Km3 Collaboration Meeting
Rome, 12-13 November 2013

NEMO-Fase II - Tower data analysis, atmospheric muon tracks reconstruction

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Post-Trigger Data

PT file selection (from PT File DB):

mysql pt_phase2 -e "select FileName from pt_files where **Comments is null** and **FileSize>1900**;" --user=Km3NeT -h fasserver.lns.infn.it --password=Km3NeTuser

Present analysis: **Two data sets corresponding to the last PMT HV setup:**

Runs	Period	N. Files
847-873	2013-06-22 -- 2013-06-28	14
874-953	2013-06-28 -- 2013-07-17	47

Total number of files: 61
Total live time: 321 hr

Since Run 847 up to now: ≈ 2000 hr

OMs Data: Data Acquisition

On-Line TRIGGER

- 1 SC (scaled 100)
- ≥ 2 SC
- 1 SC + CS (SC and CS in different PMTs)
- 1 FC

TRIGGER rates:

R ~ 100 Hz

- Expected muon trigger rate (from simulations): R ~ 0.1 Hz
- The signal is dominated by the noise: an Off-Line trigger is mandatory (same case of NEMO Phase-1)

The code HitDeco2:

•parses the PT file;

•decompresses the Fem Hits and evaluates the hit total charge in p.e.;

•evaluates the hit time from the decompressed hit wave form;

•applies the time calibration offsets;

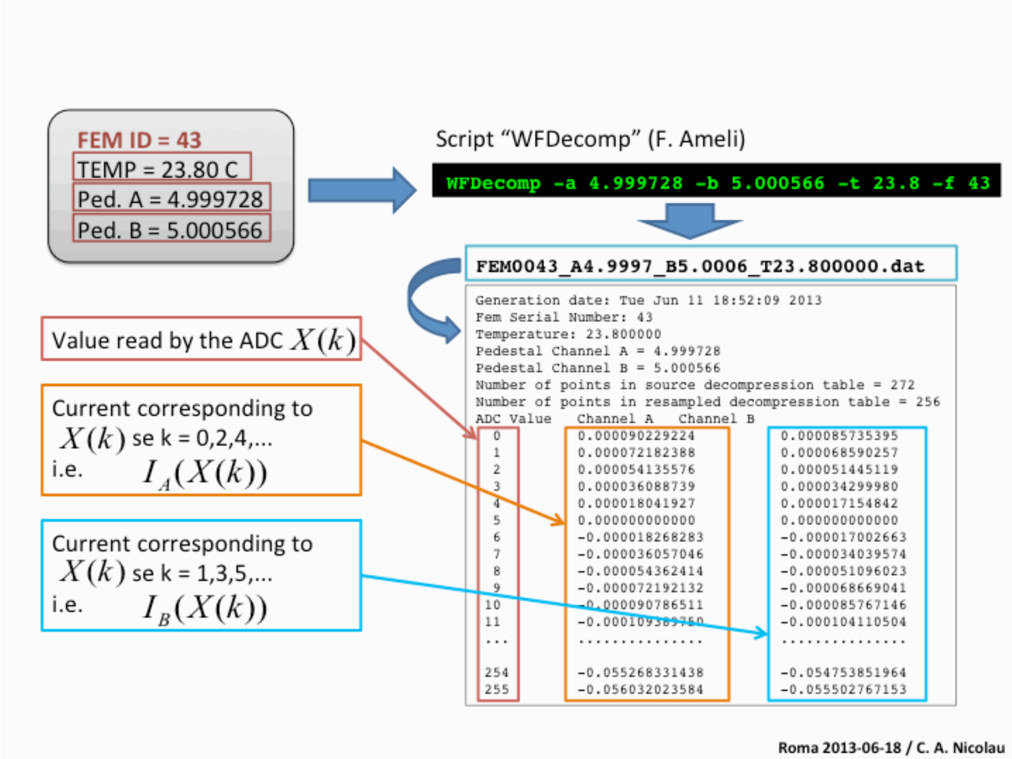
•finds the mechanical floor id from the eFCM id;

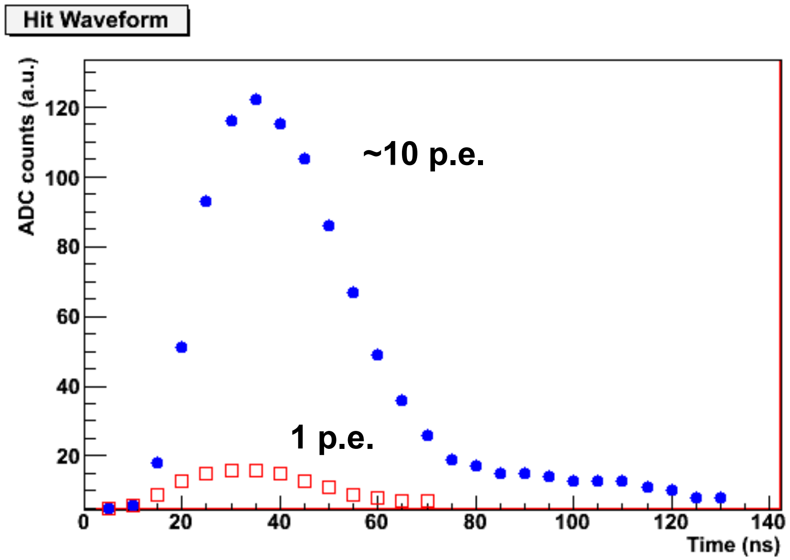
•writes the output file in the ANTARES evt format (input for *reco*).

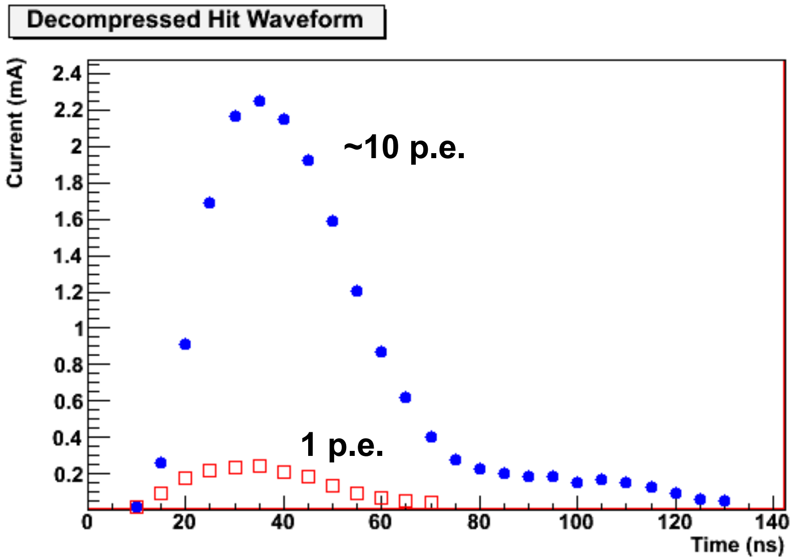
See http://wiki.infn.it/cn/csn2/km3/analysis_tools/hitdeco2 for details

The code HitDeco2:

- uses tables generated by F. Ameli to decompress the Fem Hits;







See C. Nicolau's talk in "**Analisi dati Capo Passero"** meeting, Rome 20-21 June 2013

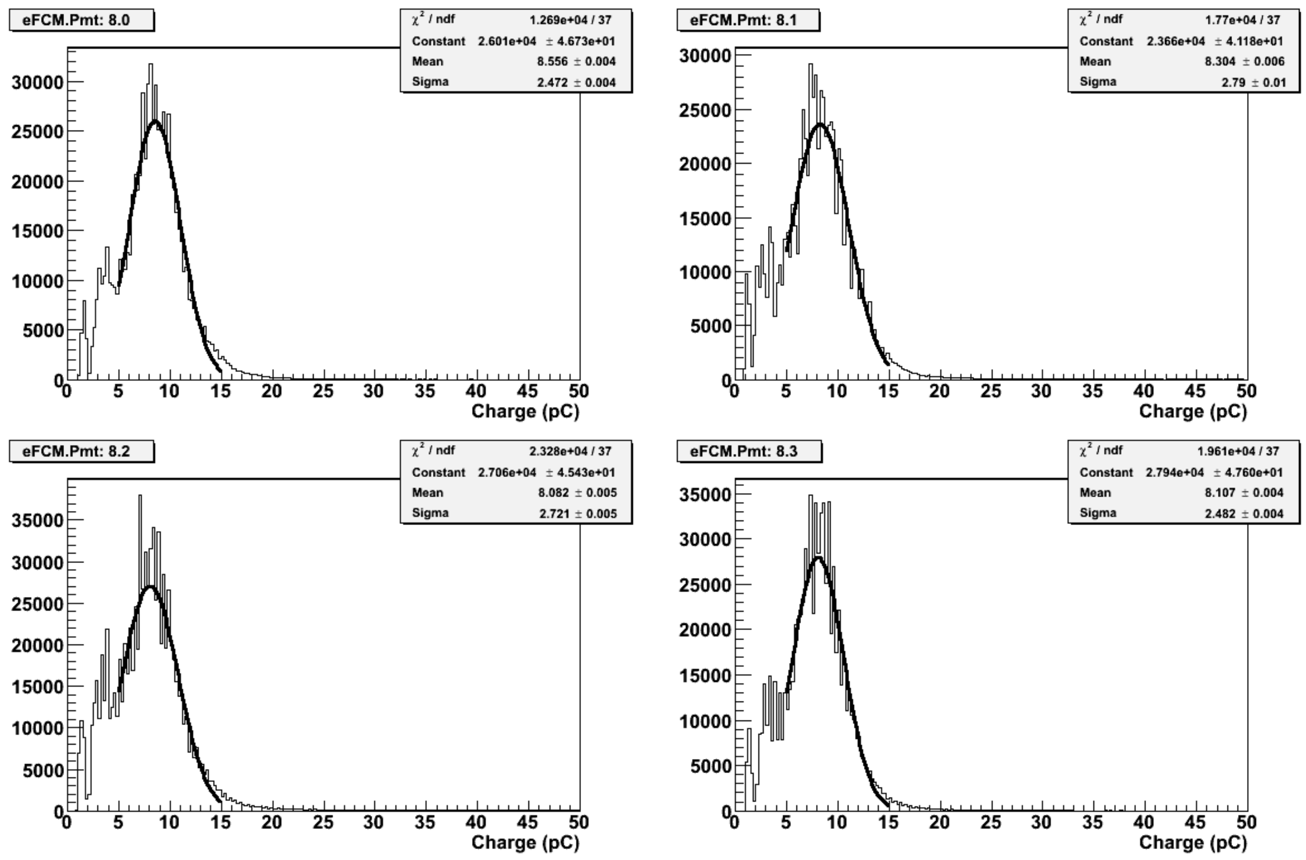
The code HitDeco2:

- evaluates the hit total charge and converts it from pC into p.e. (using an input table) ;

eFCM	Pmt	PCTOPE
1	0	8.50
1	1	8.44
1	2	8.62
1	3	8.41
2	0	8.50
2	1	8.47
2	2	7.34
2	3	7.81
3	0	8.58
3	1	8.50
3	2	8.77
3	3	8.37
4	0	8.29
4	1	8.09
4	2	8.92
4	3	8.41
5	0	8.46
5	1	8.27
5	2	8.53
5	3	7.69
6	0	8.44
6	1	8.37
6	2	8.43
6	3	8.42
7	0	8.46
7	1	7.88
7	2	-1
7	3	7.67
8	0	8.56
8	1	8.29
8	2	8.12
8	3	8.10

- is able to build the PCTOPE table (for checking or new HV set-up)

nemo_f2_pt_R00000874_F00000000.dat (Plots for all eFCMs at the end of file)



See also A. Capone talk in “**Analisi dati Capo Passero**” meeting, Rome 20-21 June 2013

The code HitDeco2:

- evaluates the hit time (threshold exceeded) from the decompressed hit wave form (σ ~1 ns?) with a linear interpolation (F. Simeone) but **possibility to implement new algorithms**;

PMT #	Offset (ns)	Comment
1.0	0	Taken as reference
1.1	0	
1.2	-4	
1.3	-9	
2.0	280	
2.1	285	
2.2	289	
2.3	279	
3.0	565	
3.1	565	Not tested - assumed the same as 3.0
3.2	568	
3.3	569	
4.0	870	
4.1	866	
4.2	868	
4.3	863	
5.0	1148	
5.1	1148	Not tested - assumed the same as 5.0
5.2	1148	
5.3	1146	
6.0	2021	
6.1	2025	
6.2	2021	
6.3	2022	
7.0	1416	
7.1	1425	
7.2	1419	
7.3	1421	
8.0	1712	
8.1	1705	
8.2	1710	
8.3	1701	

PRELIMINARY DATA based on analysis of calibration runs with external laser of mid-Oct. 2012
08 April 2013
For information: circella@ba.infn.it

M. Circella, eLog #222

- applies the time calibration offsets:
- - Oct 2012 on-shore measured values recovered from PT header file.
- - Soon, the possibility to give the table as input

Hit decompression and calibration

The code HitDeco2:

- finds the mechanical floor id from the eFCM id;
- writes the output file in the ANTARES evt format (input for *reco*).

PMT Ids

eFCM: eFCM id, ranging between 1 and 8;

Pmt: PMT id, ranging between 0 and 3;

Floor: mechanical floor id, ranging between 0 and 3;

eFCMAbs: absolute PMT referring to the eFCM id, ranging between 0 and 31 (to define arrays for calibration tables);

PMTID: absolute PMT referring to the mechanical floor id, ranging between 1 and 32 (Evt Output File);

Serial Number: PMT FEM Serial Number. It is used in the decompression table file names.

eFCM,Pmt	Floor	eFCMAbs	PMTID	Serial Number
1,0	1	0	1	2
1,1	1	1	2	18
1,2	1	2	3	61
1,3	1	3	4	48
2,0	2	4	5	33
2,1	2	5	6	7
2,2	2	6	7	31
2,3	2	7	8	40
3,0	3	8	9	62
3,1	3	9	10	34
3,2	3	10	11	67
3,3	3	11	12	4
4,0	4	12	13	64
4,1	4	13	14	1
4,2	4	14	15	35
4,3	4	15	16	20
5,0	5	16	17	54
5,1	5	17	18	42
5,2	5	18	19	47
5,3	5	19	20	43
6,0	8	20	29	56
6,1	8	21	30	37
6,2	8	22	31	29
6,3	8	23	32	25
7,0	6	24	21	55
7,1	6	25	22	59
7,2	6	26	23	6
7,3	6	27	24	16
8,0	7	28	25	36
8,1	7	29	26	65
8,2	7	30	27	41
8,3	7	31	28	19

The TriggerSim Code

Interface between evt files in the Antares Format and the Trigger Algorithms

TriggerSim (On-Line): Simulation of the OnLine Trigger

The code works on the *hit_fem* tag (see FemSim output)

TriggerSim (Off-Line): Application of the OffLine Trigger

The code works on the *hit_raw* (e.g HitDeco2 output)

Trigger Logics used by TriggerSim (same classes used by the on-line trigger at the Catania TestSite)

a) *ChargeShooting*: the hit charge exceeds a given threshold (2.5 p.e.);

b) *TimeCoincidences:*

SimpleTimeCoincidence: 2 hits in coincidence in the same storey end (20 ns);

CrossFloorTimeCoincidence: 2 hits in coincidence in different storey ends (100 ns);

and adds to the event some tags reporting trigger seeds parameters.

Written with T.Chiarusi

The SelectionPois code

Off-Line Trigger Condition:

- Ensemble of all hits participating to the Off-Line Trigger seeds
- For each hit, we calculate the number of the other hits in the ensemble causality correlated according to

$$|dt|<dr/v_{light} + 20ns$$

- We calculate the maximun number of causality relations N_{Caus}
- We selects all the events having $N_{Caus}\geq 6$ ($N_{Caus}\geq 4$ in Phase-1): not yet optimized but purity ≈ 1 at reconstruction level (from simulations)

The SelectionPois code:

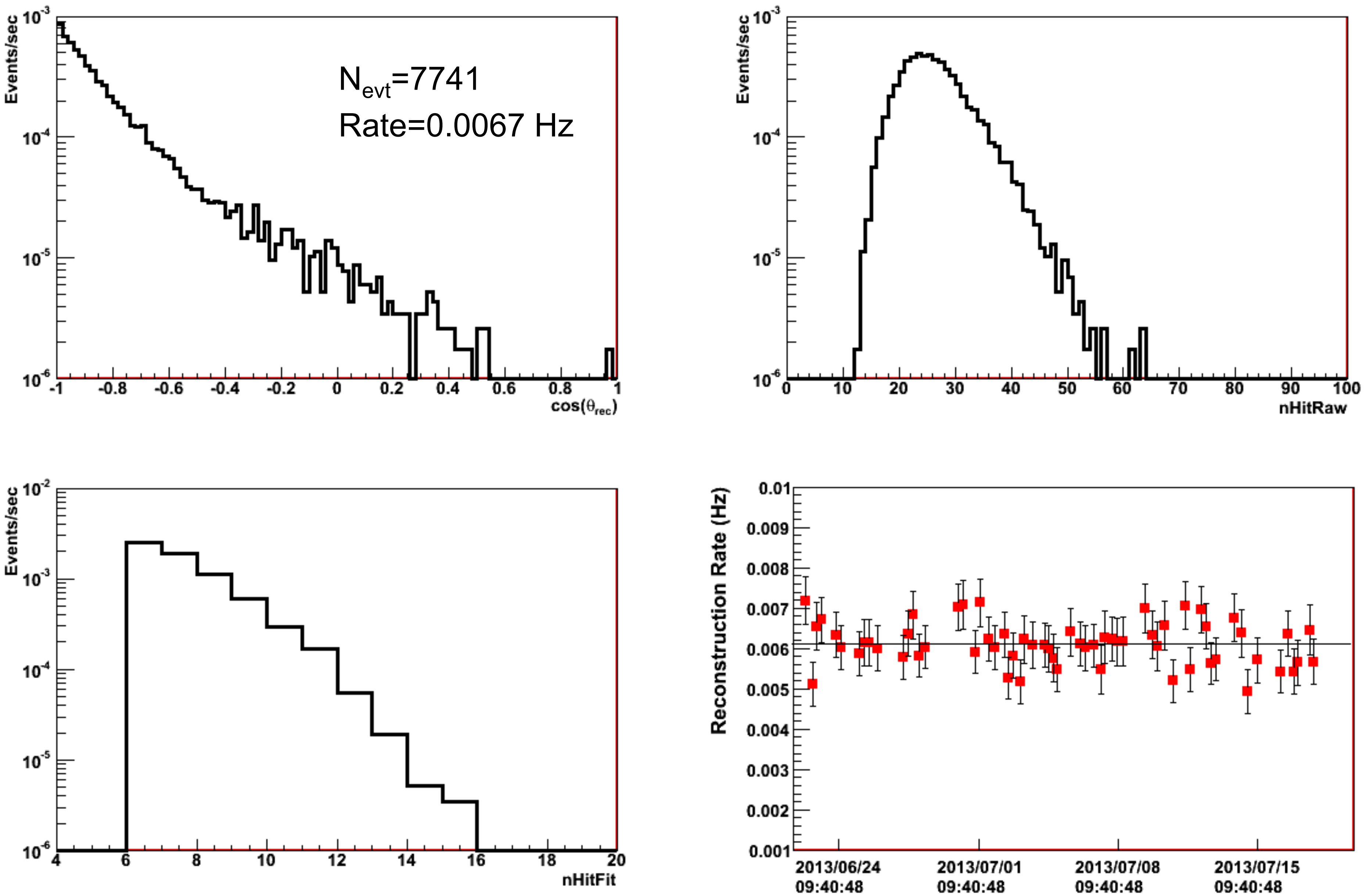
1) selects the events that satisfy the OffLine Trigger Condition (NCausMin =4)
2) rejects all hits having a charge lower tha Qmin (Qmin=0.5 p.e.)
3) ~~applies a causality filter to reject the background hits~~
4) ~~writes the events having at least 6 selected hits in the *hit_sel* tags~~

Written with S.Galatà

The output file is processed by reco:

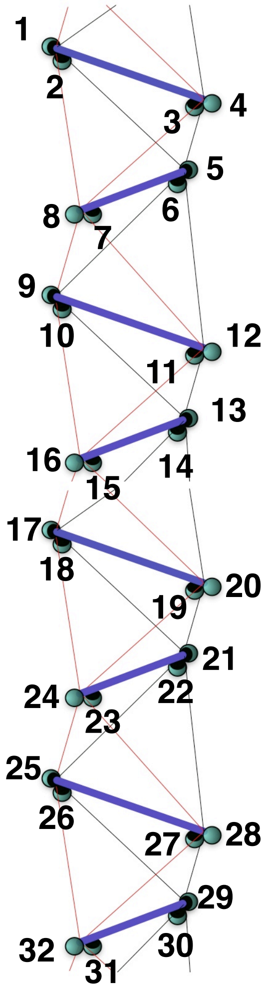
1) the tracks are reconstructed with the Aart Strategy
2) During SelectionPois and reco running, nominal geometry file is used.

