Update on Proton Calorimetric Reconstruction

Heng-Ye Liao
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Track length Calculation in LArSoft

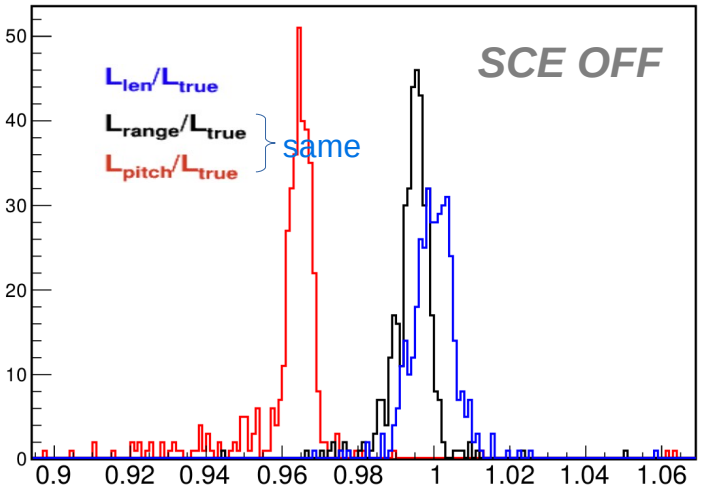
Parameter	Class Name & Operation
L^{true}	Sum of distance between neighboring MCTrajectory points
L^{len}	recob::Track()::Length()
L^{range}	anab::Calorimetry::Range()
L^{pitch}	Sum over anab::Calorimetry::TrkPitchVec()

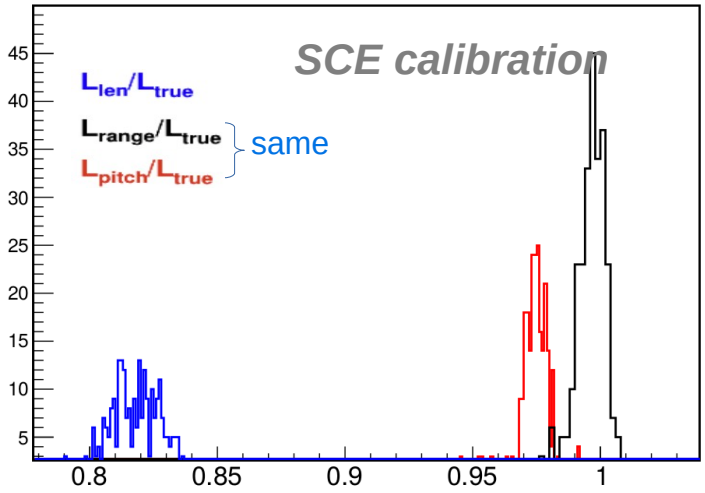
*recob::Track does NOT have SCE correction
anab::Calorimetry does have SCE correction

Track length Ratios for 1 GeV/c Stopping Protons [MC]

- Range calculation is a good choice!

	SCE OFF	SCE Calibration
L^{len}/L^{true}	0.9998 (0.0049)	0.8188 (0.0131) [No SCE correction on this item]
L^{range}/L^{true}	0.9960 (0.0024)	0.9969 (0.0046)
L^{pitch}/L^{true}	0.9647 (0.0027)	0.9745 (0.0004)

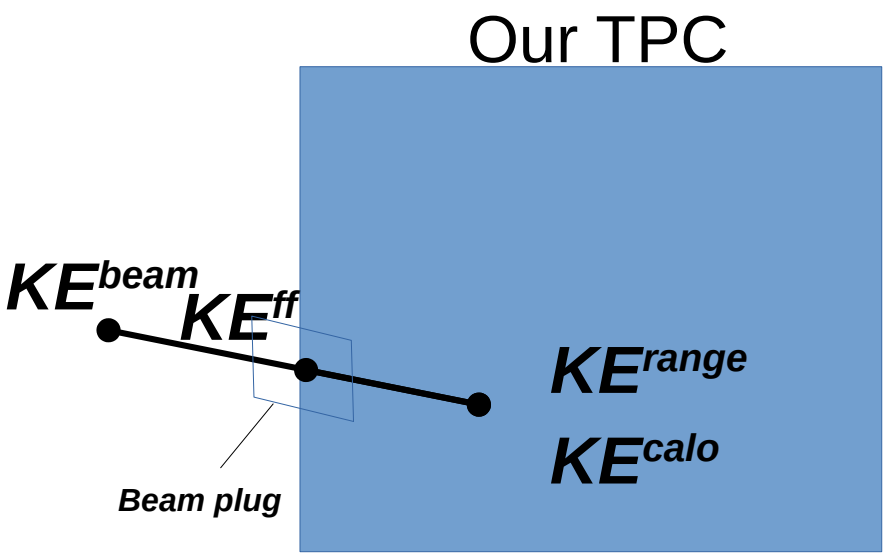




*Each column, fitted mean (sigma) of the distribution

Introduction

- Study of proton energy reconstruction using Production 2
  - For both data and MC (SCE ON)
- Reminder on proton energy reconstruction:



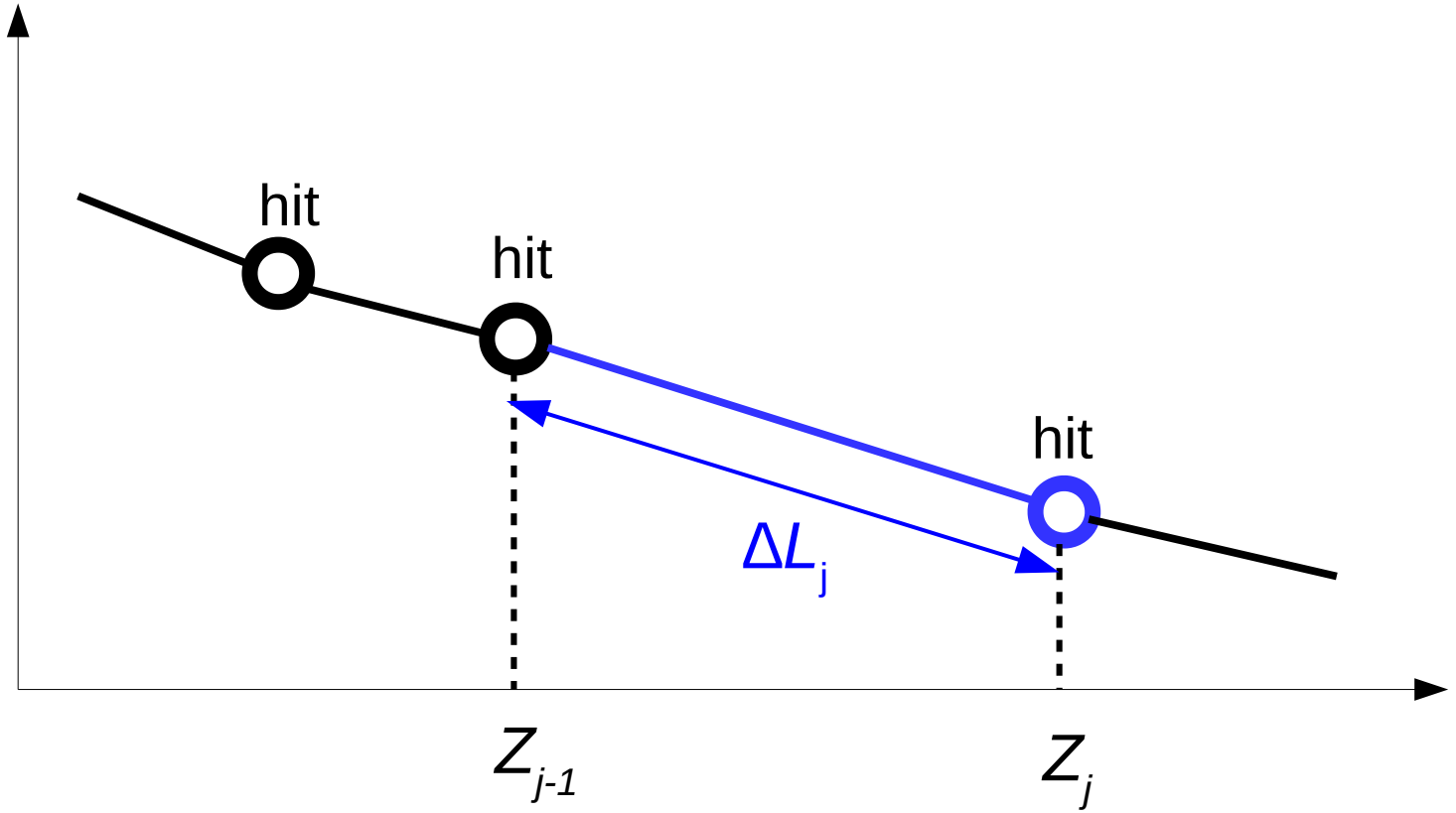
-KE^{beam}: Proton kinetic energy from beamline instrumentation

