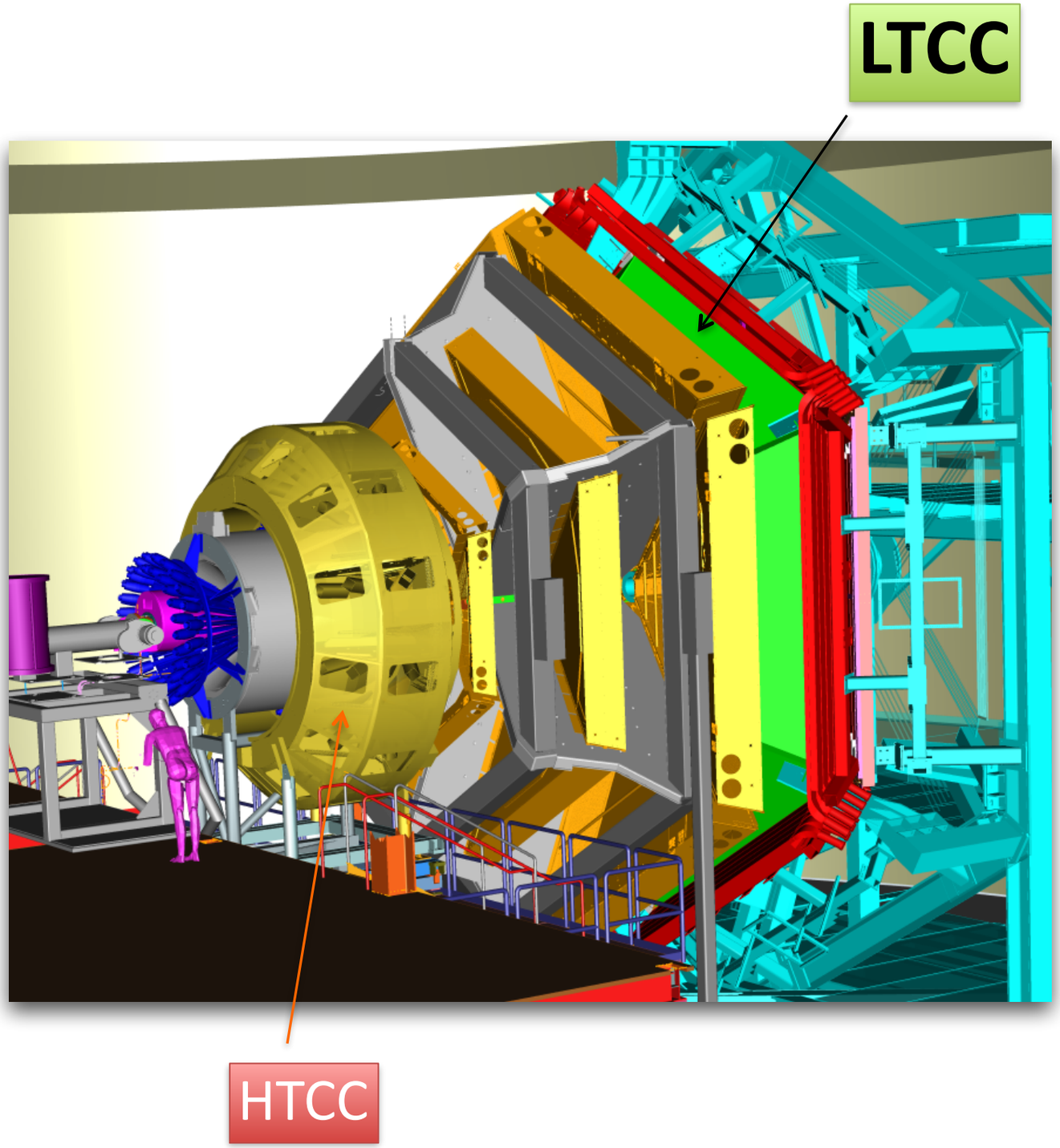
Integrating Cherenkov detectors for PID

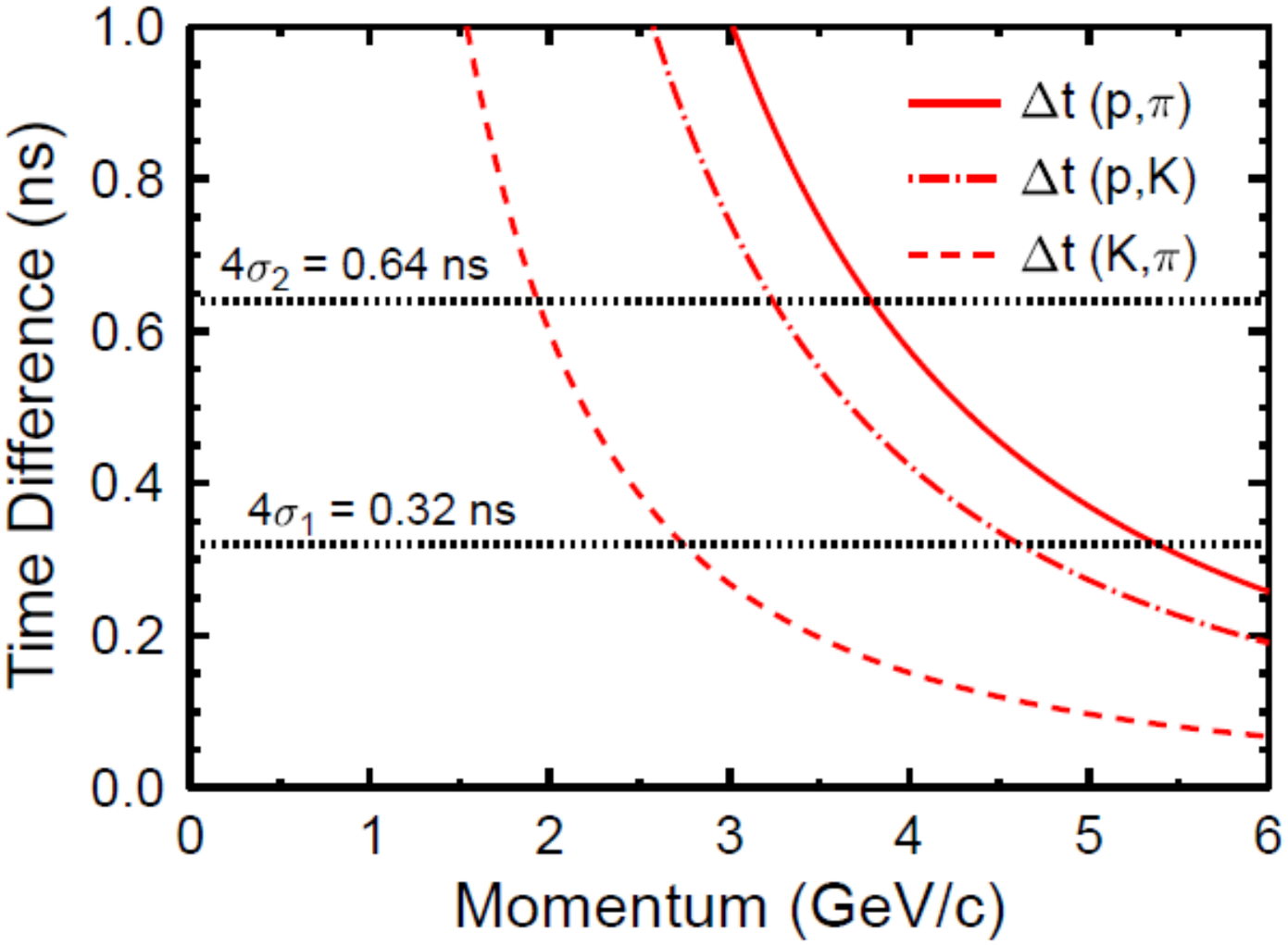
Overview of CC detectors

Efficiency Calculations

pion / kaon / proton Efficiency /
Rejections Projections to ~20 GeV



TOF + CCs PID in CLAS12



- Electron ID relies on HTCC, ECAL+PCAL

- TOF-based separation of protons, pions, and kaons, up to:

  - ~5 GeV (p, π)
  - ~4.5 GeV (p,K)
  - ~2.7 GeV (π, K)

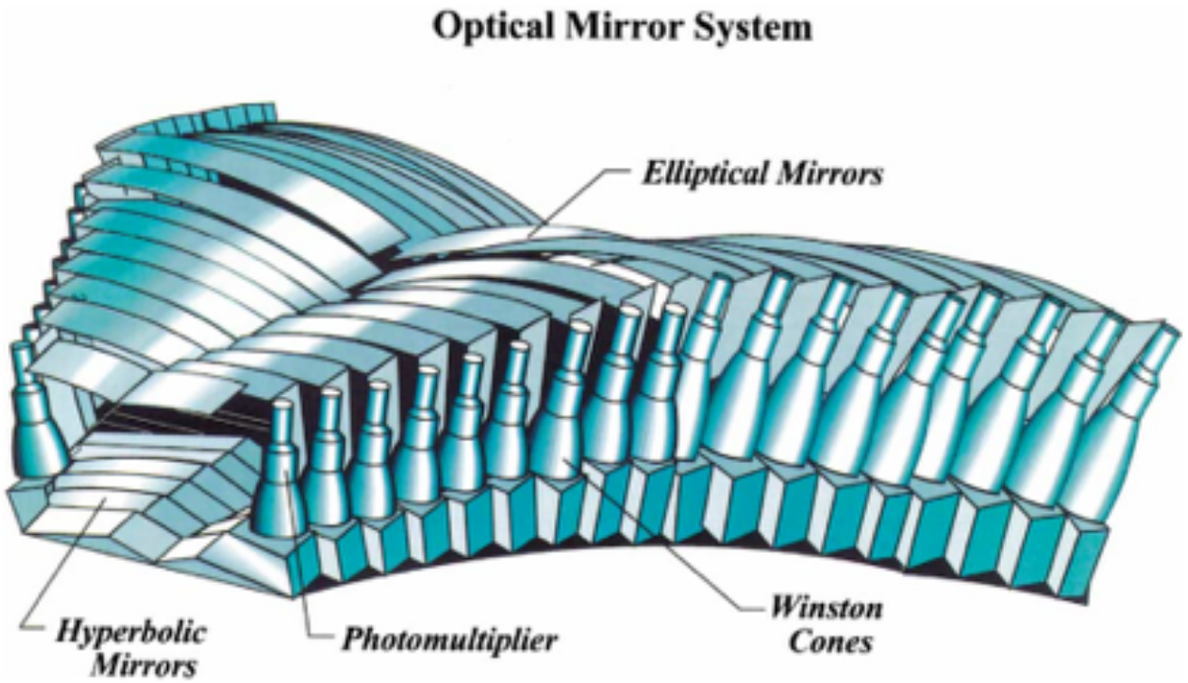
HTCC (CO_2) electron / pion discrimination up to ~5 GeV
LTCC (C_4F_{10}) for pion / K discrimination between 3.5~9 GeV

The Low Threshold Cherenkov Detector

The LTCC system is part of the forward CLAS12 detector, used for pion/kaon discrimination.

The LTCC consists of 6 sectors of lightweight mirrors, light collecting cones, 5” PMTs, and magnetic shields.

