

Test beam particle ID

Cut-based performance for 10GeV particles and first look at BDT results

Vladimir Bocharnikov
AHCAL Main meeting, 12-13 Dec 2018

HELMHOLTZ RESEARCH FOR
GRAND CHALLENGES



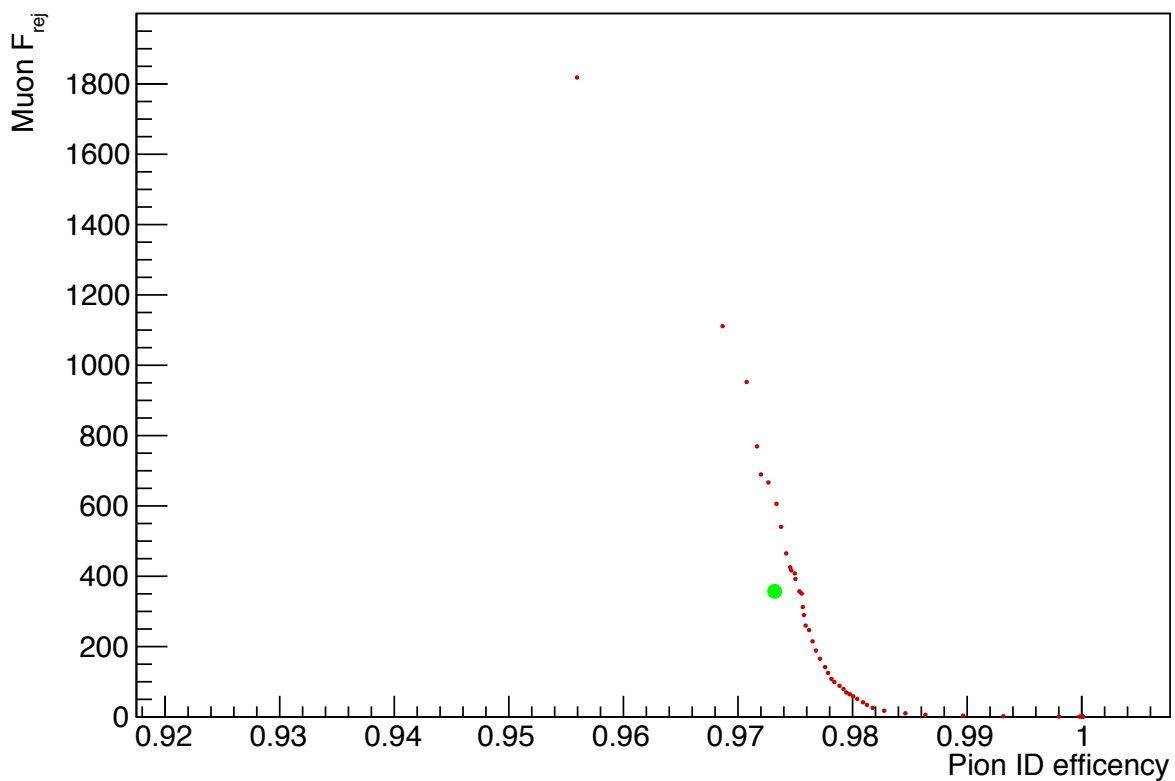
P.N. Lebedev Physical
Institute of the Russian
Academy of Science



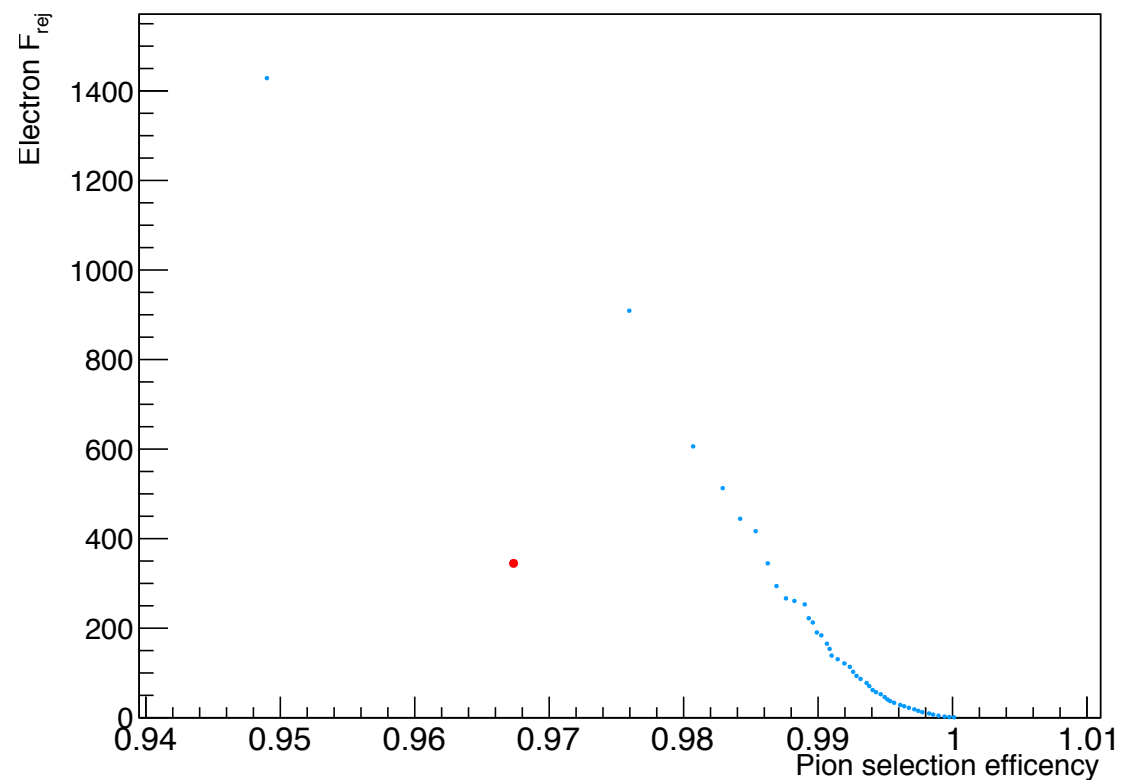
Background rejection vs signal efficiency

Another representation of performance.

Muon rejection factor vs Pion ID efficiency



Electron rejection factor vs Pion selection efficiency

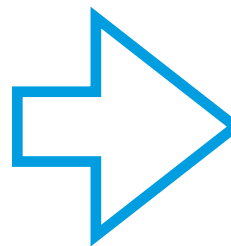
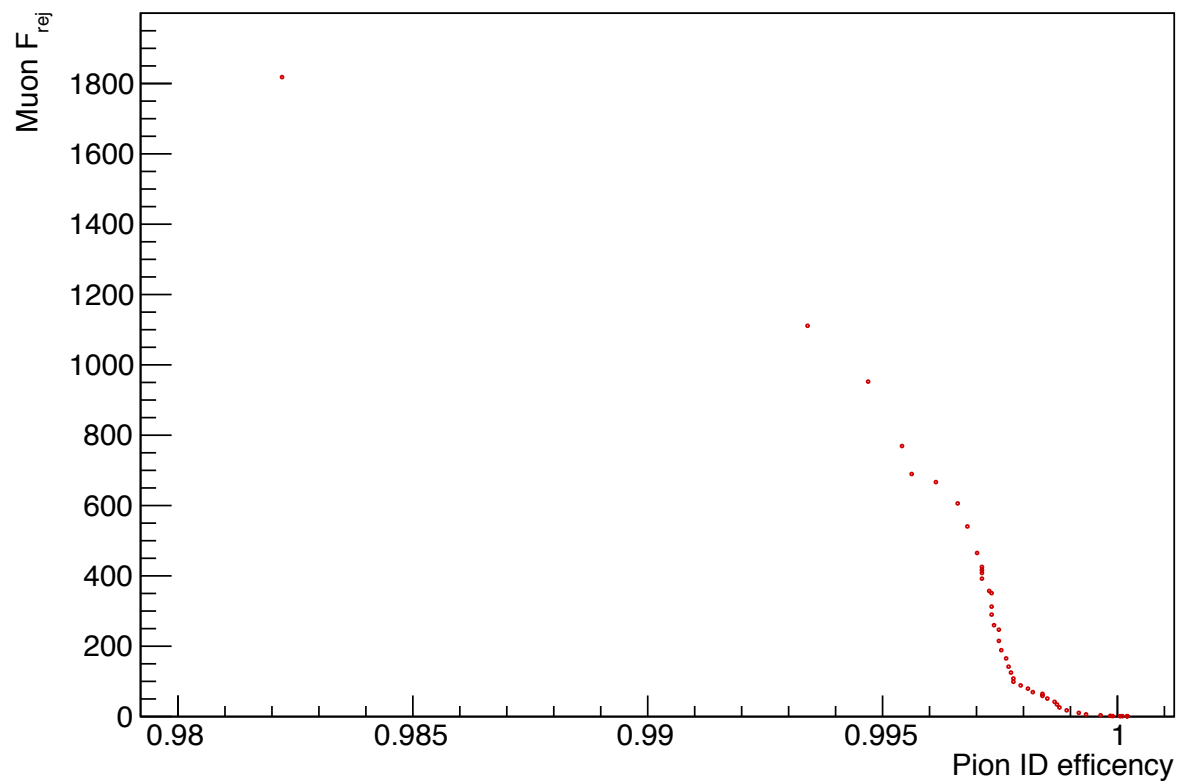


New cut for BDT input

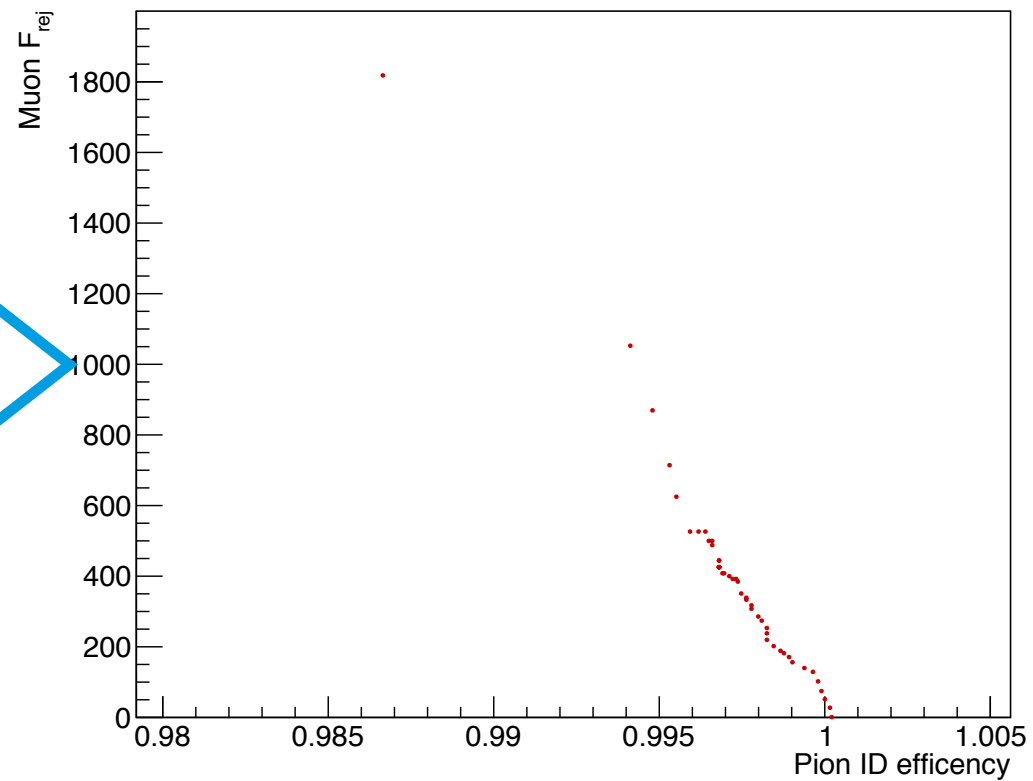
On shower start layer. Muon vs pion separation

Cut: Pion events w/o shower are thrown away.

Muon rejection factor vs Pion ID efficiency



Muon rejection factor vs Pion ID efficiency



Backup

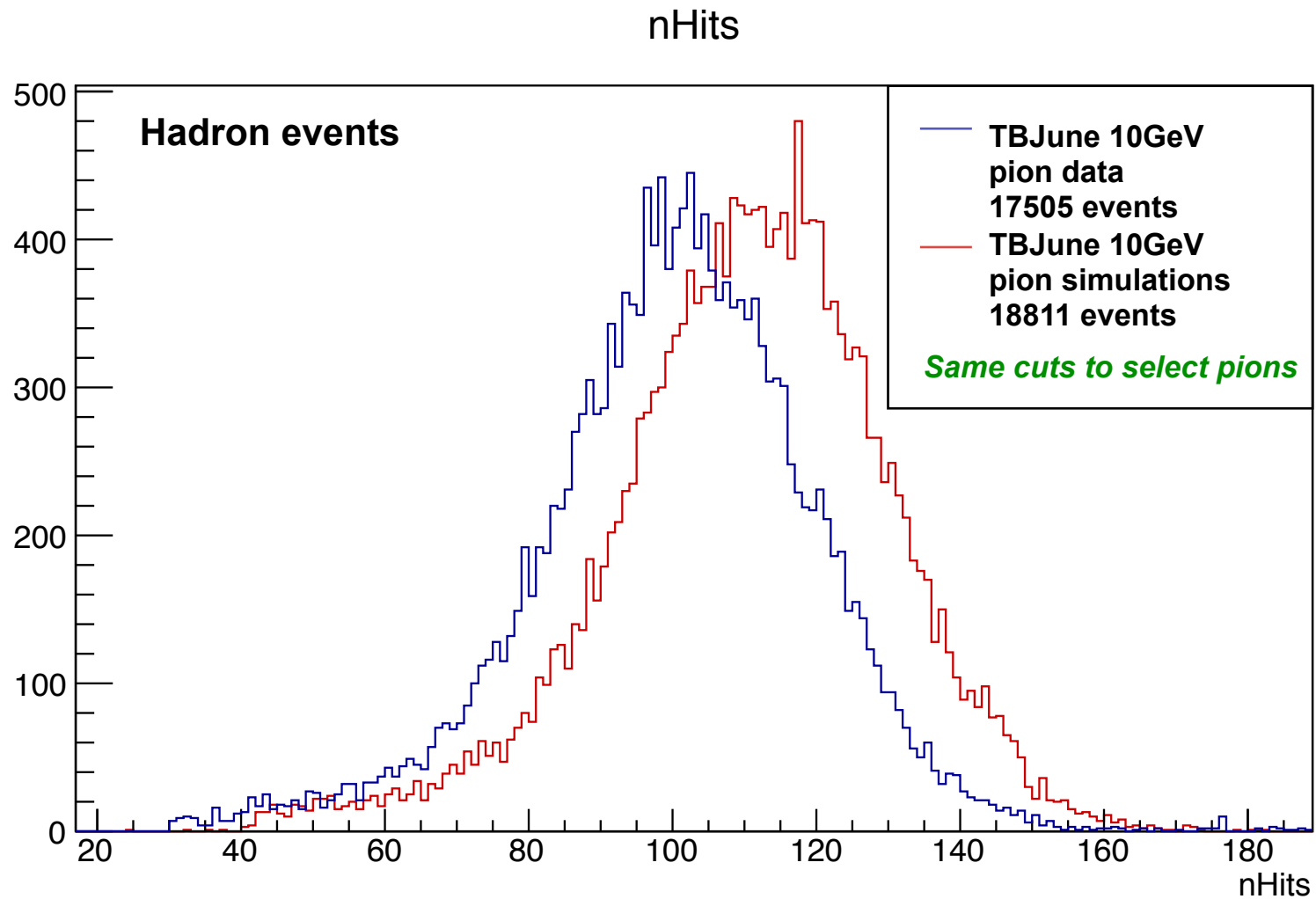
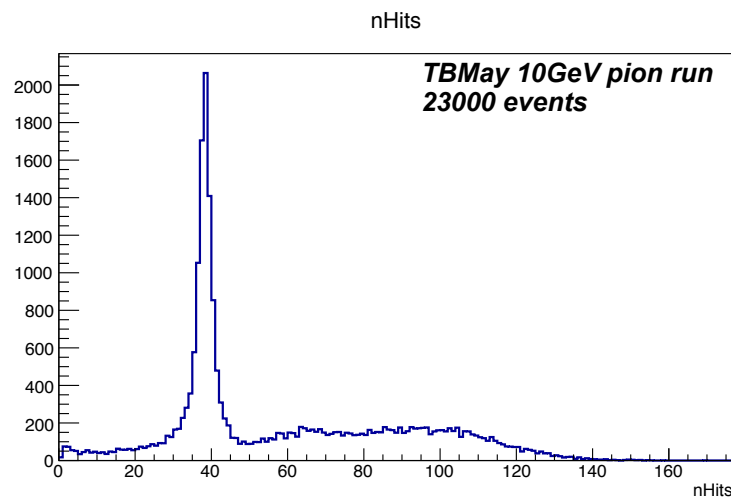
Observables

For particle ID

Number of hits per event

- “clean” μ^- : $N_{hits} \approx N_{layers}$

Probably, 0.5MIP cut gives more hits for MC

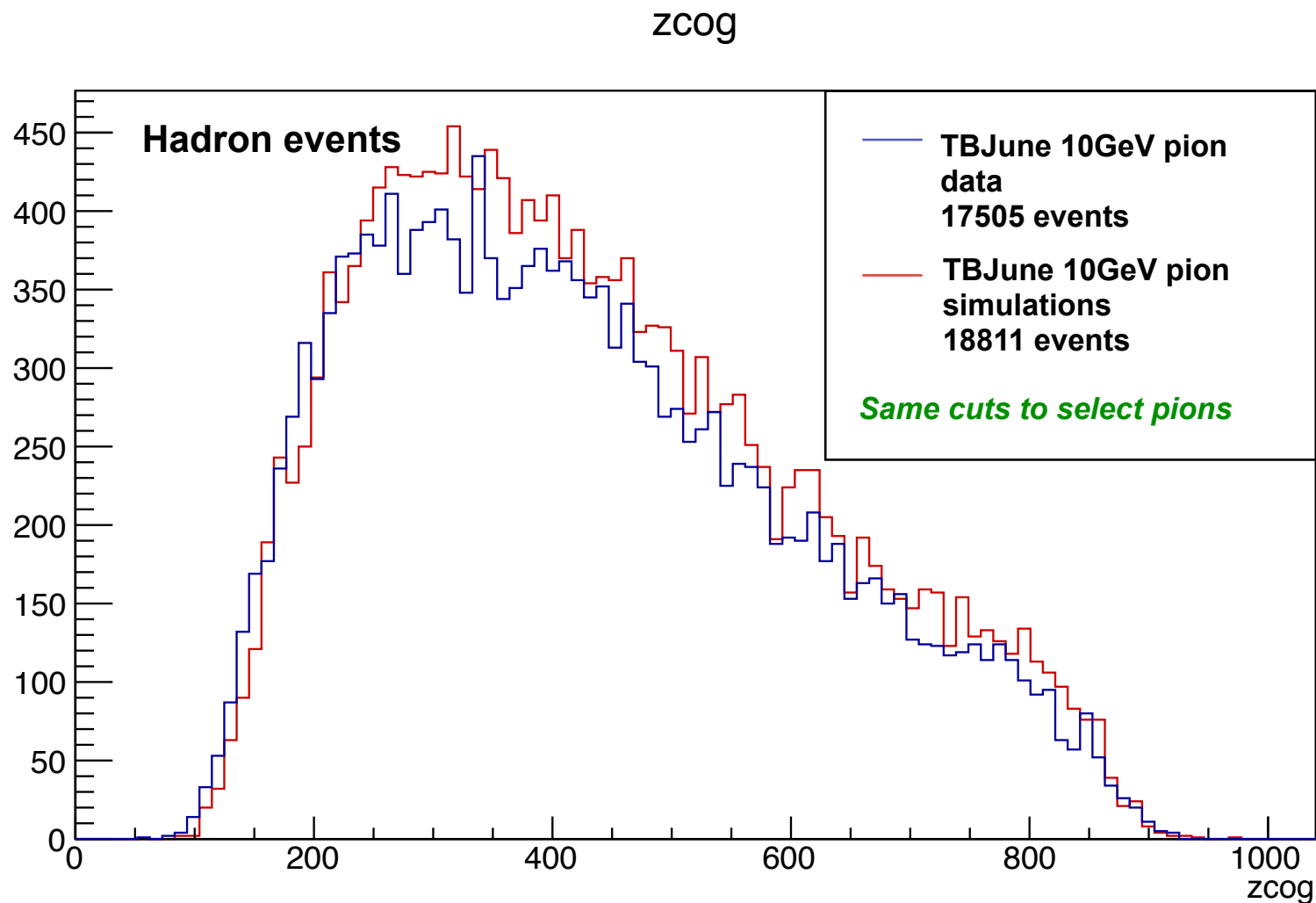
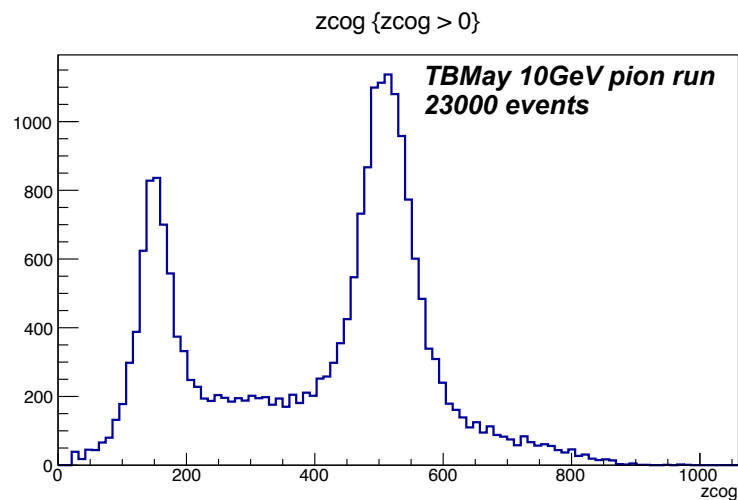


