The Mainz (MAMI) A4 Lead Fluoride Detector

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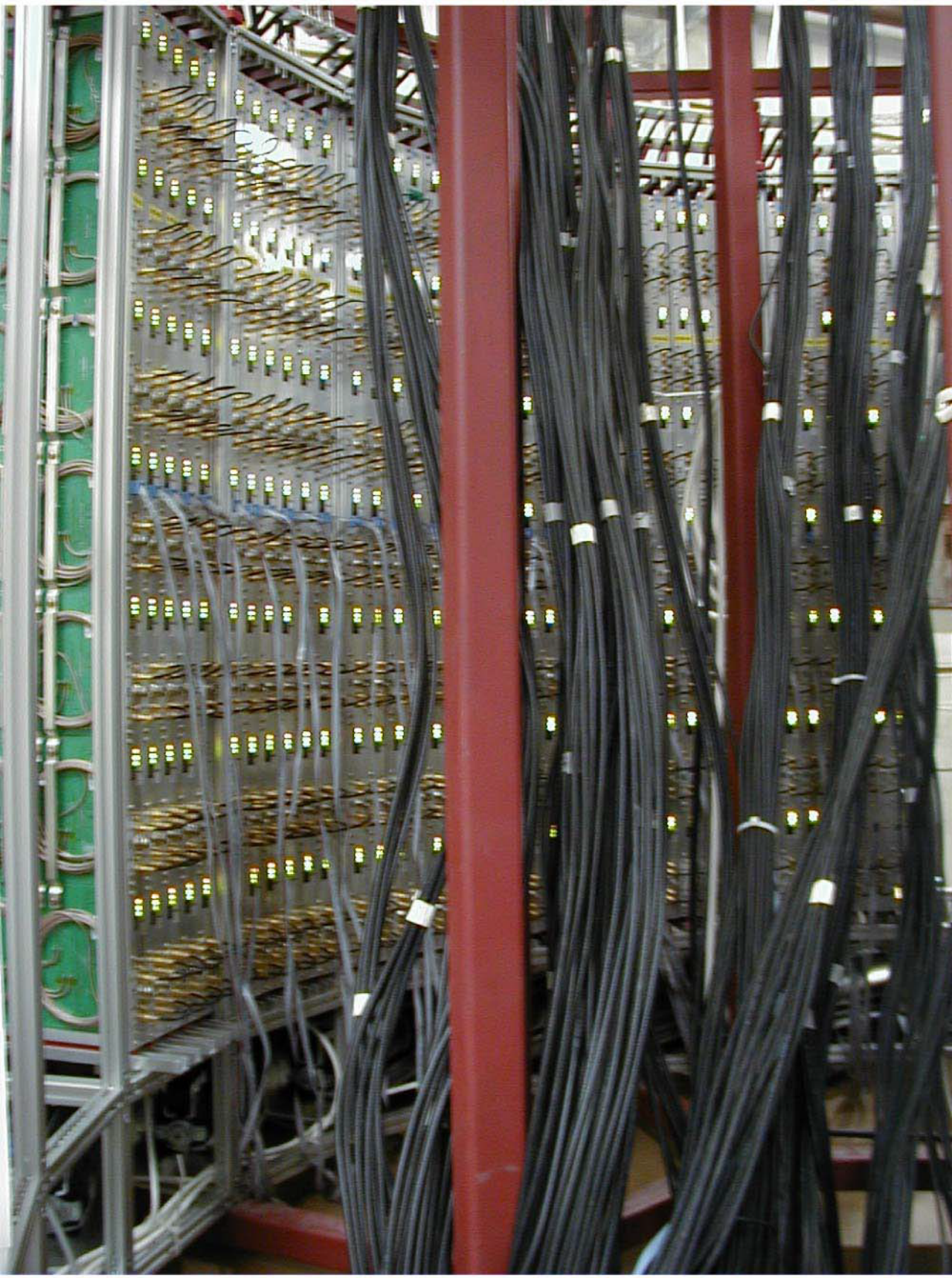

The Mainz (MAMI)
A4 Lead fluoride Detector

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Universität Mainz

- The A4 Experiment
  - parity violating measurement principle
  - electron accelerator MAMI

- PbF2
  - light yield
  - optical properties
  - radiation hardness
  - simulations
  - mechanics of the detector

- electronics (MEDUSA)

- first results (511 channels)

ingredients

Problems:

- (quasi)elastic electron scattering
  $0.1 GeV^2 < Q^2 < 1.0\ GeV^2$
  inelastic scattering
- asymmetries small
  high rates

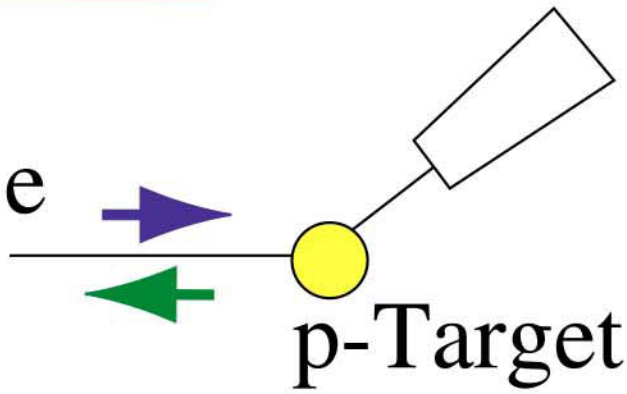
Solutions:

- separate elastic<->inelastic scattering
  low energy (SAMPLE)
  magnetic spectrometer (HAPPEX)
  crystal calorimeter (A4)
  toroidal spectrometer (G0)
- detection of particles at a high rate
  without spectrometer integrating (SAMPLE)
  focal plane current integrating (HAPPEX)
  focal surface particles counting with ToF (G0)
  elastic and inelastic particles counting
  with energy resolution (A4)

program

goal: determination of F_1^s: $\delta F_1^s < 0.02$

method: measurement of A in p(e,e')p with $\delta A = 5\%$



$$A = \frac{N_R - N_L}{N_R + N_L}$$

$\delta F_1^s = 0.02$

$\delta A_{exp} = 0.05 * A_0$

$(5\%)^2 = (3\%)^2 + (4\%)^2$

exp **stat** **sys**

first point:
E = 855 MeV
$\theta = 35^o$
$Q^2 = 0.227$ GeV
$P_e = 80\ \%$
$I = 20\ \mu A$

