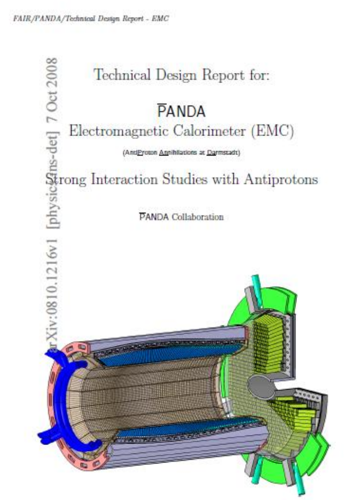
Overview : EMC calorimeter for PANDA @ FAIR

Anti-Proton ANnihilation at DArmstadt

Facility for Antiproton and Ion Research in Europe GmbH

Egle Tomasi-Gustafsson
IRFU, SPhN-Saclay,
and
R. Novotny
University of Giessen


FAIR/PANDA/Technical Design Report - EMC

arXiv:0810.1216v1 [physics.ins-det] 7 Oct 2008

Technical Design Report for:

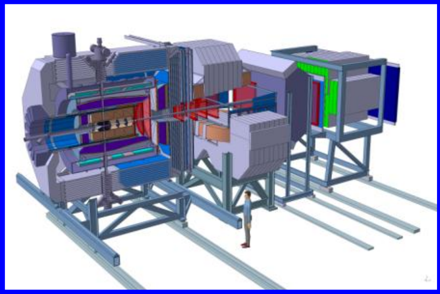
P̄ANDA

Electromagnetic Calorimeter (EMC)

(AntiProton Annihilations at Darmstadt)

Strong Interaction Studies with Antiprotons

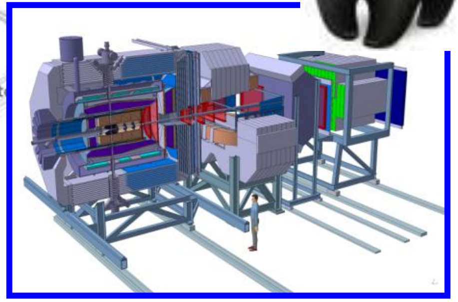
P̄ANDA Collaboration



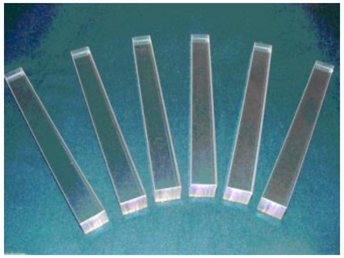
TDR arXiv:0810.1216v1 [physics.ins-det]

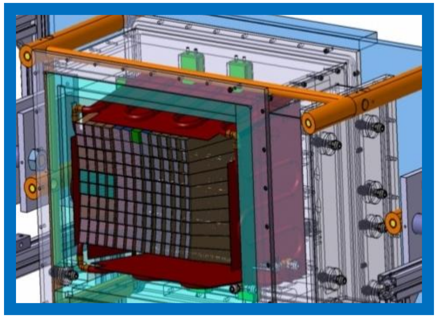
Plan

- Introduction : the landscape

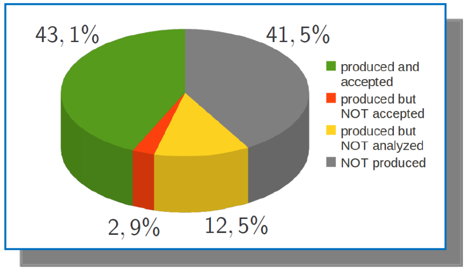


- $PbWO_4$-II (PWO): the characteristics
- EMC :the design
  - The geometry
  - The mechanics





- EMC: the tests
- The present status



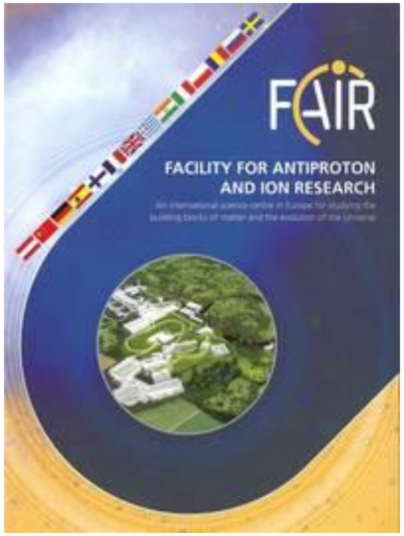
About 3000 scientists *from around the world will carry out experiments to understand the fundamental structure of matter, to explore exotic forms of it and to look for final answers of how the universe evolved from its primordial state into what we see today.*

FAIR covering four major fields: ***allows to carry out several physics programs in parallel***

APPA Physics - Atomic, Plasma Physics and Applications

CBM Compressed Baryonic Matter

NUSTAR Physics – Nuclear Structure, Astrophysics and Reactions



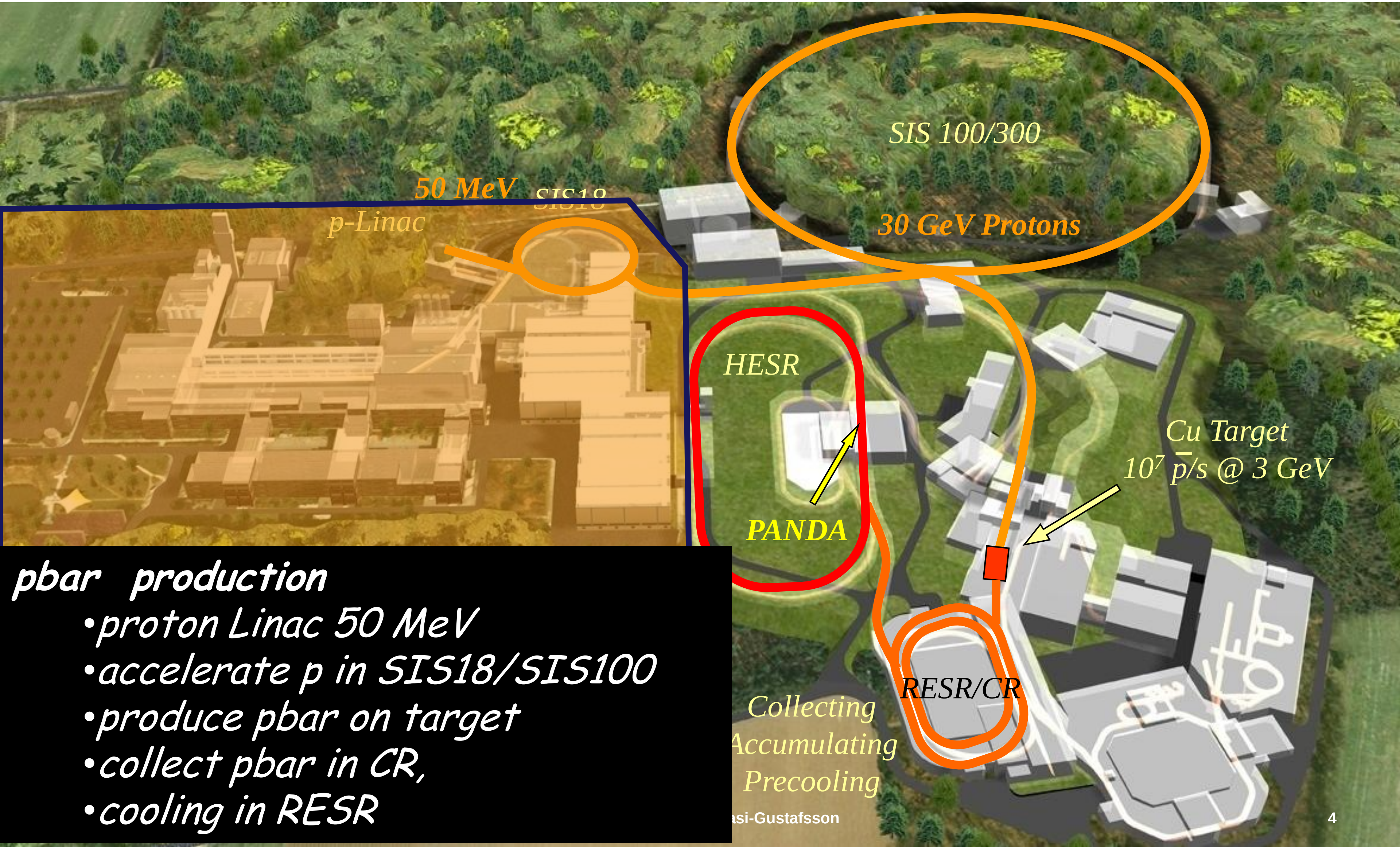
The PANDA (Antiproton Anihilation at Darmstadt) Experiment

http://www.fair-center.de

Antiprotons at FAIR

http://www.fair-center.eu/

http://www-panda.gsi.de/



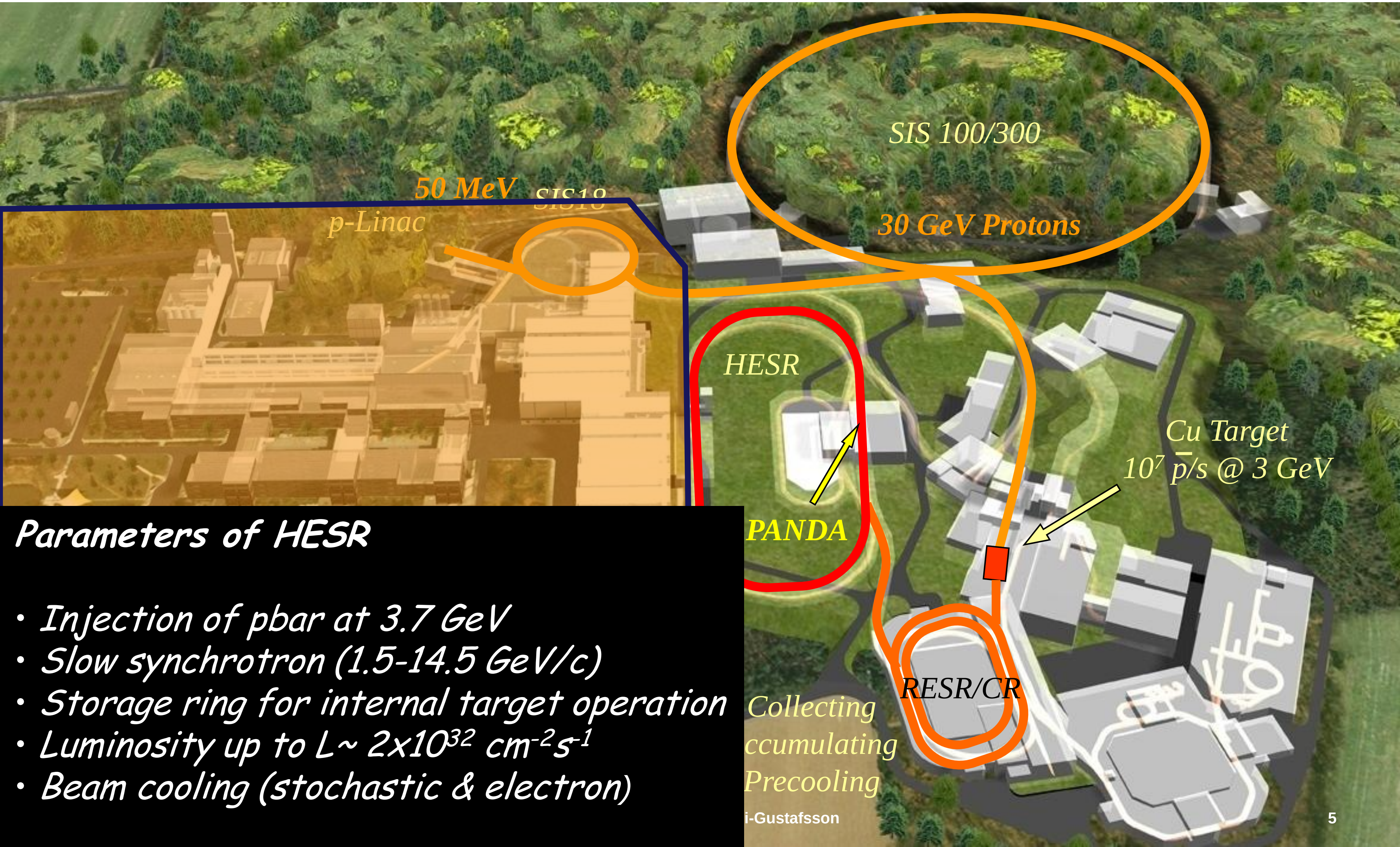
pbar production

- proton Linac 50 MeV
- accelerate p in SIS18/SIS100
- produce pbar on target
- collect pbar in CR,
- cooling in RESR

Antiprotons at FAIR

http://www.fair-center.eu/

http://www-panda.gsi.de/



Parameters of HESR

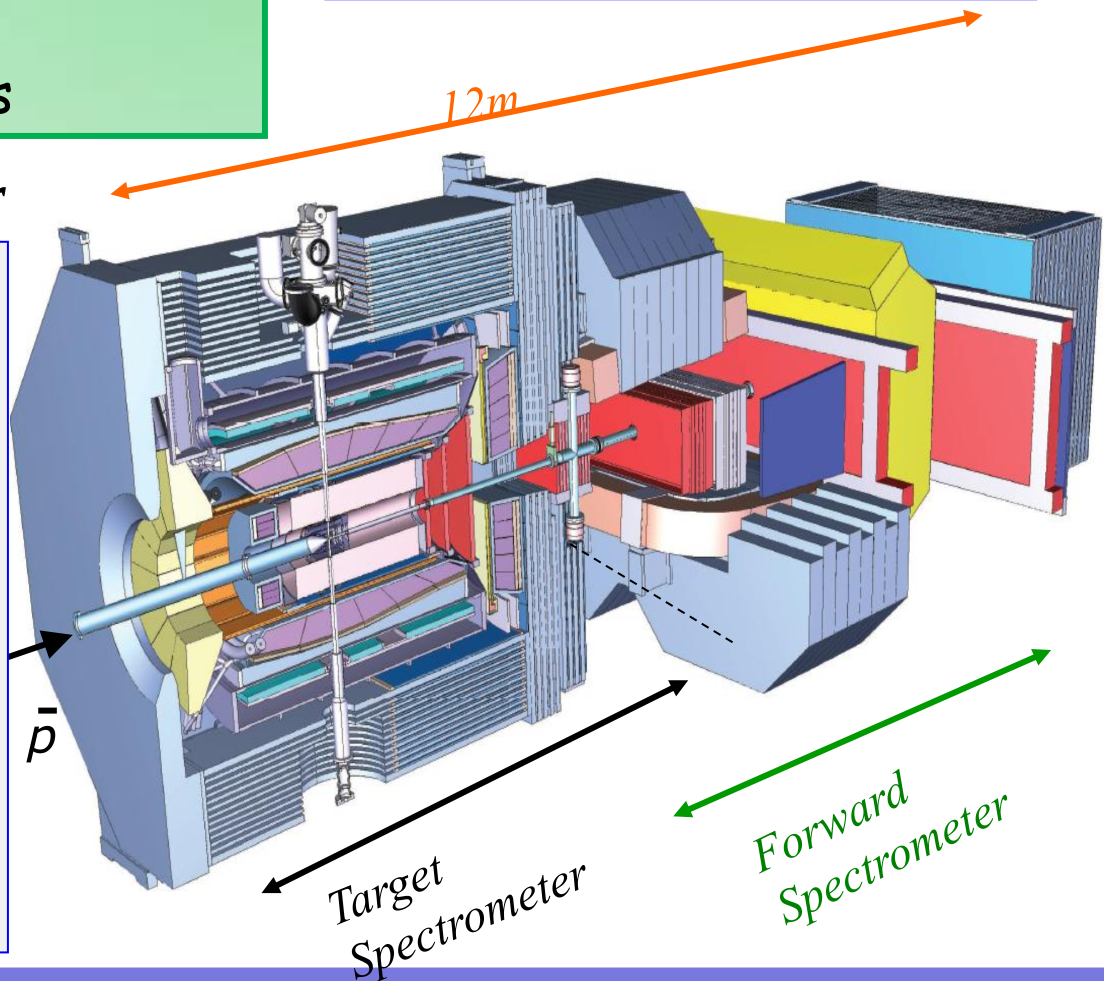
- Injection of pbar at 3.7 GeV
- Slow synchrotron (1.5-14.5 GeV/c)
- Storage ring for internal target operation
- Luminosity up to L~ 2×10^{32} $cm^{-2}s^{-1}$
- Beam cooling (stochastic & electron)

