CLAS12 forward detector: Pre-shower

Concept, R&D, PED …

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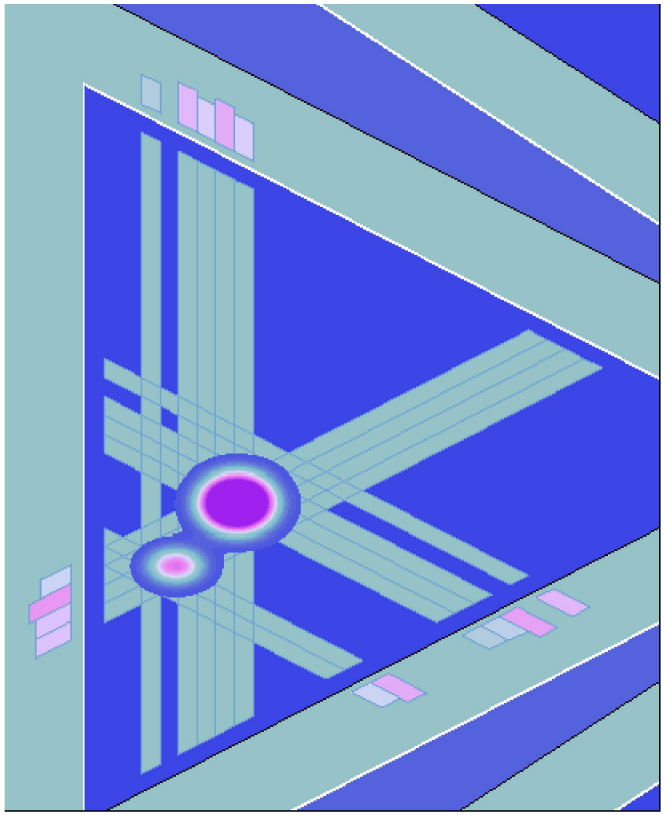
Collaborating institutions:

YerPhI, JMU, OU, NSU, Orsay-IPN

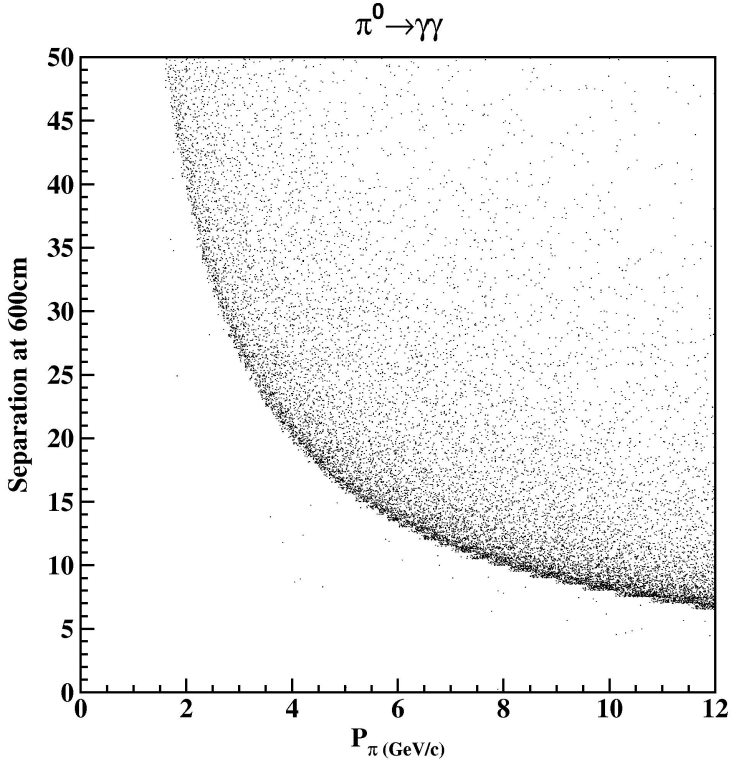
CLAS12 Detector Workshop, February 2-3, 2007 , JLAB

CLAS FEC

The width of transverse readout segmentation of the CLAS FEC is ~10cm



With increase of pion momentum, the opening angle (distance) between decay photons in p^0' gg becomes small to reconstruct them as separate clusters



Initial proposal for the pre-shower calorimeter

Basic structure - similar to FEC:

- lead-scintillator sandwich
- three stereo readout
- 9 layers of scintillators and lead
- Scintillator layer segmentation – 3cm

Covers only forward half of the FEC

Light transport to the photo-detector via green wave-shifting fibers embedded in groves on the surface of the scintillator strips

Light readout via 1’’ PMT with green sensitive photocathode

CLAS12 pre-shower project WBS 1.4.2.2.2.3 – ~$1M

Discription	FY06	FY07	FY08	FY09	FY10	FY11
R&D						
PED						
Construction						
Checkout and Installation						

- R&D:
  - full GEANT simulation and reconstruction
  - selection of the scintillator material, wave shifting fibers, and the PMT
  - build and test a prototype
- PED:
  - design of a box with end plates and mounting fixtures
  - design of the fiber routing and PMT holders
  - Design of the prototype

R&D: GEANT implementation and simulation of the pre-shower

N. Dashyan (YerPhI), K. Whitlow (SULI)

CLAS-NOTE 2007-001 & CLAS-NOTE 2007-002

Goals:

- establish optimal design parameters of the pre-shower
- determine characteristics of electromagnetic shower and p^0' gg reconstruction in the CLAS12 forward electromagnetic calorimeter

Tools:

- simulation in GSIM, the pre-shower positioned in front of EC
- reconstruction in RECSIS, using modified EC package

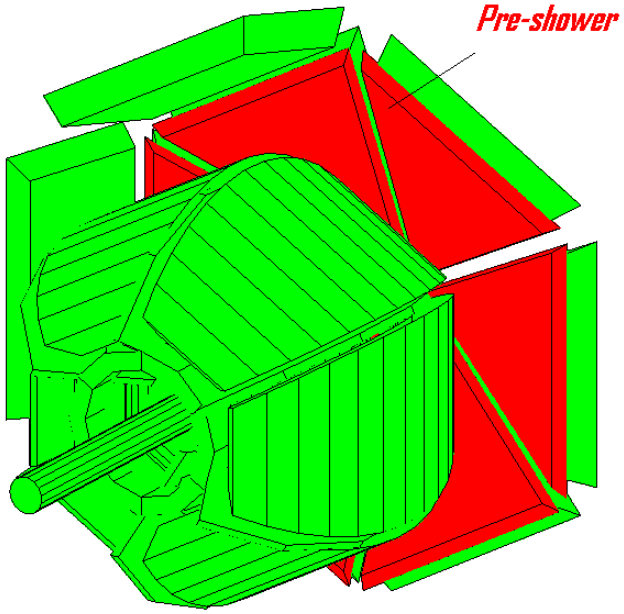
Pre-shower in GSIM

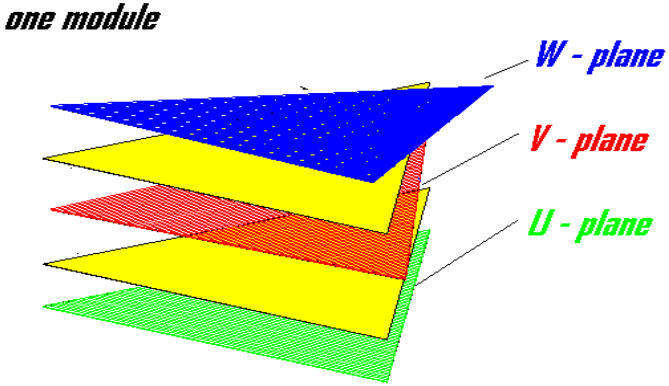
One PCAL modules in each sector

The pre-shower is a lead-scintillator sandwich with 10 mm thick scintillator layer followed by 2.2 mm thick lead shit