Reconstruction level

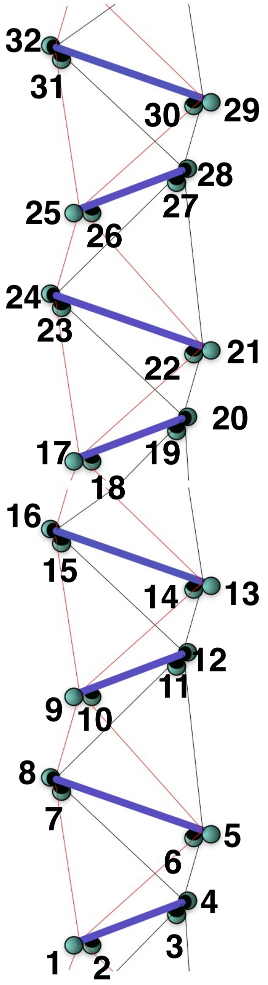


Monte Carlo Simulations

From gendet



Manually reconfigured



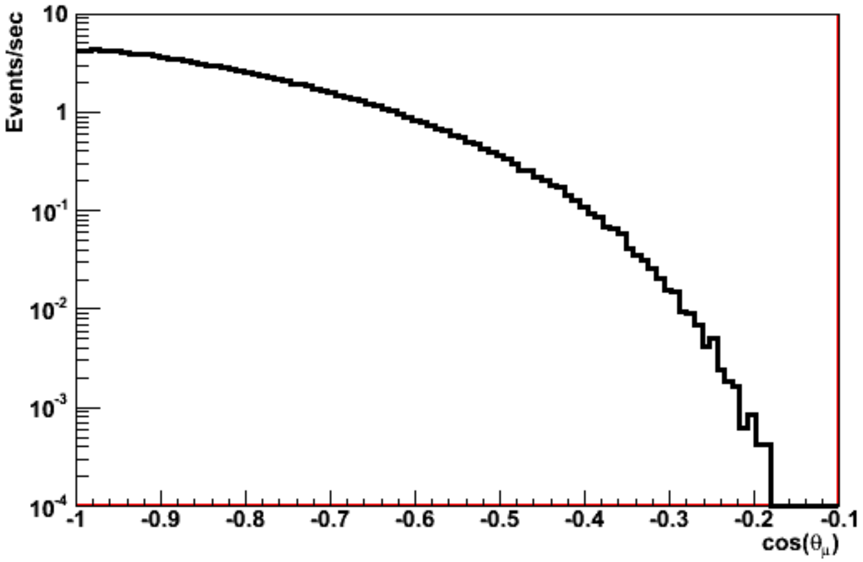
From gendet (G. De Bonis, see note in the wiki)
NEMO-PhaseII_01.det

Manually reconfigured (T. Chiarusi & L. Fusco)
NEMO-PhaseII_01_mod.det

Down-looking PMT phi angle changed (no effect)
NEMO-PhaseII_02_mod.det

OM_position: 1 -4.0000 0.0000 -20.0000 1.570796 3.141593
OM_position: 2 -3.5000 0.0000 -20.2800 3.141593 3.141593
OM_position: 3 3.5000 0.0000 -20.2800 3.141593 0.000000
OM_position: 4 4.0000 0.0000 -20.0000 1.570796 0.000000
OM_position: 5 0.0000 -4.0000 20.0000 1.570796 4.712389
OM_position: 6 0.0000 -3.5000 19.7200 3.141593 4.712389
OM_position: 7 0.0000 3.5000 19.7200 3.141593 1.570796
OM_position: 8 0.0000 4.0000 20.0000 1.570796 1.570796

OM_position: 1 -4.0000 0.0000 -20.0000 1.570796 3.141593
OM_position: 2 -3.5000 0.0000 -20.2800 3.141593 0.000000
OM_position: 3 3.5000 0.0000 -20.2800 3.141593 0.000000
OM_position: 4 4.0000 0.0000 -20.0000 1.570796 0.000000
OM_position: 5 0.0000 -4.0000 20.0000 1.570796 4.712389
OM_position: 6 0.0000 -3.5000 19.7200 3.141593 0.000000
OM_position: 7 0.0000 3.5000 19.7200 3.141593 0.000000
OM_position: 8 0.0000 4.0000 20.0000 1.570796 1.570796



MuPage (v3r5)

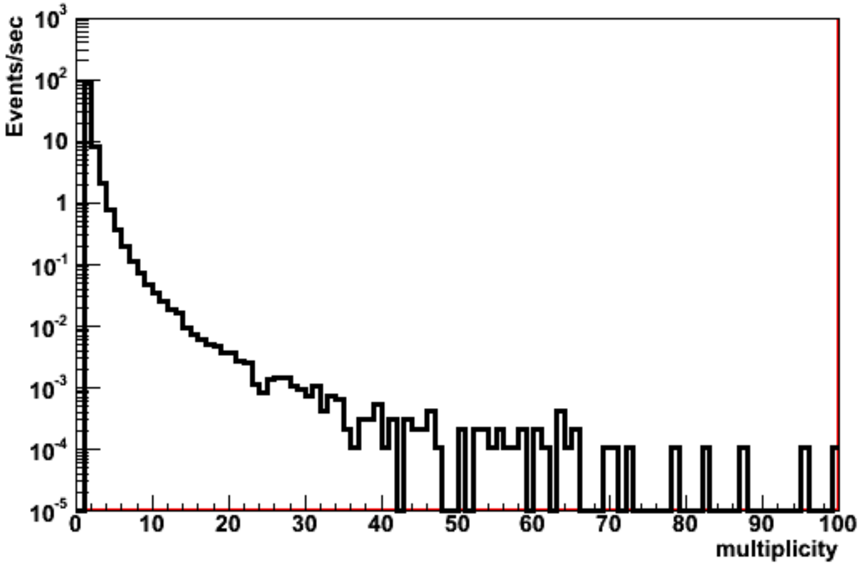
Ngen: $2{\cdot}10^8$ (bundles)

LiveTime: 534.4 hr

Geometry File: NEMO-PhaseII_01_mod.det

Sea-bottom: 3430 m

Can size: H=572.8 m R=310. m



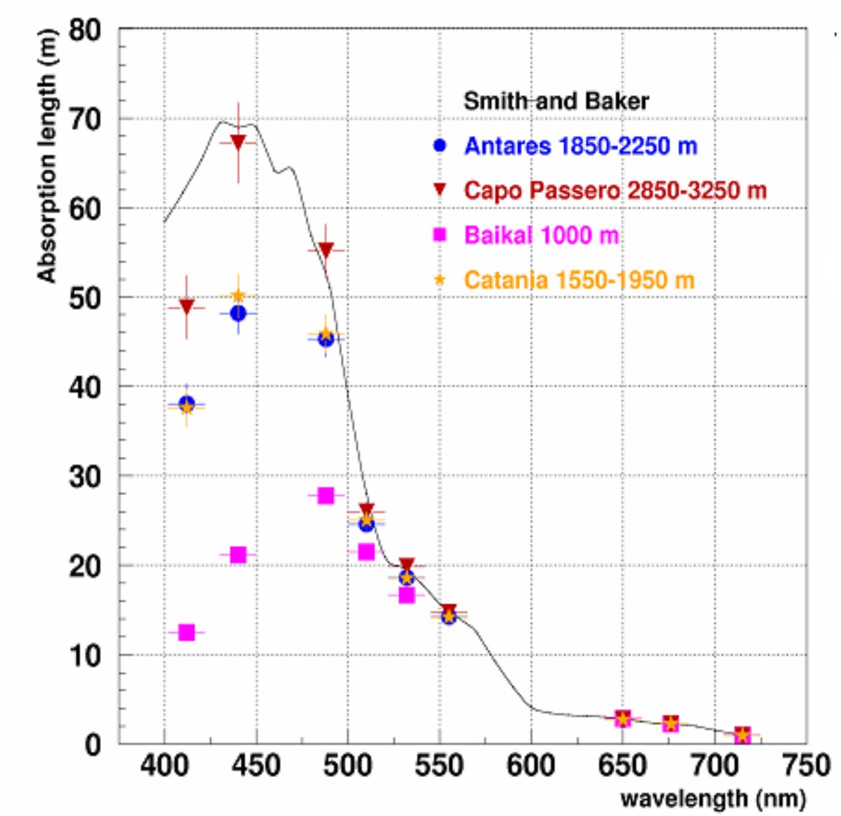
Muons @can: $2.4{\cdot}10^8$

Mean multiplicity: 1.2

(L. Fusco)

The **gen** and **hit** codes (**version v4r4**) have been used to generate ***photon tables*** simulating the CP optical parameters and the Phase2 OM. Muon tracking simulated with **km3** code (**version v4r4**) .

- Absorption length profile measured at the Capo Passero (AC9 + ANTARES)
- Scattering: partic model



Gel:

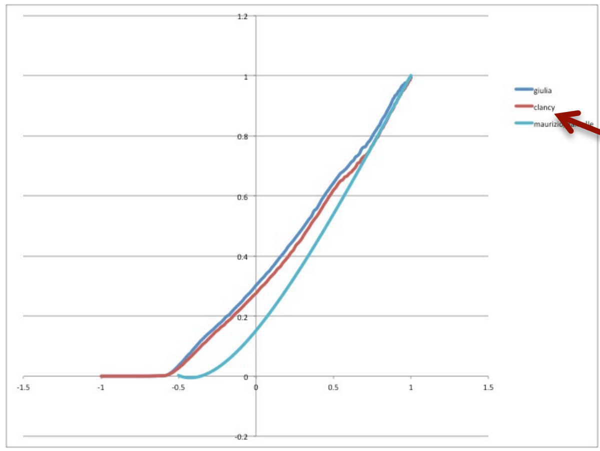
- Thickness: 1.0 cm
- Absorption length measured by Catania group

Glass:

- Thickness: 1.2 cm
- Absorption length quoted by Vitrovex

(D. Lattuada)

Angular acceptance:



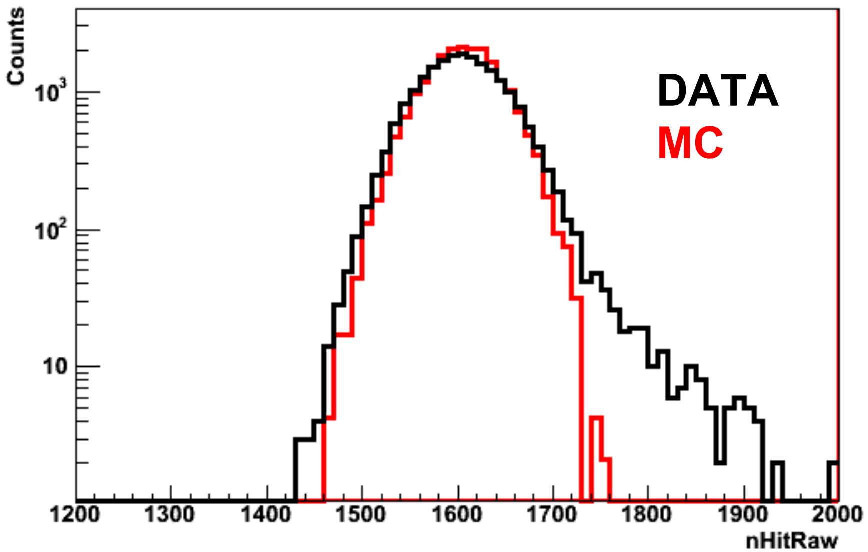
"Clancy" truncated at $\cos(\theta_C)$=-0.5 to take into account the OM shell and the bar

Still in progress:
Monte Carlo simulations (C. Hugon's talk)
Effects in muon reconstruction (S. Biagi's talk)

The GenBkg Code

The GenBkg code adds the optical background to muon events or generates only background events. The time window is chosen by the user (e.g. 6μs for Phase2)

- **Strategy 1: it generates s.p.e. hits according to a constant hit rate.**



Data: Random Trigger events
PT file:
nemo_f2_pt_R00000874_F00000000.dat

GenBkg:
Time window: 1 ms
Rate: 52 kHz

The FemSim Code

This code reads the GenBkg output file, simulates the NEMO PMT Front End electronics and generates the *hit_raw*. In particular:

It computes the total npe for all hits inside a given time interval (default 75 ns) and applies a gaussian smearing (used σ= 0.3 pC and Q_{spe}=1 pC/spe);

It applies a gaussian smearing to the hit time (used σ=2 ns).

Since we record also the PMT "waveform", a new hit format has been implemented (*hit_fem*) consistently with the TestSite DAQ Electronics

hit_fem: HitId PmtId TimeNs TimeUs Flag5ns QHit NSam S1 S2 ……

where:

- T= TimeUs*500000+TimeNs*10+Flag5ns is the hit time with the 5ns FEM precision;
- QHit is the hit charge expressed in ADC channels;
- NSam is the number of samples (S1 S2 …..) forming the hit.

Complete simulation of the NEMO PMT "waveform" not yet implemented.

Written by F. Ameli

The TriggerSim Code

Interface between evt files in the Antares Format and the Trigger Algorithms

TriggerSim (On-Line): Simulation of the OnLine Trigger

The code works on the *hit_fem* tag (see FemSim output)

TriggerSim (Off-Line): Application of the OffLine Trigger

The code works on the *hit_raw* (e.g HitDeco2 output)

Trigger Logics used by TriggerSim (same classes used by the on-line trigger at the Catania TestSite)

a) *ChargeShooting*: the hit charge exceeds a given threshold (500);

b) *TimeCoincidences:*
** *SimpleTimeCoincidence:* 2 hits in coincidence in the same storey end (2)**
** *CrossFloorTimeCoincidence*: 2 hits in coincidence in different storey ends (10)**

and adds to the event some tags reporting trigger seeds parameters.

