The AMADEUS experiment

study of the **kaonic clusters** at daΦne

Oton Vázquez Doce (LNF-INFN)
on behalf of the AMADEUS Collaboration
MESON 2008, Kraków, June 9, 2008.

- Introduction
- AMADEUS scientific case
- Framework of AMADEUS
- Performing AMADEUS
- Conclusions

- Analysis of KLOE data

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:

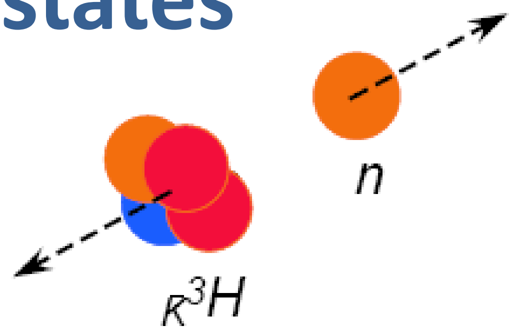
How the hadronic masses and interactions change in nuclear medium

Approach by means of the predicted

Deeply bound kaonic nuclear states

firstly suggested by S. Wycech

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

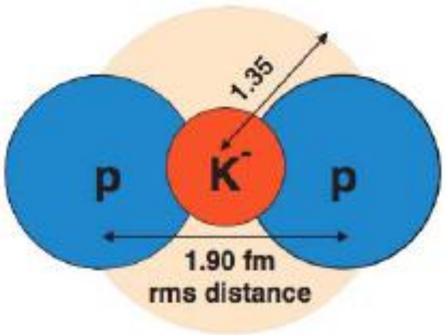


Might offer the <u>ideal condition</u> to study how the **<u>low-energy QCD</u>** spontaneous and splicit Chiral-simmetry breaking changes in the **<u>nuclear enviroment.</u>**

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)

Deeply bound kaonic nuclear states require the presence of a strong attractive $\bar{K}N$ interaction in the isospin I=0 channel

From experimental data:

- S-wave K^- nucleon scattering length is negative at threshold
- K_α line shift of kaonic hydrogen is negative

→ "repulsive-type" interaction

$\bar{K}N$ potential strongly dependent on density:

→ **repulsive-**type in **free space**

→ **attractive** in **nuclear matter**

experimental & theoretical situation

Experimental search for Kaonic Clusters

E471 @ KEK

$He^4(K^-_{stopped},n)Kppn$ 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

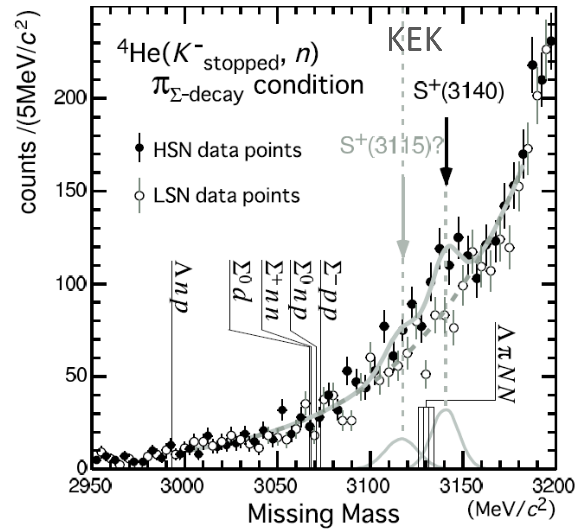
FOPI @ GSI Ni-Ni collisions

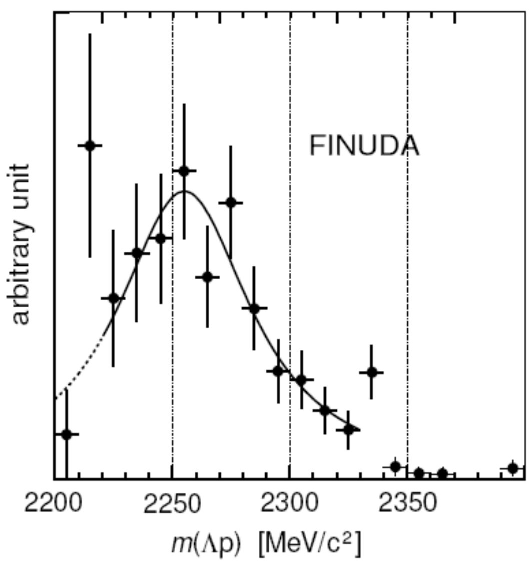
$M_{\Lambda d} = 3170$ MeV B = -149 MeV $\Gamma \approx 100$ MeV

OBELIX old data analysis

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

$(K^-_{stopped},{}^4He) \rightarrow K^-ppn$ 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 $\Lambda(1405)$ 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!

