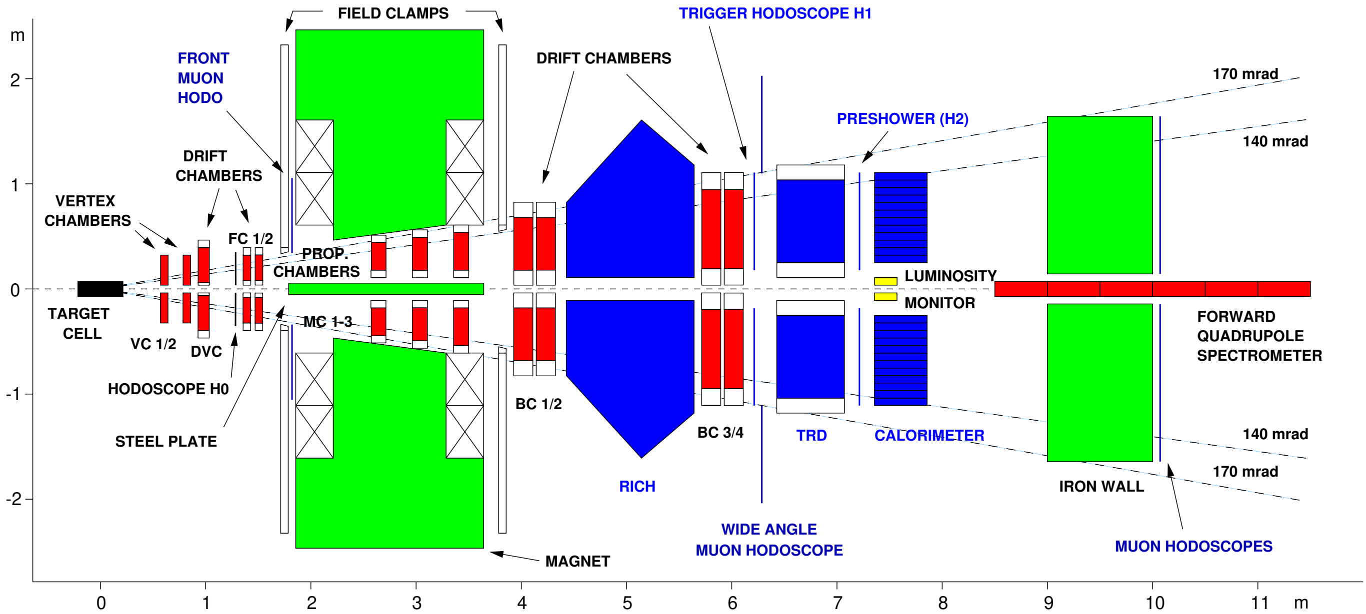
Particle Identification at HERMES

Ralf Kaiser, Wolf-Dieter Nowak,
Desy/Zeuthen
On Behalf Of The Hermes Collaboration

CERN, 21.January 2000

- The Hermes Experiment
- HERMES PID Detectors
- Likelihood Analysis
- Performance of the HERMES PID

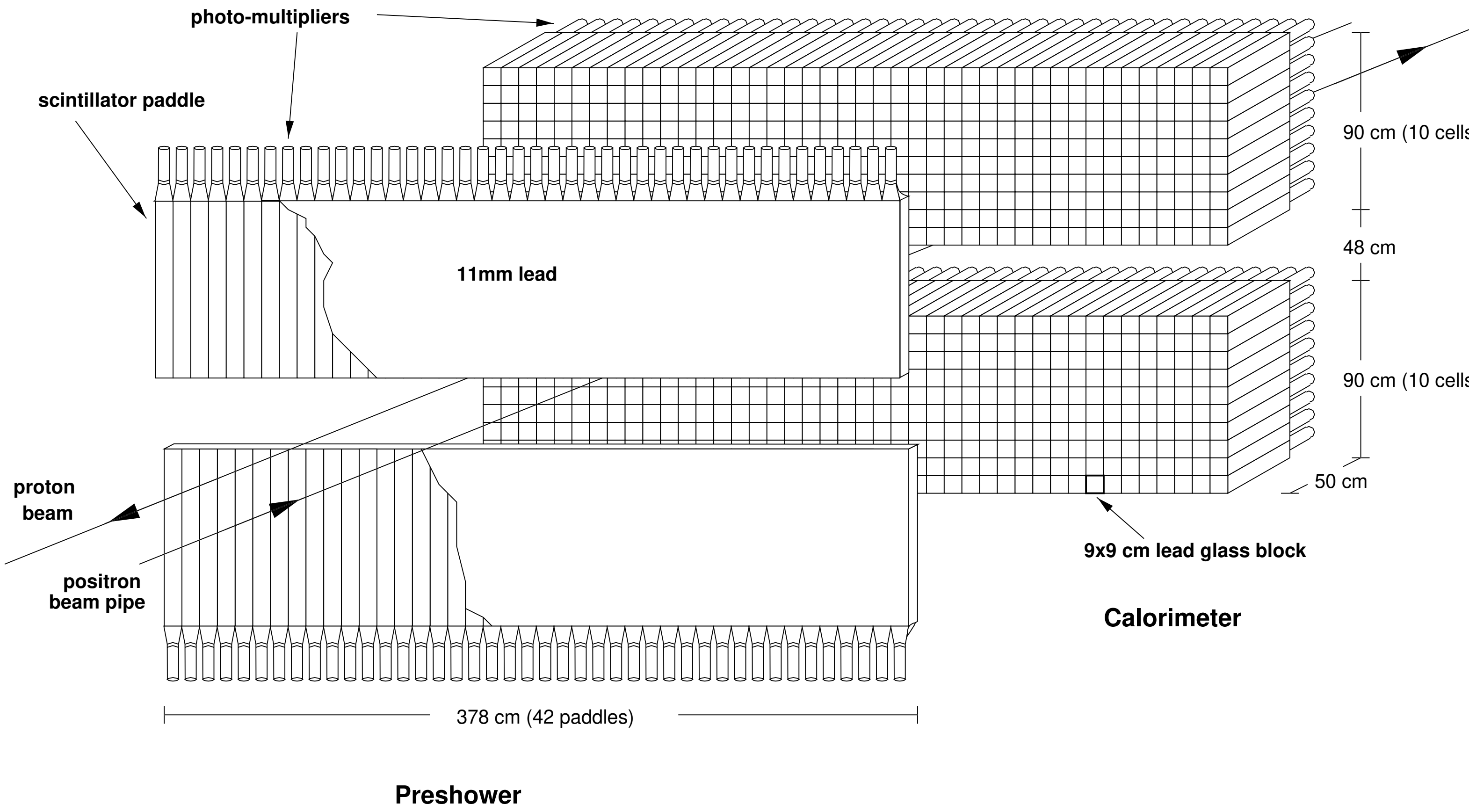
HERMES SPECTROMETER



MAGNET:	$\int B_y dz = 1.3$ Tm
TRACKING SYSTEM:	$\sigma(\Theta) = 0.6$ mrad
	$\sigma(p)/p = 0.7 \ldots 1.4\,\%$
	FOR LEPTONS
PID SYSTEM:	CALORIMETER,
	PRESHOWER,
	TRD, CERENKOV

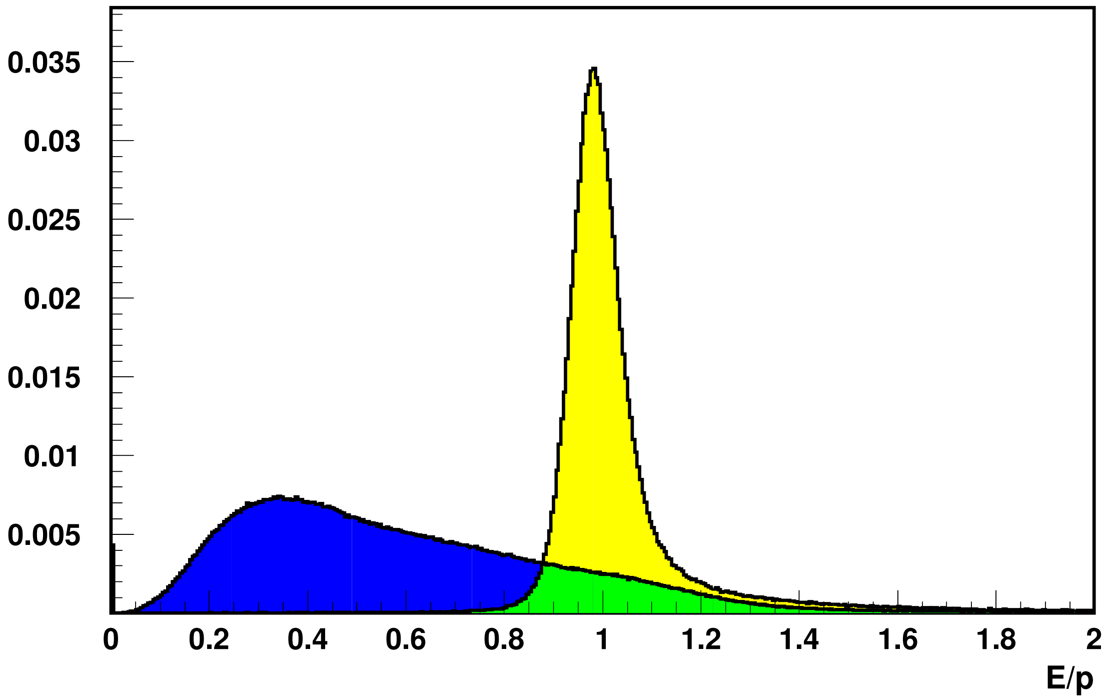
IN 1998 THE THRESHOLD CERENKOV DETECTOR HAS BEEN REPLACED BY A RICH DETECTOR.