Written with T.Chiarusi

Simulations

Atmoph. Muon Generator

Propagator and Light Simulator

Background Simulator

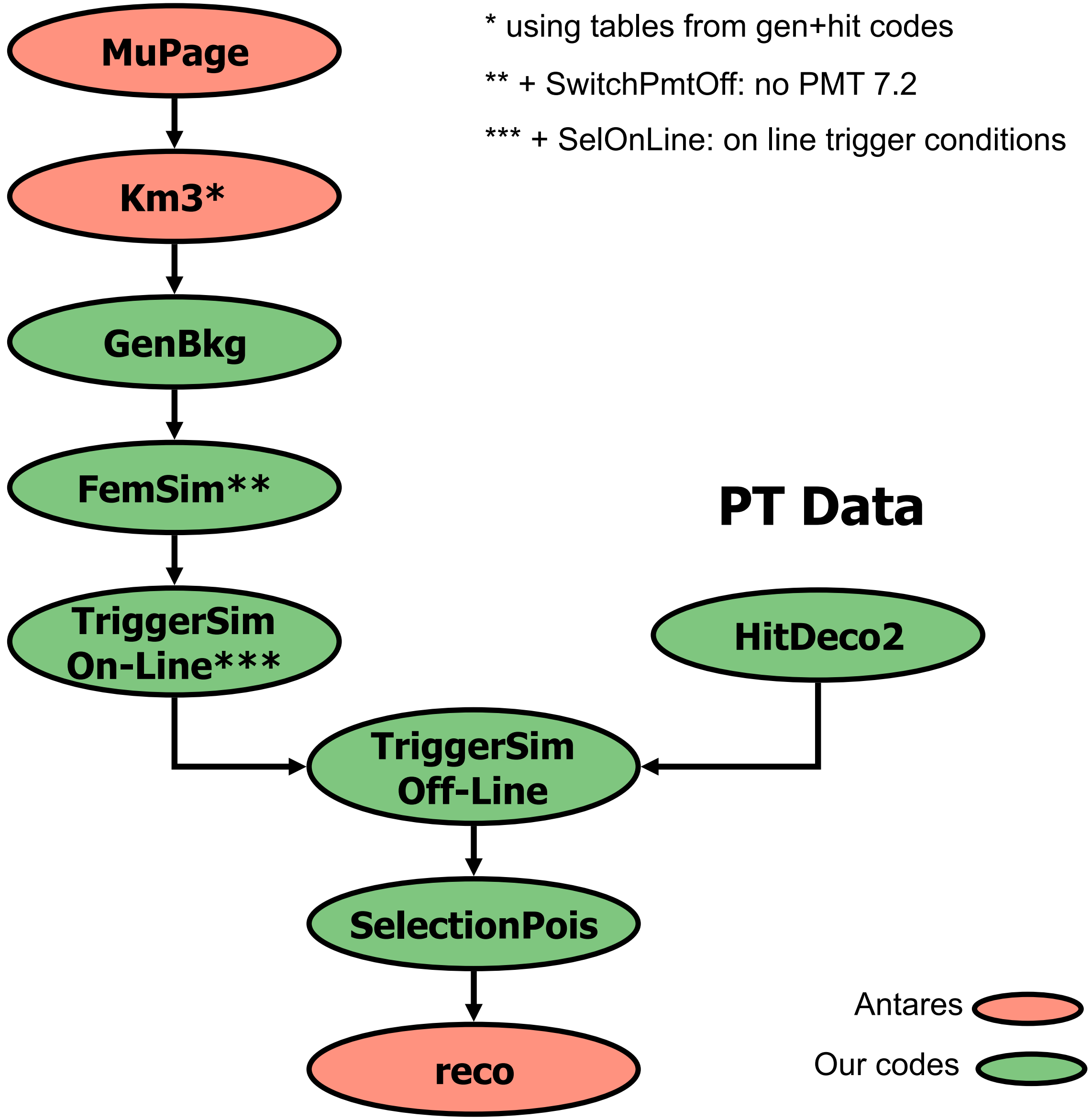
Electronics Simulator

OnLine Trigger Simulator

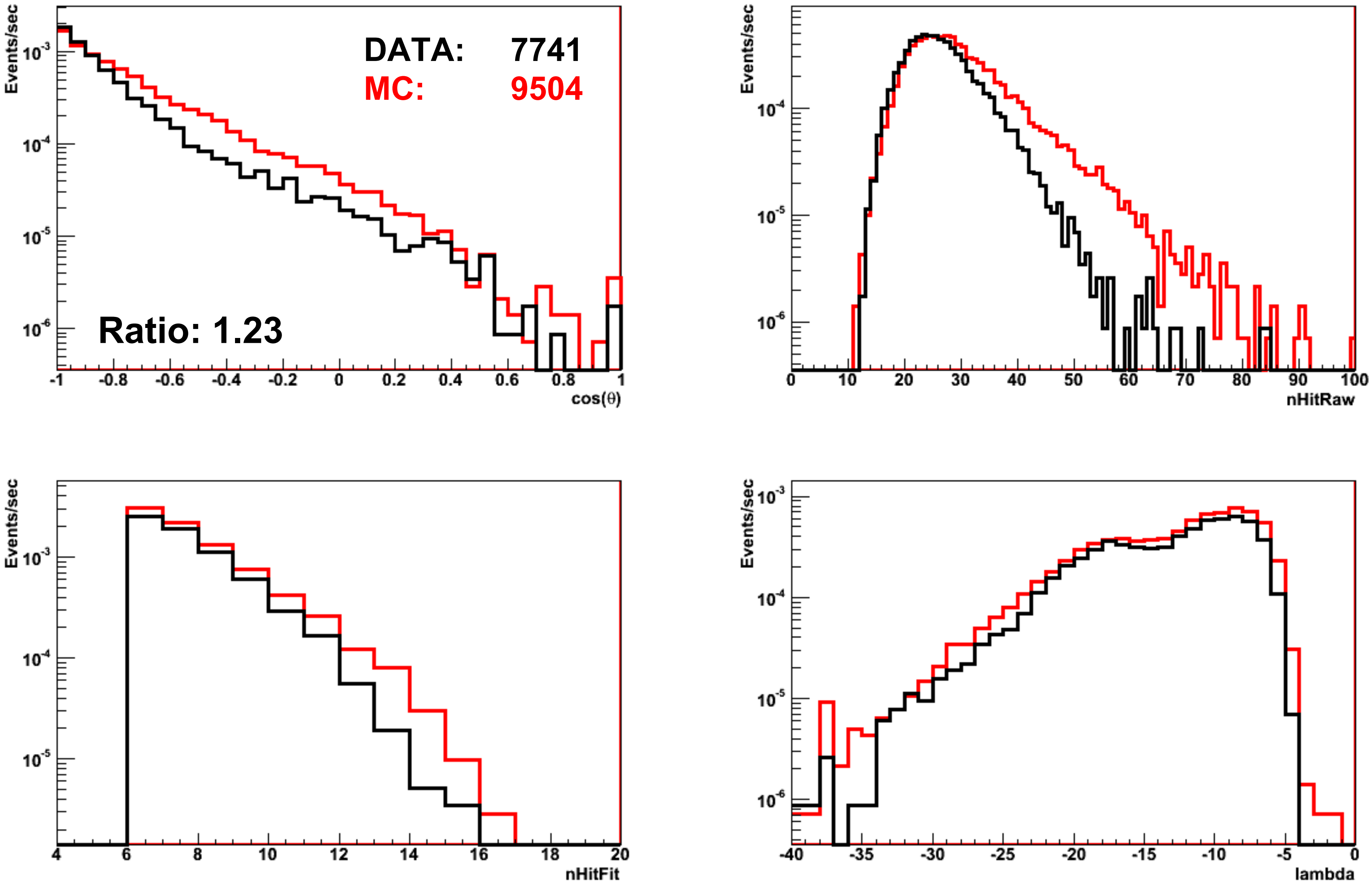
OffLine Trigger Seeds

Evt Selector (OffLine Trigger Condition + ~~Causality Filter~~)

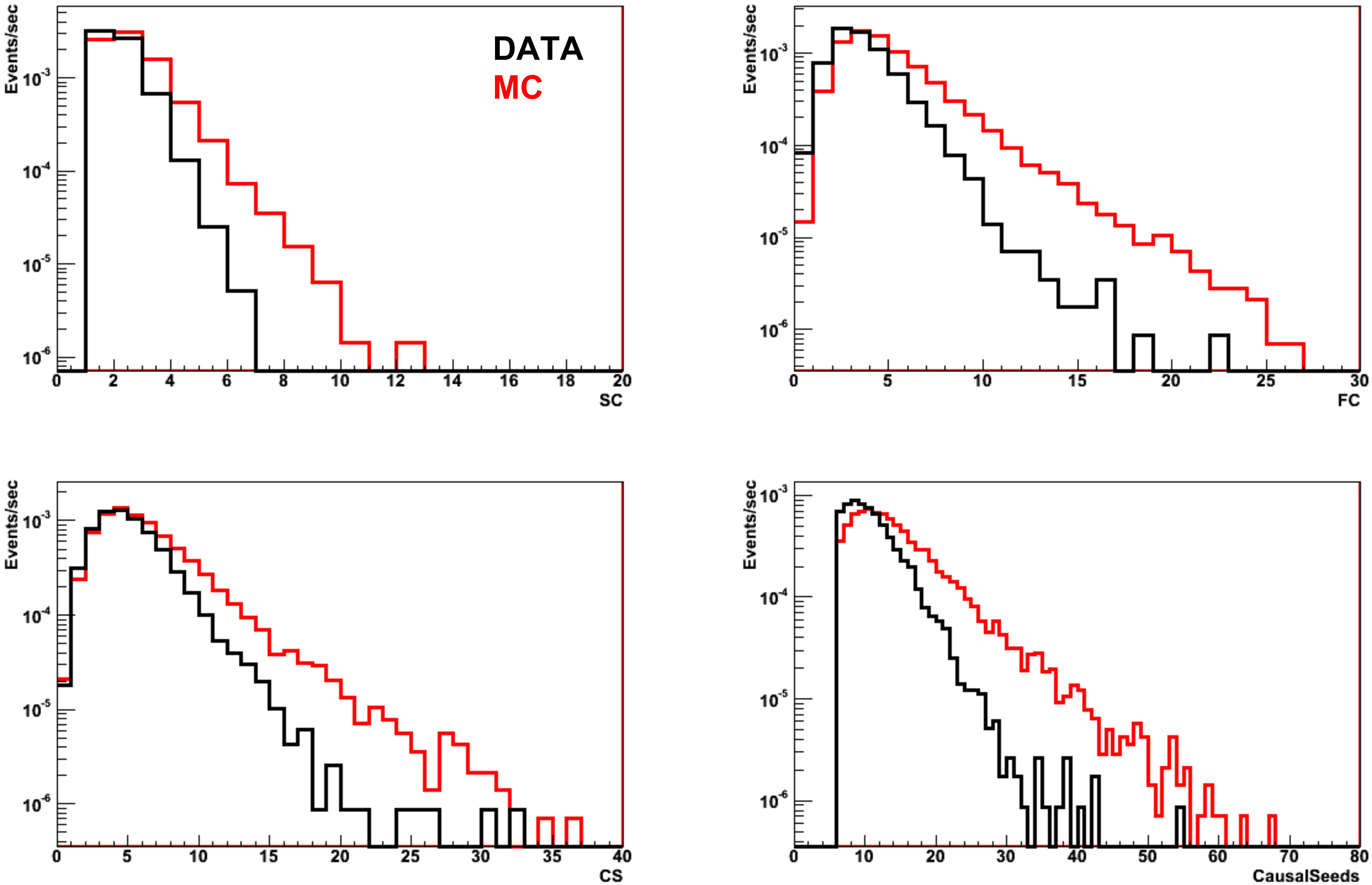
Track reconstructor



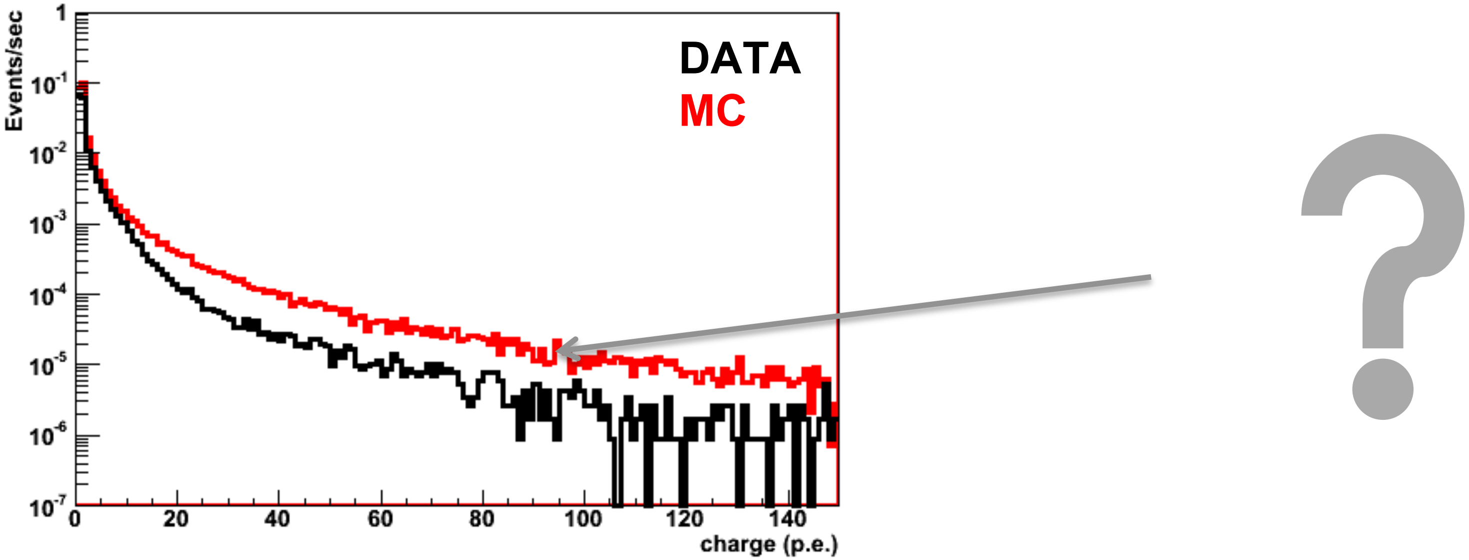
Reconstruction level

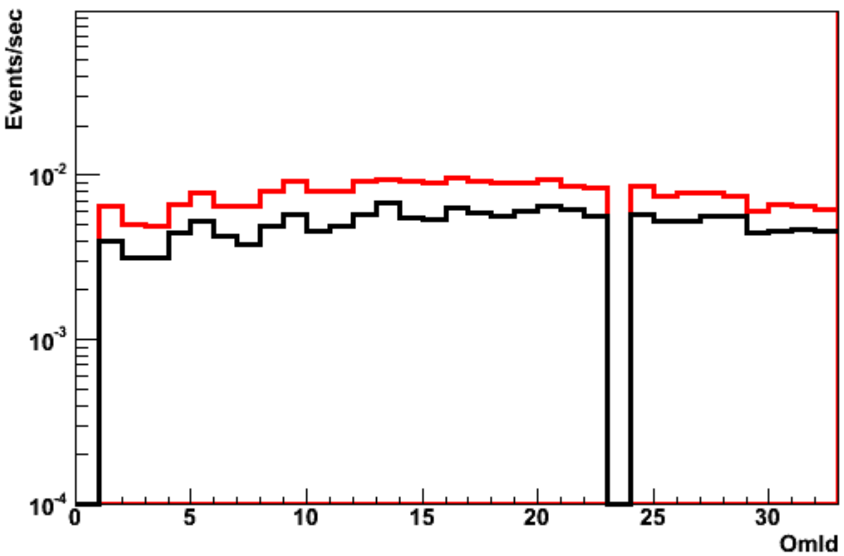


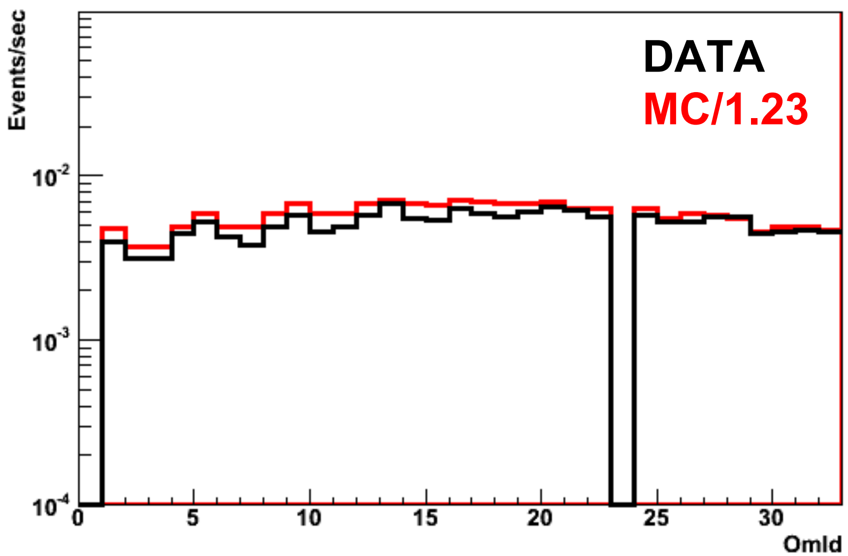
Reconstruction level (Trigger seeds computed on “calibrated hits”, tag: *hit_raw*)



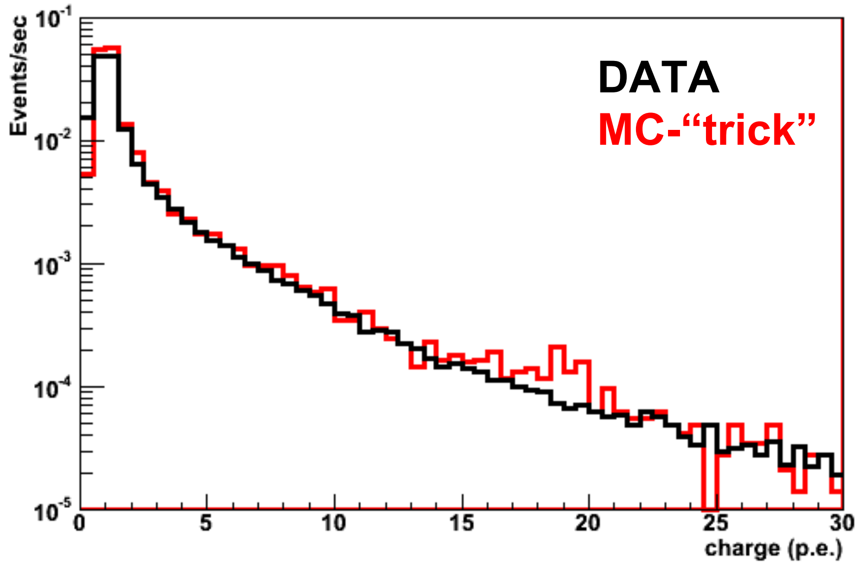
Reconstruction level





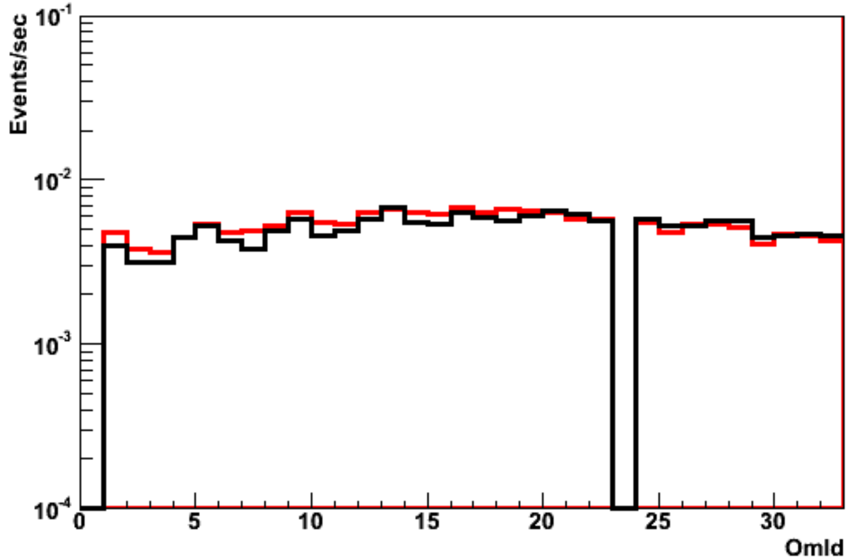


Reconstruction level



Question #1.

