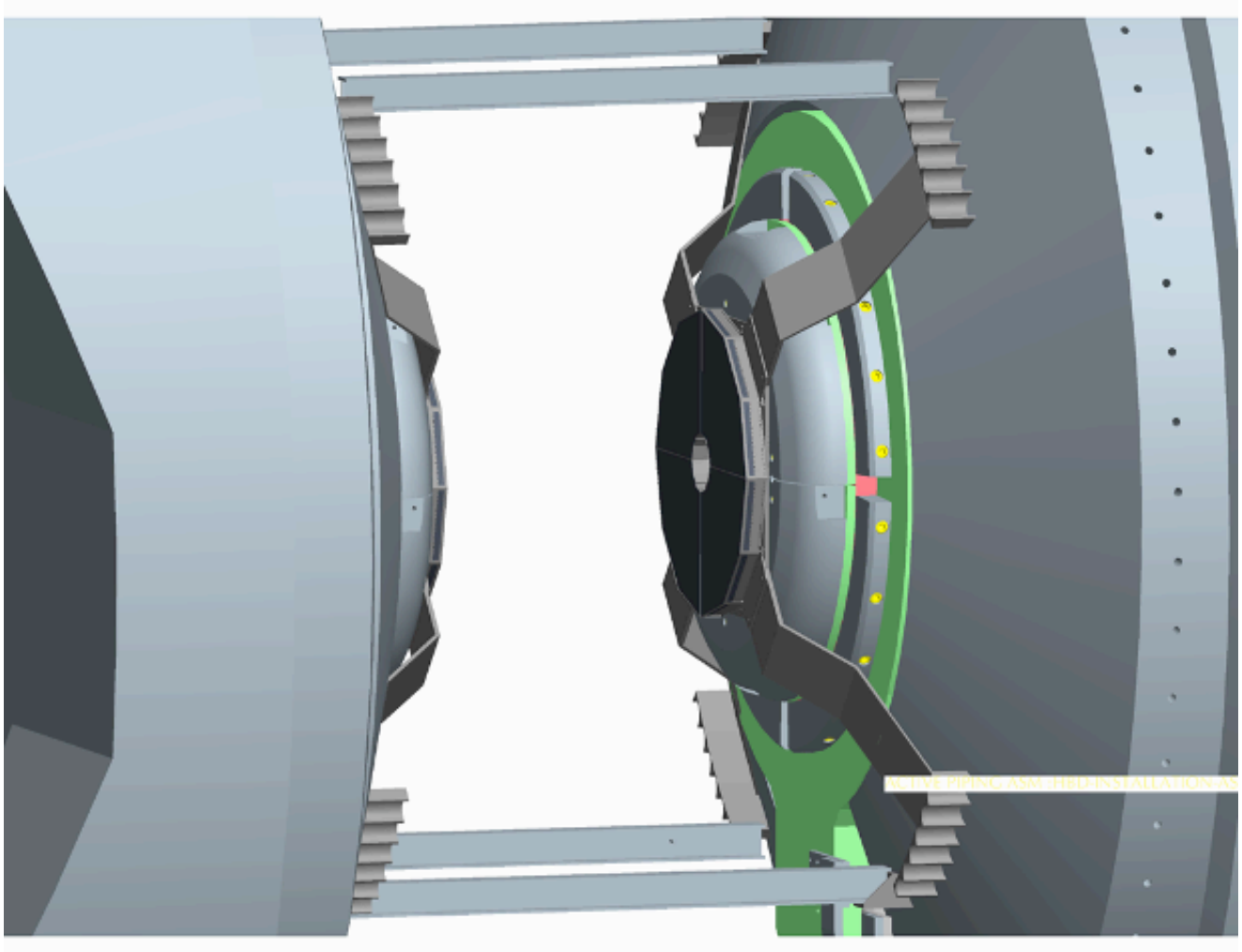
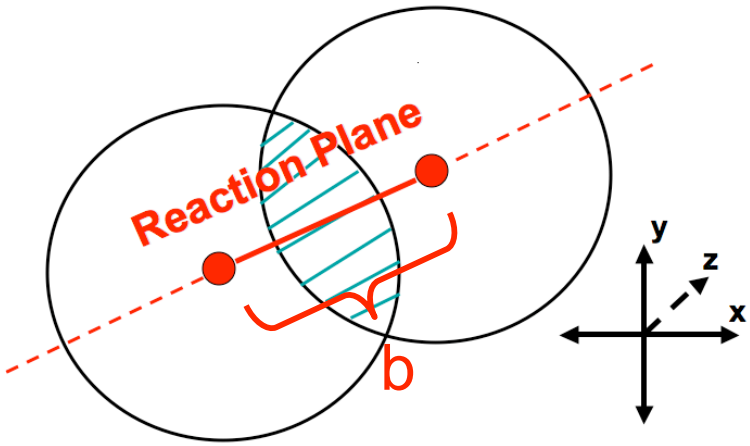
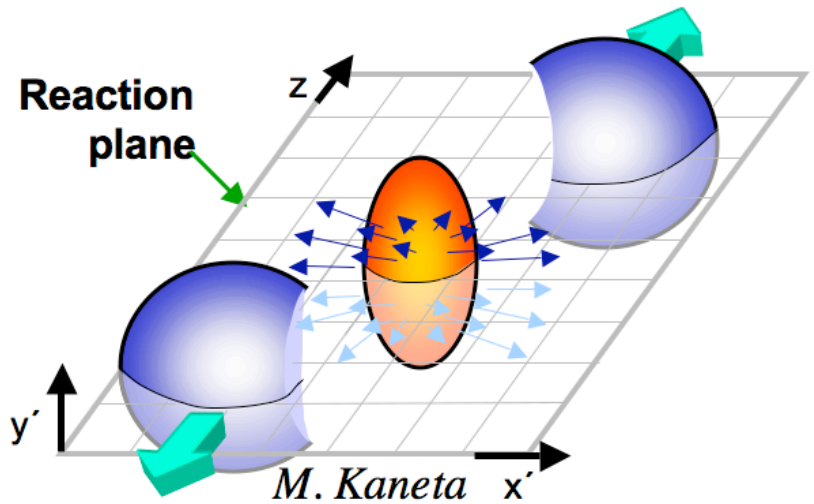
The Reaction Plane Detector



Eric Richardson
University of Maryland
PHENIX Focus Talk
1/30/07

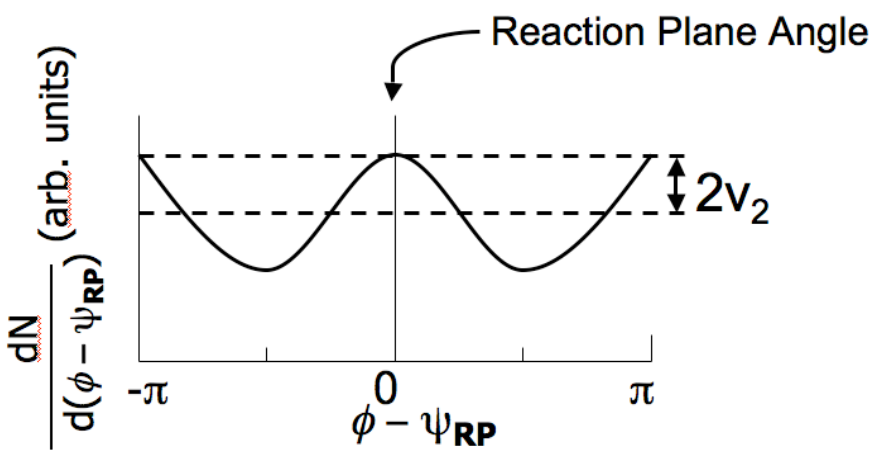
Motivation: Flow

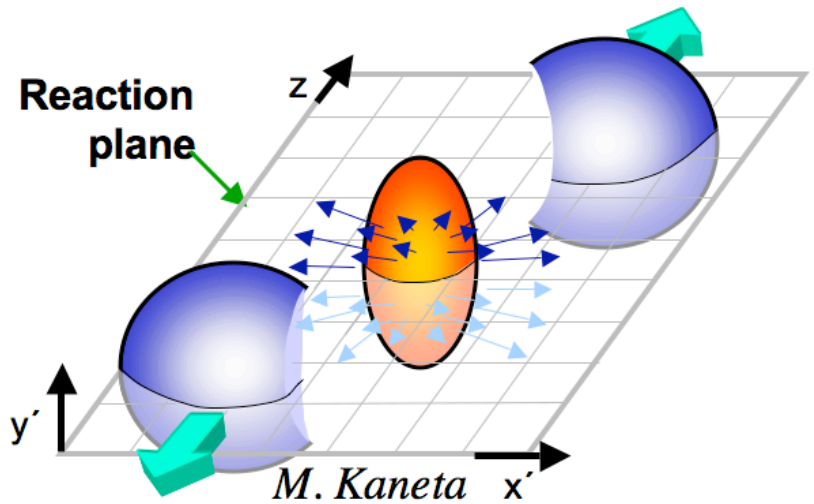




- Asymmetric distribution of produced particles in the azimuthal direction caused by a spatial anisotropy in the colliding matter
- If matter quickly becomes a thermalized system this leads to different pressure gradients

Motivation: Flow





- Asymmetric distribution of produced particles in the azimuthal direction caused by a spatial anisotropy in the colliding matter
- If matter quickly becomes a thermalized system this leads to different pressure gradients

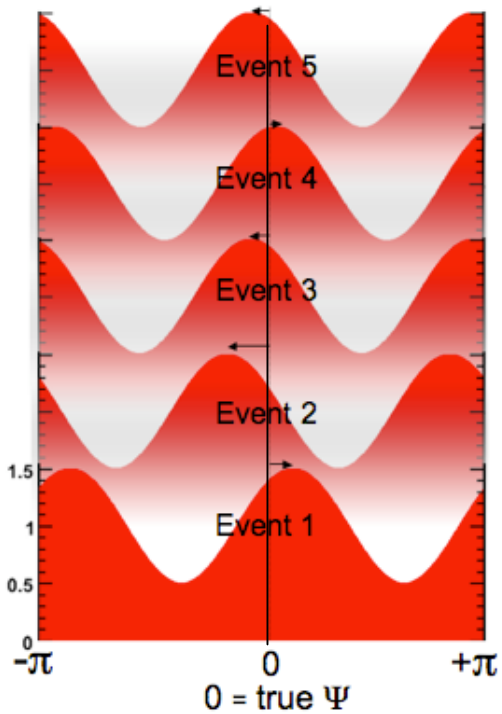
Motivation: Growing Interest

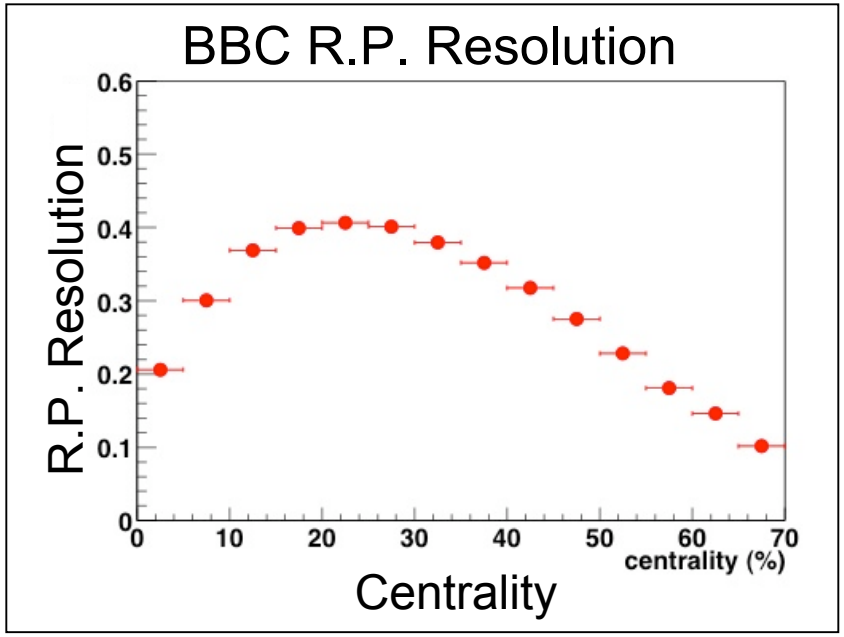
- Growing interest in measuring the flow of electrons, photons, and rare probes such as J/ψ and high p_T particles which PHENIX is ideally suited to measure
- Rare probes are difficult to measure because they are rare

Motivation: Improve Measurement

- Two ways to improve measurement
  - Improve statistics
  - Improve reaction plane resolution

- Poor reaction plane smears flow signal

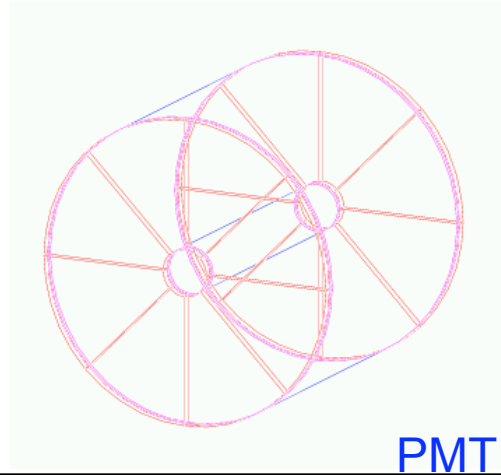


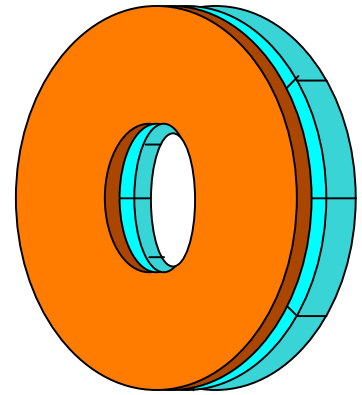


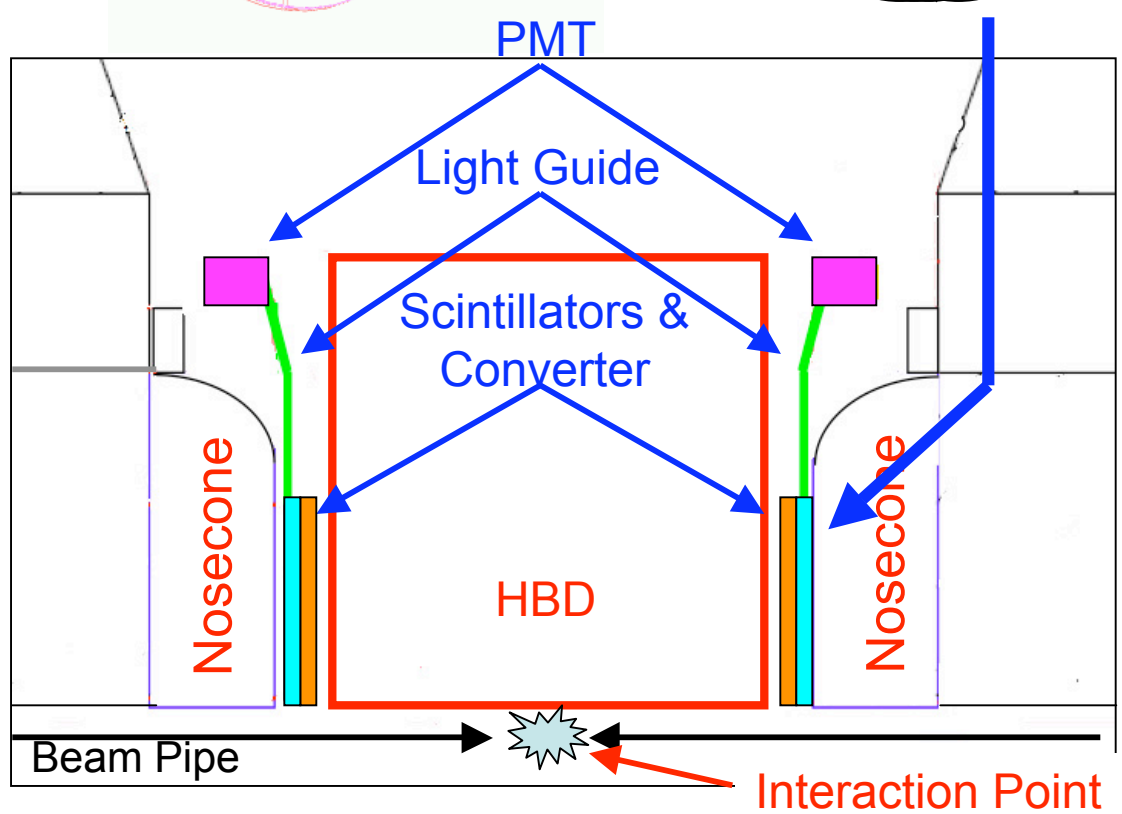
- We aim to increase this resolution with a new detector to make better flow measurements of rare probes

