

NP02 data management and accessibility

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This presentation aims to describe NP02 data management and accessibility by discussing the following points:

- 1. Raw data description and data flow**
- 2. Online data processing and electron lifetime measurement**
- 3. Offline data processing**
- 4. Raw data and online reconstruction results: accessibility and organization**

- These are wide subjects, that have required a lot of work. It is not possible to enter in all the details: only the slides on the main points will be discussed; a more complete description is available in the slides put in the addenda.
- Before starting, it is necessary to briefly remind the NP02 network architecture →

Additional documentation is available on the NP02 operation Twiki pages:

<https://twiki.cern.ch/twiki/bin/view/CENF/DUNEPProtDPOps>

➤ Software HOWTO:

https://twiki.cern.ch/twiki/pub/CENF/DUNEPProtDPOps/software_howto_v2.pdf

➤ Online processing and reconstruction:

<https://twiki.cern.ch/twiki/pub/CENF/DUNEPProtDPOps/bench.pdf>

➤ More details on the DAQ system:

https://twiki.cern.ch/twiki/pub/CENF/DUNEPProtDPOps/DAQforshifter_v2r2.pdf

➤ LArSoft information:

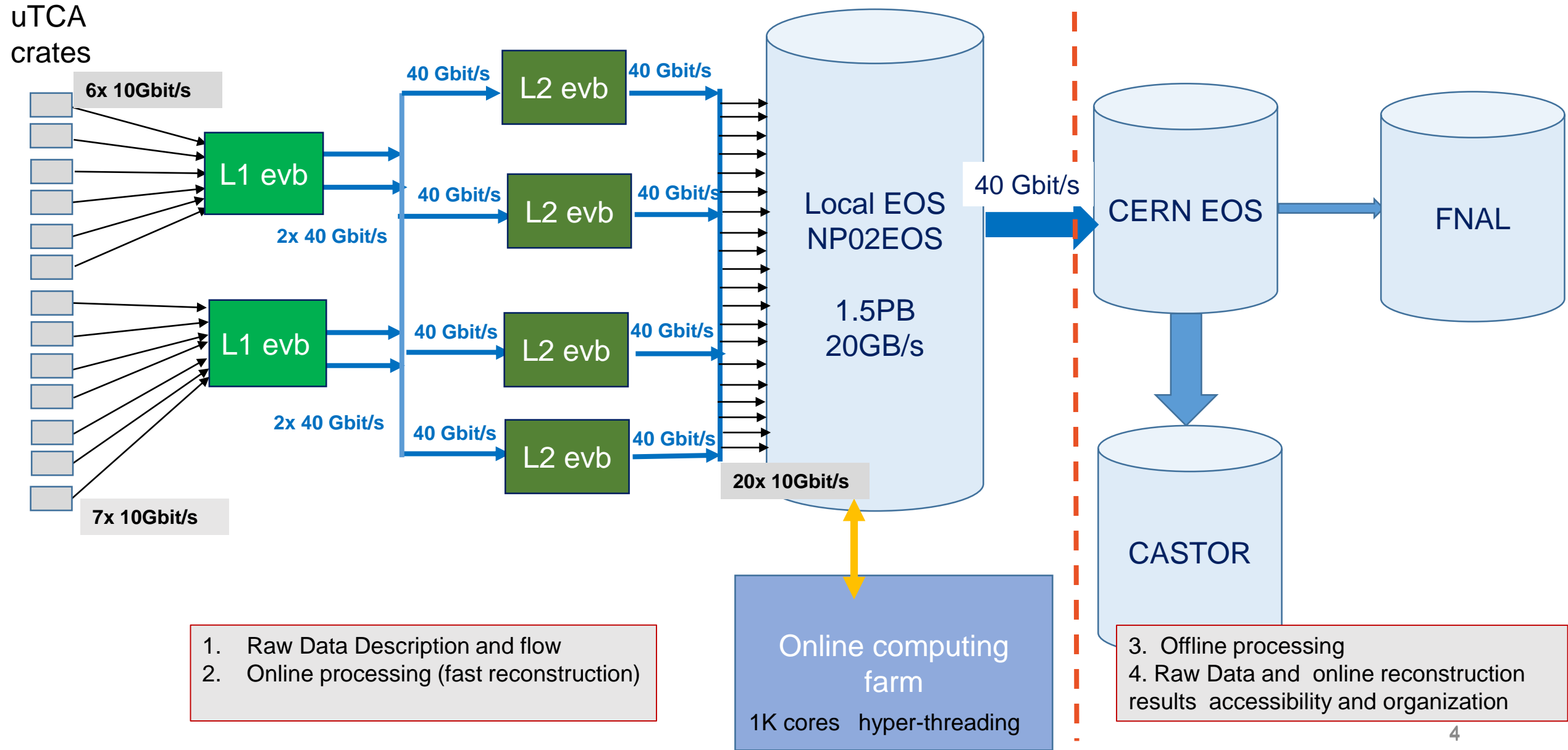
https://twiki.cern.ch/twiki/pub/CENF/DUNEPProtDPOps/protodunedp_data_dunetpc_v0.pdf

and on DocDB:

➤ DUNE data challenges:

- <https://docs.dunescience.org/cgi-bin/private/ShowDocument?docid=8034>
- <https://indico.fnal.gov/event/18681/session/1/contribution/5/material/slides/0.pdf>
- https://docs.dunescience.org/cgi-bin/private/RetrieveFile?docid=15397&filename=DUNE_Computing_Status_LBNC_01Aug2019.pdf&version=1

NP02 network architecture



Overview of DAQ back-end equipments in the DAQ room (support for 4 active CRPs readout):

- **High bandwidth (20GByte/s) distributed EOS file system for the online storage facility**

→ Storage servers: 20 machines + 5 spares (DELL R510, 72 TB per machine): up to 1.44 PB total disk space for 20 machines, 10 Gbit/s connectivity for each storage server.

- **Online storage and processing facility network architecture:**

→ Backend network infrastructure 40 Gbit/s DAQ switch (Brocade ICX7750-26Q) + 40/10 Gbit/s router (Brocade ICX 7750-48F)

→ Dedicated 10 Gbit multifibers network to uTCa crates

→ Dedicated trigger network (x2 LV1 event builders + trigger server)

→ x2 40 Gbit/s link to IT division

- **DAQ cluster and event builders:**

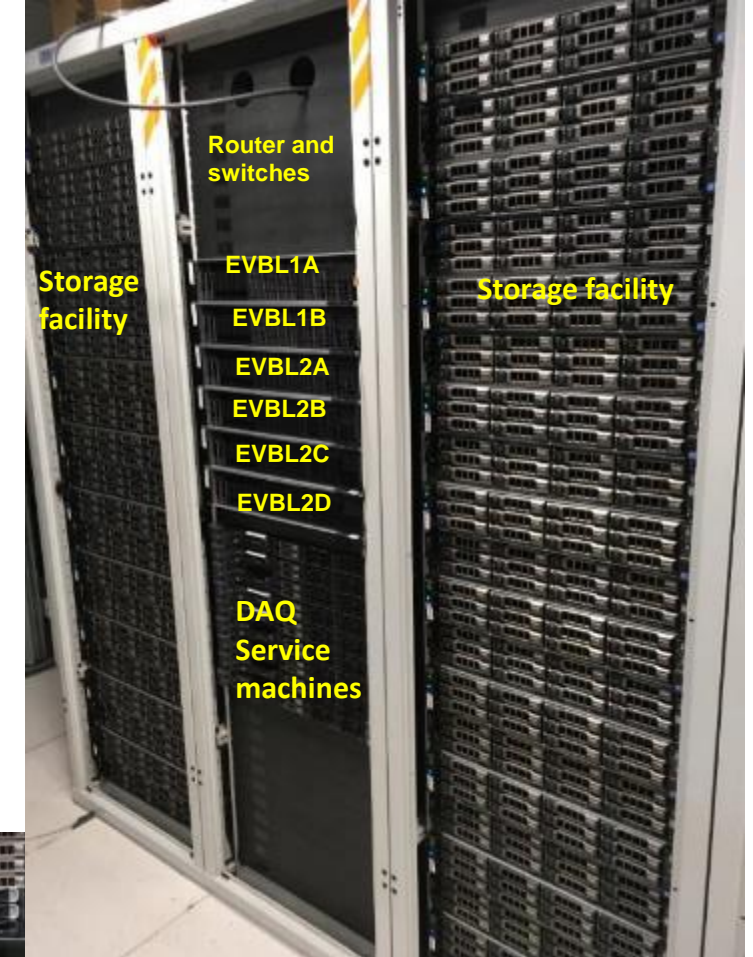
→ DAQ back-end: 2 LV1 event builders (DELL R730 384 GB RAM) + 4 LV2 event builders (DELL R730 192 GB RAM)

→ DAQ cluster service machines: 9 Poweredge R610 service units:

2 EOS metadata servers, configuration server, online processing server, batch management server, control server, ...

- **Online computing farm (room above the DAQ room):**

→ 40 servers Poweredge C6200 from IN2P3



Description of the ProtoDUNE-DP back-end system

- The ProtoDUNE-DP DAQ back-end system has already been discussed in details at DUNE collaboration meeting in September 2018 (<https://indico.fnal.gov/event/16526/session/10/contribution/164/material/slides/0.pdf>). In this presentation I will only briefly remind the main parts of the system; I will focus on 2019 activities and I will provide some results based on last data challenge
- The back-end system consists of two levels of event builder machines (EVB L1 and EVB L2) plus the network infrastructure, and the online storage/processing facility. The event builders task is to receive in input the data flow from the front-end system, build the events and cluster them in data files, and eventually write these data files into the local storage servers.
 - **L1 EVBs**: Two machines **DELL R730** are used (384 GB RAM, 2 Intel cards R710 each with 4 10Gbit/s links, 2 Mellanox Connect X3 2 ports, 40Gb/s Ethernet QSFP+, CPU type Intel XEON Gold 5122 3.6 GHz, 4 cores, 8 threads)
 - **L2 EVBs**: Four machines **DELL R730** are used: (192 GB RAM, 2 Mellanox Connect X3 , CPU type Intel XEON Gold 5122 3.6 GHz, 4 cores)
 - **Online storage facility**: [High bandwidth \(20GBytes/s\) distributed EOS file system](#) 20 machines + 5 spares, installed at CERN in September 2017 (DELL R510, 72 TB per machine): up to 1.44 PB total disk space for 20 machines, 10 Gbit/s connectivity for each storage server.
 - **Network infrastructure**: designed in collaboration with Neutrino Platform and IT: 40 Gbit/s DAQ switch + 40/10 Gbit/s router procured by CERN
- All these components were commissioned in 2018

(DUNE collaboration meeting,21/05/2019)

1. Raw Data description and flow

Raw Data description

- A run corresponds to a well defined detector configuration (HV setting), and it is composed by several Raw Data files (sequences) of a fixed size of 3GB.
- Raw Data files are produced by 2 levels of event building, two level 1 event builders (L1) and four level 2 event builders (L2)
The naming convention for Raw Data file is the following: ***runid_seqid_l2evb.datatype***, where
 - runid*** : run number,
 - seqid***: sequence id, starting from 1
 - l2evb***: can be equal to *a,b,c,d*, to identify by which L2 event builder the file was assembled
 - datatype*** can be *test, pedestal, cosmits,...*

- So, for the test run 1010 the Raw Data filenames will look like that:

1010_1_a.test
1010_1_b.test
1010_1_c.test
1010_1_d.test
1010_2_a.test
1010_2_b.test
1010_2_c.test
1010_2_d.test

- Events in a given file are not strictly consecutive: each L2 event builder includes in its treated sequences only event whose number follows an arithmetic allocation rule (based on division module), as shown in the [table here](#)

- Each file has a fixed size of 3GB, the last sequences of the run may be smaller

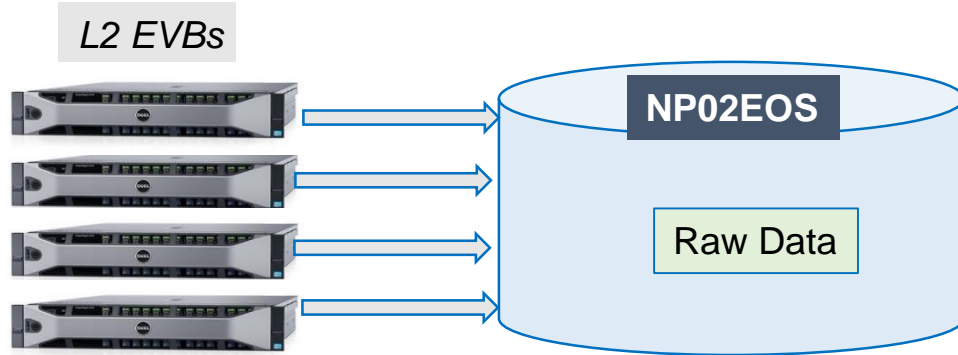
- For more details please read Addendum 1

np02evbl2a	1,5,9,13,17,...
np02evbl2b	2,6,10,14,18,..
np02evbl2c	3,7,11,15,19,...
np02evbl2d	4,8,12,16,20,...

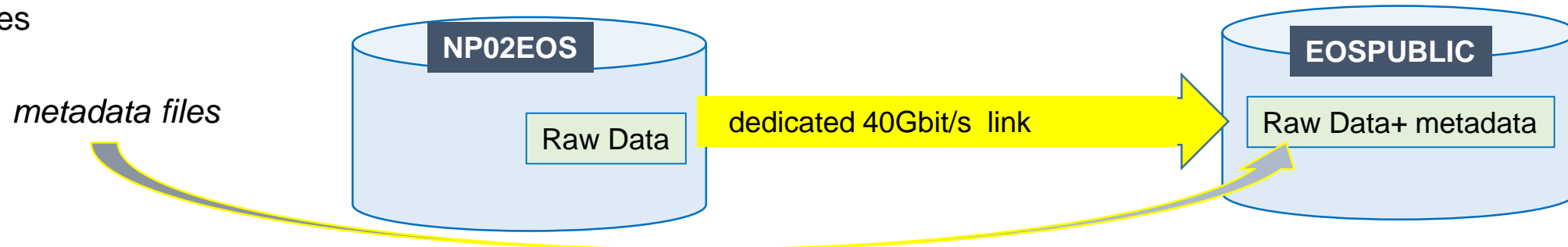
Raw Data Flow

Raw Data files are assembled by the event builders and written in their RAM memories. Three main data handling steps follow the creation of the files by the L2 event builders:

1. As soon as a data file is closed the process **L2EOS** running on each L2 event builder takes care of copying it to the online storage facility (NP02EOS) which is based on a distributed file-system and 20x24 disk units running in parallel . To fully exploit the available bandwidth (20GB/s) , several files can be copied in parallel at the same time from the same event builder.

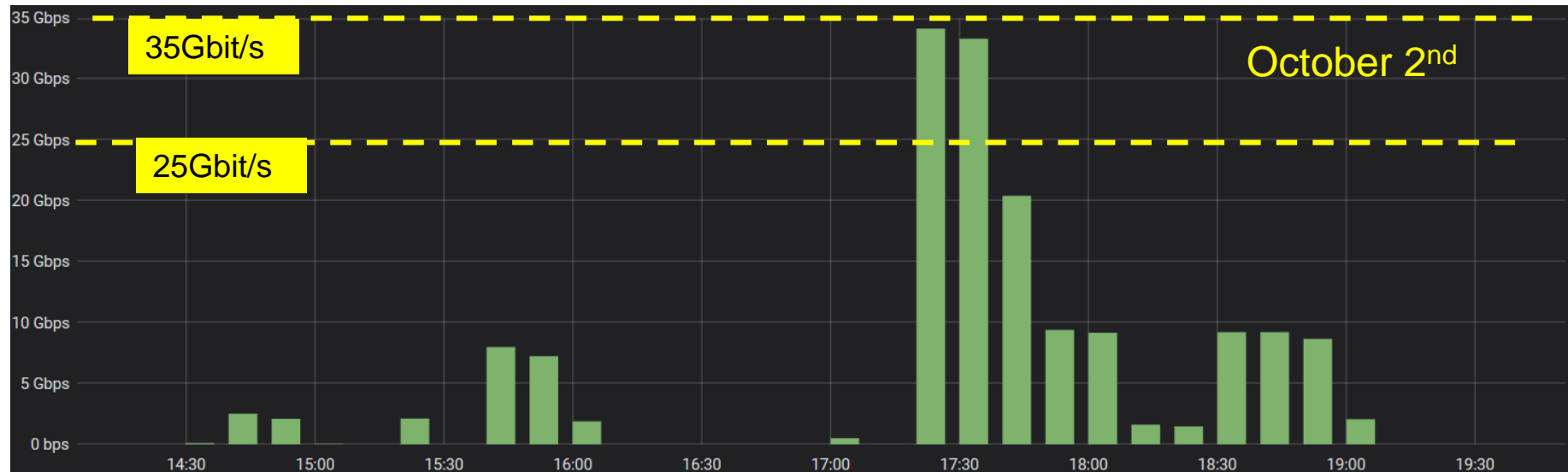
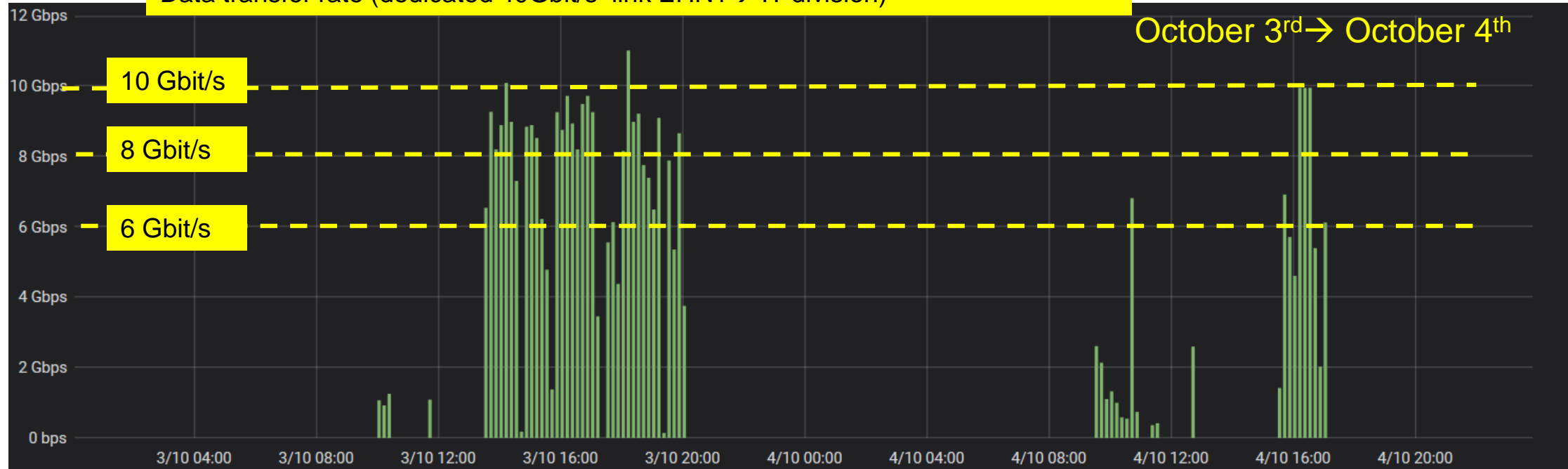


2. once on NP02EOS, the file is scheduled for transfer to EOSPUBLIC (CERN EOS). The transfer is run from the DAQ machines; for EACH Raw Data file a **metadata file** is generated as well to allow the integration of that file in the overall DUNE data management scheme (see later). The delay Δt between the creation of a Raw Data file and its availability on EOSPUBLIC is ~10 minutes



Raw Data Flow Monitoring (NP02EOS→EOSPUBLIC)

Data transfer rate (dedicated 40Gbit/s link EHN1→ IT division)



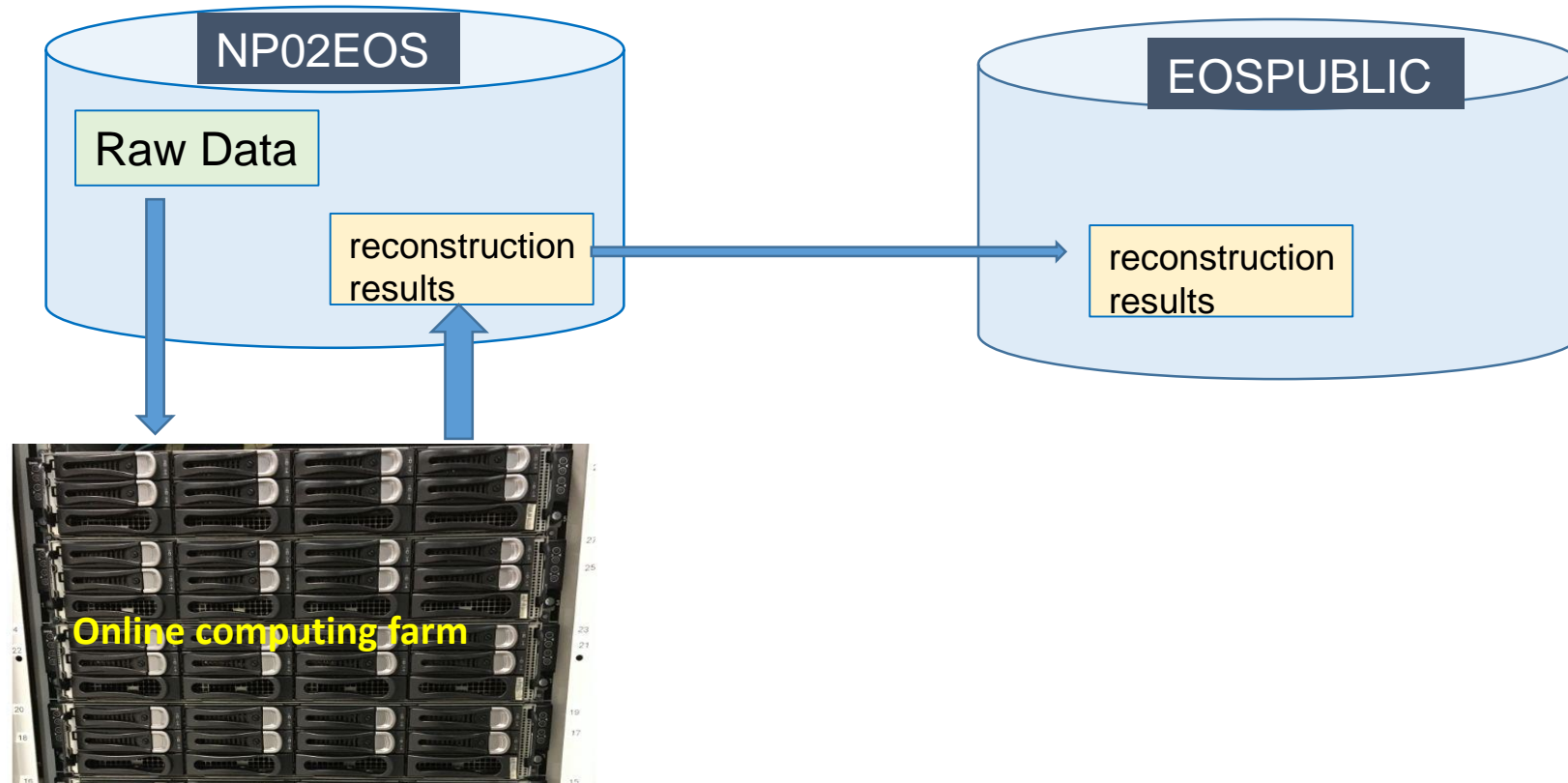
Example of metadata file

DUNE metadata files are needed to:

- 1) Trigger data transfer to CASTOR and FNAL*
- 2) Enter each file in SAM, the FERMILAB file catalog system*

```
{
  "data_tier": "raw",
  "file_type": "detector",
  "file_format": "binary",
  "checksum": [
    "adler32:794b455b" checksum value (computed during file transfer from EVBs RAM to NP02EOS)
  ],
  "file_size": "3456003188", file size
  "start_time": "2019-10-04T15:47:01", timestamp
  "data_stream": "cosmics", data stream → mandatory for steering offline production
  "file_name": "1294_1_a.cosmics", filename
  "runs": [
    [
      "1294",
      "1",
      "protodune-dp"
    ]
  ],
  "event_count": "30", # of events
  "DUNE.campaign": "NP02_run2019"
}
```

3. Data file of type cosmic are also scheduled on real time for the **online processing**.
Results from the online reconstruction are stored as well on NP02EOS and copied to EOSPUBLIC



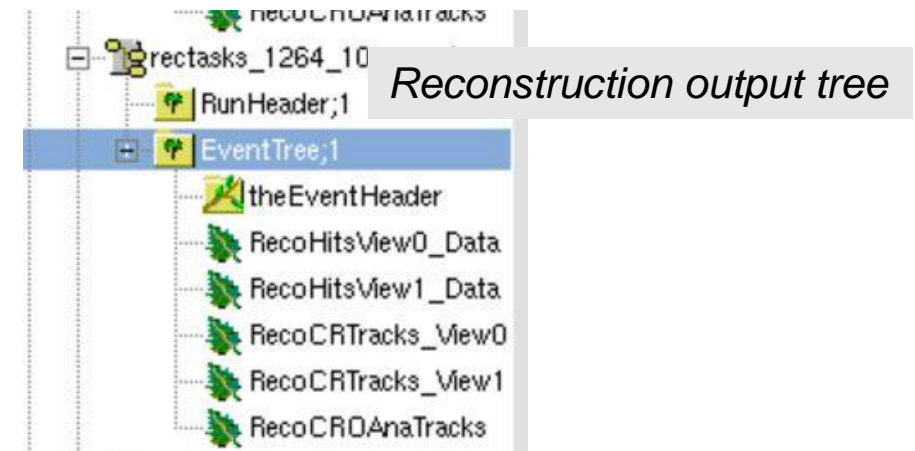
2. Online processing and electron lifetime measurement

Online processing

The online processing consists of 2 steps:

Step 1:

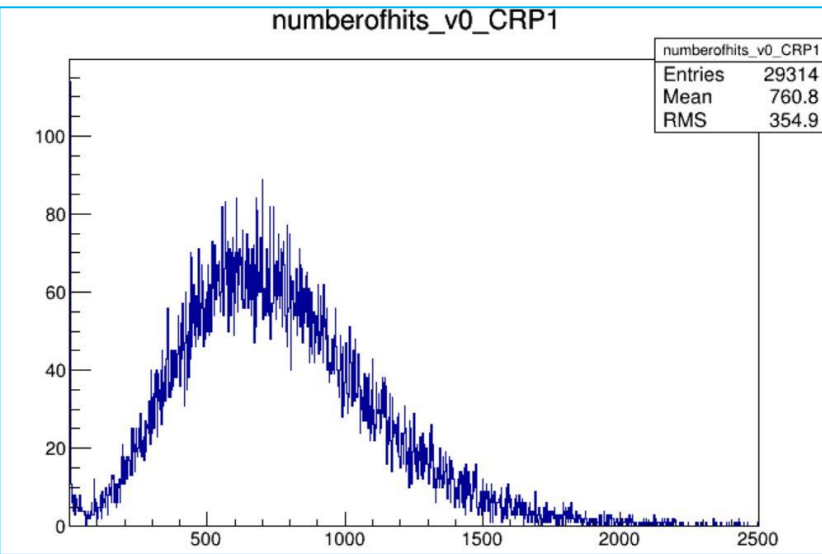
- Raw Data files are processed with a fast reconstruction program.
- This fast reconstruction is based on QSCAN (WA105Soft) which was already used for the analysis of the 3x1x1 data . The version in use on NP02 farm has been modified (Slavic) to include the ProtoDUNE-DP geometry and the decoding interface to the raw DAQ data files
- Hits, 2D tracks and 3D tracks are reconstructed. For 2D tracks, ClusFilter algorithm (Laura Zambelli, May 2017) is selected in the config file. It provides faster track reconstruction than the original tracking implementation in QSCAN although with somehow less accurate delta-ray reconstruction
- Some basic documentation can be found [here](#) (pages 12→14)



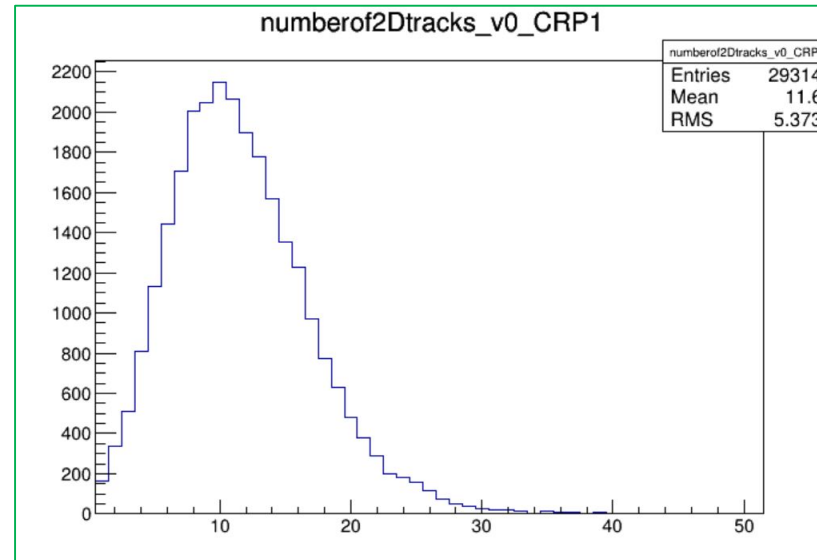
Step 2:

- The root file produced in output by QSCAN is read and processed by “*bench.exe*” and some basic histograms to check reconstruction results and data quality are produced
- As example, some histograms (for run 1294) are shown in the next slide; a complete description is provided in addendum 2

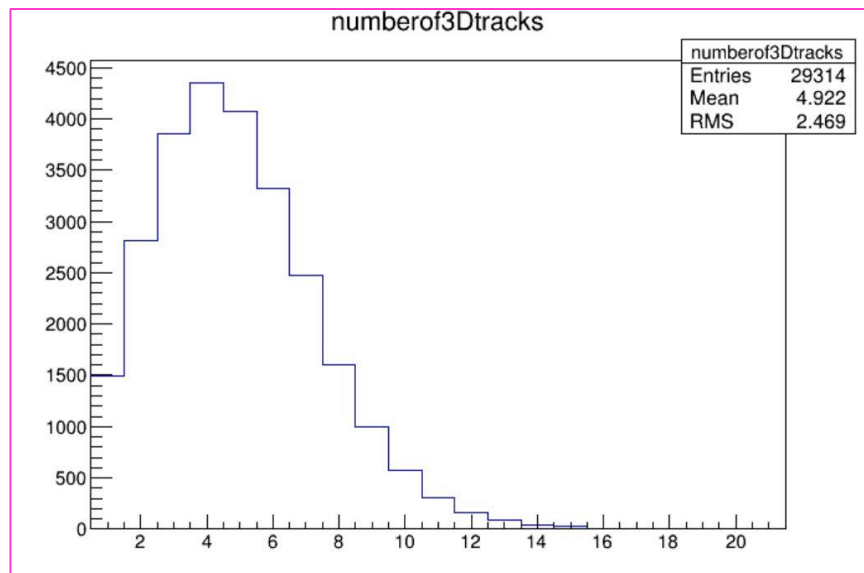
Examples of histograms to check the online reconstruction results



number of hits
view 0, CRP1



number of 2D Trks
view 0, CRP1



number of 3D Trks

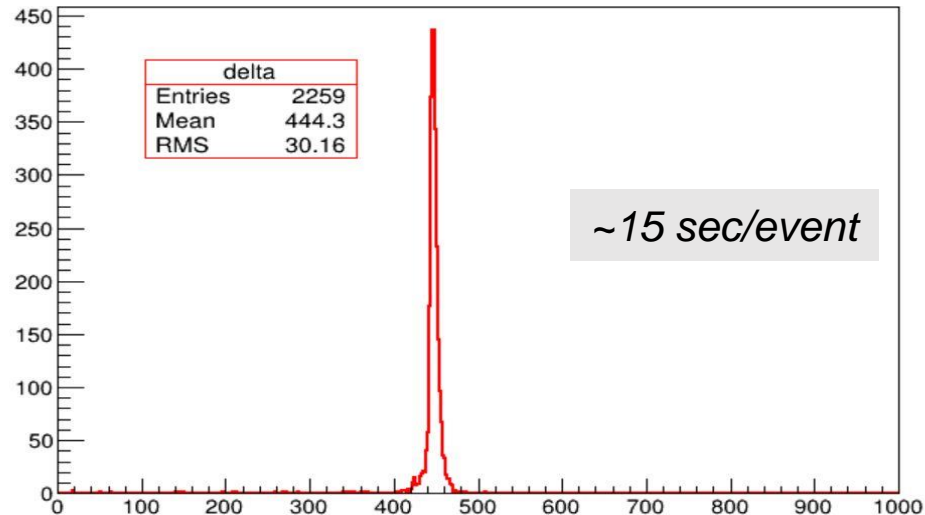
some more information on online processing ...

