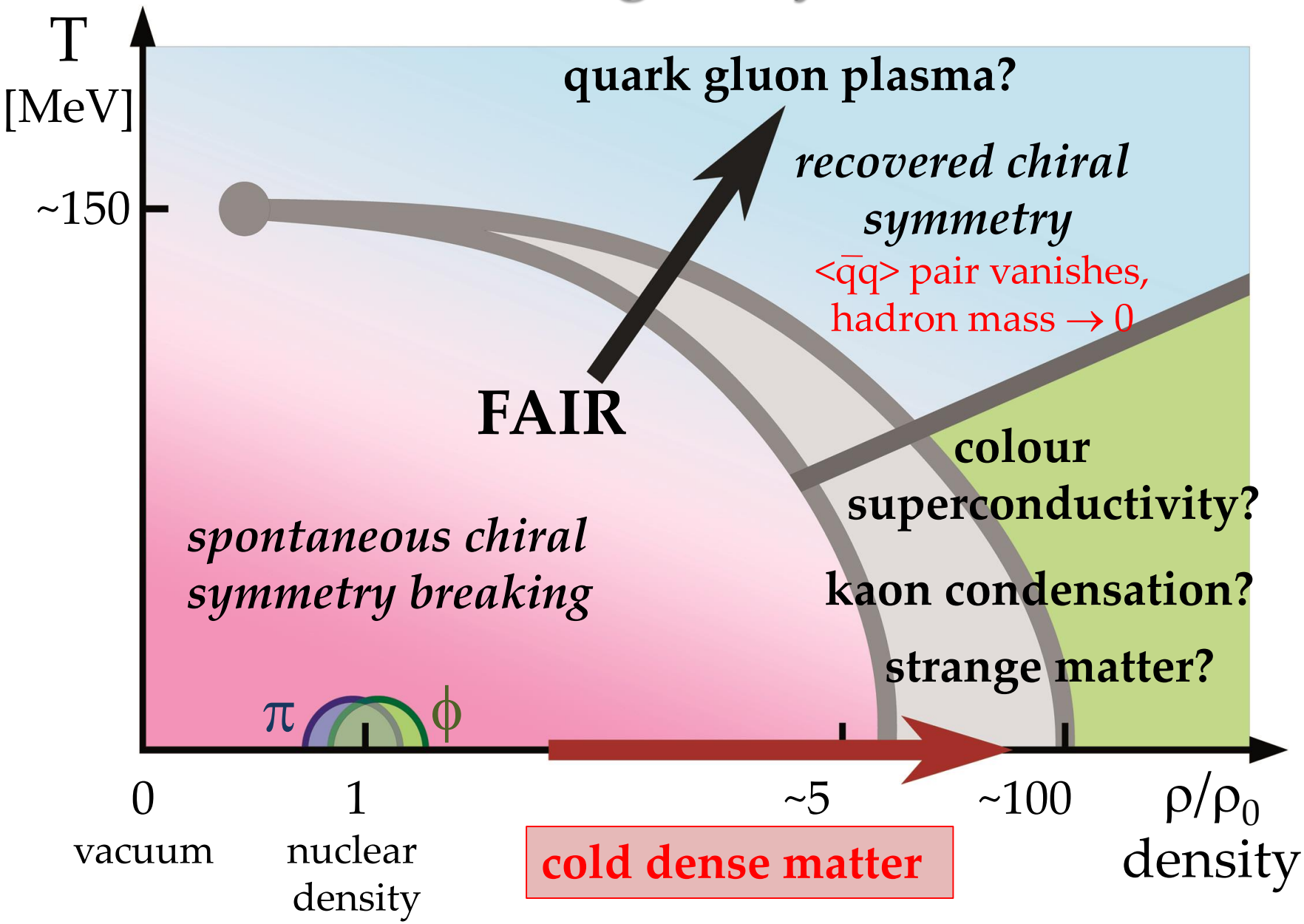
Strangeness production using stopped antiprotons

Johann Zmeskal, SMI - Vienna

Strangeness in Nuclei and in Neutron Stars
Dipartimento di Fisica, Universita di Pisa, May 20 – 21, 2015

Search for strange baryonic matter



Methods to produce (dense) baryonic matter with strangeness

- stopped K^- reactions
- in-flight K^- reactions
- protons on proton (or light nuclei)
- heavy ion collisions
- strangeness production in antiproton annihilation

Why strangeness?

Spontaneous and explicit chiral symmetry breaking in low-energy QCD

- $\bar{K}N$ interaction
- In-medium hadrons e.g., mass, magnetic moment, …?
- $\bar{K}NN$?

Baryon-baryon interaction

- 3-body force ΛNN
- the origin/nature of repulsive core

Strangeness physics

- DAΦNE @ LNF
  SIDDHARTA, AMADEUS, **FINUDA**, KLOE

- GSI – Helmholtzzentrum
  FOPI, HADES

- J-PARC
  E15, E17, E27

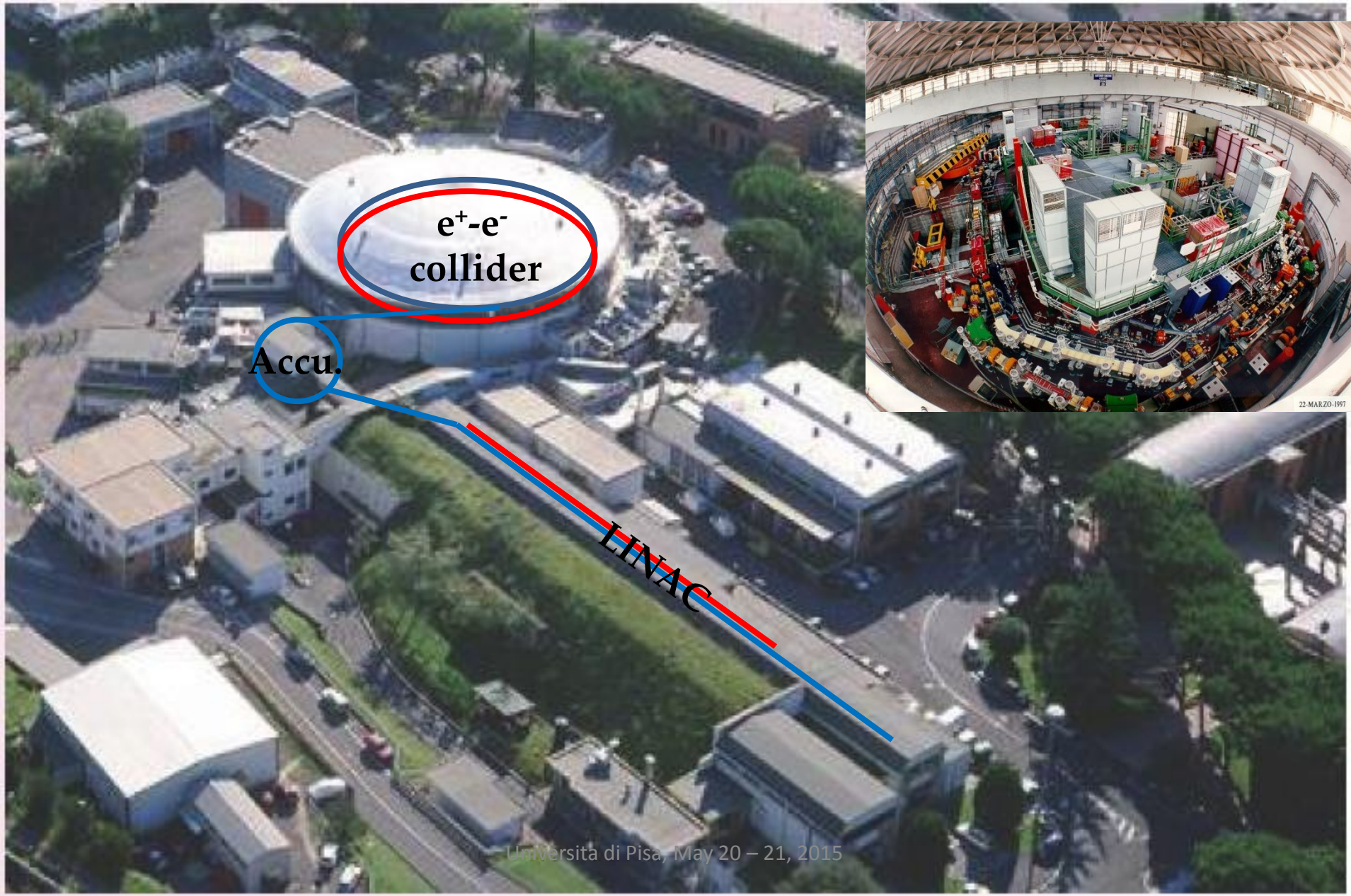
- JLab
  CLAS

- LEPS/SPring-8

- FAIR
  PANDA, FLAIR → SMILE@CRYRING

Kaon nucleon interaction AMADEUS at DAΦNE

Kaons at DAΦNE



DAΦNE principle

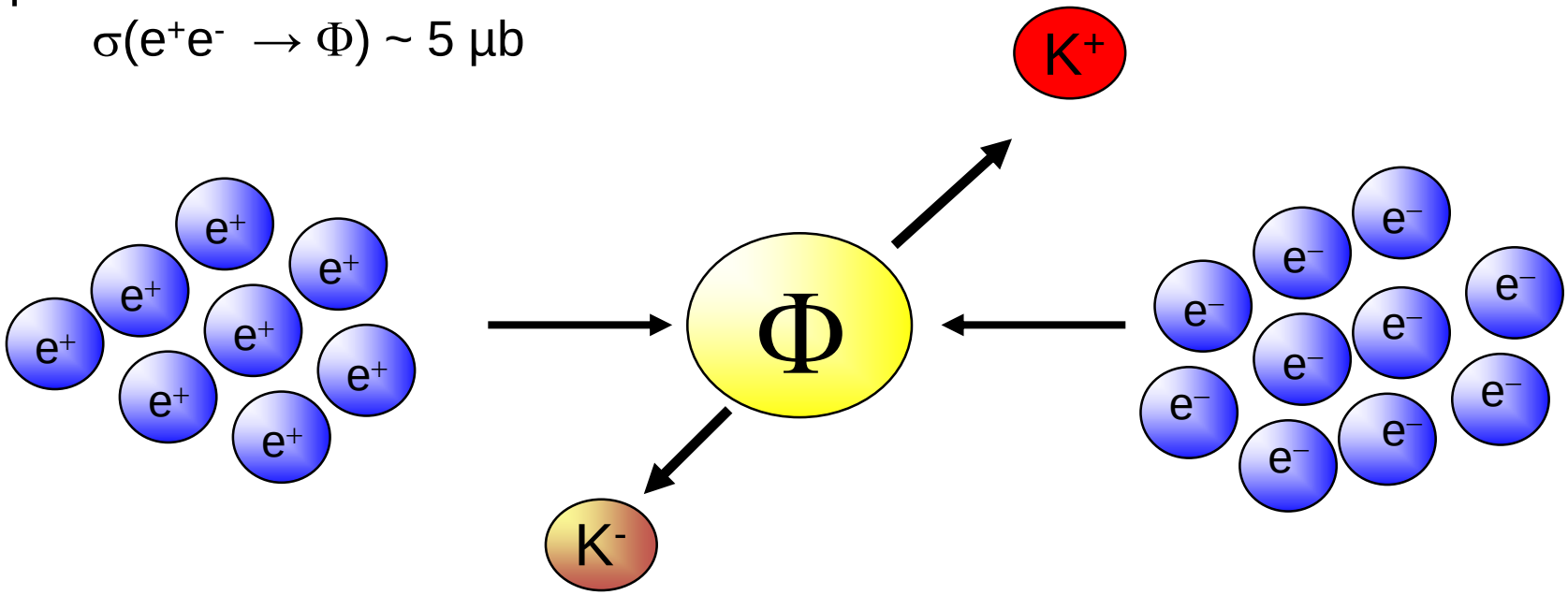
- operates at the centre-of-mass energy of the Φ meson

  mass $m = 1019.413 \pm .008$ MeV

  width $\Gamma = 4.43 \pm .06$ MeV

- Φ produced via e^+e^- collision with

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



→ Φ production rate 2.5 x 10^3 s^{-1}

→ monochromatic kaon beam (127 MeV/c)