-KE^{ff}: Proton kinetic energy at front face of TPC

-KE^{calo}: Reconstructed calorimetry of the stopping protons (sum over dE/dx*dx)

-KE^{range}: KE from reconstructed track length of the stopping protons (Range from anab::Calorimetry → KE)

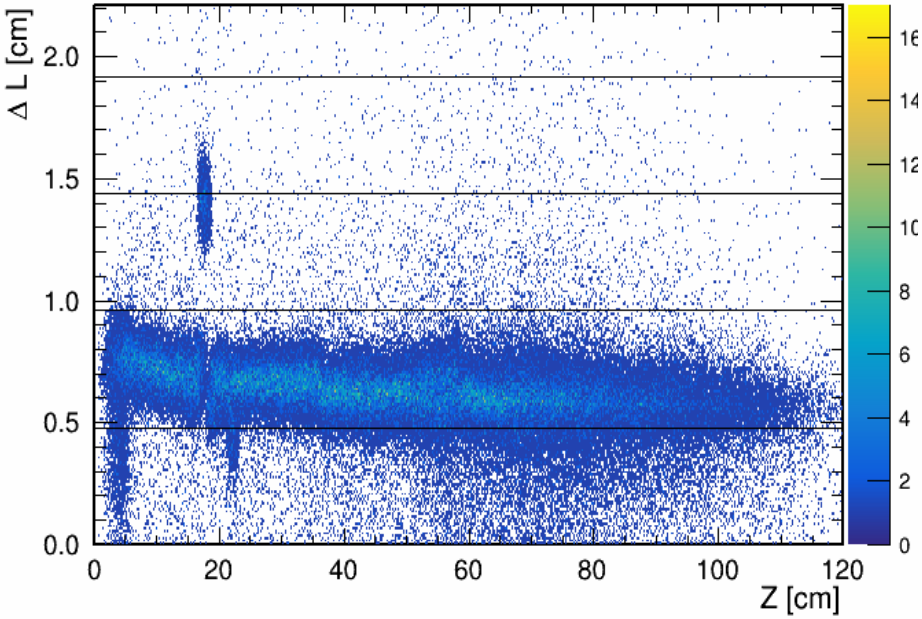
Definitions of Z & ΔL



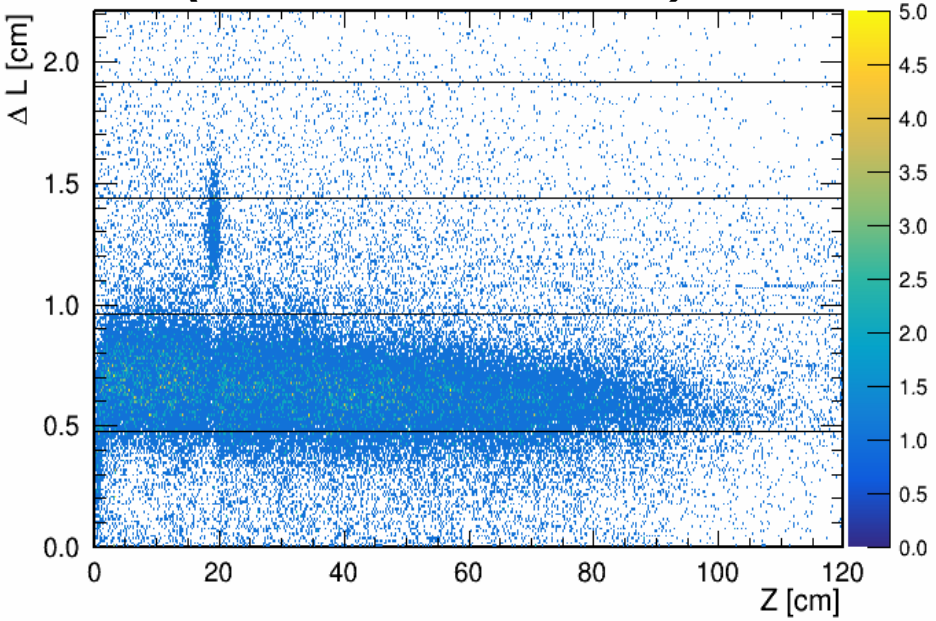
- Z_j: Z-position of j-th hit
- ΔL_j: Distance between two consecutive hits (j, j-1)

Z V.S. ΔL (Stopping Protons)

Data (after SCE calibration)

