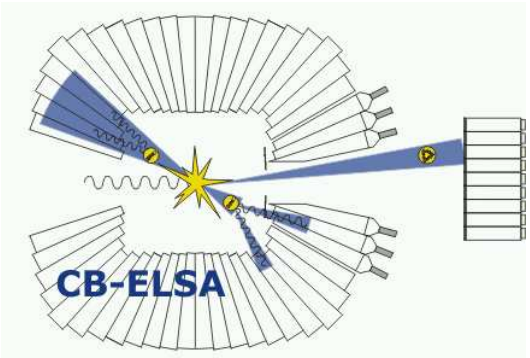
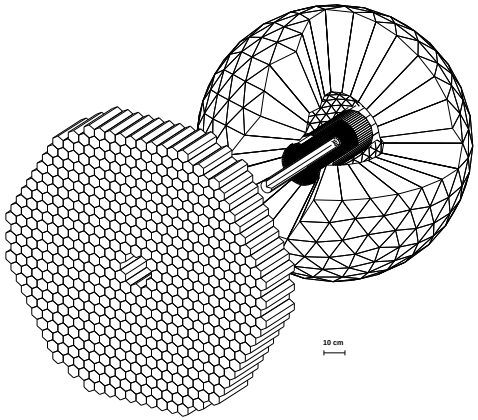
Hadron structure with photon and antiproton induced reactions
- QCD in the non-perturbative range -

- Introduction
- Present: Photoproduction of Mesons at ELSA and MAMI

CB-ELSA/TAPS Experiment



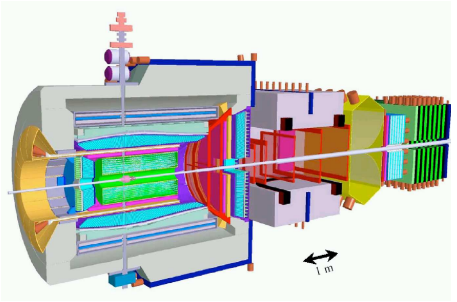
Crystal Ball/TAPS Experiment



- Future: Antiproton induced Reactions at FAIR

p a n d a

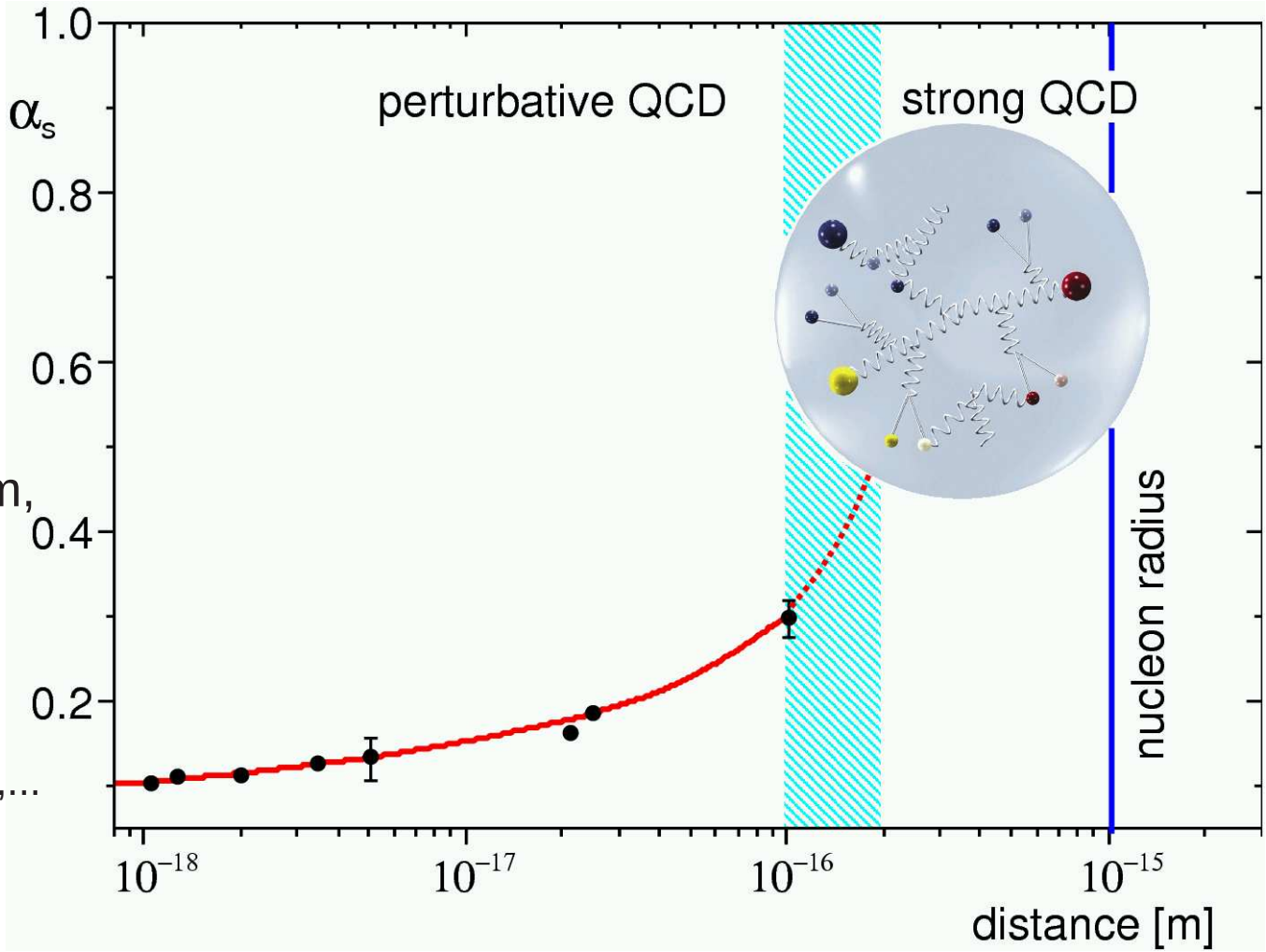
Experiment



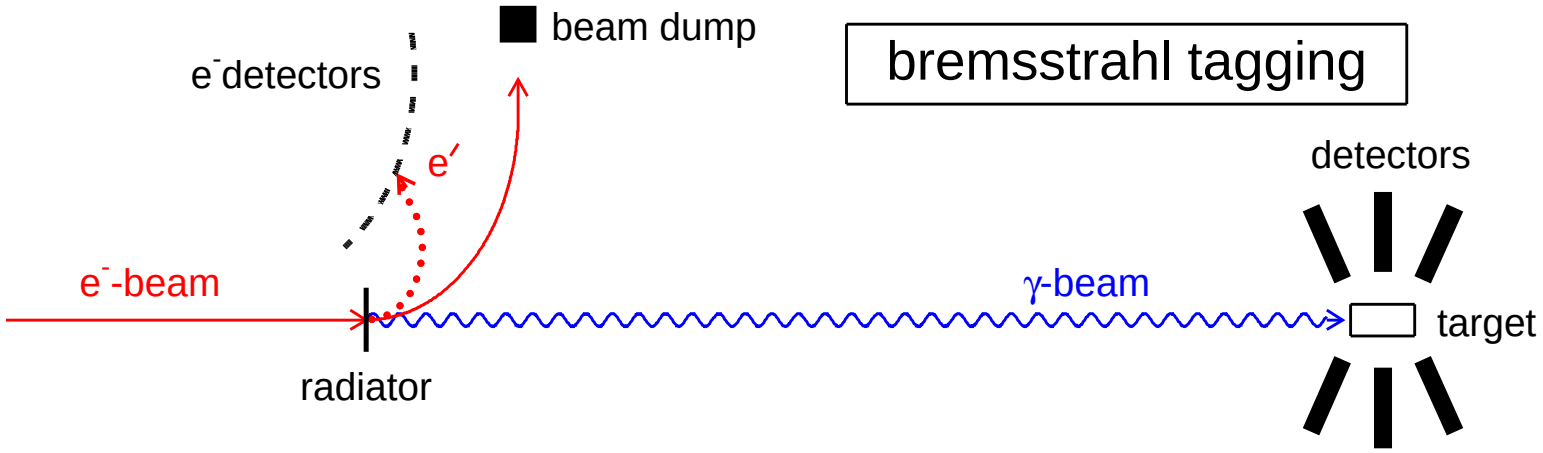
structure of hadrons - non-perturbative QCD