$A_0 = 0.0000087 = 8.7 * 10^{-6}$

$N \sim 10^{14}$ elastic events

$L = 0.5 * 10^{38} cm^{-2} s^{-1}$

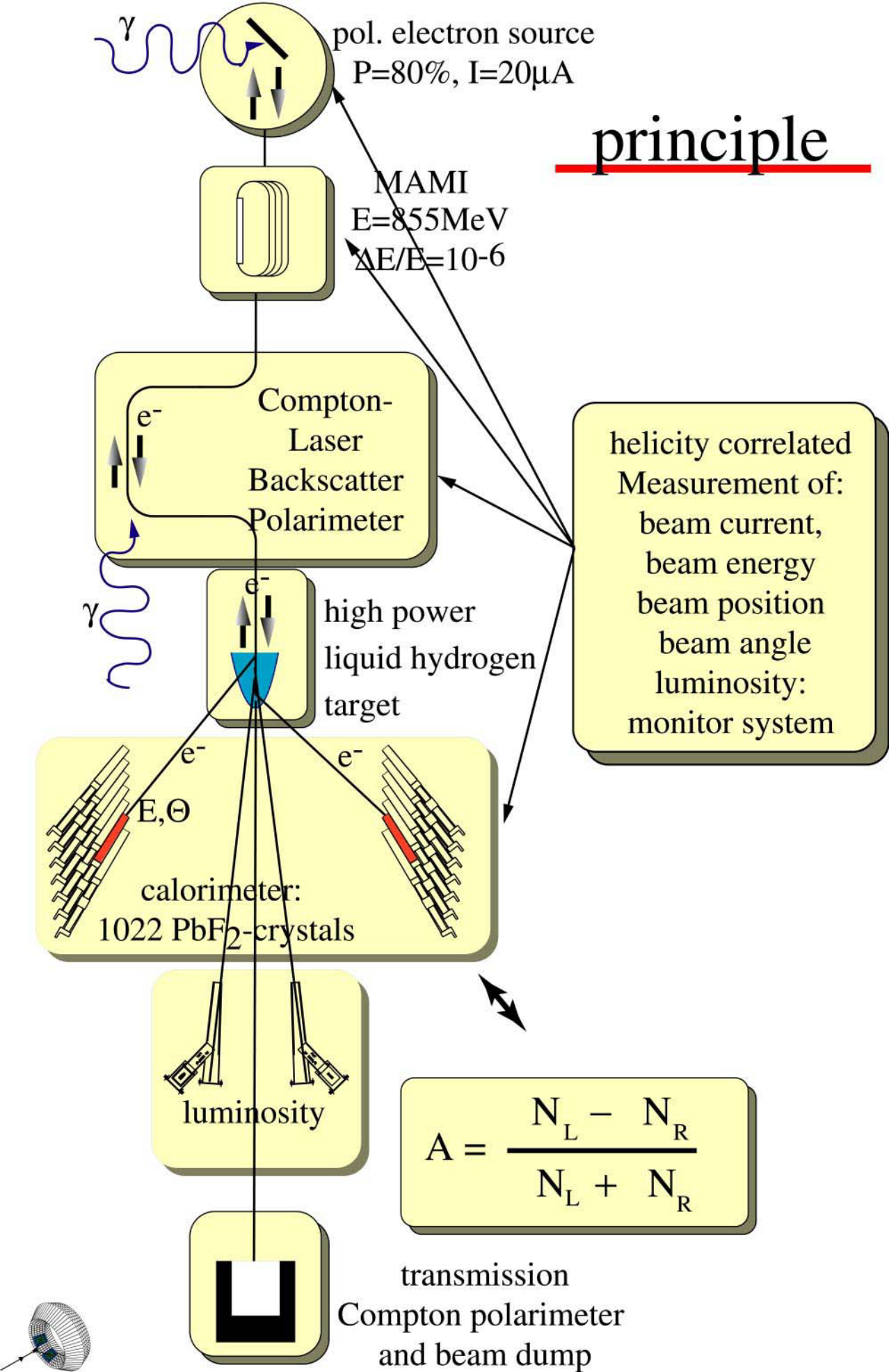
10cm / H , 20 μA

dΩ=0.7sr, ~1000h

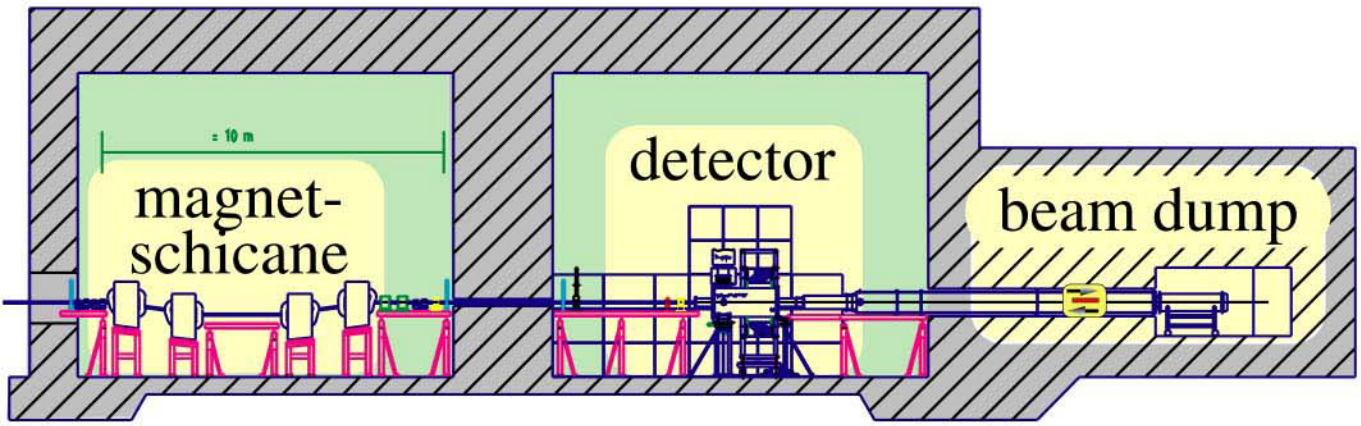
elastic: ~ 10 MHz (~ 730 MeV)

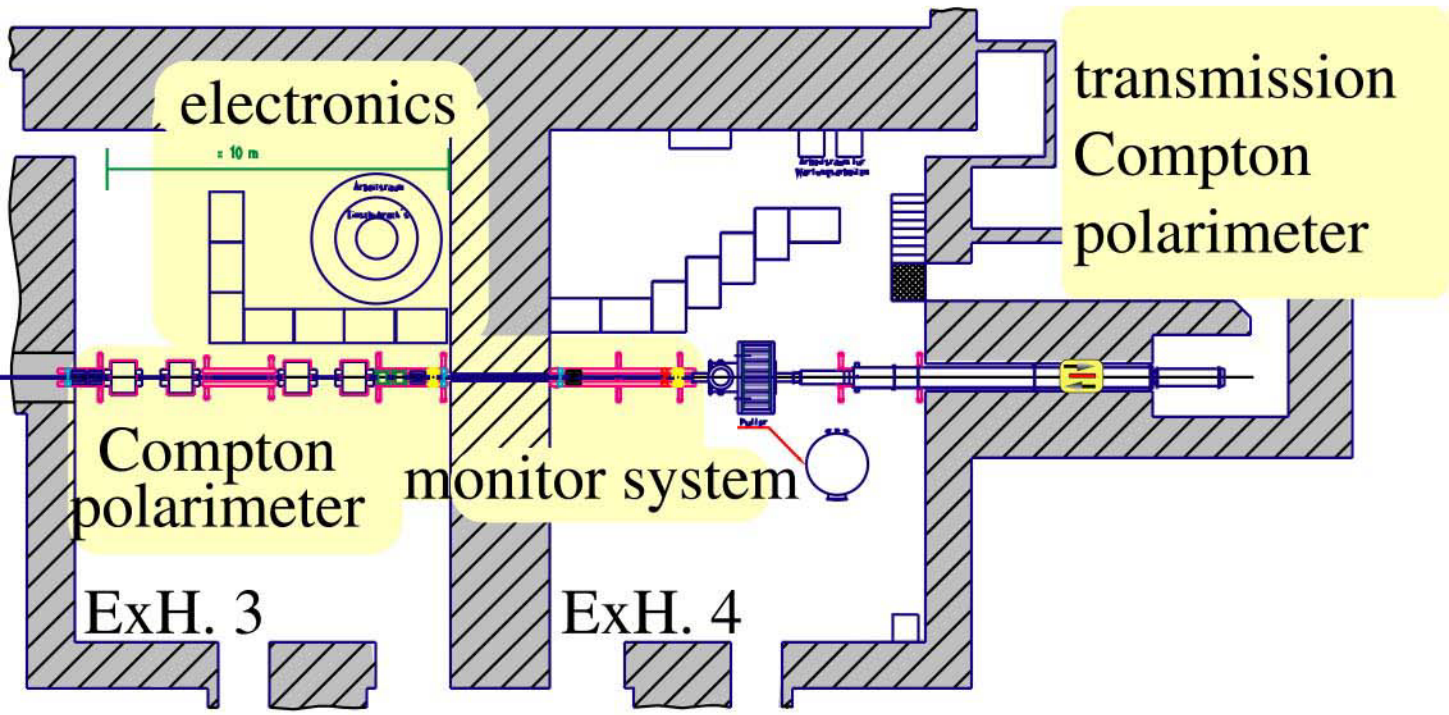
inelastic: ~ 90 MHz (~ 610 MeV)

