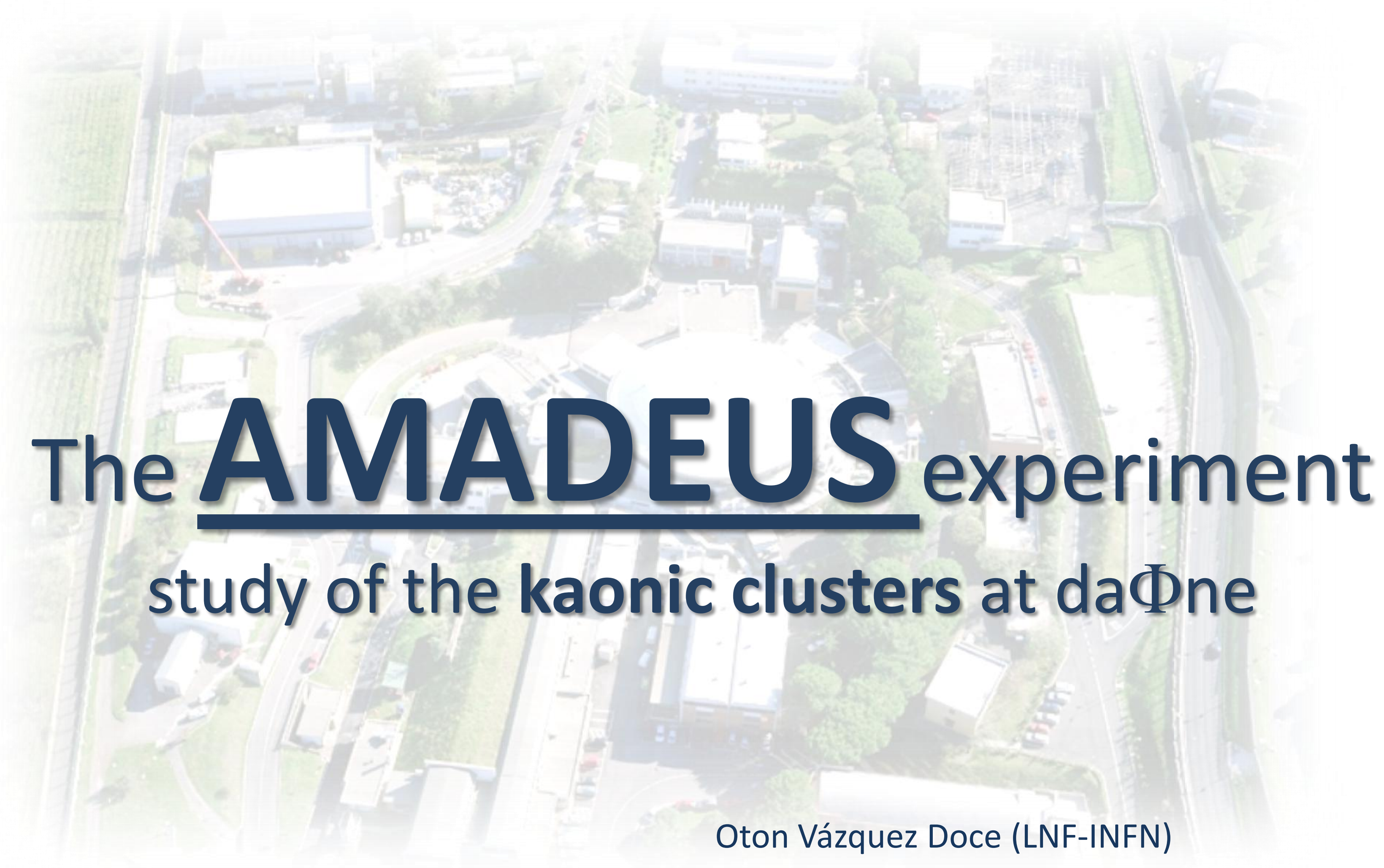


The AMADEUS experiment

study of the **kaonic clusters** at daΦne

Oton Vázquez Doce (LNF-INFN)
on behalf of the AMADEUS Collaboration

LNF Spring School, May 13, 2008.

Introduction

- What (and where) is AMADEUS?

AMADEUS scientific case

- Why to do it? What are the kaonic clusters?

Framework of AMADEUS

- What do we know about kaonic clusters?

Performing AMADEUS

- How are we going to do it? Which is the experimental setup?

Conclusions

- What do I have to remember?

-what?

-where?

ANTIKAONIC
MATTER
AT
DAΦNE: AN
EXPERIMENT
WITH UNRAVELING
SPECTROSCOPY

Letter of Intent

Study of deeply bound kaonic nuclear states at DAΦNE2

AMADEUS Collaboration

111 scientists from 33 Institutes of 13 Countries signed the LOI

March 2006

-kaonic clusters

A hadron physics important and unresolved topic:

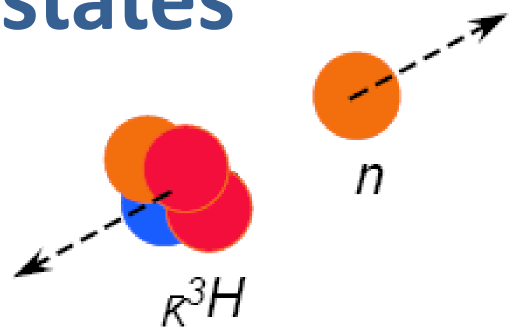
How the hadronic masses and interactions change in nuclear medium

Approach by means of the predicted

Deeply bound kaonic nuclear states

firstly suggested by S. Wycech

(S. Wycech, Nucl. Phys. A450 (1986) 399c)



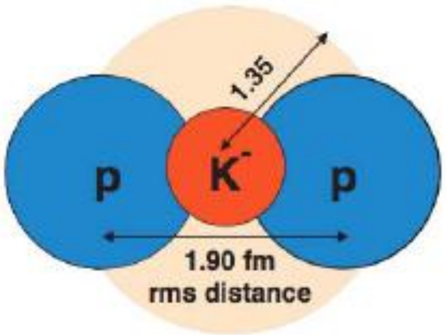
Might offer the <u>ideal condition</u> to study how the **<u>low-energy QCD</u>** spontaneous and splicit Chiral-simmetry breaking changes in the **<u>nuclear enviroment.</u>**

Y. Akaishi and T. Yamazaki *"Nuclear bound states in light nuclei"*

(Phys. Rev. C65 (2002) 044005)

•Prediction based on the interpretation of the s-wave, isospin I=0 **Λ(1405)** resonance as a **K^-p bound state**

•Creation of a $\bar{K}N$ potential as to similtaneously reproduce data from $\bar{K}N$ **scattering lenghts** and binding energy and width of **kaonic hydrogen**



Strong attractive I=0 $\bar{K}N$ interaction favors discrete nuclear states **bound 100-200 MeV** and **Γ≈20-30 MeV**.

