SHMS Particle Identification

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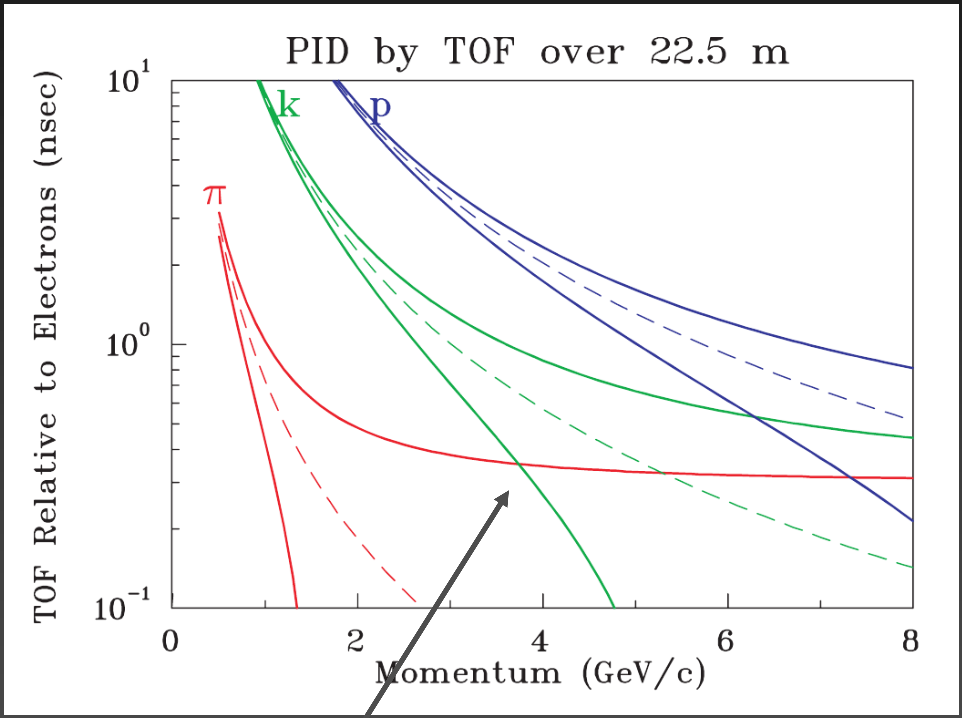
The limitation of TOF

- TOF over the short ~2.2m baseline inside the SHMS hut will be of little use for most of the momentum range anticipated for the SHMS.
- Even over a 22.5m distance from the target to the SHMS detector stack, TOF is of limited use.