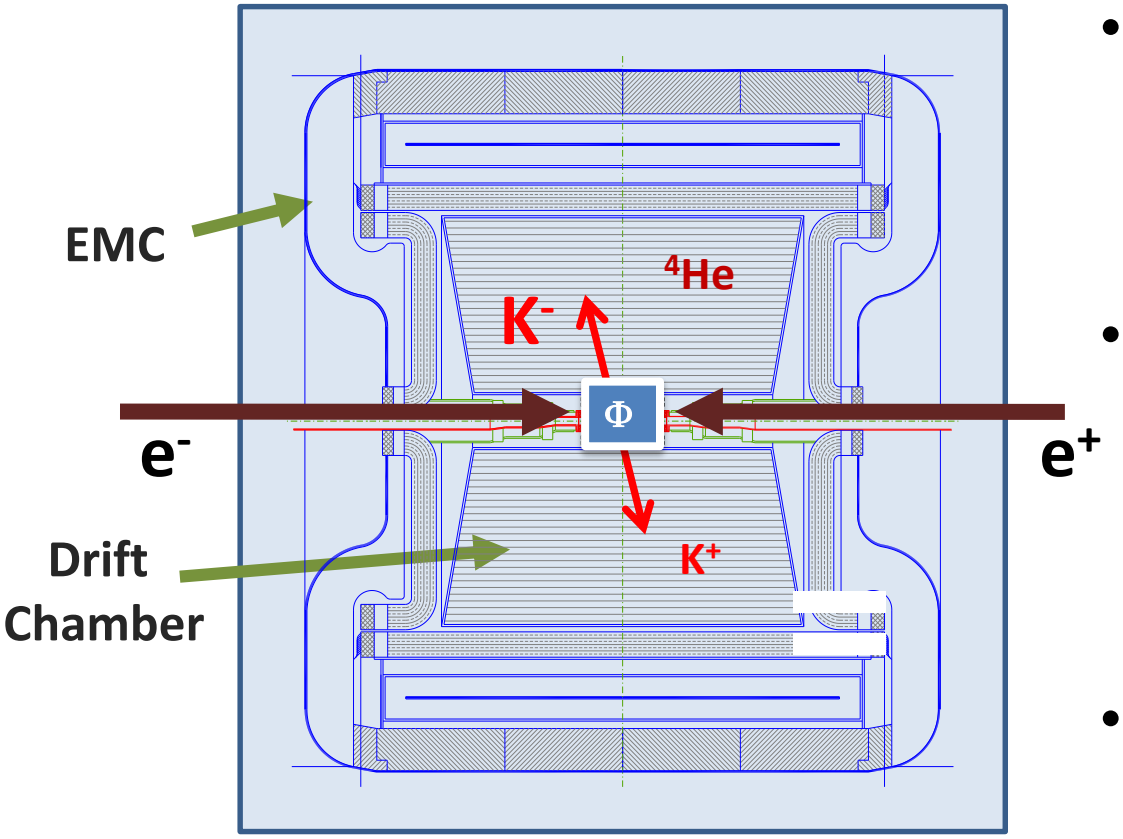
First studies of the KLOE data have shown the excellent capability of the KLOE detector to perform AMADEUS like physics

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

KLOE data analysis by the AMADEUS collaboration



- Drift chamber gas of KLOE mailny **^{4}He** (90%, 10% *isobutane*)
- analysis of KLOE data: **0.1 % of K^- stopped in DC volume**

- K^- hadronic interactions at rest

Kaon nucleon interactions

"pre" AMADEUS status

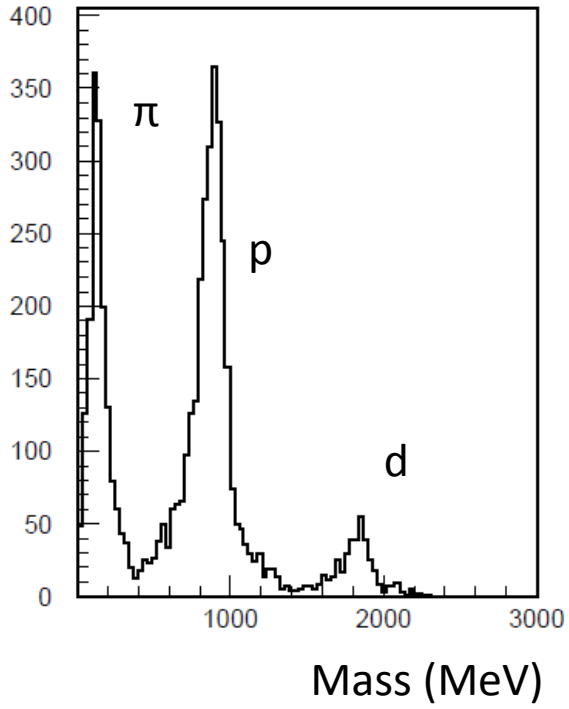
- Analyses of the 2002 – 2005 KLOE data
- Analyses of the dedicated 2012 data with pure carbon target
  - Λp from 1NA or 2NA
  - Λd and Λt channels
  - $\Lambda(1405) \rightarrow \Sigma^0\pi^0$
  - $\Lambda(1405) \rightarrow \Sigma^+\pi^-$ $(\Sigma^-\pi^+)$
  - $\Sigma N \rightarrow \Lambda N$

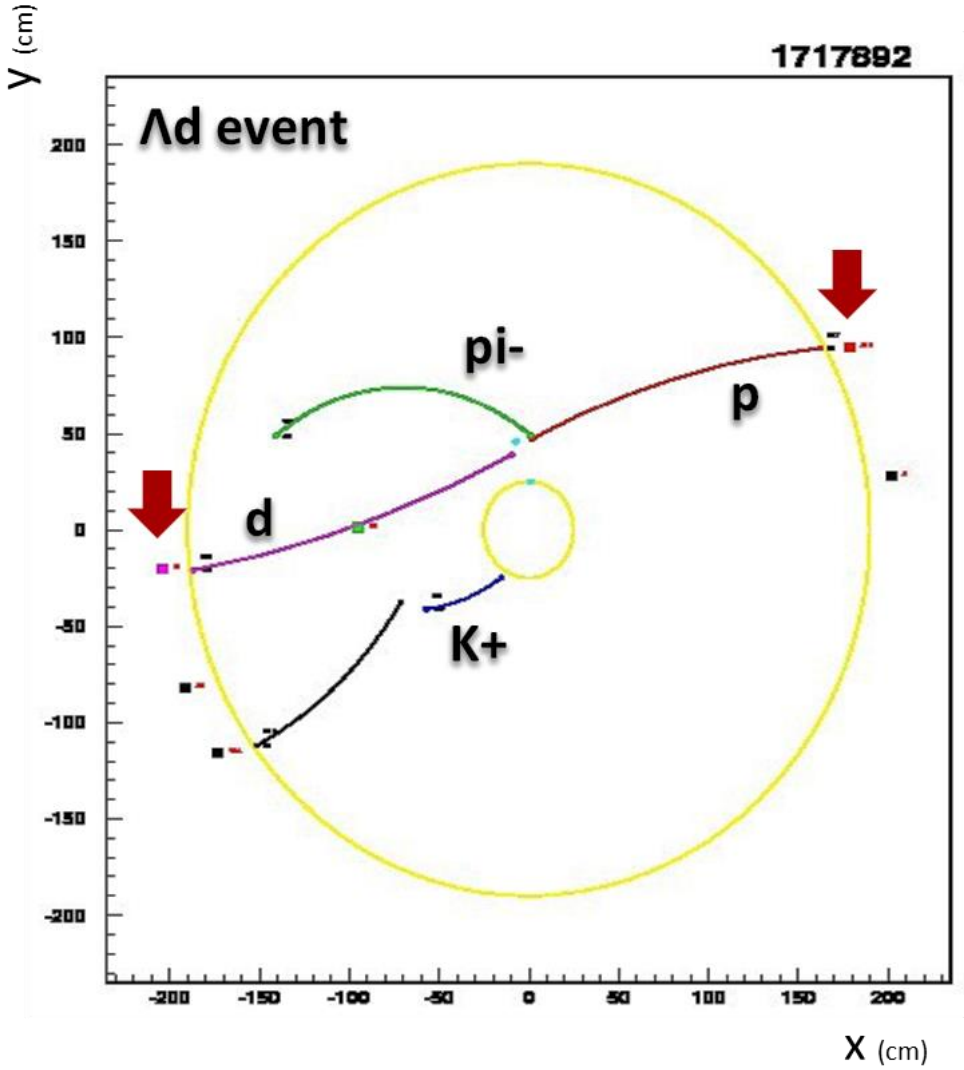
Pure carbon target inserted end of August 2012

Tools for identifying ΛN events

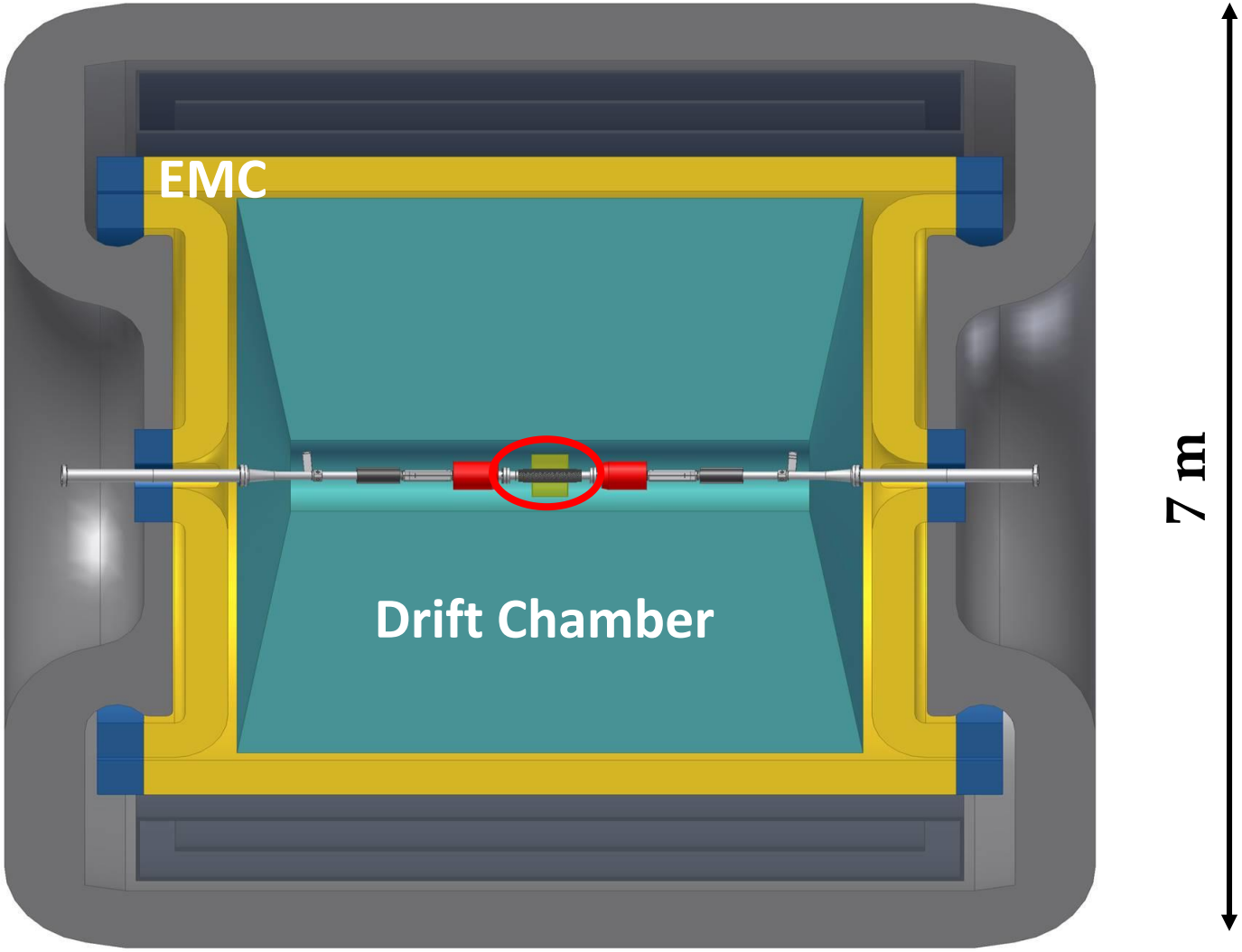
-The use of the EMC clusters associated to tracks allows to calculate particle masses

