13th Collaboration Meeting of the BM@N
JINR, Dubna, Russia, October, 8–10, 2024

Status of data analysis on Λ and K^0_s production in Run 8

JOINT INSTITUTE FOR NUCLEAR RESEARCH

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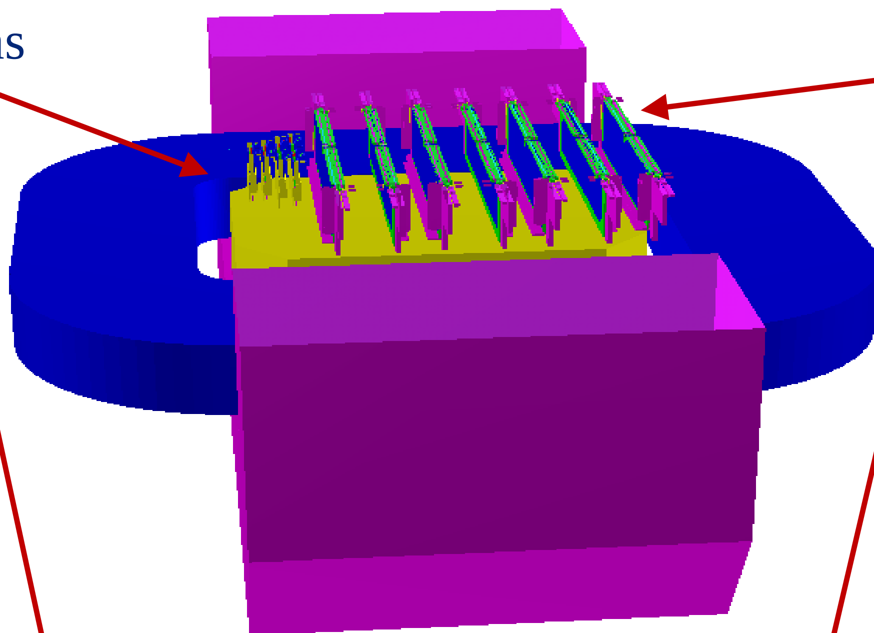
Outline

- ✓ BM@N configuration
- ✓ Reconstruction of strange particle decays
- ✓ Data quality checking
- ✓ Steps toward physics analysis:
  - ✓ Monte Carlo tuning
  - ✓ Λ lifetime measurement
  - ✓ Λ m_T spectra vs lifetime and rapidity
  - ✓ K^0_s lifetime measurement
  - ✓ K^0_s m_T spectra vs lifetime and rapidity
  - ✓ Selection of decays with machine learning
- ✓ Summary and next steps

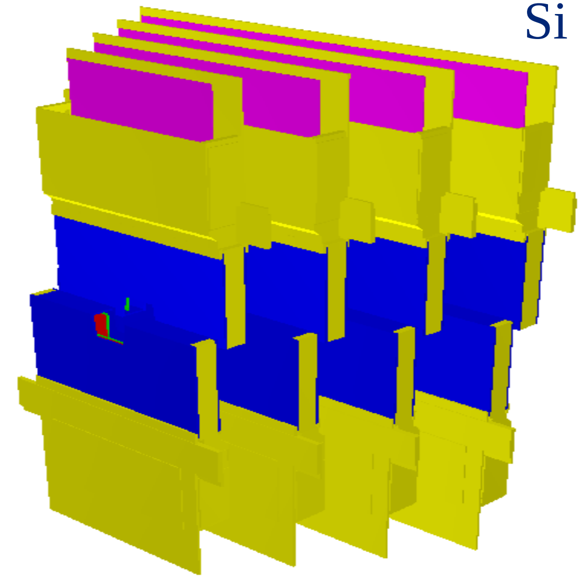
Detector geometry in Run 8

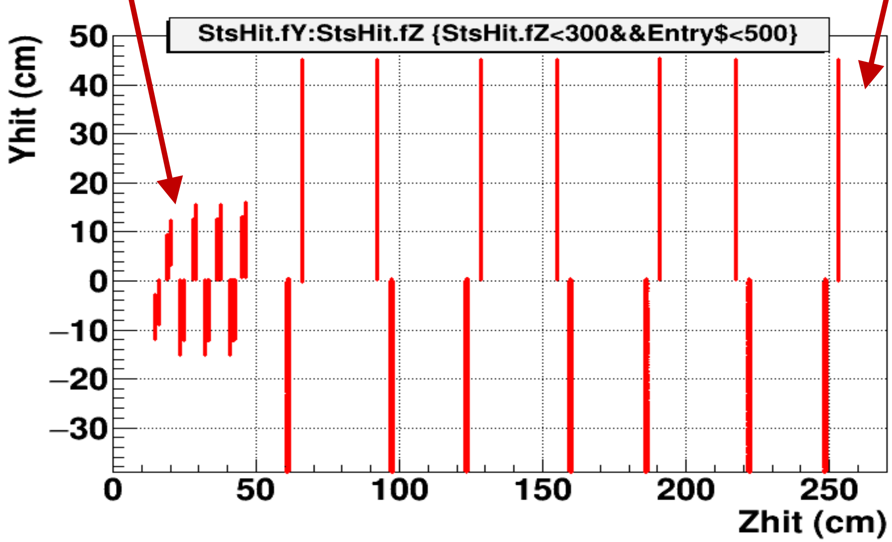
Si stations

GEMs

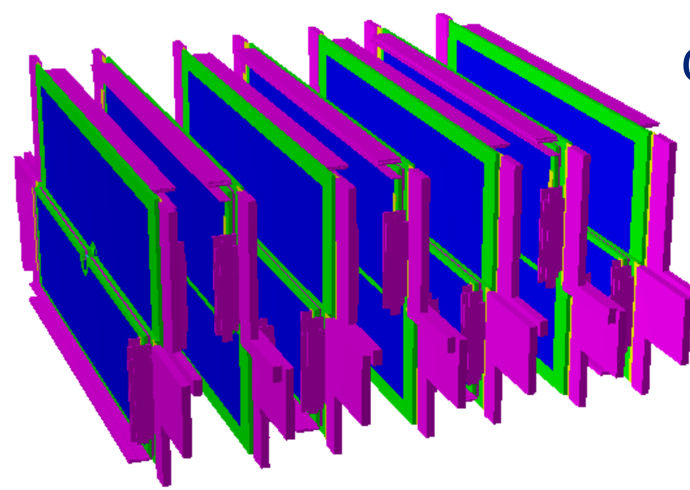


Si stations



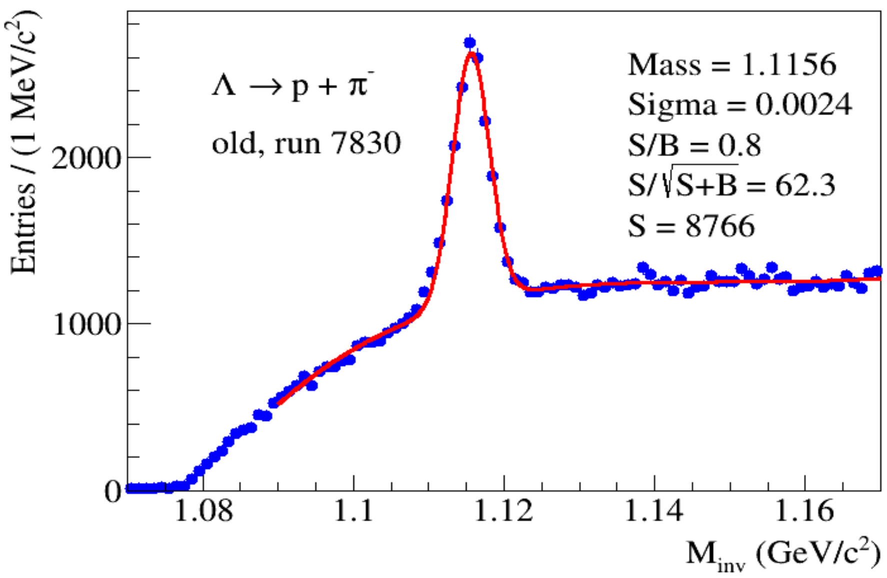


GEMs

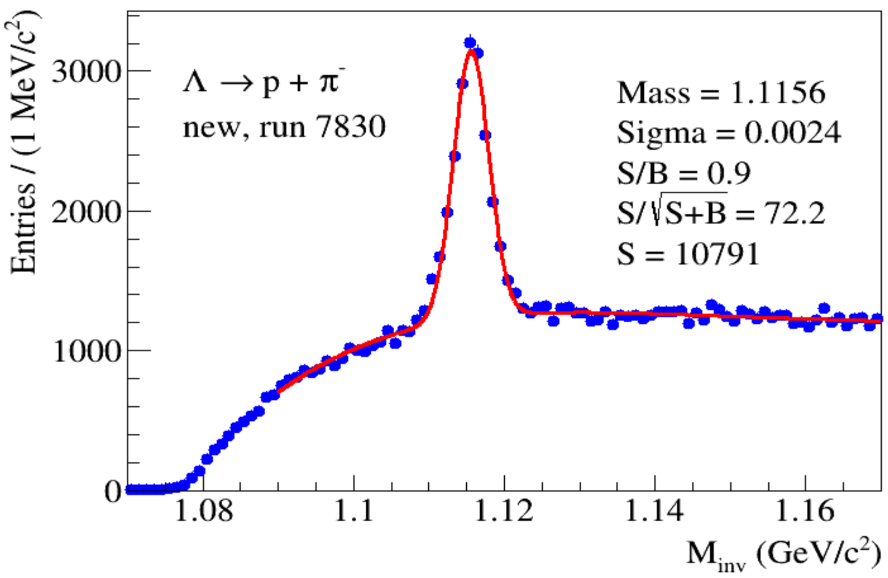


Λ selection: time evolution

Production: Dec. 2023

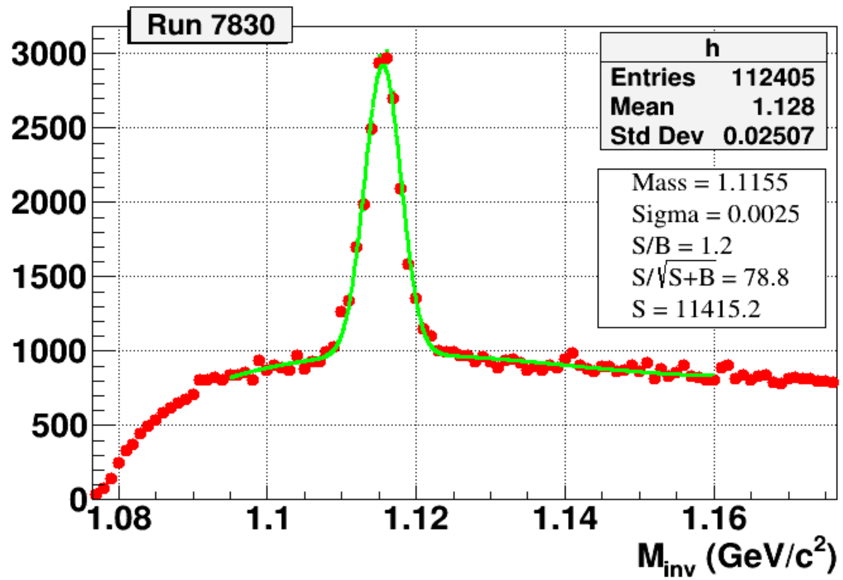


Production: Feb. 2024



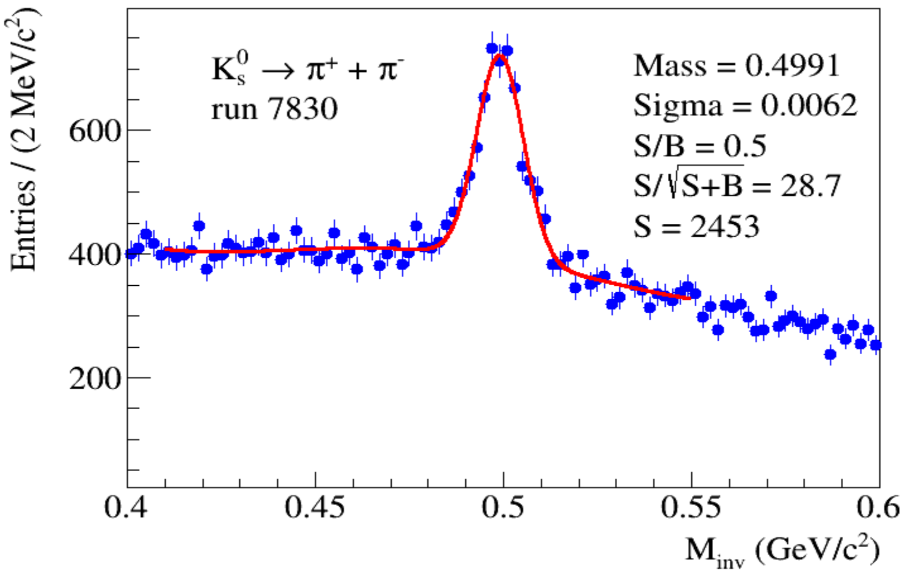
Production: Feb. 2024

Analysis: Aug. (4 cuts)

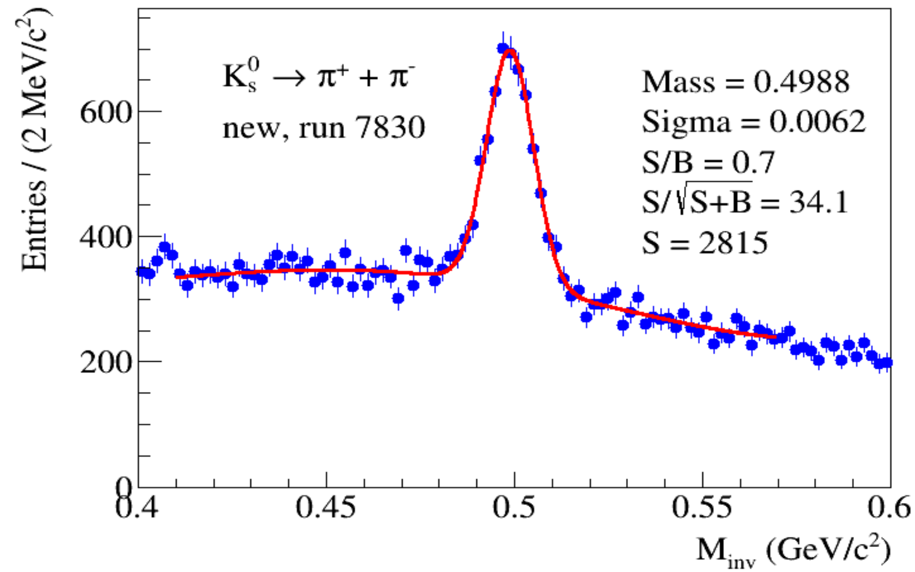


K^0_s selection: time evolution

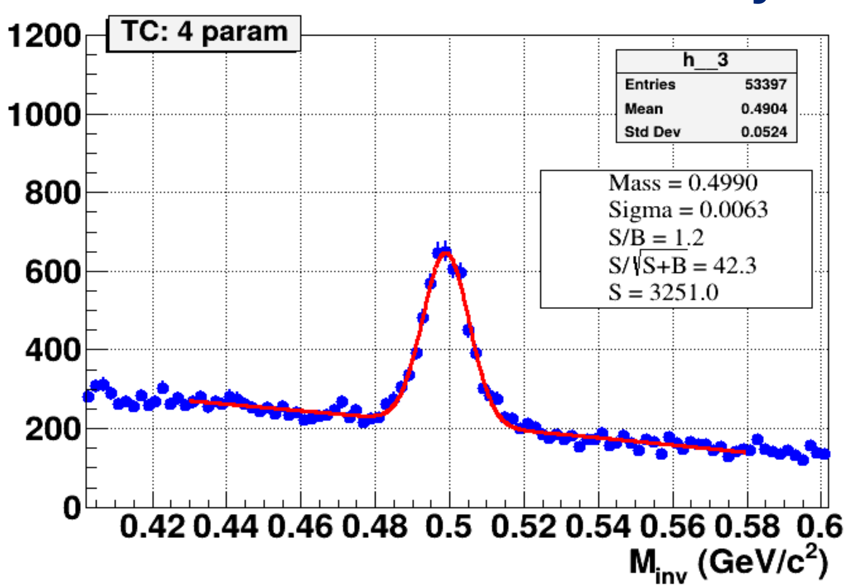
Production: Dec. 2023

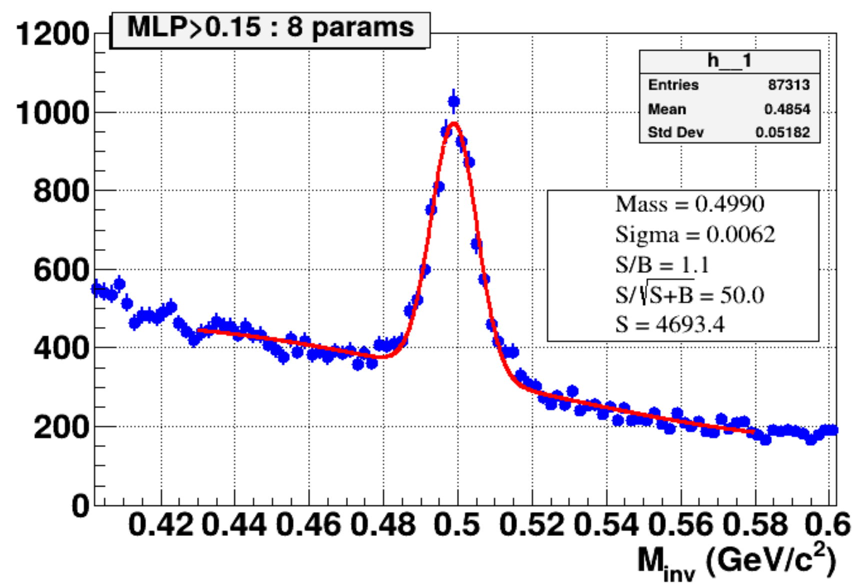


Production: Feb. 2024



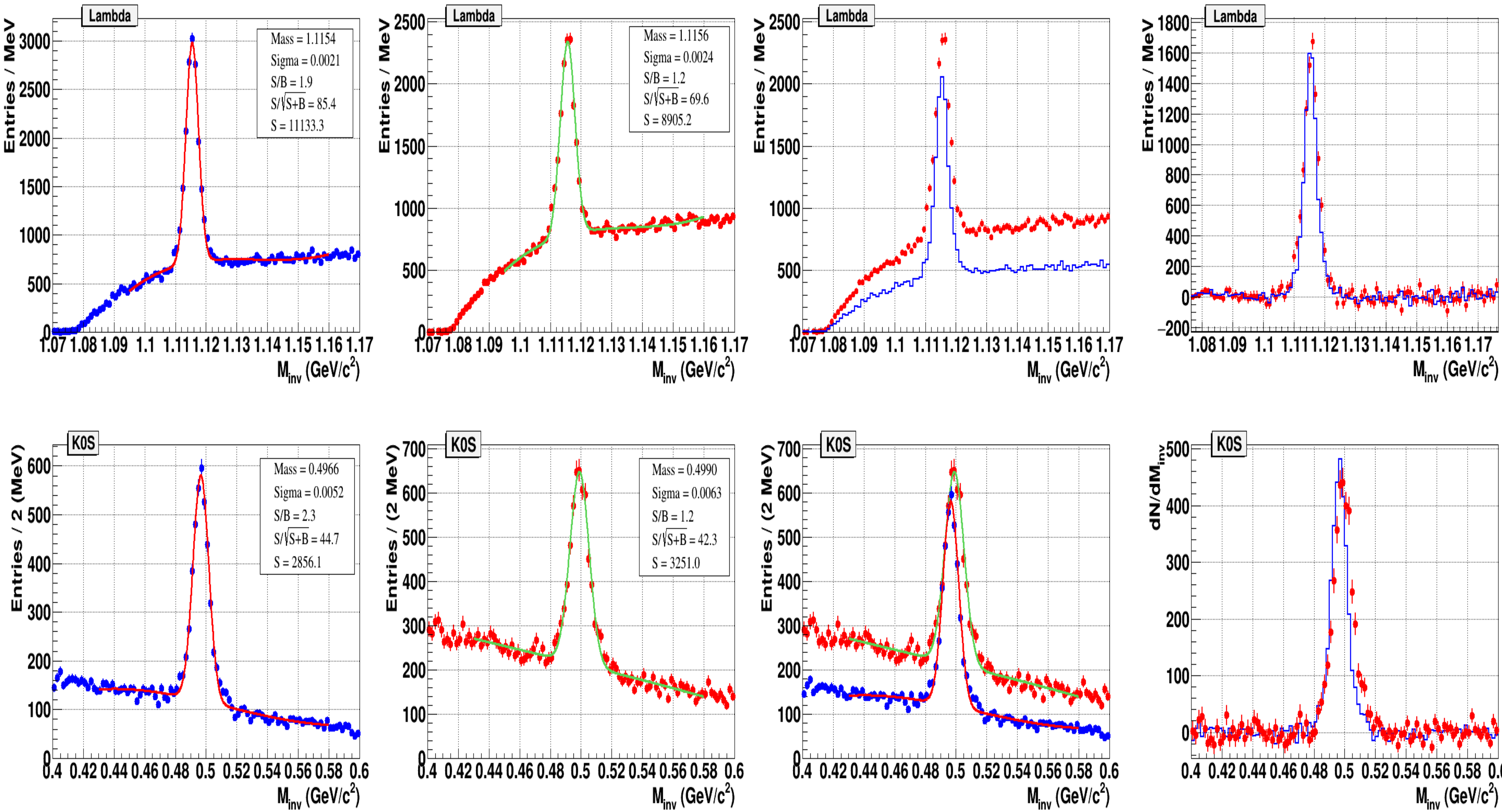
Production: Feb. 2024; **Analysis:** Aug. (4 cuts) & Oct. (MLP, 8 parameters)