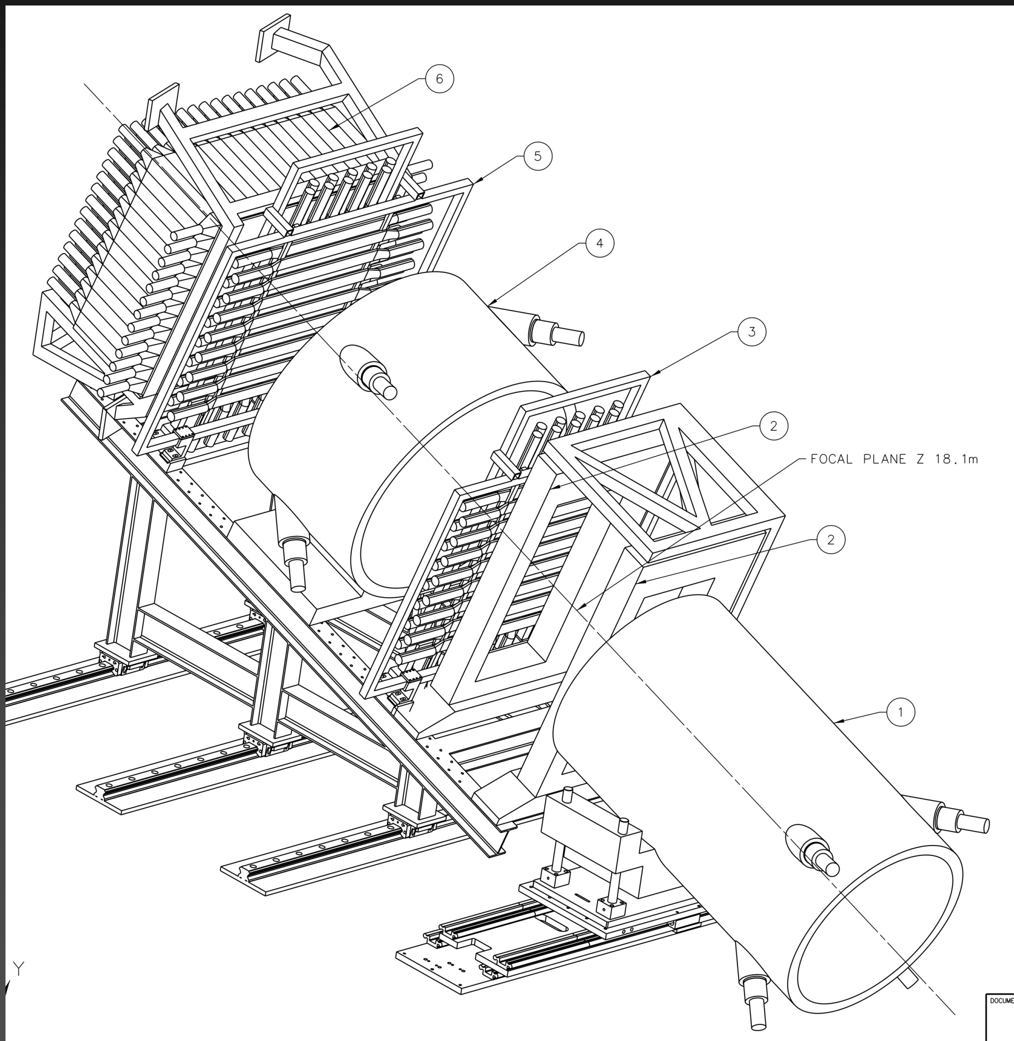


Effect of finite timing resolution (±1.5σ with σ=200ps). Separation <3σ to the right of where lines intersect.

Non-TOF techniques

- Efficient, high-confidence PID requires extensive use of non-TOF techniques such as Čerenkov detectors.
- Good PID can be obtained with a series of Čerenkov detectors:
  - e^{-}/π^{-} ⇒ Noble Gas Čerenkov (n-1 < 10^{-4})
  - π^{+}/K^{+} ⇒ Heavy Gas Čerenkov (n-1 ≤ 10^{-3})
  - K^{+}/p ⇒ Aerogel Čerenkov (n-1 ≤ 0.05)
- Lead Glass Calorimeter also plays a critical role in e^{-},e^{+} identification.

Hall-C SHMS Detector System



Noble Gas Čerenkov:
e/π separation at high momenta, where multiple-scattering is less of an issue.

Trigger Hodoscopes:
Time-of-Flight at low momenta; insensitive to photon or low-energy background.

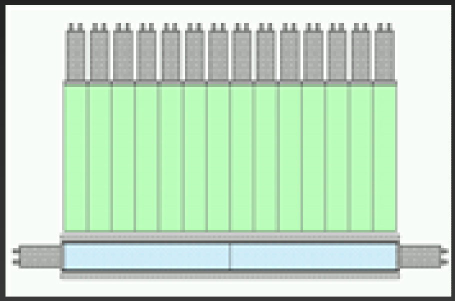
Heavy Gas Čerenkov:
π/K separation for P>3.4 GeV/c.

