Low-energy kaon-nucleon/nuclei interactions studies at DAΦNE

Johann Zmeskal, SMI - Vienna

What next LNF:
Perspectives of fundamental physics at the Frascati Laboratory

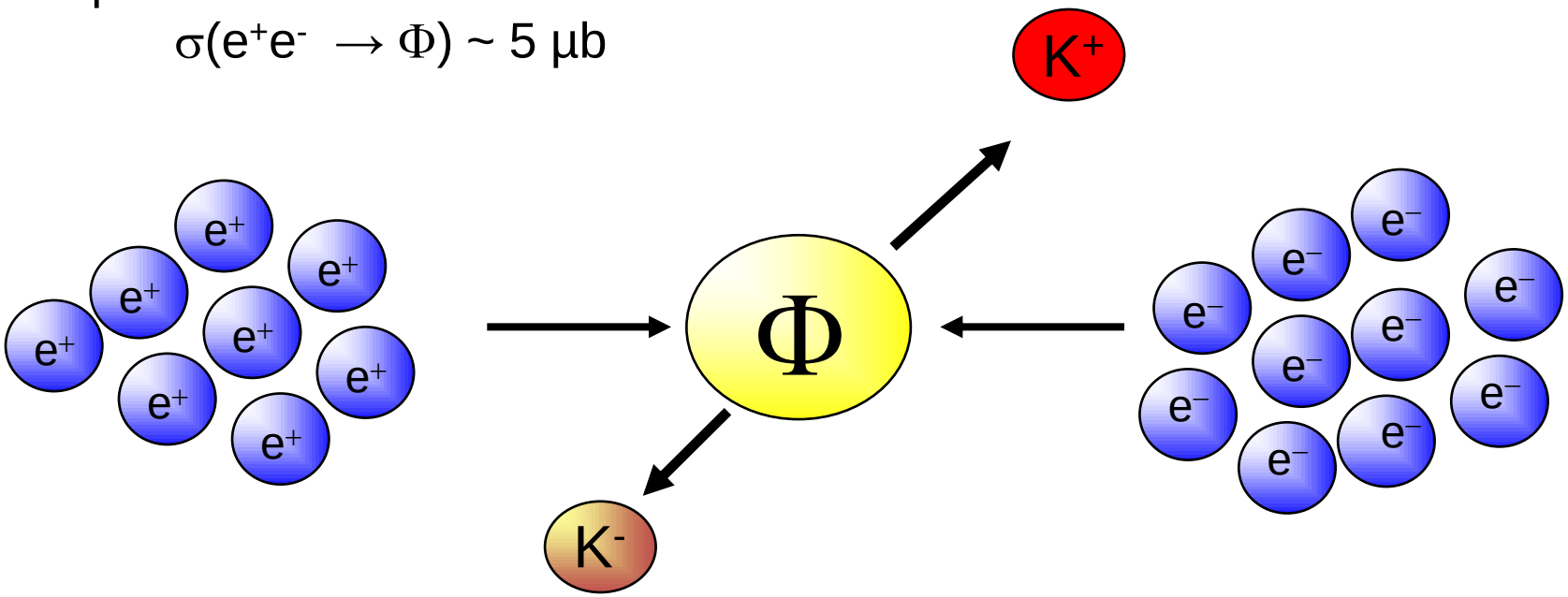
INFN - Laboratori Nazionali di Frascati
November 10-11, 2014

DAΦNE @ LNF

DAΦNE – study of low-energy QCD

- operates at the centre-of-mass energy of the Φ meson
  mass m = 1019.413 ± .008 MeV
  width Γ = 4.43 ± .06 MeV

- Φ produced via e^+e^- collision with
  $\sigma(e^+e^- \rightarrow \Phi) \sim 5\ \mu b$



→ integrated luminosity per month: ~ 150 pb^{-1}

→ monochromatic kaon beam (127 MeV/c)

Low-energy QCD with strangeness – available machines

- **DAΦNE @ LNF (unique in the world)**
  SIDDHARTA, FINUDA, AMADEUS/KLOE
- GSI – Helmholtzzentrum, Germany
  FOPI, HADES
- J-PARC, Japan
- Jlab, USA
- LEPS/SPring-8, Japan
- CERN
- **FAIR, Germany**
  PANDA, FLAIR

Kaonic atoms

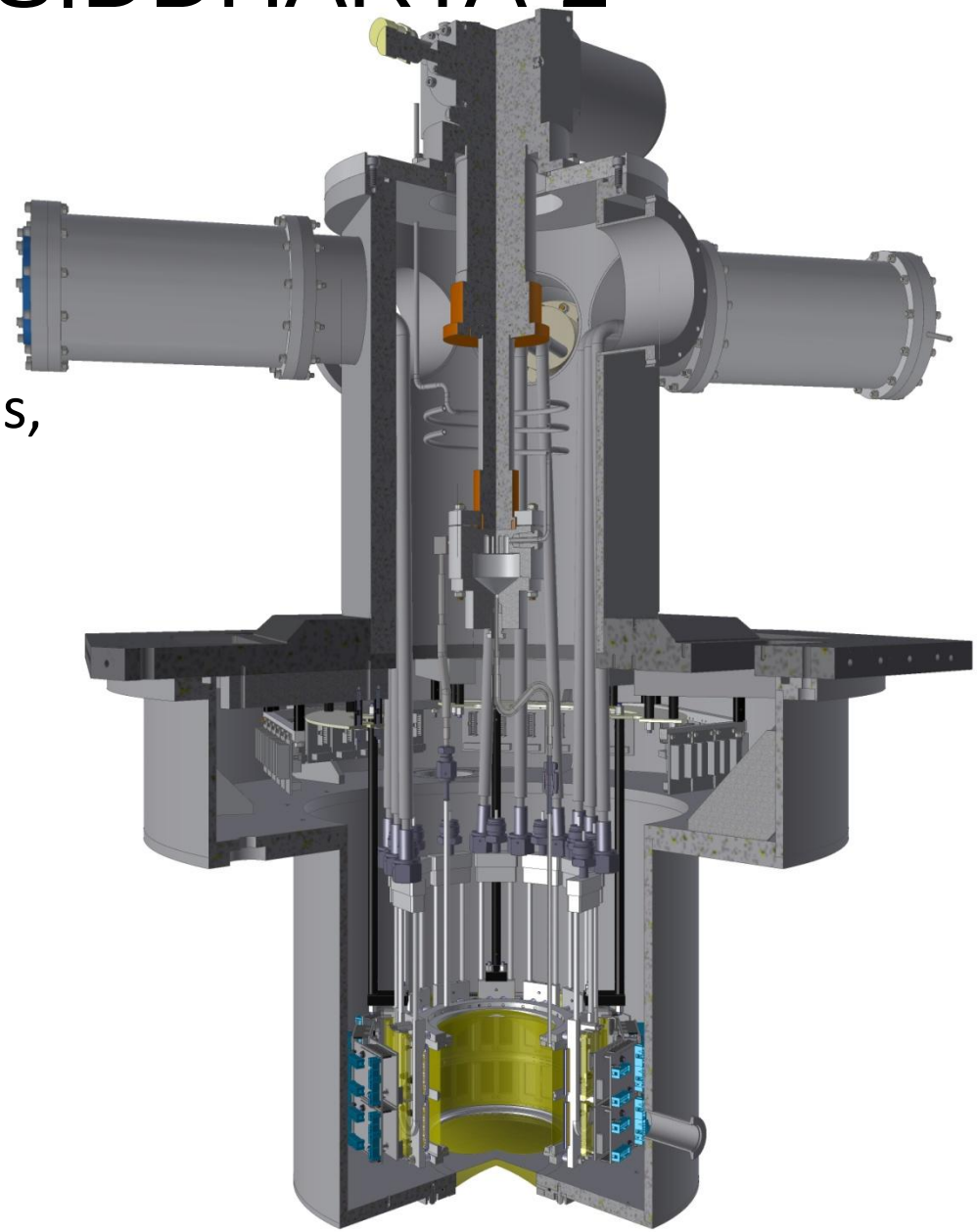
K^-d, K^-p

$K^-\,^3He$, $K^-\,^4He$

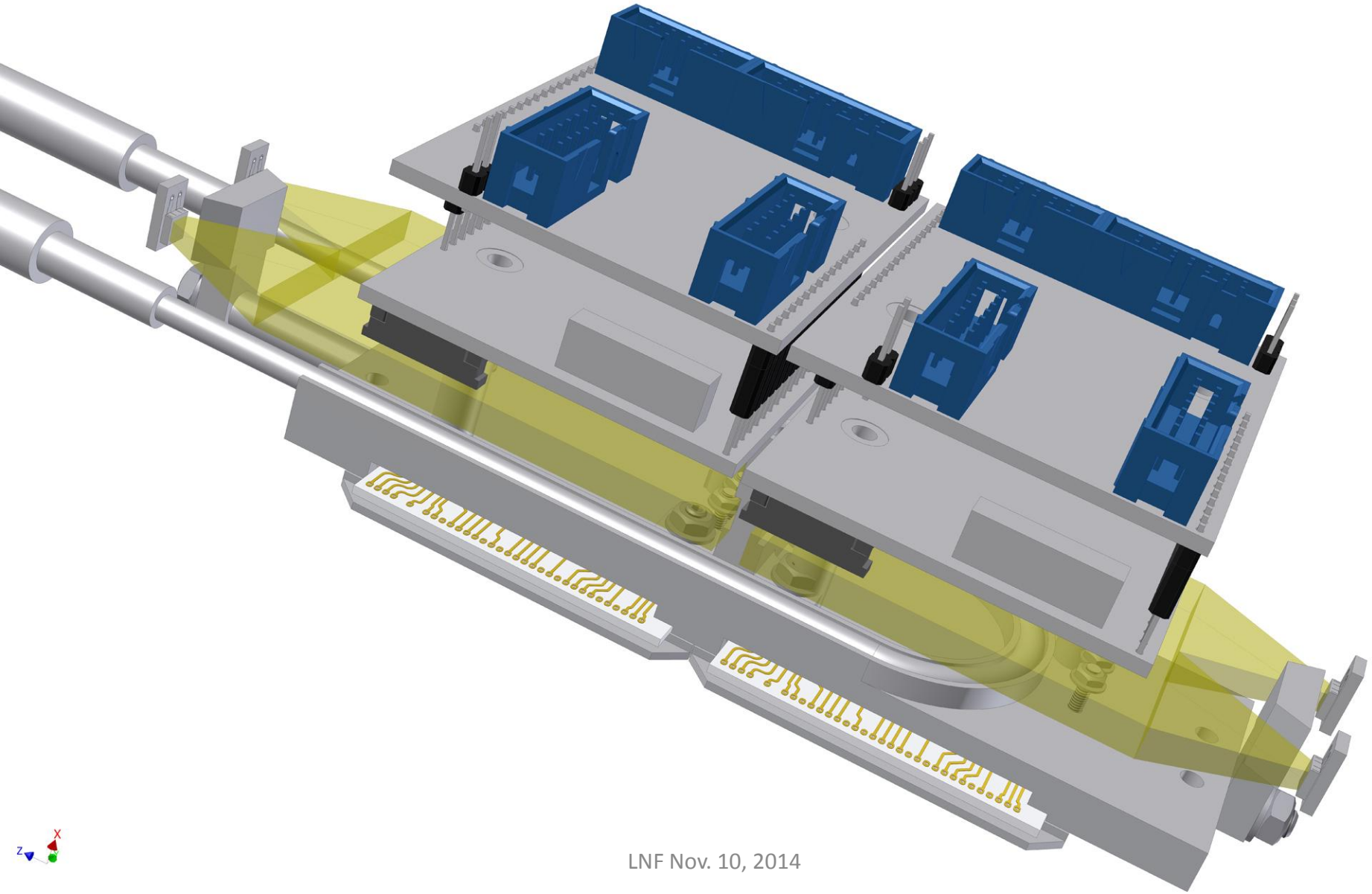
K^-d at DAΦNE - SIDDHARTA-2

Target cooling:
1 Leybold – 16 W @ 20 K
Liquid hydrogen cooling lines,
new target cell

SDD cooling:
4 CryoTiger – 60 W @ 120 K
Liquid argon cooling lines:
SDD cooling to 100 – 120 K