Given a Raw Data file, for example [1294_1_a.cosmics](#), the following 2 files will be available after the online processing:

- 1) [rectasks_1294_1_a.root](#): reconstruction output. It is obtained by running `rectask.exe` on the Raw Data file
- 2) [bench_rectasks_1294_1_a_pass13.root](#): summary histograms of reconstructed quantities. It is obtained from the file `rectasks_294_a_1.root` by running `bench.exe` with option `p=13` (see `software_howto.pdf`)

Once a run is ended and all its sequence have been processed, all the files obtained from step 2 are merged in a unique one ([bench_rectasks_1294_pass13.root](#)). Distributions in this summary file correspond to the full statistics of a run.

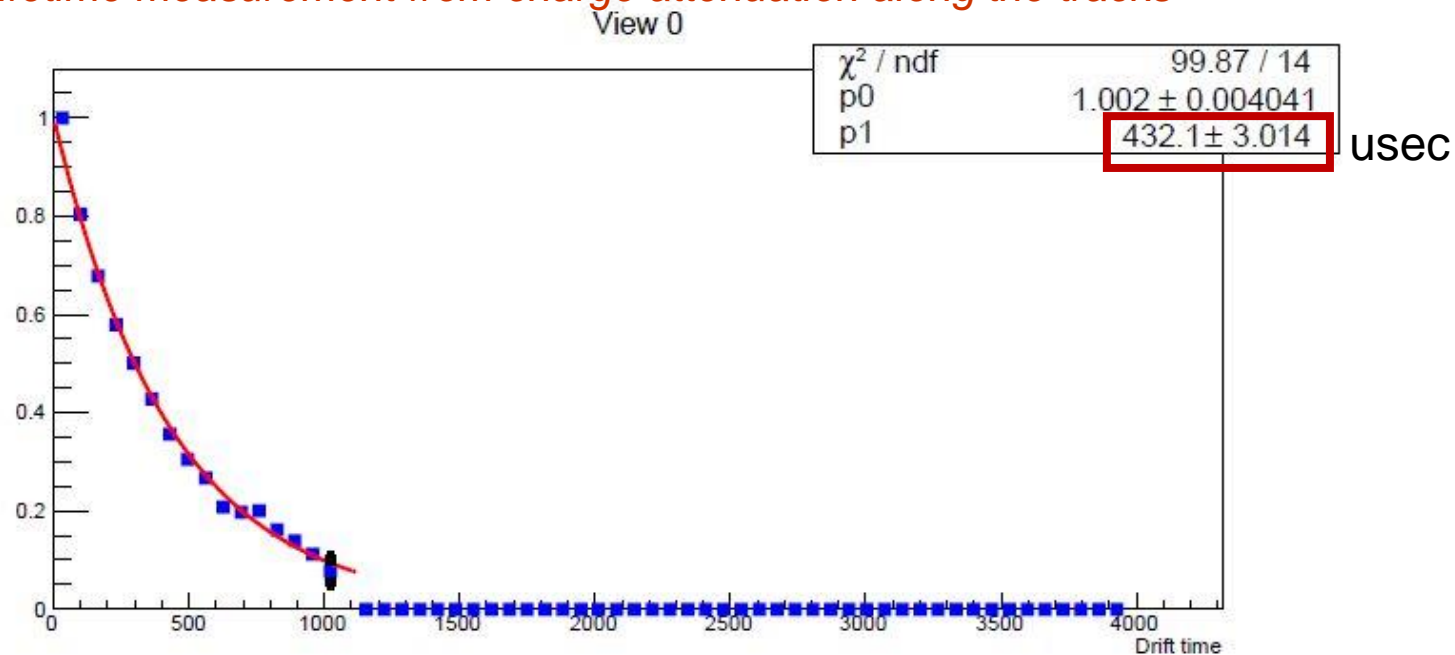
Processing time for Raw Data files of 30 events:



Electron lifetime measurement

- The electron lifetime has been measured for all cosmic runs by looking at the charge attenuation along the tracks
- The method used to evaluate the electron lifetime is based on 2D tracks reconstruction, so it requires as input the results from the online fast reconstructions.
- For each run, two measurements of the charge attenuation along the track are obtained, one for view 0 and one for view 1. This procedure was presented at the WA105 Science Board on July 6th, 2016. A detailed description is available in addendum 3
- At the moment, this measurement is started manually. Tanner Salvage (UCL) is developing the needed scripts to automatize the analysis as soon as a run ends and all sequences have been reconstructed. The higher is the number of 2D tracks available, the better the method works → all events for a given run are used to evaluate lifetime .
- At the same time some systematic studies are going on, to optimize the parameters to be used to evaluate electron lifetime
- Results obtained on the online farm are then copied to EOSPUBLIC
- As an examples, results for runs 172 and 1294, are shown in next pages.

electron lifetime measurement from charge attenuation along the tracks



Run 1272 10/03/2019

No over current behaviour observed.

Pressure abs 1.016 bar.

Pressure diff 45.3 mbar.

Purity Monitor 1 Middle, field 60-120-240 V/cm

Lifetime [us] : 965.48 +/- 7.28

QK [mV] : -53.75 +/- 0.06

QA [mV] : 39.00 +/- 0.07

t1 [us] : 25.04 +/- 1.21

t2 [us] : 287.53 +/- 0.06

t3 [us] : 14.31 +/- 0.01

Purity Monitor 2 Bottom, field 70-140-280 V/cm

Lifetime [us] : 564.37 +/- 11.04

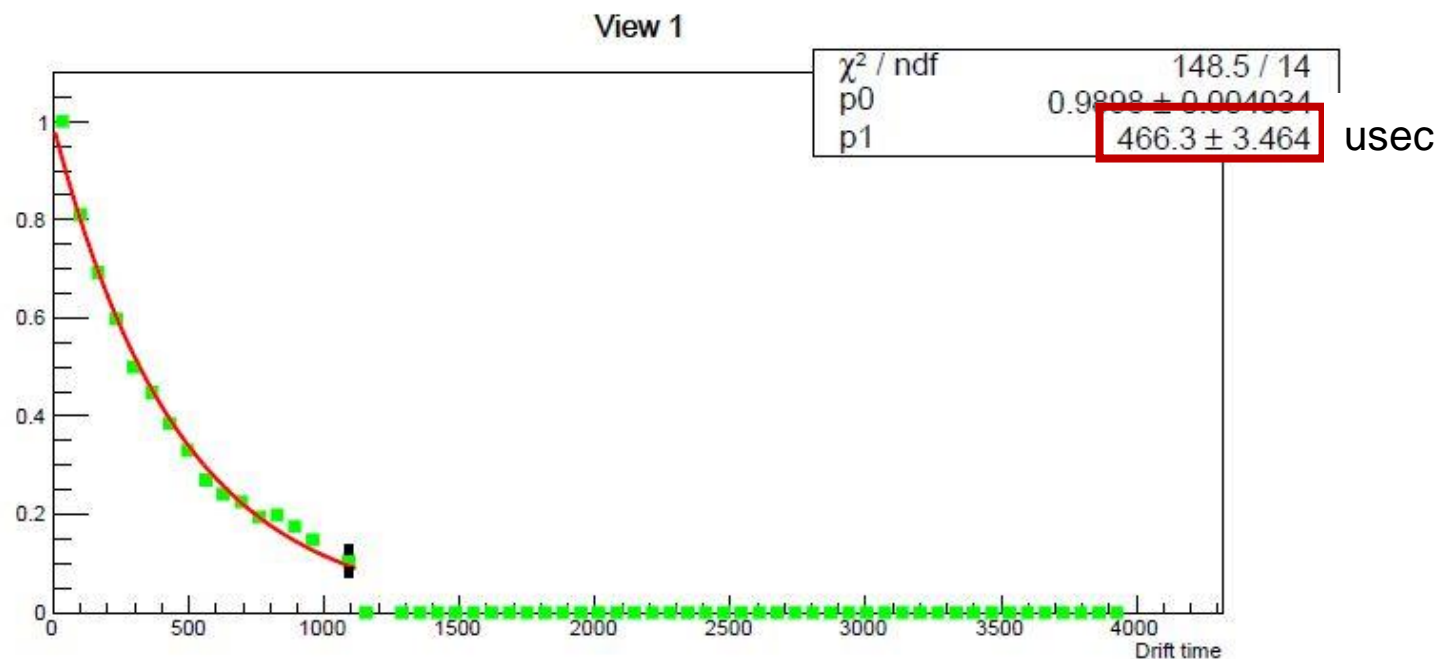
QK [mV] : -27.75 +/- 0.07

QA [mV] : 17.87 +/- 0.07

t1 [us] : 23.58 +/- 9.71

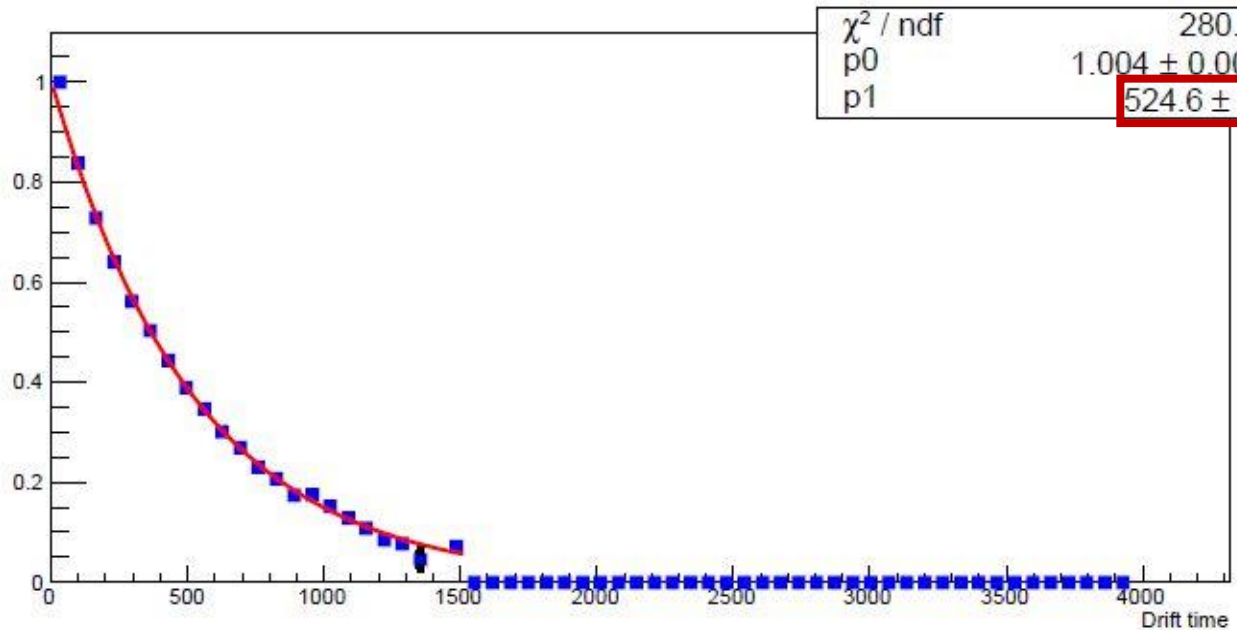
t2 [us] : 267.93 +/- 0.10

t3 [us] : 13.17 +/- 0.01



electron lifetime measurement from charge attenuation along the tracks

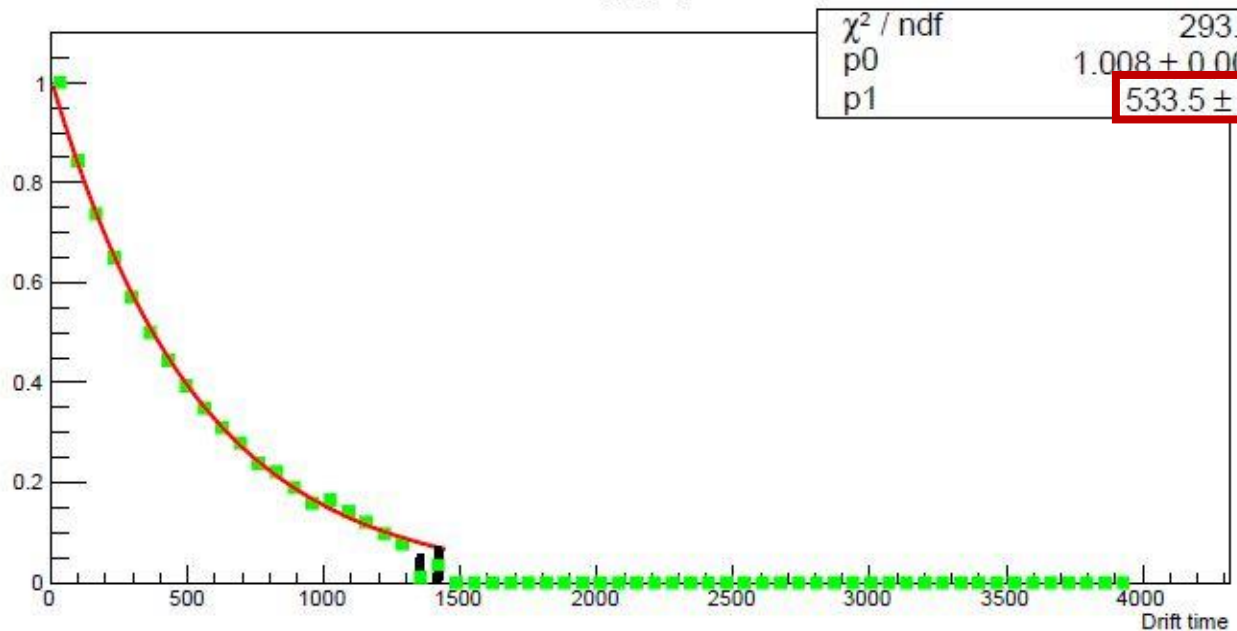
View 0



usec

Run 1294 10/04/2019

View 1



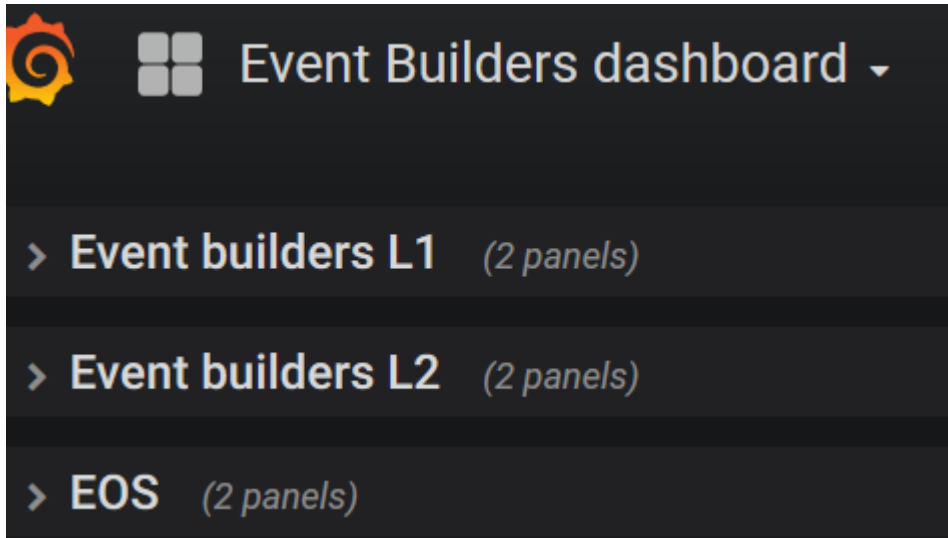
usec

Purity Monitor 1 Middle, field 60-120-240 V/cm
Lifetime [us] : 588.18 ± 2.61
QK [mV] : -66.60 ± 0.06
QA [mV] : 39.62 ± 0.07
t1 [us] : 24.78 ± 0.96
t2 [us] : 288.78 ± 0.05
t3 [us] : 13.91 ± 0.01

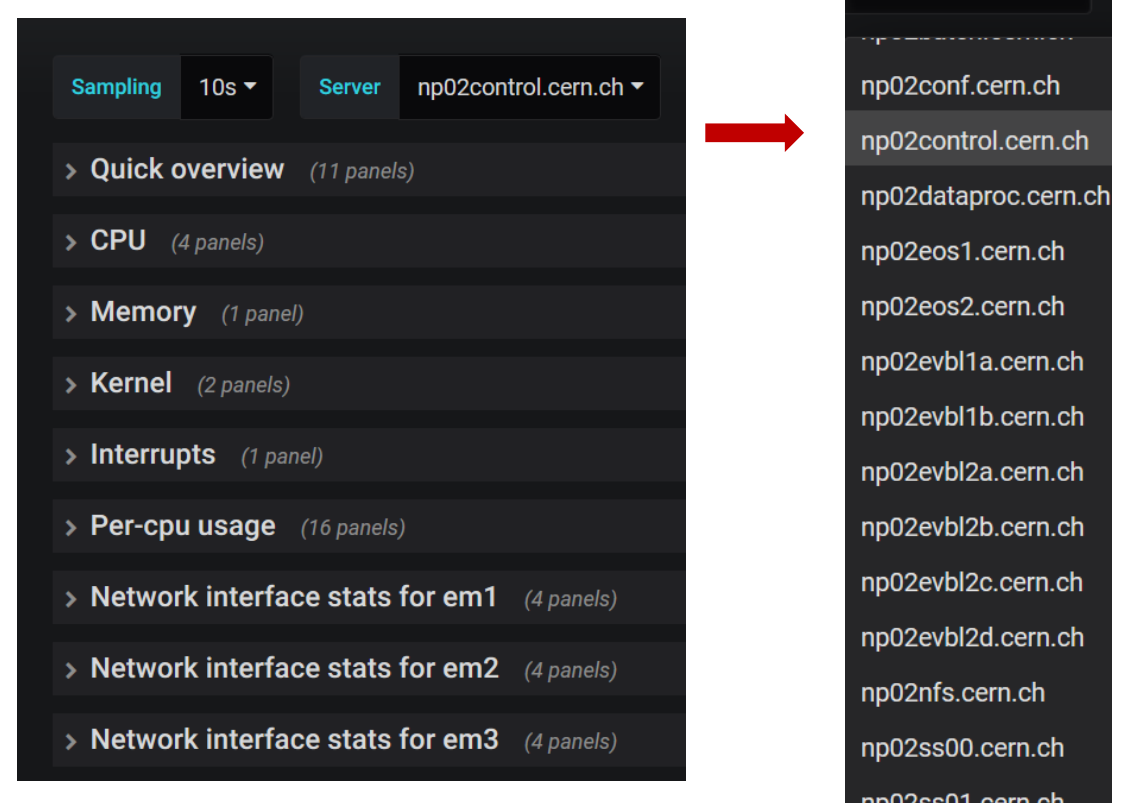
Purity Monitor 2 Bottom, field 70-140-280 V/cm
Lifetime [us] : 585.21 ± 15.73
QK [mV] : -27.84 ± 0.06
QA [mV] : 17.49 ± 0.07
t1 [us] : 23.66 ± 14.17
t2 [us] : 269.22 ± 0.08
t3 [us] : 10.57 ± 0.01

Two last considerations before moving to the discussion of the offline organization:

- 1) All steps of Raw Data online treatment are stored in a dedicated online database
- 2) The monitoring of the activity of the DAQ machines, storage and processing farm is performed with 2 Grafana dashboards



- 1) **Event Builders dashboard** → monitoring of network bandwidth of EVBL1, EVBL2, Storage servers

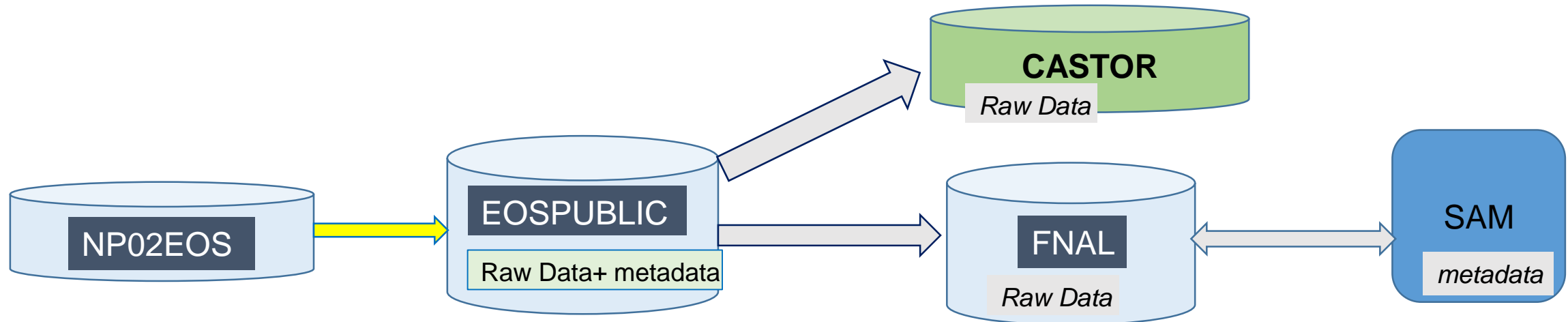


- 2) **NP02 online cluster dashboard** → detailed system view of each server in the cluster

3. Offline processing

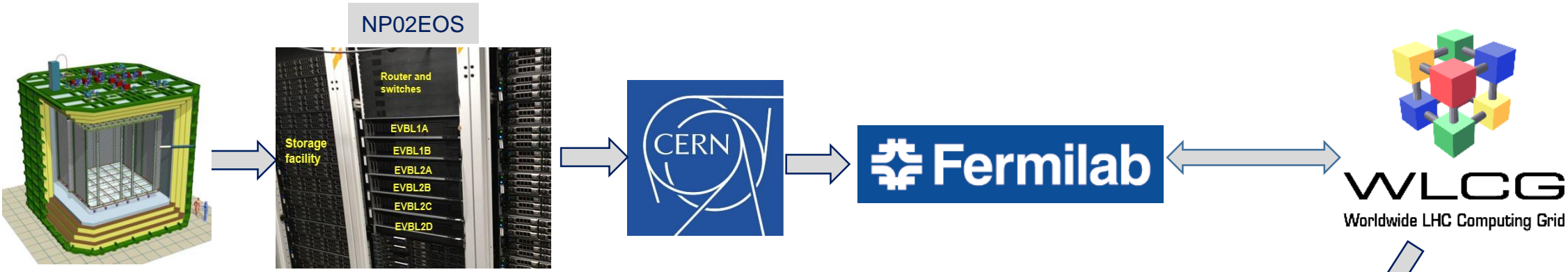
Offline processing

- As discussed before, Raw Data and reconstructed data are copied by the DAQ system from NP02EOS to EOSPUBLIC.
- As shown in previous slides, the integration of NP02 Raw Data in the general DUNE data management scheme is done by metadata files. On the online machine a metadata file is generated for each Raw Data file and copied as well to EOSPUBLIC. These metadata files trigger the data transfer to CASTOR and FNAL .
- These transfers are run by the FERMILAB data management group, as it is done for NP04



- Once Raw Data are transferred to FNAL, they are ready to be reconstructed →

- The reconstruction and analysis of ProtoDUNE-DP data is foreseen to be performed with LArSoft, similarly as for ProtoDUNE-SP, and benefit of the same environment and tools. LArSoft is a shared framework with other FNAL LAr TPC experiments, based on Art framework
- For this purpose the basic LArSoft interface to the ProtoDUNE-DP Raw Data from the DAQ system has been developed and provided, concerning this point see this presentation at the ProtoDUNE Sim/Reco meeting of 17 July 2019: <https://indico.fnal.gov/event/21266/contribution/1/material/slides/0.pdf>
- The processing of ProtoDUNE-DP data is organized in a centralized way by the FNAL computing, processing and data management groups.
- The workflow is the following:



Reconstruction output is stored on tape at CCIN2P3: space resources are already available



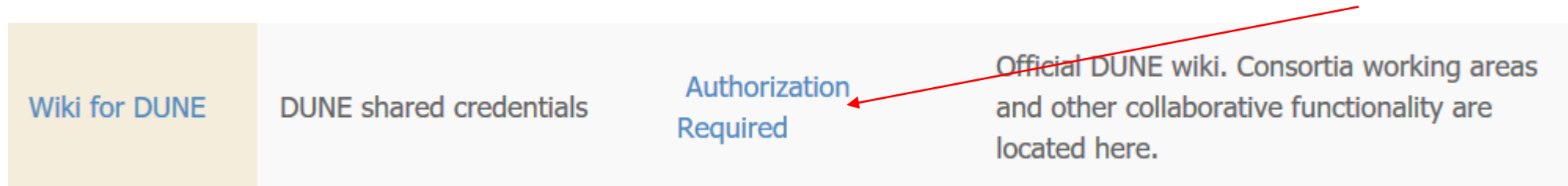
- This processing scheme has been set-up and validated with 2 dedicated data challenges, organized with CERN IT division and FERMILAB computing, processing and data management groups.

	Tested element
DC2 (April 2018)	<ul style="list-style-type: none"> • network infrastructure of NP02 • generation of metadata files by NP02 DAQ system • file transfer from EOSPUBLIC to FERMILAB
DC3 (July 2019) test of whole infrastructure	<ul style="list-style-type: none"> • same elements as DC2 • file copy to CASTOR • processing of Raw Data files moved to FERMILAB with LArSoft • copy of the reconstruction output to CCIN2P3 • metadata generation at different processing steps • integration of DP data files into SAM

- Monte Carlo data files have been used as input for DC2 and DC3.
- The status of reconstruction of NP02 Raw Data with LArSoft will be described in the next talk by Slavic; a pre-batch processing check of the NP02 data with the LArSoft version for which the interface to the NP02 data has been just completed and validated is in progress.
- The scheme agreed with FERMILAB people is to start by reconstructing data from run 1265, and check the physical output before moving to massive production

Some useful links

- The documentation about LArSoft is available from the DUNE WIKI pages here https://wiki.dunescience.org/wiki/Main_Page
- To access the WIKI pages go here: <https://atwork.dunescience.org/tools/> and ask for authorization here:



- Data accessibility tips are described as usual on: <https://dune-data.fnal.gov/> , the catalogs of the ProtoDUNE-DP data, as soon as these data become available by processing, will be available on that link as well as all the other DUNE data catalogs
- Some hints on how to get started with LArSoft (1. , 2.) , some general introductory material (3.) and a list of available algorithms (4.) can be found at:
 1. <https://web.fnal.gov/collaboration/DUNE/SitePages/Getting%20Started%20with%20LArSoft.aspx>
 2. https://cdcvs.fnal.gov/redmine/projects/larsoft/wiki/Getting_LArSoft
 3. <https://cdcvs.fnal.gov/redmine/projects/dunetpc/wiki>
 4. <https://larsoft.org/list/>
- For people having an account at CCIN2P3: [the complete working environment for LArSoft is also available at CCIN2P3 \(since 2015\).](#)

4. Raw Data and online reconstruction results accessibility and organization

Raw Data and online reconstruction results accessibility and organization

- For people interested in having a fast feedback on data, in addition to LArSoft (which takes several minutes to process an event) on LXPLUS it has been set up as well a simpler environment to access Raw Data based on the online reconstruction software
- In the following it is assumed that users have a CERN account in np-comp computing group and are members of **eos-experiment-cenf-np02-readers** egroup (see [here](#) from page 16 for more details)
- Once connected on lxplus, to define the working environment:
 - 1) verify to be connected to lxplus7.. (and not to lxplus6..). Only lxplus7... machines run CentOS7
 - 2) check that you are using bash shell:

```
[epennacc@lxplus732 ~]$ echo $SHELL  
/bin/bash
```

If this is not the case, type bash in order to start the proper shell.
- The same working environment which is used for the online processing on the DAQ cluster is defined by doing:
[source /afs/cern.ch/user/n/np02onlp/public/np02env.sh](#)
- A copy of the same software installed on the online farm machines to run the online processing and perform the electron lifetime measurement can be found here: [/afs/cern.ch/user/n/np02onlp/public/WA105Soft](#)
- **The online event display** (np02evd.exe) which is part of the DAQ system (see https://twiki.cern.ch/twiki/pub/CENF/DUNEPProtDPOps/DAQforshifter_v2r2.pdf) is also available on lxplus in order to look offline calmly at the Raw Data files offline.

Summary table of data and software availability on LXPLUS

	Variables defined in np02env.sh	path
Raw Data	\$RAWDATA	<i>/eos/experiment/neutplatform/protodune/rawdata/np02/rawdata</i>
Reconstructed data (*) Bench distributions Purity results	\$ONLINE_REC	<i>/eos/experiment/neutplatform/protodune/rawdata/np02/online_recon</i>
Code for fast online reconstruction	\$WA105Soft	<i>/afs/cern.ch/user/n/np02onlp/public/WA105Soft</i>

→ Raw Data are also available on CASTOR here:

nsls /castor/cern.ch/neutplatform/protodune/rawdata/np02/protodune-dp/raw/2019/detector

(*) : reconstructed data are not yet copied to FERMILAB, because the creation of metadata files is not yet implemented
bench distribution: only the summary file is copied

HOW TO: run offline the online event display

- In order to run offline the online event display, for instance on the sequence 10_c of cosmic run 1154, filename 1154_10_c.cosmics, use:

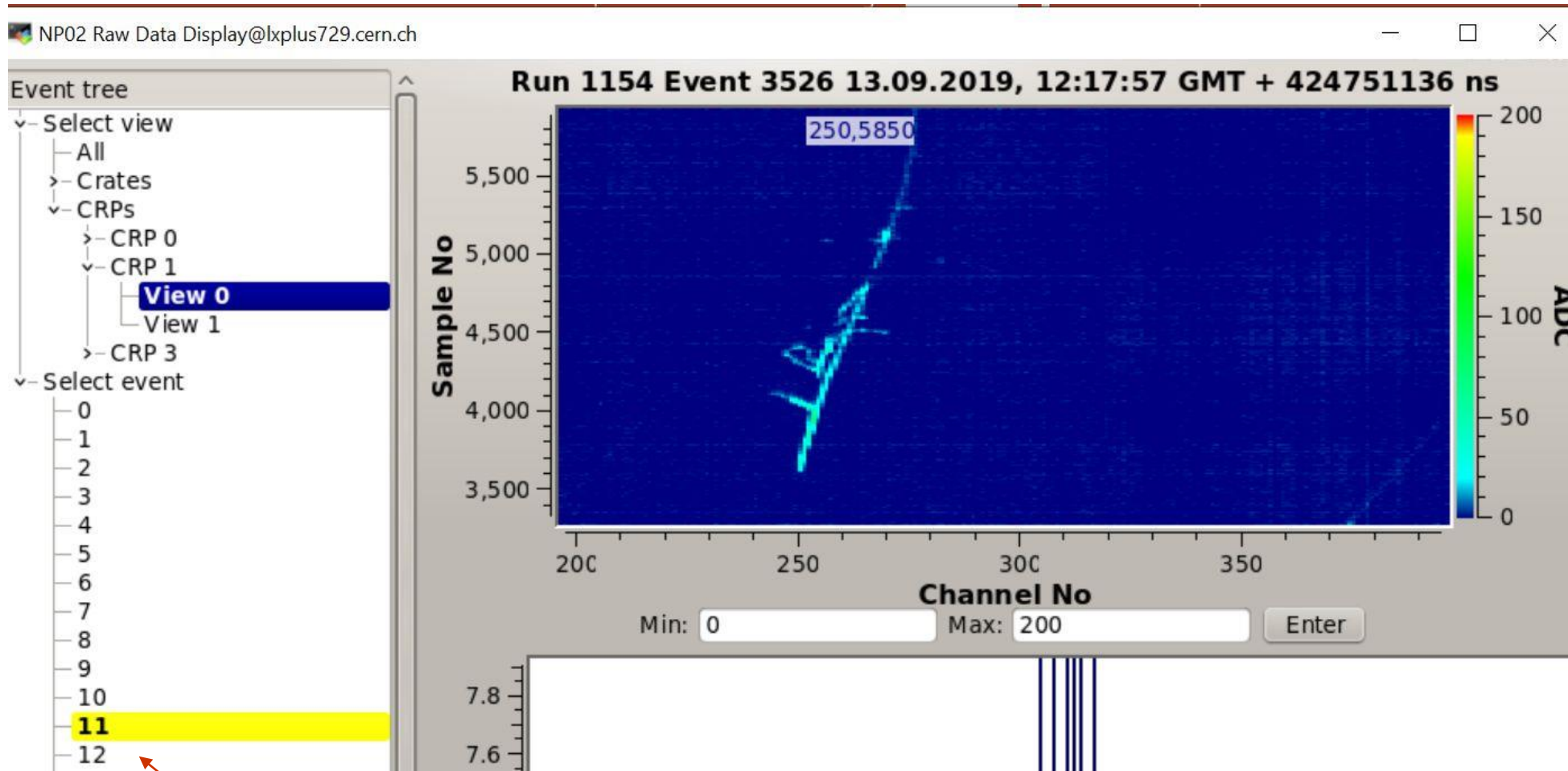
```
np02evd.exe -f $RAWDATA/1154/1154_10_c.cosmics
```

- Pedestals subtraction is enabled.
- The online event display allows for displaying the data per crate or per CRP or CRP views, to zoom on a given area and look at the waveforms of single channels or group of channels.
- **Example:** the FERMILAB news showed the event 3526 of run 1154. In order to look at it with the online event display, first find out which sequence file contains the event, by using the command *Find_event*

```
[epennacc@lxplus729 ~]$ Find_event  
enter event number:  
3526  
event 3526 is in file: 30 b ( event #12 in the file)
```

The position of the event in the file is also returned

- Run the event display: *np02evd.exe -f \$RAWDATA/1154/1154_30_b.cosmics*



Events numbering starts from 0

```
[epennacc@lxplus729 ~]$ Find_event
enter event number:
3526
event 3526 is in file: 30 b ( event #12 in the file)
```

HOW TO: run fast online reconstruction

```
recotask.exe -c $SOFTDIR/Qscan/WA105_rectasks.config -i RAWDATA/1154/1154_10_c.cosmics
```

WA105_rectask.config is the steering file, allows selecting some basic parameter as number of events to be reconstructed, Input parameters for hit and track reconstruction.

