Workshop: *Investigating the Universe with exotic atomic and nuclear matter*

Kaonic atoms studies at DAΦNE collider: from SIDDHARTA to SIDDHARTA-2

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INFN-LNF

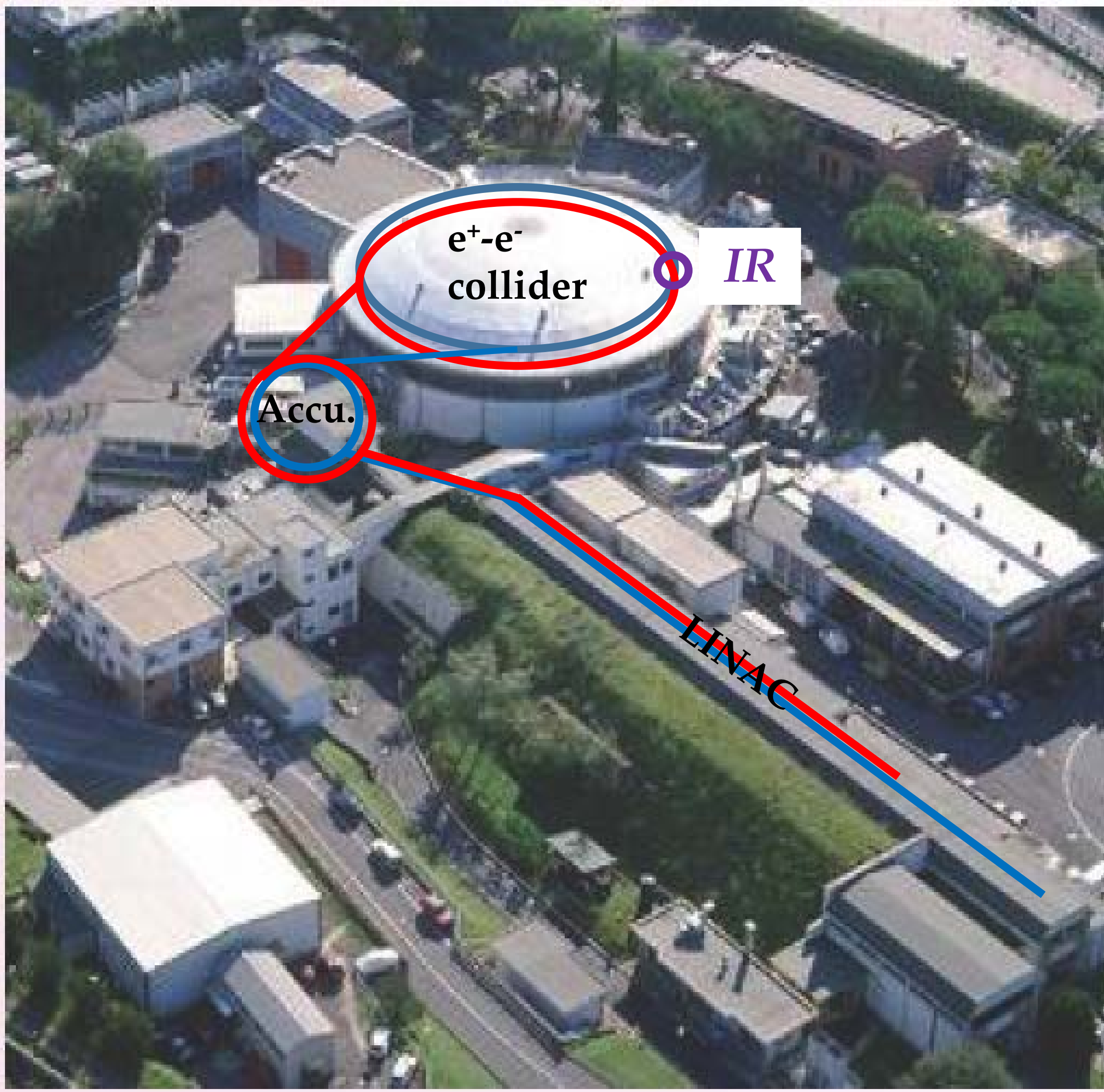
on behalf of SIDDHARTA/SIDDHARTA-2 collaborations

29 – 30 September 2020

Frascati, Italia

DAΦNE accelerator, since 1998:

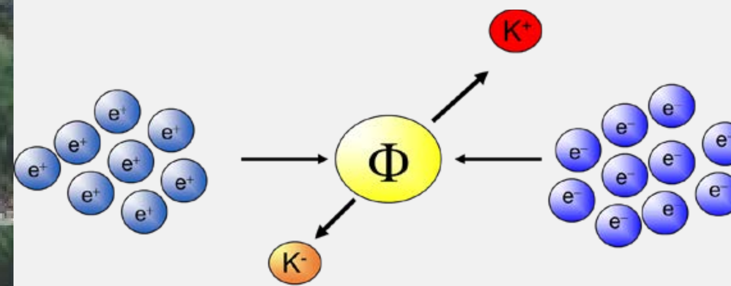
The Double Annular Φ factory for Nice Experiments



operates at the centre-of-mass energy of the Φ meson

mass $m = 1019.413 \pm .008$ MeV

width $\Gamma = 4.43 \pm 0.06$ MeV



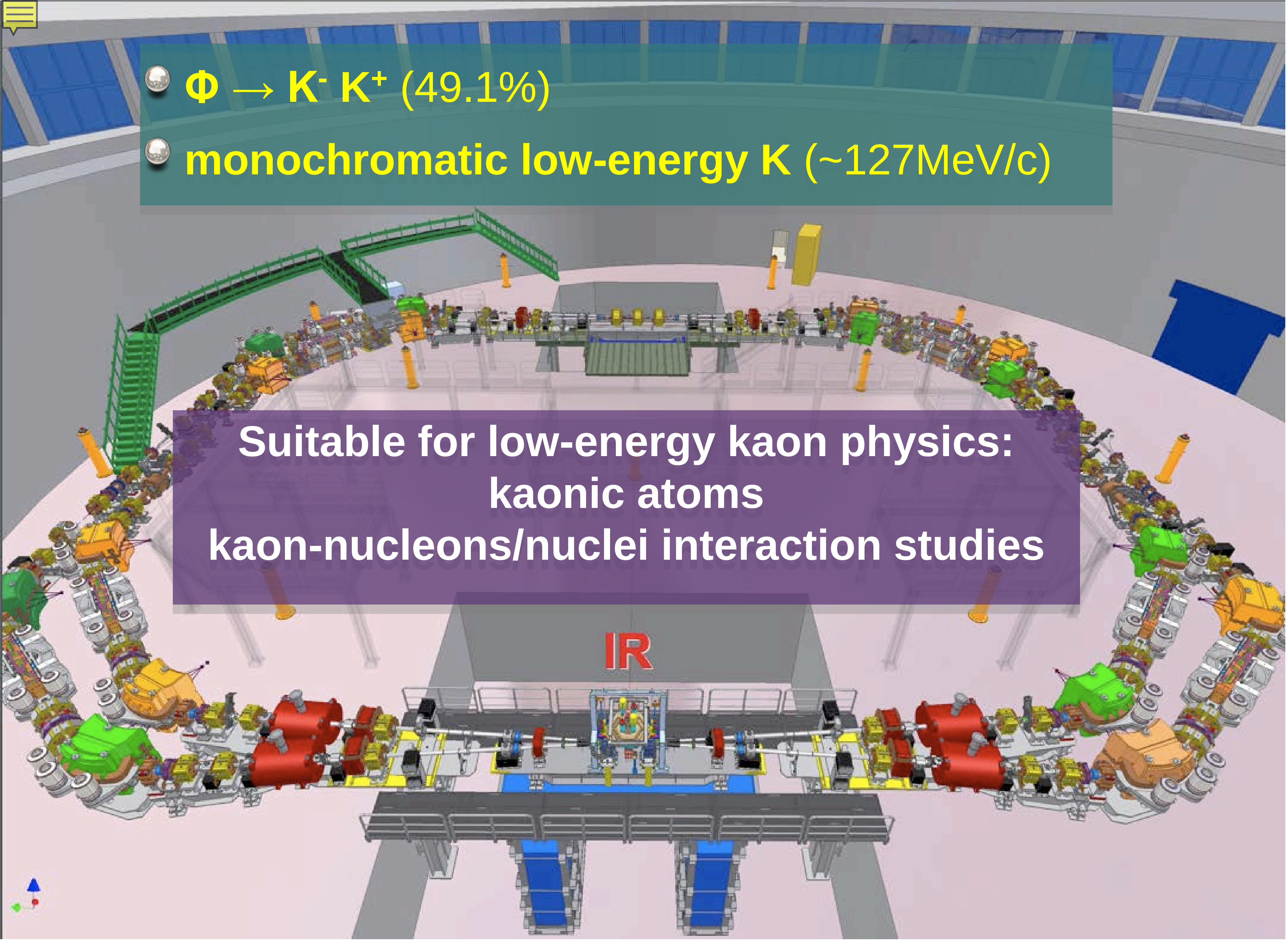
Φ produced via e^+e^- collision

$\sigma(e^+e^- \to \Phi) \sim 5\ \mu b$

→ monochromatic kaon beam (127 MeV/c)

- **$\Phi \rightarrow K^- K^+$** (49.1%)
- **monochromatic low-energy K** (~127MeV/c)

Suitable for low-energy kaon physics:
kaonic atoms
kaon-nucleons/nuclei interaction studies



SIDDHARTA-2 Collaboration

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

HadronPhysics2 — Study of Strongly Interacting Matter

HadronPhysics I3 — Study of Strongly Interacting Matter

FWF Der Wissenschaftsfonds.

Farnesina — Ministero degli Affari Esteri e della Cooperazione Internazionale

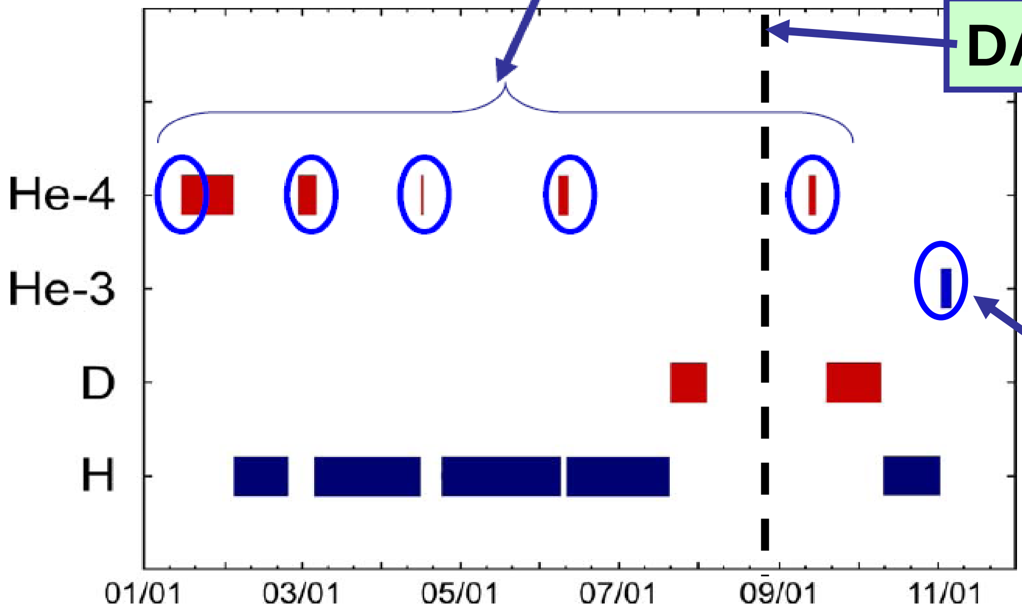
LNF- INFN, Frascati, Italy
SMI- ÖAW, Vienna, Austria
Politecnico di Milano, Italy
IFIN – HH, Bucharest, Romania
TUM, Munich, Germany
RIKEN, Japan
Univ. Tokyo, Japan
Victoria Univ., Canada
Univ. Zagreb, Croatia
Helmholtz Inst. Mainz, Germany
Univ. Jagiellonian Krakow, Poland
Research Center for Electron Photon Science (ELPH), Tohoku University
CERN, Switzerland

STRONG-2020

Croatian Science Foundation, research project 8570

SIDDHARTA data taking campaign: ended in November 2009

K-He4 data without Fe source



DAΦNE shutdown in Summer

New alignment of setup
→Improve S/N ratio

K-He3 data (~4days)

SIDDHARTA performed
kaonic atoms transitions measurements
on the upgraded DAΦNE collider

The scientific aim

SIDDHARTA measures the X-ray transitions occurring in the cascade processes of kaonic atoms

↓

Fundamental study of **strong interaction** between anti-K & nucleus at low energy limit

The scientific aim

the determination of the

isospin dependent $\overline{KN}$ scattering lengths

through a

~ precision measurement of the shift

and *of the width*

of the K_α line of kaonic hydrogen

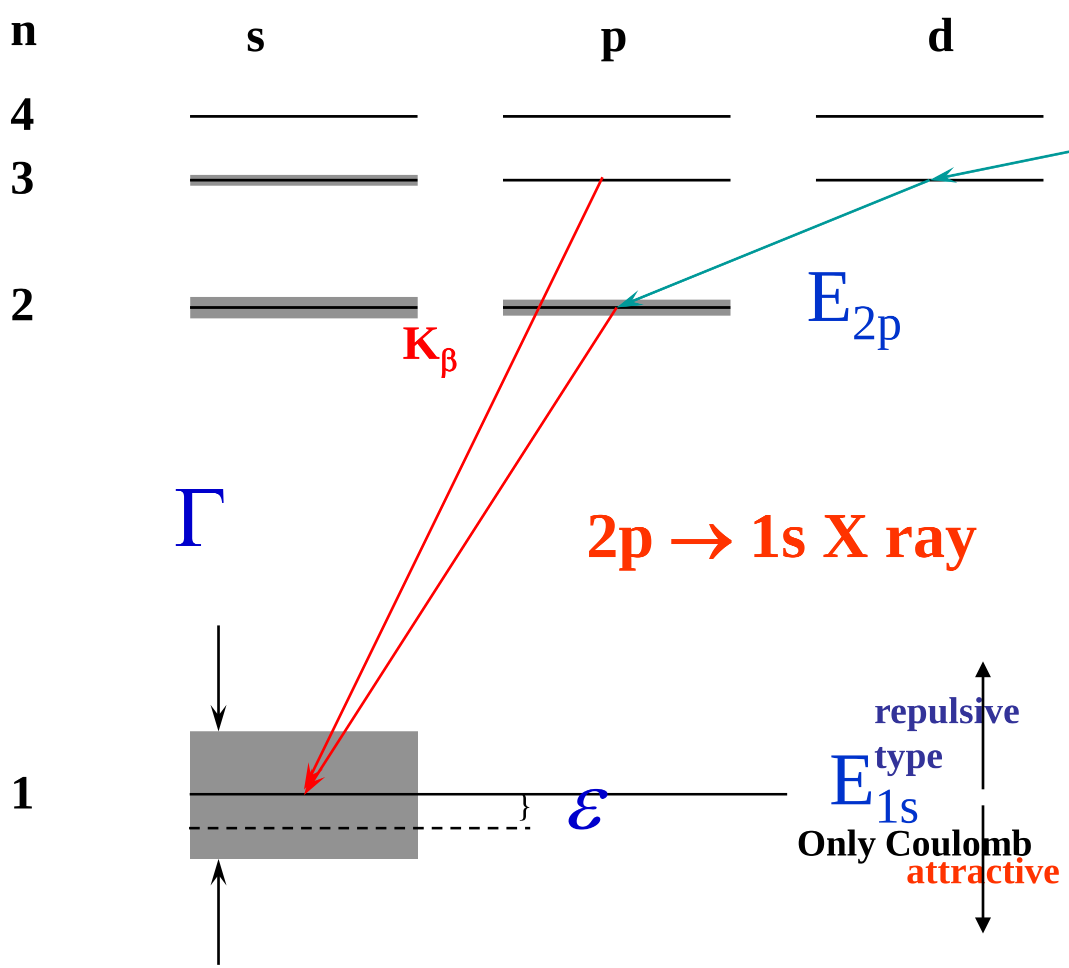
and

the *first measurement* of kaonic deuterium

Kaonic Hydrogen atoms

K- captured in excited orbit, replacing the e-

electromagnetic cascade



$$E(e.m.) \approx -\frac{1}{2}\mu c^2 (Z\alpha)^2 \cdot \left[\frac{1}{n_i^{\,2}} - \frac{1}{n_f^{\,2}}\right]$$

$$\varepsilon = E(\exp) - E(e.m.)$$
$$\varepsilon < 0\,(\text{repulsive})$$
$$\varepsilon > 0\,(\text{attractive})$$

Strong Interaction causes:

energy shift ε

of the last energy levels form their purely electromagnetic values

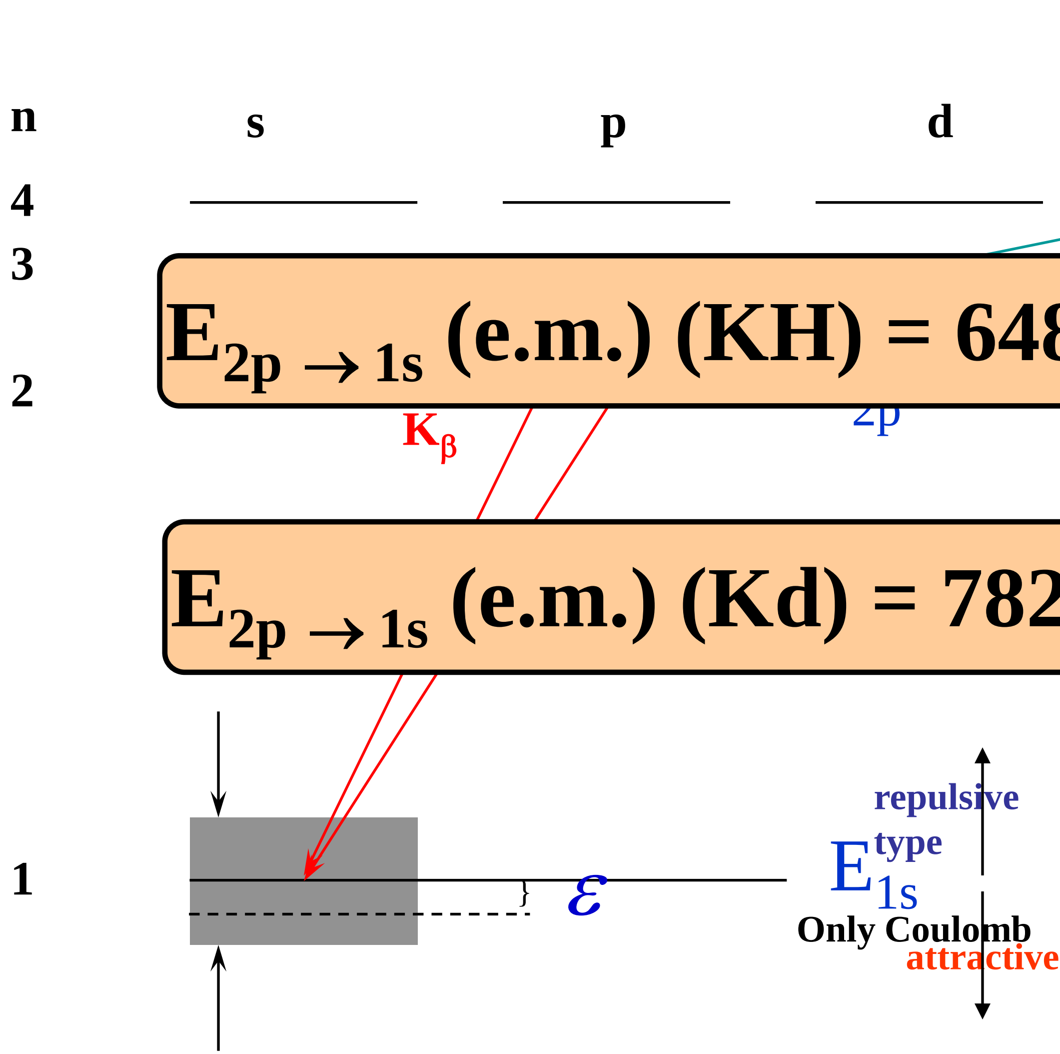
AND

level width Γ

finite lifetime of the state corresponding
to an increase in the observed level width

$$\varepsilon = E_{2p \to 1s}(\exp) - E_{2p \to 1s}(e.m.)$$

Kaonic Hydrogen atoms



$$E_{2p \to 1s}\,(\text{e.m.})\,(\text{KH}) = 6480 \pm 1\ \text{eV}$$

$$E_{2p \to 1s}\,(\text{e.m.})\,(\text{Kd}) = 7820 \pm 1\ \text{eV}$$

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

$$\varepsilon = E_{2p \to 1s}\,(\text{exp}) - E_{2p \to 1s}\,(\text{e.m.})$$

Importance of kaonic atoms studies

atomic binding energies of light systems the keV range →tens of MeV in the low-energy scattering experiments

	m (MeV/c^2)	μ (MeV/c^2)	B_{1s} (keV)	r_B (fm)	Accessible interaction
ep	0.511	0.511	13.6×10^{-3}	53 000	Electroweak
μp	105.7	95.0	2.53	279	Electroweak
πp	139.6	121.5	3.24	216	Electroweak + strong
Kp	493.7	323.9	8.61	81	Electroweak + strong
$\bar{p}p$	938.3	469.1	12.5	58	Electroweak + strong

Kaonic atoms: the unique opportunity to perform experiments equivalent to scattering at vanishing relative energies

determination of the antikaon-nucleon/nucleus interaction at "threshold", without the need of extrapolation to zero relative energy.