Hadron Physics with Antiprotons

- Dedicated experiments in the past decades for
  - Hadron spectroscopy
  - Hadron structure
  - Interaction of Hadrons

need of
- *Highest Rates*
- *Good Resolution*
- *Good Particle Identification*

panda ***detector***



Fixed target experiment

AND

Internal experiment

in HESR storage ring (not interacting antiprotons recirculate)

The accelerator and the detector are built and optimized together for the best performances

Physic topics Detector requirements

QCD bound states, hybrids, glueballs

Hadrons in nuclear matter

Electroweak physics

Electromagnetic processes

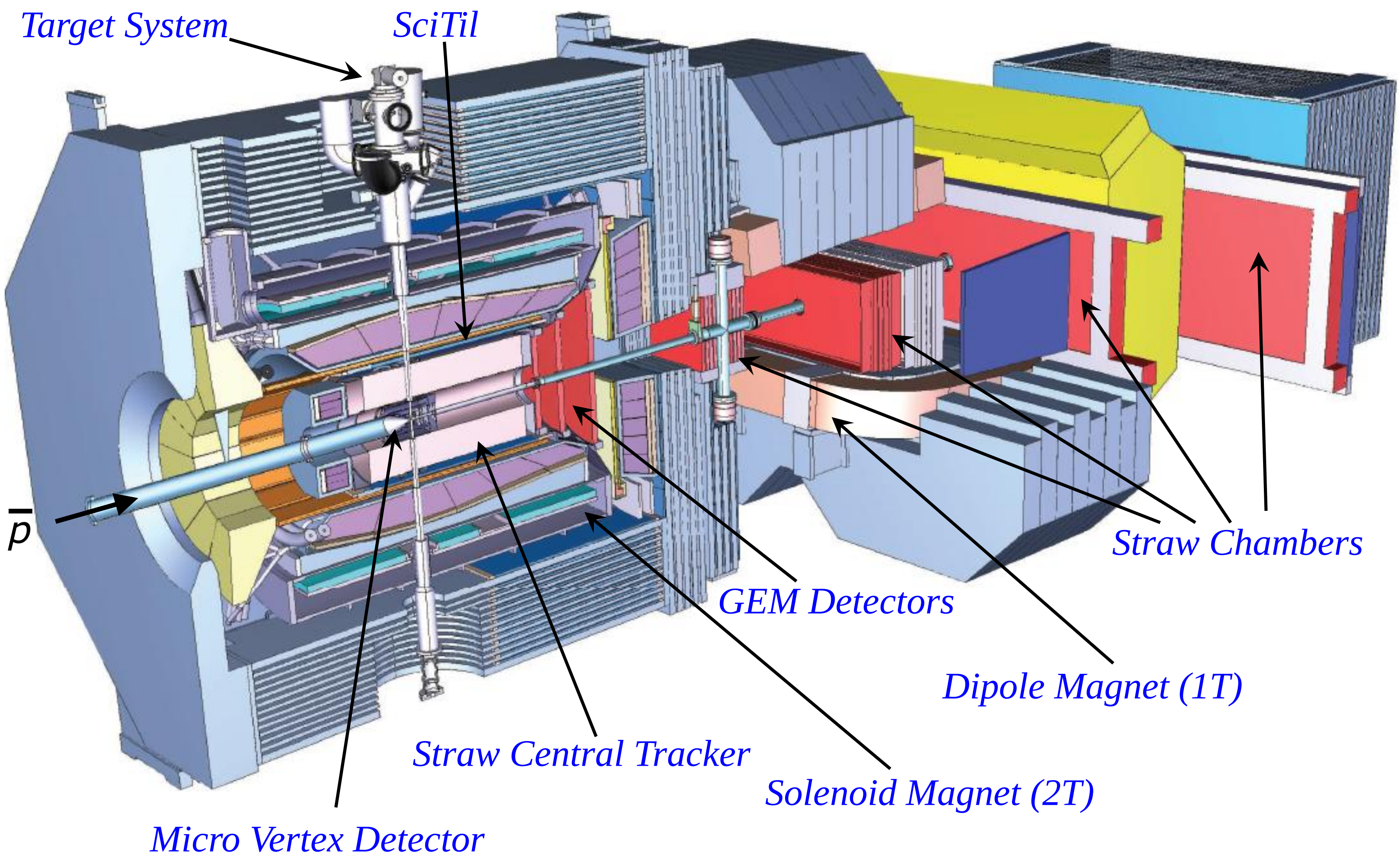
Hypernuclear Physics

- 4π acceptance
- high rate capability (average interaction rate 20 MHz)
- excellent tracking capabilities, momentum resolution 1%
- Vertex reconstruction for D, K_s , hyperons
- good PID (e, μ, π, K, p) $\rightarrow$ Čerenkov, ToF, dE/dx
- γ detection 10 MeV- 10 GeV $\rightarrow$ PWO-II crystal calorimeter
- flexible and modular design
- continuous data acquisition,
  no hardware trigger,
  intelligent software trigger

