The PHENIX Electromagnetic Calorimeter

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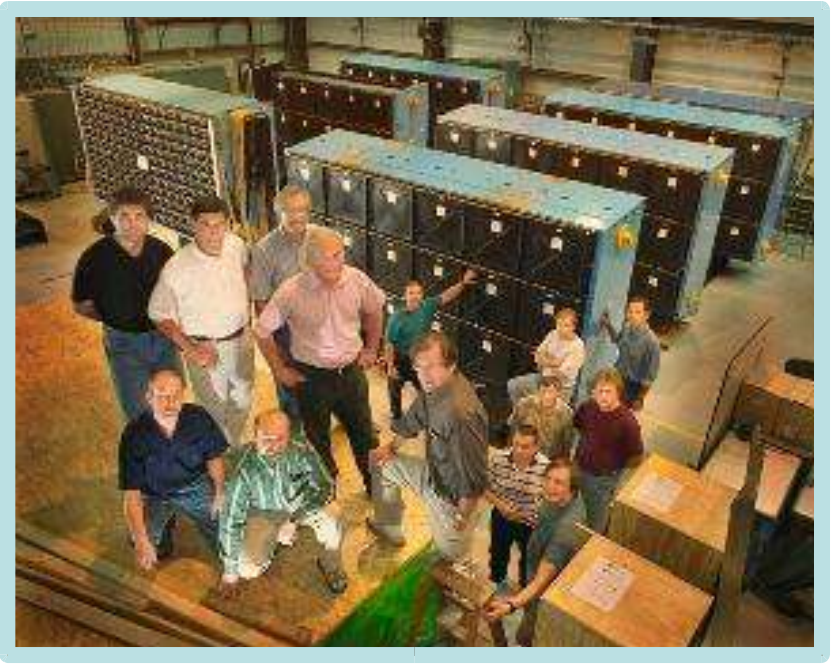


This talk: http://www.phenix.bnl.gov/WWW/run/04/focus/talks/emc/emc_talk.ppt

Thanks to Henner for his talk last year, it made my job infinitely easier...

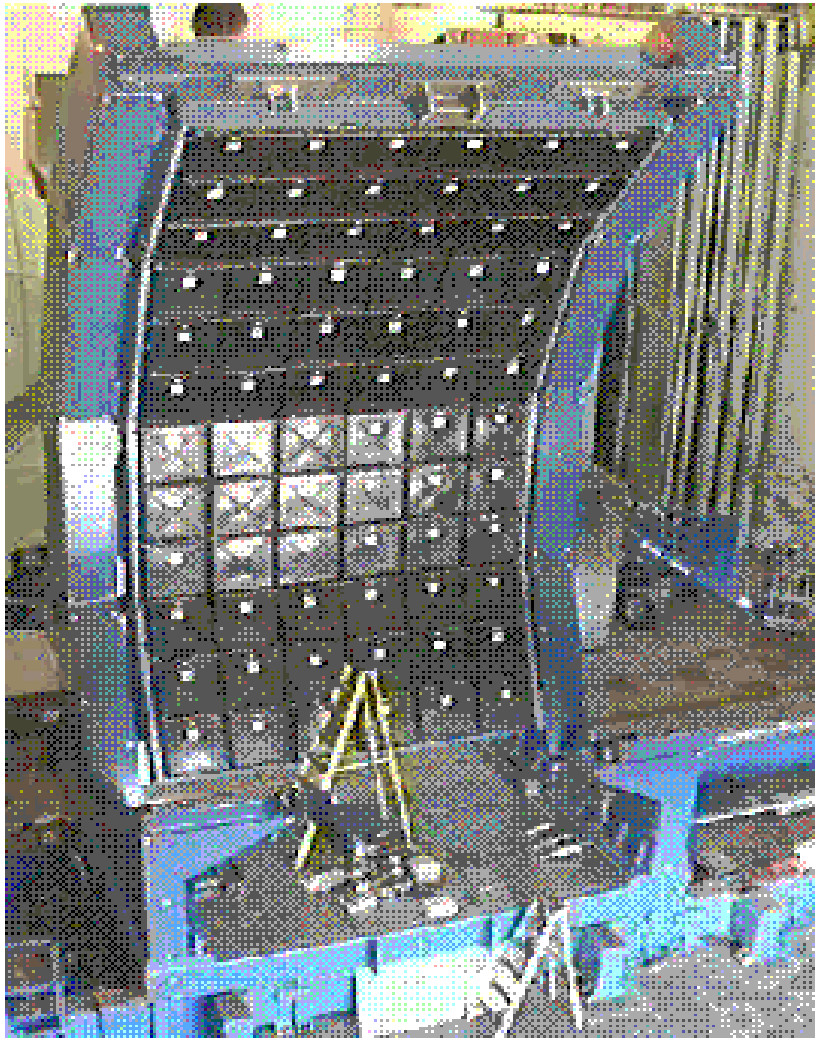
What is the EMCal?

The EMCal is an electro-magnetic calorimeter at mid rapidity. It has been designed primarily to make precision measurements of promptly produced photons and electron pairs from nucleus-nucleus collisions at RHIC.

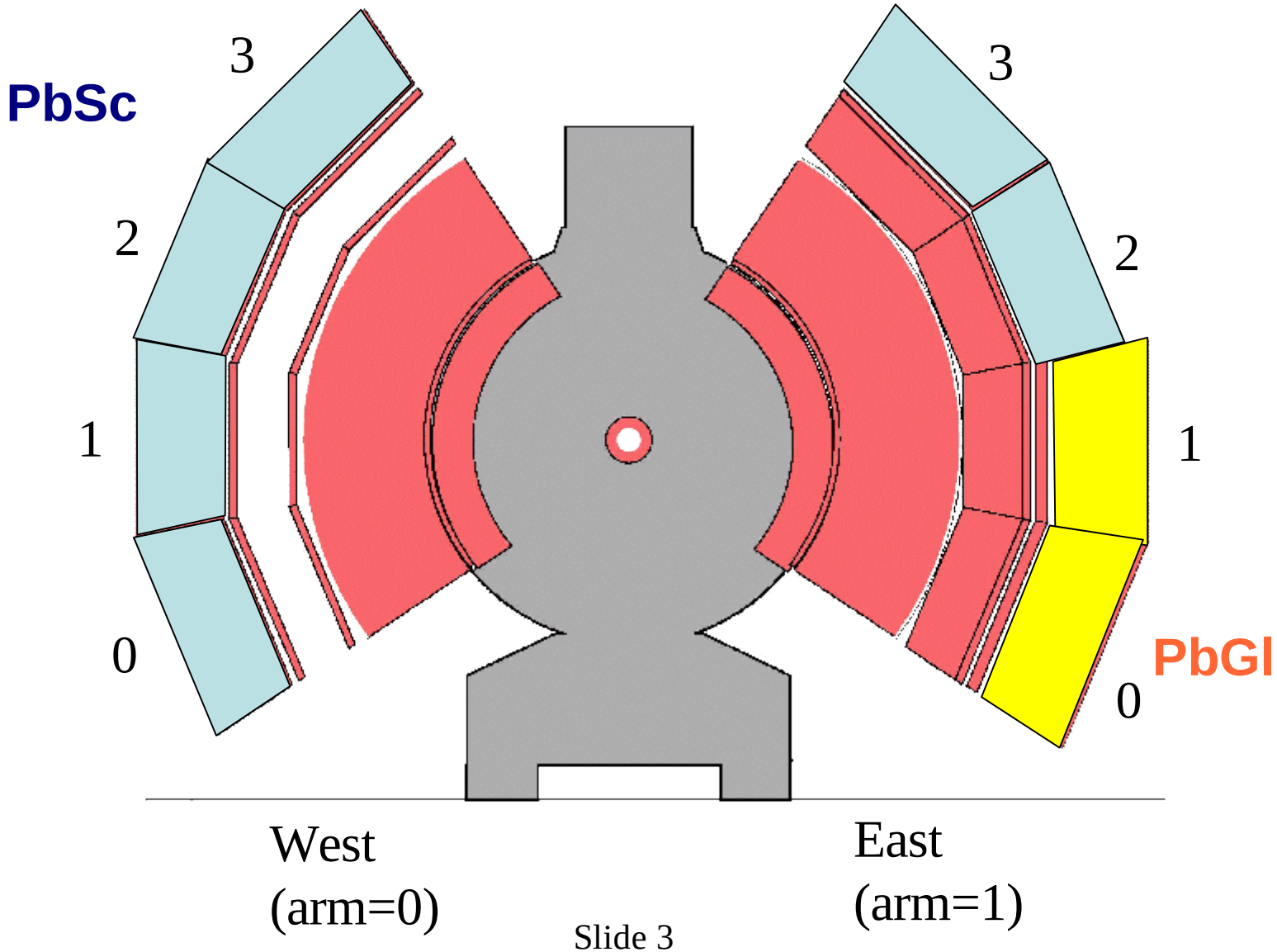
2 arms, 4 sectors in each arm

Acceptance:

