‘The strong interaction at the frontier of knowledge: fundamental research and applications’

TA3: Transnational Access to LNF

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INFN

STRONG-2020 Kick-off meeting

October 23-25, 2019

The DAΦNE Complex

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

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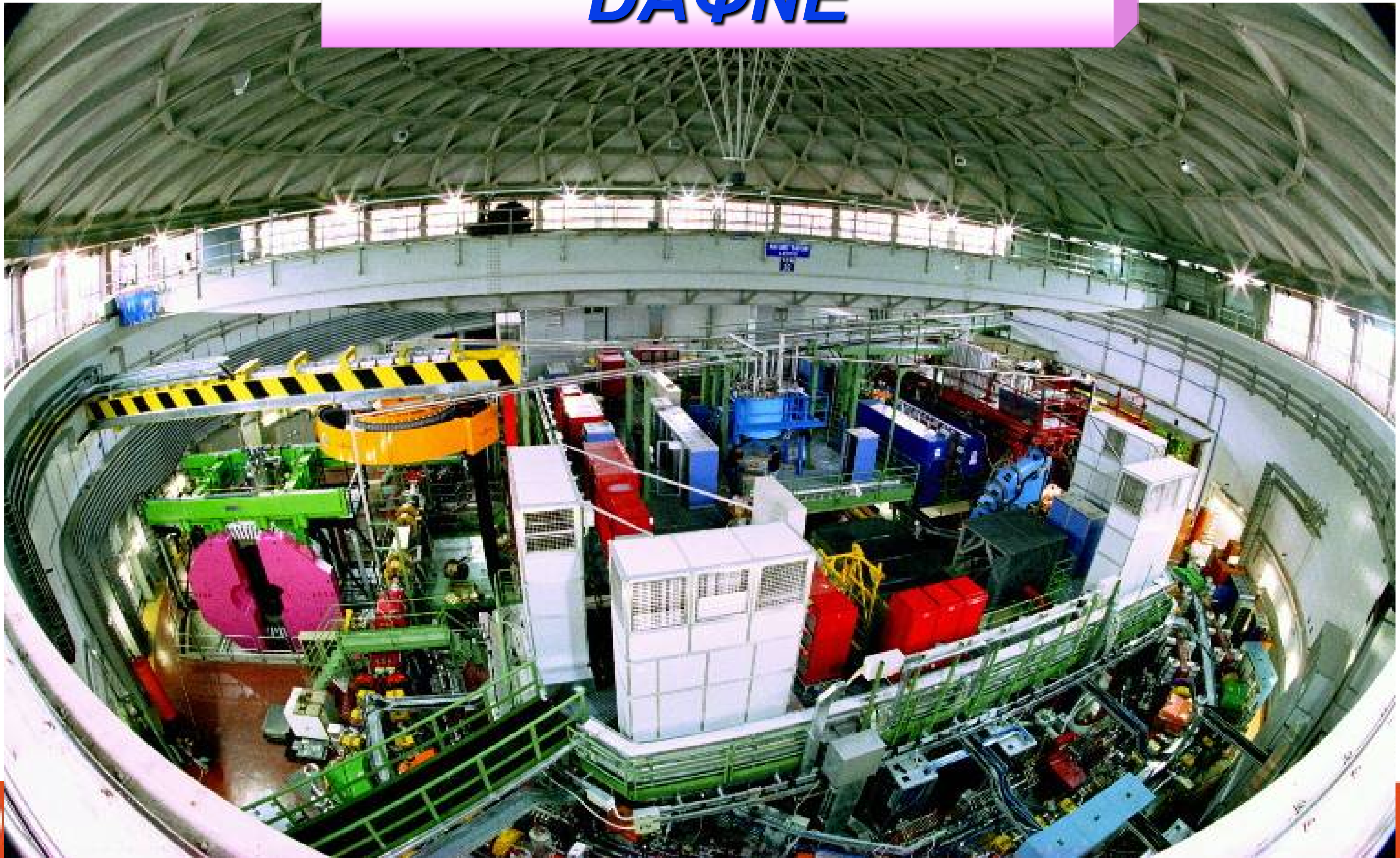
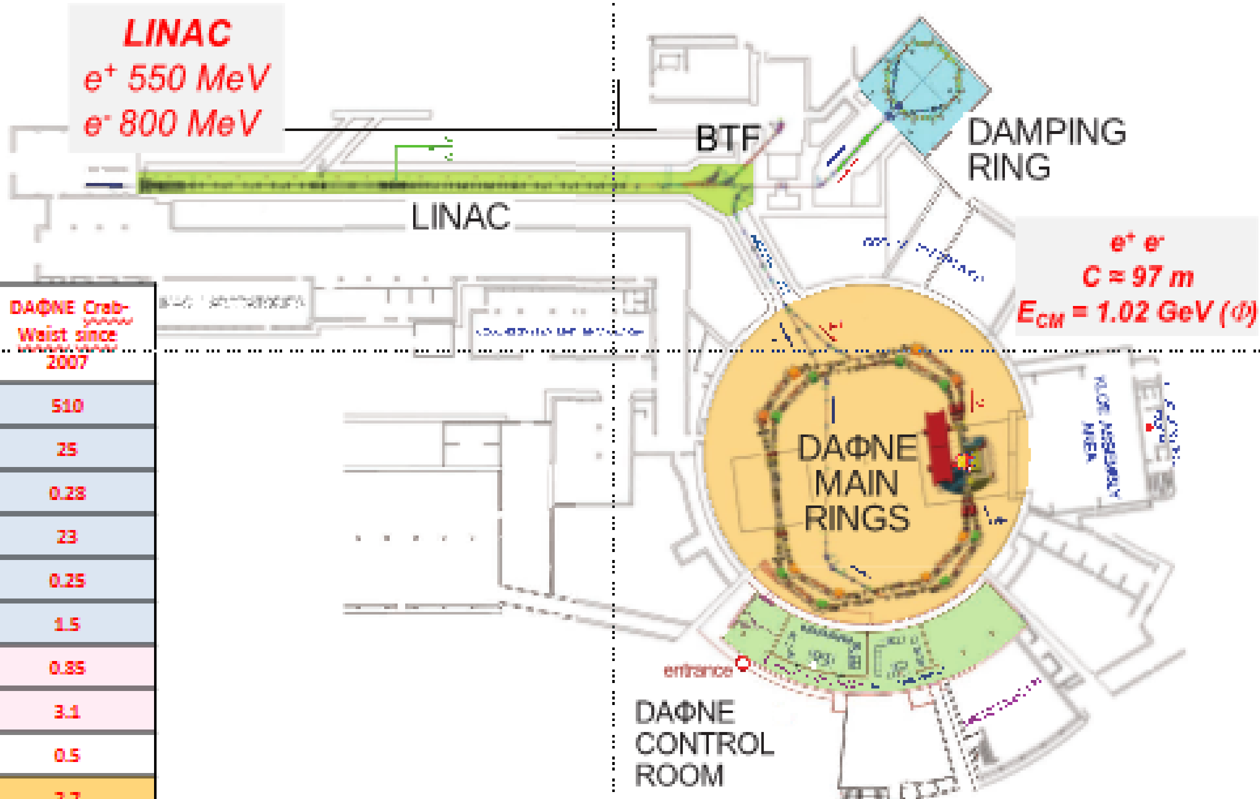
DAΦNE



DAΦNE Complex



	DAΦNE native 2000÷2006	DAΦNE Crab-Waist since 2007
Energy [MeV]	510	510
$\theta_{cross}/2$ [mrad]	12.5	25
ε_x [mm·mrad]	0.34	0.28
β_x^* [cm]	160	23
σ_x^* [mm]	0.7	0.25
$\Phi_{piwinski}$	0.6	1.5
β_y^* [cm]	1.80	0.85
σ_y^* [μm] low current	5.4	3.1
Coupling [%]	0.5	0.5
Bunch spacing [ns]	2.7	2.7
I_{bunch} [mA]	13	13
σ_z [mm]	25	15
N_{bunch}	120	120

DAΦNE implemented succesfully a new kind of beam-beam interaction: the Crab-Waist collision scheme

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Experiments on the DAΦNE complex

- SIDDHARTA-2
- PADME

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SIDDHARTA-2 Experiment

OBJECTIVES

Study of strong interaction effects in kaonic atoms

The study of the strong interaction effects was the major motivation for performing experiments with kaonic atoms. The electromagnetic interaction with the nucleus is very well known and the energy levels can be calculated at a precision of eV by solving the Klein-Gordon equation. Even a small deviation from the electromagnetic value allows to get information on the strong interaction between the kaon and the nucleus.

