Forward Spectrometer of PANDA – requirements and solutions

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Introduction

PANDA - future large-scale experiment on HESR at GSI

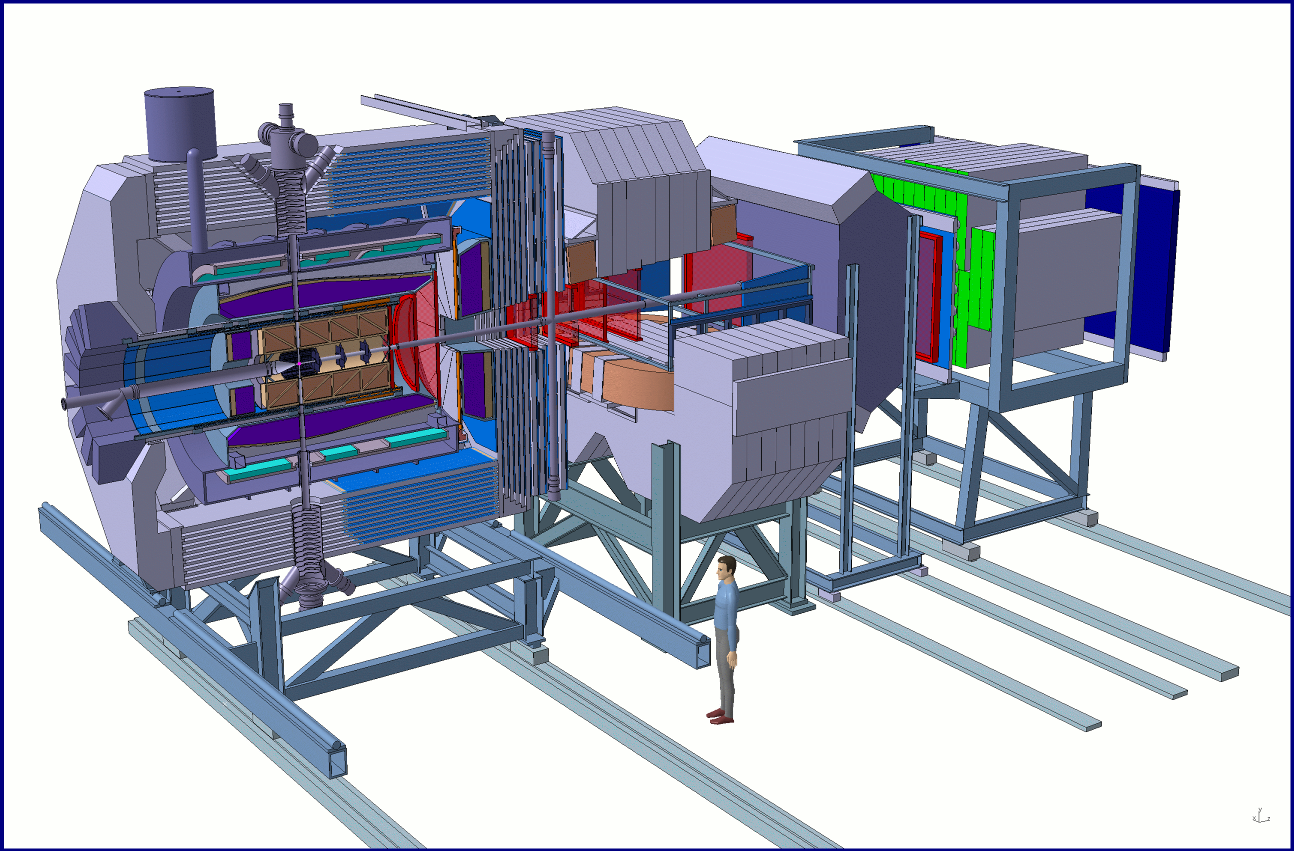
- detector description

➡ preceding talks by A.Biegun and R.Jäkel

- wide physics programme, **pbar+p** and **pbar+A** measurements
  - charmonium spectroscopy
  - exotics (hybrids, glueballs)
  - charmed particles in medium
  - $\Lambda\Lambda$ interaction via double Λ–nuclei
  - other...