$$|\eta| < 0.35, \Delta\phi = 2 \times 90^{\circ}$$



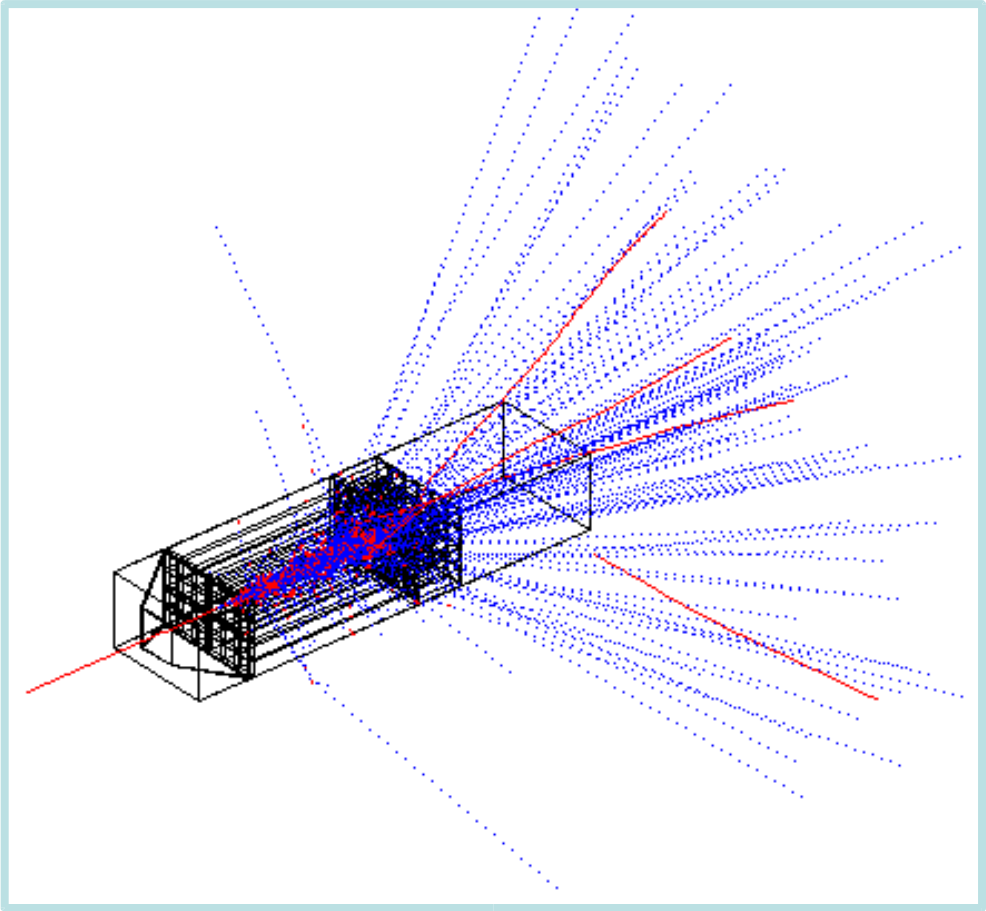
Where is the EMCal?



Principles of detection

- Electrons and photons interact electromagnetically (bremsstrahlung and pair production) and produce electromagnetic showers
- Hadrons in this energy range are typically Minimum Ionizing Particles (MIPs) and deposit only part of their energy in hadronic showers
- The calorimeter measures **position**, **energy** and **time of flight** of the incoming particles
- PbSc: sampling calorimeter, layers of lead and scintillating material
- PbGl: homogeneous, lead-glass volume, Cherenkov radiator
- The light produced in the calorimeter volume is read out by PMTs

Principles: PbGl



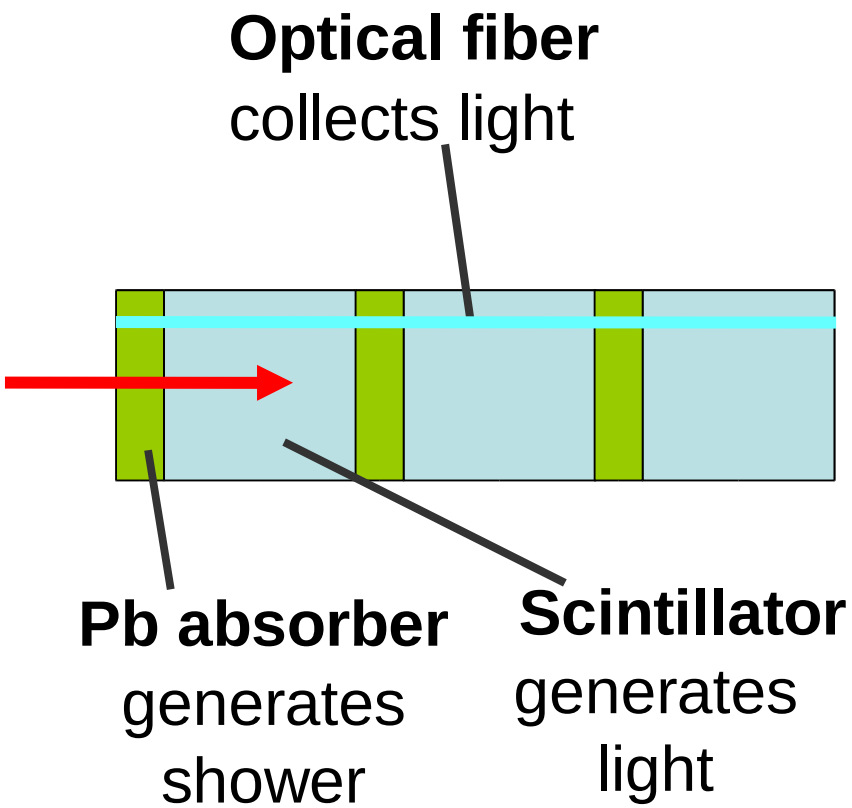
Charged particles that are faster than the speed of light in the medium (n = 1.647) produce Cherenkov light.

The Cherenkov photons propapate with a wavelength-dependent attenuation through the PbGl to the PMTs.

The shower depth is a logarithmic function of particle energy.

The number of Cherenkov photons is directly proportional to particle energy.

Principles: PbSc



Incoming, electromagnetically interacting particles generate EM showers in the Pb absorber, the showers generate flashes in the scintillating material. The produced light enters the fibers woven through the calorimeter and is taken to the photomultipliers at the back.

66 layers, each layer consists of

· 1.5 mm of Pb

· 4 mm of scintillator (1.5% PTP/0.01% POPOP)

Two parts (don't quite) make one detector

alias the great EMCal shoot-out

PbSc

- excels in timing
- better linearity in response
- larger acceptance
- response to hadrons better understood

PbGl

- excels in energy measurement
- better granularity
- proven system (WA98)

Two parts *do* make one great detector

(even if it's a pain in your favorite body part to calibrate them separately)

The EMCal!!!

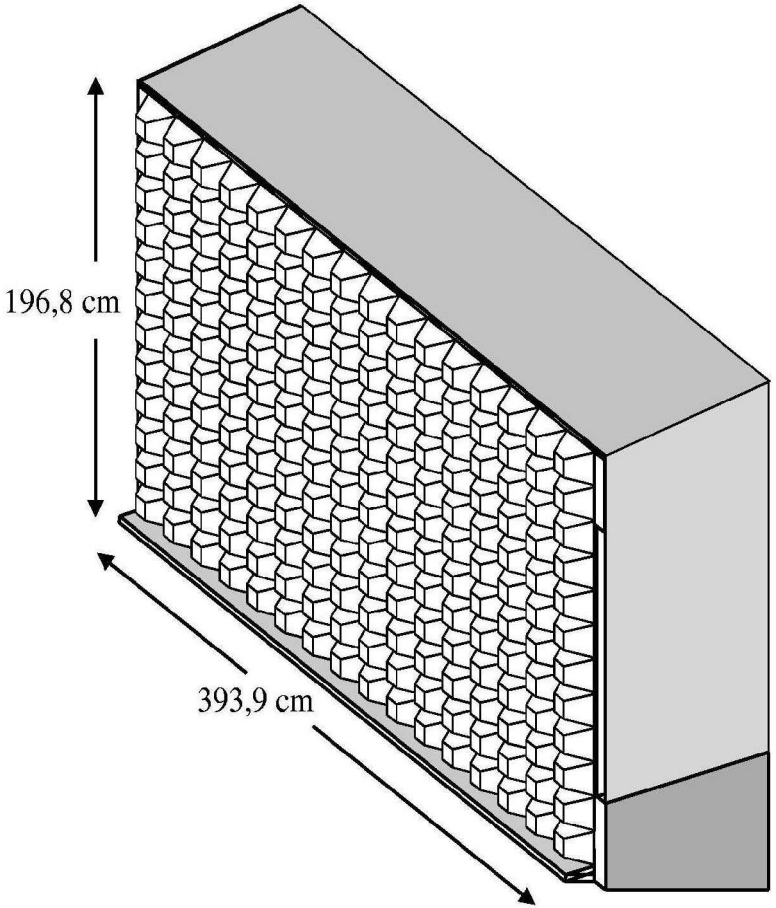
applause

The different calibrations and/or analyses and/or systematics increase confidence level in physics results.

(When they agree, that is.)

