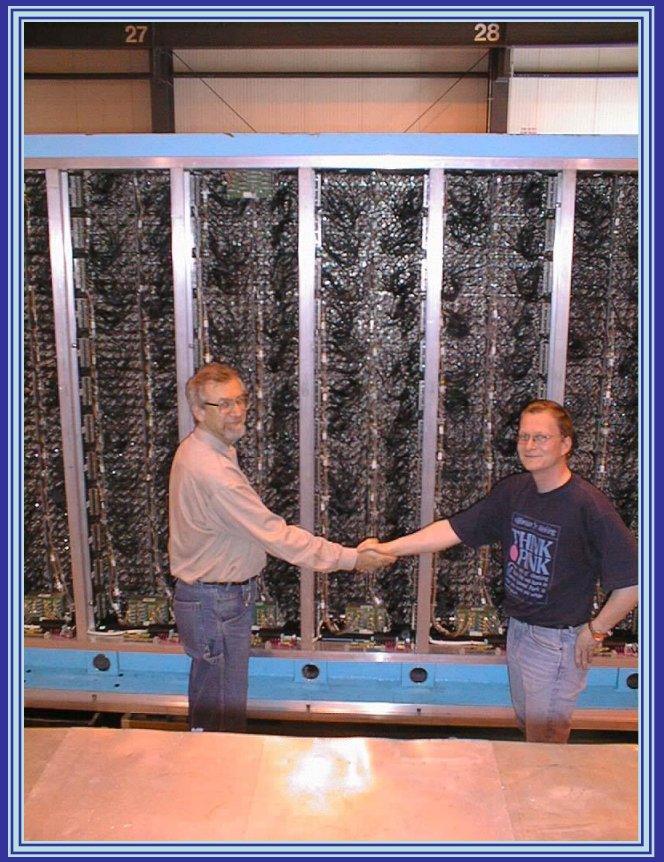
The Electromagnetic Calorimeter - EMCal -



What is EmCal?

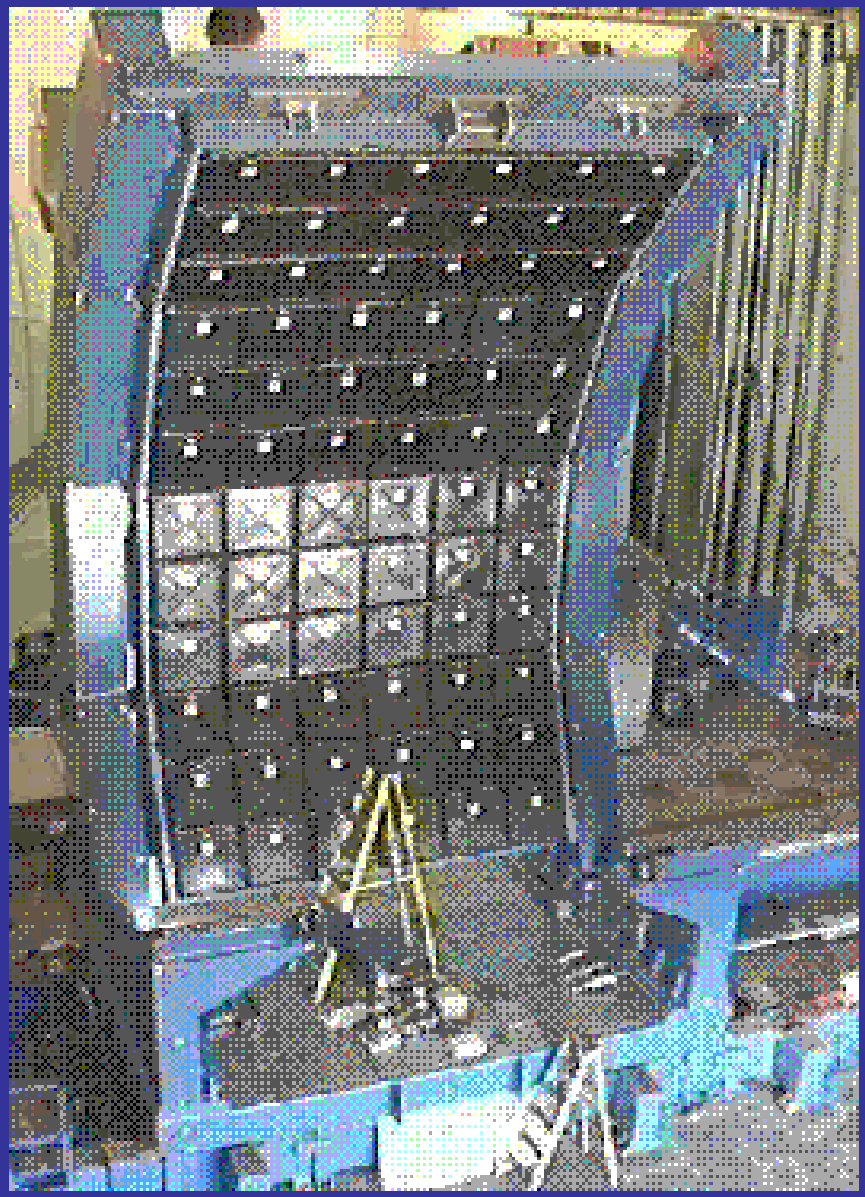
- Electromagnetic Calorimeter at mid-rapidity

- PbSc – Lead Scintillator detector
- PbGl – Lead Glass detector

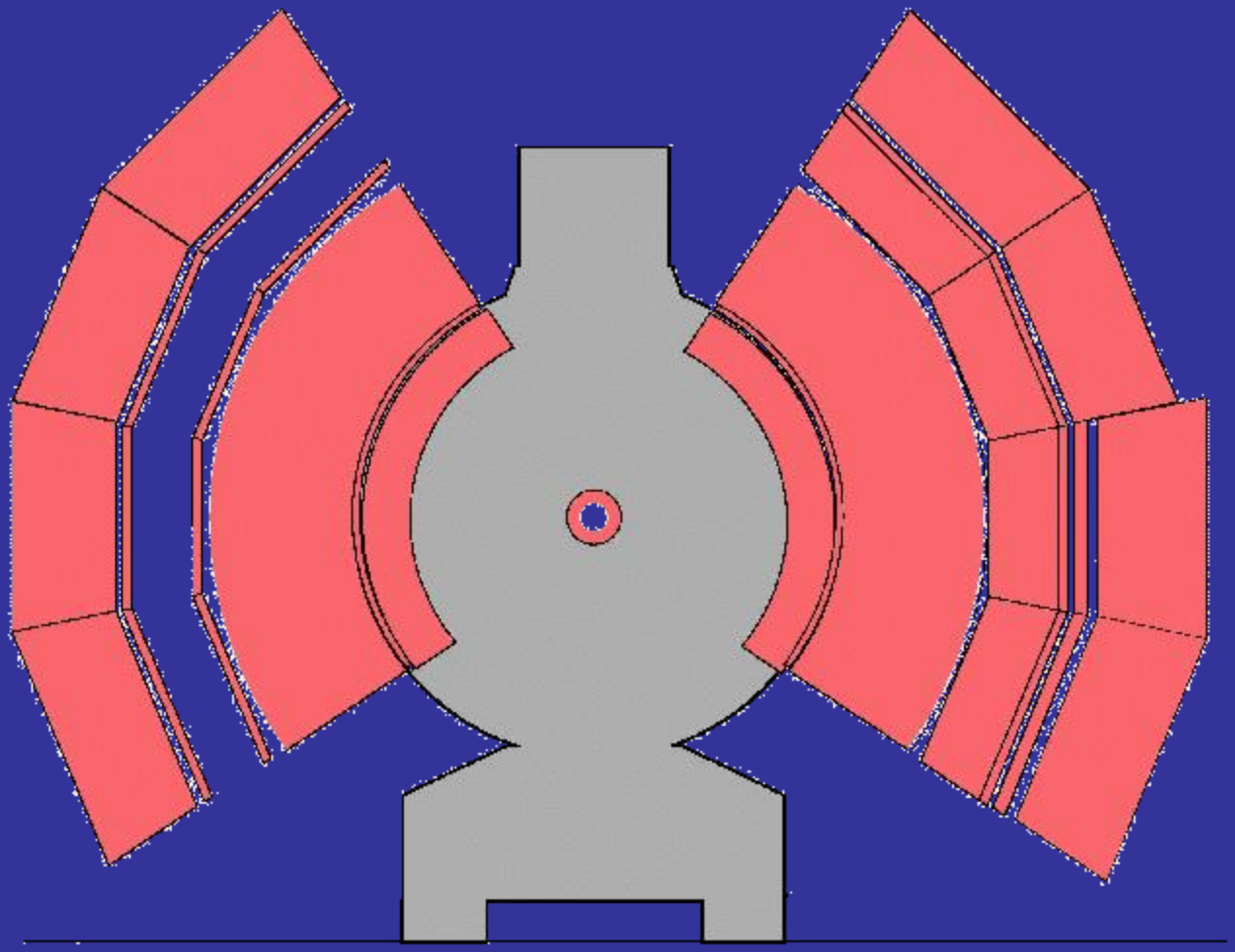
- Acceptance (central arms):

$|\eta| < 0.375$; $\Delta\phi = 90^{o} \times 2$

- 4 Sectors in each arm



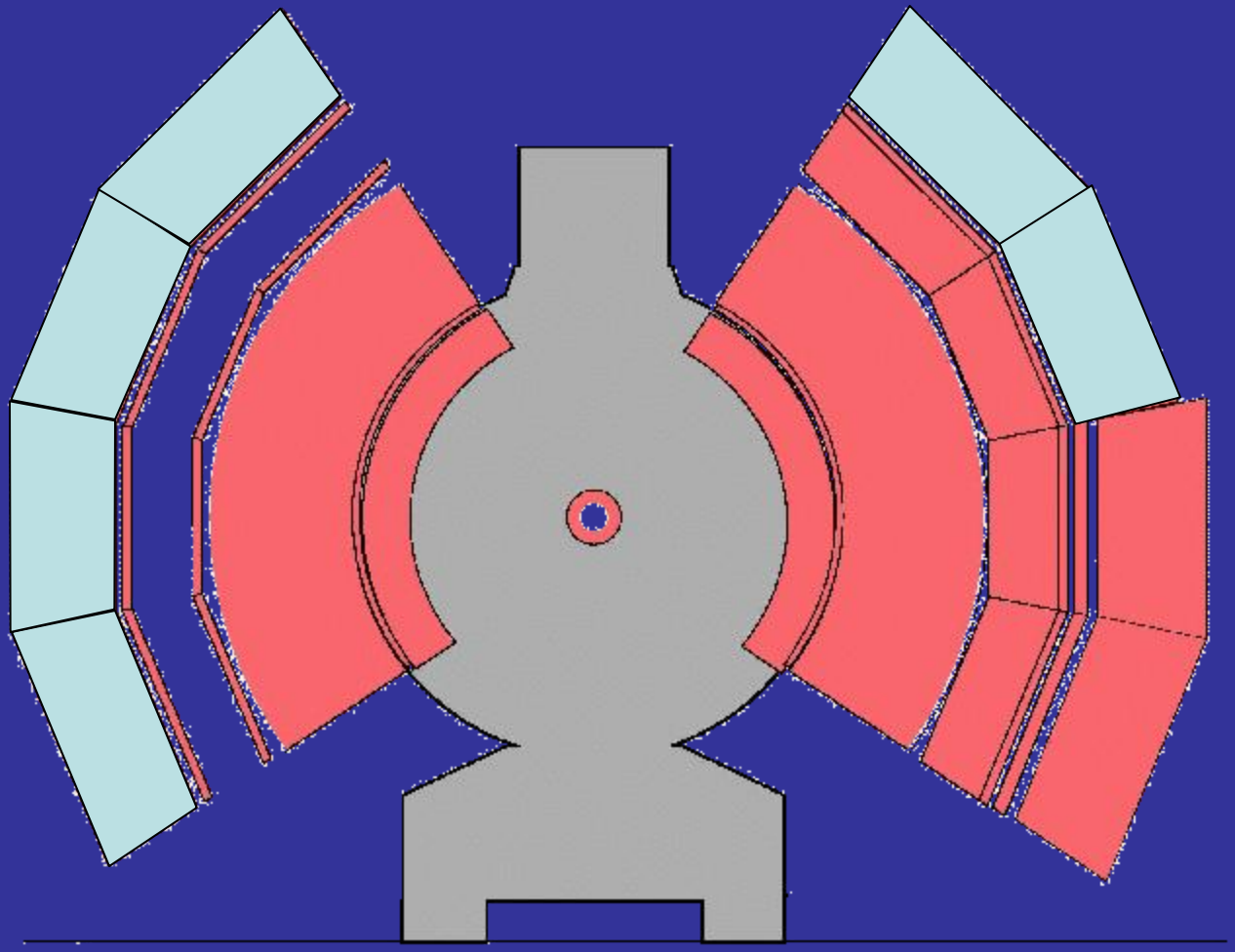
Where is the EmCal ?