Shrinkage effect of a K on core nuclei forming unusual **dense nuclear medium** (5-10 times nuclear density)

Kaonic Clusters contribution to fundamental physics

- Modification of the **Kaon mass** and of the **$\bar{K}$N interaction in the nuclear medium** (symmetry breaking of QCD)

- Transition from the **hadronic phase** to a **quark-gluon phase** (changes of vacuum properties of QCD and quark condensate)

- Partial **restoration of Chiral simetry** in nuclear medium

- Behaviour of strange particles and **kaon condensation** in dense nuclear matter (astrophysics: dynamics of supernovae, neutron stars, black holes)

- **Nuclear dynamics** under extreme conditions

-what do we know?

Experimental search for Kaonic Clusters

E471 @ KEK

$He^4(K^-_{stopped},n)K^-ppn$ neutron missing mass

$S^+(3140)$ $\Gamma \leq 23$ MeV B = -194 MeV

FINUDA @ DAΦNE

K^-pp on ^6Li, ^7Li, ^9Be

B = -115 MeV $\Gamma = 67$ MeV

E930 @ BNL-AGS inflight (K^-,n) reactions in water

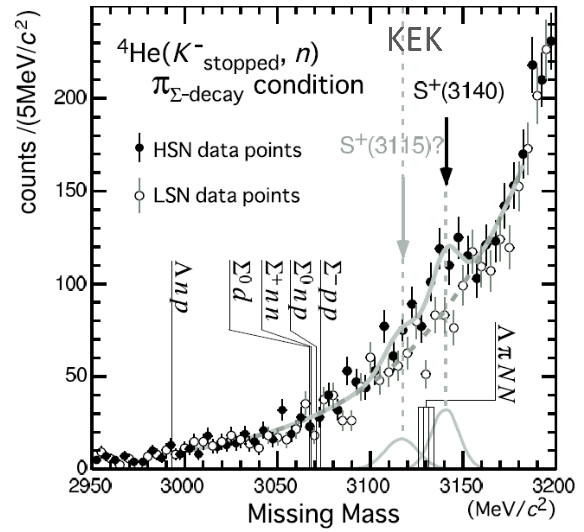
FOPI @ GSI Ni-Ni collisions

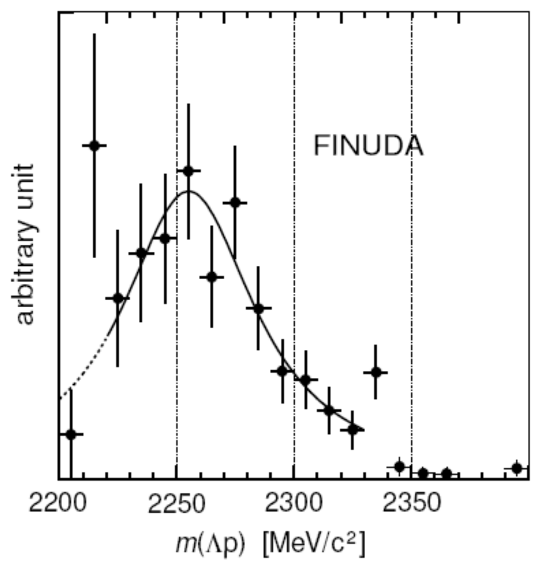
$M_{\Lambda d} = 3170$ MeV B = -149 MeV $\Gamma \approx 100$ MeV

OBELIX old data analysis

$(K^-_{stopped},Li) \to K^-pp$ B=170 MeV/c $\Gamma \leq 25$

$(K^-_{stopped},^4He) \to K^-ppn$ B=-121 MeV/c $\Gamma \leq 60$





Future experiments

FOPI @ GSI-SIS: Al-Al, p-d

E15 @ J-PARC: K^- induced reactions in flight (K^-,N) (K^-,π^-)

FAIR @ GSI

New data from:

FINUDA @ DAFNE

E570 @ KEK

… and AMADEUS!

"a global strategy to attack the major open problems of low-energy QCD"

Theoretical debate

- Alternative interpretations of the present data: double nucleon absorption followed by FSI of the produced particles with daughter nucleus

- Theoretical development of $\bar{K}N$ interaction in free space in the framework of SU(3) Chiral unitary model, and modification due to many-body efects in nuclear medium

- Nature of the Λ(1405) resonance

- Bound kaon approach in the Skyrme model also predicts Kaonic Clusters

- Interpretations with not-so-strongly attractive $\bar{K}N$ potentials

- Nucleon-Nucleon repulsion

- Deeply bound states only in heavy nucleus

⇩

theoreticians demand new complete experimental results!

-How?