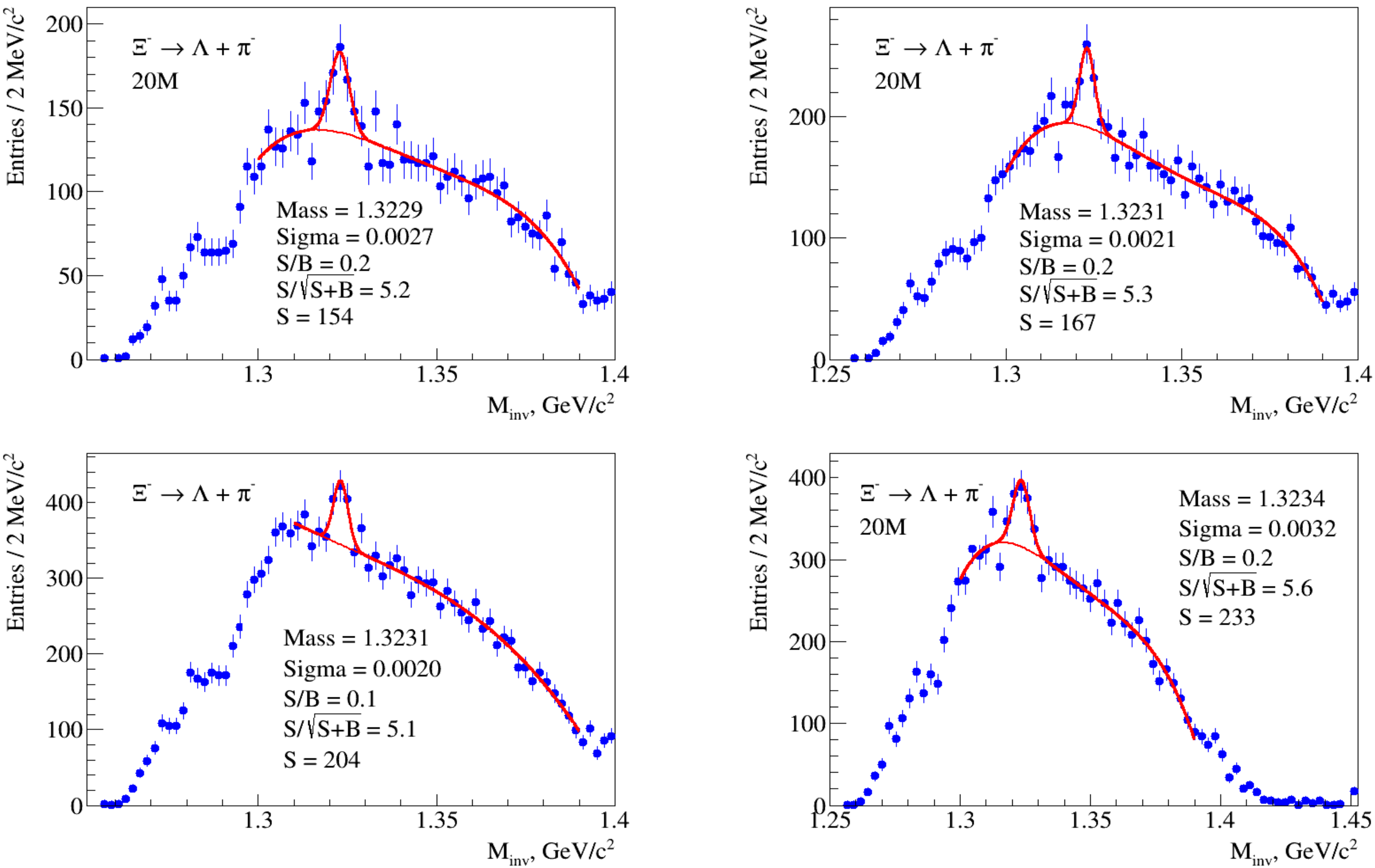


V0: Data vs MC

MC | Data | Data vs MC | Data vs MC



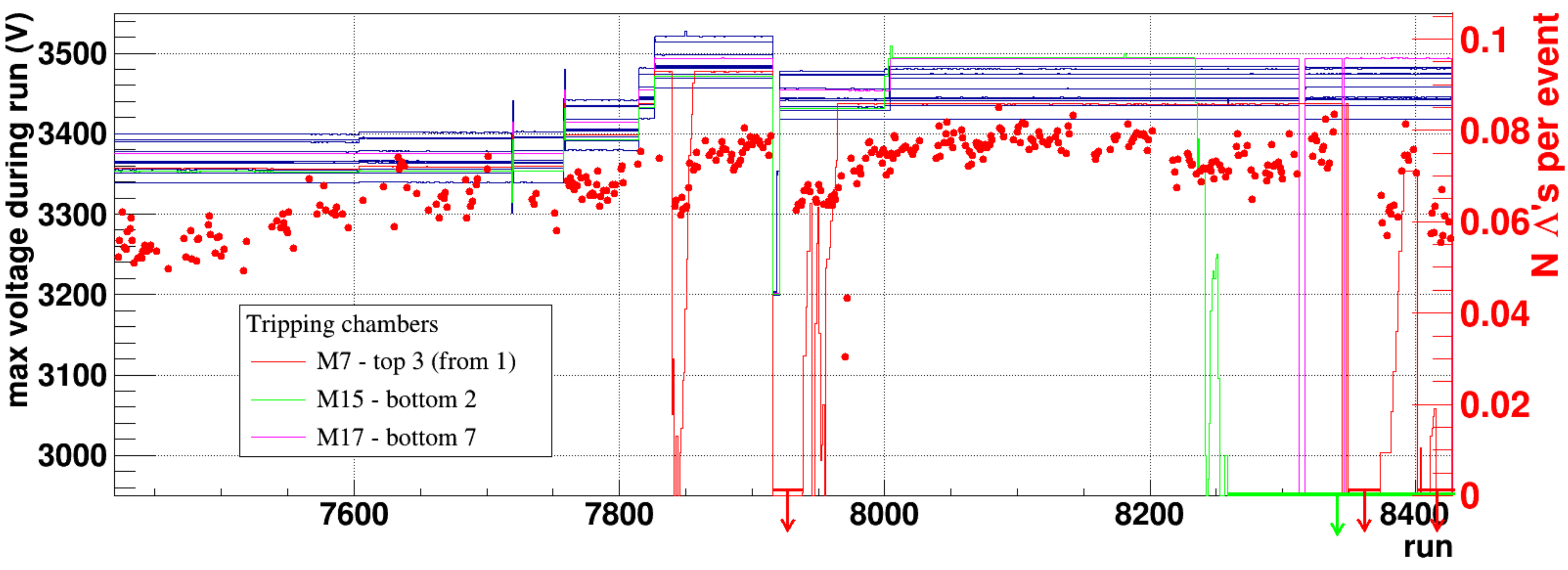
$\Xi^- \rightarrow \Lambda + \pi^-$, Data (20M events)



Run quality checking

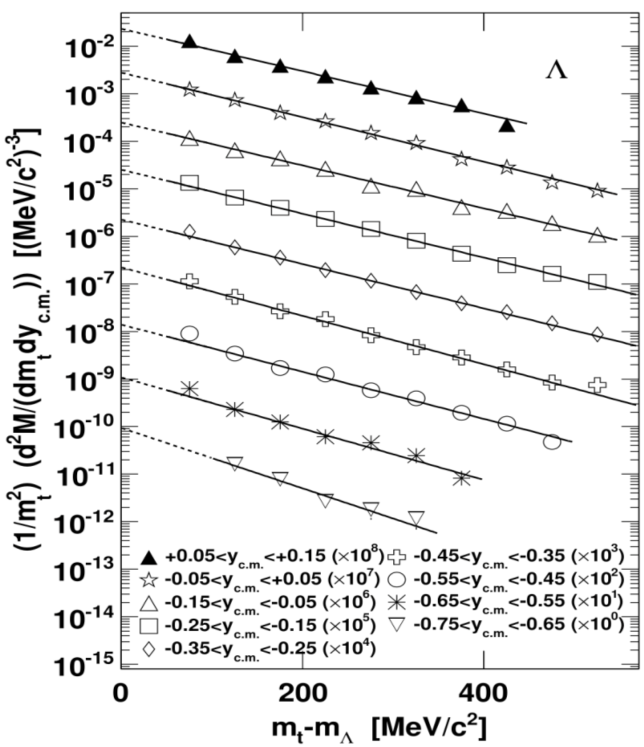
"Golden" runs:

7830, 7873, 7876, 7877, 7878, 7880, 7885, 7886, 7887, 7890, 7891, 7892, 7893, 7894, 7896, 7897, 7899, 7900, 7901, 7903, 7904, 7905, 7906, 7908, 7911, 7912, 7913, 7914 ~ 30M events

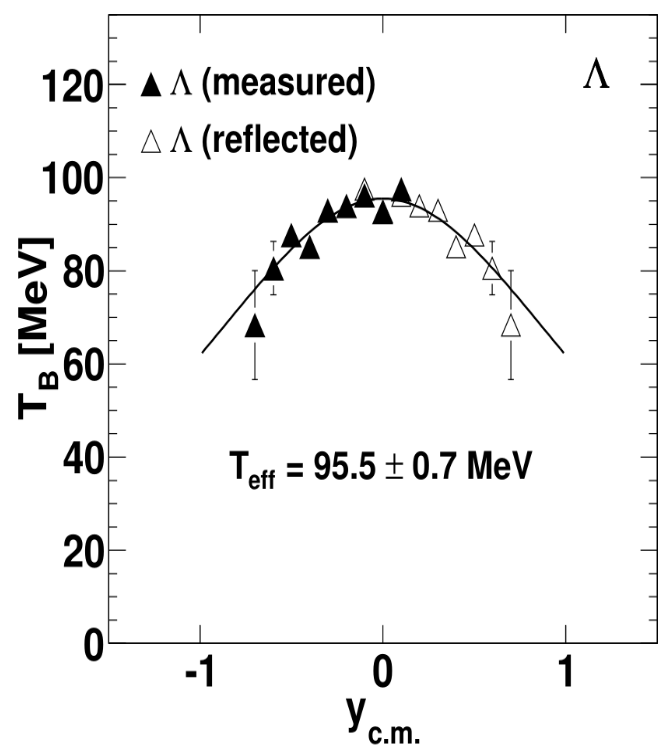


HADES strangeness production studies

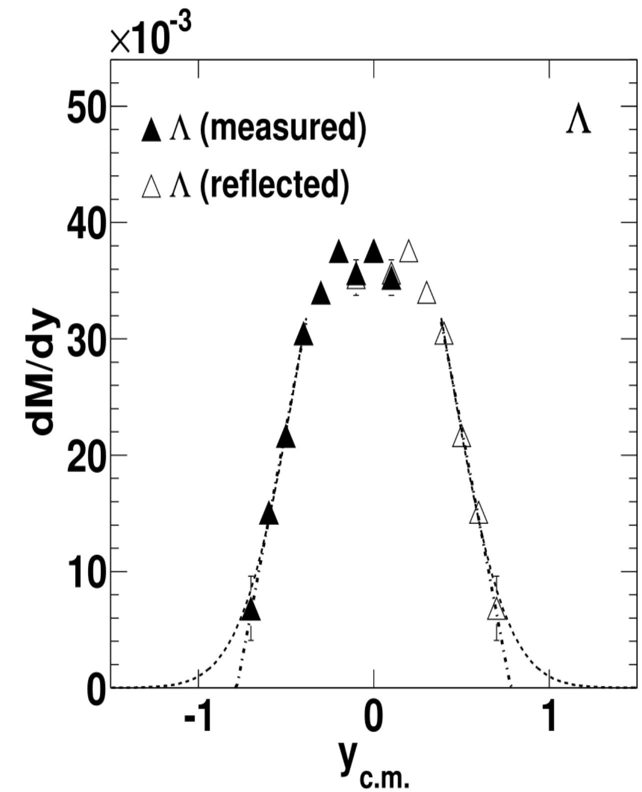
“Hyperon production in Ar+KCl collisions at 1.76A GeV”



Λ m_T–spectra



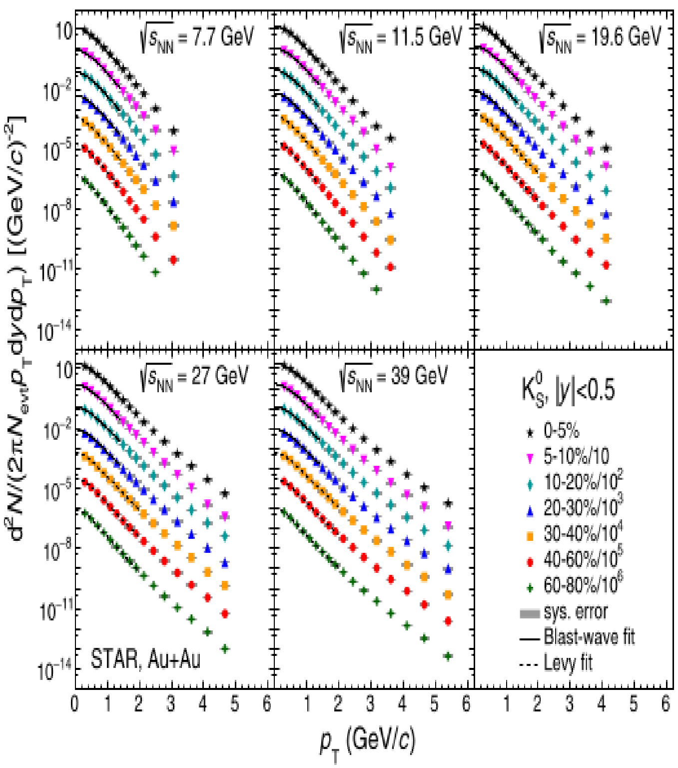
T_{eff} vs y



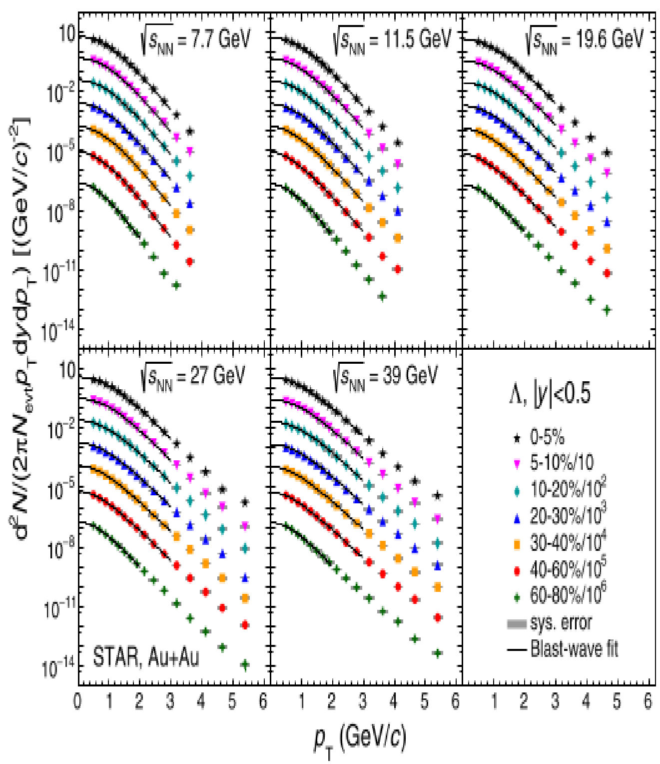
Λ y-spectrum

STAR strangeness production studies

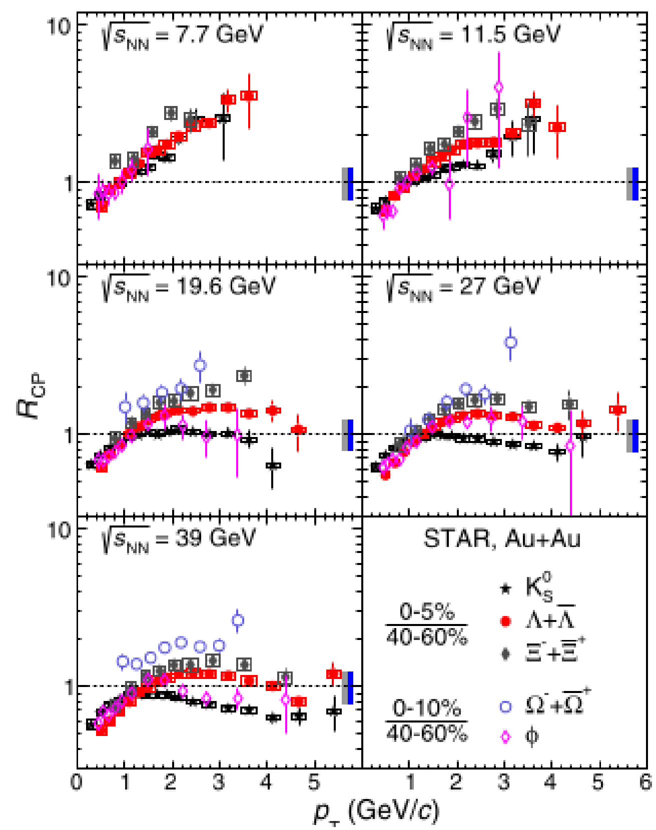
“Strange hadron production in Au + Au collisions at $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27, and 39 GeV”



K^0_s p_T–spectra



Λ p_T-spectra

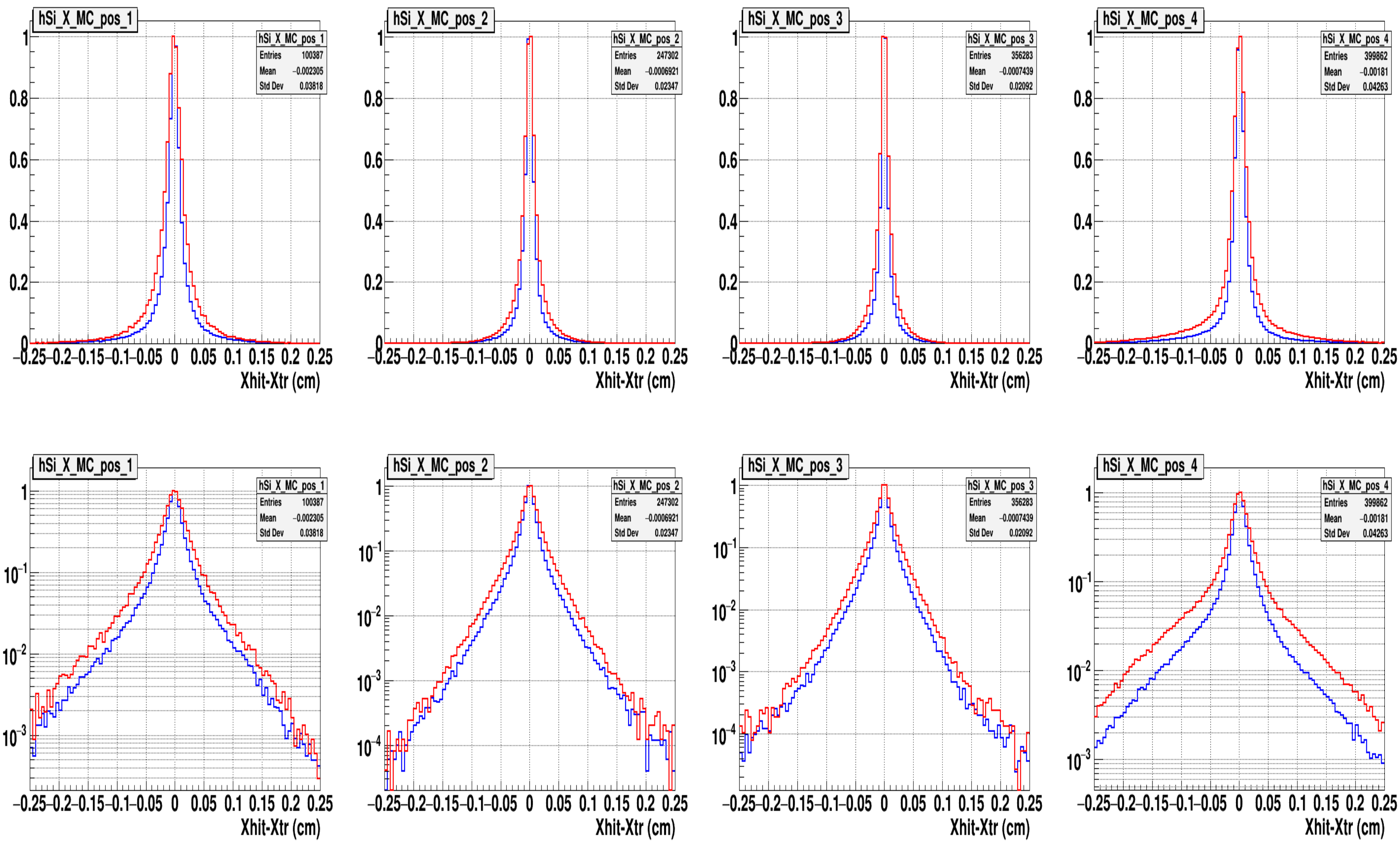


$$R_{CP} = \frac{[(dN/dp_T)/\langle N_{coll}\rangle]_{central}}{[(dN/dp_T)/\langle N_{coll}\rangle]_{peripheral}}.$$

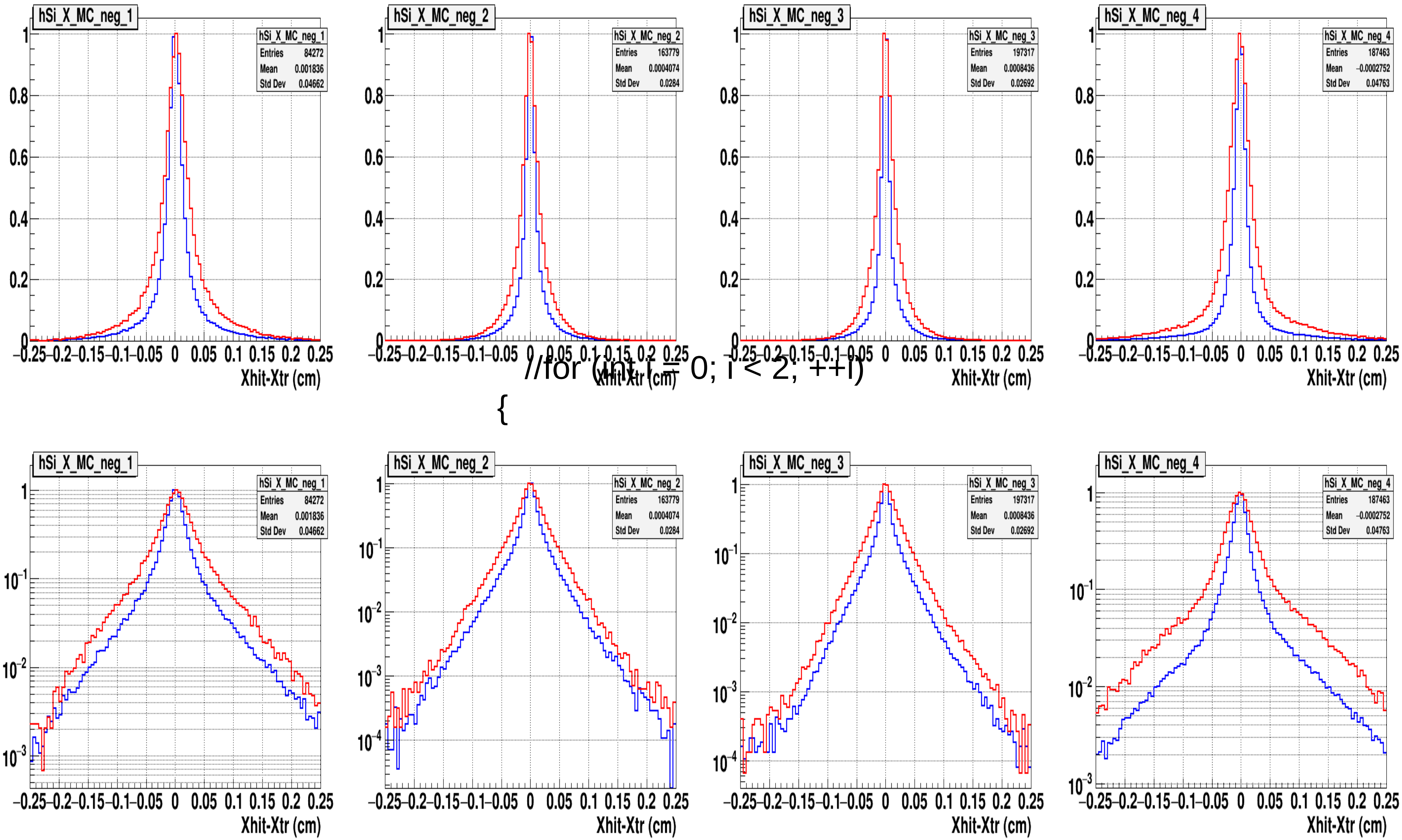
Monte Carlo tuning

Before corrections

X-residuals in Silicon (q > 0)

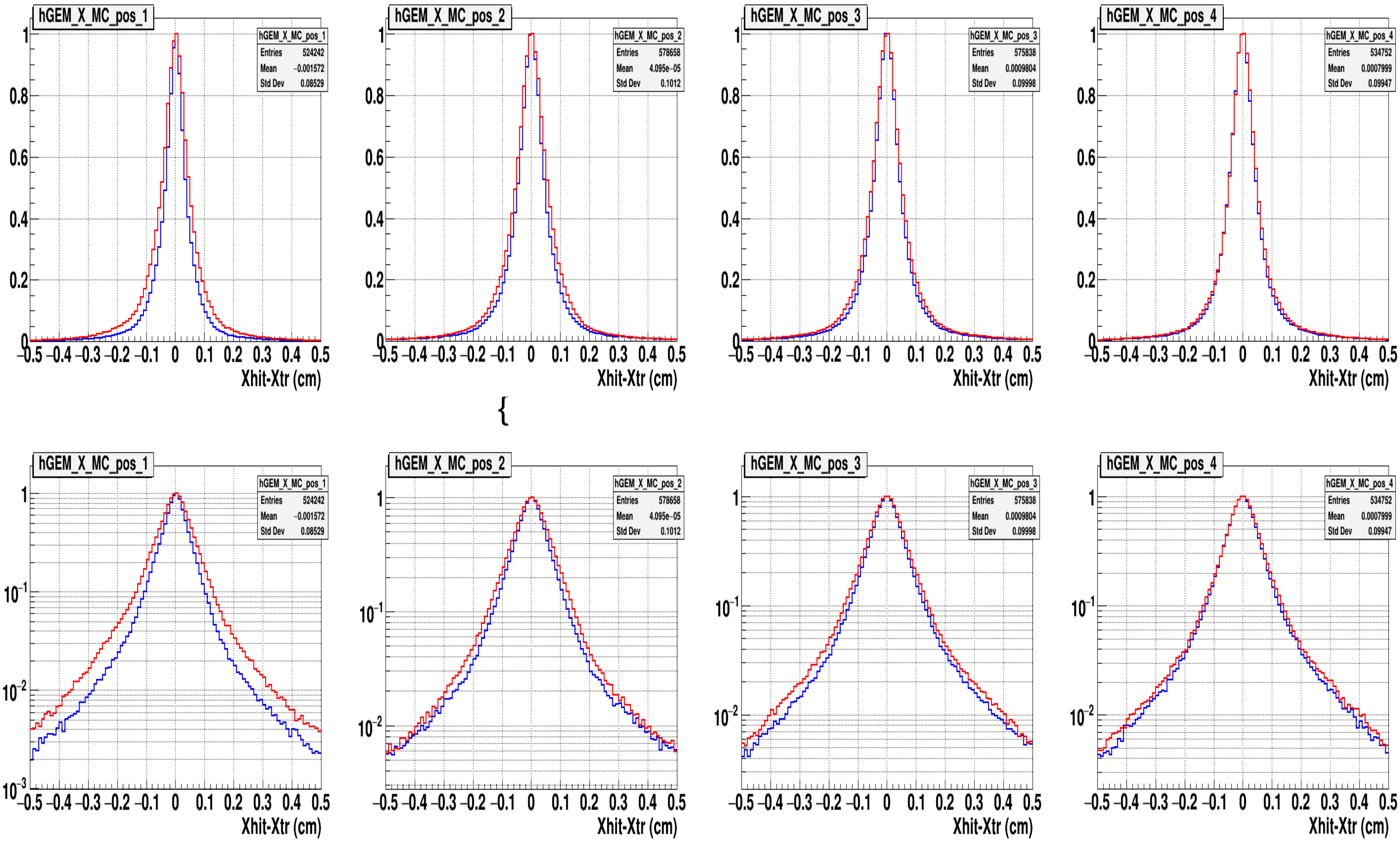


X-residuals in Silicon (q < 0)