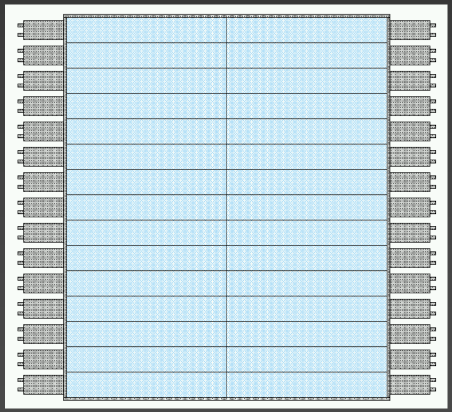
Aerogel Čerenkov(s):
Depending on the n used, K/p separation or π/K separation at low momenta.

Lead Glass Calorimeter:
e/π separation.

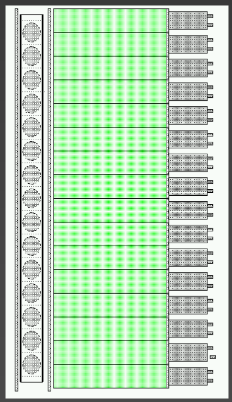
Calorimeter: e/ π separation

Plan view



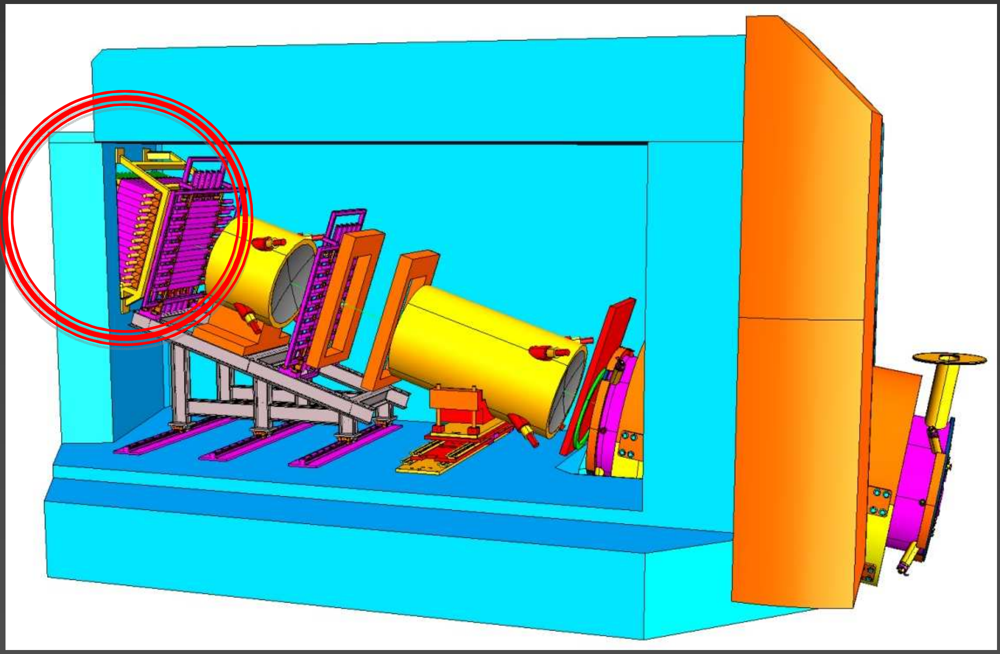


Front Elevation



Side Elevation

- •Lead-Glass Block / PMT / Base Assemblies from HERMES.
- •Expect >200:1, based on HMS Calorimeter performance.

