ND Geometric Efficiency – Analysis Update and discussions

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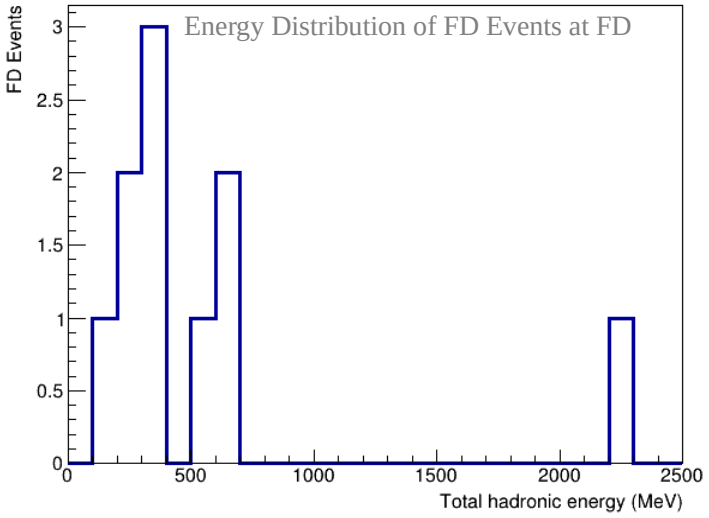
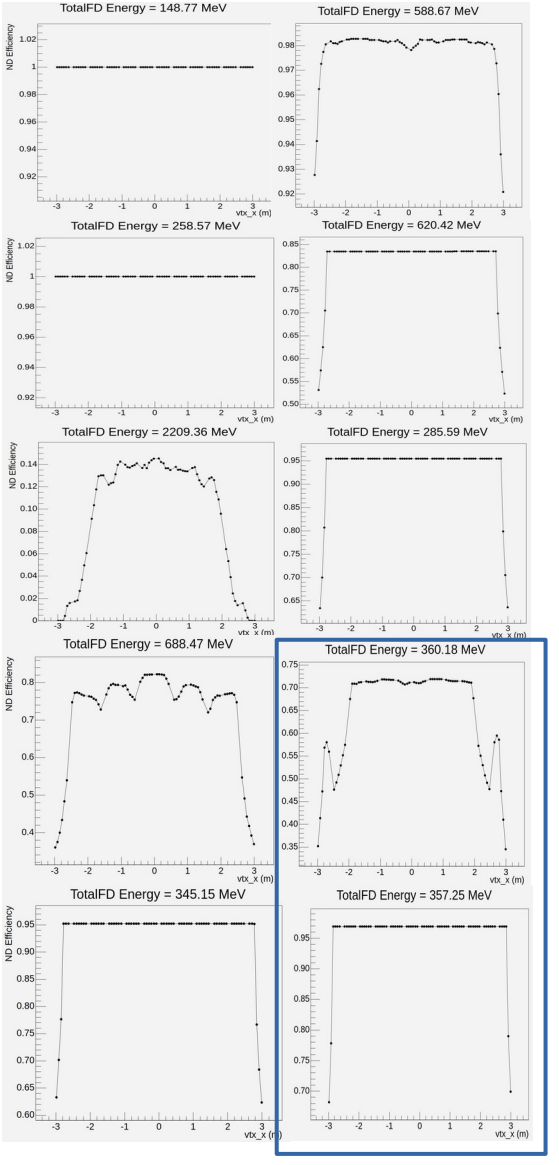
January 8th, 2024

FD Events – hadronic efficiency

- 1 ntuple – 100 simulated FD Events → 10 events selected and translated to the ND



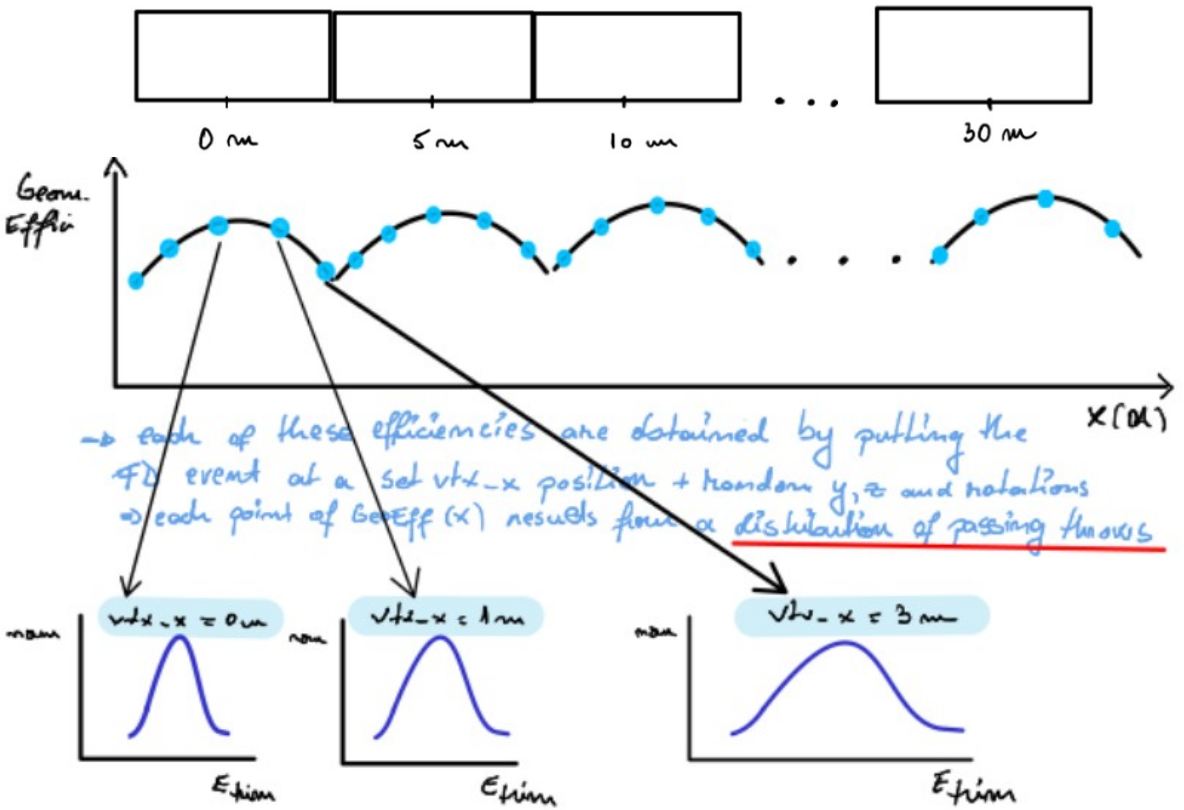
Selection Cuts:
– event has to have muon/hadronic energy deposits
– CC events
– muon as final state lepton
– event vertex inside FD FV



- Highest ND efficiency for lowest FD energy events
  – high FD energy events have in general a wider / more spread hadronic signature → ND volume is smaller than FD volume
- Much lower ND efficiency (14%) for a FD event with total hadronic energy ~ 2 GeV
  – a 2 GeV FD event would only be seen 14% of the times in the ND
- **Most important: hadronic signature and spread**
  – similar total hadronic energies can have different “deposits” in the detector → different ND efficiencies