West East

6 Sectors PbSc, covering all of West Arm and top of East Arm
PbSc has 15552 channels total

PbSc

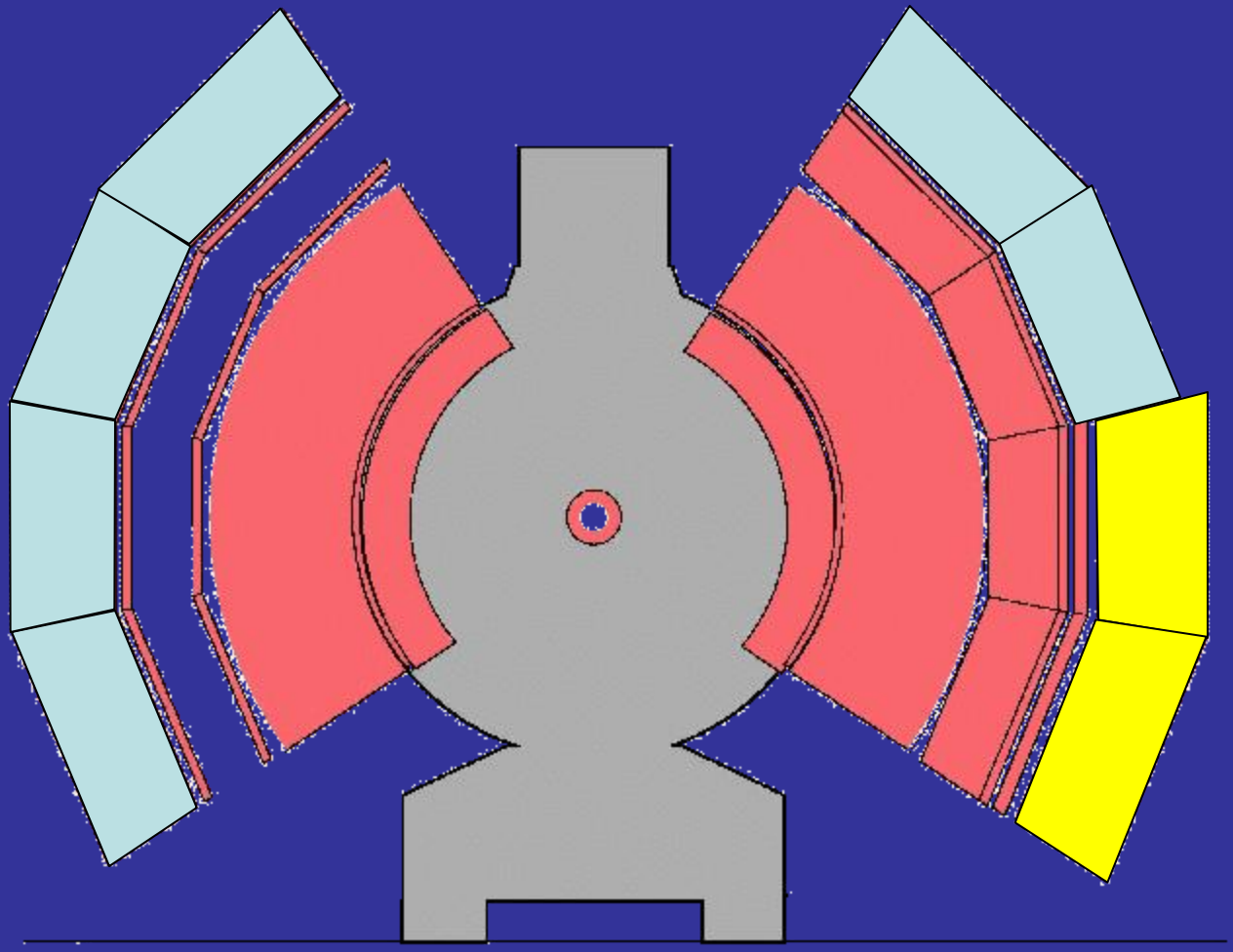


West

East

6 Sectors PbSc, covering all of West Arm and top of East Arm
PbSc has 15552 channels total

2 Sectors PbGl, covering bottom of East Arm
PbGl has 9216 channels total



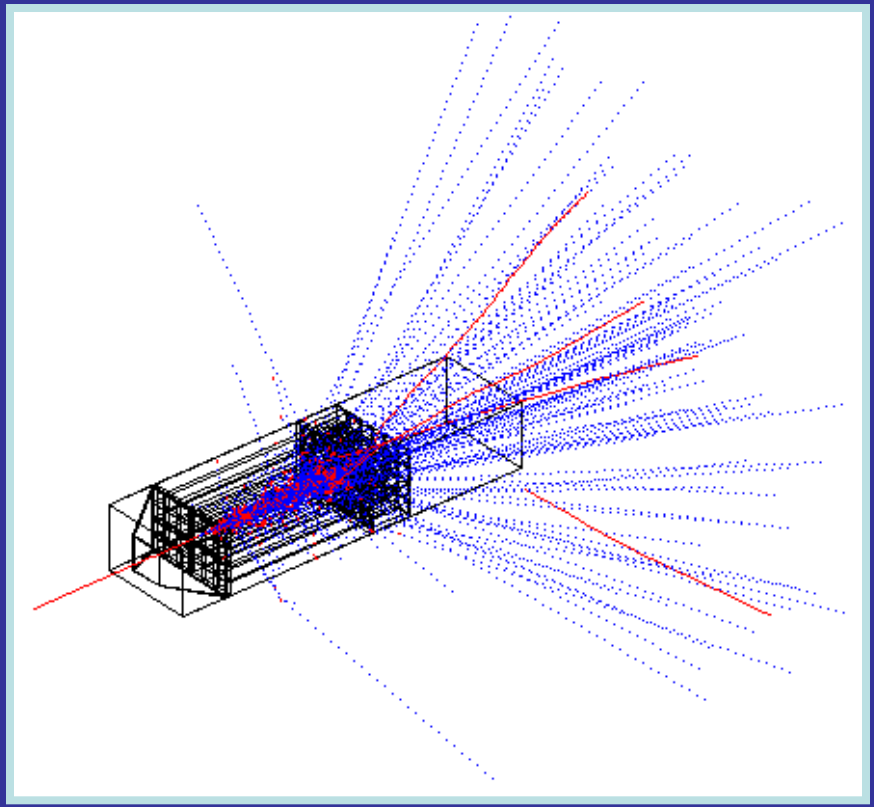
Outline

- Principle of Detection
- PbSc + PbGl
  - Design
  - Reference System
- Analysis
- Physics

Principles of Detection:

- Electrons and Photons interact electromagnetically (bremsstrahlung and pair production)
  
  electromagnetic shower
- Strongly interacting particles: hadronic shower, MIP
- Calorimeter measures energy, position, and TOF
- PbSc – sampling calorimeter, layers of lead and scintillator
- PbGl – homogeneous calorimeter, lead-glass Cherenkov radiator
- Light read by PMT

Principles: PbGl



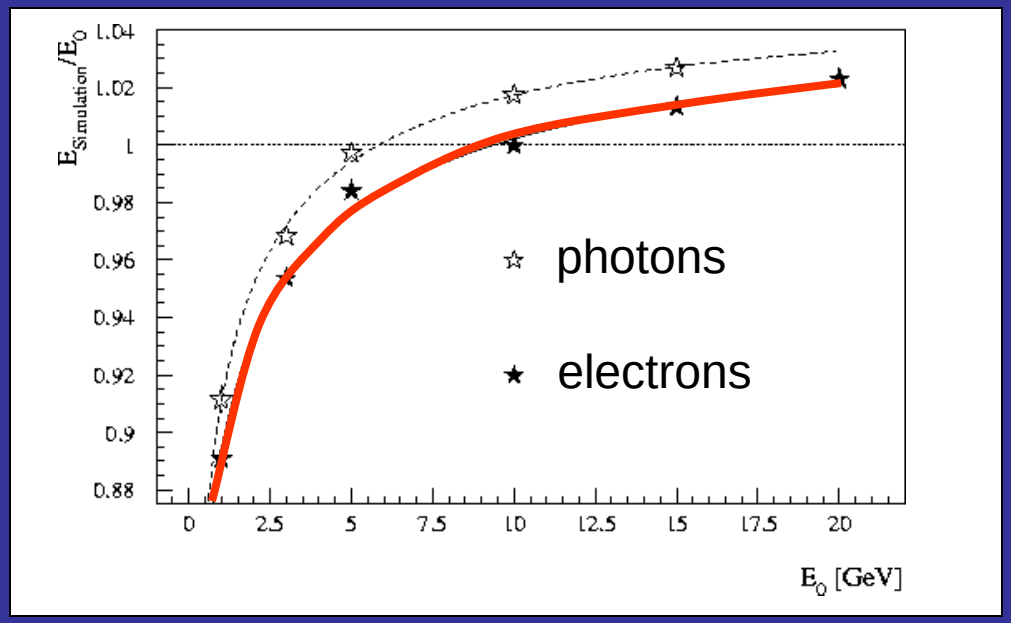
- Charged shower particles generate Cherenkov photons in the PbGl
- The Ch. Photons propagate with a wavelength dependent attenuation to the PMT
- Shower depth:

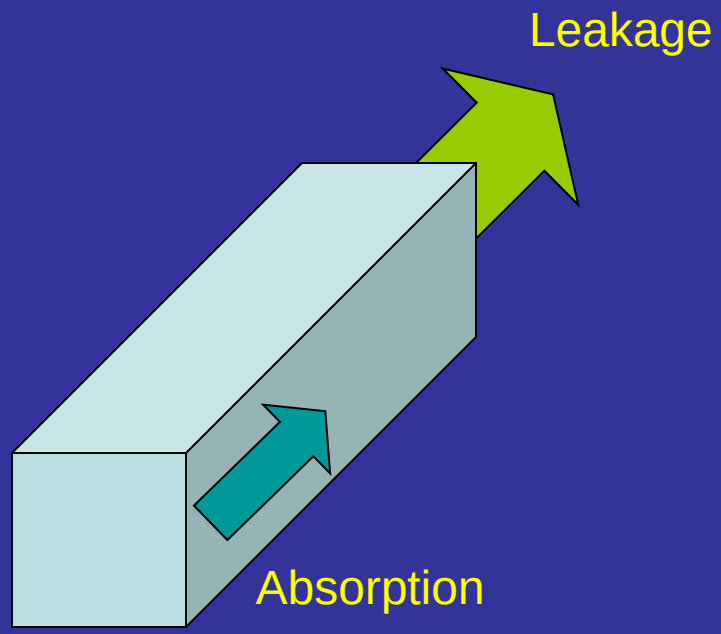
$$\frac{X_{max}}{X_0} \propto \ln \frac{E}{E_c} - t$$

- Number of generated Cherenkov photons:

$$N_{Cherenkov} \propto E_0$$

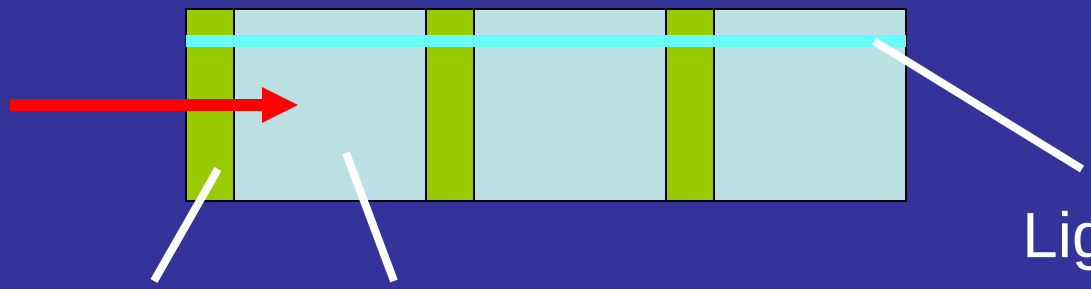
Non-Linearity Effects





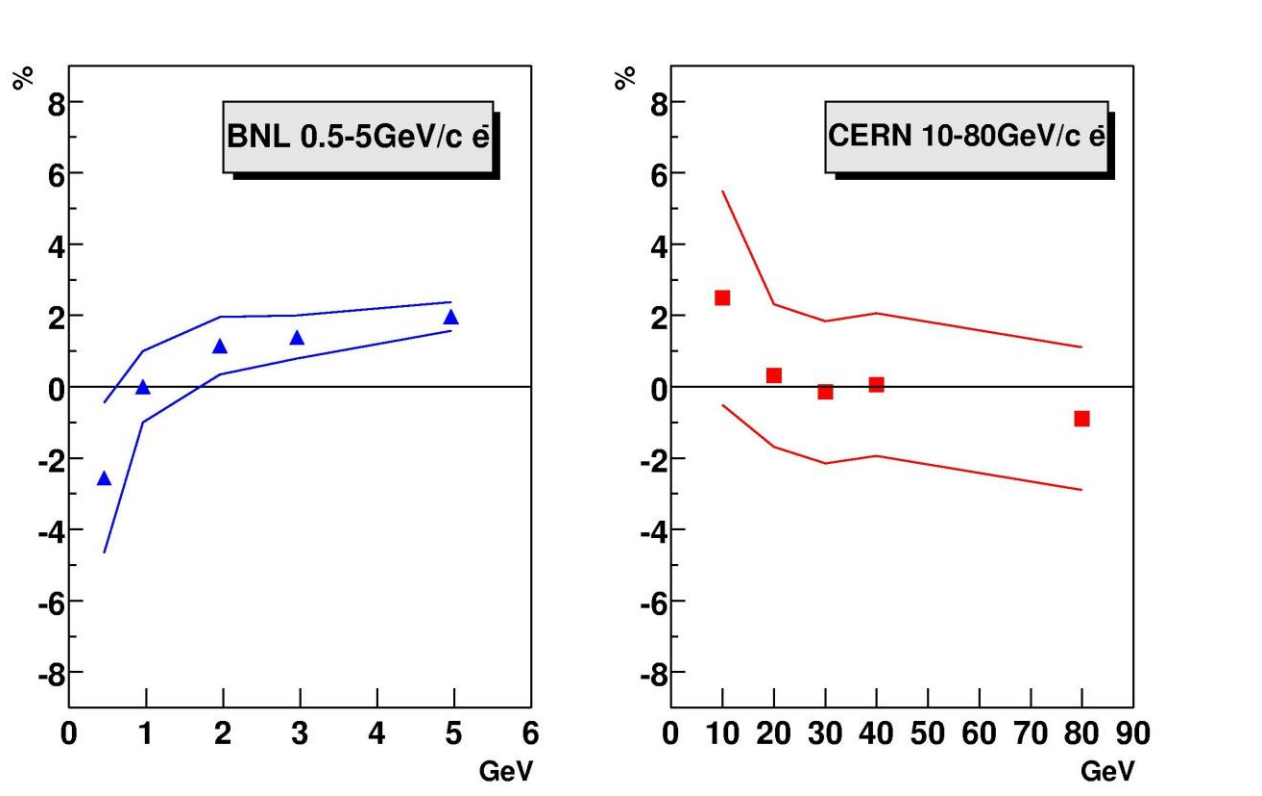
Non-linearity effects have to be corrected

Principles: PbSc



- Absorber : Pb
- Scintillator:
  1.5 % PTP / 0.01 % POPOP

Non-Linearity in the PbSc



$$\frac{E_{meas} - E_0}{E_0}$$

finite light attenuation length in WS fiber

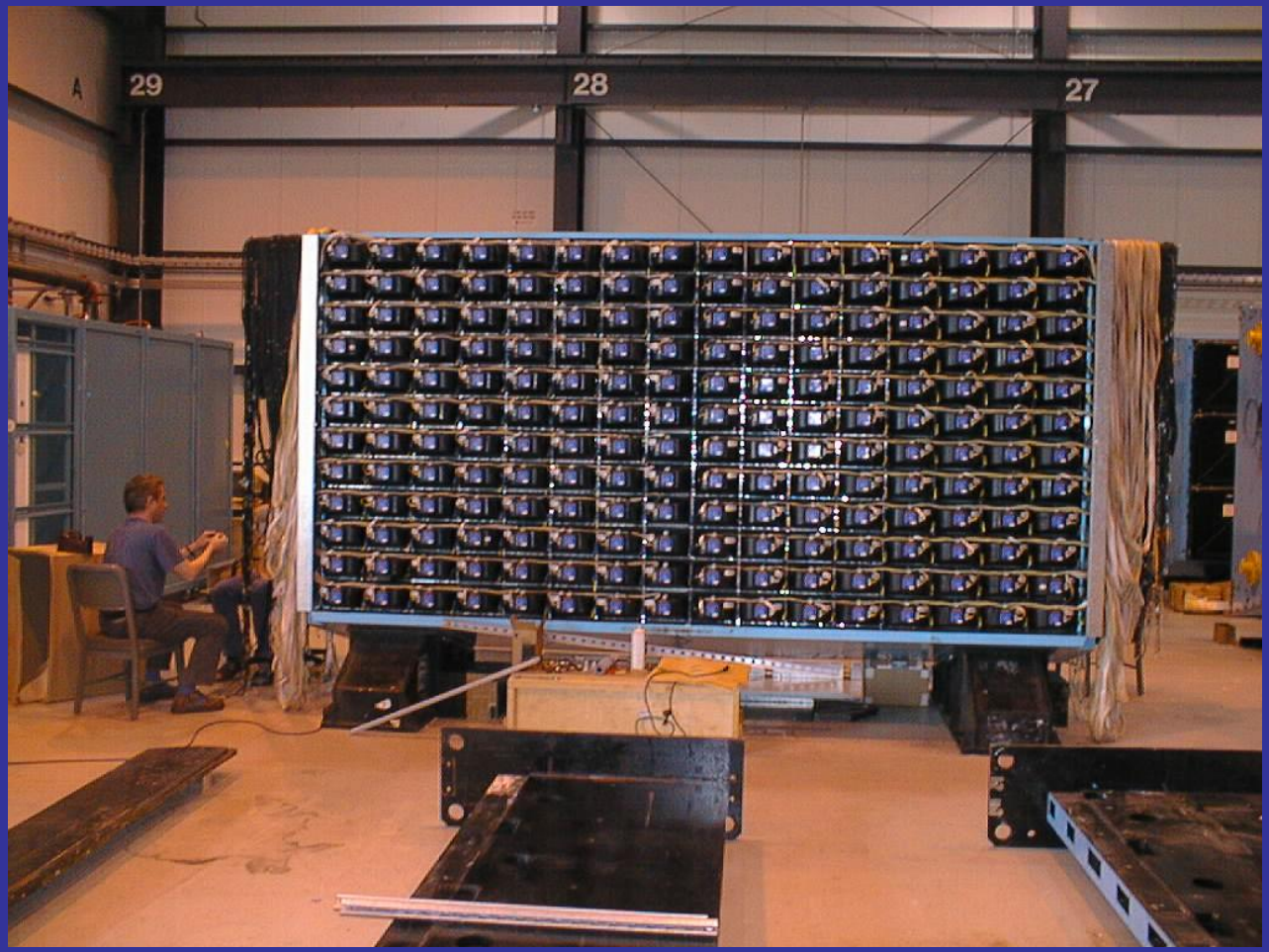
energy leakage

Two parts make one detector!

