Updates on 1 GeV beam π^+-Ar inclusive cross section measurement

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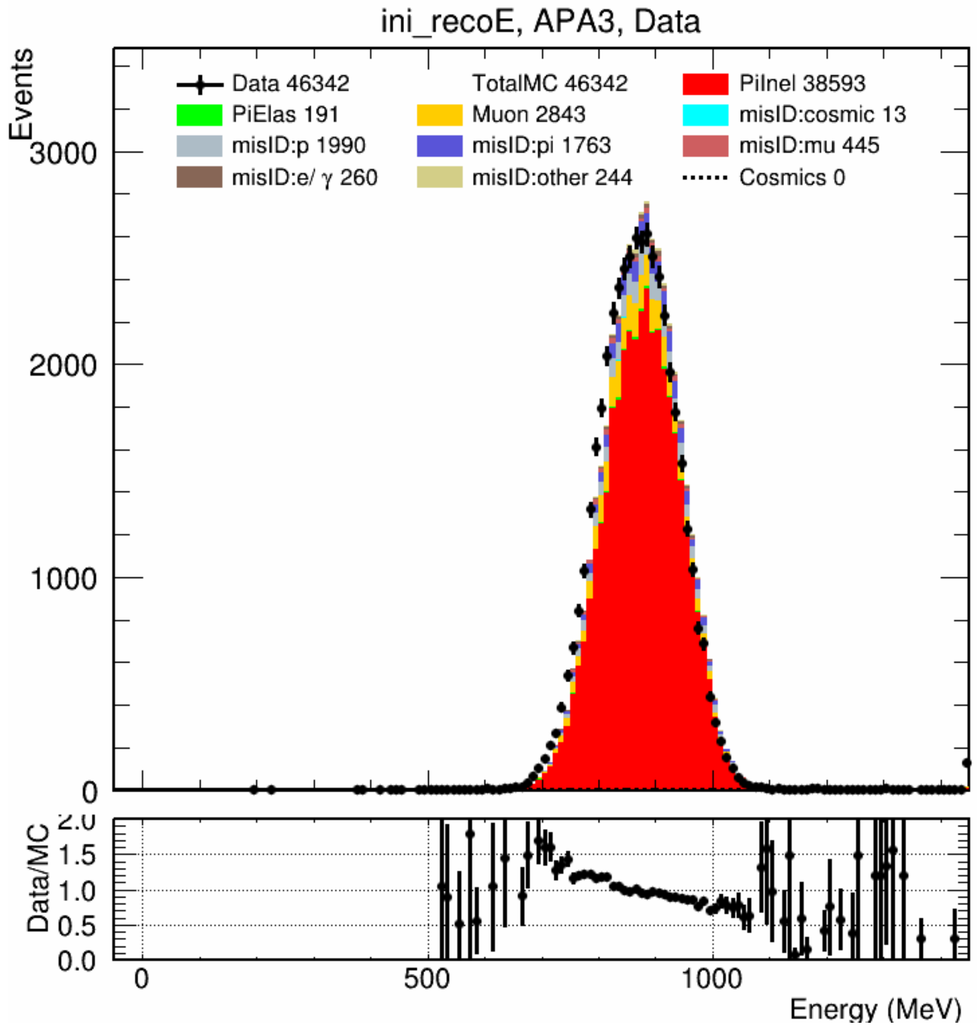
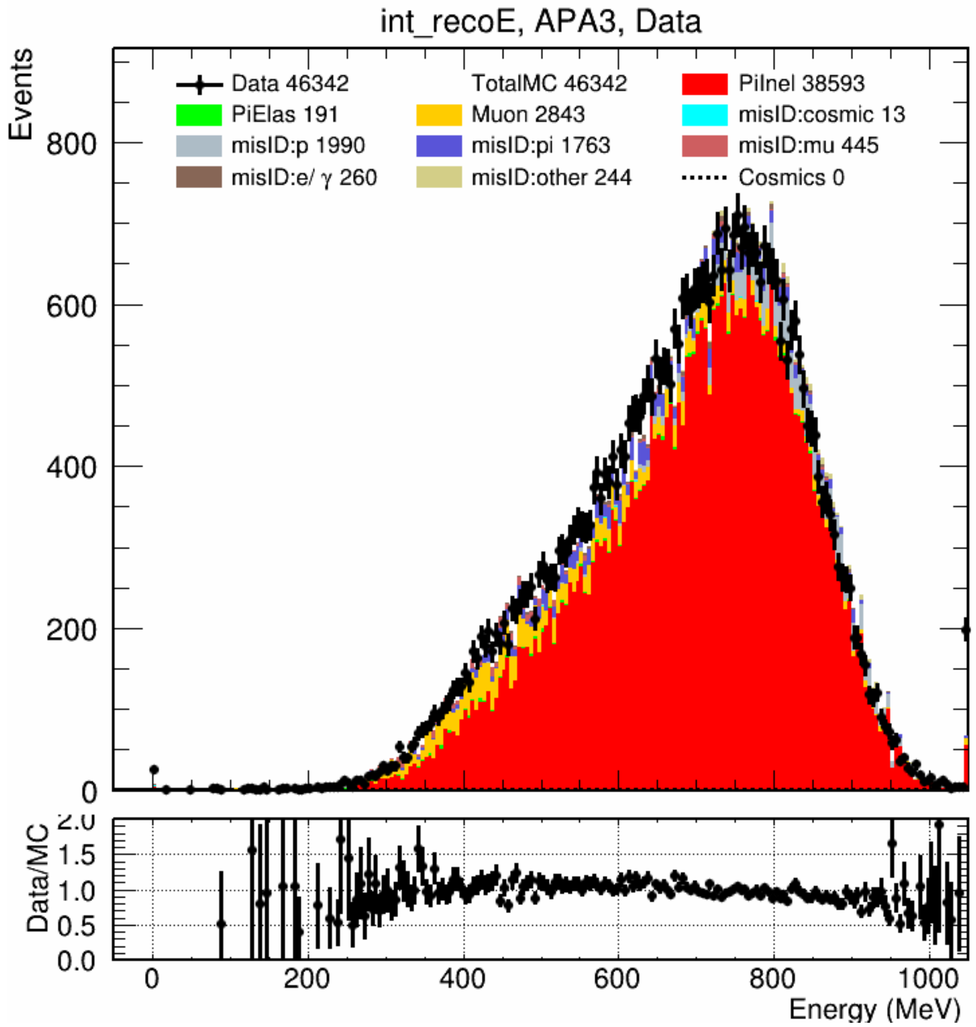
Sept. 1, 2022

After full selections (including APA3 cut)

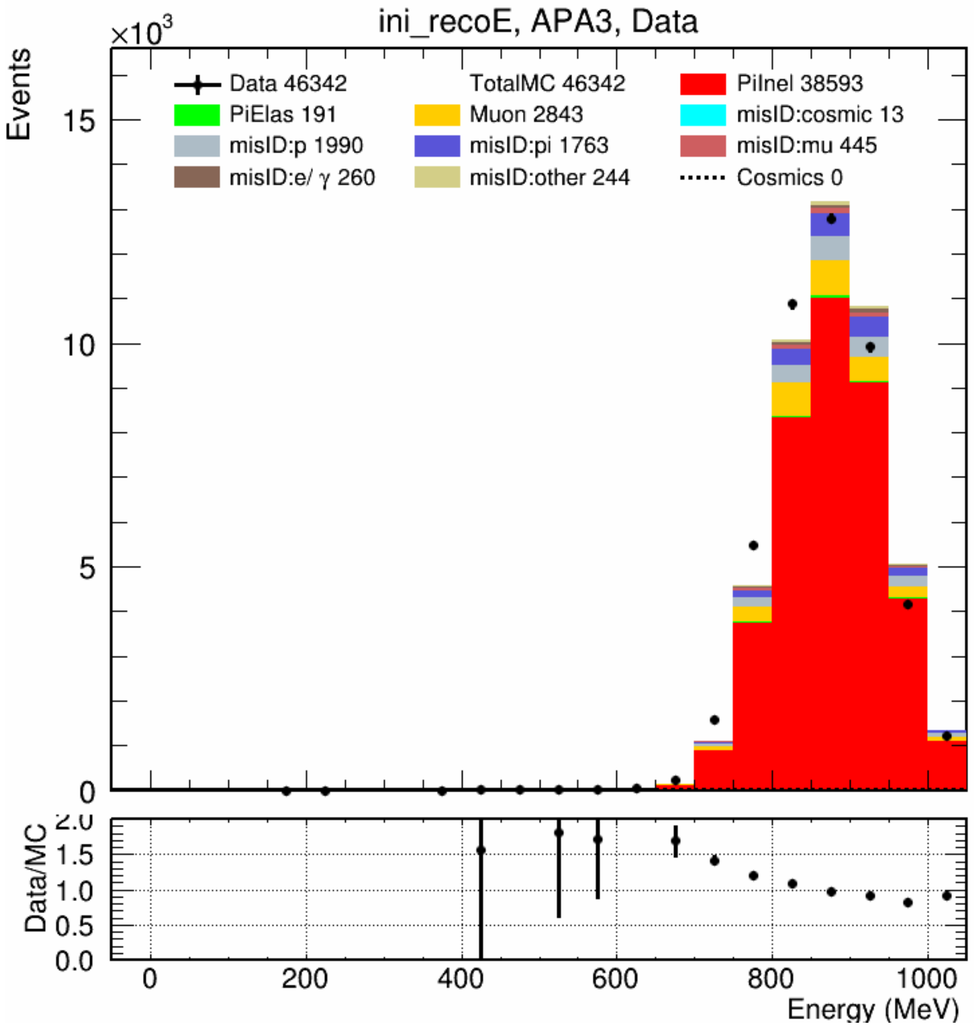
Initial and interaction E comparisons of MC and **real data**