- dE/dx
- + = **Mass by TOF**
- E@EMC

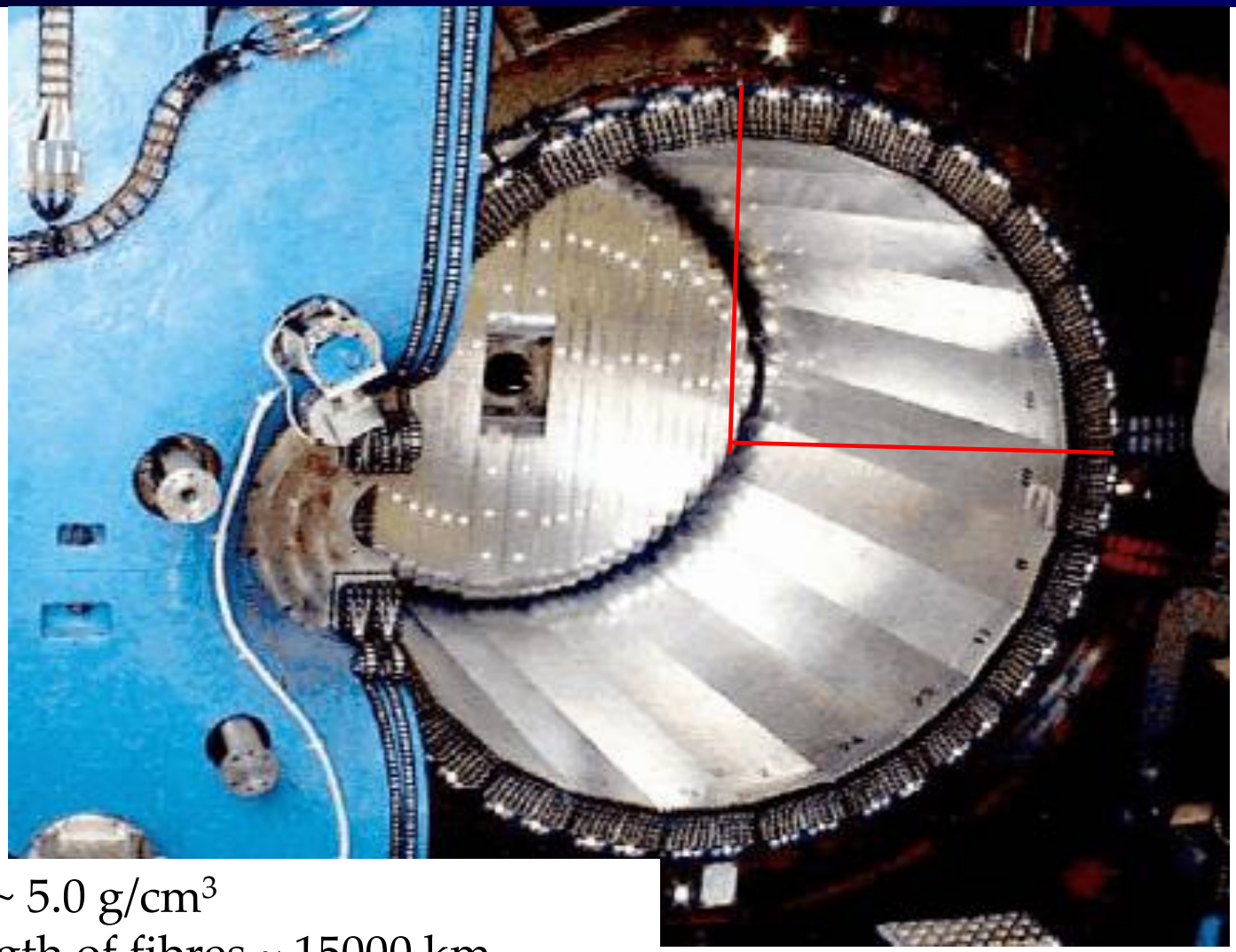




AMADEUS @ KLOE

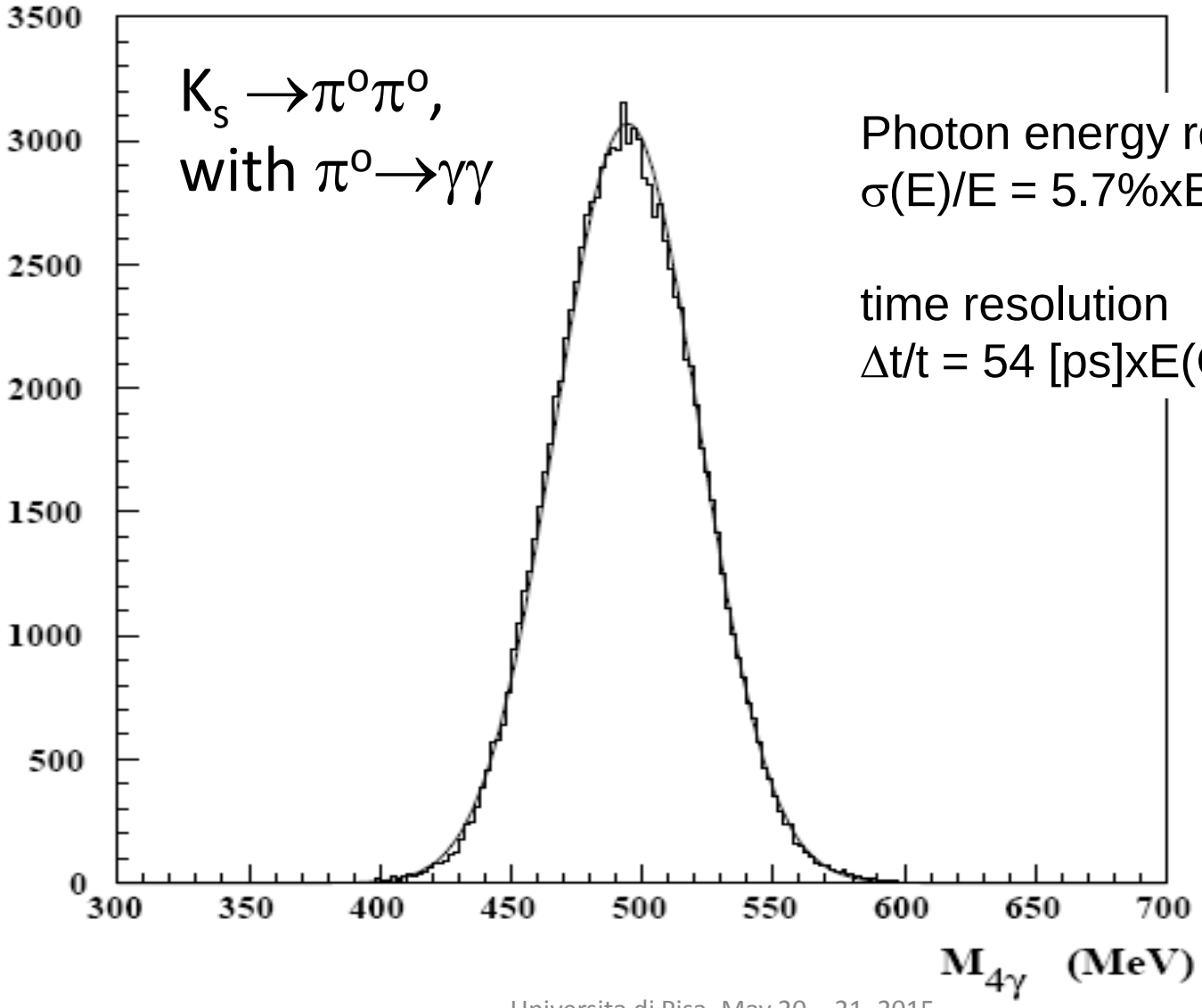


KLOE electromagnetic calorimeter



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

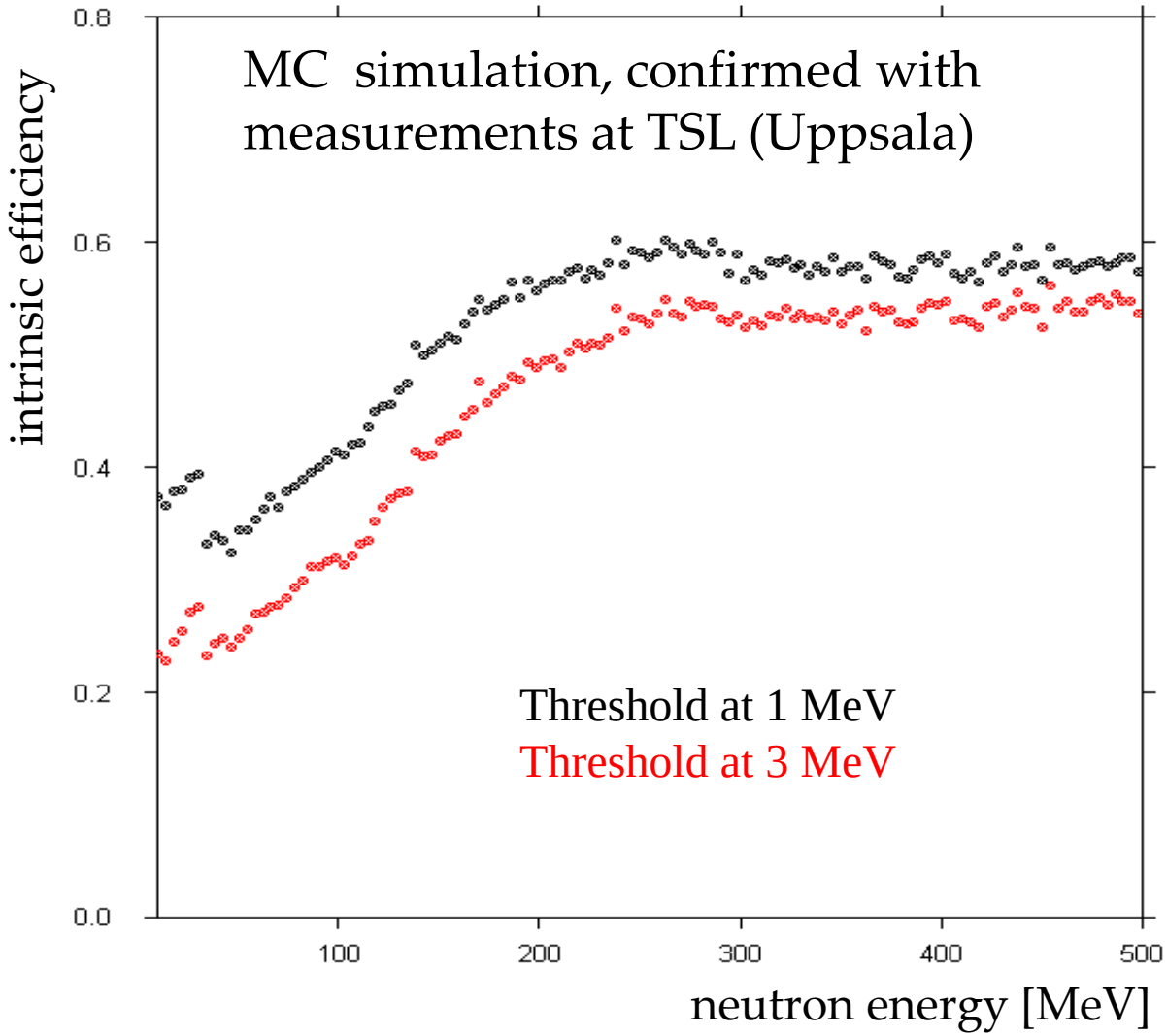
Reconstructed K_s mass



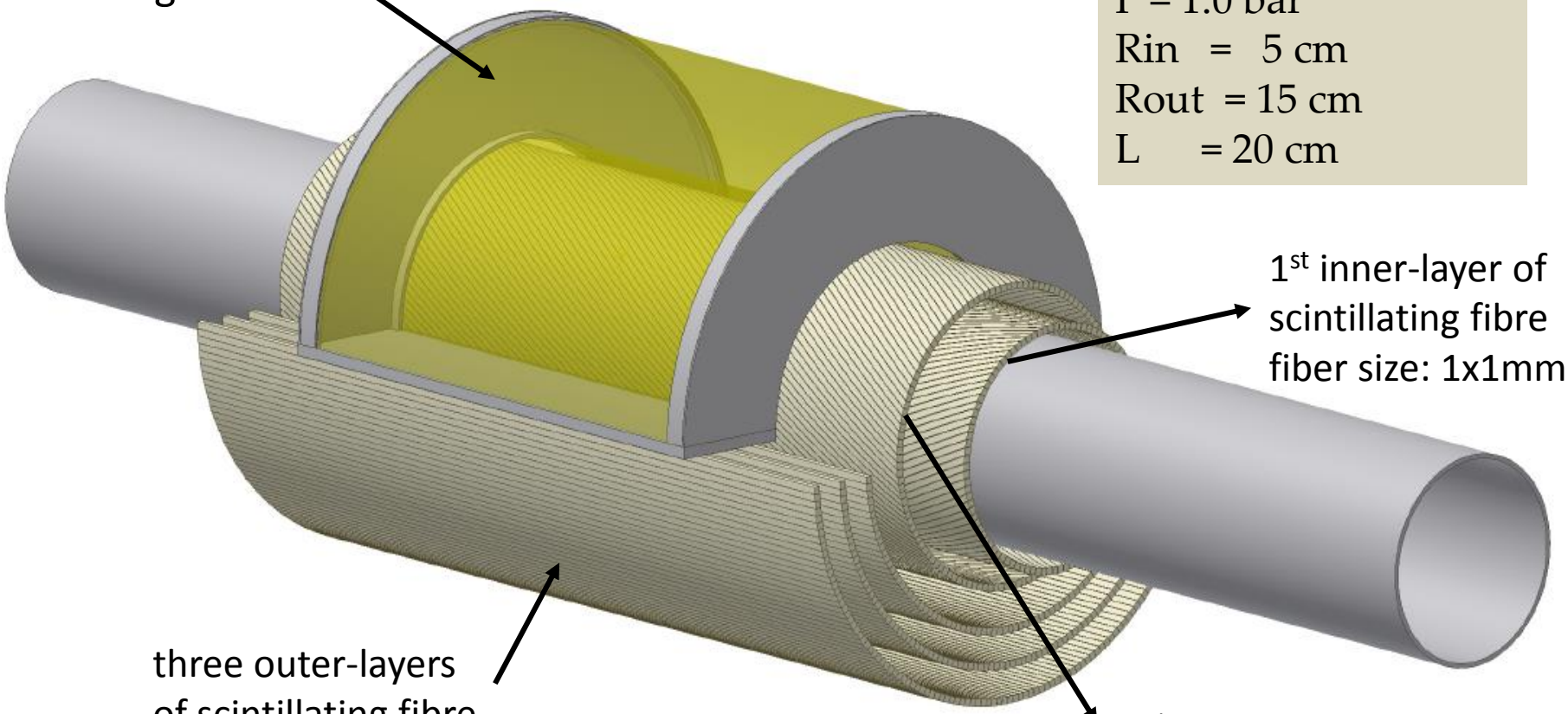
Photon energy resolution