Observables

For particle ID

Center of gravity in z

- μ^- : z_{cog} peaks in the middle of detector
- e^- : z_{cog} peaks in the first half of detector
- π^- : z_{cog} more-less spread



Observables

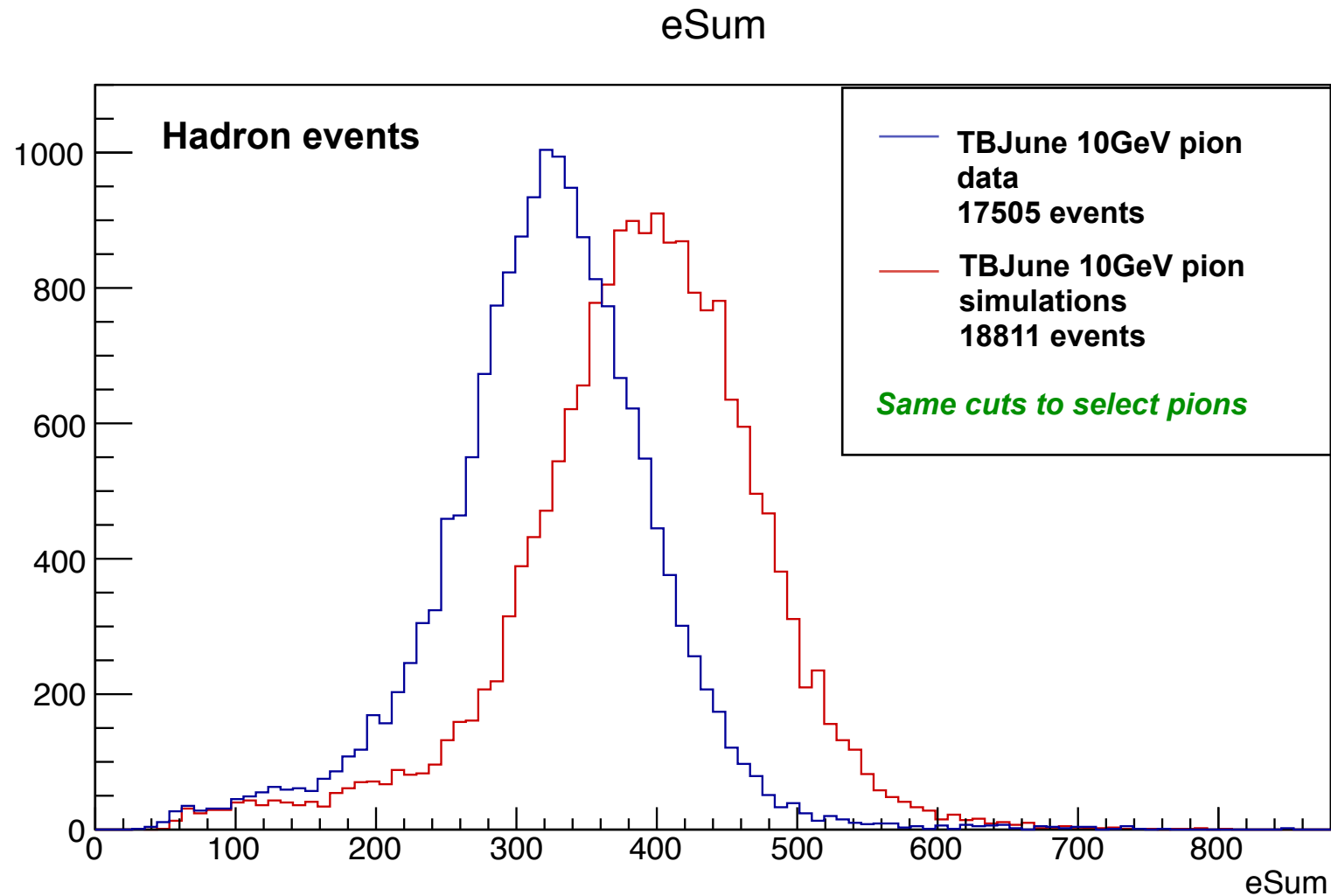
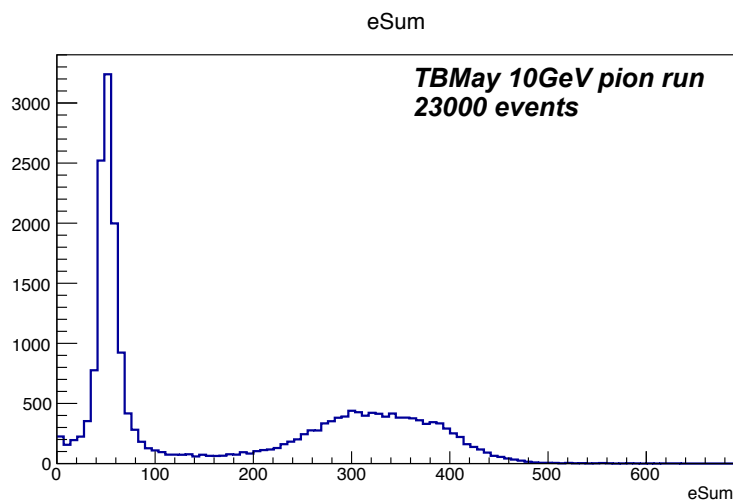
For particle ID

Energy sum per event

- “clean” μ^- : $E_{sum} \approx N_{layers} * MIP$

Bad agreement MC with data for the moment (not used).

Probably, IC problem



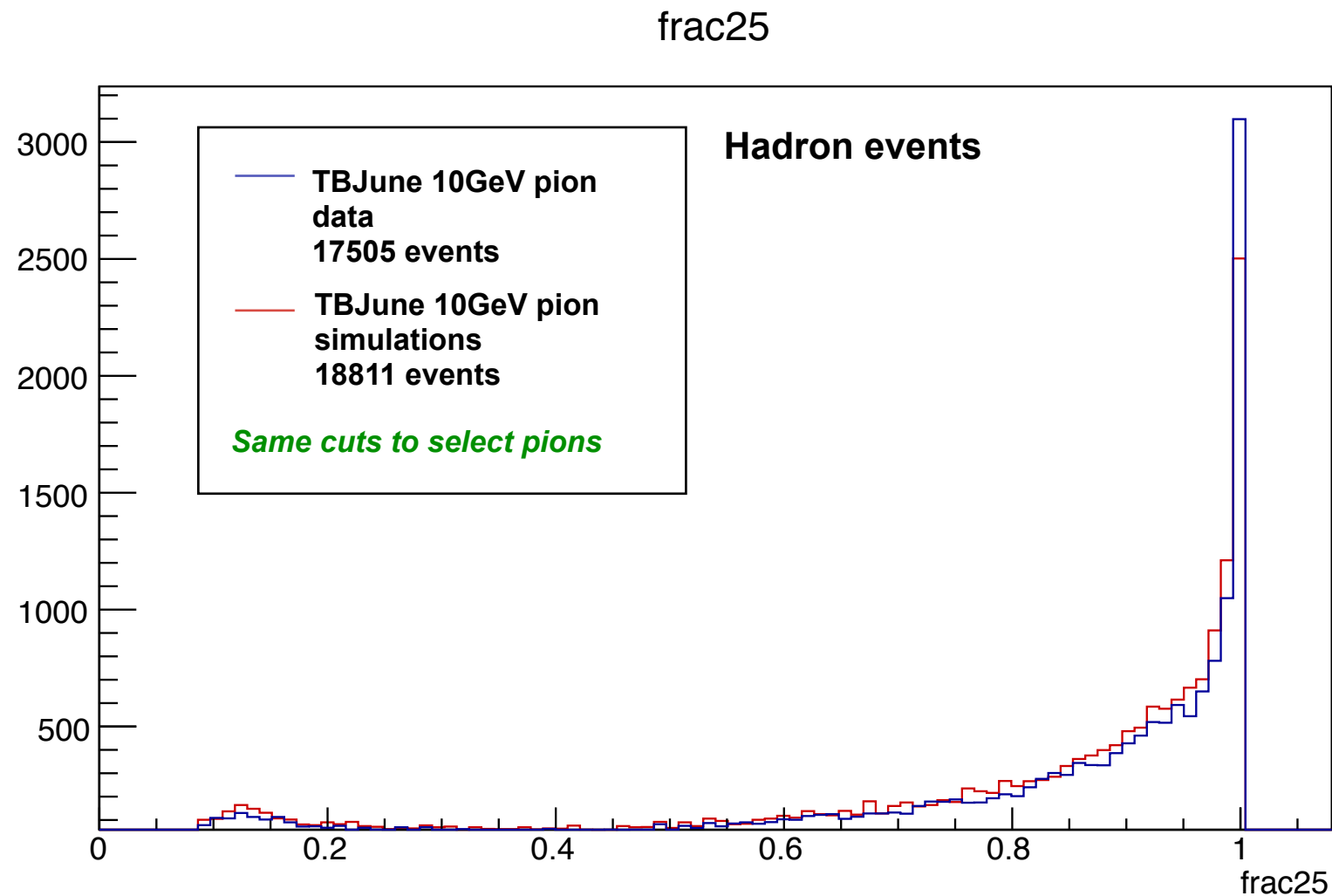
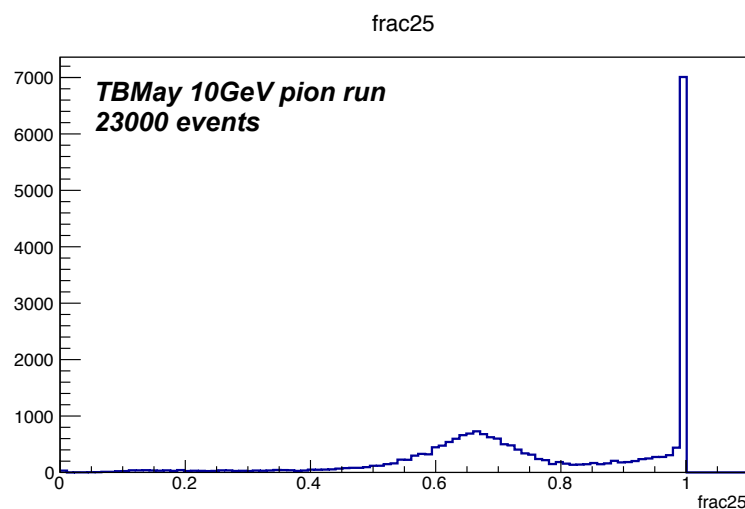
Observables

For particle ID

Fraction of energy in first 25 layers

$$(E_{25l}/E_{total})$$

- μ^- : fraction peaks at $25/N_{layers}$
- e^- : fraction ≈ 1
- π^- : fraction more-less spread

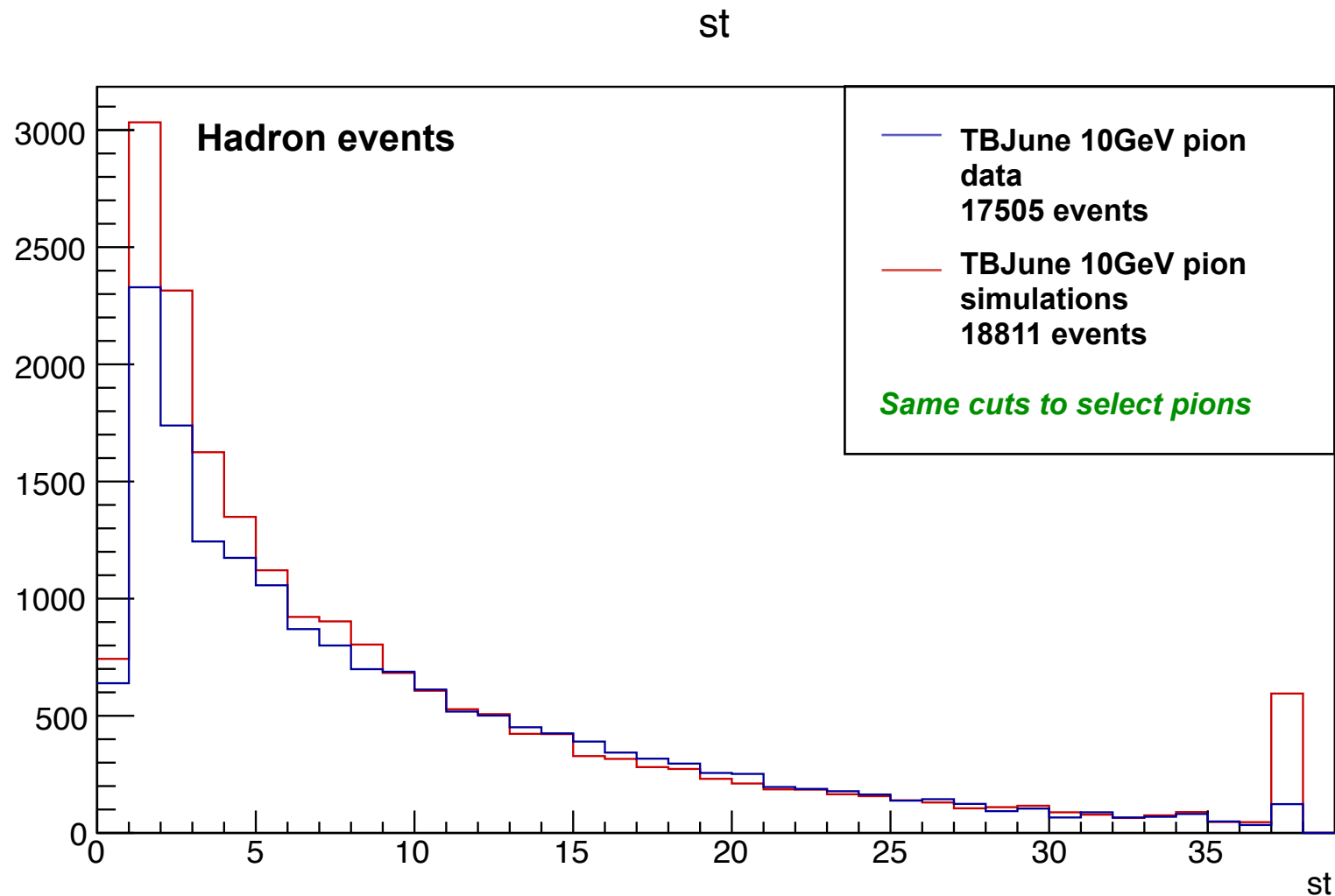
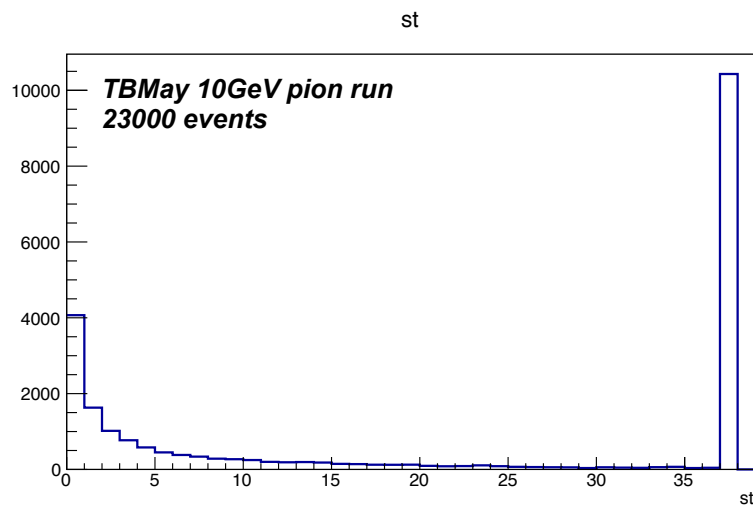


Observables

For particle ID

Shower start layer number

- “clean” μ^- : no shower
- e^- : in the first half of detector
- π^- : more-less spread

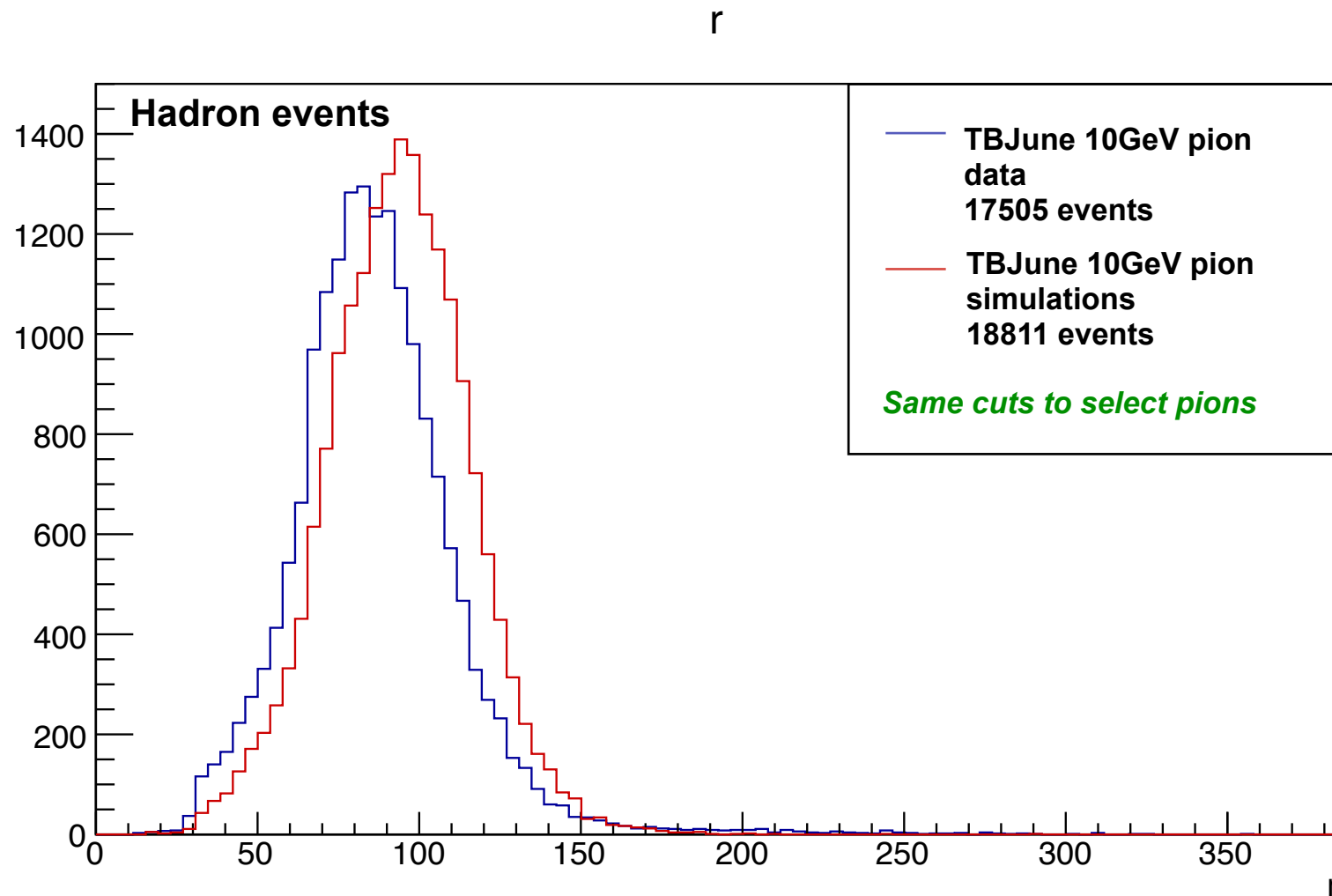
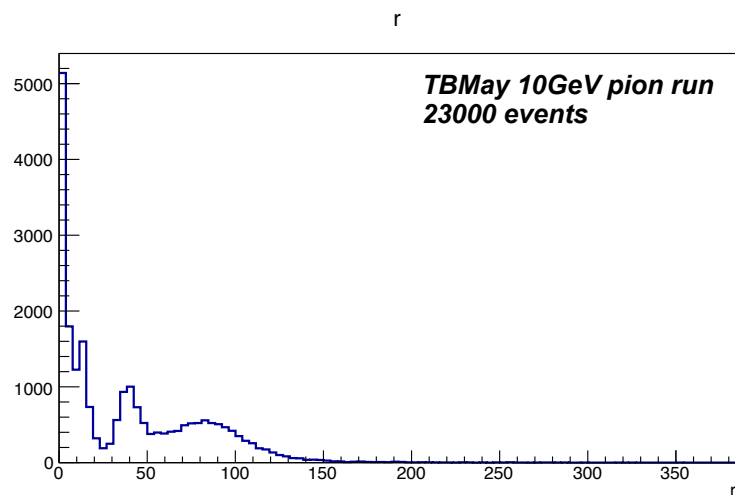


Observables

For particle ID

Shower radius

- “clean” μ^- : no shower ($R = 0$)
- e^- : R has a peak
- π^- : more-less spread



Particle ID

Cut-based method

Method* developed for physics prototype by Marina Chadeeva was taken as basement:

Calorimeter-based id by topology and cluster properties

Clustering and shower start finding precedes particle identification.