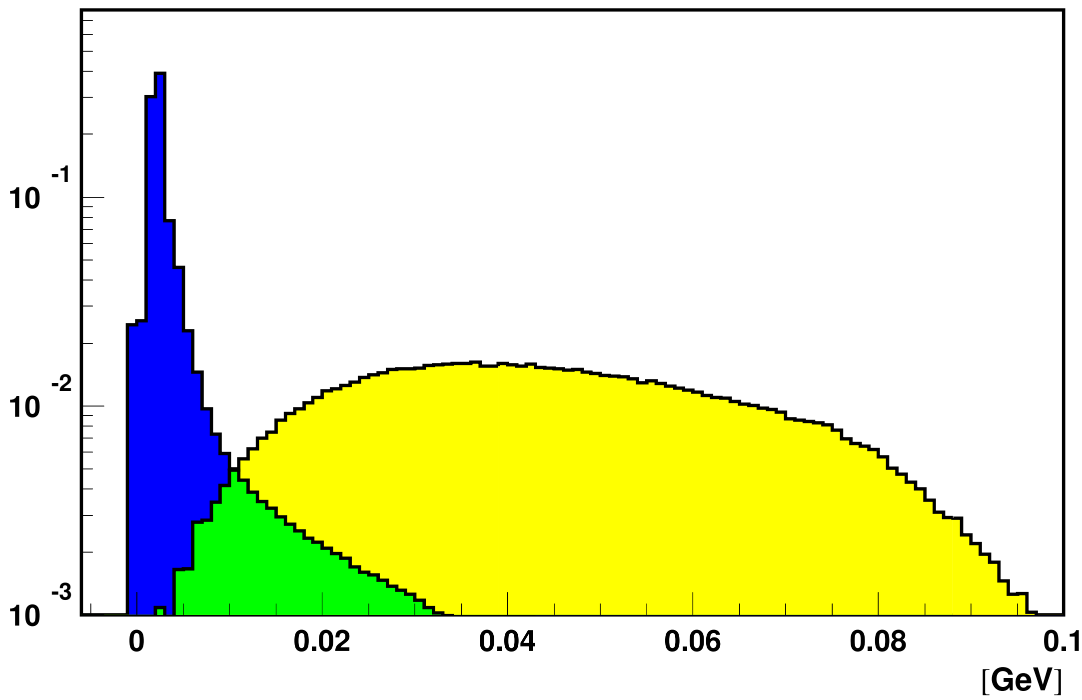
Calorimeter and Preshower Detector



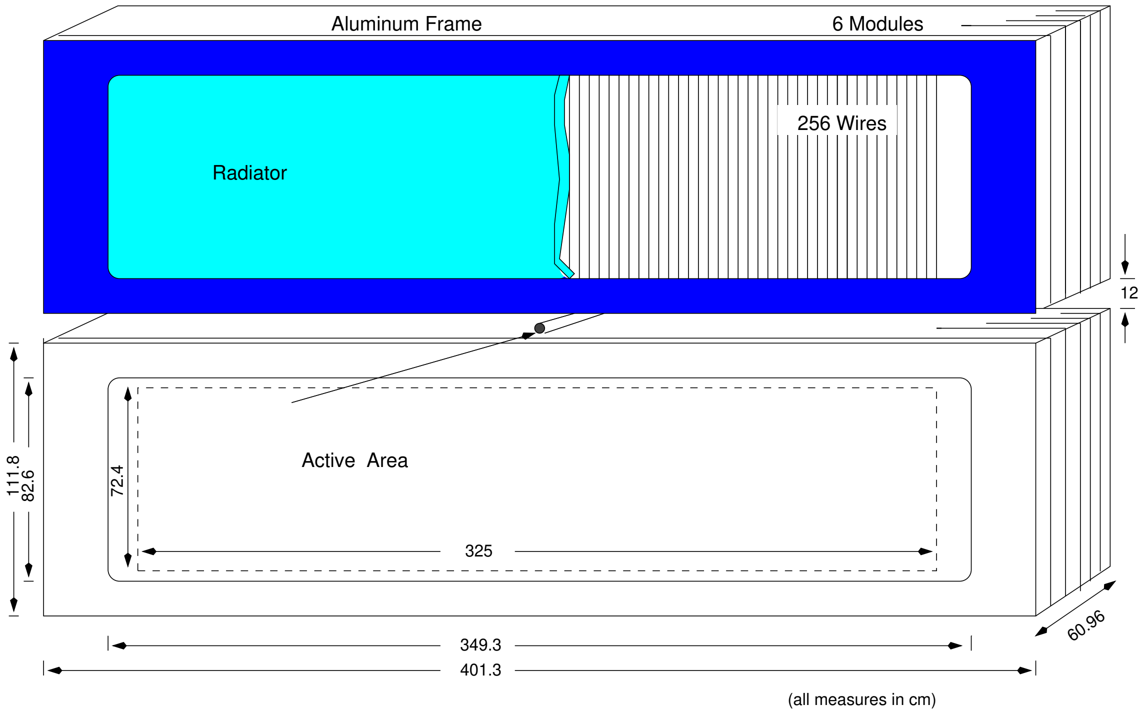
- Part of the first level trigger.
- Hadron rejection factor of $\geq$ 10 at the first level trigger and an additional factor of $\geq$ 100 in the offline analysis.
- Coarse position measurement.

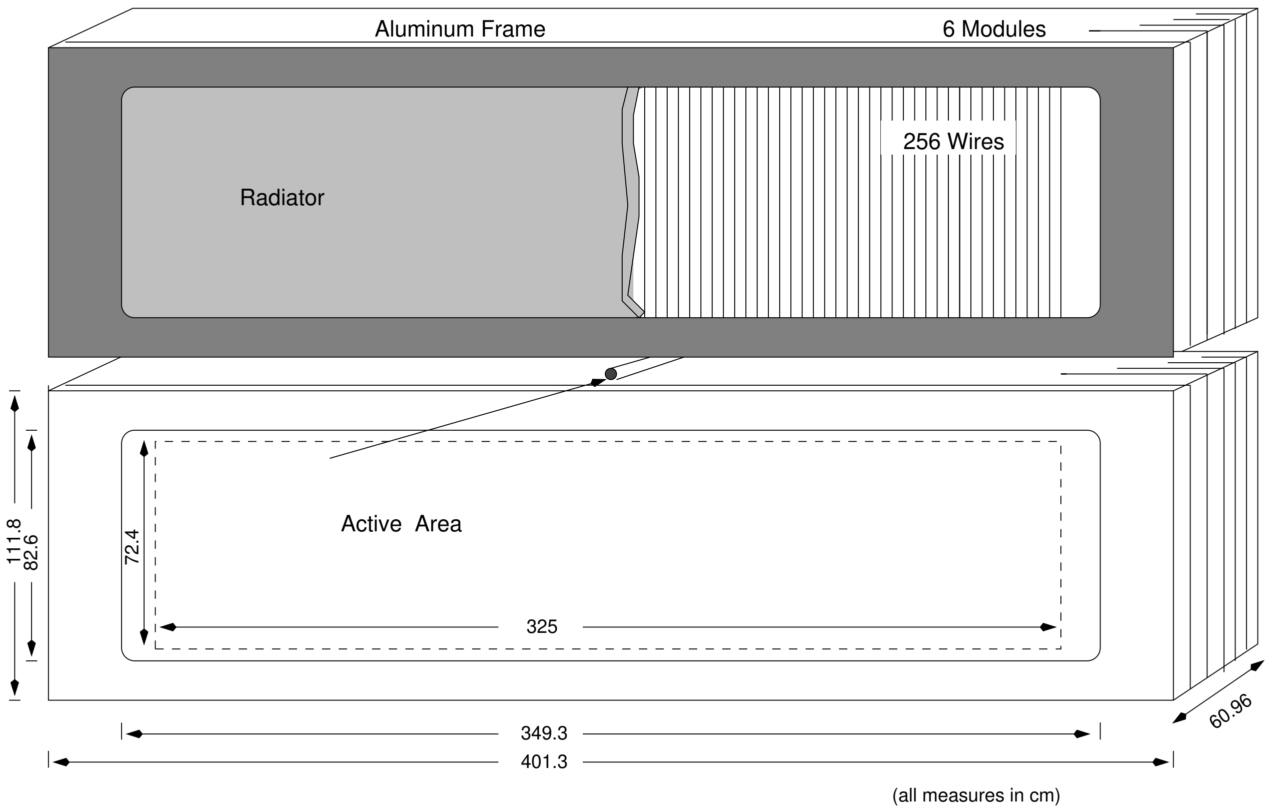
Normalized Calorimeter and Preshower Response



