Status and perspectives for low energy kaon-nucleon interaction studies at DAΦNE collider: from SIDDHARTA to SIDDHARTA-2

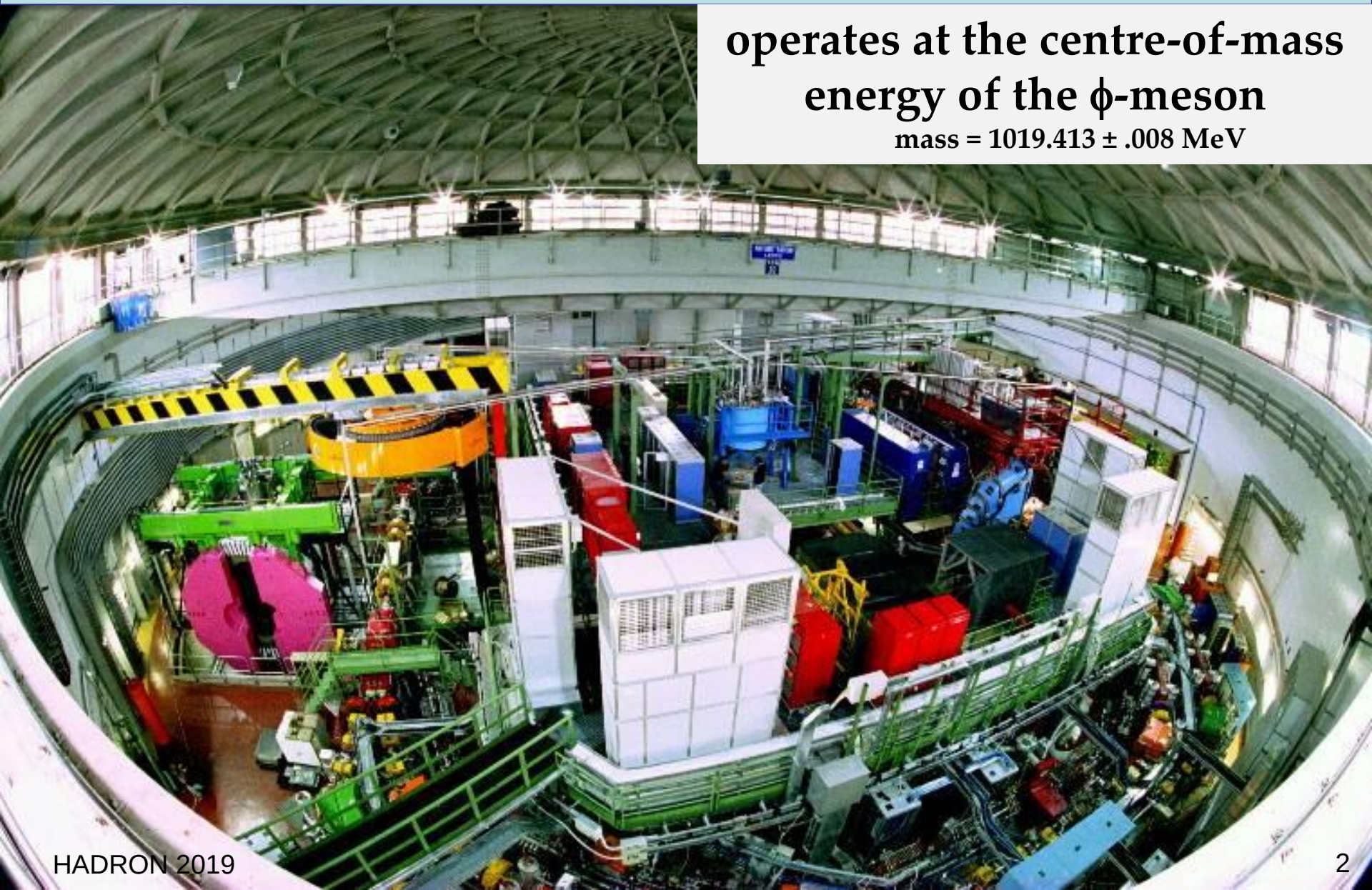
Florin Catalin Sirghi
INFN-LNF

Johann Zmeskal
SMI-OeAW

on behalf of SIDDHARTA/SIDDHARTA-2 collaborations

16 – 21 August 2019, Guilin, China

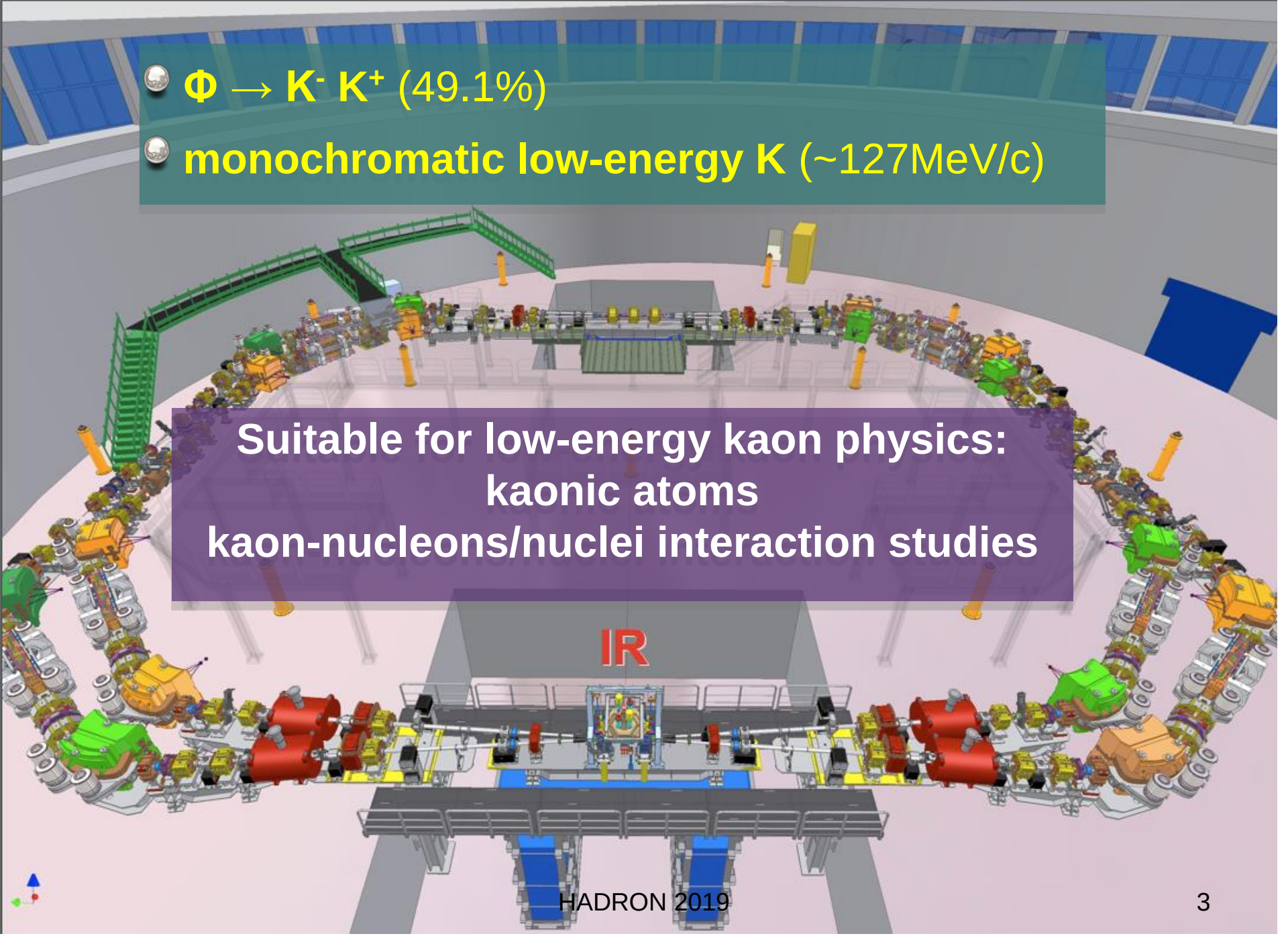
DAΦNE accelerator, since 1998:
The Double Annular Φ factory for Nice Experiments



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

mass = 1019.413 ± .008 MeV

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



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

SIDDHARTA

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

SIDDHARTA Collaboration

M. Bazzi [a], G. Beer [b], L. Bombelli [c], A.M. Bragadireanu [a,d], M. Cargnelli [e], C. Curceanu (Petrascu) [a], A. d'Uffizi [a], C. Fiorini [c], T. Frizzi [c], F. Ghio [f], C. Guaraldo [a], R.S. Hayano [g], M. Iliescu [a,d], T. Ishiwatari [e,*], M. Iwasaki [h], P. Kienle [e,i], P. Levi Sandri [a], A. Longoni [c], J. Marton [e], S. Okada [h], D. Pietreanu [a,d], T. Ponta [d], A. Rizzo [a], A. Romero Vidal [a], E. Sbardella [a], A. Scordo [a], H. Shi [g], D.L. Sirghi [a,d], F. Sirghi [a,d], H. Tatsuno [a], A. Tudorache [d], V. Tudorache [d], O. Vazquez Doce [i], B. Wünschek [e], E. Widmann [e], J. Zmeskal [e]