more:
➡ plenary talk by J.S.Lange, Mo 12:30

Forward Spectrometer in PANDA

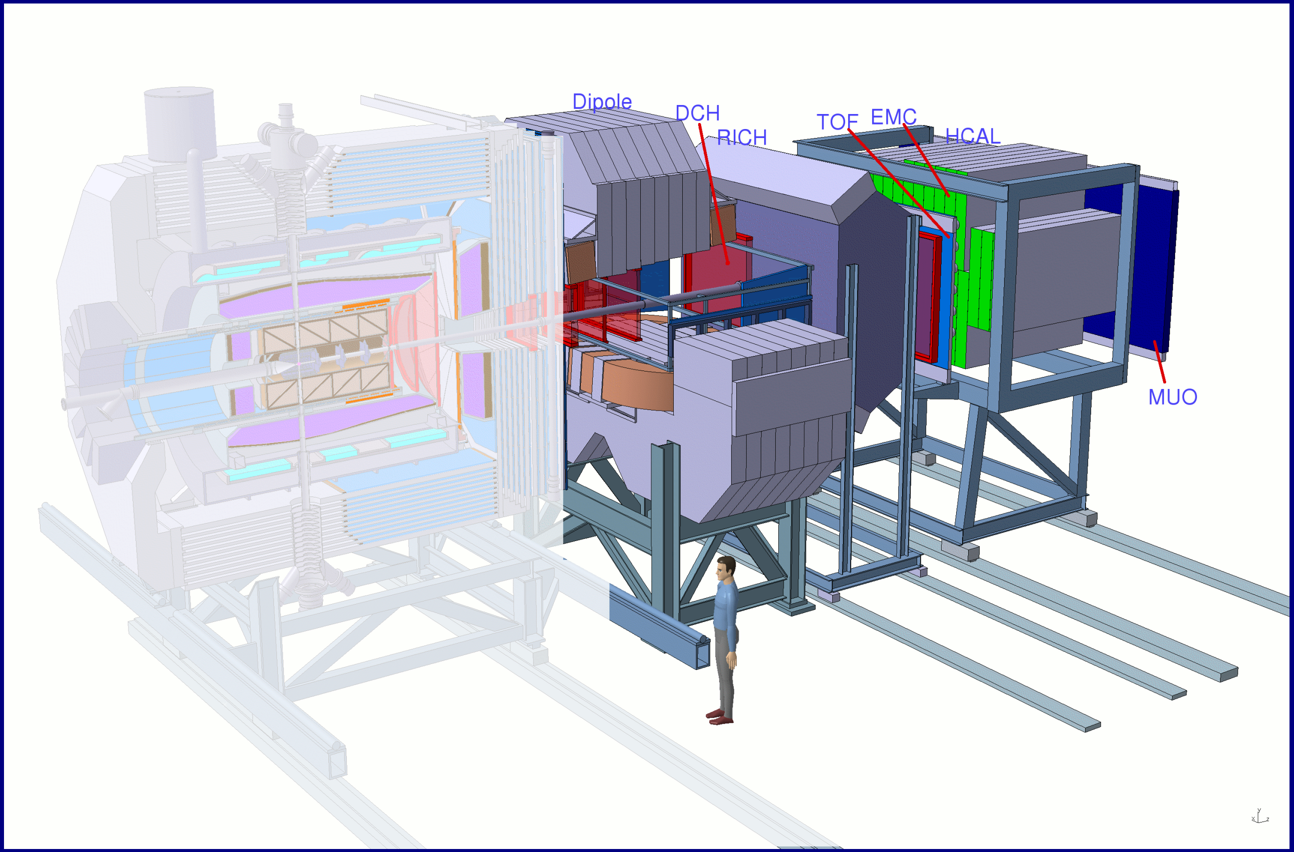


PANDA: a fixed target experiment

Reaction products boosted forward with CMS momentum

Necessity to ensure particle detection and identification at small angles

Forward Spectrometer in PANDA

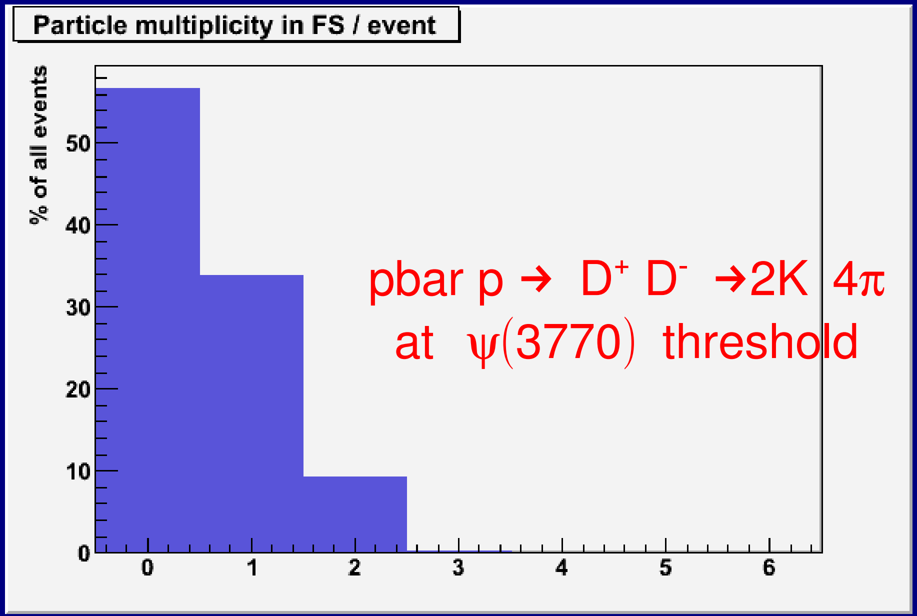


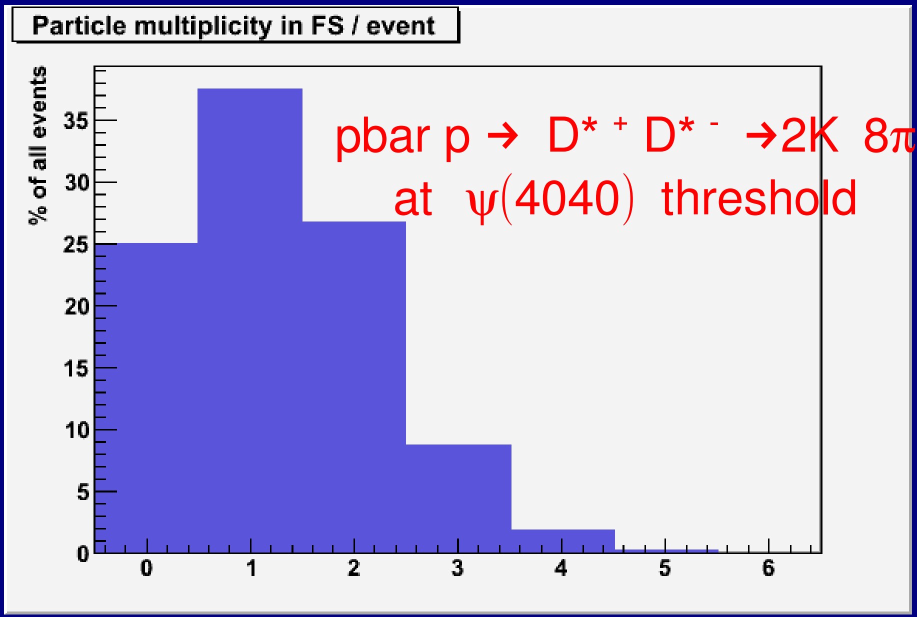
- **Acceptance of FS**
  - $\theta_X < 10$ deg.
  - $\theta_Y < 5$ deg.
- **Tasks**
  - tracking (DCH/STT)
  - PID (TOF,RICH)
  - measurement of energy (EMC,HCAL)

Physics example: charmonium spectroscopy

Charmonium = "positronium of QCD"

- Layout of charmonium spectrum dependent on the QCD potential →good insight !
- Various theoretical predictions existing
- Many states from the ladder experimentally poorly known, many completely unknown
- Among PANDA benchmark channels: formation of $\psi(3770)$ and $\psi(4040)$

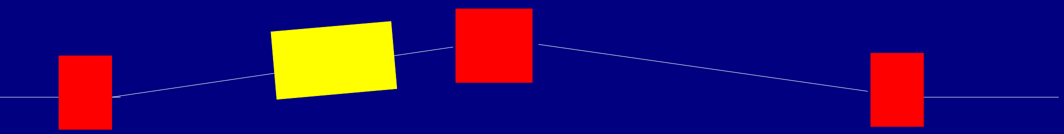




Options for beam guiding

Two options have been studied:

- guiding of unshielded beam through the dipole magnet
  - beam direction affected by B
  - need to form a chicane in the ring
  - B has to scale with p_{beam}



