Summer at CERN

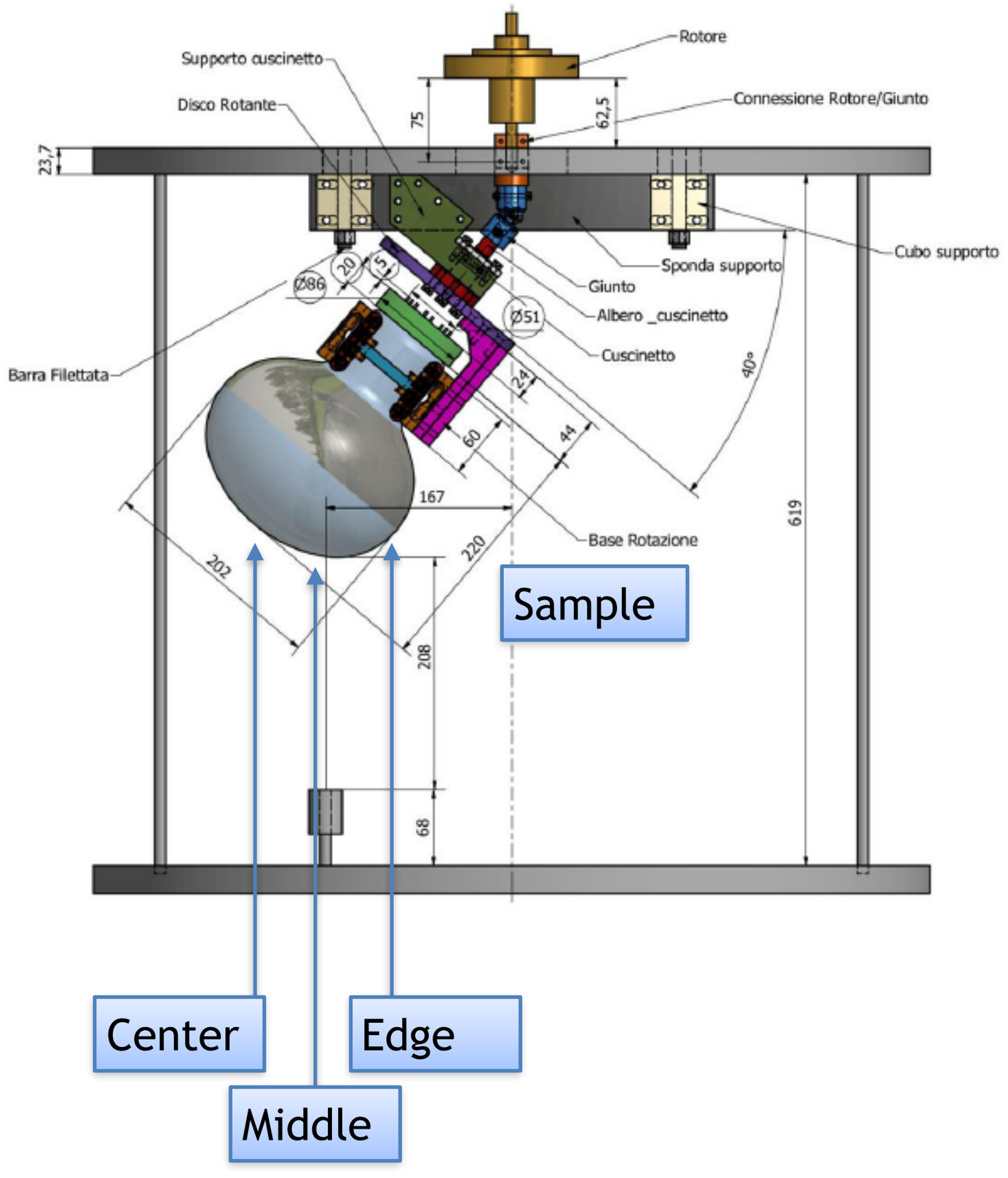
Past, present and future...

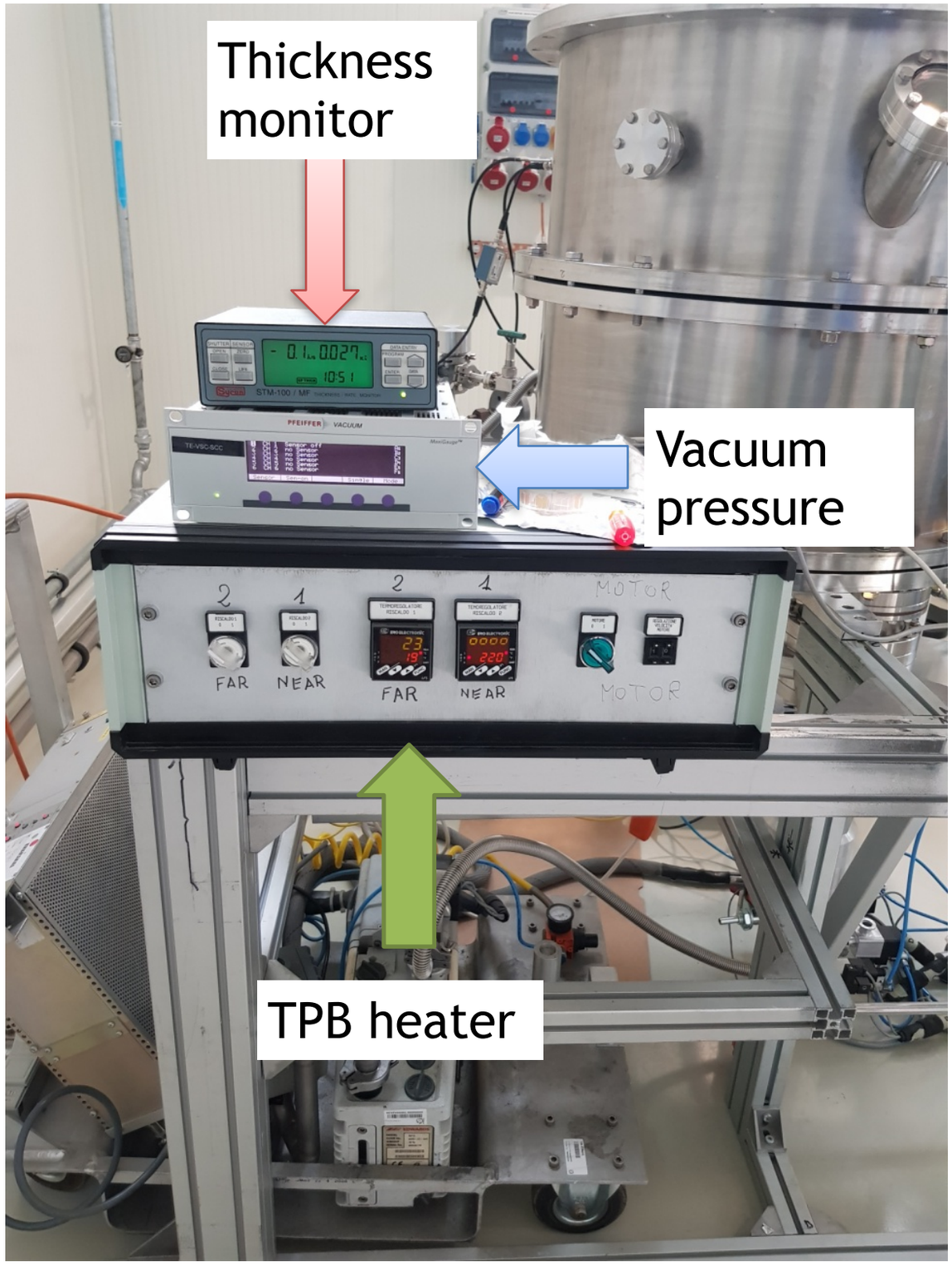
C. Jesús-Valls

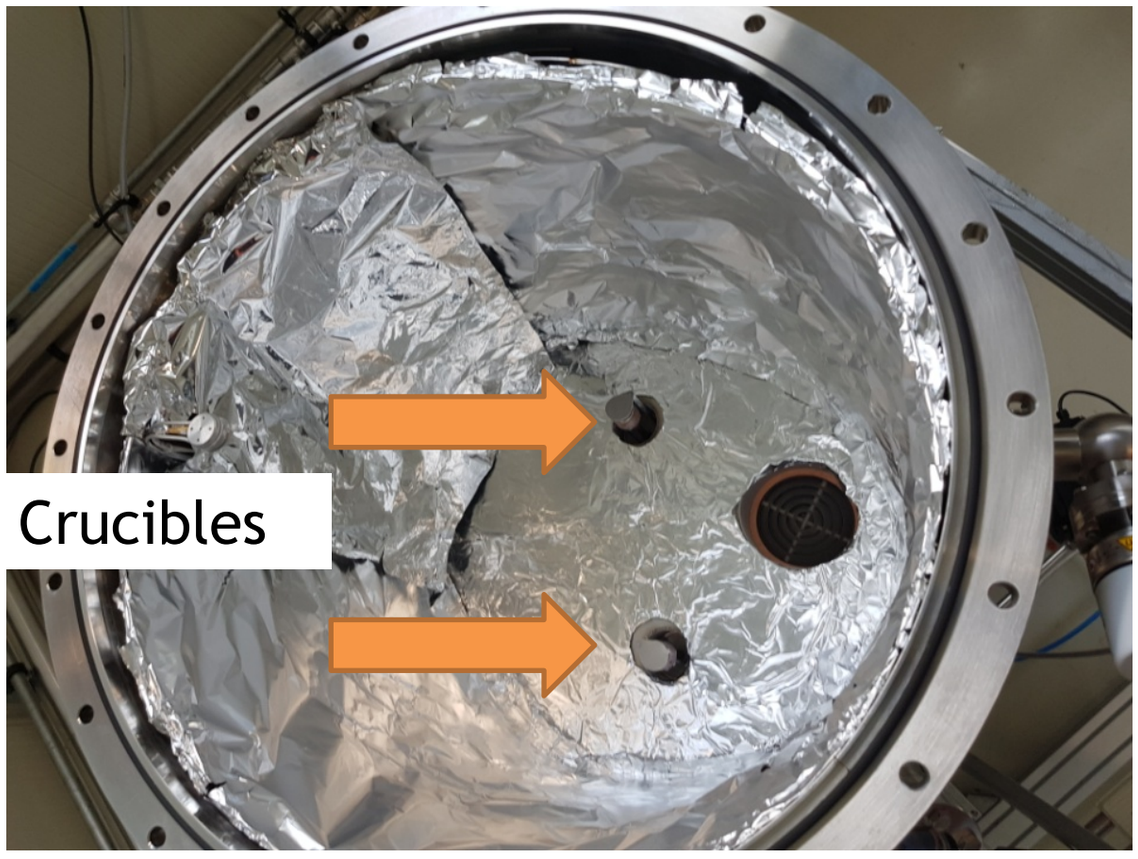
PMT COATING

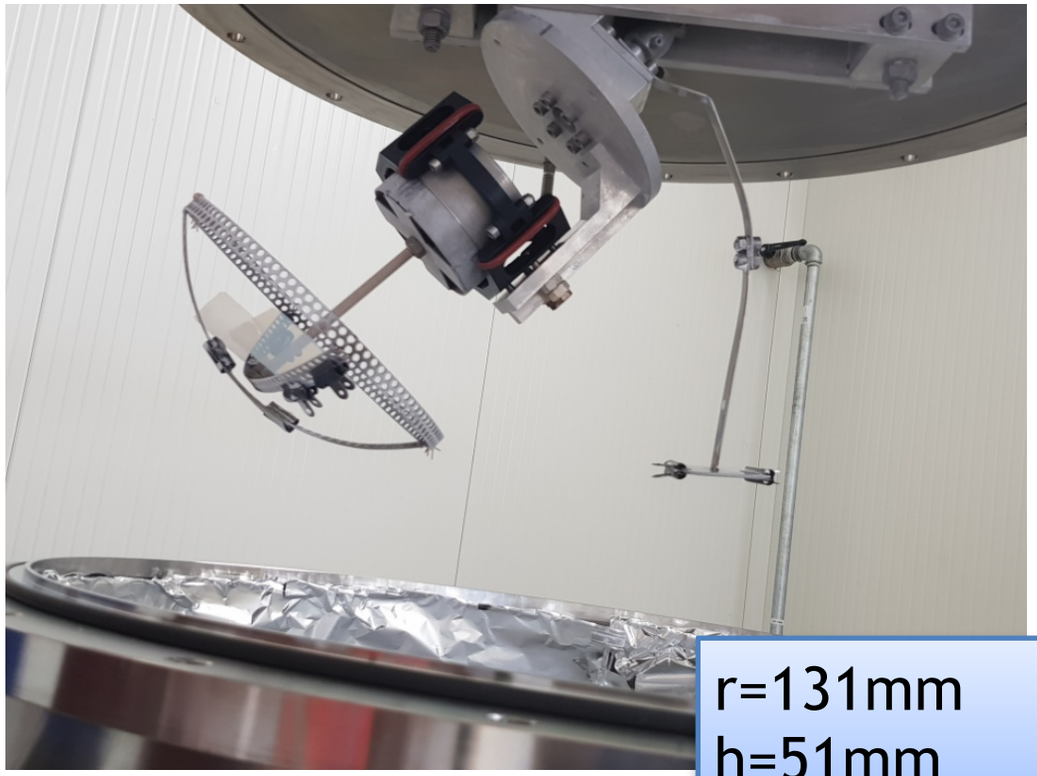
Coating Facility

- using facility developed for ICARUS experiment
- ICARUS coated 360 PMTs with it
- position of the PMT optimized for uniform coating
- full description of the system: https://arxiv.org/pdf/1807.07123.pdf
- system available at CERN for everyone
- great support from CERN Thin Film facility



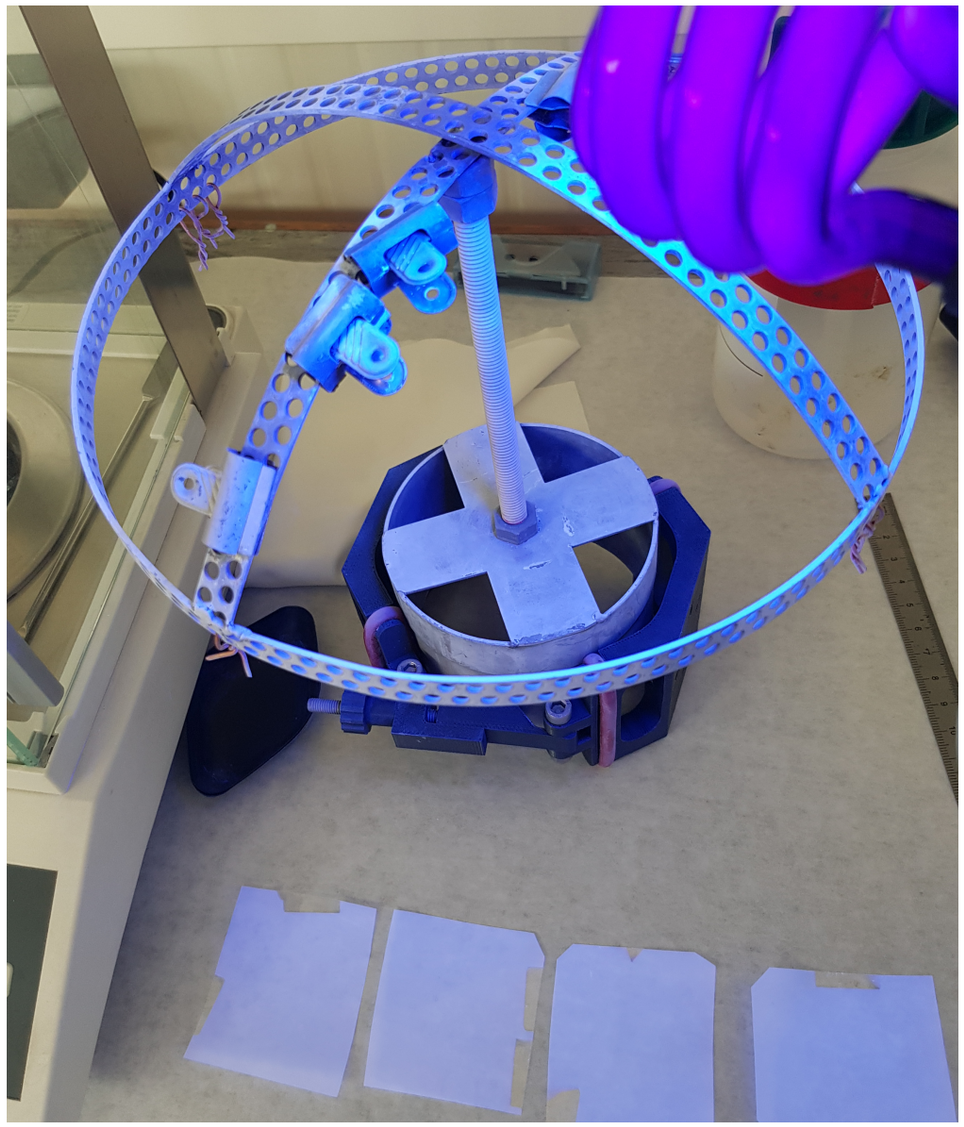

Thickness monitor
Vacuum pressure
TPB heater
FAR
NEAR
FAR
NEAR
MOTOR


Crucibles

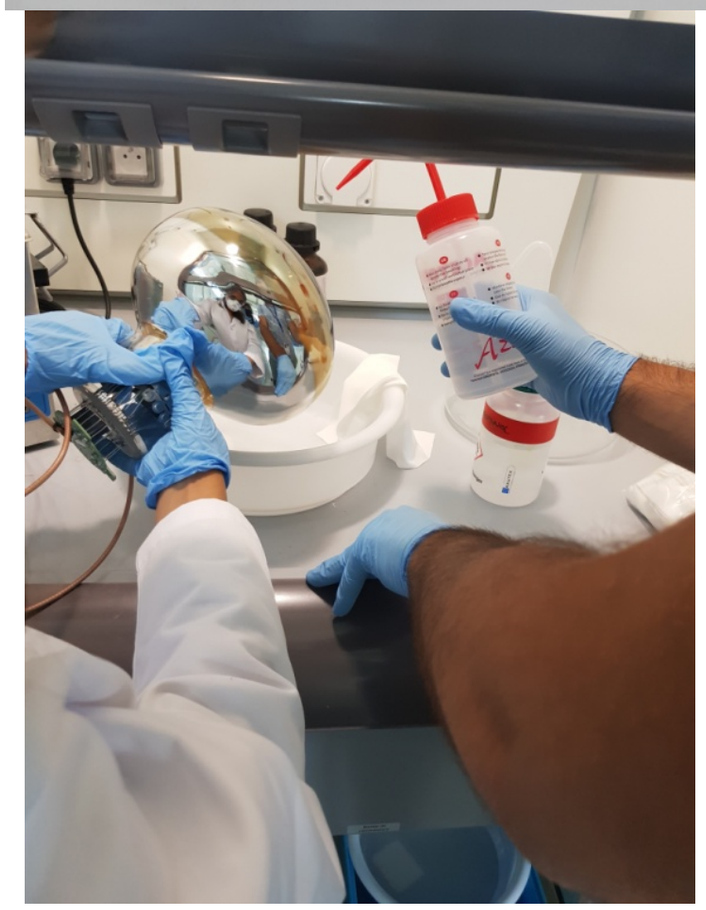


r=131mm
h=51mm

- test sample coating to test the system after transport and to learn
- spend 1.5 weeks on learning process
- easy but annoying job

