Efficiency of IceTop as veto

Delia Tosi

CR parallel session

IceCube Coll Meeting - April 29th 2015

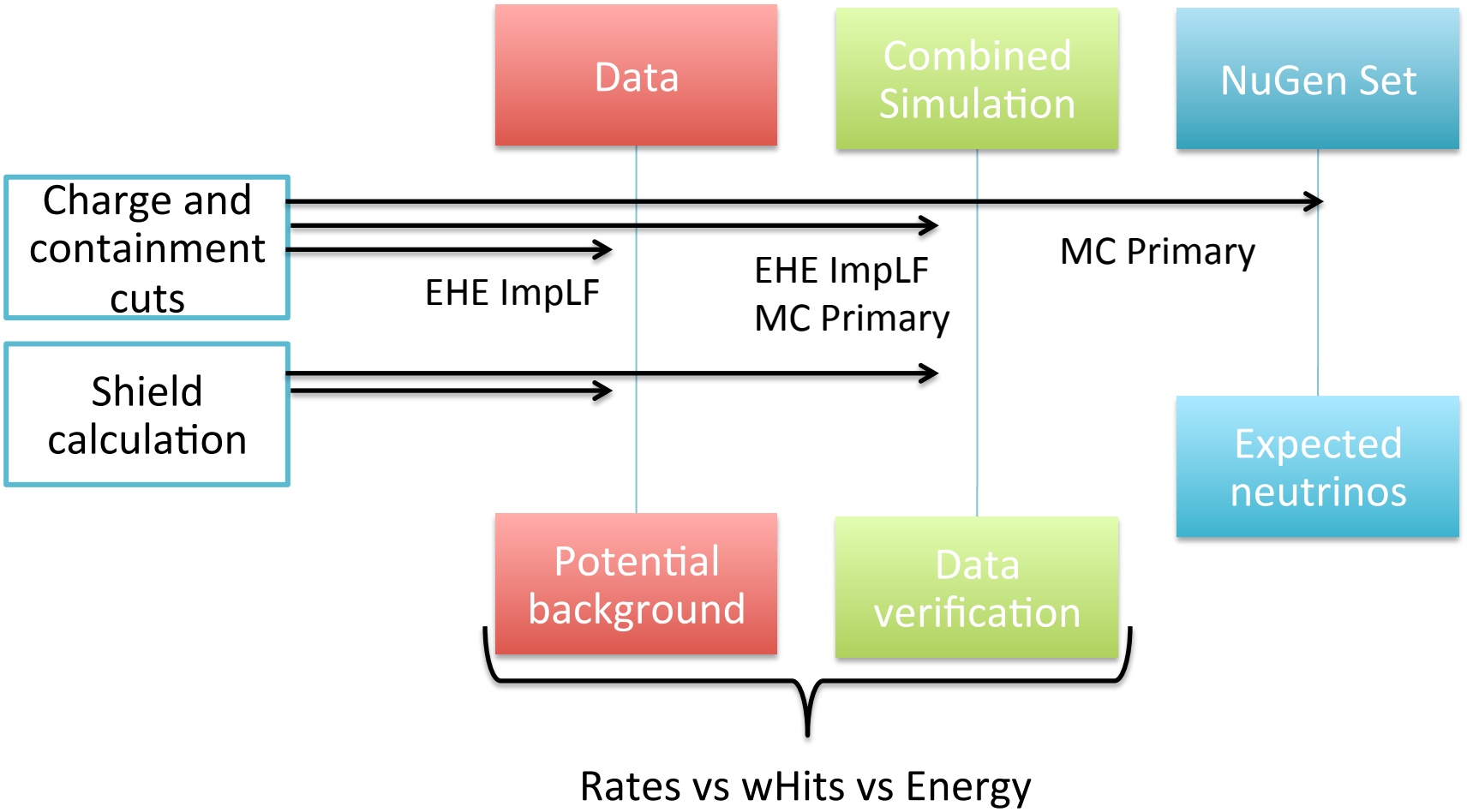
Reminder about this analysis

- Use IceTop as veto to “extend” IceCube volume up to the surface

- It should work, at least, for coincident events within 15 degrees zenith angle

- My goal: find out the real efficiency of IceTop in the most optimistic assumptions

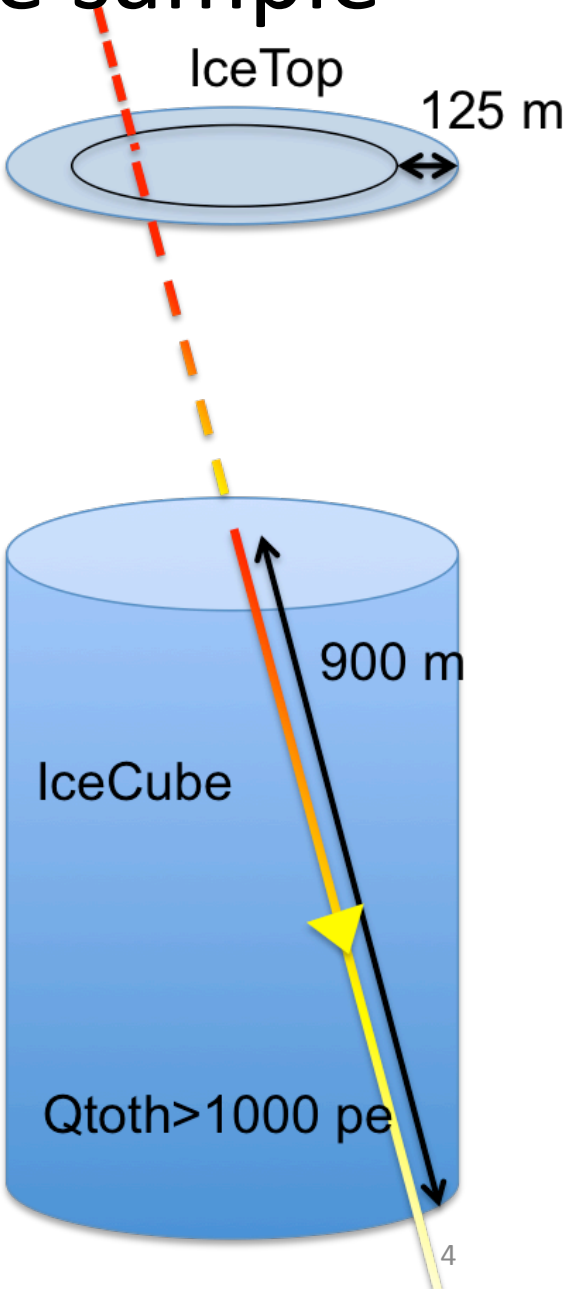
Analysis map



Hard cuts to get a very pure sample

1. "Homogenized total charge"
   Qtoth > 1000 PE
   = total charge minus DOMs with > 50% of total charge (takes off balloon events)
2. Direction: down going
3. Containment: track intersection with IceTop has to be inside IceTop border by 125 m
4. Track length (VHESelfVeto)> 900 m

Fit



Important details

- Which fits?

  → Containment, track length, direction:

  Options: SPEFit, SPEFit12, SPEFit12EHE, MPEFit, LineFit, LineFitEHE, EHEOpheliaParticleSRT_ImpLF…)

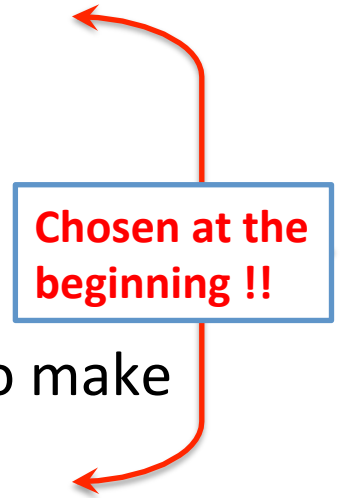
  – Use EHEOpheliaParticleSRT_ImpLF + keep some others.

- Which IceTop hits to use?

  → Shield

  Options: HLCTank, SLC, HLC

  – Use I3HLCTankPulseMerger from topeventcleaning to make SLCTank hits and use HLCTank+SLCTank



Likelihood for a hit to belong to a shower

- Calculate expected arrival time of shower and compare to time of hits in IceTop tanks
  → difference: "residual time"

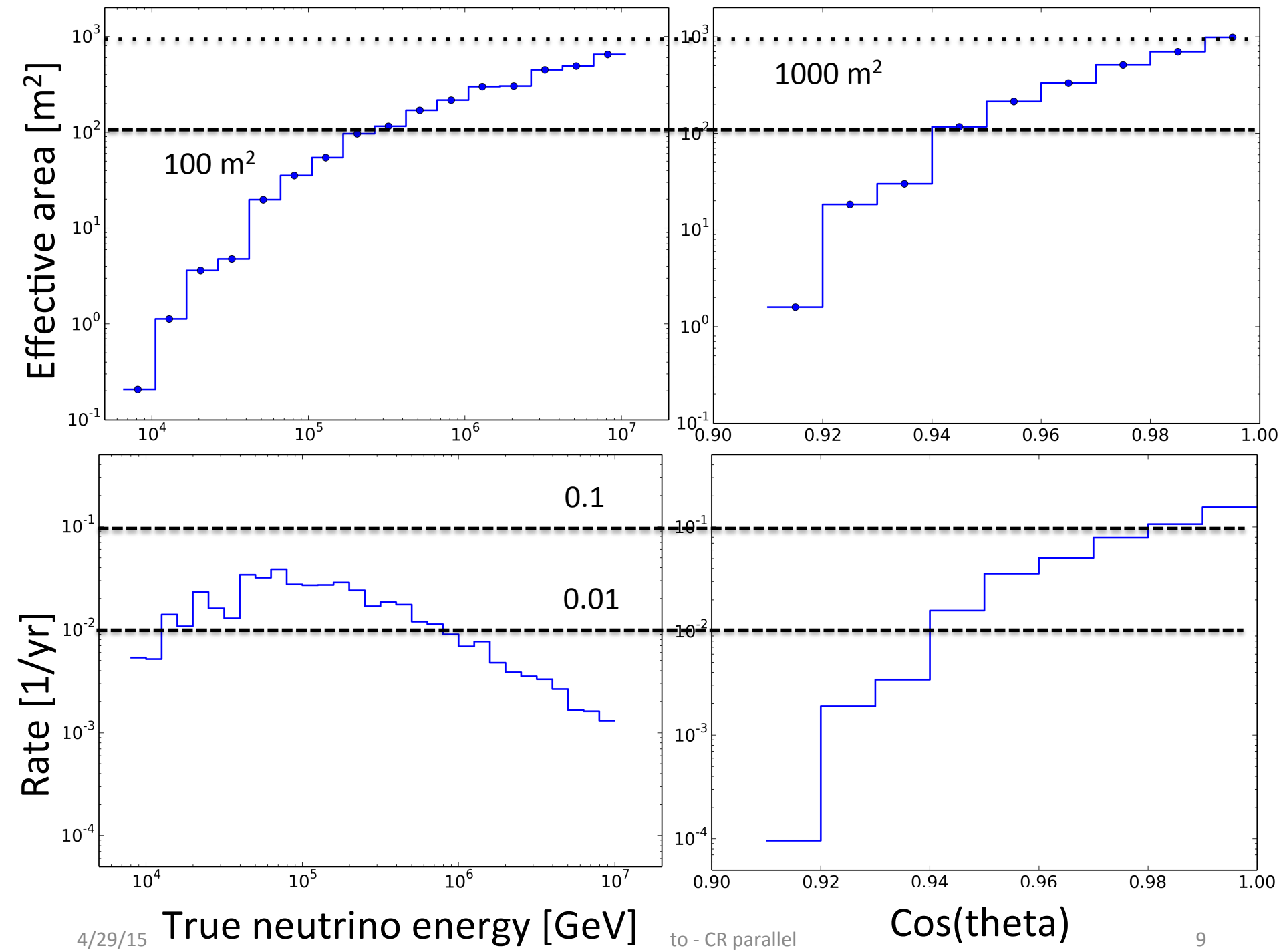
- Use the distribution of times as template to weigh hits according to their probability to be related to a shower

- Look at how many events we have vs weighted IceTop hits vs energy (MuEx)

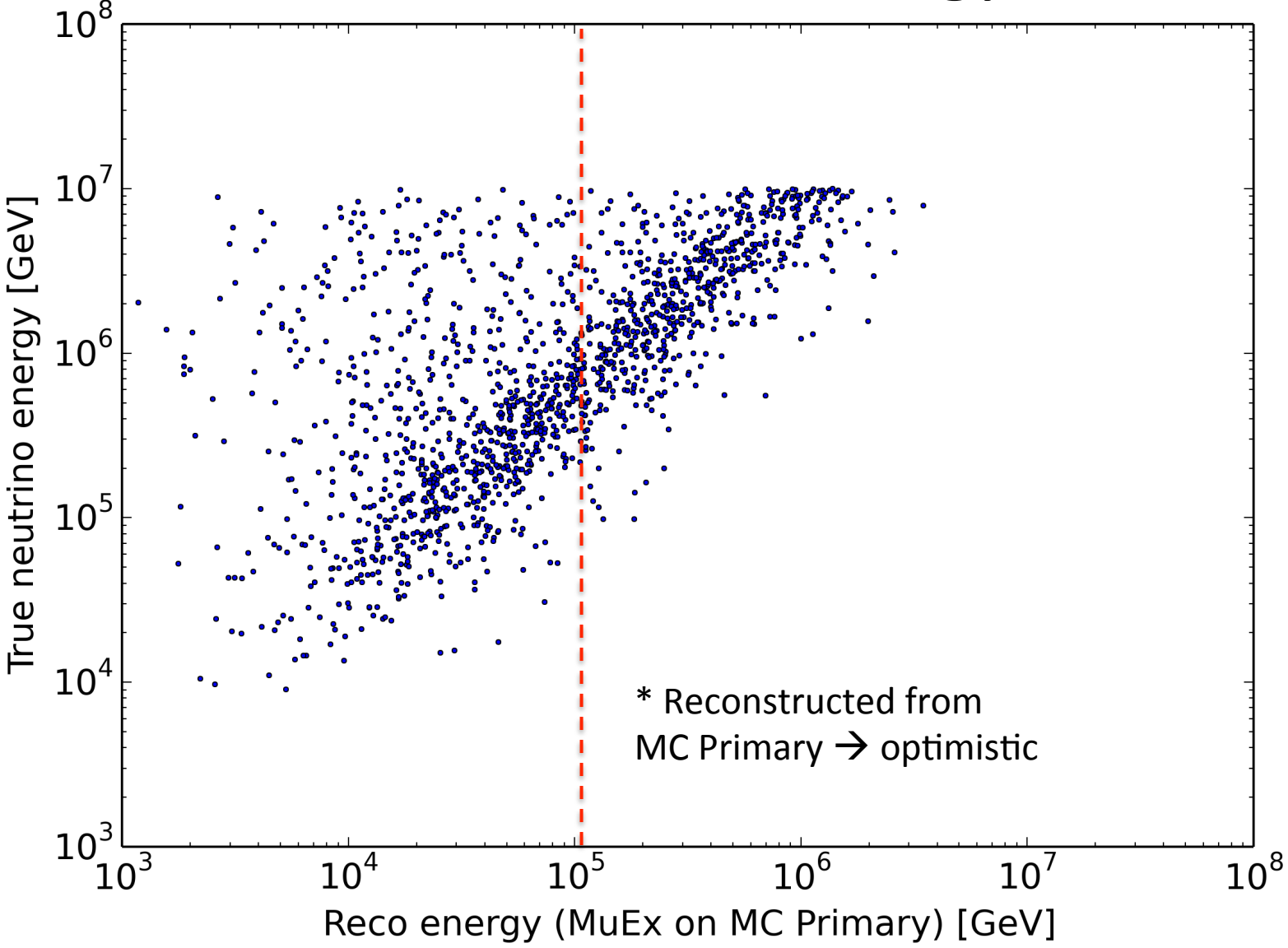
Signal

How many neutrinos do we expect?

