Event selection in FD

(based on the talk given at ESSnuSB WP5 video meeting on 15 Apr 2021)

Budimir Kliček
Ruđer Bošković Institute, Zagreb

Before we continue

- Everything is normalized to 1 year (200 days) of operation
  - “expected events” means expected events in a year
- Event selection is the same for positive and negative polarity
  - all events in positive (negative) polarity are assumed to come from neutrinos (antineutrinos) by the selection algorithm
- Migration matrices are different for neutrinos and antineutrinos
- We are optimizing for our flux using HyperK geometry

Event selection

- Every beam event in positive (negative) polarity is exclusively classified as:
  - ν_e ($\bar{\nu}_e$) CC candidate
  - ν_μ ($\bar{\nu}_\mu$) CC candidate
  - ν NC ($\bar{\nu}$ NC) candidate (new)
  - not selected
- ν_e / ν_μ discrimination is based on
  - Michel electron detection
  - fiTQun PID
- NC rejection is based on
  - charge collected by PMTs used by fiTQun (noise not included)
  - pi0 detection

Discrimination variables

- **Number of subevents**
  - 1st subevent is the earliest detector trigger that happened within beam time window (BTW)
  - 2nd and higher subevents are subsequent triggers within the BTW and a period after it
- **fiTQun particle id (PID)**
  - maximum likelihood based PID
- **Total collected charge at PMTs**
  - filtered for noise by fiTQun
- **pi0 identification**
  - maximum likelihood based PID coupled with free fit for pi0 mass
- **Reconstructed momentum of electrons**
  - used to reject dark muons
    - muon that is not detected but Michel electron is

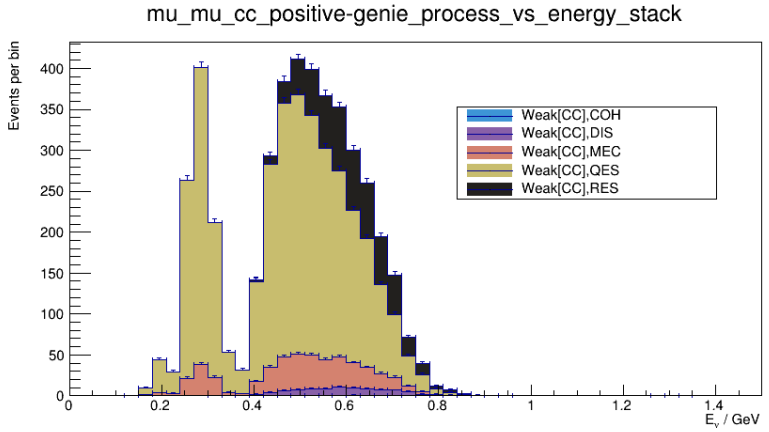
ν_e selection

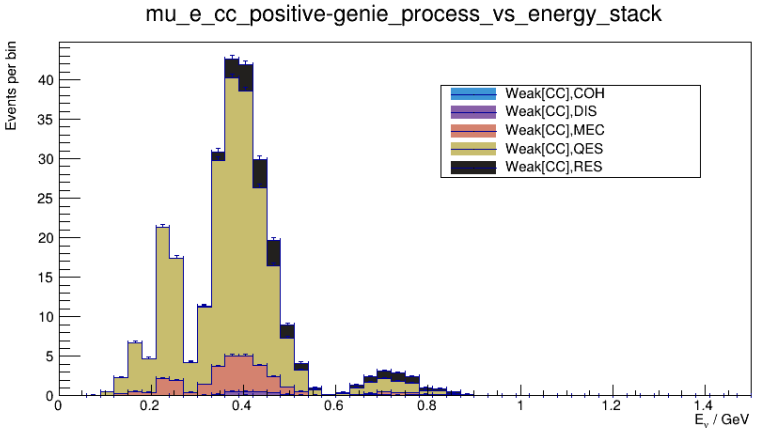
- Sequential rejection algorithm
  - Fiducial cut assuming charged lepton is an electron
  - Subevents > 1 → not ν_e
  - PID favours muon over electron → not ν_e
  - Total used PMT charge < 1000 → not ν_e
  - PID favours pi0 over electron **and** fit pi0 mass between 105 MeV and 165 MeV → not ν_e
  - charged lepton momentum assuming electron < 70 MeV → not ν_e
  - it is a ν_e

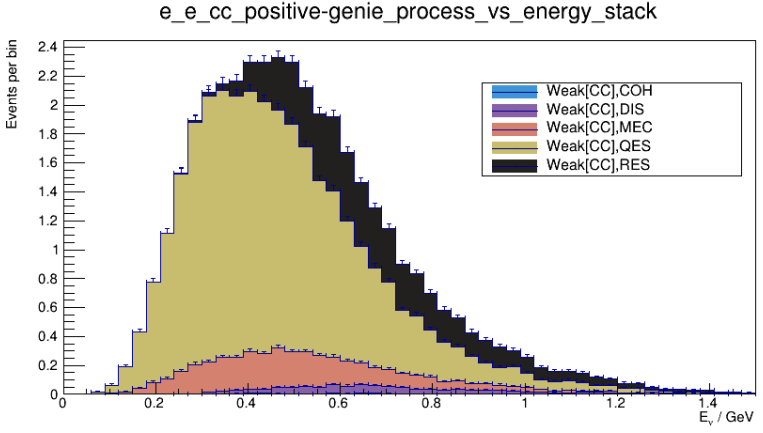
ν_μ and NC selection

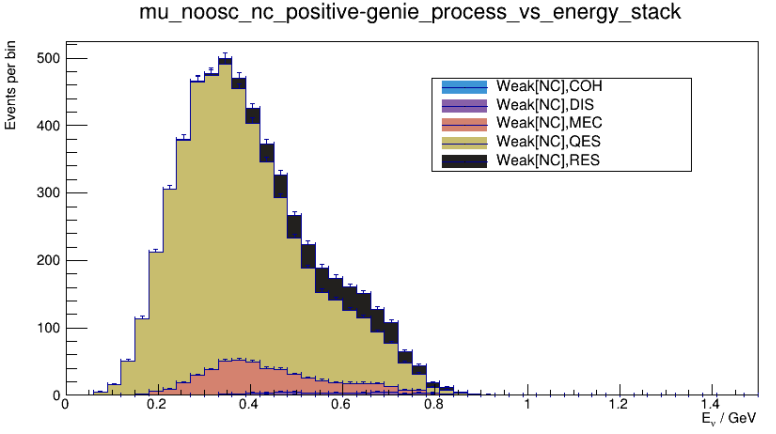
- ν_μ selection
  - selected as ν_e → not ν_μ
  - fiducial cut assuming muon as charged lepton
  - subevents < 2 → not ν_μ
  - it is ν_μ
- NC selection
  - selected as ν_e or ν_μ → not NC
  - total used PMT charge between 5 and 800 → it is NC

