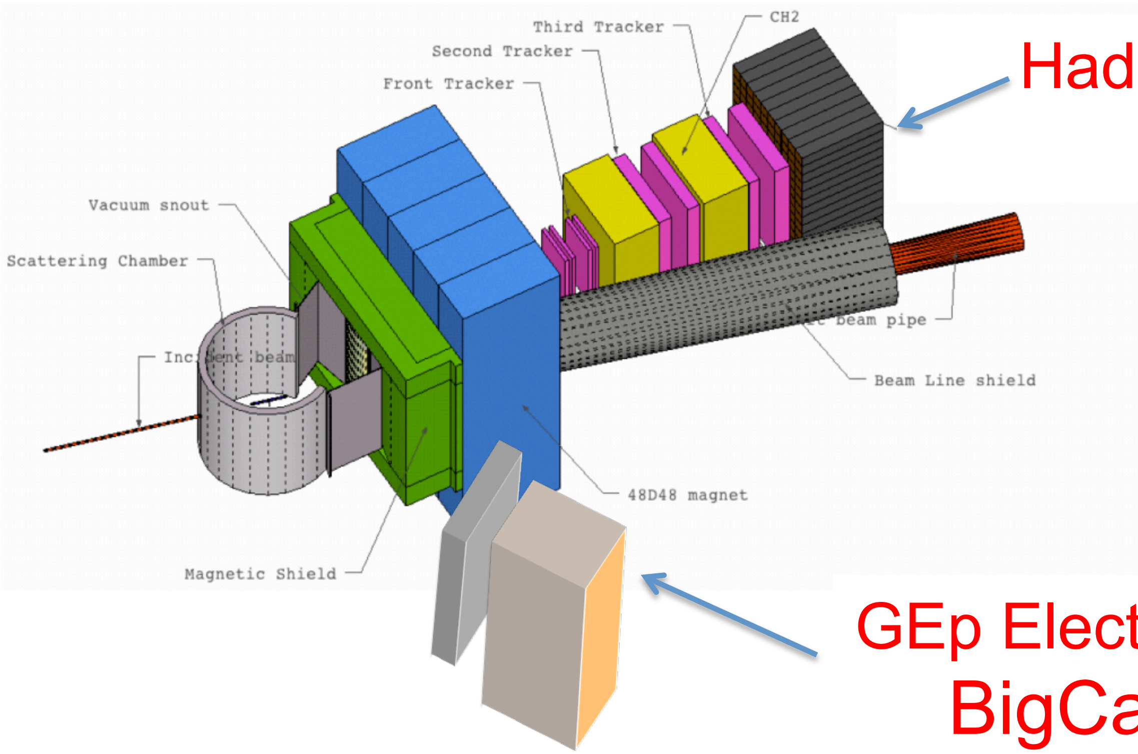
Ancillary Equipment: Calorimetry

G. Franklin, Carnegie Mellon University



Hadron Calorimeter HCAL

Carnegie Mellon
INFN, Catania
JINR, Dubna
JLab

GEp Electron Calorimeter BigCal (existing)

William and Mary
Norfolk State
Christopher Newport
JLab

HCAL-J Hadron Calorimeter

An ongoing JLab/CMU/INFN supported activity

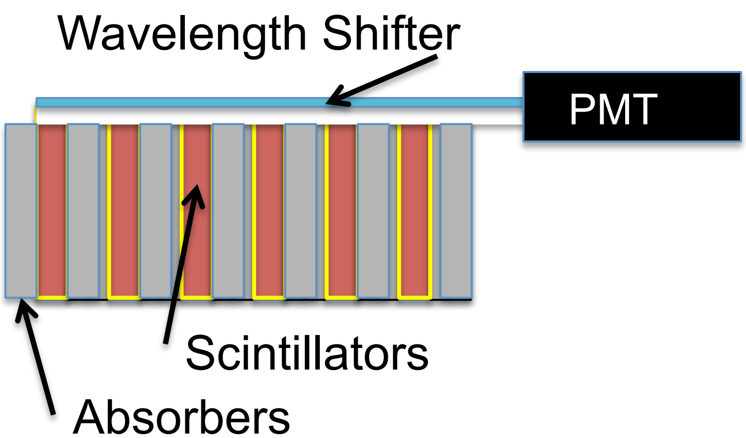
Requirements for the SBS experiments:

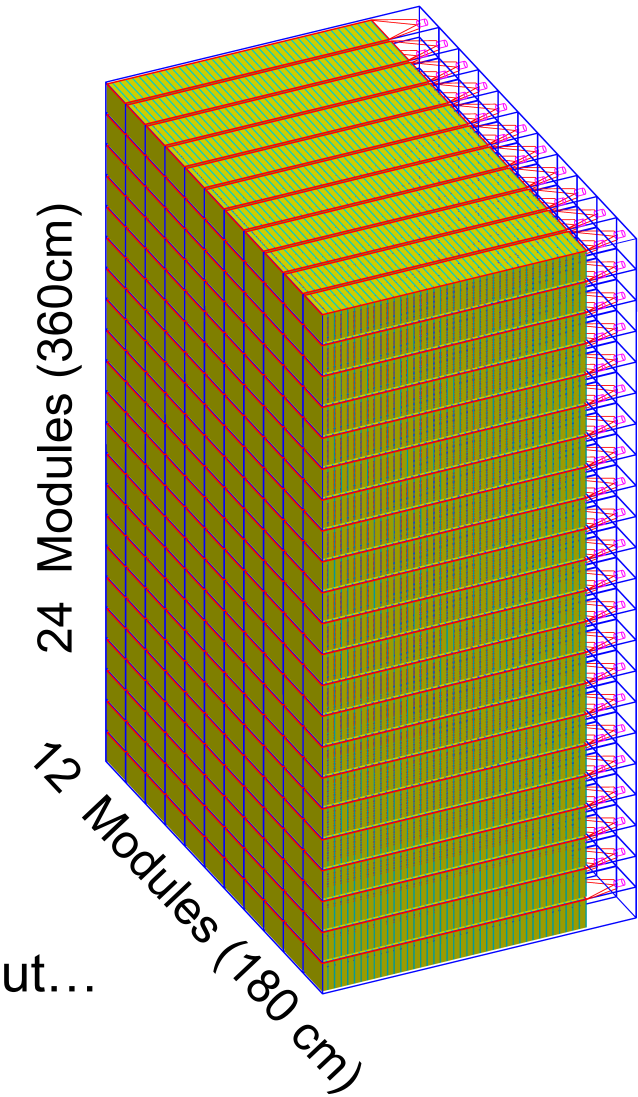
- Match acceptance of SBS magnet/polarimeter
- High threshold while maintaining high trigger efficiency
  Goal: 95% efficiency: thresholds at 25% avg. signal
- Linear energy response
- Time Resolution
  Required: TOF < 1.0 nsec (Goal: 0.5 nsec)
- Angular resolution: 5 mrad