$\sigma(E)/E = 5.7\% \times E(GeV)^{-1/2}$

time resolution
$\Delta t/t = 54\ [ps] \times E(GeV)^{-1/2}$

Neutron detection efficiency

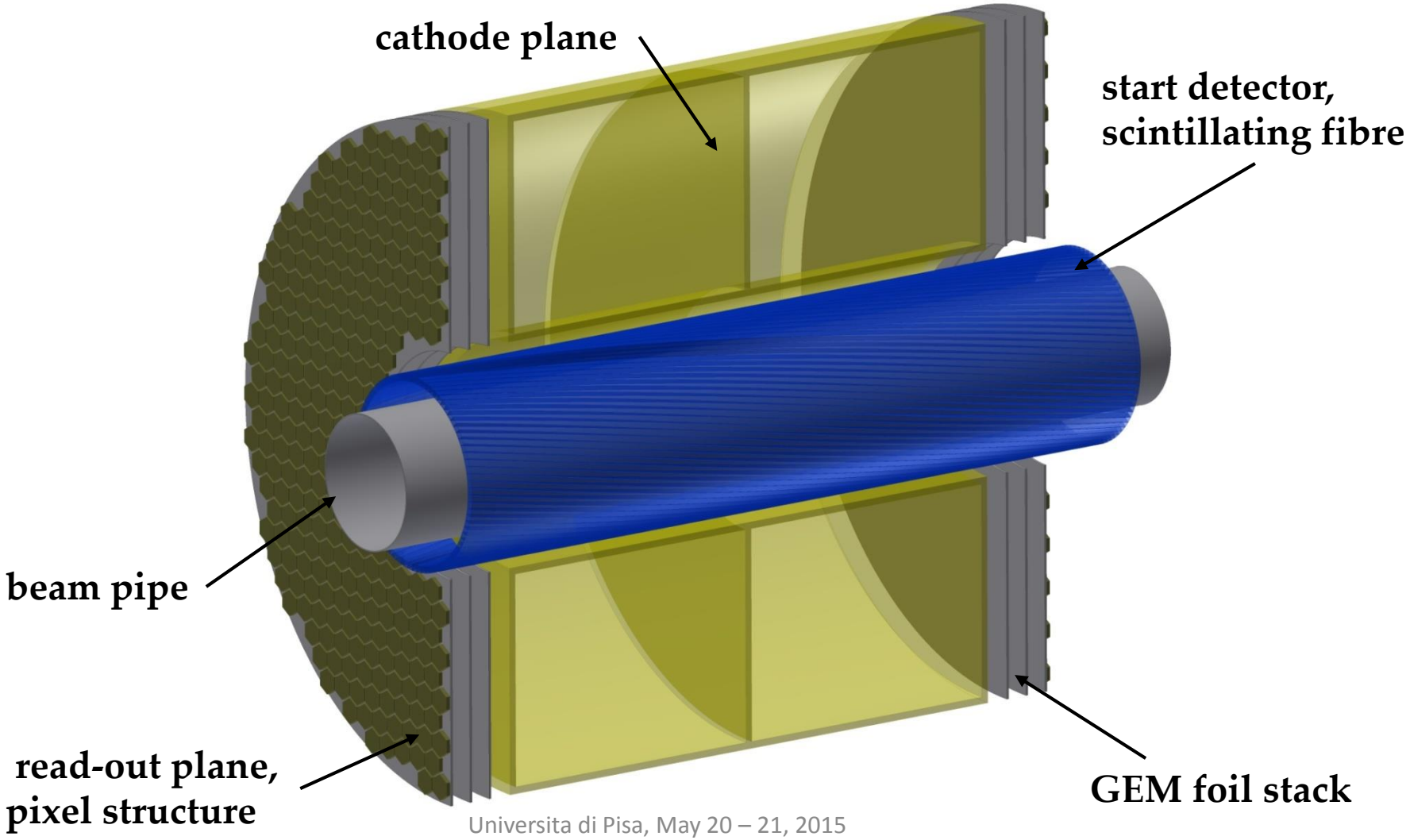


AMADEUS setup



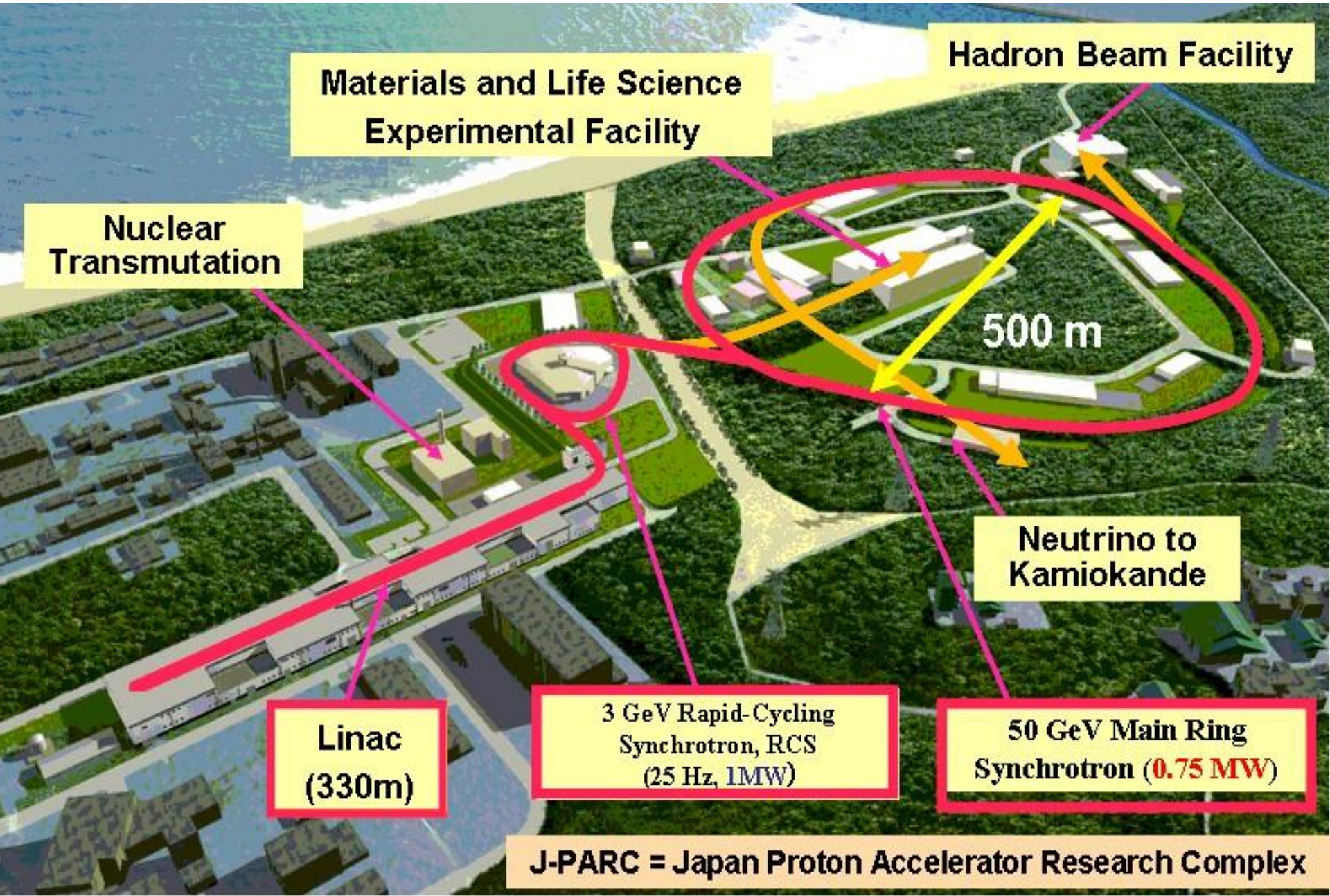
AMADEUS R&D – advanced setup

- **active target TPC with GEM technology, with 2 read-out sides**
  - R&D work within EU-FP7 HadronPhysics3

