JÜLICH
FORSCHUNGSZENTRUM

Autumn Lectures in Tbilisi

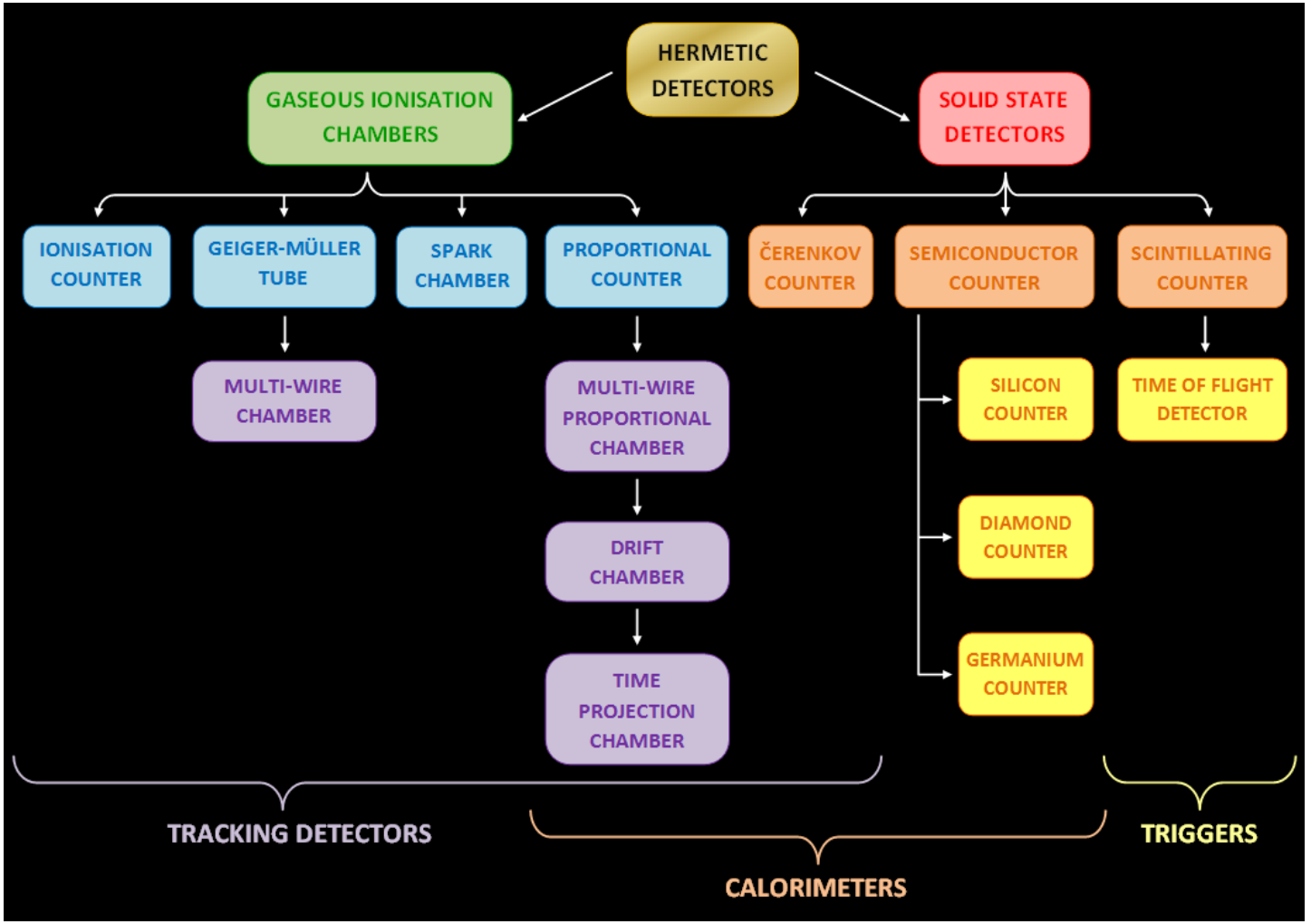
Georgian Technical University, October 15 – 22, 2013

Experimental Facilities: Examples (at COSY)

October 22, 2013 | Andro Kacharava (JCHP/IKP, FZ-Jülich)

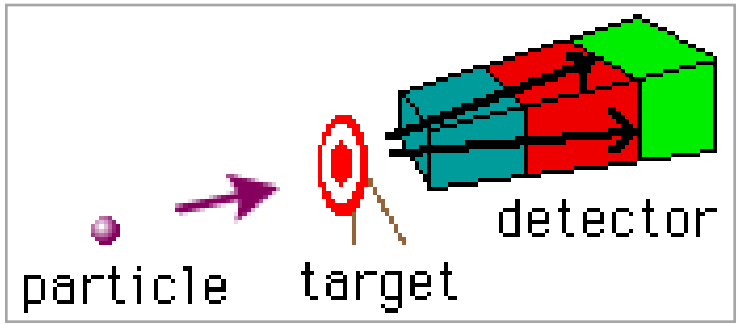
Introduction - Overview

From lecture #1 we know :

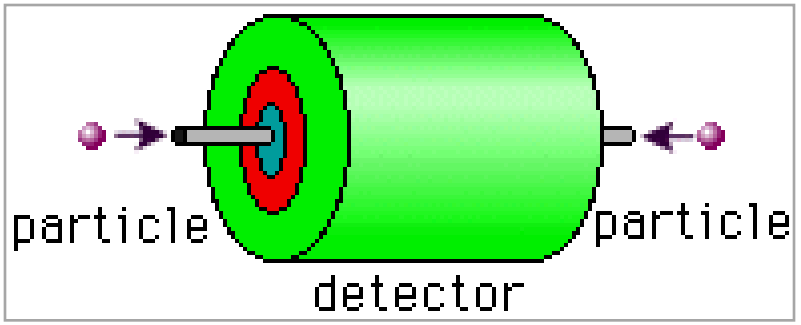


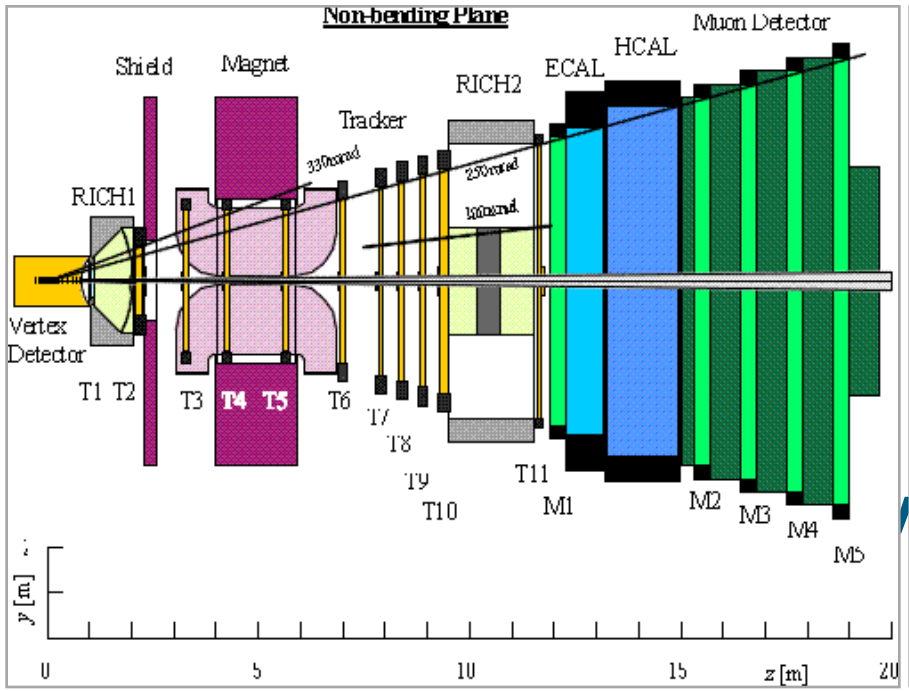
Introduction - Overview

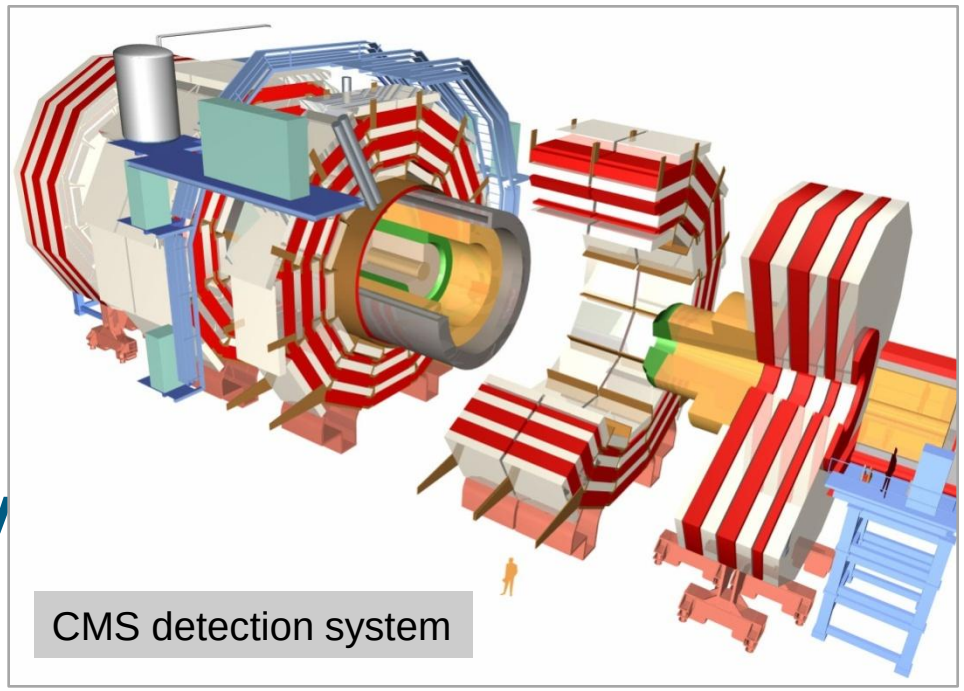
fixed target exp.