Neutrino interaction “types” (models)
Positive polarity

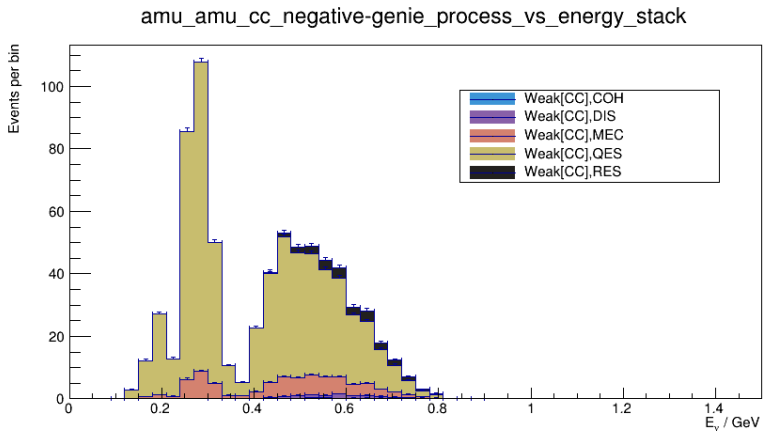


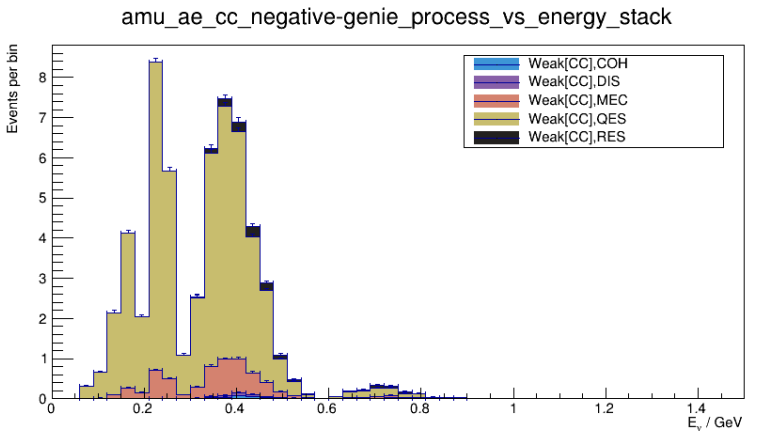


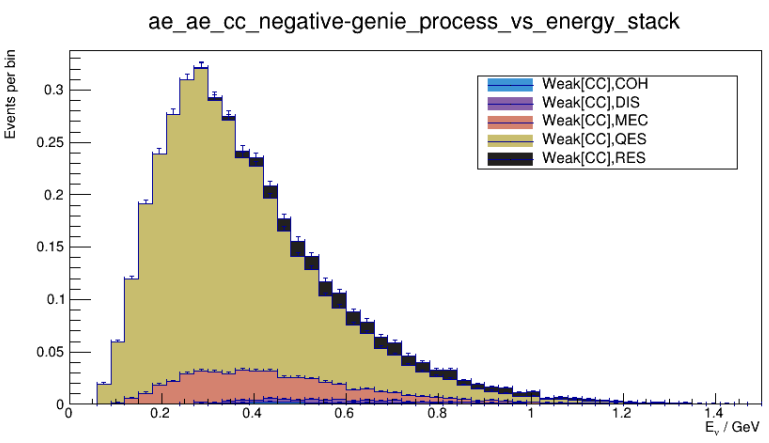


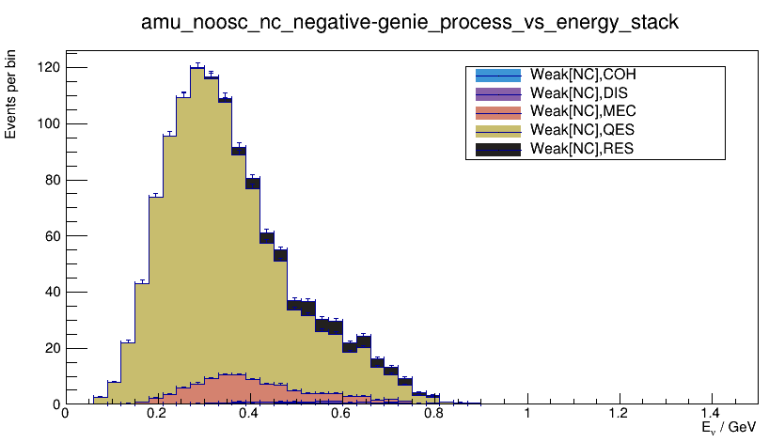


Neutrino interaction “types” (models)
Negative polarity





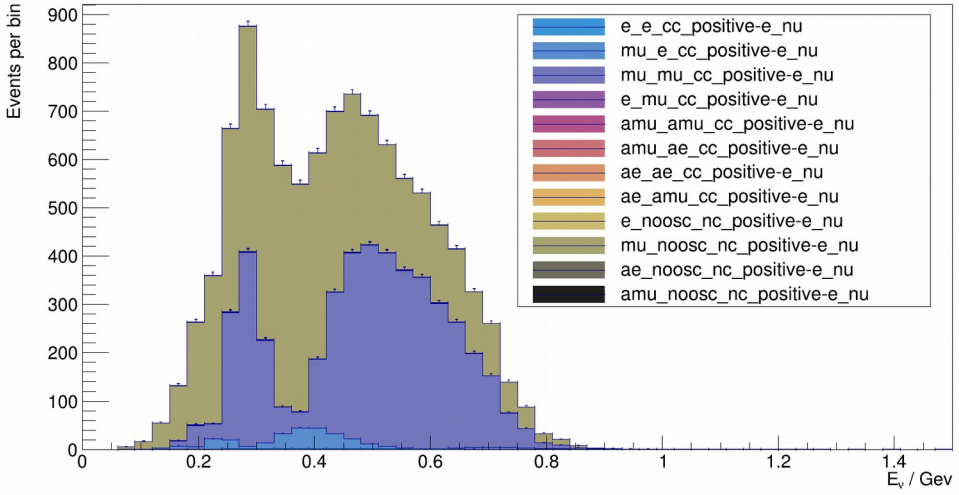




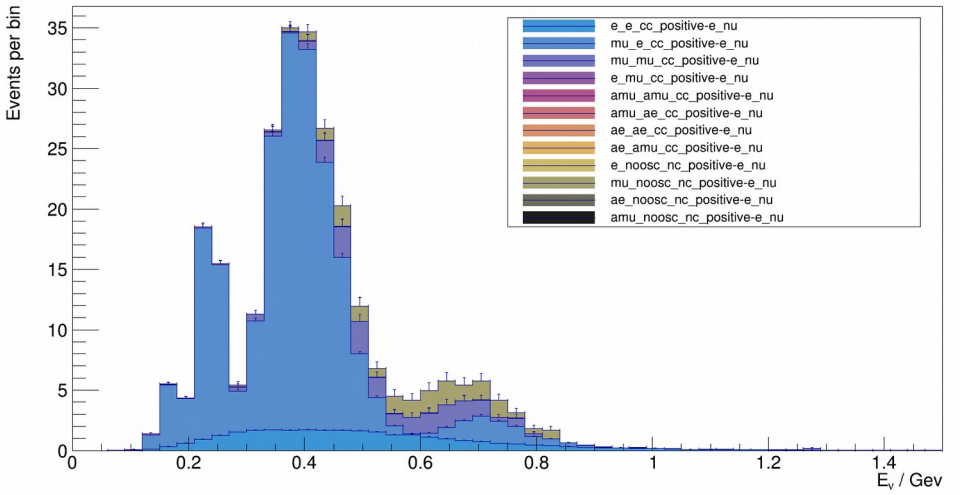
ν_e selection in detail

Positive polarity

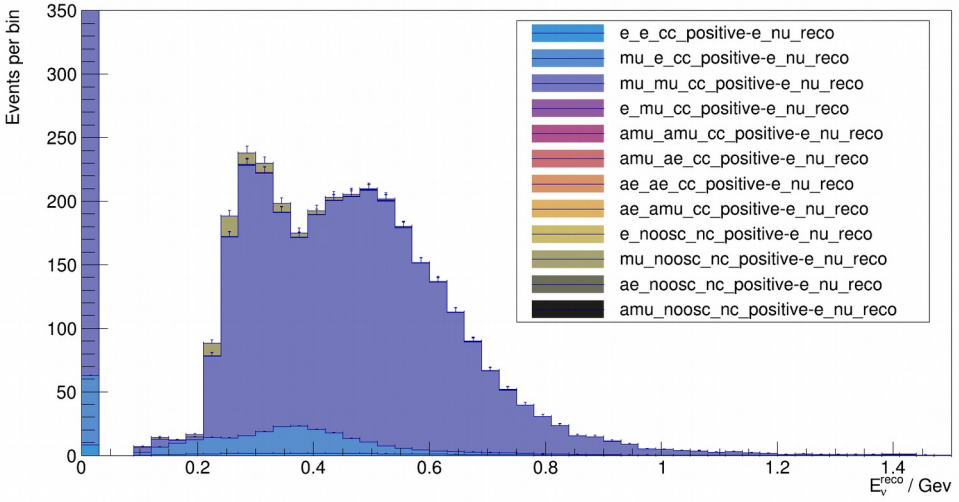
All e_nu



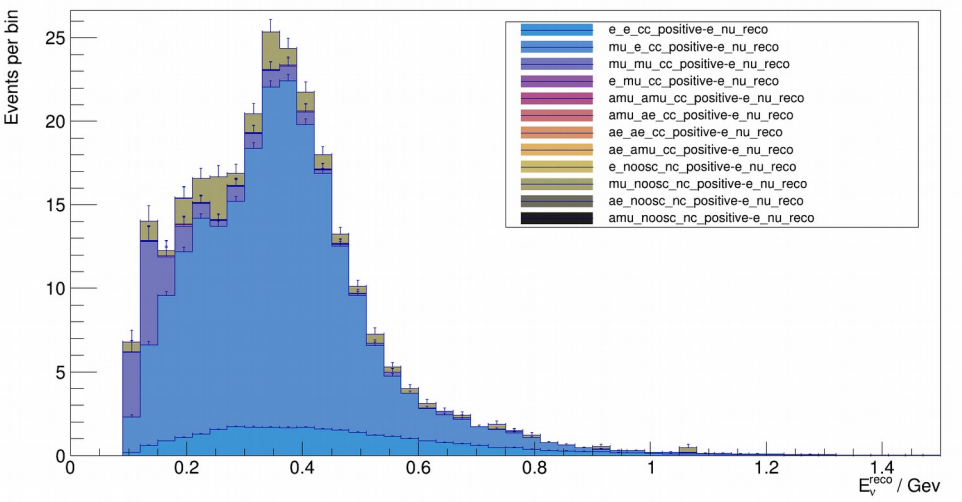
Selected e_nu



e_nu_reco

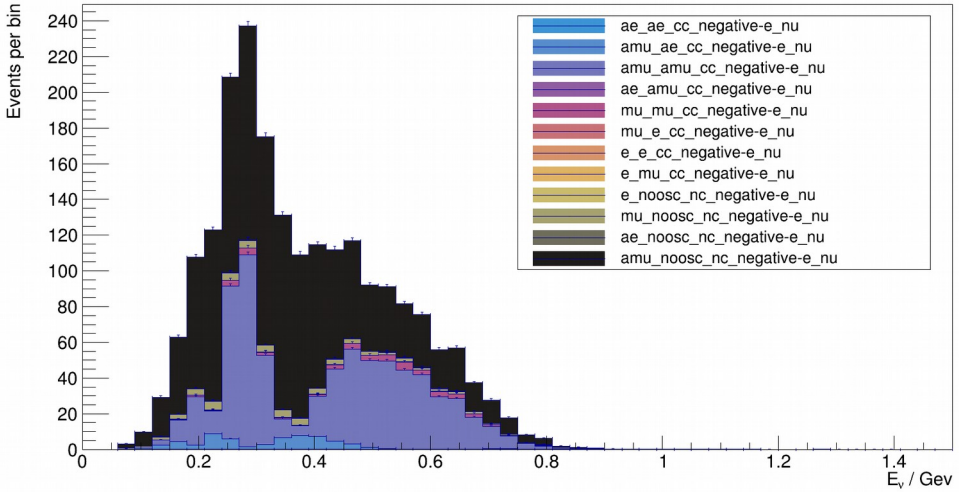


e_nu_reco

