On the Feasibility of a Cherenkov-Active LH2 Target

Paul Eugenio
Florida State University

KLF Collaboration Meeting
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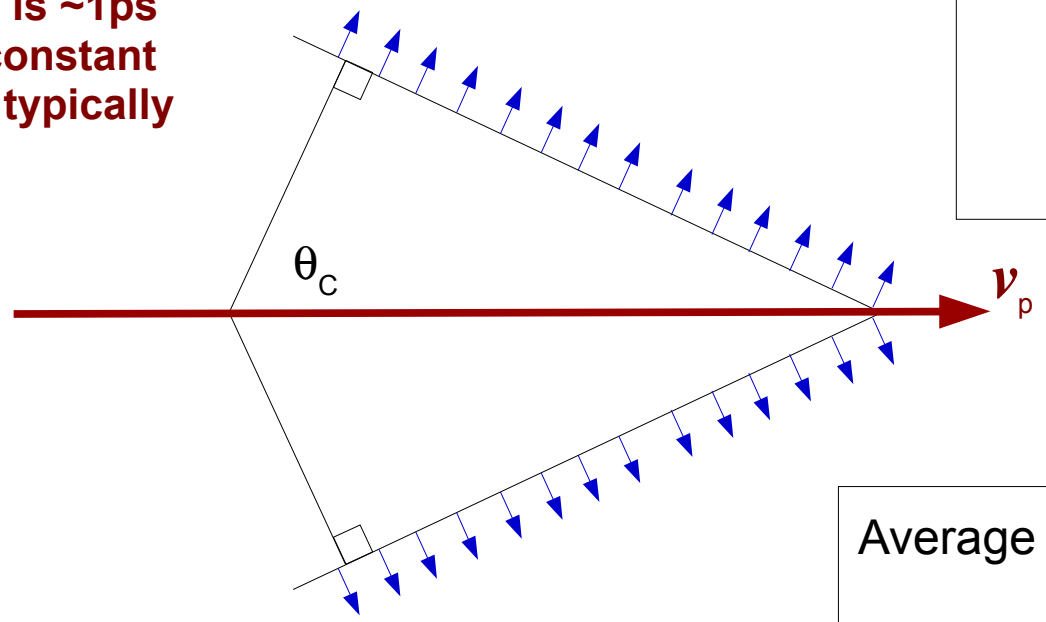
Concept

A liquid H_2 target with a good collection of the Cherenkov light emitted by the beam/target reaction products can potentially allow for very fast Cherenkov based time-of-flight (TOF) measurement for the K_L beam momentum determination

The flash duration of the Cherenkov radiation is ~1ps whereas the decay constant of fast scintillator is typically ~2 ns

Cherenkov light production

$$\frac{v_p}{v'} = \beta n > 1$$



$$\cos(\theta_C) = \frac{1}{\beta n}$$

$$\frac{dN_{p.e.}}{dx} \approx (20\text{-}80)/\text{cm}$$

Average Refractive Index of LH2

$$n \simeq 1.11$$

$$(\text{threshold velocity } \beta \simeq 0.90)$$

"The expected time measurement precision for the Cherenkov time-of-flight detector is about or less than 10 picosecond for Cherenkov radiators with lengths less than 50 cm."

S. Majewski JLab(12GeV Upgrade Proposal for Cherenkov Time of Flight Technique with Picosecond Resolution)

Interaction Point Localization by Cherenkov Effect

E. Bertolucci et al, NIM 69 (1969) 21

When the incoming π^- makes an interaction with a completely neutral final state, the amount of light emitted depends on the length of the pion path from the entrance window to the interaction point.

A 3 cm FWHM resolution was achieved in a 20 cm long target

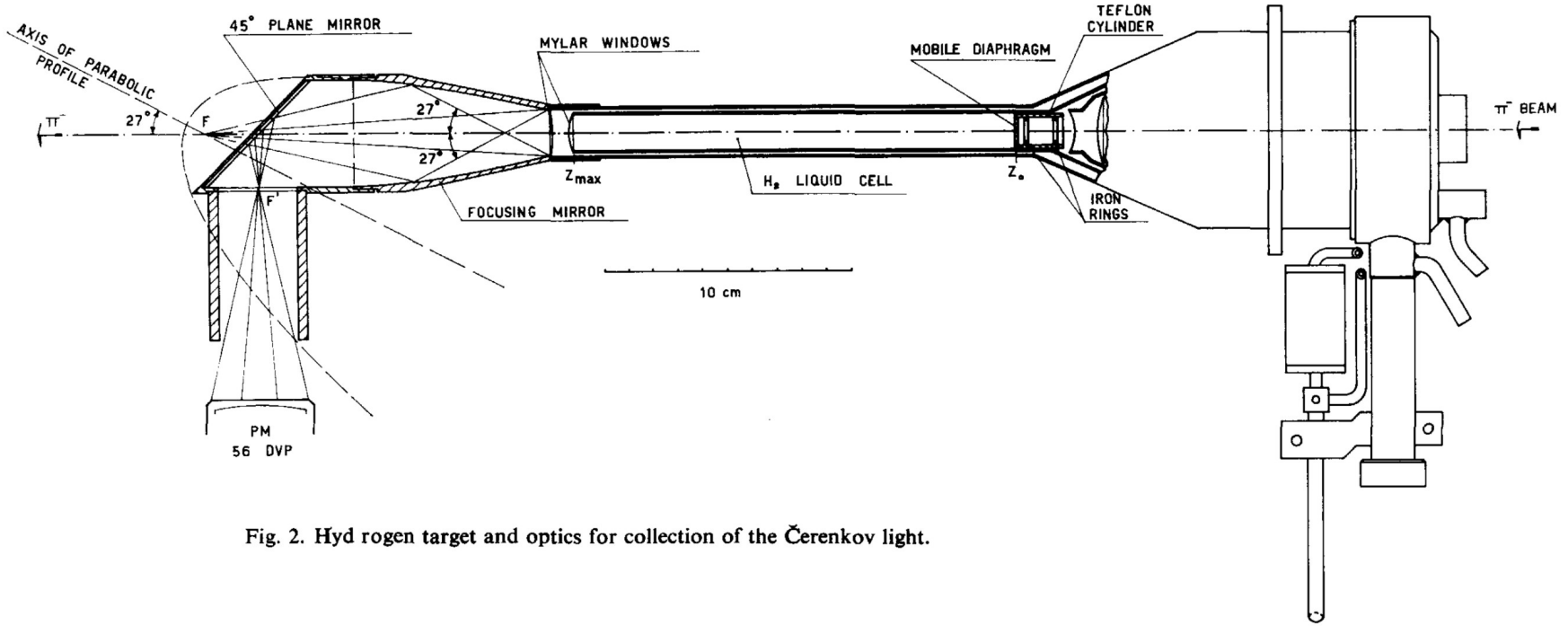


Fig. 2. Hyd rogen target and optics for collection of the Čerenkov light.