Different number of hits and charge distribution shape: they could be the source of MC-Data discrepancy?

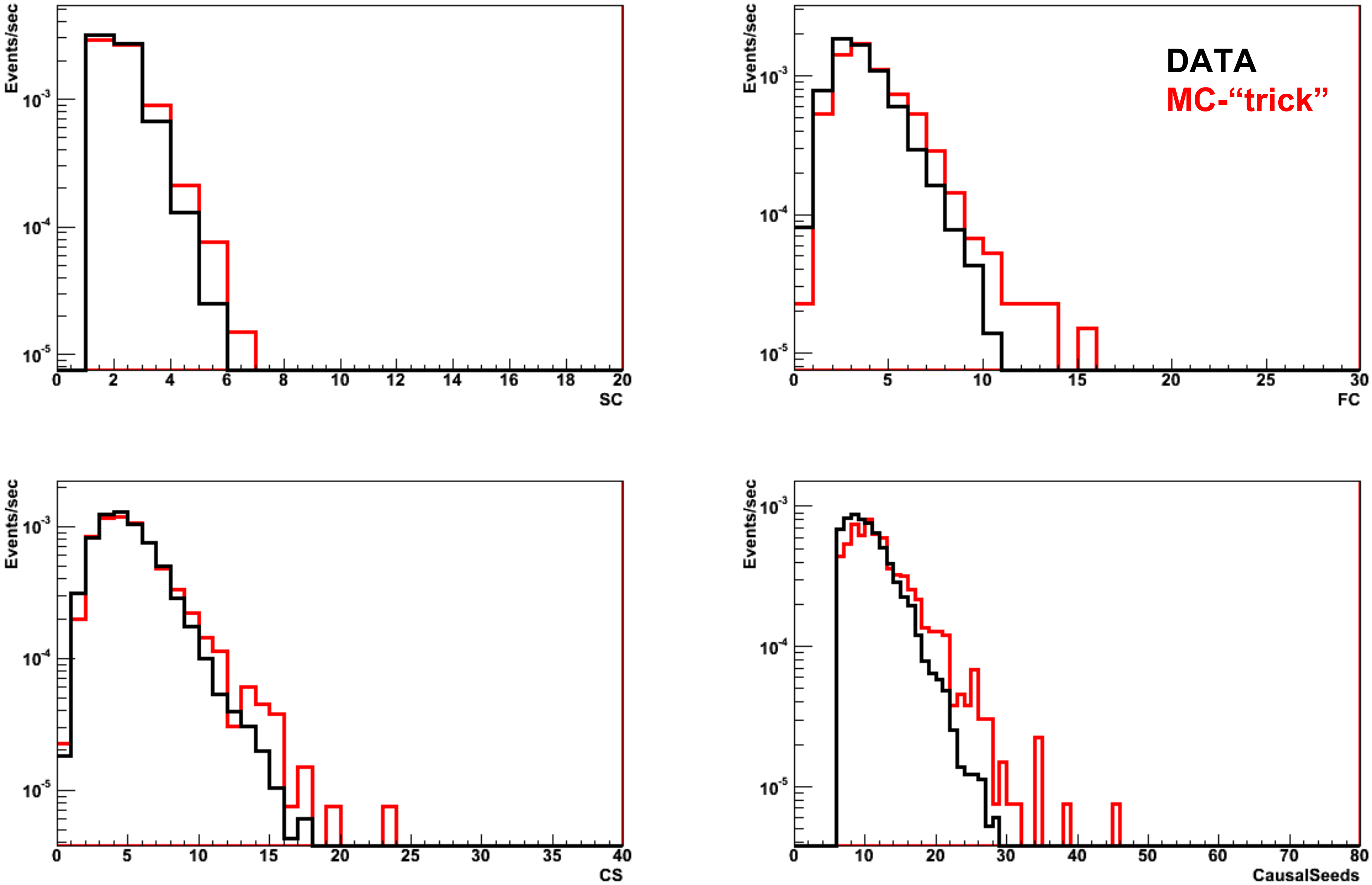


MC-“trick”:

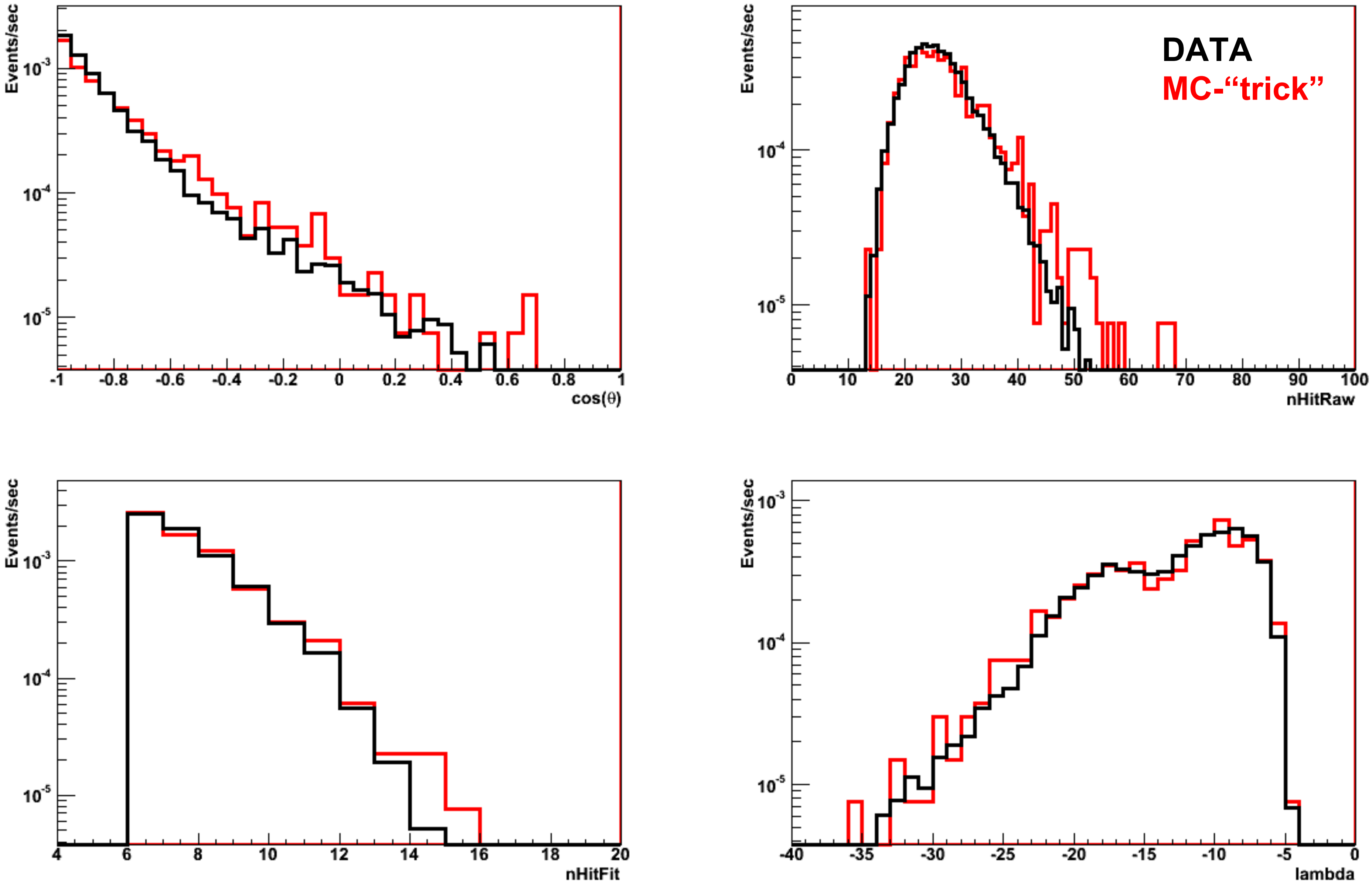
•Charge distribution data-MC ratio used as surviving probability to reject hits in MC (hit-or-miss technique).

•Hits are rejected before trigger on-line simulation.

Reconstruction level

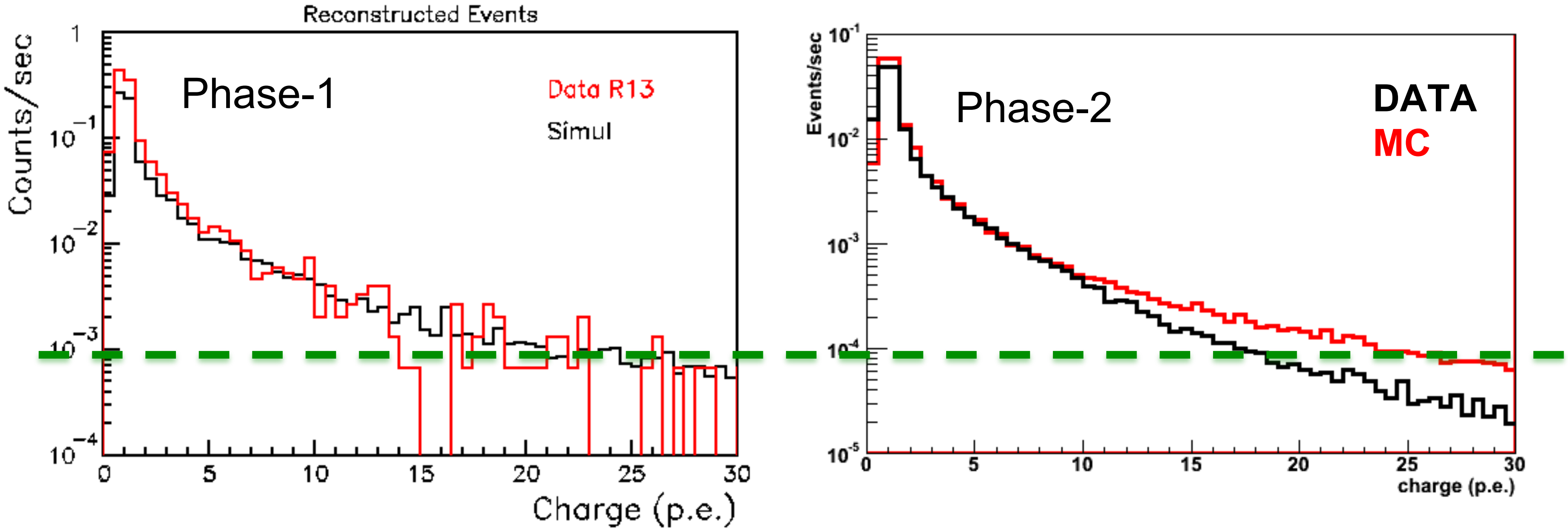


Reconstruction level



Question #2: **Too much hits in MC or too few hits in Data?**

Looking at NEMO Phase-1…

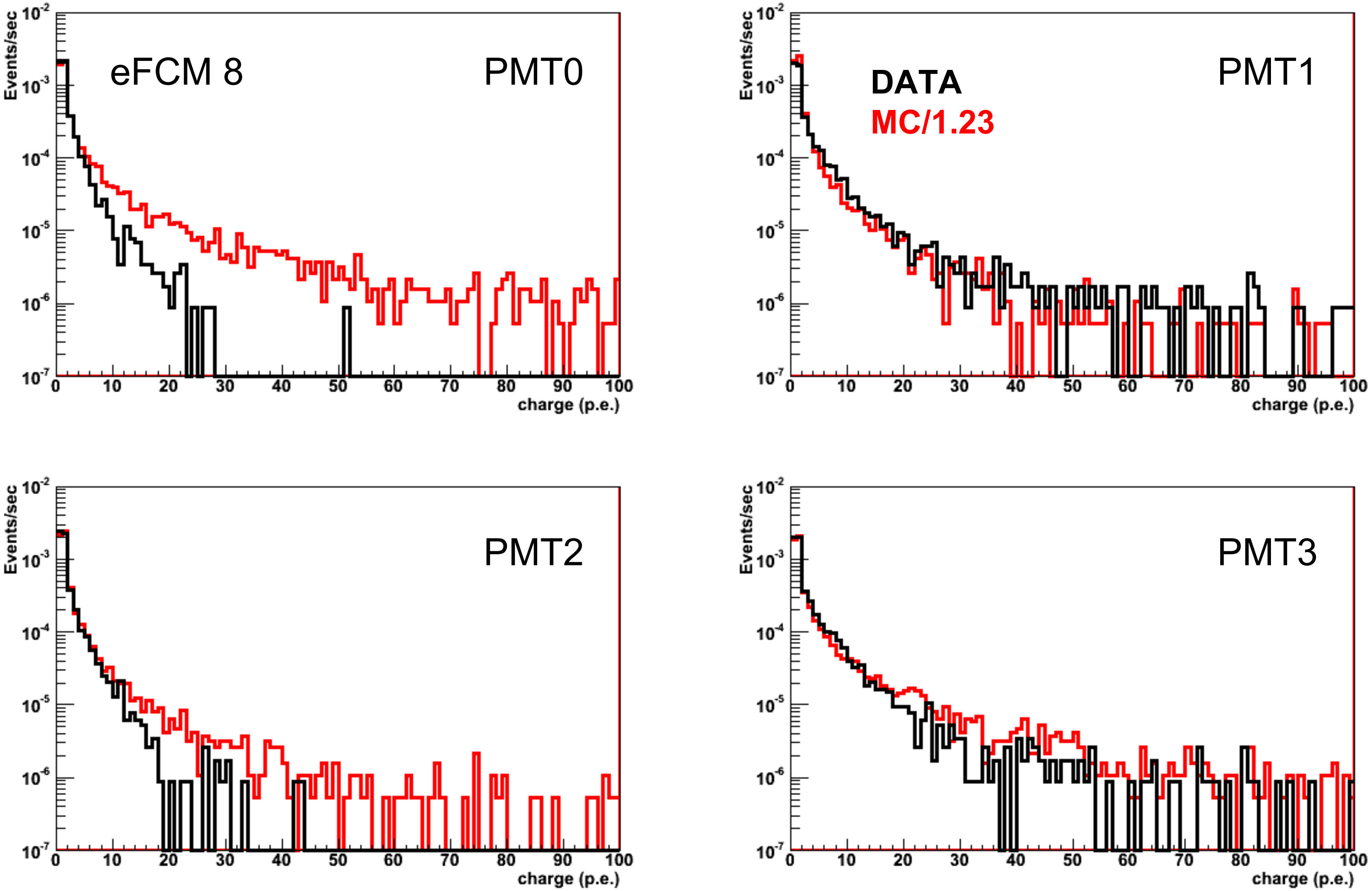


- same binning for histos
- 1 order of magnitude scale factor because of the different muon flux intensity

Charge distribution for single PMTs

LNS

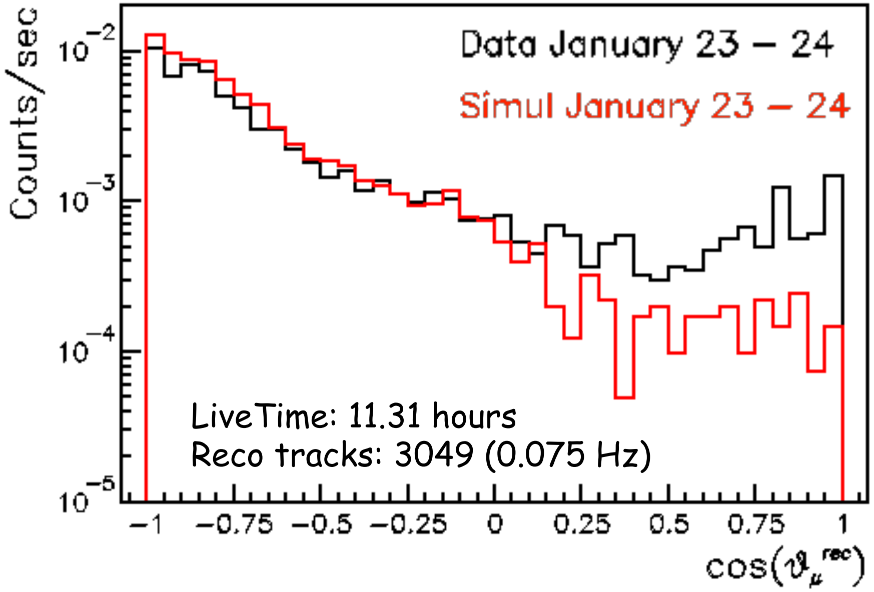
Question #3: Is the discrepancy in all PMTs?

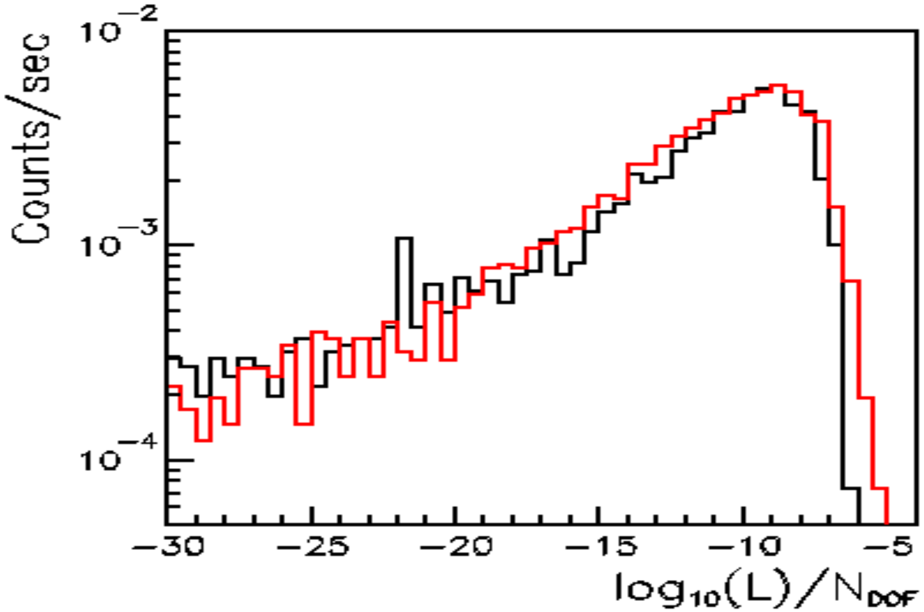


Plots for all eFCMs at the end of file.

