Is it possible to recycle HERA-B W-Sci calorimeter into PHENIX Nose Cone Calorimeter ?

Major benefits of such recycling:

- Physical capabilities are the same (almost+extra) as of the proposed W-Si calorimeter. This device works for sure.
- Dramatical reduction of development TIME & money;
- Data taking with W-Sci NCC may starts already in Run05/06;
- Participation in the PHENIX collaboration new highly experienced groups (ITEP, INFN)

Outline

- **Why is HERA-B W-Sci calorimeter?**
- **What is HERA-B W-Sci calorimeter?**
- **How it performs?**
- **Major limitations on the PHENIX NCC;**
- **Is it possible to squeeze of HERA-B calorimeter into Nose Cone limits? How calorimeter should be modified?**

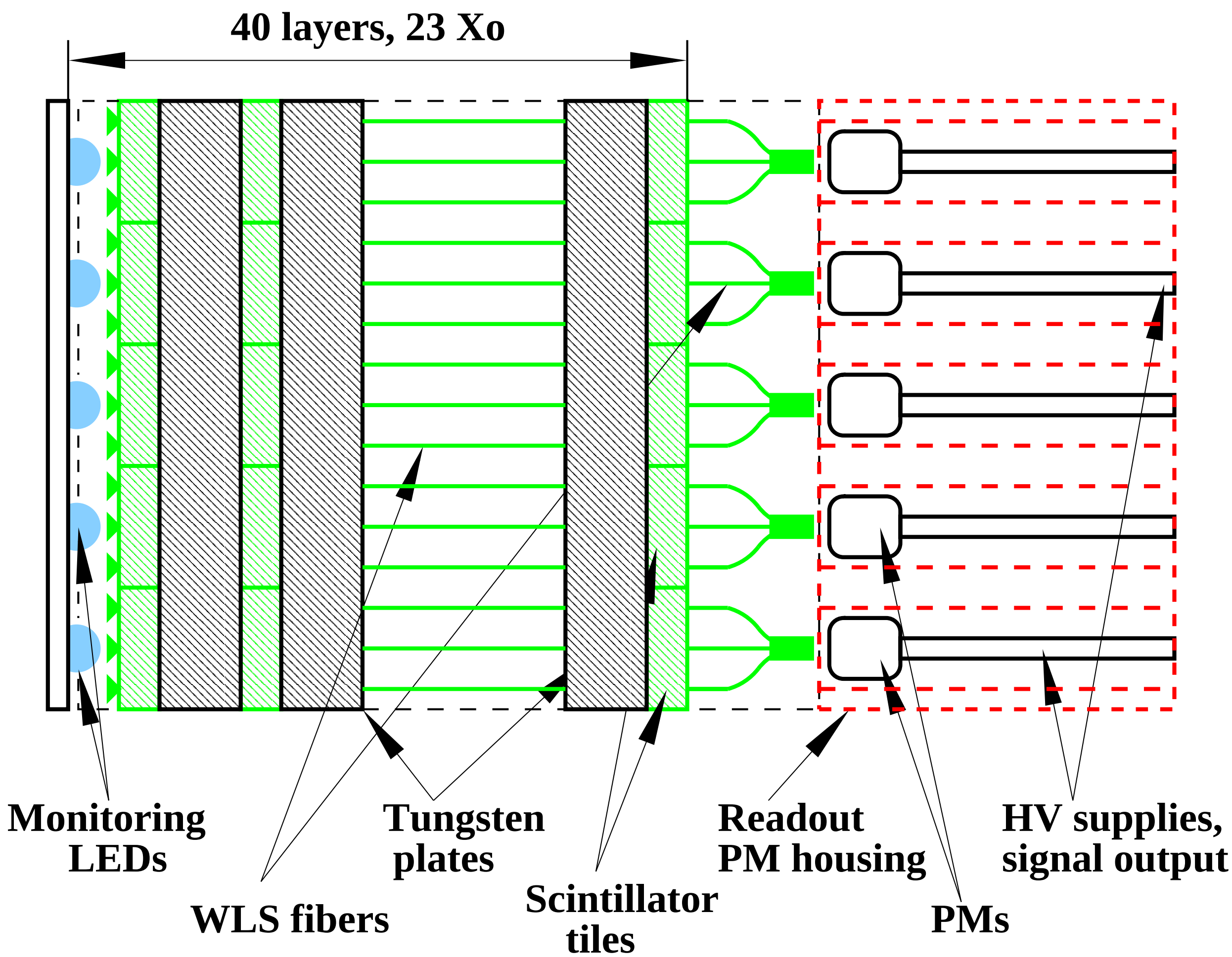
Why is HERA-B W-Sci calorimeter?