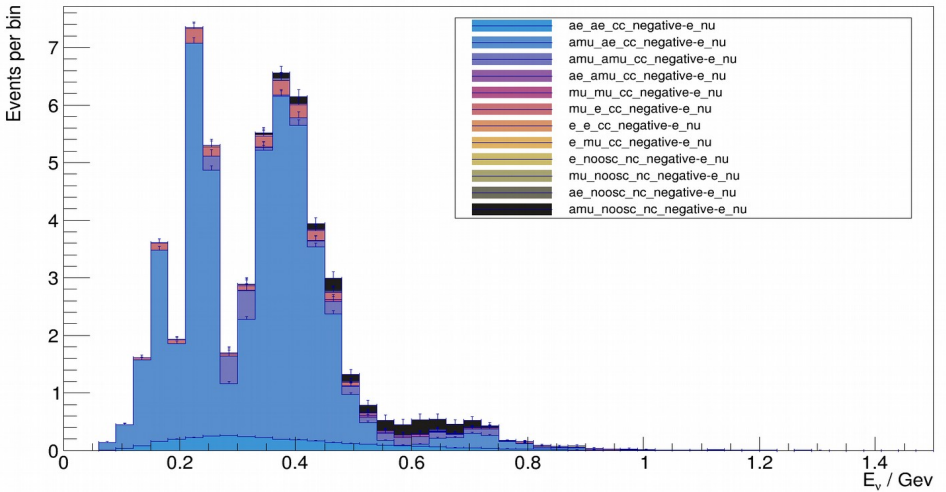


Negative polarity

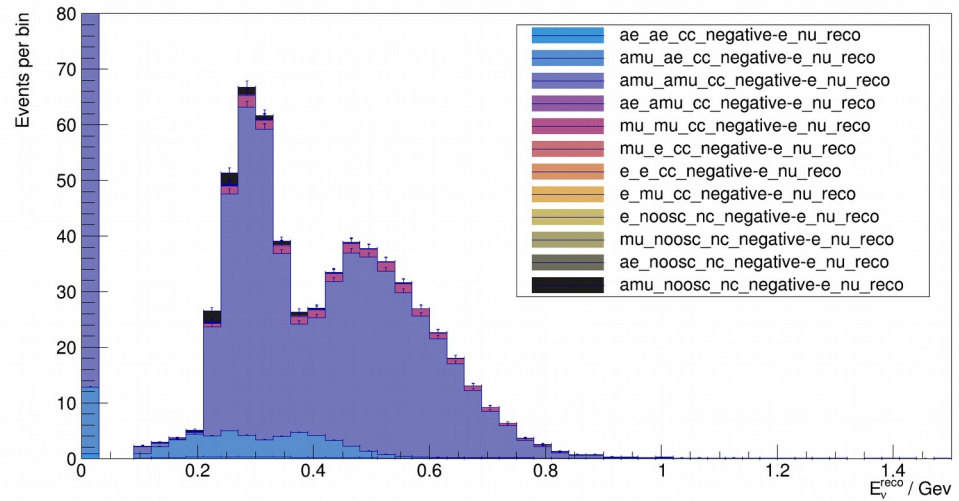
All e_nu



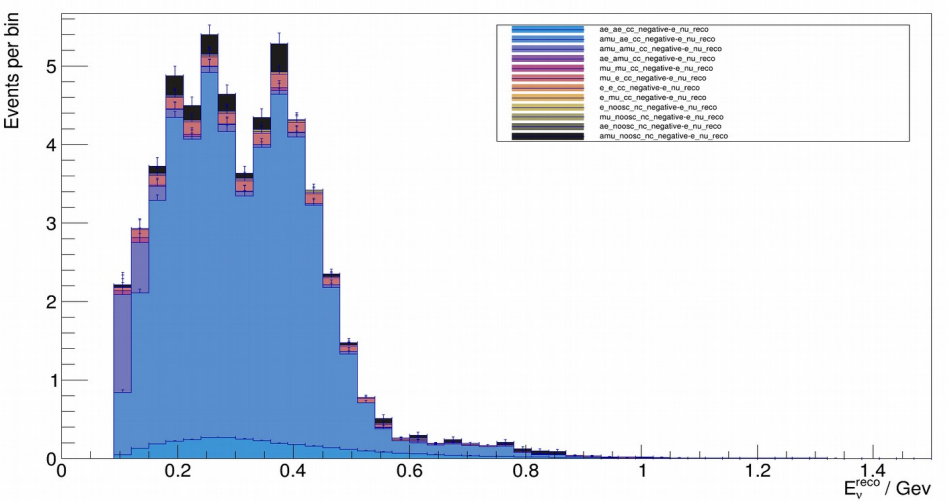
Selected e_nu



e_nu_reco

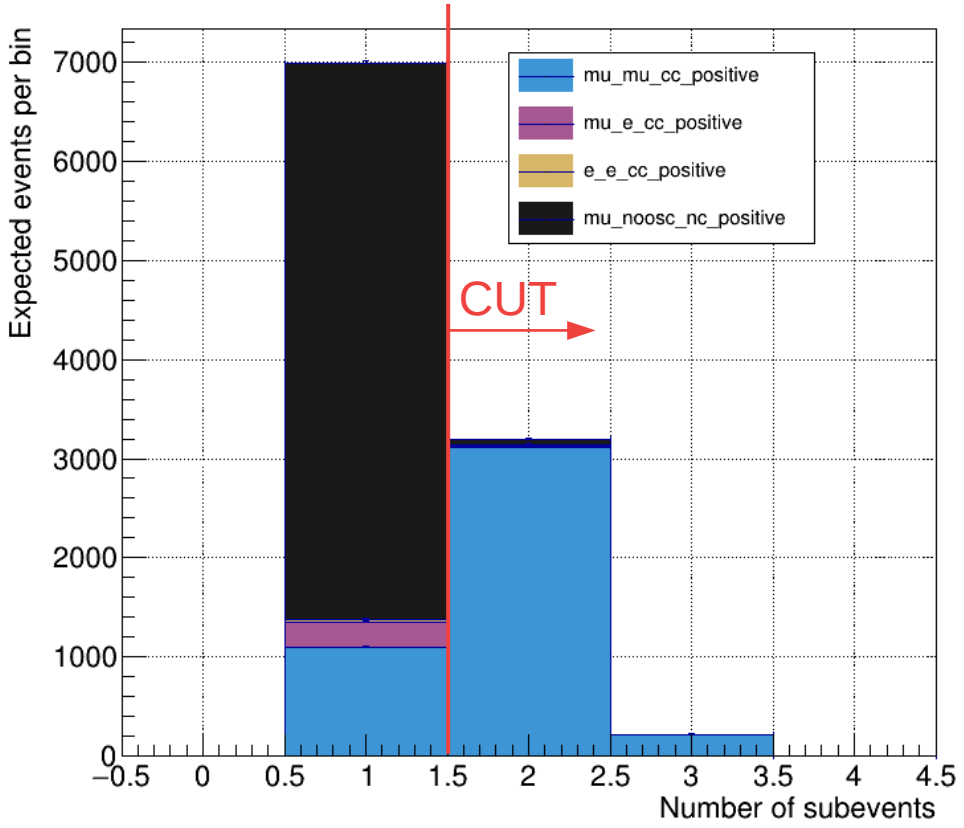


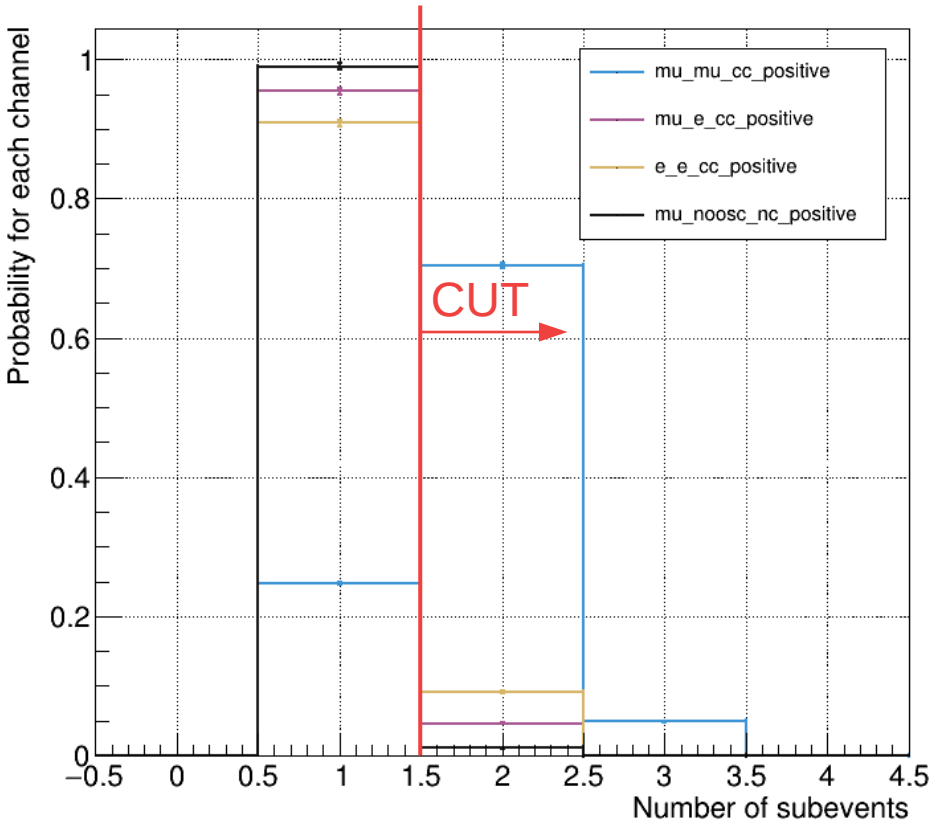
e_nu_reco



Subevent selection

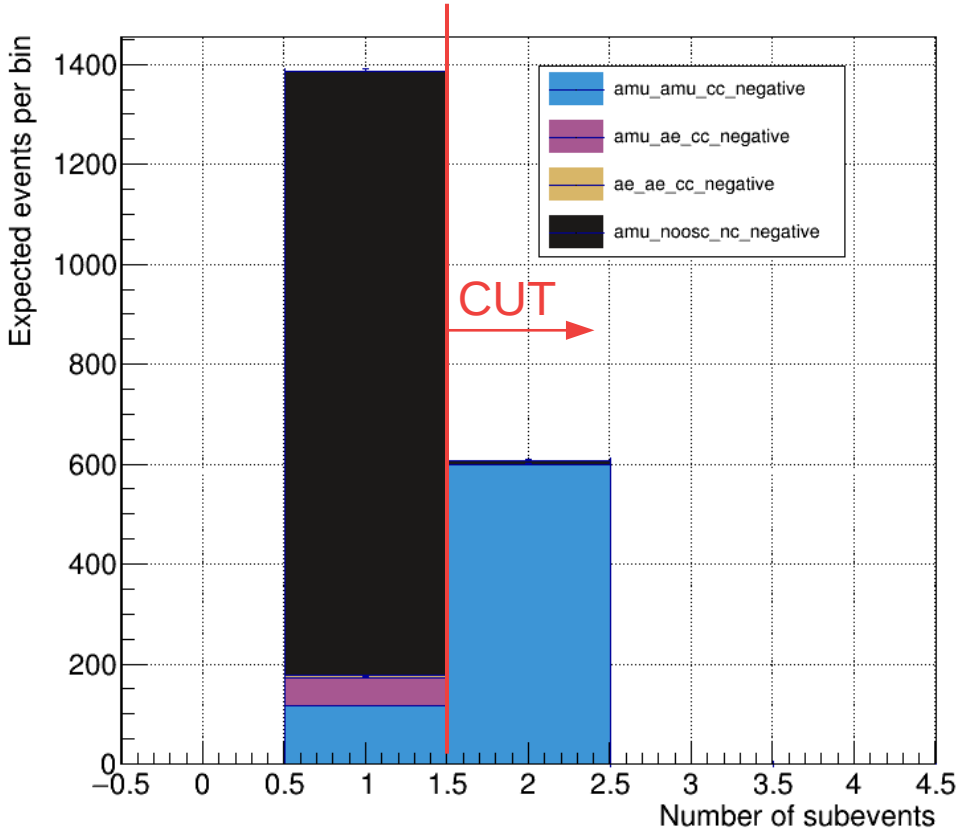
Positive polarity

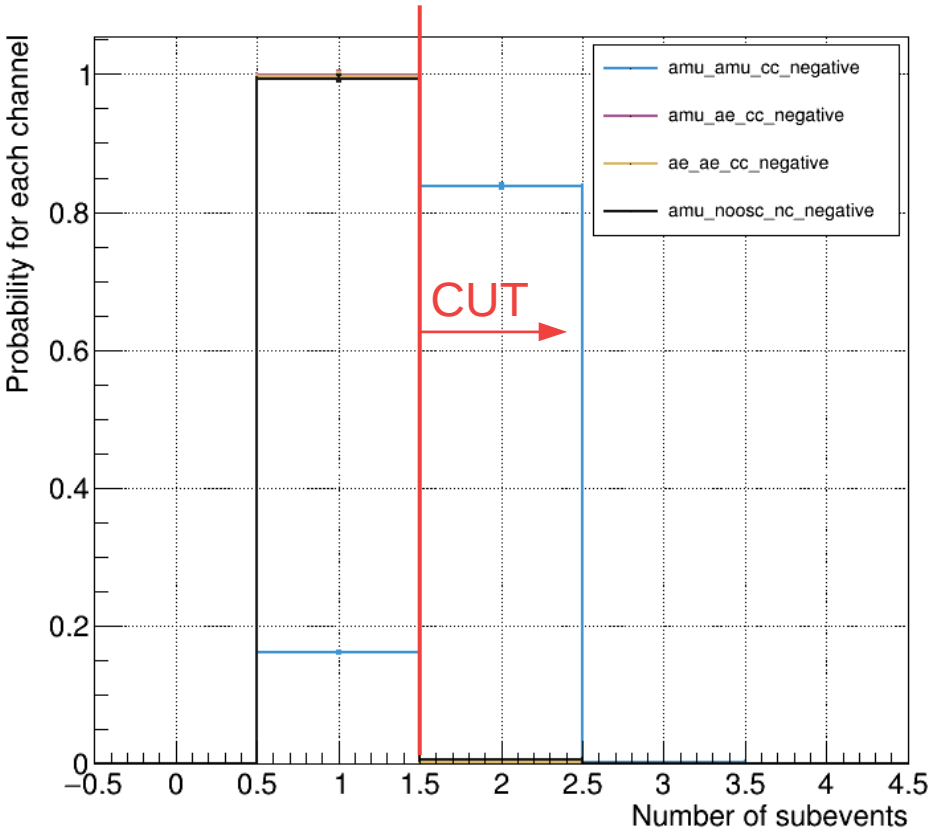




Subevent selection

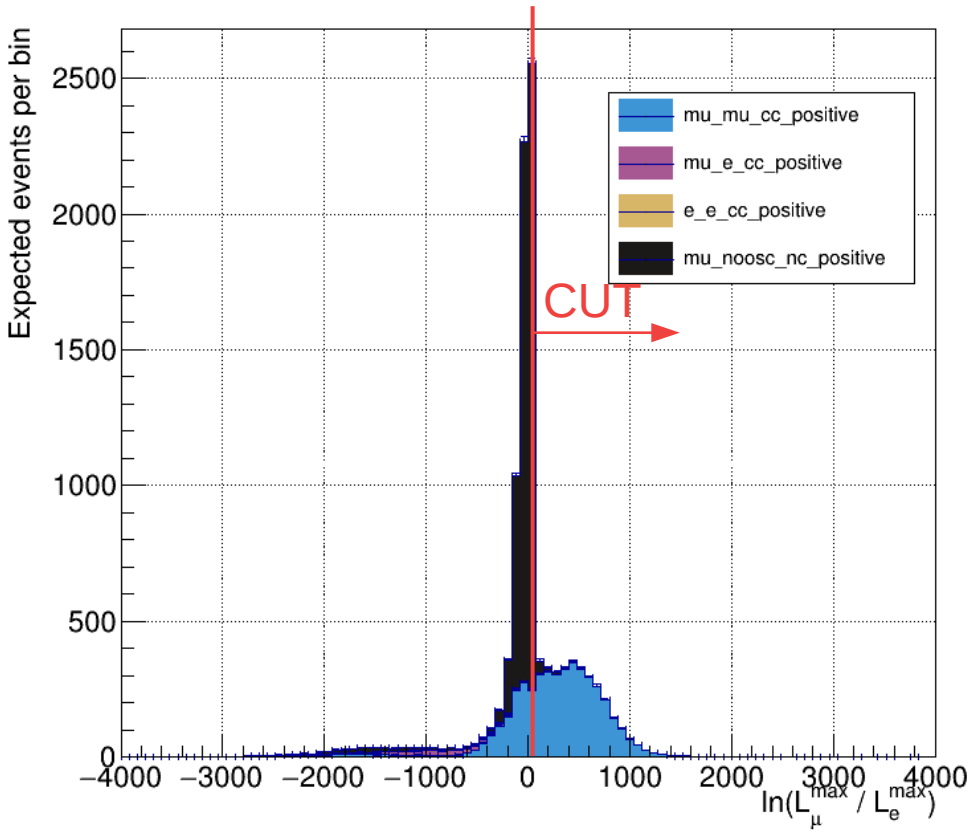
Negative polarity

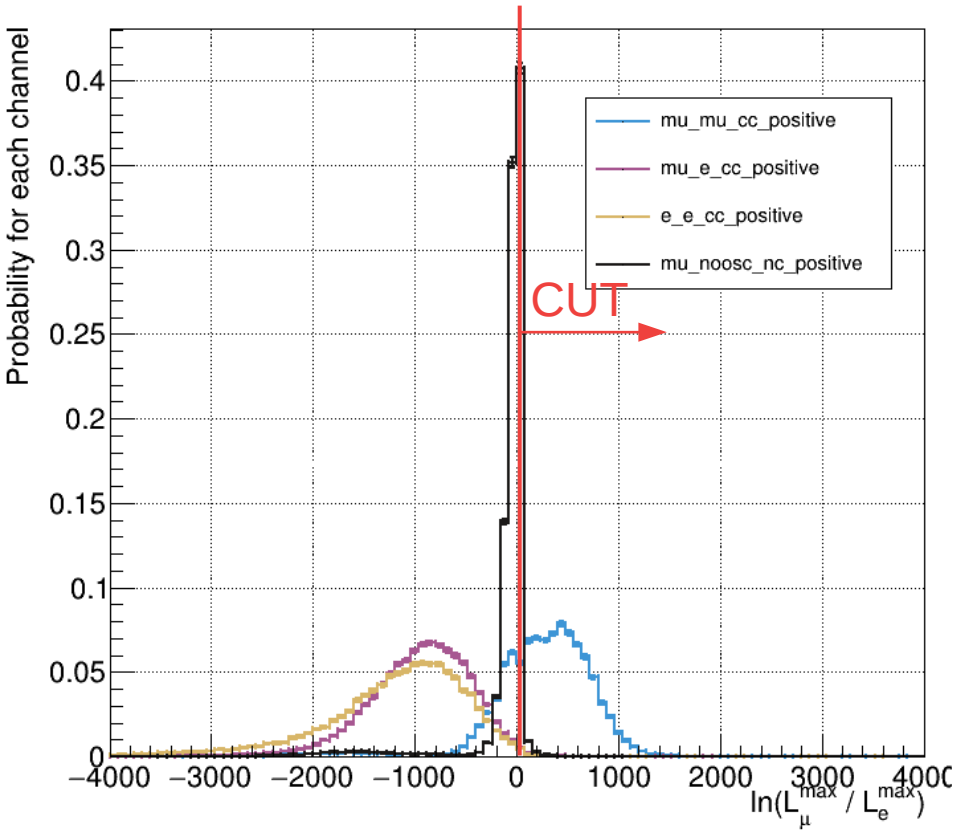




PID selection

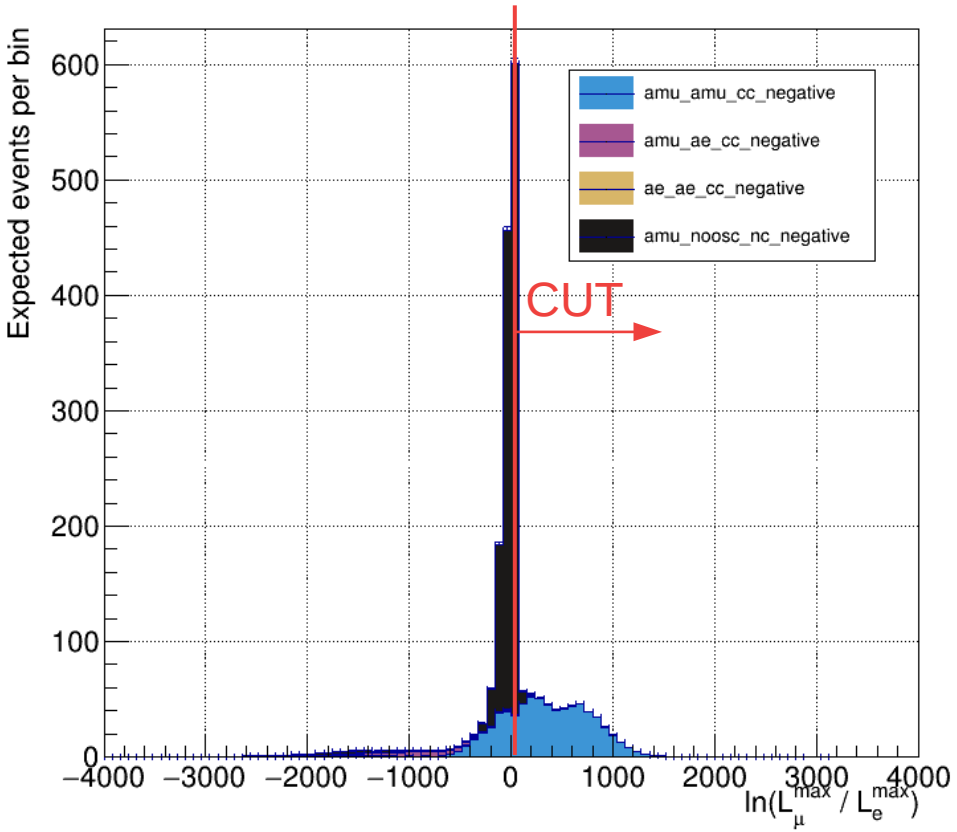
Positive polarity