The binding energy of the ground state (K-, p)system is 8,61 KeV, to be compared with the tens of MeV in the low-energy scattering experiments.

Hence, kaonic atoms offer the unique opportunity to study the antikaon-nucleon/nucleus interaction, nearly "at threshold", namely at zero relative energy.

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SIDDHARTA-2 Experiment

Formation of kaonic atoms

When a negatively charged particle other than an electron enters a target it is slowed down to a kinetic energy of a few tens of eV by ionisations and excitations of the molecules of the target. An exotic atom is formed when this particle is stopped inside the target and is captured by a target atom into an outer atomic orbit, replacing an electron.

When the particle is a kaon, the kaon cascades down via Coulomb deexcitation, external Auger emission, radiative transitions until interacts with the nucleus. The levels are shifted and broaded with respect to the e.m. value.

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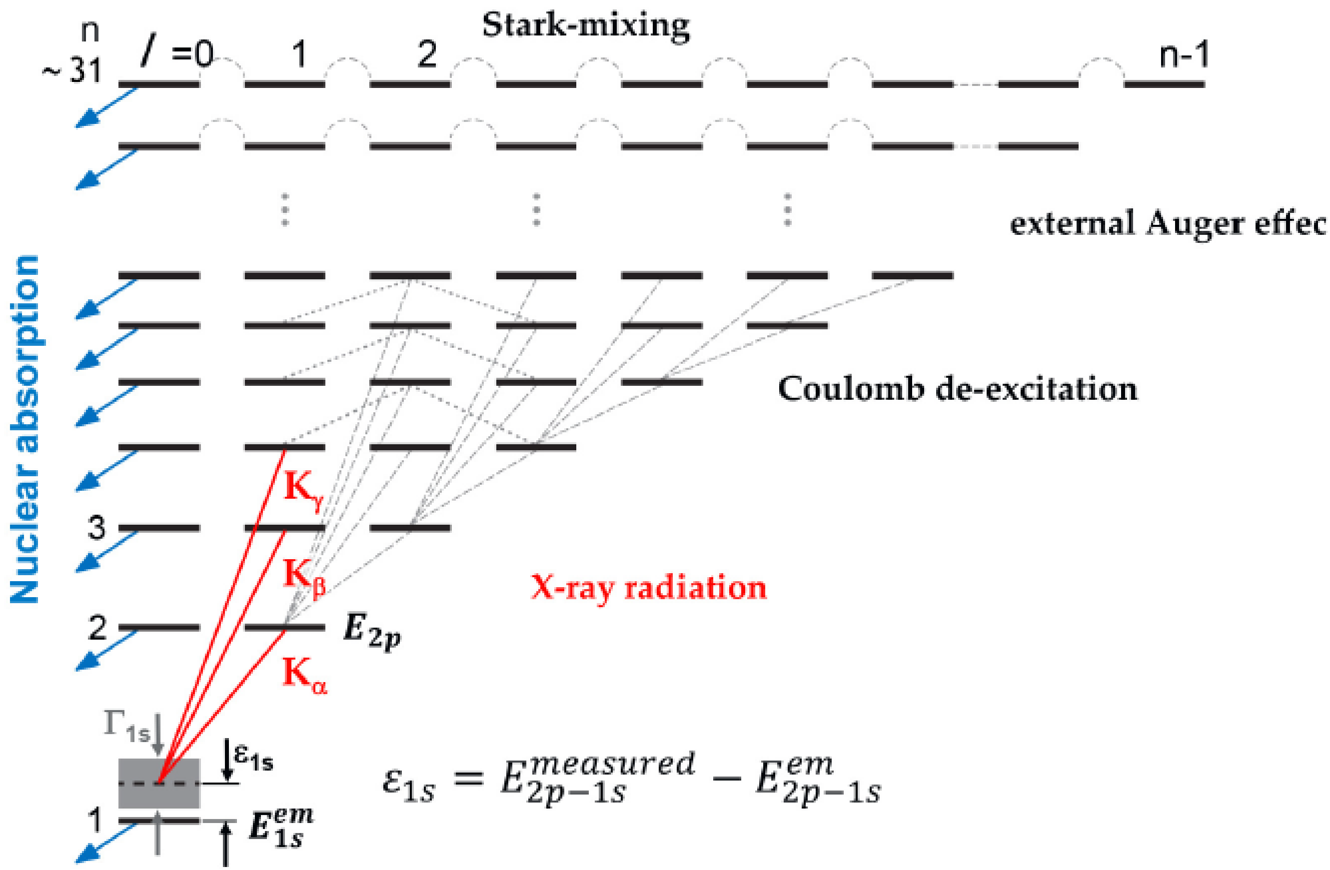
SIDDHARTA-2 Experiment

Kaonic hydrogen



STRONG 2020

SIDDHARTA-2 Experiment

Kaonic hydrogen

SCATTERING LENGTHS

Deser-type relation connects shift ε_{1s} and width Γ_{1s} to the real and imaginary part of $a_{K\text{-}p}$

$$\varepsilon_{1s} - \frac{i}{2}\Gamma_{1s} = -2\alpha^3\mu_c^2 a_{K^-p}\left(1 - 2\alpha\mu_c(\ln\alpha - 1)a_{K^-p}\right)$$

(μ_C reduced mass of the K^-p system, α fine-structure constant)