experimental setup

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

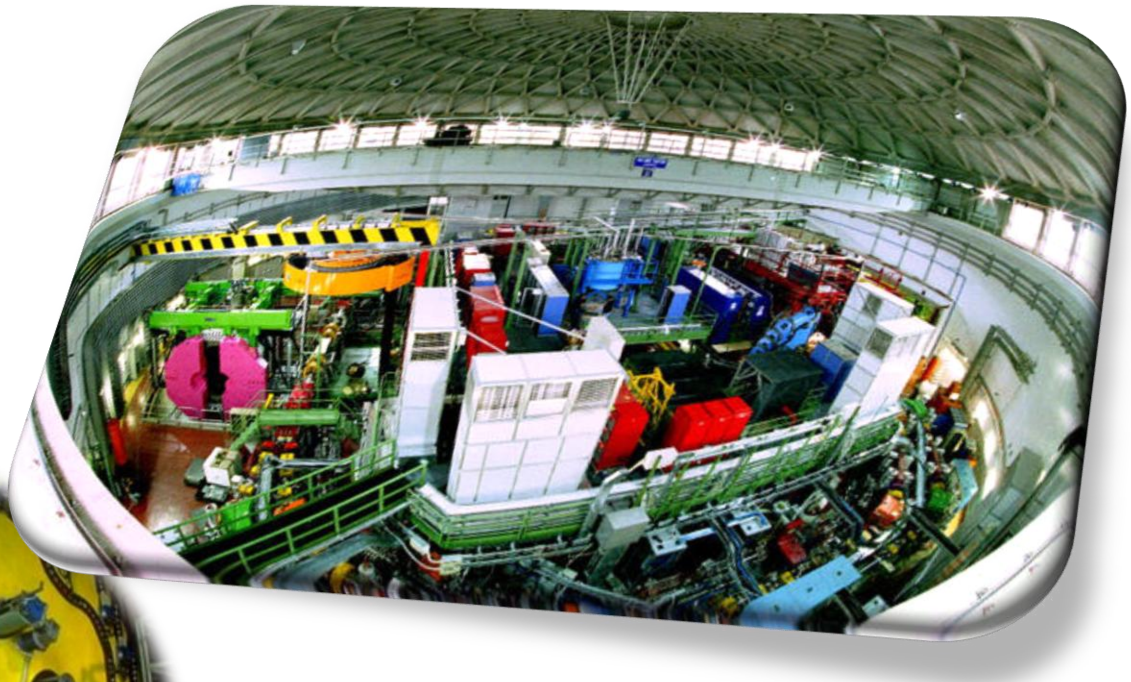
In-medium full hadron spectroscopy

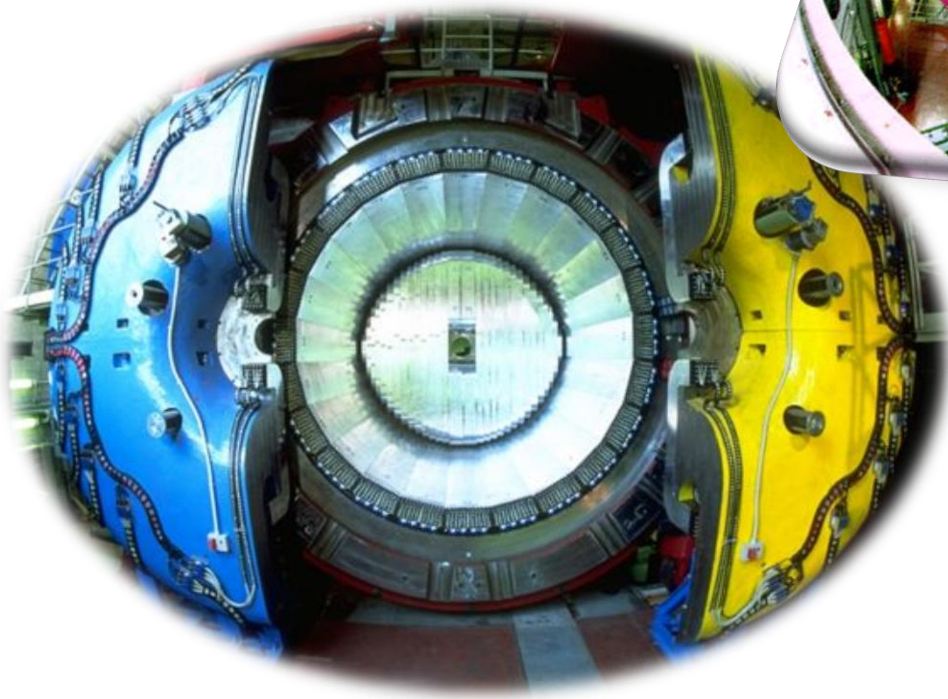
A complete determination of all **<u>formation and decay channel</u>** measuring, binding energies, widths, angular momenta, isospin, sizes, densities…

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

Requirements satisfied by…

DAΦNE





KLOE

Setup performance requirements

Formation processes

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

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

$\Rightarrow$ **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**

$\hookrightarrow$ KLOE has an experimentally proved capability for neutron detection (KLOnE)