AMADEUS aims to **confirm or deny** the existance of such an exotic states by performing a good measurement in a high performance detector on a suitable accelerator using

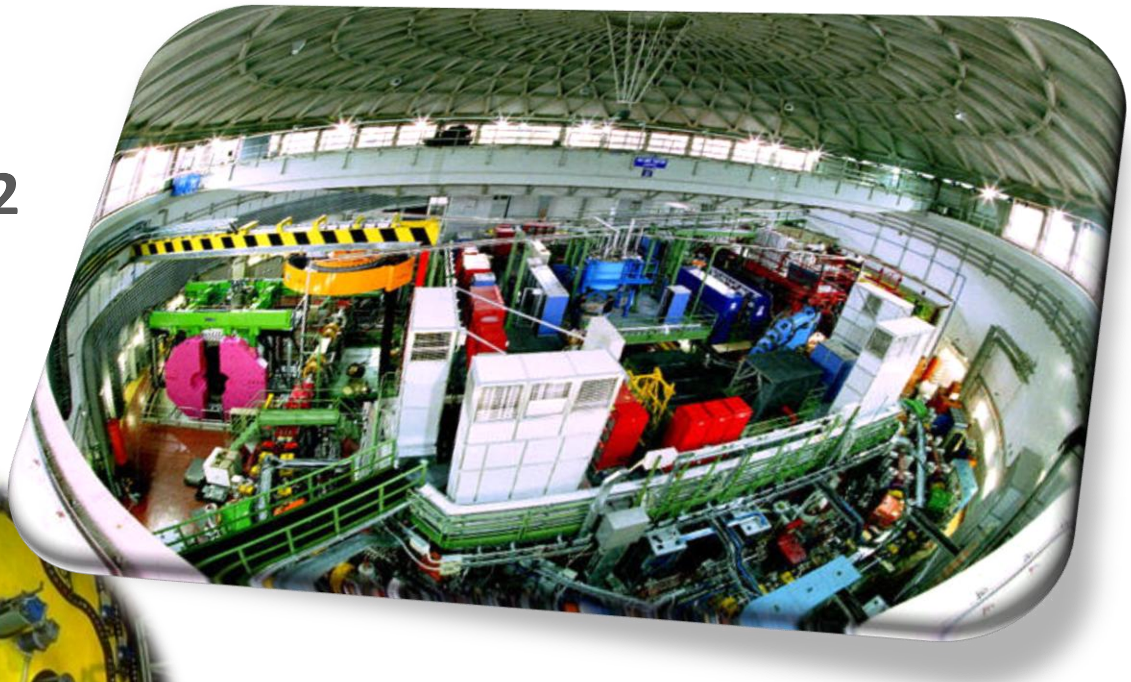
In-medium full hadron spectroscopy

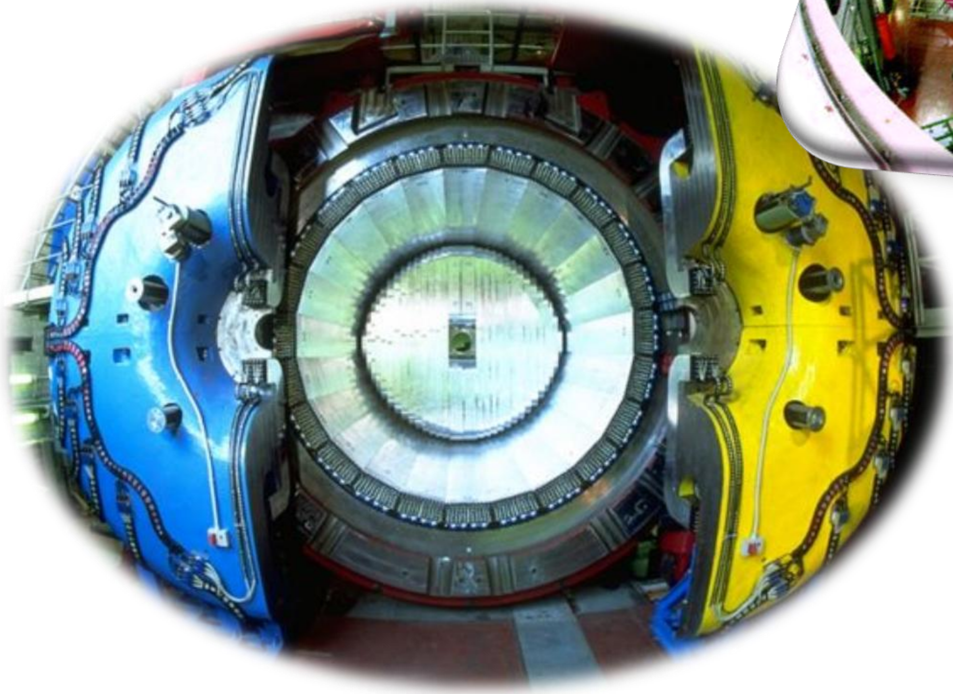
A complete determination of all **formation and decay channel** measuring, binding energies, widths, angular momenta, isospin, sizes, densities…

Detection of:
- charged and neutral particles
- up to about 800 MeV/c
- high efficiency and resolution
- **in 4π geometry (full acceptance)**

Requirements satisfied by…

DAΦNE2





KLOE

Setup performance requirements

Formation processes

$$K^-_{stopped} + {}^4He \rightarrow p + (K^-pnn)$$

$$K^-_{stopped} + {}^4He \rightarrow n + (K^-ppn)$$

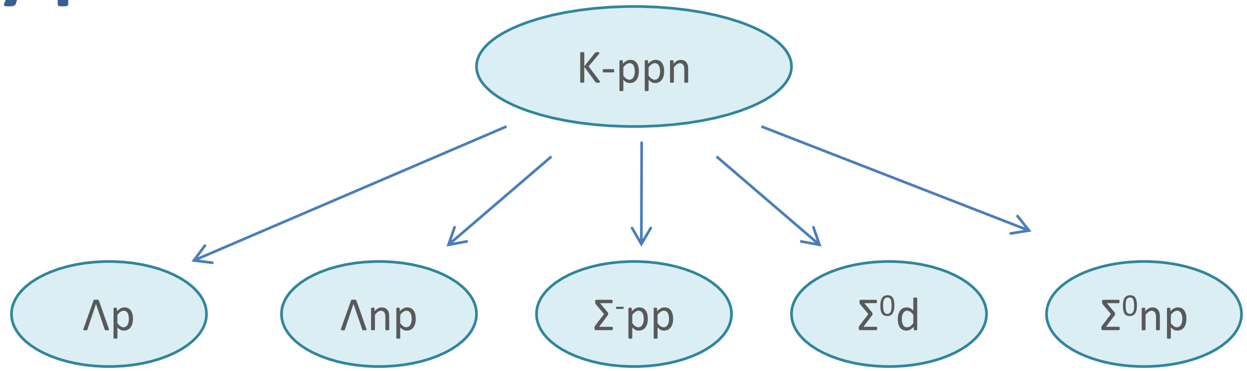
Exotic states produced with (K^-, N) reactions will be observed by the energy distribution of the **ejected protons and neutrons** via the **missing mass spectra** of the (K^-, p) and (K^-, n) reactions.

