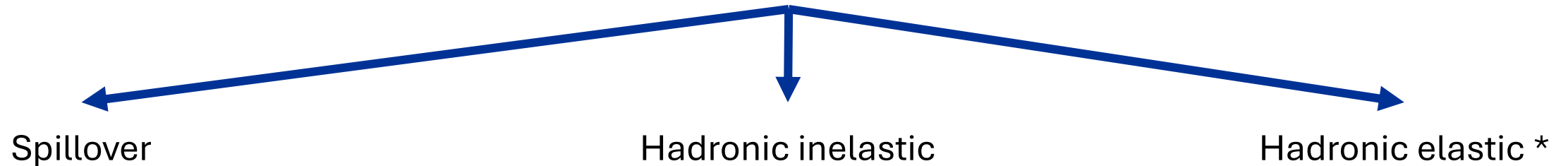


Fully connected neural network for background suppression in \overline{He} research

Francesco Rossi

Sources of charged confused events

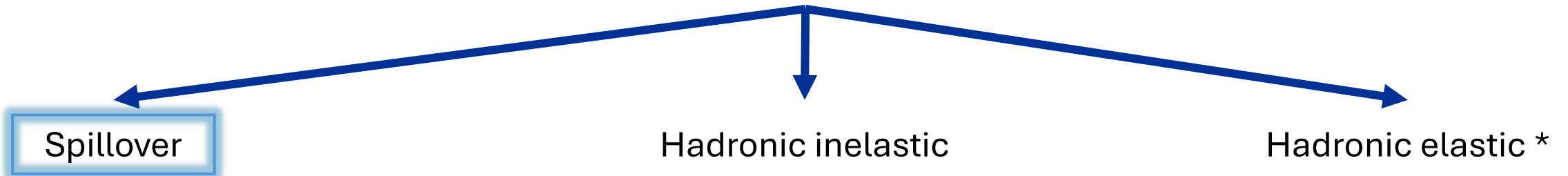
Using He Monte Carlo B1236 L1-focused and L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**



* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**

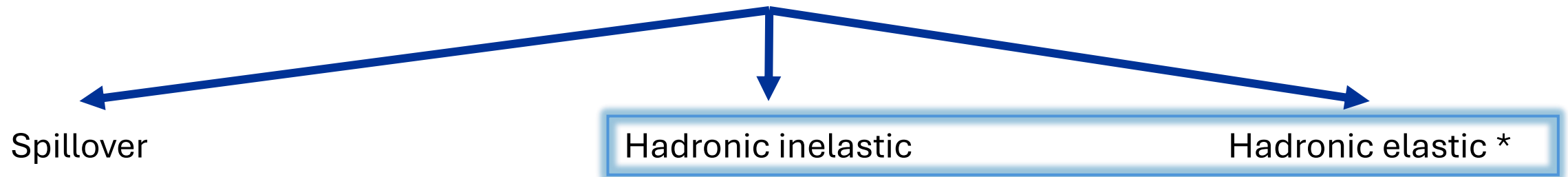


Silicon tracker finite resolution

* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**

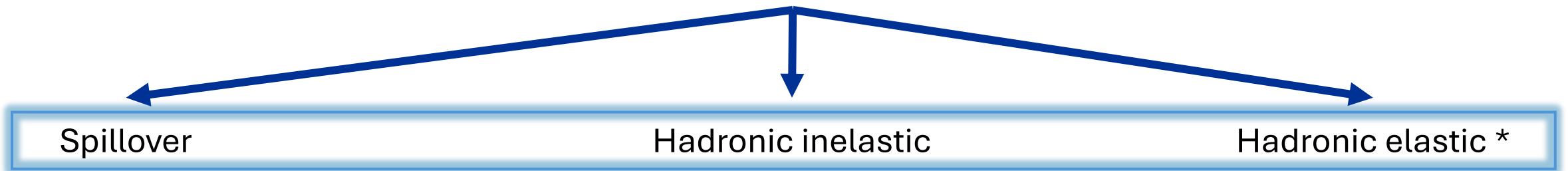


Interactions within the detector

* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**

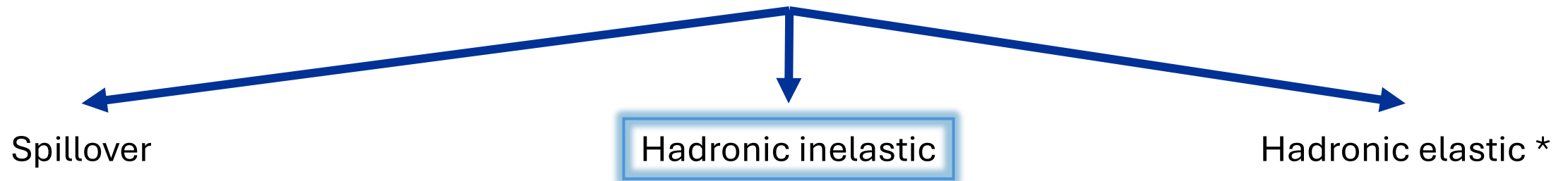


For each source, we select a sample to be used in the training of a Fully Connected Neural Network

* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**

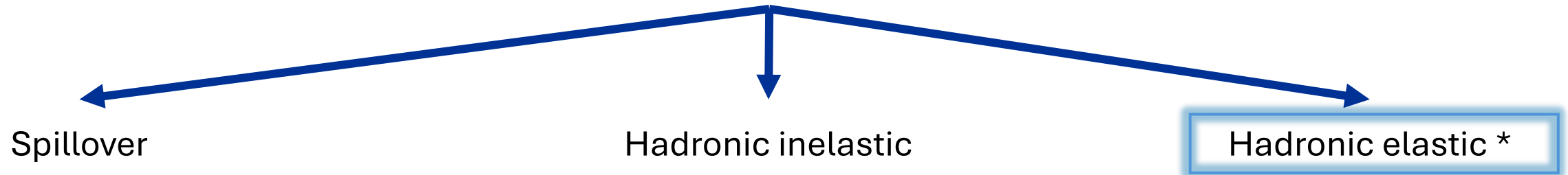


Search in the secondaries list looking for inelastic interaction products inside the inner tracker

* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**



P. Zuccon added a MC flag for events interacting elastically at gBatch level.

The tag is added every time that a discrete elastic scattering is called.

It stores info about the scattering nuclei, scattering angle, initial and final momentum of primary particle.

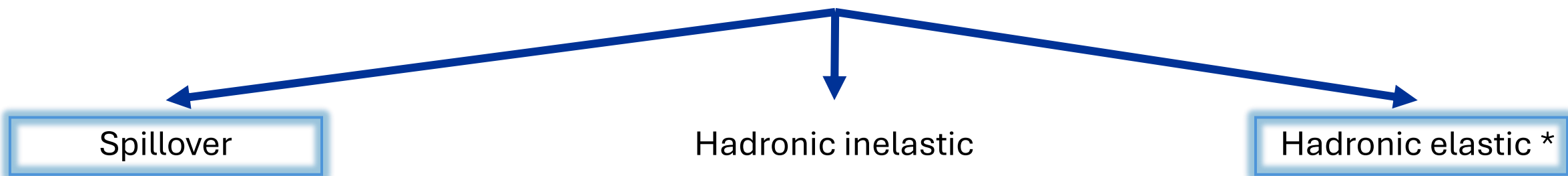
More info available in NAIA pzv1.2.0 on Gitlab.

1'000 naia ntuple produced on Trento AMS server, $R_{true} \leq 200$ [GV].

* Large angle scattering

Sources of charged confused events

Using He Monte Carlo B1236 L1-focused and B1236 L1-L9 focused, and selecting the **reconstructed events with $R < 0$** , we identified **three sources of charge confusion**



Search in the secondaries list looking for secondaries produced inside the inner tracker (HasSecondary)

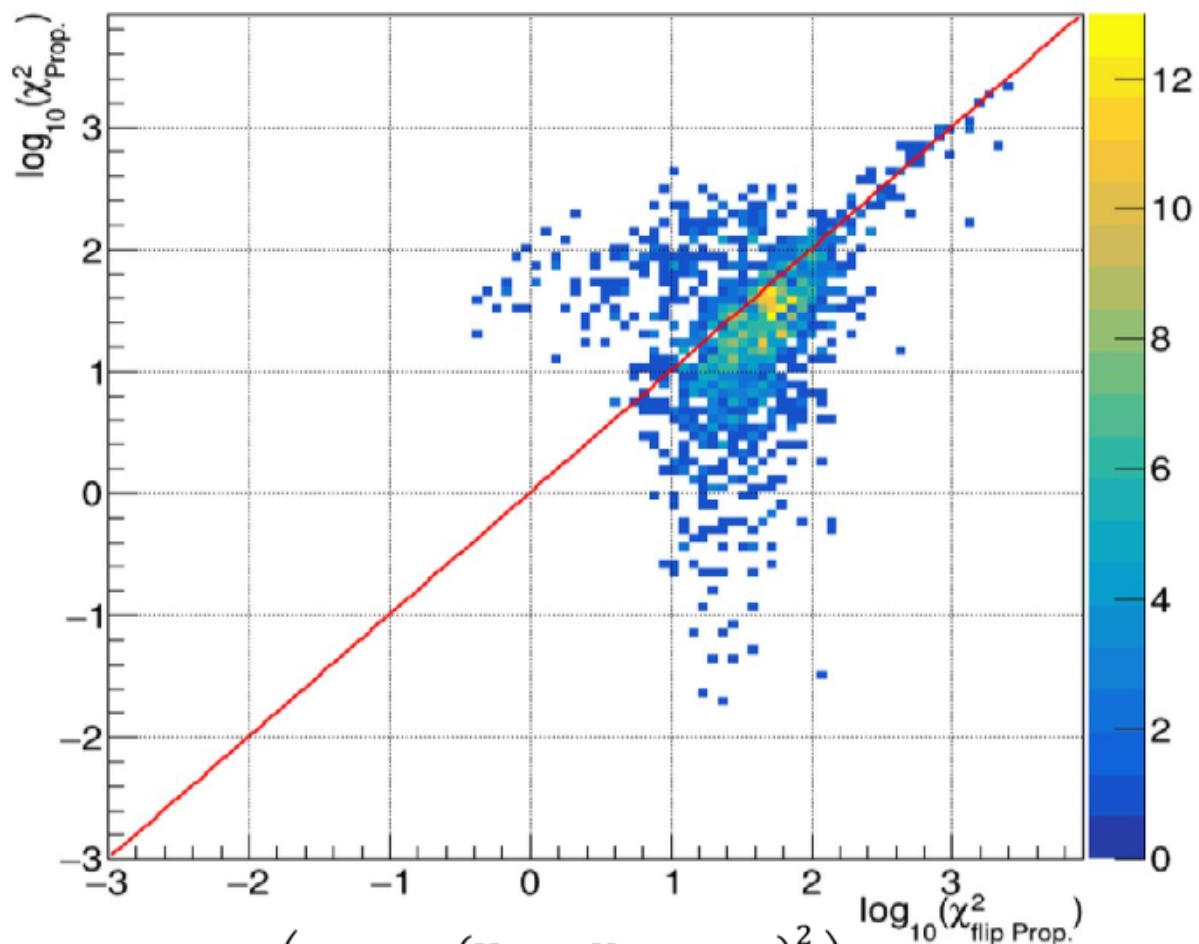
Events are not Had. Inel. Interactions and primary nuclei reaches L2

Propagation of two tracks: $R_{true}(L2)$ and $R_{inner} (< 0)$
Build two χ^2 comparing y coordinate with MC true info on each layer.

$\frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2} \leq 0.85$	\rightarrow El. scat.
$1.15 \leq \frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2}$	\rightarrow (HasSecondary) ? Other : Spillover
$0.85 < \frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2} \leq 1.15$	\rightarrow (HasSecondary) ? Other : Spillover

$R_{\text{inner}} < 0$ (no secondaries within inner tracker)

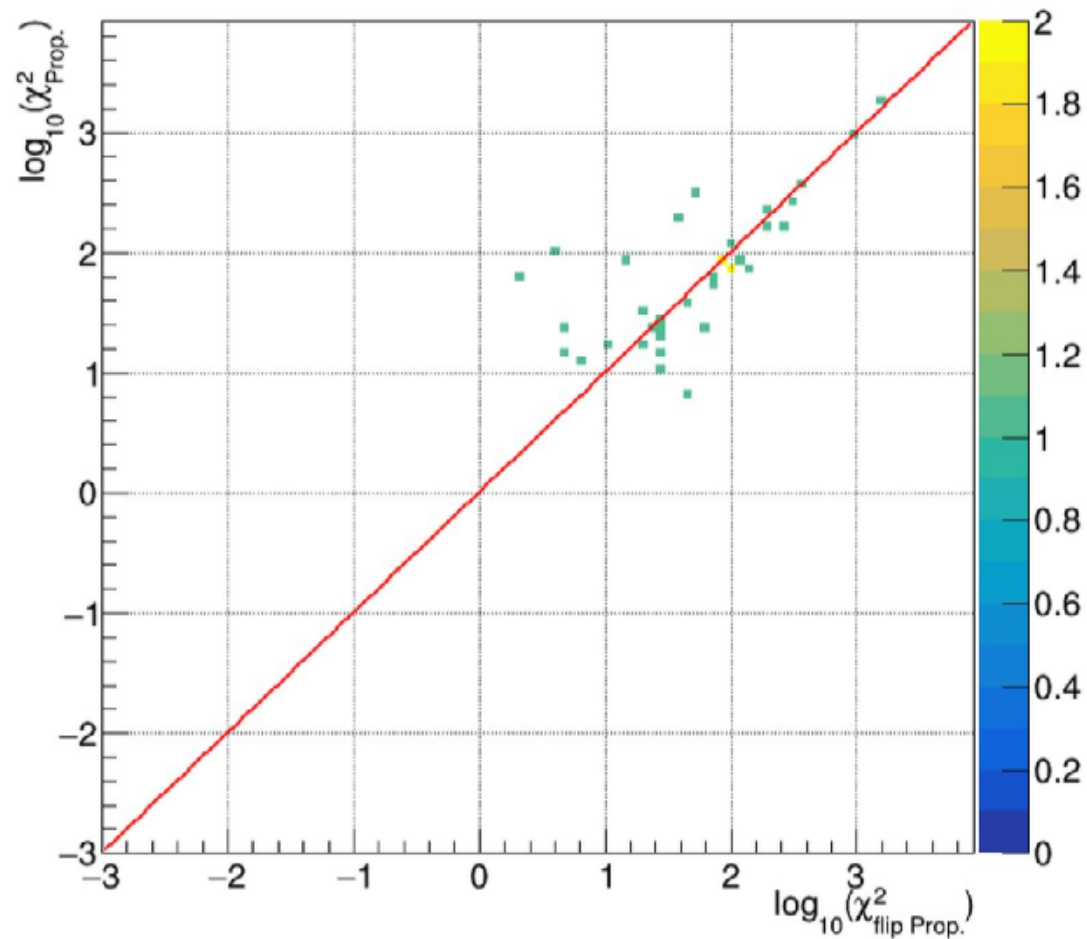
N_FlipProp_bin_(104.337868_130.184189)_xy



$$\chi_{prop}^2 = \frac{\left(\sum_{i\text{-layer}} \frac{(Y_{MC} - Y_{prop.track})^2}{\sigma_{hit}^2} \right)}{Ndof}$$

$R_{\text{inner}} < 0$ (elastic scattering within inner tracker)

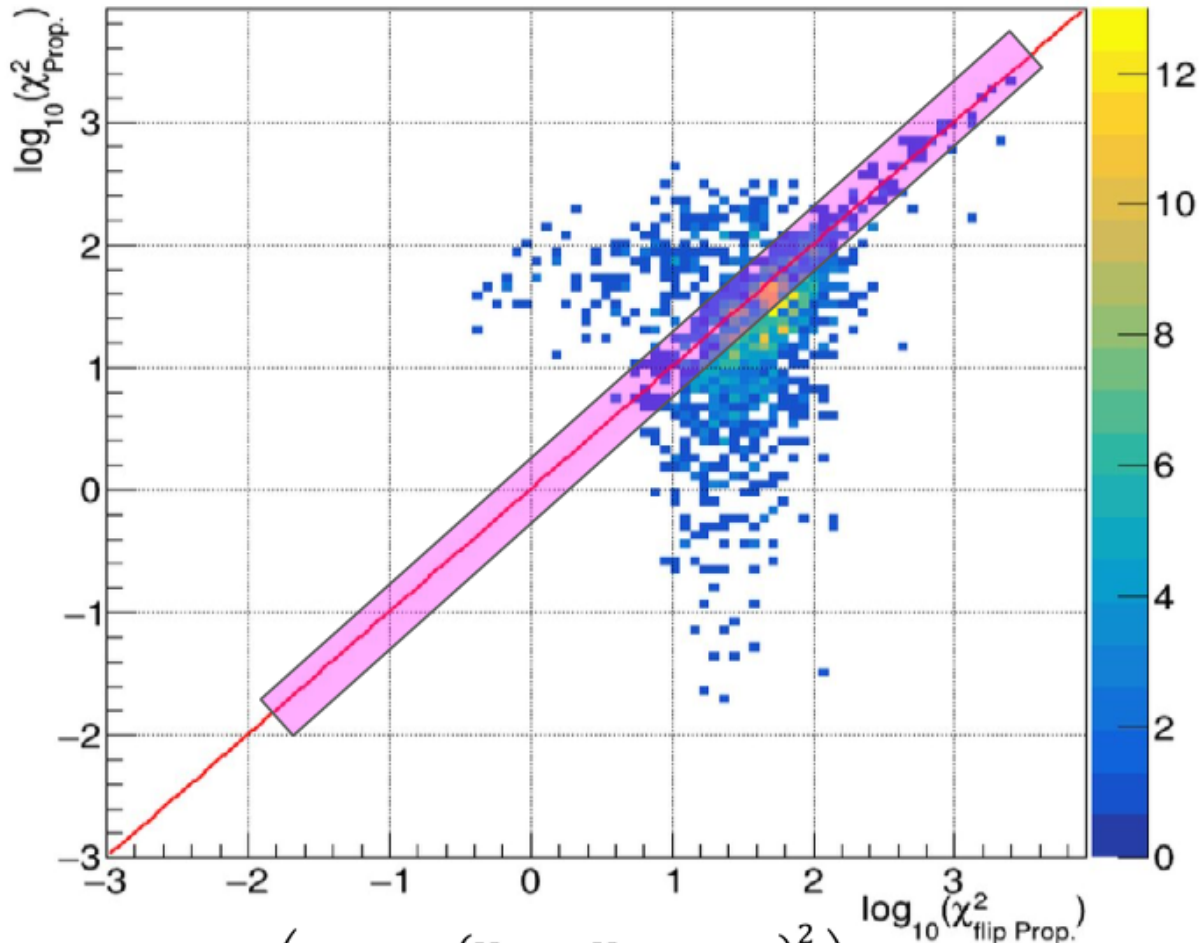
N_FlipProp_bin_(104.337868_130.184189)_xy



$$\sigma_{hit}^2 = 15 \mu\text{m}$$

$R_{\text{inner}} < 0$ (no secondaries within inner tracker)

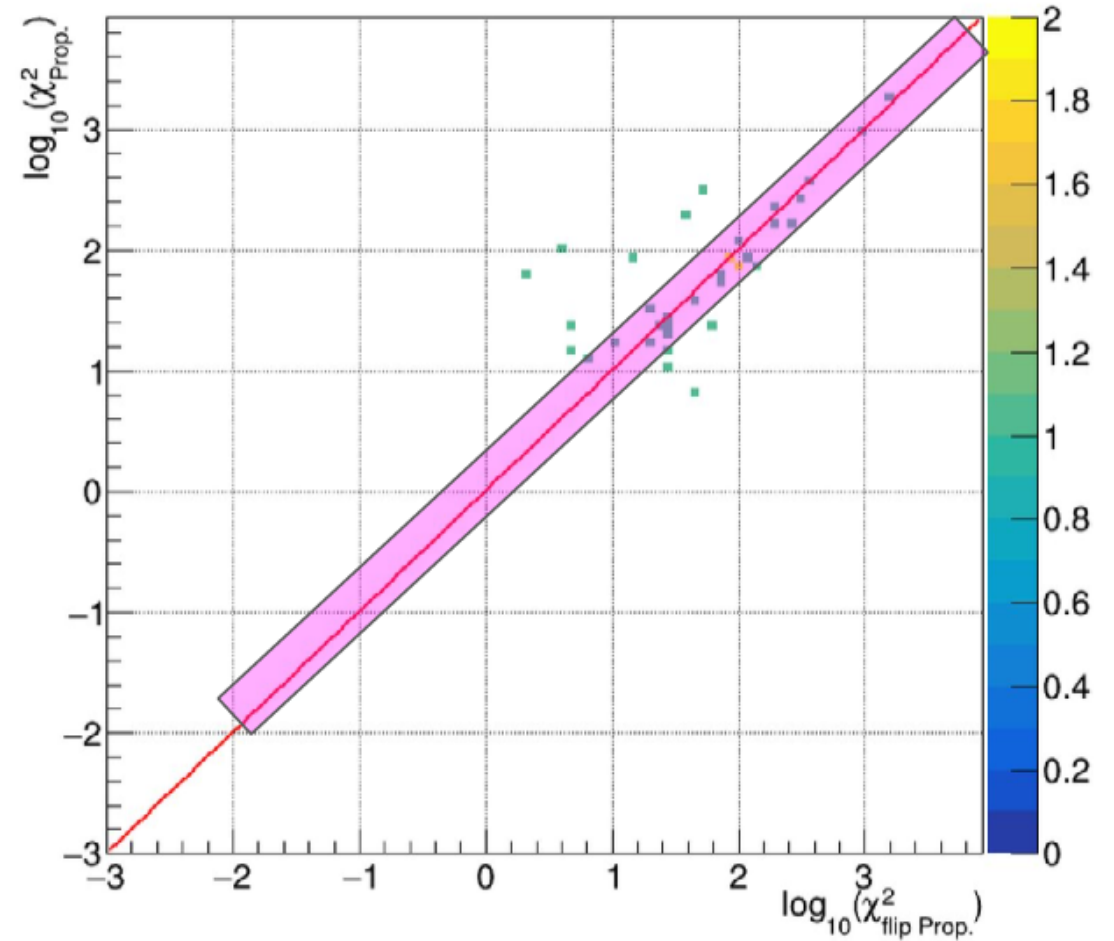
N_FlipProp_bin_(104.337868_130.184189)_xy



$$\chi_{\text{prop}}^2 = \frac{\left(\sum_{i\text{-layer}} \frac{(Y_{MC} - Y_{\text{prop.track}})^2}{\sigma_{\text{hit}}^2} \right)}{N_{\text{dof}}}$$

$R_{\text{inner}} < 0$ (elastic scattering within inner tracker)