U.-G. Meißner, U.Raha, A.Rusetsky, Eur. phys. J. C35 (2004) 349
next-to-leading order, including isospin breaking

$$a_{K^-p} = \frac{1}{2}[a_0 + a_1]$$

$$a_{K^-n} = a_1$$

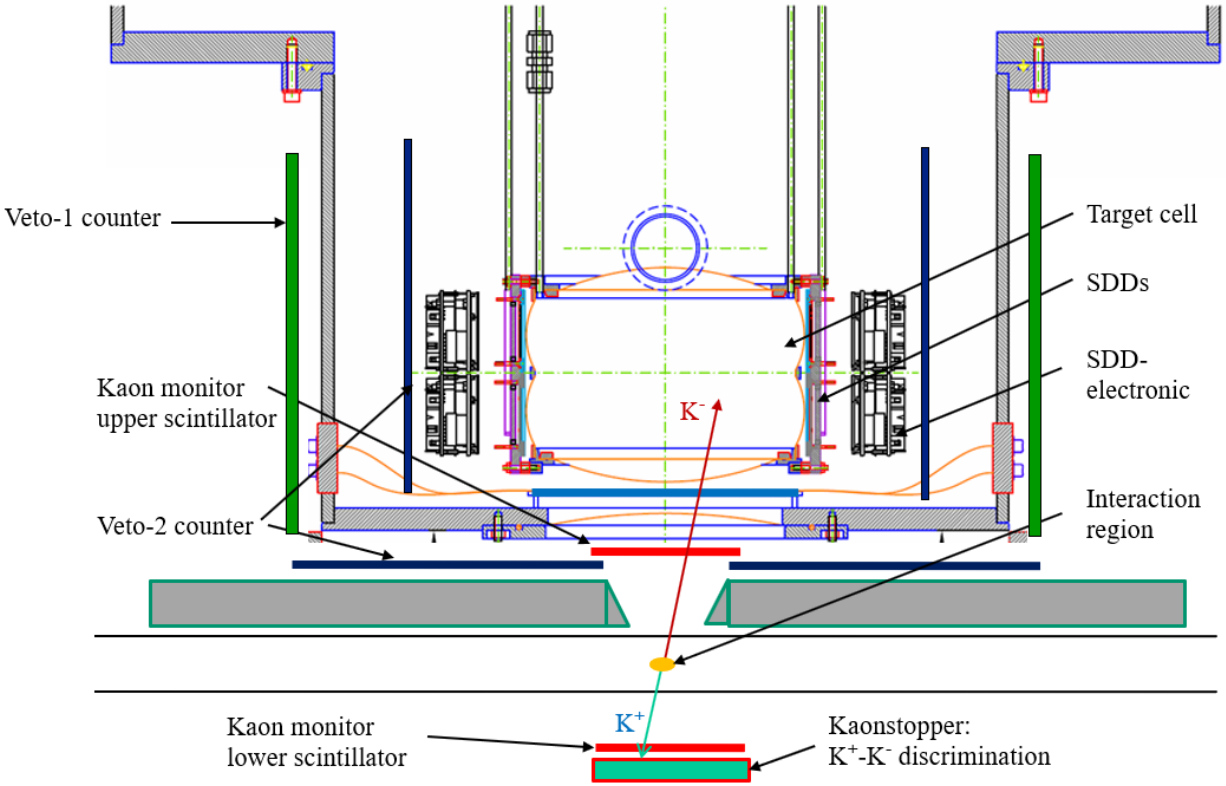
←

$$a_{K^-d} = \frac{k}{2}\left[a_{K^-p} + a_{K^-n}\right] + C = \frac{k}{4}[a_0 + 3a_1] + C$$

$$k = \frac{4[m_n + m_K]}{[2m_n + m_K]}$$

SIDDHARTA-2 Experiment

TASKS



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SIDDHARTA-2 strategy

Phase 1:

during the commissioning of DAΦNE

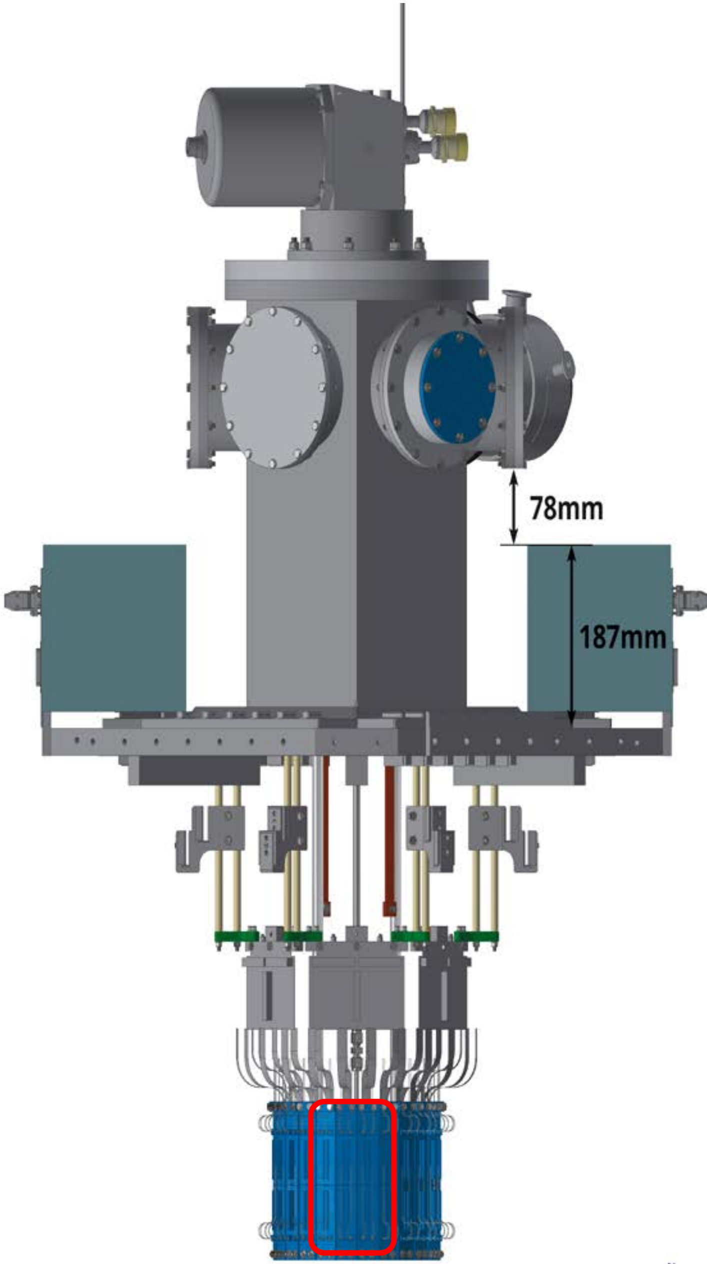
SIDDHARTINO: measurement of K-^{4}He (8 SDD arrays)

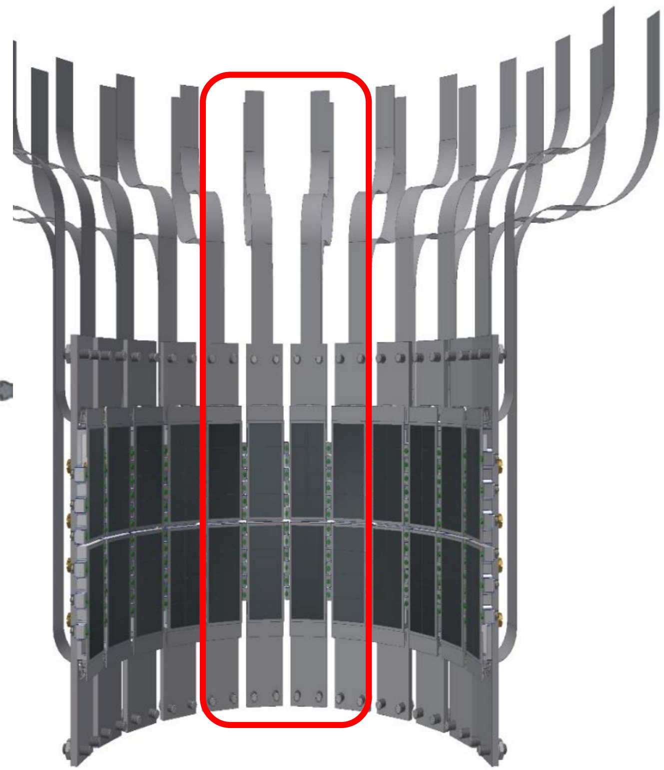
Phase 2:

when DAΦNE operating condition is comparable (S/B) with SIDDHARTA ones

kaonic deuterium **(48 SDD arrays) run for 800 pb^{-1}**

SIDDHARTINO = SIDDHARTA-2 with 8 SDD's

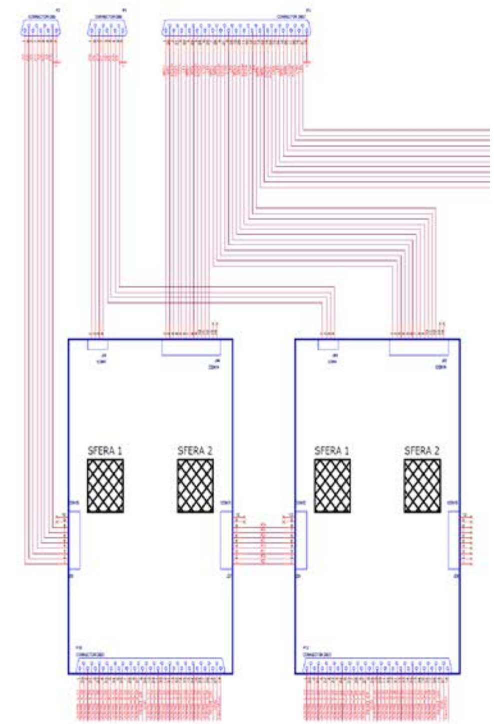




ONLY
8 SDD arrays
(out of 48)
1 BUS structure

DAQ – BUS structure

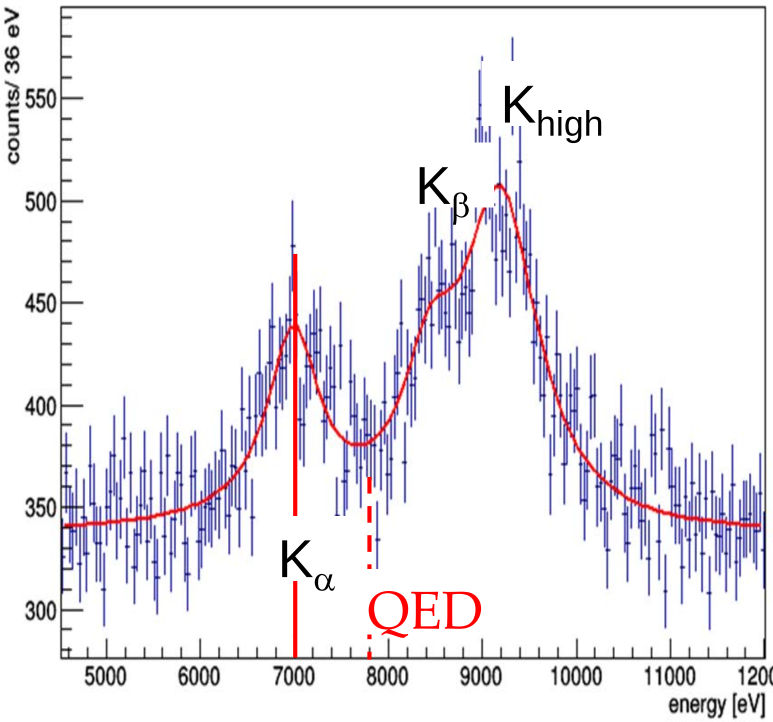
- 4 SFERA ASICs
- 8 SDD arrays
- 4 ADC channels



SIDDHARTA-2 Experiment

SIDDHARTA-2 K-d measurement
Monte Carlo simulations

Kaonic deuterium run in
2020/2021 for 800 pb^{-1}
to perform the first
measurement of the strong
interaction induced
energy shift and width
(similar precision as $K^{-}p$)



achievable precision:
shift: 30 eV
width: 75 eV

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TA3 – Transnational Access to LNF

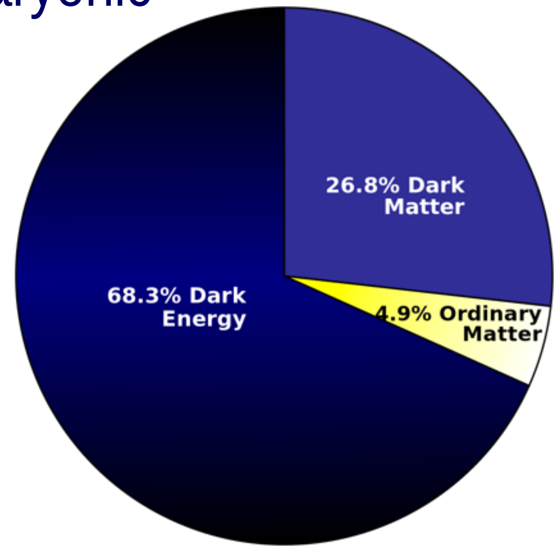
PADME Experiment

OBJECTIVES

The Dark Matter issue

From Cosmological and Astrophysical observations of gravitational effects, something else than ordinary Baryonic matter should exist.

The abundance of this new entity is 5 times larger than SM particles.



Dark Matter is the best indication of physics Beyond SM (BSM)

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PADME Experiment

A new mediator

There are many attempts to look for new physics phenomena to explain Universe **dark matter** and energy.

One class of simple models just adds an additional U(1) symmetry to SM, with its corresponding vector boson (*A'*)

$$U(1)_Y + SU(2)_{Weak} + SU(3)_{Strong} [+U(1)_{A'}]$$

The *A'* could itself be the **mediator** between the **visible** and the **dark sector** mixing with the ordinary photon. The effective interaction between the fermions and the dark photon is parametrized in term of a factor ε representing the mixing strength.

The search for this new mediator *A'* is the goal of the PADME experiment at LNF.

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A' production at PADME

PADME aims to produce *A'* via the reaction:

$$e^{+}e^{-} \rightarrow A'\gamma$$

This technique allows to identify the *A'* even if it is stable or if predominantly decay into dark sector particles.

Know e^+ beam momentum and position

Tunable intensity (in order to optimize annihilation vs. pile-up)

Measure the recoil photon position and energy

Calculate $M^2{}_{miss} = (\bar{P}_{e^+} + \bar{P}_{e^-} - \bar{P}_{\gamma})^2$

Only minimal assumption: *A'* couples to leptons

$$\sigma(e^+e^- \to \gamma A') = 2\epsilon^2\sigma(e^+e^- \to \gamma\gamma).$$

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TA3 – Transnational Access to LNF

PADME experiment

TASKS

Run1 (Oct. 2018 – Feb. 2019) devoted to beam and background studies to have the cleanest possible data sample.

Run2 (Jul. 2019) meant to study primary beam.

Run3 foreseen in Autumn 2019.

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Signal and Background

PADME signal events consist of single photons measured with high precision and efficiency by a forward **BGO calorimeter**.