HCAL-J Design

Modular Design:

- 15 cm x 15 cm x ~ 1m modules
- 40 Layers scintillator and iron per module
- 288 Modules (36 tons)





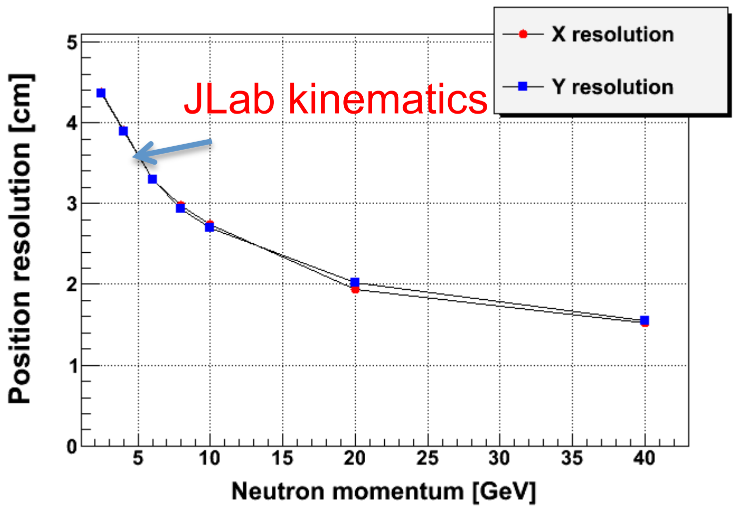
288 modules for JLab HCAL

HCAL-J concept is based on COMPASS HCAL1, but…

- Faster scintillator and wavelength shifter
- Wavelength shifter moved to center
- Novel light guide
- 2 inch PMTs faster, better quantum efficiency

Technical Approach:

Simulations extrapolate documented COMPASS high-energy performance to JLAB energies.



Spatial Resolution Simulation

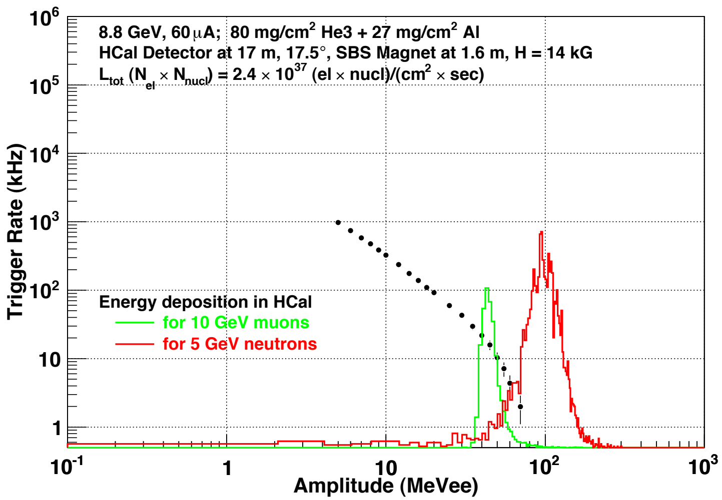
COMPASS performance: 1.5 cm

Simulation: 1.5 cm at high energies

5 cm at JLab energies

HCAL positioned 17 m from target:

5 cm / 17 m --> 3 mrad resolution



Trigger Efficiency Simulations

Energy	2.5 GeV	5.0 GeV	10.0 GeV
Resolution: σ/E	48%	31%	22%
Efficiency at 1/4 mean signal: Neutrons	97.3%	99.2%	99.1%
Efficiency at 1/4 mean signal: Protons	98.8%	99.6%	99.0%

2011 Review panel report:

Finding:

While not formally part of the SBS program, the HCAL calorimeter and its good performance are essential for the envisioned suite of experiments. The planned HCAL is very similar to that used by COMPASS, but with some modifications. The actual construction of the HCAL modules is scheduled to begin in calendar 2012 at the Joint Institute for Nuclear Research (JINR) shops. A necessary HCAL improvement over COMPASS is timing resolution; results from simulation and extrapolation from prototypes at CMU suggest that faster WLS and PMTs may indeed get the desired timing resolution.

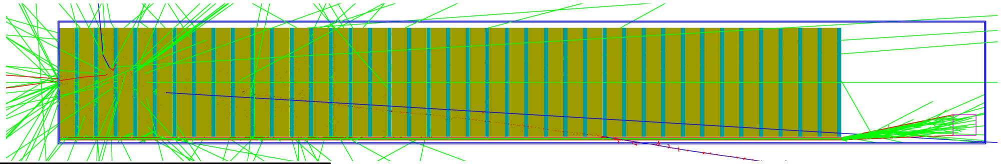
Comment:

The SBS collaboration should consider relevant HCAL specifications including components, and fabrication and QA procedures, as well as provide production oversight at JINR to ensure the desired HCAL performance.

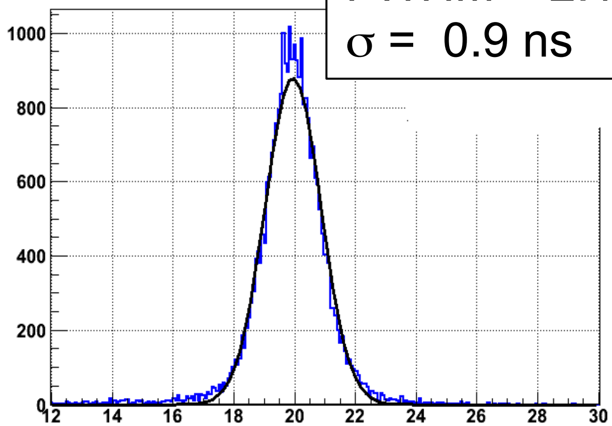
Response: Plan revised, construction at CMU