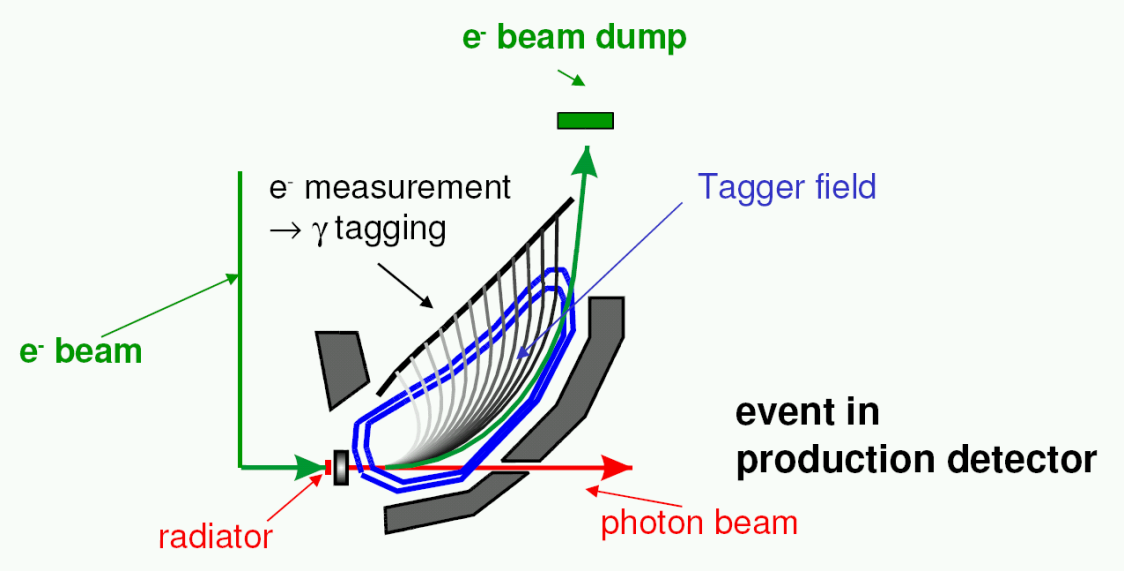
Topics:

- how is mass generated?
  (≈2 % of nucleon mass
  due to Higgs-mechanism)
- transition from current to constituent quarks?
- hadron excitation spectrum, hadron models, lattice calculations
- Do exotic hadrons exist?
  glueballs, hybrids, pentaquarks,...

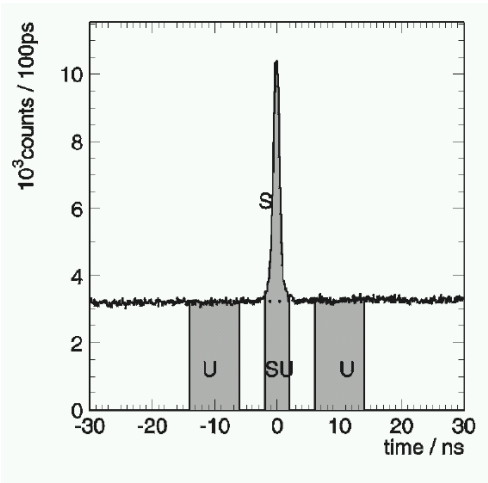


quasi-monochromatic photons from bremsstrahl tagging





time coinidence:
tagger - production detector



photoproduction of mesons: experimental observables

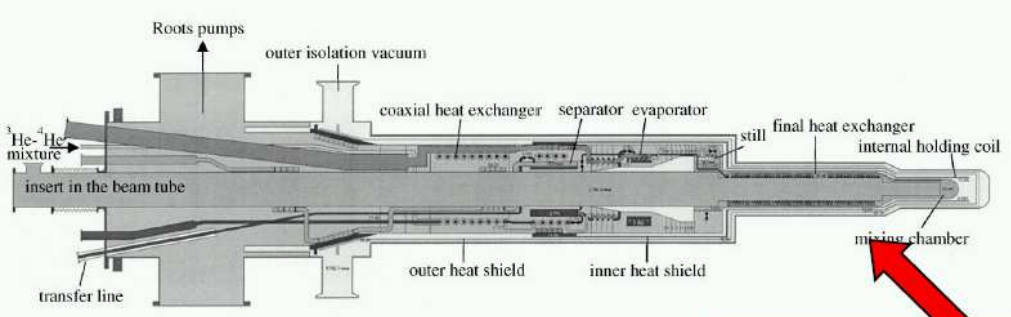
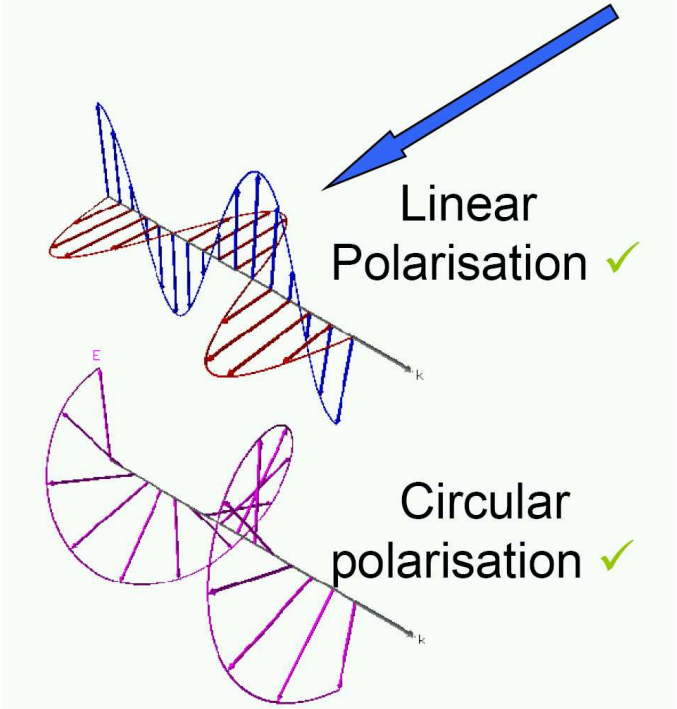


Fig. 4. Schematic diagram of the dilution refrigerator.