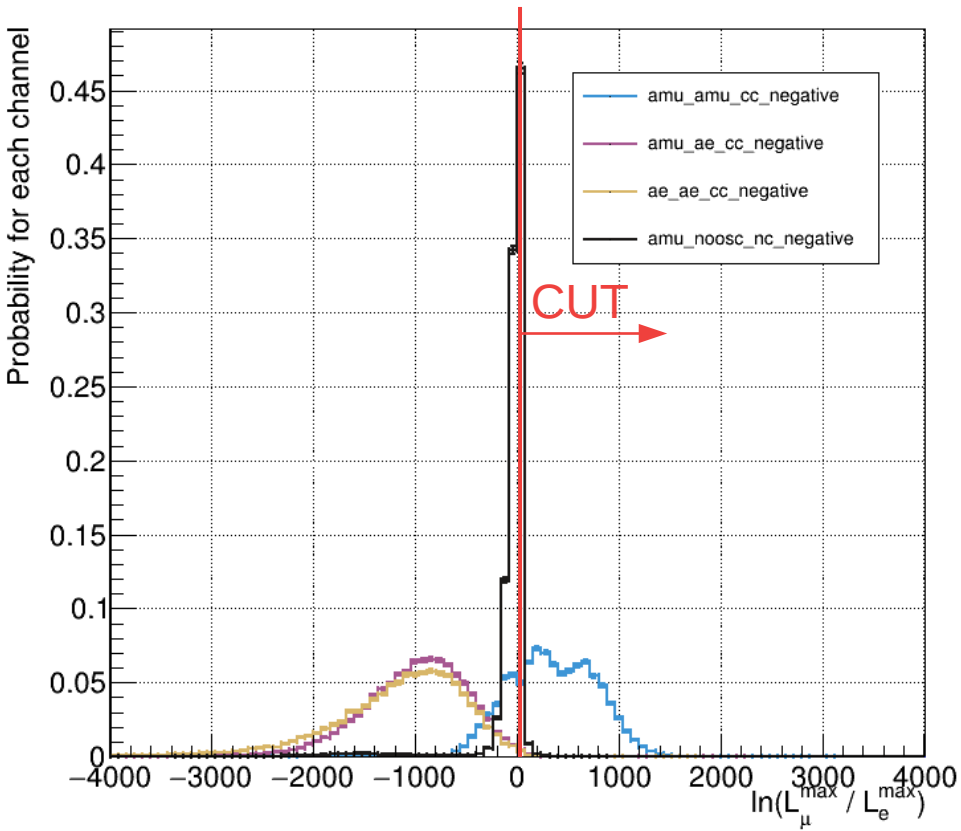




PID selection

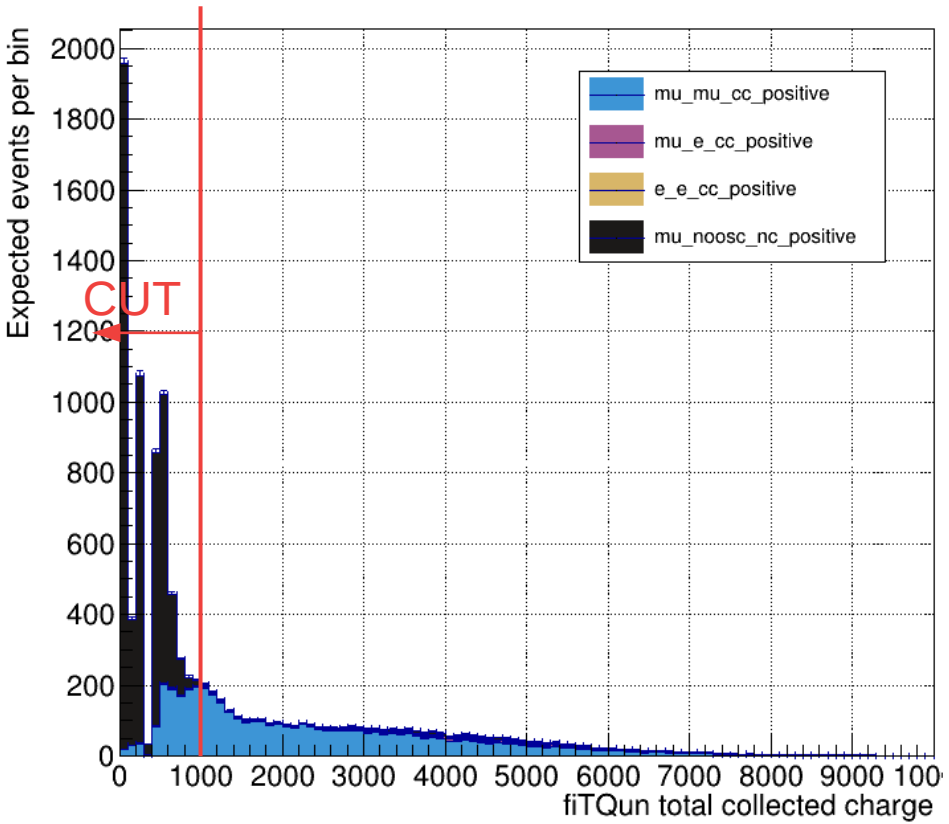
Negative polarity

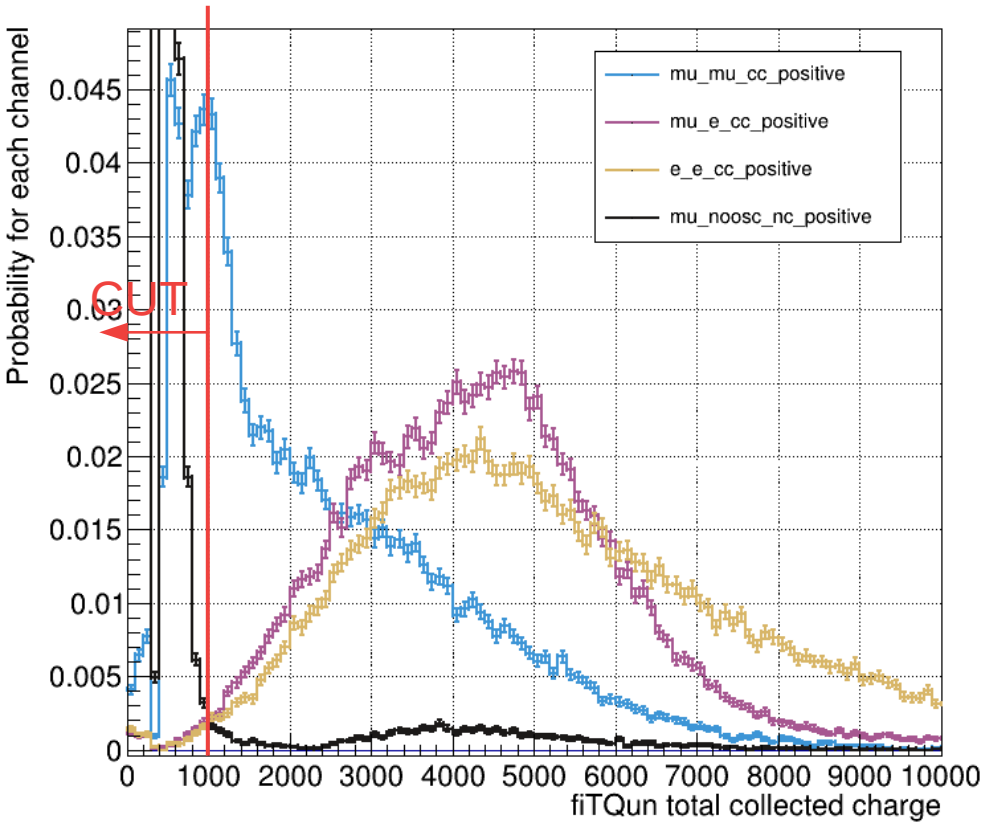




fiTQun collected charge selection

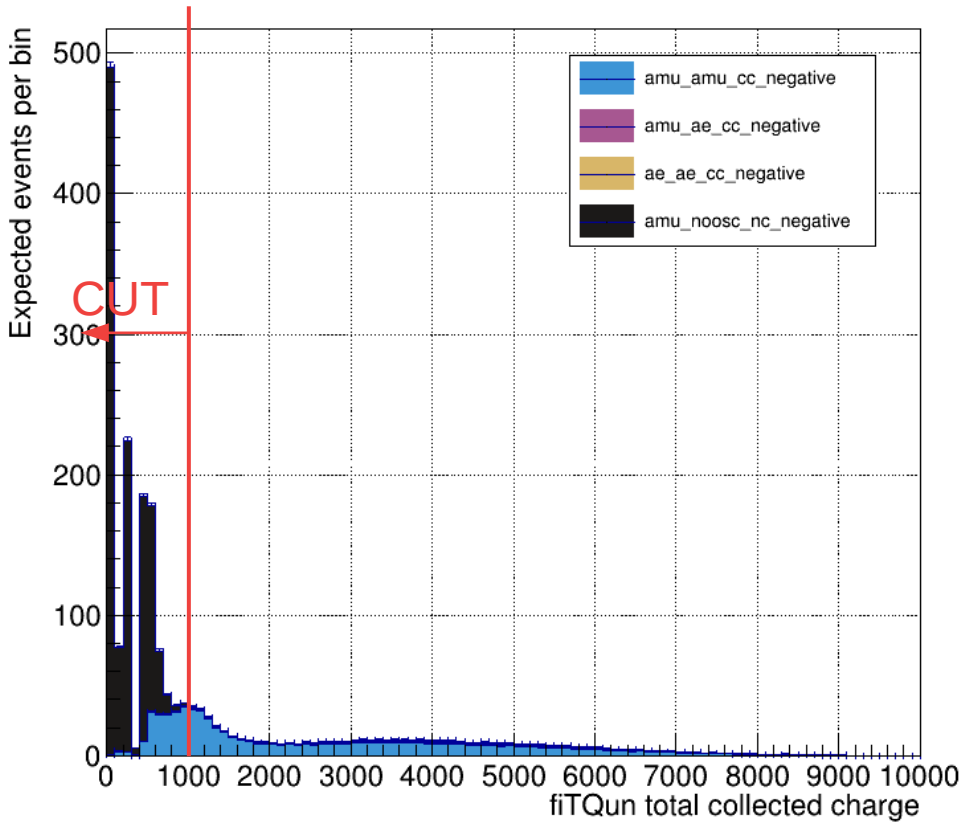
Positive polarity

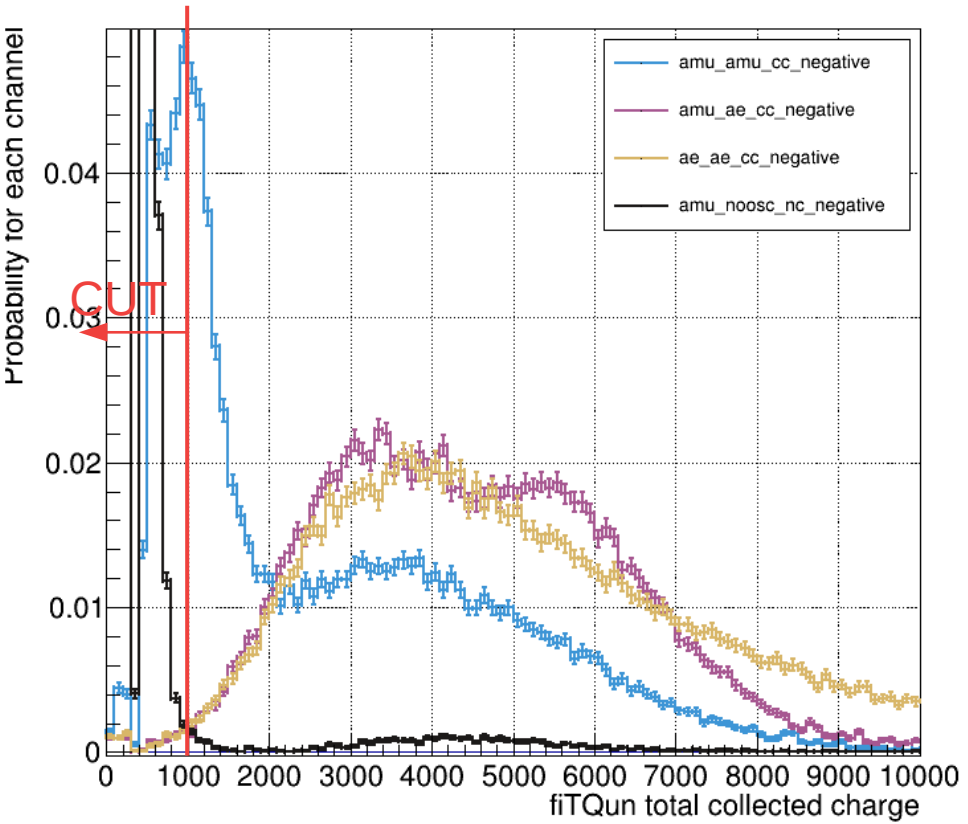




fiTQun collected charge selection

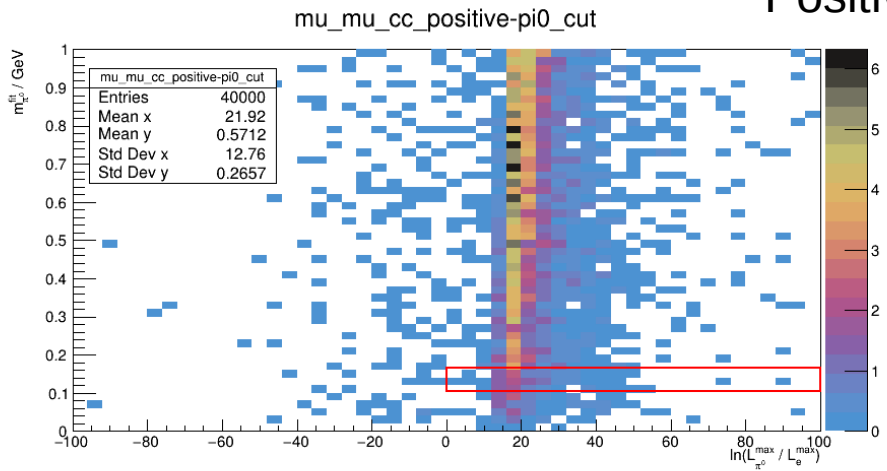
Negative polarity

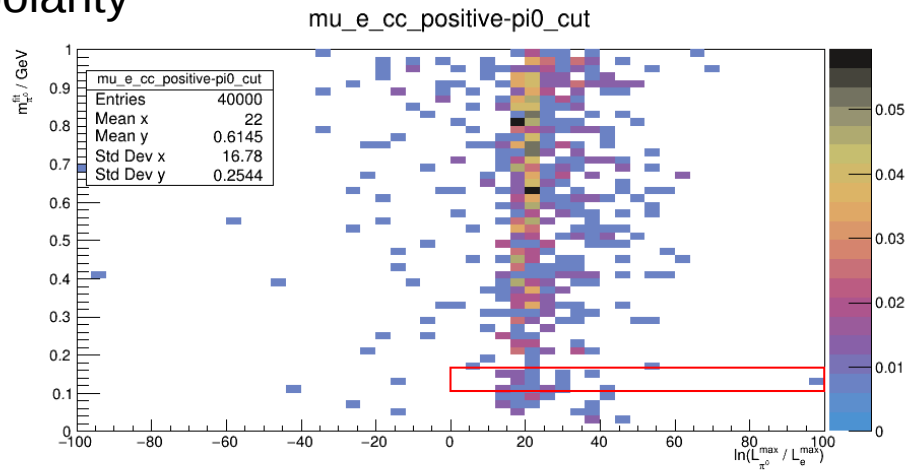


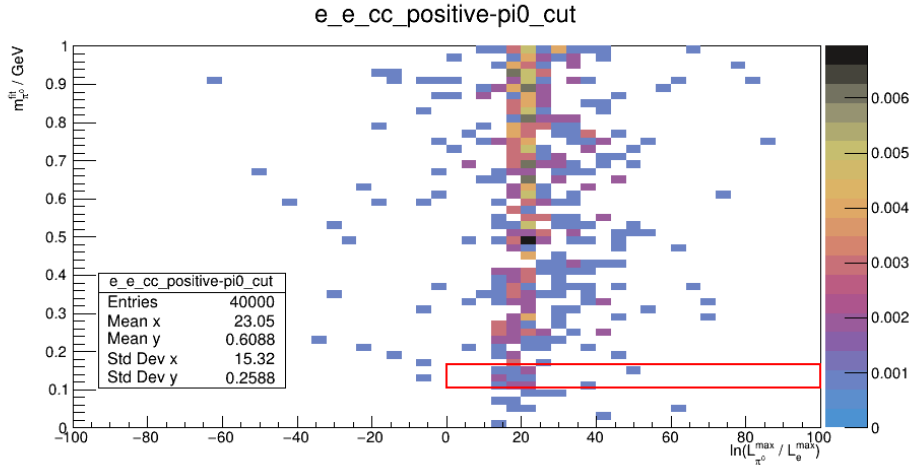


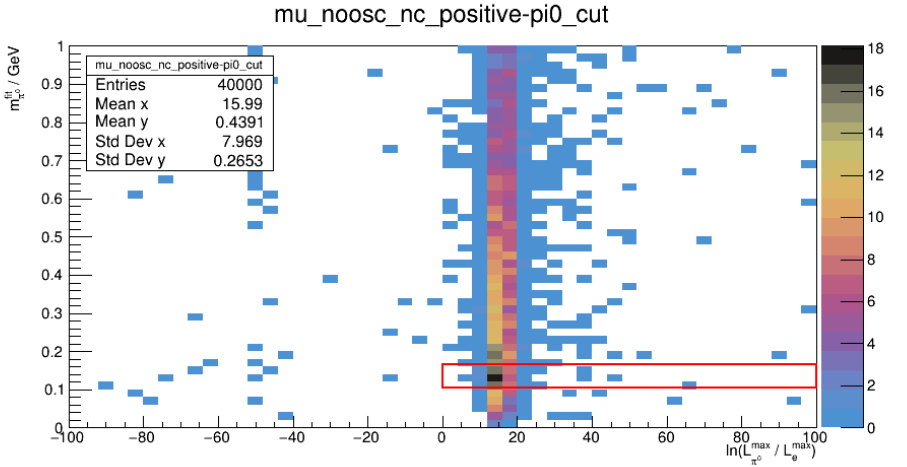
pi0 cut

Positive polarity



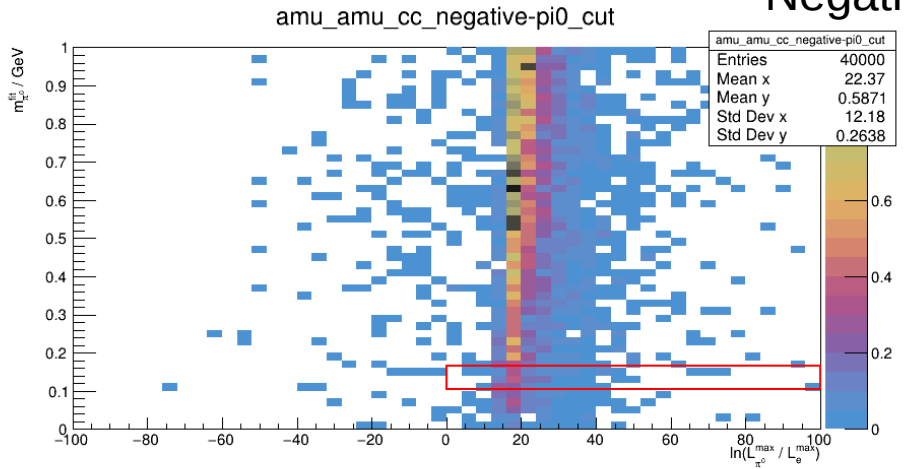


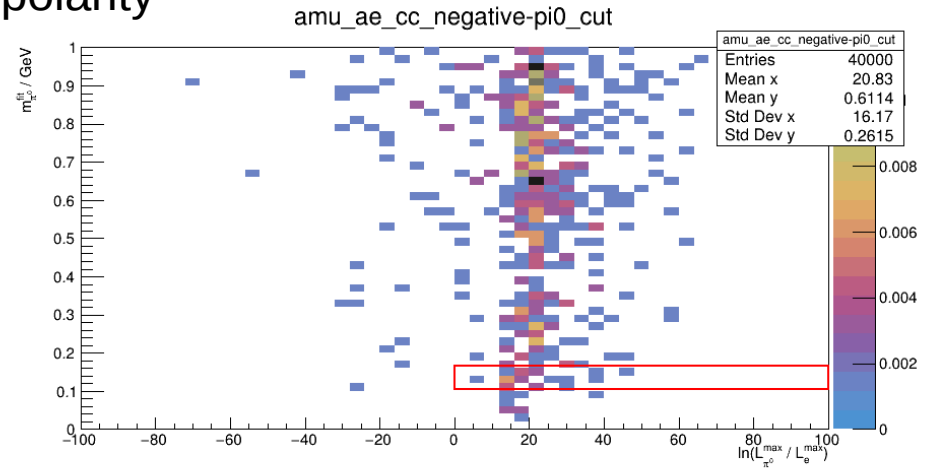


