Outline

- Science goal of ECAL
  - Search for signatures of sources and spectral features
  - Extend measurements of the electron spectrum to high energies
  - ATIC has measured electron spectrum and reports a feature in the electron spectrum
  - Conduct long duration balloon flights for 50 days total exposure
  - Improve electron/proton discrimination
  - Background electrons
- Instrument concept based on ATIC heritage
  - Thin imaging ionization calorimeter with particle identification detector optimized for hadron measurements
  - Replaced target section with a fine tracking detetctor
  - Altered the SiMat design to better separate Z=0, 1 & 2 particles
  - Using same data system and mechanical structure (3 LDB flights completed)
- Electron Identification techniques
  - Charge identification
  - Shower shape
  - Starting point/first interaction depth
  - Ratio of shower core signal to full shower signal
  - Depth of 95% of energy deposition in calorimeter
  - Number of Neutrons detected
- Simulations of Secondary Neutrons
  - Number of neutrons produced in hadronic versus electro-magnetic interactions
  - Number of neutrons detected at different points of the detector volume
- Conceptual Design
- Detection efficiency
- PMT operations
- Conclusions

Electron Calorimeter Experiment

COSPAR, Montreal Canada

July 2008

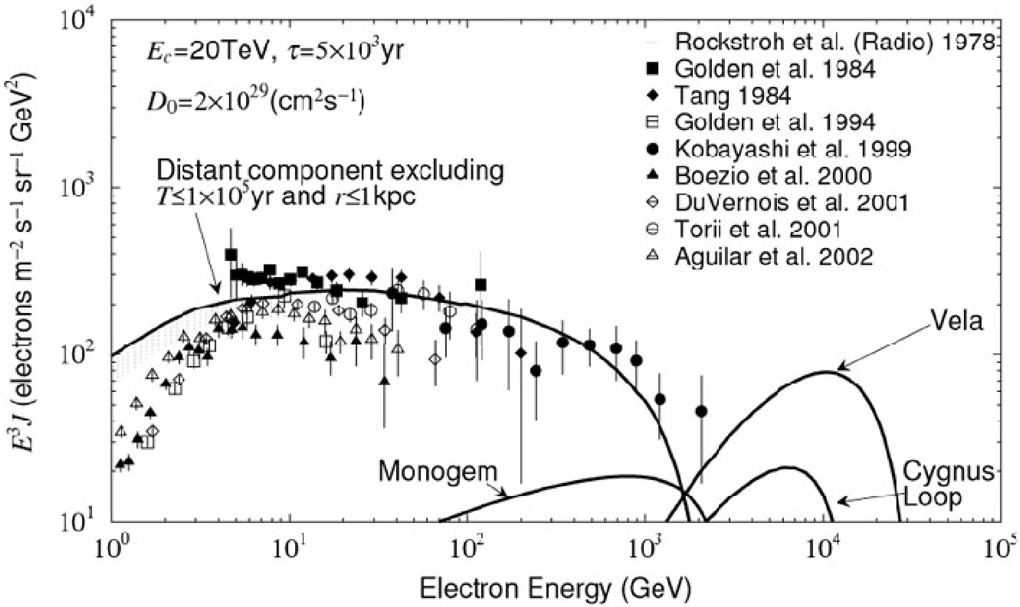
James H. Adams[1] for the ECAL Collaboration

[1]MSFC/NASA Huntsville AL. 35812

Science Motivation

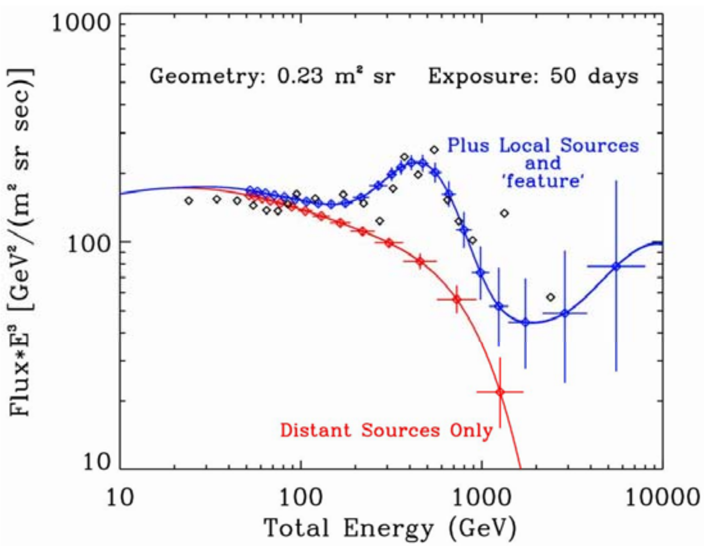
- Measure electron spectrum and search for signatures of sources and spectral features
- ATIC measured the electron spectrum and reports a feature in the electron spectrum
- ECAL will be implemented on long duration balloon flights for a total exposure of 50 days
- Requires proton rejection capability to achieve the measurement
- Background electrons

Science Goal

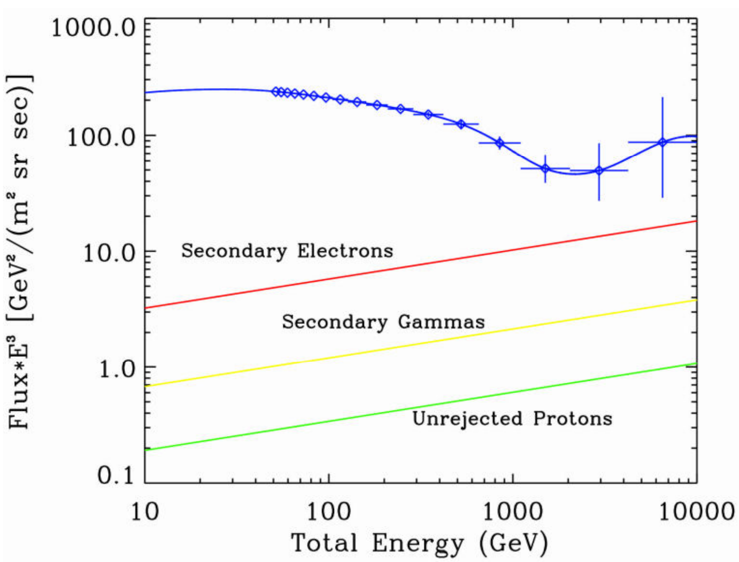


Existing data and model calculations for candidate nearby sources

Calculated background electron flux and errors due to miss identified primary particles



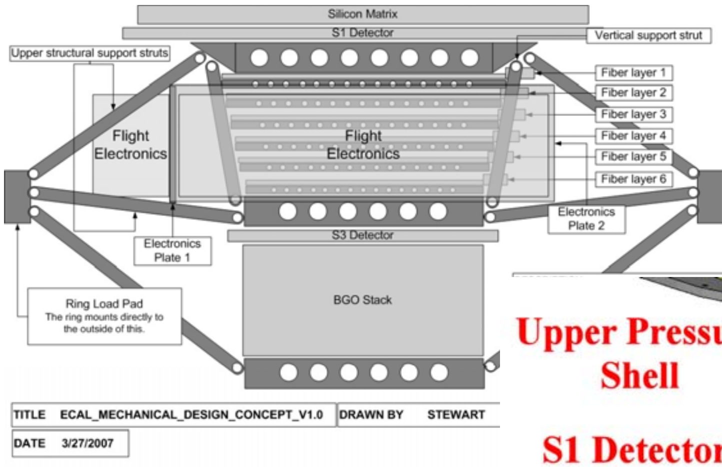
Expected reach and flux sensitivity for ECAL on LDBs