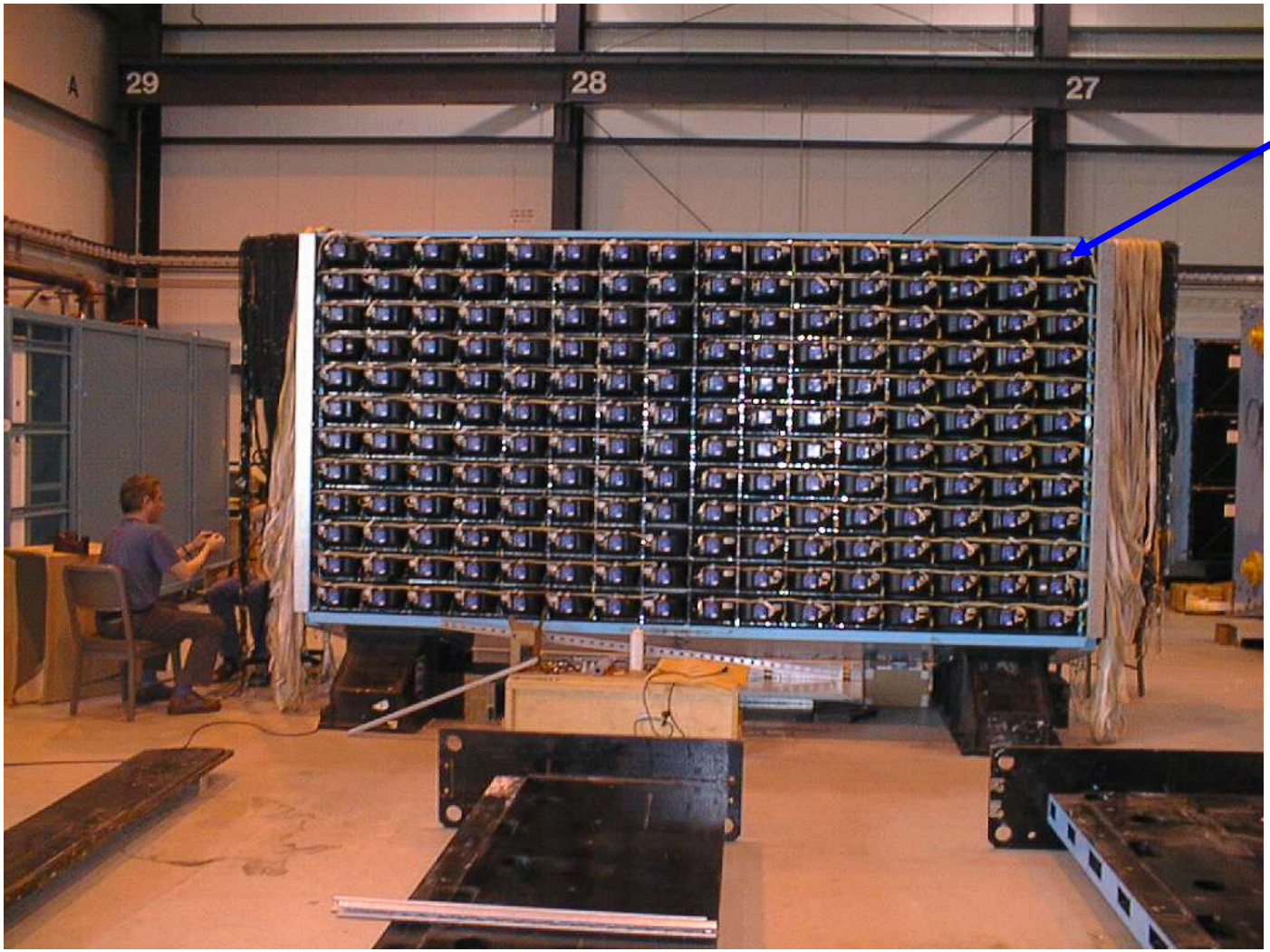
The PbGl sector

- 2 sectors (E0, E1)
- sectors consist of 16x12 supermodules
- each SM is a 6x4 array of towers and has a separate reference system
- each FEM reads out 2x3 supermodules or 12x12 towers ("Super-Duper Module")



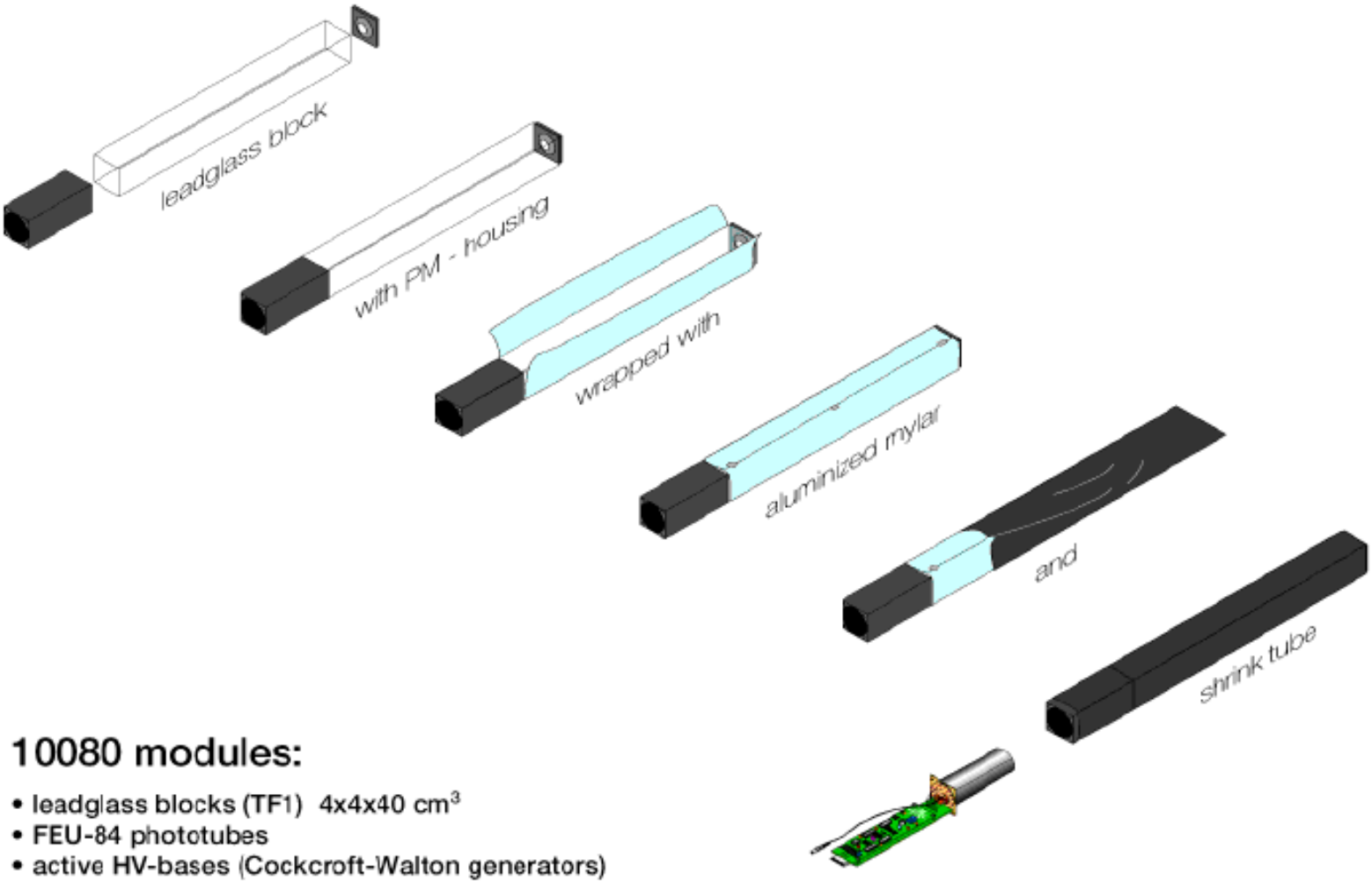
1 sector = 192 SMs = 32 SDMs = 32 FEMs = 4608 towers

A PbGl sector in real life



Supermodules

A PbGl tower



10080 modules:

- leadglass blocks (TF1) 4x4x40 cm^3
- FEU-84 phototubes
- active HV-bases (Cockcroft-Walton generators)

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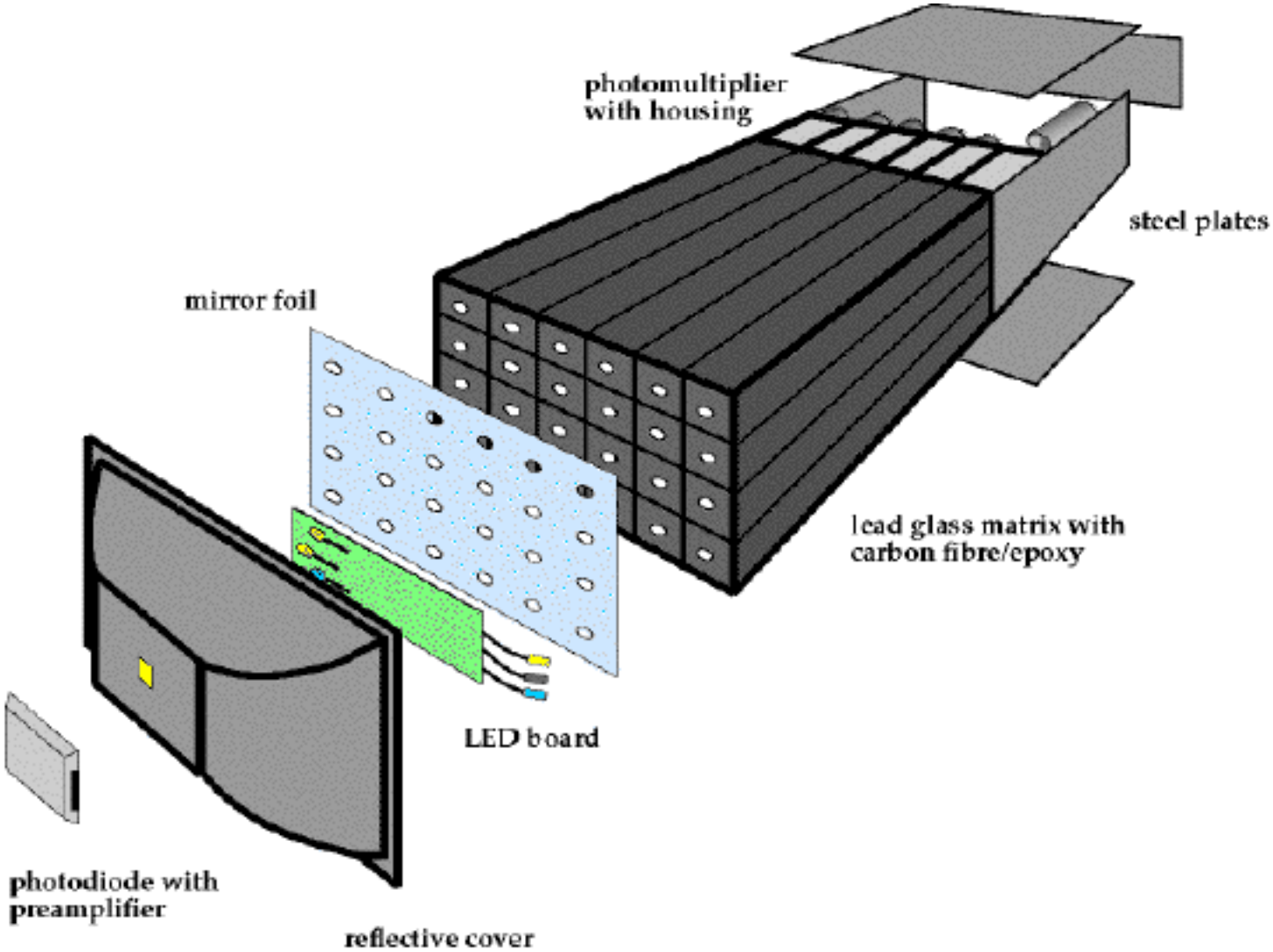
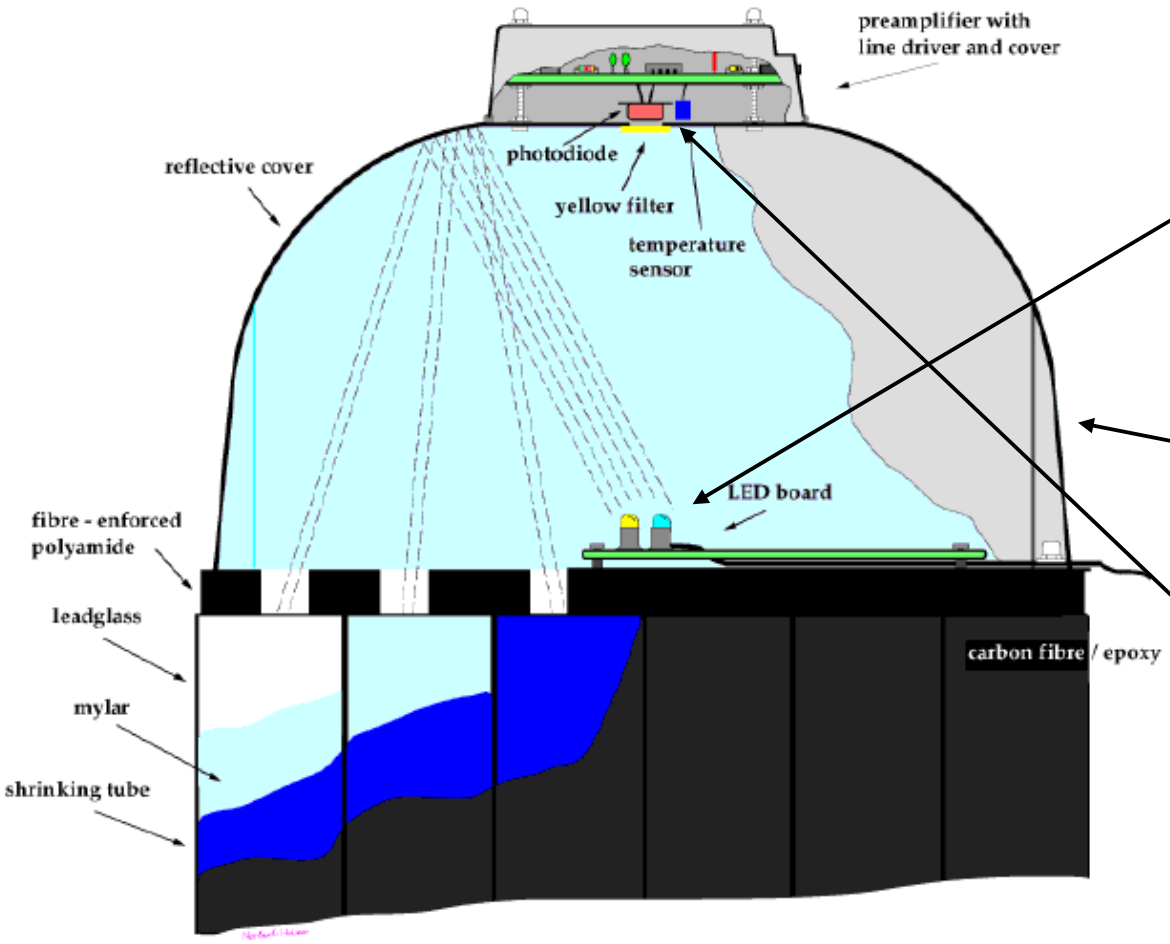
PbGl structure