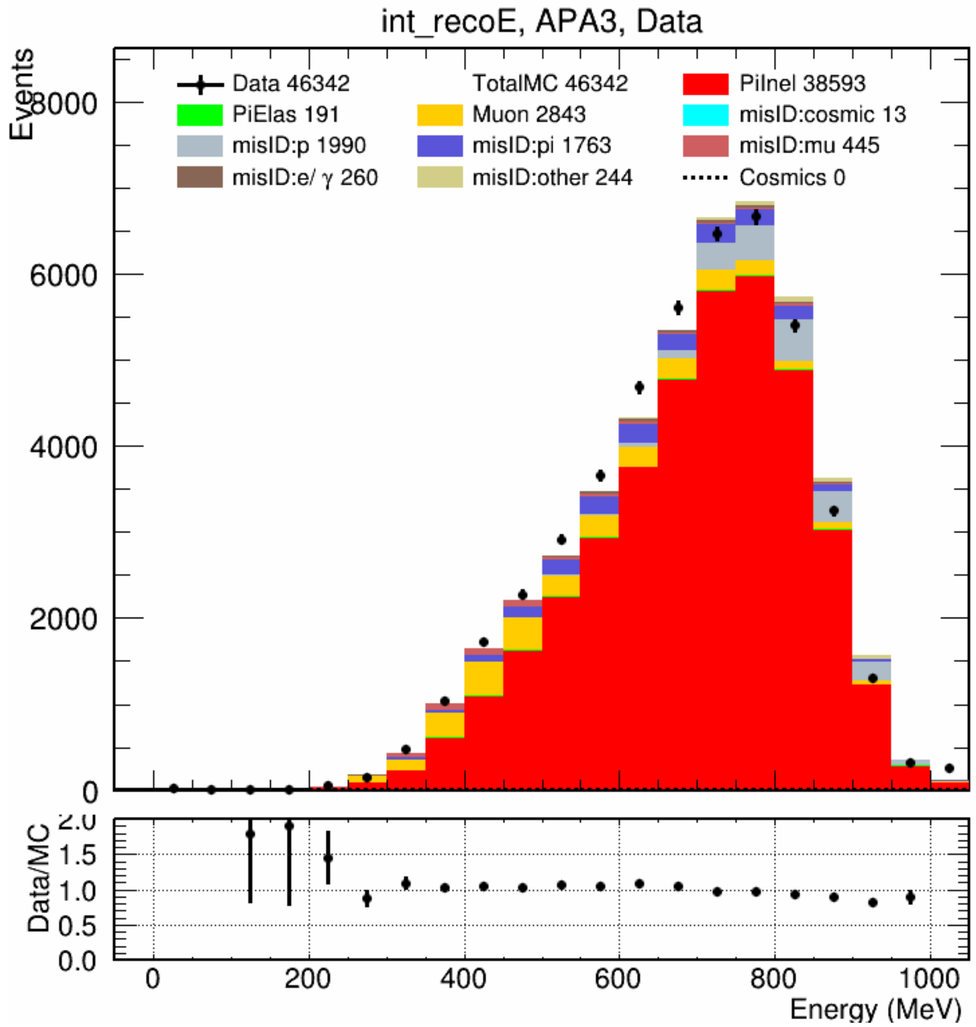


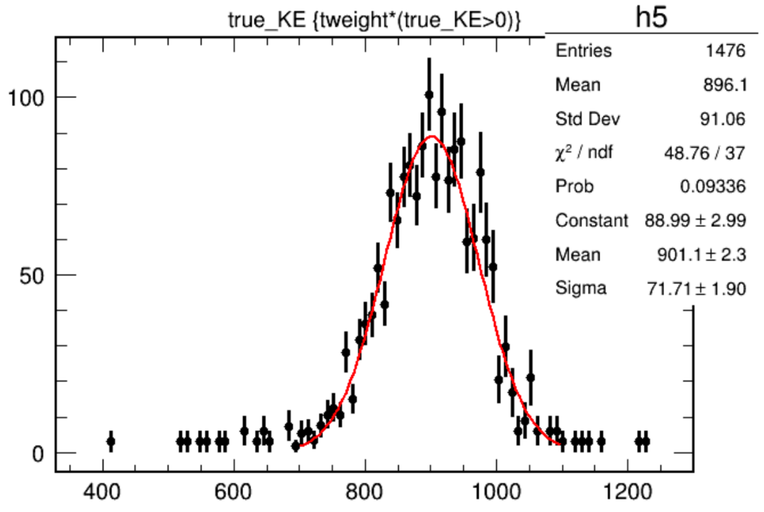


After full selections (including APA3 cut)

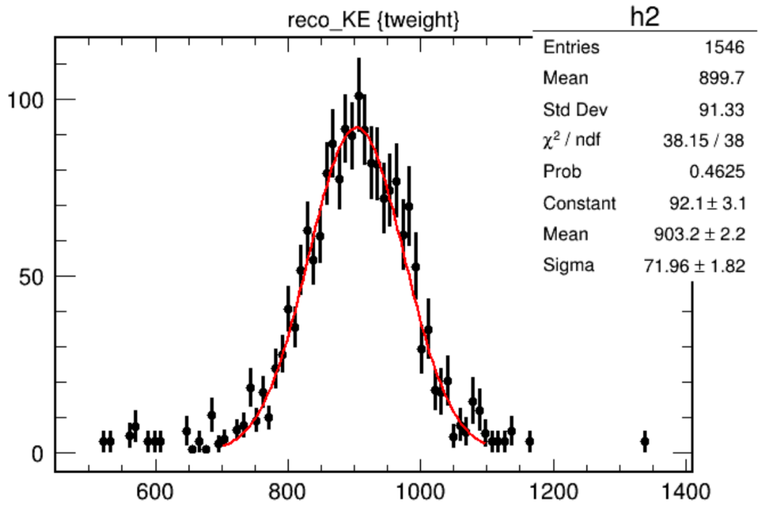
Wider bins (50 MeV)