Basic Detector Thoughts

- Place mirror image detectors of flat scintillating segments over each nosecone
- Place converter in front of scintillators to increase energy deposition
- Detect and amplify signal with PMT's
- Connect scintillator and PMT's with light guide

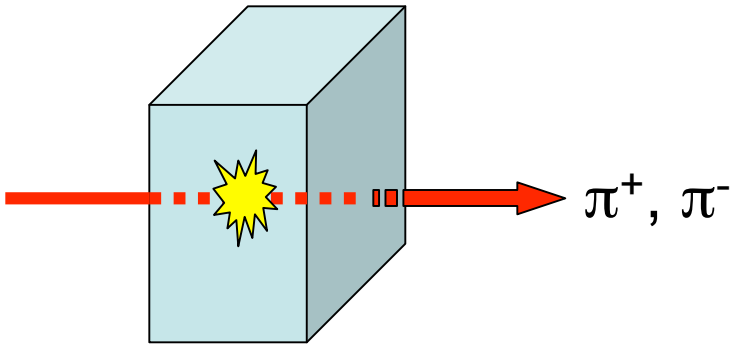


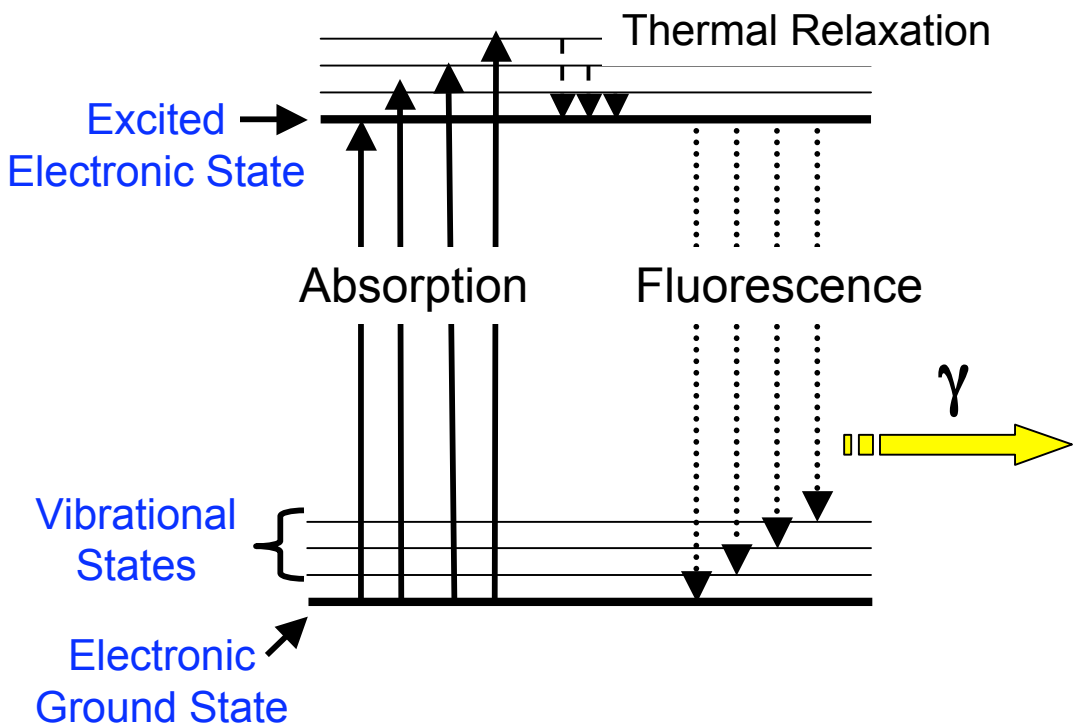




Basic Detector Components

Scintillator Basics



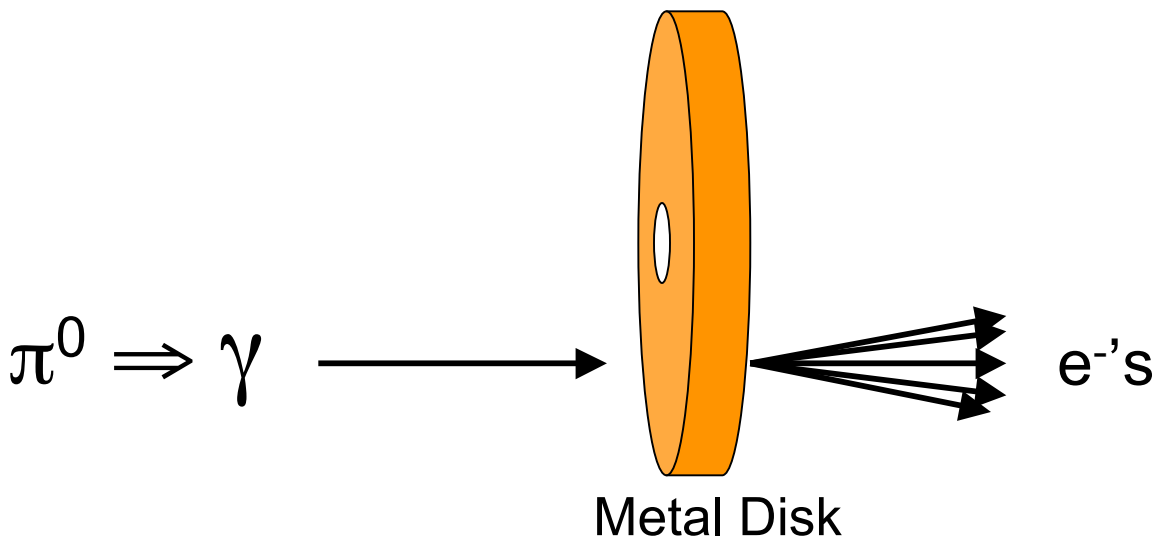


- Particle goes through plastic scintillator
- Particle deposits energy and excites electrons
- Electrons undergo thermal relaxation
- Electrons emit photons through fluorescence and return to ground state

- Generally scintillators do not detect neutral particles well

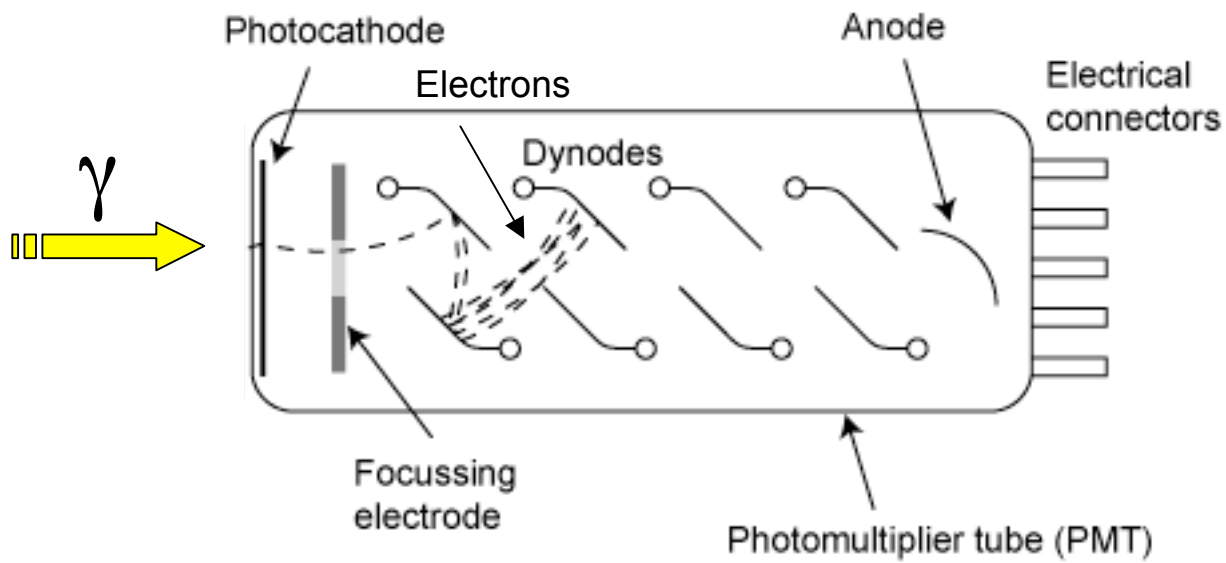
Converter Basics

- Converter is a thin metal disc placed in front of a scintillator
- Particles from collision hit converter, expelling many electrons
- This increases number of charged particles that hit scintillator, which increases energy deposition
- A way to amplify the signal
- Also helps to reduce low energy background



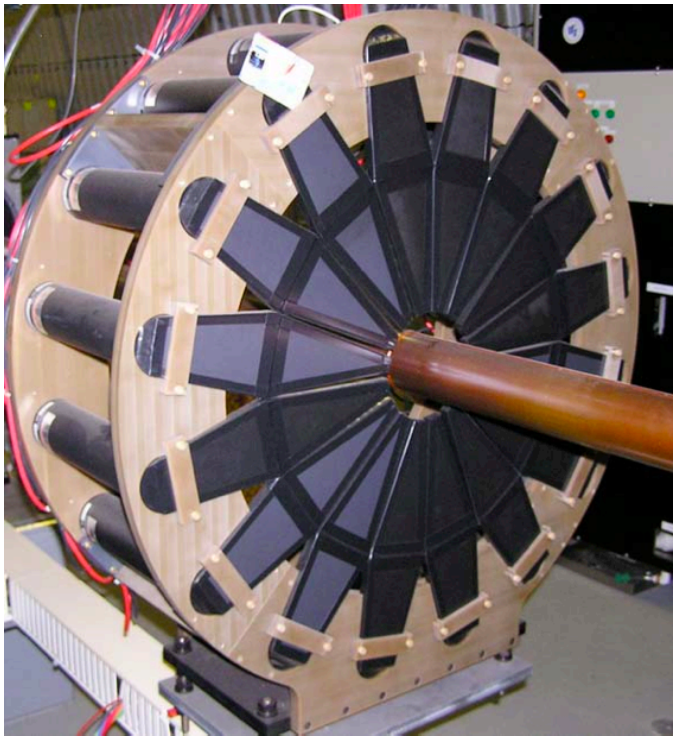
PMT Basics

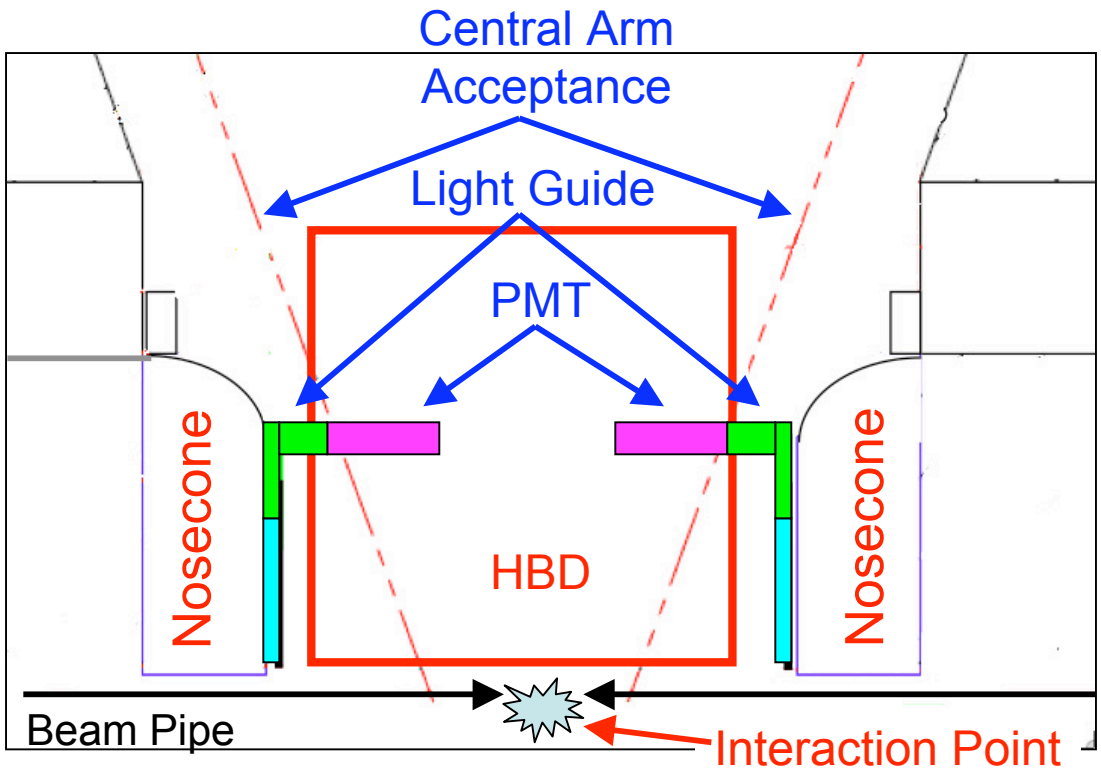
- Particles hits scintillator and generates light, which hits the photocathode and expels an electrons
- Electrons accelerates toward dynode and deposits energy
- This energy releases several electrons which are accelerated to the next dynode where even more electrons are released
- This cascading process continues until the electrons reach the anode where the current can be measured
- While in the dynamic range of the PMT the amount of current measured is directly proportional to energy deposited into the scintillator



Original Idea

- Use PHOBOS paddles
- Quickly realized paddles would intrude on HBD volume
- Would have to make so many changes it wouldn't be worth it
- Would have to start from scratch





Design Criteria: Paddle Design

- Operate in a strong magnetic field (~1T)
- Nonmagnetic
- Physically fit in the designated space
- Robust
- Avoid central arm acceptance
- Inexpensive

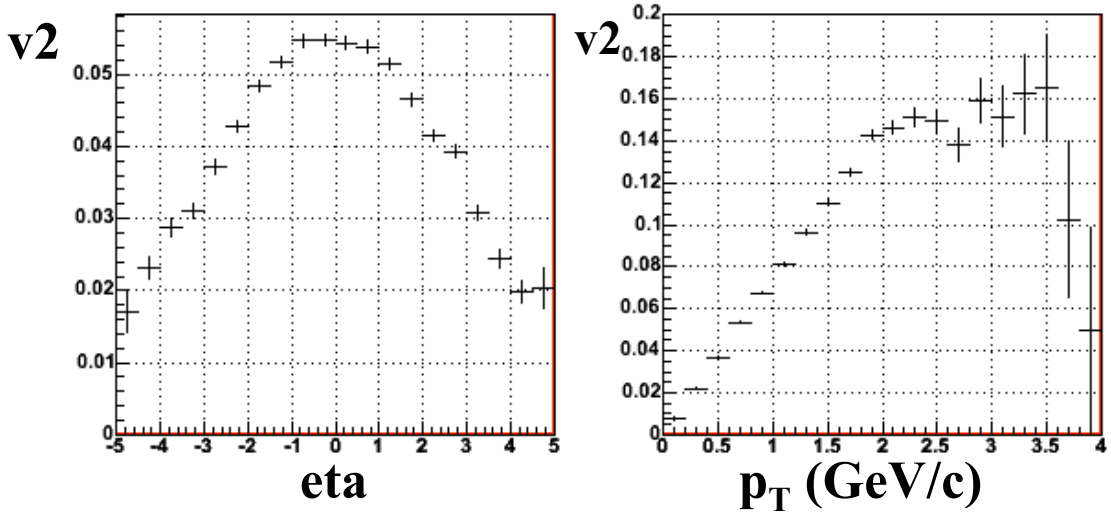
Simulations

- Done using PISA GEANT
- Performed by Shinlchi Esumi and Jiangyong Jia
- Used to study design and optimize reaction plane resolution
  - Converter thickness
  - Scintillator thickness
  - Number of scintillator segments in phi and eta