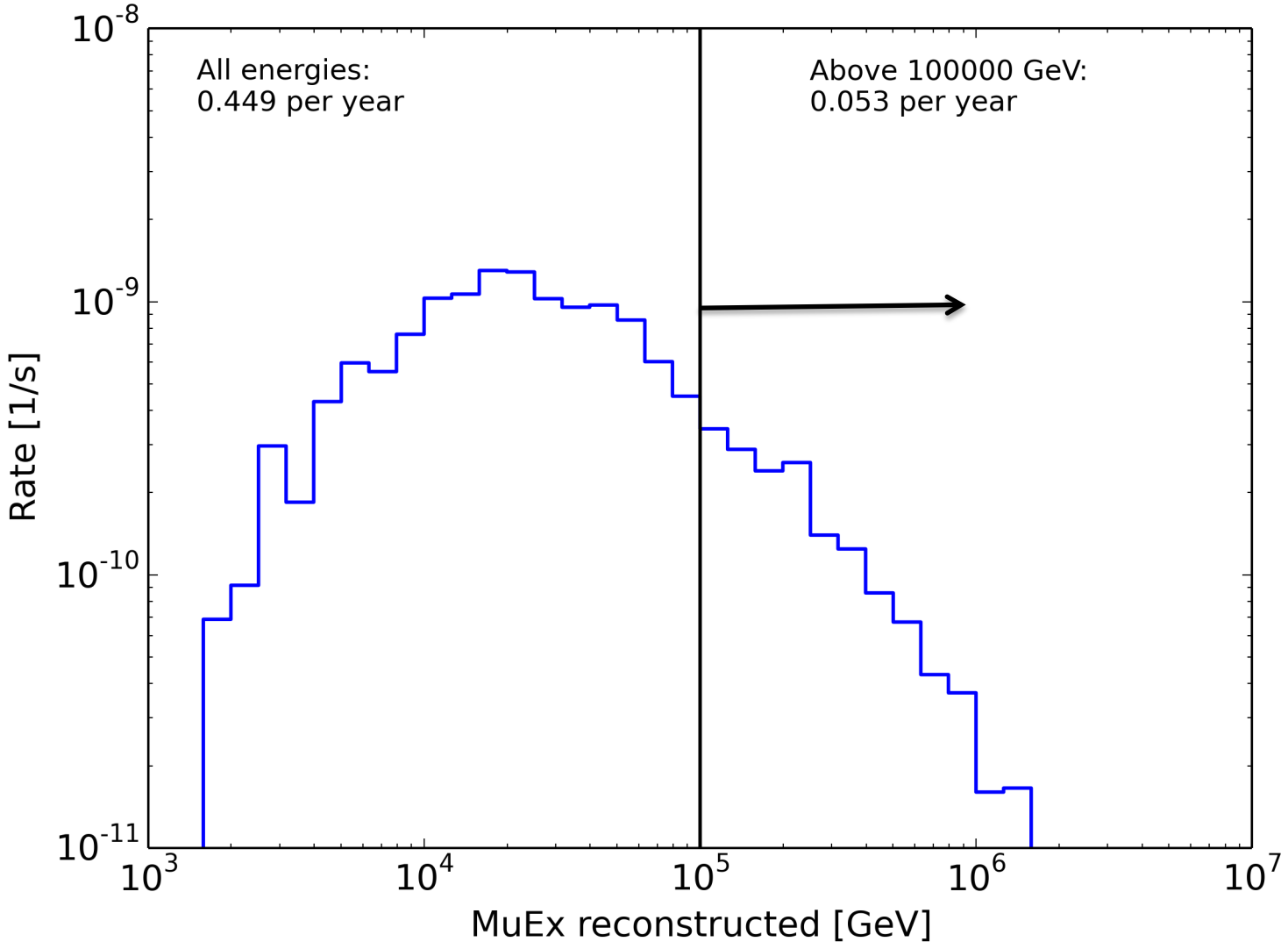
- NuGen dataset 10634:
  - SPICEMie HybridCLSim
  - Angular range of 0. deg < theta < 180. deg
  - energy range of 10^2 GeV < Enu < 10^7 GeV.
- Re-weighted to astrophysical flux (HESE 3yrs)
- Use MC Primary information to reconstruct energy (not a fit → OPTIMISTIC!)
- Apply identical cuts for containment, count events


Effective area [m²]
100 m²
1000 m²
Rate [1/yr]
0.1
0.01
True neutrino energy [GeV]
Cos(theta)

Relationship between true neutrino energy and reconstructed* energy



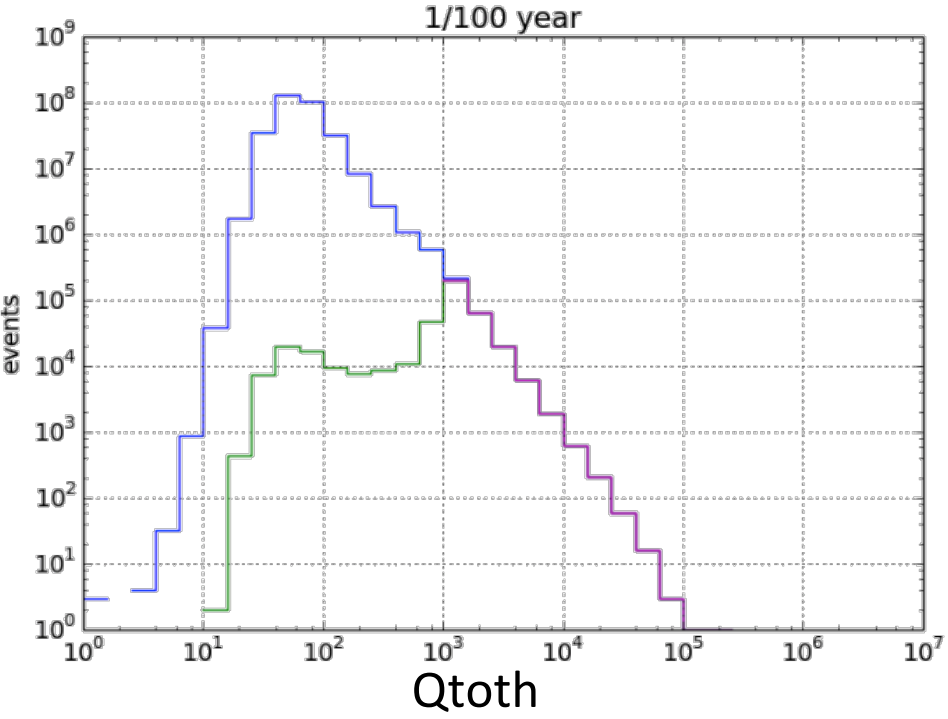
Counting neutrinos above certain energy proxy



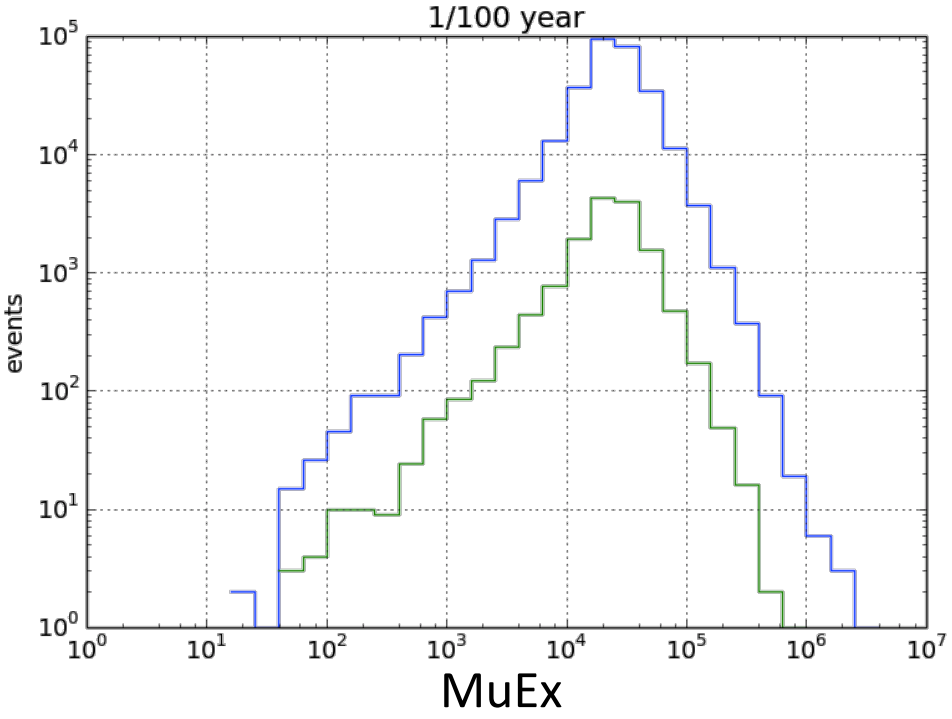
Data: burn sample 2012-13-14 (0.26 years, 96 days)

Rates reduction by cuts (projected to one year)

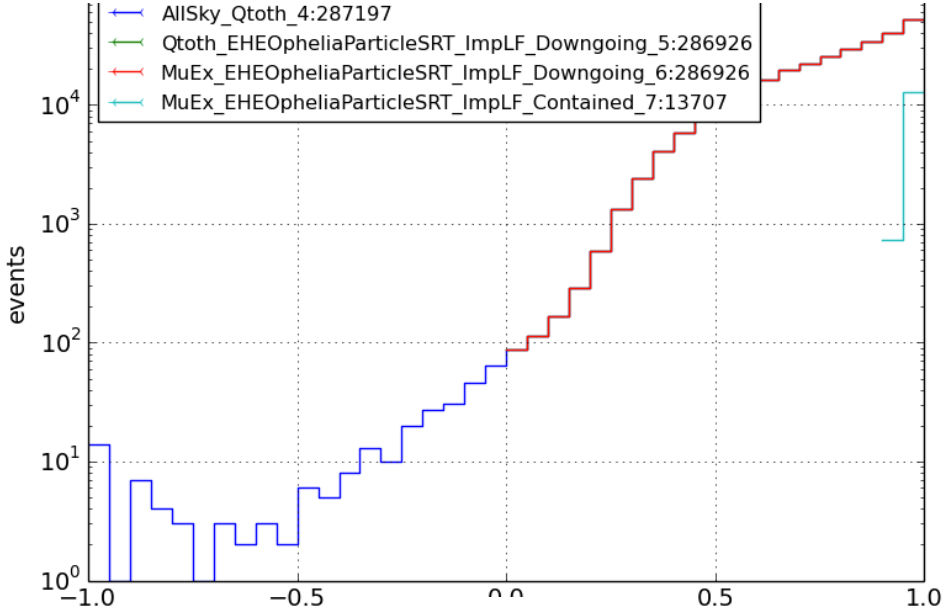
Cut	# events in 1 year	Passing fraction	
L2, no cuts	3 Billion	100%	
Qtoth > 1000 pe	30 Million	1%	100%
Downgoing	~30 Million	~1%	99.9%
Contained	1.4 Million	0.046%	4.6%



