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Design, Construction and Simulation of an ADRIANO Prototype Detector

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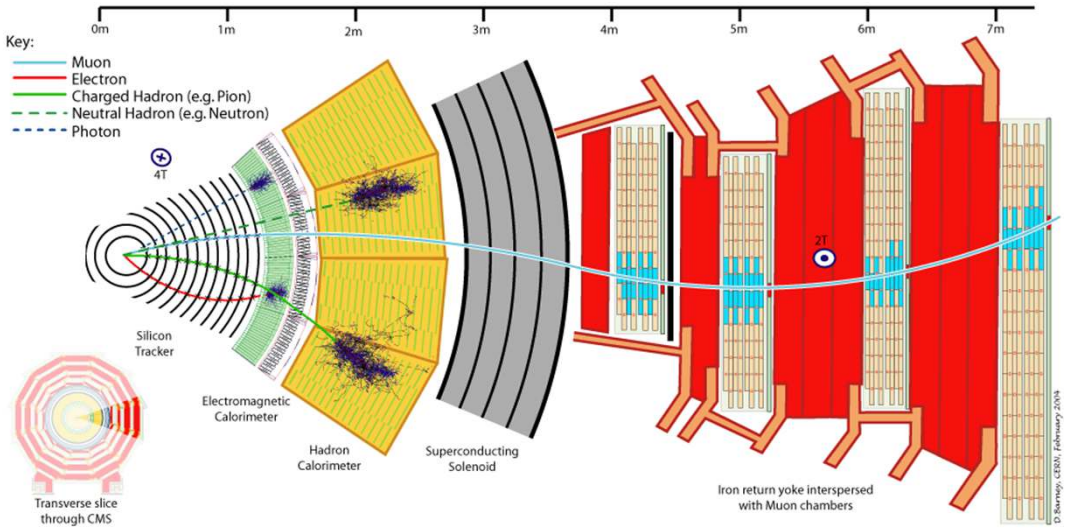
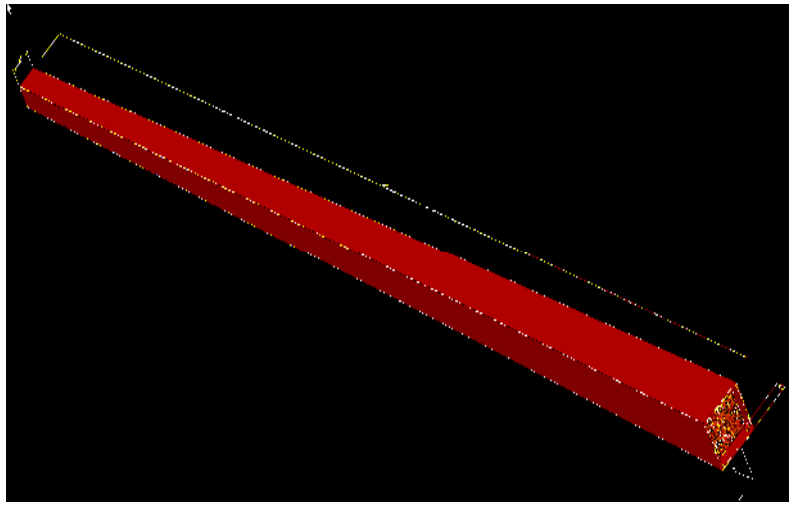
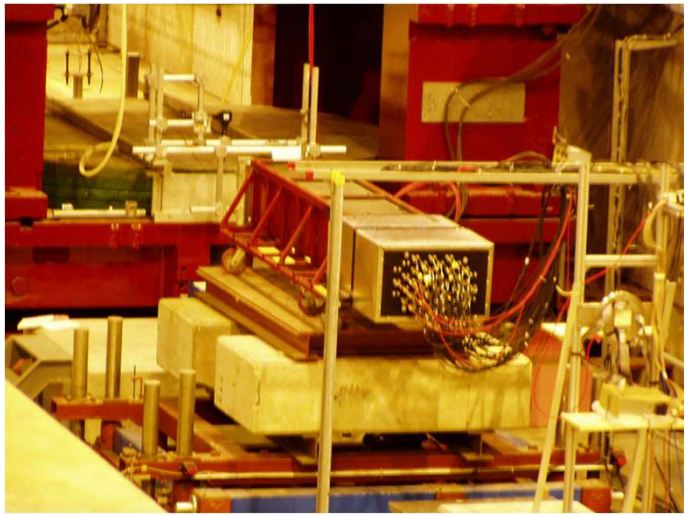
Mentor: Corrado Gatto, INFN Sezione di Napoli
25 July 2014

Introduction

- Detectors at the LHC
- Dual-readout Calorimetry
- Sampling Technique
  - Metal to initiate shower
  - Small active sections
  - Dim output
  - Large unbalance between čerenkov and scintillating light

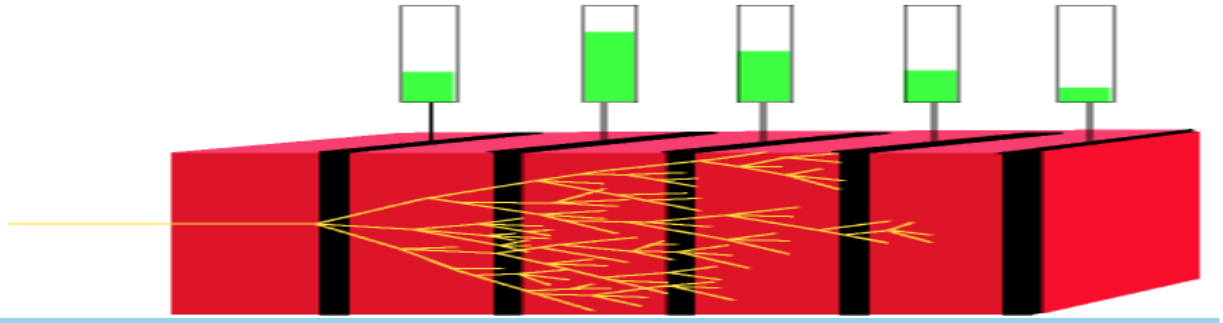






Calorimetry

- Determining particle energy by absorption
- 2 primary categories: EM & Hadronic (EM, Ionizing, neutral)
- Particles enter the calorimeter and shower, creating hits
- $N_{hits} \propto$ energy
- Conventional calorimetry gives same signal for all three
- EM is simple: $\sigma \approx\propto 3\text{–}10\%$
- Hadronic is not: $\sigma \approx\propto$ 50-100%
- Knowing the amount of each group in a shower will allow hits to be weighted to determine #hits per category and ultimately energy



Dual-readout Calorimetry

- Čerenkov threshold allows for EM detection
- Hadrons are almost always too slow and heavy
- Scintillator collects light from unexciting fermions
- Also collects light from neutrons that scatter protons
- $E_{D.R.} \propto \check{C}_{(EM)}|_{\check{c}} + S_{(EM+ion+n)}|_{s}$
- Most EM and ionizing radiation absorbed by 50 ns
- Neutrons last over 1000 ns
- $WF(t) = \propto (\check{C}_n) + \beta(n)$
- $E_{T.R.} \propto (\cup|_{(} + S|_{s}) + N|_{n}$

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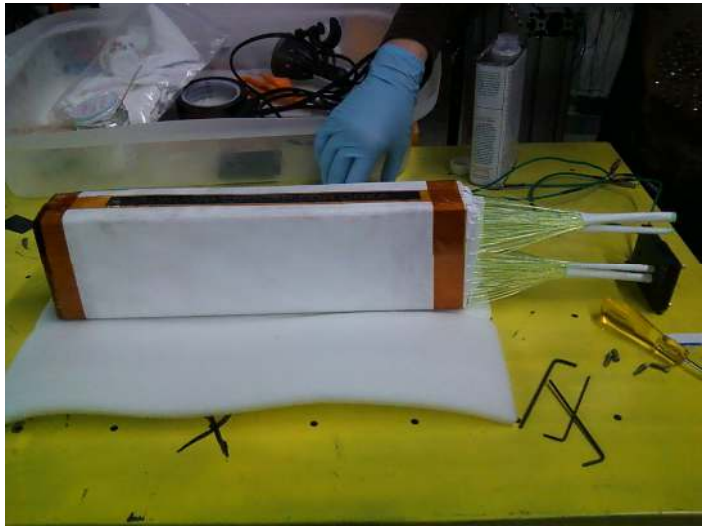
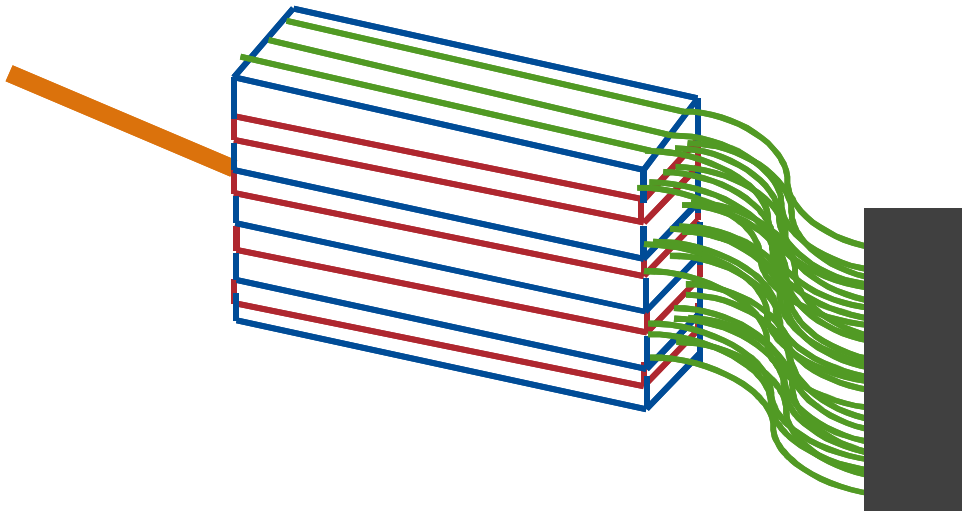
The ADRIANO Technique

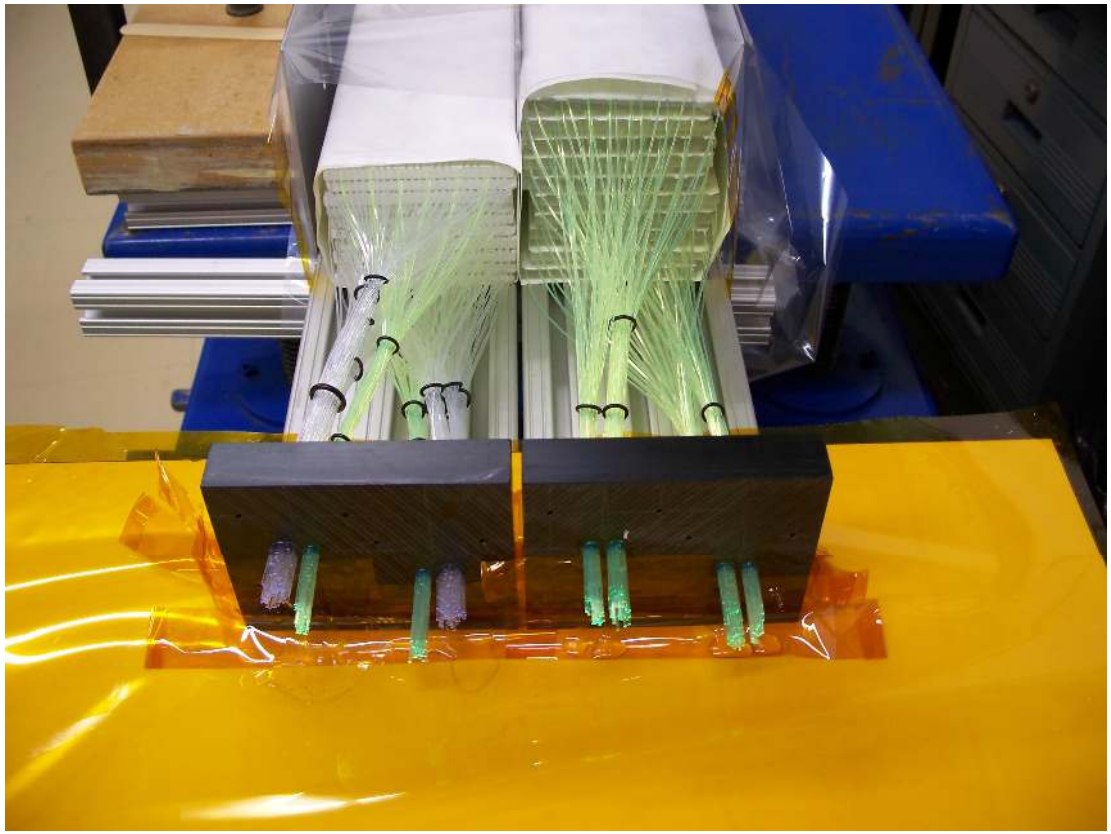
- **A** **D**ual **R**eadout **I**ntegrally **A**ctive **N**on-homogenous **O**ption
- Layers of heavy lead glass ($n_i \approx 1.5$) bonded to WLS fibers
- Layers of scintillating plastic/glass/fibers
- Two mediums separated by layers of Teflon
- PMTs or SiPMs attached to the bundles of fibers
- Currently using TB4 DAQ designed by Paul Rubinov