Geometric Efficiency within PRISM framework

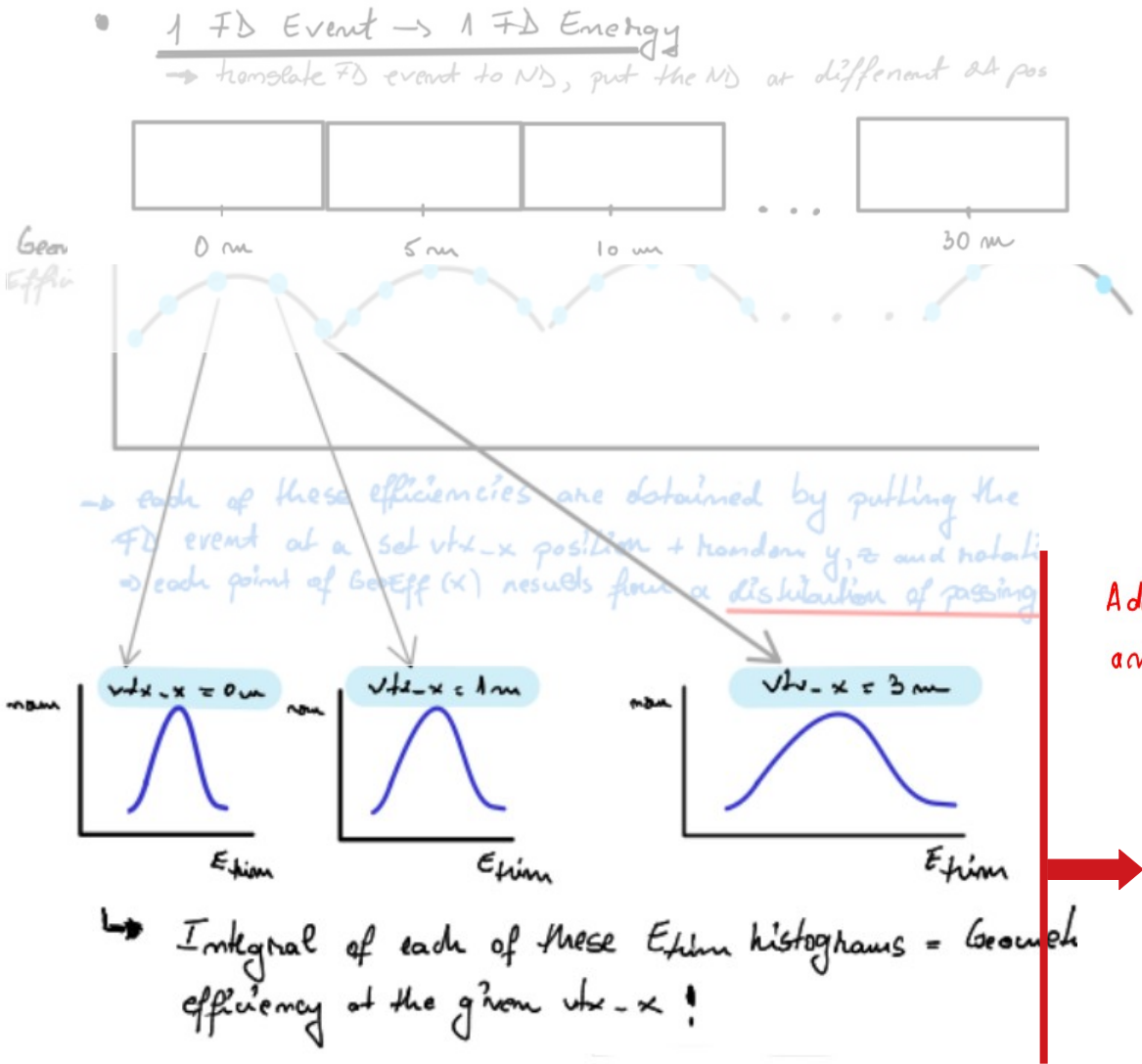
- 1 FD Event → 1 FD Energy
  - → translate FD event to ND, put the ND at different x pos



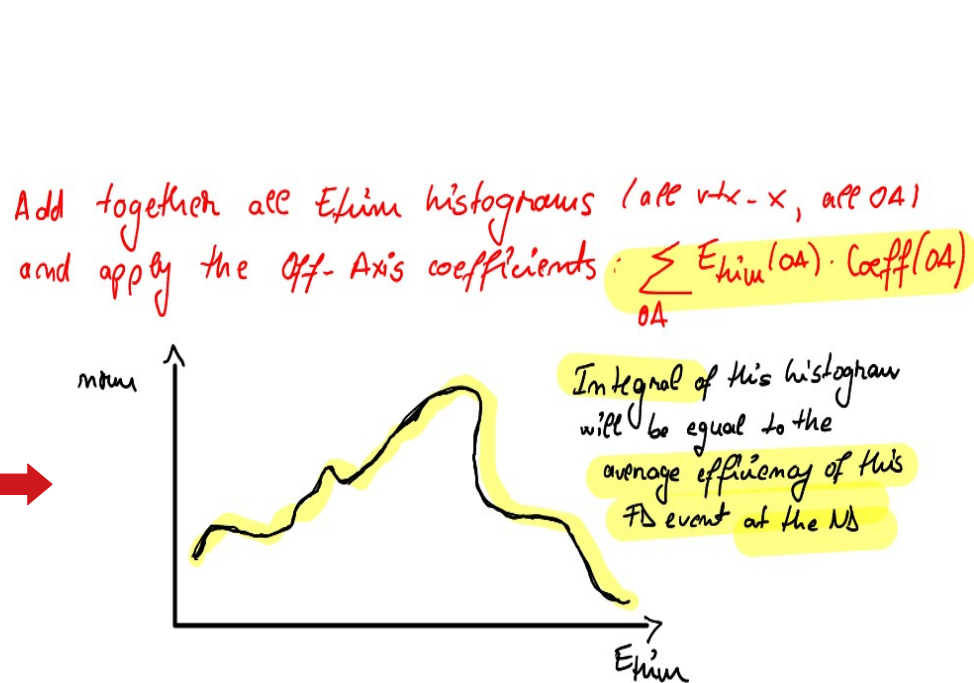
→ each of these efficiencies are obtained by putting the FD event at a set vtx_x position + random y, z and rotations
→ each point of GeoEff (x) results from a distribution of passing muons

→ Integral of each of these Etrue histograms = Geometric efficiency at the given vtx_x !

Geometric Efficiency within PRISM framework



- To get the **average geometric efficiency of a FD event at the ND:** add all Etrim histograms and linearly combine them



Distribution of all FD events as seen in the ND (hadron efficiency corrected)

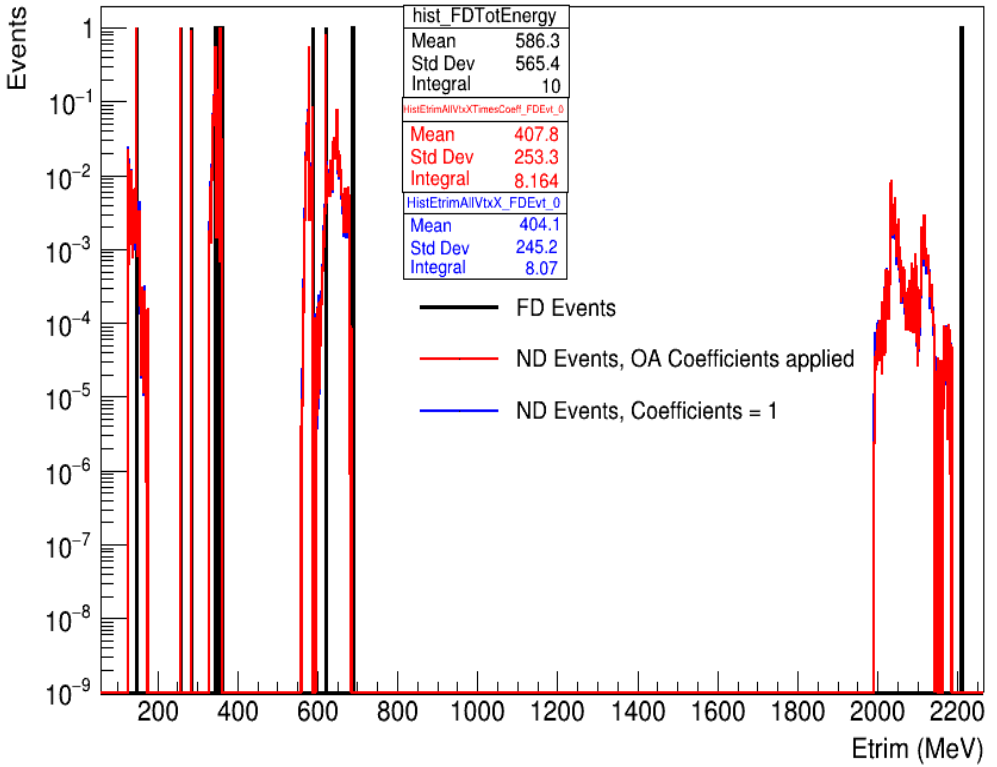
- 10 FD events selected and translated to the ND
  - → calculate the final ND Etrim distribution for each of the events and add them together to see their distribution in the ND
    - – detector position sampling same as the ND CAFs