- Tight limitation on available space (20 cm along the beam)→ only very dense material like tungsten may be used as absorber by analogy with the proposed W-Si sampling calorimeter;
- HERA-B experiment (DESY) has completed its life circle. W-Sci(ntillator) sampling shashlik type calorimeter with fine transverse segmentation has been used in this experiment. After redesign it may be squeezed into the space(???);
- Performance of the HERA-B calorimeter is close to performance (or exceed it) of the proposed W-Si NCC calorimeter;
- Recycle **TIME** and expenses are relatively small in comparison with W-Si NCC. Proven "low-tech" technology, commercially available components. Existing FE electronics may be partially recycled, including fast pre-trigger system a'la PHENIX EMCal ERT.
- It may serves as peripheral part of combined W-Si + W-Sci NCC with super fine segmented central part made of W-Si → money reduction.

What is HERA-B W-Sci calorimeter?

- HERA-B W-Sci calorimeter is “standard” absorber+scintillator sampling electromagnetic calorimeter with WLS fiber read-out (aka “shashlik” type). It consist of 84 modules with 112mm x 112mm cross section and 130mm depth (body only). Each module is subdivided into 25 (5 x 5) cells with 22.4mm x 22.4mm cross-section.
- Scintillator is polystyrene based PSM115, WLS is Y11 type with decay time ~11ns and maximum in emission spectrum of ~550nm (“green” light).
- Light yield is ~100PhEl / 1Gev of electromagnetic energy with PMT readout. For APD readout it will be ~(600-900) PhEl / 1Gev.
- Design and performance (experimentally measured) are presented on next slides (all results are borrowed from proceedings of “Calors 99,…, Calors 2004” conferences)

Inner section module solution

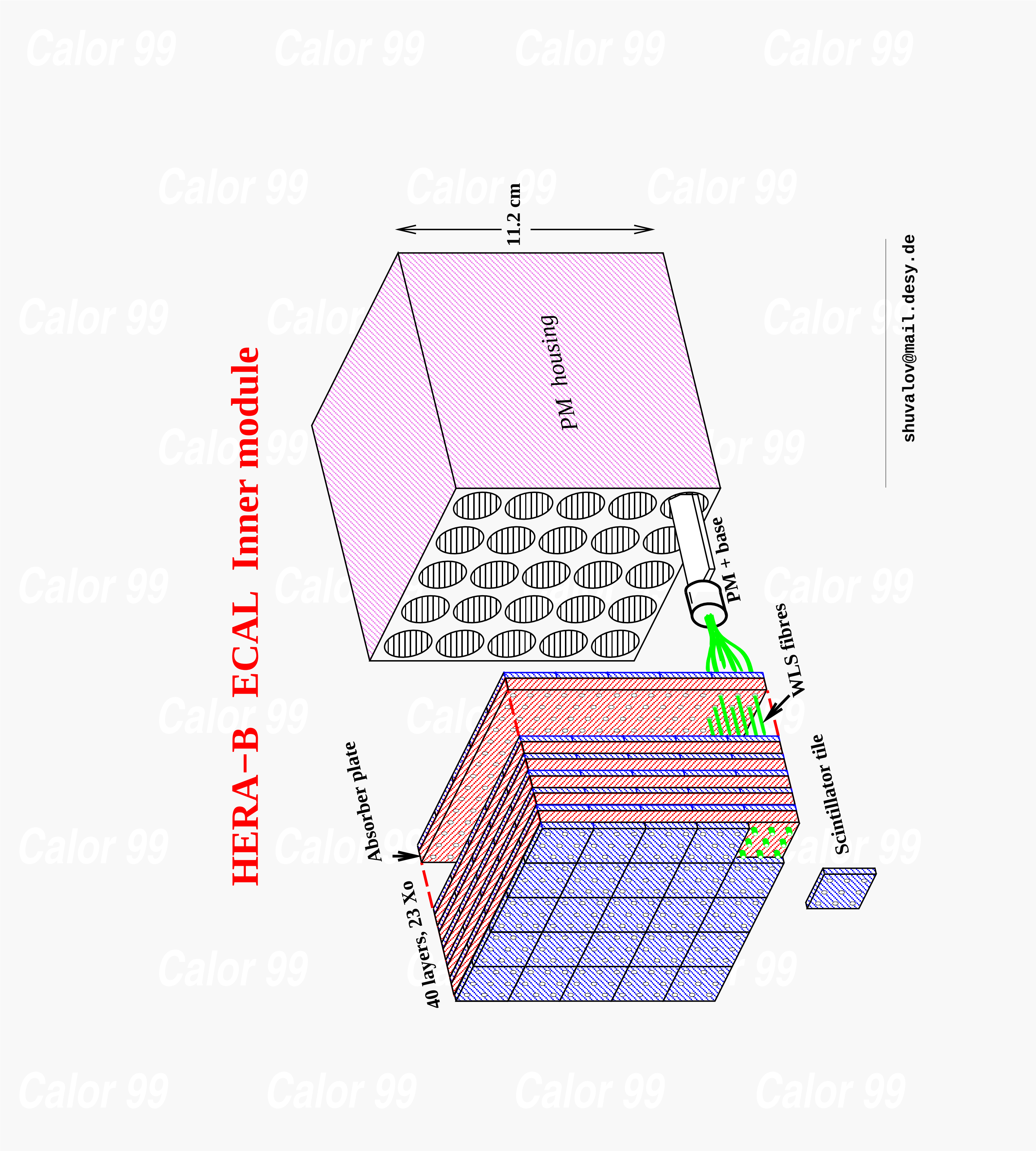


Sampling SHASHLIK technology

Size:	11.18 cm	Moliere radious:	1.24 cm
Granularity:	25 cells/module	Depth:	13 cm (23 Xo)
Scintillator:	based on PSM115	Volume ratio:	W:Sc 2:1
Absorber:	Tungsten	Readout PMs:	HAMAMATSU R−5600, FEU−68
Fibers:	Kuraray Y−11	Monitoring LED:	Blue Marl Red L934SRCB
Light yield:	130 p.e./GeV		