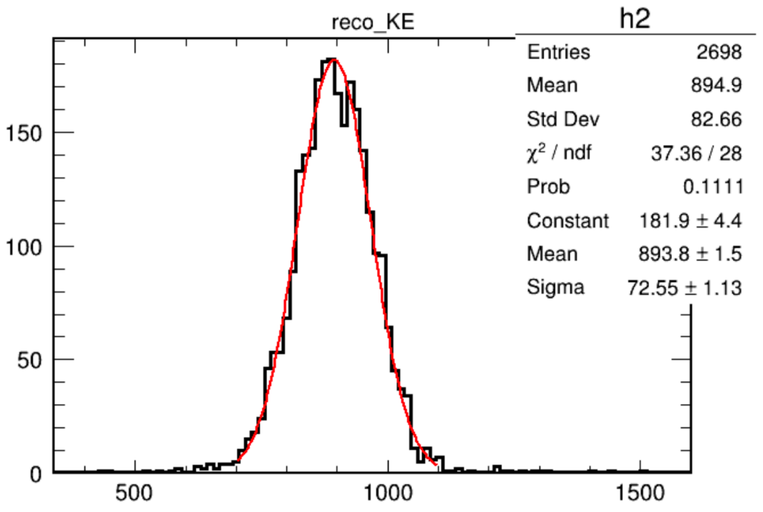




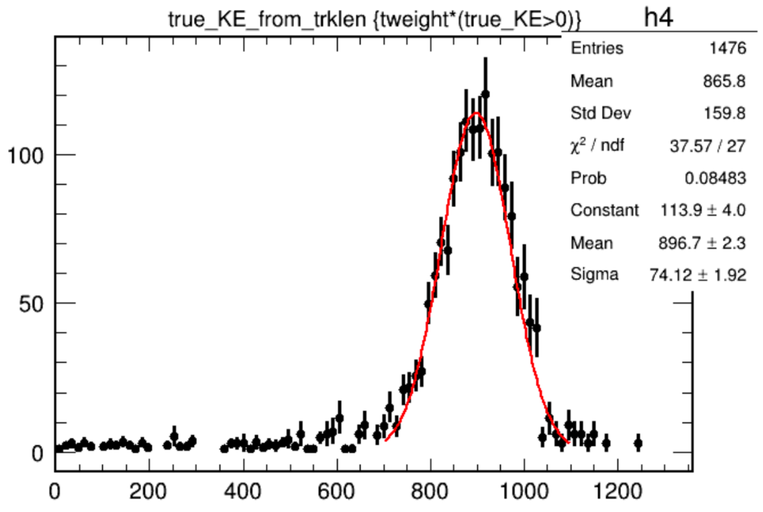
MC true KE



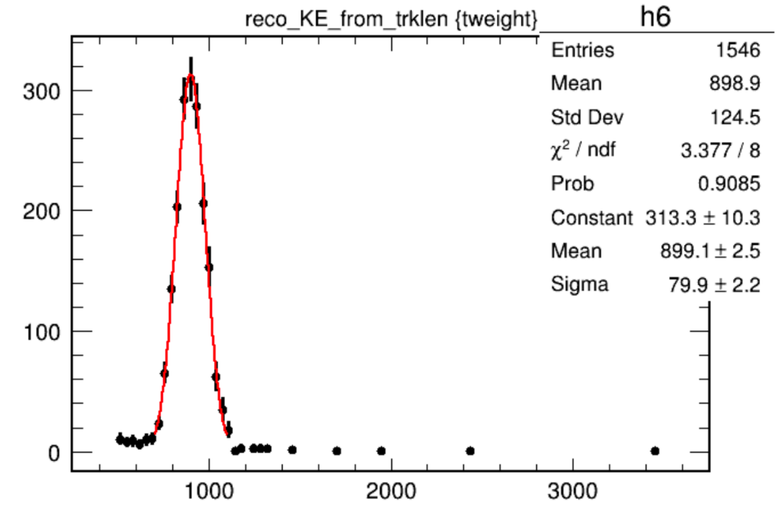
MC reco KE



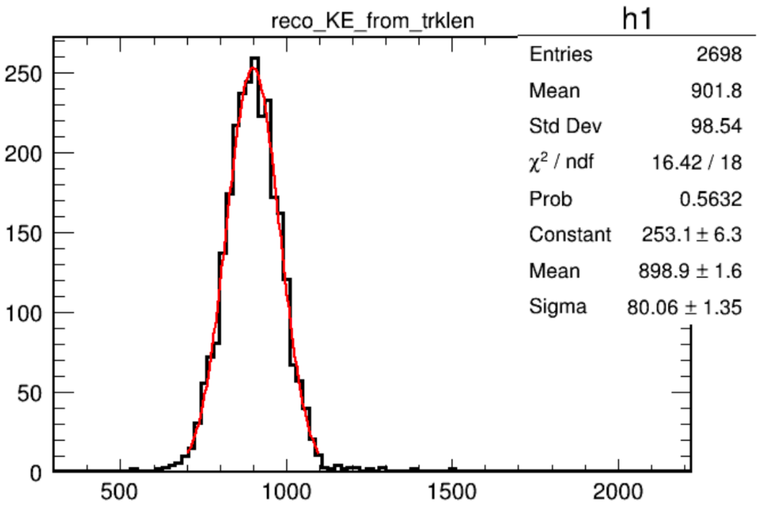
Data reco KE



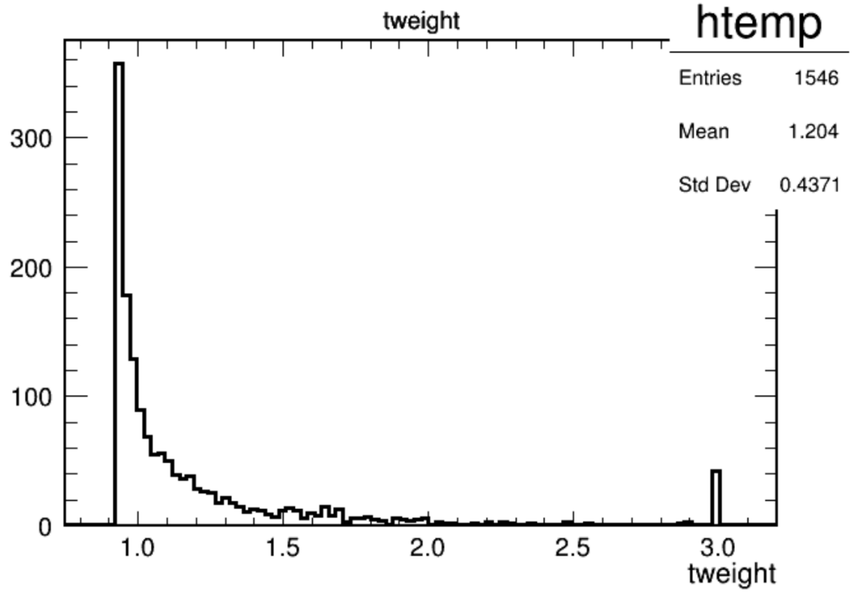
MC KE calculated by true length



MC KE calculated by reco length



Data KE calculated by reco length

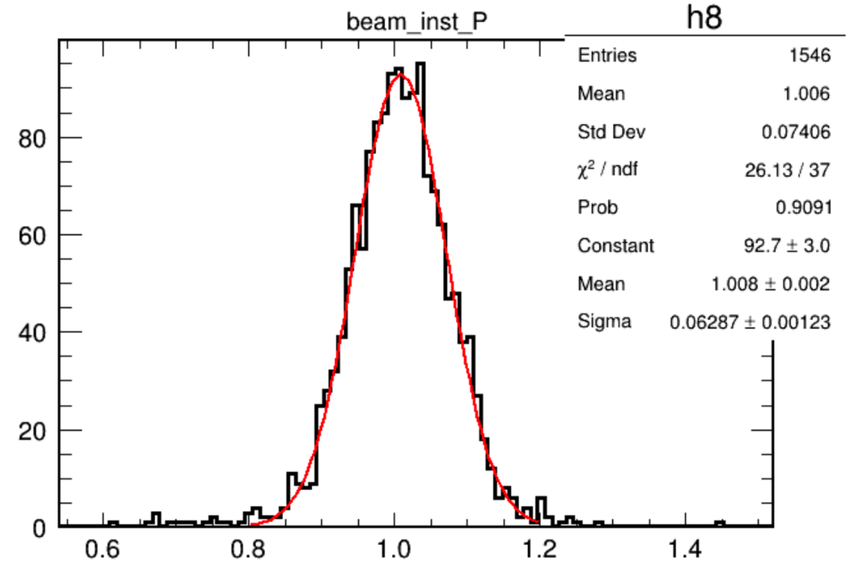


MC weight

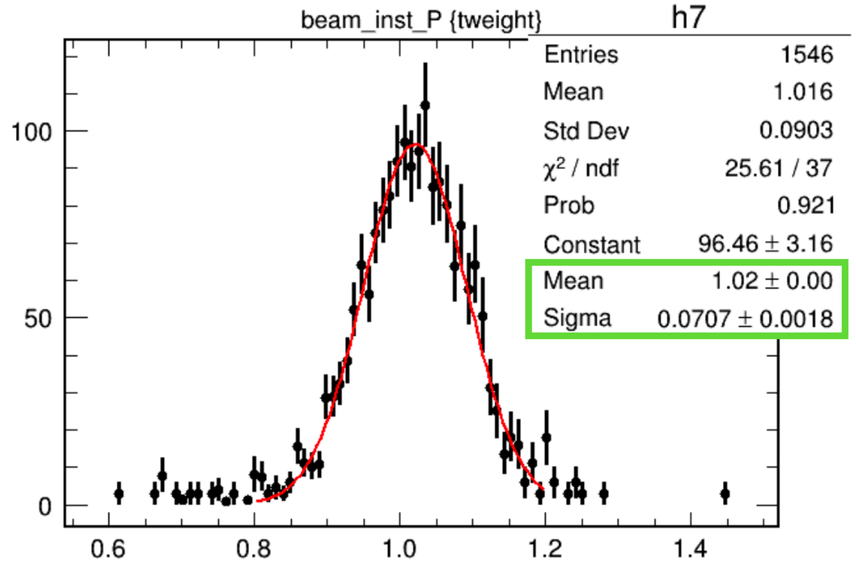
Difference in upstream E loss

Gaus(-9.85, 17.756843) MeV

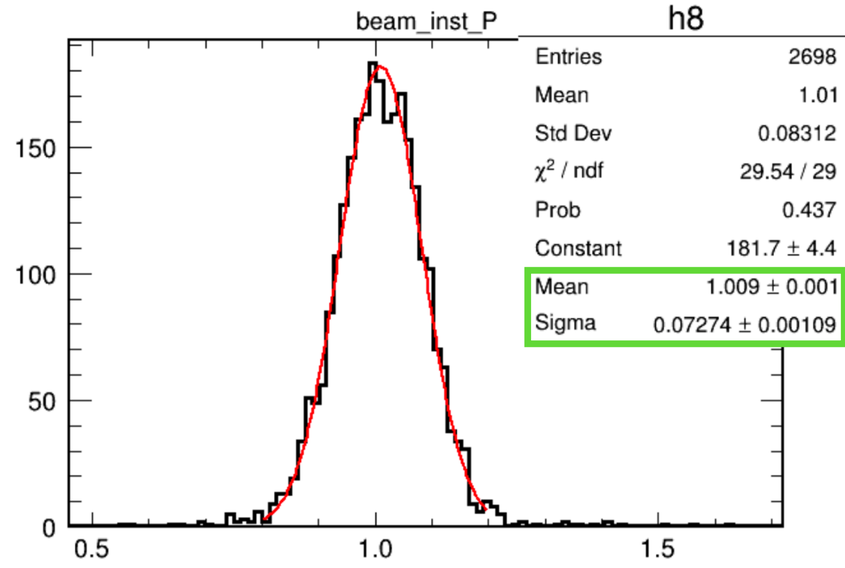
Extra smearing



MC beam momentum



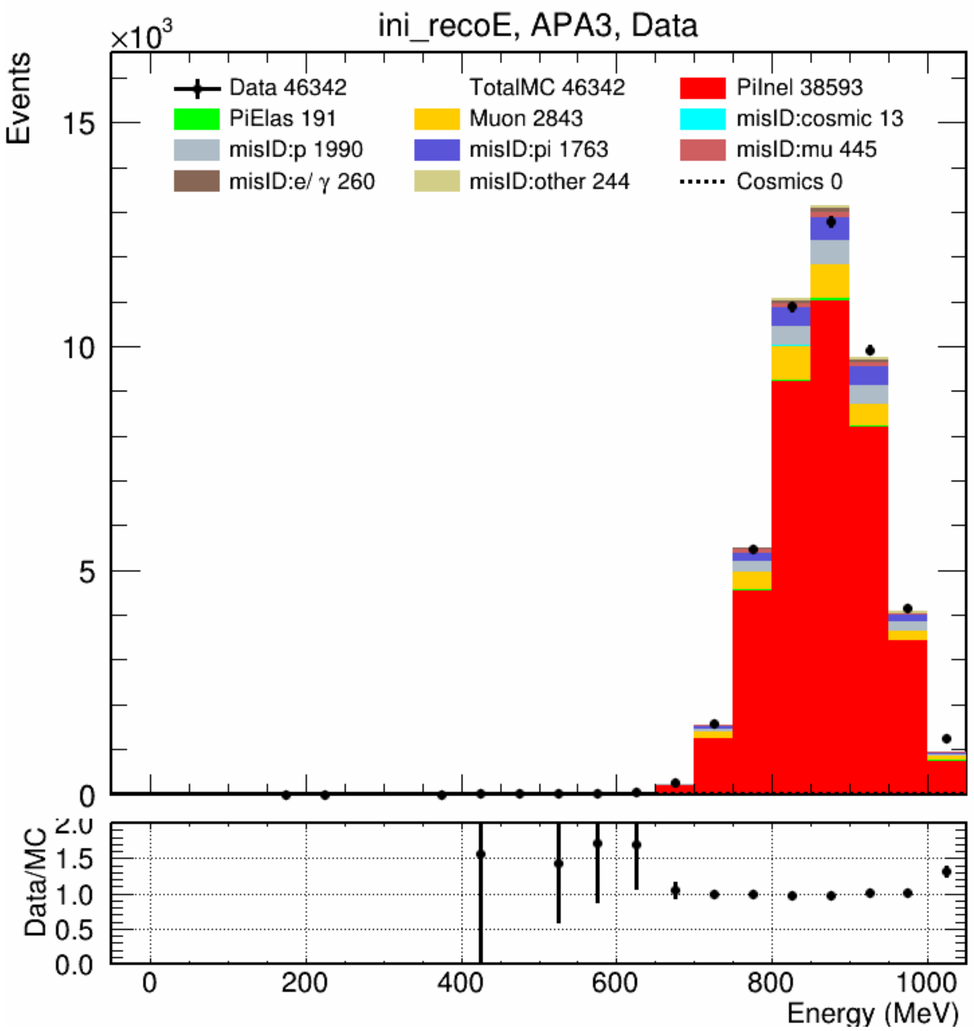
MC reweighted beam momentum

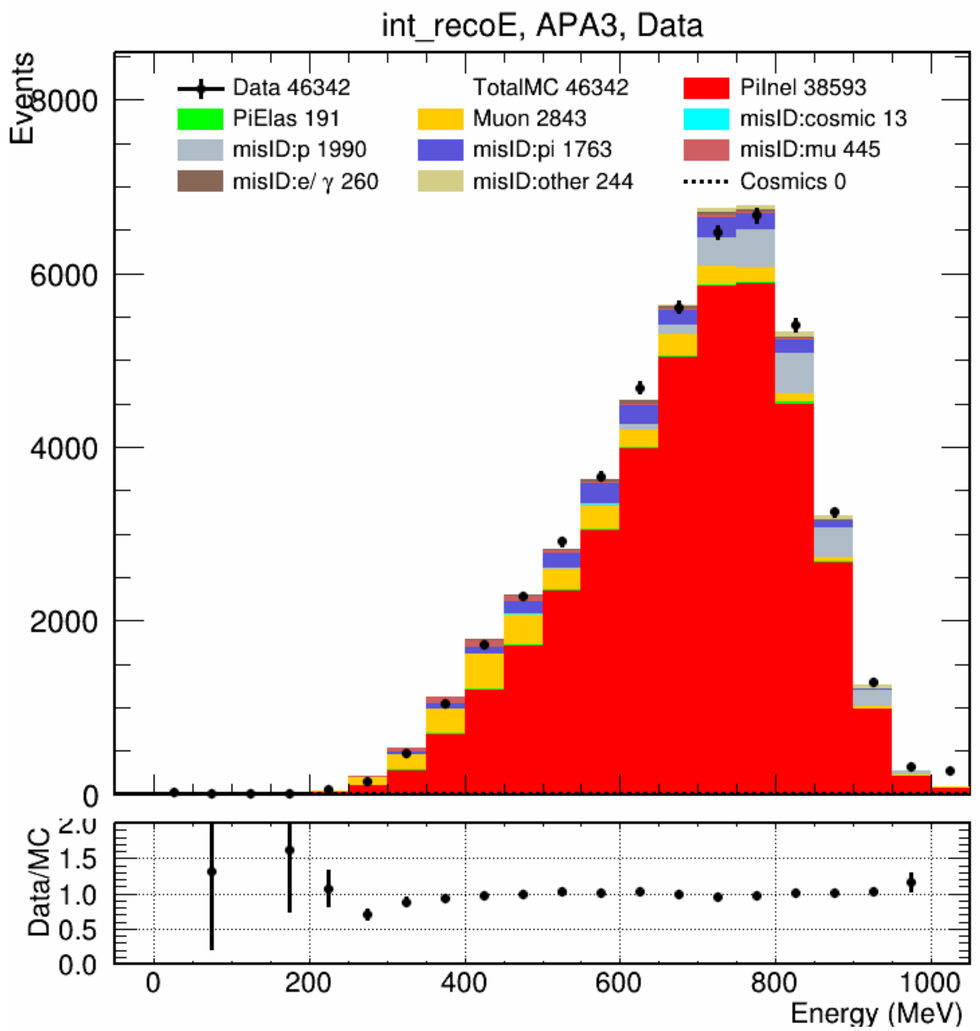


Data beam momentum