Decay processes

K^-ppn

Λp | Λnp | Σ^-pp | Σ^0d | Σ^0np

Invariant mass spectroscopy

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

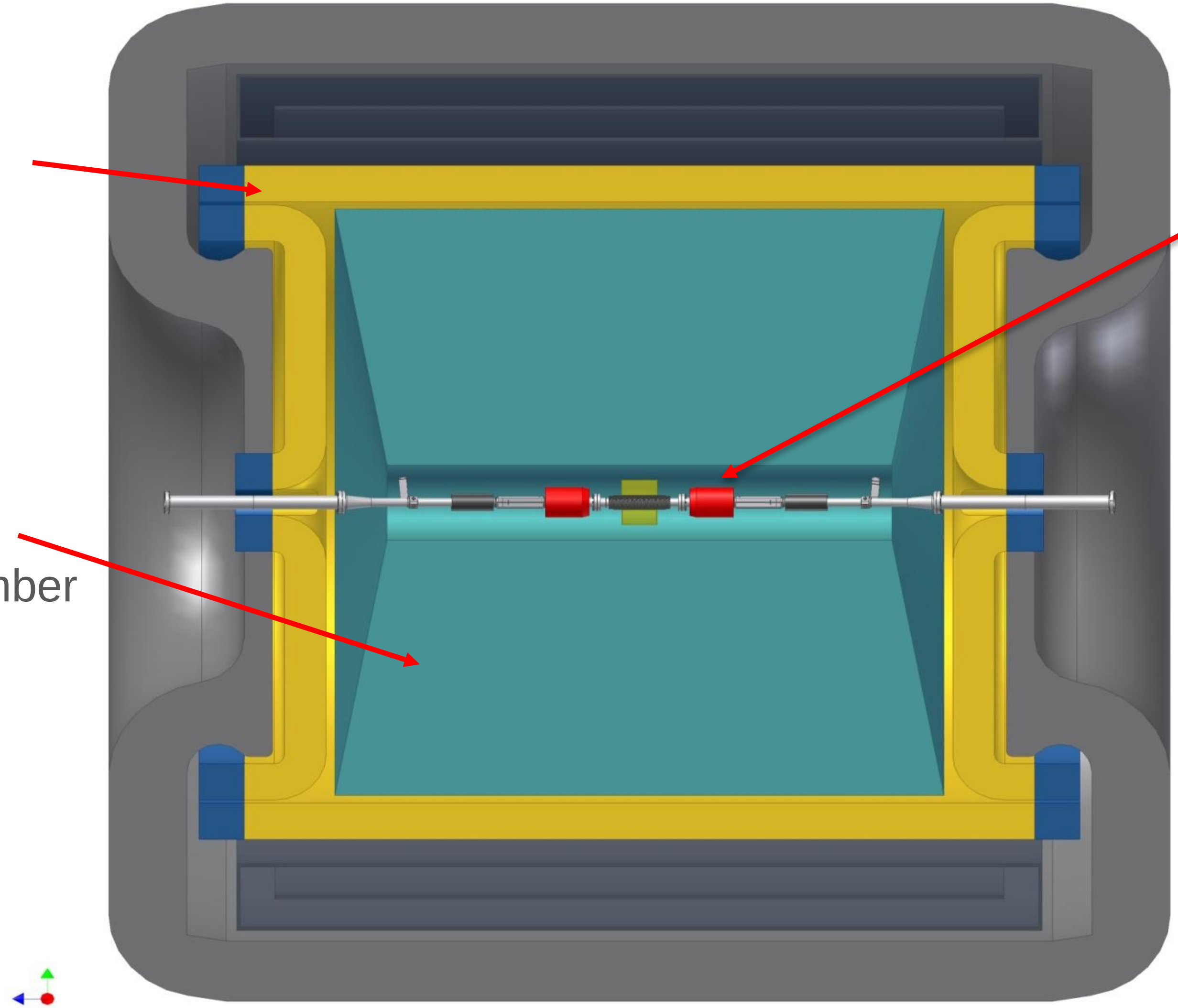
→ 4-momenta of **charged an neutral** particles must be determined