SDDs with charge particle veto



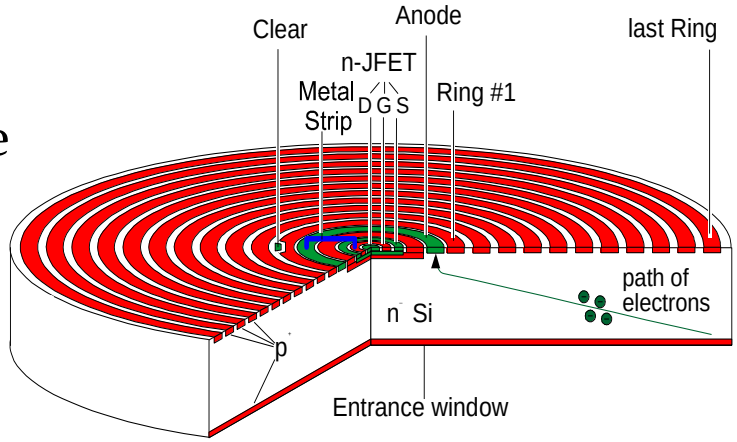
SDDs - new development

JFET integrated on the SDD

lowest total anode capacitance

limited by JFET performances

sophisticated SDD+JFET technology



144 cm² ready to go

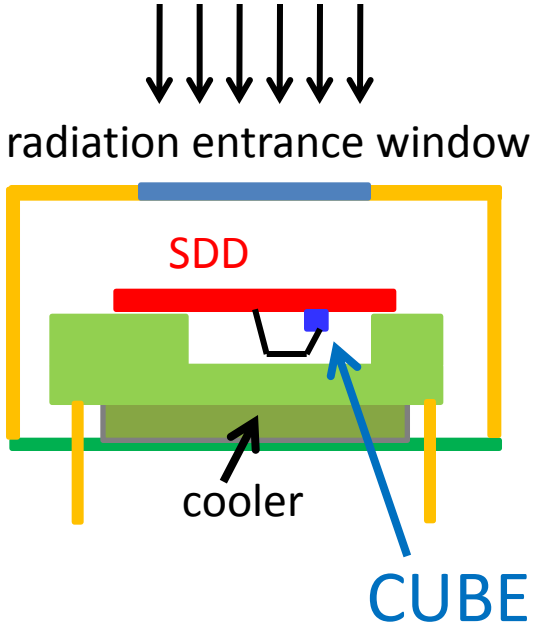
EU-FP6 HadronPhysics

external CUBE preamplifier (MOSFET input transistor)

larger total anode capacitance

better FET performances

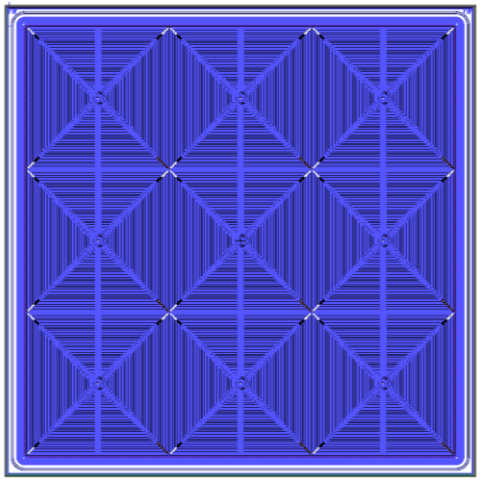
standard SDD technology

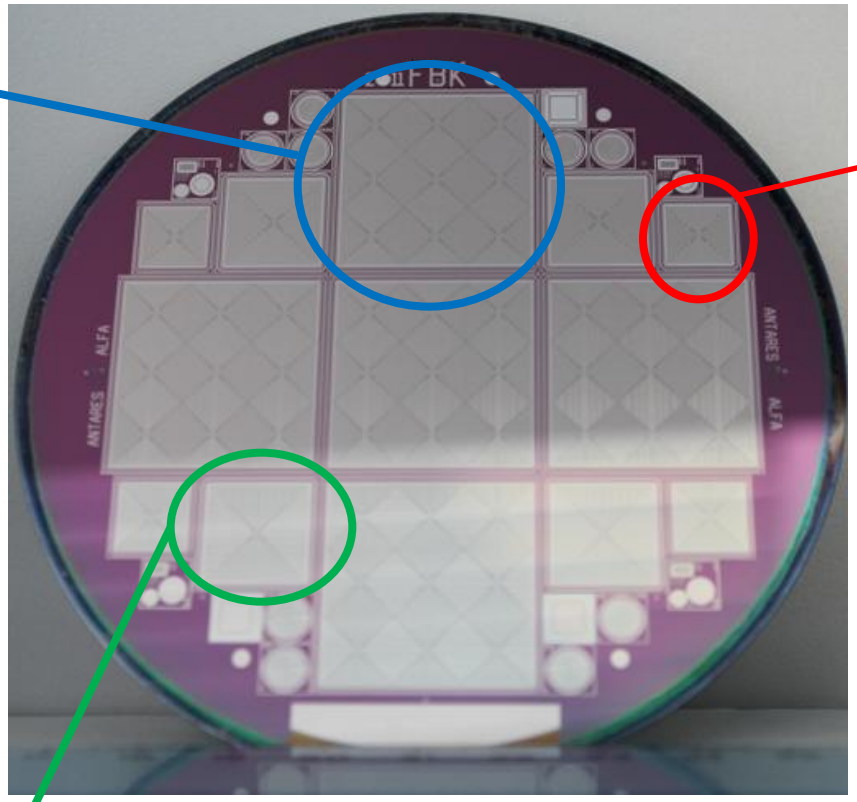


new SDDs for K^-d under production 250cm²

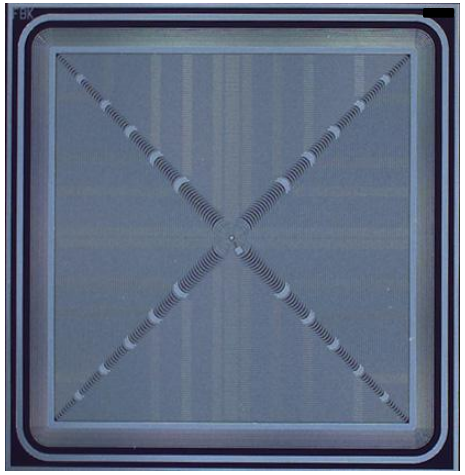
Development of new SDDs at FBK

Array: 9 SDDs (8 x 8 mm^2 each)





8 x 8 mm^2 single SDD

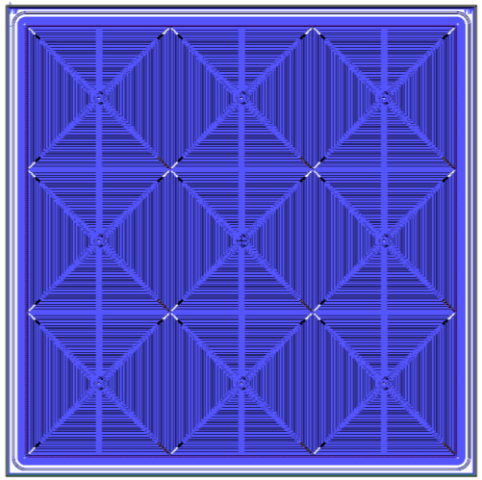


12 x 12 mm single SDD

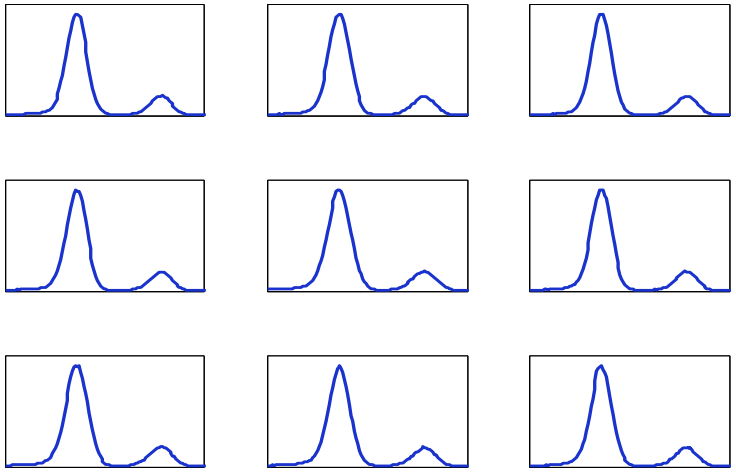
FBK production:

- 4” wafer
- 6” wafer upgrade just finished

Monolithic array of 3x3 SDDs

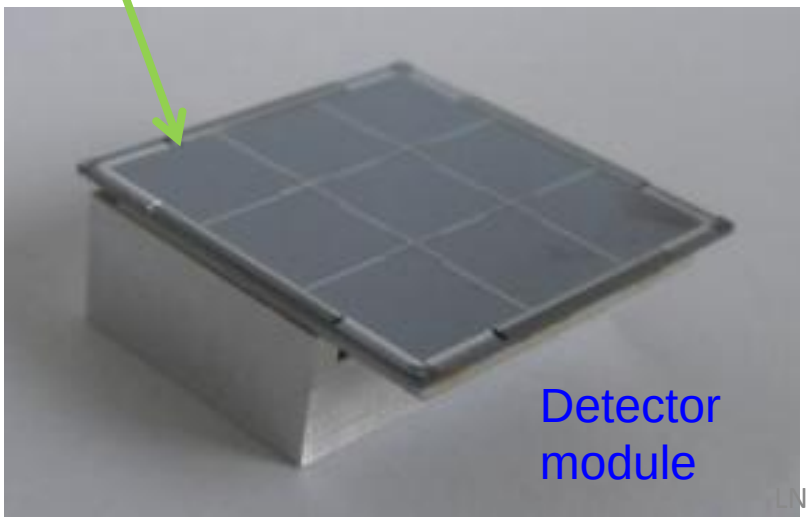


26mm

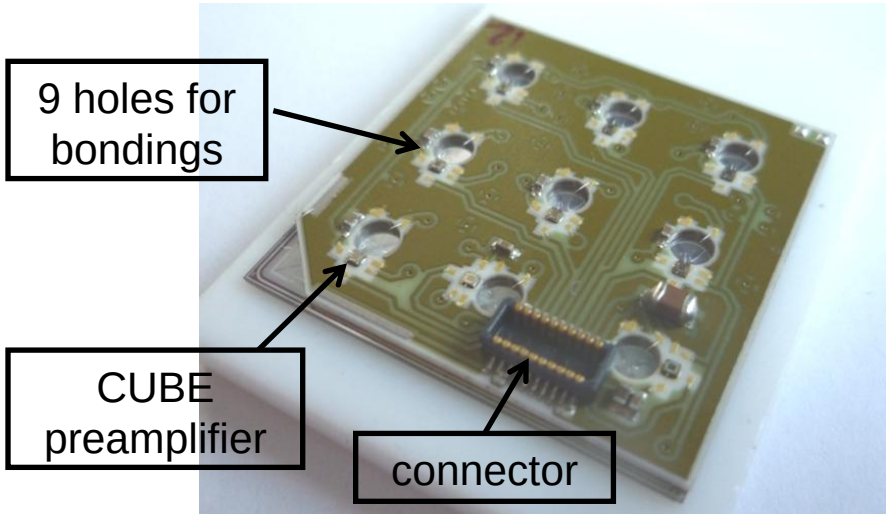


- ^{55}Fe spectra
- T=-20°C

1mm dead space on each side: 85% active area



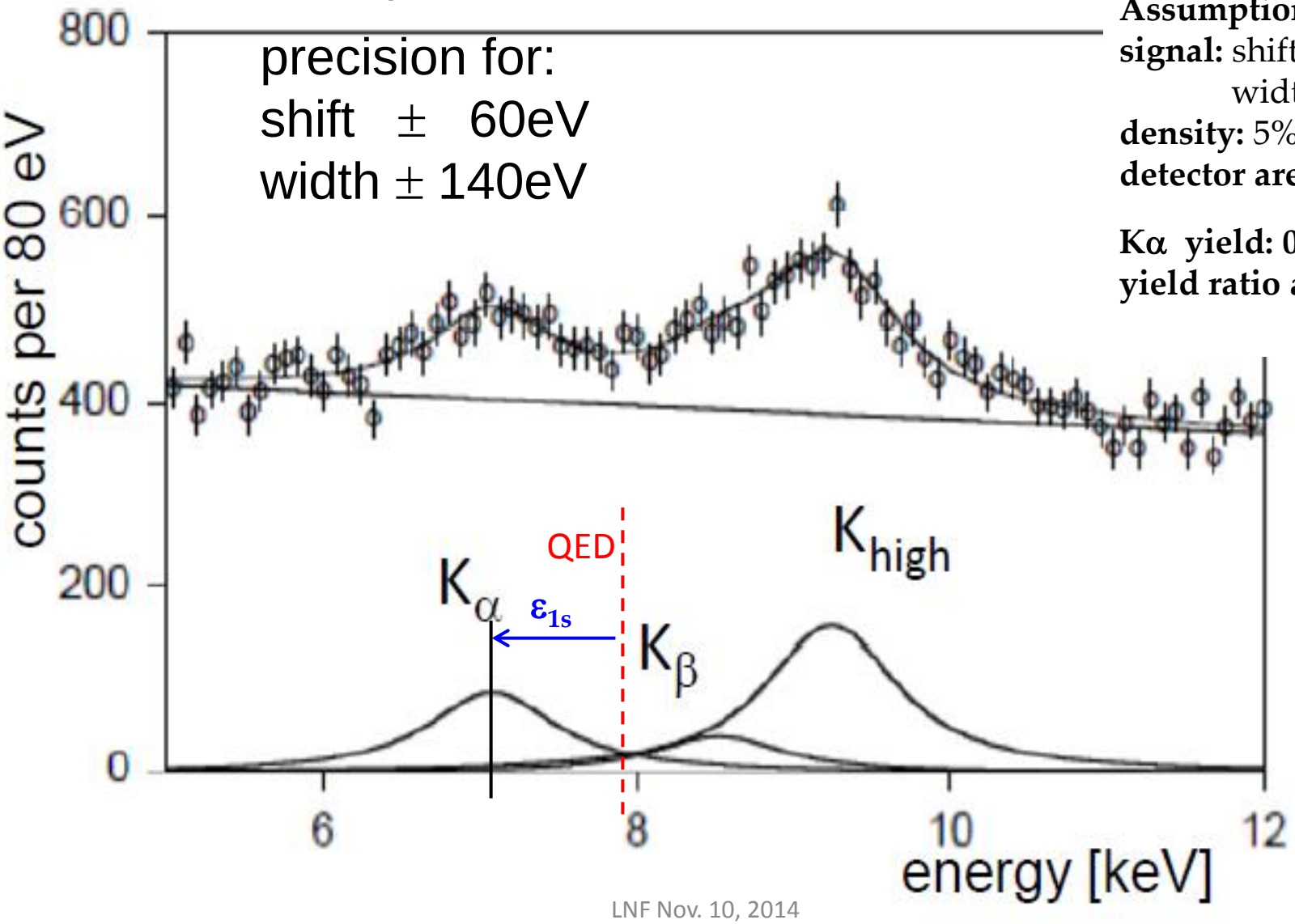
Detector module



Ceramic carrier

Kaonic deuterium X-ray spectrum

L = 500pb^{-1}

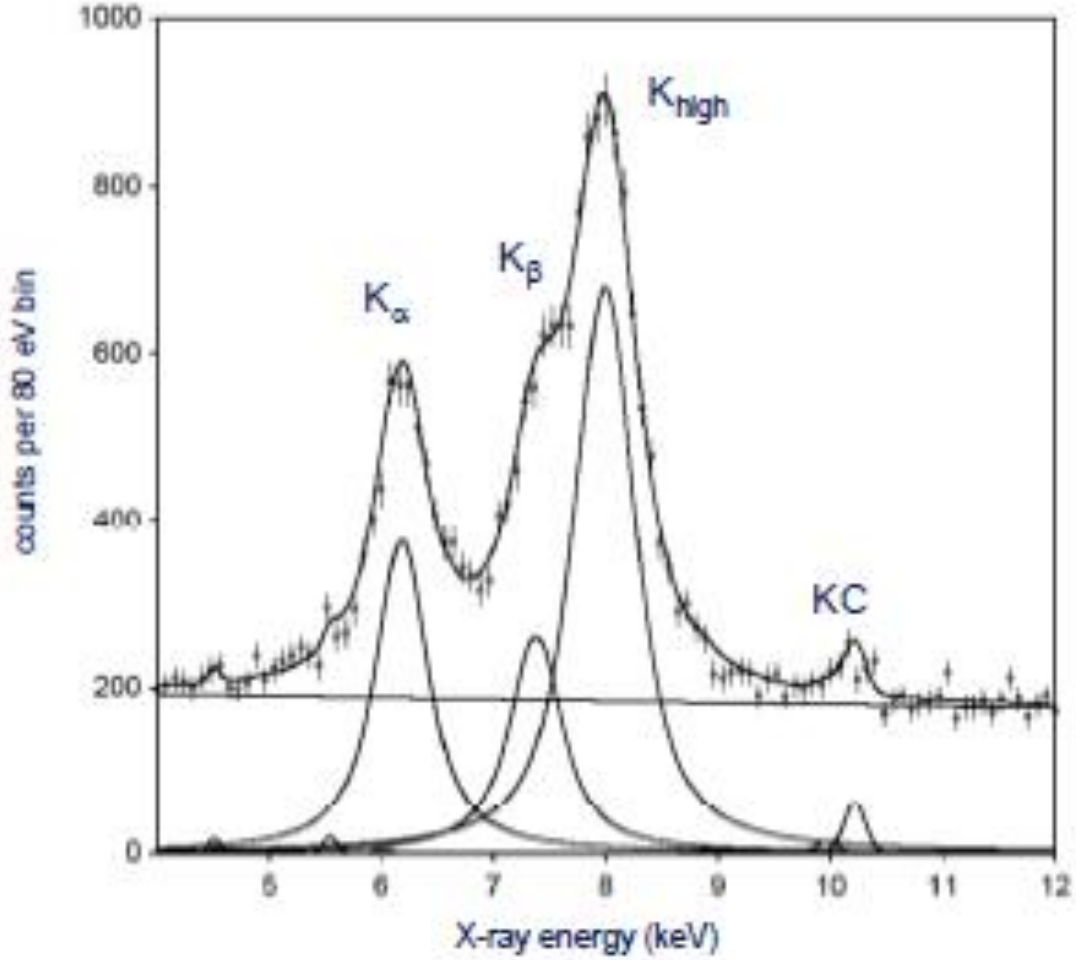


Assumptions
signal: shift - 800 eV
width 750 eV
density: 5% (LHD)
detector area: 246 cm^2

Kα yield: 0.1 %
yield ratio as in K$^-$p

Kaonic hydrogen L = 100 pb^{-1}

Factor 3-4 better than SIDDHARTA:



SIDDHARTA-2 with 246 cm^2 new SDDs from FBK

S/B= 10:3 = sum(K_α) / sum(bg in FWHM of signal)
precision: σ(shift) ~ 10 eV, σ(width) ~ 21 eV

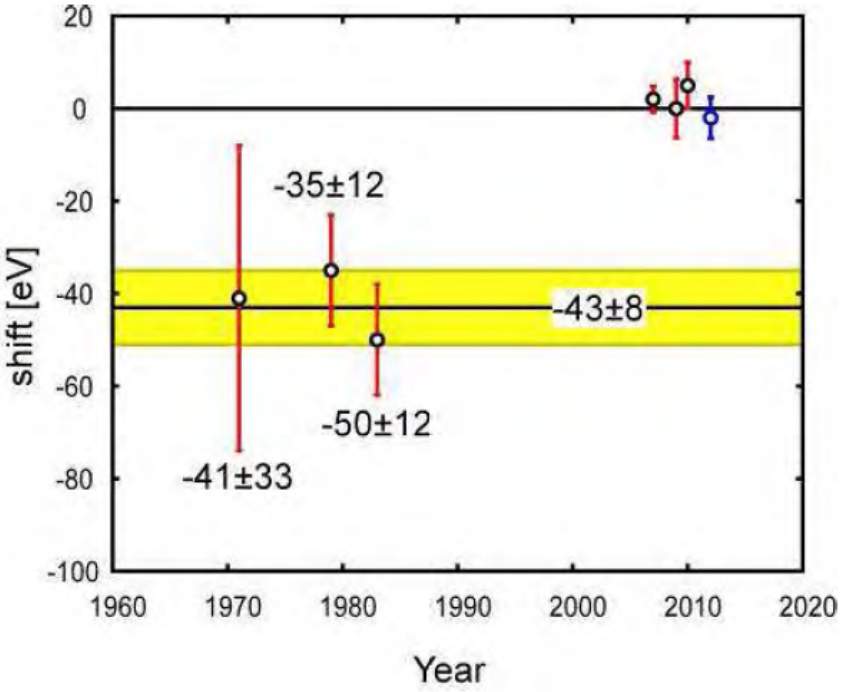
Kaonic atoms

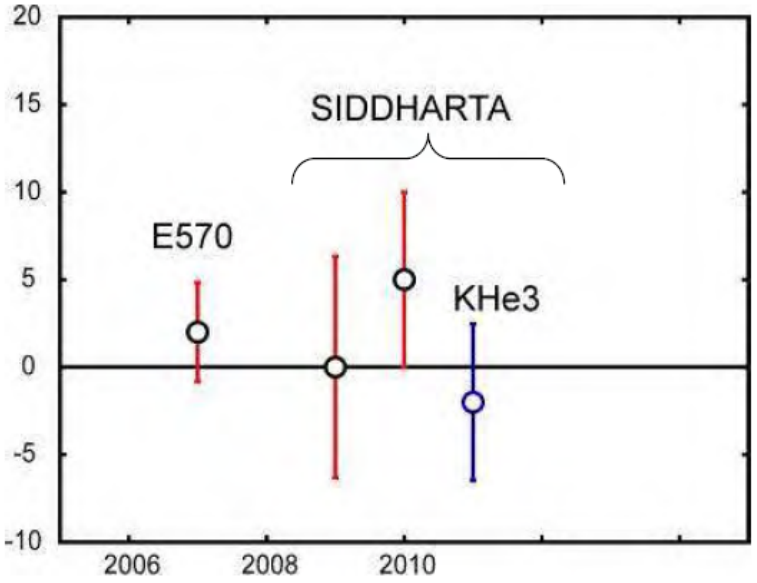
$K^- d$, $K^- p$

$K^- {}^3He$, $K^- {}^4He$

Kaonic helium results - SIDDHARTA

	Shift [eV]	Reference
KEK E570	+2±2±2	PLB653(2007)387
SIDDHARTA (He4 with 55Fe)	+0±6±2	PLB681(2009)310
SIDDHARTA (He4)	+5±3±4	arXiv:1010.4631, PLB697(2011)199
SIDDHARTA (He3)	-2±2±4	





- **with new SDDs + CZT measurement of the 1s state**
- **with cryogenic detector (high resolution) 2p state**

- **successfully tested at PSI**

16 Sept, 2014
EXA14 @ Vienna

High-resolution hadronic-atom x-ray spectroscopy with cryogenic detectors

Shinji OKADA (RIKEN)

The HEATES collaboration
- **H**igh-resolution **E**xotic **A**tom x-ray spectroscopy with **TES** microcalorimeter -

S. Okada[1], D.A. Bennett[2], C. Curceanu[3], W.B. Doriese[2], J.W. Fowler[2], T. Hashimoto[1], R.S. Hayano[4], M. Iliescu[3], S. Ishimoto[5], K. Itahashi[1], M. Iwasaki[1], J. Marton[6], G.C. O'Neil[2], H. Outa[1], M. Sato[1], D.R. Schmidt[2], D.S. Swetz[2], H. Tatsuno[2,6], J.N. Ullom[2], E. Widmann[6], S. Yamada[7], J. Zmeskal[6]