Target System and Tracking Devices

PANDA detector

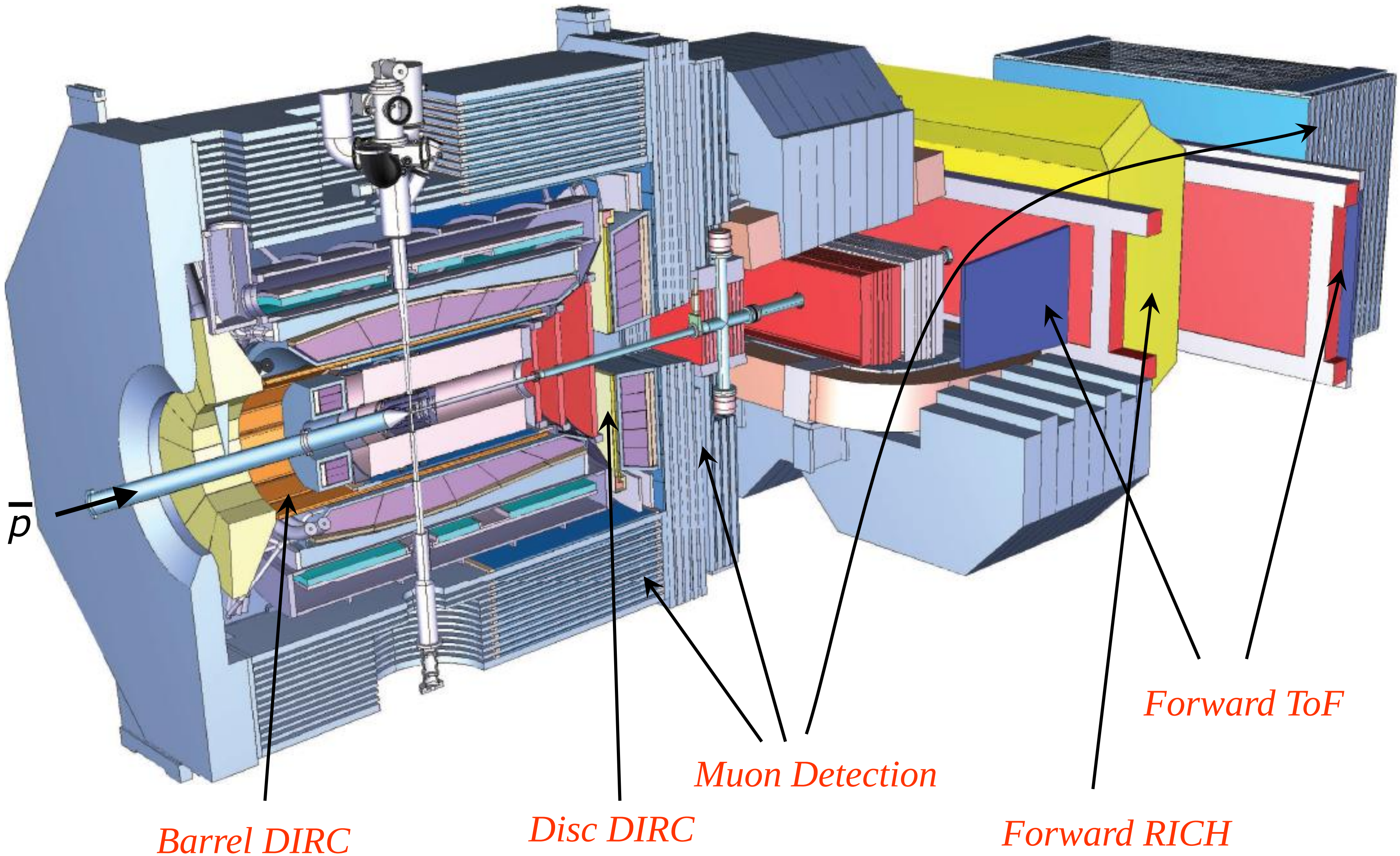
G.Boca , U. Pavia, Italy



Particle ID detectors

panda *detector*

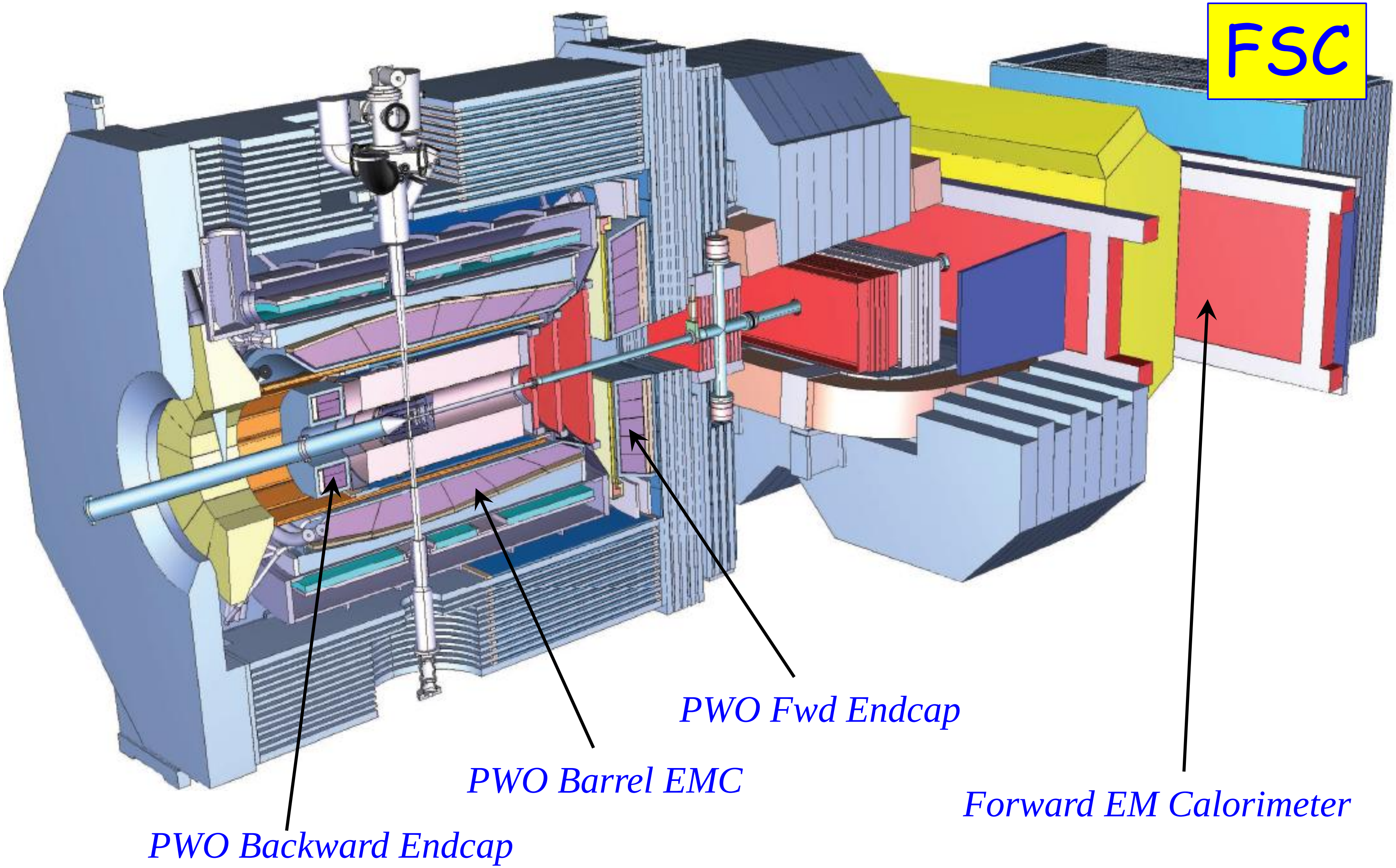
G.Boca, U. Pavia, Italy



Calorimetry

panda *detector*

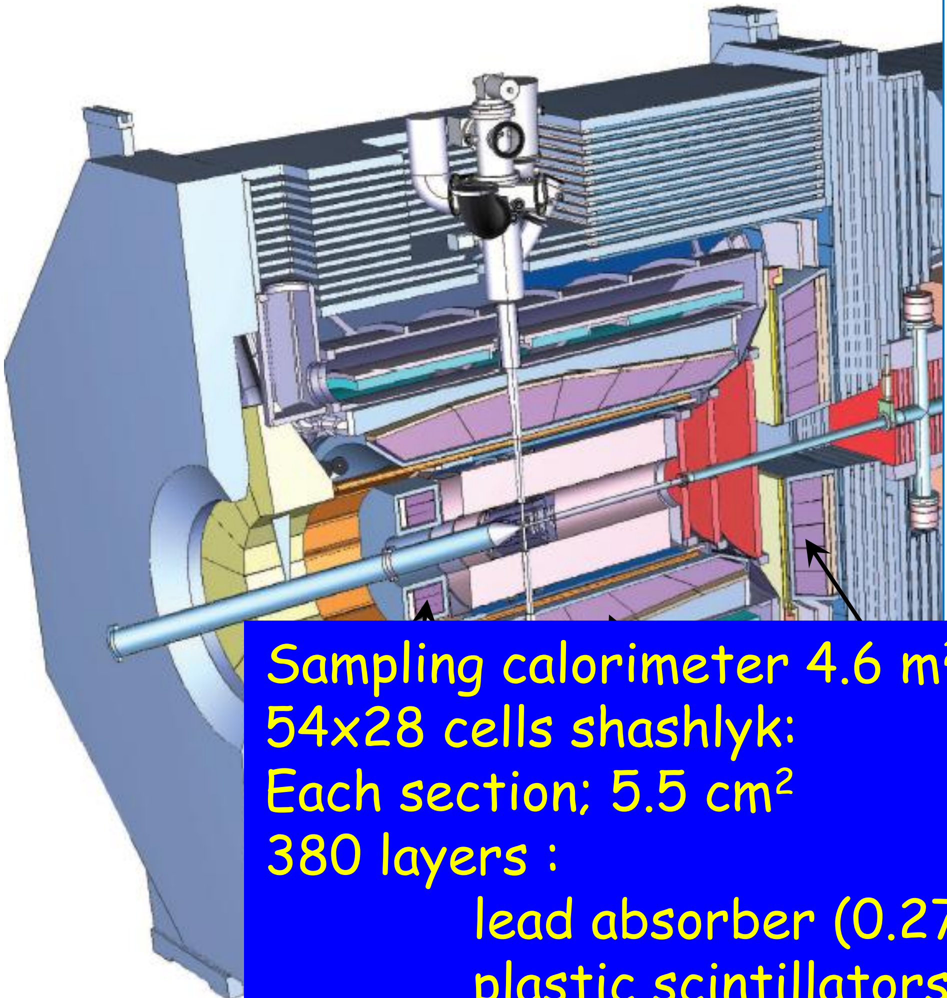
G.Boca , U. Pavia, Italy

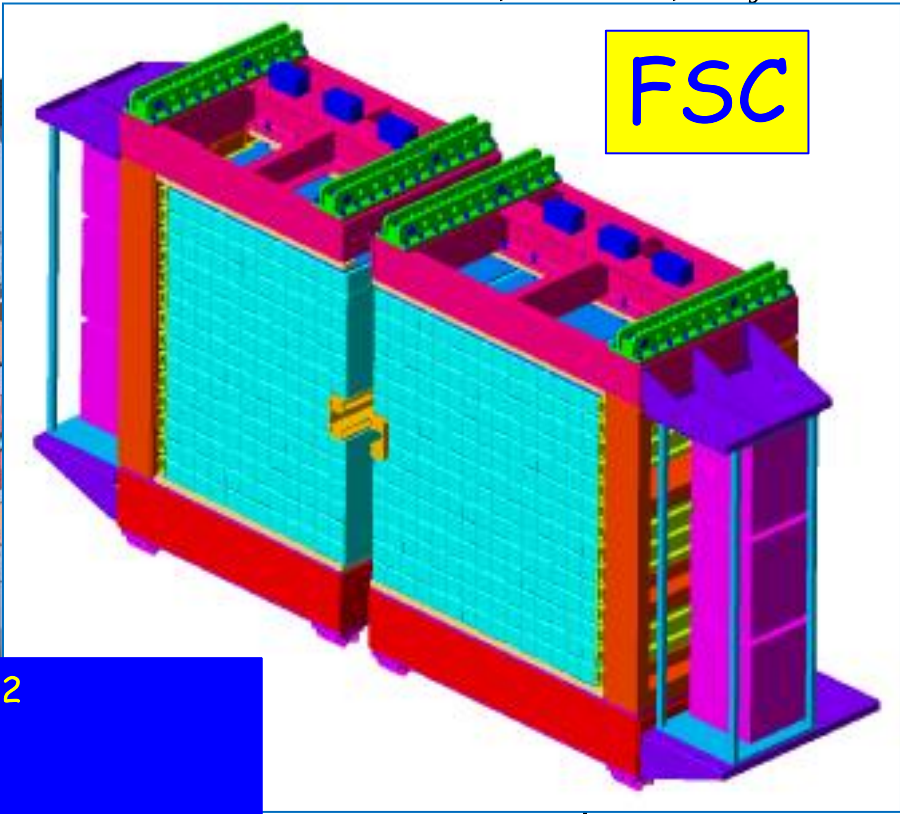


Calorimetry

panda ***detector***

G.Boca , U. Pavia, Italy



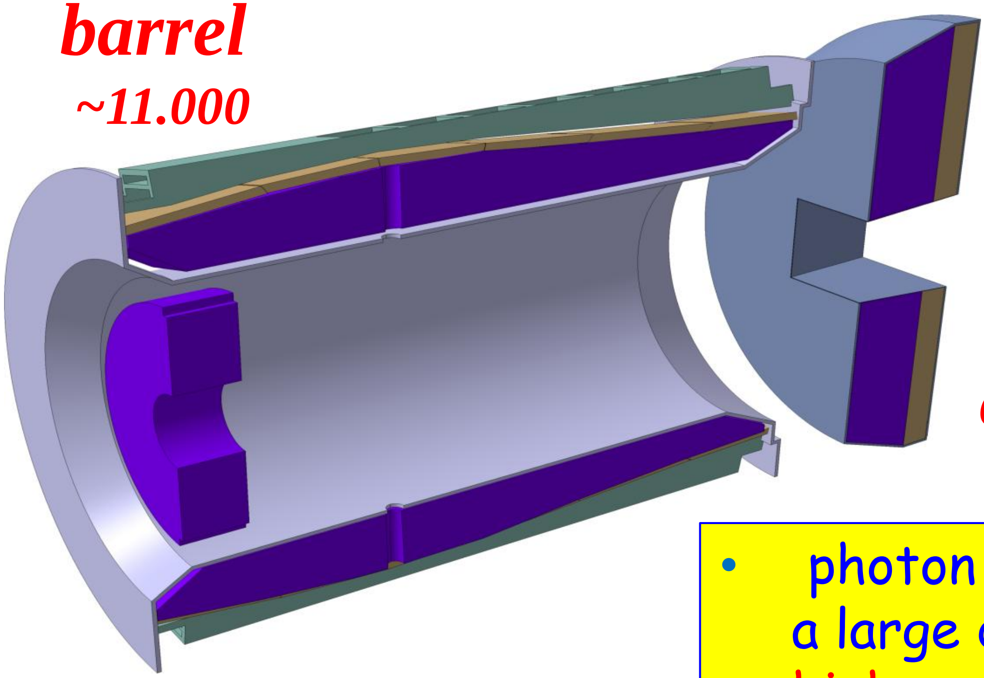


Sampling calorimeter 4.6 m^2
54x28 cells shashlyk:
Each section; 5.5 cm^2
380 layers :
- lead absorber (0.275 mm)
- plastic scintillators (1.5mm)

Total length 64.cm~19.6X_0

Forward EM Calorimeter

Why PWO-II?



PWO-II

200mm ($23X_o$)

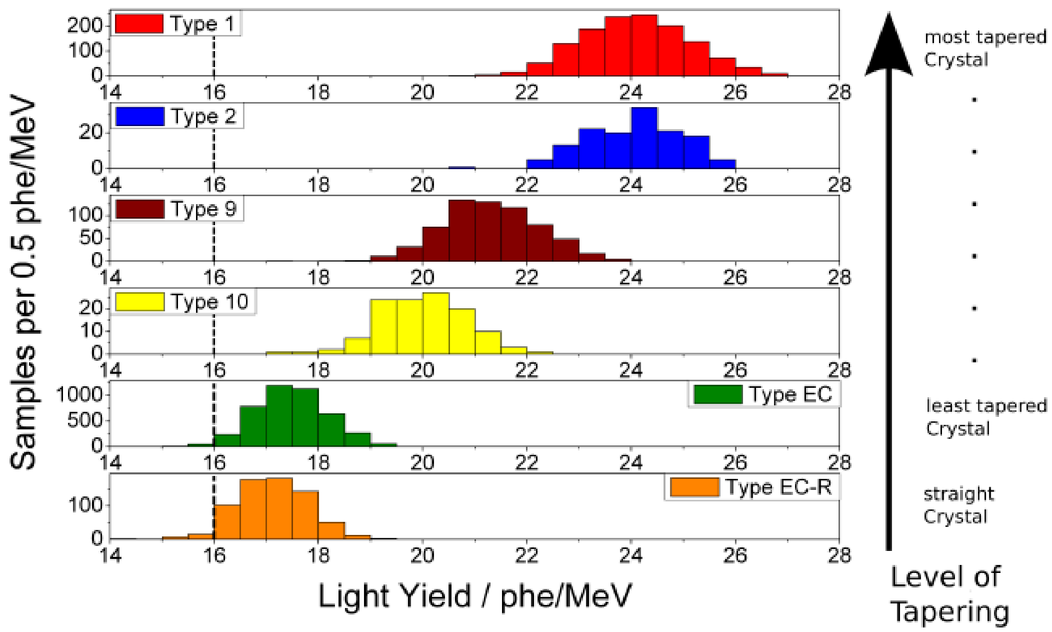
- Compactness
- Fast response
- Short decay time
- Radiation hardness

- photon detection with high resolution over a large dynamic range: 10MeV < $E\gamma$ < 15GeV
- high count-rate capability ($2\cdot10^7$ annihilations/s)
- nearly 4π coverage
- timing information for trigger-less DAQ concept

BTCP: Bogorodinsk Technical Chemical Plant

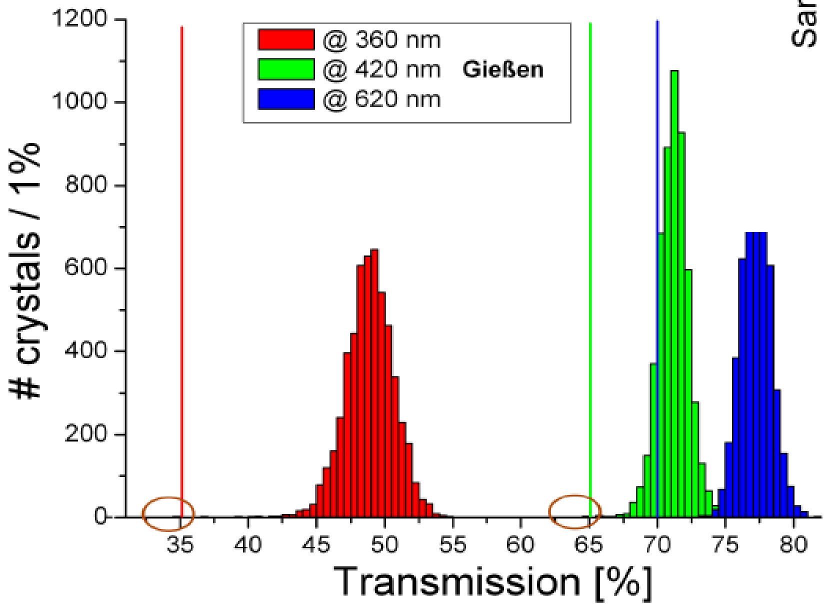
Why PWO-II (1)?

Light yield @RT



Optical Transmission

Measured longitudinally
and transversally
to the crystal axis:
Above the specification limits



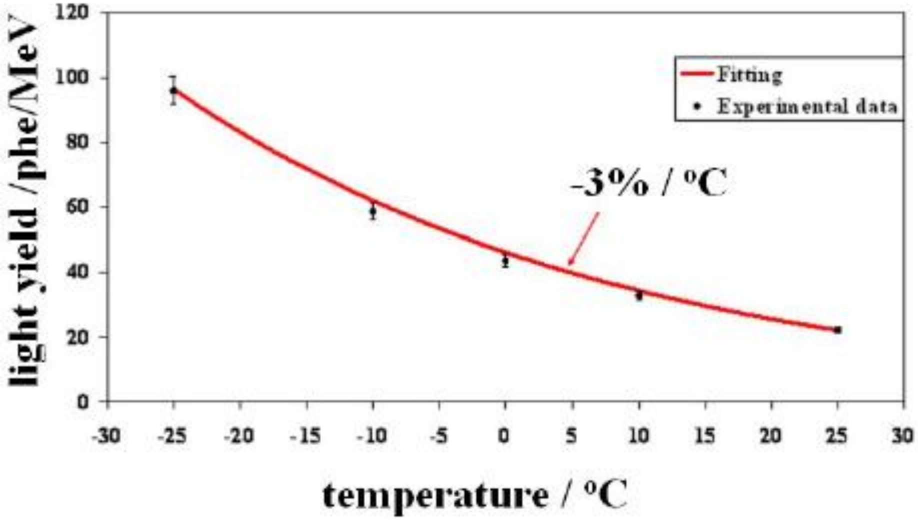
Room temperature
90% of light collected in a time gate
of 100 ns
(at T=-25°, too)

Quality Control and Performance

- physical goals of PANDA require further development

	PWO-I (CMS)	PWO-II (PANDA)
luminescence maximum, nm	420	420
La, Y concentration level, ppm	100	40
expected energy range of EMC	150MeV - 1TeV	10MeV - 10GeV
light yield, phe/MeV at room temperature	8-12	17-22
EMC operating temperature, °C	+18	-25
energy resolution of EMC at 1GeV, %	3,4	2,0

Quality Control and Performance



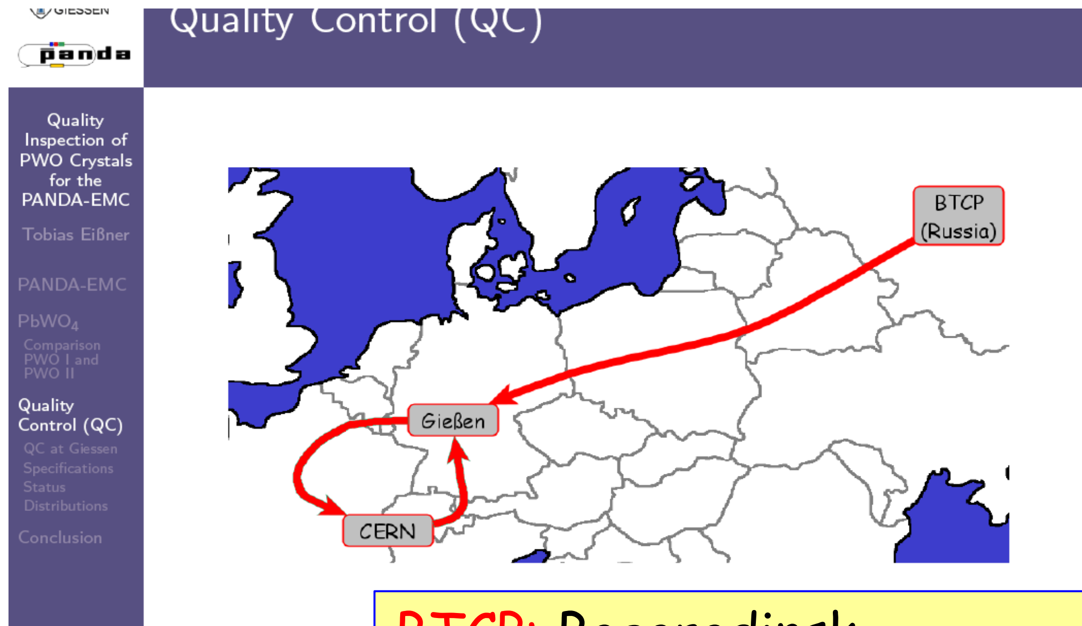
T=-25° : light yield x 4

- Radiation hardness and loss of light yield depend on the dose rate (l2 orders of magnitude << CMS)
- Interplay beween damaging and recovering mechanisms (faster at room temperature)
- At low temperature, the relaxation time of color centers becomes slow (>200 hours)
- Continuous and asymptotic reduction of the light output with saturation after 30-50 Gy and maximum loss of light 30%
- **Stimulated recovery by illumination with external light**
  for blue light nearly 90% of the original signal can be recovered in 200 min with a photon flux of 10 photons/s

R&D V. Dormenev, R. Novotny, IEEE Trans.Nucl.Sci. 55 (2008) 1283-1288

Quality Control and Performance

CERN: CMS/ECAL Collaboration, ACCOS machine adapted to Panda geometry and specifications



BTCP: Bogorodinsk Technical Chemical Plant

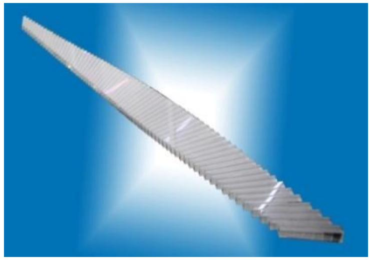
GIESSEN: measurement of radiation hardness, absolute light yield, low temperature tests.