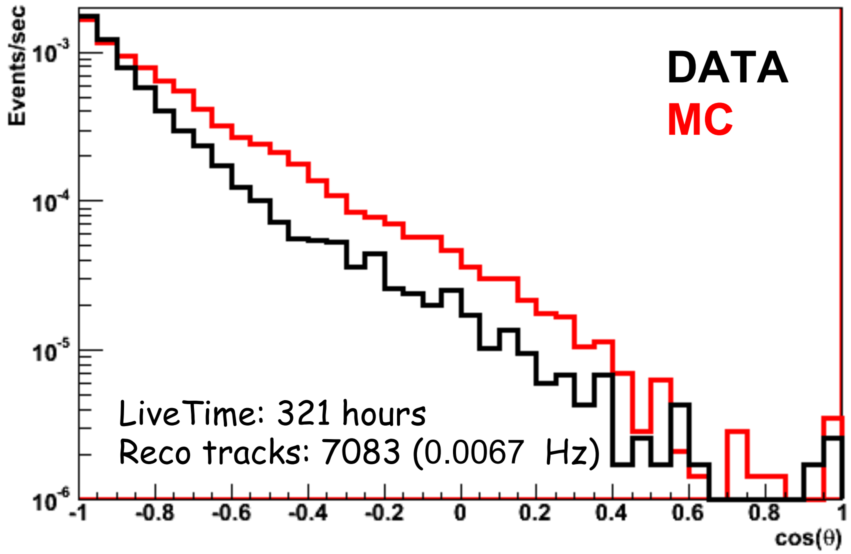
Comparison with NEMO-Phase1

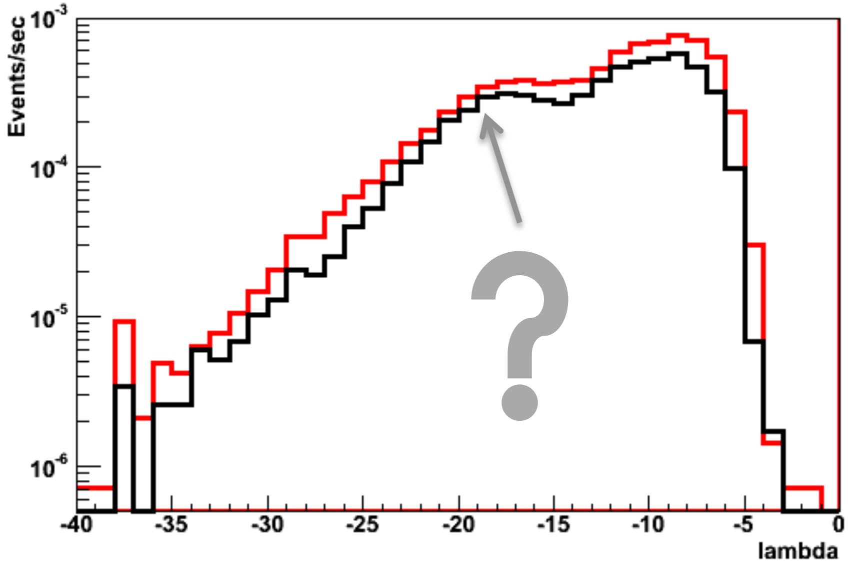
Phase1



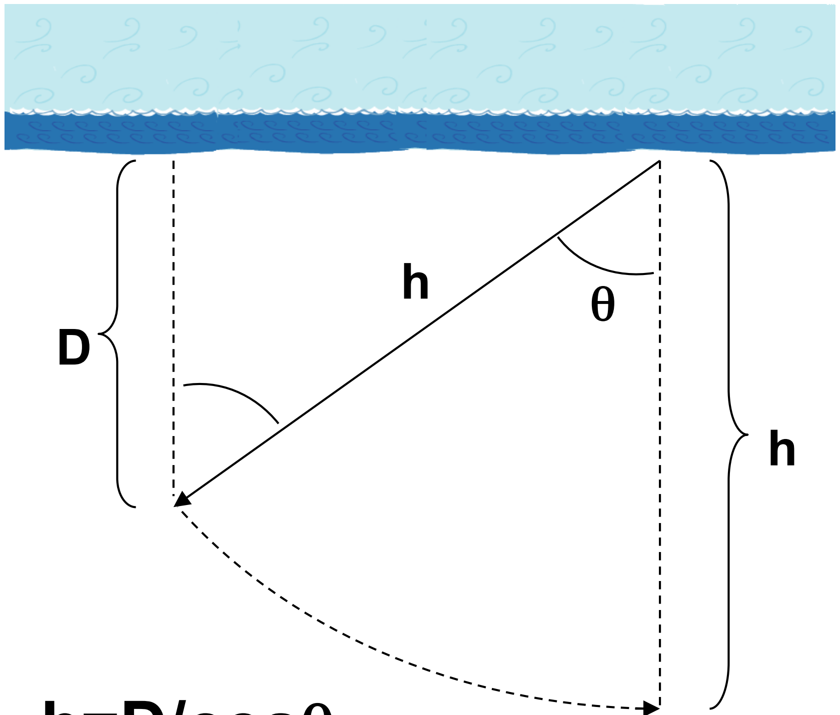


Phase2

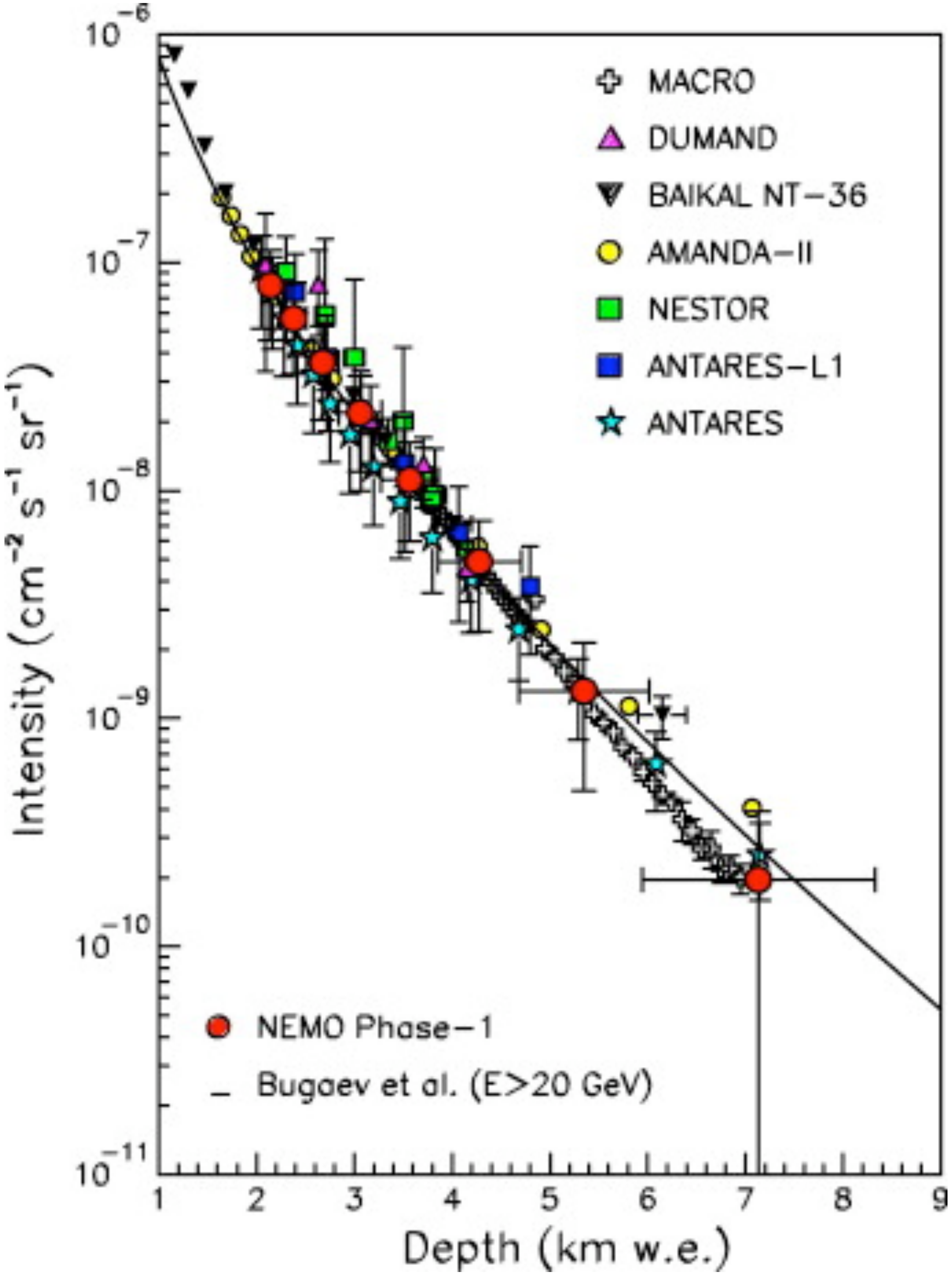




Depth Intensity Relation: DIR



h=D/cosθ



Vertical Muon Intensity as a function of Depth

Depth Intensity Relation: DIR

Code **CalcDir** (NEMO Phase-1)

Vertical Flux:

$I(h = D/\cos\theta) = I(\theta)\cdot\cos\theta\cdot c_{corr}$

Flux Angular Dependence:

$I(\theta) = N_{\mu}(\theta)\, m(\theta)\, /T\ \Delta\Omega\ A^{eff}(\theta)$

$N_{\mu}(\theta)$: number of detected muons (deconvolution)

T: livetime

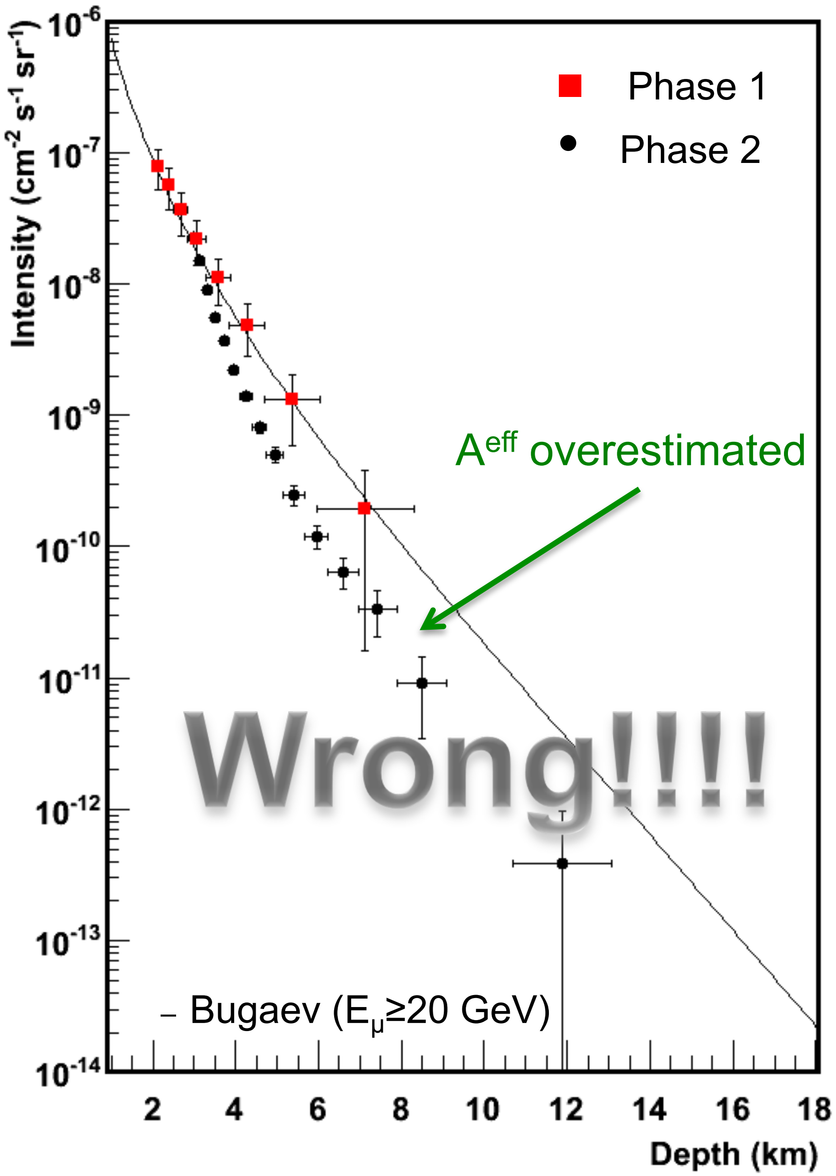
$\Delta\Omega$: solid angle

$A^{eff}(\theta)$: effective area*

$m(\theta)$: multiplicity*

* From Monte Carlo simulations

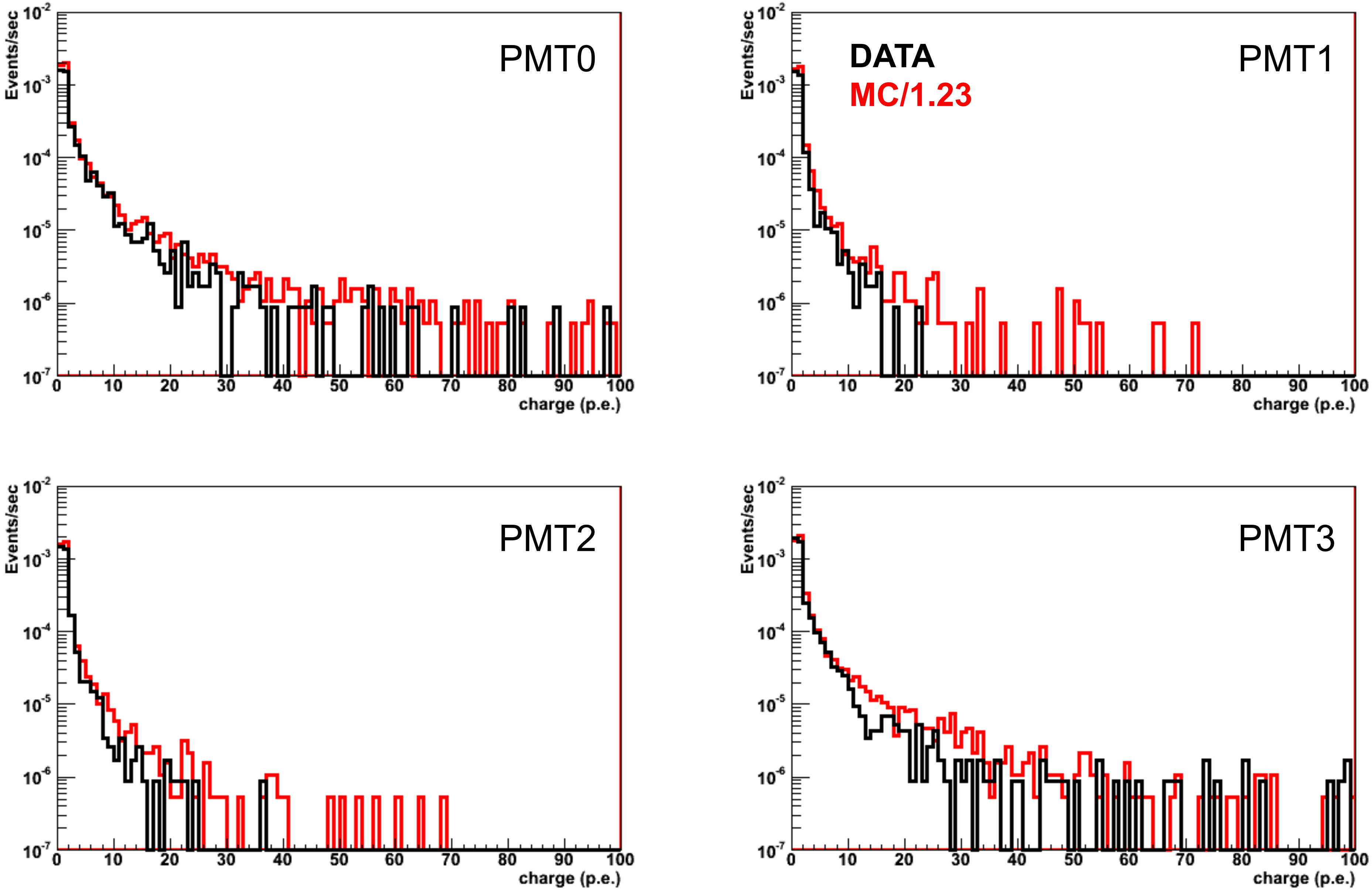
Wrong DIR because of the discrepancy between Data and MC but ready for computation!!!