After full selections (including APA3 cut)

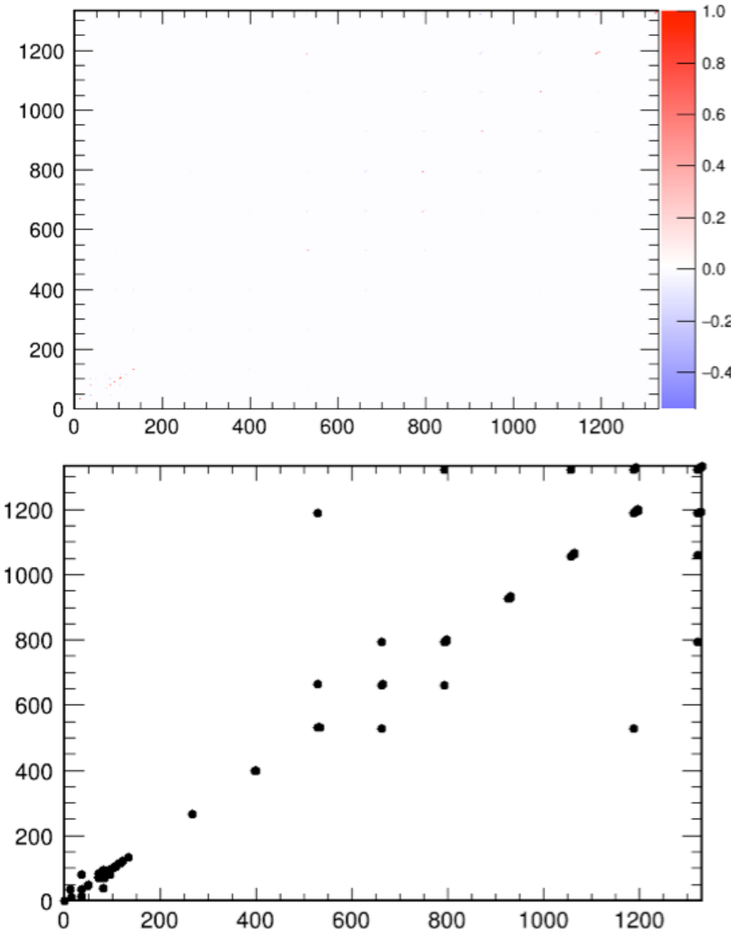
MC beam_inst_P add Gaus(**-9.85**, 17.756843) MeV





Error propagation

- Jacobian matrix $J = \begin{pmatrix} \frac{\partial f_1}{\partial x_1} & \cdots & \frac{\partial f_1}{\partial x_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial f_m}{\partial x_1} & \cdots & \frac{\partial f_m}{\partial x_n} \end{pmatrix}$
- Covariance matrix $V = \begin{pmatrix} \sigma_{11} & \cdots & \sigma_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_{n1} & \cdots & \sigma_{nn} \end{pmatrix}$
- $V_f = J \cdot V_x \cdot J^T$



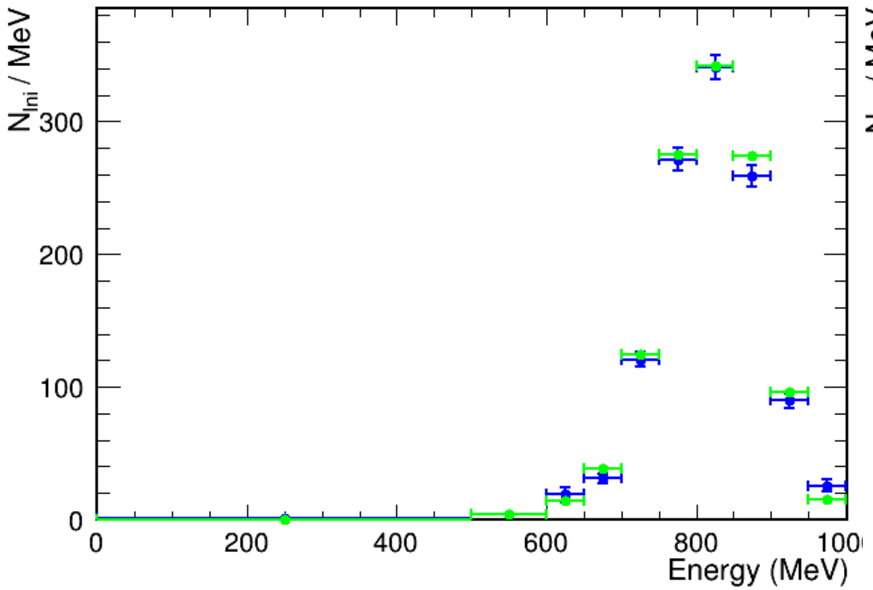
Covariance matrix provided by the 3D unfolding of $(N_{\text{ini}}, N_{\text{end}}, N_{\text{int}})$