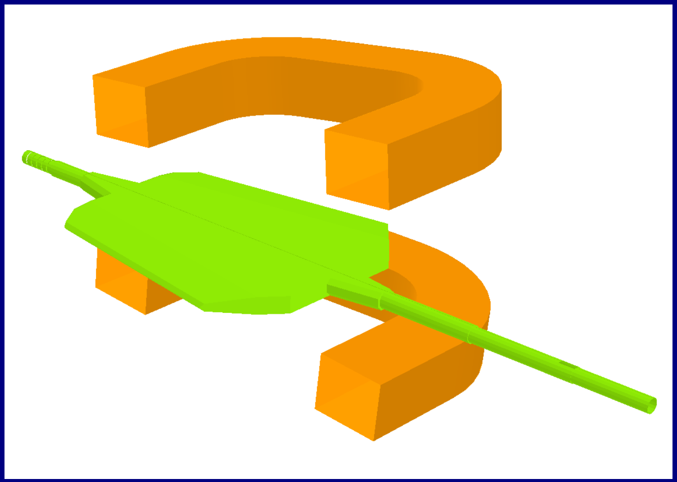
- using an iron plate to schield the beam from B
  - beam goes straight through the dipole
  - for each p_{beam} B=const.
  - acceptance losses and secondary particles in the detector

Simulation study of

- acceptance
- resolution
- background from secondaries
- hit rates and fluxes

for several benchmark channels.

Conclusion: chicane option wins.

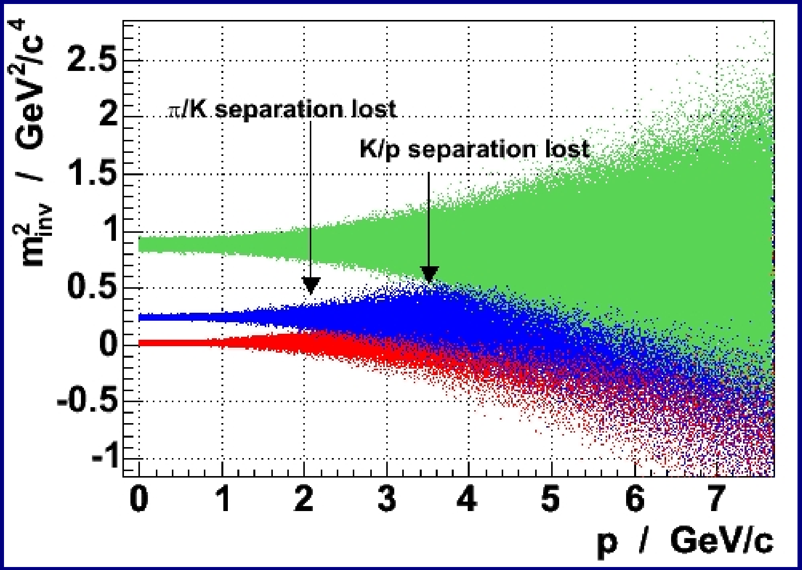


PID detectors: TOF and RICH

TOF foreseen with $\sigma(t)$=100 ps works well for low momenta

(π/K separation for p<2 GeV/c

K/p separation for p<3.5 GeV/c)



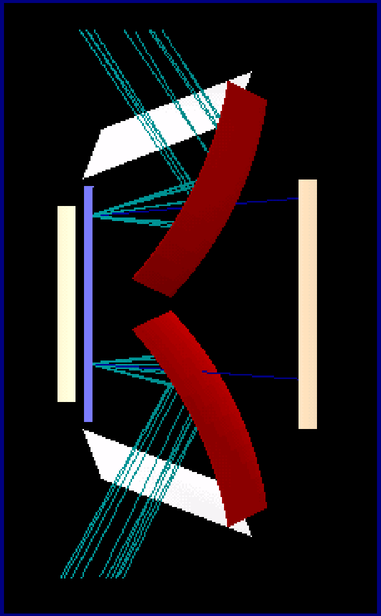
RICH should work where TOF fails: p=(2...15) GeV/c

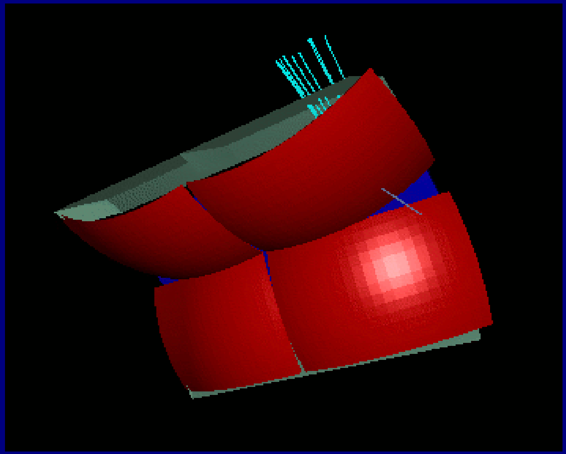
Proposal: dual-radiator RICH

examples of realisations: HERMES, LHCb

radiators: aerogel + gas (C_4F_{10})

First simulation of the geometry done.





Electromagnetic calorimeter

FS: large area to cover

higher energies of particles

↓

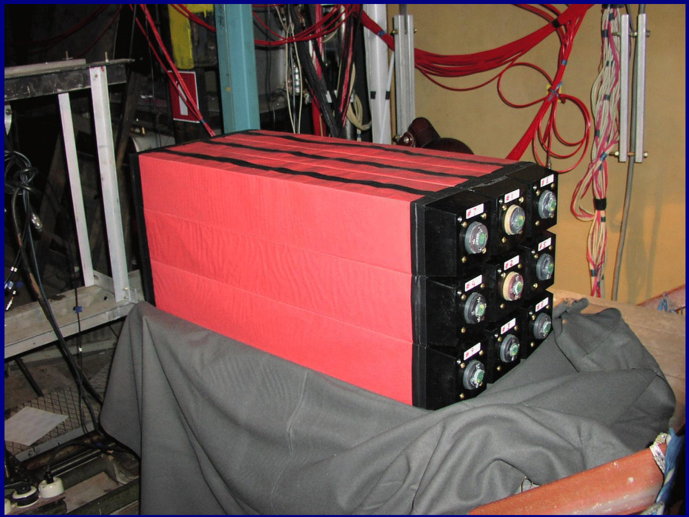
sampling cal. of shaslyk type meets PANDA requirements and is cheaper than PWO

(example of technique: KOPIO)

Techical details:

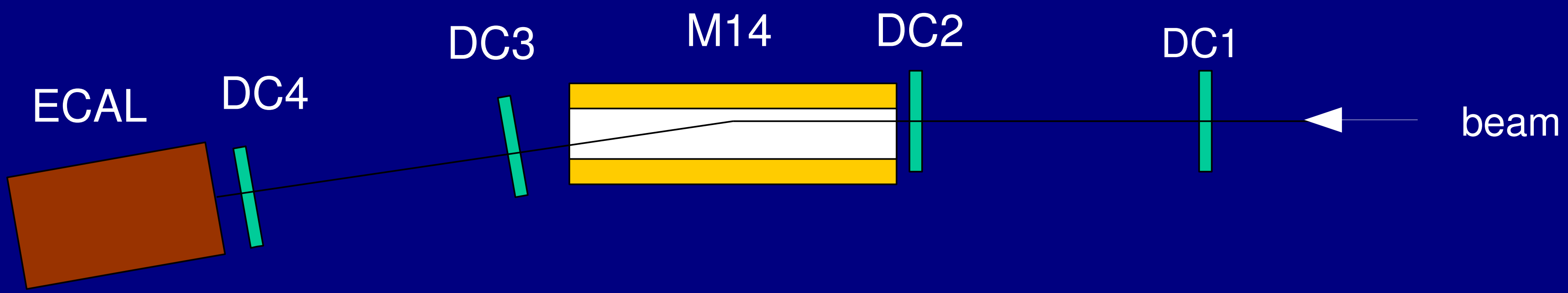
- 400 layers of Pb and scintillator (ca. 20 X_0)
- d(Pb) =0.275 mm
- d(scint.)=1.5 mm
- # of fibres / module = 72 or 144
- readout: PMT
- design resolution of 4%/sqrt(E)

Test 3x3 setup at IHEP



Electromagnetic calorimeter – prototype tests

Test setup at IHEP, Protvino:
spectrometer and set of 4 DCH



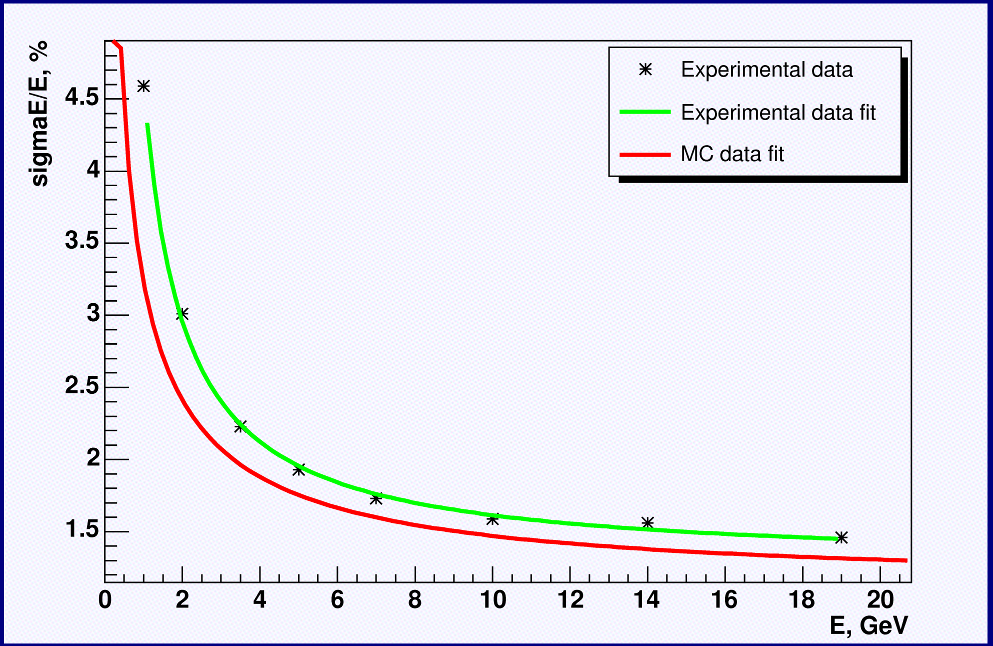
in the test, energy and position resolution were determined for the 3x3 array of 11x11 cm^2 modules. Results for σ_E:

$$\sigma_E/E = a/E \oplus b/\sqrt{E} \oplus c \quad [\%],$$

$a = 3.5 \pm 0.3$

$b = 2.8 \pm 0.2$

$c = 1.3 \pm 0.04$



Hadron Calorimeter

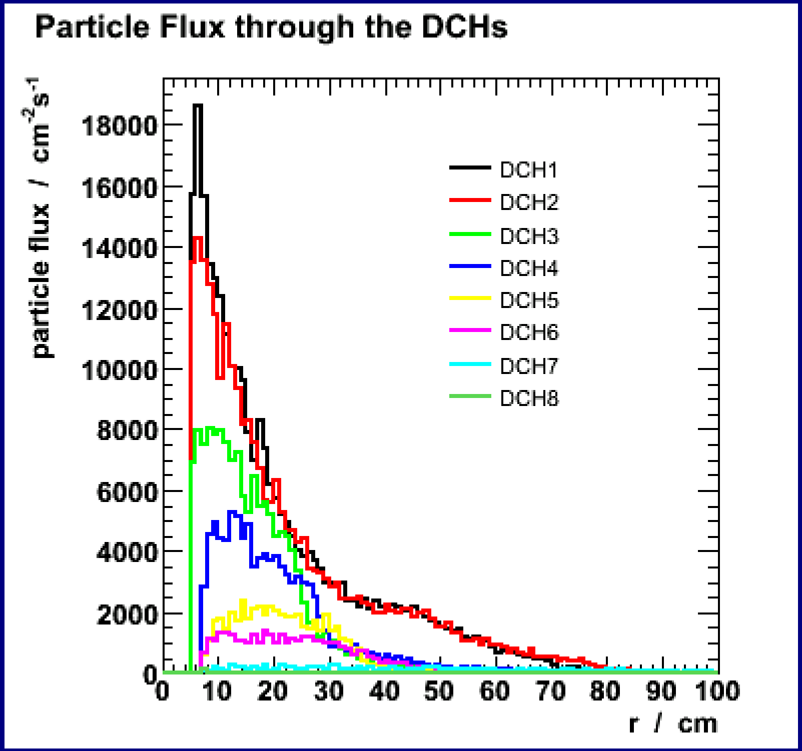
- Detection of neutral hadrons - in particular neutrons and anti-neutrons – important, e.g. for triggering
- Number of events with a neutral hadron in FS increases with p_{beam} and exceeds 30% for p_{beam}>5 GeV/c (where acceptance of FS for anti-neutrons > 50%)