HOW TO: look at reconstruction results

if the file reco.root is the output from recotask.exe

```
bench.exe -p 13 -f reco.root
```

The code available in \$WA105SOFTDIR/bech/src/bench.cc is a an example on how to loop on events in the output reconstruction file, and access reconstruction results as: number of hits, hit charge, 2D and 3D tracks properties,.....

This is just an example, every user can copy the code in its working directory, and run her/his own analysis

List of cosmic runs taken in stable conditions, and processed online
(taken from the online database)

runid	lemDV	Vgrids	comments
1104	2.9	5.5	
1105	2.9	5.5	
1106	2.9	5.5	
1107	2.9	5.5	
1108	2.9	5.5	
1115	2.9	5.5	
1116	2.9	5.5	
1117	2.9	5.5	
1153	2.9	6	
1154	2.9	6	
1184	0	3.5	CRP4
1185	0	3.5	CRP4
1186	0	3.5	CRP4
1187	0	3.5	CRP4
1210	2.9	6	

runid	lemDV	Vgrids	comments
1211	0	0	cosmics triggers
1212	2.9	6	
1213	2.9	6	
1214	2.9	6	
1215	2.9	6	
1216	2.9	6	
1217	3	6	
1219	3.1	6	
1250	2.9	6	LP
1251	2.9	6	network pb
1254	3	6.1	
1255	3	6.1	
1256	3.1	6.2	
1262	2.9	5.5	run stopped because of sparks
1263	3	5.5	
1264	3.1	5.5	
1265	3.1	5.5	some instabilities at the end of the run
1267	3.1	5.3	network instabilities
1269	3.1	5.4	trip
1271	3.1	5.4	
1272	3.1	5	
1273	3.1	4.5	
1276	3.1	4.5	
1294	3.2	5.3	very unstable

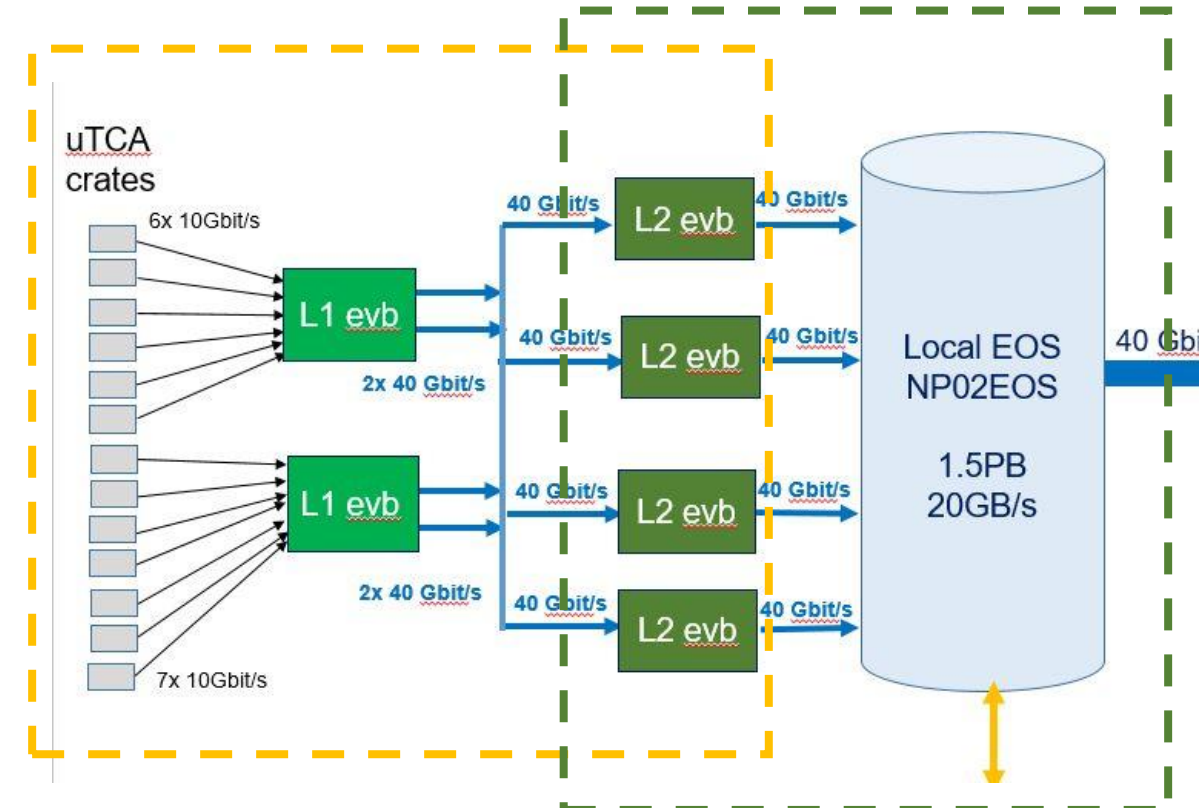
Conclusions

- NP02 Raw Data are available on EOSPUBLIC; they are copied as well to FERMILAB and CASTOR.
- The online processing of raw data is well in place, hits, 2D and 3D tracks are reconstructed. Reconstruction results are copied on EOSPUBLIC. Some histograms to check reconstructed quantities are automatically produced as well. Electron lifetime measurement is also performed. Results are also copied on EOSPUBLIC
- The offline treatment of NP02 data is done within DUNE. The workflow is well established as it has been validated with 2 dedicated data challenges. The production has started
- For people interested in having a fast feedback from the data, the same working environment of the online processing farm has been put in place on lxplus. The event display can be used offline, the fast reconstruction code is available; in particular an example on how to loop on events on the reconstruction output file is provided.

Addendum 1:
NP02 back end system
(DUNE collaboration meeting,21/05/2019)

- The charge readout electronics and DAQ system was installed in between February and April 2019.
- All the part of the system (hardware and software) have been extensively tested and characterized in Lyon before installing them to EHN1, and this has allowed to be ready to operate the system in real condition as soon as it became available. It is important to consider that the back-end system has been designed in such a way that we can work on it (and operate it) from Lyon, and actually this is a main activity for our group.
- **Since months we are running the whole DAQ system.** It is possible to identify 2 main components:

1
From the uTCA to the L1 Event builders and L2 event builders (from bits to datafiles....)



2
From the L2 event builders to NP02 EOS instance

(data on the online storage facility are then moved to central CERN EOS, but this will not be discussed during this talk)

1

From the uTCA to the L1 Event builders and L2 Event builders (from bits to datafiles...)

- LV1 Event builders receive data from the uTCA crates (link at 10 Gbit/s from each crate)
On each LV1 EVB there is a LARGUI process reading the data from the crates attached to the EVBs via a private network
- Each L1 EVB write on its ram disk one half of the event:
 - np02evbl1a: data from crate 1 to crate 6
 - np02evbl1b: data from crate 7 to crate 10

The L1 ram disks are mounted via network to the L2 machines

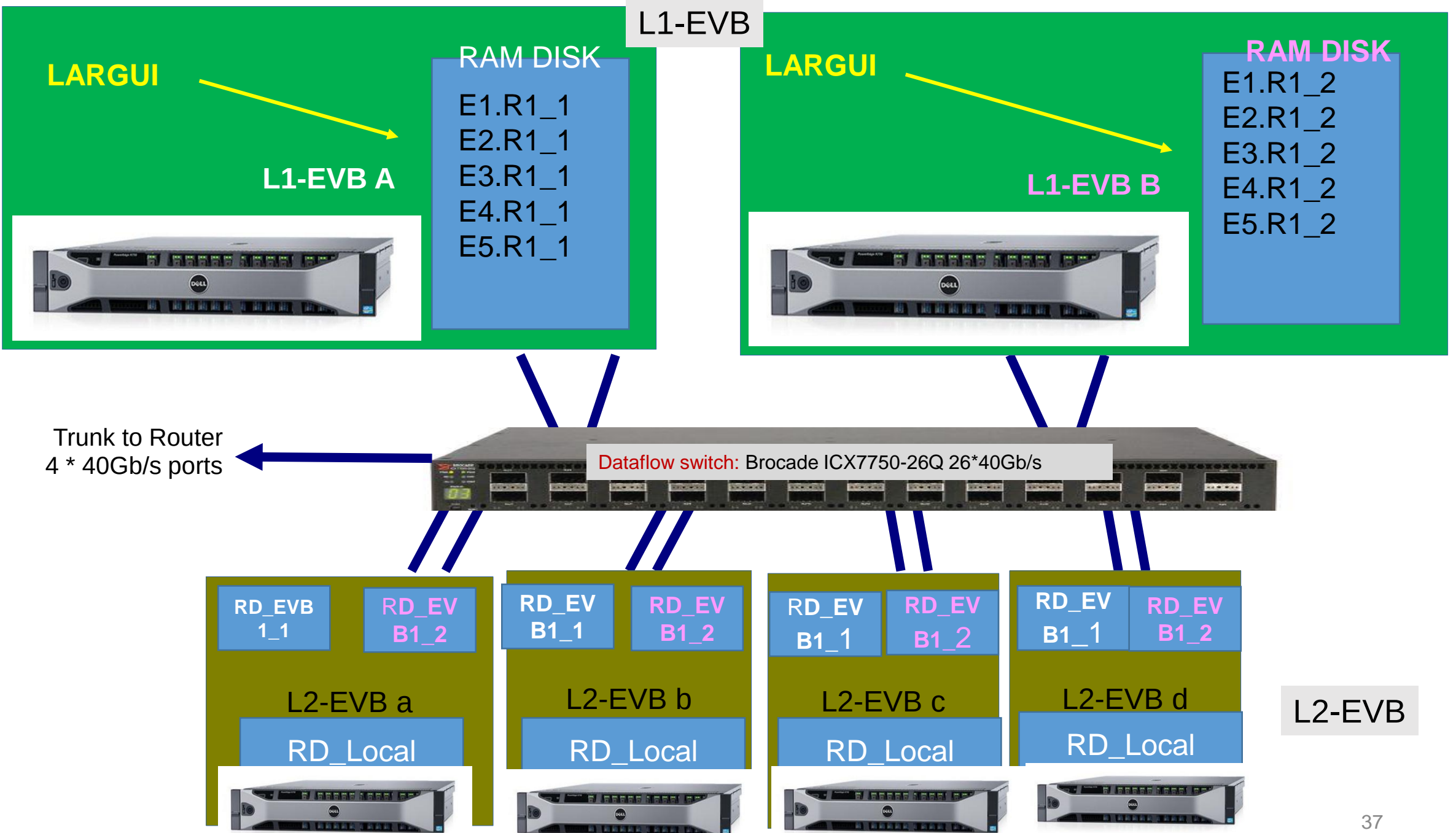
- The task of the L2 event builders is to read the events halves written by the L1 event builders, merge them to build the whole event, and pack several events to build data files of 3GB size on its ram disk. This is done by a **MERGE2** process, running on each L2 event builder.

How **MERGE2** works (*4 merging nodes running in parallel*):

- Each L2 event builder receives from the Run Control the start of run signal. The number of events per sequence is sent by the Run Control together with the run number, the data type (pedestal, cosmics) and the number of active L1 and L2 event builders.
- As soon as the run start, each L2 event builder starts checking the L1 ramdisk, where event halves are written
Each LV2 event builder chooses the half events to be included in its sequences from the LV1 RAM disks on the basis of the event numbers by using an arithmetic allocation rule (based on division module)



np02evbl2a	1,5,9,13,17,...
np02evbl2b	2,6,10,14,18,..
np02evbl2c	3,7,11,15,19,...
np02evbl2d	4,8,12,16,20,...



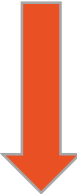
L2-EVB

How a sequence is built:

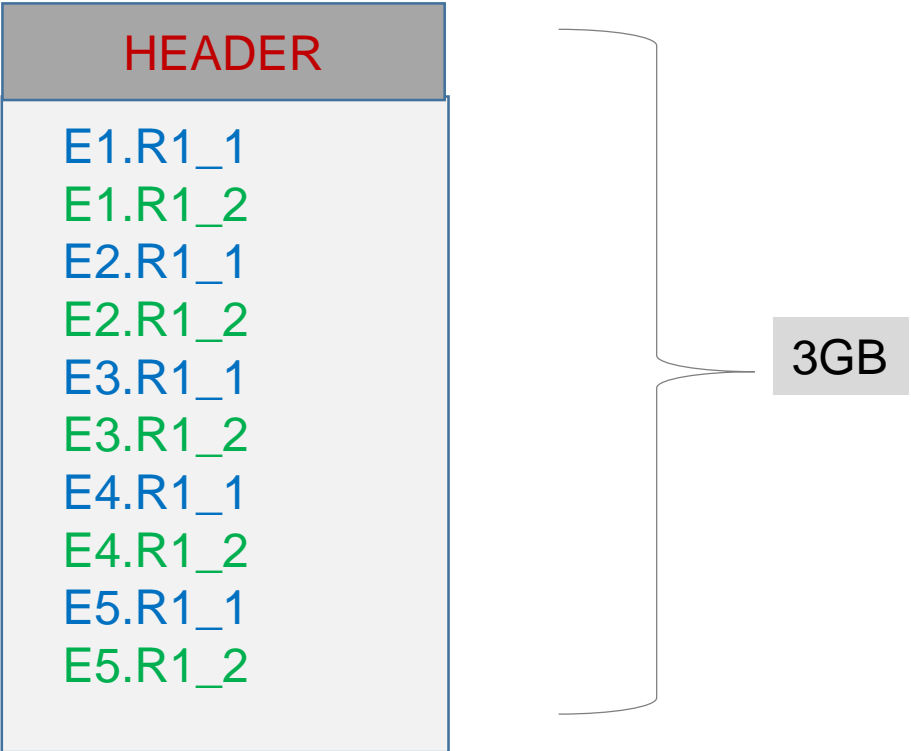
L1-EVB A L1-EVB B

E1.R1_1	E1.R1_2
E2.R1_1	E2.R1_2
E3.R1_1	E3.R1_2
E4.R1_1	E4.R1_2
E5.R1_1	E5.R1_2

each half event half is composed by an header, followed by LRO and CRO data



the sequence is constructed by adding event chunks one after the other . The sequence **header** is created and filled with the event list and their size



(DUNE collaboration meeting,21/05/2019)

→ Assuming to run with **compressed**(**uncompressed**) events, data files must contain **200(20)** events. So, each L2 EVB checks how many events are available on L1 ram (following the allocation rule), and if at least **200(20)** files are available, it starts writing the sequence file in its own ramdisk. The events are merged and then added one after the other in the datafile.

→ If there are less than **200(20)** events, **MERGE2** waits to have enough events

→ At the stop of run, all events available in L1 ram disk are merged and put in a data file (that will be shorter)

→ For each data file the checksum value is computed

→ An online mysql database **np02onlp** has been setup to log all information about data files (timestamp , statistics and checksum value)

2 From the L2 event builders to NP02EOS instance

→ As soon as a data file is closed, a different process **L2EOS** running on each L2 event builder takes care of copying it to the online storage facility (NP02EOS) which is based on a distributed file-system and 20x24 disk units running in parallel . To fully exploit the available bandwidth (20GB/s) , several files can be copied in parallel at the same time from the same event builder.

→ This process also generates the **metadata files** needed for data transfer to FNAL.

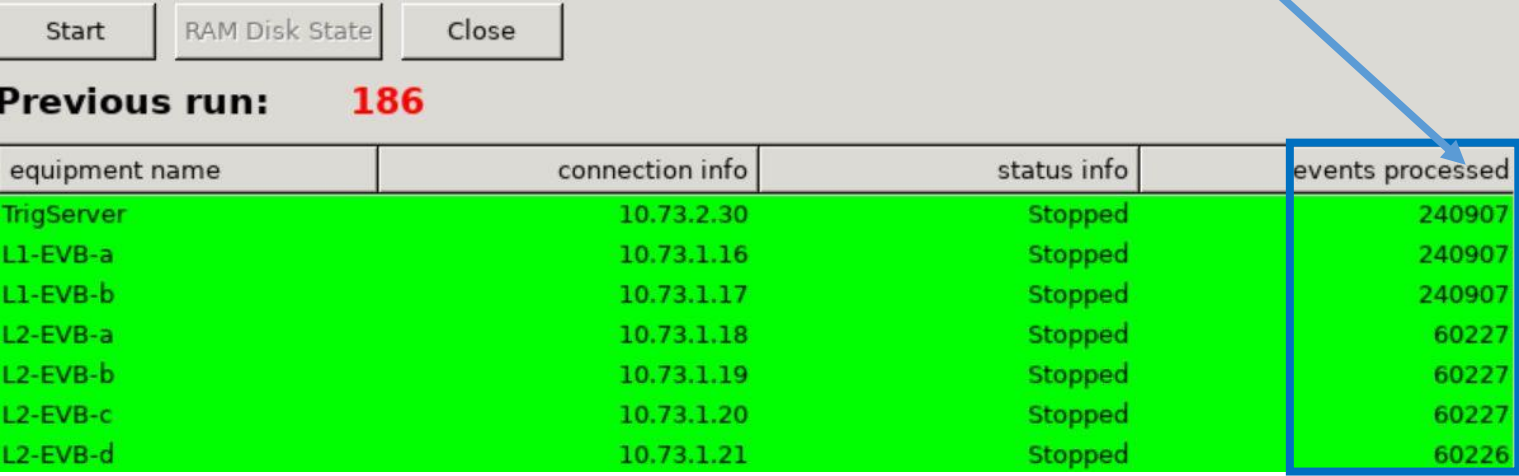
→ The status of files transfer to NP02EOS is also logged in the database

Once the data file is copied on NP02EOS:

- 1) the online event display is notified that a new file is available → the event display systematically shows events from the latest produced file, that can be written from any L2 event builder.
- 2) the **EOS2IT** process that takes care of moving files from NP02EOS to CERN EOS is notified that a new files is available

During the last months, we are running the two parts together (single uninterrupted run duration ~ a few hours) to understand the system and find out its time stability. These tests allowed to benchmark the system.

One example: run 186, 240907 events, 60227 events processed by each L2 evbs



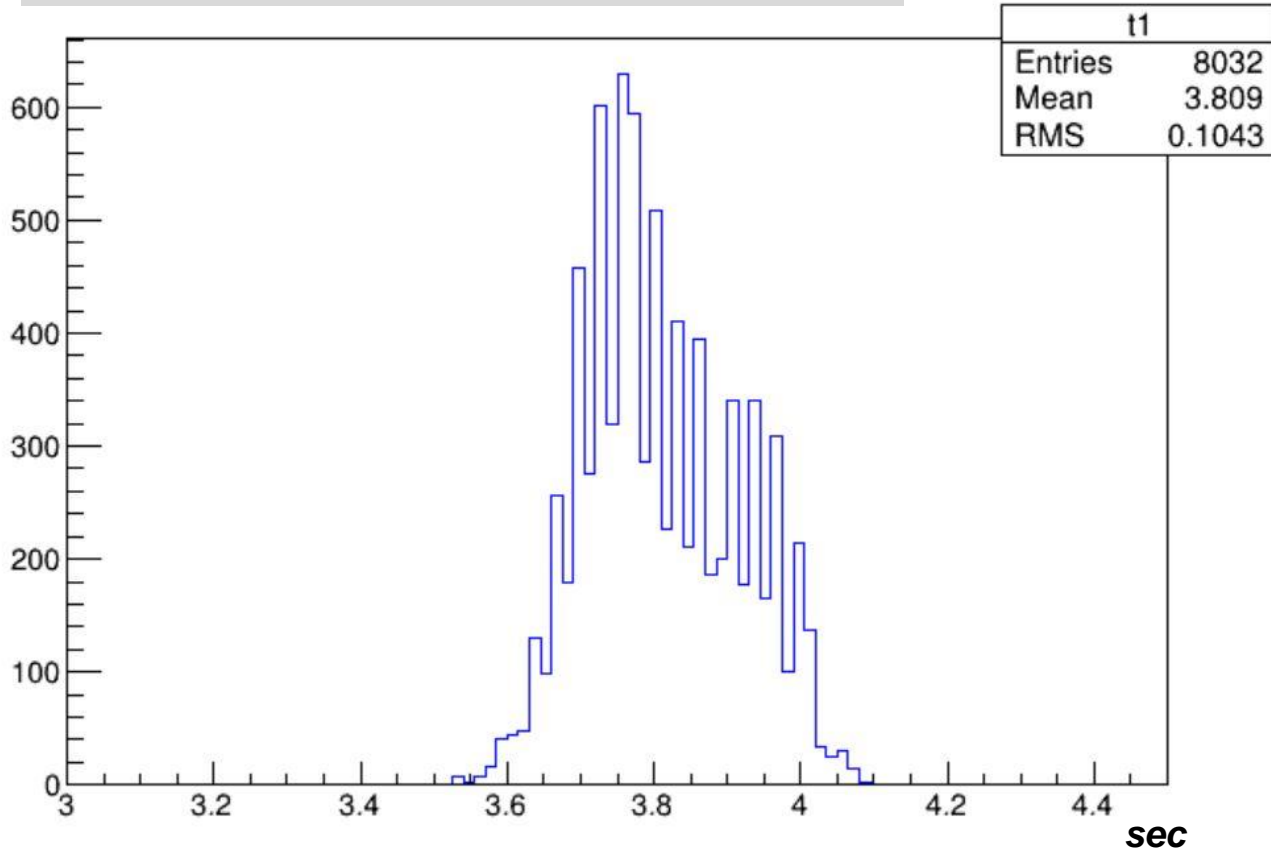
Start RAM Disk State Close

Previous run: **186**

equipment name	connection info	status info	events processed
TrigServer	10.73.2.30	Stopped	240907
L1-EVB-a	10.73.1.16	Stopped	240907
L1-EVB-b	10.73.1.17	Stopped	240907
L2-EVB-a	10.73.1.18	Stopped	60227
L2-EVB-b	10.73.1.19	Stopped	60227
L2-EVB-c	10.73.1.20	Stopped	60227
L2-EVB-d	10.73.1.21	Stopped	60226

- During this run, each L2 evb wrote 2008 datafiles in its ram disk, for a total of 8032 datafile written, and a data volume of ~25 TB.
- 8032 data files have been moved to NP02EOS (2008 from each L2 event builder)
- All operations have been logged in the online database independently by each L2 event builder.

Time to write a sequence file (all EVBs)



→ Each L2 event builder can write a 3.3 GB datafile in ~ 4sec (for testing, we are now writing files a bit larger wrt to the foreseen size of 3GB).

→ This time includes also the logging of all data taking information in the online database, as described before, this is done independently by each L2 event builder.

→ Assuming compressed events, a datafile of 3.3 GB includes 200 events:

the back end system of NP02 can handle 800 events in 4 seconds. This can comfortably fit the 100 Hz design data rate of NP02

Addendum 2

Benchmark histograms

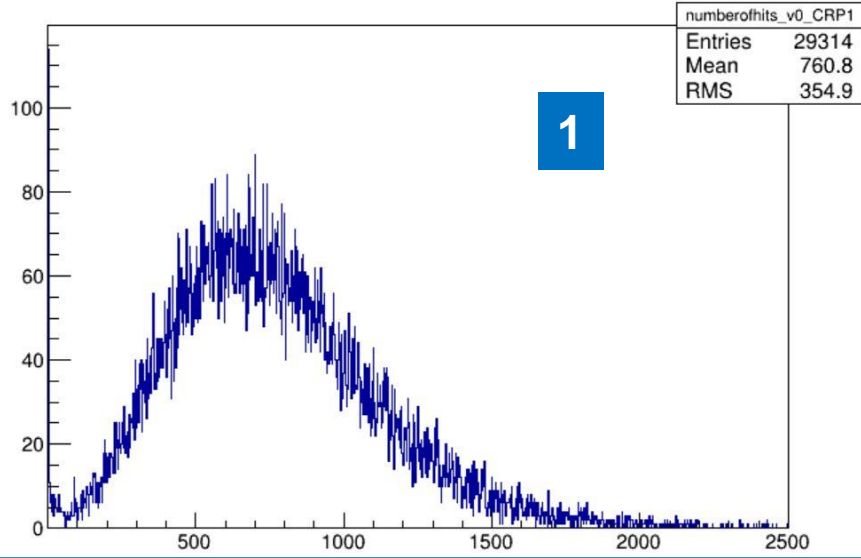
Hits reconstruction

For CRP 1, 2, 4, view 0 and view 1

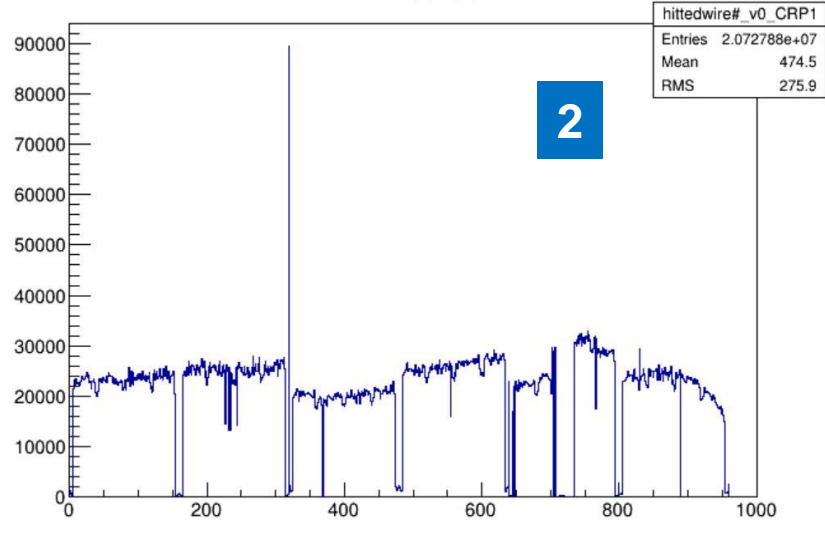
1. **numberofhits** *total number of hits*
2. **hittedwire#** *number of hits on each channel (to detect holes or sparking wires)*
3. **hitsperwire** *number of hits/wire*
4. **hitcharge** *hits charge (fC)*
5. **hitt0** *hits time (us)*
6. **hitx** *hits position (cm)*
7. **tothitcharge** *sum of the charge of all hits in each channel (fC)*

As an example, in the next 2 slides, these distributions will be shown for run 1294, CRP 1, view 0