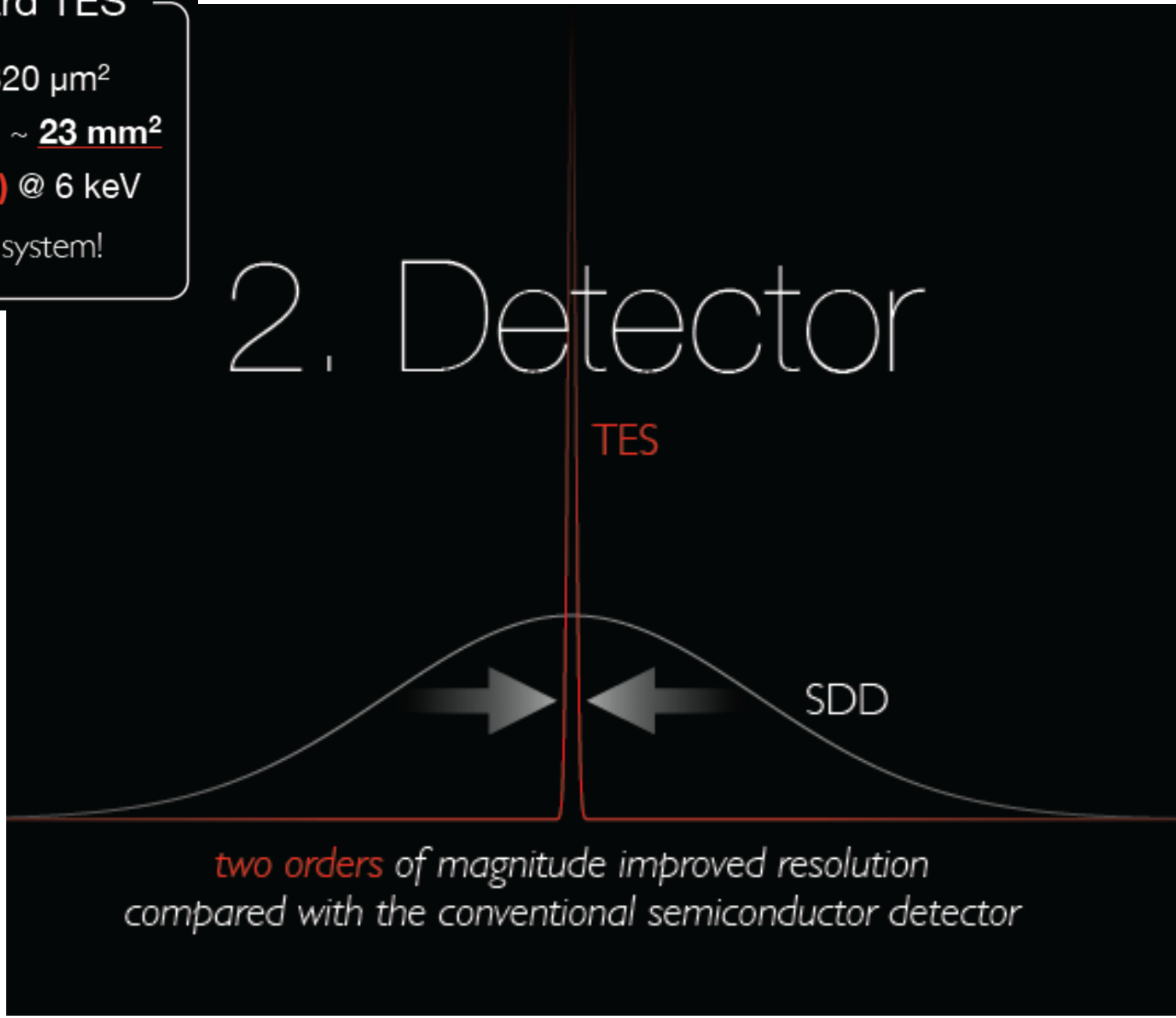
RIKEN[1], NIST[2], INFN-LNF[3], Univ. of Tokyo[4], KEK[5], Stefan Meyer Institut[6], Tokyo Metropolitan Univ.[7]

NIST's standard TES

- 1 pixel : 300 x 320 μm²
- 240 array : total ~ **23 mm²**
- **2~3 eV (FWHM)** @ 6 keV

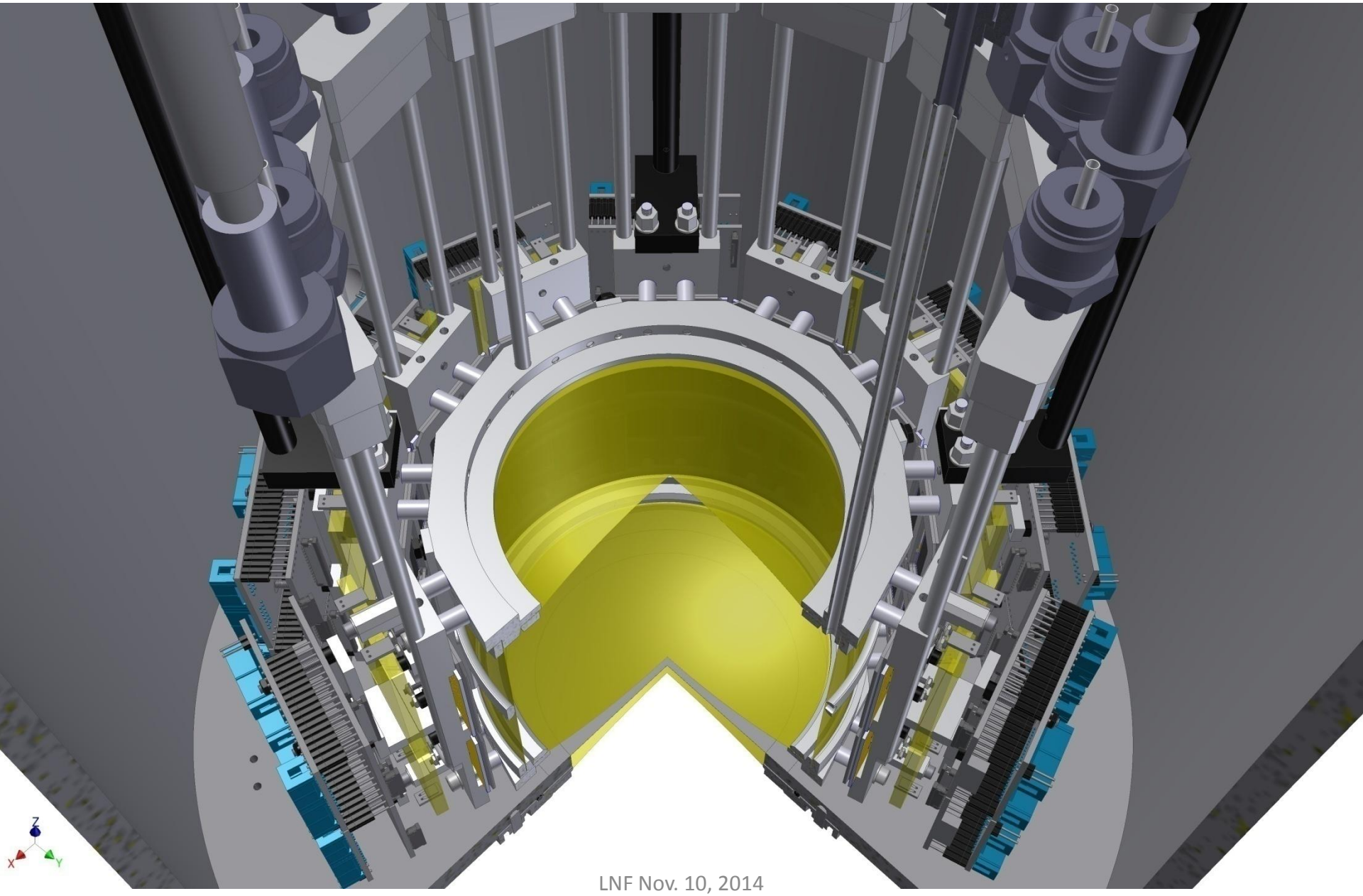
well established system!

2. Detector



two orders of magnitude improved resolution compared with the conventional semiconductor detector