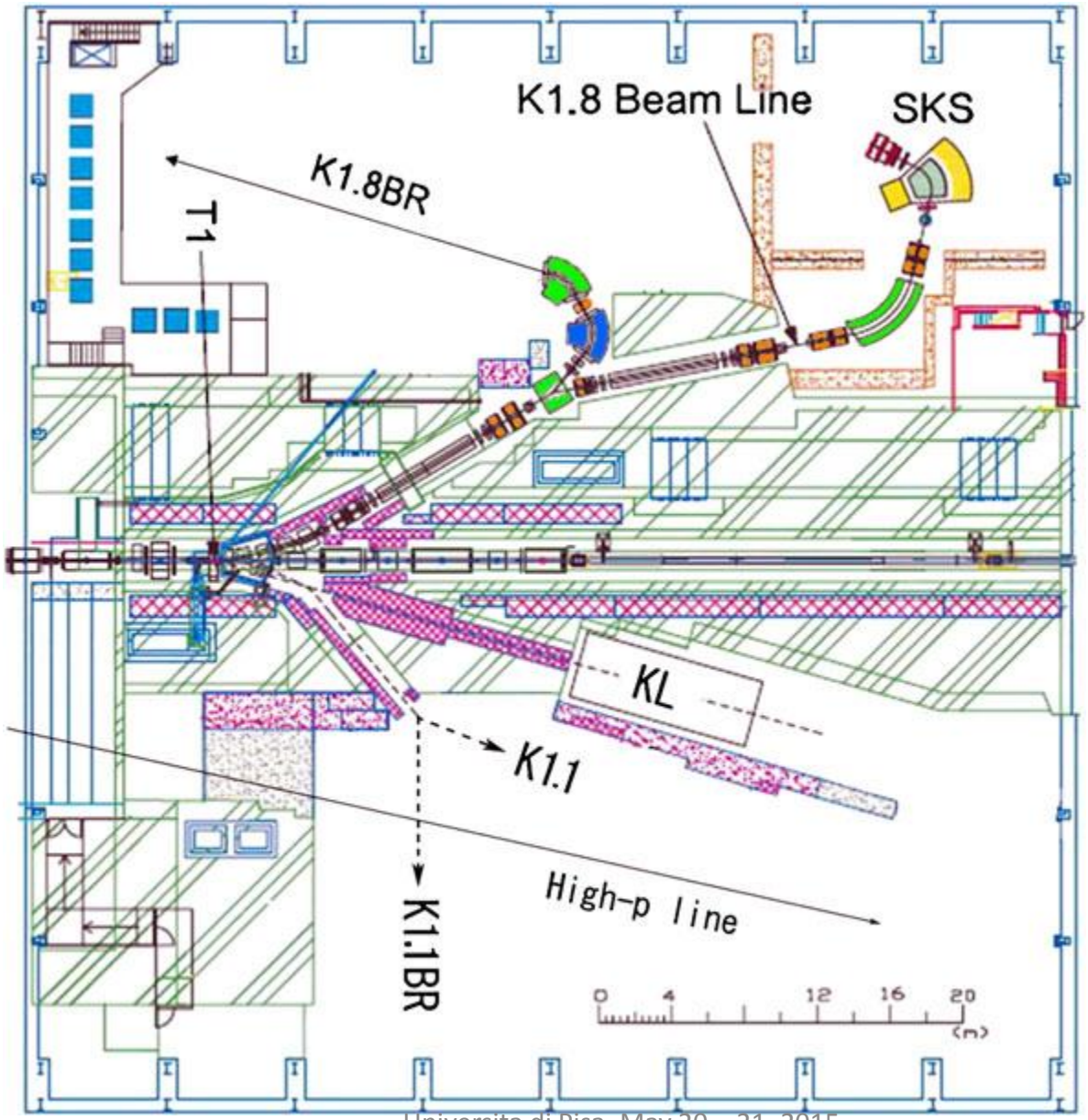


Antikaons and antiprotons at J-PARC

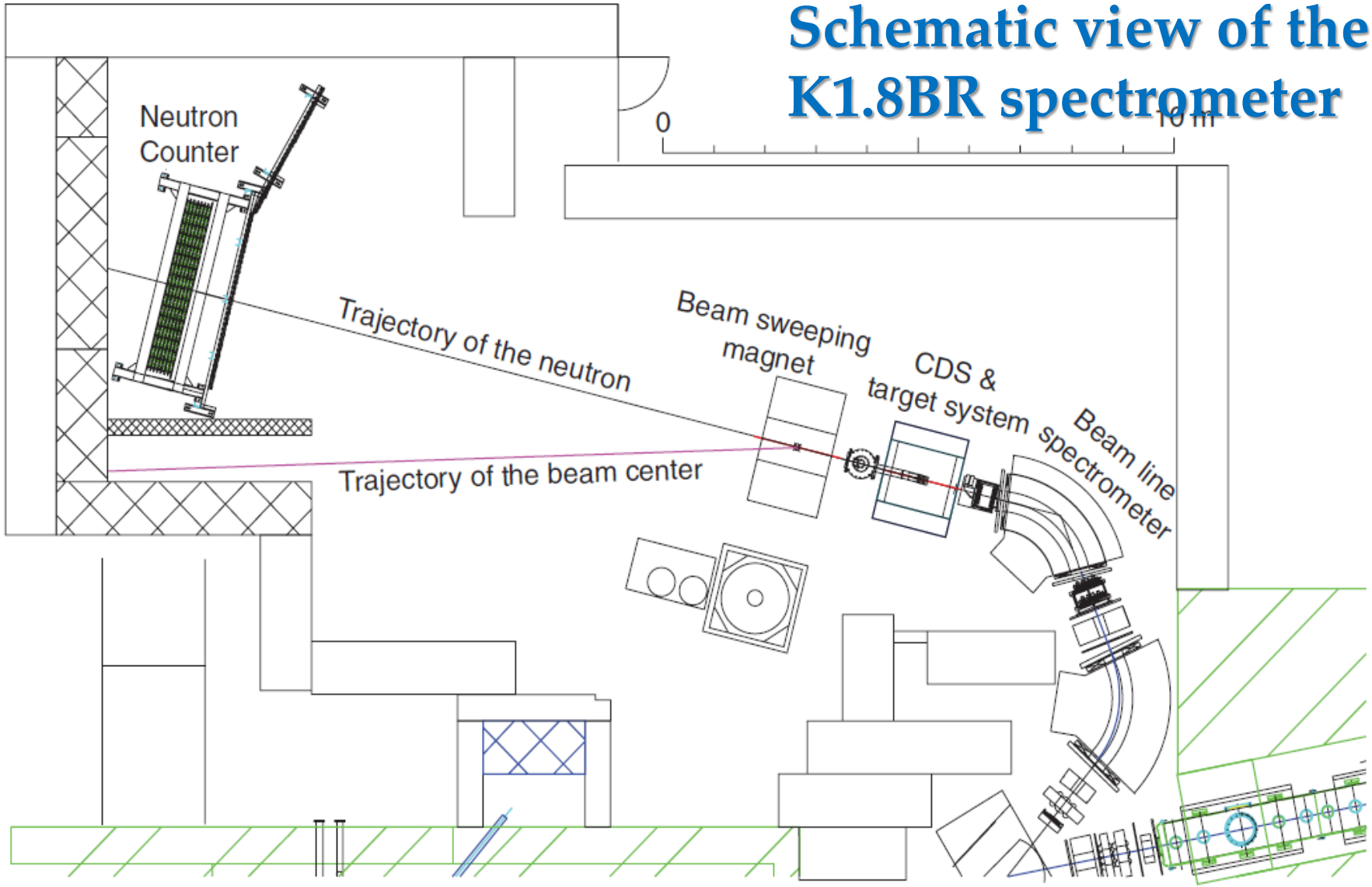
J-PARC, a facility for kaons and p^{bars}



K^-d at J-PARC, a possible alternative



Schematic view of the K1.8BR spectrometer



The spectrometer consists of a beam line spectrometer, a cylindrical detector system that surrounds the liquid 3He/4He/D2 target system to detect the decay particles from the target region, a beam sweeping magnet, and a neutron time-of-flight counter located ~15m downstream from the target position.

Cylindrical Detector System (CDS)

- Track secondary charged particles → apply target volume cut

Drift chamber

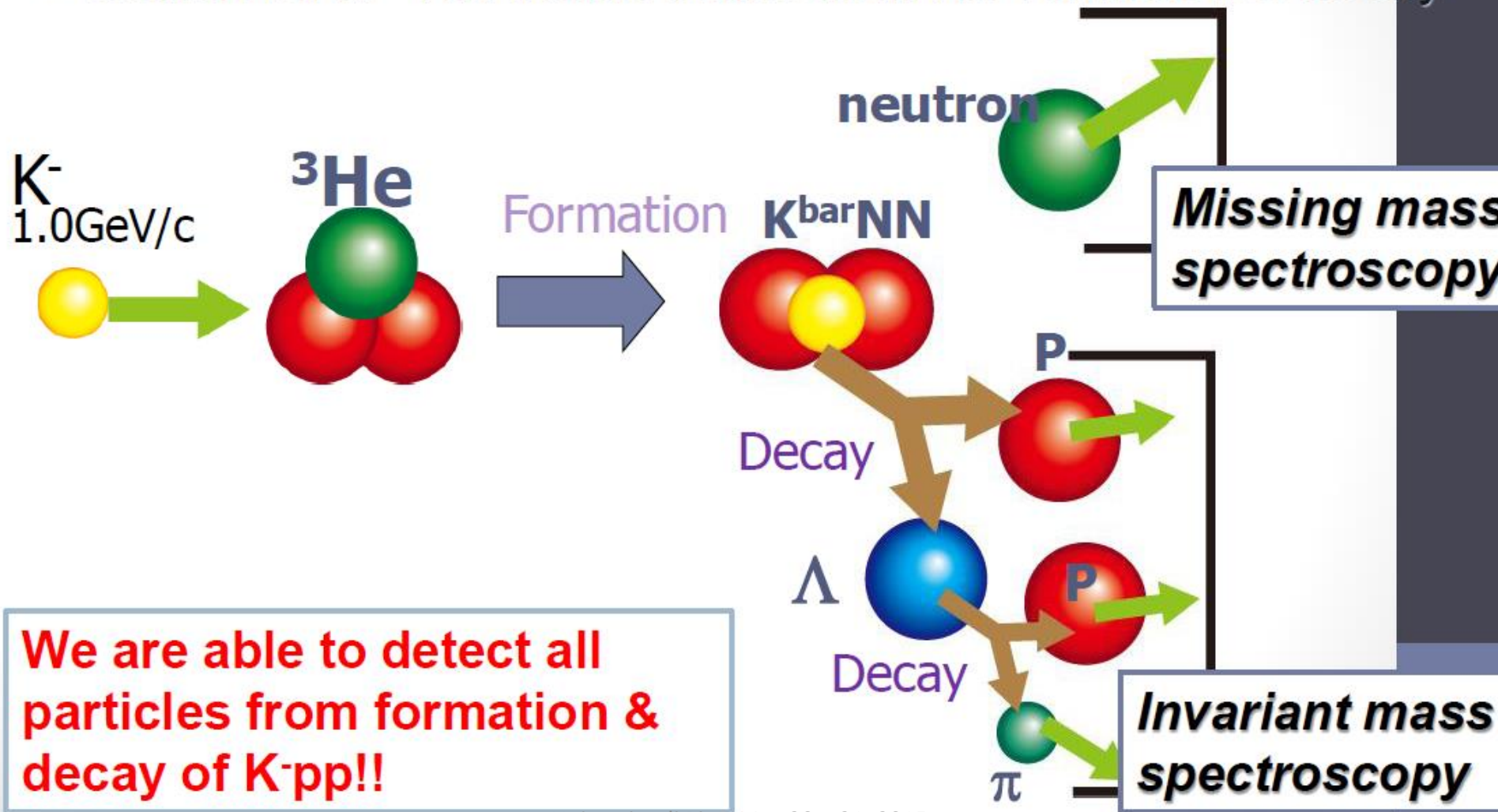
Hodoscope

Geometrical acceptance:
~ 2.6 π

J-PARC E15 experiment

in-flight ^{3}He(K^{-}, n) reaction & its exclusive measurement

=> Search for K^{bar}NN bound states both via formation & Decay



We are able to detect all particles from formation & decay of K^{-}pp!!