Determined isospin dependent KN scattering lengths are key ingredients for all models and theories dealing with low-energy QCD in systems with strangeness

- **Explicit and spontaneous chiral symmetry breaking (mass of nucleons)**
- **Dense baryonic matter structure**
- **Neutron (strange?) stars EOS**

SIDDHARTA results:

- Kaonic Hydrogen: 400pb^{-1}, most precise measurement ever,Phys. Lett. B 704 (2011) 113, Nucl. Phys. A881 (2012) 88; Ph D

- Kaonic deuterium: 100 pb^{-1}, as an exploratory first measurement ever, Nucl. Phys. A907 (2013) 69; Ph D

- Kaonic helium 4 – first measurement ever in gaseous target; published in Phys. Lett. B 681 (2009) 310; NIM A628 (2011) 264 and Phys. Lett. B 697 (2011);; PhD

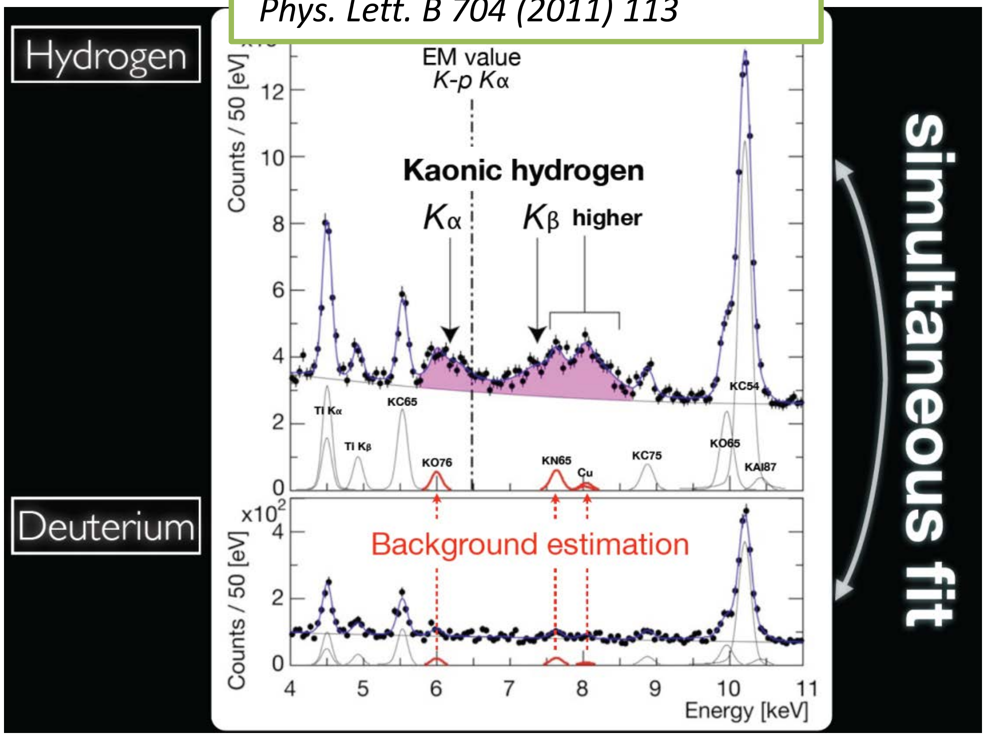
- Kaonic helium 3 – 10 pb^{-1}, first measurement in the world, published in Phys. Lett. B 697 (2011) 199; Ph D

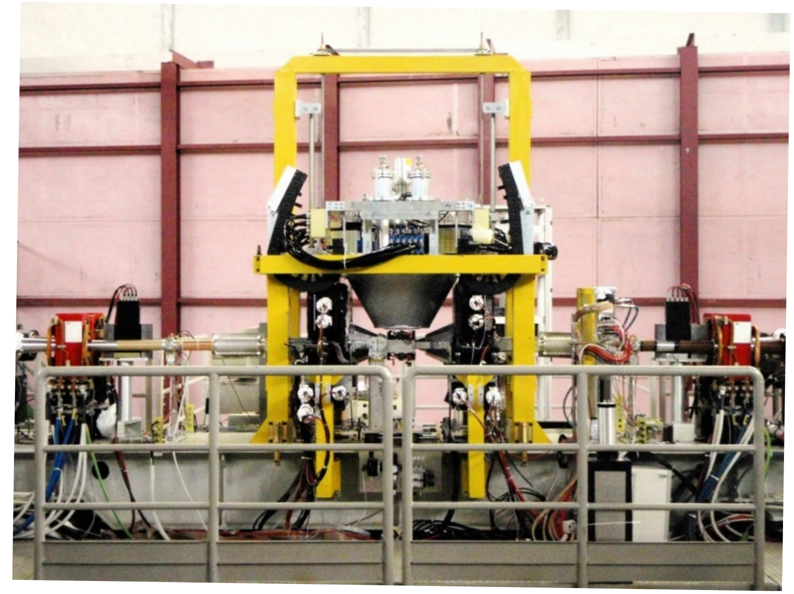
- Widths and yields of KHe3 and KHe4 - Phys. Lett. B714 (2012) 40; kaonic kapton yields – Nucl. Phys. A916 (2013) 30; yields of the KHe3 and KHe4 –EPJ A(2014) 50; KH yield – Nucl. Phys. A954 (2016) 7.

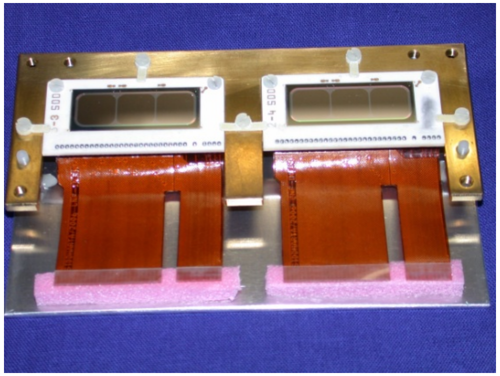
SIDDHARTA – important TRAINING for young researchers

SIDDHARTA results: KH (2009)

Phys. Lett. B 704 (2011) 113







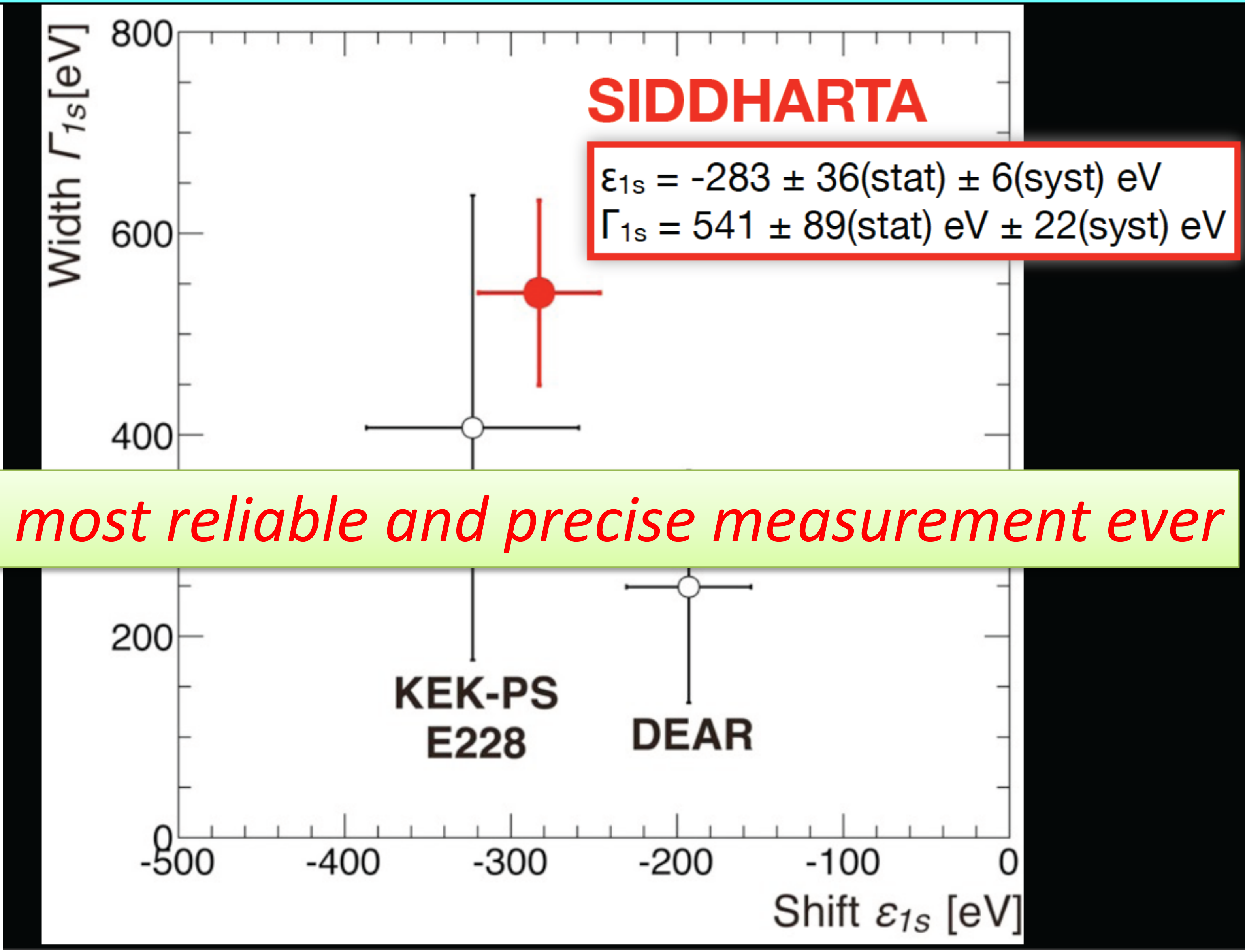
ε_{1S}= −283 ± 36(stat) ± 6(syst) eV

Γ_{1S}= 541 ± 89(stat) ± 22(syst) eV

Gas target (22 K, 2.5 bar)
144 SDD used as X-ray detector
Good energy resolution (140eV @ 6 keV)
Timing capability (huge background)

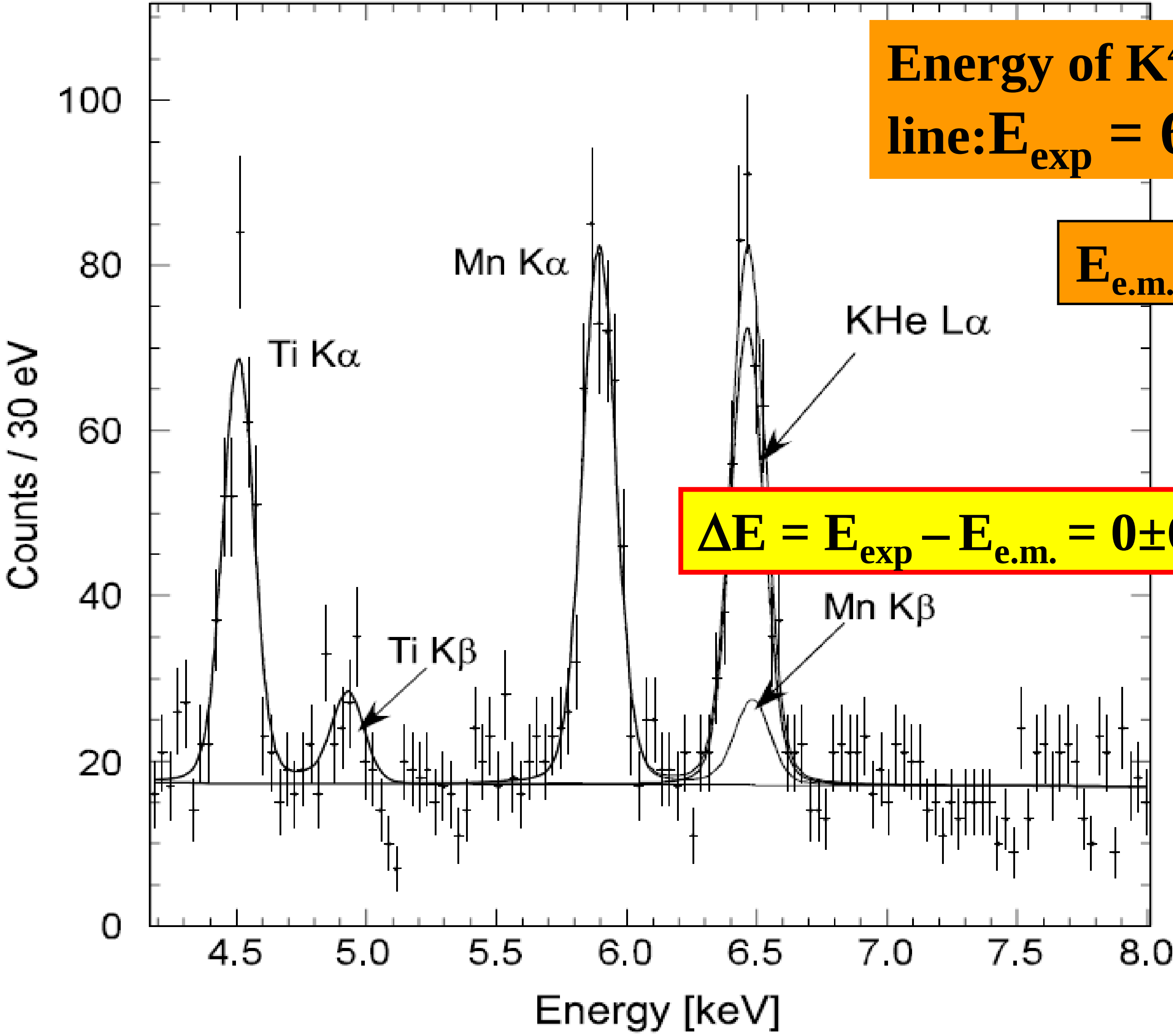
Drastically improved S/B ratio

SIDDHARTA results: KH (2009)



most reliable and precise measurement ever

SIDDHARTA results: K-^{4}He



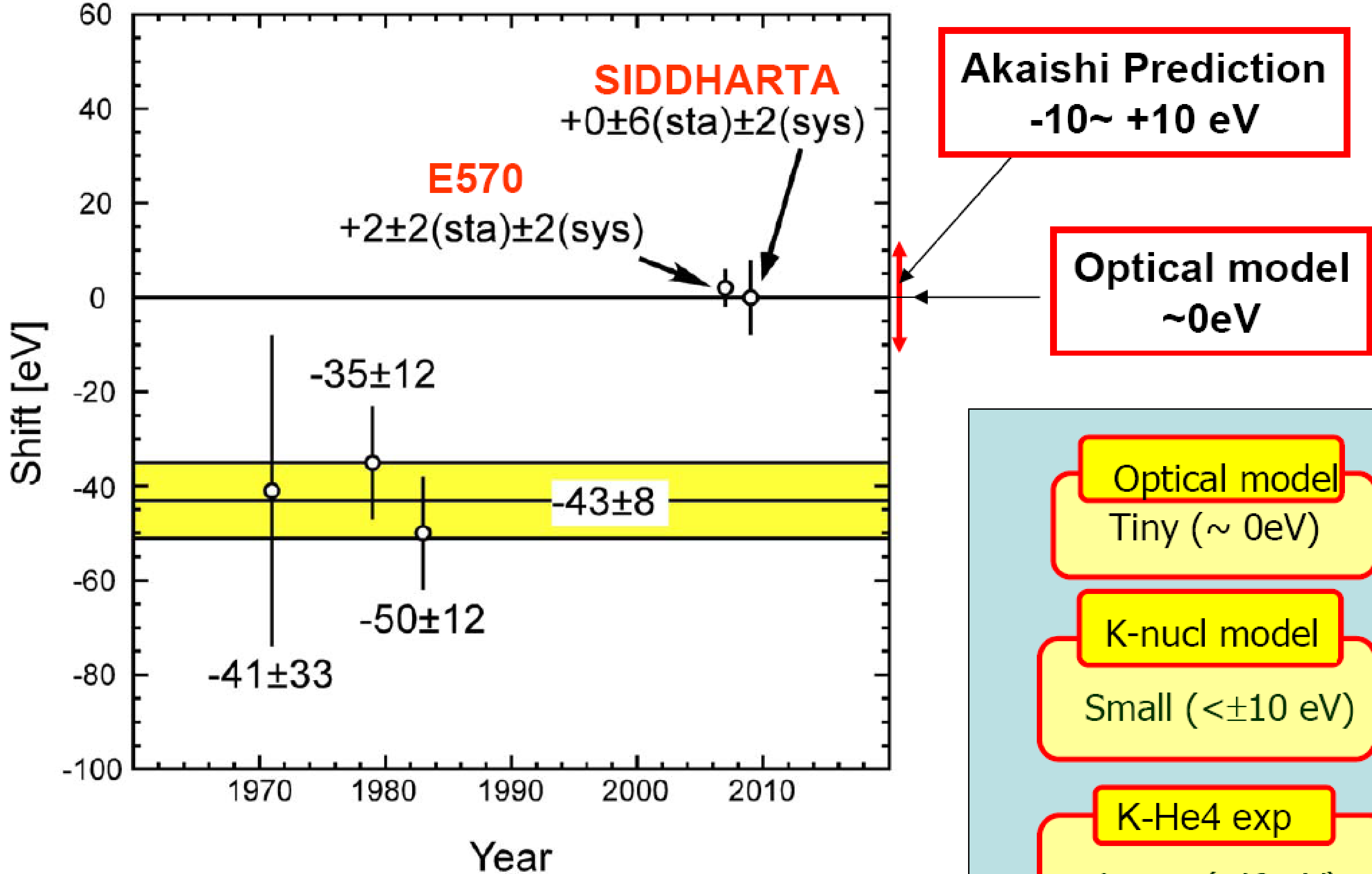
Energy of K^{4}He L$_{\alpha}$ (3d→2p) line: E_{exp} = 6463.6±5.8 eV

$E_{e.m.}$ = 6463.5±0.2 eV

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

PLB 681 (2009) 310

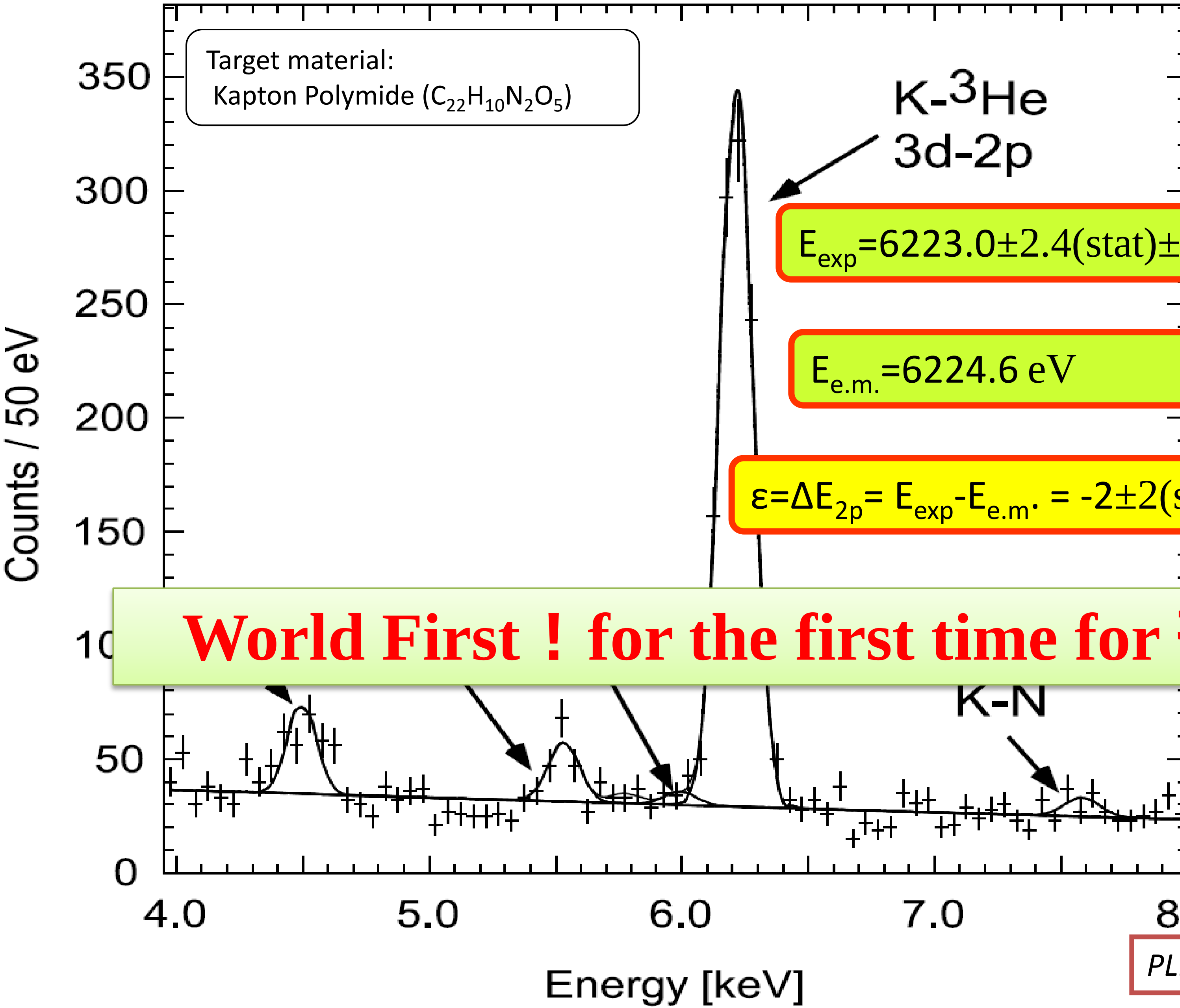
Summary of the K-^{4}He shifts



Optical model	Tiny (~ 0eV)	✓
K-nucl model	Small (<±10 eV)	✓
K-He4 exp	Large (-40 eV)	✗

for first time in a gaseous target for ^{4}He

SIDDHARTA results: K-^{3}He



E_{exp}=6223.0±2.4(stat)±3.5(syst.) eV

$E_{e.m.}$=6224.6 eV

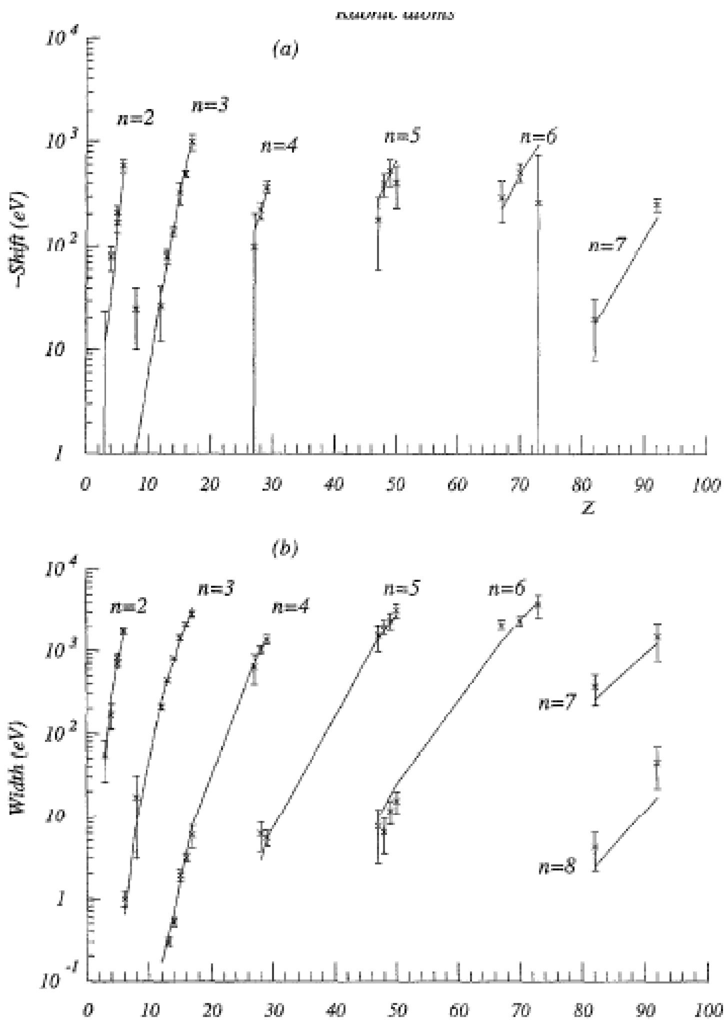
ε=ΔE_{2p}= E_{exp}-$E_{e.m.}$ = -2±2(stat)±4(syst)