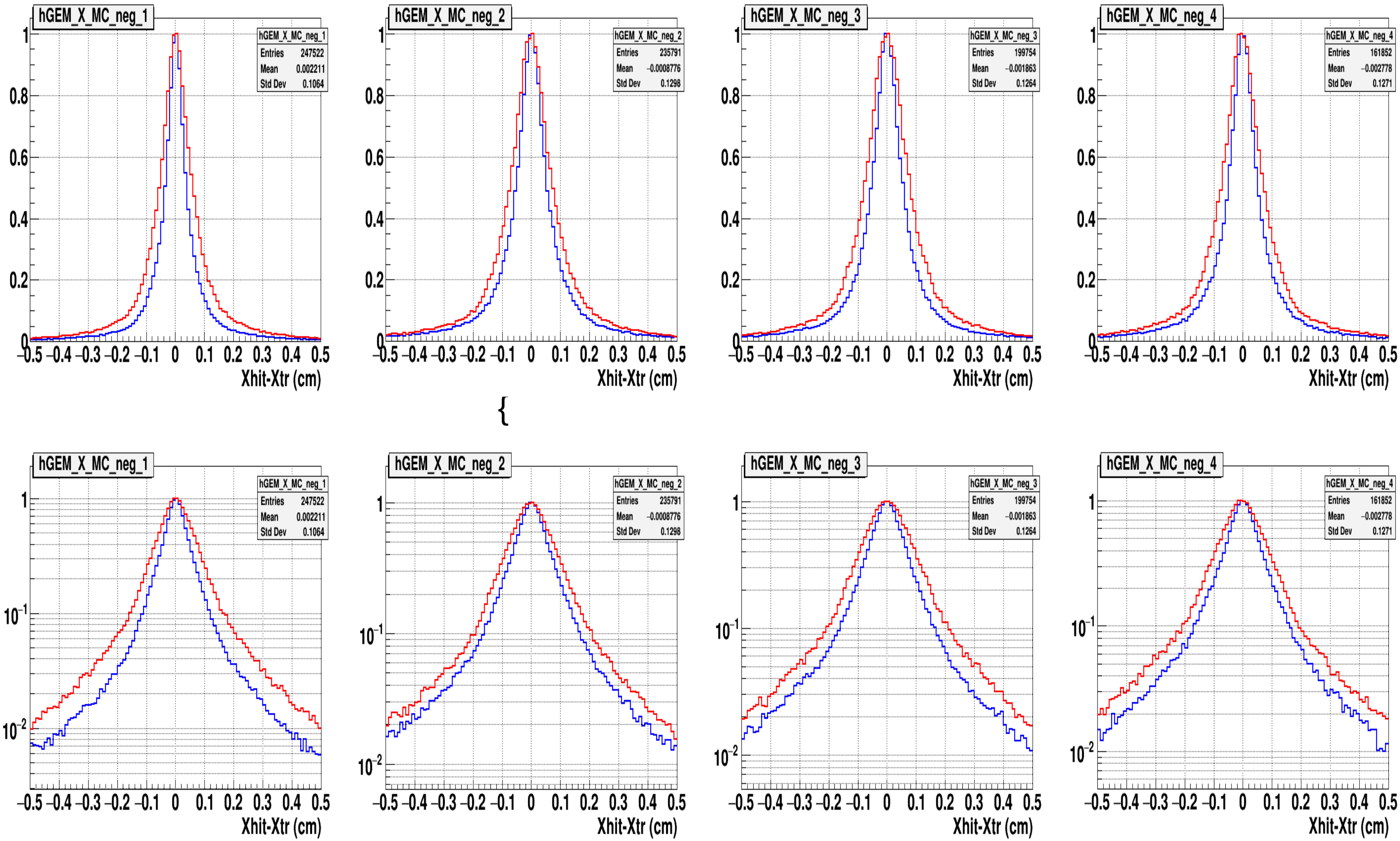


//for (int i = 0; i < 2; ++i)
{

X-residuals in GEM (q > 0)

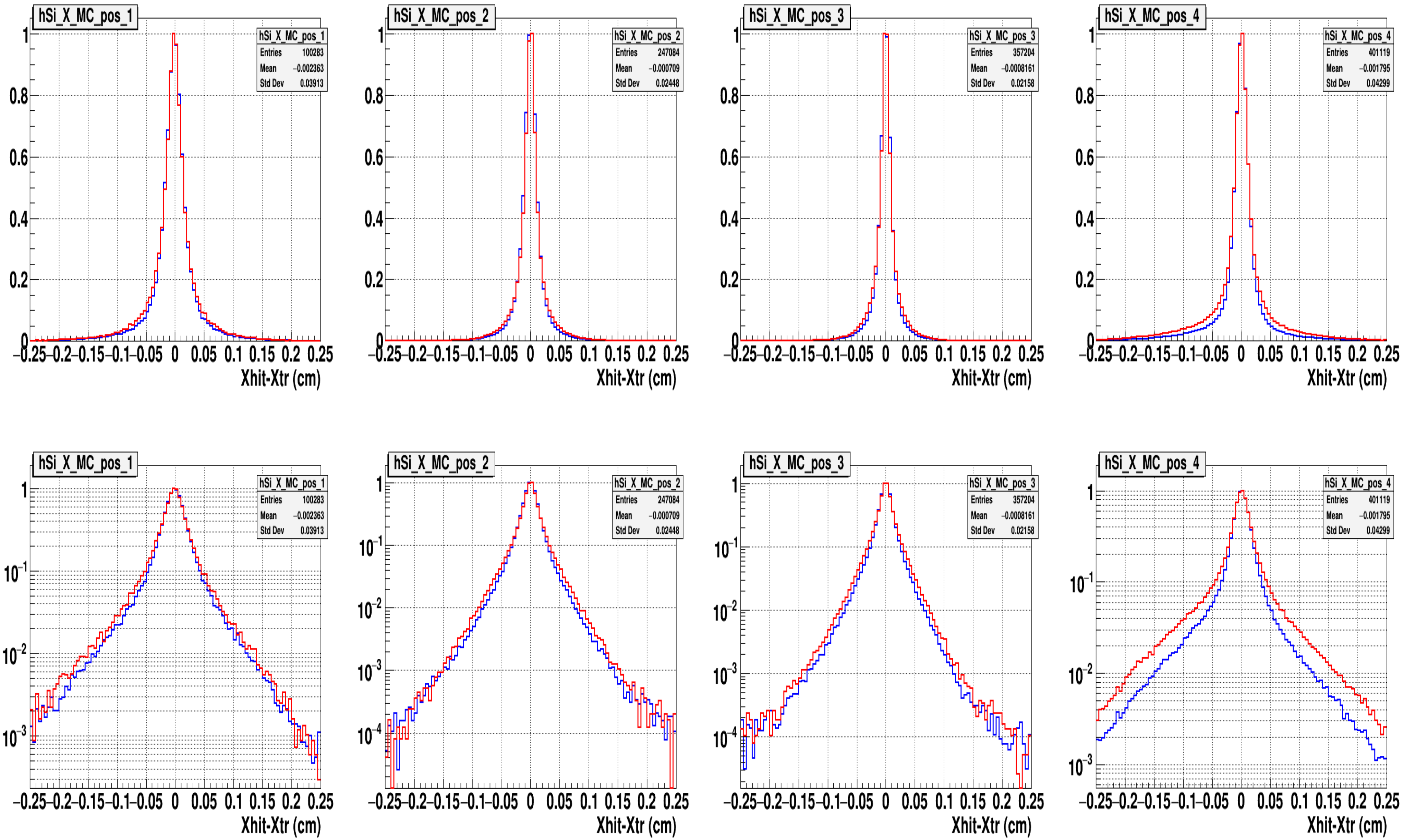


X-residuals in GEM (q < 0)

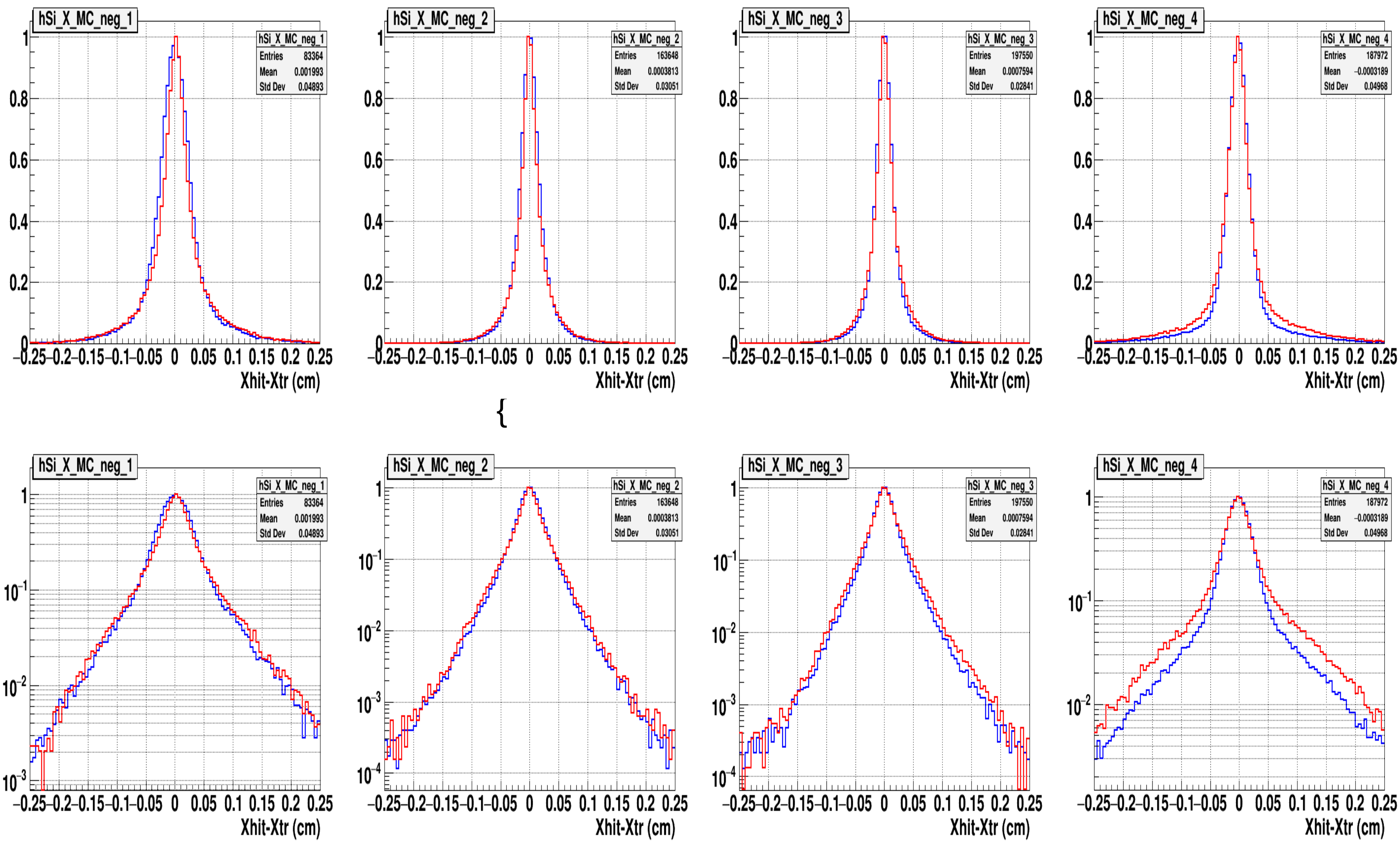


After corrections

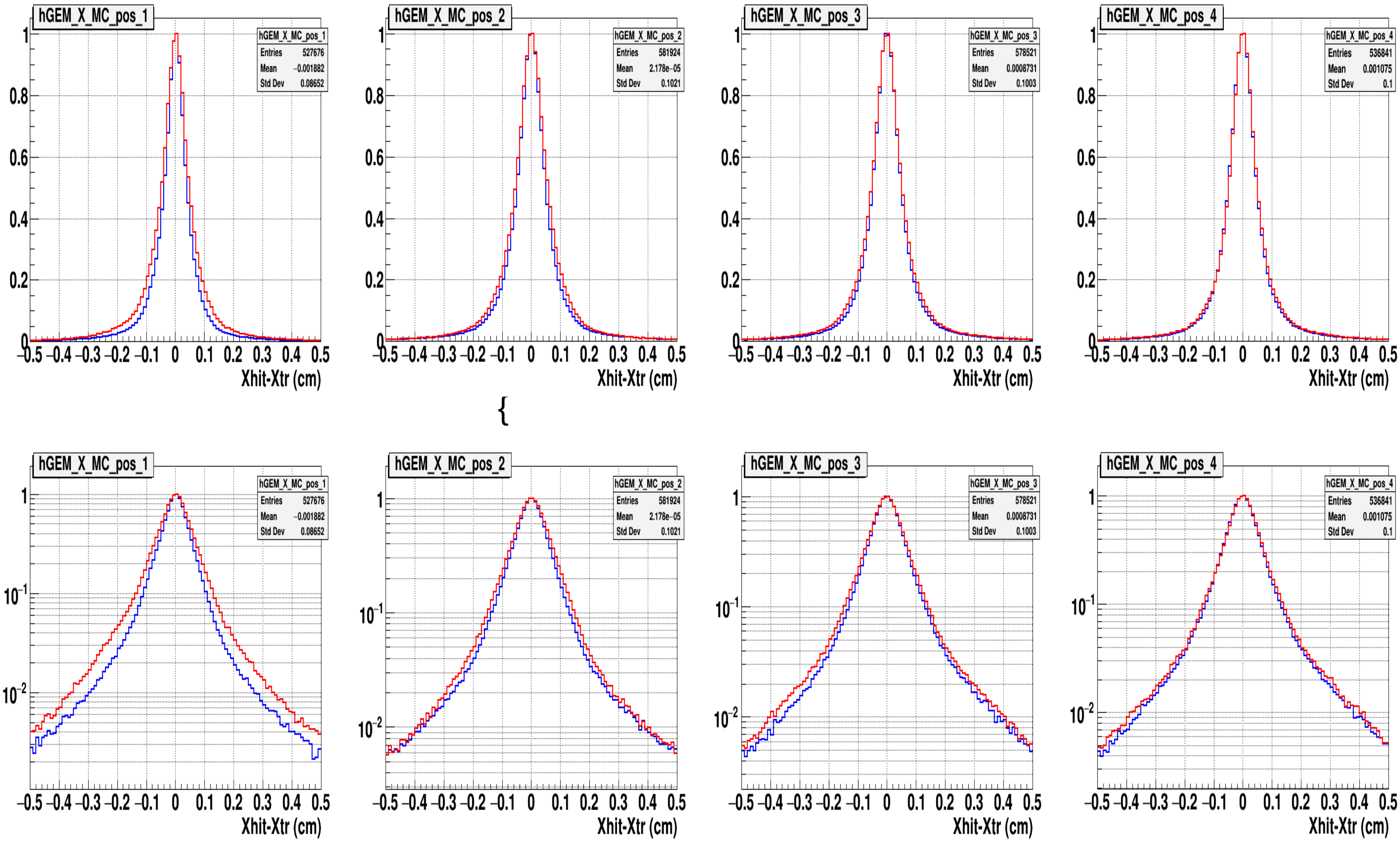
X-residuals in Silicon (q > 0)



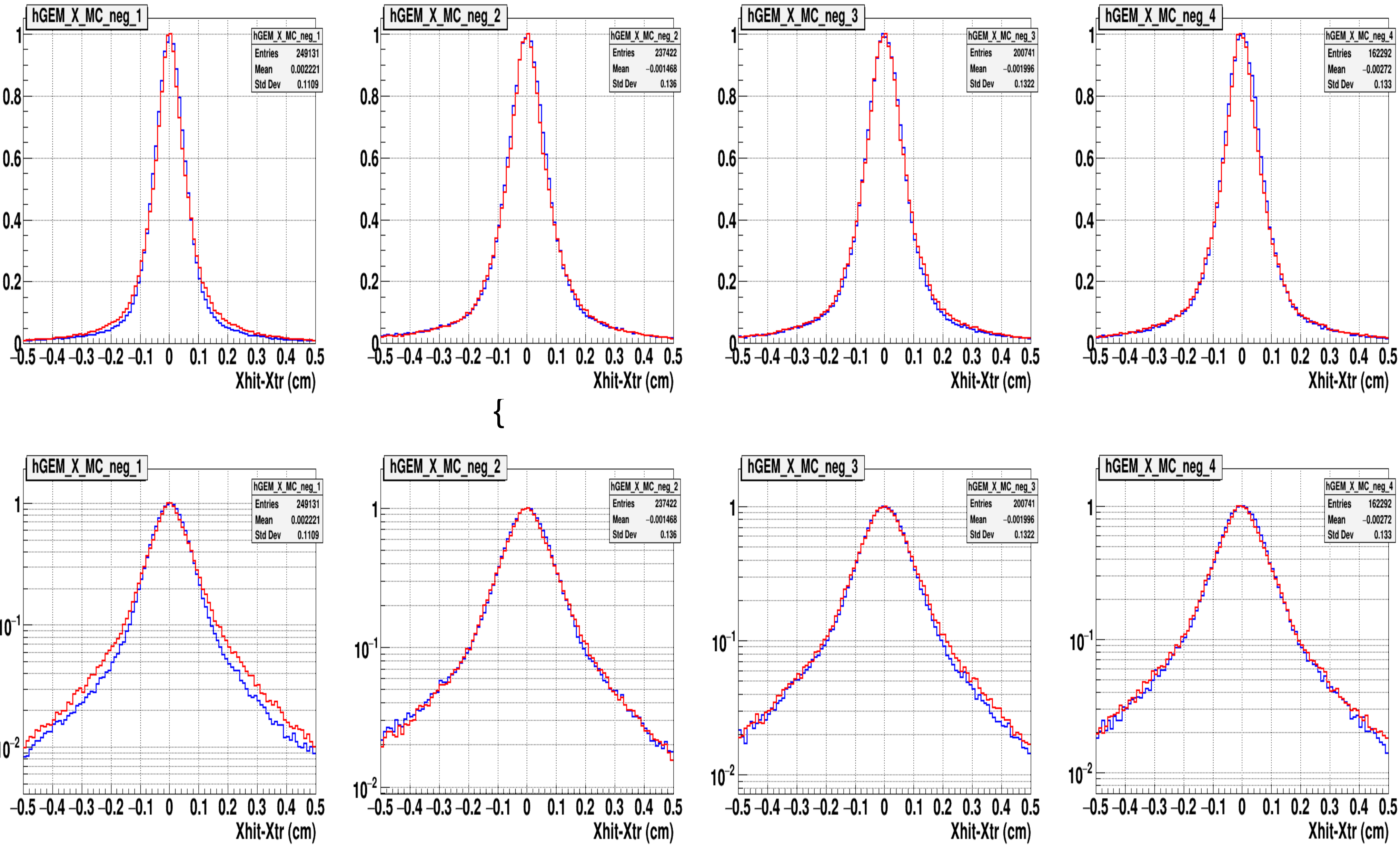
X-residuals in Silicon (q < 0)



X-residuals in GEM (q > 0)

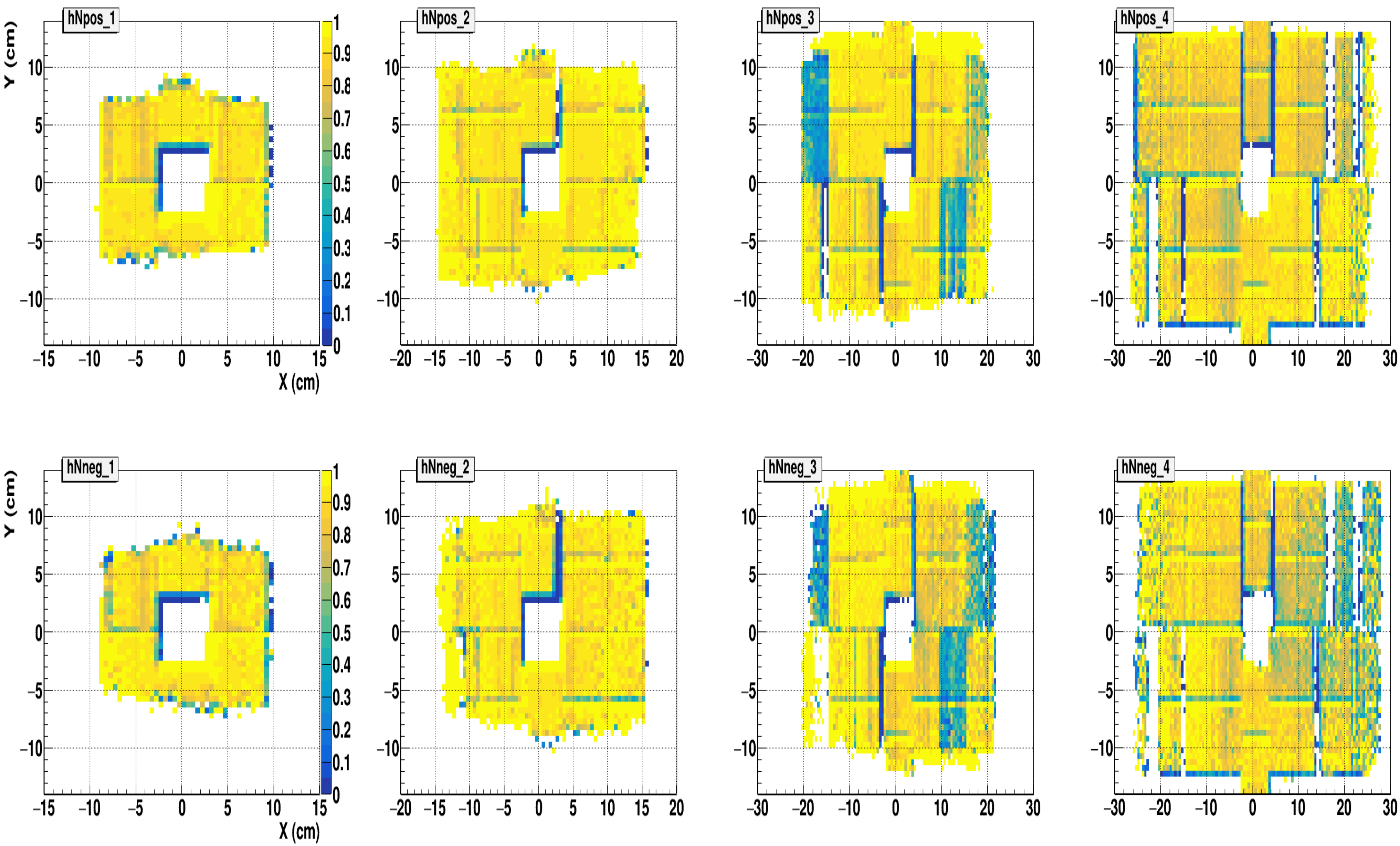


X-residuals in GEM (q < 0)