SIDDHARTA-2 for kaonic helium 1s

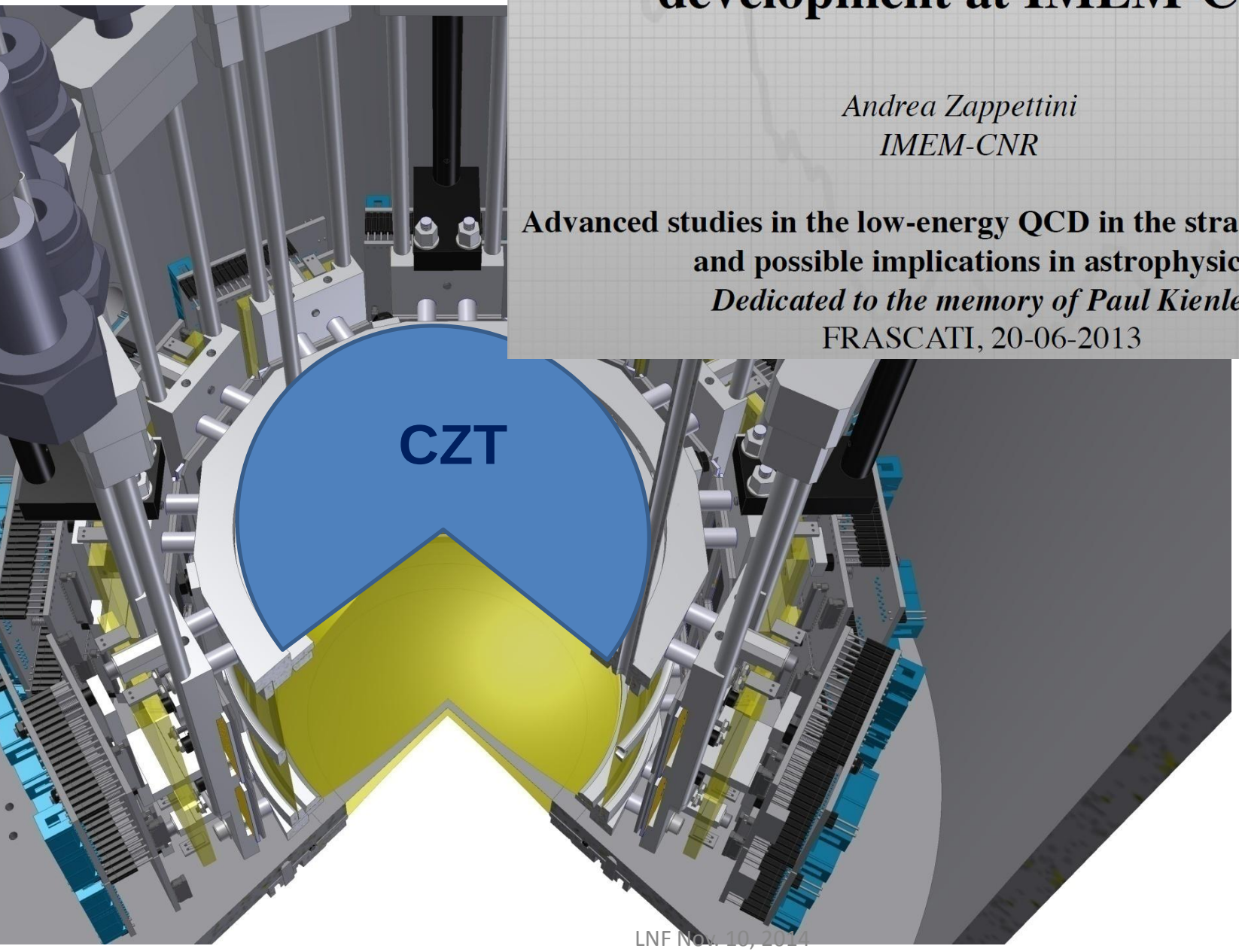


K^-d setup +

CZT-based detector development at IMEM-CNR

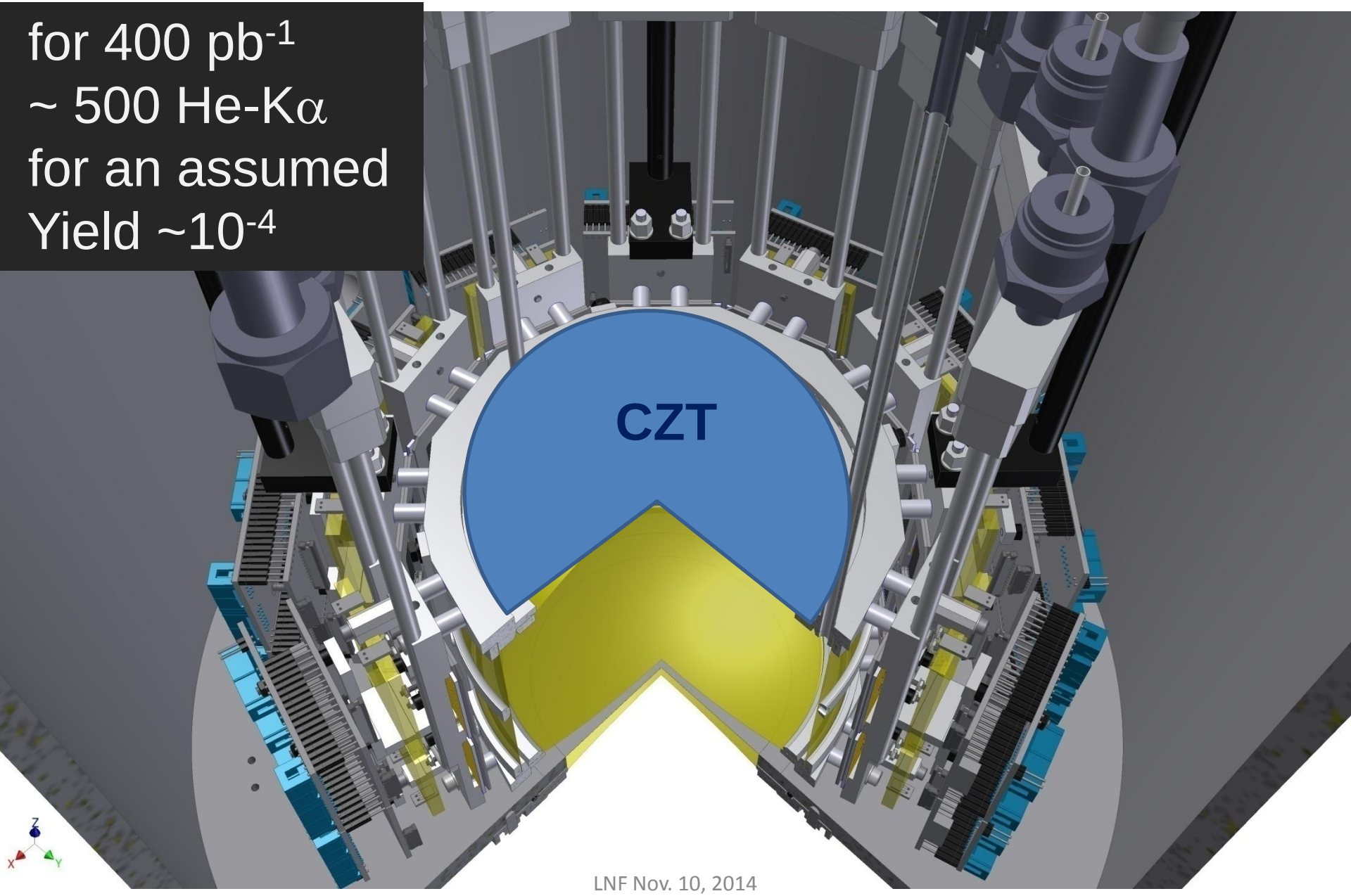
Andrea Zappettini
IMEM-CNR

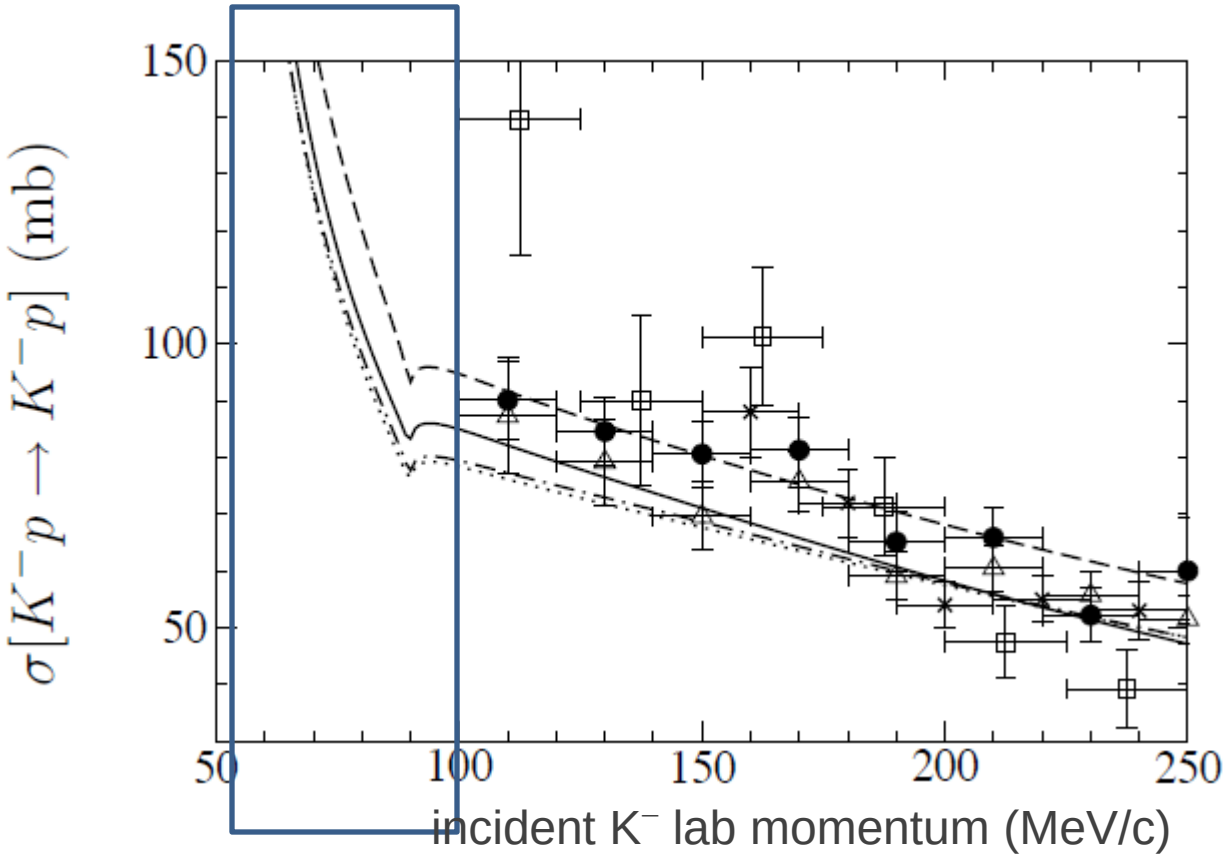
Advanced studies in the low-energy QCD in the strangeness sector and possible implications in astrophysics.
Dedicated to the memory of Paul Kienle
FRASCATI, 20-06-2013



K^-d setup +

for 400 pb^{-1}
~ 500 He-Kα
for an assumed
Yield ~10^{-4}

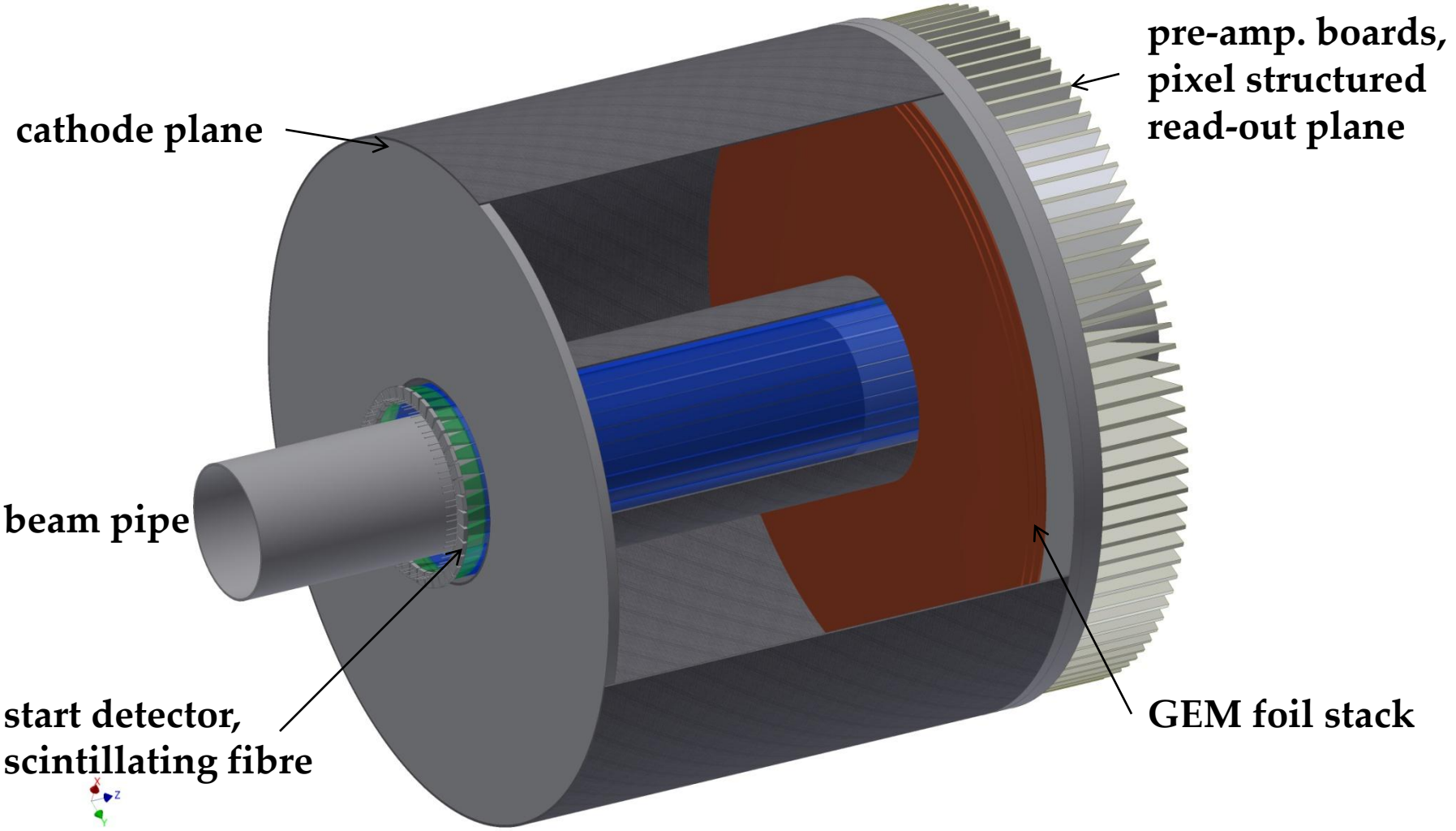




Kaon scattering

R&D – advanced setup

- **active target TPC with GEM technology, with 6000 pads**
  - R&D work within EU-FP7 HadronPhysics3