Search for double strangeness production in antiproton annihilation

Letter of Intent for J-PARC

Double Anti-kaon Production in Nuclei by Stopped Anti-proton Annihilation

dated on 17 / 06 / 2009

M. Iwasaki[1], P. Kienle[2,3], H. Ohnishi[1], F. Sakuma[1*], and J. Zmeskal[2]
[1] *RIKEN, Japan*
[2] *Stefan Meyer Institut für subatomare Physik, Austria*
[3] *Technische Universitat Munchen, Germany*

Abstract

We propose to search for double strangeness production by $\bar{p}$ annihilation on helium nuclei at rest. The proposed experiment will provide significant information on double strangeness production and double strangeness cluster states.

CONCLUSIONS I

- **DAΦNE: e^+e^- collider**
  - low-energy, monochromatic kaons 127 MeV/c
  - ideal suited for
    - Kaonic atom studies
    - low-energy Kaon scattering
    - low-energy Kaon-nucleon interaction

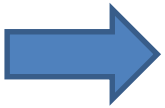
- **J-PARC**
  - hadron machine, kaons ~ 1.8 GeV/c + antiprotons
    - Kaonic atoms (E17, K^-d proposal)
    - K^-pp search (E15, E27)
    - $\Lambda(1405)$ studies (E31)
    - S=-2 production (Letter of Indent)

Experimental studies of double-strangeness production with low-energy antiprotons

Strangeness S=-2 production

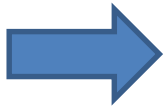
To use the antiproton annihilation reaction on light nuclei to produce and study double-strange nuclei in reactions such as:

$$\bar{p} + p \rightarrow K^- + K^- + K^+ + K^+$$

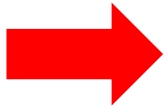


energetically forbidden at rest (-98 MeV)

$$\bar{p} + A \rightarrow K^+ + K^+ + [K^- K^- pp(A-3)]$$



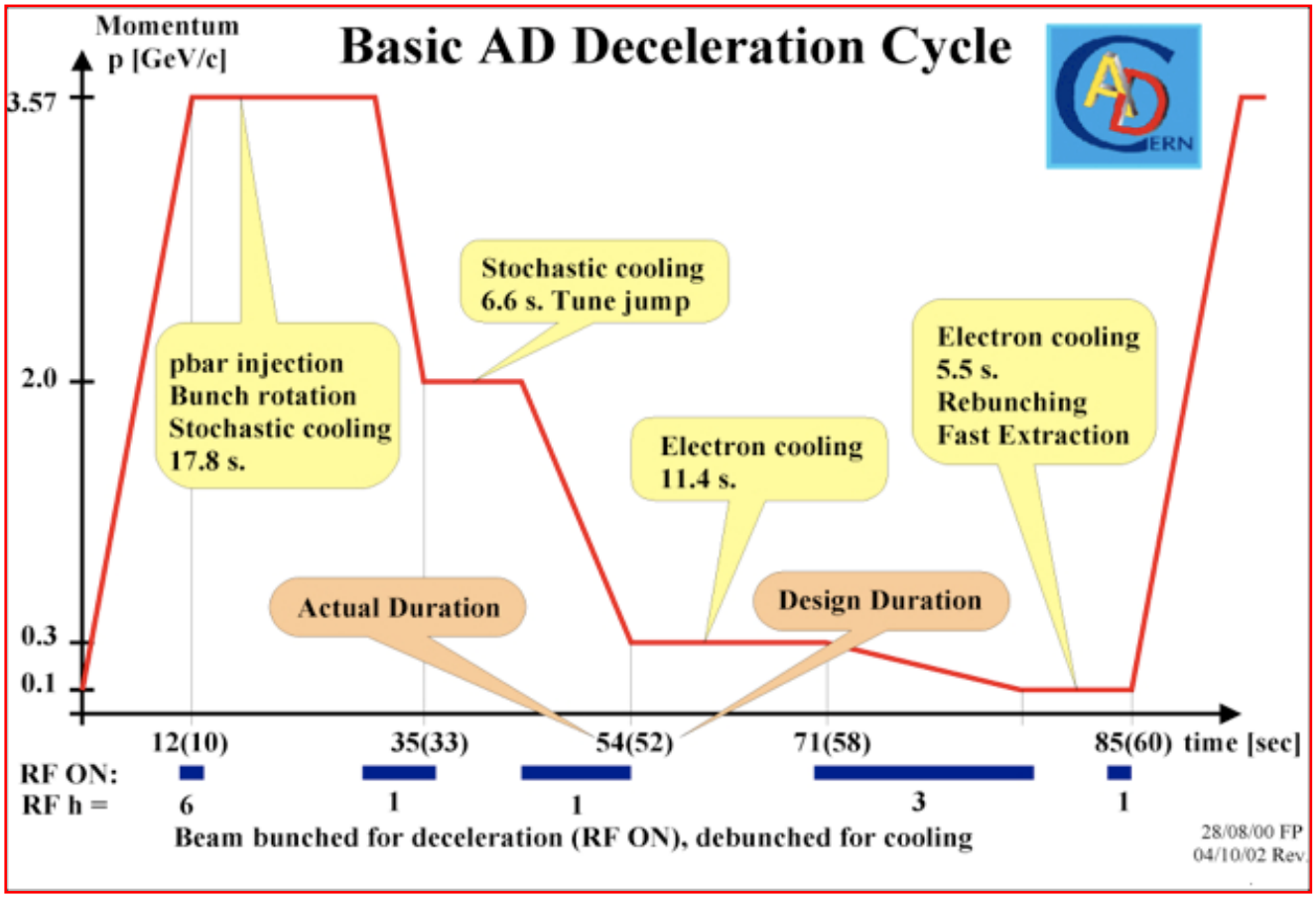
bound state formation $\rightarrow$ E_B



2 K^+ indicate a strong binding of the K^- pair in the nucleus

at CERN/AD ?