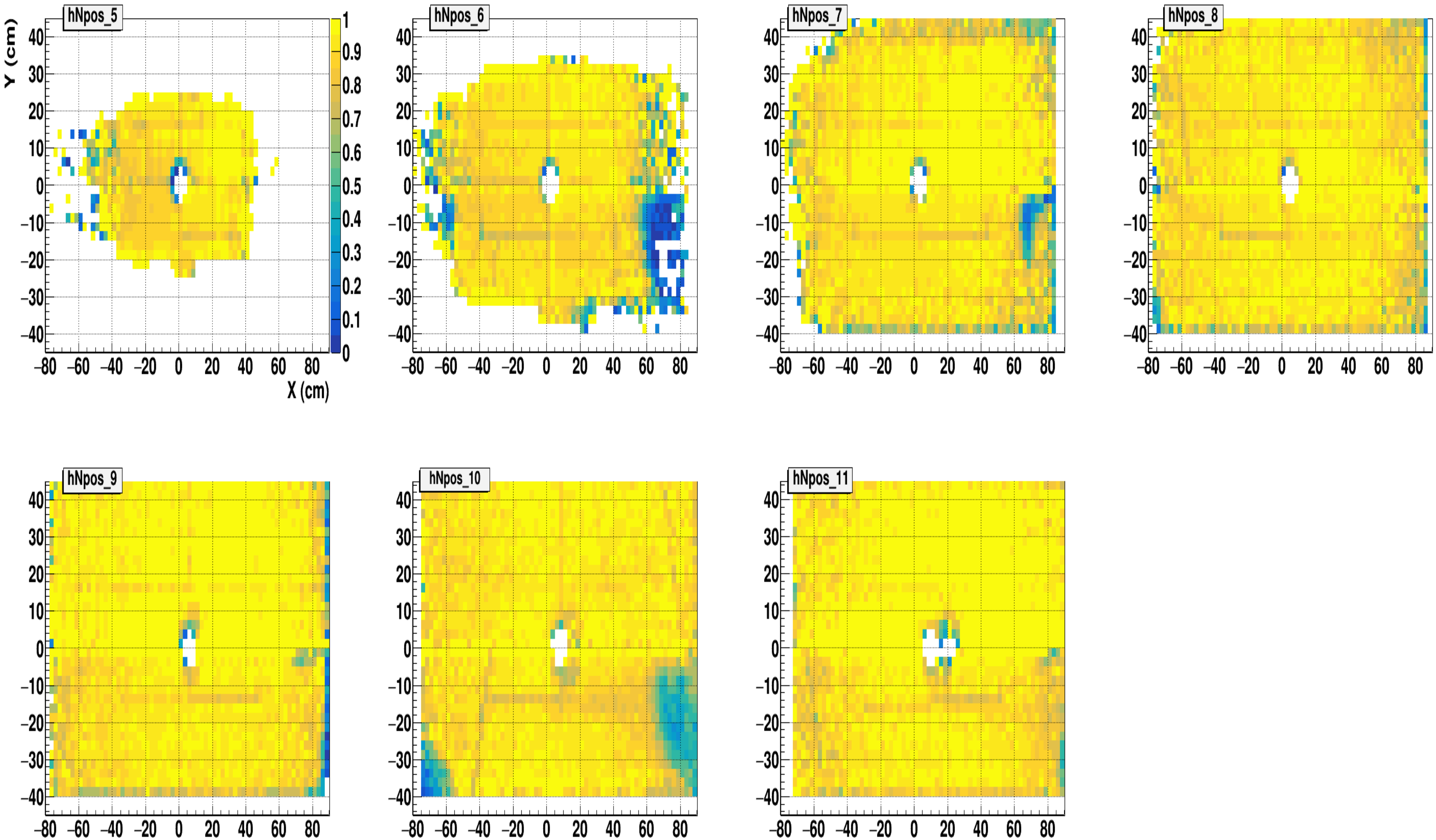


Station efficiency

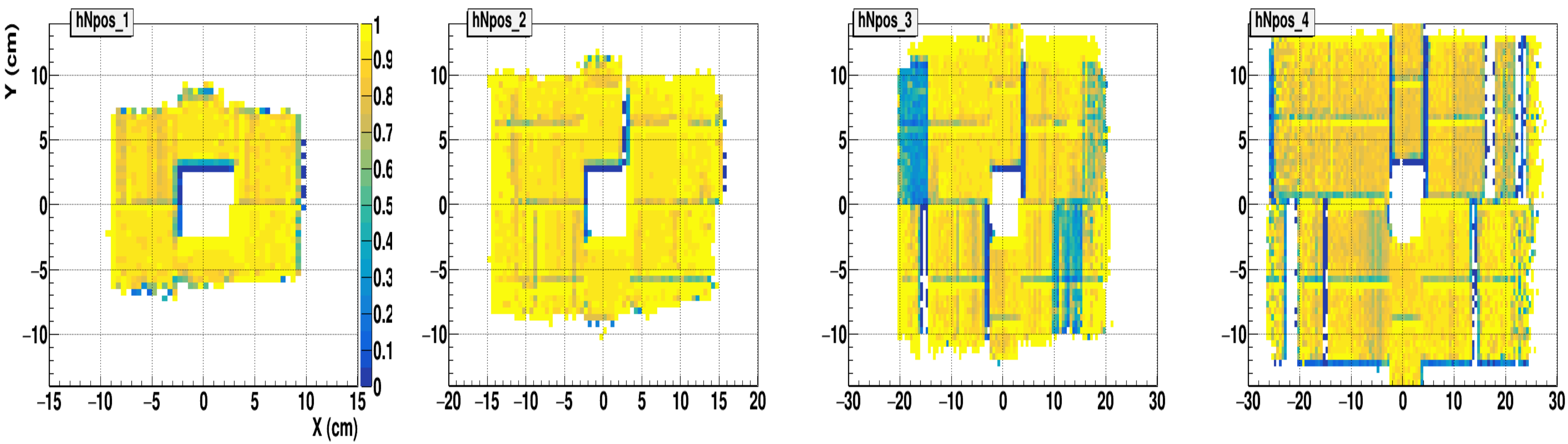
Station efficiencies: Si



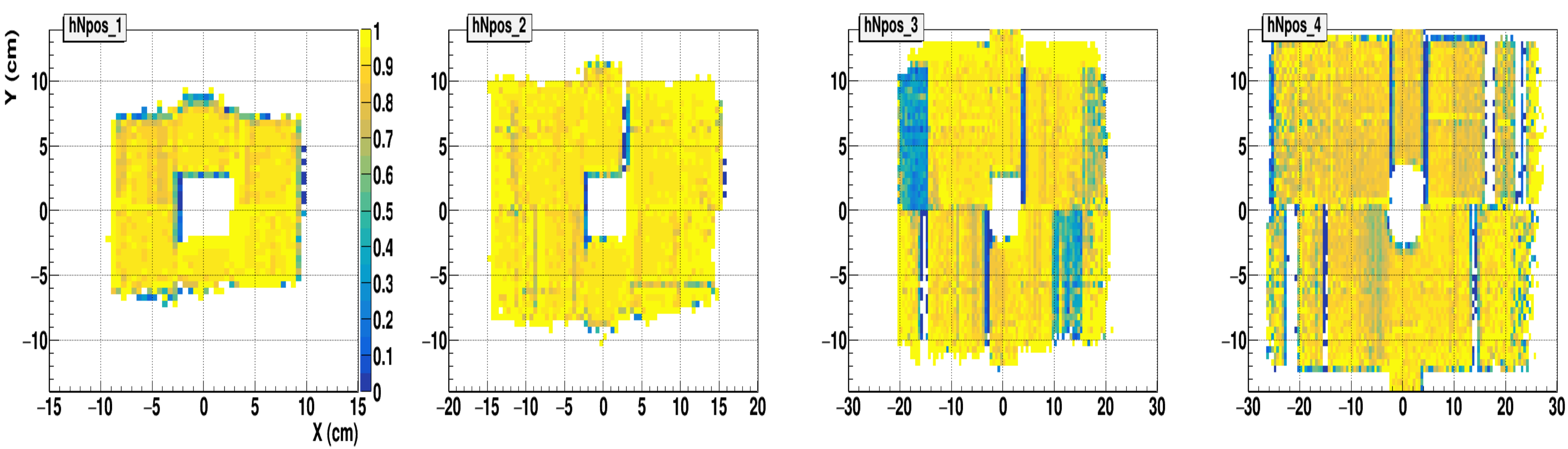
Station efficiencies: GEM



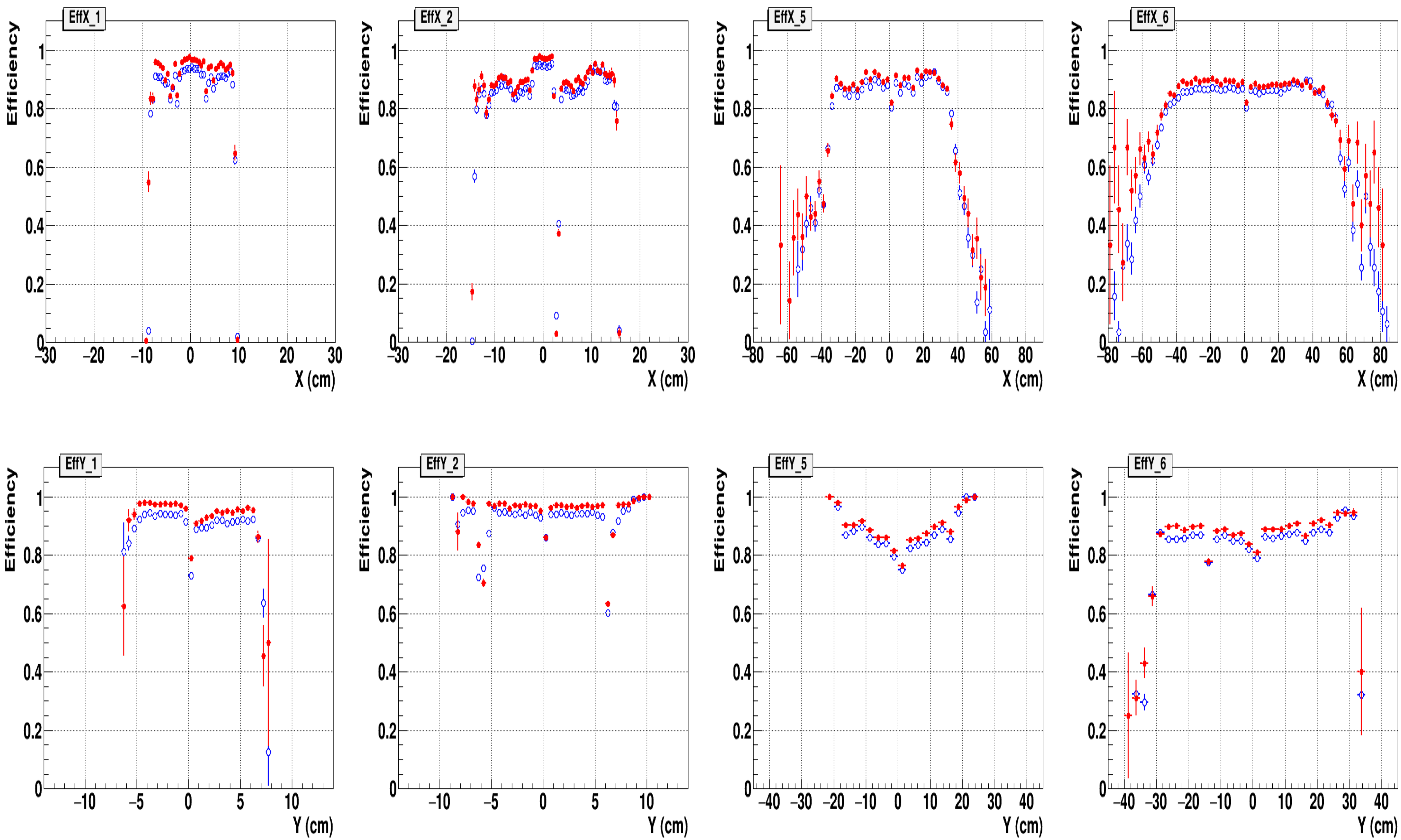
Station efficiencies: Si



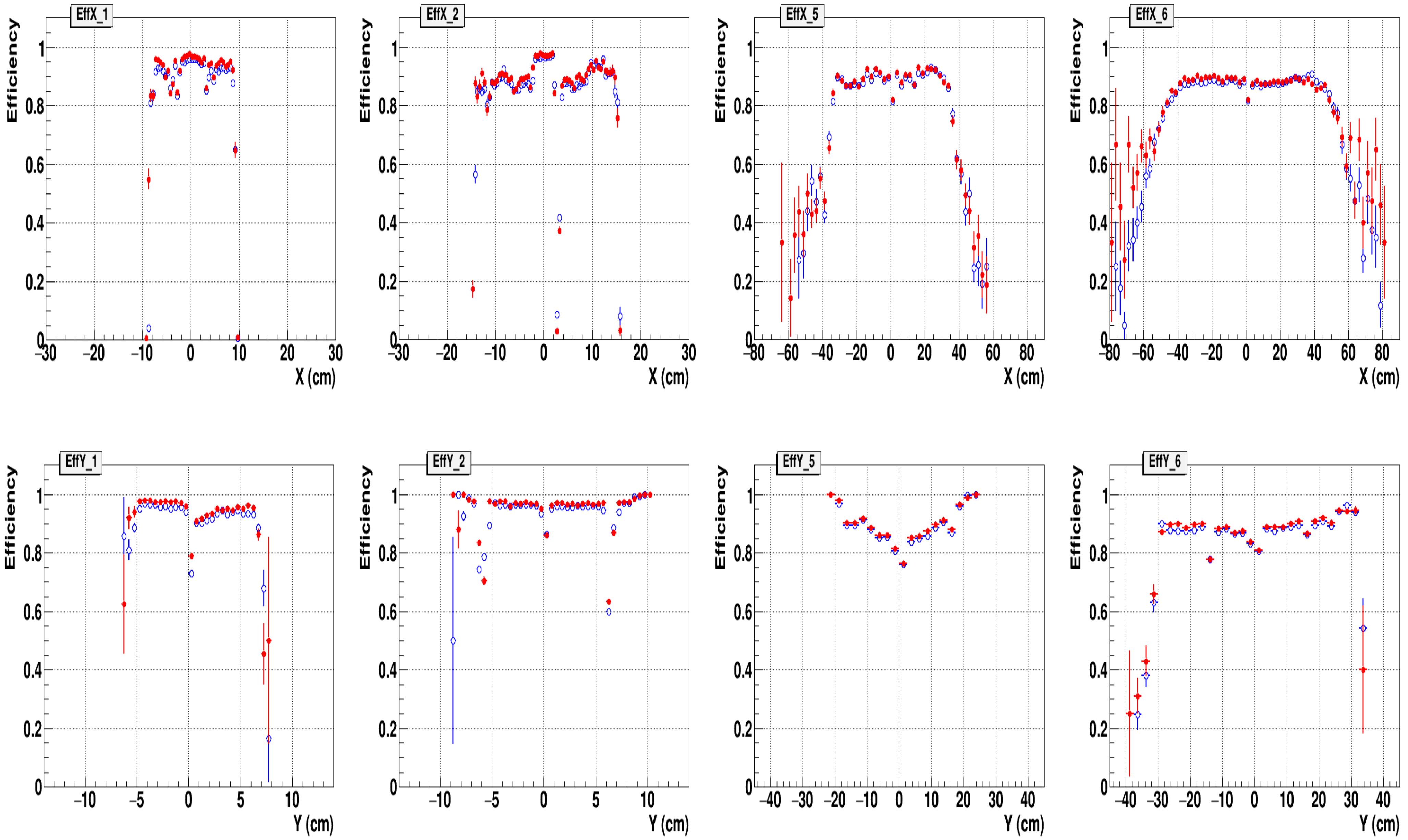
Shift hits in Y by 3 mm



Station efficiency (hits on tracks)



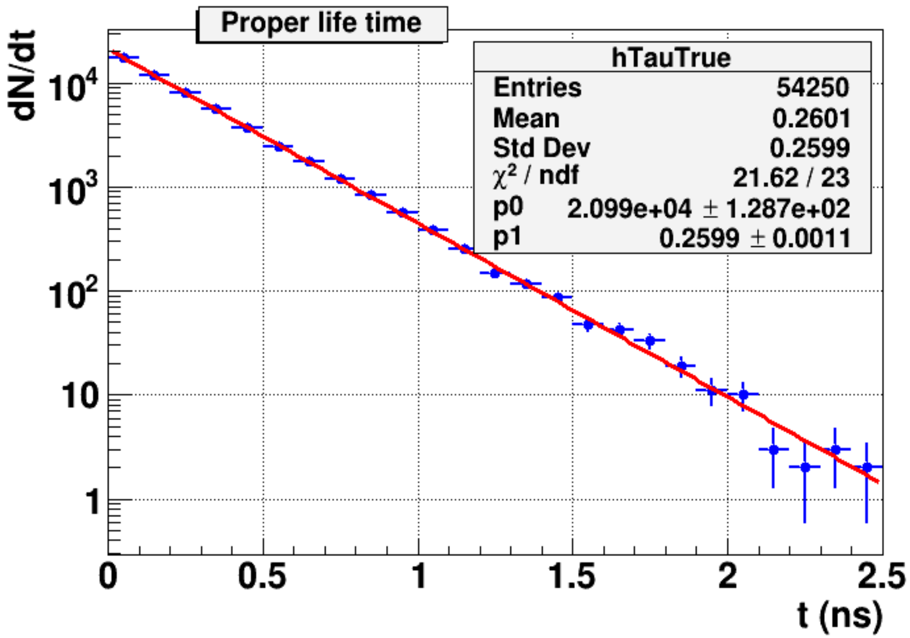
Detector efficiency (hits on tracks)

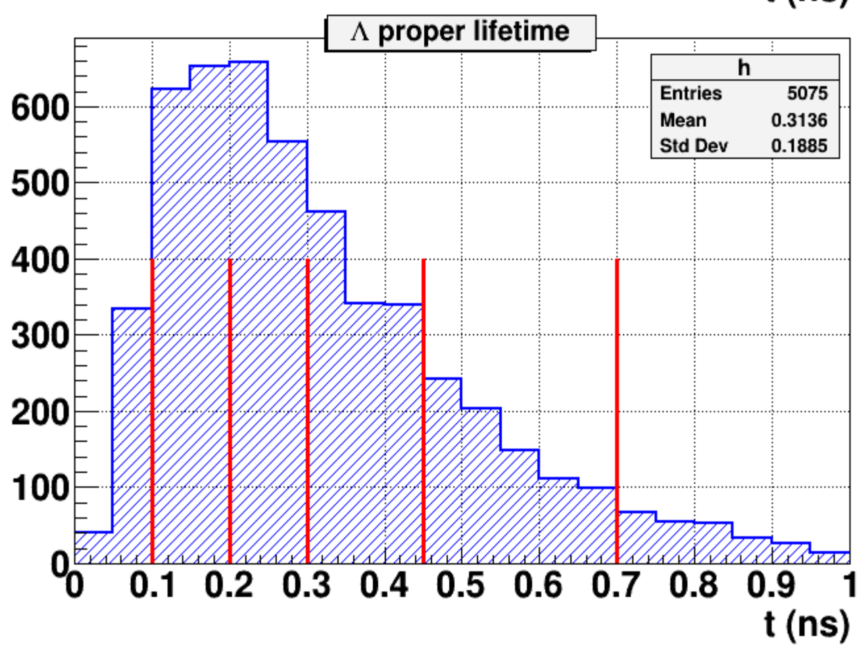


Lambda

This material was a part of Roman Zinchenko's magister thesis

Lifetime of Λ: MC





Decay formula:

$dN / dt = N_0 / \tau * exp(-t/\tau)$,

$N_0 = p0 * p1 = 54574$

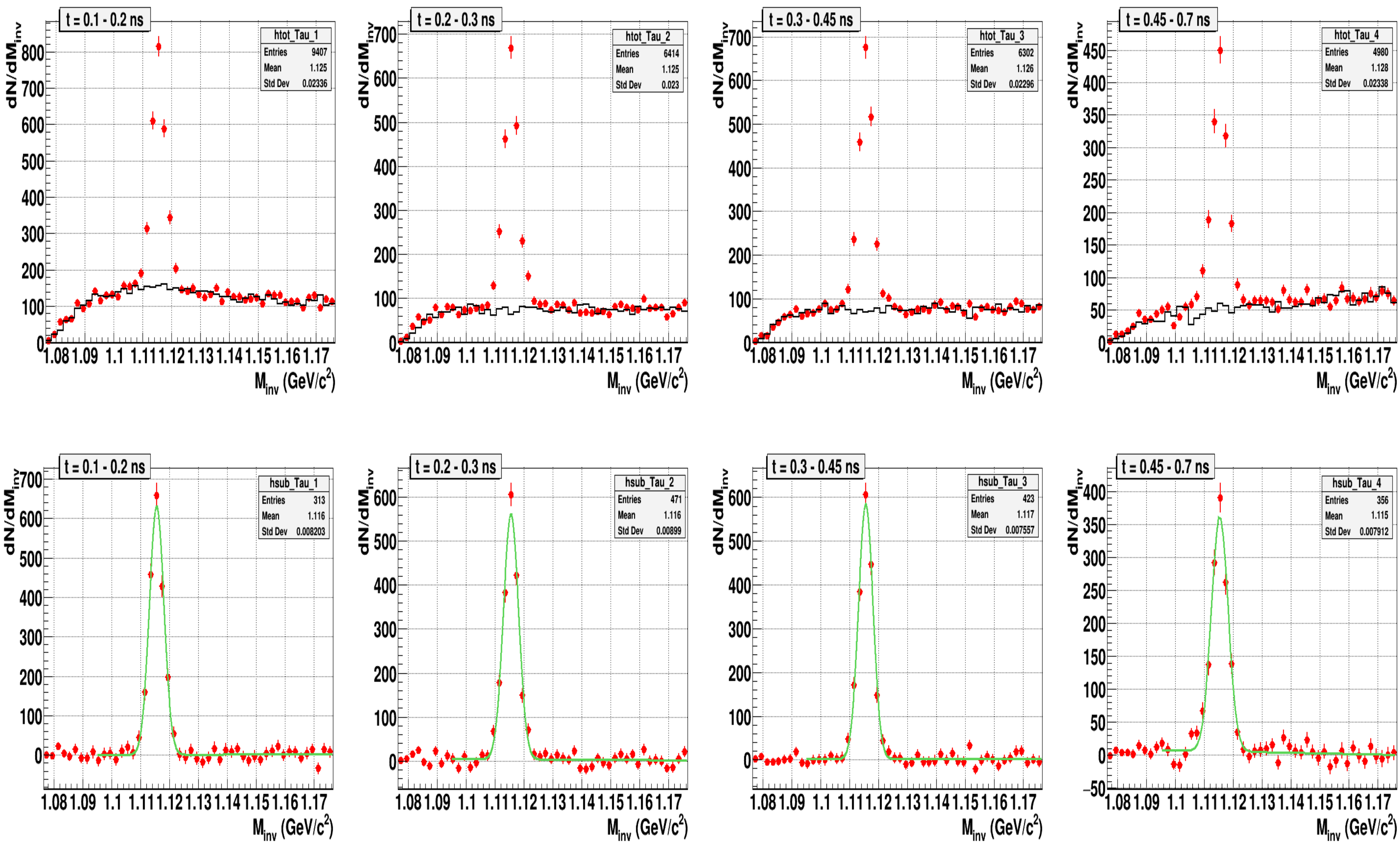
Proper life time:

$\tau = lm / (pc)$

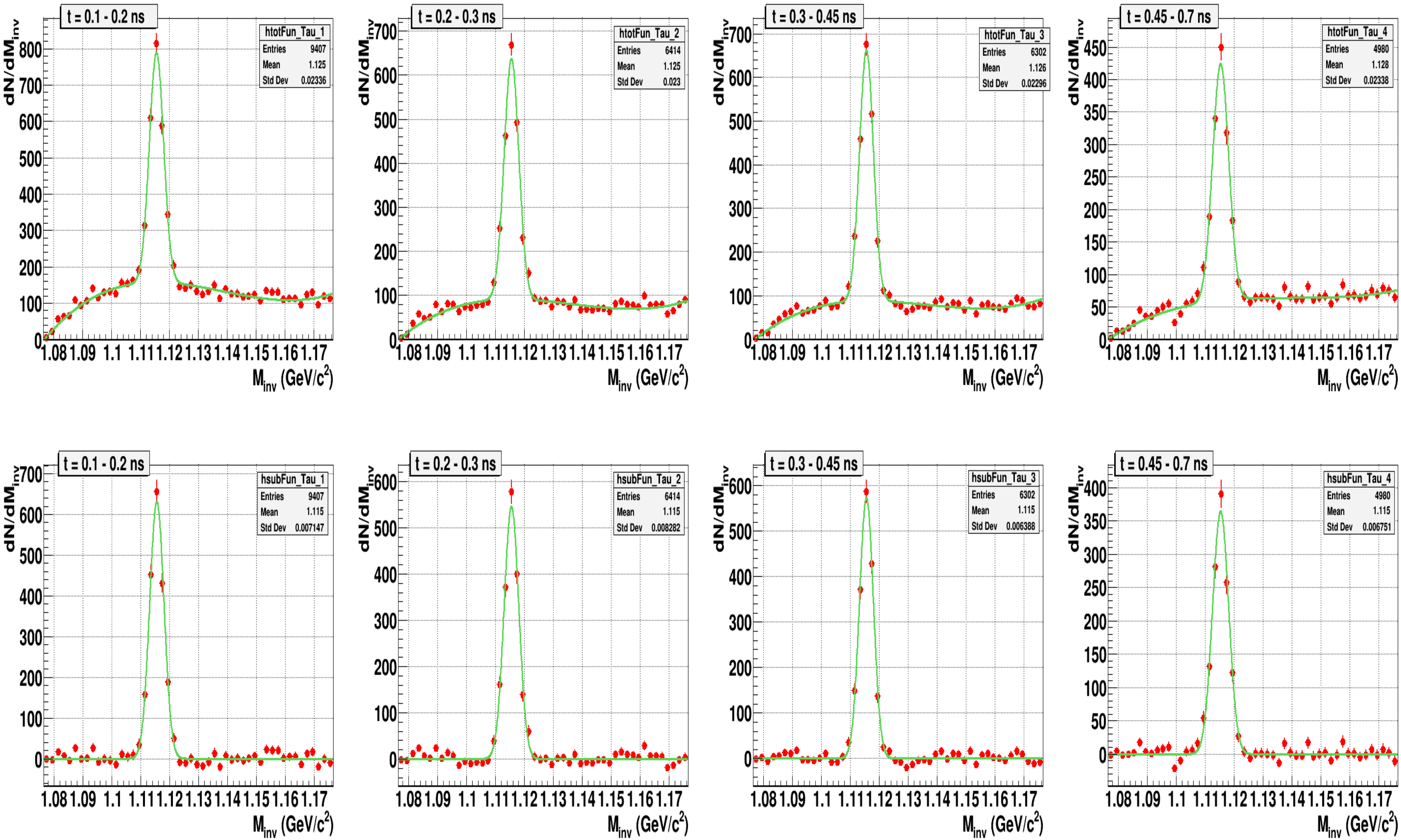
Used statistics:

1M MC events
1M exp. data (run 7830)

