The Electromagnetic Calorimeter of the future PANDA Detector

AntiProton ANnihilations at DArmstadt

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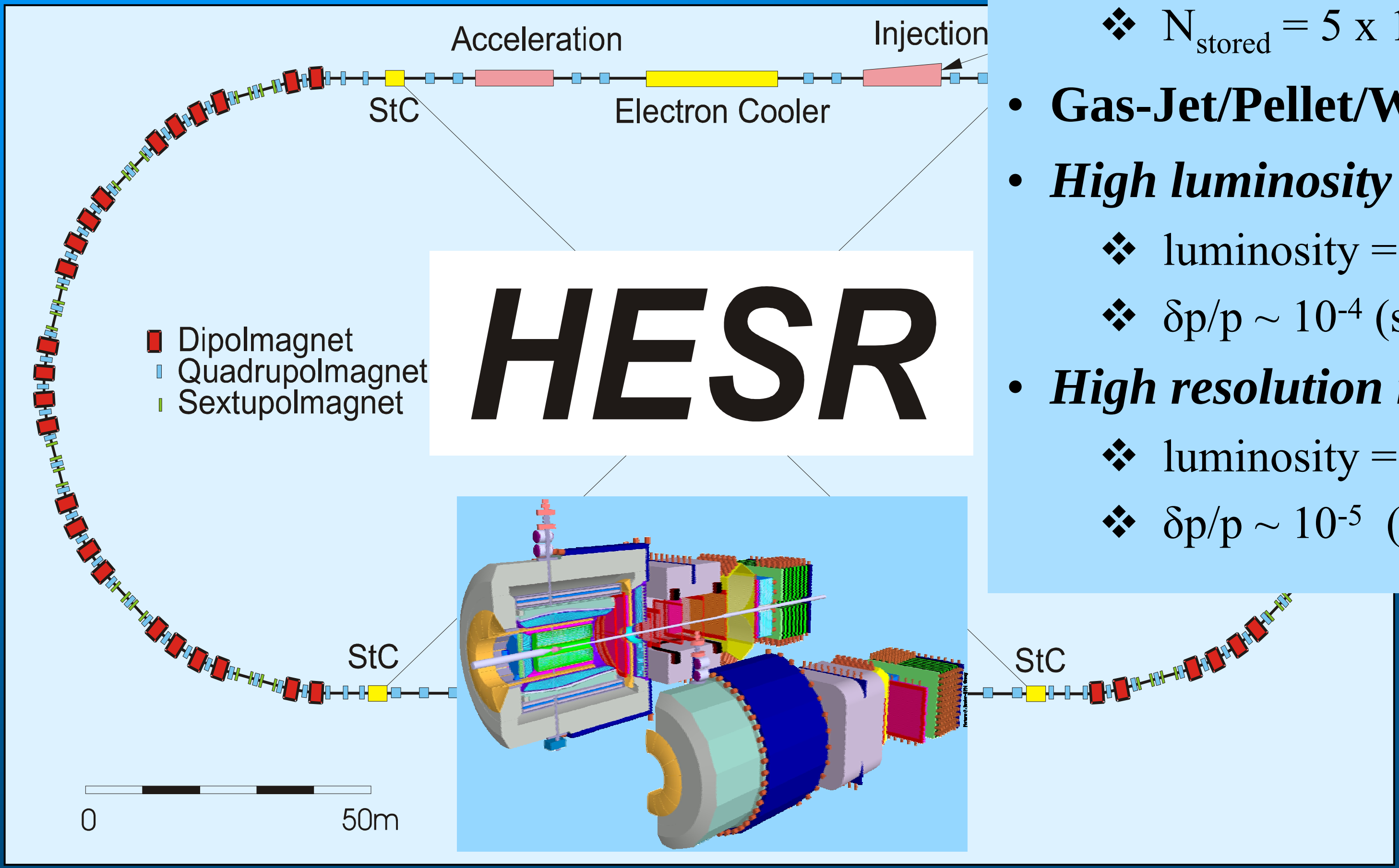
for the
PANDA collaboration

- **PANDA at FAIR/GSI**
  - **physics program**
  - **experimental requirements**
- **the detector concept of the EMC**
- **the new generation of $PbWO_4$: PWO-II**
  - **the scintillation properties**
  - **thermal quenching**
  - **response functions (PM- or APD-readout)**
  - **ongoing R&D**
- **status and time-schedule for operation**

the GSI, Darmstadt (Germany): now and in near future

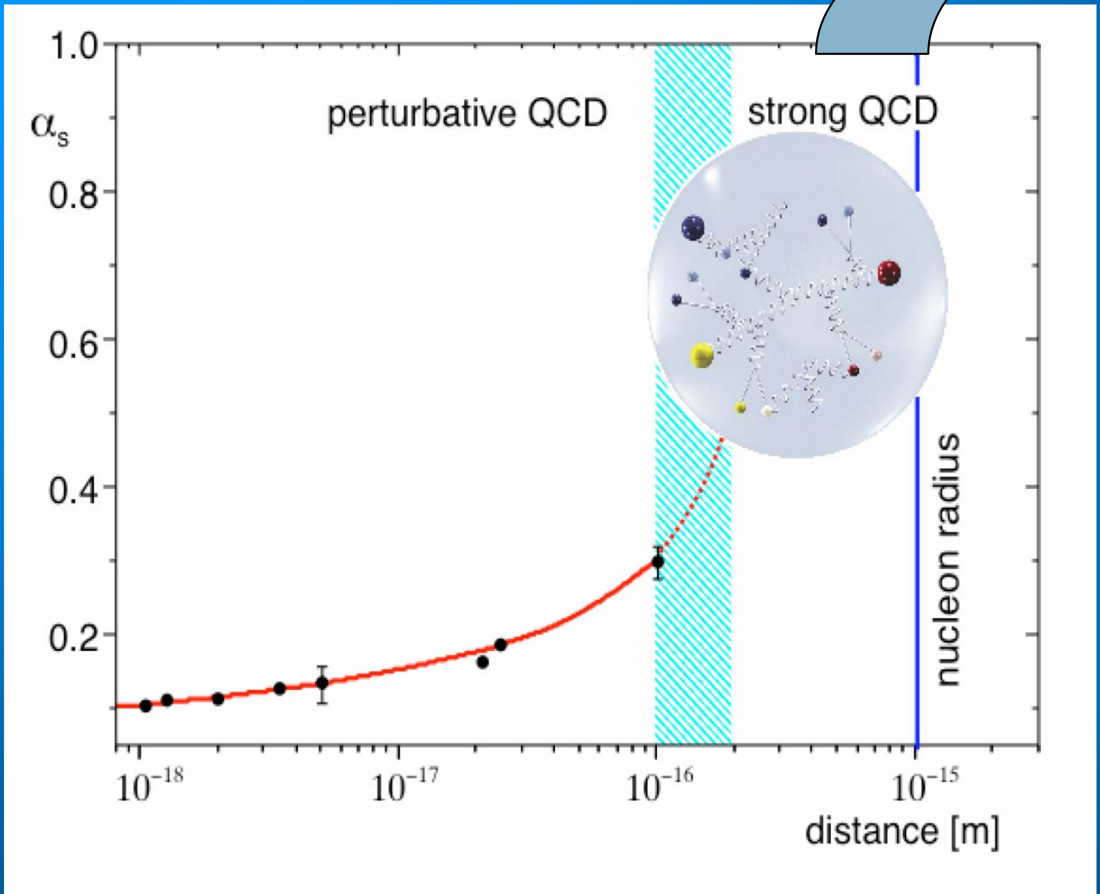
- double ring synchrotron **SIS 100/300** — **2.4/34 GeV/u U**
- **C**ollector **R**ing — **740 MeV/u, A/q=2.7**
- **N**ew **E**xperimental **S**torage **R**ing — **740 MeV/u, A/q=2.7**
- **HESR** — **0.8 – 14.5GeV antiprotons**
- super **FR**agment **S**eparator

the PANDA environment

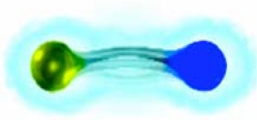


- $\bar{p}$ - production similar to CERN
- **HESR** = High Energy Storage Ring
  - ❖ production rate 10^7/s
  - ❖ P_{beam} = 1.5 - 15 GeV/*c*
  - ❖ $N_{stored} = 5 \times 10^{10}$ p
- **Gas-Jet/Pellet/Wire-Target**
- ***High luminosity mode***
  - ❖ luminosity = 2×10^{32} cm^{-2}s^{-1}
  - ❖ $\delta p/p \sim 10^{-4}$ (stochastic cooling)
- ***High resolution mode***
  - ❖ luminosity = 10^{31} cm^{-2}s^{-1}
  - ❖ $\delta p/p \sim 10^{-5}$ (electron cooling)