$\tau = 20$ ns, $\frac{\sigma_E}{E} = 3.5\ \%(1\ GeV)$

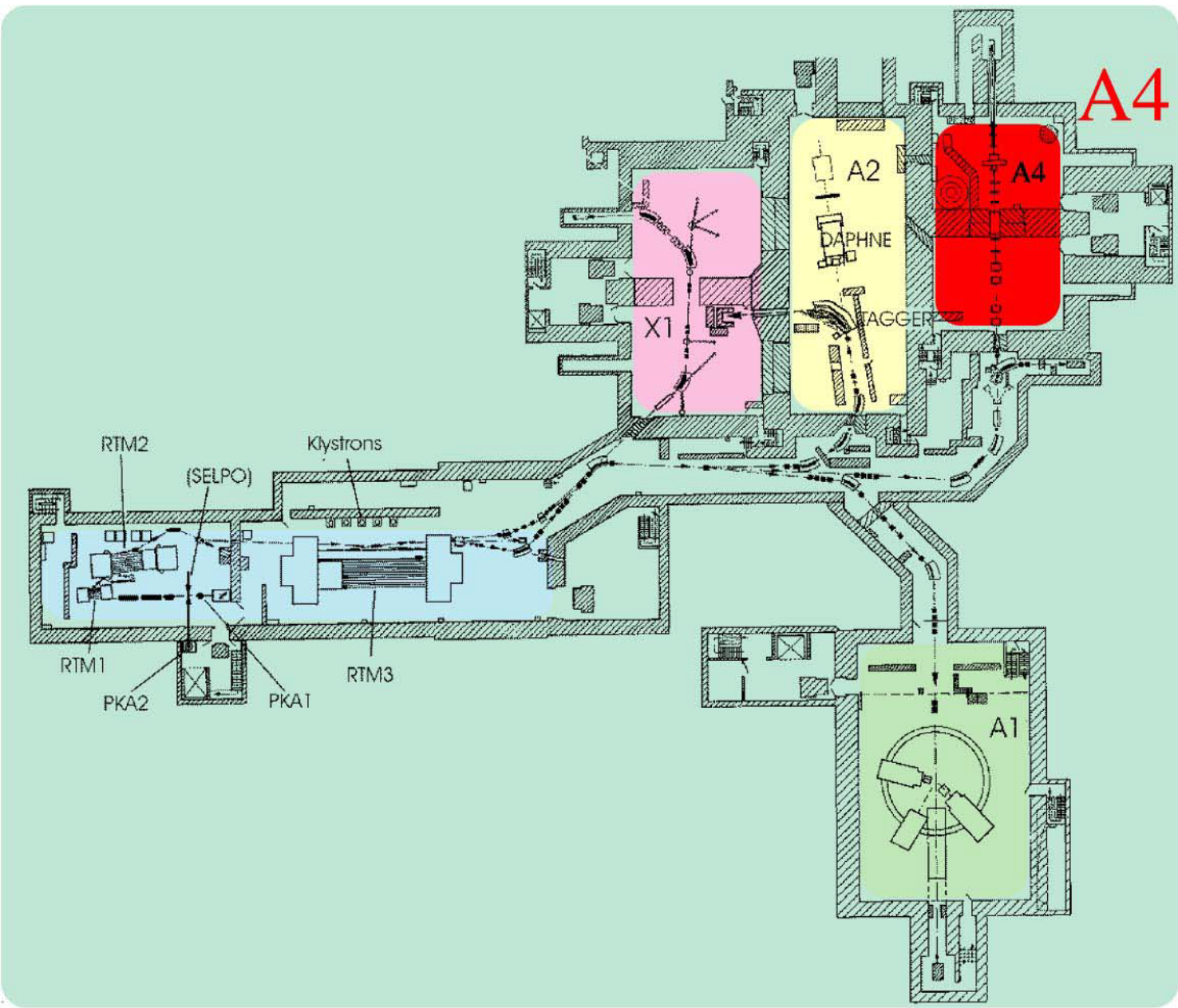

γ
pol. electron source
P=80%, I=20μA
principle
MAMI
E=855MeV
ΔE/E=10-6
e-
Compton-
Laser
Backscatter
Polarimeter
helicity correlated
Measurement of:
beam current,
beam energy
beam position
beam angle
luminosity:
monitor system
γ
e-
high power
liquid hydrogen
target
e-
e-
E,Θ
calorimeter:
1022 PbF2-crystals
luminosity
A = (N_L − N_R) / (N_L + N_R)
transmission
Compton polarimeter
and beam dump

experimental setup



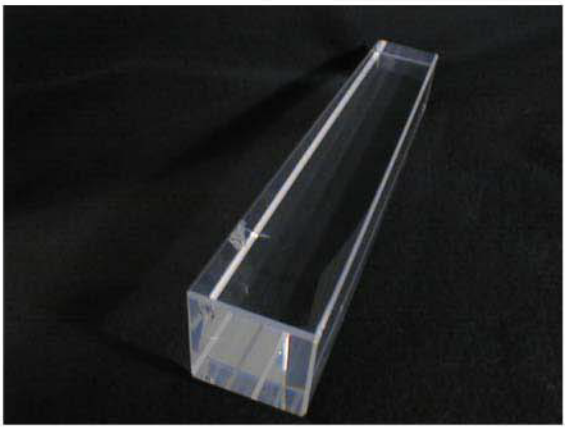


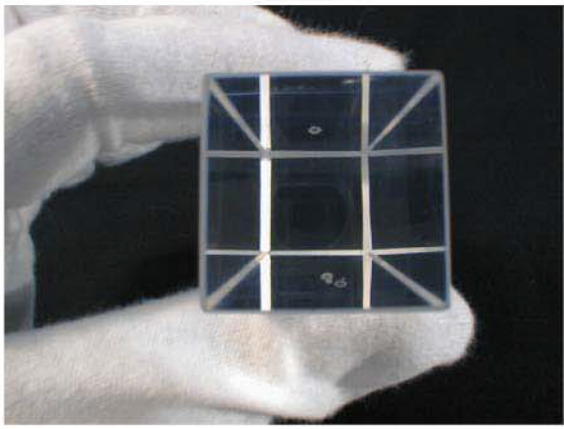
MAinzer MIkrotron:



- 0 - 100 µA cw unpolarised electrons
- up to 30 µA cw polarised (80 % Pol.)
- energy: 14 MeV up to 855 MeV

lead fluoride (PbF_2)





- Cerenkov: intrinsically fast
- compact: $r_M = 2.2\ (1.8)$ cm
  $X_0 = 0.9$ cm
  $r = 7.8$ g/cm
  $n = 1.8 \ldots 2$
- not birefringent
- two components
- timing: excellent (< 20 ns, no scintillation)

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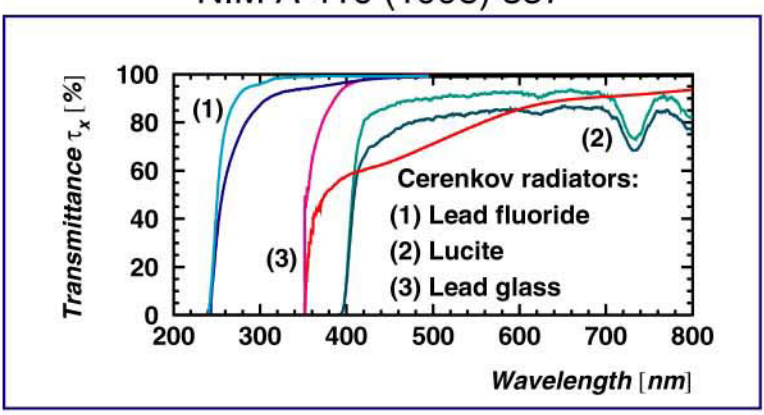
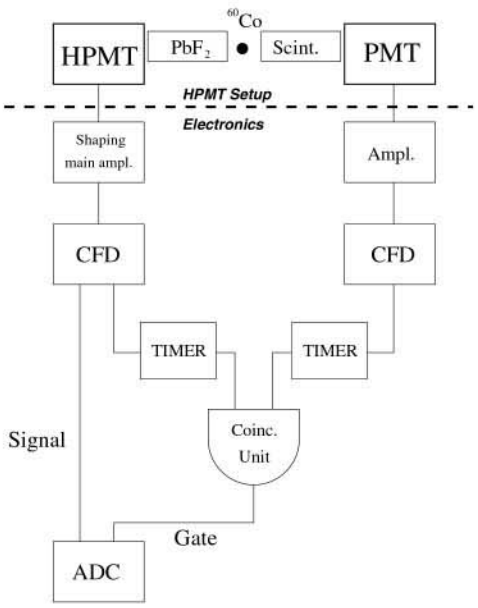
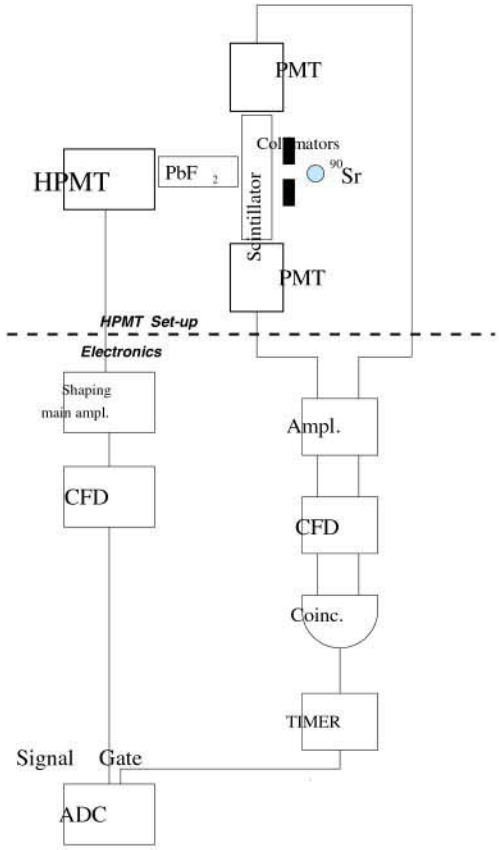
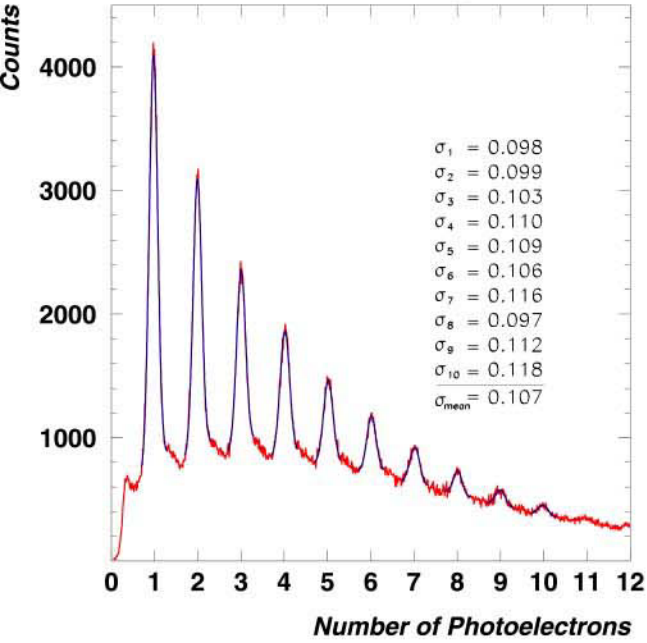