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

AMADEUS setup within KLOE

KLOE – EMC

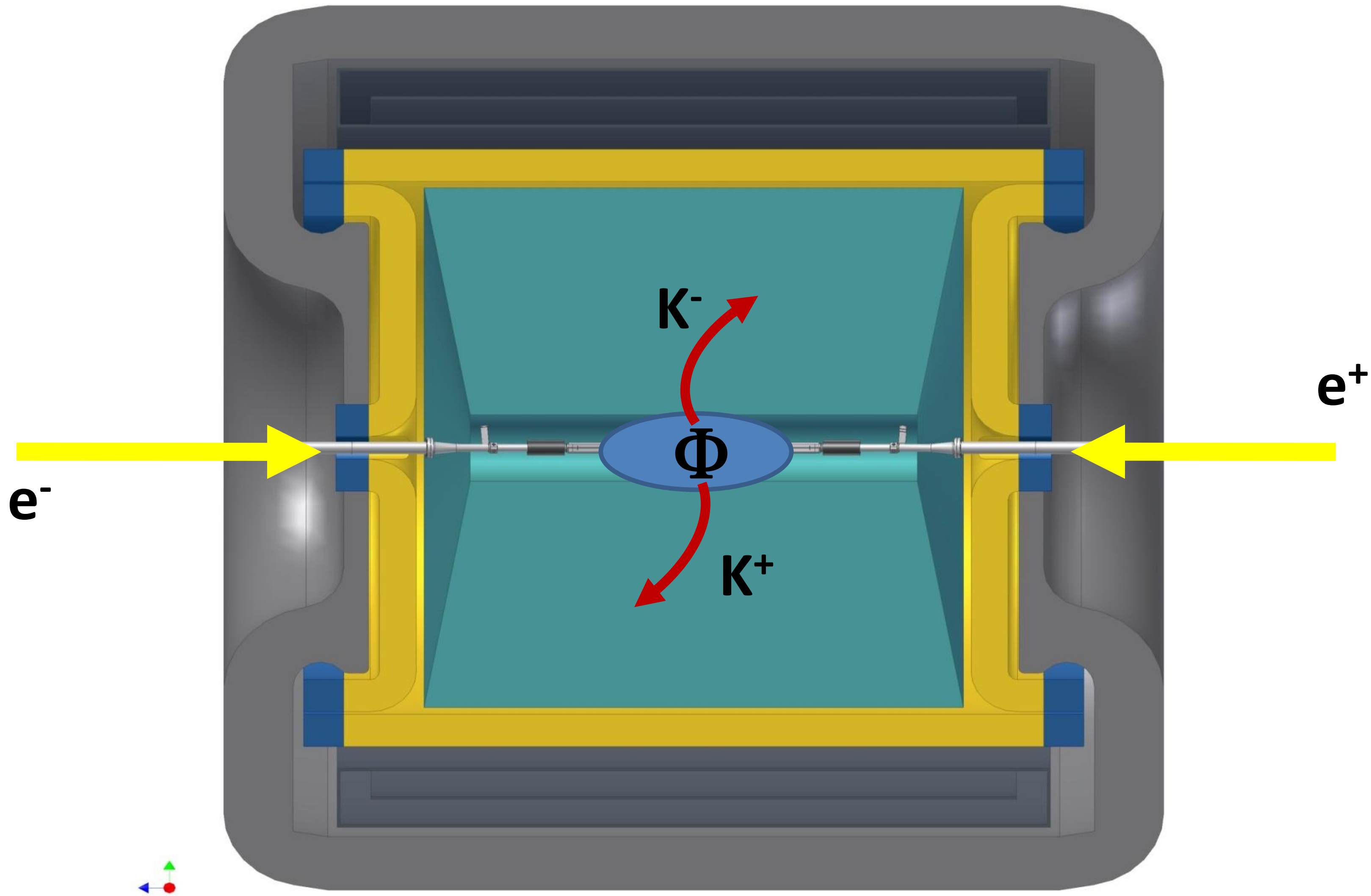
KLOE – Drift Chamber



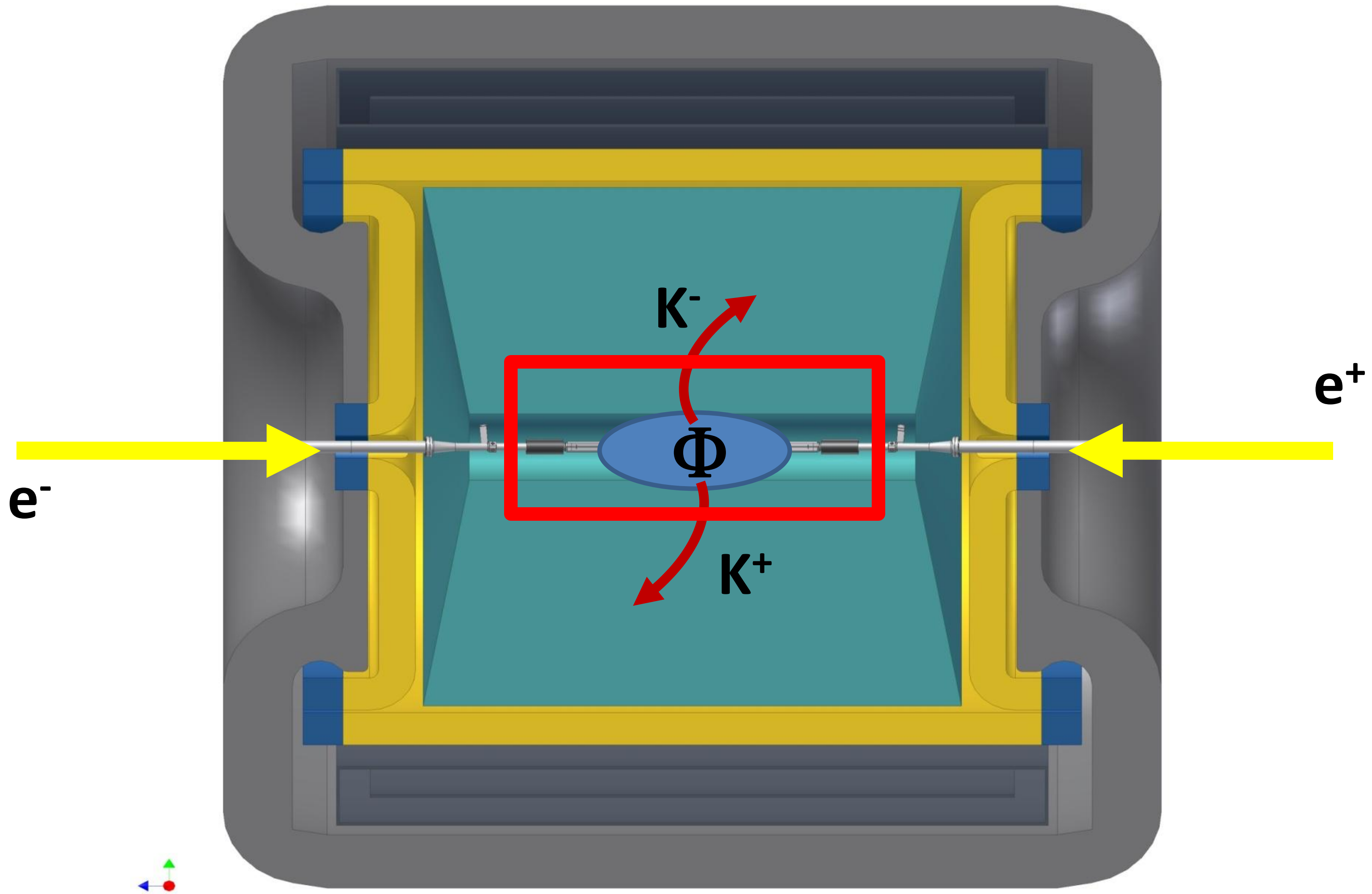
Possible setup for AMADEUS within KLOE:

Cryogenic target
Inner tracker
Kaon trigger

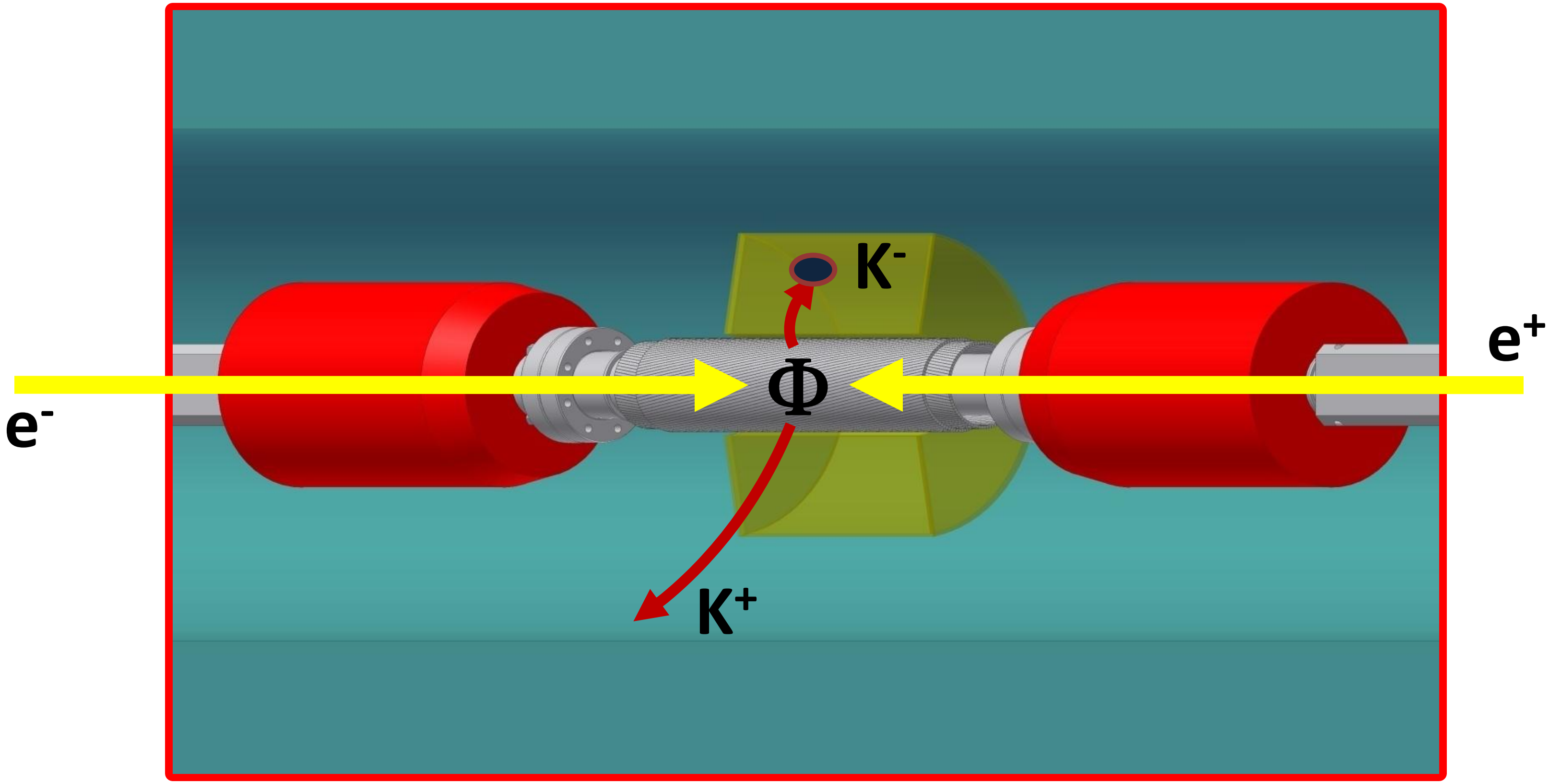
Without AMADEUS setup



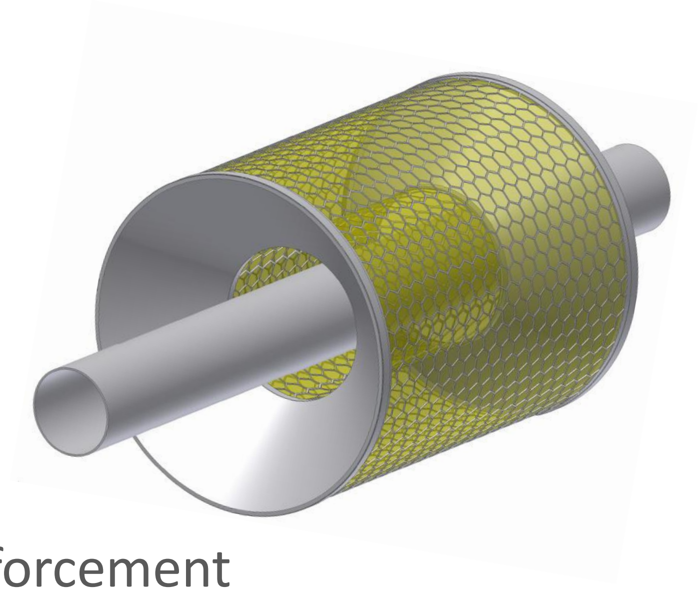
Without AMADEUS setup



WITH AMADEUS setup



AMADEUS inner region setup



→ Gaseous or thin solid **target**