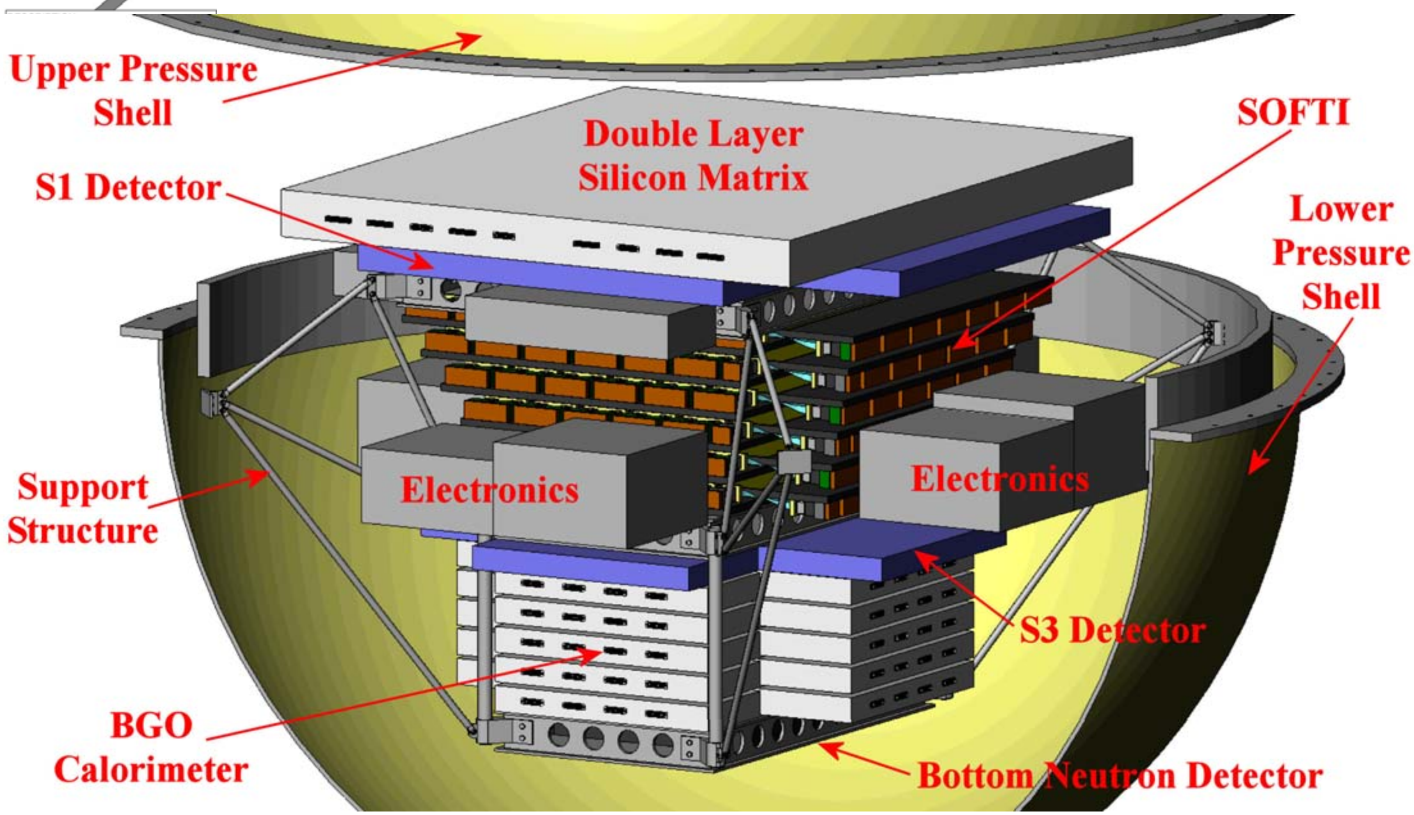


ECAL Instrument

- Based on ATIC heritage: thin imaging ionization calorimeter with particle identification detector optimized for hadron measurements
- Replaced target section with a fine tracking detector
- Modify the SiMat design to better separate Z=0, 1 & 2 particles
- Uses same data system and mechanical structure (3 LDB flights completed)

Electron Calorimeter Experiment for LDB

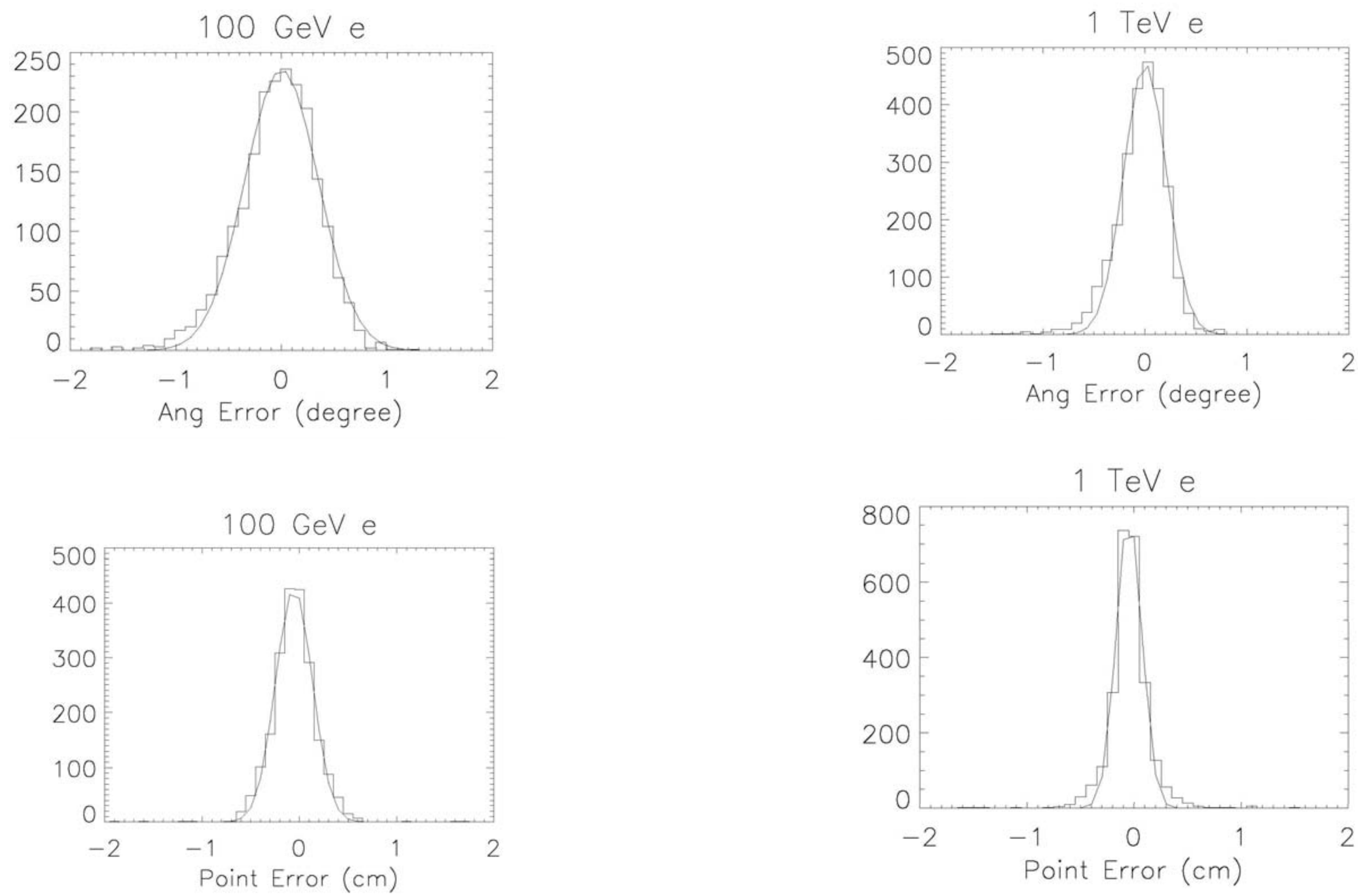




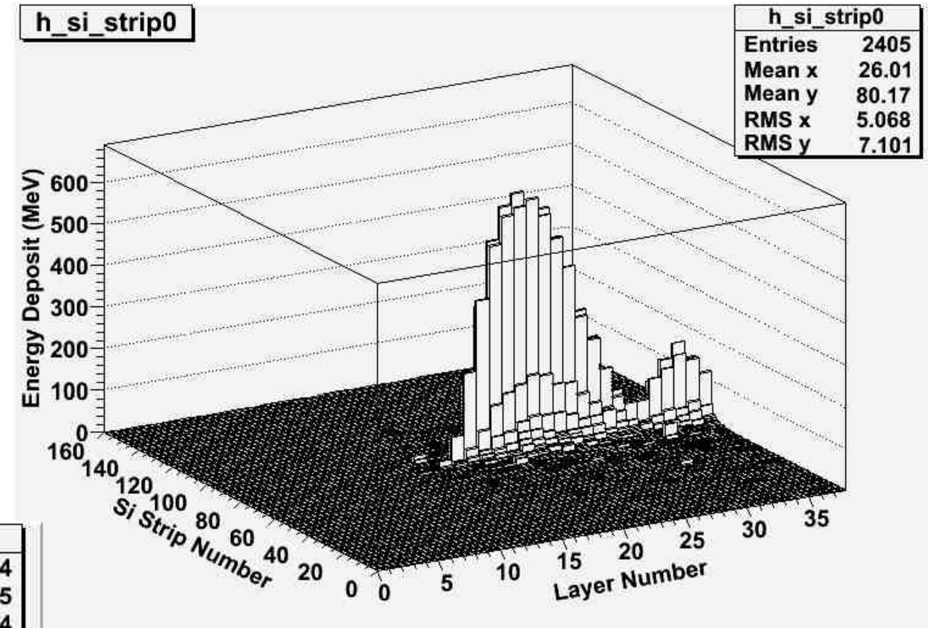
Electron Identification techniques

- Charge identification
- Starting point/first interaction depth
- Shower shape
- Ratio of core signal strength to full shower
- Depth of 95% of energy deposition in calorimeter
- Number of neutrons detected