PbGl reference system



3 LEDs (blue, yellow, avalanche yellow) emit light (imitate Cherenkov photons)

The "dome" reflects it back to the towers

PIN diode used for normalization

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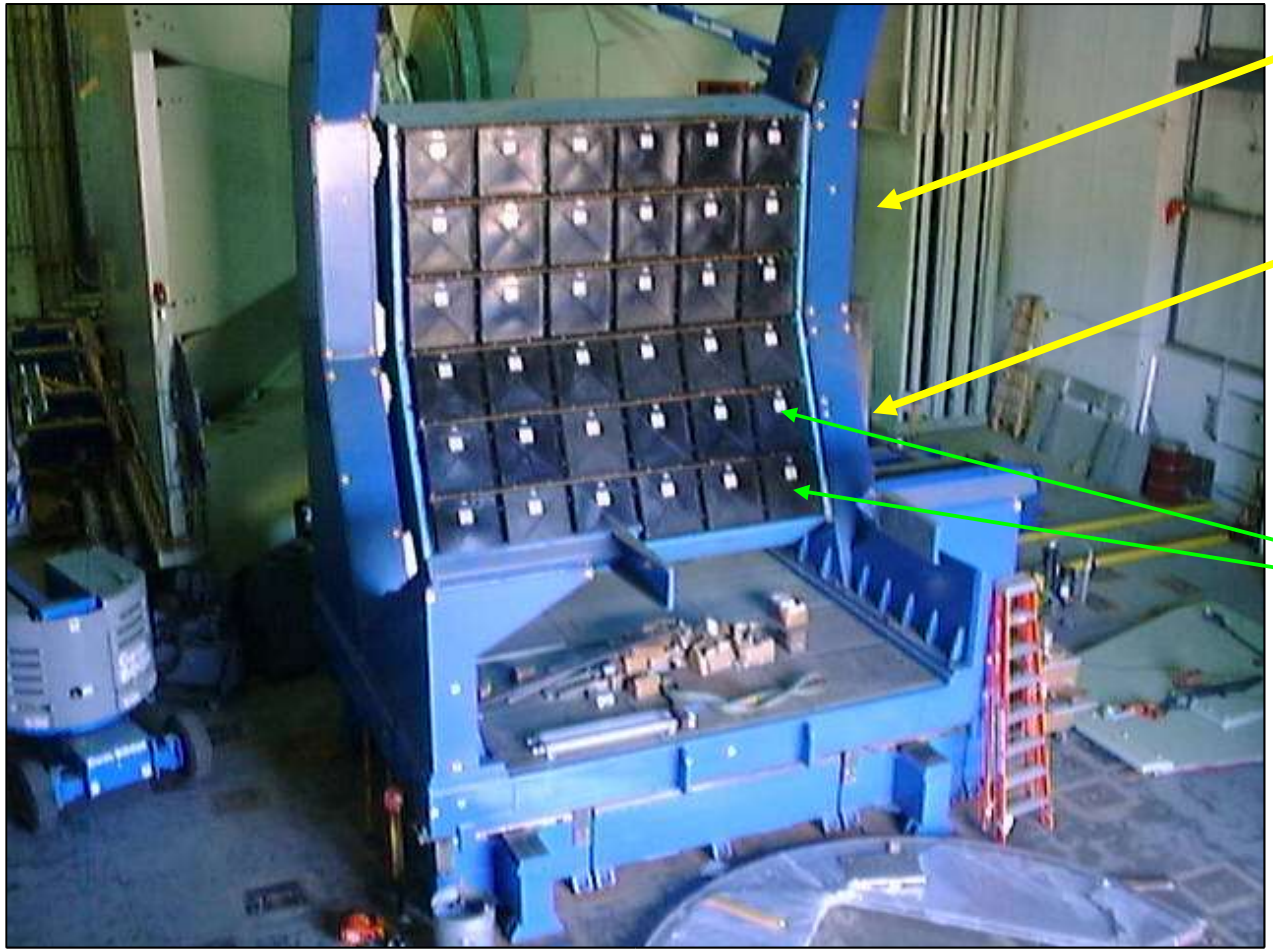
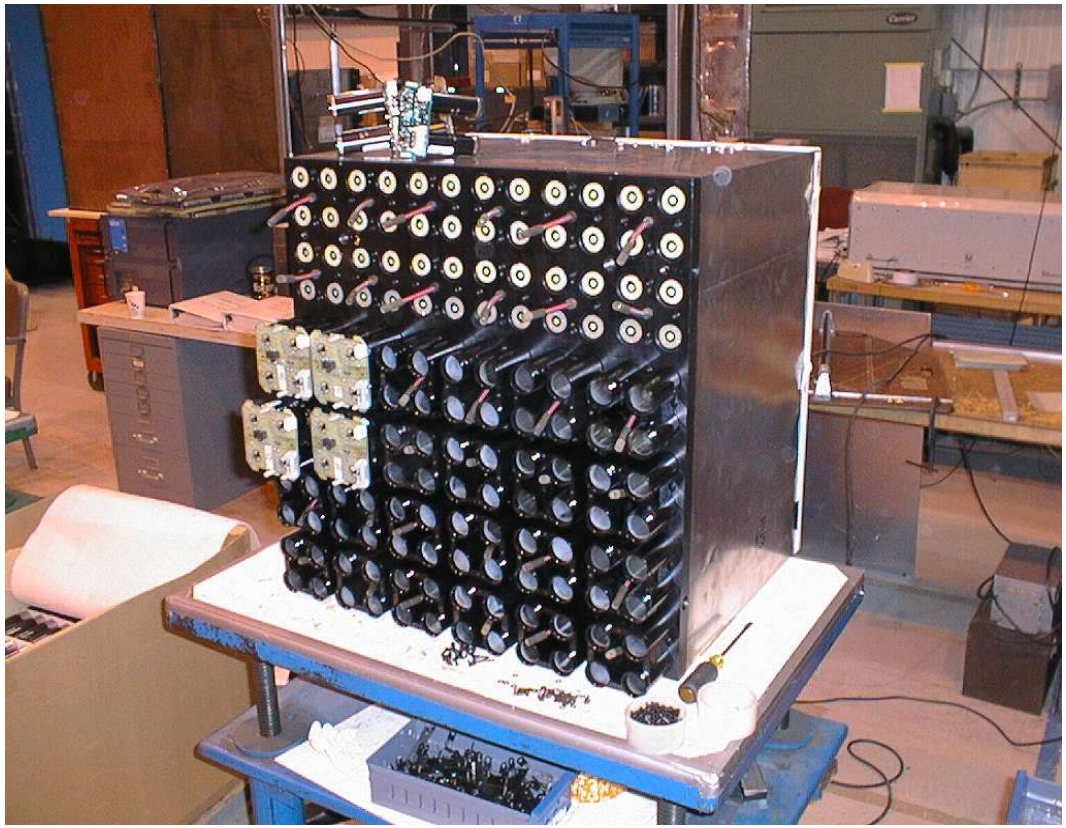
The lead scintillator