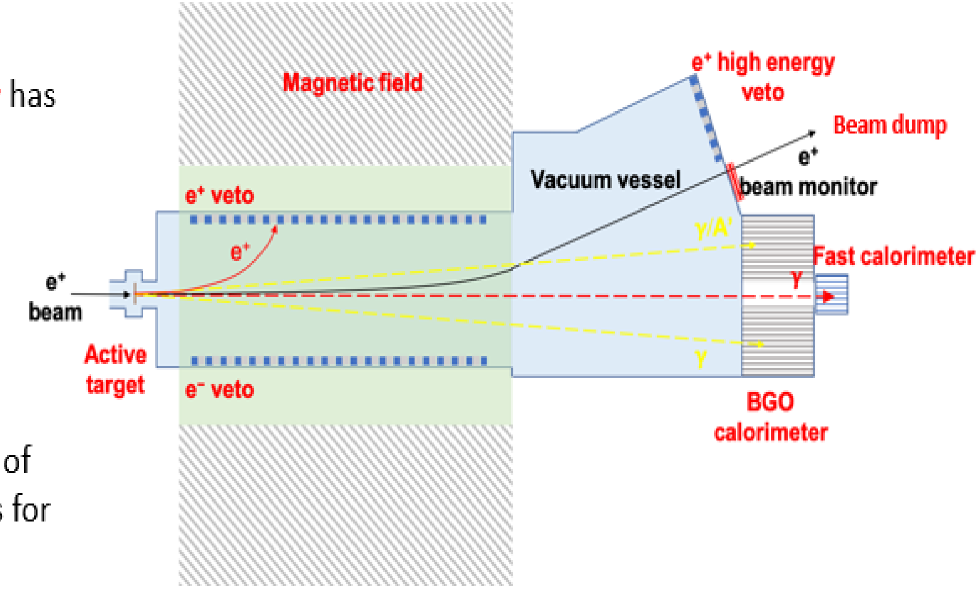
Since the **active target** is extremely thin (~100 μm), the majority of the positrons do not interact.
A **magnetic field** is mandatory to precisely measure their momentum before deflecting them on a **beam dump**.

The main source of background for the A' search are Bremsstrahlung events. This is why the **BGO calorimeter** has been designed with a central hole.

A **fast calorimeter** vetos photons at small angle (θ<1°) to cut backgrounds:

$$e^+N \rightarrow e^+N\gamma; e^+e^- \rightarrow \gamma\gamma; e^+e^- \rightarrow \gamma\gamma\gamma$$

In order to furtherly reduce background, the inner sides of the **magnetic field** are instrumented with **veto** detectors for positrons/electrons.



For higher energy positron another **veto** is placed at the end of the vacuum chamber.

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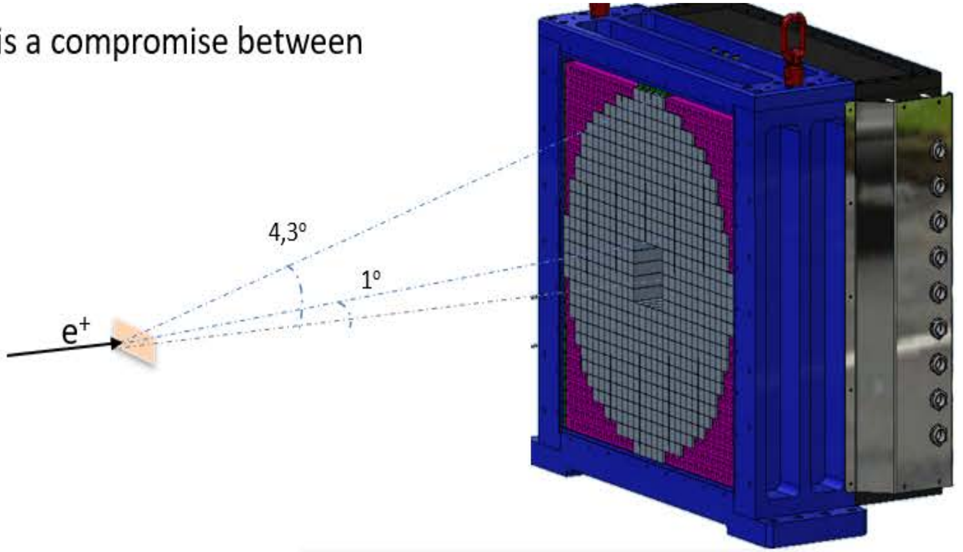
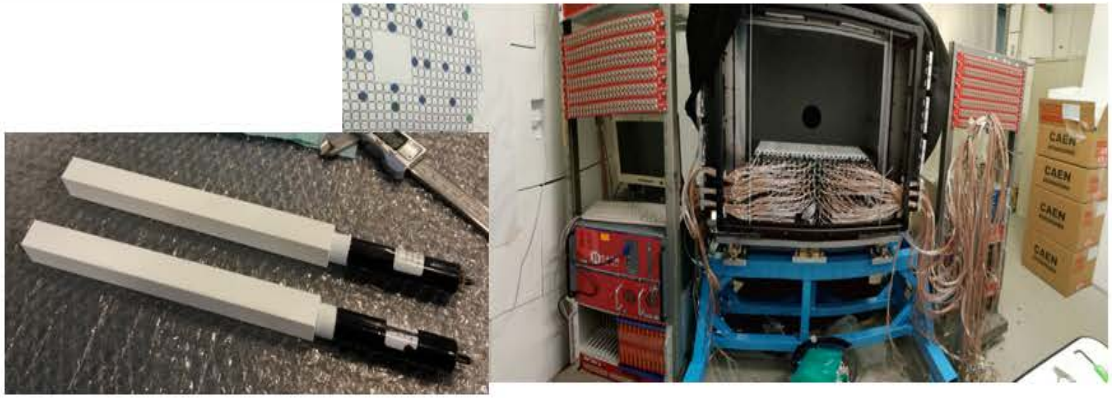
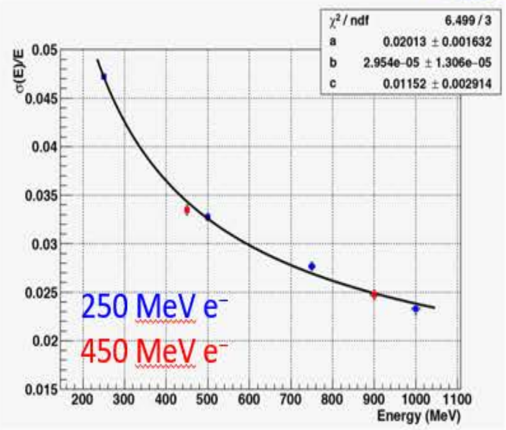
BGO Calorimeter

This is PADME main detector. Its final design is a compromise between performance, dimensions, cost.

- Cylindrical shape: radius 300 mm, depth of 230 mm
  - 616 crystals **21×21×230 mm^3**
  - Inner hole 5 crystals
- Material BGO: high LY, high ρ, small X_0 and MR, long τ_{decay} (L3 calorimeter obtained for free)
- Detector performance:
  - $\sigma(E)/E \approx 2\%/\sqrt{E}$
  - $\sigma(\theta) \sim$ 1-2 mrad
  - Angular acceptance (20 – 75) mrad