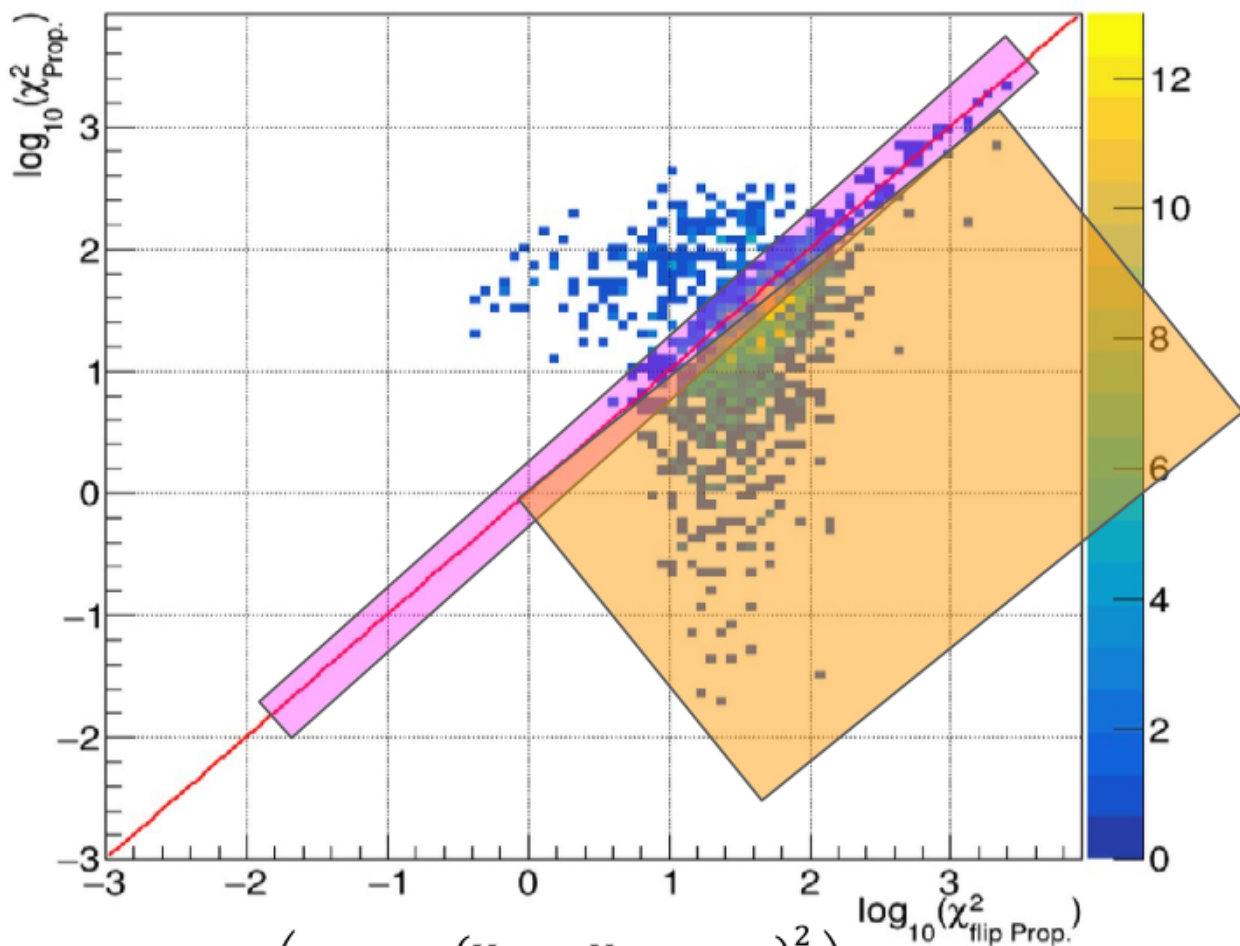
N_FlipProp_bin_(104.337868_130.184189)_xy



$$\sigma_{\text{hit}}^2 = 15 \mu\text{m}$$

$R_{inner} < 0$ (no secondaries within inner tracker)

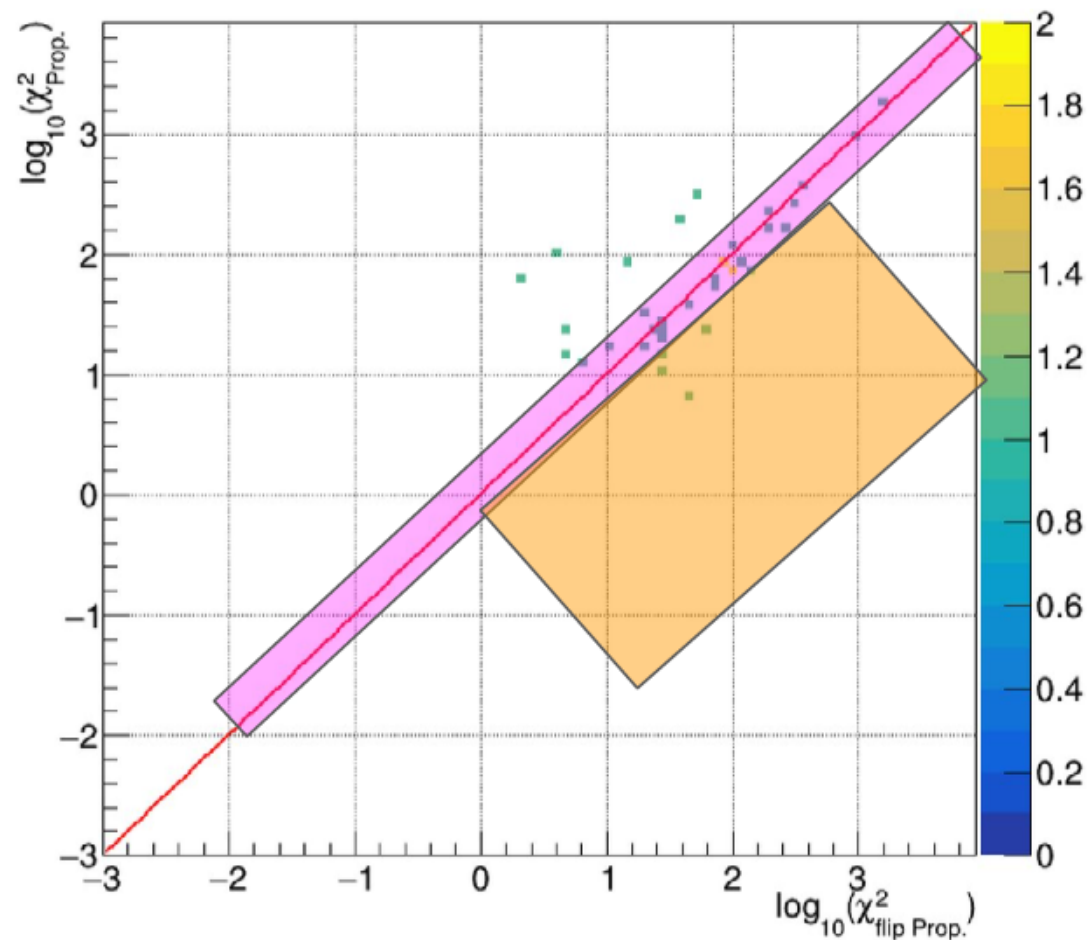
N_FlipProp_bin_(104.337868_130.184189)_xy



$$\chi_{prop}^2 = \frac{\left(\sum_{i-layer} \frac{(Y_{MC} - Y_{prop.track})^2}{\sigma_{hit}^2} \right)}{Ndof}$$

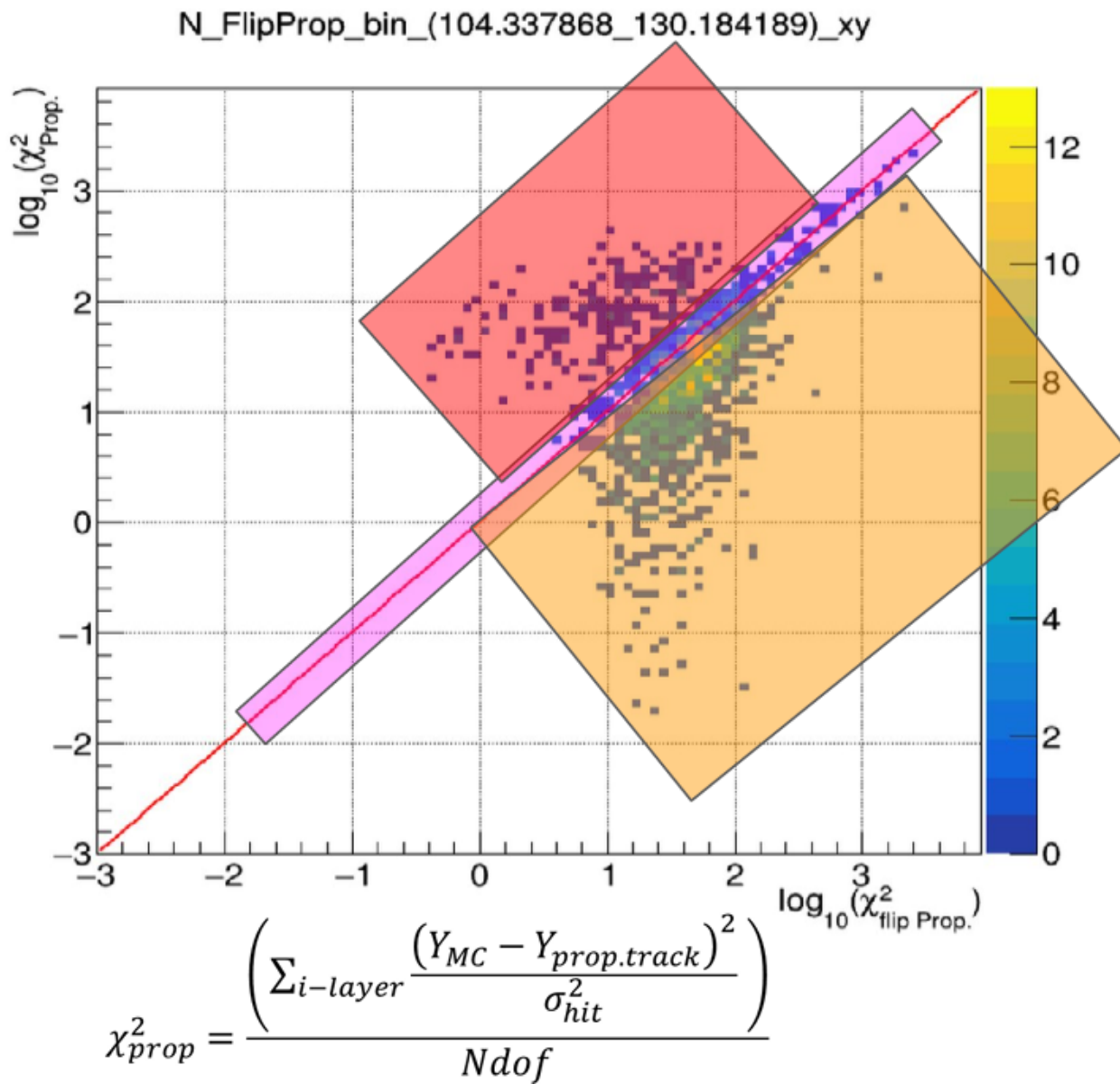
$R_{inner} < 0$ (elastic scattering within inner tracker)

N_FlipProp_bin_(104.337868_130.184189)_xy

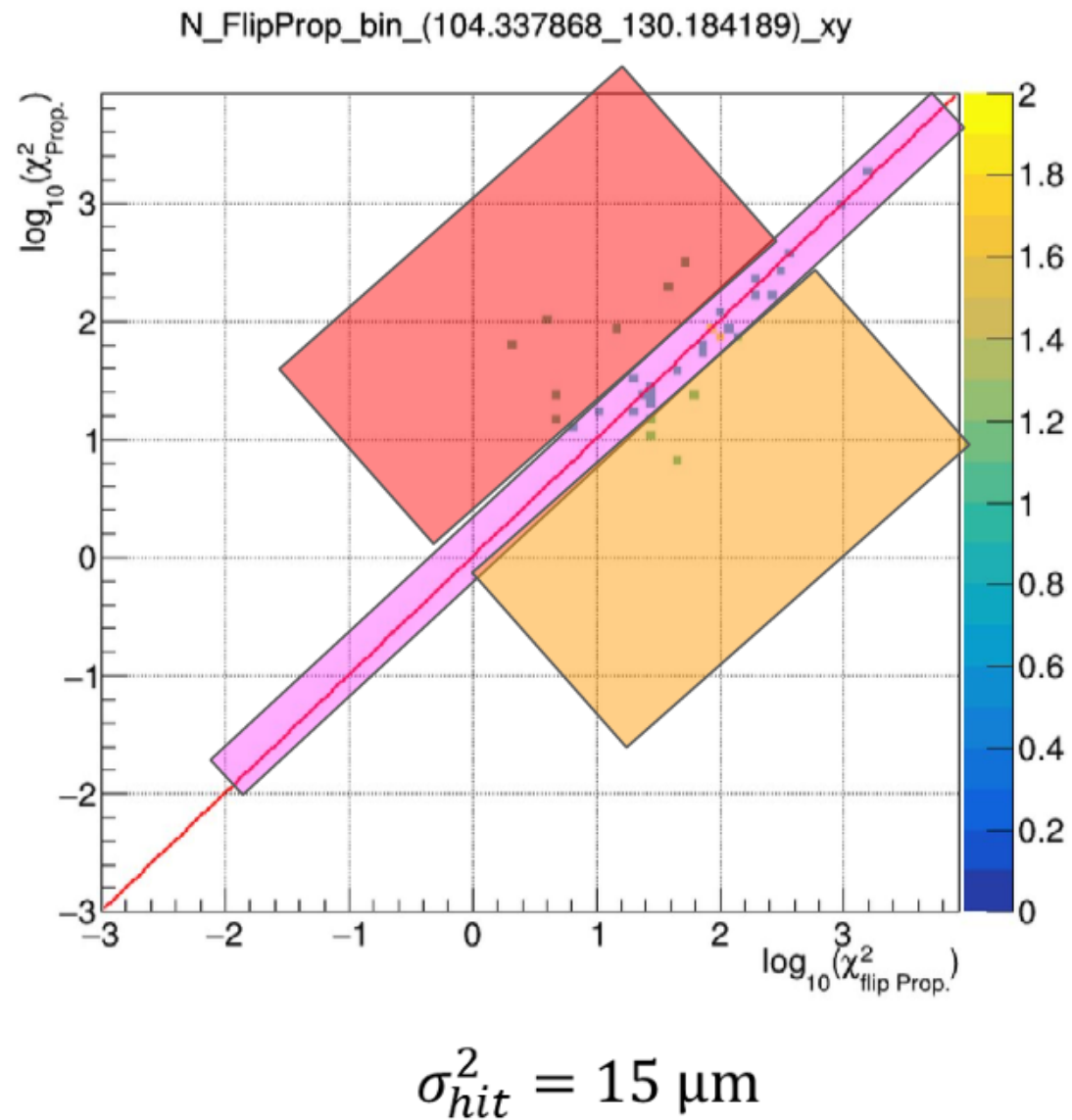


$$\sigma_{hit}^2 = 15 \mu\text{m}$$

$R_{inner} < 0$ (no secondaries within inner tracker)



$R_{inner} < 0$ (elastic scattering within inner tracker)



Monte carlo selection (He B1236 L1-focused and L1-L9 focused)

IsPhysicsTrigger

TOF hits ≥ 4

$\beta > 0$

$\chi_{COO}^2 < 4$

Track number ≥ 1

track pattern L1&L2&(L3|L4)&(L5|L6)&(L7|L8) (≥ 5)

charge STD (inner) $\in [1.7, 2.4]$

charge STD (L1) $\in [1.6, 3.0]$

Inner fiducial volume

L1 fiducial volume

$\chi_Y^2 < 10$

charge UTOF $\in [1.5, 3.0]$

charge LTOF ≥ 1.5

Sign inner upper half (UH) and lower half (LH)

Tracker fiducial volume cut:

L1: $|R| < 62\text{cm}$, $|Y| < 47\text{cm}$

L2: $|R| < 62\text{cm}$, $|Y| < 40\text{cm}$

L3: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L4: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L5: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L6: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L7: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L8: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

UH = Rig. [UH-inner]

LH = Rig. [LH-inner]

Inner = Rig. [inner]

If (Inner > 0) \rightarrow (UH > 0, LH > 0)

If (Inner < 0) \rightarrow (UH < 0, LH < 0)

Monte carlo selection (He B1236 L1-focused and L1-L9 focused)

IsPhysicsTrigger

TOF hits ≥ 4

$\beta > 0$

$\chi_{COO}^2 < 4$

Track number ≥ 1

track pattern L1&L2&(L3|L4)&(L5|L6)&(L7|L8) (≥ 5)

charge STD (inner) $\in [1.7, 2.4]$

charge STD (L1) $\in [1.6, 3.0]$

Inner fiducial volume

L1 fiducial volume

$\chi_Y^2 < 10$

charge UTOF $\in [1.5, 3.0]$

charge LTOF ≥ 1.5

Sign inner upper half (UH) and lower half (LH)

Composition:

**76% Spillover,
21% El. Scat.
2% Had. Inel
0.04% Other**

$\sim 0.9 \cdot 10^6$ training

$\sim 0.4 \cdot 10^6$ testing

Input features for Fully Connected Neural Network (FCNN)

- Distance between track hit and strip with max energy deposit on L8.
 - ACC clusters
- Number of hits in L3-L8 inner tracker Y side.
 - Track hit energy deposition on L8.
- Total energy deposition of tracker clusters on L8 Y-side.
- Ratio between cluster amplitude and its neighbouring 10 strips (L8)
- Max cluster energy deposit on L8 Y-side.
- Number of hits in L3-L8 inner tracker X side.
 - Track hit energy deposition on L7.
- Total energy deposition of tracker clusters on L7 Y-side.
- Ratio between cluster amplitude and its neighbouring 10 strips (L2)
- Max cluster energy deposit on L7 Y-side.

Input features for Fully Connected Neural Network (FCNN)

- Distance between track hit and strip with max energy deposit on L8.
- Number of hits in L3-L8 inner tracker Y side.
 - Track hit energy deposition on L8.
- Total energy deposition of tracker clusters on L8 Y-side.
- Ratio between cluster amplitude and its neighbouring 10 strips (L8)
- Max cluster energy deposit on L8 Y-side.

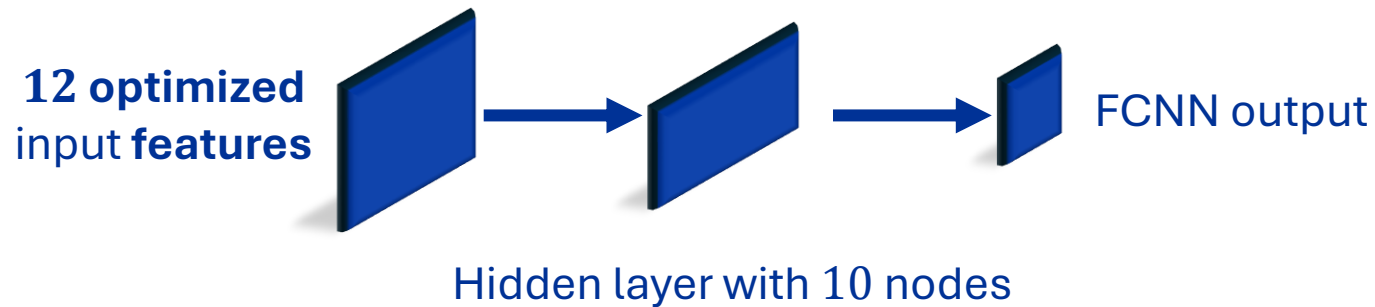
- ACC clusters

- Number of hits in L3-L8 inner tracker X side.
 - Track hit energy deposition on L7.
- Total energy deposition of tracker clusters on L7 Y-side.
- Ratio between cluster amplitude and its neighbouring 10 strips (L2)
- Max cluster energy deposit on L7 Y-side.

Fully Connected Neural Network (FCNN) for classification

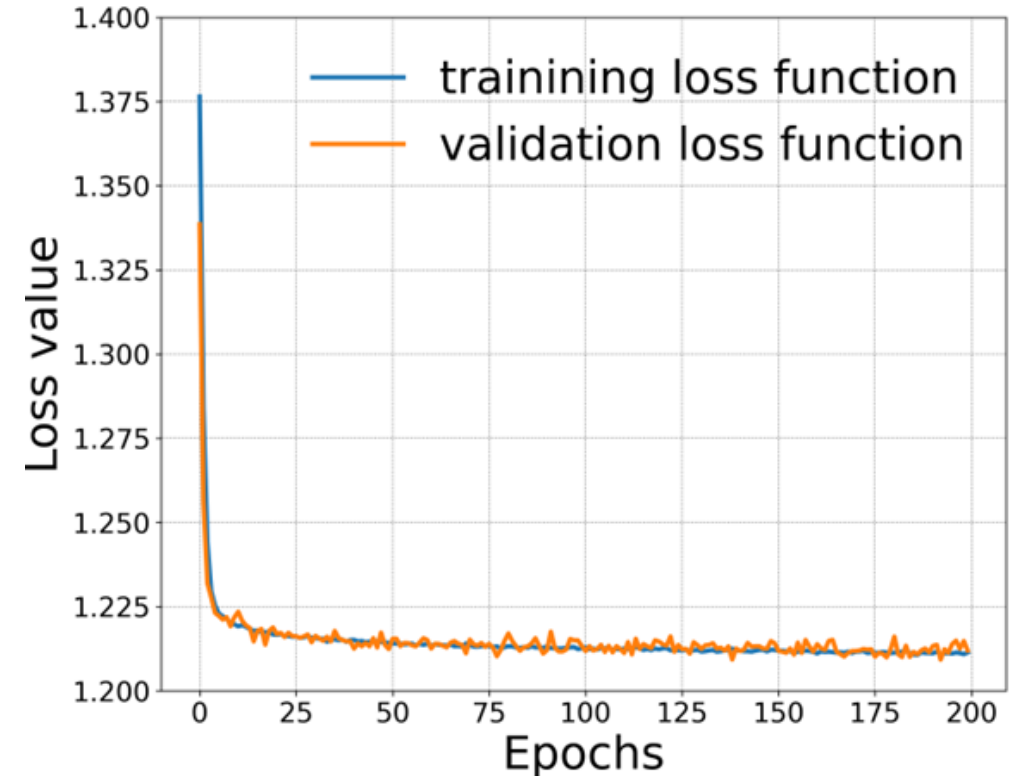
- **FCNN structure:**

- PyTorch
- Five linear layers: [12, 10, 10, 10, 4].