Set of cut-based topological discriminants is based on published CANs and papers.

- **Multi-particle events:** OR-based combination of discriminants
 - several clusters in first layers
 - parallel tracks
 - too high deposition
- **Muons or muon-like:** complex combination of discriminants
 - number of hits
 - energy comparison in calorimeters
 - track finding
- **Electrons:** AND-based combination of discriminants
 - cluster radius < 37 mm
 - CoG depth $< 10 \cdot X_0$
 - 90% of measured energy deposited in first $24 \cdot X_0$
 - shower start before $6 \cdot X_0$
- **Hadrons:**
 - remaining species after above rejection
 - Cherenkov-based discrimination of hadron types

*https://agenda.linearcollider.org/event/7454/contributions/38731/attachments/31380/47203/chadeeva_Fe-W_LL2017.pdf

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- **Same approach**
- **Same variables are used**
- First **cut adjustment** was done using MC data sets simulated and fully reconstructed according to **TBMay18** and **TBJune18** setups using QGSP_BERT_HP physics list
- **CALICE software** was modified to **centralise** the **calculation** of all common **variables**
- Clustering and tracking analyses are not implemented yet
- **Only AHCAL hits** are taken into account

Current cuts

For particle ID (10 GeV particles)

Electron events:

- **Hits:** $45 < n\text{Hits} < 95$
- **(&)Shower start layer:** $st < 10$
- **(&)Shower radius:** $0 < r < 65$ [mm]
- **(&)COGz:** $zcog < 400$ [mm]
- **(&)Fraction in first 25 layers:** $\text{frac25} > 0.9$

Empty events(optional):

- **Hits:** $n\text{Hits} < n\text{Hits}_{\text{min}}$

Muon (muon-like) events:

- **Hits:** $0 < n\text{Hits} < 70$
- **(&)Energy:** $0 < E < 5$ GeV (will be used after proper calibration)
- **(&)Shower radius:** $0 < R < 30$ [mm]
- **(&)COGz:** $260 < zcog < 800$ [mm]
- **(&)Fraction in first 25 layers:** $\text{frac25} < 0.95$

Remaining events are classified as **hadron events**.

Note: multi-particle event filtering not implemented yet (in todo list).

Performance

Of cut-based ParticleID method for 10GeV particles.

Input. ↓ Output →	Hadron events	Muon-like events	Electron events	Empty (nHits < 30)
MC pions 20000 events	18811 events 94%	536 events 2,7%	653 events 3,3%	Cut is not applied (0 events)
MC muons 20000 events	56 events 0,3%	19941 events 99,7%	3 events ~0%	Cut is not applied (0 events)
MC electrons 20000 events	57 events 0,3%	0 events 0%	19943 events 99,7%	Cut is not applied (1 event)
10GeV pion run TBJune18 23000 events	17505 events 76,1%	3685 events 16%	807 events 3,5%	1003 events 4,3%
10GeV pion run TBMay18 23000 events	7630 events 33,2%	9824 events 42,7%	3664 events 15,9%	1887 events 8,2%

>12 main cut values making tuning of selection efficiency complicated

BDT method.

BDT input

10GeV pion selection.

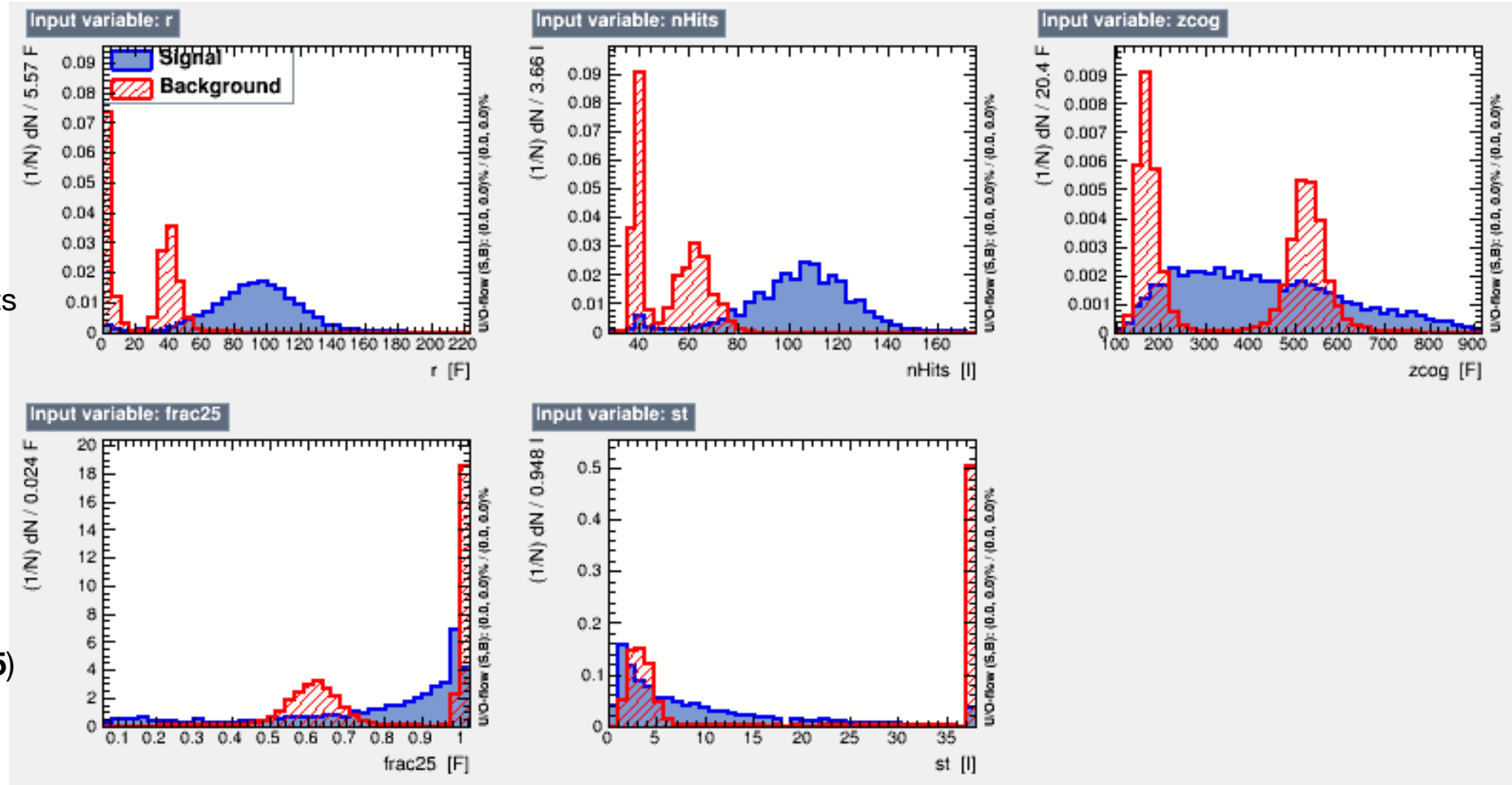
Training data:

- 10GeV MC pions - 20k events (**signal**)
- 10GeV MC muons - 20k events (**bckgr**)
- 10GeV MC electrons - 20k events (**bckgr**)

Variables:

- Shower radius (**st**)
- Number of hits (**nHits**)
- COGz (**zcog**)
- Fraction in first 25 layers (**frac25**)
- Shower start layer (**st**)

No cuts



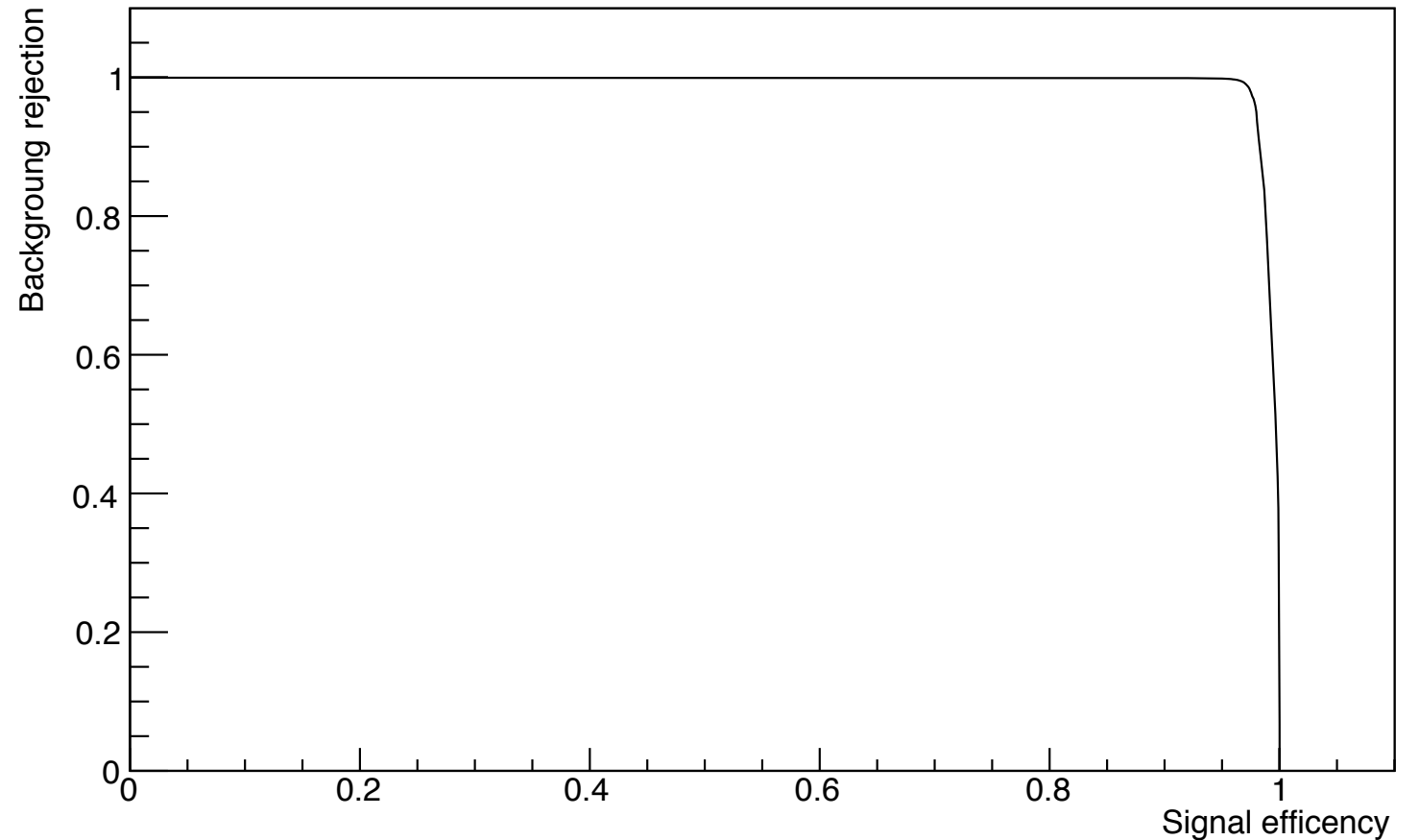
BDT output

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Background rejection vs Signal efficiency

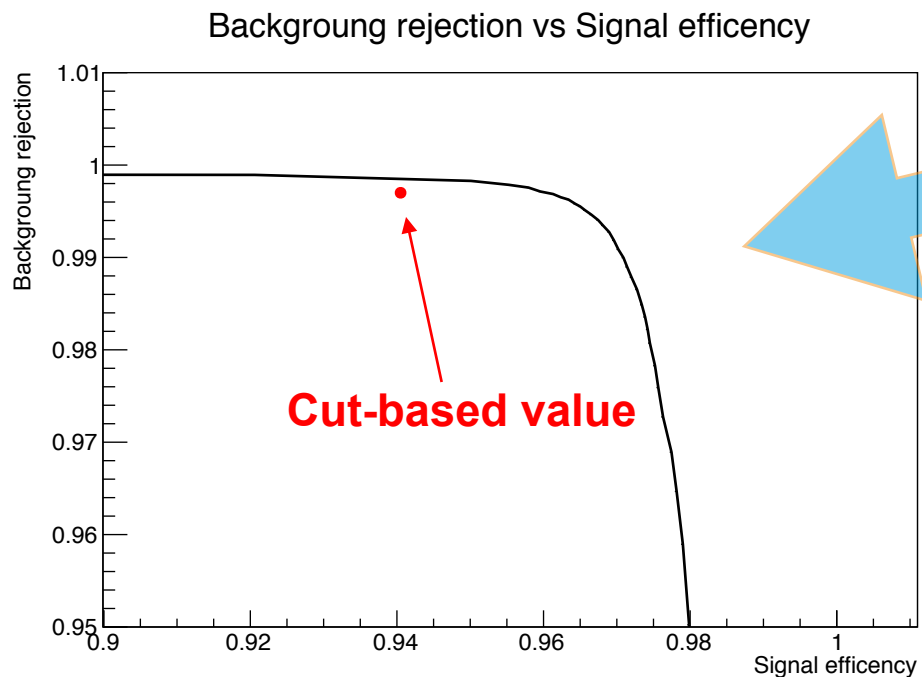


BDT output

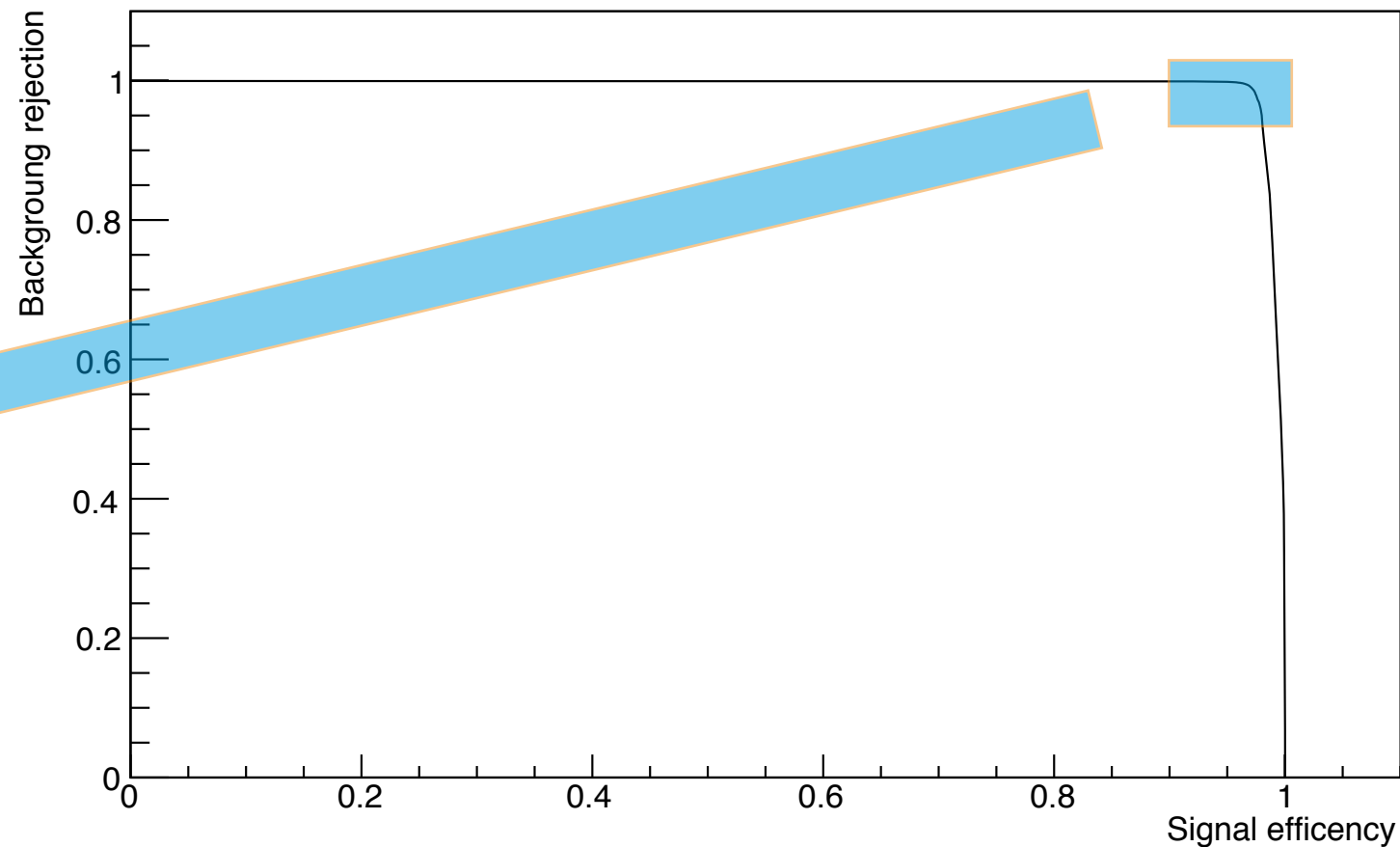
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Background rejection vs Signal efficiency



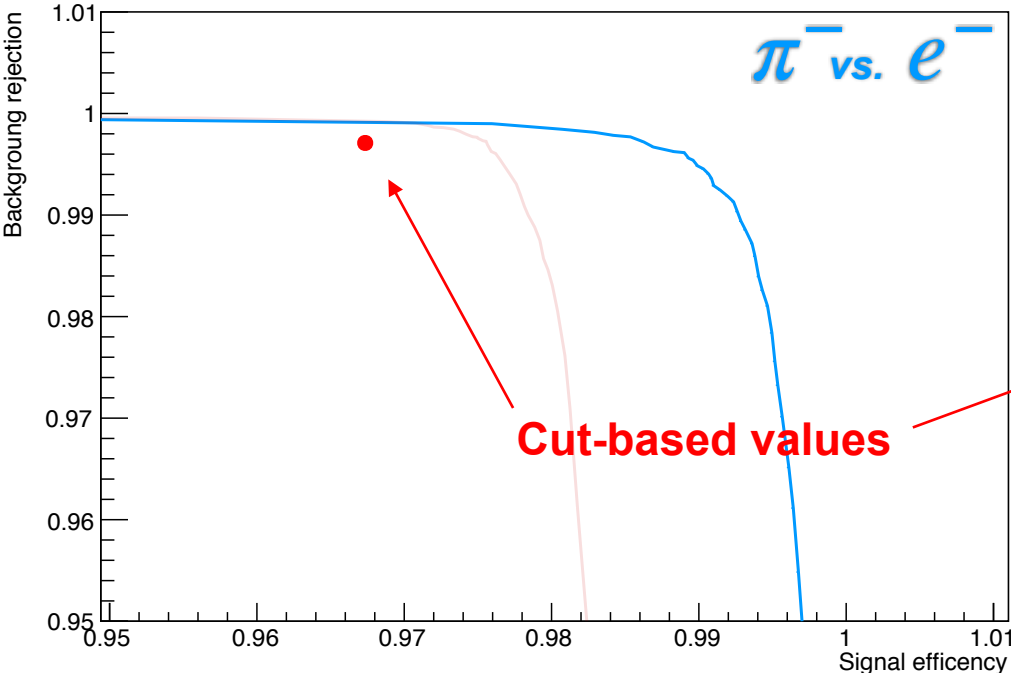
Pions vs electrons & pions vs muons

BDT output.

Training/test data:

- 10GeV MC **pions** - 20k events (**signal**)
- 10GeV MC **electrons** - 20k events (**bckgr**)
- **No cuts**

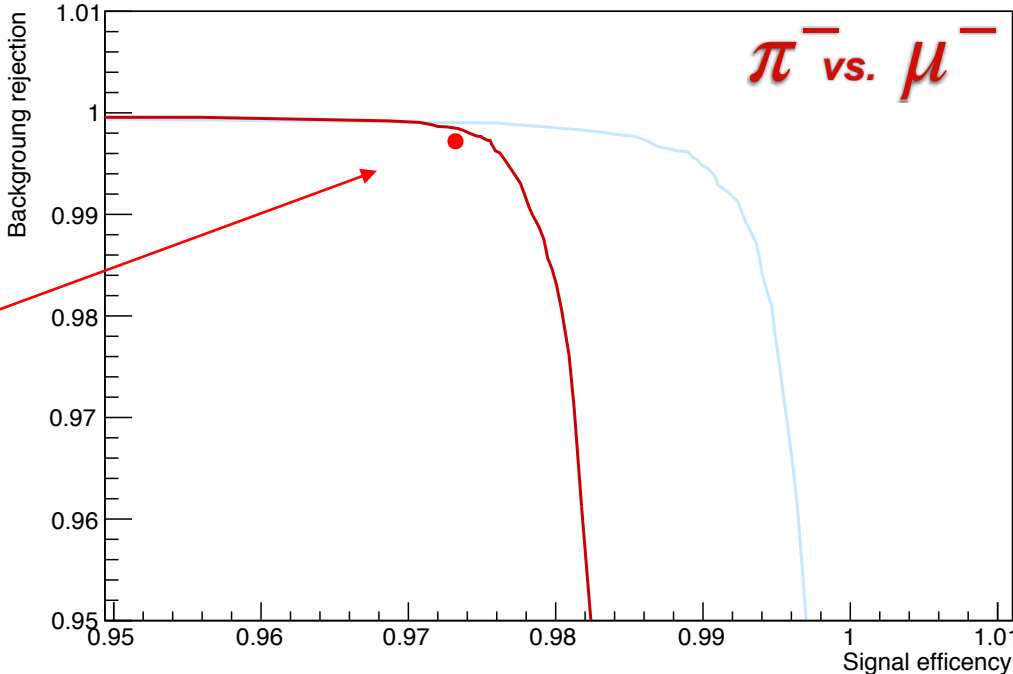
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Background rejection vs Signal efficiency



Pions vs electrons & pions vs muons

BDT output.