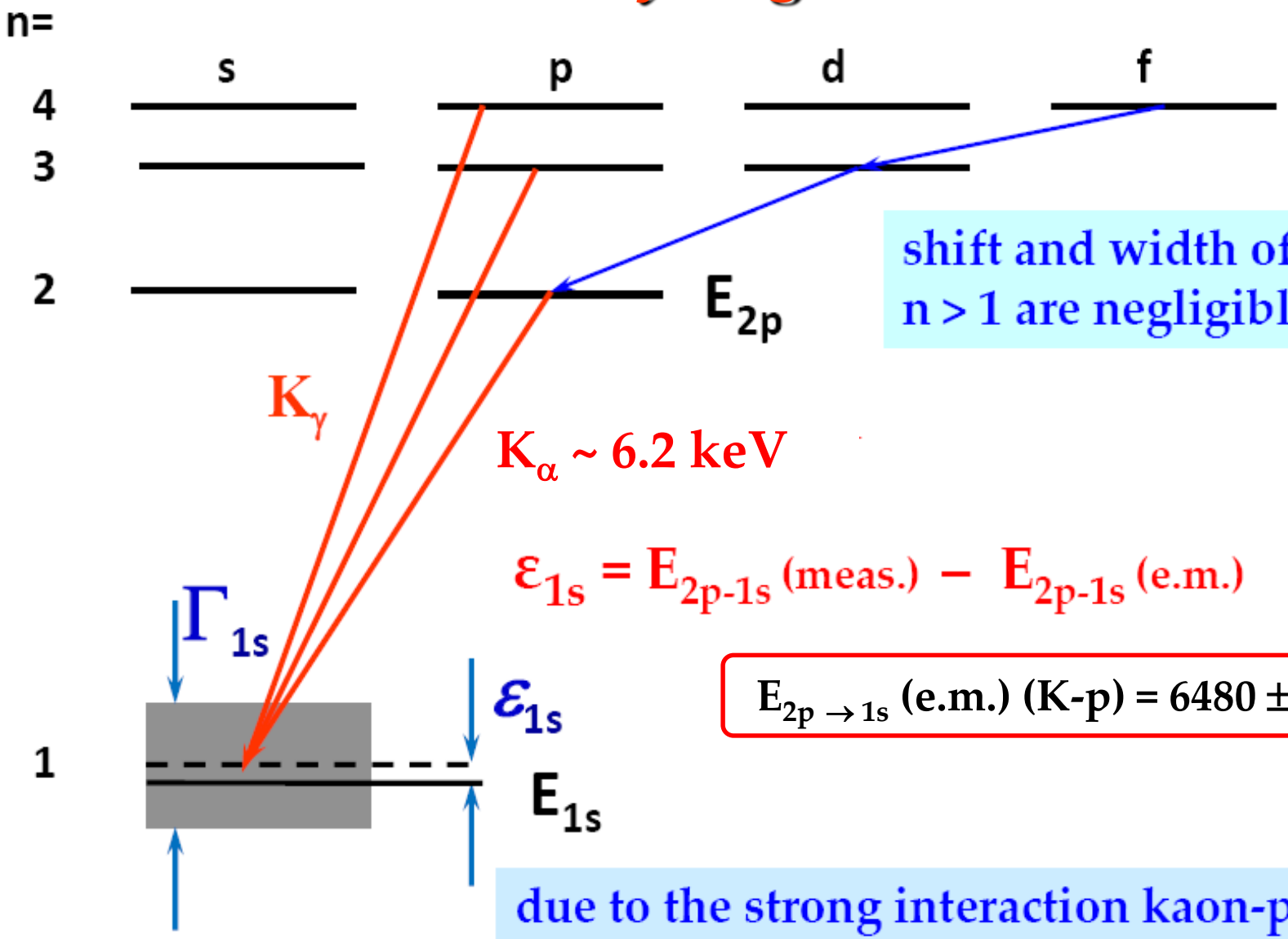
[a] *INFN, Laboratori Nazionali di Frascati, Frascati (Roma), Italy*
[b] *Dep. of Phys. and Astro., Univ. of Victoria, Victoria B.C., Canada*
[c] *Politecnico di Milano, Sez. di Elettronica, Milano, Italy*
[d] *IFIN-HH, Magurele, Bucharest, Romania*
[e] *Stefan-Meyer-Institut für subatomare Physik, Vienna, Austria*
[f] *INFN Sez. di Roma I and Inst. Superiore di Sanita, Roma, Italy*
[g] *Univ. of Tokyo, Tokyo, Japan*
[h] *RIKEN, The Inst. of Phys. and Chem. Research, Saitama, Japan*
[i] *Excellence Cluster Universe, Tech. Univ. München, Garching, Germany*

The scientific aim

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

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

Kaonic Hydrogen atoms



shift and width of states $n > 1$ are negligible

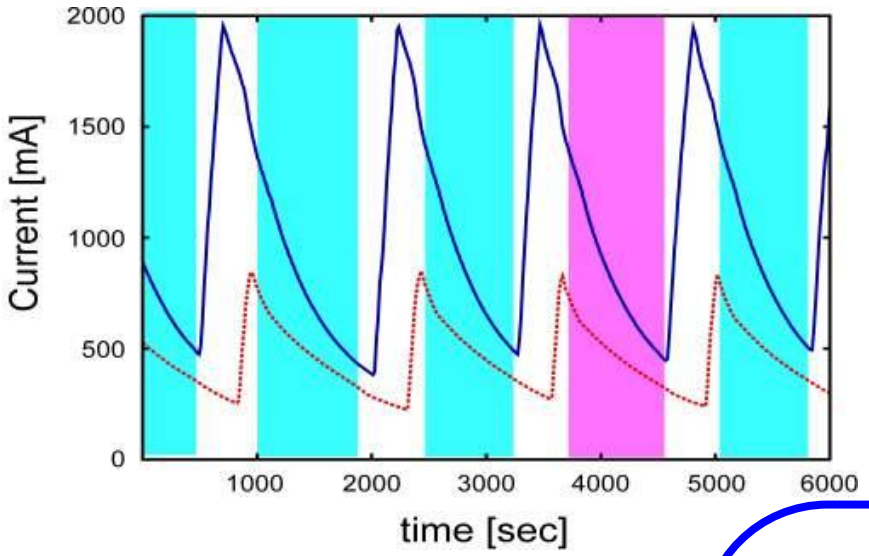
$K_\alpha \sim 6.2$ keV

$\varepsilon_{1s} = E_{2p\text{-}1s}$ (meas.) $- E_{2p\text{-}1s}$ (e.m.)