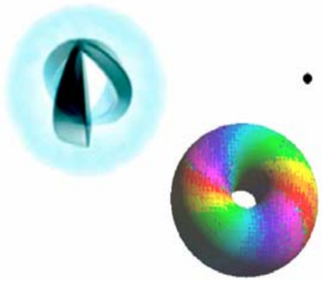
physics objectives



exploring non-pertubative QCD



- hybrids: "ordinary" quark states containing excited glue

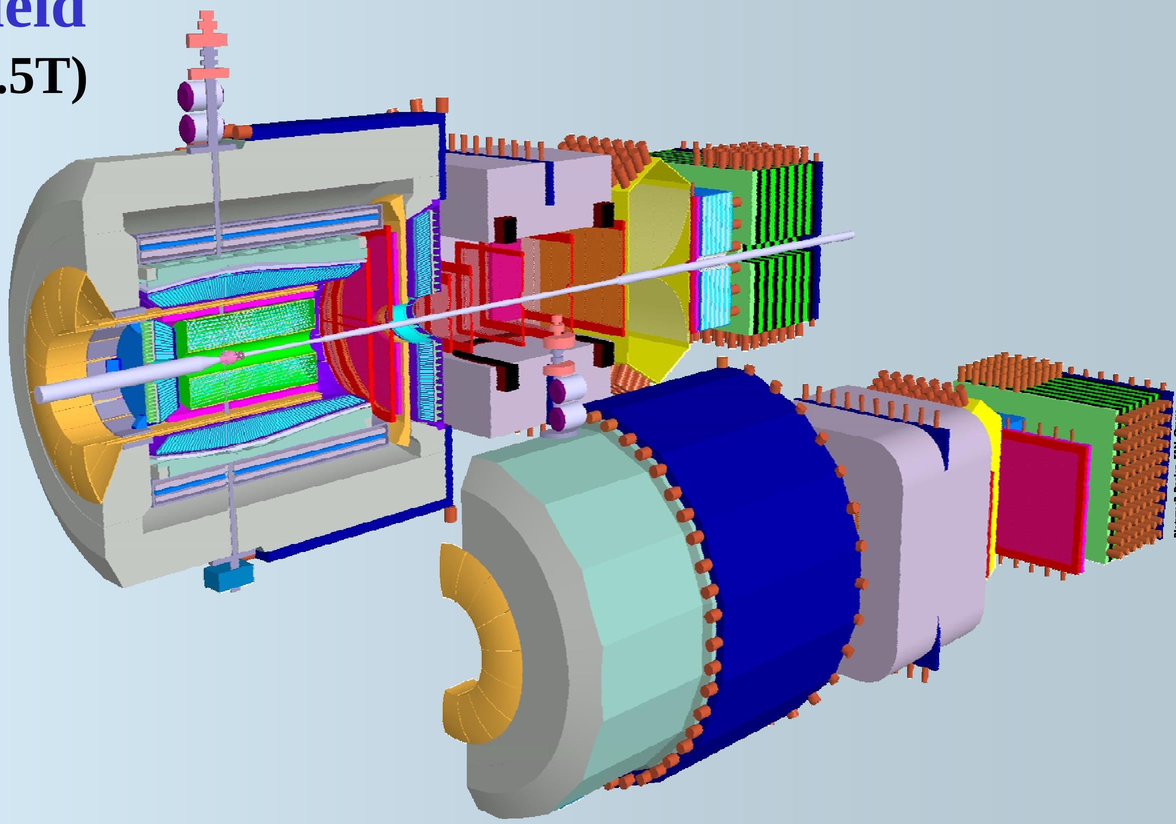


- glueballs: gluonic states without valence quark contribution

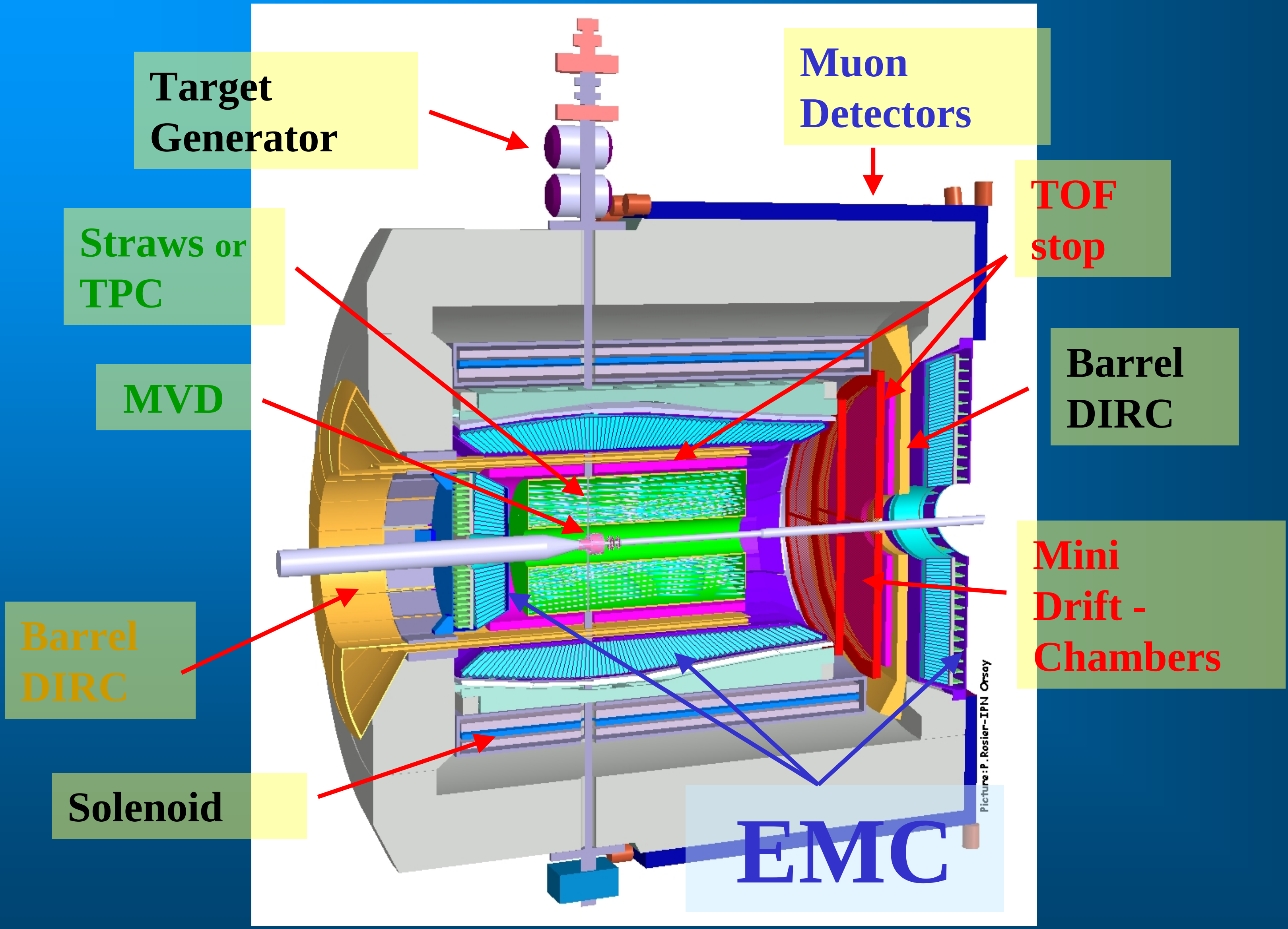
- charmonium spectroscopy
- gluonic excitations (hybrids, glueballs, ...)
- open and hidden charm in nuclei
- γ-ray spectroscopy of hypernuclei