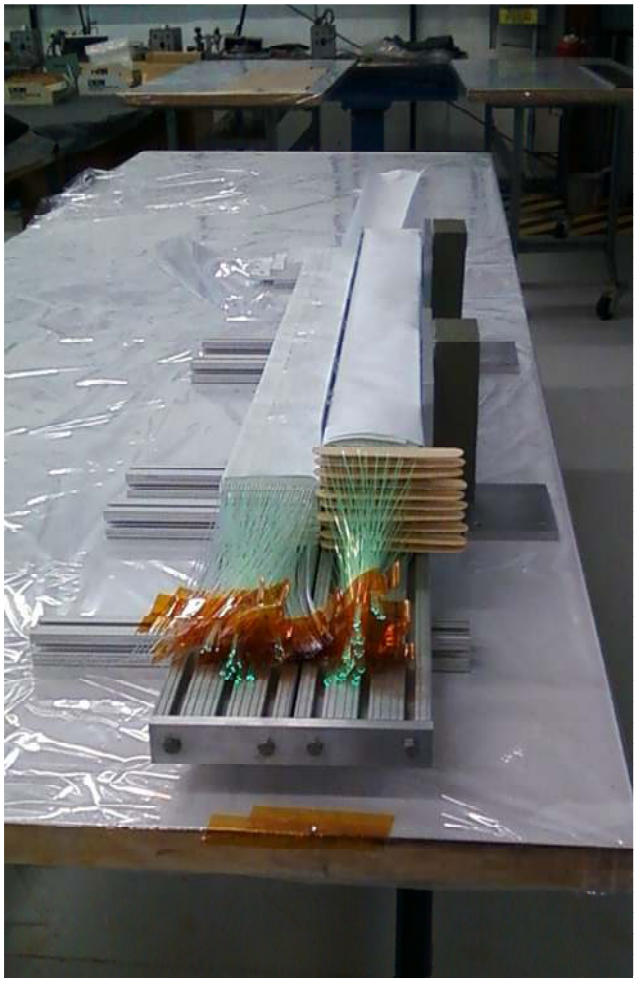




Design

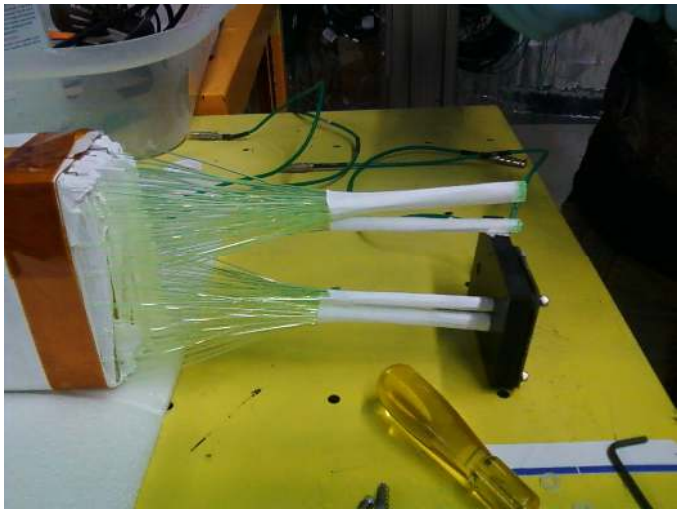
- Multiple versions of ADRIANO prototype
- Each test different materials for Active Dual Readout

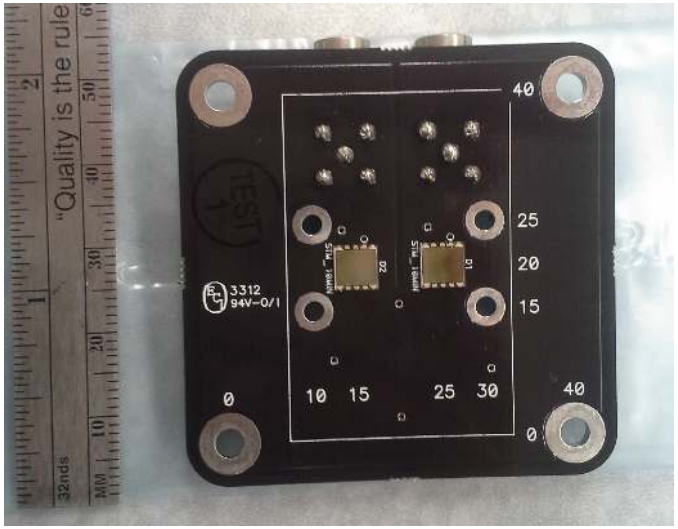




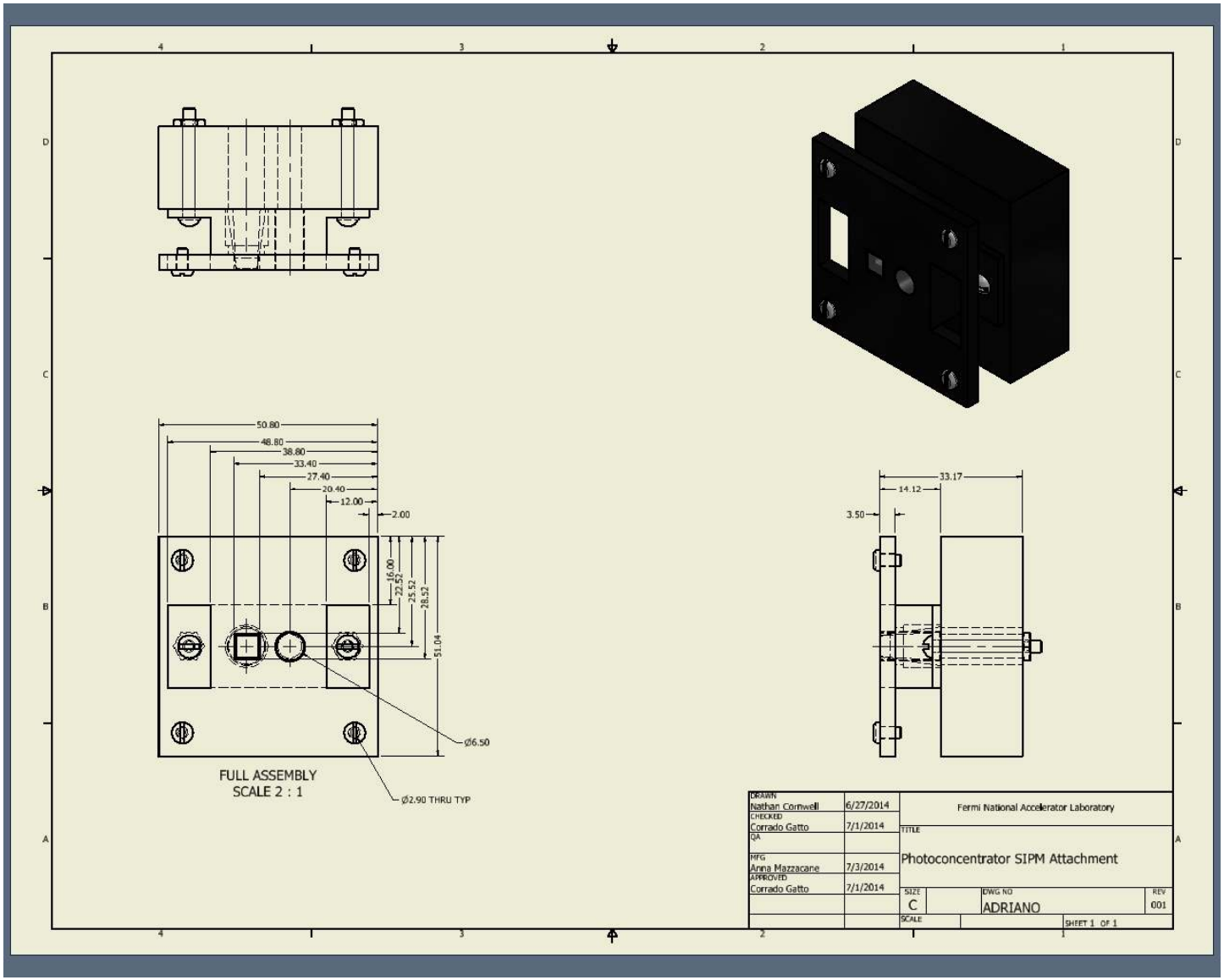
My Design

- Top WLS bundle 2x diameter of SiPM
- Photoconcentrator from INFN-*Treiste* experiment
- Used for 2011 ADRIANO test beam
- Designed and 3D printed adapter for attaching photoconcentrator to SiPM
- Also determined viability of 3D printing in laboratory setting
- Proved immensely useful