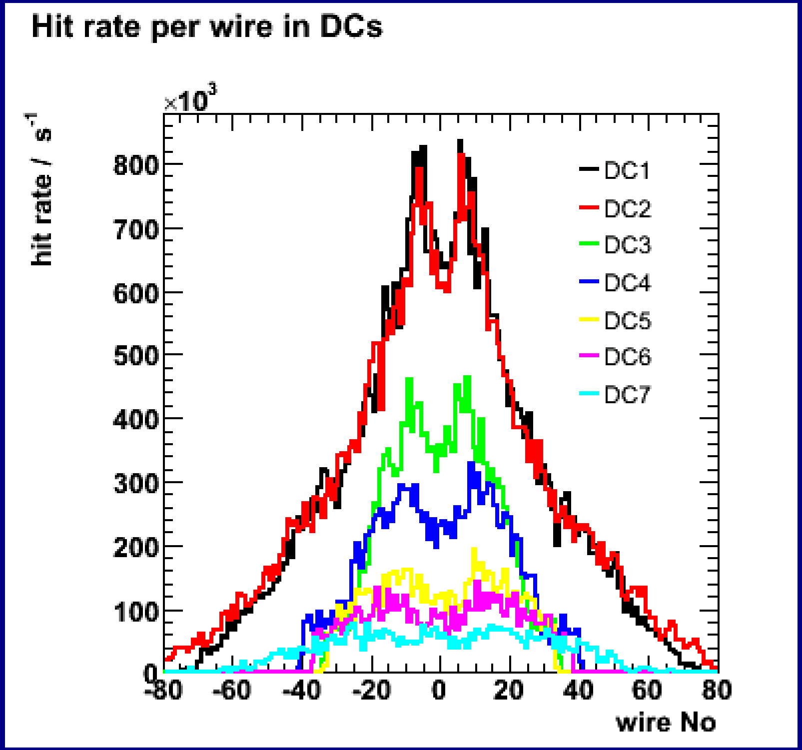
- Two options of HCAL considered now:
  - MIRAC type: 8mm steinless steel plates sandwiched with 3.2mm scintillator plates, read out through WLS fibres
    - $\sigma E/E = 0.034 \oplus 0.34/\sqrt{E}$
    - idea to refurbish old MIRAC calorimeter; first test measurement done, but inconclusive
  - Muon Filter: 3cm stainless steel plates interlaced with gas detectors
    - allows also to distinguish between charged hadrons and muons

Tracking detectors DCH vs. STT

In FS, in particular close to the beam pipe, severe conditions for a conventional tracking detector

- high particle flux (➔ageing!)
- high hit rates (➔problems for DAQ)



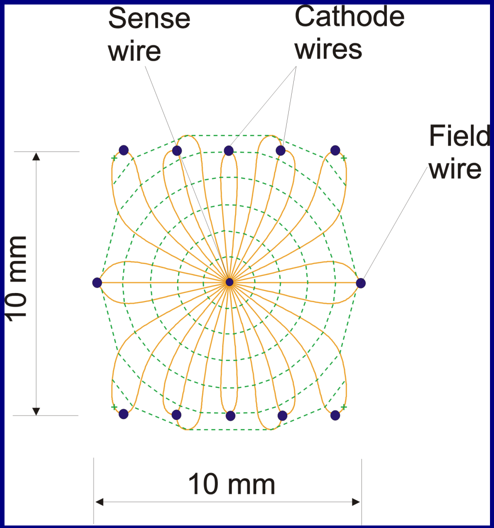


Tracking detectors: DCH

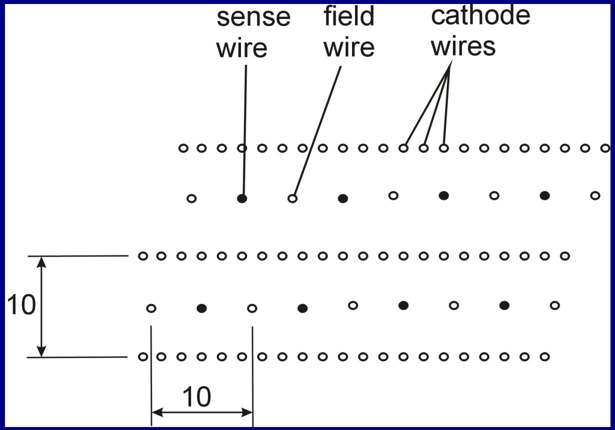
Prototype chamber built in Cracow

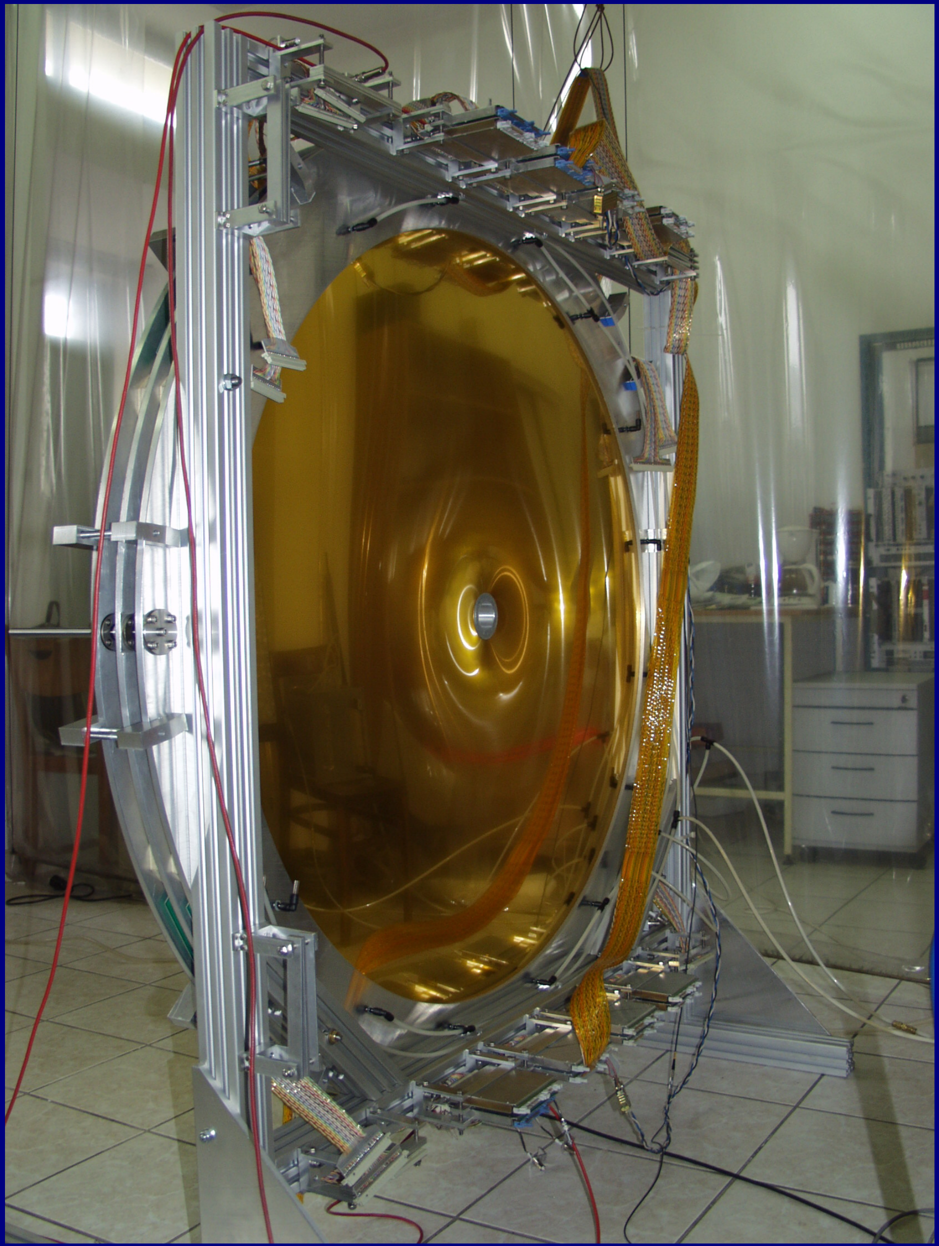
- Two double layers with vertical wires
- Ø(active area) = 120 cm
- Ø(beam-pipe) = 5 cm