Qtoth

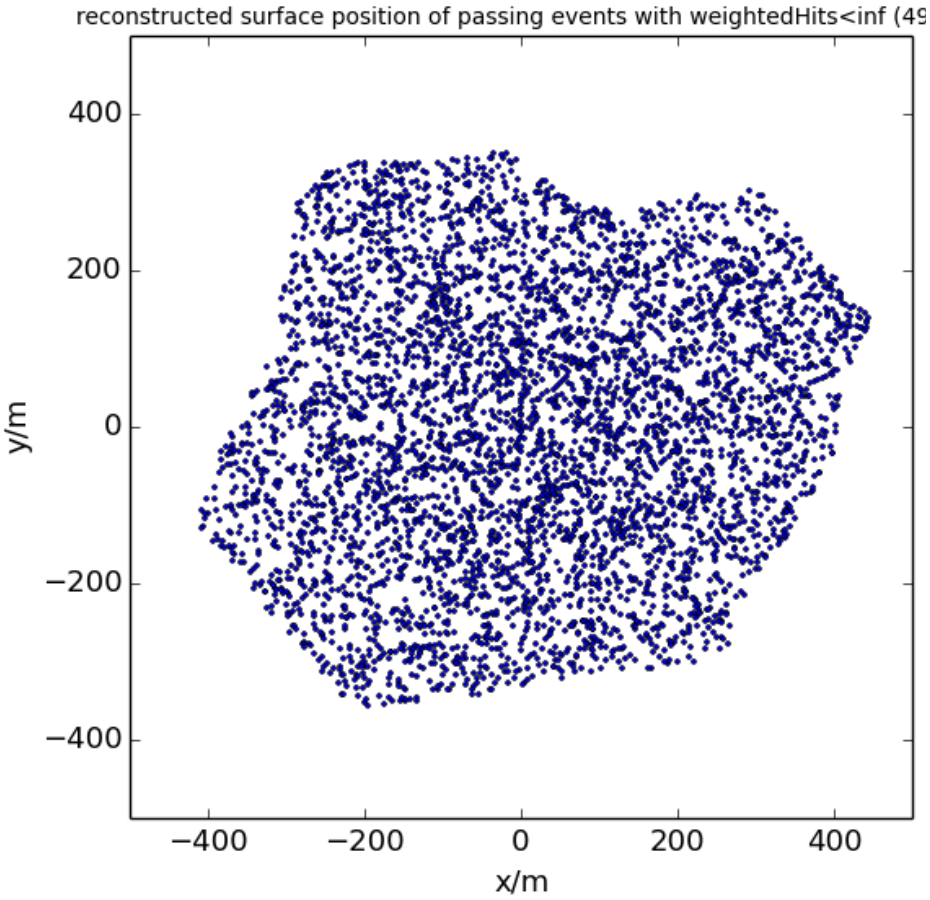


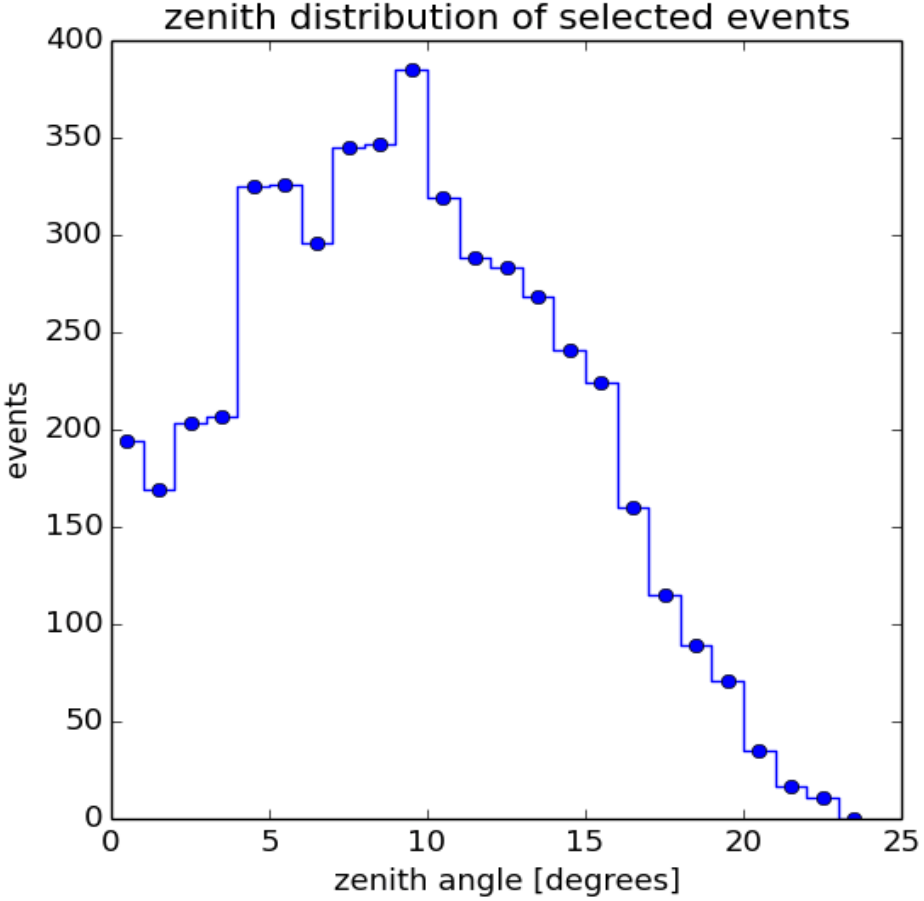
MuEx



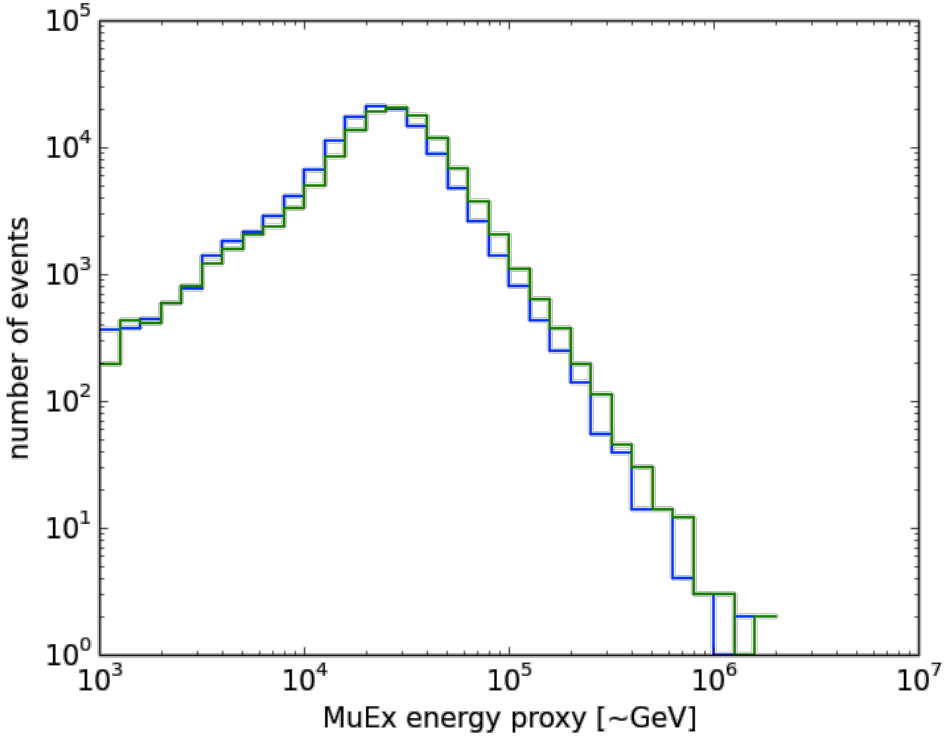
Cos(theta)

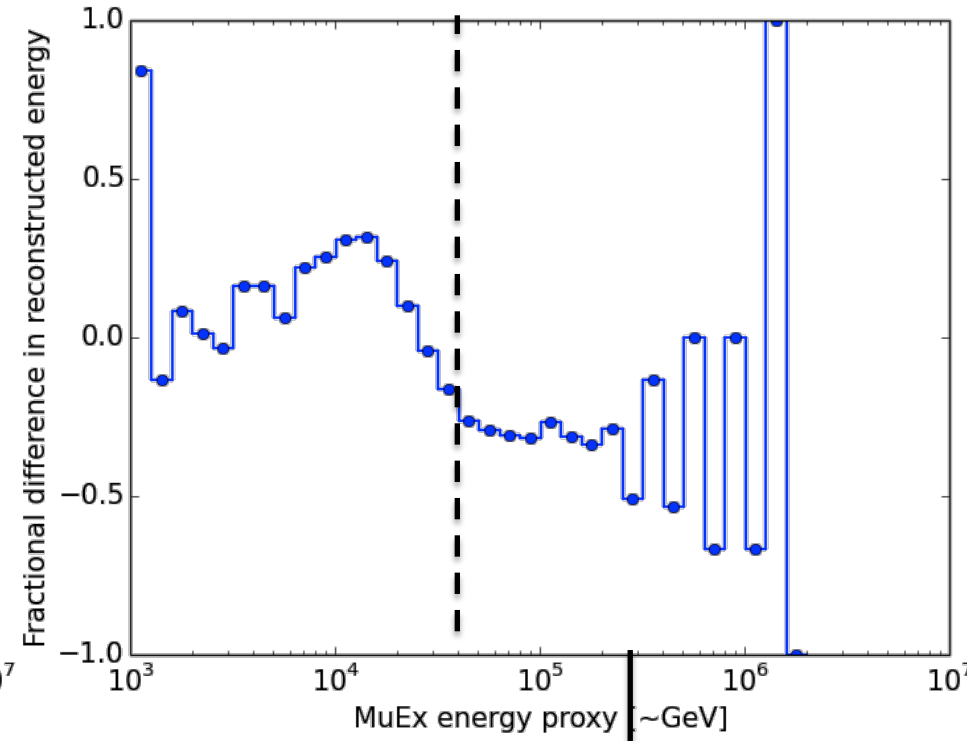
Reconstructed surface position & zenith of sample of selected events