Status: Fall 2011

Most R&D aimed at achieving timing goal



FWHM = 2.1 ns
σ = 0.9 ns

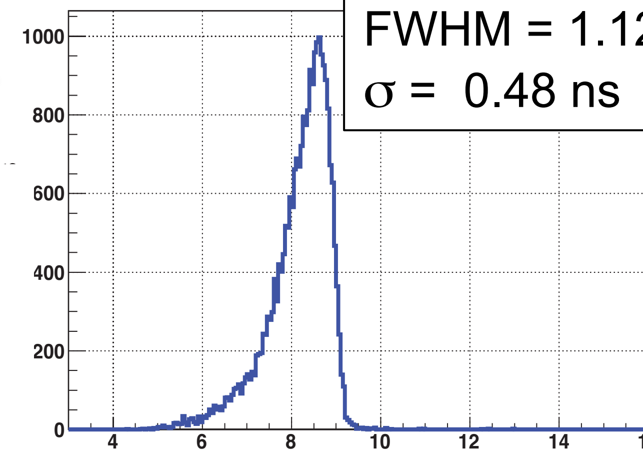


Trigger Time (ns)

Waveshifter decay time
8 ns --> 0.5 ns

PMT rise time
10 ns --> 2.5 ns

FWHM = 1.12 ns
σ = 0.48 ns



Trigger Time (ns)

Simulation using COMPASS parameters

Agrees with published COMPASS HCAL performance

Simulation using faster waveshifter dye and PMTs

Meets SBS requirements

To be confirmed with prototype HCAL module

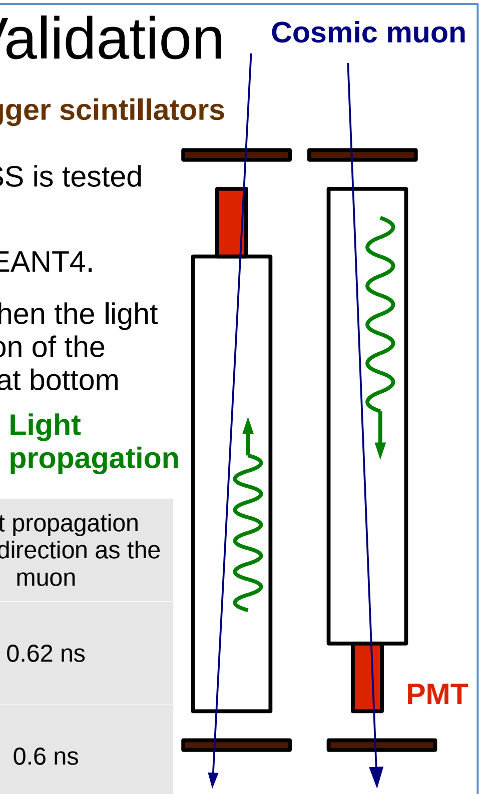
Fall 2011 / Spring 2012

- COMPASS Module Tests

CMU funds 9 JINR built modules
Validate Timing Monte Carlo

Simulation Validation

- A module of similar design as in COMPASS is tested using cosmic ray muons.
- The COMPASS module is simulated in GEANT4.
  - Module time resolution is measured when the light propagation in the module is in direction of the cosmic muon and opposite to it (PMT at bottom and at top positions).



	Light propagation opposite to muon direction	Light propagation same direction as the muon
Time resolution (experiment)	0.76 ns	0.62 ns
Time resolution (simulation)	0.77 ns	0.6 ns

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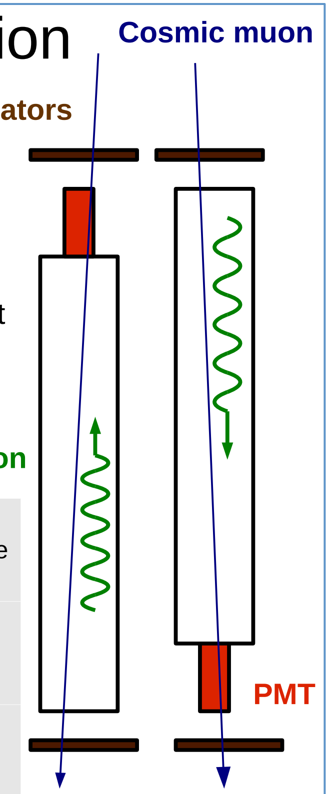

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- Fast Scintillator/ WLS tests

  Tested Fast Scintillators/WLS
  St. Gobain Scintillators
  & WLS

  WLS total cost ~$50k
  But commercial scintillators too expensive

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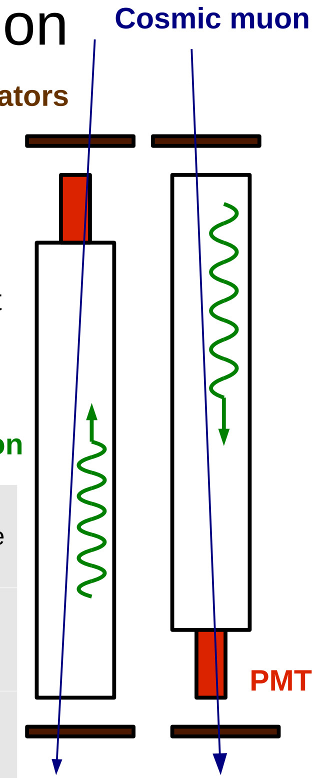

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- Needed “PPO only” scintillator samples to complete tests
  Standard scintillators use “PPO” and “POPOP” dyes

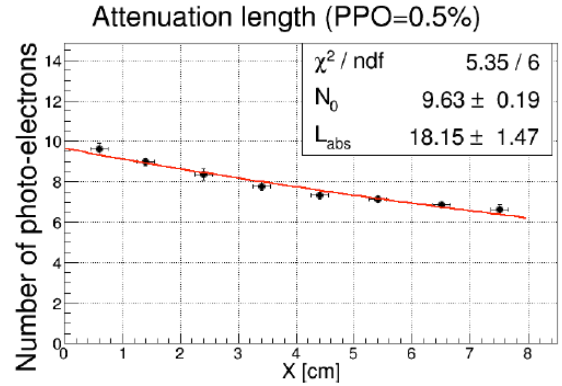
Spring 2013 Critical R&D Completed

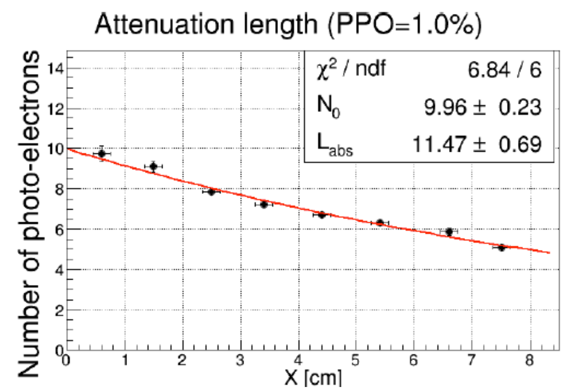
- Contract with FNAL Scintillator Extrusion Facility
  FNAL produces extruded scintillator samples
  No “POPOP” added to scintillator
  PPO concentration varied