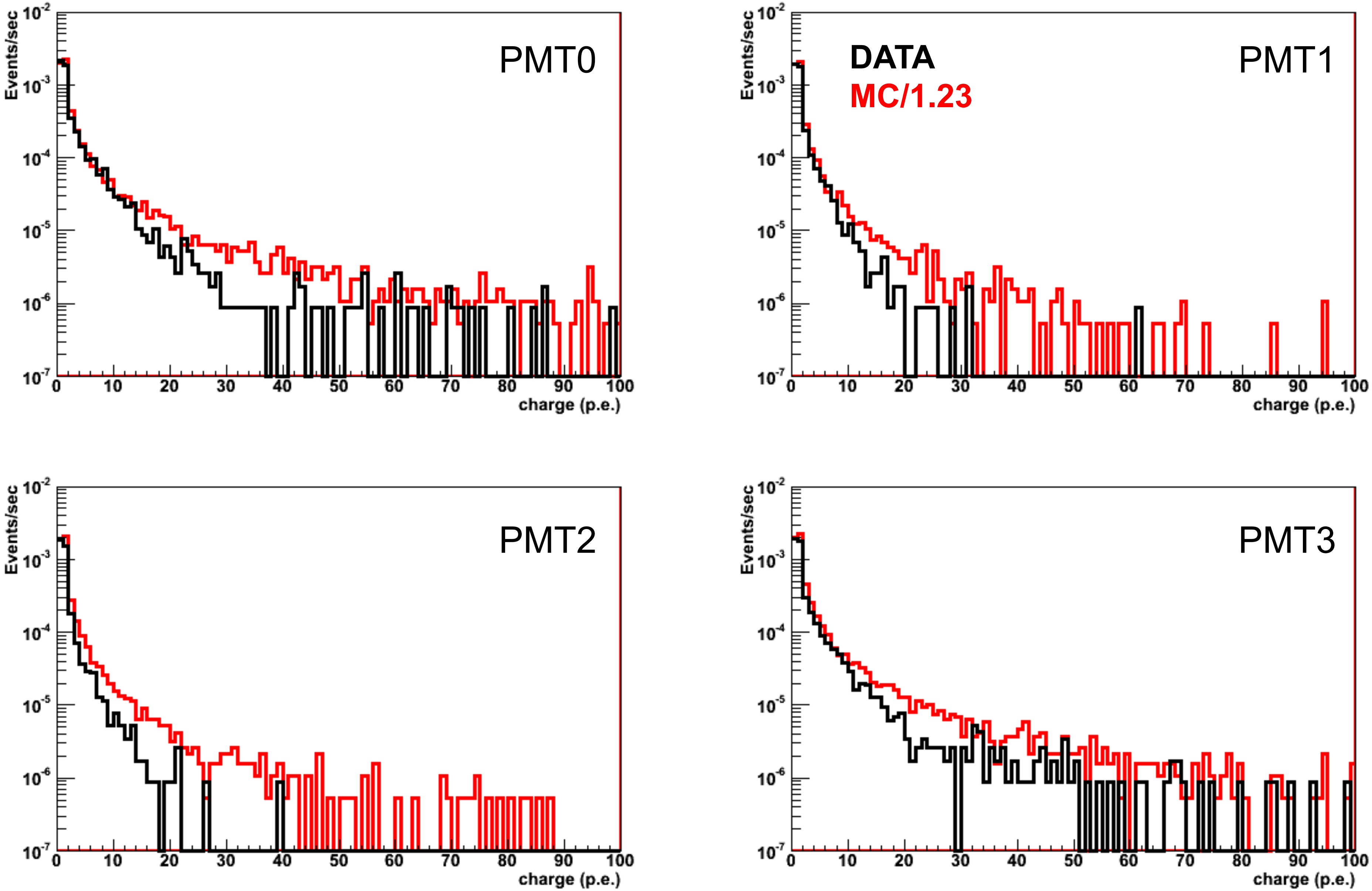
Summary

- We started the atmospheric muon analysis.
- A total number of 61 PT files (live time: 321 hr) have been analysed. The whole data set will be analysed when we'll be sure of the data calibration procedure (better hit time evaluation?).
- We reconstruct 7741 muon tracks, corresponding to a rate of 0.0067 Hz.
- Data analysis results have been compared with Monte Carlo simulations.
- Simulations exceed the data by a factor 1.23 but also discrepancy in number of hits per event and in charge distributions.
- Probably, discrepancies are because PMTs have different behaviours (and differences with NEMO Phase-1), but…
- … Monte Carlo still in progress: PMT angular acceptance.
- Waiting for Data-MC agreement: update of code CalcDir. Wrong DIR at the moment because of overestimate of the effective area but ready for the computation.

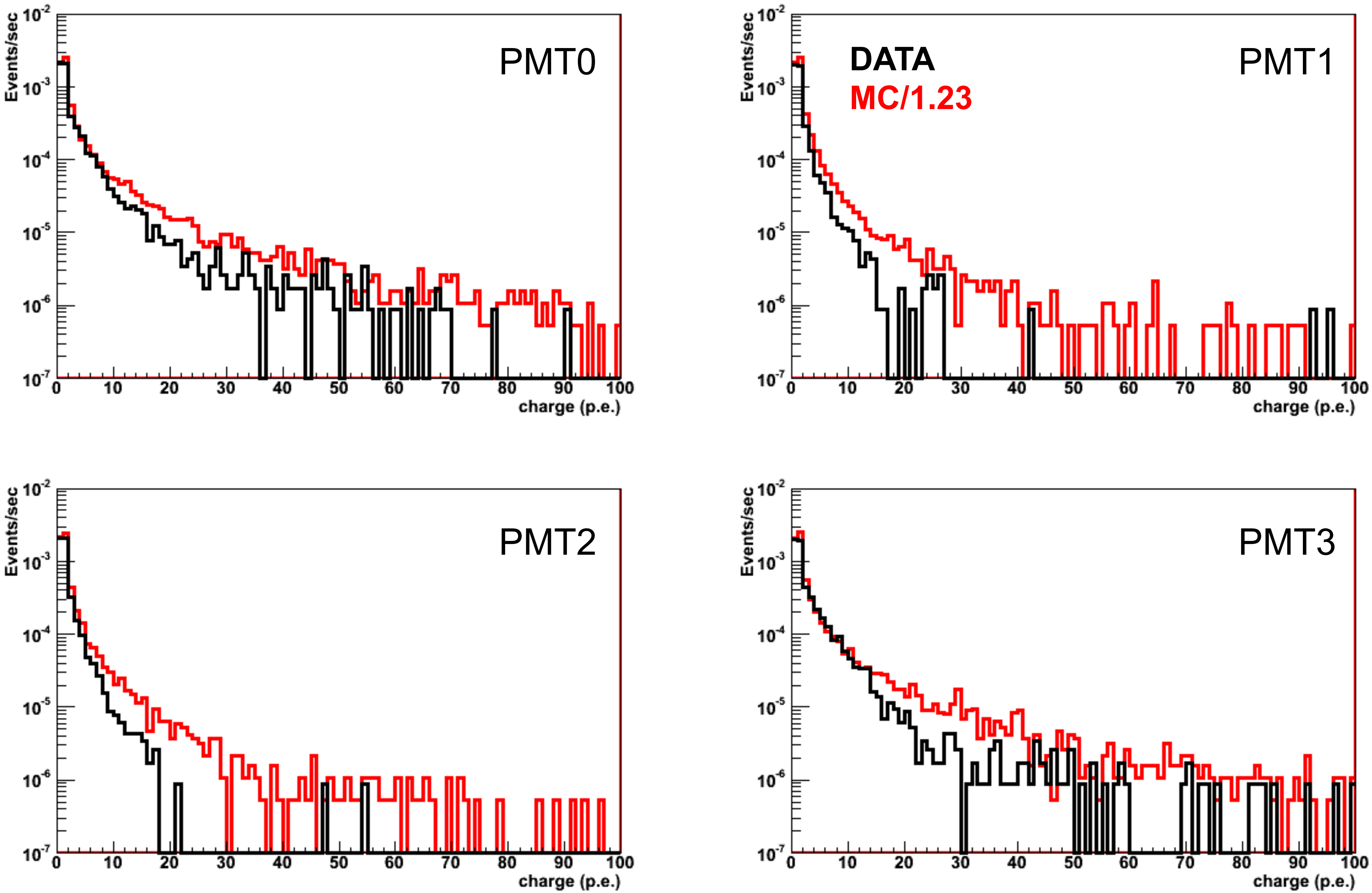
eFCM 1: Charge



eFCM 2: Charge



eFCM 3: Charge



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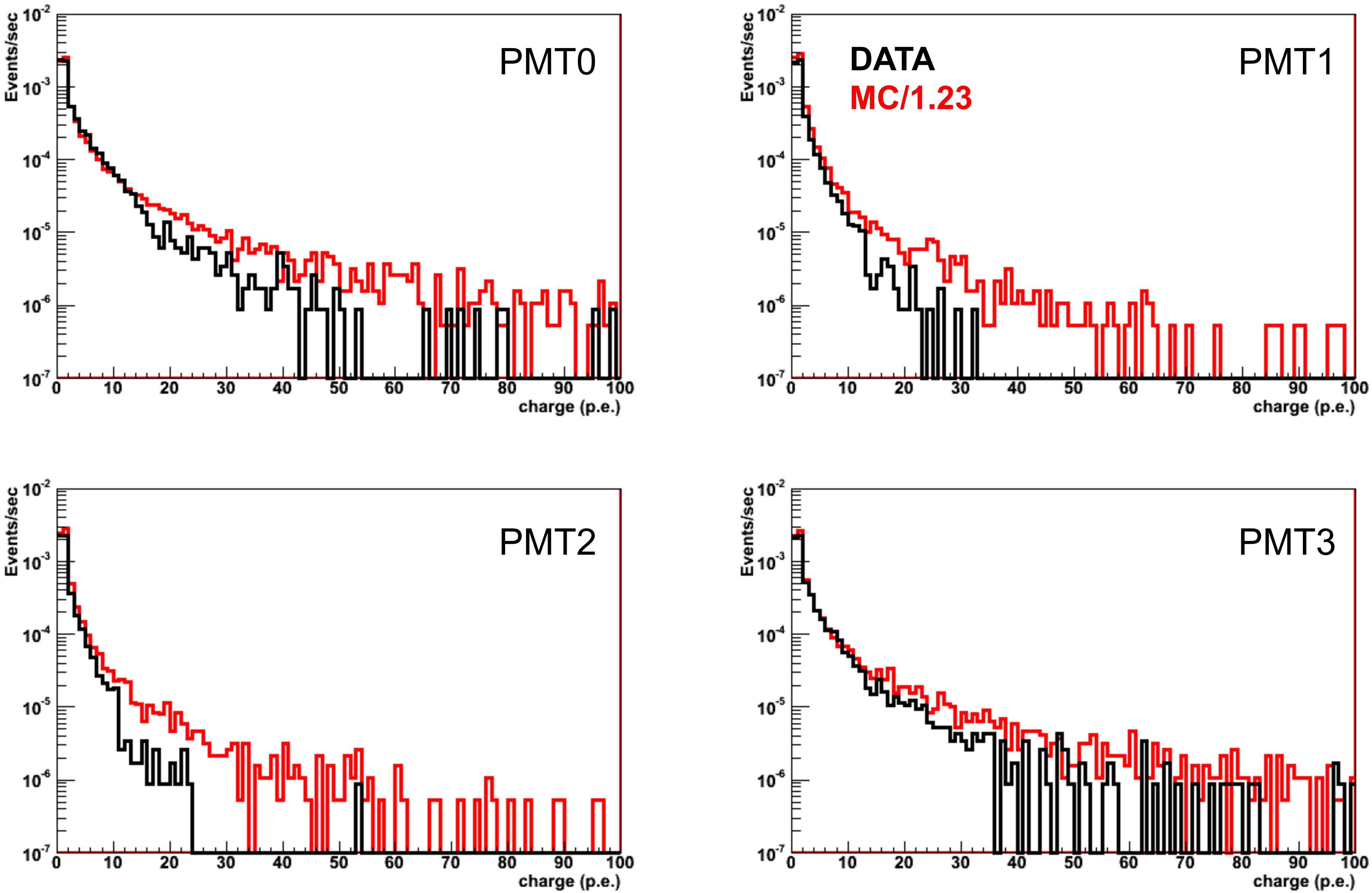

eFCM 5: Charge

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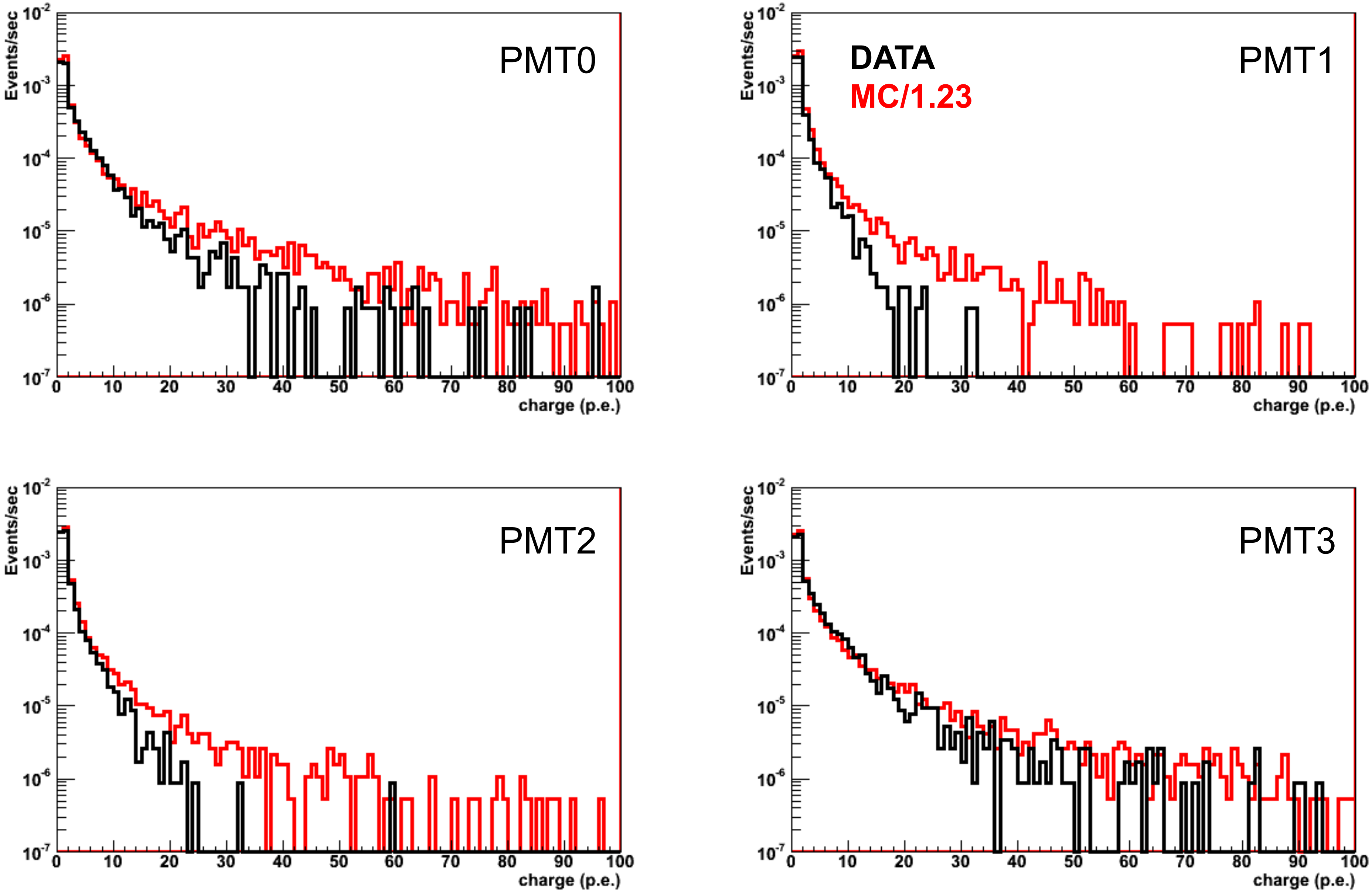

eFCM 6: Charge

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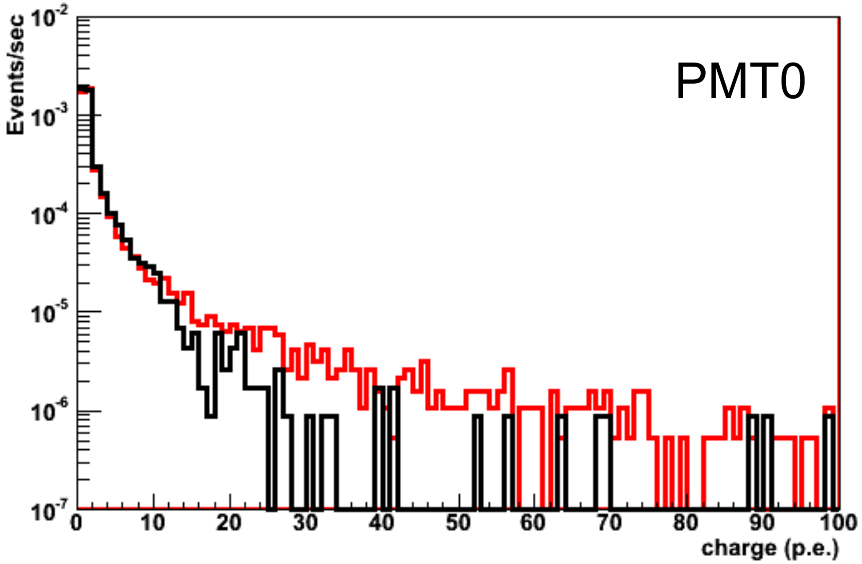