World First ! for the first time for ^{3}He

PLB 697 (2011) 199

Kaonic atom 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

Kaonic atom data (Z≥3)

Used for studies of $K^{bar}N$ interaction

Optical model

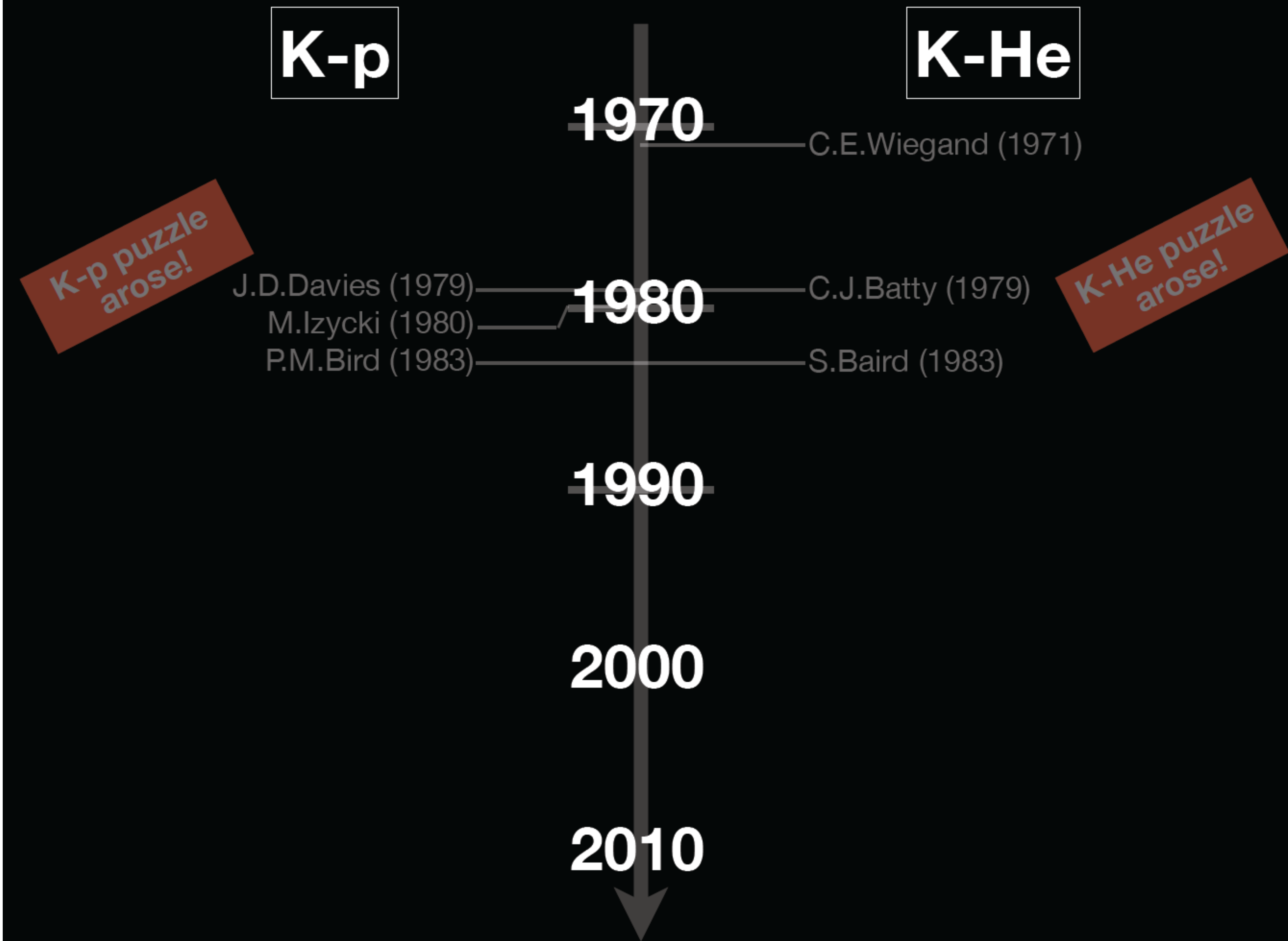
$$2\mu V_{\mathrm{opt}}^{(2)}(r) = -4\pi\left(1+\frac{\mu}{m}\right)b_0\rho(r).$$

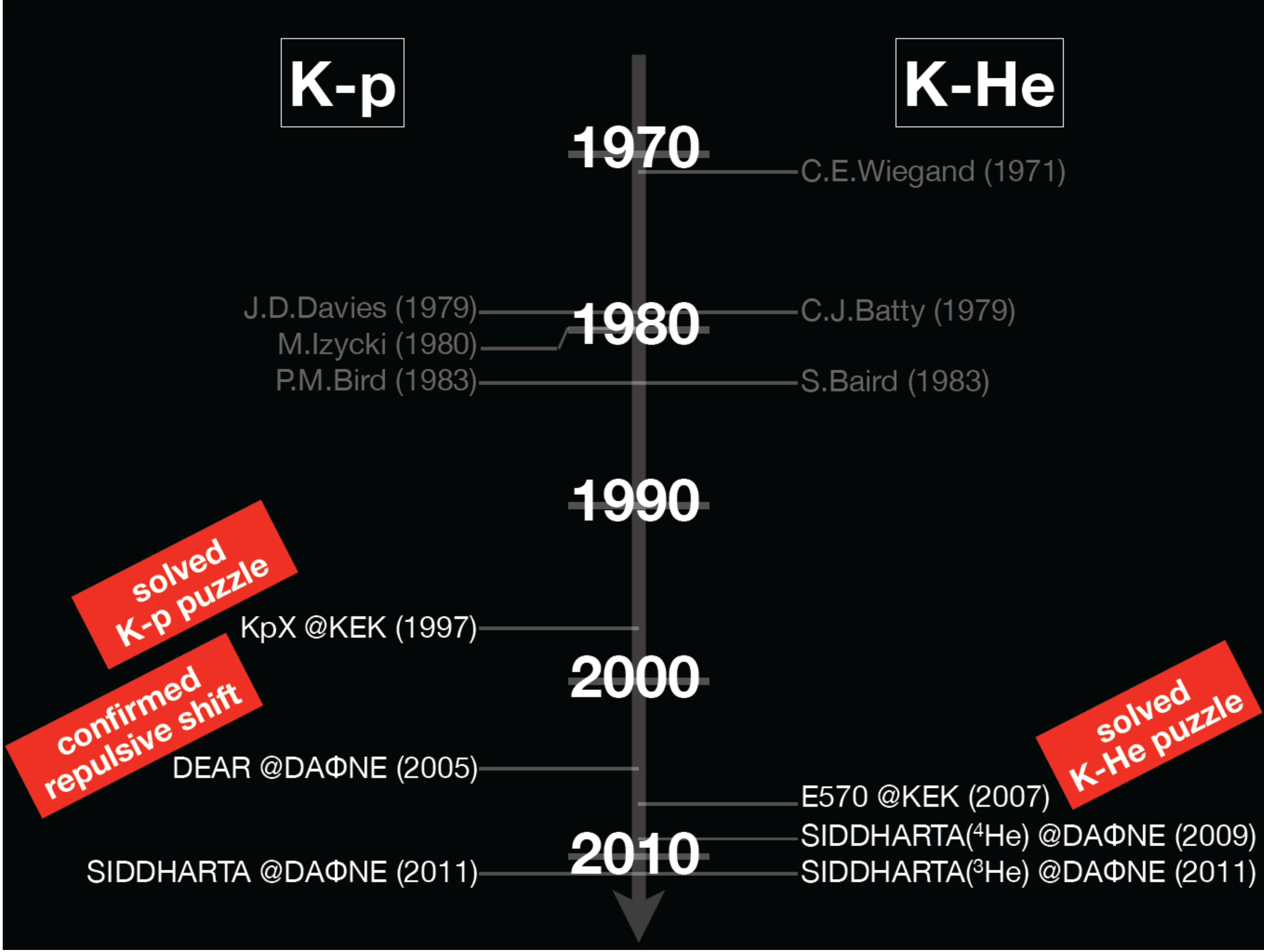
Experimental X-ray data of shift & width:
Well fitted with optical potentials

Expected shift of K-4He 2p state:
ΔE ~ 0 eV

There are discrepancies for:

Kaonic Hydrogen (Z=1)	**Kaonic Helium (Z=2)**


K-p
K-He
1970
C.E.Wiegand (1971)
K-p puzzle arose!
J.D.Davies (1979)
M.Izycki (1980)
P.M.Bird (1983)
1980
C.J.Batty (1979)
S.Baird (1983)
K-He puzzle arose!
1990
2000
2010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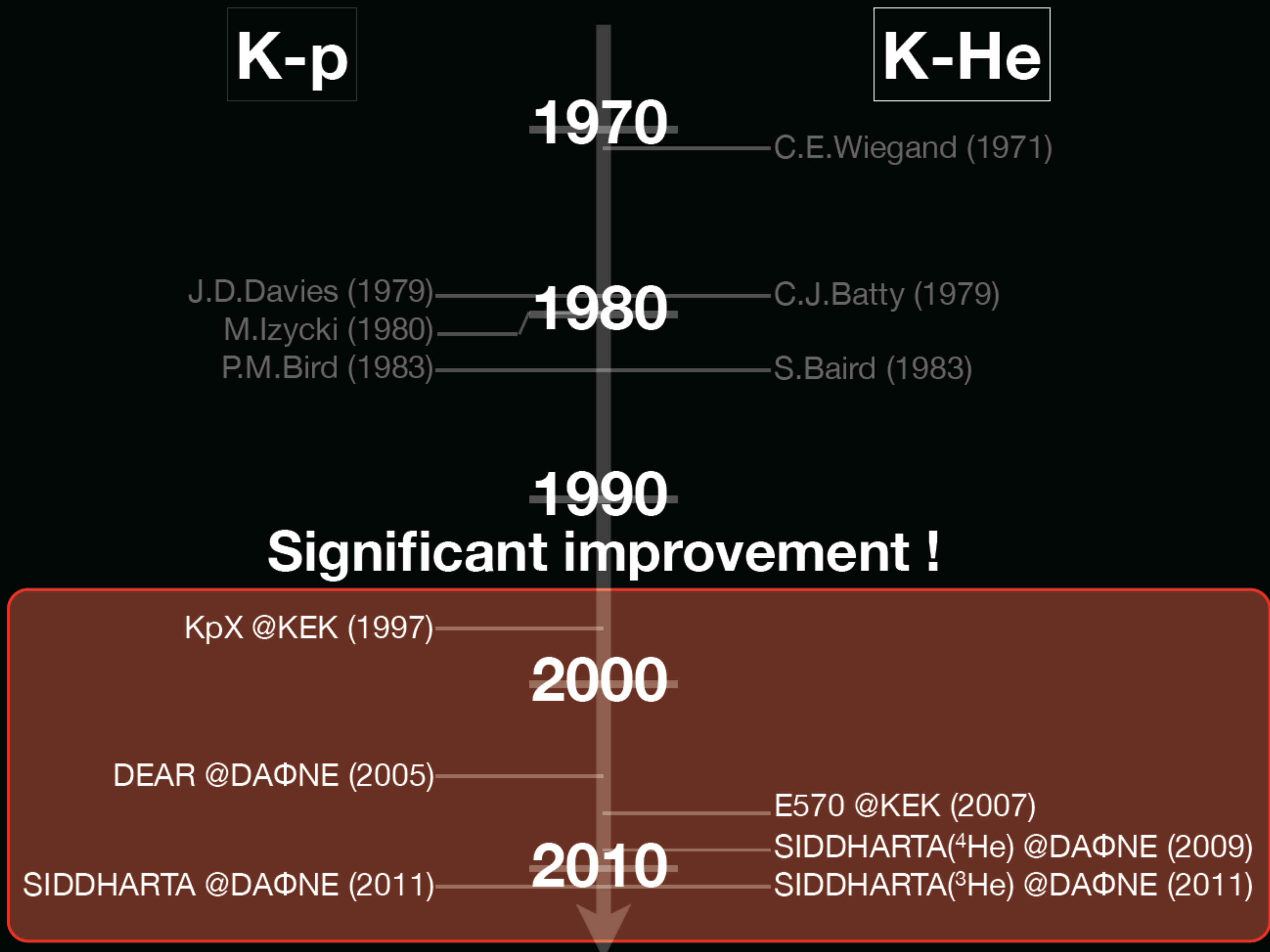
M.Izycki (1980)
P.M.Bird (1983)
S.Baird (1983)
1990
solved K-p puzzle
KpX @KEK (1997)
2000
confirmed repulsive shift
DEAR @DAΦNE (2005)
solved K-He puzzle
E570 @KEK (2007)
SIDDHARTA(4He) @DAΦNE (2009)
2010
SIDDHARTA @DAΦNE (2011)
SIDDHARTA(3He) @DAΦNE (2011)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S.Baird (1983)
1990
Significant improvement !
KpX @KEK (1997)
2000
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SIDDHARTA(^{4}He) @DAΦNE (2009)
2010
SIDDHARTA @DAΦNE (2011)
SIDDHARTA(^{3}He) @DAΦNE (2011)

K-p

K-He

1970

STILL MISSING!!!

the measurement of the kaonic deuterium

the most important experimental information missing in the field of the low-energy antikaon-nucleon interactions

SIDDHARTA-2 collaboration

starting from 2019 at DAFNE accelerator

DEAR @DAΦNE (2005)

E570 @KEK (2007)

SIDDHARTA(^{4}He) @DAΦNE (2009)

2010

SIDDHARTA @DAΦNE (2011)

SIDDHARTA(^{3}He) @DAΦNE (2011)

The scientific aim of SIDDHARTA-2

To perform precision measurements of kaonic atoms X-ray transitions

- unique information about QCD in the non -perturbative regime in the strangeness sector not obtainable otherwise

Starting with the precision measurement of ***shift*** and ***width*** of ***kaonic hydrogen***

- **NOW first measurement of kaonic deuterium**

To extract the antikaon-nucleon isospin dependent scattering lengths

- chiral symmetry breaking (mass problem), EOS for neutron stars

Deser Formula

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

$$\varepsilon_{1s} + \frac{i}{2}\Gamma_{1s} = 2\alpha^3\mu^2 a_{K-p}[1 - 2\alpha\mu(ln\alpha - 1)a_{K-p} + \ldots]$$

A similar formula holds for $a_{K\text{-}d}$

$$\varepsilon_{1s} + \frac{i}{2}\Gamma_{1s} = 2\alpha^3\mu^2 a_{K-d}[1 - 2\alpha\mu(ln\alpha - 1)a_{K-d} + \ldots]$$

The connection between the scattering lengths $a_{K\text{-}p}$ and $a_{K\text{-}d}$ and the s-wave $\bar{K}N$ isospin dependent (I=0,1) isoscalar a_0 and isovector a_1 scattering length:

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

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

$$a_{K-d} = \frac{4[m_N + m_K]}{[2m_N + m_K]} Q + C$$

$$Q = \frac{1}{2}[a_{K-p} + a_{K-n}] = \frac{1}{4}[a_0 + 3a_1]$$

C, includes all higher-order contributions, namely all other physics associated with the K^-d three-body interaction.

Fundamental inputs of low-energy QCD effective theories.

SIDDHARTA-2 improvements

SIDDHARTA-2 is a development

both on the detector side and on target side.

SIDDHARTA-2, consists in a series of improvements with respect to the SIDDHARTA setup aiming to dramatically:

increase the S/B ratio and also the signal rate:

- by gaining in solid angle
- taking advantage of new SDDs

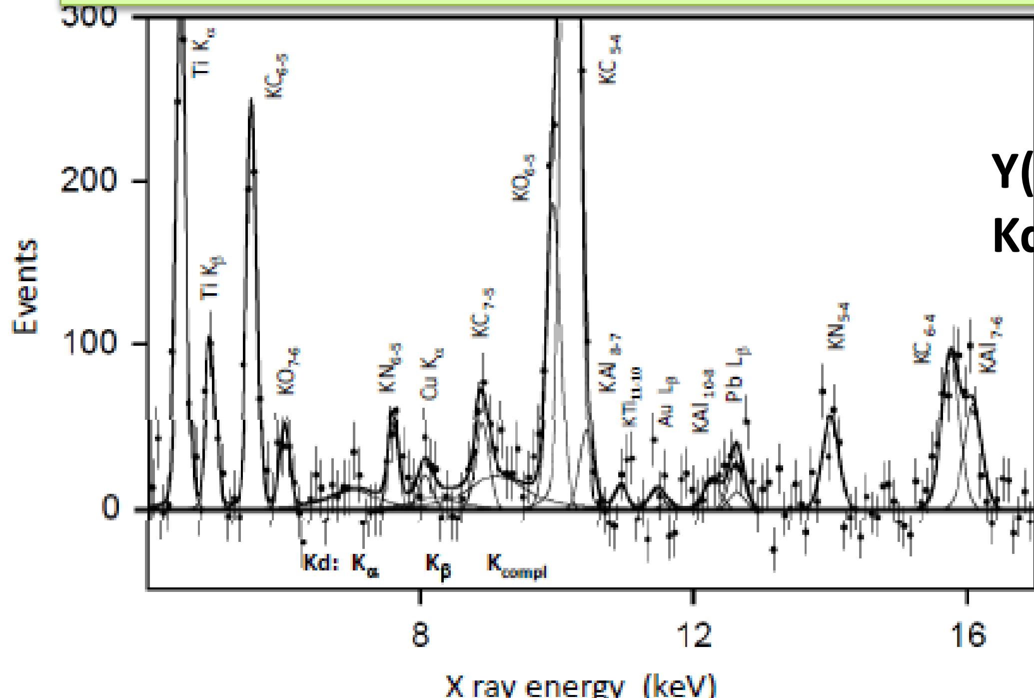
and

of the reduction of the background:

- by improving the SDDs timing
- implementing of an additional veto system

SIDDHARTA Kd exploratory measurement

First exploratory measurement for Kd



$Y(K_{tot})$ = 0.0077 ±0.0051

Kd K_α yield $Y(K_\alpha)$ = 0.0019 ± 0.0012

Yield of a factor about 10 smaller then the KH yield, estimated to be 1 to 2 % for K_α.

an enhancement by one order of magnitude of the signal-to background ratio is required for SIDDHARTA-2.

Experimental challenges towards K^-d

- X-ray yield: K^-p ~ 1 %
  K^-d ~ 0.1 %

- 1s state width: K^-p ~ 540 eV
  K^-d ~ 800 – 1000 eV

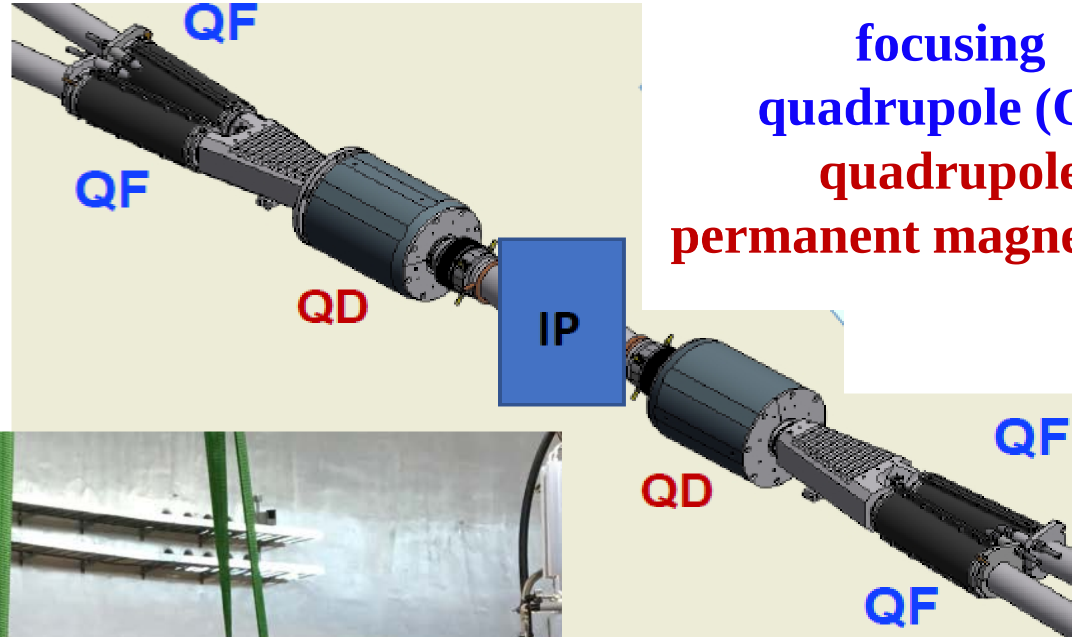
BG sources: asynchronous BG → timing
synchronous BG → spatial correlation

an enhancement by one order of magnitude of the signal-to background ratio is required for SIDDHARTA-2.