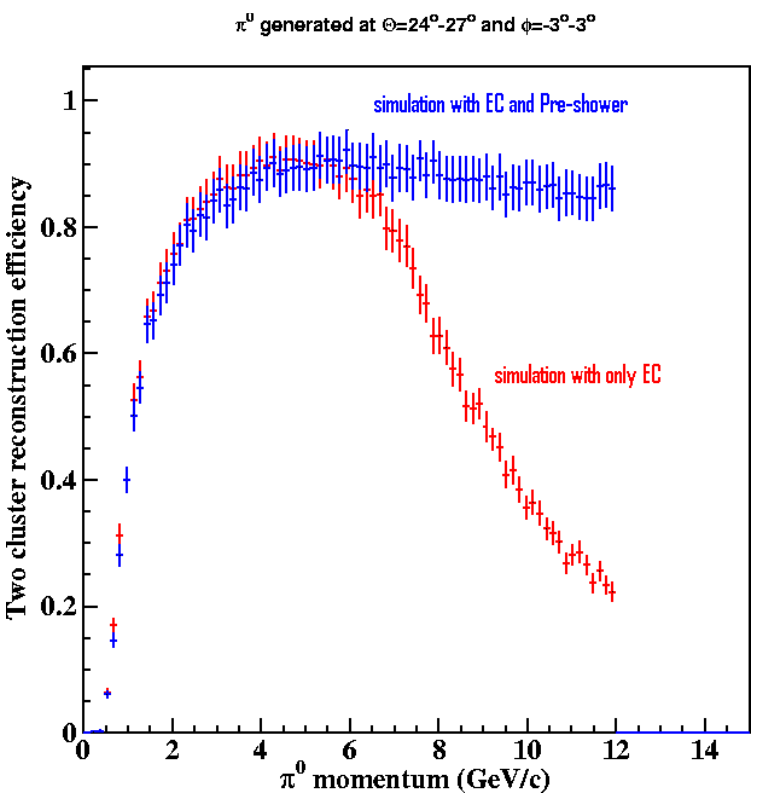
Every triangular scintillator layer was slides parallel to the one of the edges of the triangle into up to 108 equal width strips. The slicing alternates with each scintillator layer, forming tree orientations U, V and W, repeats in every fourth layer (3-stereo readout planes)

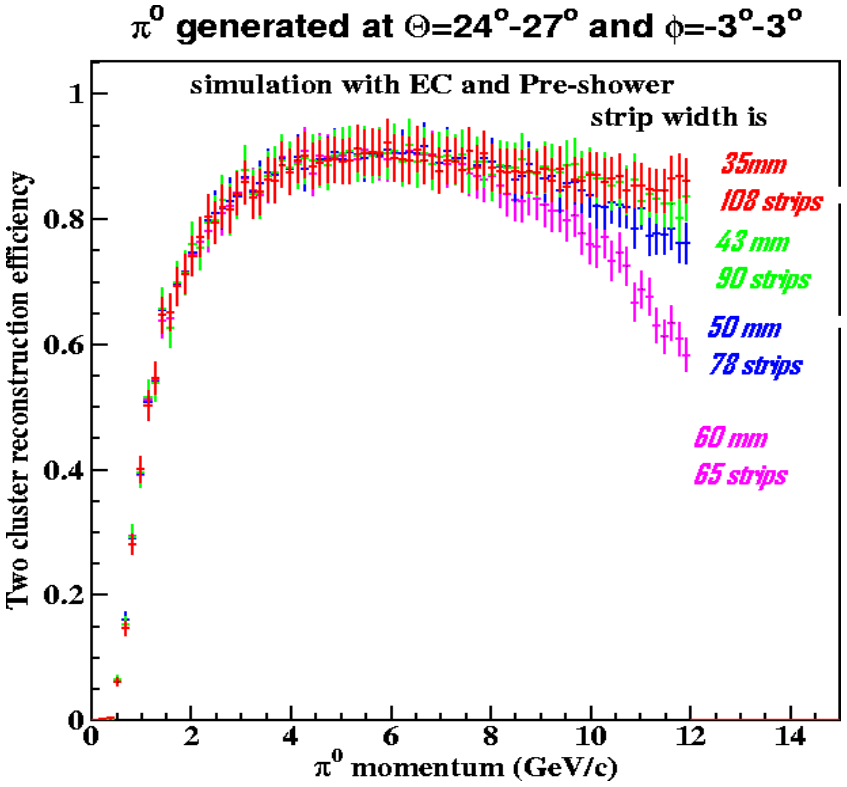
Modules with 9, 12, and 15 scintillator layers and 15 layers of lead were tested