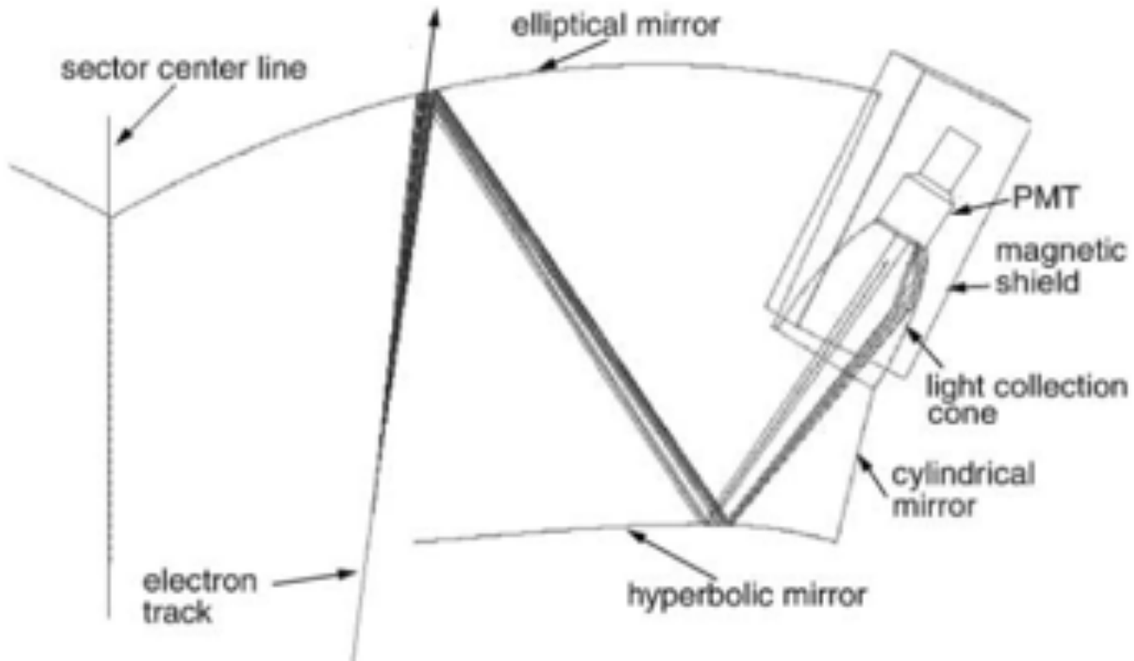
The sectors are filled with C4F10 gas, providing pion/kaon discrimination from 3.5 to 9 GeV/c over the forward angular acceptance available to CLAS12.



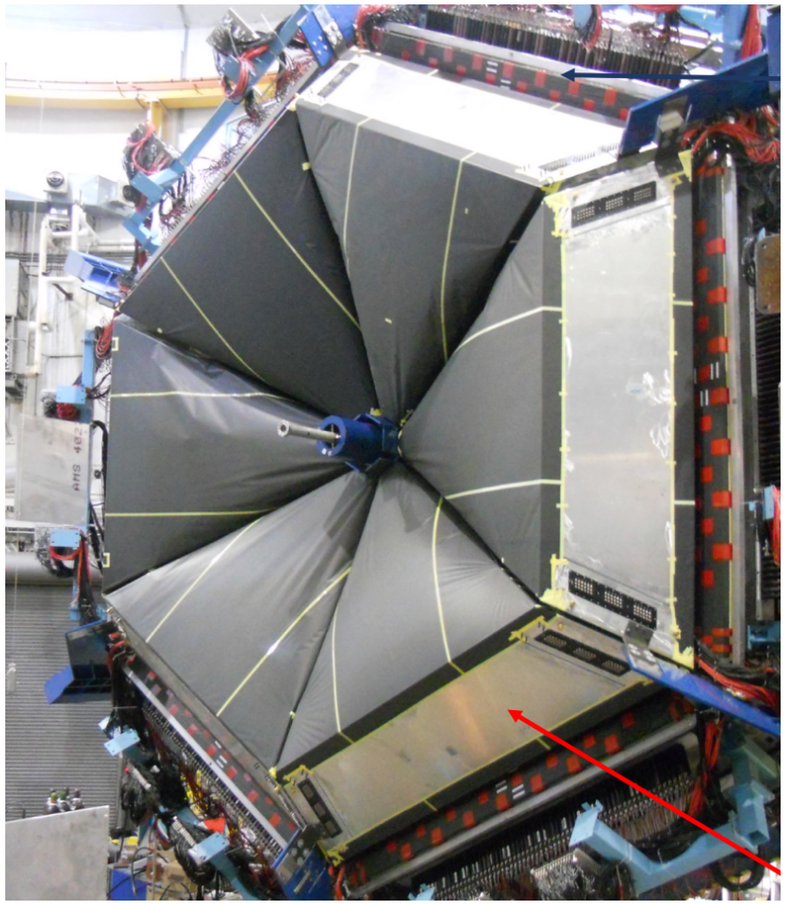
- 108 lightweight mirrors
- 36 Winston Cones
- 36 5’’ Photonis X4500B PMT
- 36 Magnetic Shields

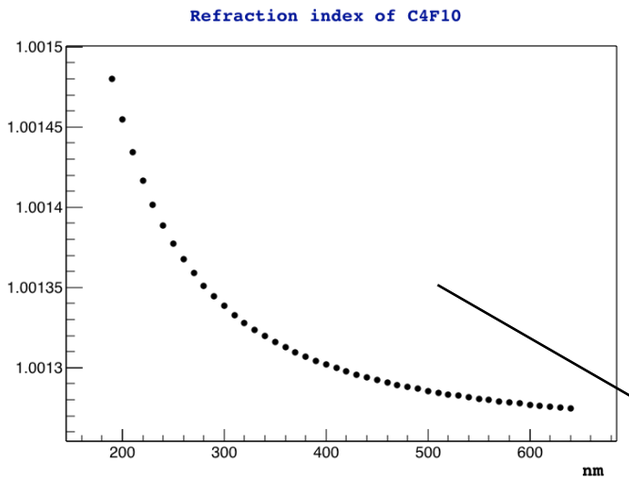
One Sector

- C4F10 Gas, r.i. 1.00134
- CLAS6: e-/π discrimination
- π theo threshold: ~2.6 GeV
- K theo threshold: ~ 8 GeV



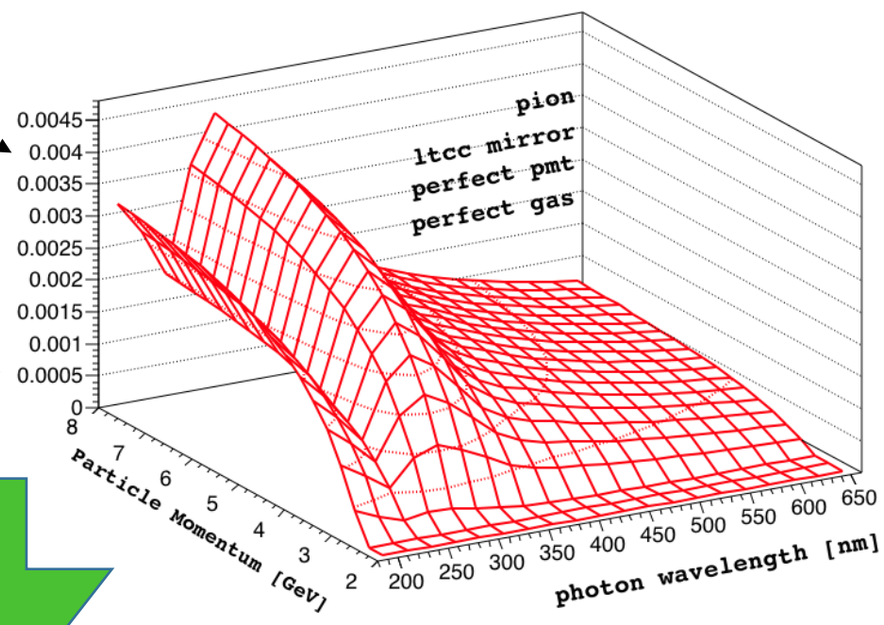
The Low Threshold Cherenkov Detector

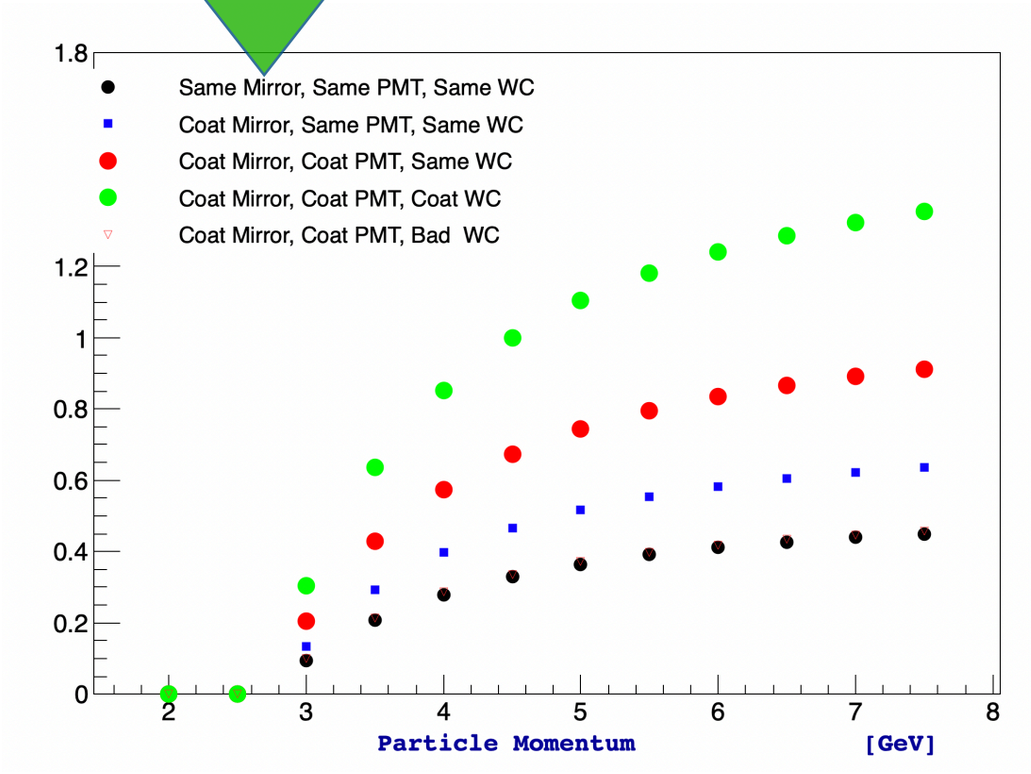




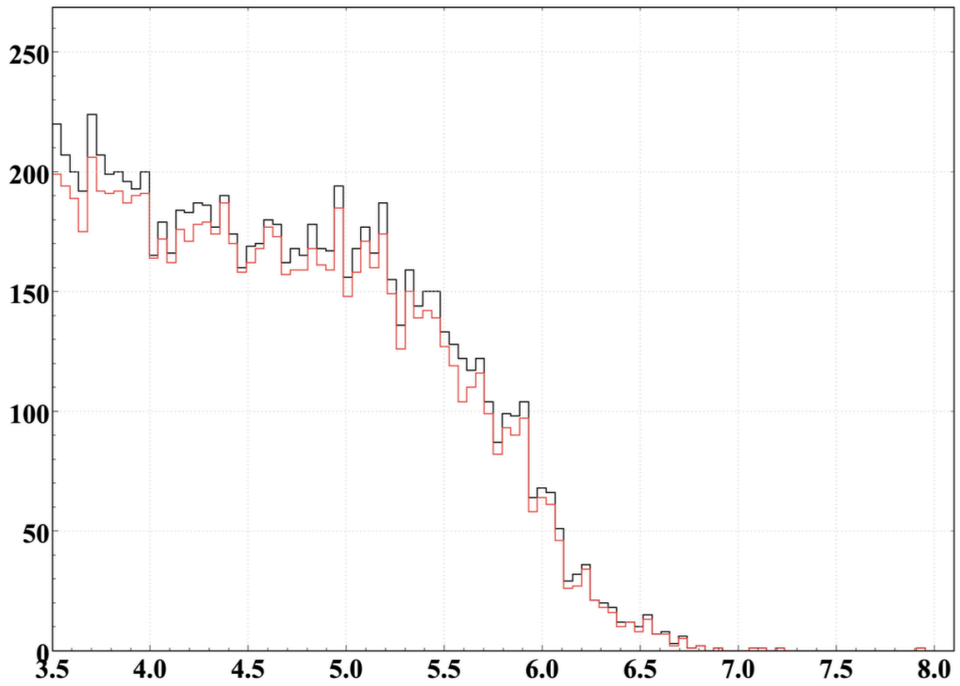
$$\frac{d^2N}{d\lambda dx} = \frac{2\pi\alpha}{\lambda^2}\left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right)$$

- Measured Mirrors, WC reflectivities,
- PMT Q.E
- Gas Transparency and thickness