Important features of the SIDDHARTA-2 setup

- New interaction region and beam pipe
- Special designed shielding
- Lightweight cryogenic target
- Silicon Drift Detector
- Veto-2 system
- Luminosity monitor

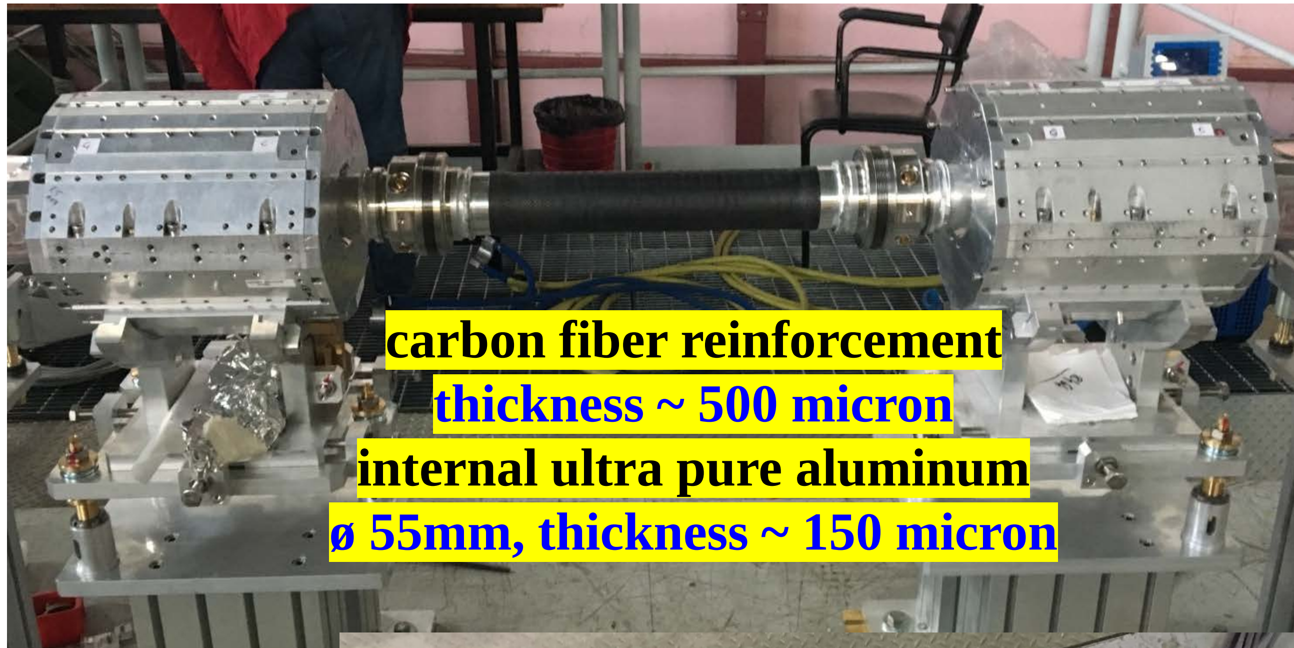
New interaction region

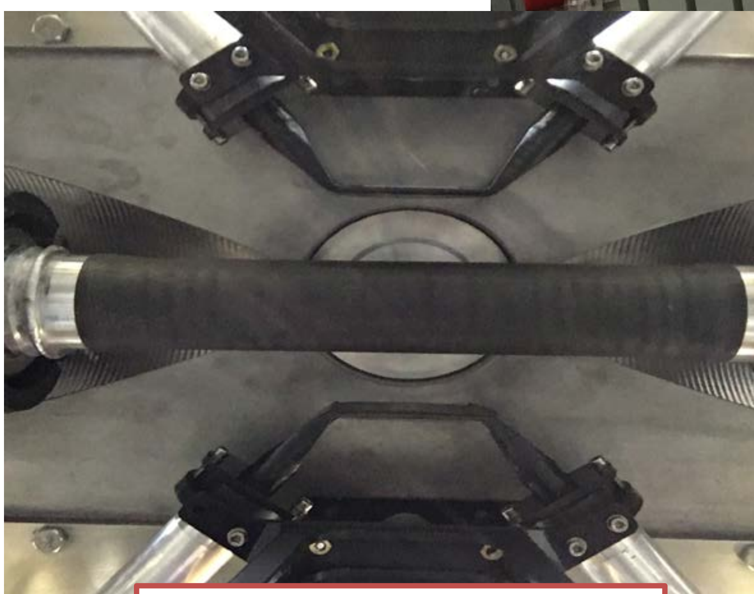


focusing quadrupole (QF)
quadrupole permanent magnet (QD)

New beam pipe

flanges removed
major source of
asynchronous
background



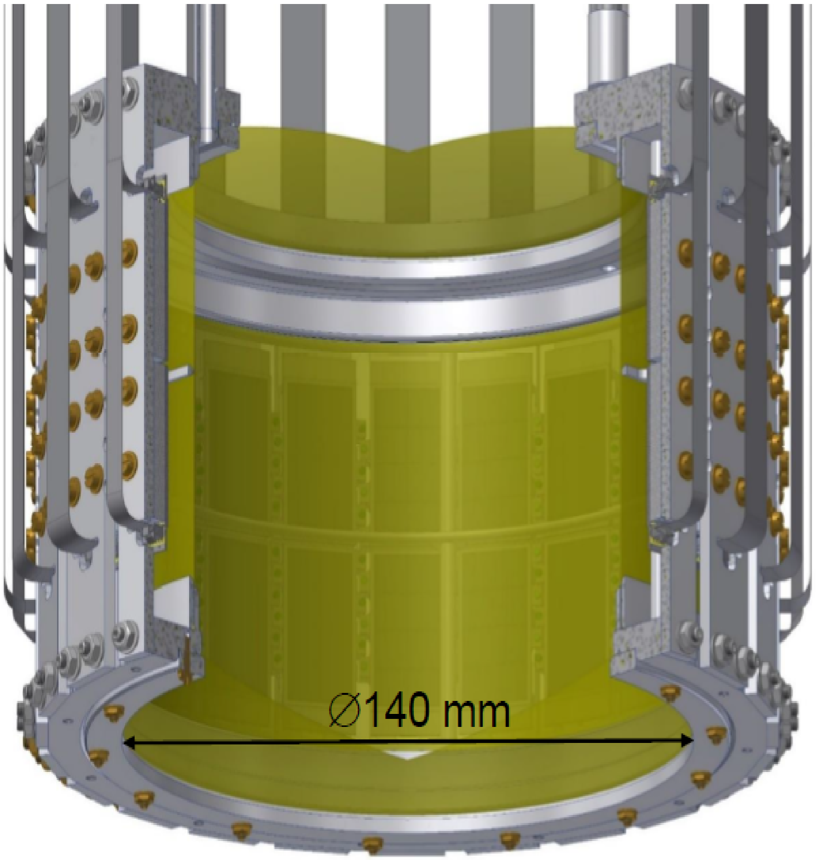


SIDDHARTA-2 luminosity monitor

DAΦNE luminosity monitor

SIDDHARTA-2 cryogenic target

Working temperature: 30 K
Working pressure : 0.3 MPa



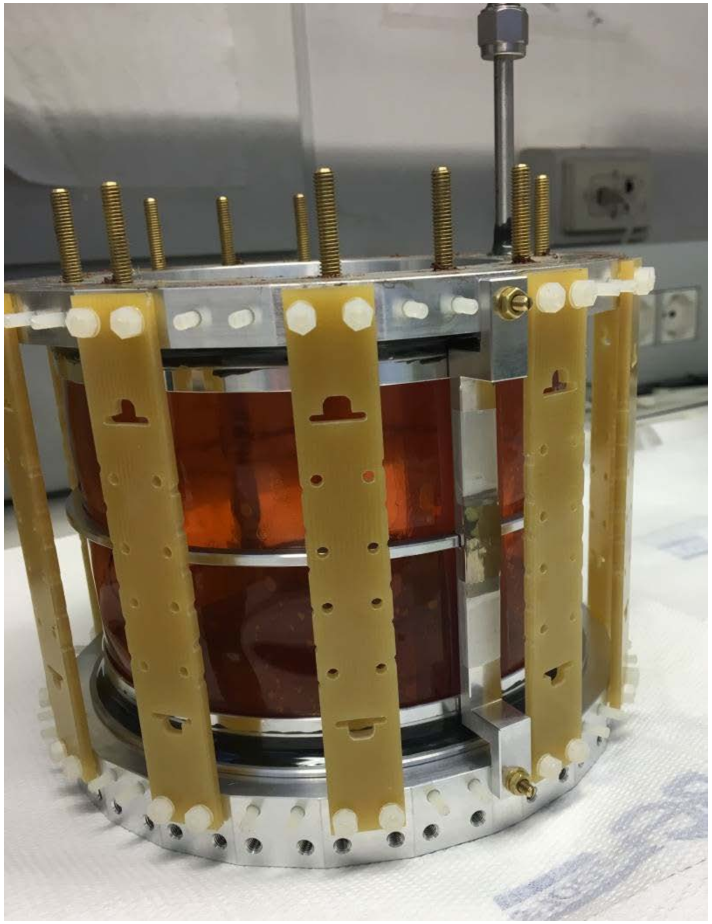
Final test during summer 2017:
Pressurised for 16 days
with P = 0.3 MPa (overP)

Cooling/pressure test
- 2.5 weeks 30 K / 0.19 MPa
- 3.5 days 30 K / 0.31 MPa

➢ Target cell wall is made of a 2-Kapton layer structure (25 μm + 25 μm + Araldit < 100 μm)

➢ **HP Deuterium generator**

Light target and Silicon Drift Detector assembly

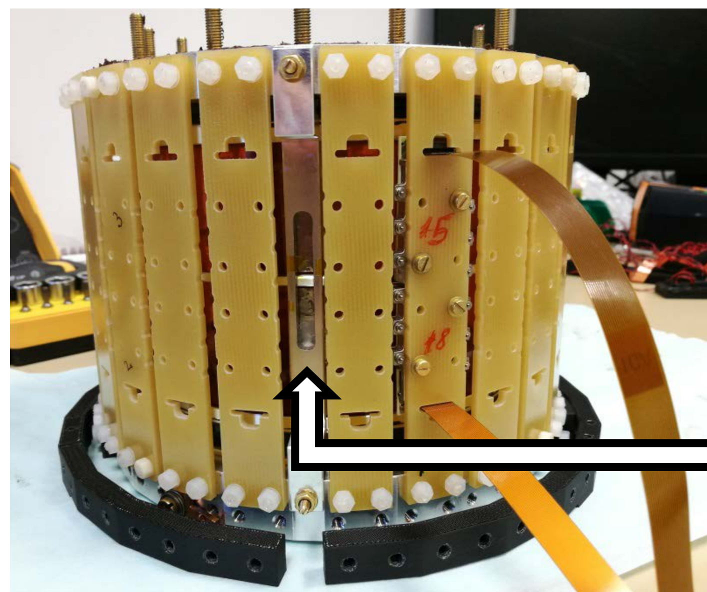


increase the target stopping power

almost double gas density with respect to SIDDHARTA (3% LHD)

SDDs placed 5 mm from the target wall

Target cell wall is made of a 2-Kapton layer structure (75 µm + 75 µm + Araldit)

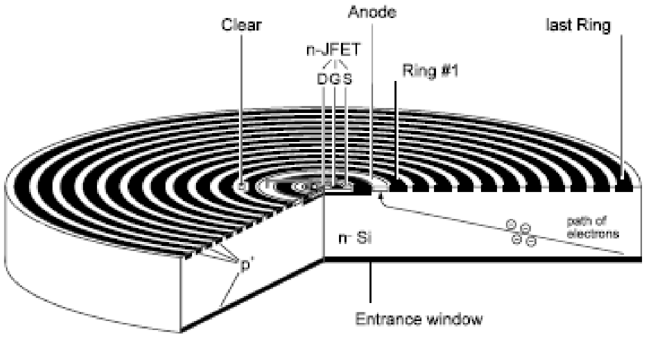


calibration foils inserted near to the SDD are activated by the X-ray tubes

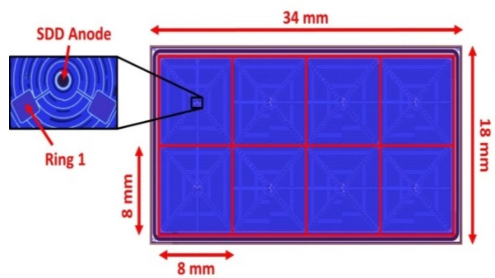
New SDD detectors

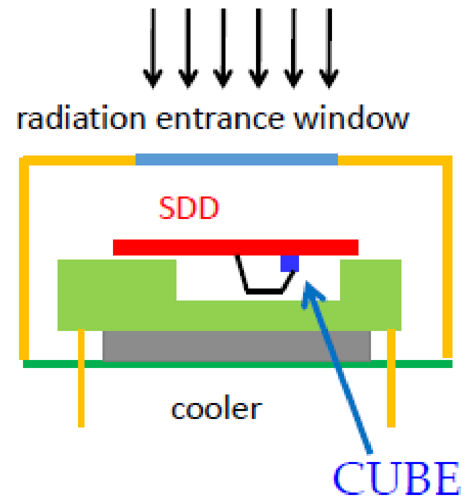
difference with respect to the SDDs in SIDDHARTA:

- the change of the preamplifier system from the JFET structure on the SDD chip to a complementary metal-oxide semiconductor integrated charge sensing amplifier CUBE), able to operate at very low temperatures (below 50 K) (standard SDD technology)
- reduction of the single element size (from 10 × 10 to 8 × 8 mm2)



Better drift time of 300 ns compared to the SDDs in SIDDHARTA (~800 ns)





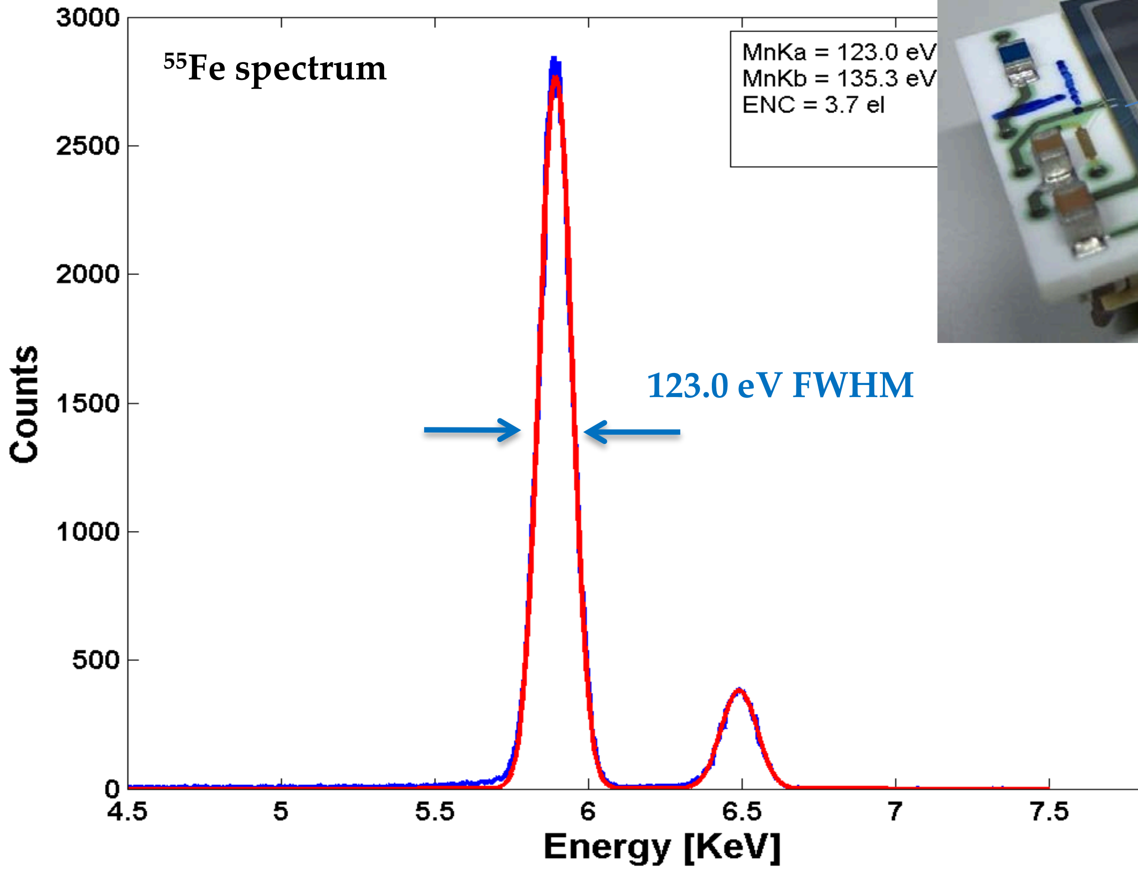
Monolitic 4x2 SDD array - single unit

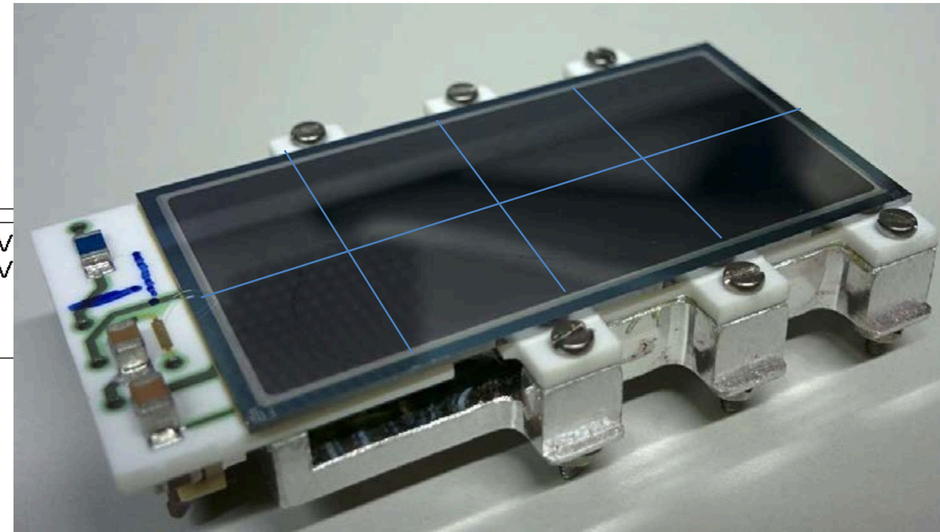
SDD characteristics:

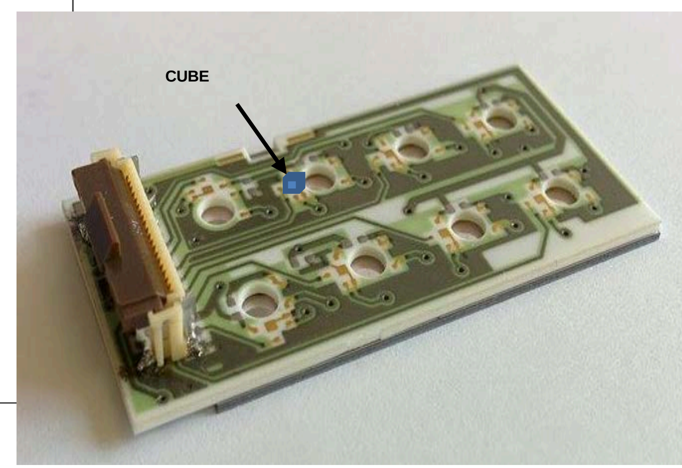
- area/cell = 64 mm^2
- total area = 512 mm^2
- T = - 100°C
- drift time < 500 ns

SIDDHART-2 new X-ray detector

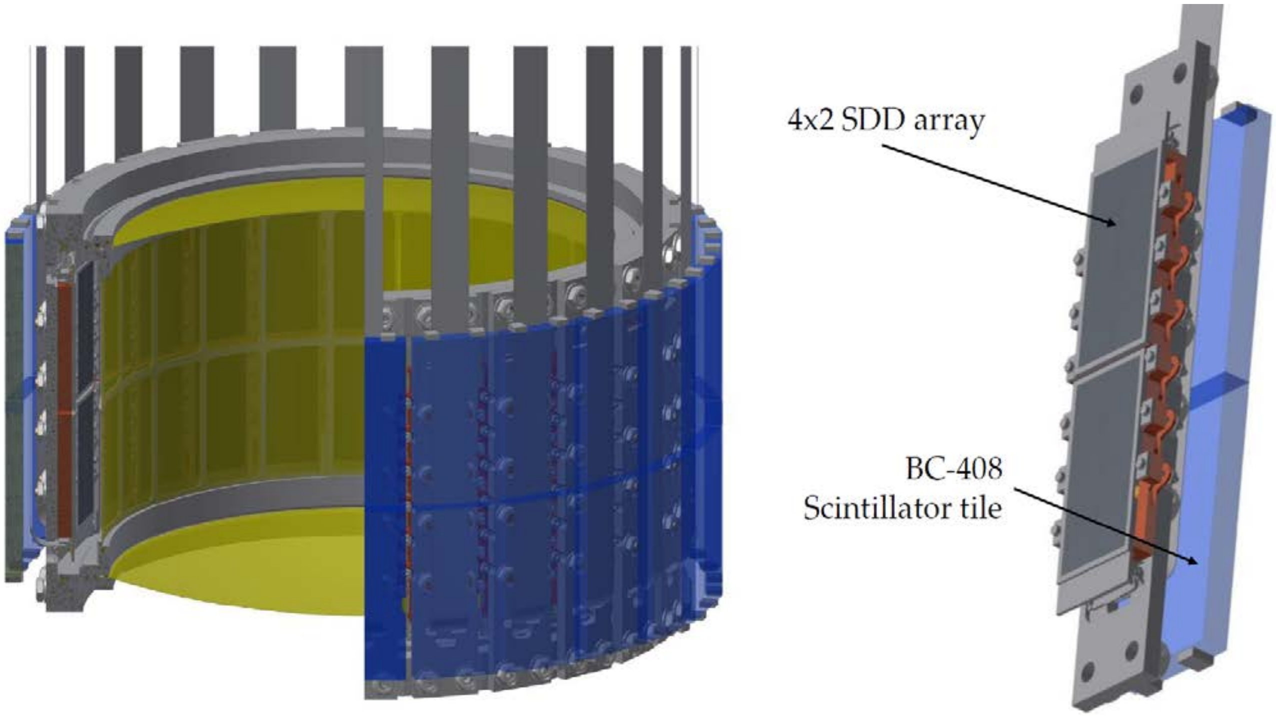
New SDD technology with CUBE preamplifier