Single drift cell



Layout of double layer





Readout of prototype DCH

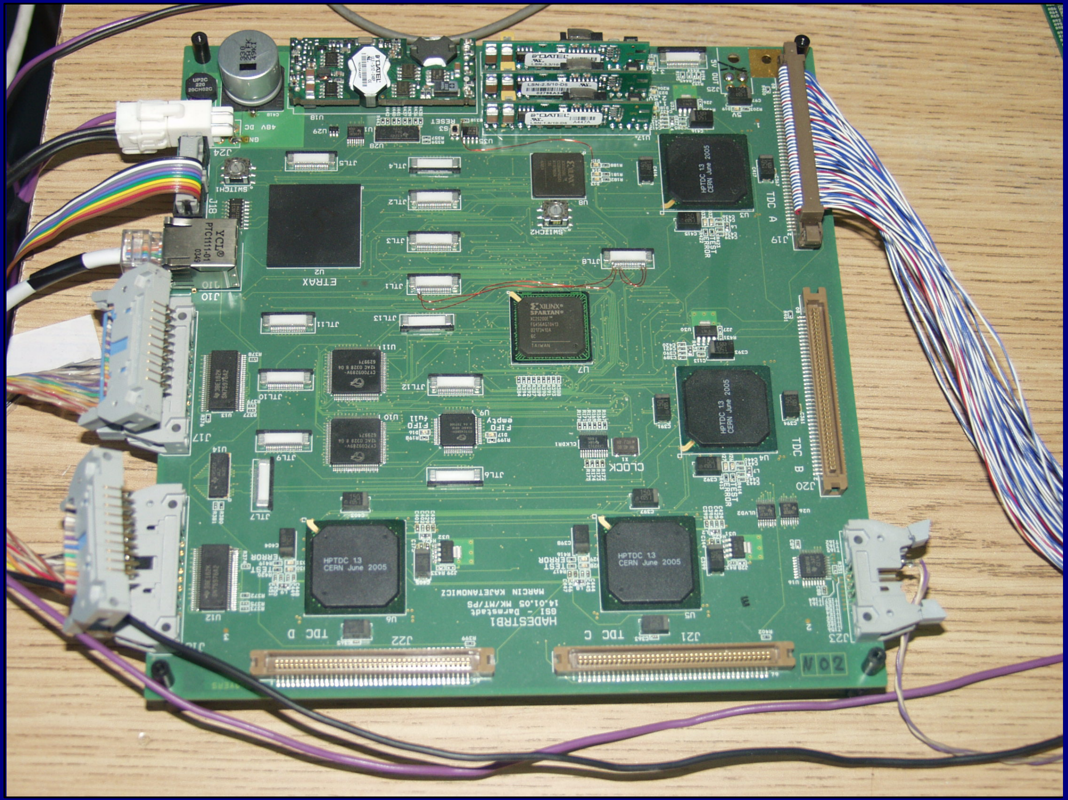
- Read-out chain:
  - Juelich-Cracow preamplifier and discriminator

    ↓
  - ECL→ LVDS converter

    ↓
  - 128ch. TRB based on HPTDC chips

    ↓
  - 100 Mb ethernet

    ↓
  - Personal Computer

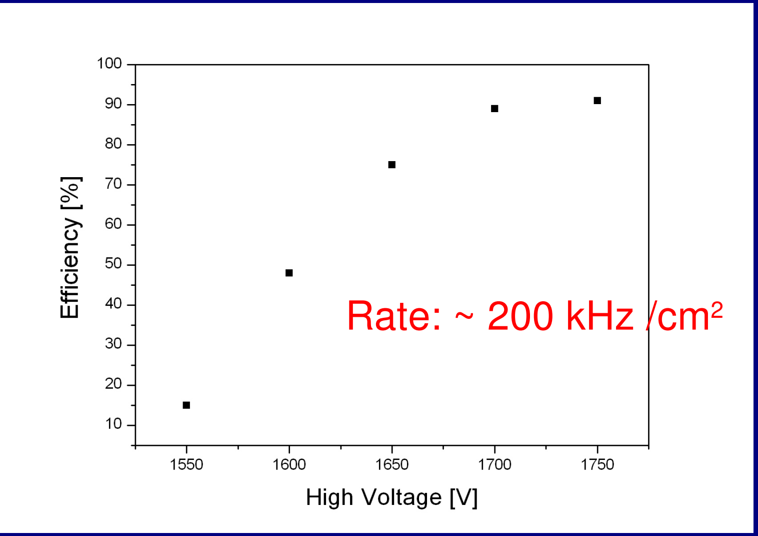


- TRB: TDC Readout Board
  - possibility to work in a trigger-mode or triggerless-mode (triggered by a clock)
  - contains FPGA-programmable unit
  - possibility to measure time-over-threshold