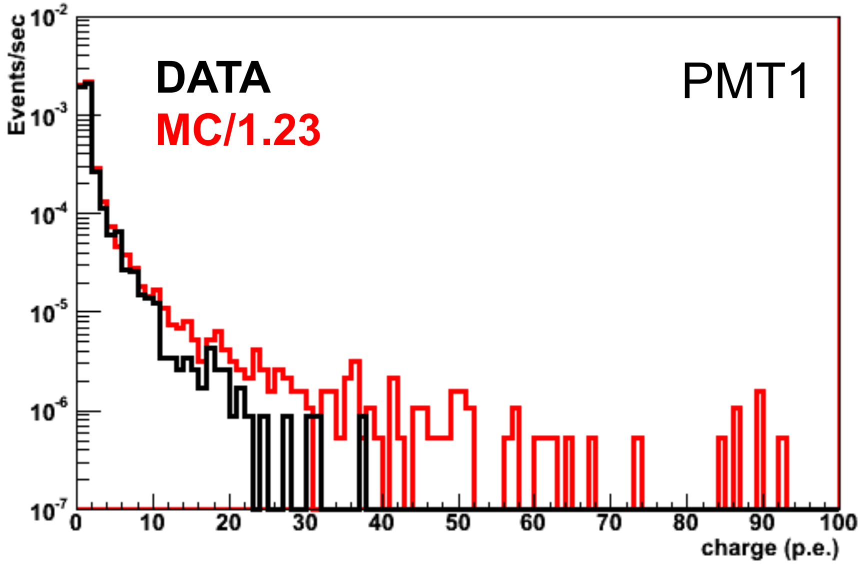

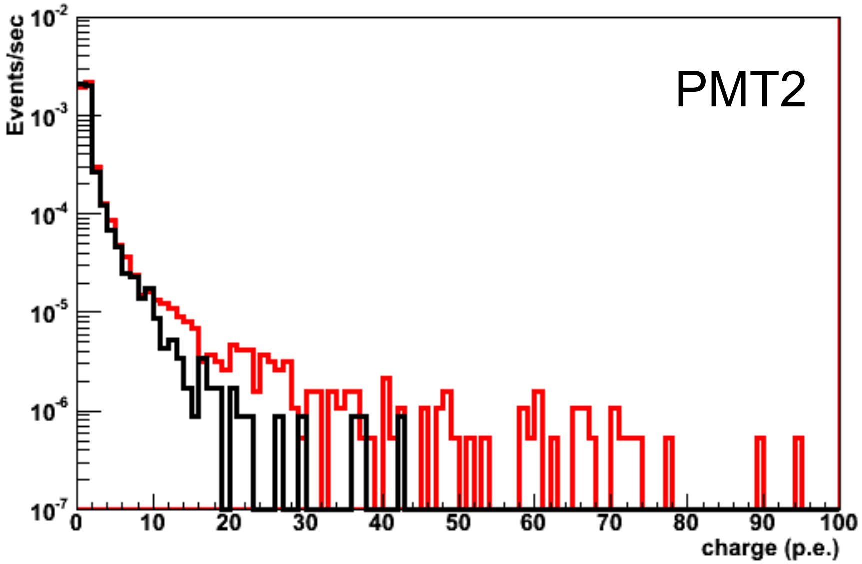

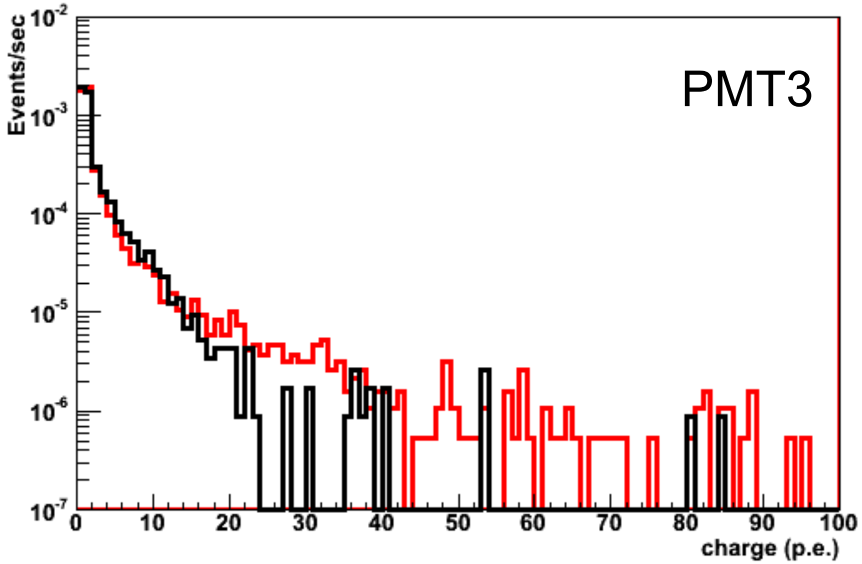

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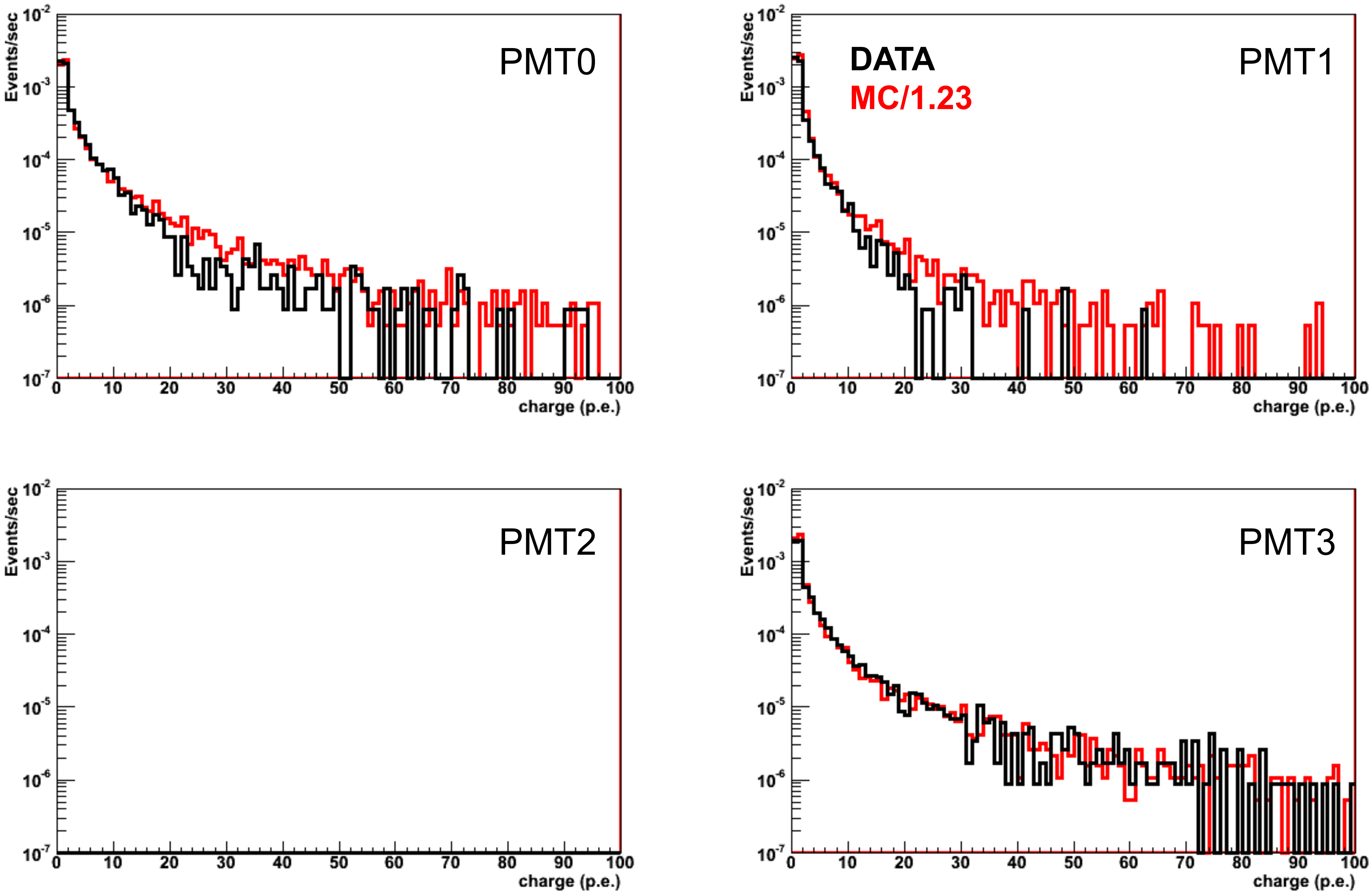
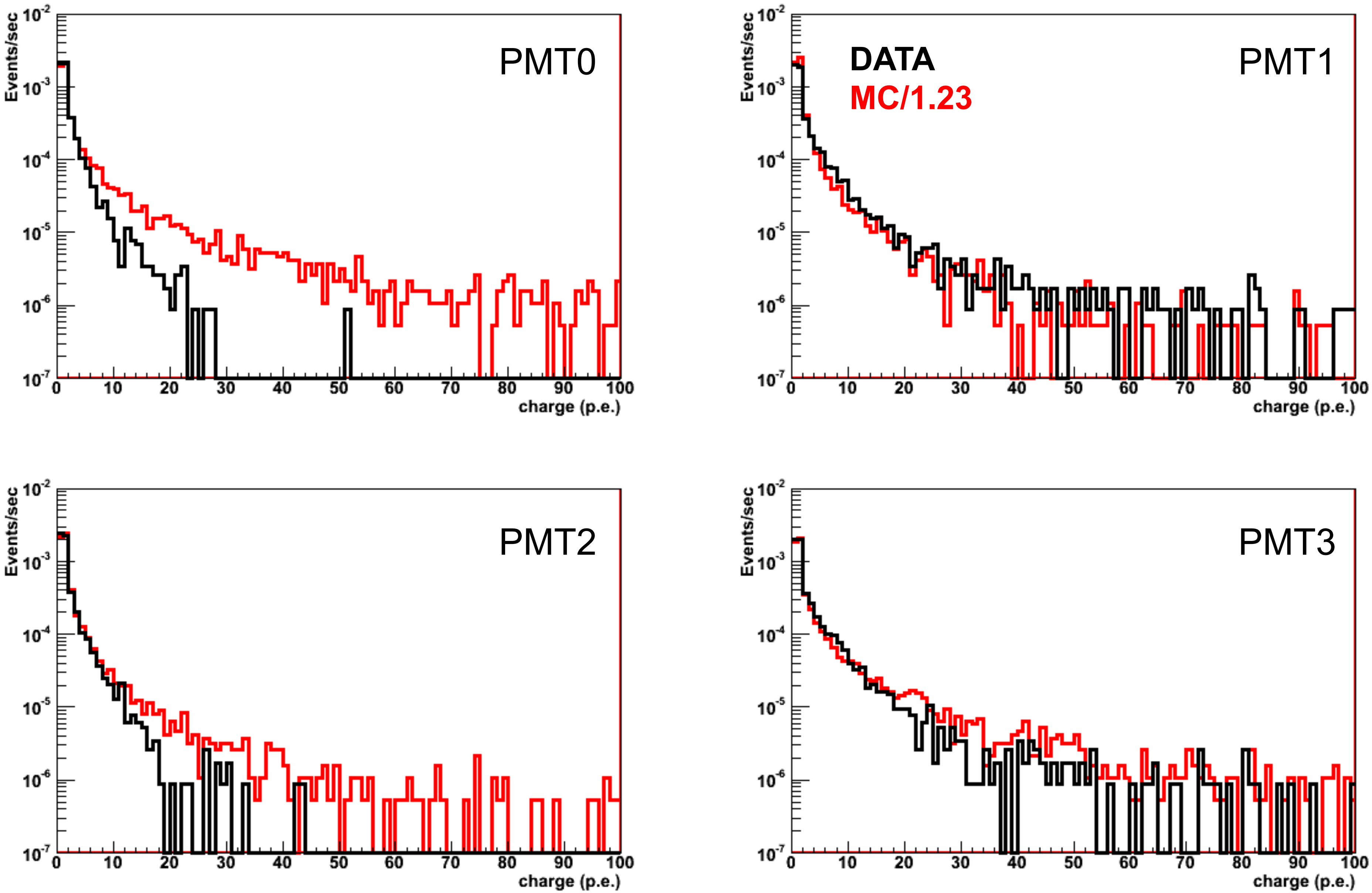


eFCM 8: Charge



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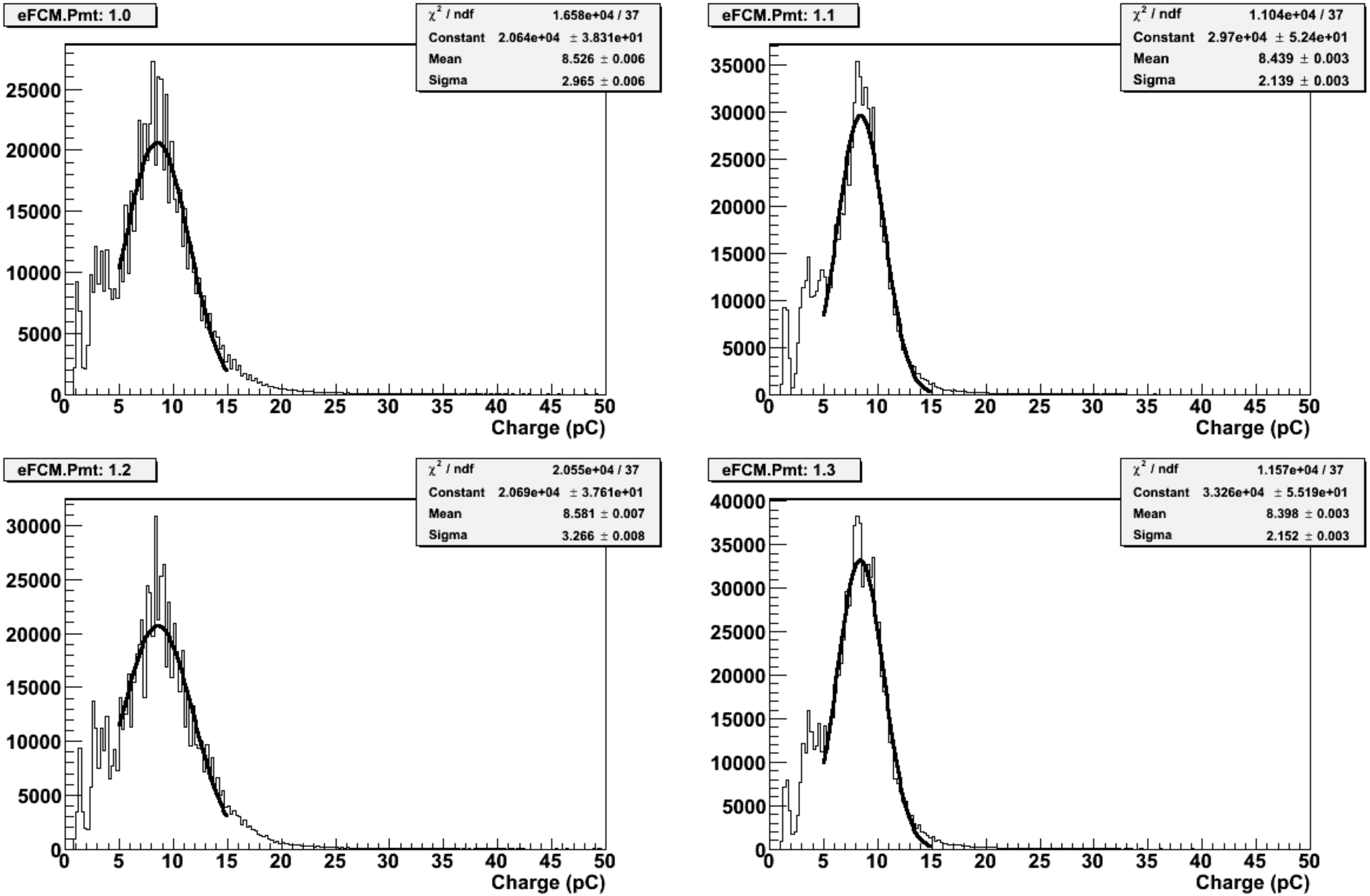

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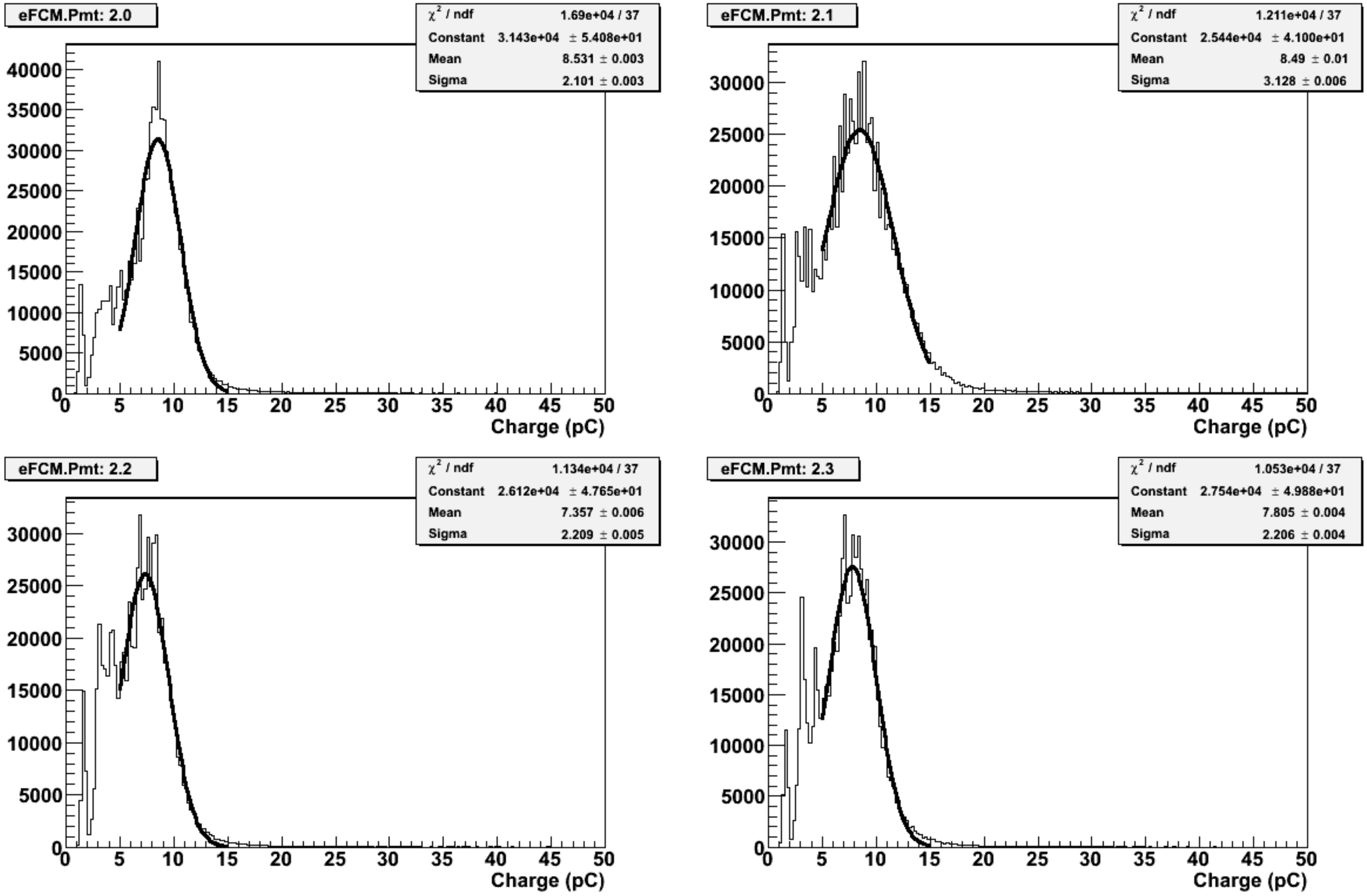