My Design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48.80
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22.52
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51.04
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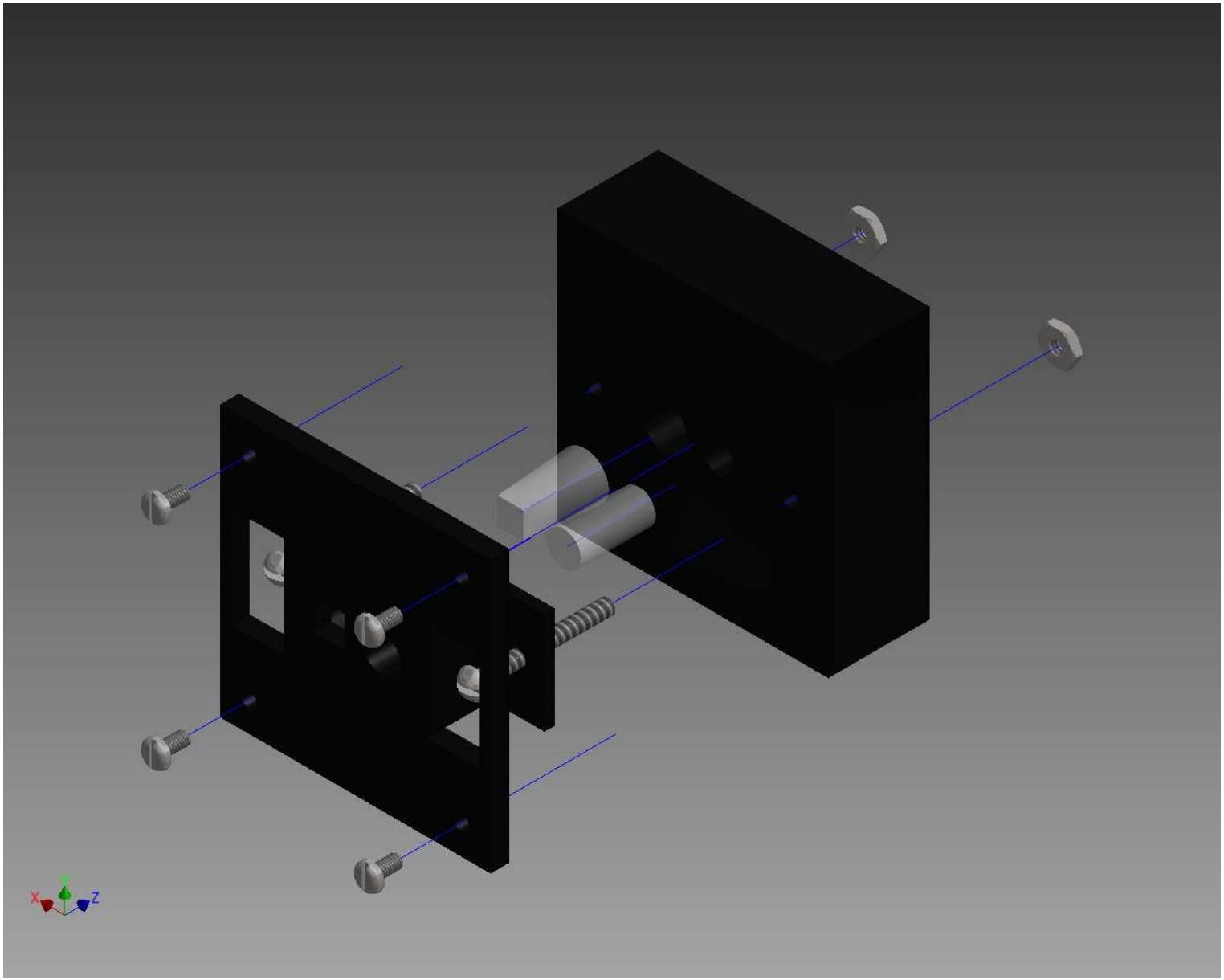
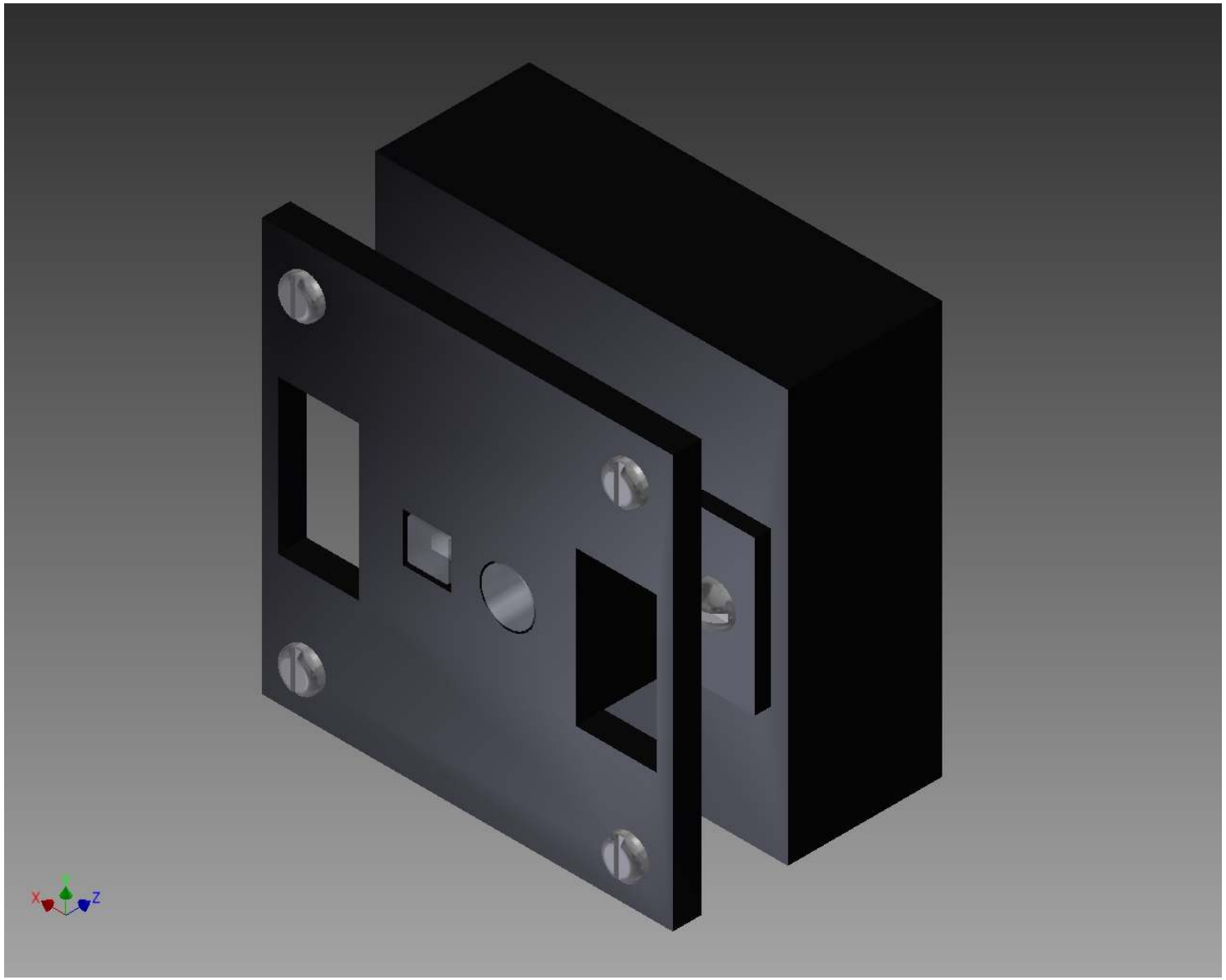
FULL ASSEMBLY
SCALE 2 : 1
33.17
14.12
3.50
DRAWN Nathan Cornwell 6/27/2014
CHECKED Corrado Gatto 7/1/2014
QA
MFG Anna Mazzacane 7/3/2014
APPROVED Corrado Gatto 7/1/2014
Fermi National Accelerator Laboratory
TITLE
Photoconcentrator SIPM Attachment
SIZE C
DWG NO ADRIANO
REV 001
SCALE
SHEET 1 OF 1

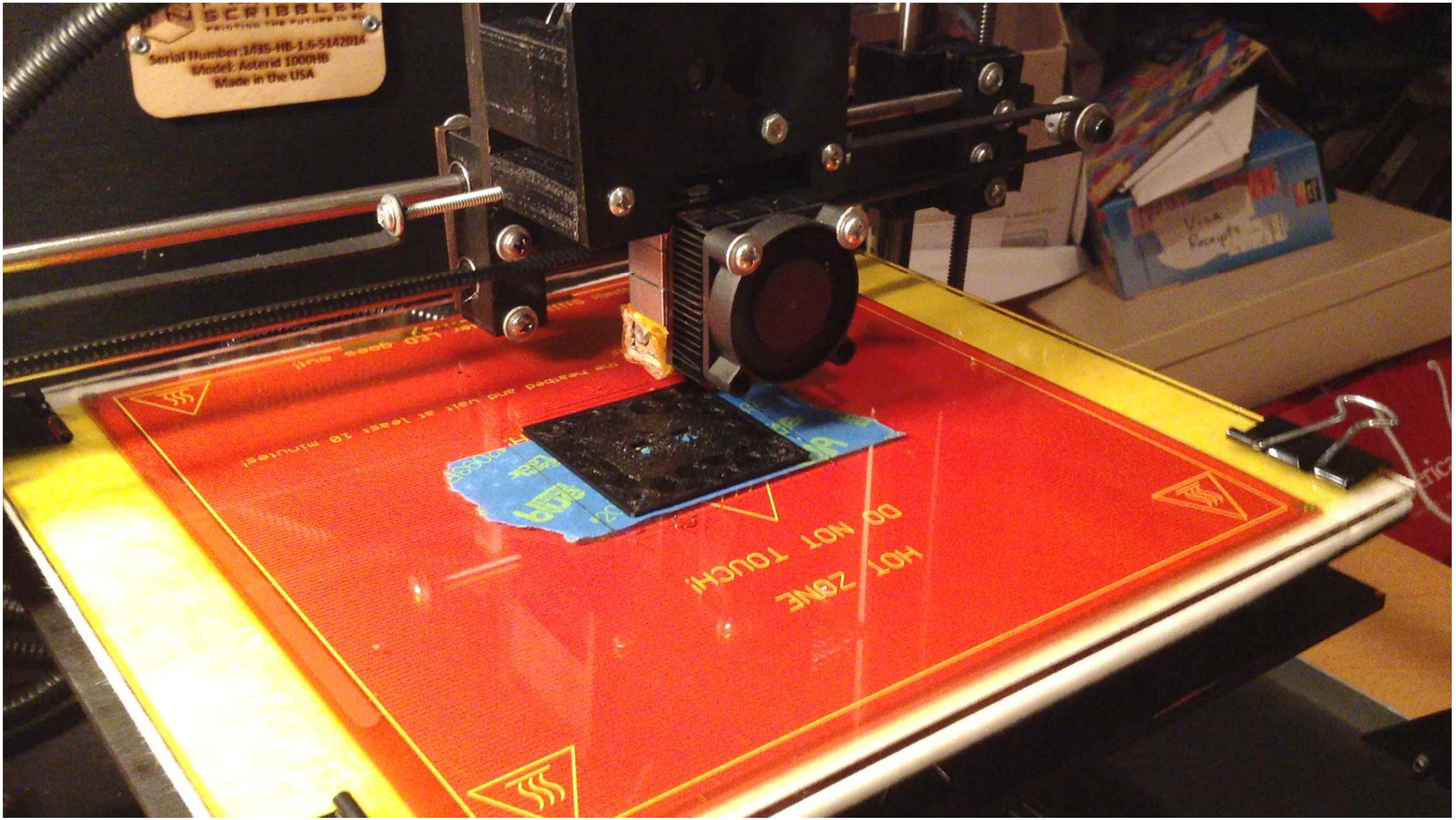
My Design



My Design



3D Printing



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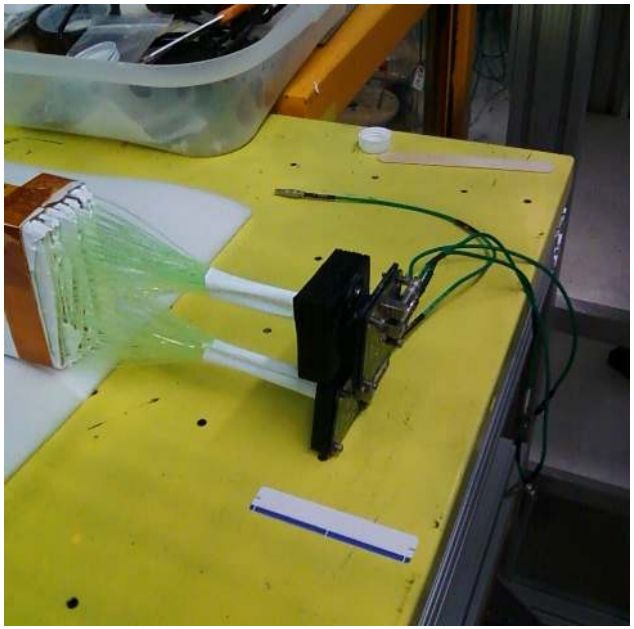
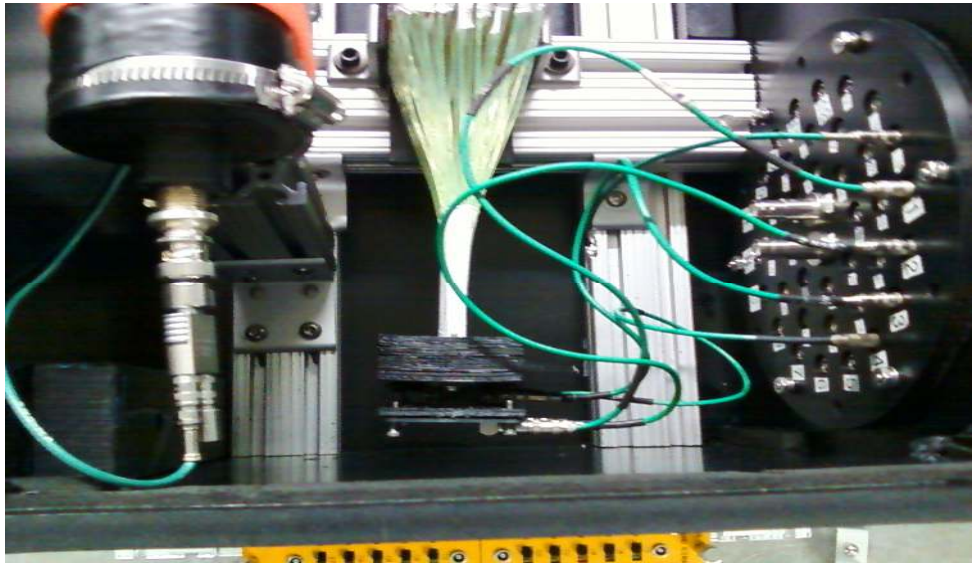
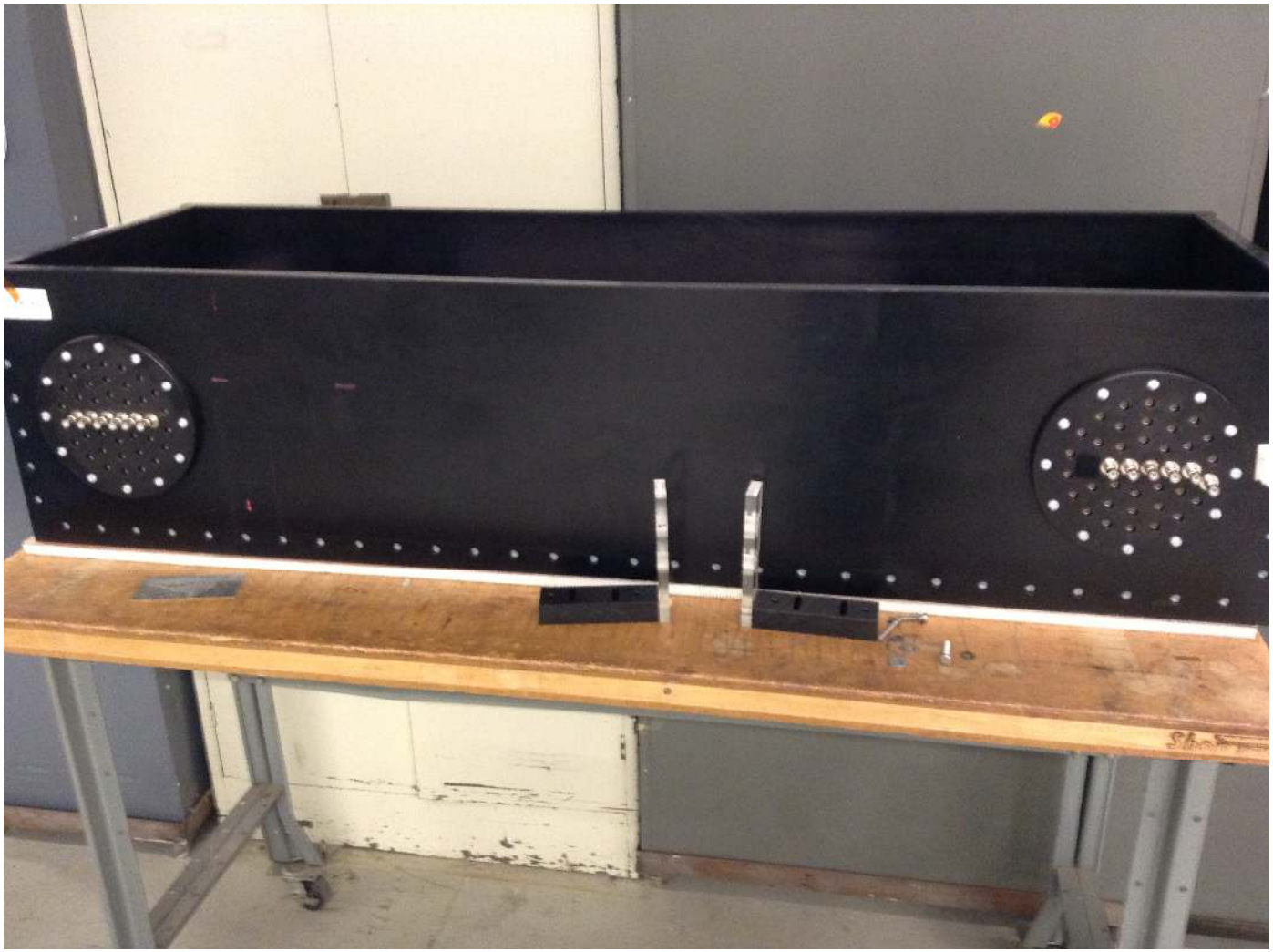
Final Product