colliding beams



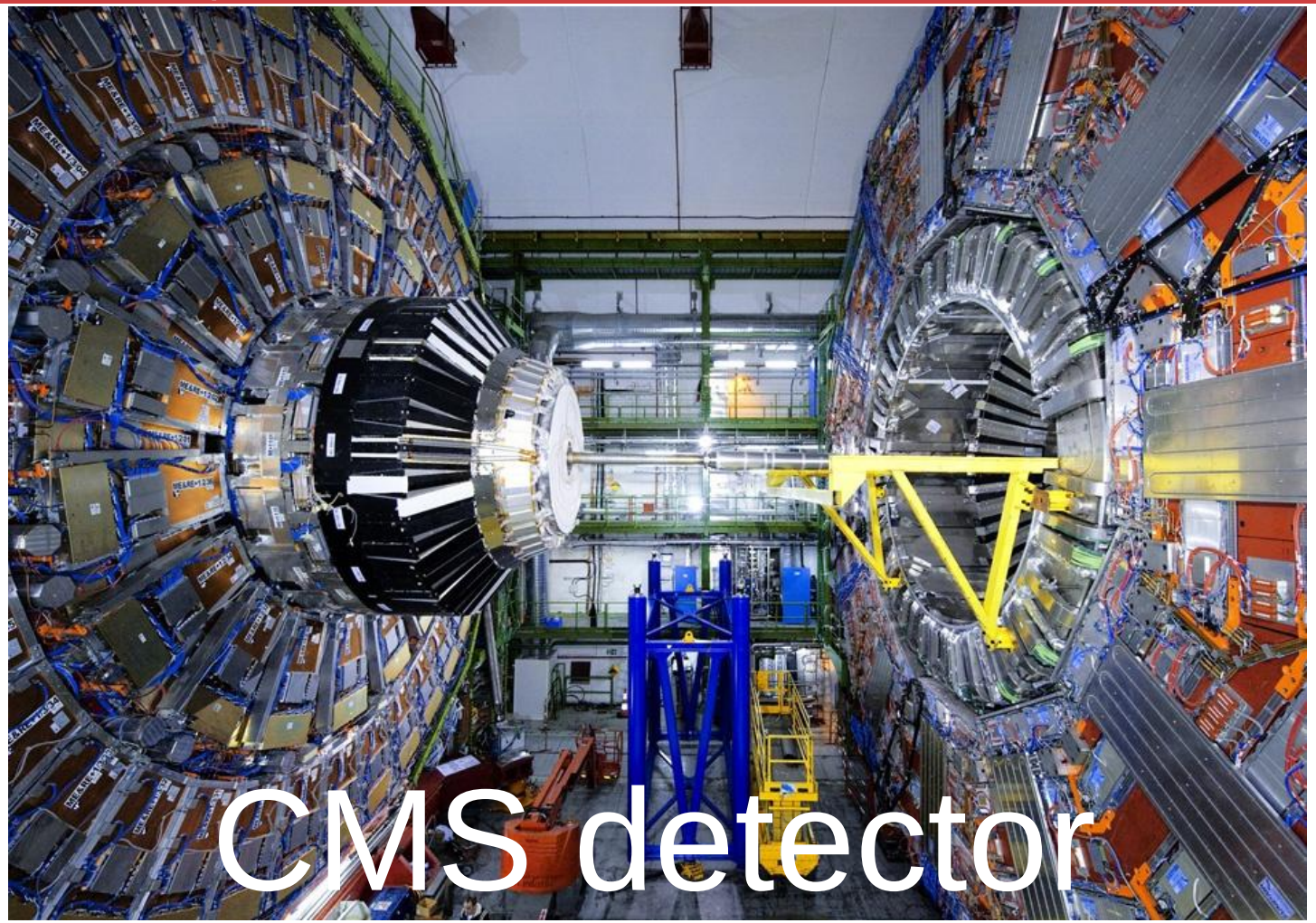




CMS detection system

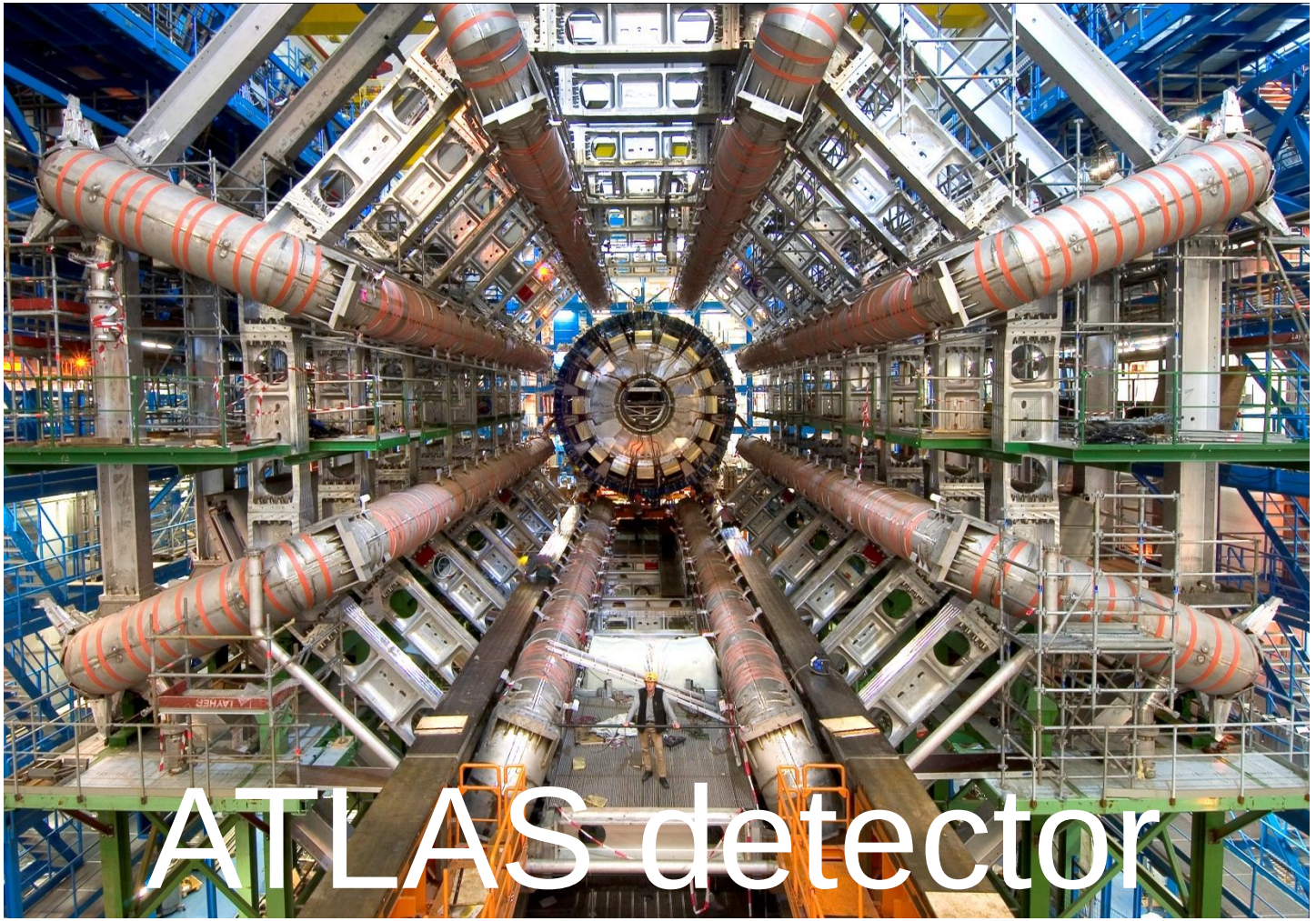
Modular Detector Systems - CMS

Compact **M**uon **S**olenoid experiment at CERN‘s LHC



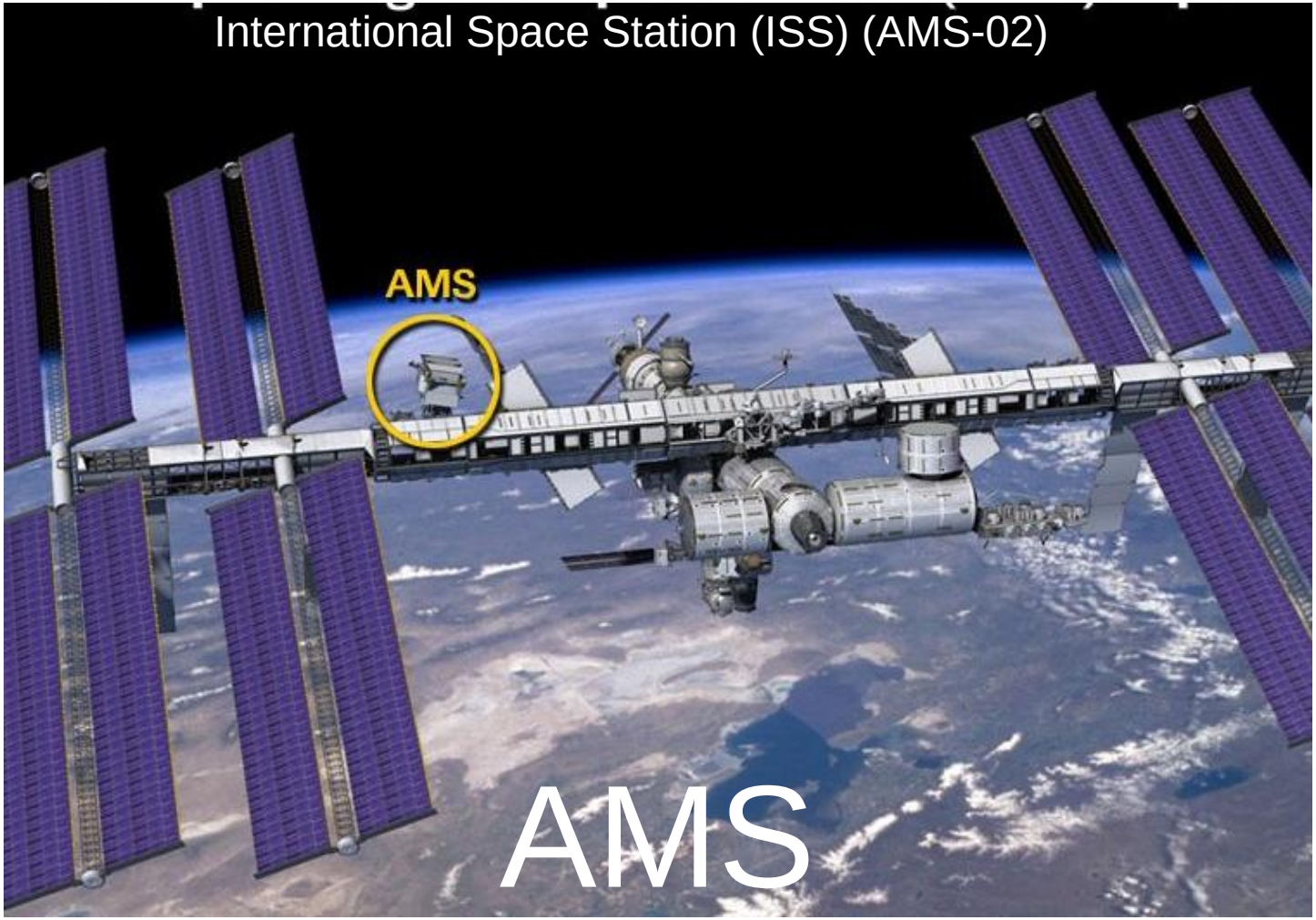
Modular Detector Systems - ATLAS

ATLAS: A Toroidal LHC Apparatus



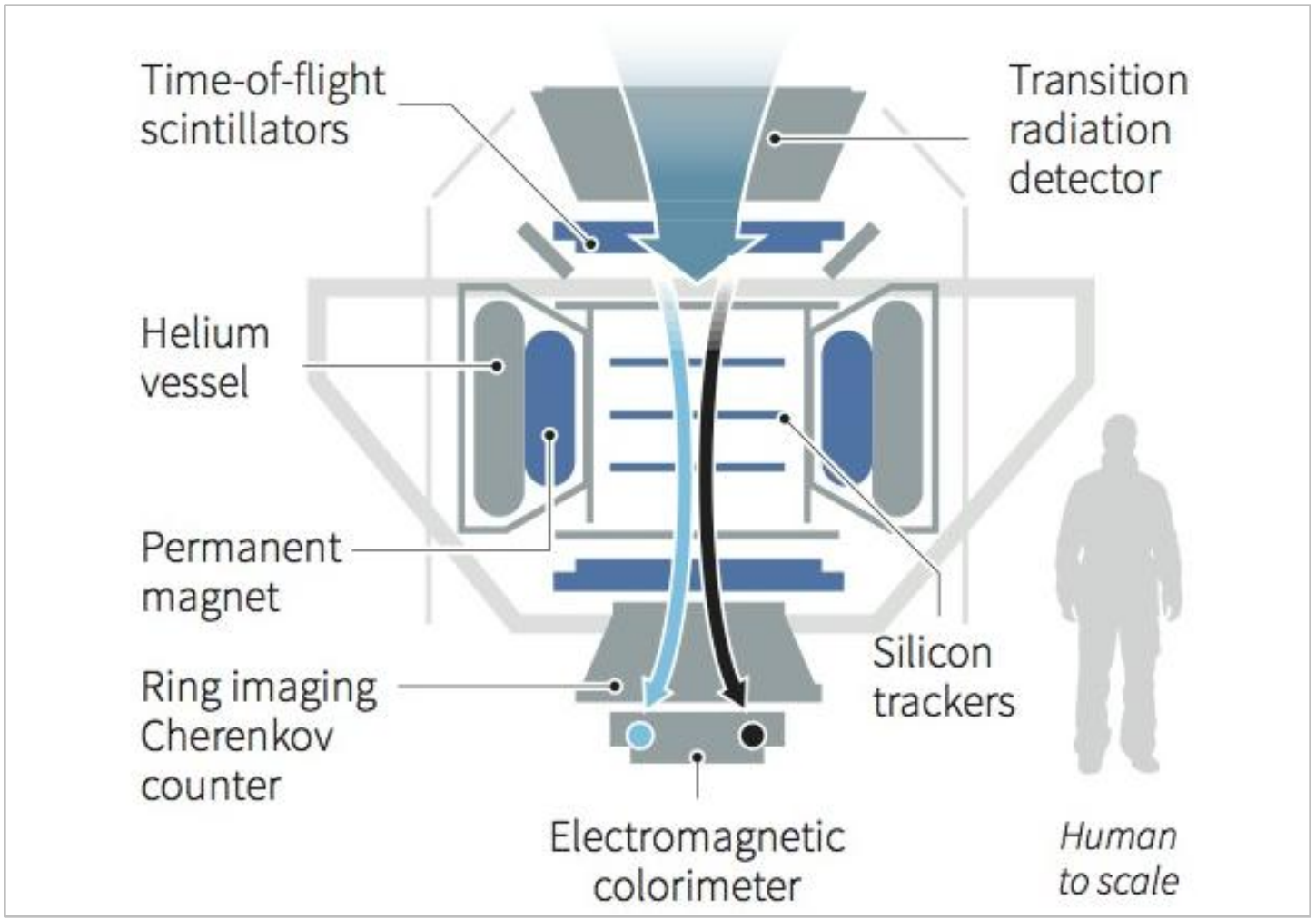
Modular Detector Systems - AMS

The Alpha Magnetic Spectrometer (AMS) Experiment

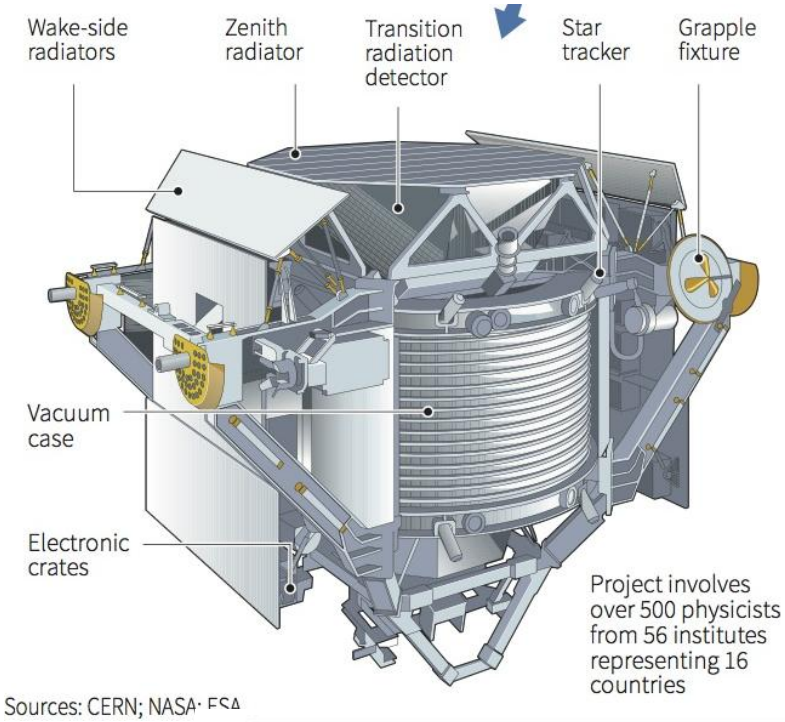


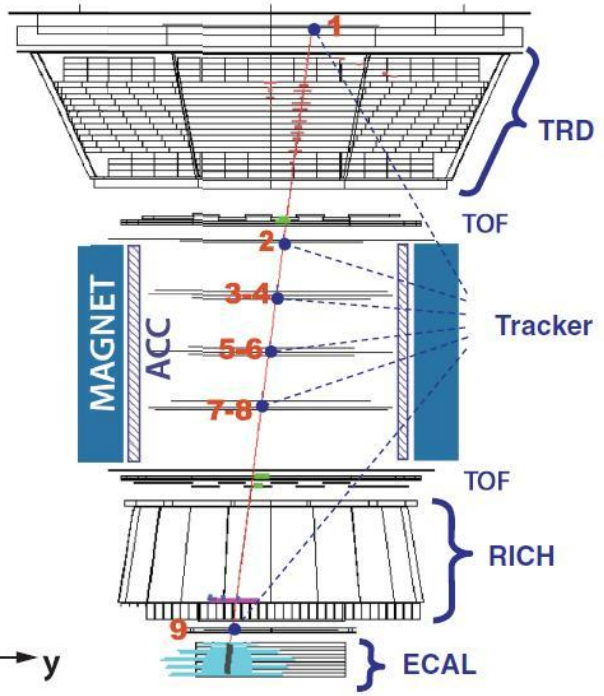
Modular Detector Systems - AMS

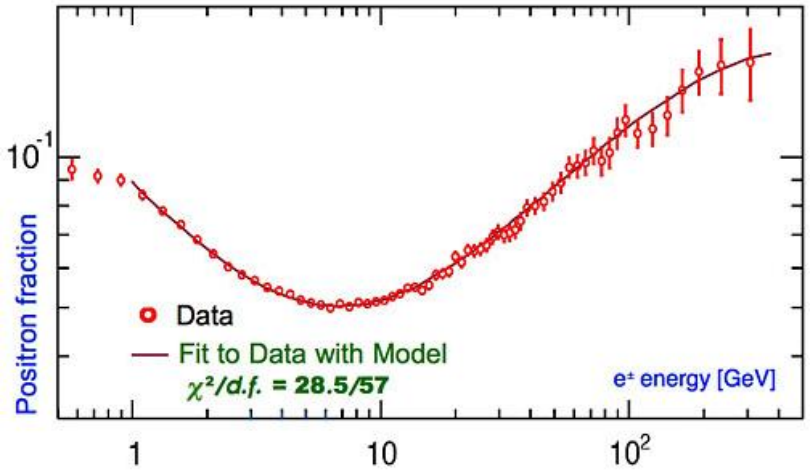
Modular Detector Systems - AMS



Modular Detector Systems - AMS





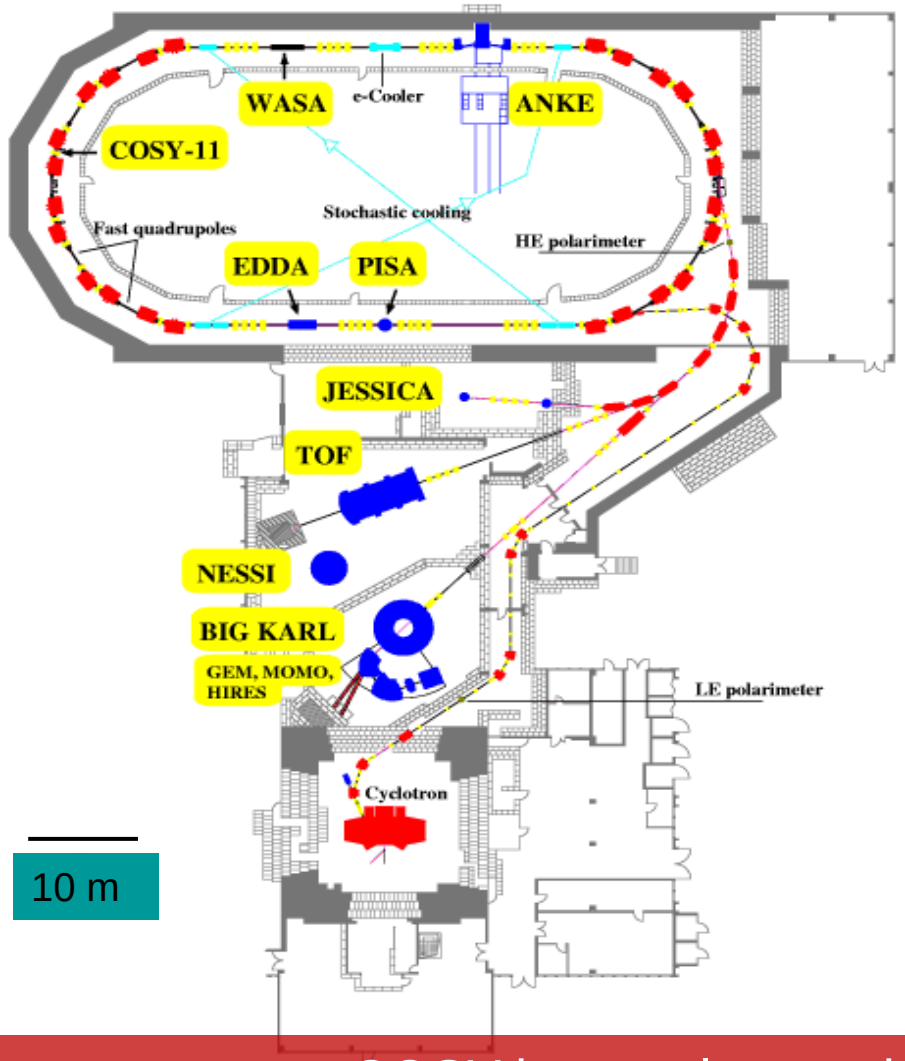


- Ratio of positron flux to combined flux in primary cosmic rays
- No fine structure
- First results: PRL 110 (2013)

Introduction – Experimetal Facilities

E.g., COSY, the *COoler SYnchrotron* at Forschungszentrum Jülich

Introduction – COSY



Characteristics:

- Energy range:

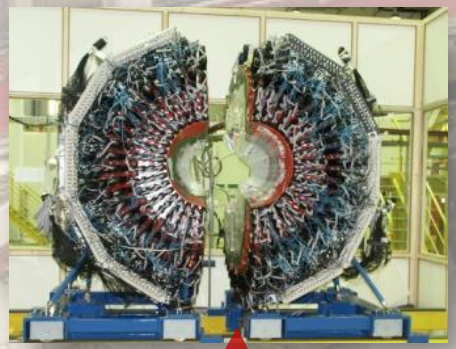
  0.045 – 2.8 GeV (p)

  0.023 – 2.3 GeV (d)
- Max. momentum ~ 3.7 GeV/c
- Energy variation (ramping mode)
- Electron and Stochastic cooling
- Internal and external beams
- High polarization (p,d)
- Spin manipulation

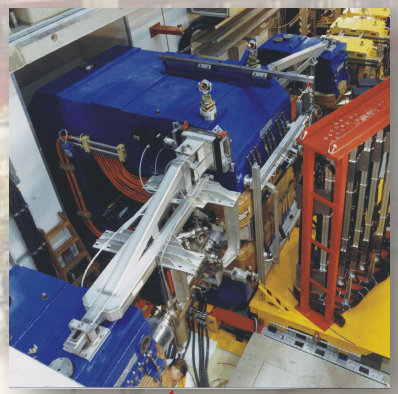
COSY is a cooler synchrotron and a storage ring

Introduction – Experiments at COSY

Experimental set-up‘s

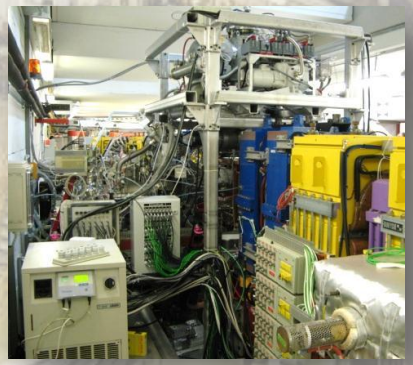


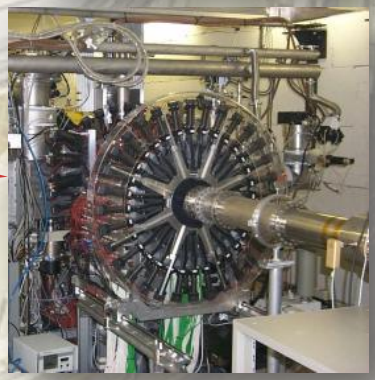
WASA



ANKE

PAX





EDDA

Internal experiments inside the COSY ring

Introduction – Experiments at COSY

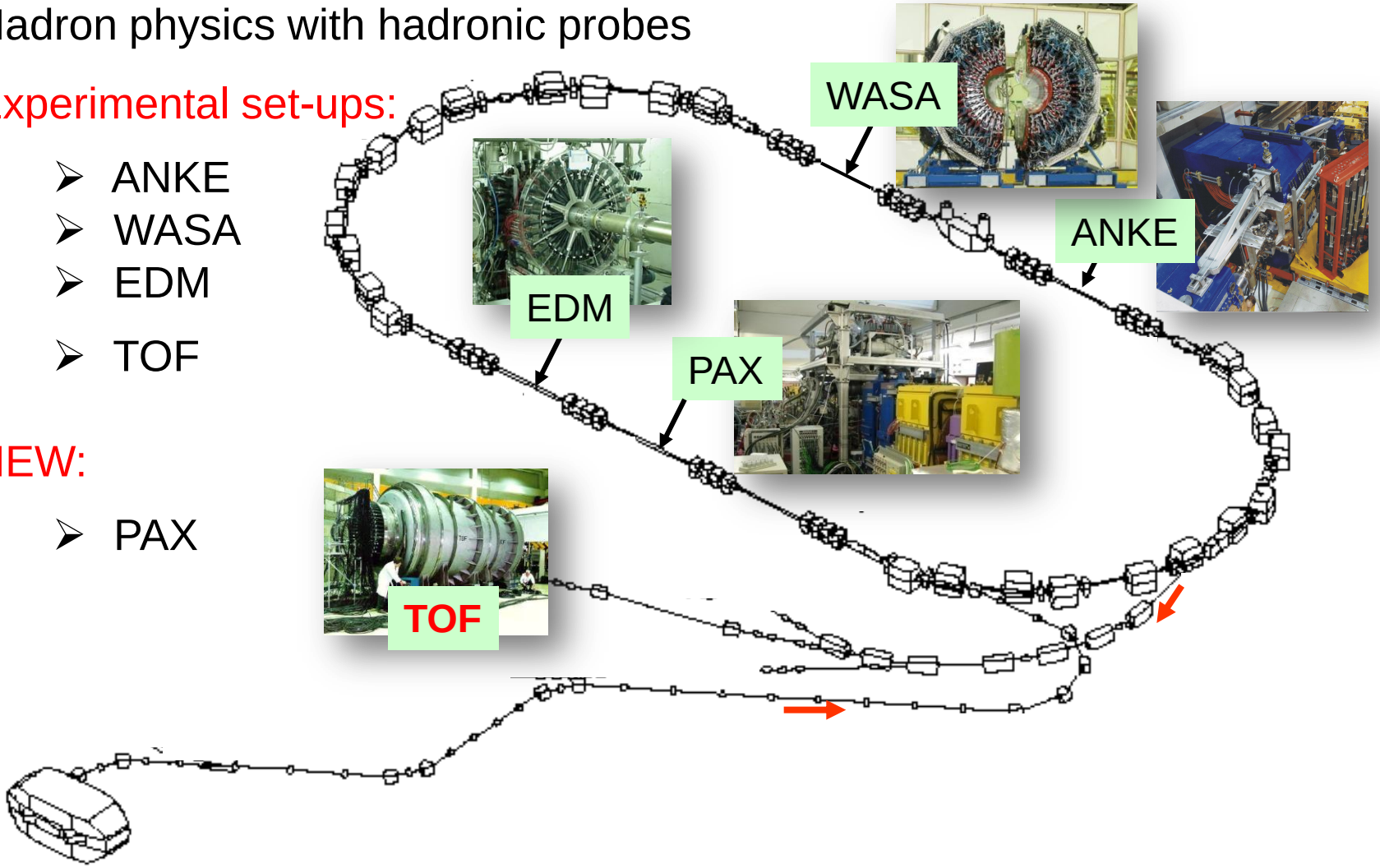
Hadron physics with hadronic probes

Experimental set-ups:

- ANKE
- WASA
- EDM
- TOF

NEW:

- PAX

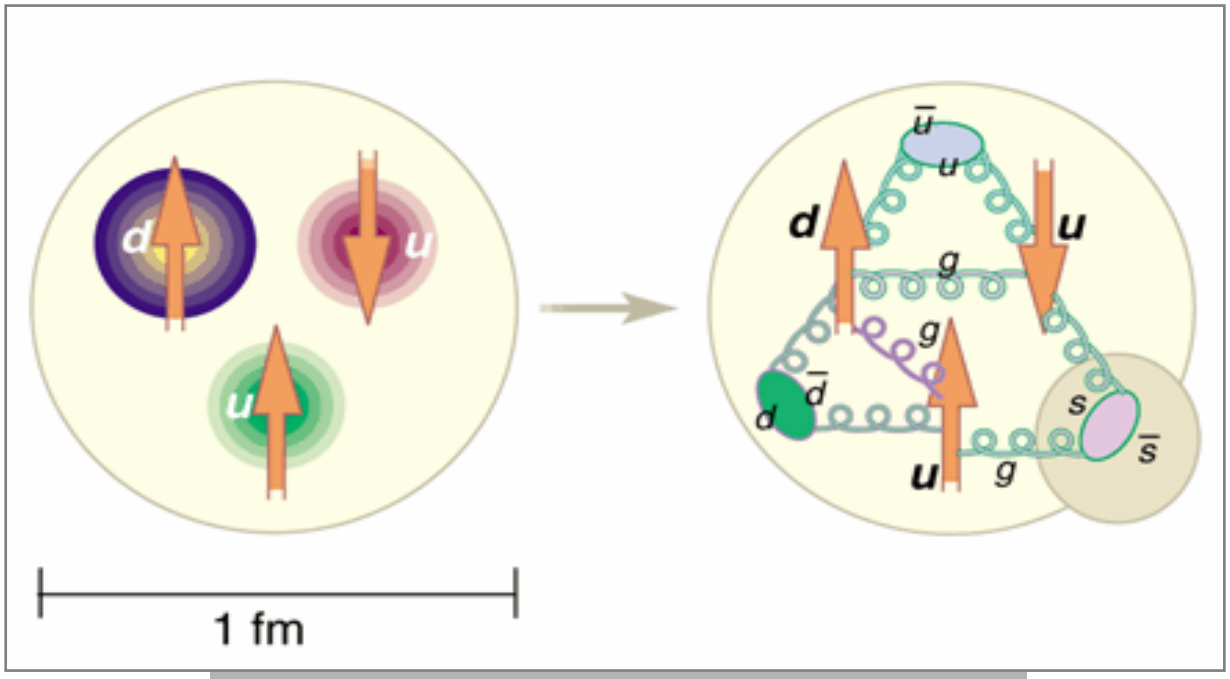


... experiments at COSY ring – TOF: *external* set-up

Introduction – Physics at COSY

<u>Hadron Physics:</u> Understanding of all matter comprised of quarks and gluons:

How does Nature *make* hadrons?



Evolution of our view of the nucleon

Introduction – Physics at COSY

Experimental program:

Nucleon-nucleon interactions

Nucleon resonances

Meson-nucleon/nucleus interaction

Meson production

Strangeness production (nucleons, nuclei)

Symmetries and symmetry breaking

Polarization build-up

(…)

ANKE

TOF

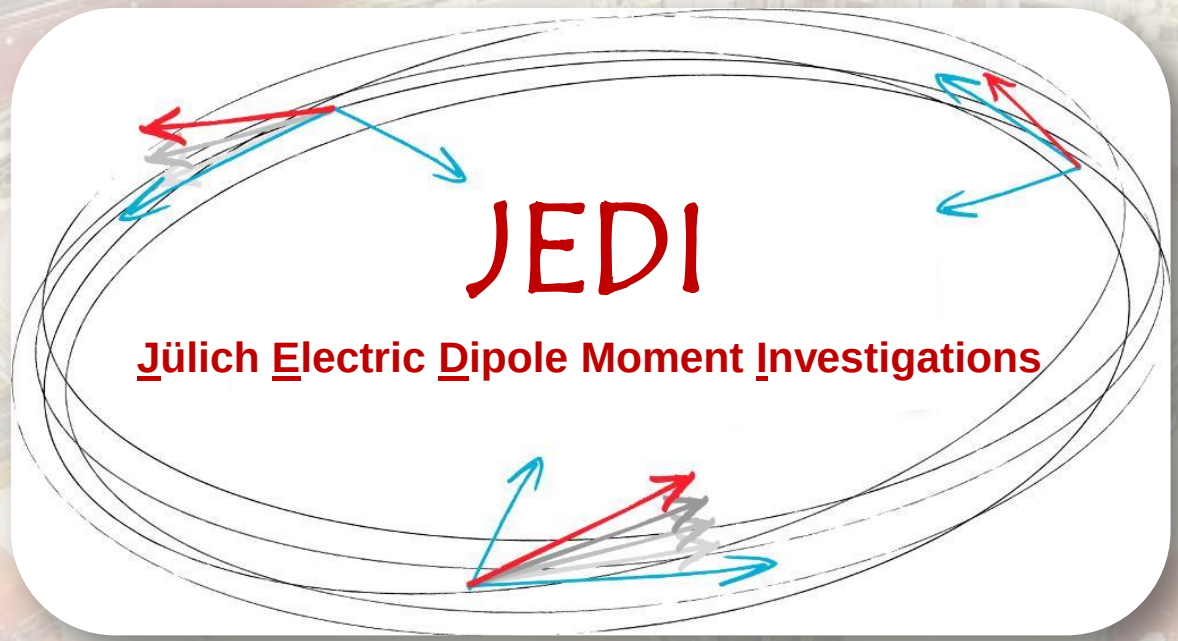
WASA

PAX

COSY is *the* hadron physics (spin) machine using hadronic probes

Introduction – Future Plans

Search for Electric Dipole Moments (EDM) at Storage Rings:

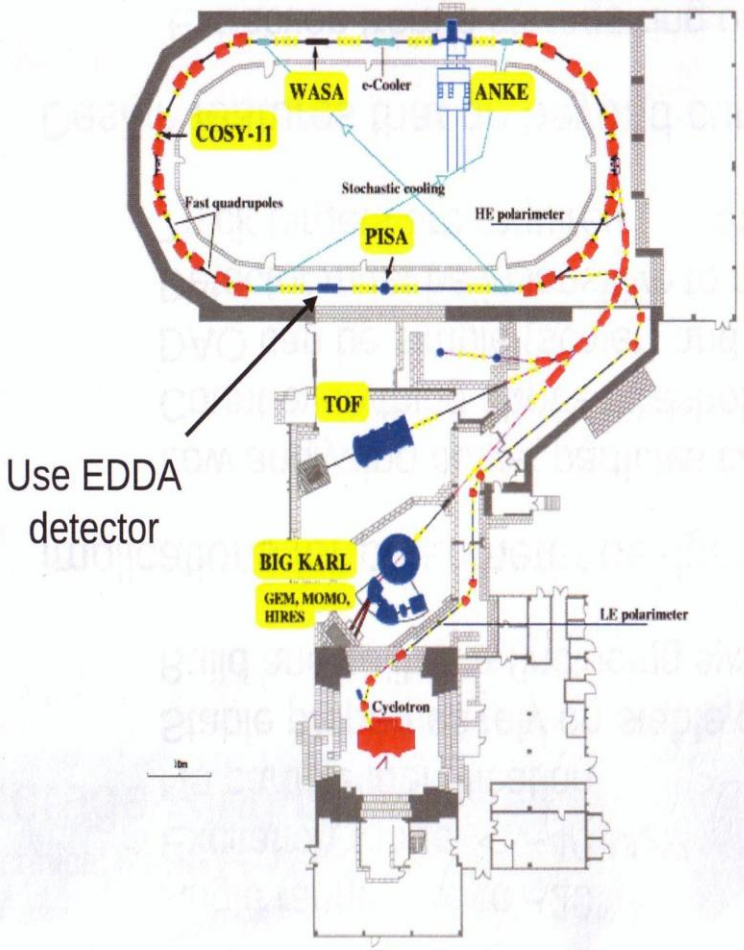


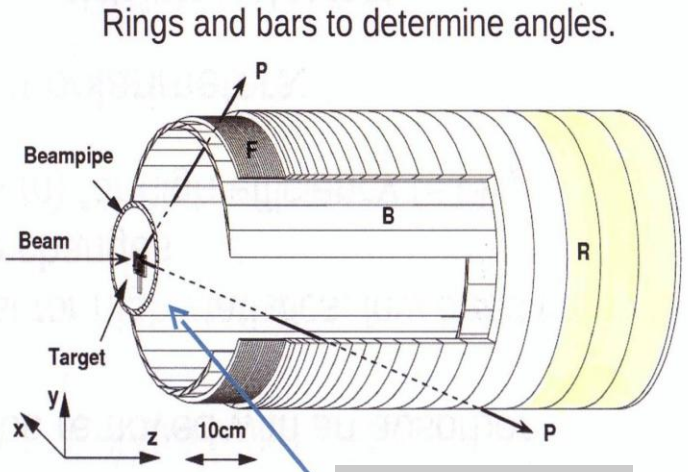
http://collaborations.fz-juelich.de/ikp/jedi/

1st step: precursor exp´t, … 2nd step: injector for dedicated EDM-SR

EDDA – COSY Internal Experiment

Early 90‘s: 1st generation experiment at COSY





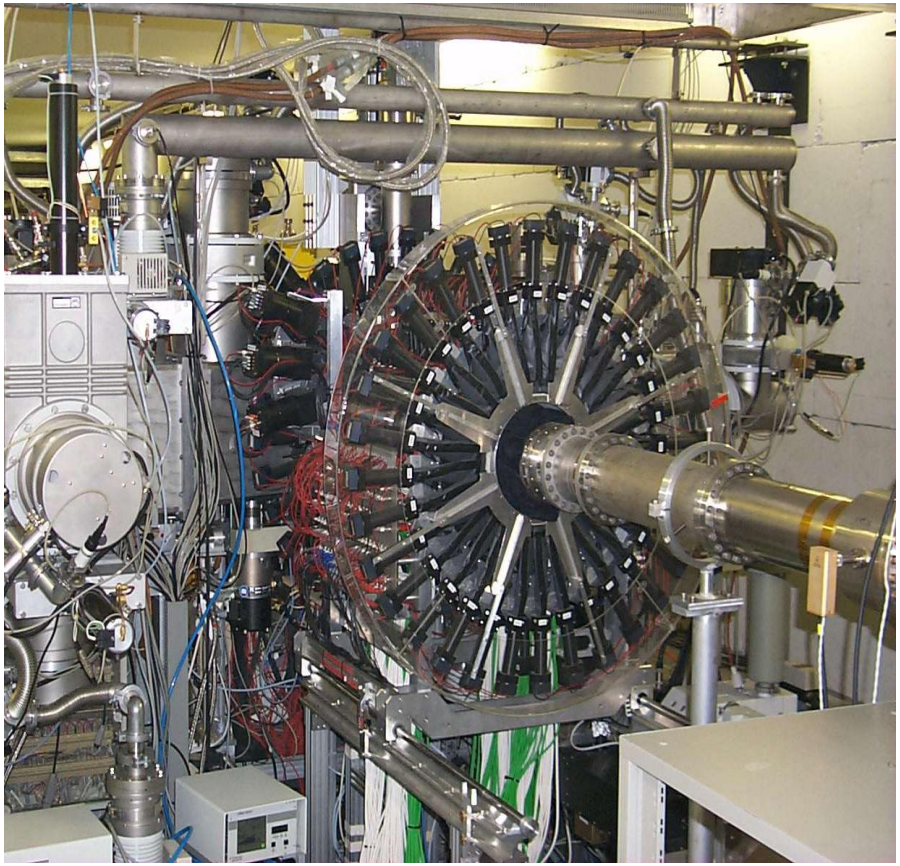
pp → pp

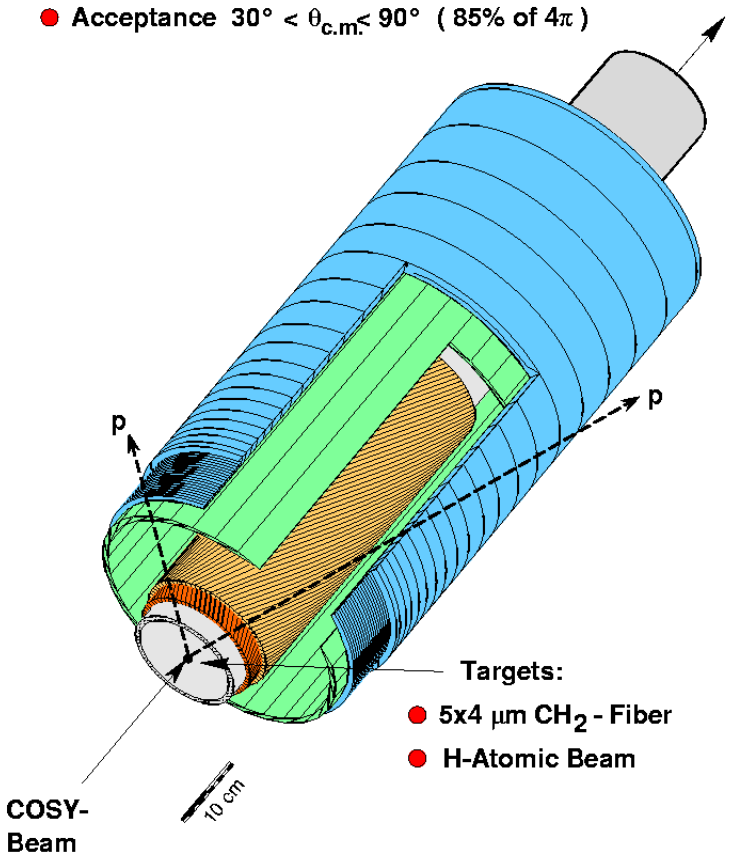
- Polarized Deuterons, Carbon Target, ABS
- L(+), L(-), R(+), R(-), D(+), D(-), U(+), U(-)
- Cross Ratio Asymmetry pA=(r-1)/(r+1)

  with r=sqrt [L(+)R(-) / L(-)R(+)]

EDDA – COSY Internal Experiment

Excitation Function Data Acquisition Designed for Analysis of phase Shift





ANKE – History

Early 90´s: a 2nd generation internal target experiment at COSY

Meson Studies at the 0° Facility in COSY

K. Sistemich[1], M. Büscher[1], V. Abaev[2], U. Bechstedt[1], P. Birien[3], W. Borgs[1], W. Cassing[4], S. Dienel[5], H. Dombrowski[6], S.V. Dshemuchadze[5], J. Ernst[7], R. Eßer[1], D. Gotta[1], D. Grzonka[1], A. Hardt[1], F. Hinterberger[7], M. Ivanov[8], L. Jarczyk[9], B. Kamys[9], St. Kistryn[9], H.R. Koch[1], V.I. Komarov[8], V. Koptev[2], A. Kozela[9], A. Krykin[8], K.W. Leege[5], H. Müller[5], W. Oelert[1], H. Ohm[1], R. Santo[6], Chr. Schneidereit[5], O.W.B. Schult[1], H. Seyfarth[1], V. Shelkov[8], J. Smyrski[9], A. Strzalkowski[9], K.–H. Watzlawik[1], B.Zh. Zalyhanov[8], and N.I. Zhuravlev[8], and P. Zolnierczuk[9]

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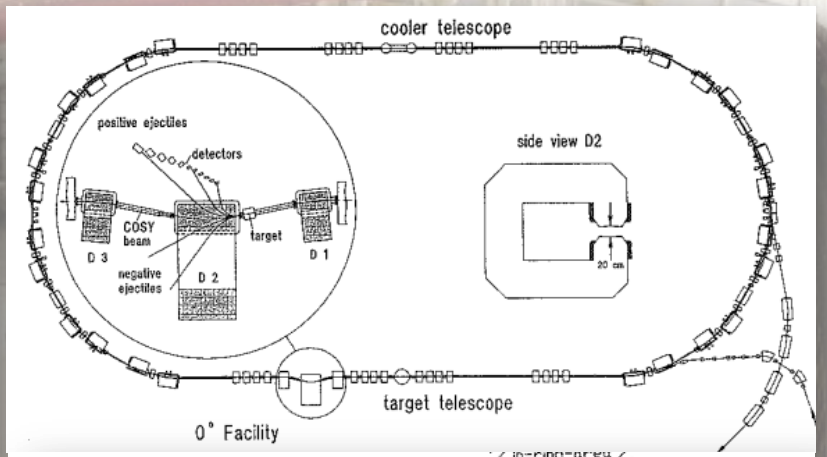
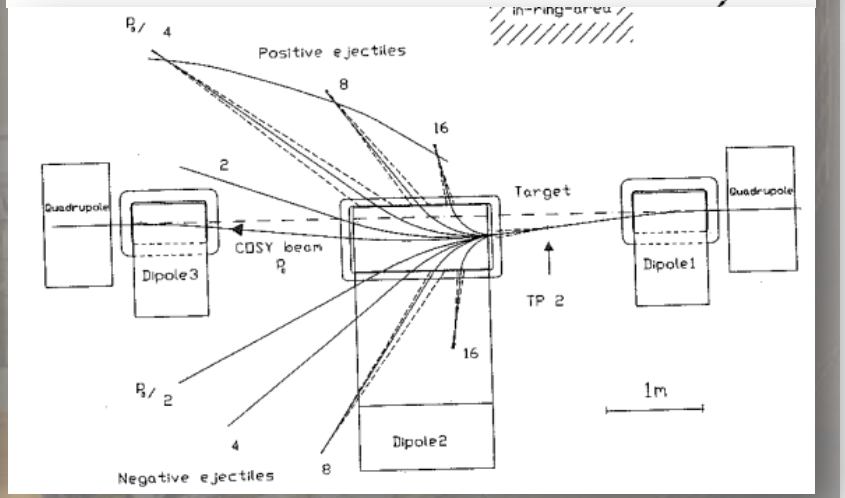
8 Joint Institute for Nuclear Research, Dubna, P.O.B. 79, 101000 Moskva, Russia
9 Inst.of Physics, Jagellonian Univ., Reymonta 4, PL–30059 Cracow, Poland

Abstract

A universal facility is in preparation for the study of mesons which are produced in nuclei of an internal target at COSY–Jülich. This device will consist of three dipole magnets and will be installed at the target place TP2. The status of the design of this facility is discussed. A major goal of the experimental program with this instrument is the investigation of the K⁺–meson production at projectile energies below the NN threshold. The detector setup is described which will allow the measurement of the momentum spectra of K⁺ mesons and of accompanying light particles in spite of a large background of protons and pions.