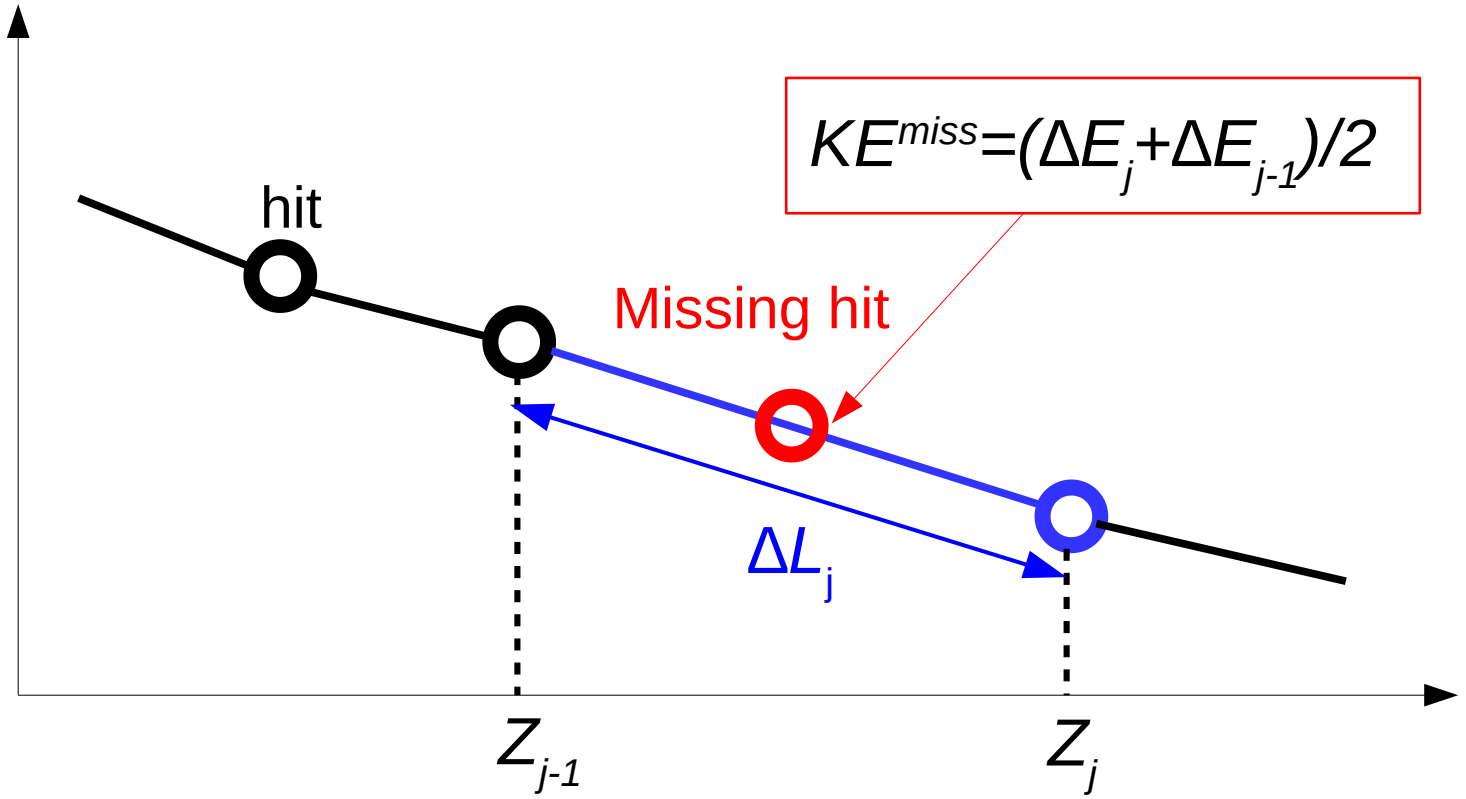


MC (after SCE calibration)



	Data	MC
Cut to select dead wires	16.3 cm < Z < 18.9 cm 1.17 cm < ΔL < 1.7 cm	
# of missing hits	3981	481
# of total hits	528233	148799
Fraction	0.75 %	0.32 %

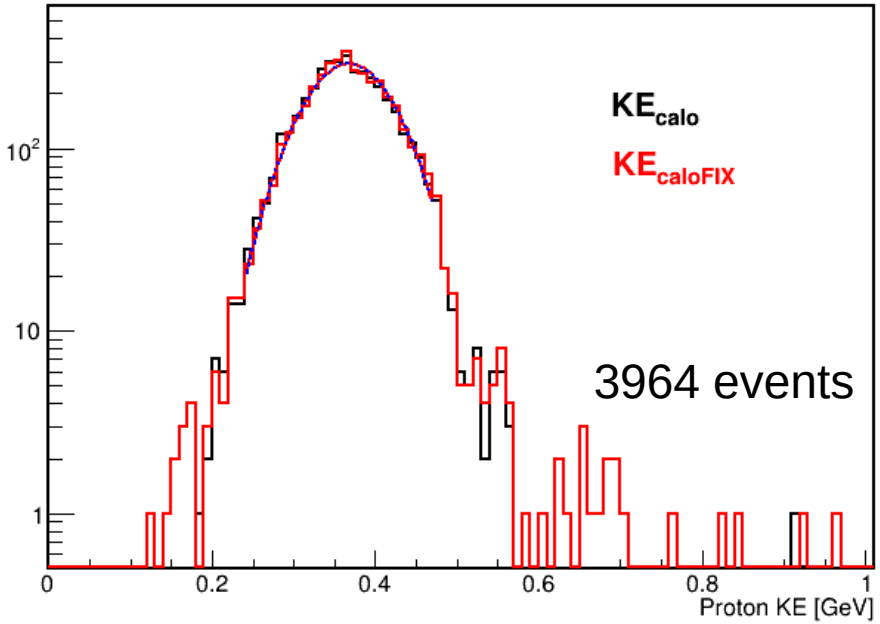
Compensation of Energy Loss due to Dead Wires



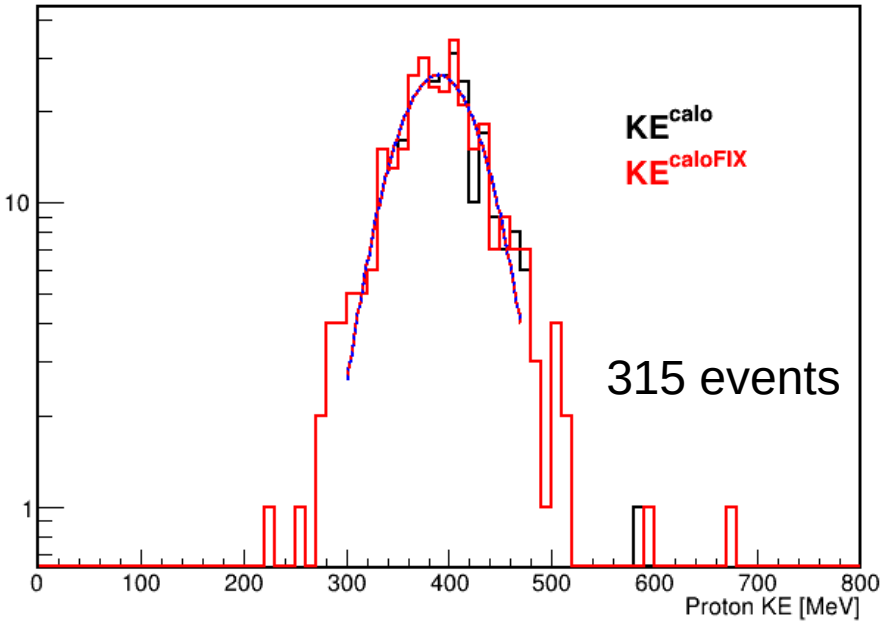
- $KE^{calo}=\sum_j \Delta E_j \cong \sum_j \frac{dE_j}{dx_j}\Delta x_j$
- Compensation of energy loss because of the dead wires
  → $KE^{caloFIX}=KE^{calo}+KE^{miss}$

KE^{calo} & $KE^{caloFIX}$

Data (after SCE calibration)



MC (after SCE calibration)