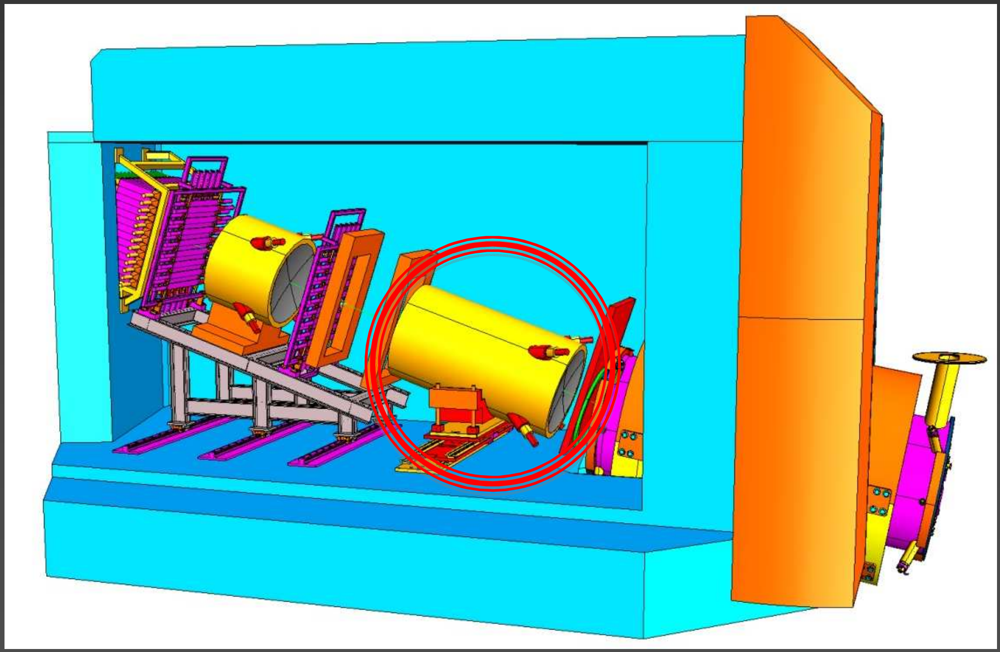


Noble Gas Cerenkov: e/π (or π /K) separation at high momenta

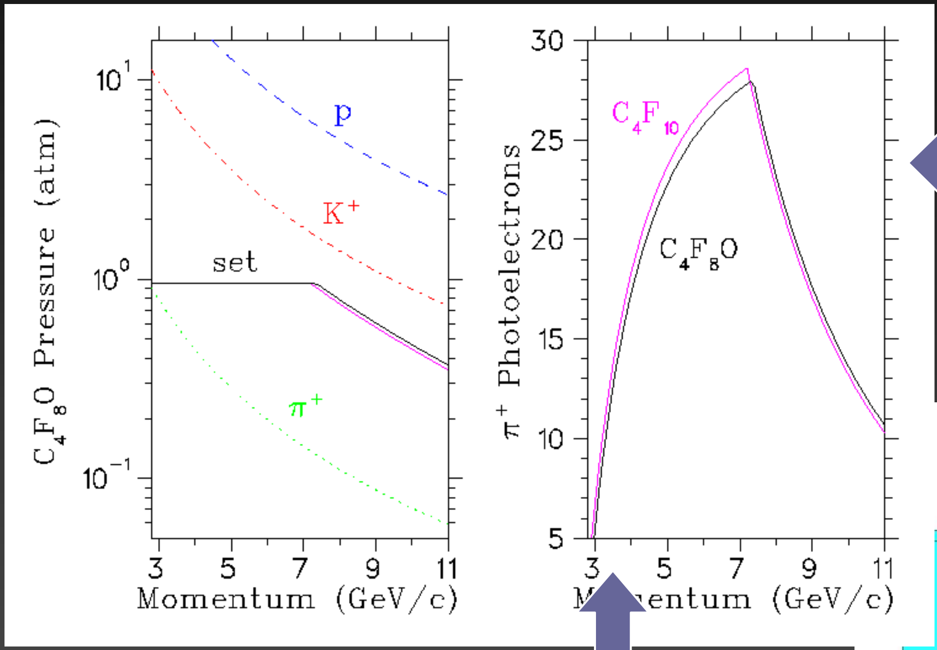
2.5 m long gas radiator at atmospheric pressure.