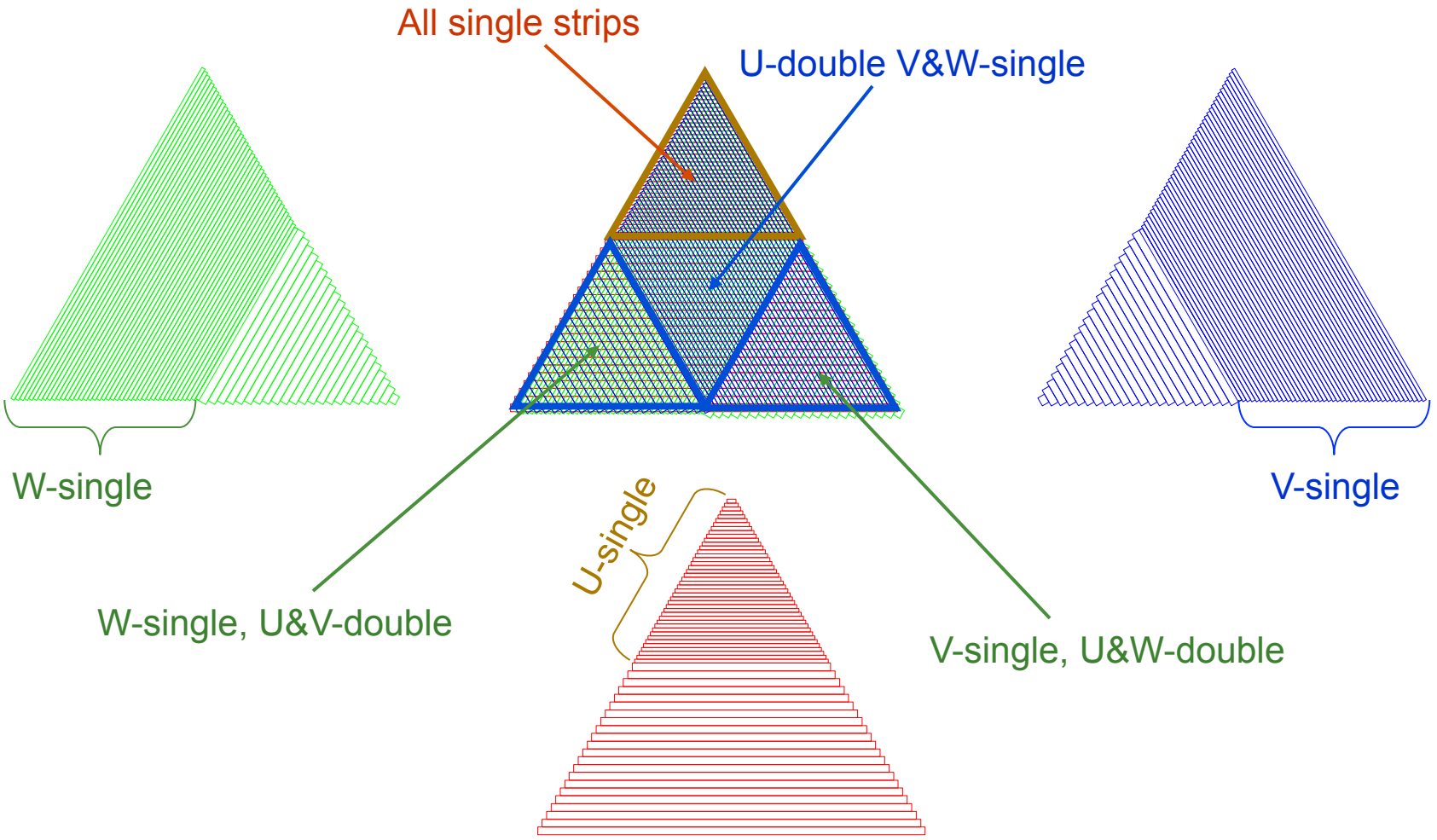
Main results





Optimal configuration based on a single photon detection efficiency, shower energy resolution, and the reconstruction efficiency of two clusters from p^0 decay is: 15 layers of lead and scintillators with 4.5 cm wide strips in forward region

Double strip readout at large angles – limit 196PMTs/sector



Summary of simulations

- Initial design parameters of the pre-shower are set using a full GEANT simulation (see CLAS-NOTEs):
  - 15 layers of the lead and scintillator, 2.2mm lead, 10mm scintillator
  - 4.5 cm segmentation of the scintillator layers in forward region

Must be done:

- Implementation of the final arrangement of the readout segmentation after initial design is finished
- p^0 reconstruction efficiency studies with realistic event generators
- Reconstruction of energies of two hits when only in the PCAL cluster were separated
- Implementation of the photoelectron statistics and the attenuation of the light in the fibers for determination of realistic energy resolution
- Integration of the PCAL into CLAS12 GEANT4 framework

R&D: Test of the readout components and the prototype

G. Asryan, H. Voskanyan, Hall B engineering

Tests include:

- measurements of the relative light yield for several different scintillator-fiber-PMT combinations
- study of the multiple fiber readout
- study the light attenuation and the time characteristics for the scintillator-fiber-PMT combinations with the highest light yield

The final combination of scintillator-fiber-PMT will be selected based on performance and the price

Build a prototype to check the design of individual elements, to test assembly procedures, and the pre-shower performance

Pre-shower components for test

Test setup (in the EEL)

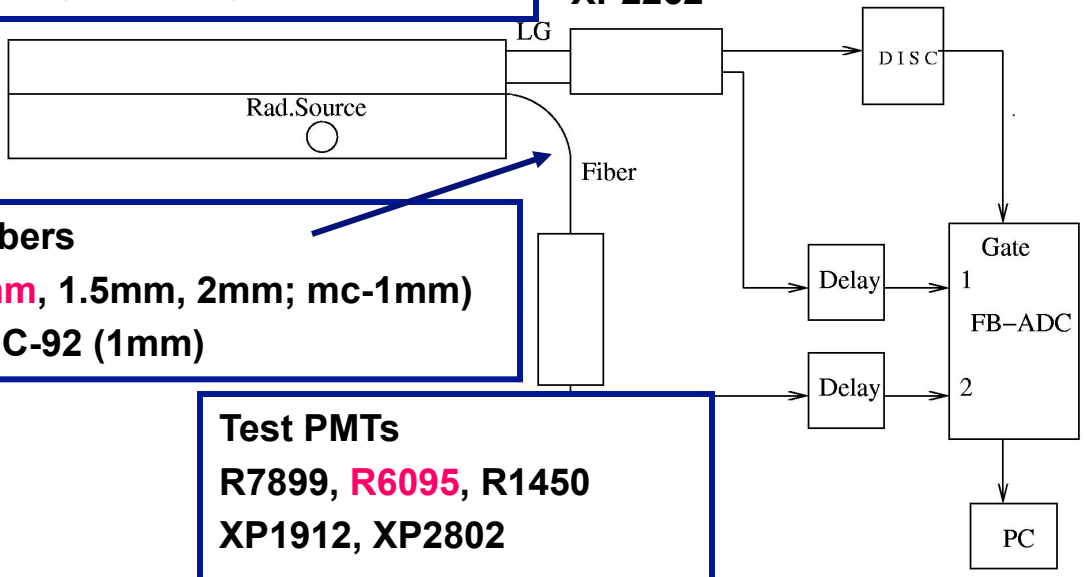
4 m long dark box with moving cart and support fixtures (Hall B engineering)

Simple DAQ (CODA) – FASTBUS with LeCroy ADC

Test scintillator with grove(s)

FNAL, Kharkov, ELJEN

Trigger PMT XP2262



Test WS fibers

Y11(sc-1mm, 1.5mm, 2mm; mc-1mm)

BC-91A, BC-92 (1mm)

Test PMTs

R7899, R6095, R1450

XP1912, XP2802

9224B

Rad.Sources:

^{90}Sr and ^{207}Bi

Cosmic muons with second trigger PMT

Measurements technique

- For each PMT, a single photoelectron peak position and the width, at given HV, was determined using two Gaussian fit to the ADC distributions of attenuated light
- For each combination, the average number of photo-electrons was extracted as a function trigger PMT ADC value, the fit function:

$$ADC_T = c_1 \sum_i P_i(n_{pe}) \times C_i(n_{ch}) + c_2 e^{-\frac{(x - x_p^0)^2}{2\sigma_p^2}}$$

$$P_i(n_{pe}) = \frac{(n_{pe})^i e^{-n_{pe}}}{i!}$$

$$C_i(n_{ch}) = \frac{1}{\sigma_1 \sqrt{i}} e^{-\left(\frac{n_{ch} - c_3 a_1}{\sigma_1 \sqrt{2i}}\right)^2}$$

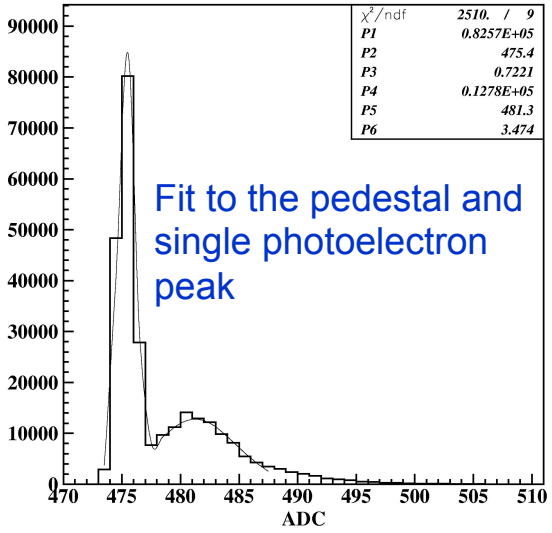
Fit parameters: c_1, c_2, c_3, and n_{pe}