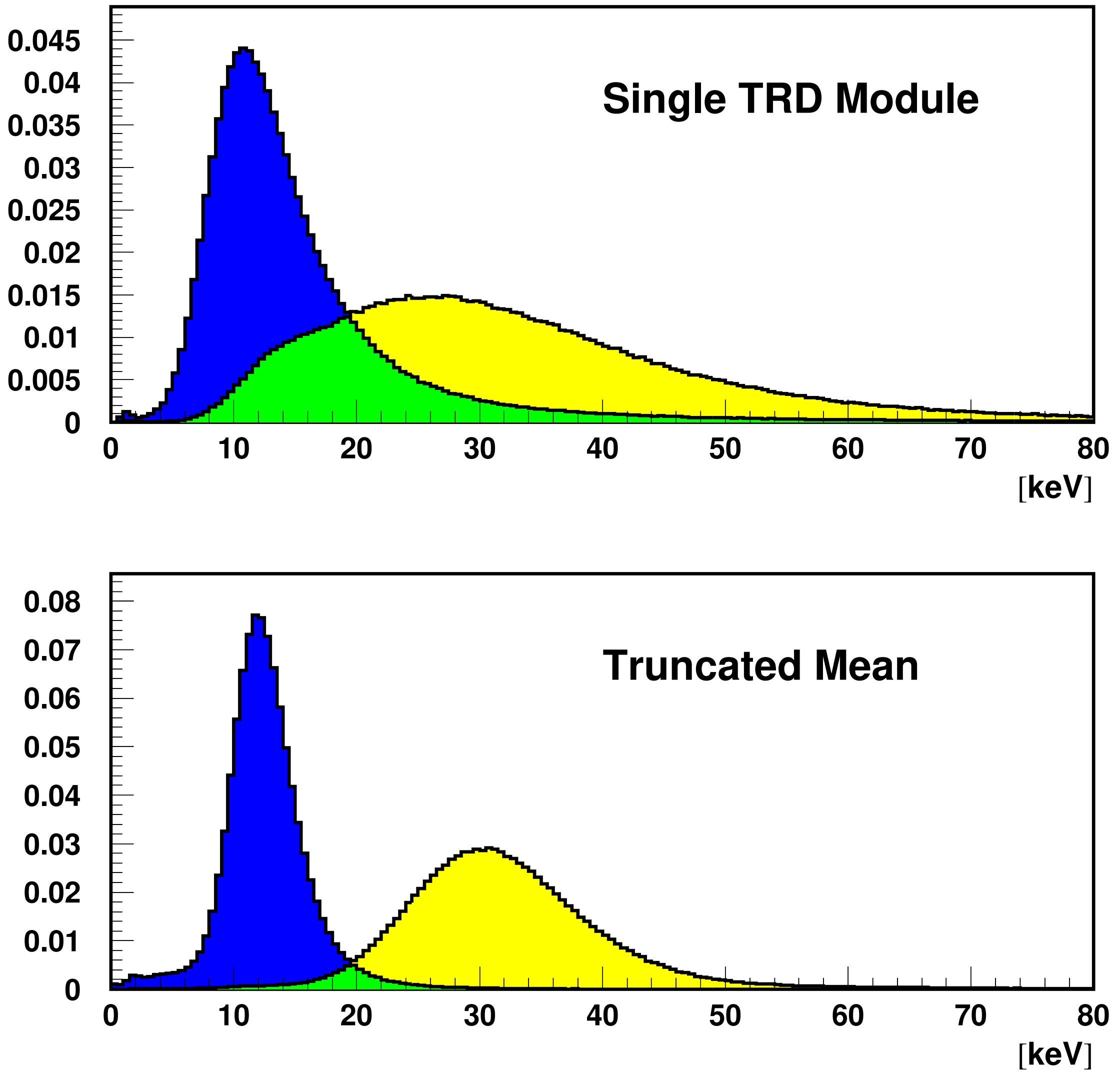


Transition Radiation Detector





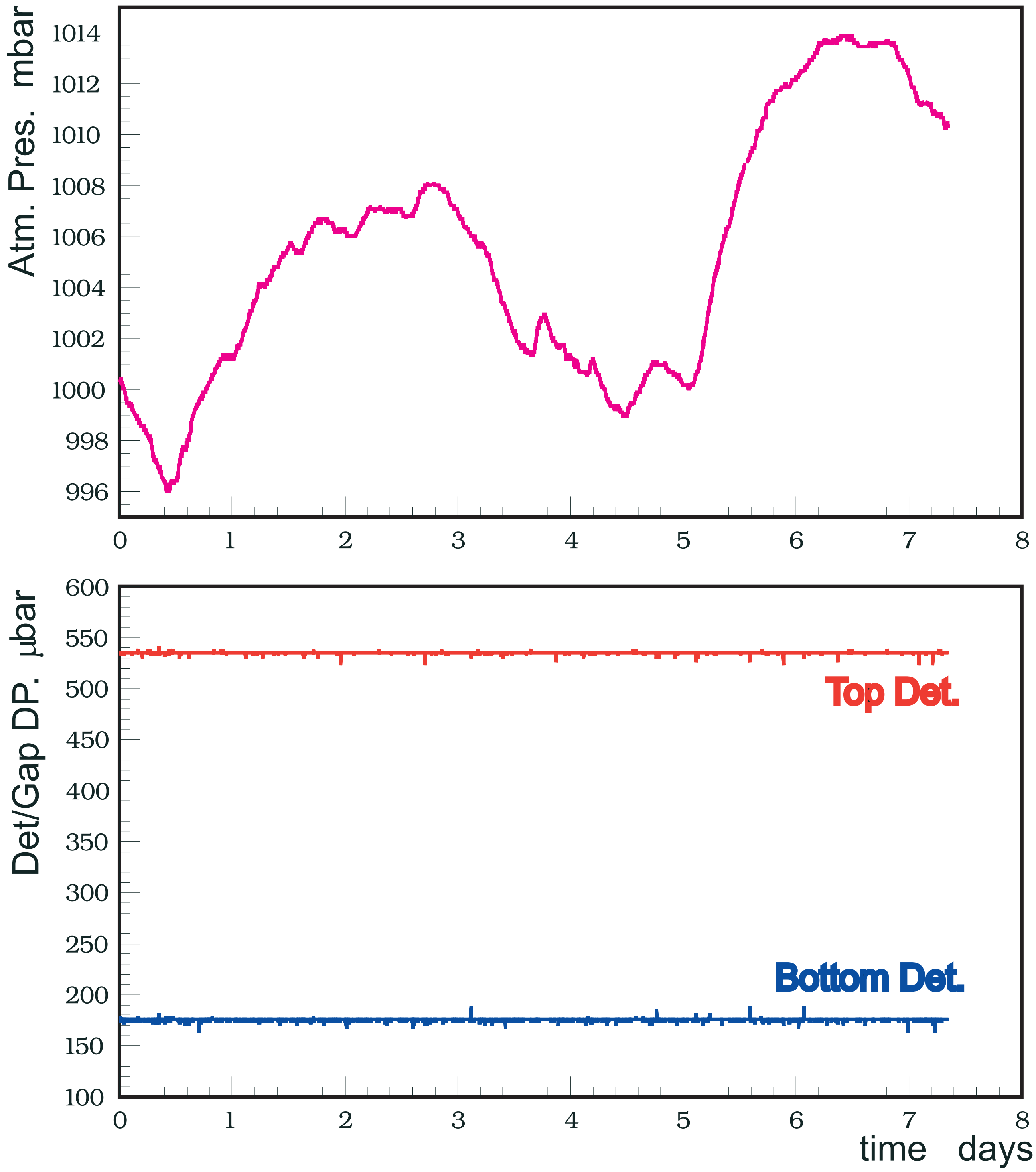
TRD Response



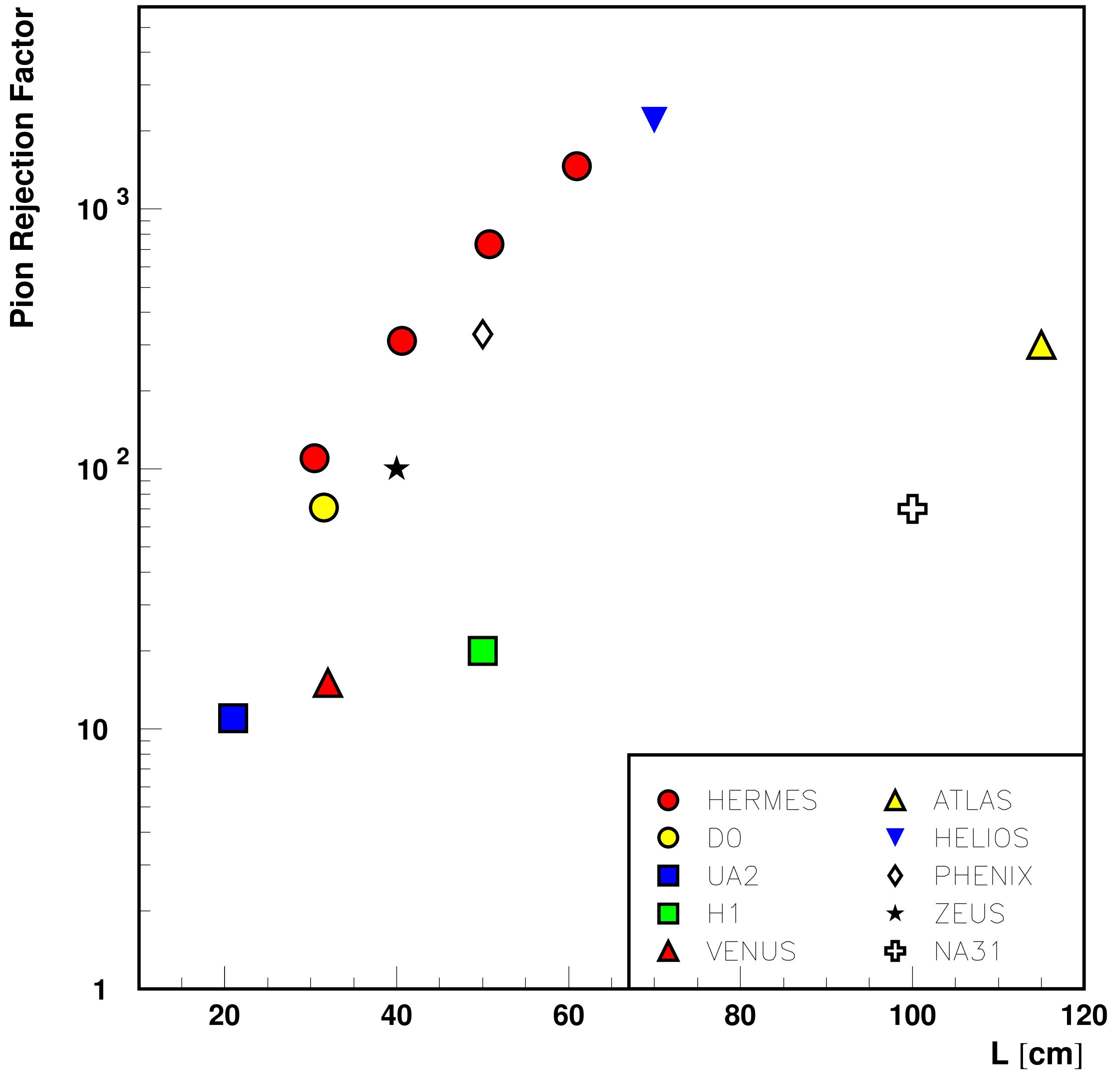
Truncated Mean:

$$E_{TM} = \frac{\sum_{i=1}^{n} E_i - max(E_i)}{n-1}$$