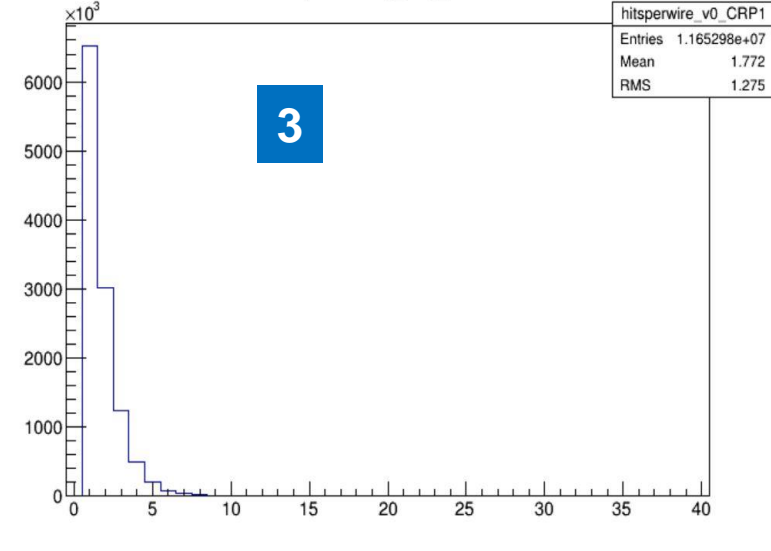
numberofhits_v0_CRP1



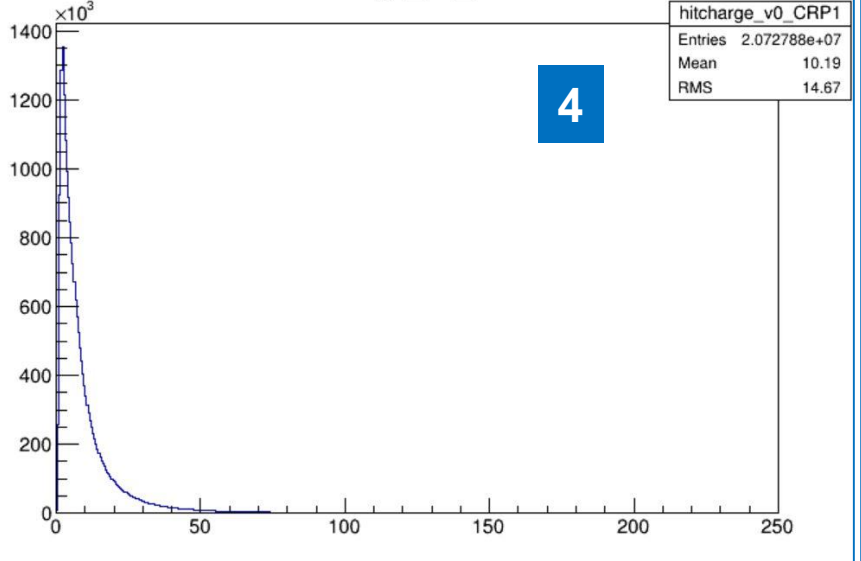
hittedwire#_v0_CRP1



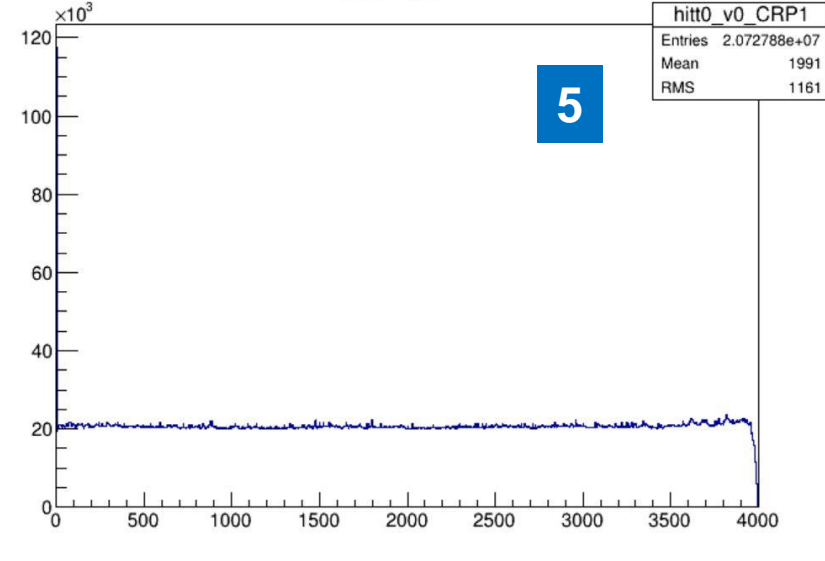
hitsperwire_v0_CRP1



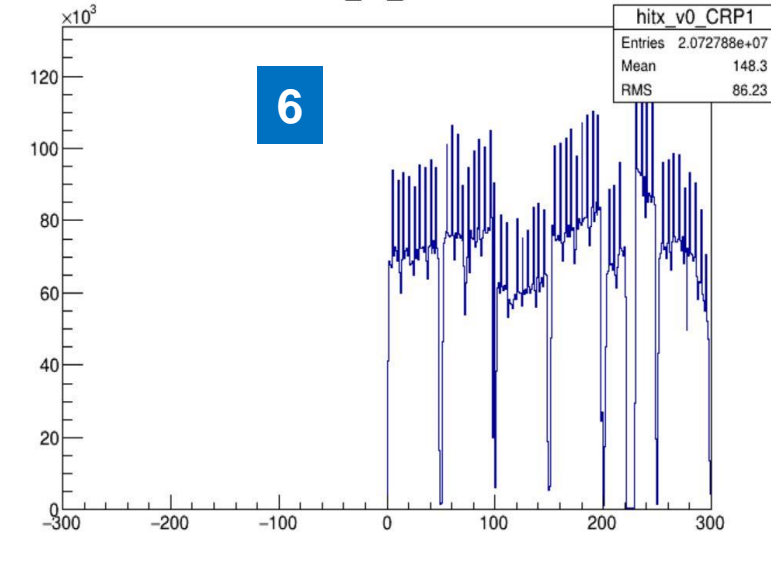
hitcharge_v0_CRP1

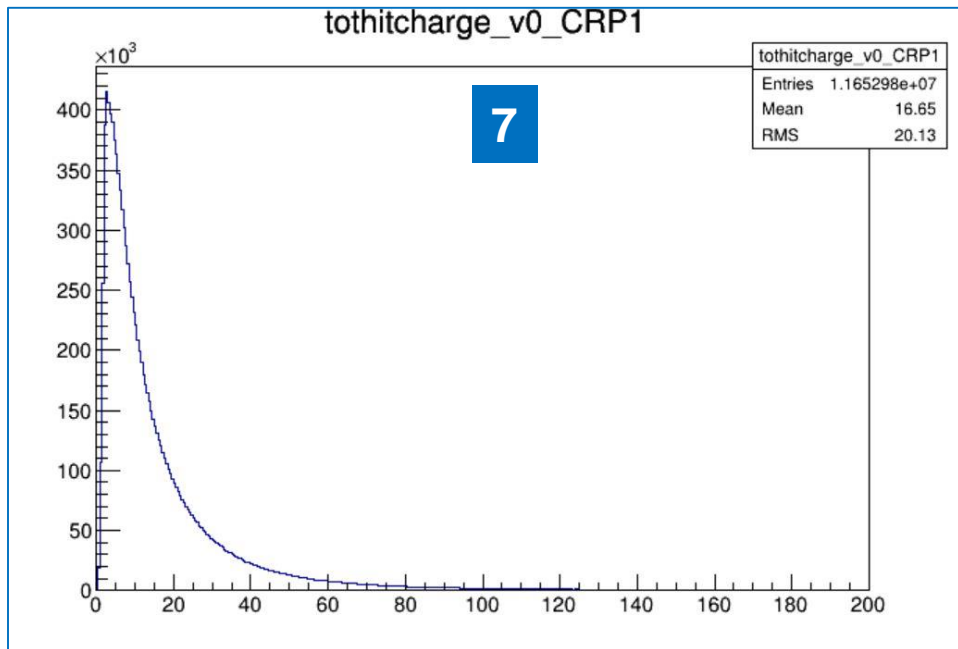


hitt0_v0_CRP1



hitx_v0_CRP1





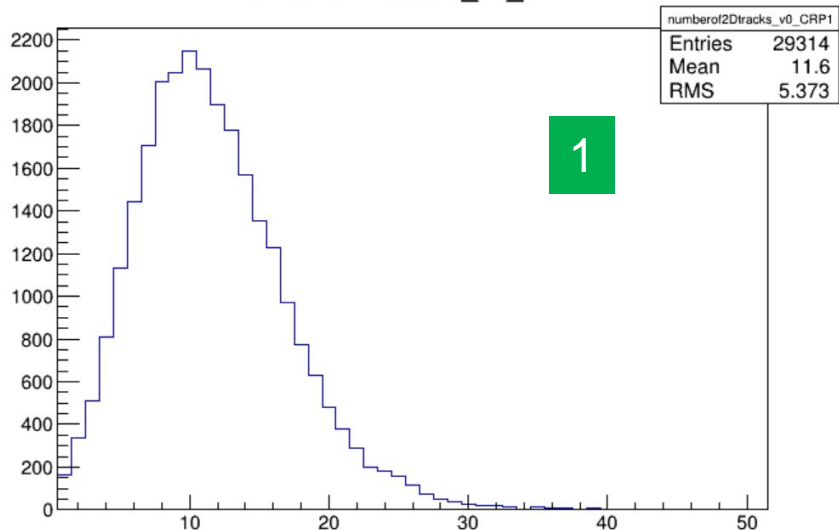
2D track reconstruction

For CRP 1, 2, 4, and for tracks obtained by merging segments from different CRP; view 0 and view 1

1. `numberof2Dtracks` *total number of reconstructed 2D tracks*
2. `numberofhits/trk` *total number of hits belonging to each 2D track*
3. `track_length` *tracks length*
4. `track_totQ` *total charge deposition from 2D tracks (fC)*
5. `dedx` *dE/dx (fC/mm)*

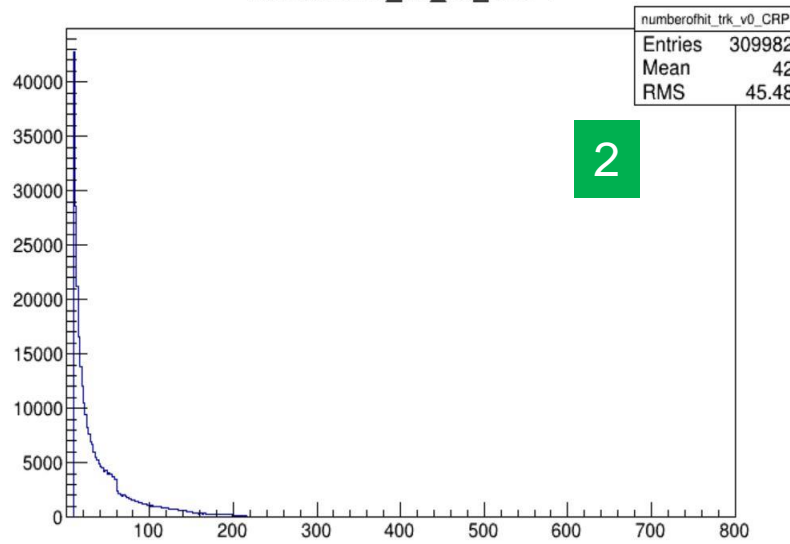
As an example, in the next 2 slides, these distributions are shown for run 1294, CRP 1, view 0

numberof2Dtracks_v0_CRP1



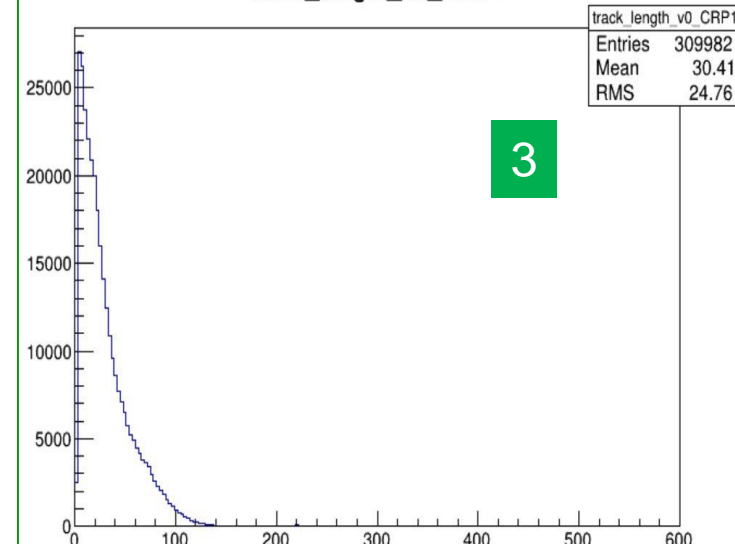
1

numberofhit_trk_v0_CRP1



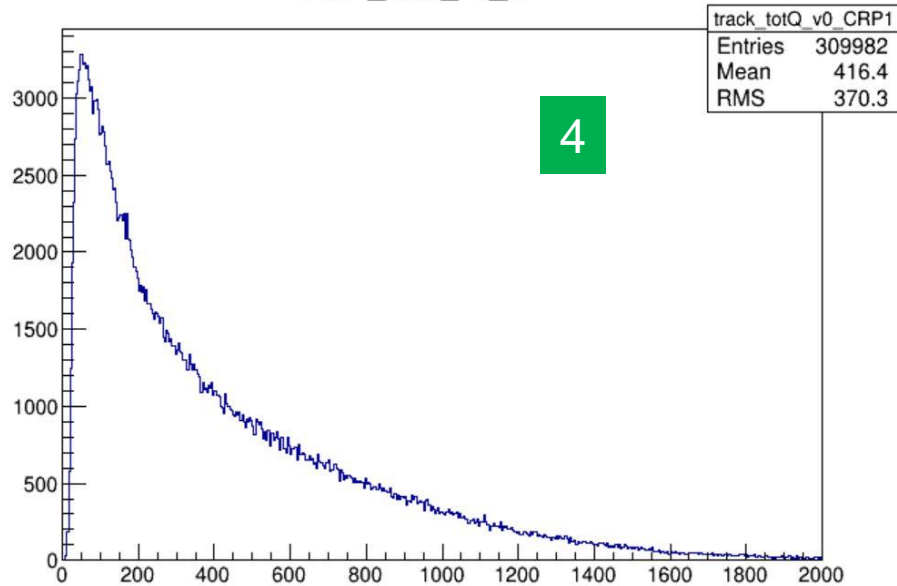
2

track_length_v0_CRP1



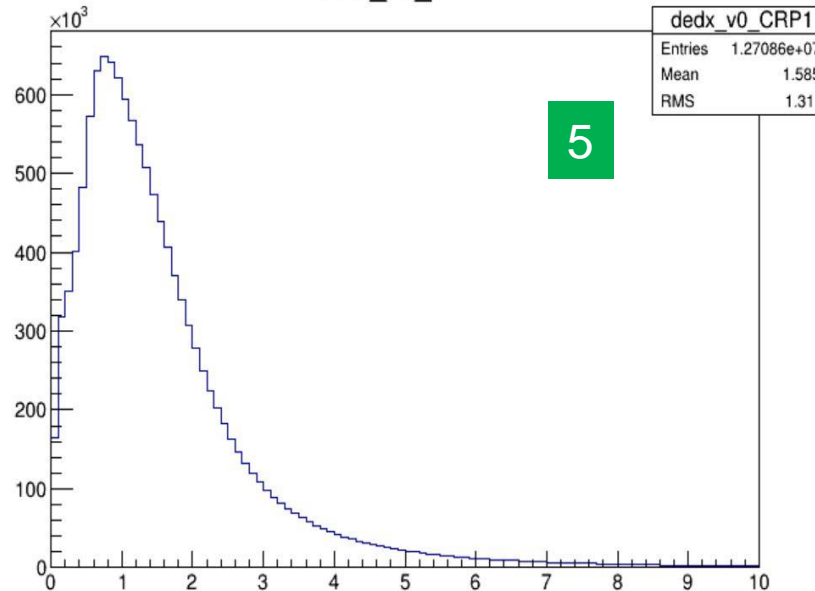
3

track_totQ_v0_CRP1



4

dedx_v0_CRP1

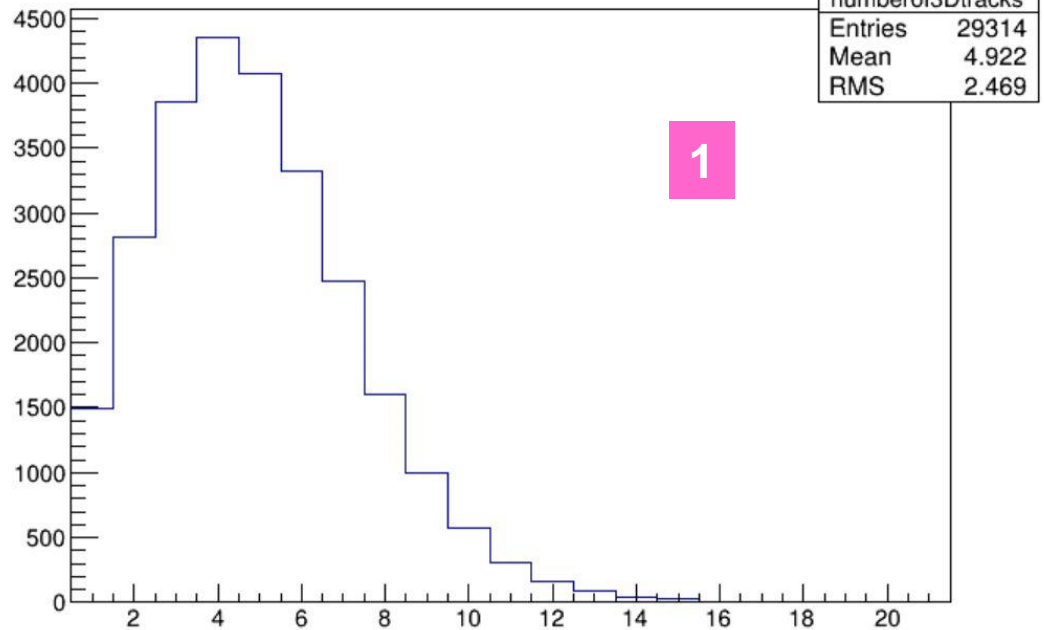


5

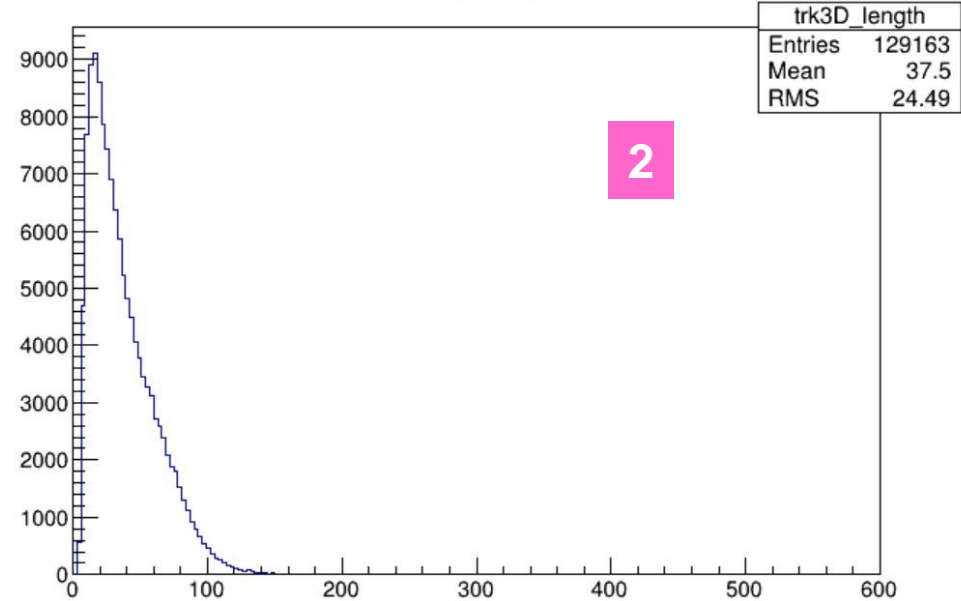
3D track reconstruction

1. **numberof3Dtracks** *total number of reconstructed 3D tracks*
2. **trk3D_length** *tracks length*
3. **dedx_v0** *de/dx (fC/mm) from 2D track (view 0) used to build a 3D track*
4. **dedx_v1** *de/dx (fC/mm) from 2D track (view 1) used to build a 3D track*

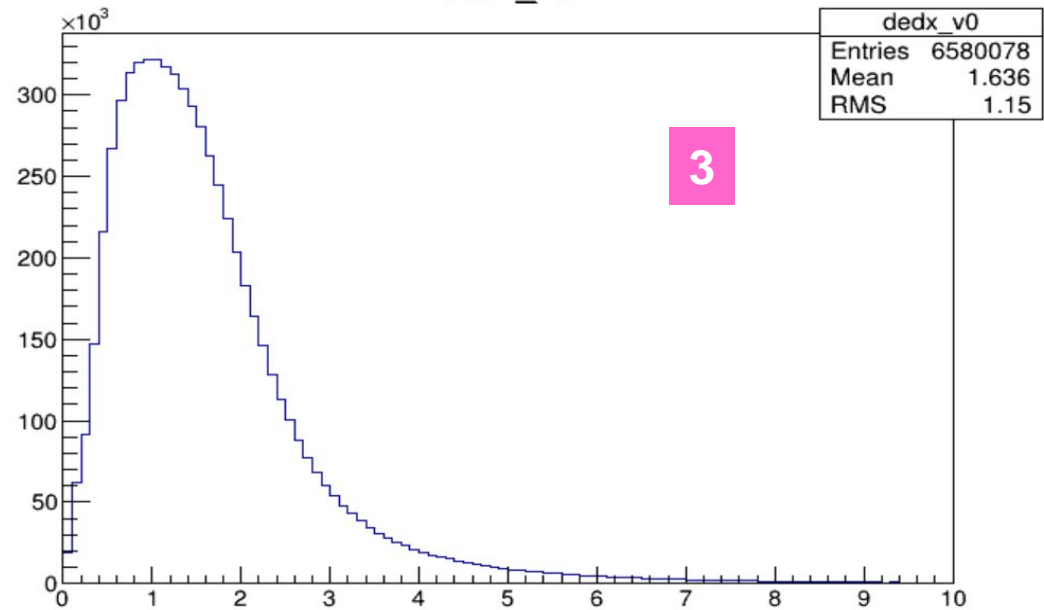
numberof3Dtracks



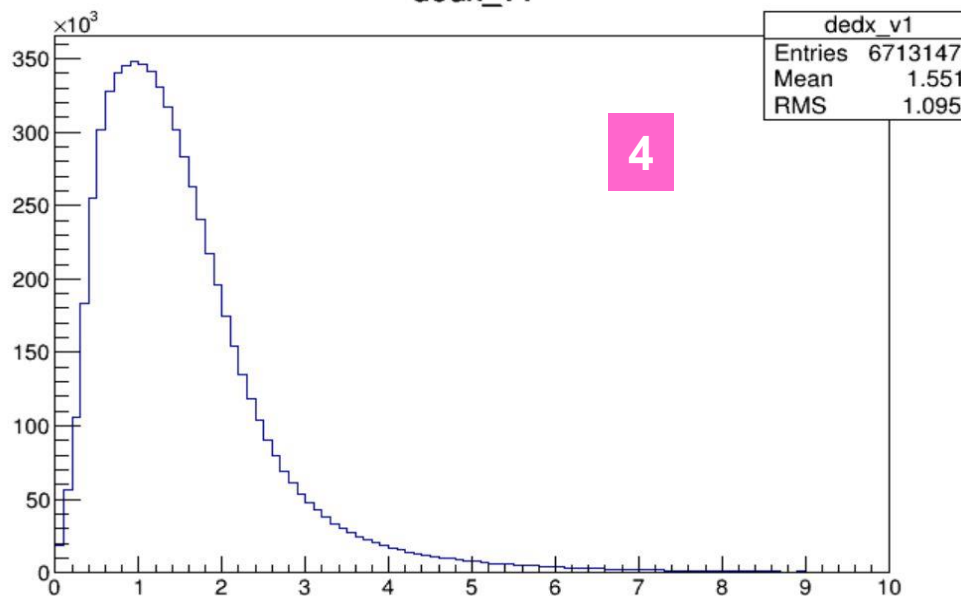
trk3D_length



dedx_v0



dedx_v1

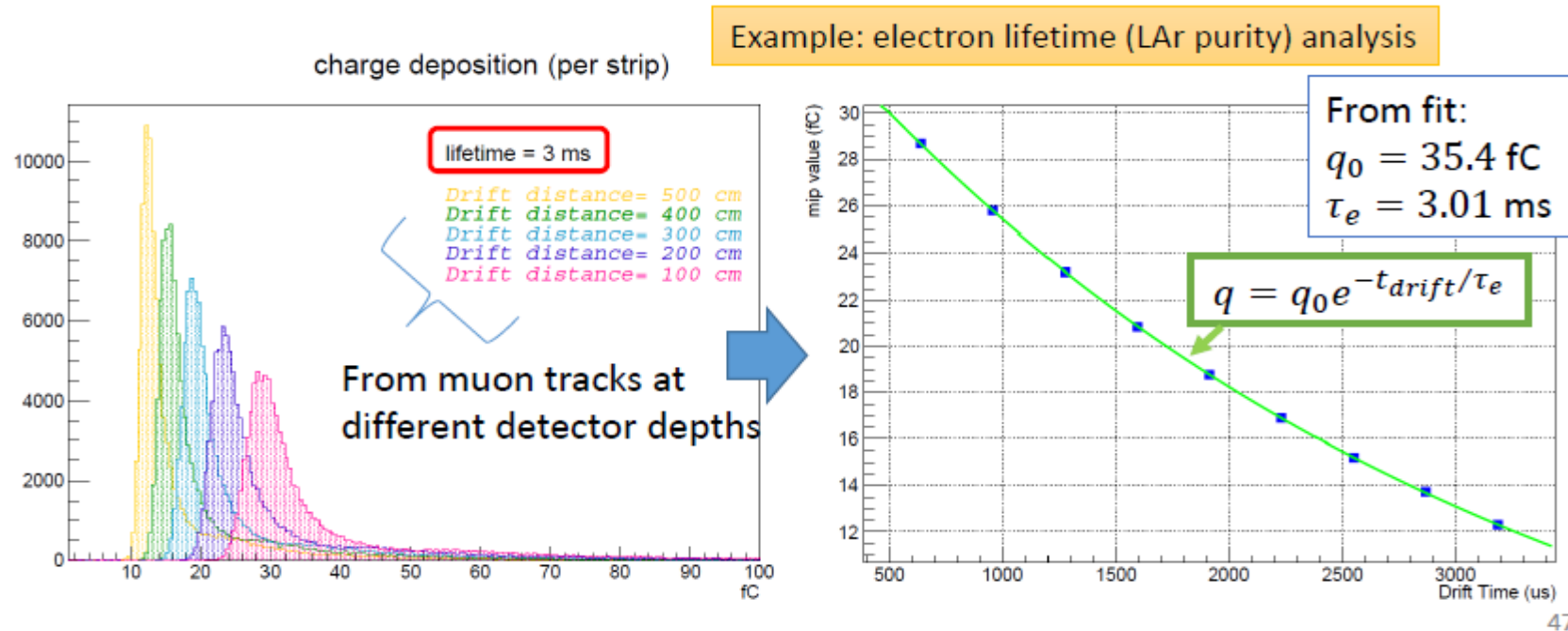


Addendum 3

Electron lifetime from muon tracks

(WA105 Science Board meeting , July 6th, 2016)

- One of the task of the online monitoring is the measurement of the purity.
- this measurement is performed using cosmic rays tracks
- The feasibility of this measurement has been tested using Raw Data (horizontal tracks), and results were presented at the Science Board meeting (18/11/2015), at the General meeting (03/08/2016), and were also included in the SPSC report

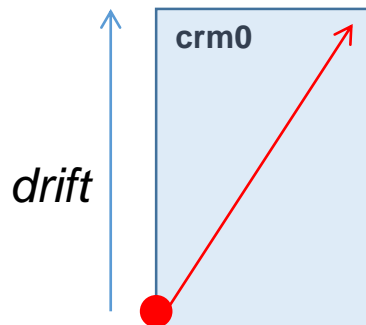
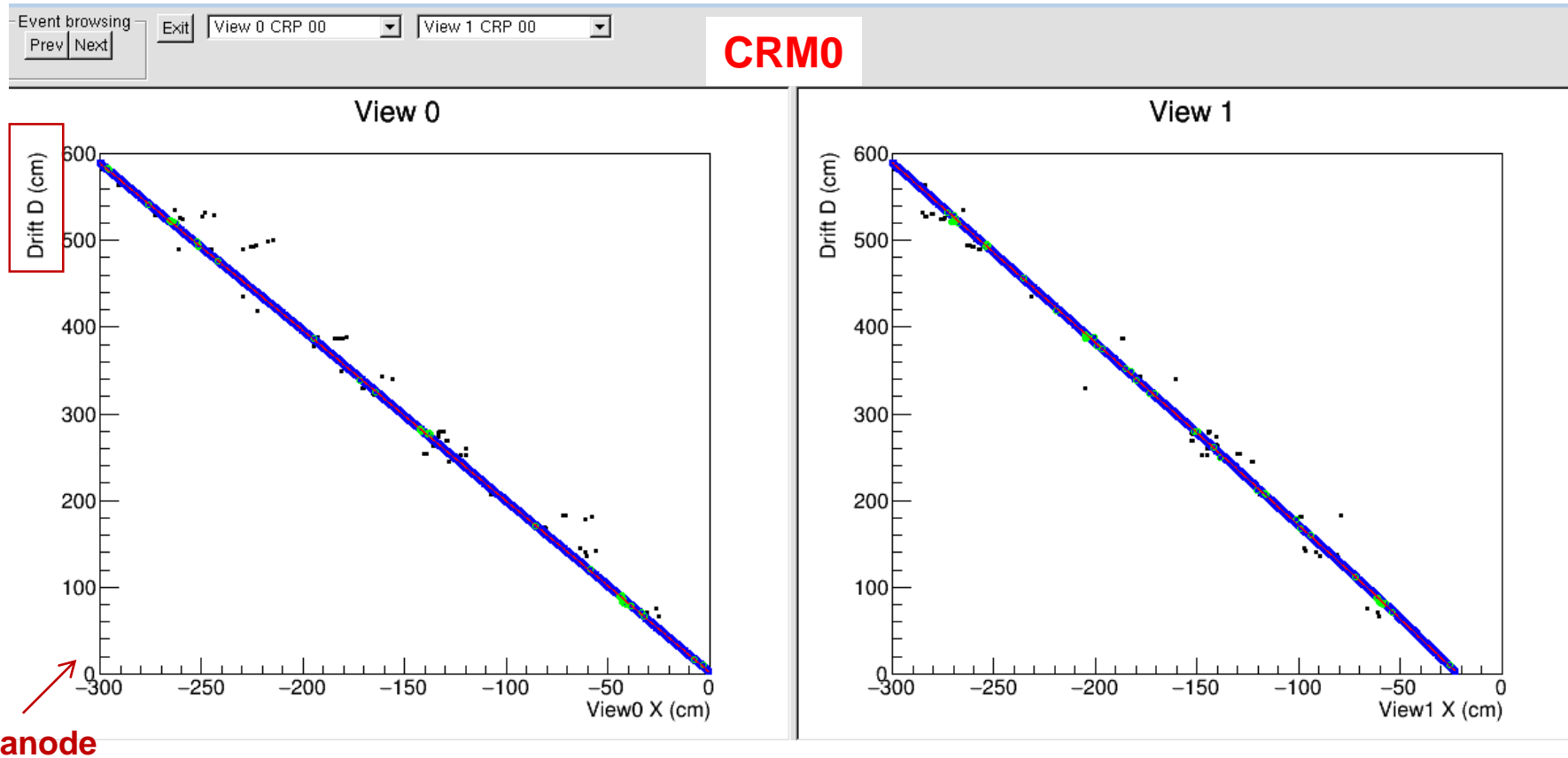


- This study has been repeated with reconstructed tracks.
(the code used for tracking reconstruction is available on the svn server)

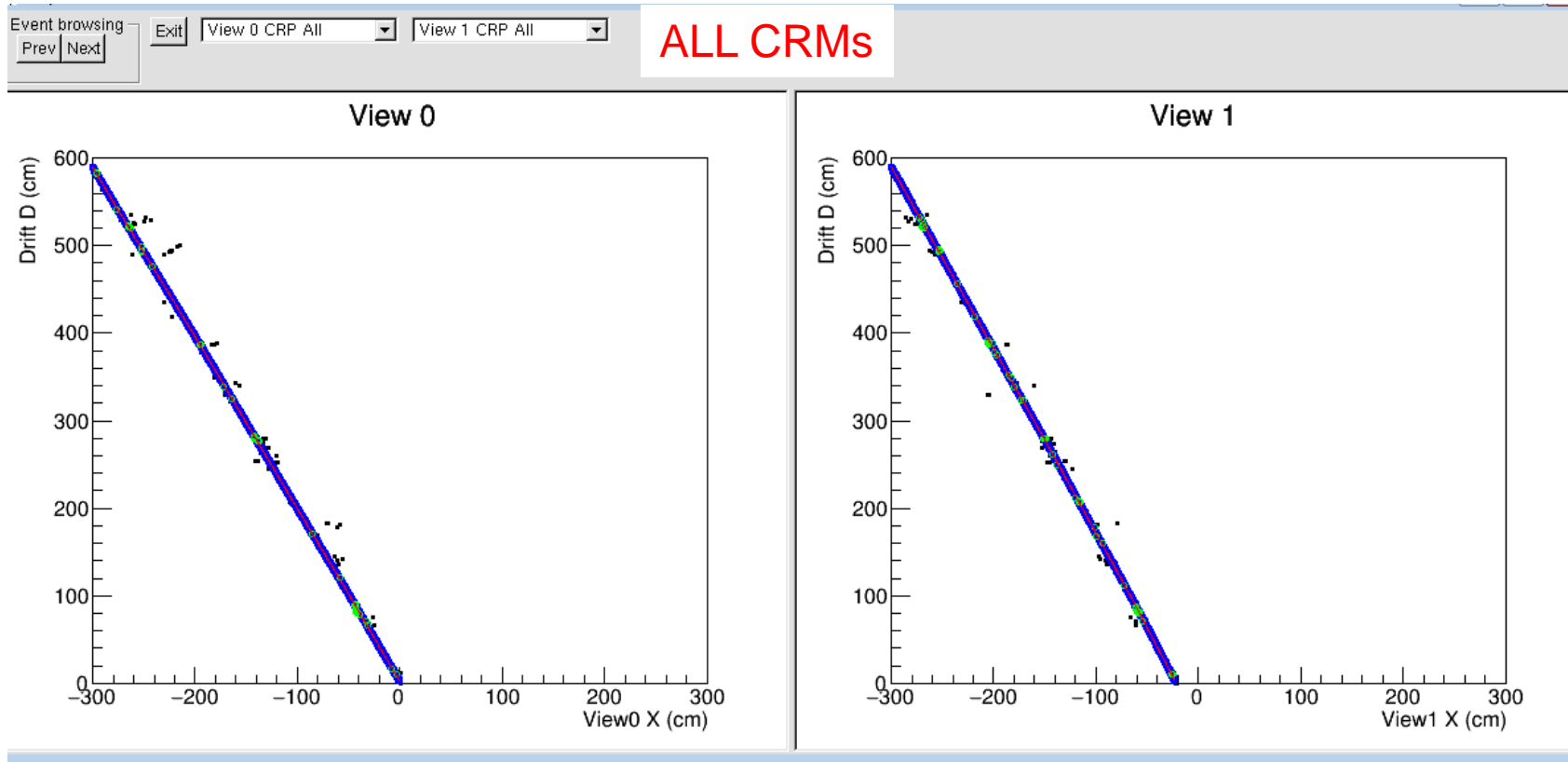
Analysis methodology

- To set up the method, the 6x6x6 geometry has been used, to exploit the full drift distance.
- Only one CRM will be taken into account (CRM0) : our priority is the data taking of September with the 3x1x1 prototype whose anode counts only one CRM
- The method has been tested on samples of muon at different generation angles
- Once the method has been set up, it has been applied to 3x1x1, to check the results

1st sample: muons at 4 GeV, 2K events $\theta=45^\circ$, crossing only CRM0, $t=3\text{ms}$