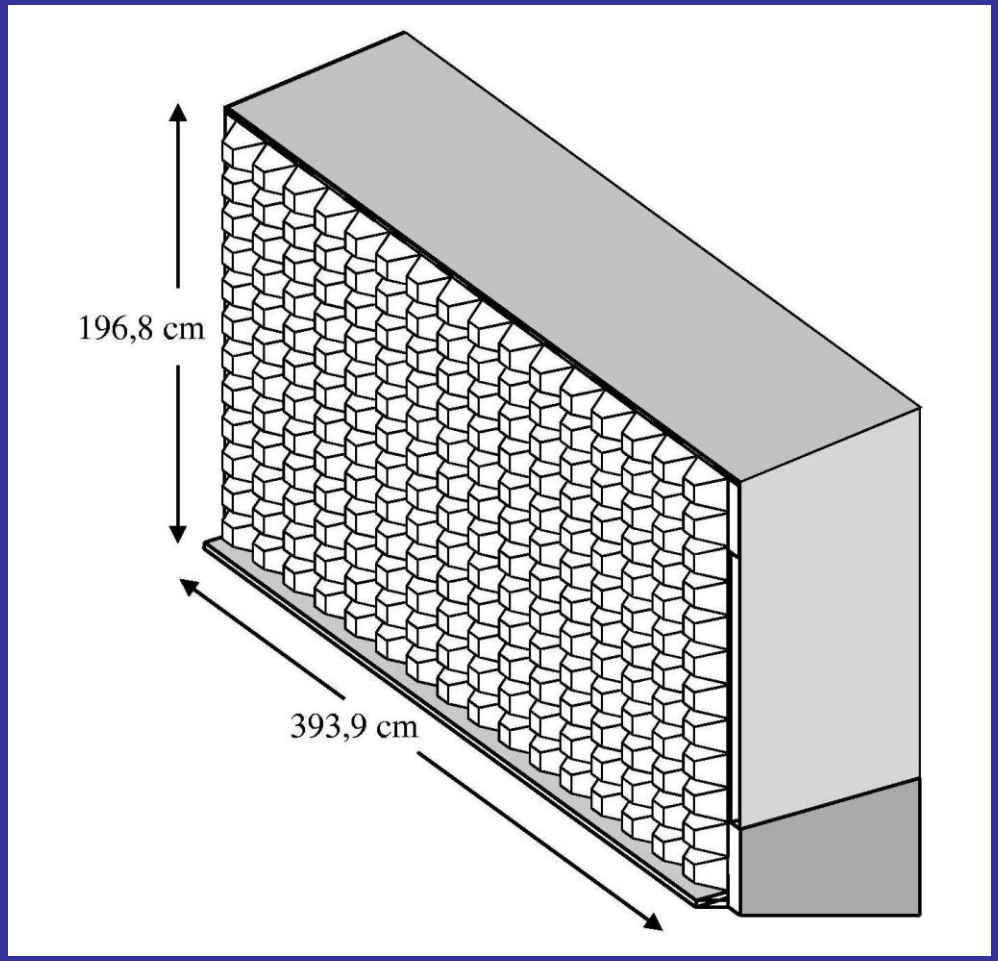
- PbSc:
  - Excels in timing
  - Better linearity in response
  - In principle, response to hadrons better understood
- PbGl:
  - Excels in energy measurement
  - Better granularity
  - Proven system (WA98)
- Two detectors = different systematics

  ⇒ increase confidence level of physics results

The Leadglass Detector

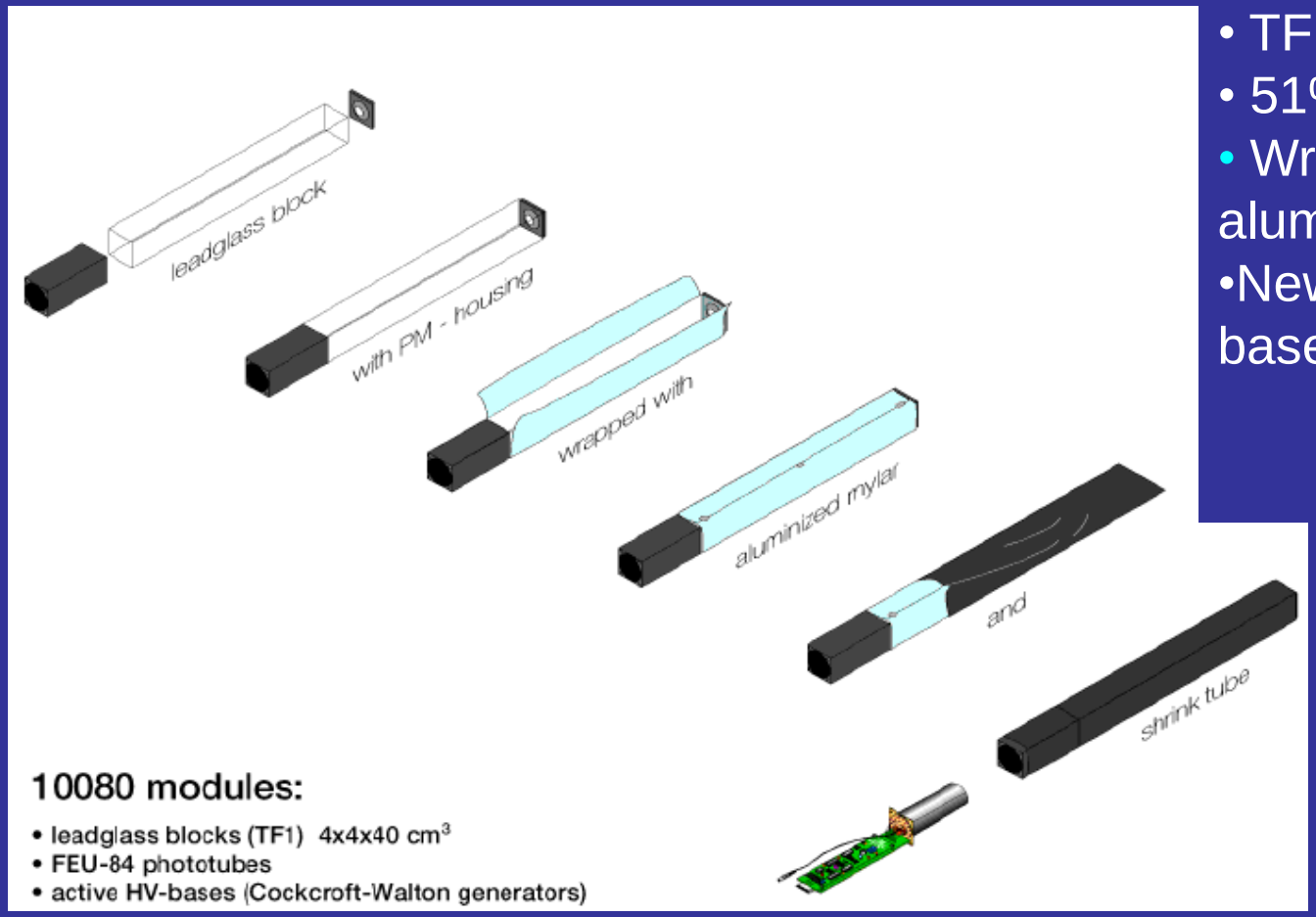


PbGl-Sector



- 2 Sectors PbGl
- 1 PbGl Sector
  - 16x12 supermodules (SM)
- 1 PbGl SM
  - 6x4 towers
  - Separate reference system
- 1 FEM
  - Reads out 2x3 supermodules or 12x12 towers

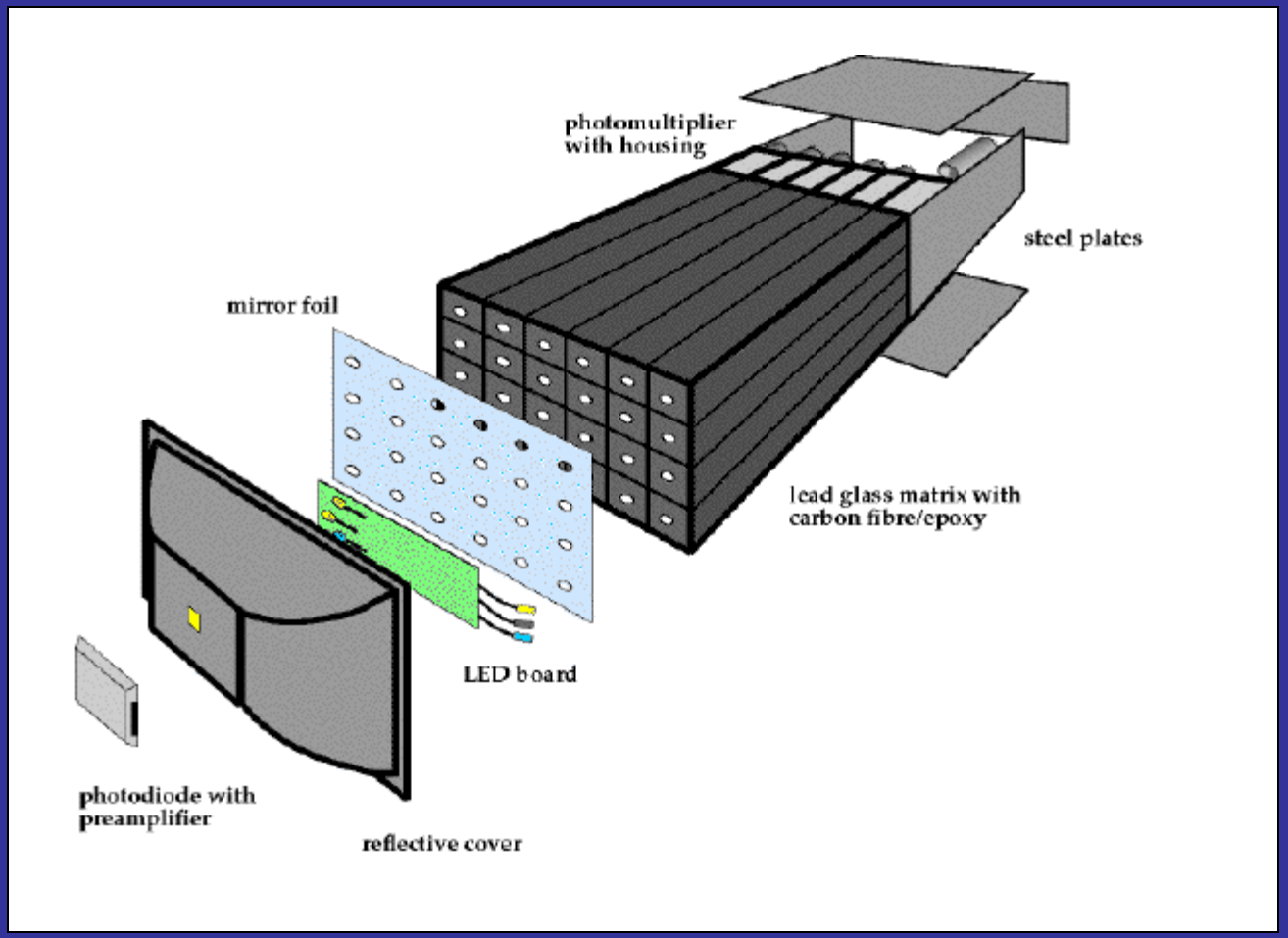
PbGl Structure - Module



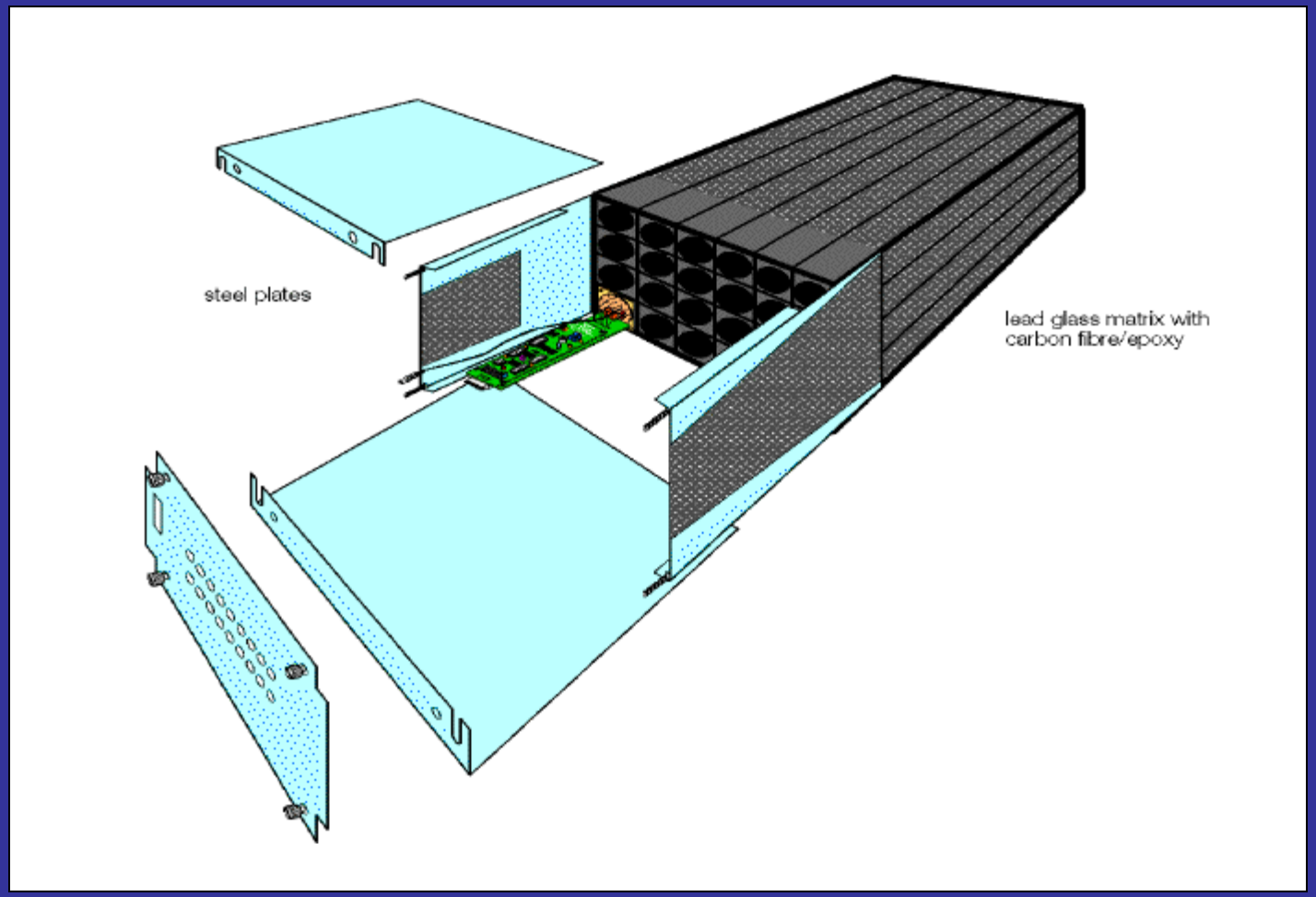
- TF1 PbGlass
- 51% Pb-Oxide
- Wrapped with aluminized mylar foil
- New developed HV-bases