Design Options

Cherenkov-active LH2 target design
CERN PS185

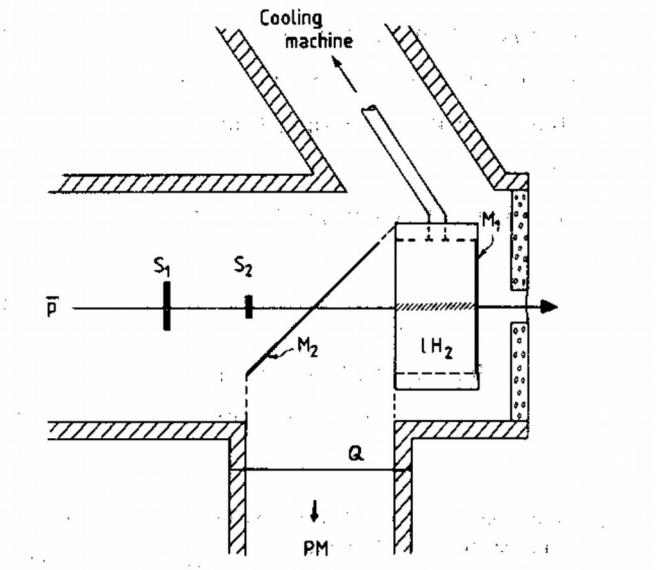
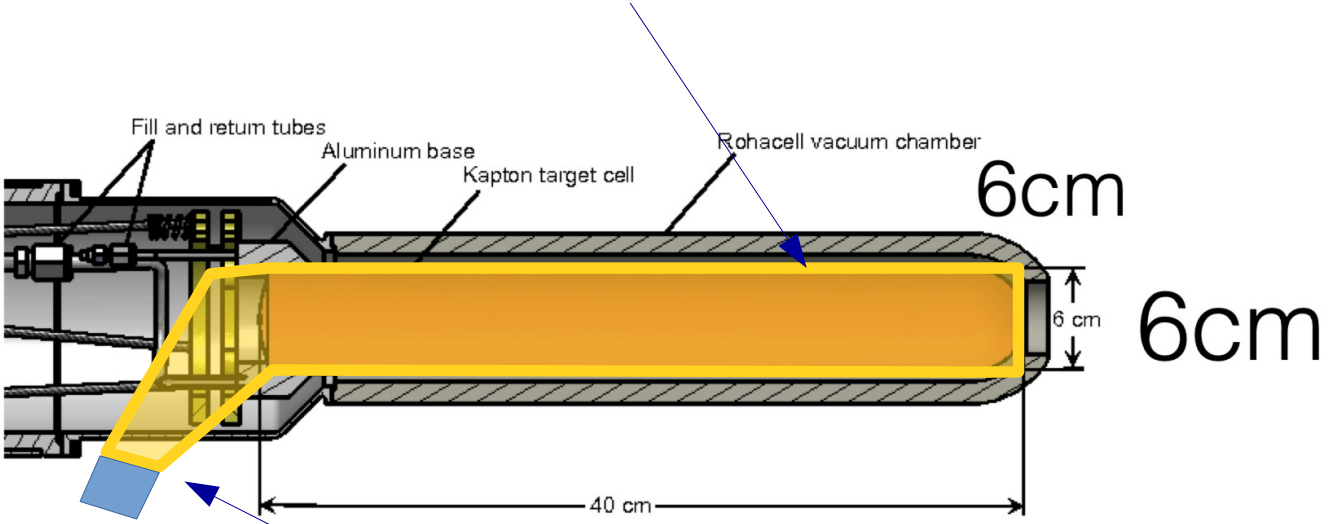
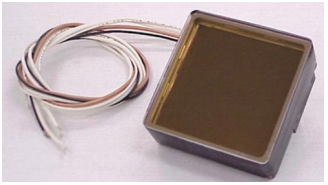


Fig. 4 Arrangement in the target region. The LEAR $\bar{p}$ beam comes from the left, passes through beam-defining scintillation counters (S_1, S_2), and enters the LH_2 target cell. Cherenkov light is collected by Al-coated Mylar foils (M_1, M_2) and is viewed by the photomultiplier through a quartz window (Q).

KLF LH2 target design

Cherenkov light is collected by ESR foil





An ESR light guide directs light to a MCP-PMT/LAPPD photodetector

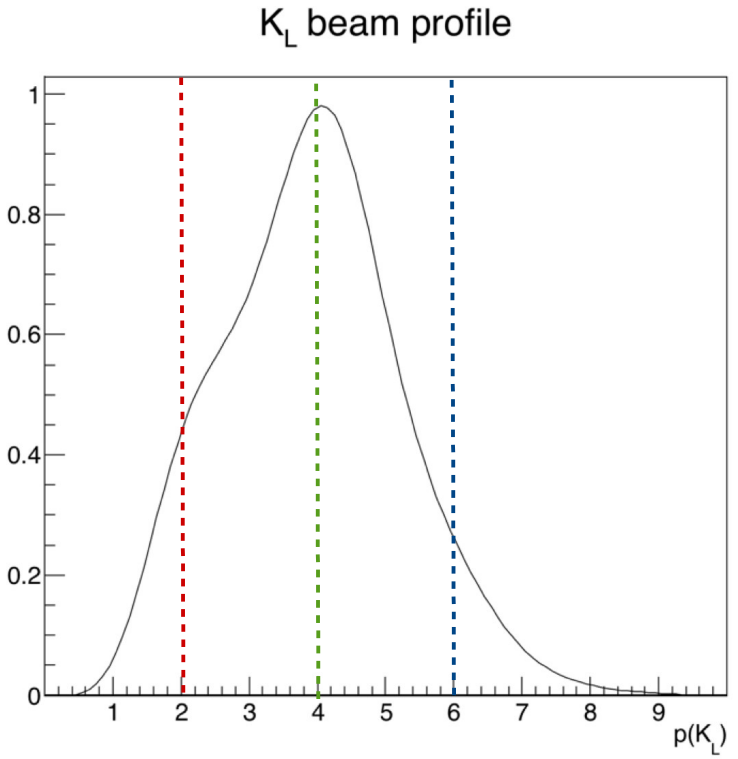
Simulations of Hyperion Channels

Generated s-channel phase space

1. $K_L\, p \rightarrow K_s\, p$
2. $K_L\, p \rightarrow K^+\, n$
3. $K_L\, n \rightarrow K^+\, \Xi^-$
4. $K_L\, p \rightarrow \pi^+\, \Lambda$

Cherenkov light production

$$\frac{v_p}{v'} = \beta n > 1$$



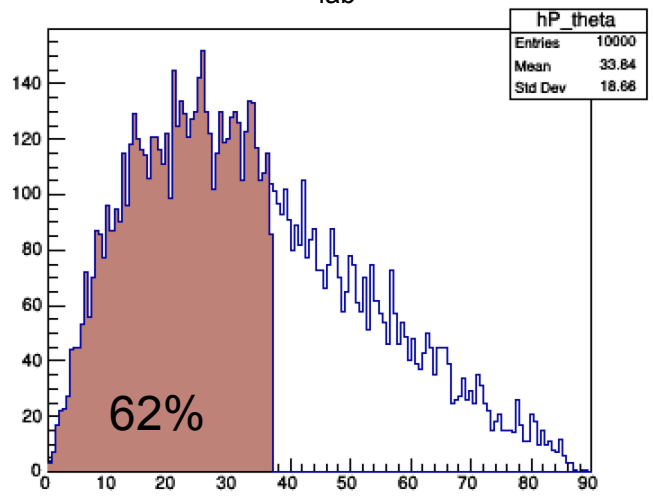
Generated data set for
2 GeV, 4 GeV, & 6 GeV