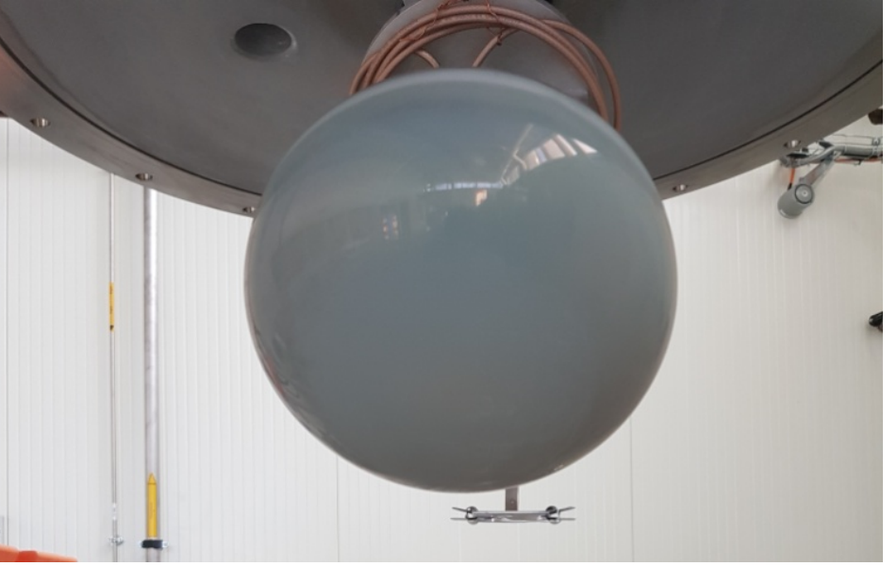


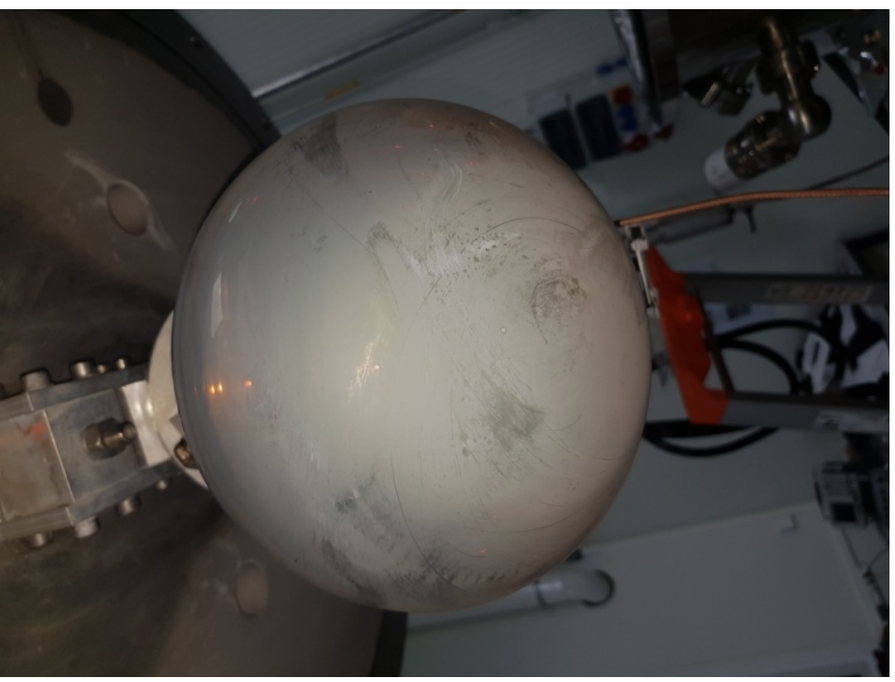
- test samples also useful for thickness calibration
- all PMT have been coated with more than 0.2mg/cm^2 in the middle.
- maximum difference in thickness is expected to be <20% from the extreme edge to the middle (middle-center <5%).



Procedure

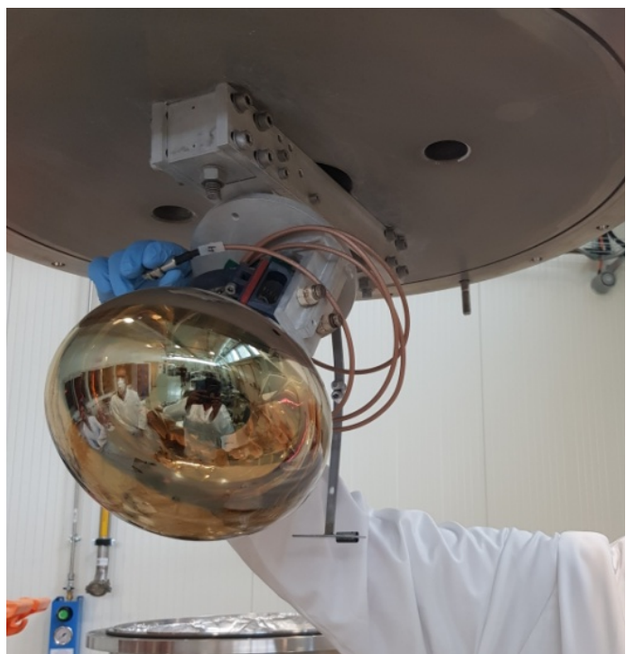
- visual inspection of box => all fine
- PMT was left in box, HV cable was taken out, the box was covered with black sheets
- Dark count test at 1200 V => all fine
- Photo from PMT outside box to have reference for PMT orientation
- dismanteling of the PMT+support
- cleaning of the PMT surface with acetone and isopropanol + drying the surface => **crucial for good coating quality**

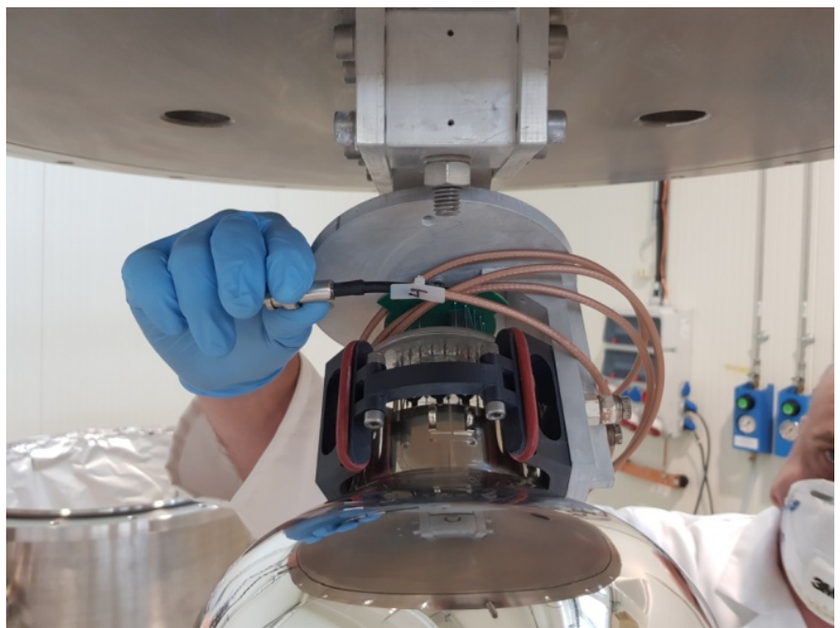


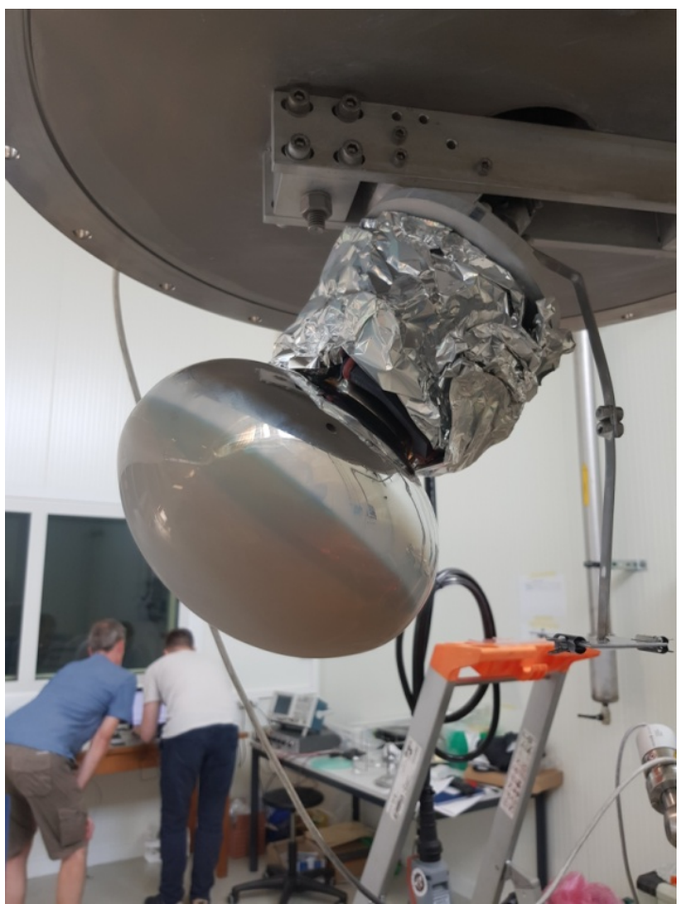


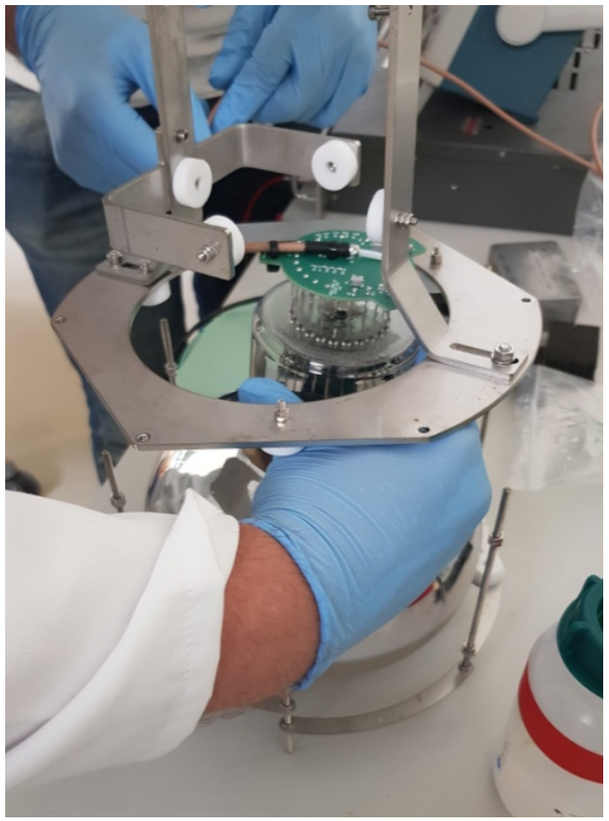
Procedure

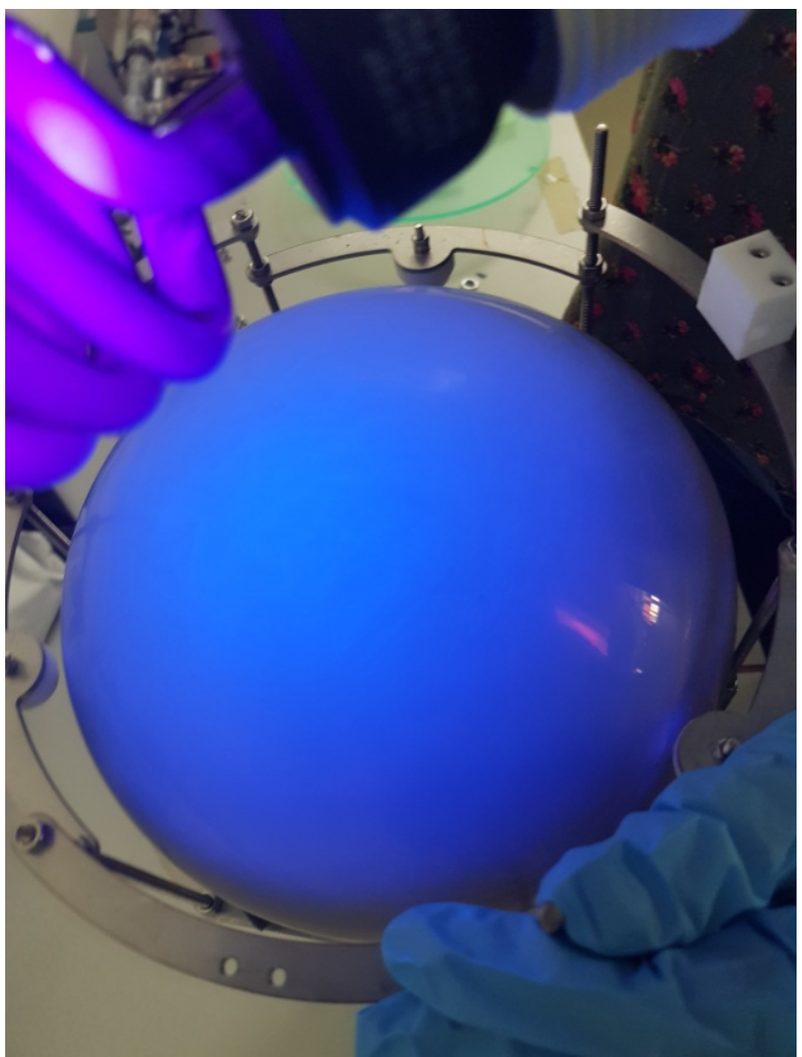
- Fixing the PMT in the vessel
- Placing carefully the cable so that the PMT can rotate
- cover cable and base with alu foil
- pumping down to below 3*10-5 mbar
- heating up TPB to 220 C monitoring every minute the parameters