light yield of PbF_2 with a hybrid photomultiplier



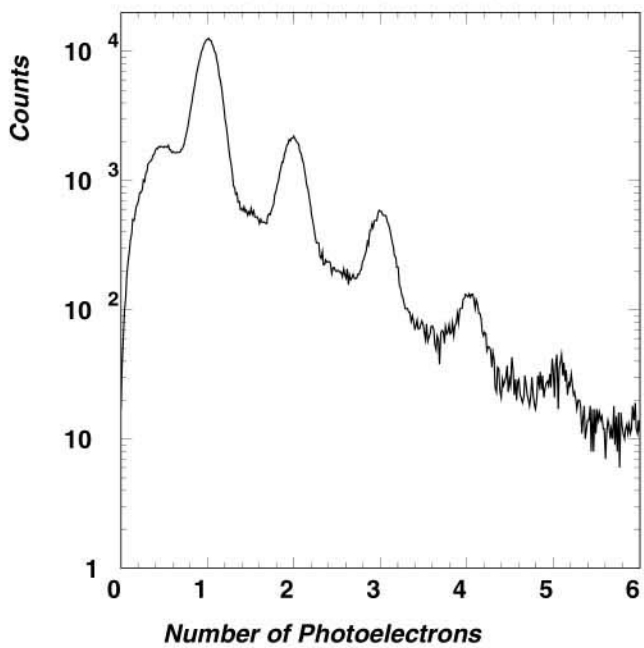


small sample



1.9 p.e./MeV

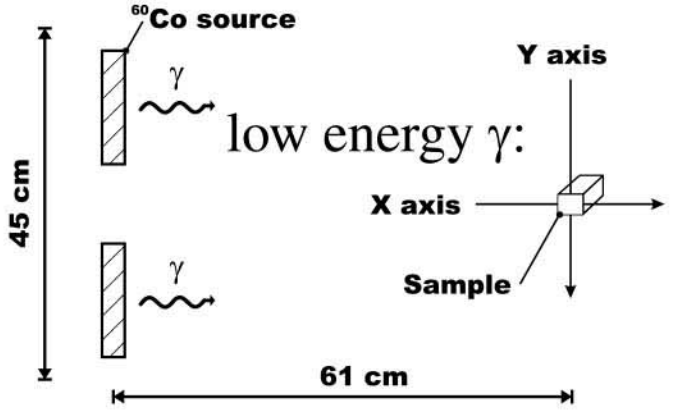
real size Xstal



1.7 p.e./MeV

best wrapping material
Immobilon-P (millipore):
12 % more

radiation hardness and healing by light



production of colour cent.

$dD=(D_x+D_0)\gamma Dt$

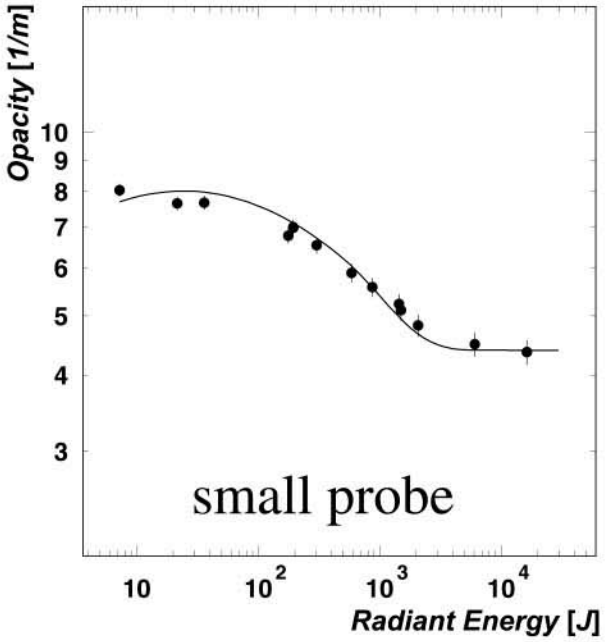
$\gamma=10^{-4}/Gy$

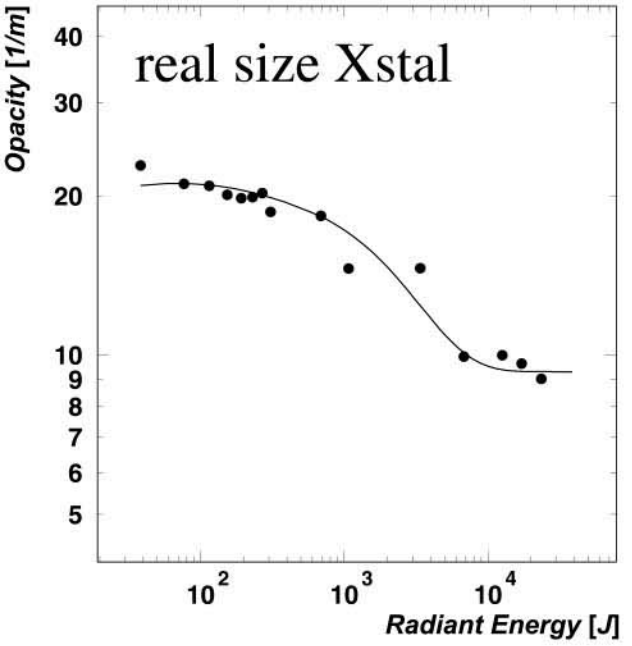
regeneration of colour cent.