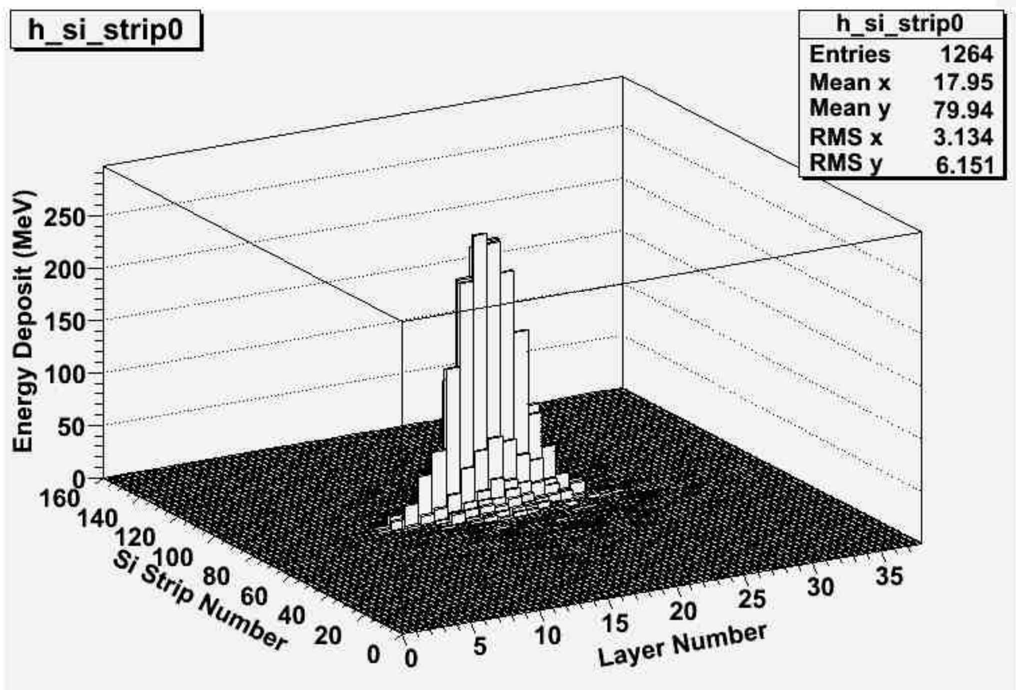
Point back accuracy to CID



Cascade Imaging

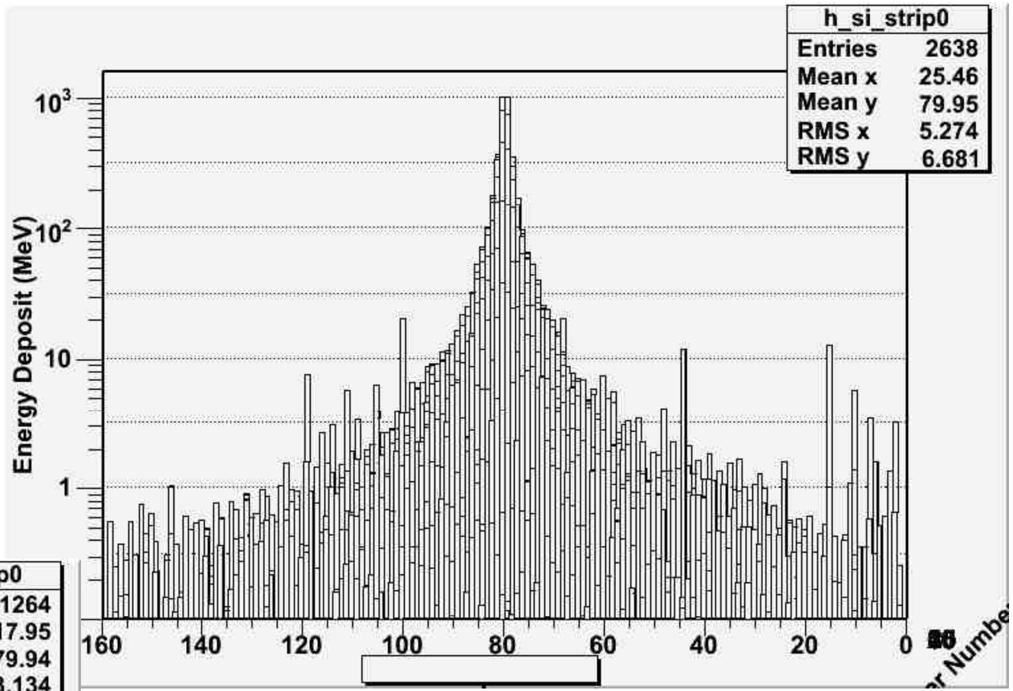


Electron cascades are consistently smooth and well defined

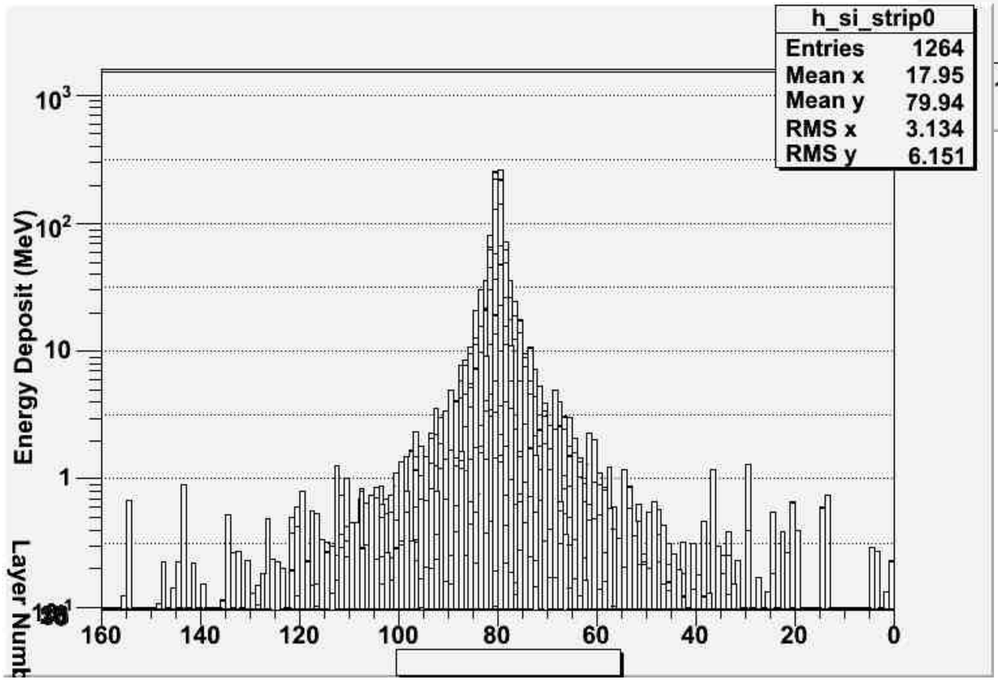


Proton cascades are irregular and vary greatly from event-to-event

Cascade Imaging (continued)



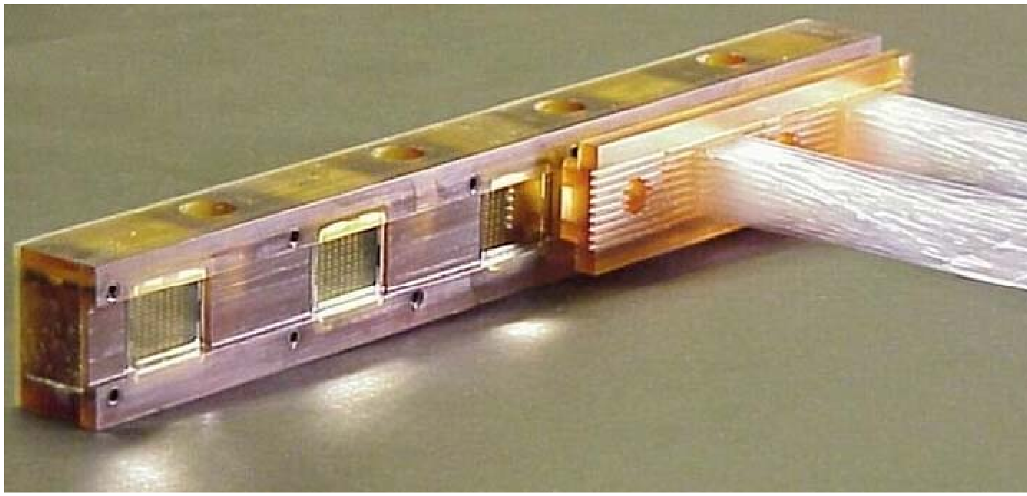
Electron cascades are confined to a small lateral width with few signal spikes on the wings

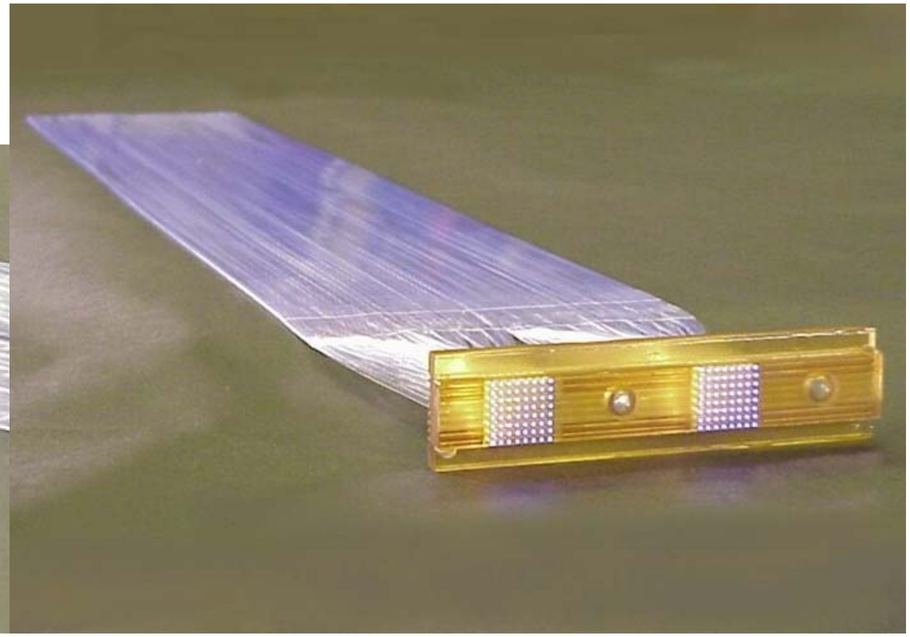


The principal part of proton cascades develop on top of widely scattered singly charged particles.