	Mean [GeV]	*FWHM [GeV]*	*ΔE/E (sigma)*
KE^{calo}	0.365	0.129	15.1 %
$KE^{caloFIX}$	0.367	0.129	14.9 %

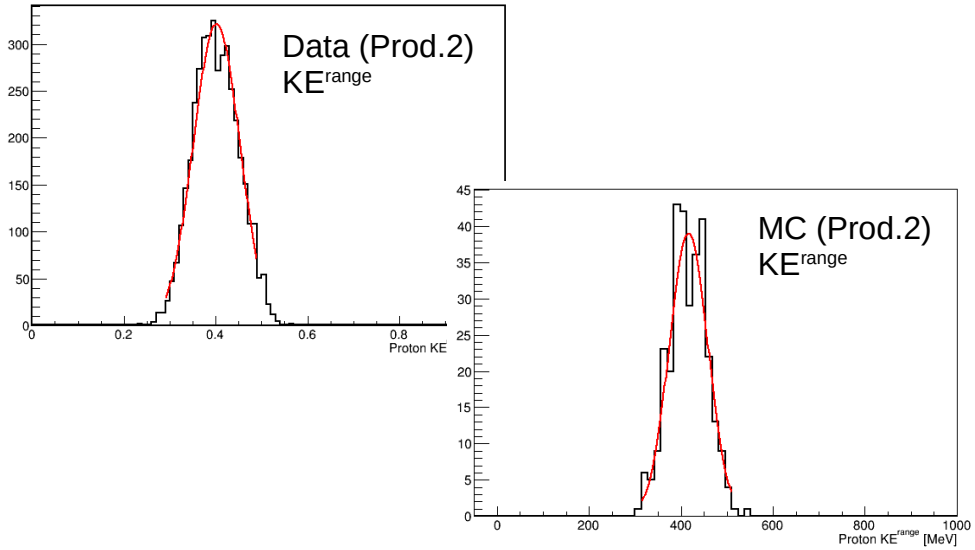
	Mean [GeV]	*FWHM [GeV]*	*ΔE/E (sigma)*
KE^{calo}	0.388	0.097	10.7 %
$KE^{caloFIX}$	0.389	0.097	10.6 %

- The energy compensation is in consistent with our expectation of one noisy channel (ch 2169): ~2 MeV (~4 MeV/cm * 0.5 cm)

Calorimetric Reconstruction - Data/MC

Data (Prod. 1)

	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)
KE^{range}	0.356	0.103	12.3 %
KE^{calo}	0.361	0.122	14.4 %
KE^{beam}	0.398	0.102	10.9 %



Data (Prod. 2)

	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)
KE^{range}	0.401	0.119	12.6 %
KE^{calo}	0.365	0.129	15.1 %
$KE^{caloFIX}$	0.367	0.129	14.9 %
KE^{beam}	0.435	0.118	11.5 %

MC (Prod. 2)

	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)
KE^{range}	0.416	0.099	10.1 %
KE^{calo}	0.388	0.097	10.7 %
$KE^{caloFIX}$	0.389	0.097	10.6 %
KE^{beam}	0.434	0.104	10.2 %

Calorimetric Reconstruction - Data/MC

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KE^{beam}	0.398	0.102	10.9 %

- Prod. 1: No SCE calibration
  Prod. 2: With SCE calibration
- KE^{range}:
  * Track length (Prod. 2>Prod. 1)
    → KE^{range} (Prod. 2>Prod. 1)
  * KE^{range} (data) < KE^{range} (MC)
    → Energy loss: data > MC
    → SCE correction is not perfect for data

Data (Prod. 2)

	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)
KE^{range}	0.401	0.119	12.6 %
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- KE^{calo}:
  Less sensitive to SCE calibration (sum over dE/dx*dx)

Data (Prod. 2)

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Calorimetric Reconstruction - Data/MC

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KE^{range}	0.356	0.103	12.3 %
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KE^{beam}	0.398	0.102	10.9 %

- KE^{beam}:
  - Prod. 2: Re-calibration of beam momentum
  - Beam momentum of Prod. 2 close to 1 GeV/c [data & MC]
  - 9 % increase in KE^{beam} (Prod. 1 → Prod. 2)

Data (Prod. 2)

	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)
KE^{range}	0.401	0.119	12.6 %
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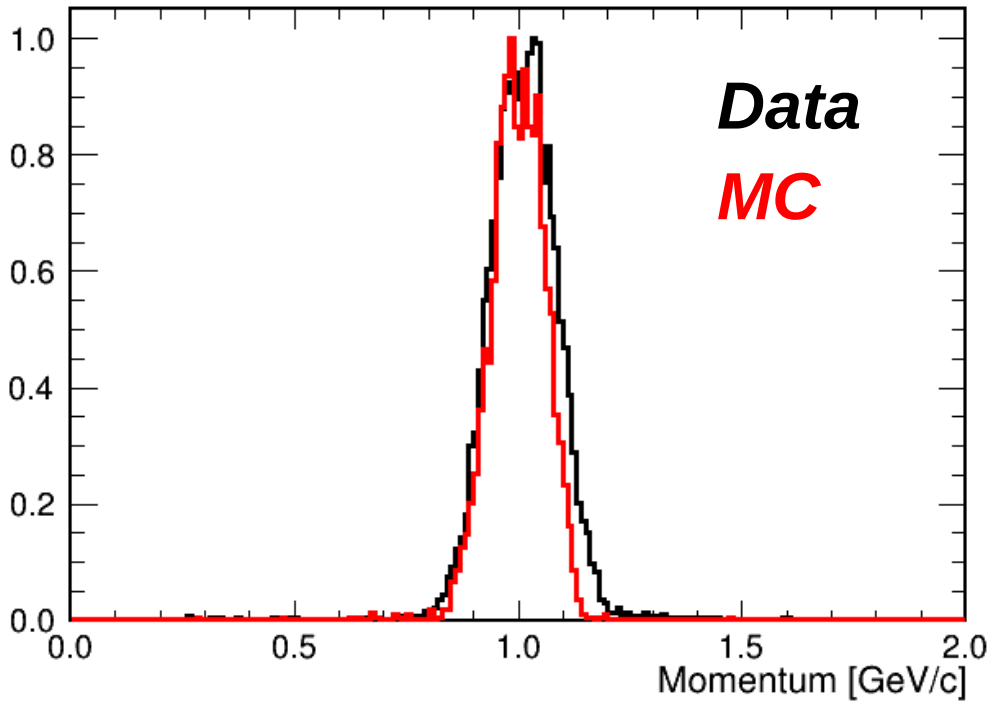
KE^{beam}	0.434	0.104	10.2 %

KE^{beam} – Data/MC [Prod. 2]