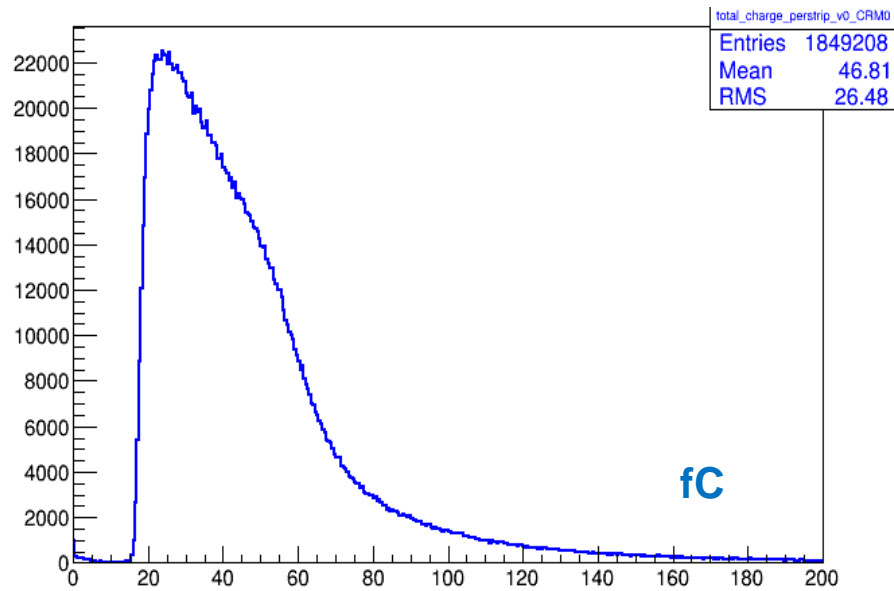


WA105 Science Board meeting , July 6th, 2016

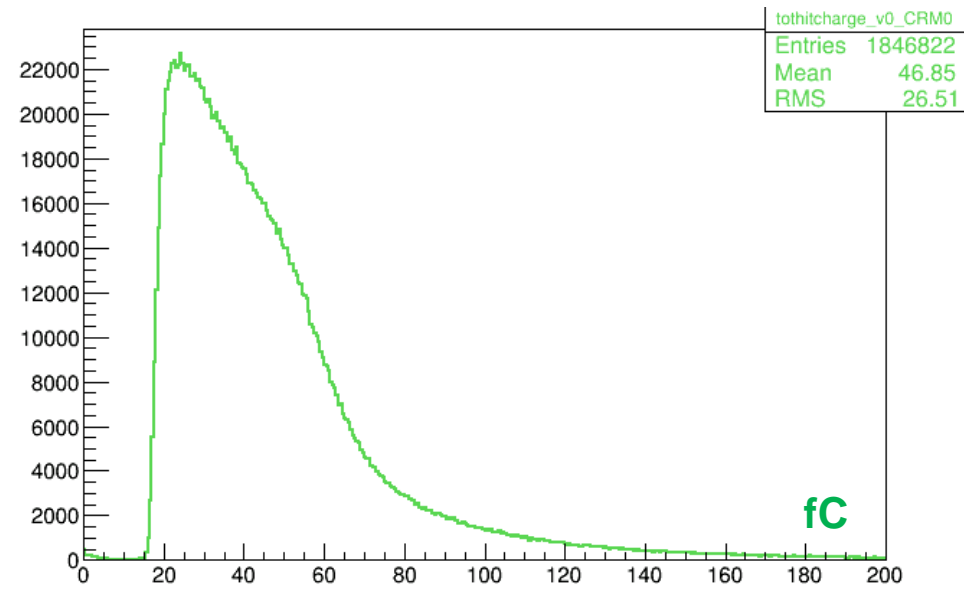


Some crosschecks on the total charge at raw level, hits and track

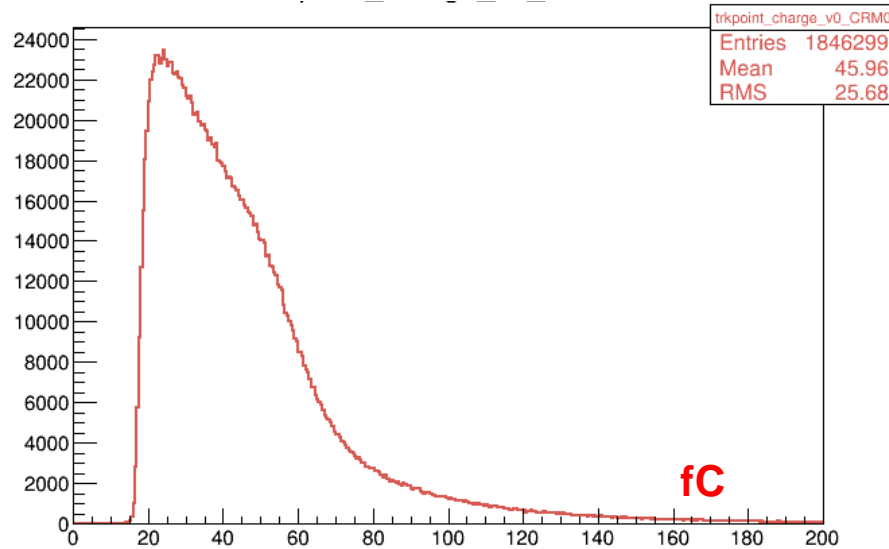
Total charge collected on strips (Raw Data)



Total charge collected from hit reconstructions

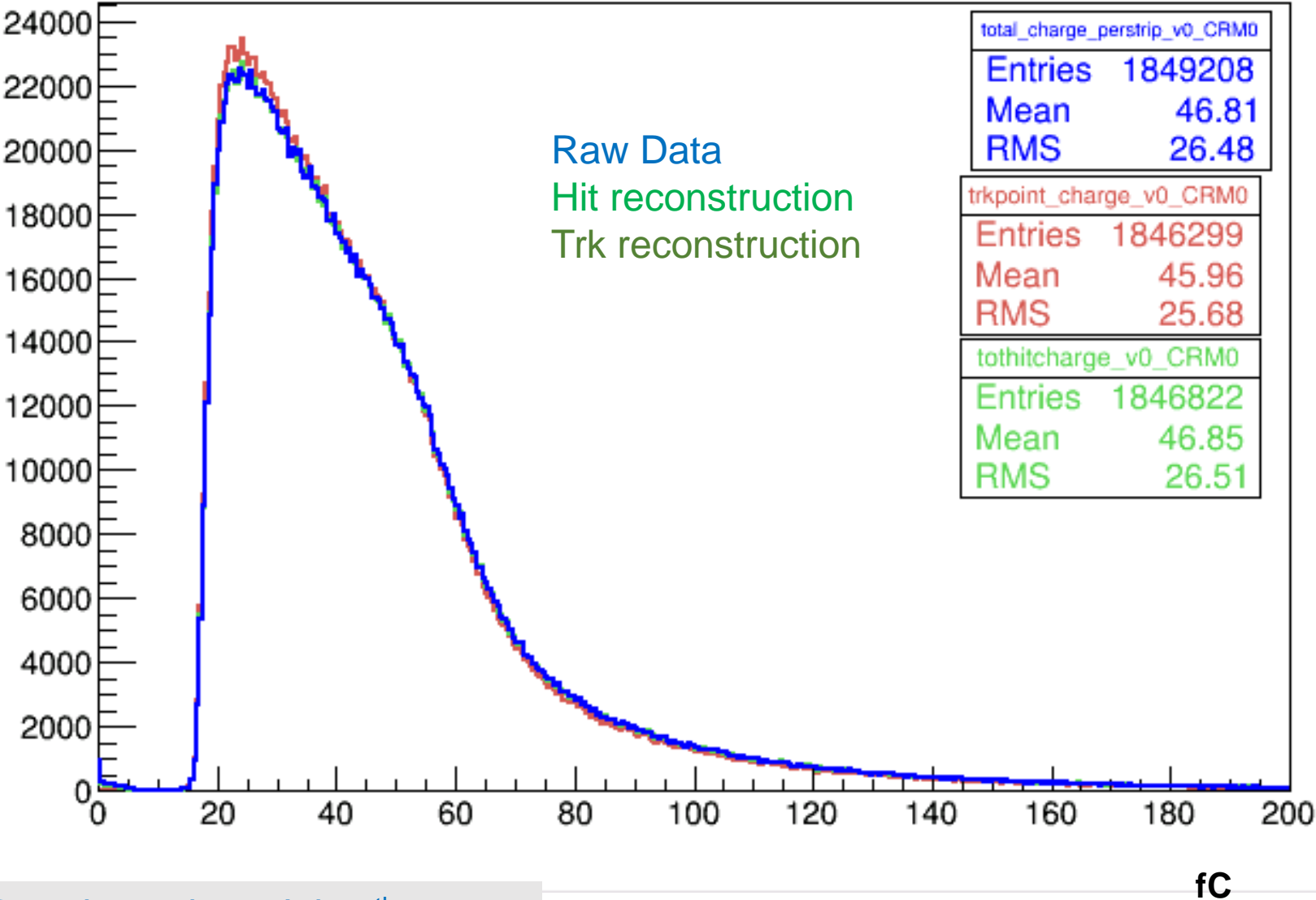


Total charge collected from track reconstruction

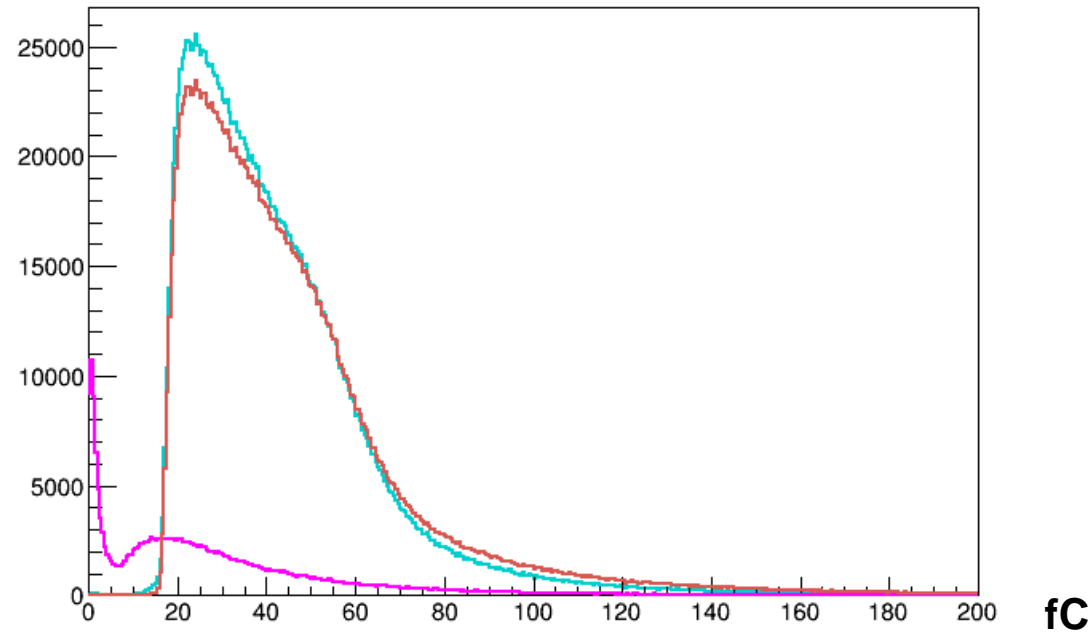
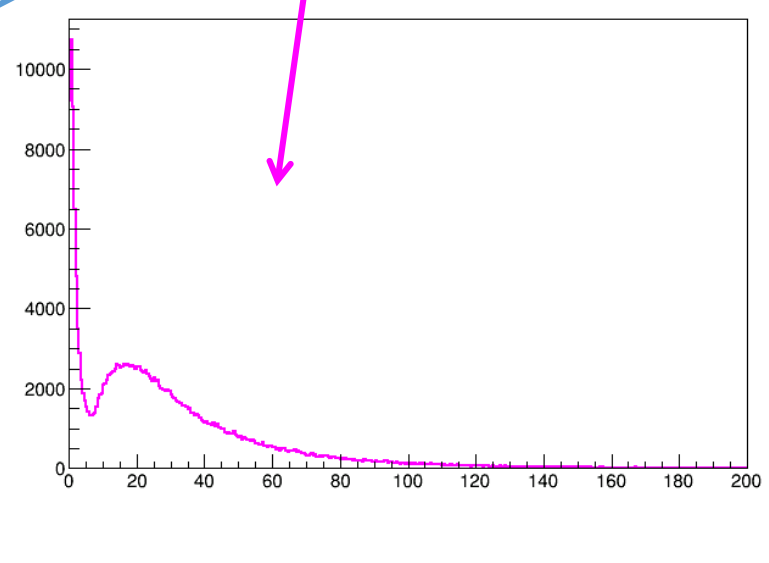
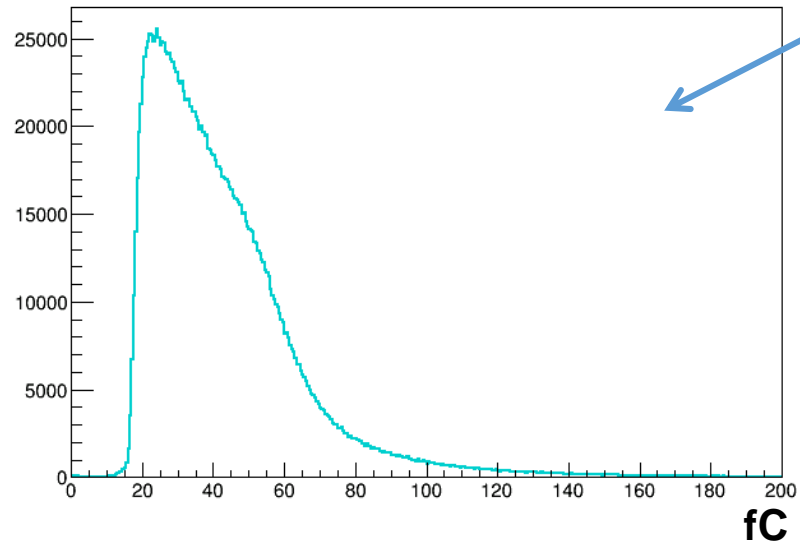


(see later)

the 3 distributions are in good agreement

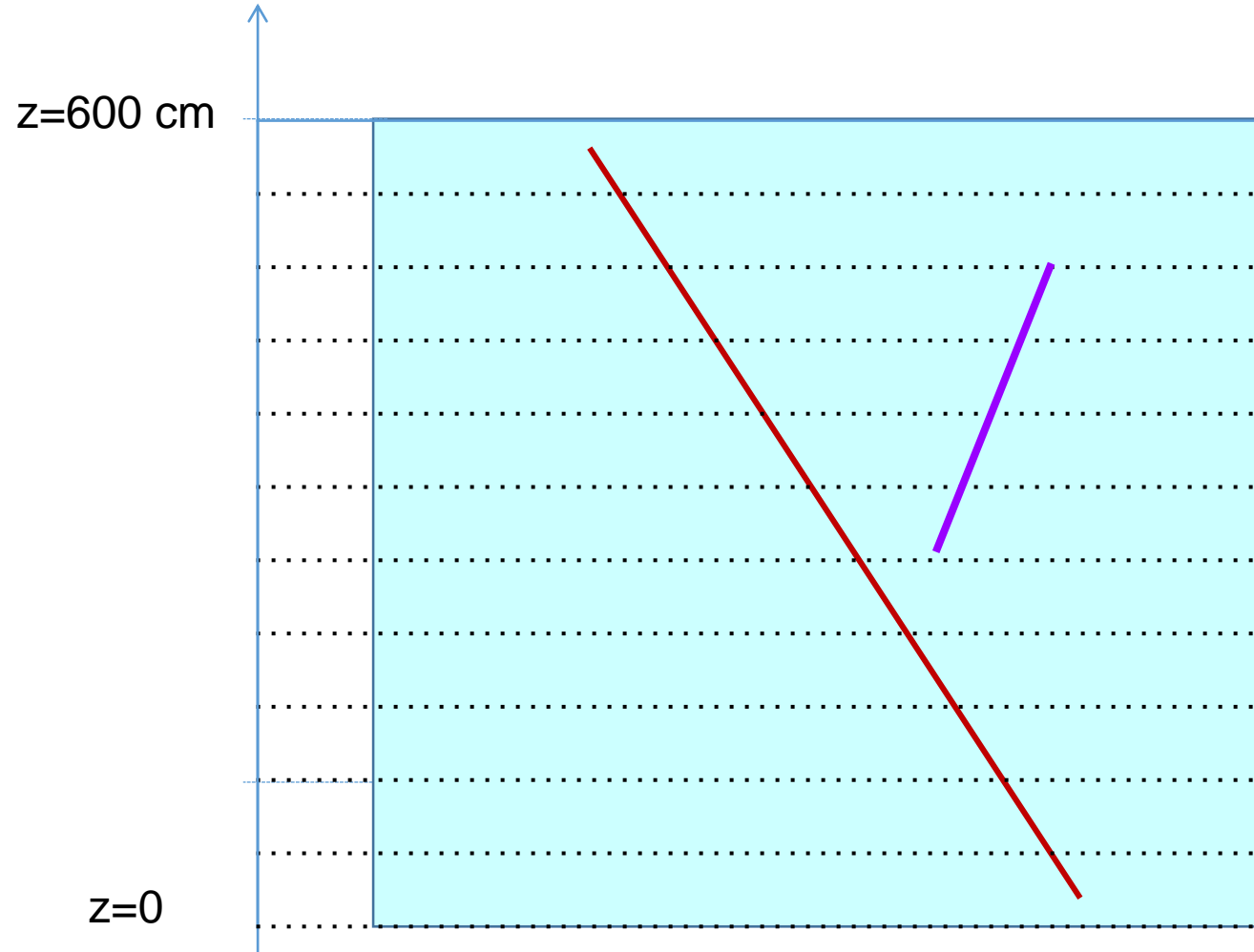


Before moving to the purity measurement, it is useful to remind that the charge collected using track reconstruction information is obtained from hits and delta rays associated to the track



WA105 Science Board meeting , July 6th , 2016

- Due to impurities, the collected charge is a decreasing function of drift time $Q=f(t_{\text{drift}})$.
- Points belonging to this function can be represented as $P=(t_{\text{drift}}, Q)$;
- To build these points, the drift distance is divided into n equal bins



Let's assume now to divide the full drift distance (6m) in 60 bins

→ Expected loss on one bin ~2%:

1 bin= 10cm, 0,067 ms each → $e^{-\left(\frac{0.067}{3}\right)} \sim 98\%$ ←

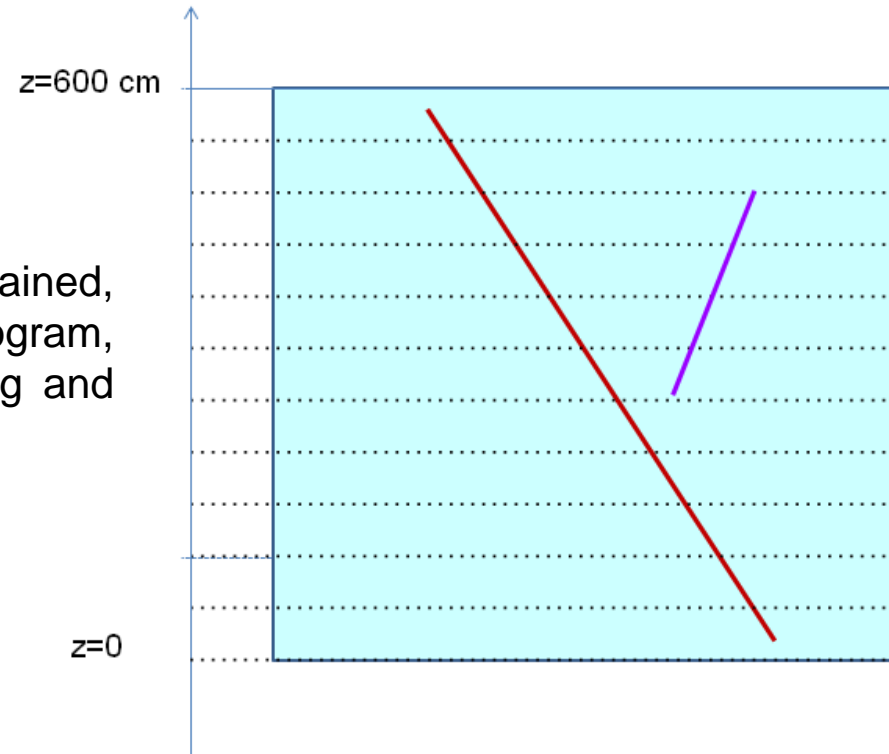
5 cm → $e^{-\left(\frac{0.067}{3}\right)} \sim 99\%$

20 cm → $e^{-\left(\frac{0.134}{3}\right)} \sim 95\%$

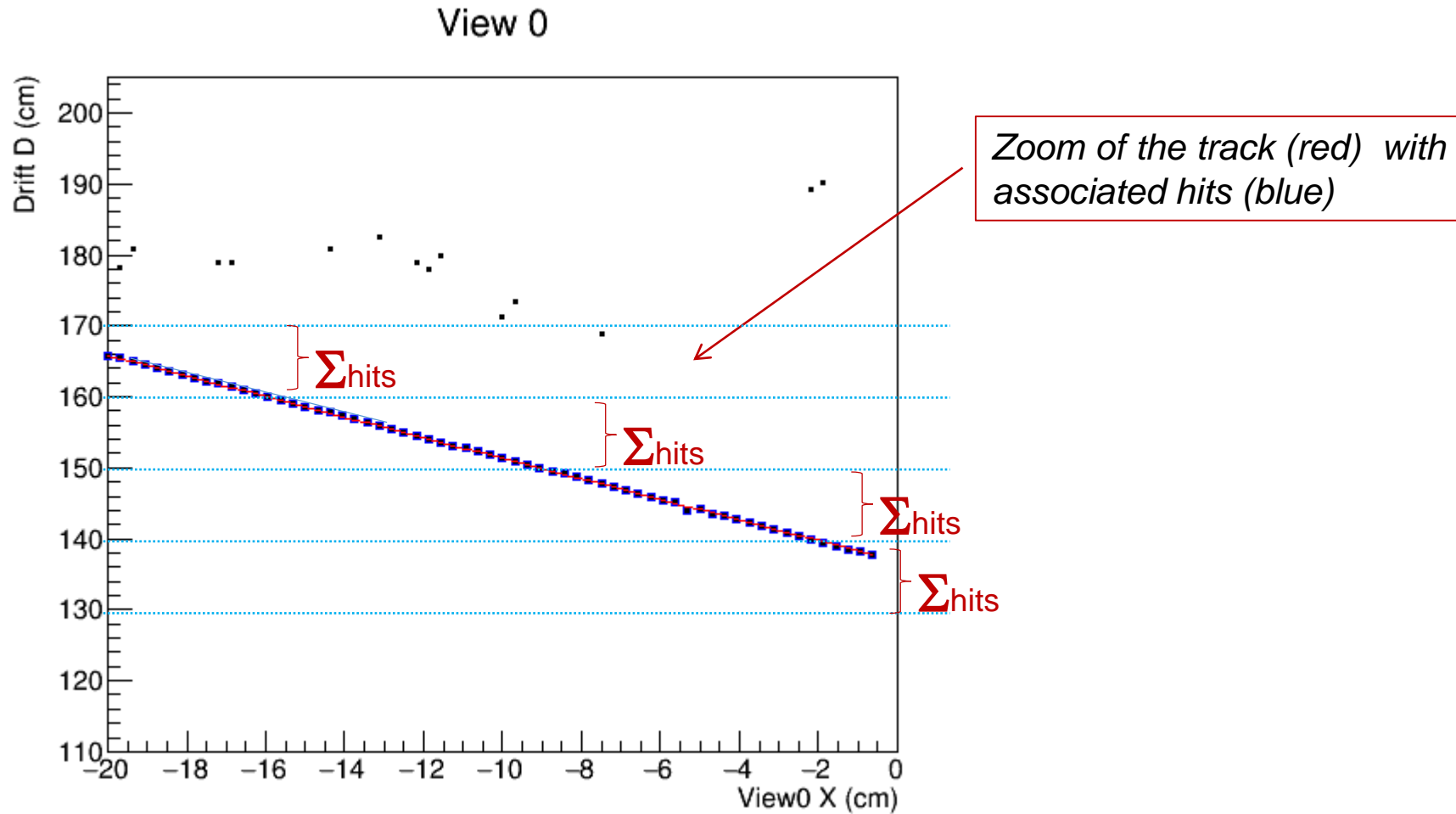
50 cm → $e^{-\left(\frac{0.335}{3}\right)} \sim 89\%$

1 m → $e^{-\left(\frac{0.67}{3}\right)} \sim 80\%$

A set of histograms (60) for each view is obtained, and each track enters in each histogram, depending on its length and on its starting and ending points



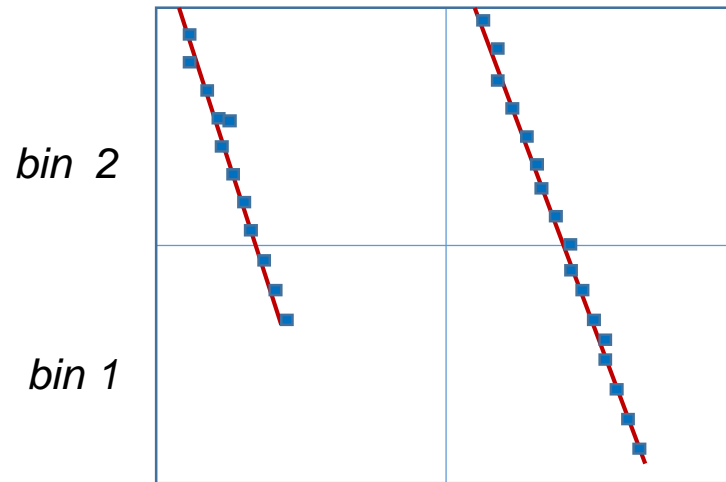
Sum of hits belonging to the same 10 cm bins:



the track is divided in n bins of 10cm in z , and, for each bin, the charge depositions of all hits belonging to the tracks are summed \rightarrow a “vector” of charge depositions is built

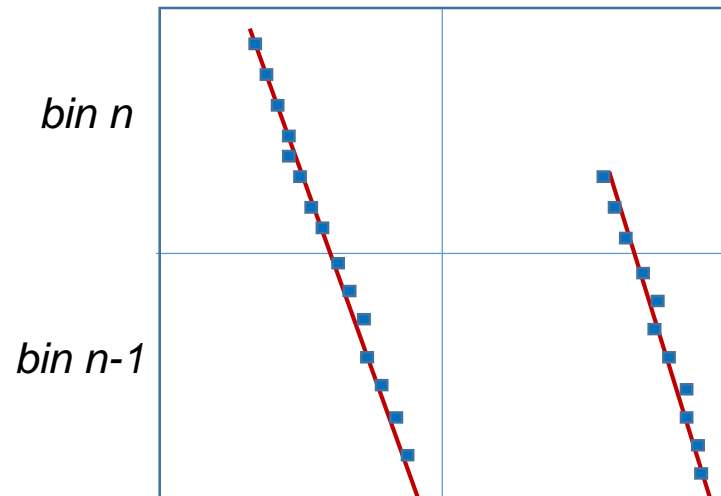
Effect of bin quantization

Considering 2 tracks with their first point in bin 1:



→ the charge deposition in the first bin depends on the starting point of the track inside the bin

and their last point in bin n :



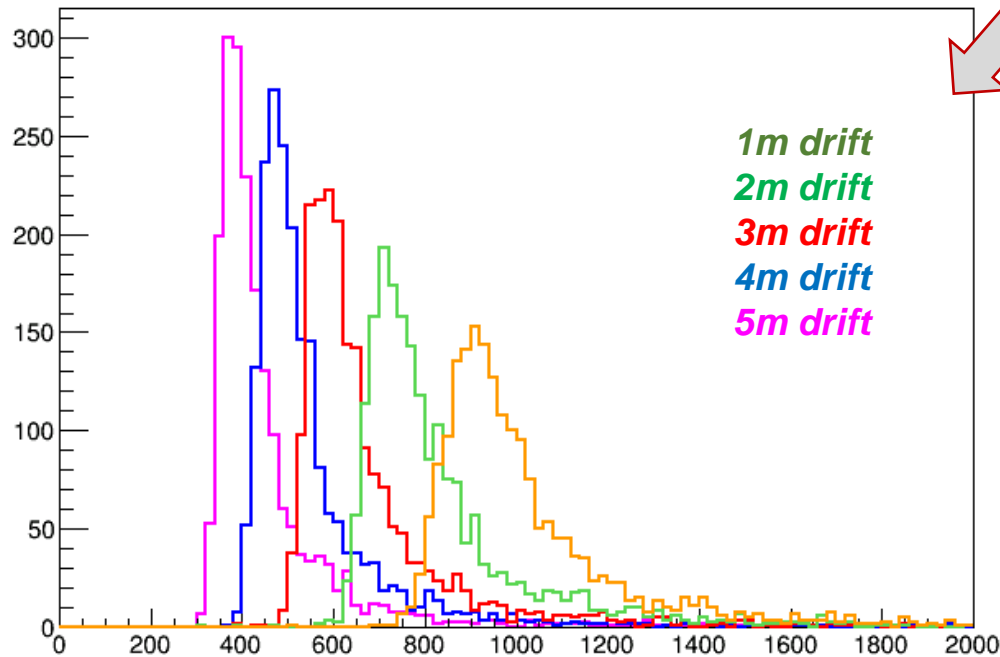
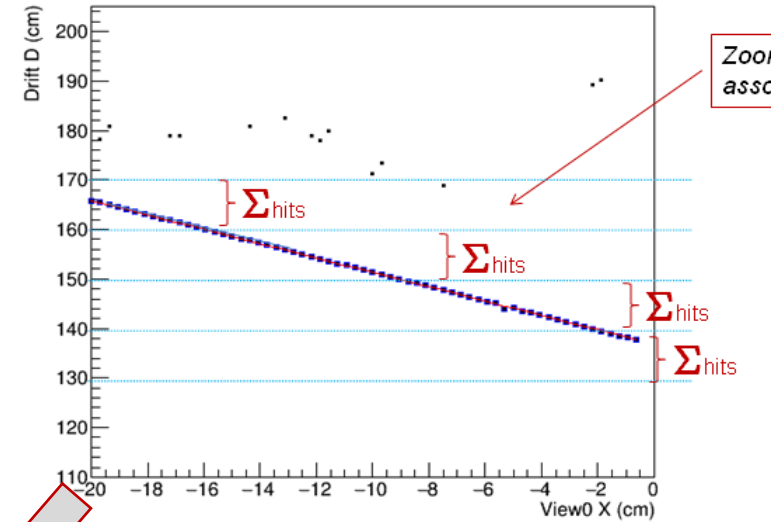
The same effect is also present in the last bin.