1 PbGl tower = 1 PbGl module

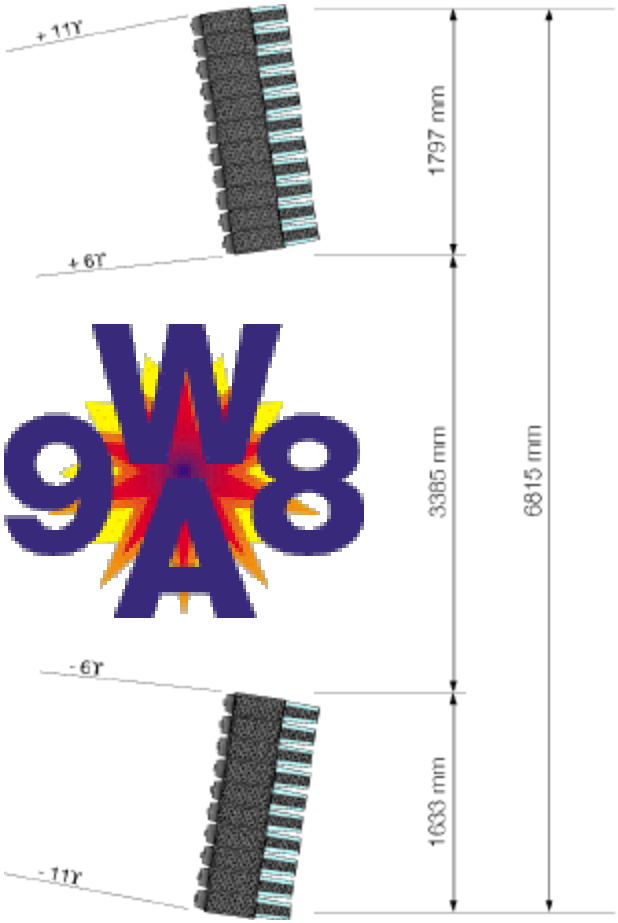
PbGl Structure II

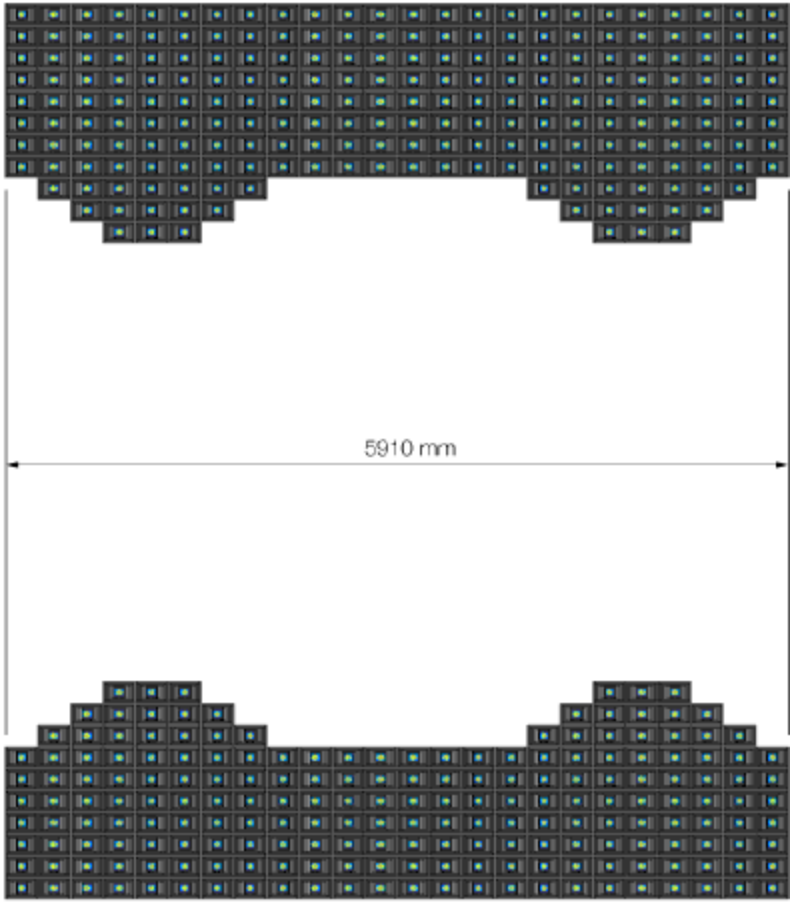


PbGl Structure III

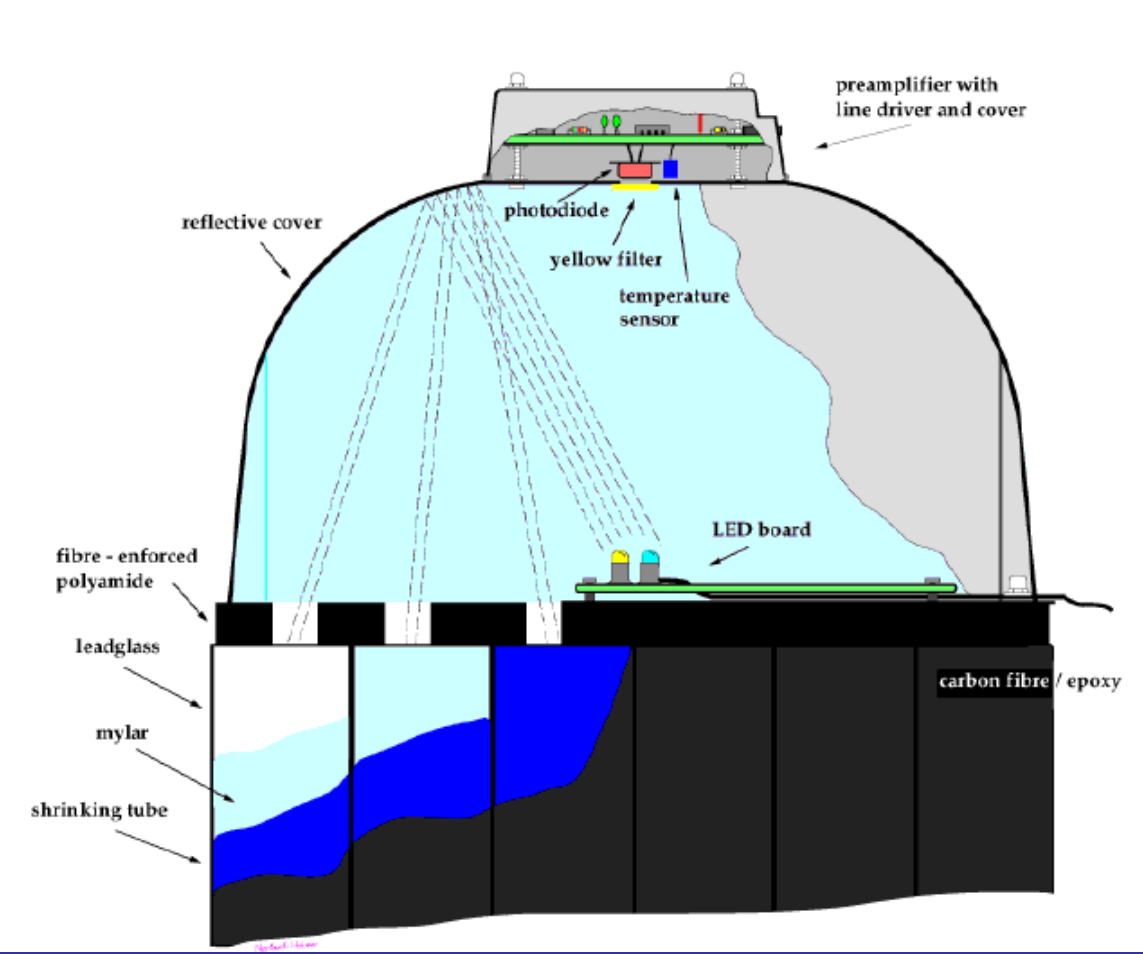


Variable Layout





Reference System



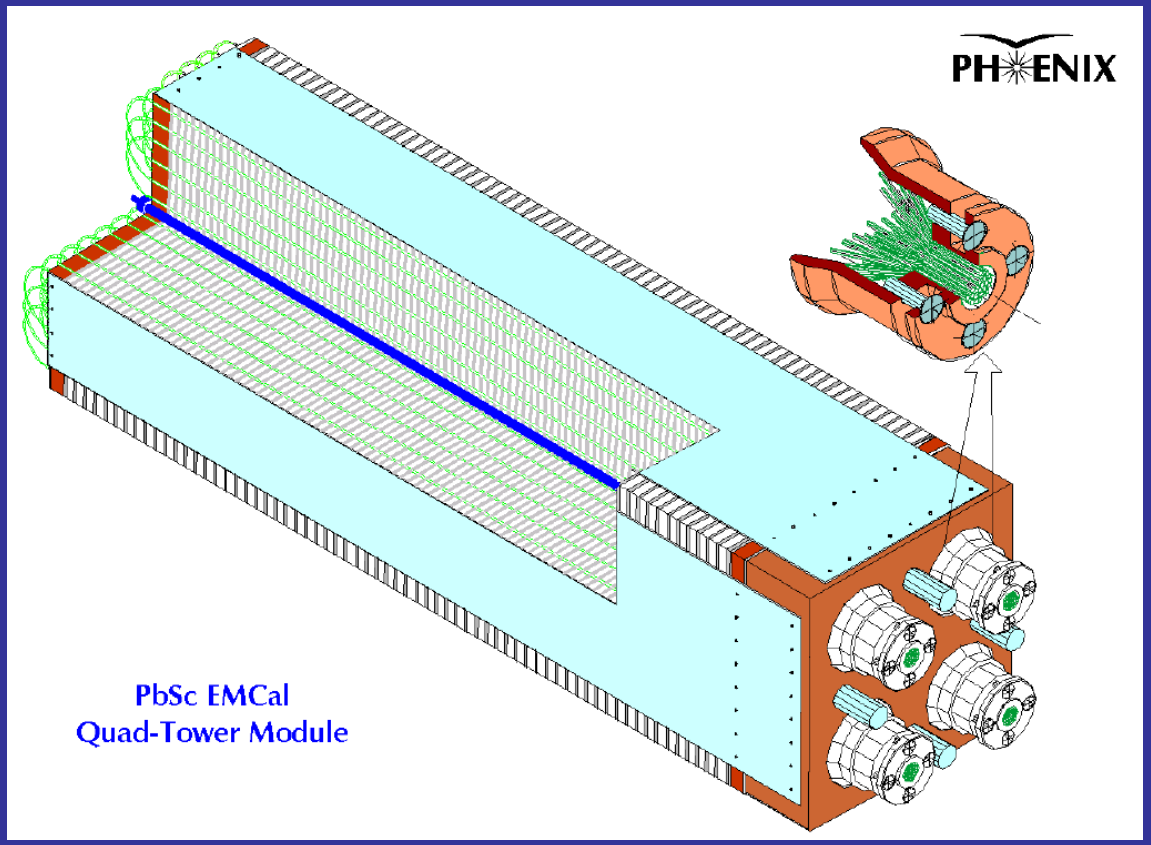
- Three LEDs
  - Blue
  - Yellow
  - Avalanche Yellow
- PIN Diode
- Try to imitate Cherenkov photons

Reference System

The Lead Scintillator

PbSc Structure

- 1 Sector = 6x3 Supermodules (SM)
- 1 PbSc SM = 12x12 towers
- PbSc towers: 5.52 x 5.52 x 33 cm^3 (18 X_0)
- 15552 blocks total