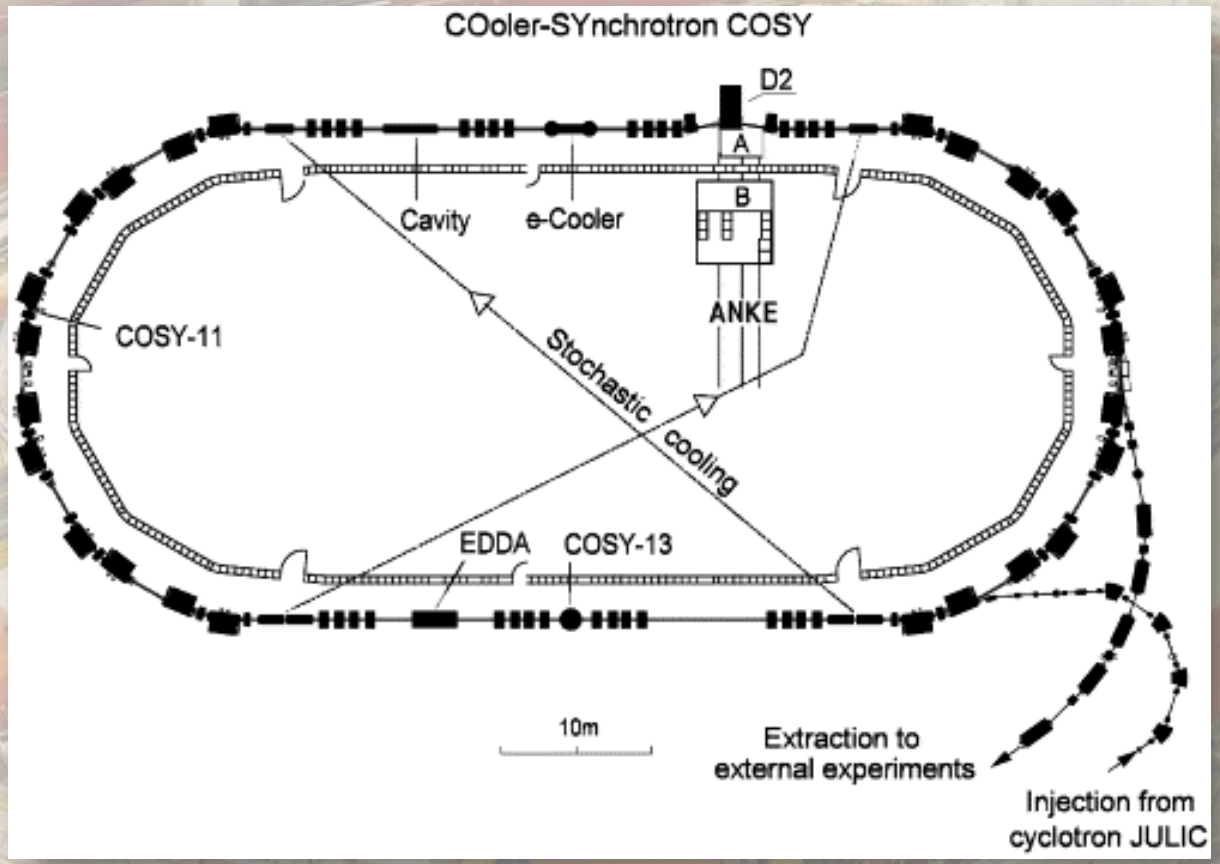




0° Facility at TP2 in COSY

ANKE – History

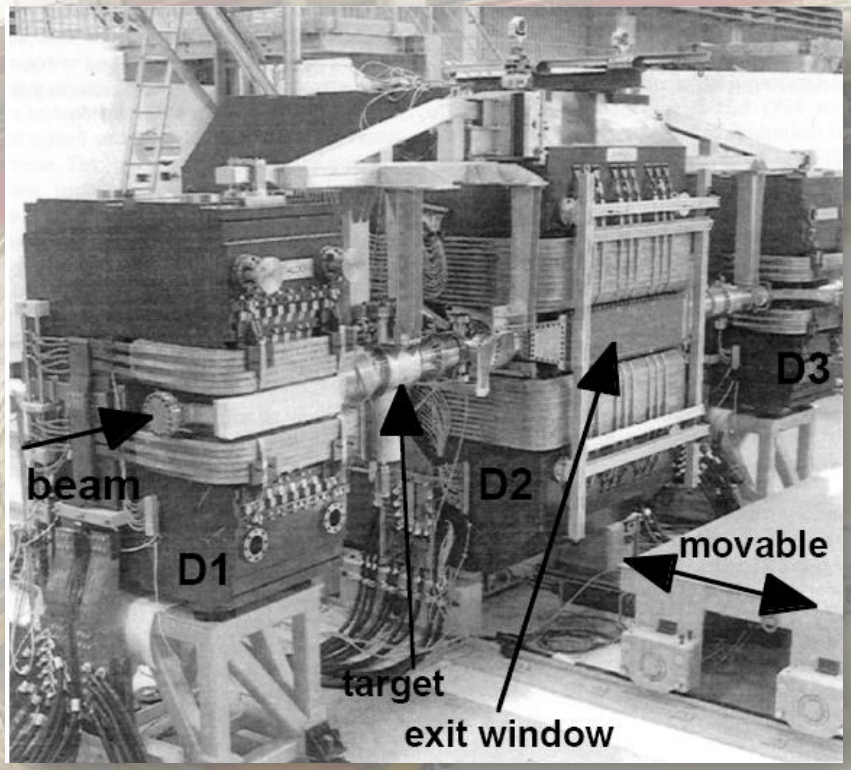
Early 90´s: a 2nd generation internal target experiment at COSY

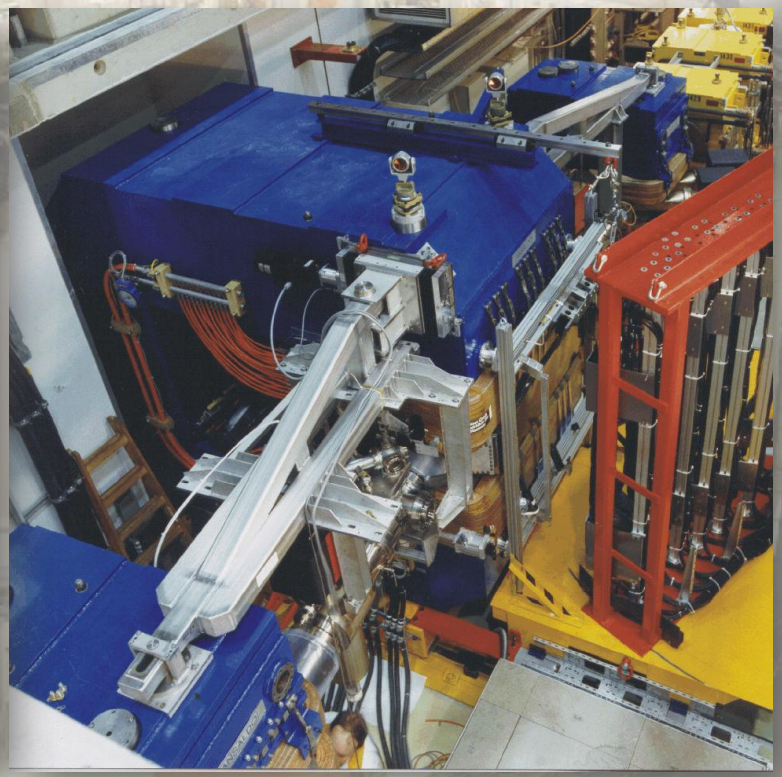


Facility moves to other side of COSY ring

ANKE – History

From plans to realization:

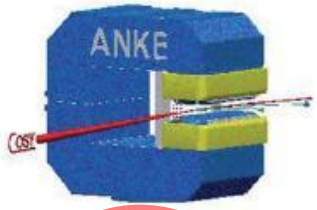




ANKE, the ***A**pparatus for **N**ucleon and **K**aon **E**jectiles*

ANKE – History

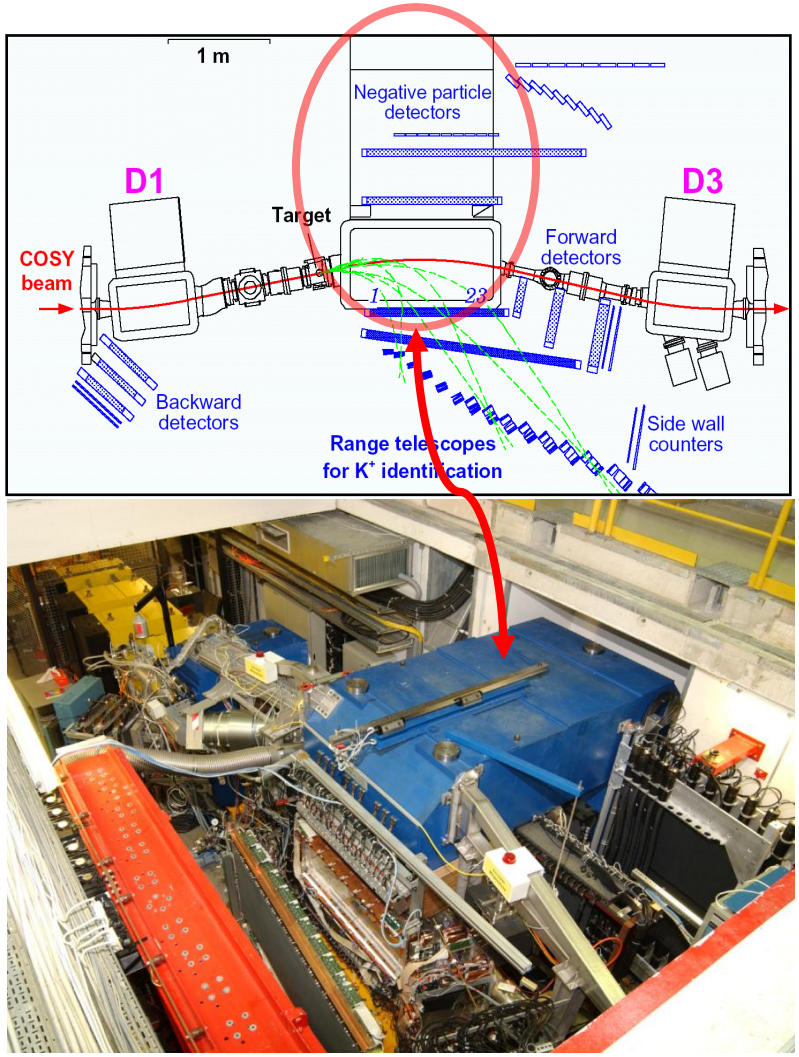
10 Years of ANKE Experiments at COSY-Jülich (1998 – 2008)



ANKE : "**A**pparatus for **S**tudies of **N**ucleon and **K**aon **E**jectiles"

ANKE – Dipole spectrometer

Apparatus for Nucleon and Kaon Ejectiles (COSY-Jülich)



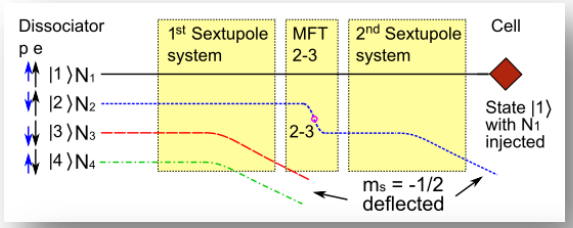
ANKE (double polarization):

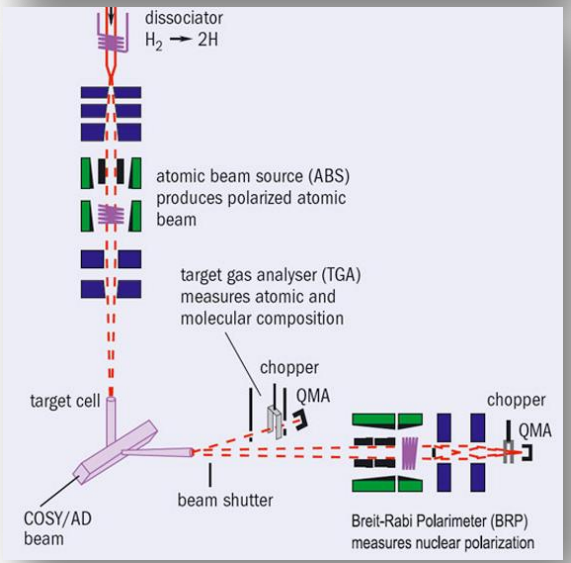
- Magnetic spectrometer (3 dipoles)
- Focal plane telescopes
- Internal beam
- Strip targets (kaon program)
- (Un-), polarized target (PIT)

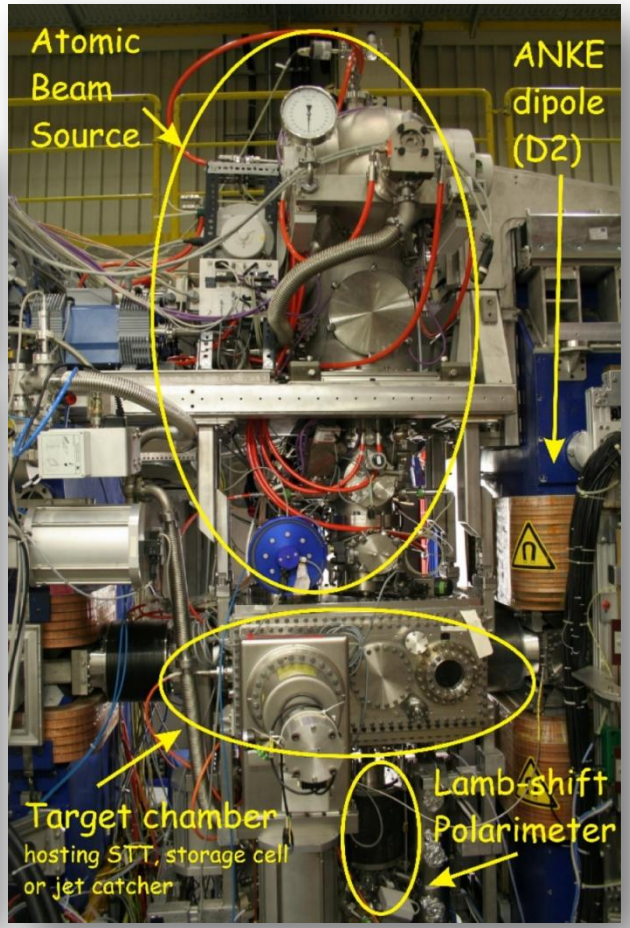
ANKE – Targets

Polarized hydrogen and deuterium targets:

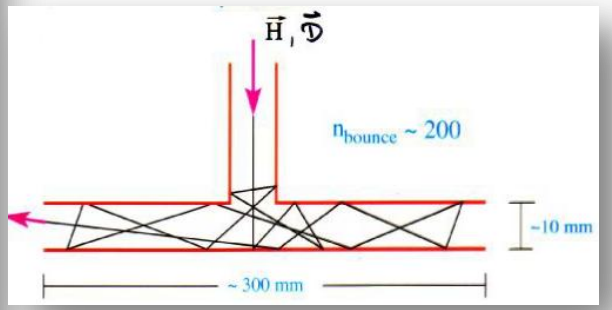
Operation principle

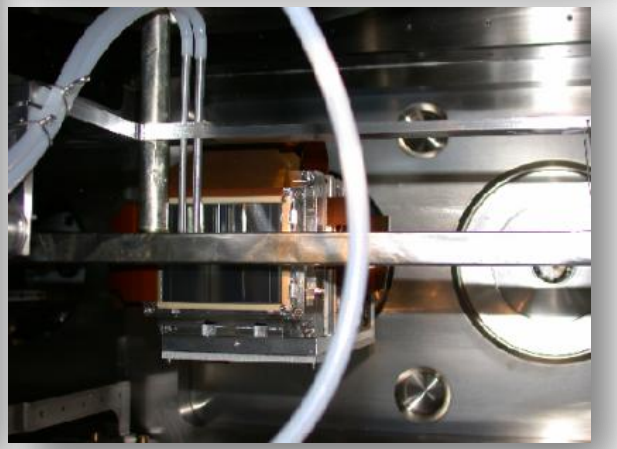






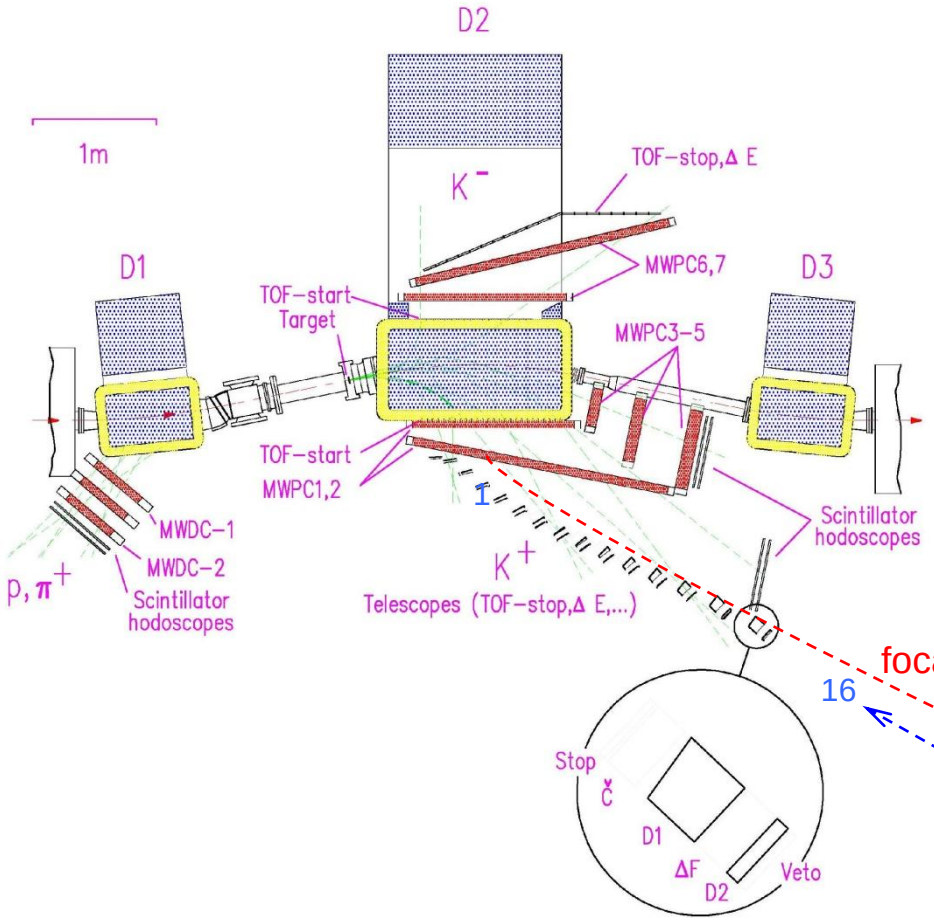
Storage cell





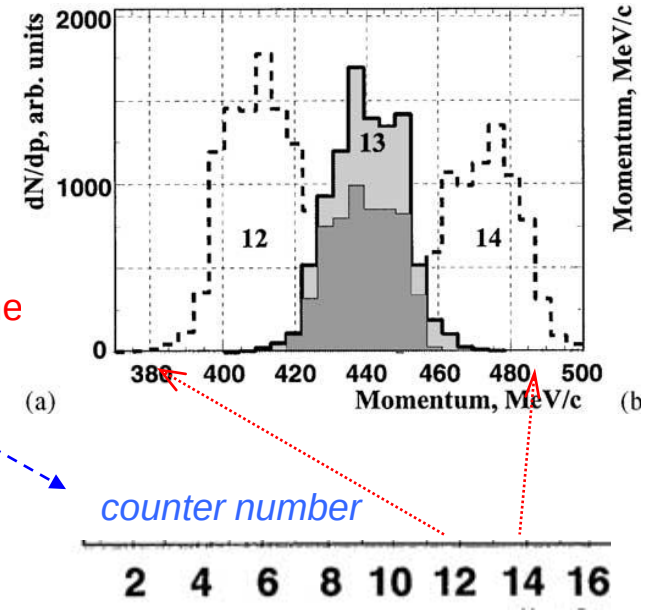
ANKE – Charged particle identification

Measure simultanuously positively and negatively charged particles:
***e.g.*, pp → pp $K^+ K^-$**



particle identification by dE/dx

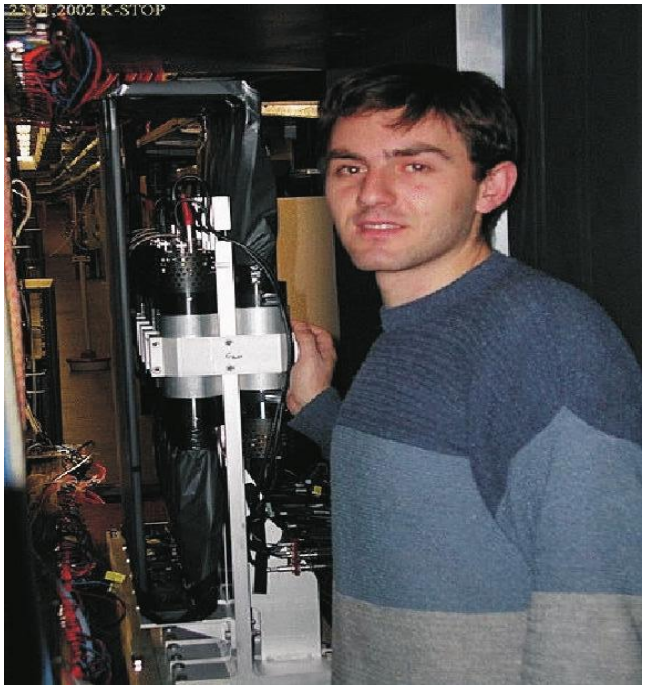
$$\frac{dE}{dx} \propto \frac{1}{v^2} \propto \frac{m}{T} \propto \frac{m^2}{p^2}$$



ANKE (history) – Georgian expertise

Strong contribution to: Hardware & Software & Analysis in Hadron Physics Experiments at COSY

Few examples from ANKE: Cherenkov detectors proposed and manufactured by HEPI TSU

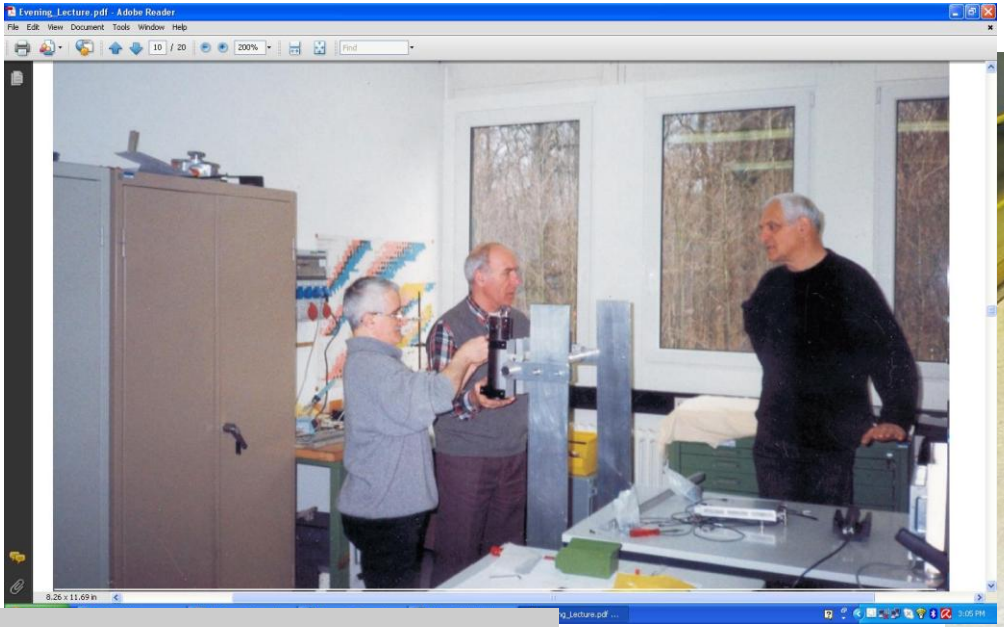


ANKE (history) – Georgian expertise

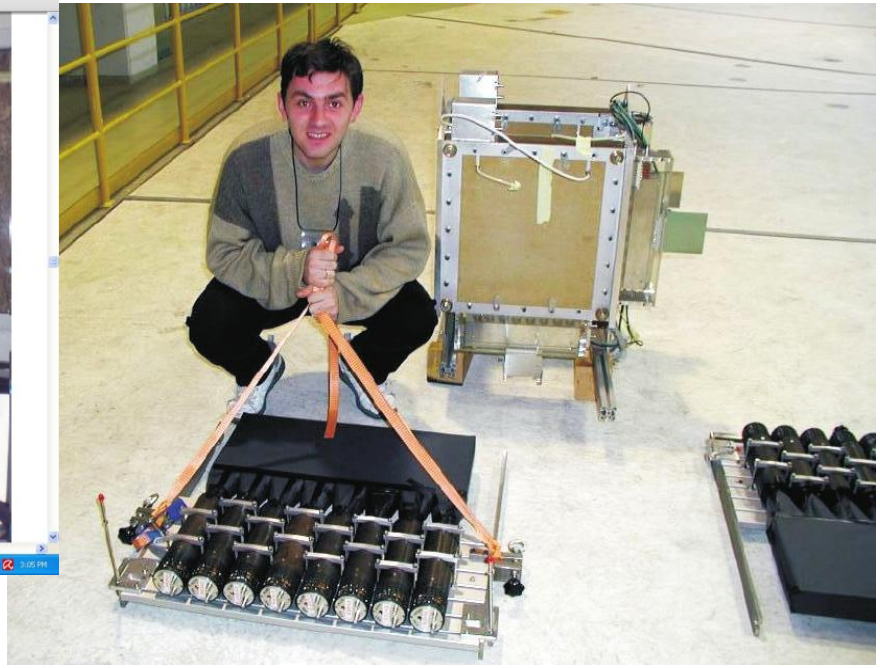
Strong contribution to: Hardware & Software & Analysis in Experiments

at COSY: 4 PhD and 5 Master thesis !

Few examples from ANKE: Cherenkov counters (HEPI TSU & IKP)



Final assembly in IKP (1999)



ANKE – Cherenkov counters

Nuclear Instruments and Methods in Physics Research A 10606 (1996) 356–360

ELSEVIER

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

Beam test of Cherenkov counter prototype for ZDF setup

A. Kacharava [a,1], G. Macharashvili [a,1], M. Nioradze [a], V. Komarov [b], V. Sopov [c], V. Tchernyshev [c]

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[c] *Institute for Theoretical and Experimental Physics, Moscow, 117259 Bolshaya Cheremushkinskaya St.89. Russian Federation*

Received 7 November 1995; revised form received 15 January 1996

If $\theta_R + \delta > \theta_C$ no total internal reflection !

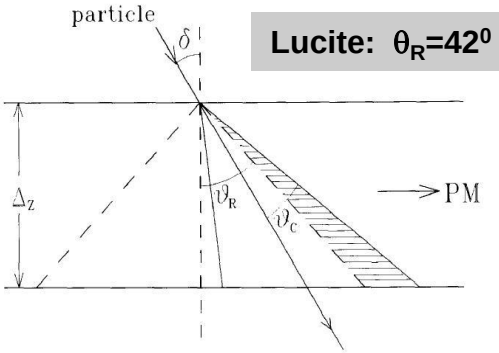


Fig. 1. The angle definitions in the radiator. The shaded area corresponds to the $\Delta\phi$ projection (see text).

Lucite: θ_R=42⁰

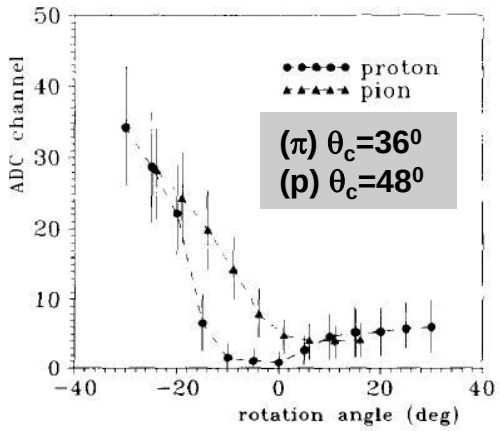


Fig. 4. Measured pulse heights for protons and pions vs the inclination angle δ_0 at 1.5 GeV/c.

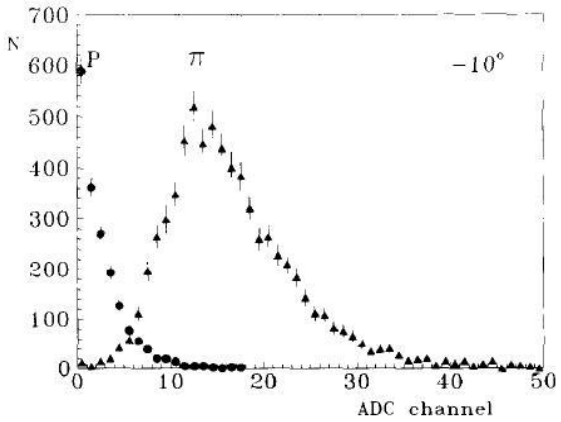
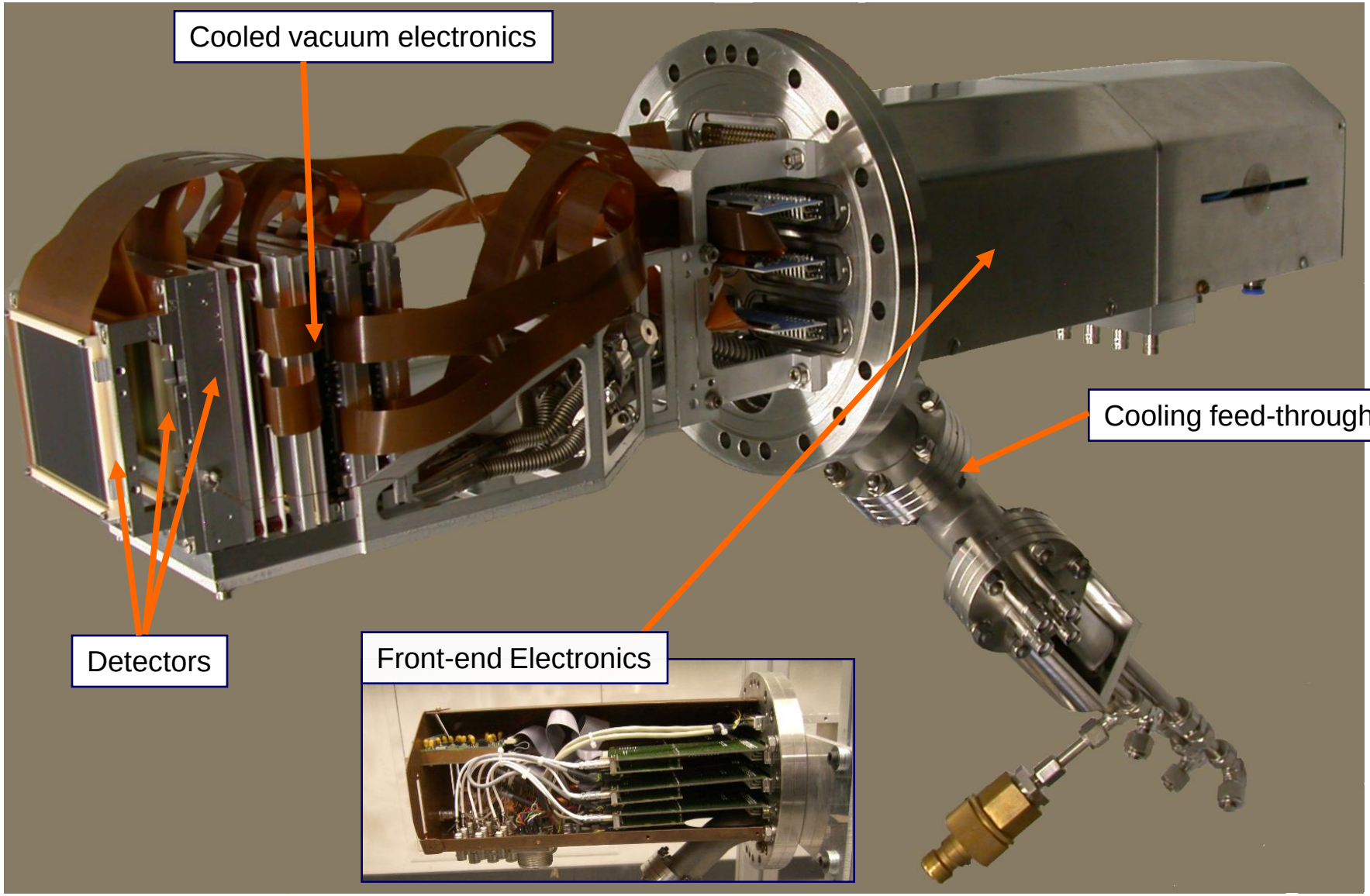


Fig. 5. Pulse-height distributions for protons and pions at 1.5 GeV/c, corresponding to the inclination angle $\delta_0 = -10°$ in Fig. 4.