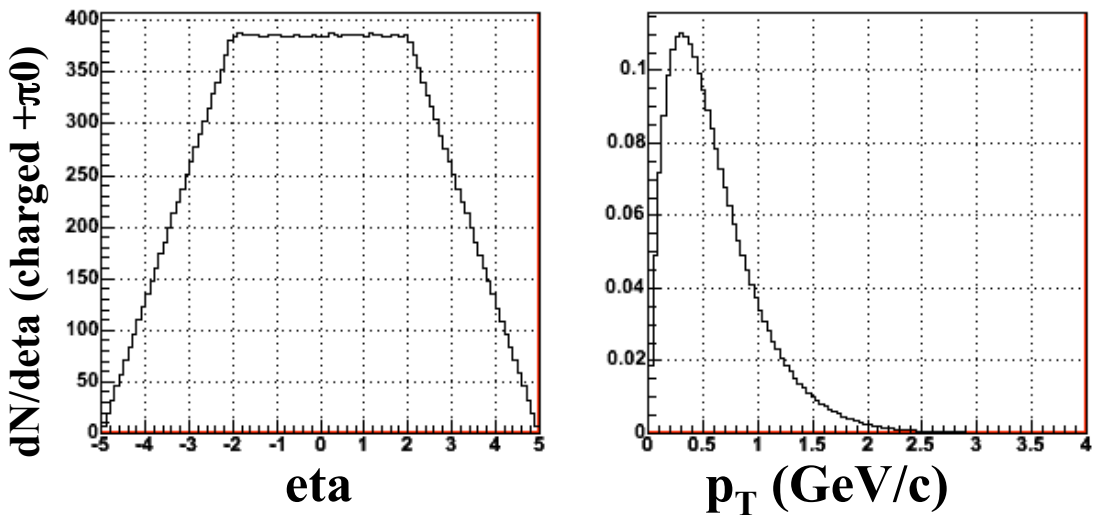
Simulation Input

- Values taken from PHOBOS experimental measurements at 200 GeV Au+Au collisions

Flow Signal



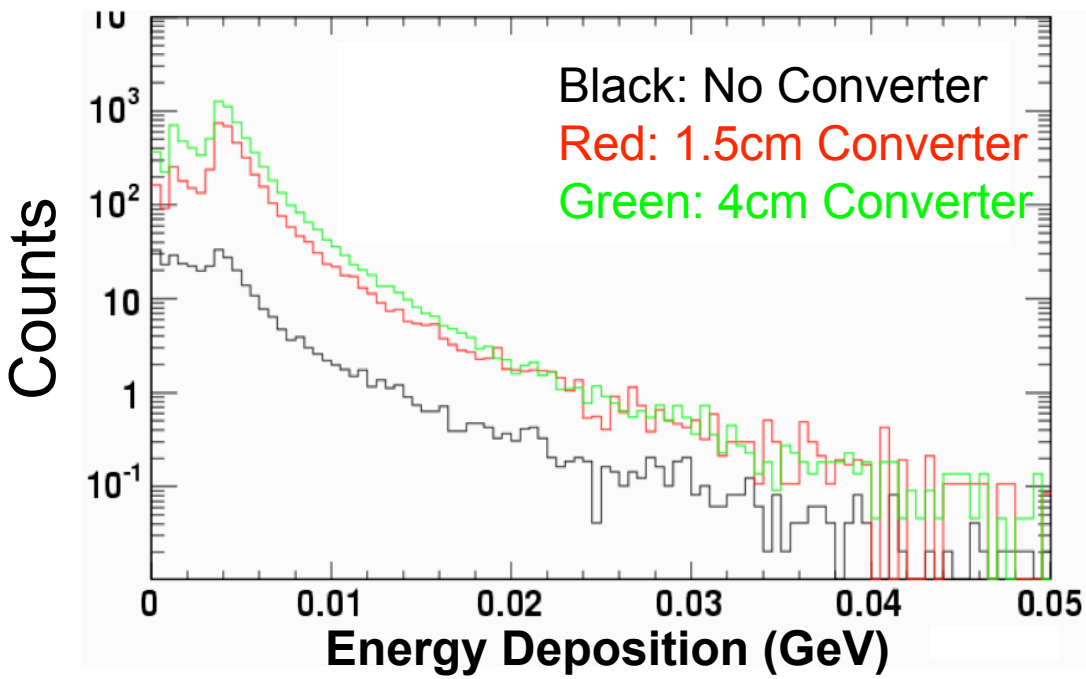
Multiplicity Distribution



Converter

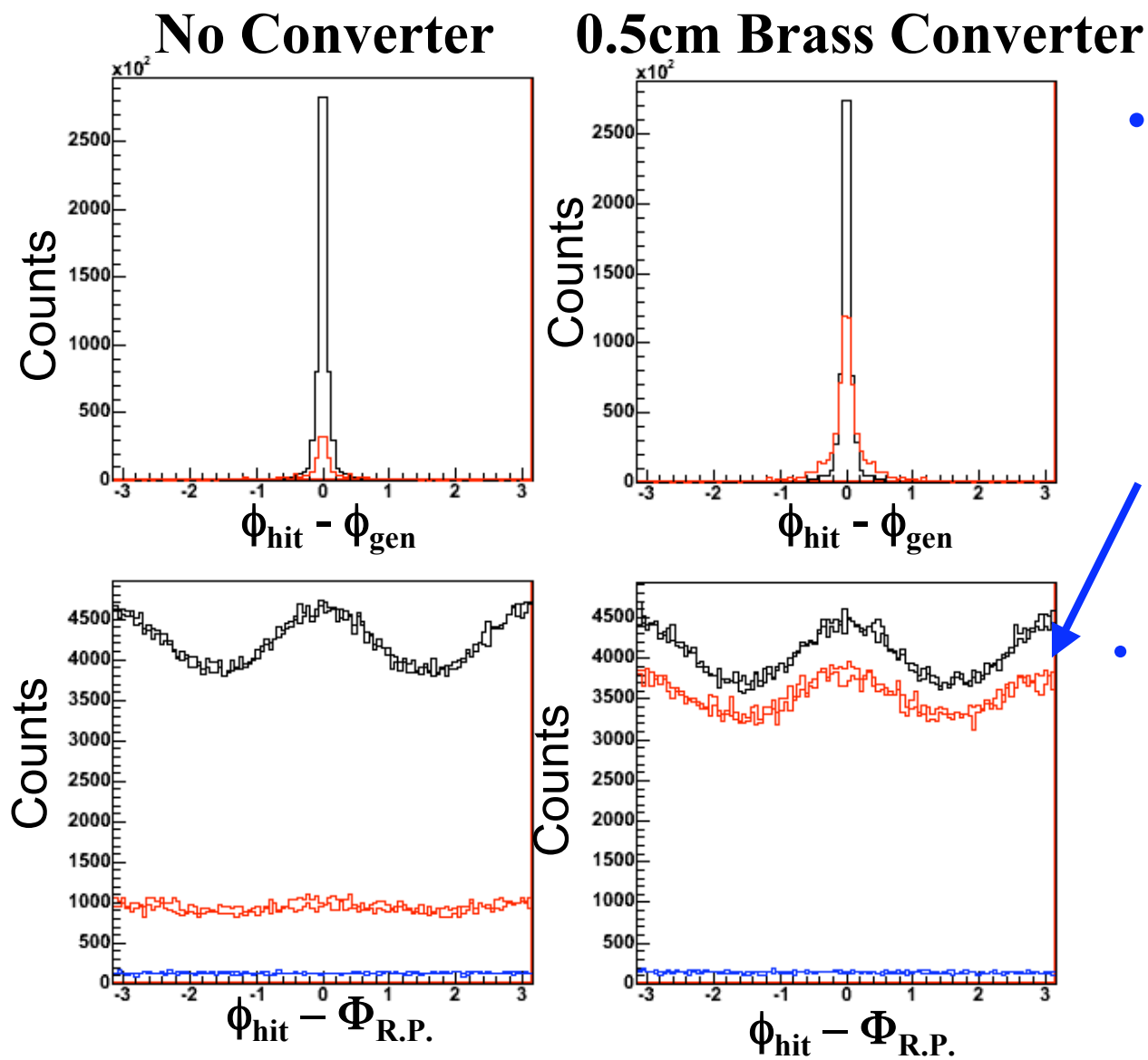
Per Segment / Per Event

	No Converter	1.5cm Converter	4cm Converter
Primary charged particles	151	132	103
Secondary charged particles	78	391	723
Total Charged Particles	**229**	**472**	**826**



Converter

Black: Primary $\pi^{+,-}$
Red: Secondary - same eta



- Converter does not alter original path of particle

With converter flow signal is re-enforced with secondary particles

- The thicker the converter the better the resolution, but because of physical limitations the thickest converter we can have is 2cm

Converter Material

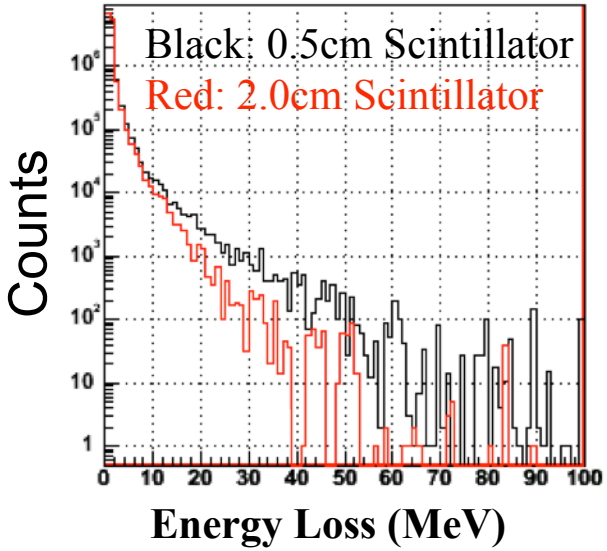
Brass vs. Pb
for fixed scintillator thickness

Converter thickness (cm)	0	1	**2**
Resolution (Brass)	0.53	0.65	**0.71**
Resolution (Pb)	0.53	0.73	**0.75**

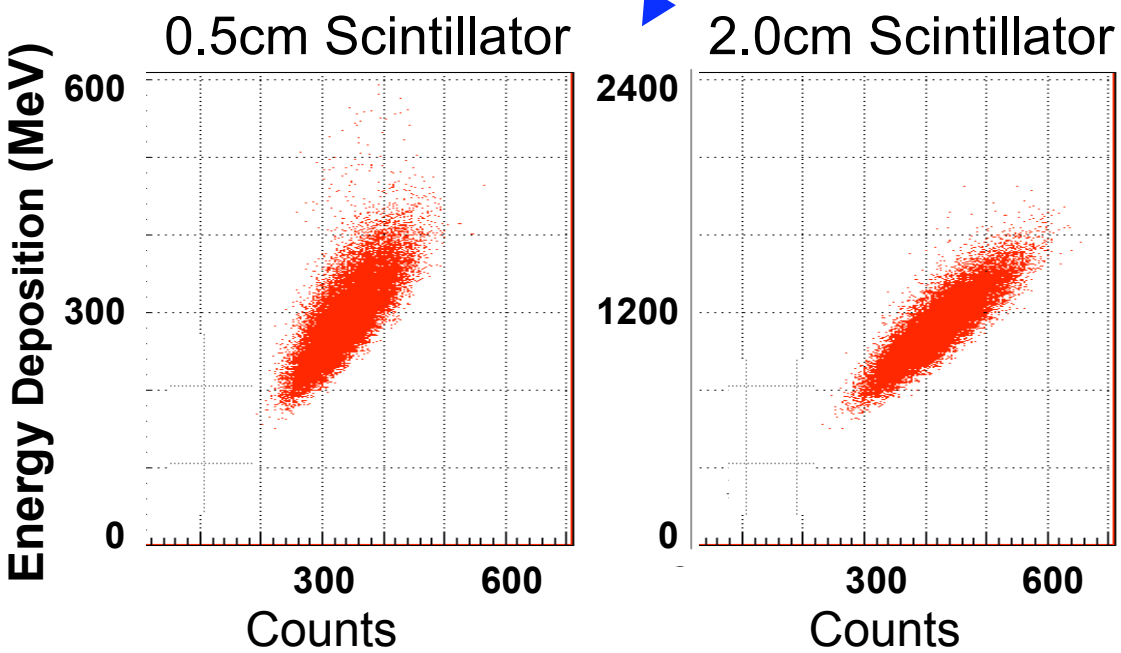
Pb provides slightly better resolution

Scintillator Thickness

2cm Converter

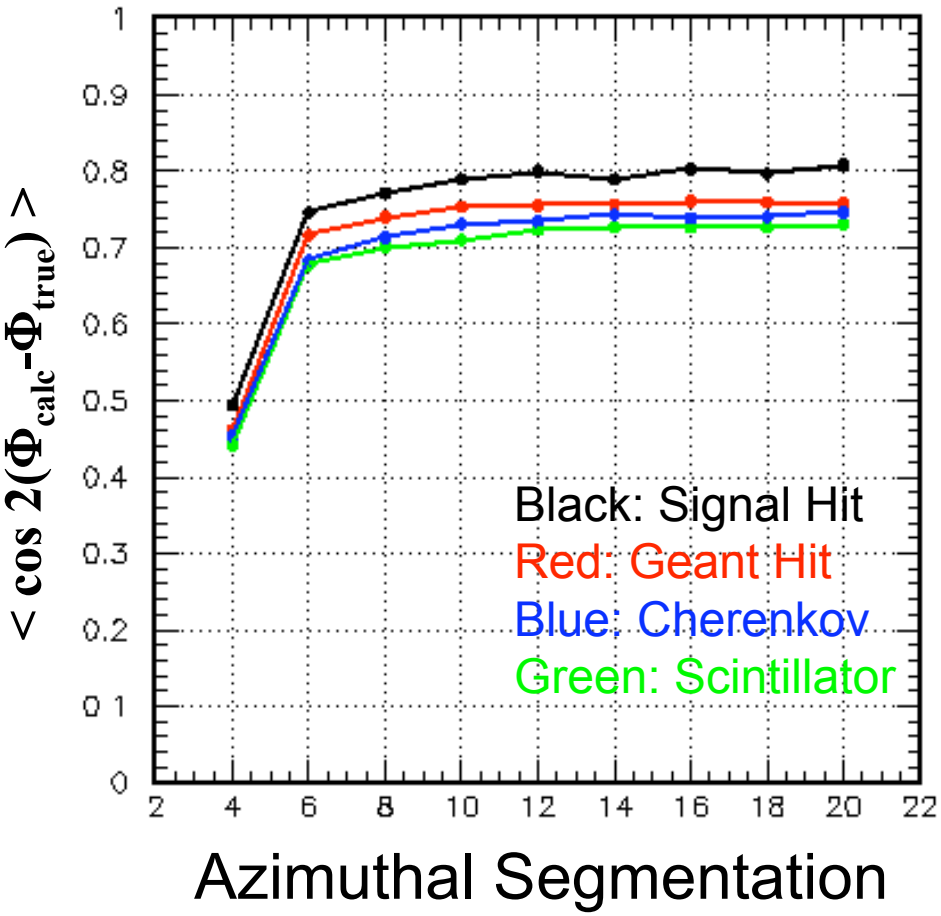


- Thicker scintillator
  - Gives sharper energy distribution
  - Magnitude of energy deposition is greater

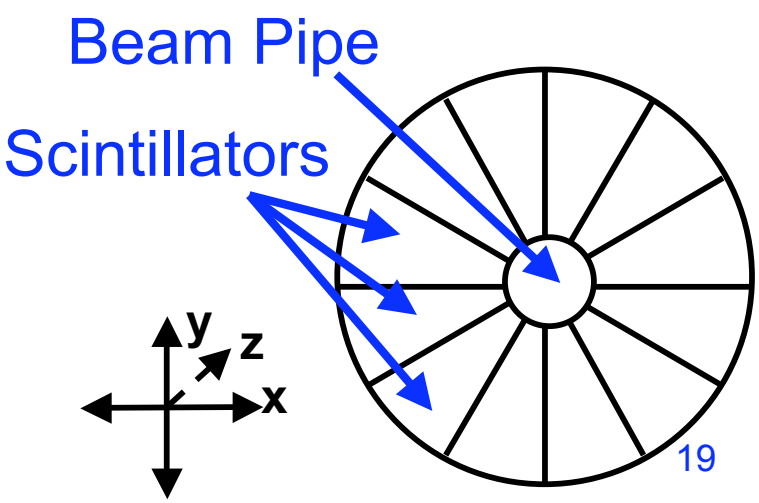


- The thicker the scintillator the better, but because of physical limitations the thickest we can use is 2cm