PbSc structure



a PbSc supermodule and its PMTs

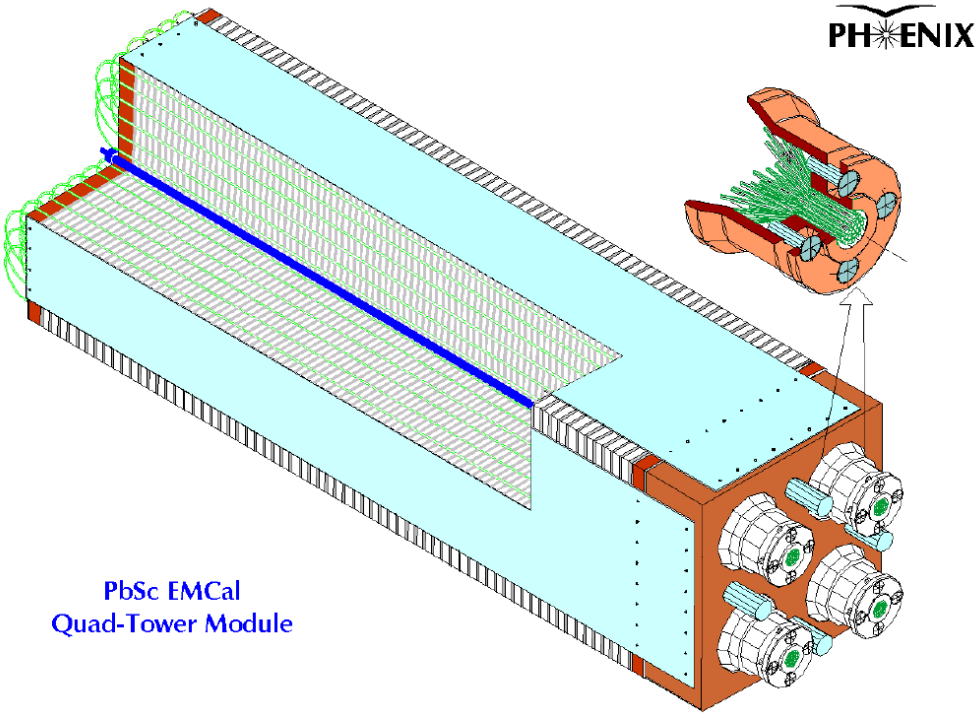
- 6 sectors (W0, W1, W2, W3, E3, E2)
- sectors consists of 6x3 supermodules
- PbSc SMs are 12x12 arrays of towers
- 1 FEM reads out 1 SM

Warning: the definition of supermodules is different in PbSc and PbGl!

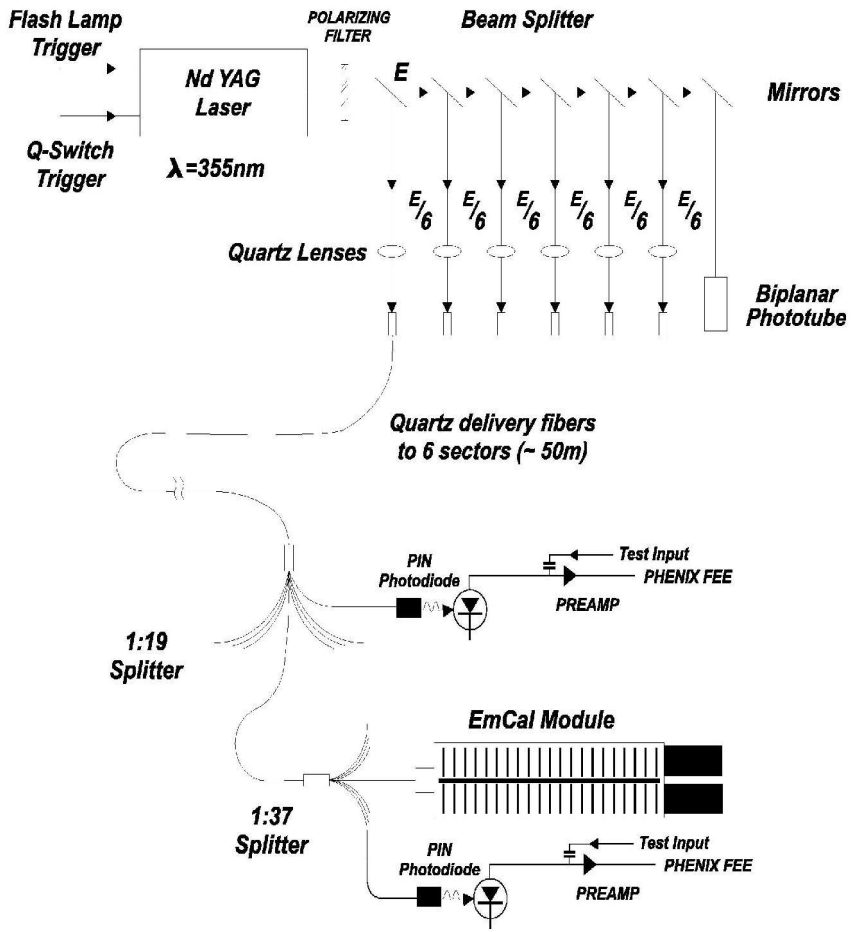
1 sector = 18 SMs = 18 FEMs = 2592 towers

PbSc towers

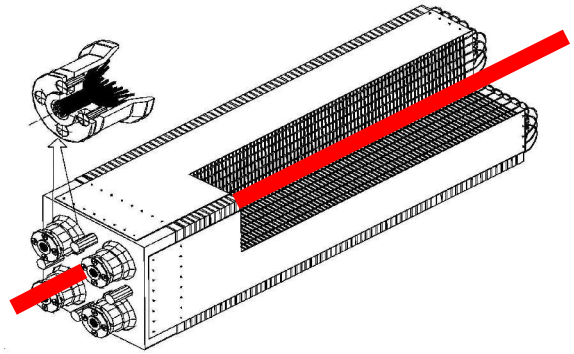
- PbSc tower: 5.52x5.52x33cm^3 (18X_0)
- 15552 towers total (6x2592)
- each PbSc tower consists of 66 layers, where each layer is 1.5mm lead + 4mm scintillator. Penetrating wavelength shifting fibers weave through all layers and carry the scintillator's light to the phototubes mounted at the back end of each tower.



Reference system



A Nd:YAG laser fires between physics events. Its light is split multiple times and carried to the calorimeter by fibers. Leaking fibers go through quad-tower modules, the leaked light imitates the shower depth profile of a 1 GeV EM shower.



One use of the ref.: online monitoring

PbGl

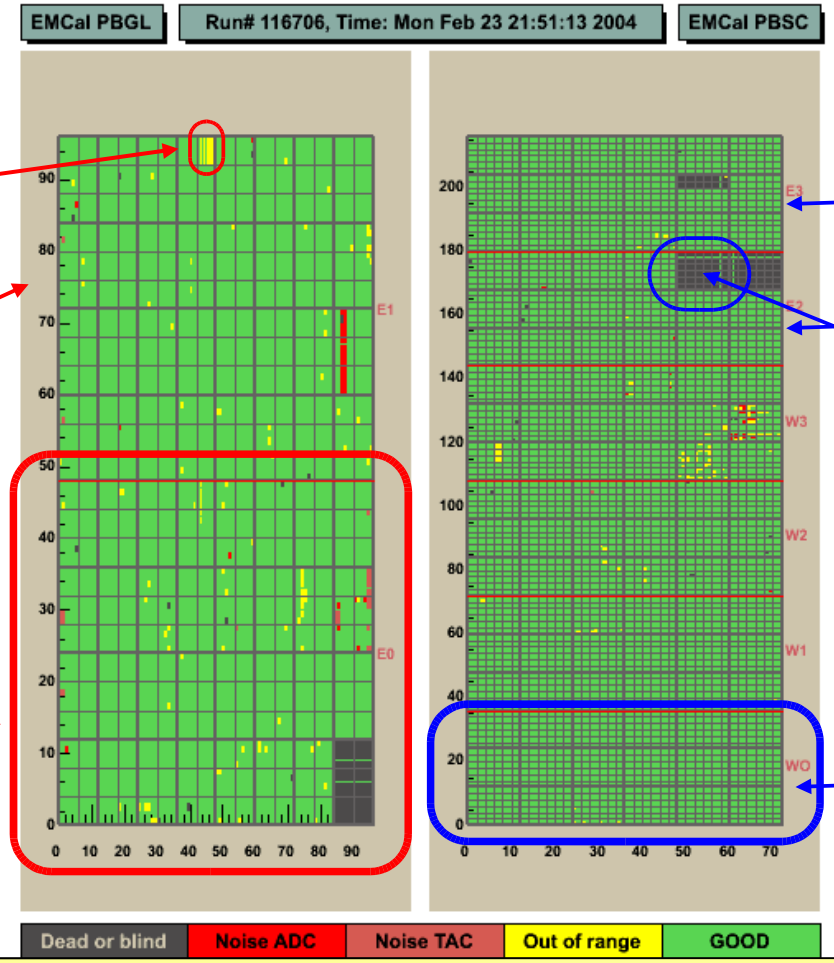
PbSc

SM

E1

E0

sector: 96x48 towers
(16x12 SMs)



E3

E2

SM

sector: 72x36 towers
(6x3 SMs)

W0

Not to scale!

In reality PbSc and PbGl sectors are the same size.

Some more online monitoring...