Construction

- Assembly in Lab 7 by Eileen Hahn

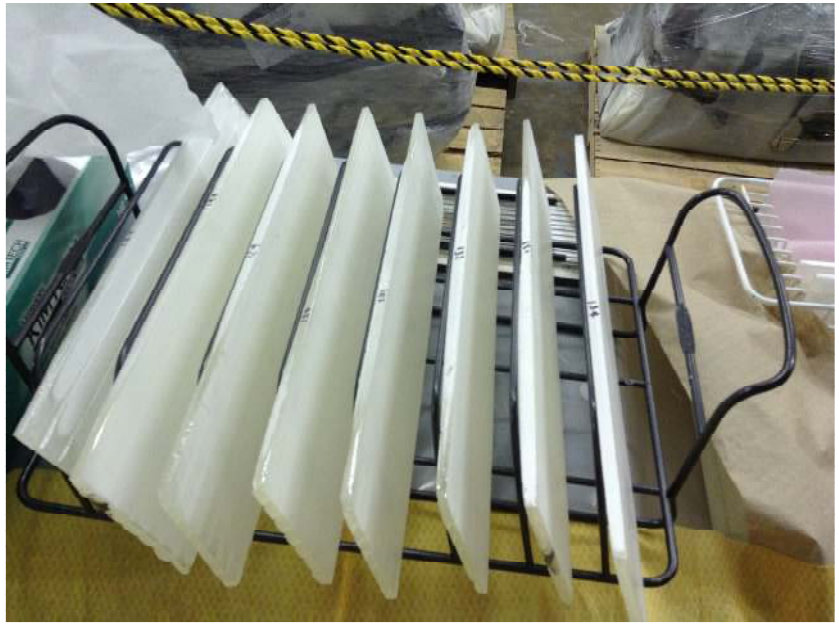


Precision Molding of Lead Glass









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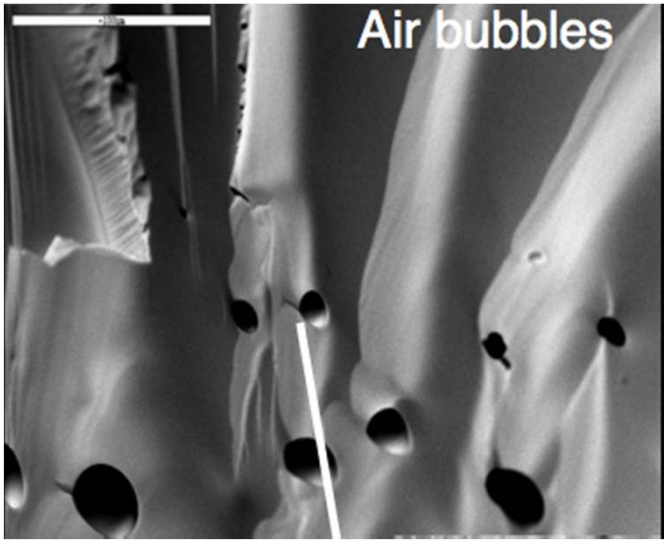
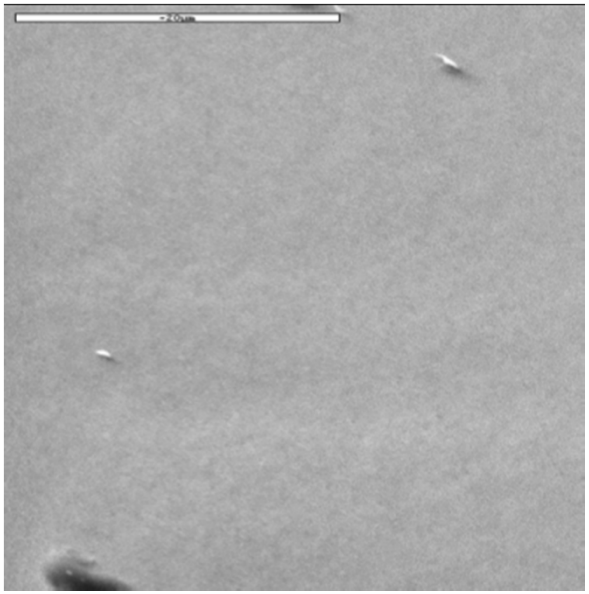
Glass Quality Control





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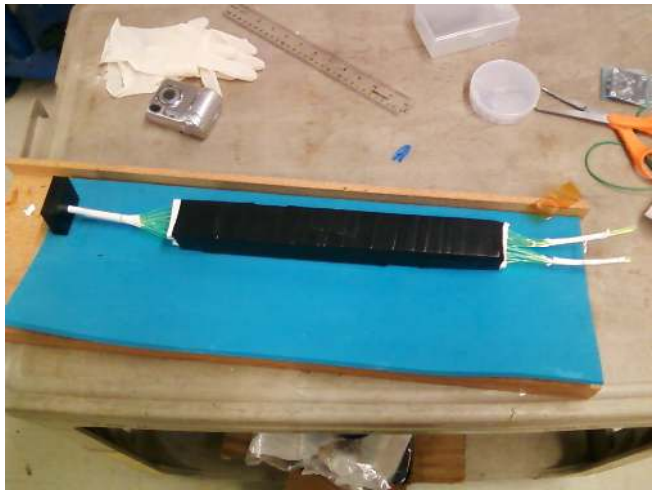
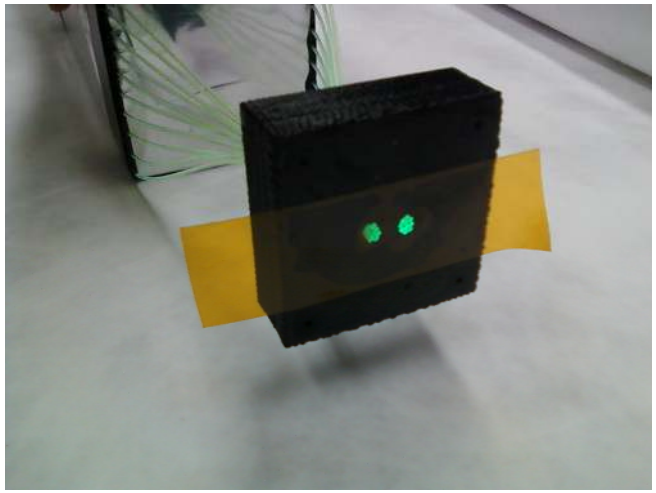
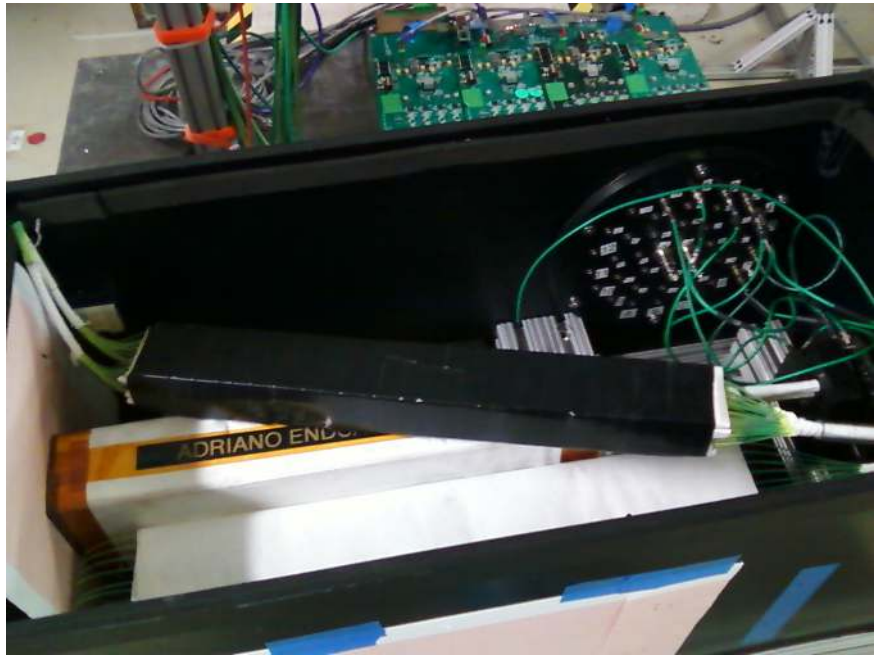
More Detectors