Radiation hardness

According to TDR expected radiation dose was up to 5 Mrad per HERA−B year (several LHCb years). Due to revised physical program currently accumulated dose is ~ 3Mrad (shower max). No rad. damage is seen neither in modules nor in phototubes and HV supplies


HERA-B ECAL Inner module
11.2 cm
PM housing
PM + base
WLS fibres
Absorber plate
Scintillator tile
40 layers, 23 Xo
shuvalov@mail.desy.de
Calor 99

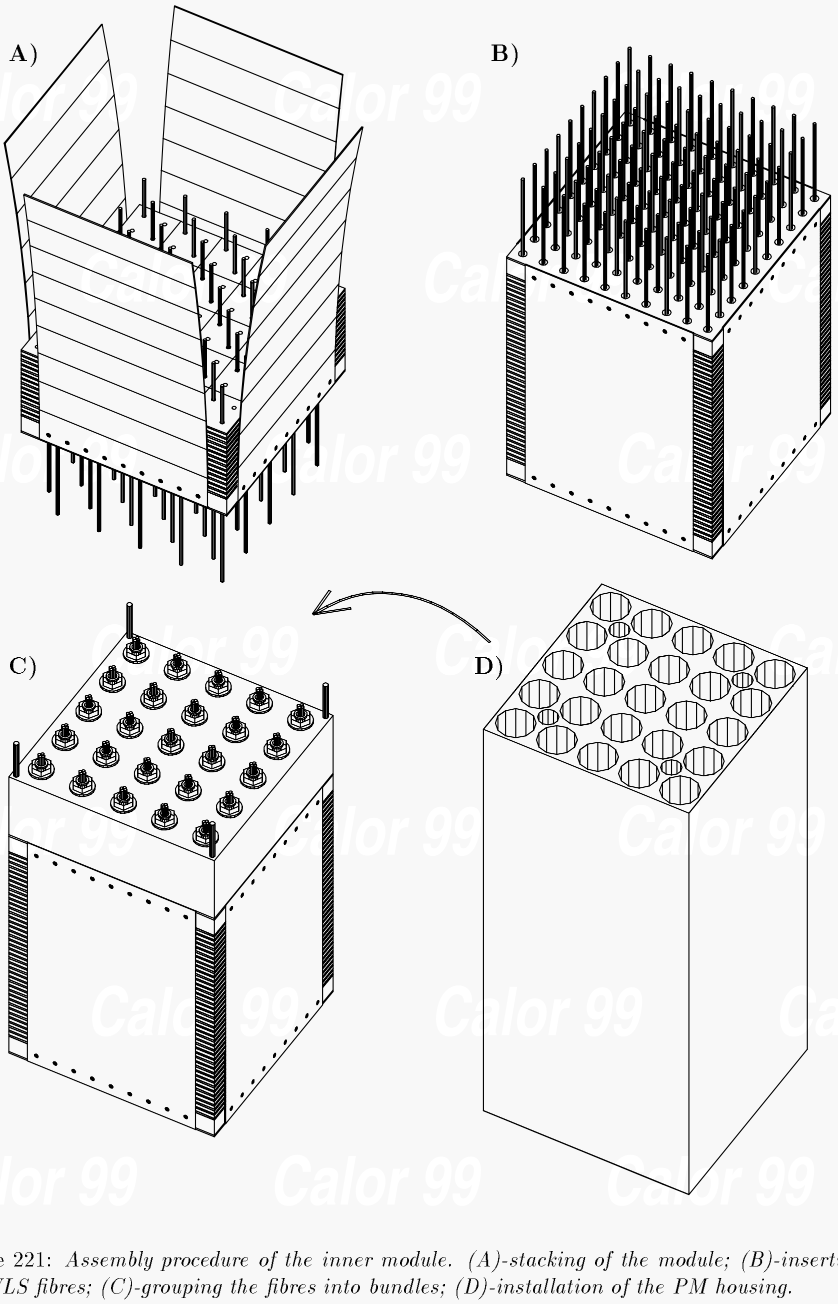


Figure 221: *Assembly procedure of the inner module. (A)-stacking of the module; (B)-insertion of the WLS fibres; (C)-grouping the fibres into bundles; (D)-installation of the PM housing.*


TEKSCOPE
Digital Real-Time
Oscilloscope with DMM
shuvalov@mail.desy.de

Windowless - Large Area APDs

Electro-Optical Characteristics

All specifications apply when APD is operated at 23°C and at a gain of 200.