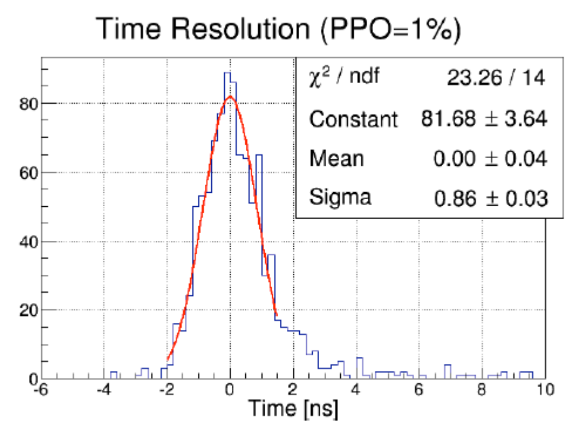
- CMU tests FNAL PPO-only scintillator
  Coupled to BC-484 WLS (St. Gobain)
  Coupled to EJ 299-27 WLS (Eljen)

  Acceptable attenuation lengths found
  Excellent timing and photo-electrons
  Optimal solution found:
  0.5% to 1.0% PPO FNAL Scintillator
  BC-484 WLS

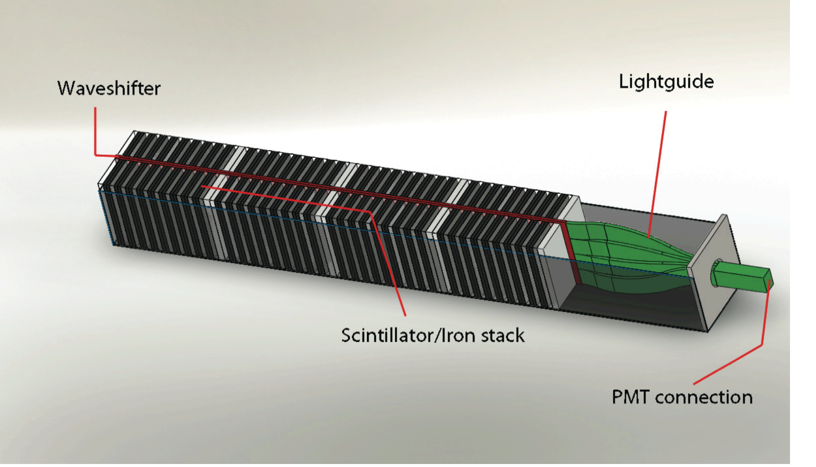
Selected combination meets required specification!







Spring 2013 Decisions: PLAN is FINALIZED



- Geometry fixed

  WLS moved from side to center of module
  Two (15 cm x 7.5 cm x 1 cm) scintillators/layer
  7.5 cm x 1 cm within capabilities of FNAL
  Minimizes light attenuation (WLS in middle)
  Eliminates small asymmetric tail in spatial resolution function

  PMT Housing designed to allow N_2 to inhibit helium poisoning of PMTs

- FNAL will produce scintillators

  FNAL will extrude 3.5 km of (7.5 cm x 1 cm) novel scintillator
  CMU will chop into 15 cm lengths. (Need 24,000 pieces)
  Cost ~$100k. (Compare to St. Gobain quote of $1,140k)

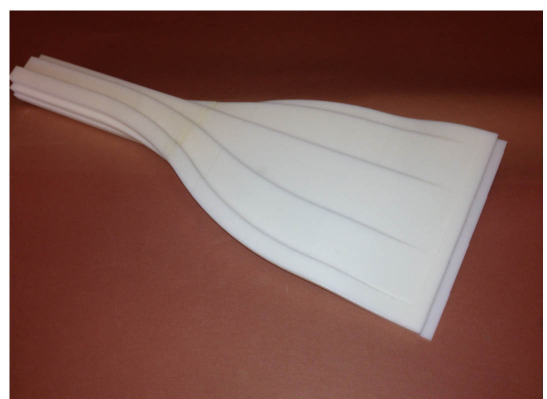
- INFN will fund WLS and oversee Light Guide production

- Modules will be assembled at Carnegie Mellon

Fall 2013 Status:

- Scintilllator
  - FNAL work supported by JLab
  - Manufacturing of Extrusion Die in progress
  - First extrusion run pending
  - CMU custom saw will be used for chopping
- Wavelength Shifters
  - INFN has ordered BC-484 WLS
- Light Guides
  - CMU optimized geometry
  - INFN overseeing production
- Iron absorbers
  - Quotes obtained by CMU
- Module housing and assembly
  - Prototype under production at CMU

Module prototype assembly
Will be filled with FNAL scintillator



3D-printed light guide model

o-ring sealed PMT bases

Workforce and Projected Schedule:

- FNAL
  - Workforce: Dr. Pla-Dalmau + Extrusion facility techs
  - Extruded scintillator early 2014
- INFN
  - Workforce: Dr. Bellini, Mech.Eng. F.Noto + INFN funded techs.
  - Wavelength Shifters Dec. 2013
  - Light Guides, spring 2014
- CMU
  - Workforce: Dr. Franklin, Dr. Quinn +Post Doc + Machinist
    Need additional technician + Undergrads
  - Prototype Feb., 2014
  - Scintillator preparation Spring 2014 (400 hours)
  - Ribs and end-plates Summer 2014
  - Assembly 1 calendar year (Complete Summer 2015)
- JLab
  - Workforce: Dr. Camsonne, Dr. Wojtsekhowski + Designer
  - Detector stand, cabling, HV.
  - DAQ

Summary

- Design of module finalized
- HCAl-J Collaboration enlarged
- HCAL-J production plan on based of US vendors
- Scintillator production underway at FNAL
- WLS is ordered from St. Gobain (INFN funding)
- Light guide parts in procurement (INFN funding)
- Prototype module under construction at Carnegie Mellon
- Projected cost of $300k (less than estimated two years ago)