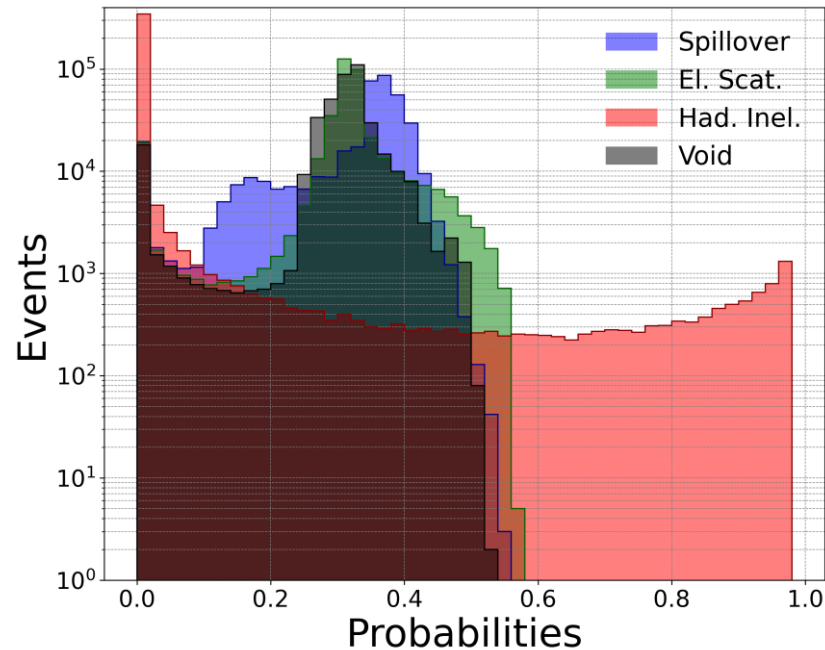
- **FCNN hyperparameters:**

- Optimizer: Adam
- Learning rate: $1.0 \cdot 10^{-3}$
- Batch size: $5.0 \cdot 10^3$
- Loss function: Cross Entropy



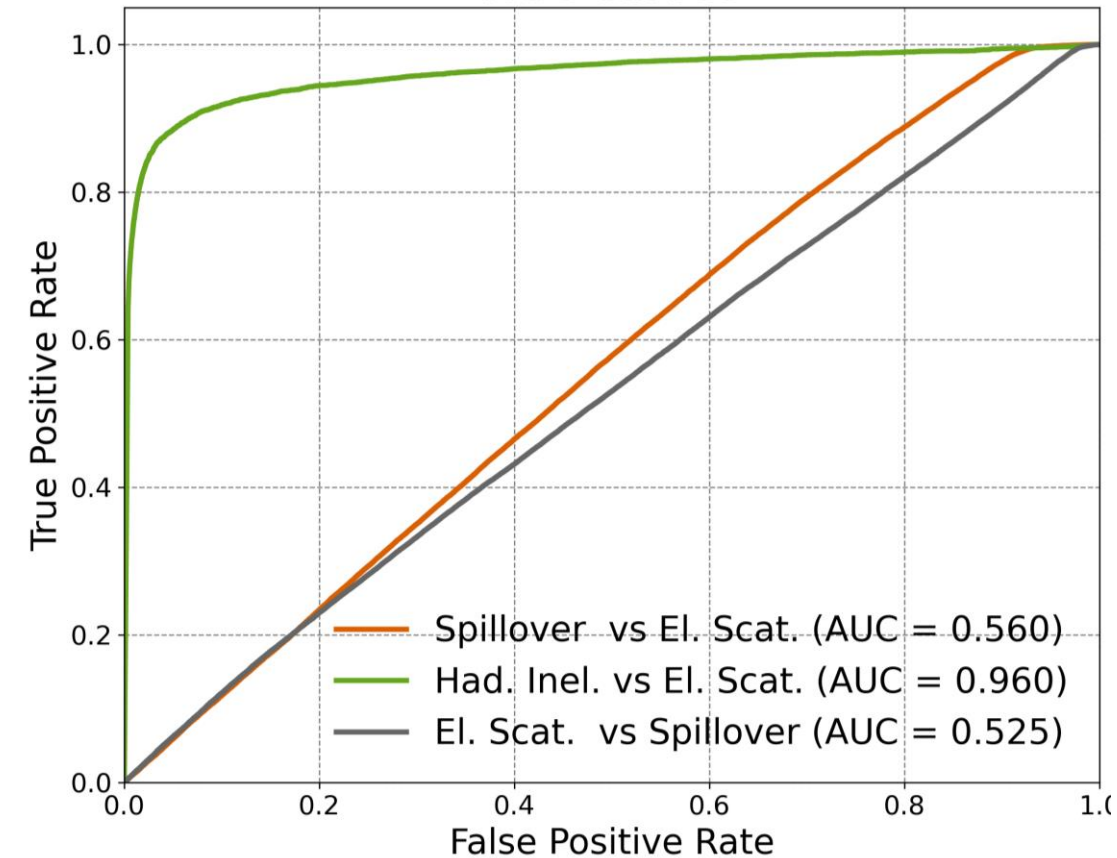
Fully Connected Neural Network (FCNN) for classification

- Training (200) epochs on $9 \cdot 10^5$ events
- Validation on $4 \cdot 10^5$ events
- **Training and validation dataset are unbalanced**



The classifier predict random probabilities, maybe due to samples unbalance.

ROC curves



The network is not able to distinguish Spillover and El. Scat.

Discriminants

- The network returns a vector of three elements.
 - Each element corresponds to the probability that the current event is belonging to the 1st, 2nd, 3rd or 4th class:

$$\text{FCNN output} = (p_{\text{spillover}}, p_{\text{Had.Inel}}, p_{\text{El.Scat.}}, p_{\text{Other}})$$

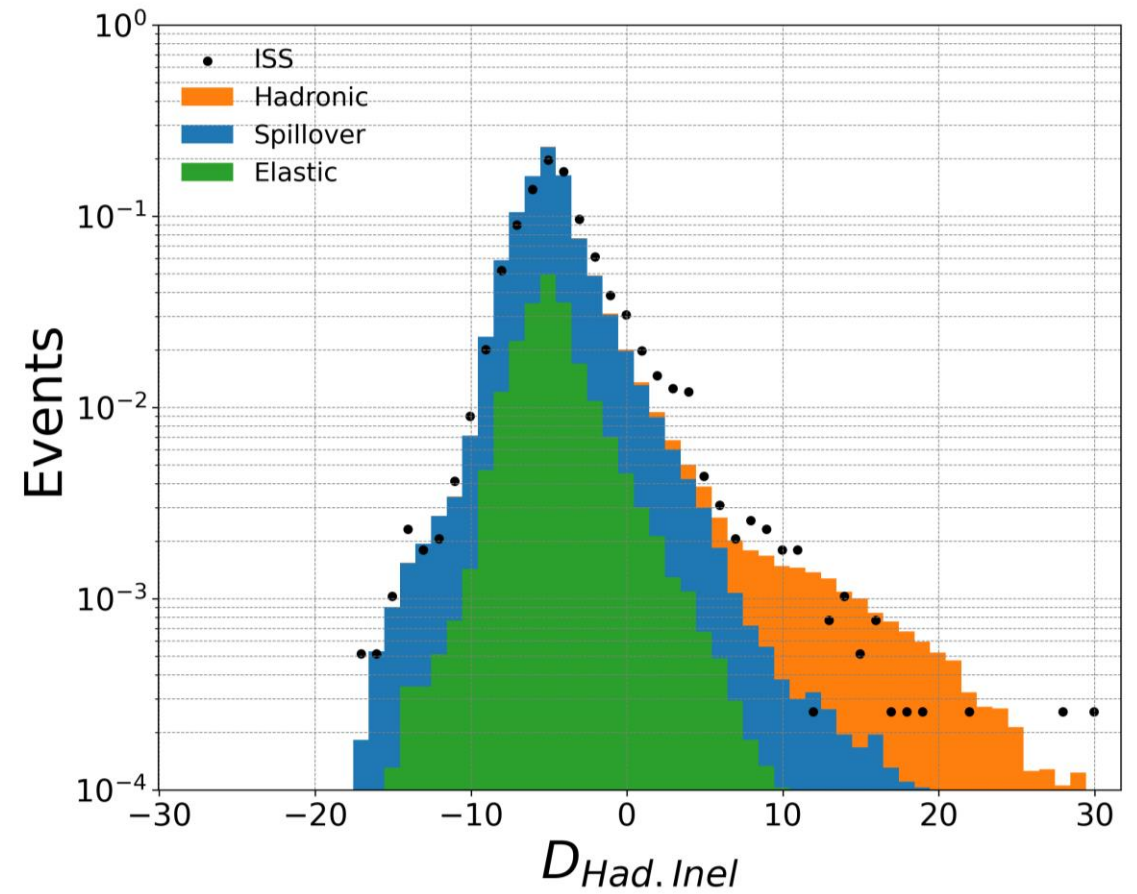
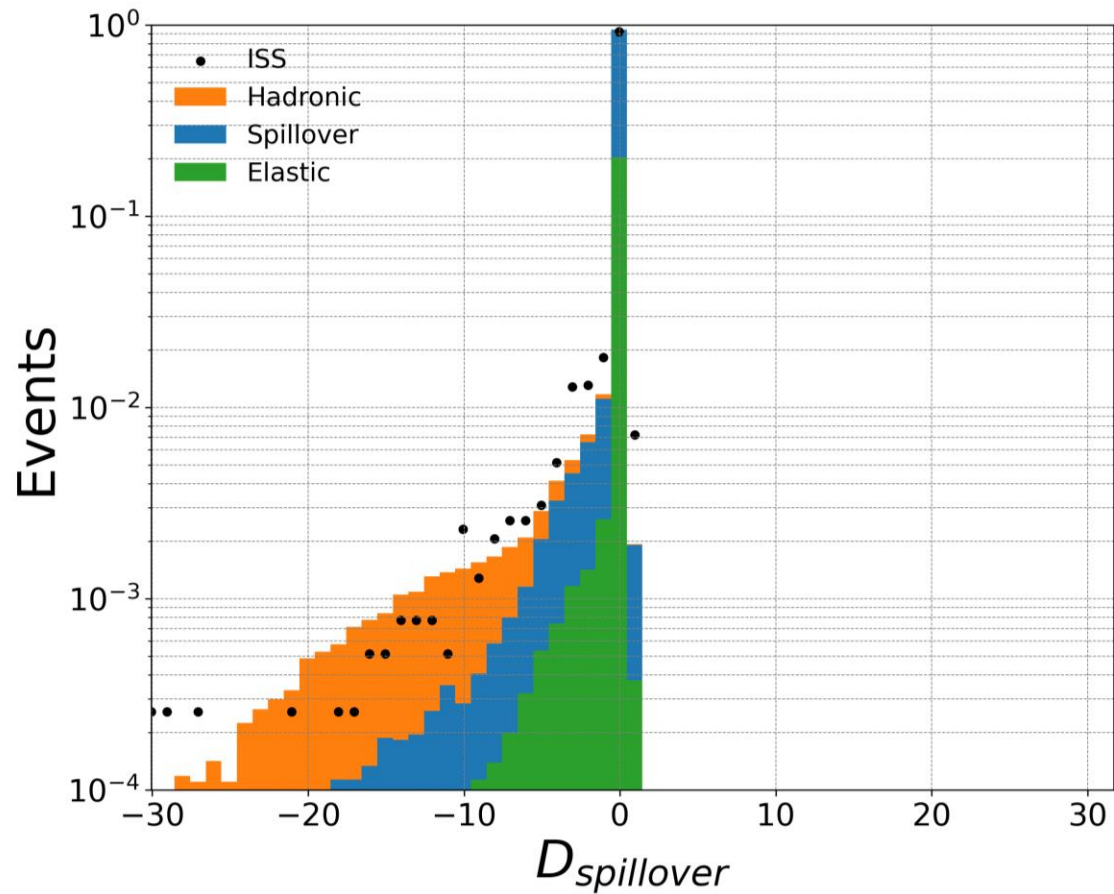
- The fraction of each class is defined as:

$$f_{\text{Had.inel.}} = \frac{\# \text{Had.inel.}}{\# \text{Spillover} + \# \text{Had.Inel} + \# \text{El.sc.} + \# \text{Other}}$$

- The discriminant is defined as

$$D_{\text{Spillover}} = \log_{10} \left(\frac{p_{\text{Spillover}}}{f_{\text{Had.inel.}} \cdot p_{\text{Had.inel.}} + f_{\text{El.sc.}} \cdot p_{\text{El.sc.}} + f_{\text{Other}} \cdot p_{\text{Other}}} \right)$$

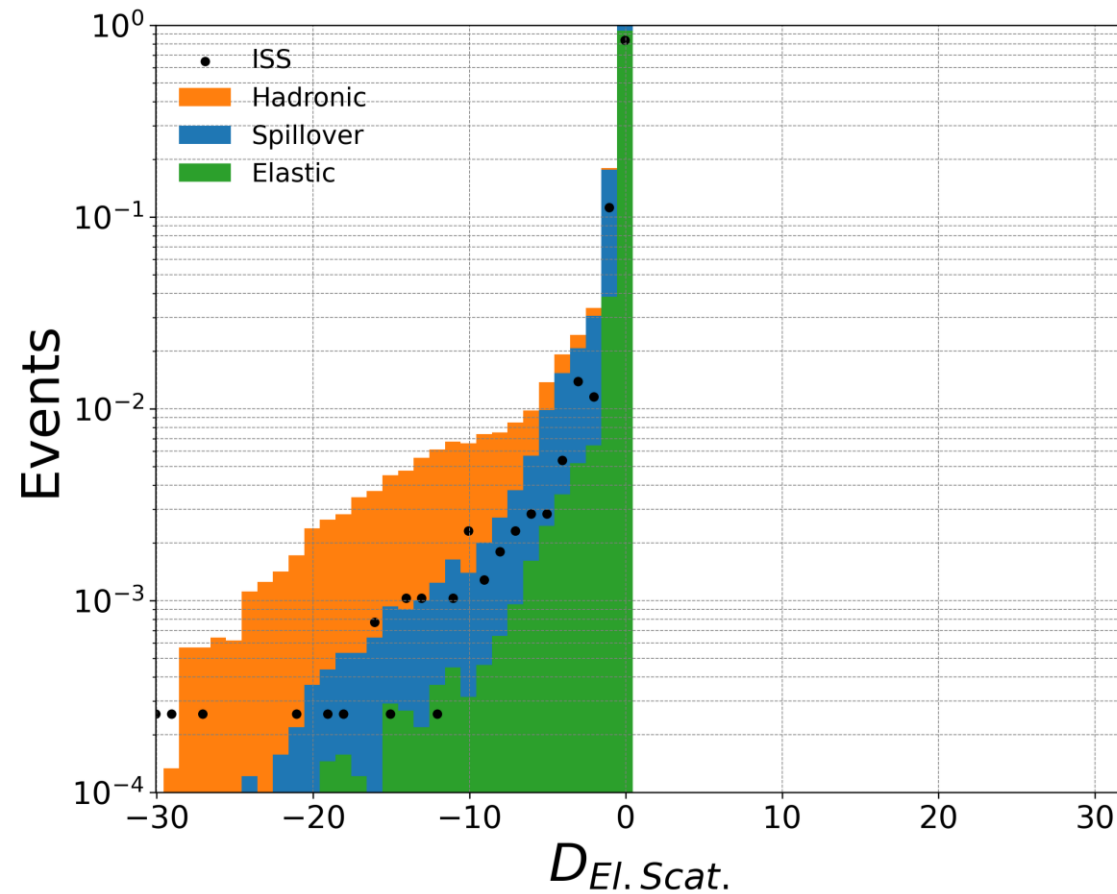
Discriminants for spillover and had. Inel.



$$D_{Spillover} = \log_{10} \left(\frac{p_{Spillover}}{f_{Had.inel.} \cdot p_{Had.inel.} + f_{EL.sc.} \cdot p_{EL.sc.} + f_o \cdot p_o} \right)$$

$$D_{EL.sc.} = \log_{10} \left(\frac{p_{Had.inel.}}{f_{Spillover} \cdot p_{Spillover.} + f_{EL.sc.} \cdot p_{EL.sc.} + f_o \cdot p_o} \right)$$

Discriminant for el. scat.



$$D_{El.sc} = \log_{10} \left(\frac{p_{El.sc}}{f_{Had.inel} \cdot p_{Had.inel} + f_{Spillover} \cdot p_{Spillover} + f_0 \cdot p_0} \right)$$

Prospects

- Propagator does not take into account energy losses and multiple scattering.
- Study alternative label definition in the MC sample.
- Investigate new input features to discriminate between spillover and elastic scattering.
- Rigidity dependence of the input variables.

- Reweight the MC; more on checks on agreement between MC and data
- Train the network on balanced dataset and validate on unbalanced sample.
- Improve data statics (~ 40 bartel rotations to be analyzed).

- MC B1306 is not focused, interesting to integrate the P.Z. flag for elastic interactions.
- Modify NAIA to save each secondary produced by hadronic (inelastic and elastic) interactions.

- **Study possible alternative ML techniques as anomaly detection.**

Prospects

- Propagator does not take into account energy losses and multiple scattering.
- Study alternative label definition in the MC sample.
- Investigate new input features to discriminate between spillover and elastic scattering.
- Rigidity dependence of the input variables.
- Reweight the MC; more on checks on agreement between MC and data
- Train the network on balanced dataset and validate on unbalanced sample.
- Improve data statics (~ 40 bartel rotations to be analyzed).
- MC B1306 is not focused, interesting to integrate the P.Z. flag for elastic interactions.
- Modify NAIA to save each secondary produced by hadronic (inelastic and elastic) interactions.
- **Study possible alternative ML techniques as anomaly detection.**

**Thank you
for your
attention!**

Backup

Monte Carlo label definition

1. Check for secondary production due to the primary particle within the inner tracker (HasSecondary)
2. Check for inelastic interactions (HasHadInel).
 1. If true the event is tagged as Had. Inel.
 1. Otherwise:
 1. If primary reaches L2 propagate two different tracks inside the inner tracker: $R_{true}(L2)$ and $R_{inner}(< 0)$.
 1. Build two χ^2 comparing y coordinate with MC true info on each layer.
 2. Check the χ^2 ratio, i.e.:
$$\frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2} \leq 0.85 \rightarrow \text{El. scat.}$$
$$1.15 \leq \frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2} \rightarrow (\text{HasSecondary}) ? \text{Other : Spillover}$$
$$0.85 < \frac{\chi_{R_{inner}}^2}{\chi_{R_{true}}^2} \leq 1.15 \rightarrow (\text{HasSecondary}) ? \text{Other : Spillover}$$

Known problems: no MS and E losses in propagator

Monte carlo selection (He B1236 L1-focused and L1-L9 focused)

IsPhysicsTrigger

TOF hits ≥ 4

$\beta > 0.2$

$\chi_{COO}^2 < 4$

Track number ≥ 1

track pattern L1&L2&(L3|L4)&(L5|L6)&(L7|L8) (≥ 5)

charge STD (inner) $\in [1.7, 2.4]$

charge STD (L1) $\in [1.6, 3.0]$

Inner fiducial volume

L1 fiducial volume

$\chi_Y^2 < 10$

charge UTOF $\in [1.5, 3.0]$

charge LTOF ≥ 1.5

Sign inner upper half (UH) and lower half (LH)

Tracker fiducial volume cut:

L1: $|R| < 62\text{cm}$, $|Y| < 47\text{cm}$

L2: $|R| < 62\text{cm}$, $|Y| < 40\text{cm}$

L3: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L4: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L5: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L6: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L7: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L8: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

UH = Rig. [UH-inner]

LH = Rig. [LH-inner]

Inner = Rig. [inner]

If(Inner > 0) \rightarrow (UH > 0, LH > 0)

If(Inner < 0) \rightarrow (UH < 0, LH < 0)

Monte carlo selection

Events that passed each single cut

	NoCut		
	500491312		1
RTIGood	500491312		1
RTIIsInSAA(0)	500491312		1
RTILiveTimeFraction(0.5)	500491312		1
RTIMaxIGRFCutoff(1.2)	500227657		0.9581
IsPhysicsTrigger	220888791		0.4428
NTOFBetaClusters(4)	171550001		0.3434
BetaPos(0.2)	169748467		0.3411
BetaChi2Coo(4)	123648484		0.2471
NTrTracks(1)	123648484		0.2471
CheckTrackPattern(5)	88062811		0.1739
HasGBLFitInner	87993945		0.1785
HasGBLFitInnerL1	80523904		0.1540
ChargeInnerTrackerYJ(1.7,2.4)	74476455		0.1513
ChargeLayer1(1.6,3)	73880952		0.1478
CheckFiducialInner	67828295		0.1373
IsInsideL1Fiducial	65066199		0.1307
Chi2Y_GBL_InnerOnly(10)	62374412		0.1245
ChargeUpperTof(1.5,3)	61801388		0.1233
ChargeLowerTof(1.5,30)	61325352		0.1224
HasGBLFitUHInner	59564150		0.1191
HasGBLFitLHInner	59554190		0.1191
SignUHandLH	48911442		0.0978

MC with large angle scattering flag

Selection

Selezione comune attualmente usata

IsPhysicsTrigger

$\beta > 0$

TOF hits = 4

Chi2Coo < 4

Track number ≥ 1

charge YJ (inner) $\in [1.7, 2.4]$

inner fiducial volume

charge YJ (L1) $\in [1.6, 3.0]$

track pattern 5/8 (L1-inner)

$\chi_Y^2 < 10$

charge (UTOF) $\in [1.5, 3.0]$

charge (LTOF) > 1.5

($R_{UH}, R_{LH} < 0$) oppure ($R_{UH}, R_{LH} > 0$)

NoCut	15376772	1
RTIGood	15376772	1
RTIIsInSAA(0)	15376772	1
RTILiveTimeFraction(0.5)	15376772	1
IsPhysicsTrigger	7526862	0.4892
BetaPos(0.2)	6383353	0.4148
NTOFBetaClusters(4)	5849648	0.3801
BetaChi2Coo(4)	4476765	0.2907
NTrTracks(1)	4476765	0.2907
HasGBLFitInner	4472418	0.2904
ChargeInnerTrackerYJ(1.7,2.4)	3905926	0.2535
CheckFiducialInner	3311273	0.2149
ChargeLayer1(1.6,3)	2997280	0.1946
IsInsideL1Fiducial	2997274	0.1946
CheckTrackPattern(5)	2680073	0.1740
Chi2Y_GBL_InnerOnly(10)	2573763	0.1672
ChargeUpperTof(1.5,3)	2550871	0.1657
ChargeLowerTof(1.5,30)	2529516	0.1642
HasGBLFitUHInner	2434282	0.1581
HasGBLFitLHInner	2433791	0.1580
SignUHandLH	2379294	0.1545

$R_{inner} < 0 \longrightarrow 696 \text{ eventi}$

Distribution of the scattering angle ($R < 0$)

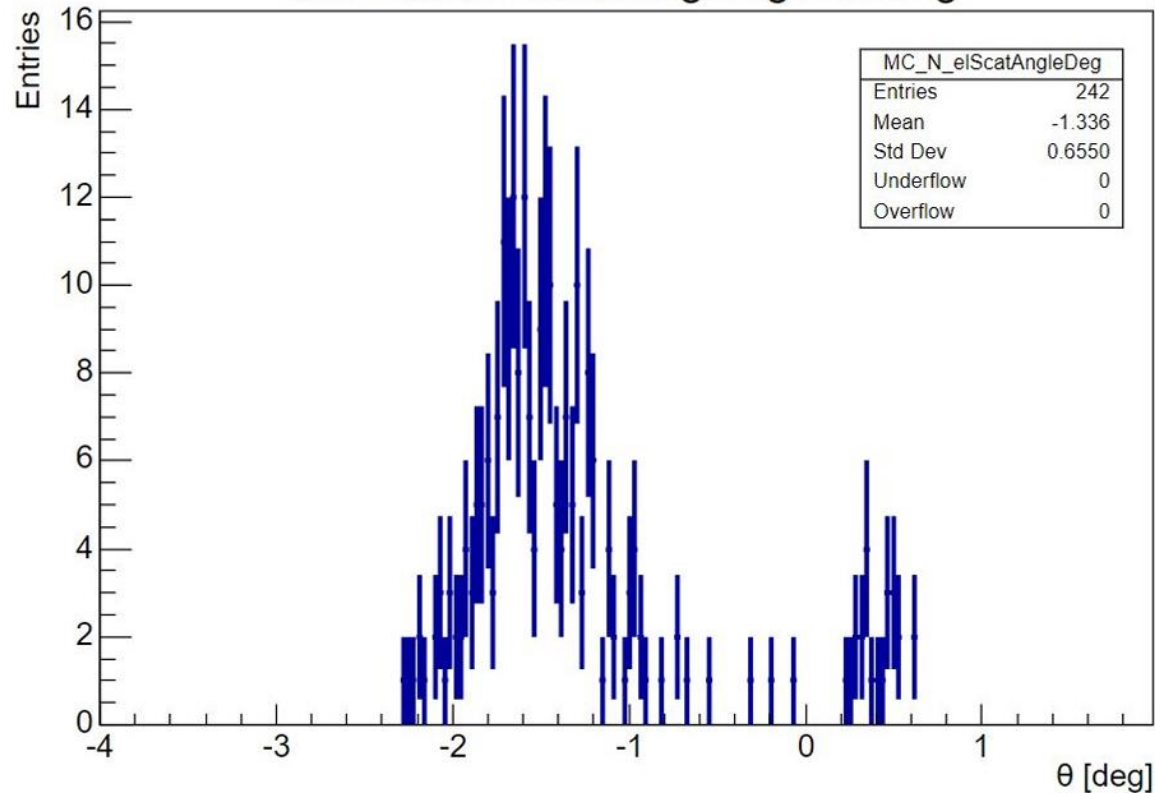
$R_{\text{inner}} < 0$ \longrightarrow 696 eventi