Cascade starting point

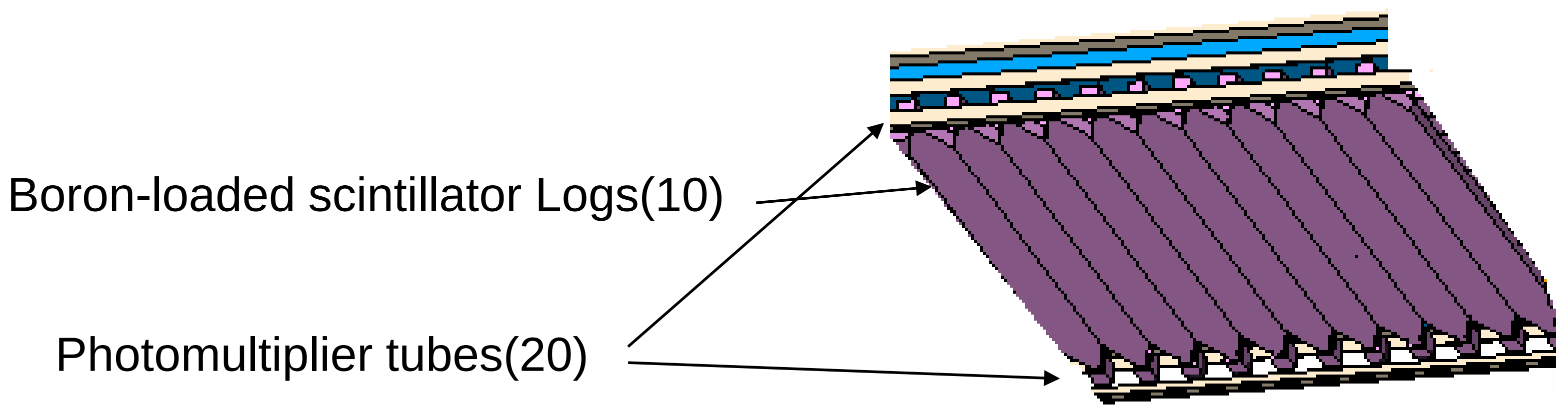
- Fine lateral and longitudinal sampling in upper detector
- Small nuclear interaction cross section (λ = 0.15)
- Several radiation lengths to initiate electron cascade high in detector
- MIP sensitivity with sub-millimeter position resolution





Neutron detector concept

- ECAL total mass 1600kgs (λ_{total}=1.3 MFP)
- Neutrons are detected using boron-loaded scintillators viewed by photomultiplier tubes (PMTs)
- 10 Scintillators 5×5×50 cm^3 , each viewed by two 2” dia. PMTs
- Multiple detector locations possible (secondary neutrons are present all around the detector mass)
- e/p discrimination enhanced by material selection for hadronic interactions and neutron moderation

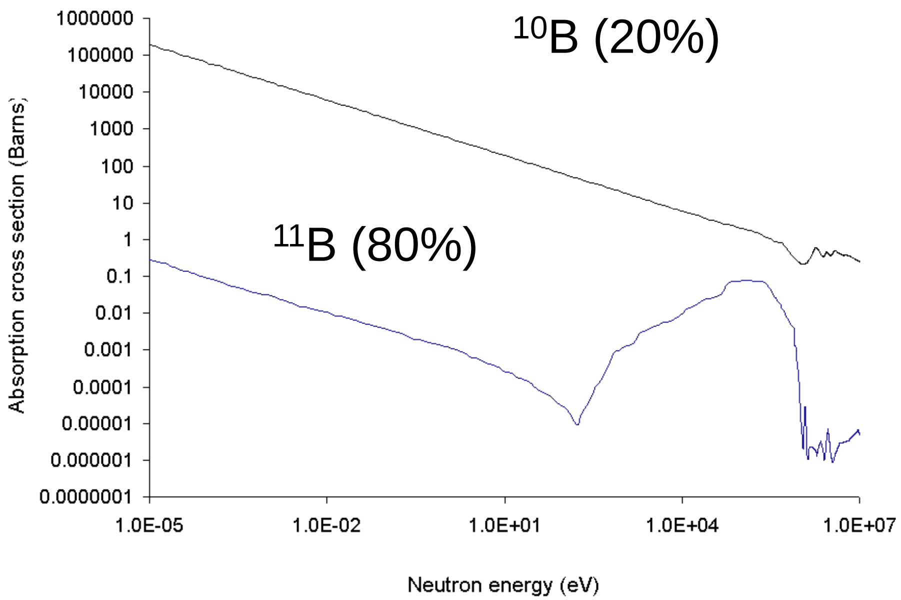


Detection Principles

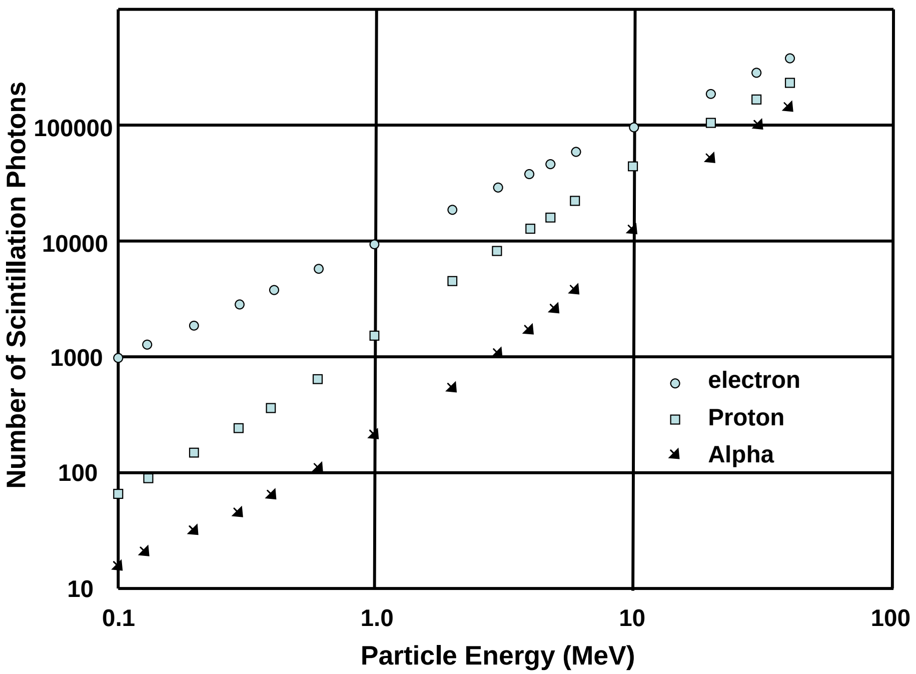
$$\mathbf{n} + {}^{10}\mathbf{B} \rightarrow \left\{ \begin{array}{ll} {}^{4}He + {}^{7}Li & \color{blue}{6\%} \\ \hline {}^{4}He + {}^{7}Li + \gamma(0.48MeV) & \color{green}{94\%} \end{array} \right.$$

$$\mathbf{Q} = \color{blue}{\mathbf{2.8}}\ \mathbf{(}\color{green}{\mathbf{2.3}}\mathbf{)\ MeV}$$