Mixed background subtraction: Data



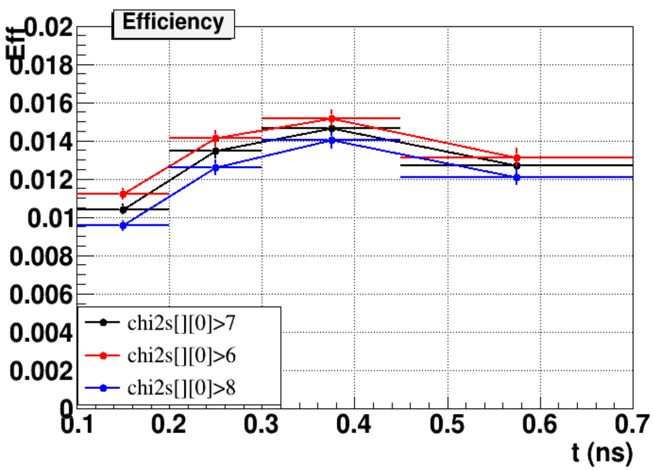
Fitted background subtraction: Data

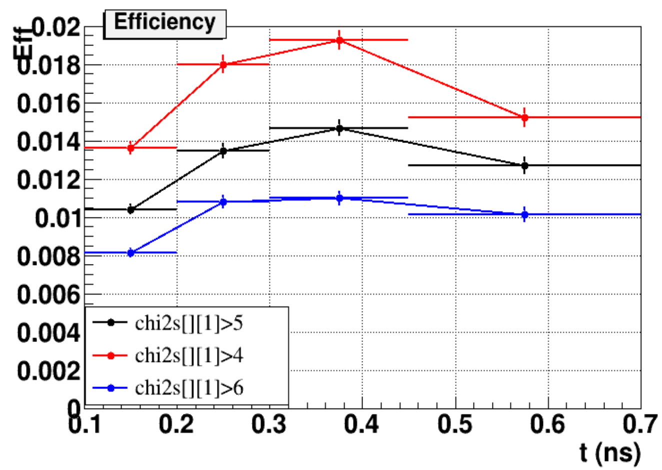


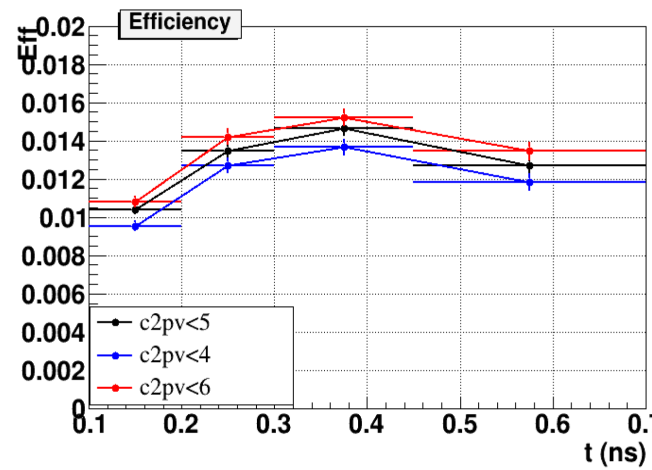
Lifetime of Λ

Cuts: chi2s[0]>7&&chi2s[1]>5&&c2pv<5&&pts[0]>0.05&&pts[1]>0.1

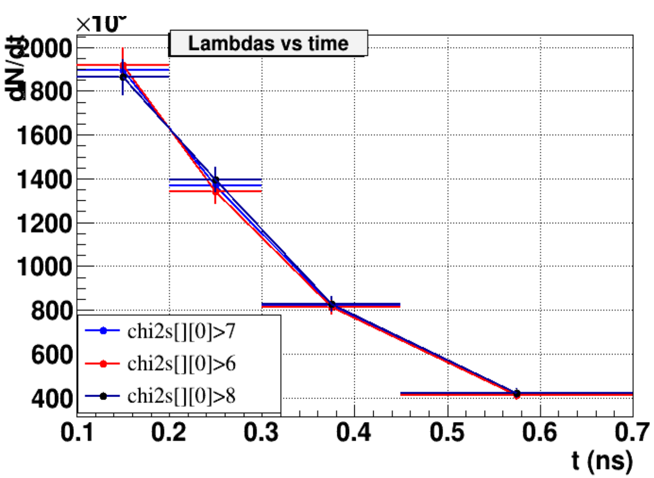
MC

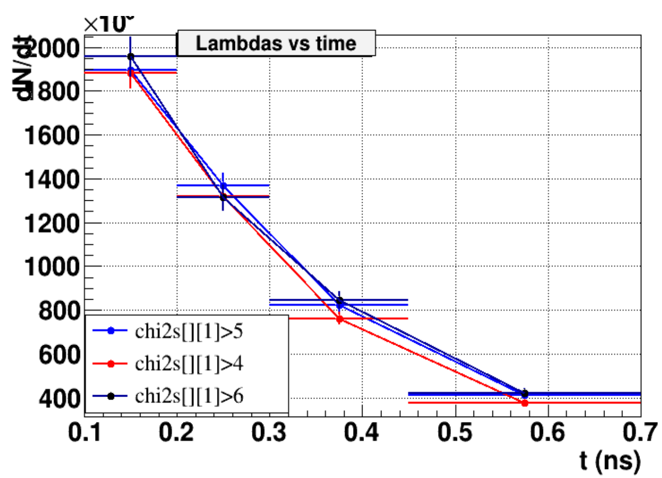


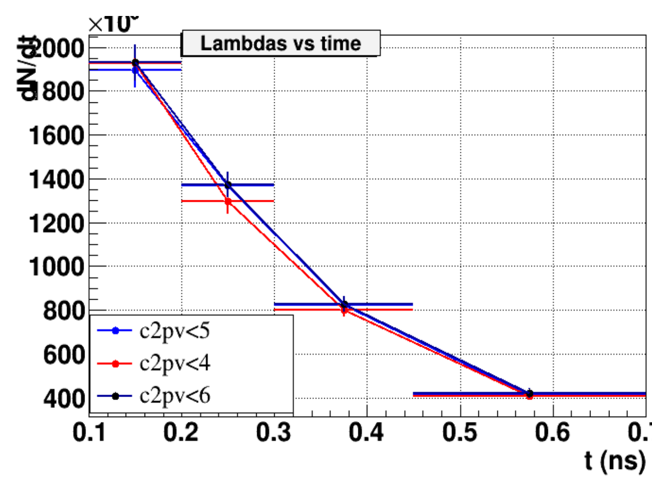




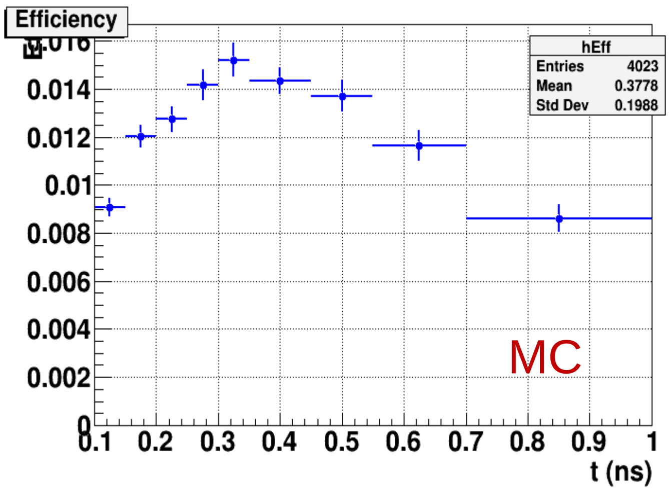
Data corrected for efficiency

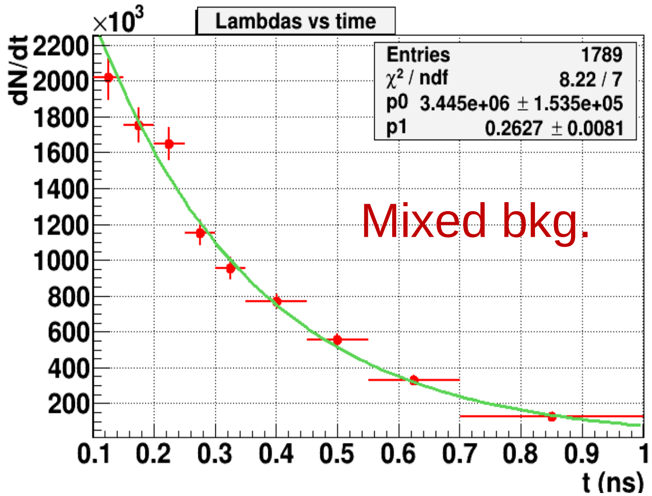


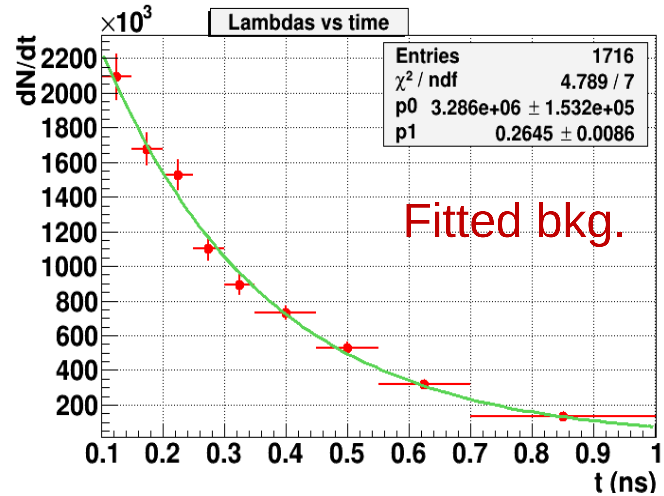




Lifetime of Λ



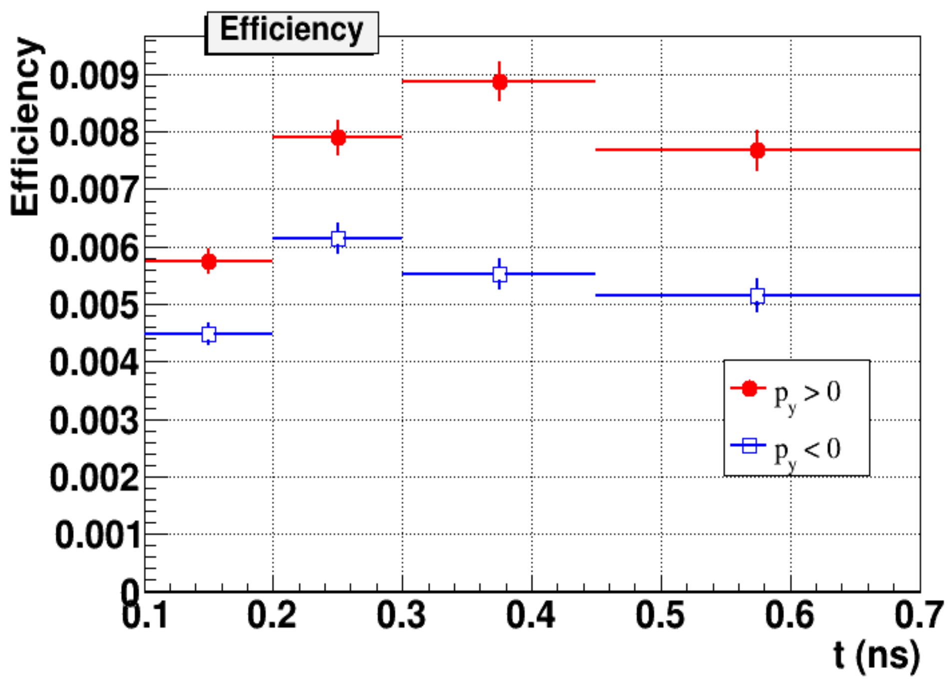




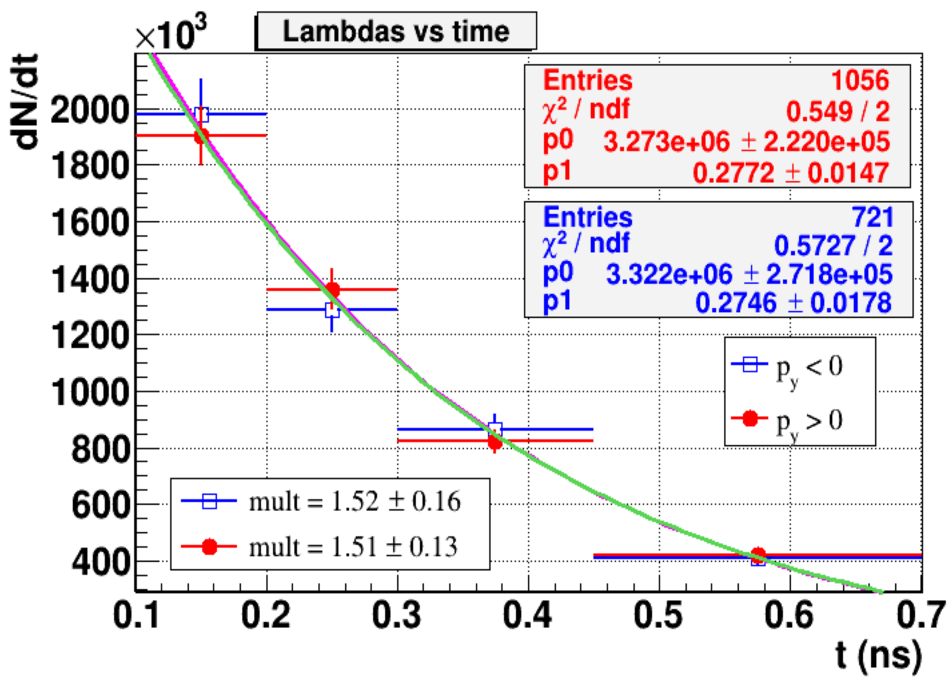
Selection:	Ω3>2.3	Ω3>1	3 cuts (4 bins)	5 cuts	3 cuts (9 bins)
τ, ns	0.301±0.014	0.302±0.016	0.270±0.011	0.240±0.008	0.262±0.008
Multiplicity	1.168±0.082	1.228±0.097	1.499±0.100	1.359±0.075	1.510±0.082
χ^2 / NDF	0.71 / 2	2.61 / 2	1.01 / 2	1.50 / 2	8.22 / 7

3 cuts:	centr. Value	c2pv<4	c2pv<6	chi2s[1]>4	chi2s[1]>6	chi2s[0]>6	chi2s[0]>8
τ, ns	0.270±0.011	0.262±0.011	0.265±0.011	0.254±0.010	0.263±0.012	0.266±0.011	0.269±0.012
Mult.	1.499±0.100	1.430±0.100	1.460±0.100	1.360±0.090	1.500±0.110	1.420±0.100	1.470±0.100
χ^2/NDF	1.01 / 2	1.00 / 2	0.63 / 2	2.23 / 2	1.49 / 2	0.88 / 2	1.10 / 2

Lifetime of Λ: upper and lower detectors



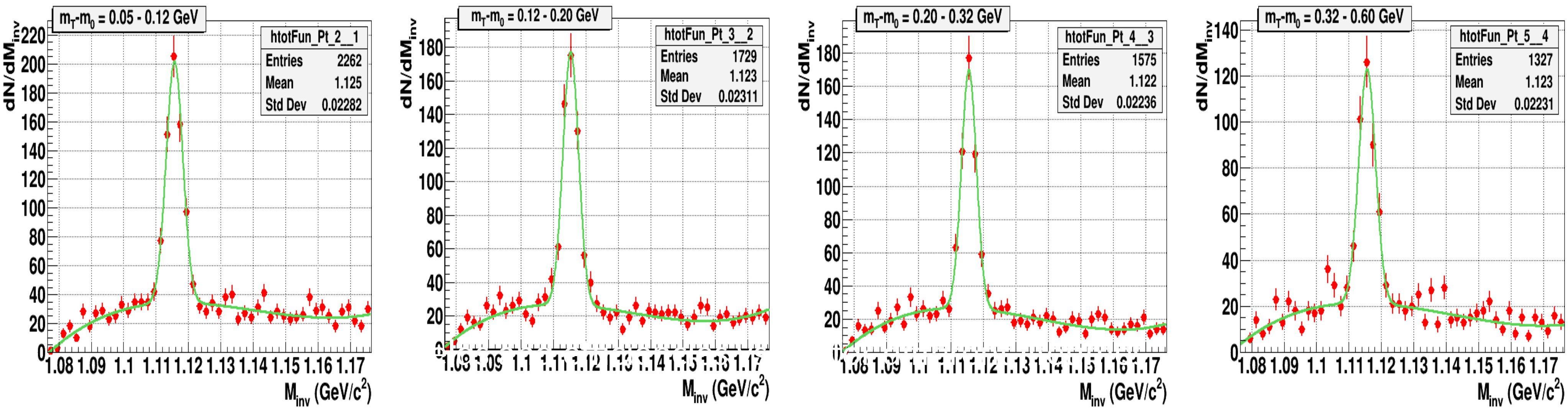
MC



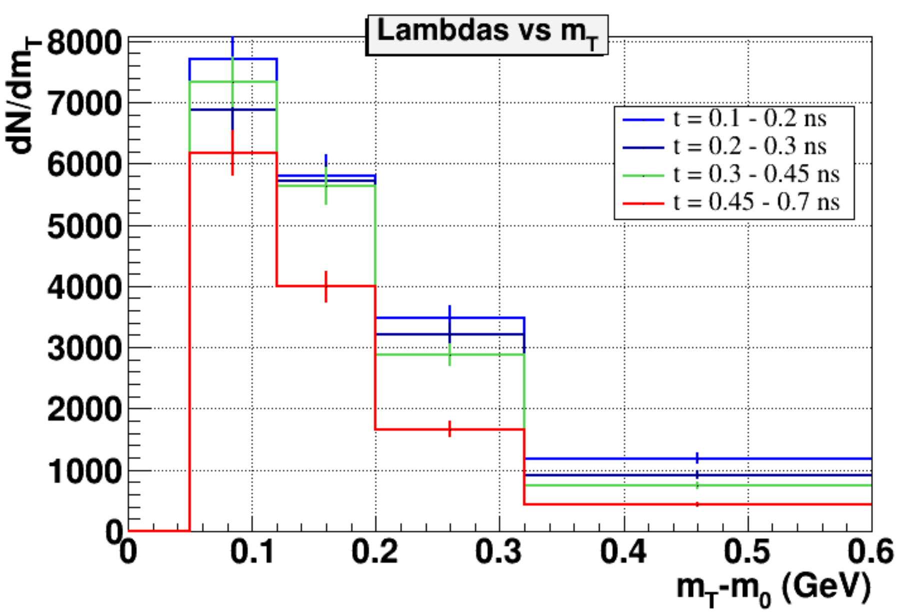
Data corrected for efficiency

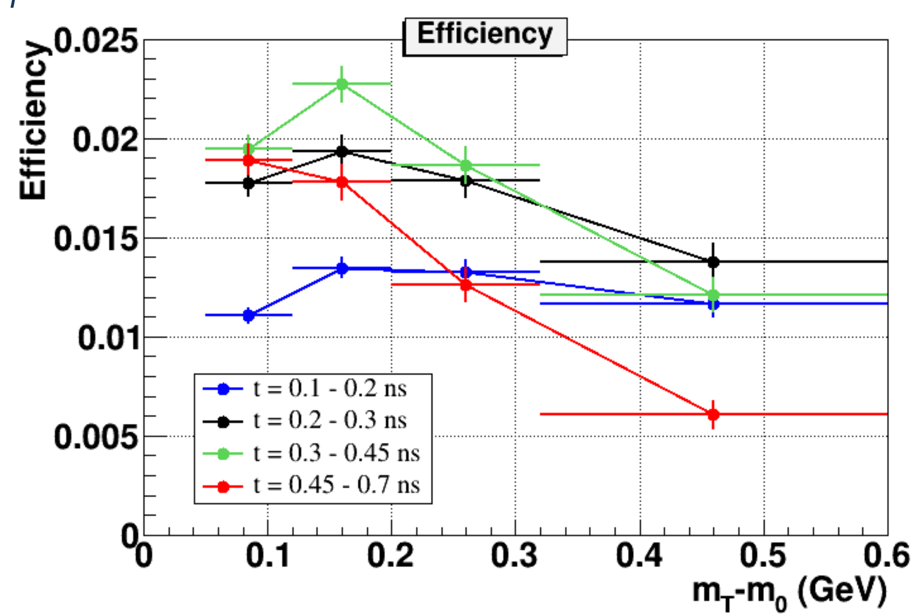
Λ double-differential spectra

Λ M_{inv} spectra for lifetime 0.1-0.2 ns



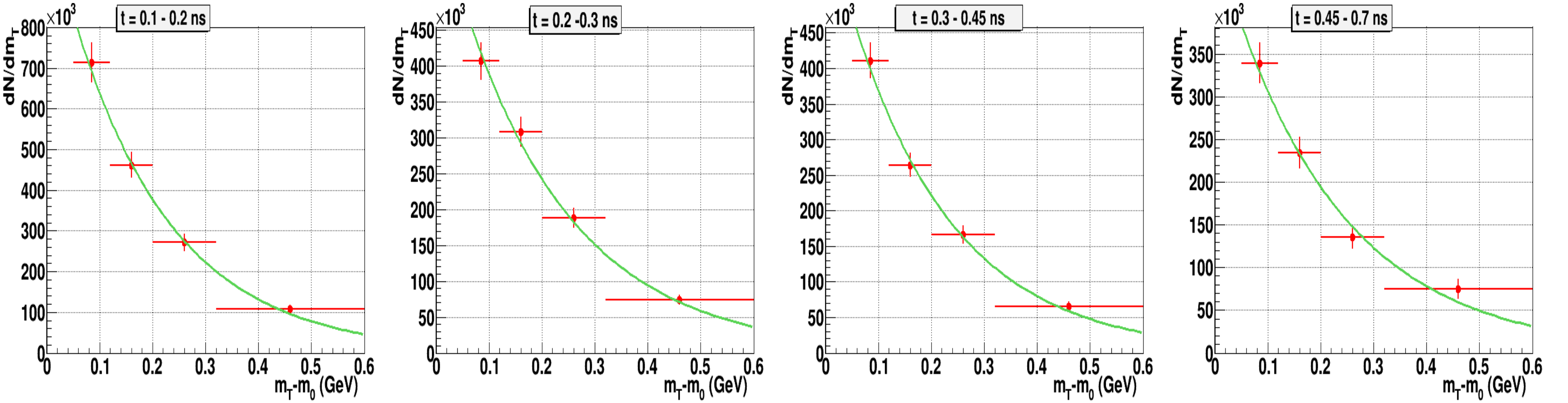
Yields and efficiencies vs m_T for different lifetimes

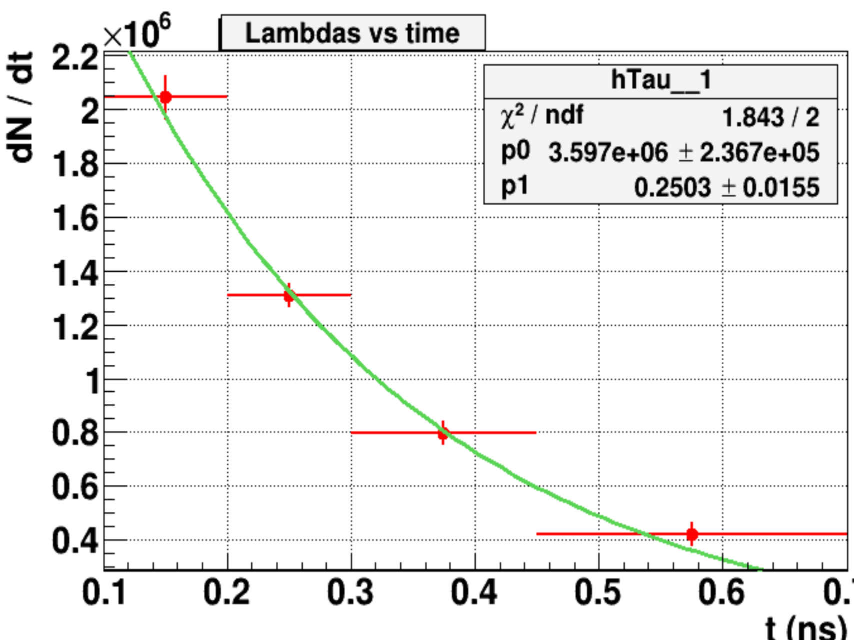




Λ m_T spectra

Corrected for efficiency m_T spectra for different lifetimes





Λ decay curve reconstructed from integrated m_T spectra

Λ spectra

Effective temperatures for different lifetimes

Boltzman distribution from HADES paper

$$\frac{1}{m_t^2}\frac{d^2M}{dm_t dy} = C(y)\exp\left(-\frac{(m_t-m_0)c^2}{T_B(y)}\right)$$

Effective temperature (MeV)