Longitudinally polarised proton target ✓
Transversely polarised ✓

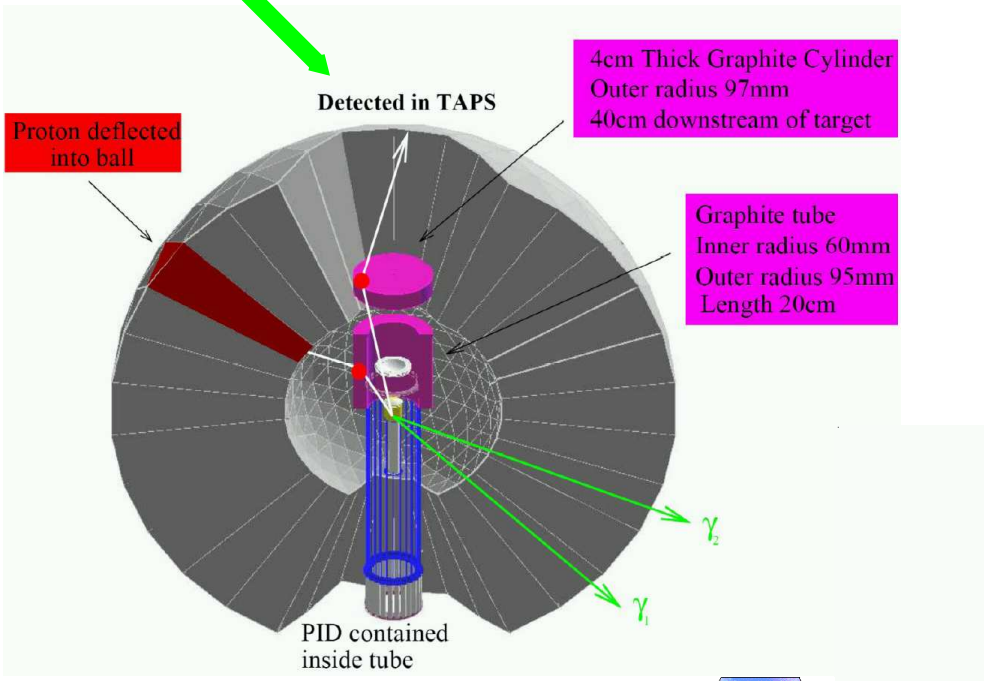
$$\gamma + N \rightarrow N + m$$

Nucleon polarisation:
scattering in carbon ✓

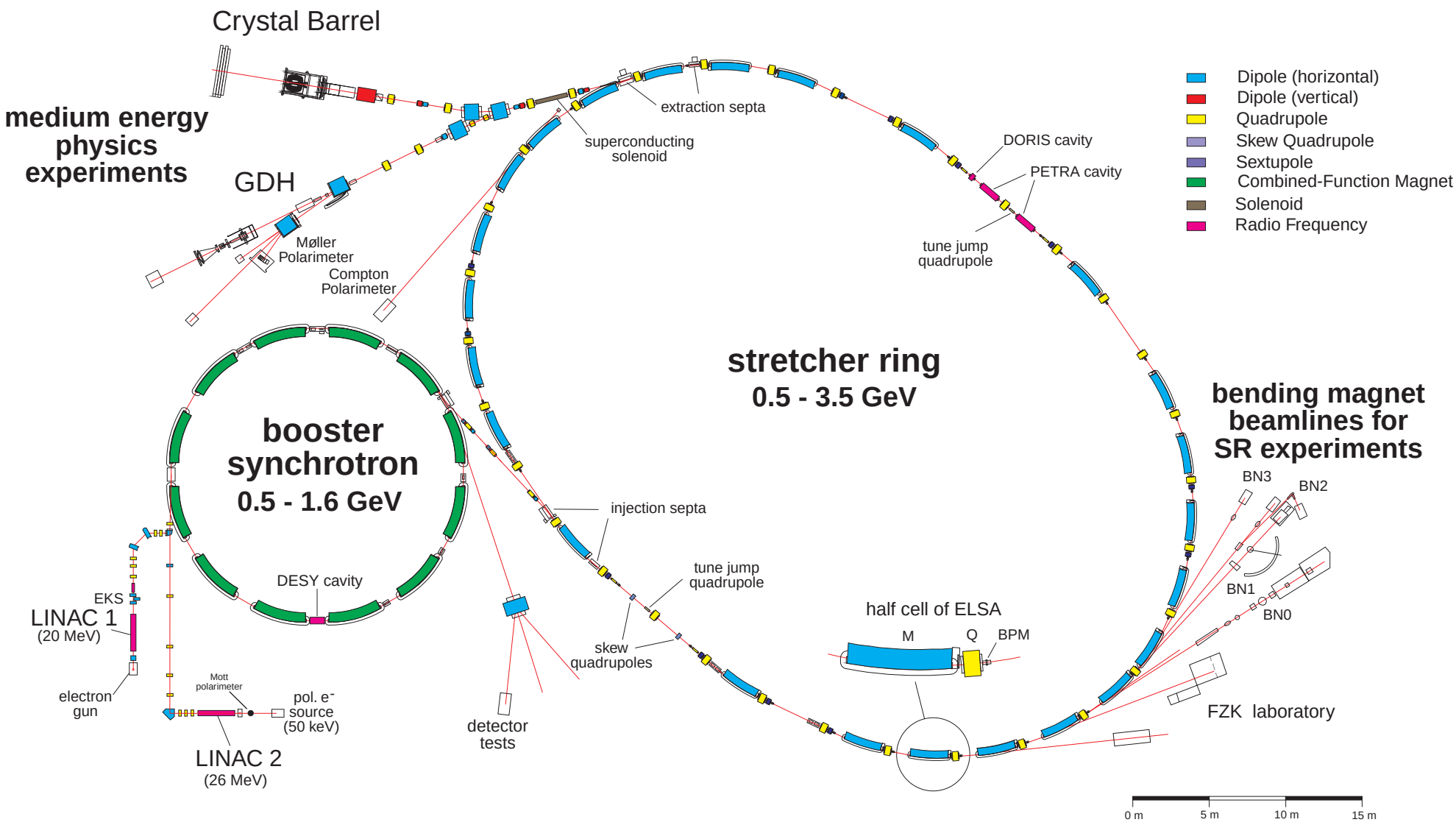


Linear Polarisation ✓

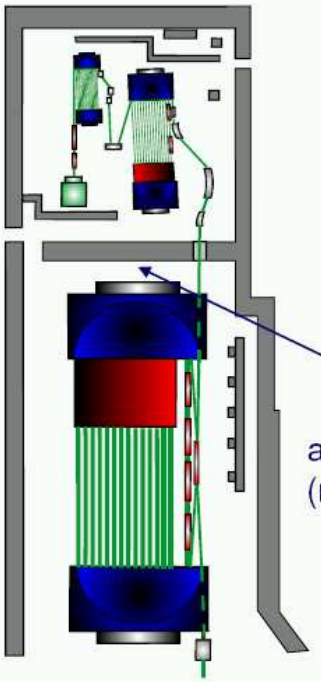
Circular polarisation ✓



Electron Stretcher Accelerator (ELSA)



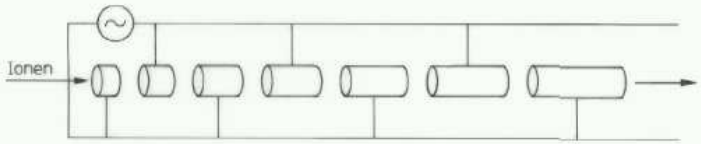
MAMI accelerator in Mainz

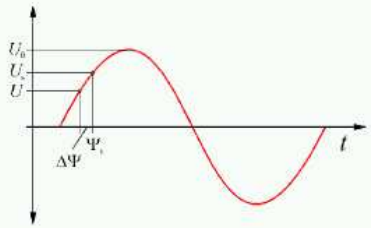


accelerators
(racetrack microtrons)

Mainz Microtron (MAMI)
continuous wave electron accelerator, max. beam energy 883

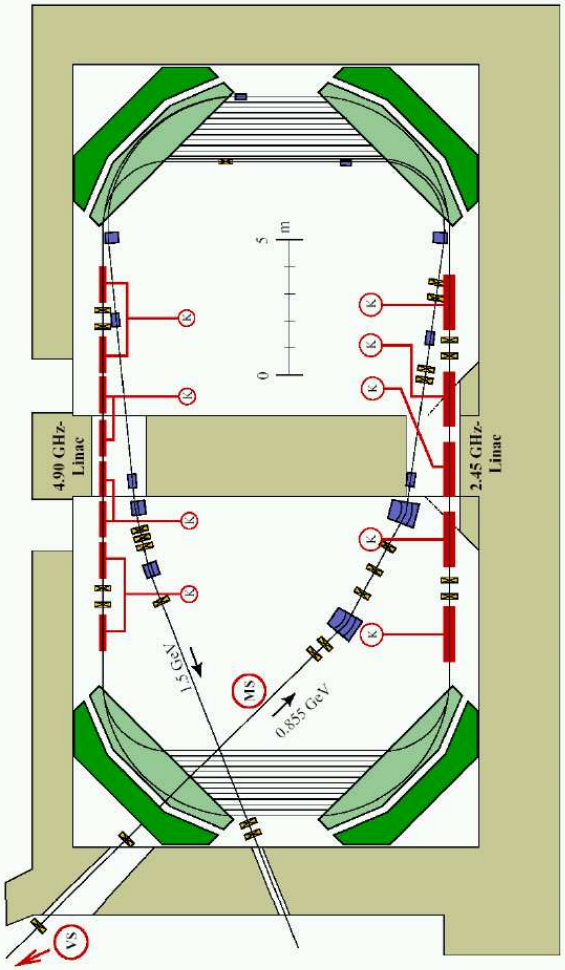
0. Stage: Linac (2.5 GHz, 3.45 MeV)





1.-3. Stage: Ractrack Microtrons:

- microbunches of 0.4ns
- linear accelerator structures
- constant B field ⇒ varing radii (18, 51, 90 return cycles)
- very efficient acceleration and continuous mode
- high current (0.1mA)



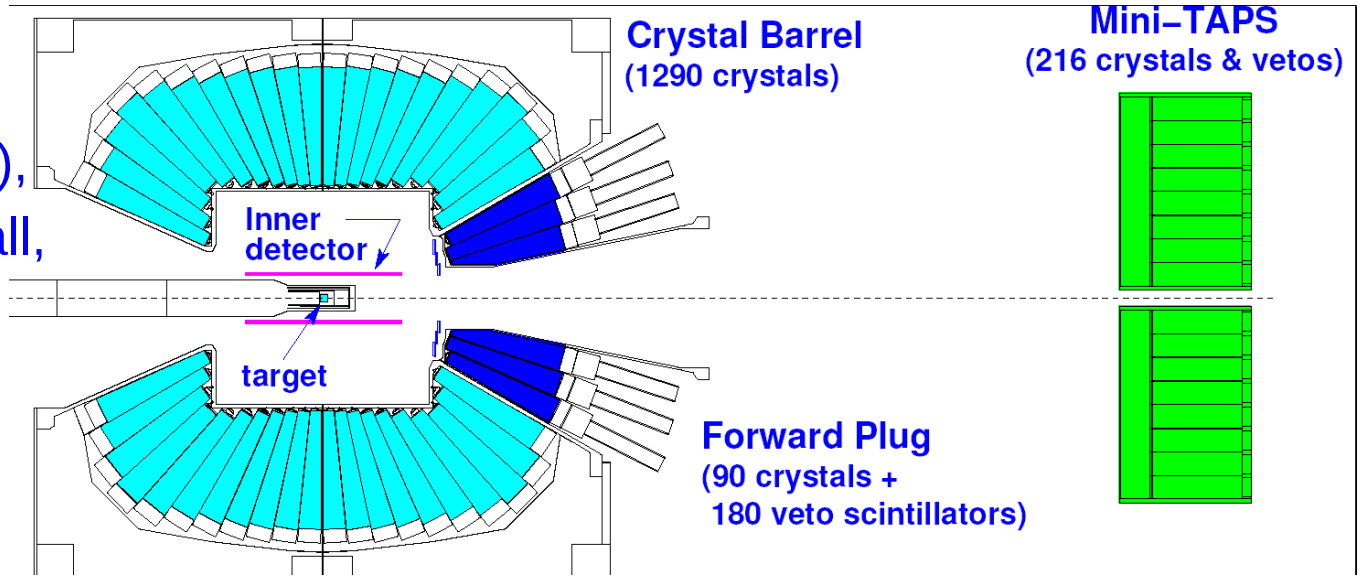
4. Stage: Harmonic Double Sided Microtron
maximum energy: 1.5 GeV

experimental setups - Ball, Barrel and TAPS and ...