TRD Pressure Stability

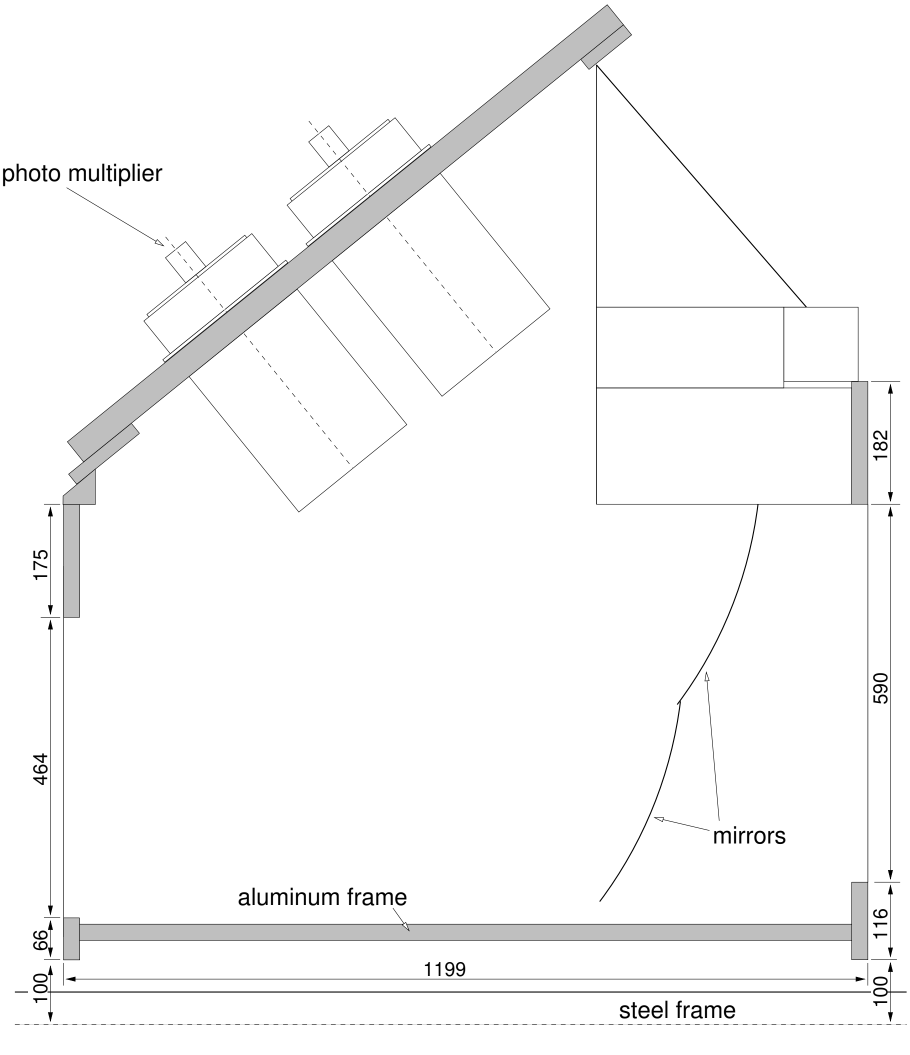


TRD Pion Rejection Factor



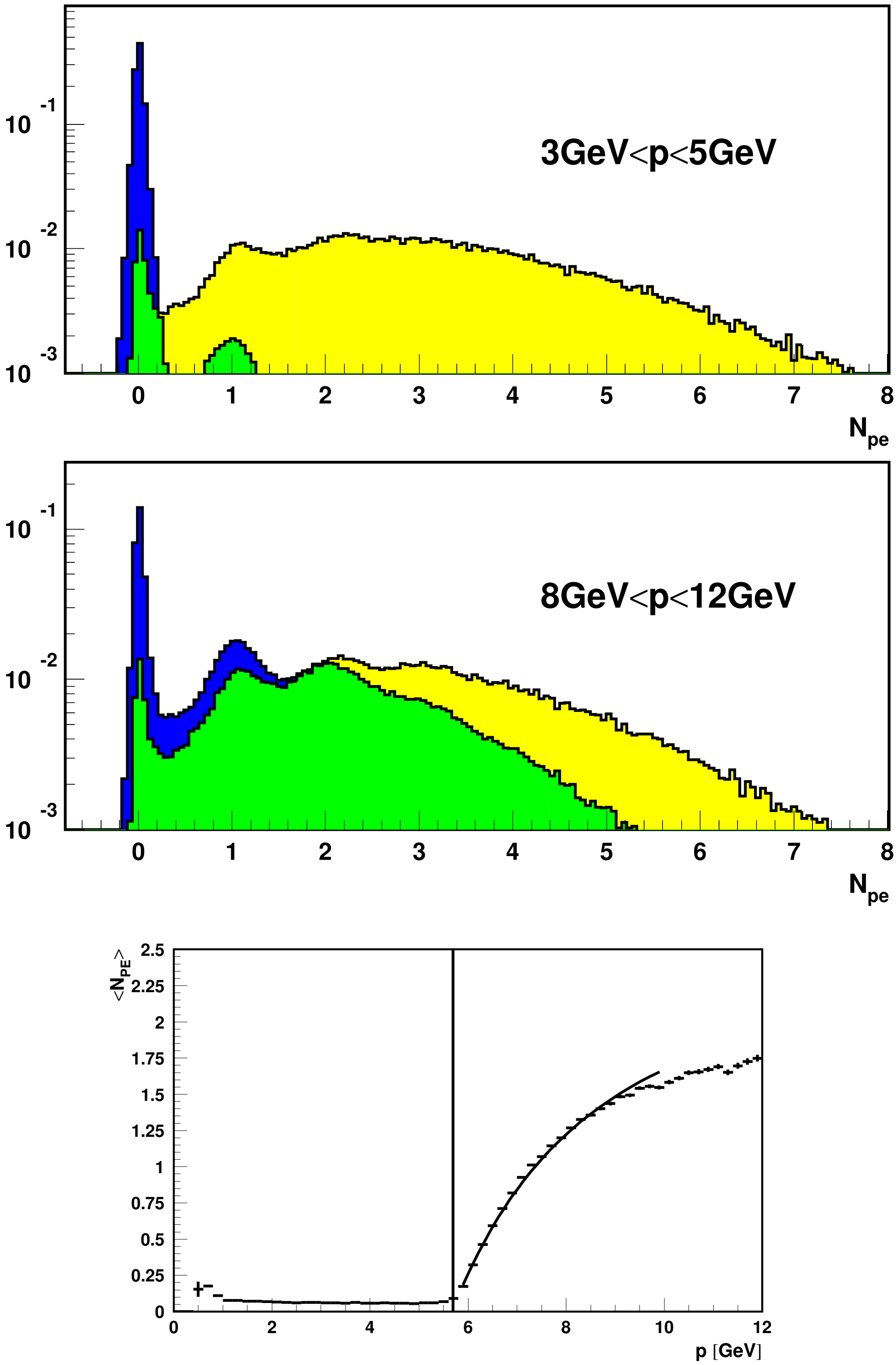
PRF(90% positron efficiency) $\sim$ 1460$\pm$130 using the full probability analysis.