$E_{2p \rightarrow 1s}$ (e.m.) (K-p) = 6480 ± 1 eV

due to the strong interaction kaon-proton the 1s level is shifted and broadened

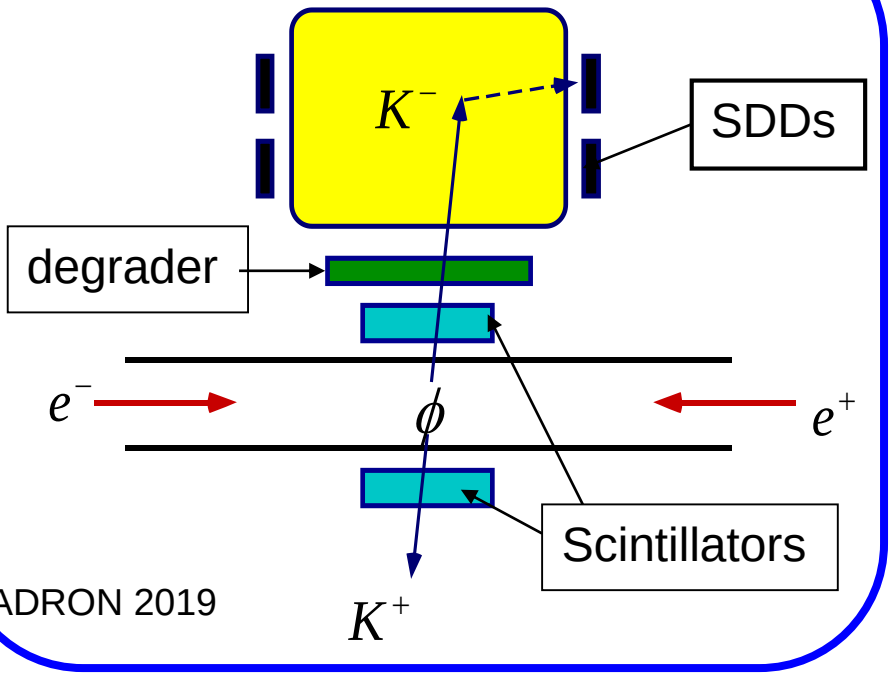
Data taking scheme at DAΦNE



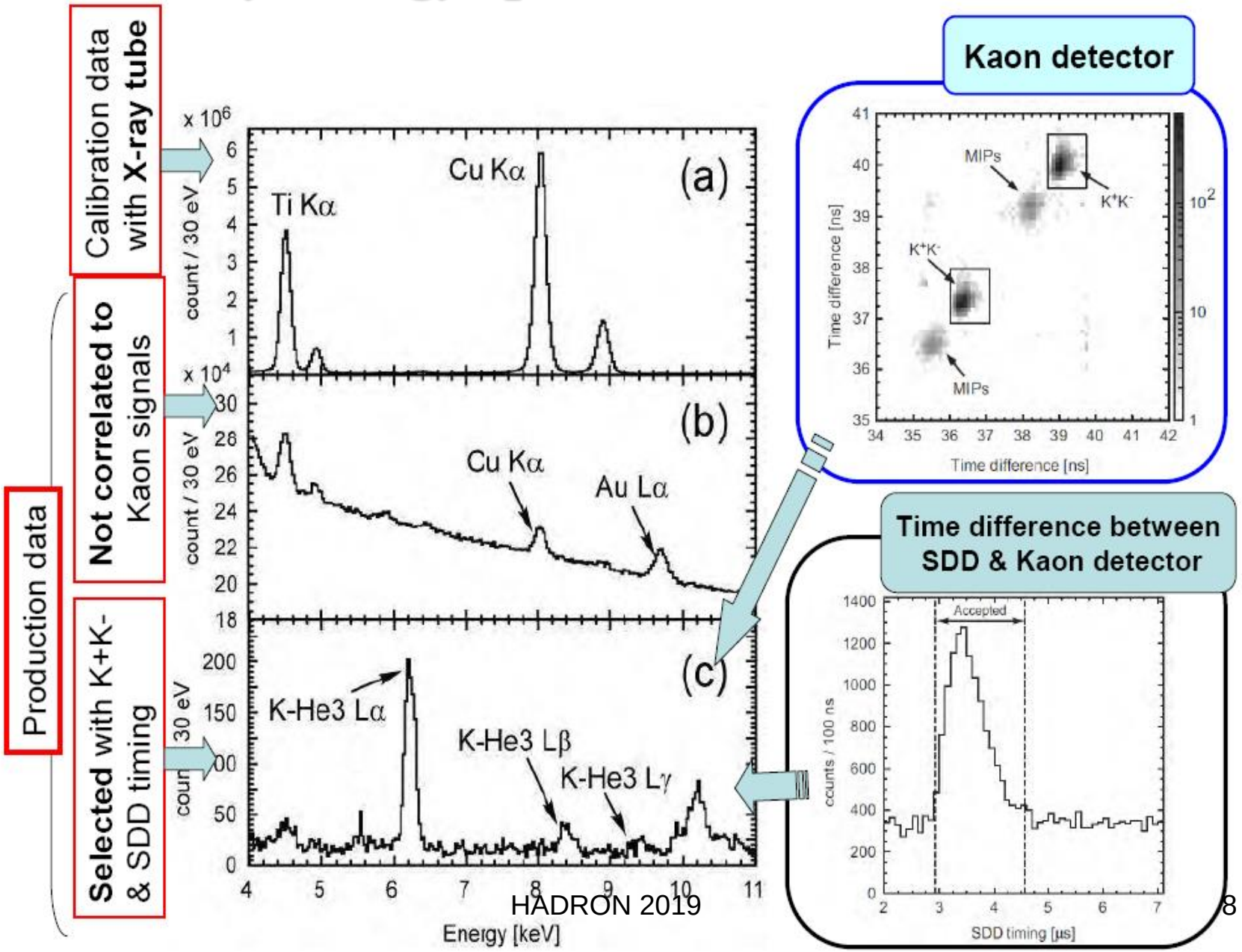
K^+K^- pairs produced at DAΦNE

triple coincidence

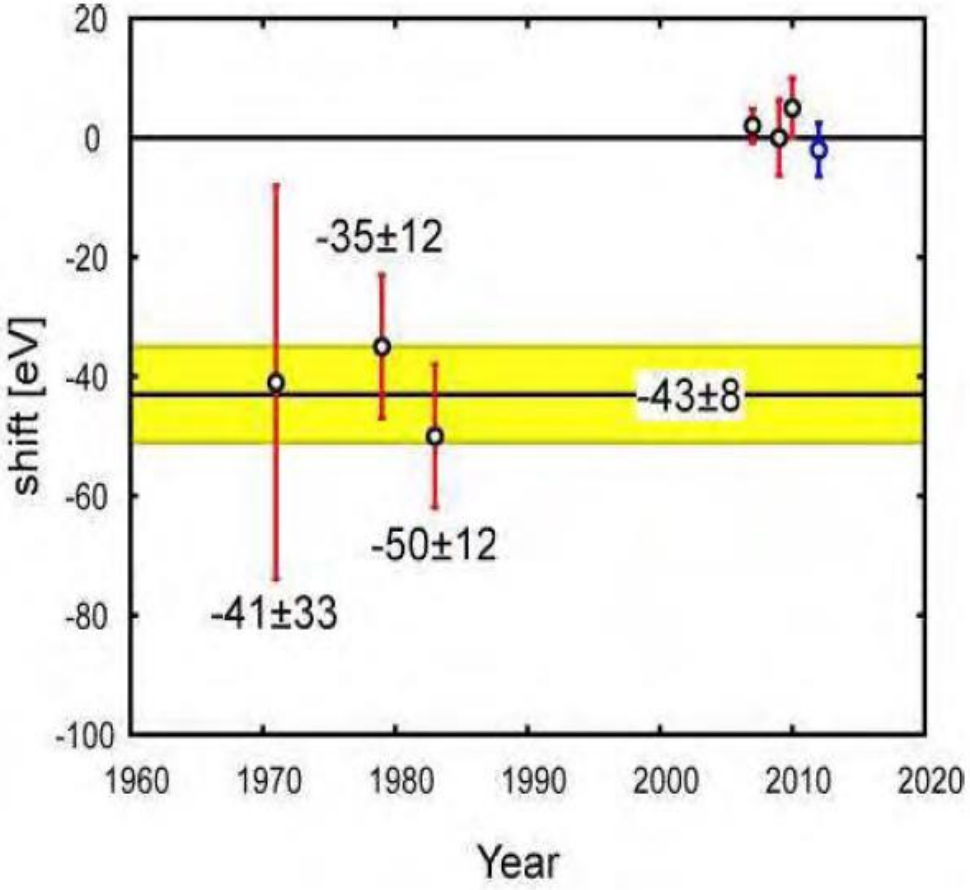
Production data

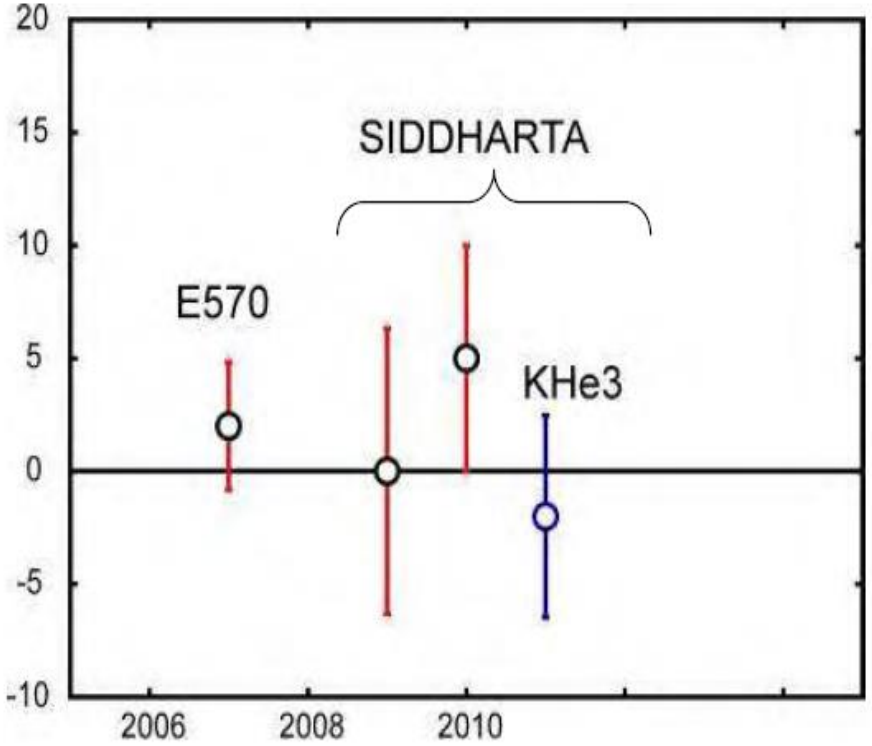


SDD X-ray energy spectra

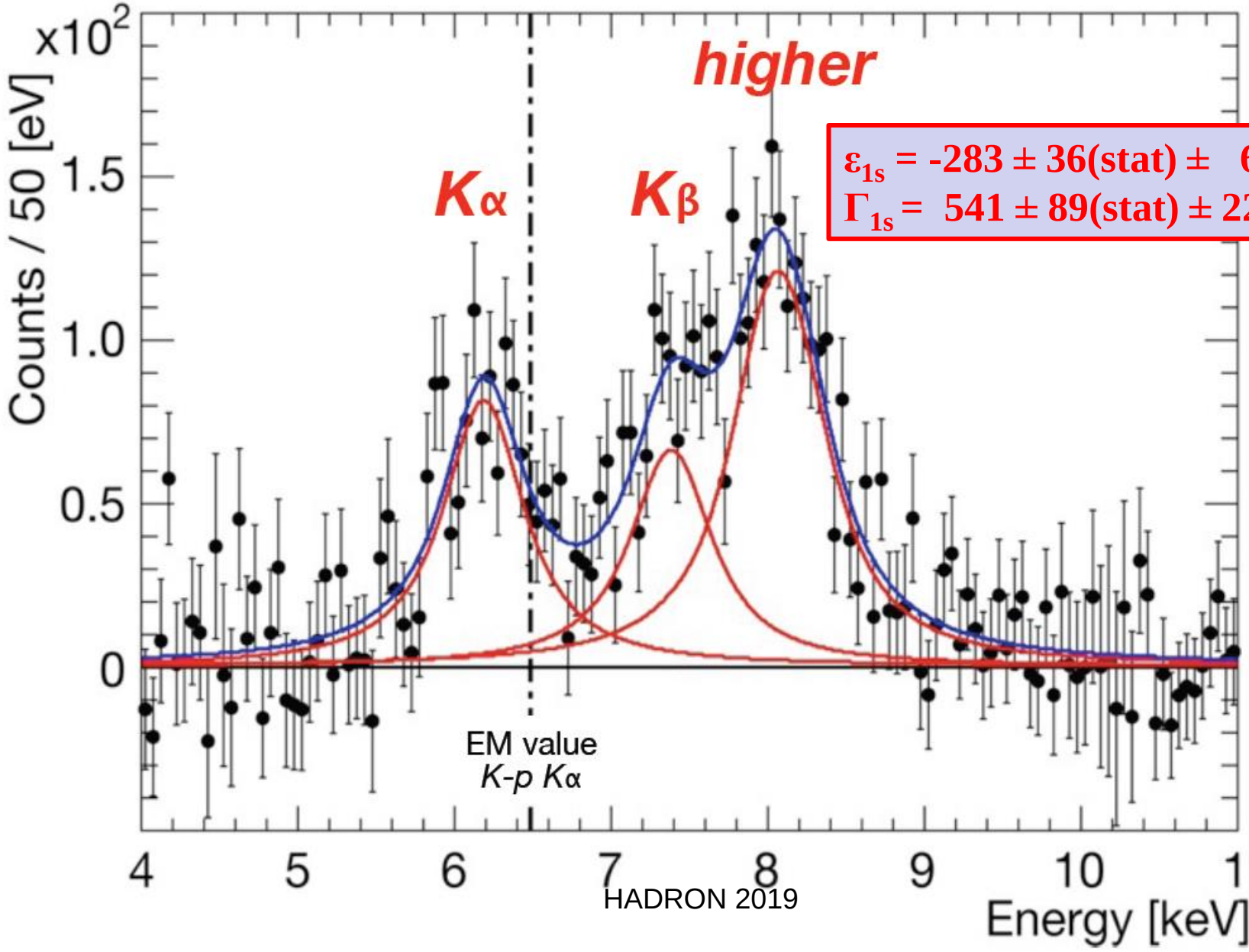


Kaonic helium results



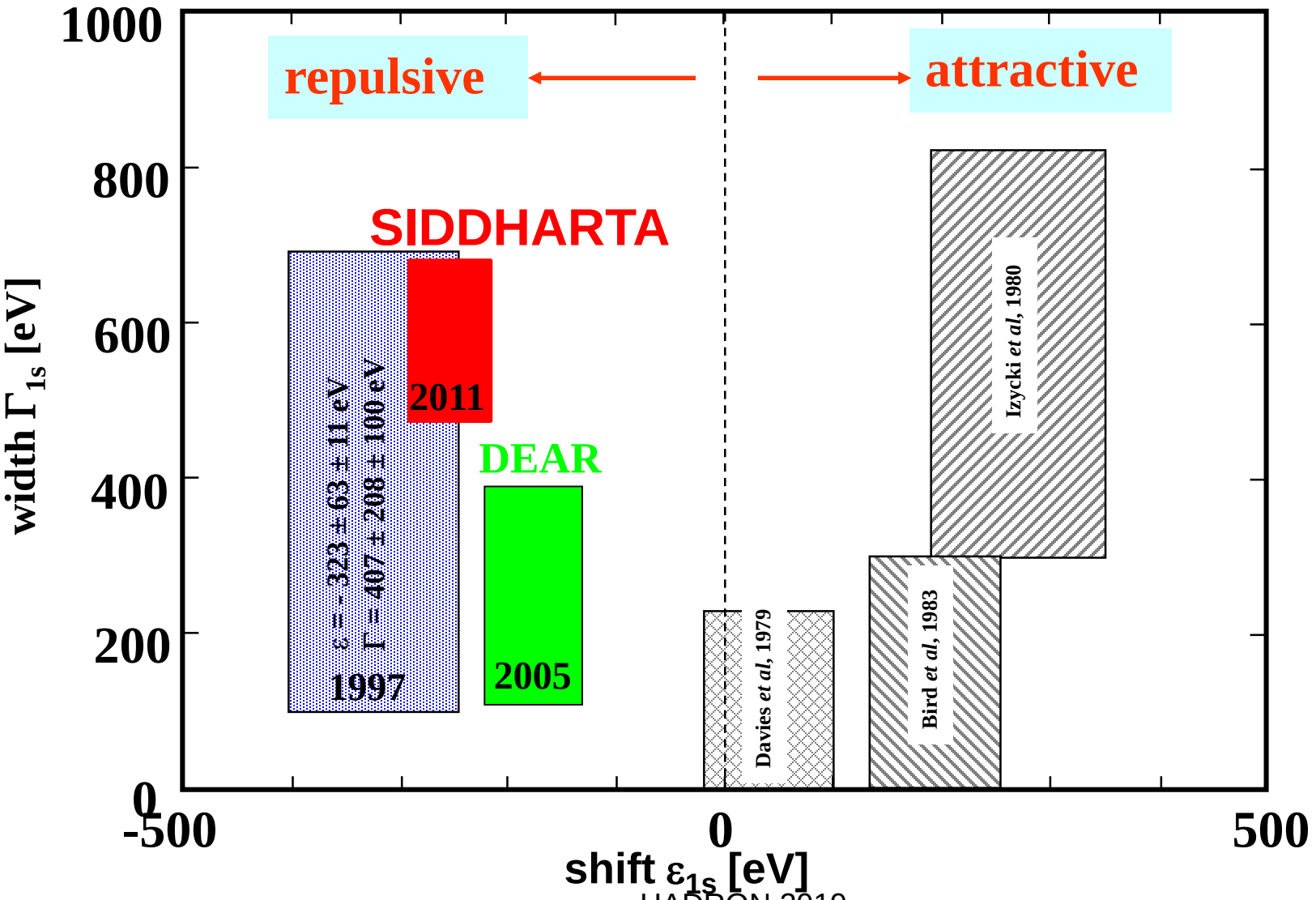


K^-p spectrum, BG subtracted



ε_{1s} = -283 ± 36(stat) ± 6(syst) eV
Γ_{1s} = 541 ± 89(stat) ± 22(syst) eV