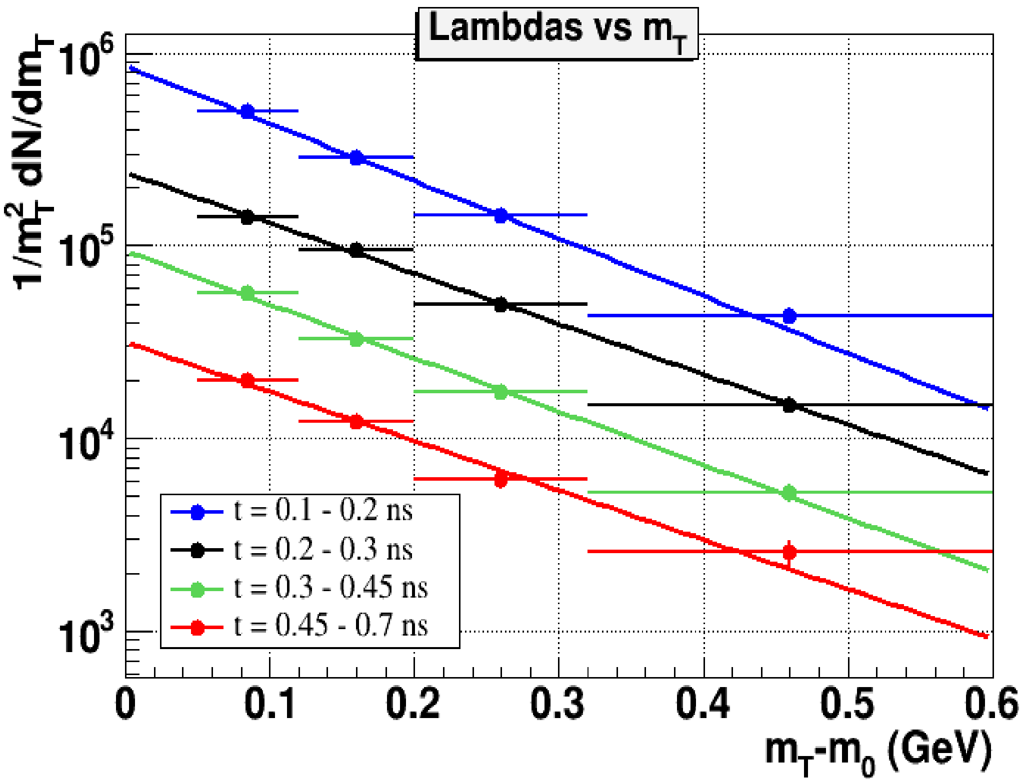
T1 = 146±7

T2 = 158±8

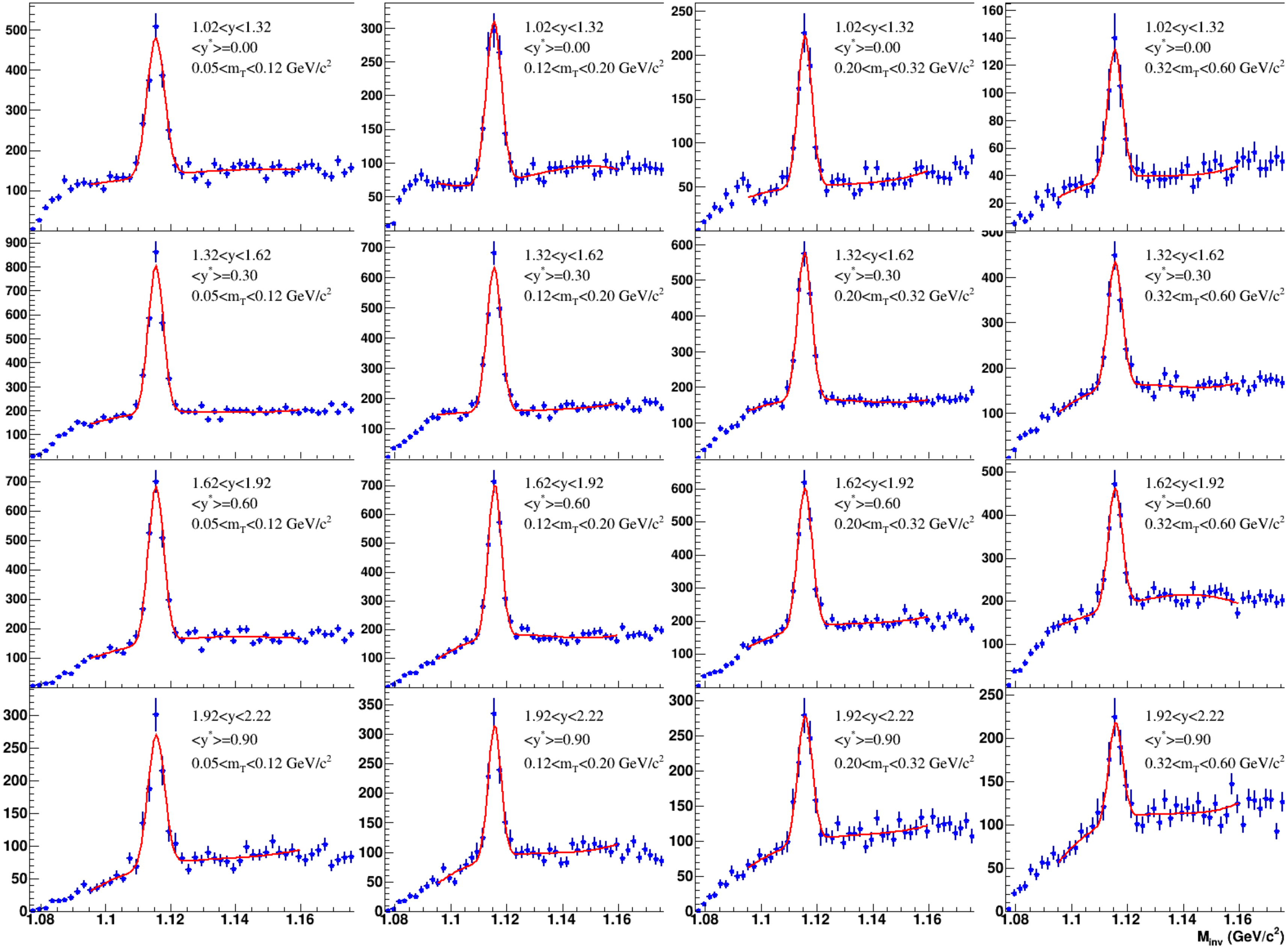
T3 = 149±8

T4 = 163±13

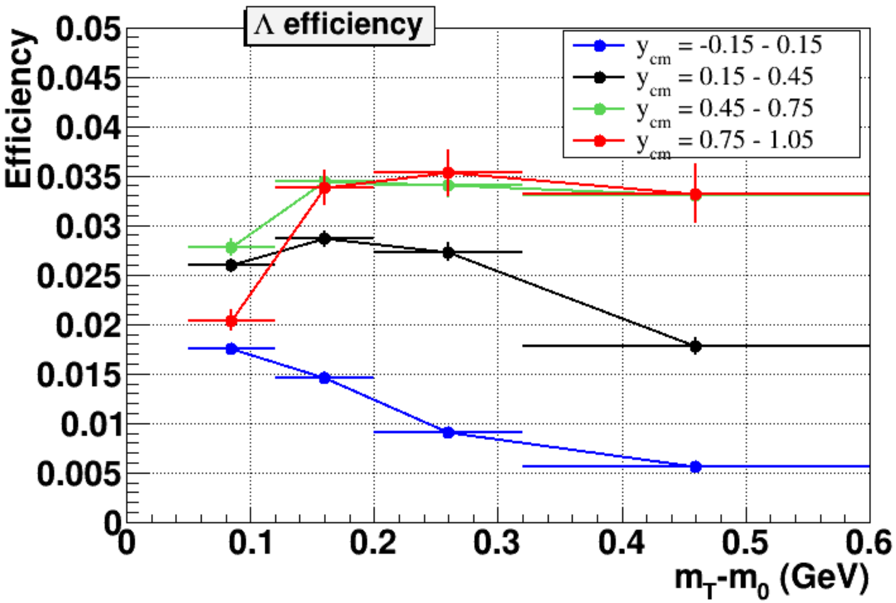
T MC = 122±4

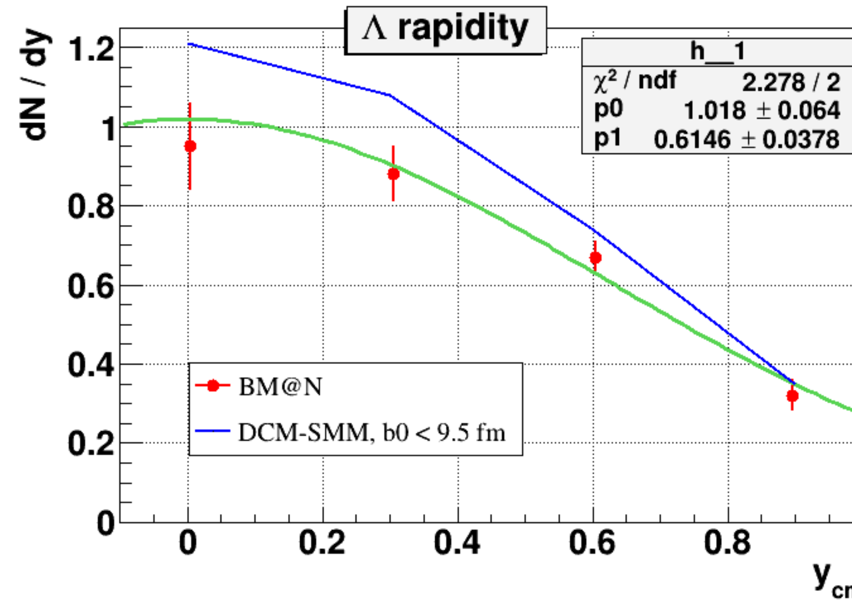


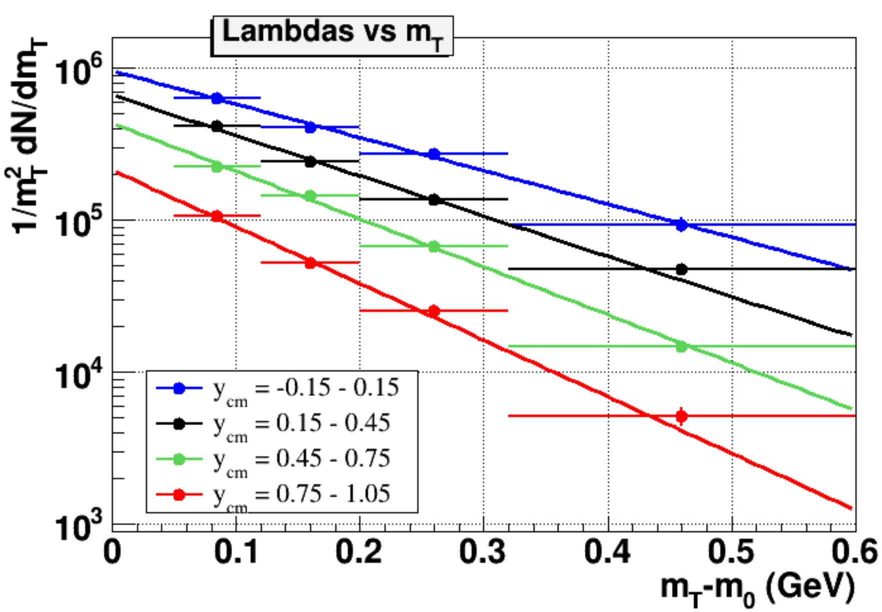
Λ: bins y vs m_T


1.02<y<1.32
<y*>=0.00
0.05<m_T<0.12 GeV/c²
1.02<y<1.32
<y*>=0.00
0.12<m_T<0.20 GeV/c²
1.02<y<1.32
<y*>=0.00
0.20<m_T<0.32 GeV/c²
1.02<y<1.32
<y*>=0.00
0.32<m_T<0.60 GeV/c²
1.32<y<1.62
<y*>=0.30
0.05<m_T<0.12 GeV/c²
1.32<y<1.62
<y*>=0.30
0.12<m_T<0.20 GeV/c²
1.32<y<1.62
<y*>=0.30
0.20<m_T<0.32 GeV/c²
1.32<y<1.62
<y*>=0.30
0.32<m_T<0.60 GeV/c²
1.62<y<1.92
<y*>=0.60
0.05<m_T<0.12 GeV/c²
1.62<y<1.92
<y*>=0.60
0.12<m_T<0.20 GeV/c²
1.62<y<1.92
<y*>=0.60
0.20<m_T<0.32 GeV/c²
1.62<y<1.92
<y*>=0.60
0.32<m_T<0.60 GeV/c²
1.92<y<2.22
<y*>=0.90
0.05<m_T<0.12 GeV/c²
1.92<y<2.22
<y*>=0.90
0.12<m_T<0.20 GeV/c²
1.92<y<2.22
<y*>=0.90
0.20<m_T<0.32 GeV/c²
1.92<y<2.22
<y*>=0.90
0.32<m_T<0.60 GeV/c²
M_inv (GeV/c²)

Λ m_T spectra in bins of y







Boltzman distribution from HADES paper

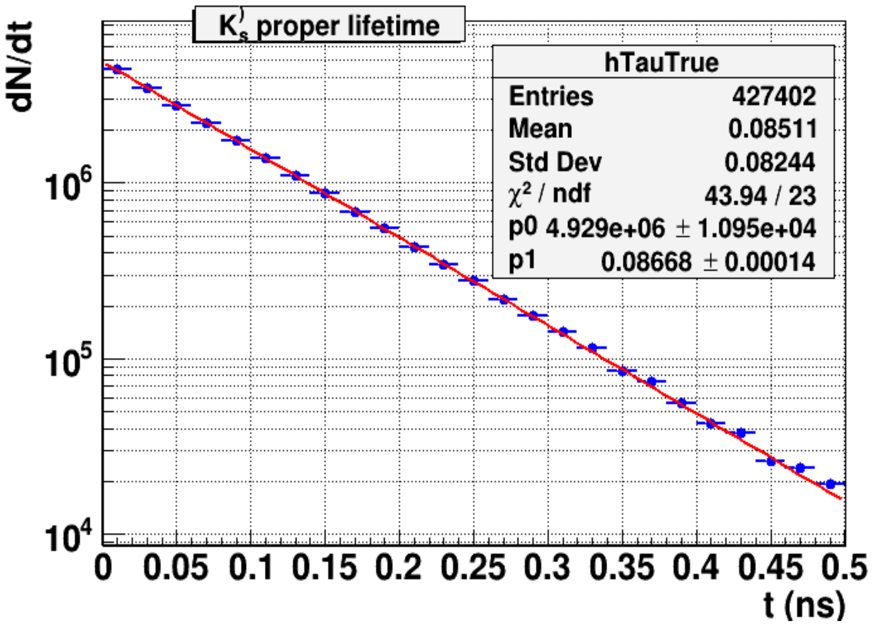
$$\frac{1}{m_t^2}\frac{d^2M}{dm_t dy} = C(y)\exp\left(-\frac{(m_t - m_0)c^2}{T_B(y)}\right)$$

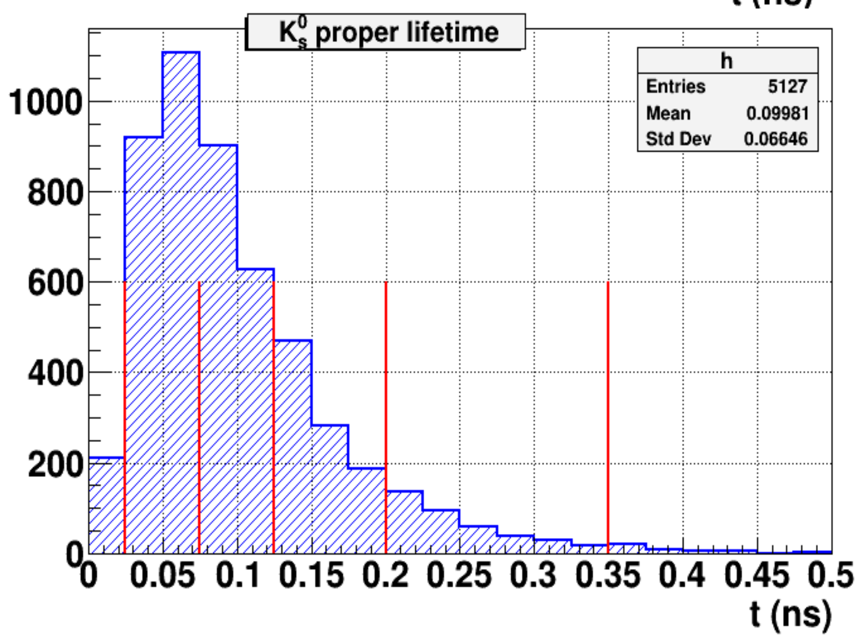
T = 198±12, 164±7, 138±4, 117±6 MeV

Kaons

This material was a part of Roman Zinchenko’s magister thesis - redone

Lifetime of K^0_s: MC





Decay formula:

$dN / dt = N_0 / \tau * exp(-t/\tau),$

$N_0 = p0 * p1 = 427241$

Proper life time:

$\tau = lm / (pc)$

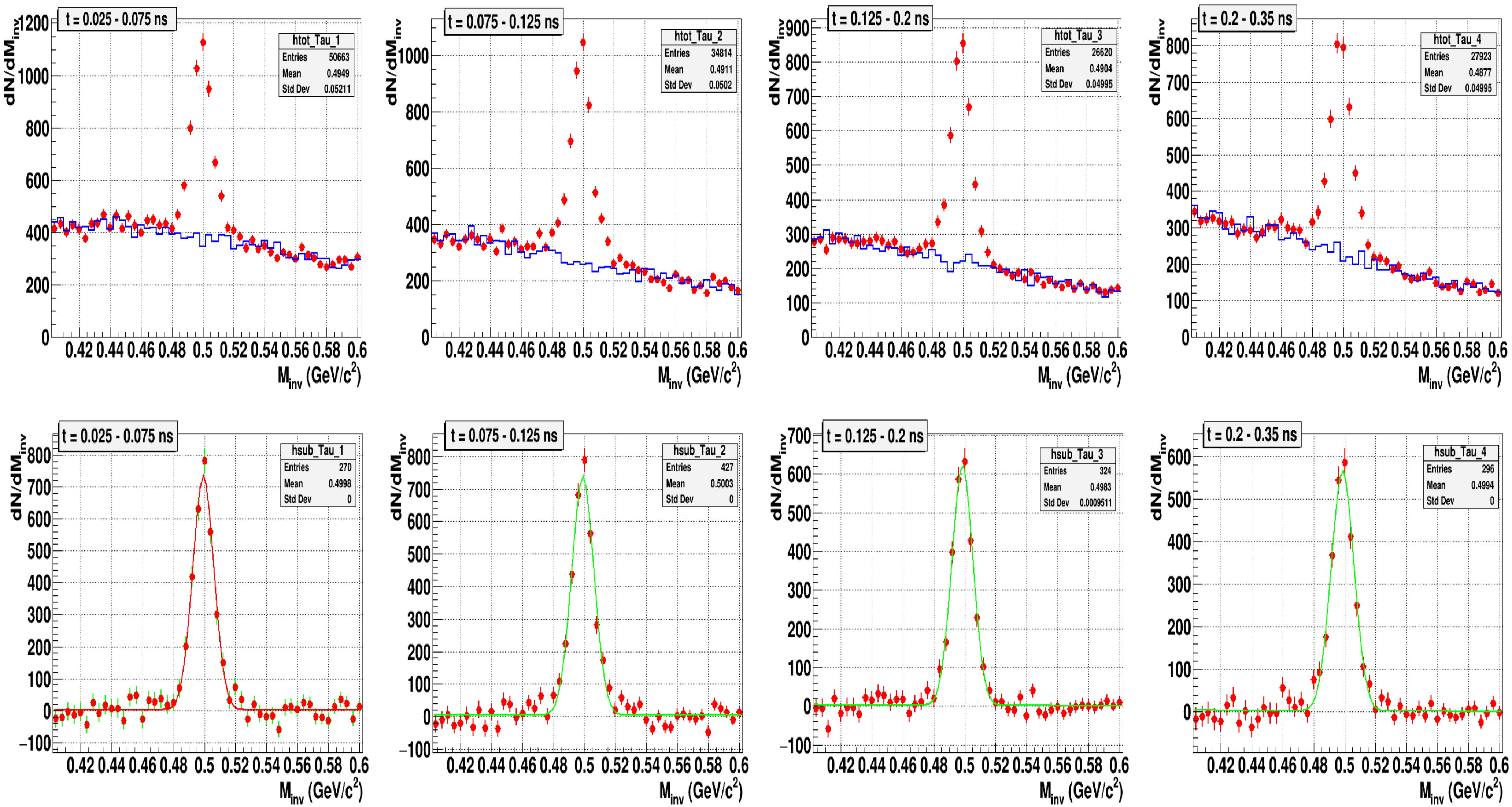
Table value τ= 0.0895 *ns*

Used statistics:

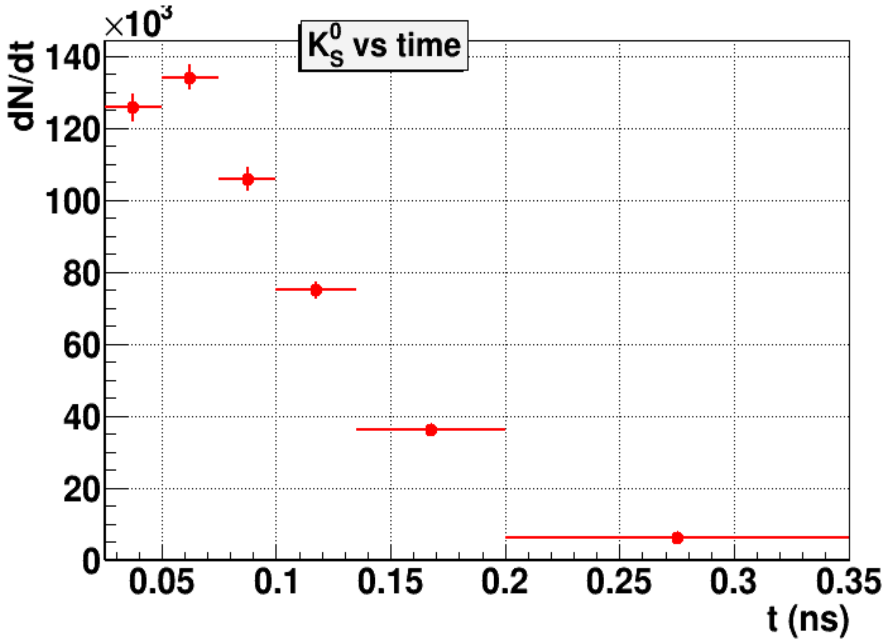
1M MC events
1M exp. data (run 7830)