Gas Threshold Cerenkov

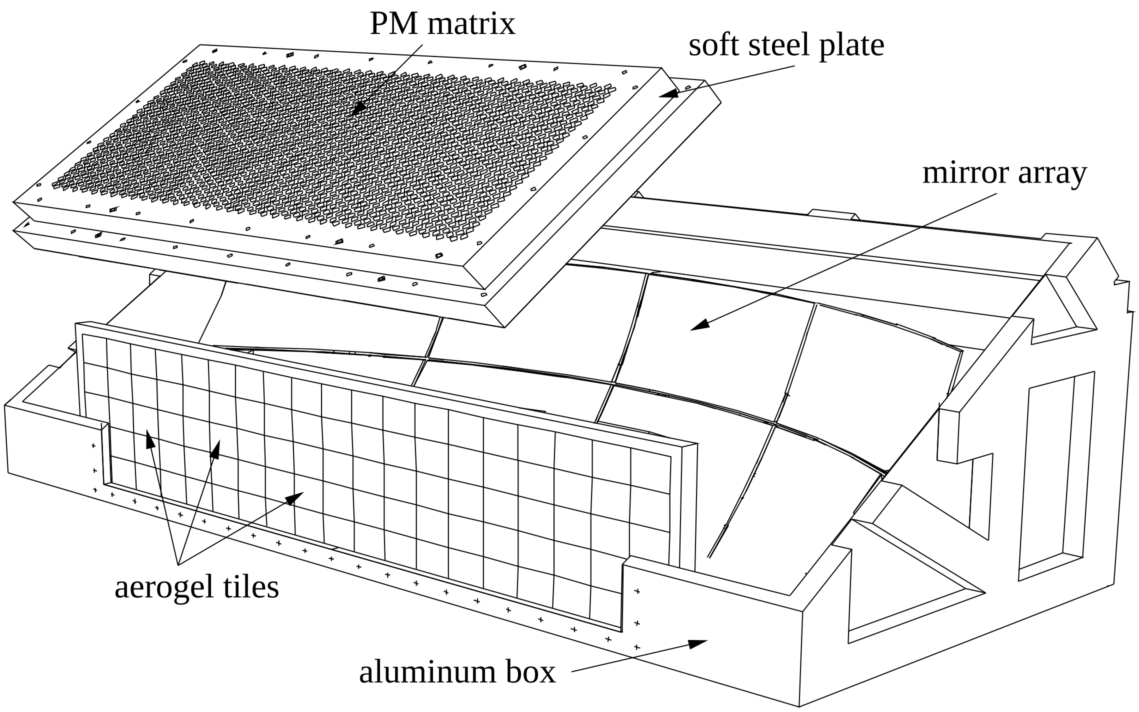


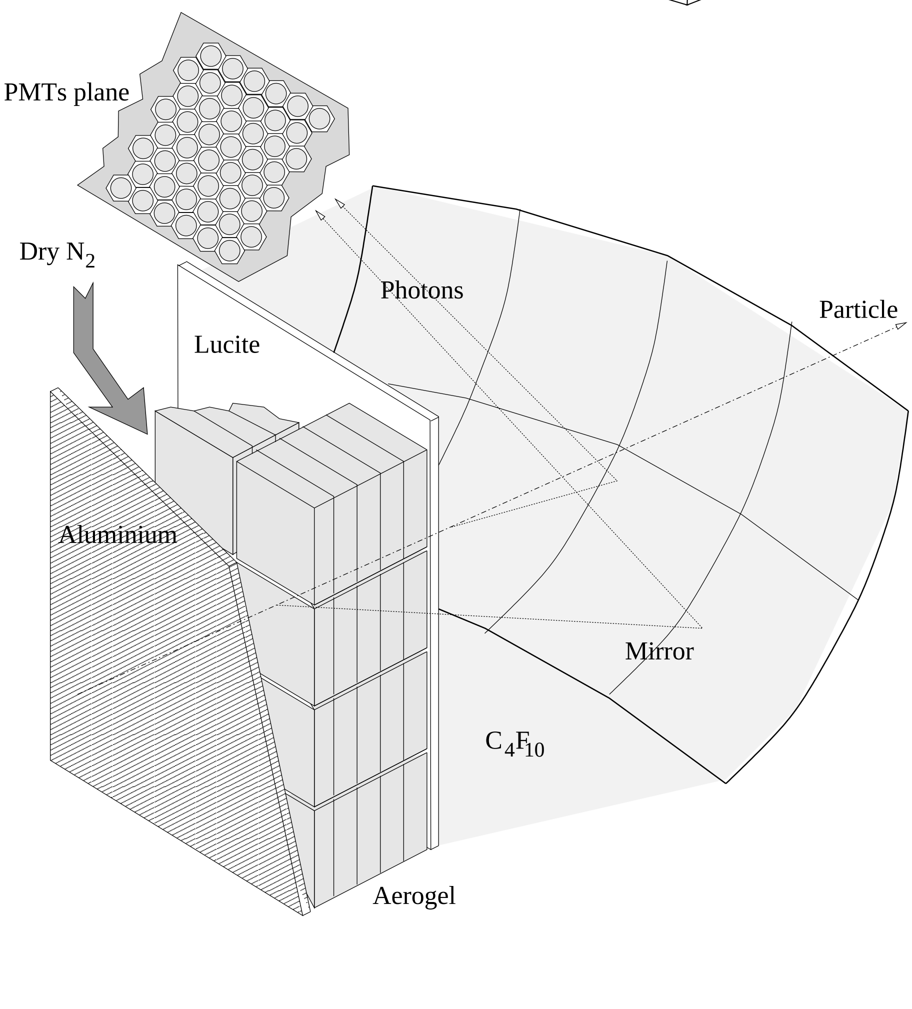
	1995	1996/97
RADIATOR	N_2	C_4F_{10},N_2
N	1.000298	1.000611
$p_t(e)$	0.021 GeV	0.015 GeV
$p_t(\pi)$	5.72 Ge	3.99 GeV
$p_t(K)$	20.23 GeV	14.13 GeV