$K_L\ p \rightarrow p\ K_s$ @ 4 GeV

$\beta n > 1$

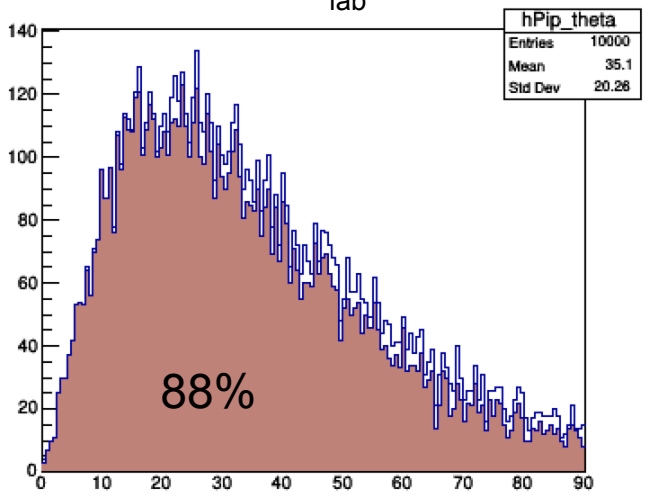
Proton

θ_{lab}



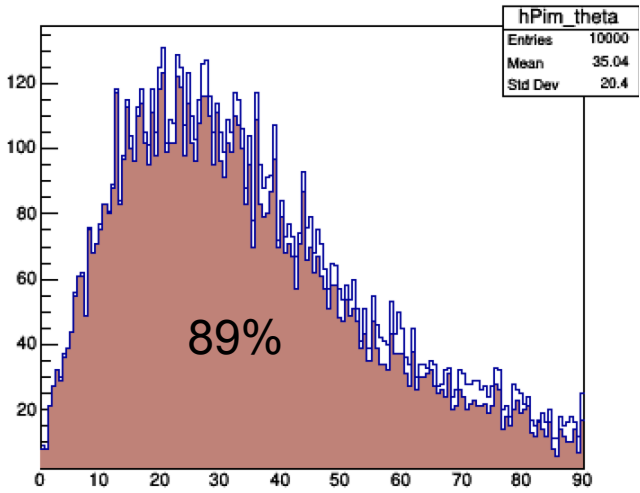
PiPlus

θ_{lab}

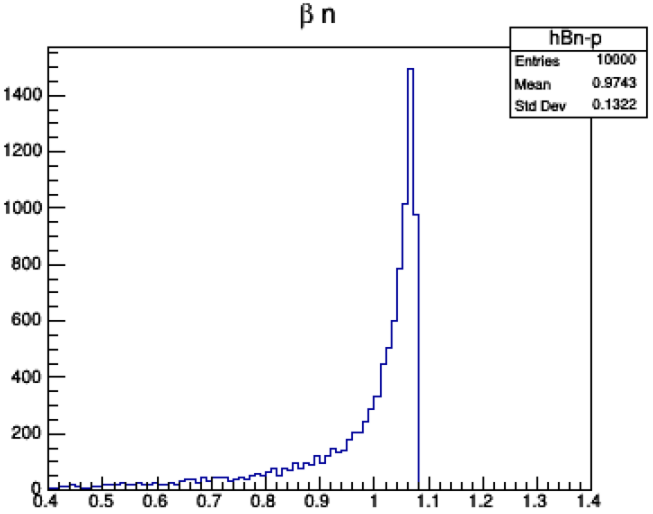


PiMinus

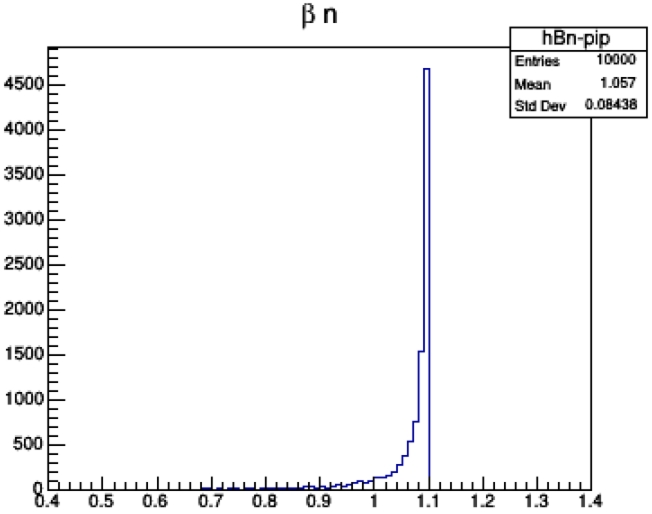
θ_{lab}



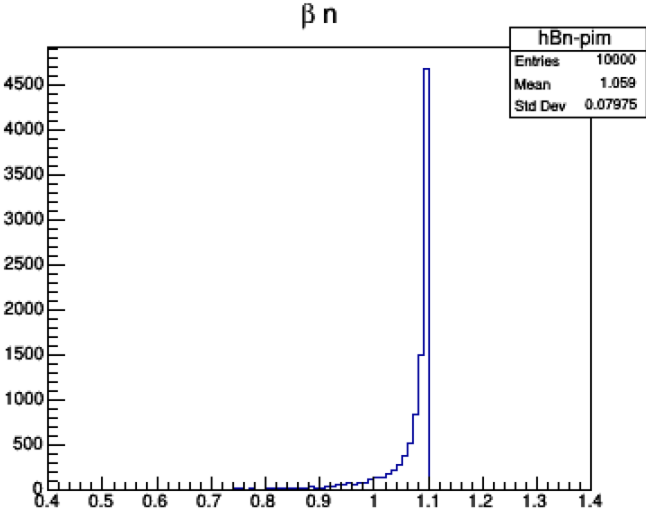
β n



β n



β n



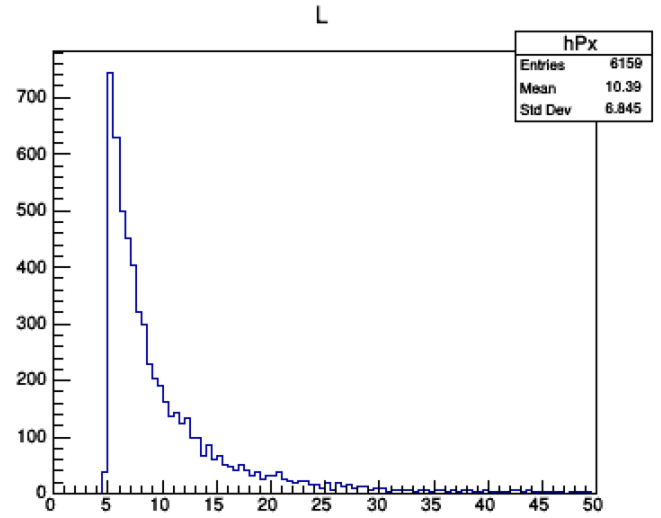
Combined Acceptance: 99.9%

$K_L\ p \rightarrow p\ K_s$ @ 4 GeV

$\beta n > 1$

straight path target track length & Cherenkov cone half-angle

Proton



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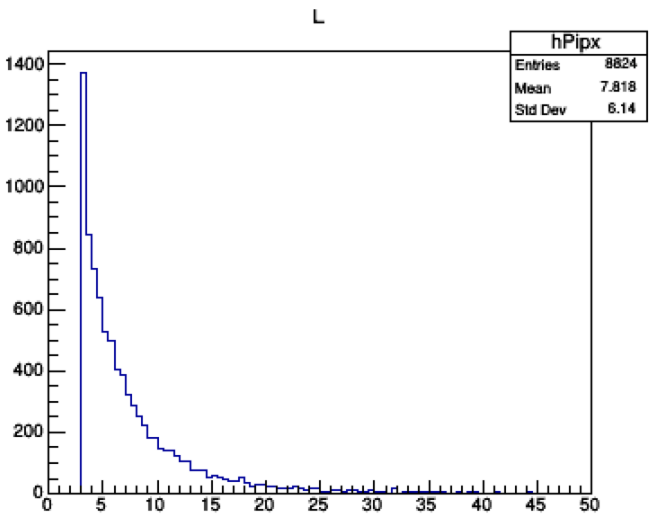

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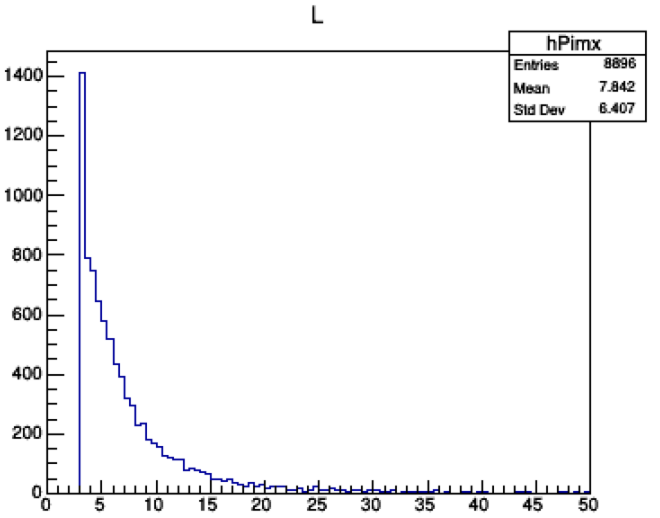
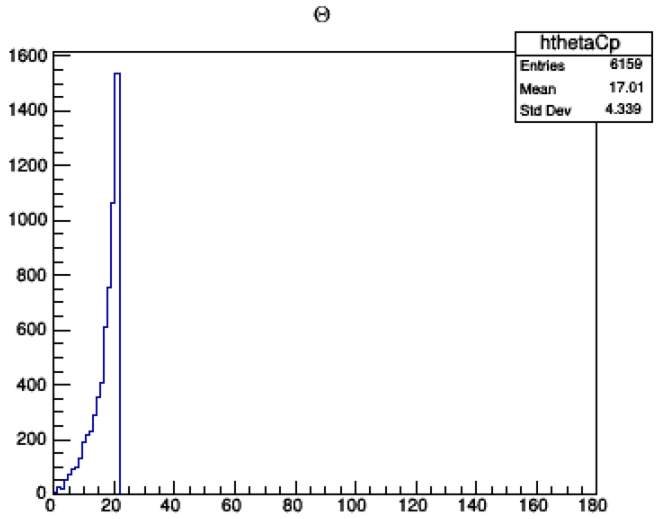
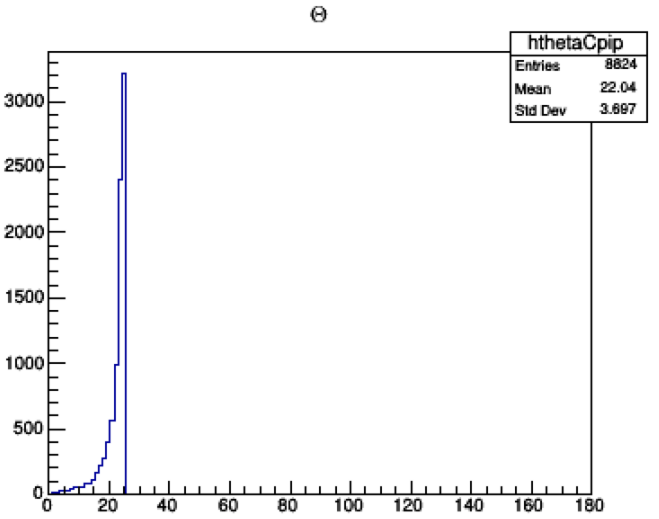
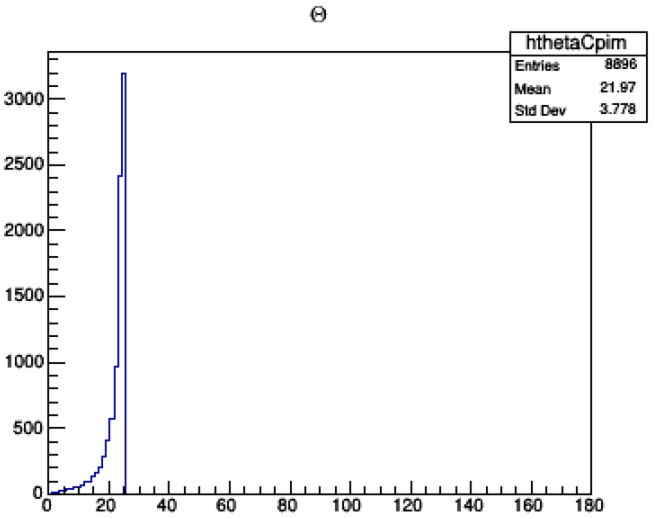