Detector Segmentation

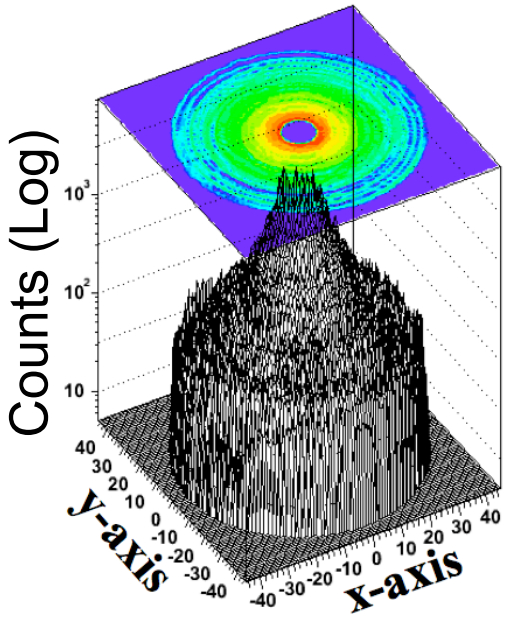


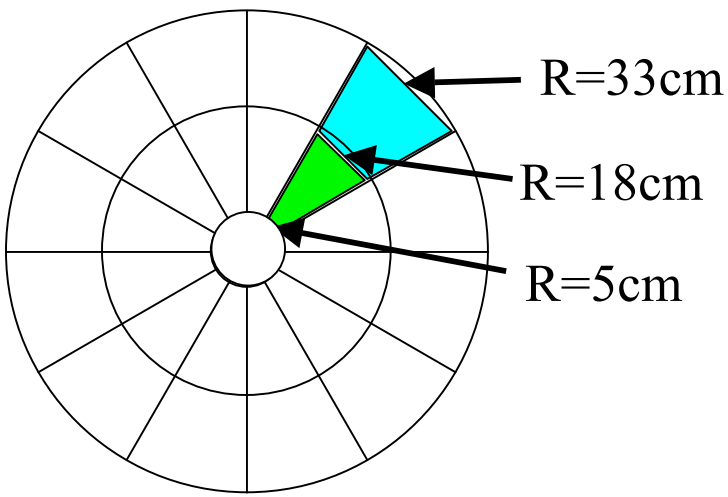
- Resolution doesn't increase much beyond 8 segments
- Decided on 12 segments in case a PMT breaks



Eta Segmentation

Particle Distribution





Problem

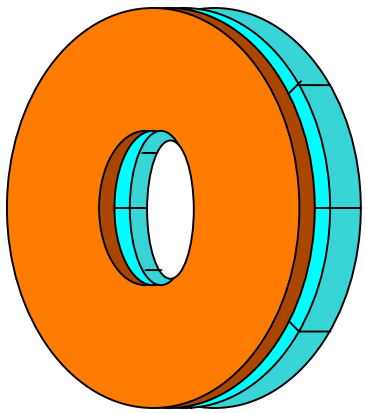
- Large number of particles hit tip of scintillator
- Could cause saturation rendering detector ineffective
- Jet correlations could saturate a single segment

Solution

- **Separate detector into two eta segments**

Simulation Summary

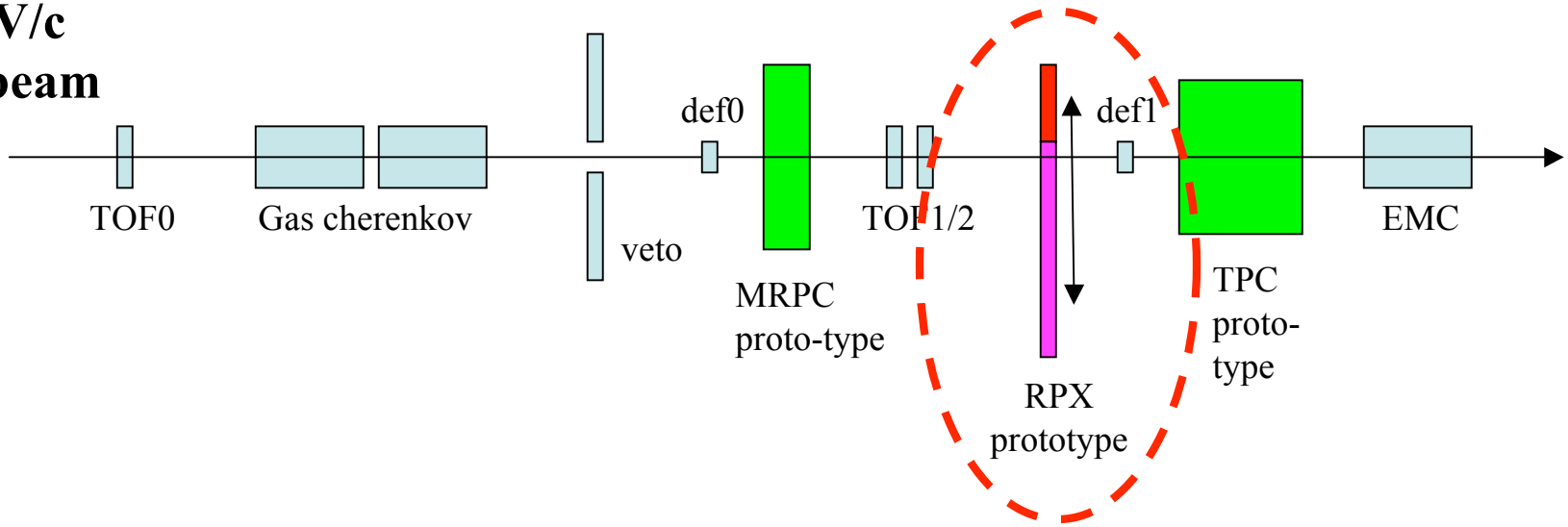
- Decided to use
  - 2cm Pb converter
  - 2cm Scintillator
  - 12 segments in phi
  - 2 segments in eta

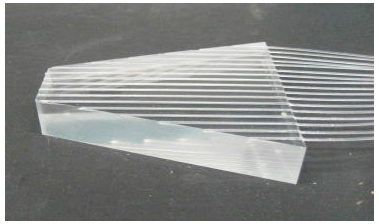


- On to finalizing rest of detector design

KEK-PS Beam Tests

1-2GeV/c
p/π/e beam





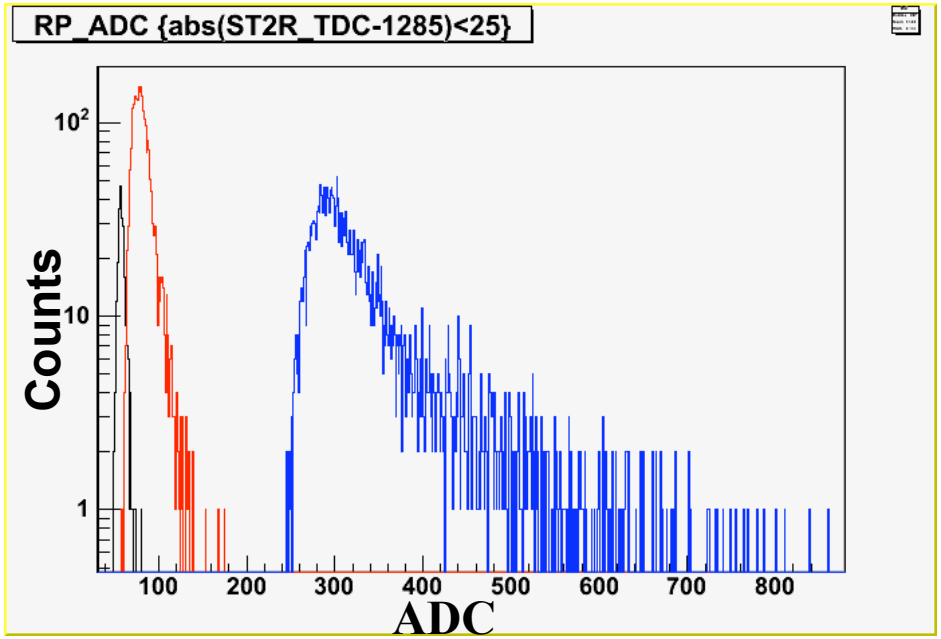
	Scintillator	Cherenkov
Solid Light Guide	Scintillator + Solid Light Guide	Cherenkov + Solid Light Guide
Embedded Fiber Light Guide	Scintillator + Fiber Light Guide	Cherenkov + Fiber Light Guide

- Test signal strength and dependence on particle position for each combination

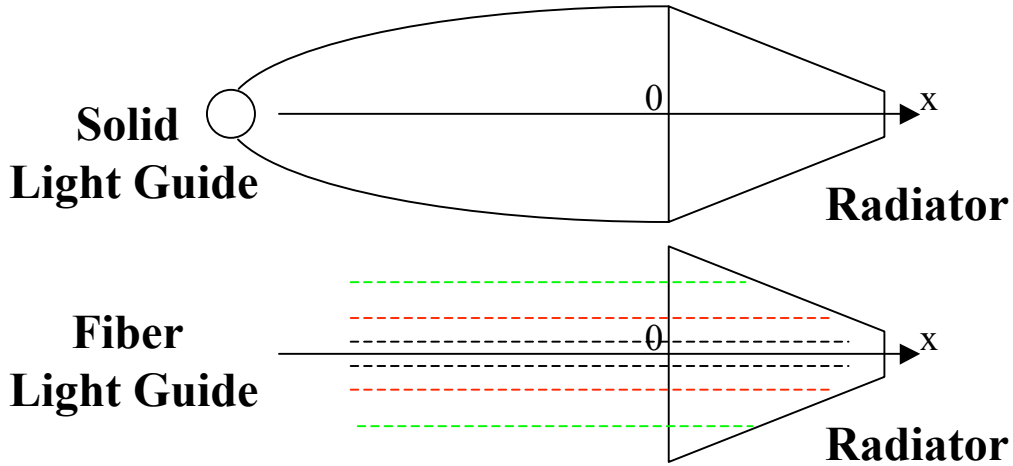
Pulse Heights

Beam is 1cm^2 and perpendicular at the center of the detector

Scintillator + solid light guide
Scintillator + fiber light guides
Cherenkov + solid light guide
Cherenkov + fiber light guides
(pulse height too small to be considered)



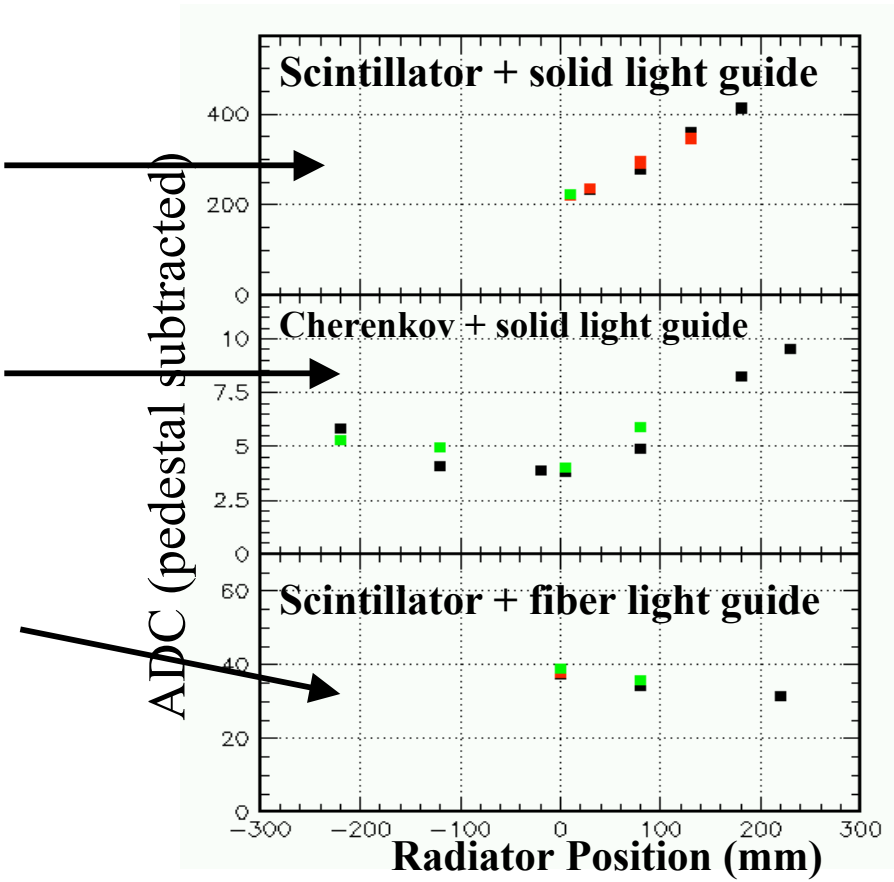
Position Dependence



1) Scintillatior + solid light guide = Energy deposited is heavily dependent on position. Caused by different reflection in transmission

2) Cherenkov + solid light guide = Energy deposited is heavily dependent on position. Caused by different reflection in transmission.

3) Scintillatior + fiber light guide = Energy deposited is much more uniform. (Measured with 1mm diameter fiber with 1cm spacing)