– 10 events in FD

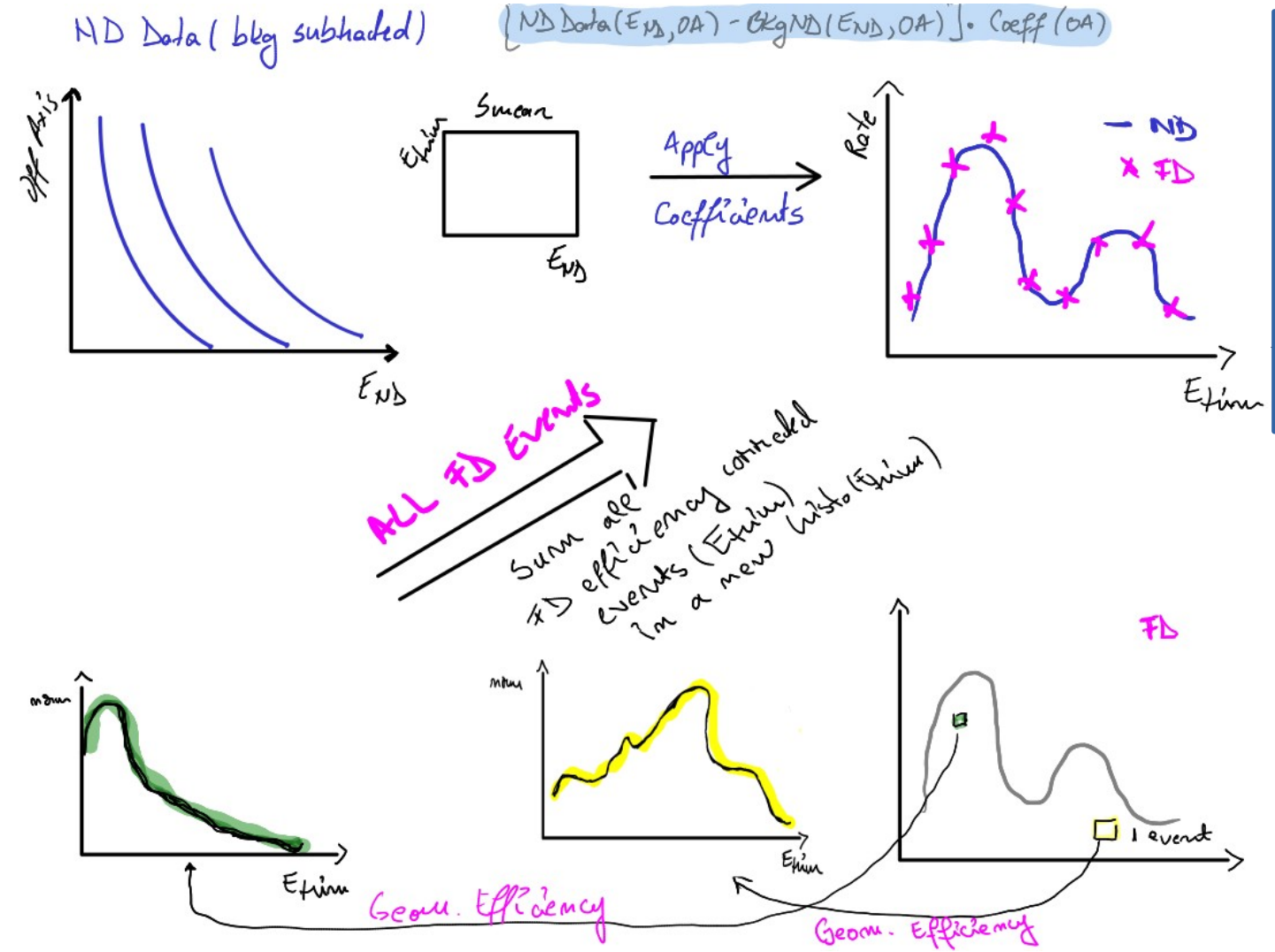
– 8.164 events seen in the ND

* highest FD total energy = 2.2 GeV
– expecting way less events seen by the ND for higher energy events

ND Events distribution of FD Events as seen in the ND (efficiency corrected)



Geometric Efficiency within PRISM framework



1. Start with ND data (bkg subtracted) vs OA vs E_{ND}
2. Smear ND data to Etrim
3. Apply OA coeficients

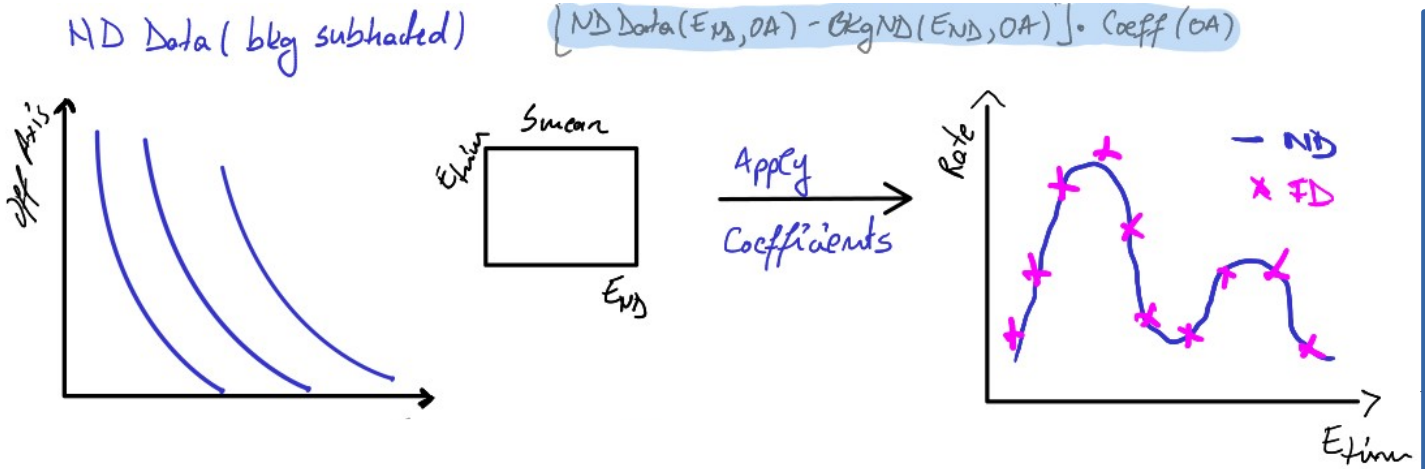
*** no efficiency correction: work with data (selected) events only**

PRISM linear combination

1. Start with FD oscillated spectrum (FD hadronic Energy)
2. For each FD event: geometric efficiency correction (Etrim)
3. Sum all FD events (efficiency corrected) distribution vs Etrim

Distribution of FD Events (eff. corrected) as seen by ND vs Etrim

Geometric Efficiency within PRISM framework



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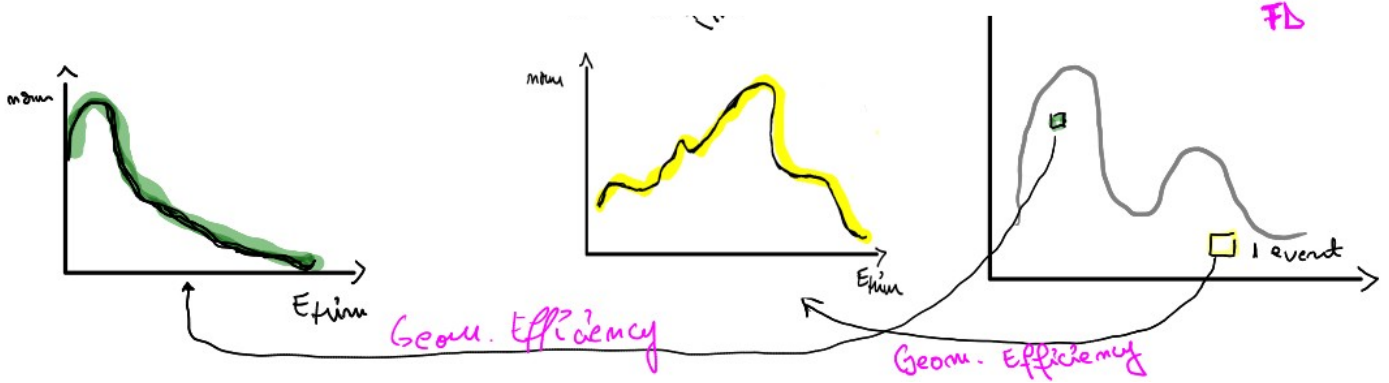
PRISM linear combination

So far no muon efficiency: assumed 100% muon efficiency in this scenario



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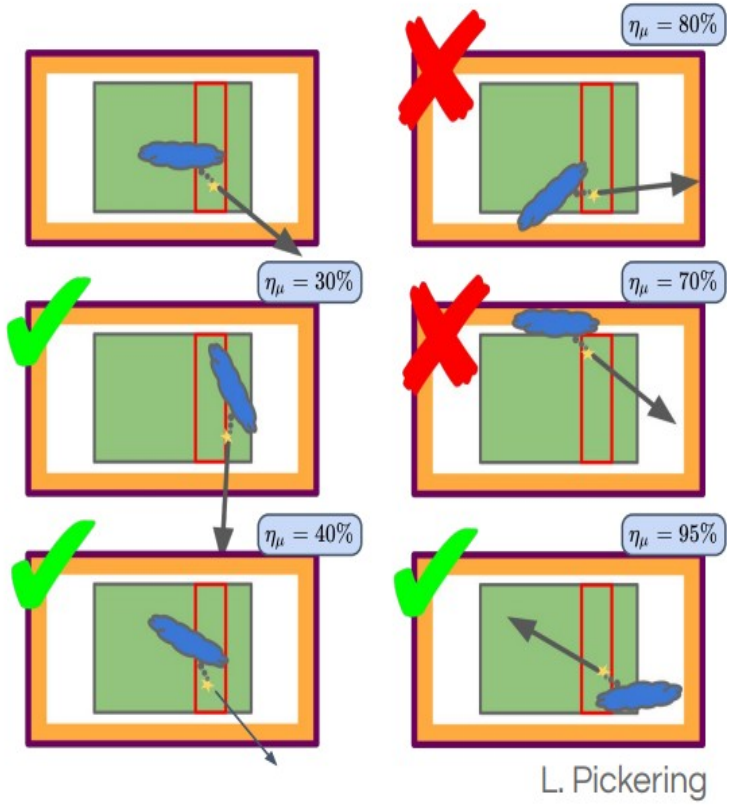
Distribution of FD Events (eff. corrected) as seen by ND vs Etrim