SIDDHARTA results: K^-p (2011)



SIDDHARTA results:

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

Kaonic deuterium *- 100 pb^{-1}, as an exploratory measurement*
Nucl. Phys. A907 (2013) 69

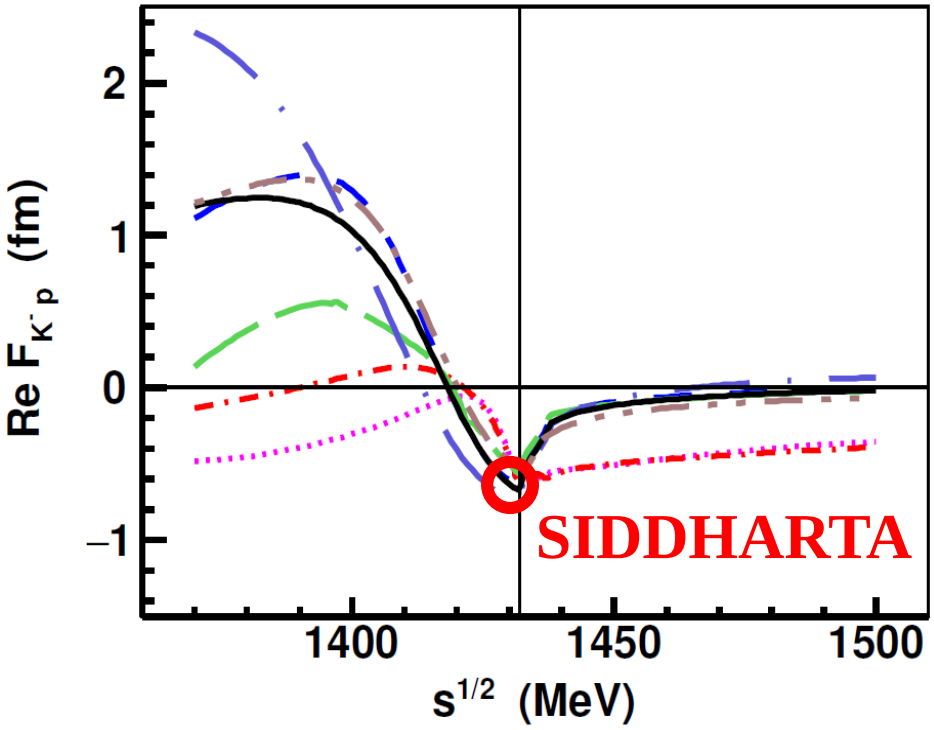
Kaonic helium 4 *– first measurement ever in gaseous target*
Phys. Lett. B 681 (2009) 310; NIM A628 (2011) 264;
Phys. Lett. B 697 (2011);

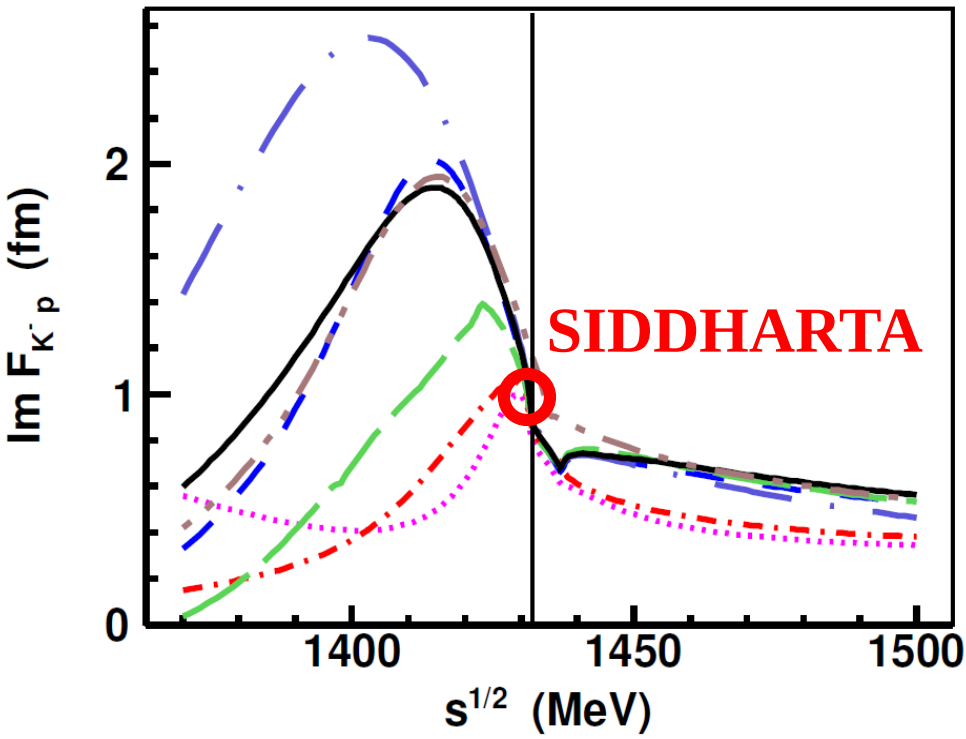
Kaonic helium 3 *– 10 pb^{-1}, first measurement in the world*
Phys. Lett. B 697 (2011) 199

Widths and yields *of KHe3 and KHe4*
Phys. Lett. B714 (2012) 40; Nucl. Phys. A916 (2013) 30; EPJ A(2014) 50; Nucl. Phys. A954 (2016) 7