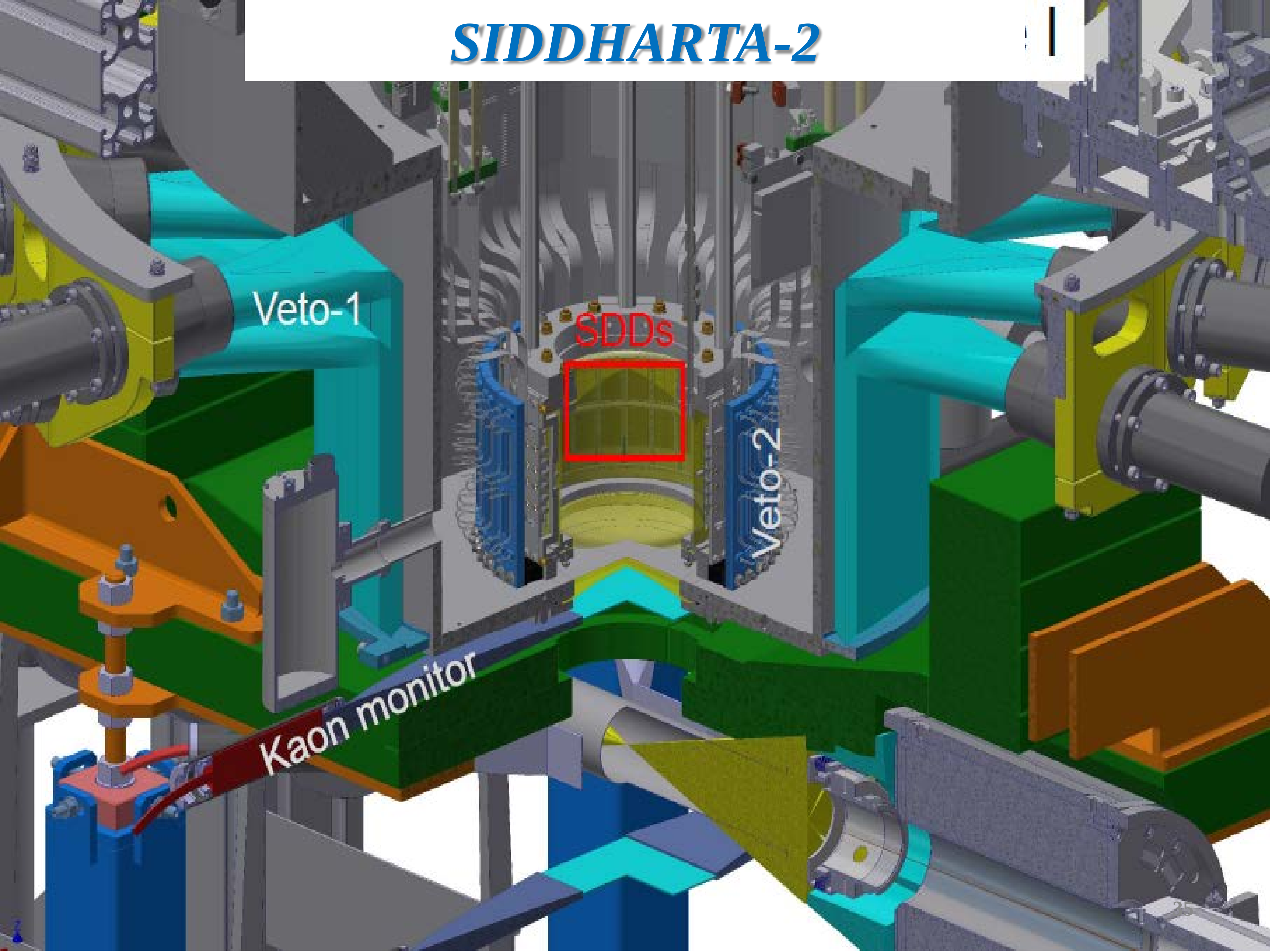
The 4 x2 SDD array around the target cell



The new advance technology will allow to setup a cryogenic target detector system with an efficient detector packing density,
covering a solid angle for stopped kaons in the gaseous target of ~ 2π.

48 monolithic SDD arrays will be around the target with a total area of about 246 cm^2

SIDDHARTA-2

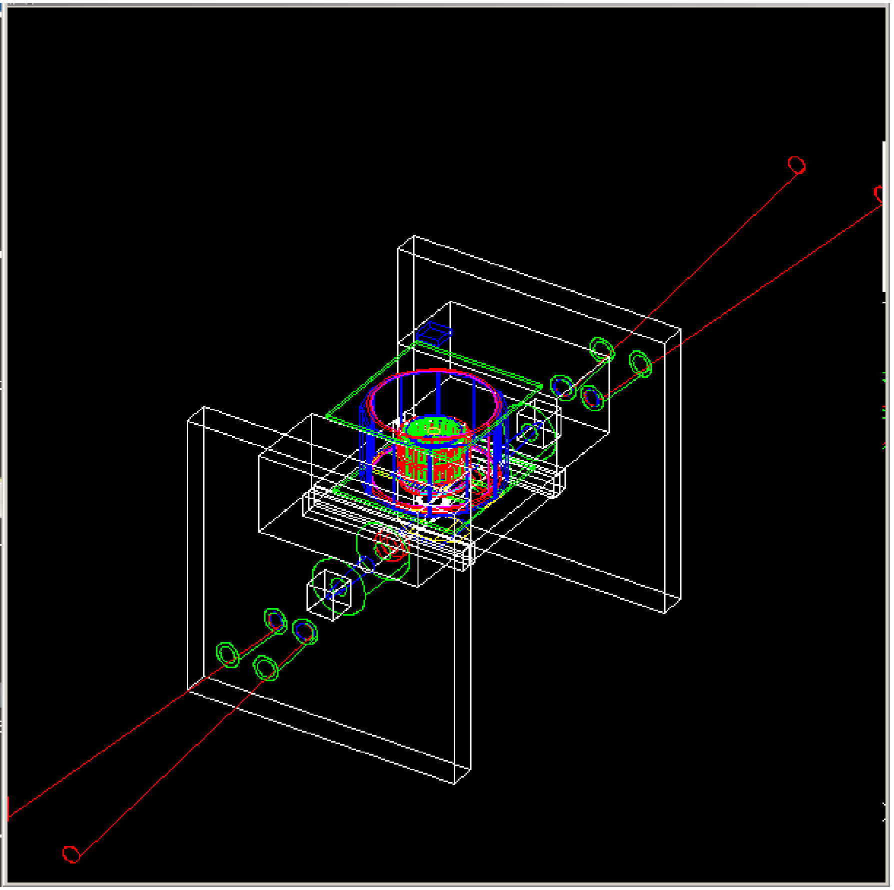


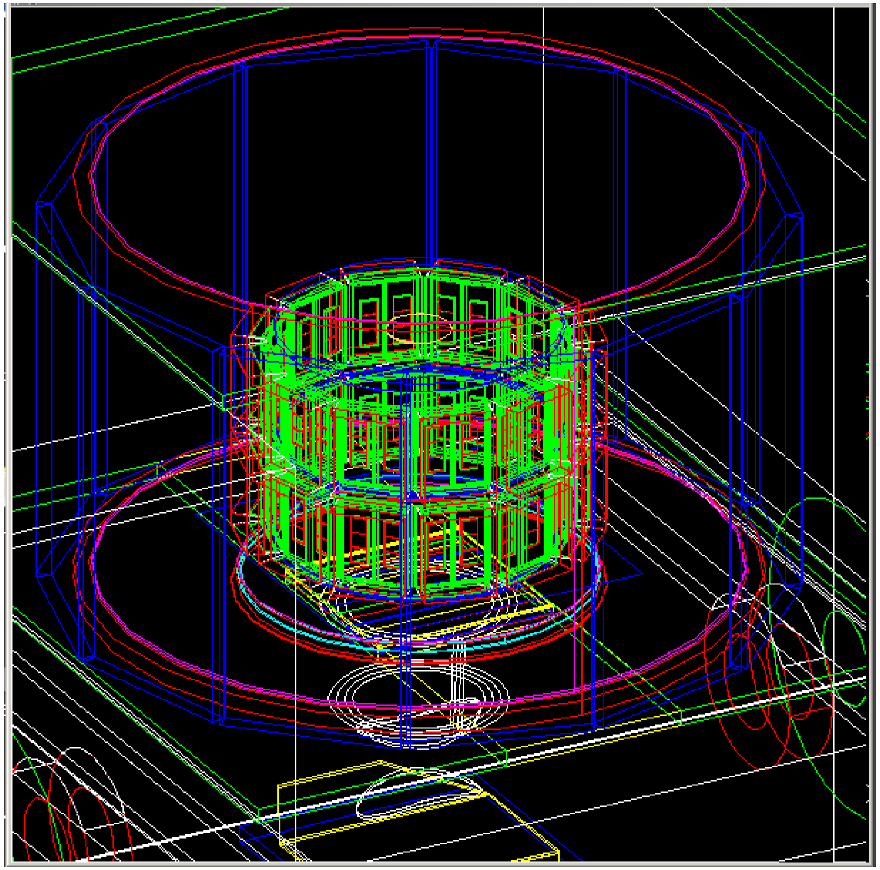
The Monte Carlo simulations

Simulation in the framework of GEANT4

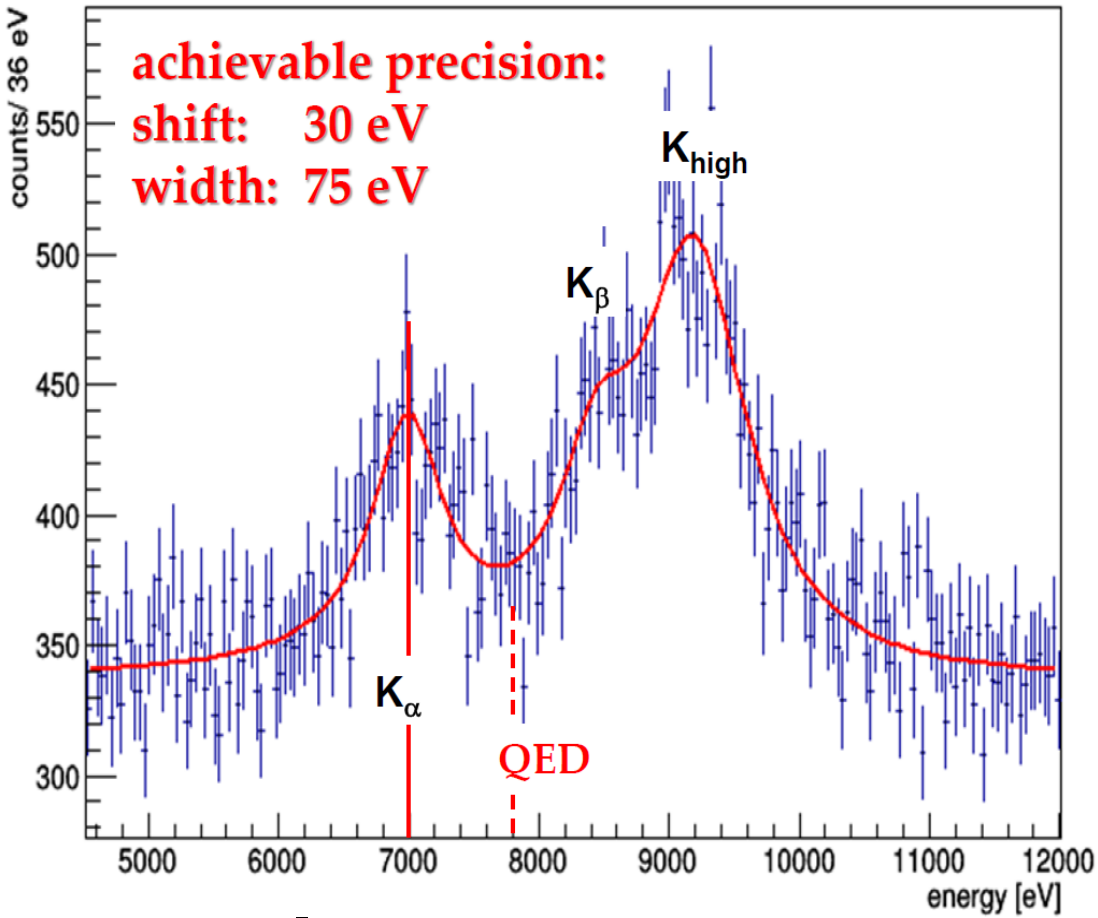
The yiled of K-d: one order of magnitude below the K-p yield

Machine conditions – similar with SIDDHARTA 2009





Geant4 simulated K^-d X-ray spectrum for 800 pb^{-1}



signal: shift - 800 eV
width 800 eV
density: 3% (LHD)
detector area: 246 cm^2

Kα yield: 0.1 %
yield ratio as in K^-p
S/B ~ 1 : 3

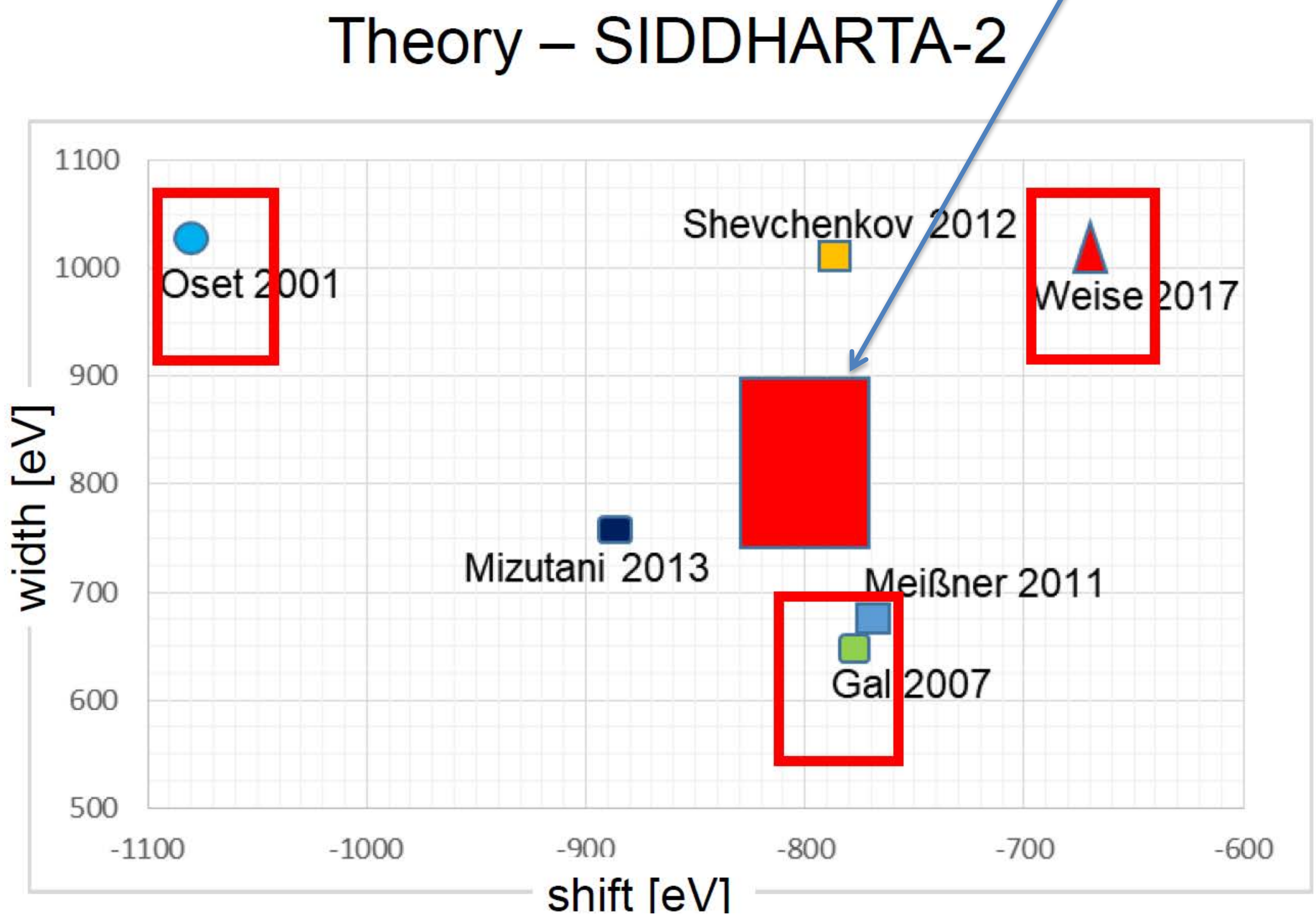
- charged particle veto
- asynchronous BG

KH results:

$\varepsilon_{1S} = -283 \pm 36(stat) \pm 6(syst)$ eV

$\Gamma_{1S} = 541 \pm 89(stat) \pm 22(syst)$ eV

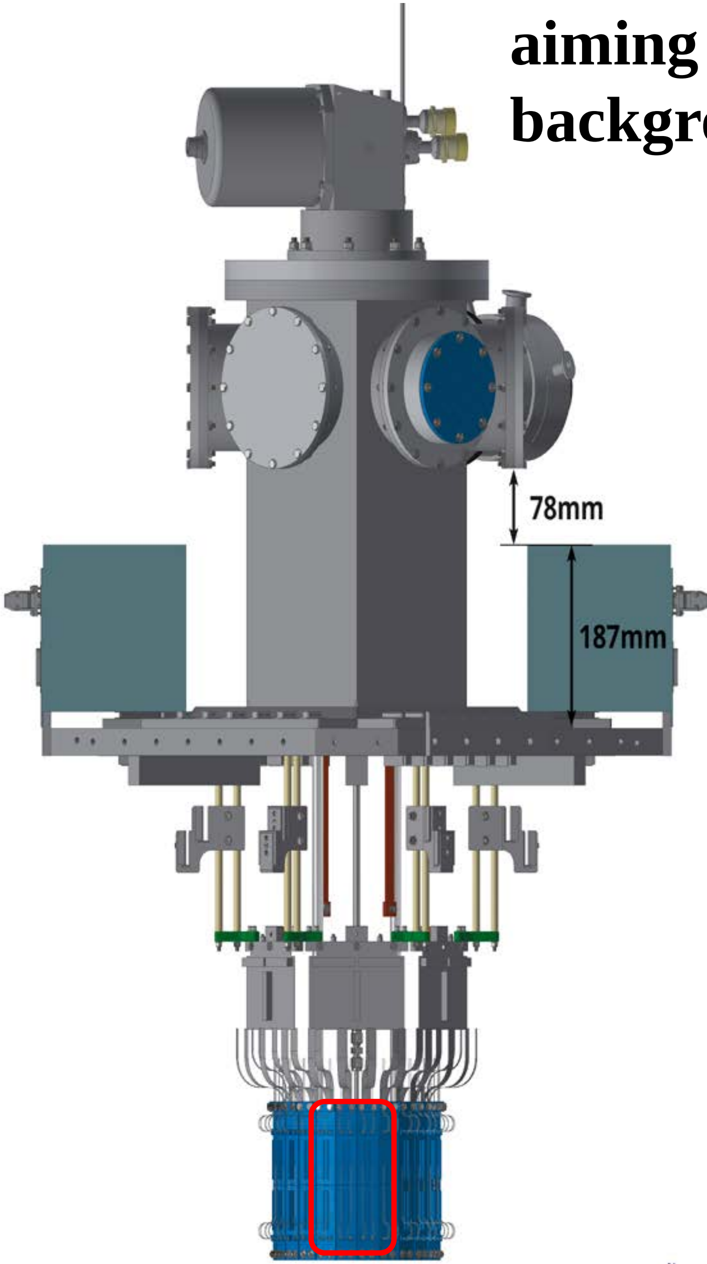
SIDDHARTA-2 targeted precision

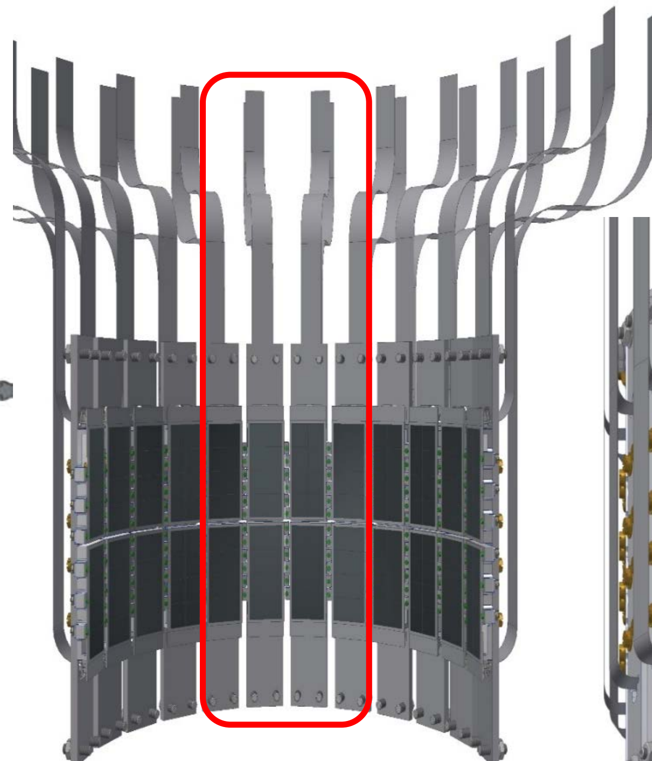


The experimental result will set essential constraints for theories and will help to disentangle between different theoretical approaches