Selectivity

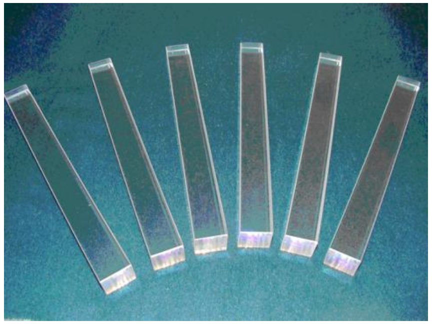
- *Optical transmittance*
- *Homogeneity*
- *Light Yield*
- *Scintillation kinetics*
- *Radiation hardness*

The design

- The design is driven by fixed target experiment:
  focusing momenta in forward direction

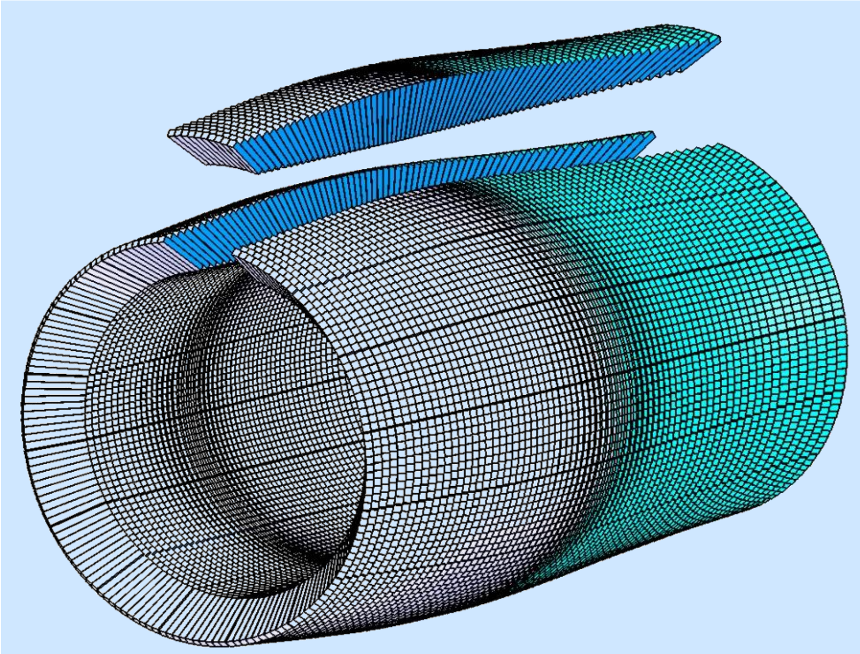


- The granularity: is a compromise
  - Maximum tolerable counting rate of individual module
  - Optimum shower distribution for E and position reconstruction
  - Minimization of energy losses due to dead material
- The dimensions:
  - square front face 21.3mm
  - rear-readout face 27.3mm
  - average mass of 0.98 kg.

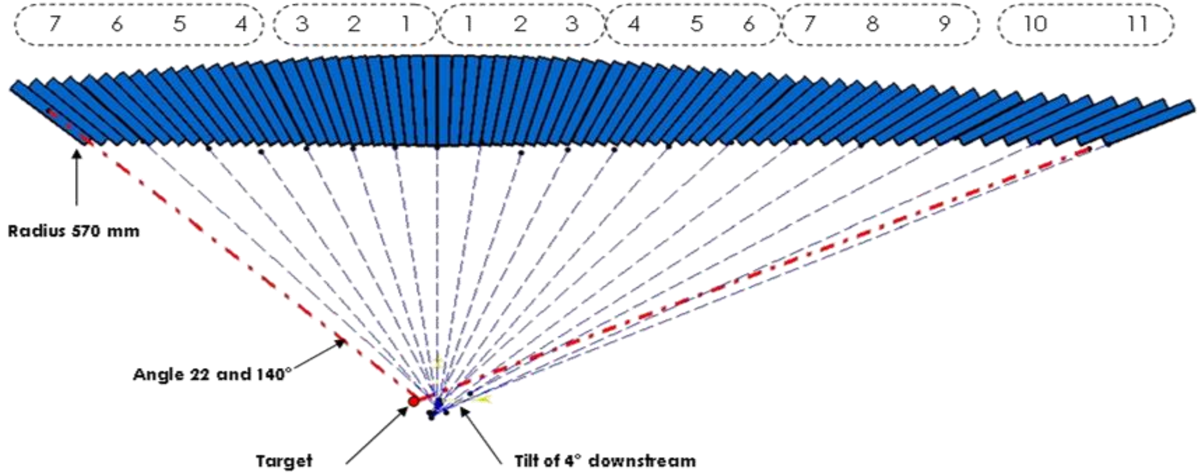


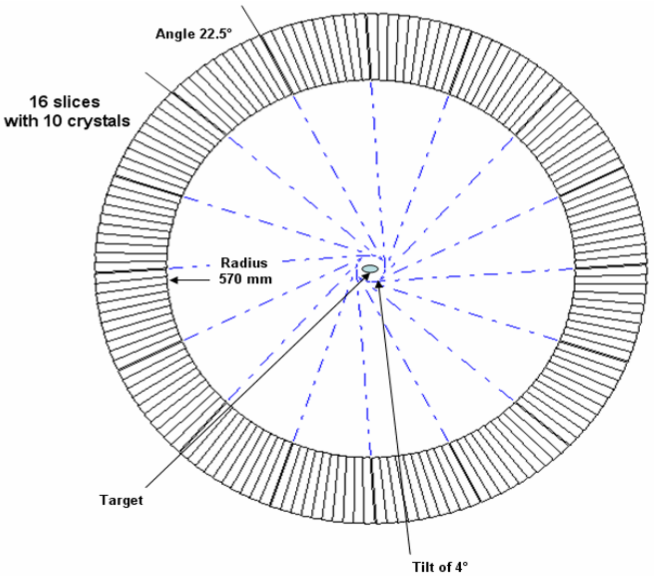
- common length of 200 mm ~ 22 radiation length
  - allows shower containment up to 15 GeV
  - limits nuclear counter effect in photosensor
- The crystals are wrapped in a foil (reflectivity >98%) and inserted in carbon fiber alveoles
  - The nominal distance between crystals is 600 μm (reflector: 2x65 μm and carbon fibers 2x200 μm)

The geometry: barrel



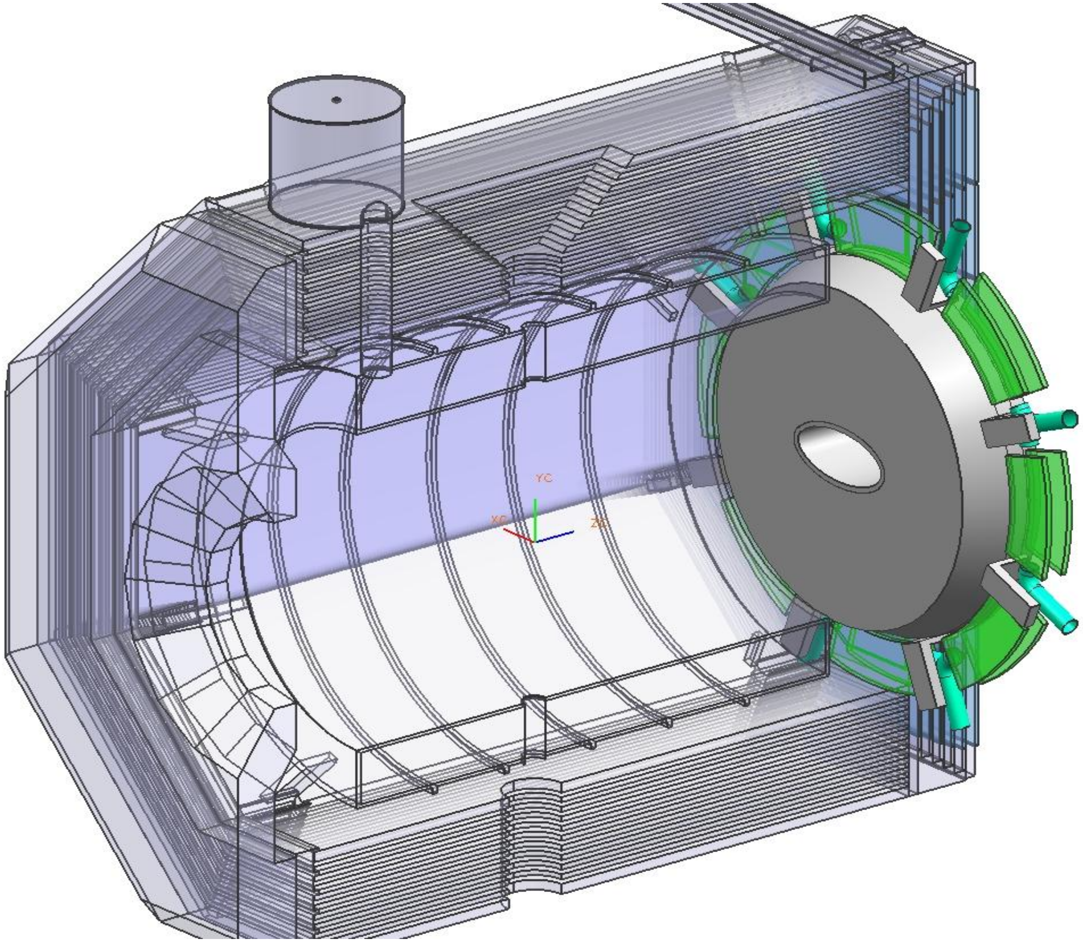
- *16 slices*
- *pointing off-target*
- *11 360 crystals*
- *200 mm long ($22X_o$)*
- *2 x 11 tapered shapes*

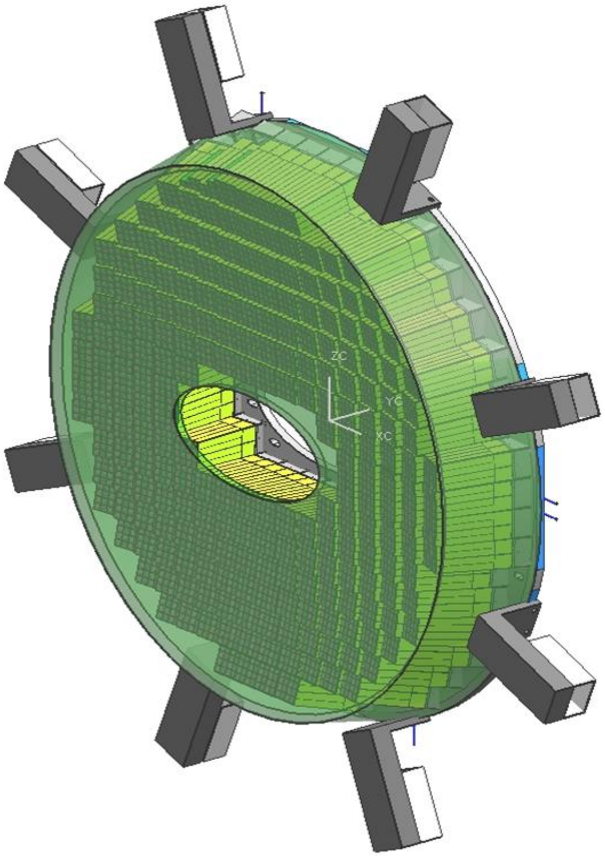




The geometry: forward endcap

3864 crystals

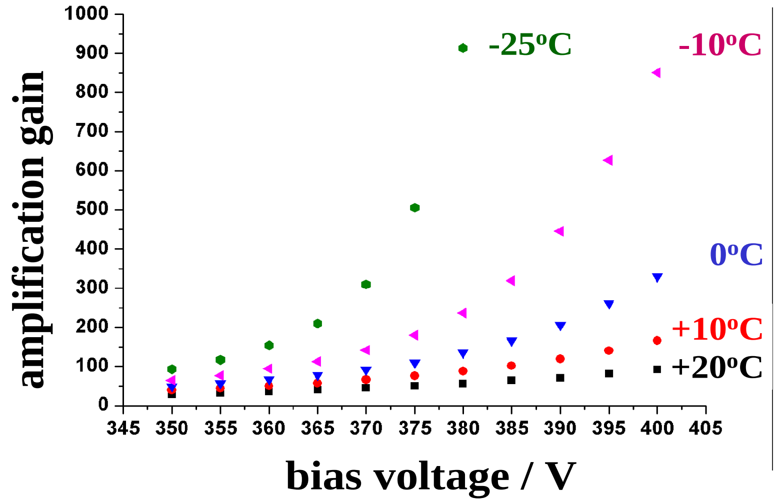




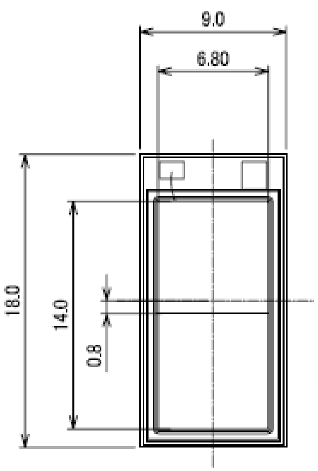
Large area avalanche photo diods (LAAPD)

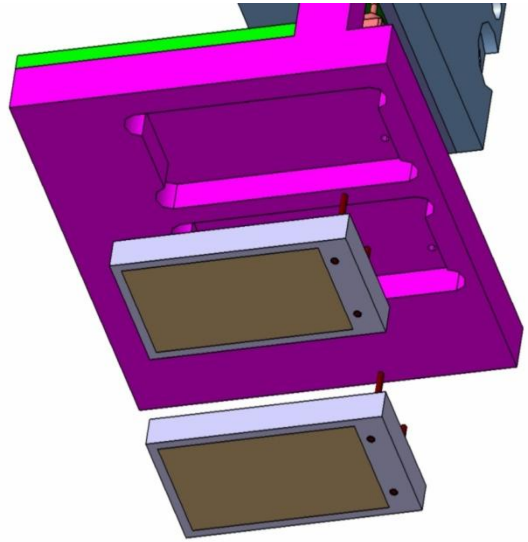
in collaboration with Hamamatsu Photonics

- Excellent performance at RT and T = -25°C
- Radiation resistent up to 10^{13} protons
- Work in a 2T solenoidal field



dimensions
7 x 14 mm²



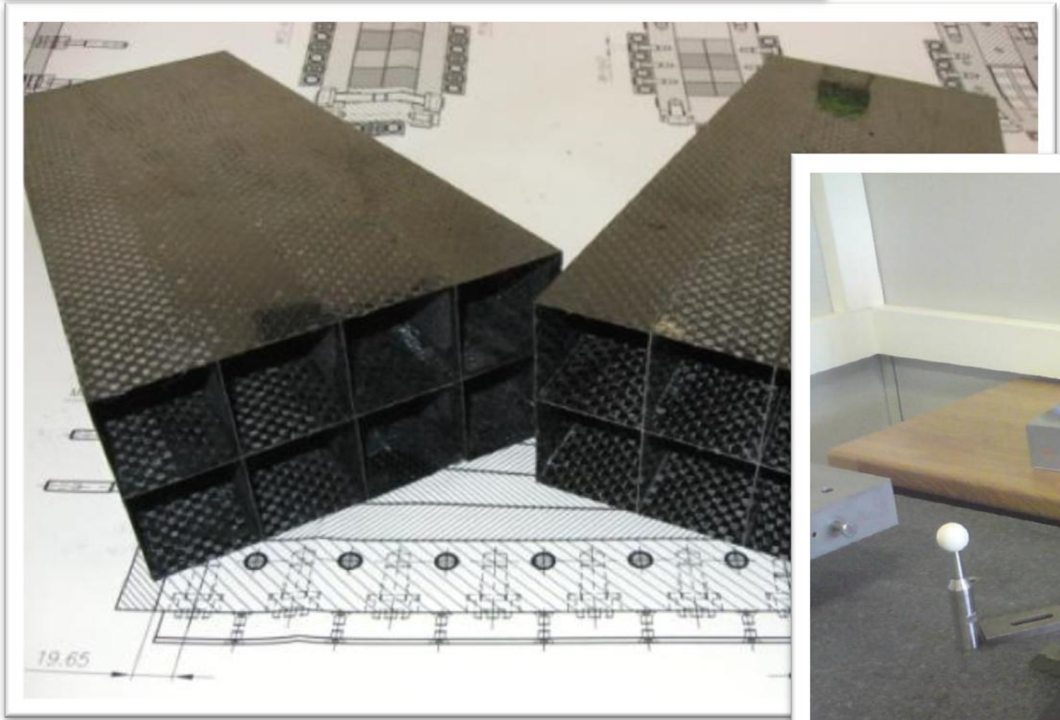


Final concept:
2 LAAPDs/crystal, individual readout
- *maximize the surface*
- *redundancy*