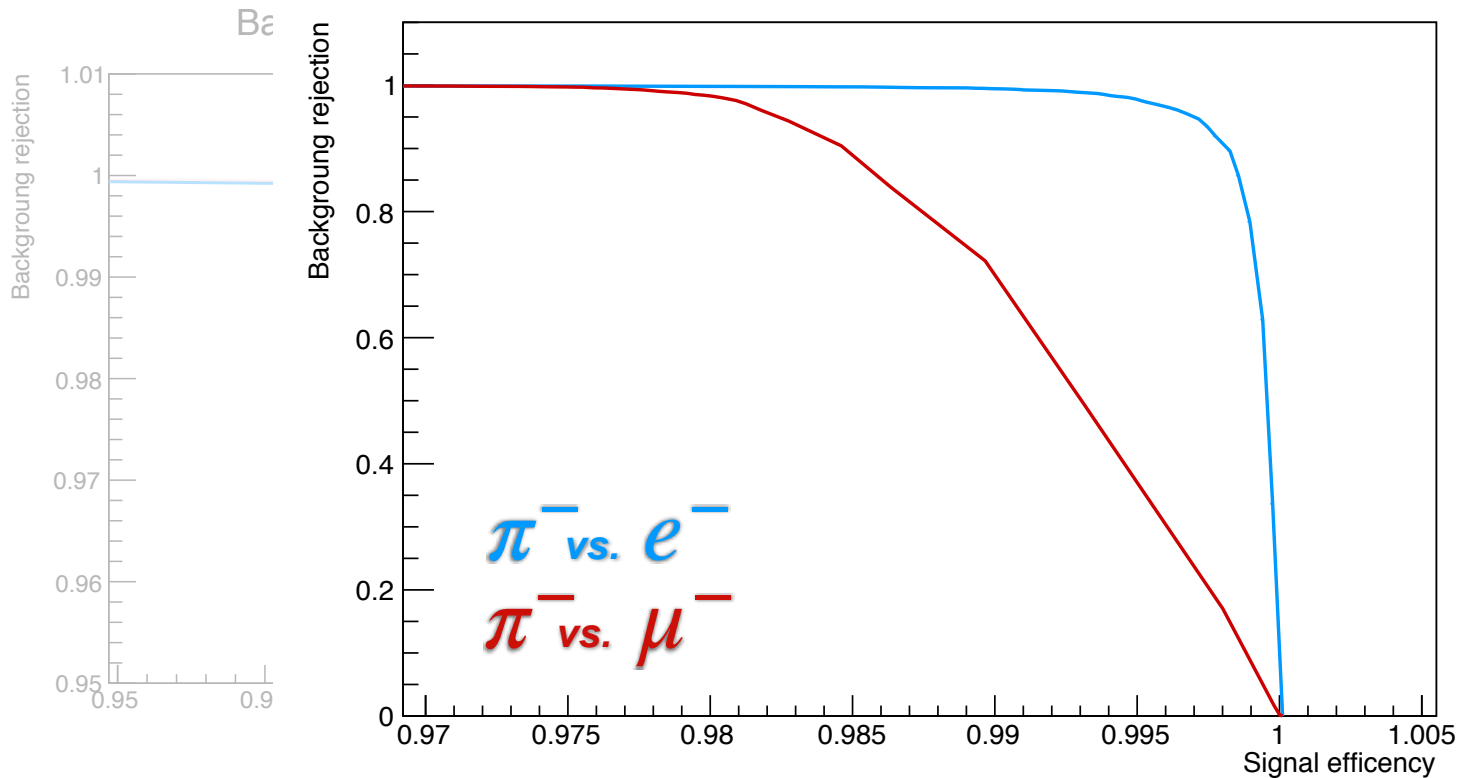
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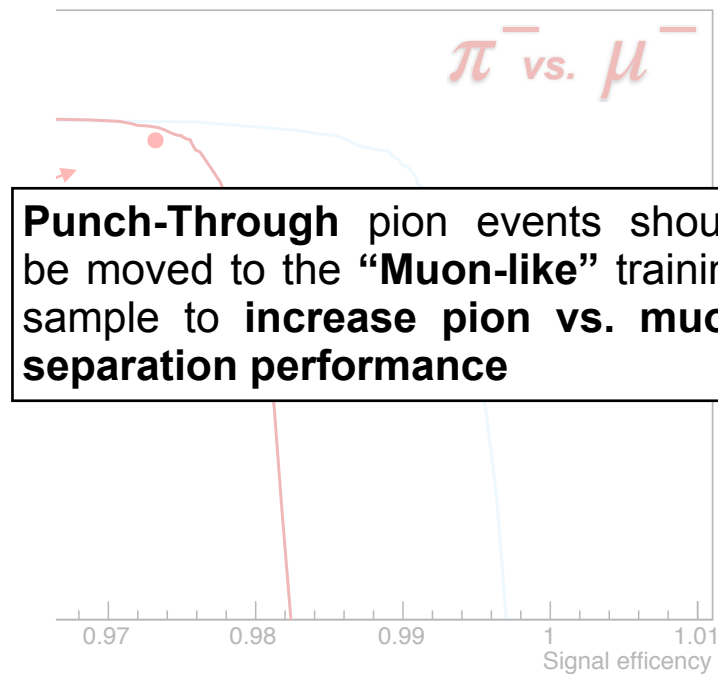
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Background rejection vs Signal efficiency

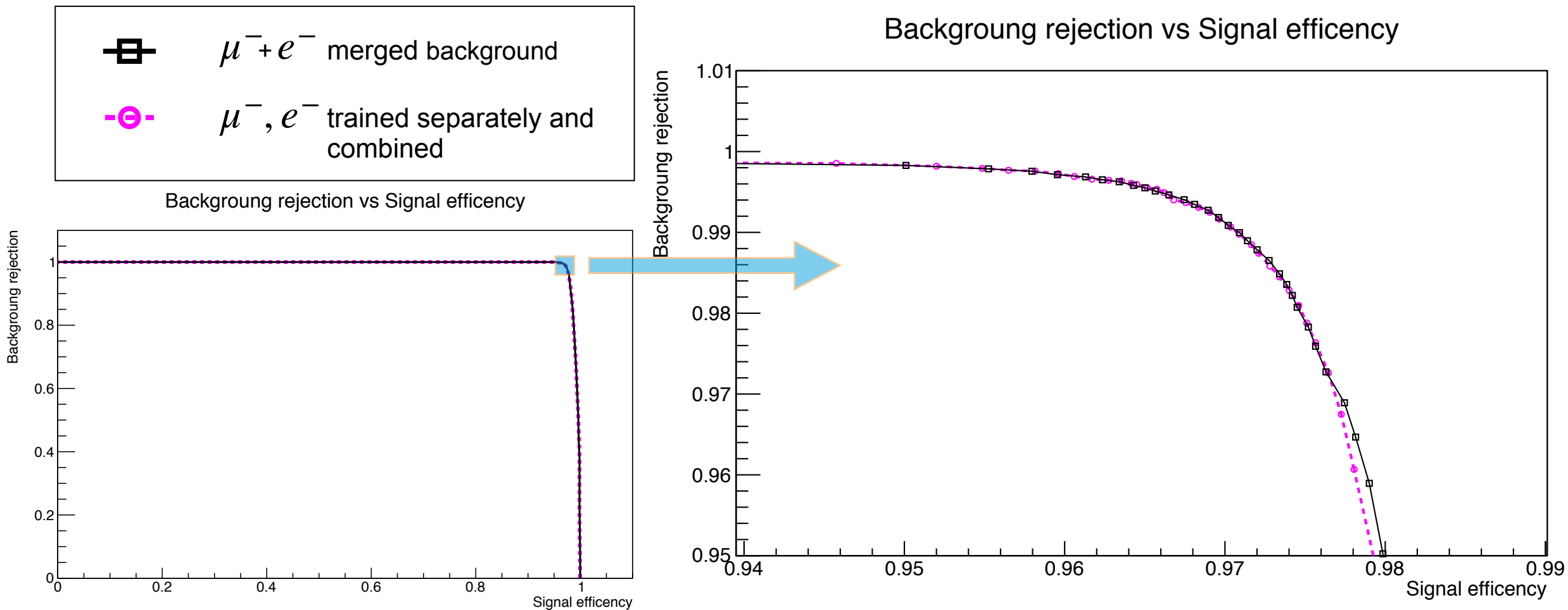


Background rejection vs Signal efficiency



Separation of pion “background”

Comparison of different BDT output



Conclusion & ToDo list

Particle ID

- At 10GeV we have satisfying cut-based identification
 - Software infrastructure is ready for more precise studies
 - MC check of energy dependent cuts is needed
 - Investigate problem with energy and number of hits in simulations
- We need to implement event quality selection for data:
 - Multi-particle events
 - Early showering particles
 - ...
- BDT method gives promising results
 - Cuts for training samples
 - Train BDT with all TB energies
 - ...

Confluence page

TBParticleID processor

Content:

- Description including using variables
- Input
- Output
- Important parameters

link: <https://confluence.desy.de/display/Calice/TBParticleID+processor>



Important parameters:

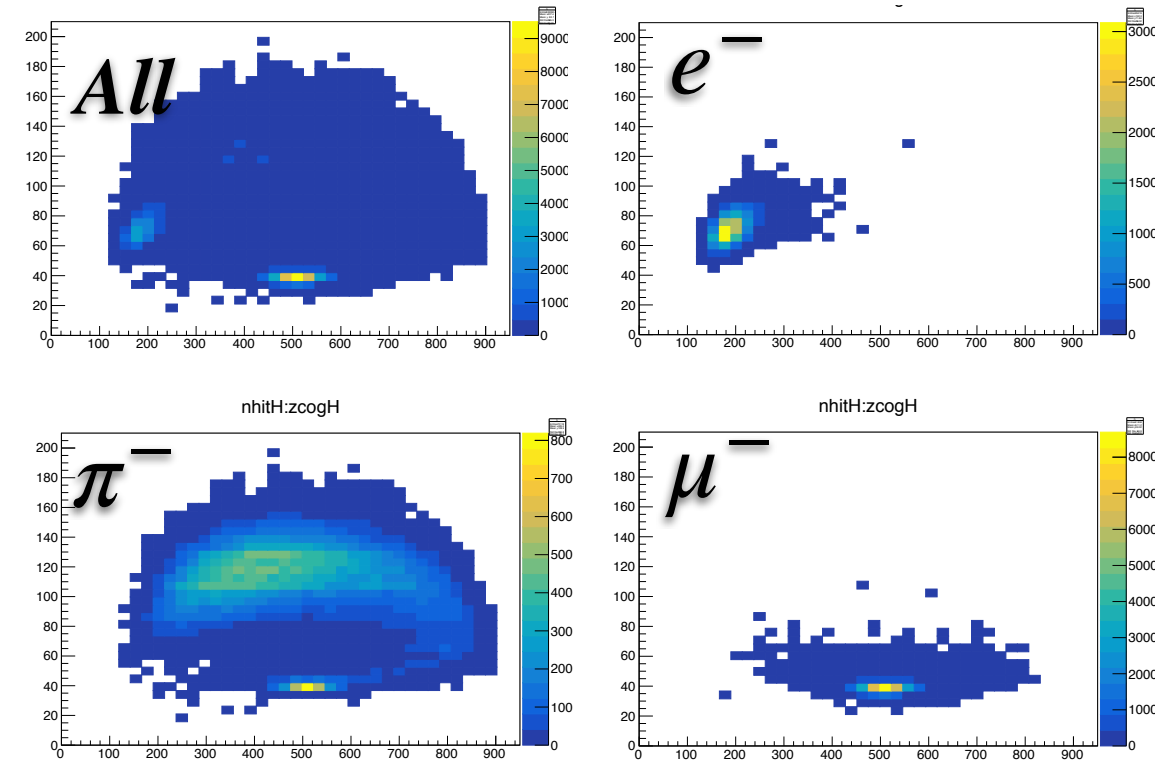
- Beam energy in GeV - using only to find shower start layer
- IDMode: 0 - keep all, 1 - only hadron events, 2 - only muon-like events, 3 - only electron events
- Minimum number of hits - to reject empty events
- Path to IDCuts.txt file

Adjustment of cuts

2D plots are useful to check the cuts

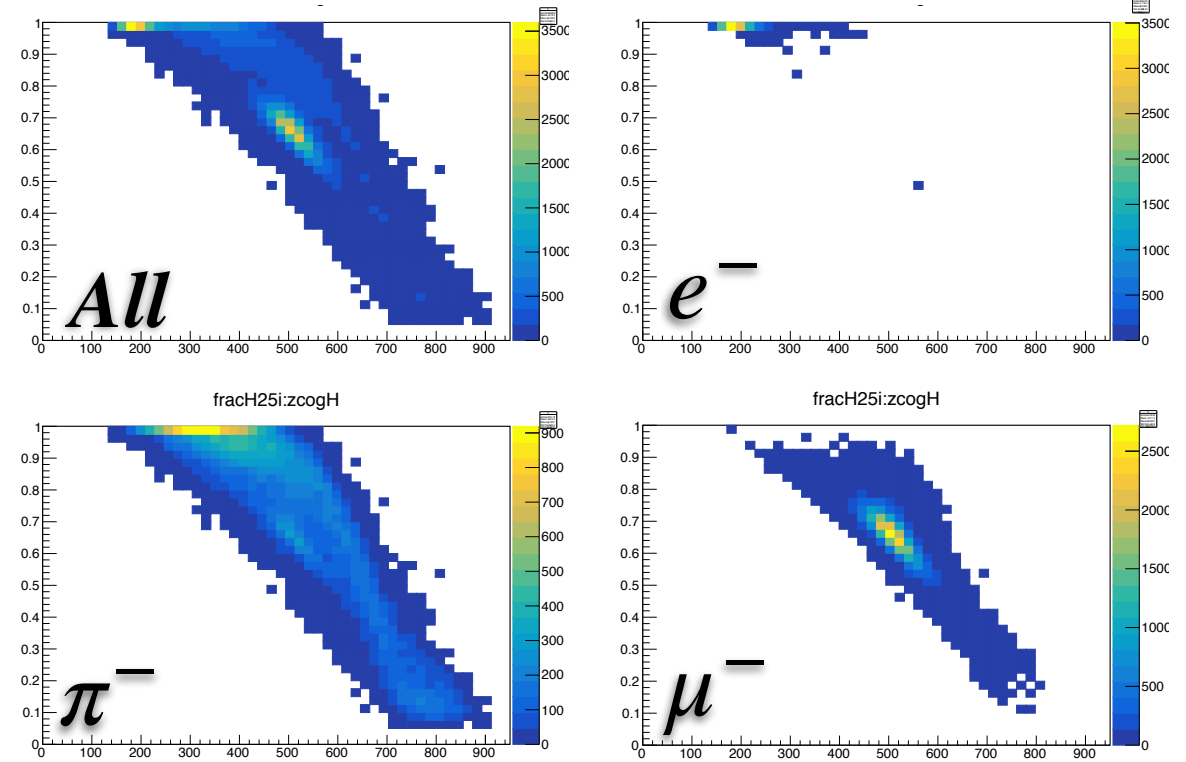
Number of hits vs CoG in z

10GeV MC particles. No cuts.



Fraction in first 25 layers vs CoG in z

10GeV MC particles. No cuts.



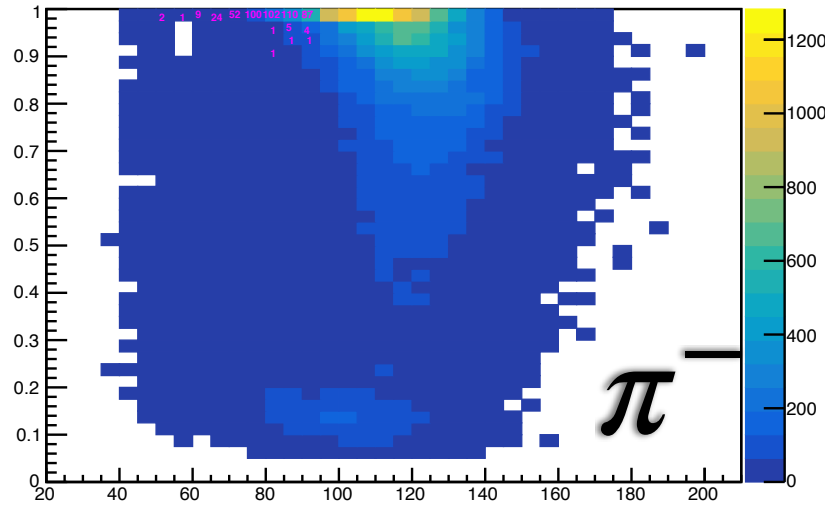
Root script for cut adjustment

MC 10GeV particles

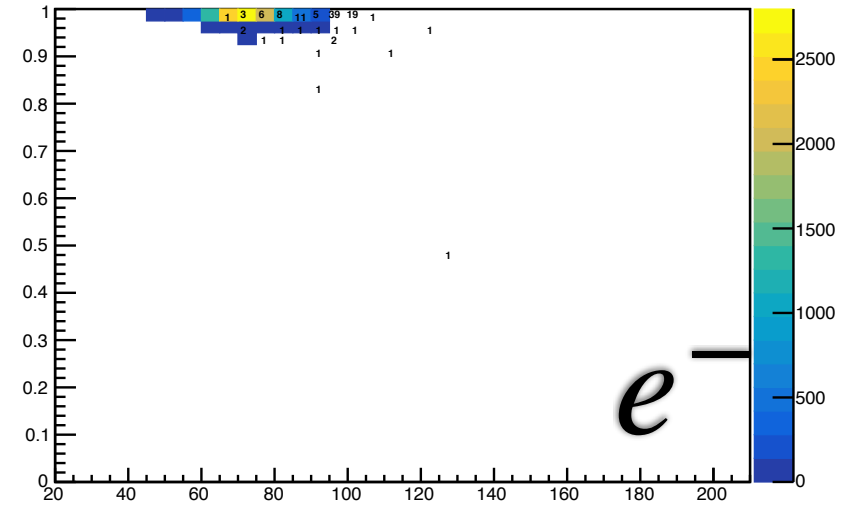
Before cuts:

π^- : 70118 events
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 e^- : 26419 events
total : 138395 events

Fraction in first 25 layers vs number of hits.