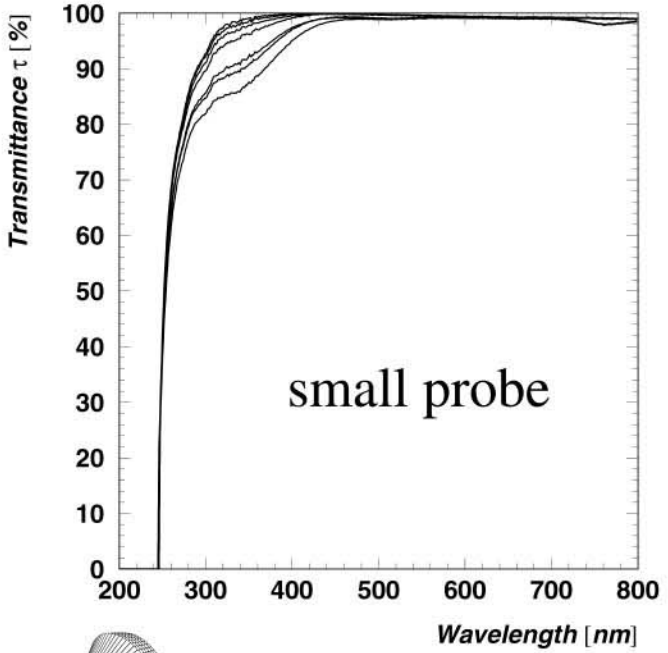
$D=D_x+D_0\, e^{-\beta\phi t}$

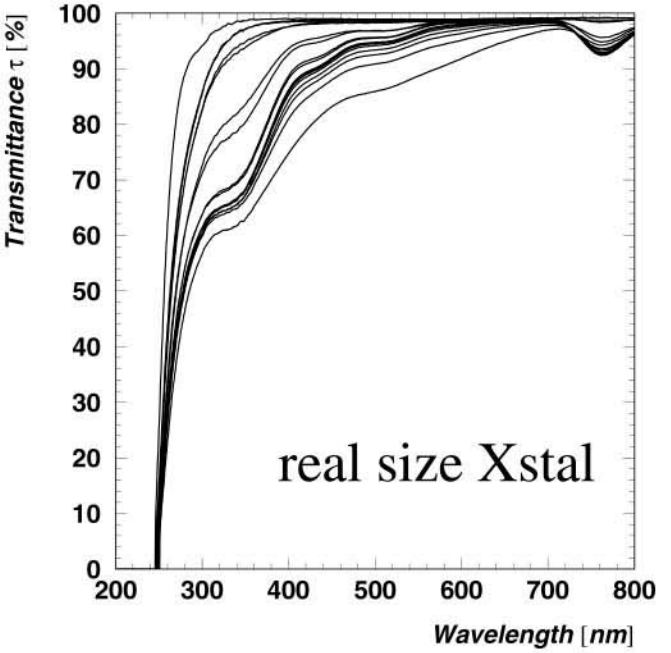
$\beta=4.32/Wh$

healing by visible light



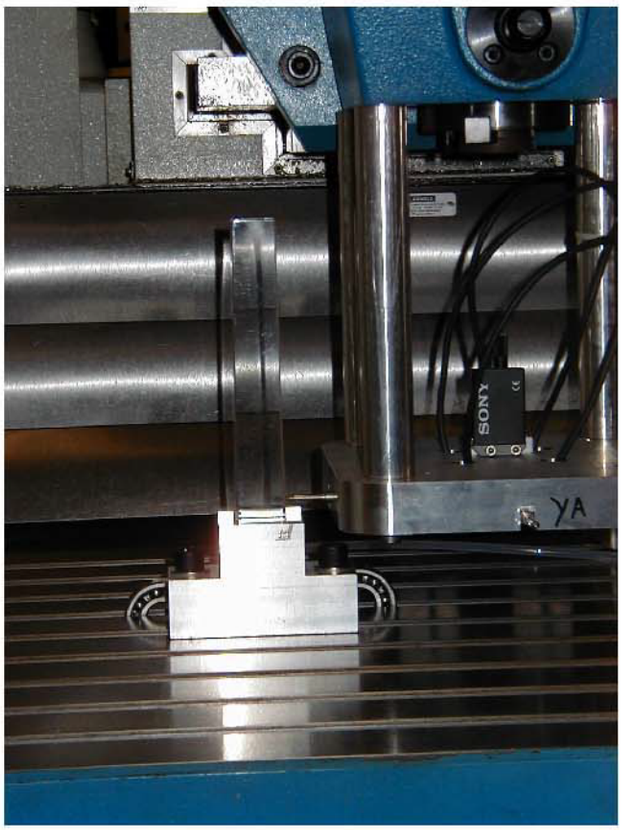


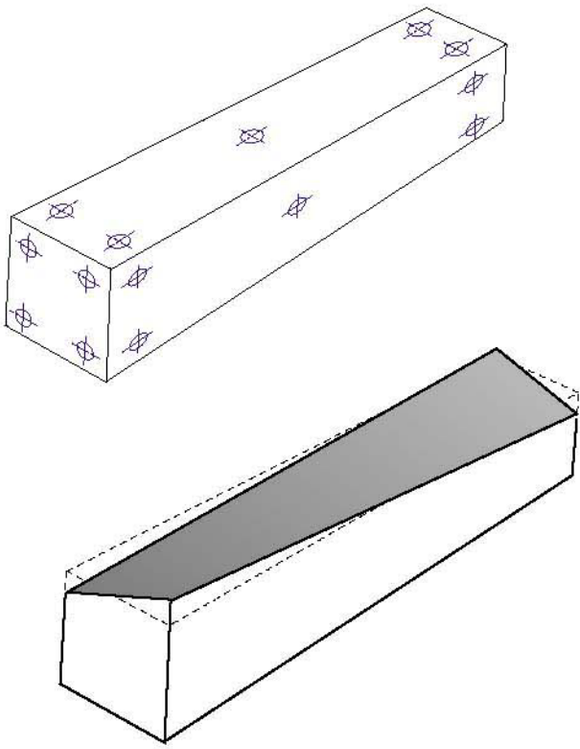




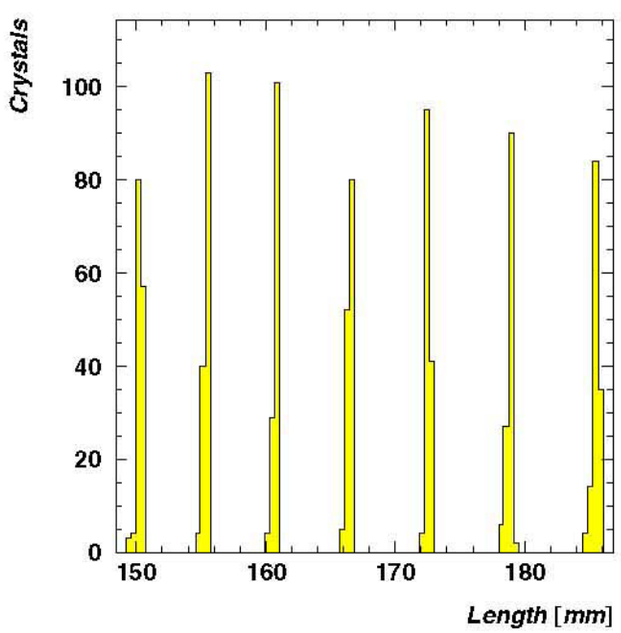
mechnical dimensions

geometry: tolerances: 0.3mm bis 0.5mm
5 probes, accuracy 0.005mm

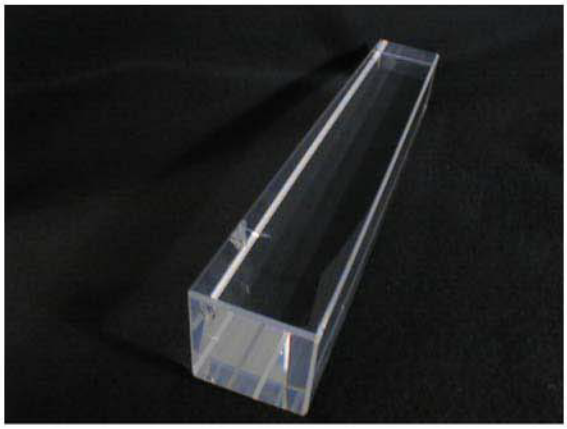


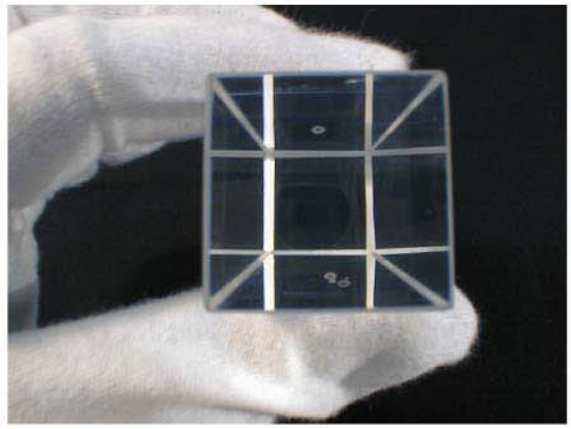


length of Xstals (7 types)

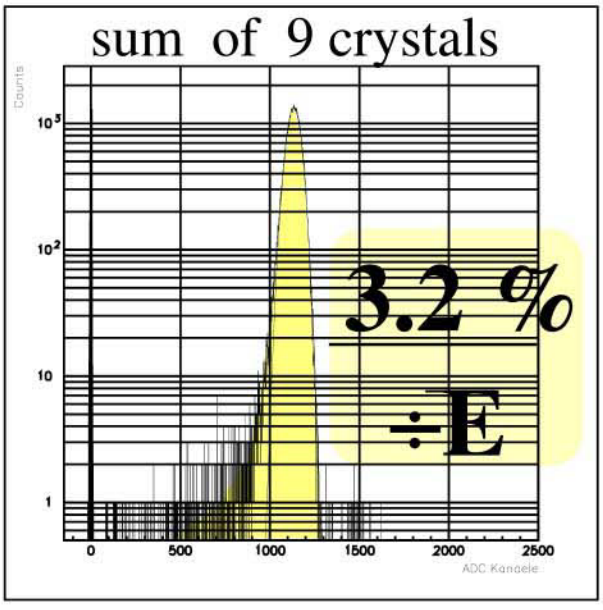


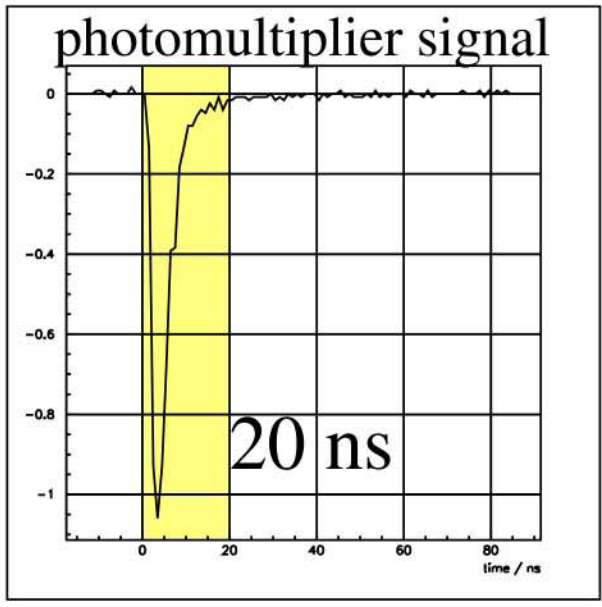
lead fluoride (PbF_2)