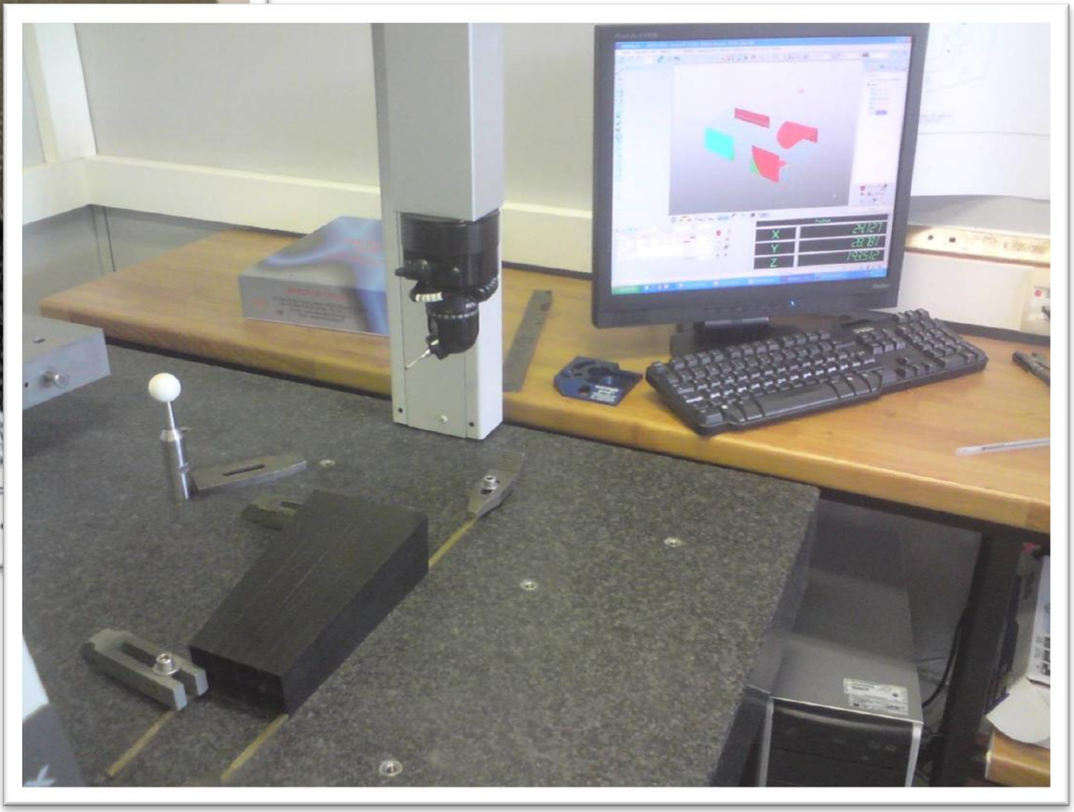
Each crystals, LAAPDs, preamplification and shaping circuits are contained in a carbon fiber alveole

Carbone Alveoles

Crystal collected by 16
Hold in the back



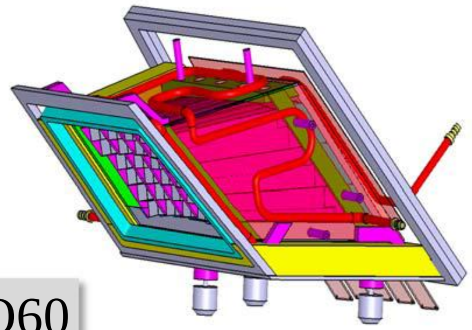
Alveoles production @ Protvino
and measured @ Orsay



Precision:
10 μm on thickmess
20 μm on length

Prototype tests

M. Kavatsyuk et al., [PANDA Collaboration],
Performance of the prototype of the em calorimeter for PANDA
Nucl.Instrum.Meth. A648 (2011) 77-91

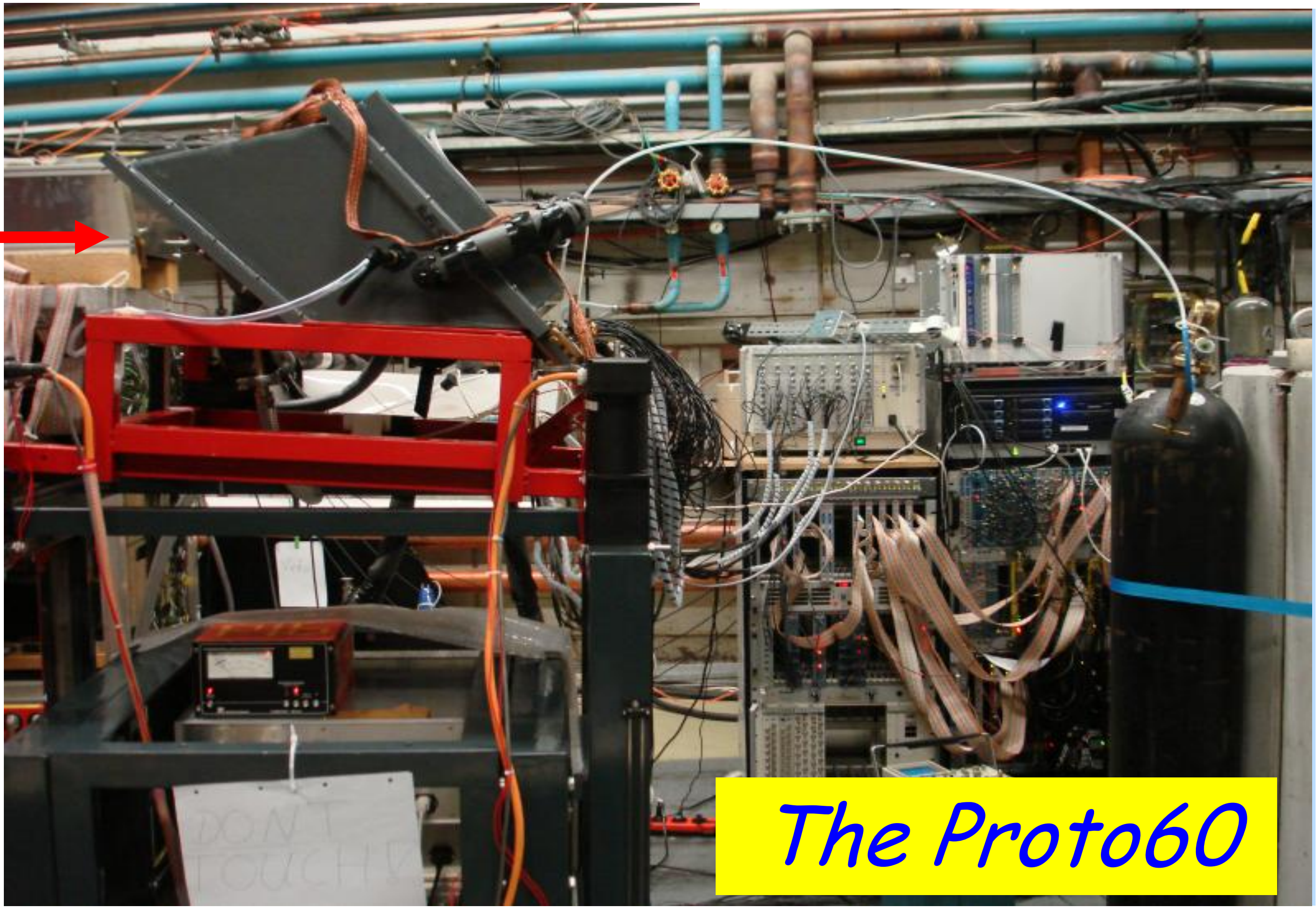


PROTO60

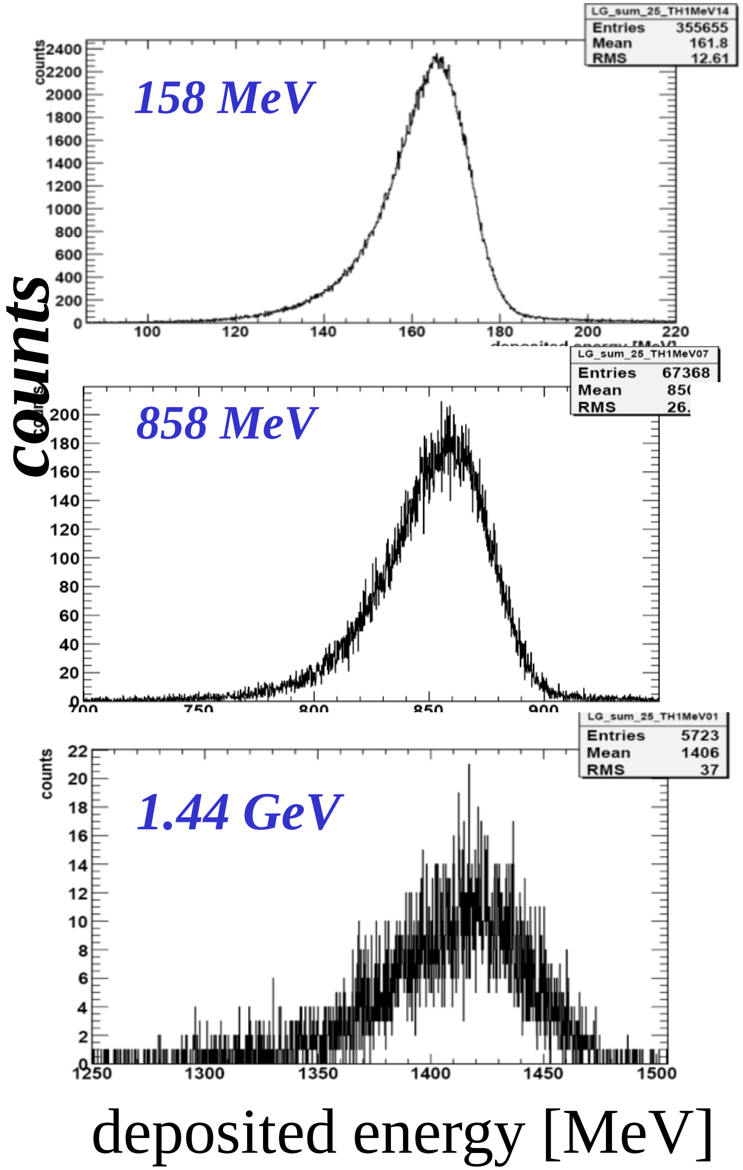
photon beam

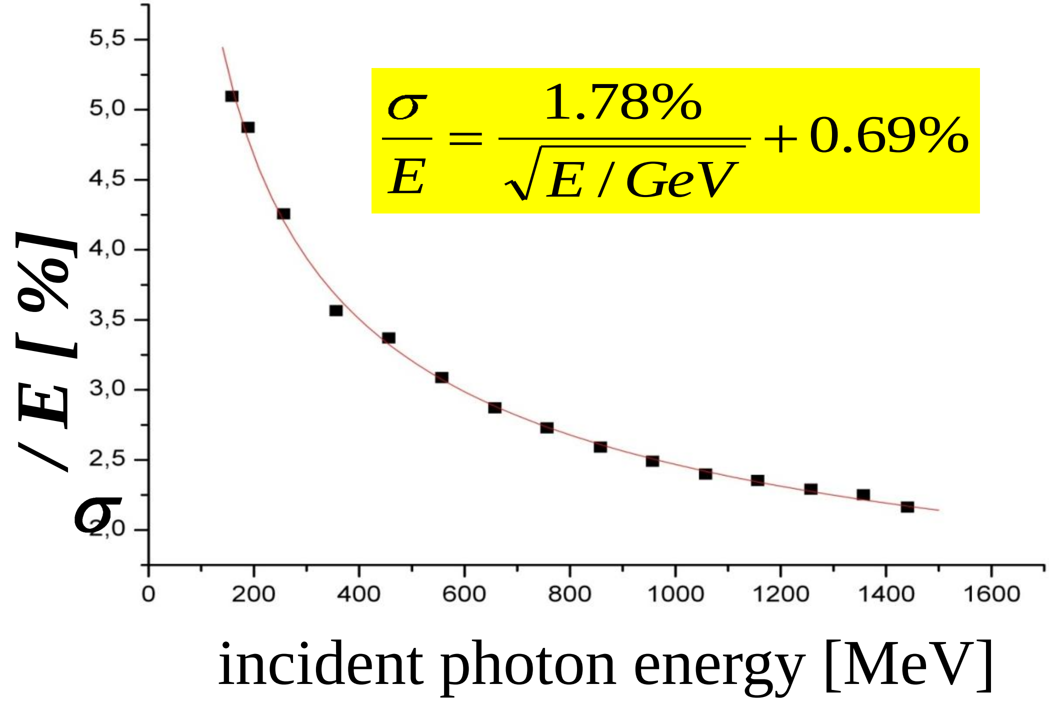
- 0.02 - 1.5 GeV γ
  MAXLab (Lund)
  MAMI, (Mainz)