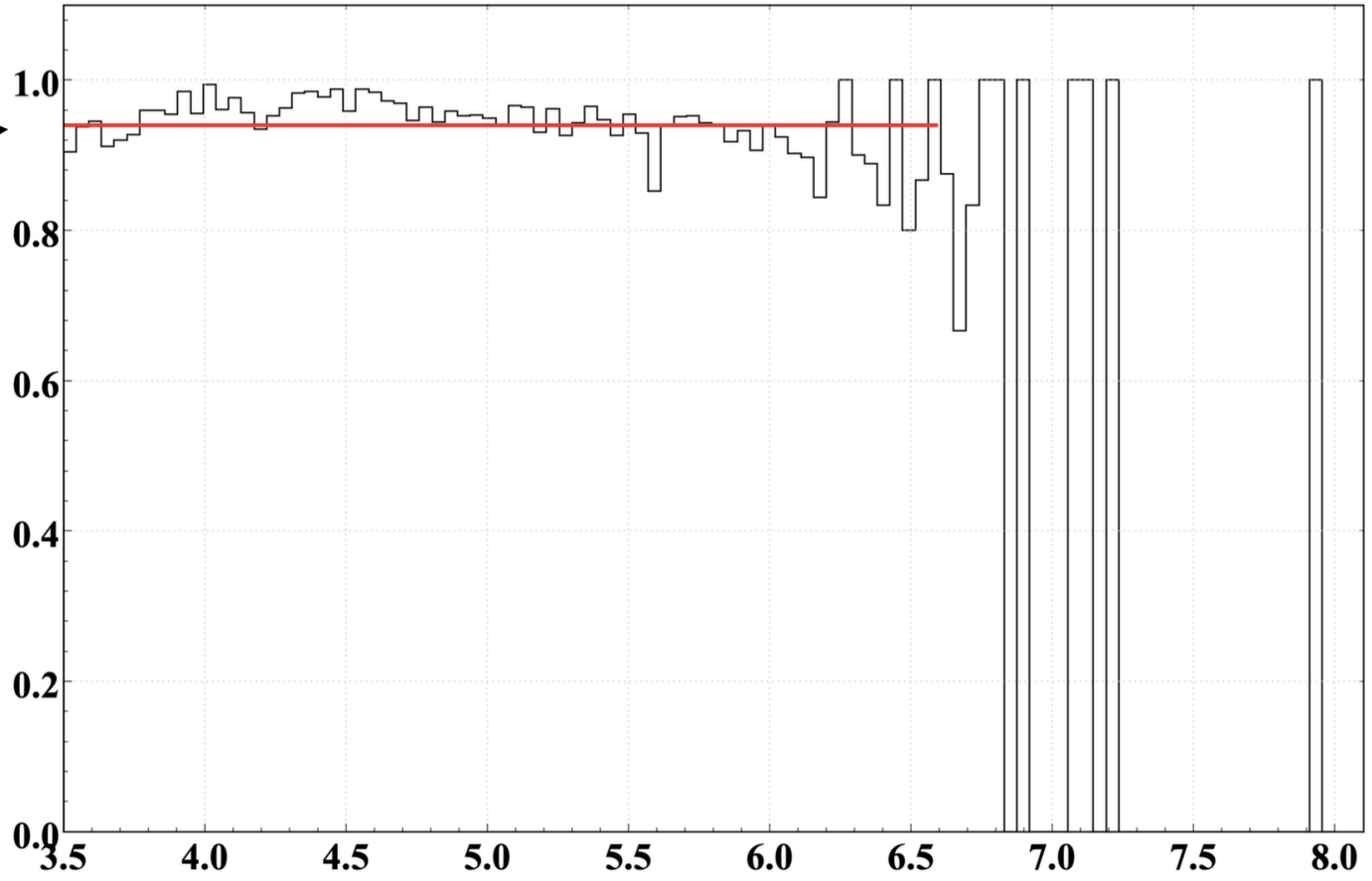


LTCC Electron Efficiency



- Electrons momentum selected in the expected pion response range;
- Electrons identified using the reconstruction event builder algorithm (no extra EC cuts);
- Electrons must be within a fiducial volume of the LTCC.

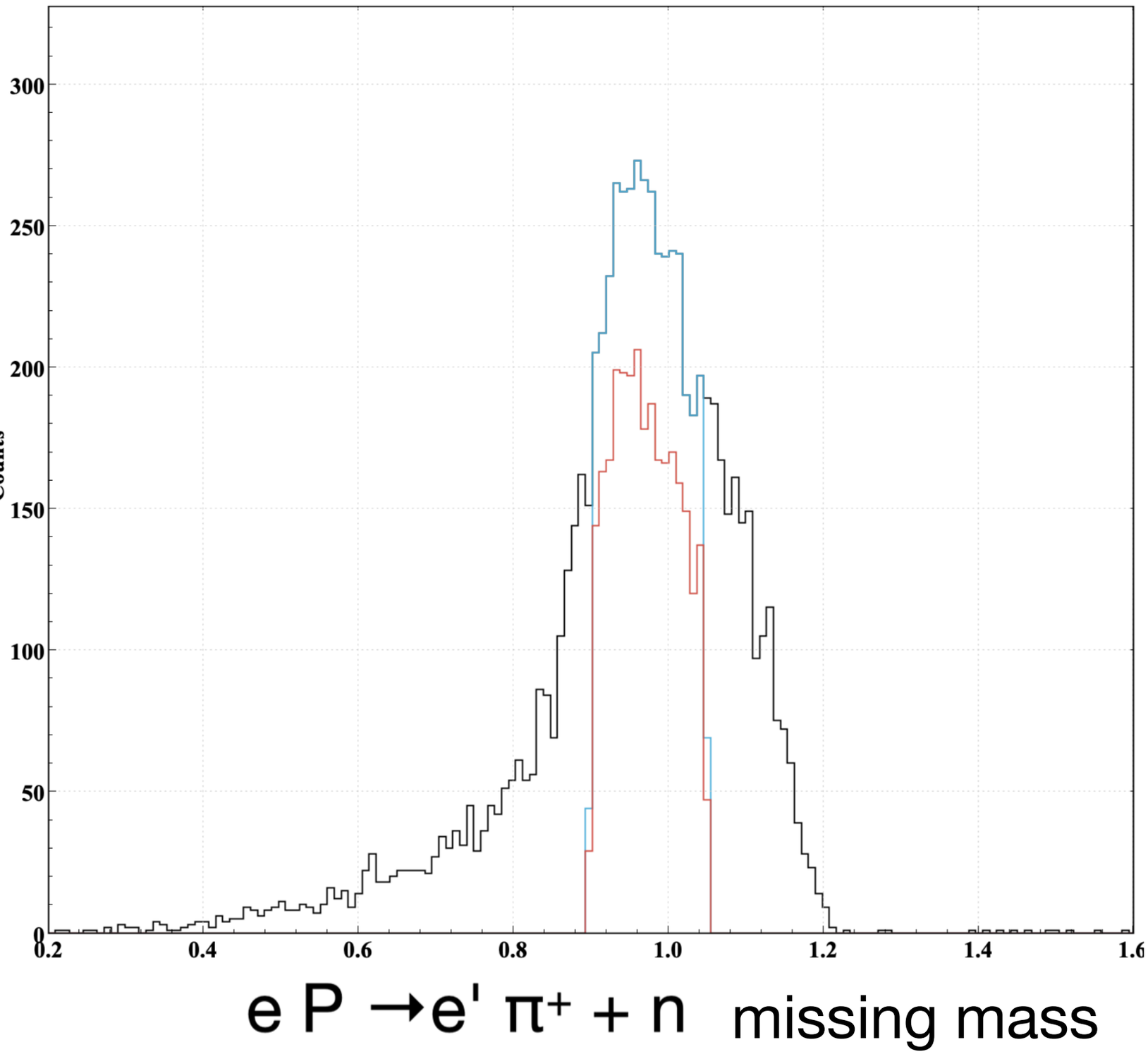
94%



Not 99%. Maybe due to:

- uncalibrated data
- no extra EC cut
- not pure gas
- other systems inefficiencies

LTCC Pion Efficiency PART 1



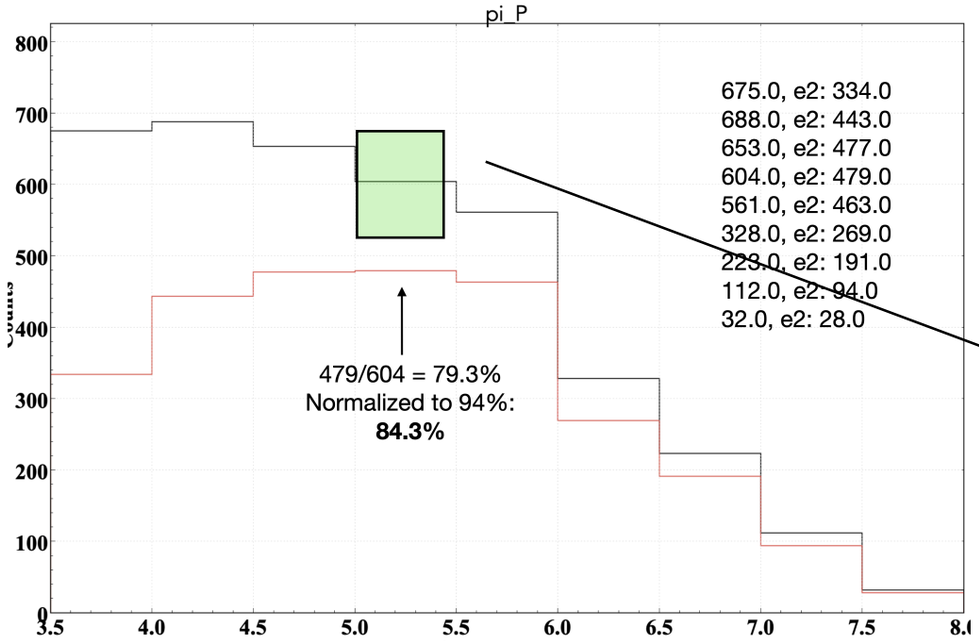
$e\,P \rightarrow e'\,\pi^+ + n$ missing mass

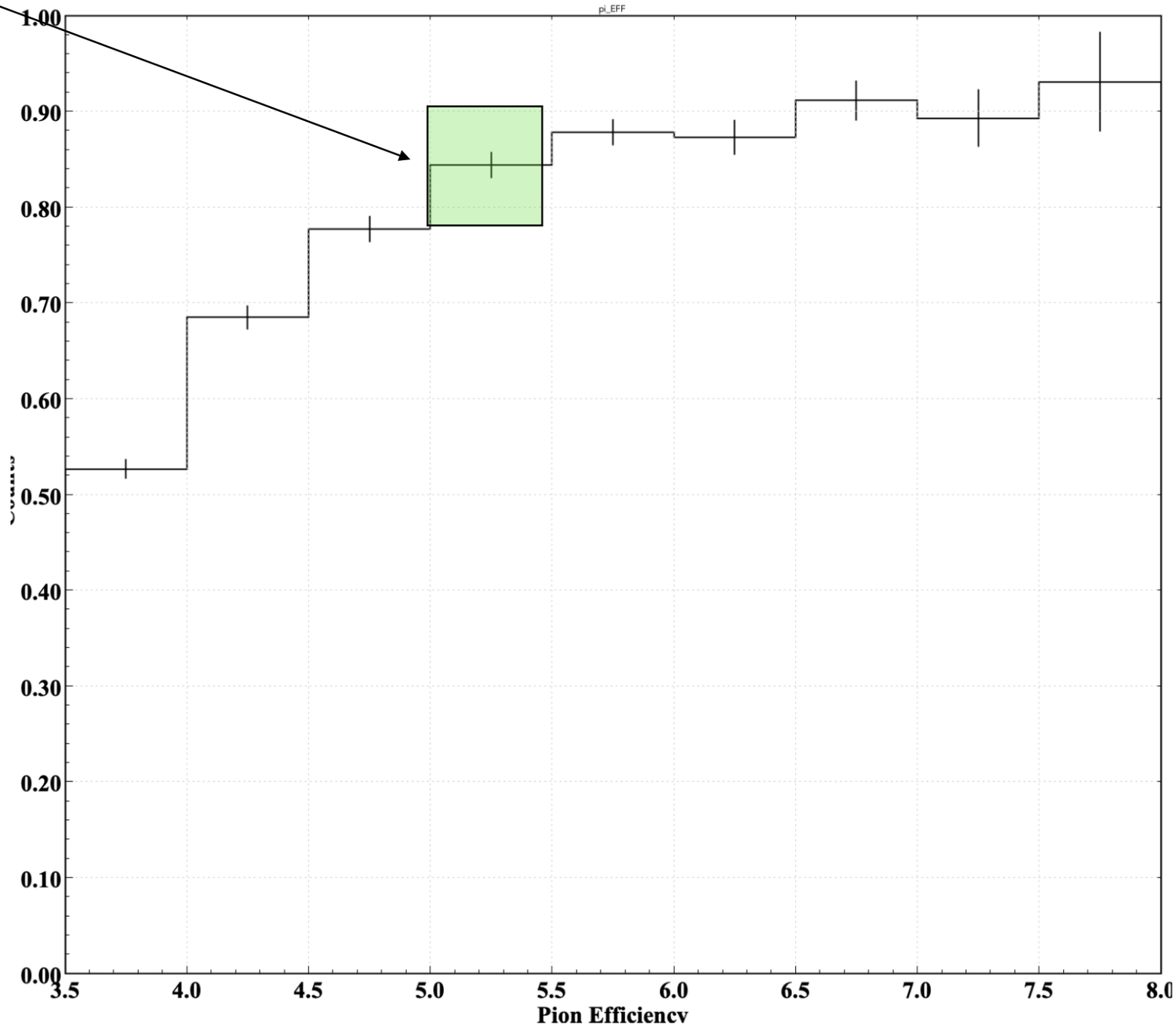
$e\,P \rightarrow e'\,\pi^+ + n$

- electron selection
- positive tracks candidates within the fiducial volume
- neutron missing mass cut:

0.95 < mm < 1.05

LTCC Pion Efficiency PART 1

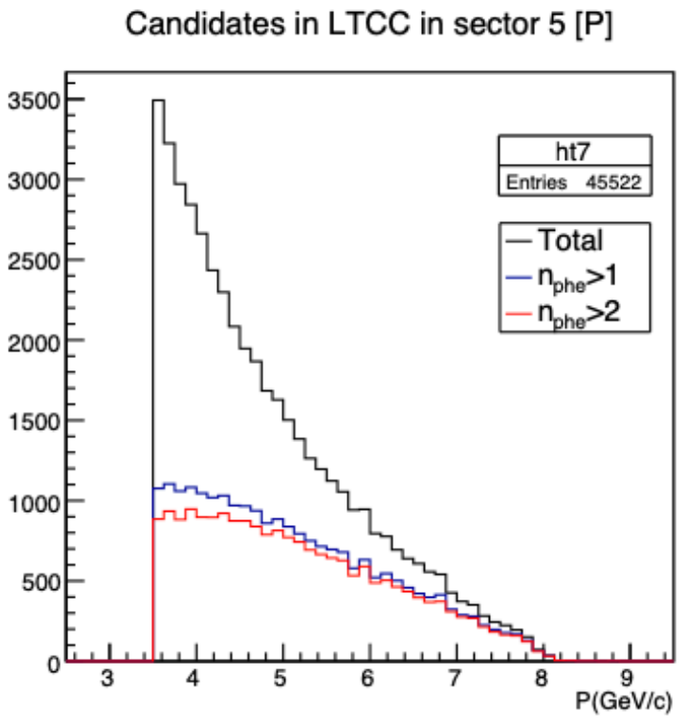


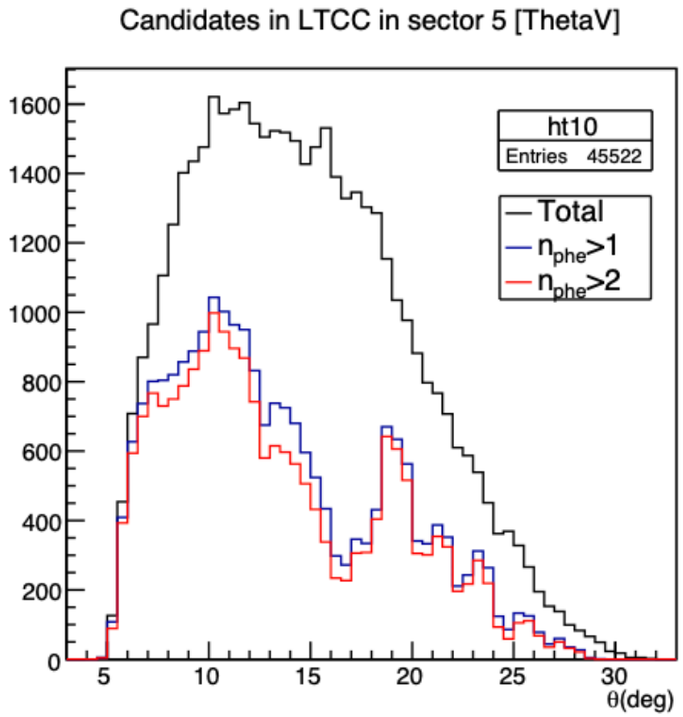


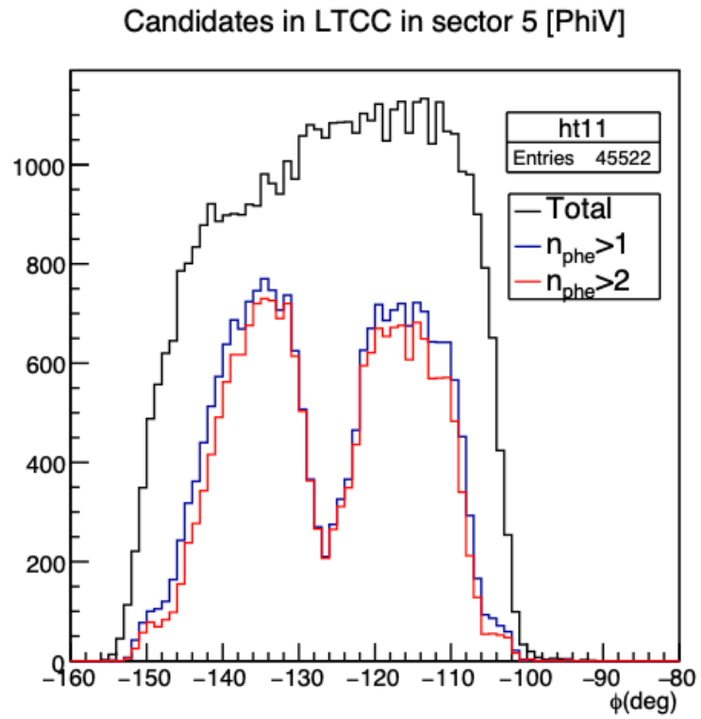
- Very narrow box in max acceptance region
- Gas not completely pure
- Integrated over phi/theta

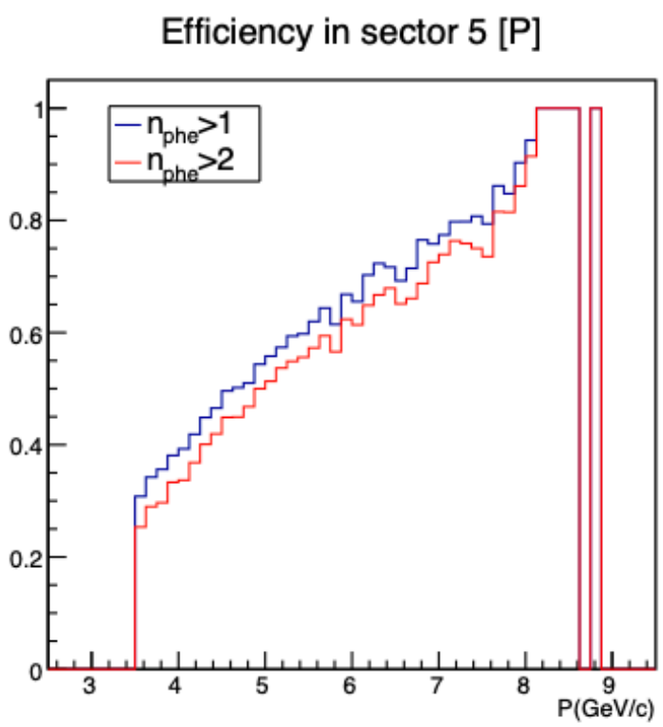
LTCC Pion Efficiency PART 2

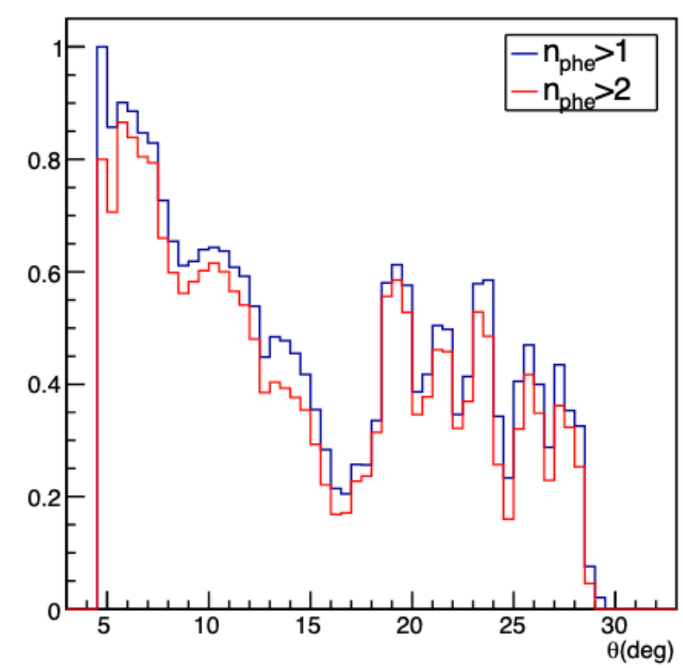
Extended analysis, See LTCC pion efficiency analysis, CLAS12 Note 2021-006