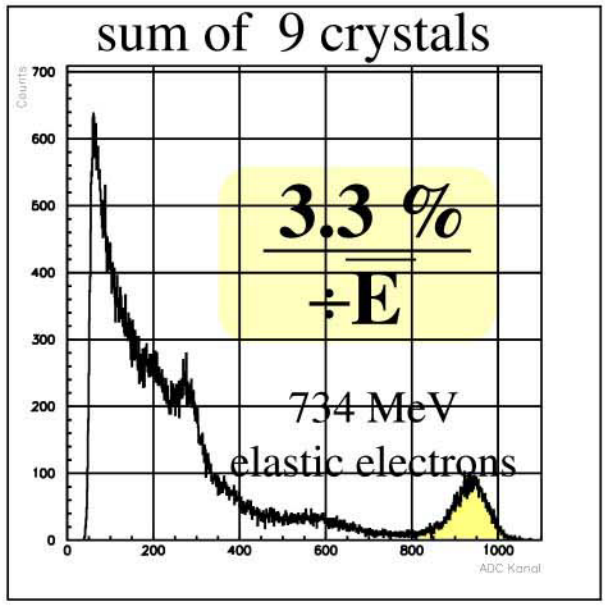


direct beam
(855 MeV electrons)





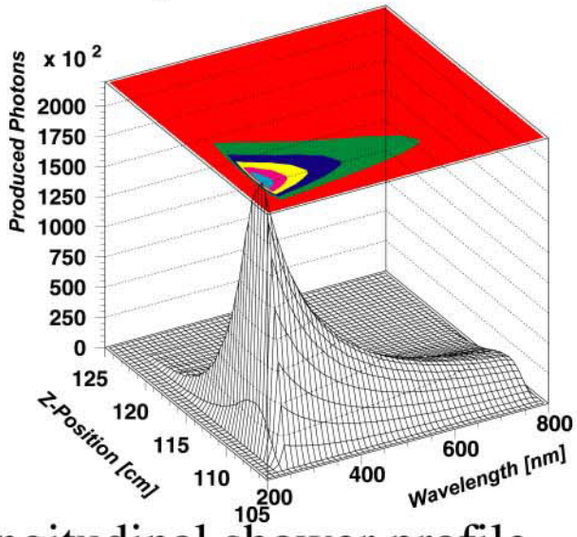
scattered particles
from lH2 target



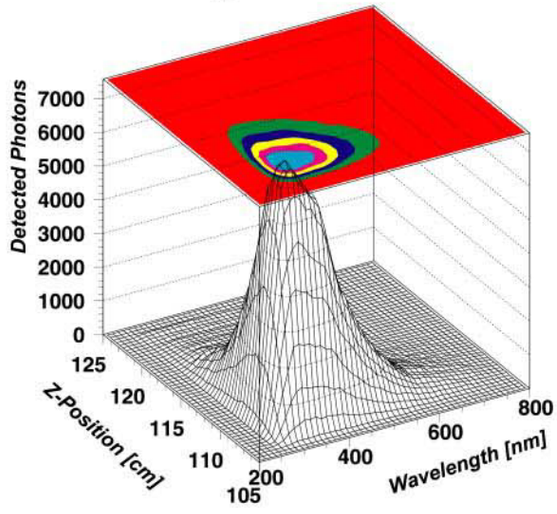
- timing excellent (< 20 ns)
- energy resolution better than required

simulations (geant)

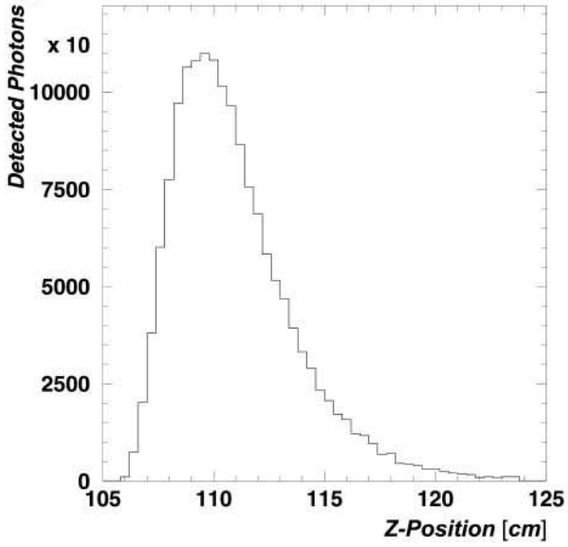
generated photons



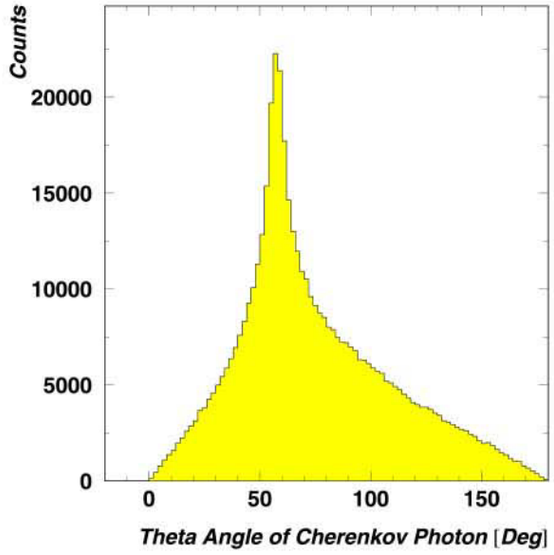
detected photons



longitudinal shower profile (photons)