- 15 GeV e^+
  CERN



The tests: proto60



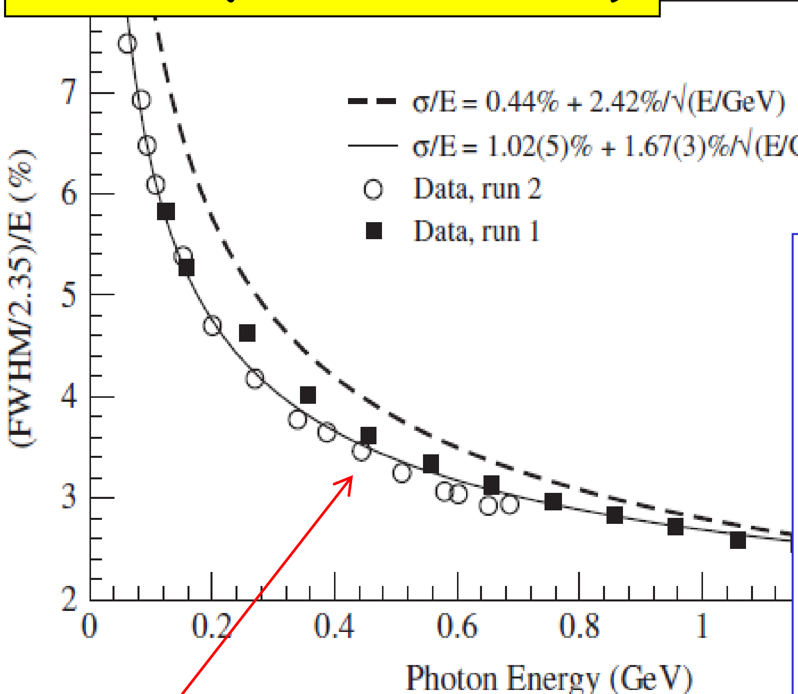


$$\frac{\sigma}{E} = \frac{1.78\%}{\sqrt{E/GeV}} + 0.69\%$$

T=-25º
Digitization:
shaping /peak-sensing ADC

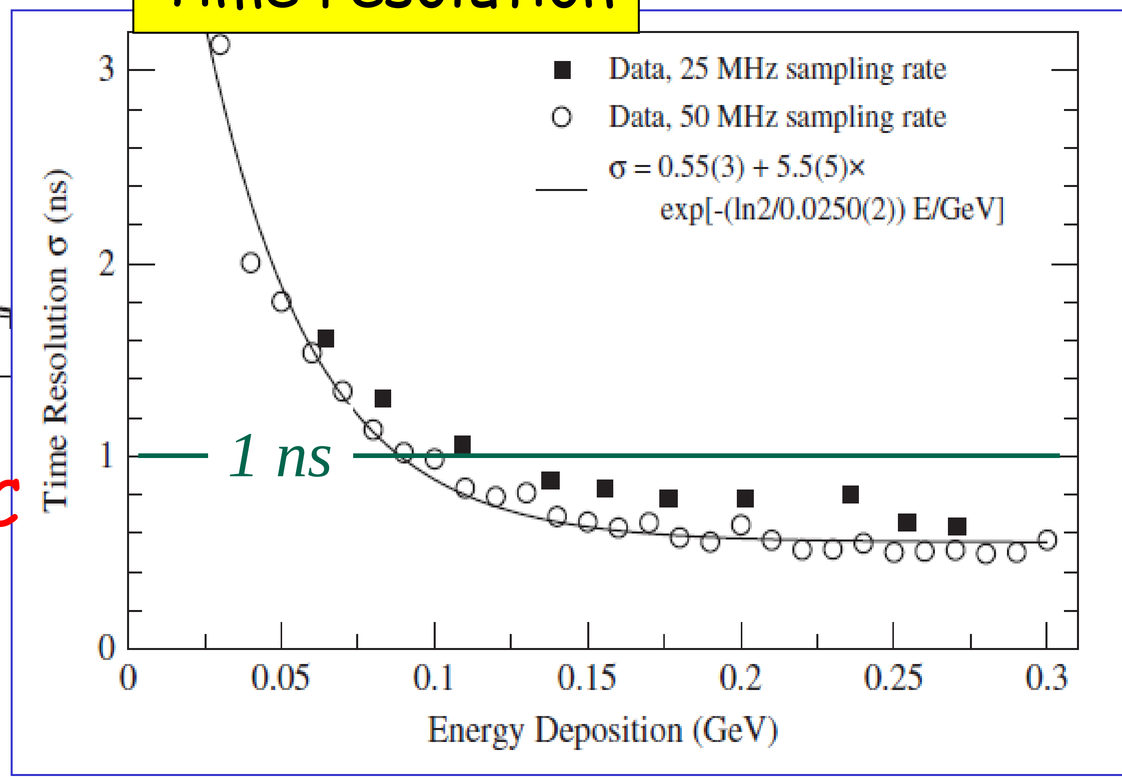
Energy and time resolution

Energy resolution (3x3 matrix)



Readout via Sampling ADC

Time resolution

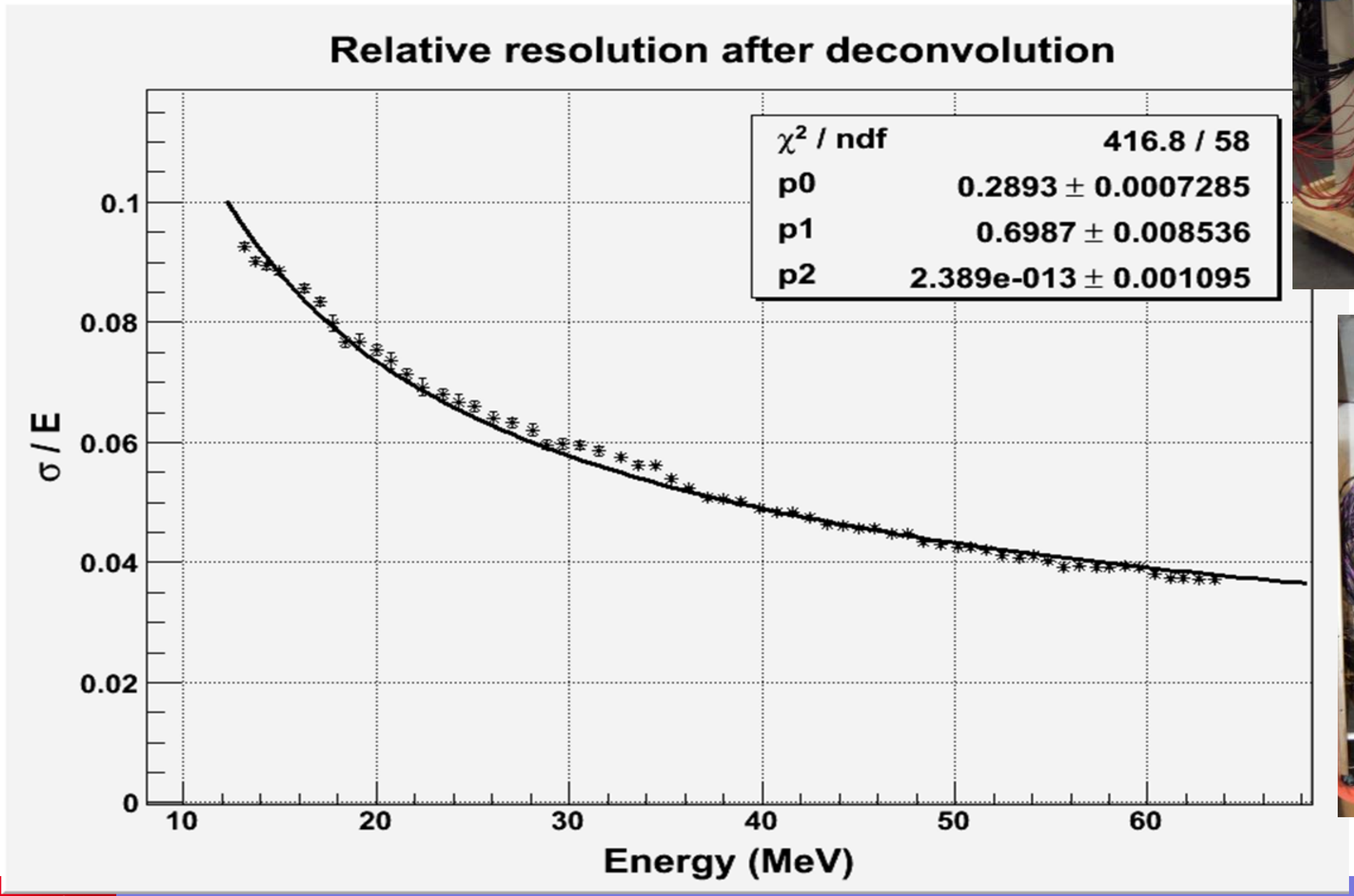


$\sigma/E<13\%$ at $E\gamma\sim20$ MeV
$\sigma/E<1.5\%$ at $Ee^{+}\sim15$ GeV

The tests: Proto60

Extension to energies < 50MeV @ MaxLab

- optimized light output: PWO-II
- cooling: operation at T=-25°C

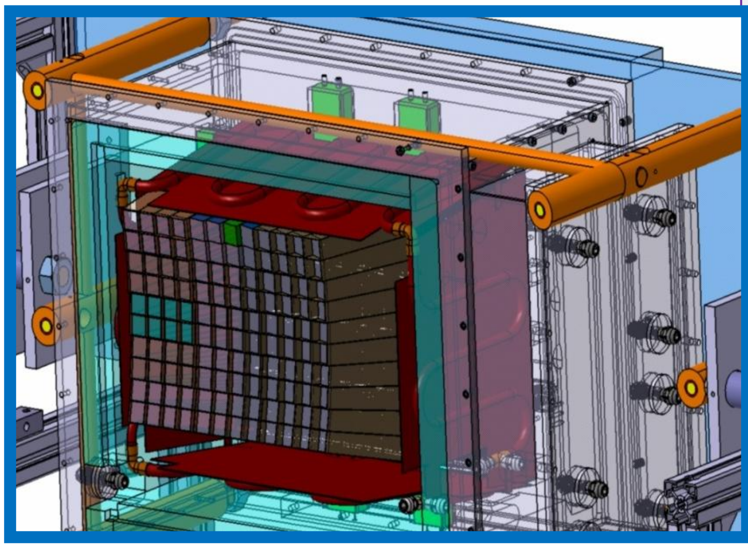


Status of the project

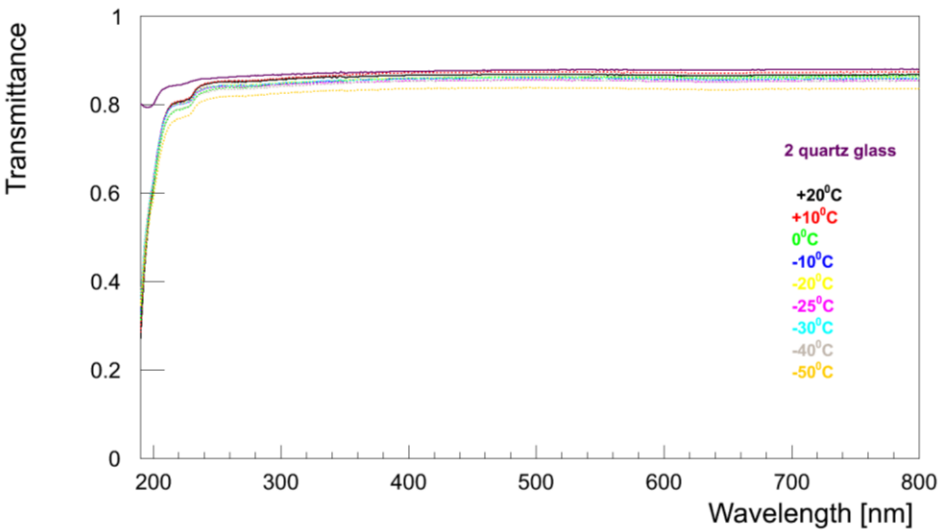
__Proto 120__

120 PWO - II crystals operated at

-25   0.2



- ***Fully designed at IPN Orsay***
- ***Under construction***
- ***To be tested with cosmics and photon beam (2014-2015)***

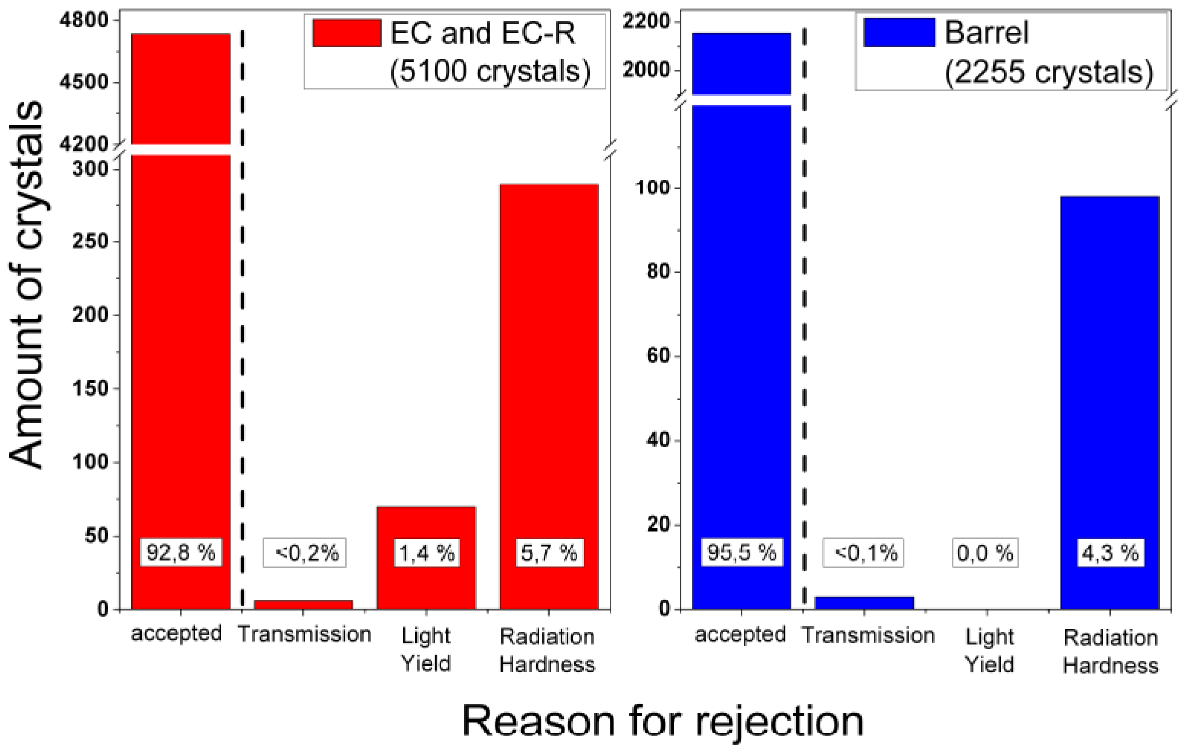


Barrel Calorimeter

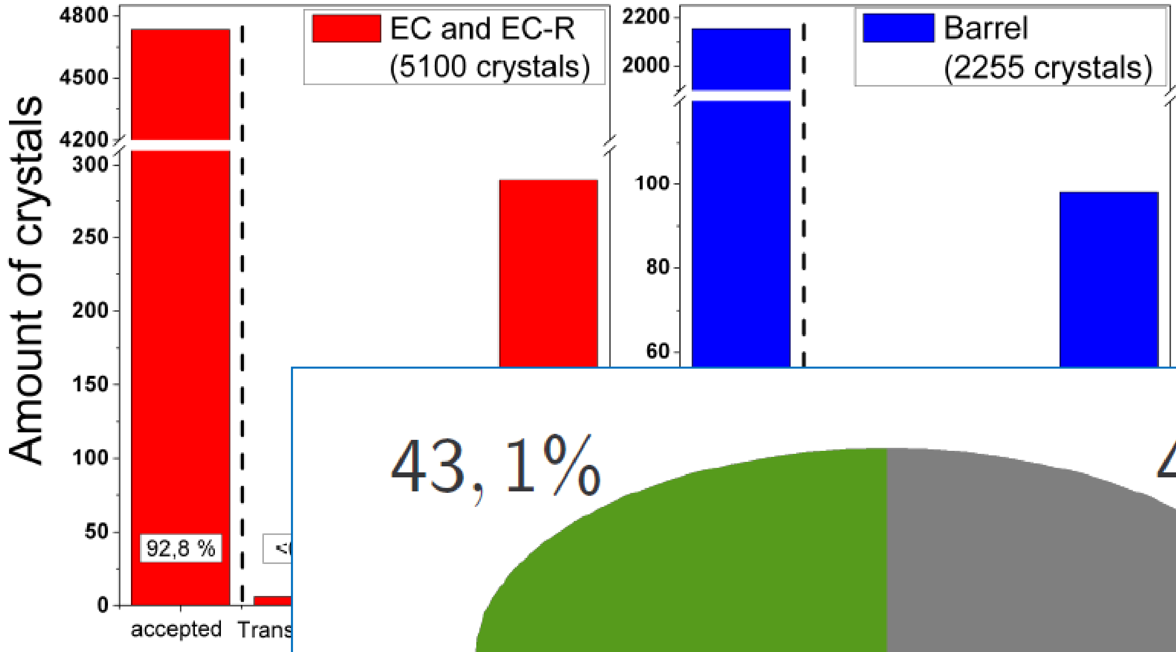
- Test of optical glues at low temperature
- Radiation hardness
- Mechanical and thermal tests