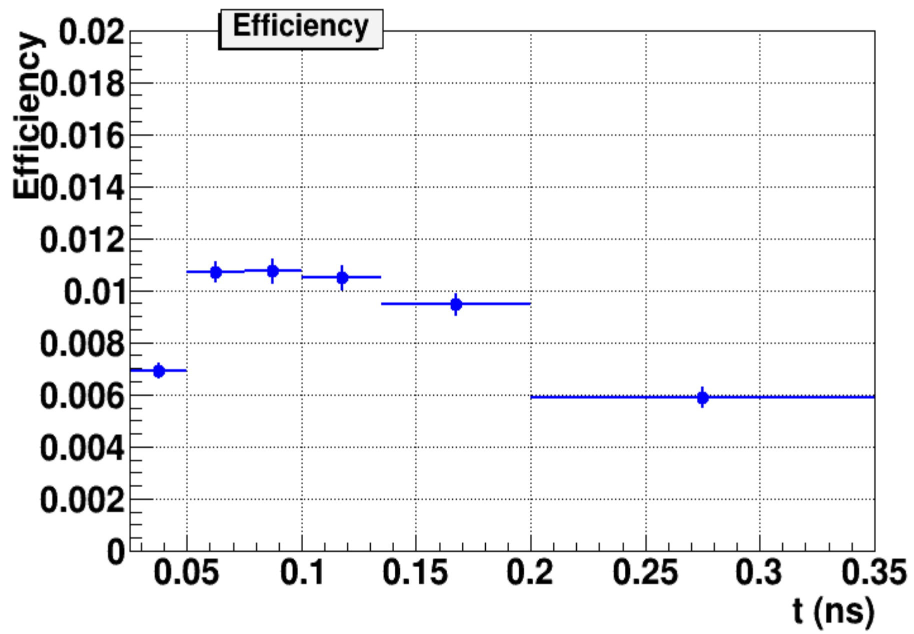
K^0_s invariant mass distributions

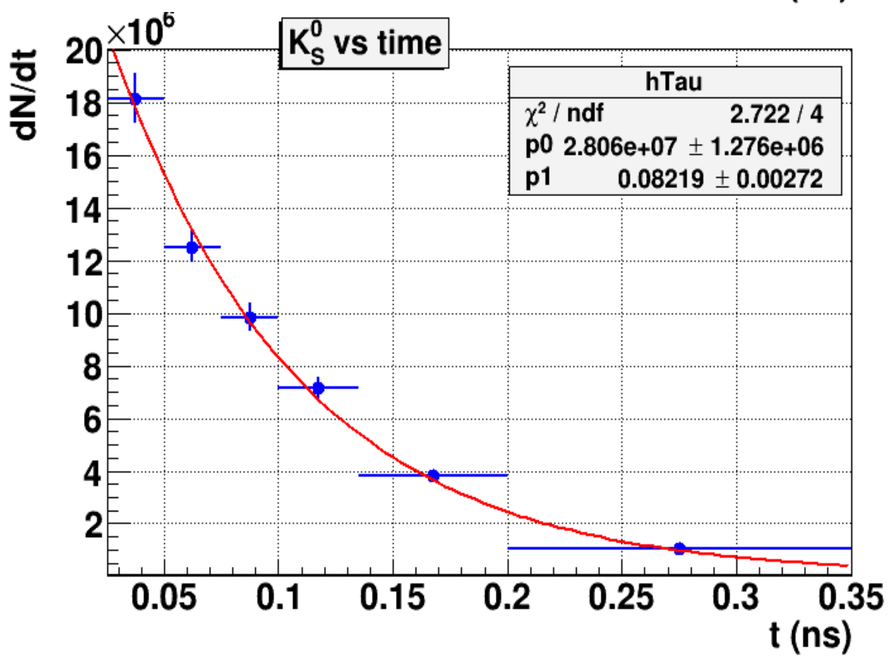
For different lifetimes



K^0_s raw yield and efficiency



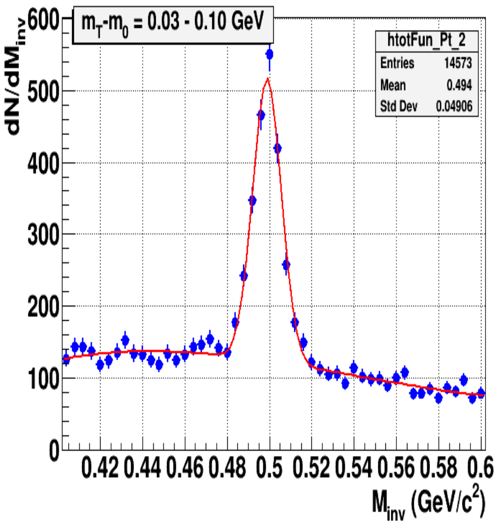


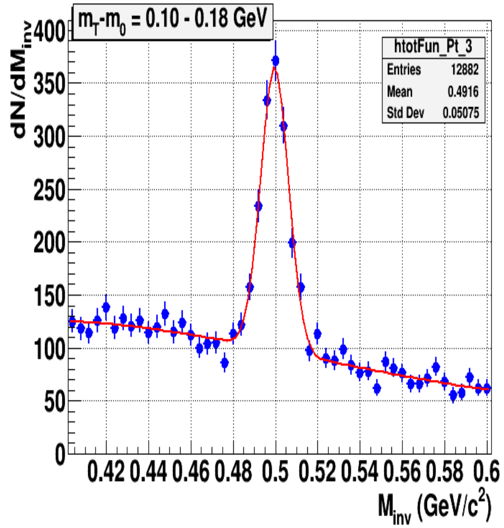


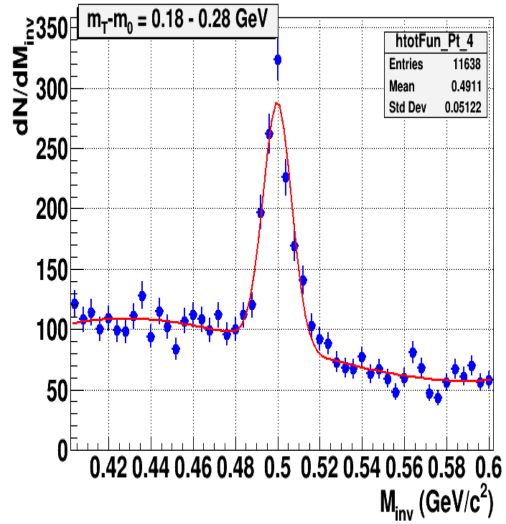
Efficiency-corrected yield vs lifetime

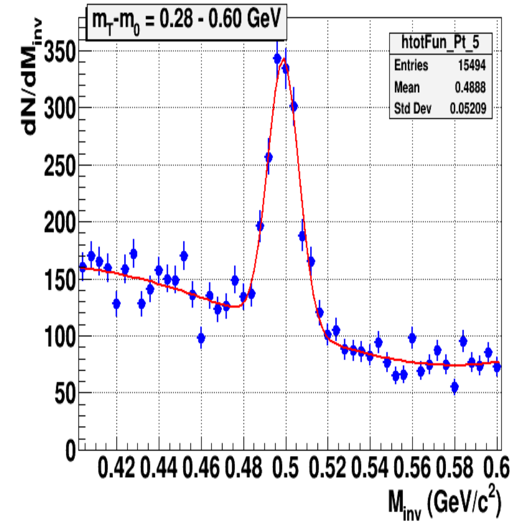
K^0_s double-differential spectra

K^0_s M_{inv} spectra for lifetime 0.025-0.075 ns

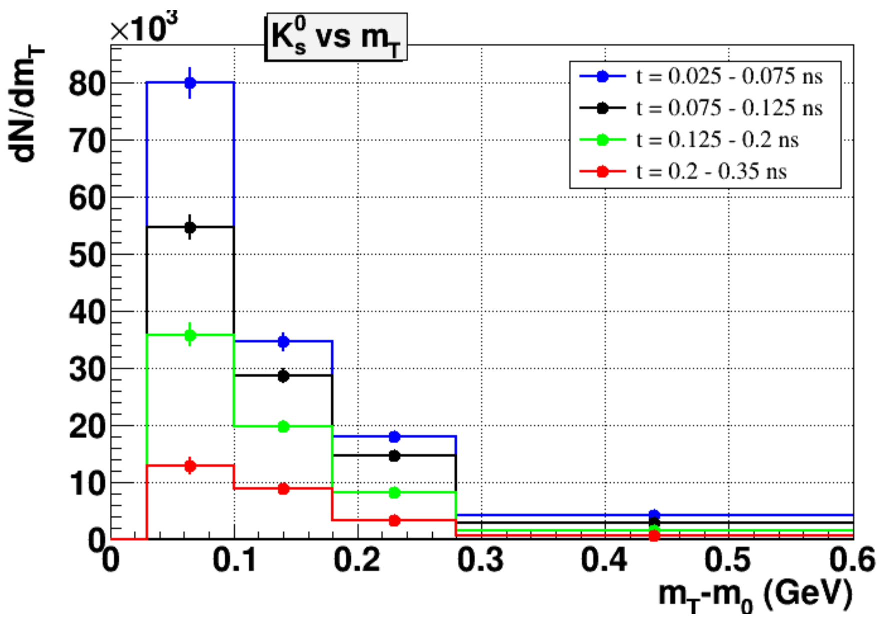


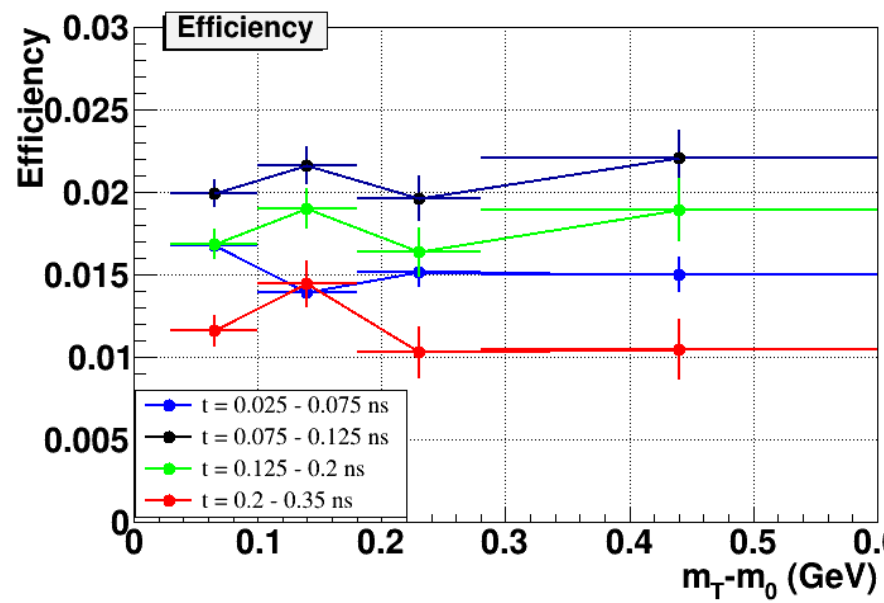






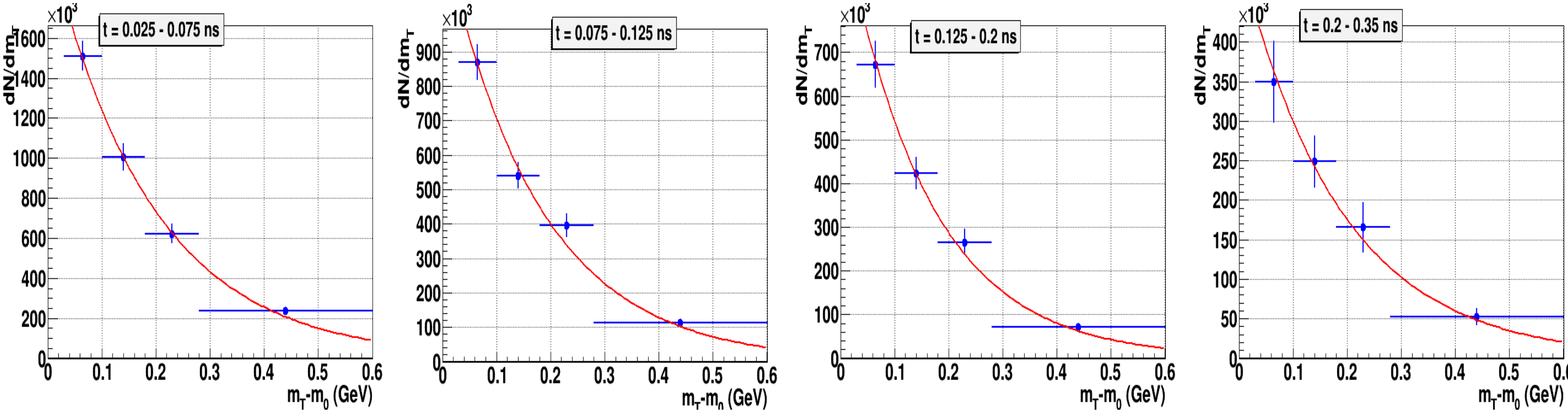
Yields and efficiencies vs m_T for different lifetimes

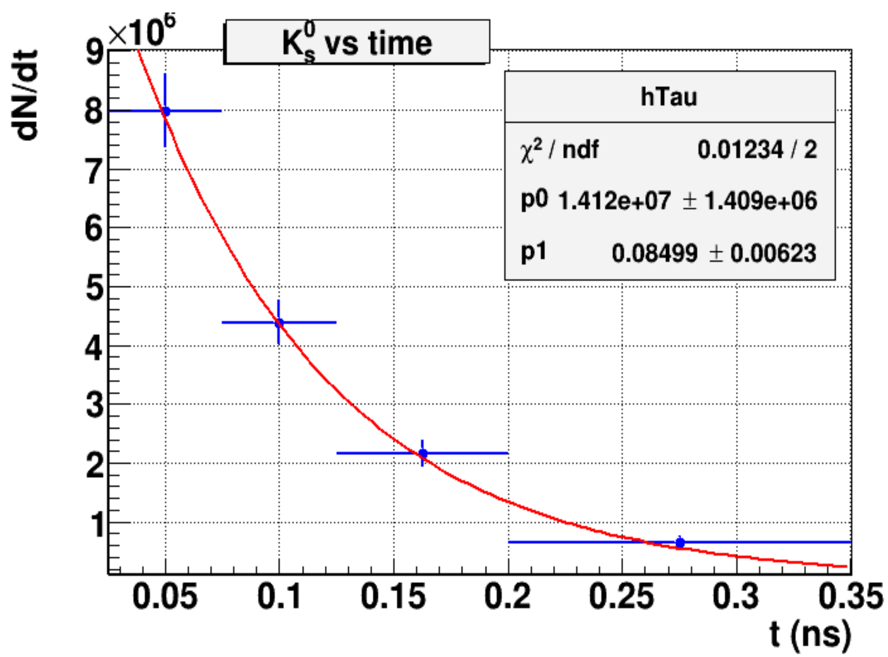




K^0_s spectra

Corrected for efficiency m_T spectra for different lifetimes





K^0_s decay curve reconstructed from integrated m_T spectra

K^0_s spectra

Effective temperatures for different lifetimes

Boltzman distribution from HADES paper

$$\frac{1}{m_t^2}\frac{d^2M}{dm_t dy} = C(y)\exp\left(-\frac{(m_t-m_0)c^2}{T_B(y)}\right)$$

Effective temperature (MeV)

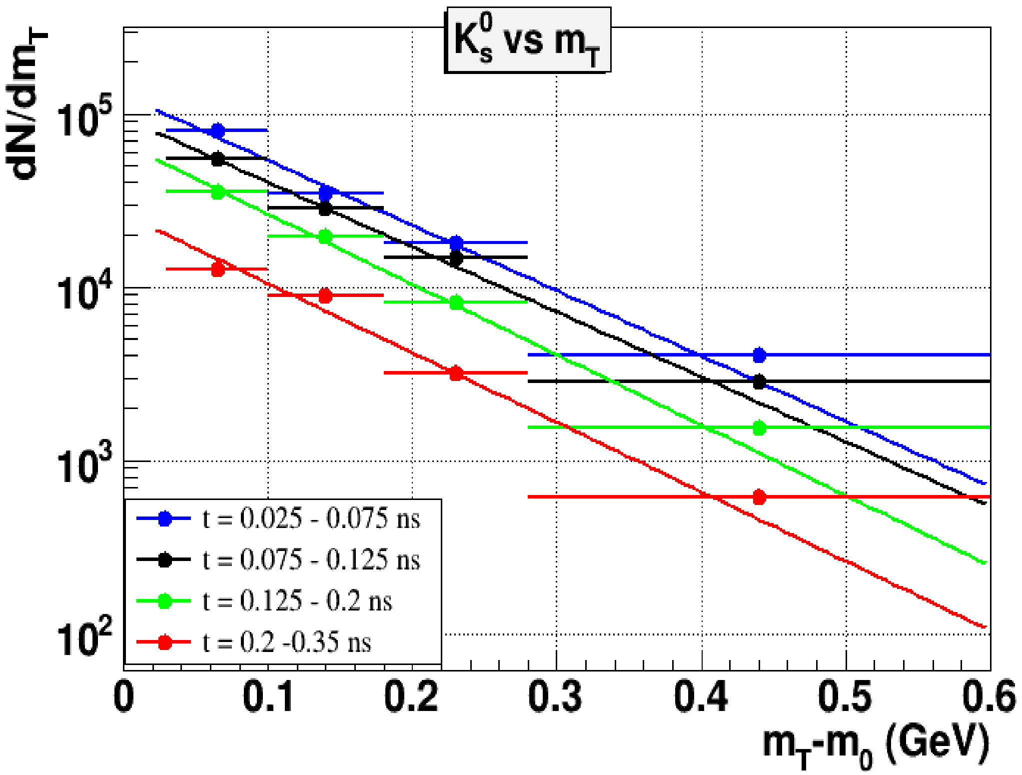
T1 = 115±3 (117±5)

T2 = 116±3 (113±5)

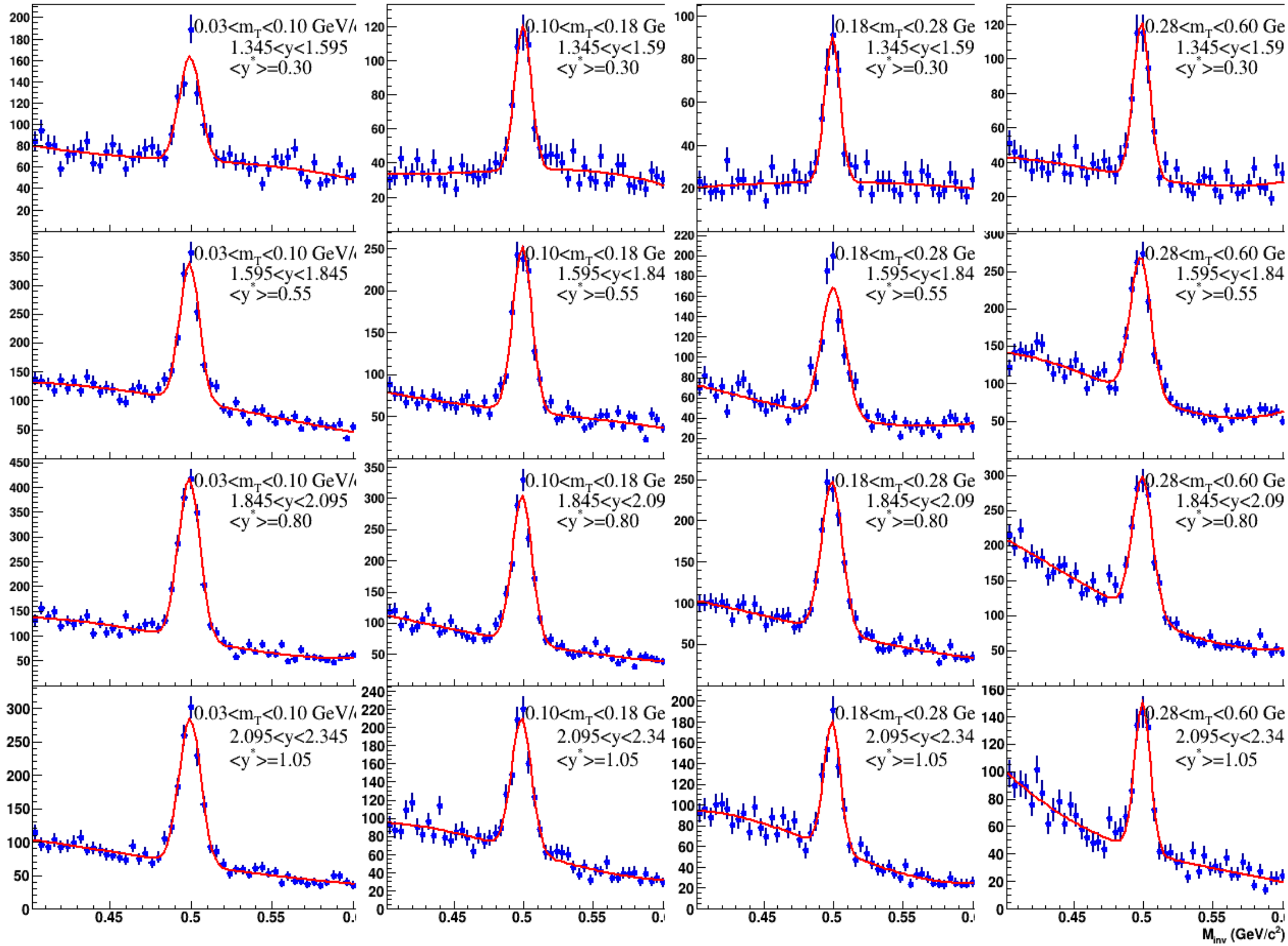
T3 = 107±3 (108±6)

T4 = 108±5 (125±16)

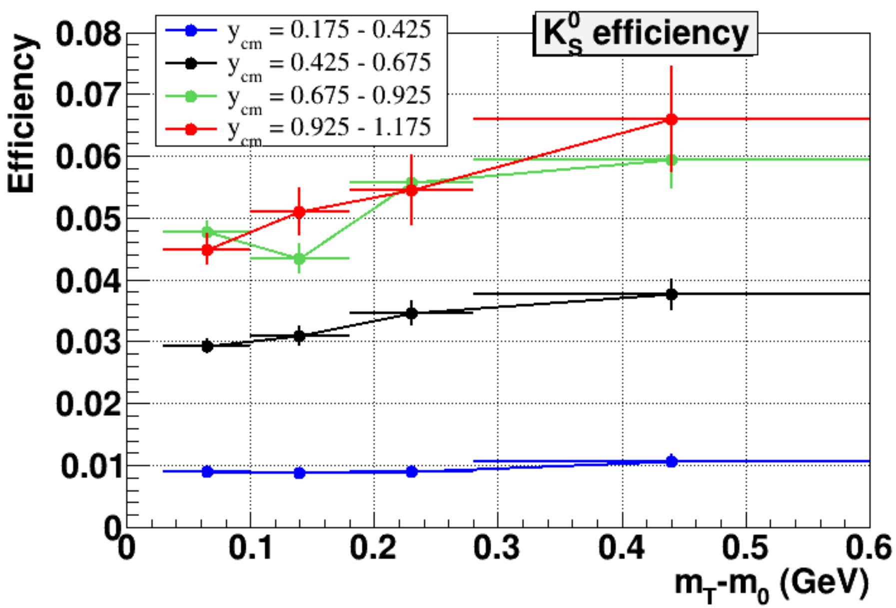
T MC = 97±6

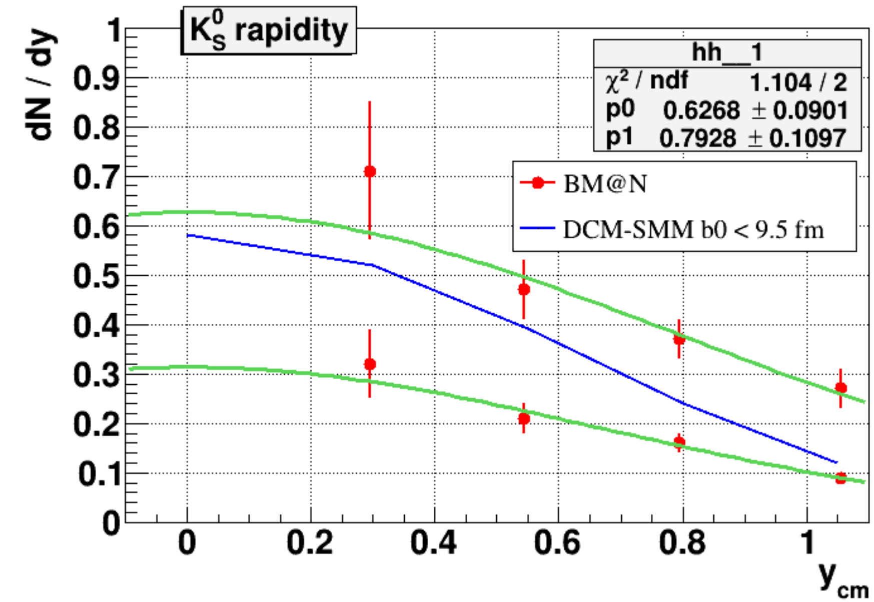


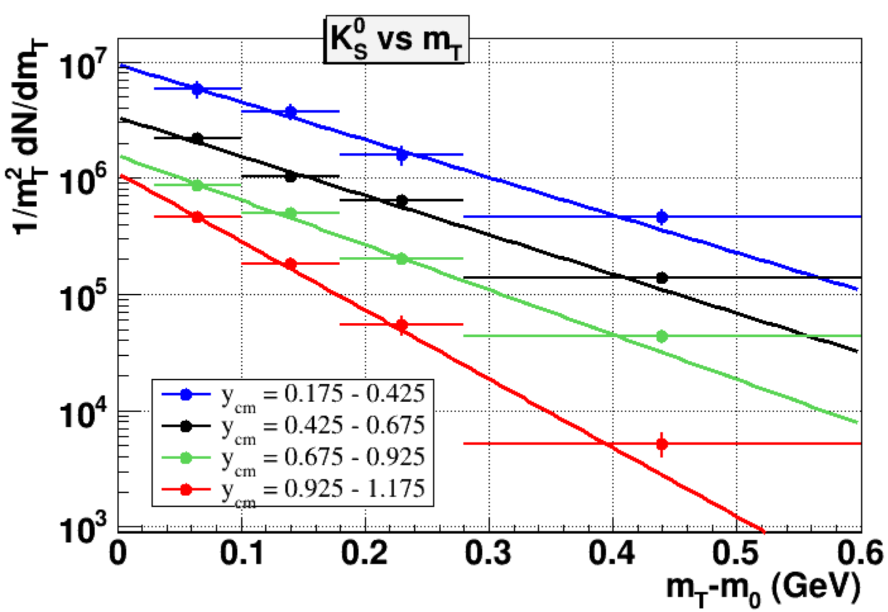
K^0_s: bins y vs m_T



K^0_s m_T spectra in bins of y (may 2024 tune)