Verità MC per scattering elastic



242 eventi con scattering elastico nell'inner tracker

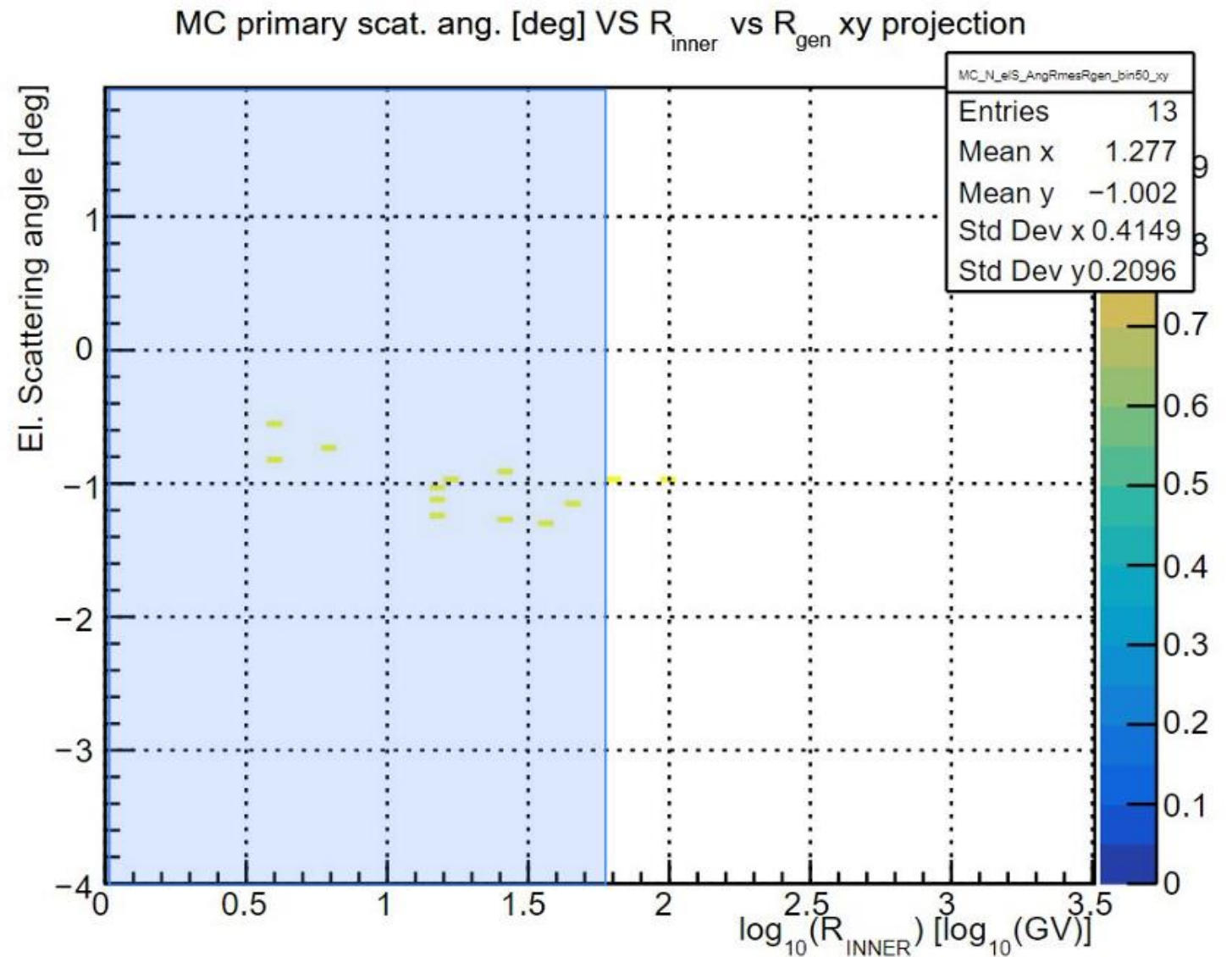
MC elastic scattering angle in deg



$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [0, 50[$$

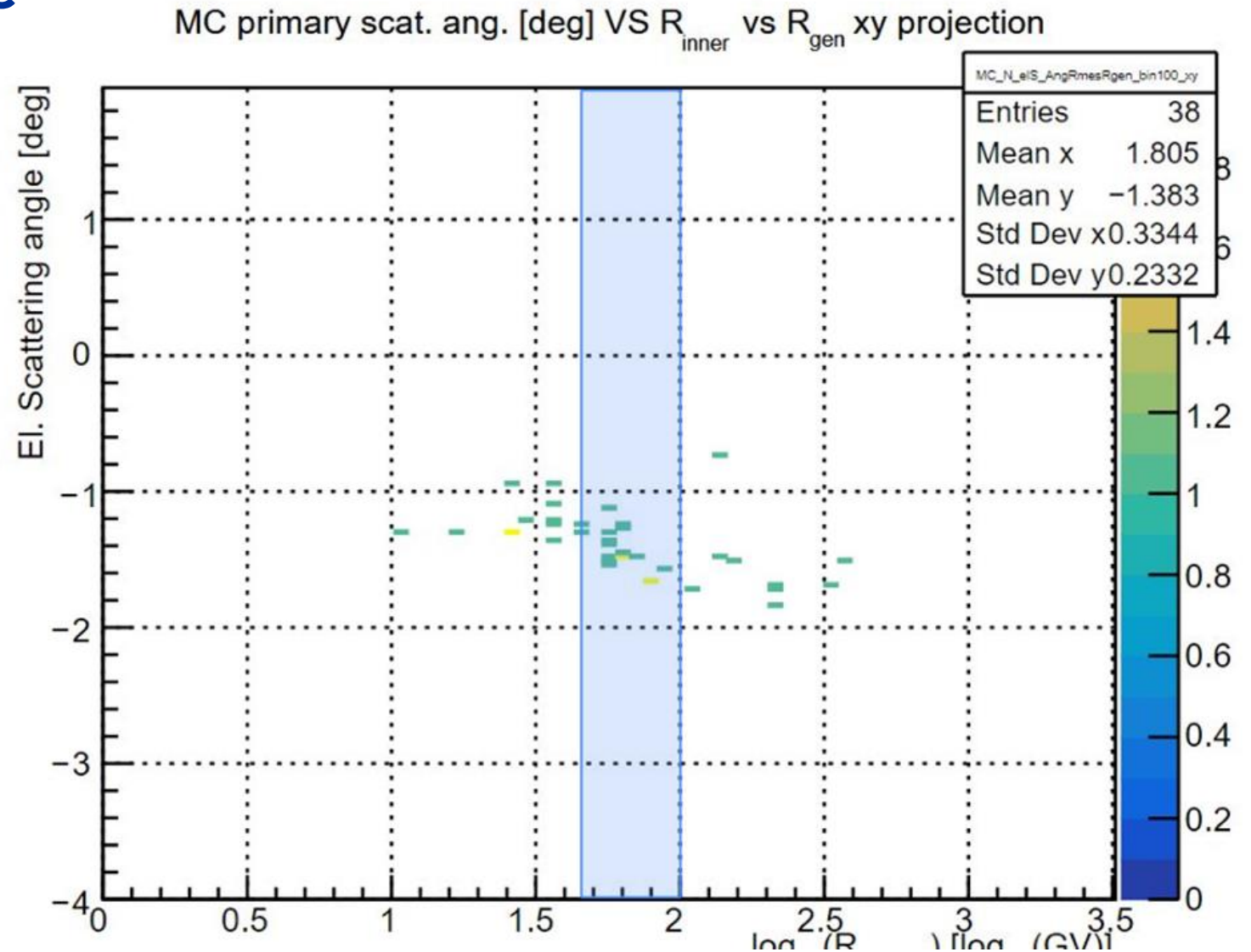
$$\log_{10}(R_{gen}) < 1.67$$



$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [50, 100[$$

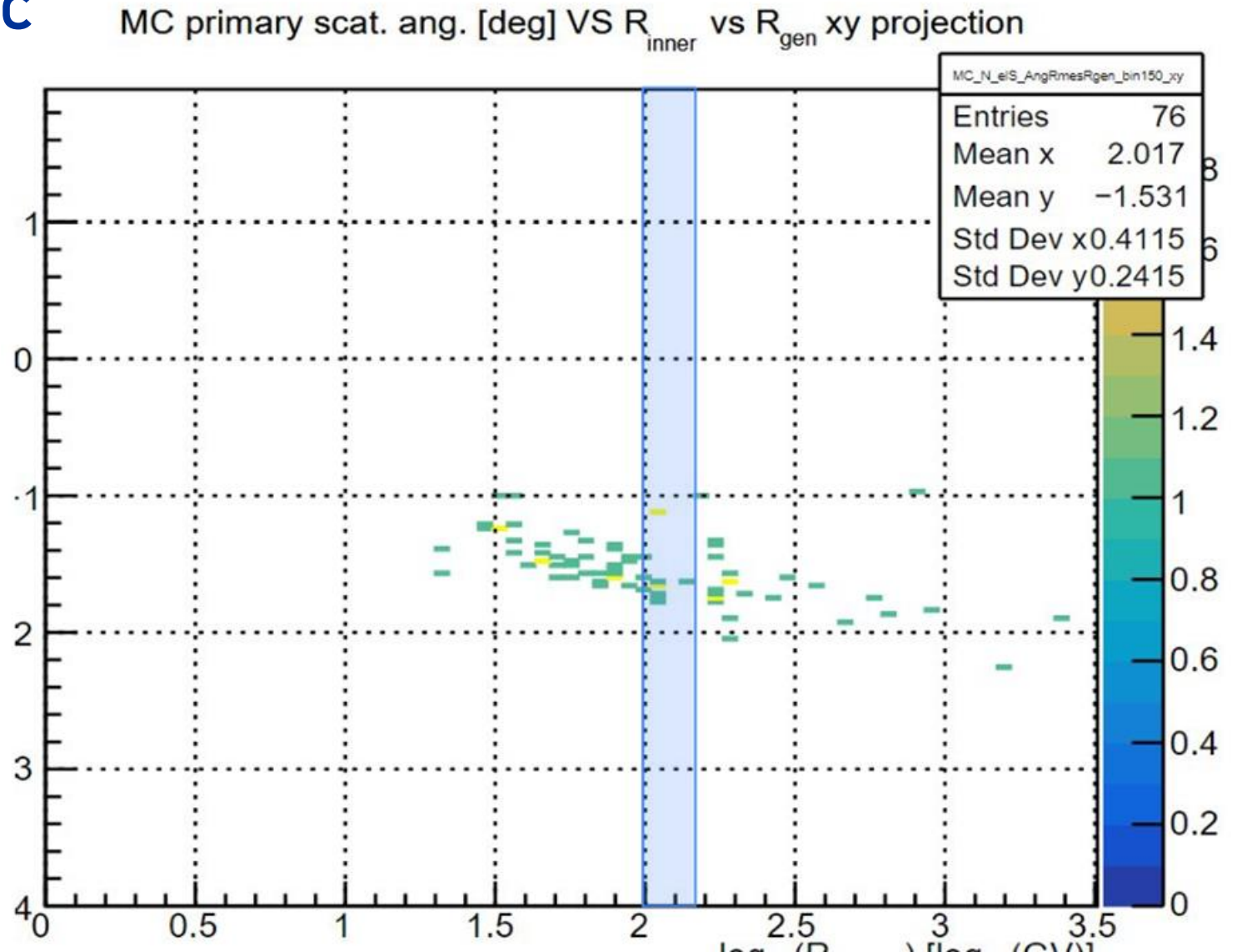
$$\log_{10}(R_{gen}) < 2.0$$



$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [100, 150[$$

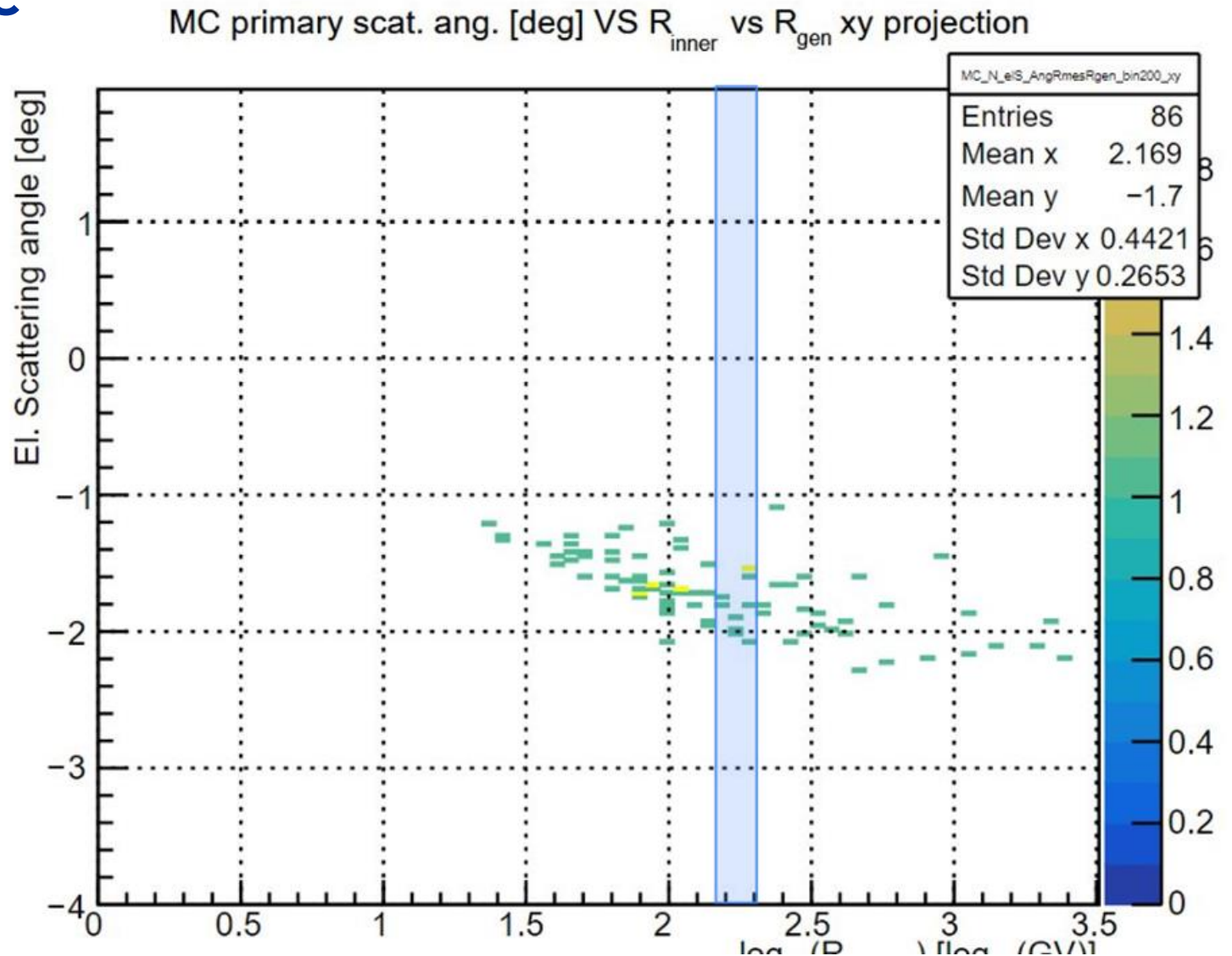
$$\log_{10}(R_{gen}) < 2.18$$



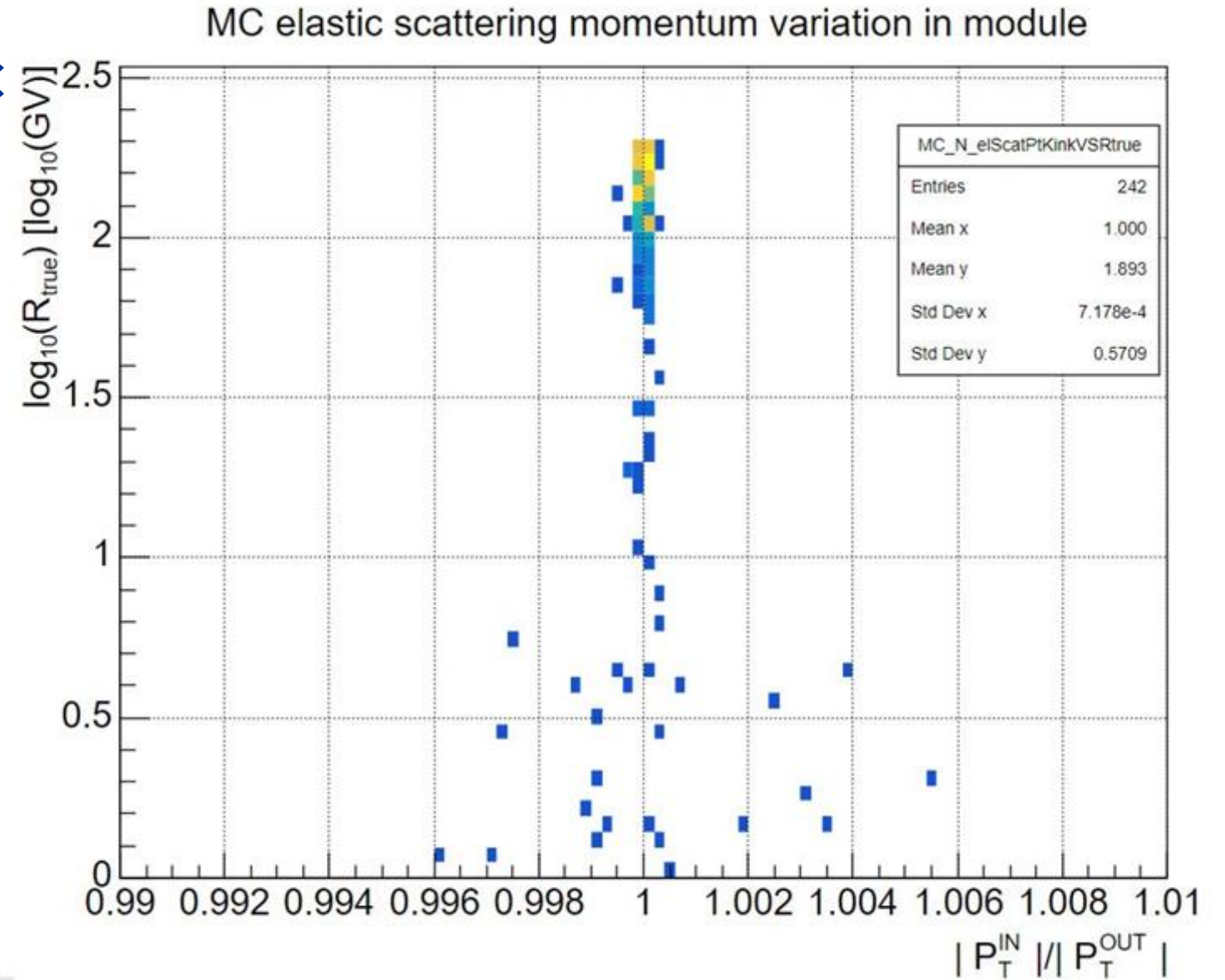
$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [150, 200[$$

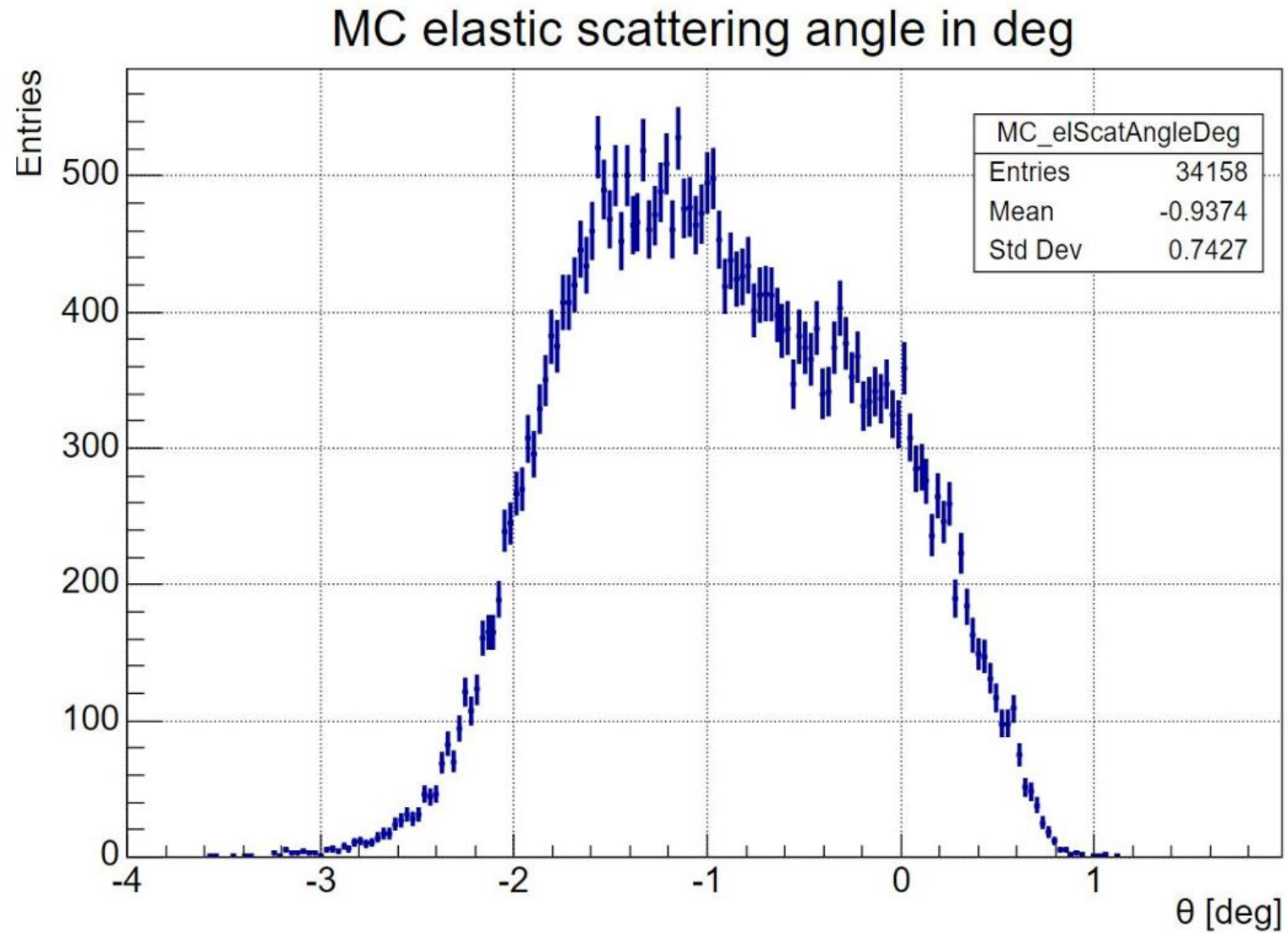
$$\log_{10}(R_{gen}) < 2.30$$



$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

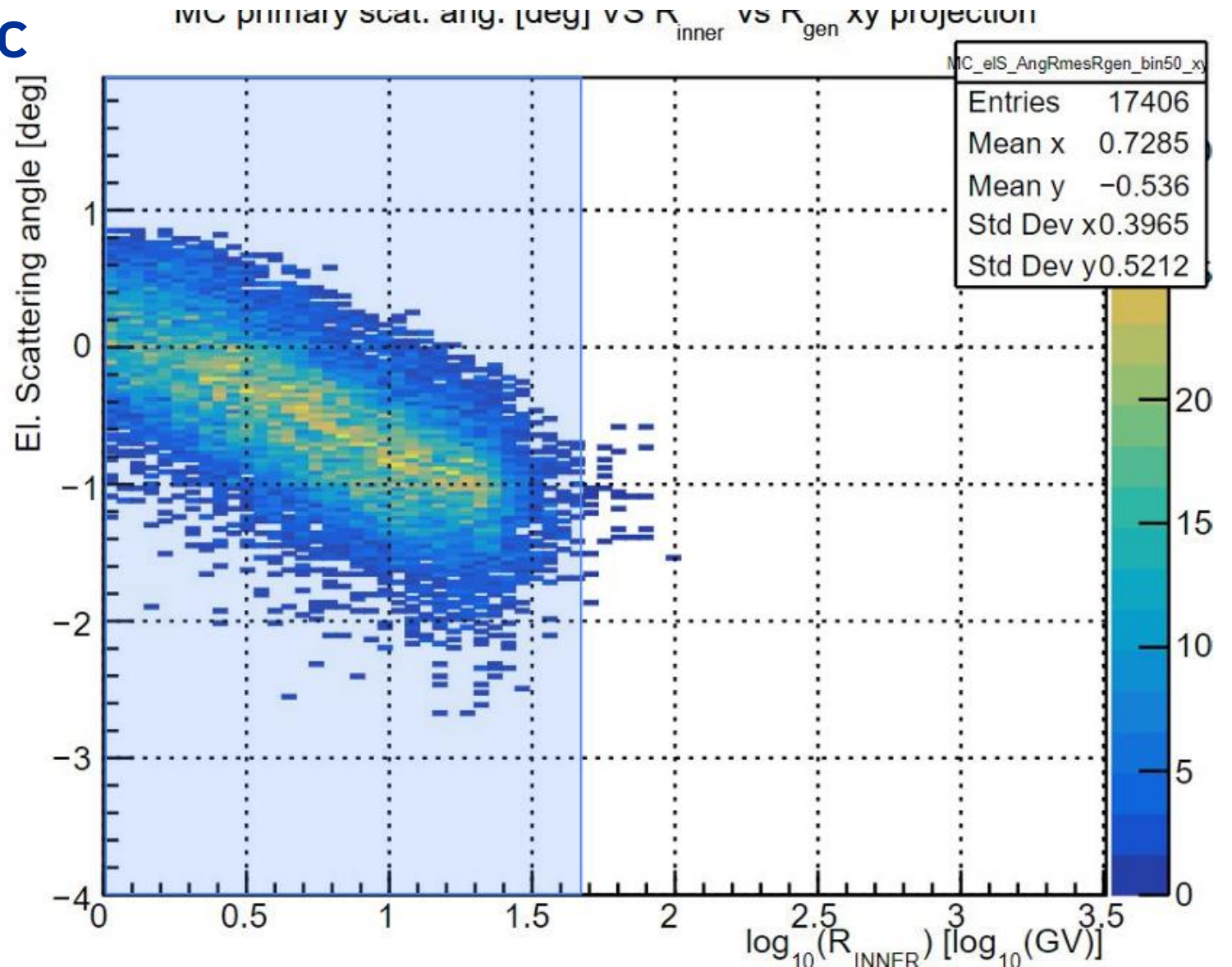


Distribution of the scattering angle ($R > 0$)