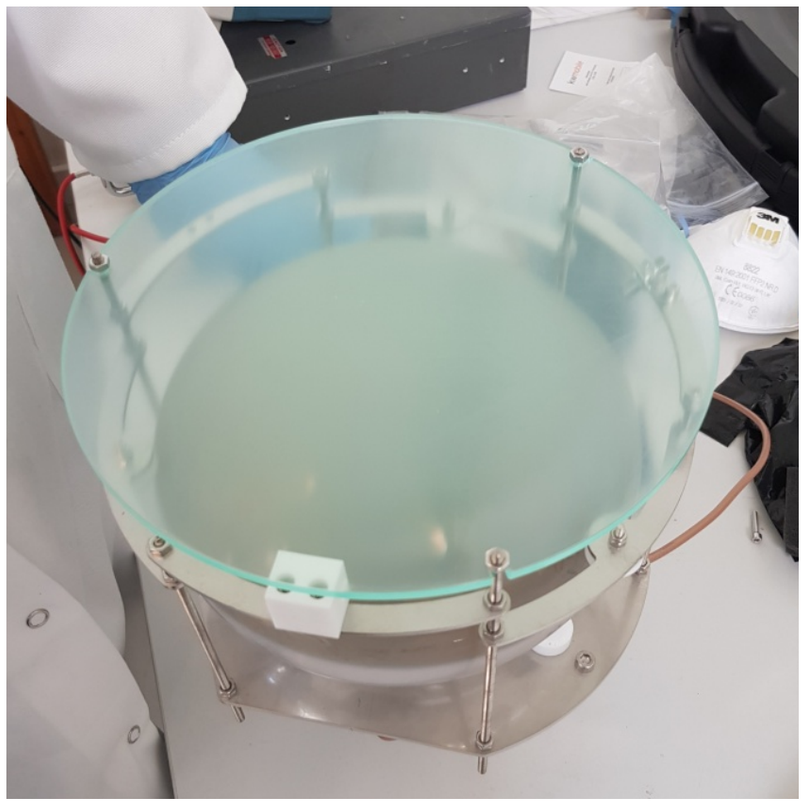






Procedure

- Re-assembling of the support structure with PMT
- checking coating with UV lamp + photo
- adding acrylic plate to protect TPB
- place in box with silikat gel to keep dry => 35 of 40
- Dark count test after coating



Documentation

- each PMT treatment/coating document following ICARUS scheme
- Parameters measured:
  - mass of TPB used (m=0.815 g)
  - thickness on test sample
  - coating duration
  - pressure
  - hour + date
  - change of TPB bottle

PMT No	Serial No.	Box No.	DarkCount Rate Test before coating	Date of Coating	Hour of Coating	TPB Weight [g]	Starting Pressure [*10 (-5) mbar]	Opening Pressure [*10 (-5) mbar]	Final Pressure [*10 (-5) mbar]	Time Coating (min)	End total thickness	Mylar before [g]	Mylar after [g]	delta weight [g]	coated area sample (mm2)	density [mg/cm2]	DarkCount Rate Test after coating	Comments
1	FA0116	3	Passed	19/07/2018	evening	0.8124	2.80	4.36	1.94	13:39	6.124	0.1957	0.1995	0.0038	2510	0.15139	Passed	
2	FA0121	4	Passed	10/08/2018	morning	0.8152	2.00	3.92	2.03	14:54	6.451	0.1796	0.1836	0.0040	2353	0.17000	Passed	new drying method
3	FA0123	1	Passed	02/08/2018	evening	0.8140	2.50	4.31	1.90	14:21	5.988	0.1742	0.1778	0.0036	2394	0.15038	Passed	new drying method
4	FA0143	test	Passed	17/07/2018	evening	0.8115	2.83	5.00	2.20	13:35	5.912	0.1859	0.1900	0.0041	2325	0.17634	Passed	Test PMT sent to CERN already one year ago; 1st TPB bottle
5	FA0114	2	Passed	30/07/2018	evening	0.8151	2.87	3.92	1.93	13:20	6.230	0.1736	0.1775	0.0039	2355	0.16561	Passed	4th TPB bottle started
6	FA0132	2	Passed	31/07/2018	evening	0.8154	1.60	3.17	1.38	13:29	5.957	0.1882	0.1922	0.0040	2411	0.16591	Passed	
7	FA0153	3	Passed	23/07/2018	evening	0.8146	2.85	3.95	1.98	14:42	6.028	0.1752	0.1793	0.0041	2384	0.17198	Passed	
8	FA0120	4	Passed	13/08/2018	evening	0.8159	2.75	4.17	2.50	14:31	6.374	0.1669	0.1704	0.0035	2401	0.14577	Passed	new drying method, first coating attempt failed due to non uniformities
9	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
10	FA0155	1	Passed	03/08/2018	morning	0.8155	0.55	2.80	0.54	13:42	6.558	0.1808	0.1852	0.0044	2420	0.18182	Passed	5th TPB bottle started, new drying method
11	FA0115	2	Passed	31/07/2018	evening	0.8129	2.77	3.13	1.92	13:57	6.016	0.1793	0.1829	0.0036	2350	0.15319	Passed	
12	FA0139	4	Passed	14/08/2018	morning	0.8171	1.60	3.60	1.70	15:00	7.032	0.1803	0.1844	0.0041	2373	0.17278	Passed	7th TPB bottle started, new drying method
13	FA0113	1	Passed	03/08/2018	evening	0.8113	2.60	4.10	1.96	14:10	6.190	0.1703	0.1742	0.0039	2330	0.16738	Passed	new drying method
14	FA0107	3	Passed	23/07/2018	evening	0.8144	2.95	4.04	2.07	13:46	6.138	0.1760	0.1798	0.0038	2272	0.16725	Passed	
15	FA0129	3	Passed	23/07/2018	morning	0.8112	0.38	2.30	0.38	13:25	6.241	0.1912	0.1955	0.0043	2537	0.16949	Passed	2nd TPB bottle started, first coating attempt failed due to non uniformities
16	FA0110	2	Passed	27/07/2018	evening	0.8153	0.60	2.41	0.59	14:16	6.555	0.1665	0.1704	0.0039	2311	0.16876	Passed	
17	FA0133	4	Passed	14/08/2018	evening	0.8159	2.84	5.53	2.51	14:31	6.678	0.1599	0.1634	0.0035	2197	0.15931	Passed	new drying method, without humidity bag
18	FA0140	3	Passed	25/07/2018	evening	0.8145	2.64	4.40	1.91	13:43	6.130	0.1815	0.1853	0.0038	2376	0.15993	Passed	
19	FA0137	3	Passed	18/07/2018	evening	0.8146	2.81	4.75	2.10	13:50	6.097	0.1895	0.1933	0.0038	2384	0.15940	Passed	
20	FA0148	1	Passed	06/08/2018	morning	0.8131	0.37	2.30	0.37	13:57	6.431	0.1797	0.1834	0.0037	2300	0.16087	Passed	new drying method
21	FA0105	4	Passed	15/08/2018	morning	0.8110	1.50	3.01	1.52	14:56	6.859	0.1794	0.1832	0.0038	2333	0.16288	Passed	new drying method, without humidity bag
22	FA0111	4	Passed	15/08/2018	evening	0.8172	2.90	4.21	2.56	14:49	6.851	0.1620	0.1653	0.0033	2068	0.15957	Passed	new drying method, without humidity bag
23	FA0106	2	Passed	02/08/2018	morning	0.8191	0.61	2.70	0.60	13:58	6.046	0.1780	0.1816	0.0036	2248	0.16014	Passed	new drying method
24	FC0005	1	Passed	07/08/2018	evening	0.8157	2.81	3.99	1.92	13:52	6.410	0.1724	0.1766	0.0042	2454	0.17115	Passed	new drying method
25	FA0134	4	Passed	15/08/2018	evening	0.8157	2.89	4.42	2.56	15:16	6.845	0.1748	0.1787	0.0039	2380	0.16387	Passed	new drying method, without humidity bag
26	FA0149	1	Passed	06/08/2018	evening	0.8154	1.97	3.98	1.48	14:39	6.536	0.1631	0.1670	0.0039	2214	0.17615	Passed	new drying method, first coating attempt failed due to non uniformities
27	FA0135	1	Passed	08/08/2018	morning	0.8173	0.64	2.25	0.63	14:42	6.612	0.1811	0.1854	0.0043	2405	0.17879	Passed	new drying method
28	FA0151	3	Passed	24/07/2018	evening	0.8125	2.50	4.15	1.85	13:34	6.258	0.1720	0.1758	0.0038	2320	0.16379	Passed	
29	FA0147	1	Passed	08/08/2018	evening	0.8163	2.95	4.81	2.04	13:47	6.473	0.1775	0.1815	0.0040	2360	0.16949	Passed	6th TPB bottle started, new drying method
30	FA0157	3	Passed	26/07/2018	morning	0.8189	0.51	2.25	0.49	13:00	6.142	0.1885	0.1928	0.0043	2400	0.17917	Passed	3rd TPB bottle started
31	FA0112	3	Passed	25/07/2018	morning	0.8126	0.57	2.74	0.56	13:54	6.186	0.1742	0.1780	0.0038	2304	0.16493	Passed	
32	FA0104	3	Passed	20/07/2018	morning	0.8157	0.59	2.71	0.59	13:48	6.320	0.1930	0.1970	0.0040	2417	0.16549	Passed	
33	FA0124	1	Passed	09/08/2018	morning	0.8178	0.55	2.41	0.53	13:40	6.764	0.1739	0.1777	0.0038	2357	0.16122	Passed	new drying method
34	FA0150	4	Passed	16/08/2018	evening	0.8163	2.96	5.05	2.31	13:52	6.887	0.1783	0.1824	0.0041	2487	0.16486	Passed	new drying method, without humidity bag
35	FA0156	2	Passed	27/07/2018	evening	0.8120	2.95	4.81	2.03	13:33	5.910	0.1705	0.1742	0.0037	2330	0.15880	Passed	After change of cristal to measure total thickness
36	FA0119	2	Passed	30/07/2018	morning	0.8131	0.22	2.68	0.78	15:00	-----	0.1719	0.1756	0.0037	2325	0.15914	Passed	Xtal fail in the thickness mesurement
37	FA0122	1	Passed	09/082018	evening	0.8144	1.50	3.57	1.29	13:57	6.534	0.1744	0.1781	0.0037	2374	0.15586	Passed	new drying method
38	FA0146	2	Passed	30/07/2018	evening	0.8146	2.95	3.86	1.91	13:53	5.894	0.1743	0.1778	0.0035	2392	0.14632	Passed	
39	FC0004	4	Passed	16/08/2018	evening	0.8185	2.55	4.03	1.92	14:30	7.143	0.1554	0.1590	0.0036	2156	0.16698	Passed	8th TPB bottle started, new drying method, without humidity bag
40	FA0136	2	Passed	01/08/2018	evening	0.8147	2.89	4.97	2.31	13:19	6.199	0.1795	0.1835	0.0040	2361	0.16942	Passed	Sensibility not that good as the others => want to say very low DC rate but might be d
41	FA0130	2	Passed	26/07/2018	evening	0.8139	2.54	3.21	1.82	14:29	5.943	0.1777	0.1815	0.0038	2388	0.15913	Passed	Sensibility not that good as the others => want to say very low DC rate but might be d
																PMTs fully finished:	40	
																Percentage	100	
			40															

Qeff Measurement

- 40 PMTs now stored in EHN1
- 4 PMTs will be brought back to Meyrin for Qeff measurement
- producing missing part currently => after 7th of September
- only >200 nm and quantitative not qualitative
- trying to contact ICARUS group to explore possibility to measure at 128 nm
- not clear if setup still exists

Absolute QE measurements

from Thin Film & Glass lab

http://cdsweb.cern.ch/record/1164394/files/PH-EP-Tech-Note-2009-001.pdf

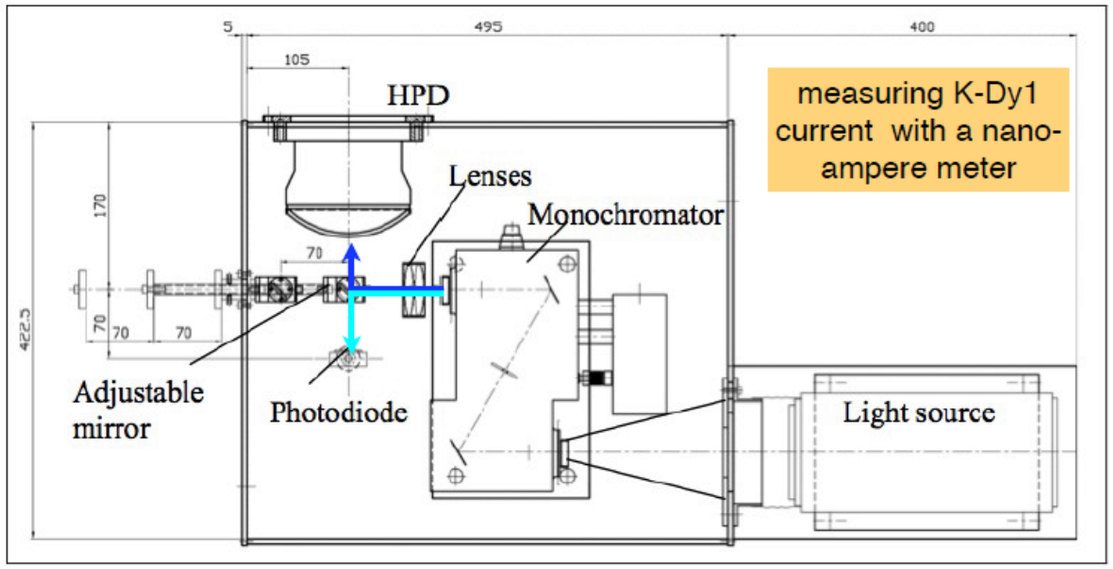
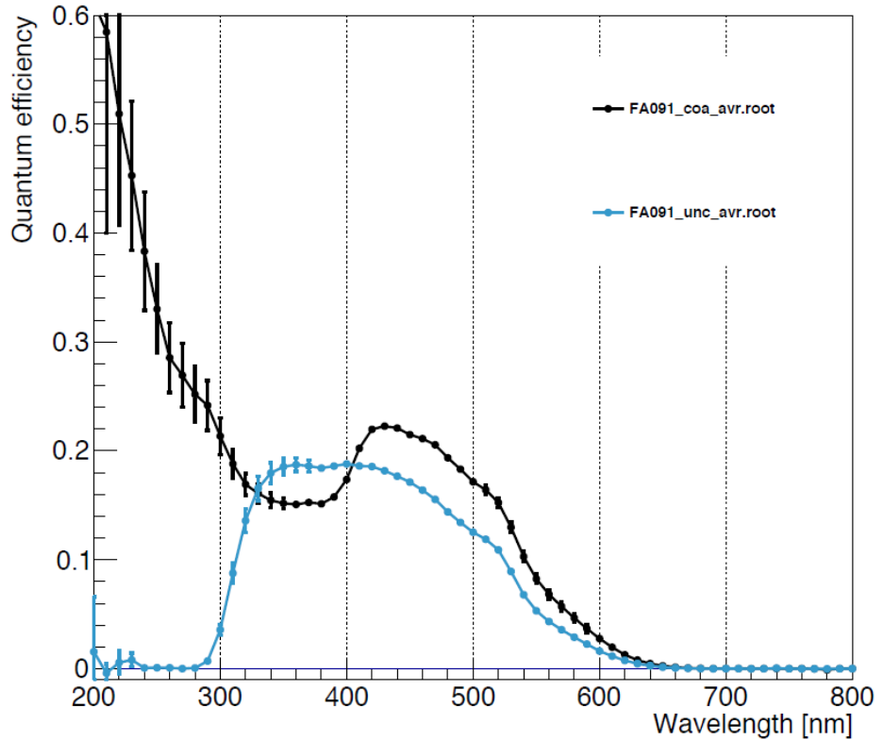


Figure 15: Overview of the mechanical setup of the measurement system. Dimensions in mm.