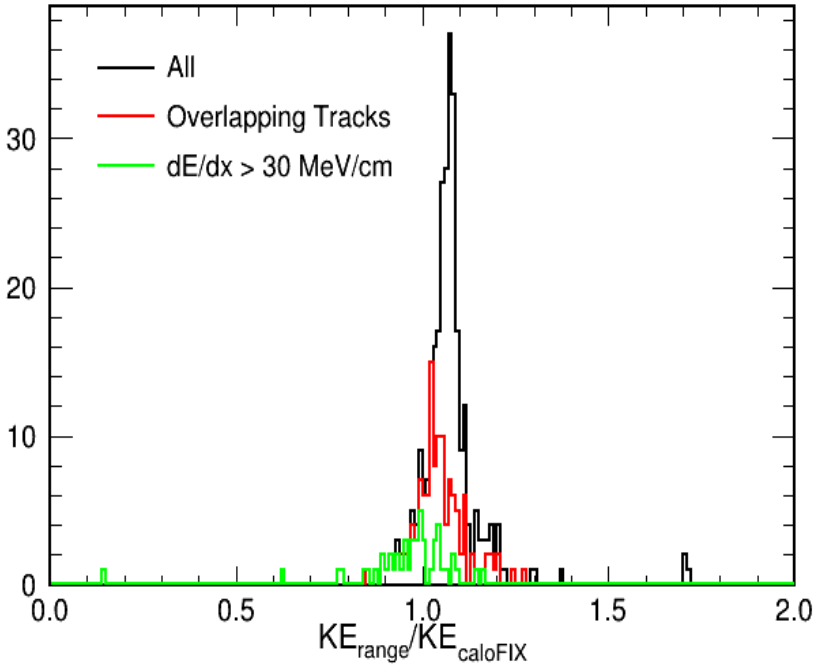
	Mean [GeV]	FWHM [GeV]	ΔE/E (sigma)	Mean [GeV/c]	FWHM [GeV/c]	ΔP/P (sigma)
Data	0.435	0.118	11.5 %	1.0117	0.17007	7.15 %
MC	0.434	0.104	10.2 %	1.0022	0.14458	6.14 %



*Beam momentum smearing ~ 2% (Jake's work), no beam optics in MC

Other Remarks on KE^{calo}

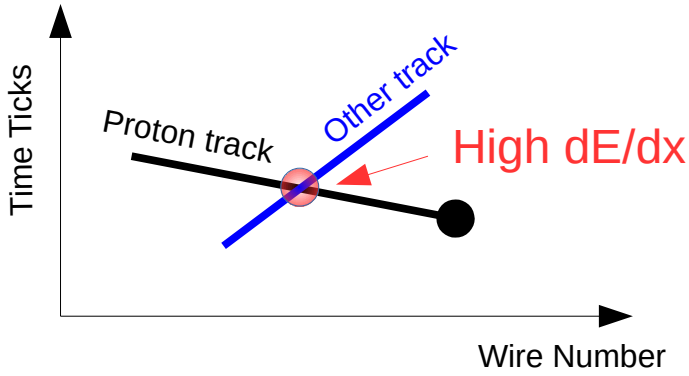
MC (after SCE calibration)



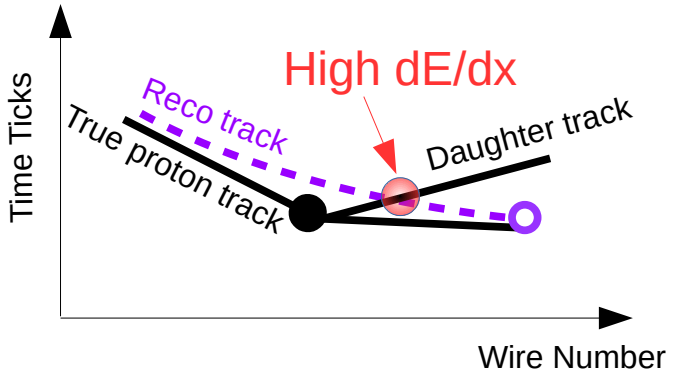
- The tail on the left understood
- The tail on the right need more investigation

- Energy overestimation

1 **Overlapping tracks***



2 **Daughter particles**



KE Ratios - Data/MC [Prod. 2]

	Data	MC
$KE^{caloFIX}/KE^{range}$	0.923 (0.025)	0.940 (0.030)
$KE^{caloFIX}/KE^{beam}$	0.861 (0.046)	0.891 (0.017)
$KE^{caloFIX}/KE^{ff}$	0.907* (0.049)	0.934 (0.032)
KE^{range}/KE^{beam}	0.924 (0.045)	0.953 (0.012)
KE^{range}/KE^{ff}	0.975* (0.053)	0.988 (0.013)

- KE^{calo} is lower than KE^{range}

* Assume an average energy loss (21.72 MeV) in data (from beamline to TPC front face)

- KE^{ff}: Assume no extra material between FC and cryostat wall
  If we assume 1 cm Lar in between FC and cryostat, +~1.3 % in the KE^{range}/KE^{ff} column

Each column, fitted mean (sigma) of the distribution
No overlapping & high dE/dx cut applied