3 mm

Active Area Diameter (mm)	Bias Voltage Range† (V)	Temperature Coefficient of Breakdown Voltage (%/°C)	Capacitance f = 100kHz Typ (pF)	Dark Current Typ (nA)	Dark Current Max (nA)	Noise Current Spectral Density f = 100kHz Typ (pA/√Hz)	Noise Current Spectral Density f = 100kHz Max (pA/√Hz)	Rise Time λ = 675 nm Load = 50Ω Typ (ns)	Rise Time λ = 675 nm Load = 50Ω Max (ns)
3	1700 to 2000	+0.1	15	25	60	0.7	1.4	8	12
5			25	35	100	1.0	2.0	10	15
10			65	90	230	1.5	3.0	12	18
16			140	280	600	2.5	5.5	15	22

5 mm

Part Number	Active Area Diameter (mm)	Spectral Enhancement	Responsivity Typical (A/W)
118-70-75-520	3	DUV	30 @ 160nm
118-70-73-520		UV	38 @ 350nm
118-70-74-520		Blue	70 @ 500nm
118-70-72-520		Red/IR	100 @ 750nm
197-70-75-520	5	DUV	30 @ 160nm
197-70-73-520		UV	38 @ 350nm
197-70-74-520		Blue	70 @ 500nm
197-70-72-520		Red/IR	100 @ 750nm
394-70-75-5X0‡	10	DUV	30 @ 160nm
394-70-73-5X0‡		UV	38 @ 350nm
394-70-74-5X0‡		Blue	70 @ 500nm
394-70-72-5X0‡		Red/IR	100 @ 750nm
630-70-75-5X0‡	16	DUV	30 @ 160nm
630-70-73-5X0‡		UV	38 @ 350nm
630-70-74-5X0‡		Blue	70 @ 500nm
630-70-72-5X0‡		Red/IR	100 @ 750nm

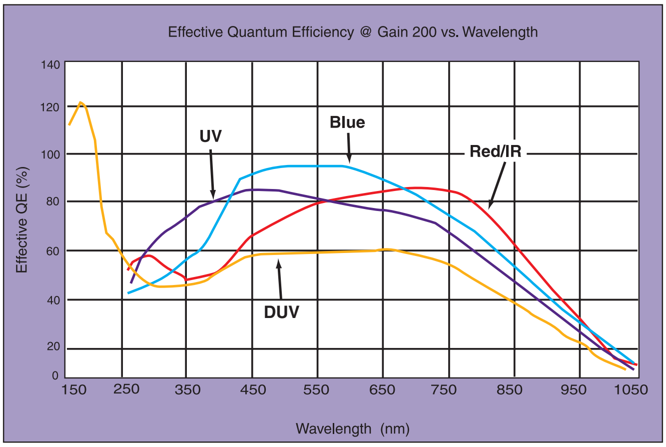
Absolute Maximum Ratings◊

Gain, M @ λ=675nm	250
Operating Temp Range (°C)	-20 to +50
Storage Temp Range (°C)	-55 to +70
Power Dissipation @23°C (W)	3mm - 0.12 5mm - 0.2 10mm - 0.4 16mm - 0.6

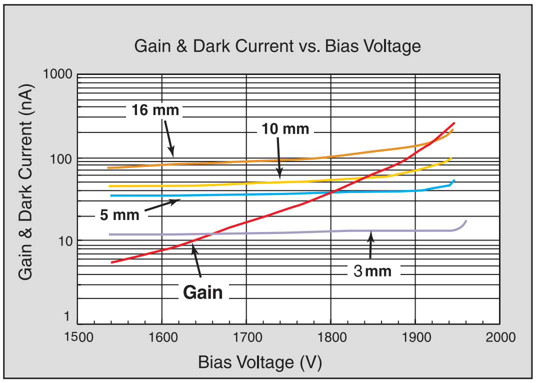
10 mm

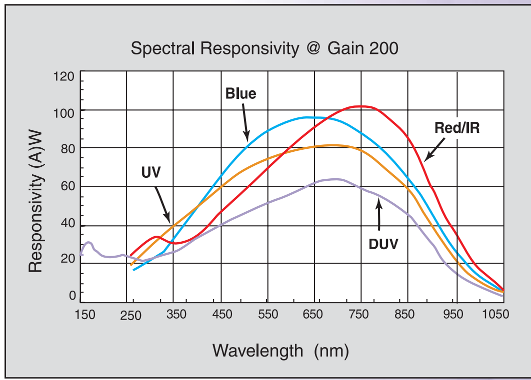
† Positive high voltage (HV) is applied to the cathode contact. The maximum value for the operating HV is specified with each device.
‡ "X" indicates package style; "0" = SHV connector (supplied with mating connector) and "1" = a single pin connection.
◊ Operating beyond these limits may cause permanent damage to the device.