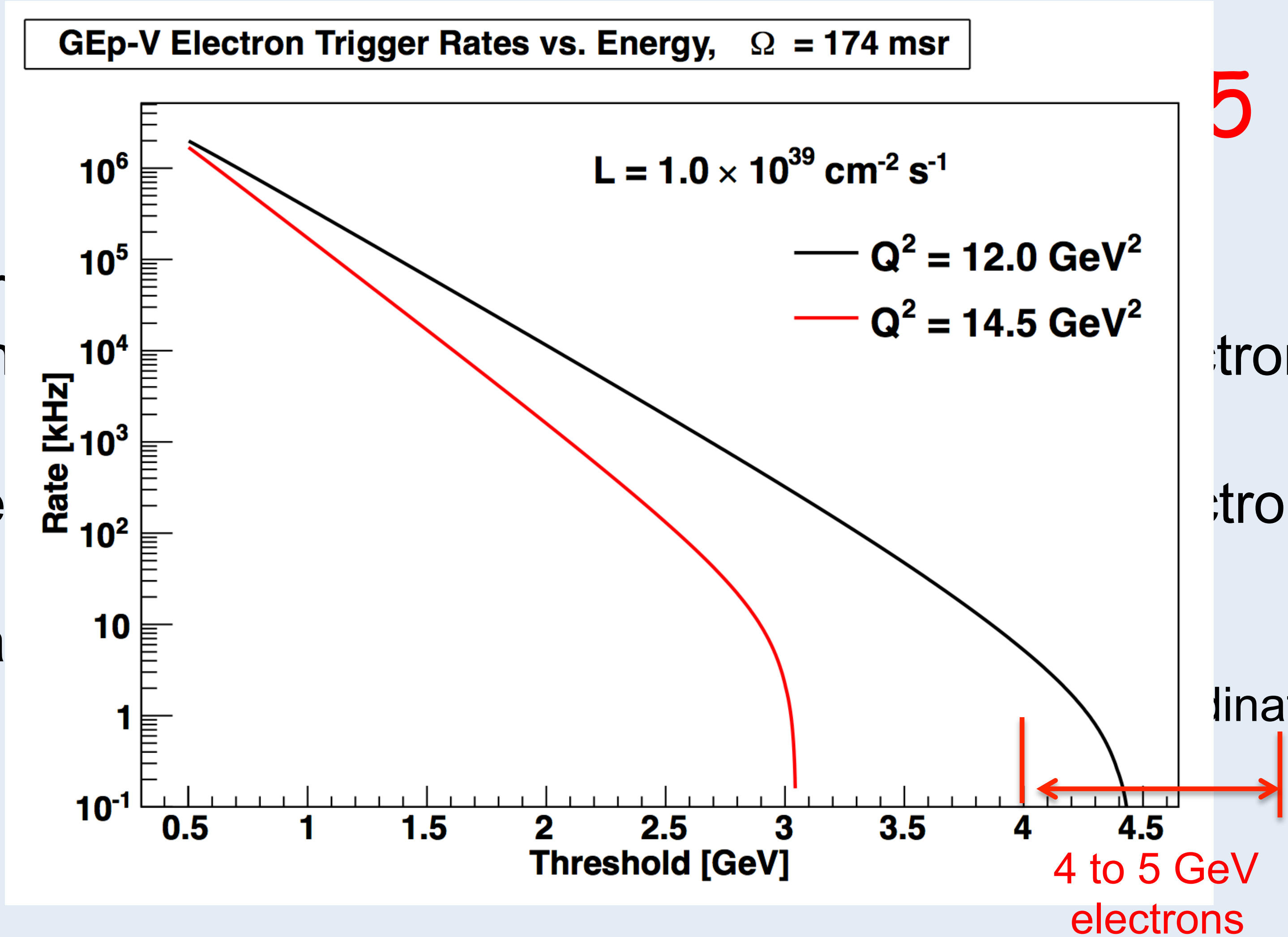
BACKUP

Electron Calorimeter For GEp5

Performance Requirements

• Function:	Detect 4.0 to 5.0 GeV Electrons
• Energy resolution:	σ/E ~10% for 3.5 GeV electrons
• Spatial resolution:	~8 mm (2 to 3 mm with upstream coordinate detector)
• Full luminosity:	10^{39} Hz/cm^2
• Trigger:	20 cm thick AL reduces background Signal summing capabilities Trigger at 75% of elastic peak

5

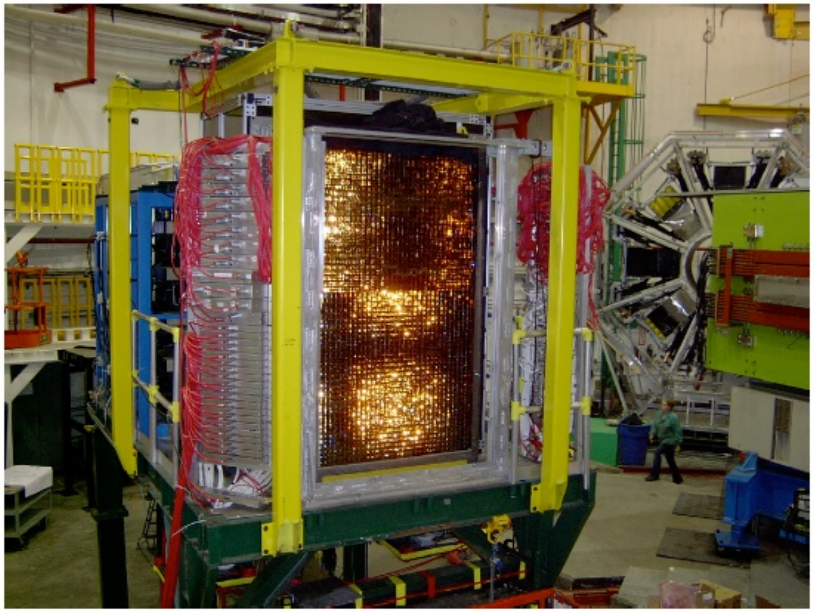


Perfor

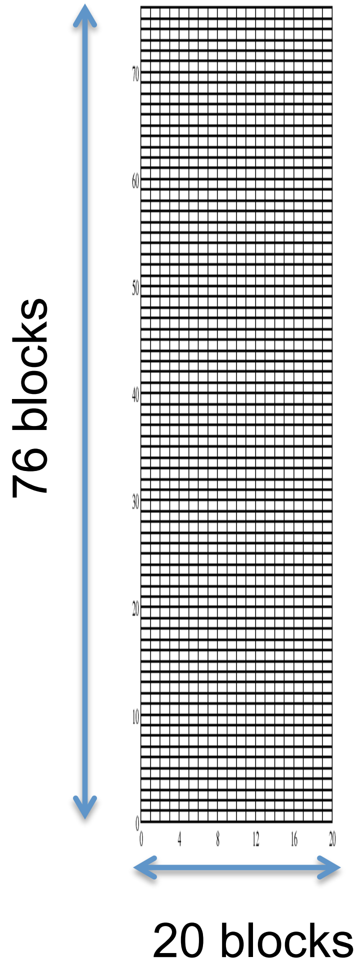
- Fun ... trons
- Ene ... trons
- Spa ... dinate detector)
- Full
- Trigger: 20 cm thick AL reduces background
  Signal summing capabilities
  Trigger at 75% of elastic peak