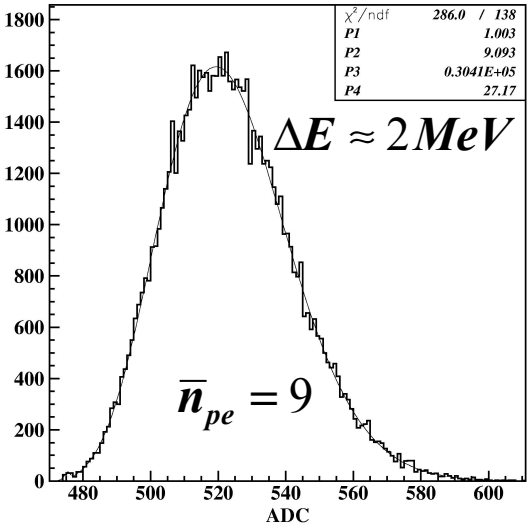
Fits to ADC distributions

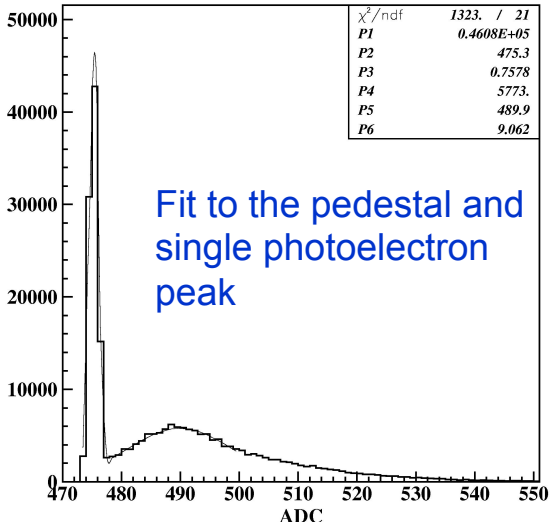
Hamamatsu R7899EG, Green sensitive photocathode

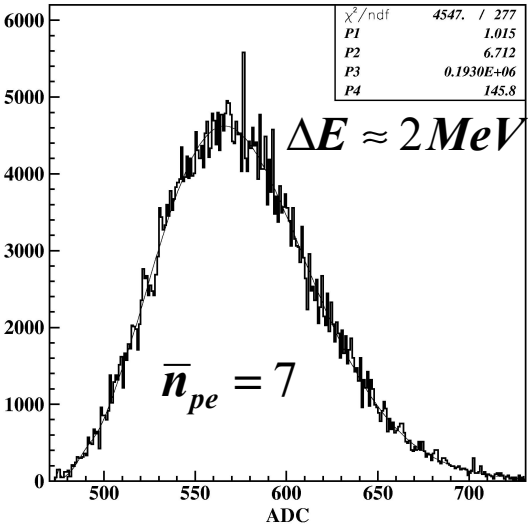
FNAL scintillator with one grove, Kurary Y-11 single clad fiber

Hamamatsu R6095, 15% QE at 500nA





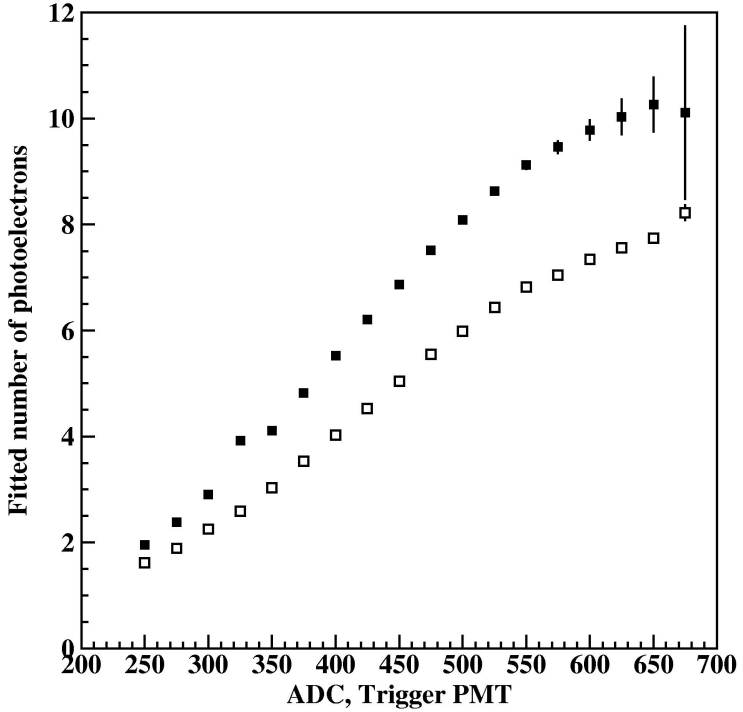




Fit to the ADC distributions from ^{90}Sr

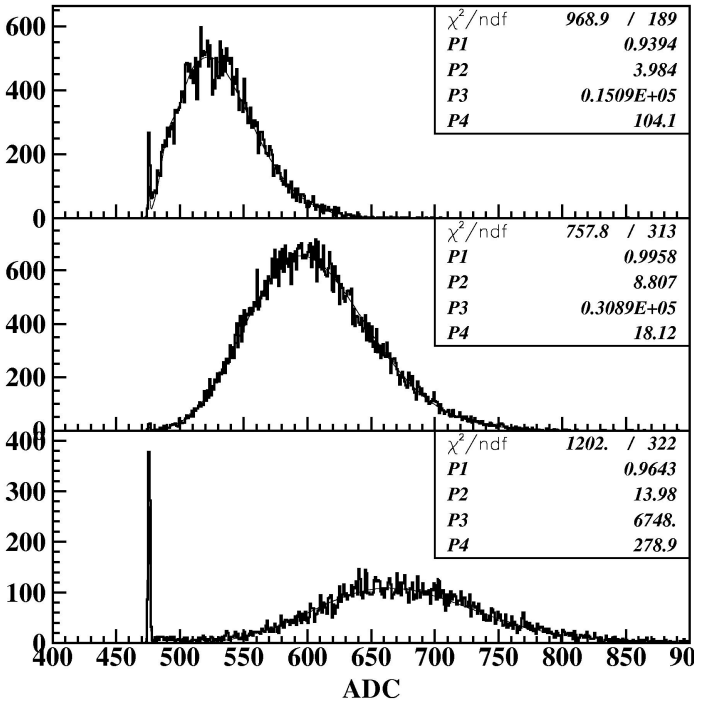
Fit to slices of trigger PMT ADC distribution

$$^{90}Sr \rightarrow 0.546 MeV(\beta^-) + ^{90}Y \rightarrow 2.28 MeV(\beta^-)$$