- **Argon: π threshold ~ 6 GeV/c.**
- **Adding Neon: π threshold may be varied up to 12 GeV/c.**
- **Para-Terphynyl PMT window over-coating .**
- **Performance 20 photoelectrons (worst case: pure Neon).**

At low momenta: remove mirrors, insert coupling so that the tank becomes part of the vacuum system – reduces MCS.

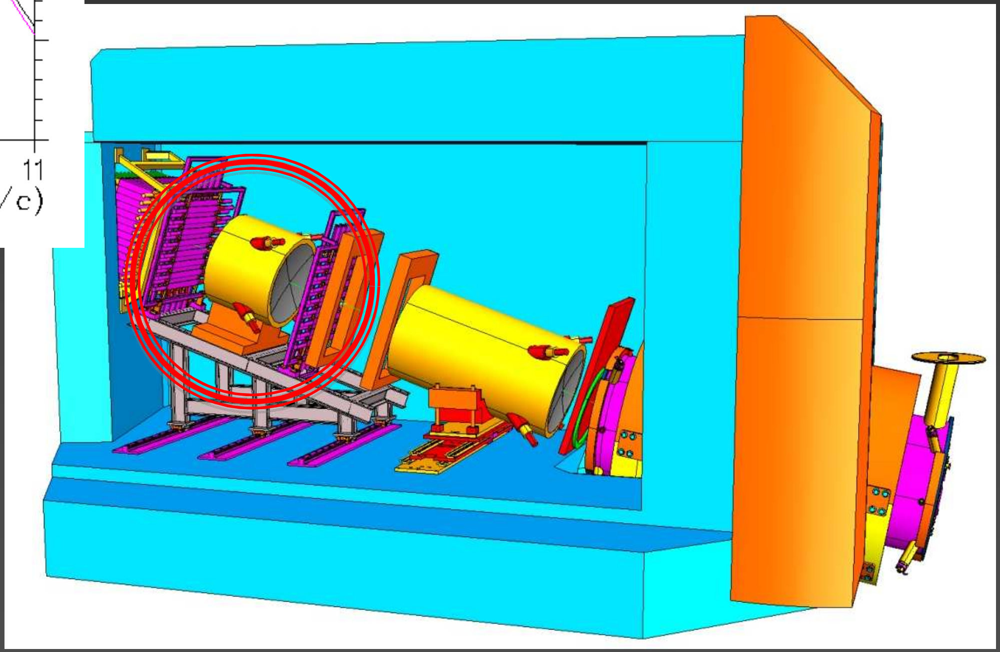


Heavy Gas Cerenkov: π /K separation for momenta > 3.4 GeV/c



To maintain good π/K separation, it is necessary to reduce the gas pressure above 7 GeV/c.

Lowest $\pi^{\pm}$ identification efficiency occurs at 3.4 GeV/c (~10 p.e.).



Electron-Pion Discrimination

- The most stringent requirements arise when the SHMS is set to negative polarity.
- Both e^-/π^- and π^-/e^- separations are required:

Expt	P_{SHMS} (GeV/c)	Worst Fore/Bkd Rate Ratio	Noble Gas Č	Pb-G Cal	Total e:π Reject
F_π (E12-06-101)	5.1,6.5	1 (π-):1000(e-)	50:1	200:1	10000:1
SIDIS p_T (PR12-09-017)	1.5-5.0	1 (π-):10 (e-)	Not used for lowest P.	250:1	250:1
x>1 (E12-06-105)	4.8-10.6	1(e-):50(π-)	50:1	100:1	5000:1
DIS-parity (E12-07-102)	4.9-6.7	3(e-):1(π-)	10:1	100:1	1000:1