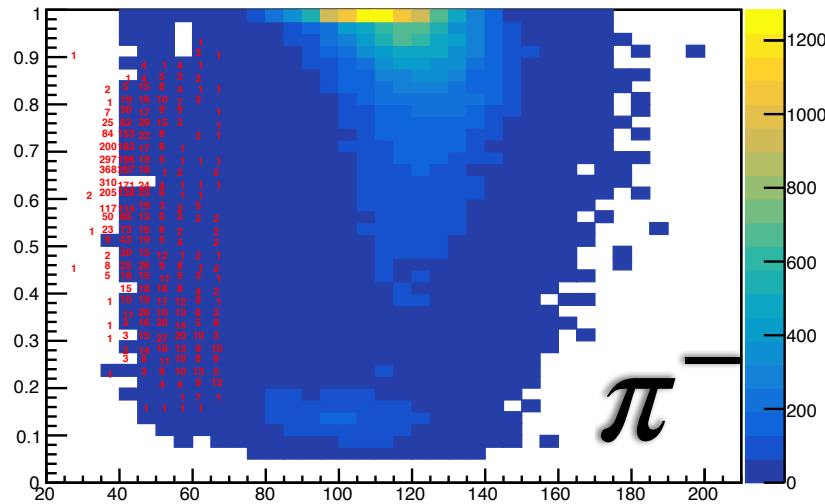
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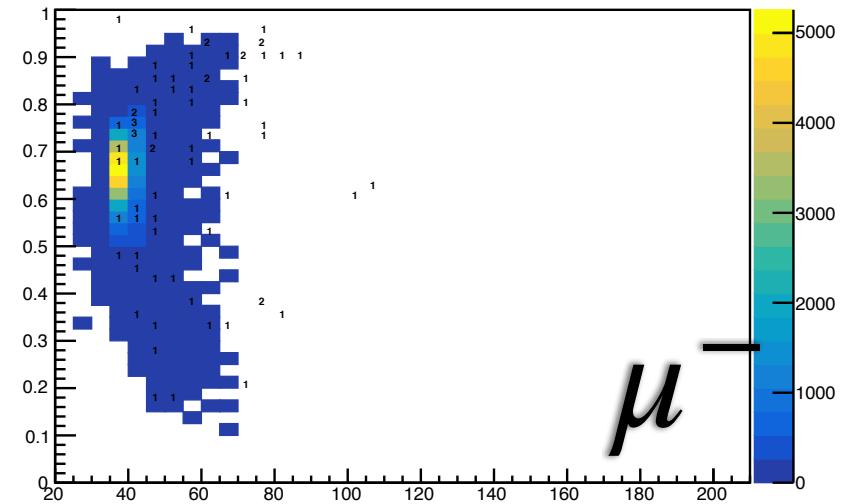
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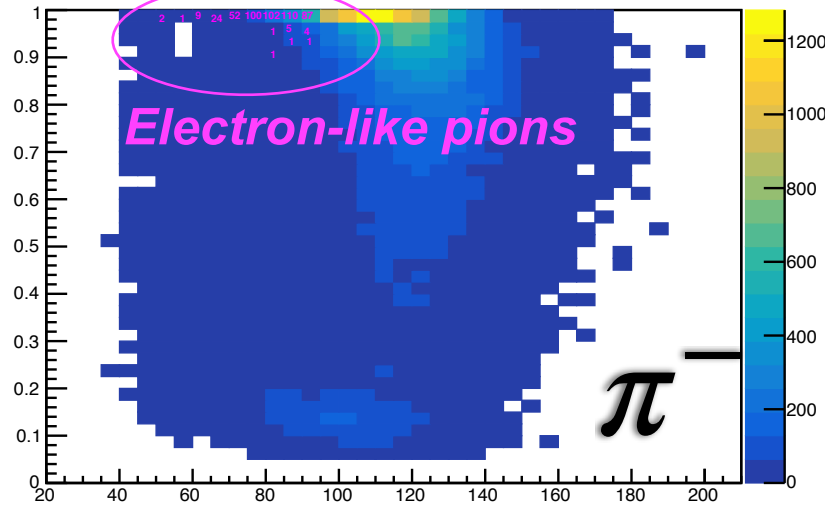
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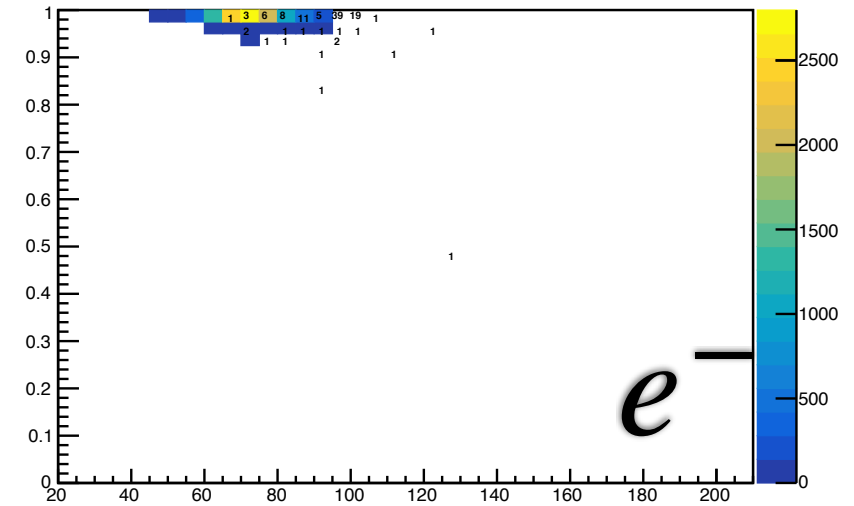
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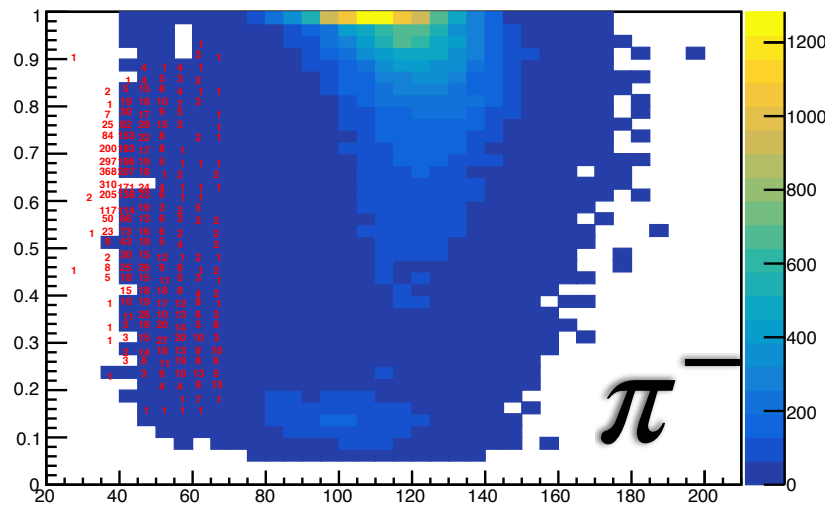
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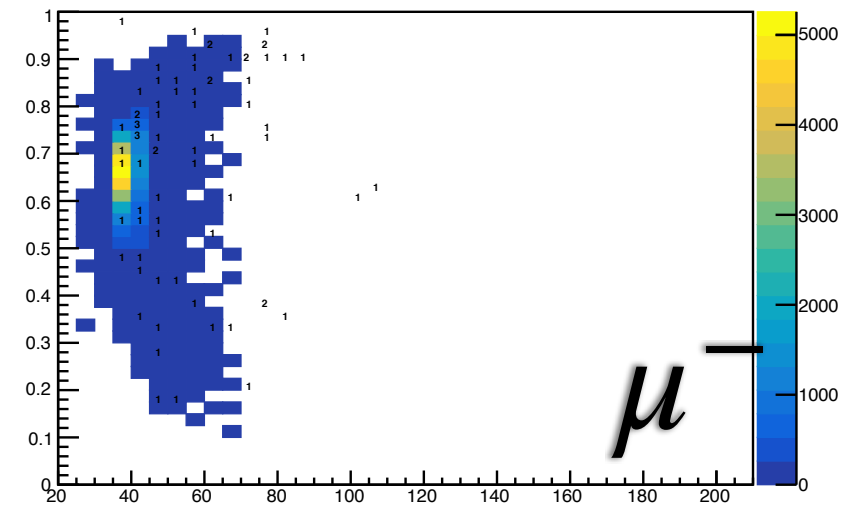
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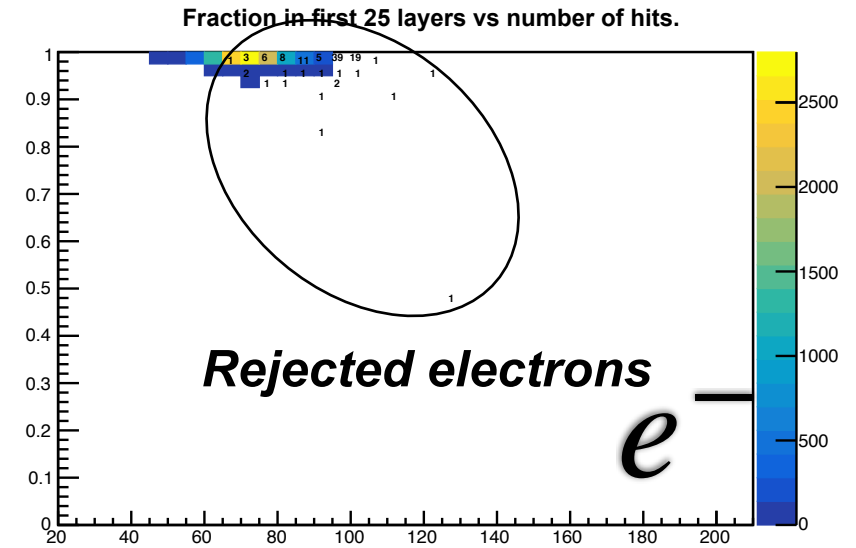
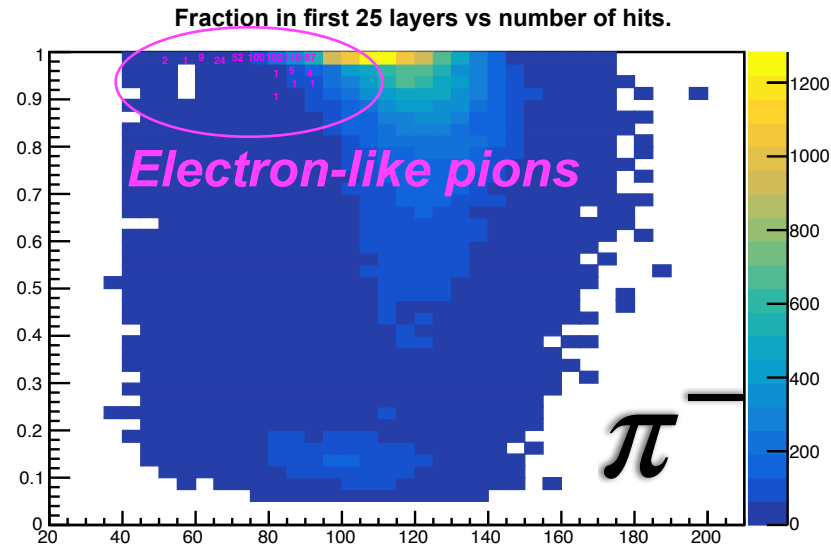


Root script for cut adjustment

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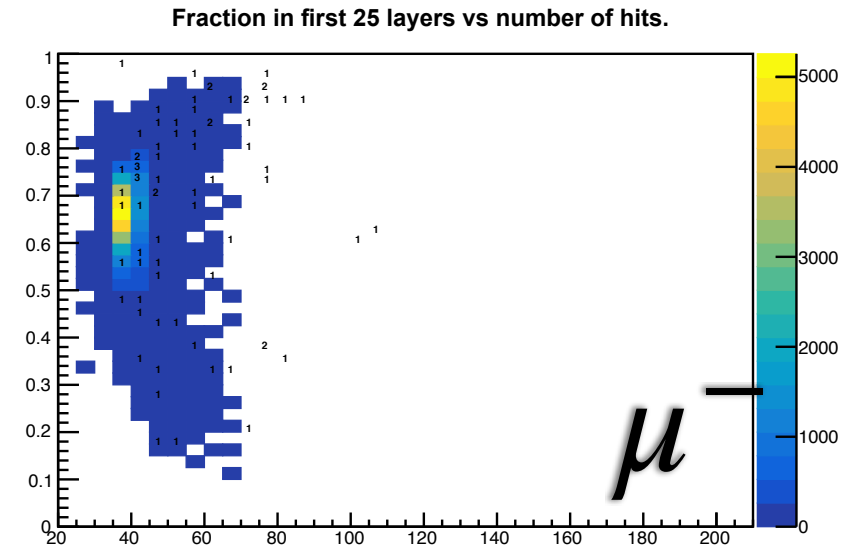
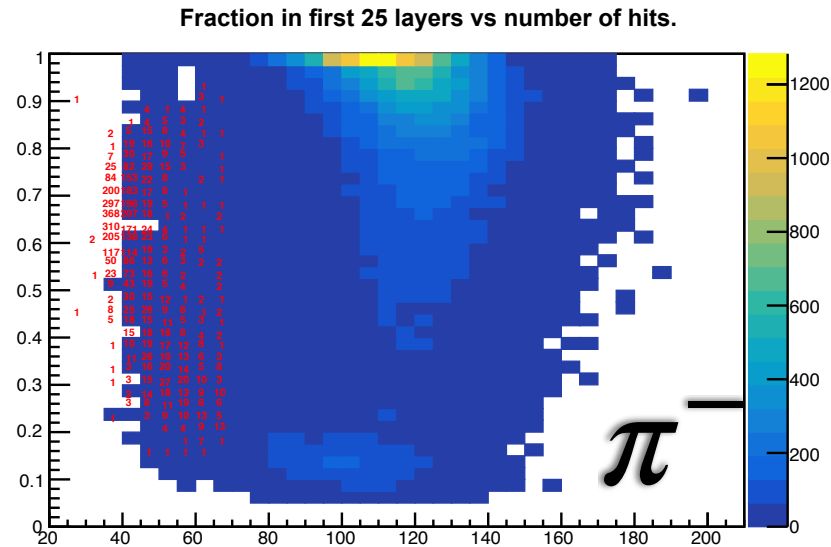
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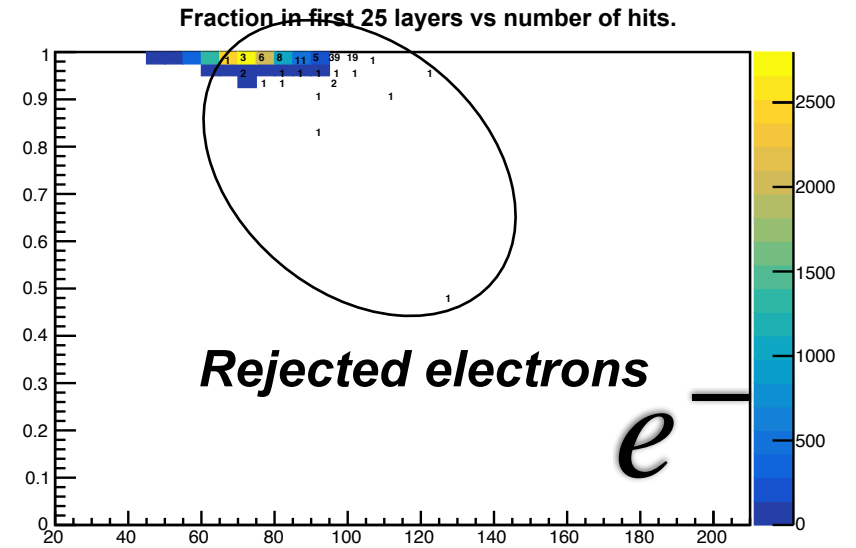
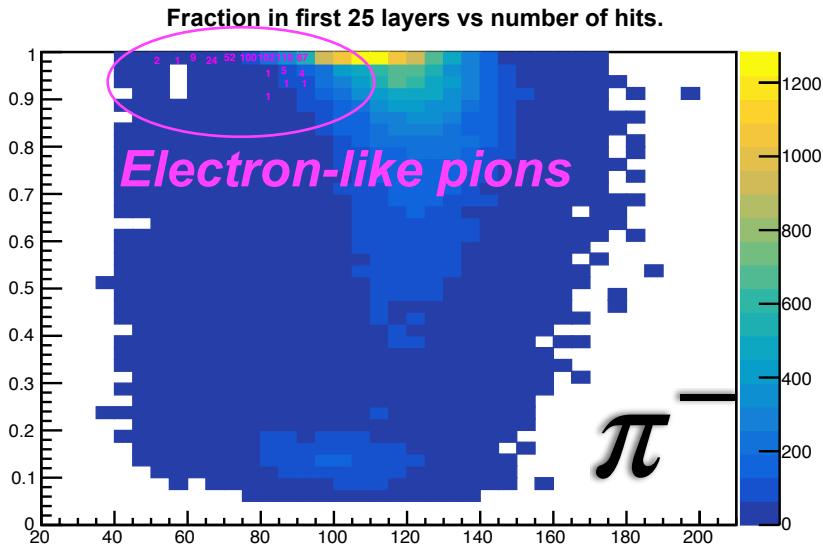


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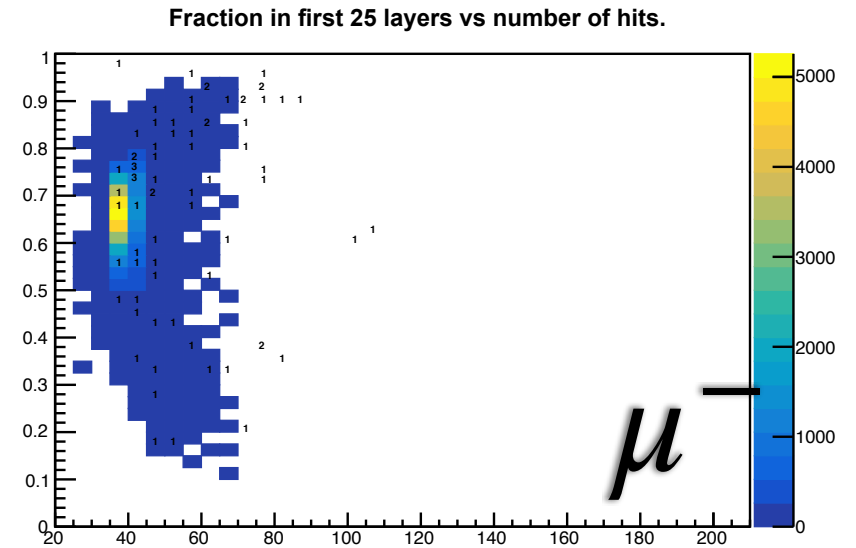
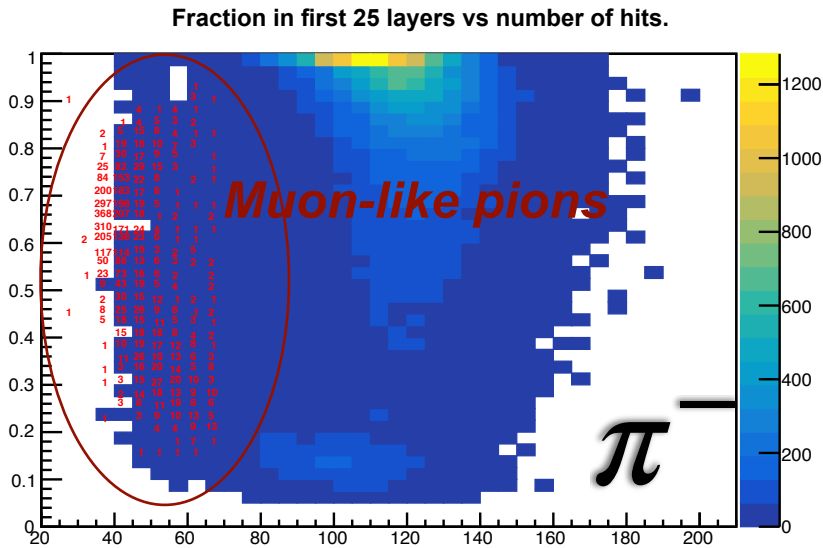
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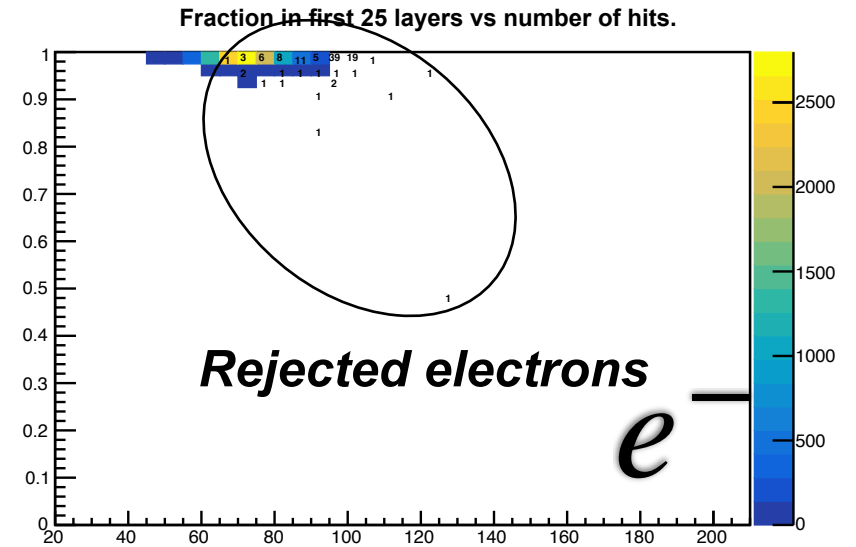
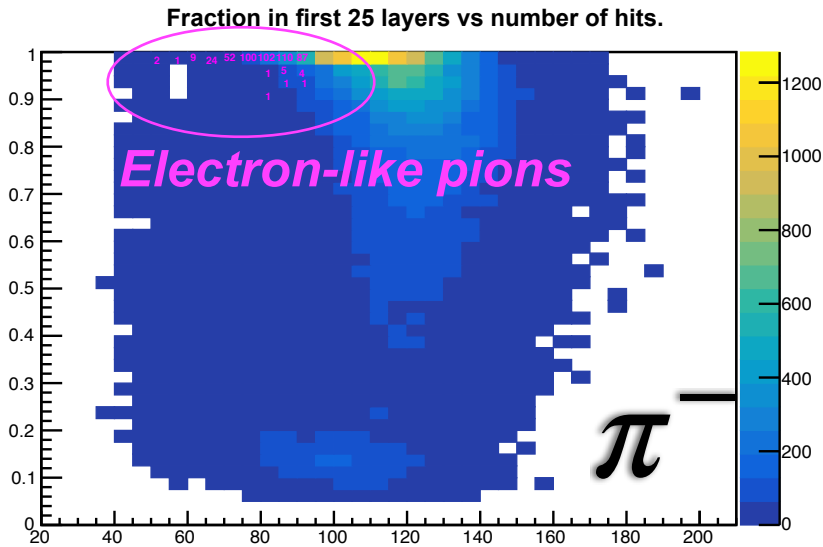