$\Rightarrow$ **The setup should be capable to measure:**

- Position of K^- stop: primary vertex and K^+ tracking (trigger)
- Outgoing **neutrons** and **protons 400 - 600 MeV/c**

  → KLOE has an experimentally proved capability for neutron detection (KLOnE)

Decay processes



Invariant mass spectroscopy

→ all decay products have to be identified, including hyperons decay products

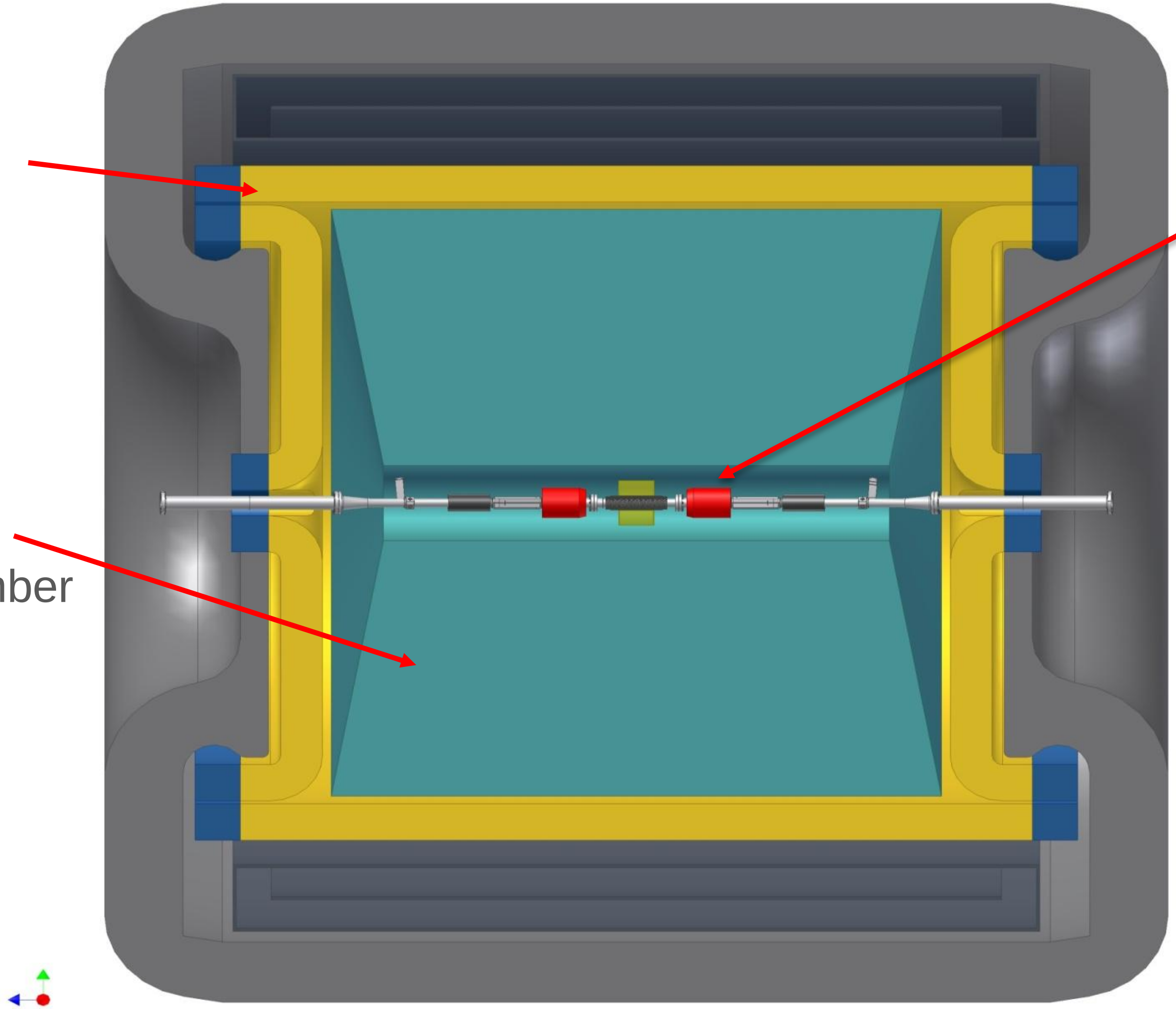
→ 4-momenta of **charged an neutral** particles must be determined

- **protons** 200 - 500 MeV
- **pions** 50 -200 MeV
- **neutrons** 200 -500 MeV
- **deuterons**...