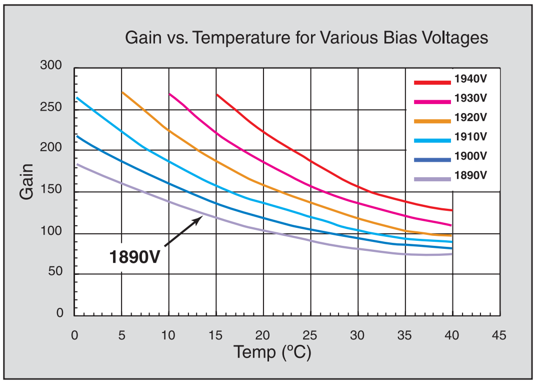
16 mm

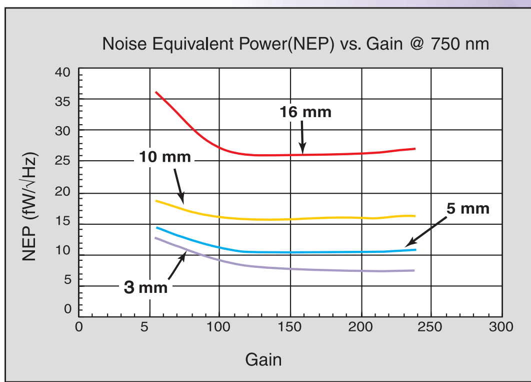


Typical Performance Graphs

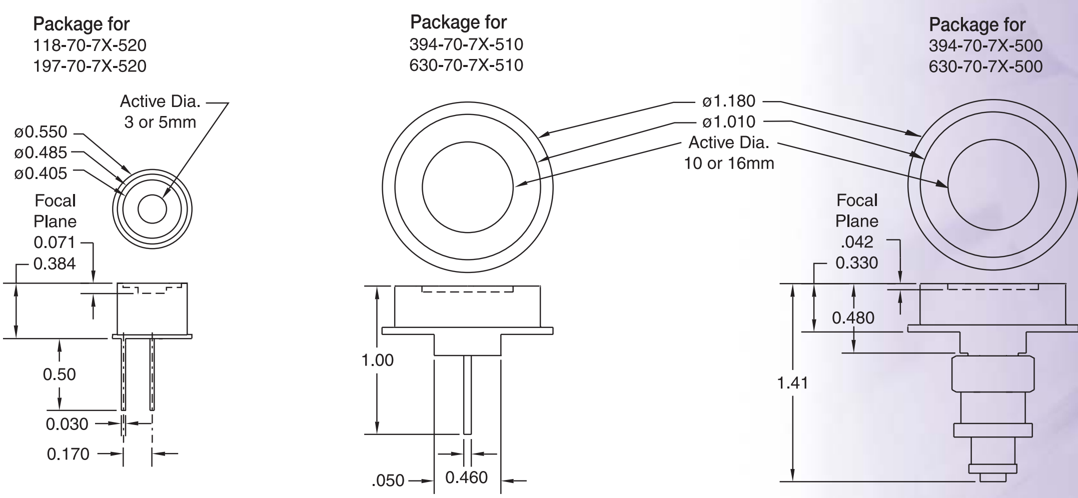








Mechanical Dimensions

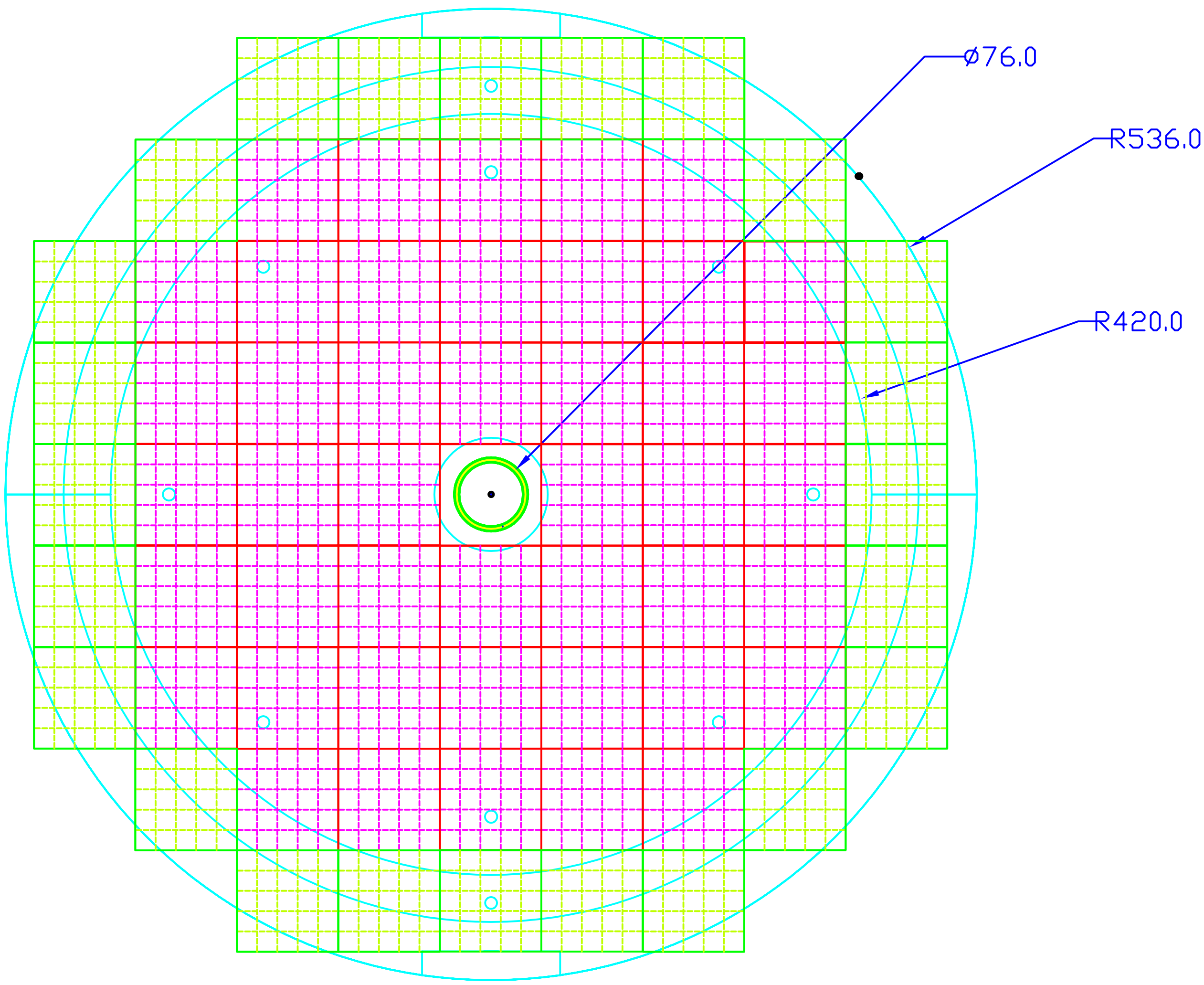


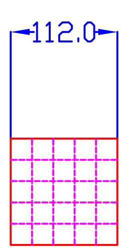
Center pin on all three package types is the APD's cathode and case is the APD's anode.

Total available 84 modules (2100 ch);

RED - 44 modules (1100 ch);

RED+GREEN - 44+24=68 modules (1700 ch).

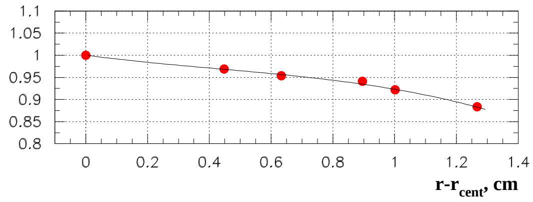




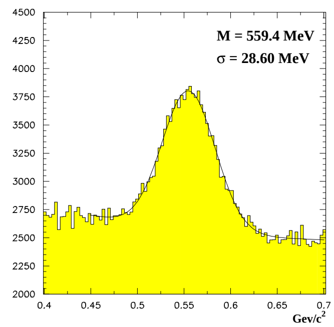
5 x 5 cells
(22.4mm x 22.4mm cell)