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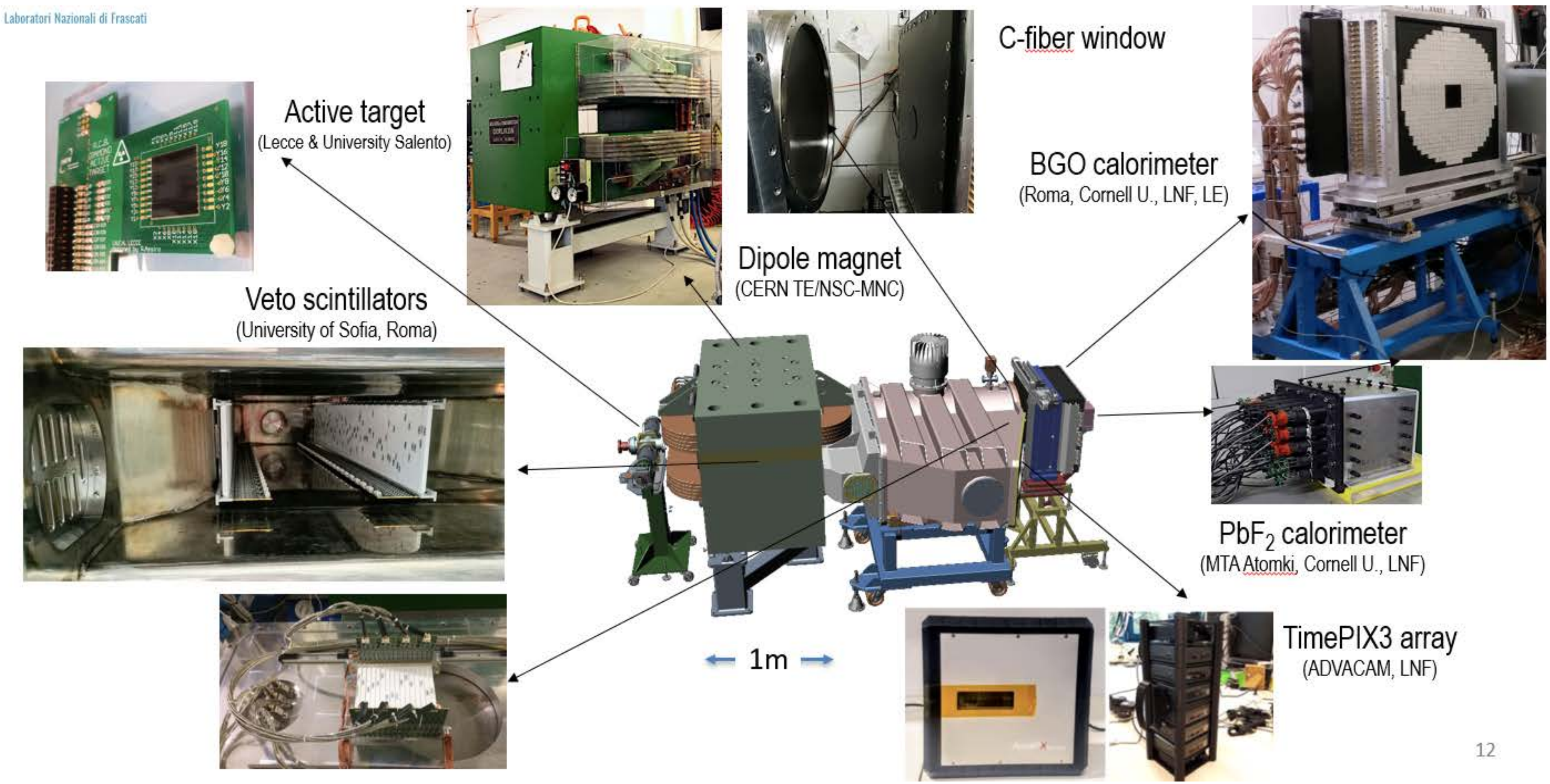
The PADME detector in a nutshell



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TA3 – Transnational Access to LNF

Update on progress

- Management
- Experiments

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TA3 – Transnational Access to LNF

Update on progress

- Management
  - Implementation TA3-LNF website
  - Implementation User Selection Panel
  - Launch of the first call

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TA3 – Transnational Access to LNF

TA3-LNF web site

http://www.lnf.infn.it/cee/STRONG2020/index.html

STRONG-2020

TA3

TRANSNATIONAL ACCESS TO LNF

INTRODUCTION

TA-LNF

TA-LNF is the acronym for Transnational Access (TA) to the Research Infrastructure Frascati National Laboratories (LNF) of Istituto Nazionale di Fisica Nucleare.

The objective of TA-LNF is to provide researchers from European Member States and Associated Countries with free access to the facilities of LNF. The external users take advantage of infrastructural, logistical, technological and scientific support (including travel and subsistence). Transnational Access is one of the three blocks of activities (Networking, Joint Research, Transnational and Virtual Access) which are the pillars of the Integrating Activity STRONG-2020.

STRONG-2020 "The strong interaction at the frontier of knowledge: fundamental research and applications" has received funding from the European Union's Horizon2020 research and innovation programme under the Grant Agreement n° 824093.

STRONG-2020 is coordinated by CNRS (France).

Know More

under grant agreement No 824093.

TA3 – Transnational Access to LNF

User Selection Panel (USP)

Frank Maas (chairperson)	**Helmholtz Institute, Mainz (Germany)**	external member
Josef Pochodzalla	**Johannes Gutenberg University, Mainz (Germany)**	external member
Edoardo Milotti	**Trieste University (Italy)**	external member
Antonella Antonelli	**Laboratori Nazionali di Frascati (Italy)**	internal member

The USP bases its selection on scientific merit and following the Article 16, Section 1, Chapter 4 of the Grant Agreement 824093 — STRONG-2020.

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TA3 – Transnational Access to LNF

Launch of the first Call

Call n.	Publication	Deadline submission	USP meeting	Start projects
1	01/07/2019	31/07/2019	05/09/2019	09/09/2019
2	03/02/2020	29/02/2020	04/03/2020	09/03/2020

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Results of the first Call

Facility	Project Number	Project Title	Acronym	Institution	Days	Travels	Users
PADME	1	Search for dark photon at the Frascati BFT	UCL_DP	University College London	30	1	1
	2	Searching for new light particles with PADME	DarkAndRare	University of Sofia St. Kl.Ohridski	130	7	7
SIDDHARTA	3	Studying kaonic deuterium atoms with SIDDHARTA-2	SIDDHARTA-2	Stefan Meyer Institute for Subatomic Physics	155	21	8
	4	Investigation of kaonic deuterium atoms with SIDDHARTA-2	KRAKOW@SIDDHARTA-2	Jagiellonian University	240	16	6
	5	Strangeness in Low Energy QCD with SIDDHARTA-2	AntiKD	Technische Universität Munchen	30	6	2
	6	Exotic Atoms Research with SIDDHARTA-2	EARS-2	IFIN-HH	30	3	1
	7	SIDDHARTA-2 preparation and data taking with HPGe tests	SIDDHARTA-2 & HPGe	University of Zagreb	80	6	4
	8	Kaonic Atoms at SIDDHARTA-2	IGFAE-Kd	IGFAE and USC	10	1	1

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Update on progress

EXPERIMENTS

- SIDDHARTA-2
- PADME

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Update on progress

SIDDHARTA-2 EXPERIMENT

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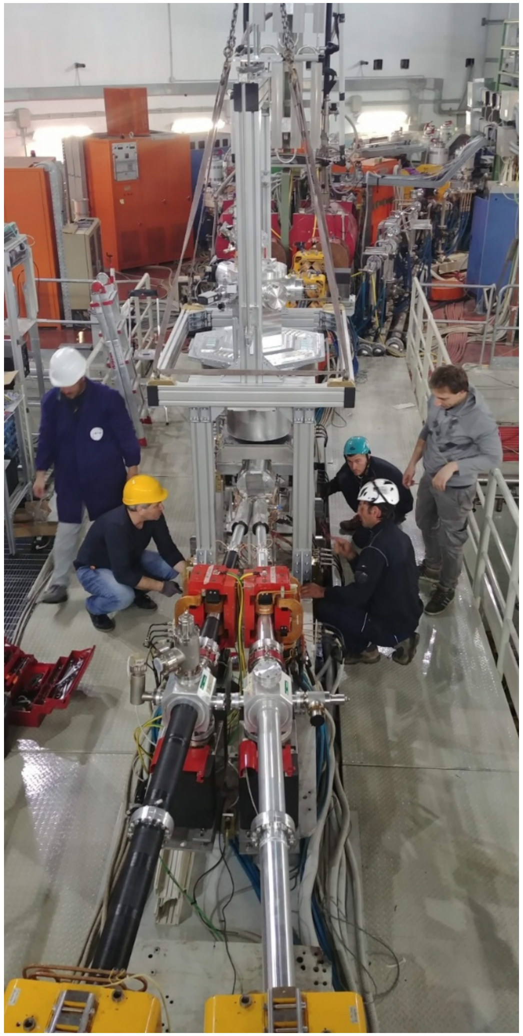