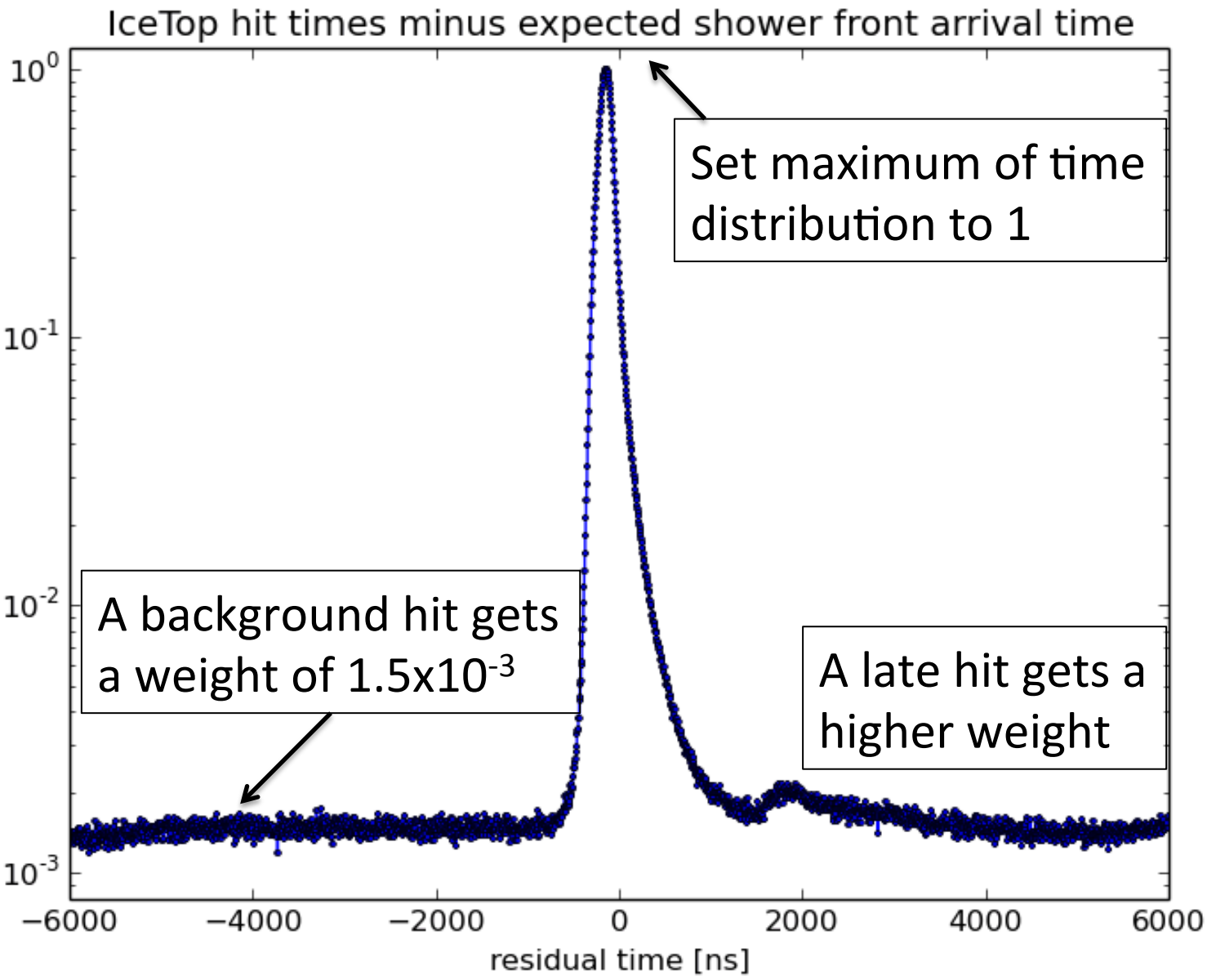
Comparison between sp3 and mie

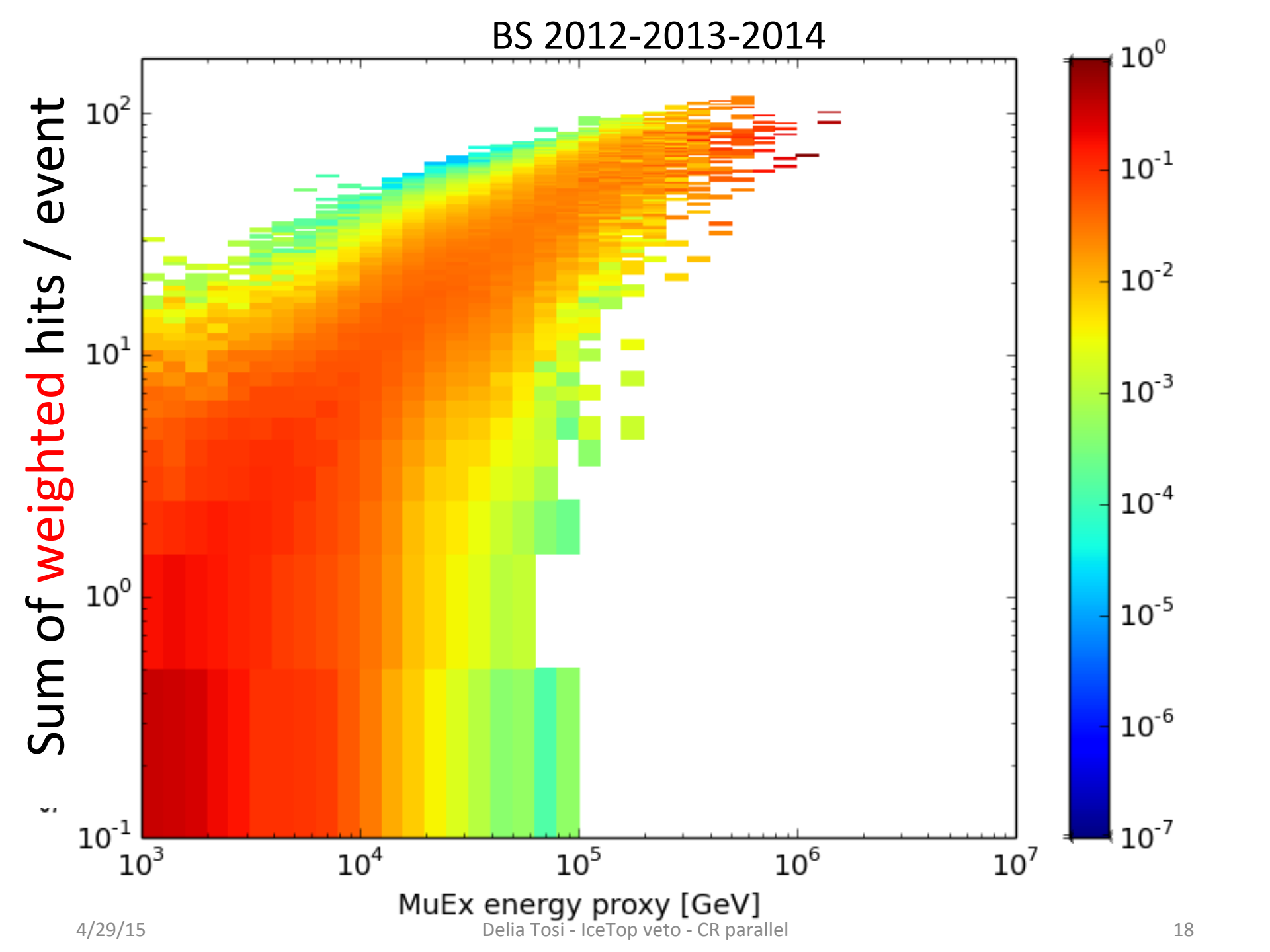


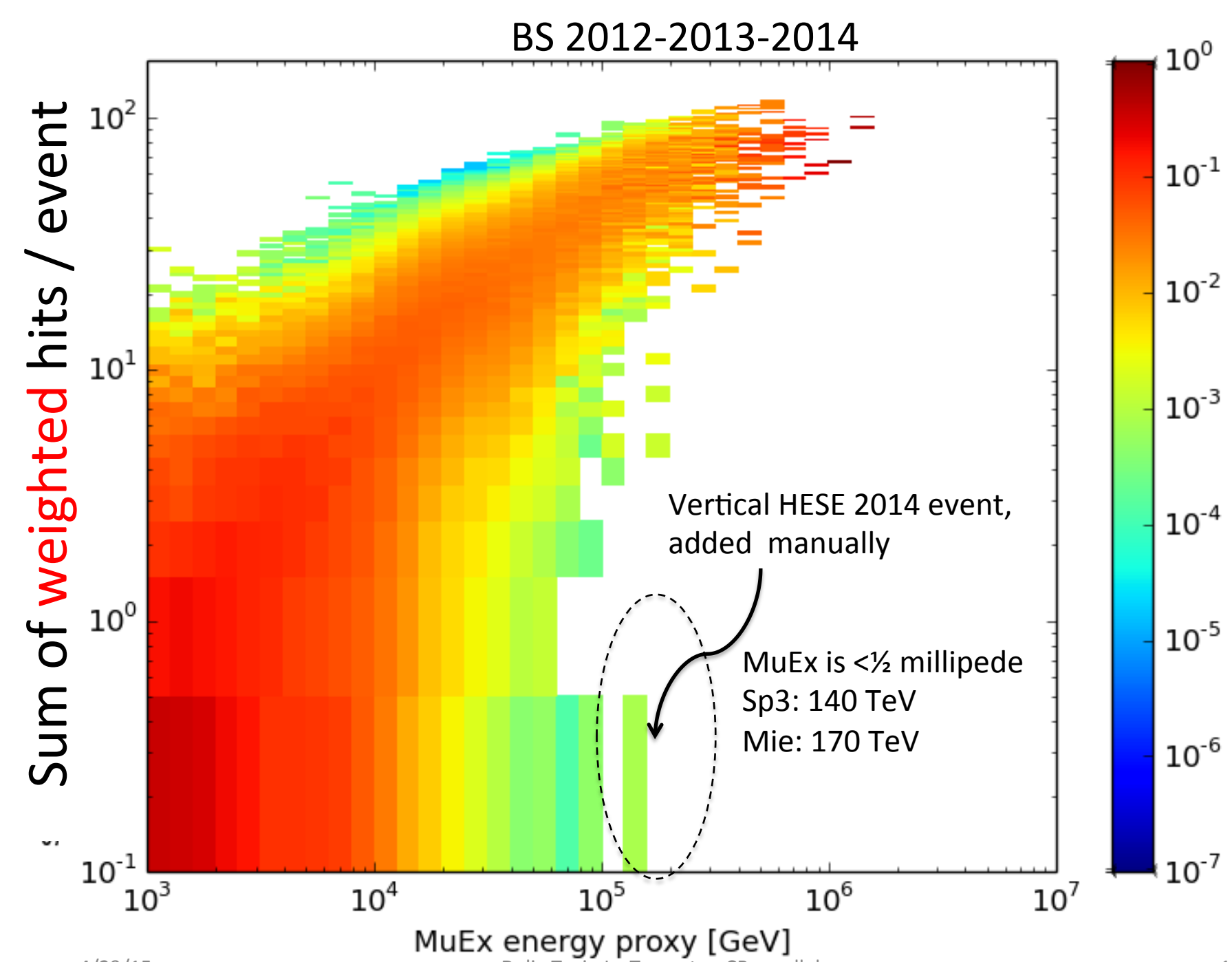


-30% energy > 50 TeV

Weight assignment

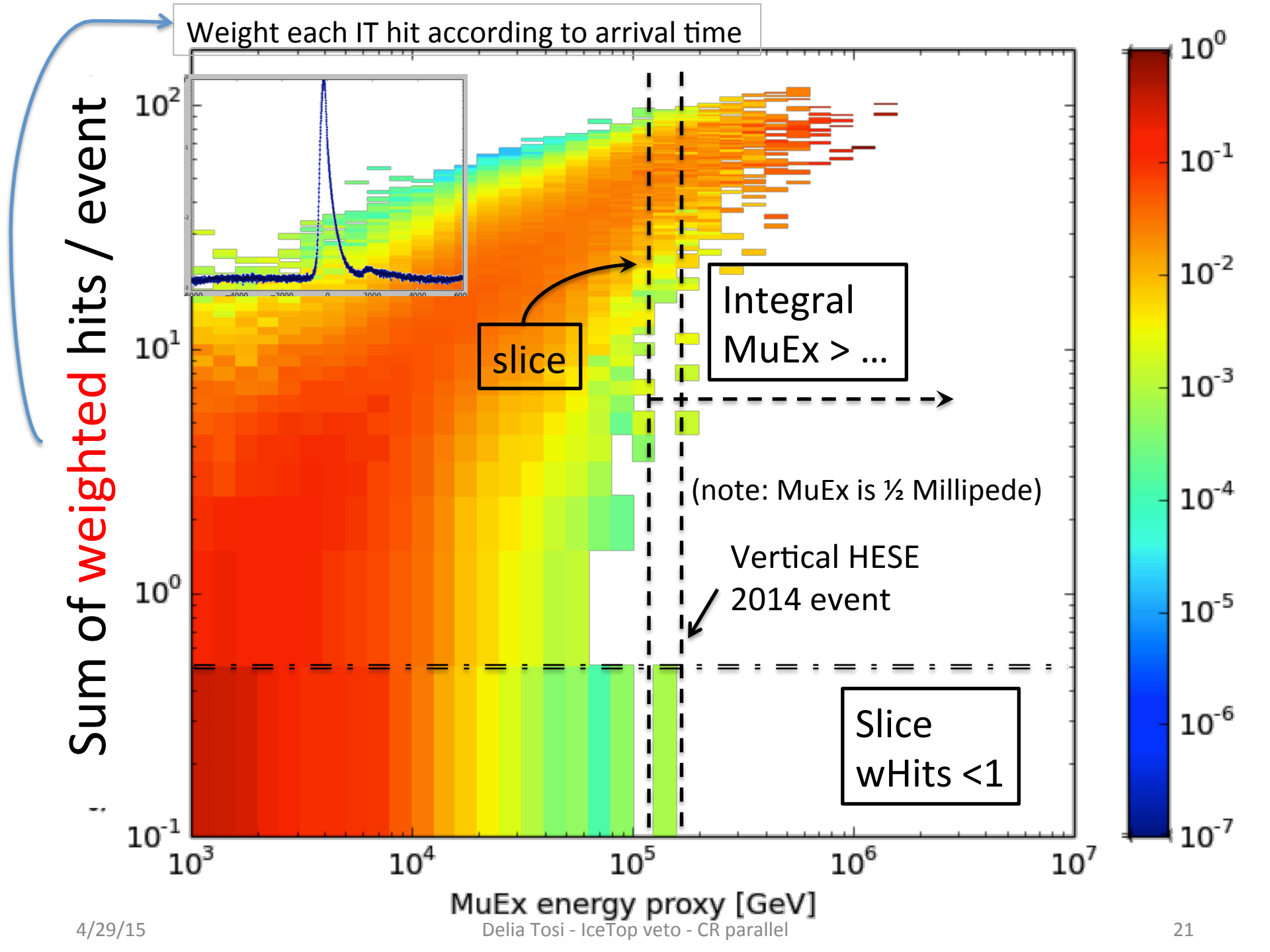


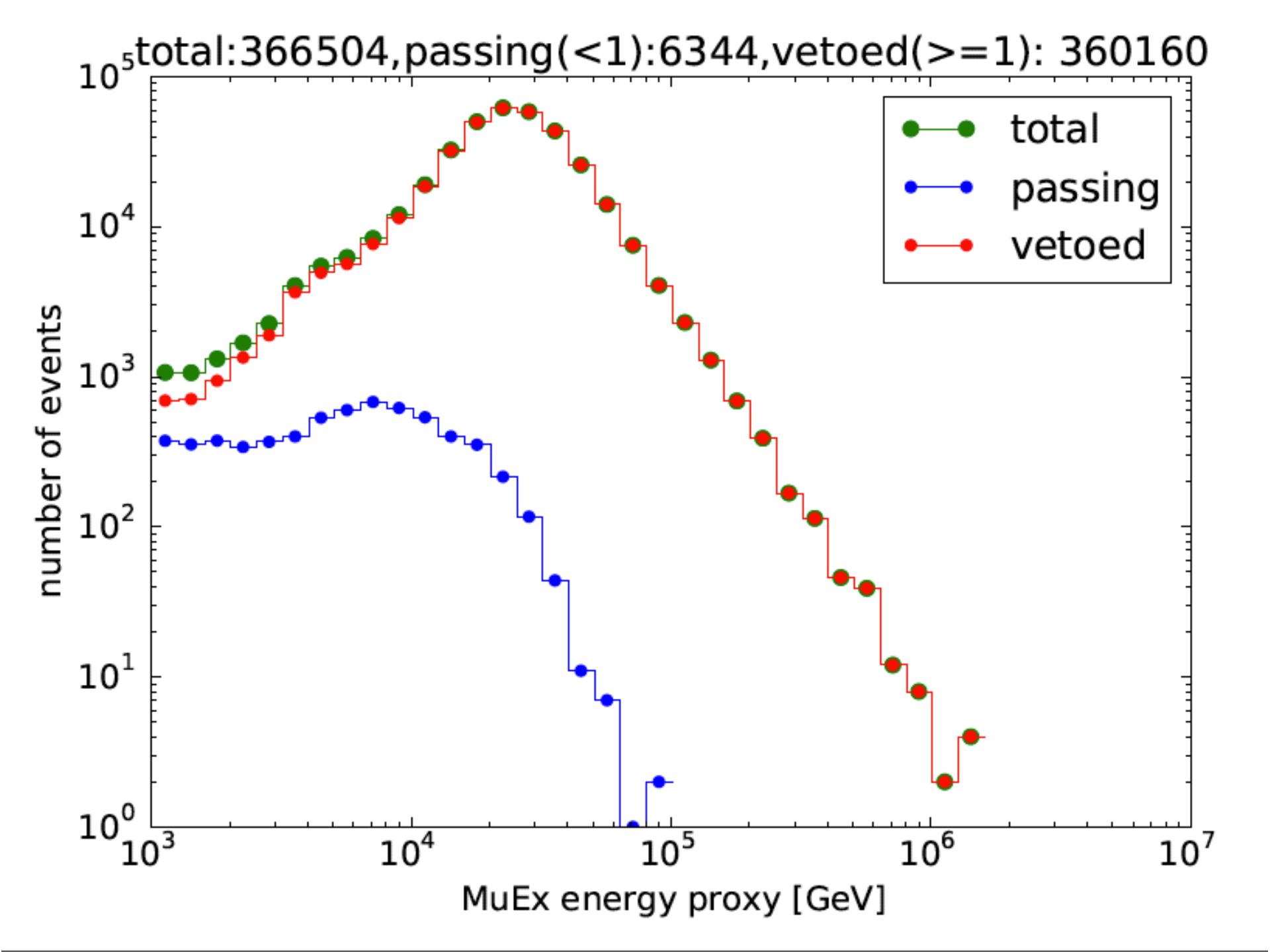

BS 2012-2013-2014
Sum of weighted hits / event
MuEx energy proxy [GeV]
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

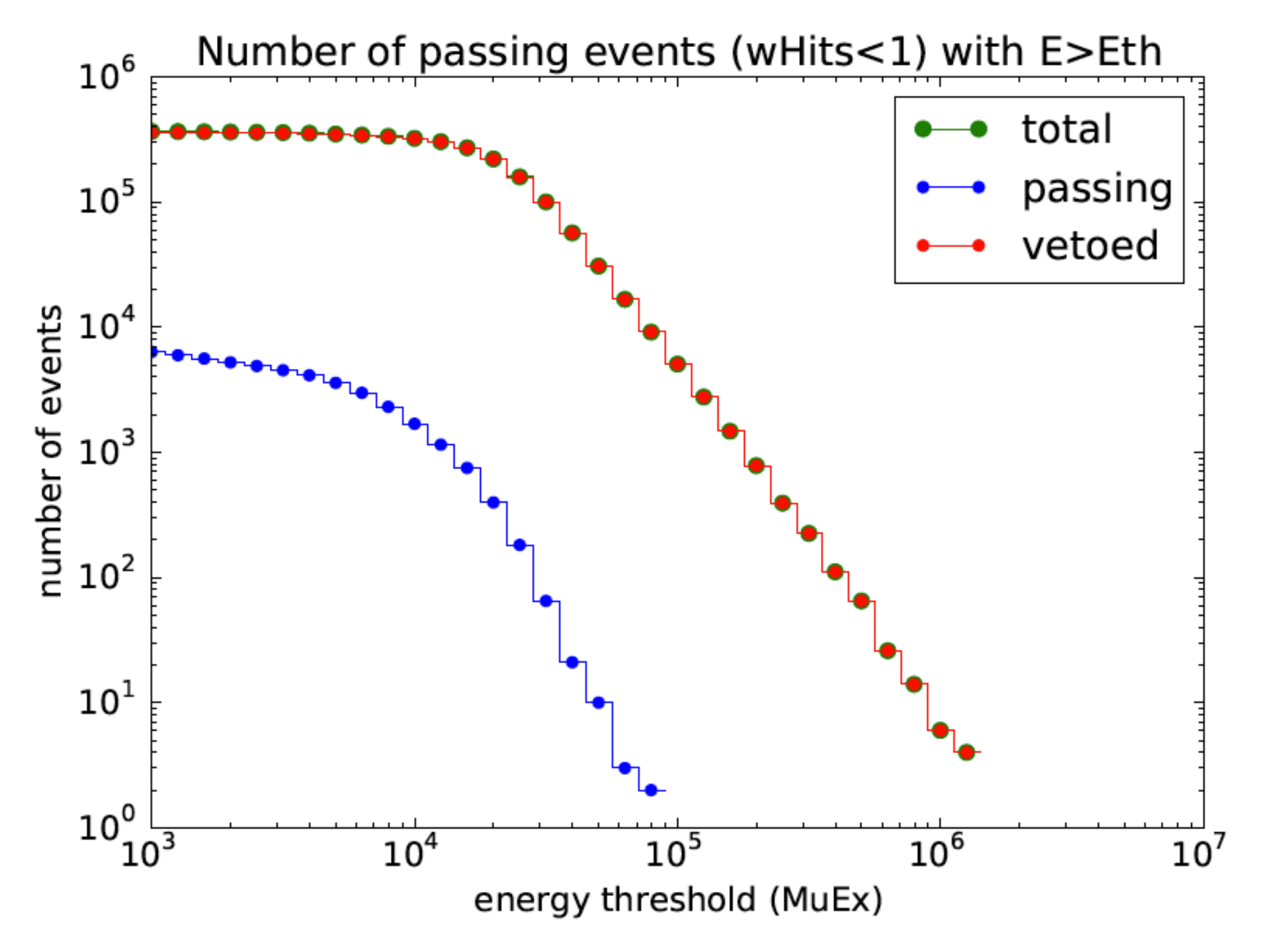

BS 2012-2013-2014
Sum of weighted hits / event
MuEx energy proxy [GeV]
Vertical HESE 2014 event, added manually
MuEx is <½ millipede
Sp3: 140 TeV
Mie: 170 TeV

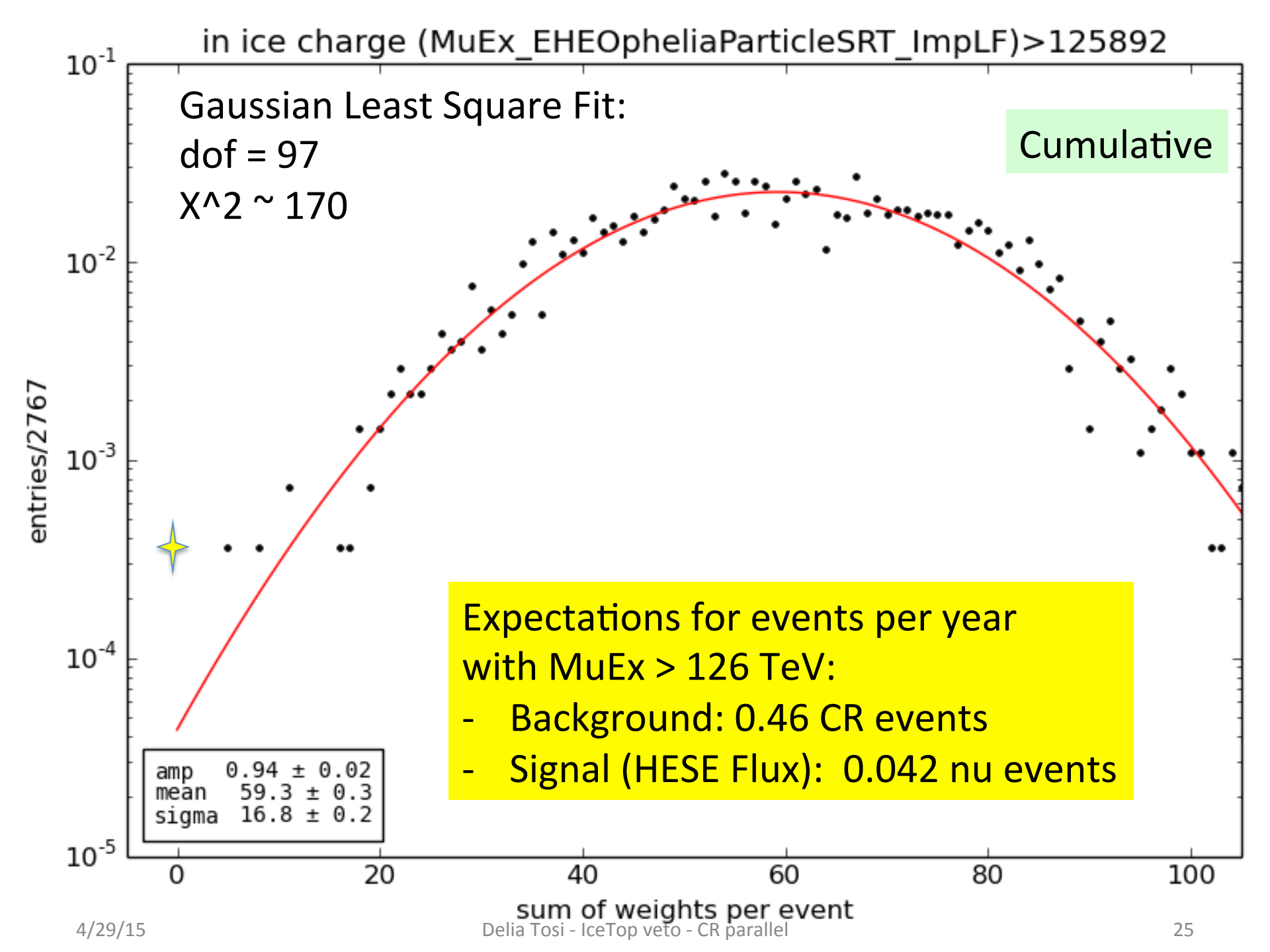
What is the chance that a cosmic ray shower gives no or few hits ?