$K^- p \to K^- p$ forward scattering amplitude

- subthreshold amplitudes not yet well determined

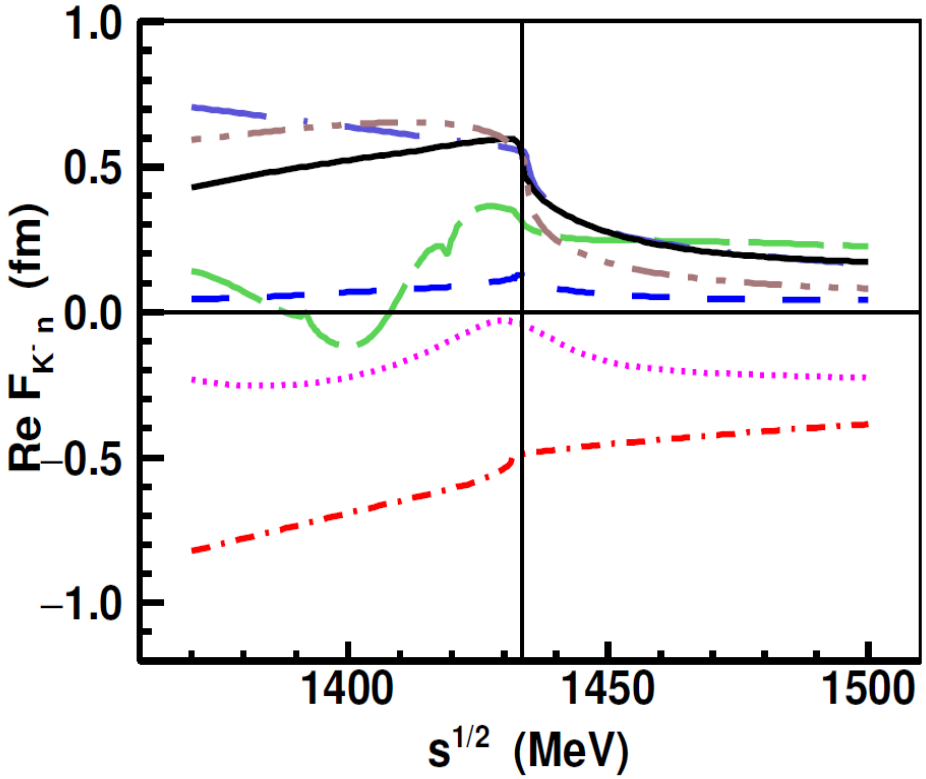


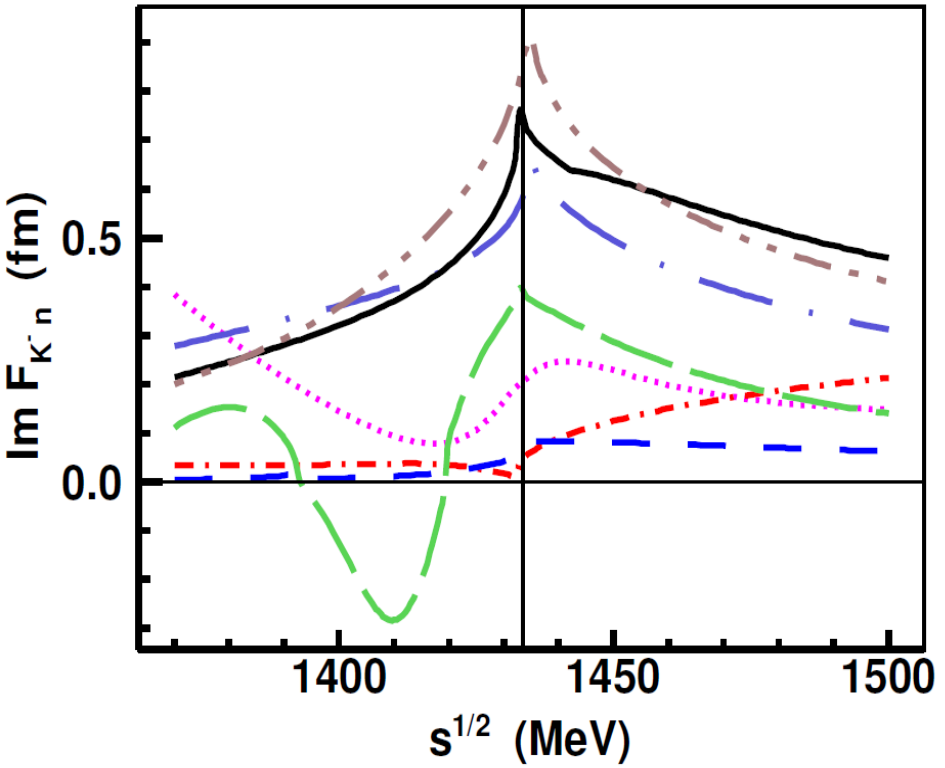


Kyoto-Munich
Murcia 1
Prague
Bonn 2
Murcia 2
Barcelona
Bonn 4

$K^- n \to K^- n$ forward scattering amplitude

- K-d will set constraints at threshold





Kyoto-Munich
Murcia 1
Prague
Bonn 2
Murcia 2
Barcelona
Bonn 4

SIDDHARTA-2

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications

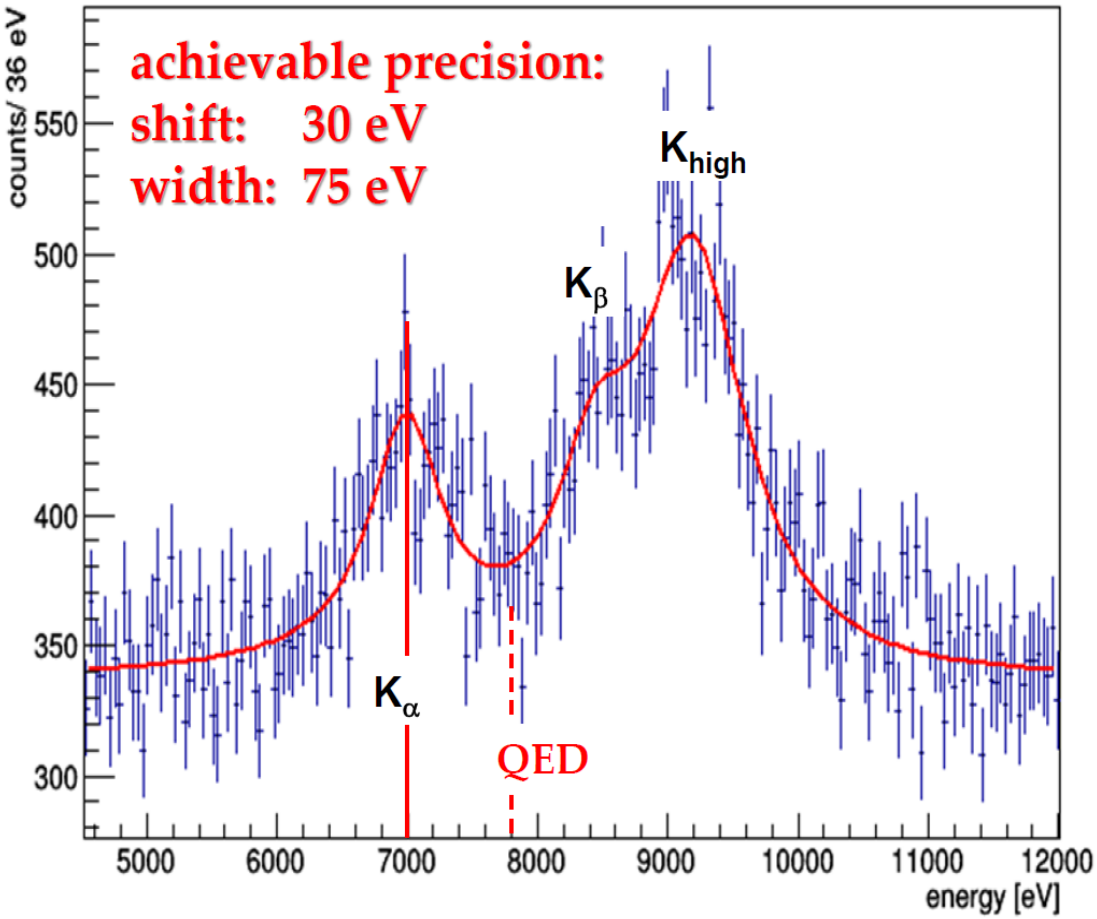
LNF- INFN, Frascati, Italy
SMI- ÖAW, Vienna, Austria
Politecnico di Milano, Italy
IFIN – HH, Bucharest, Romania
TUM, Munich, Germany
RIKEN, Japan
Univ. Tokyo, Japan
Victoria Univ., Canada
Univ. Zagreb, Croatia
Helmholtz Inst. Mainz, Germany
Univ. Jagiellonian Krakow, Poland
Research Center for Electron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