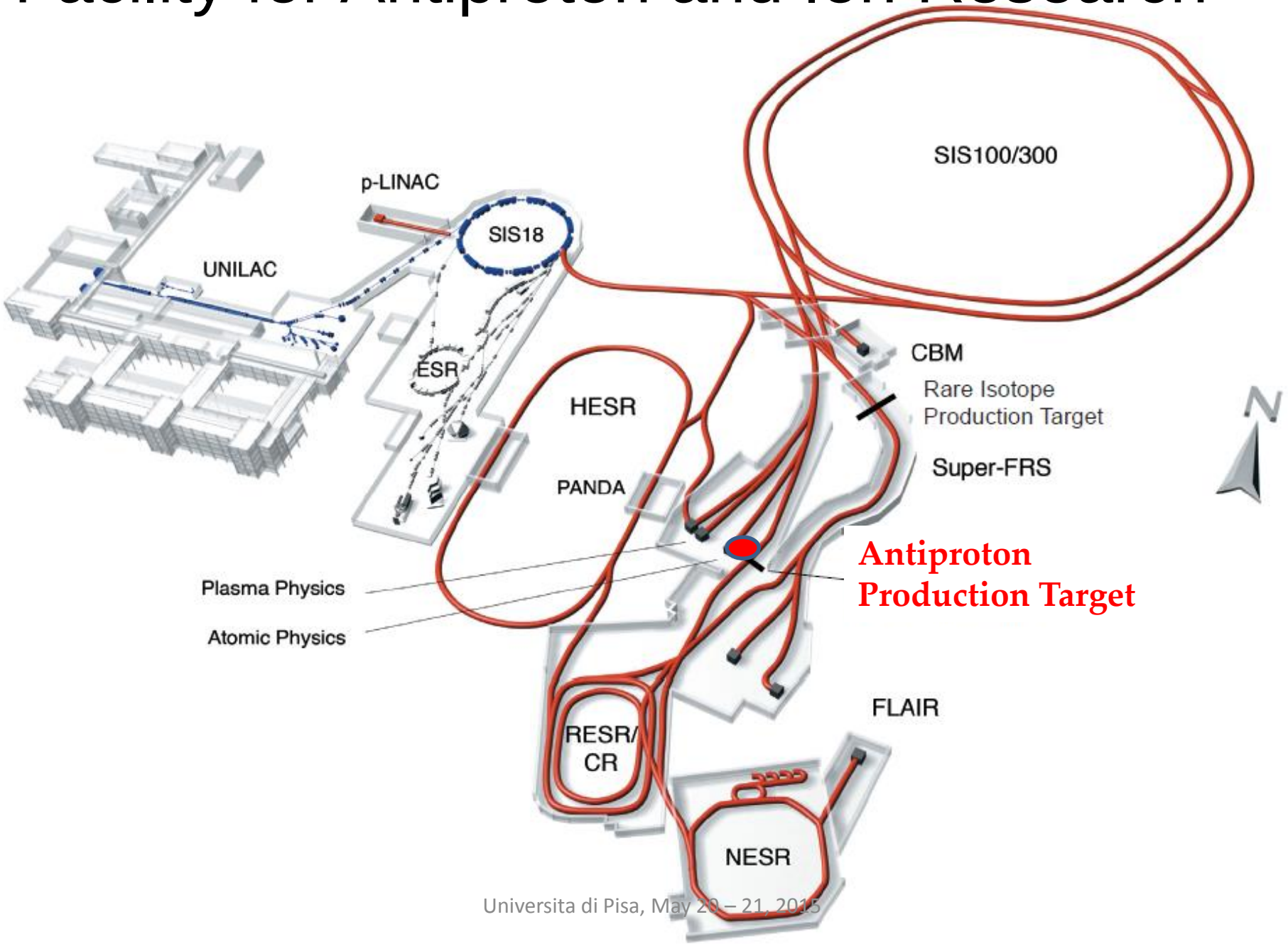
AD @ CERN: started 2000



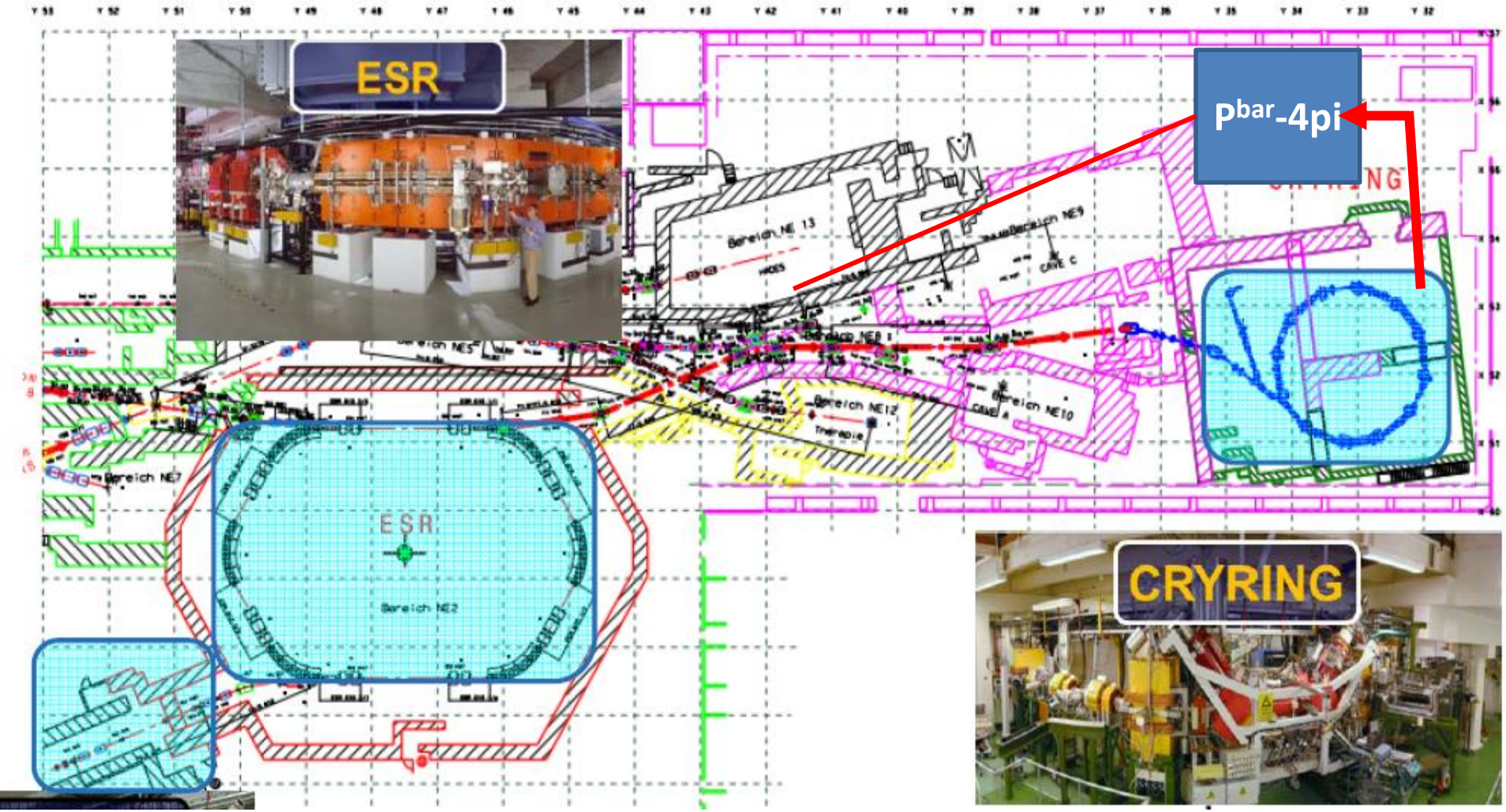
- All-in-one machine:
  - Antiproton capture
  - deceleration & cooling
  - 100 MeV/c (5.3 MeV)

- Pulsed extraction
- 2-4 x 10^7 antiprotons per pulse of 100 ns length
- 1 pulse / 85−120 seconds

Facility for Antiproton and Ion Research



CRYRING and ESR a perfect match for low-energy antiprotons

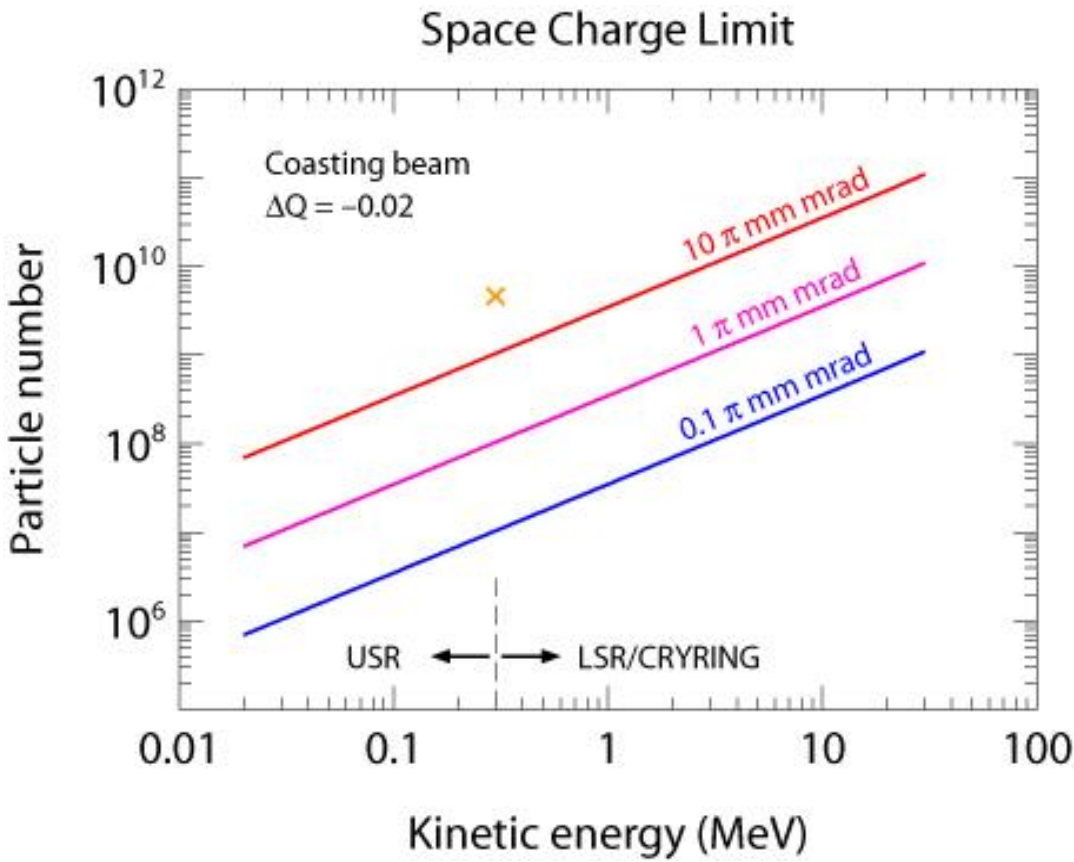


Expected Antiproton Rates for F(L)AIR

- Production: 10^8 p^{bar}/ 4 s

- Deceleration time ~ 20 s

- Limits from space charge in rings:
  300 keV: 3 x 10^6 / s
  for 0.1 π mm mrad



OBELIX (CERN/LEAR) data for double strangeness production

S=-2 strangeness production in $\bar{p}^4He$ annihilations at rest

G. Bendiscioli, T. Bressani, *L. Lavezzi, A. Panzarasa and P. Salvini*

channel	events	yield (10^{-4})
$K^+K^+\Sigma^-\Sigma^-p_s$	34+/-8	0.17+/-0.04
$K^+K^+\Sigma^-\Sigma^+n\pi^-$	36+/-6	2.71+/-0.47
$K^+K^+\Sigma^-\Lambda n$	16+/-4	1.21+/-0.29
$K^+K^+K^-\Lambda nn$	4+/-2	0.28+/-0.14

ELSEVIER

14 October 1999

PHYSICS LETTERS B

Physics Letters B 464 (1999) 323–330

Double strangeness production in $\bar{p}Xe$ annihilation at low energy

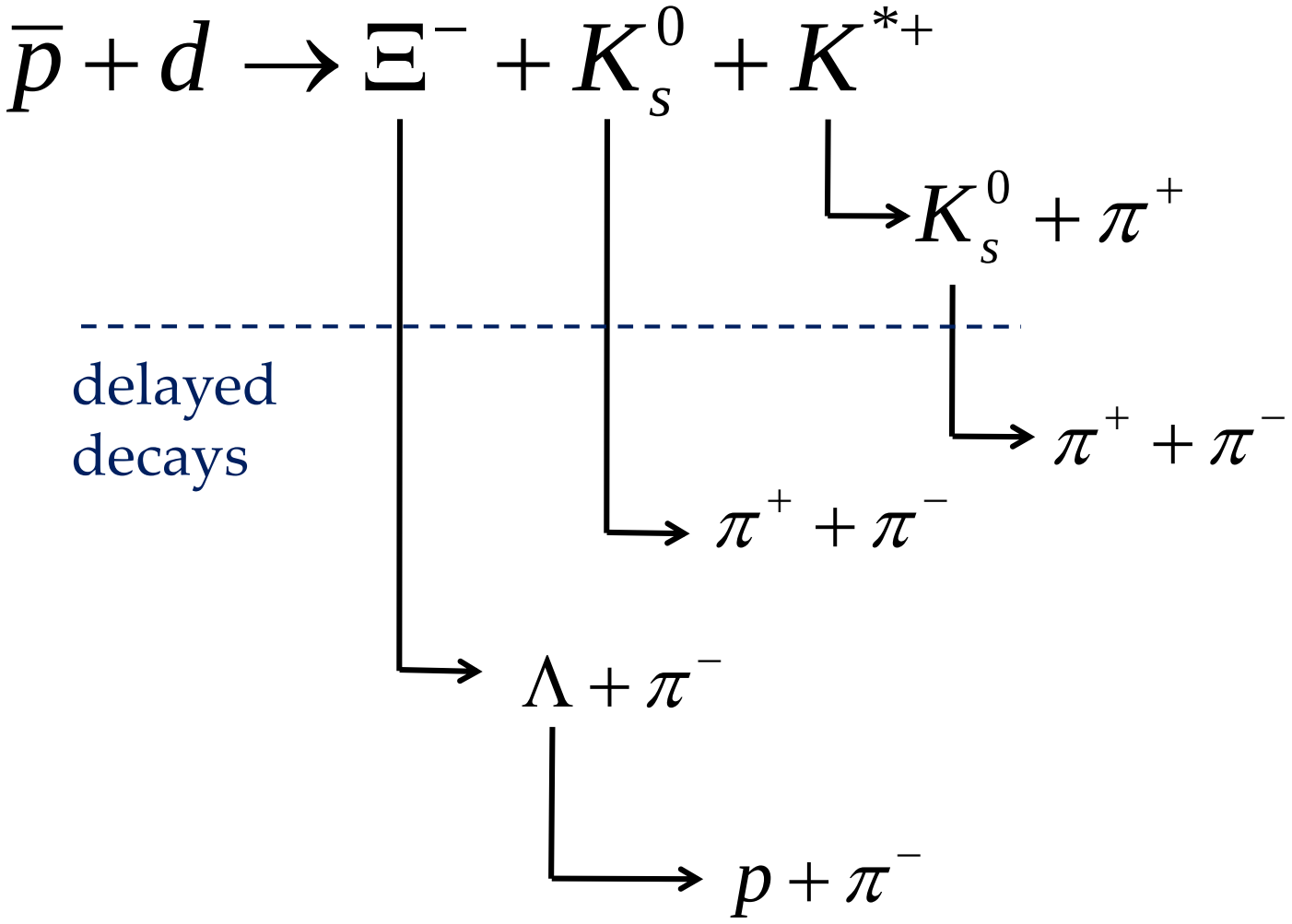
DIANA Collaboration

V.V. Barmin [a], V.G. Barylov [a], V.S. Borisov [a], G.V. Davidenko [a], A.G. Dolgolenko [a], C. Guaraldo [b], V.A. Matveev [a], G.S. Mirosidi [a], K. Myklebost [c], M. Olsen [c], C. Petrascu [b,1], V.A. Shebanov [a], N.N. Shishov [a], A.A. Sibirtsev [d], L.I. Sokolov [a], B.S. Volkov [a], N.K. Zombkovskaya [a]