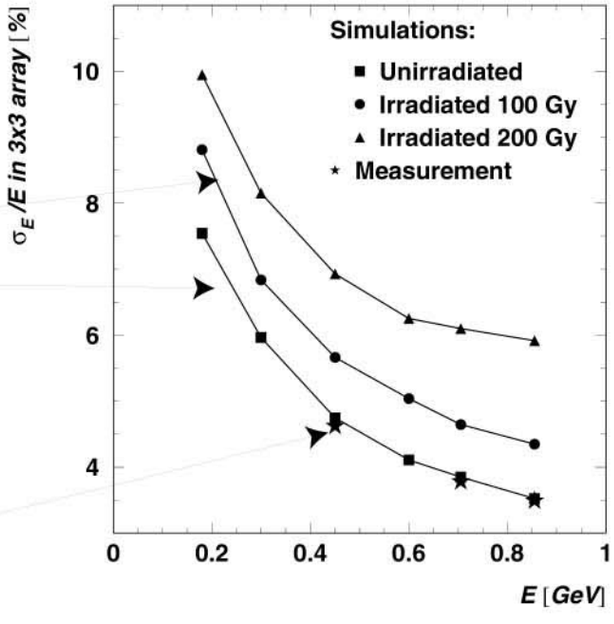


angular photon distr. versus axis

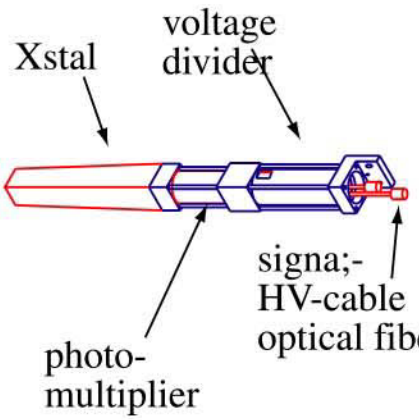


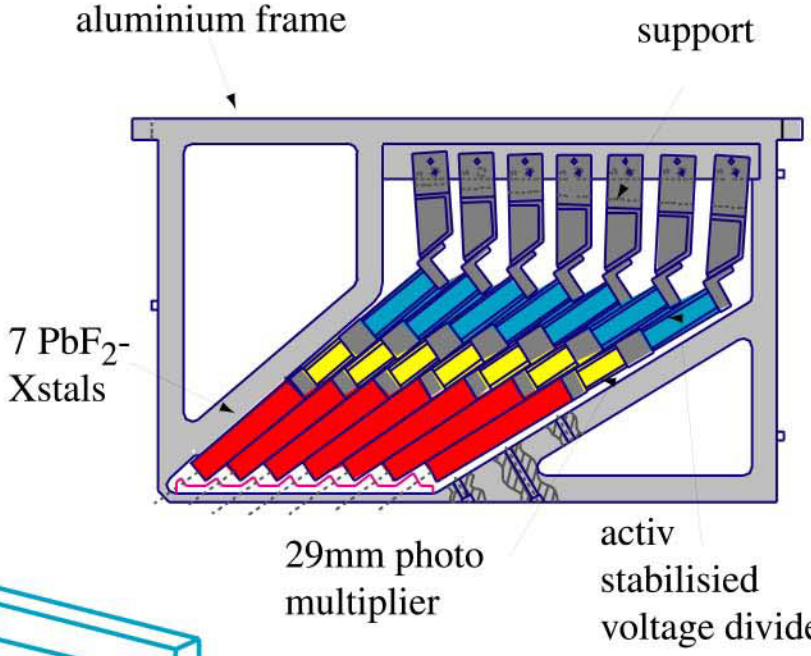
simulated detector response

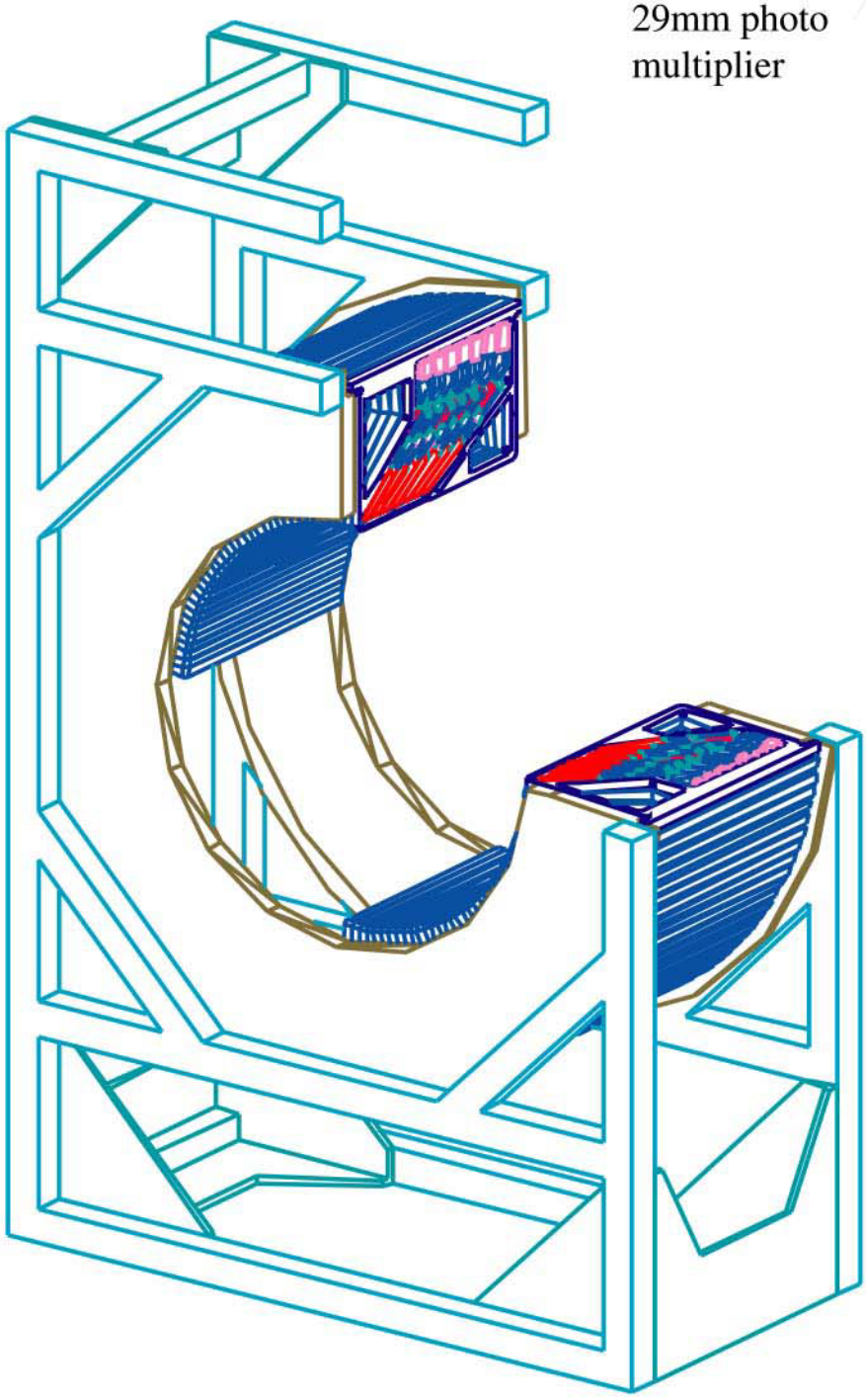
measured detector response



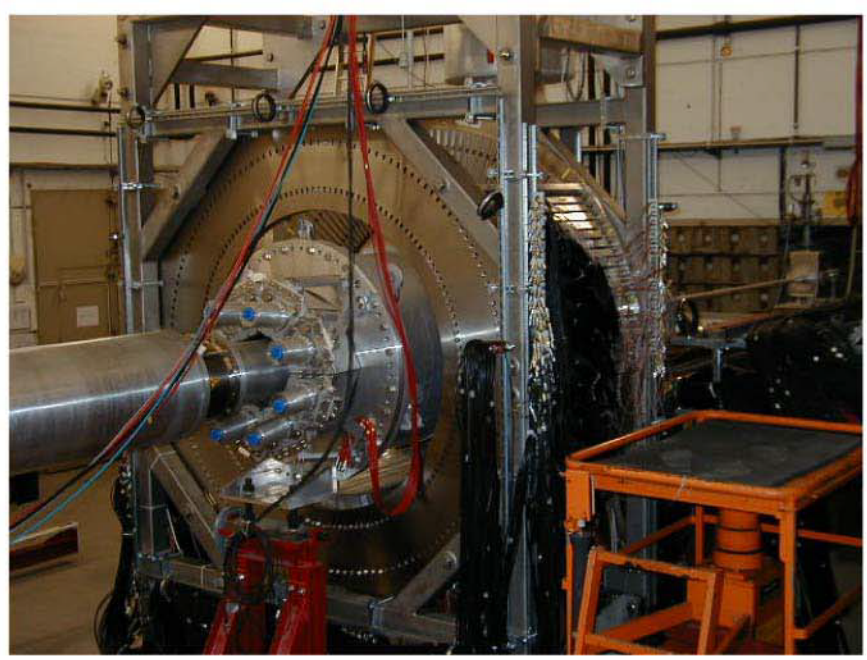
511 PbF2 detectors





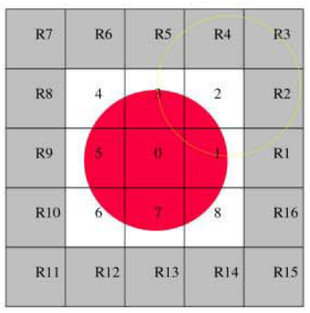


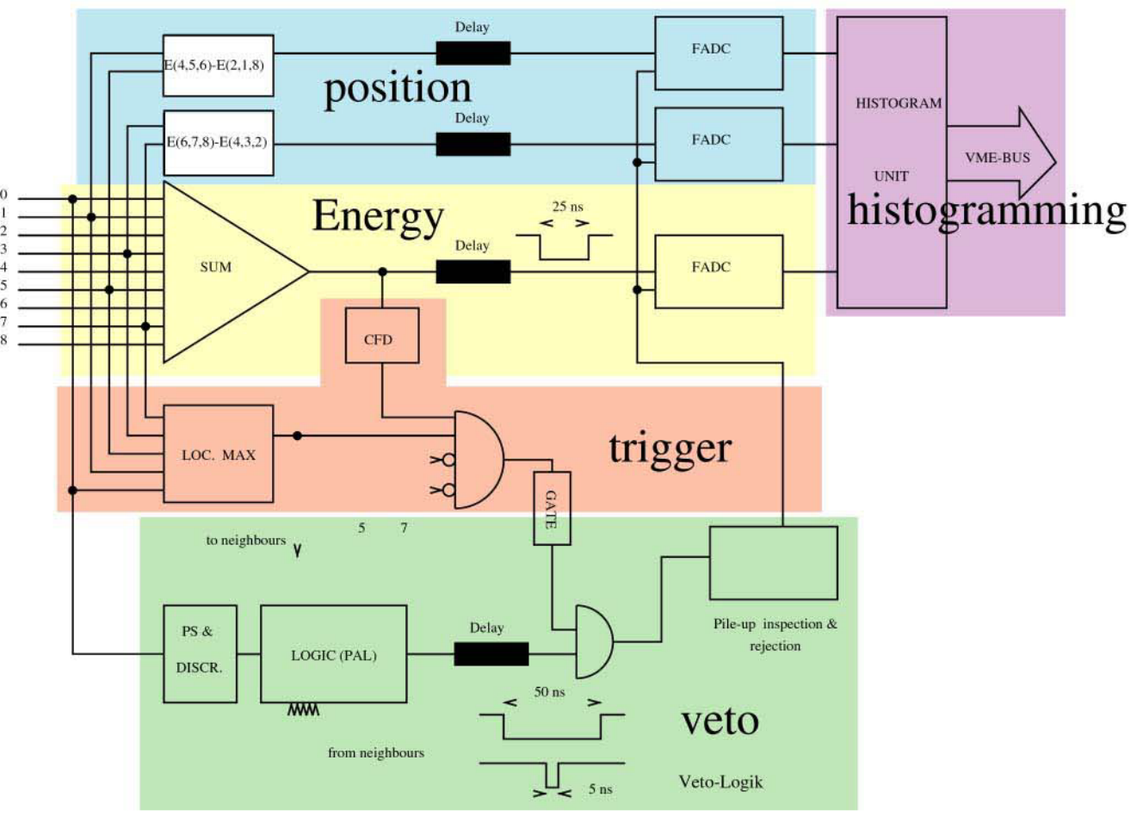
511 PbF2 detectors



MEDUSA

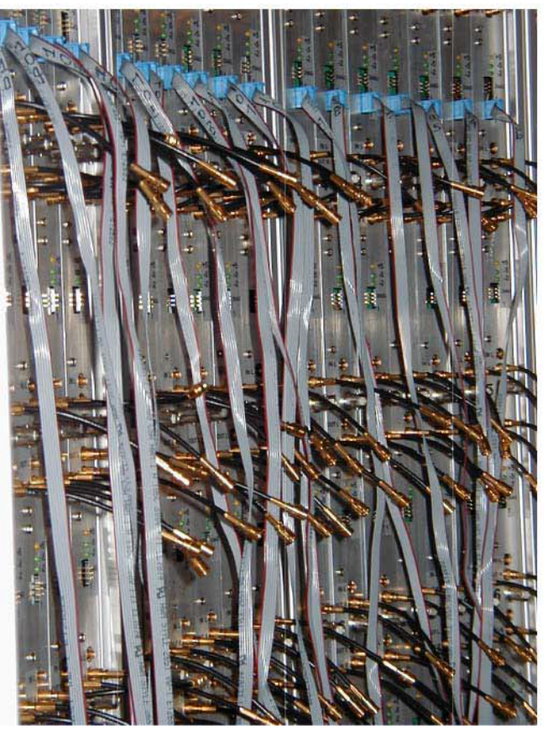
20ns, 3.5%





- 1022 parallel modules
- no single events
- 4 dimen. Histogramming
- analogue "Analysis"