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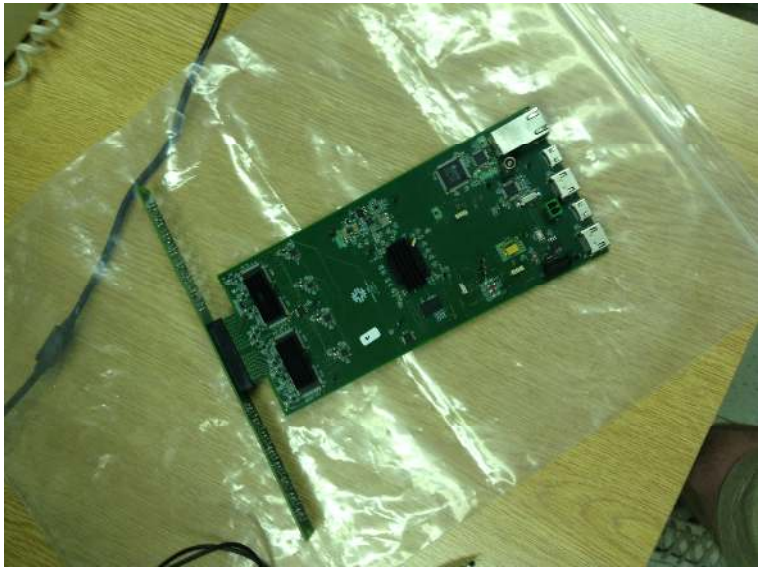
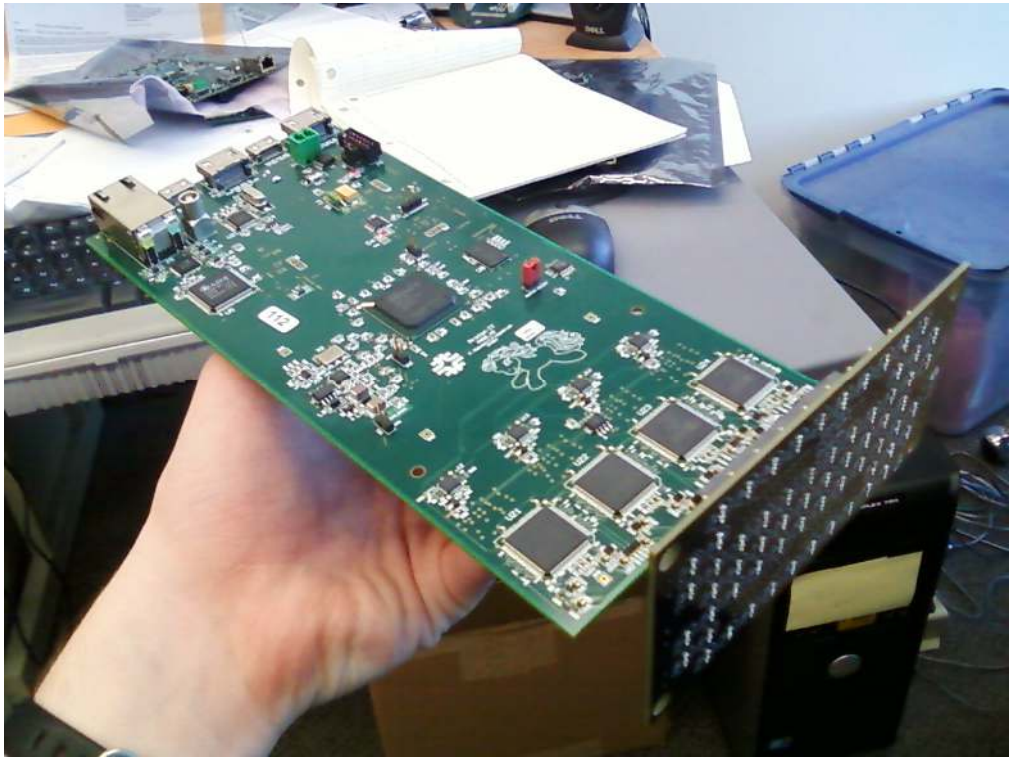
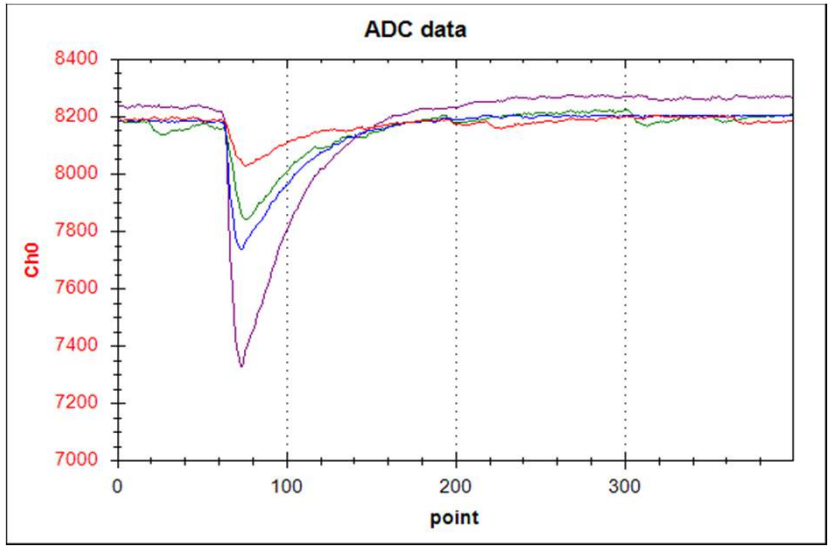
Data Acquisition (DAQ)







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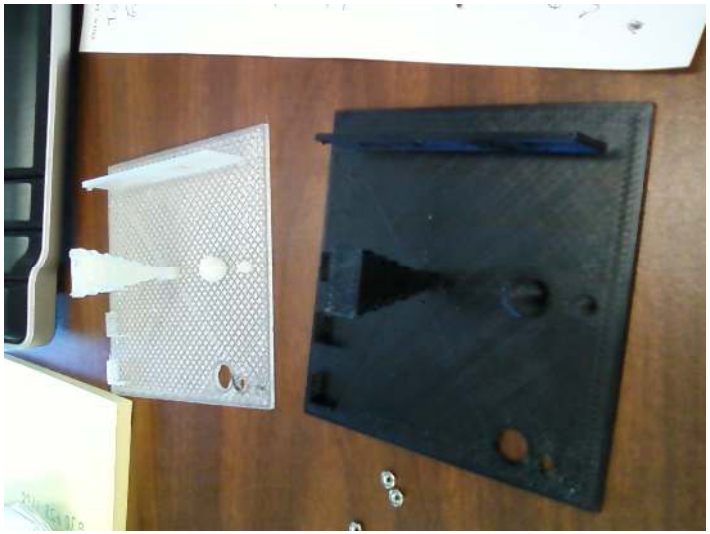
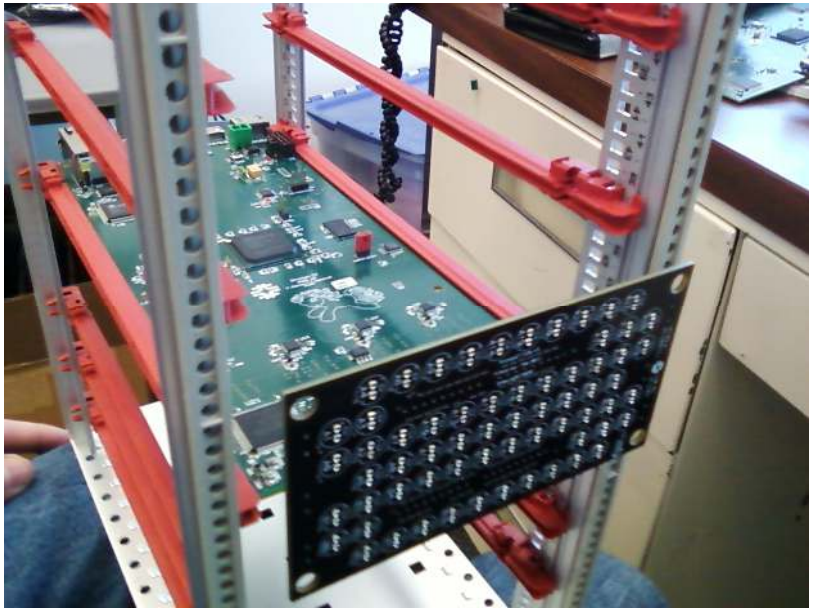
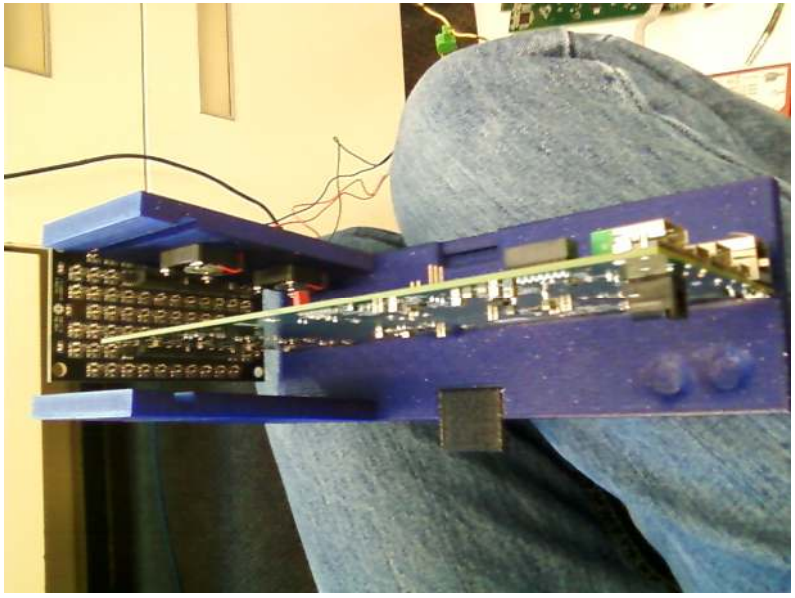
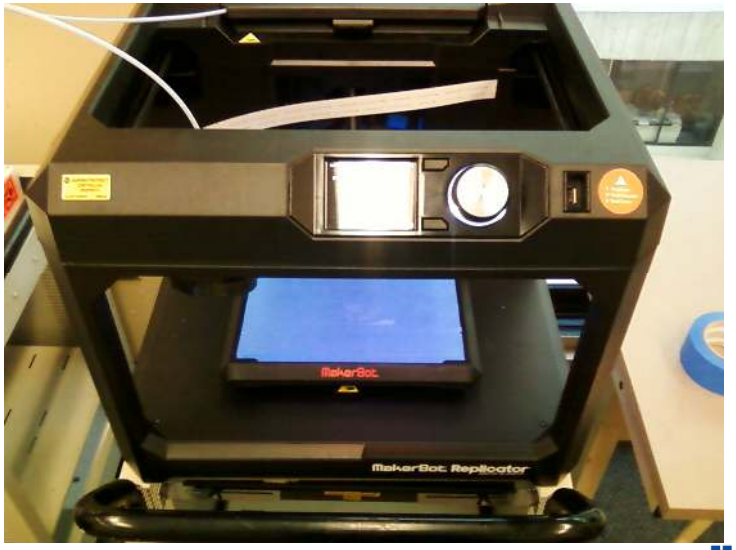
Another Project