Error propagation

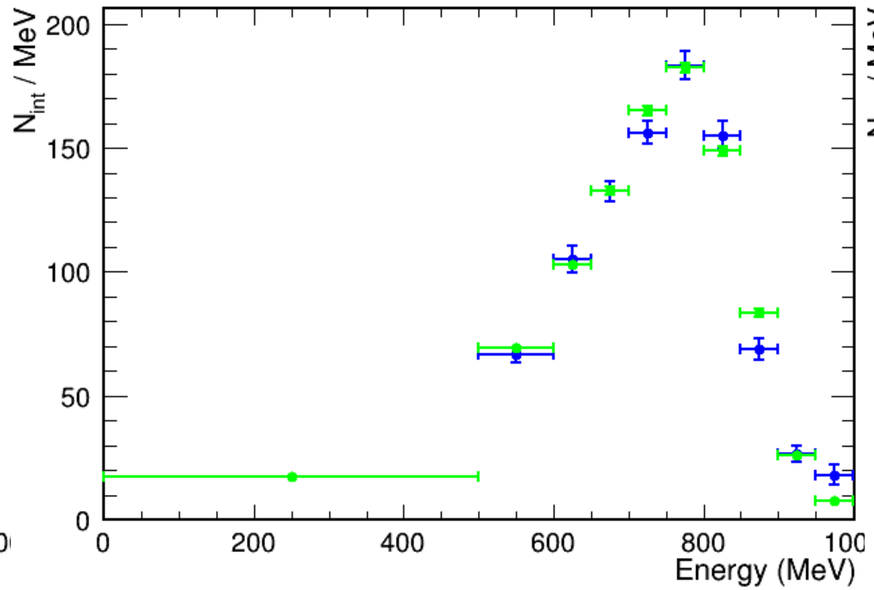
- $N+1$ is the number of bins (plus one unphysical underflow)
- $A_{(N+1)^3\times(N+1)^3}$ for the combined variable $(N_{\text{ini}}, N_{\text{end}}, N_{\text{int}})$ is provided by unfolding
- $B_{3(N+1)\times3(N+1)}$ for N_{ini}, N_{end} and N_{int} e.g. $N_{\text{ini}} = \sum_{N_{\text{end}},N_{\text{int}}} (N_{\text{ini}}, N_{\text{end}}, N_{\text{int}})$
- $C_{2N\times2N}$ for N_{inc} and N_{int} (leave out the underflow bin)
  - $N_{\text{inc}}(i) = \sum_{j=i}^{N} N_{\text{end}}(j) - \sum_{j=i+1}^{N} N_{\text{ini}}(j)$ or $N_{\text{inc}}(i) = \sum_{j=1}^{i} N_{\text{ini}}(j) - \sum_{j=1}^{i-1} N_{\text{end}}(j)$
- $D_{N\times N}$ for XS: $\sigma = \frac{M_{\text{Ar}}}{\rho N_A \Delta E}\frac{dE}{dx}\ln\left(\frac{N_{\text{inc}}}{N_{\text{inc}} - N_{\text{int}}}\right)$