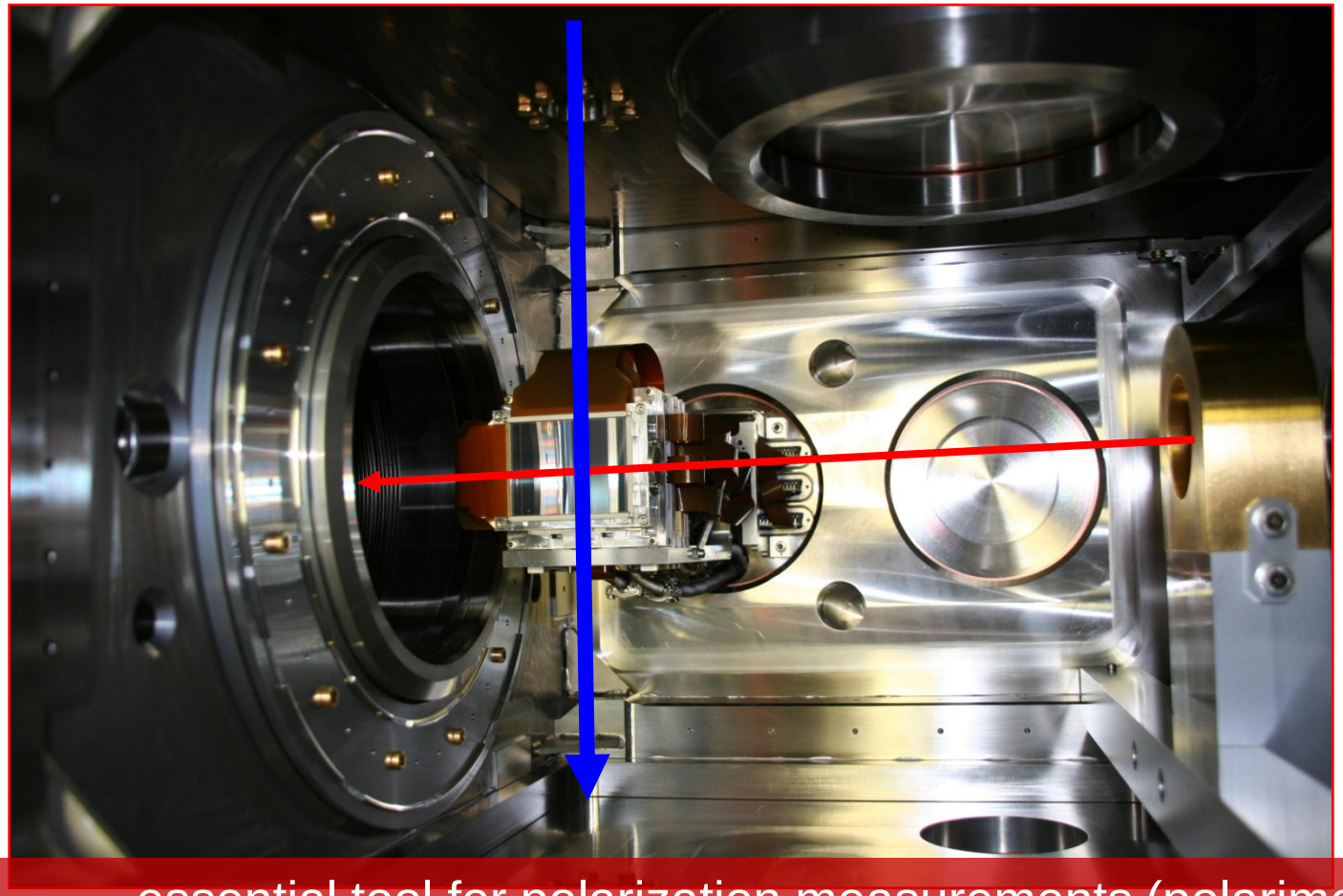
before ANKE, there were the test experiments at ITEP (Moscow)

ANKE – Silicon Tracking Telescope



ANKE – STT in target chamber

Cluster Target Beam



COSY Beam

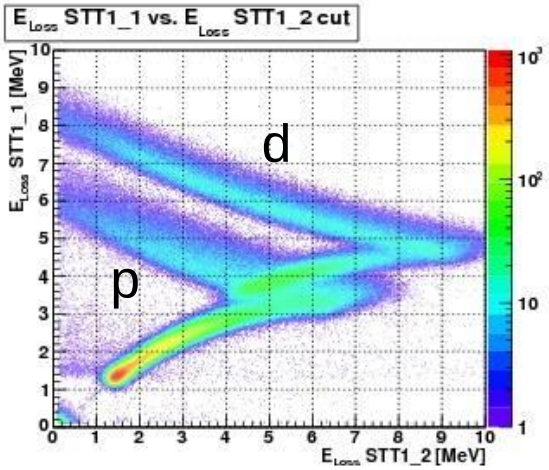
essential tool for polarization measurements (polarimetry)

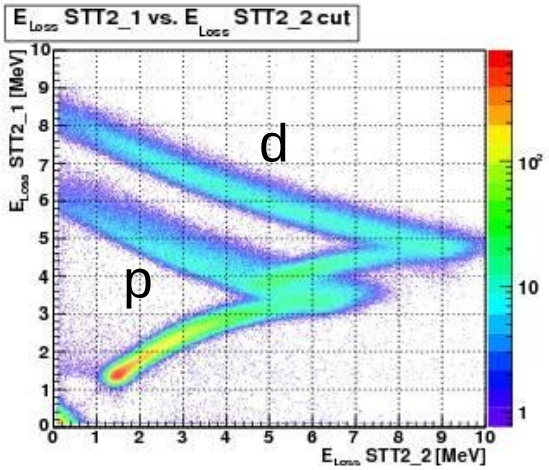
ANKE – STT calibration

Left Telescope

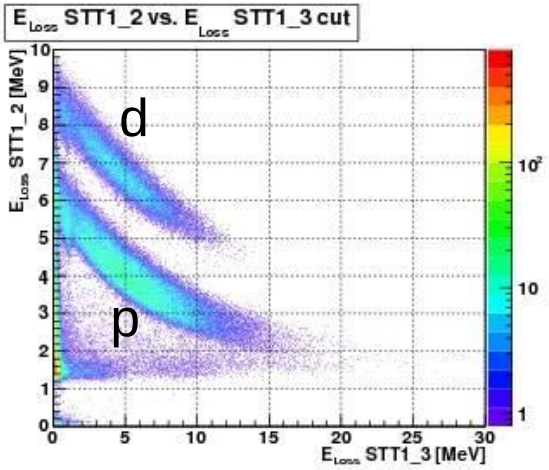
Right Telescope

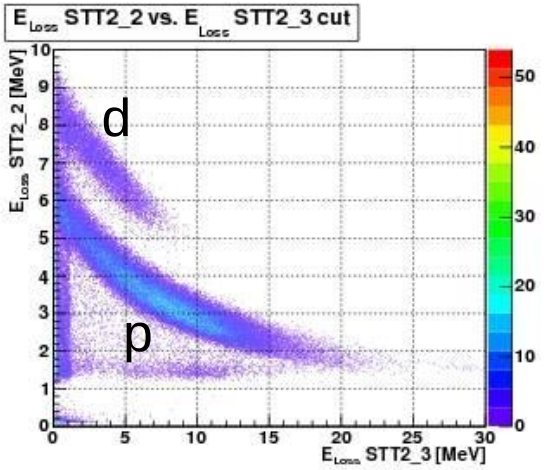
$\Delta E_1(300\mu m)$ vs. $\Delta E_2(300\mu m)$





$\Delta E_2(300\mu m)$ vs. $\Delta E_3(5000\mu m)$

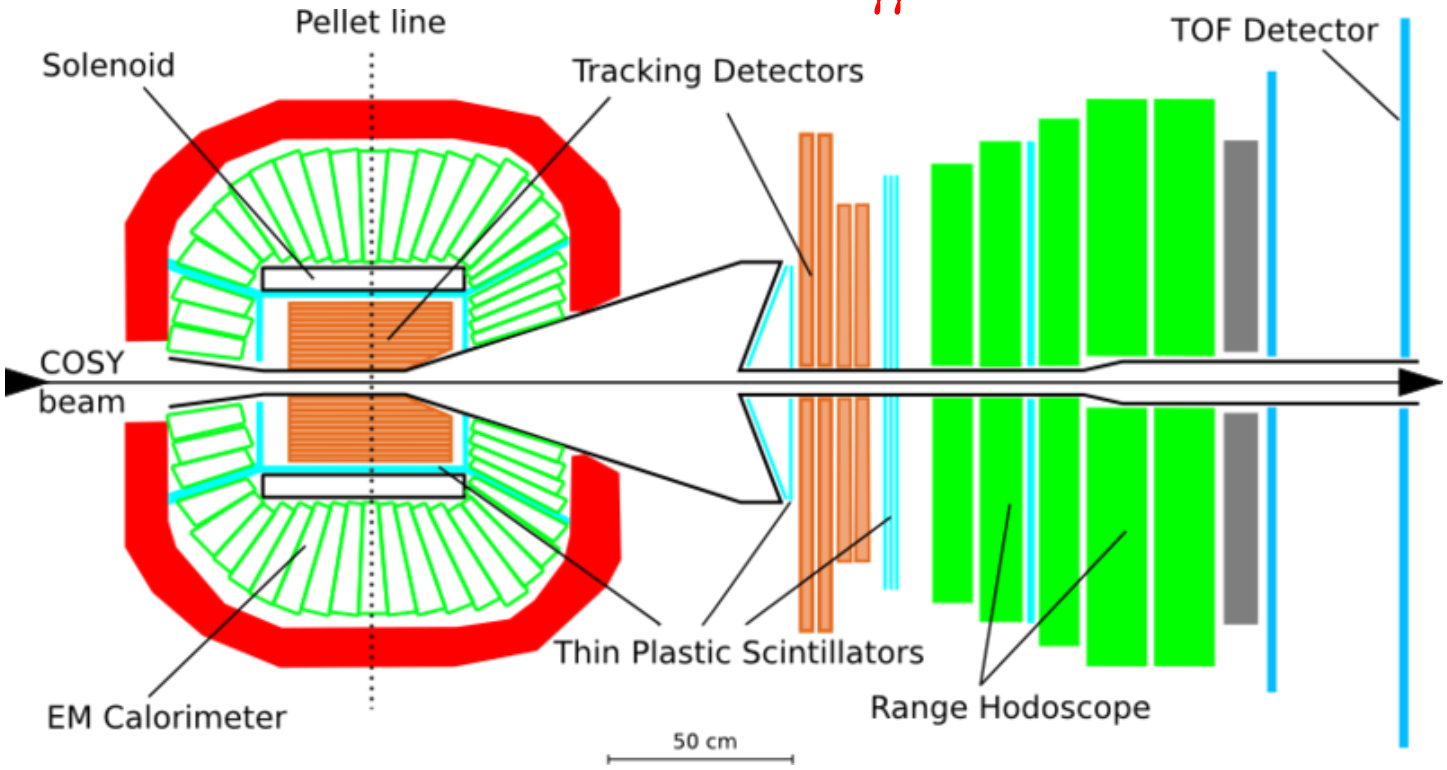




WASA – Neutral particle measurements

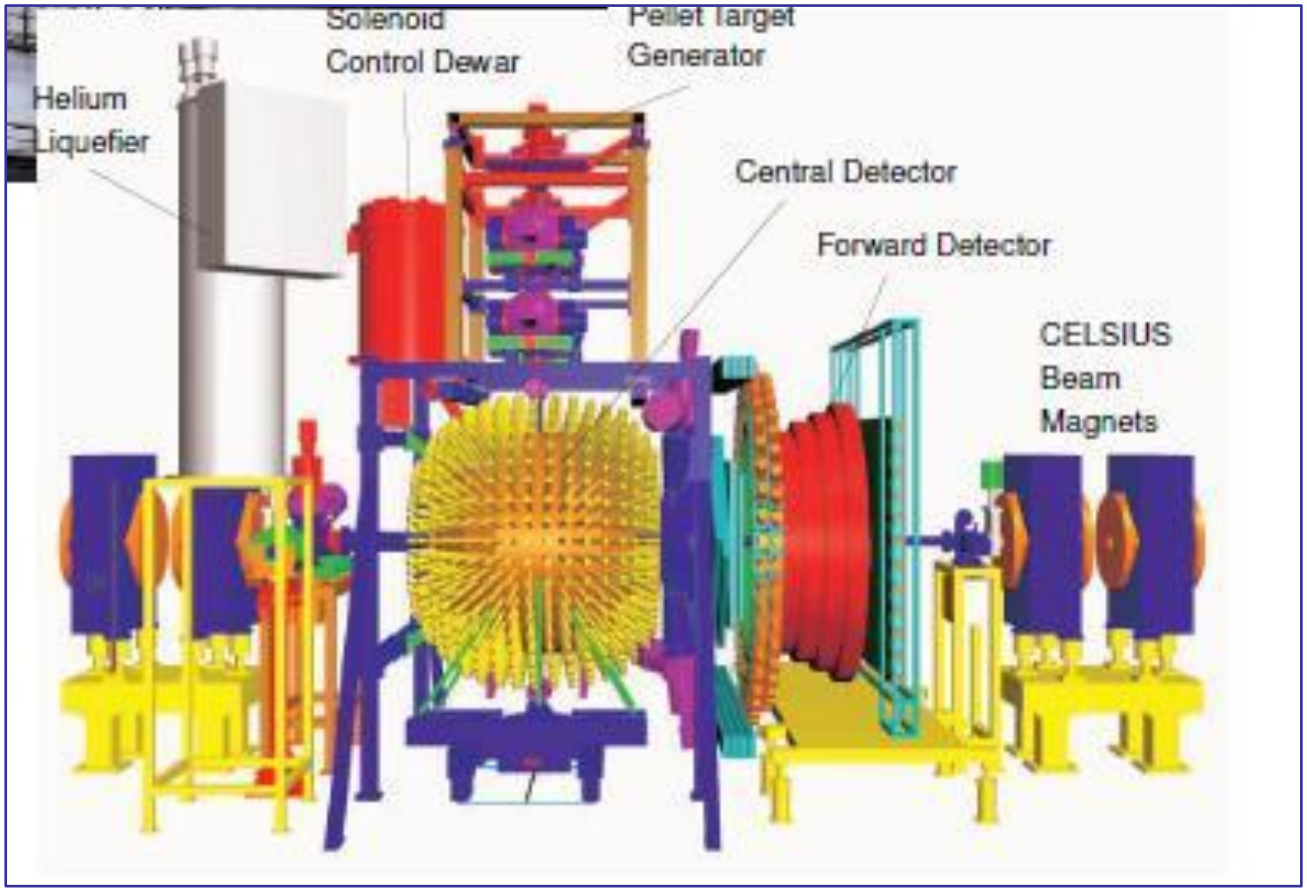
Measure photons from neutral particle decay in coincidence with charged particles

***e.g.*, dd → ^{4}He π^0**
↓
$\gamma\gamma$

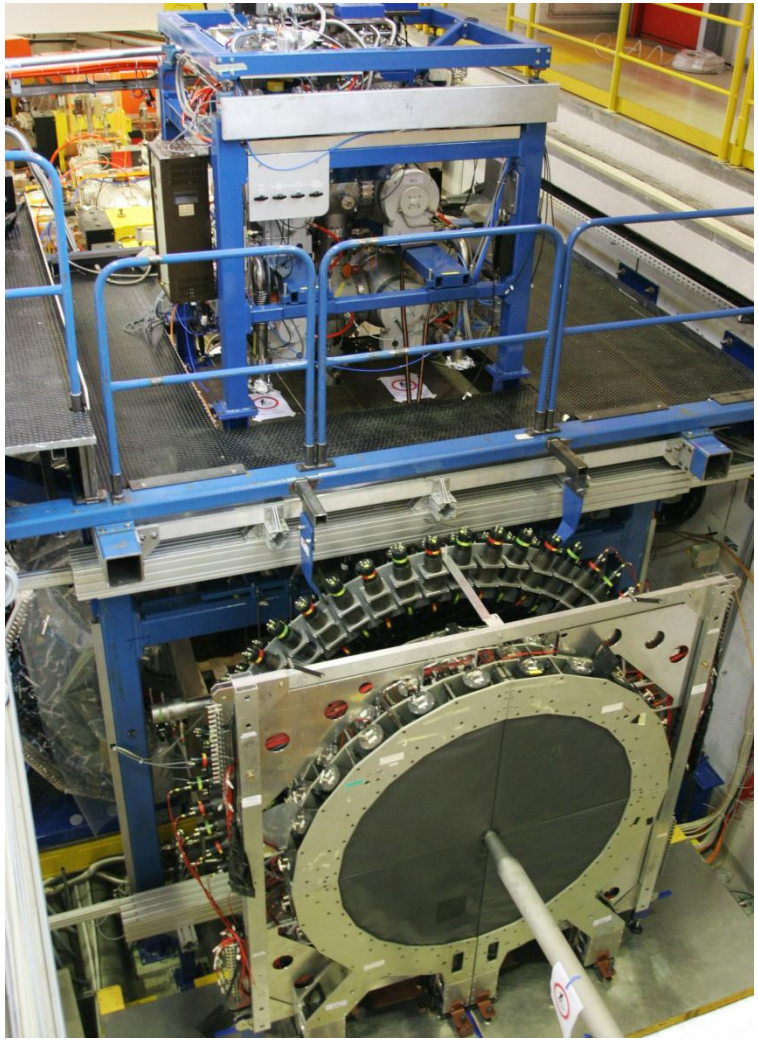


photon detector: calorimeter ***charged particle detector: forward hodoscope***

WASA – Wide Angle Shower Apparatus



WASA – Wide Angle Shower Apparatus

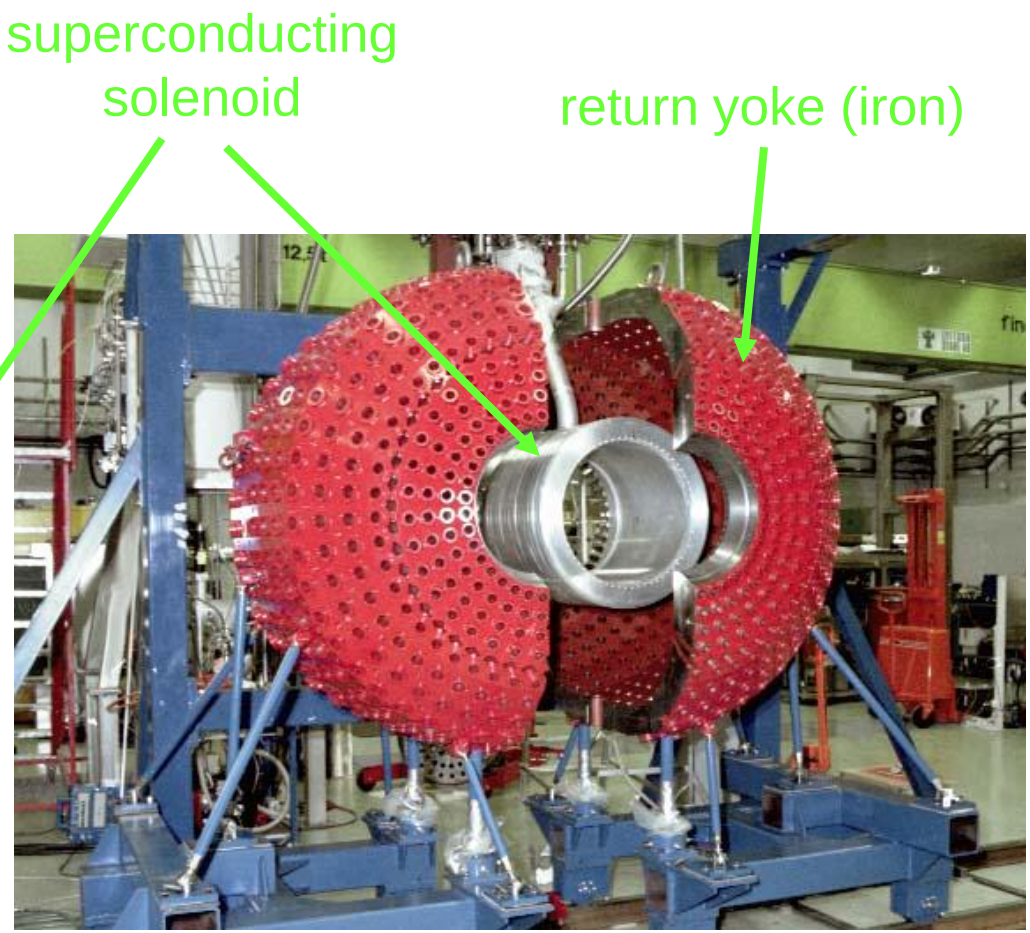


WASA at COSY:

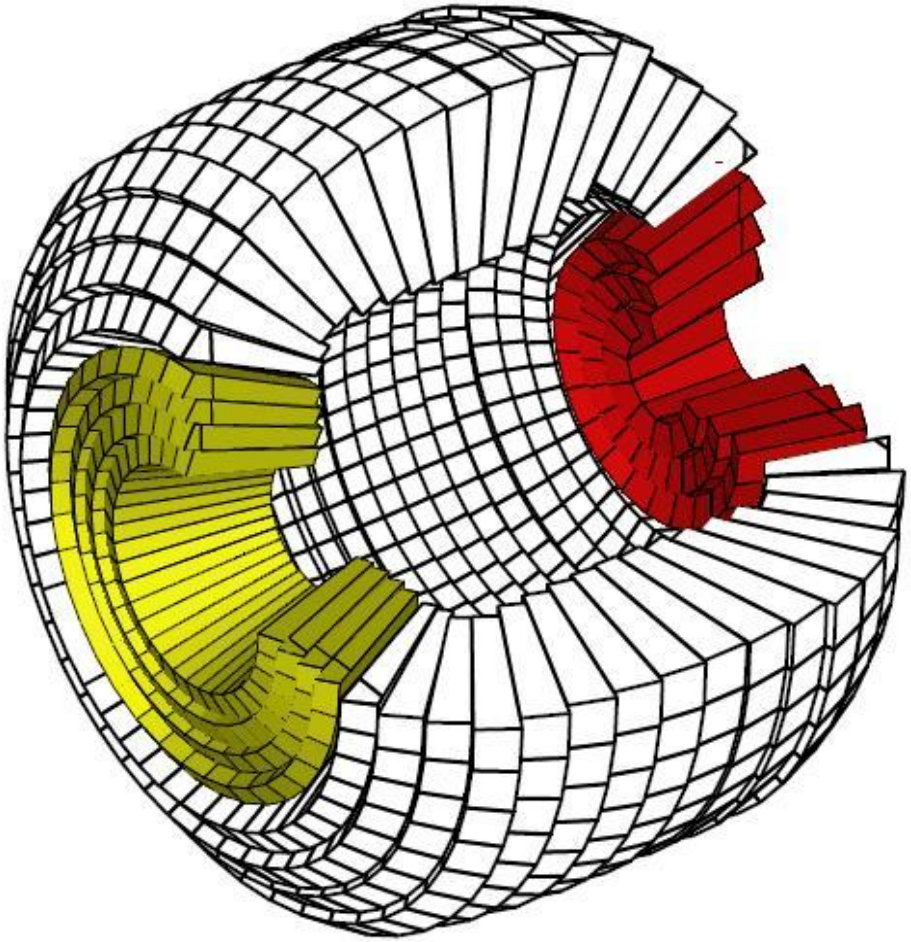
- Internal beam
- Electromagnetic calorimeter
- SC solenoid
- Inner and forward tracking
- Pellet target (unpolarized)

→ Charged particle and photon detection

WASA – Solenoid



WASA – Calorimeter

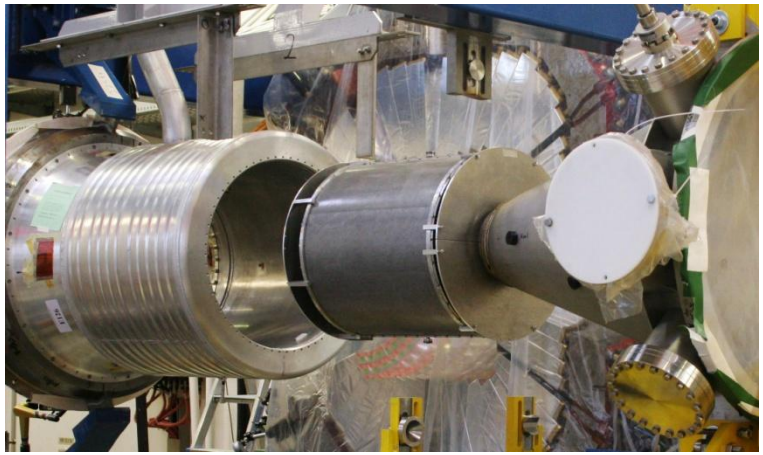


- Scintillator Electromagnetic Calorimeter consists of 1012 sodium doped CsI crystals
- 24 layers along the beam

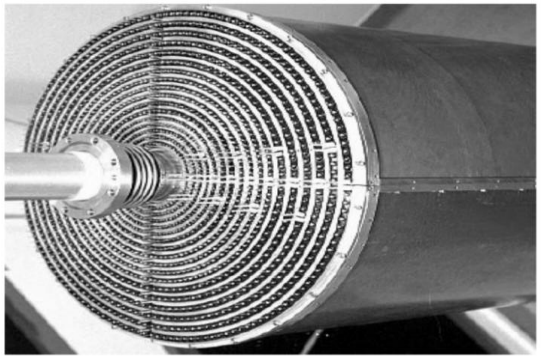
WASA – Calorimeter

WASA – Forward Hodoscope

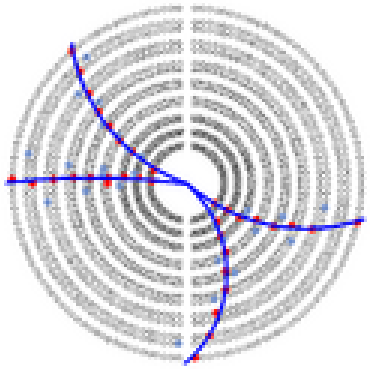
WASA – Mini drift chamber



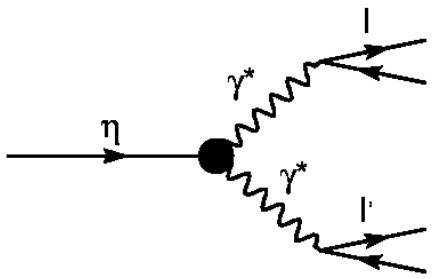
put in magnetic field



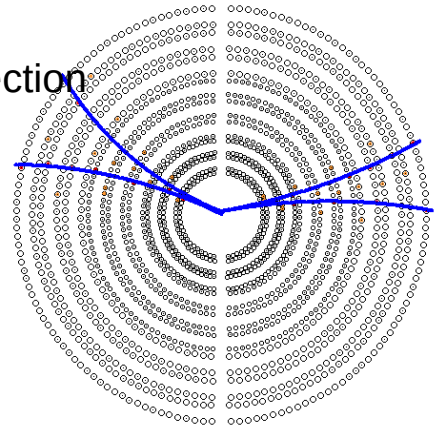
get curved particle trajectories



WASA – Example: $\eta \rightarrow e^+e^- e^+e^-$



XY-projection



$\eta \rightarrow e^+ e^- e^+ e^-$ candidate event display, blue lines: fitted particle tracks

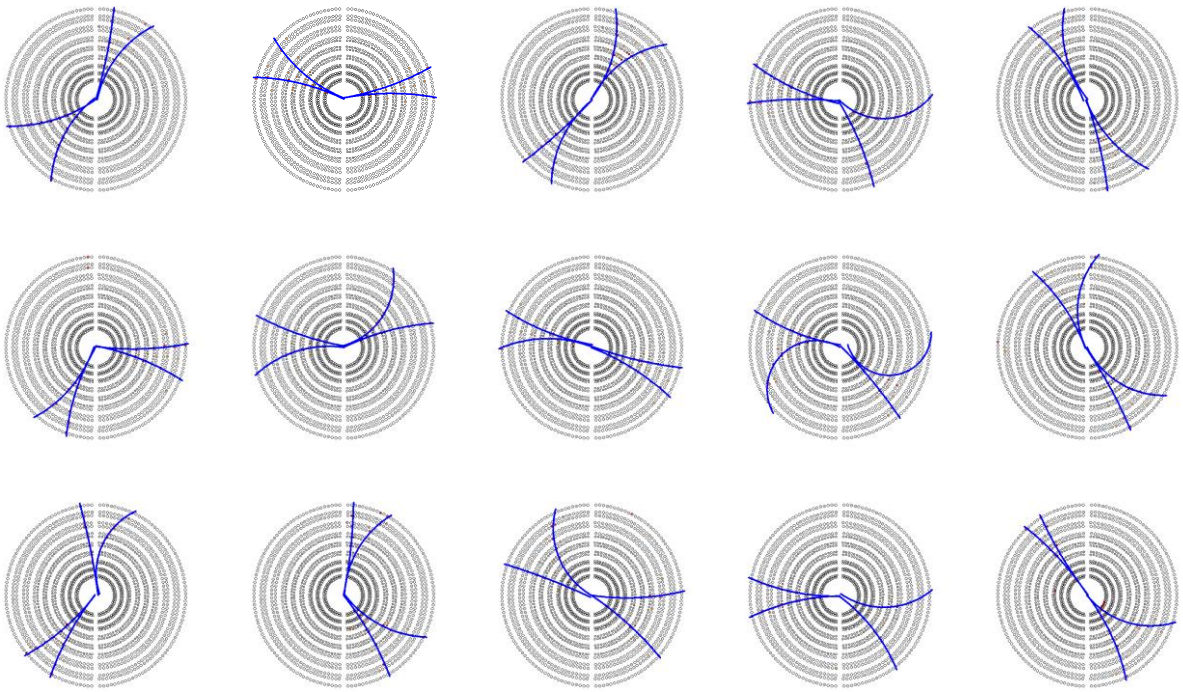
this is a rare decay

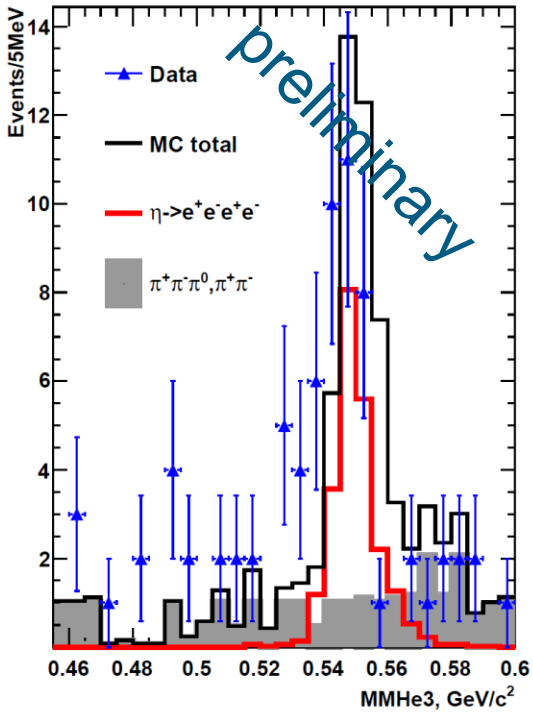
how many such events can one find?

→ determination of branching ratio

WASA – Example: $\eta \rightarrow e^+e^- e^+e^-$

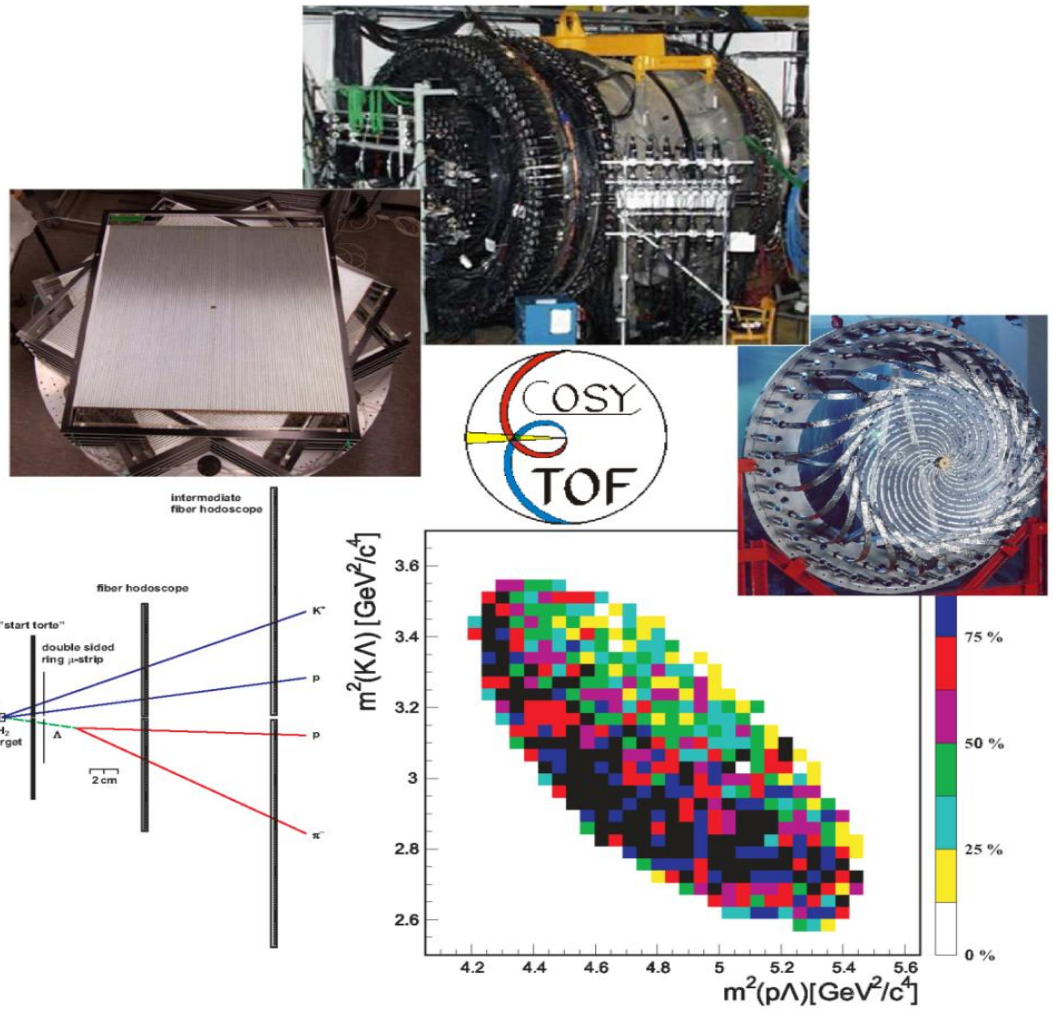
preliminary result: 15 event candidates, 4 weeks pd → ^{3}He η





(22 candidates)

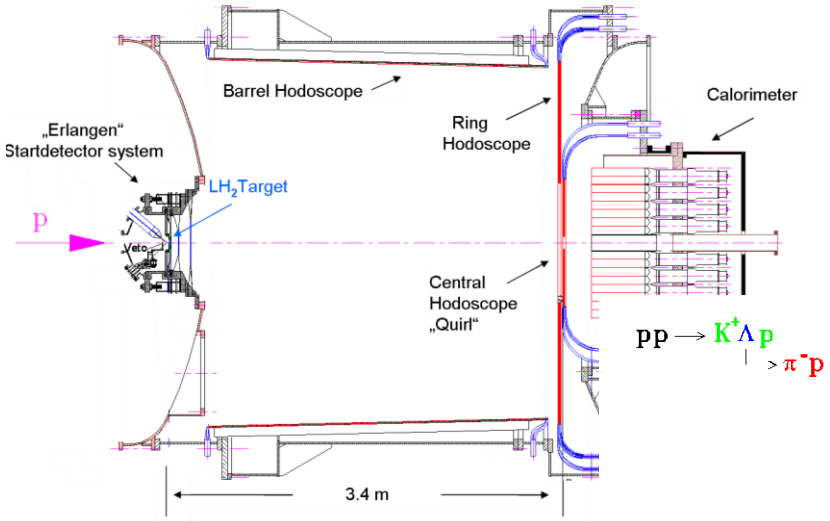
TOF – Time-Of-Flight Spectrometer at COSY



TOF:

- Non-magnetic (t-o-f) spectrometer
- Extracted beam
- Large acceptance
- Un- (polarized) cryo-targets