Muon Efficiency correction

For a complete efficiency correction → muon efficiency correction (contained || tracker) for each of the events that pass the veto cut

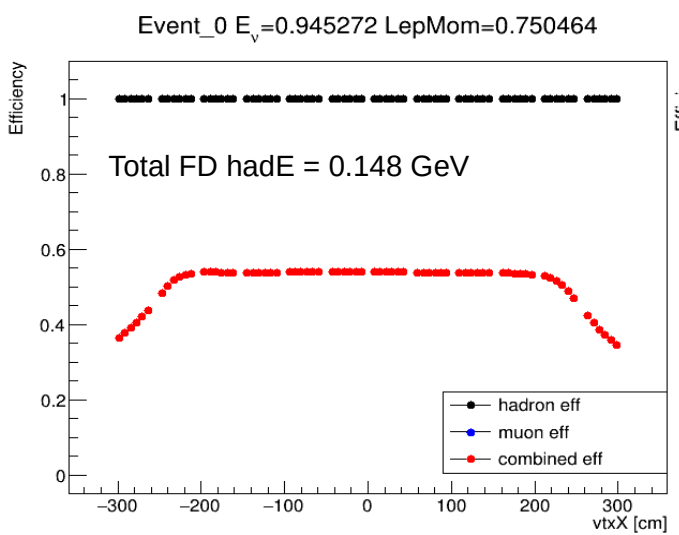
1. Apply the muon efficiency (network probability) to the FD events translated to the ND

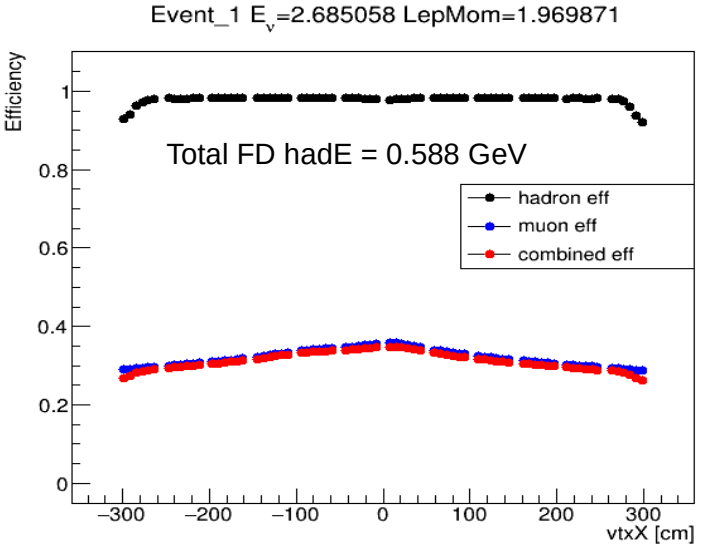
– access the throws rotations, x, y, z and evaluate the muon probability for each individual throw
– get the combined efficiency by summing:
Sum_throws [Pmuon * PassHadVeto] / nTotalThrows

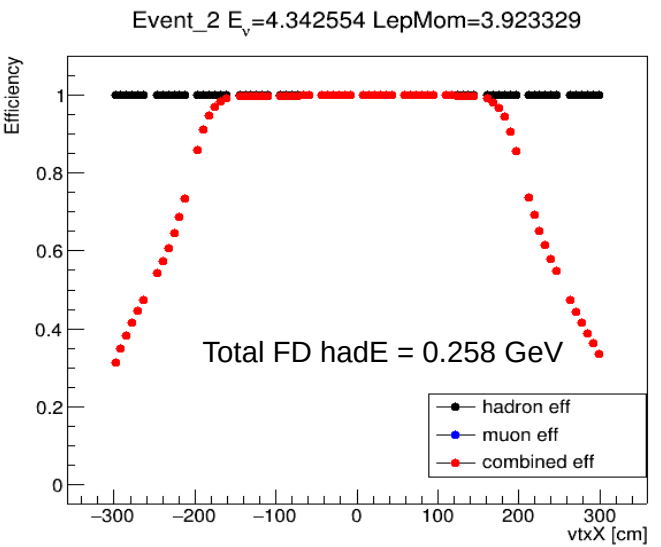


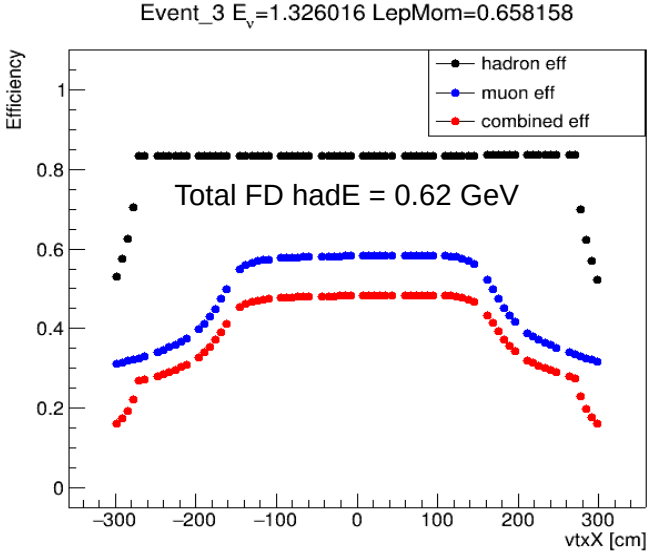
$$\eta = \frac{0\times0.8+1\times0.3+0\times0.70+1\times0.4+1\times0.95}{5} = 33\%$$

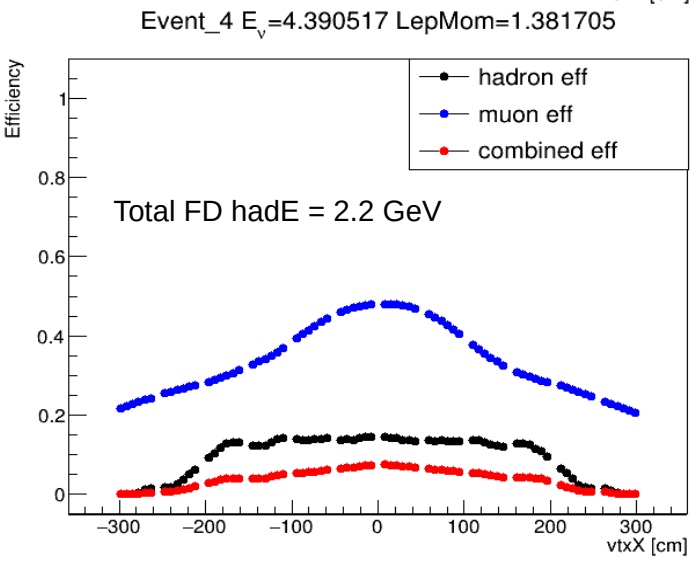
Muon, Hadron and Combined Efficiency correction

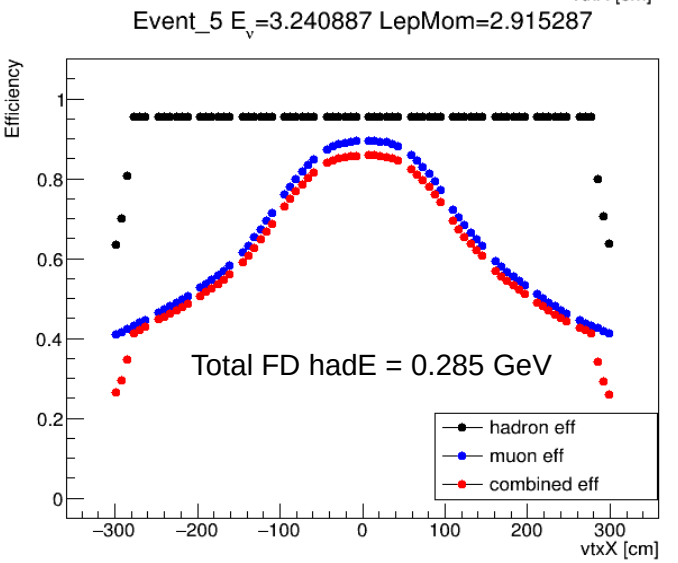












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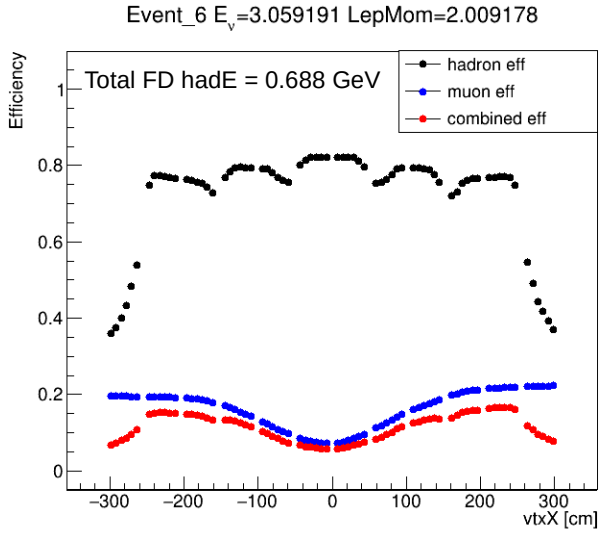