STRONG-2020

Croatian Science Foundation, research project 8570

SDDHARTA-2 expected result

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

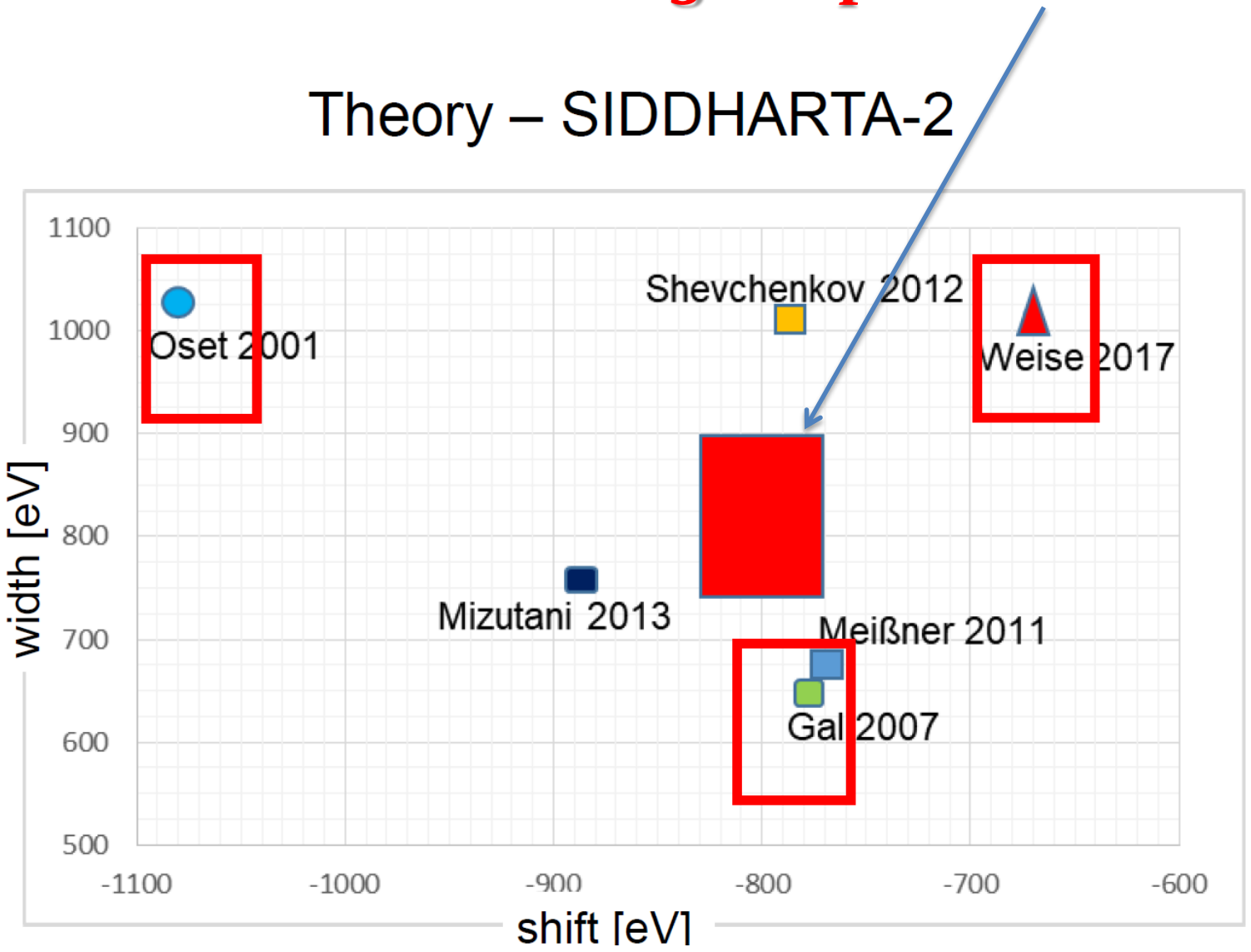


signal: shift - 800 eV
width 800 eV
density: 3% (LHD)
detector area: 246 cm^2

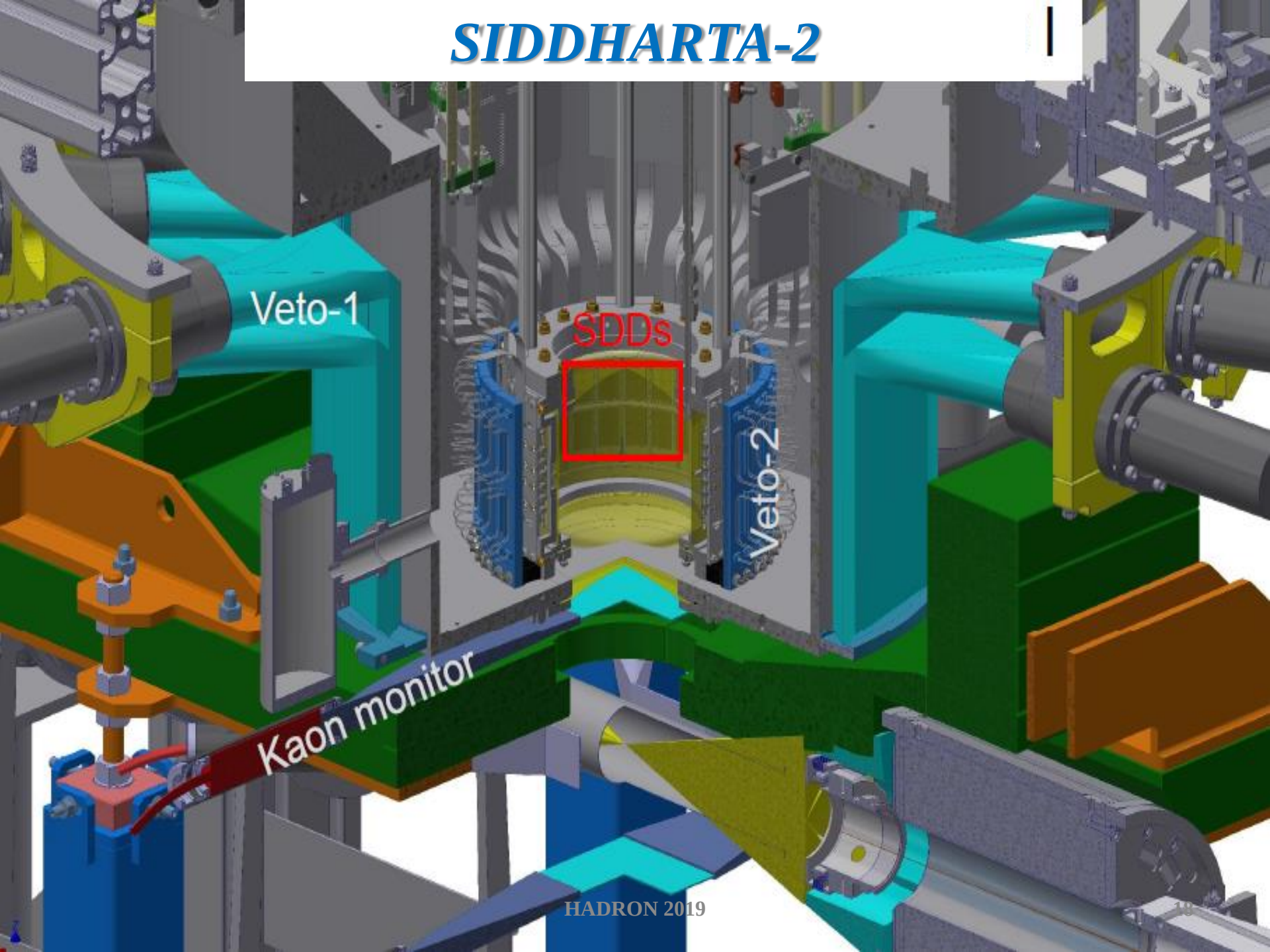
Kα yield: 0.1 %
yield ratio as in K^-p
S/B ~ 1 : 3

- charged particle veto
- asynchronous BG

SIDDHARTA-2 targeted precision



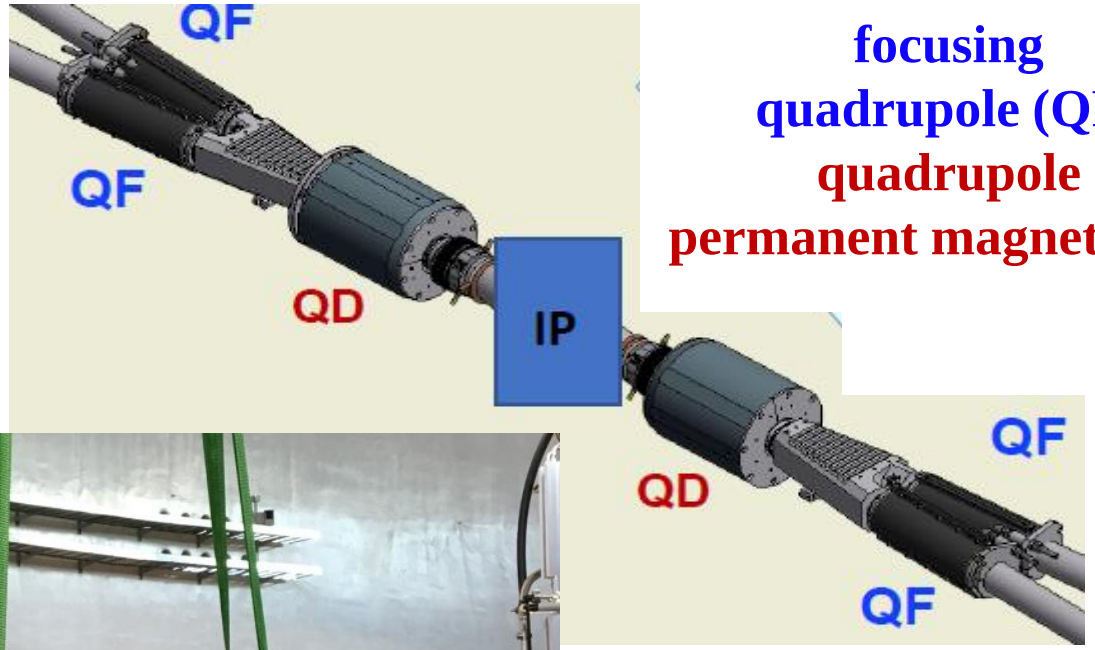
SIDDHARTA-2



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

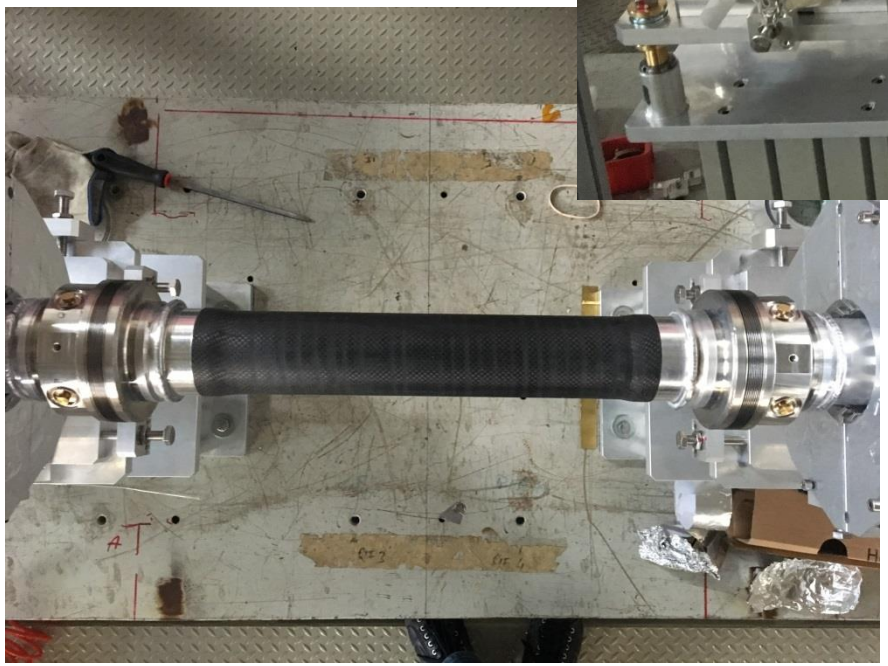
New interaction region



focusing quadrupole (QF)
quadrupole permanent magnet (QD)

New beam pipe

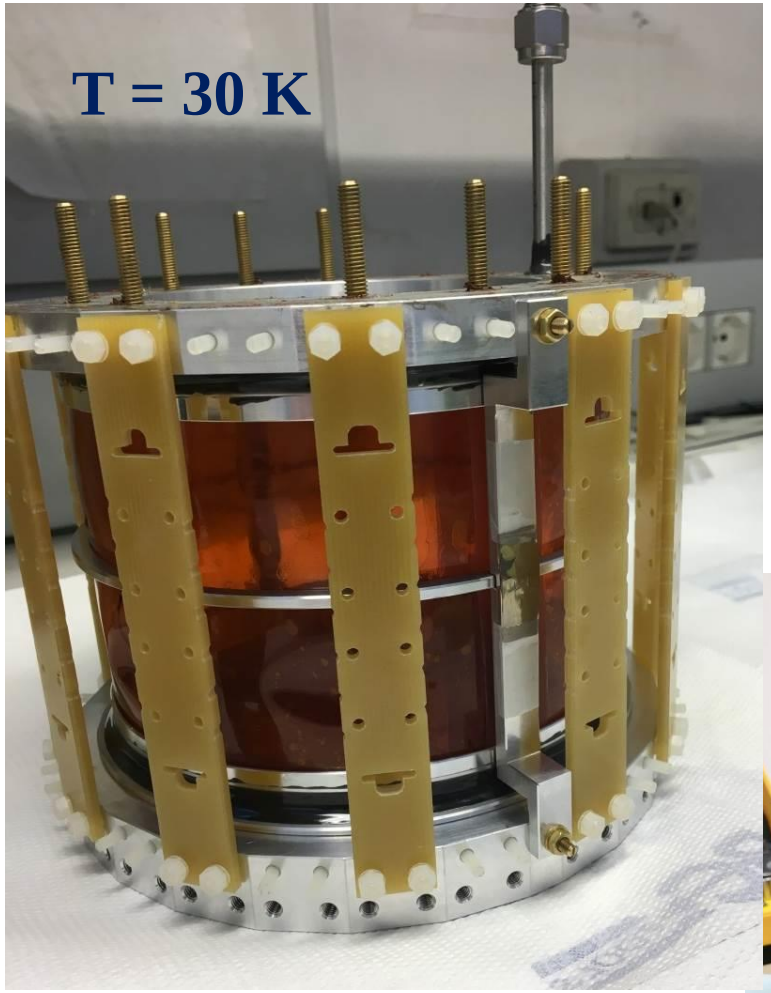
flanges removed
major source of
asynchronous
background



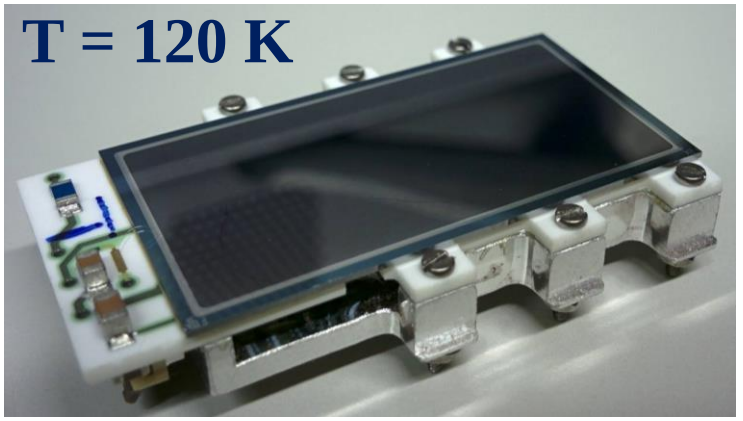
carbon fiber reinforcement
thickness ~ 500 micron
internal ultra pure aluminum
ø 55mm, thickness ~ 150 micron