aimed detector capabilities

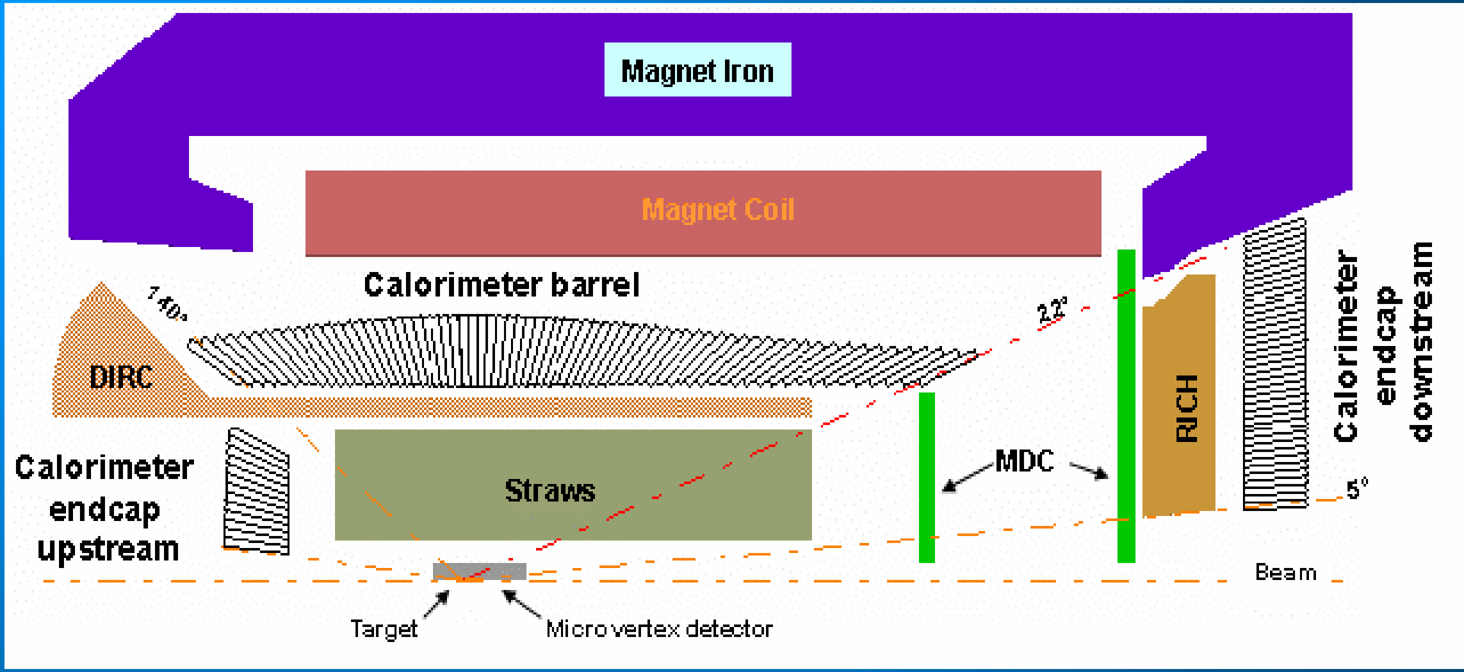
- **high count rates**
  - **$2 \cdot 10^7$ interactions/s (σ ~ 55mb)**
- **vertex reconstruction**
  - **D, K_s, Λ, ...**
- **tracking in magnetic field**
  - **solenoid (2T), dipole (3.5T)**
  - **$\Delta p/p$ ~ 1%**
- **charged particle ID**
  - **$e^\pm$, $\mu^\pm$, $\pi^\pm$, p, ...**
- **EM calorimetry**
  - **γ, π^0, η, ...**
- **forward spectrometry**
  - **leading particles**
- **complex triggers**
  - **e, μ, K, D, Λ**
- **modular design**
  - **hypernuclei studies**



target spectrometer



electromagnetic calorimeter EMC



- nearly 4π coverage ➤ compactness ➤ dense scintillator, small X_o, R_M
- high rate capabilities ➤ granularity, fast response ➤ fast scintillator, short decay time, timing information
- high resolution ($10 \text{ MeV} < E_\gamma < 8 \text{ GeV}$) ➤ high luminescence, effficient photosensor ➤ bright scintillator, insensitive to MF

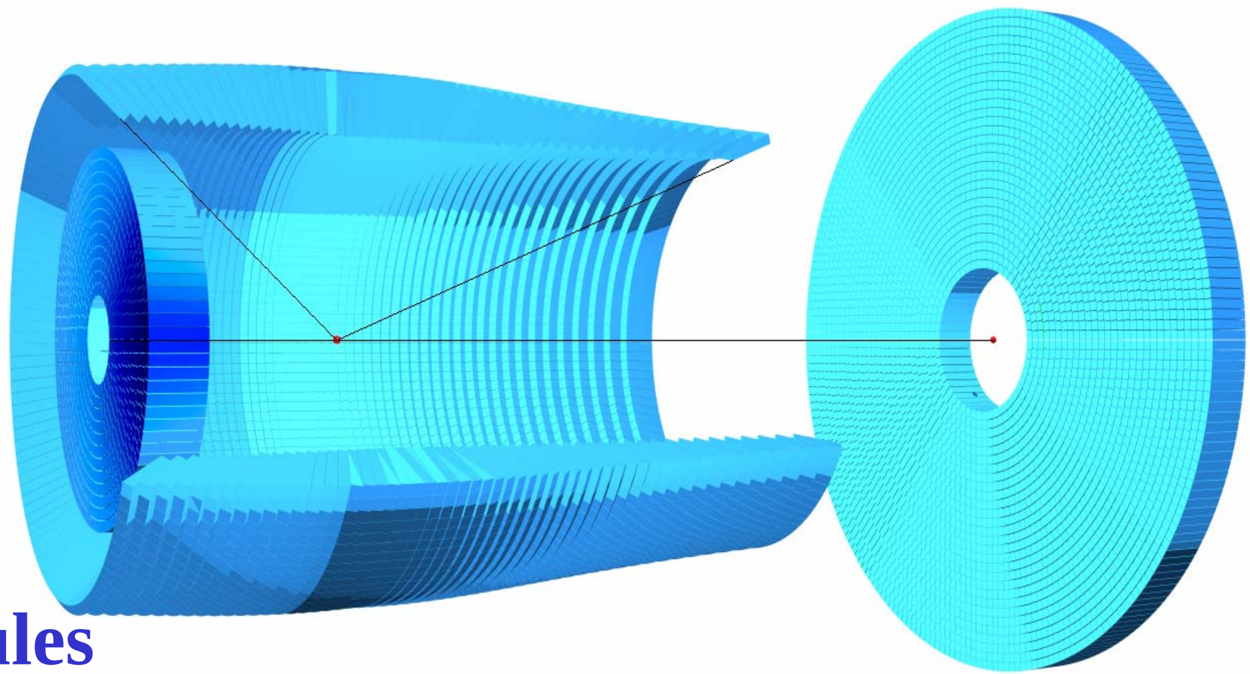
EMC detector material: $PbWO_4$ (PWO)

- ✓ **compact:** $X_0 = 0.9$ cm, $R_M = 2.2$ cm
- ✓ **fast:** $\tau < 10$ ns
- ✓ **radiation hard:** slight reduction of optical transmission → monitoring
- ✓ **readout in magnetic field:** $\lambda = 420$ nm, adapted to APD
- ? **good energy resolution:** down to 10 – 20 MeV

barrel:
11360 crystals

forward endcap:
6864 crystals

backward endcap:
816 crystals



total ~ 20,000 modules

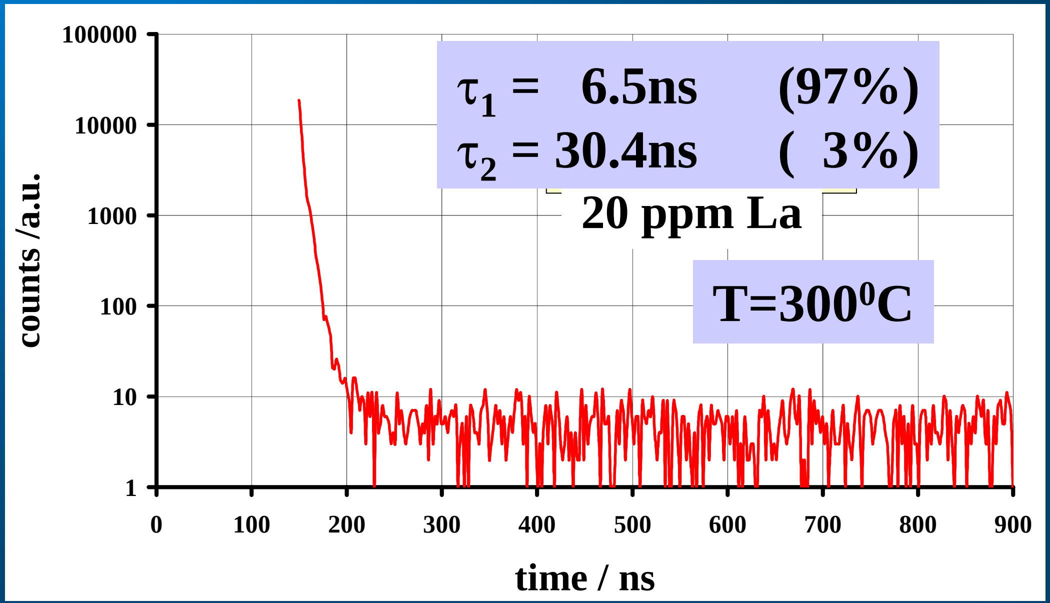
EMC development of PWO-II

optimization of $PbWO_4$ in collaboration with RINP, Minsk and the manufacturer BTCP at Bogoroditsk, Russia