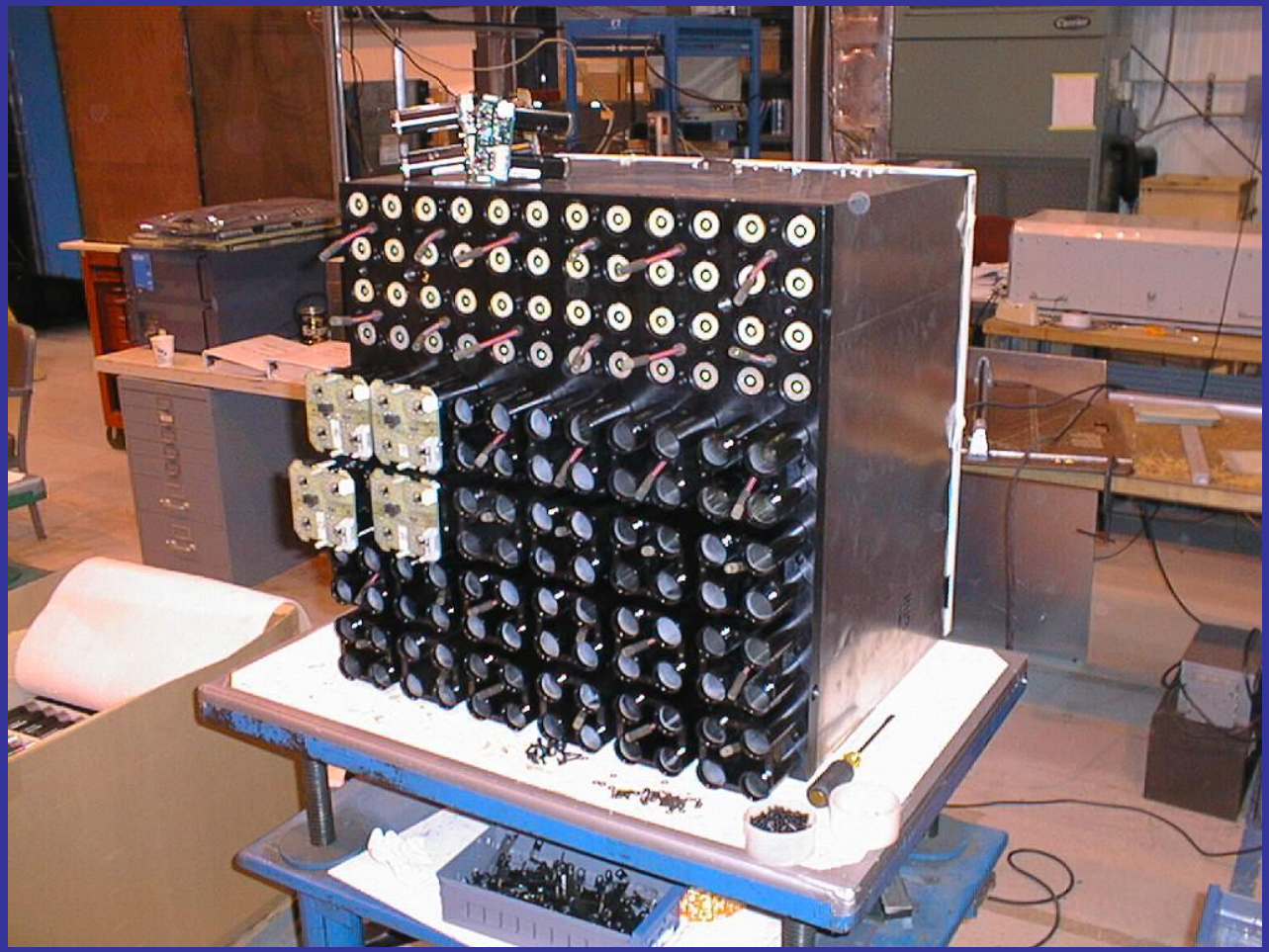


1 PbSc tower:

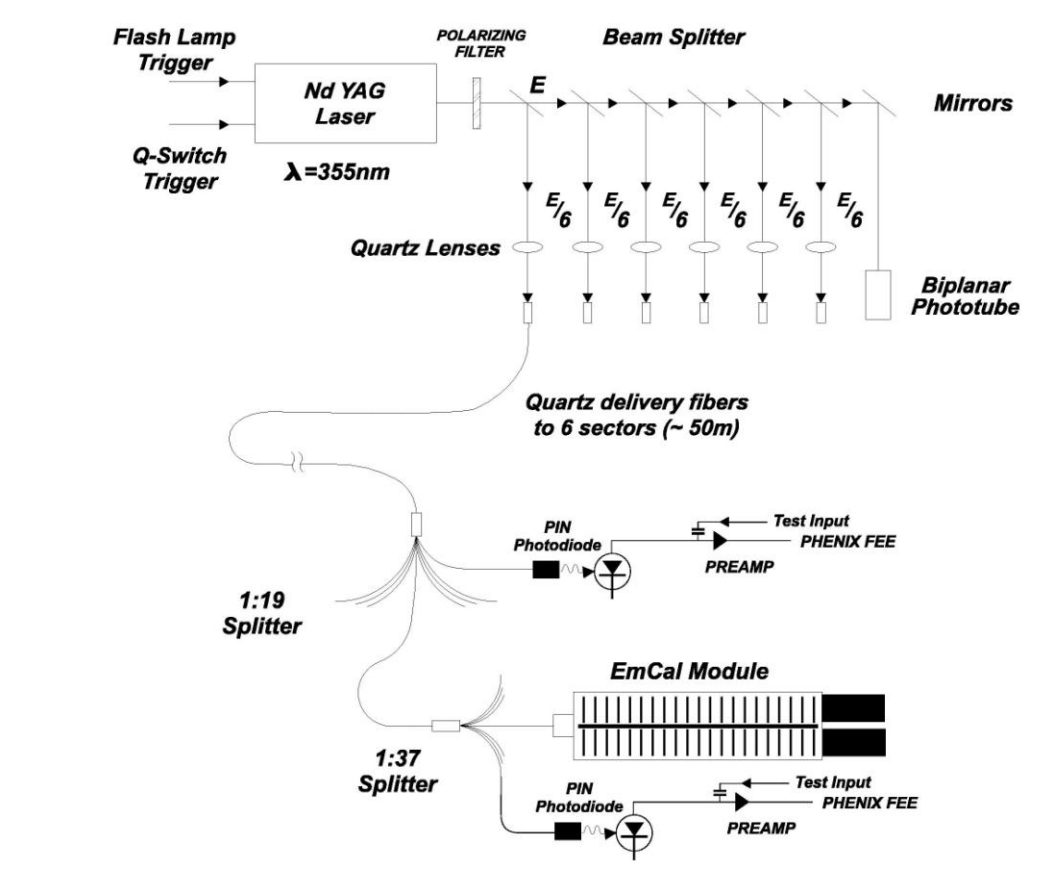
- 66 sampling cells
- 1.5 mm Pb, 4 mm Sc
- Ganged together by penetrating wavelength shifting fibers for light collection
- Readout: FEU115M phototubes

1 FEM reads out 1 Supermodule

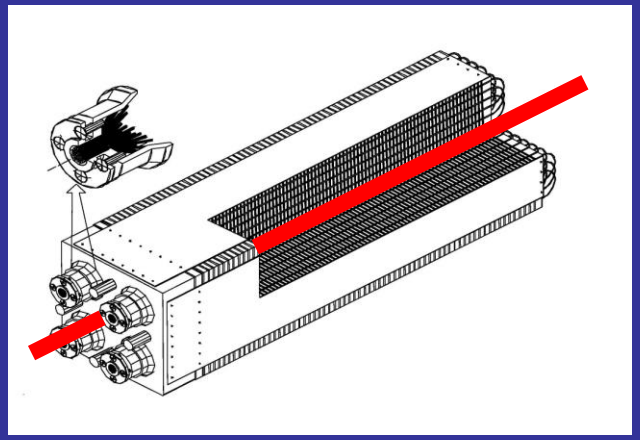
PbSc Supermodule



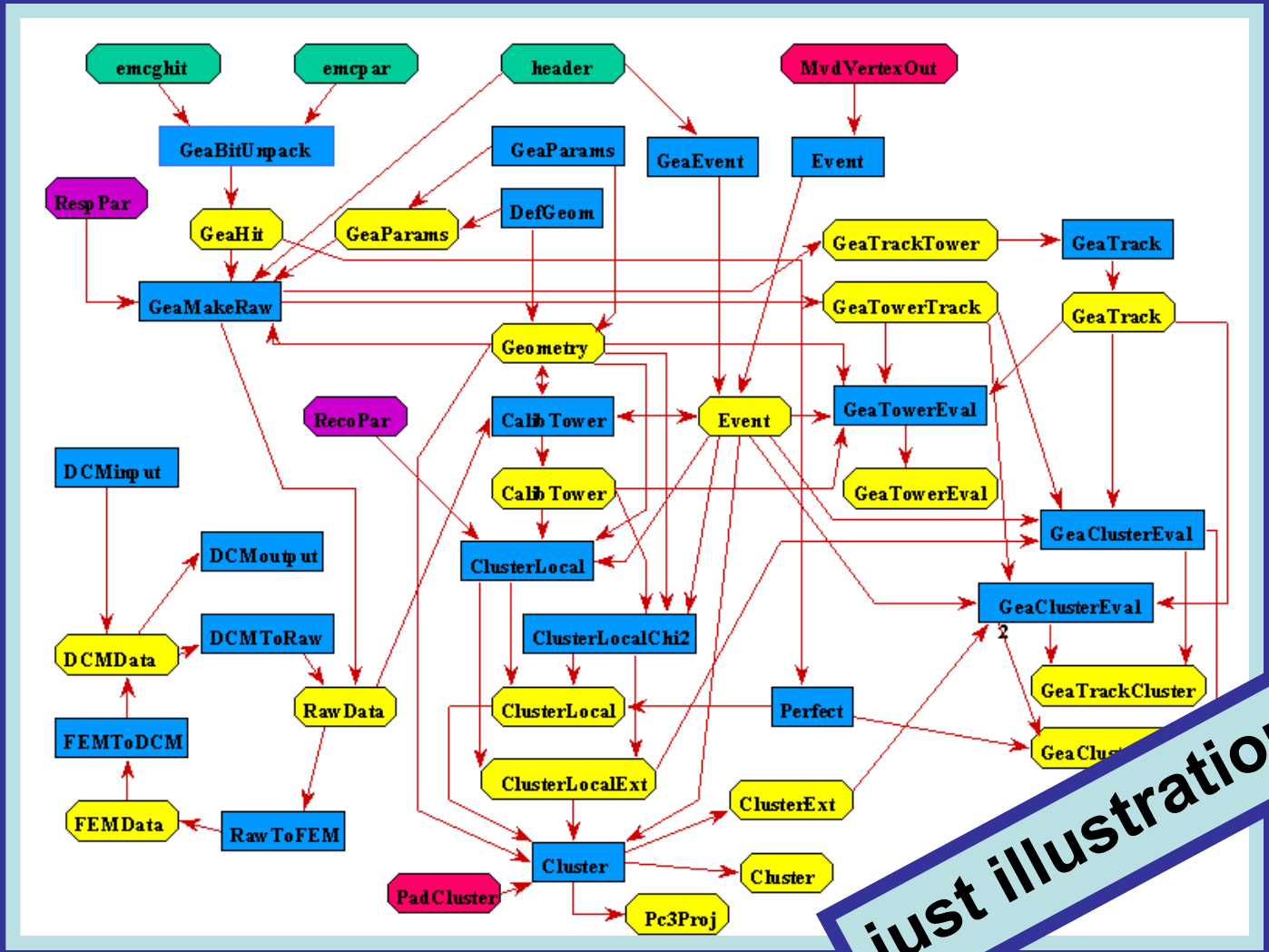
Reference System



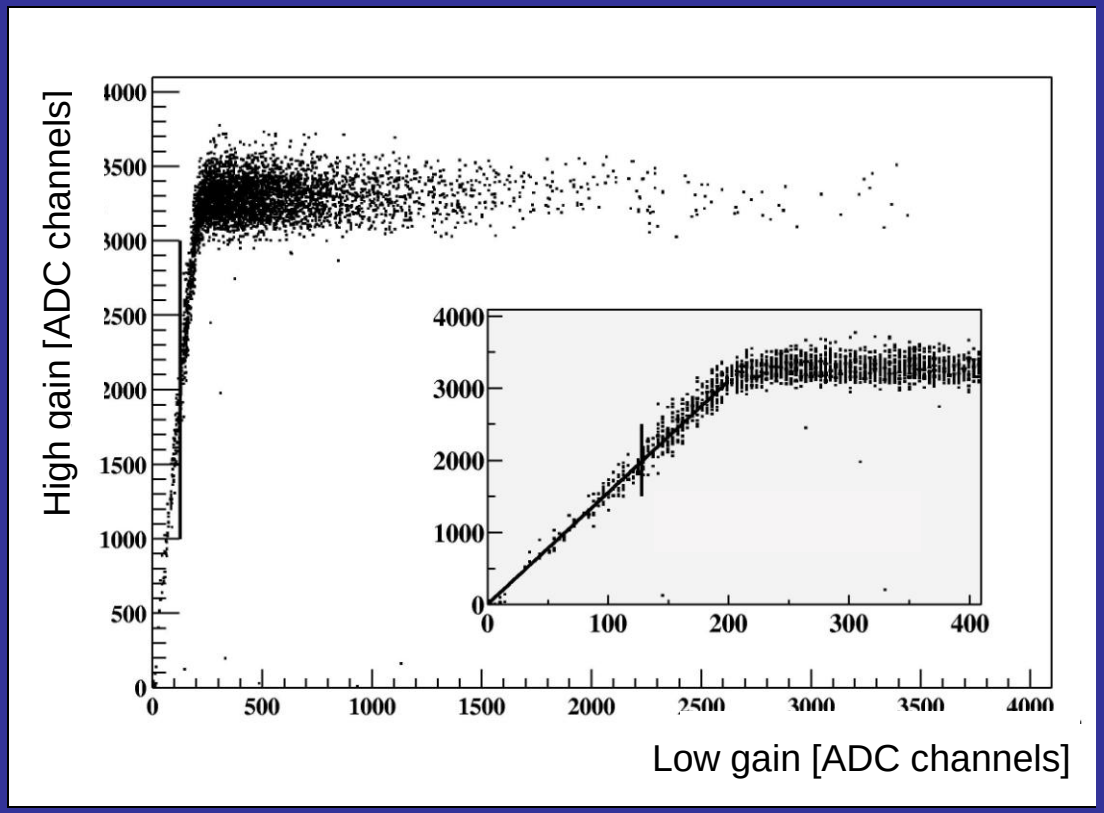
- 1 YAG laser
- Optical splitters/fibers
- Leaking fibers
  - 38 cm long
  - 2 mm diameter
- Simulating 1 GeV e. m. shower depth profile



Analysis

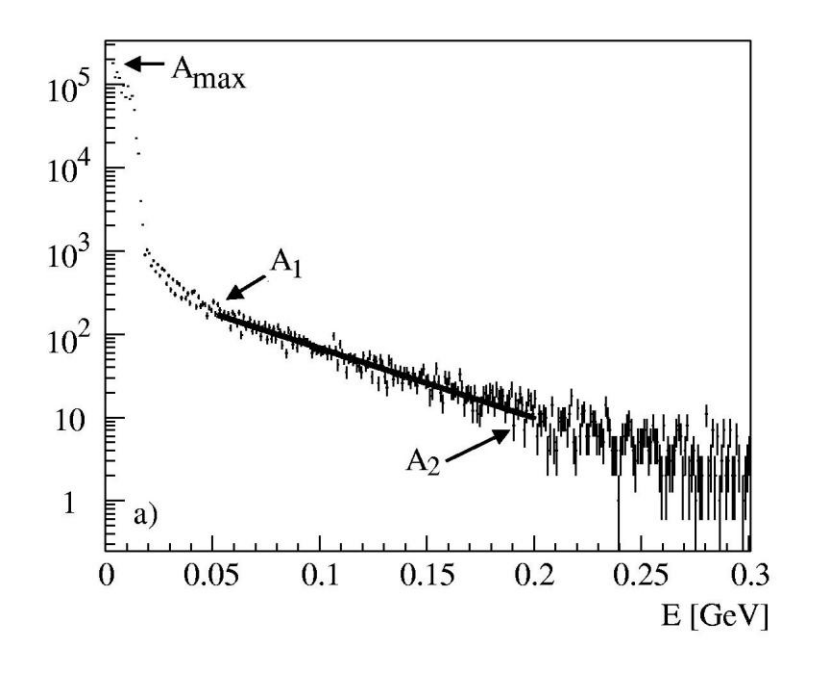

emcghit
emcpar
header
MvdVertexOut
GeaBitUnpack
GeaParams
GeaEvent
Event
RespPar
GeaHit
GeaParams
DefGeom
GeaTrackTower
GeaTrack
GeaMakeRaw
GeaTowerTrack
GeaTrack
Geometry
RecoPar
CalibTower
Event
GeaTowerEval
DCMInput
CalibTower
GeaTowerEval
GeaClusterEval
DCMOutput
ClusterLocal
GeaClusterEval 2
DCMData
DCMToRaw
ClusterLocalChi2
GeaTrackCluster
RawData
ClusterLocal
Perfect
FEMToDCM
ClusterLocalExt
ClusterExt
FEMData
RawToFEM
Cluster
Cluster
PadCluster
Pc3Proj
just illustration

FEM Data



- Information:
  - Pre + Post cell
  - High + Low gain
  - Timing
- Post-Pre offset corr.
- Gain adjustment