- Bonn ELSA accelerator:

  Crystal Barrel (1380 CsI),
  TAPS (BaF_2) forward wall,
  inner detectors

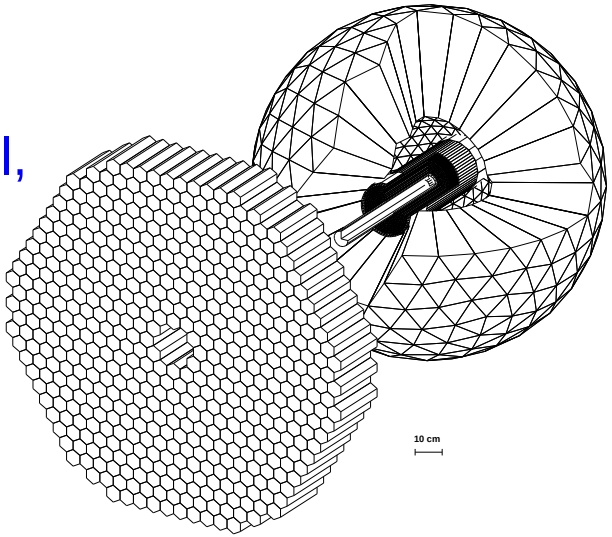
  $E_\gamma \leq$ 3.5 GeV,
  lin. pol.: available,
  circ. pol.: available

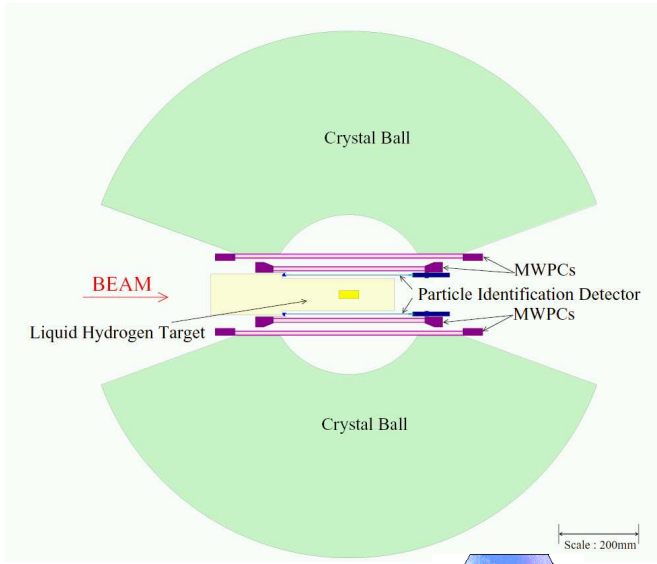


- Mainz MAMI accelerator:

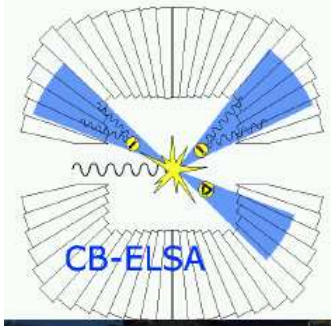
  Crystal Ball (672 NaJ),
  TAPS (BaF_2) forward wall,
  inner detectors

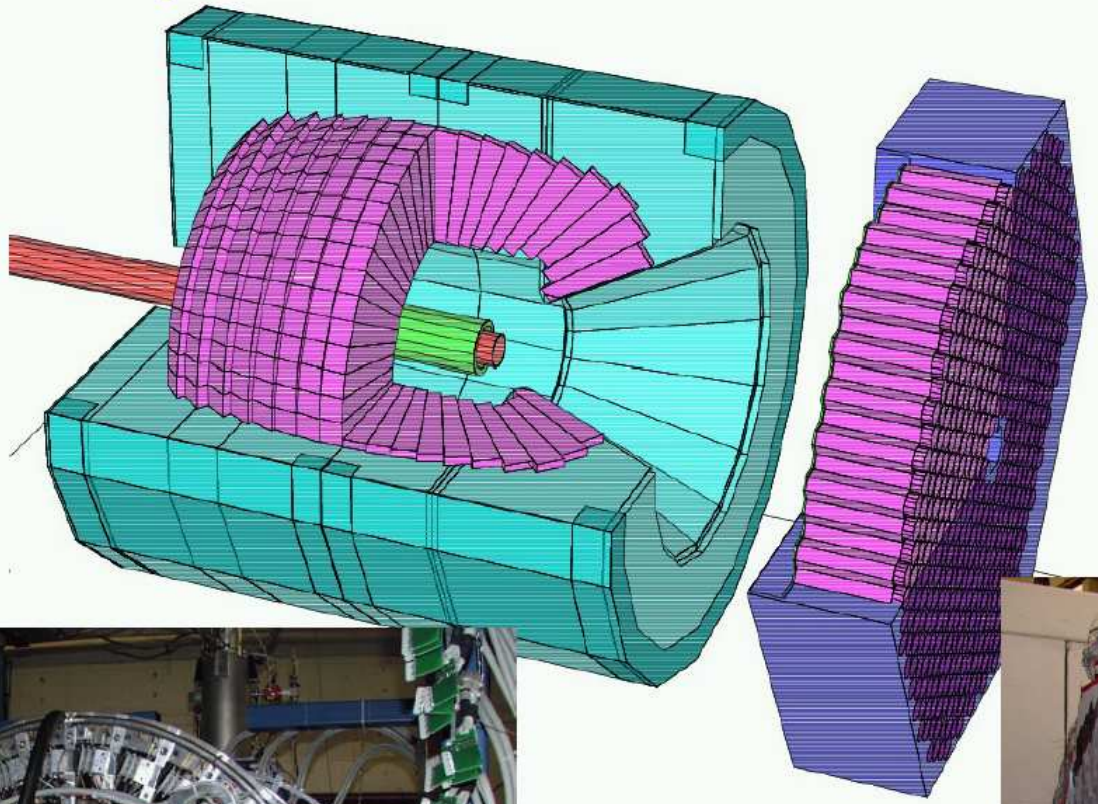
  $E_\gamma \leq$ 1.5 GeV,
  lin. pol.: available,
  circ. pol.: available