Normalized Threshold Cerenkov Response

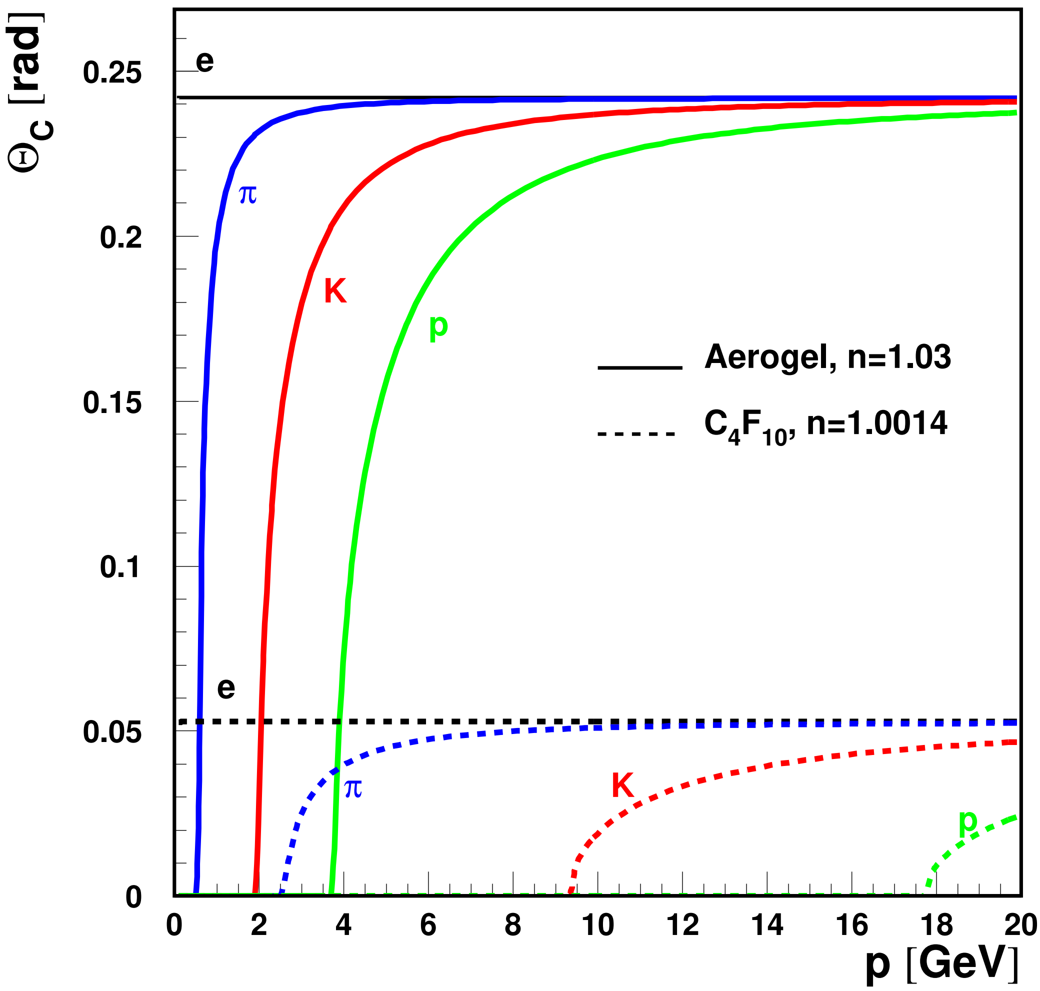


RICH DETECTOR





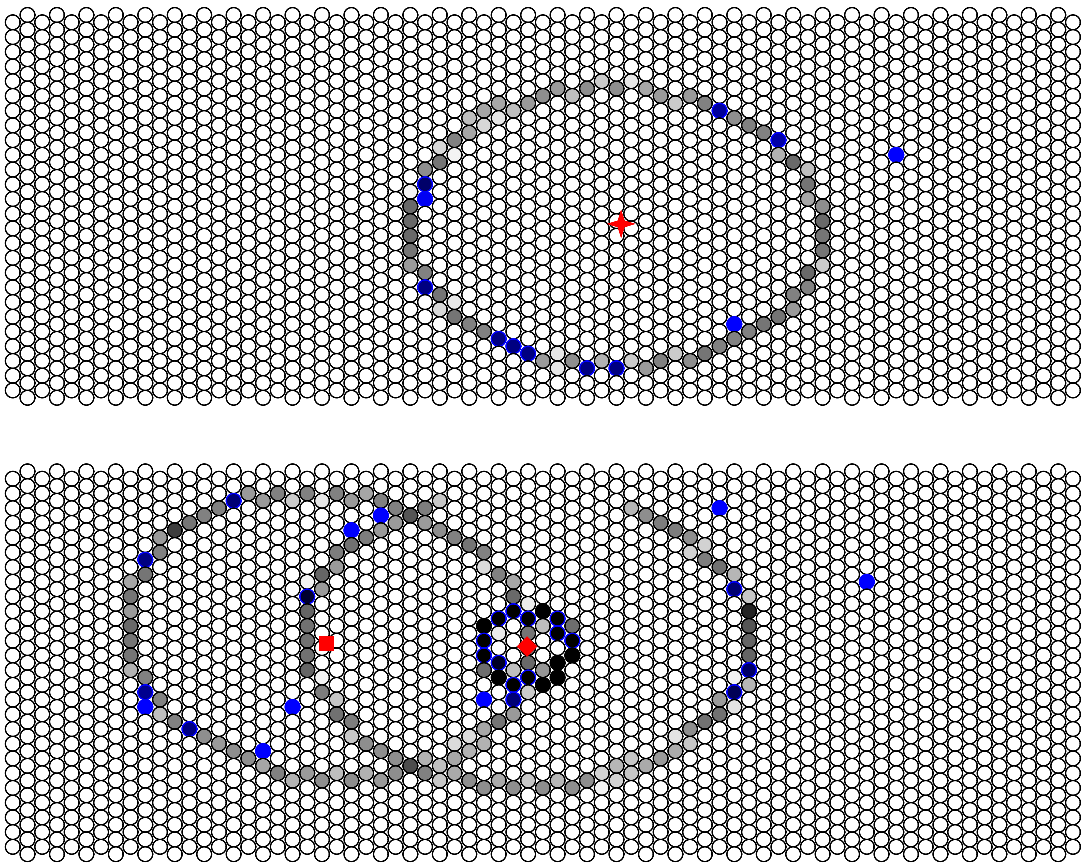
Aerogel and Gas Radiators



$$\cos\theta_c = \frac{1}{\frac{v}{c}n} \qquad p = \frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}$$

$(p, n, \theta_c) \rightarrow m_0 \rightarrow$ Particle ID $2-15$ GeV

RICH Event:
Charm Meson Candidate

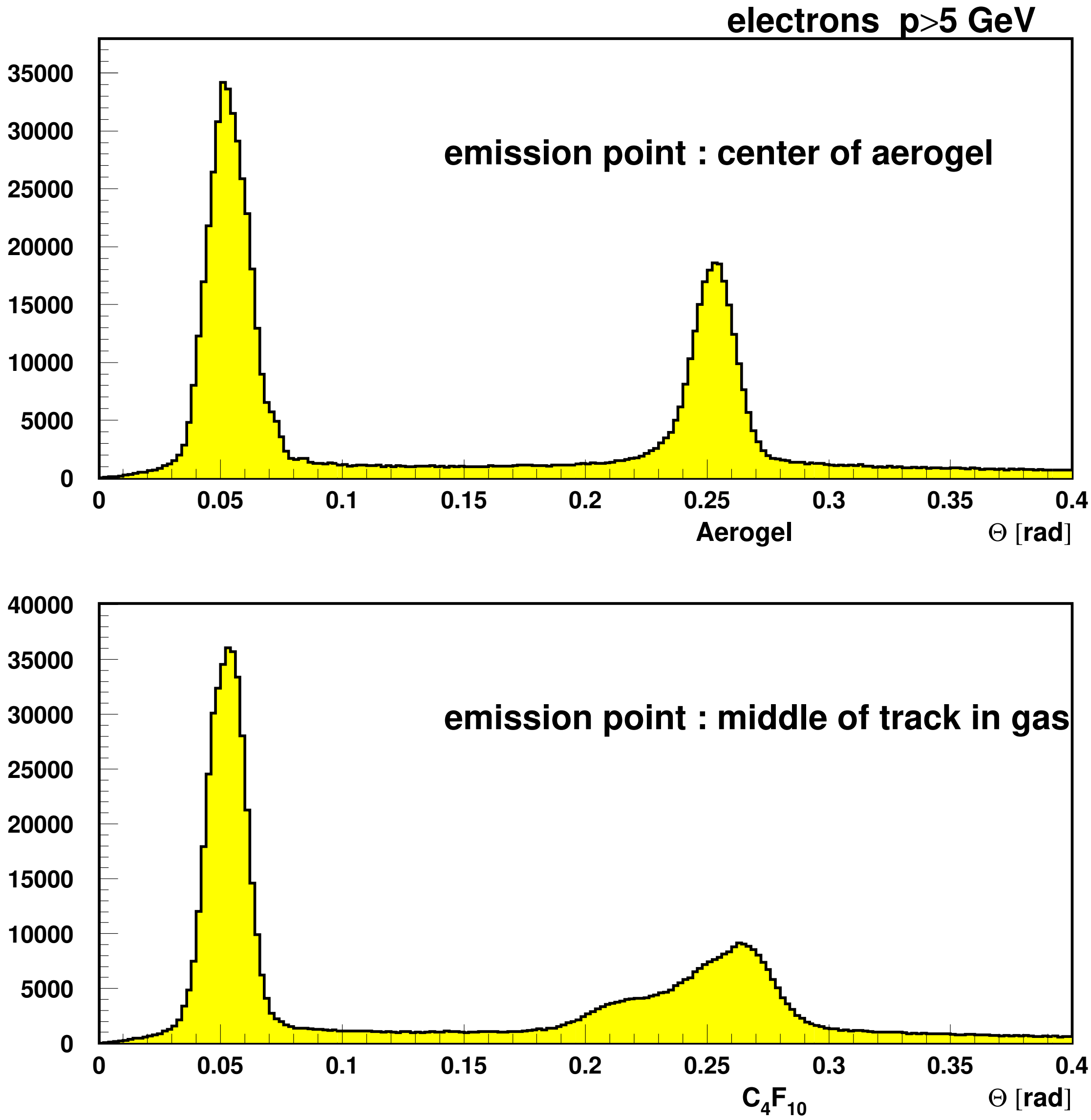


Run: 3360 | Event: 20097411 | Time: Mon Nov 23 05:39:09 1998 | Number of tracks: 3

Particle	1	2	3
Momentum(GeV/c)	5.54	1.52	14.61
Type(est)	Kaon+	Pion-	Electron
Position	Top	Bottom	Bottom

No hits 1 or more hits

RICH Response
IRT Angle Spectra



Likelihood Analysis for Electron/Hadron Separation

The responses of the PID detectors can be converted into conditional probabilities $\mathcal{L}^i_D$ that the response of the detector D was caused by a particle of the type i.