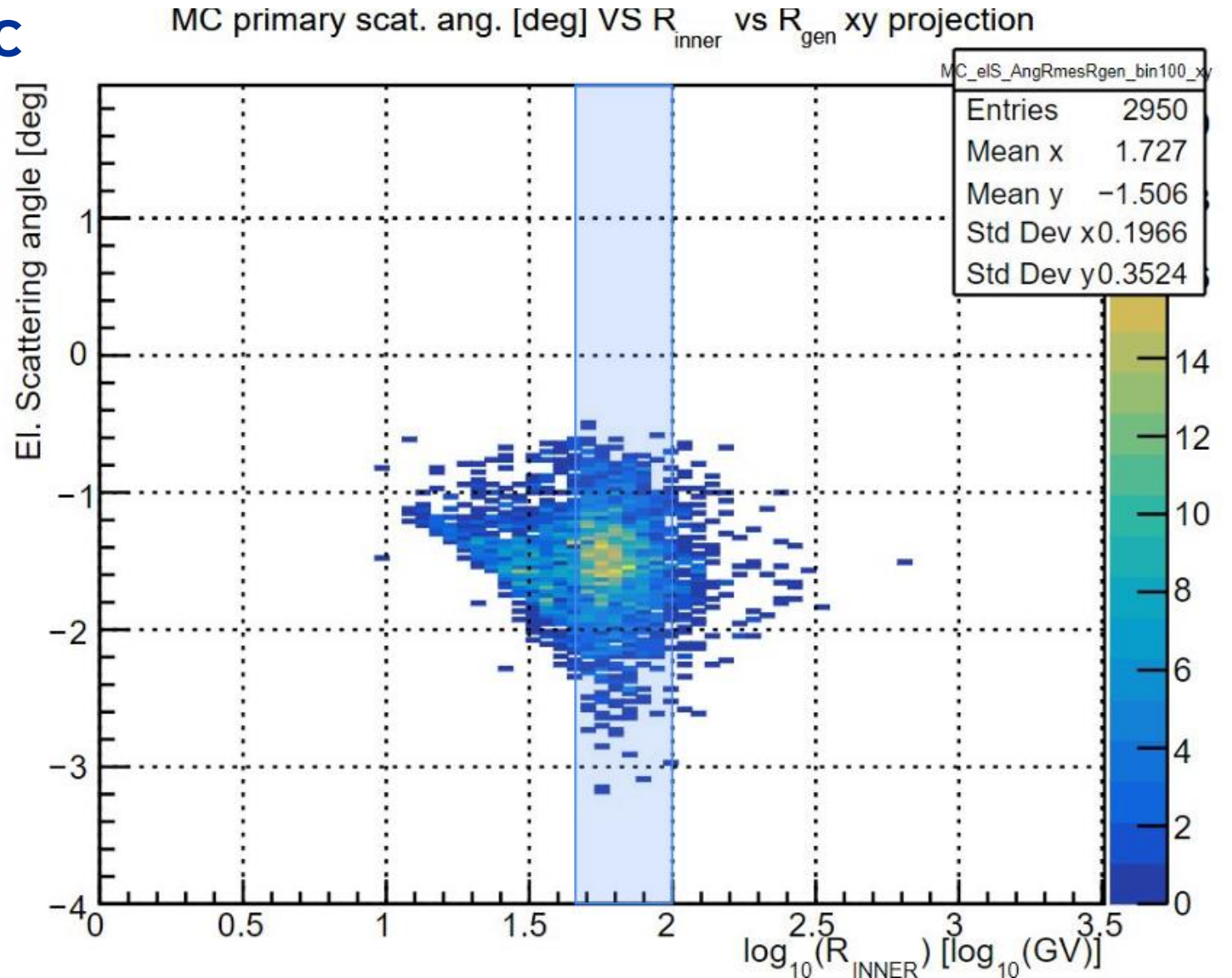
$(R_{inner} > 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [50, 100[$$
$$\log_{10}(R_{gen}) < 2.0$$



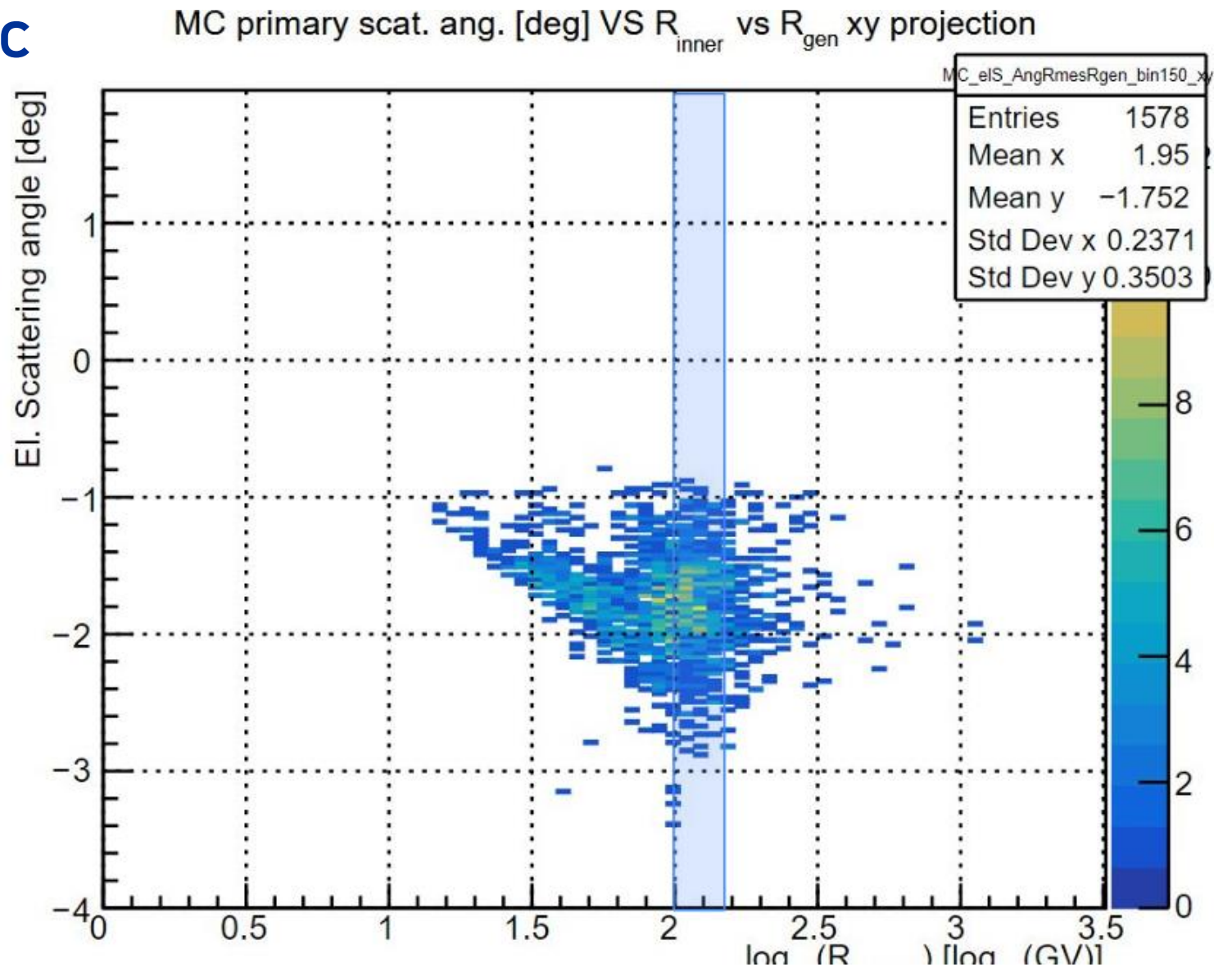
$(R_{inner} > 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [50, 100[$$
$$\log_{10}(R_{gen}) < 2.0$$



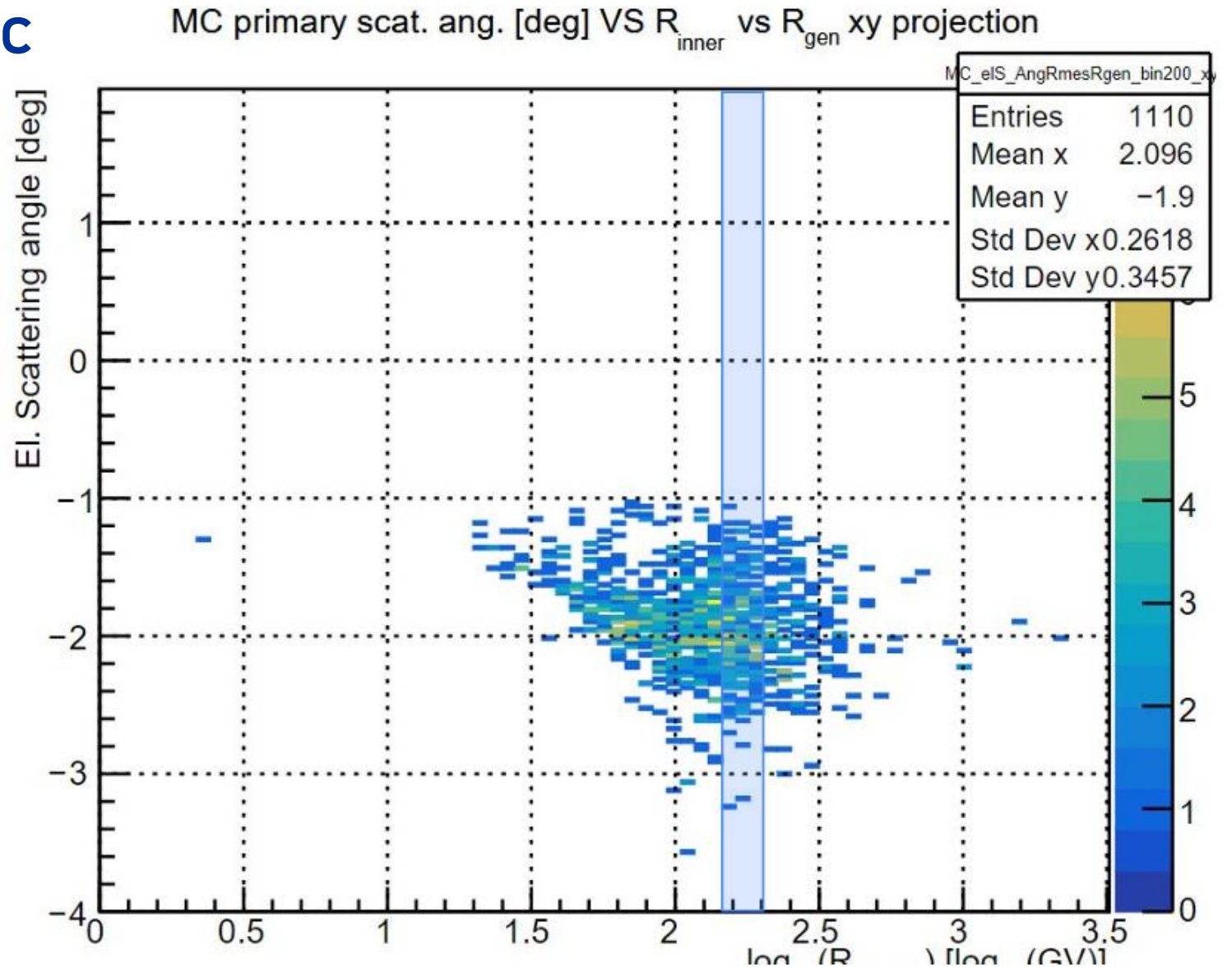
$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [100, 150[$$
$$\log_{10}(R_{gen}) < 2.18$$



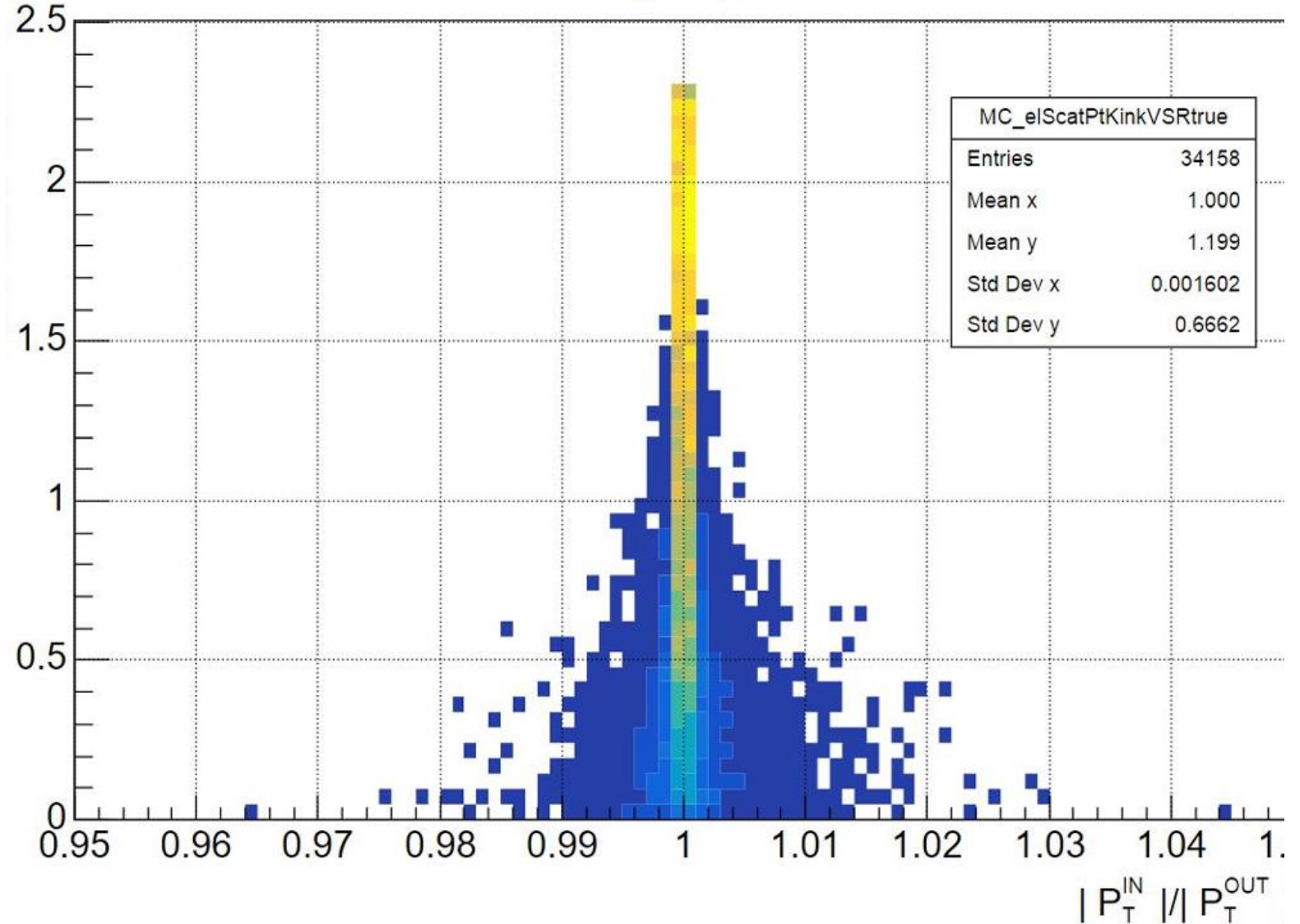
$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

$$R_{gen} \in [150, 200[$$
$$\log_{10}(R_{gen}) < 2.30$$



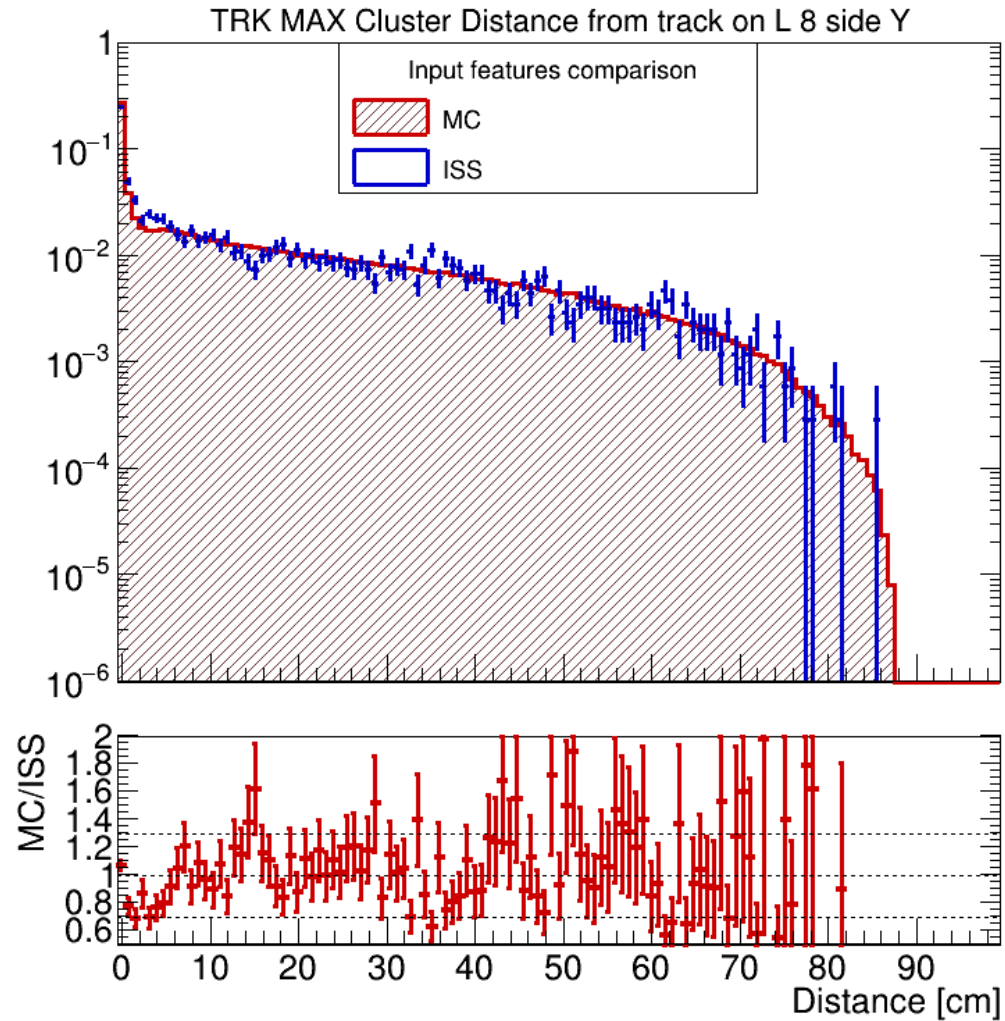
$(R_{inner} < 0)$ and elastic scattering inside the inner tracker