→ To avoid disuniformities the first and the last bin of each track are not taken into account

Each component of the charge depositions vector corresponds to one point $P=(t_{\text{drift}}, Q)$ where

t_{drift} = center of the time bin,
135, 145, 155 cm in the example

Q = shits charge



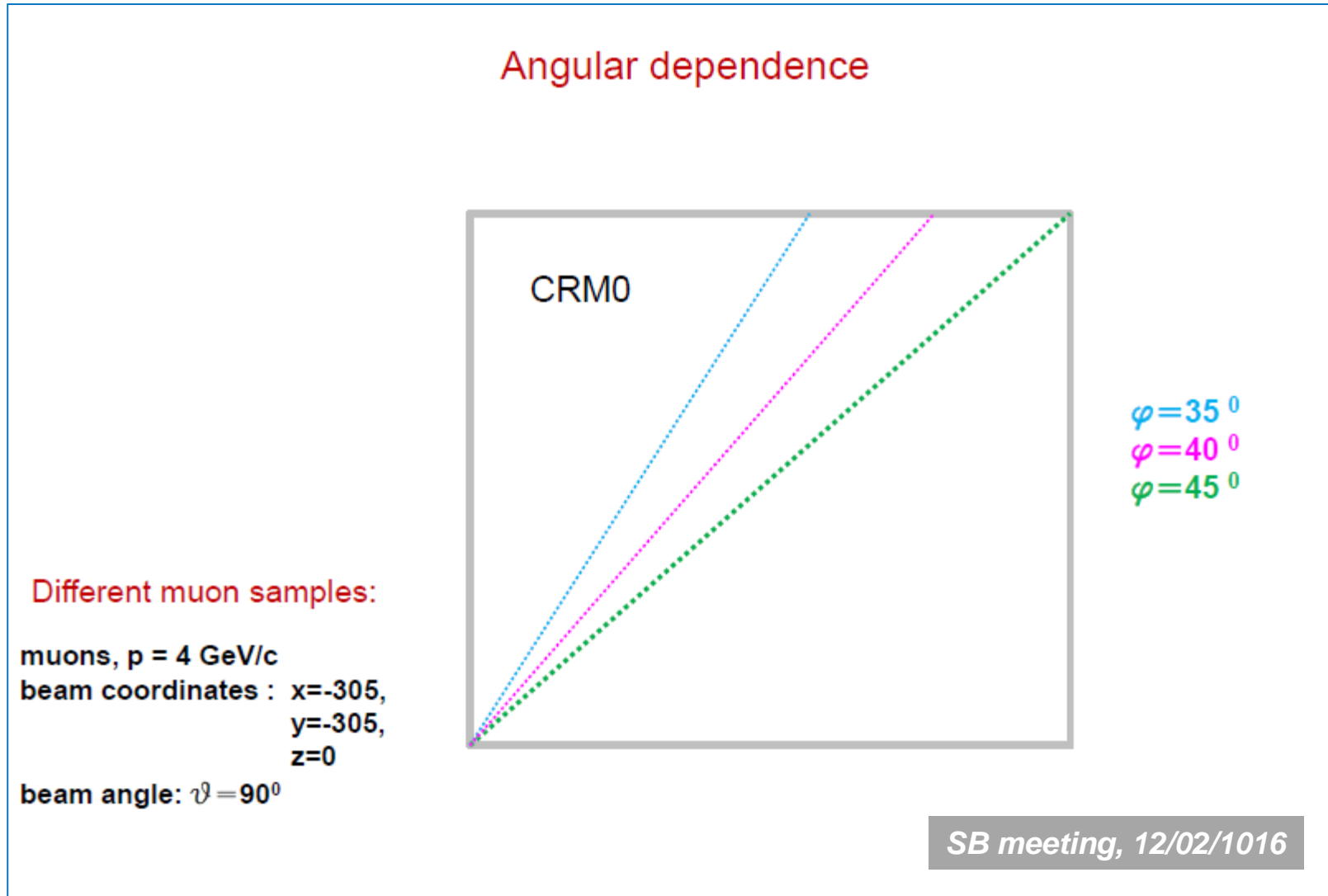
→ Charge depositions in bins of 10 cm corresponding at different drift distances

→ moving to longer drift distances, the peak moves to lower values and the distribution becomes narrower as expected due to the charge reduction $q=q_0 \cdot \exp(-t/\tau)$

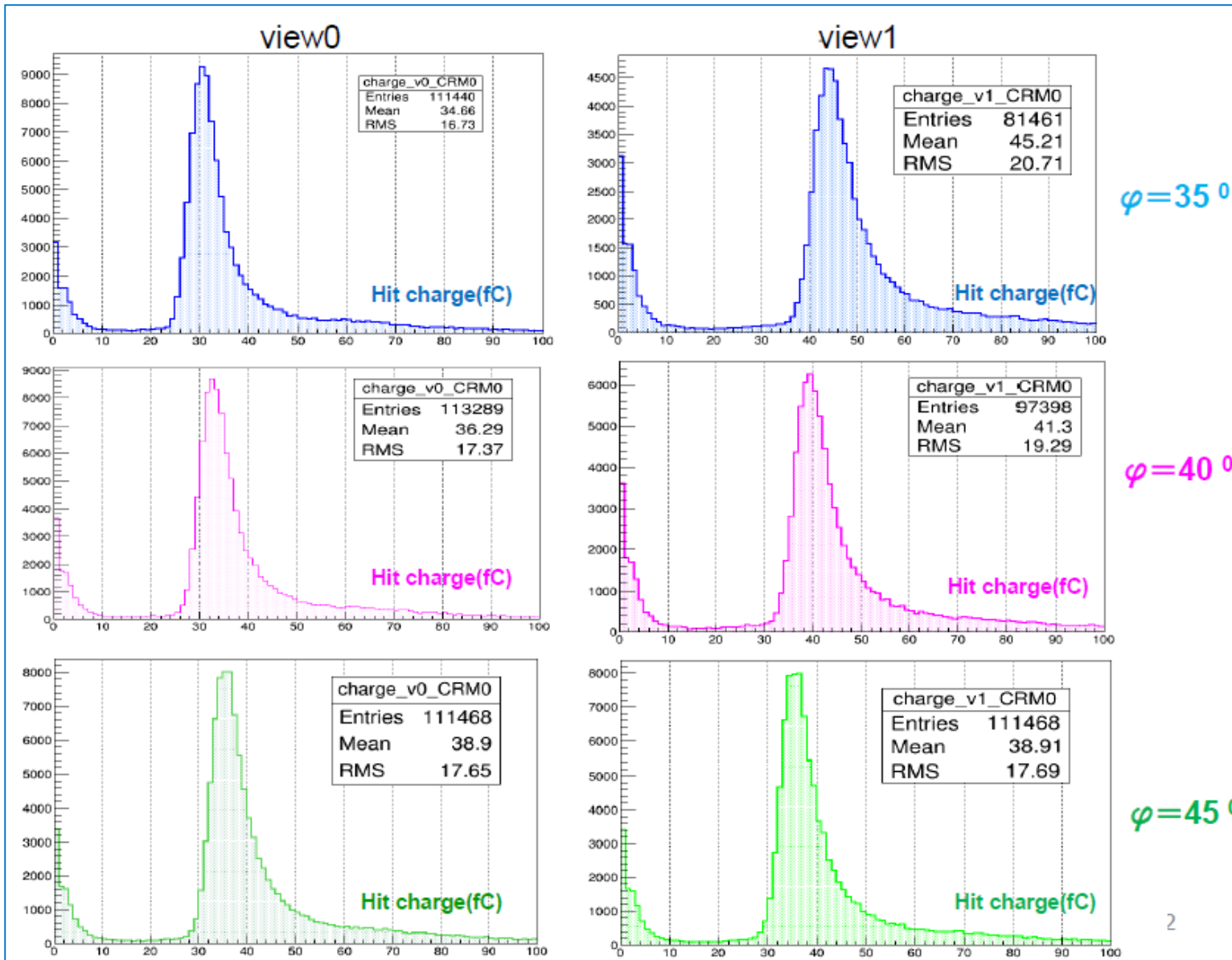
Before moving on in setting up a method to measure purity, it is necessary to come back to some slides shown in the SB meeting hold on December 2nd

<https://laguna.ethz.ch/indico/conferenceDisplay.py?confId=177>

The subject of these slides was the dependence of the mip position on track angle:

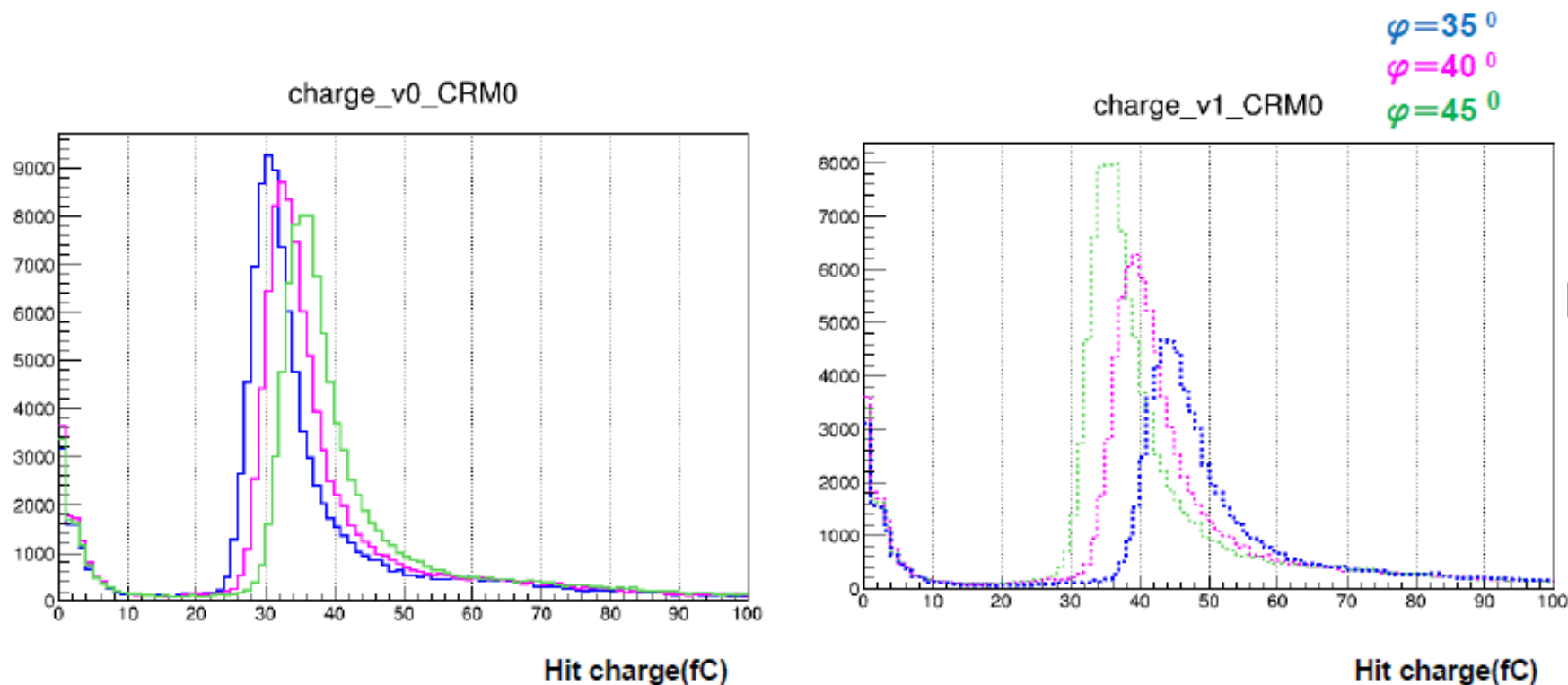


WA105 Science Board meeting , July 6th, 2016



WA105 Science Board meeting , July 6th, 2016

The 2 views are no longer equivalent, and the charge hits varies with angle:

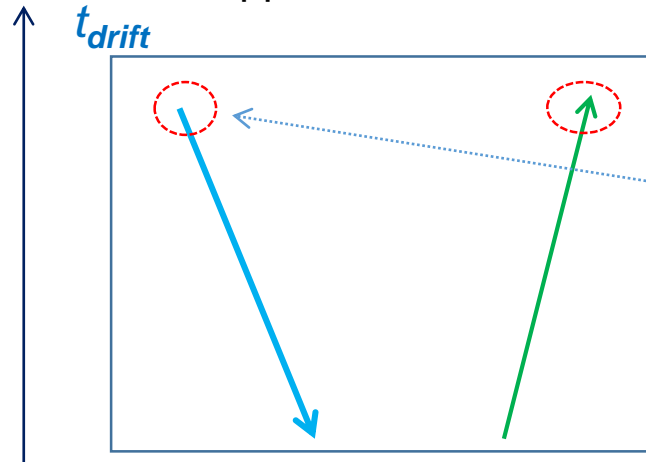


It is necessary to associate to each hit the “**effective pitch**”, depending from angles, It represents the **width of the LAr slice** seen by the hit

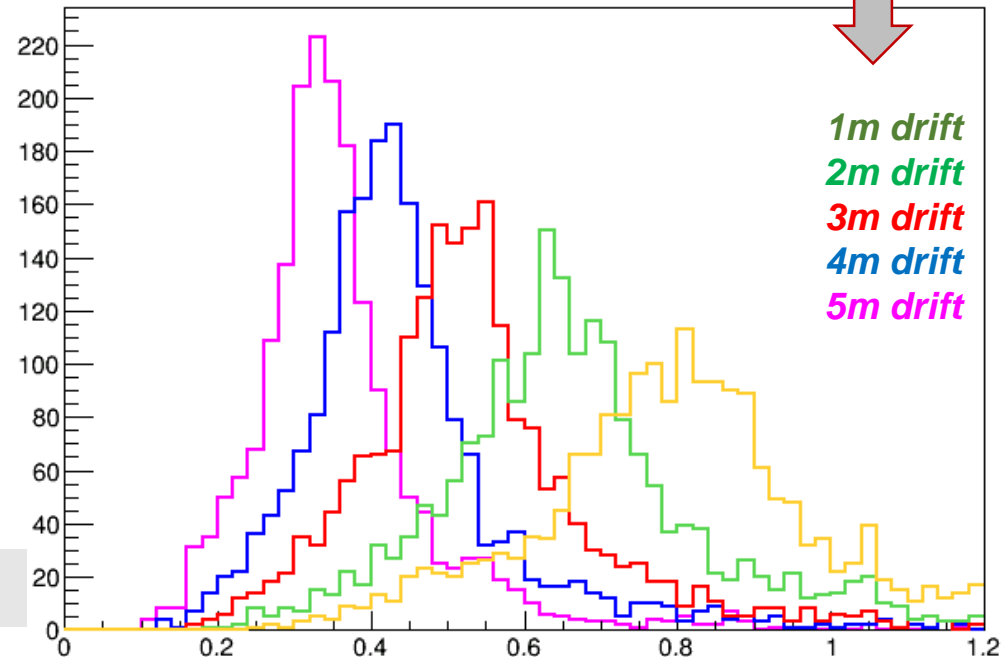
SB meeting, 12/02/1016

To take into account this angular effect the value of the charge deposition has to be “normalized” w.r.t the track angles, using angles provided by reconstruction.

A different approach can also be used → **normalize the bins to the one with shortest drift** :



- Example of tracks going **upwards** or **downwards** (with respect to drift coordinate)
- The first bin of the vector is defined to be the one corresponding to the minimum drift time
- The charge value of different bin is normalized to the one of the first bin (all are, on average, less than 1)



These histograms are then fitted with a gaussian , to get the peak value:

```
b_inf=(h->GetMean())-(h->GetRMS());  
b_sup=(h->GetMean())+(h->GetRMS());  
  
1 if (nent>99) {  
    h->Fit("gaus", "Q", "", b_inf, b_sup); 2  
    TString fitresult=gMinuit->fCstatu;  
    if (fitresult.BeginsWith("CONVE")) itowrite=1;  
}
```

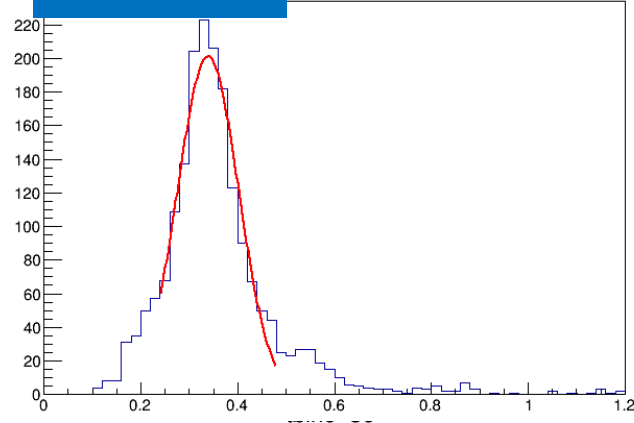
1 to get meaningful results from the fit it is required to have at least 100 entries, otherwise the fit is not done

2 the fit is performed in an interval defined starting from histogram mean value and rms

Results are written to an external file, and then a fit to measure lifetime is performed →

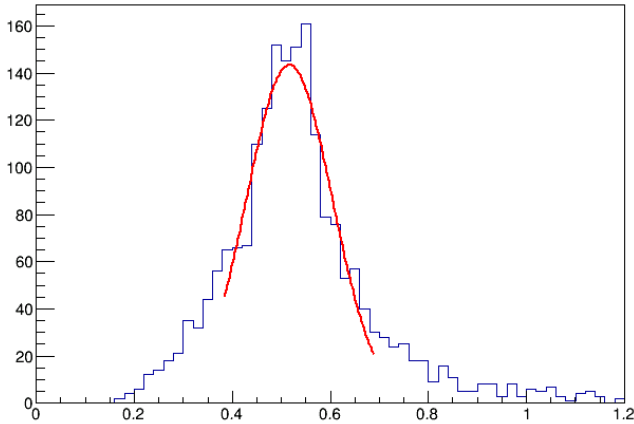
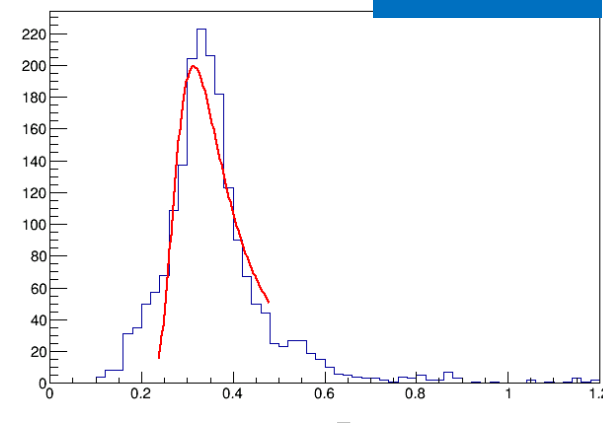
Fit examples for different drift lengths

Gaussian fit

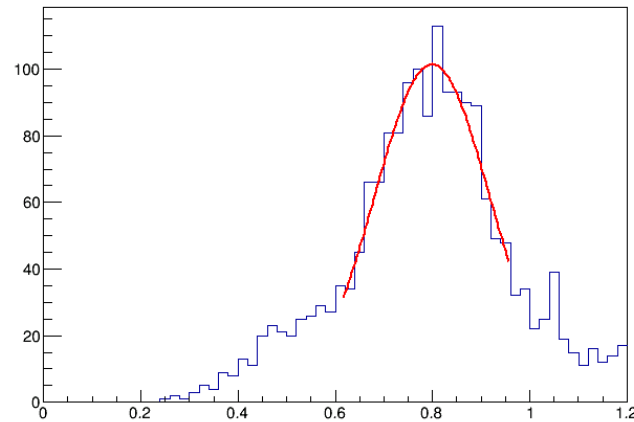
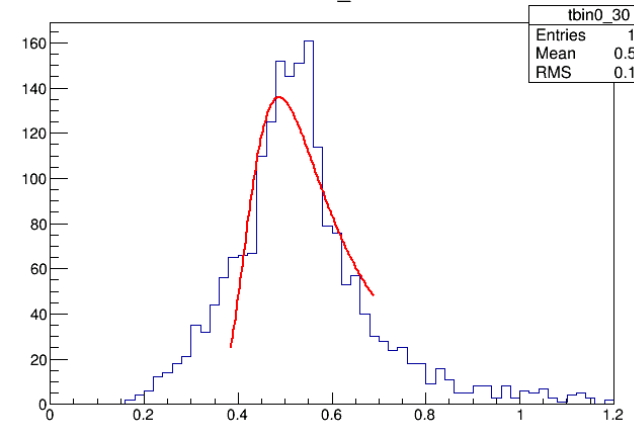


5m drift

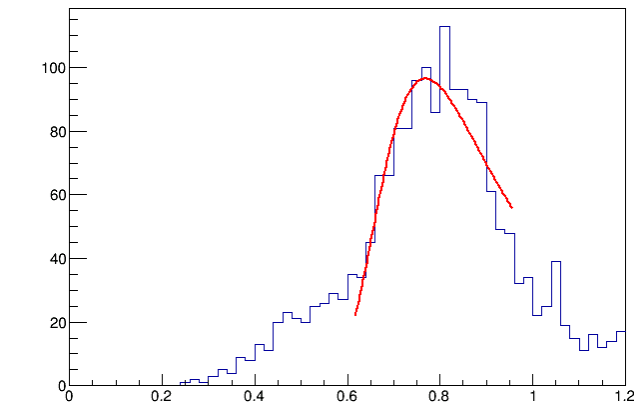
Landau fit



3m drift



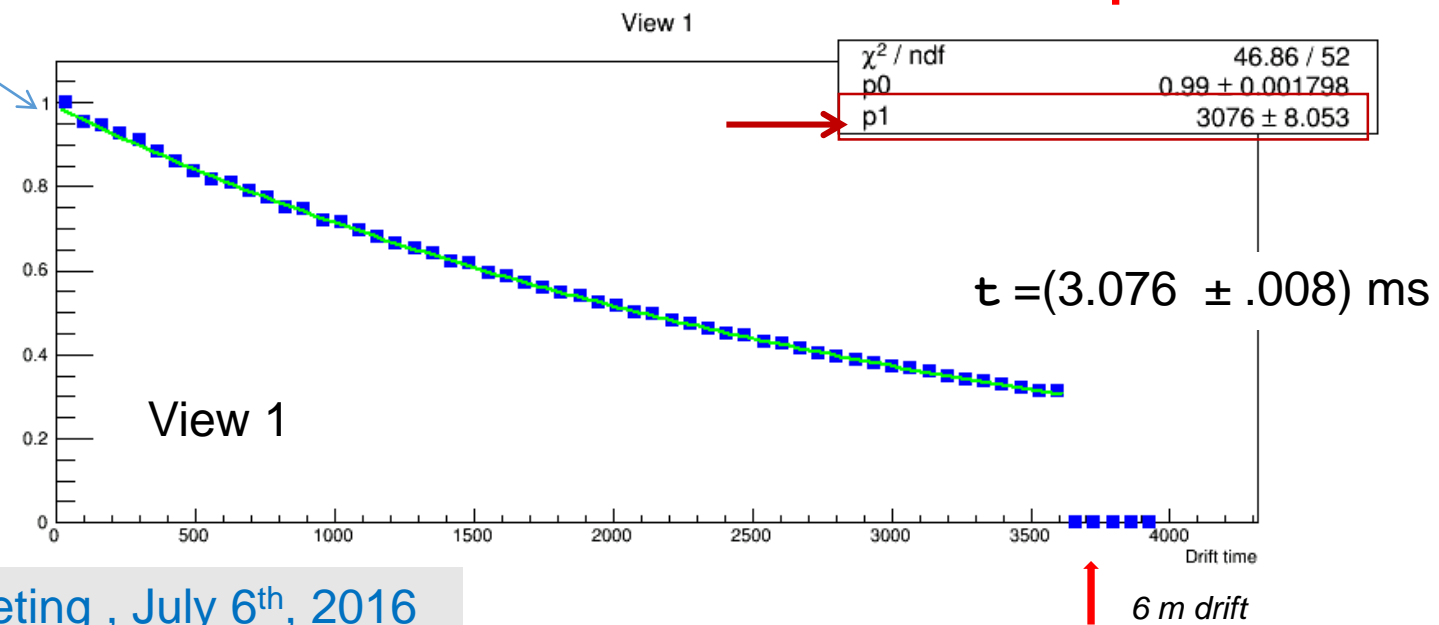
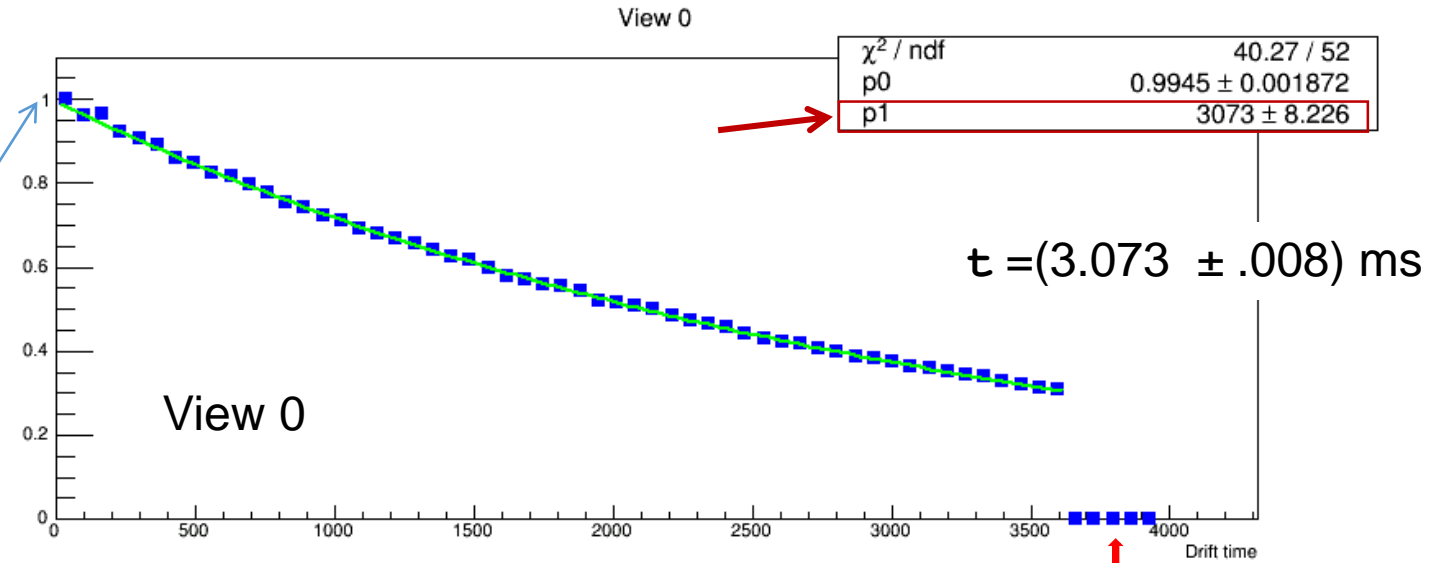
1m drift



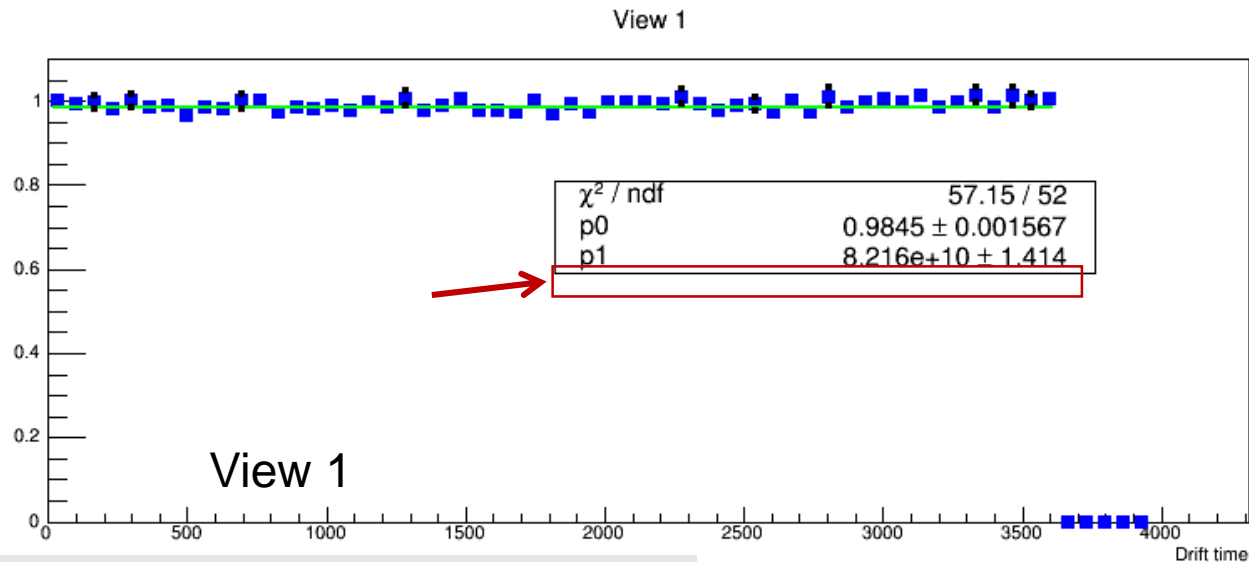
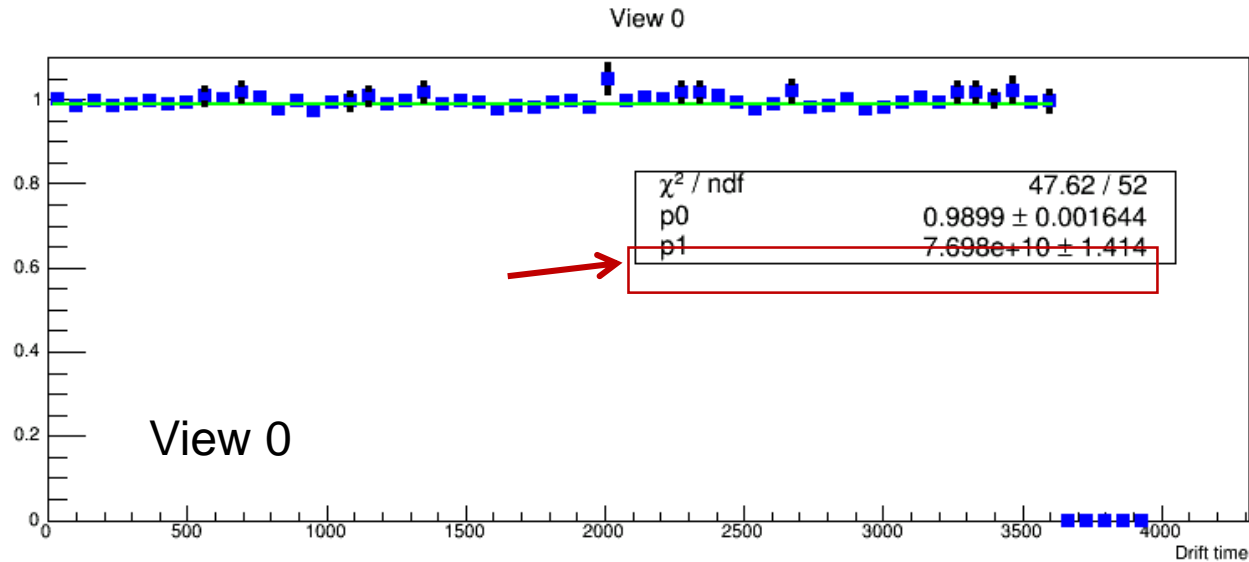
WA105 Science Board meeting, July 6th, 2016

Fit results:

Fit starts from 1 as expected

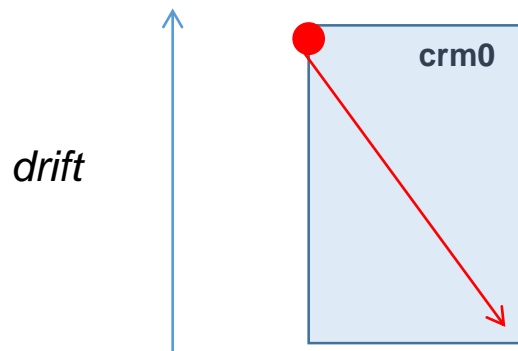
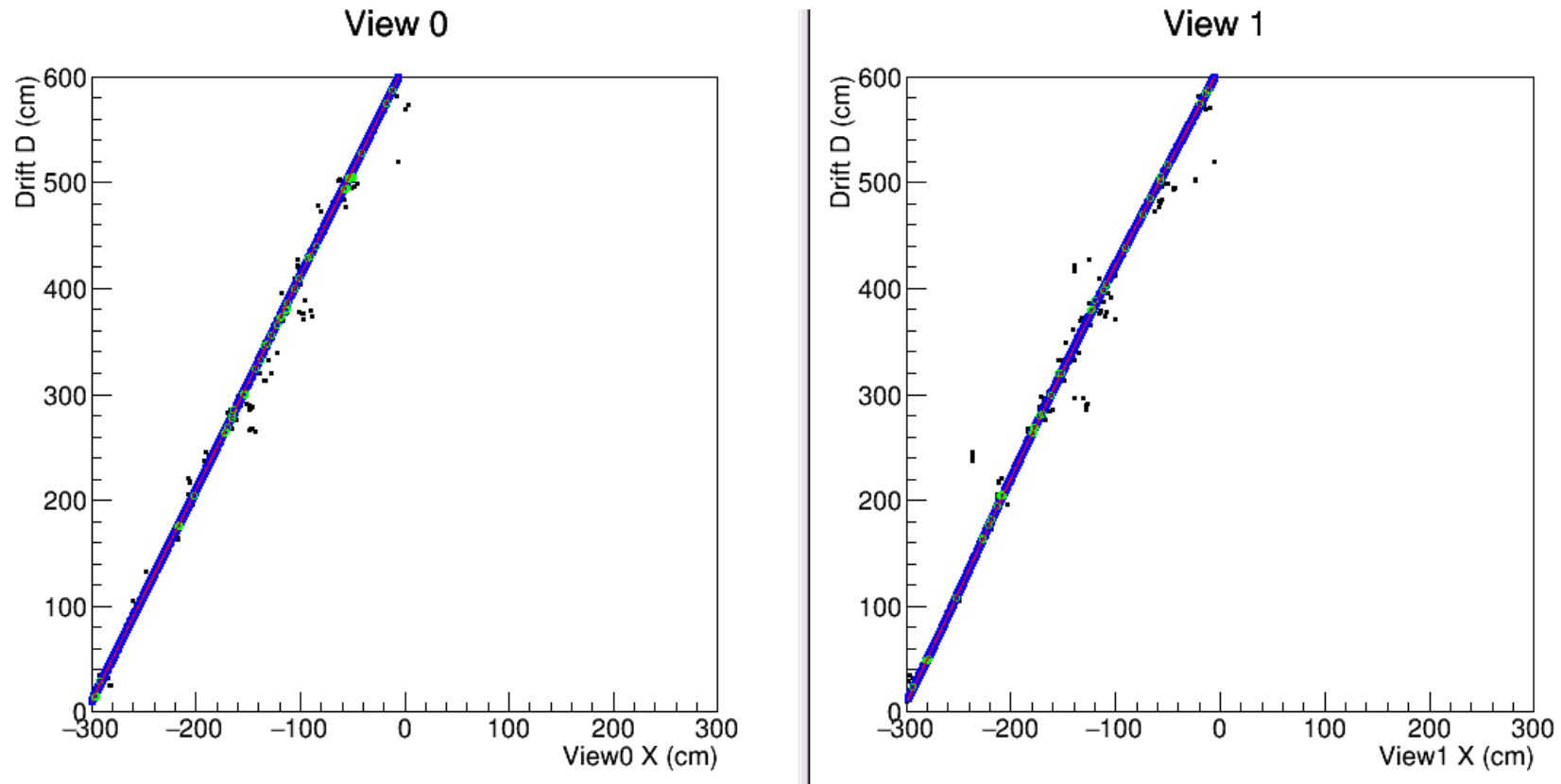


The method has been tested on a sample of muon generated without lifetime effect...