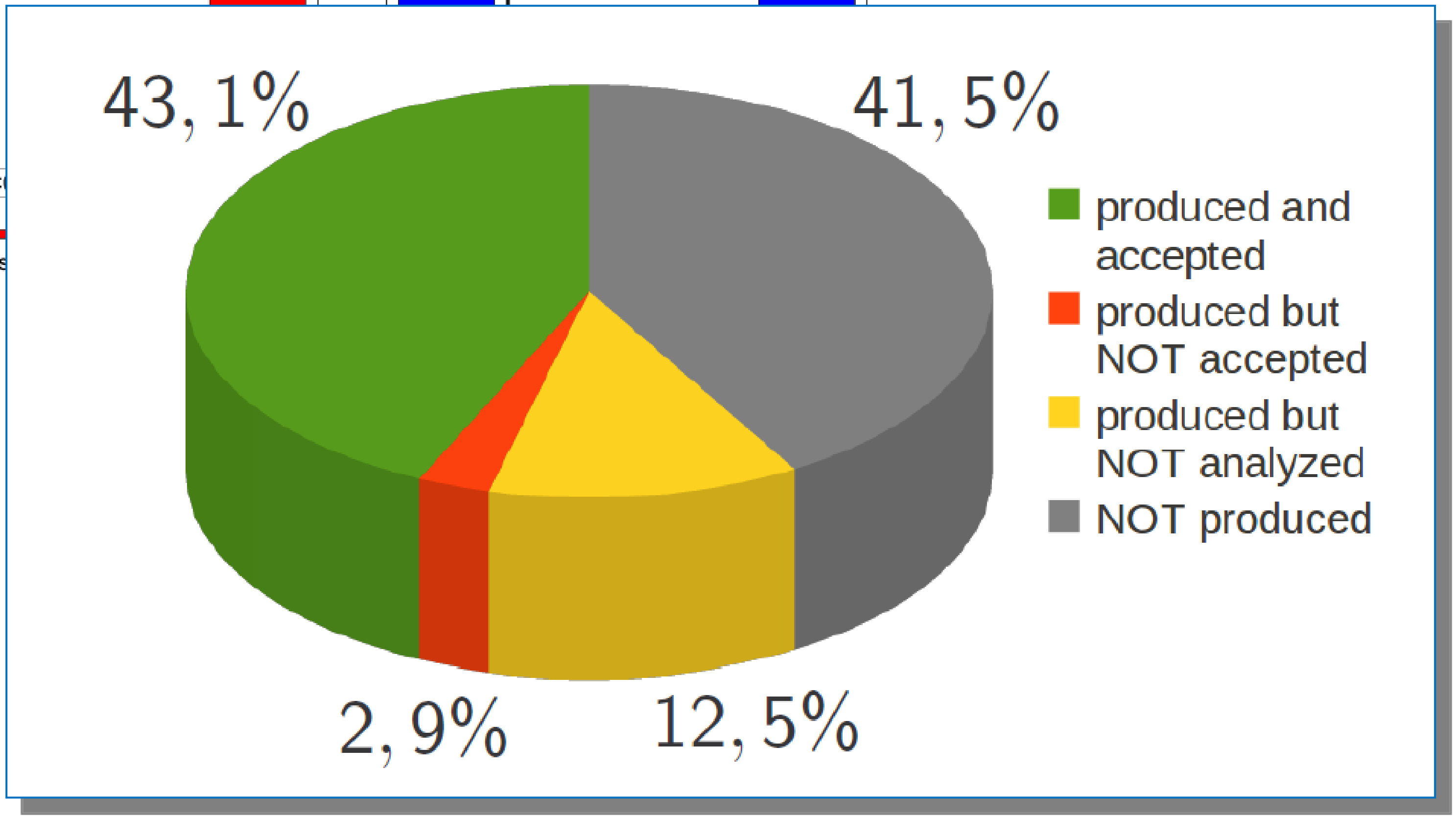
A. Dbeyssi,E.T-G et al, NIM A722(2013) 82

Status of the Project



Status of the Project





Quality and Status

BITP (Russian federation)

SICCAS (China)

Crytur-Turnov (Czech republic)
in close collaboration with Minsk

The Collaboration

The PANDA collaboration

520 people

67 institutions

17 countries

Spokepersons: J. Ritman, D. Bettoni

The EMC detector

Rainer Novotny

Andrea Wilms

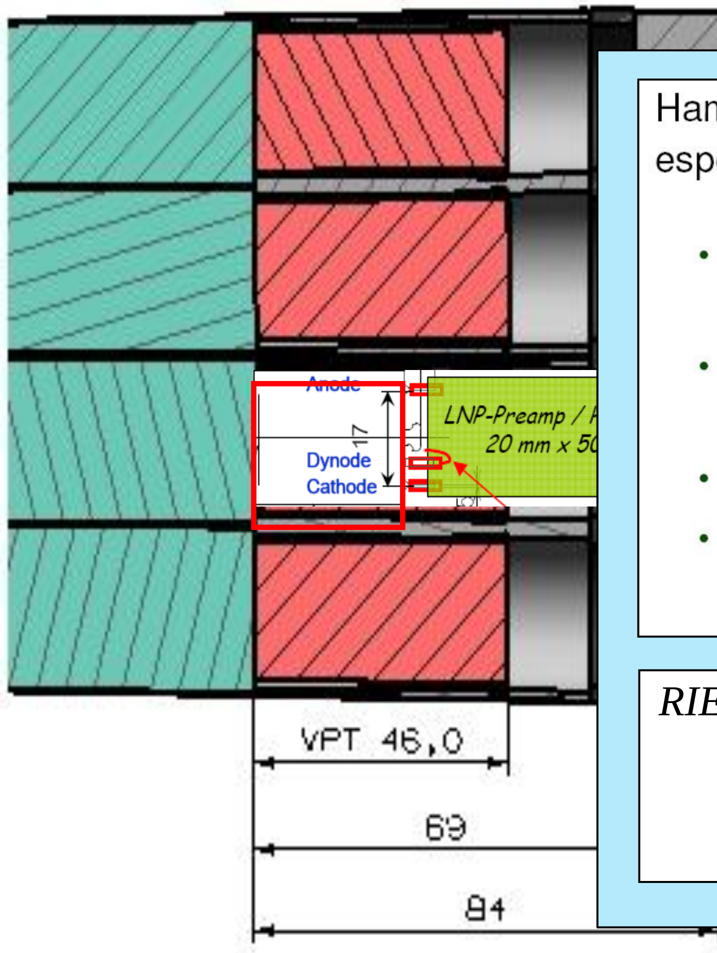
Univ. Basel,
Univ. Bochum,
Univ. Gießen,
GSI,
KVI Groningen,
FZ Jülich,
IMP Lanzhou,
Univ. Mainz,
Univ. Minsk,
TU München,
IPN Orsay,
Univ. Stockholm,
IHEP Protvino,
Univ. Uppsala,
SINS Warsaw

Thank you for your attention!

5.11.2012. FAIR employees planted the first 500 trees today

photosensors:

- *to adapt to higher countrates (>500kHz) in forward direction*
- *faster response – better timing options*



Hamamatsu R2148MOD
especially made for $\overline{\text{P}}$ANDA, $\varnothing < 24$ mm

- $\varnothing = 23.7$ mm
  $\ell = 30$ mm
- $U_A = 750$ V
  $U_D = 500$ V
- G = 9.3
- QE = 32 %
  (at 420 nm)

RIE St. Petersburg, Russia

- *Tetrode (photo cathode, 2 dynodes, anode)*
- *G = 24 – 45*
- *QE = 14 – 20%*

Some numbers

- FAIR will provide antiproton and ion beams with unprecedented intensity and quality.
- In the final construction FAIR consists of eight ring colliders with up to 1,100 meters in circumference, two linear accelerators and about 3.5 kilometers beam control tubes.
- The existing GSI accelerators serve as a pre-accelerators.

More numbers

- Almost 600,000 cubic metres of concrete
- Over 35,000 tonnes of steel
- 500,000 tonnes of other construction material will be used to build FAIR.
- Over one million cubic metres of soil will be excavated during construction and used at a later stage to cover underground structures.
- Work on the foundations is set to start shortly. This will involve embedding around 1,500 piles, with diameters of 1.2 metres, up to 65 metres into the ground to create a suitable foundation for the buildings.
- During the most intensive construction periods, up to 600 construction workers, technicians and engineers will be working at the site.

consequences of cooling:

- *fast decay kinetics even at T=-25°C*

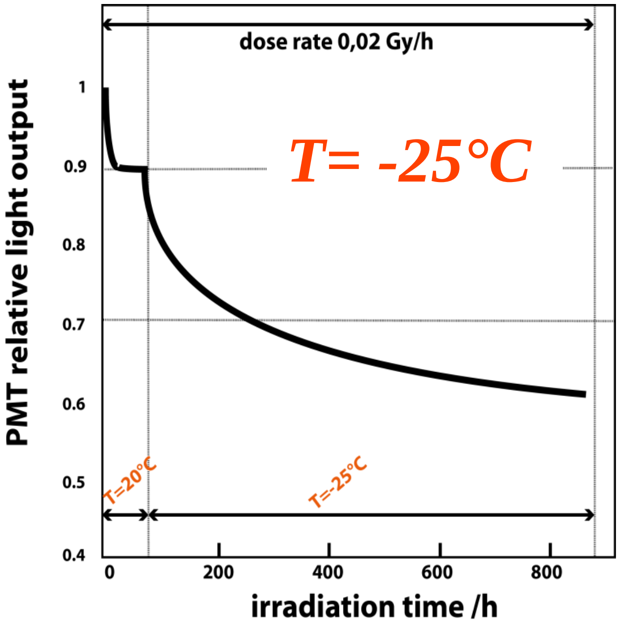
  LY(100ns)/LY(1µs) > 0.9

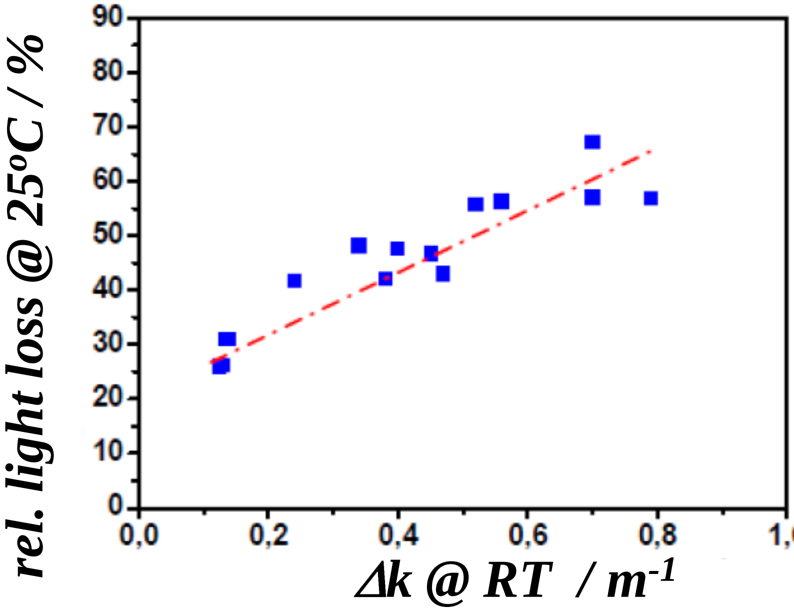
- ***constant ratio***

  LY(-25°C)/LY(+18°C) = 3.9

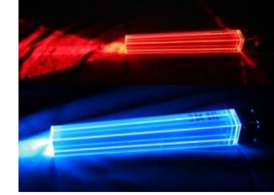
- ***„no“ recovery of radiation damage at T=-25°C***

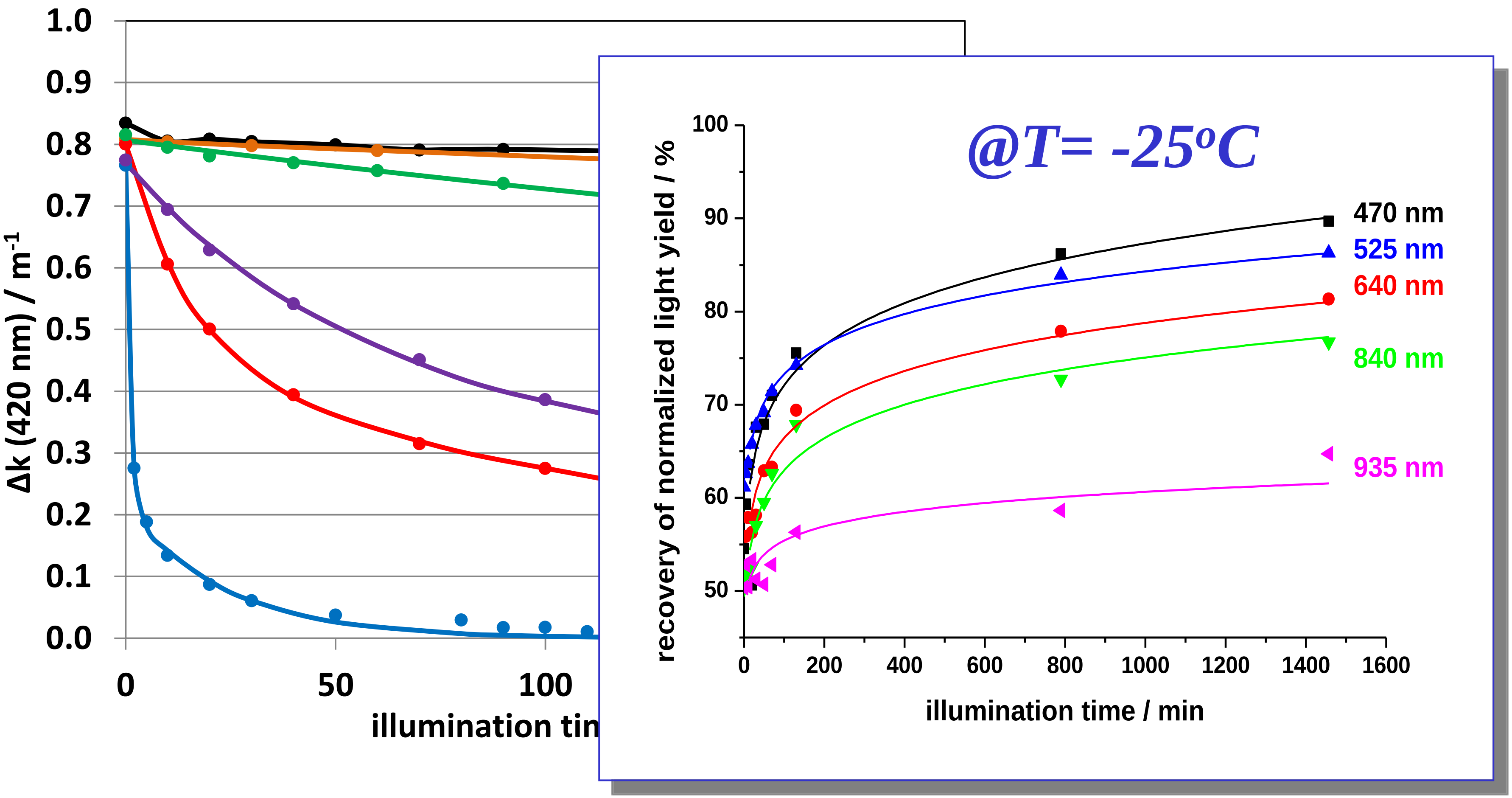
  asymptotic light loss correlated with Δk (RT)