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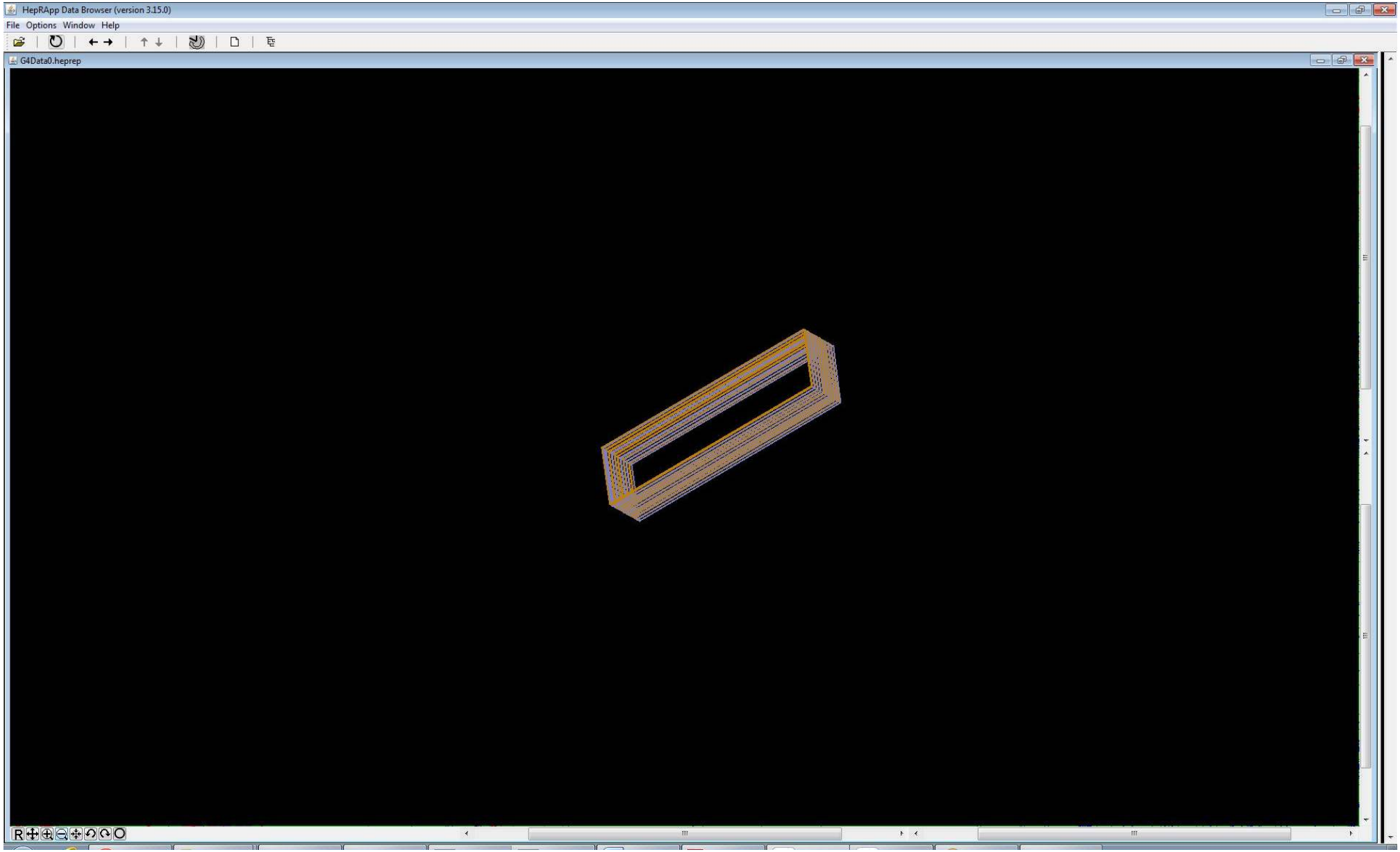
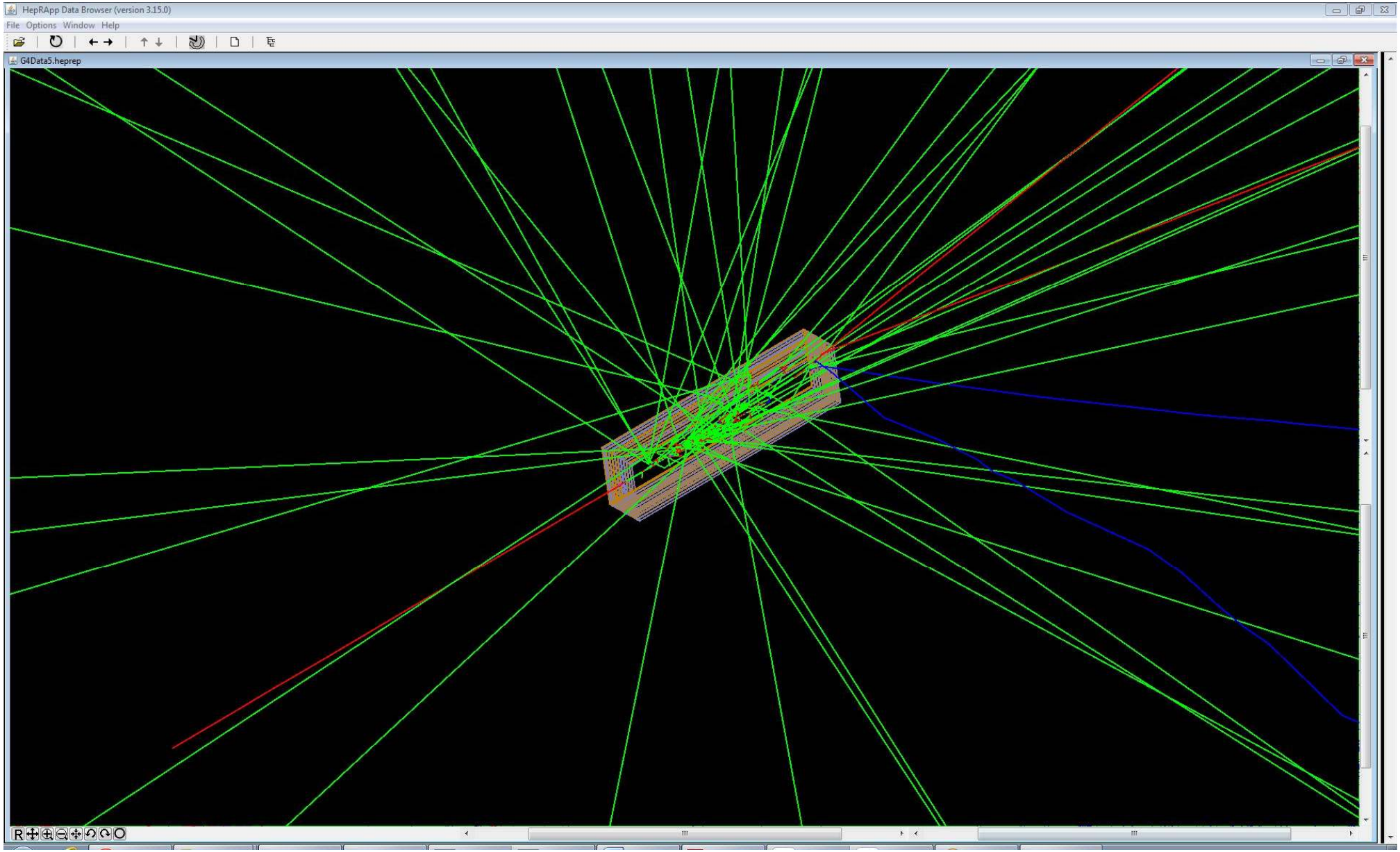
Simulation


HepRApp Data Browser (version 3.15.0)
File Options Window Help
G4Data0.heprep

Simulation



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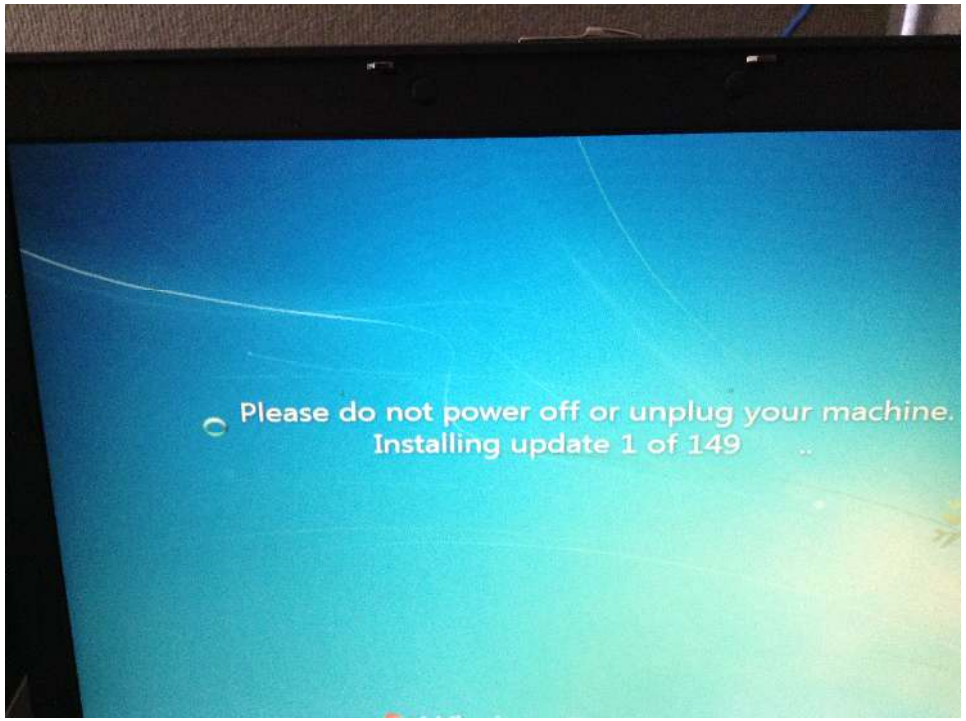
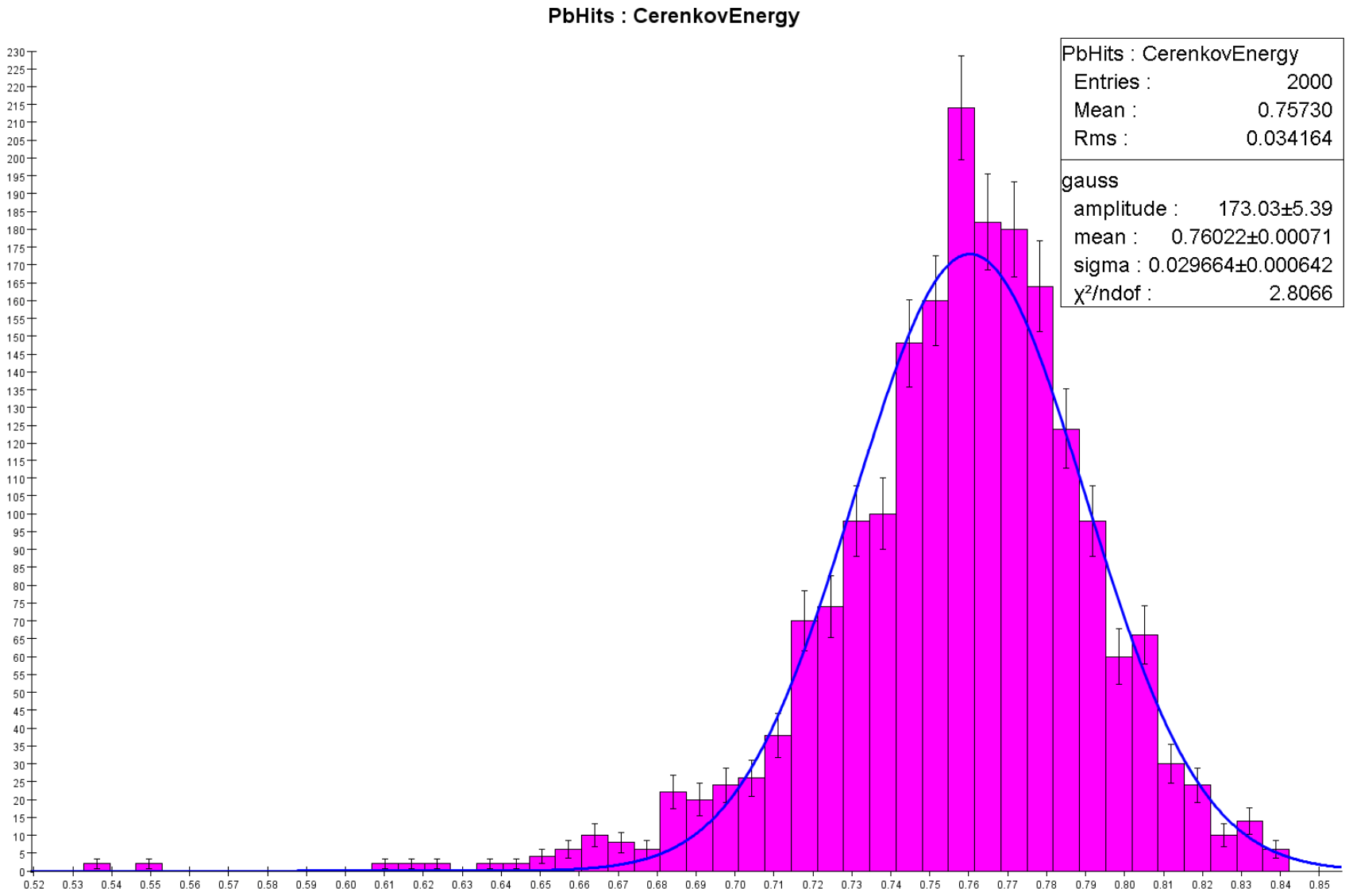
Simulation