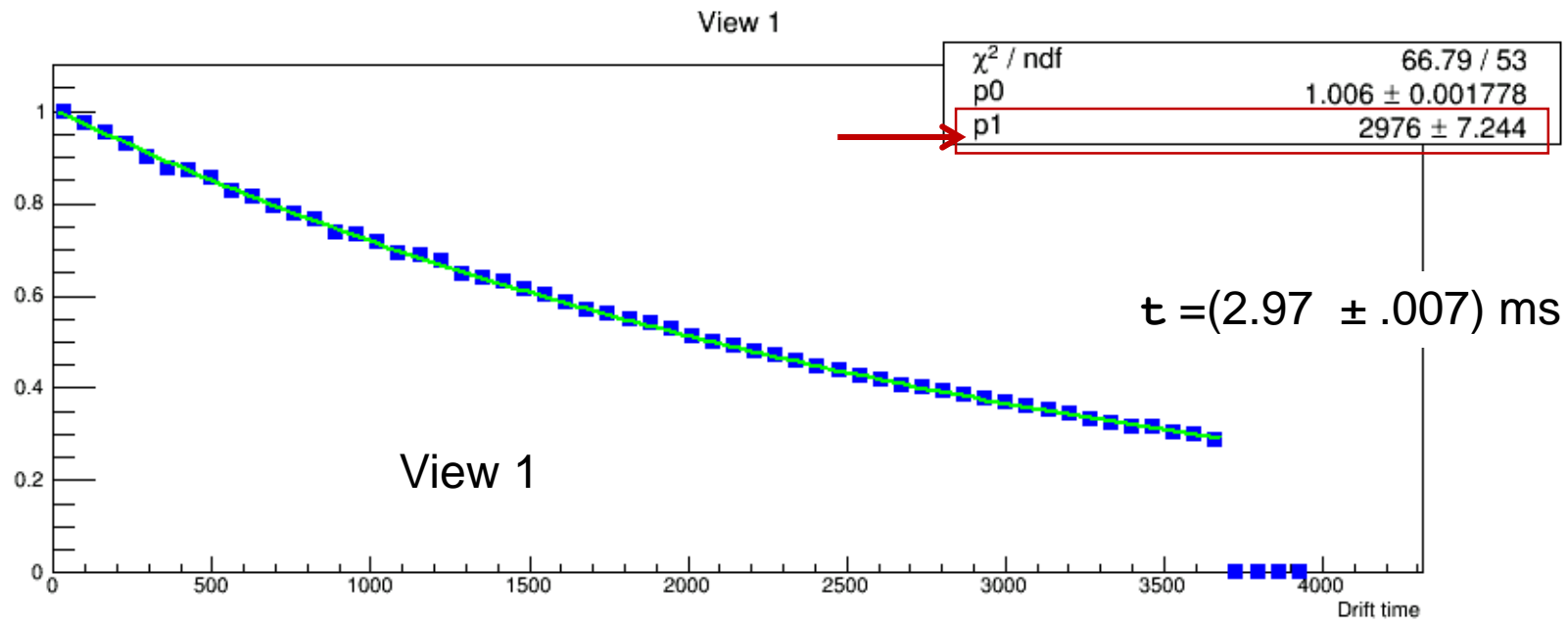
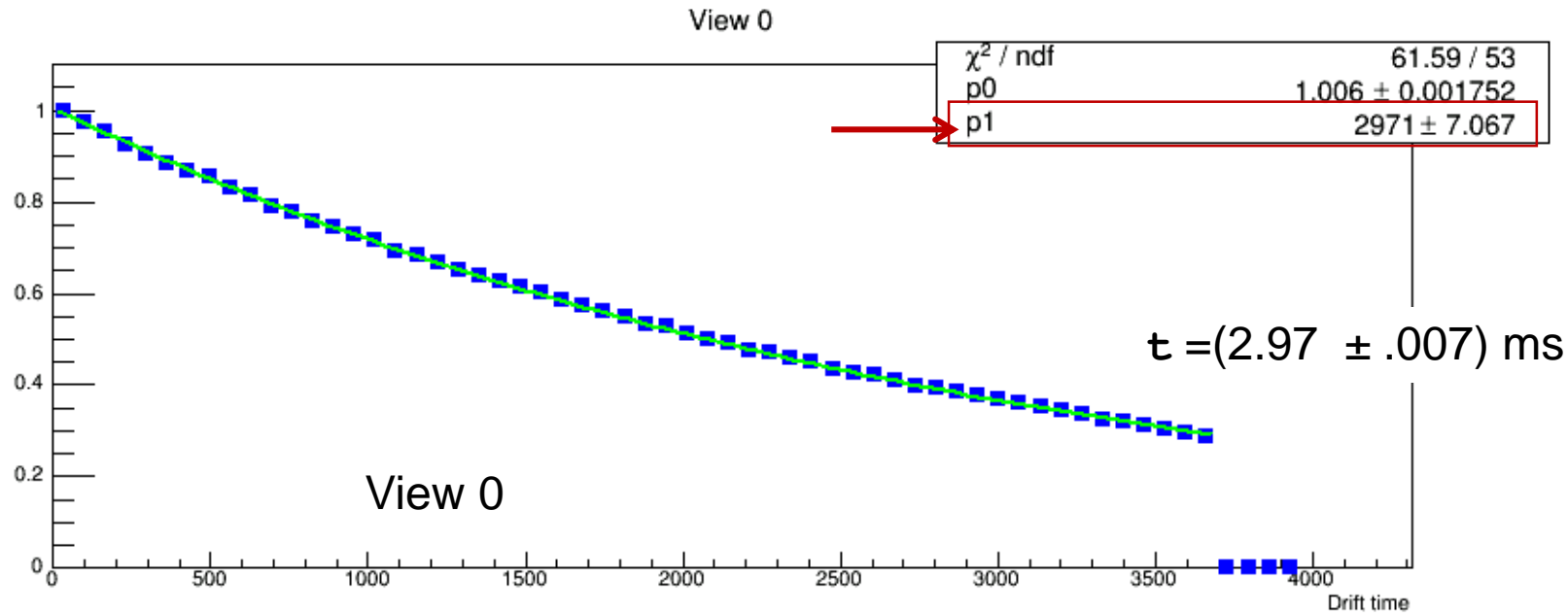


The distributions are flat, as expected

..and on a sample of muons crossing the detector from top to bottom:

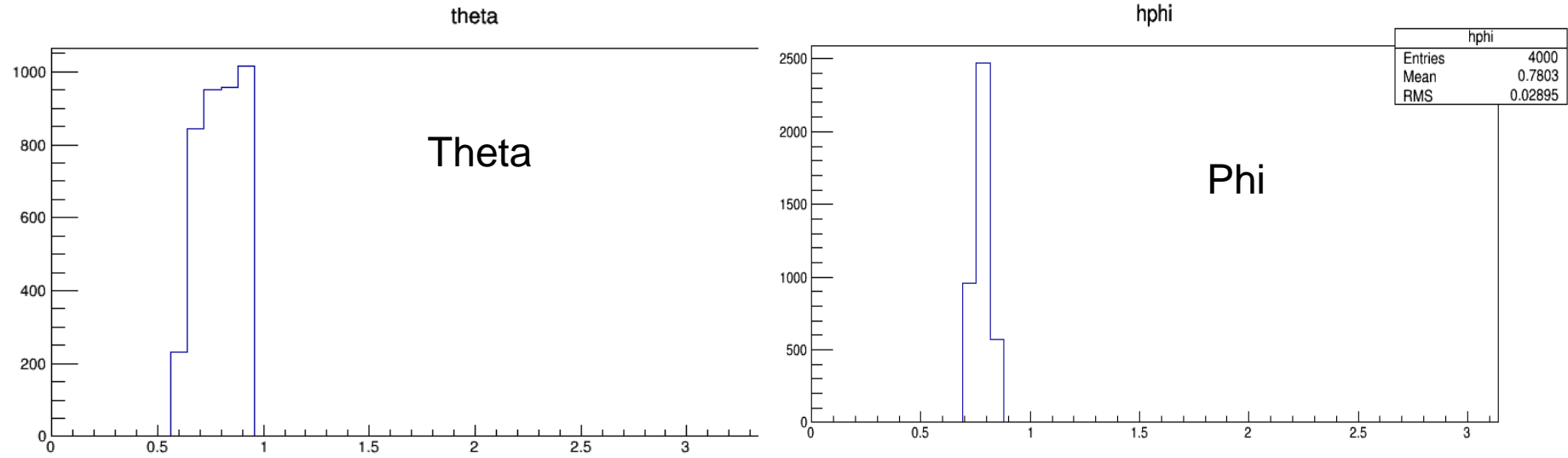


WA105 Science Board meeting , July 6th, 2016

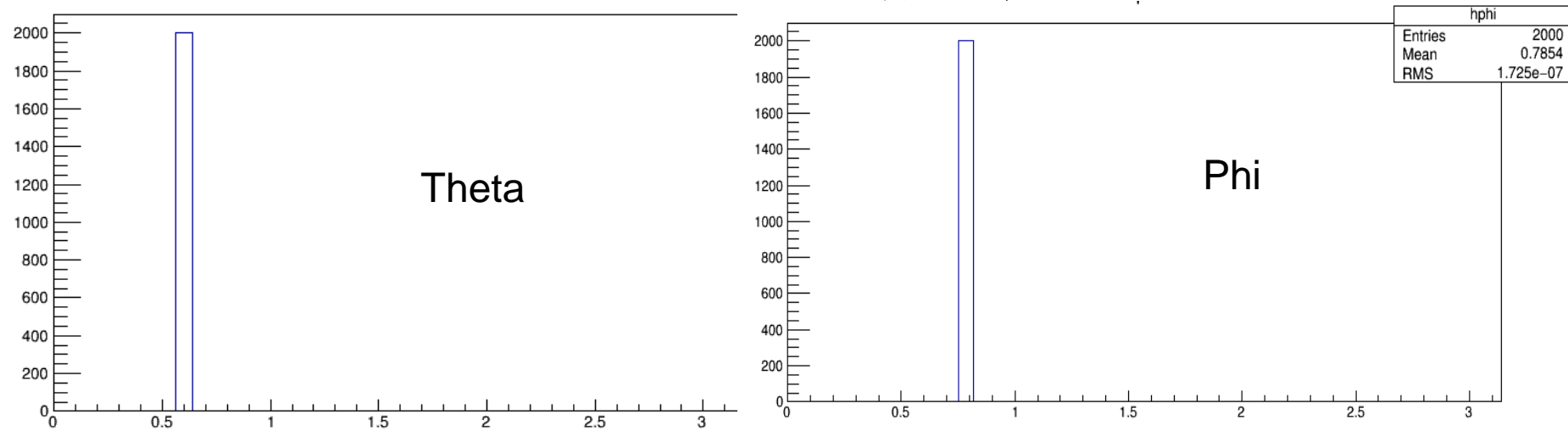


WA105 Science Board meeting, July 6th, 2016

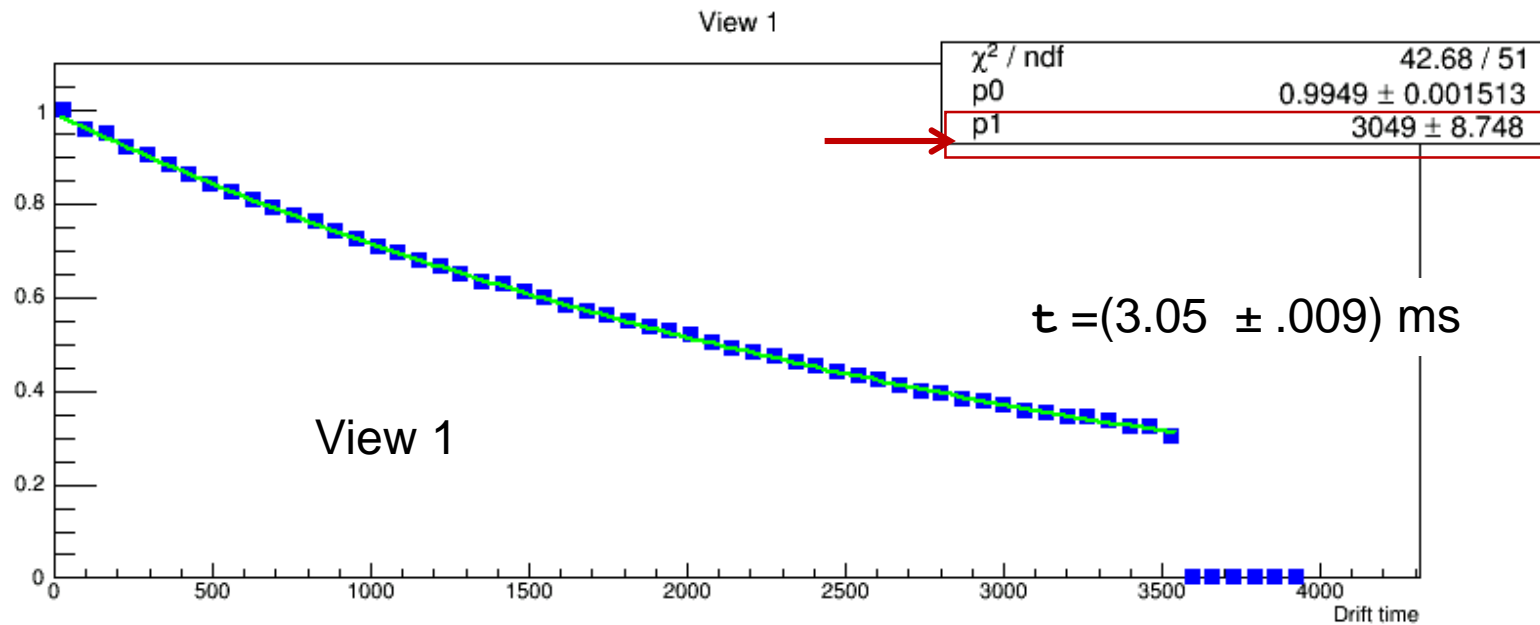
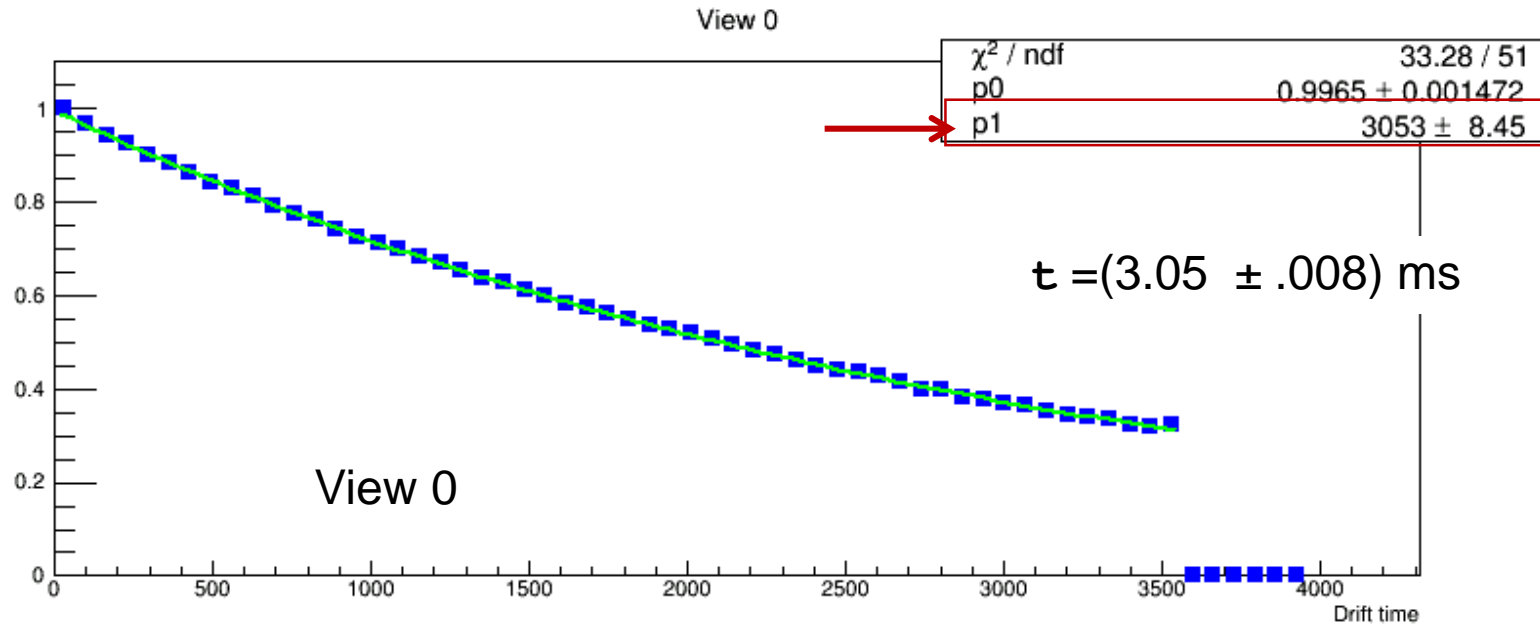
The method has been tested on a sample of tracks at different angles:



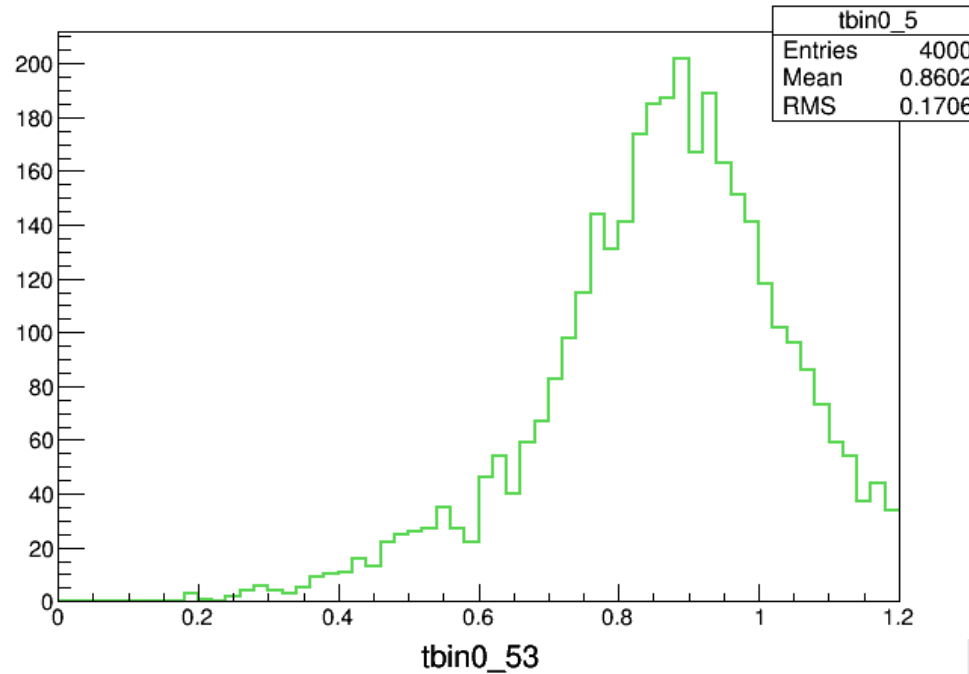
For comparison: values for previous sample:



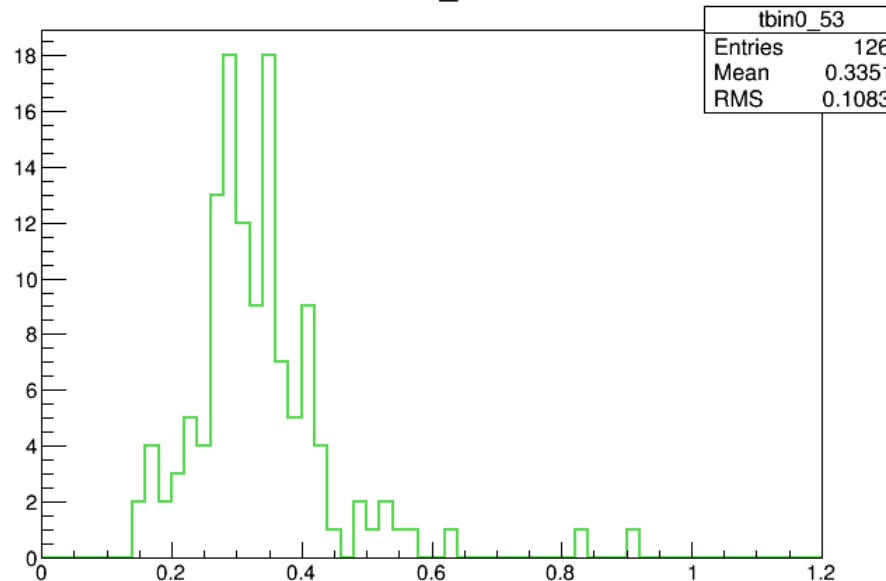
Fit results on the sample with random angular directions:



The sample with random directions used for the fit corresponds to 4K tracks:

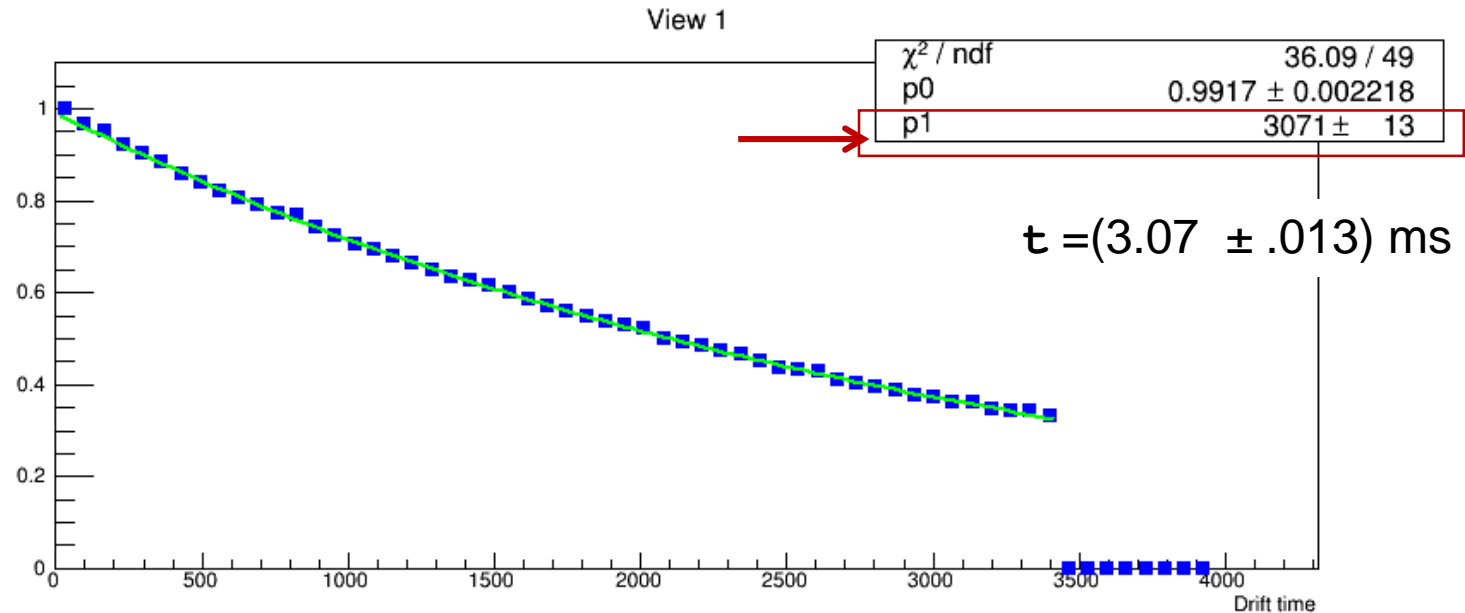
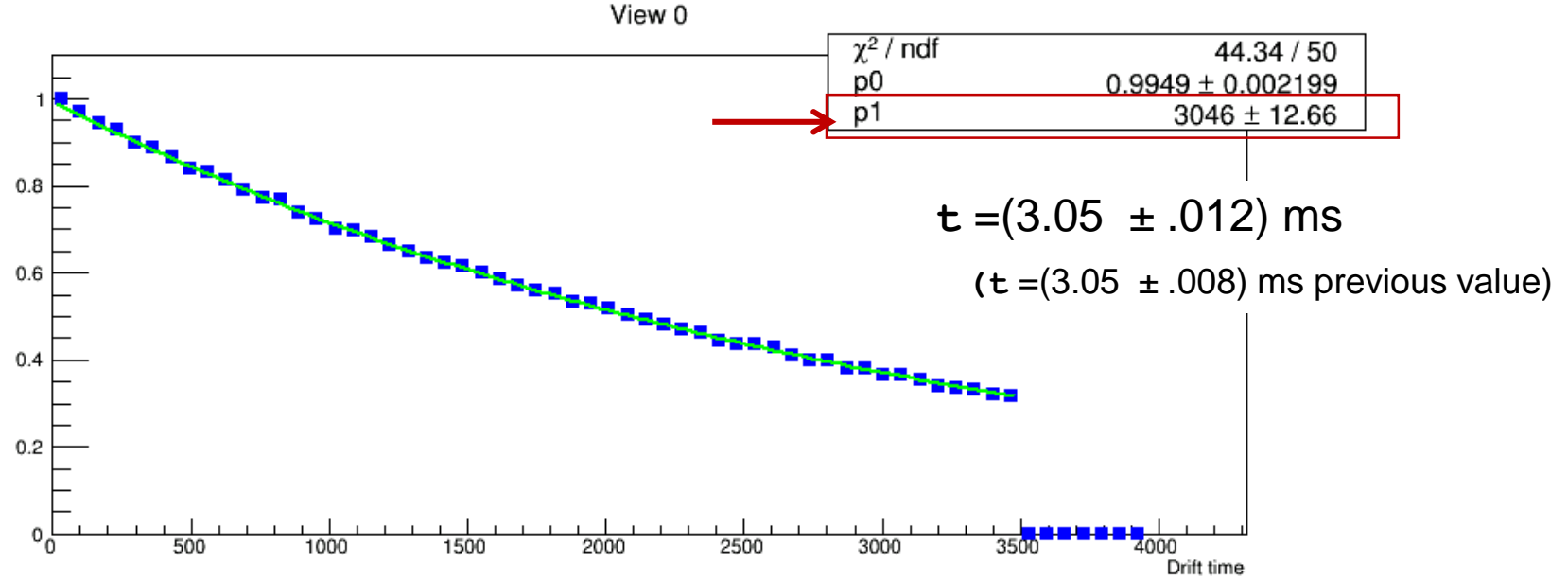


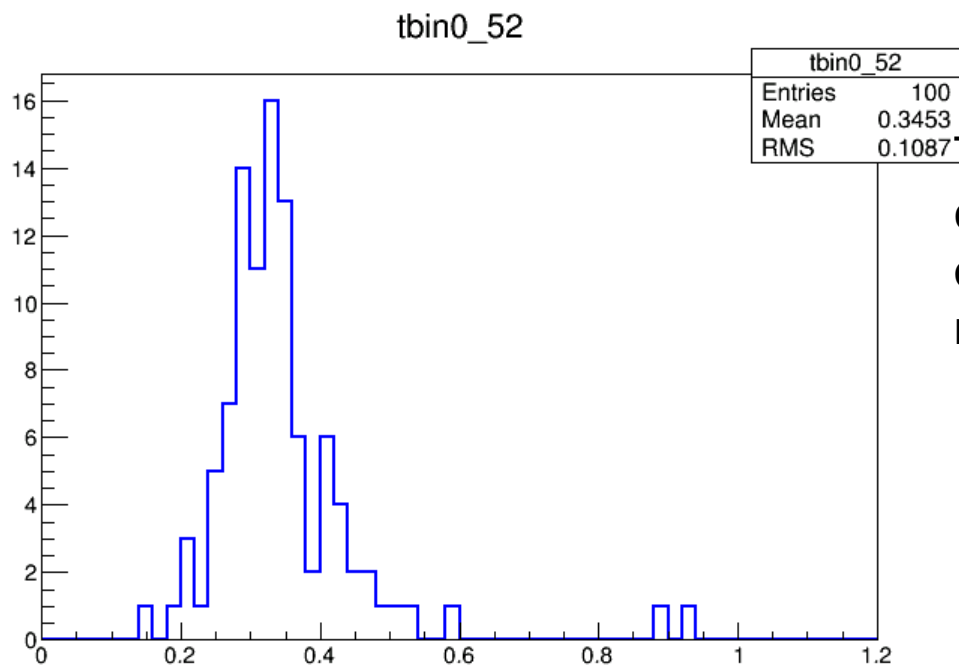
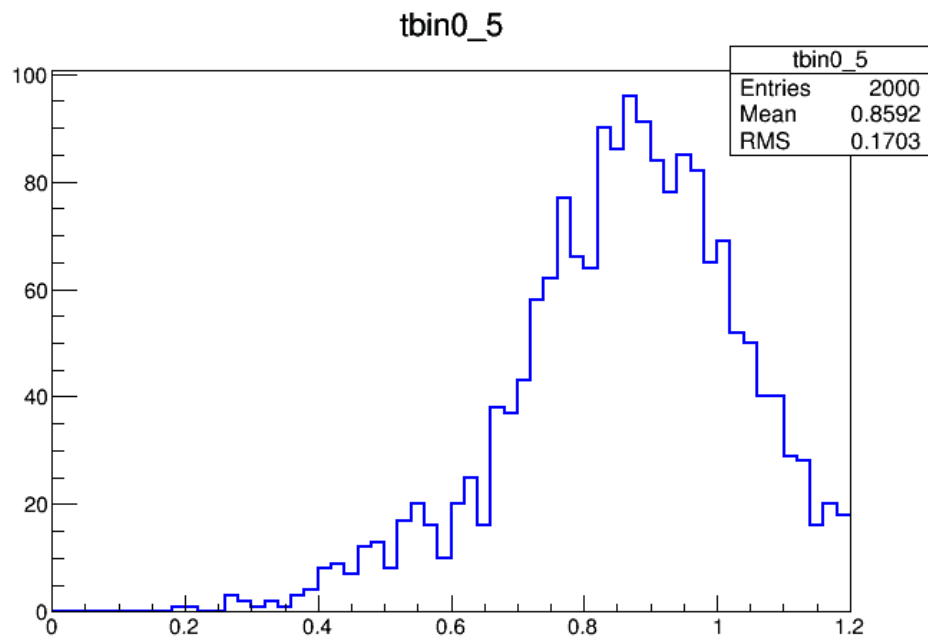
Normalized charge deposition
for a drift distance of 50 cm



The last bin used in the fit
shown at page 43 corresponds
to a drift distance of ~5.3 m with
a population of 126 tracks