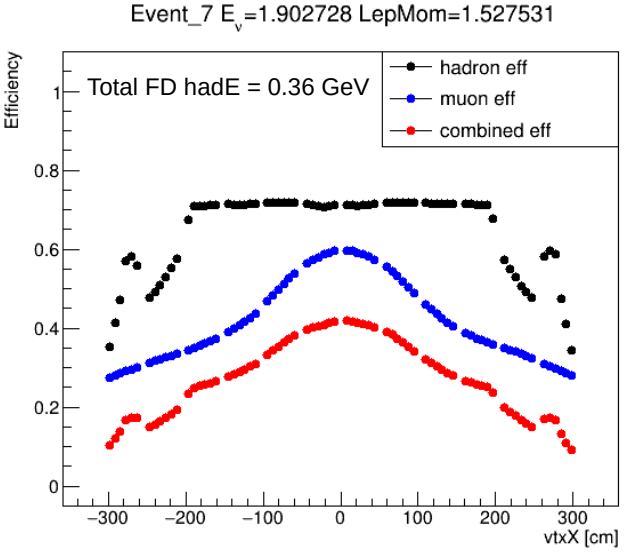

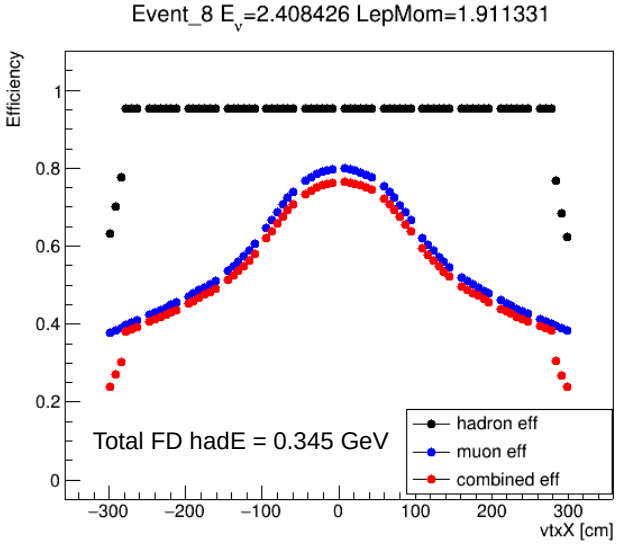

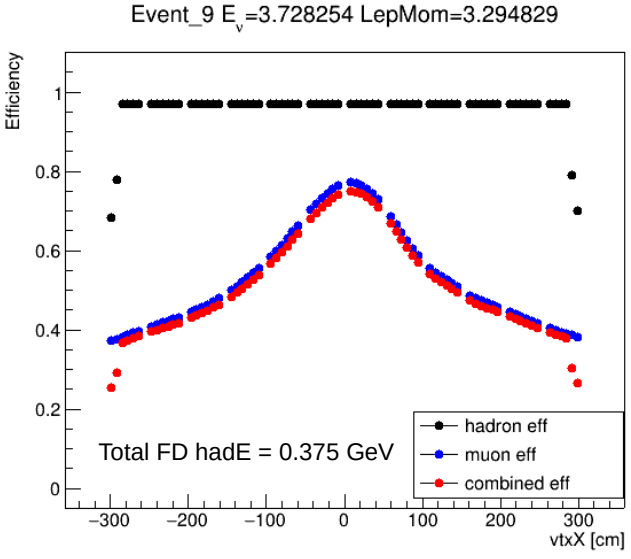

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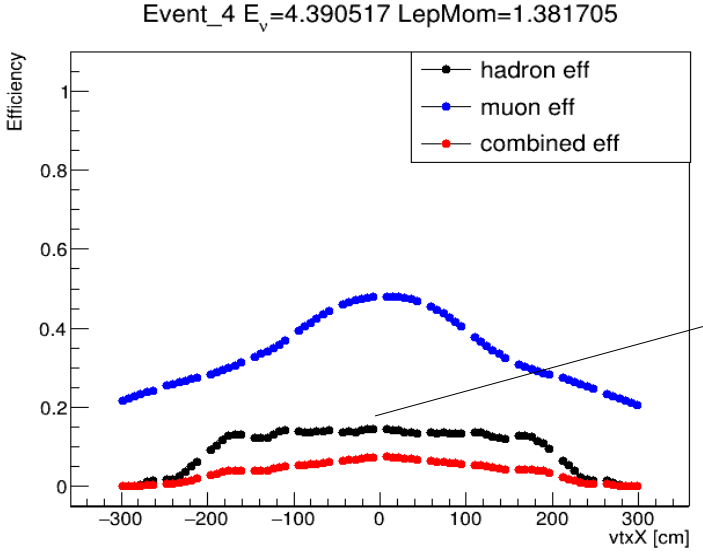
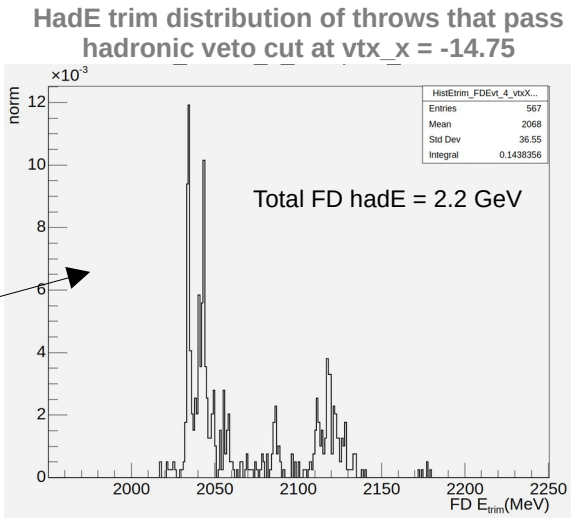
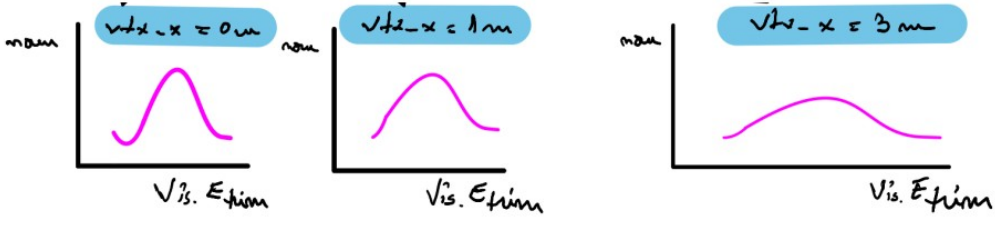




Each entry in these histograms = passing throw (rotation, y, z) for **hadronic cut**

– each passing throw has a corresponding **muon geometric efficiency:** probability muon contained

→ apply this probability: N(Etrim, throw) * P(Emu, throw)

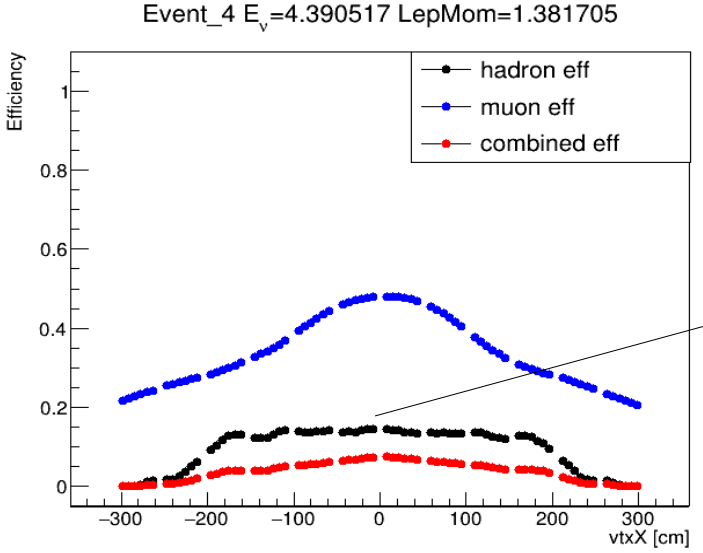


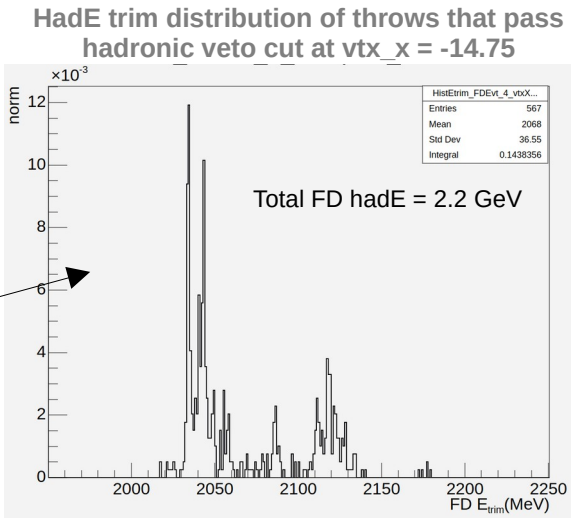
1. Take the muon probability and apply it to each entry in the histogram?