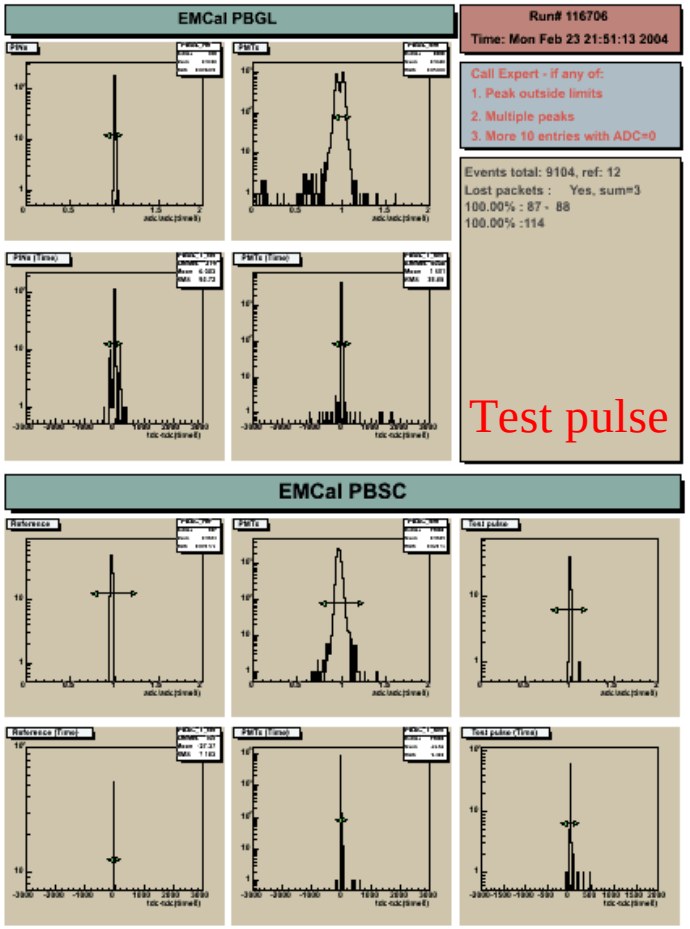
PbGl

adc/adc(time0)

tdc - tdc(time0)

PbSc

PINs PMTs



Some more online monitoring...

PbGl

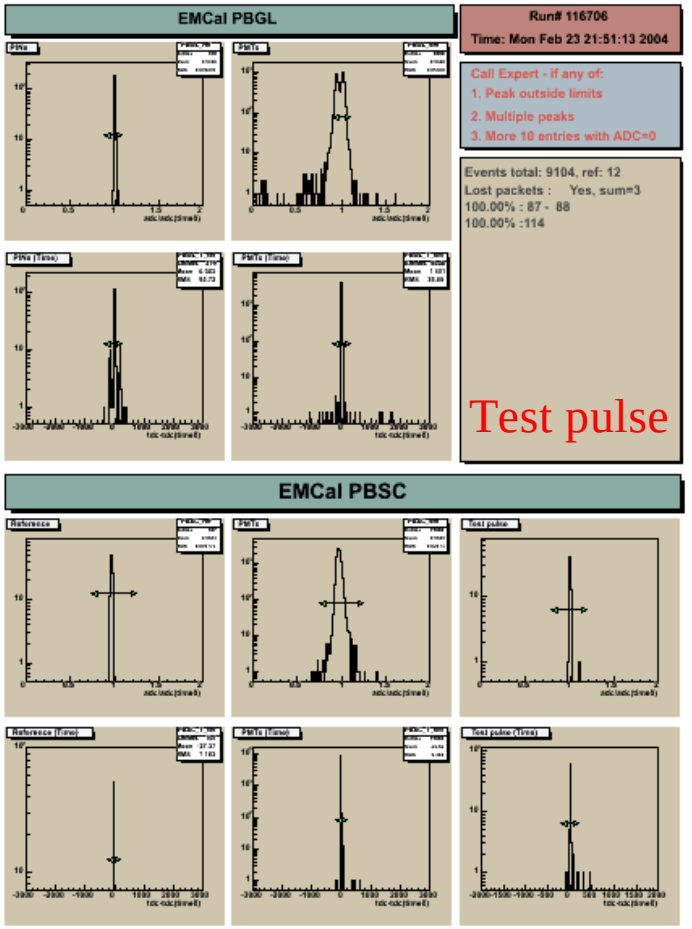
adc/adc(time0)

tdc - tdc(time0)

PbSc

Reminder to the OS:
there are **no** 4-letter words
in this crossword...

PINs PMTs



Calibration

We have to calibrate energy and time - a plethora of methods:

- test beam (CERN, BNL)
- calibration inherited from WA98 (PbGl)
- reference system:
  - laser/LEDs track gain changes of PMTs, PIN diodes track laser/LEDs, test pulse tracks amplifier, etc...
  - track timing shifts (problem: cross-talk in electronics)
- physics data:
  - MIP, π^0, electron...
  - photons, charged pions, kaons, protons...

The calibrations ideally should not change too fast. In real life, our calibrations are run-, time-, sector-, tower-, ~~moonphase~~-dependent...

The quest for the Holy Grail of methods (which would solve all our calibration problems) is still under way. (More knights errand would be appreciated...)

Reconstruction

During reconstruction, the EMCal code has to

- apply all calibrations (and there are quite a few)
- correct the non-linearities
- correct the angular dependence
- do the clustering (determine which individual tower hits came from the same particle)
- disentangle overlapping clusters (especially in Au-Au)

In the reconstruction 2 EMCal nodes are created, the EmcTowerContainer and the EmcClusterContainer. For your analysis, you need the clusters; the towers are only needed by the EMCal folks for their recalibration efforts...

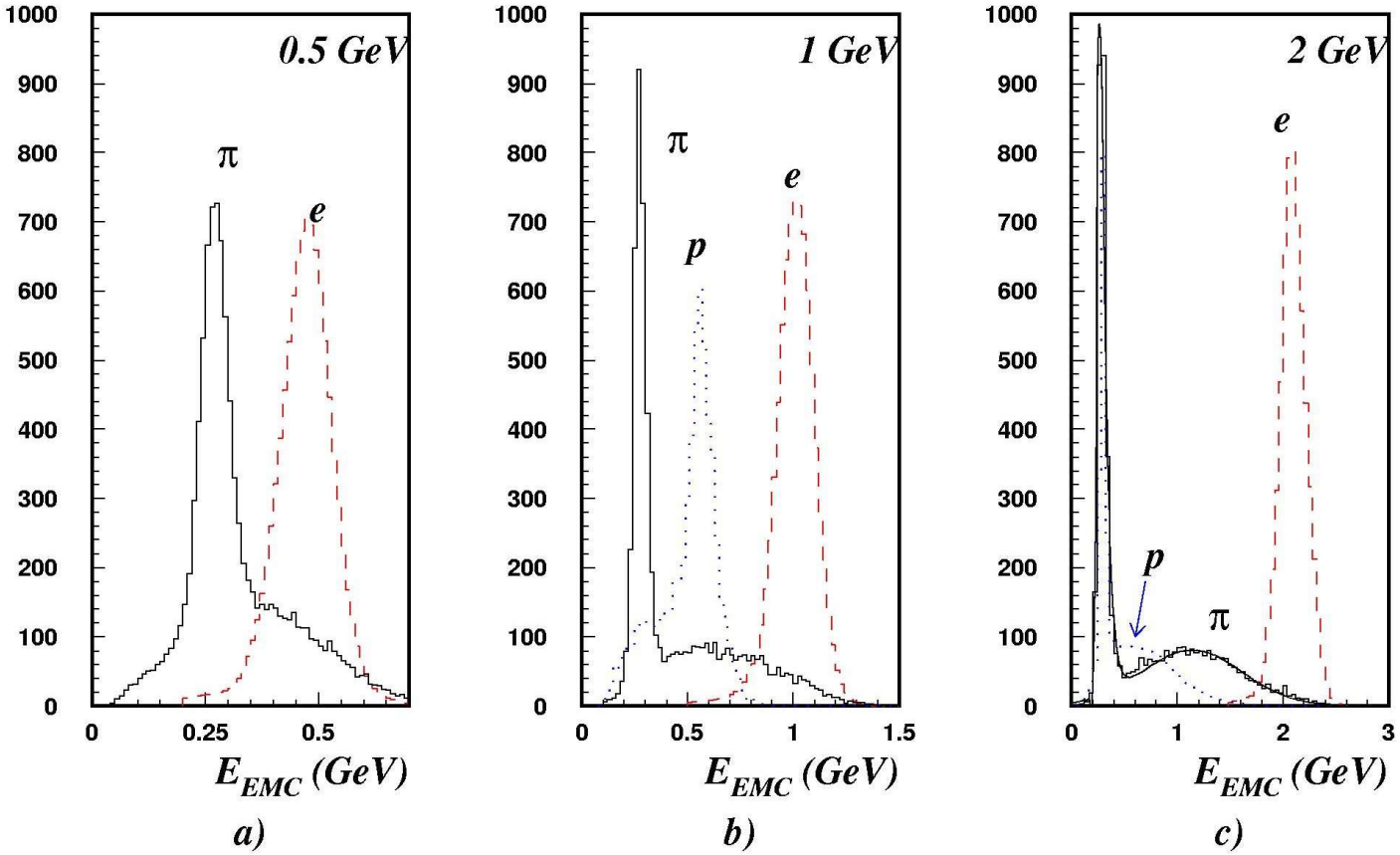
Detour: those pesky EMCal energies...

- ***E***: sum of tower energy in the cluster (if above threshold)
- ***Ecore***: energy with the assumption that the cluster is a photon; should never be used for MIP or other hadron analysis. It only makes sense for PbSc.
- ***Ecorr***: energy corrected for nonlinearities assuming the shower is EM. It only makes sense for PbGl.
- ***Ecorecorr***: an effort before QM02 to combine *ecore* and *ecorr* in one variable.
- ***E9***: energy in 3x3 array around the tower with the highest energy deposit in the cluster.
- ***Ecent***: energy in the "central" tower (the one with the highest deposited energy).
- ***Etofmin, etofmax***: energy in the towers with the earliest and latest valid time in the cluster. TOF of a cluster is always the time measured by the central tower.