Fake data

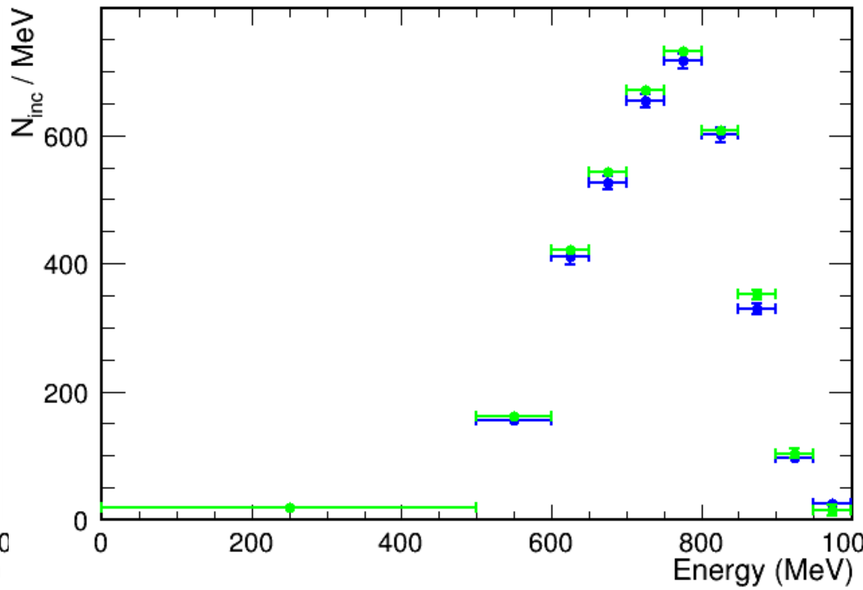
3D unfolding 10 iterations



Initial histogram



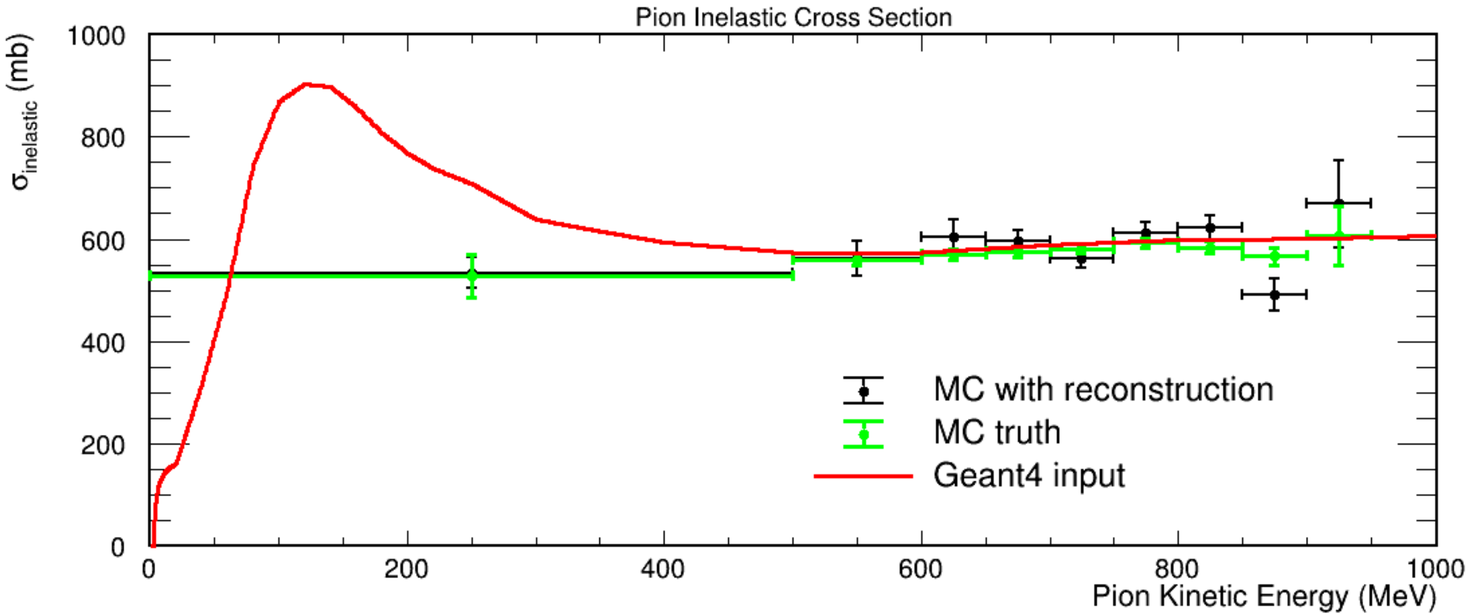
Interaction histogram

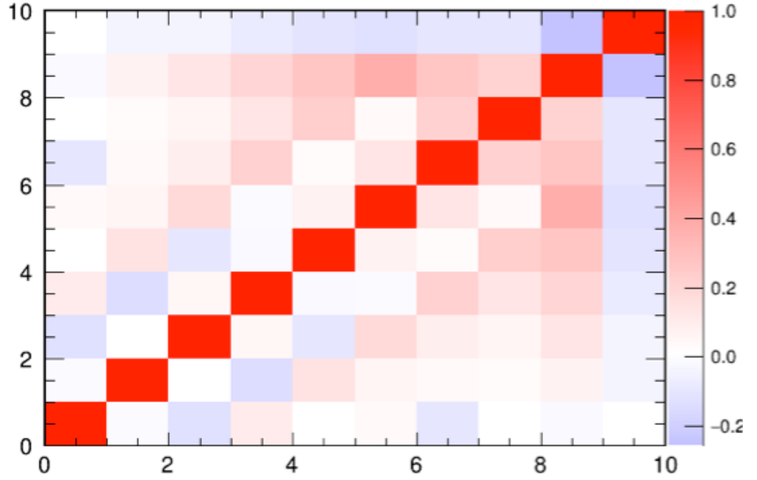


Incident histogram

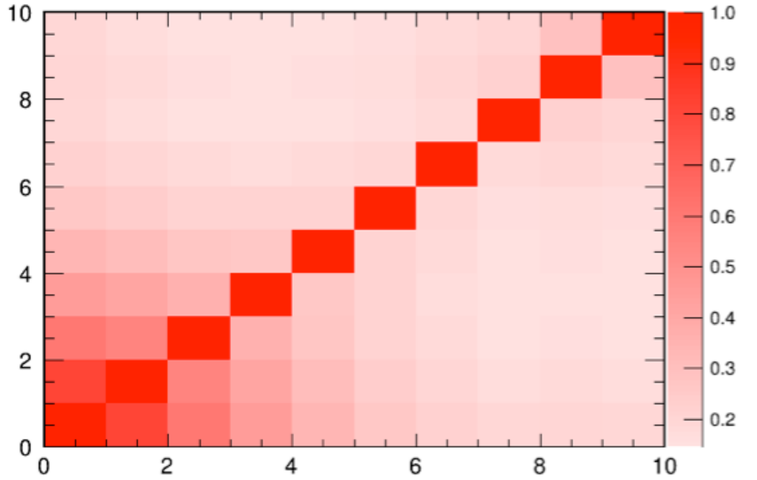
Fake data

3D unfolding 10 iterations





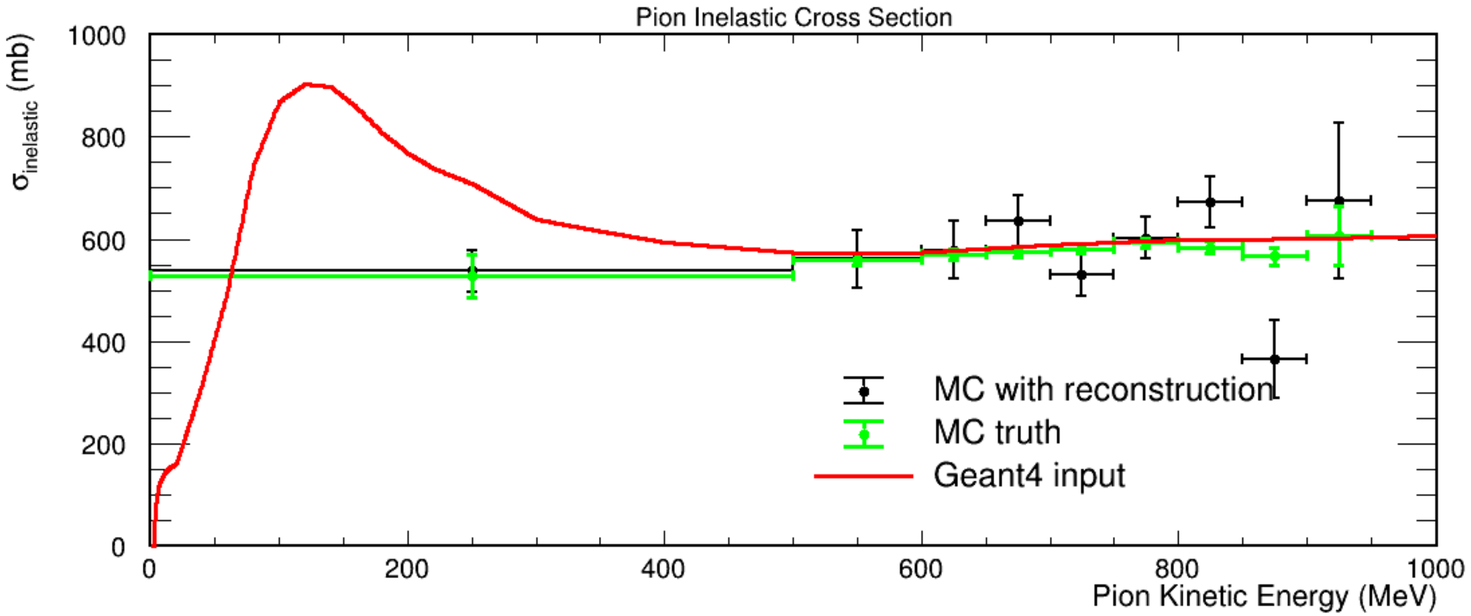
Correlation matrix for reco XS

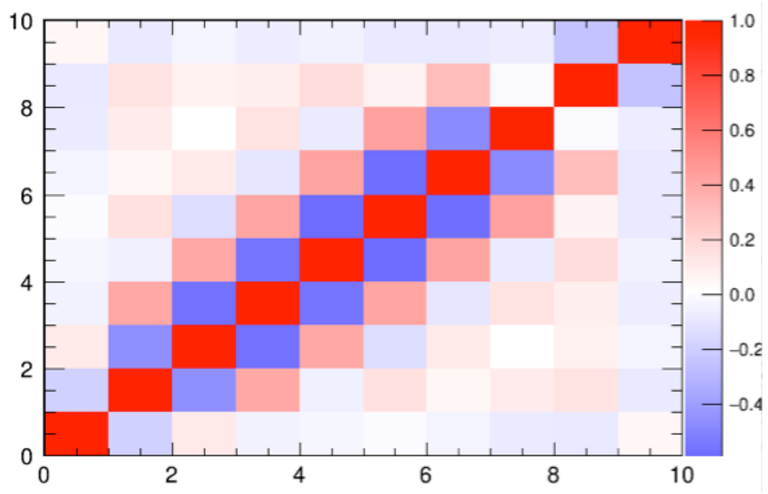


Correlation matrix for true XS

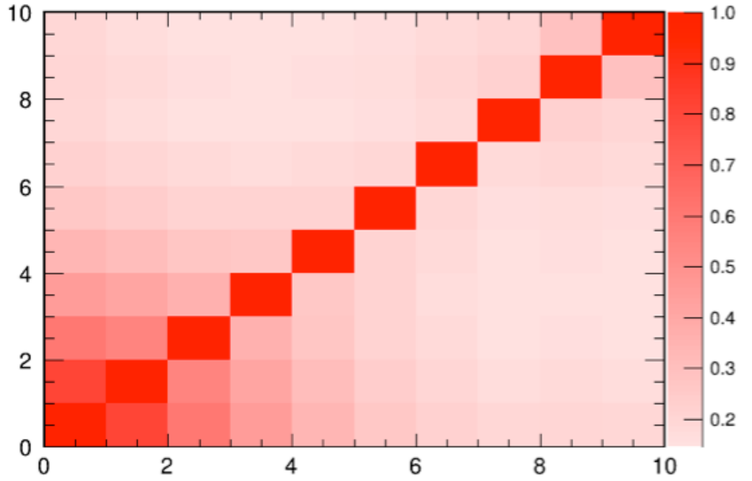
Fake data

3D unfolding 200 iterations





Correlation matrix for reco XS

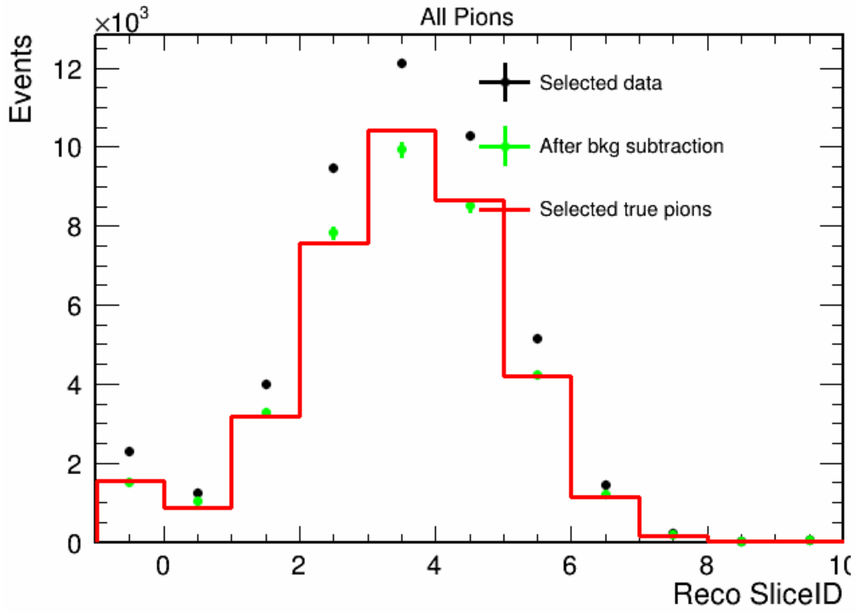


Correlation matrix for true XS

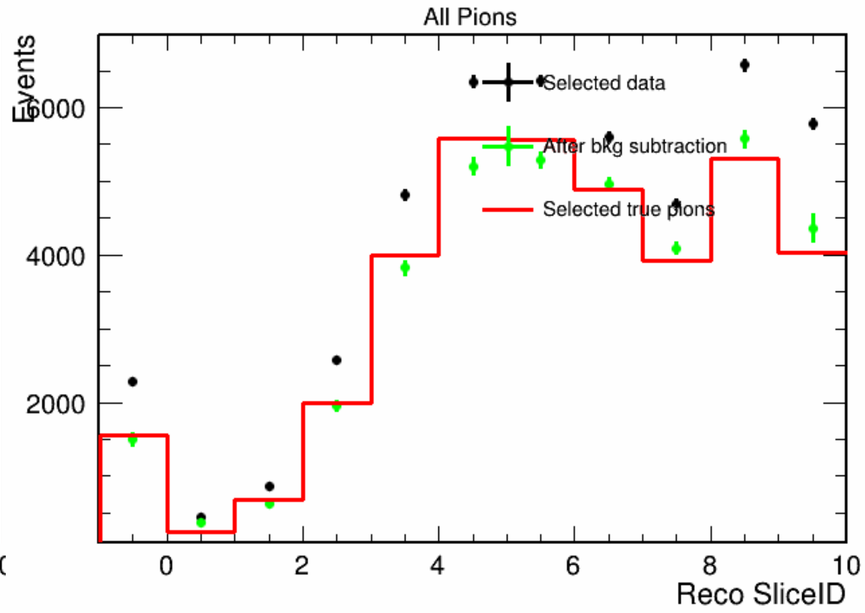
Real data

Muon scaling factor: 0.60 ± 0.13
Proton scaling factor: 1.80 ± 0.15
Pion scaling factor: 1.45 ± 0.14