$$\epsilon_{PMT} = \frac{I_{PMT}}{I_{PD}} \epsilon_{PD}$$

Sosuke's slide @ArDM meeting



Summary + Outlook

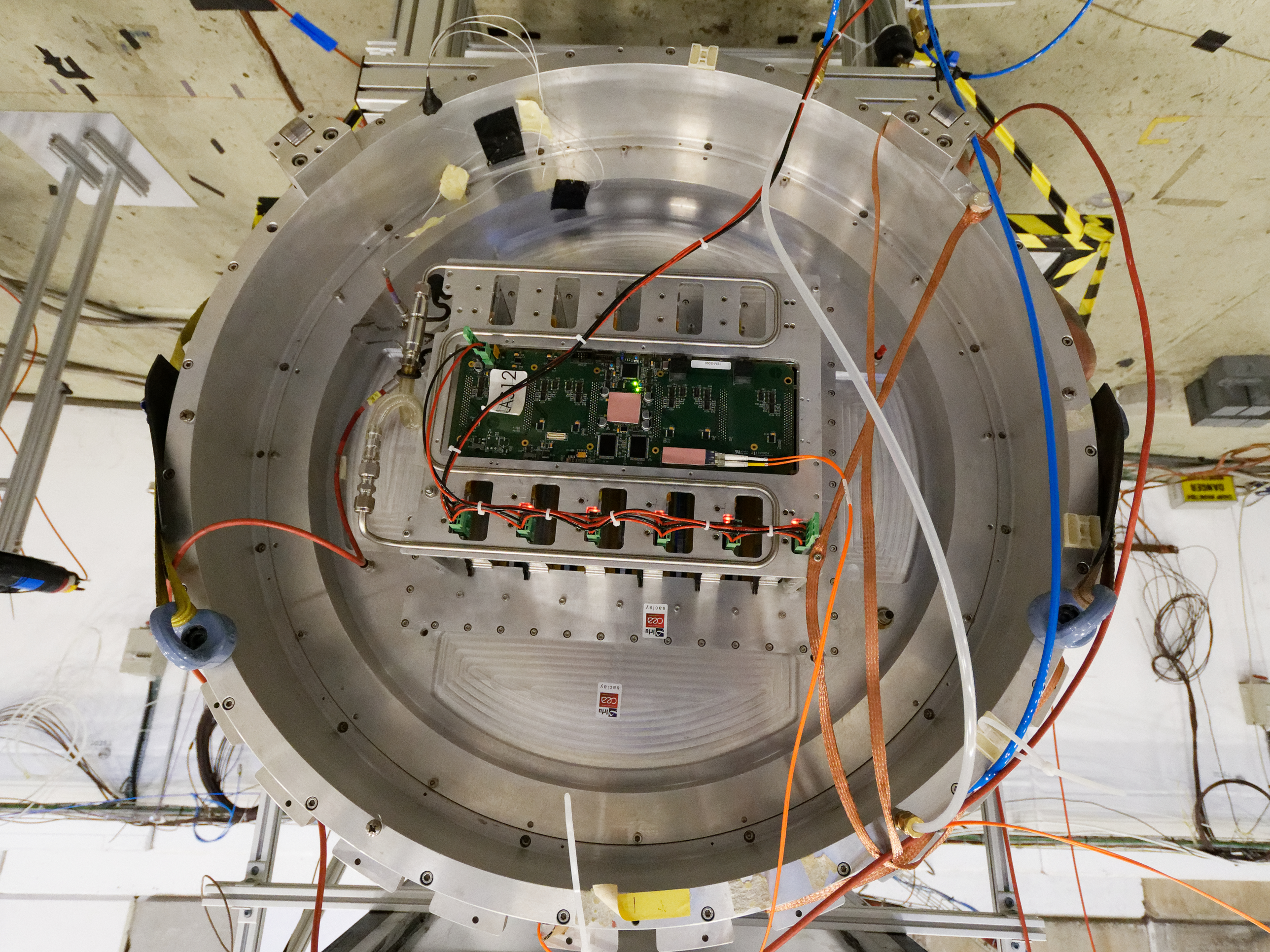
- 40 PMTs were coated with ICARUS facility at CERN
- 2 PMTs/day coated (ICARUS w/o base 4 PMTs/day)
- Learned a lot:
  - Drying process after cleaning crucial
  - PMTs ideally stored after coating in sealed Mylar/Alu bag
- Visual inspection with UV lamp fine
- Open question: Surface preparation => ArDM seemed to have no preferences but ICARUS sand blasted all 360 PMTs
- Trying to organize Qeff measurement at 128 nm
- PMTs at EHN1 waiting for installation

TESTBEAM

beamline for schools

CERN

CERN & Society


irfu
cea
saclay

Test Beam data summary

Different runs contain:

- Different particles:
  1. "**Electrons**" = Scintillators * Cherenkov
  2. "**Pions**" (+ **muons**) = Scintillators * not_protons * not_electrons
  3. "**Protons**" (+ kaons) = S1_delayed * S2 (delay ~ proton TOF between S1 and S2)
  4. "**CR**" from icarus trigger module but only out of SPILL
  5. In addition there were **^{55}Fe clusters**, from a radioactive source.

- Different **momentum** for the beam.
- Different **HV** in MM.
- **Temperature** dependence.
- **Pressure** dependence.
- 6 different **FECs**, with 4 **ADC** each one.
- Different **threshold** conditions.
- Different **shaping** time.

Preliminary data shows high quality of data
Many possible studies

Track Selection Algorithm

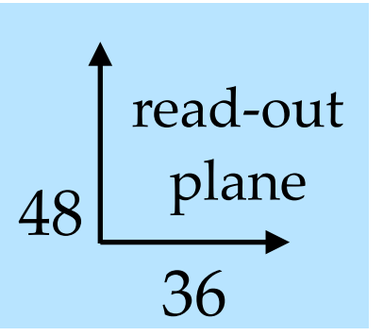
Selection Algorithm (Developed by S.Suvurov)

Common structure for the analysis:

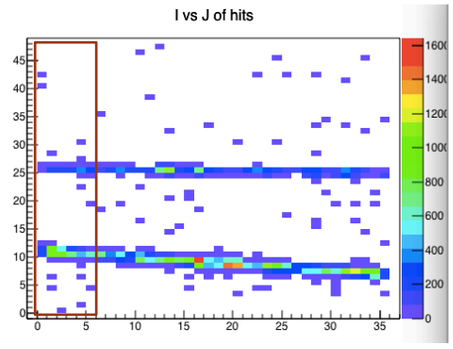
- Loop over channels
- Search of the maxADC in each channel.
- Store information.

Selection Input

A. Store maxADC for each channel.
B. Variation: Store ADC integrated in a window around the maxADC.
C. Store time of max ADC.



1728 pads
7x10 mm²



Selection (COSMIC / BEAM)

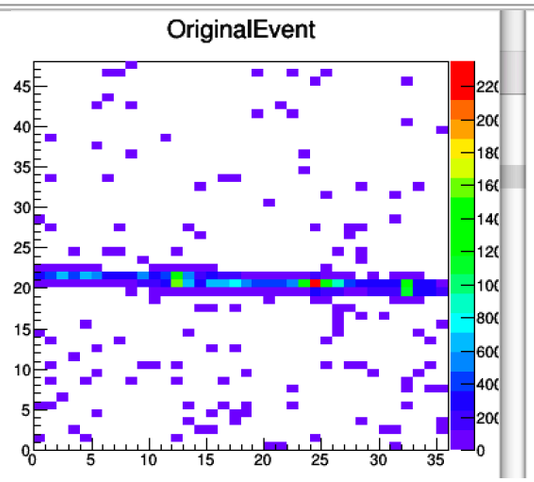
- Cosmic and Beam selection works in the same way (just rotating definitions).
- In one margin (Top for Cosmics, right for Beam) a clustering algorithm classify the pads in sets of pads (clusters) with common position and time requirements.
- A linear fit is applied to the largest cluster.
- If the quality of the fit is good all pads around the fitted straight line are selected.

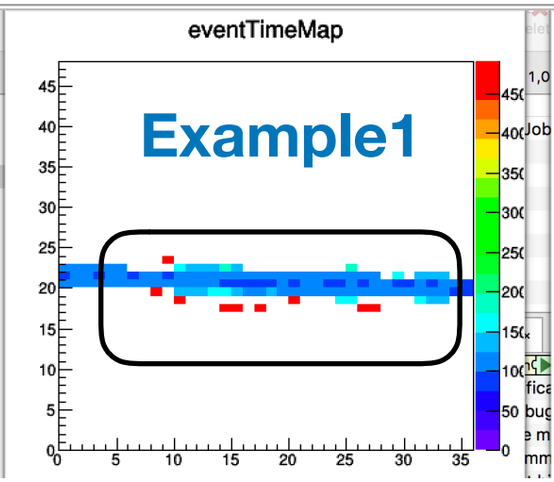
Selection Output

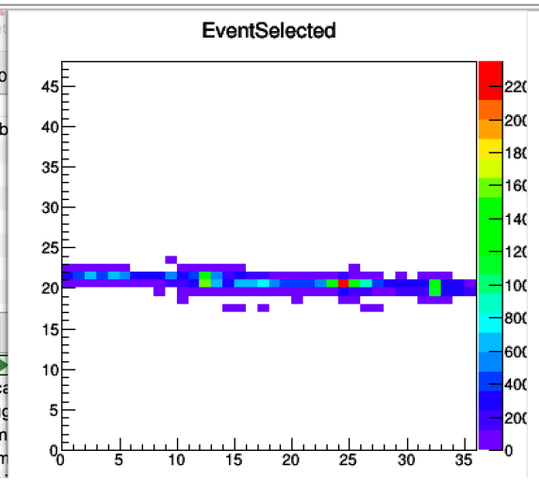
Track Selection Known Problems

Problem!

Since we have 3D tracks selected from a 2D developed algorithm we are selecting “wrong” noise pads.

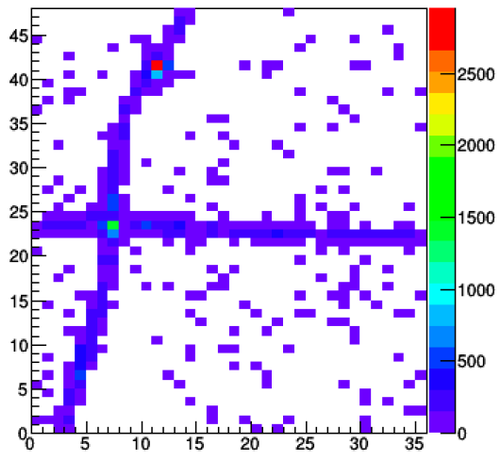


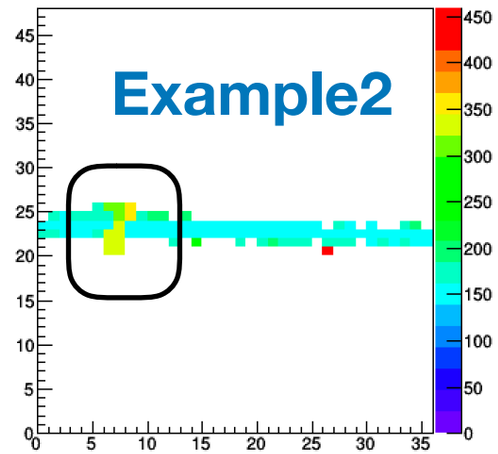




No easy 2D solution

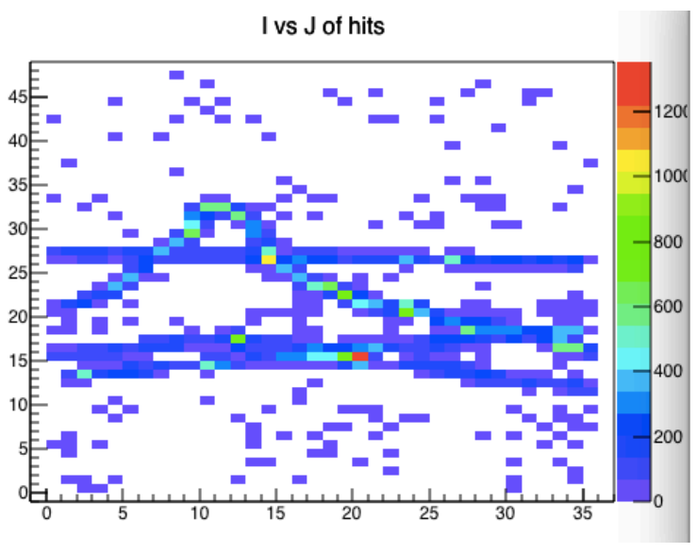
Cut in time after selection can by applied to solve this (done in PRF studies)
However does not work for COSMICS that are not perpendicular to time axis!!



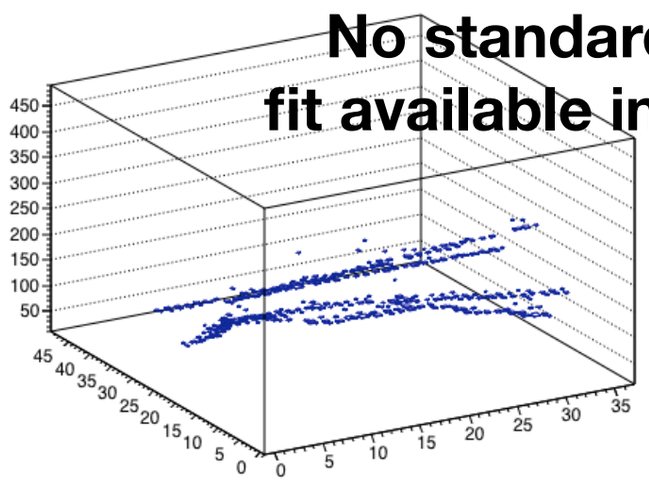


Solution? Move to 3D

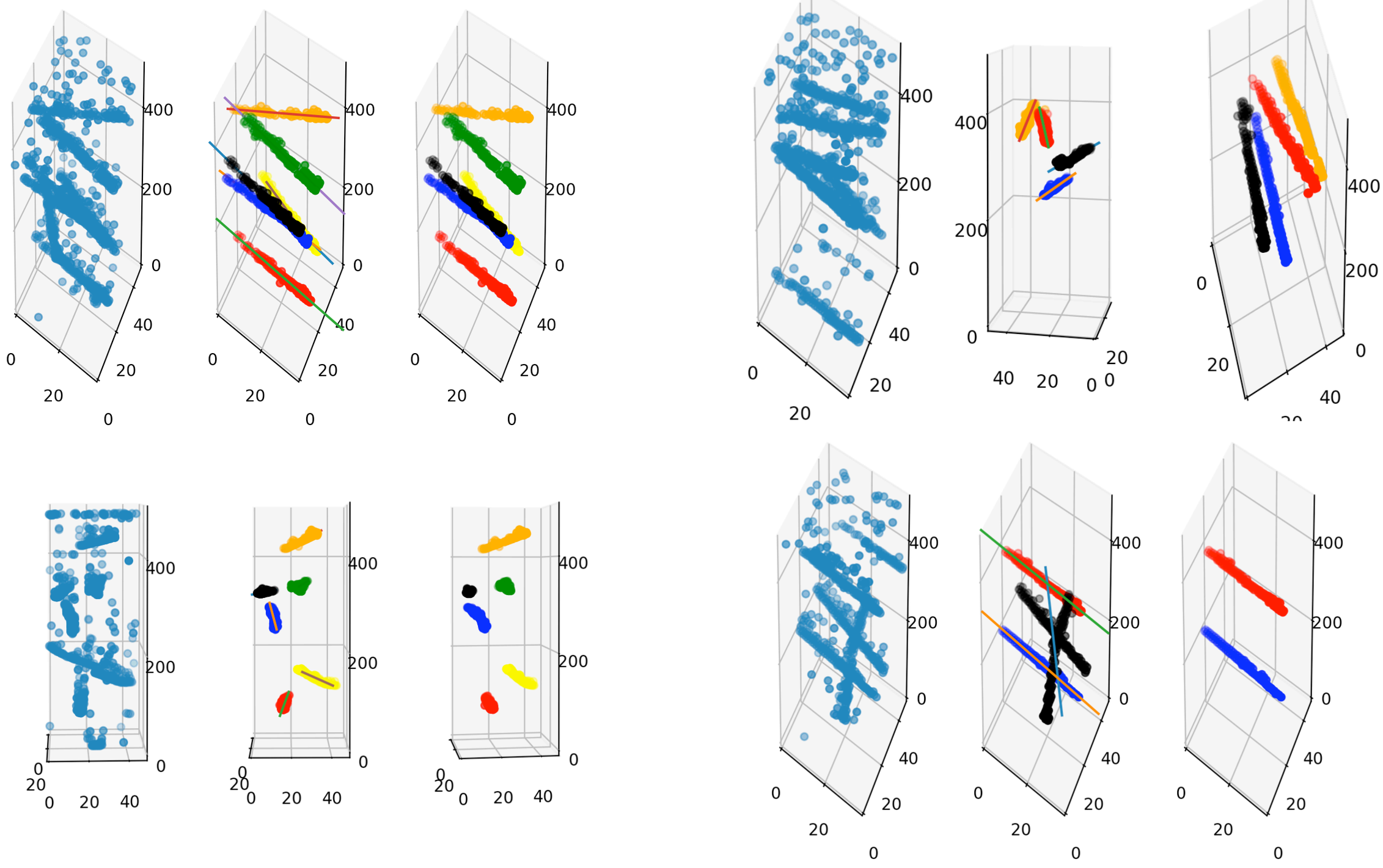
Exploit full power of 3D information to implement better selection.