track length measured from target center

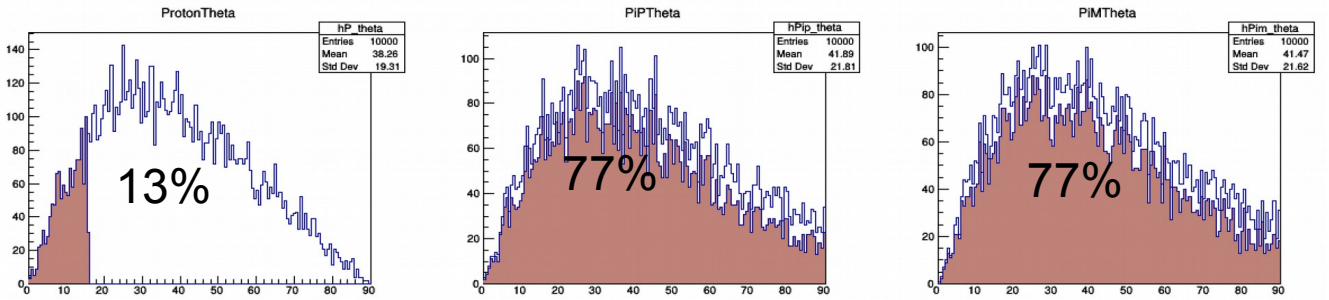


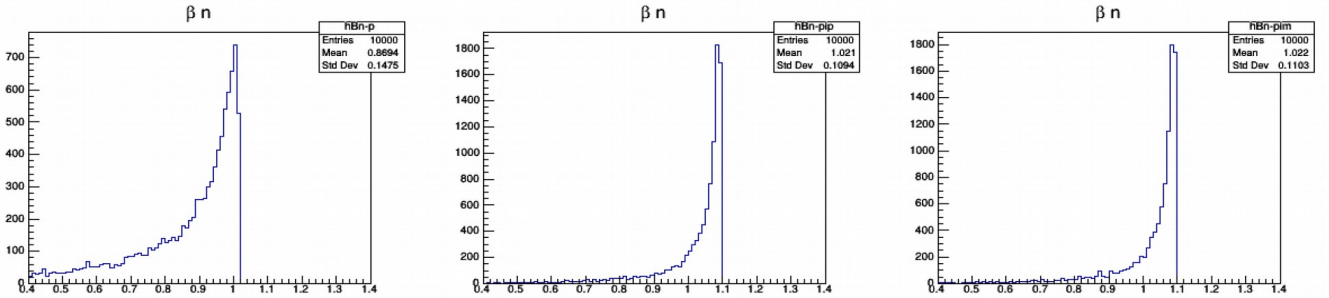




$K_L\ p \rightarrow p\ K_s$

$\beta n > 1$



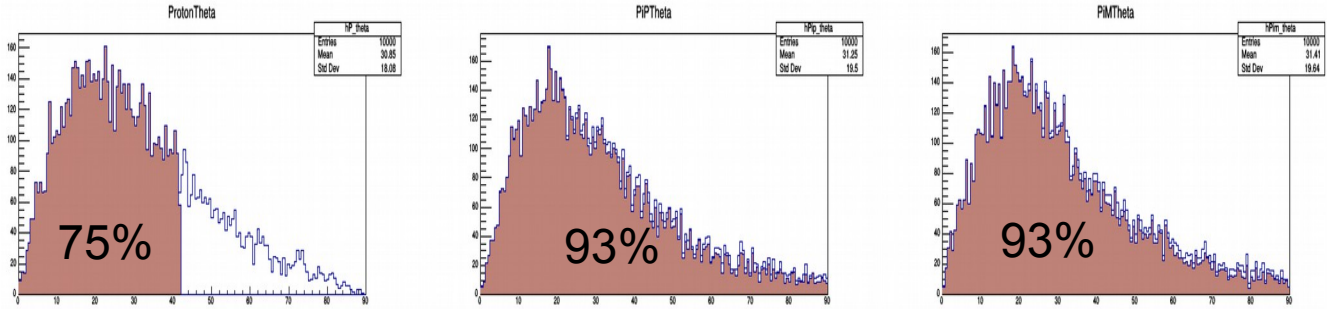


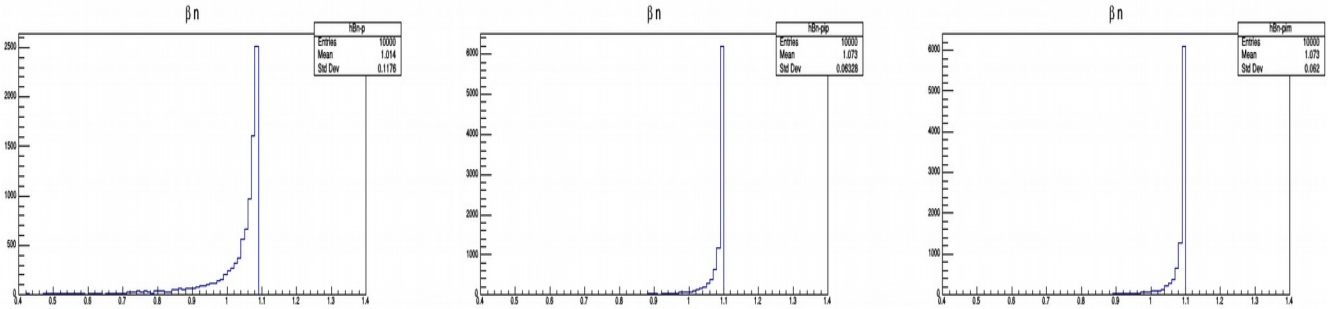
2 GeV Beam

Combined Acceptance: 99%

6 GeV Beam

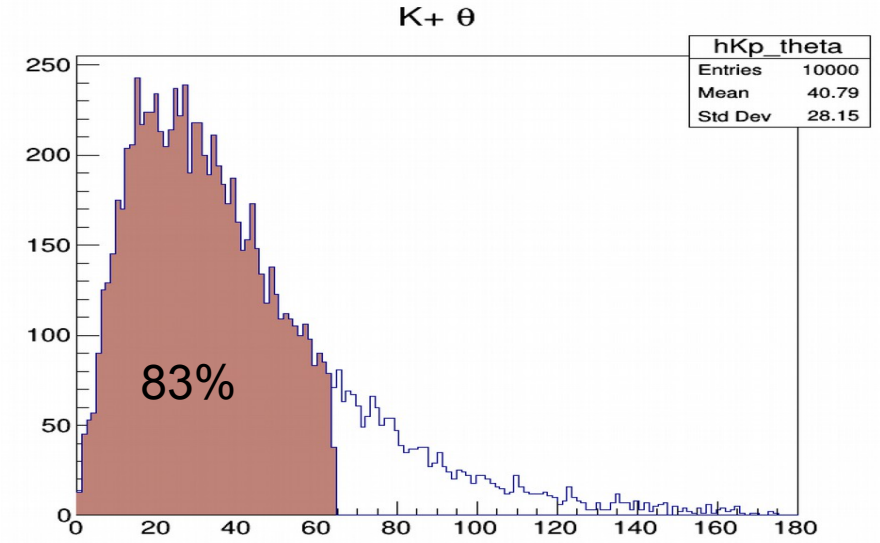
Combined Acceptance: 99%

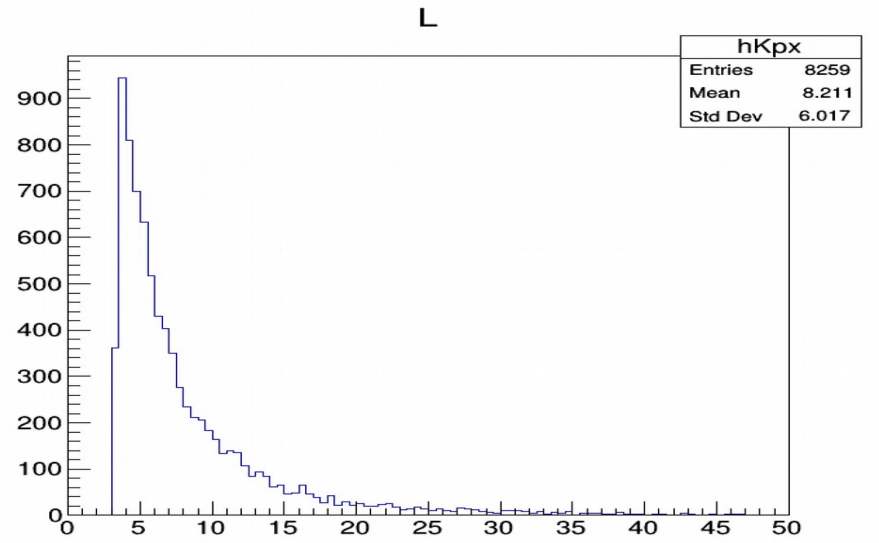


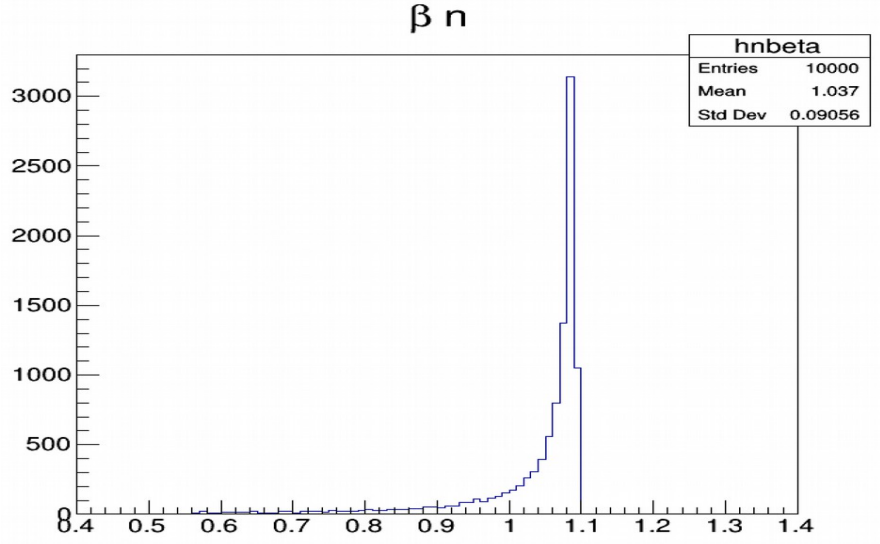


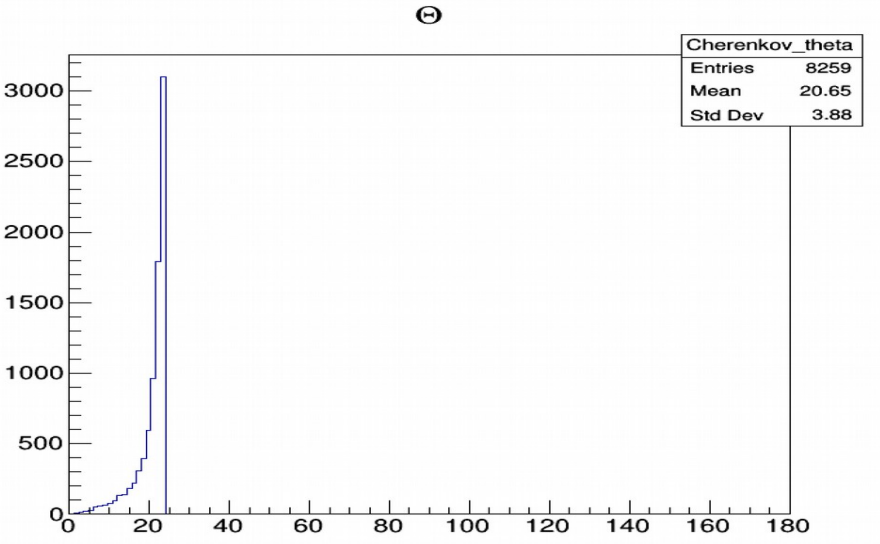
$K_L\ p \rightarrow n\ K^+$ @ 4 GeV

$\beta n > 1$