Electromagnetic shower parametrization: NIM A499 (2003) 521

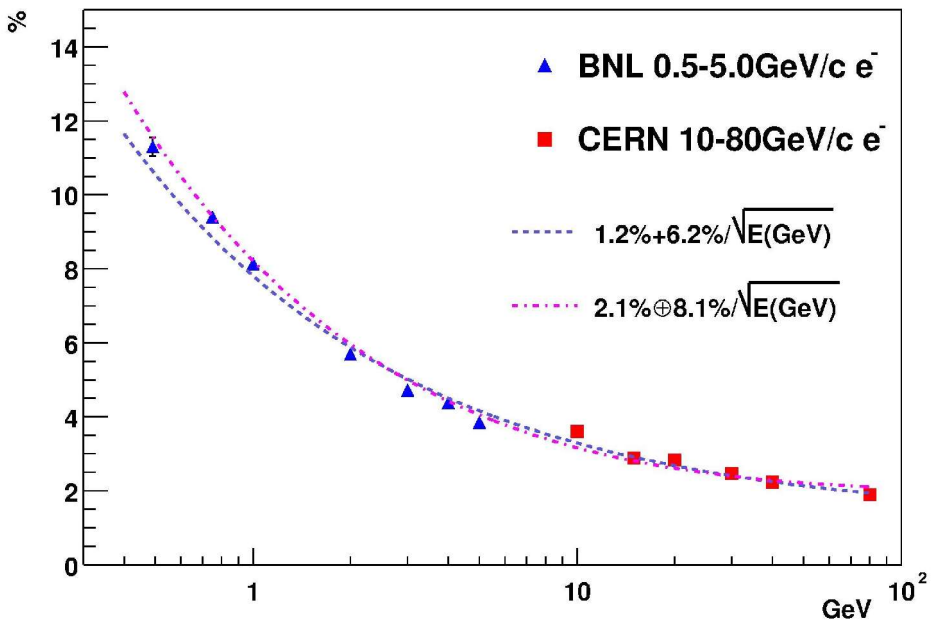
Chi2: PHENIX analysis note an144

Hadrons



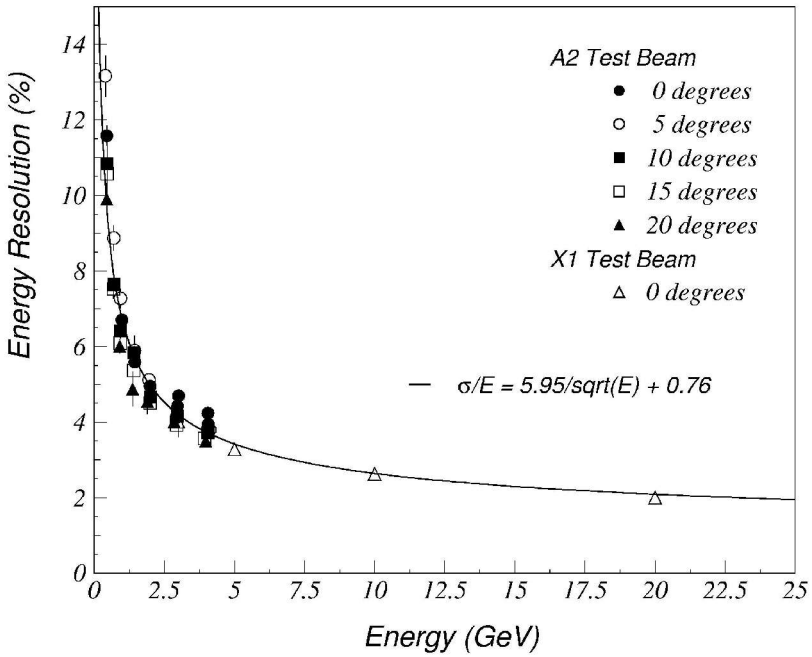
Warning: Different response to electrons and hadrons!

Energy resolution



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

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



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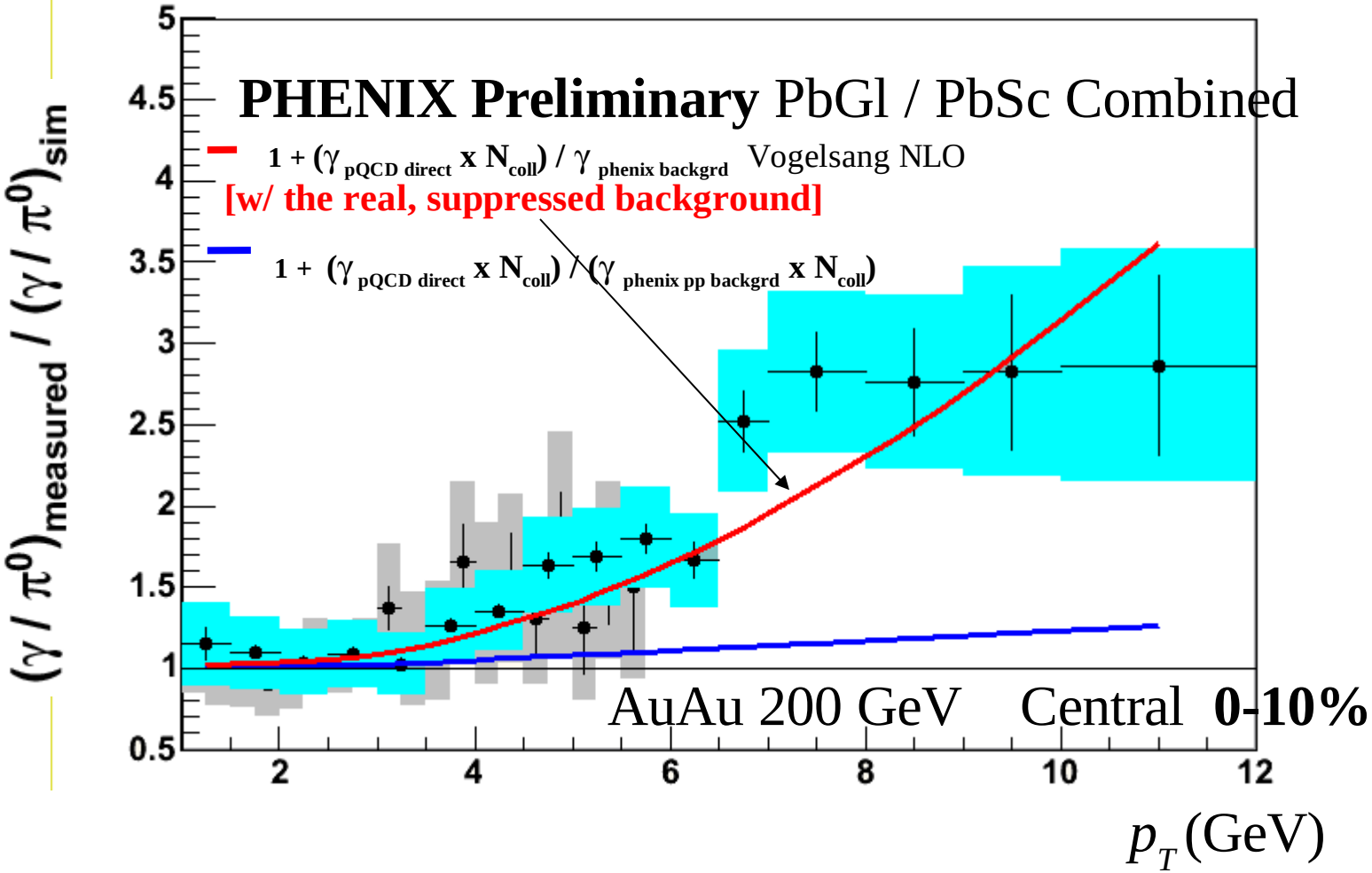
Physics topics

- Direct photon measurement
- Identified neutral pions up to high p_T
- Electron measurement with RICH and TEC
- Transverse energy
- Hadron PID
- Θ^-
- (ERT: enhance high p_T particles)

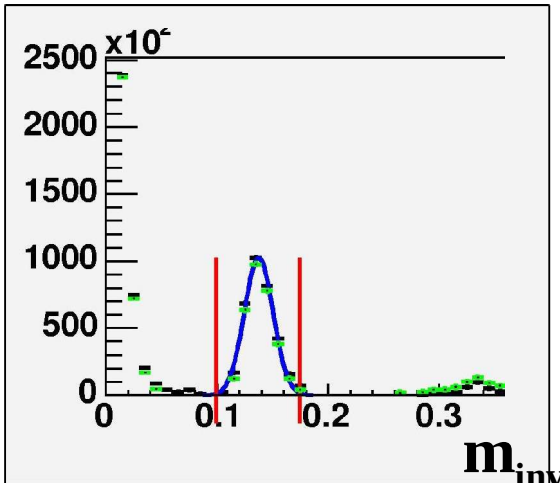
Direct photons

Justin Frantz



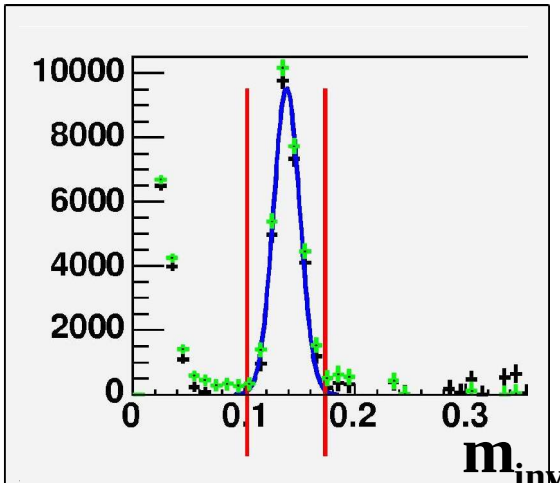
Neutral pions

Henner Büsching



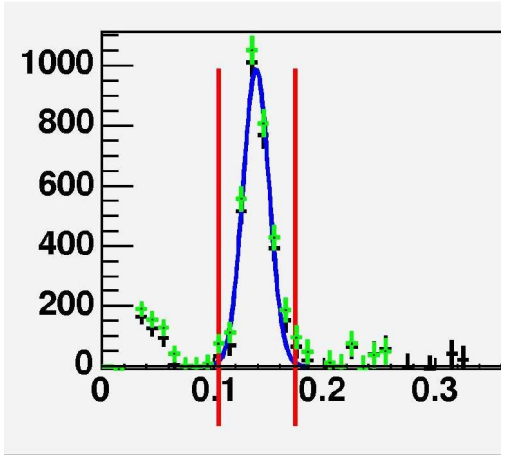
m_{inv}

$1 < p_T < 2$ [GeV]