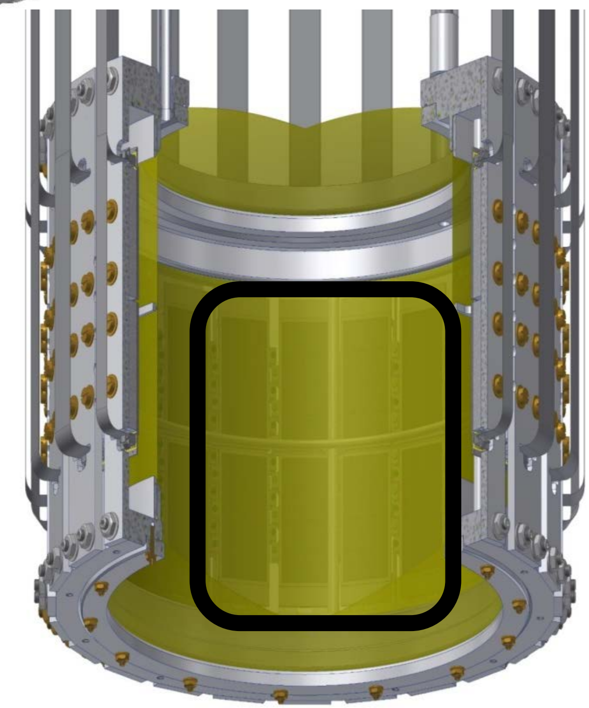
SIDDHARTINO = SIDDHARTA-2 with 8 SDDs

aiming to measure kaonic helium to quantify the background in the new DAFNE configuration

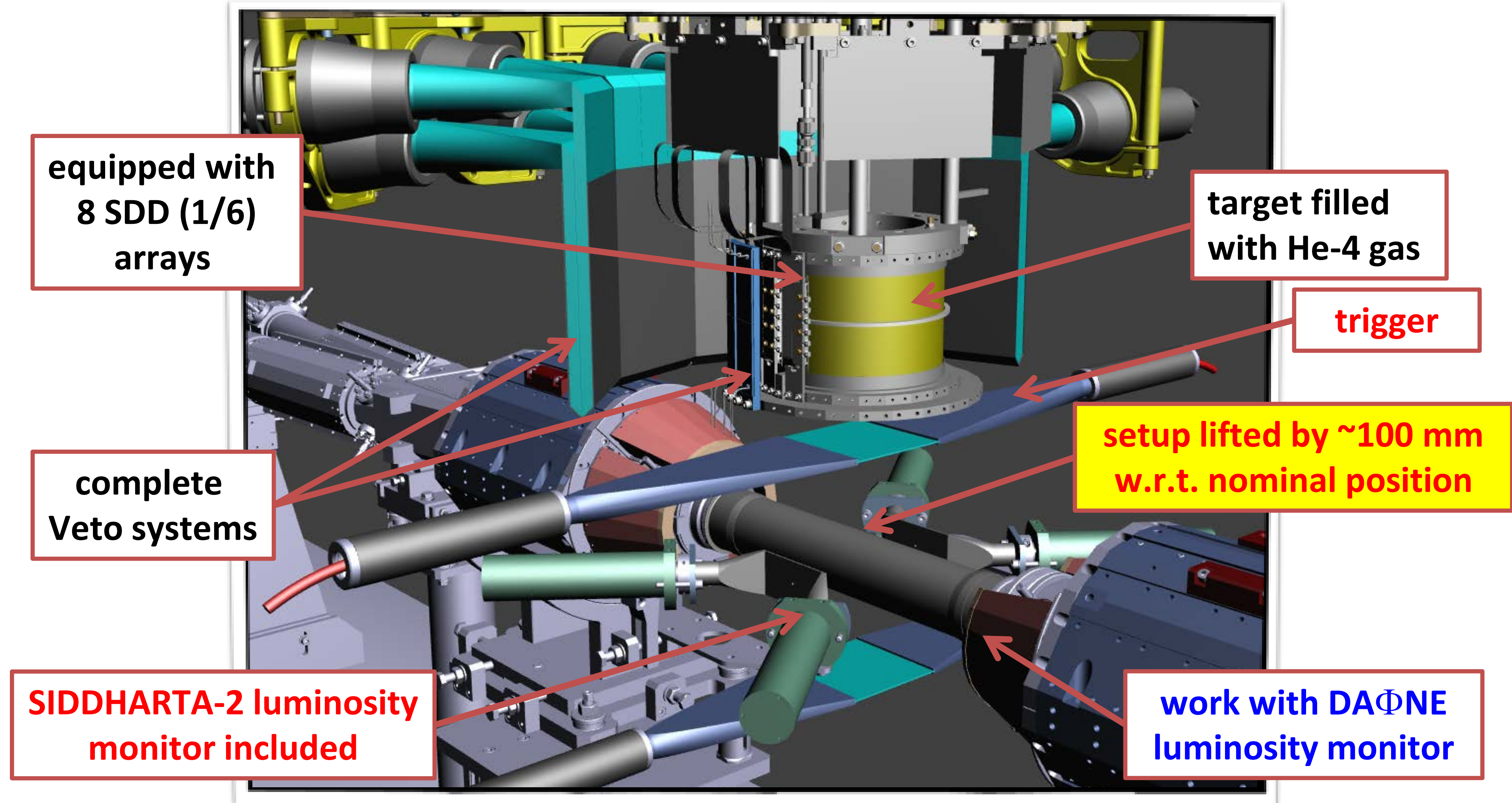




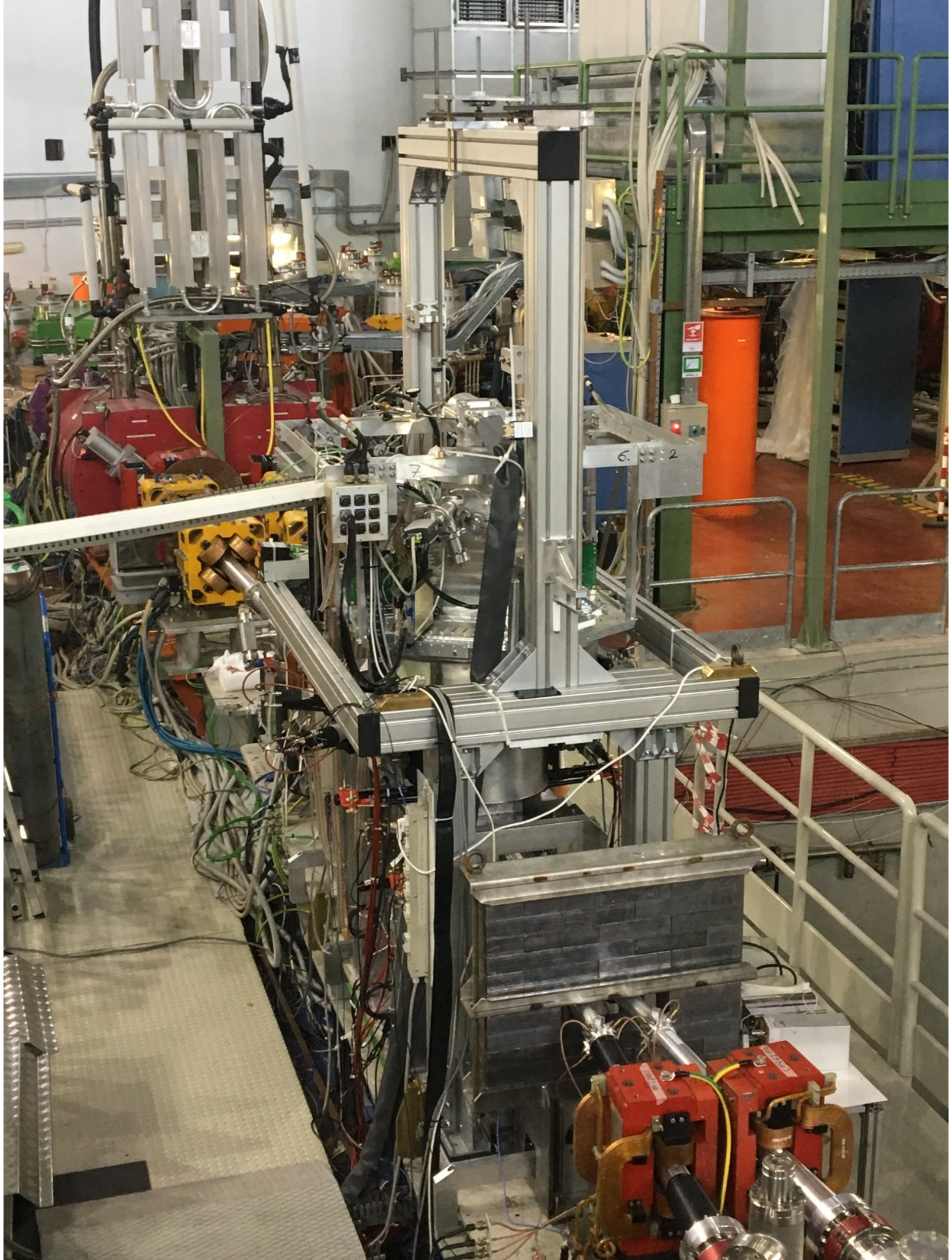
ONLY
8 SDD arrays
(out of 48)
1 BUS structure



SIDDHARTINO apparatus and constraints

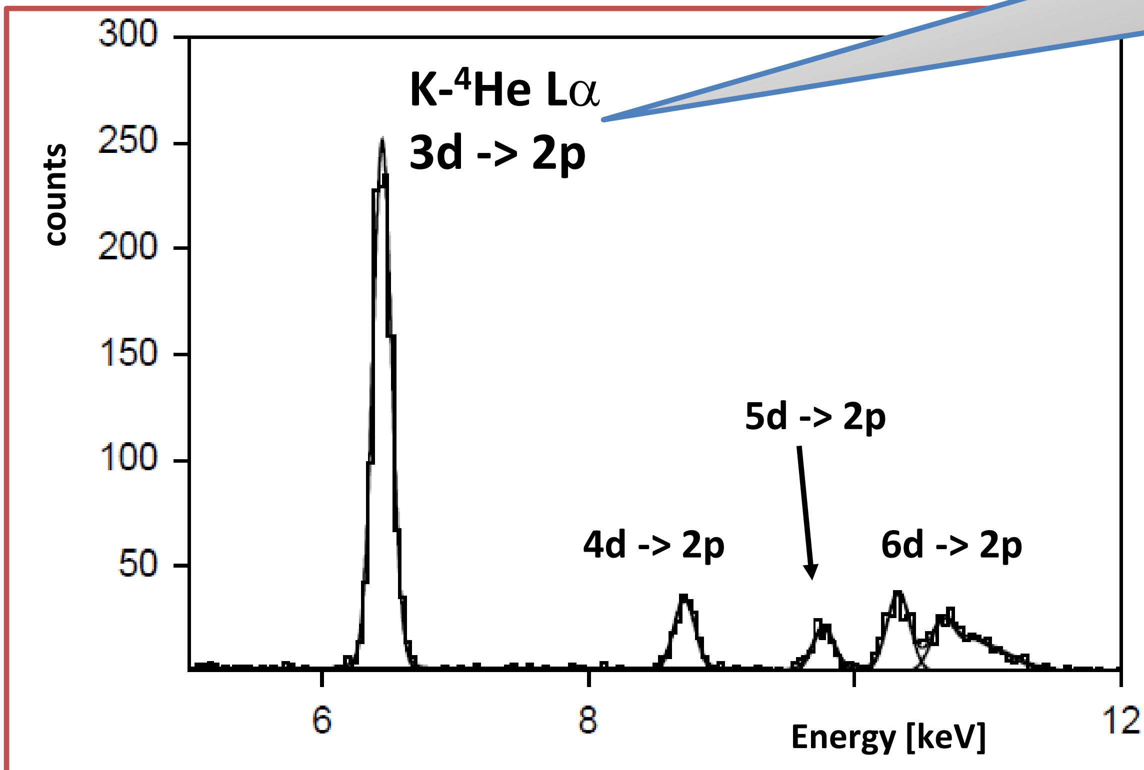


Aim: confirm when DAΦNE background conditions are similar to those in SIDDHARTA 2009



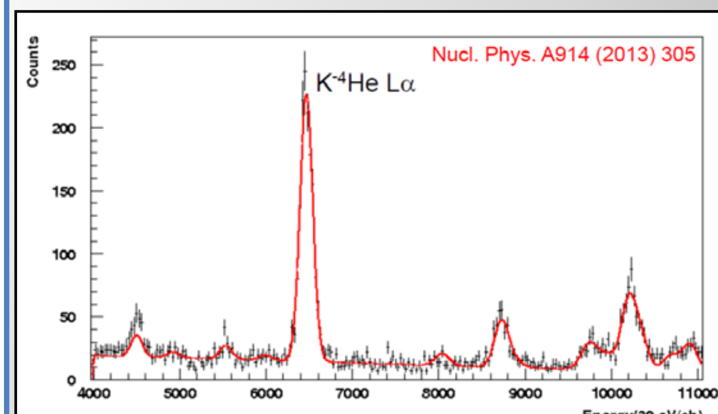
SIDDHARTINO – K-^{4}He test measurement

SIDDHARTINO expected spectrum for ~ 50 pb^{-1}
(one week of data taking in SIDDHARTA-like conditions)



About 1000 events in Lα peak, S/B > 100/1
(ideally should be 300/1)
Position precision :
6.452 +- 0.002 (stat) keV

SIDDHARTA measurement



S/B was 10/1 for the K-^{4}He measurement with ~ 30 pb^{-1}


SIDDHARTA and SIDDHARTA-2 experiments on DAΦNE collider provide unique quality results for the understanding of the low-energy QCD in the strangeness sector.
Many thanks to the DAFNE team
and LNF Management
and to gr 3!

SPARES

Phase-2: SIDDHARTA-2 K-d measurement

Kaonic deuterium run in (all) 2021

for S/B as 1/3:

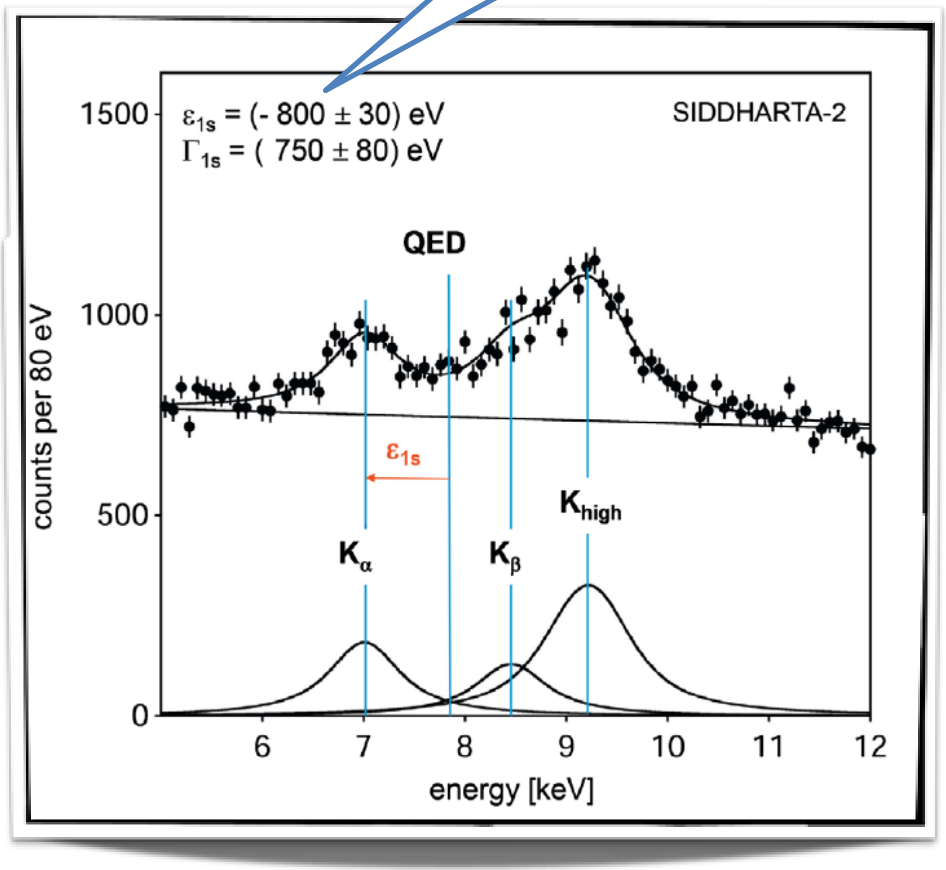
for an integrated luminosity of 800 pb^{-1}

to perform the first measurement of the strong interaction induced energy shift and width of the kaonic deuterium ground state (similar precision as K^-p) !

Includes:

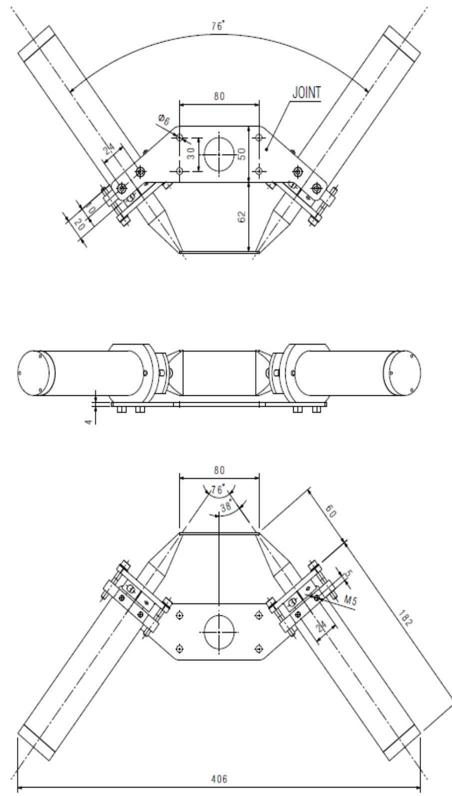
- Optimization grounding, automatization – remote control (covid), calib….
- Optimizations SDD, vetos
- Shielding, trigger….

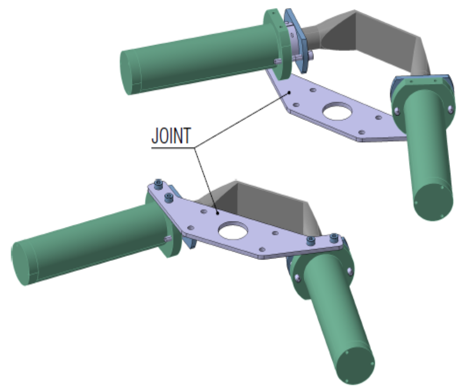
achievable precision

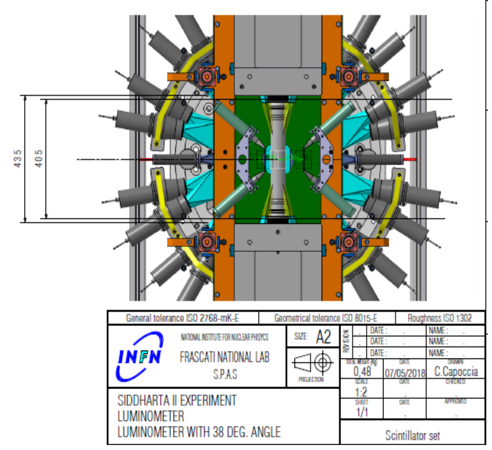


Luminometer of SIDDHARTA-2

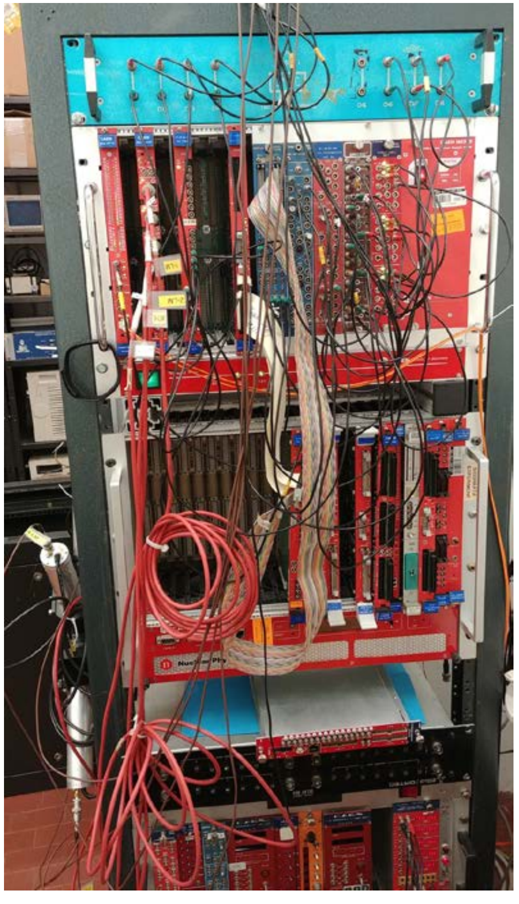
- scintillator: 80x40x2 mm^3 Scionix **EJ-200** (BC408)
- **R4998** PMTs (at an angle of 38deg with respect to scintillator axis)
- lightguides
- aluminum tube + μMetal (0.1mm)
- reflective and light proof foil
- optical cement