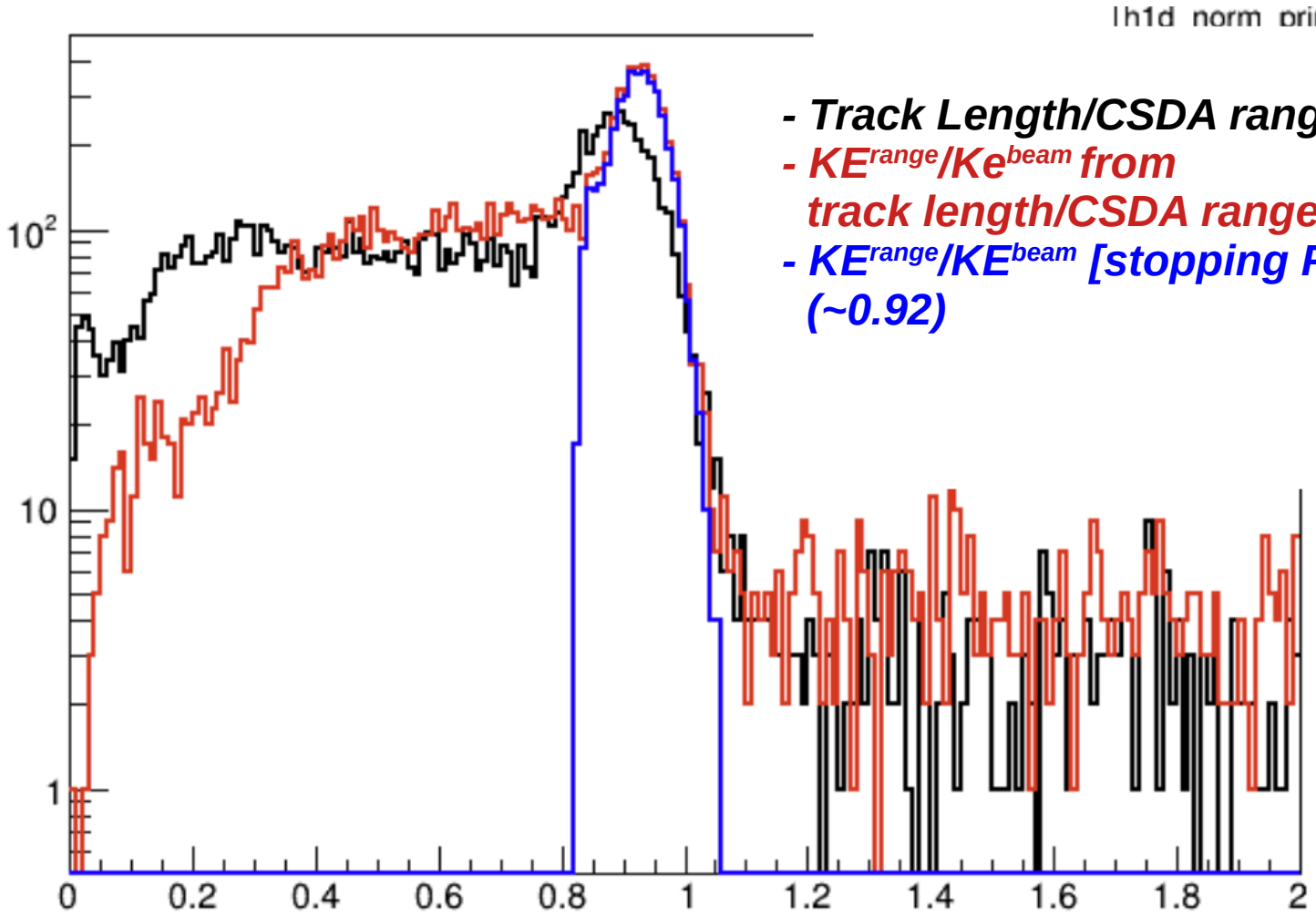
Summary

- KE^{range} does not match between data and MC
  → Possible reasons:
  (1) MC underestimates the upstream energy loss
  (2) SCE correction is not perfect for data
  [4 cm residual z offset]

- Bias between KE^{range} and KE^{calo}
  → Reason for this is under investigation
  → Ajib is working on the similar study using the stopping muons

Backup

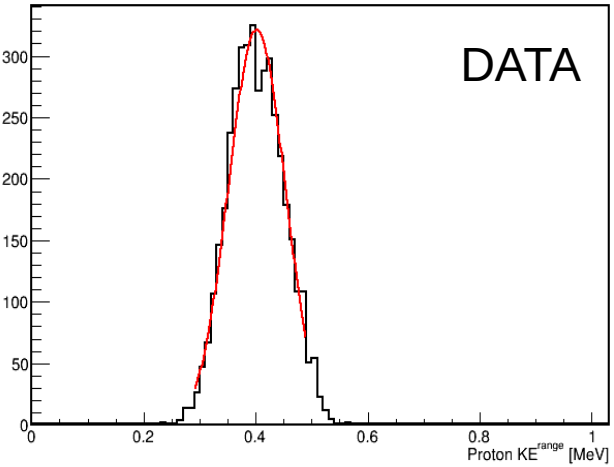
Check on KE^{range}/KE^{beam}

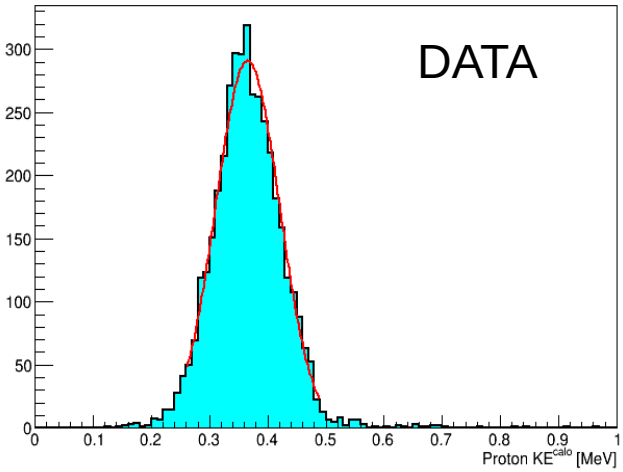


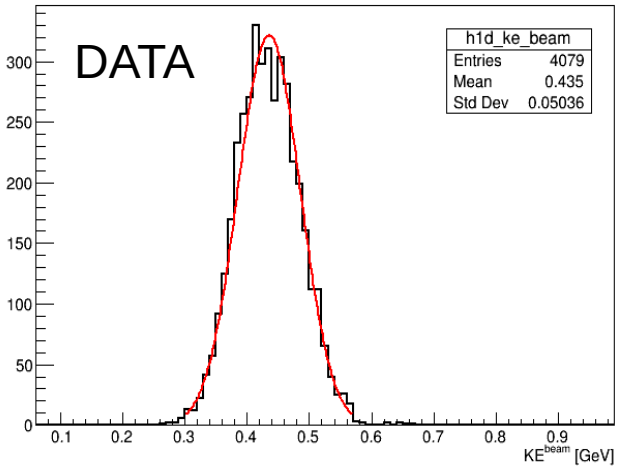
- ***Track Length/CSDA range (~0.90)***
- ***KE^{range}/Ke^{beam} from track length/CSDA range (~0.92)***
- ***KE^{range}/KE^{beam} [stopping Protons] (~0.92)***

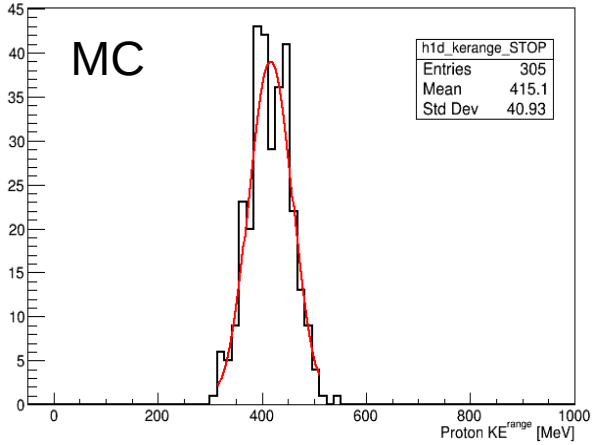
- 2 % difference between track length/CSDA and KE^{range}/KE^{beam}
  Why? → Non-linearity of CSDA v.s. KE in our region of interest

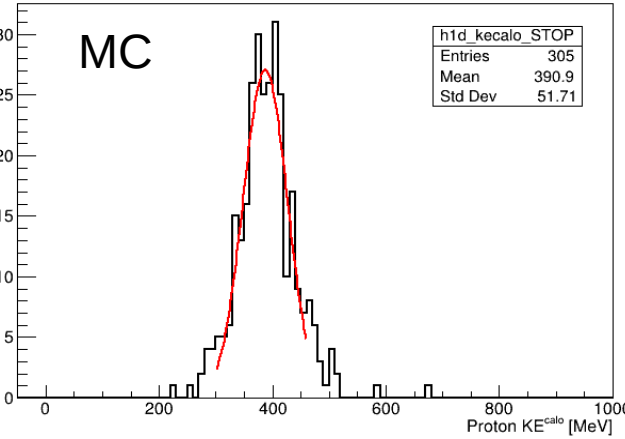
Proton KE Spectrum [Prod. 2]