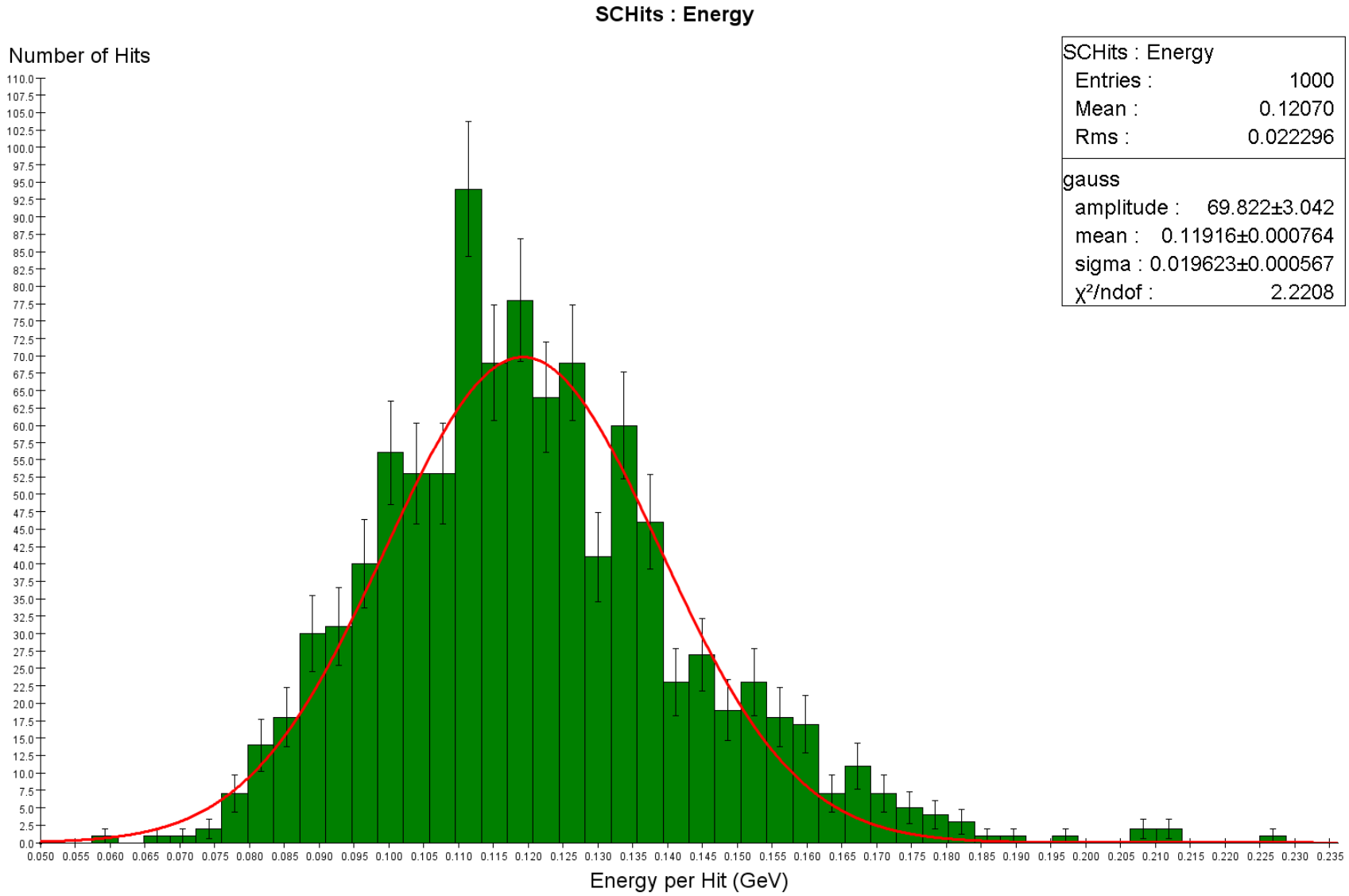
- FreeCAD
- CAD => GDML
- GDML => LCDD
- CLHEP + Geant4 + LCDD = SLIC
- SLIC => LCIO
- LCIO => JAS3
- NetBeans => JAS3
- JAS3 => AIDA
- AIDA => Presentation!



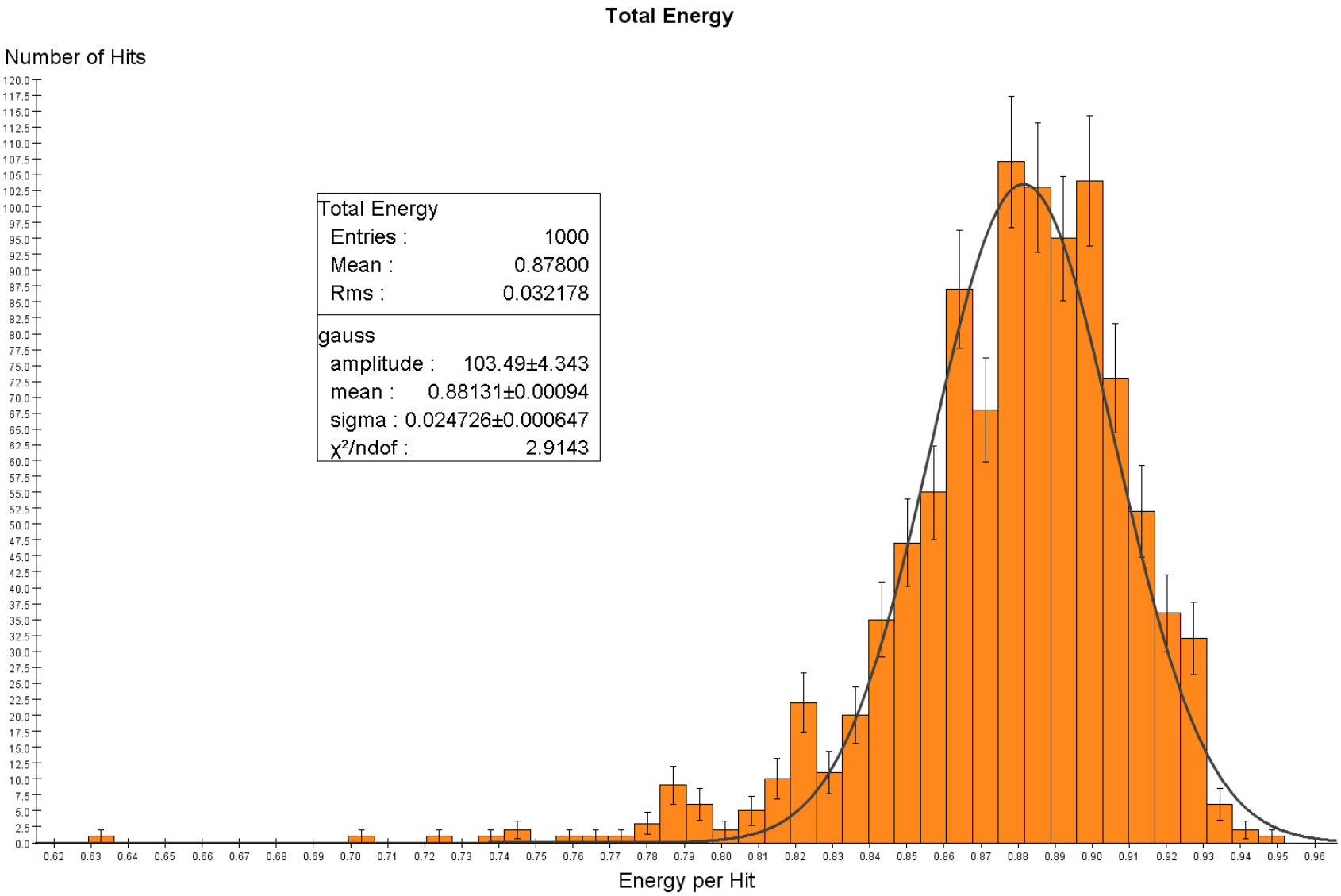
1 GeV


PbHits : CerenkovEnergy
PbHits : CerenkovEnergy
Entries : 2000
Mean : 0.75730
Rms : 0.034164
gauss
amplitude : 173.03±5.39
mean : 0.76022±0.00071
sigma : 0.029664±0.000642
χ²/ndof : 2.8066

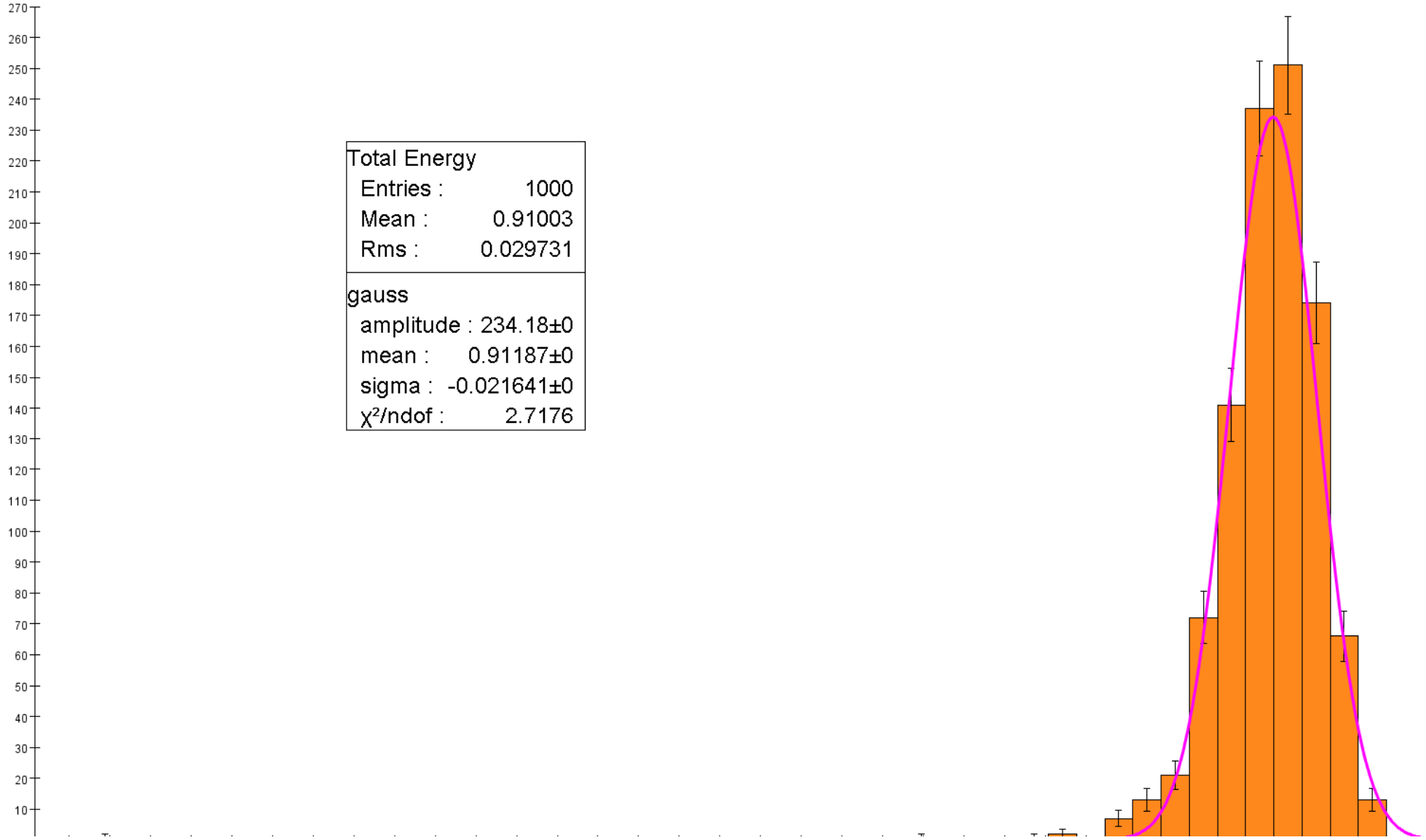
1 GeV


SCHits : Energy
Number of Hits
Energy per Hit (GeV)
SCHits : Energy
Entries : 1000
Mean : 0.12070
Rms : 0.022296
gauss
amplitude : 69.822±3.042
mean : 0.11916±0.000764
sigma : 0.019623±0.000567
χ²/ndof : 2.2208

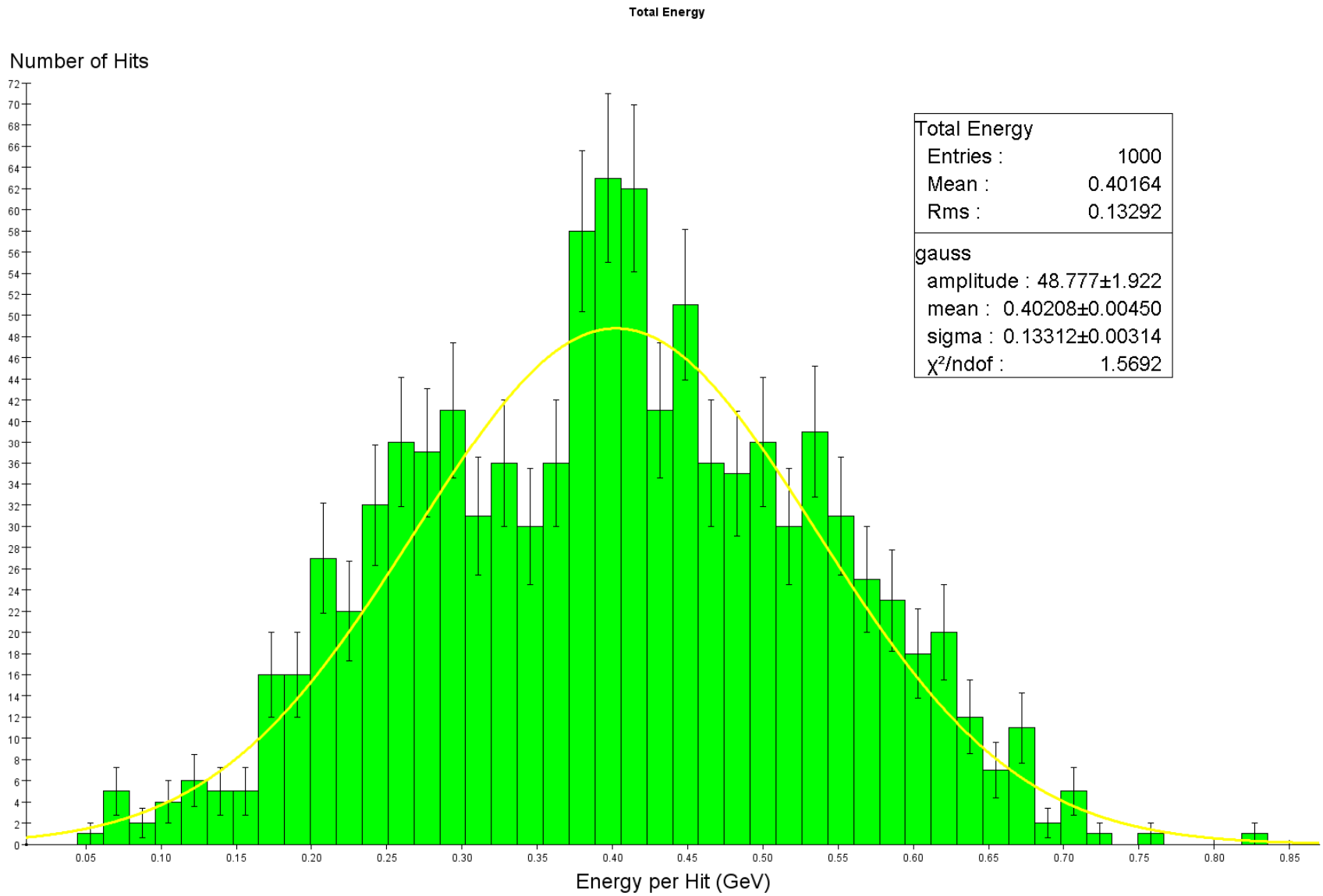
1 GeV


Total Energy
Number of Hits
Total Energy
Entries : 1000
Mean : 0.87800
Rms : 0.032178
gauss
amplitude : 103.49±4.343
mean : 0.88131±0.00094
sigma : 0.024726±0.000647
χ²/ndof : 2.9143
Energy per Hit