- ✓ reduction of defects (oxygen vacancies)
- ✓ reduced concentration of La-, Y-Doping
- ✓ better selection of raw material
- ✓ optimization of production technology

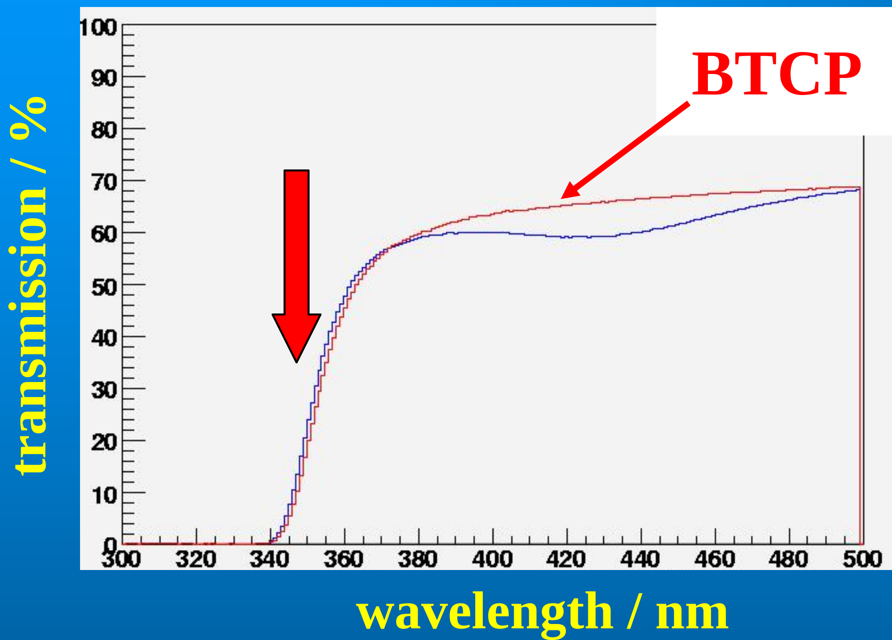
scintillation mechanism

- extreme short decay time (even at -25°C)
- **no** slow components



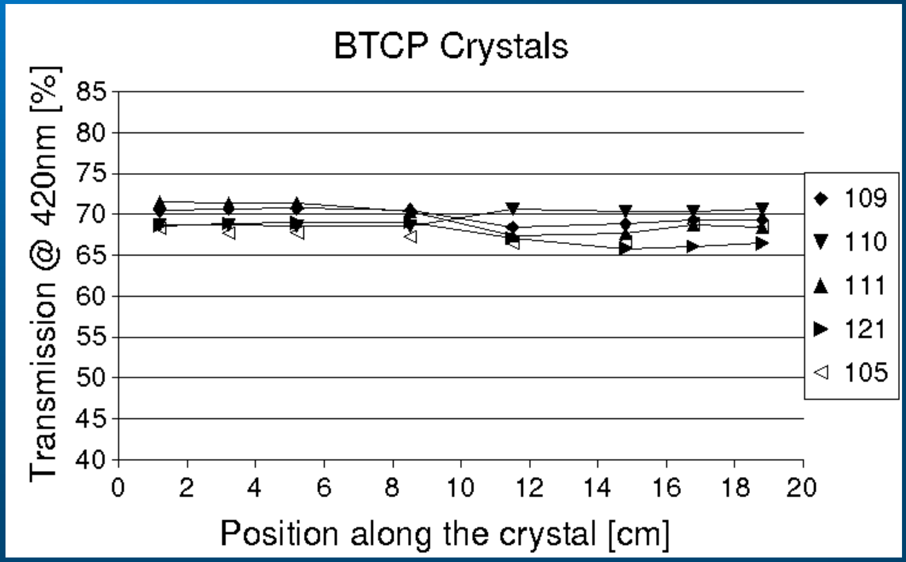
EMC development of PWO-II

optical quality



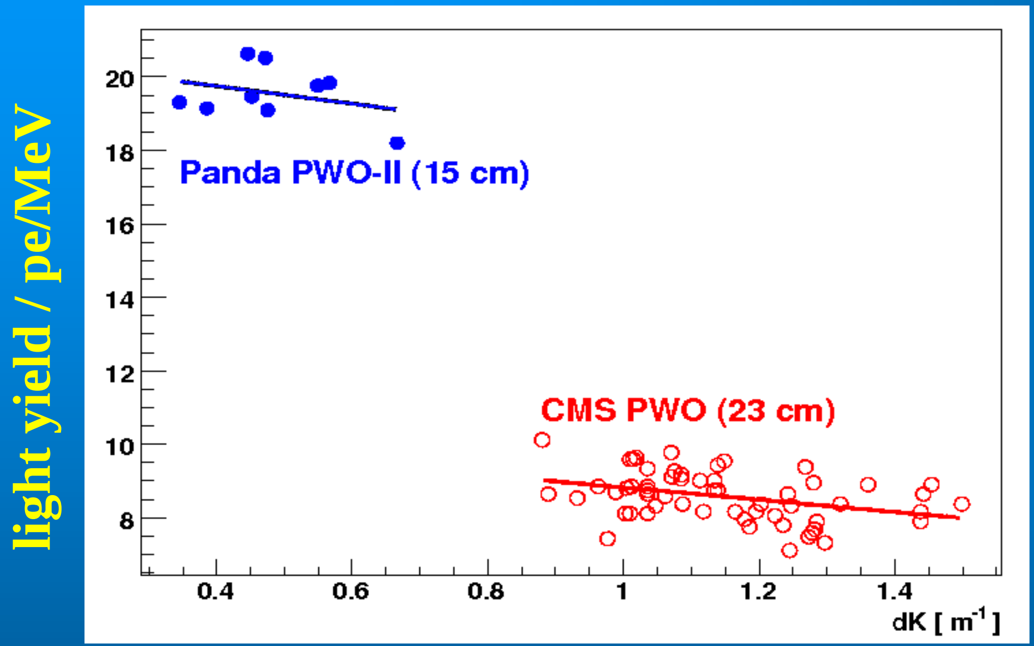
- ✓ no absorption bands
- ✓ low absorption edge