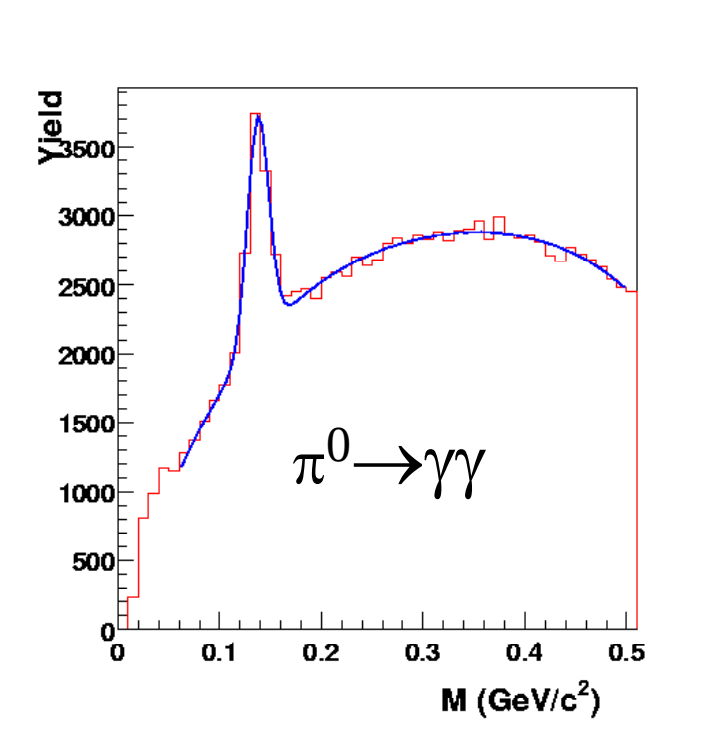
Calibration I



- Detectors calibrated with test beam
- PbSc: MIP peak
- PbGl: calibration from WA98
- Time dependent calibration
- Rel. adjustment of towers

  - important for trigger -

Calibration II



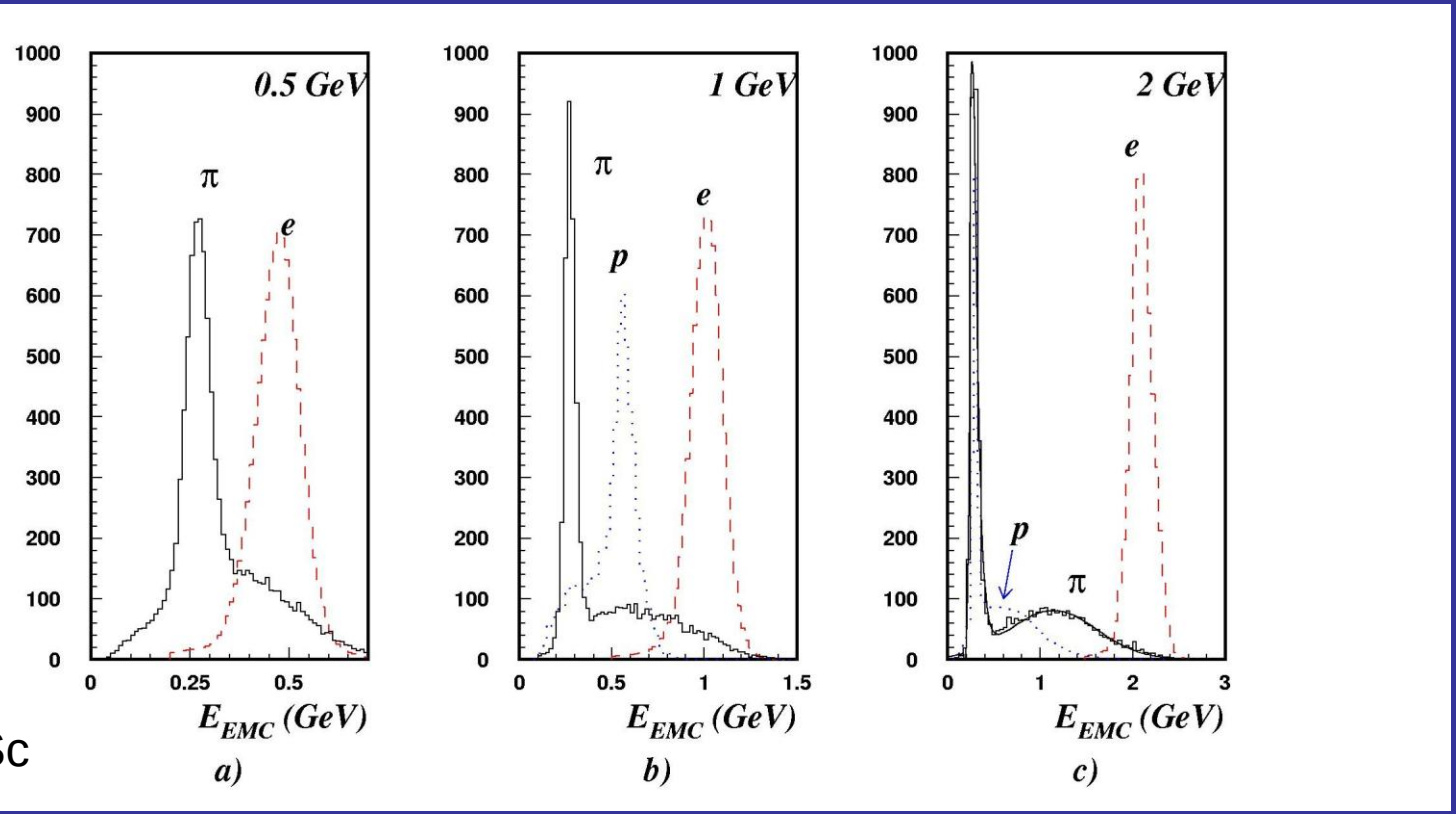
Test: π^0 mass peak

Peak position verifies absolute energy calibration

Cluster Reconstruction

- Cluster algorithms
- Position reconstruction
- Correction of energy non-linearity
- Angular dependence
- Overlap effects

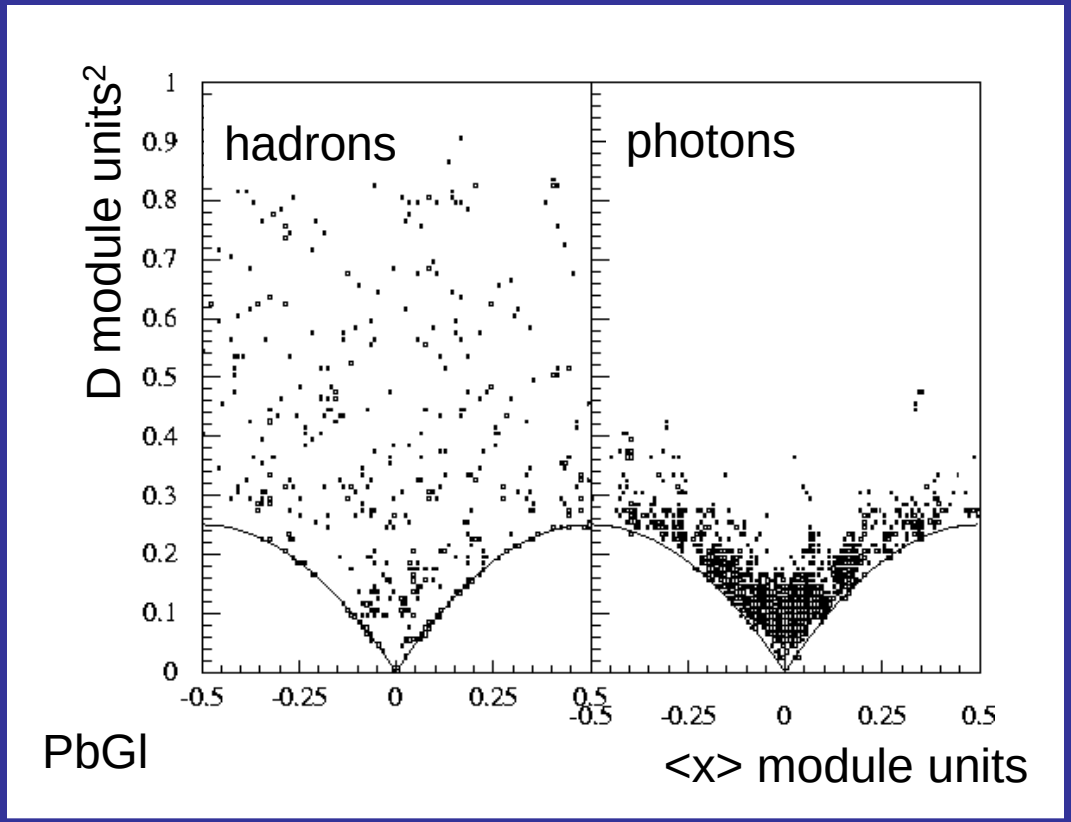
Hadrons



PbSc

Different response to electrons and hadrons !

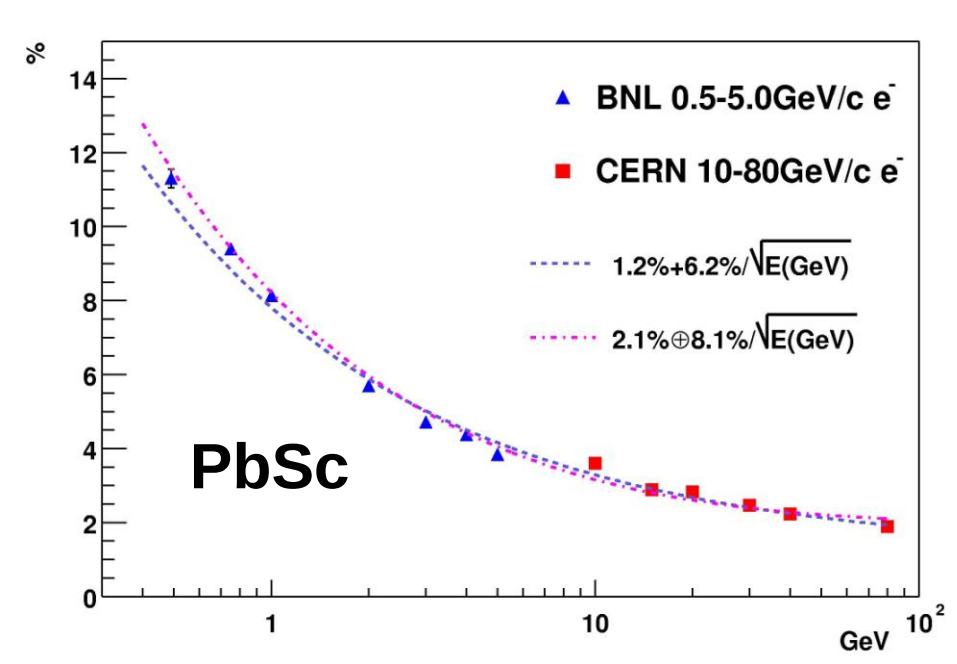
Hadrons II

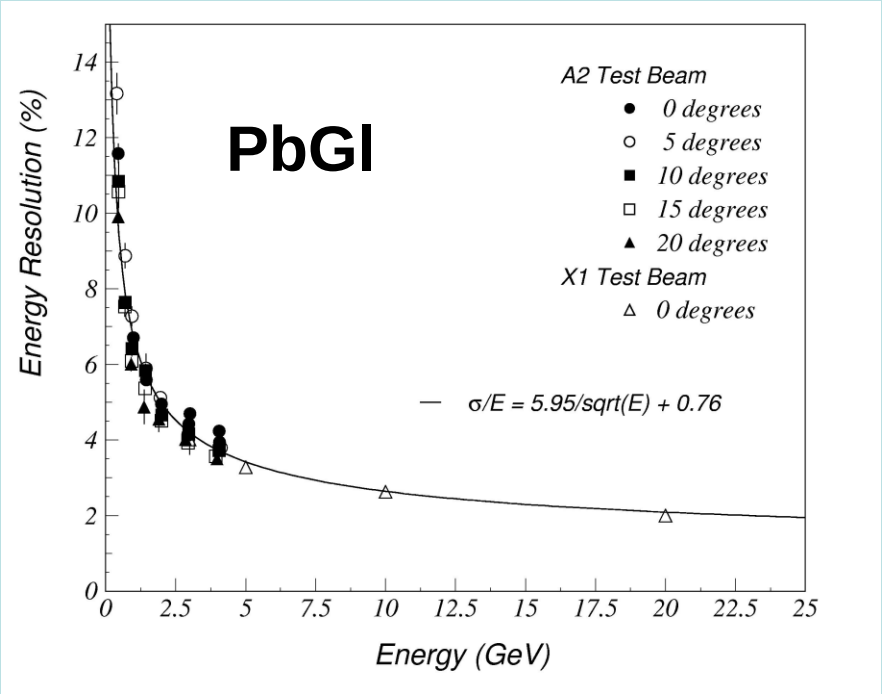


- Photon ID:
  - PbGl: dispersion cut
  - PbSc: shower shape
  - Timing

Energy Resolution

$$\frac{\sigma_E}{E} = \frac{8.1\%}{\sqrt{E}} \oplus 2.1\%$$





$$\frac{\sigma_E}{E} = \frac{5.95\%}{\sqrt{E}} \oplus 0.76\%$$

Physics topics

- Direct photon measurement

Physics topics

$\gamma \quad \pi^0$

- Direct photon measurement
- Identified neutral pions ($\pi^0 \rightarrow \gamma\gamma$) up to high p_T

Physics topics

γ π^0 e^-

- Direct photon measurement
- Identified neutral pions ($\pi^0 \rightarrow \gamma\gamma$) up to high p_T
- Electron measurement with RICH and TEC

Physics topics

γ π^0 e^- E_T

- Direct photon measurement
- Identified neutral pions ($\pi^0 \rightarrow \gamma\gamma$) up to high p_T
- Electron measurement with RICH and TEC
- Transverse energy

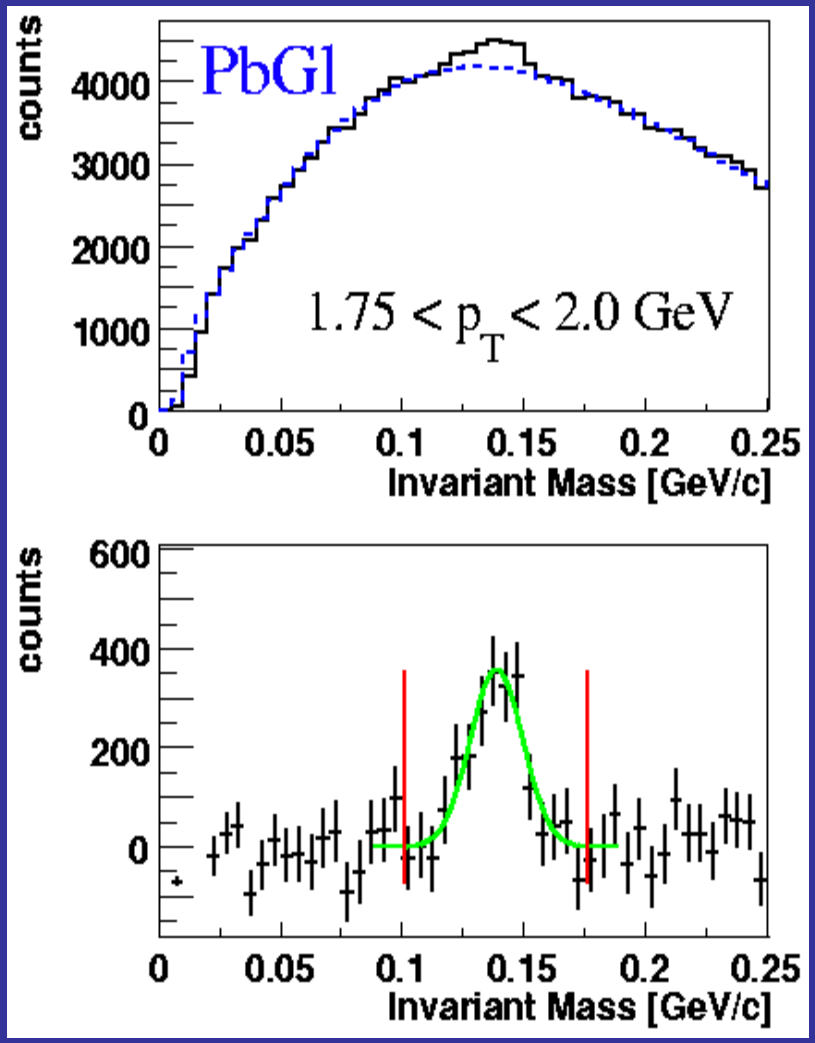
Physics topics

γ π^0 e^- E_T h

- Direct photon measurement
- Identified neutral pions ($\pi^0 \rightarrow \gamma\gamma$) up to high p_T
- Electron measurement with RICH and TEC
- Transverse energy
- Hadron PID with TOF