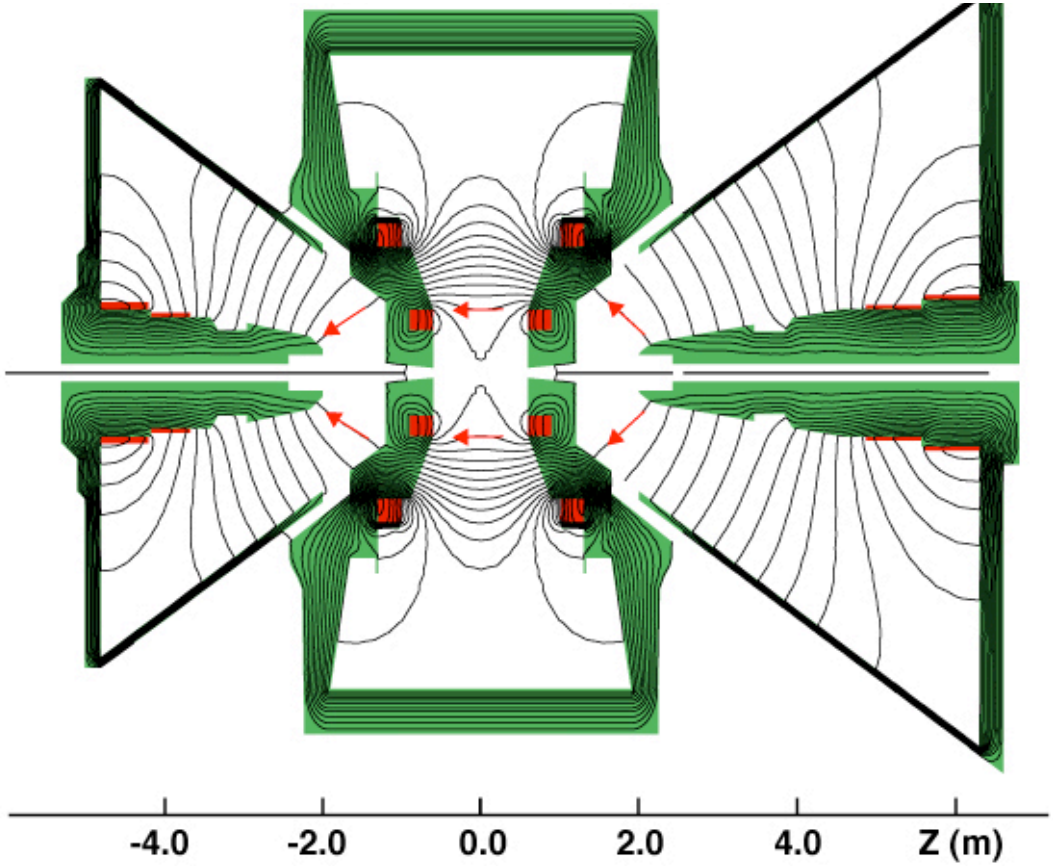
KEK-PS Test Summary

Blue = Good
Red = Bad

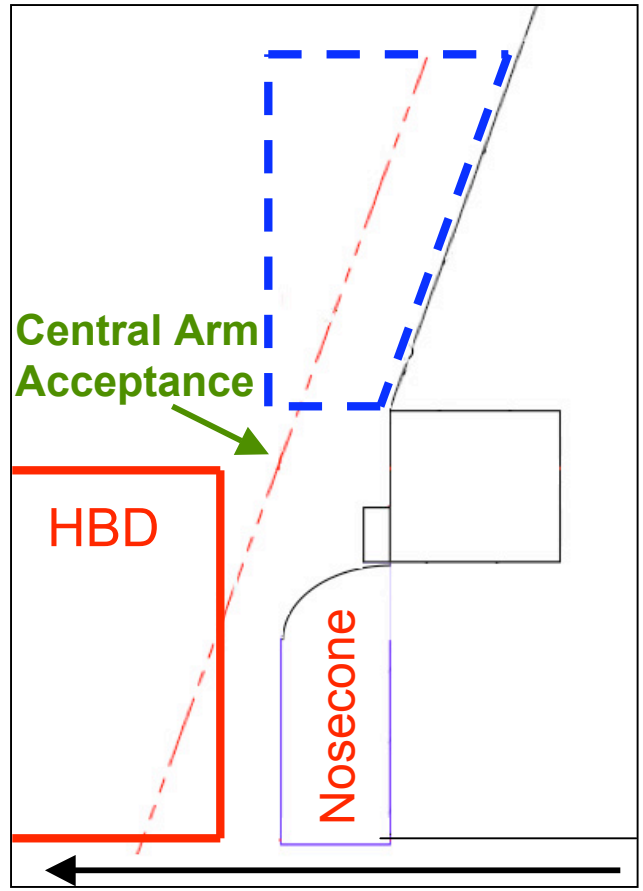
Cherenkov + Fiber Light Guide	• ~2-4mV pulse hight • Too small to be considered
Cherenkov + Solid Light Guide	• Sharp pulse height • Non-uniformity of light collection worsens reaction plane resolution • Does not allow flexibility for positioning PMT 's
Scintillator + Solid Light Guide	• Strong signal (longer tail) • Non-uniformity of light collection worsens reaction plane resolution • Does not allow flexibility for positioning PMT 's
Scintillator + Fiber Light Guide	• Reasonable pulse height ~120mV, small signal tail • Allows flexibility for PMT positioning • More uniformity in light collection

PMT Performance in Magnetic Field

- PMT's do not work at an angle greater than 60 deg wrt magnetic field
- Magnetic field will be in +- configuration for upcoming run
- Calculated where in IR PMT's can be placed

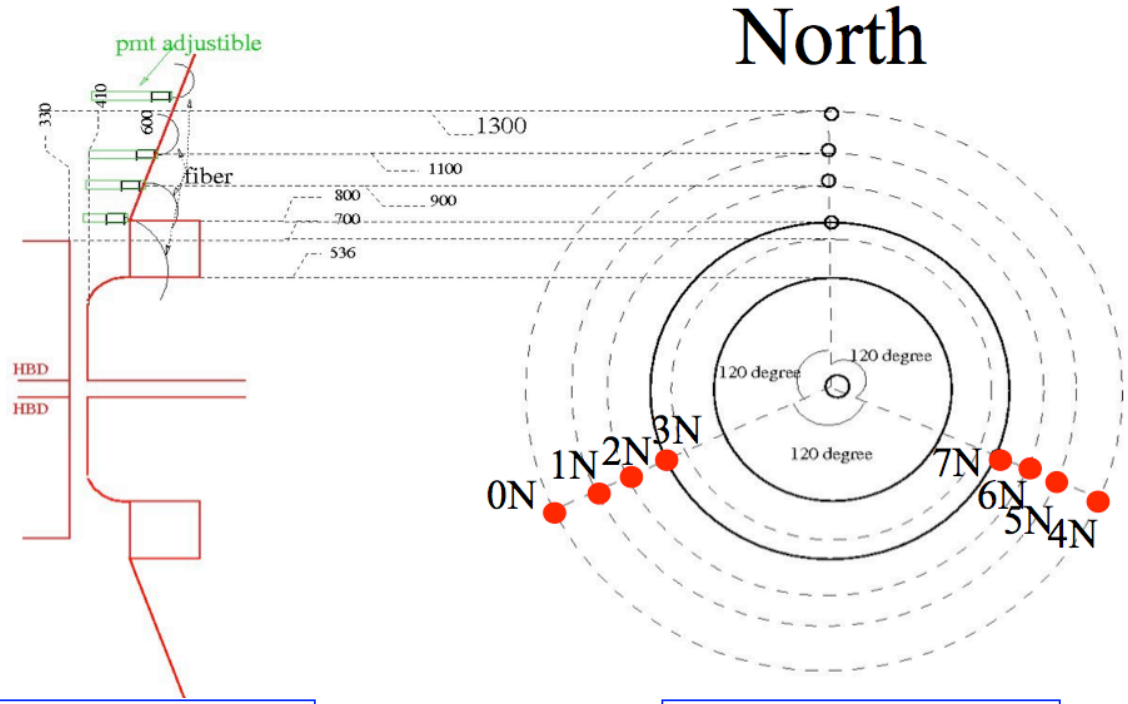


Magnetic field lines for the two Central Magnet coils in reversed (±) mode



Testing PMT performance in IR

- Tested in ++ and +- field
- PMT's located 80, 90, 110, and 130 cm from beam pipe
- Tested parallel and 30 deg wrt beam pipe
- Compared gain at 0 field to full field
- Used LED box to generate signal (Mike Lenz)

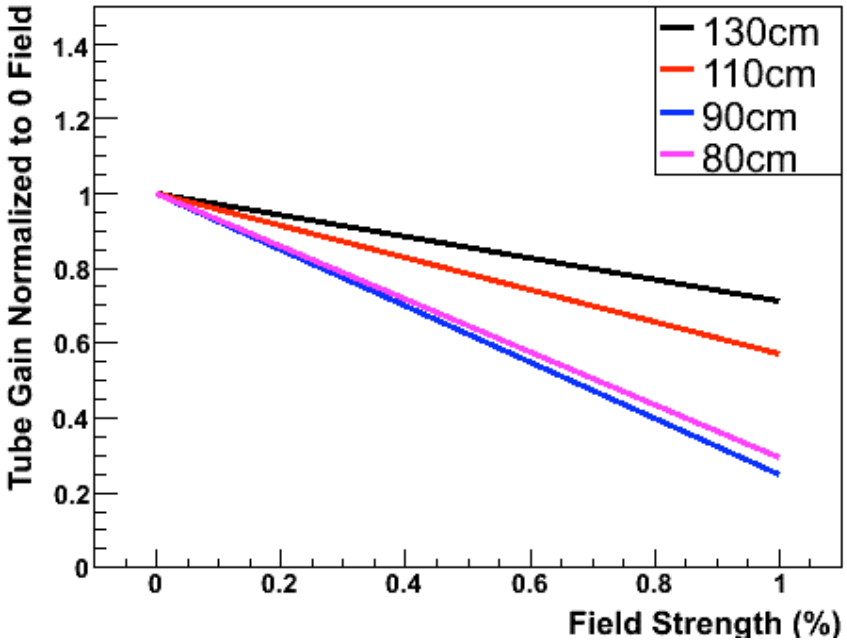


Side View

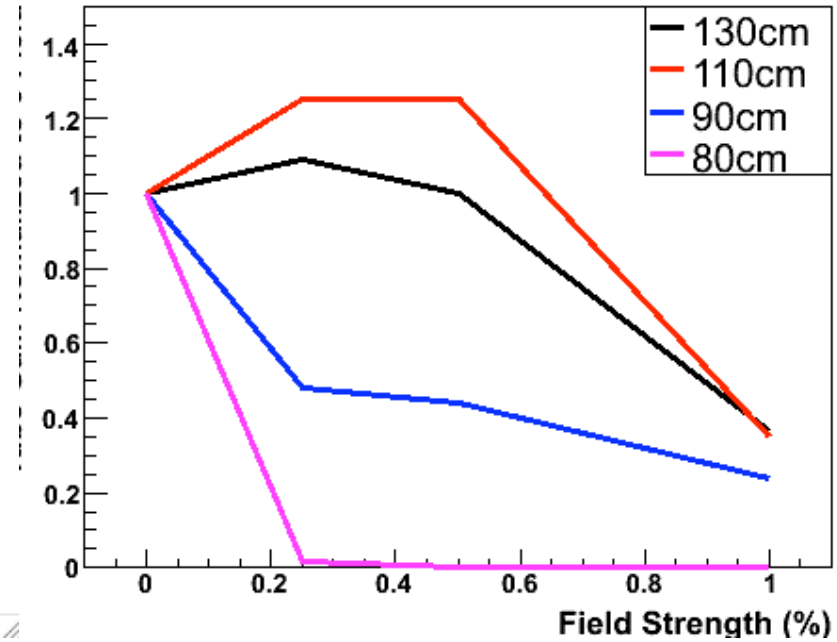
Front View

IR Test Results

+-, Parallel

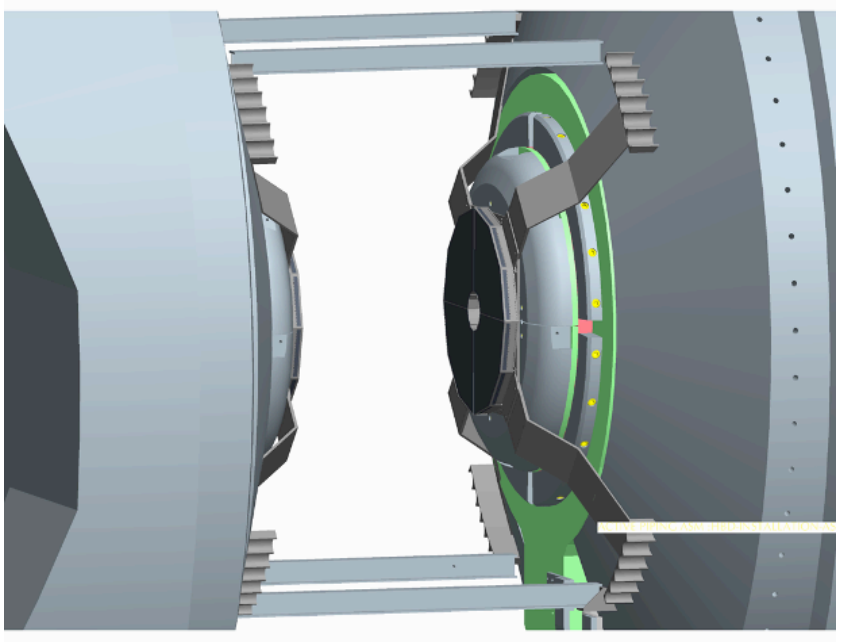


+-, 30 deg

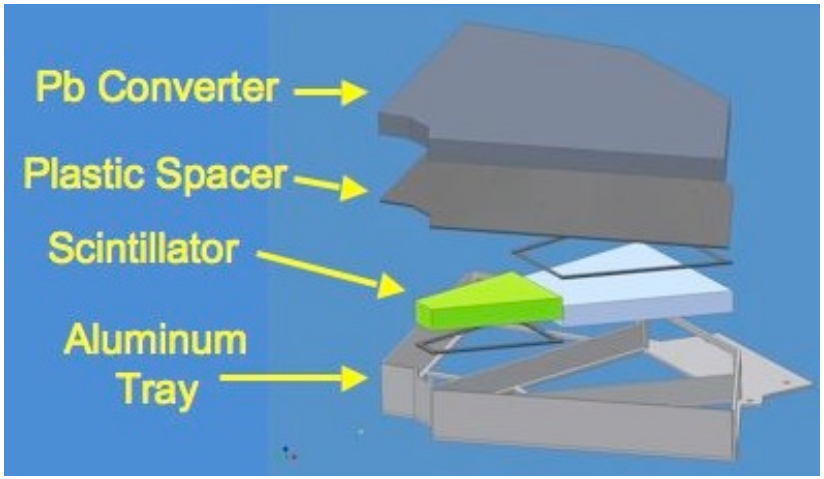


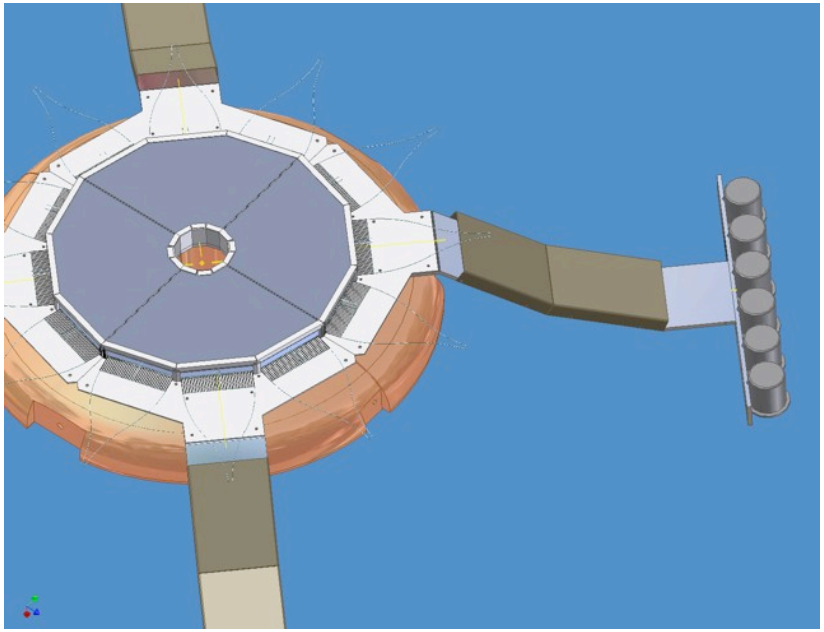
- Results show stronger PMT gain when >90cm from beam pipe and parallel to it
- Decided to locate PMT's at 130cm and parallel to the beam pipe

Final Detector Conceptual Drawings



- Detector has North and South halves
- Each half divided into quadrants
- Each quadrant contains:
  - 1 Pb converter
  - 3 inner & 3 outer scintillators
  - 6 fine mesh PMT's