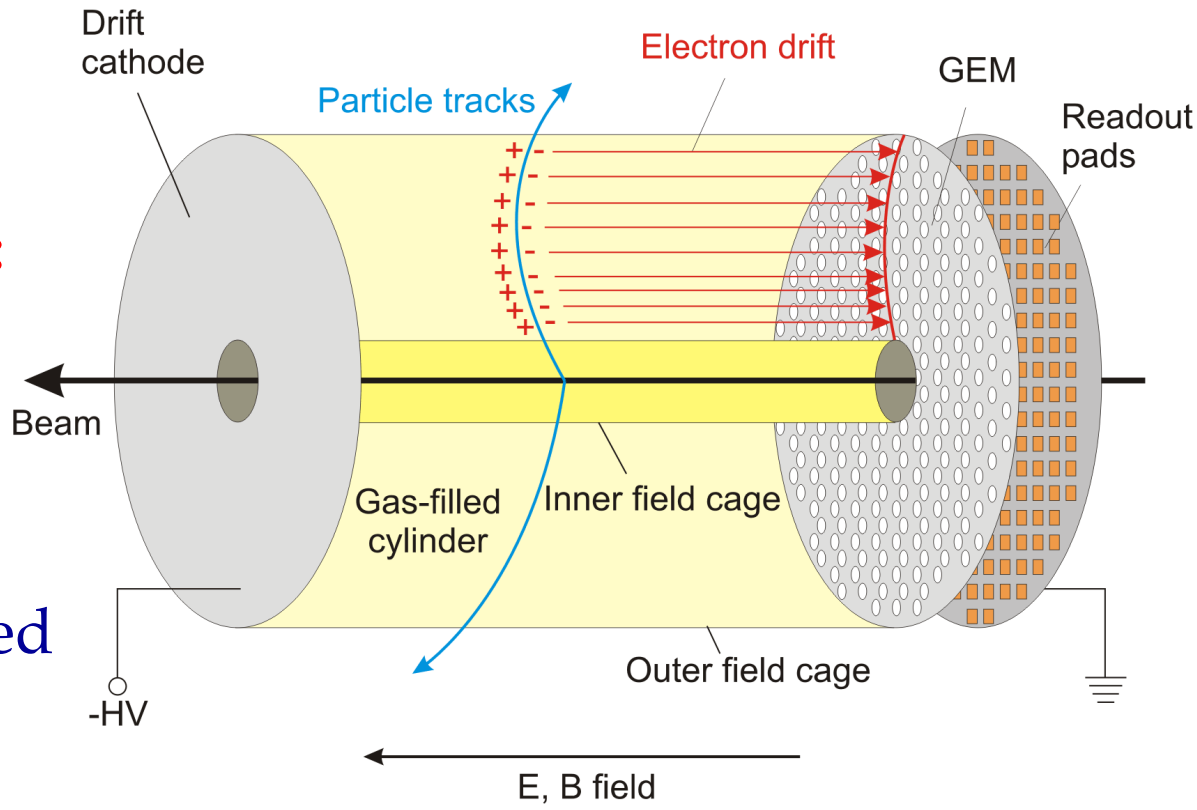


TPC with GEM Readout

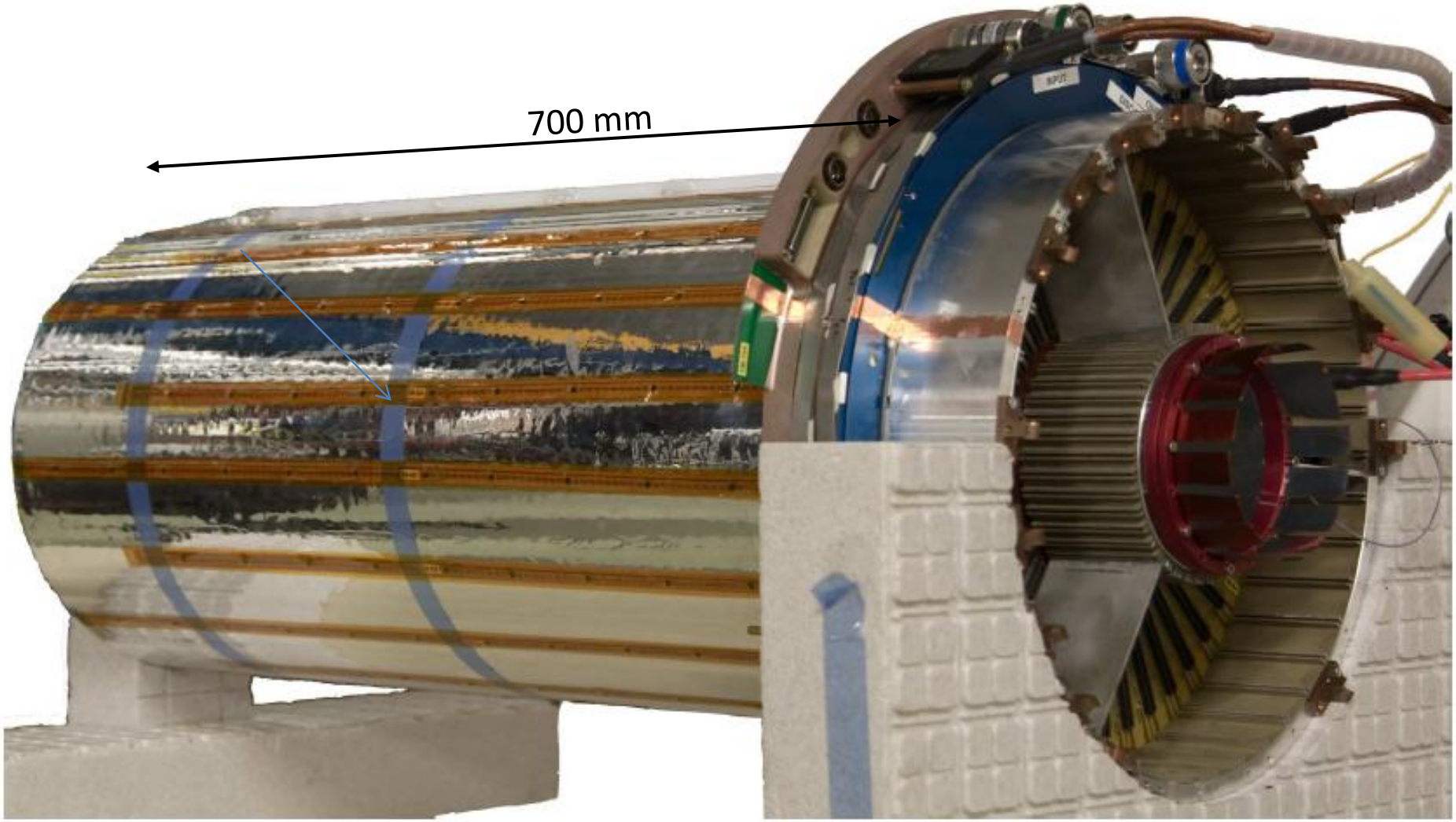
- EU-FP7 HadronPhysics2 WP24: JointGEM
  → **large TPC prototype**
- EU-FP7 HadronPhysics3 WP24: JointGEM
  → **active TPC**

TPC with GEM readout:

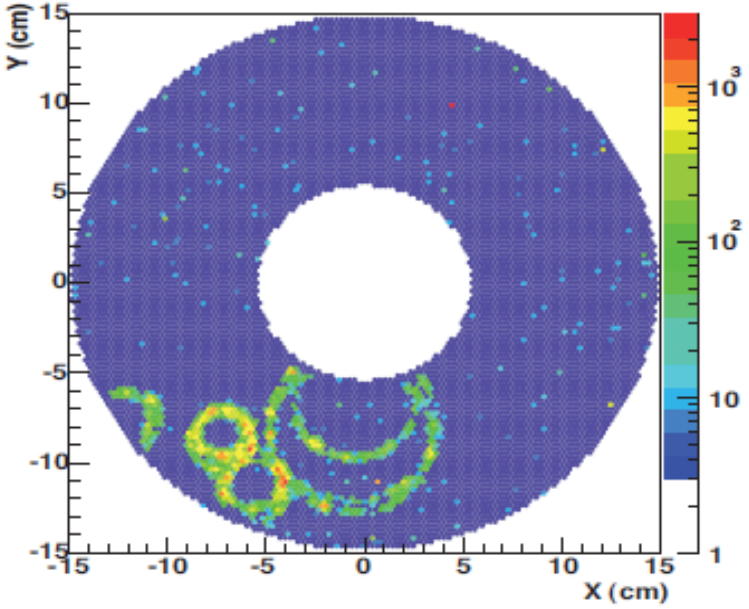
- High granularity
- Fast signal
- Multi-track resolution
- Ion feedback suppressed