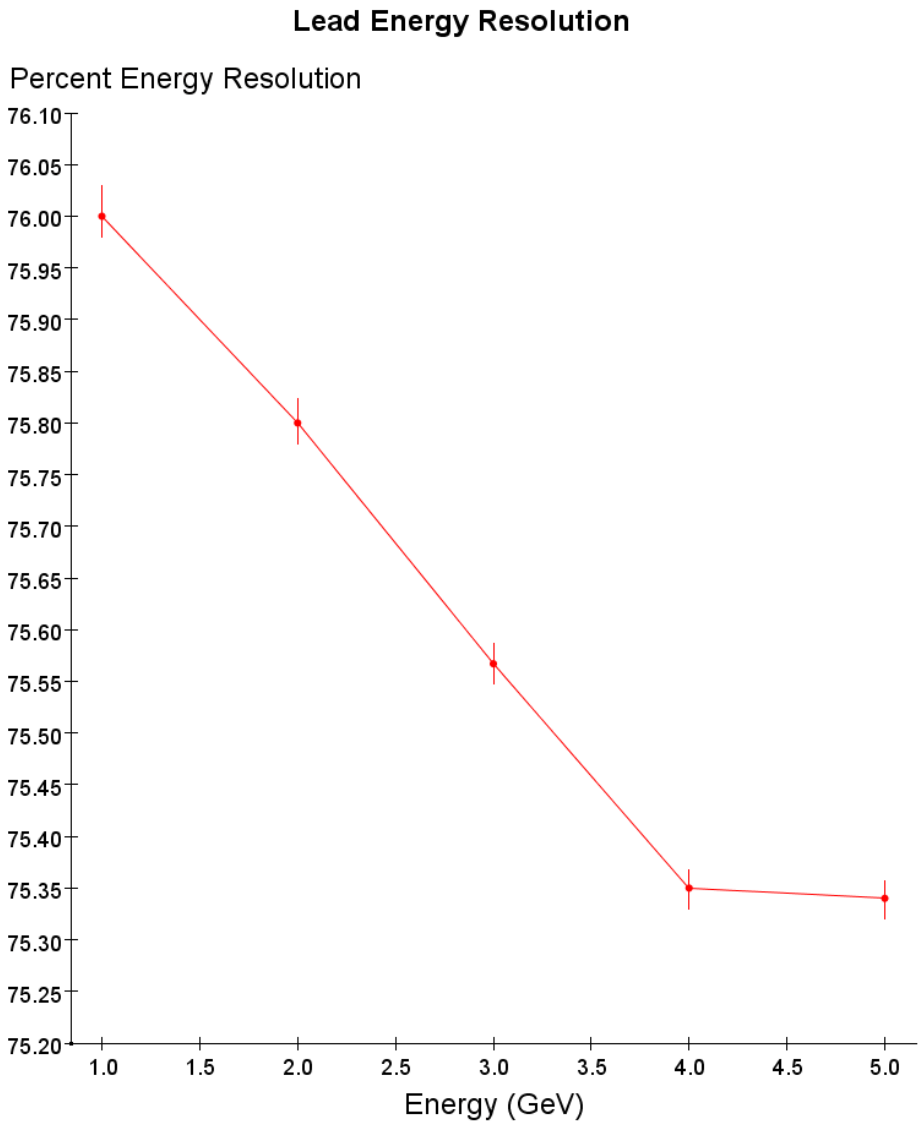
1 GeV Lead Glass



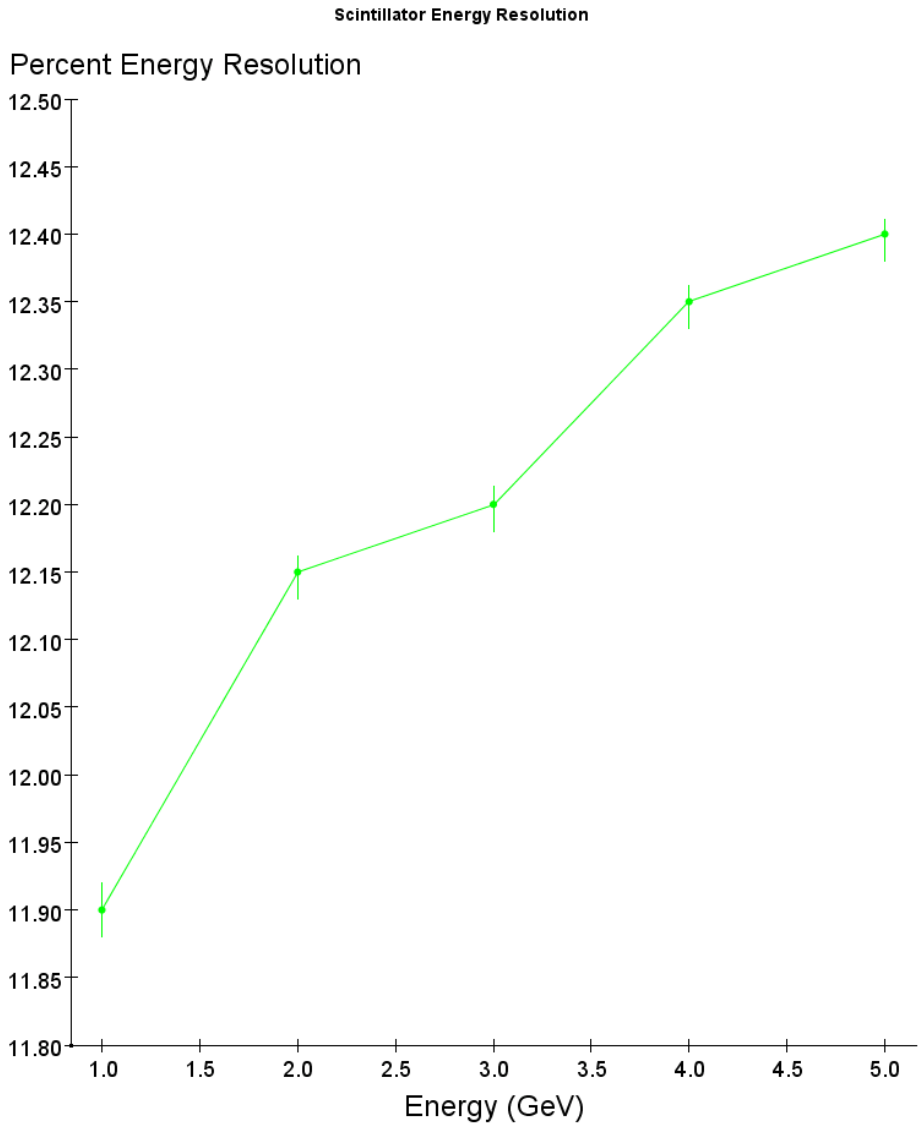
1 GeV Plastic Scintillator



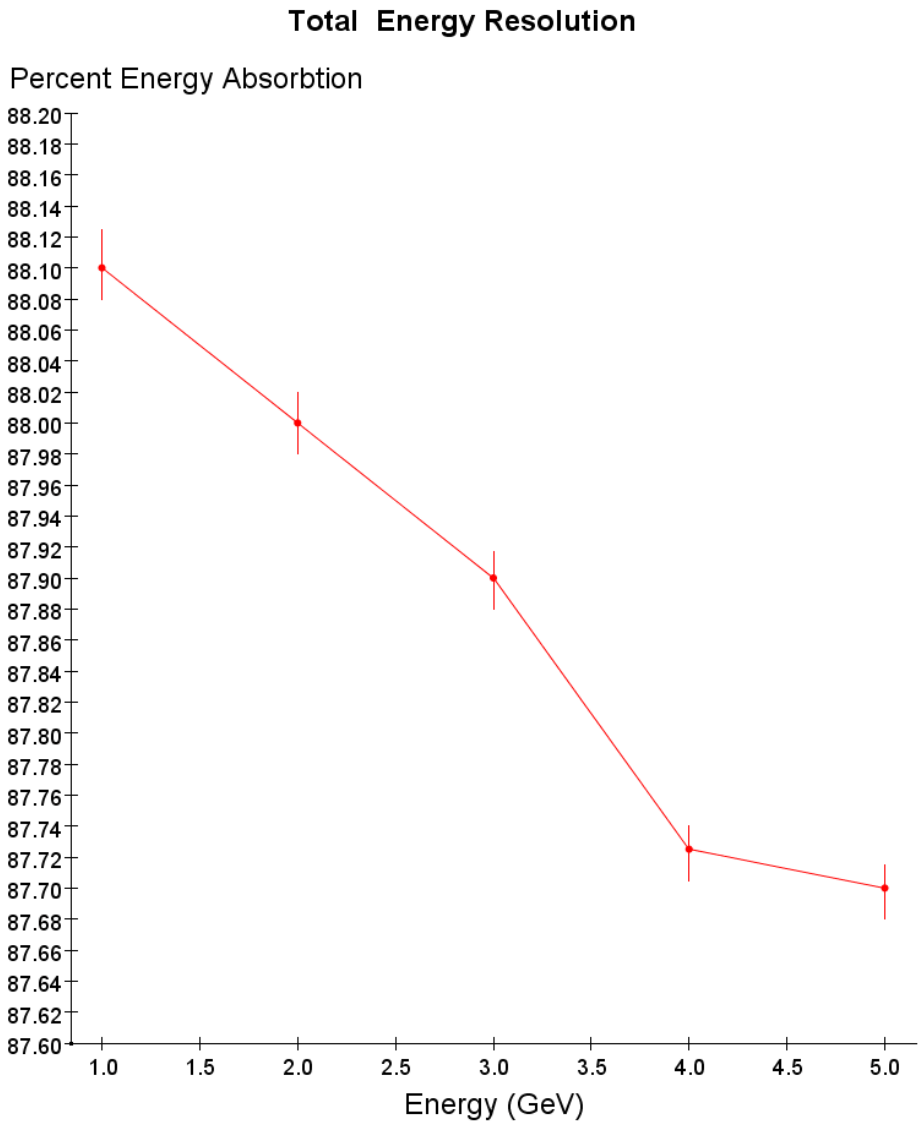
Lead Energy Resolution



Scintillator Energy Resolution



Total Energy Resolution



Conclusion

- At lower energy levels, ADRIANO shows remarkable containment
- A larger cell would be necessary as energy increases
- Current data should be adjusted to account for loss in energy
- Regardless of size (ADRIANO is only a prototype), active dual readout calorimetry is able to provide substantial data with minimal losses
- There has been so much to learn
- I have gained many wonderful experiences
- A career in science is definitely a possibility!

Acknowledgements

None of this would be possible without the endless help from:

- Corrado Gatto
- Chris Stoughton, George Dzurisko and Ian McNair
- Anna Mazzacane and Vito di Benedetto
- Estella Barbosa de Souza and Nikki Mastrud
- Eileen Hahn and Anna Pla
- Paul Rubinov
- Erik Ramberg, Aria Soha, JJ Schmidt, Todd Nebel, Ewa Skup and Bill Frank