✓extreme **homogeneity**
along the full crystal length of 20cm



EMC development of PWO-II

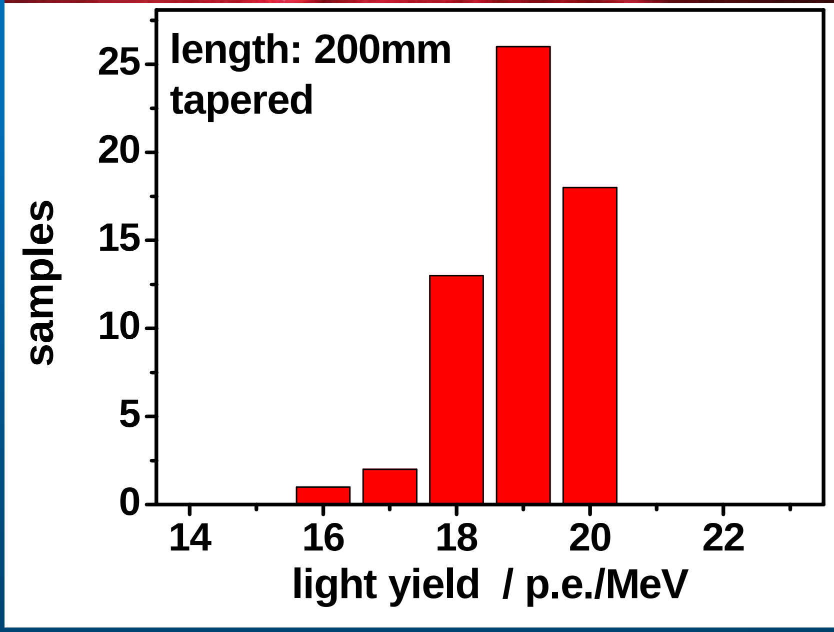
luminescence yield



60 prototype crystals for PANDA

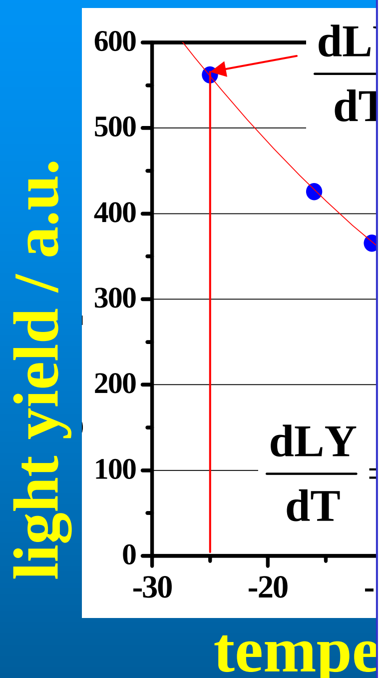
✓ mass production possible

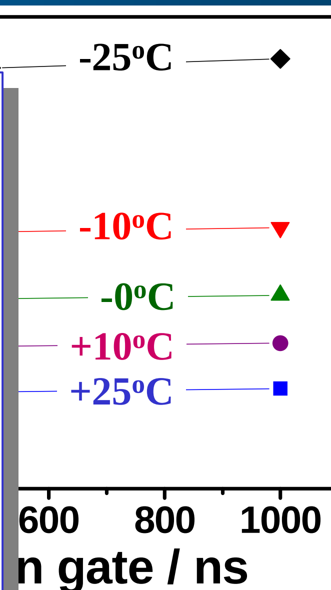
✓ doubled light yield

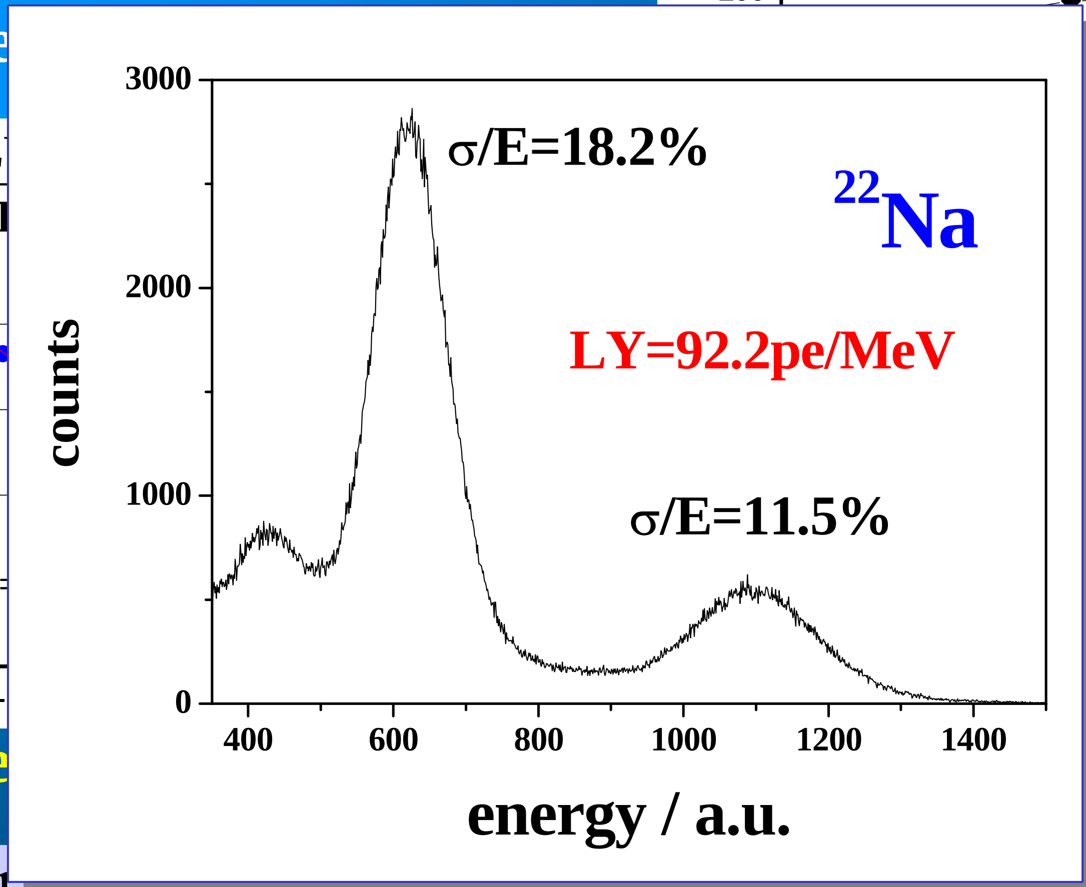


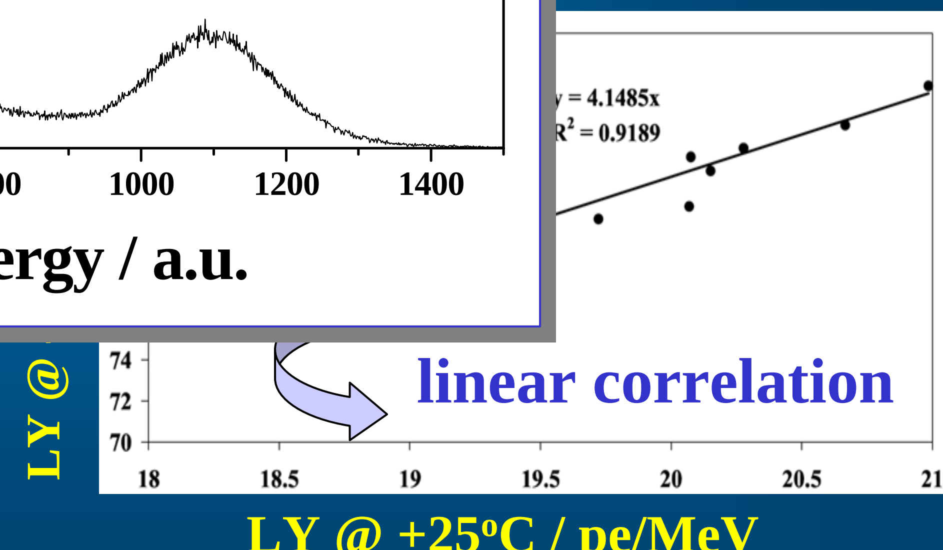
EMC development of PWO-II

luminescence







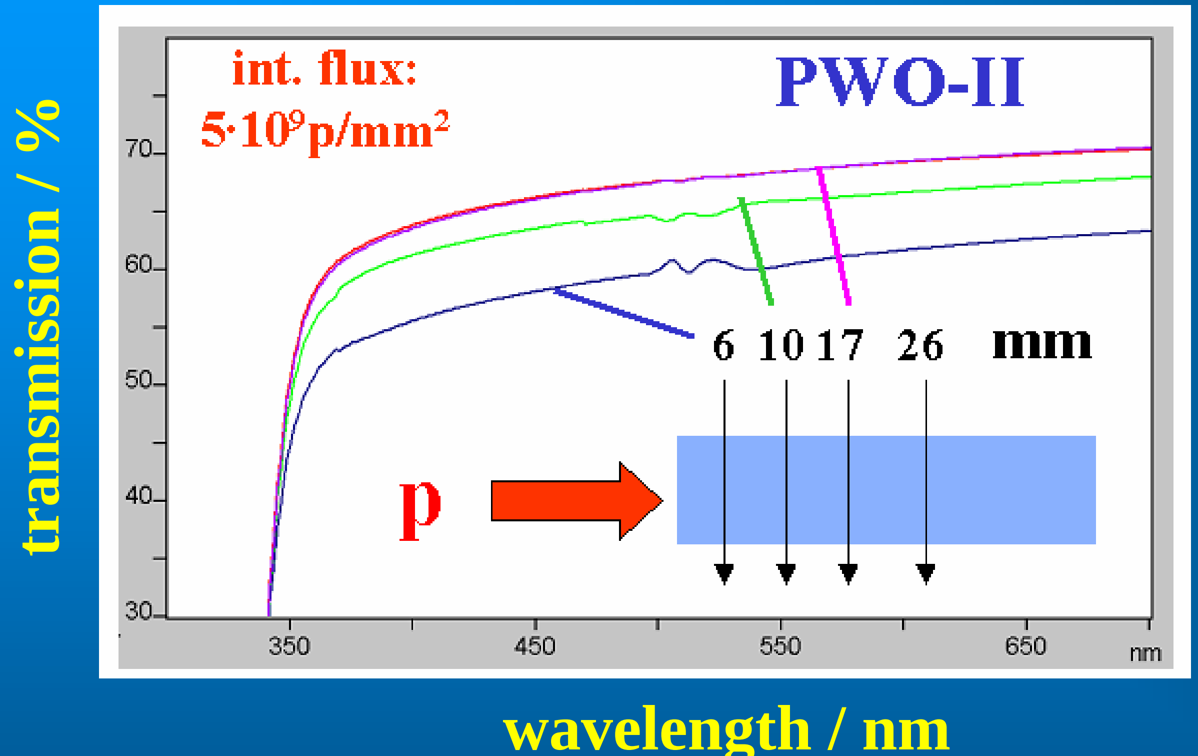


reduction of thermal quenching

3-4-fold light yield compared to RT

EMC development of PWO-II

radiation hardness



dose:

10^{13} protons

E_p = 90 MeV

@ KVI, Groningen

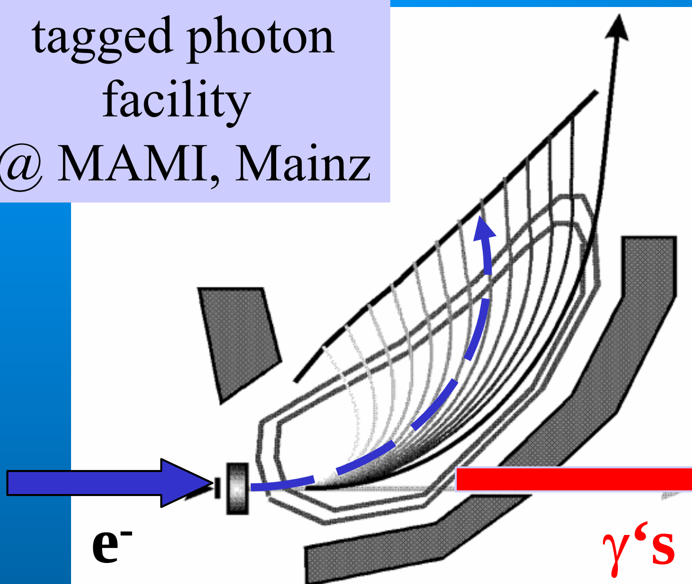
- ✓ no permanent damage due to defect formation
- ✓ activation due to proton induced reactions
- ✓ reduction of optical transmission