BigCal for GEp experiment

Used in Hall C GEp3



Reconfigure



- Existing lead-glass calorimeter
- Reconfigure: 1520 blocks
- Block size : $4x4x40 cm^3$ and $3.8x3.8x45 cm^3$
- Area: 0.80 m x 3.04 m = $2.4 m^2$

Electron Calorimeter

October 2011 review panel comment:

The rearrangement of the components of the BigCal lead glass calorimeter for use in the SBS setups is not an issue. While the recovery of radiation damage in lead glass by UV exposure is well known, in the present application this may be pushed to an extreme in terms of recovery timescale. Different damage and/or cure rate time components could complicate the proposed scheme. The lead glass radiation damage and cure rates should be tested with prototype setups under realistic conditions (e.g., high dose in 7 hours, full cure in 1 hour) before this can be viewed as a feasible strategy. Similarly, in-situ UV effects on the PMT photocathode should be studied.

Response:

ECAL preparation is in its development stage with several options under consideration

eCal Development

Per Review panel comment: The lead glass radiation damage and cure rates should be tested with prototype setups under realistic conditions

- Plan is: UV recovery (need 5x UV power density rel. GEp3)
  - Test irradiations at Idaho State University
  - Existing experience from GEp3

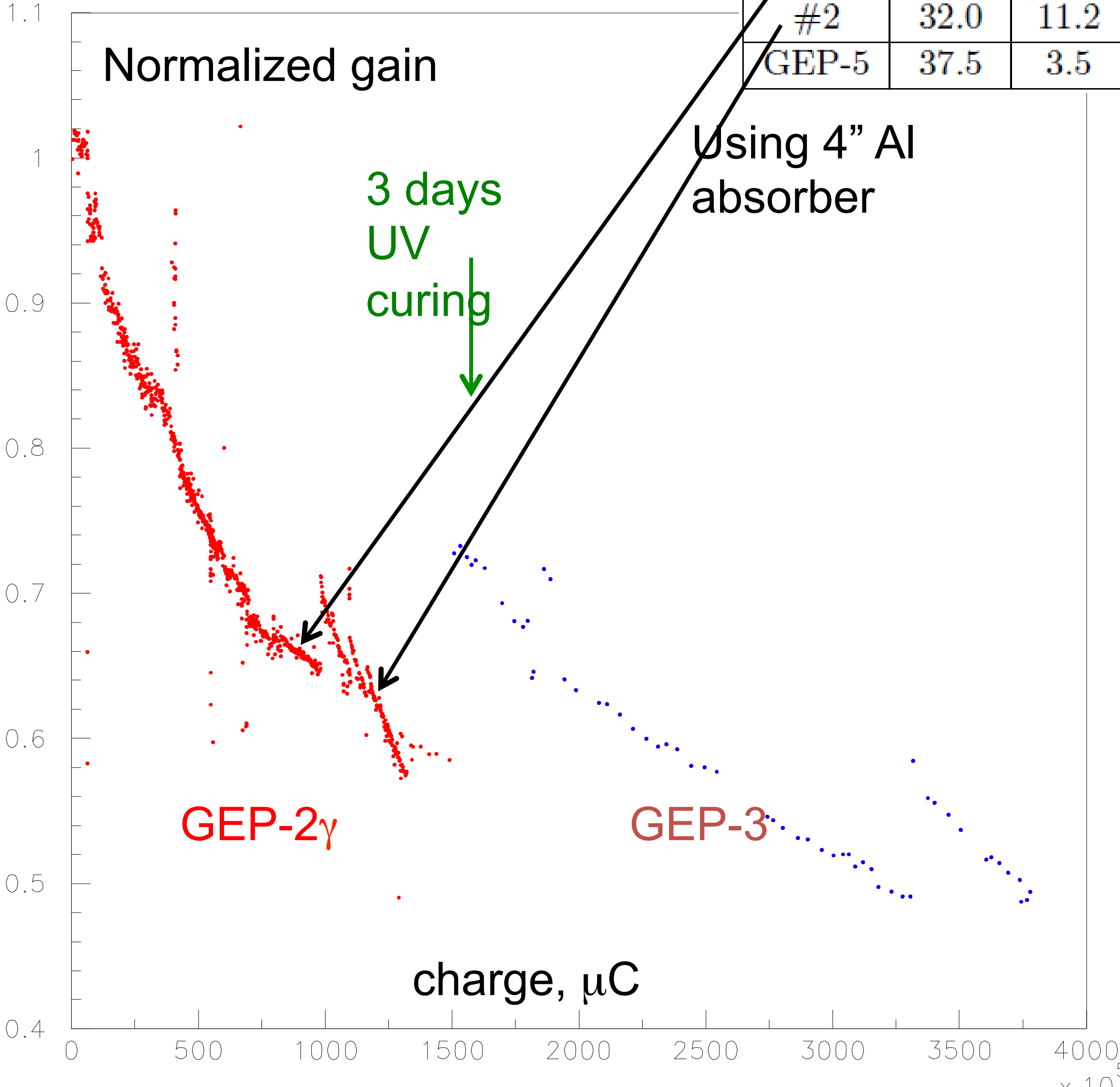
- New idea: Continual bake-out scheme
  - Heat front of crystals to 300 C
  - Thermal radiation appears acceptable for PMT
  - Tests are under preparation

- Alternative to BigCal:
  - LAC calorimeter (Pb-scint. bars) acquired from CLAS6
  - Used calorimeter from DESY