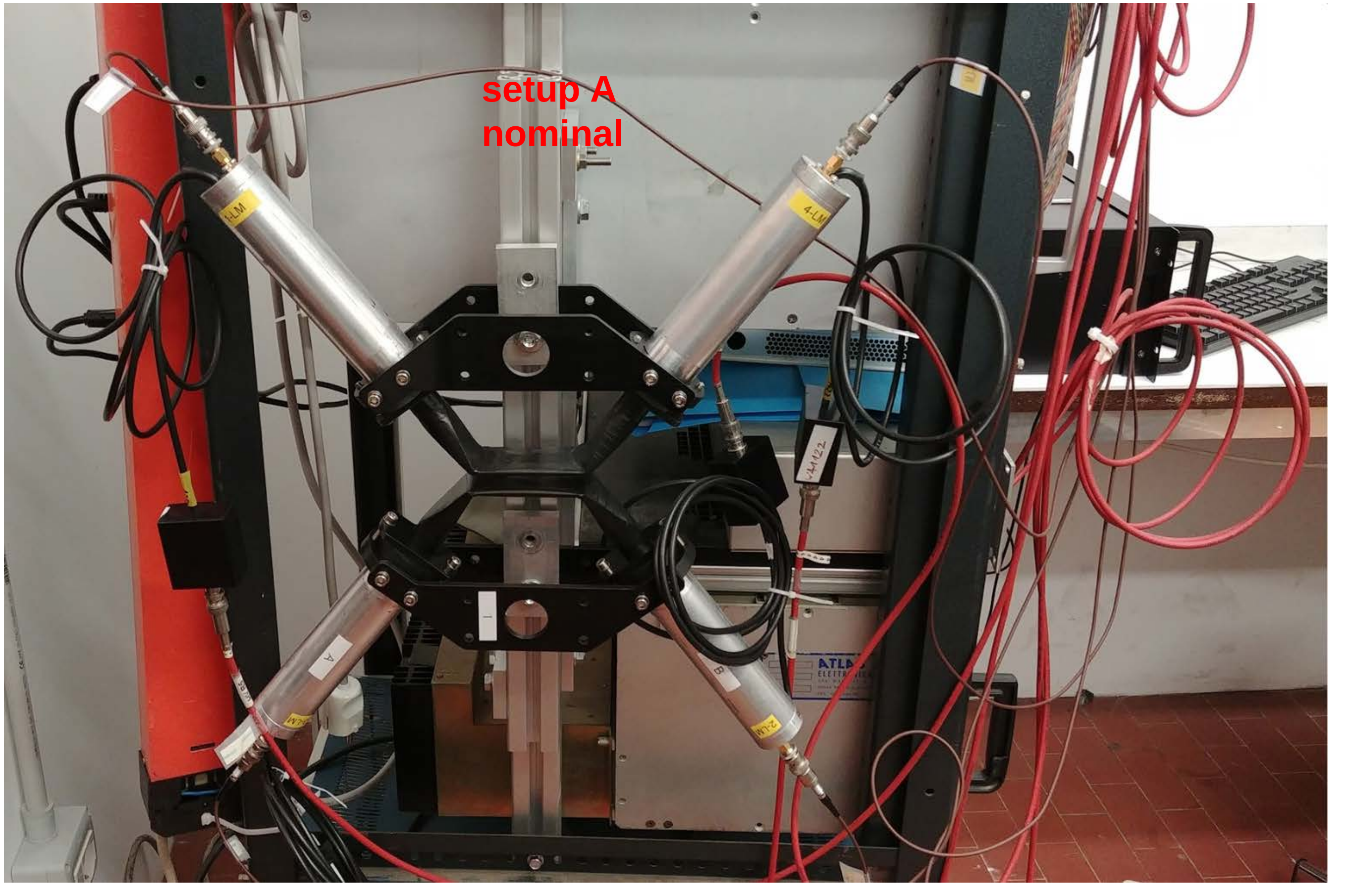




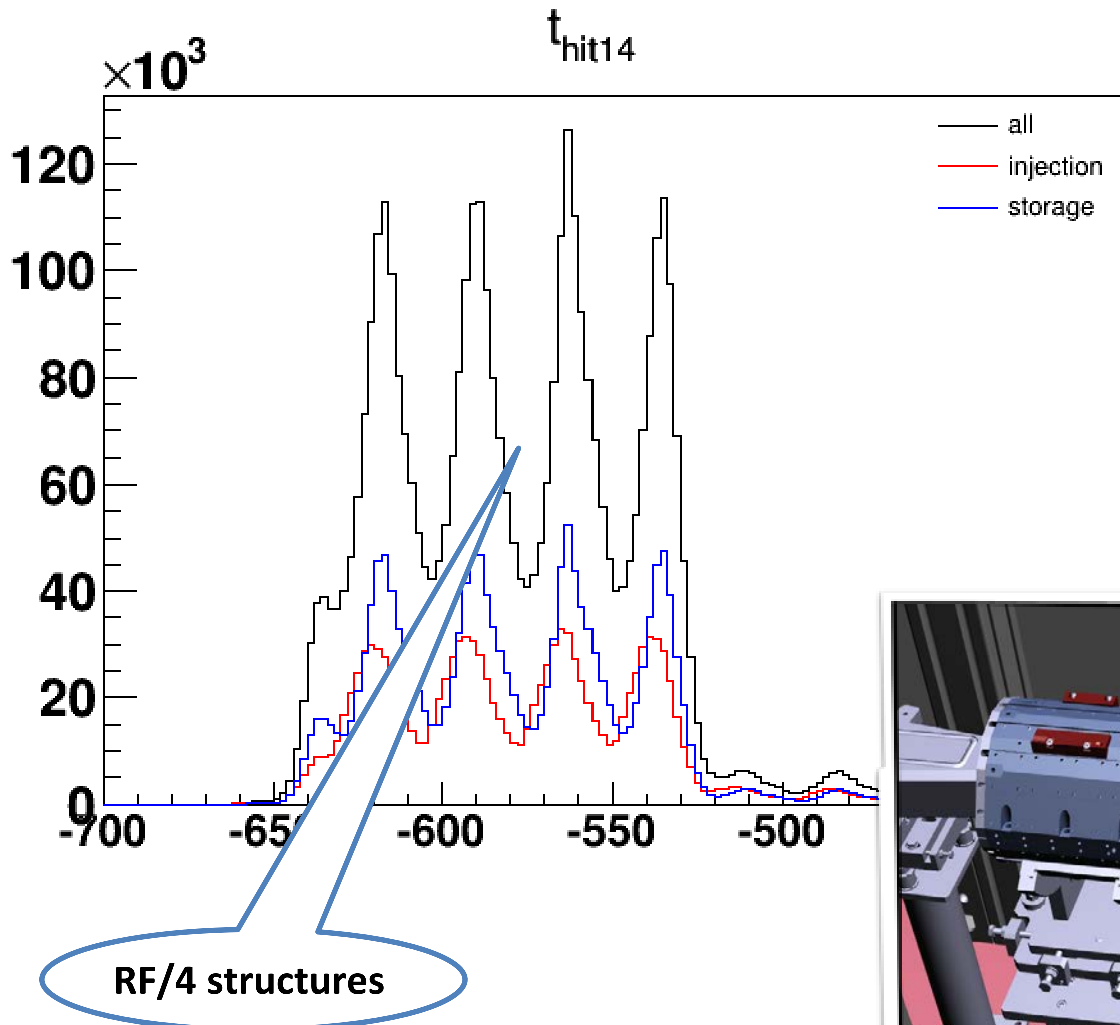


Luminometer tests in SIDDHARTA-2 lab

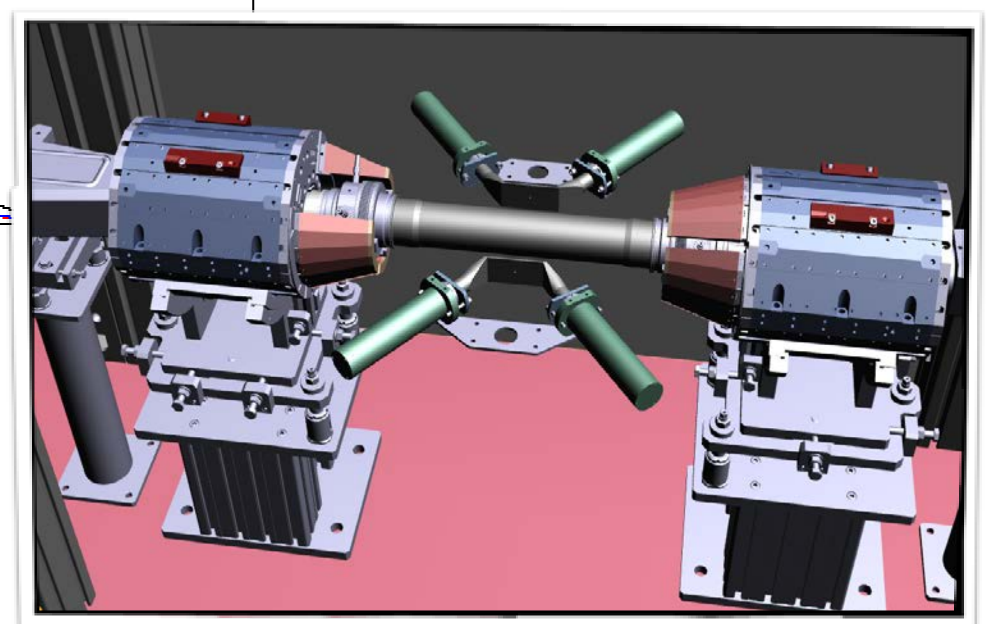




SIDDHARTA-2 Luminosity monitor

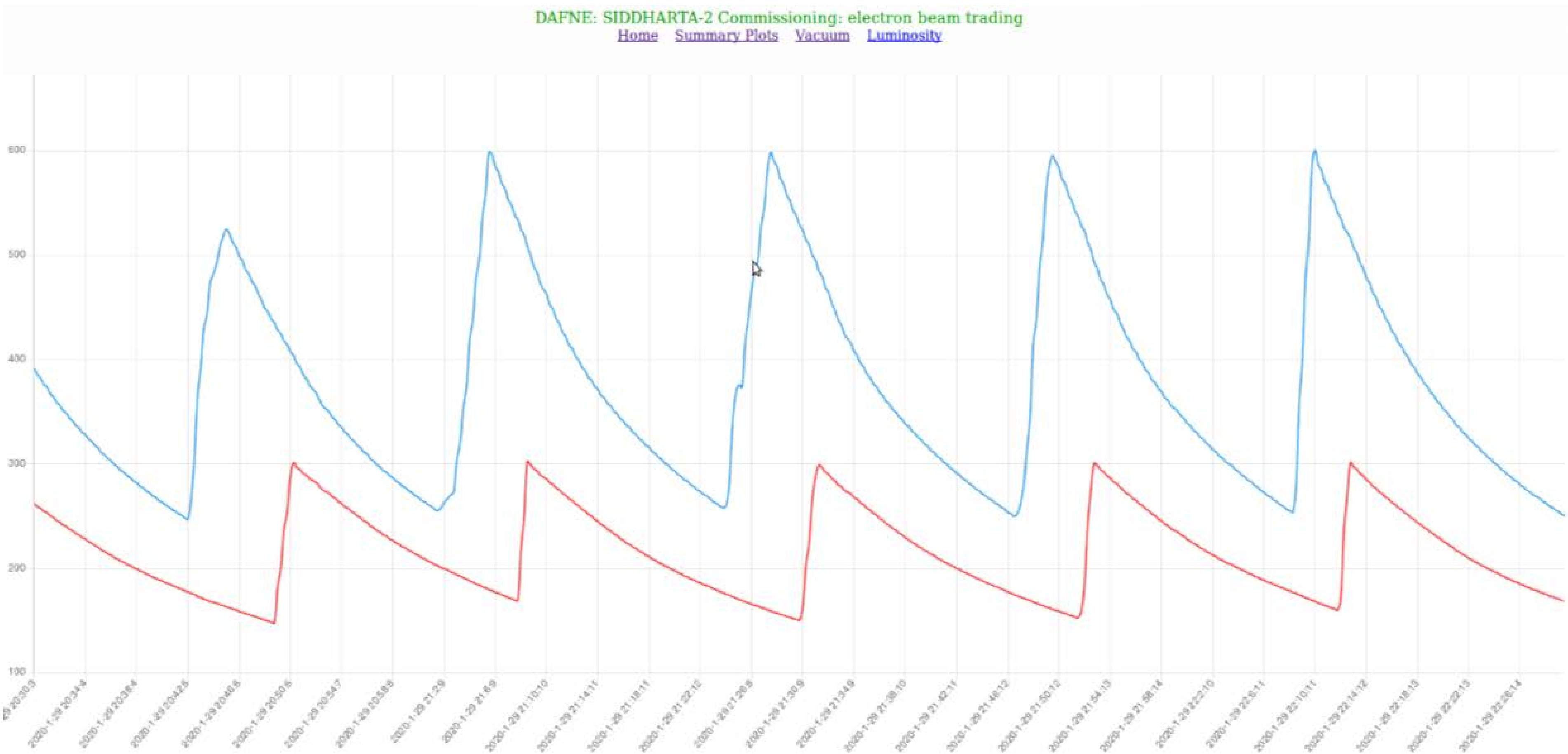


- 2 pairs of scintillators: 80x40x2 mm^3 Scionix EJ-200
- R4998 PMTs Hamamatsu
- light-guides
- aluminum tube + μMetal (0.1mm)
- reflective and light proof foil
- optical cement