The conditional probabilities from several detectors D can be combined into an overall conditional probability

$$\mathcal{L}^i = \prod_D \mathcal{L}^i_D$$

The conditional probabilities can be transformed into true probabilities using Bayes' theorem:

$$\mathcal{P}^i = \frac{\phi^i(p,\theta)\mathcal{L}^i}{\sum_j \phi^j(p,\theta)\mathcal{L}^j}$$

$$\mathcal{P}^e = \frac{\mathcal{L}^e}{\Phi\mathcal{L}^h + \mathcal{L}^e}$$

PID parameter

In this case it is equivalent to create a PID parameter from the ratio of the positron and hadron probabilities by taking the logarithm:

$$PID = \log_{10}\left(\frac{\mathcal{P}^e}{\mathcal{P}^h}\right) = \log_{10}\left(\frac{\mathcal{L}^e}{\mathcal{L}^h}\right) - \log_{10}\Phi$$

PID parameter for each detector:

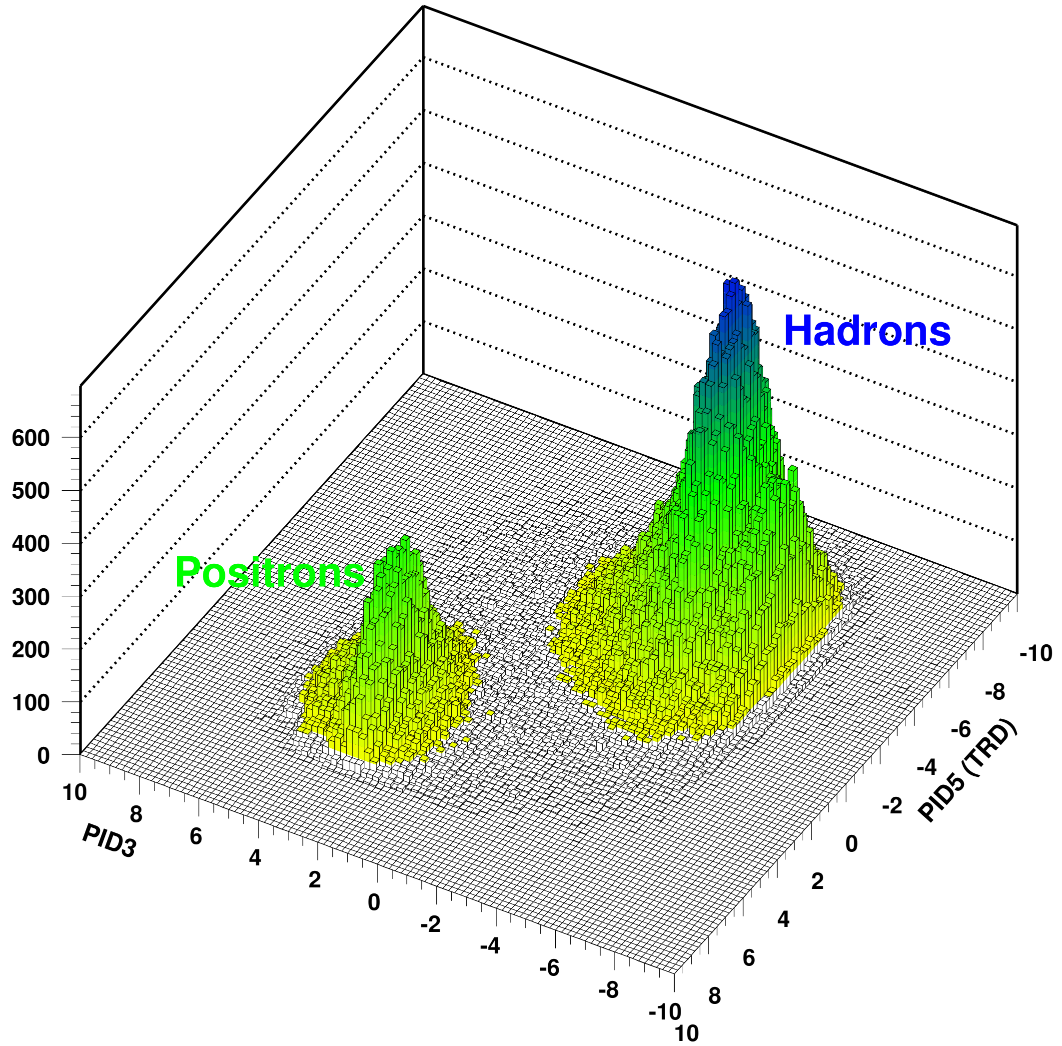
$$PID_D = \log_{10}\left(\frac{\mathcal{L}_D^e}{\mathcal{L}_D^h}\right)$$

Hermes PID parameter:

$$\begin{aligned} PID3 &= PID_{cal} + PID_{pre} + PID_{cer} \\ &= \log_{10}\left(\frac{\mathcal{L}_{cal}^e \mathcal{L}_{pre}^e \mathcal{L}_{cer}^e}{\mathcal{L}_{cal}^h \mathcal{L}_{pre}^h \mathcal{L}_{cer}^h}\right) \end{aligned}$$

(since 1998 PID2 - without Cerenkov - instead of PID3)