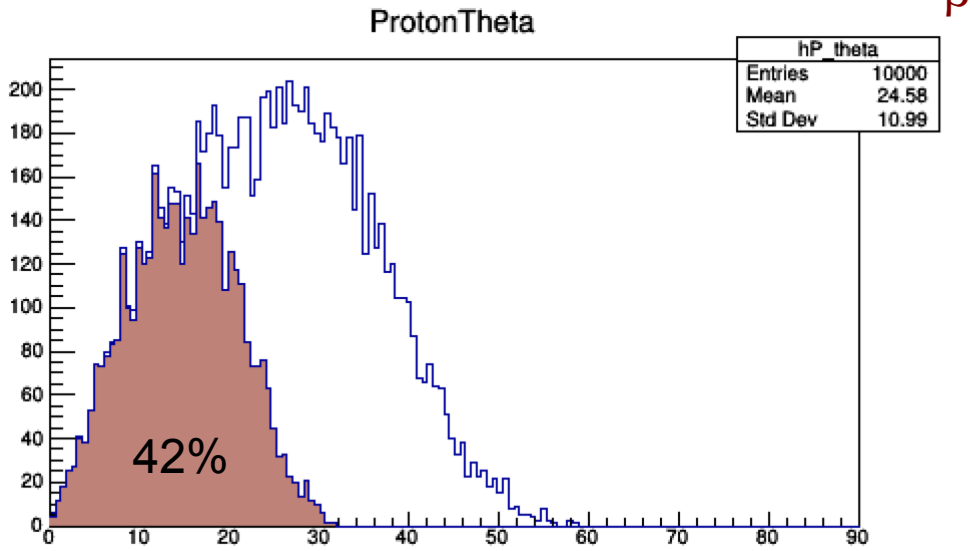


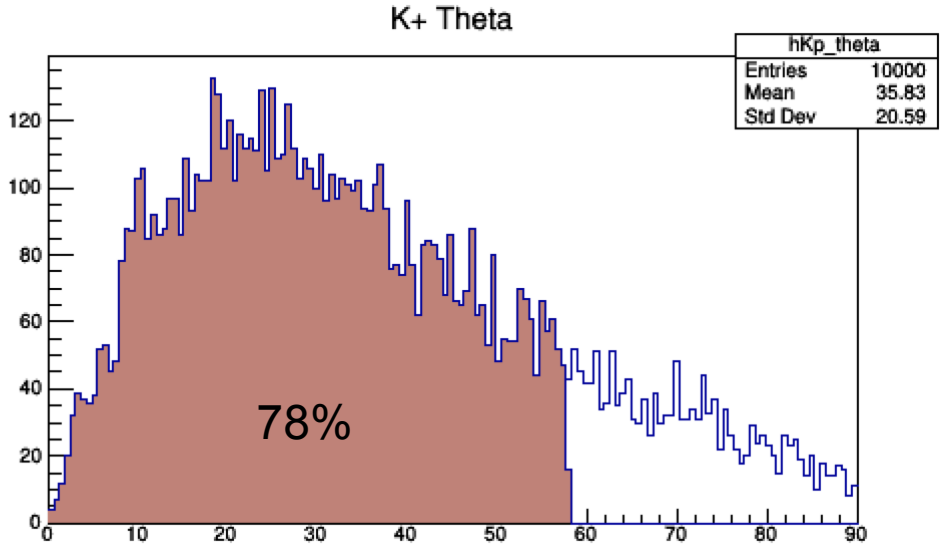
Acceptances

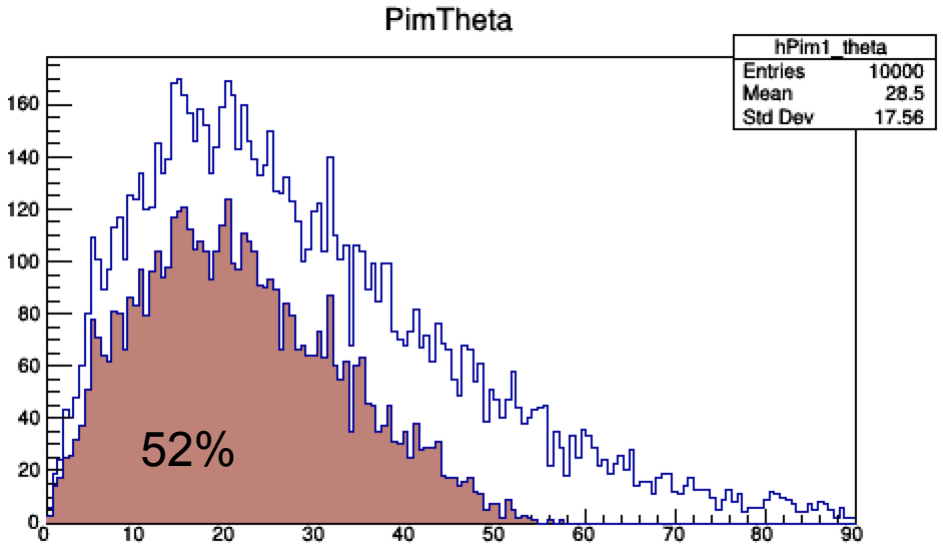
2 GeV: 57% 4 GeV: 83% 6 GeV: 99%

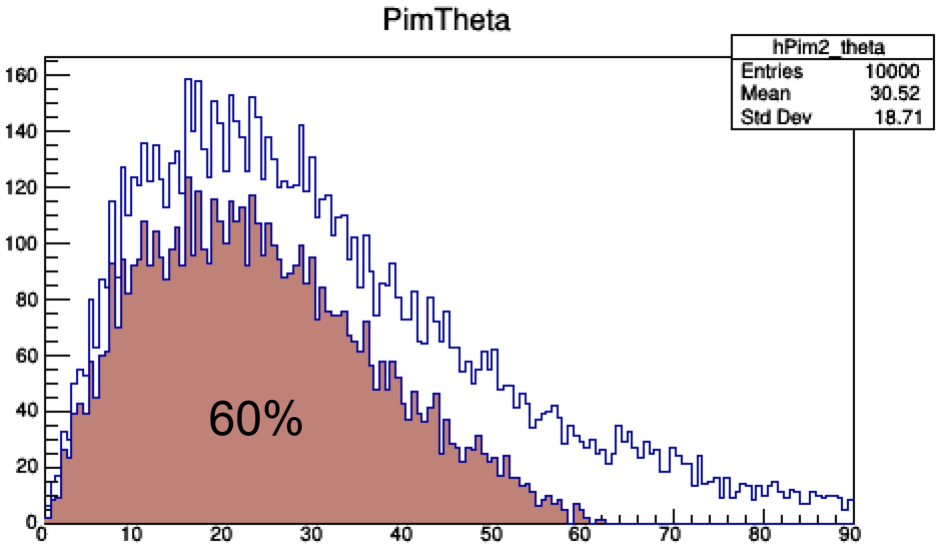
$K_L\ p \rightarrow \Xi^- K^+$ @ 4 GeV

$\beta n > 1$









Combined Acceptances

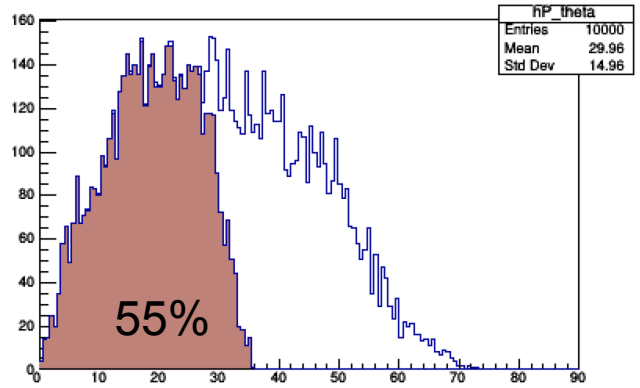
2 GeV: 77% 4 GeV: 99% 6 GeV: 99%

$K_L\ p \rightarrow \Lambda\pi^+$ @4 GeV

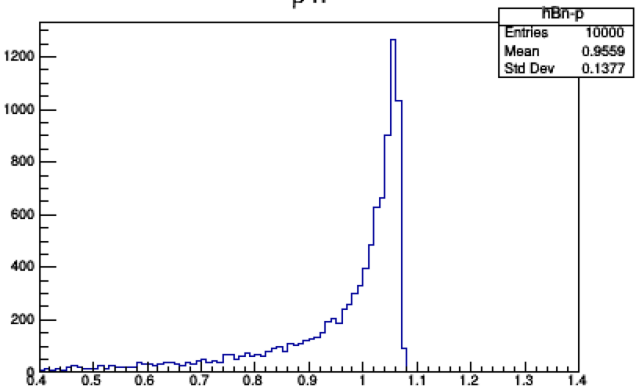
$\beta n > 1$

Proton

θ_{lab}

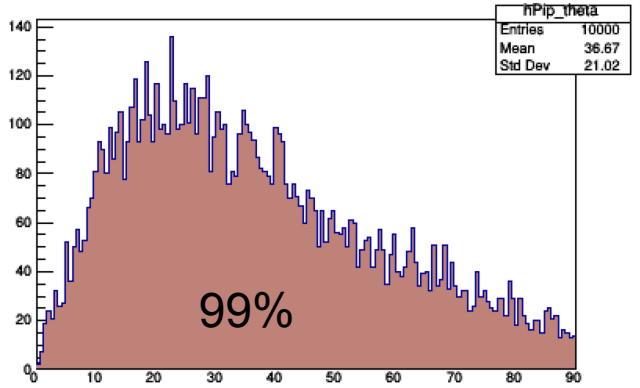


β n