AMADEUS setup within KLOE

KLOE – EMC

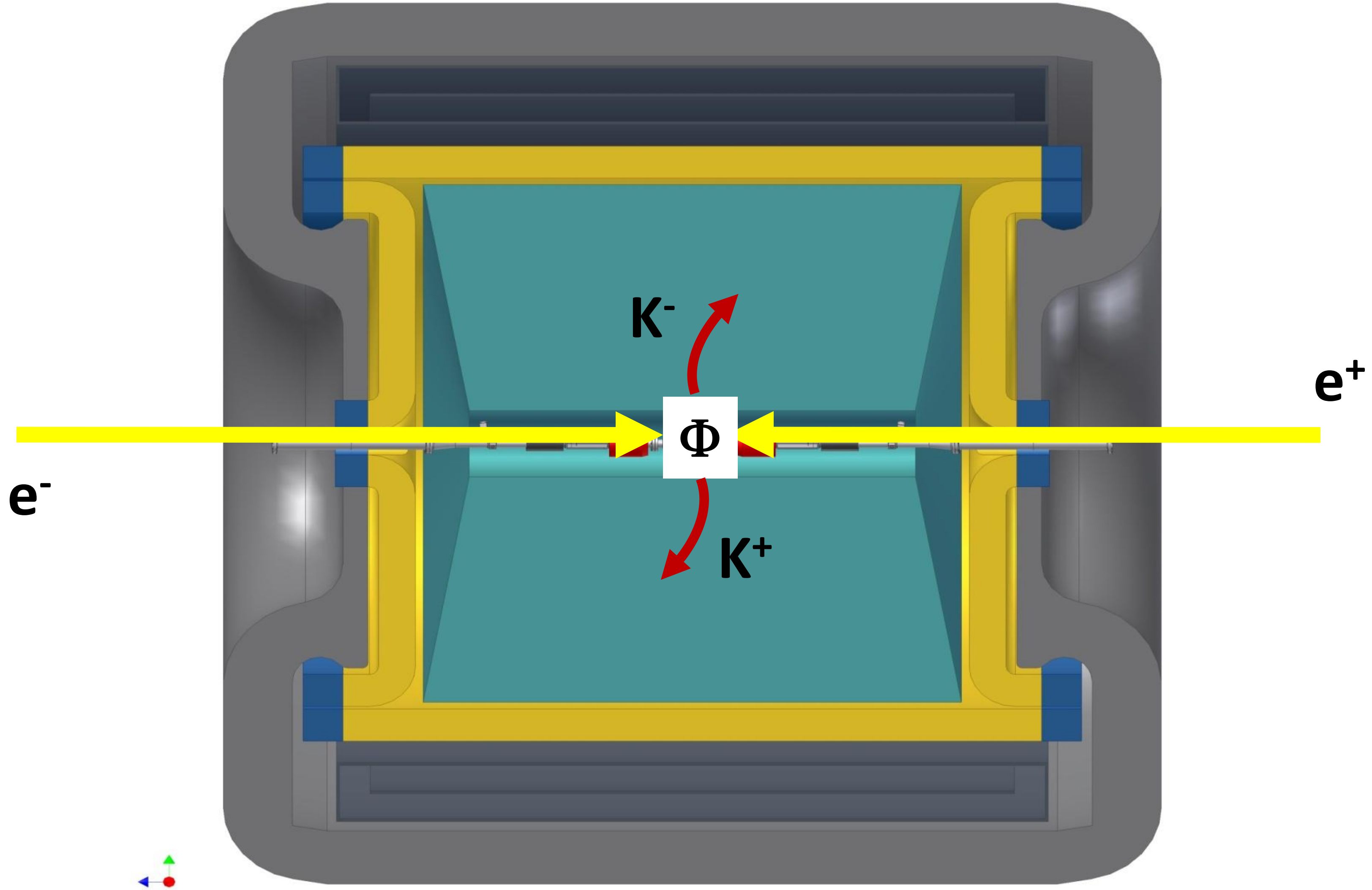
KLOE – Drift Chamber



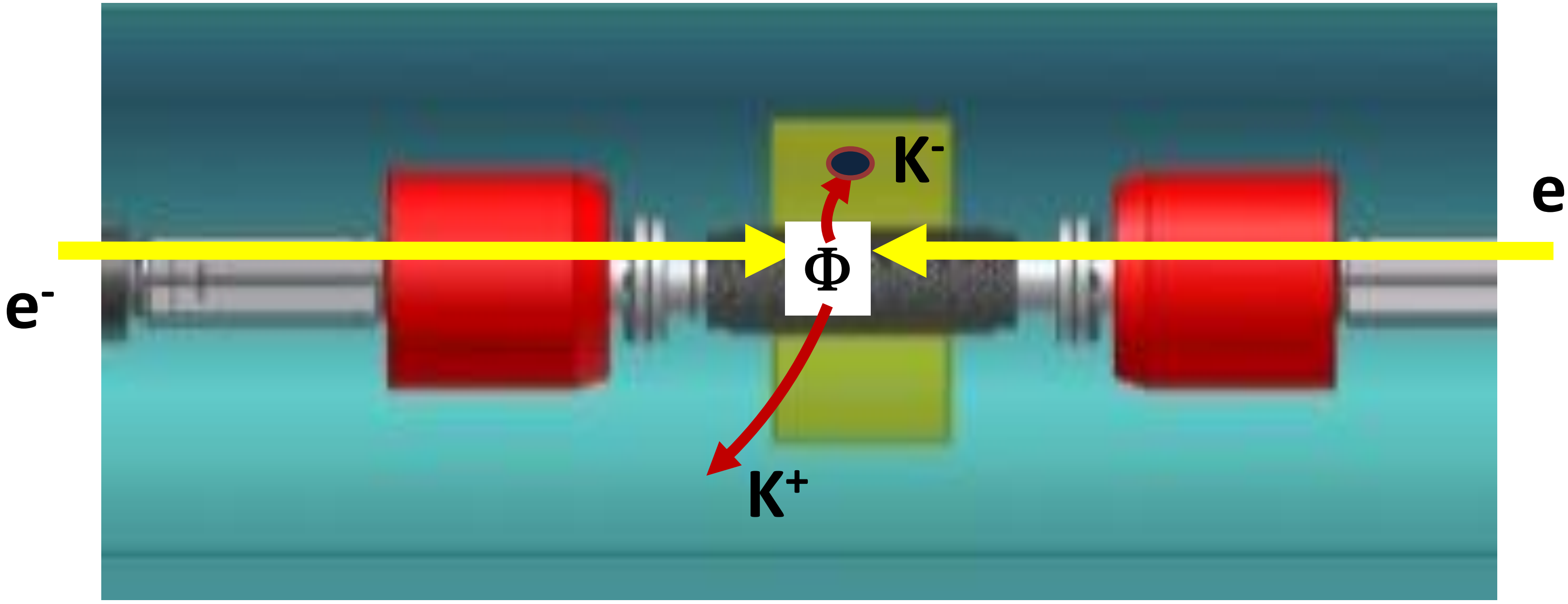
Possible setup for AMADEUS within KLOE:

Cryogenic target
Inner tracker
Kaon trigger

Without AMADEUS setup



WITH AMADEUS setup

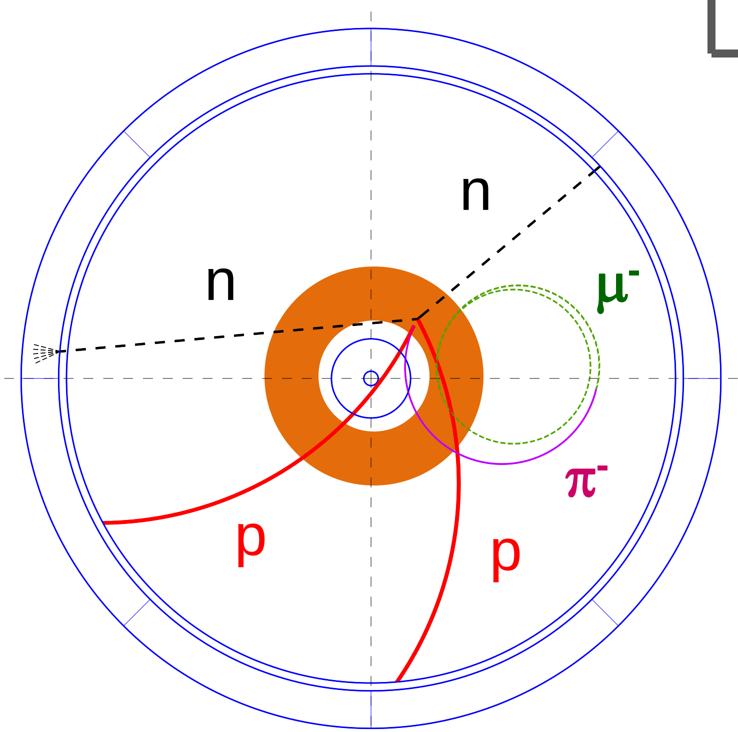


Example of Strange tribaryon formation and decay detection

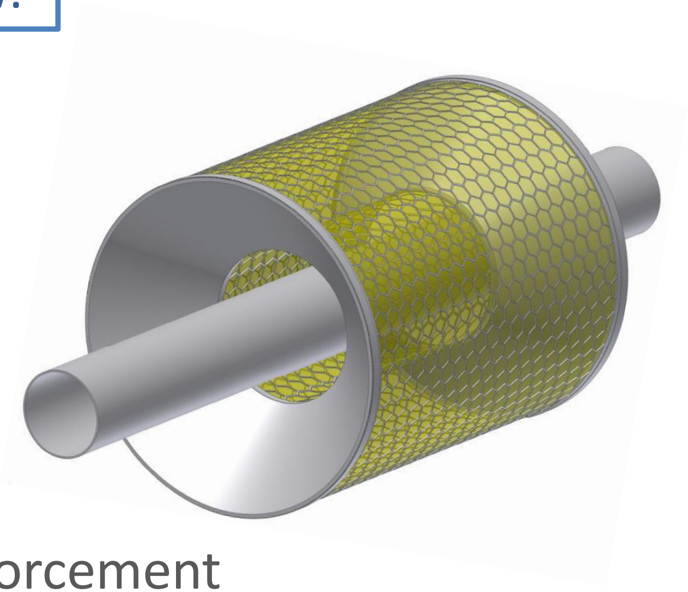
$$^{4}He + K^{-} \rightarrow K^{-}ppn + n$$

$$\hookrightarrow \Lambda + p + n$$

$$\hookrightarrow p + \pi^{-}$$



AMADEUS inner region setup



→ Gaseous or thin solid **target**

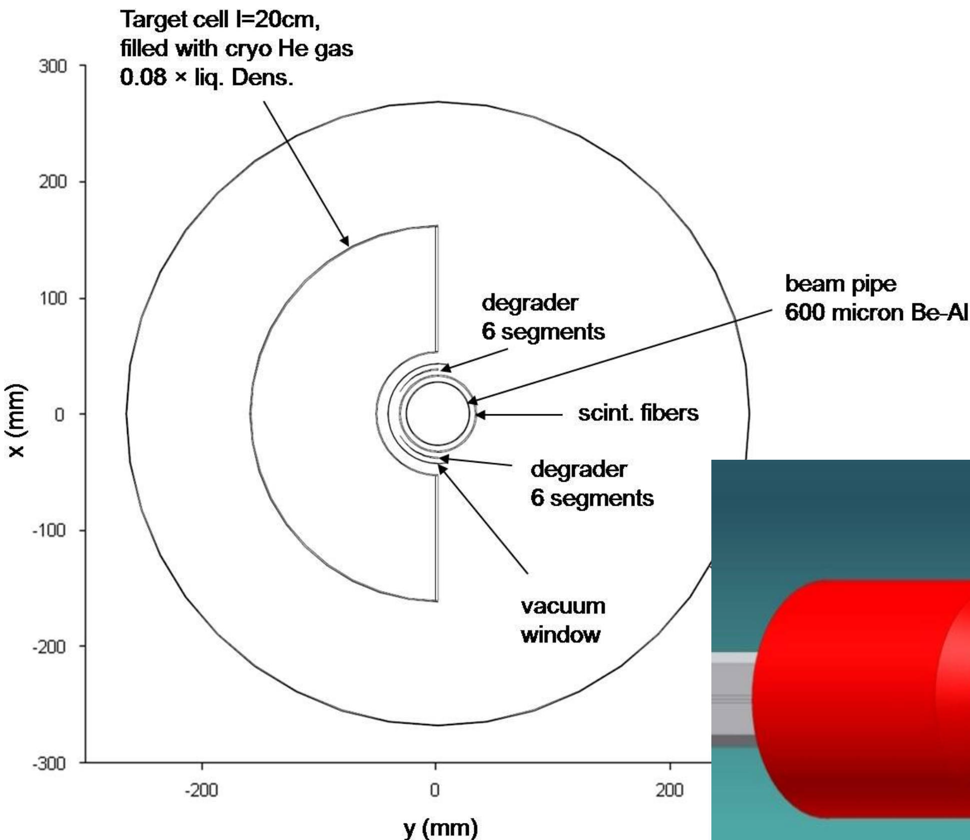
Draft design of a **toroidal cryogenic cell target**:

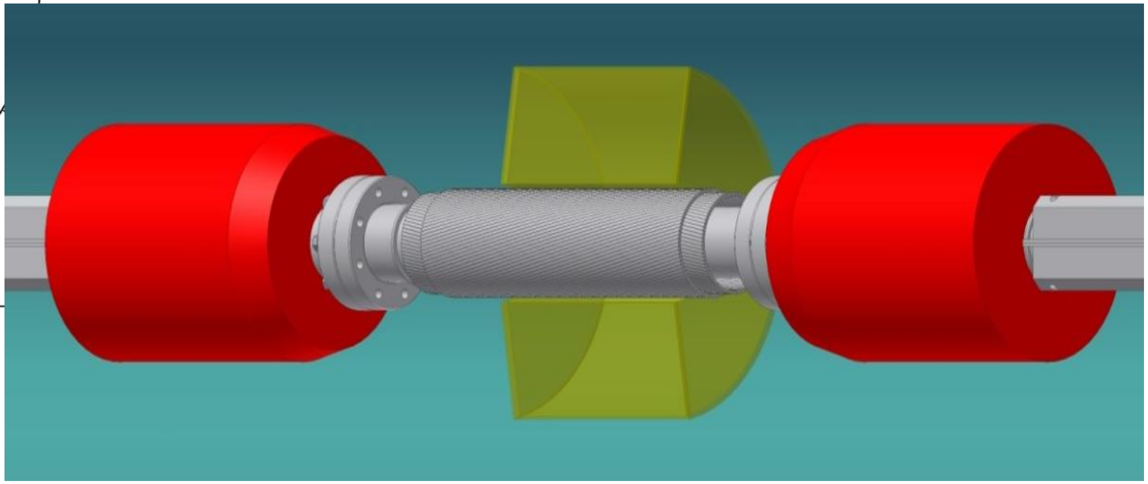
- 2 bar
- 10 K
- 150 NTP density
- 75µm Kapton, with aluminum grid reinforcement
- 30-40% of K^- stopped

→ A **tracking/vertex detector** (a **Multilayer cilindrical GEM** or a **Time Projection Chamber (TPC) with GEM-readout** surrounding the half toroidal cryogenic target cell with the kaon trigger configuration.

AMADEUS @ KLOE, phase-1

AMADEUS Phase-1 -> Integrated luminosity request **3.5 - 4 fb^{-1}** in order to study the tribaryon DBKNS, dibaryon DBKNS and low-energy kaon-nuclear dedicated measurements.



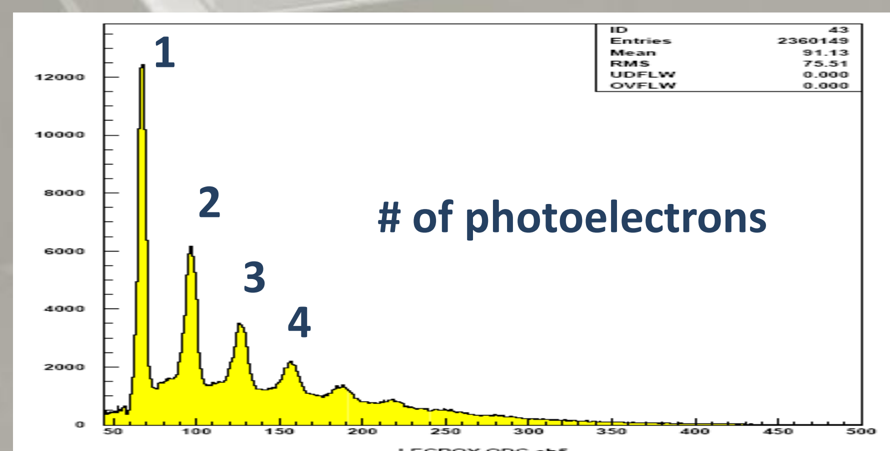


http://www.lnf.infn.it/sis/preprint/pdf/getfile.php?filename=LNF-07-24(IR).pdf

LNF test of SiPM (Hamamatsu)

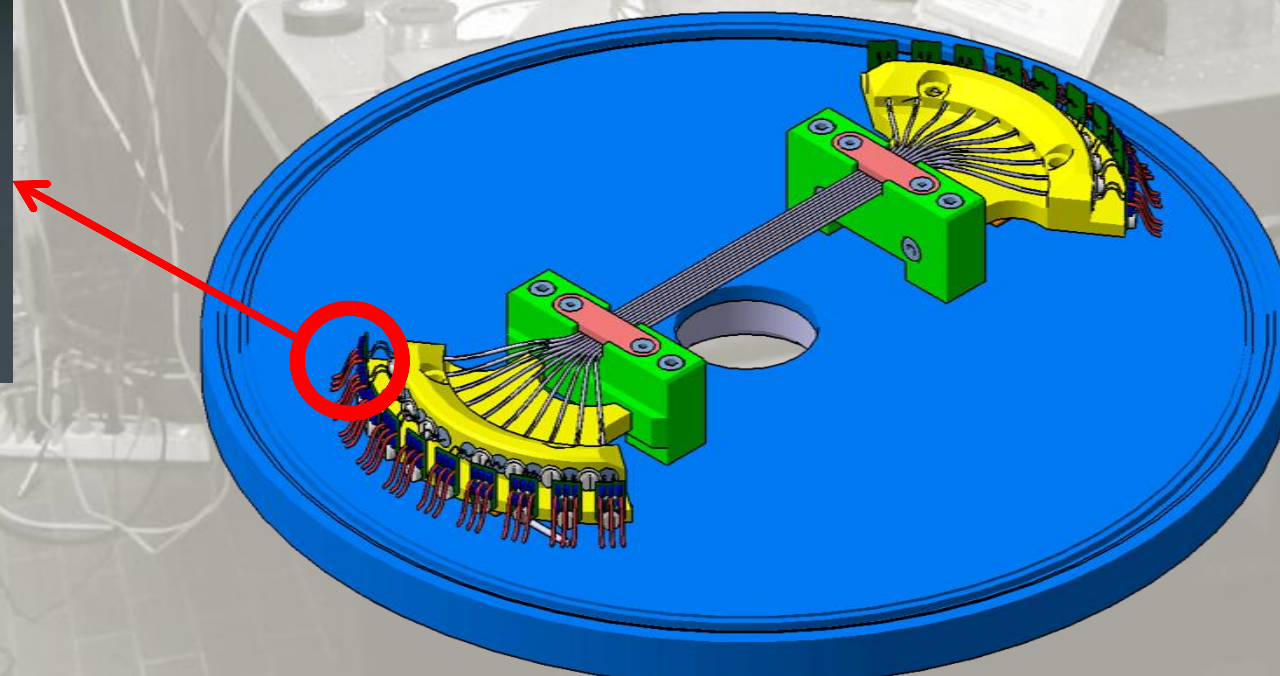
SiPM = Silicon Photomultipliers (array of APDs)