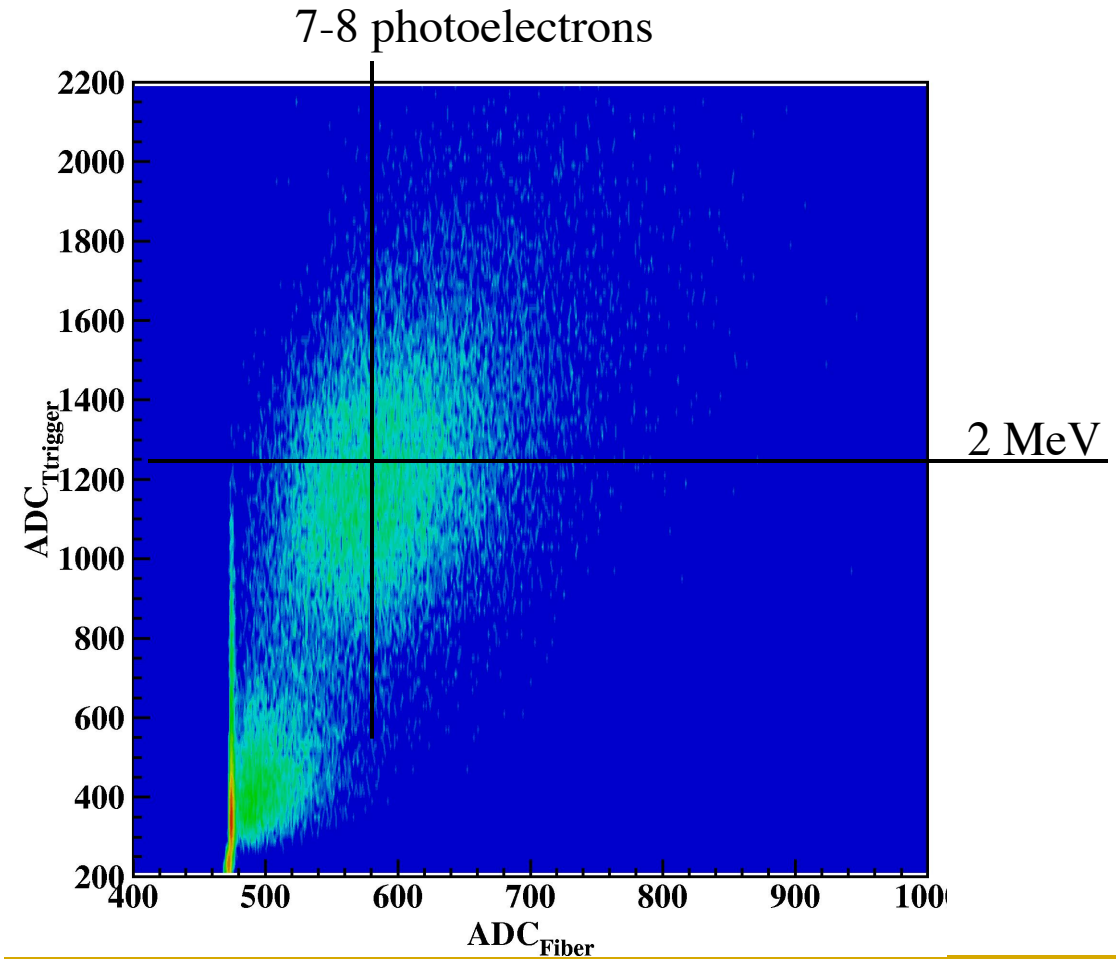
Scintillator strips with 3-grooves, Kharkov. ADC distributions of XP2802 for one, two, and three fiber readout

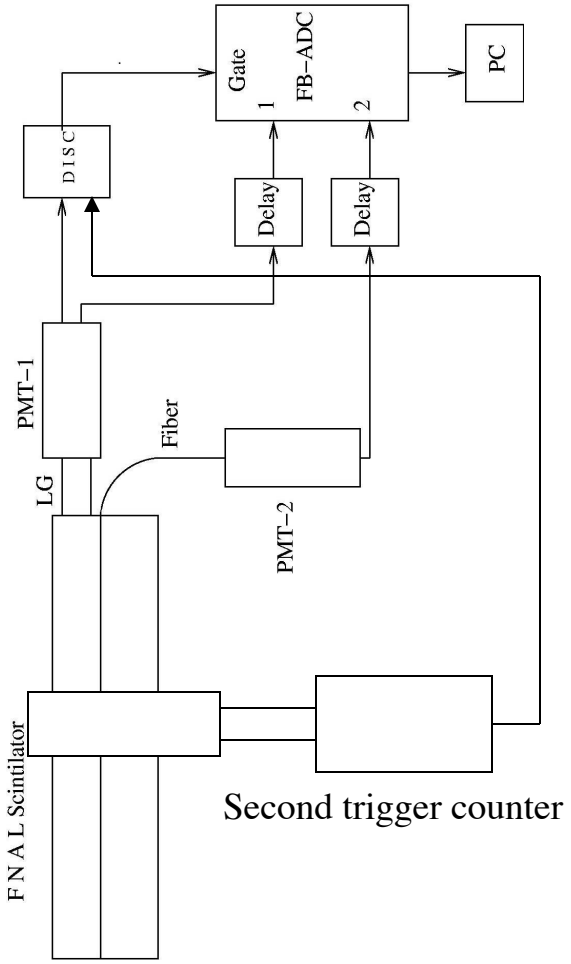
$$n_{pe}(3\,fibers) \approx 3 \times n_{pe}(1\,fibers)$$



Absolute light yield with cosmic muons

FNAL scintillator, 1 cm thick, with 1mm WS fiber,
Kurary Y-11 s.c., PMT Hamamatsu R6095





Summary of test measurements

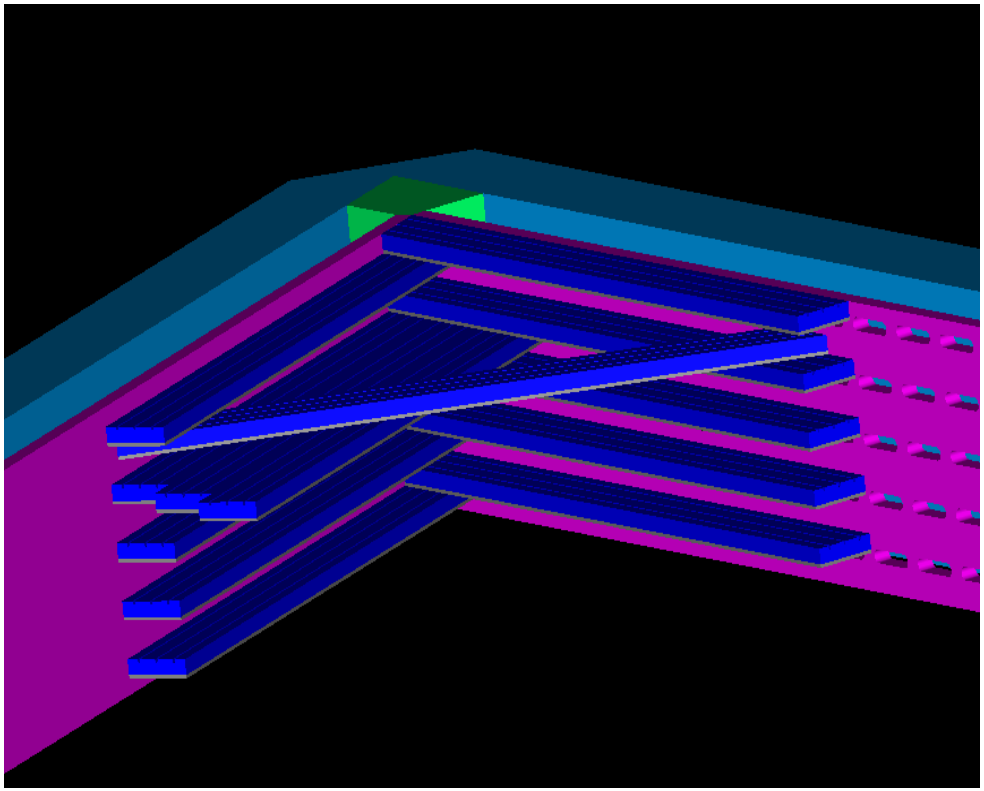
- By performance, the best PMT is the HAMAMATSU R7899EG, $280/each. Photoelectron yield of the HAMAMATSU R6095, selected with QE>16% at 500nA, for the same scintillator and fiber, is lower only by 25%. Price for R6095 is $180($160). All other PMTs, yet with green sensitive photocathode, did not perform better than R7899EG and are expensive, >$250
- Multi-clad fiber produces 20% more light than a single-clad fiber, but 30% more expensive
- FNAL extruded scintillator with Y-11 fiber has the best light yield, mostly due to good reflective cover. It is also reasonable in price, $20-$25/meter. Scintillators from Kharkov are close, but will need some R&D to match the performance of the FNAL scintillators
- The best combination by the light yield and price is: FNAL scintillator – Kurary Y11 single clad – HAMAMATSU R6095. Light yield ~11p.e./MeV for 3 fibers is expected (light yield for FEC readout ~7p.e./MeV)