- EmCal-RICH Trigger to enhance particles at high p_T

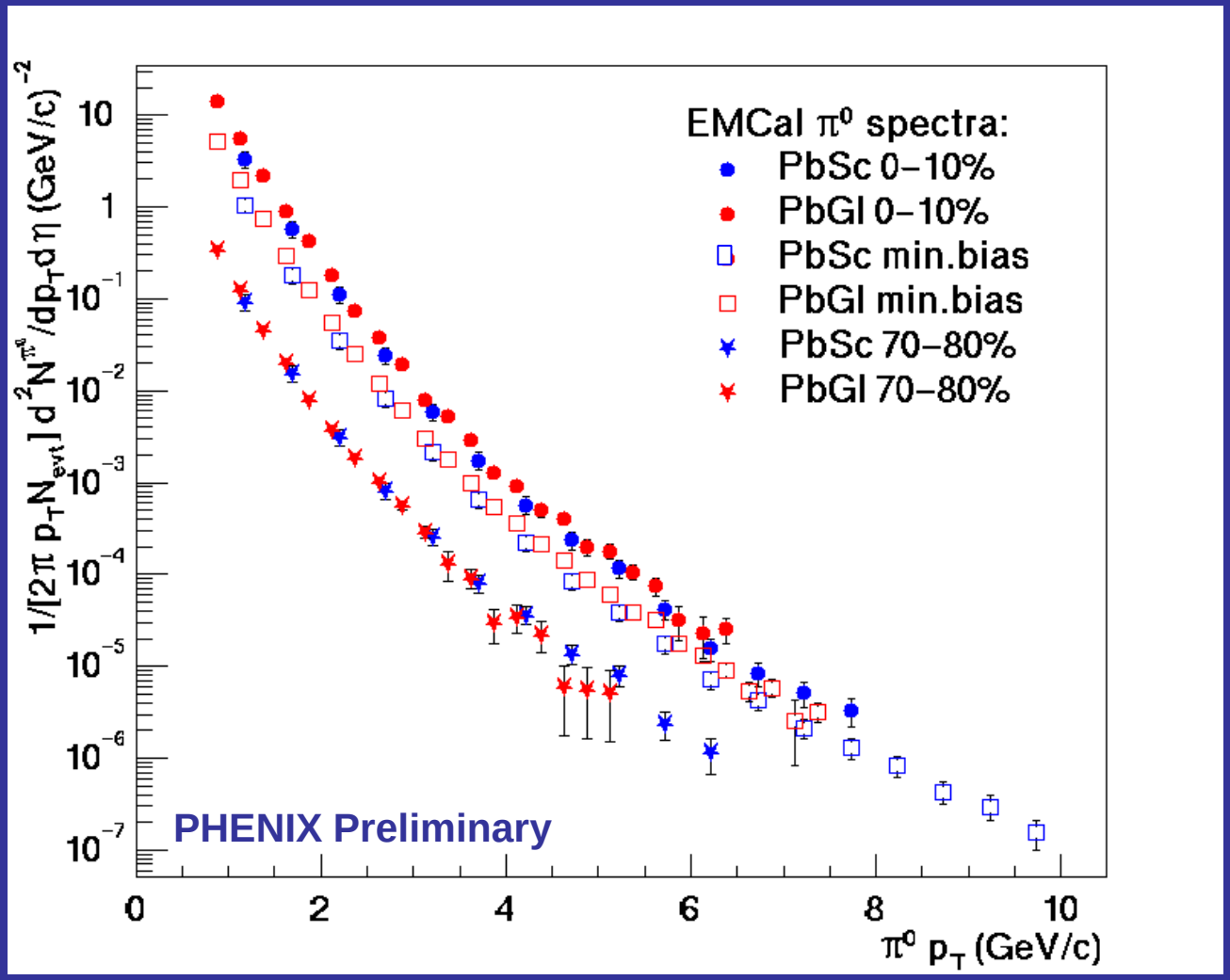
Measuring π^0



- Measure π^0 via 2-γ-decay
- Reconstruct π^0 via M_{inv}
  - $M_{inv} = \sqrt{2E_1E_2(1-\cos(\psi))}$
- Combinatorial background:
  - mixed events
- M_{inv} distribution for each p_T bin
- Subtract mixed events
- Integrate peak region

From: Stefan Bathe DPG-talk

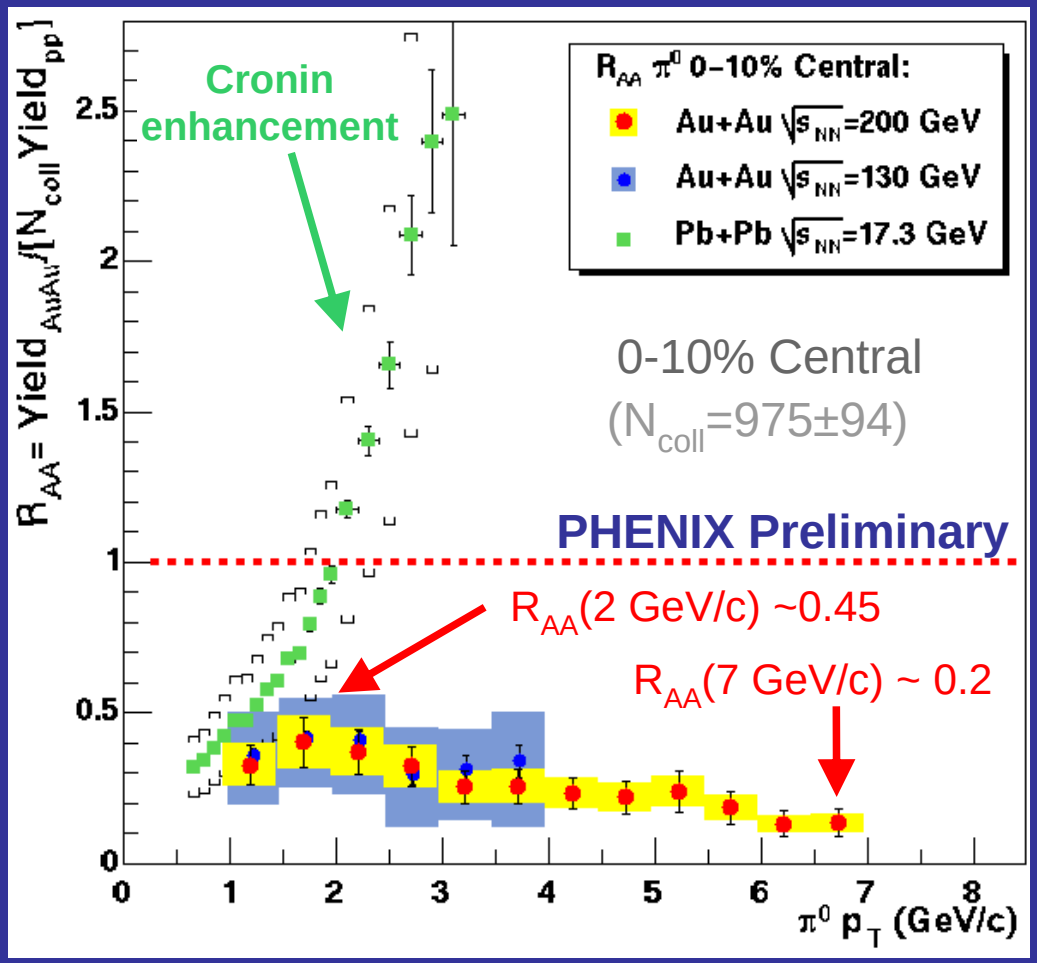
PbGl - PbSc π^0 spectra



Differences PbSc/PbGl
Consistent with
systematic errors: <25%

From: David d'Enterria QM-talk

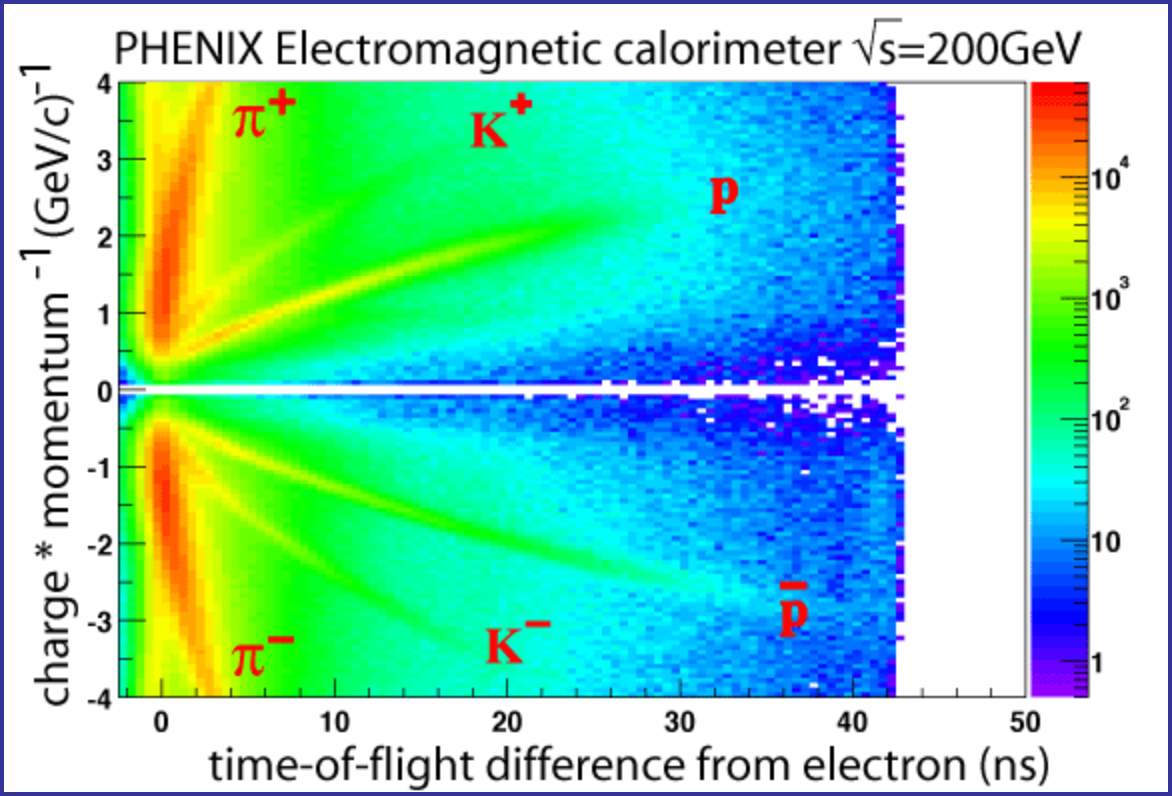
Nuclear modification factor



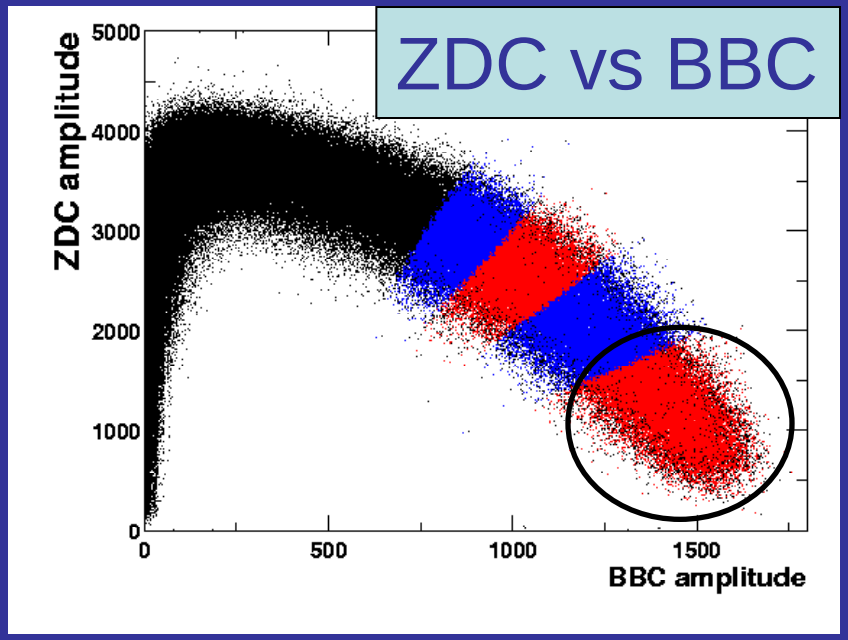
$$R_{AA}(p_T) = \frac{(dN/dp_T)_{AA}}{\langle N_{coll}\rangle (dN/dp_T)_{pp}}$$