DAΦNE luminosity monitor

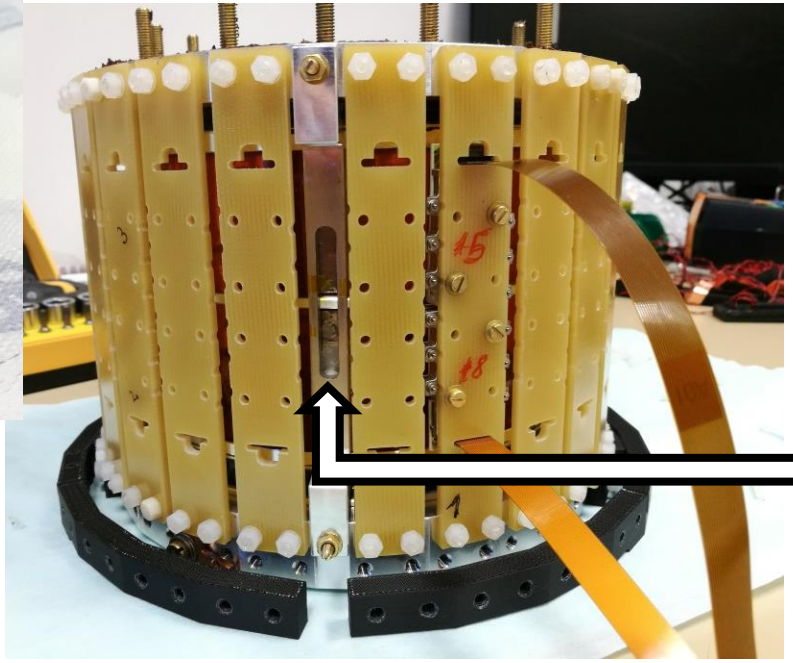
Lightweight cryogenic target and X-ray detector



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



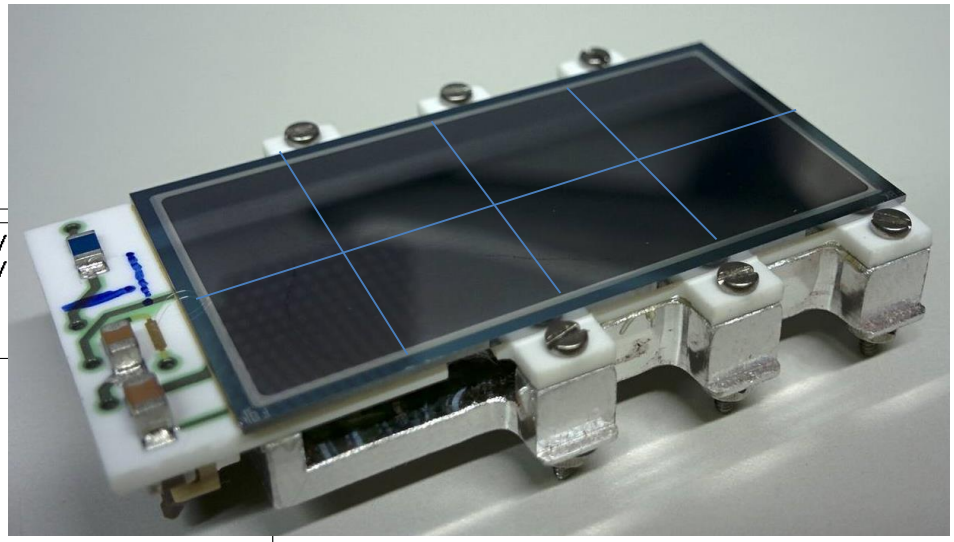
SDDs placed 5 mm from the target wall

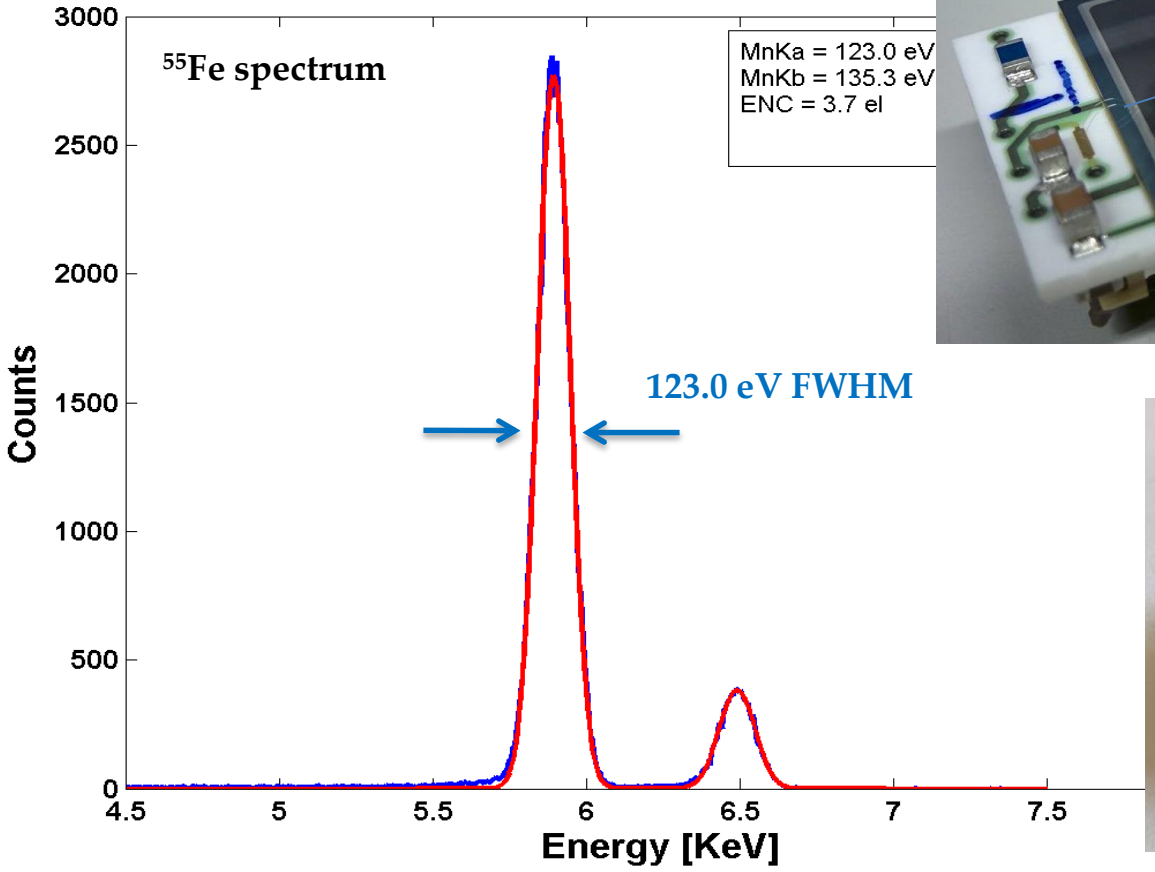


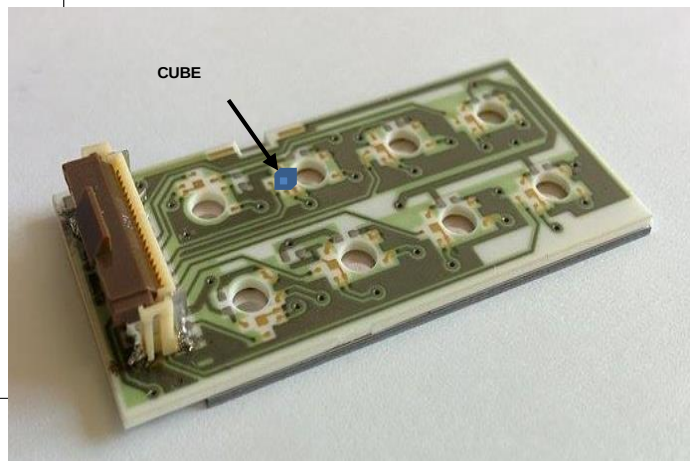
calibration foils inserted near to the SDD are activated by the X-ray tubes