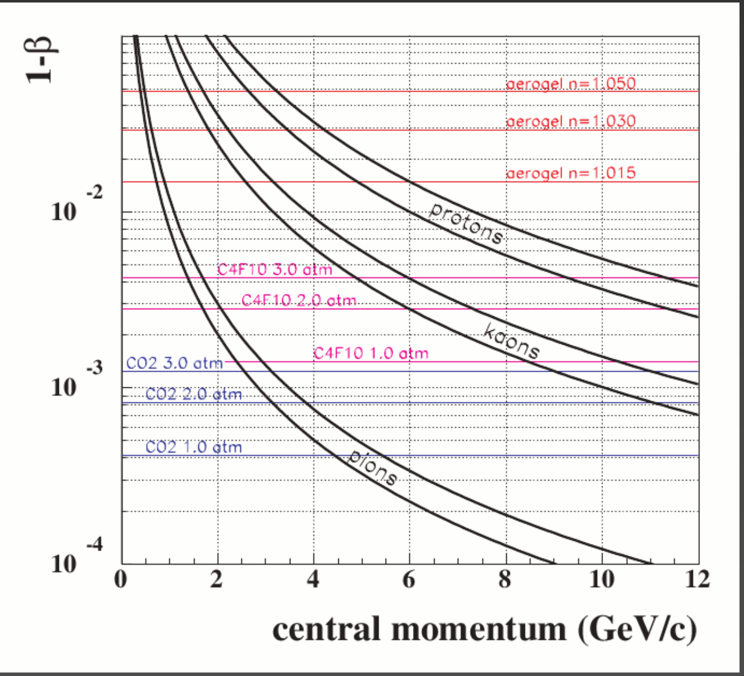
Pion-Kaon Discrimination

- Equally applicable for positive or negative SHMS polarity.
- Supplemental Aerogel or TOF must supplement Heavy Gas Čerenkov at low momentum.

Expt	**P_{SHMS} (GeV/c)**	**Worst Fore/Bkd Rate Ratio**	**Heavy Gas Č P>3.4 GeV/c**	**Aerogel Č P<3.4 GeV/c (n=1.010)**
F_π (E12-06-101)	2.2-8.1	2(π):3(K+p)	1000:1	300:1
CT (E12-06-107)	5.1-9.6	1(π):1(K+p)	1000:1	NA
π Factorization (E12-07-102)	2.4-8.5	2(π):3(K+p)	1000:1	300:1
K Factorization (PR-09-011)	2.6-7.1	1(K):30(π)	1000:1	

Aerogel Čerenkov

- Reliable *K/p* separation over a wide momentum range is a challenge.
- Although only one aerogel Čerenkov is required at any particular momentum, two detectors would allow flexibility over a greater range.
- *K/p* separation gets progressively more difficult as (n-1) is reduced at higher momenta.



p_{SHMS} (GeV/c)	n (10cm)	K p.e.	p p.e.
2.5-3.0	1.030	13-46	<0.5
3.1-3.7	1.020	12-31	<0.5
3.8-4.3	1.015	13-24	<0.5
4.4-5.1	1.010	5.5-	<0.5
5.2-6.2	1.0075	5.5-13	<1
6.4-7.3	1.0055	6-9	<1