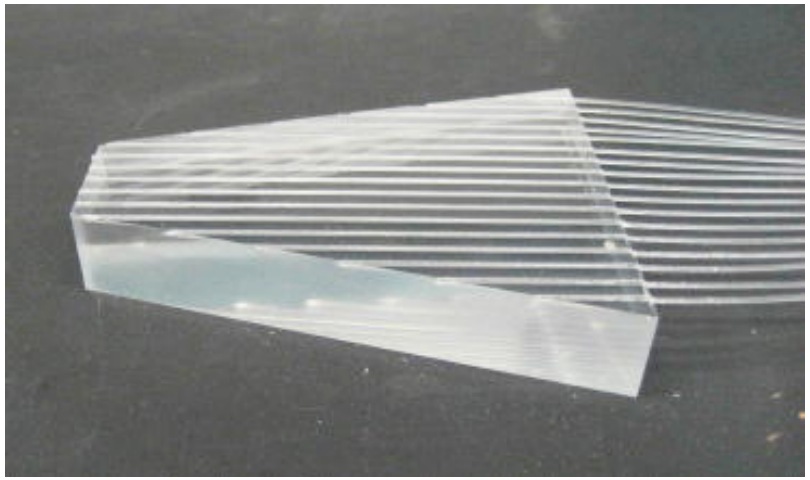




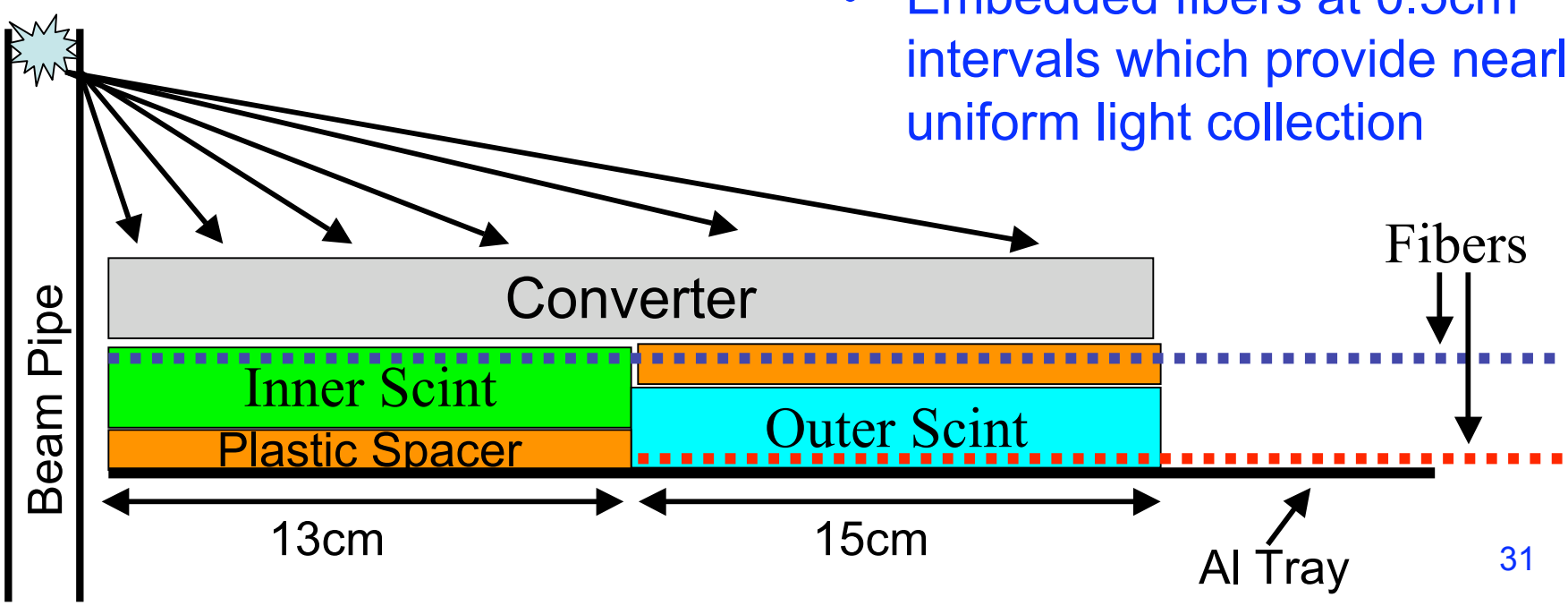
Converter

- 2 cm thick
- 98% Pb + 2% Sb
- Improves Statistics by
  - Converting neutral particles to electrons
  - Reducing low energy background

Plastic Scintillator



- Equivalent to BC-408
- Sensitive to charged particles
- 2cm thick
- Inner scintillator
  $\eta = 1.5 \rightarrow 2.8$
- Outer scintillator
  $\eta = 1.0 \rightarrow 1.5$
- Embedded fibers at 0.5cm intervals which provide nearly uniform light collection



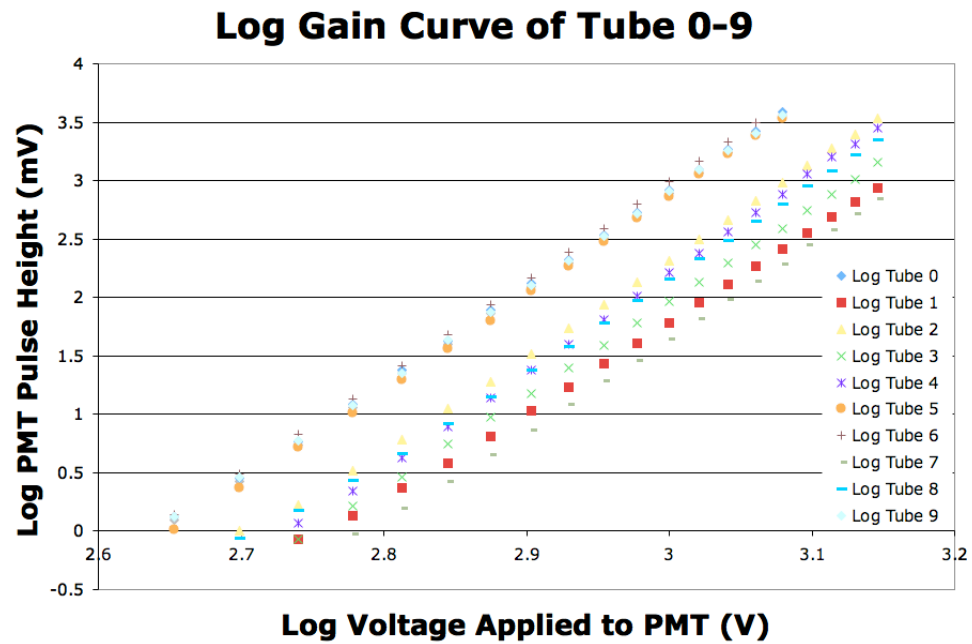
PMT and Fibers

- Fibers
  - Wavelength shifting to optimize PMT response

- PMT's
  - 3in fine mesh from Hamamatsu (R5543)
  - Capable of operating in the high magnetic field of the PHENIX central region
  - Borrowed 52 PMT's from a KEK experiment E325

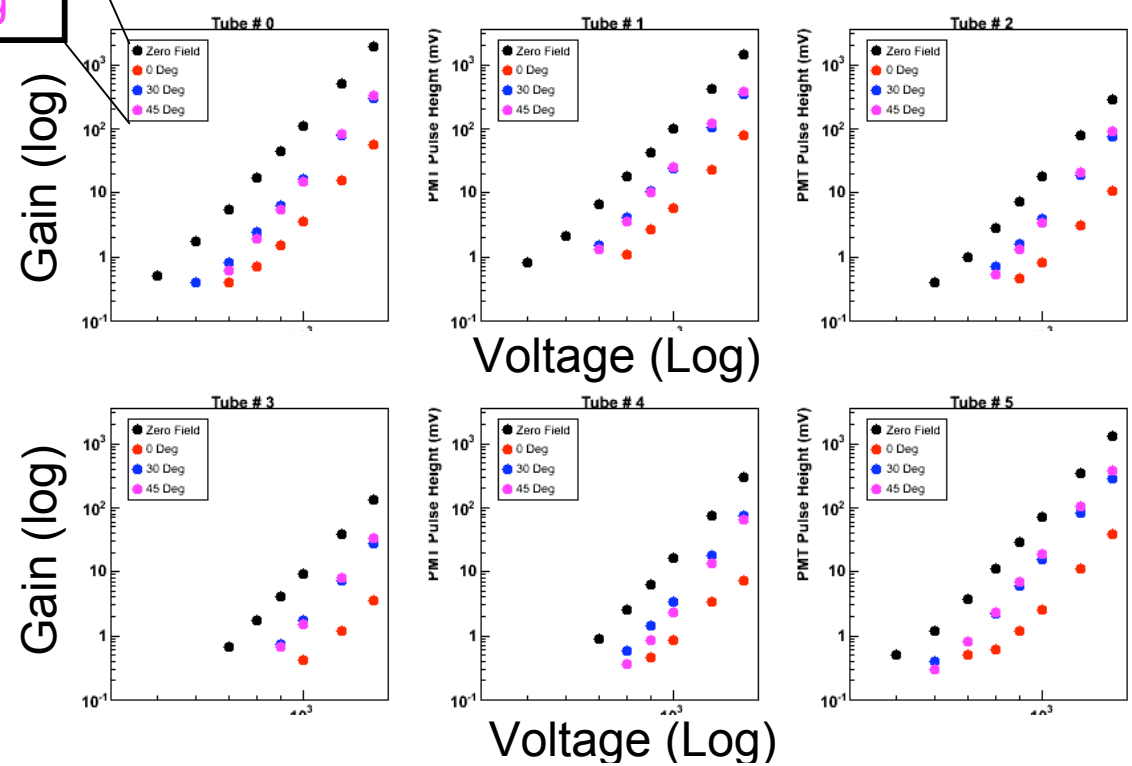
PMT's Tests

- Gain response outside magnetic field

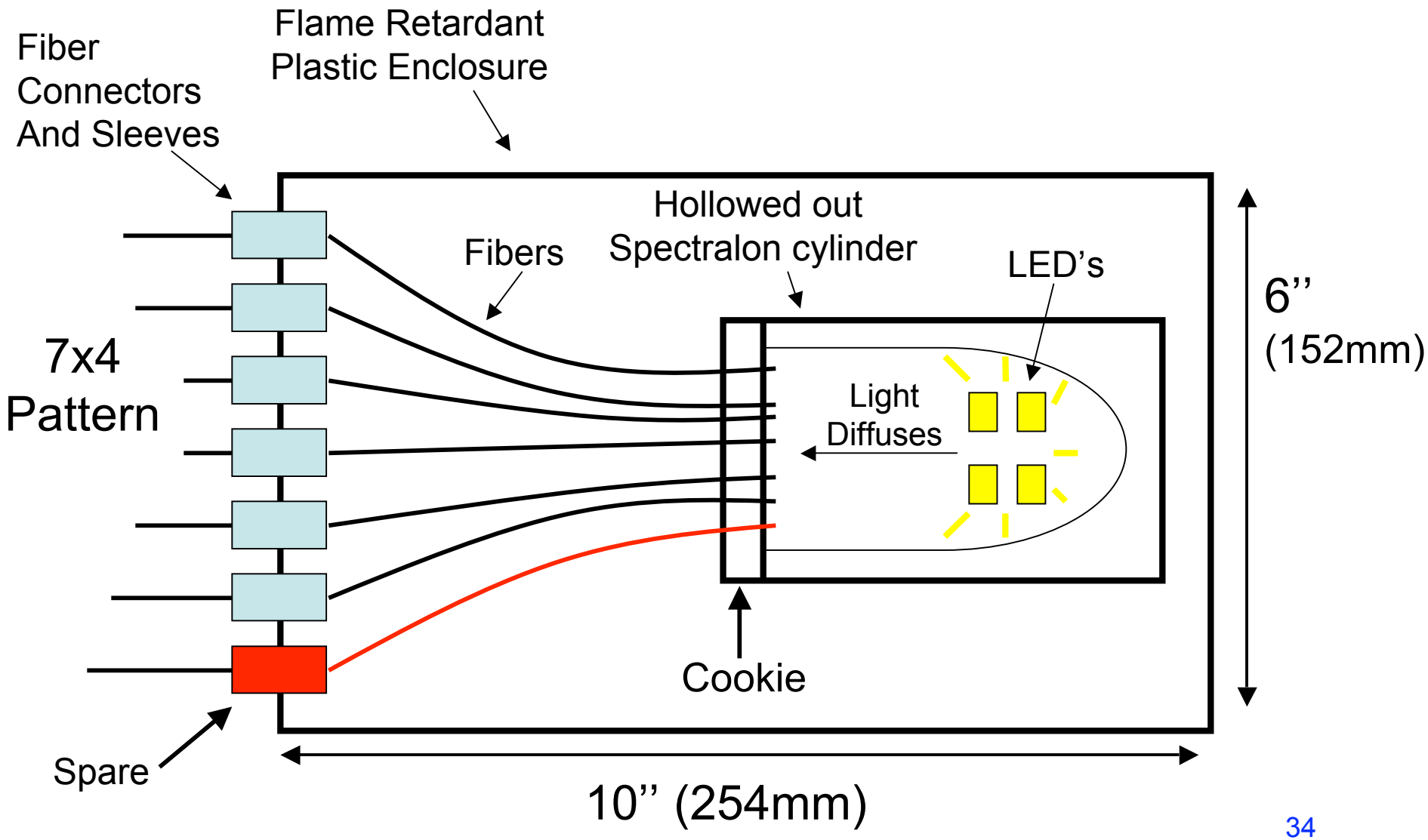


Zero Field 0 Deg
30 Deg 45 Deg

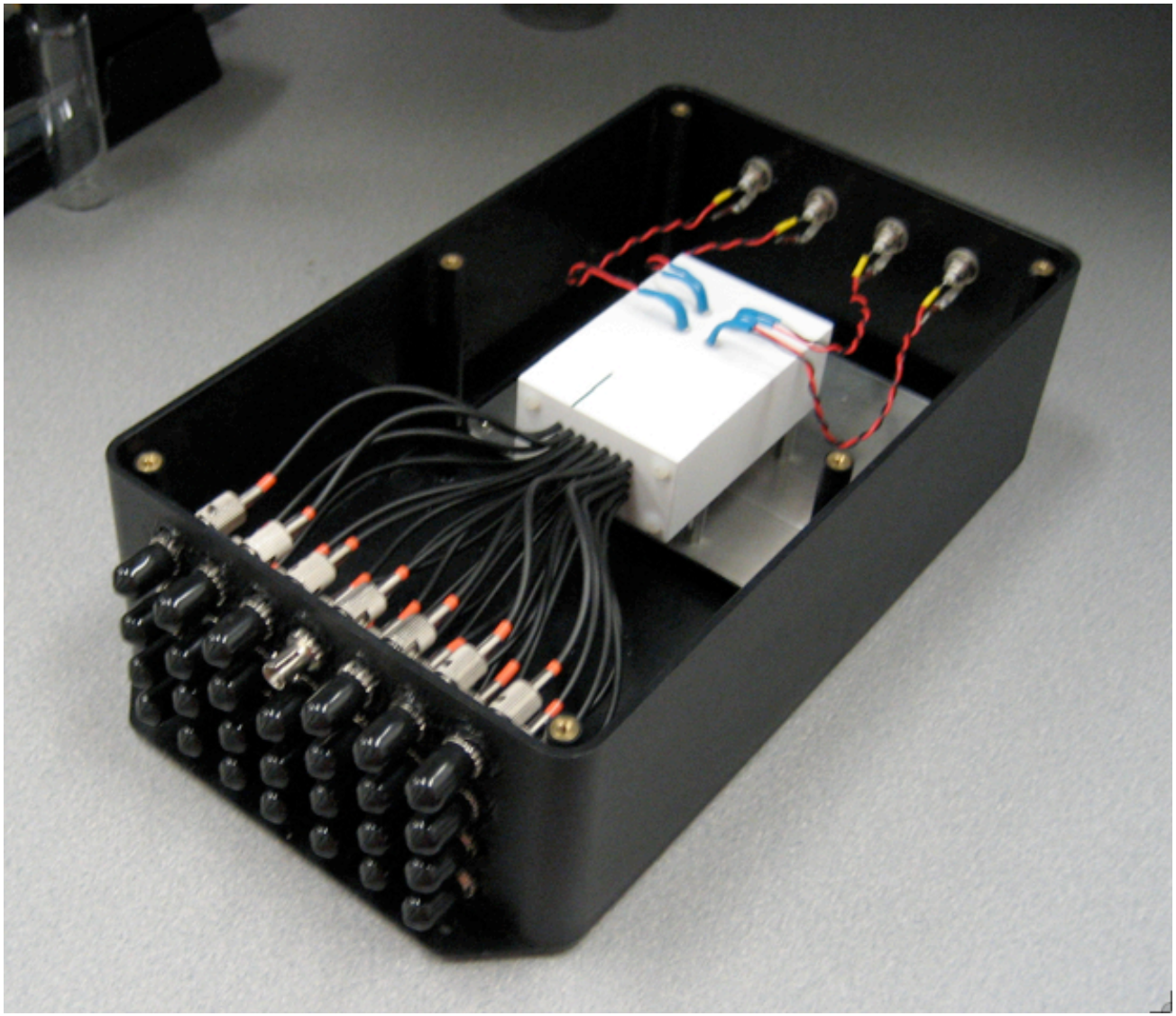
- Gain response inside magnetic field (0.7T)
- Used to find our best 48 PMT's



LED Calibration Box (Top View)