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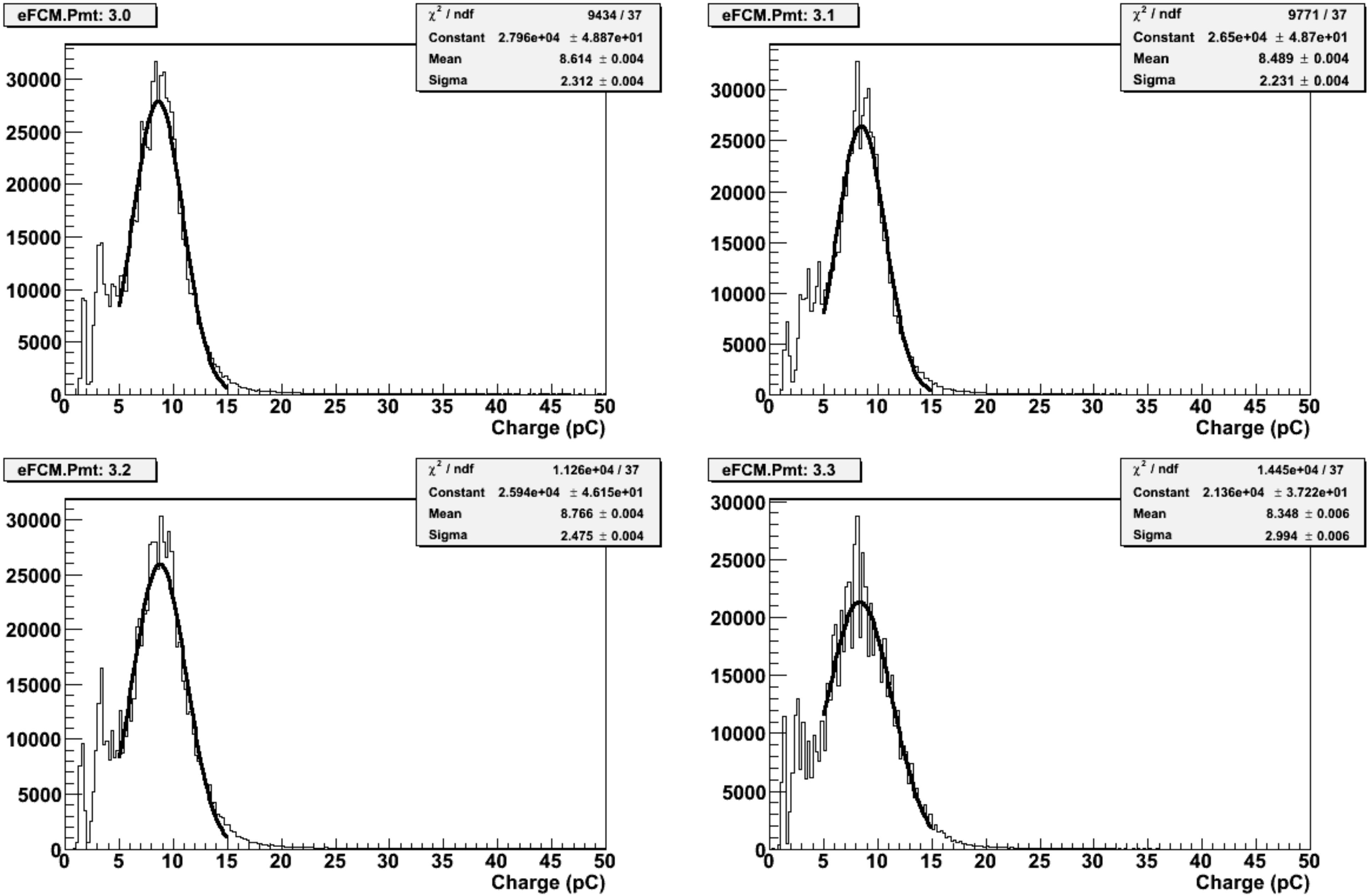

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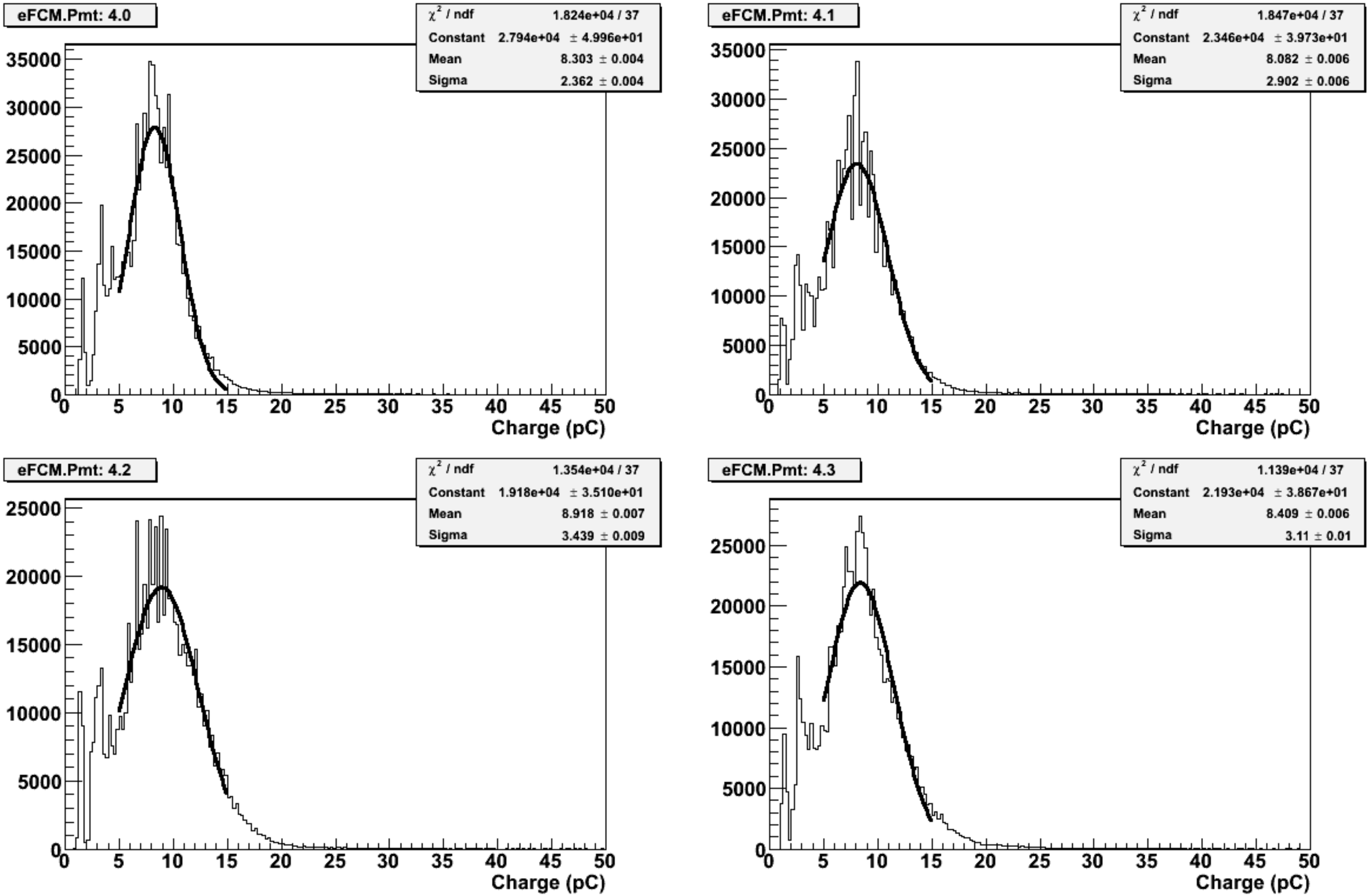

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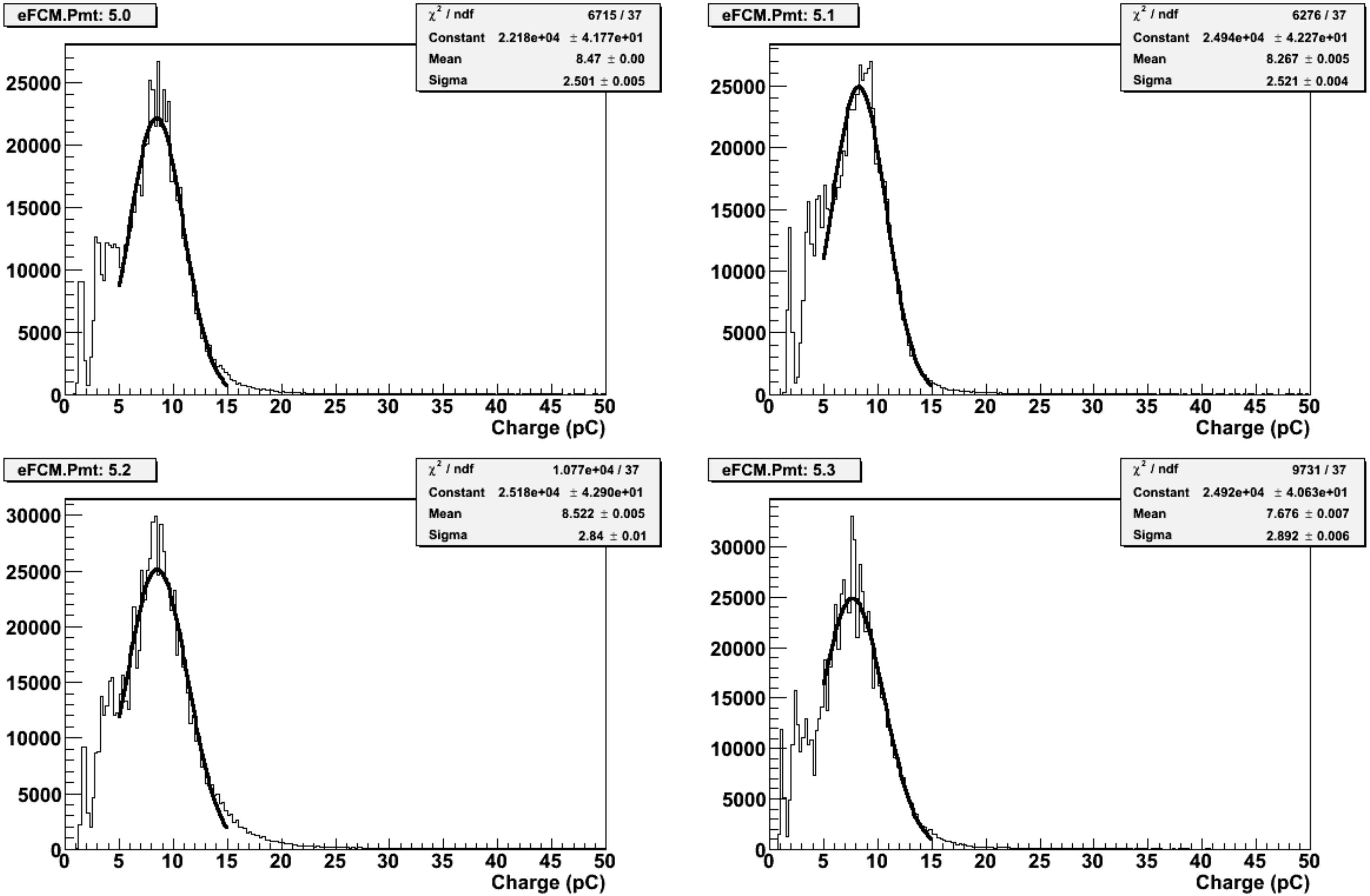

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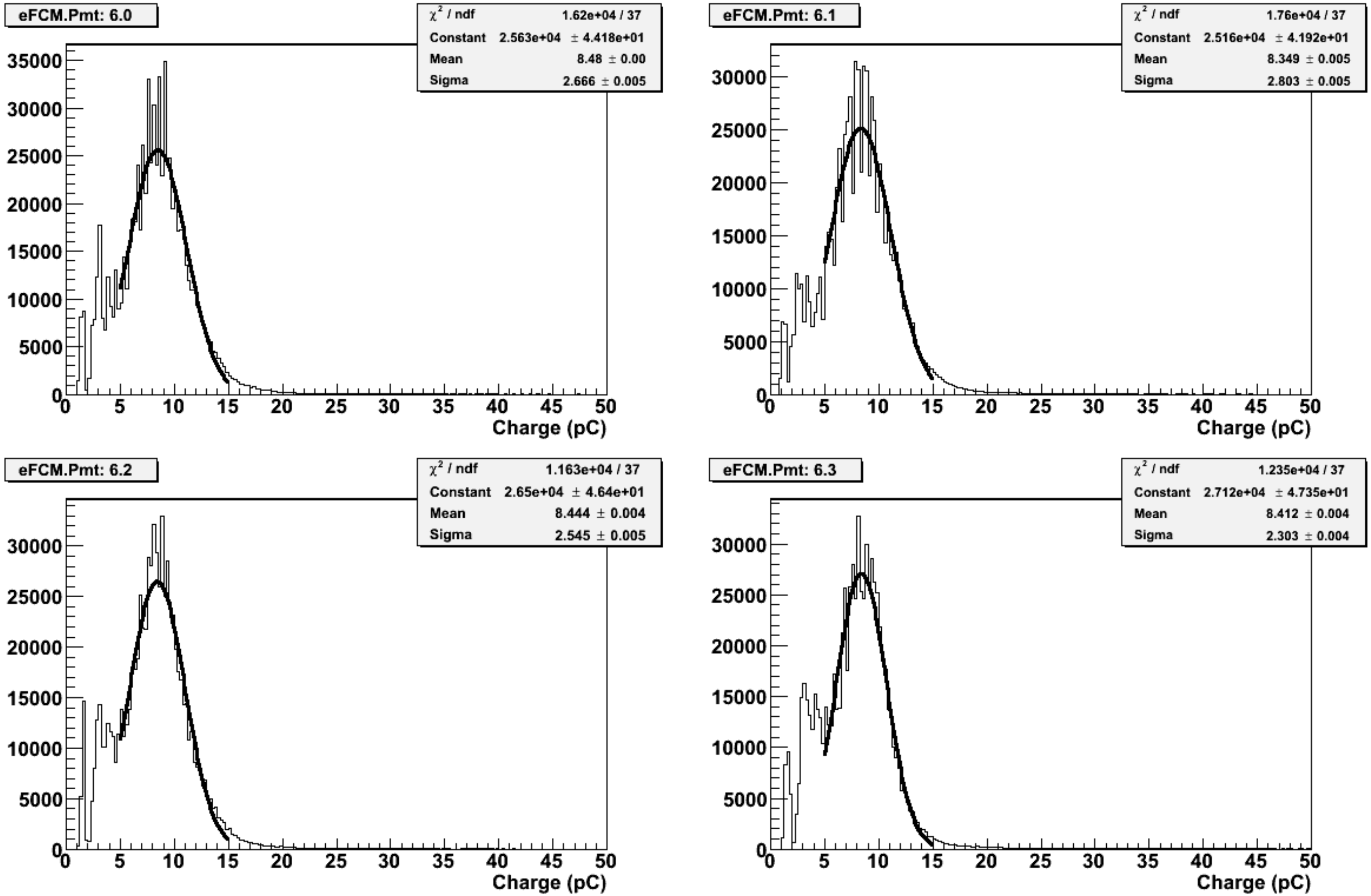

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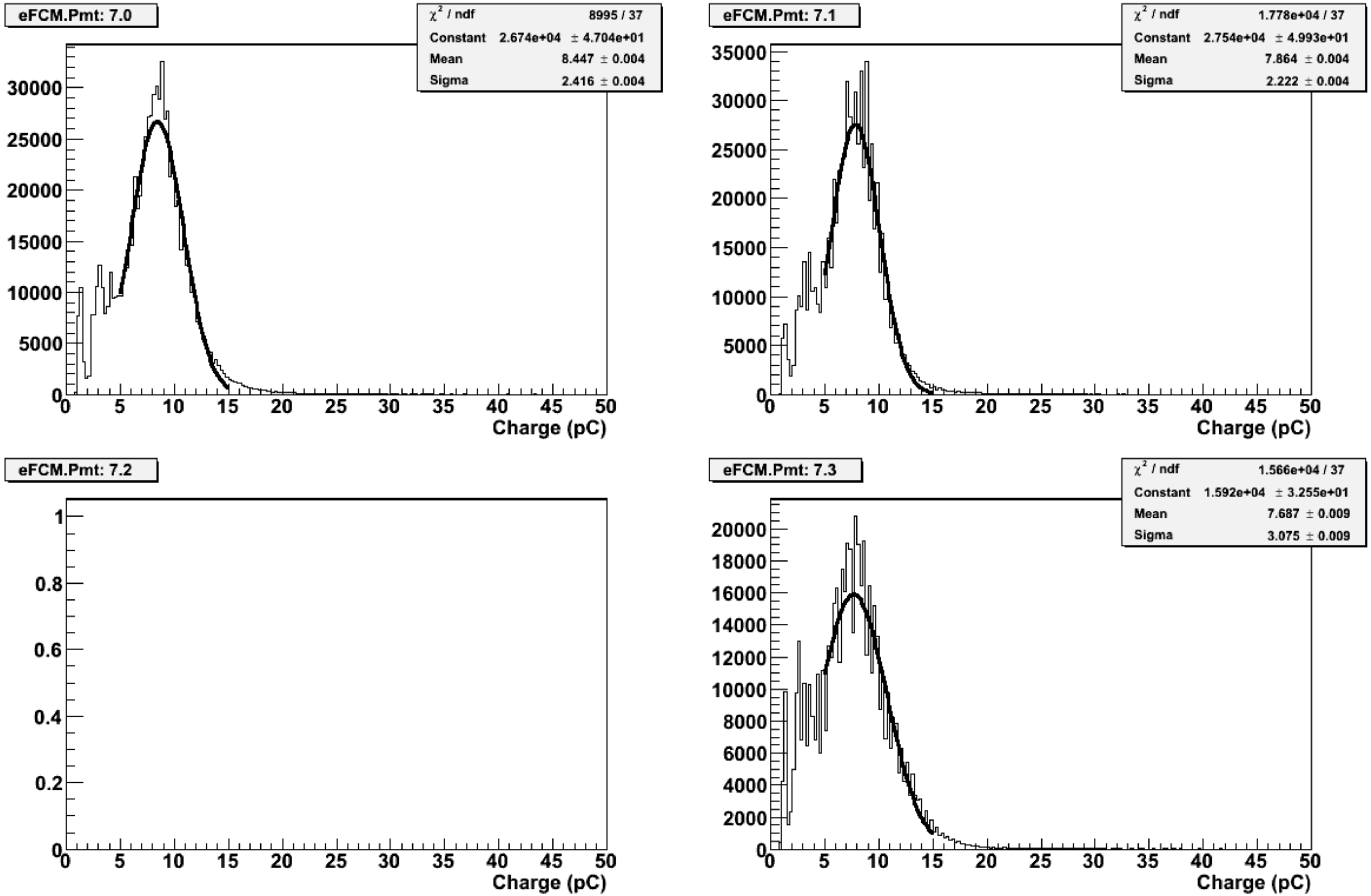

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