Neutron Capture

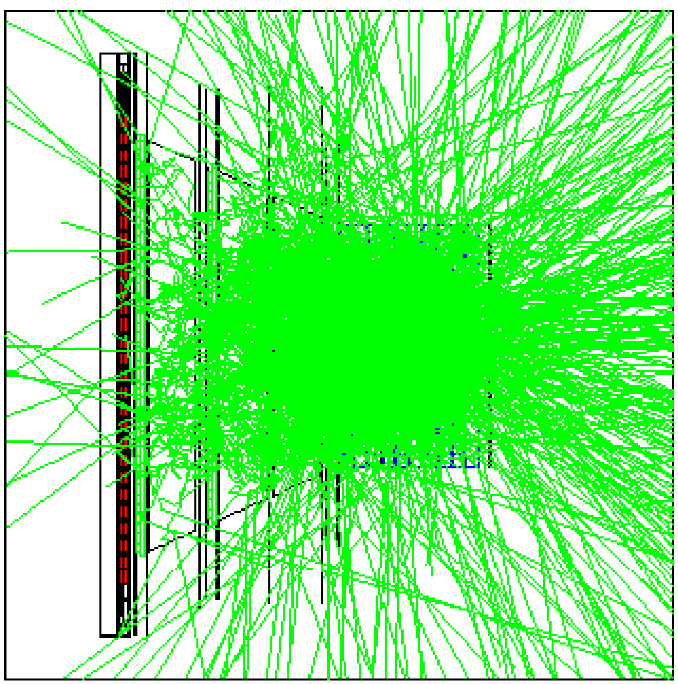


Scintillation Efficiency

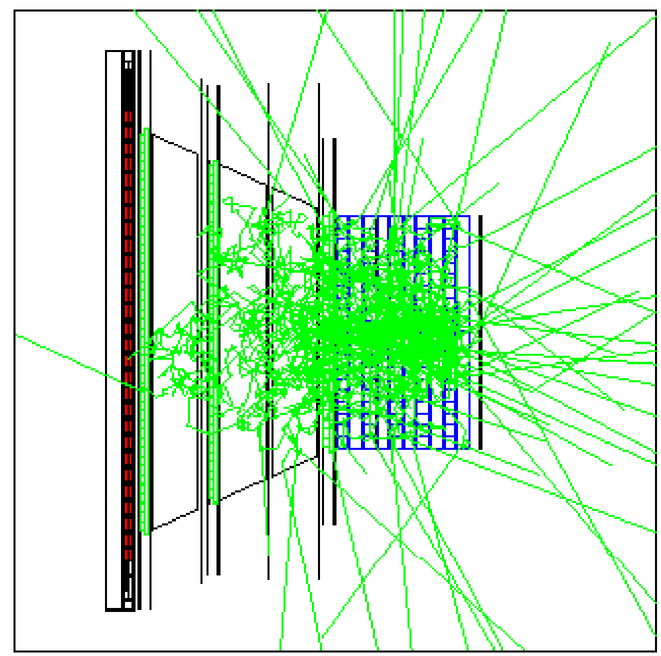


Simulations of Secondary Neutrons

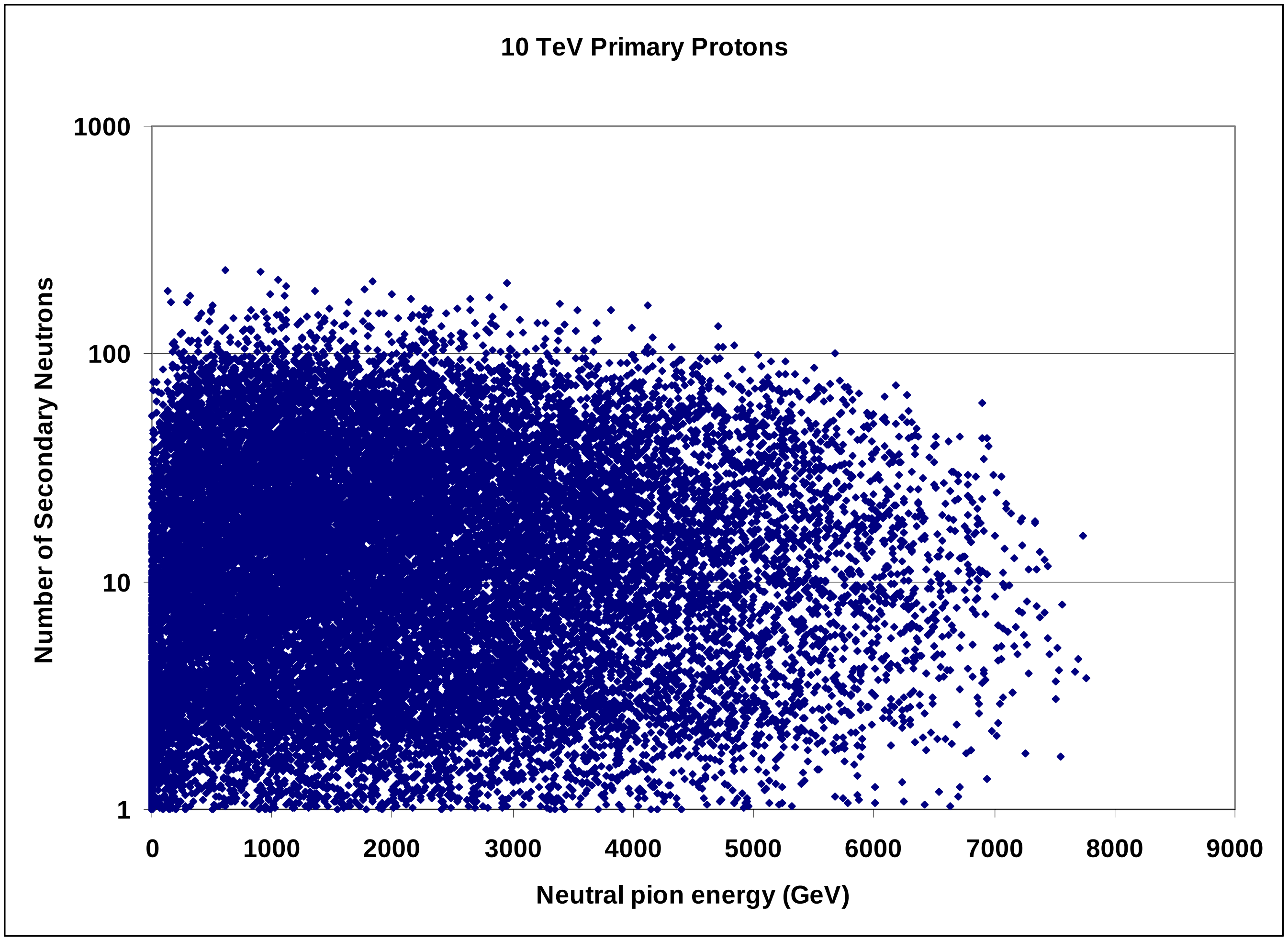
GEANT4 Simulation
Neutrons from a 0.3 TeV
Proton incident on ATIC



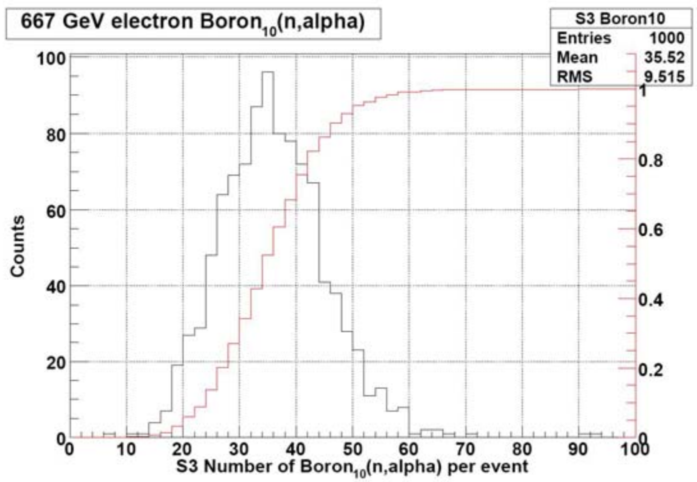
GEANT4 Simulation
Neutrons from a 0.3 TeV
Electron incident on ATIC

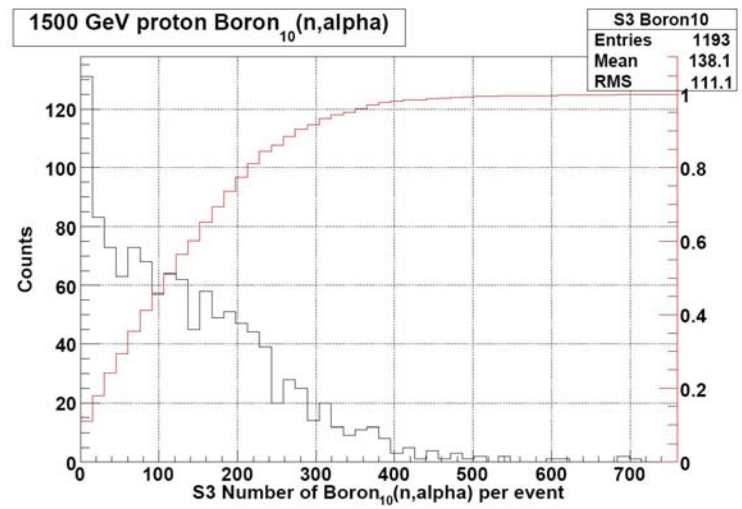


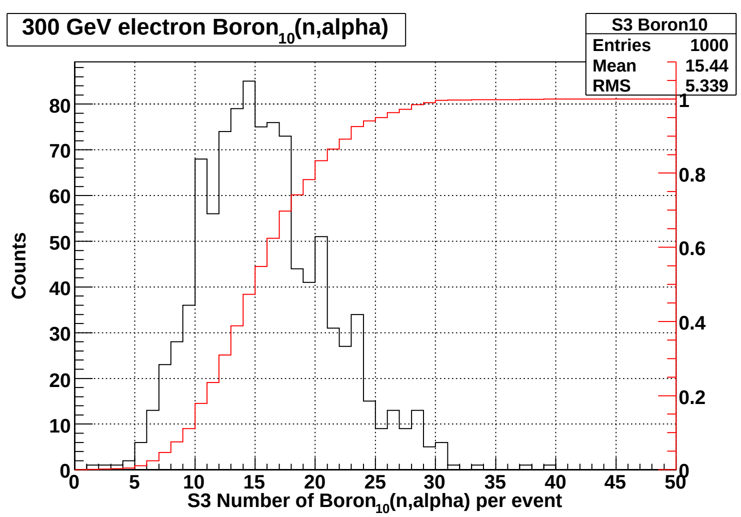
Secondary neutron production by 10 TeV protons