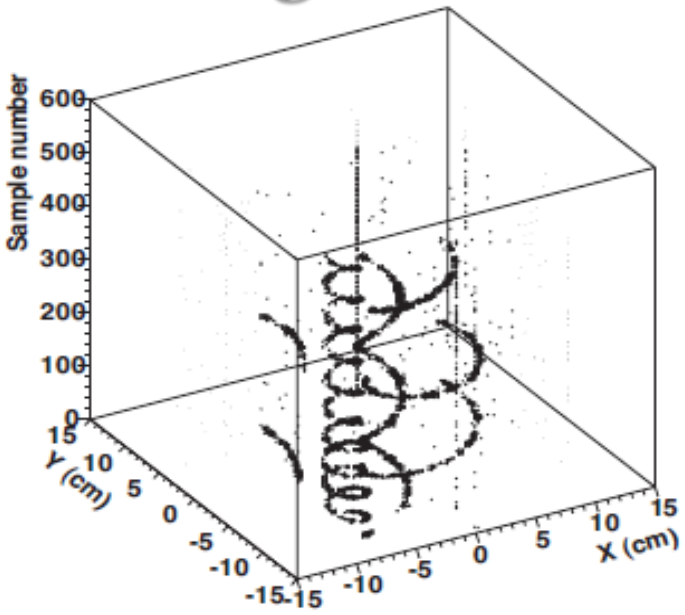


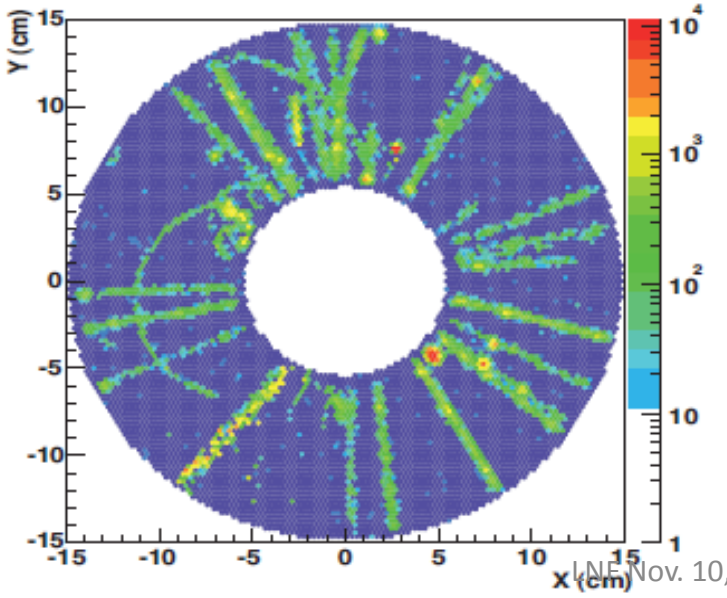
TPC prototype for PANDA

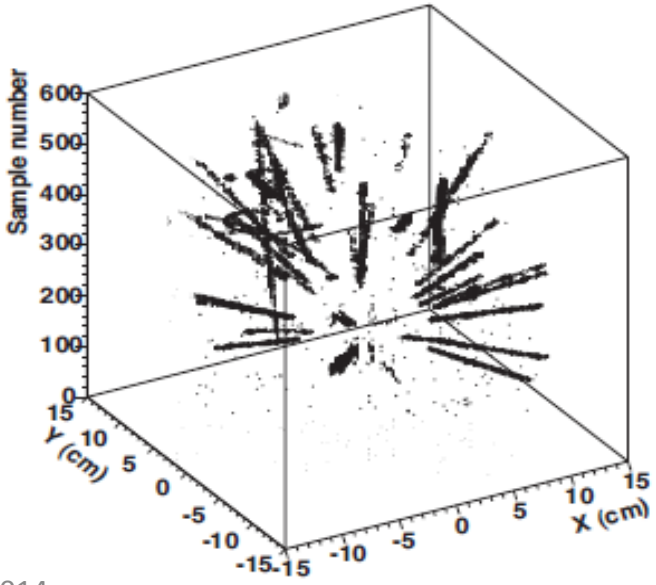


^{22}Ne beam on Al target

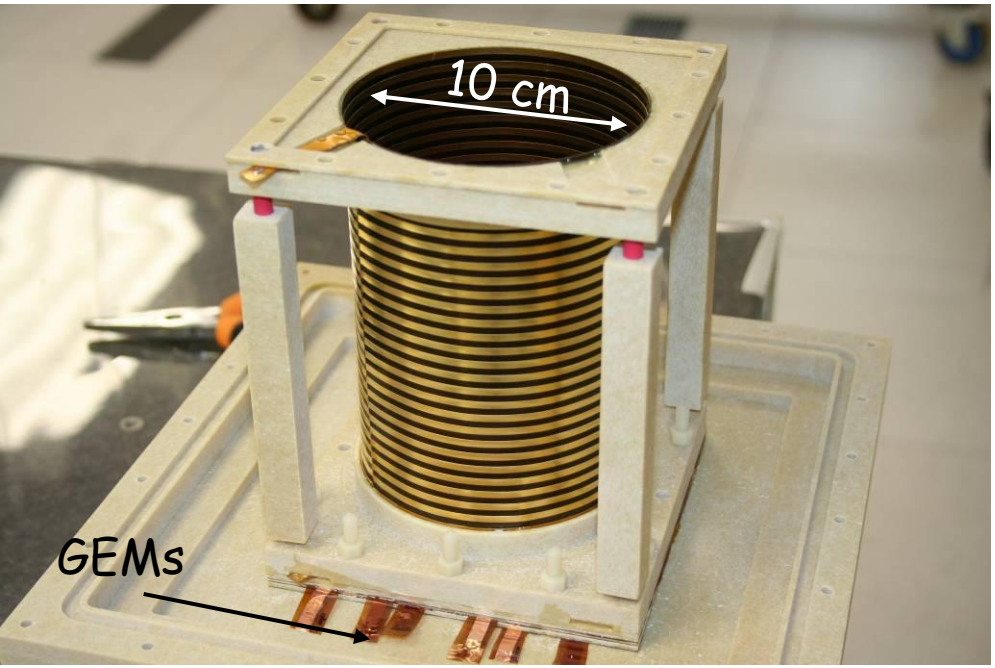


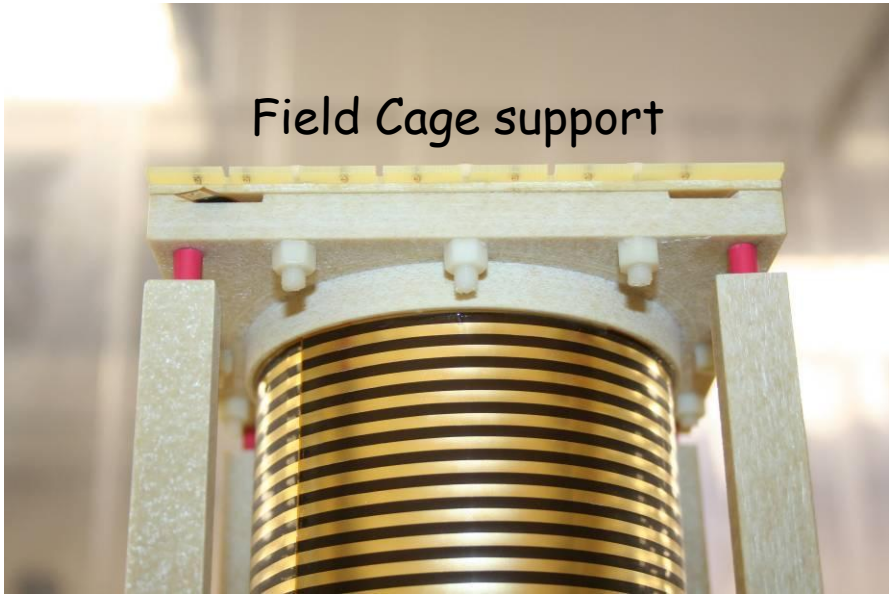


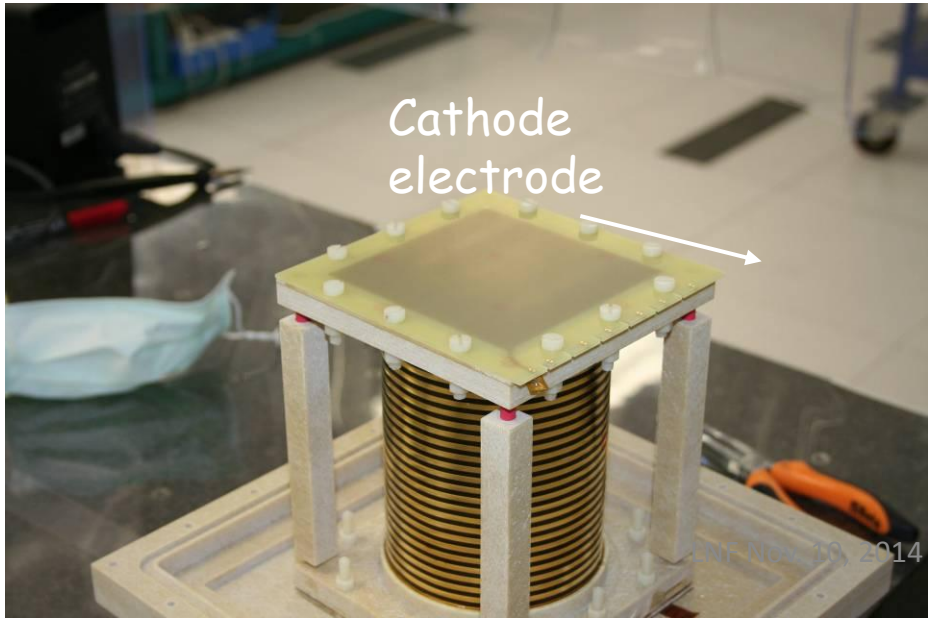




“active” TPC-GEM test setup at LNF







Tests at PSI

Low-energy kaon nucleon interaction studies

First studies of the KLOE data have shown the excellent capability of the KLOE detector to perform AMADEUS like physics

Experimental programme of AMADEUS

Studies of the low-energy charged kaons interactions with nuclear matter with ***gaseous targets (p, d, ^{3}He, ^{4}He)*** in order to obtain unique quality information about:

- $\Lambda(1405)$
- Low-energy charged kaon cross sections for momentum lower than 100 MeV/c (missing today)
- Interaction of K^- with one and two nucleons
- Kaon nuclear clusters

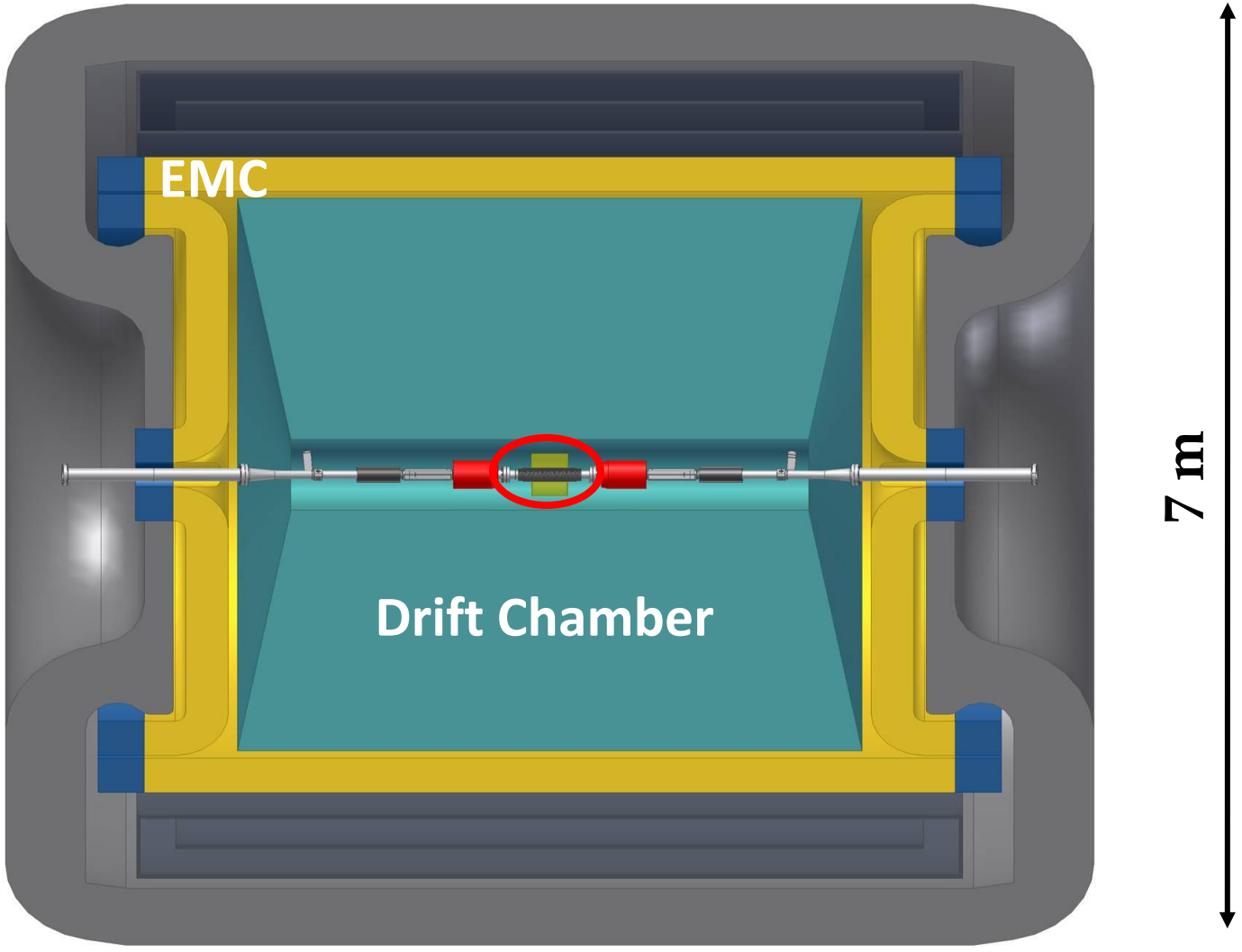
Kaon nucleon interactions

"pre" AMADEUS status

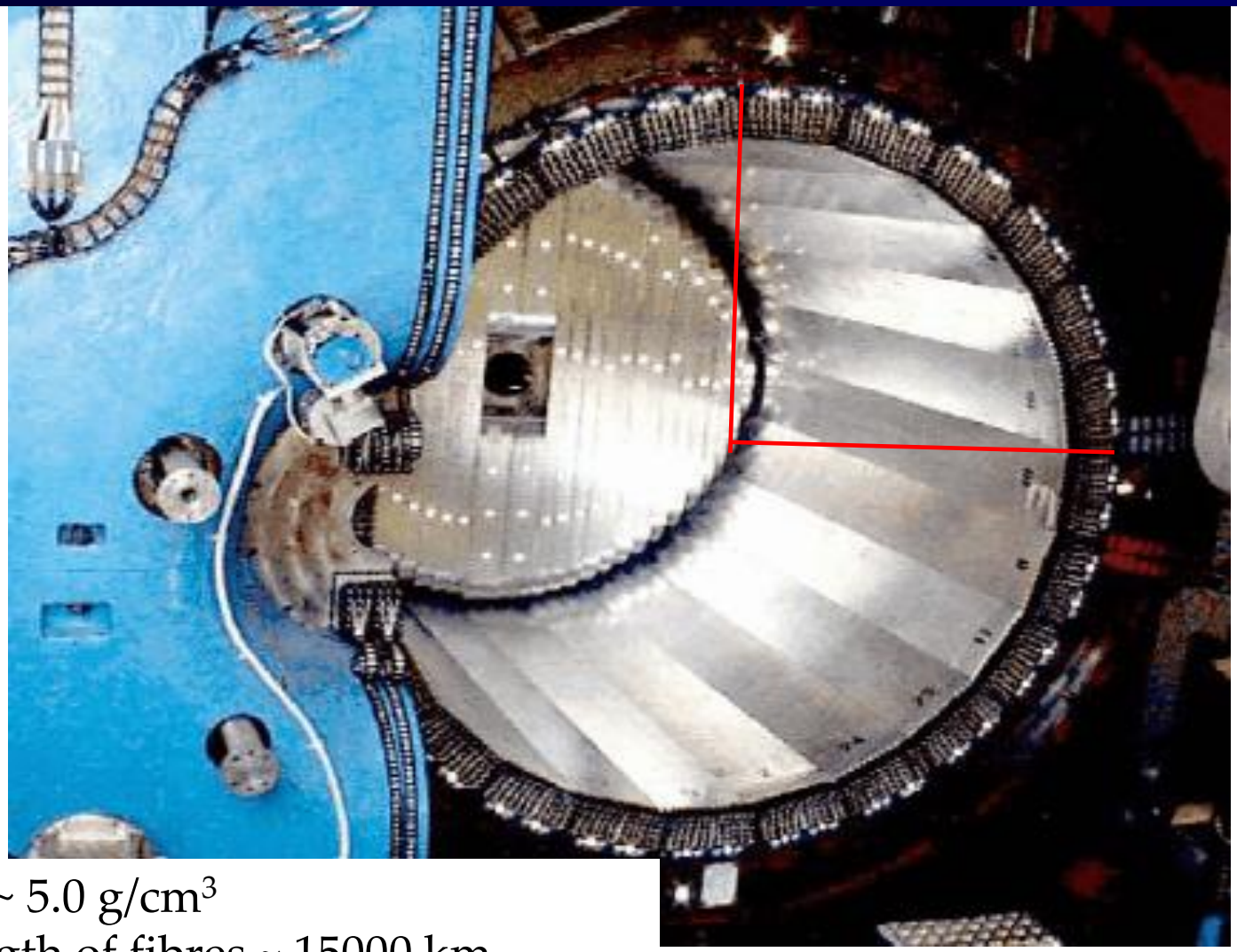
- Analyses of the 2002 – 2005 KLOE data
- Analyses of the dedicated 2012 data with pure carbon target
  - Λp from 1NA or 2NA
  - Λd and Λt channels
  - $\Lambda(1405) \rightarrow \Sigma^0\pi^0$
  - $\Lambda(1405) \rightarrow \Sigma^+\pi^-$ $(\Sigma^-\pi^+)$
  - $\Sigma N \rightarrow \Lambda N$