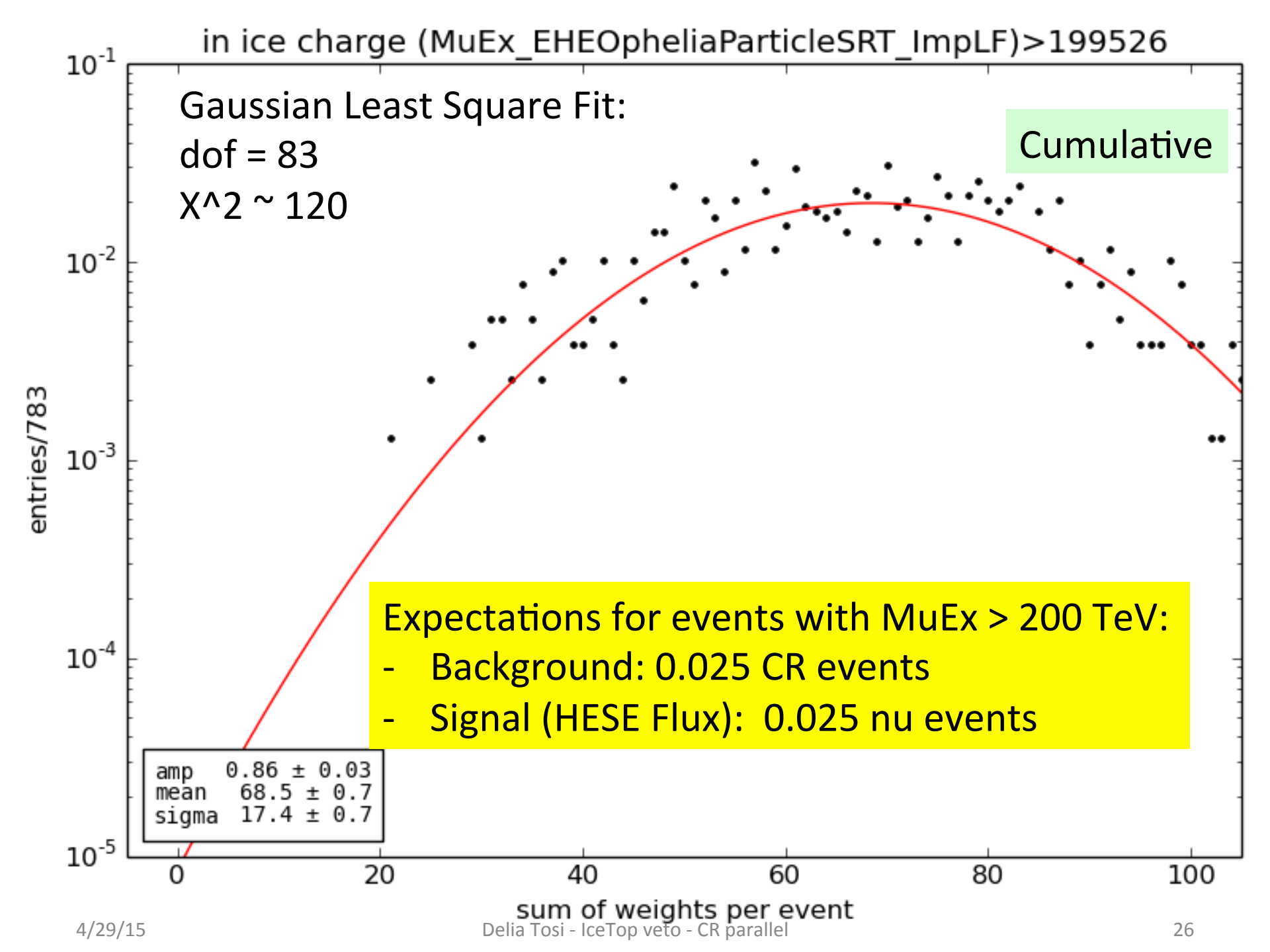
Estimate background from data


Weight each IT hit according to arrival time
Sum of weighted hits / event
MuEx energy proxy [GeV]
slice
Integral MuEx > …
(note: MuEx is ½ Millipede)
Vertical HESE 2014 event
Slice wHits <1

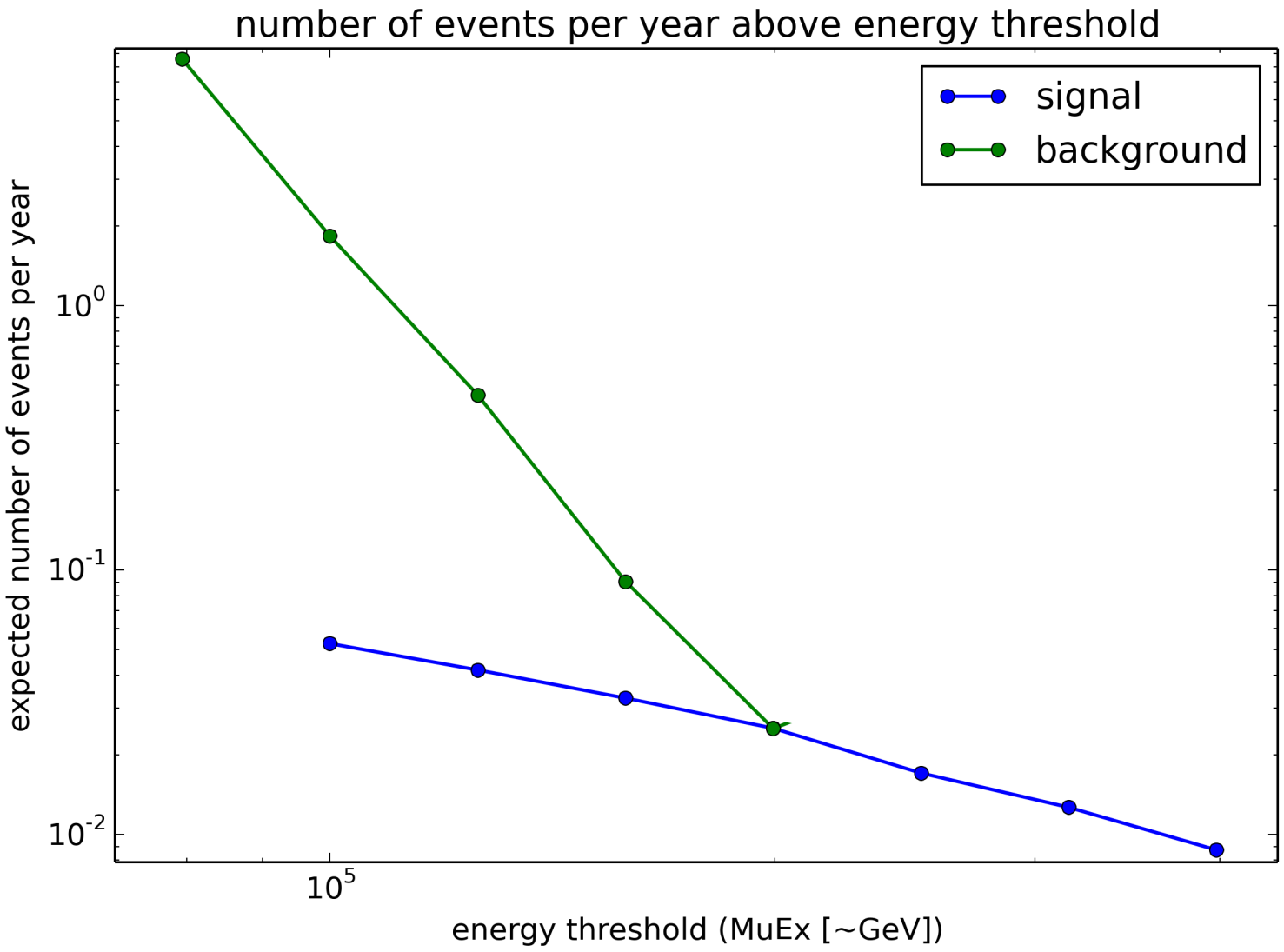

total:366504,passing(<1):6344,vetoed(>=1): 360160
total
passing
vetoed
number of events
MuEx energy proxy [GeV]
10^0
10^1
10^2
10^3
10^4
10^5
10^3
10^4
10^5
10^6
10^7


Number of passing events (wHits<1) with E>Eth
total
passing
vetoed
number of events
energy threshold (MuEx)
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^3
10^4
10^5
10^6
10^7


in ice charge (MuEx_EHEOpheliaParticleSRT_ImpLF)>125892
Gaussian Least Square Fit:
dof = 97
X^2 ~ 170
Cumulative
Expectations for events per year
with MuEx > 126 TeV:
- Background: 0.46 CR events
- Signal (HESE Flux): 0.042 nu events
amp 0.94 ± 0.02
mean 59.3 ± 0.3
sigma 16.8 ± 0.2
entries/2767
sum of weights per event


in ice charge (MuEx_EHEOpheliaParticleSRT_ImpLF)>199526
Gaussian Least Square Fit:
dof = 83
X^2 ~ 120
Cumulative
Expectations for events with MuEx > 200 TeV:
- Background: 0.025 CR events
- Signal (HESE Flux): 0.025 nu events
amp 0.86 ± 0.03
mean 68.5 ± 0.7
sigma 17.4 ± 0.7
entries/783
sum of weights per event

Neutrinos vs CR background

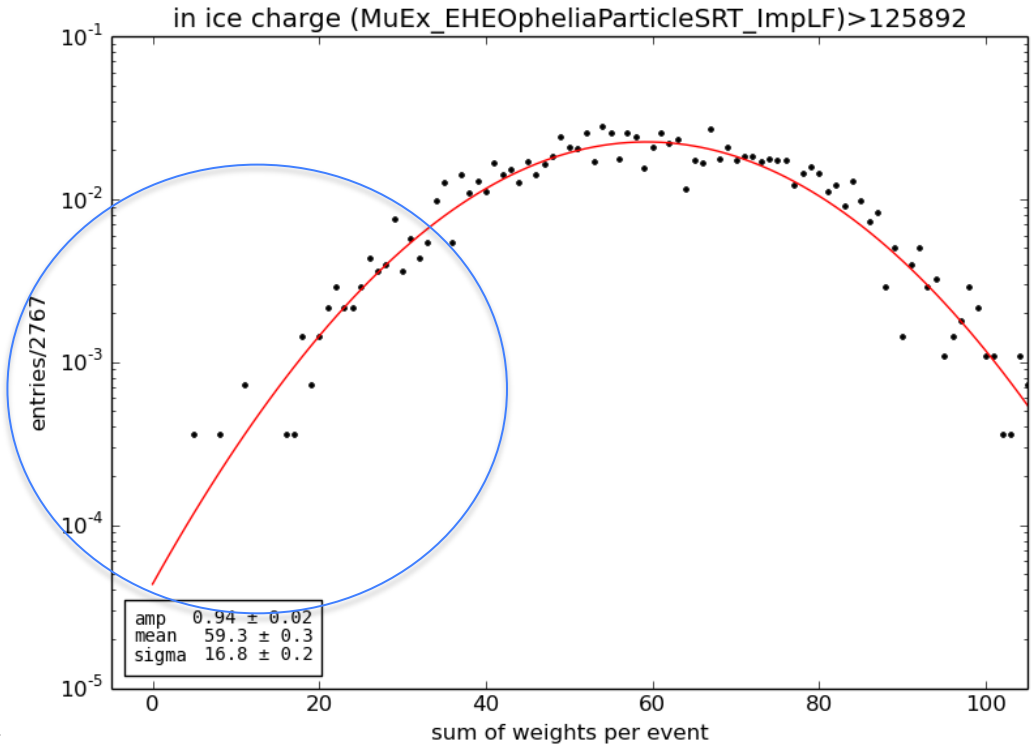


Is this approximation correct?

Simulations!