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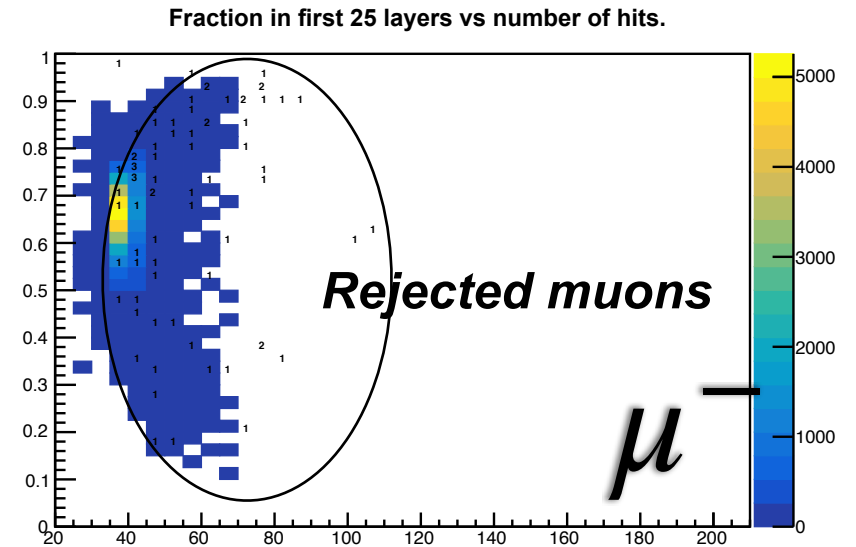
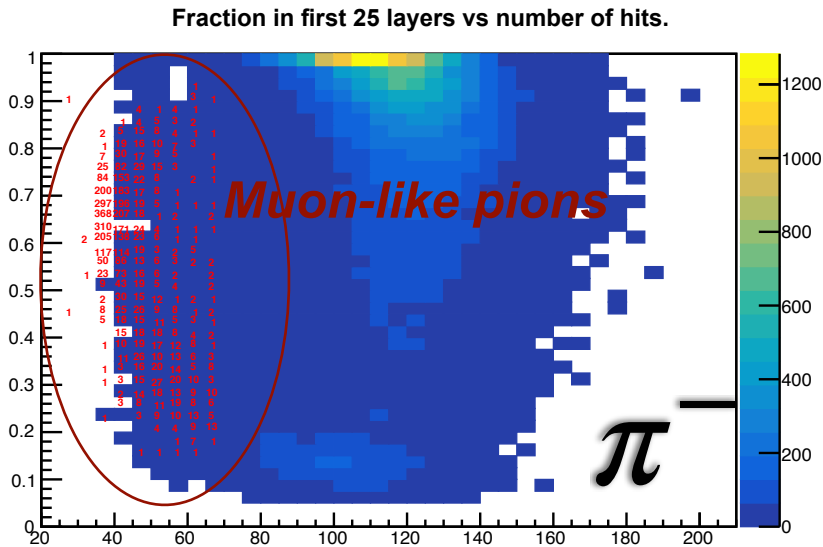
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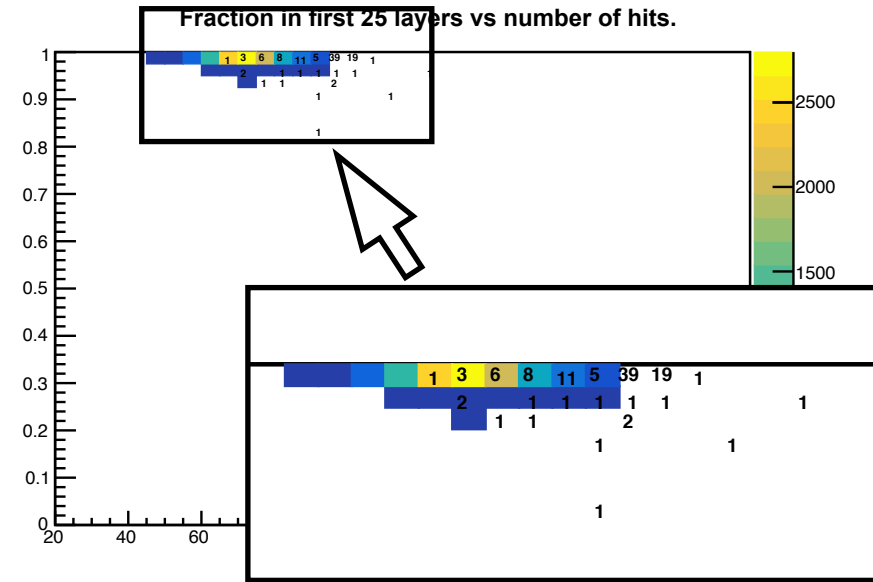
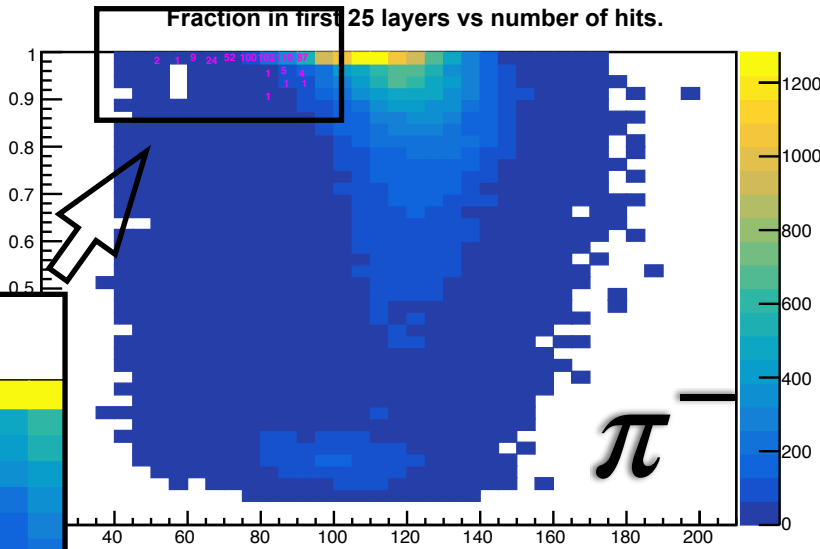
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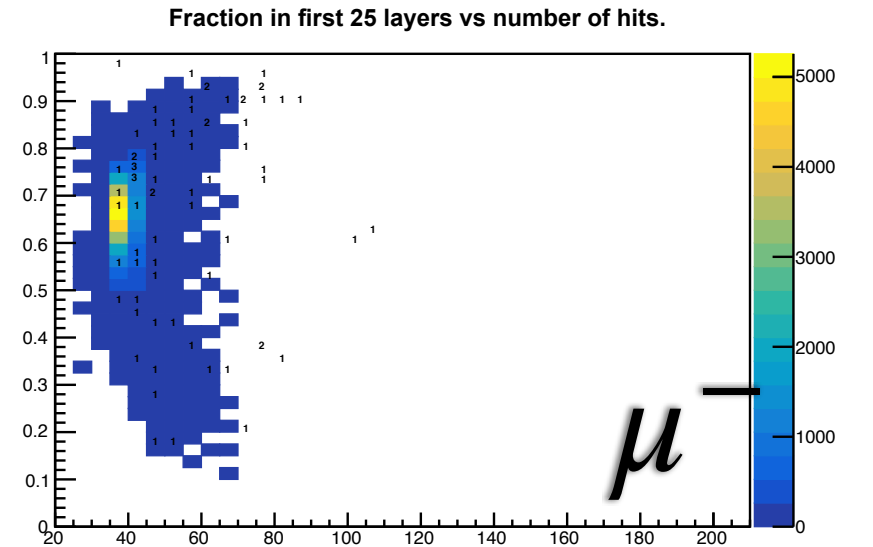
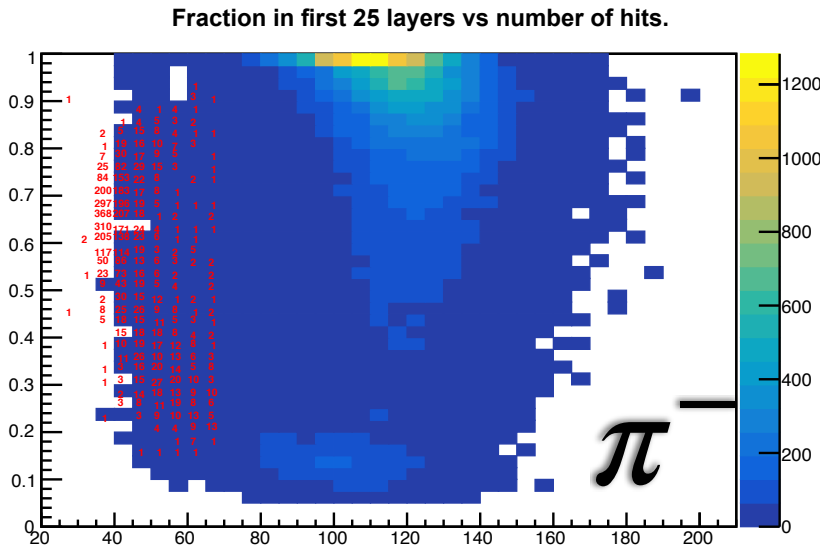


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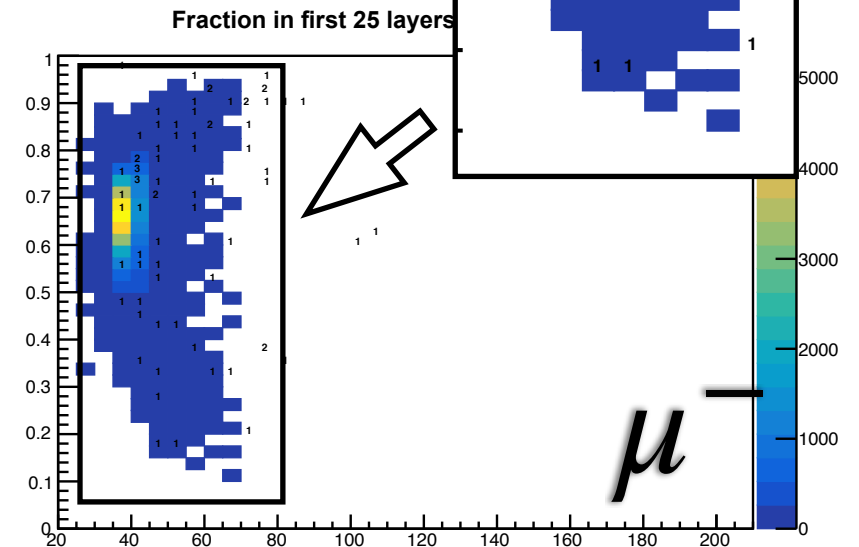
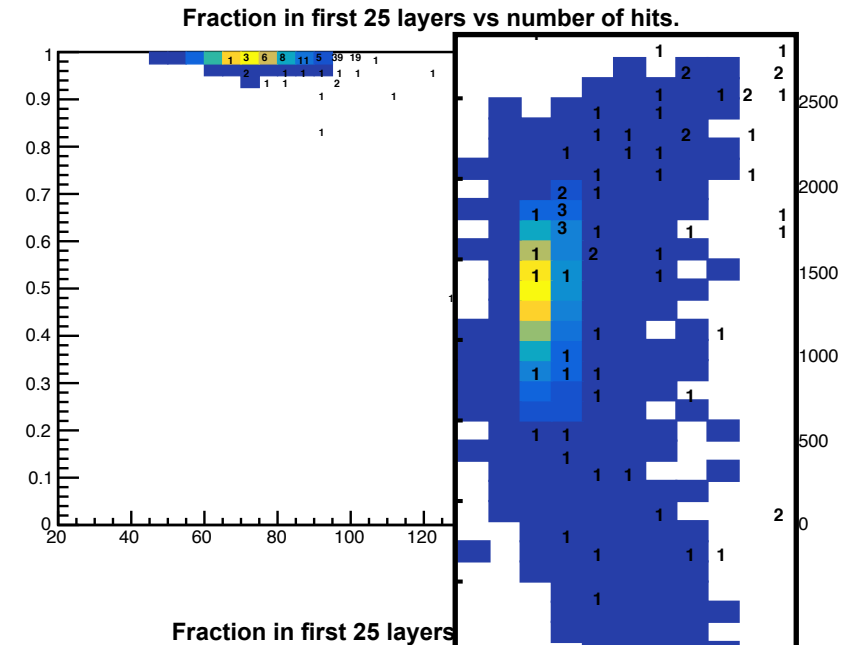
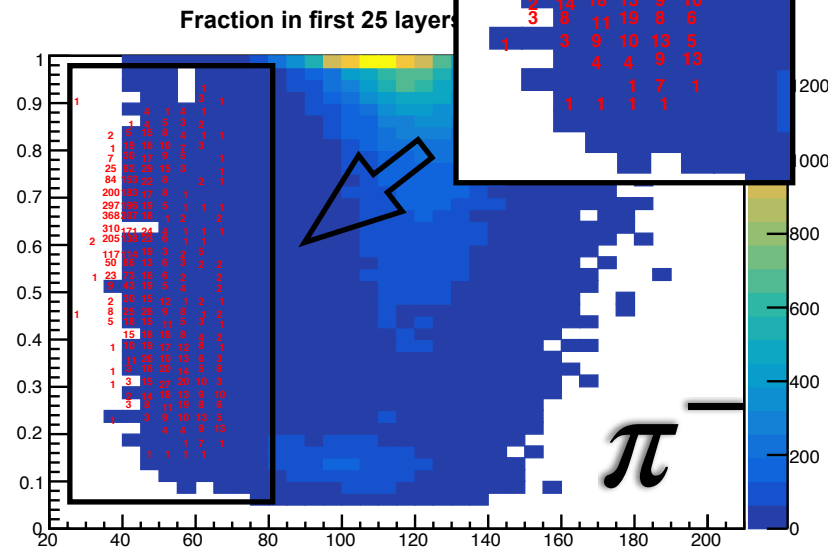
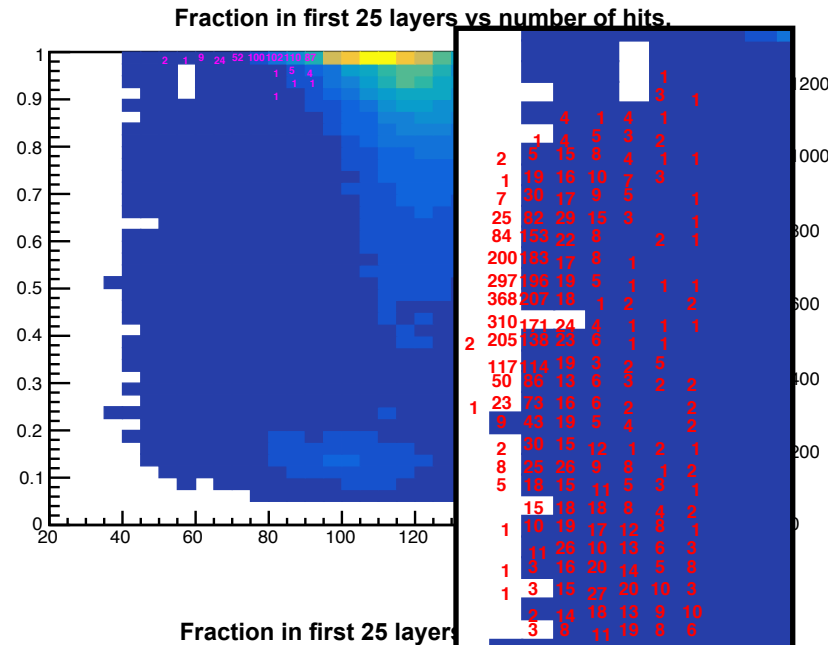
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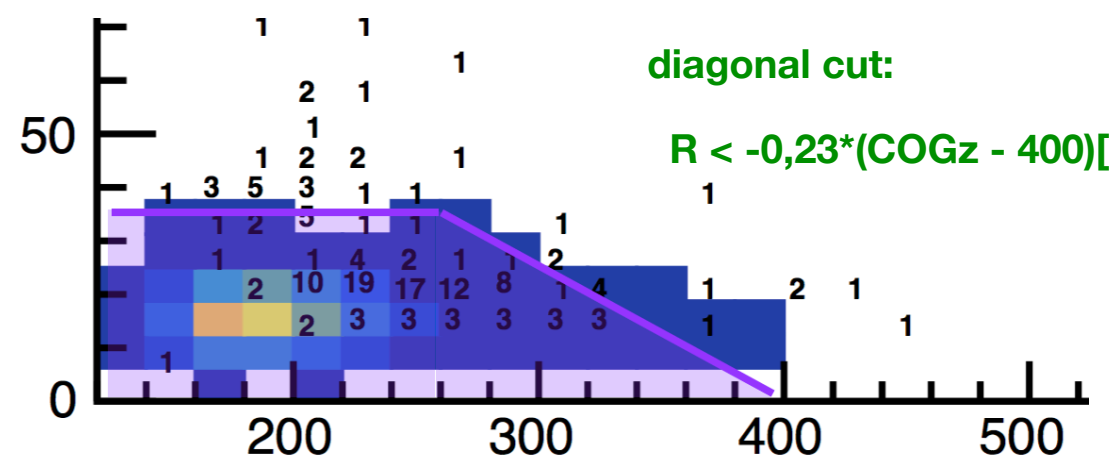
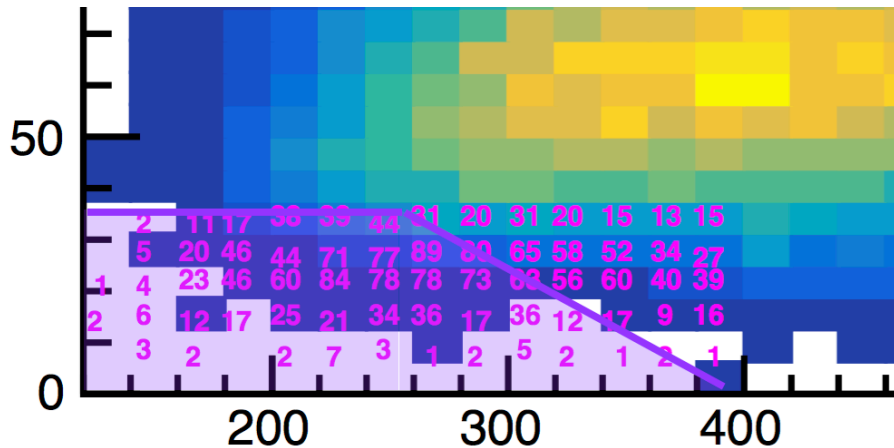
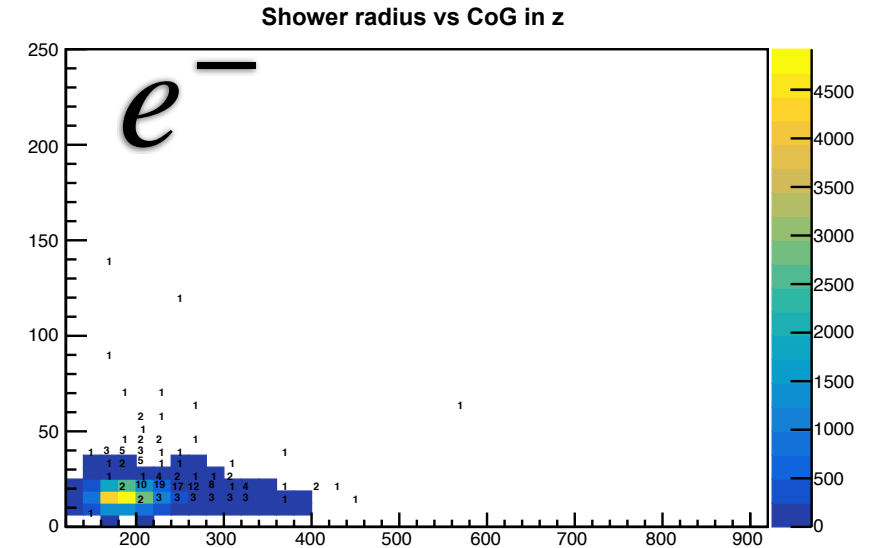
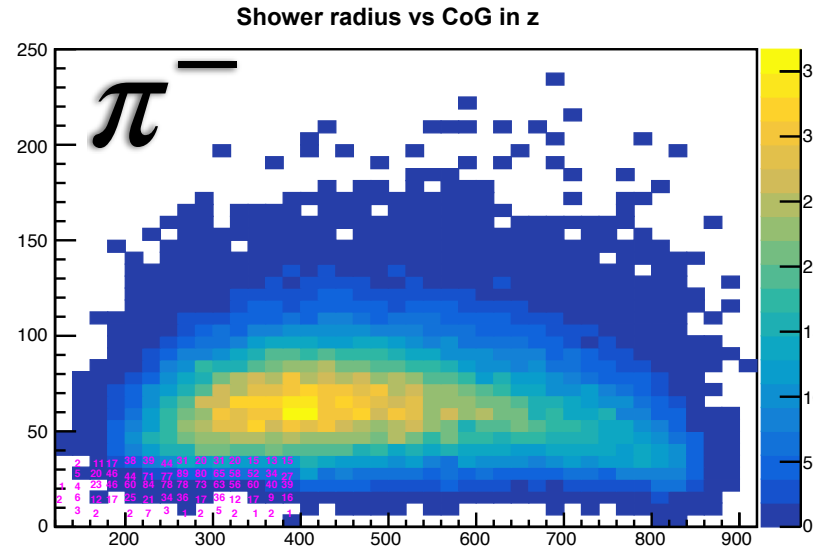
Additional cut for shower radius vs CoG in z.