Prototype DCH – results of tests

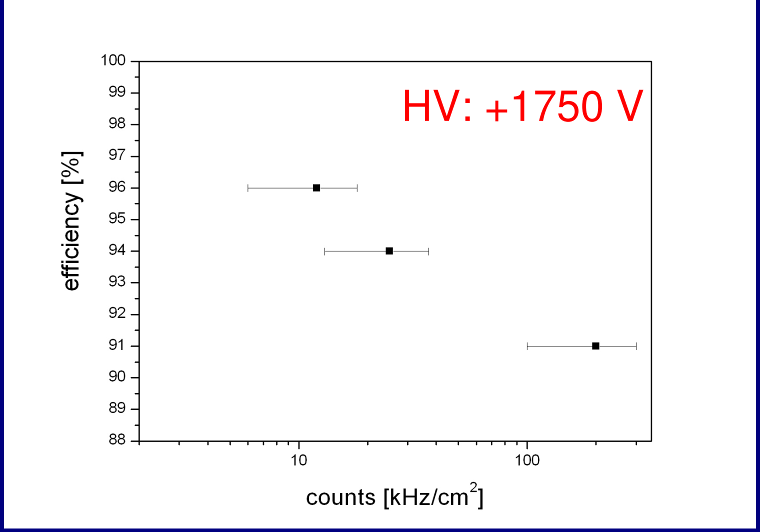
Tests performed at COSY-Jülich:

- p_{beam} = 2.9 GeV/c
- $I_{max} = 5 \cdot 10^6$ protons/s
- max. rate / wire = 1.5 MHz
- max. rate / cm^2 = 200 kHz



Results:

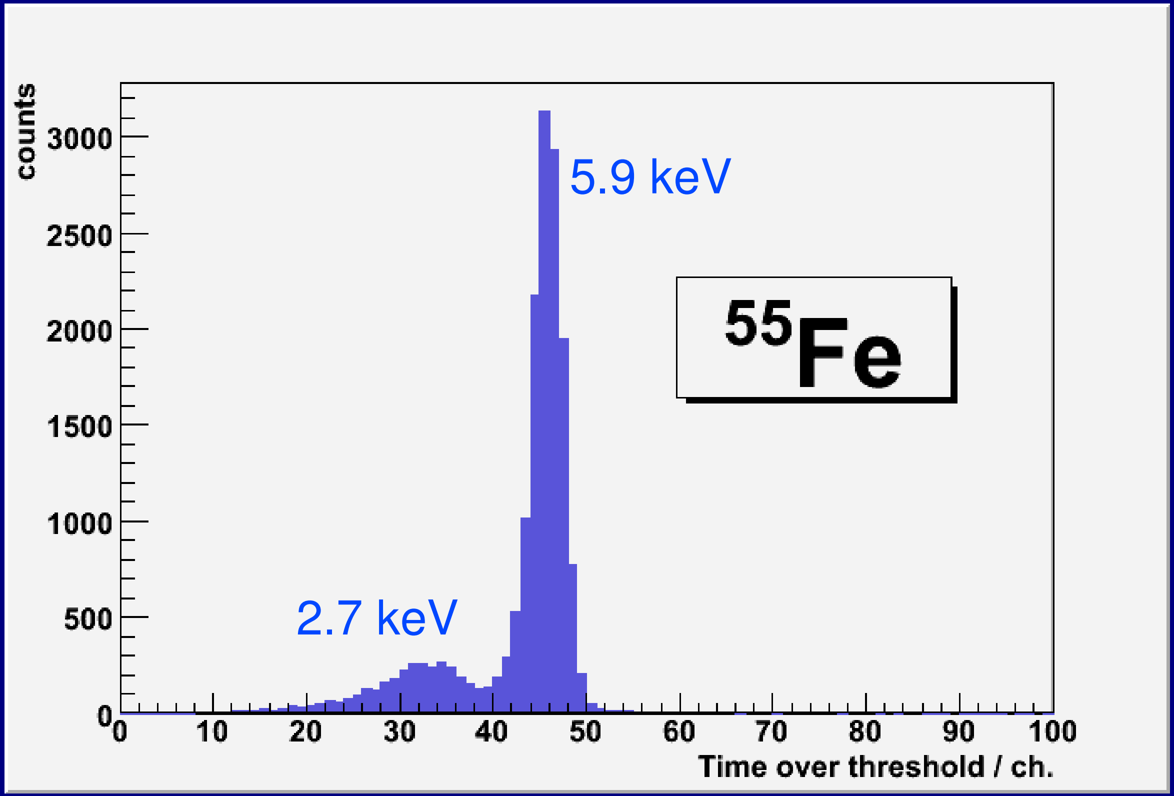
- Read-out electronics passed the test excellently
- The detection efficiency drops from 96% to 91% when increasing the rate from 12 kHz /cm² to 200 kHz /cm²



Prototype DCH – results of tests

More laboratory tests:

- Time-over-threshold (=indirect measurement of Q) measured for ^{55}Fe
- Measurement done in the triggerless mode
- Results reveal the expected shape



Summary and Outlook

- Forward Spectrometer is an important part of PANDA
- Different detectors are currently:
  - in the design phase (RICH, HCAL)
  - being in the phase of building and testing the prototypes (EMC, DCH)
- Results of EMC prototype tests yield results in line with simulations, optimisation of module size for PANDA purposes in progress (IHEP)
- Beam and laboratory tests with DCH verified the read-out electronics positively, but drop of efficiency with increasing hit rate is worrying (test other preamplifier: CARIOCA, try with different detector: STRAWS)