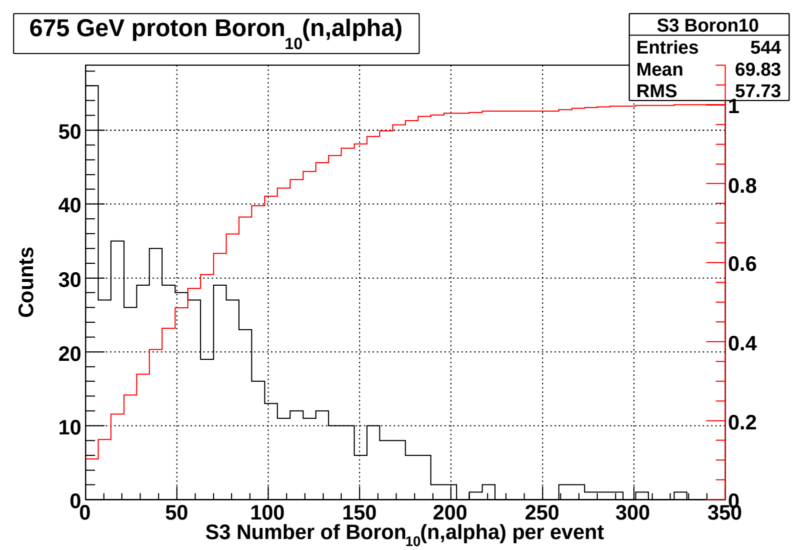


Comparison of secondary neutrons produced by proton and electron events







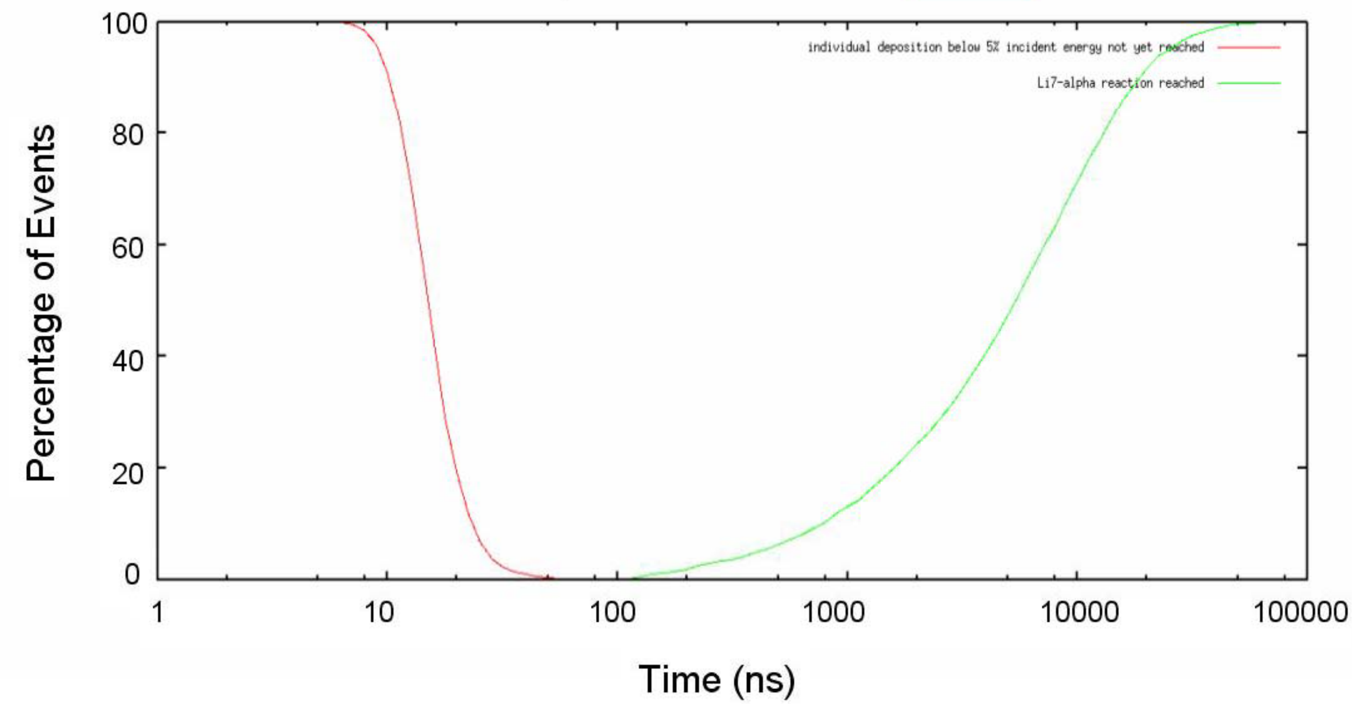


Timing characteristic of secondary neutrons in ECAL

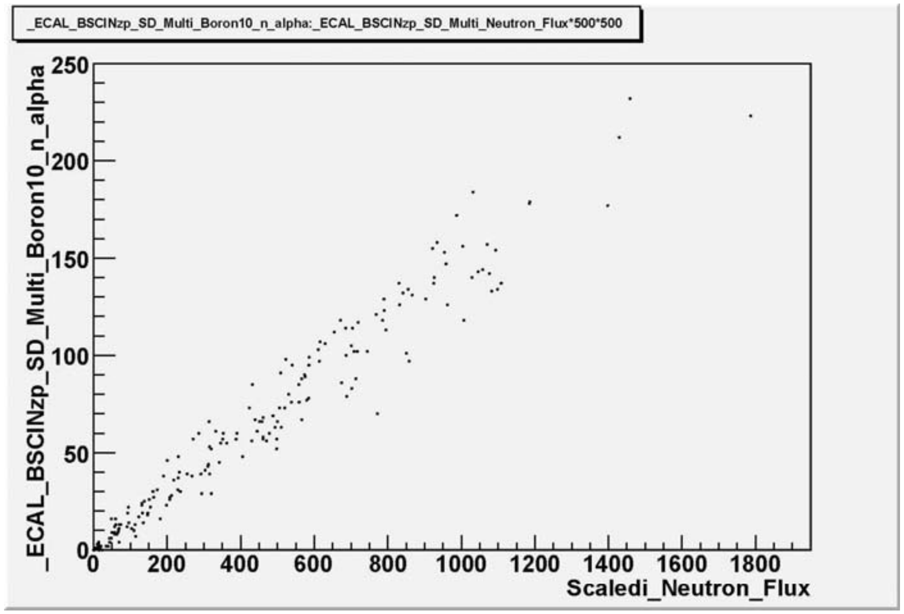
Cumulative Distributions

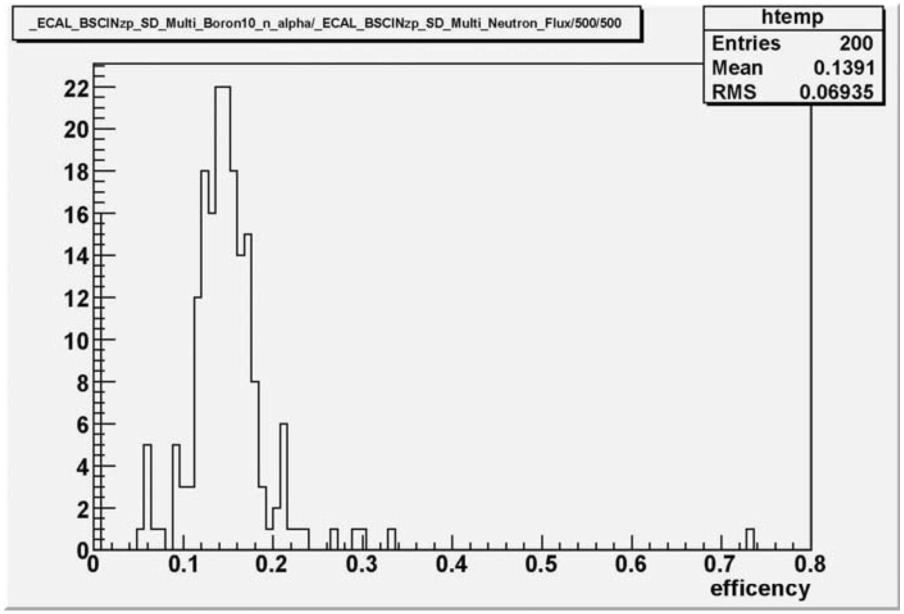
Time when 95% energy deposition occurs

Time when ^{7}Li alpha reaction occurs

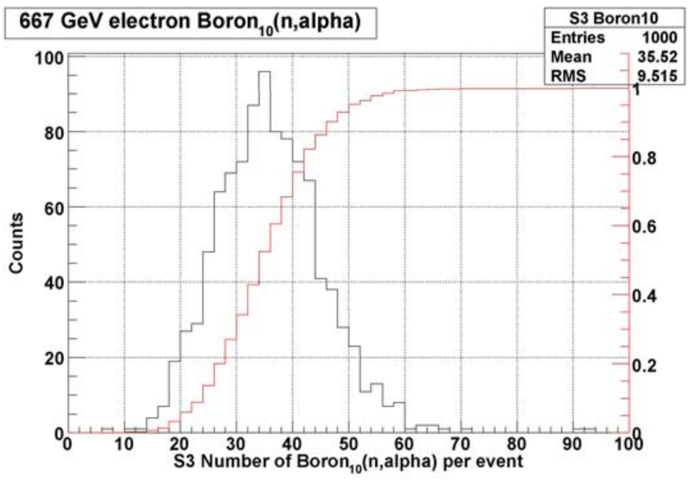


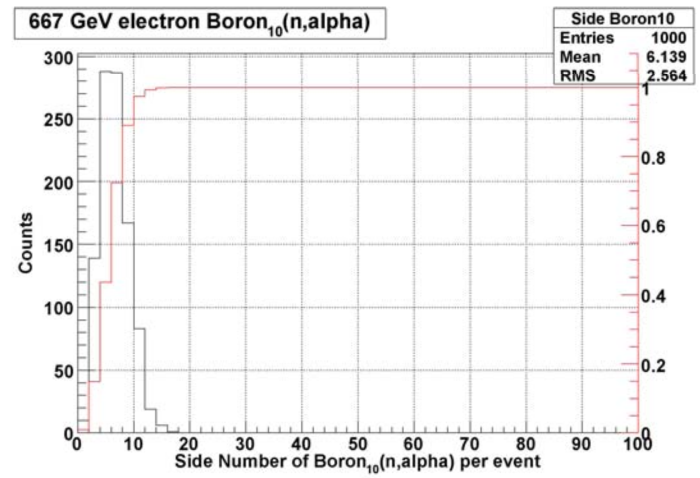
Secondary neutron capture efficiency

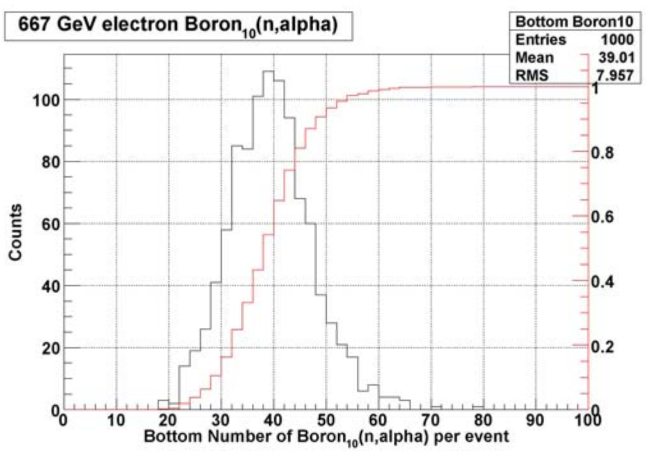


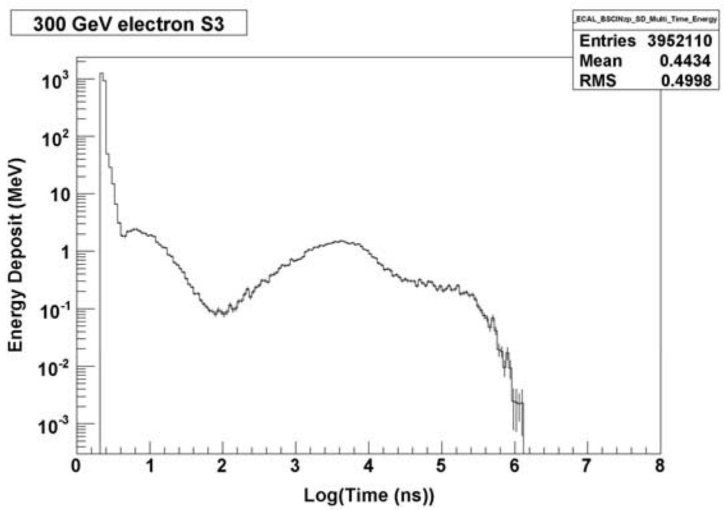


Spatial distribution of secondary neutron flux in ECAL (electrons)

