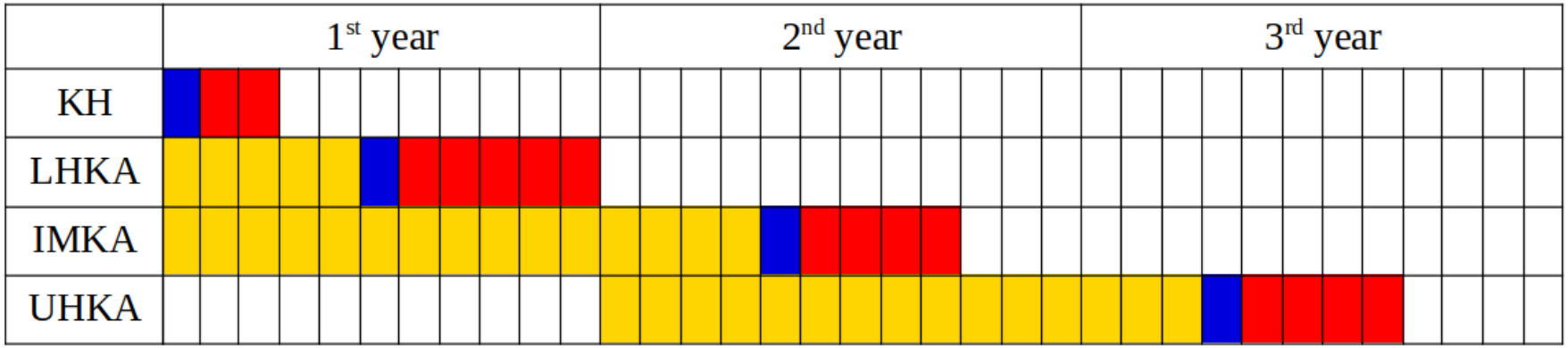


HAPG mosaic crystals in Von Hamos configuration:
- Higher intrinsic reflectivity wrt standard crystals
- VH configuration to exploit sagittal focusing
- Optical optimisation to work with millimetric/centimetric sources

JINST 13 (2018) 04, C04002 CSN5 Young Research (Scordo)

Gantt chart – possible implementation of the kaonic atoms measurements

Total integrated Luminosity:
200 + 400 (200) + 400 (200) + 400 pb^{-1}



Preparation of the experiment
Installation and commissioning
Data taking

In Conclusion, we propose to perform fundamental Physics at the strangeness frontier at DAΦNE studies:

High Precision Kaonic Atoms Measurements on DAΦNE:

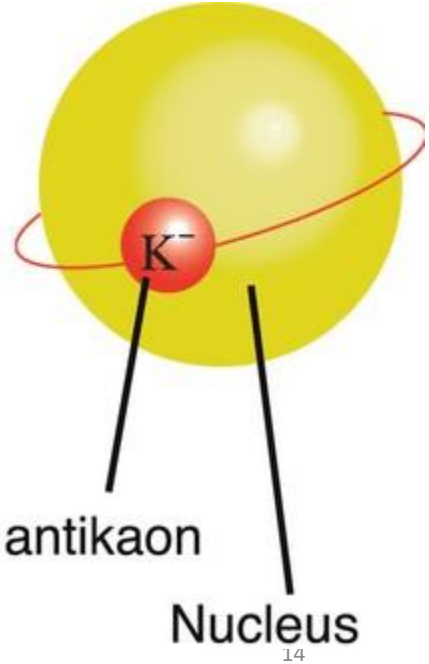
The strangeness Mendeleev table

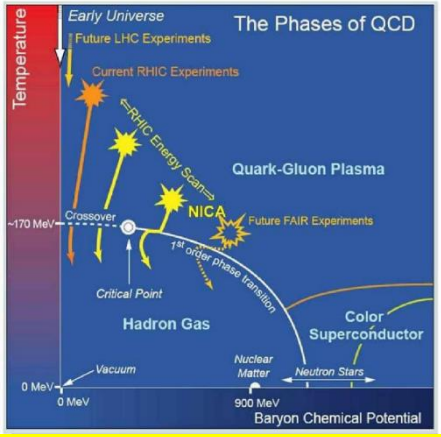
We presented a program for performing unique measurements of kaonic atoms along the periodic table to contributing to understand physics going from the strong interaction (symmetry breaking) to neutron stars, and from Dark Matter to Physics Beyond Standard Model, setting LNF in forefront of these studied.

A strong international community is putting forward this realistic and feasible programme in particular in terms of the required integrated , that can be delivered within the upcoming 3-5 years, with support from National and European projects.

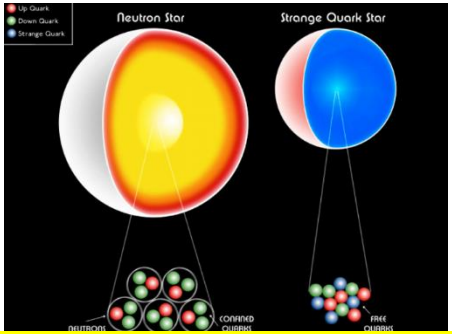
EXtensive Kaonic Atoms research:
from LIthium and Beryllium to Uranium

EXKALIBUR

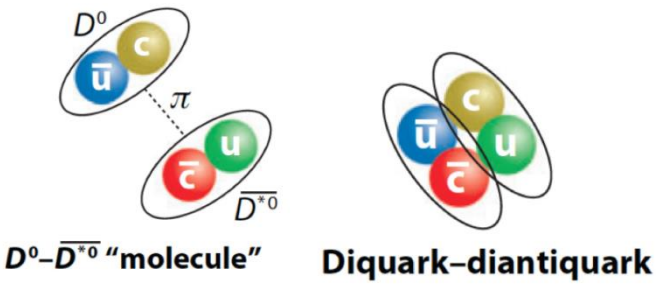




Cold Dense matter

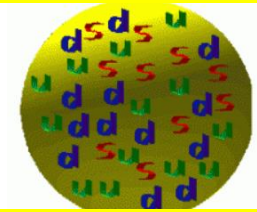


Neutron star EOS



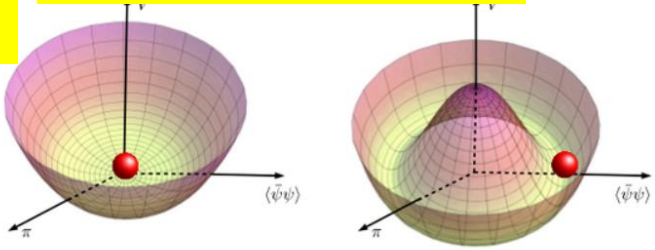
Particles structure

Strangeness Fundamental Physics

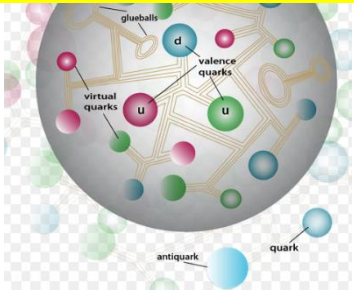


Strangelets & Dark Matter

QCD Chiral symm.



Mass generation, visible Universe



"Fundamental physics with exotic atoms and radiation detectors" Symposium

FQXi FOUNDATIONAL QUESTIONS INSTITUTE

INFN-LNF – 25-26/11/2021 – Aula Salvini

STRONG-2020

25–26 Nov 2021
Laboratori Nazionali di Frascati
Europe/Rome timezone

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