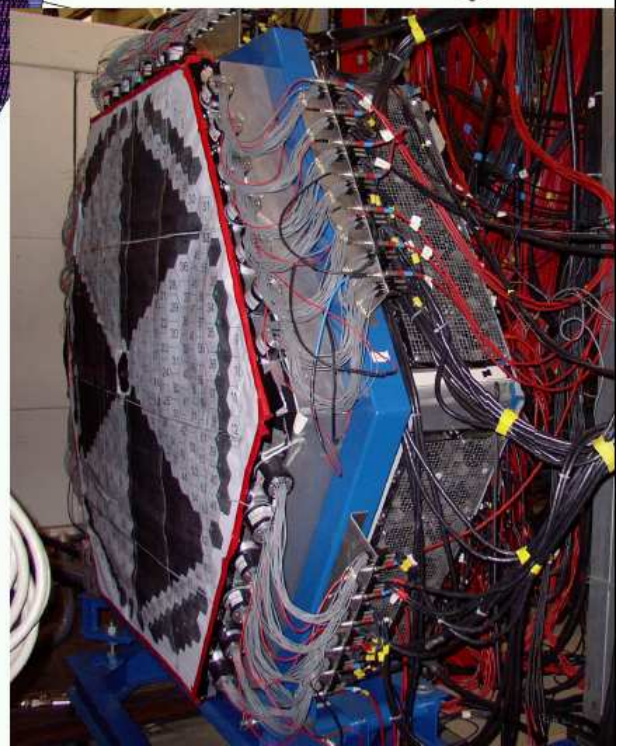


Crystal Barrel and TAPS

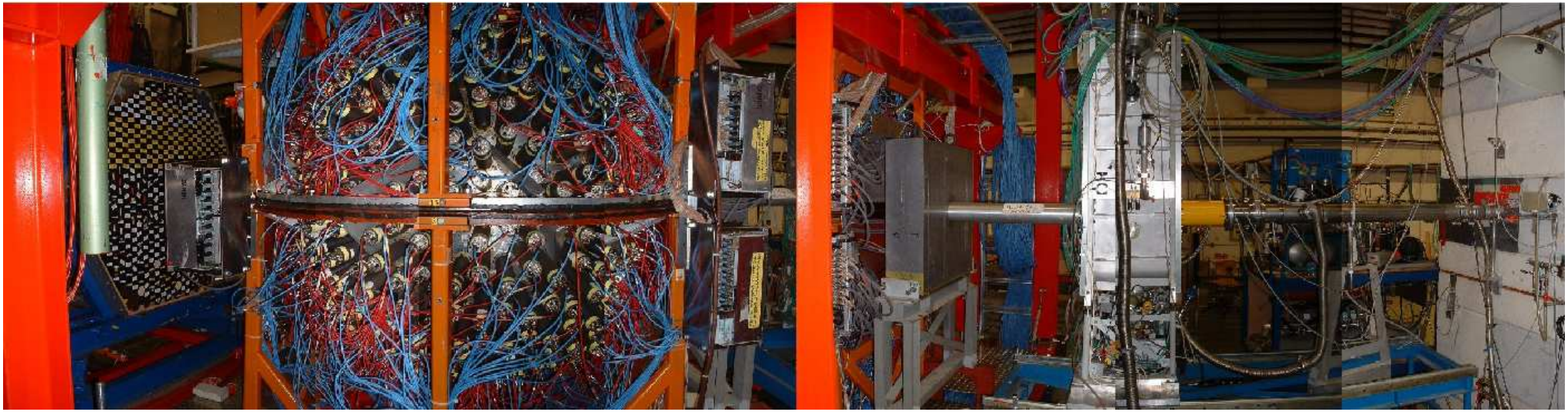




TAPS



TAPS Crystal Ball - at MAMI



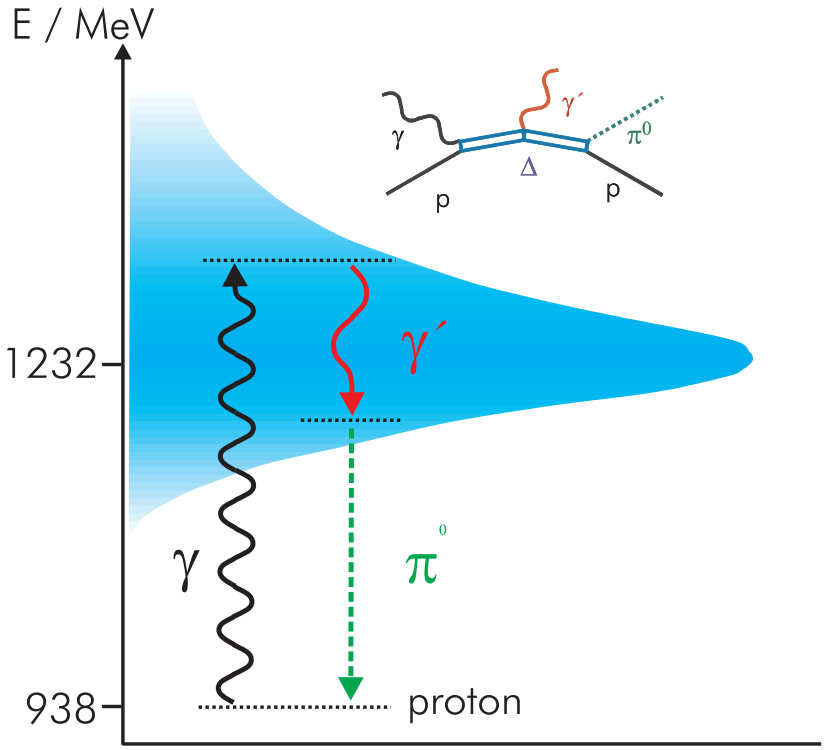
Example I: magnetic dipole moment of the Δ^+-resonance

- **principle:**

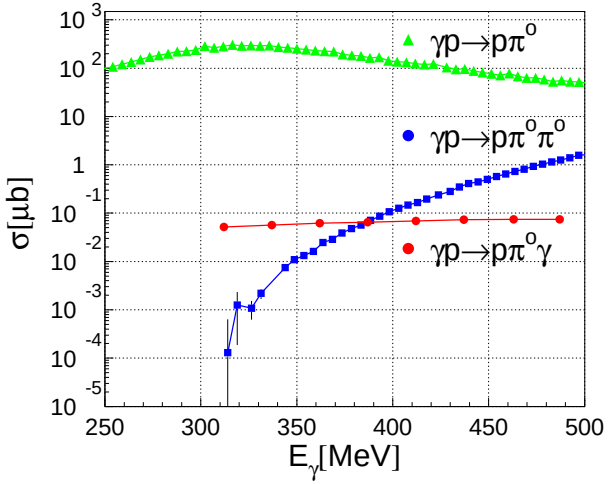
  M1 re-alignment photon from

  $\gamma p \rightarrow \Delta^+ \rightarrow \Delta^+ \gamma' \rightarrow p\gamma'\pi^o$

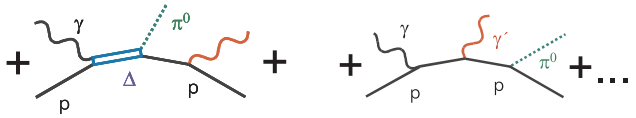
  sensitive to $\mu(\Delta^+)$



- **problems:**
  - small cross section:

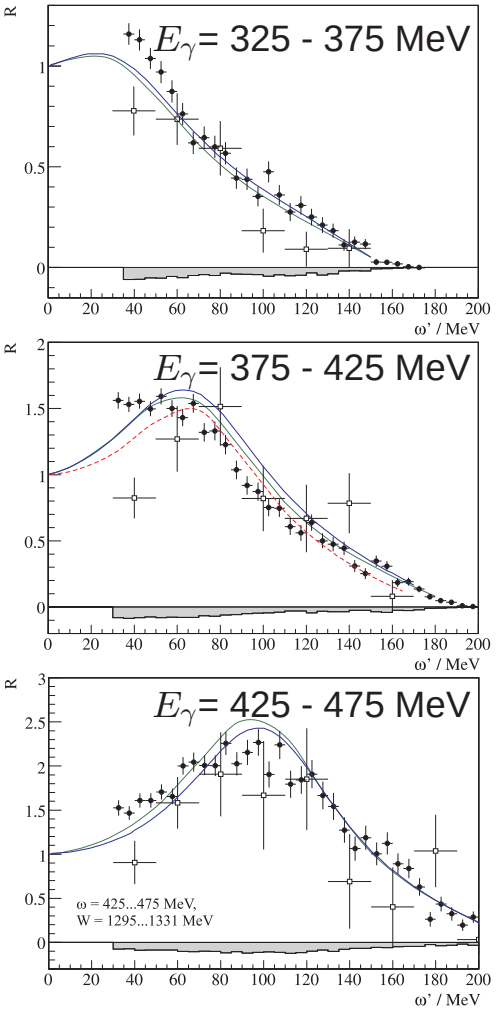


  - 'background' diagrams: bremsstrahlung



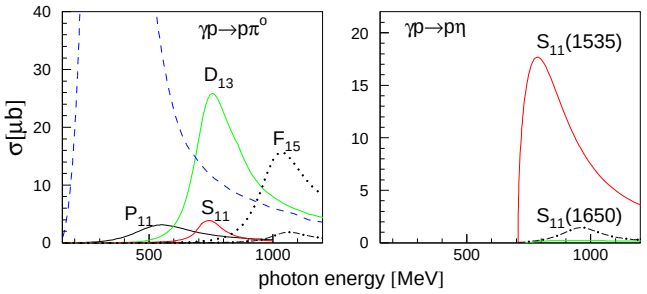
  → models needed

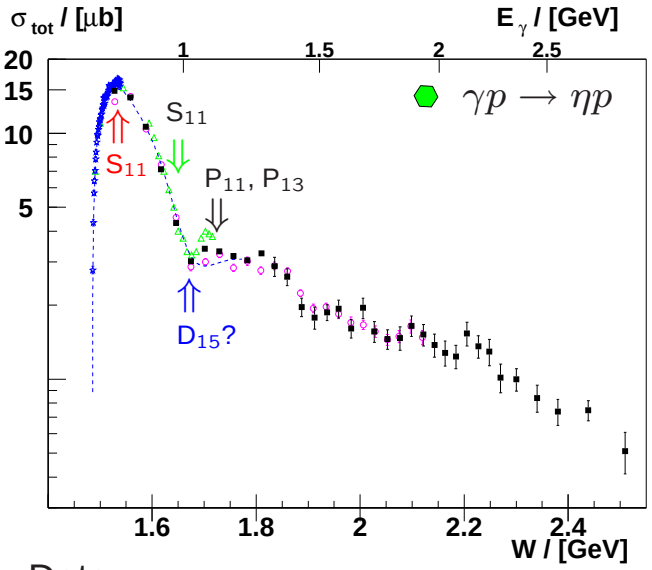
- **preliminary results:**



Example II: specific meson channels - isospin degree of freedom

- $\gamma p \rightarrow p\eta$ dominated by $S_{11}(1535)$ resonance

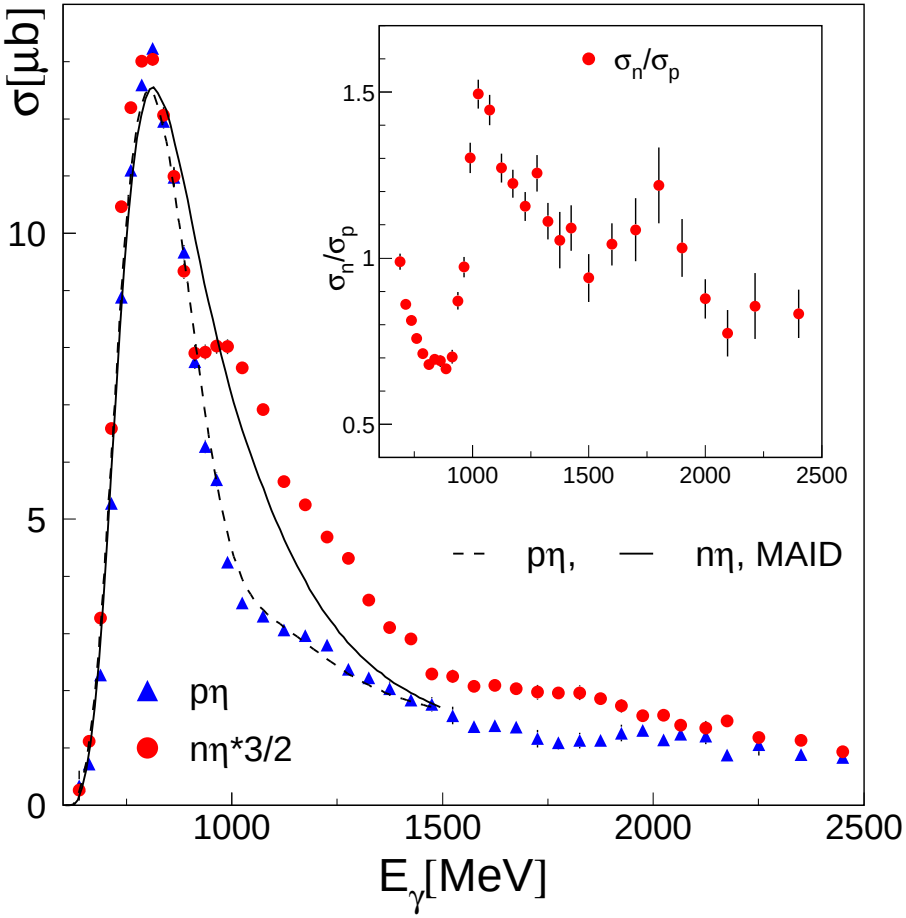




Data:

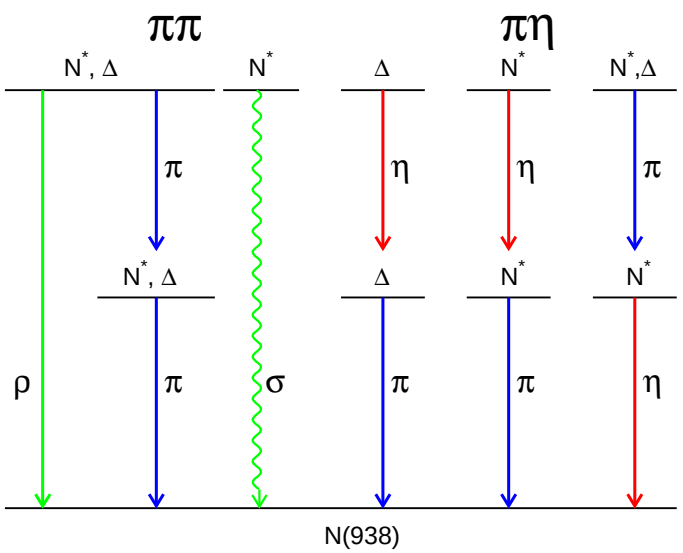
- TAPS: B. Krusche et al., PRL74 (1995) 3736
- GRAAL: F. Renard et al., PLB528 (2002) 215
- CLAS: M. Dugger et al., PRL89 (2002) 222002
- Crystal Barrel: V. Crede et al., PRL94 (2005) 012004

- $\gamma n \rightarrow n\eta$: unexpected structure (narrow) resonance with much stronger coupling to neutron?

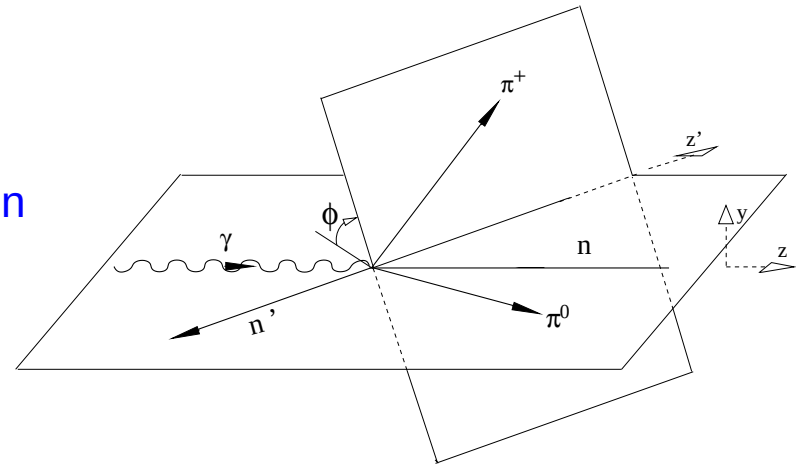


Crystal Barrel: I. Jaegle et al., PRL 100 (2008) 252002

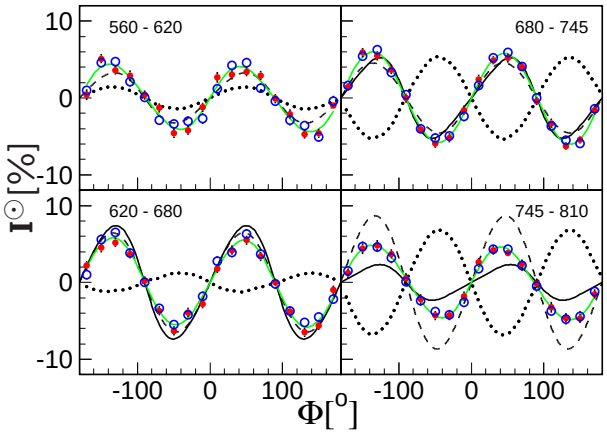
Example III: the power of polarization degrees of freedom



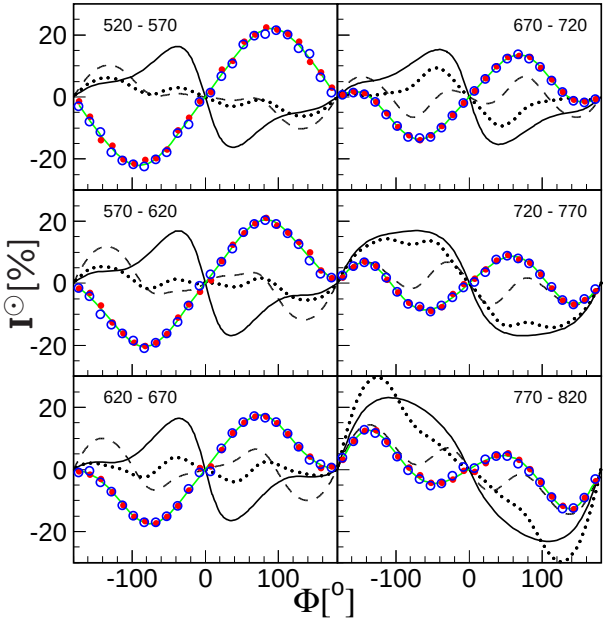
- Search for resonances with small probabilty for ground state decays: multiple meson production
- Powerful tool for test of reaction models: polarization observables; e.g. helicity asym. for double pion production