No standard 3D fit available in ROOT



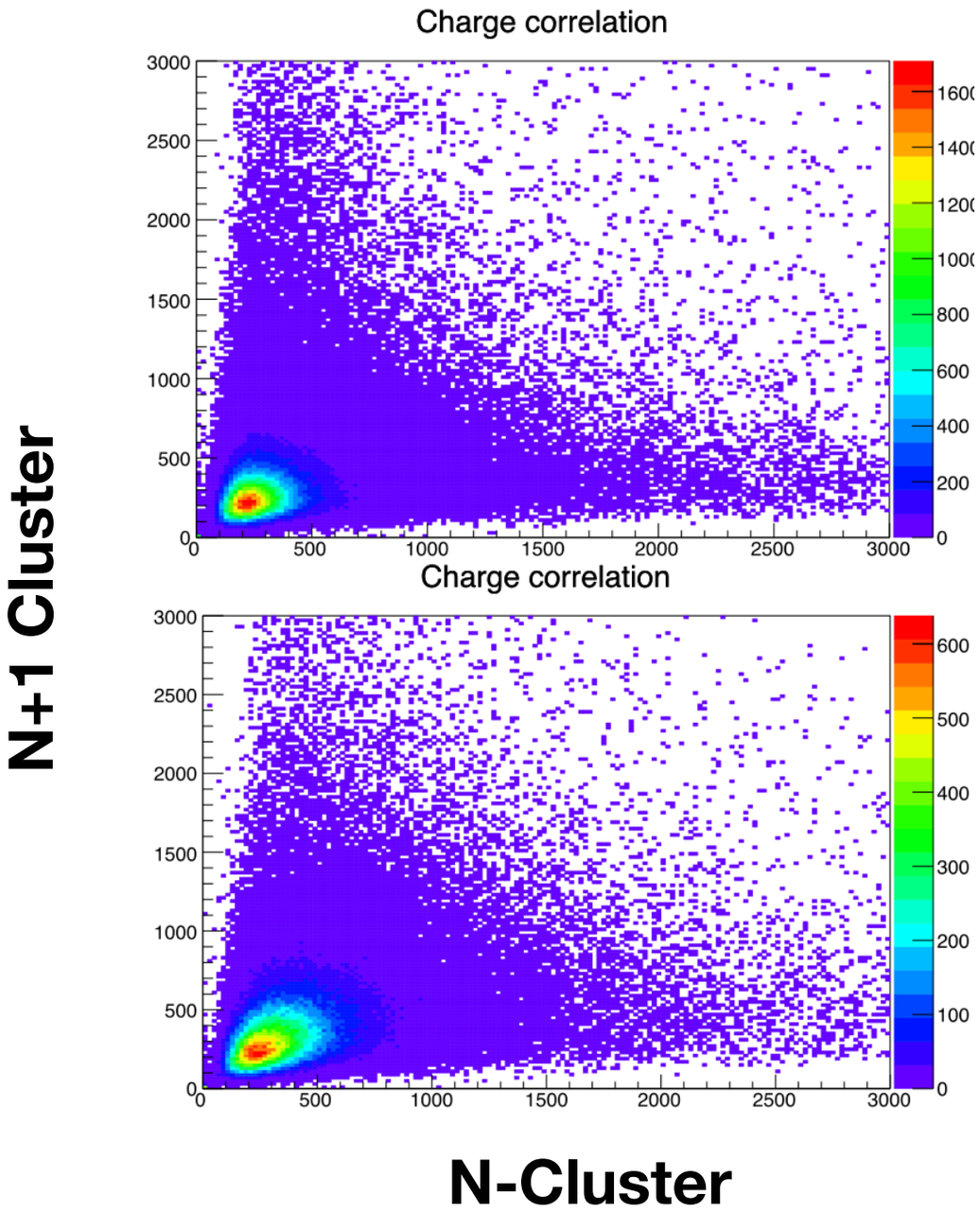
3D selection



ANALYSIS STATUS

Charge correlation

From S.Suvurov

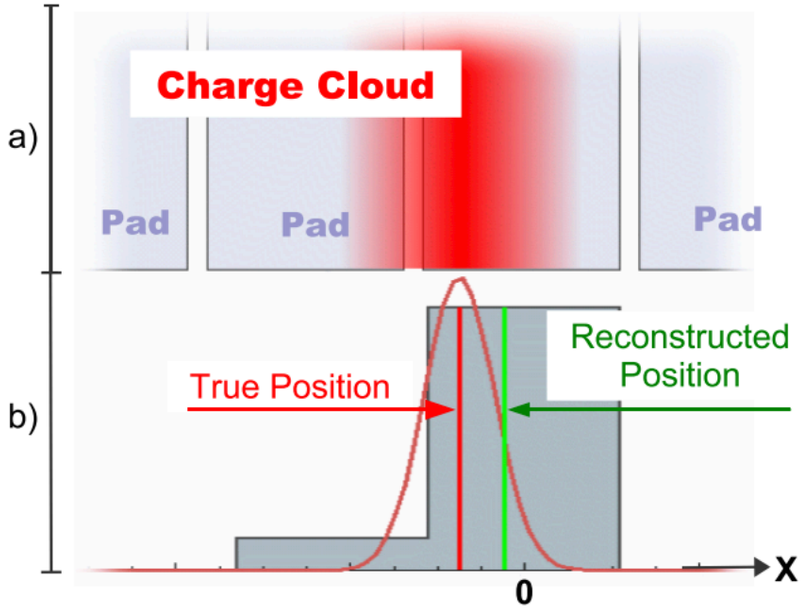


Sample:

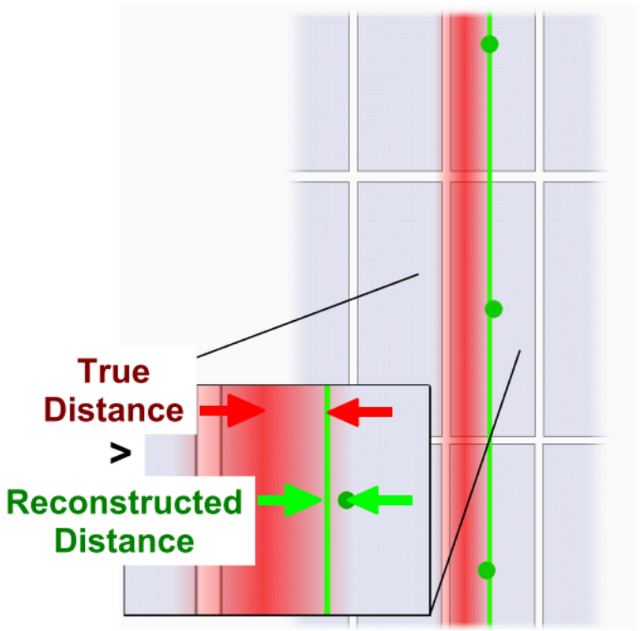
2 Gev/c muon

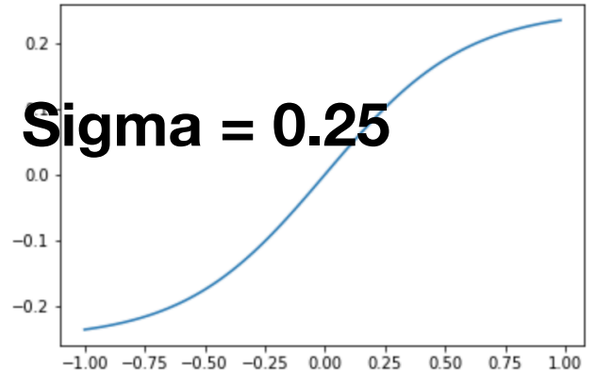
0.8 Gev/c pion trigger
(pion + electron)

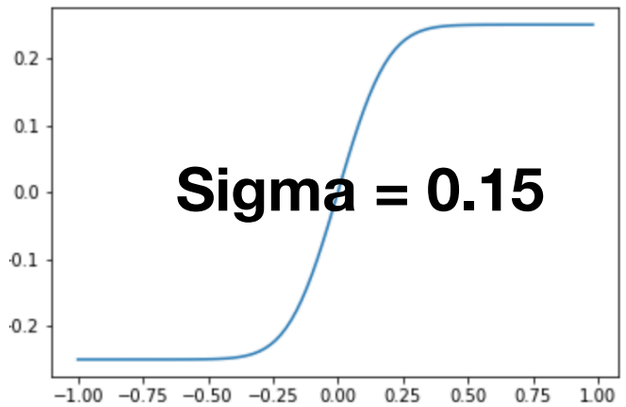
Charge correlation

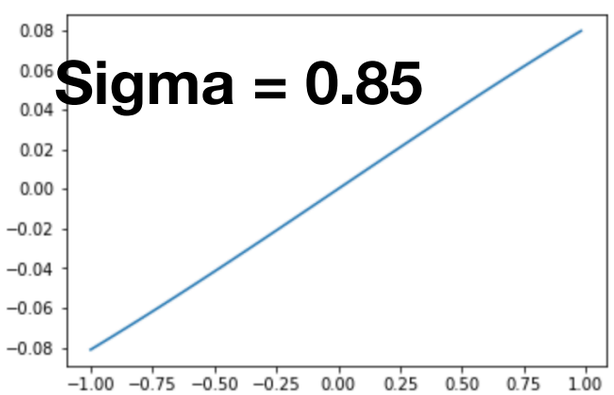


There is source of bias coming
from the size of pads…
the way to characterize and correct
his effect is using the
Pad Response Function (PRF)

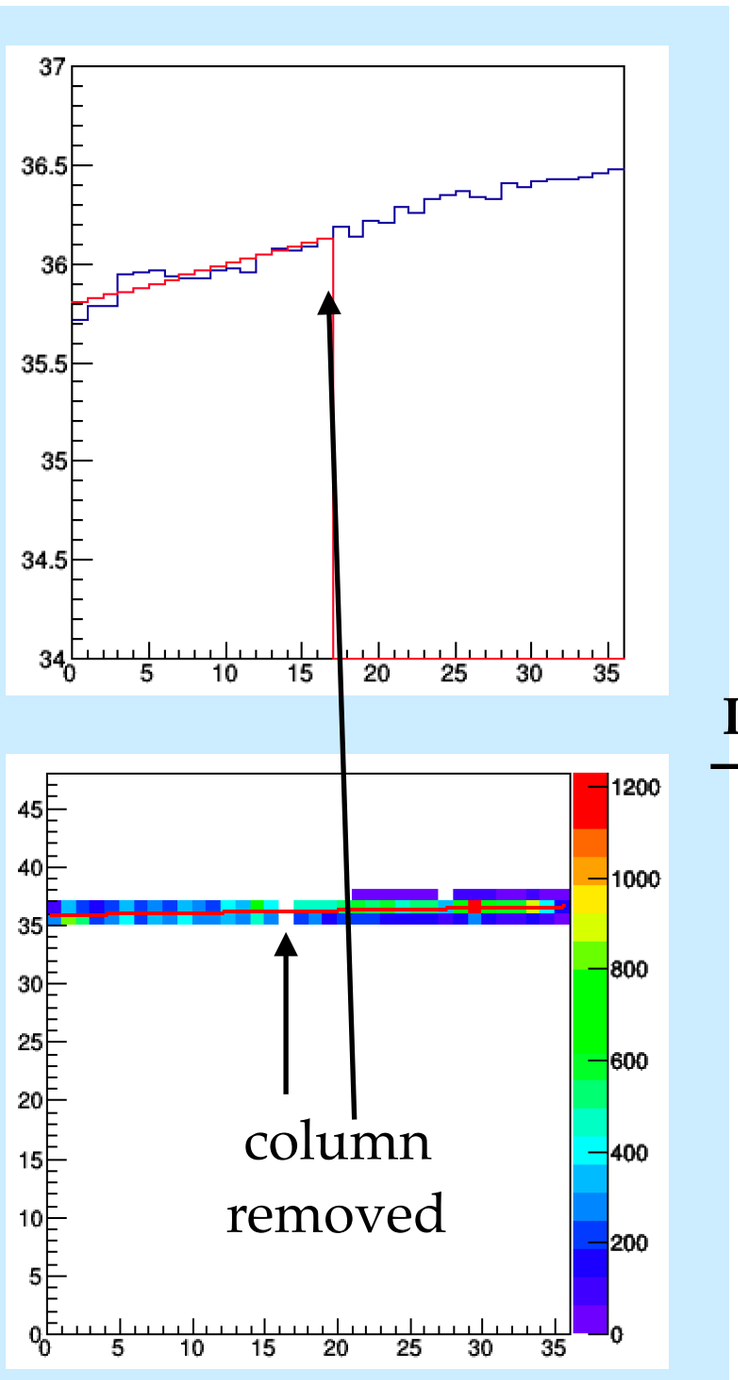




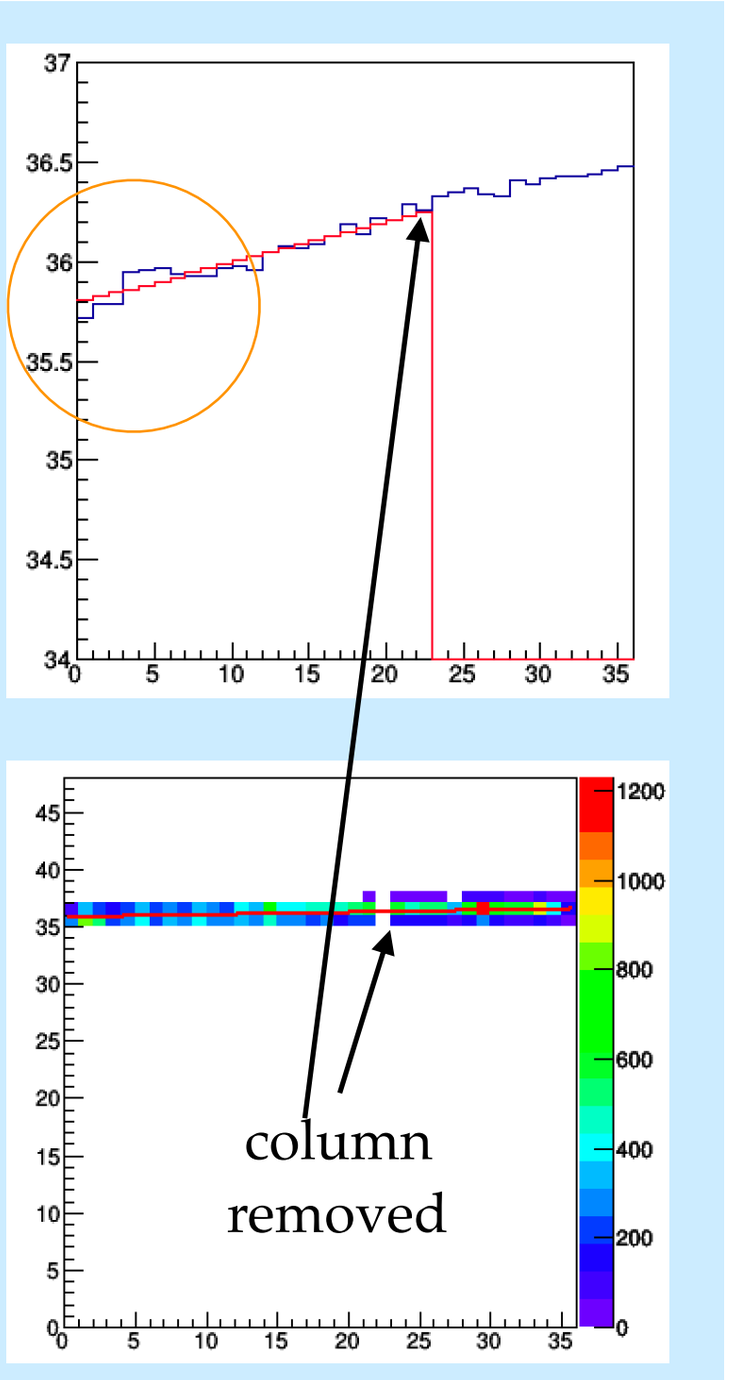




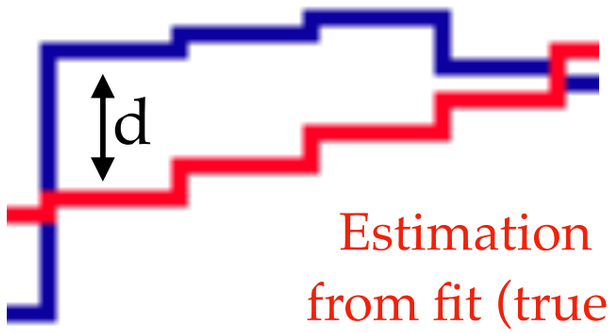
Variables definition



Column Iterations



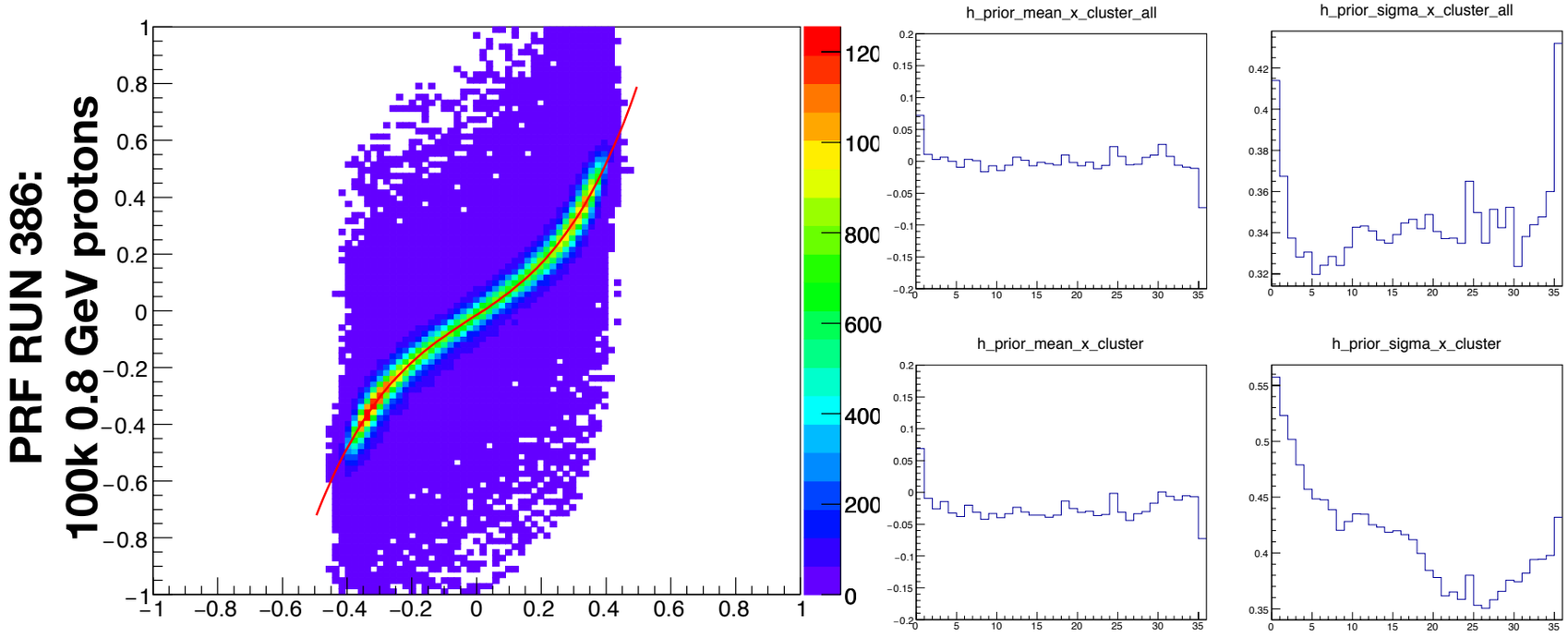
Gravity Center of the column (reconstructed)