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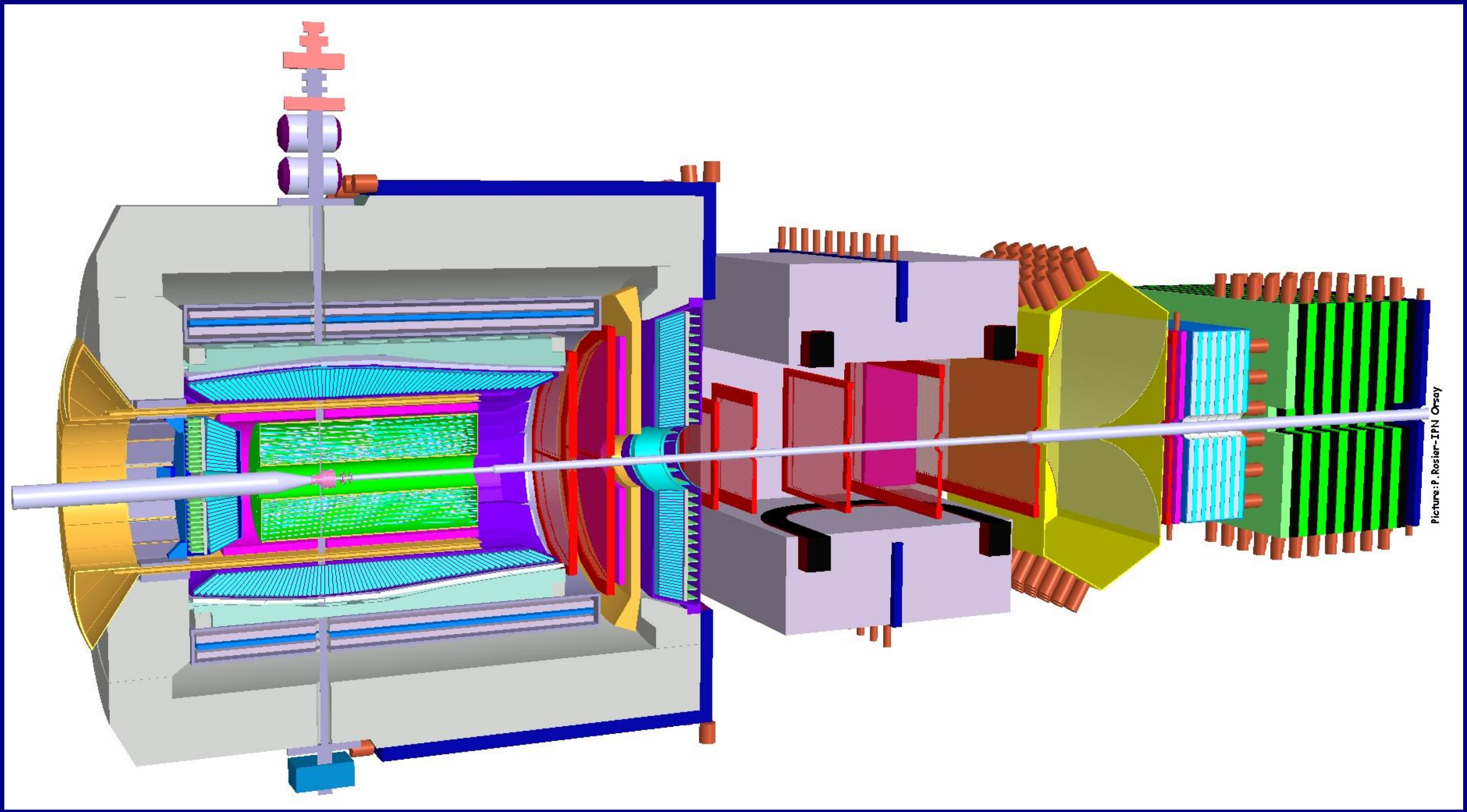

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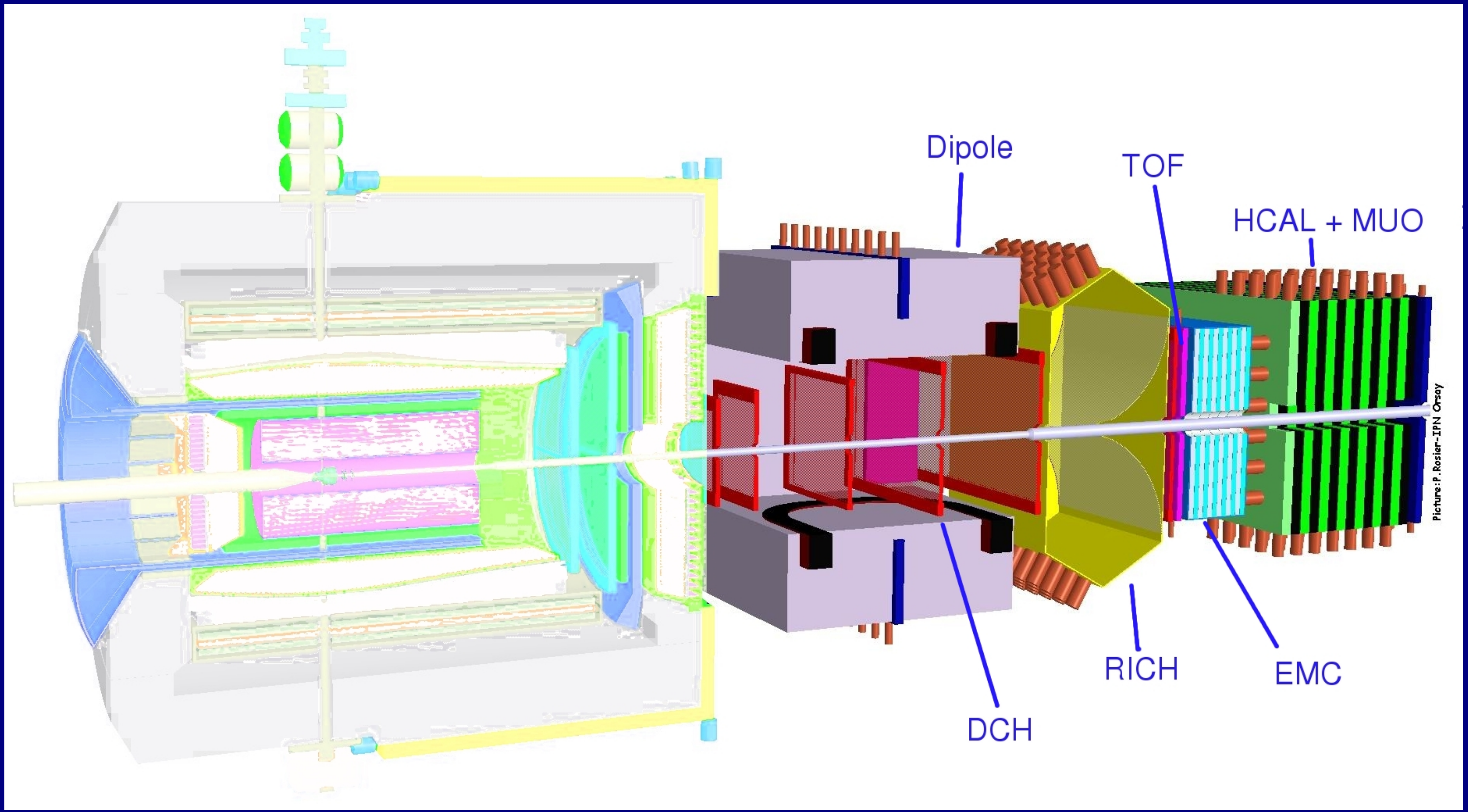

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