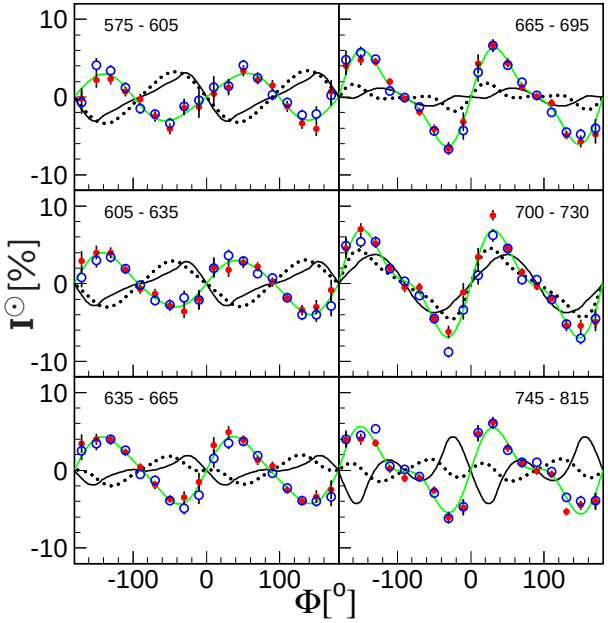
$\gamma p \rightarrow p\pi^o\pi^o$



$\gamma p \rightarrow n\pi^o\pi^+$



$\gamma p \rightarrow p\pi^-\pi^+$



summary tagged photon experiments

Very active experimental program for investigation of Baryon Resonances at ELSA and MAMI exploring:

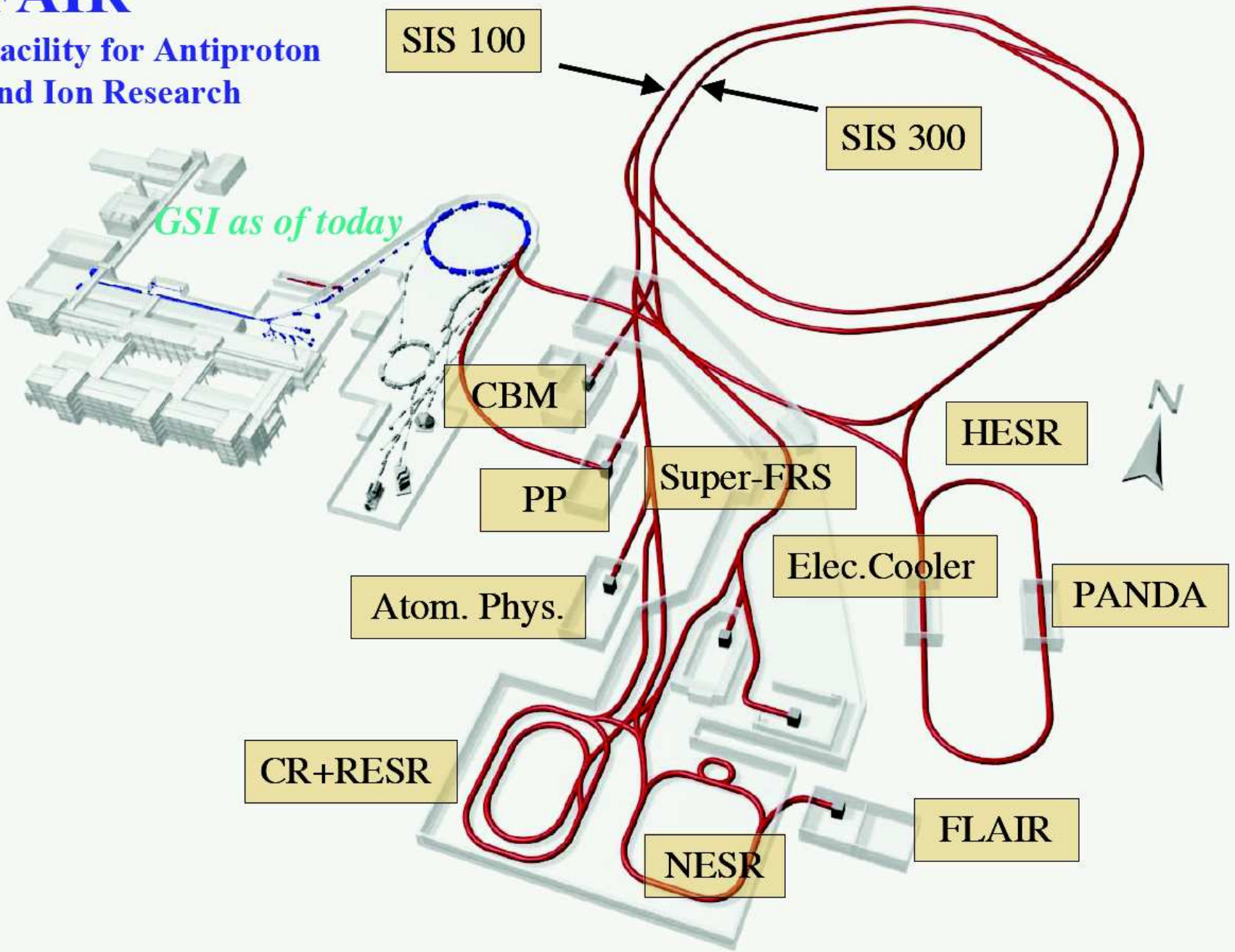
- High quality tagged photon beams
- (Almost) 4π detectors for photons, charged, and neutral particles
- linearly and circularly polarized photon beams
- longitudinally and transversely polarized targets
- polarization of recoil protons
- many different single and multiple meson production reactions
- deuterium targets as quasifree neutron targets

Further topics in this program:

- in-medium properties of hadrons
- rare decays of mesons (η, η')