MC 10GeV particles

Before additional cut:

π^- : 63748 events (90,9%)

e^- : 26264 events (99.4%)



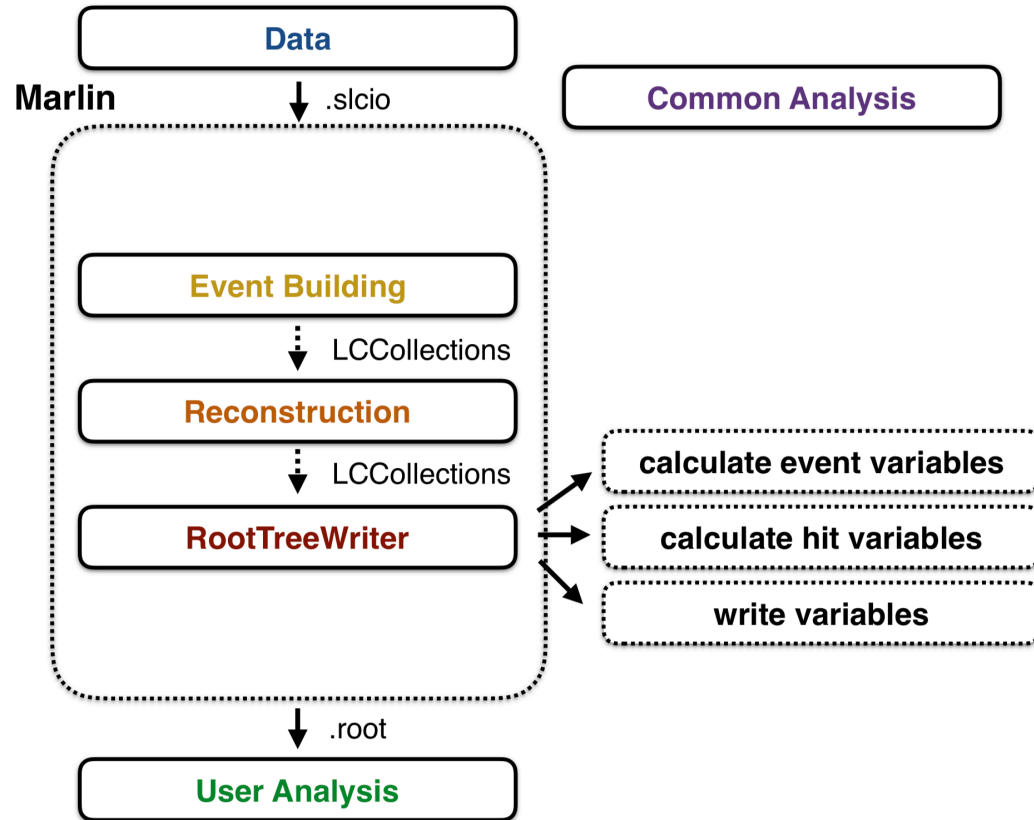
- Additional shower radius diagonal cut:
 $R < -0,23 \cdot (\text{COGz} - 400) [\text{mm}]$

Software architecture studies

To implement particle ID as a standard tool

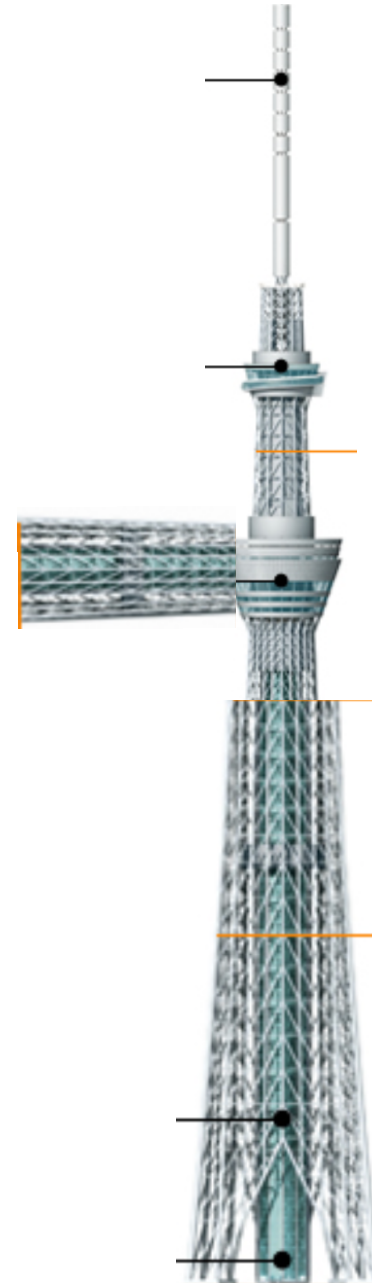
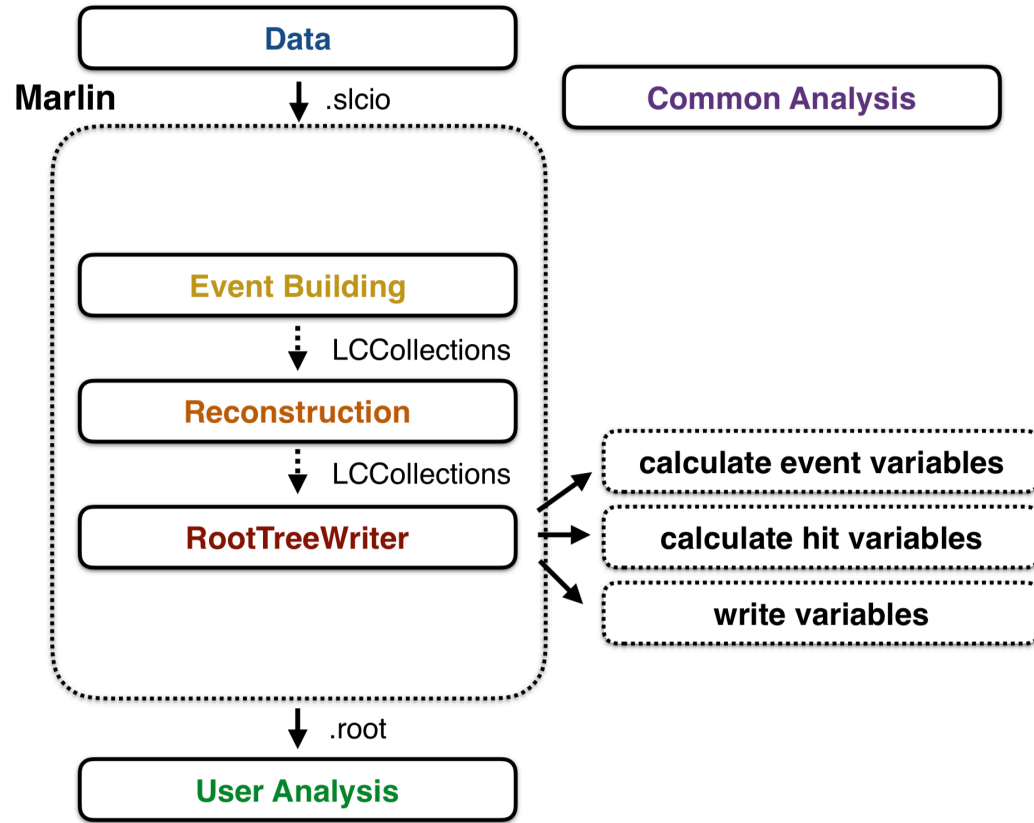
Software architecture

Current state



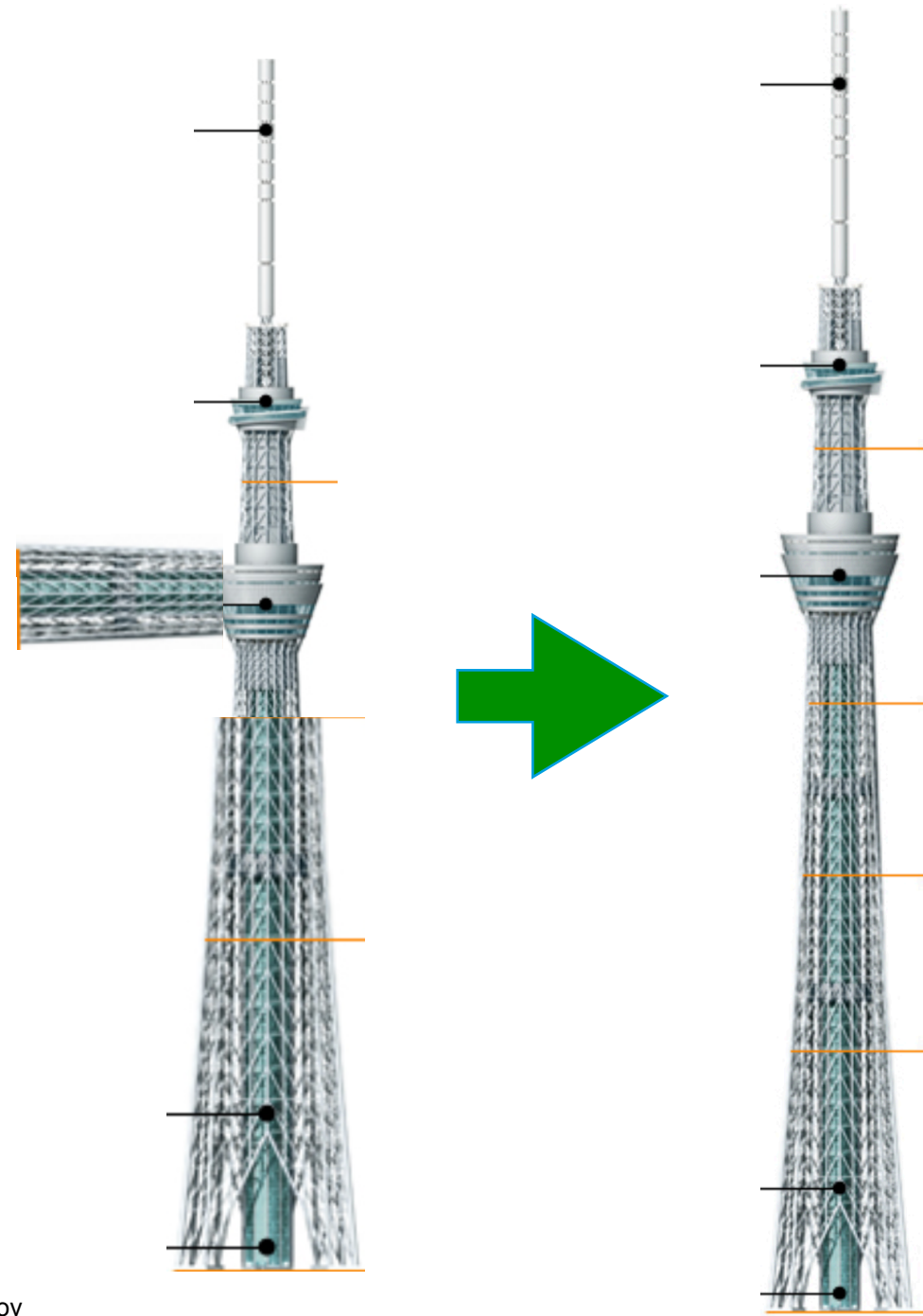
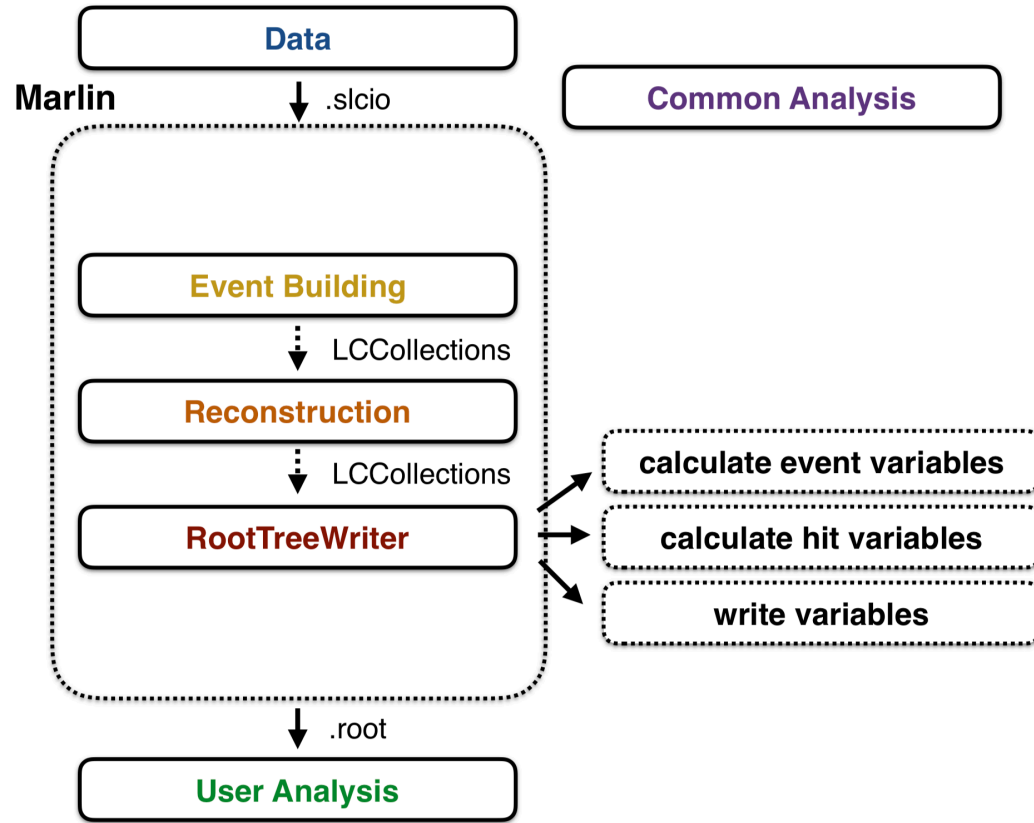
Software architecture

Current state



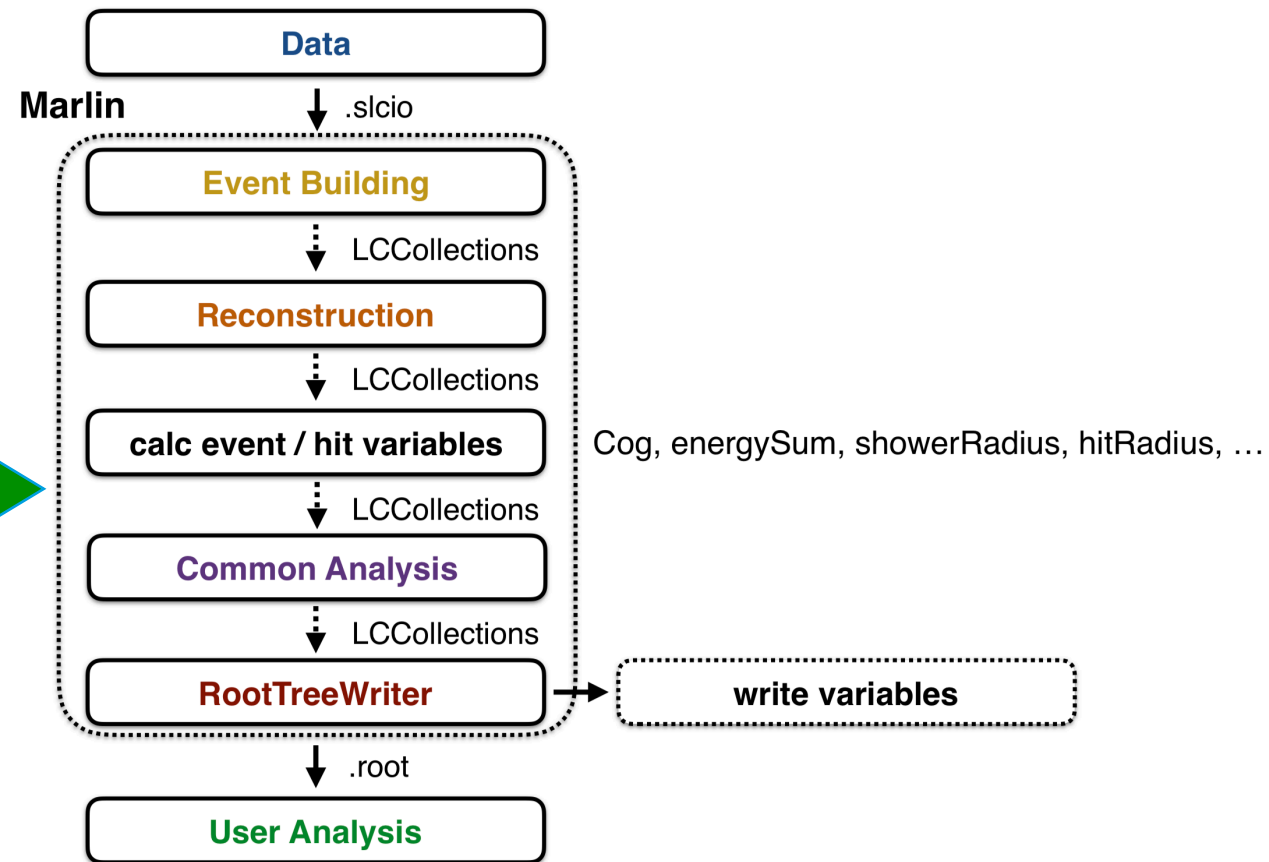
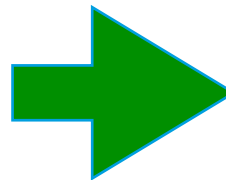
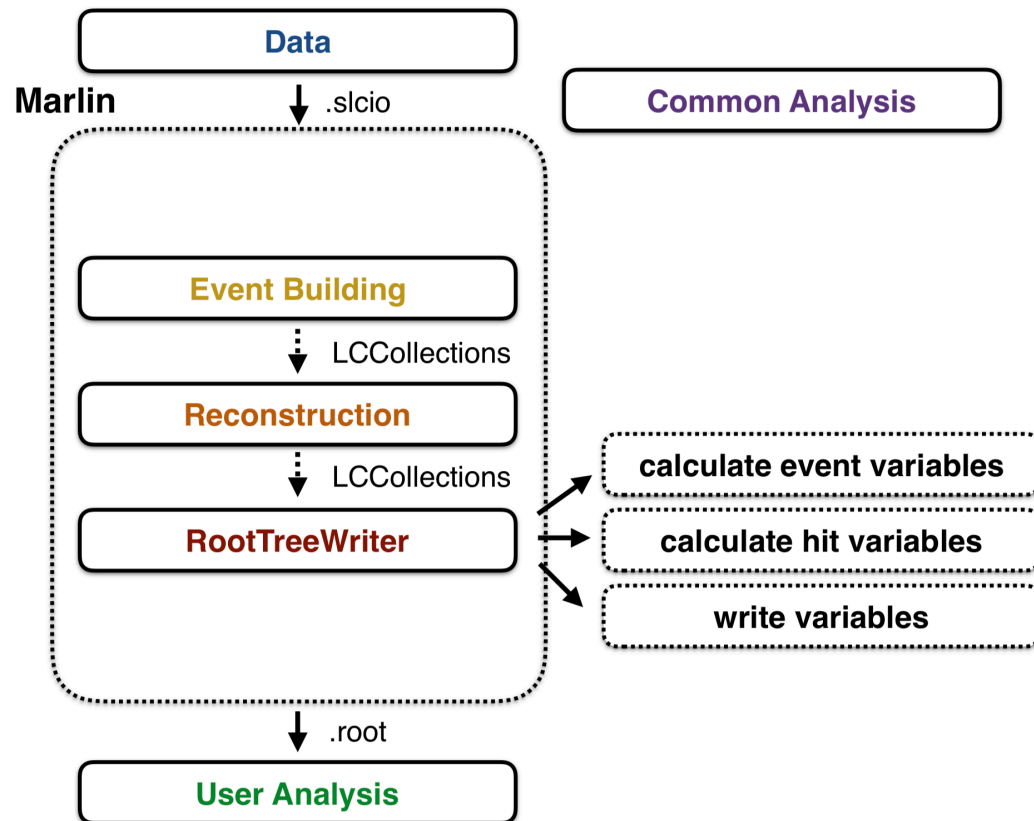
Software architecture