LED Box

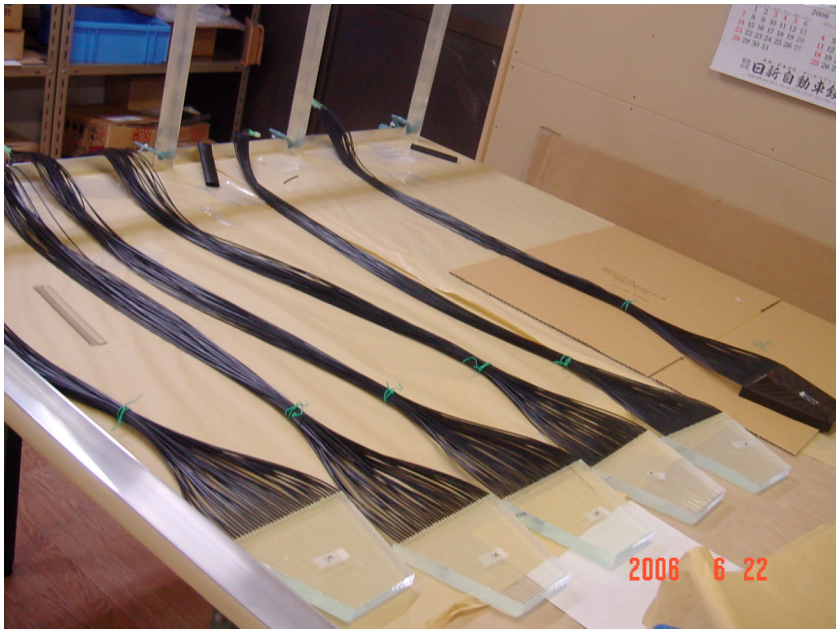


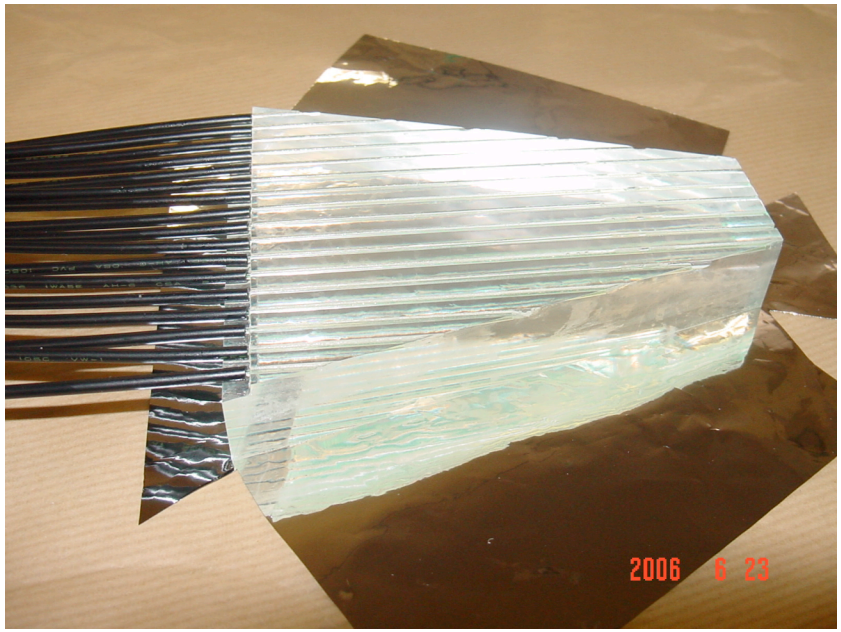
Many Thanks to Mike Lenz, Sean Stoll, and Chemistry Machine Shop

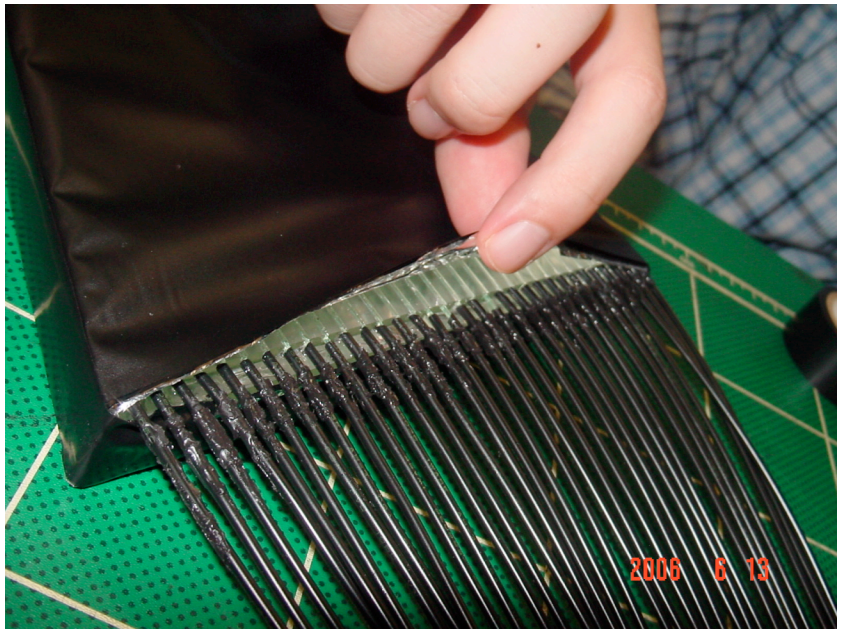
Assembly Photos

Assembly @ Tsukuba

Wrapping 54 Scintillators

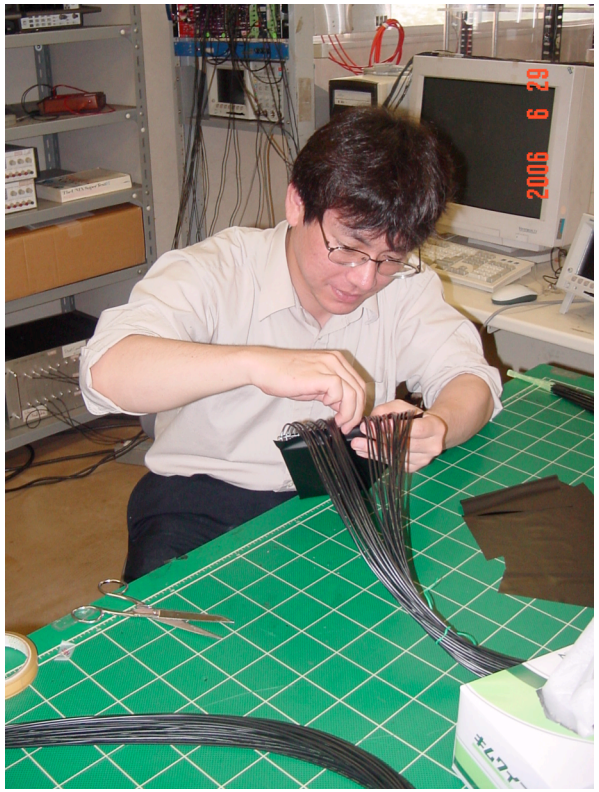






2006 6 29

2006 6 29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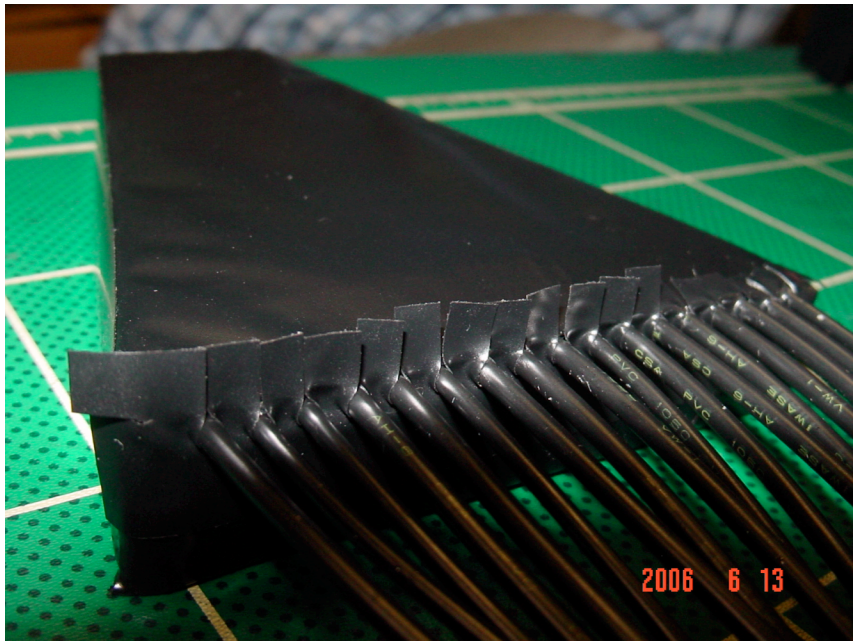

2006 6 13

2006 6 13

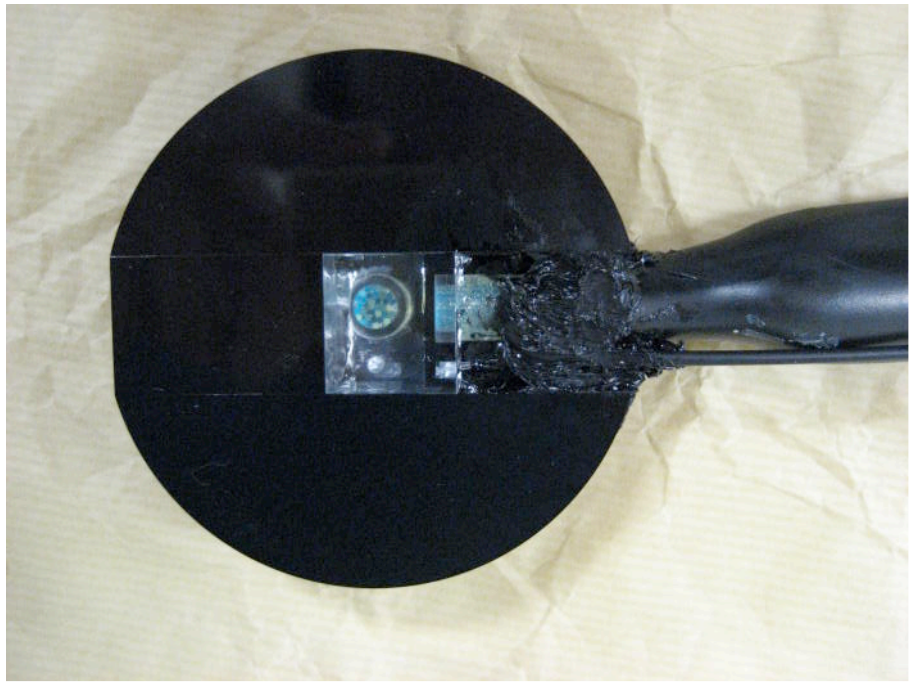
品名コード 26
品名 JET-STANDARD
20巻入／箱×10
LOT No. 3711837
2006 6 25

2006 7 3

11
2006 7 3

Off to BNL!!!

Assembly @ BNL



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2006 7 25

2006 7 24

2006 7 24

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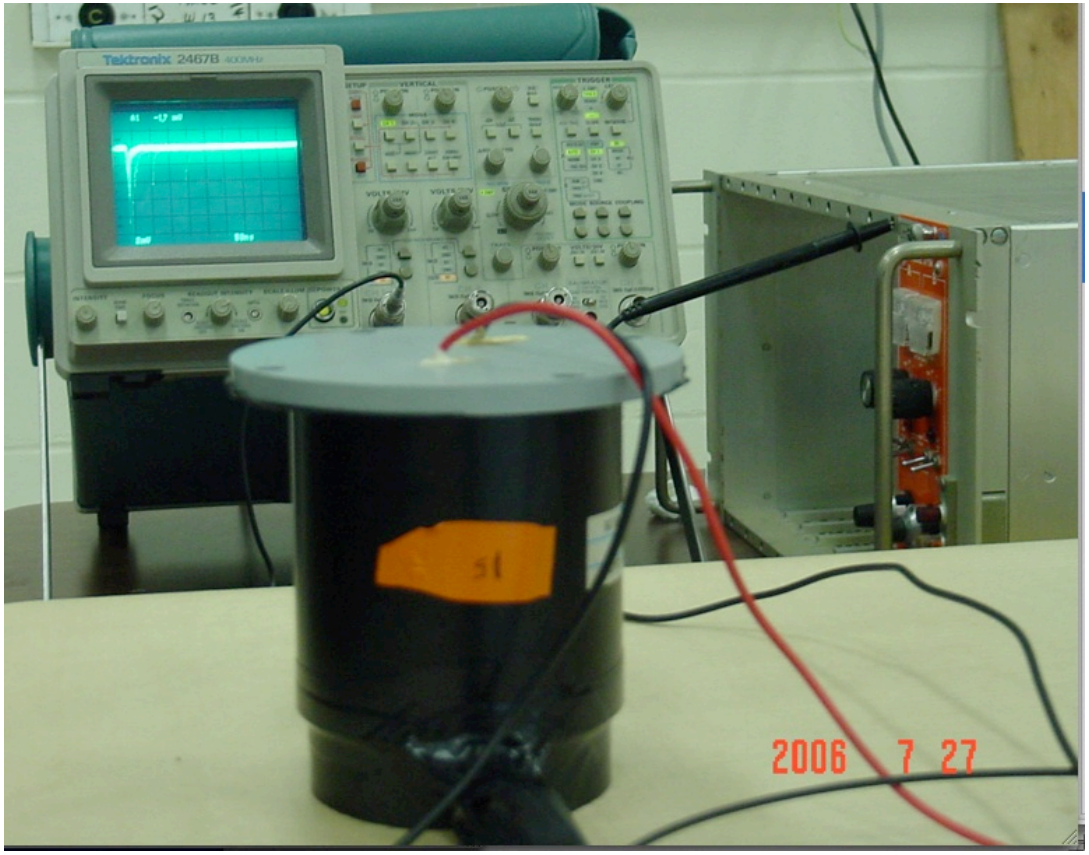
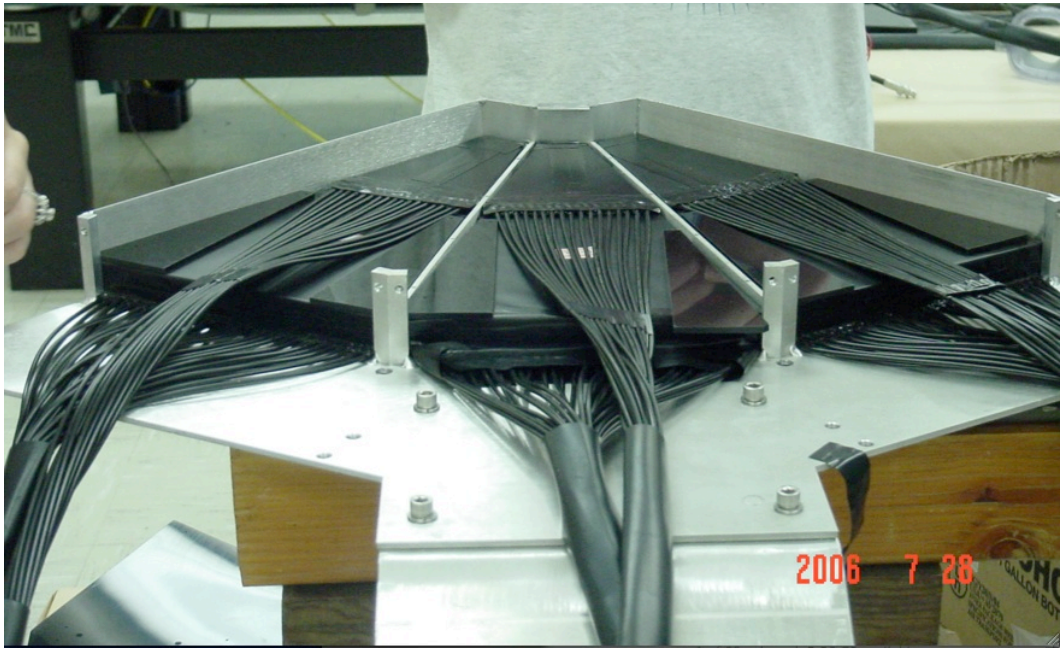
2006 7 25