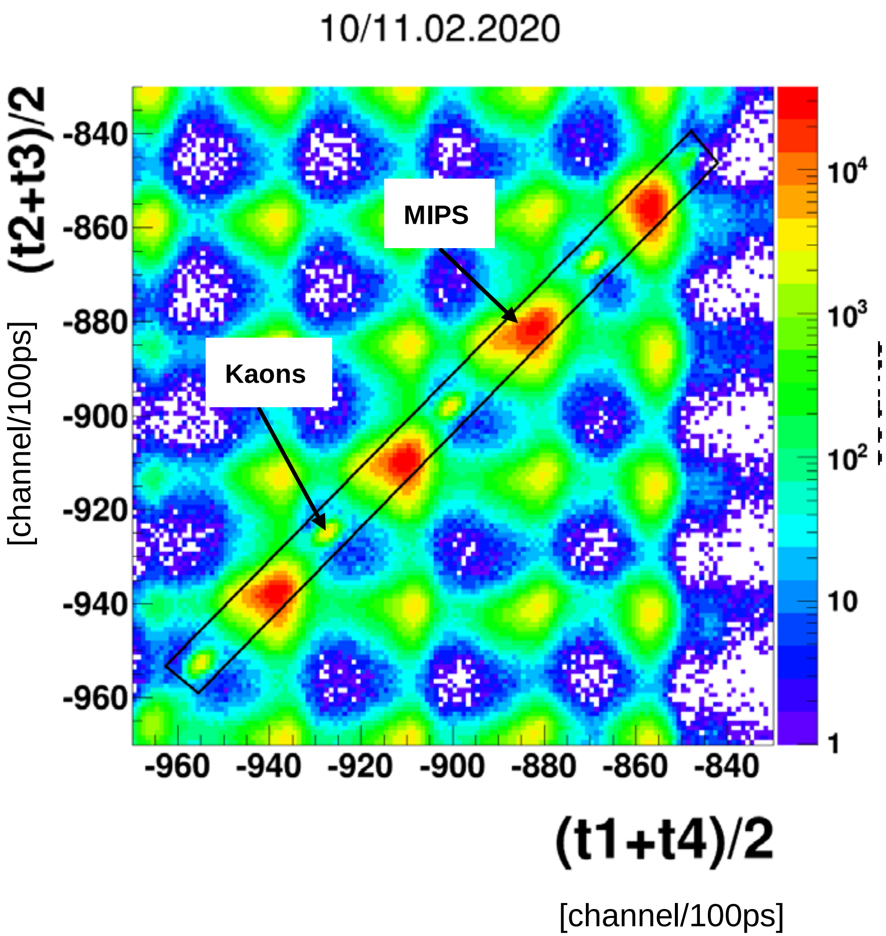


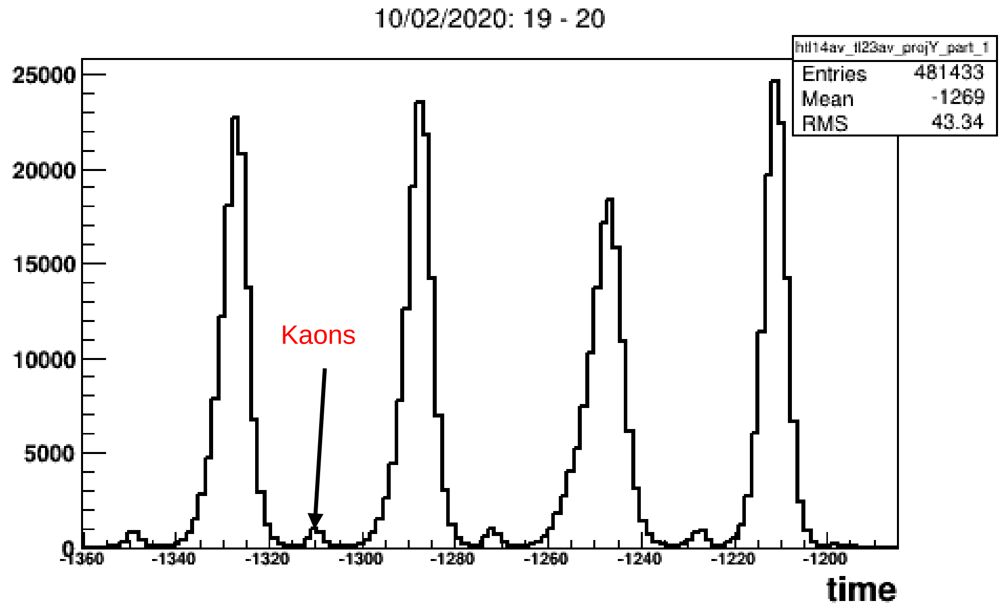
SIDDHARTA-2 Interaction regions

Measurement
29/01 18:30 - 30/01 8:30

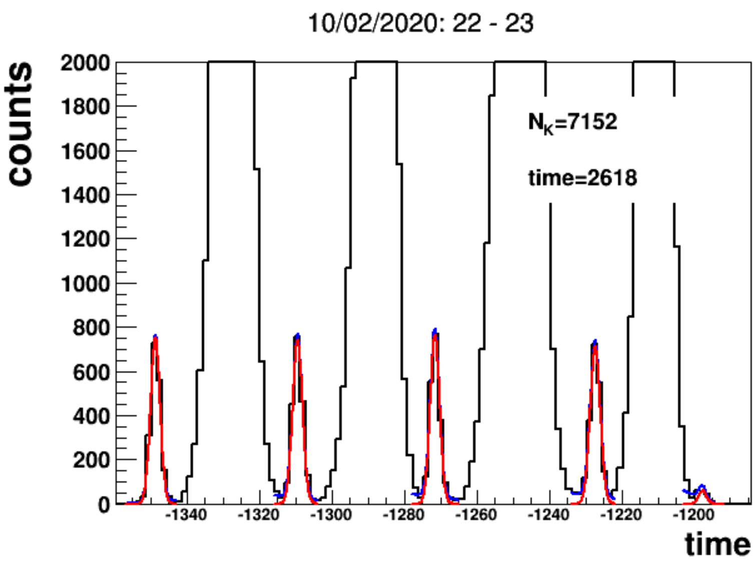


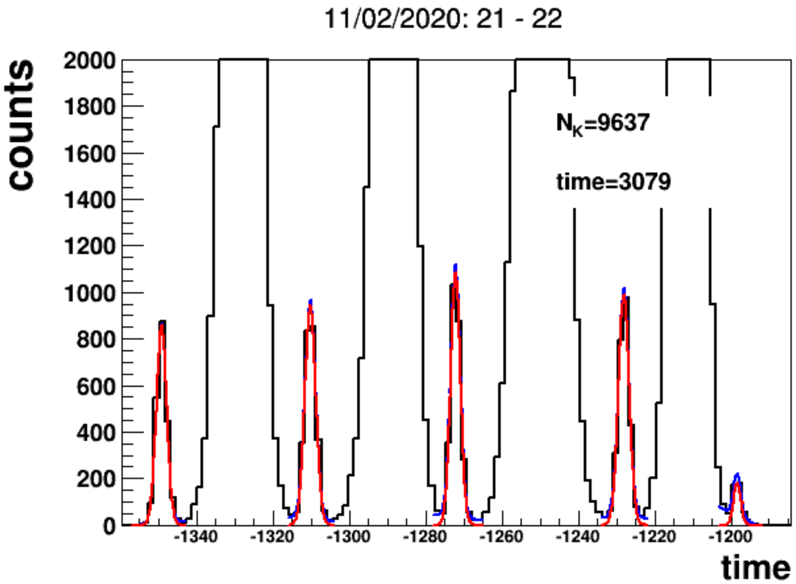
Projection on diagonal





11/02/2020 1 hour slots

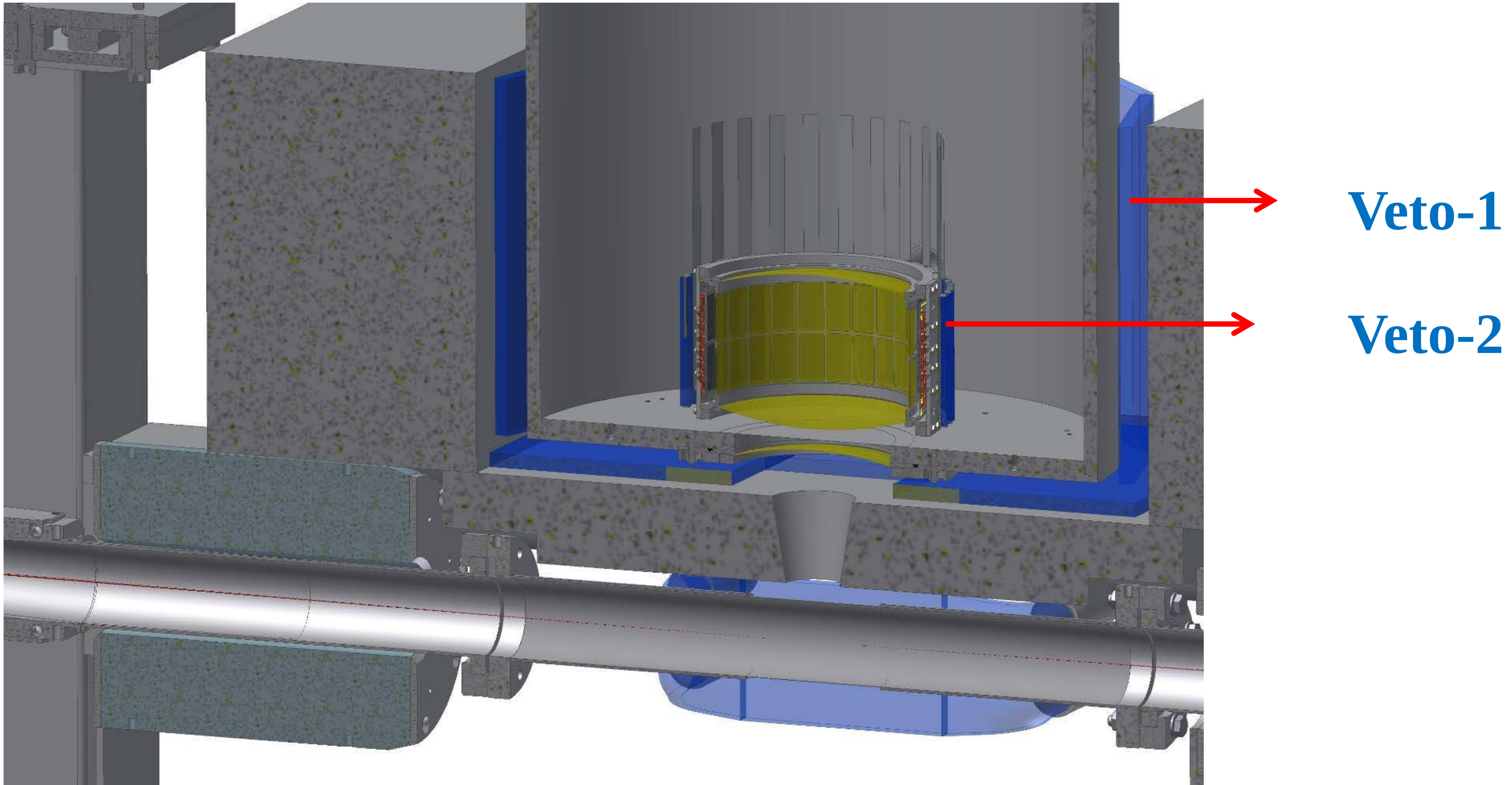




The veto system

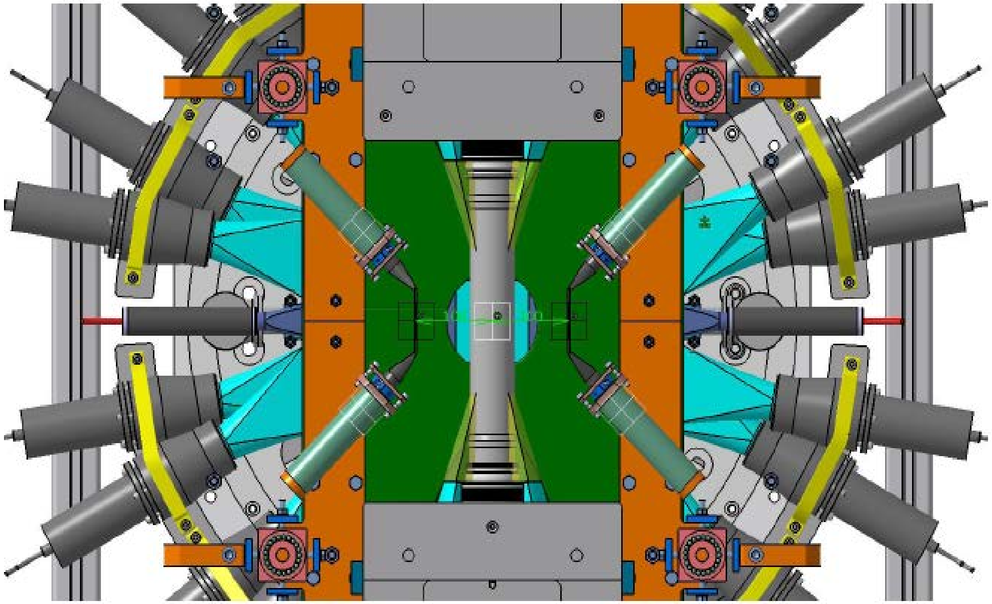
Veto system:

- veto-1: outer barrel of scintillators, acting as a gas stopping detector (and, possibly, as active shielding)- to identify the products of K- absorption on gas nuclei, characterized by a long moderation time (4-5 ns) (suppress the X-rays produce by the kaons stopped in gas from kaons stopped in setup material)
- veto-2: an inner ring of scintillator tiles (SciTiles) placed as close as possible behind the SDDs for charge particle tracking

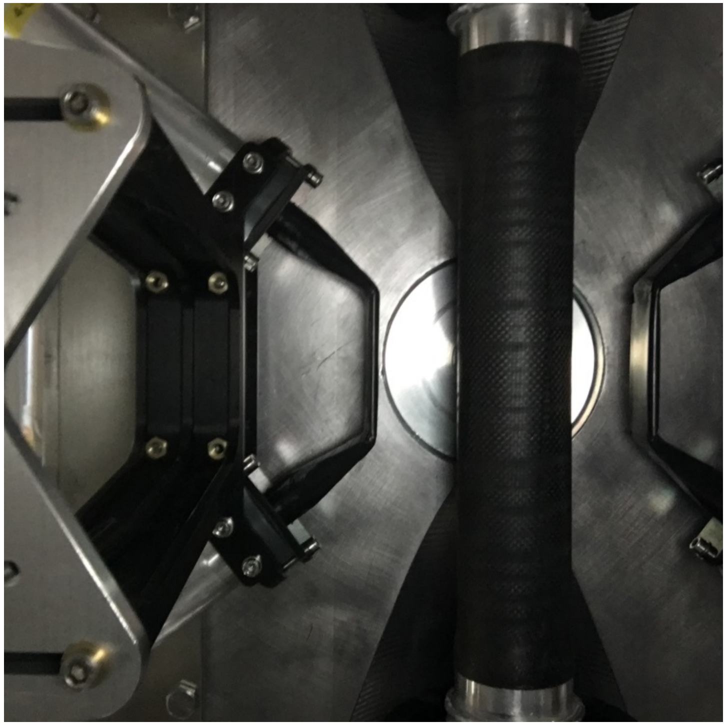


SIDDHARTA-2 Luminosity monitor

- 2 pairs of scintillator: 80x40x2 mm^3
  Scionix EJ-200
- R4998 PMTs Hamamatsu



SIDDHARTA-2
Interaction regions bottom view



- **Fast detectors & FEE**
- **Real time acquisition**
- **Accidental rate << Signal rate**

Allows:

- **Collision optimization**
- **Machine feedback**

Luminosity ~ 10 ^{32} cm^{-2} s $^{-1}$
Rate ~ 50 - 60 Hz

SIDDHARTA-2 schedule

We are presently in:

Phase 1:

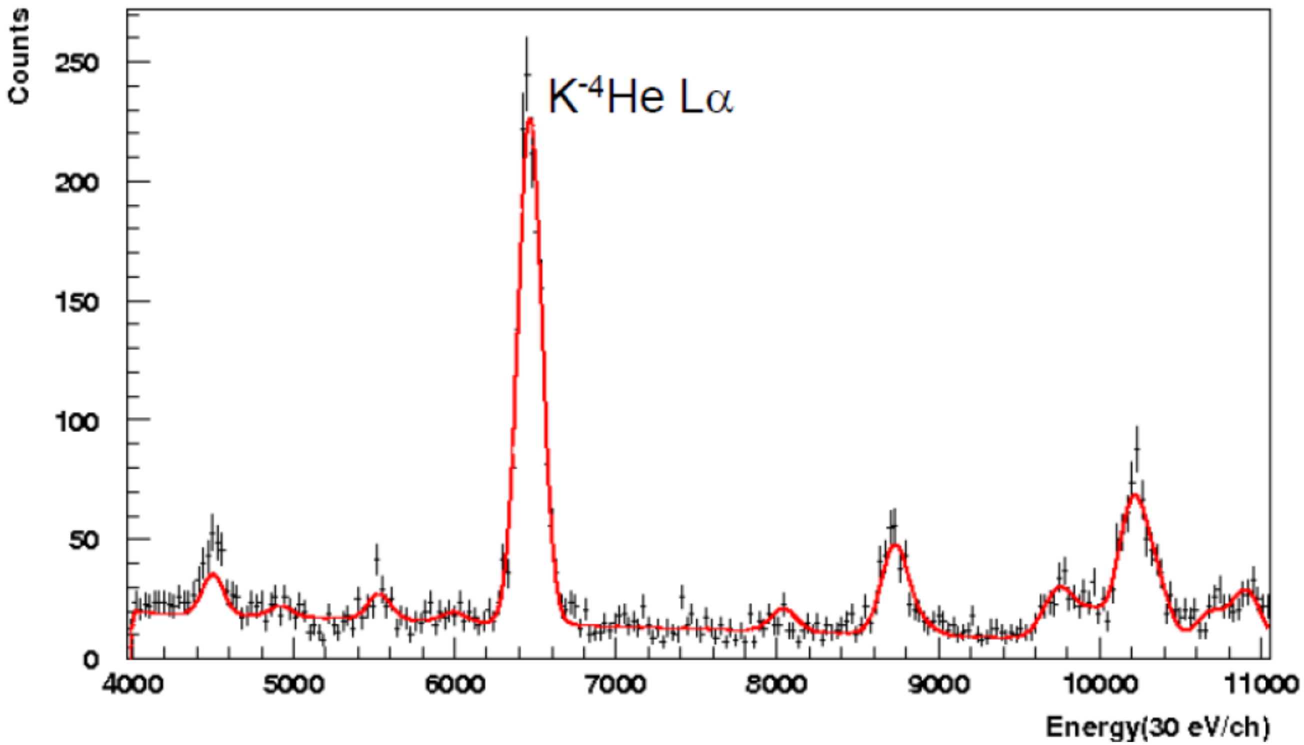
during the commissioning of DAΦNE

SIDDHARTINO for K-^{4}He (8 SDD arrays)

May 2019 – 1 November 2019 or until the aim (S/B on KHe as better than 100/1) is reached (in agreement with the LNF management)

SIDDHARTINO – K-^{4}He test measurement

kaonic helium-4
about 28 pb^{-1}
S/B 10:1



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Nuclear Physics A 914 (2013) 305–309

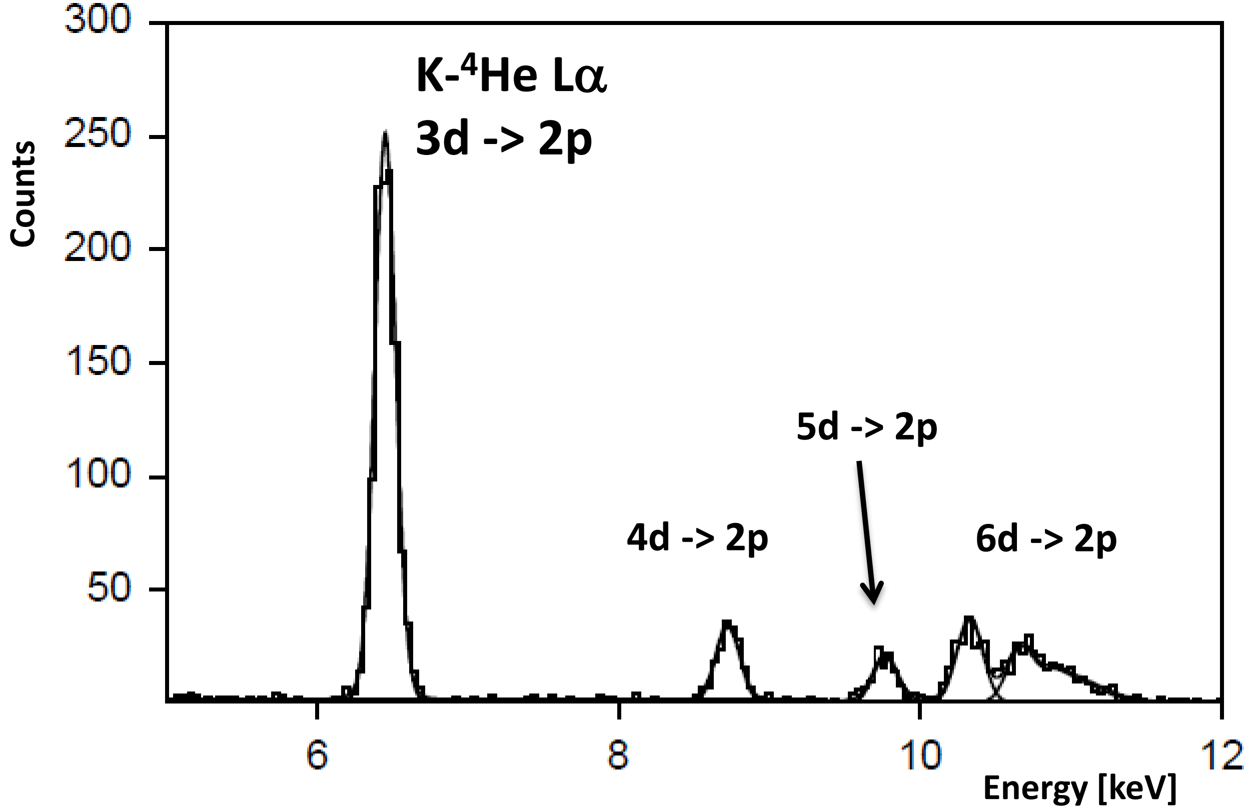
NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Kaonic Helium-4 SIDDHARTINO expected spectrum for about 50 pb^{-1}

(one week of data taking in SIDDHARTA-like conditions)

About 1000 events in La peak, S/B > 100/1
(ideally should be 300/1)
Position precision : 6.452 +- 0.002 (stat) keV



SIDDHARTA-2 future perspectives

- Feasibility studies in parallel with SIDDHARTA-2 (HPGe and VOXES)

- Plans for the extension of the scientific programme
  - Charged kaon mass, precision measurement < 7 keV
  - Kaonic helium transition to the 1s level
  - Other light kaonic atoms
  - Radiative kaon capture - Λ(1405) studies
  - Investigating the possibility to measure other hadronic exotic atoms (sigmonic hydrogen?)

SIDDHARTA-2 is already installed at DAΦNE and ready to start to take data in 2020

Thanks for your attention

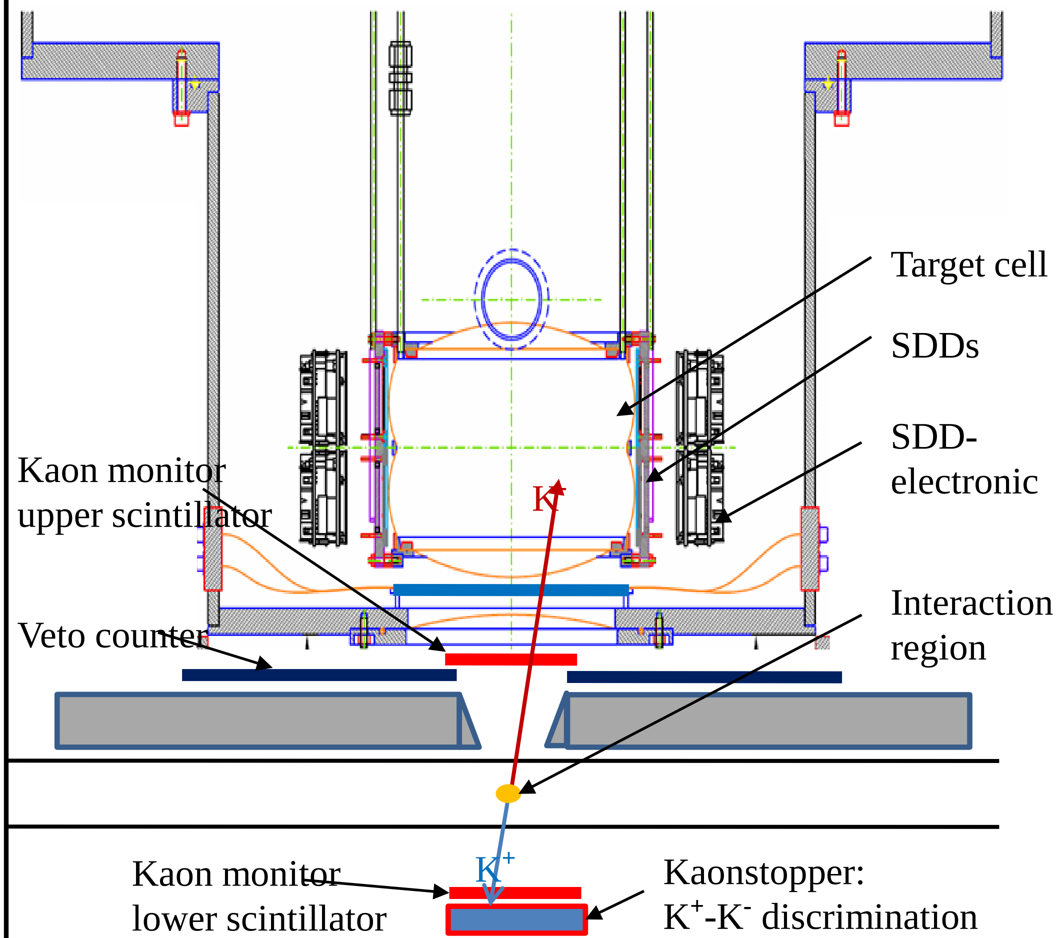
New SIDDHARTA-2 Kaon monitor

The SIDDHARTA kaon monitor:
scintillator pair, placed above and below the IP, taking advantage that the φ-meson is decaying almost back-to-back to a K+K- pair (49.2%). The K+ and K- are identified in coincidence in each of the two detectors.

The basic change in the trigger configuration:

- **a new shape for the upper scintillator of the kaon monitor**
- **its placement just below the kaon entrance window, above the shielding.**

With this new position (which was not possible in SIDDHARTA) only those kaons, which are reaching directly the entrance flange of the vacuum chamber will be selected.



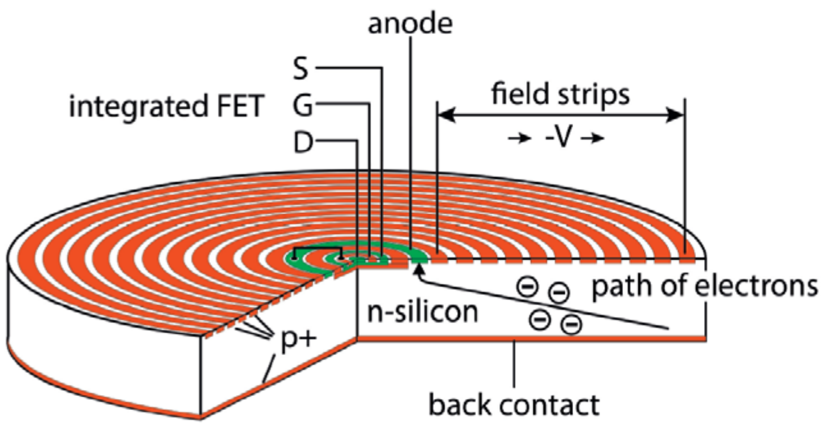
Compared with the "old" geometry, a reduction of the hadronic and e.m. background is expected.

Comparison of X-ray detectors for kaonic atom

Detector	Si(Li)	CCD	SDD
Experiment	KEK 1998	DEAR 2005	SIDDHARTA 2009
Effective area (mm^2)	200	724	3×100
Thickness (mm)	5	0,03	0,45
Energy resolution (eV) @6 keV	410	150	160
Drift time (ns)	290	-	800
Efficiency @6 keV	≈ 100%	≈ 60%	≈ 100%

Silicon Drift Detector for SIDDHARTA

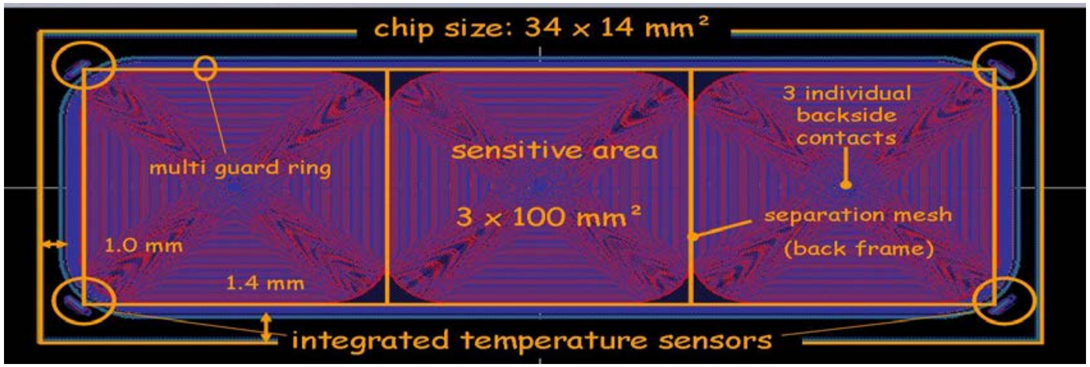
New SDDs specially designed for SIDDHARTA, as well as readout electronics.

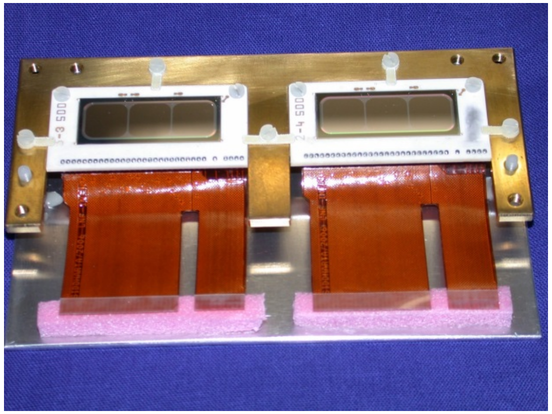


SDD design:
one side: concentric ring-shaped p$^+$ strip system for the generation of the drift field and the collecting anode in their center.
opposite surface : covered by a non-structured p$^+$ junction (called "continuous back-plane") acting as homogeneous radiation entrance window.

The key feature:

- Small anode → Small capacitance
- Integration of the JFET transistor connected to the anode → small capacitance → small noise→ new detectors with large are an reduced thickness
- High resolution, with thin depletion layer





DAFNE background

It includes two main sources:

SYNCRONOUS: It's associated to K production, or Φ decays. It can be considered a hadronic background.

ASYNCRONOUS: It's dued to final products of electromagnetic cascade produced in the accelerator and to other materials activated by electrons lost from the beam. Moreover it also contains Touschek effect (same bunch particles' interactions)

The main contribute comes from the asyncronous background, wich can be reducted using a trigger and fast detectors:

SDD (Silicon Drift Detector)

Winning card of the SIDDHARTA experiment