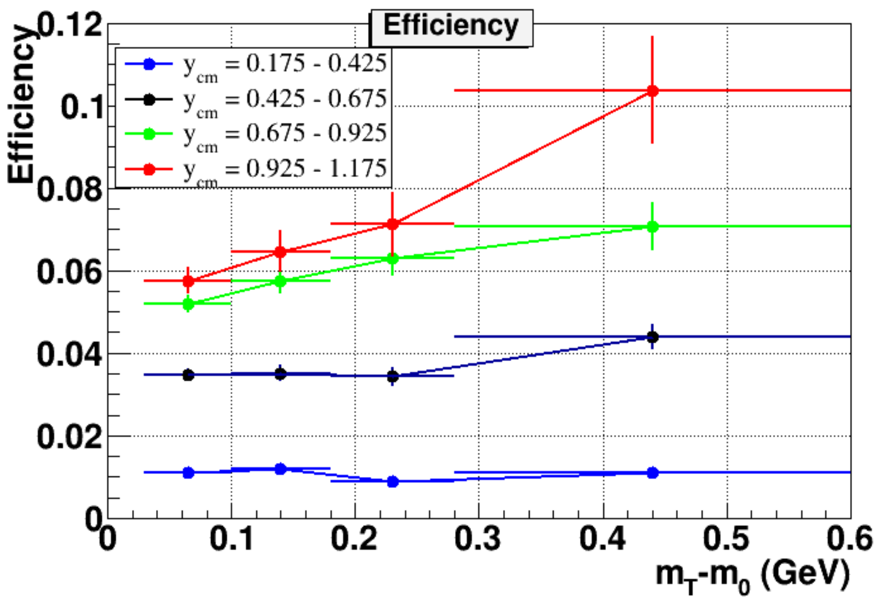


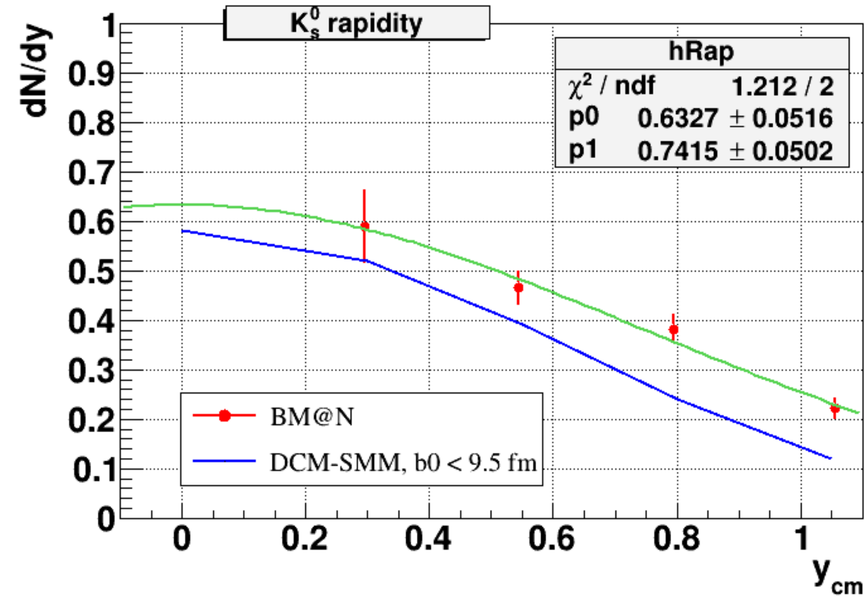
Boltzman distribution from HADES paper

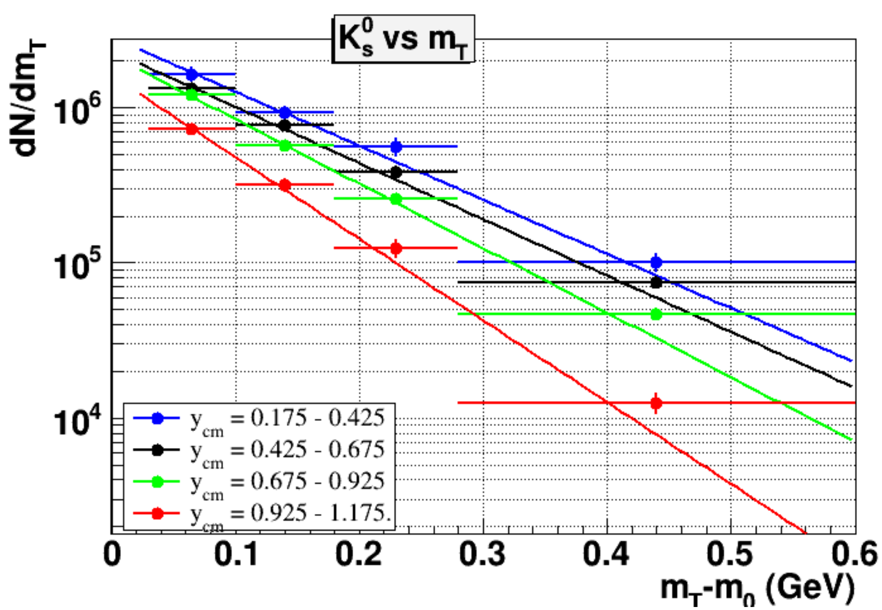
$$\frac{1}{m_t^2}\frac{d^2M}{dm_t dy} = C(y)\exp\left(-\frac{(m_t-m_0)c^2}{T_B(y)}\right)$$

T = 134±13, 129±8, 113±6, 73±4 MeV

K^0_s m_T spectra in bins of y







Boltzman distribution from HADES paper

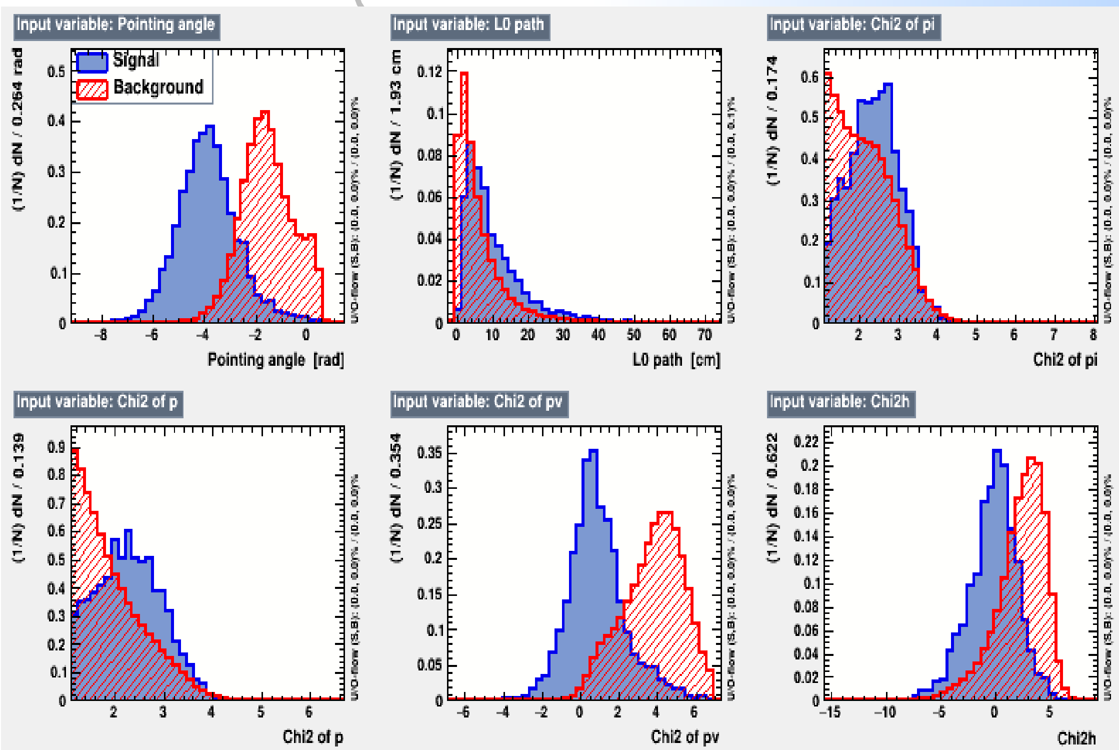
$$\frac{1}{m_t^2}\frac{d^2M}{dm_t dy} = C(y)\exp\left(-\frac{(m_t - m_0)c^2}{T_B(y)}\right)$$

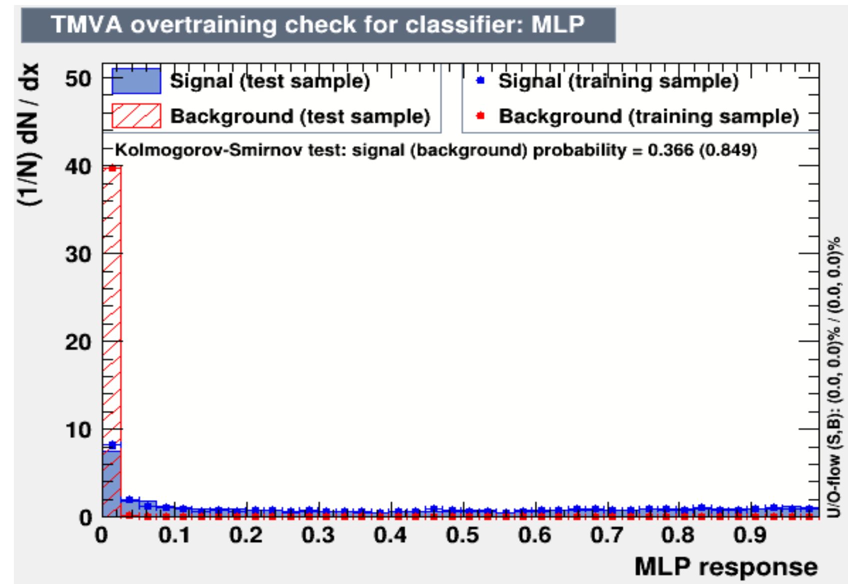
T = 124±8, 120±5, 104±4, 82±3 MeV

Machine learning method

K^0_s: MC and Data

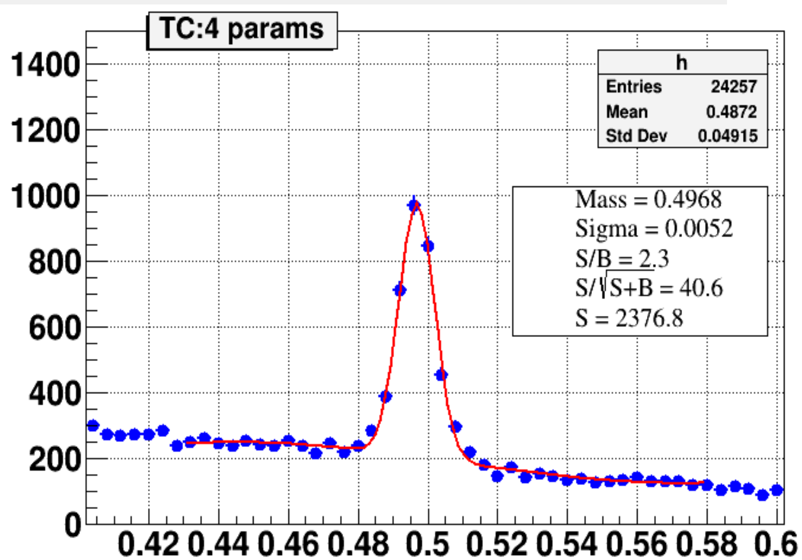
K^0_s: MC, MLP (6 parameters)

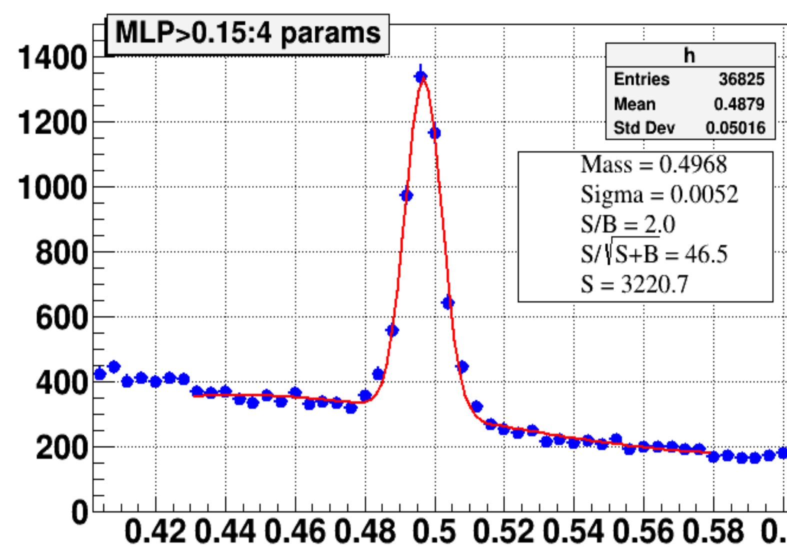




MC (1M):

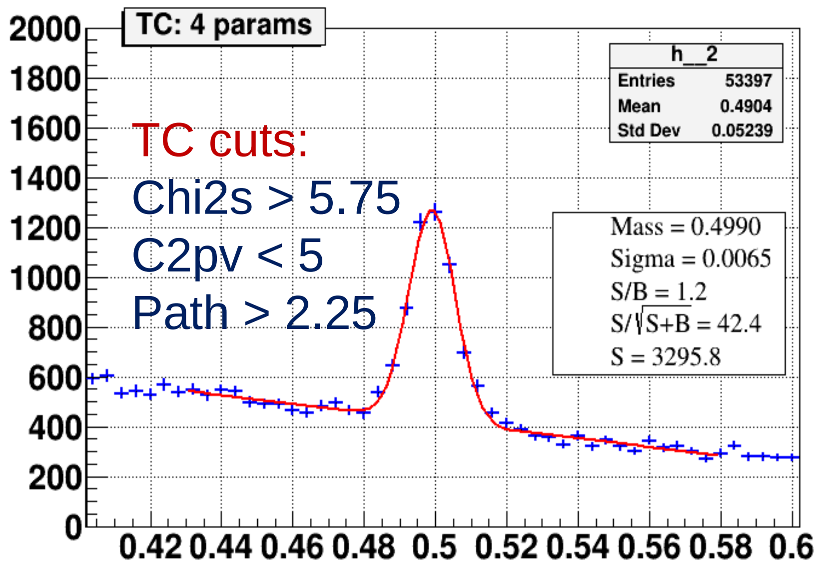
TC vs MLP

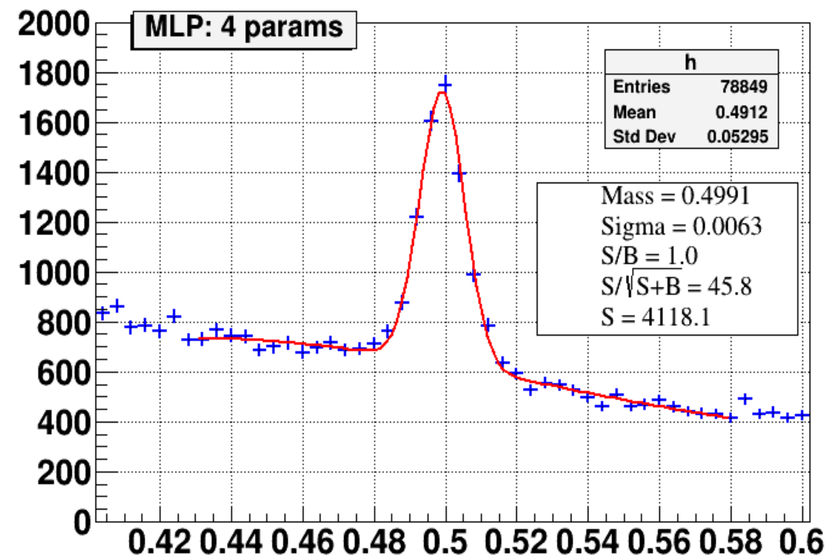


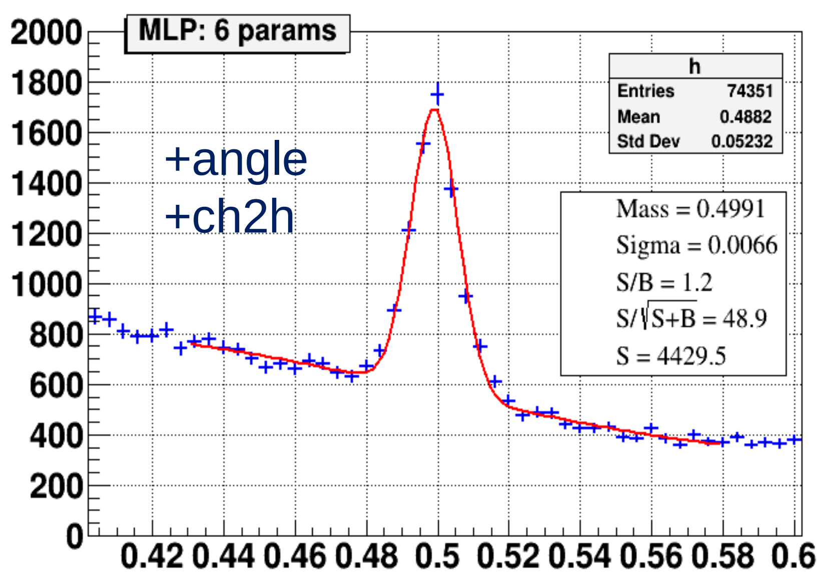


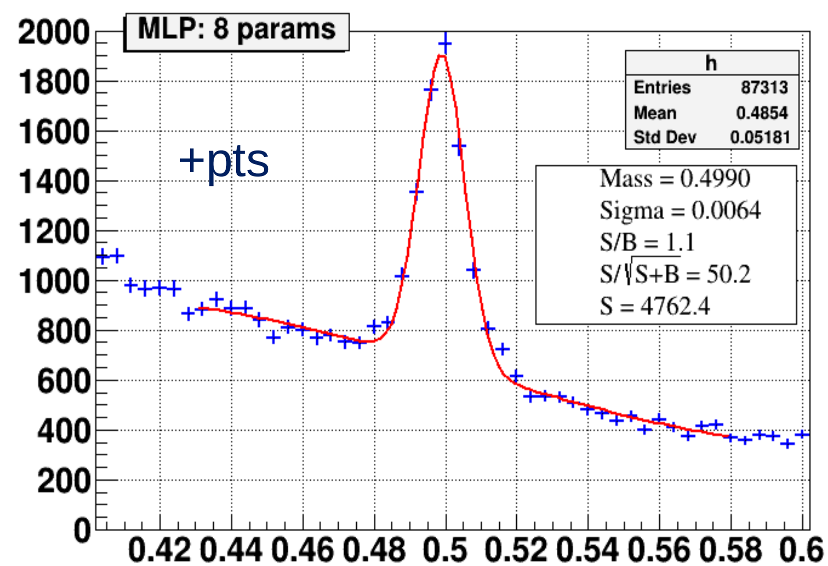
K^0_s: TC vs MLP, Data (run 7830)

Production: Feb. 2024, training with MC

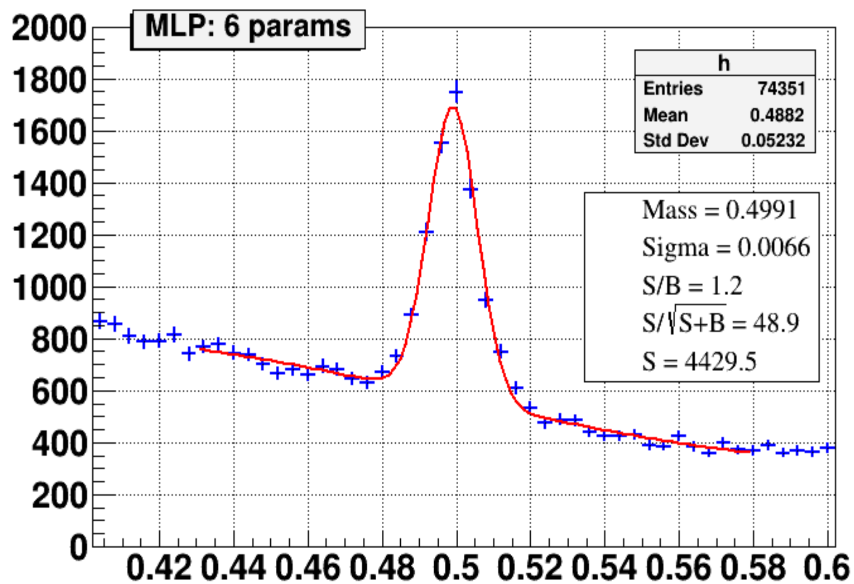


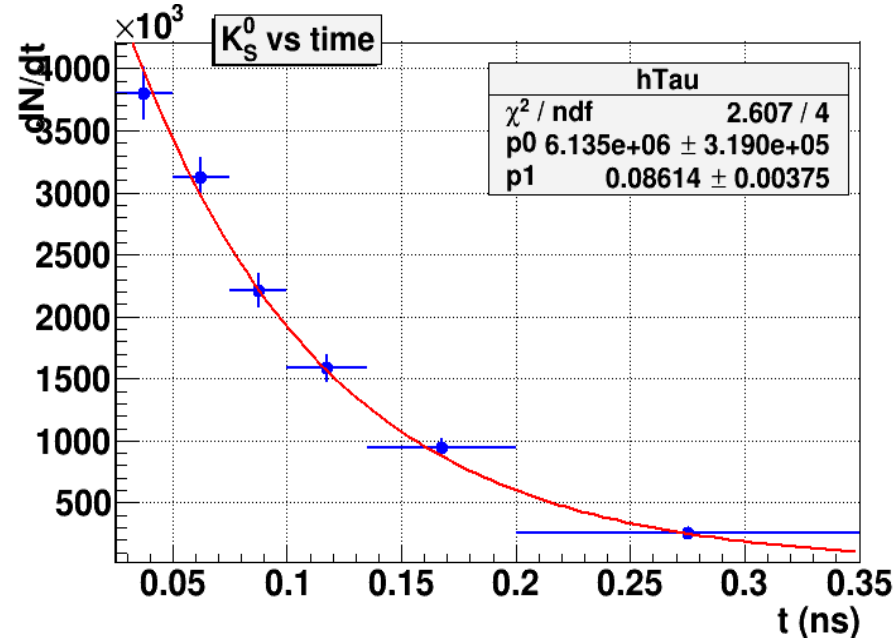


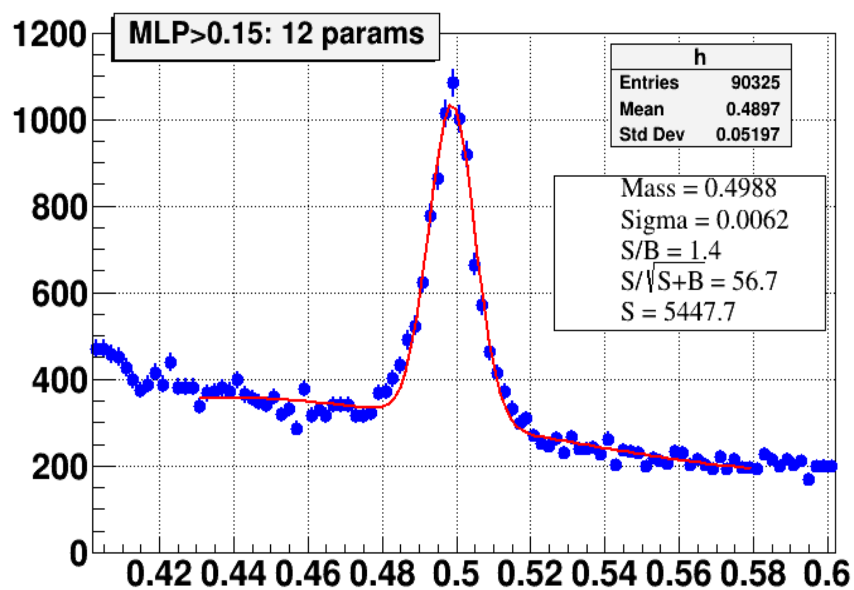


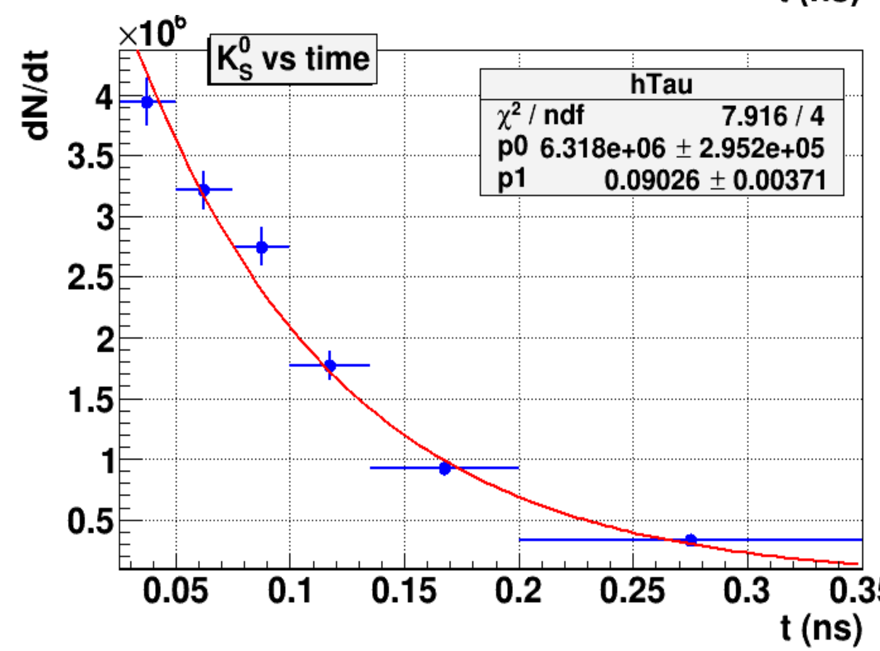


K^0_s: decay curve with ML (6 vs 12 params, run 7830)









Summary and next steps

- ✓ Monte Carlo needs another round of tuning.
- ✓ The procedure for Λ and K^0_s analysis was implemented.
- ✓ Machine learning for decay selection looks promising. Additional checks will be done.
- ✓ Centrality selection and trigger efficiency corrections (pile-up rejection) should be considered.

Thank you for your attention

Backup slides