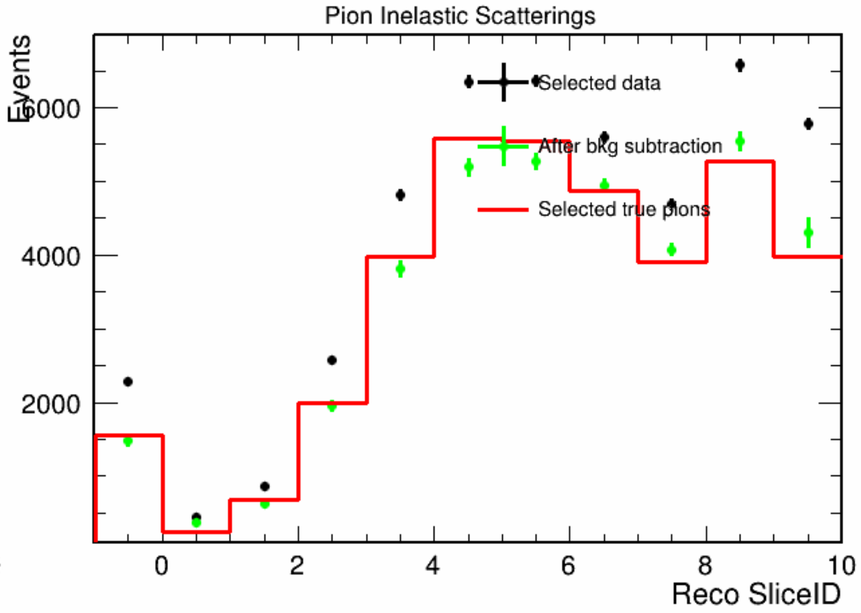
- After bkg subtraction



Initial sliceID



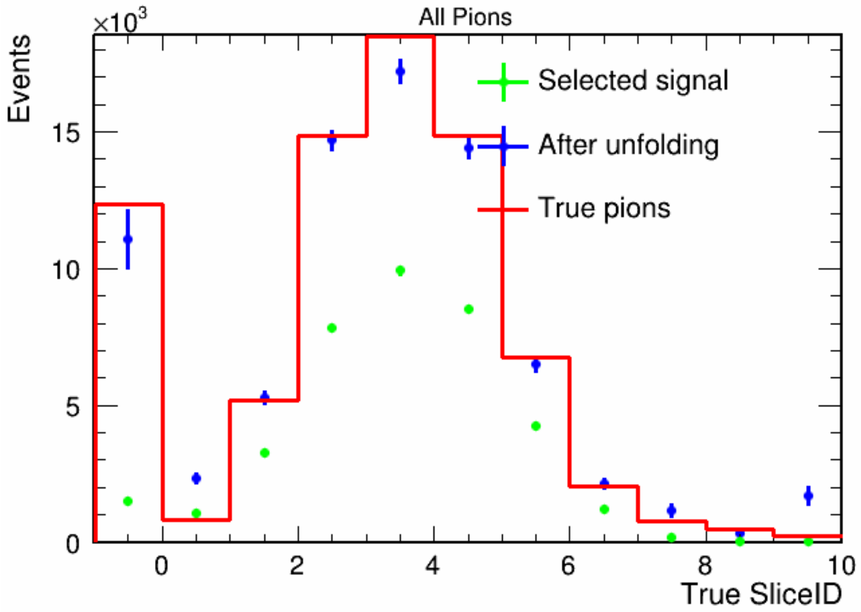
End sliceID



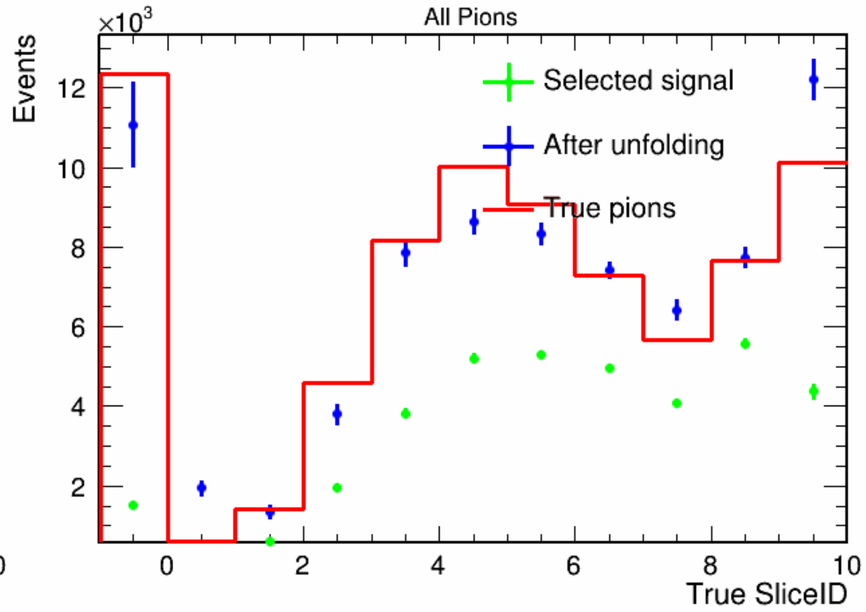
Interaction sliceID

Real data

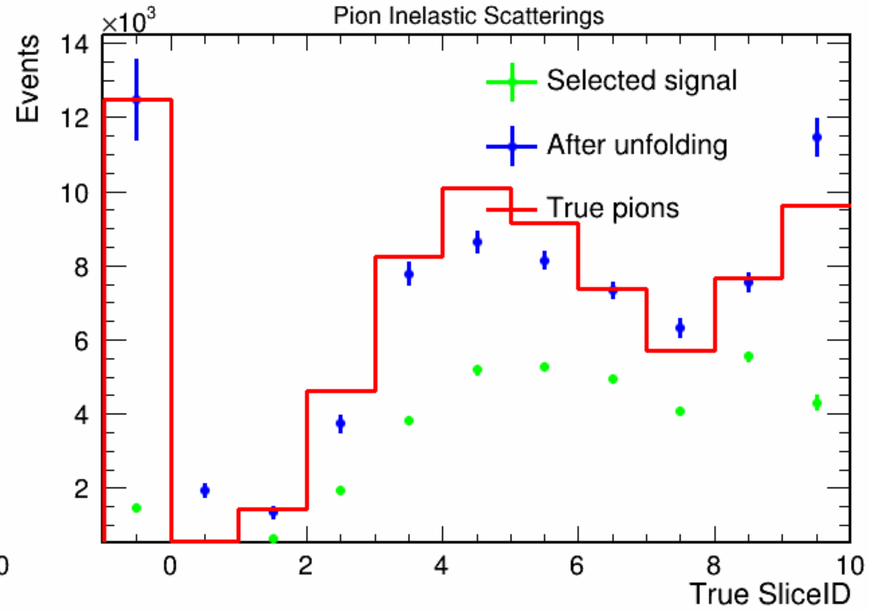
- After unfolding



Initial sliceID



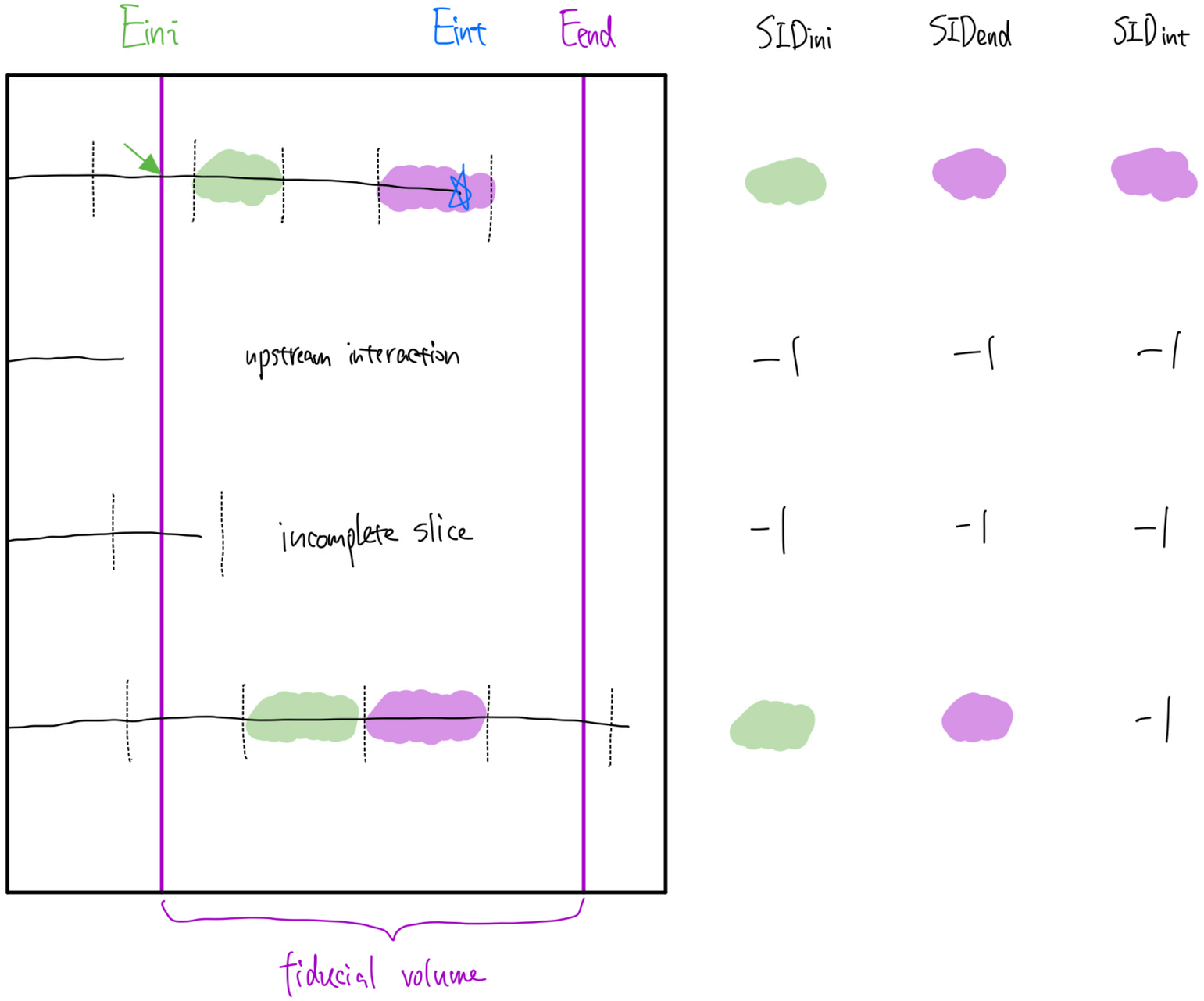
End sliceID



Interaction sliceID

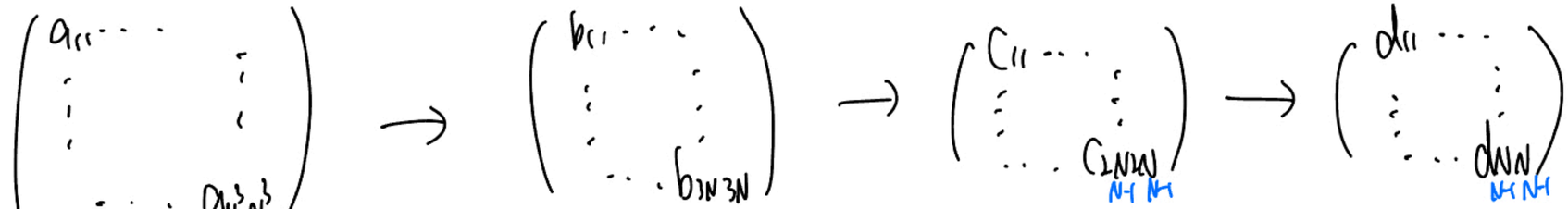
Back-ups

Definition of sliceIDs



Some notes for error propagation

reco



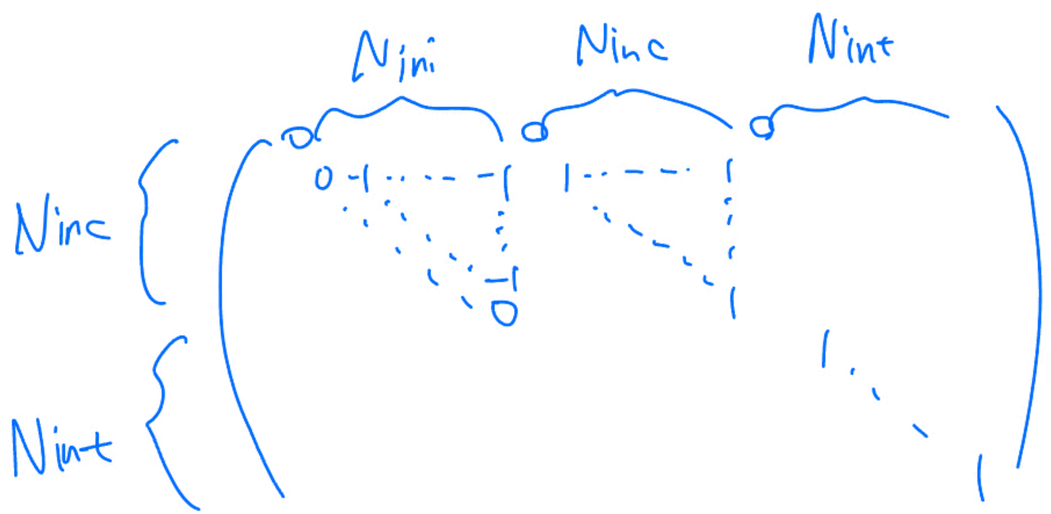
unfolding provide

N_{ini}, N_{end}, N_{int}

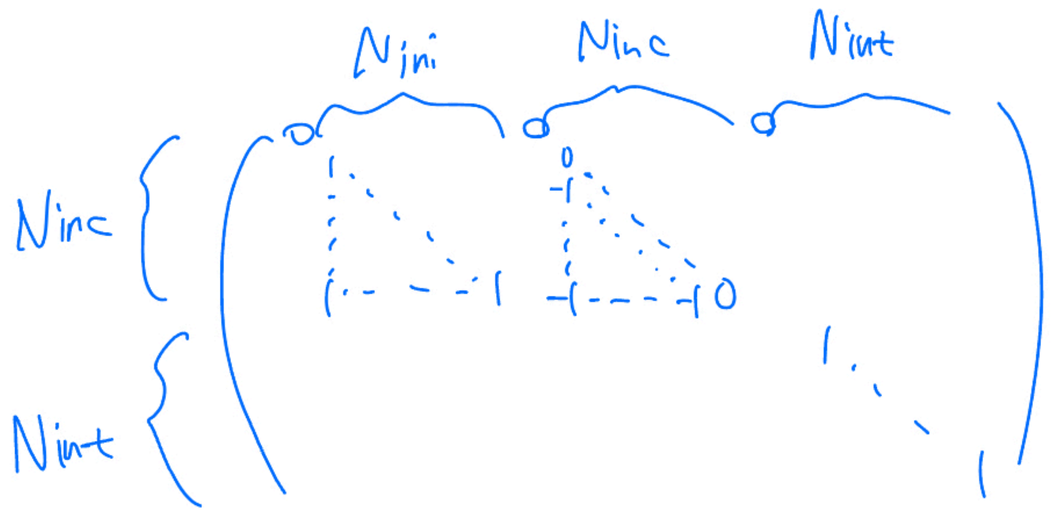
N_{inc}, N_{int}

XS

true



or



Some notes for error propagation

$$\sigma = \underbrace{\frac{M_{Ar}}{\rho N_A \Delta E}\frac{dE}{dx}}_{C} \ln\frac{N_{inc}}{N_{inc}-N_{int}} \quad \text{XS} \quad \left(\frac{\partial\sigma}{\partial N_{inc}}\overbrace{\quad}^{N_{inc}} \quad \frac{\partial\sigma}{\partial N_{int}}\overbrace{\quad}^{N_{int}}\right)$$