Questions:

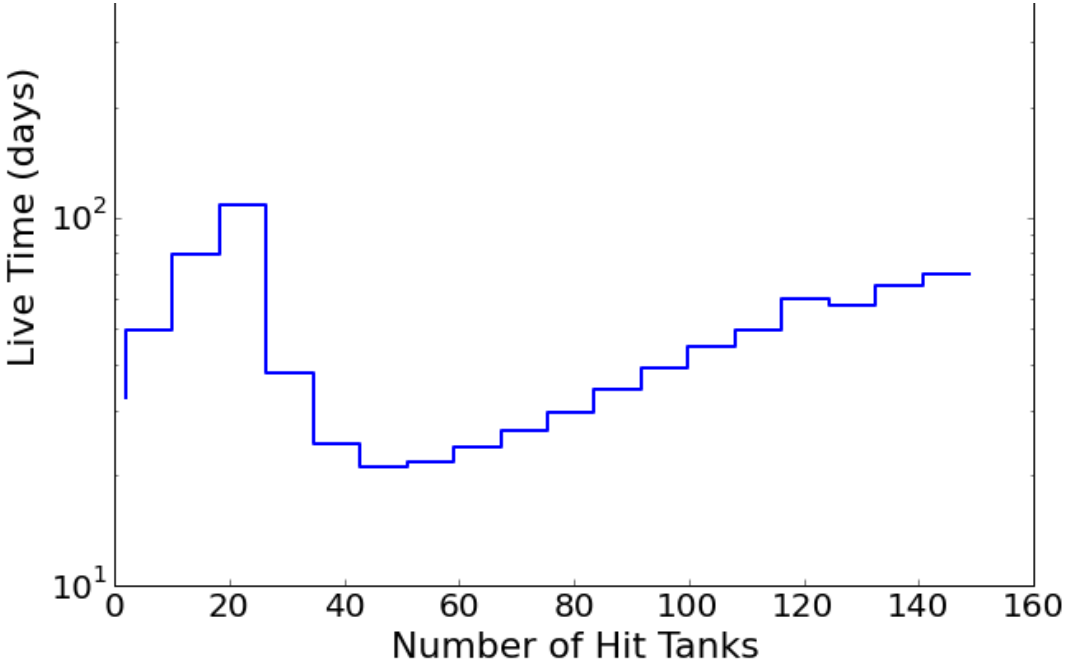
- What is the chance that a cosmic ray shower gives no or few hits ?
  - Simulation required to understand tails: are these penetrating muons? Or muons which gets most primary energy?
  - Thanks to Kyle, first test-set of combined simulation

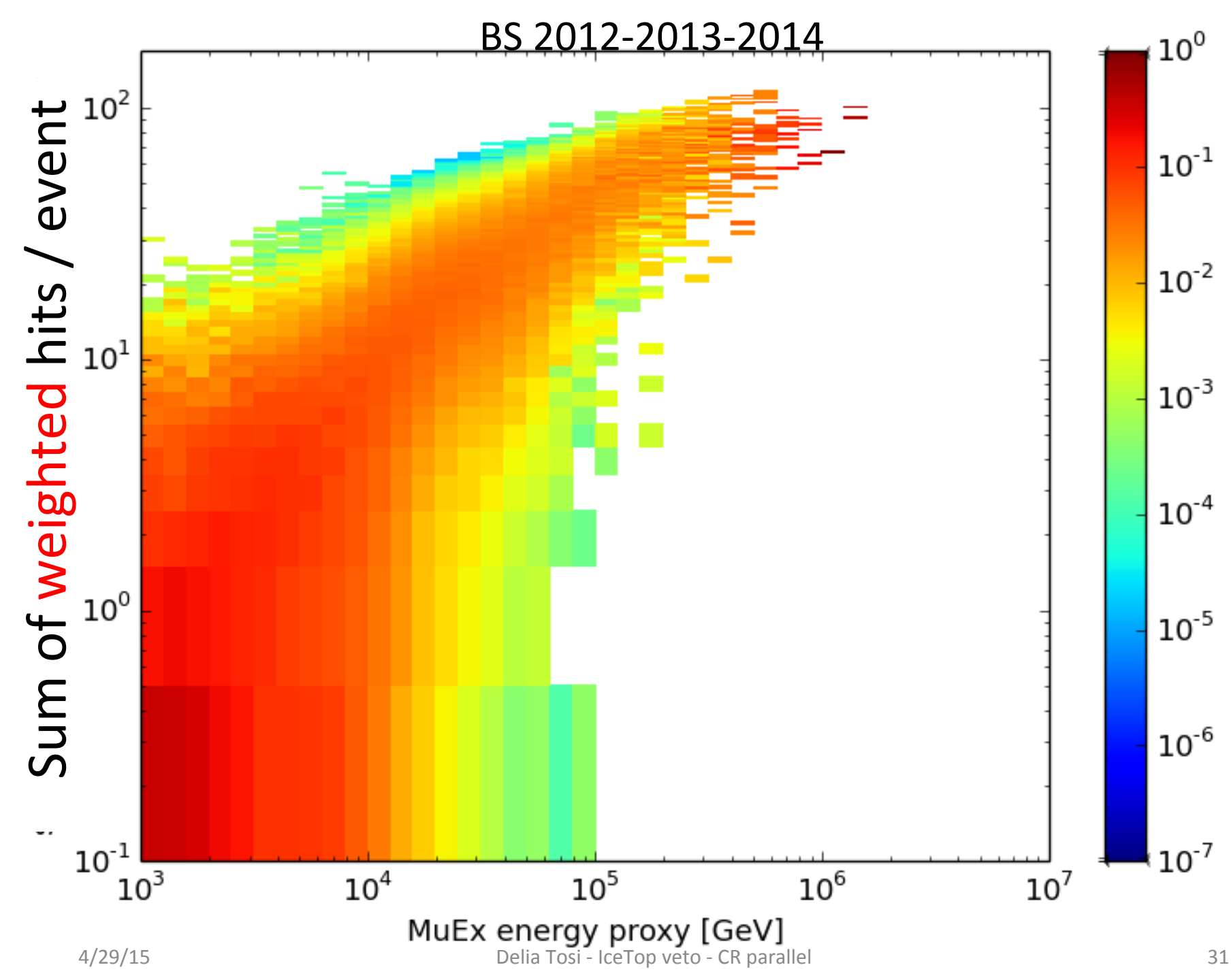


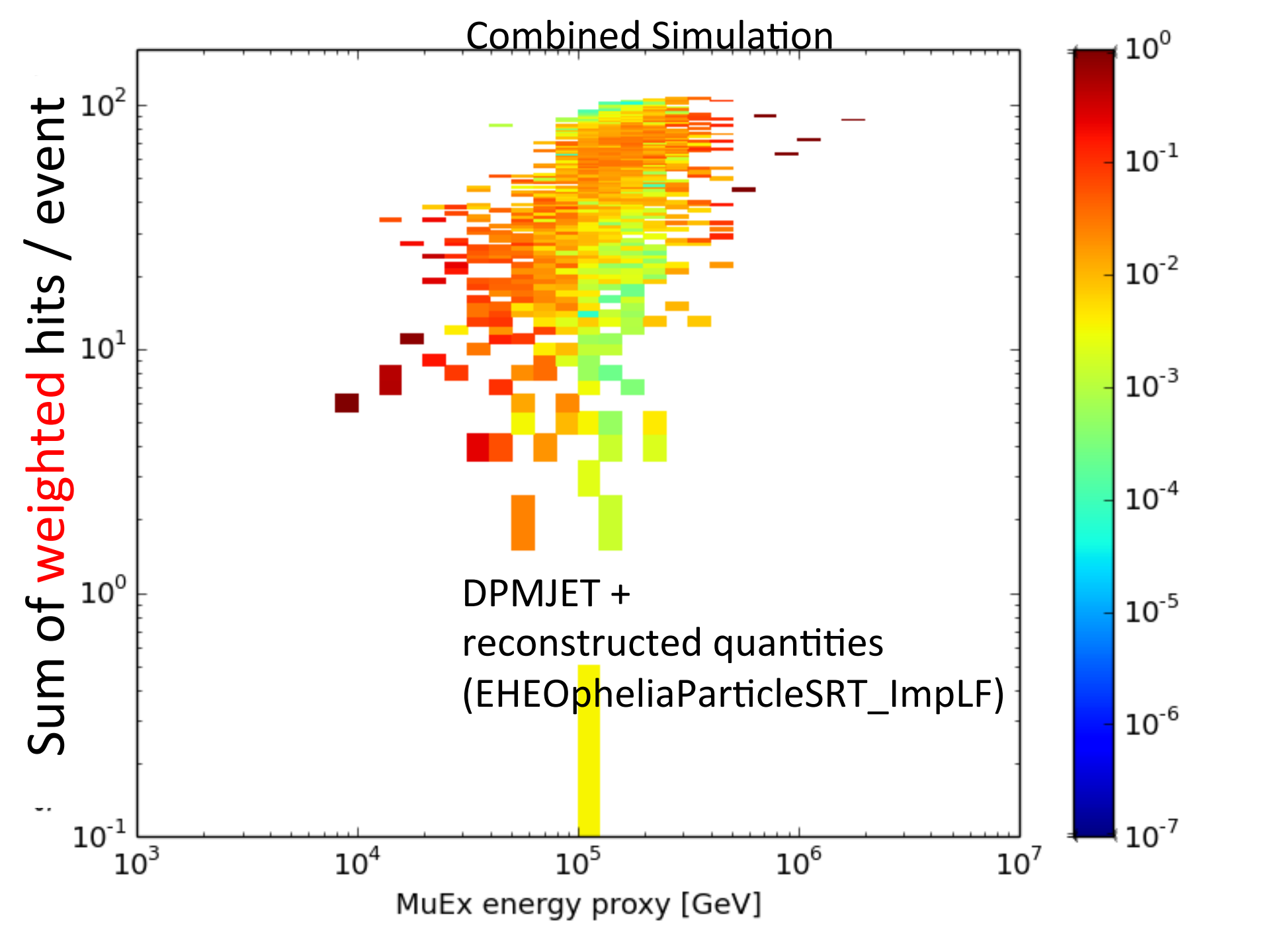
Simulation details

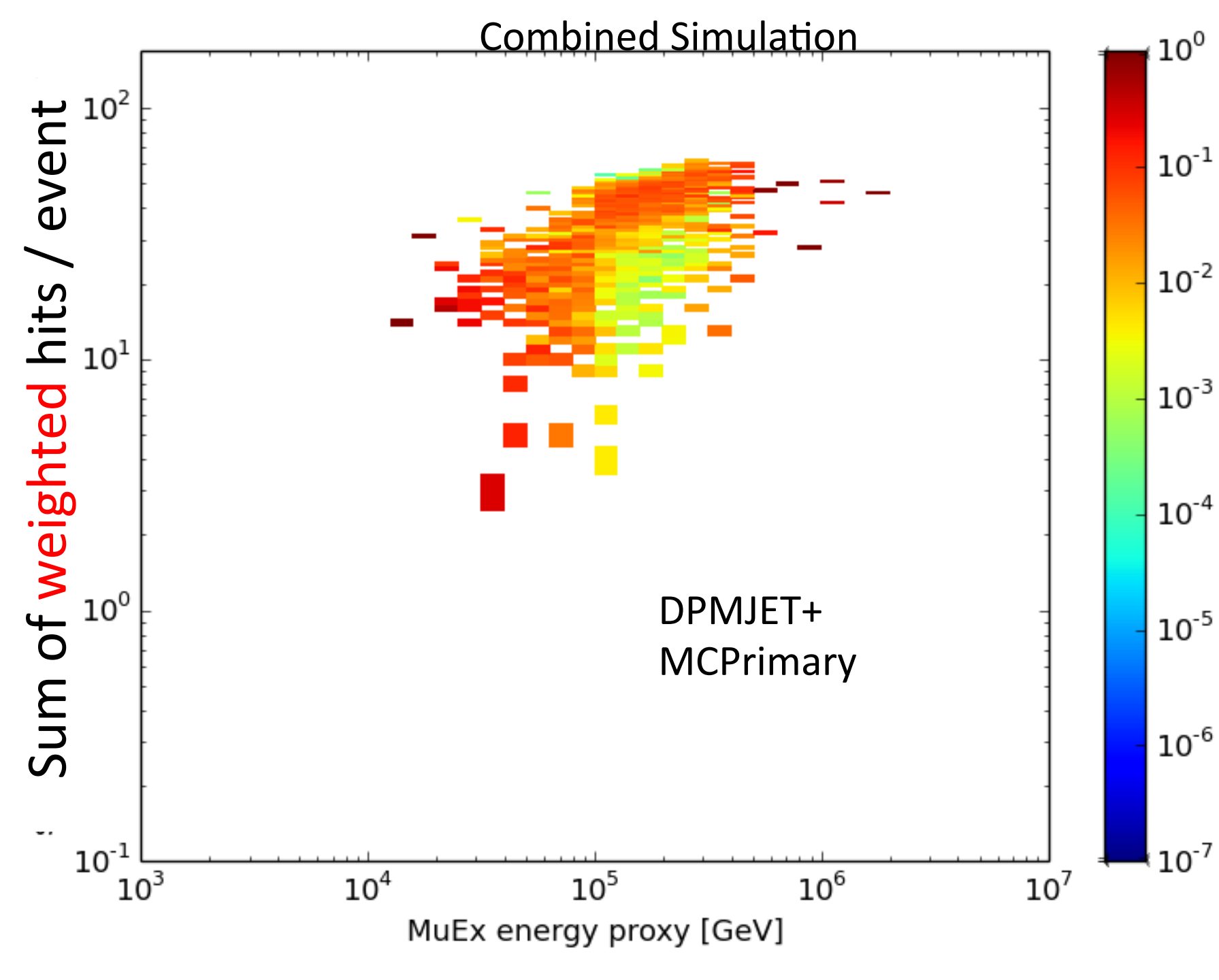
- Simulated a dataset as July 2013
  - 1 million showers 400TeV to 400PeV
  - 31% PPlus, 31% He4, 15% N14, 8% Al27, 15% Fe56
  - Live time as shown in figure

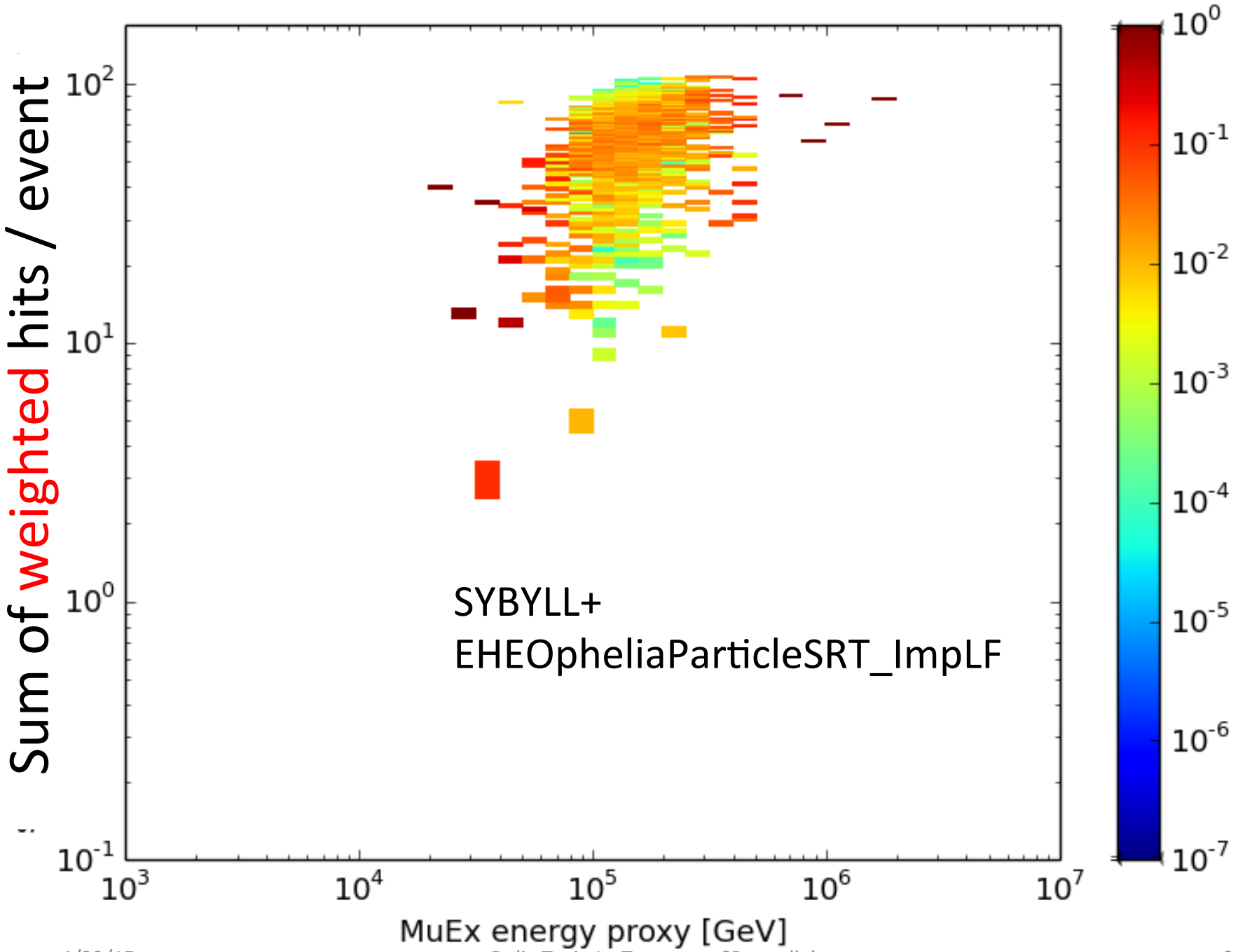
- Low hit tanks special set with DPMJet and SYBYLL (not yet processed)