ECAL module light yield nonuniformity

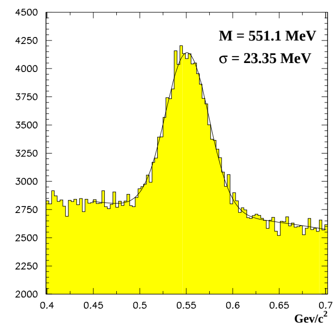
Inner section



Normalized light yeald
r−dependence

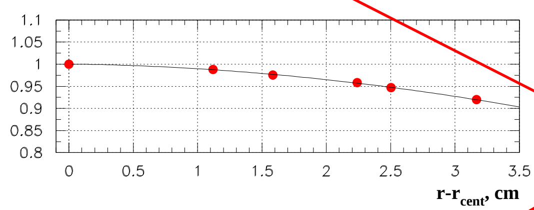


Before
correction

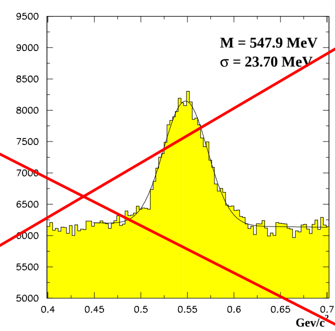


After
correction

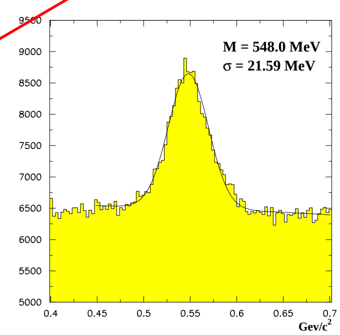
Middle section



Normalized light yeald
r−dependence

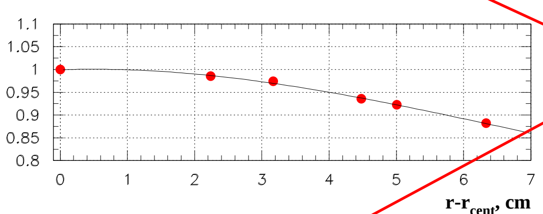


Before
correction

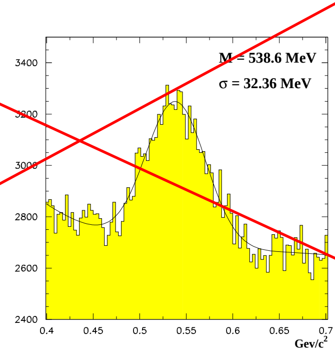


After
correction

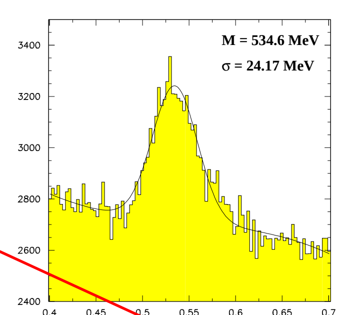
Outer section



Normalized light yeald
r−dependence



Before
correction



After
correction

ECAL HV system

- Large phototube gain spread
  - Big inequality in energy deposition range over calorimeter
  - Large occupancy conditions
  - Tight geometry in Inner section

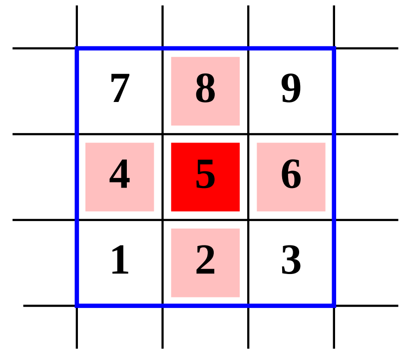
  → phototube HV supply solution is made on the basis of Cocroft−Walton voltage multiplier
- Digital HV control (10 bit)
- Matrix−like addressing scheme allows to address individual phototube and precisely ajust high voltage on it.

ECAL readout

- Individual phototube signal digitization: charge integrator (60 ns) + 12−bit (for InnerMost section − 13−bit) ADCs.
- ADCs are grouped into FED board (32 ADC / board)
- Each FED board contains also:
  - 256 events deep pipeline to store ADC readings
  - SHARC interface to transfer data to the common HERA−B DAQ system.
  - LUTs for ADC−>energy conversion
  - Serial interface to transfer calibrated 7−bit compressed data to ECAL pretrigger
  - Analog sum output − used to inhibit events with extremely high multiplicity
  - VME inerface + build−in test facilities
- Readout system is synchronized with HERA−B bunch crossing rate (10 MHz)

ECAL pretrigger system

- Provide energetic cluster candidate as a track seed for First Level Trigger processing.
- Pretrigger input is 7−bit data from FED board, which contains compressed energy (ADC readings with pedestal subtracted and normalized according current calibration).
- Cluster is identified as candidate if:
  - cell 5 is a local maximum
  - $\Sigma E_i > E_{thr}$
  - $E_5 > E_{thr} / 2$

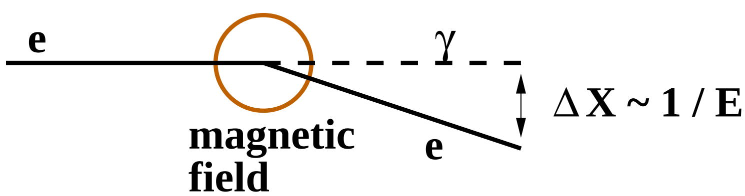


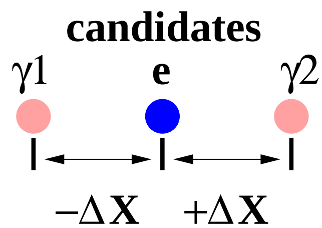
- Position of candidate is estimated as corrected center of gravity:

  $x = x_5 + A \text{ arctang}(B \, \Sigma \, x_i E_i \; / \; \Sigma E_i)$

  $y = y_5 + A \text{ arctang}(B \, \Sigma \, y_i E_i \; / \; \Sigma E_i)$

- Bremsstrahlung recovery feature is foreseen to improve the trigger efficiency for electrons