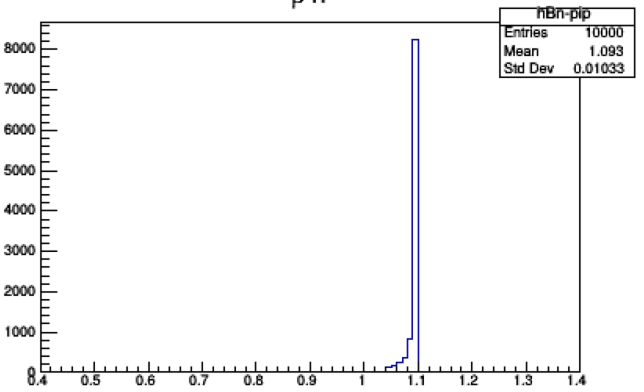


PiPlus

θ_{lab}

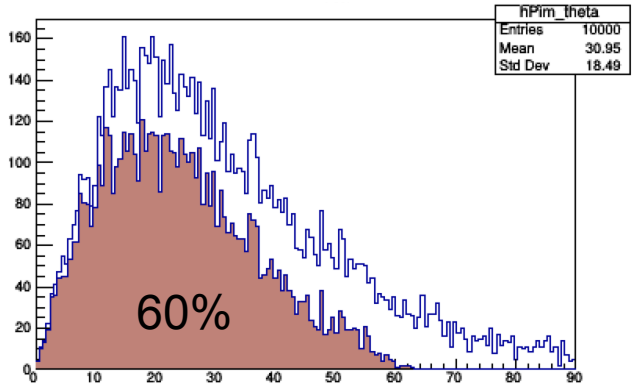


β n

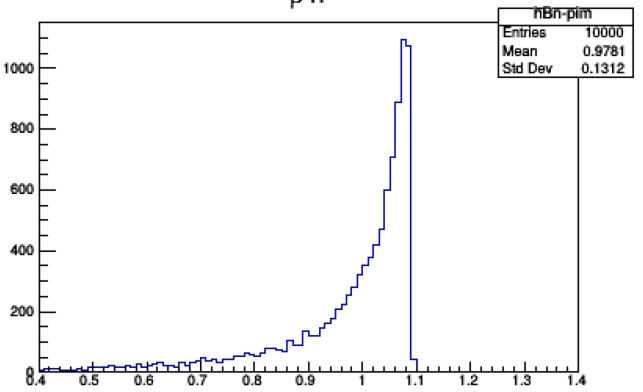


PiMinus

θ_{lab}



β n



<u>Combined Acceptances</u>

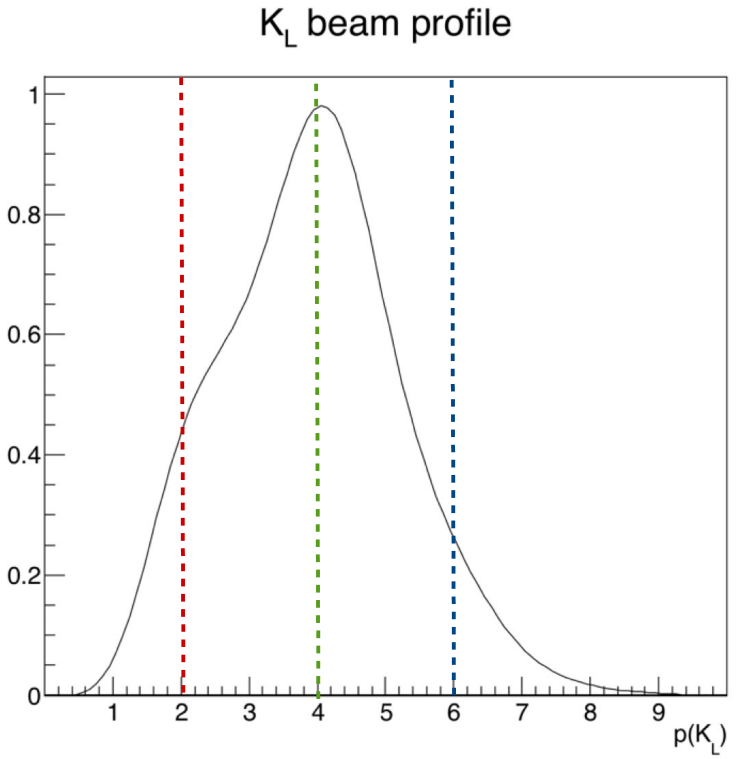
2 GeV: 99% 4 GeV: 99% 6 GeV: 99%

Simulations of Strange Meson Channels

Generated t-channel phase space

$$\frac{d\sigma}{dt} \propto e^{-b|t|} \qquad b = 4\,GeV^{-2}$$

1. $K_L\, p \rightarrow p\, K^-\, \pi^+$
2. $K_L\, p \rightarrow \Delta^{++}\, K^-\, \pi^0$
3. $K_L\, n \rightarrow p\, K^-\, \pi^-\, \pi^0$