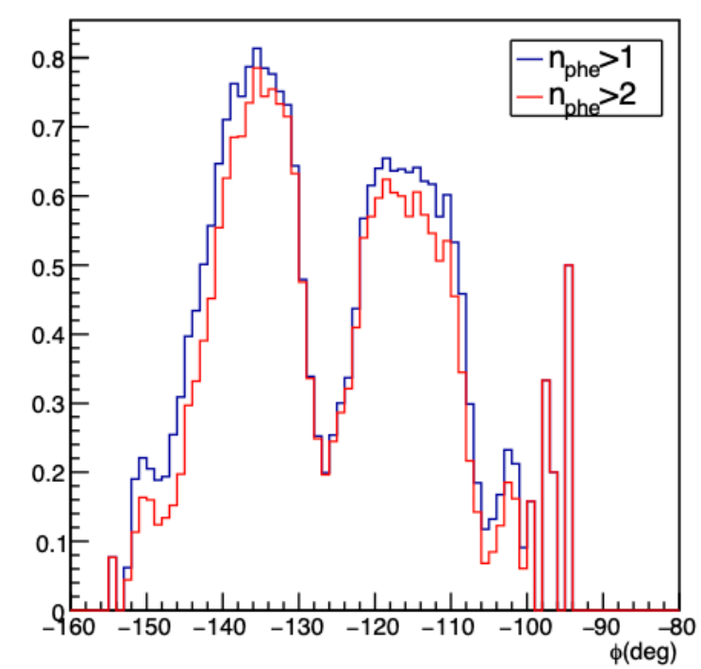








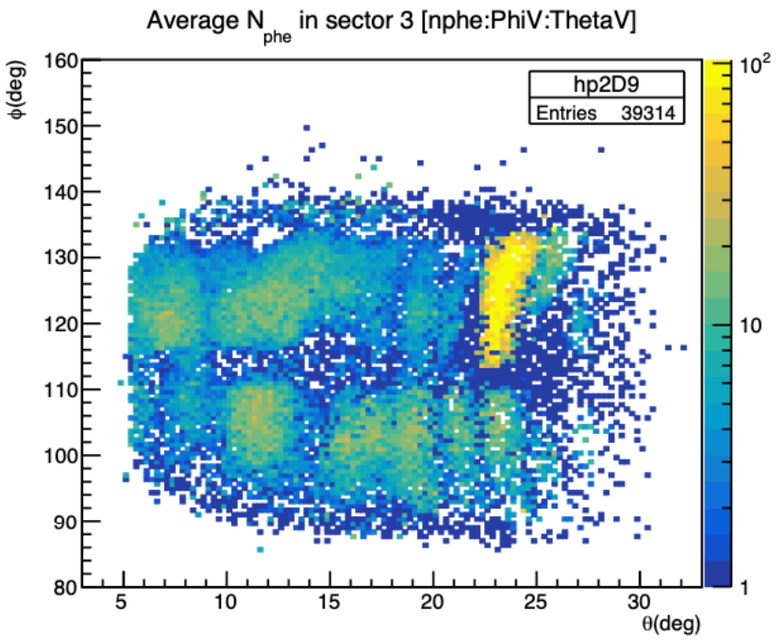


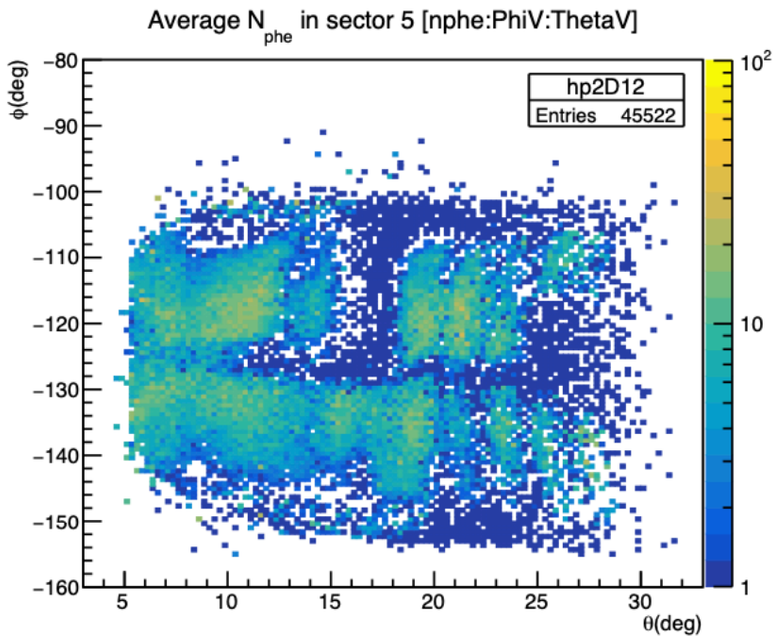


S3, 5 (not purified) - all CLAS12 Acceptance

LTCC Pion Efficiency PART 2

Extended analysis, See LTCC pion efficiency analysis, CLAS12 Note 2021-006

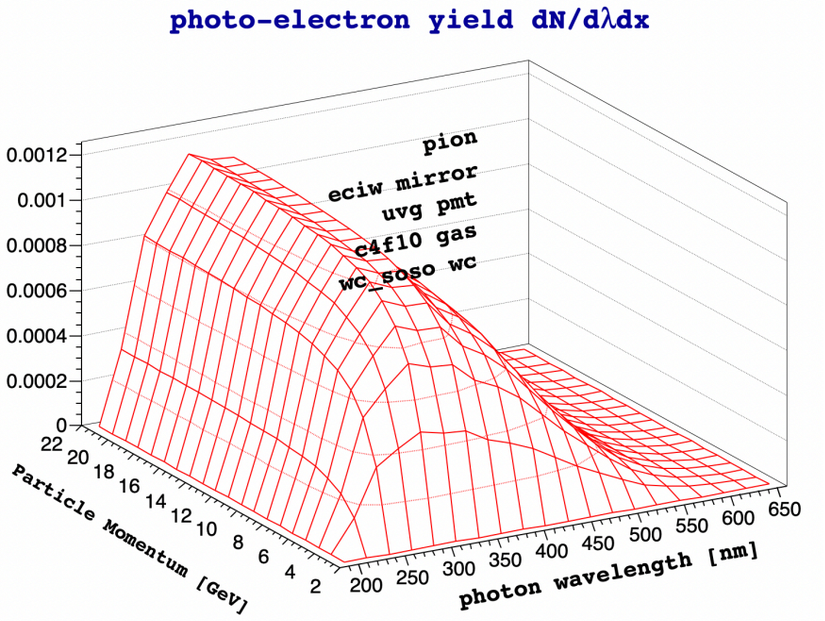


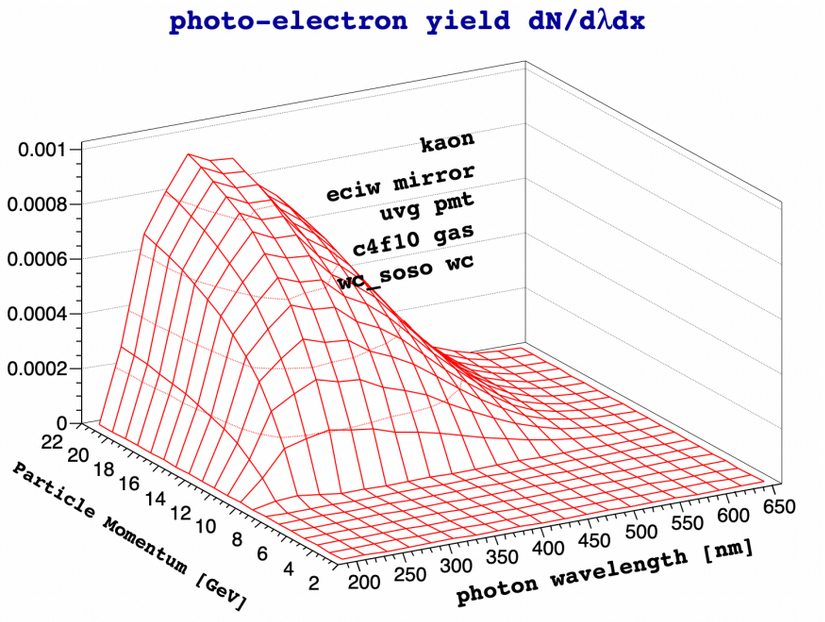


Conclusions:

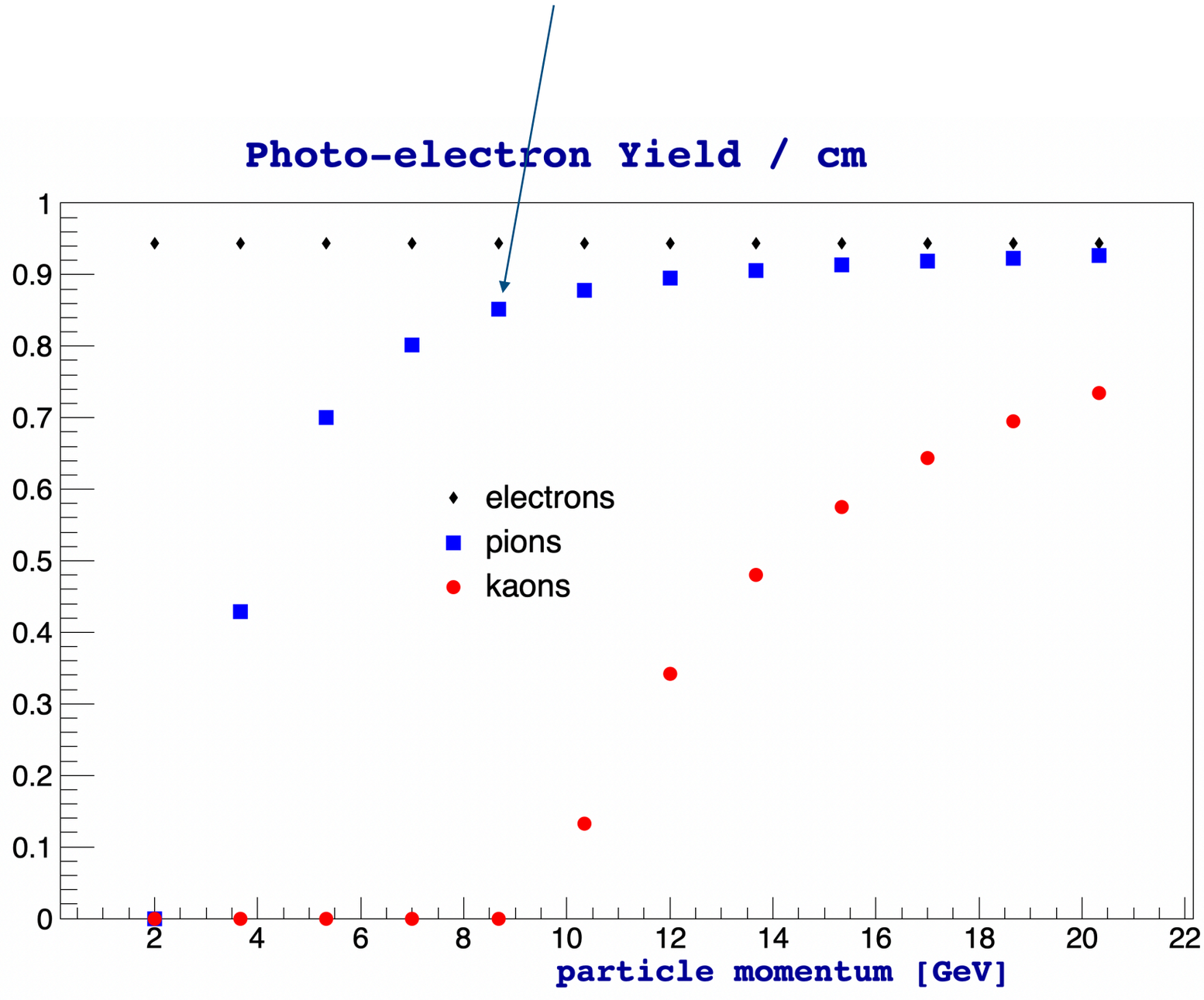
- LTCC needs dedicated fiducial cuts
- Within limited phase space efficiency is between 75-90%