– different distribution (I.e if Pmu = 0 → no event in the histo)

– visEtrim (= hadE_trim + Emu) distribution of FD events that would be seen (both hadronic veto and muon) by the ND at a given vtx_x

Muon, Hadron and Combined Efficiency correction





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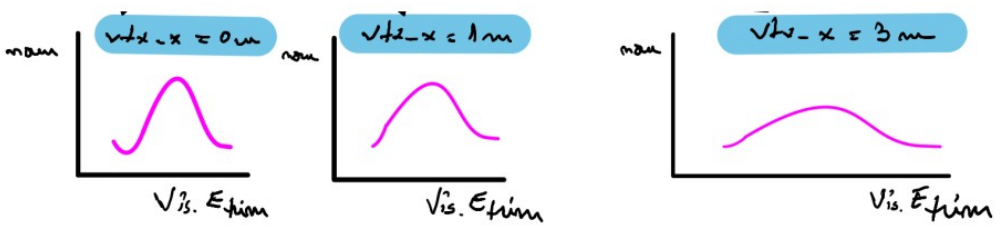

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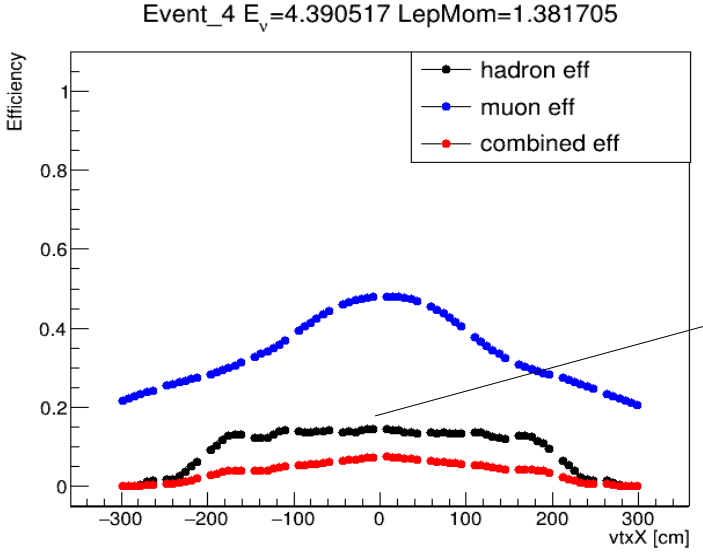
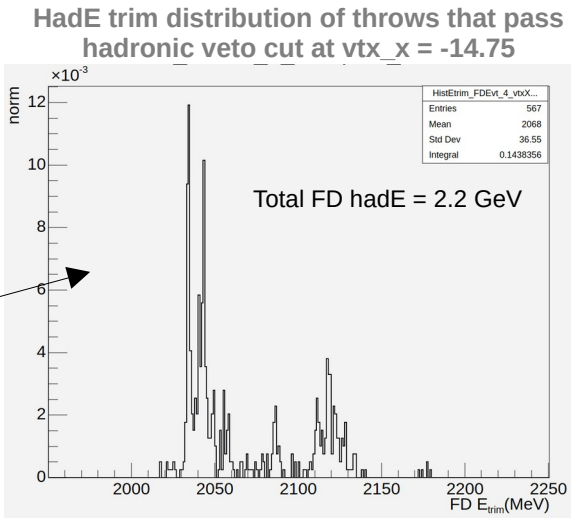
– different distribution (I.e if Pmu = 0 → no event in the histo)

– visEtrim (= hadE_trim + Emu) distribution of FD events that would be seen (both hadronic veto and muon) by the ND at a given vtx_x

THEN: proceed as before (apply OA coeffs and add together all visEtrim histograms → **distribution of FD events that would be seen** (both hadronic veto and muon) **by the ND** – compare to the **linear combination of (ND data - bkg)**

Muon, Hadron and Combined Efficiency correction





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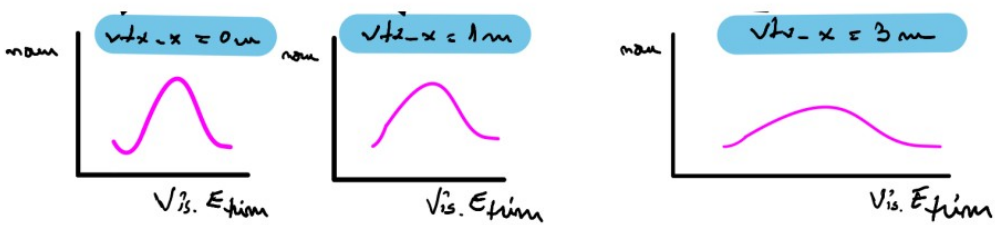
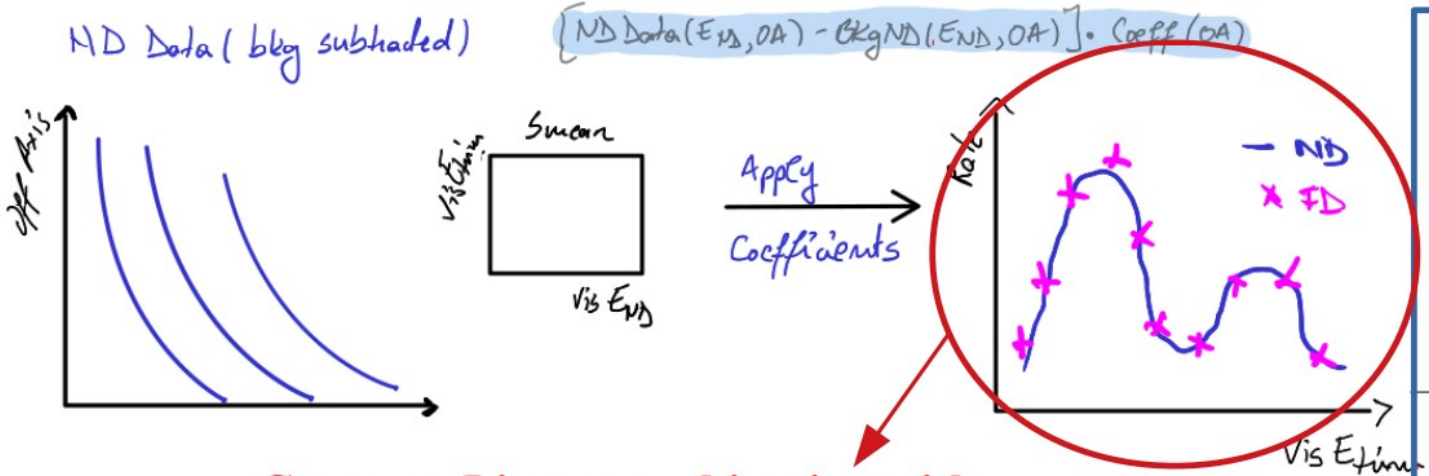
– each passing throw has a corresponding **muon geometric efficiency:** probability muon contained
→ apply this probability: N(Etrim, throw) * P(Emu, throw)

Or just scale it by the muon efficiency(vtx_x = -14.75)?