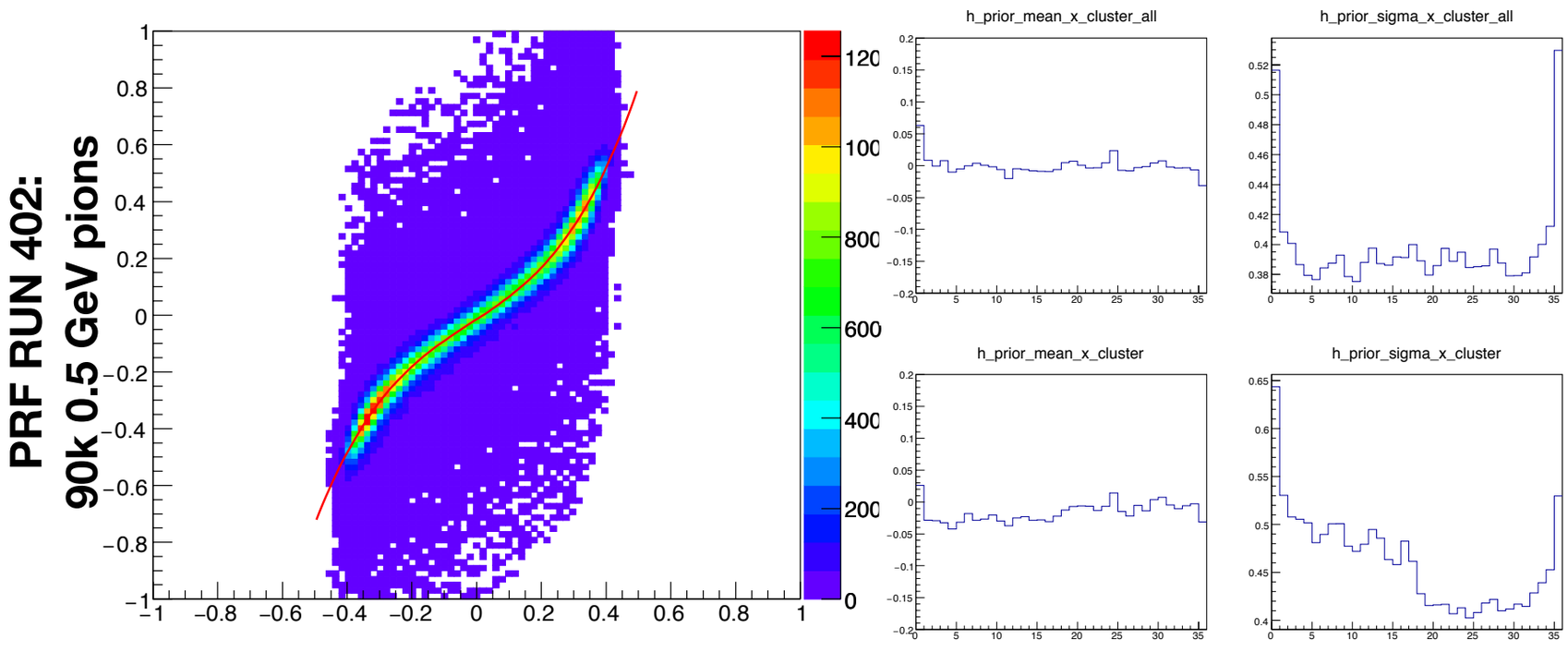
Fit can be done in 2 ways (also 2 possible distances):

1. All-1 Columns (d_1)
2. All Columns (d_2)

Pad response function
and non-corrected point resolution



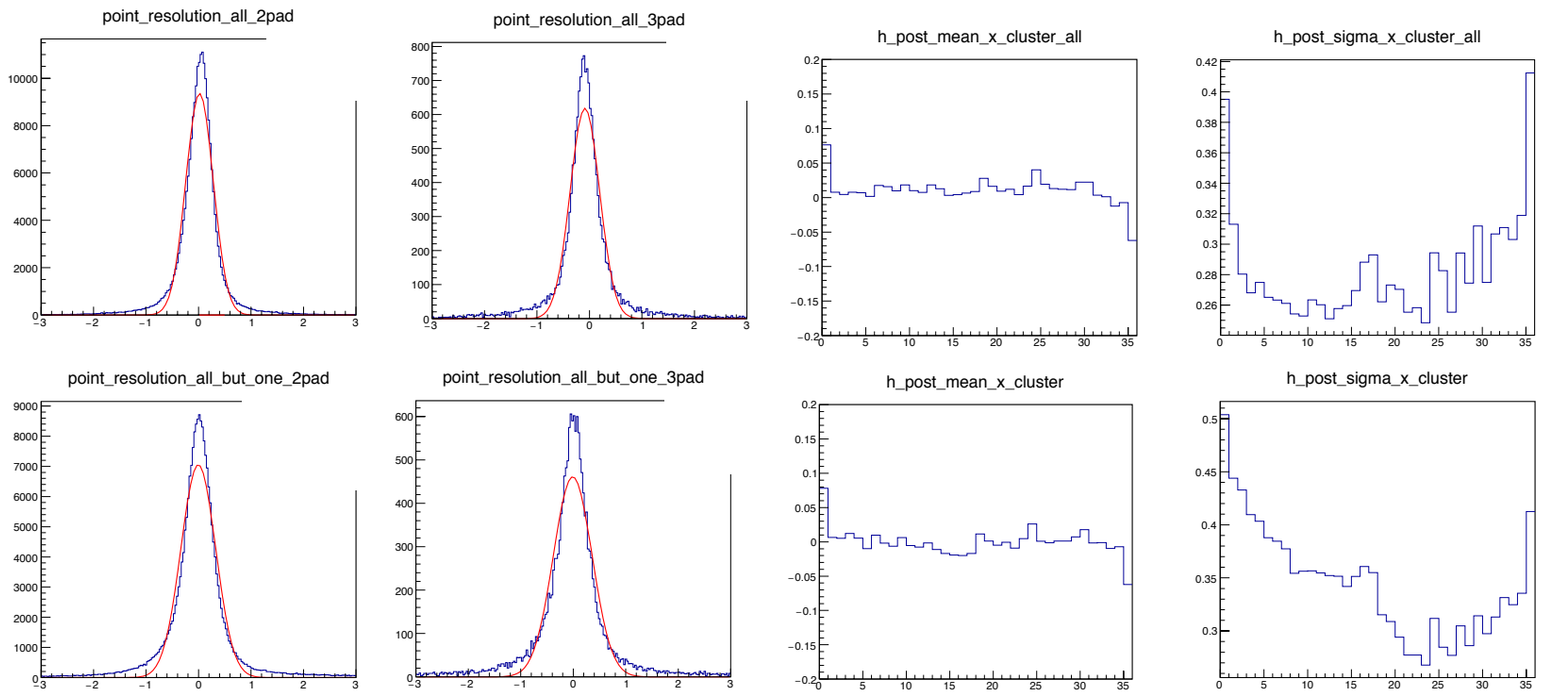
NPAD: 236312 Entries
Point resolution fitting all clusters: 0.354401
Point resolution fitting all-1 clusters: 0.442227
Final (convined) point resolution: 0.395886
1PAD: 16541 Entries
Point resolution fitting all clusters: 0
Point resolution fitting all-1 clusters: 0
Final (convined) point resolution: 0
2PAD: 204600 Entries
Point resolution fitting all clusters: 0.34006
Point resolution fitting all-1 clusters: 0.424929
Final (convined) point resolution: 0.380133
3PAD: 15171 Entries
Point resolution fitting all clusters: 0.352337
Point resolution fitting all-1 clusters: 0.418354
Final (convined) point resolution: 0.383929



NPAD: 132536 Entries
Point resolution fitting all clusters: 0.425528
Point resolution fitting all-1 clusters: 0.528037
Final (convined) point resolution: 0.47402
1PAD: 10429 Entries
Point resolution fitting all clusters: 0
Point resolution fitting all-1 clusters: 0
Final (convined) point resolution: 0
2PAD: 103721 Entries
Point resolution fitting all clusters: 0.405356
Point resolution fitting all-1 clusters: 0.512995
Final (convined) point resolution: 0.456011
3PAD: 18386 Entries
Point resolution fitting all clusters: 0.403901
Point resolution fitting all-1 clusters: 0.48147
Final (convined) point resolution: 0.440984

corrected point resolution

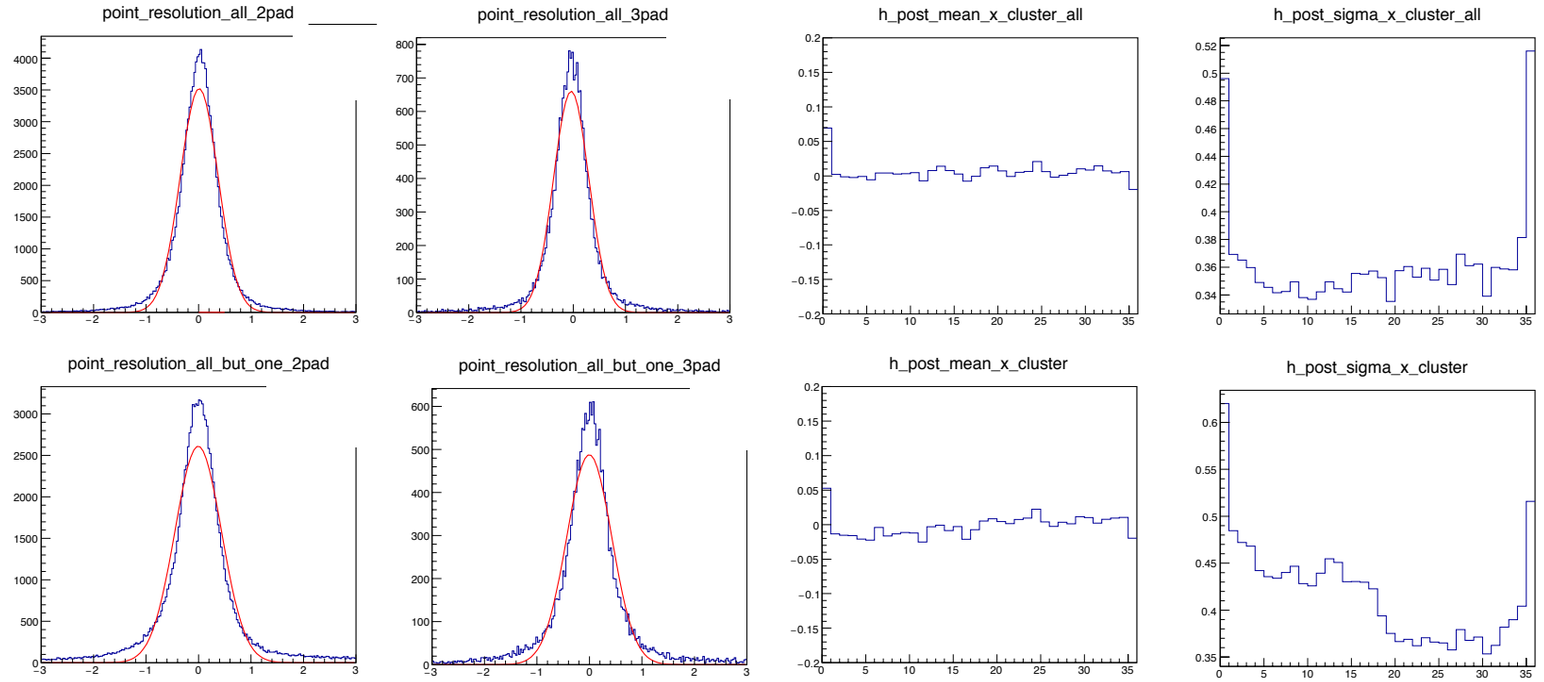
PRF RUN 386:
100k 0.8 GeV protons



NPAD: 261663 Entries
Point resolution fitting all clusters: 0.277438
Point resolution fitting all-1 clusters: 0.34883
Final (combined) point resolution: **0.311093**
2PAD: 226554 Entries
Point resolution fitting all clusters: 0.261646
Point resolution fitting all-1 clusters: 0.331938
Final (combined) point resolution: 0.294704
3PAD: 17011 Entries
Point resolution fitting all clusters: 0.28182
Point resolution fitting all-1 clusters: 0.369522
Final (combined) point resolution: 0.322705

The improvement after using PRF information is: **21.4186%**

PRF RUN 402:
90k 0.5 GeV pions



NPAD: 146711 Entries
Point resolution fitting all clusters: 0.376979
Point resolution fitting all-1 clusters: 0.461613
Final (combined) point resolution: **0.417155**
2PAD: 114867 Entries
Point resolution fitting all clusters: 0.361851
Point resolution fitting all-1 clusters: 0.444799
Final (combined) point resolution: 0.401187
3PAD: 20457 Entries
Point resolution fitting all clusters: 0.338284
Point resolution fitting all-1 clusters: 0.430047
Final (combined) point resolution: 0.381416

The improvement after using PRF information is: **11.9962%**

PRF different approach by Sergey

From S.Suvorov

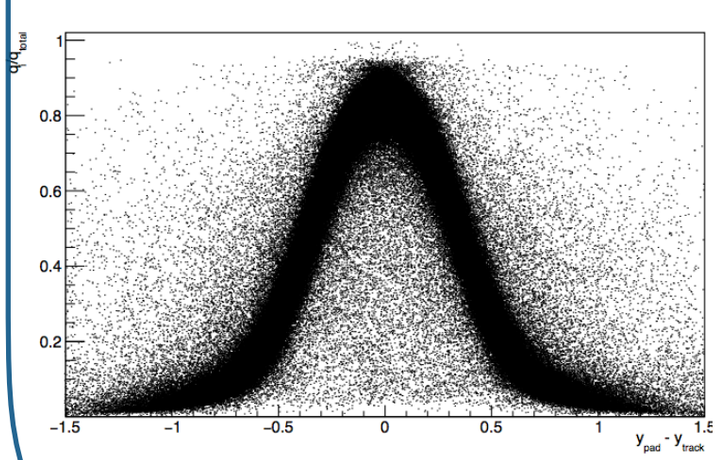
- Started with center of charge
- Perform few iterations x → PRF → x → PRF

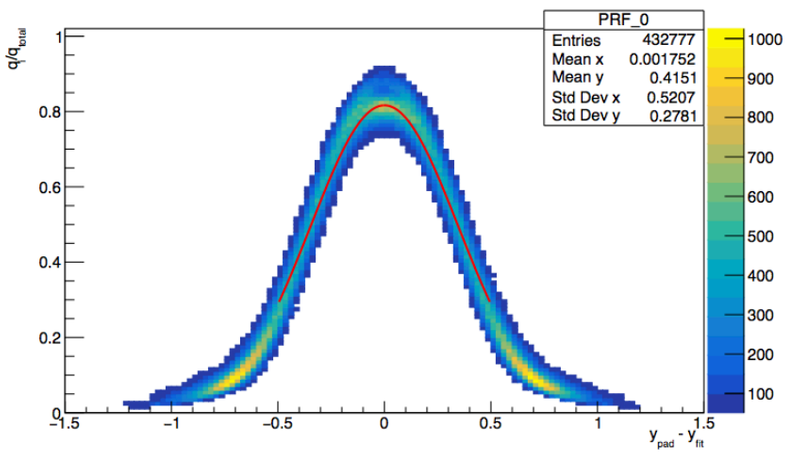
- Look at the PRF function and fit with Gaussian & Lorentzian function