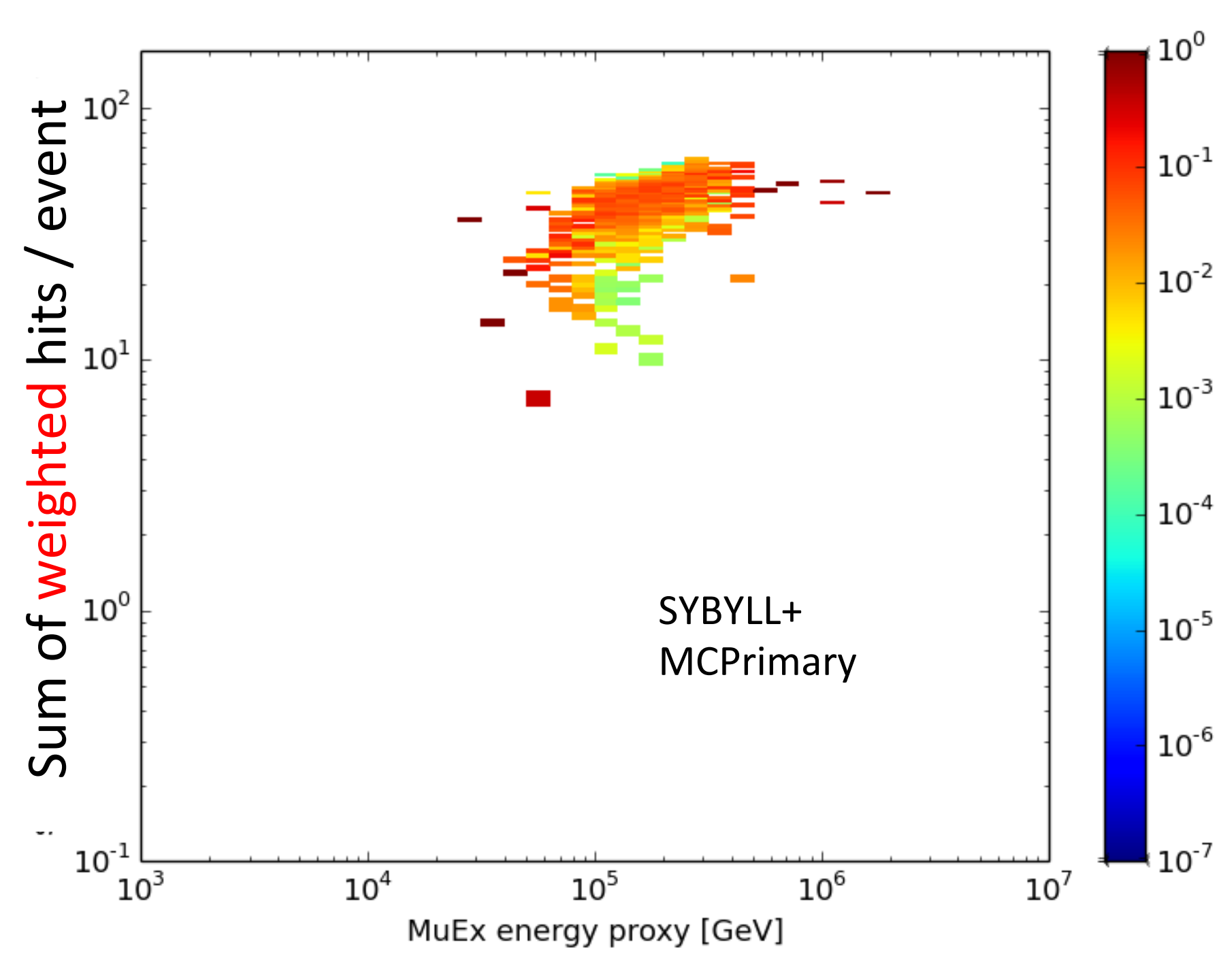


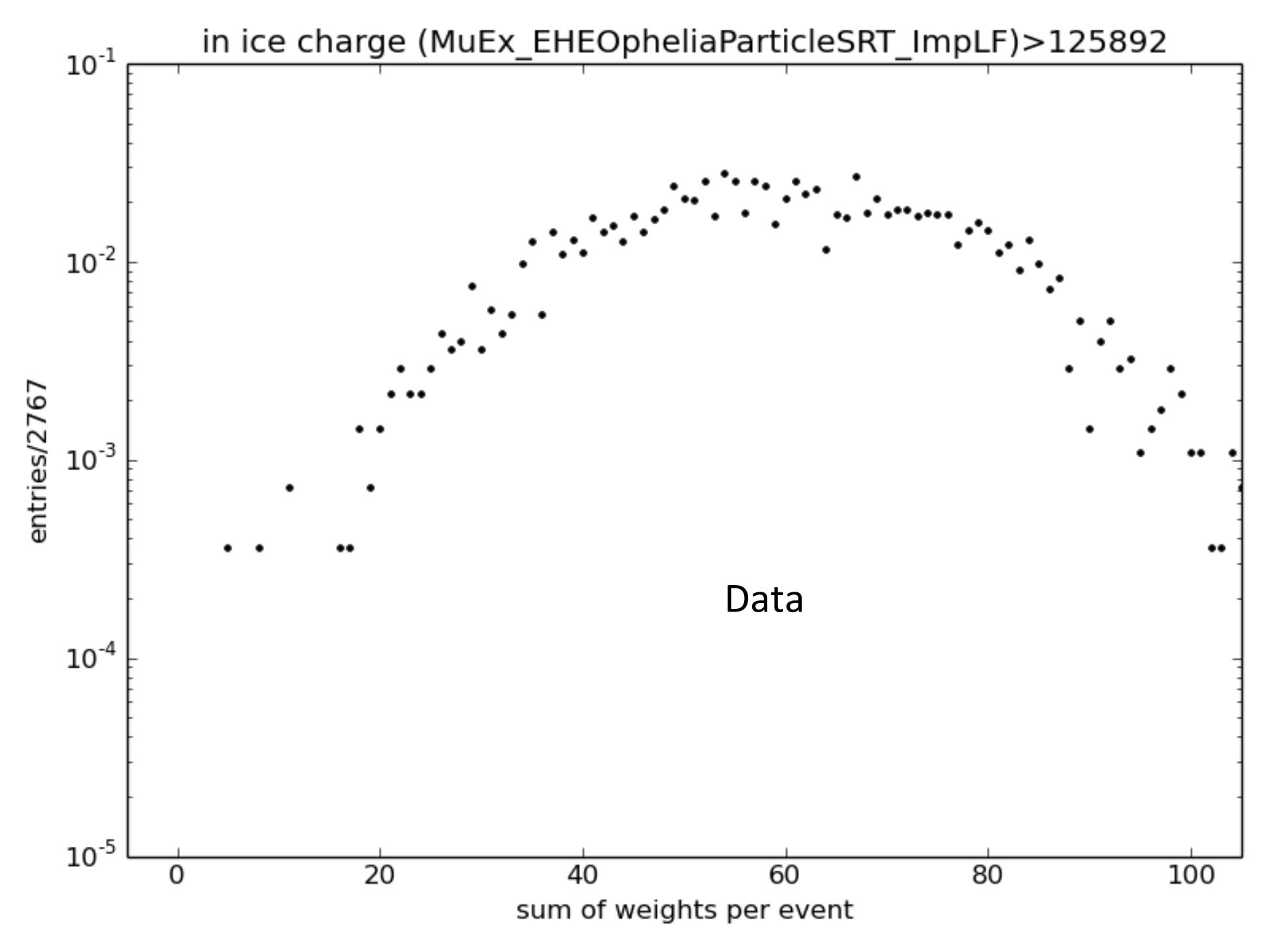

BS 2012-2013-2014
Sum of weighted hits / event
MuEx energy proxy [GeV]
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

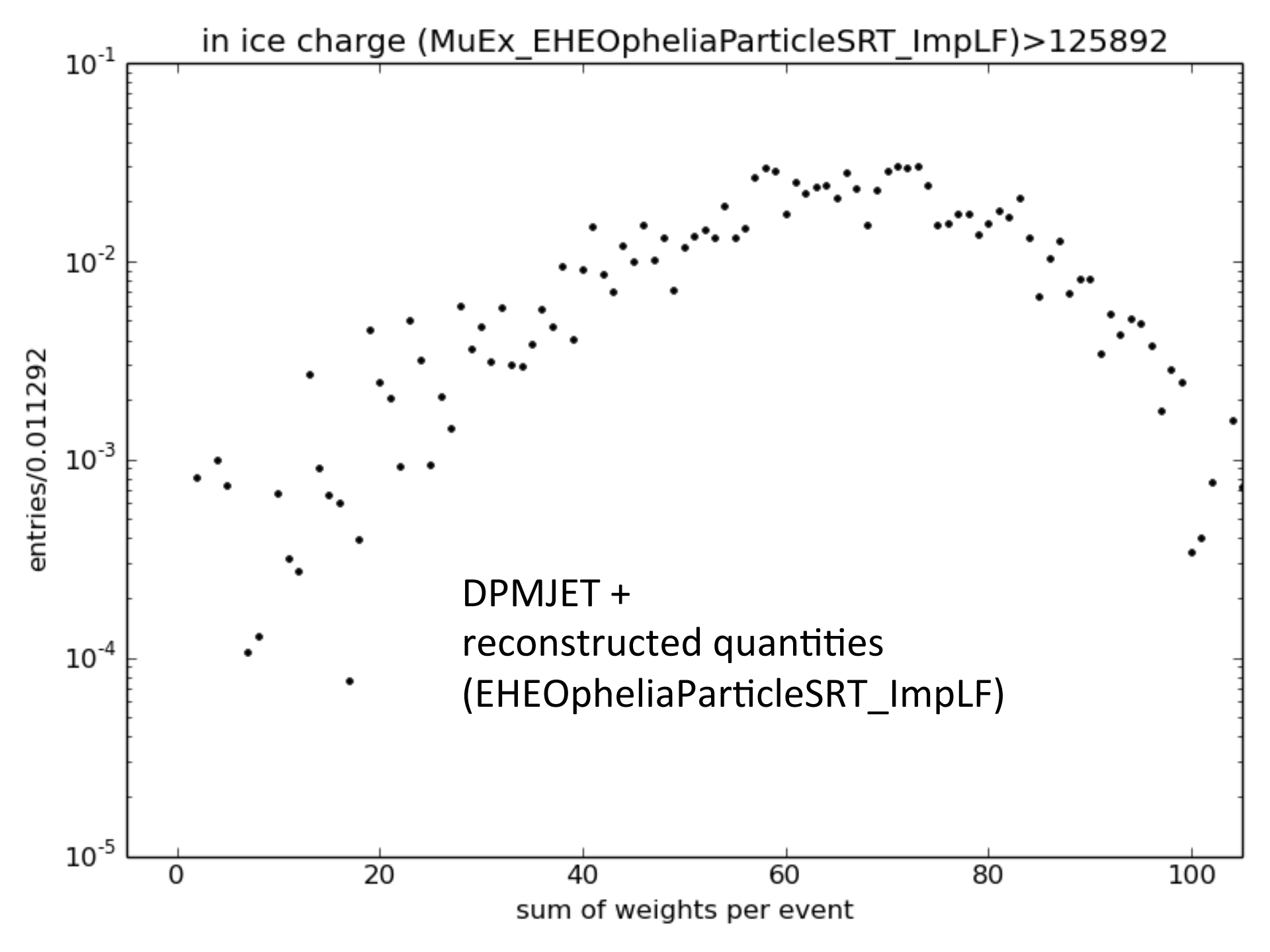

Combined Simulation
Sum of weighted hits / event
10^{2}
10^{1}
10^{0}
10^{-1}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
MuEx energy proxy [GeV]
DPMJET +
reconstructed quantities
(EHEOpheliaParticleSRT_ImpLF)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

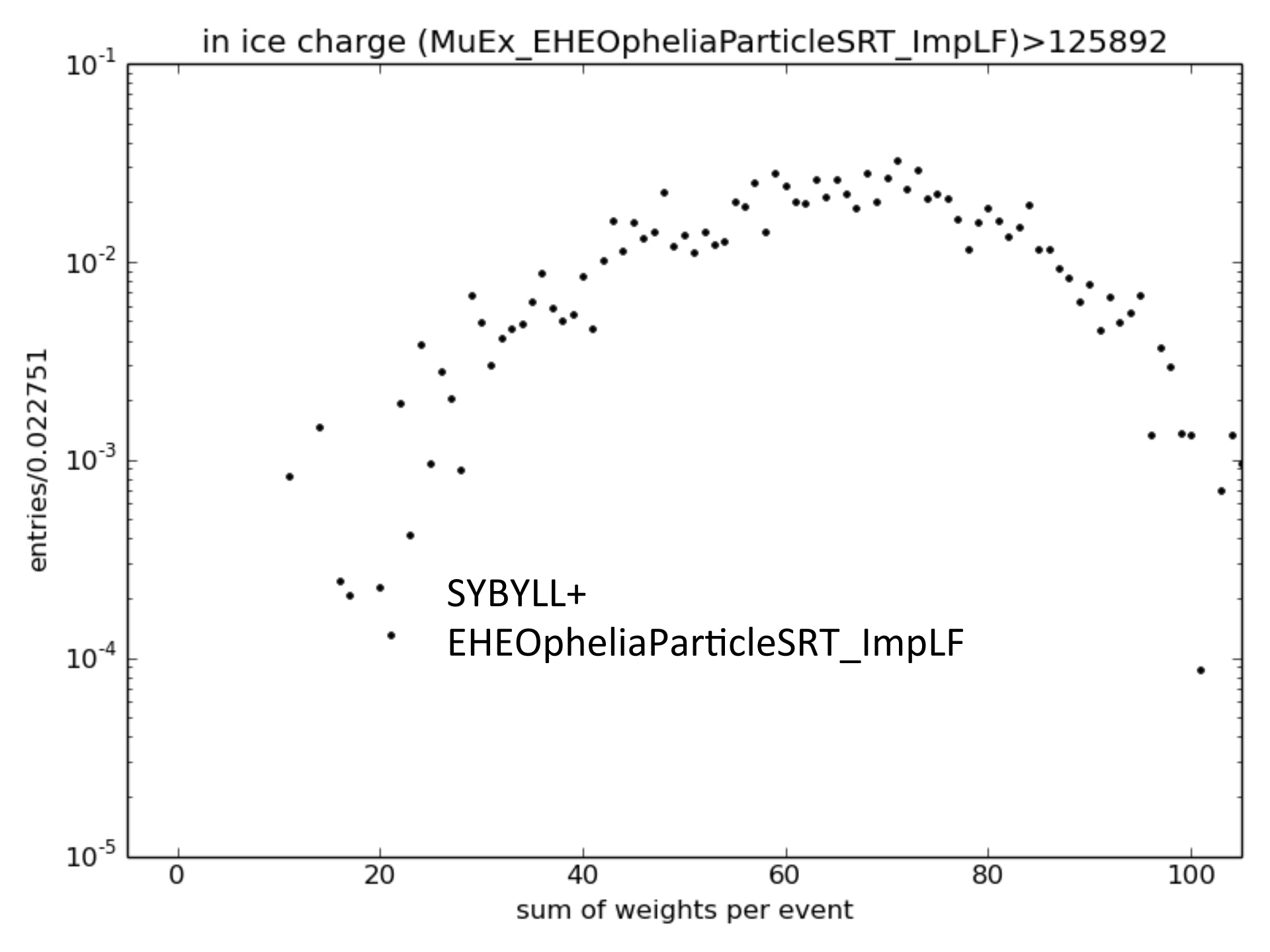

Combined Simulation
Sum of weighted hits / event
10^2
10^1
10^0
10^{-1}
10^3
10^4
10^5
10^6
10^7
MuEx energy proxy [GeV]
DPMJET+
MCPrimary
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