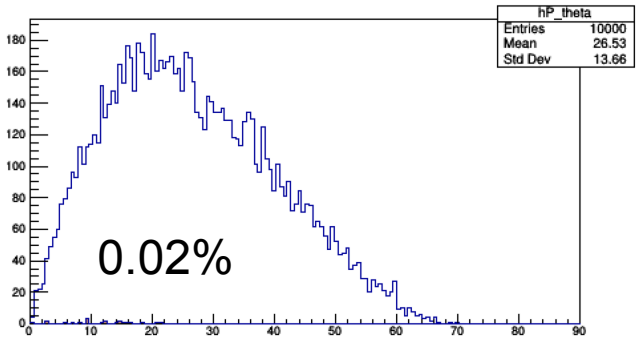
Generated data set for
2 GeV, 4 GeV, & 6 GeV

$K_L\ p \rightarrow \Delta^{++} K^- \pi^0$

$\beta n > 1$

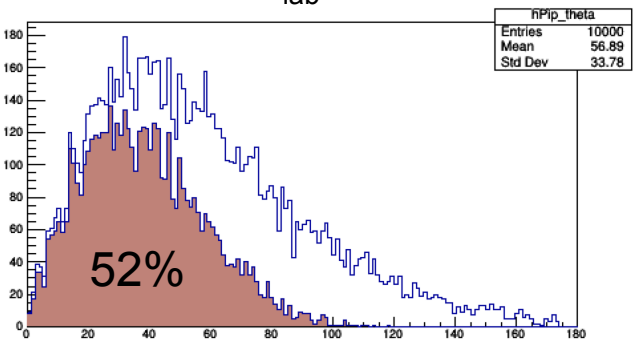
Proton

θ_{lab}



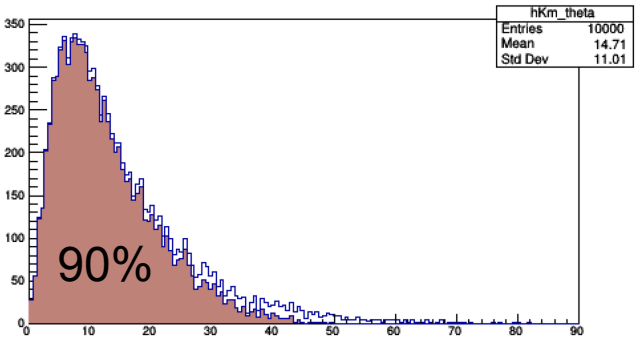
π+

θ_{lab}

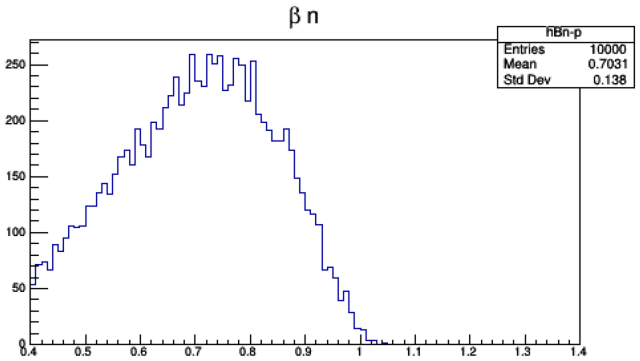


K-

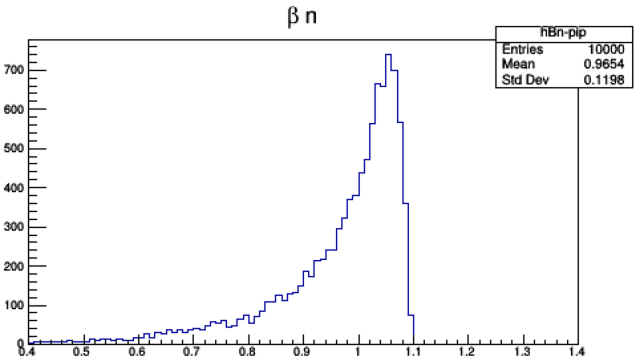
θ_{lab}



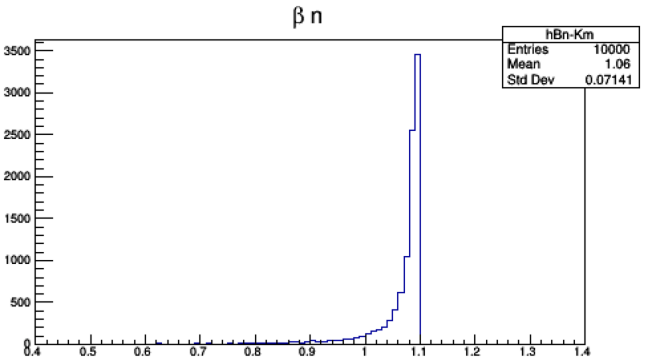
β n



β n



β n



<u>Combined Acceptances</u>

2 GeV: 60% 4 GeV: 92% 6 GeV: 96%

<u>Average Combined Path Length</u>

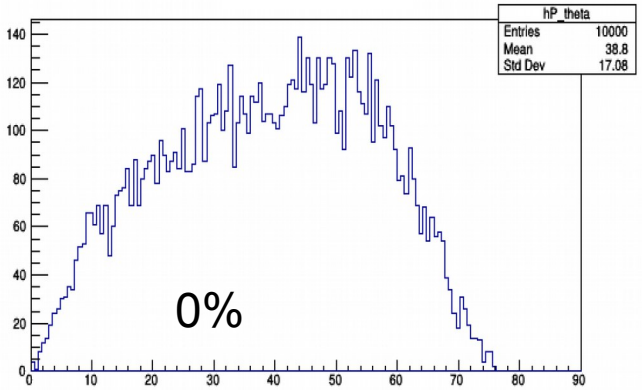
2 GeV: 13 cm 4 GeV: 20 cm 6 GeV: 22 cm

$K_L\ p \rightarrow p\ K^-\pi^+$

$\beta n > 1$

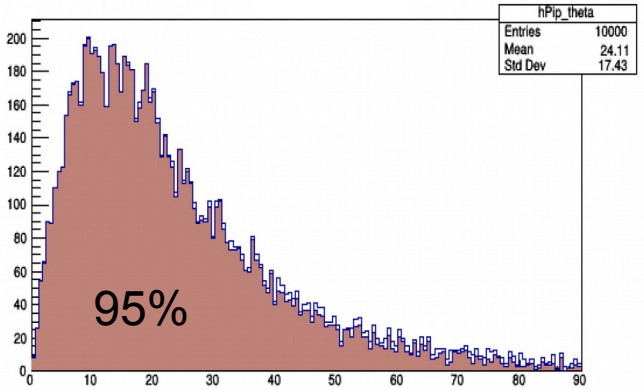
Proton

θ_{lab}



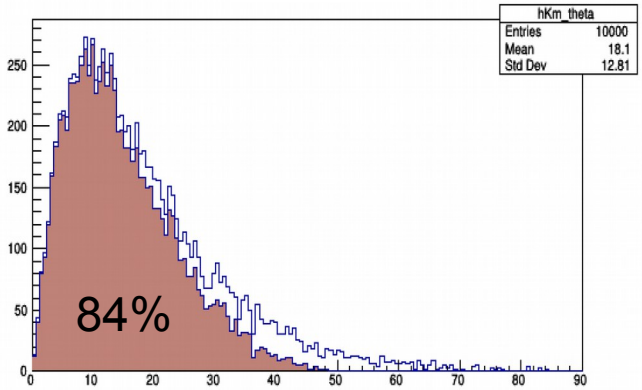
π+

θ_{lab}

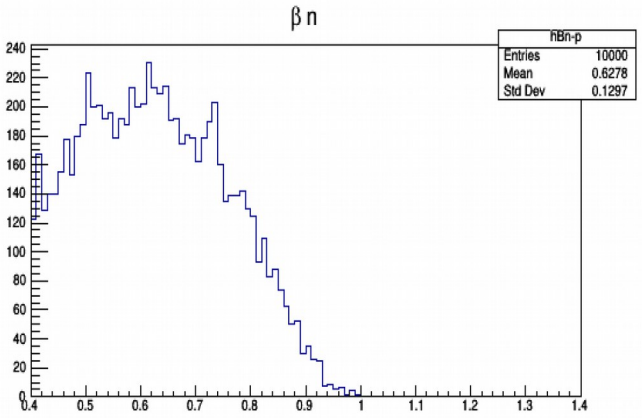


K-