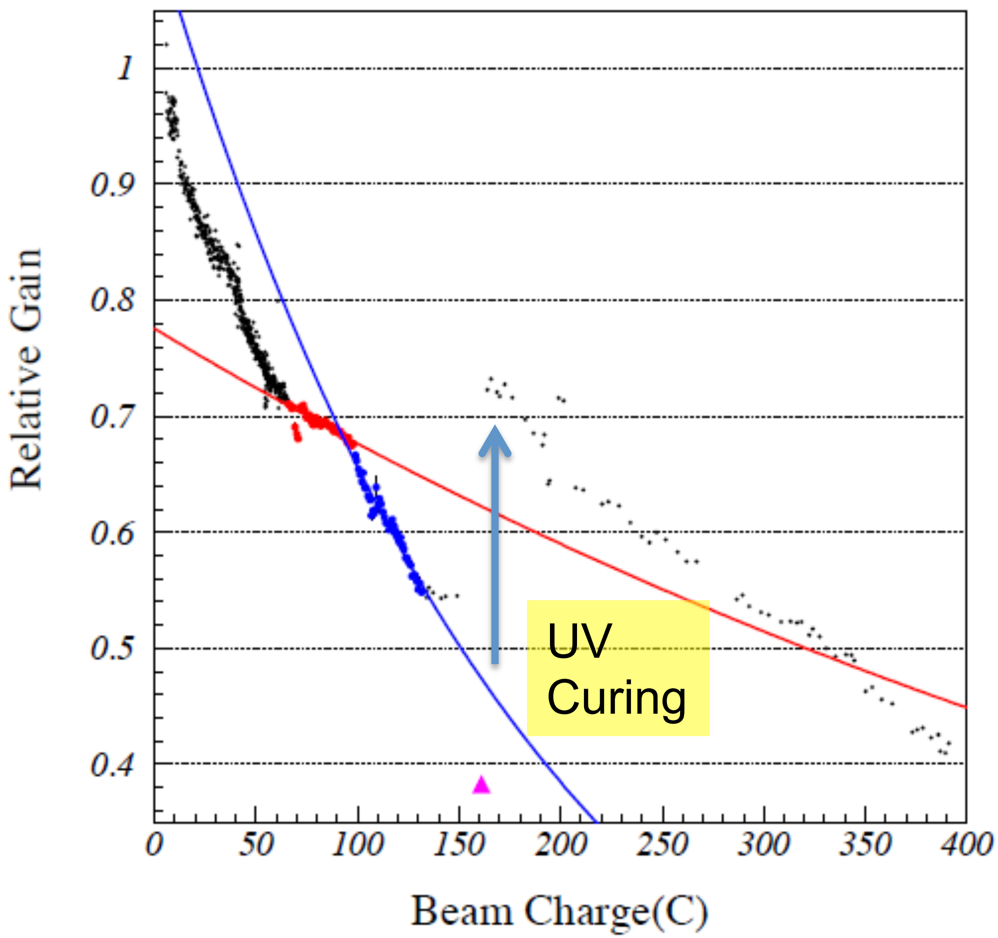
BigCal Radiation damage and UV curing

kin.	angle deg.	Dist. m	Target cm	E GeV	Gain loss rate b	soft photon flux J/cm^2/C
#1	44.9	12	20	2.839	0.14%/C	0.0039
#2	32.0	11.2	20	3.539	0.53%/C	0.013
GEP-5	37.5	3.5	40	3.539	~6.7%/C	0.17

Data Geant3 simulations estimation



UV Curing



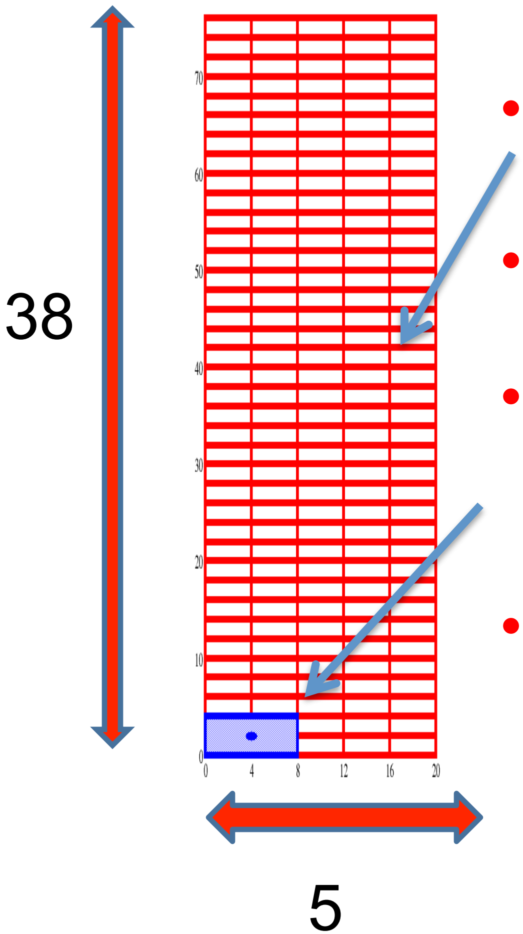
Hall C Experience:

- UV cured the BigCal for 3 days on each ¼ of the detector.
- Improved the gain from 39% to 74%
- Rate of improvement is 1.24%/hr

GEp5:

- Need to curing 6% /hr
- Will increase UV intensity by x5
- UV cure for 1hr after 7 hours of running. (Need to have HV off)

BigCal Electronics



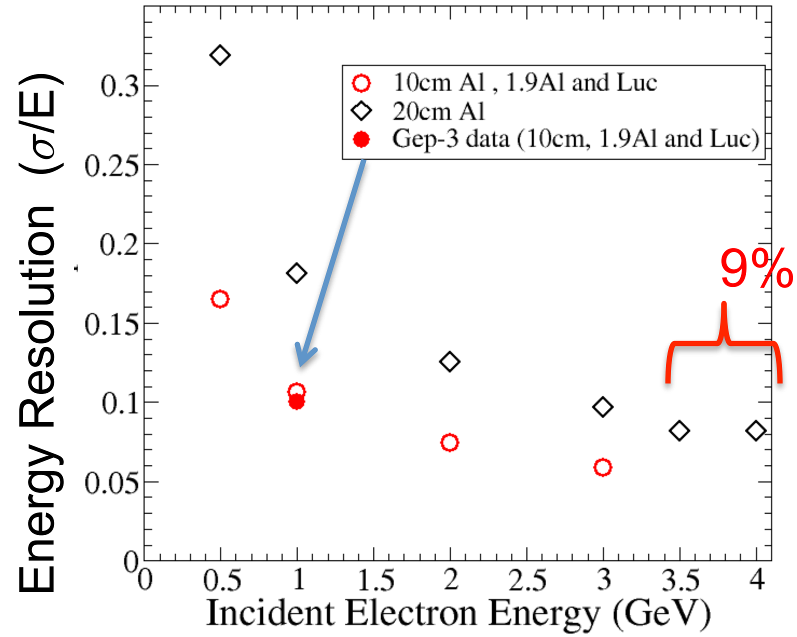
- 1520 PMT signals (20 x 76 array)
- 1520 existing Fastbus ADC channels
- "Group of 8": 4x2 grouping of PMT signals into existing custom "summing" modules.
- "Group of 32": formed for trigger by analog summing of 4 "group of 8" signals using existing Lecroy NIM FI/FO.