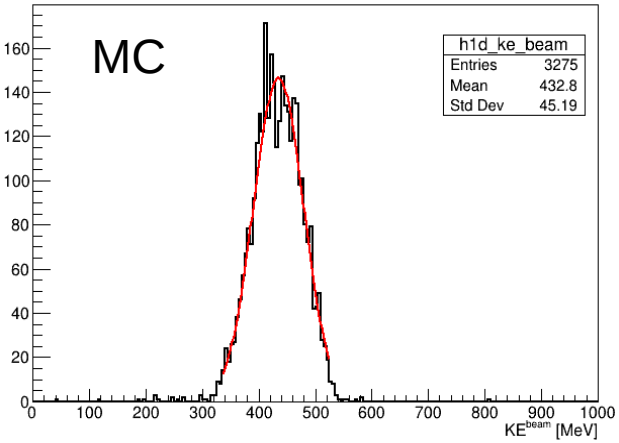




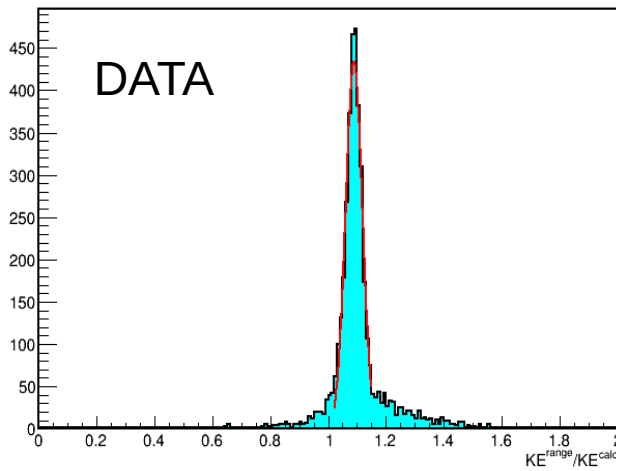


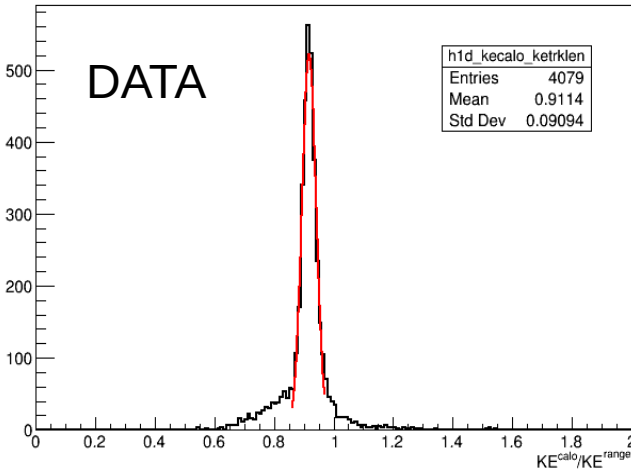


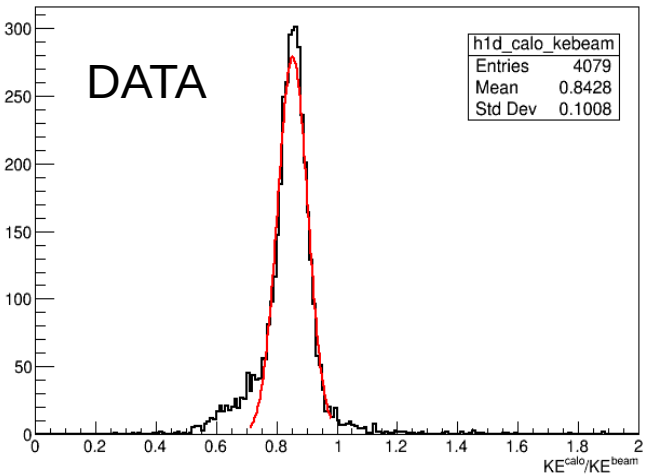


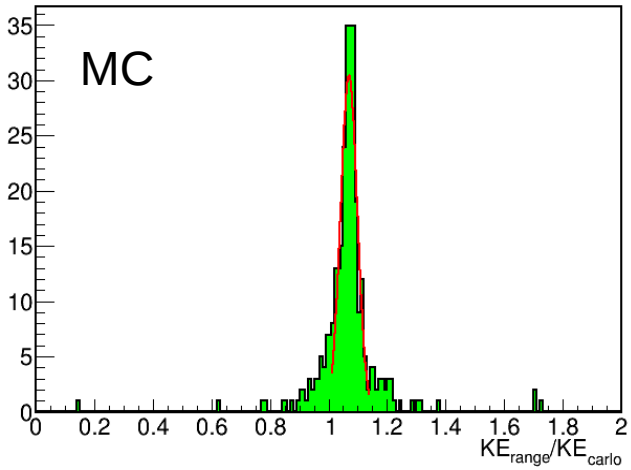


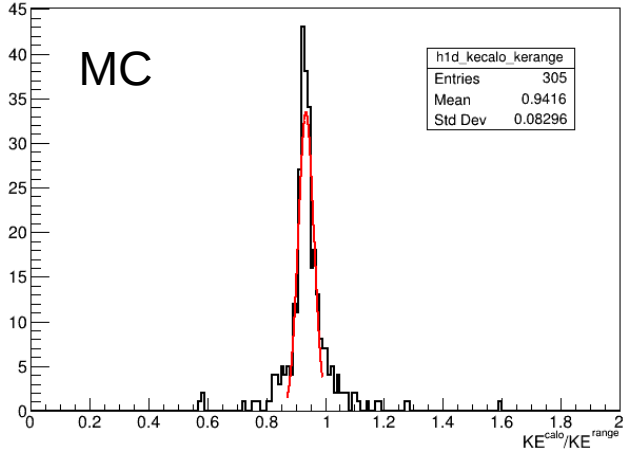
Proton KE Ratios [Prod. 2]