LTCC Projections





empirical normalization based on previous results

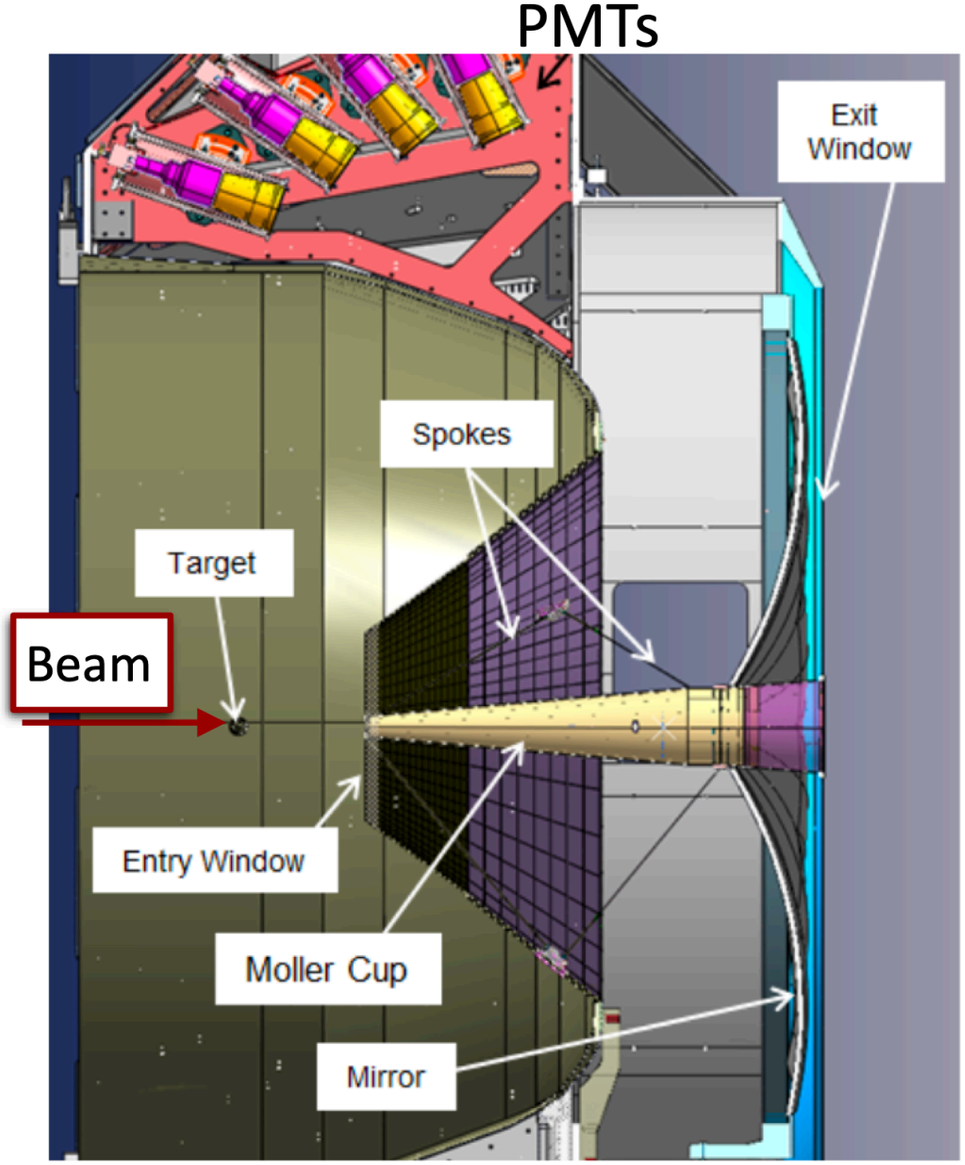


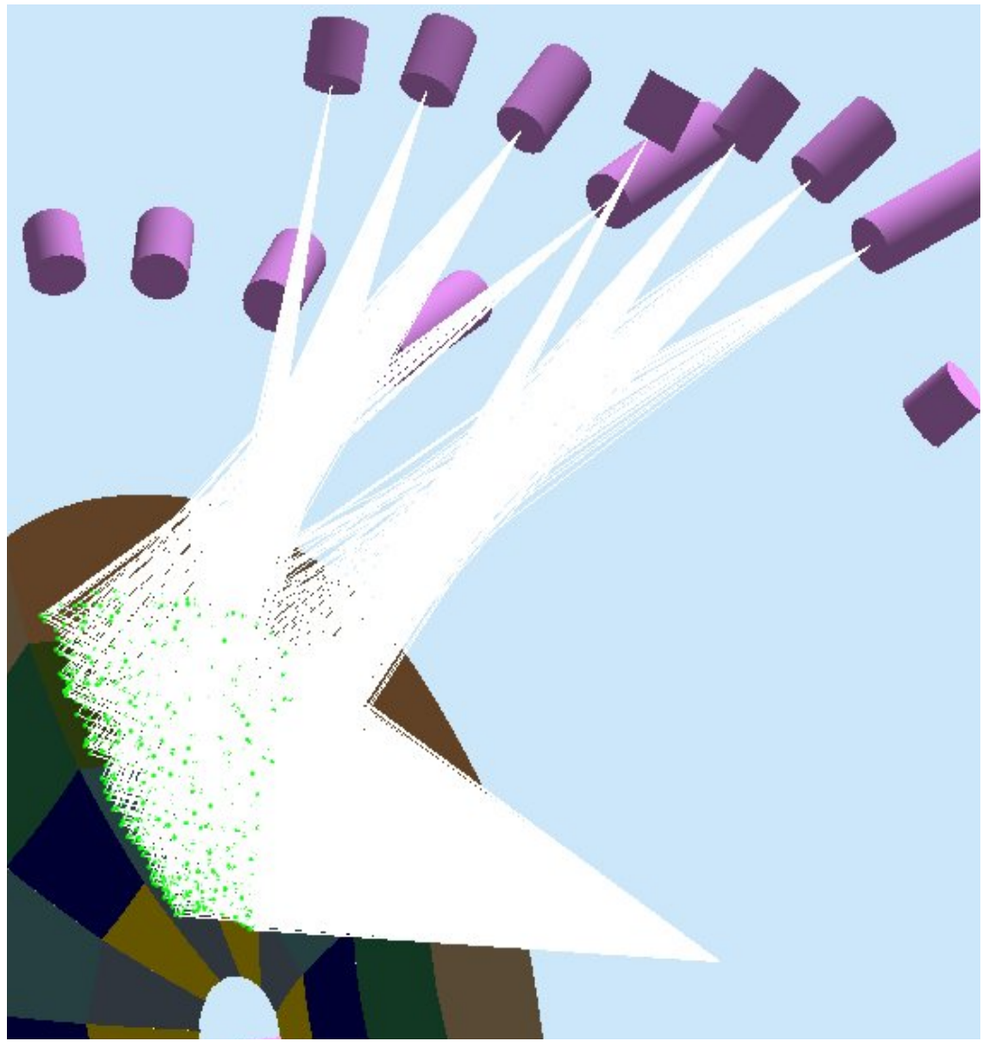
The High Threshold Cherenkov Detector

The HTCC system is part of the forward CLAS12 detector used for electron/pion discrimination.

The core component is a multifocal mirror consisting of 60 lightweight composite ellipsoidal mirrors.

Each sector of the CLAS12 is covered with 2 identical half-sector mirrors that are focusing Cerenkov light on eight 5-inch phototubes (total of 48 channels for entire detector).



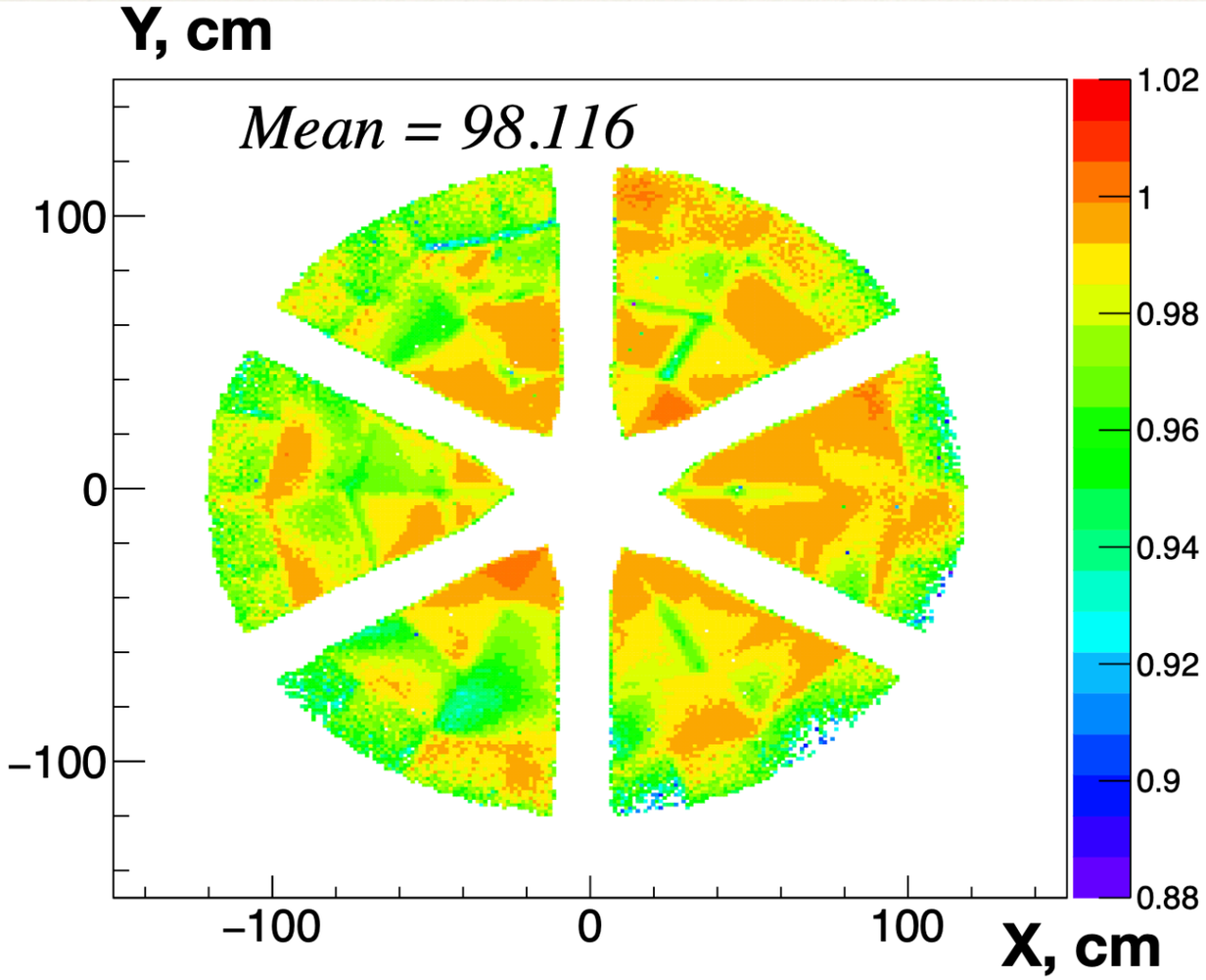


Working Gas	**CO_2@1atm, 25°C**
Angular Coverage	**ϑ= 5° – 35°; ϕ= 0° – 360°**
Threshold	**15 MeV/c** (electrons)
Threshold	**4.9 GeV/c** (charged pions)
Rejection of pions at 2 GeV/c	**~10^3** (99.9% electron detection efficiency)
Rejection of pions at 4 GeV/c	**~0.5x10^3** (99.9% electron detection efficiency)
Number of Channels	**(12x4) = 48**
Photomultiplier Tubes	**Electron Tubes 9823QKB** (5”, quartz window)
Number of Reflections	**1 (80%) + 2 (20%)**