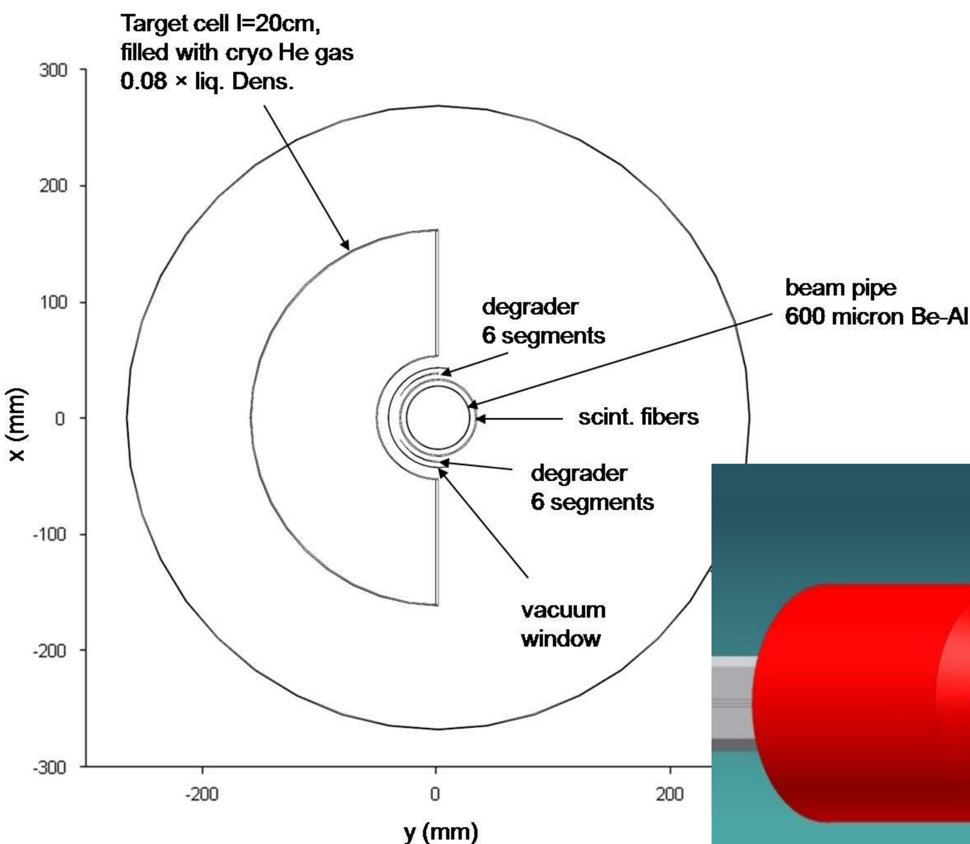
Draft design of a **toroidal cryogenic cell target**:

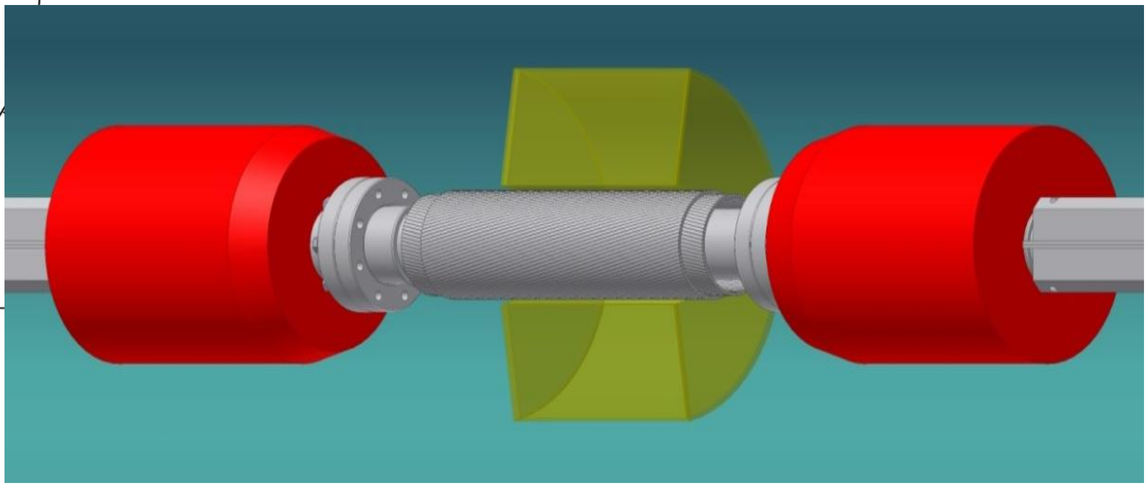
- 2 bar
- 10 K
- 150 NTP density
- 75μm Kapton, with aluminum grid reinforcement
- 30-40% of K^- stopped