TOF – Characteristics of the COSY-TOF

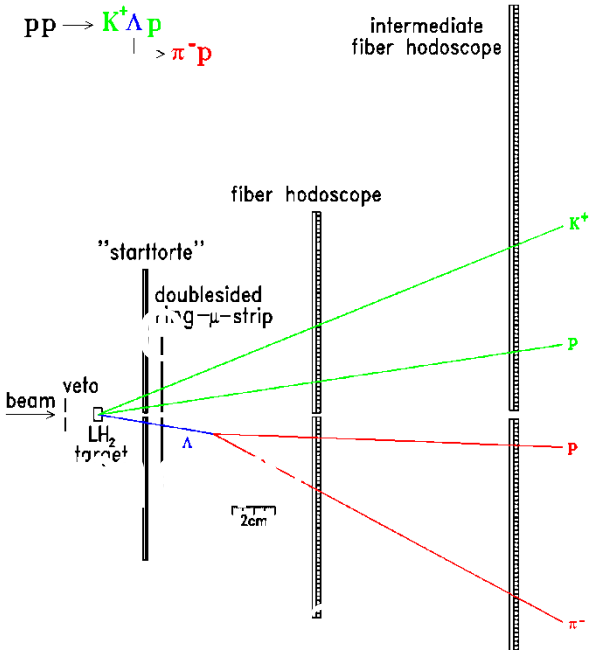


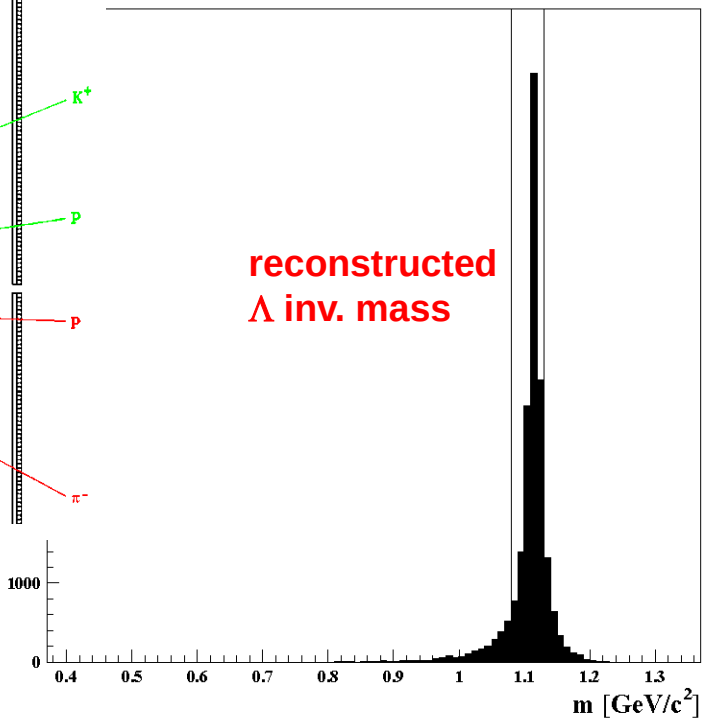
Ideal for: strangeness final states;

full angular distributions;

differential observables including polarization

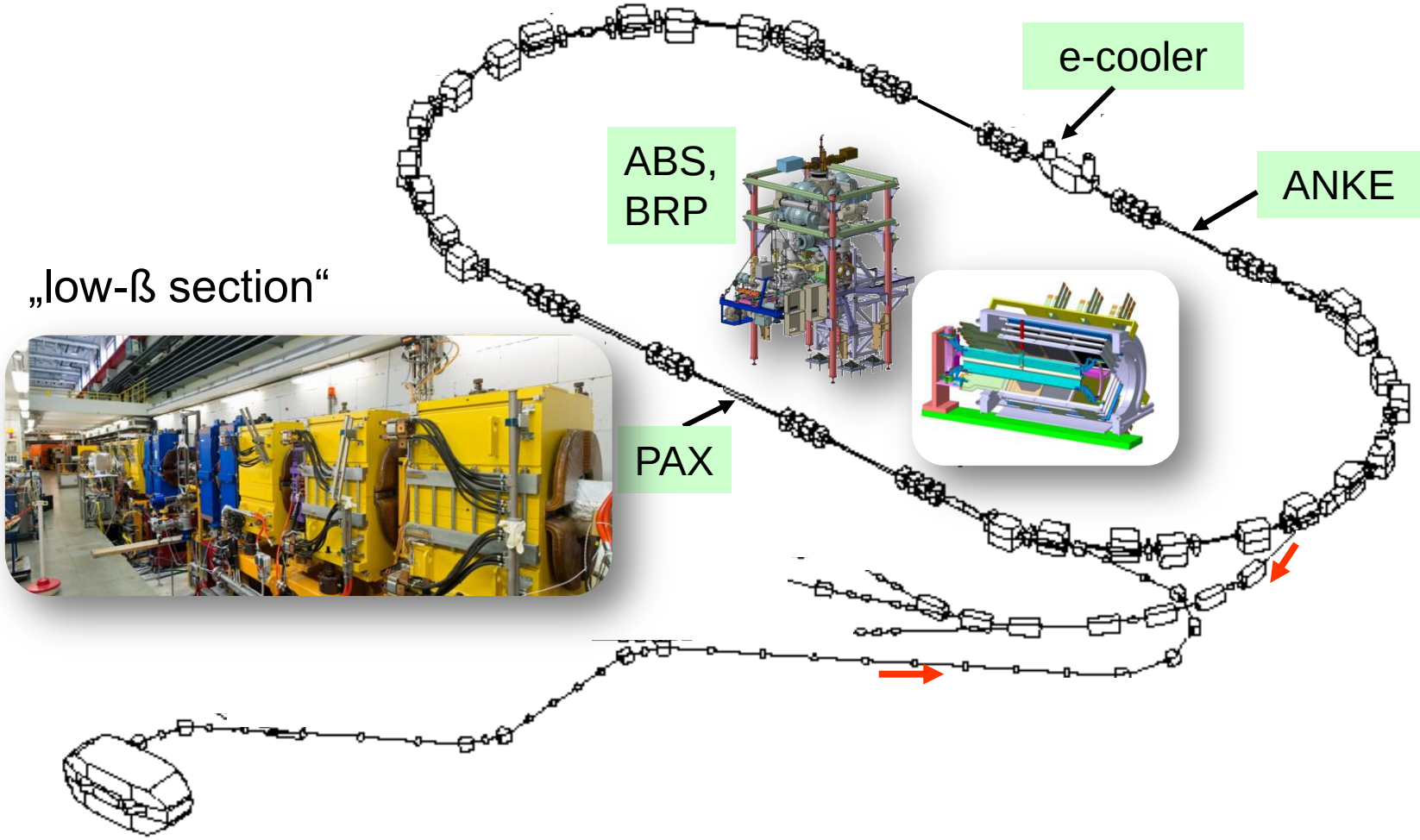
- large acceptance
- azimuthal symmetry
- good track resolution
- „strangeness“ trigger:
  $\Lambda \rightarrow p\pi^-$, $K_s \rightarrow \pi^+\pi^-$
- delayed vertex reconstruction:
  Λ, Σ^+, K_s



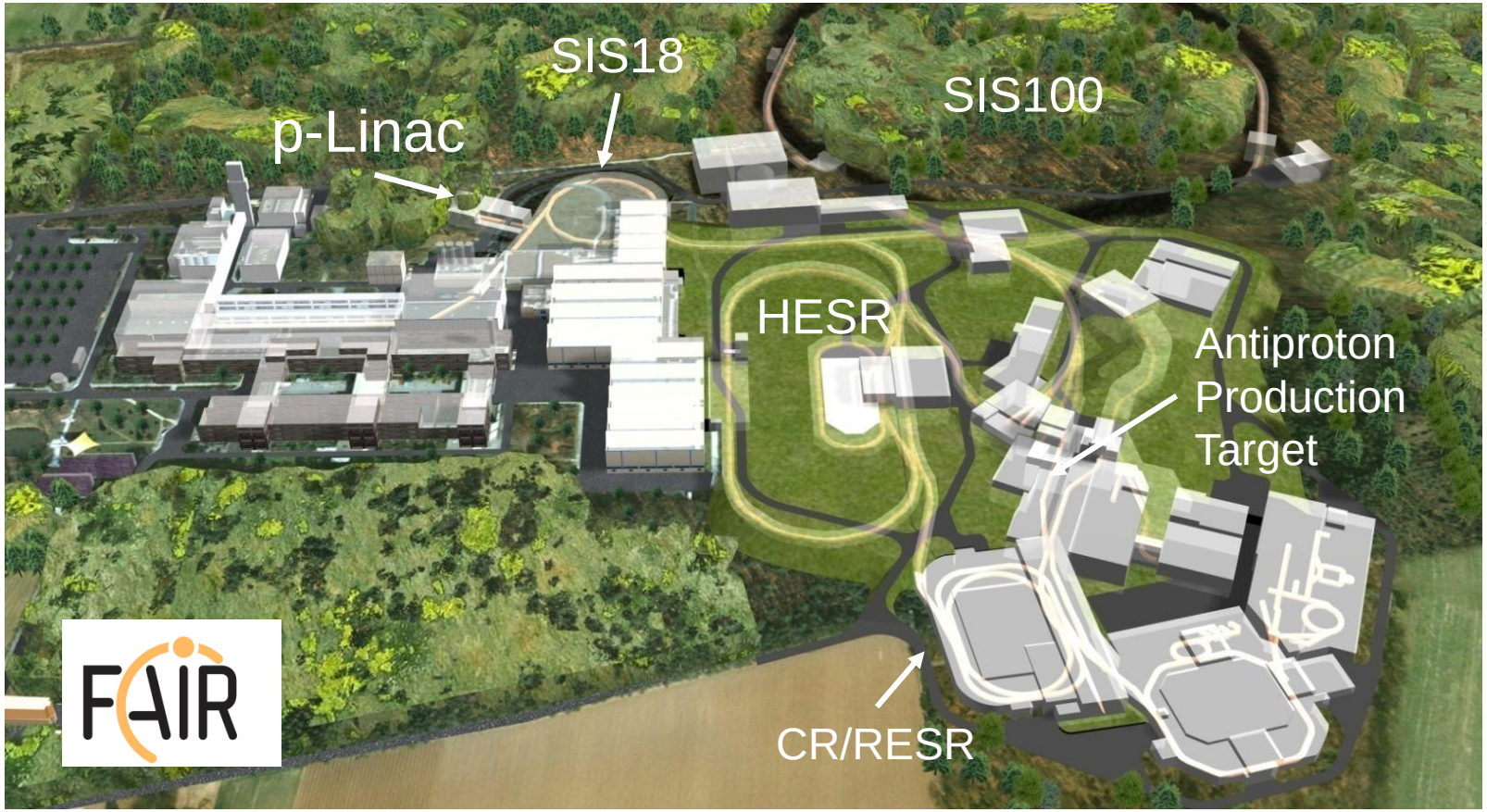


PAX – Polarized Antiproton EXperiments

Spin-filtering to produce polarized (anti-)proton beam:

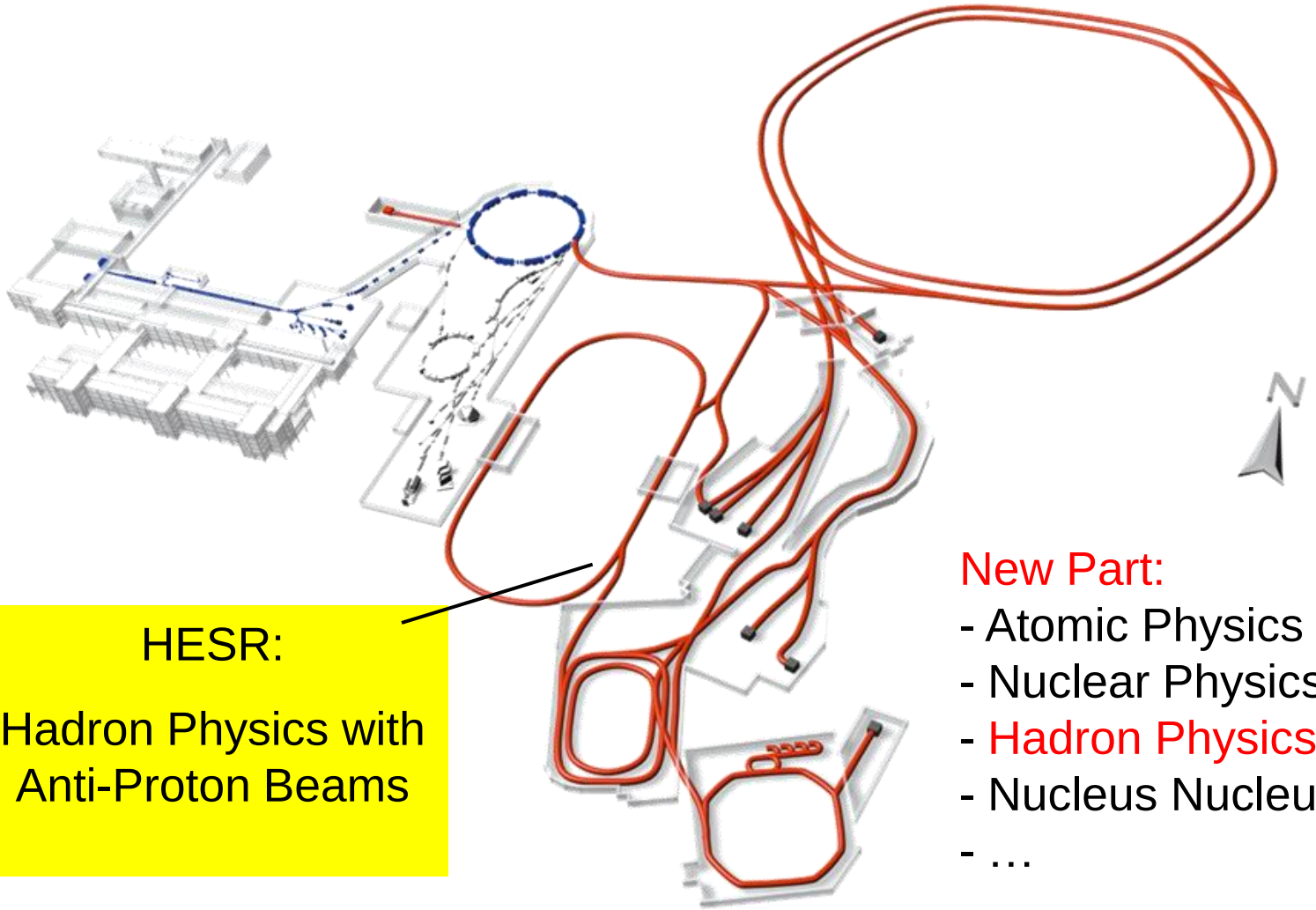


Facility for Antiproton and Ion Research



- **Unpolarized** proton, antiproton (and ion) beams, …
- HESR: stored and cooled antiprotons, momenta up to 14 GeV/c
- Internal experiment PANDA → Hadron Physics, e.g., nucleon structure

Future project– FAIR Facility at GSI (Darmstadt)

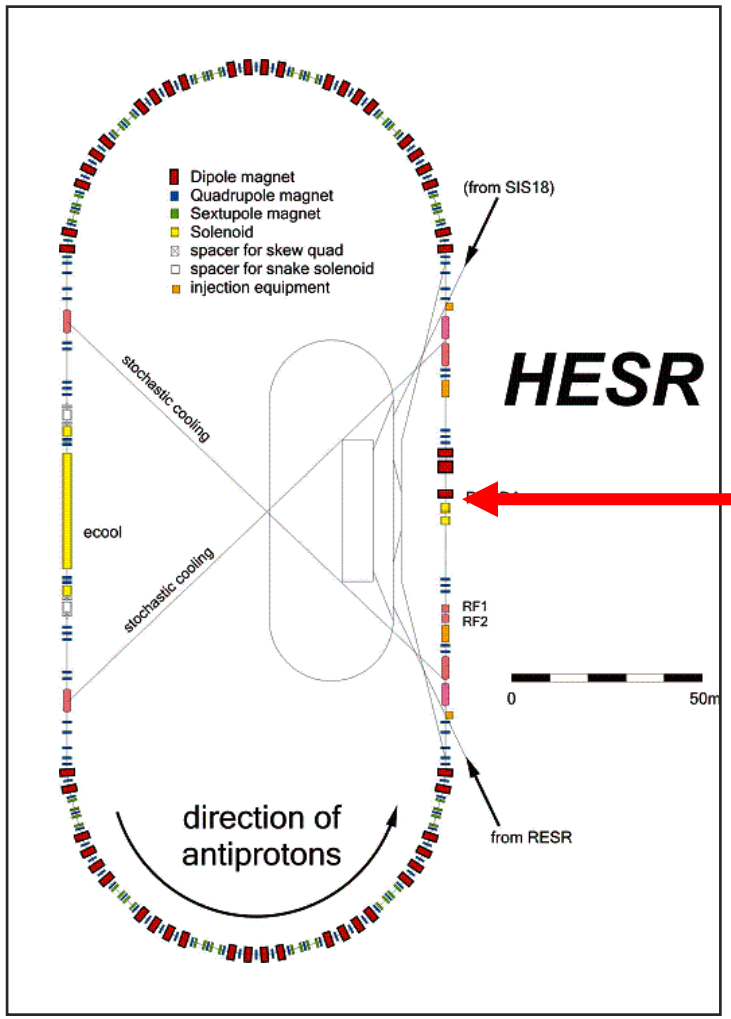


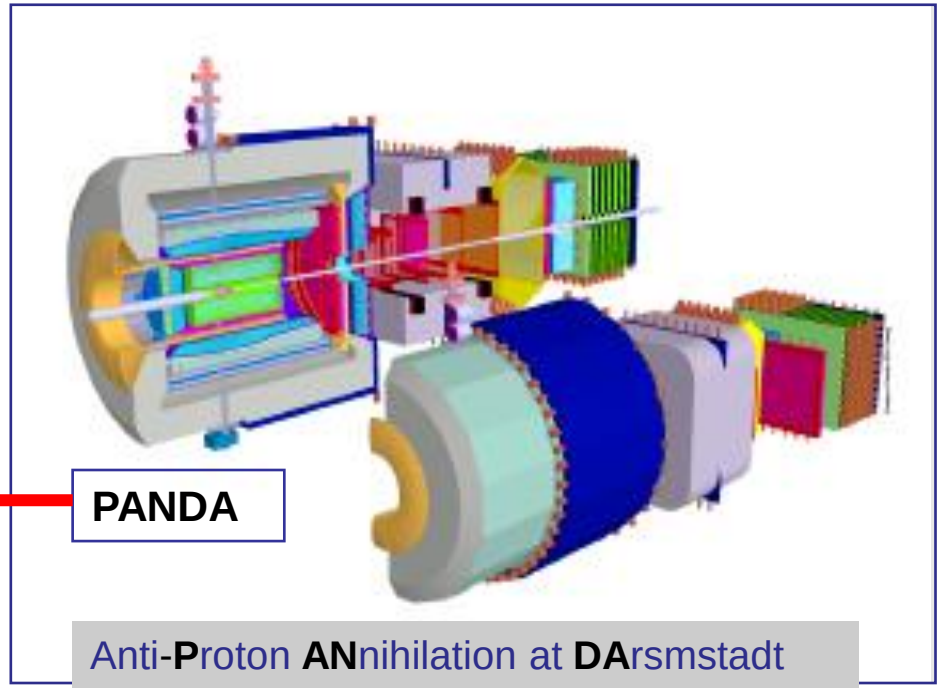
HESR:

Hadron Physics with Anti-Proton Beams

New Part:
- Atomic Physics
- Nuclear Physics (RIB)
- Hadron Physics
- Nucleus Nucleus Coll.
- …

Future facility– High Energy Storage Ring





Future upgrade option:

Polarized anti-protons

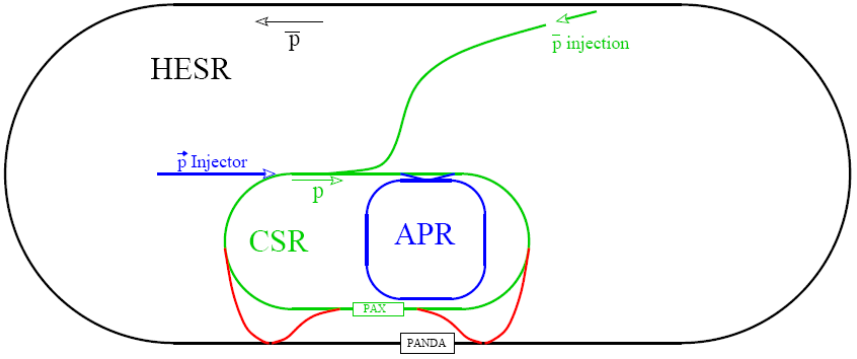
Future project– HESR upgrade (PAX)

Method: Spin Filtering ⇒ proton polarization due to multi-pass interaction with polarized targets (also works for antiprotons)

Polarized Antiproton EXperiments

Physics: Transferse spin structure of the nucleon

⇨ towards an asymmetric polarized antiproton-proton collider



- Depolarization of beams with unpolarized targets (COSY)
- Polarization build-up (COSY)
- Antiprotons (AD at CERN)

Experimental Facilities – Summary

Todays facilities are …

- Essential for the advancement in particle physics
- Gigantic and costly (because of uniqueness)
- Technologically state-of-the-art (data aquisition, …)
- …


Thank you!