[a] *Institute of Theoretical and Experimental Physics, 117218 Moscow, Russia*
[b] *Laboratori Nazionali di Frascati dell' INFN, C.P. 13, I-00044 Frascati, Italy*
[c] *Physics Department, University of Bergen, N-5007 Bergen, Norway*
[d] *Institut für Theoretische Physik, Universität Giessen, D-35392 Giessen, Germany*

33 double kaon events were found
yield ~ 10^{-4}

Production of S=-2: Ξ^-



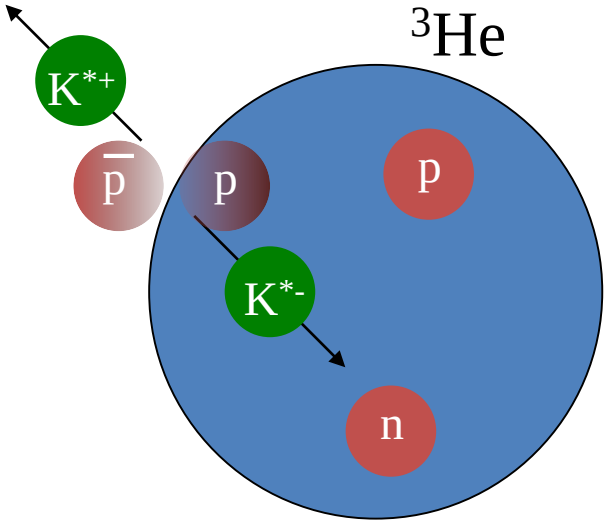
Production of S=-2 baryonic states

via $(\bar{K}^*, K)$ using stopped p^{bar}

C. Guaraldo
LNF-INFN
K. Kilian, W. Oelert, D. Grzonka
Forschungszentrum Jülich

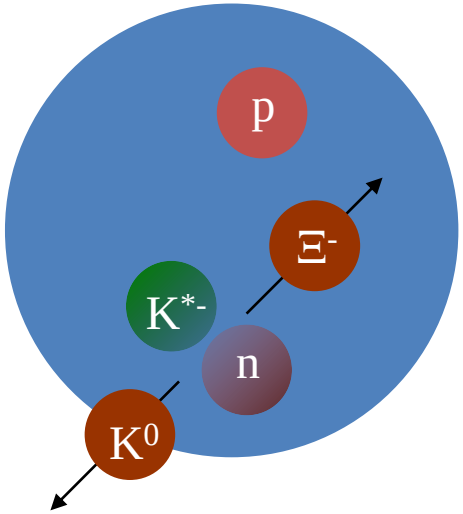
step 1 : $\bar{p}\,(p\,n\,p) \rightarrow K^{*-}\,K^{*+}$

large $\bar{p}$ stop rate on a ^{3}He target



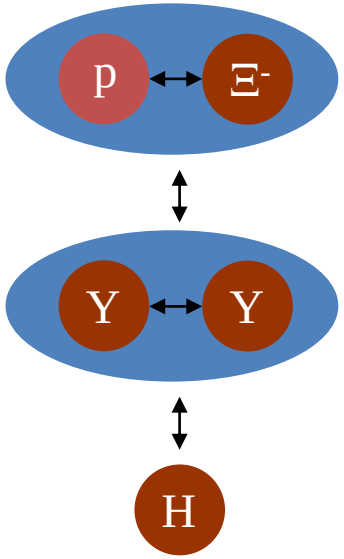
step 2 : $K^{*-}\,(n\,p) \rightarrow \Xi^-\,K^0$

very low recoil on Ξ^-
(recoil free kinematics)



S= - 2 states

low relative energy



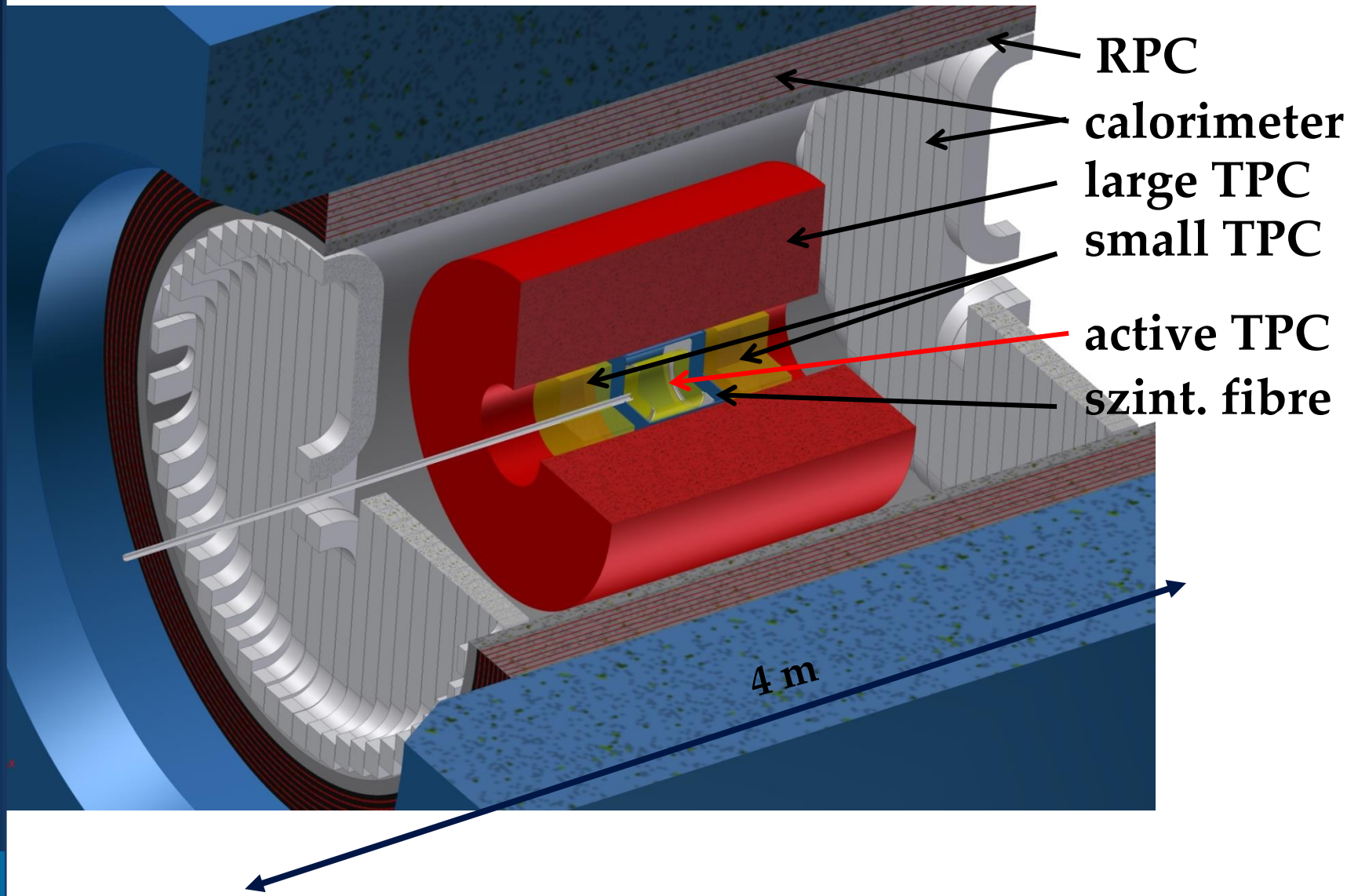
Detector concept

- acceptance - 4π
- material budget
- good energy resolution
- good time resolution

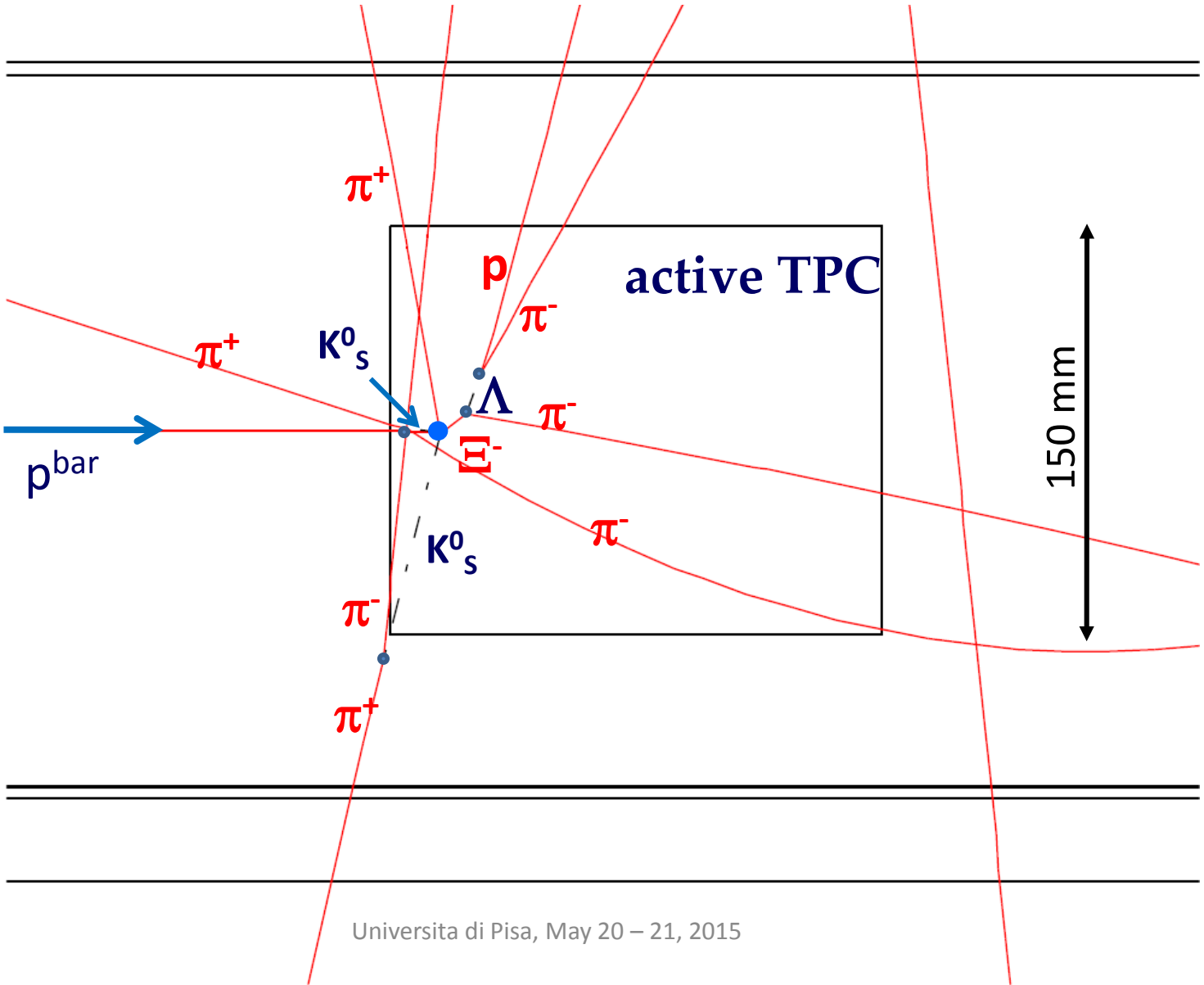
- charged particle tracking
- neutral particle detection

Unique 4π-detector system – SMILE

(Strange Matter Investigation at Low Energies)



$$\bar{p} + d \rightarrow \Xi^- + K^{*+} + K_s^0$$



CONCLUSIONS II

The CRYRING at FAIR could become a high-intensity source for low-energy, “slow”-extracted (single) antiprotons, to produce and study baryonic systems with strangeness S=-2.

SMILE (using the FOPI-magnet) will have:

– tracking capability at the interaction point

– the capability to measure charged particles to very low energy

- and the possibility to measure neutrons and gamma rays

DAΦNE - J-PARC - GSI - CRYRING@FAIR