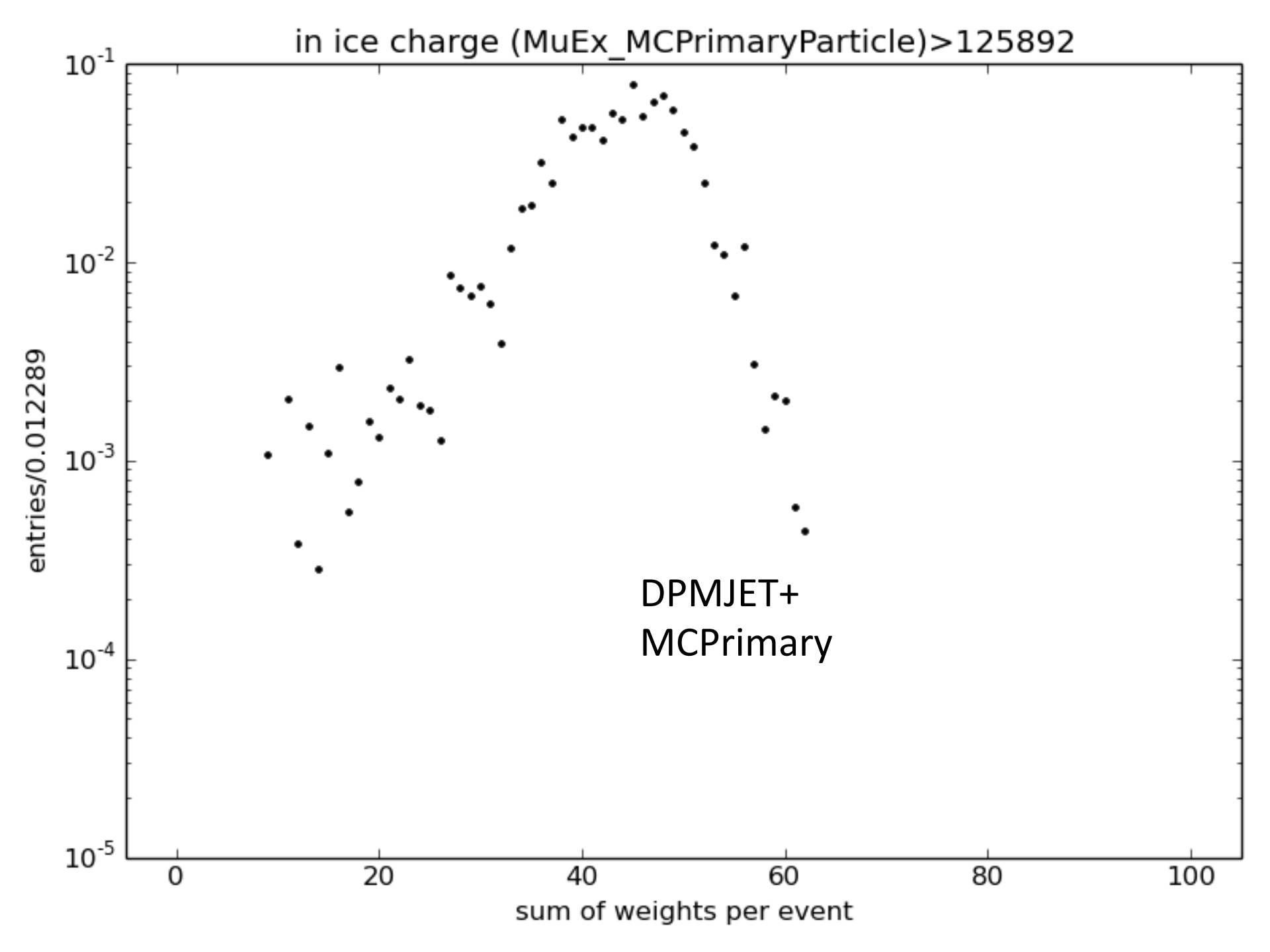

Sum of weighted hits / event
10^2
10^1
10^0
10^{-1}
10^3
10^4
10^5
10^6
10^7
MuEx energy proxy [GeV]
SYBYLL+
EHEOpheliaParticleSRT_ImpLF
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}

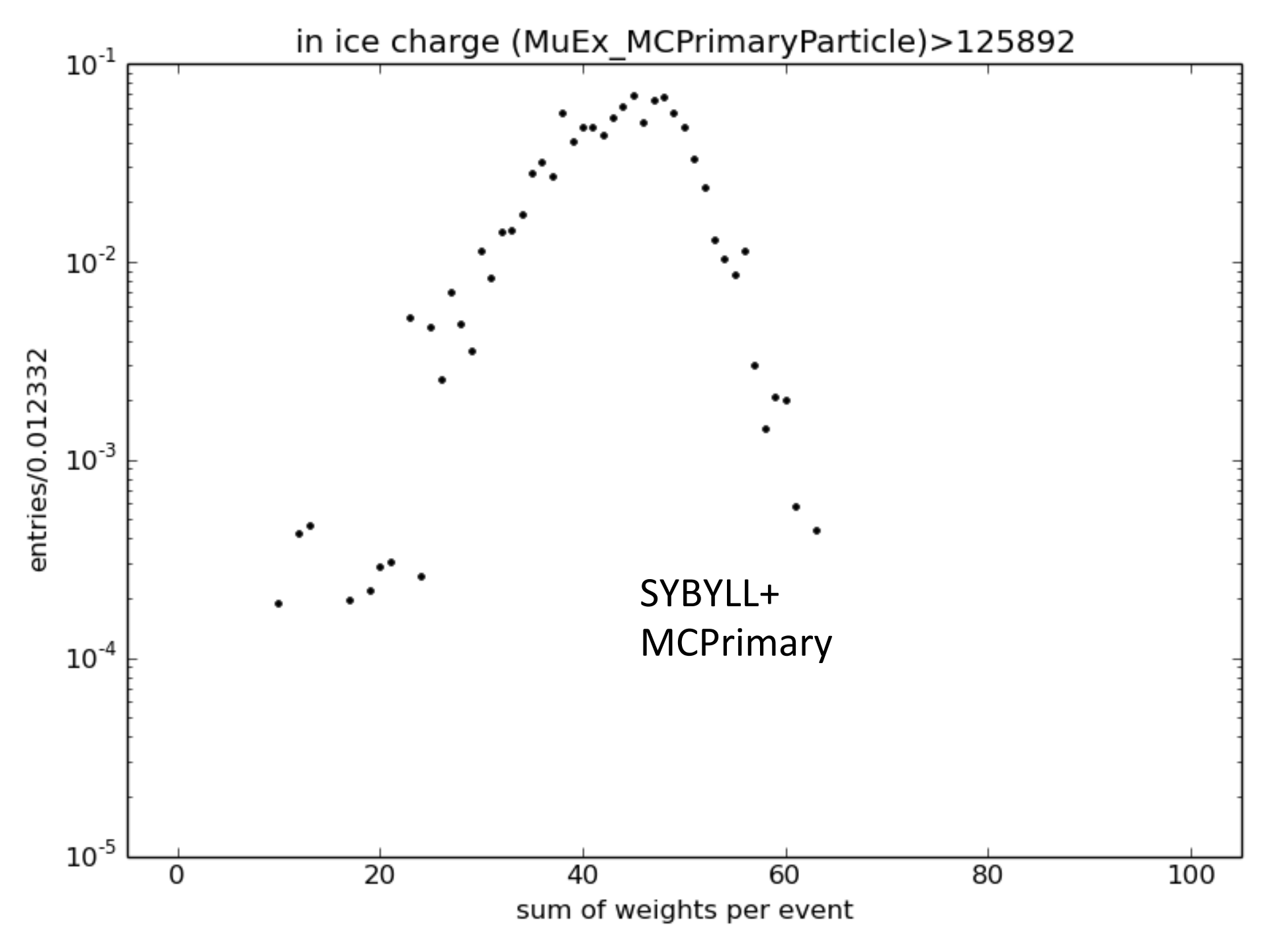

Sum of weighted hits / event
10^{2}
10^{1}
10^{0}
10^{-1}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}
MuEx energy proxy [GeV]
SYBYLL+
MCPrimary
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}


in ice charge (MuEx_EHEOpheliaParticleSRT_ImpLF)>125892
entries/2767
sum of weights per event
Data
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0
20
40
60
80
100


in ice charge (MuEx_EHEOpheliaParticleSRT_ImpLF)>125892
entries/0.011292
sum of weights per event
DPMJET +
reconstructed quantities
(EHEOpheliaParticleSRT_ImpLF)


in ice charge (MuEx_EHEOpheliaParticleSRT_ImpLF)>125892
entries/0.022751
sum of weights per event
SYBYLL+
EHEOpheliaParticleSRT_ImpLF

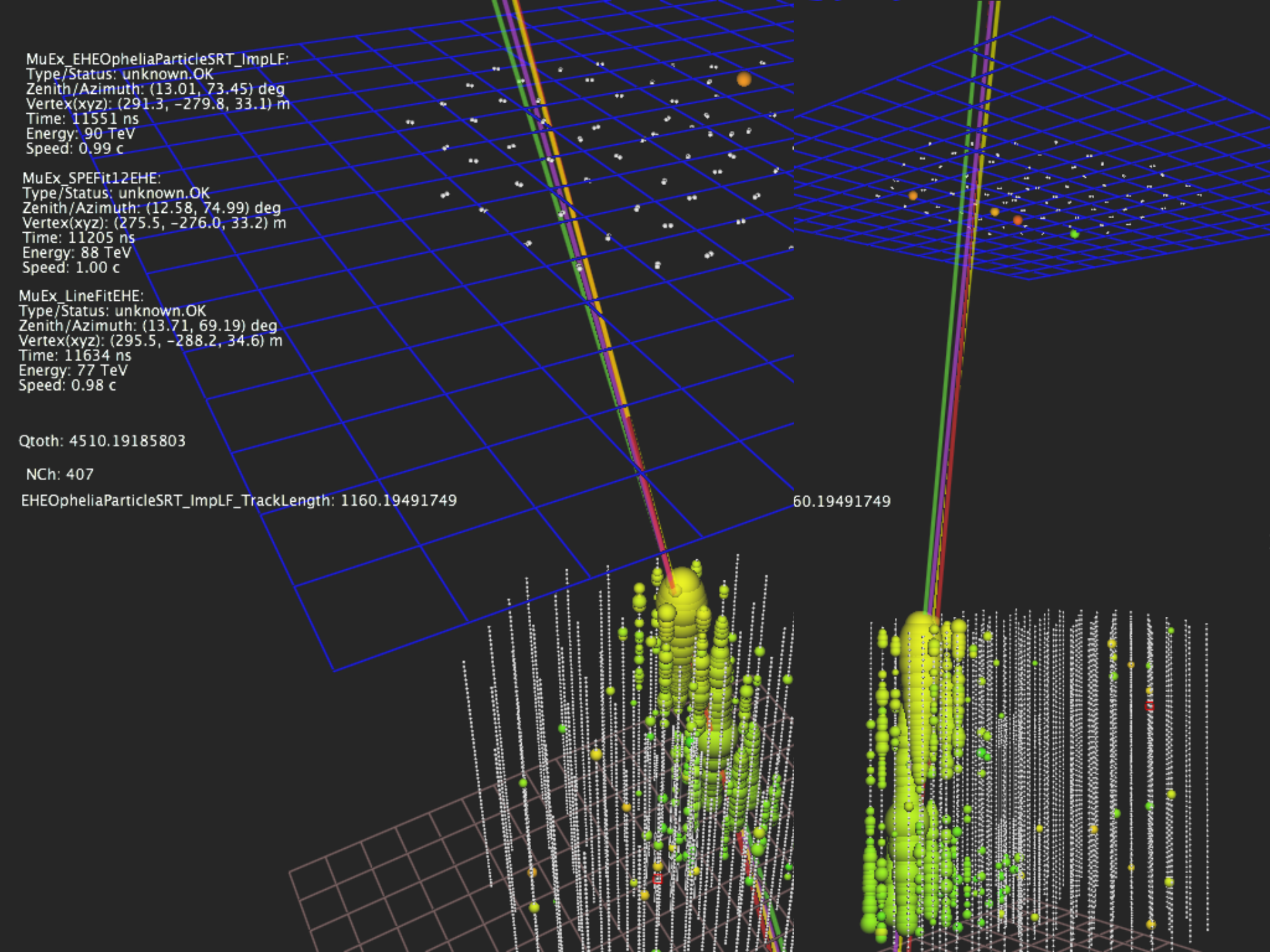

in ice charge (MuEx_MCPrimaryParticle)>125892
entries/0.012289
sum of weights per event
DPMJET+
MCPrimary


in ice charge (MuEx_MCPrimaryParticle)>125892
entries/0.012332
sum of weights per event
SYBYLL+
MCPrimary

Possible reasons for discrepancies

- IceTop DAQ bug affecting 8 stations on the edge of the array (roughly included in previous plots: hits from those tanks are not counted)
- Atmospheric variations (July gives more IceTop hits than average?)
- Snow depth not appropriate?
- DPMJET vs SYBILL seems to make a difference

- …. More investigations undergoing


MuEx_EHEOpheliaParticleSRT_ImpLF:
Type/Status: unknown.OK
Zenith/Azimuth: (13.01, 73.45) deg
Vertex(xyz): (291.3, -279.8, 33.1) m
Time: 11551 ns
Energy: 90 TeV
Speed: 0.99 c
MuEx_SPEFit12EHE:
Type/Status: unknown.OK
Zenith/Azimuth: (12.58, 74.99) deg
Vertex(xyz): (275.5, -276.0, 33.2) m
Time: 11205 ns
Energy: 88 TeV
Speed: 1.00 c
MuEx_LineFitEHE:
Type/Status: unknown.OK
Zenith/Azimuth: (13.71, 69.19) deg
Vertex(xyz): (295.5, -288.2, 34.6) m
Time: 11634 ns
Energy: 77 TeV
Speed: 0.98 c
Qtoth: 4510.19185803
NCh: 407
EHEOpheliaParticleSRT_ImpLF_TrackLength: 1160.19491749
60.19491749

My to-do list

- Look into timing issue which seems to cause a few fake low hits events (both in data and simulation), possibly fix it.
- Look at simulated events which have low hits (even with no reconstruction involved)
- Compare different energy proxies

Summary

- Event selection based on IceTop as veto
- Analysis has been developed on very hard cuts, it may be possible to loose them and gain sensitivity
- Highest energy event in 3 months of lifetime: ~70TeV (muEx)
- Suggests that IceTop works above 100-200 TeV MuEx as a veto.
- Basis for calibrating advanced veto simulations (-> see also Kyle's talk)
- Developed a basis for Gen2 veto studies
- Planning to unblind 3 years of data later in summer