… precise adjustments . …

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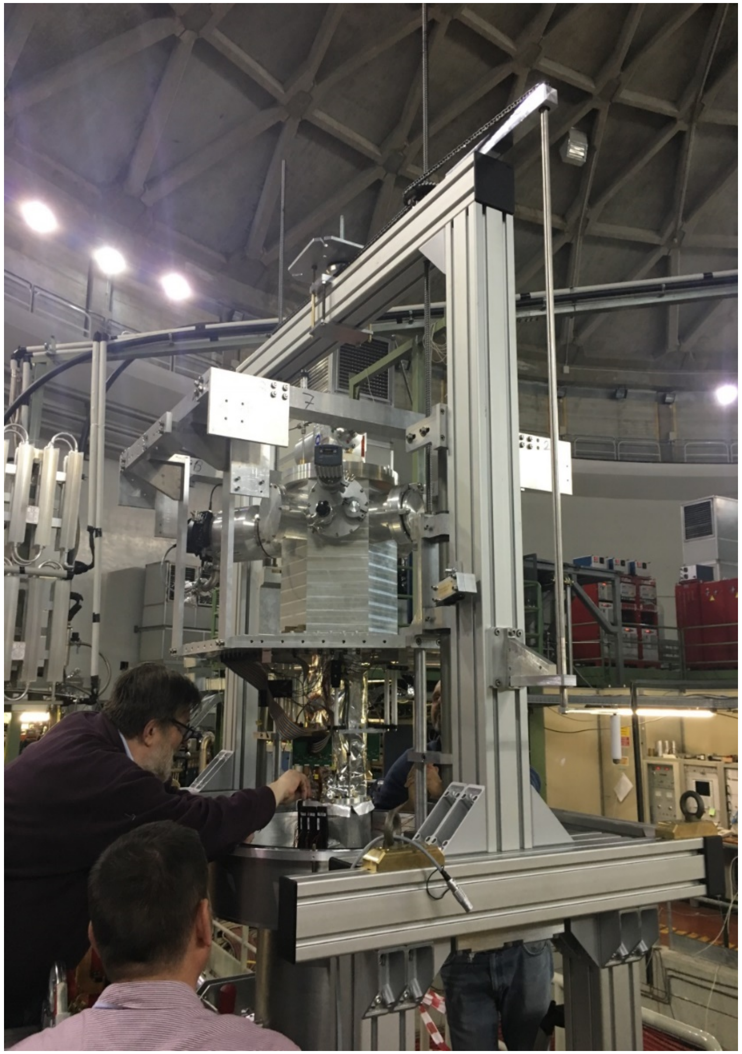

… internal components

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SIDDHARTINO installed on DAΦNE (17 April 2019)

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Update on progress

PADME EXPERIMENT

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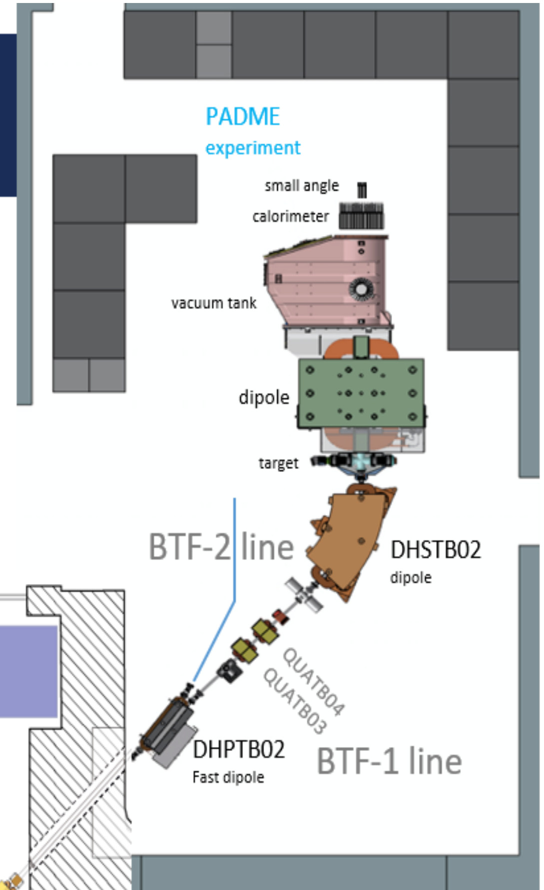
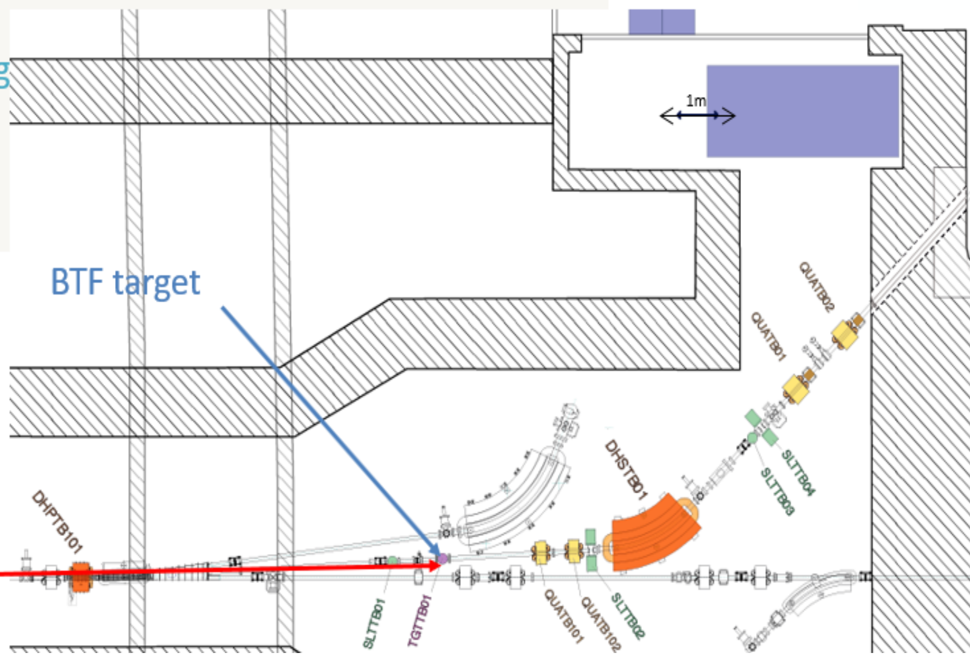
PADME beam line

Primary electrons come from a gun and are accelerated up to 800 MeV
Primary positrons come from a converter (2 X_0 W-Re target):

- Hit by electrons at 220 MeV
- Captured positrons accelerated up to 550 MeV

Secondary positron can be produce by a BTF 1.7 X_0 Cu target.
Energy selection collimation on the BTF transfer-line for defining momentum, spot size, and intensity.