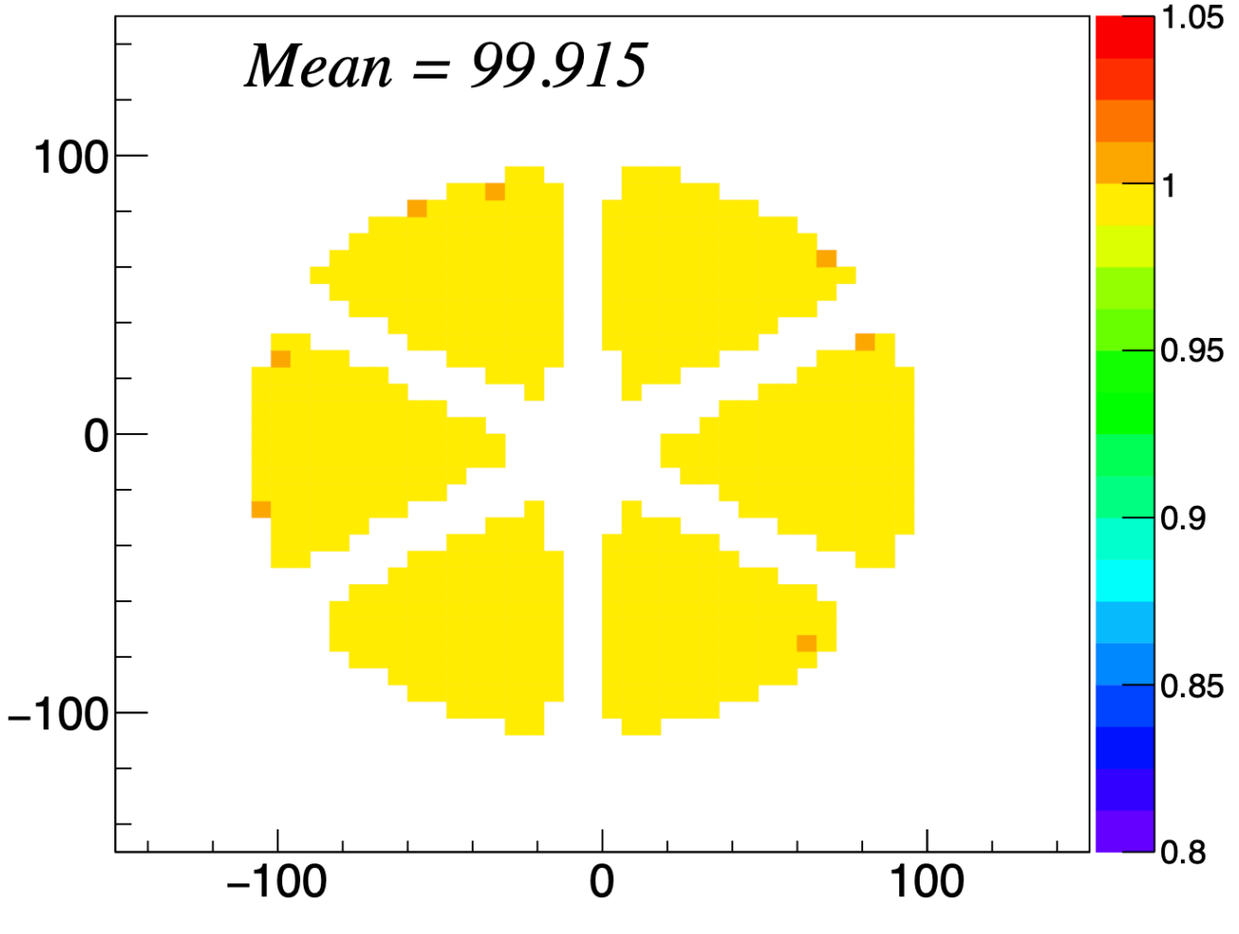
The High Threshold Cherenkov Detector

Electron efficiency

Data



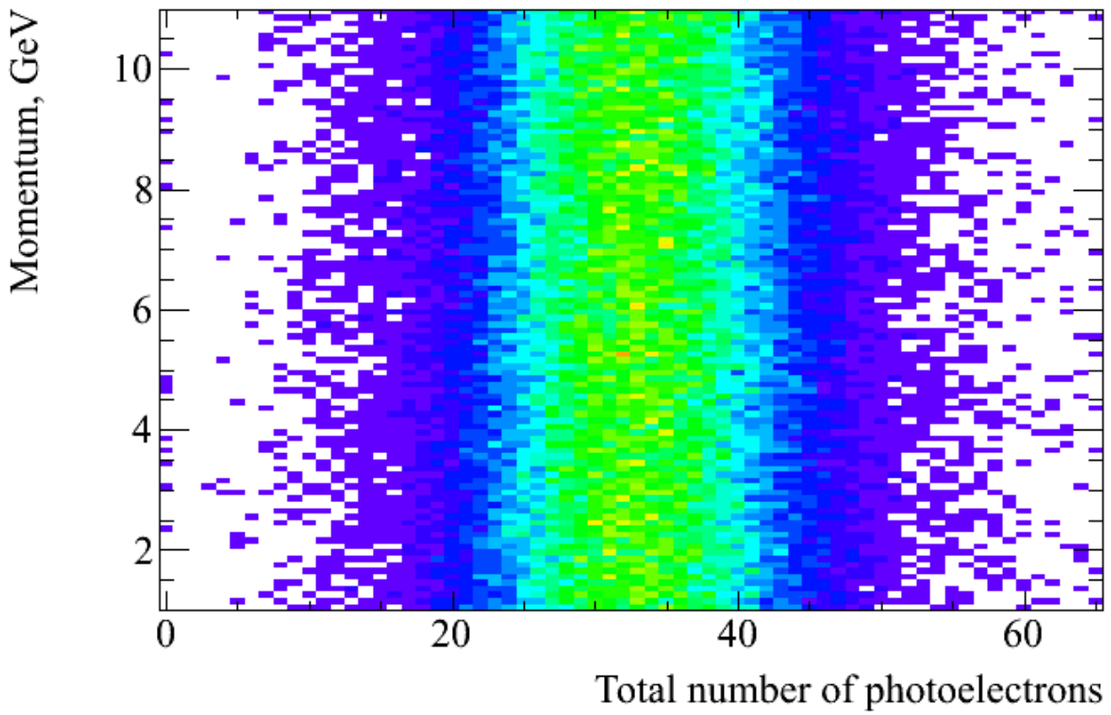
Simulation

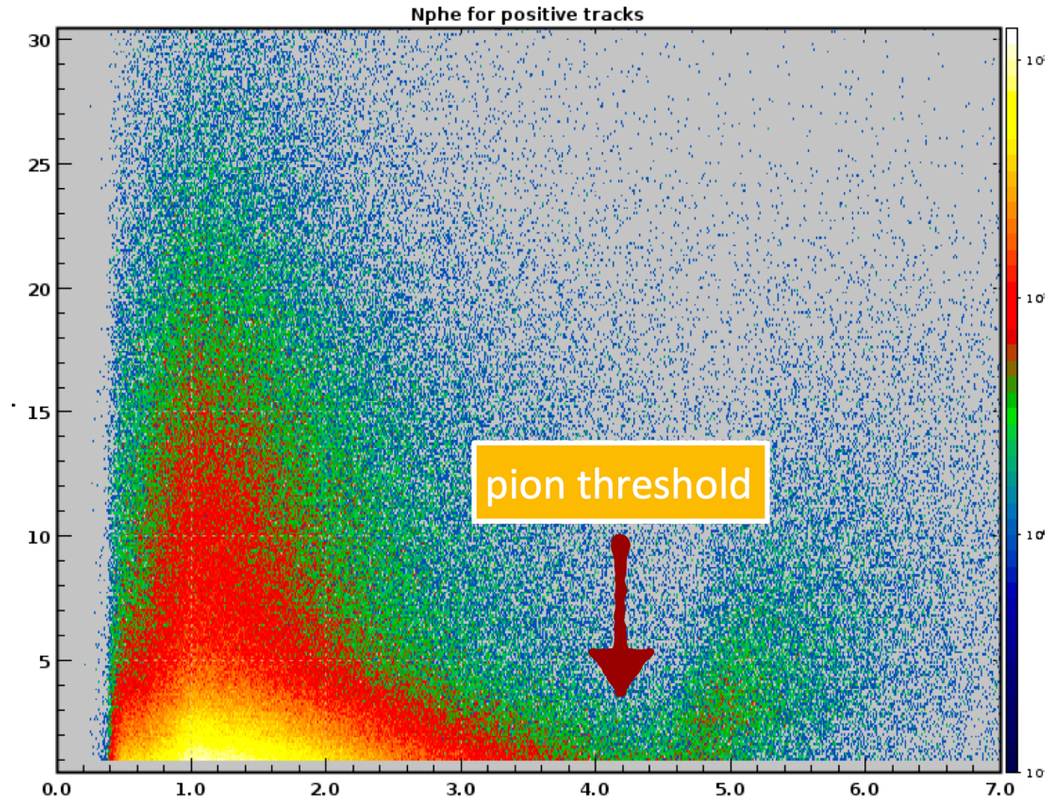


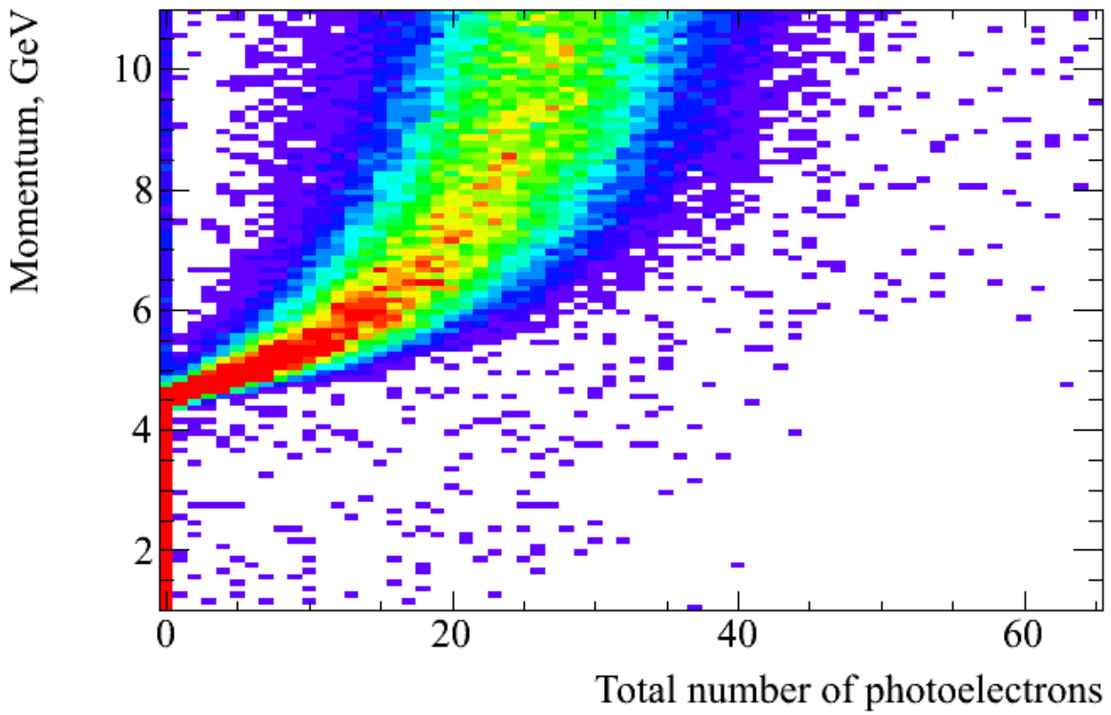
Nick Markov, CLAS12 detection efficiency, June 2021 Collaboration Meeting**