Pure carbon target inserted end of August 2012

AMADEUS @ KLOE

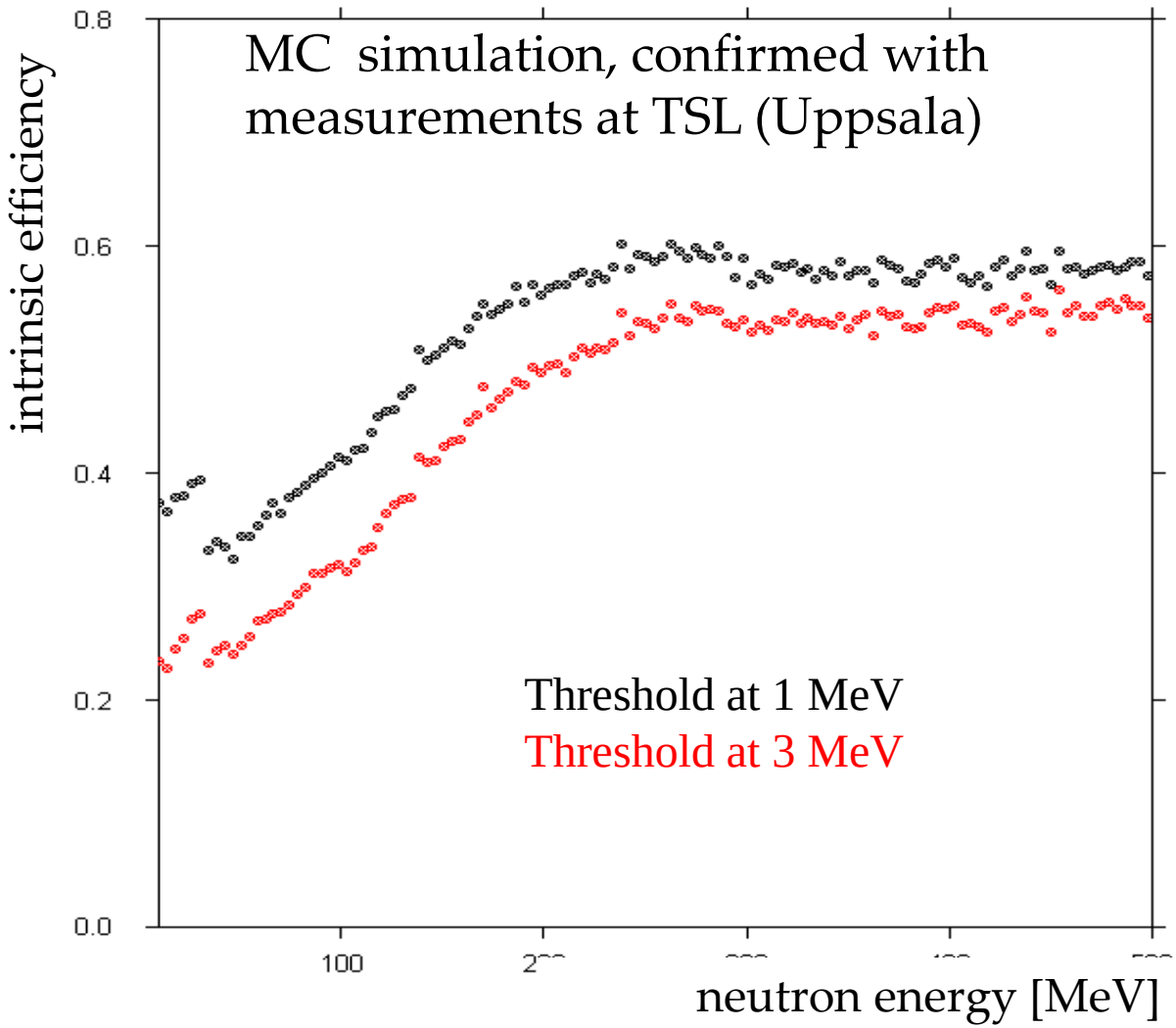


KLOE electromagnetic calorimeter

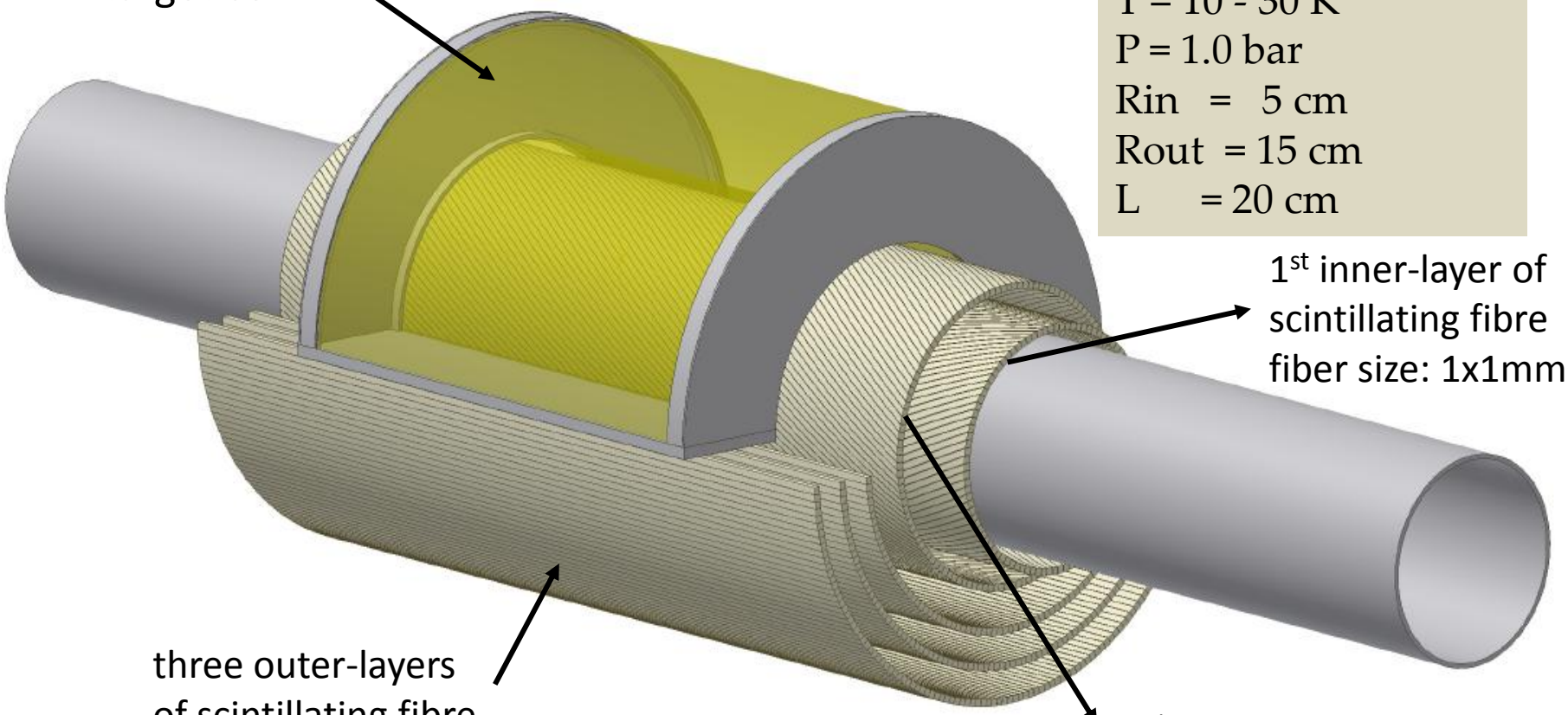


density ~ 5.0 g/cm^3
total length of fibres ~ 15000 km
read out by ~ 5000 mesh PM

Neutron detection efficiency



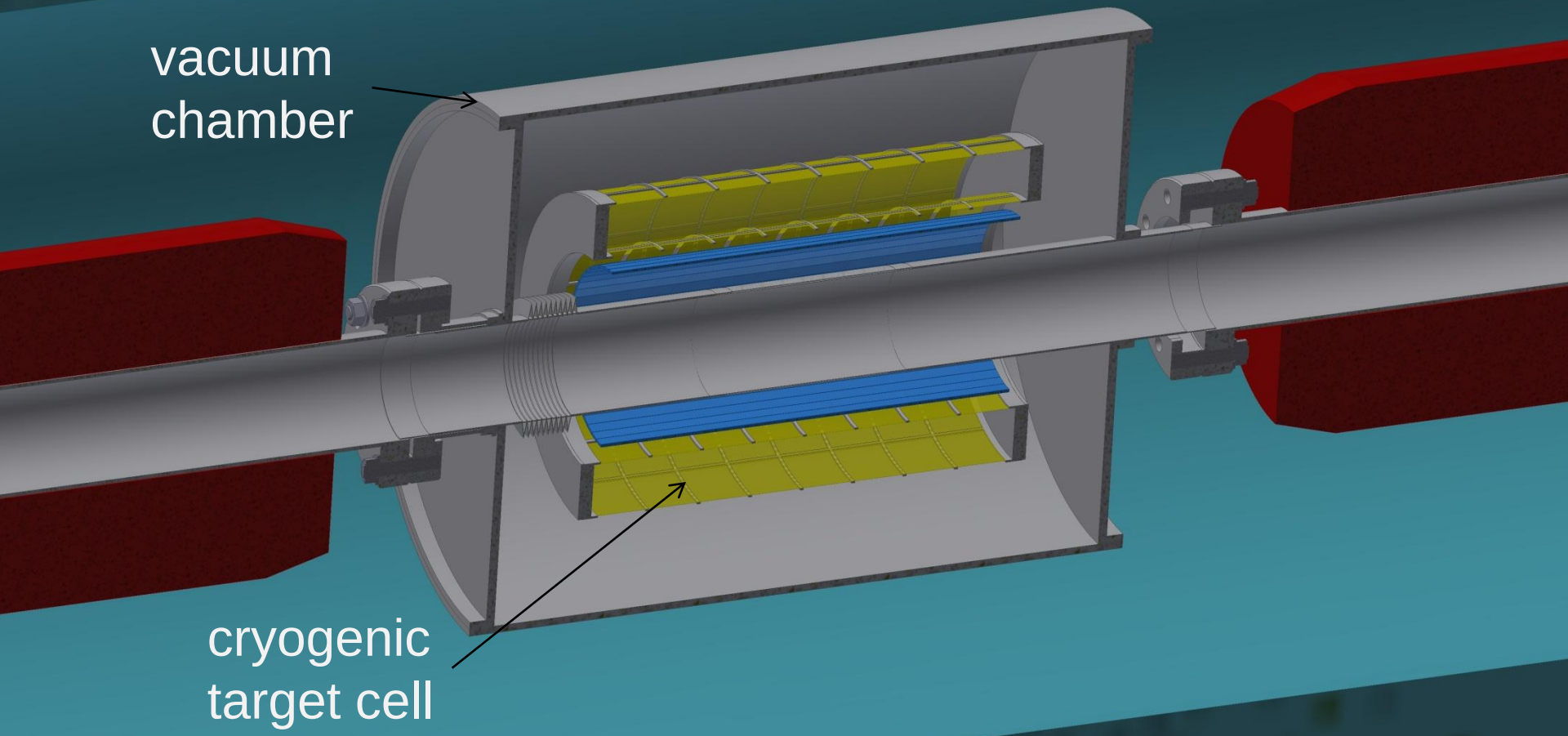
AMADEUS - cryogenic target



Gaseous/liquid target cell:
T = 10 - 30 K
P = 1.0 bar
Rin = 5 cm
Rout = 15 cm
L = 20 cm

AMADEUS - cryogenic target

Gaseous/liquid targets: H2 - D2 - 3He - 4He



KLOE - CDC

CONCLUSIONS

DAΦNE e^+e^- collider → worldwide unique machine

- monochromatic kaons 127 MeV/c;
- L^{int} = 150 pb^{-1}/month
  - – ideal suited for
    - kaonic atom studies
    - low-energy kaon scattering
    - low-energy kaon-nucleon interaction

Kaonic atoms / nuclei

- setup for K^-d ready,
- upgrade with new SDDs under development
- TES detector successfully tested at PSI (S. Okada)
- CZT prototype tests at LNF and SMI
- cryogenic target system – ready to be built
- R&D work on active TPC within EU-HP3

➢ **strong international collaboration**