Geometric Efficiency within PRISM framework



1. Start with ND data (bkg subtracted) vs OA vs vis E_{ND}
2. Smear ND data to Vis Etrim
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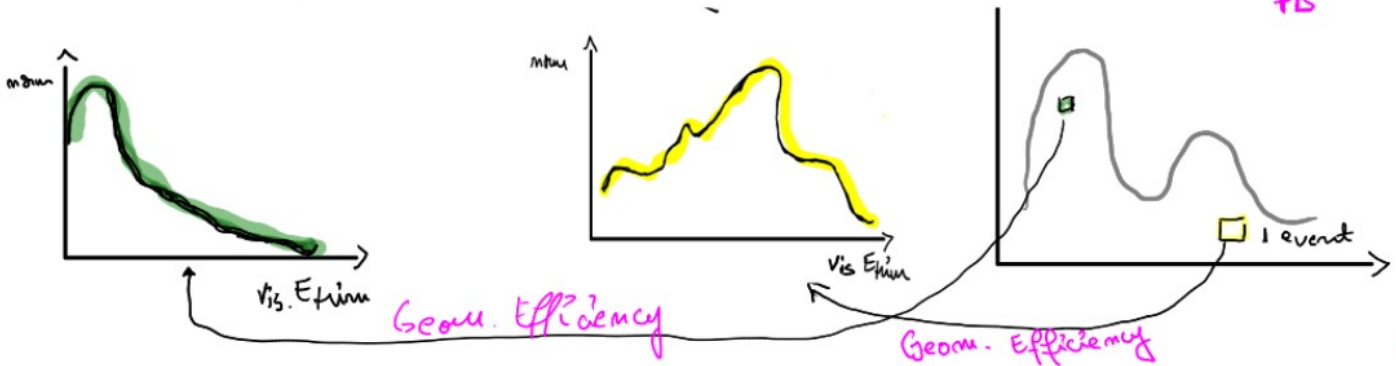
*** no efficiency correction: work with data (selected) events only**

PRISM linear combination

Compare Linear combination with Oscillated FD Events corrected for their efficiency at ND

→ (fit would be done in ND Vis Etrim)



1. Start with FD oscillated data (FD hadronic Energy)
2. For each FD event: geometric efficiency correction (vis Etrim)
3. Sum all FD events (eff. corr.) distribution vs vis Etrim

Distribution of FD Events (eff. corrected) as seen by ND vs vis Etrim

Muon Efficiency correction

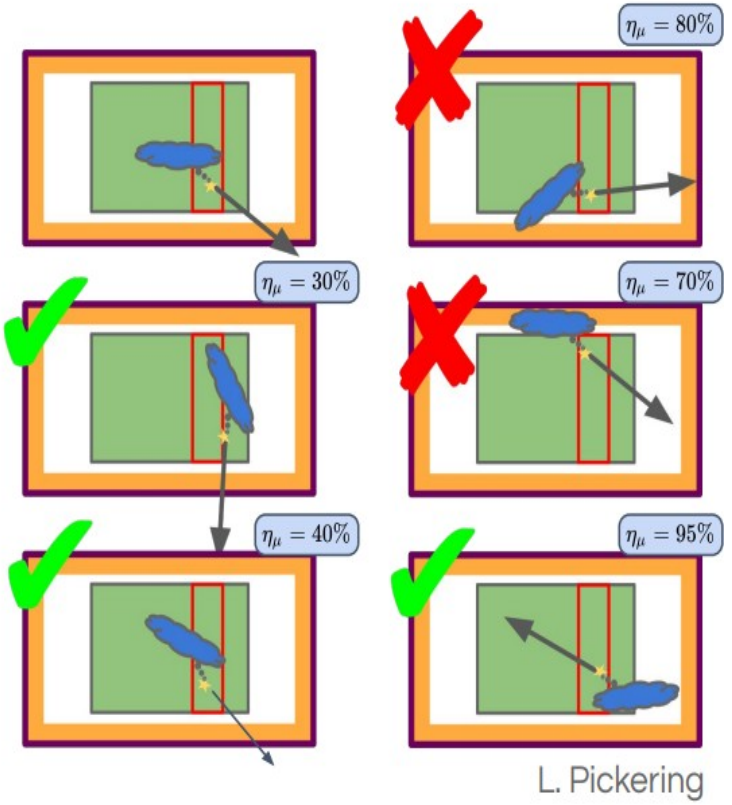
For a complete efficiency correction → muon efficiency correction (contained || tracker) for each of the events that pass the veto cut

1. **Apply the muon efficiency** (network probability) **to the FD events translated to the ND**

   – access the throws rotations, x, y, z and evaluate the muon probability for each individual throw
   – get the combined efficiency by summing:
   Sum_throws [Pmuon * PassHadVeto] / nTotalThrows

2. **Apply the muon efficiency** (network probability) **to the ND events** – to the existent ND CAFs (info stored about rotations and translaions

   – muon efficiency correct the (ND Data - bkg)
   – compare muon efficiency corrected and linearly combined (NDData – bkg) with the FD events distribution as seen by the ND when only hadron efficiency is applied ..



$$\eta = \frac{0\times0.8+1\times0.3+0\times0.70+1\times0.4+1\times0.95}{5} = 33\%$$

Where we are...

- Can properly run the muon efficiency (both for ND events at ND and for FD events at ND)
  → FD events at ND focus right now
  – methods should be equivalent – at some point try doing it both ways..

- Muon efficiency (vtx_x), hadron efficiency (vtx_x), combined efficiency (vtx_x)
  – discussion how to further proceed with muon efficiency: already have access to the muon probability Pmu of each throw → still need to figure out how to properly and efficiently save this info (lots of data.. NpassThrows doubles for each event)
  → first combined (muon and hadron) efficiency corrected FD events as seen by the ND soon

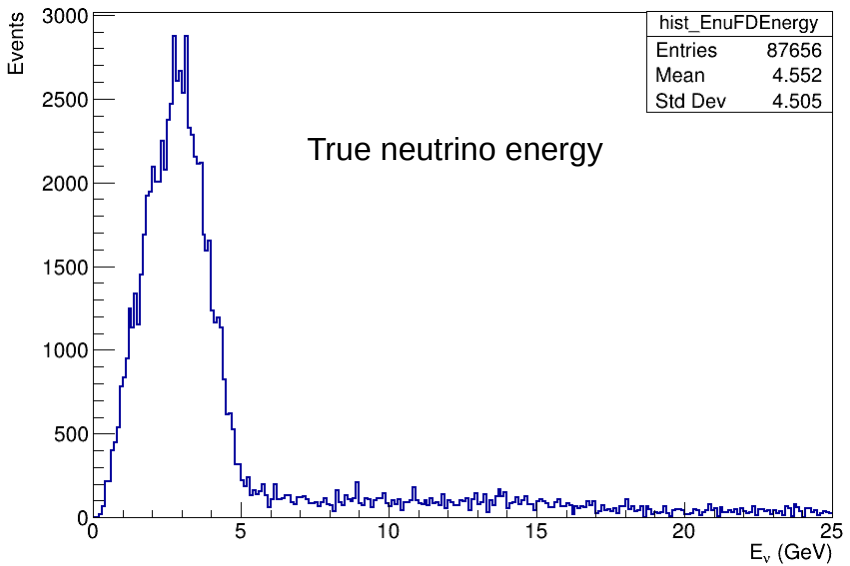
TO DOs (near future)

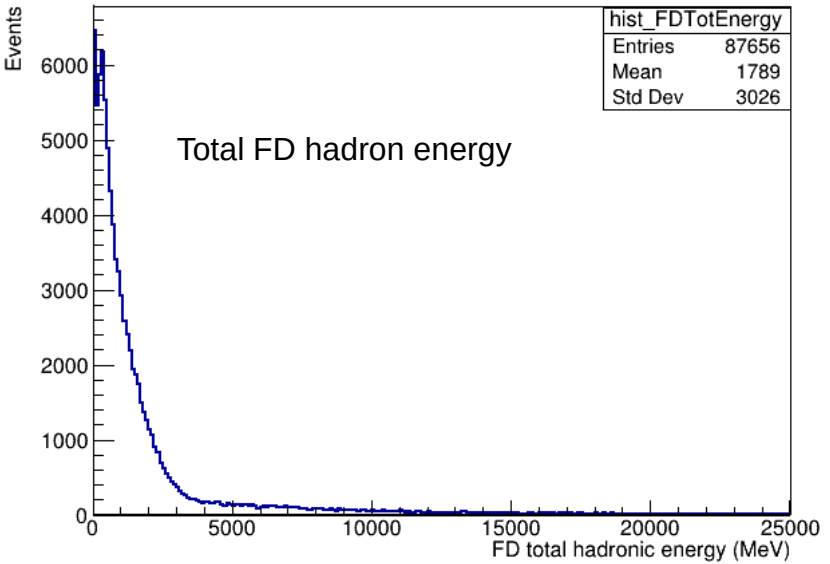
- Once first efficiency corrected FD events as seen by the ND: reproduce FD ntuples for an oscillated spectrum and first comparison between the linearly combined NDData – bkg to the FD events distribution (visEtrim)
  – assuming that efficiency is same for all OA positions → long term need to cross check and correct for this

Geometric efficiency – first results with higher statistics

- 9070 ntuples (all ntuples created by Flynn) – 907 000 simulated FD Events
  → **87 656 events selected and translated to the ND** (~ 10 % of simulated FD events pass selection)

Selection Cuts:
– event has to have muon/hadronic energy deposits
– CC events
– muon as final state lepton
– event vertex inside FD FV





!!! Un-oscillated spectra..