$$\frac{\partial\sigma}{\partial N_{inc}} = C\cdot\frac{N_{inc}-N_{int}}{N_{inc}}\,\frac{N_{inc}-N_{int}-N_{inc}}{(N_{inc}-N_{int})^2} = C\cdot\frac{-N_{int}}{N_{inc}(N_{inc}-N_{int})}$$

$$\frac{\partial\sigma}{\partial N_{int}} = C\cdot\frac{N_{inc}}{N_{inc}(N_{inc}-N_{int})} = C\cdot\frac{1}{N_{inc}-N_{int}}$$

RooUnfold print table

Bin	Train Truth	Train Measured	Test Truth	Test Input	Unfolded Output	Error on Unfolding	Diff	Pull
1, 1, 1	11128	1481		1552	12115.8	884.9		
2, 1, 1	0	0		0	0.0	0.0		
3, 1, 1	0	0		0	0.0	0.0		
4, 1, 1	0	0		0	0.0	0.0		
5, 1, 1	0	0		0	0.0	0.0		
6, 1, 1	0	0		0	0.0	0.0		
7, 1, 1	0	0		0	0.0	0.0		
8, 1, 1	0	0		0	0.0	0.0		
9, 1, 1	0	0		0	0.0	0.0		
10, 1, 1	0	0		0	0.0	0.0		
11, 1, 1	0	0		0	0.0	0.0		
1, 2, 1	0	0		0	0.0	0.0		
2, 2, 1	12	2		2	12.0	8.5		
3, 2, 1	0	0		0	0.0	0.0		
4, 2, 1	0	0		0	0.0	0.0		
5, 2, 1	0	0		0	0.0	0.0		
6, 2, 1	0	0		0	0.0	0.0		
7, 2, 1	0	0		0	0.0	0.0		
8, 2, 1	0	0		0	0.0	0.0		
9, 2, 1	0	0		0	0.0	0.0		
10, 2, 1	0	0		0	0.0	0.0		
11, 2, 1	0	0		0	0.0	0.0		
1, 3, 1	0	0		0	0.0	0.0		
2, 3, 1	0	0		0	0.0	0.0		
3, 3, 1	12	0		0	0.0	0.0		
4, 3, 1	0	0		0	0.0	0.0		