Current state



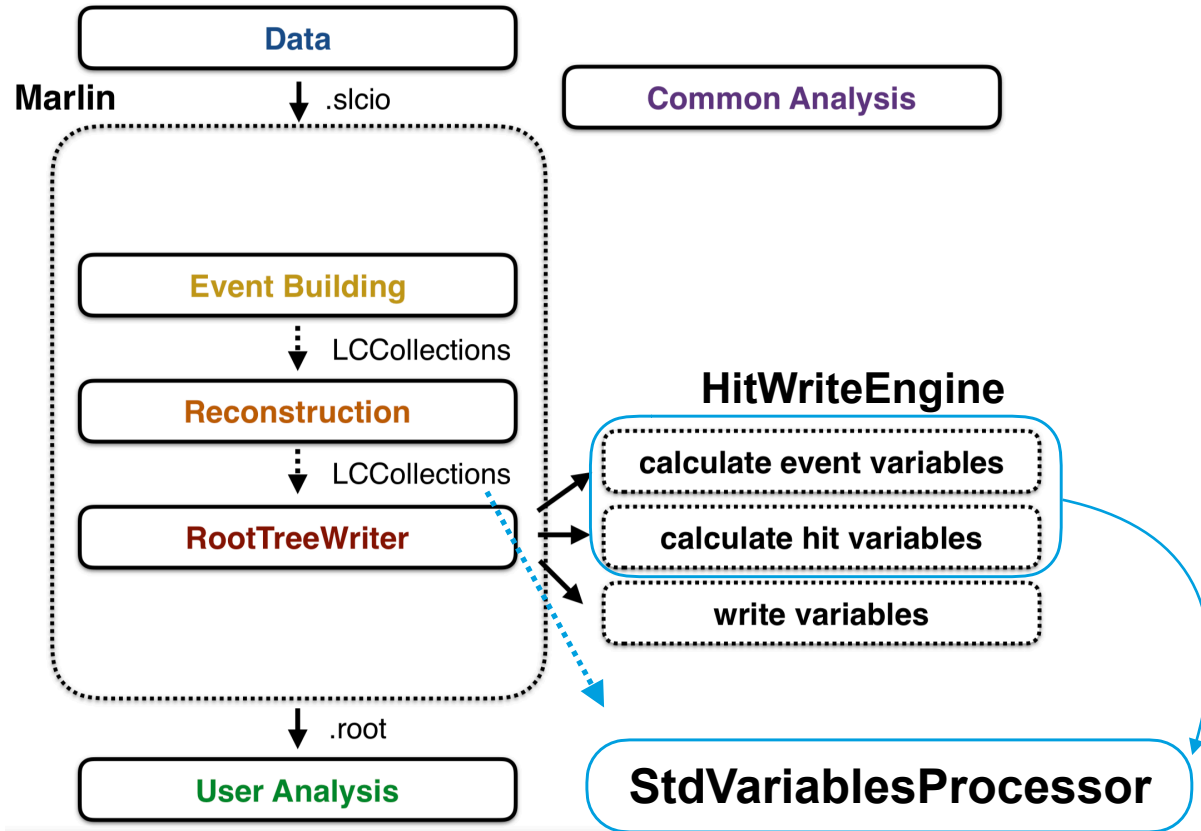
Software architecture

Current state & goal



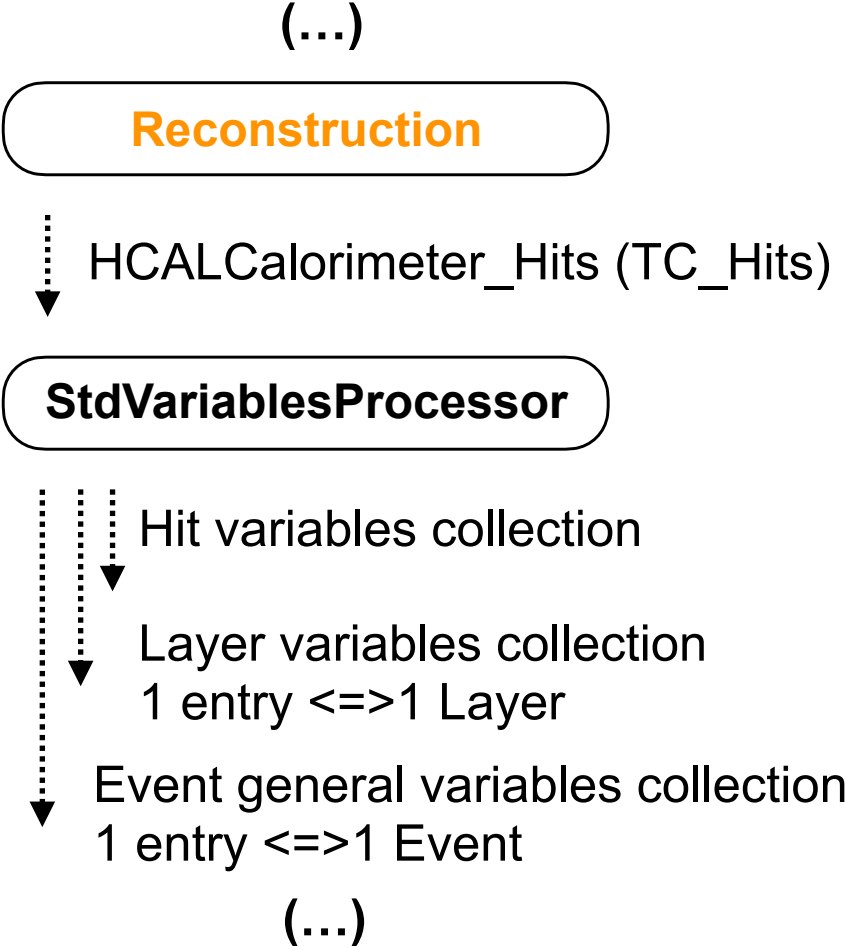
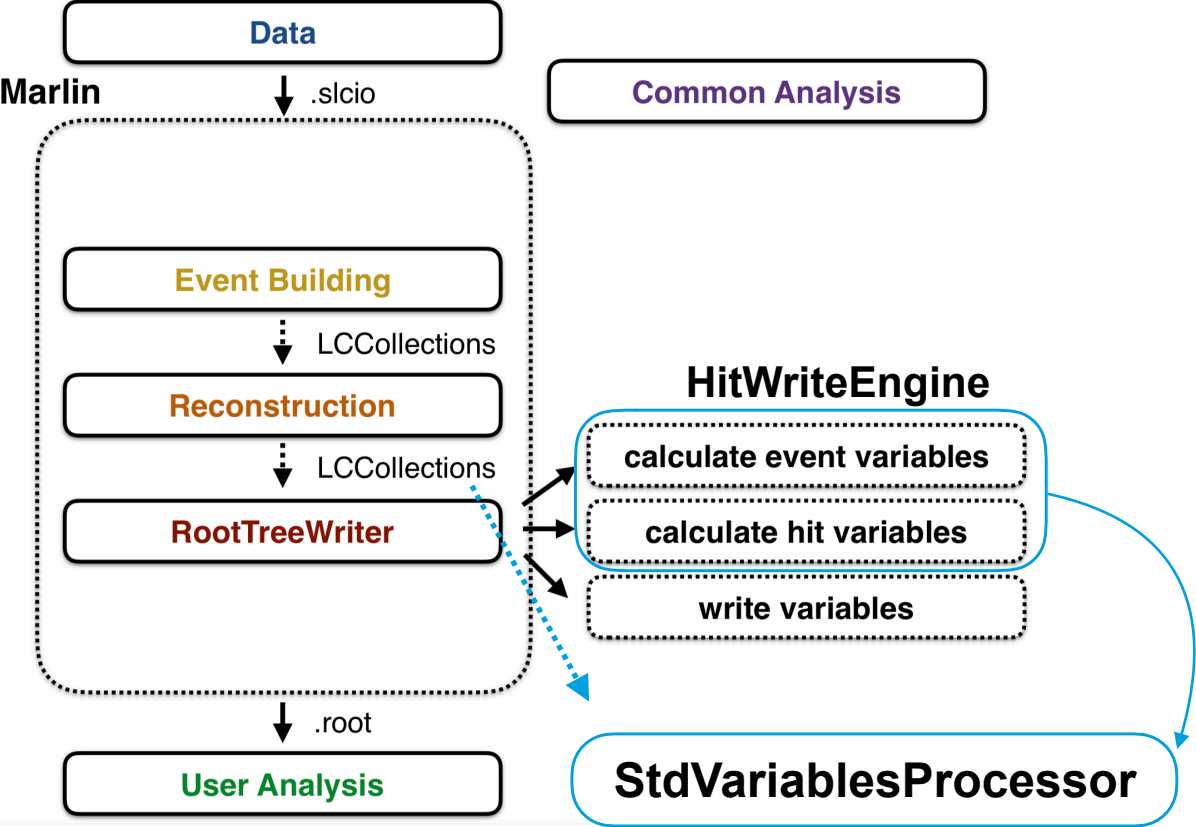
Software architecture

Variables calculation



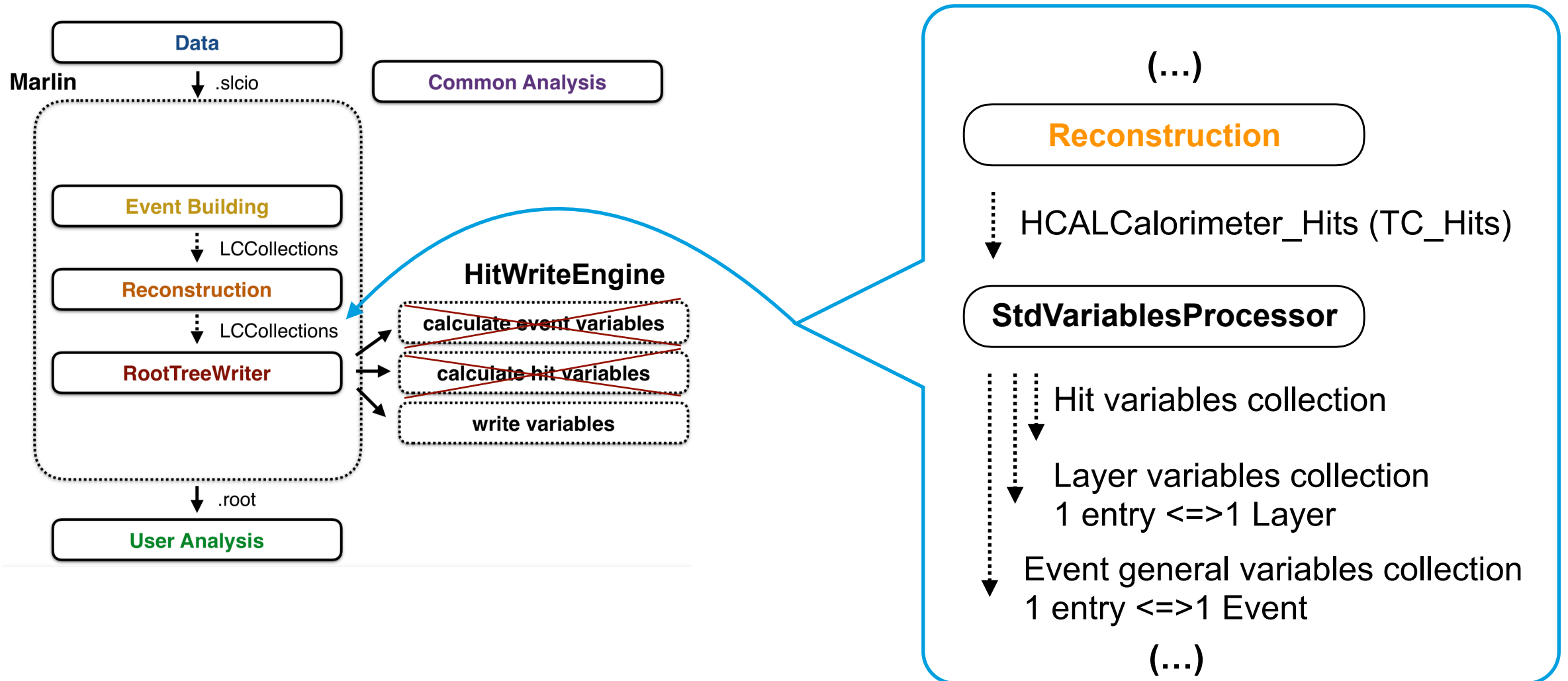
Software architecture

Variables calculation



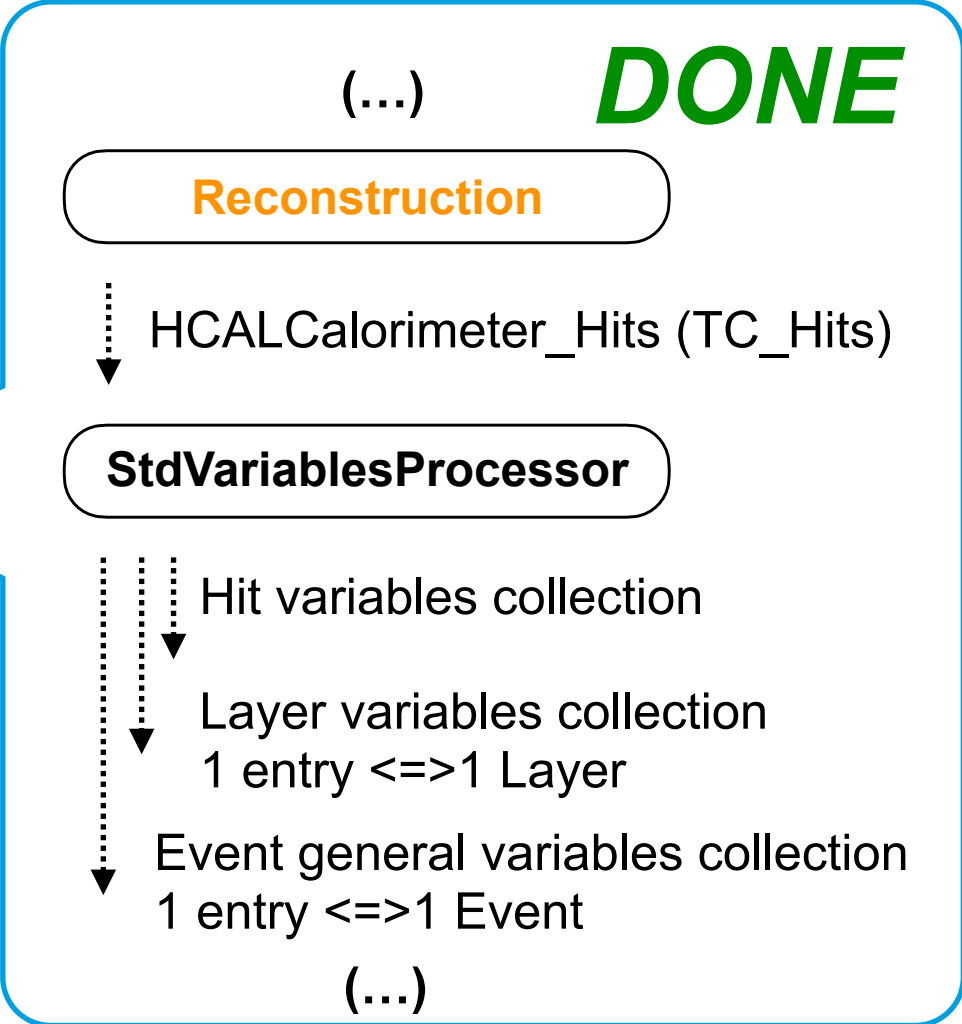
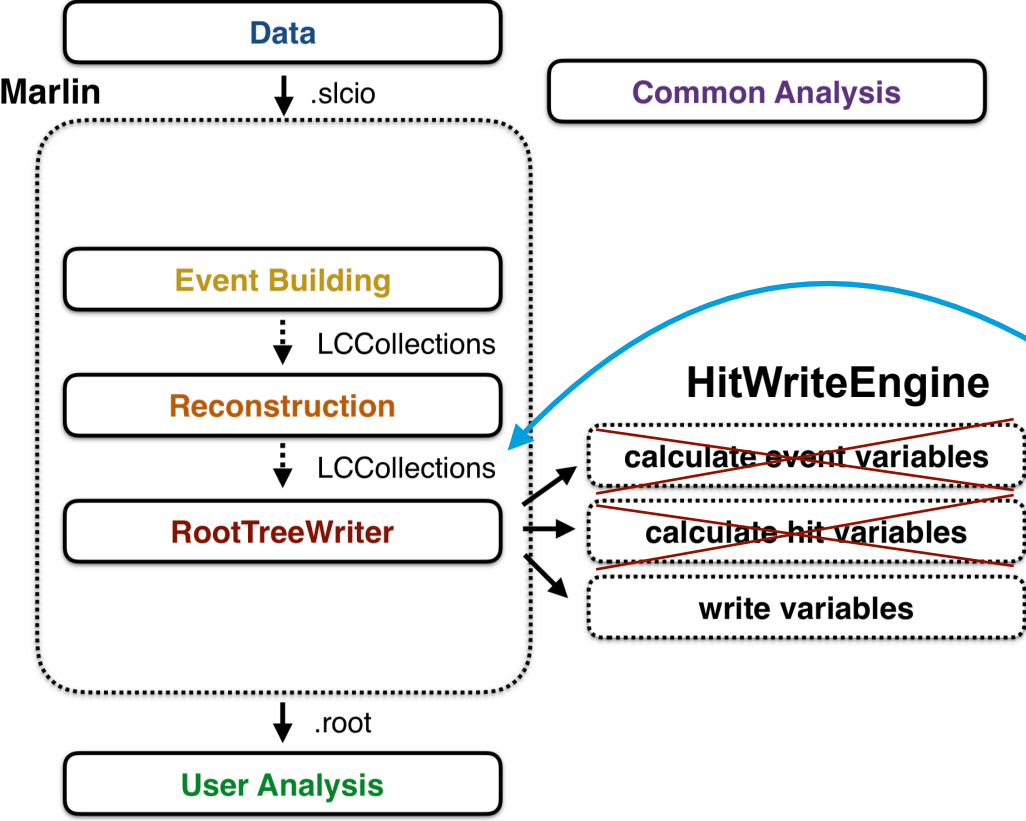
Software architecture

Variables calculation



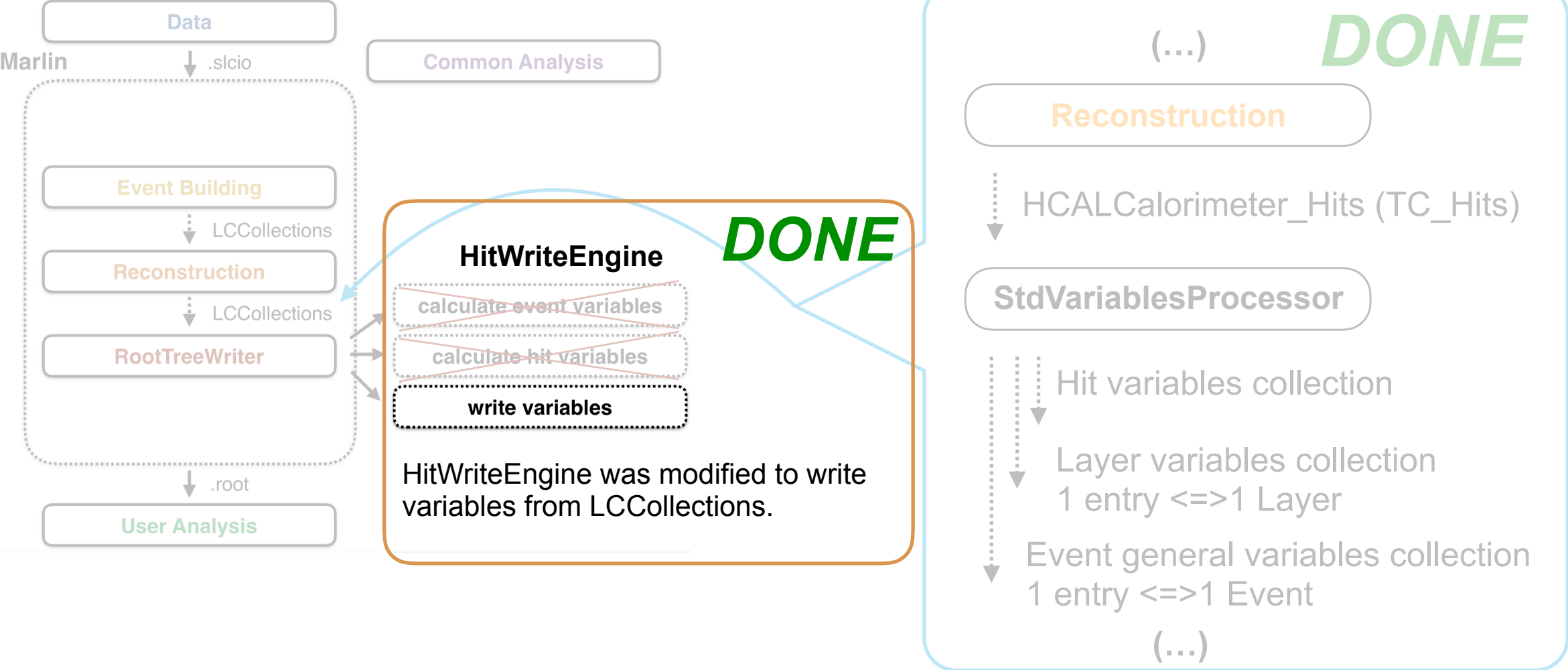
Software architecture

Variables calculation



Software architecture

Variables calculation



Software architecture

Variables calculation