Geometric efficiency – first results with higher statistics

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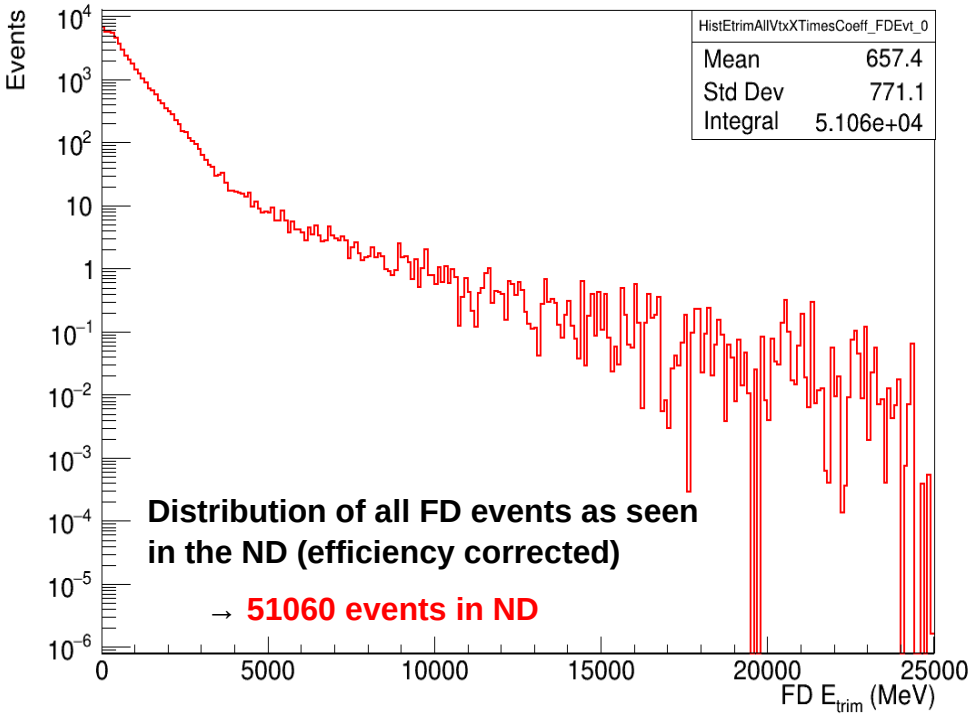

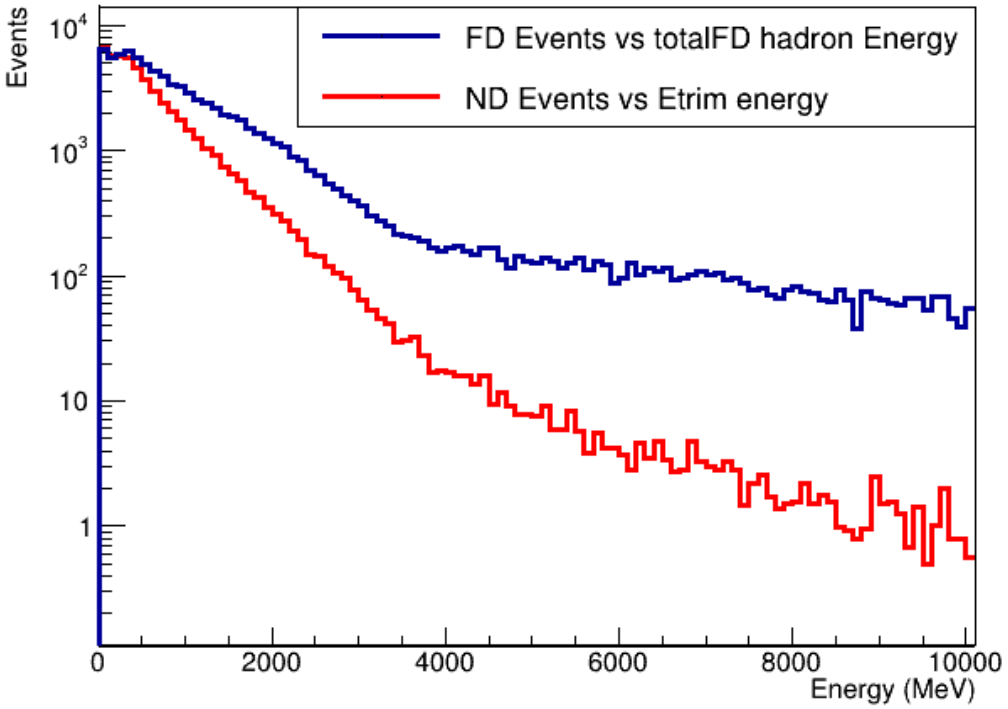

Geometric efficiency – first results with higher statistics

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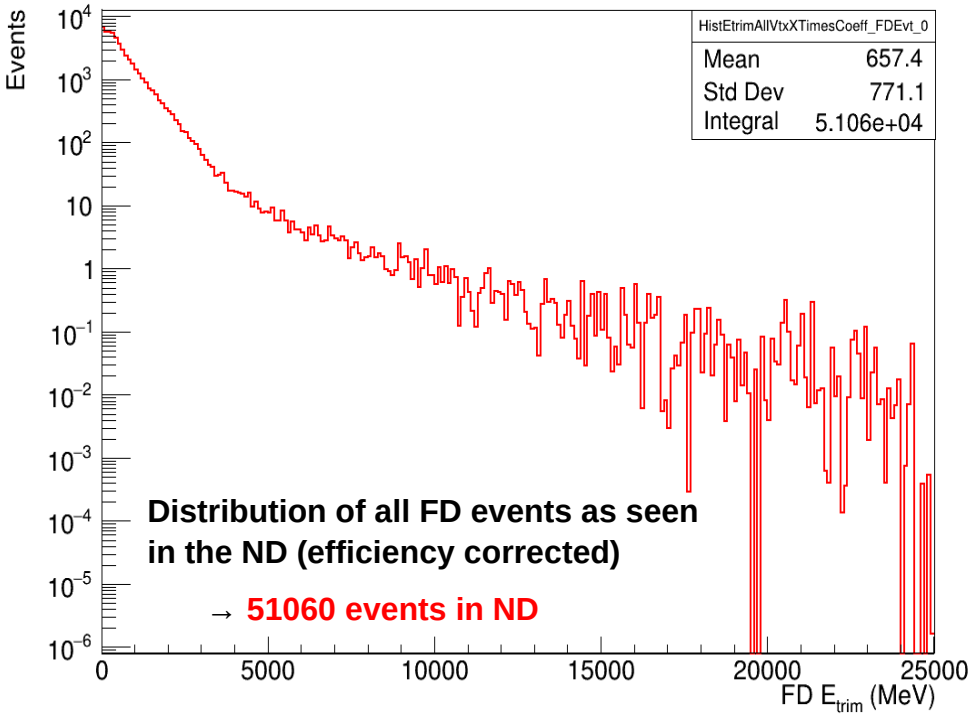

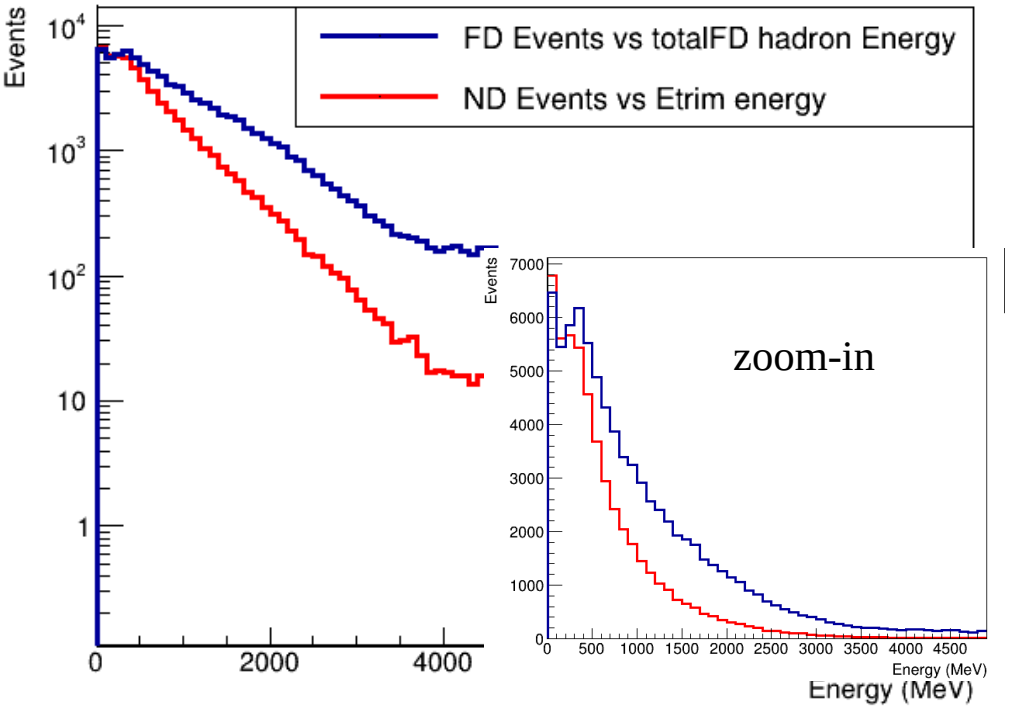

- Spectrum of FD Events in the ND (efficiency corrected) vs Etrim seems to be following the FD events spectrum vs total FD hadronic energy (less events at high FD energies and more at very low Etrim)
  - but it does not look oscillated at all..
- Neutrino spectra in the FD is unoscillated → **TODO:** try to re-weight / repeat the same study with NuFit4.0 param.