Tektronix 2467B
51
2006 7 27

2006 7 27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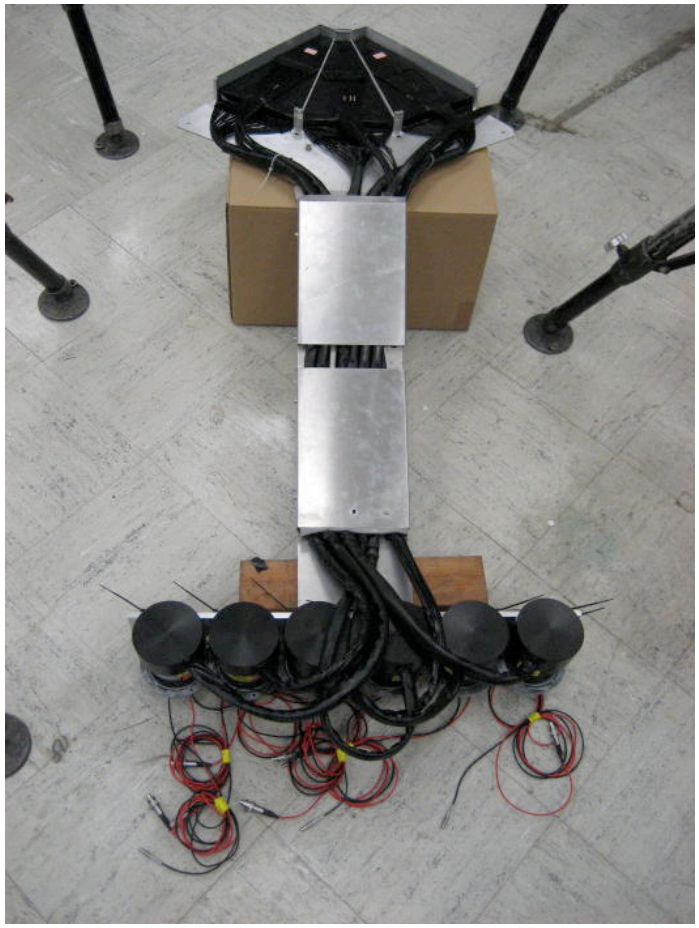


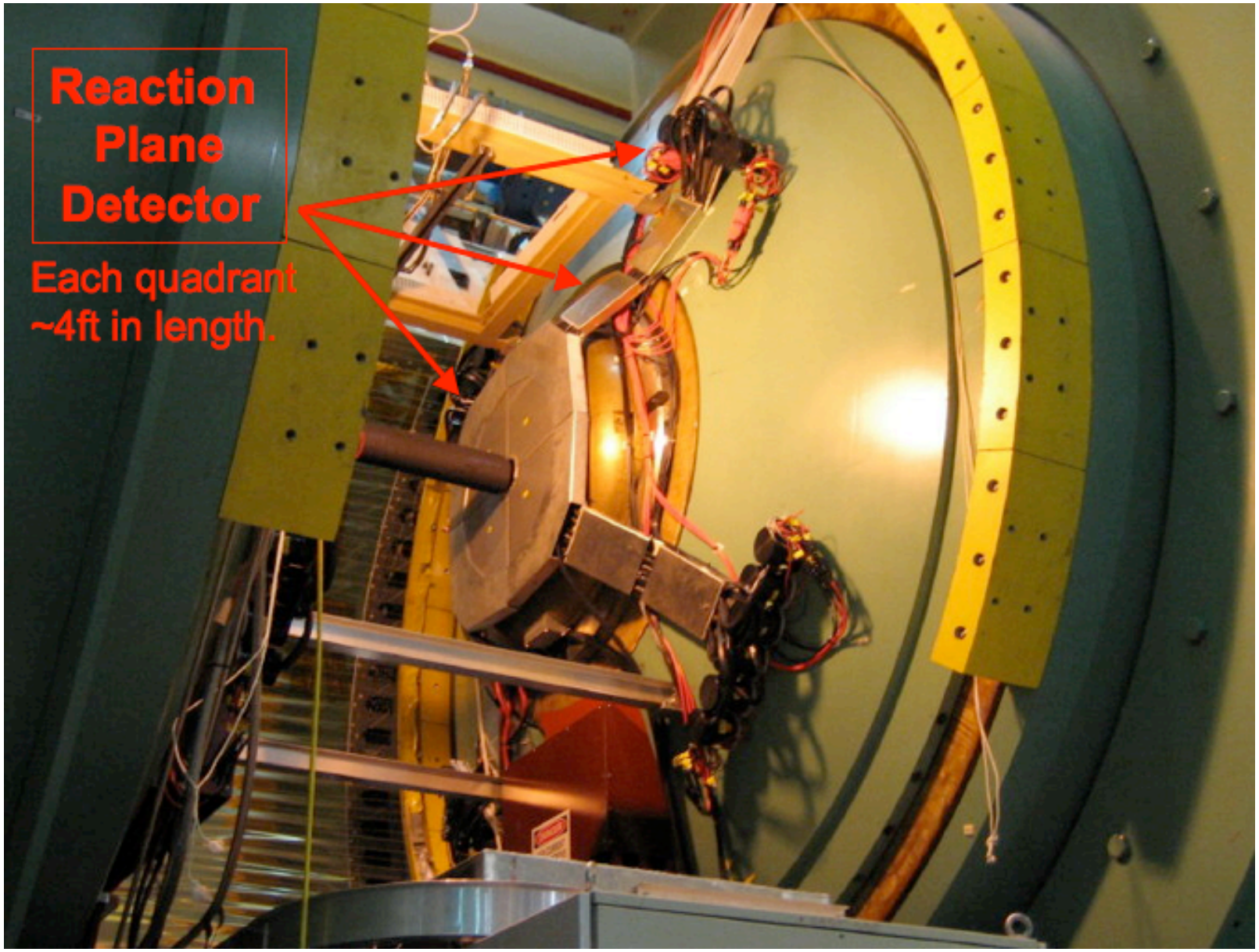
Installation

Kenny and Sal

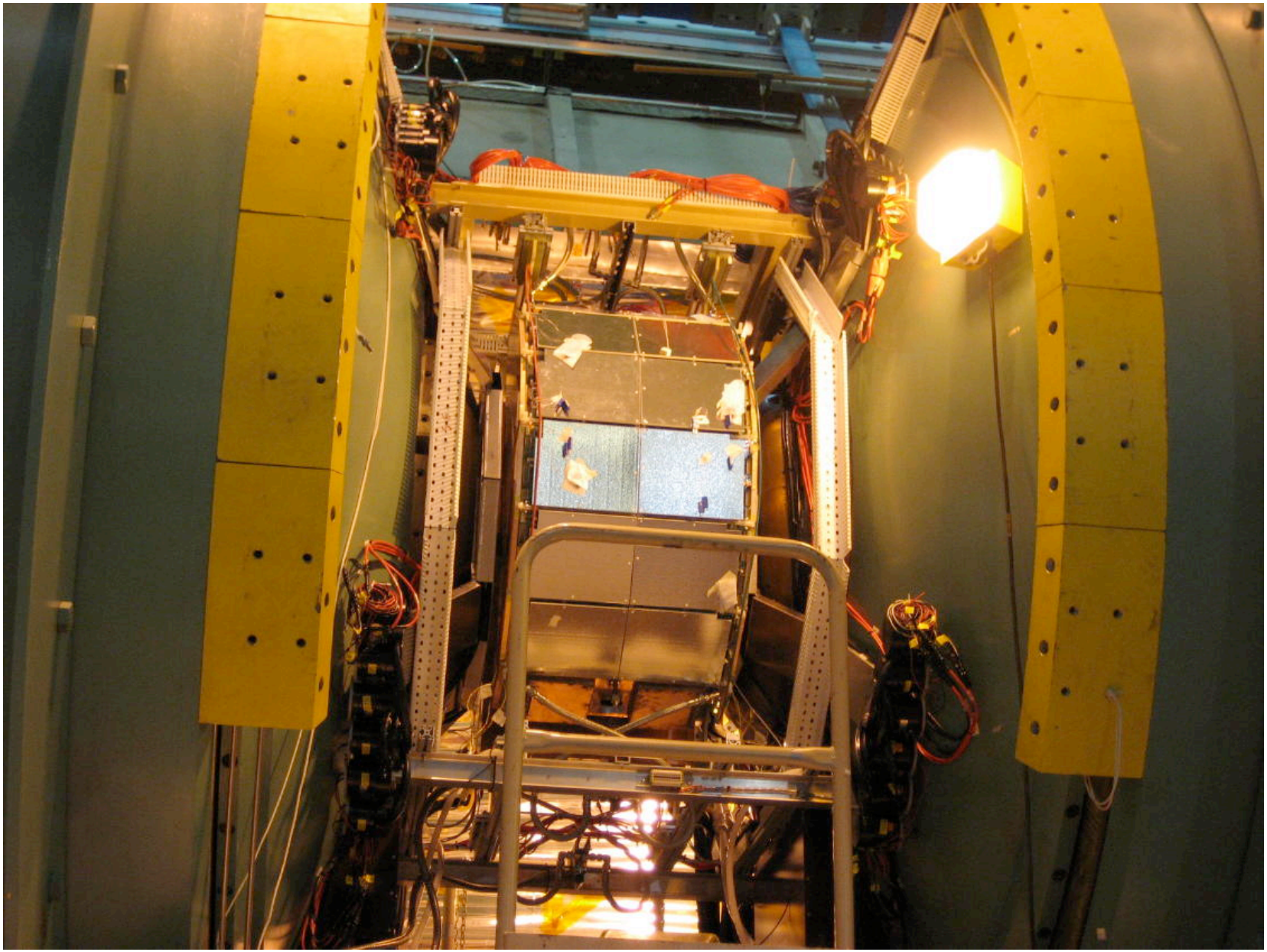
John

Jimmy

Fully Installed!!!

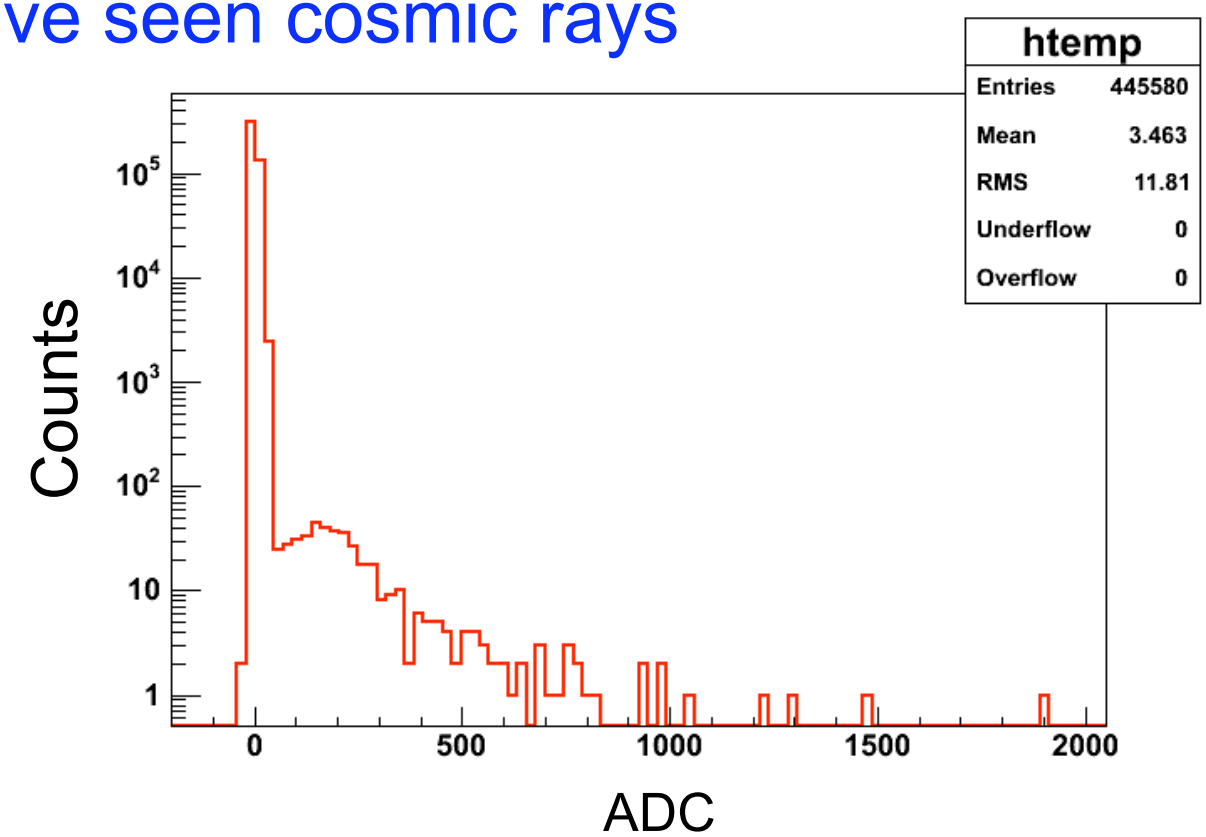


With HBD Installed



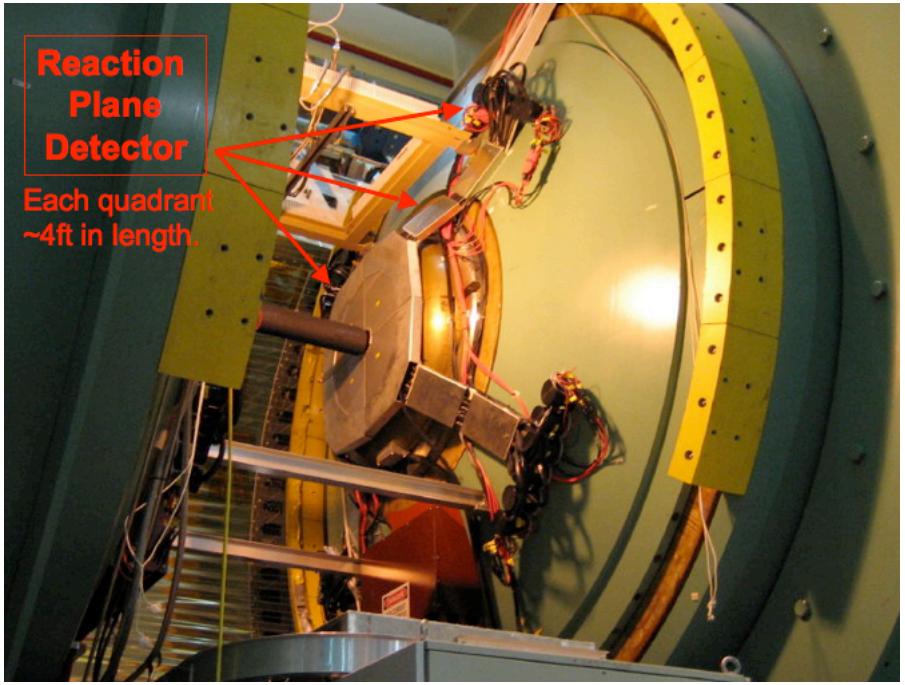
Today

- Finishing up commissioning of
  - Software
  - Electronics
- Have seen cosmic rays



Contributors to the RxNP Project

(w/o including PHENIX technicians and engineers)



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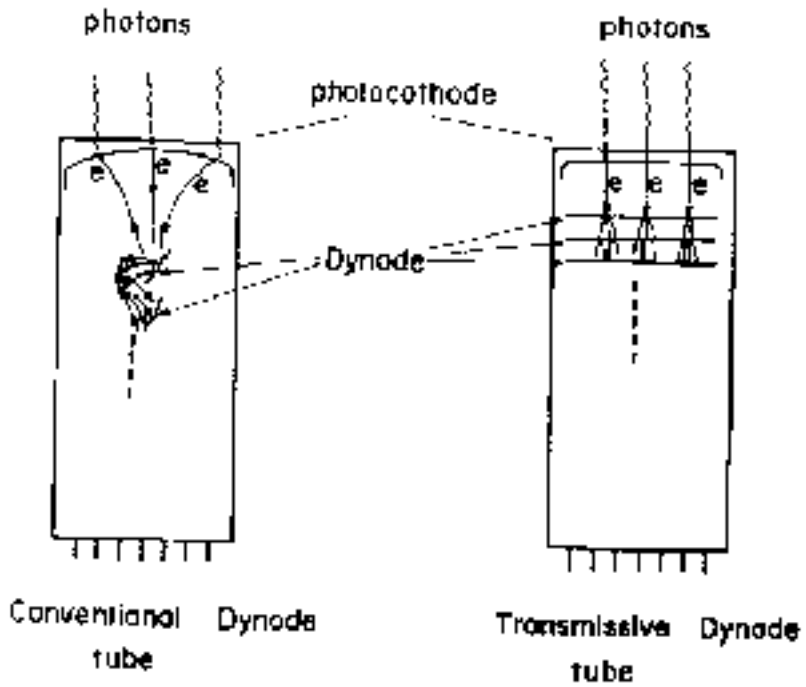
Fine Mesh PMT