MC elastic scattering P_T variation in module

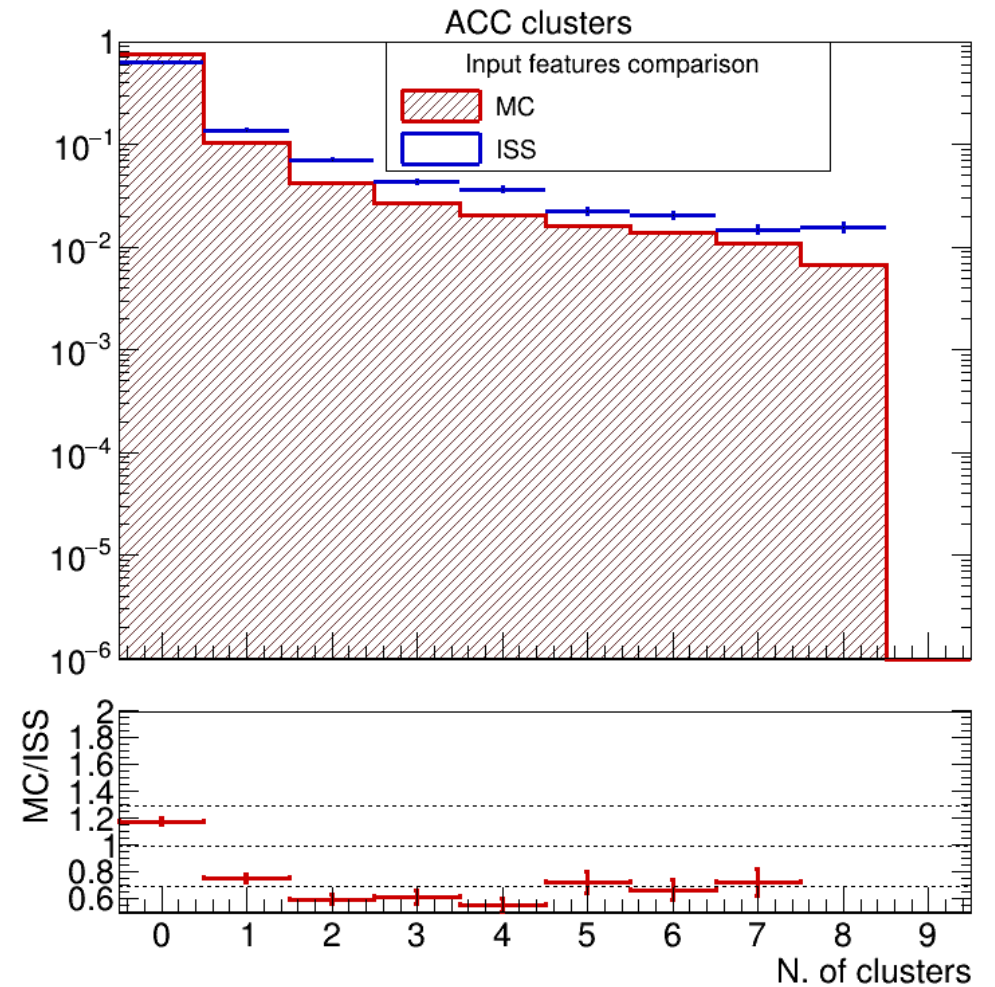


MC and ISS-data comparison

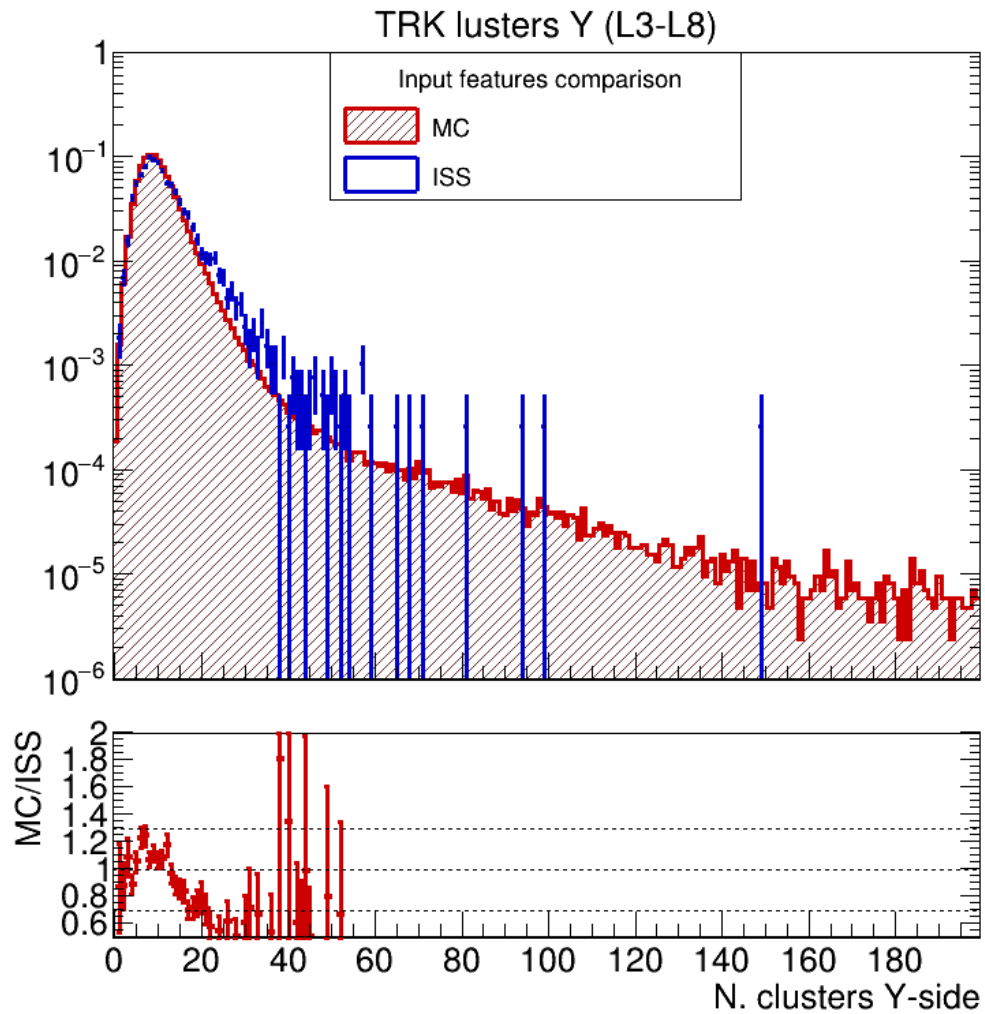
Distance between track hit and strip with max energy deposit on L8.



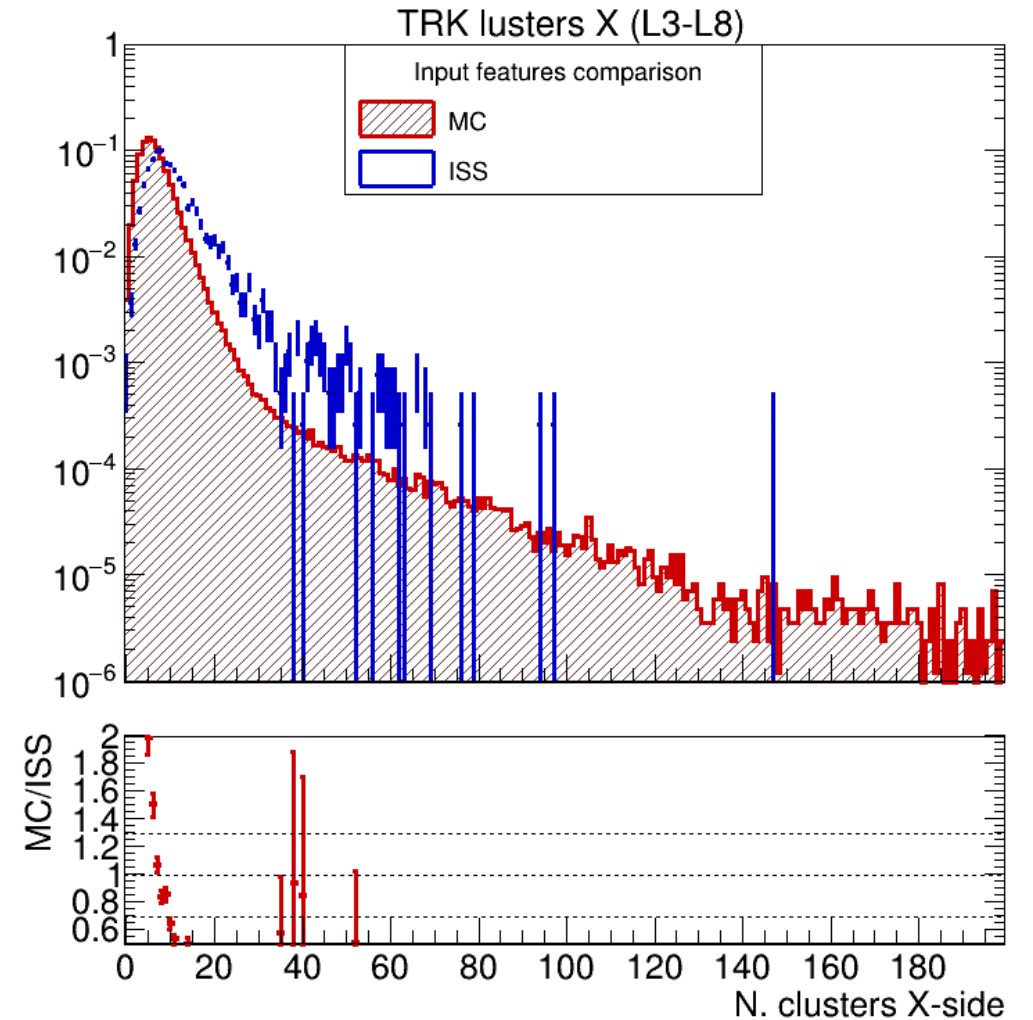
ACC clusters



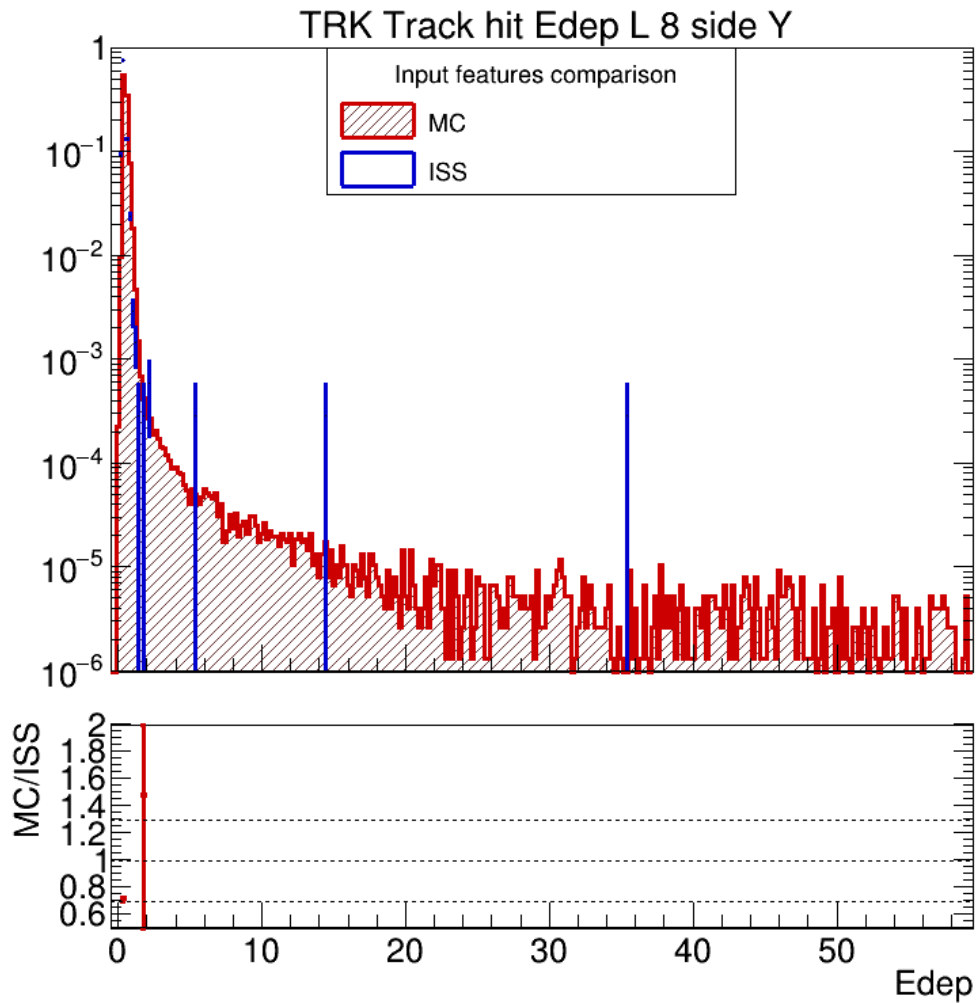
Number of hits in L3-L8 inner tracker Y side.



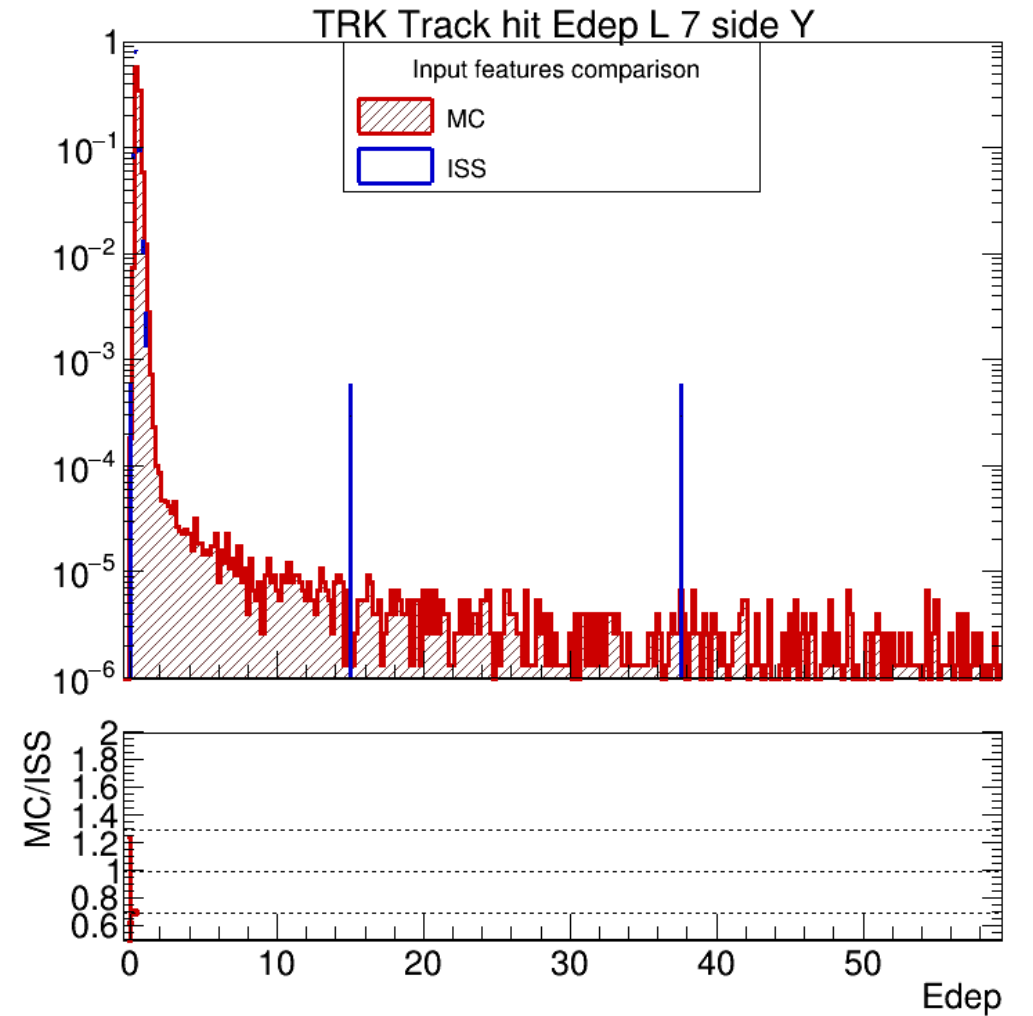
Number of hits in L3-L8 inner tracker X side.



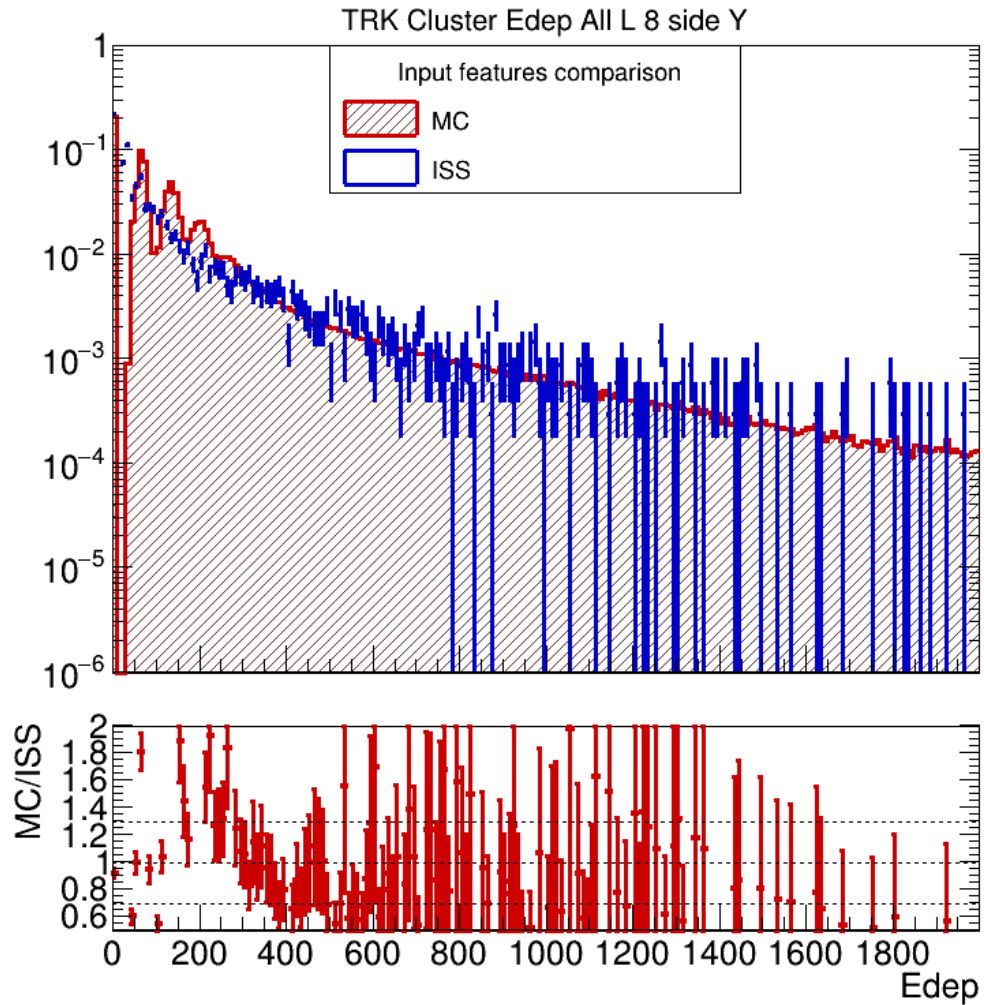
Track hit energy deposition on L8.



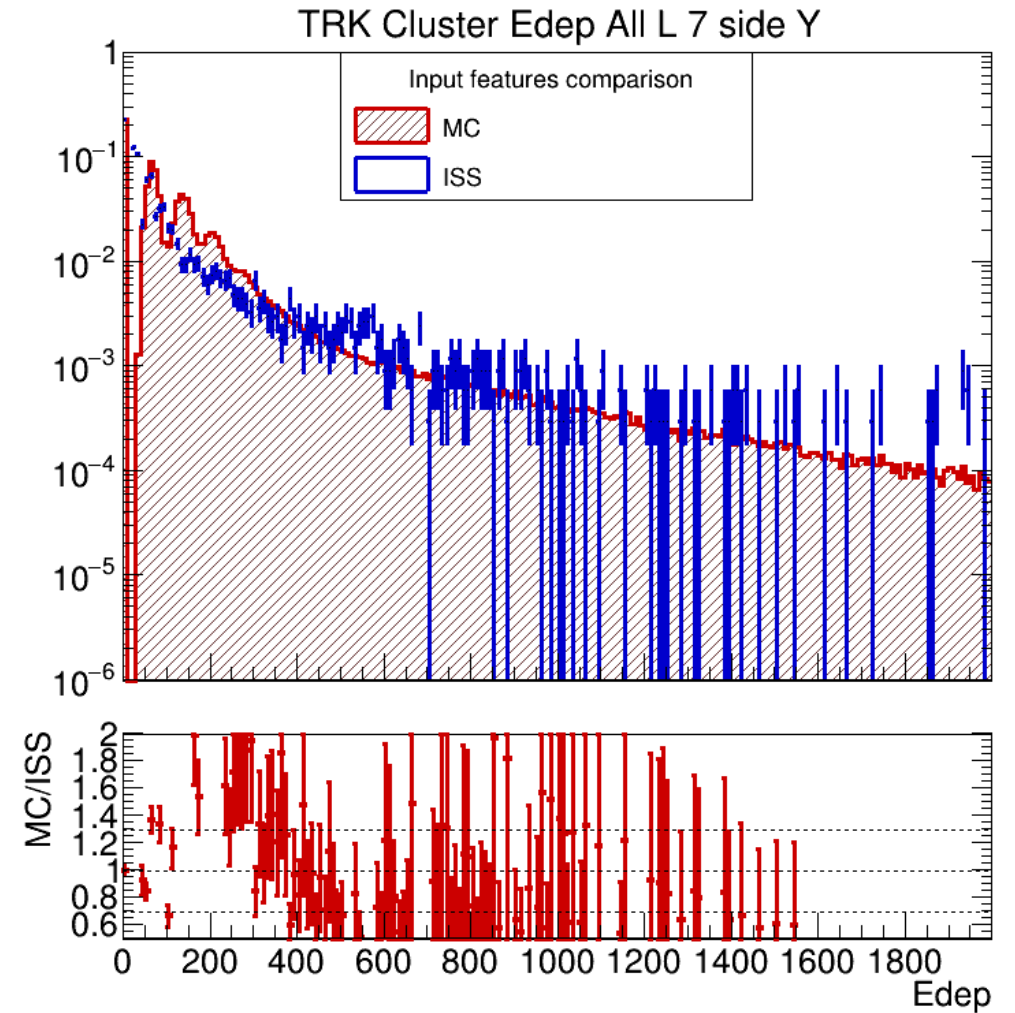
Track hit energy deposition on L7.



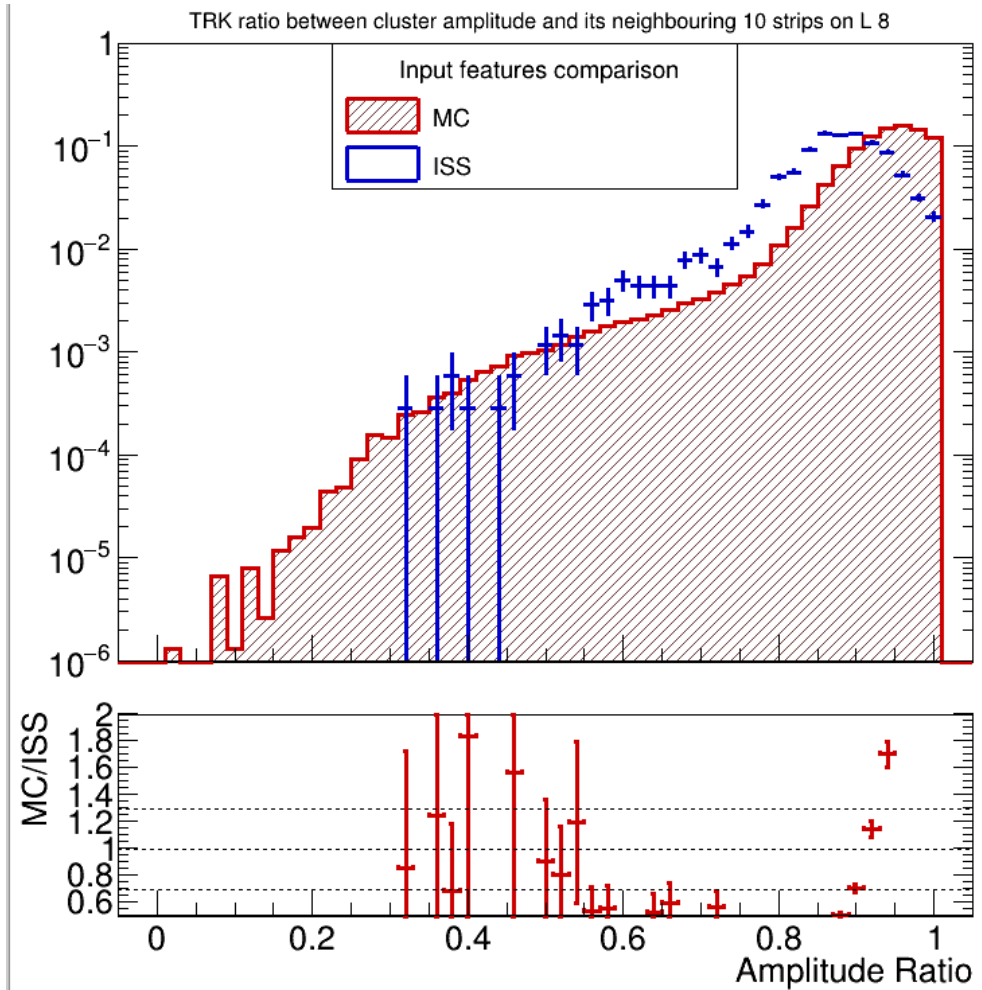
Total energy deposition of tracker clusters on L8
Y-side .