Next in the test measuremnts

- Test and tuning of the die for the FNAL extruder with 1x4.5 cm^2 cross section and with three grooves on the surface has been started
- After extruder is tuned, scintillator strips for a prototype can be ordered
- Long scintillator strips will be produced for the light attenuation length measurements
- Proposed prototype - 15 layers with 32-U, 32-V, and 32-W strips
- Prototype will be used to workout design details, assembly procedures, and the pre-shower performance
- Before the main prototype, a small scale prototype with two orthogonal views can be build

PED FY07

The goal of the PED in FY07 is the initial design of the pre-shower that can be used to build a prototype



Pre-shower model is in IDEAS with few details: front and back plates, side walls, scintillator holders

Concept of support from FEC and central hub is in development

There is a concept of PMT mount

Arrangement of the scintillator and lead layers are in progress

Summary

- Pre-shower R&D and PED are in progress
- Main design parameters were established using the full GEANT simulations
- Advances in the reconstruction allowed to use wider readout segmentation
- New design covers ~4 times bigger area with the same number of readout channels and has more layers
- Final combination of scintillator-fiber-PMT is selected based on the light yield measurements and available price quotes
- FNAL is working on the production of scintillator strips with exact geometry
- More measurements will be done using the new scintillators as a part of the R&D
- For prototype, components must be ordered soon

Backups

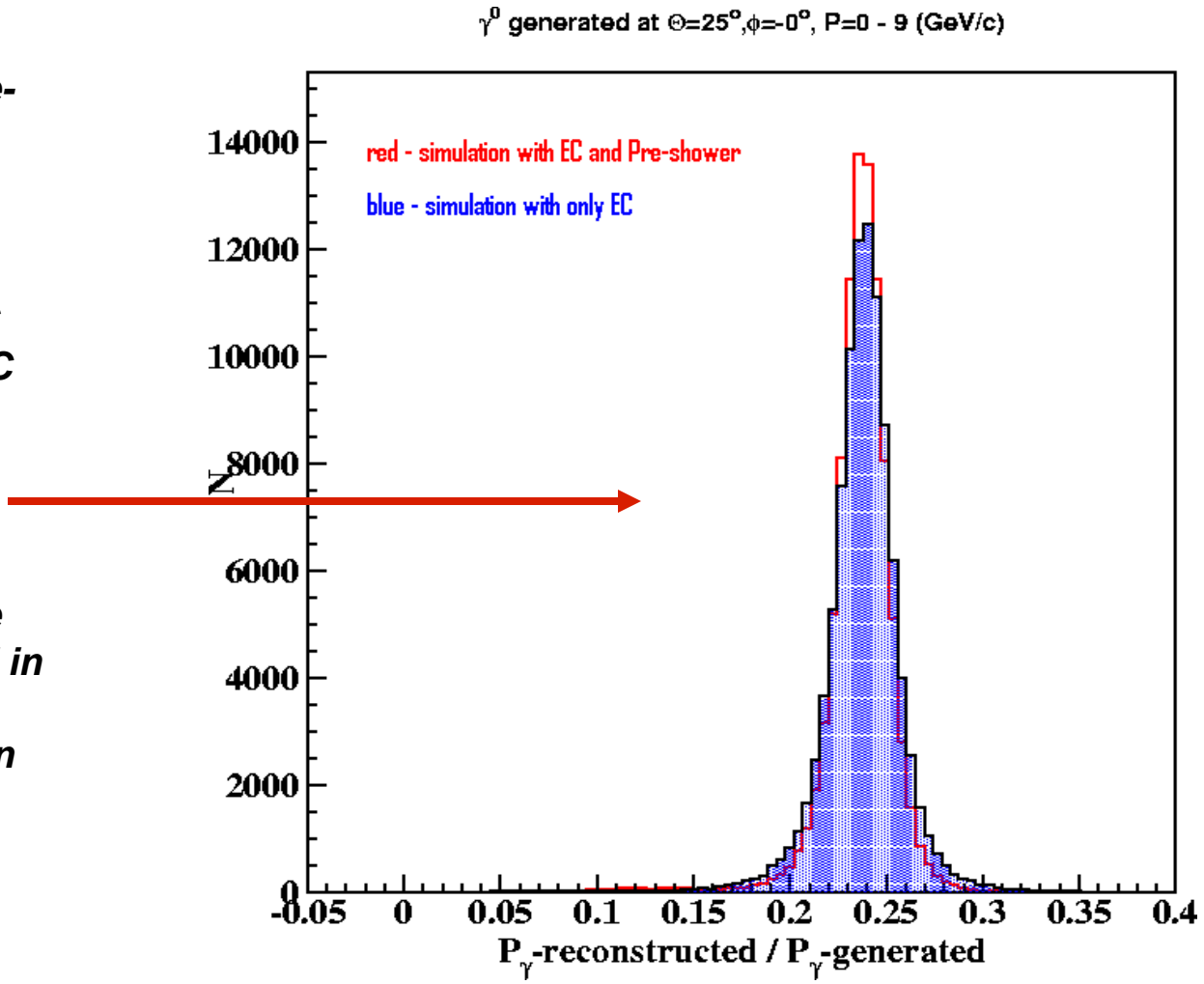
New price estimate

Construction	Amount	Unit price	Total	Source
Box assembly	6	$50K	$300K	FEC ($150K)
Scintilators	16000m	$20	$320K	FNAL
WS fibers	50000m	$1.60	$95K	Kurary
PMT	1152	$180($160)	$207.36K(184.32K)	Hamamatsu
Divider	1152	$50	$57.6K	Hamamatsu
Light Guid	1152		$10K	
Lead			$25K	FEC($150K)
Cables			$30	
Accessor.			$18K	
Total			$1063K	