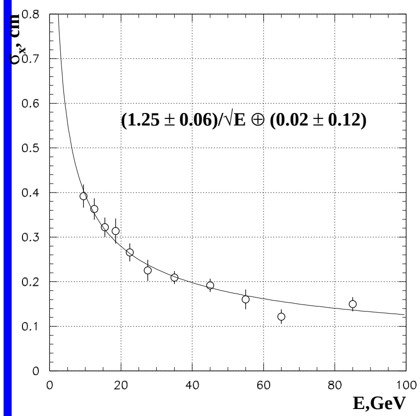




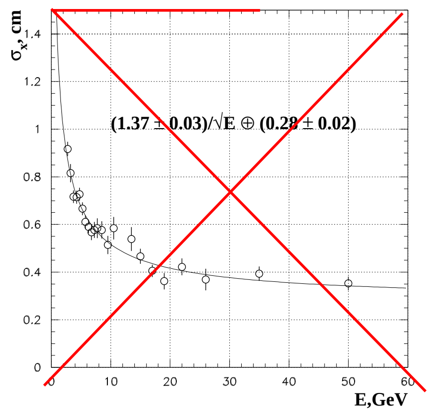
- Thresholds and method of summation are programmable. Most oftently used settings are:
  - Estimation of cluster energy / position is done by summation of ’cross’ cells (2, 4−6, 8)
  - $E_{thr} > 1$ GeV / c J / Ψ trigger, at least 2 candidates per event
  - $E_{thr} > 3$ GeV / c High Pt dedicated runs, at least 1 candidate per event

ECAL performance II

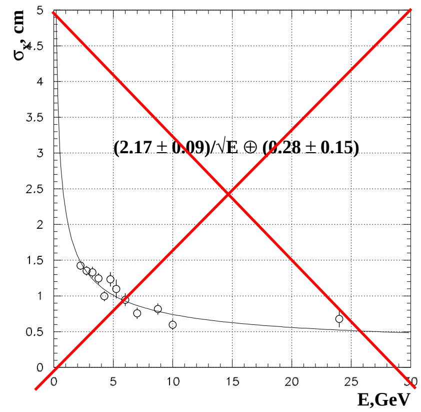
Spatial resolution



Inner section



Middle section



Outer section

Inner : $\sigma_x = (1.25 \pm 0.06) / \sqrt{E} \oplus (0.02 \pm 0.12)$

Middle : $\sigma_x = (1.37 \pm 0.03) / \sqrt{E} \oplus (0.28 \pm 0.02)$

Outer : $\sigma_x = (2.17 \pm 0.09) / \sqrt{E} \oplus (0.28 \pm 0.15)$

Energy resolution

Work is in progress.

Preliminary results are:

Inner : $\sigma_E / E = (0.205 \pm 0.002) / \sqrt{E} \oplus (0.012 \pm 0.014)$

Middle : $\sigma_E / E = (0.118 \pm 0.001) / \sqrt{E} \oplus (0.014 \pm 0.017)$

Outer : $\sigma_E / E = (0.108 \pm 0.002) / \sqrt{E} \oplus$???

Errors in constant term for Inner/Middle sections are large, for Outer section it is still uncertain.

Waiting for final tracker resolution results for further studies.

Cluster shape analysis

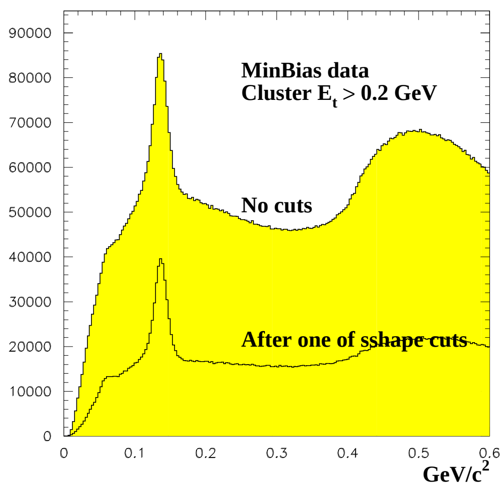
- **Primary goal:**

  separation of single γ−signal from energetic $\pi^0 \rightarrow \gamma\gamma$ decays, which are also identified as one cluster in ECAL due to small opening angle (in the frame of hard photon production studies)

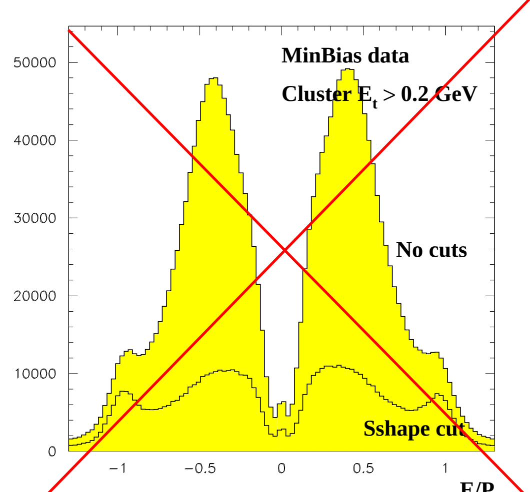
  Also:

  suppression of hadrons to improve electron and γ signals

- **Several cuts were developed, based on difference in profiles for electromagnetic and hadronic (or 2 overlapped electromagnetic) showers**



2−body invariant mass
Inner ECAL section



E/P distribution
Middle ECAL section

- **Efficiency to single γ from π^0 peak: 0.815 ± 0.005**

- ~~**Efficiency to single electron: 0.72 ± 0.02**~~

- ~~**Hadron suppression factor 4.18 ± 0.01**~~