- analogue Summation
- temporal and spatial pileup
- 100kHz event processing per channel

511 channels of MEDUSA

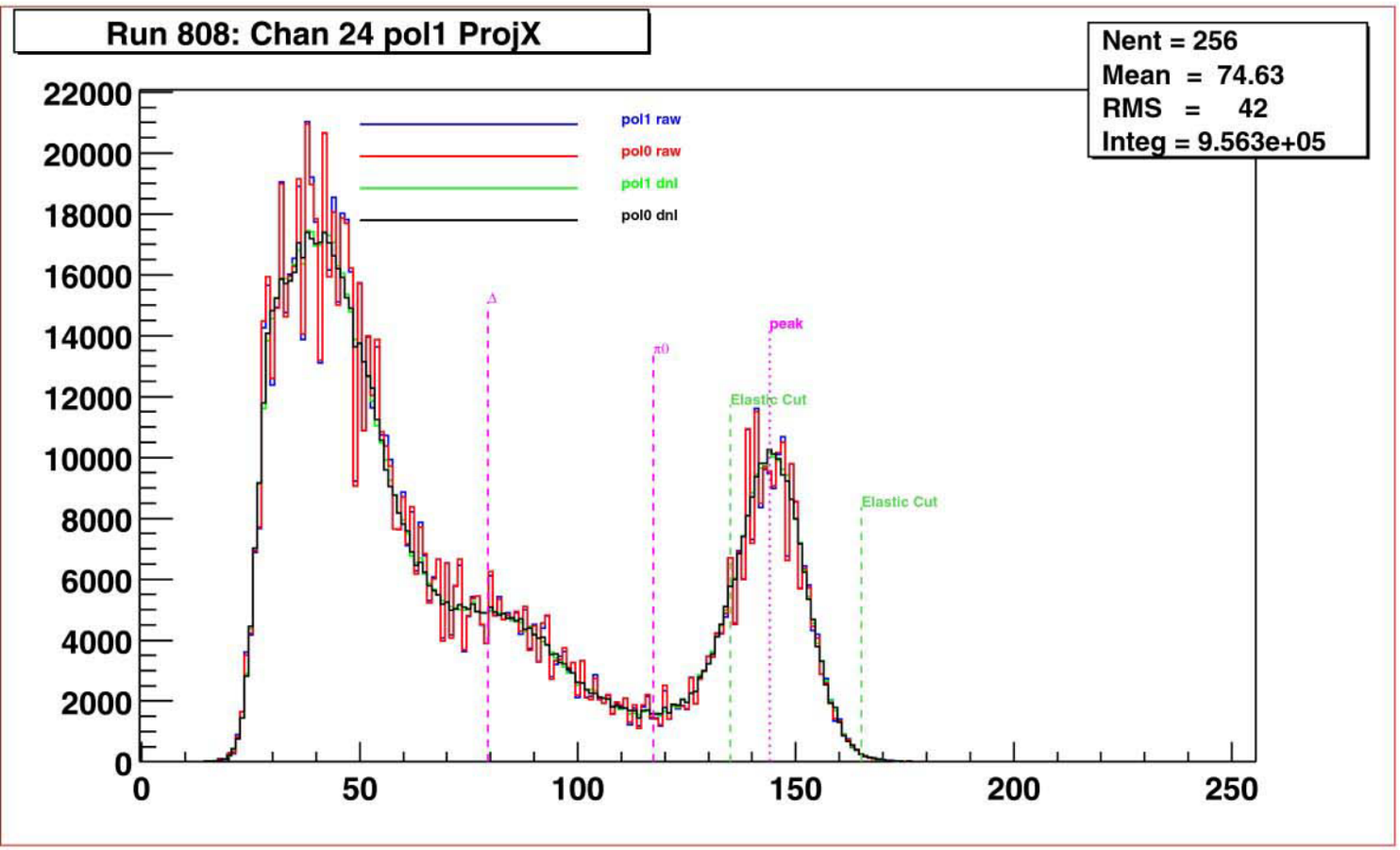


- highly connected
- 5 cables per channel

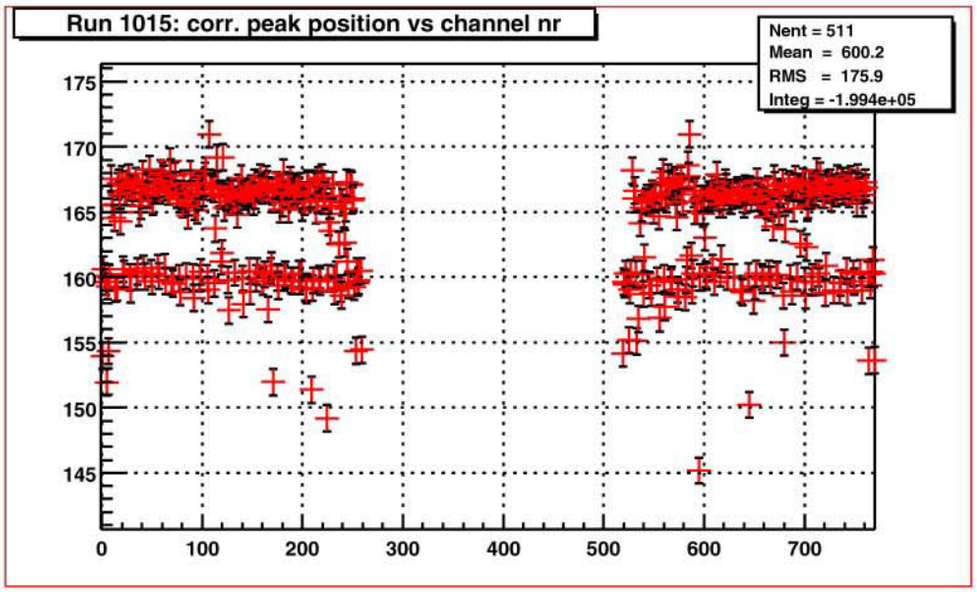
(5000 connectors)

511 spectra

- no single event
- no single detector information
- only histogramm sum signals
- how to calibrate?
- each channel sum of 9
- each channel contributes
  amount x to neighbours
- from elastic line derive signal
- do calibration by solving lin. equ.
- adjust high voltage
- only 3 steps necessary



peak positions



energy resolution