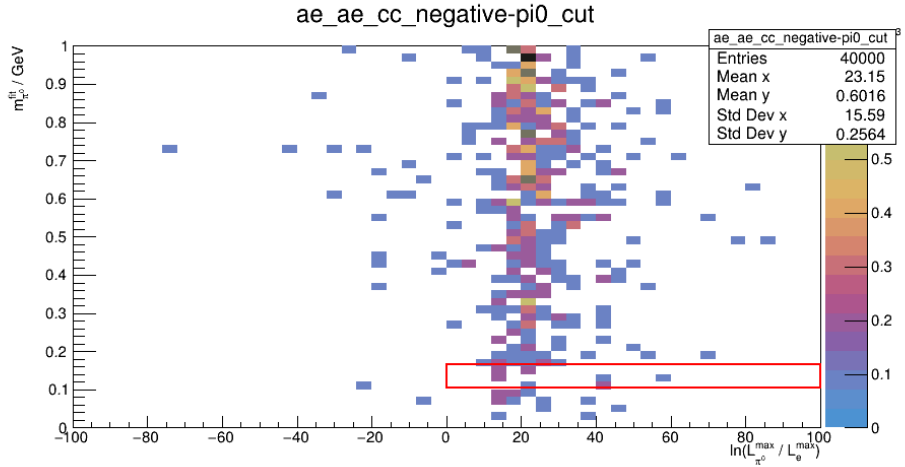


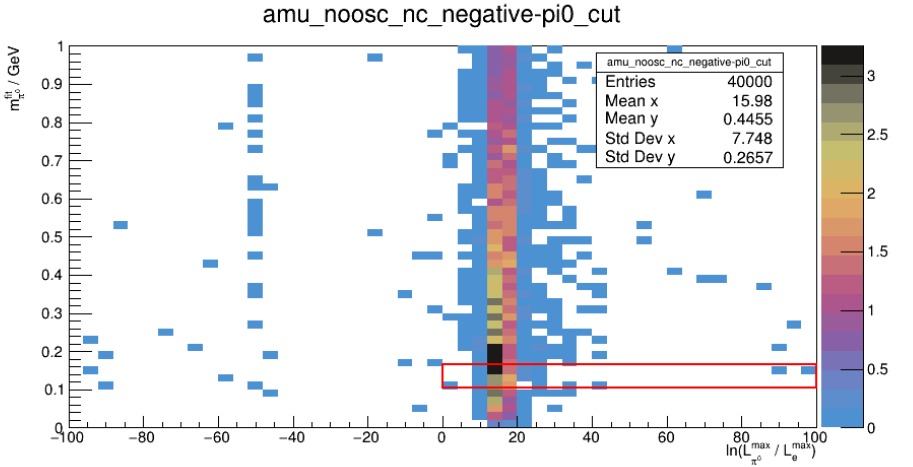
pi0 cut

Negative polarity



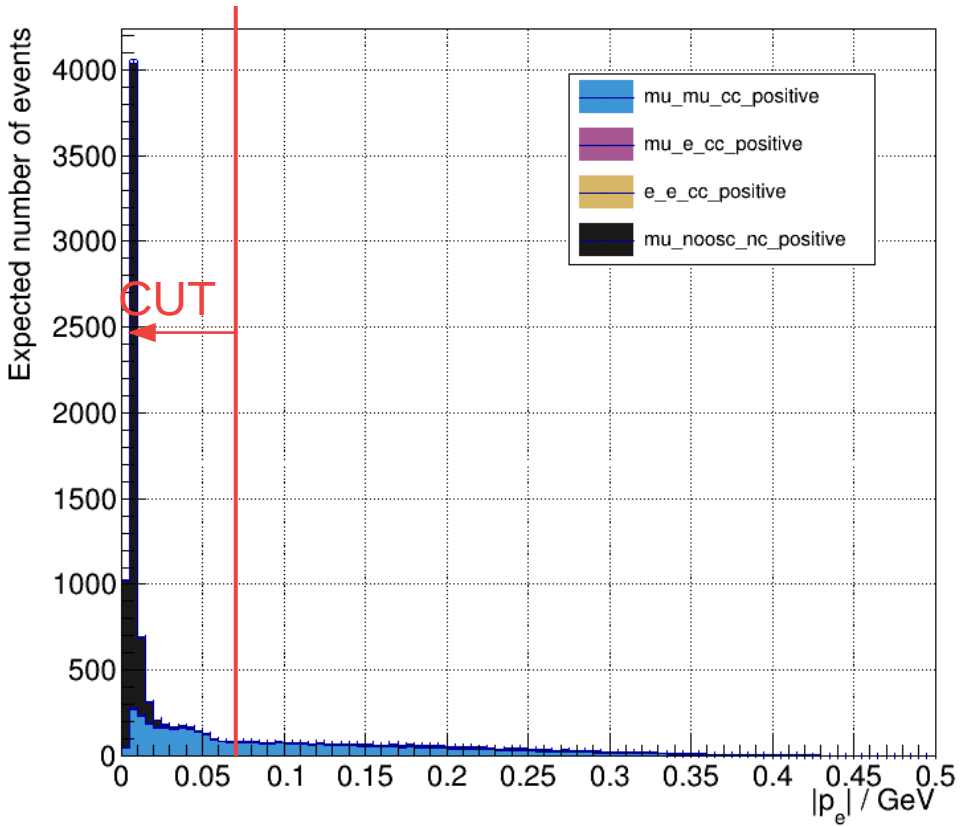


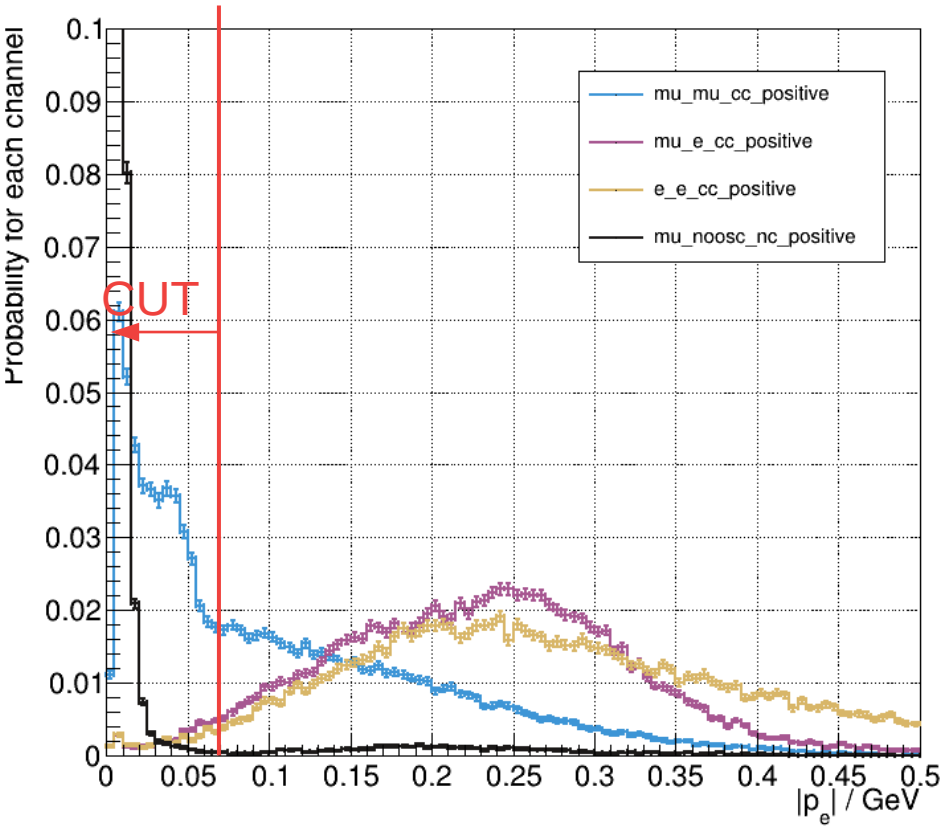




Electron momentum selection

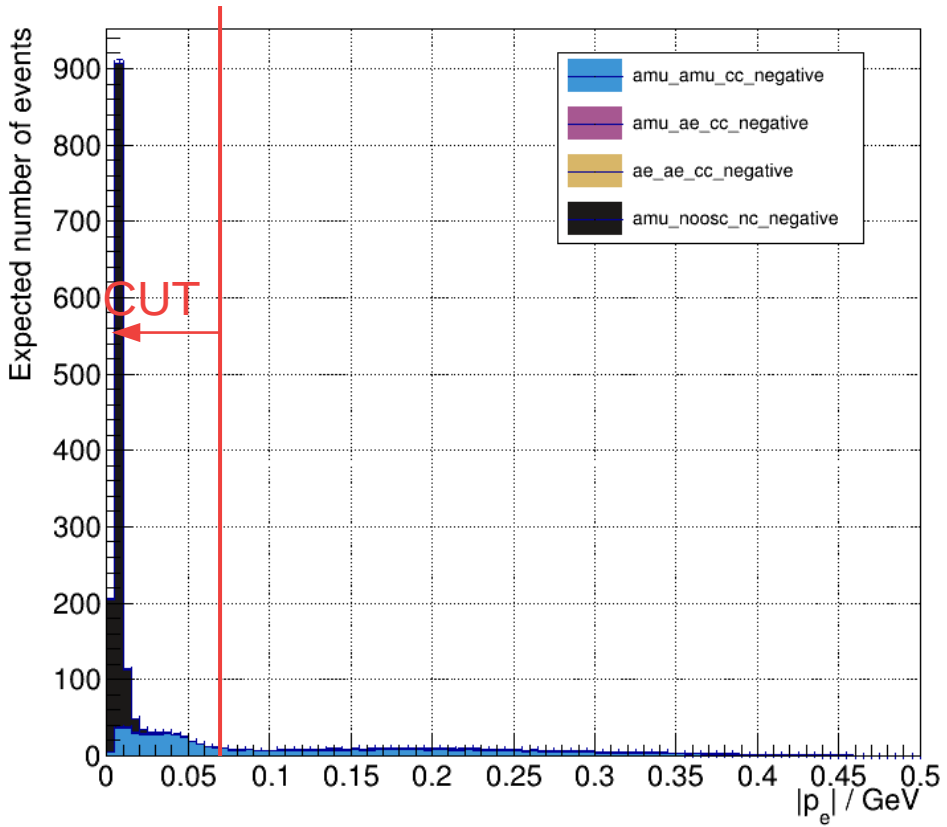
Positive polarity

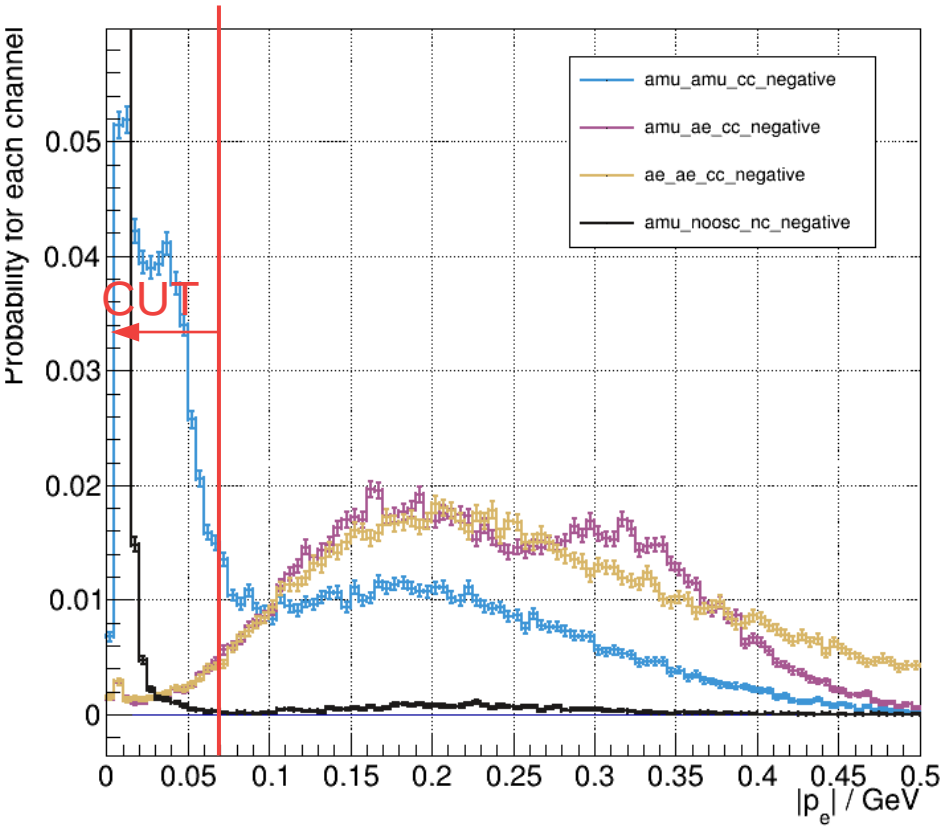




Electron momentum selection

Negative polarity





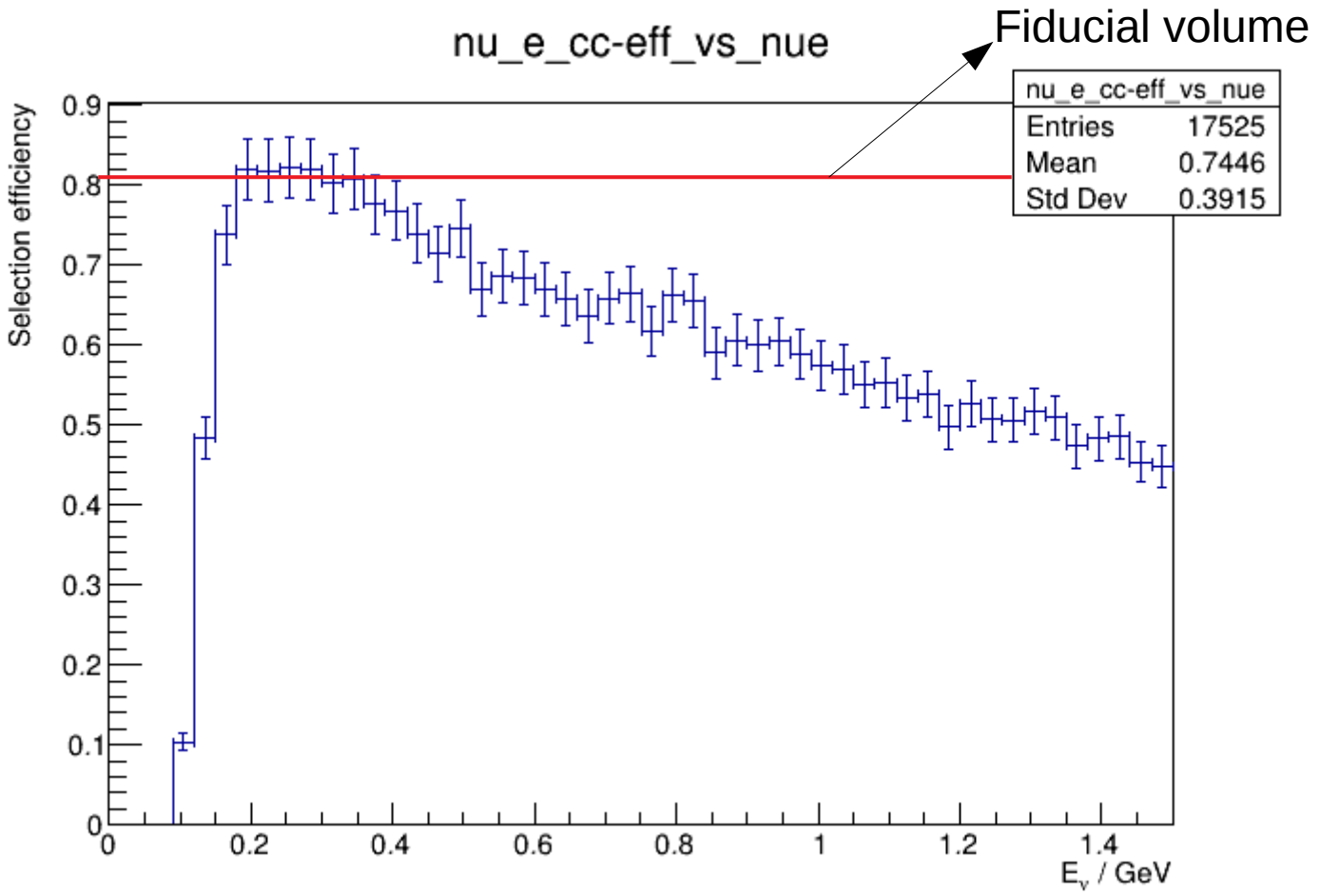
Positive polarity selection breakdown

	$\nu_\mu \rightarrow \nu_e$		$\nu_\mu \rightarrow \nu_\mu$		ν_μ NC	
	Events	Part total	Events	Part total	Events	Part total