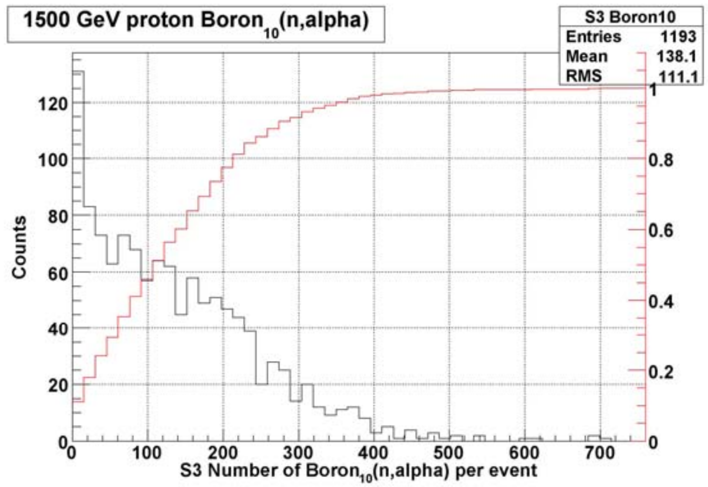


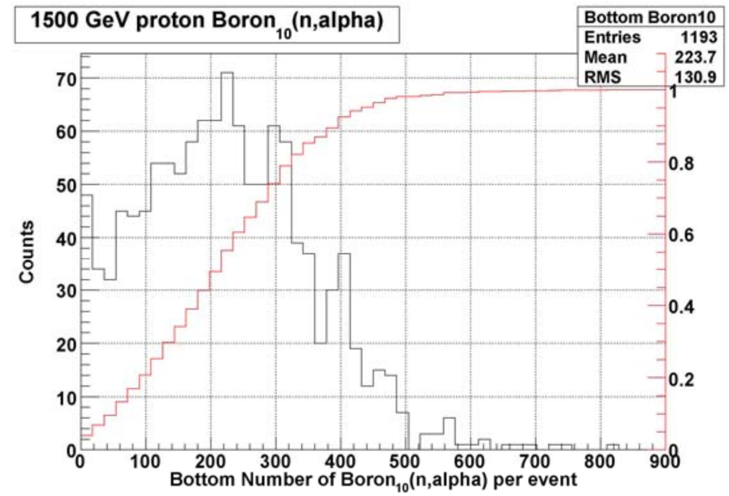


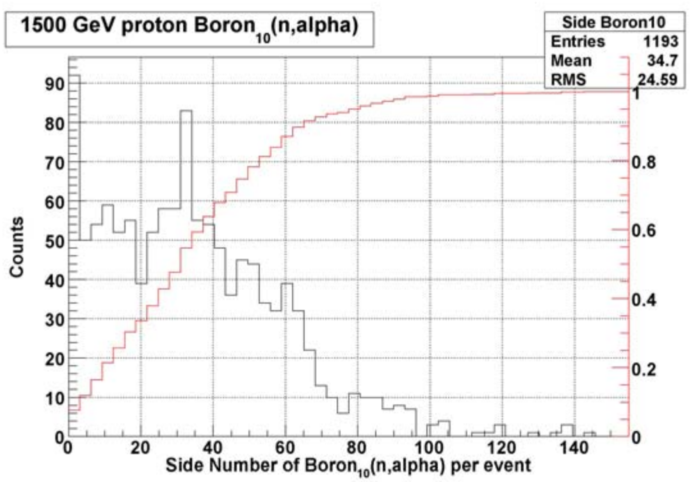


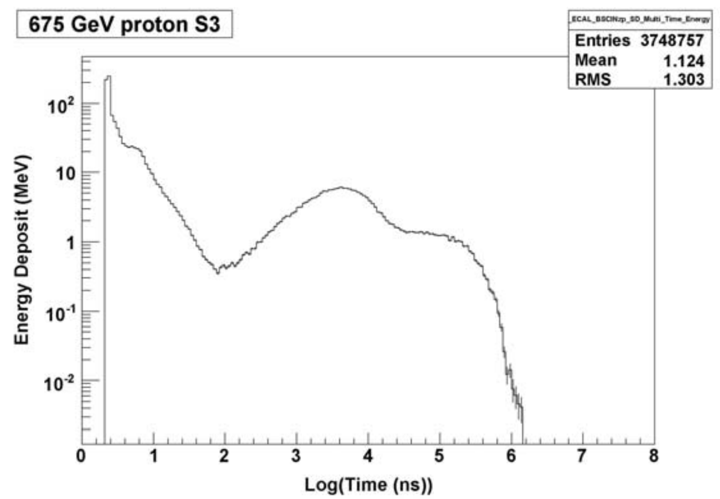


Secondary neutrons due to protons



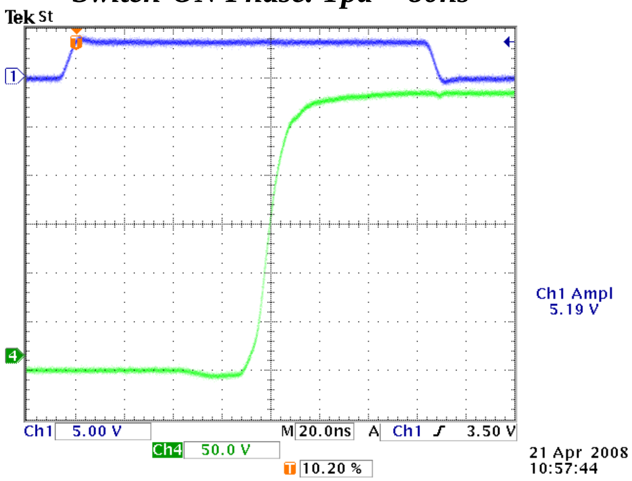




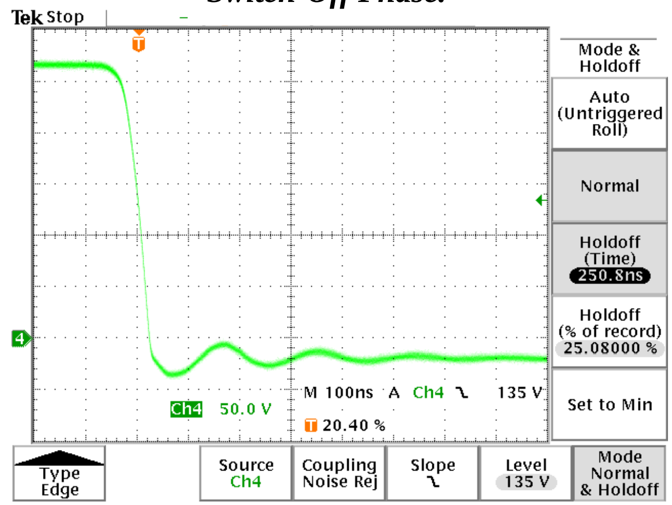


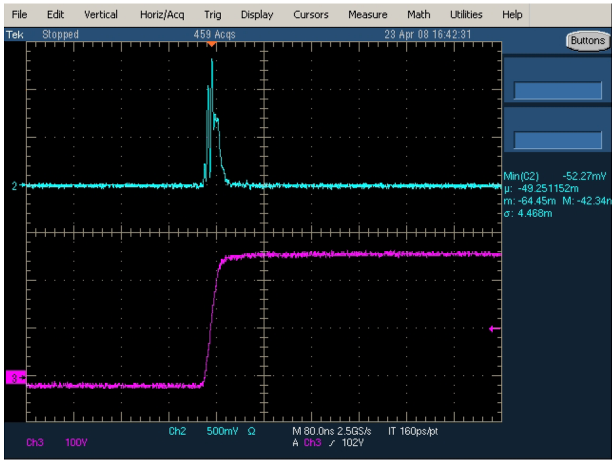
PMT Operation: Blanking high voltage

Switch-ON Phase. Tpd = 80ns

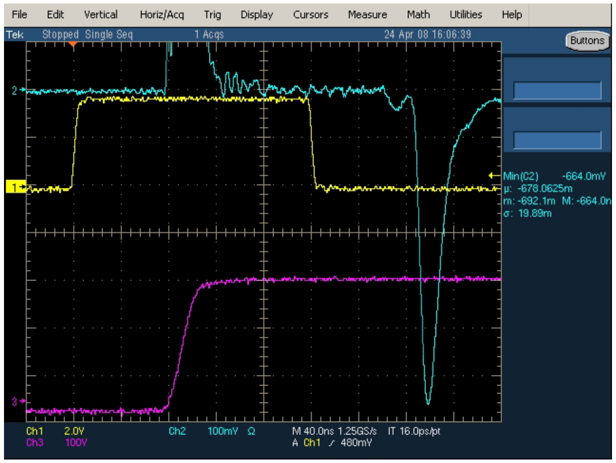


Switch-Off Phase.