⇨ monitoring mandatory

EMC development of PWO-II

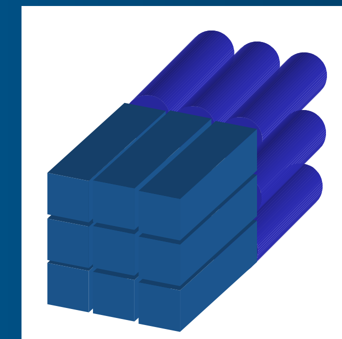
response to high energy photons

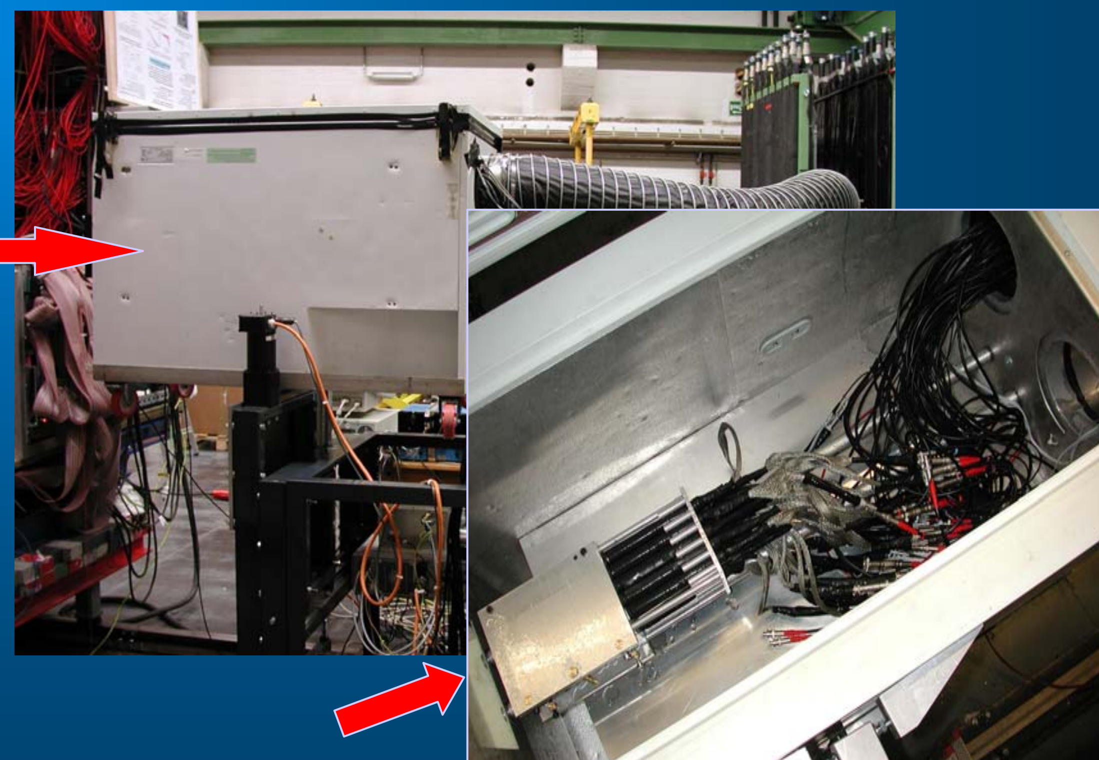
tagged photon facility @ MAMI, Mainz



64 MeV < E_γ < 520 MeV

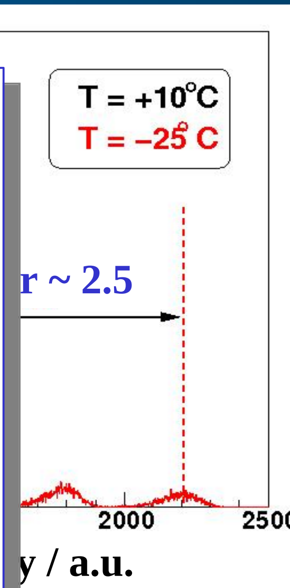
3x3 Matrix
PM-Auslese
20x20x200mm³

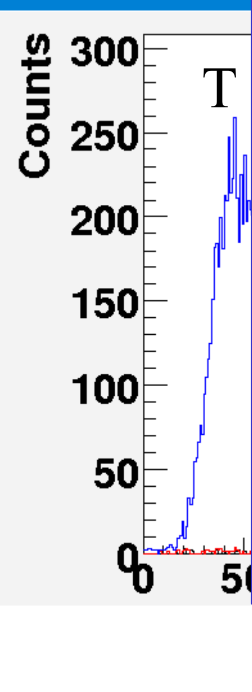


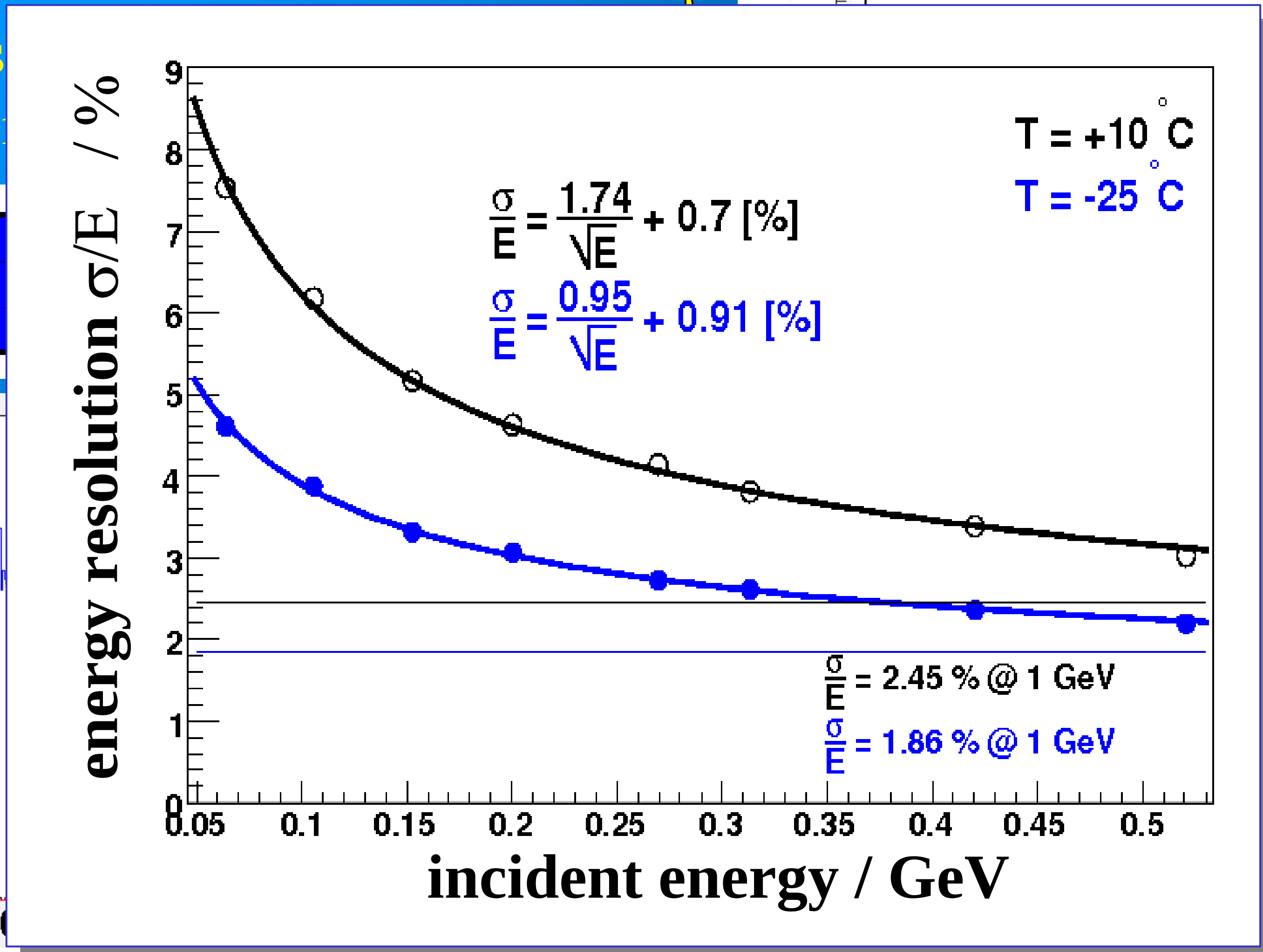


EMC development of PWO-II

comparis…
at 2 differ…







…nergy
…MeV

…achieved
resolution

EMC

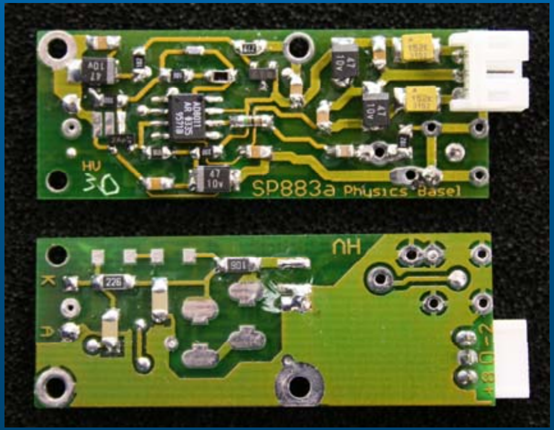
readout with Large Area Avalanche Photo Diodes (LAAPD)

in collaboration with
Hamamatsu Photonics

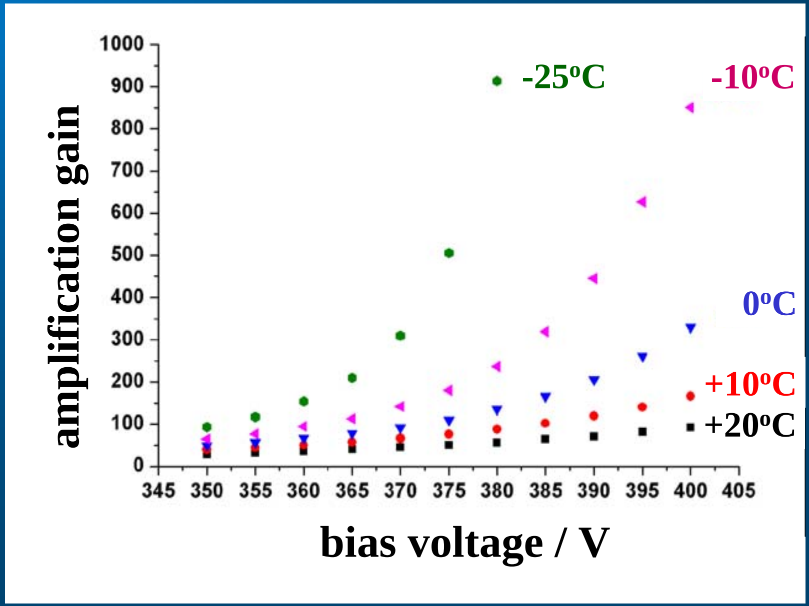
$10x10mm^2$ $5x5mm^2$

- excellent performance
  at RT and T = –25°C
- radiation resistent
  up to 10^{13} protons
  in particular at T = -25°C