Characterization of SiPM detectors reading light from thin scintilliating fibers

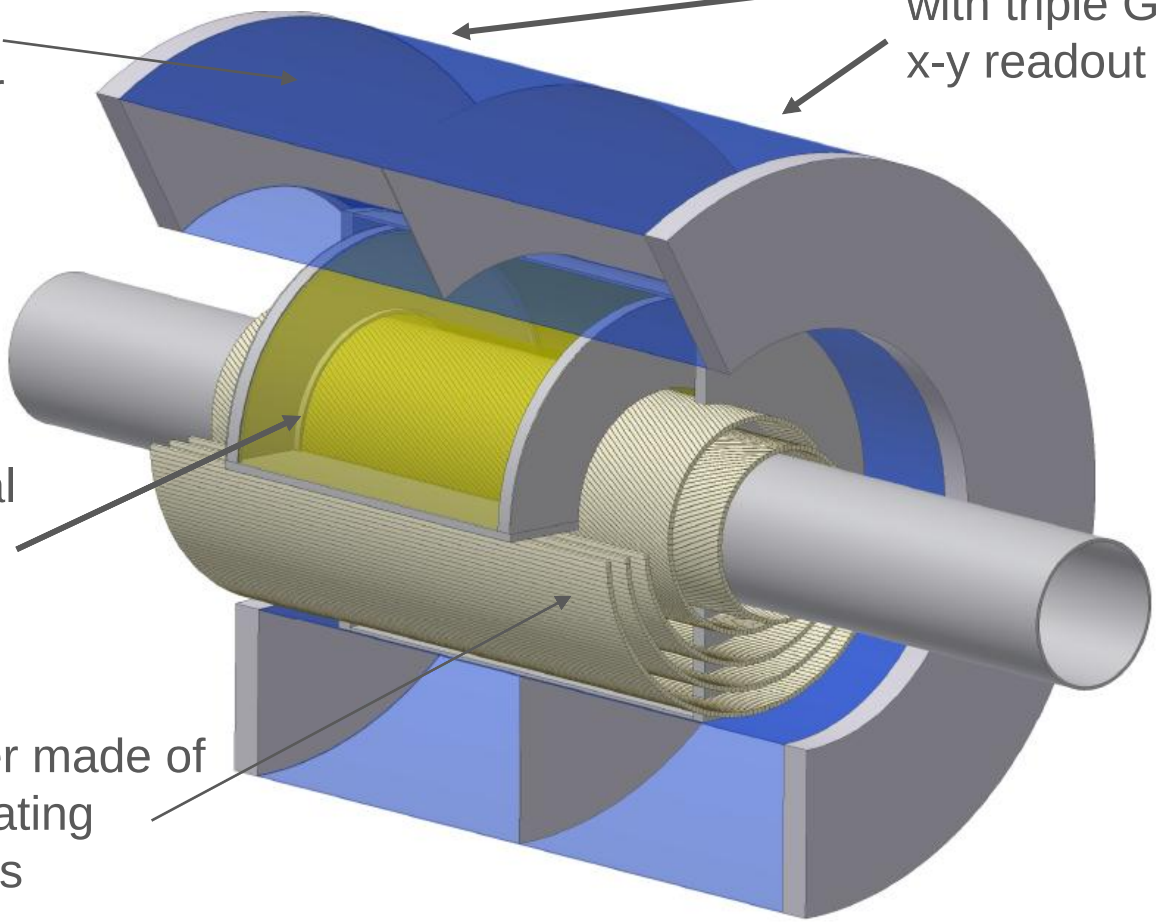


LNF test of SiPM (Hamamatsu)

-Stabilized Power Supply realization
-Preamplifier design
-Test setup design and realization (mechanics, cooling, electronics…)



Additional tracking device?



From preliminary Monte Carlo simulation

Φ production cross section

peak luminosity

branching ratio for $K^{\pm}$

$$R = \mathcal{L} \, \sigma \, b = 1500 \, s^{-1}$$ production rate for $K^{\pm}$ pairs

10^{33} $cm^{-2}s^{-1}$

3×10^{-30} cm^2

0.49

40% K^- stopped in He target → 12.5×10^{8} ^4He-K^- atoms/month

10^{-3} cluster formation yield → **12.5×10^{5} kaonic clusters/month**

Identification & tracking efficiencies → **10^{5} events/month *(~1000 pb^{-1})***

From AMADEUS LOI:

*"In conclusion, an initial programme based on the study of the **^{3}He and the ^{4}He targets, to investigate dibaryonic and tribaryonic states**, would require an integrated luminosity from 2 to 6 fb^{-1}, according to depth of the investigation"*

Further requests (other targets) depend on the results of these first measurements

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Possible at DAΦNE with luminosity upgrade
(before J-PARC, FOPI, FAIR)

- **Full hadron spectroscopy with 4π geometry**
- **Target+trigger+tracking devices in existing KLOE setup**