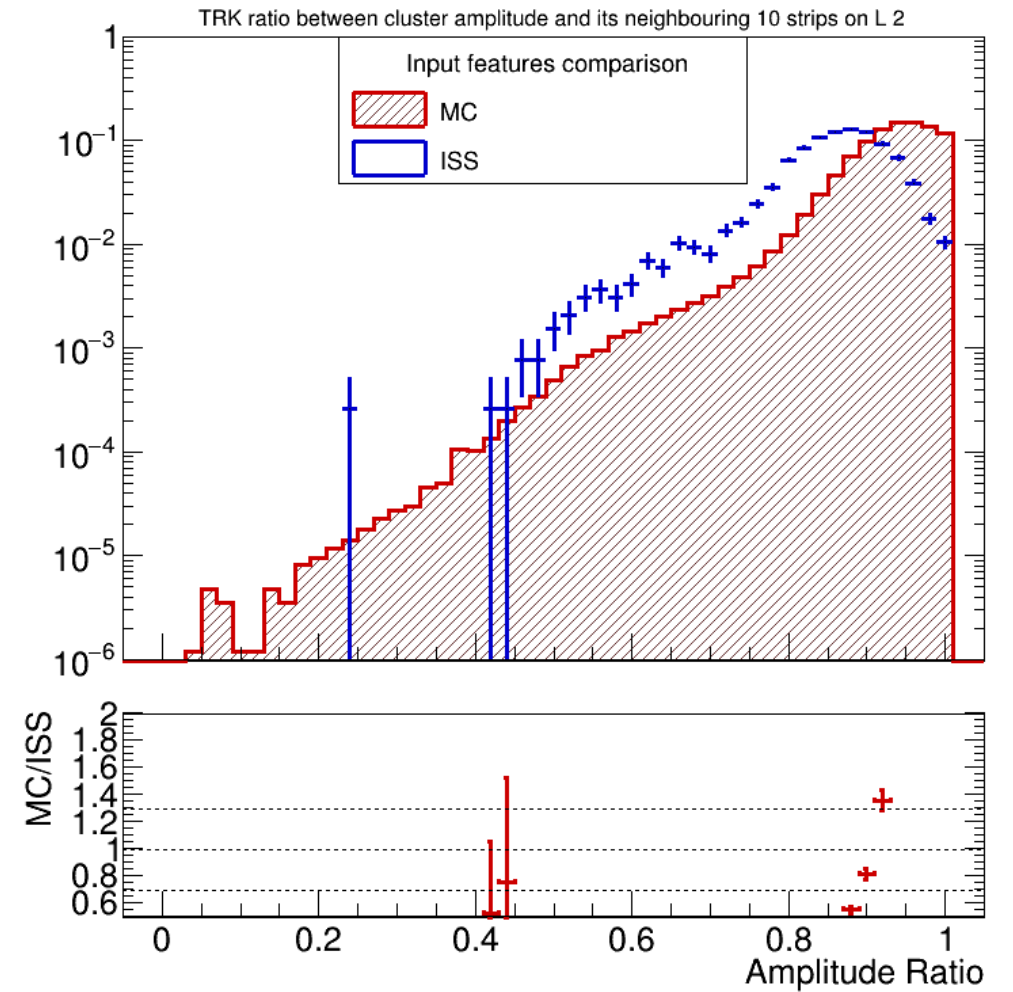
Total energy deposition of tracker clusters on L7
Y-side .



Ratio between cluster amplitude and its neighbouring 10 strips (L8)



Ratio between cluster amplitude and its neighbouring 10 strips (L2)



ISS selections for skimming and analysis

ISS-data skimming cutflow

No cut	1.3638e+10	1	
RTI good	1.36258e+10	0.999109	
SAA	1.28328e+10	0.941883	
LiveTimeFraction > 0.5	1.27602e+10	0.936756	
Zenith < 40 deg	1.27443e+10	0.93578	
Physics Trigger	1.20464e+10	0.887975	
NBetaClusters > 4	7.89321e+09	0.581799	
Beta > 0	6.61817e+09	0.487718	
BetaChi2Coo < 8	6.15594e+09	0.453648	
NTracks >= 1	6.15594e+09	0.453648	
Track pattern 5/8	1.65662e+09	0.122044	
GBL fit Inner	1.65602e+09	0.121999	
GBL fit InL1	1.41551e+09	0.104254	
Inner CH [1.7, 2.4]	1.60342e+08	0.0118012	
L1 CH [1.6, 3.0]	1.54294e+08	0.0113556	
Inner fiducial volume	1.43048e+08	0.01053	
L1 fiducial volume	1.3741e+08	0.0101151	
ChiSq Inner < 20	1.32873e+08	0.00978084	

0 1 2

RTIgood = 0

isInSAA

LiveTimeFraction > 0.5

Zenith < 40 deg

IsPhysicsTrigger

TOF hits ≥ 4

$\beta > 0$

$\chi_{COO}^2 < 8$

Track number ≥ 1

charge STD (inner) $\in [1.7, 2.4]$

Inner fiducial volume

charge STD (L1) $\in [1.6, 3.0]$

track pattern L1&L2&(L3|L4)&(L5|L6)&(L7|L8) (≥ 5)

$\chi_Y^2 < 20$

Tracker fiducial volume cut:

L1: $|R| < 62\text{cm}$, $|Y| < 47\text{cm}$

L2: $|R| < 62\text{cm}$, $|Y| < 40\text{cm}$

L3: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L4: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L5: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L6: $|R| < 46\text{cm}$, $|Y| < 36\text{cm}$

L7: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

L8: $|R| < 46\text{cm}$, $|Y| < 44\text{cm}$

ISS-data analysis cutflow

Events that passed each single cut

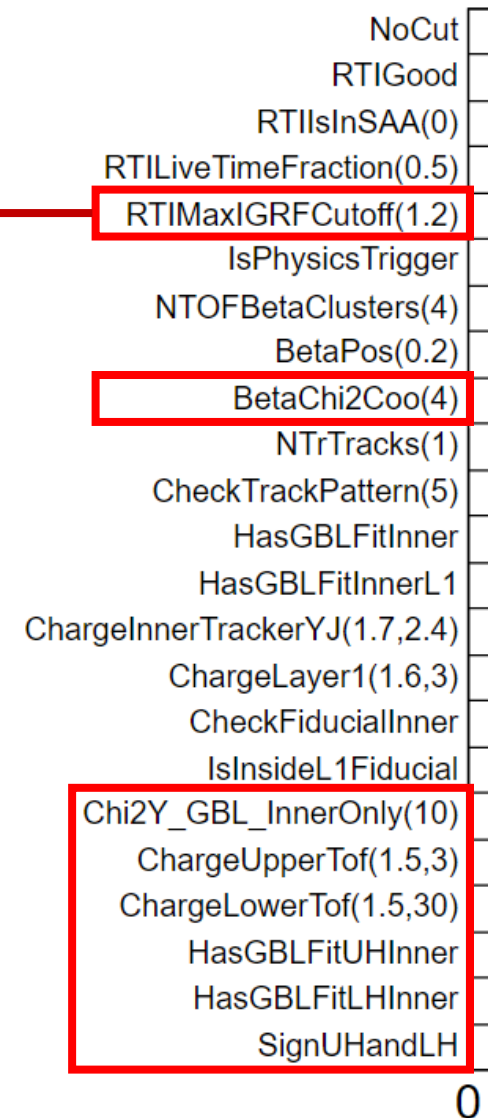
NoCut	129027523	1
RTIGood	129027522	0.9934
RTIIsInSAA(0)	129027522	0.9934
RTLIVETimeFraction(0.5)	128498662	0.9879
RTIMaxIGRFCutoff(1.2)	116341190	0.8941
IsPhysicsTrigger	116341190	0.8941
NTOFBetaClusters(4)	116341190	0.8941
BetaPos(0.2)	116341028	0.8941
BetaChi2Coo(4)	114566686	0.8804
NTrTracks(1)	114566686	0.8804
CheckTrackPattern(5)	114566686	0.8804
HasGBLFitInner	114566686	0.8804
HasGBLFitInnerL1	114566686	0.8804
ChargeInnerTrackerYJ(1.7,2.4)	113643991	0.8733
ChargeLayer1(1.6,3)	113218442	0.8701
CheckFiducialInner	113218025	0.8701
IsInsideL1Fiducial	113218024	0.8701
Chi2Y_GBL_InnerOnly(10)	109520915	0.8416
ChargeUpperTof(1.5,3)	108300092	0.8323
ChargeLowerTof(1.5,30)	107384487	0.8252
HasGBLFitUHInner	104075720	0.7997
HasGBLFitLHInner	104057083	0.7995
SignUHandLH	103846950	0.7979

ISS-data analysis cutflow

L1Inner = Rig. [L1-inner]
IGRFCutoff = rti_info.MaxIGRFCutoff[40°][ch_sign]
Hist = Rig. Histogram with binning from [He 7 5y](#)

if (L1Inner <= hist->GetBinLowEdge(hist->FindBin(1.2 * IGRFCutoff)+1))

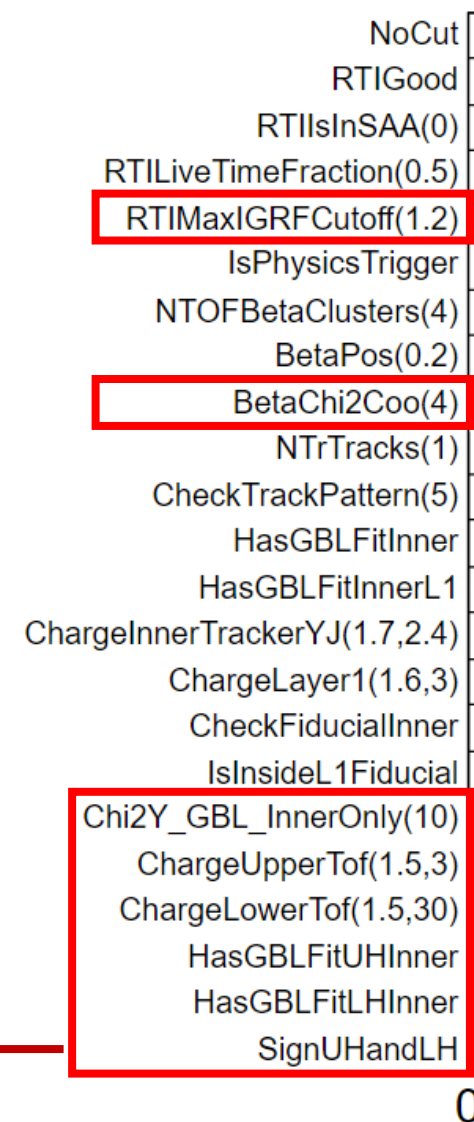
Do I have to consider positive or negative charges?



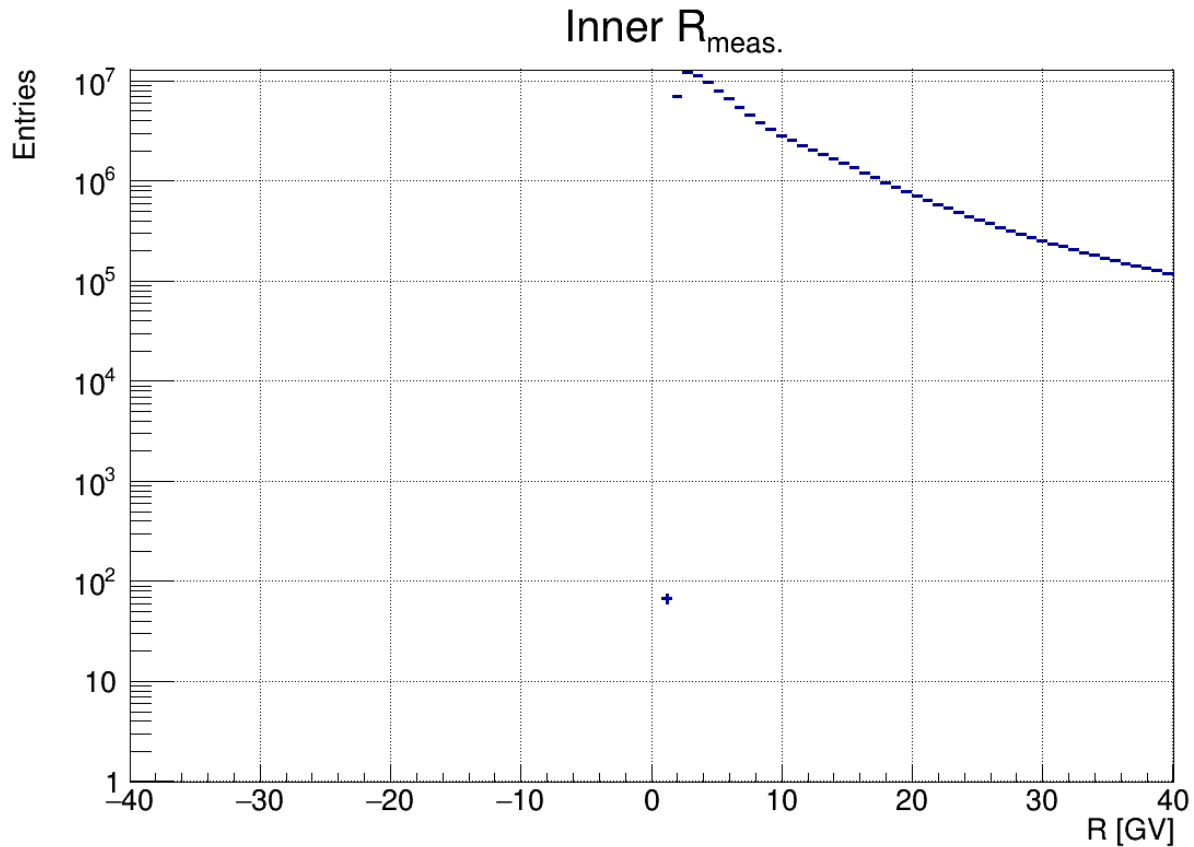
ISS-data analysis cutflow

UH = Rig. [UH-inner]
LH = Rig. [LH-inner]
Inner = Rig. [inner]

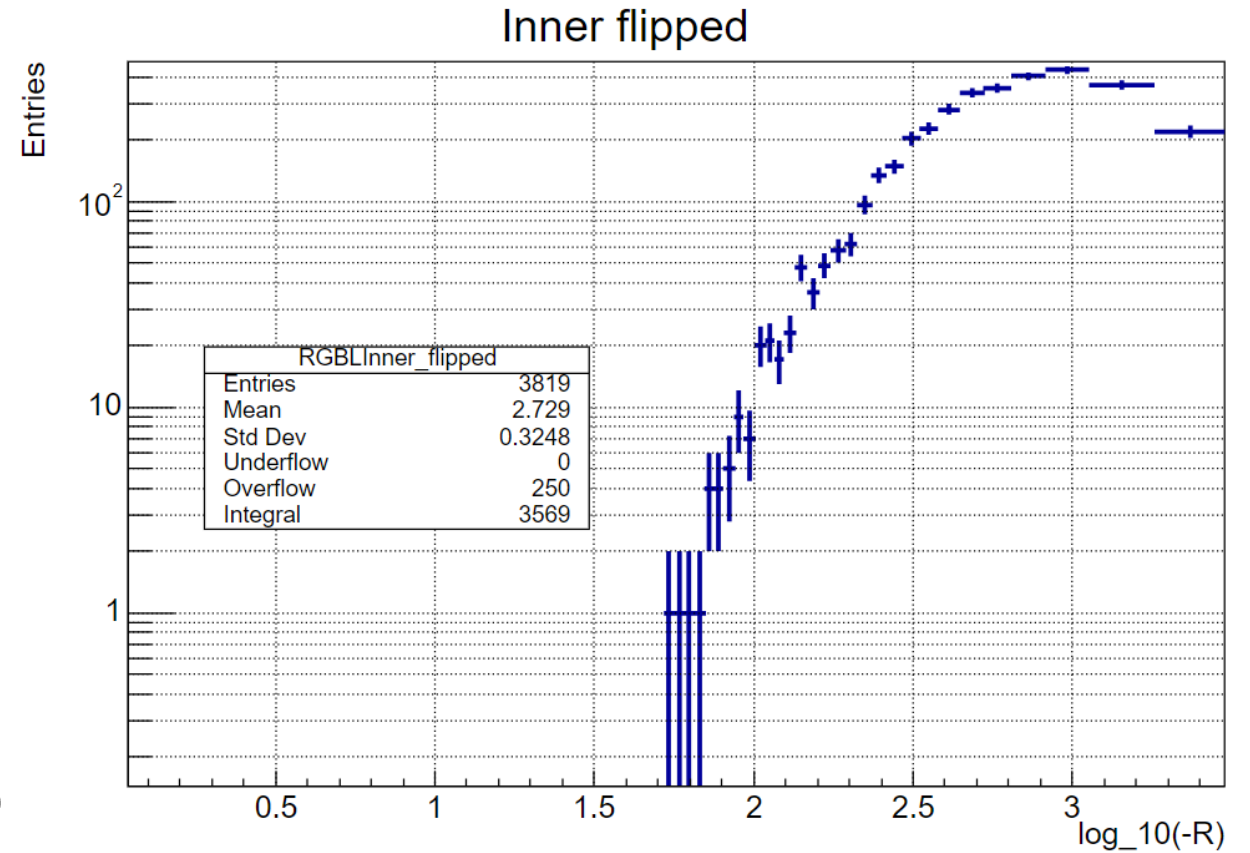
If(Inner > 0) → (UH > 0, LH > 0)
If(Inner < 0) → (UH < 0, LH < 0)



Measured inner tracker rigidity:



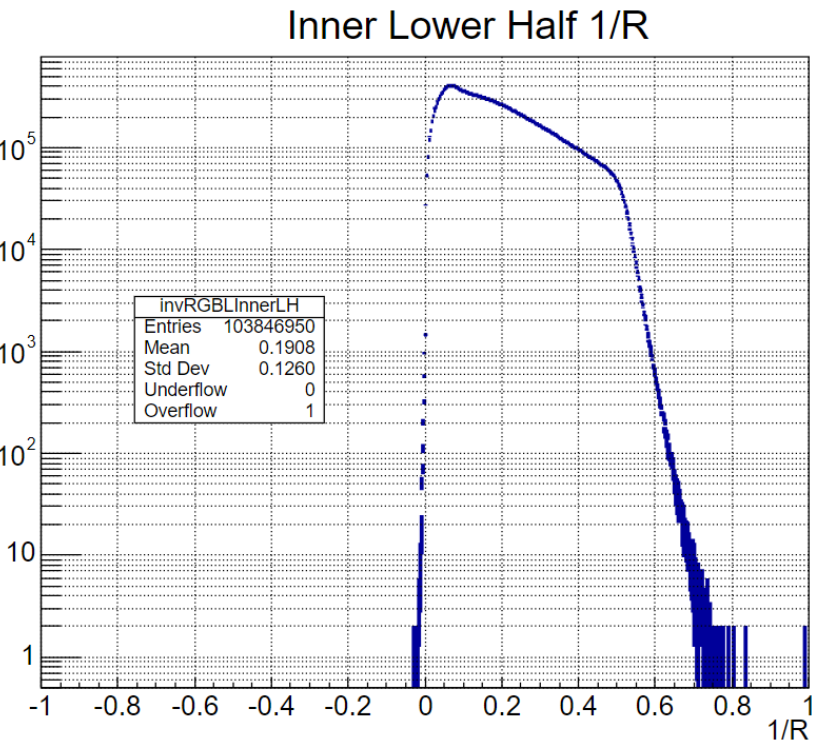
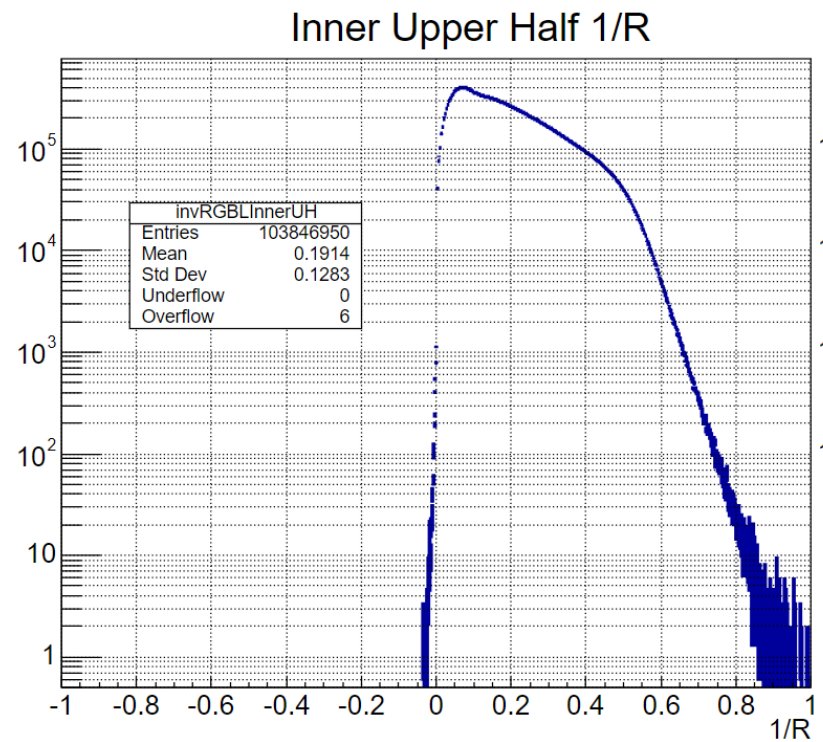
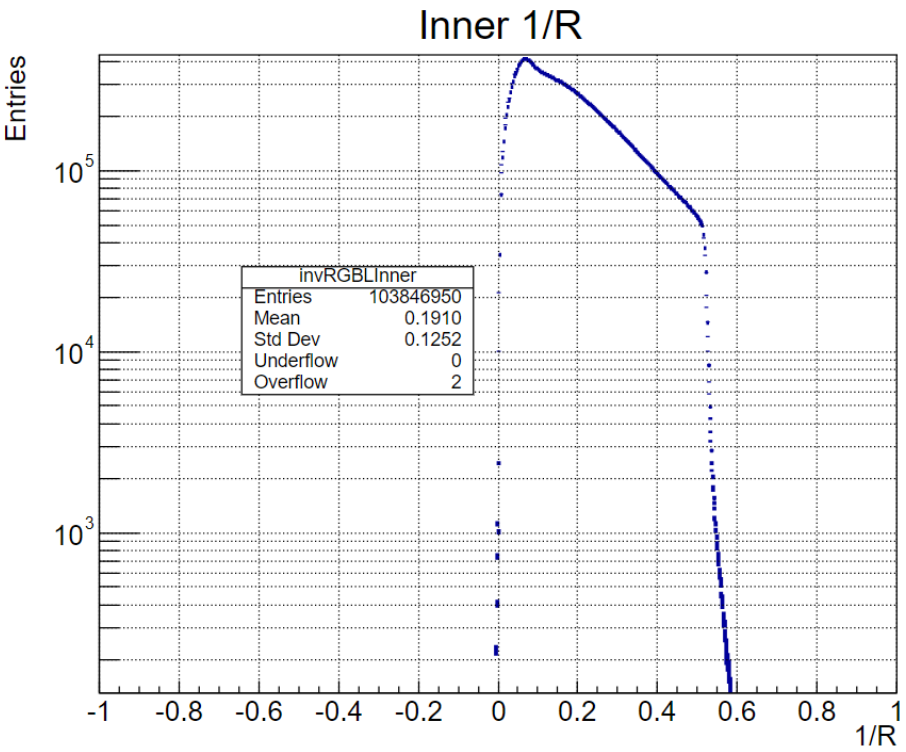
Measured inner tracker rigidity < 0:

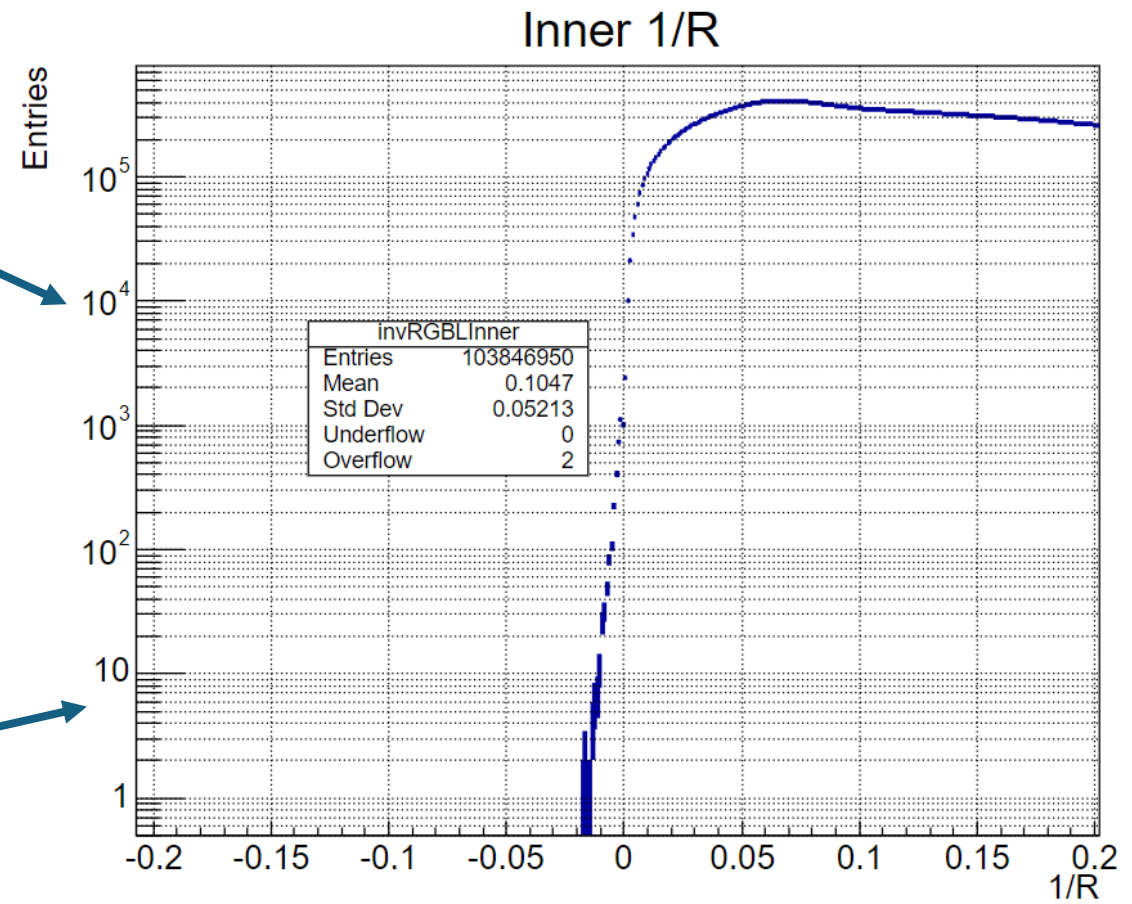
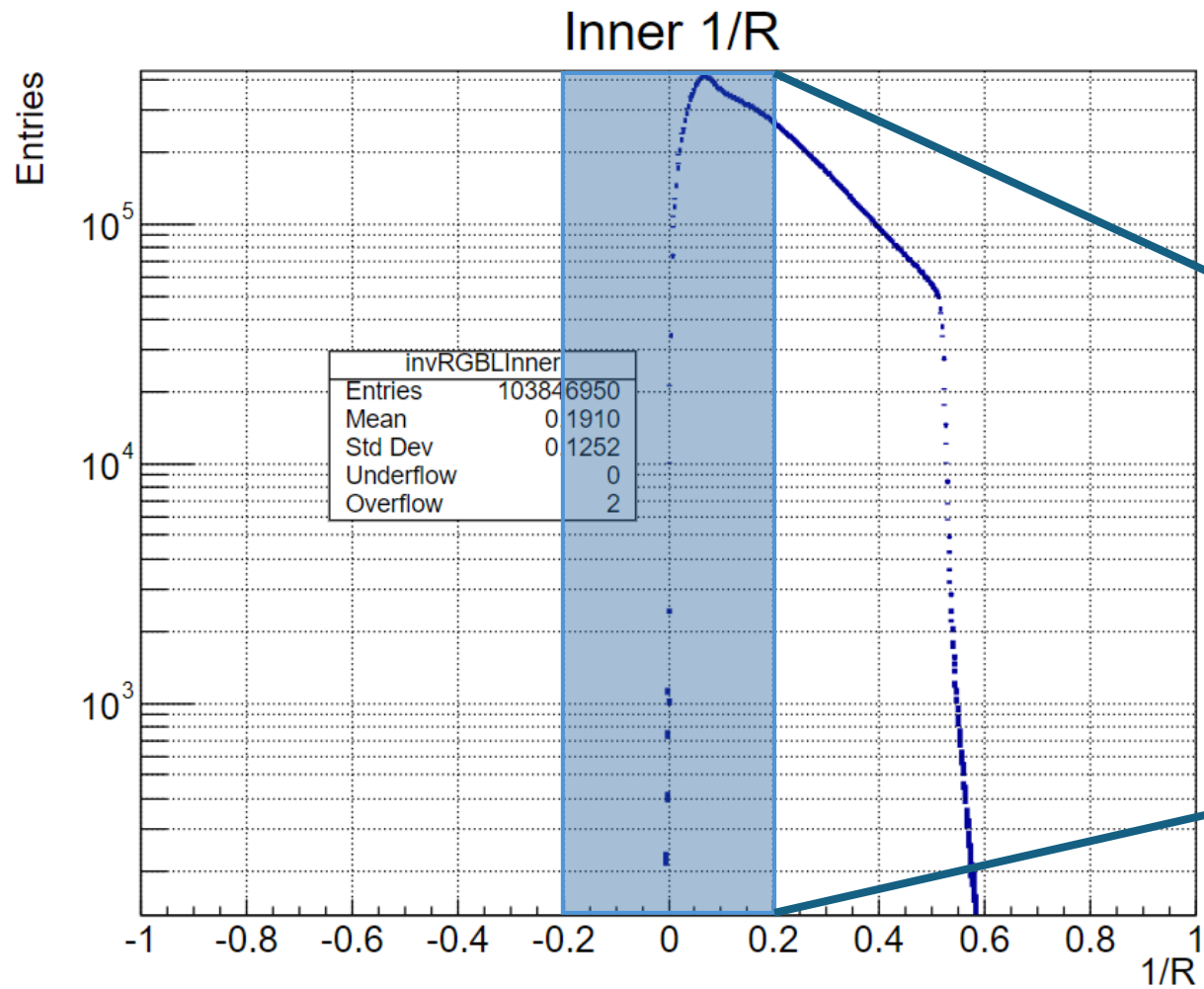


No events with $R_{\text{inner}} \in [-40, 0]$.

$1.3 \cdot 10^8$ events with $R_{\text{inner}} > 0$

$3.8 \cdot 10^3$ events with $R_{\text{inner}} < 0$



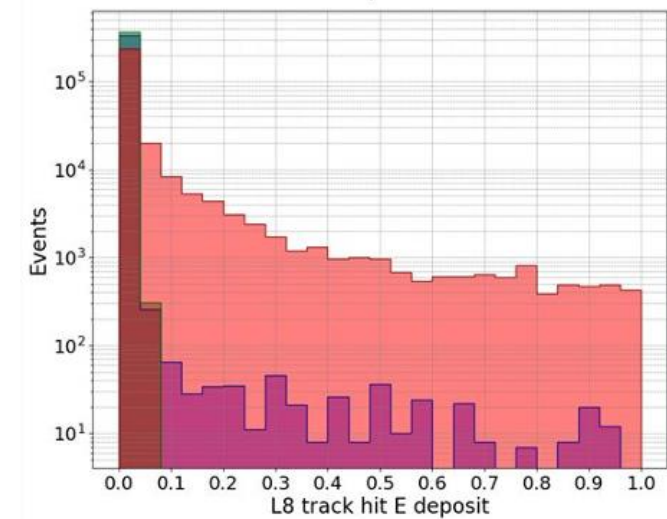
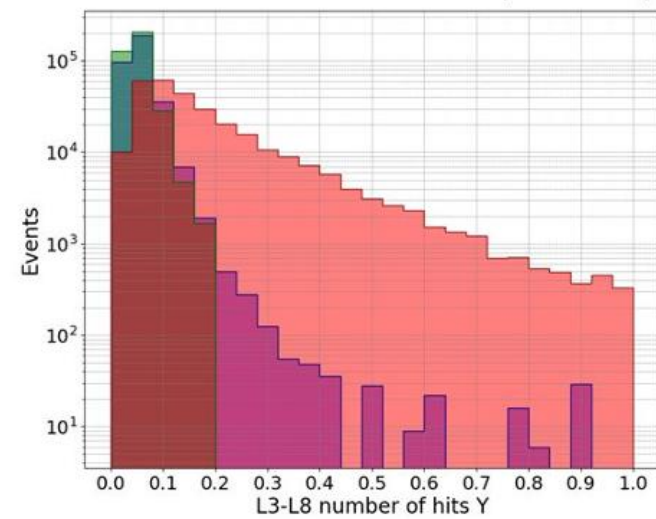
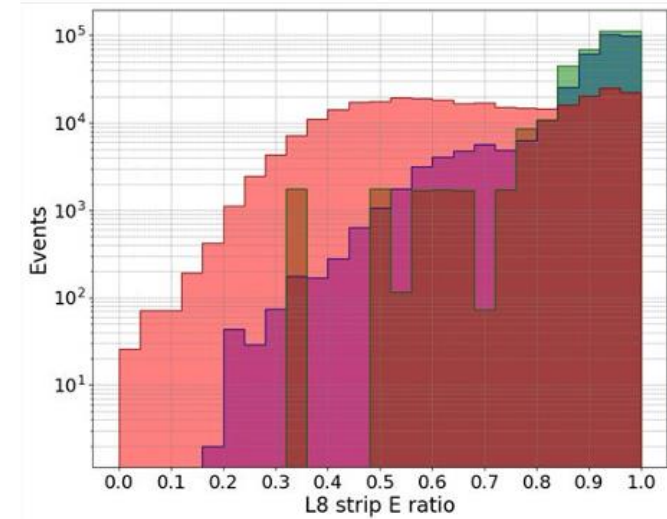
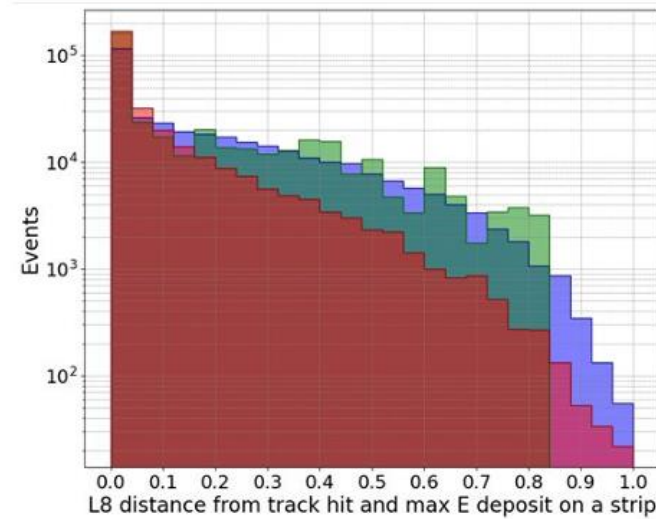


FCNN input features (old selection)

Input features 1

- Distance between track hit and strip with max energy deposit on L8.
- Ratio between strip energy deposition and its neighbouring 10 strips, on L8.
- Number of hits in L3-L8 inner tracker Y side.
- Track hit energy deposition on L8.

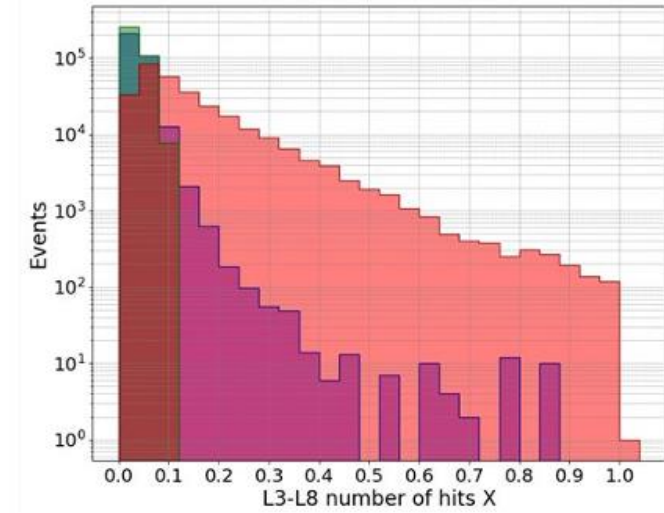
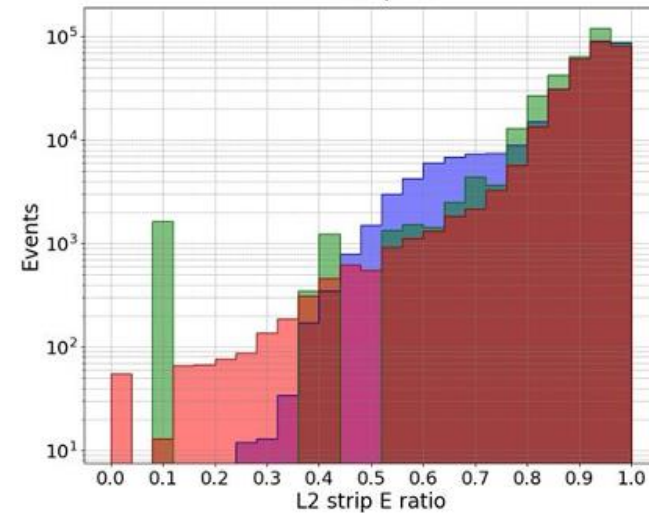
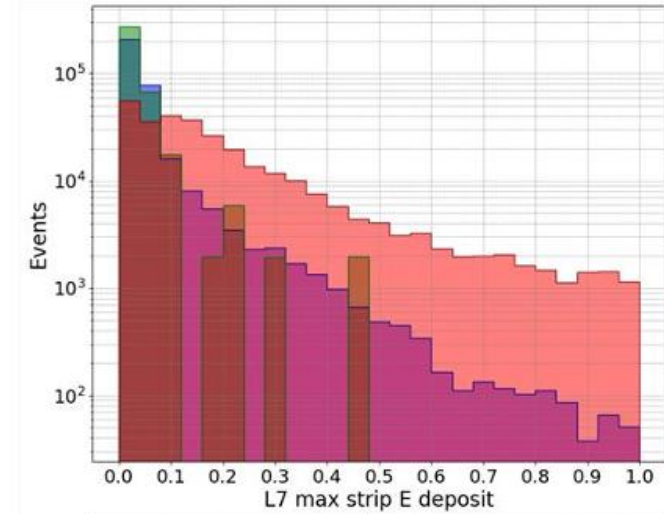
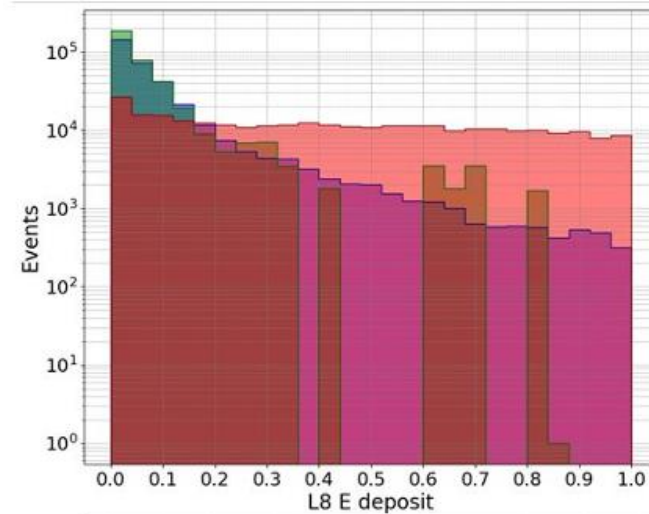
Spillover ■ Had. Inel ■ El. Scat. ■



Input features 2

- Total energy deposition on L8.
- Max energy deposit on a single strip on L7.
- Ratio between strip energy deposition and its neighbouring 10 strips, on L2.
- Number of hits in L3-L8 inner tracker X side.

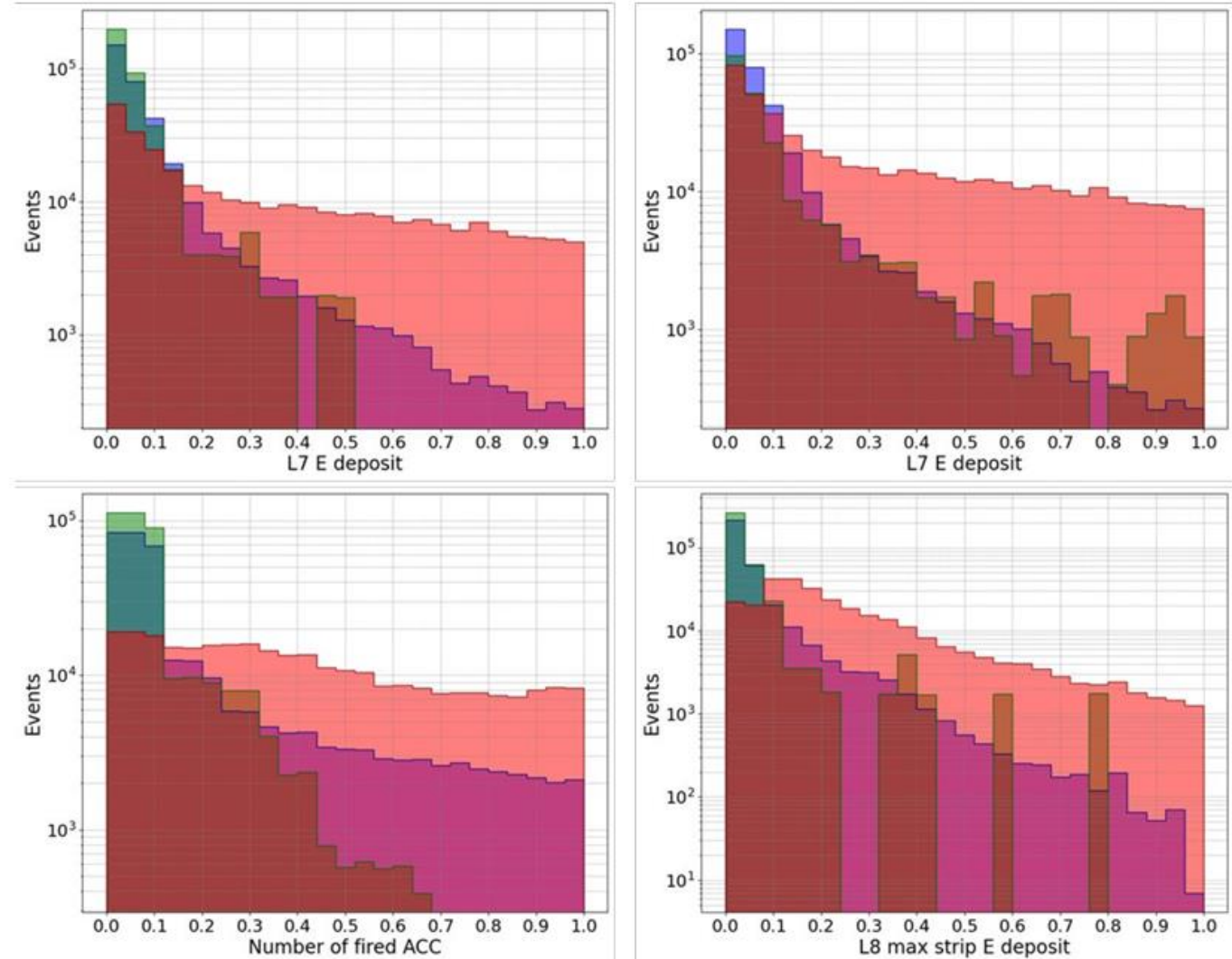
Spillover ■ Had. Inel ■ El. Scat. ■



Input features 3

- Track hit energy deposition on L7.
- Total energy deposition on L7.
- Number of fired ACC.
- Max energy deposit on a single strip on L8.

Spillover ■ Had. Inel ■ El. Scat. ■



Correlation matrix and features ranking

Correlation matrix

Hit on track E (L8)	1.00	-0.04	0.17	-0.10	-0.11	-0.04	-0.08	-0.08	-0.15	-0.11	-0.08	-0.14
Max strip E (L8)	-0.04	1.00	-0.08	0.05	0.05	0.02	0.04	0.04	0.07	0.05	0.04	0.07
SR (L8)	0.17	-0.08	1.00	-0.21	-0.21	-0.08	-0.17	-0.17	-0.30	-0.22	-0.17	-0.28
Strip E (L8)	-0.10	0.05	-0.21	1.00	0.13	0.05	0.10	0.10	0.18	0.13	0.10	0.17
ACC	-0.11	0.05	-0.21	0.13	1.00	0.05	0.10	0.10	0.19	0.13	0.11	0.17
Clusters Y	-0.04	0.02	-0.08	0.05	0.05	1.00	0.04	0.04	0.07	0.05	0.03	0.06
Clusters X	-0.08	0.04	-0.17	0.10	0.10	0.04	1.00	0.08	0.14	0.11	0.08	0.13
Max strip E (L7)	-0.08	0.04	-0.17	0.10	0.10	0.04	0.08	1.00	0.15	0.10	0.08	0.13
Max strip distance (L8)	-0.15	0.07	-0.30	0.18	0.19	0.07	0.14	0.15	1.00	0.18	0.14	0.24
Strip E (L7)	-0.11	0.05	-0.22	0.13	0.13	0.05	0.11	0.10	0.18	1.00	0.10	0.17
SR (L2)	-0.08	0.04	-0.17	0.10	0.11	0.03	0.08	0.08	0.14	0.10	1.00	0.13
Hit on track E (L7)	-0.14	0.07	-0.28	0.17	0.17	0.06	0.13	0.13	0.24	0.17	0.13	1.00
	Hit on track E (L8)	Max strip E (L8)	SR (L8)	Strip E (L8)	ACC	Clusters Y	Clusters X	Max strip E (L7)	Max strip distance (L8)	Strip E (L7)	SR (L2)	Hit on track E (L7)

Feature ranking