θ_{lab}



β n



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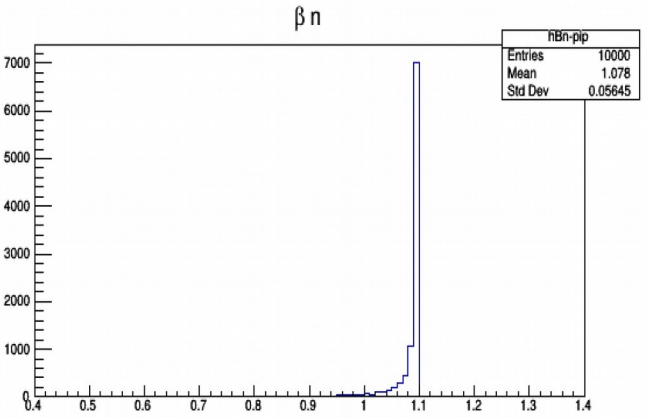
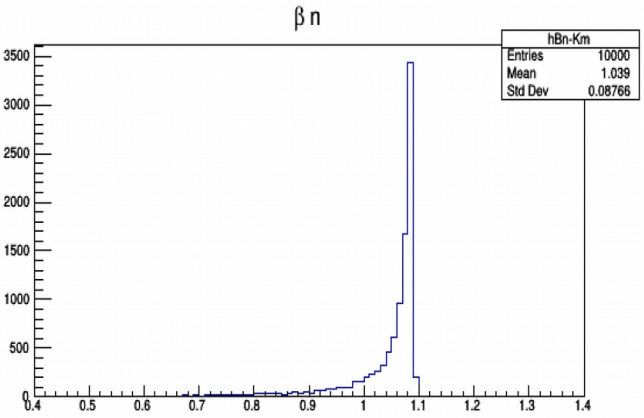


β n



<u>Combined Acceptances</u>

2 GeV: 99% 4 GeV: 99% 6 GeV: 99%

<u>Average Combined Path Length</u>

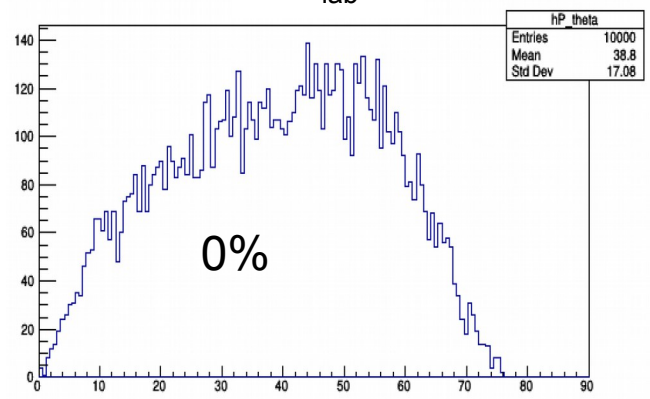
2 GeV: 16 cm 4 GeV: 26 cm 6 GeV: 31 cm

$K_L\ p \rightarrow p\ K^-\pi^+\pi^0$

$\beta n > 1$

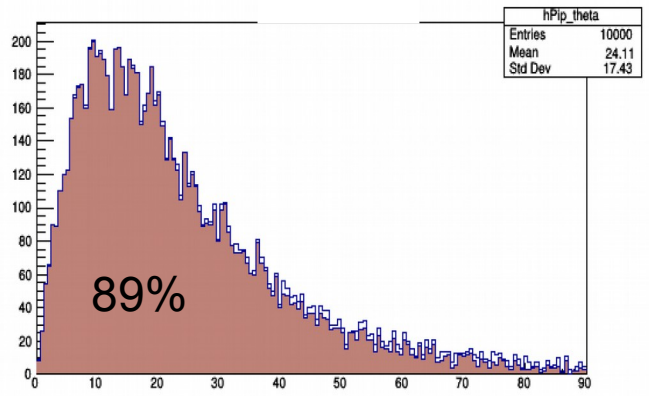
Proton

θ_{lab}



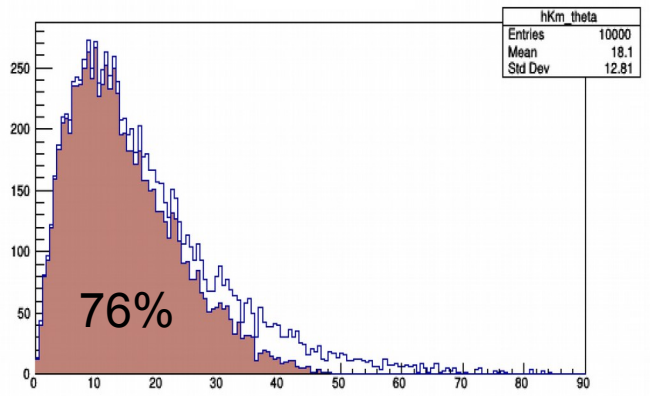
π+

θ_{lab}

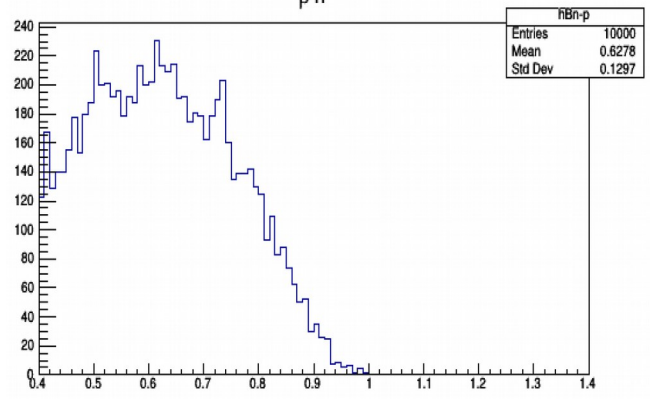


K-

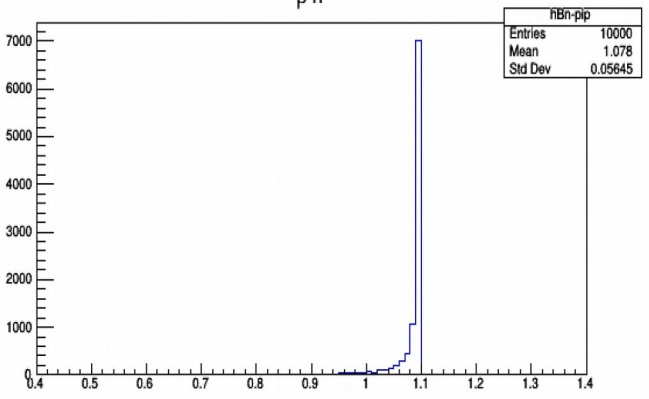
θ_{lab}



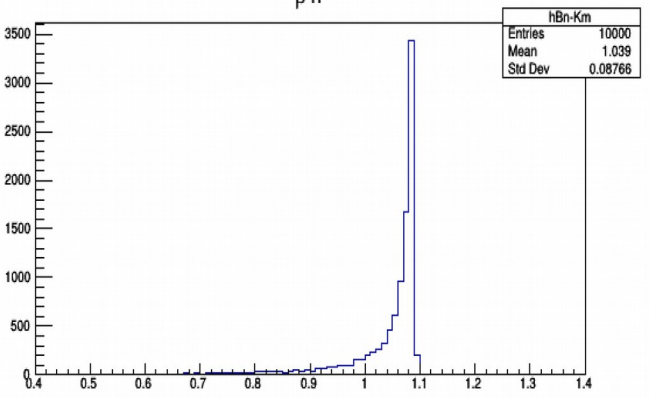
β n



β n



β n



<u>Combined Acceptances</u>

2 GeV: 77% 4 GeV: 99% 6 GeV: 99%

<u>Average Combined Path Length</u>

2 GeV: 14 cm 4 GeV: 24 cm 6 GeV: 29 cm