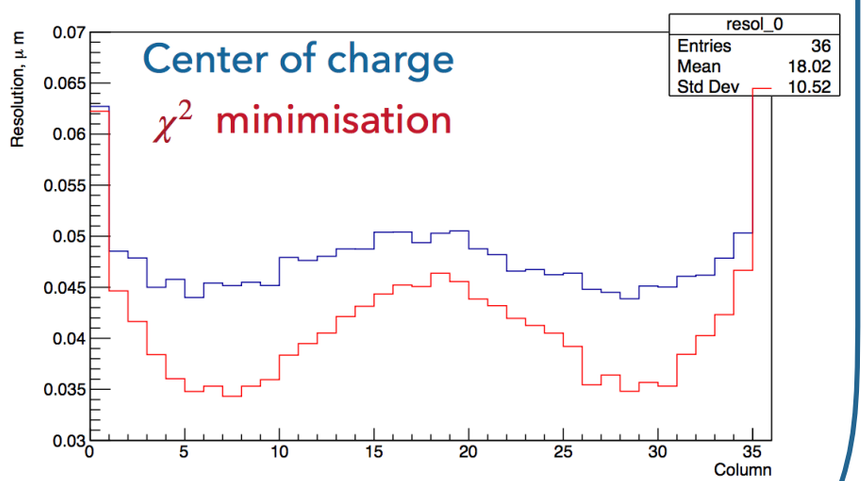
$$PRF(x,r,w) = \frac{\exp[-4\ln 2(1-r)x^2/w^2]}{1+4rx^2/w^2}$$

$$\chi^2 = \sum_{column} \left[\frac{a - PRF(y_{track} - y_{pad})}{\sigma_a} \right]^2 \qquad a = q_i/q_{total} \qquad \sigma_a = \sqrt{q_i}/q_{total}$$

$$PRF = q_i/q_{cluster}$$





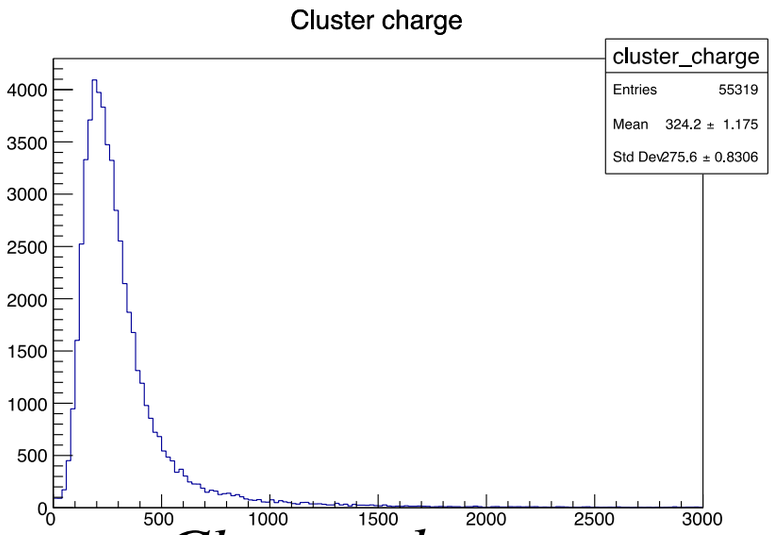


dE/dx resolution

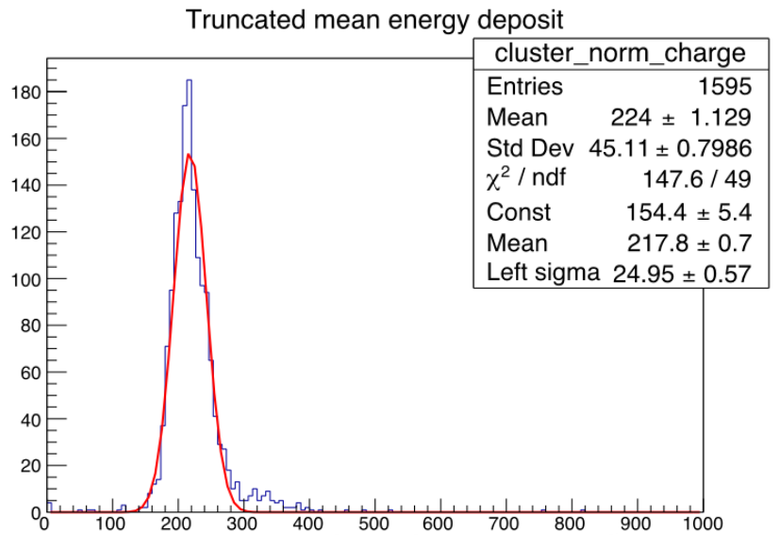
- The method:

From S.Suvorov

1. Apply the track selection
2. Take the maximum ADC vs. time for each pad
3. Sum up all pads in a column to make a ‘cluster’
4. Truncate the most higher energetic clusters take 70% of clusters sorted by increasing charge
5. Fit → profit!