Old price tag for half angular coverage and 9 layers $850K (2003-2004)

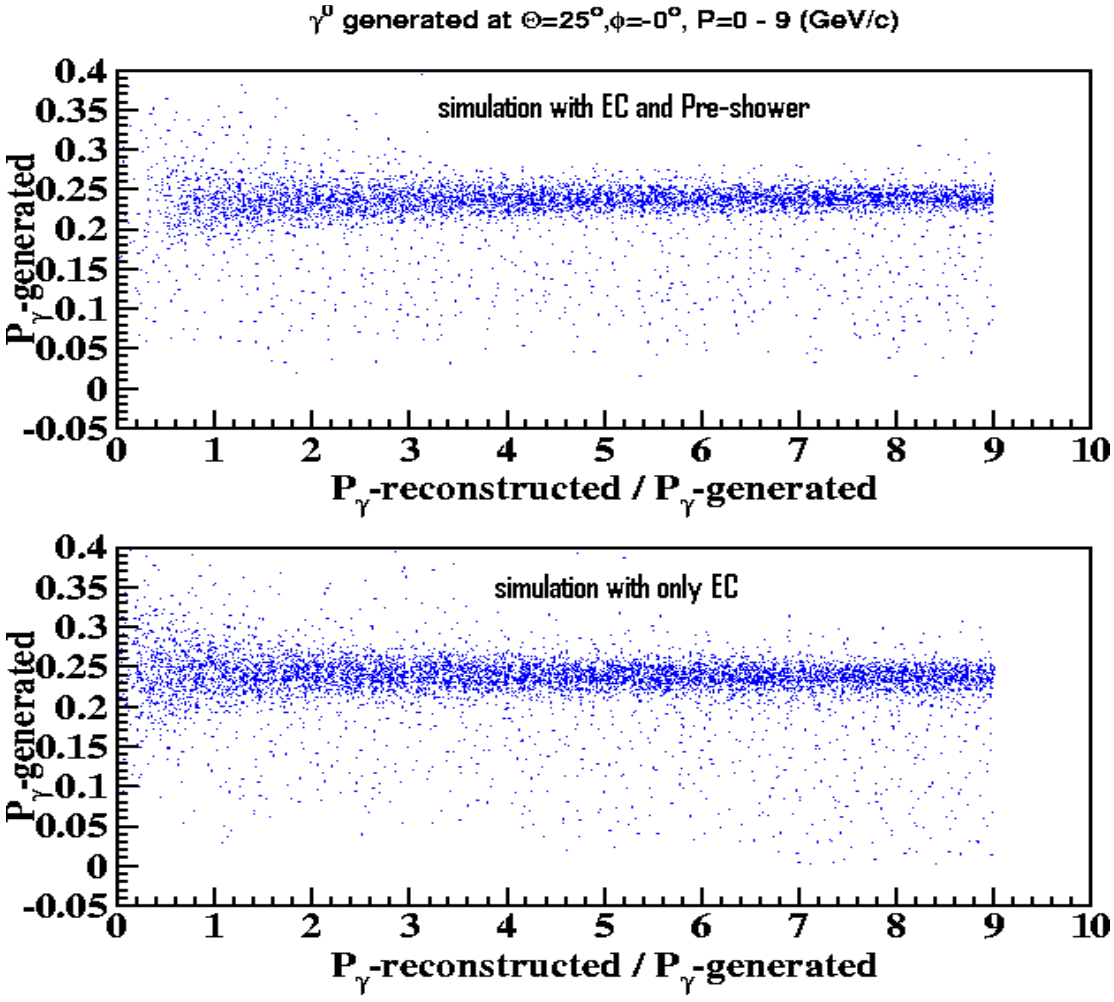
Simulations

- ***To be sure that the pre-shower is working correctly simulations were performed with single photons in the central part of the FEC only as well as the FEC with Pre-shower.***
- ***Sampling fraction distribution for both cases.***
- ***Sampling fraction –the total energy deposited in the scintillators, expressed as a fraction of the incident particle energy.***

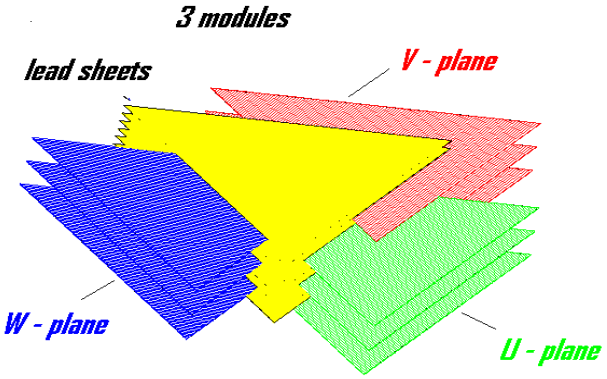


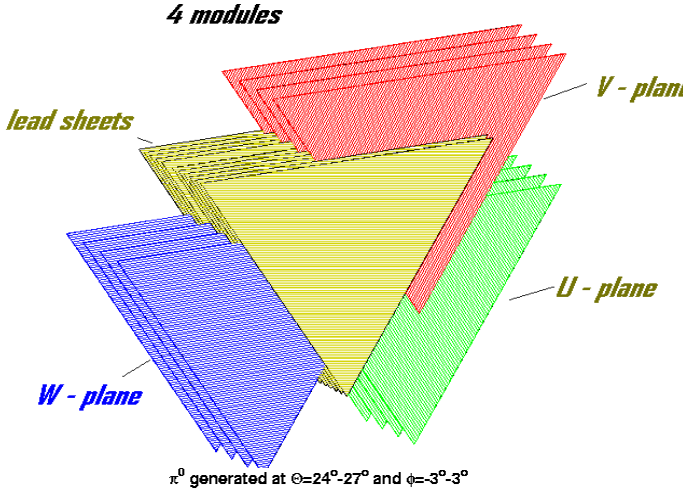
Simulations

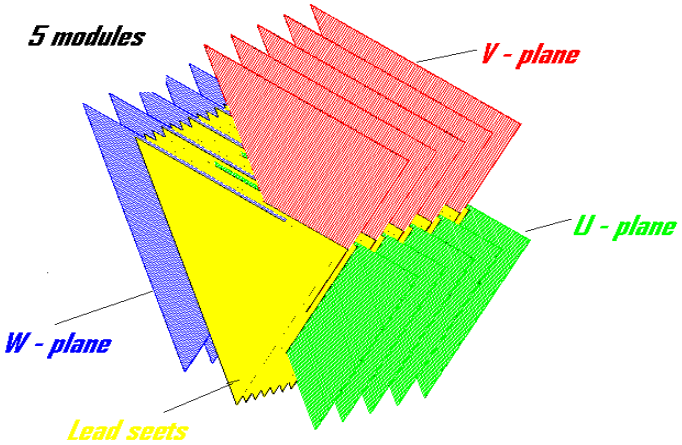
- ***The figures represent a dependence of the sampling fraction for both cases on the photon energy.***