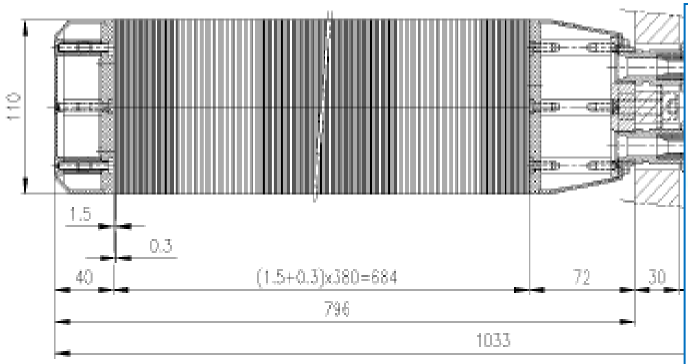
recovery of radiation damage @RT

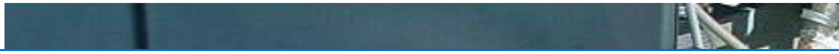


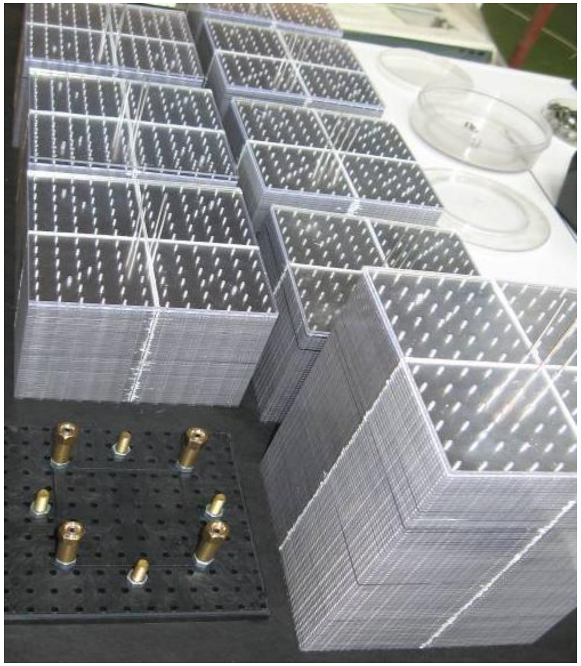


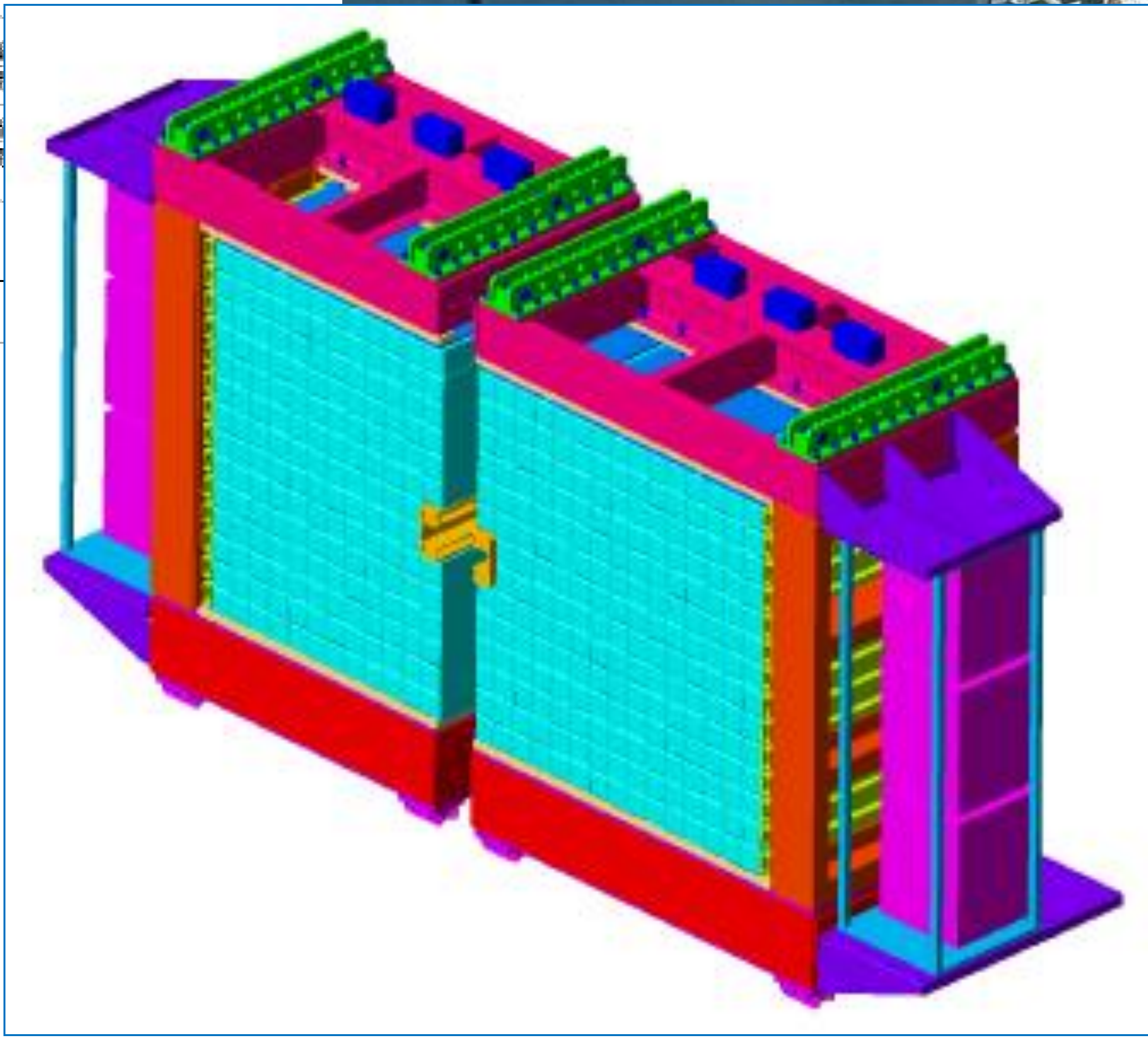
applied integral dose of ^{60}Co: D = 30Gy

forward EMC

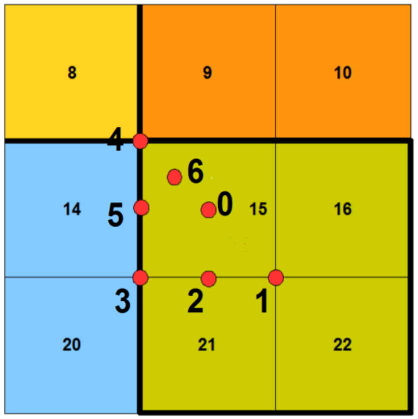


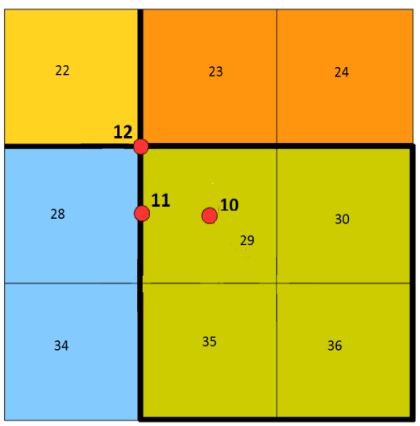






forward EMC


8
9
10
4
6
14
5
0
15
16
3
2
1
20
21
22


22
23
24
12
28
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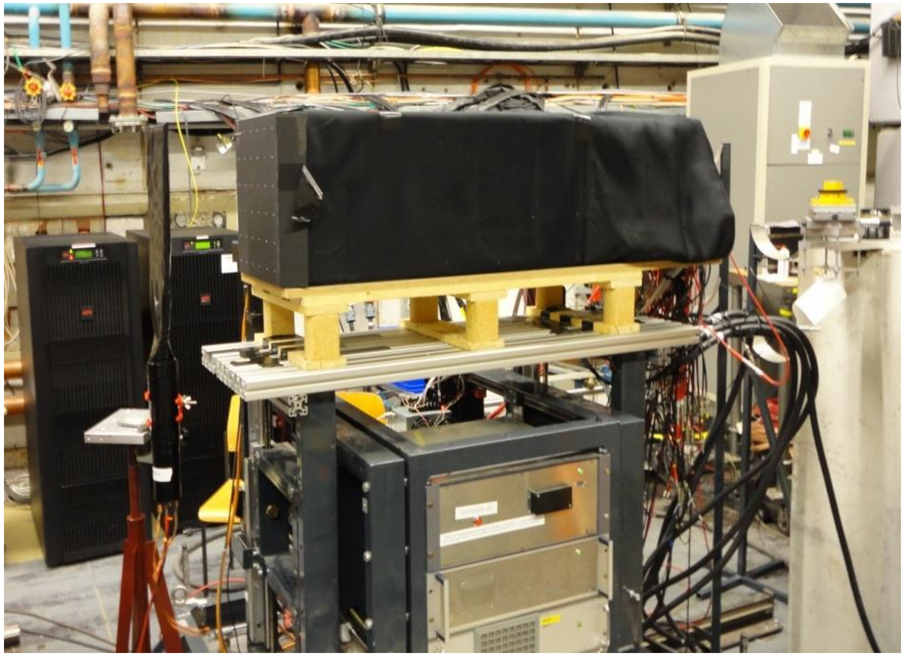
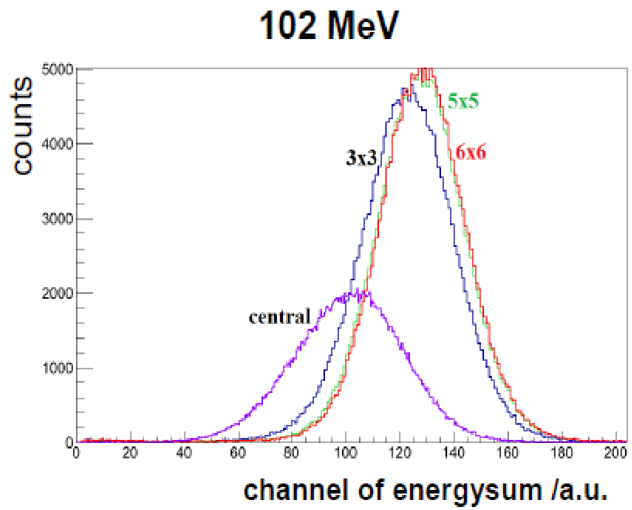
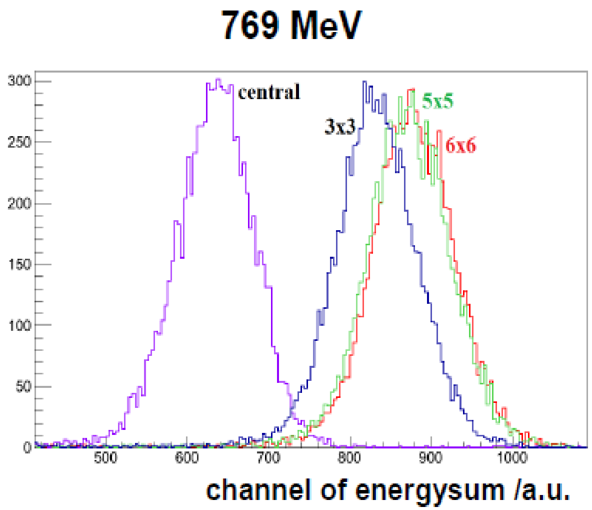
35
36

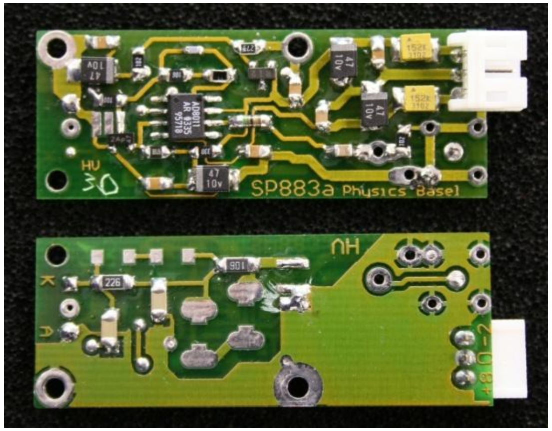



102 MeV
counts
5x5
6x6
3x3
central
channel of energysum /a.u.


769 MeV
central
3x3
5x5
6x6
channel of energysum /a.u.

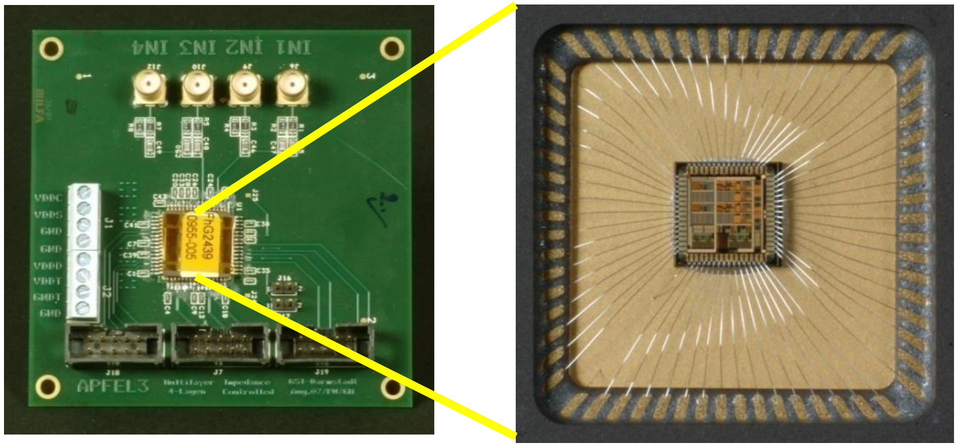
Development of low noise, low power preamplifiers

Design of discrete components for prototype studies



18mm

ASIC (APFEL) large dynamic range



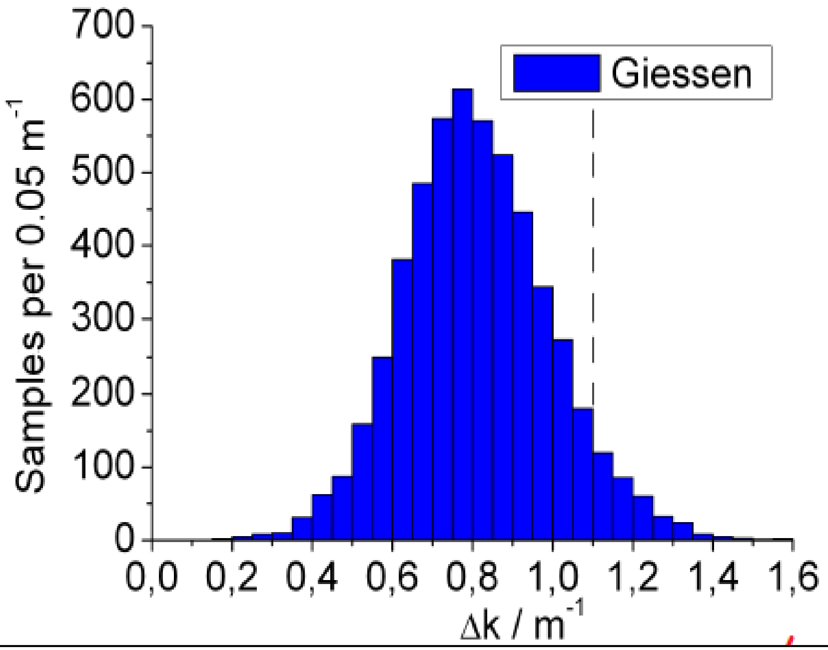
- 2 channels/ 2 ranges
- overall range 1 – 10.000
- noise level (cooled) << 2 MeV

Why PWO-II? (2)

Radiation Hardness : absorbtion coefficient Δk

- $T = \exp(-k \cdot x)$ with $x = 20\text{cm}$
- $\Delta k = k_{\text{after irr.}} - k_{\text{before irr.}}$
- irradiation with an integral dose of 30Gy (^{60}Co source)

(dose rate: 4Gy/minute)



$\Delta k < 1.1\ m^{-1}$

- Δk measured up to λ=900 nm
- delayed by 30 minutes after irradiation to exclude fast recovery process
- light losses tolerable during 6 months operation

Quality Control and Performance

Improved luminiscence yield: impurities La,Y highly reduced