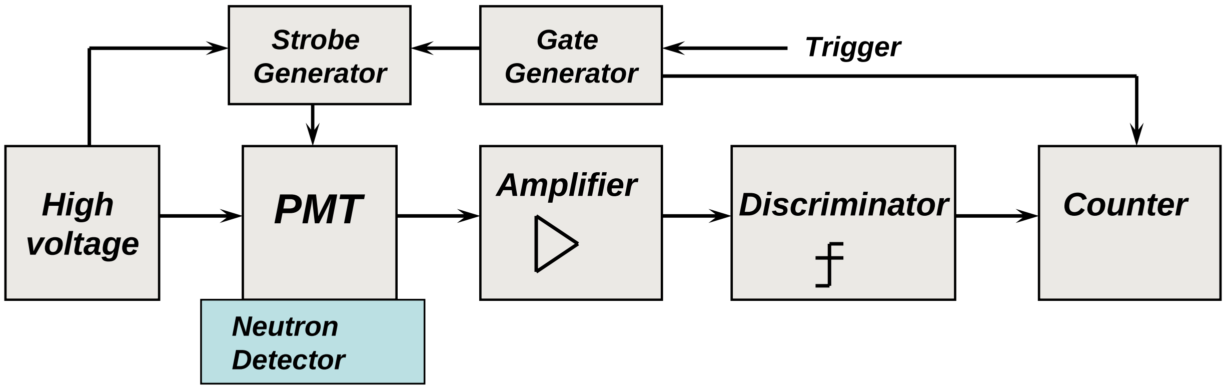


PMT Strobe (magenta). Switch-On crosstalk on the PMT output

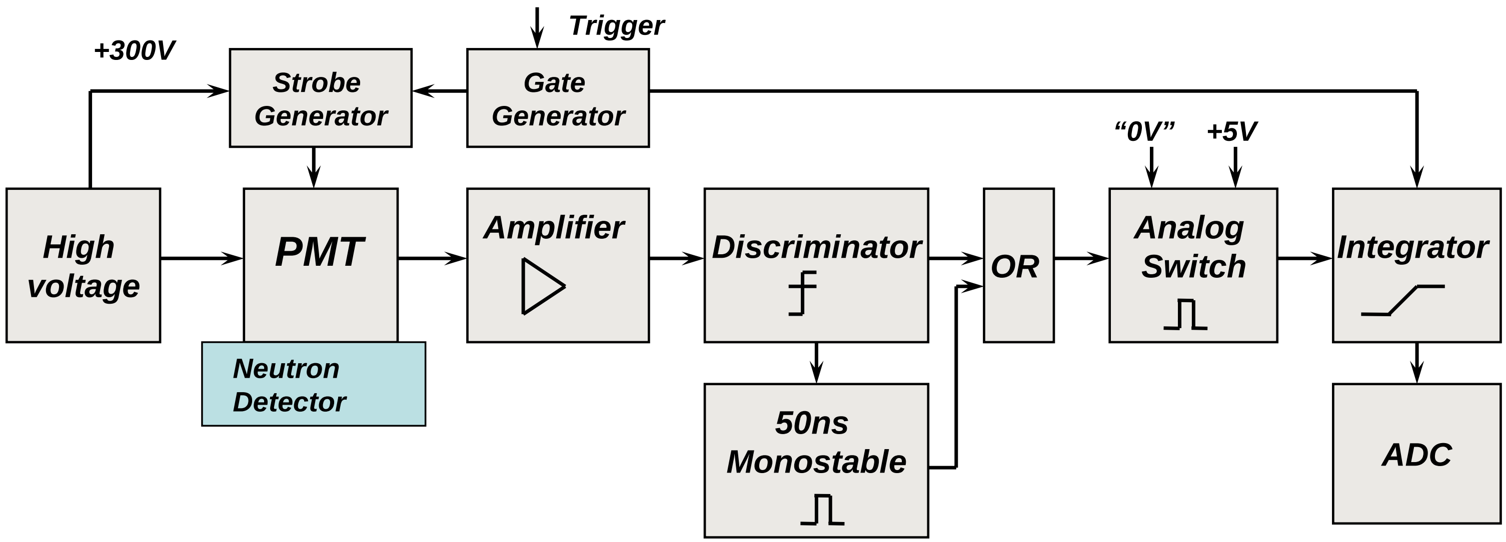


Trigger Pulse (yellow). PMT Strobe (magenta). PMT response to the Light Pulse (blue)

Data Acquisition



Counting technique. *(counting og single PMT pulses)*

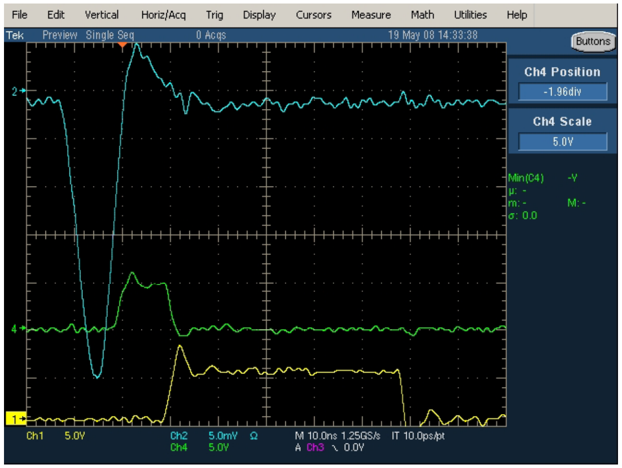


Integrating technique *(integrating of single and piled up PMT pulses)*

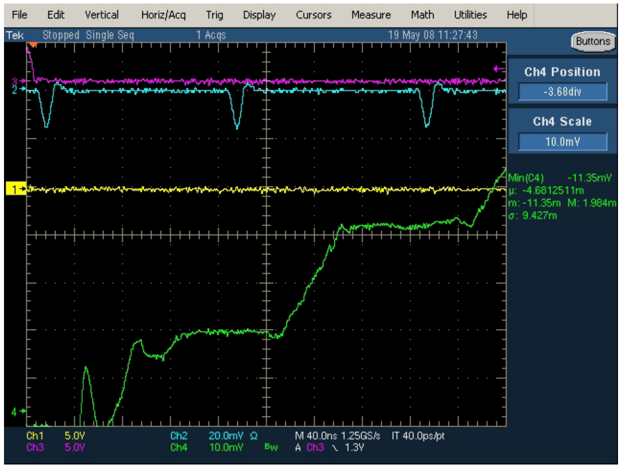
PMT Counting Mode

PMT Strobe (magenta), PMT output (blue). Source – Light Pulser

Integrated PMT Pulses

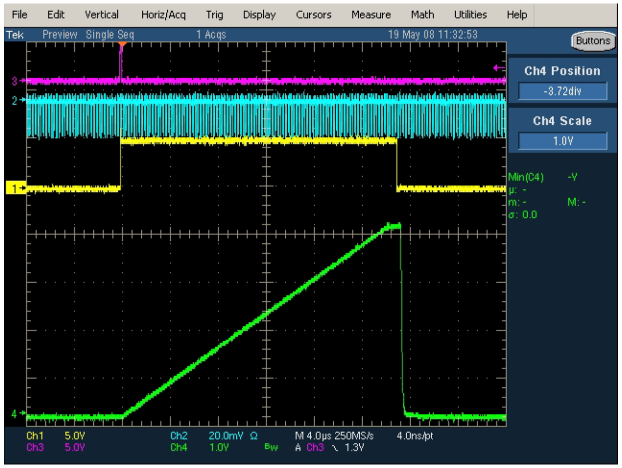


PMT pulse (blue); Discr. output (green); 50ns one shot (yellow)



Integrator output (green) 40ns/div scale

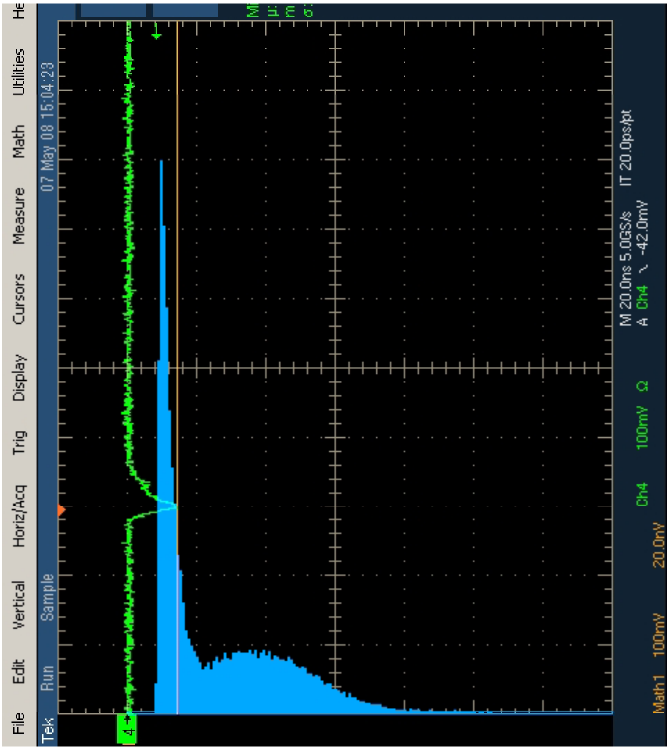
Trigger, PMT, monostable and Inegrator (green) outputs



Inegrator output (green); Integrating gate (yellow)

Laboratory Test

- Source
  AmBe + HDPE$\rightarrow$ thermal neutrons
- Detector
  Bicron BC-454: 1”×1” dia.
  Wrapped with Tyvek
- PMT
  Hamamatsu R8900u-03



PHA of anode signal

Conclusions

- Boron loaded scintillators are suitable for measuring secondary neutrons produced by high-energy particles: protons & electrons
- Neutron flux can be used to discriminate hadron and electro-magnetic particles
- Combined effectiveness of all e/p discriminators techniques employedTBD
- Only moderate improvement in detection efficiency for ^{10}B concentrations >few% in thick moderators
- Bottom scintillator might serve as cascade penetration counter (TBC)