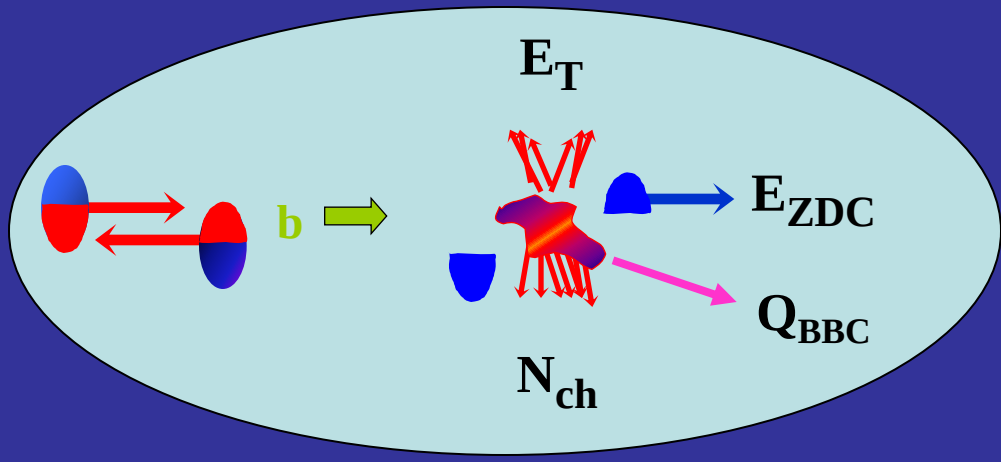
From: David d'Enterria QM-talk

Hadron ID with TOF

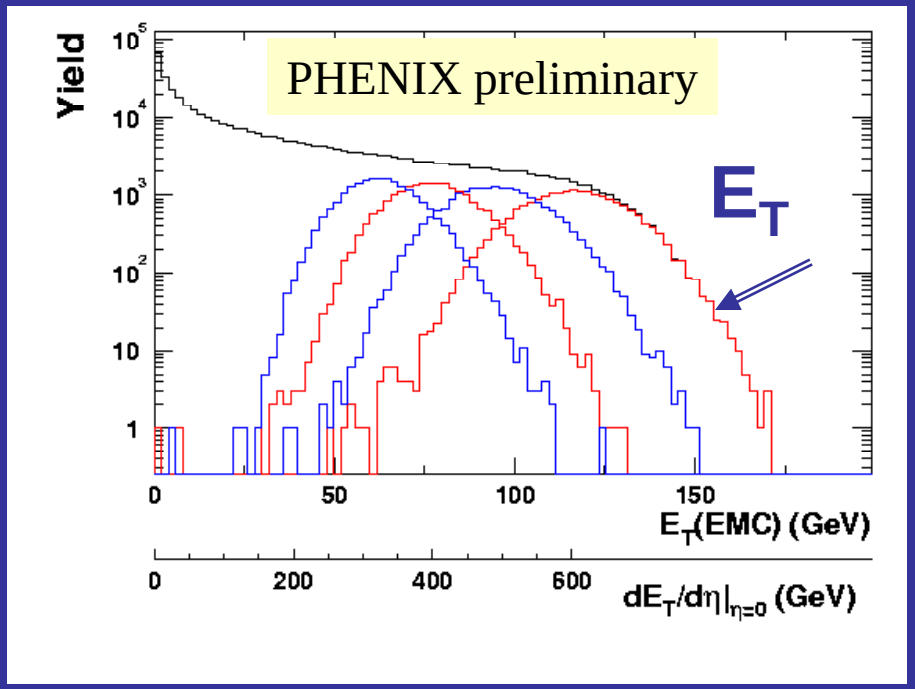


Transverse Energy



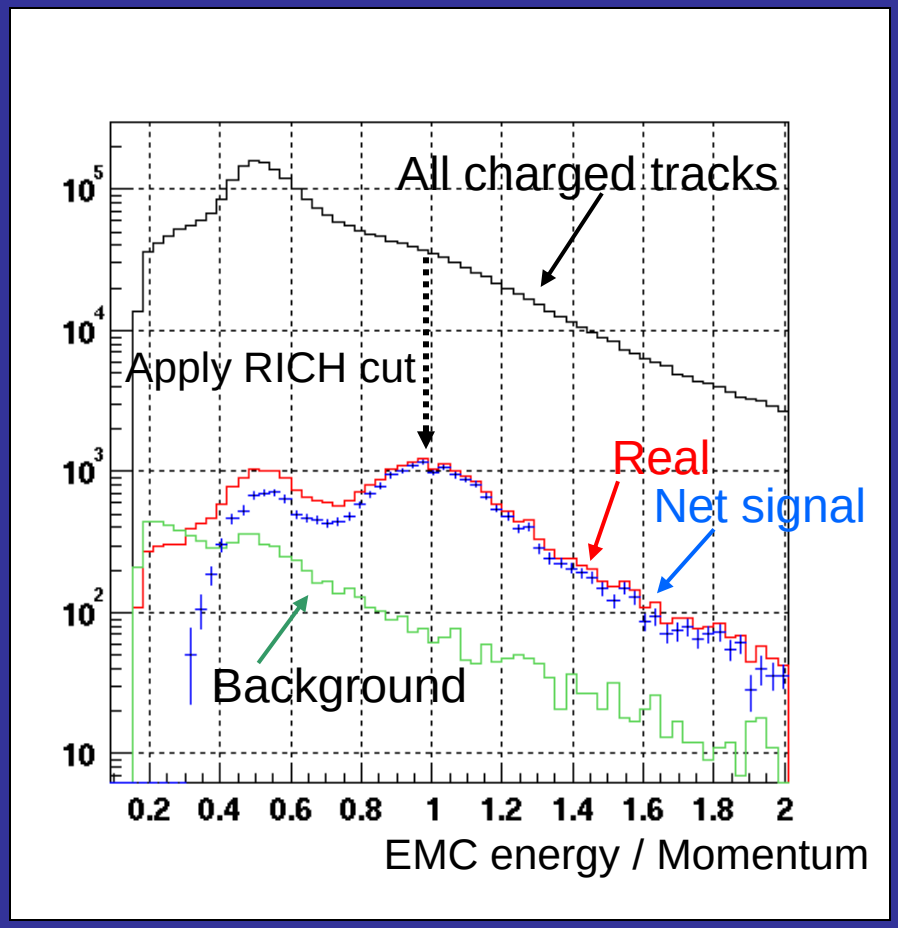


$$E_T = \sum_i E_i \sin\theta_i$$



From: S. Bazilevsky QM-talk

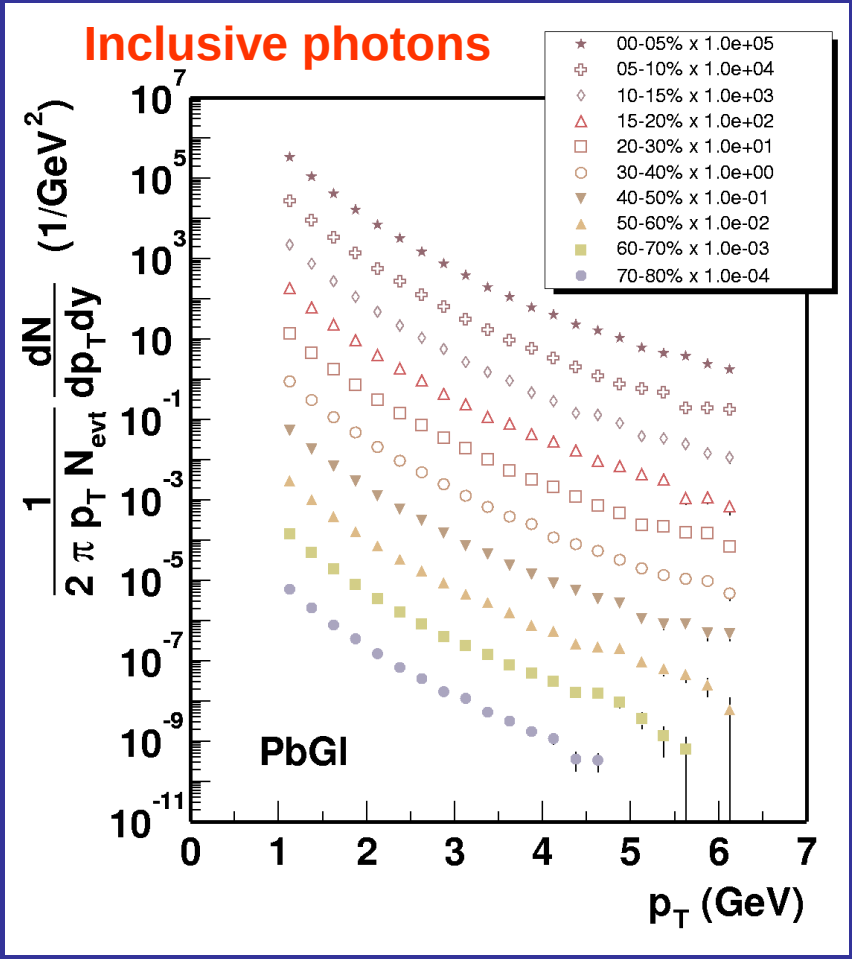
Electron Identification

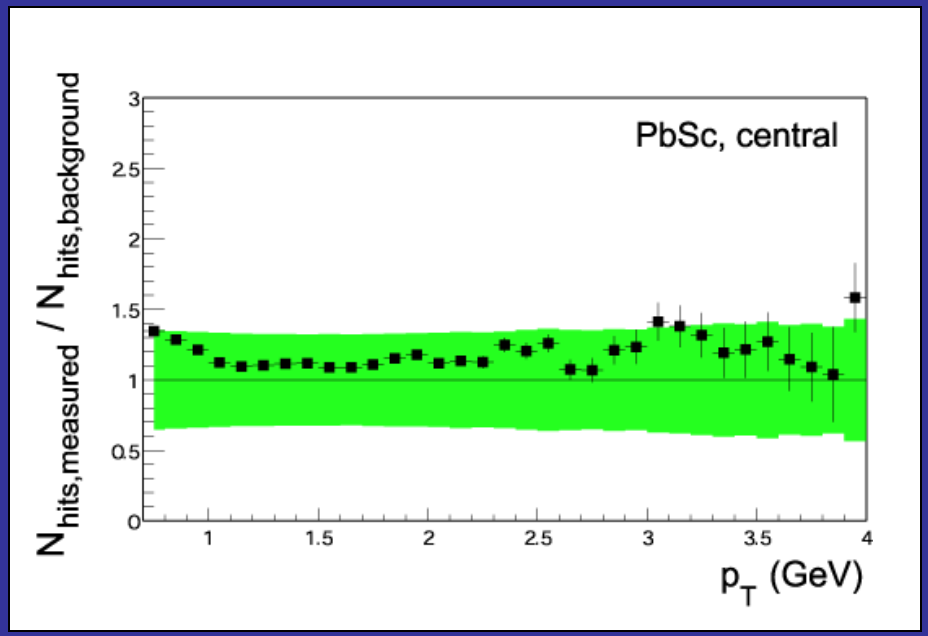


- RICH: Threshold selection
- TEC: dE/dx measurement
- EmCal: Energy-Momentum match

From: J. Nagle QM-talk

Direct Photons

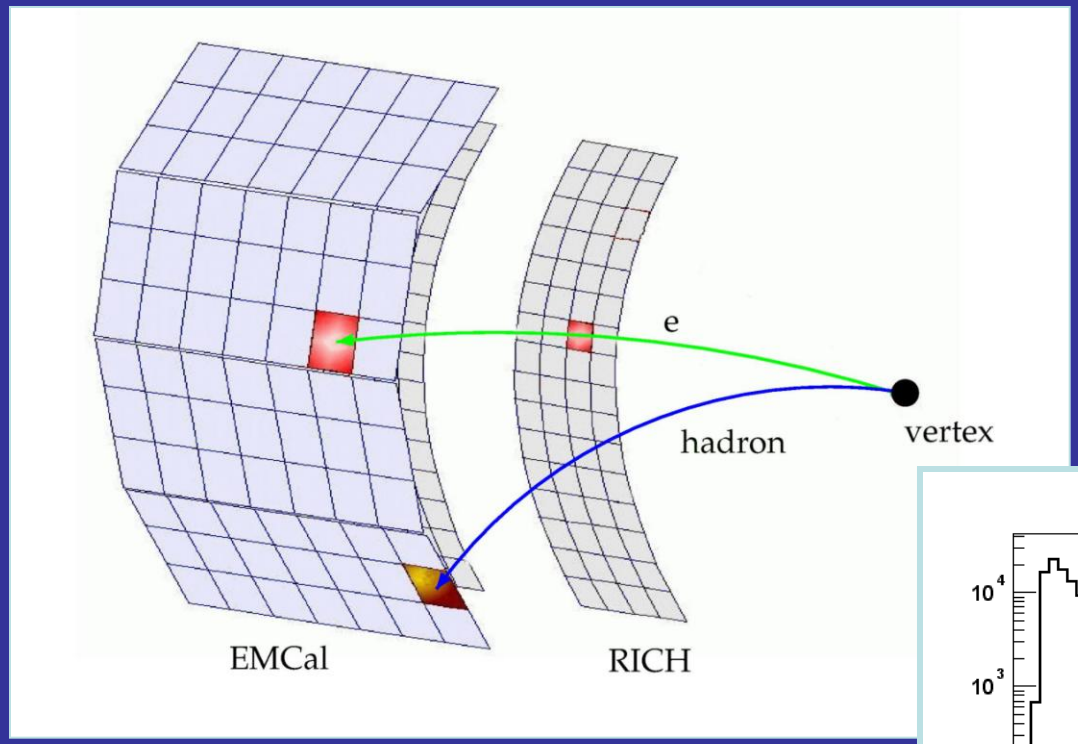




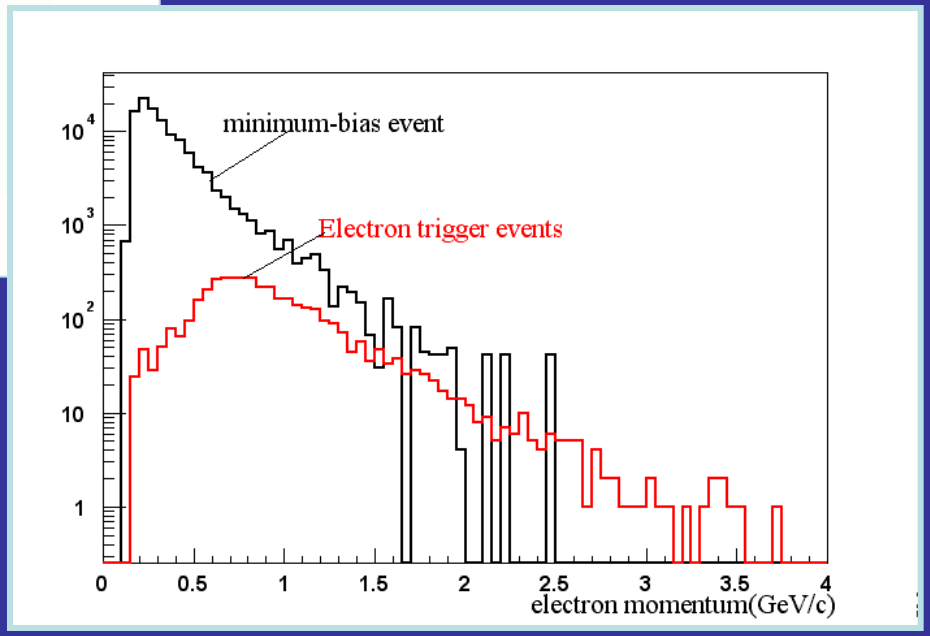
- Trying to extract direct photon signal from inclusive photons
- Determine background

From: K. Reygers QM-talk

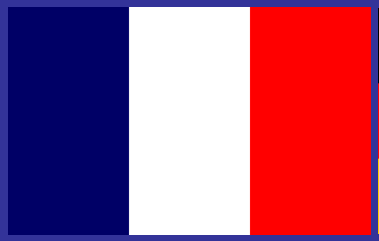
EmCal-RICH-Trigger

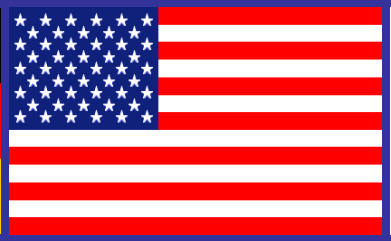
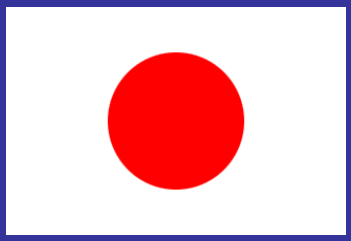


PHENIX has a working level-1 electron trigger from the combination of EMCal and RICH.



Who ?

IHEP Protvino

Kuchatov Moscow

SUBATECH Nantes

University of Muenster

ORNL Oak Ridge

RIKEN BNL Brookhaven

Iowa State Ames

BNL Brookhaven

Kyoto University

Who ?

And many more