Kaon-Proton Discrimination

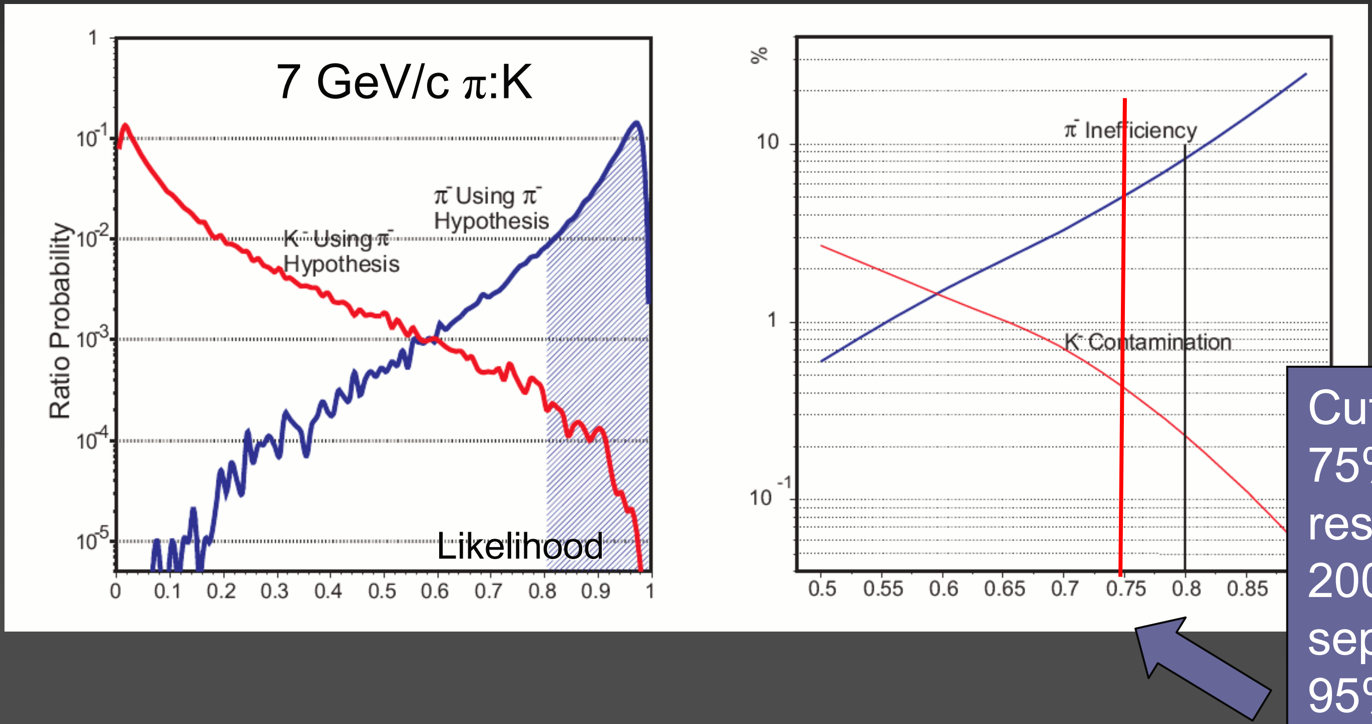
- Only relevant for SHMS positive polarity.
- Several experiments have similar stringent requirements:

Expt	Momenta (GeV/c)	Worst Fore/Bkd Rate Ratio	Aerogel Č (worst case)
CT (E12-06-107)	5.1-9.6	1(K):10(p)	100:1
SIDIS p_T (PR12-09-017)	1.5-5.0		200:1
K Factorization (PR12-09-011)	2.6-7.1	1(K):3(p)	100:1

← Additional PID helpful at higher P

Supplementary K/π 7 GeV/c

- pCDR includes a supplemental K/π identification technique utilizing the dE/dx distribution of particles traversing the wire chambers.
- Requires analog readout for groups of wires.



Cut placed at 75% likelihood results in 200:1 π:K sep. separation with 95% efficiency.

Summary

- Particle identification requirements of approved and proposed SHMS experiments are largely met by the planned detector package.
- At least one Aerogel Čerenkov is required for $\pi^{\pm}$ identification at P<3.4 GeV/c and for $K^{\pm}$ identification up to at least 5 GeV/c.
- The need to supplement K identification at higher momenta seems clear.
  - Addition of pulse-height info to the wire chamber readout is a particularly attractive option.
  - Requires new readout electronics, but cost is offset by the need for fewer sets of aerogel (different n) and less overhead when changing momentum.
  - Likely cost effective over the longer term.