FAIR

Facility for Antiproton and Ion Research

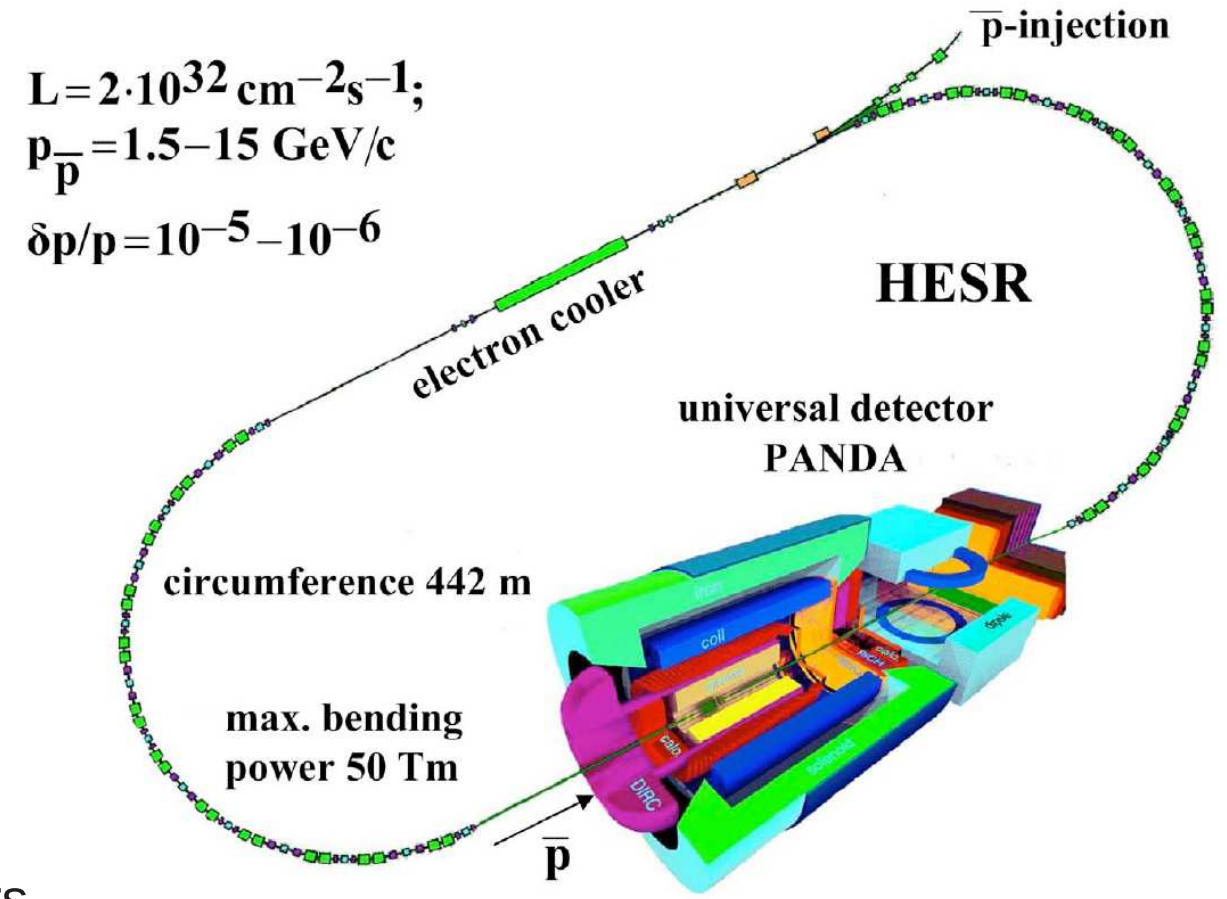


The PANDA-project at GSI

At present: A group of 390 physicists from 52 institutes in 17 countries

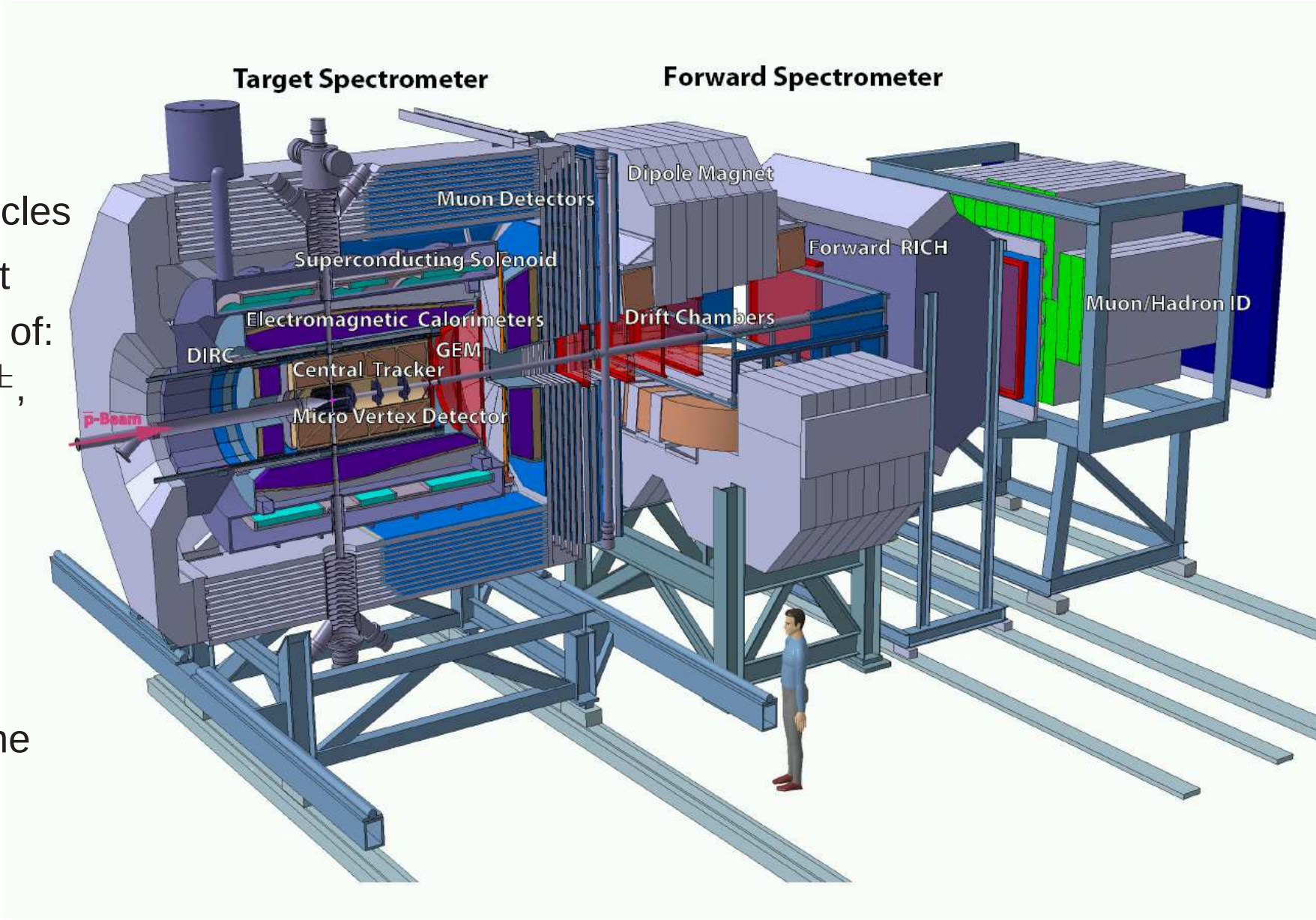
The PANDA-project

- Physics topics:
  - charmonium spectroscopy
  - search for QCD predicted gluonic excitations (charmed hybrids, glueballs)
  - D meson spectroscopy (rare decays)
  - in-medium modifications of hadrons (partial chiral symmetry restoration)
  - γ-spectroscopy of hypernuclei
  - electromagnetic processes: wide angle Compton scattering, $p\bar{p} \rightarrow e^+e^-$ (nucleon from factors in time-like region)



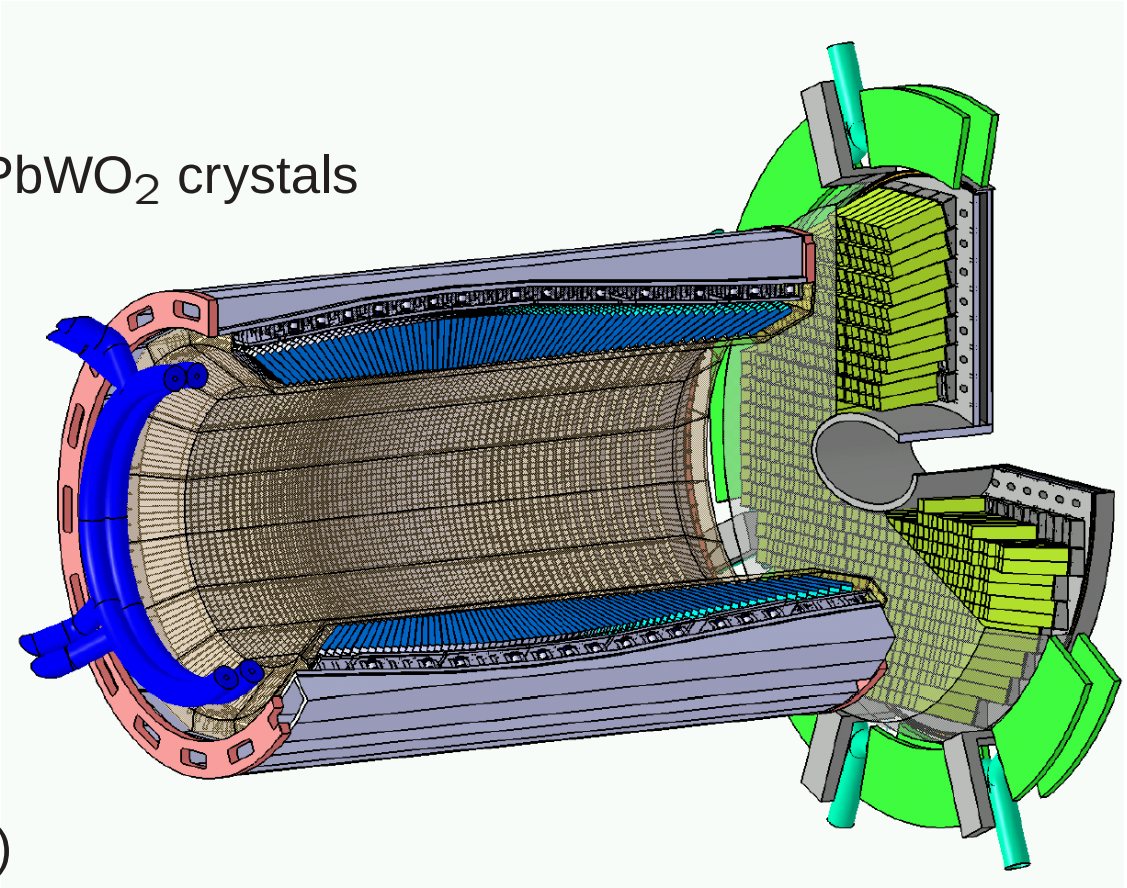
The Panda detector

- features:
  - tracking of charged particles
  - measurement /identification of: γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, $\bar{p}$, p
  - high rate capability
  - sophisticated and fast trigger scheme



central component: the electromagnetic calorimeter

- calorimeter:
  - building on CMS experience with $PbWO_2$ crystals
  - length: all crystals 22 X_o (20cm)
  - improved PWO-II material and operation at -25 ^{o}C provides factor 4 gain in light output



- contributions from Basel group:
  - Front-end-electronics (low-noise, low-power preamplifier)
  - HV-systems
  - Construction and tests of prototype arrays

- Barrel calorimeter: 11360 crystals
- Forward calorimeter: 3600 crystals
- Backward part: 592 crystals

status of the PANDA-EMC development

- 60-channel prototype for barrel calorimeter in test phase
  (coll. U. Basel, U. Giessen, Orsay)
- 192-chan. prototype for forward part under construction
  (coll. U. Basel, U. Bochum, U. Giessen, KVI Groningen, Orsay)
- EMC Technical Design Report positively evaluated
- Grant from German BMBF for forward part (4 MEur) for German groups
- Contract for delivery of crystals for forward part signed last week