Interactions	263.52	1.0	4432	1.0	5664	1.0
Fiducial cut	218.2	0.83	3668	0.83	3111	0.55
Subevents = 1	208.2	0.79	825	0.19	3060	0.54
PID	207.4	0.78	353	0.08	2763	0.49
Total collected charge	206.7	0.78	176	0.04	206.3	0.03
pi0 cut	202.8	0.77	162	0.04	27.33	0.005
electron momentum	199.7	0.75	21	0.005	18.4	0.003

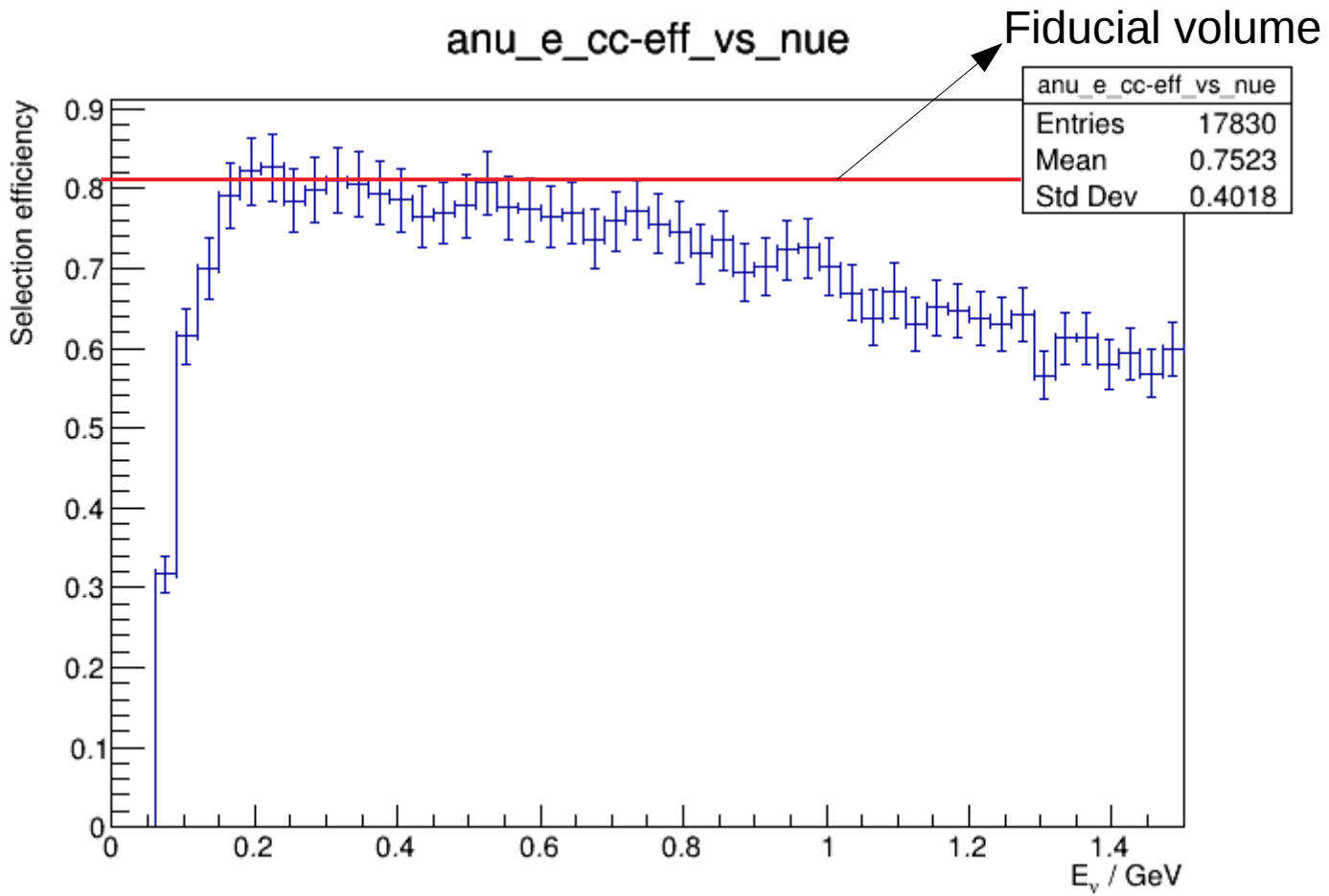
Negative polarity

	$\bar{\nu}_\mu \rightarrow \nu_e$		$\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$		$\bar{\nu}_\mu$ NC	
	Events	Part total	Events	Part total	Events	Part total
Interactions	58.0	1.0	714	1.0	1216	1.0
Fiducial cut	47.9	0.83	593	0.83	609	0.50