Cluster charge, c.u

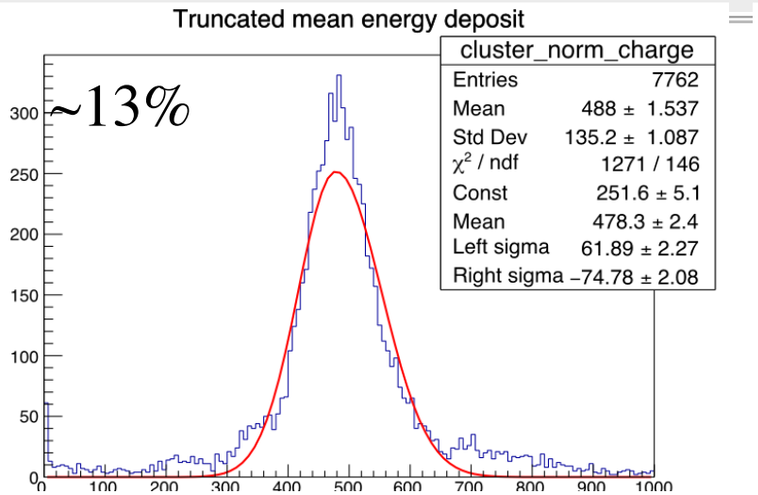


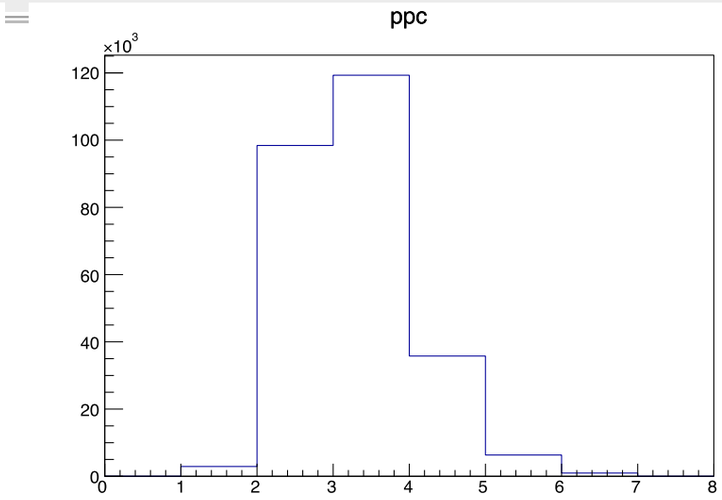
Truncated Cluster charge, c.u

0.5 GeV/c muons

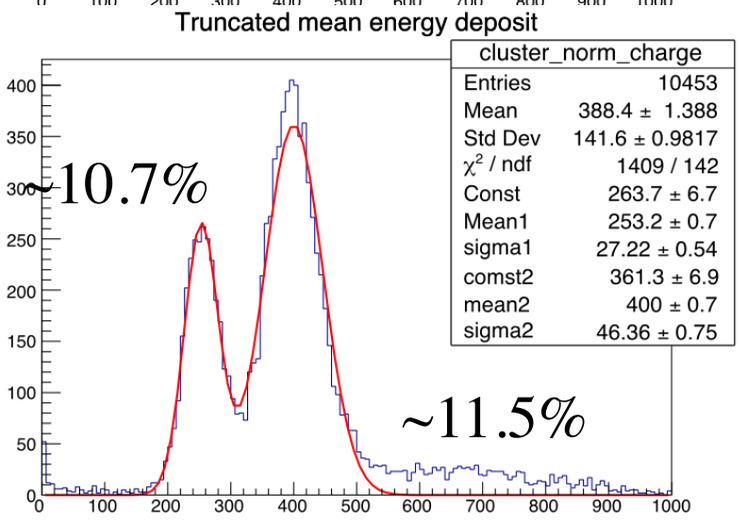
dE/dx resolution

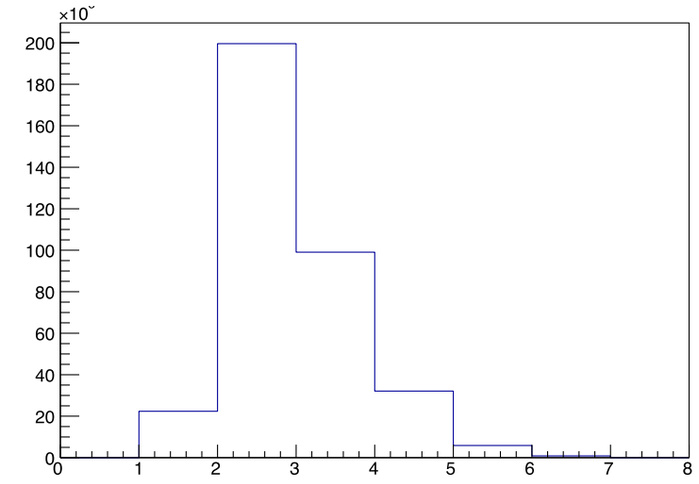
From S.Suvorov



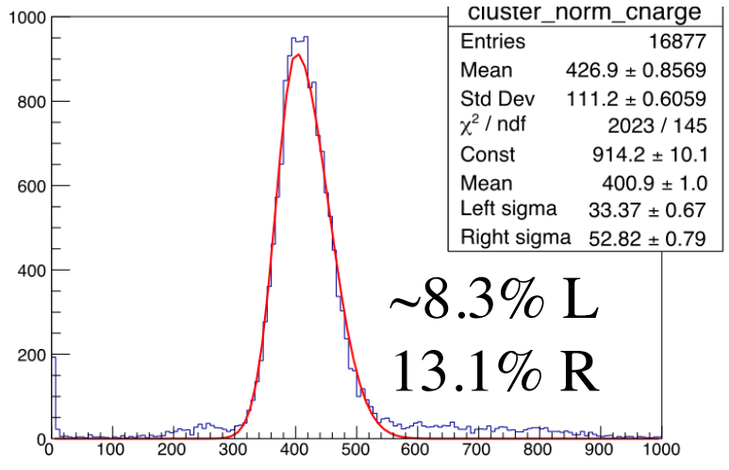


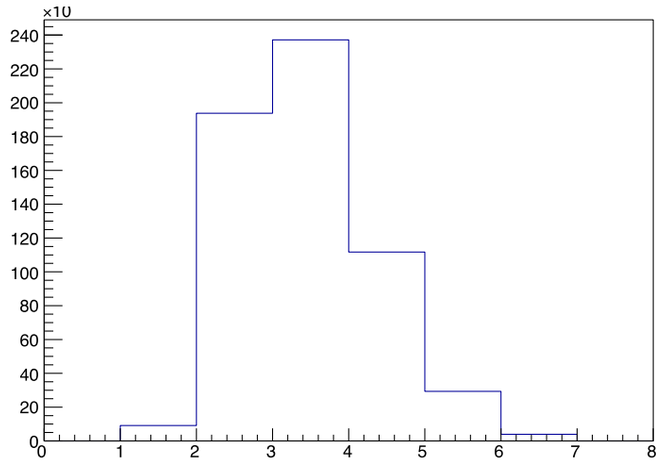
0.8 GeV/c proton





0.8 GeV/c pion trigger

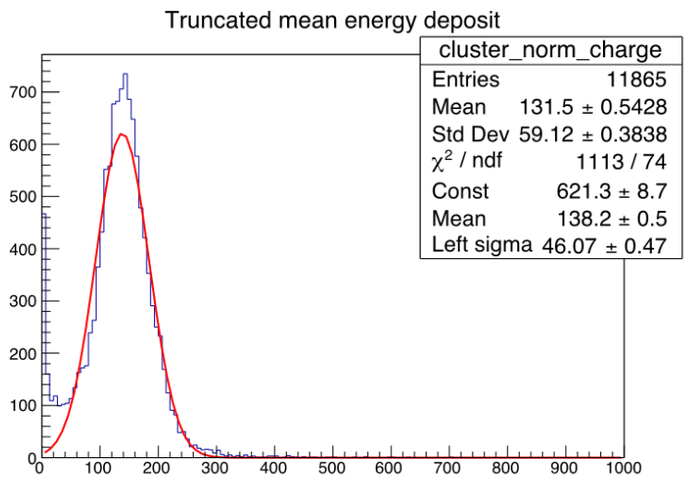


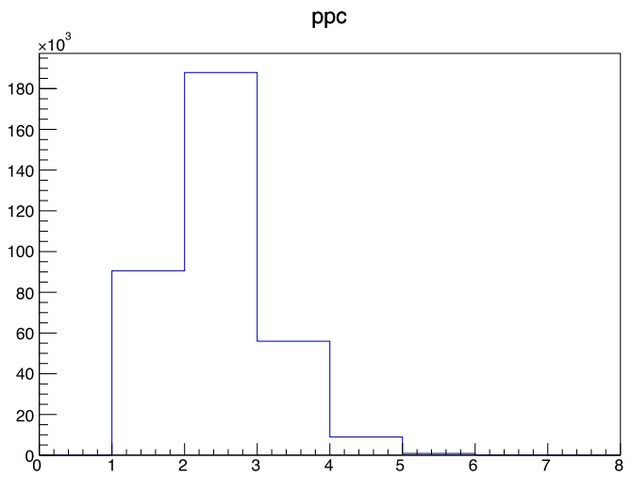


0.8 GeV/c electron trigger

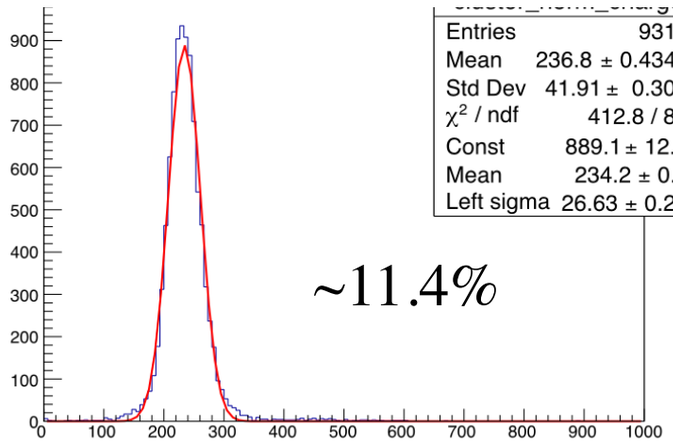
dE/dx resolution

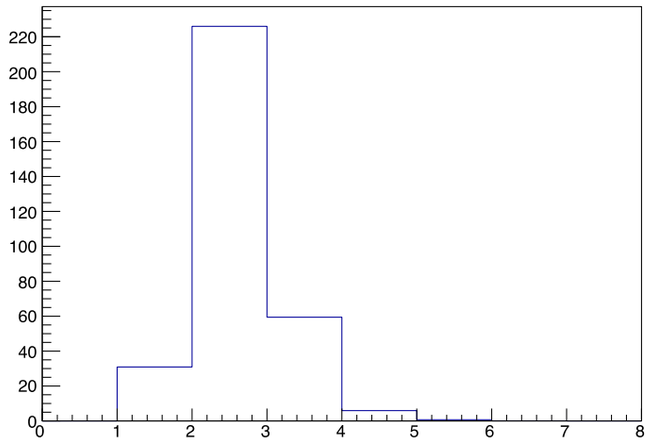
From S.Suvorov



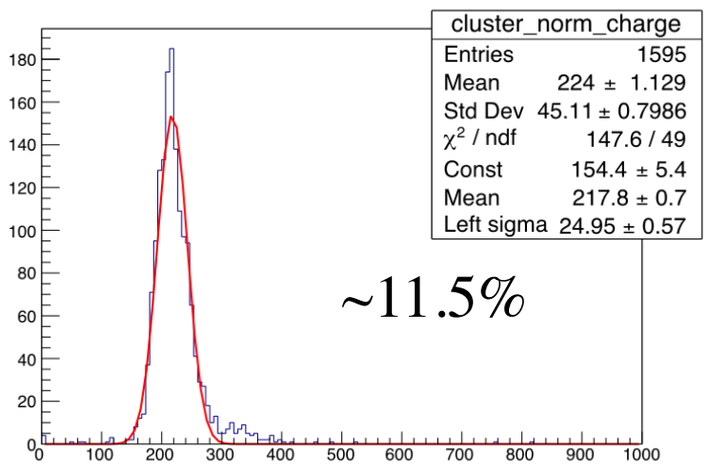


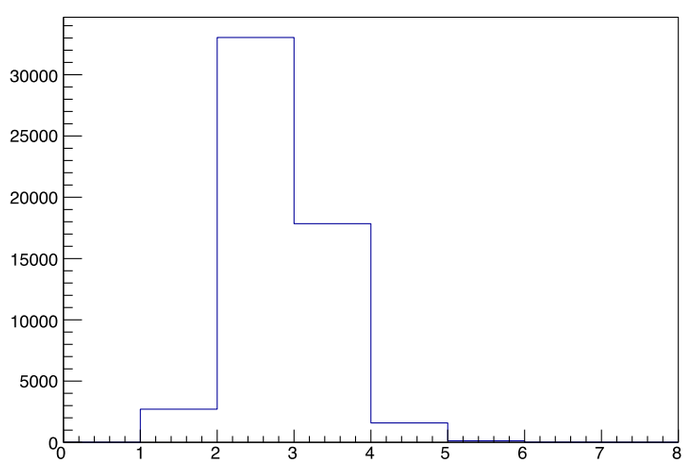
cosmic





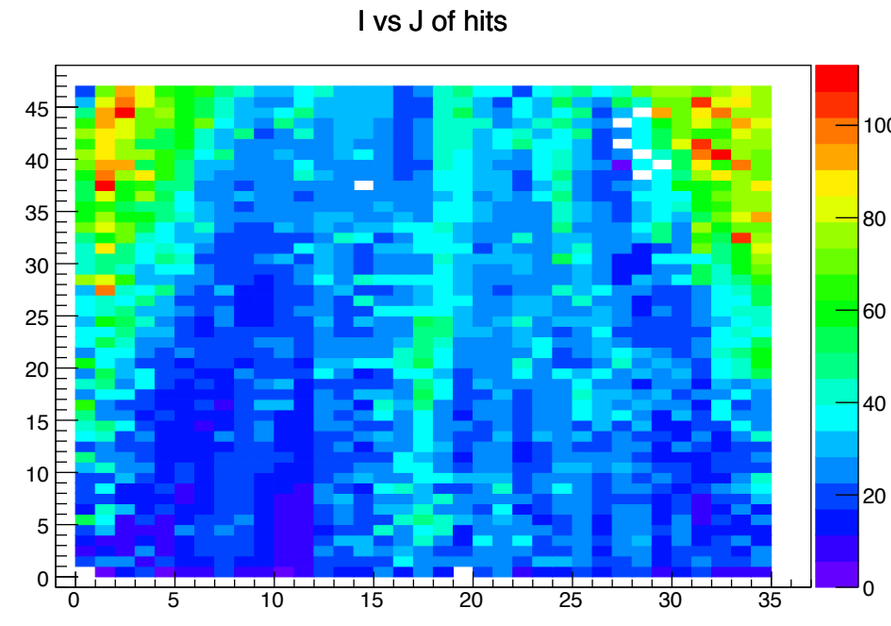
2 GeV/c muon

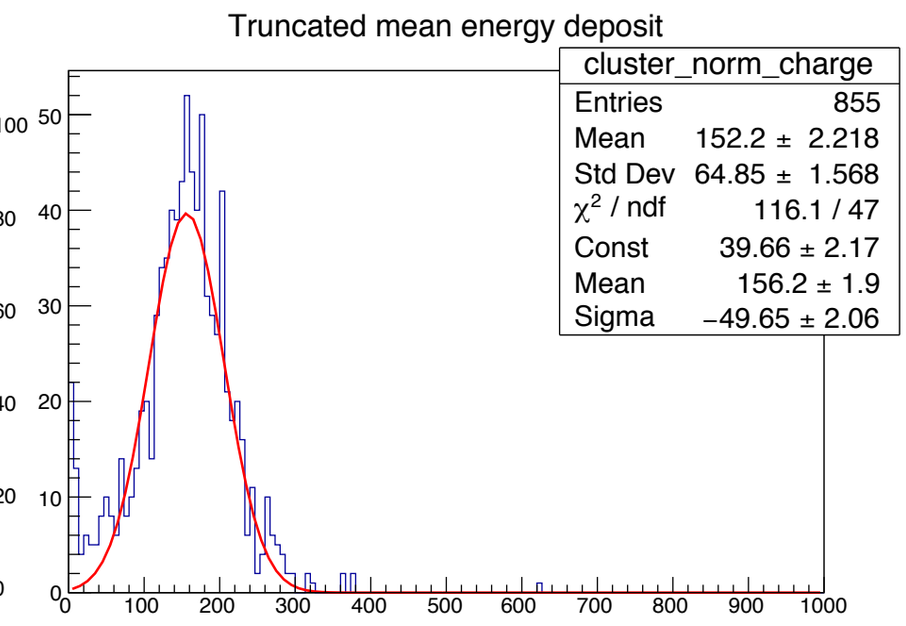


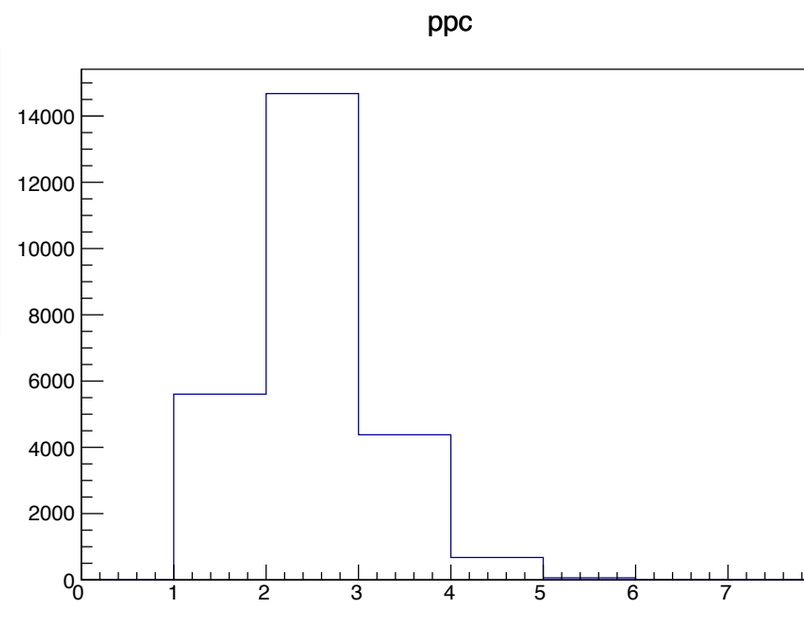


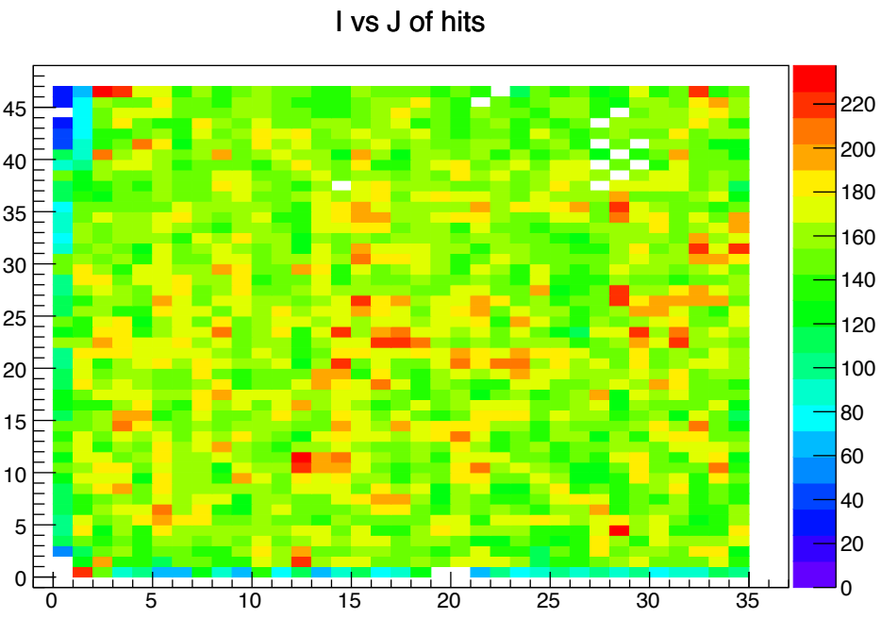
0.5 GeV/c muon

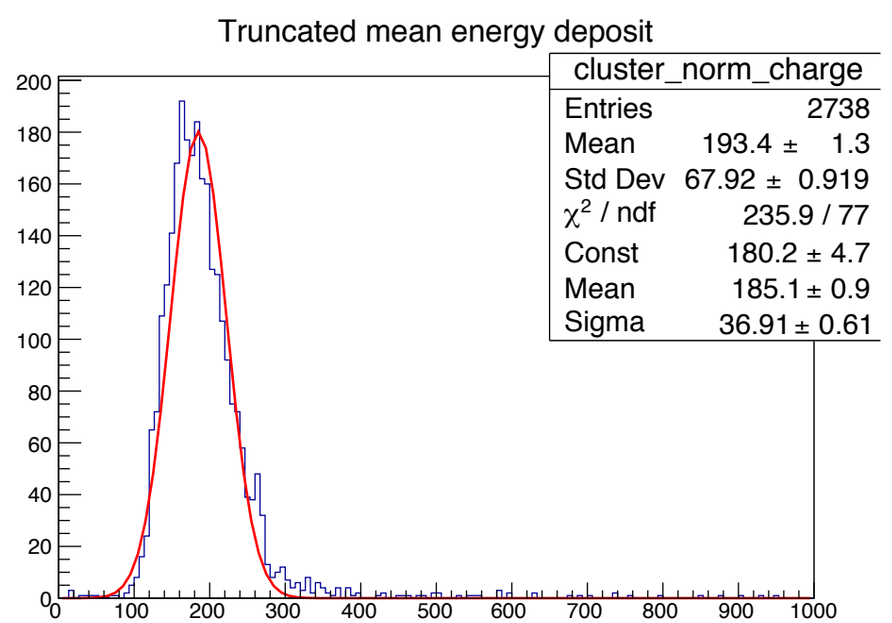
dE/dx resolution

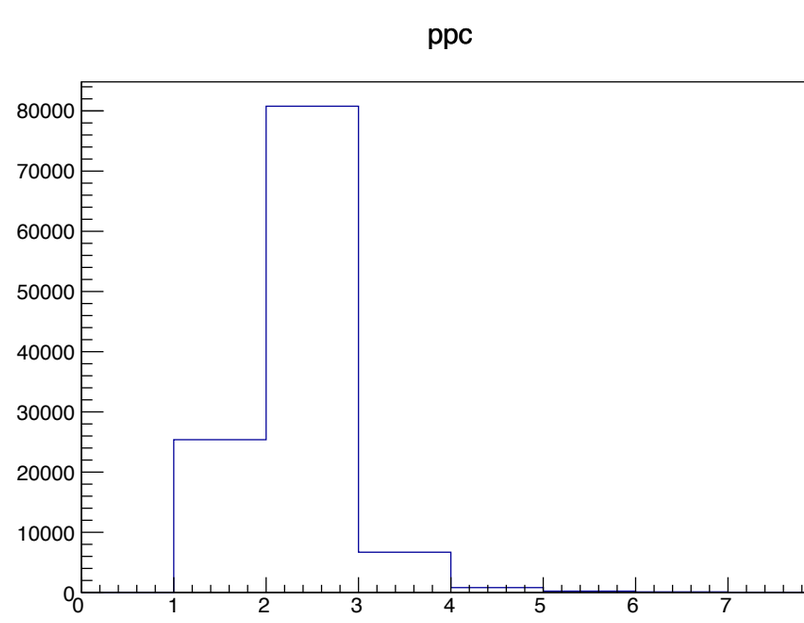






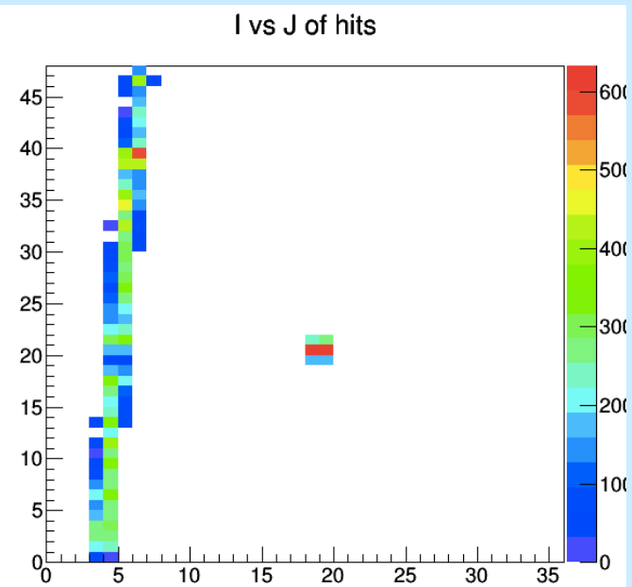


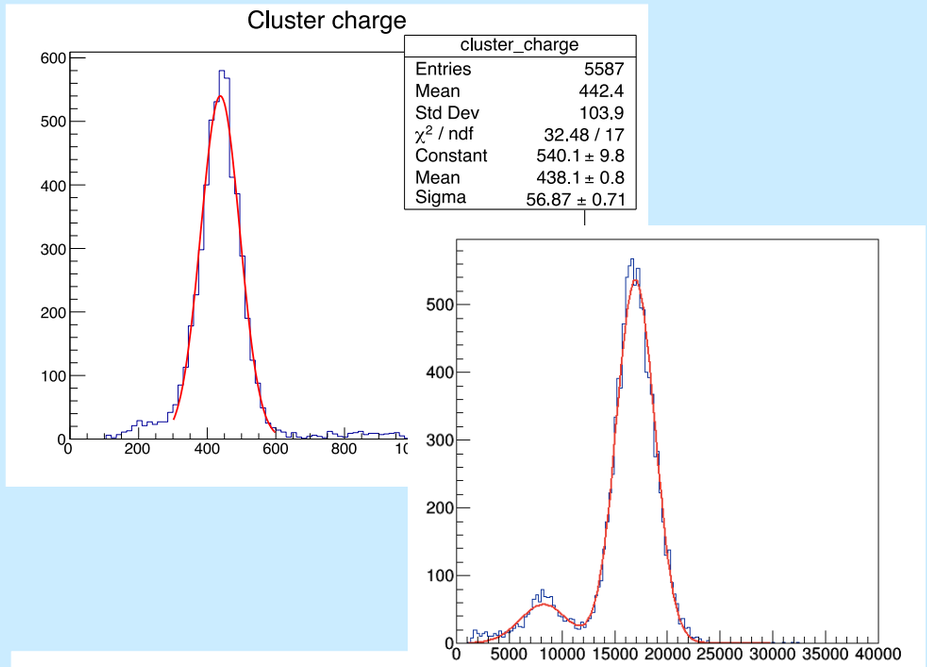


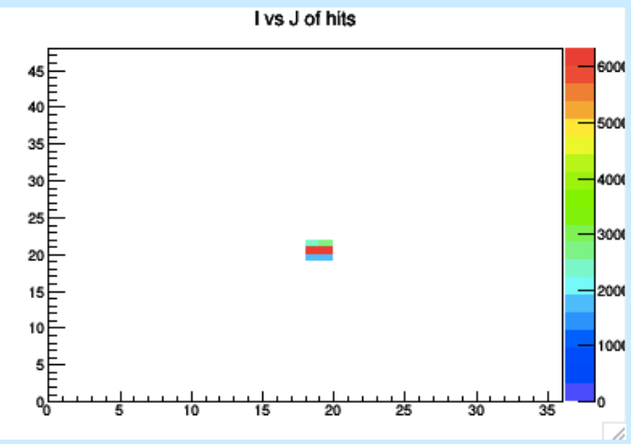


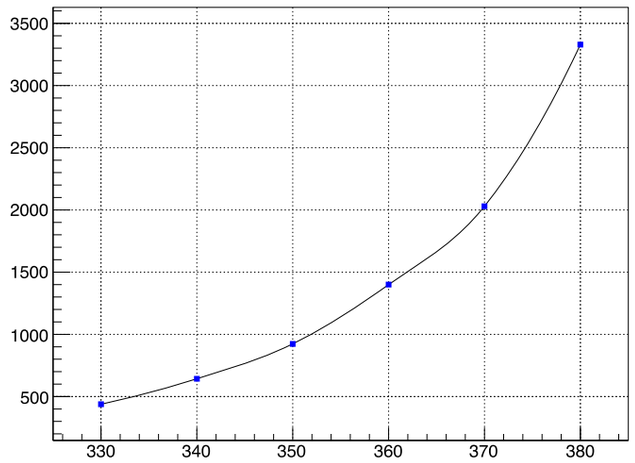
Iron 1 Cluster Selection

Duplicated Study









Iron 2 Cluster Selection

A 2 cluster selection was also developed
but it is only reliable for events with no tracks!

… very few statistics.

Looking into it it could be possible to compute
experimentally Argon absorption length
(from reabsorbed 2.9 keV photons)

It is tricky… abs length at that wavelength is know
to be ~3cm, 2 iron clusters are expected to happen
very close.