SIDDHART-2 new X-ray detector

New SDD technology with CUBE preamplifier

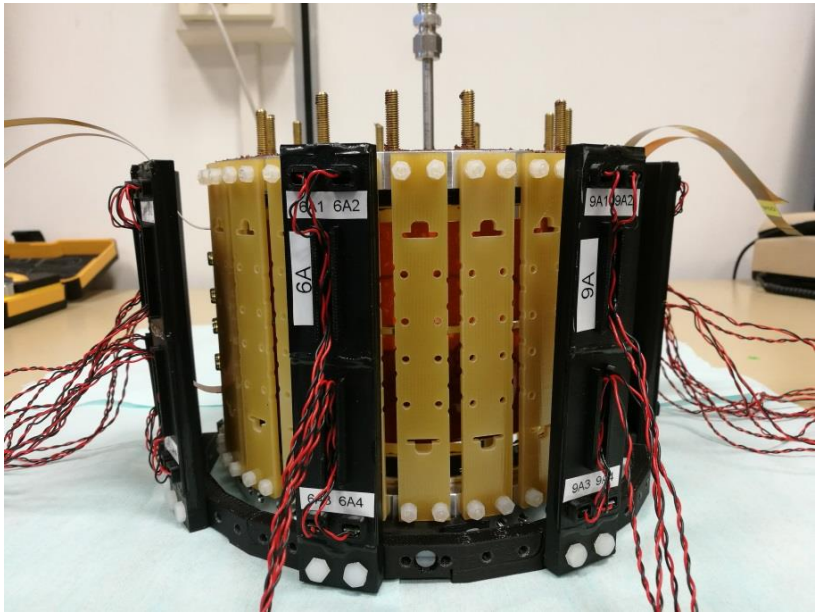


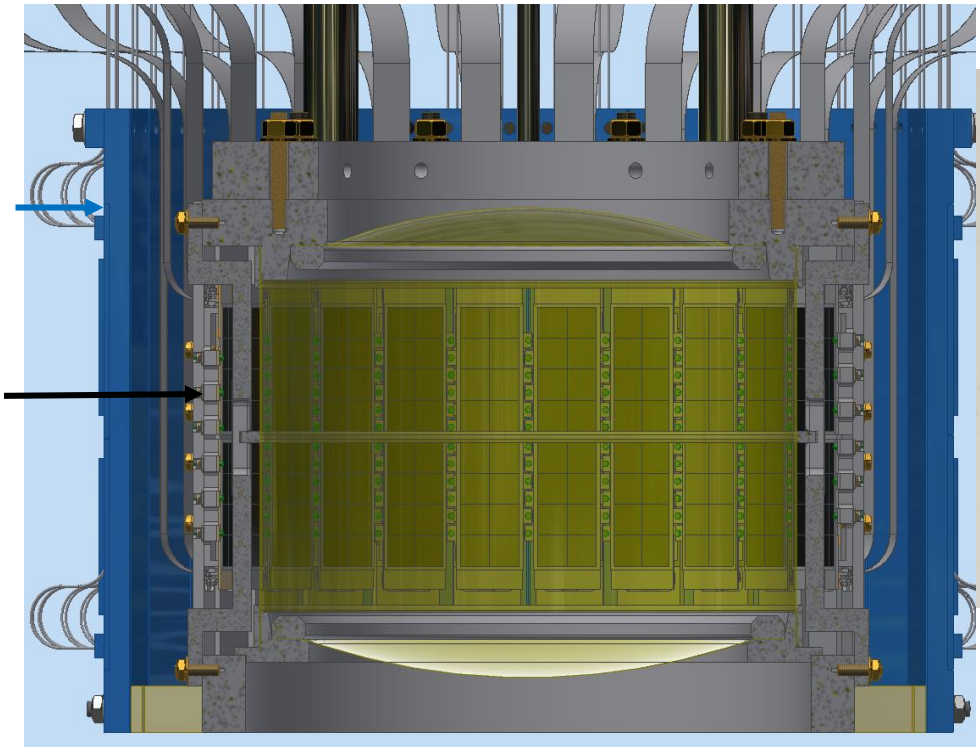


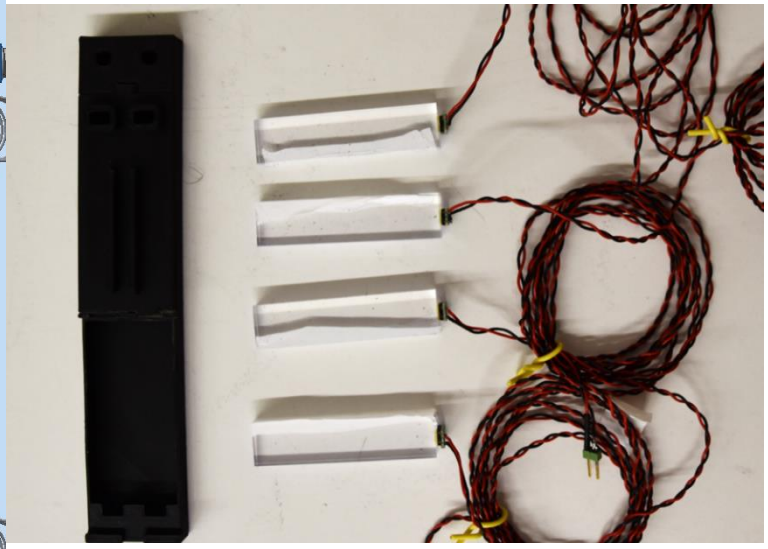


The veto-2 system

an inner ring of scintillator tiles (SciTiles) placed as close as possible behind the SDDs for charge particle tracking



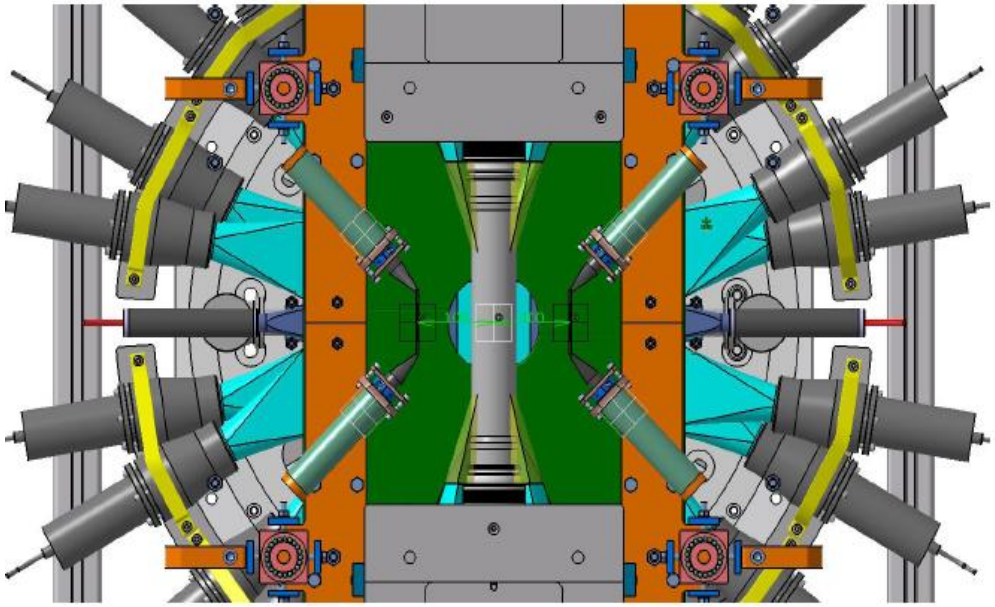




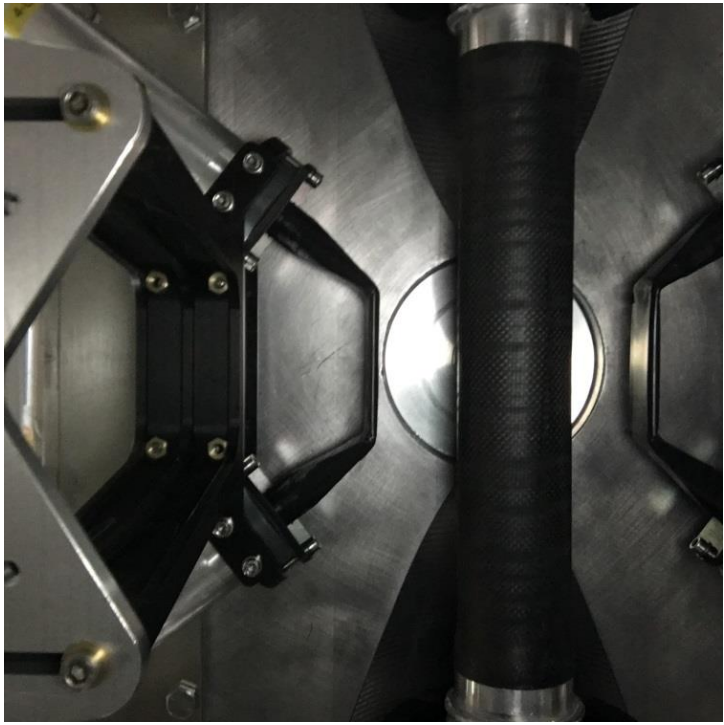
BC-408 scintillator tiles with 4x4 mm^2 SiPM

SIDDHARTA-2 Luminosity monitor

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



SIDDHARTA-2
Interaction regions bottom view



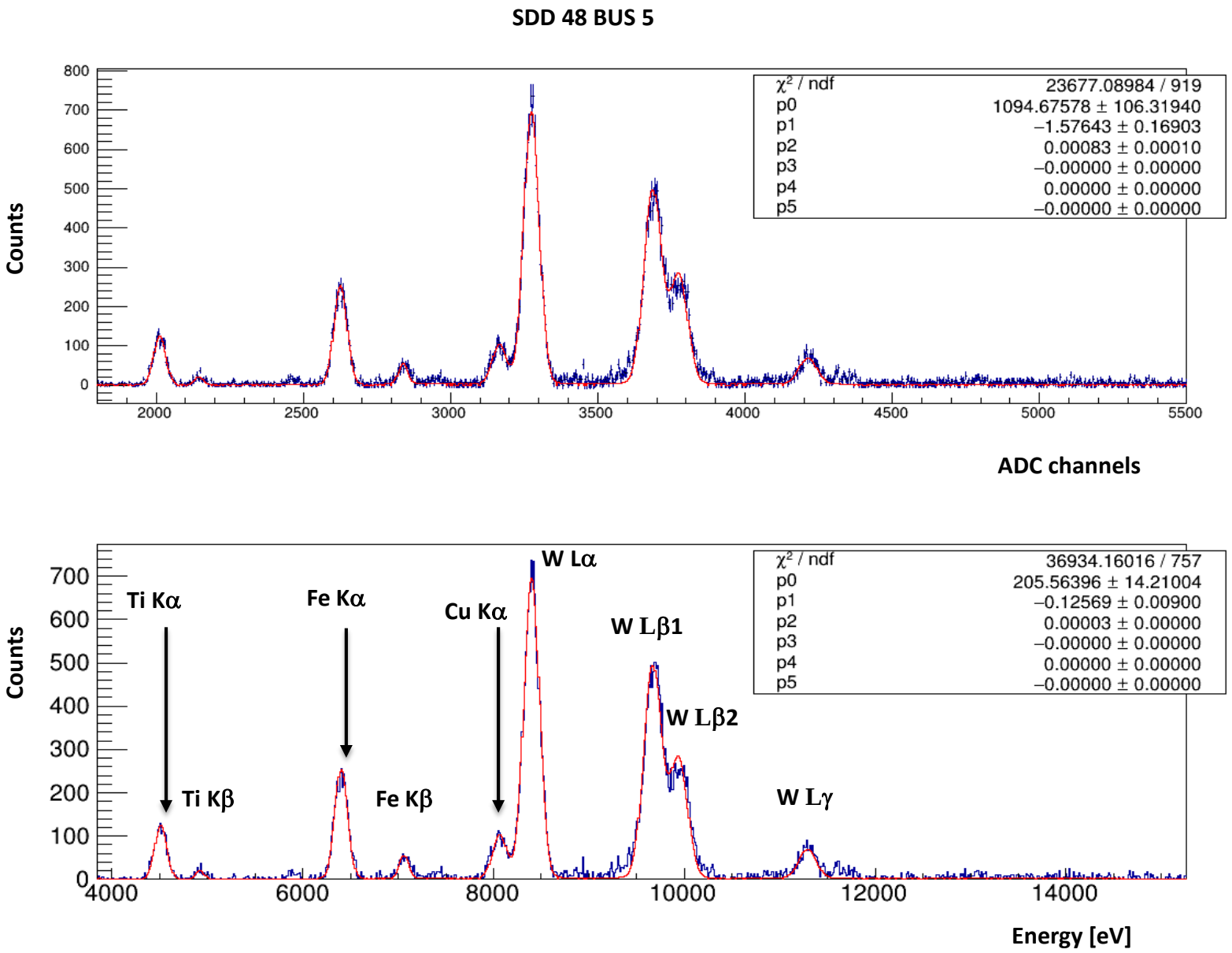
- **Fast detectors & FEE**
- **Real time acquisition**
- **Accidental rate << Signal rate**

Allows:

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

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

Calibration of SDDs with the x-ray tube in DAΦNE



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