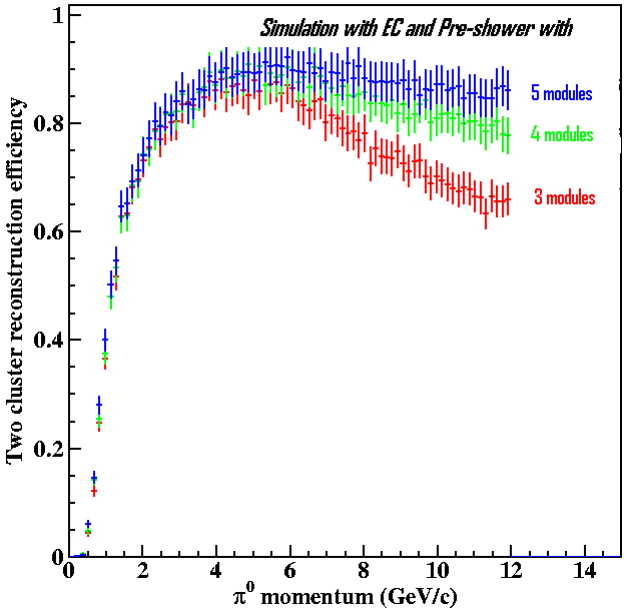


Configurations with 9, 12, and 15 layers

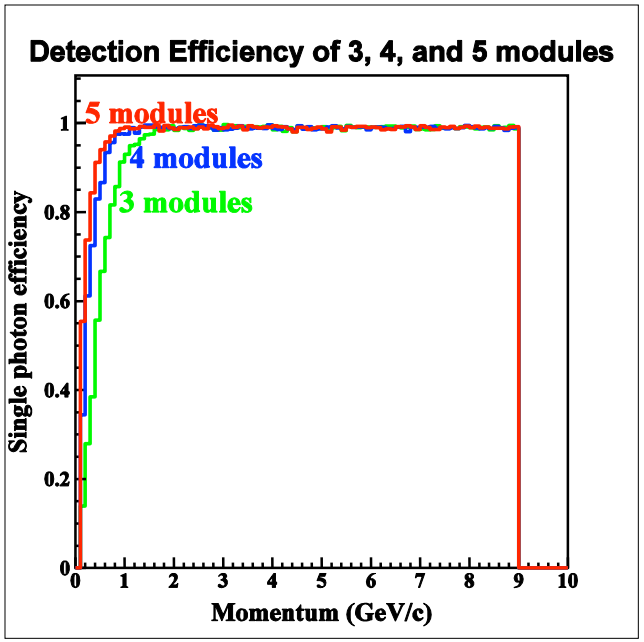


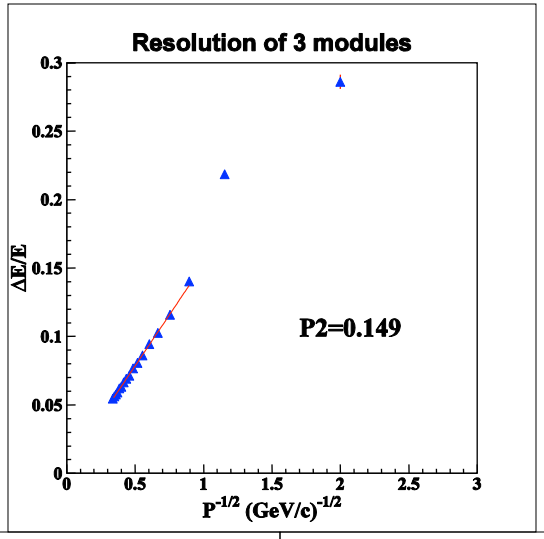


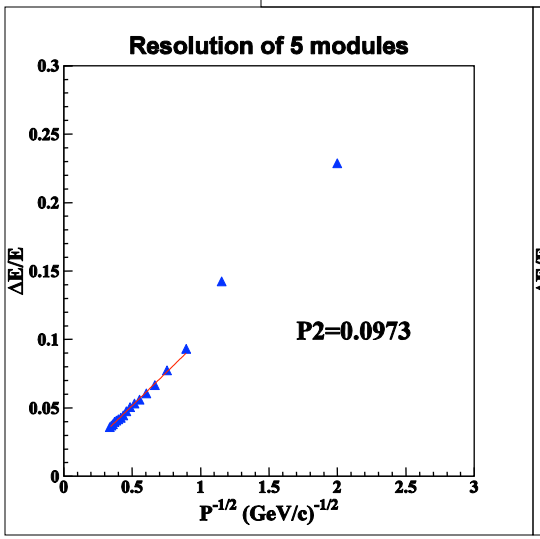


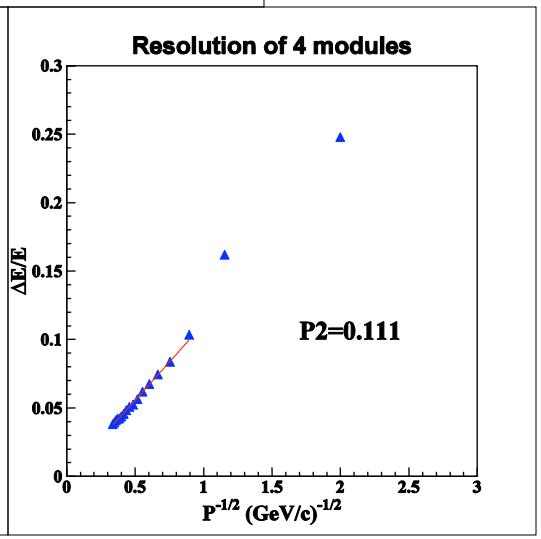


Dependence on layer number









Manpower for R&D and PED for FY06

Act ID	Act. Description	Duration	Selected resources	Labor in MW	Expenses/ Procurements	Predecessors	Planned Start Date
1	GEANT studies	6 months		visiting scientist 24MW	$24,000		Jan-06
2	Purchase of materials	6 months		scientist 2MW	$12,000		Jan-06
3	Build a setup (dark box)	2 month	semi-clean room	technician 2MW	$200		Apr-06
4	Light yield measurements	6 months	setup (dark box)	visiting scientist 20MW	$20,000	#3	Jun-06
5	Purchase of materials with highest light yield	2 months		scientist 2MW	$5,000	#4	Sep-06
6	Attenuation and time measurements	6 months	setup (dark box)	visiting scientist 24MW	$24,000	#3, #4 and #5	Oct-06
7	Initial design of the box assembly	5 months		ENG 5.3MW DES 22.9MW			Oct-06
8	Purchase of materials for the prototype	4 months		scientist 2MW	$50,000	#1 and #6	Jan-07
9	Manufacturing the box and fixtures	3 months		ENG 1MW, DES 2MW, technician 12MW	$50,000	#6	Feb-07
10	Assembly of the prototype	6 months	semi-clean room	visiting scientist 48MW, technician 16MW	$50,000	#7 and #8	Apr-07
11	Test of the prototype	1 months	space in the Hall B and beam time			#10	Sep-07

PED FY07

Details of the initial stage of the pre-shower design and the resources associated with it

ITEM	FY 07 Man weeks PED ENG	FY 07 Man weeks PED DES
Designing the mounting	2	4
Design a box with end plates	1	6
Design holders	1	4
design lead sheets	0.3	0.5
design pmt holders		1
Design fiber routing		2
design light guides		1
Locate PMTs		2
Design a lifting plan and hardware	1	2
Total	5.3	22.9

The goal of the PED in FY07 is the initial design of the pre-shower that can be used to build a prototype