→ 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

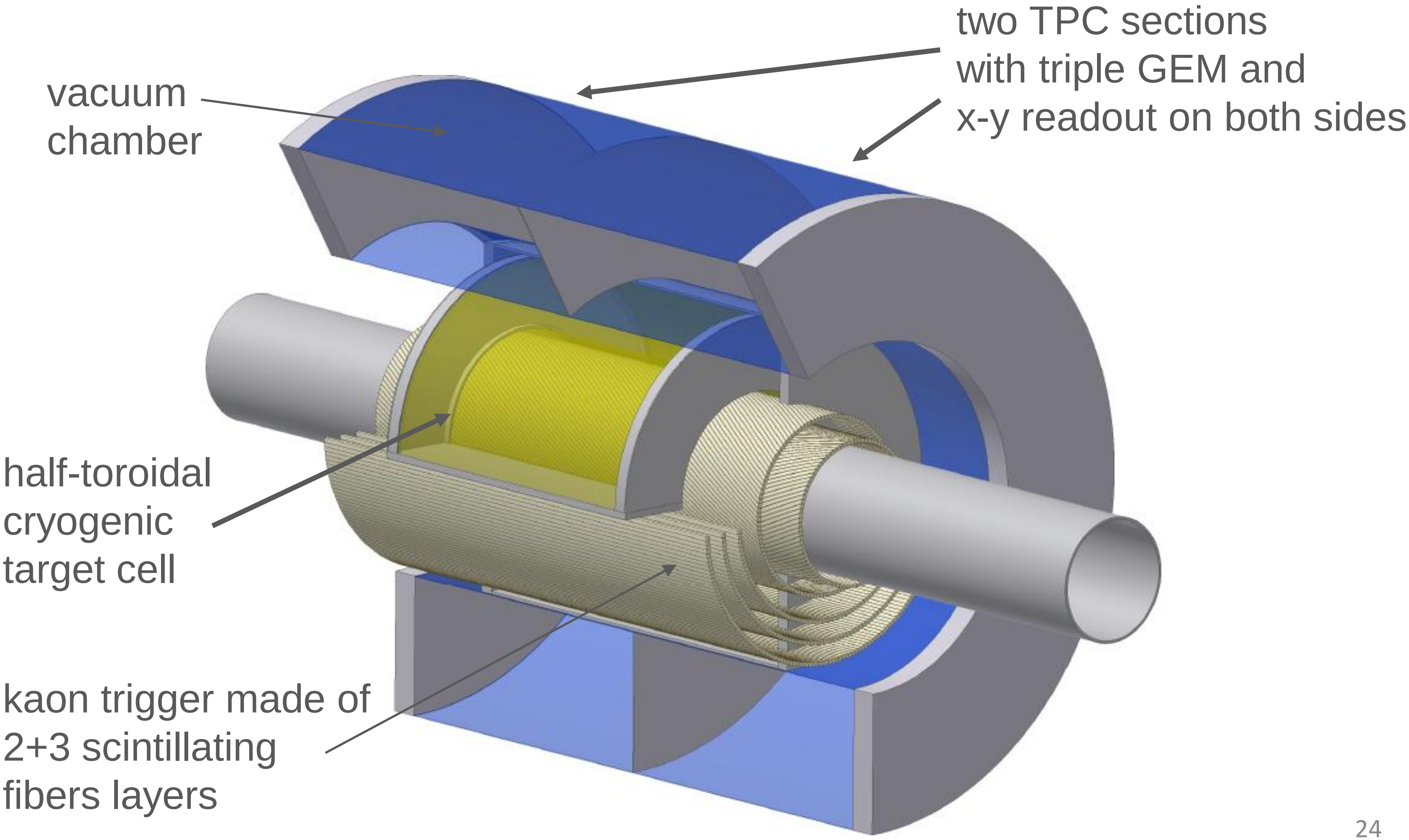
AMADEUS Phase-1 -> Integrated luminosity request **3.5 - 4 fb^{-1}** in order to study the tribaryon DBKNS, dibaryon DBKNS and low-energy kaon-nuclear dedicated measurements.





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

Additional tracking device?



From preliminary Monte Carlo simulation

Φ production cross section

peak luminosity

branching ratio for $K^{\pm}$

$$R = \mathcal{L}\,\sigma\,b = 1500\ \mathrm{s}^{-1}$$

production rate for $K^{\pm}$ pairs

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

$3 \times 10^{-30}\ \mathrm{cm}^2$

0.49

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

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

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

From AMADEUS LOI:

Study of deeply bound kaonic nuclear states at daΦne

"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} "*

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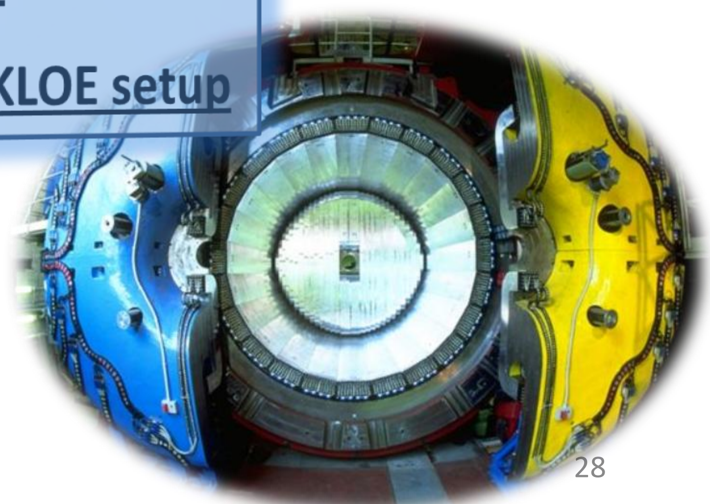
- **Full hadron spectroscopy with 4π geometry**
- **Target+trigger+tracking devices in existing KLOE setup**



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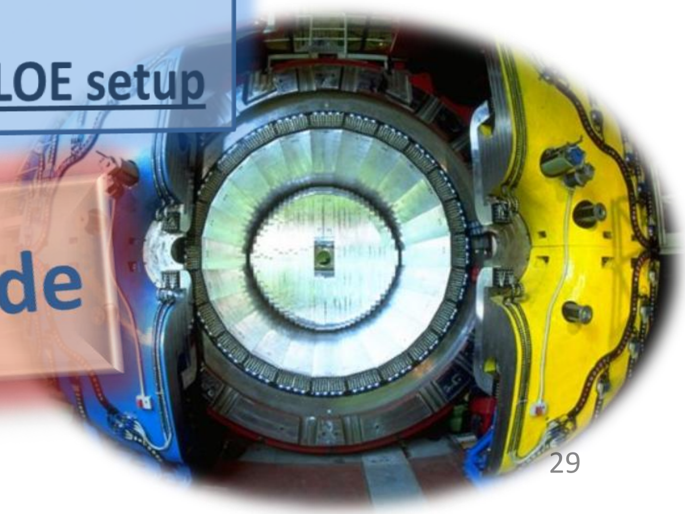
Possible at DAΦNE with luminosity upgrade