Subevents = 1	47.8	0.83	80.0	0.11	602	0.49
PID	47.7	0.82	53.9	0.08	541	0.44
Total collected charge	47.5	0.82	31.5	0.04	29.8	0.02
pi0 cut	46.7	0.80	31.0	0.04	3.5	0.003
electron momentum	45.9	0.79	2.7	0.004	1.88	0.0015

ν_e selection efficiency

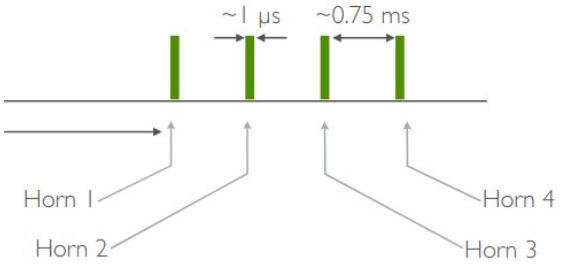


$\bar{\nu}_e$ selection efficiency



Some considerations on ν_e selection

- Compared to previous (EuroNu?) selection, the efficiency is is better almost by factor two – significant increase in ESSnuSB sensitivity
  - see Monojit's talk
- A few posed questions:
  - Is there a possibility that there is an atmospheric neutrino interaction while we wait for the decay of the muon?
    - No, the probability is < 1.5e-8
  - Could muon decay happen in the next beam bunch?
    - No, the bunches are separeted by 750 us, muon decay constant is 2.2 us



Conclusions

- Event selection at FD optimized for our beam is ready
  - **but,** it is done using HyperK geometry
  - it is significantly better than one currently in use by WP6
- Tuning of fiTQun for our FD geometry is almost ready
  - since HyperK geometry is quite similar to our FD geometry, we do not expect much difference
  - we expect to make first MC productions in the next weeks