Positron beam parameters:

- 1% energy spread
- 1.5 mm spot size
- 1 mrad emittance

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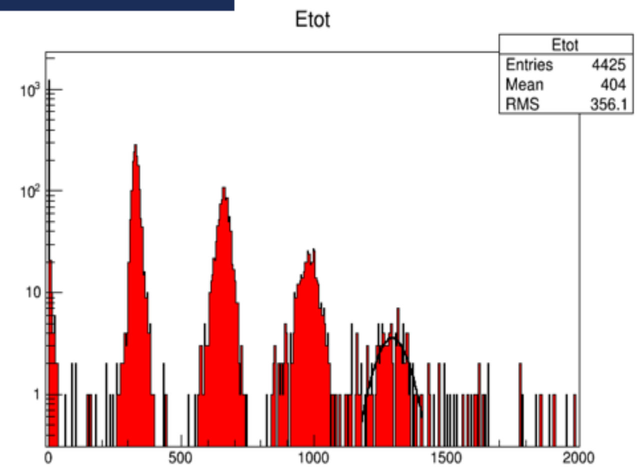
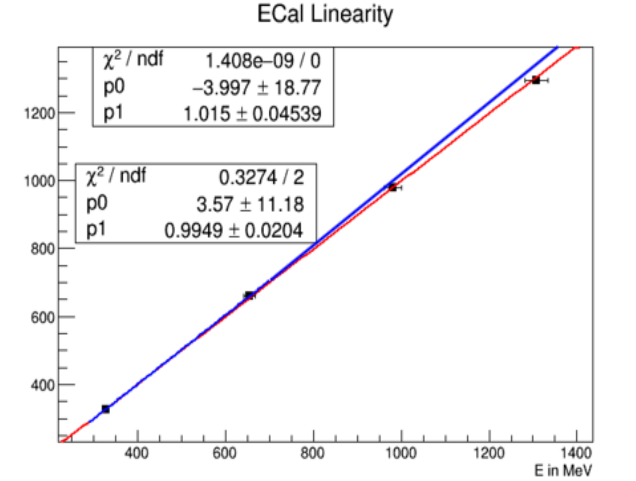
ECAL operation

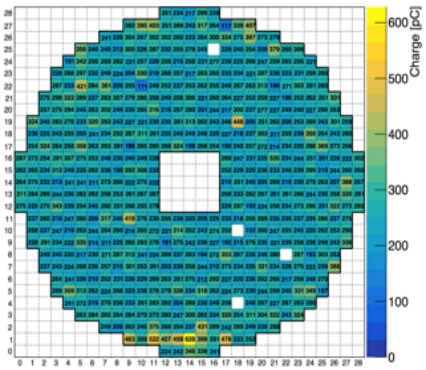


The BGO calorimeter is working as expected.

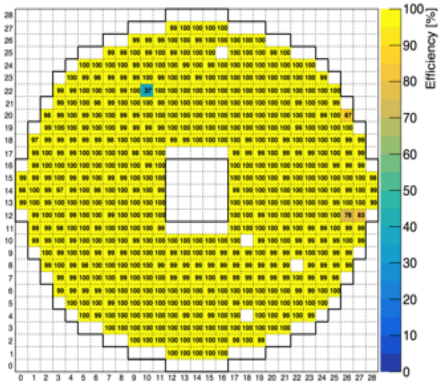
Calibration is performed online using cosmic-ray m.i.p.



Expected E_{dep}=17.8 MeV~270pC



Avg eff 99.8%
only 4 dead crystals



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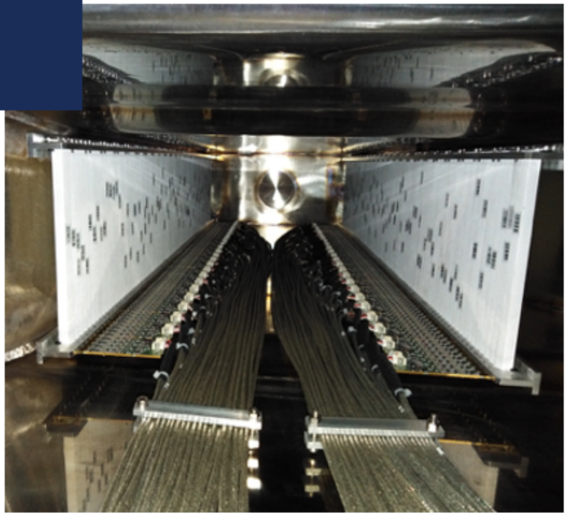
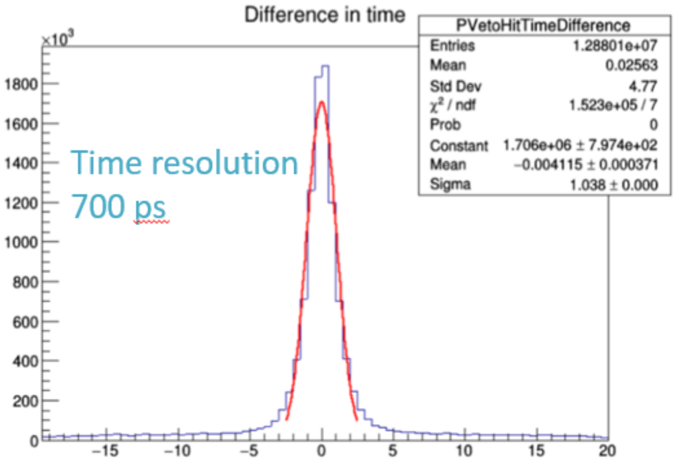
Charged particle veto



To detect and veto irradiating positrons, inside the magnet (low energy e^+) and close to beam exit (high energy e^+)

- Plastic scintillator bars 10×10×200 mm^3
- 3 sections for a total of 208 channels:
  - electrons (96), positrons (96), and high energy positrons (16)
- Inside vacuum and magnetic field region
- Main characteristics:
  - Time resolution < 1 ns
  - Efficiency better than 99.5% for MIPs



The position of the hit gives a rough estimate (2%) of the particle momentum.

Readout performed with SiPM (Hamamatsu 13360) that collect the light via WLS placed in a groove along the slab.

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Update on progress

PADME EXPERIMENT

Run1 (Oct. 2018 – Feb. 2019) devoted to beam and background studies to have the cleanest possible data sample.

Run2 (Jul. 2019) meant to study primary beam. Conditioning problems of the experiment hall prevented taking data.

Run3 foreseen in Spring 2020.

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TA3 – Transnational Access to LNF

Deliverables

D5.1) Transnational Access provision (first 18 months)

D5.2) Transnational Access provision (next 18 months)

D5.3) Transnational Access provision (whole project)

D5.1 : Transnational Access provision - multi annual implementation plan over the first 18 months

Unit of access: beam-hour
Unit cost : 80 EUR/hour
Min. quantity of access to be provided: 937,5 beam-hours
Estimated number of users: 82,5
Estimated number of days spent at the infrastructure: 750
Estimated number of projects: 22,5

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TA3 – Transnational Access to LNF

Advanced delivery after 6 months of deliverable D5.1

Delivery month (Grant Agreement)	Estimated number of days	Estimated number of users	Estimated number of projects
18	750	82.5	22.5
Extrapolation 6	250	27.5	7.5
1st Call	405	30	9

Note: The effective numbers of users and projects in the first Call reproduce in fairly good agreement the estimations in GA. The greater number of assigned man*days was a choice made in consideration of the first Call.

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THANK YOU
FOR THE ATTENTION!

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