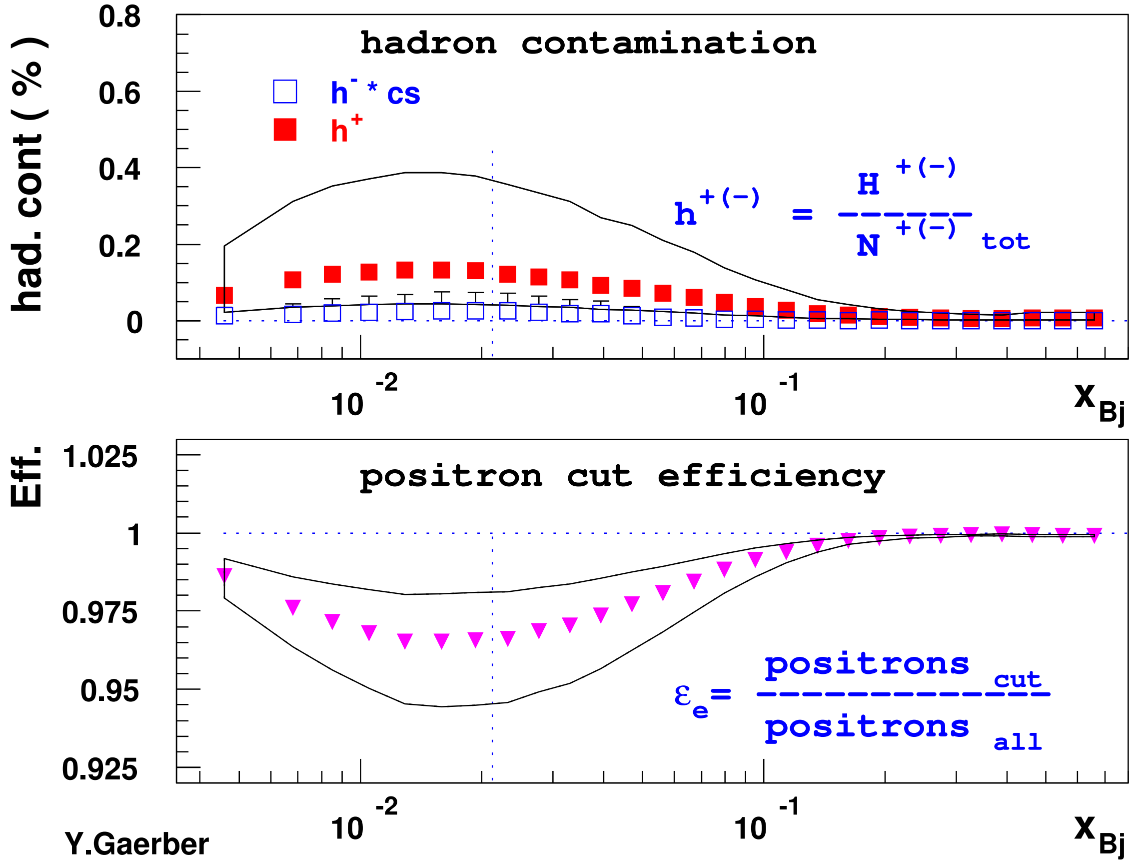
Electron/Hadron Separation



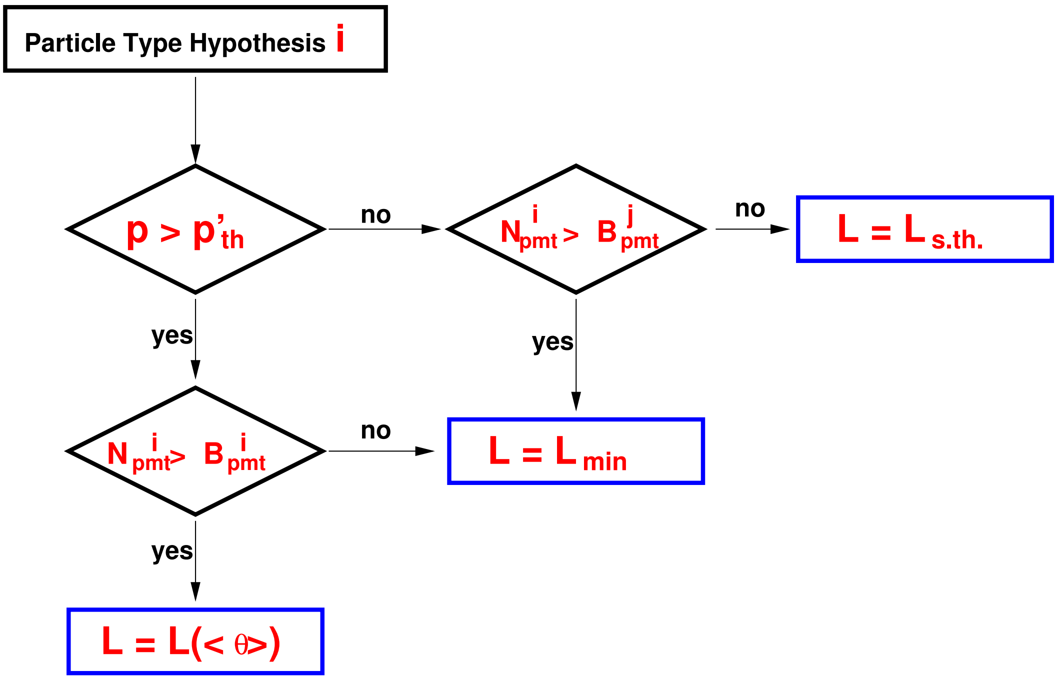
$$PID3 = \log_{10}\left(\frac{\mathcal{L}^{e}_{cal}\mathcal{L}^{e}_{pre}\mathcal{L}^{e}_{cer}}{\mathcal{L}^{h}_{cal}\mathcal{L}^{h}_{pre}\mathcal{L}^{h}_{cer}}\right)$$

99% electron identification efficiency with $< 1\%$ hadron contamination (for DIS events).

Electron/Hadron Separation
Contamination and Efficiency



RICH IRT Likelihood Algorithm



$$p'_{th} = p_{th} + \Delta p_{th}$$

$$B^i_{PMT} = \begin{cases} B^0_{PMT} & N^{out}_{PMT} \leq C_{out} \\ B^1_{PMT} & N^{out}_{PMT} > C_{out} \end{cases}$$

$$L_{min} = L(\theta = \theta_{th} + \sigma_w)$$

$$L(\langle\theta\rangle) = exp(-\frac{(\theta_{th} - \langle\theta\rangle)^2}{2\sigma^2_{\langle\theta\rangle}})$$

$$\sigma_{\langle\theta\rangle} = \frac{\sigma_\gamma}{\sqrt{N_{PMT} - 1}}$$

RICH quality parameter

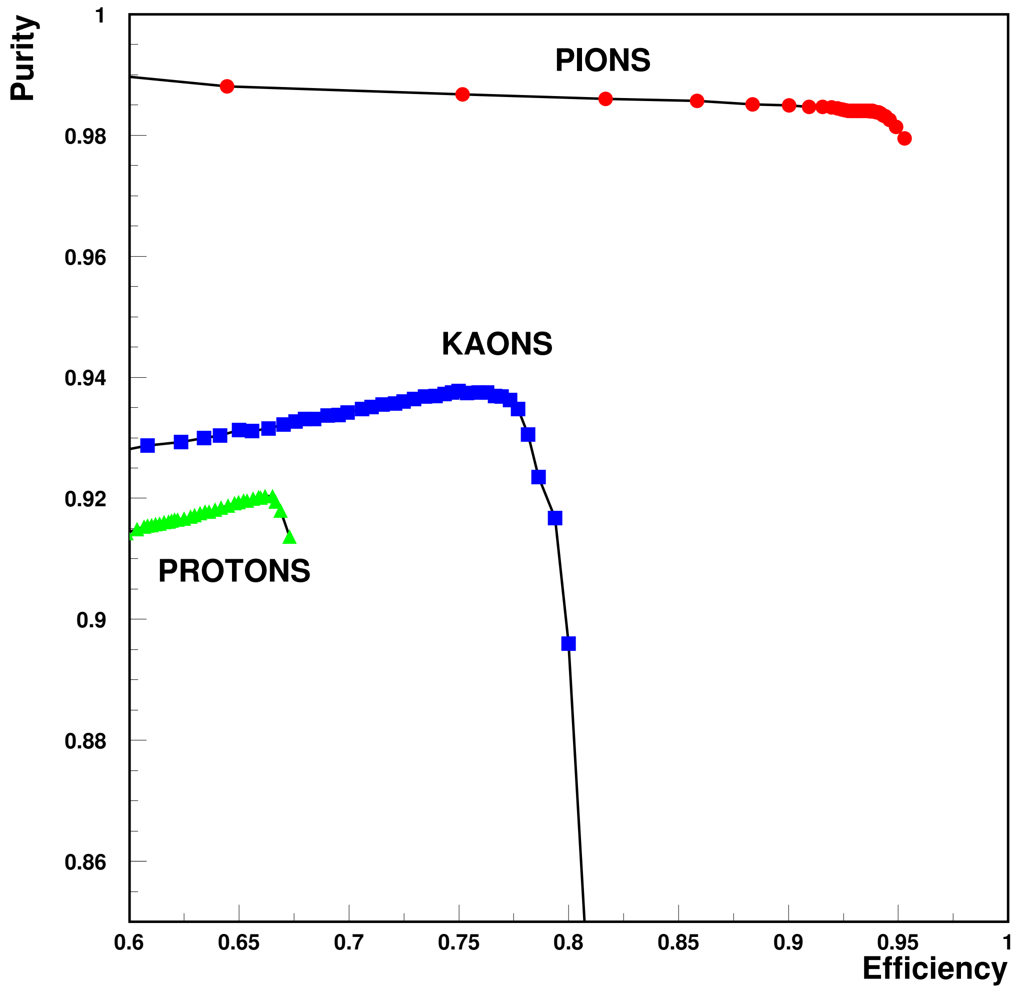
The output of the RICH likelihood analysis is the most likely particle type (π,K,p) and a quality parameter indicating how reliable the identification is.

$$qp = \log_{10}\left(\frac{L_1}{L_2}\right)$$

where L_1 and L_2 are the highest and the second highest hadron likelihood.

For only two particle types the RICH quality parameter becomes equivalent to the HERMES PID parameter (PID2/3), if the particle type is expressed as '-' for hadrons and '+' for electrons.

RICH Hadron Identification



ID. AS	π	K	P	PURITY
π	24624	89	322	0.99 ± 0.01
K	21	2995	188	0.94 ± 0.02
P	81	333	4771	0.92 ± 0.02
NO ID.	1419	438	1951	
ε	0.94 ± 0.01	0.78 ± 0.02	0.66 ± 0.02	

DIS MC data, $qp > 0.5$, $p > 2$ GeV

Summary and Outlook

- hadron/electron separation with high efficiency ($> 97\%$) and low contamination ($< 0.2\%$)

- RICH allows to identify hadrons from 2-15 GeV

- RICH likelihood analysis based on IRT is working

- additional hadron identificaton at low momenta wit ToF

- muon identification with the μ-hodoscopes

- improvement of RICH performance using DRT and event level analysis

Bibliography

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