- preamplifier development

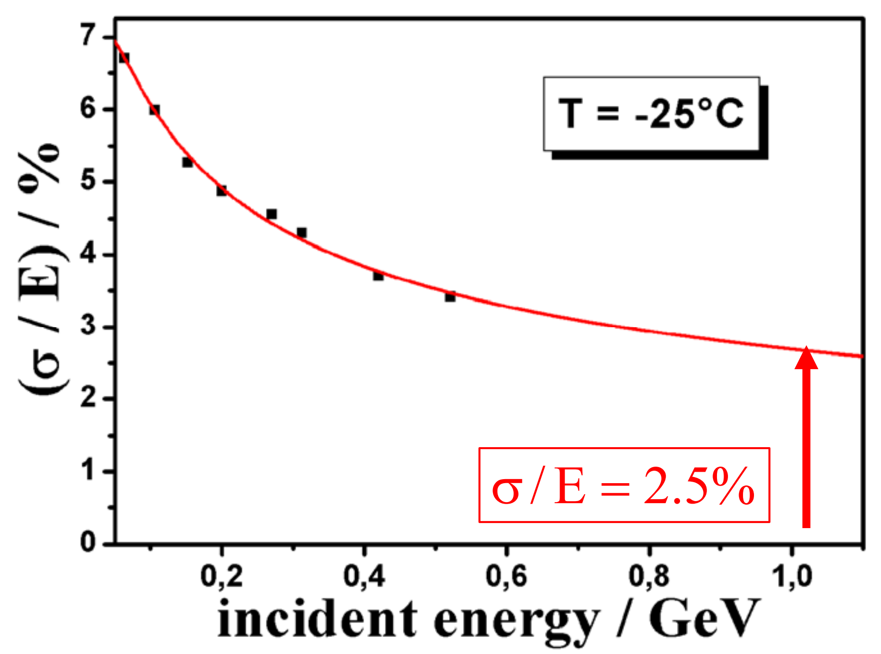


18mm



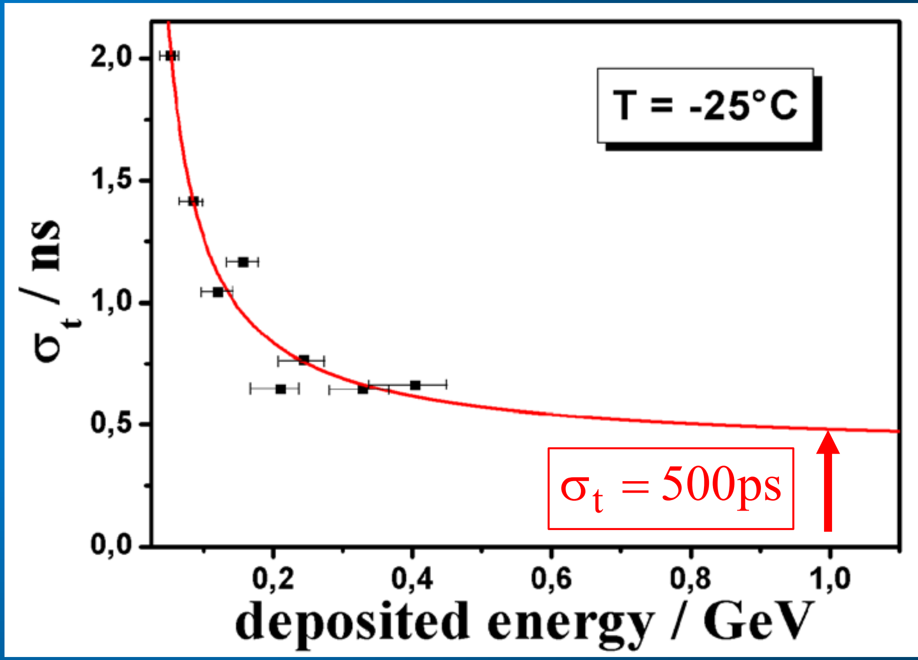
EMC

energy resolution



time resolution

central module versus *tagger*

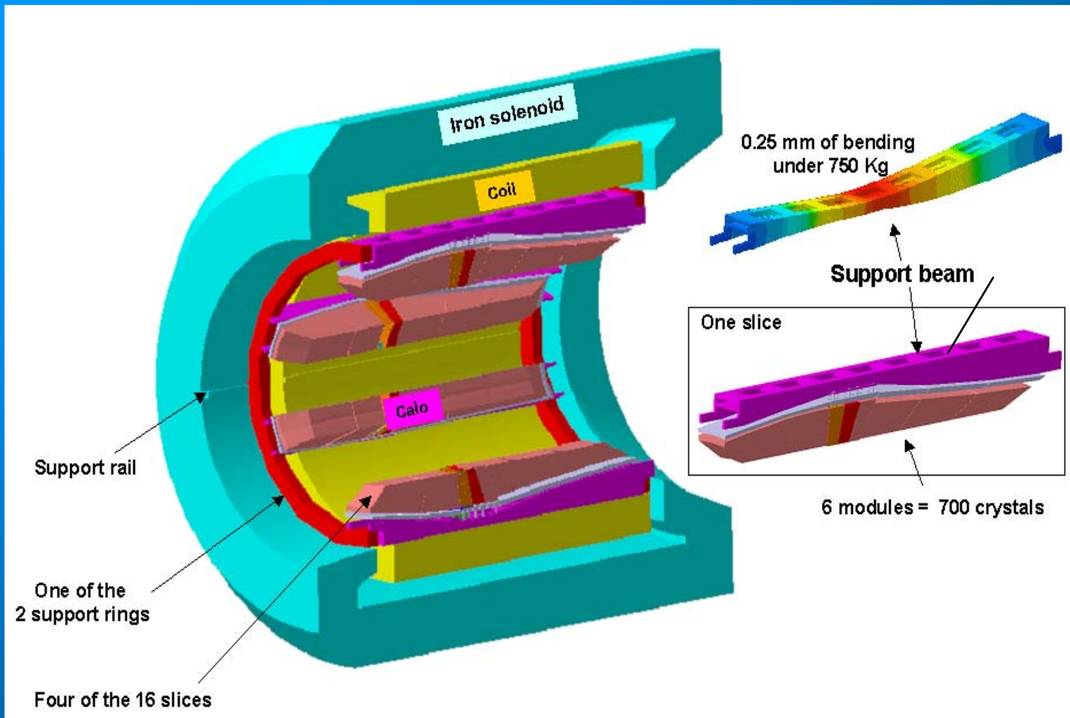


excellent resolution in spite of
- **incomplete matrix**
- **shower leakage (3x3)**

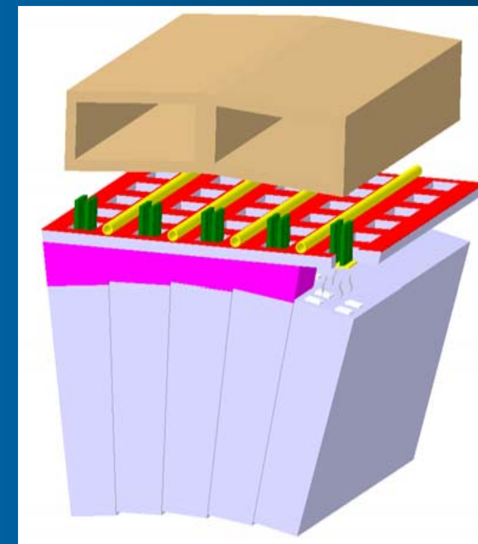
no optimum setup, but:
- **σ_t < 1ns above E_γ ~150MeV**
- **fast calorimetry, PID**

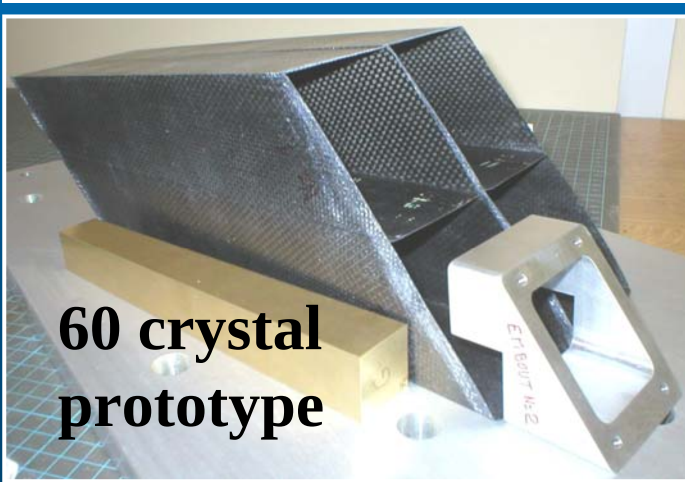
EMC

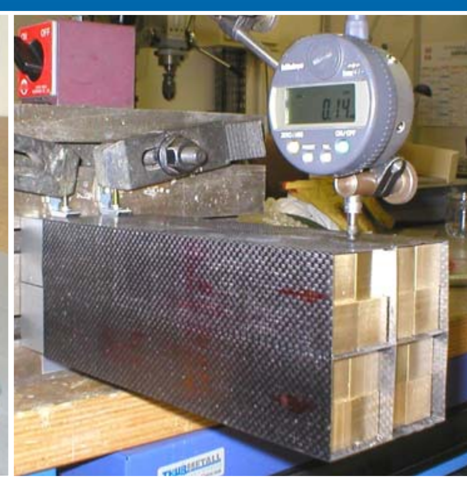
calorimeter to be operated at – (25.0±0.1)ºC !

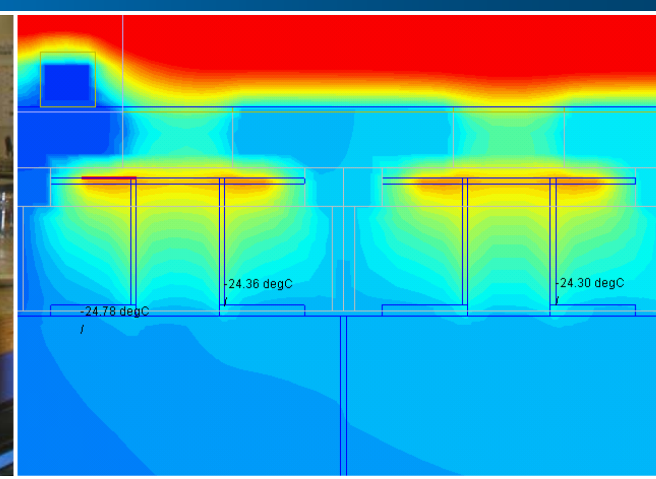


- cooling
- temperature stabilization









- **very complex and ambitious detector**
- **concept mostly fixed, but R&D still ongoing:**

  cooling technology

  FE-electronics (ASIC), large dynamic range
  energy and timing information
  photosensor of forward endcap (APD/VPT)

EMC very advanced – design to be fixed in middle of 2007

ordering crystals in 2008

- **PANDA detector to be completed in 2011**
- **2012: start of operation of *PHASE 1***

spokesperson: Ulrich Wiedner - Bochum
deputy: Paola Gianotti - LNF

PANDA Collaboration

Universität Basel, IHEP Beijing, Ruhr-Universität Bochum, Universität Bonn, Università di Brescia + INFN, Università di Catania, University of Silesia, University Cracow, GSI Darmstadt, TU Dresden, JINR Dubna, JINR Dubna [illegible] University Edinburgh, Universität Erlangen [illegible] University, INFN Sezione di Ferrara [illegible], LNF-INFN Frascati, INFN Sez[illegible]ersità di Genova, Universität G[illegible] Glasgow, KVI Groningen, Instit[illegible]nki, FZ Jülich - IKP I, FZ Jülich [illegible]u, Universität Mainz, Un[illegible] München, Universität Münster, [illegible]sk, IPN Orsay, Università di Pavia, PNPI [illegible] St. Petersburg, IHEP Protvino, Stockholm [illegible]niversity , Università di Torino, Università de Piemonte, Università di Trieste + INFN, Universität Tübingen, Uppsala Universitet, TSL Uppsala, Universidad de Valencia, Stefan Meyer Institut für subatomare Physik, Vienna, SINS Warschau

additional partners very welcome

15 countries – 47 institutes – 370 scientists