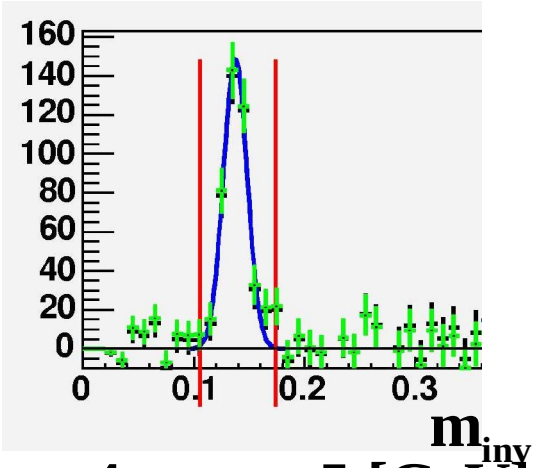


m_{inv}

$2 < p_T < 3$ [GeV]

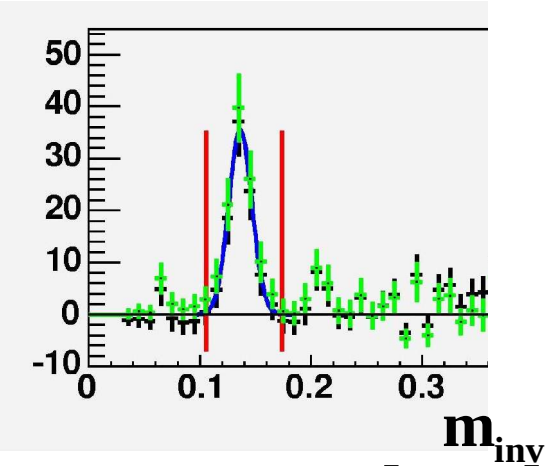


$3 < p_T < 4$ [GeV]



m_{inv}

$4 < p_T < 5$ [GeV]



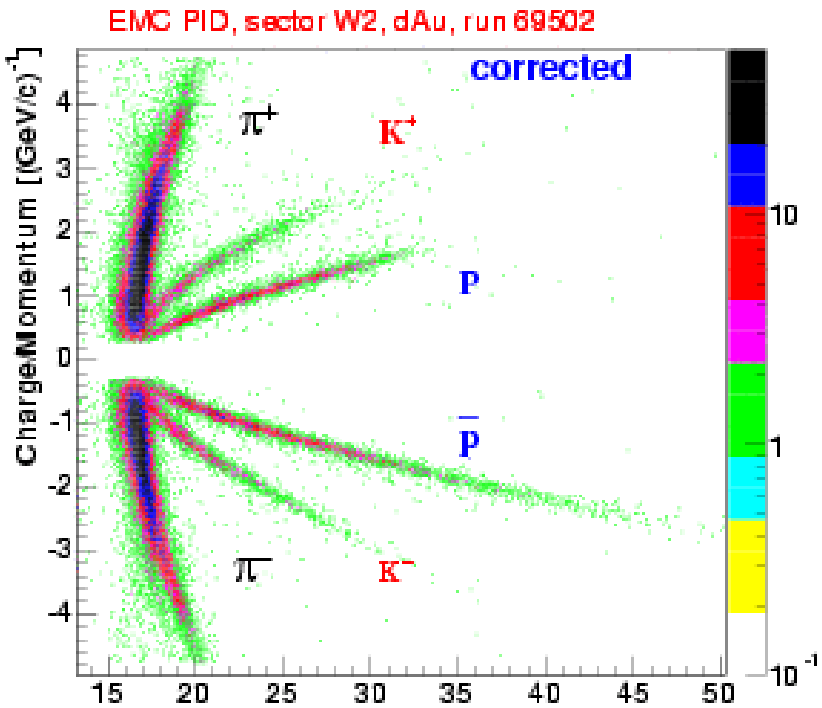
m_{inv}

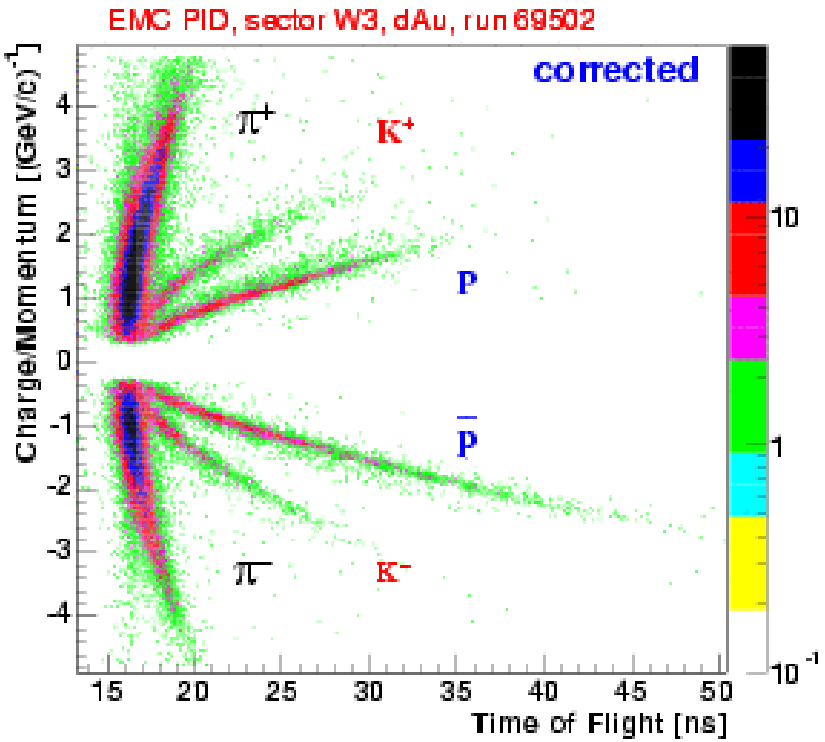
$5 < p_T < 6$ [GeV]

Run4!!!

Hadron PID

Arkadij Taranenko

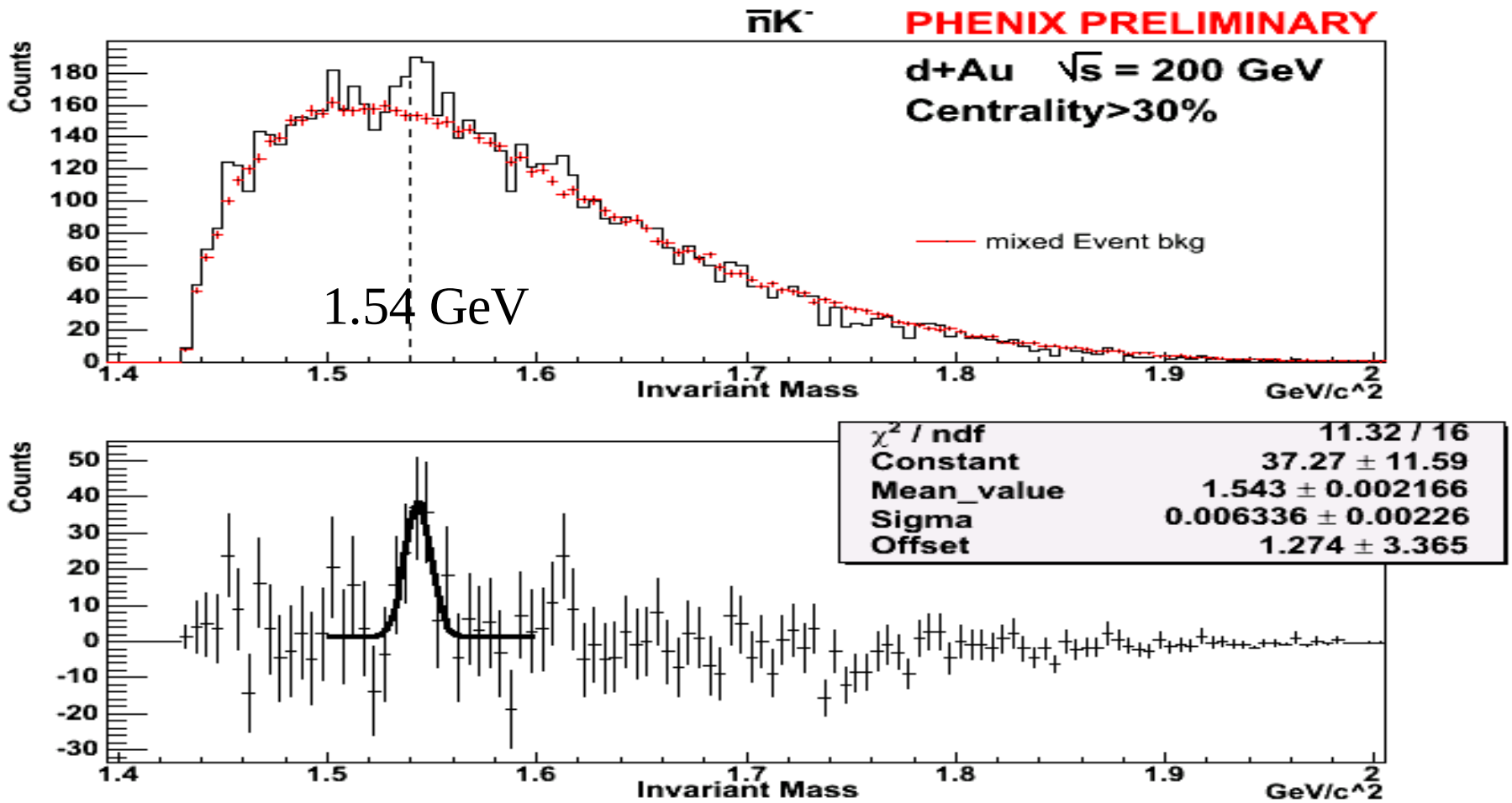




Run3 d-Au

Pentaquark

Chris Pinkenburg



And...

...much, much more...!