(More details in talk by A. Camsonne)

BigCal Performance

Energy Resolution

Simulation shows 10% energy resolution maintained even after increasing absorber thickness

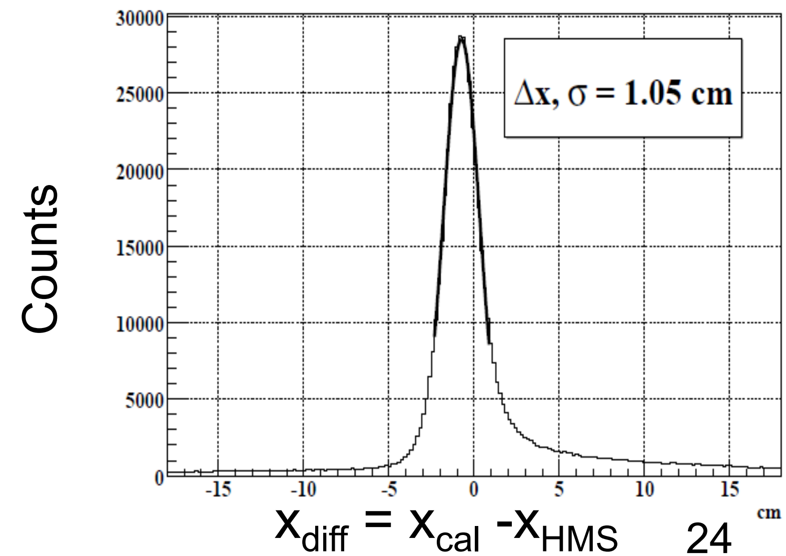


Spatial Resolution

Measured in GEp3

Subtract contributions of HMS,
Add additional absorber

→ achieve σ~6 mm



Hera-B calorimeter

G. Avoni et al. / Nuclear Instruments and Methods in Physics Research A 580 (2007) 1209–1226 1211

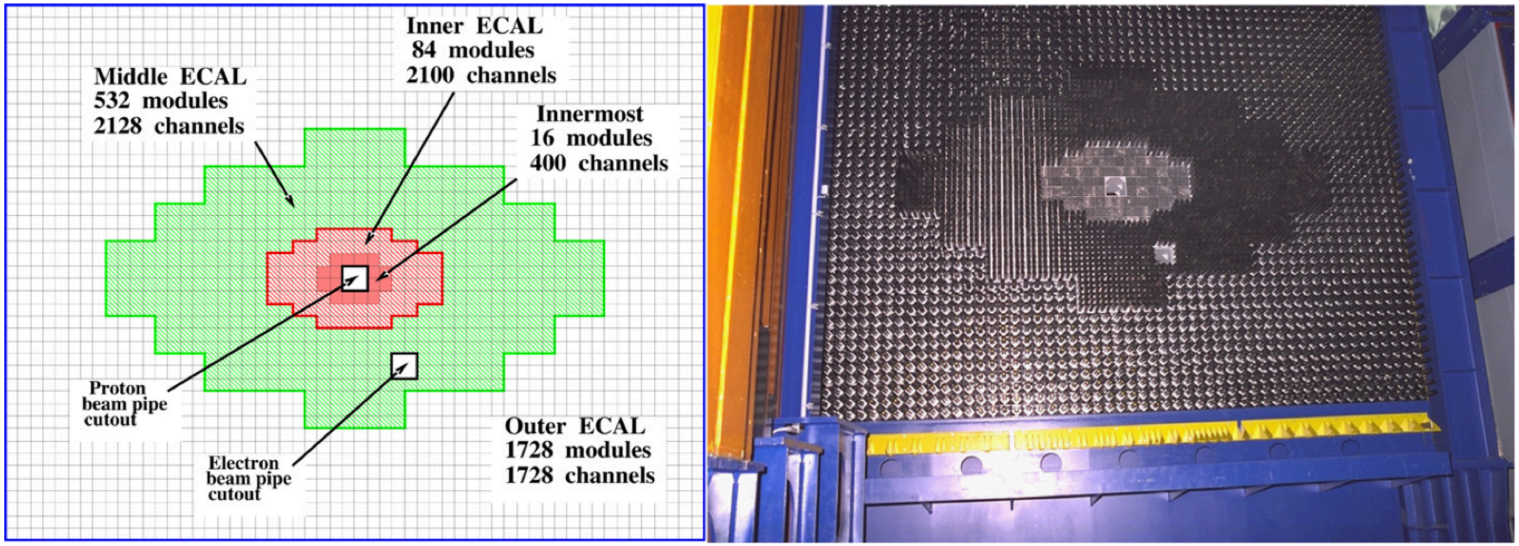


Fig. 2. The HERA-B electromagnetic calorimeter structure.

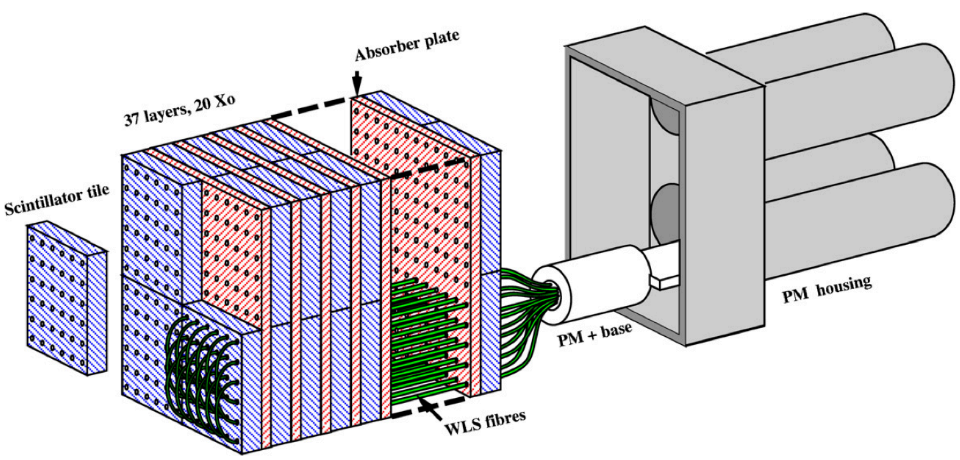


Fig. 4. MIDDLE ECAL module structure.