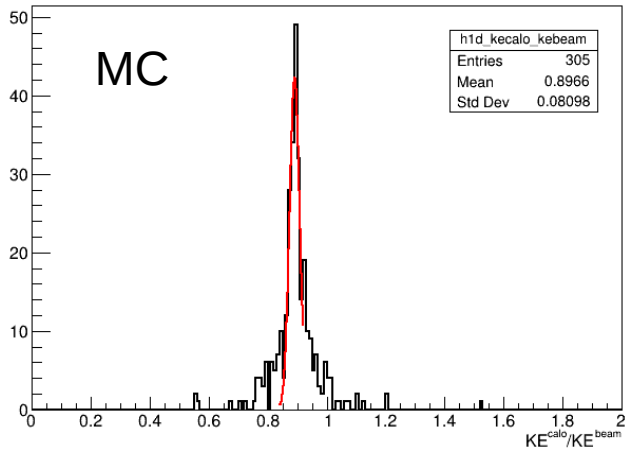




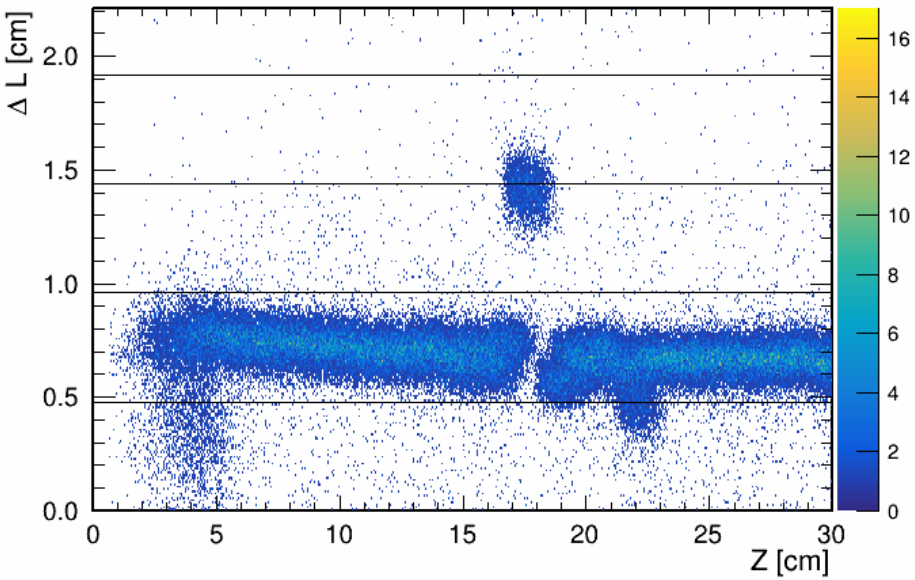


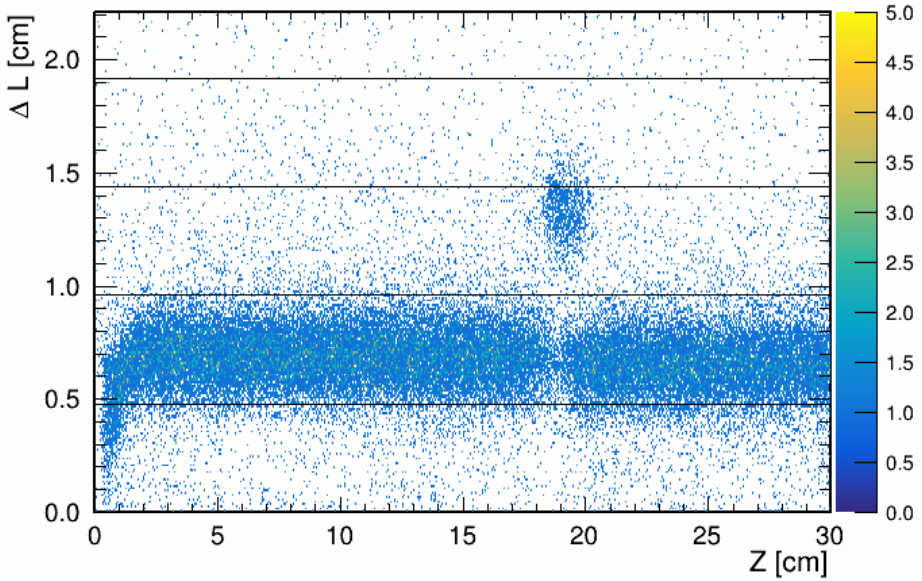




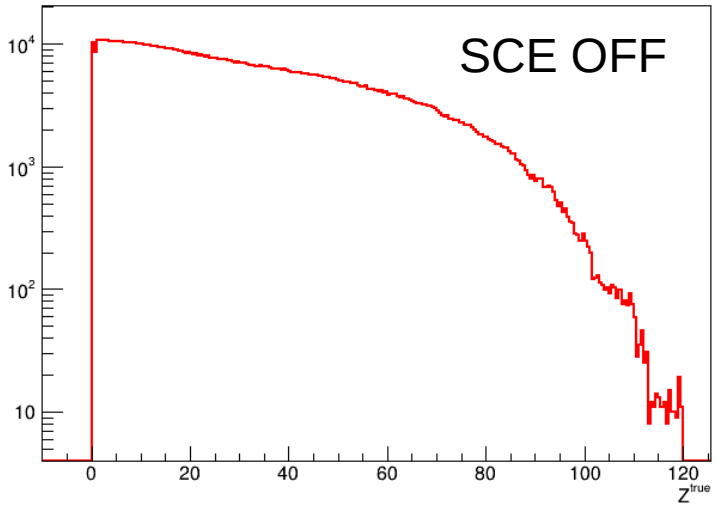


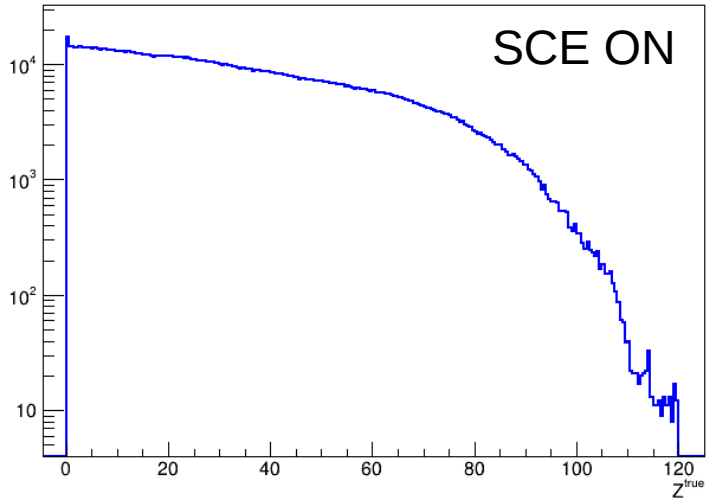
Zoom-in of Z v.s. ΔL





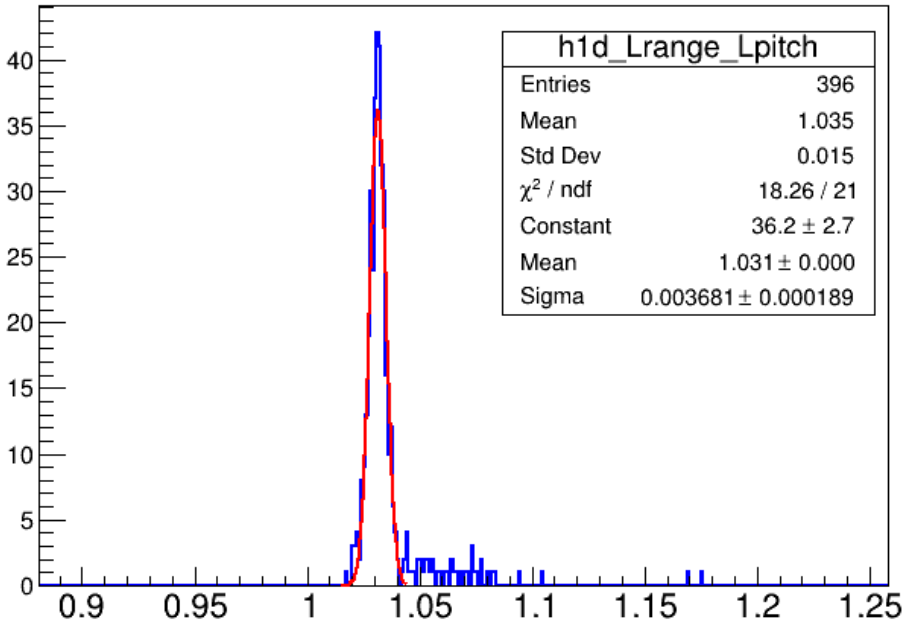
Sanity Check on Z^{true}





Lrange/Lpitch

SCE OFF



SCE ON