Before AMADEUS…

ANALISYS OF KLOE DATA

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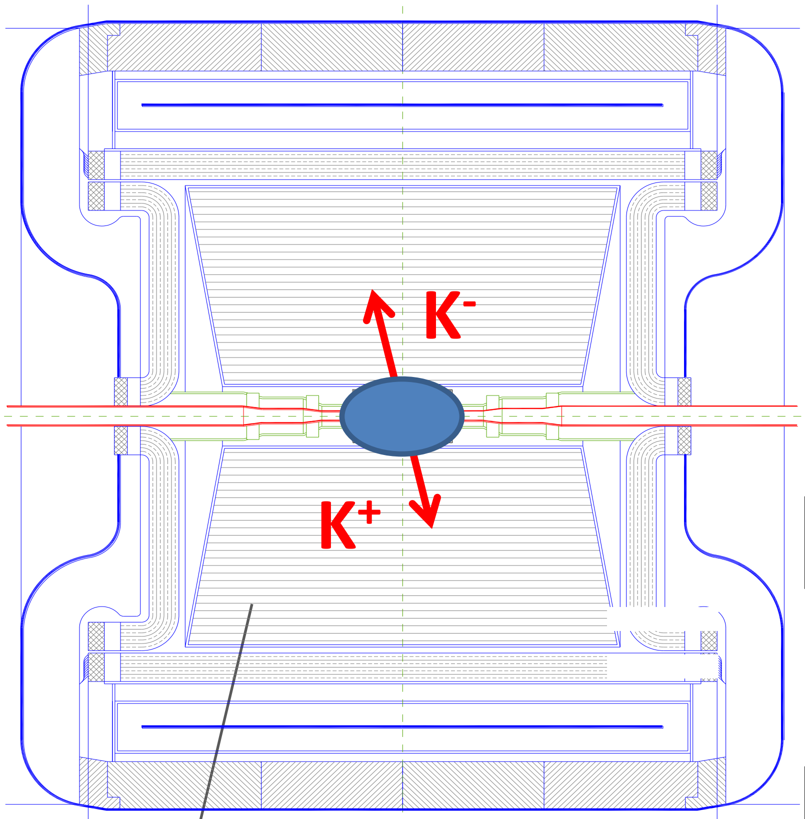
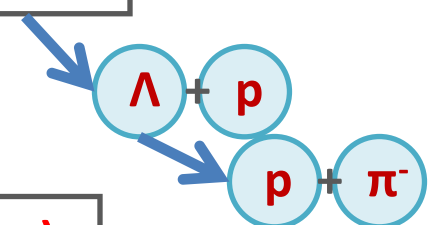


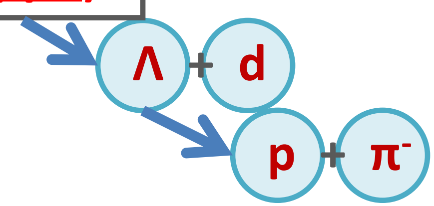
KLOE –
Drift Chamber

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

$K^-_{stopped}$ + ^{4}He → n + n + **(K^-pp)**



$K^-_{stopped}$ + ^{4}He → n + **(K^-ppn)**



Before AMADEUS…

ANALISYS OF KLOE DATA

Lambda invariant mass

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

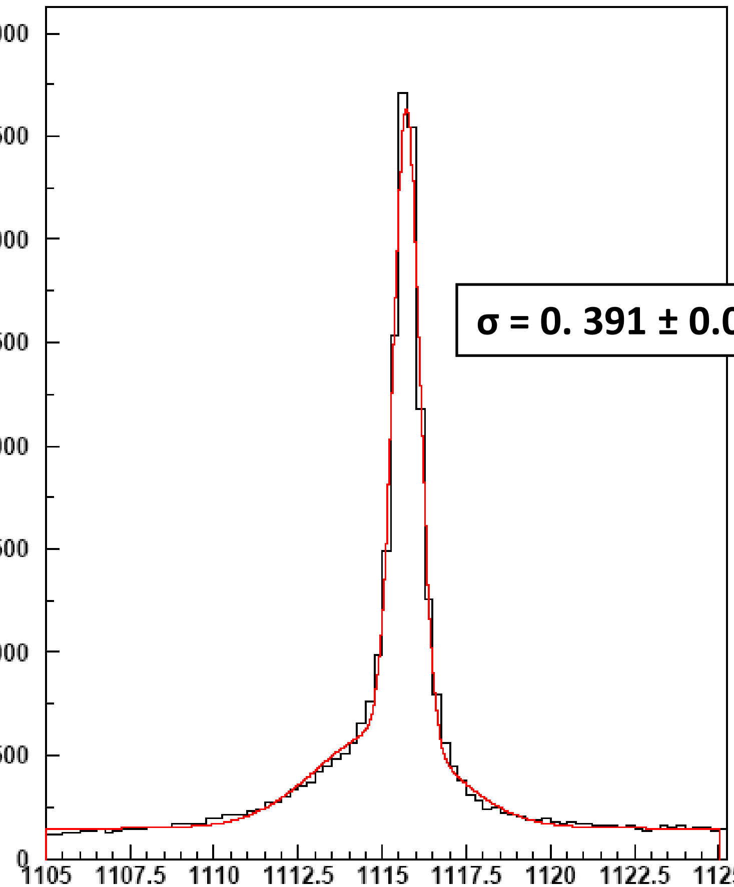
-> analyzed up to an integrated luminosity of **1.1 fb^{-1}** from KLOE data

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

$(K^-pp) \rightarrow \Lambda + p$

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

$(K^-ppn) \rightarrow \Lambda + d$



$\sigma = 0.391 \pm 0.003$ MeV/c²

$M_{inv} = 1115{,}723 \pm 0.002$ MeV/c²

PDG: $M_\Lambda = 1115{,}683 \pm 0.006$ MeV/c²

Before AMADEUS...

ANALISYS OF KLOE DATA