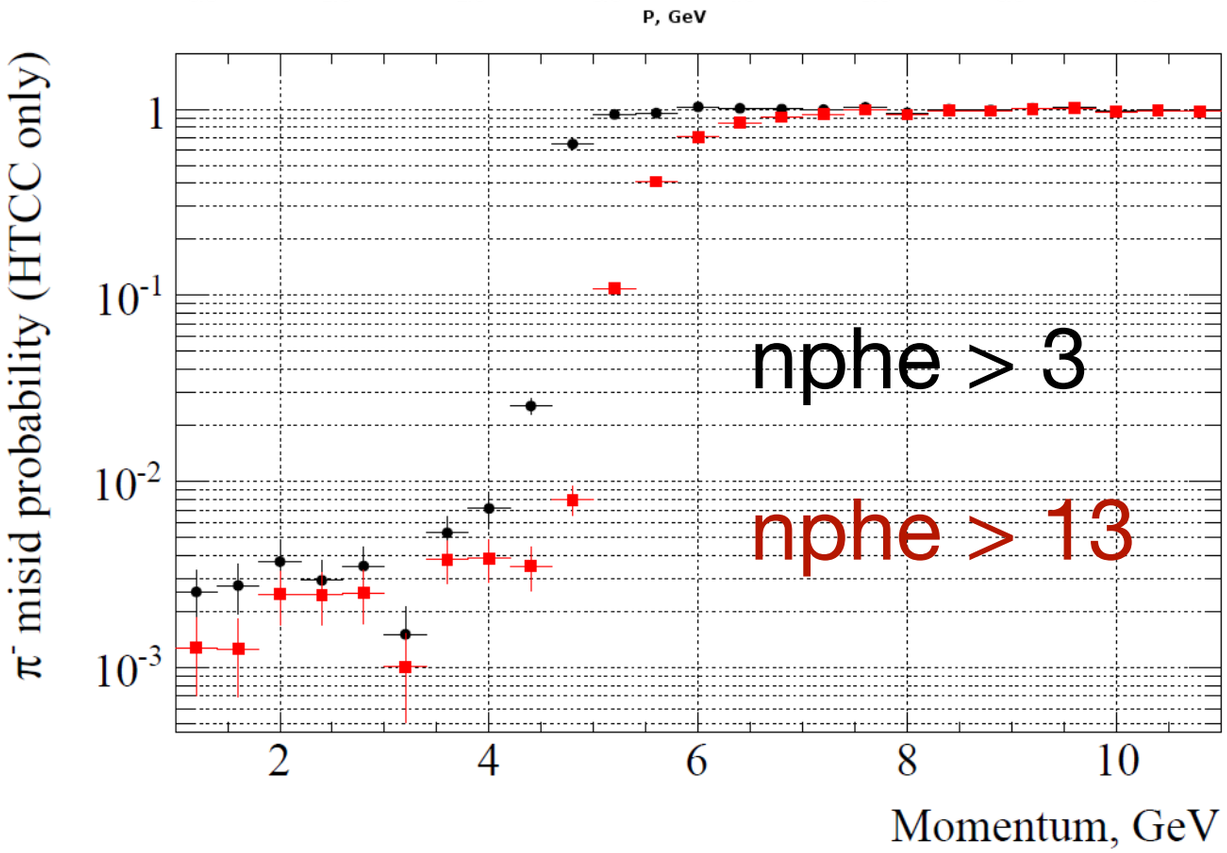
** recalculation may be needed

The High Threshold Cherenkov Detector









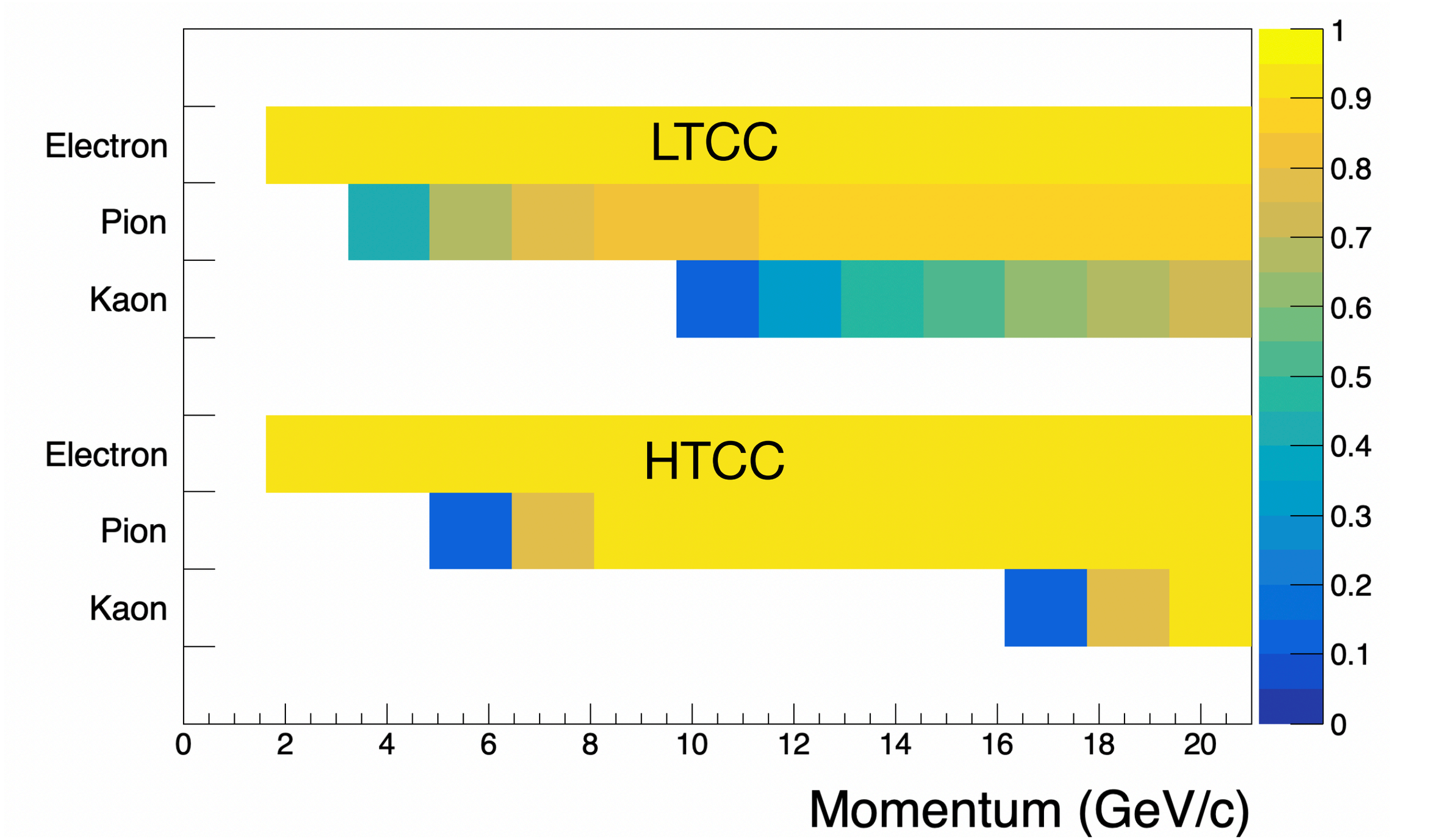
Putting it all together:

LTCC, HTCC efficiencies

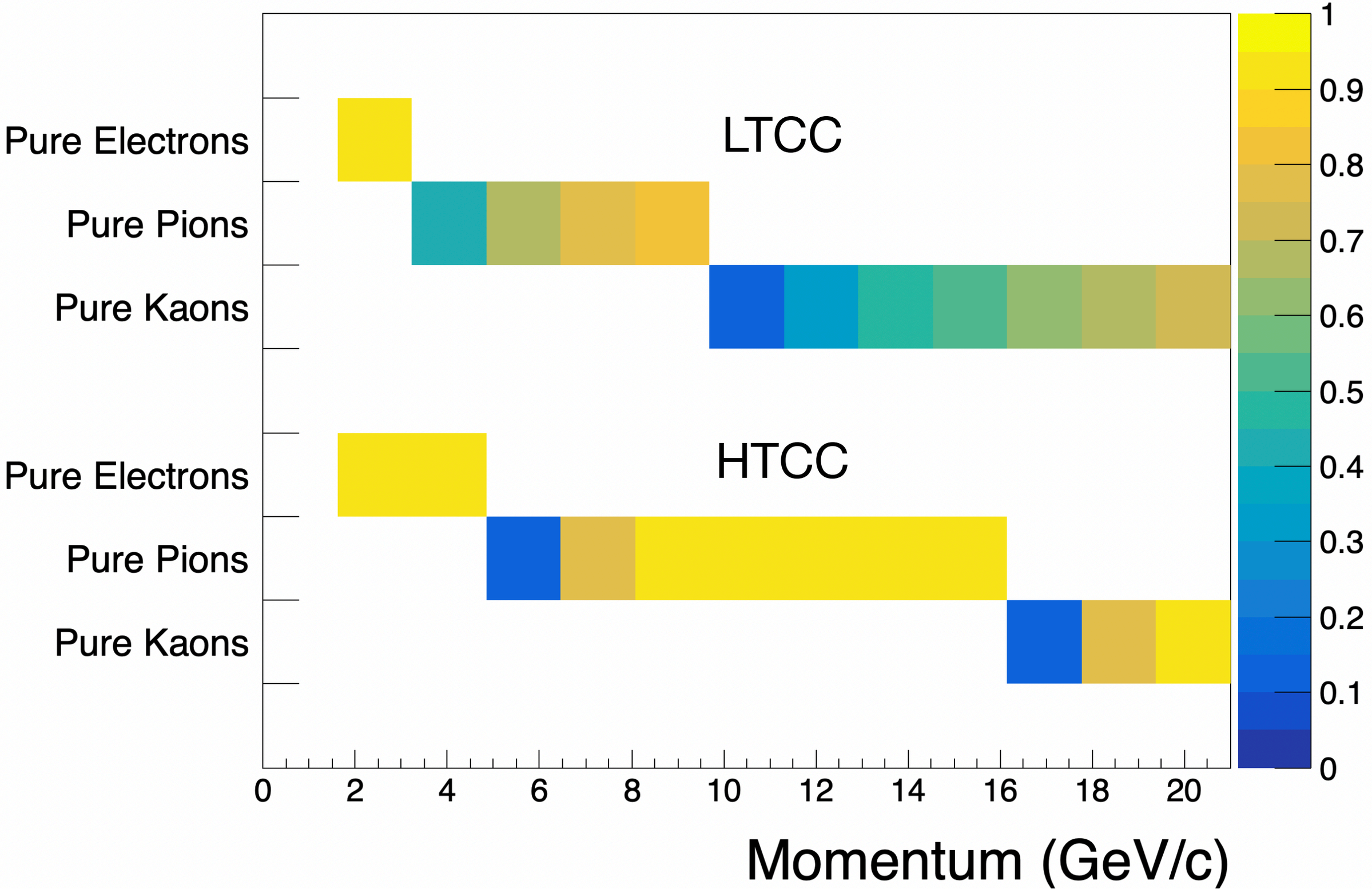
LTCC: based on Normalized Tamm’s projections, empirically normalized to data. Assumes fiducial cut.

HTCC: based on flat > 95% efficiency (measured, needs re-evaluating), with steep rise after threshold.

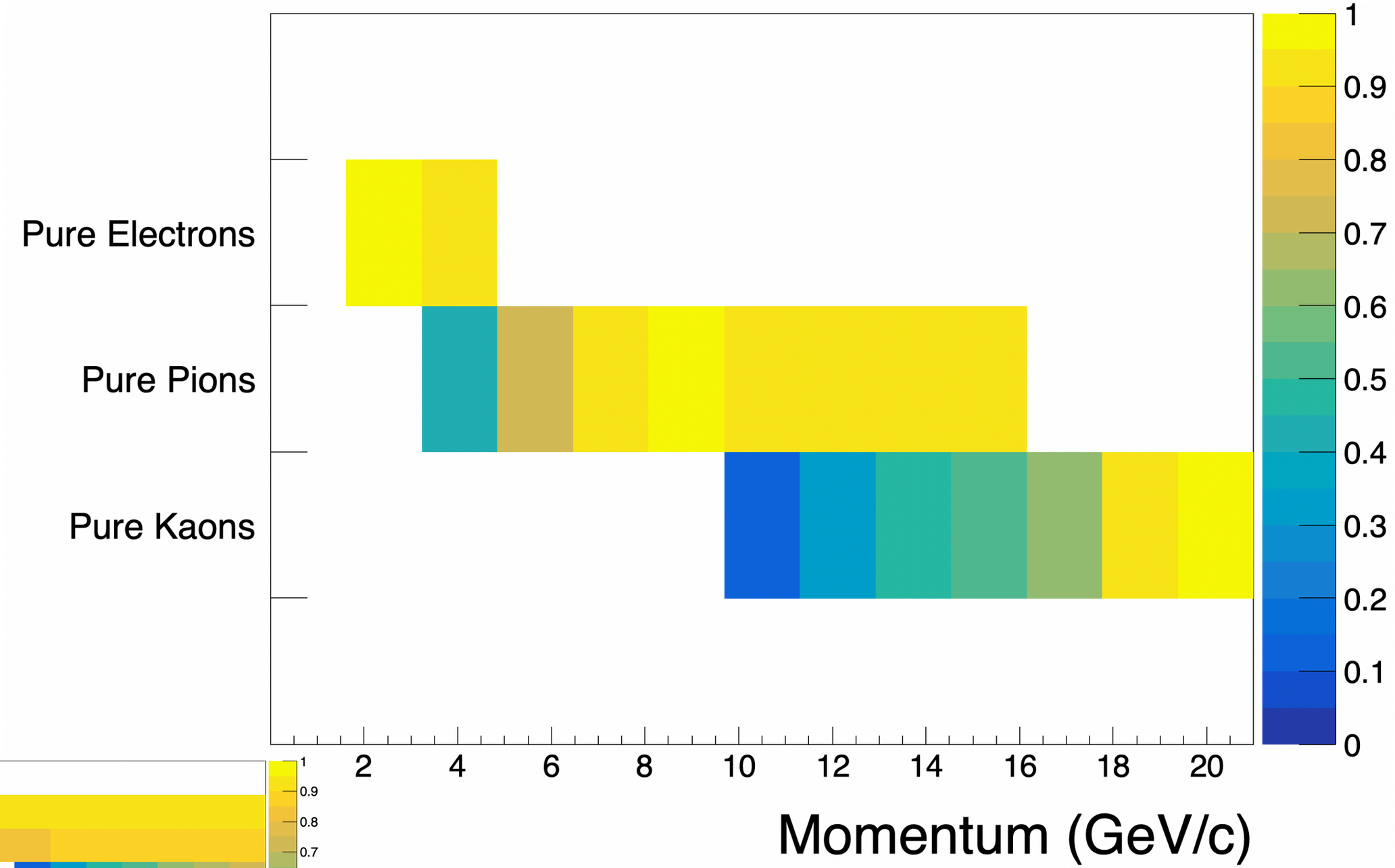
LTCC + HTCC Efficiency

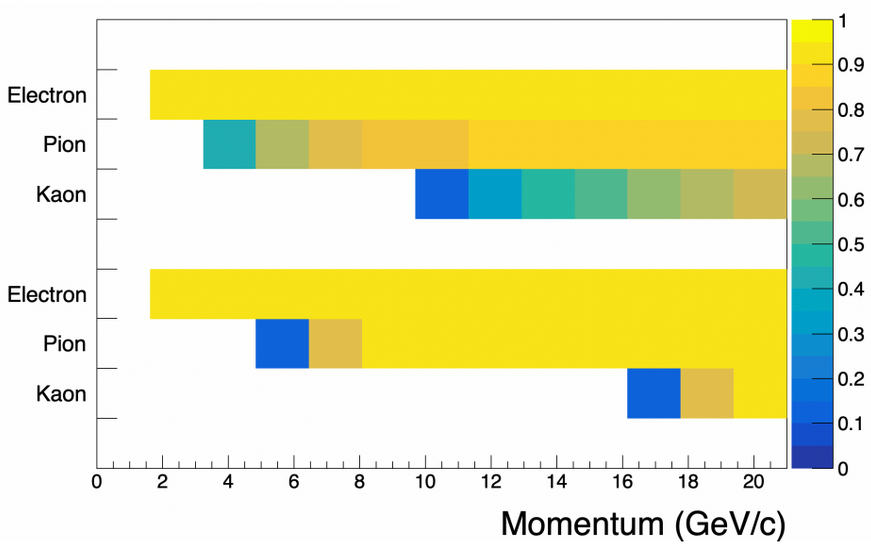


LTCC / HTCC Efficiency * Rejection



Summary: combined CC Efficiencies * Rejection





Plots based on empirical normalization to data

LTCC Projections