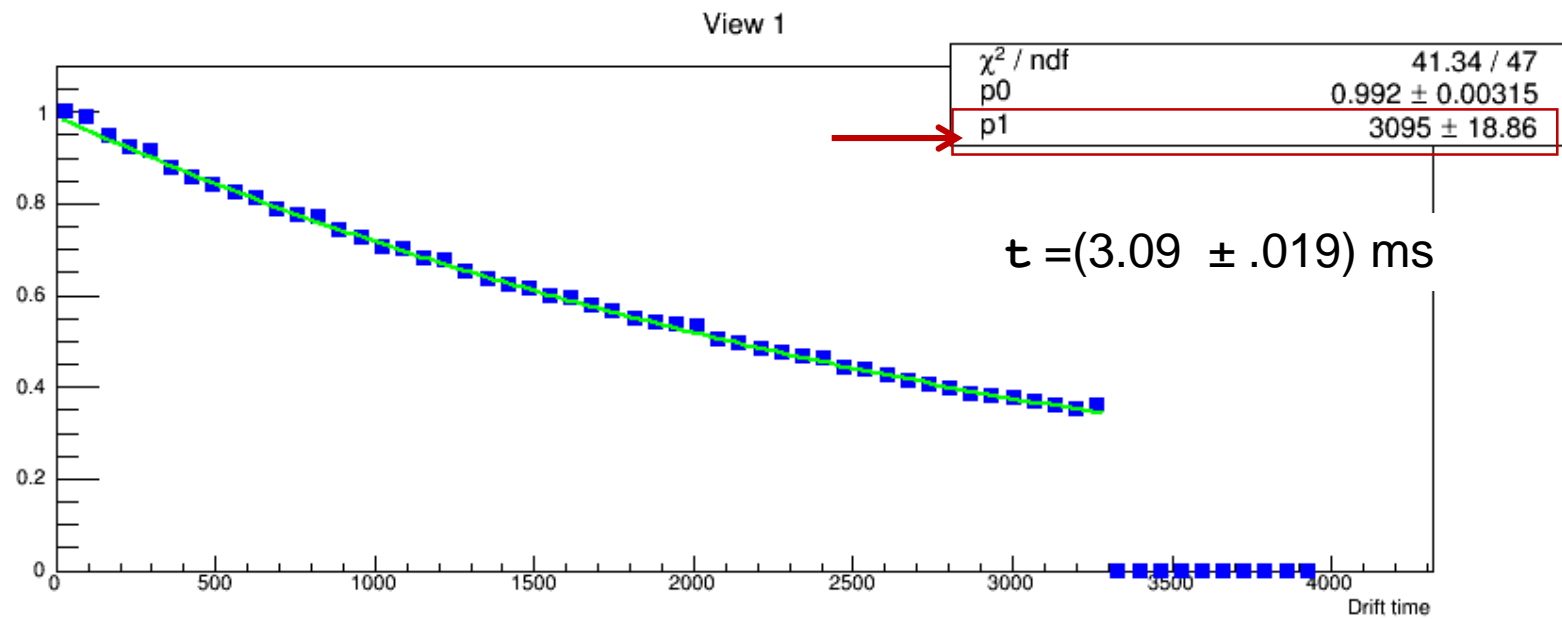
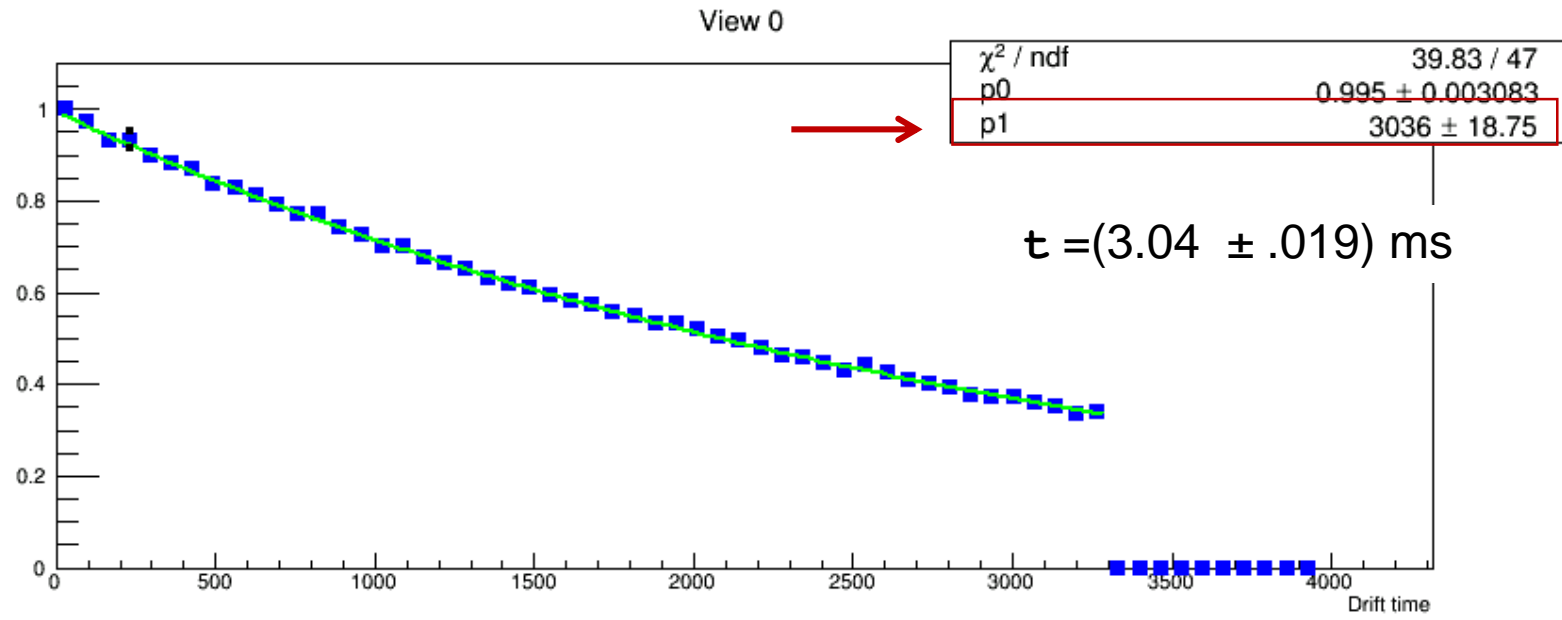
Fit results with lower statistics (a subsample of 2K tracks):



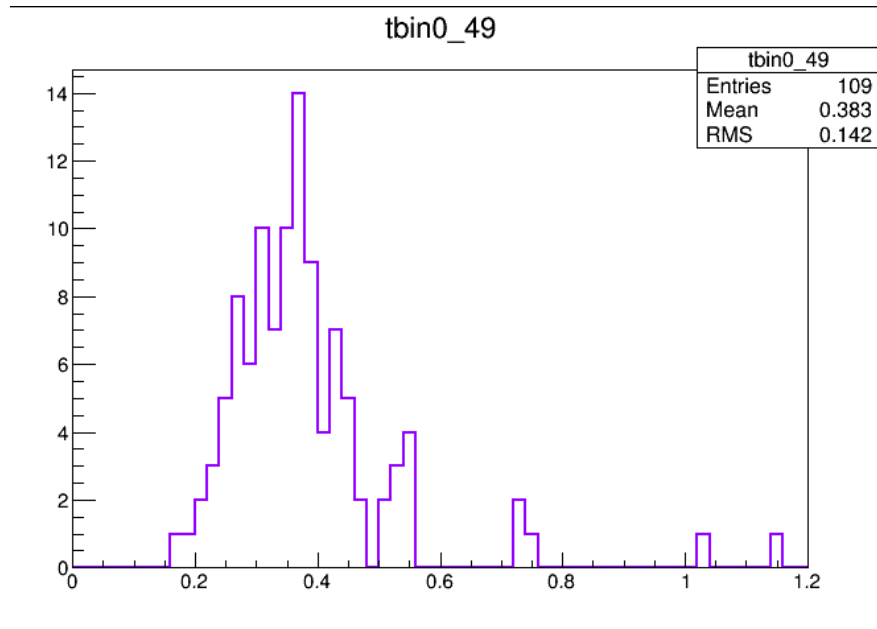


The last bin used in the fit corresponds to a drift distance of ~5.2 m with 100 tracks, the next bins do not have statistics

Fit results with lower statistics (a subsample of 1K tracks):



Last useful bin: 100 track, drift distance ~5m



Summary:

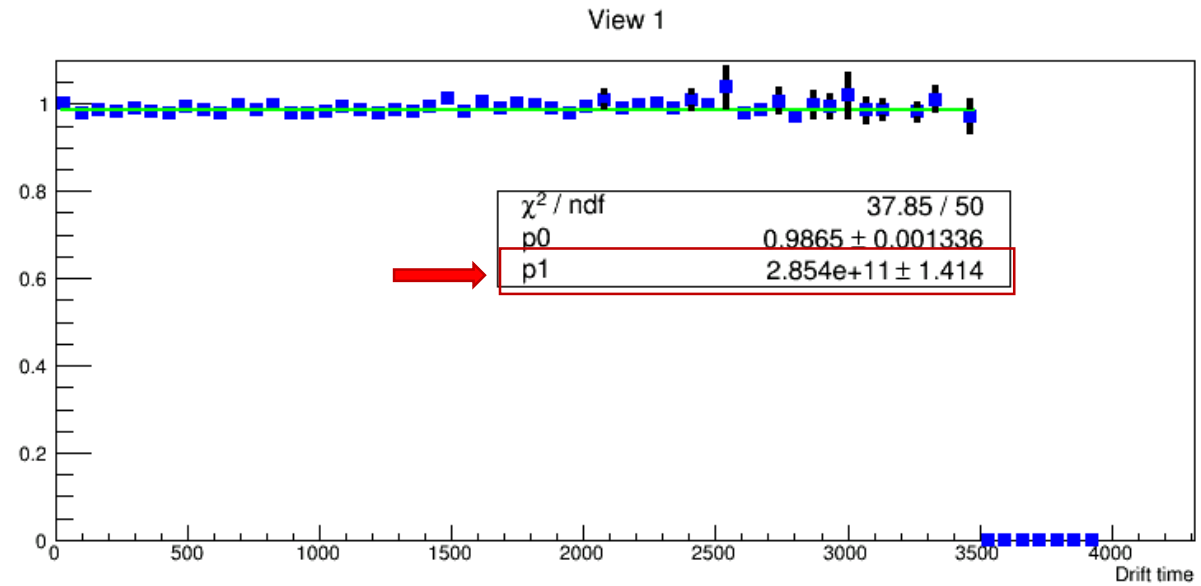
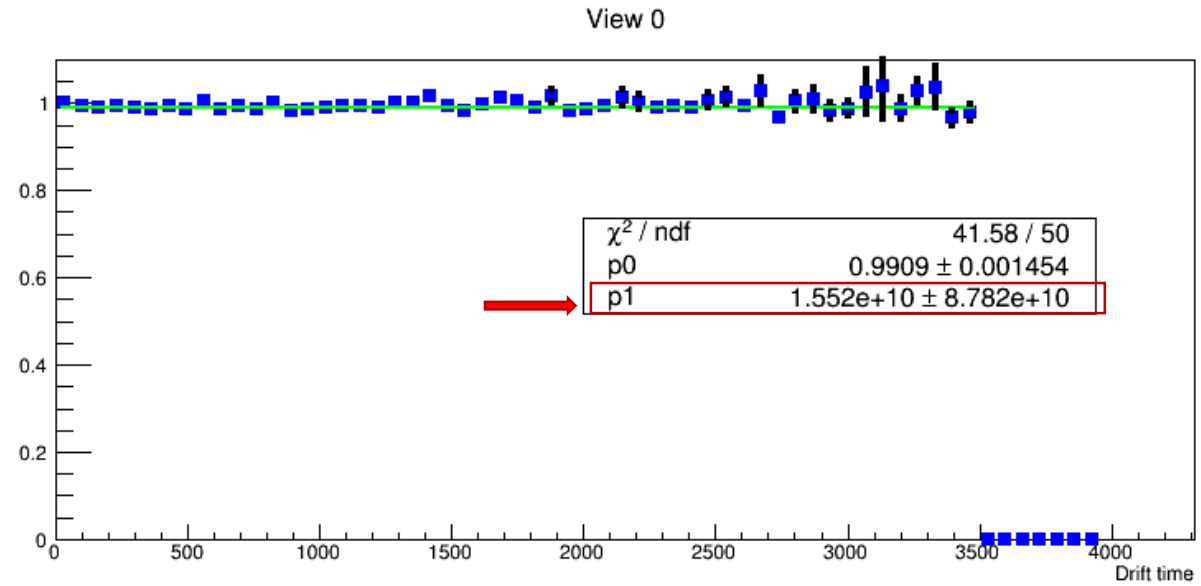
Real lifetime $\tau = 3.00$ ms

4k tracks $\tau = (3.05 \pm .008)$ ms

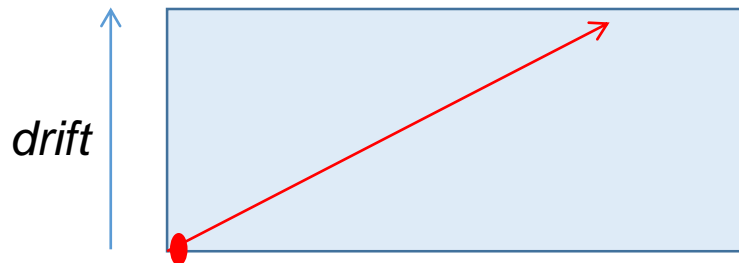
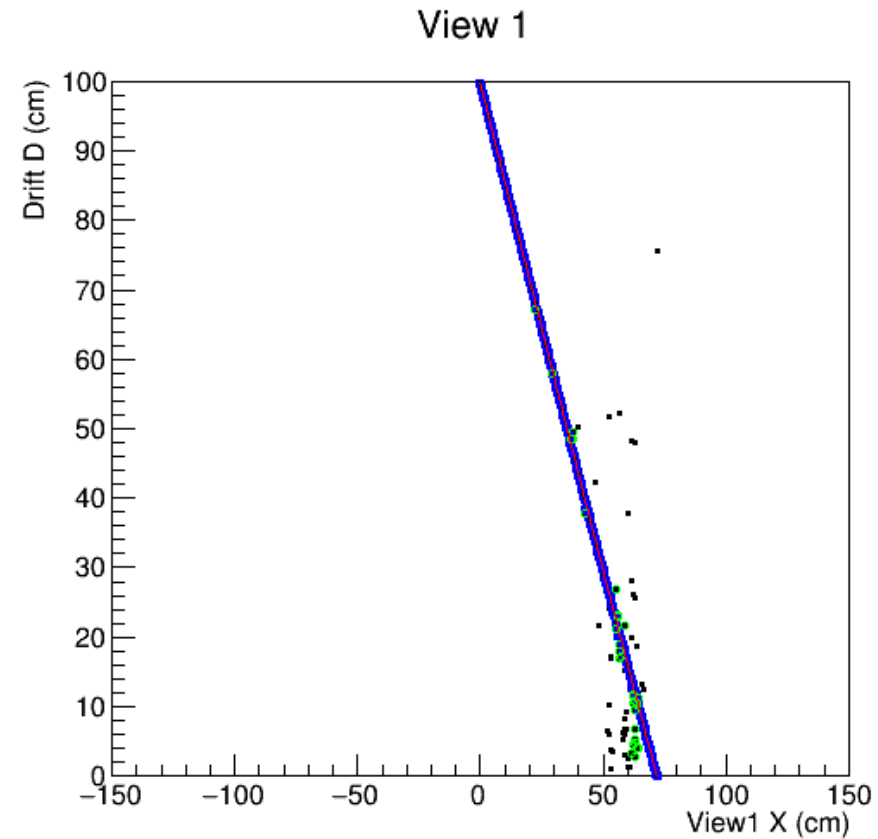
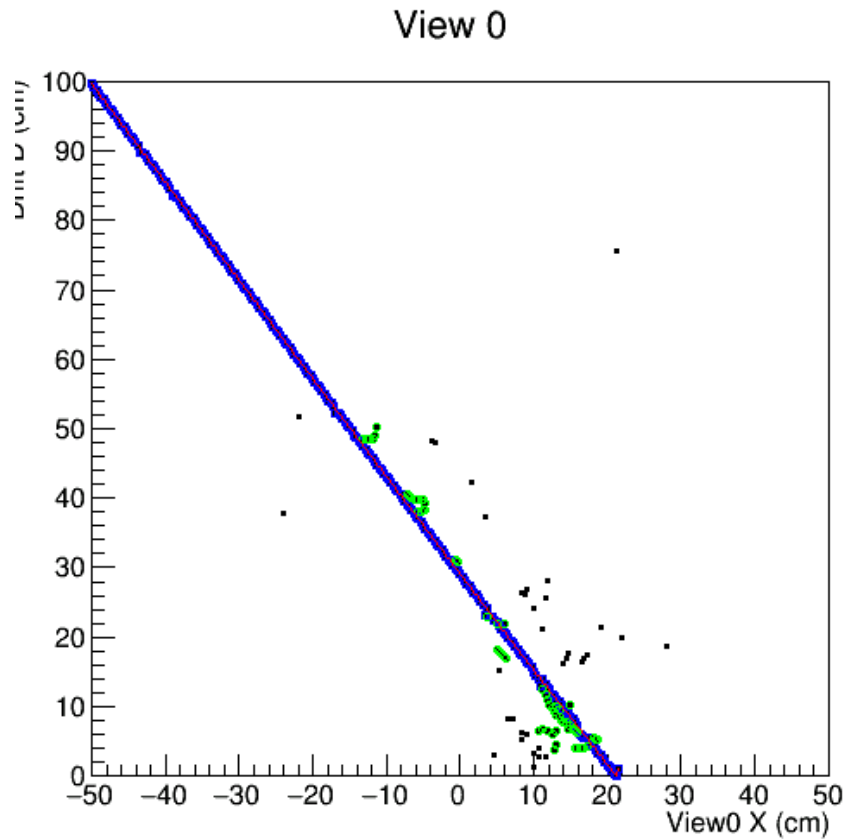
2k tracks (subsample) $\tau = (3.05 \pm .012)$ ms

1k tracks (subsample) $\tau = (3.04 \pm .019)$ ms

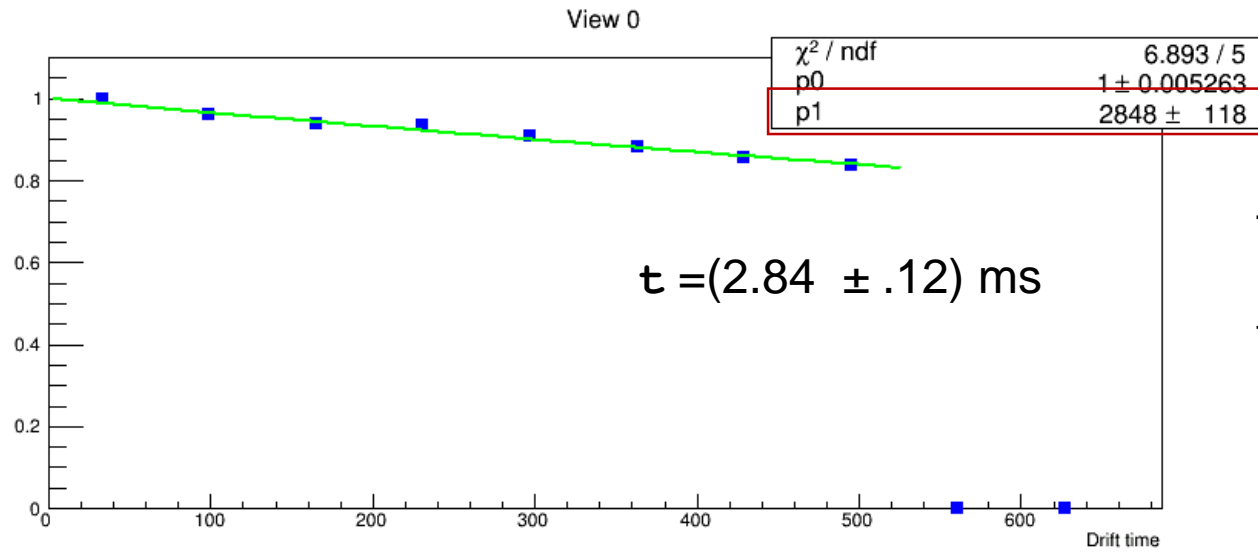
just for check → same sample of muon generated without lifetime effect:



The same method has now been applied to muon generated assuming the 3x1x1 configuration:

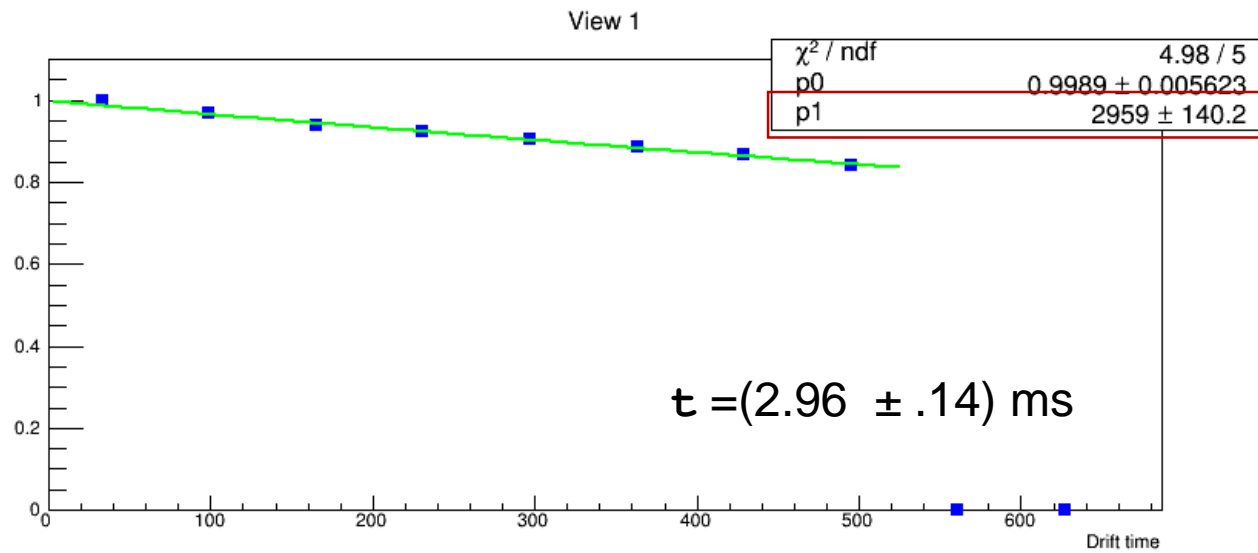


Fit results:

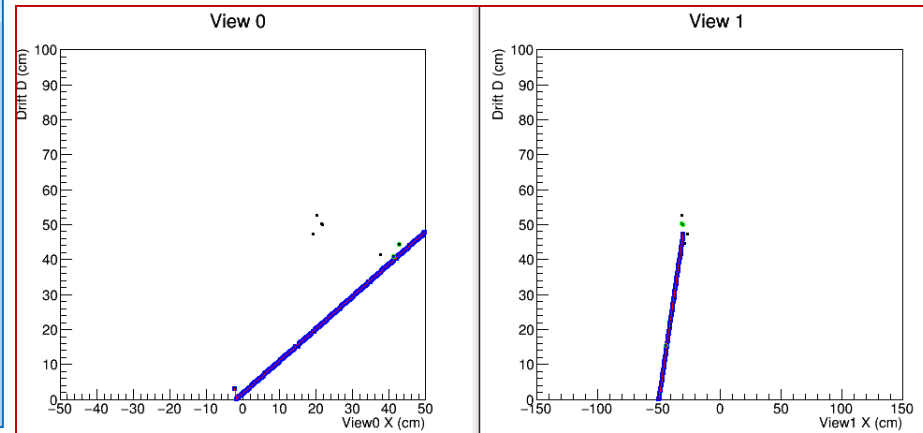
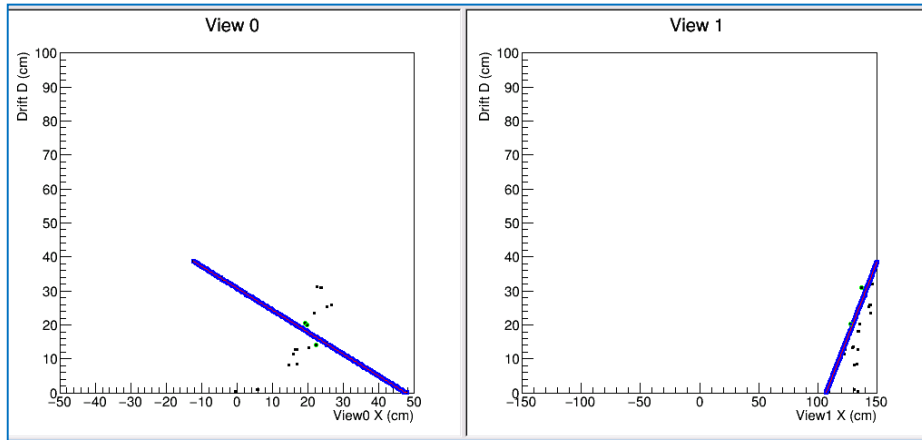
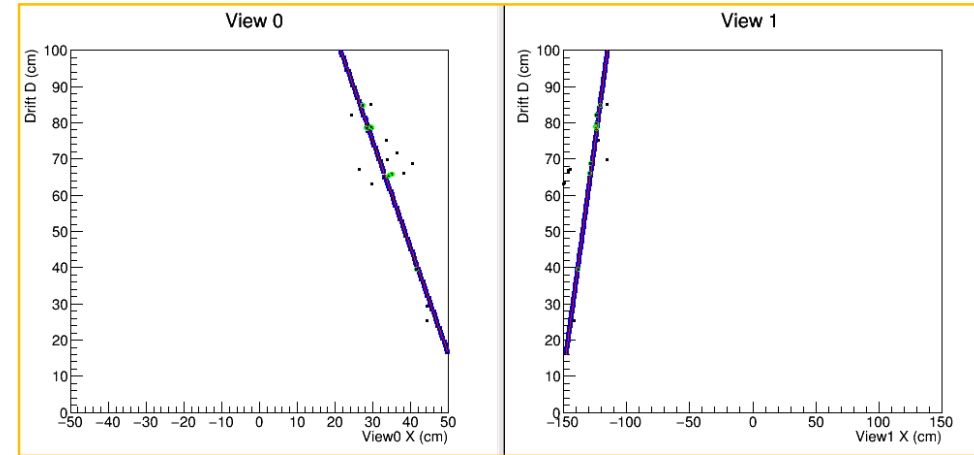
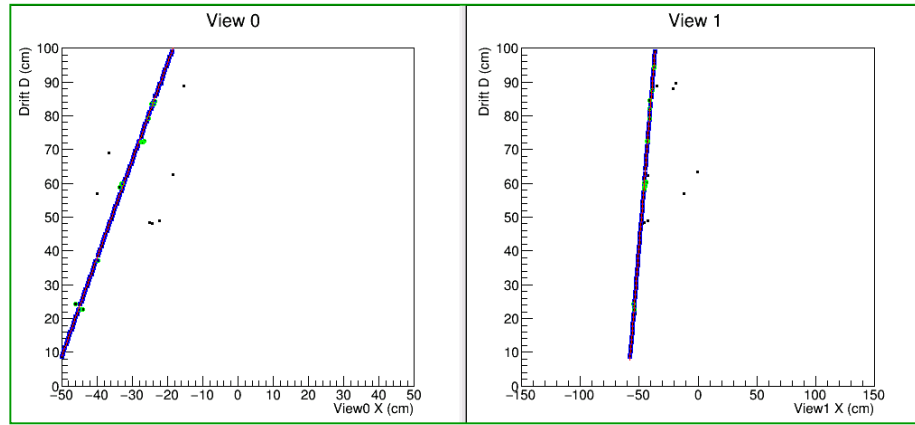


Tracks are shorter \rightarrow
Bigger error and worst
fit result w.r.t. 6x6x6

~4K tracks, 70 cm drift length

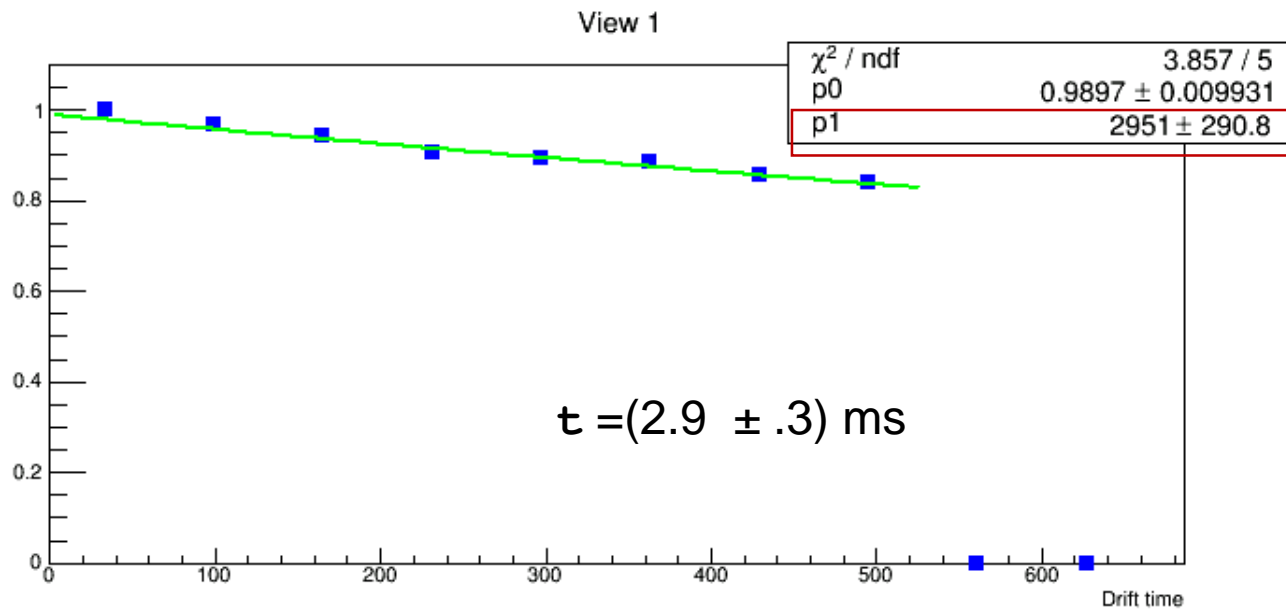
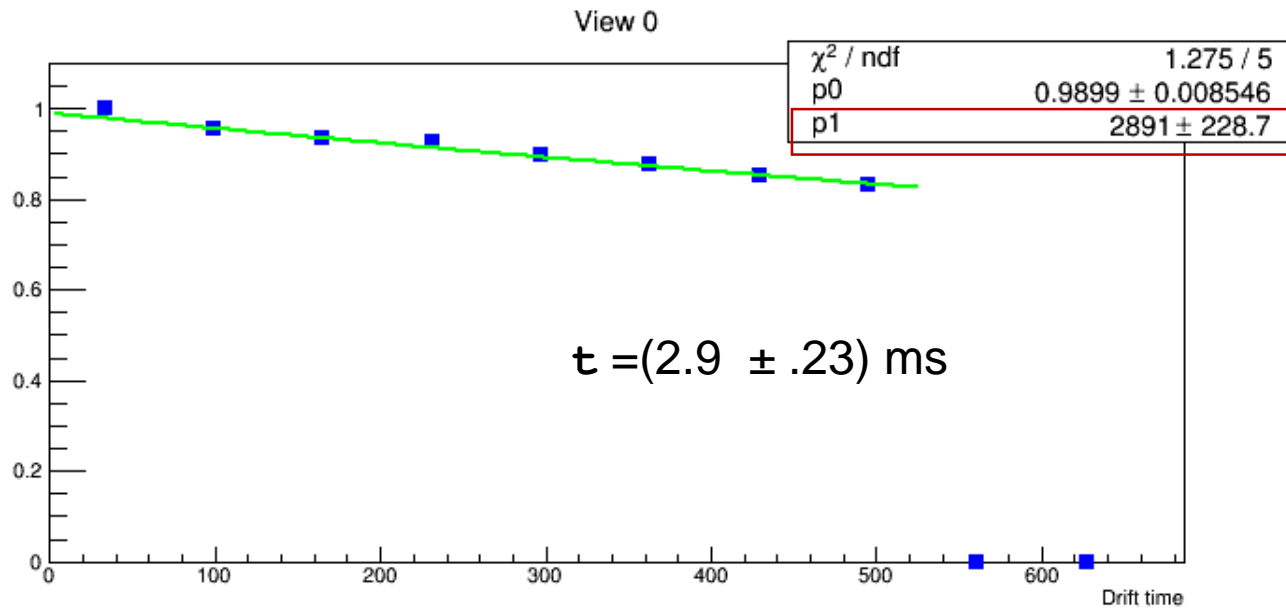


To test the method in a realistic situation, a sample of cosmic has been generated.
Some examples:



tracks with different slopes and different starting points

results of purity measurement:



~1500 tracks