The PRISMA magnetic spectrometer: analysis and data processing

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AGATA Analysis Workshop 2025

Lyon, January 2025

Overview

Goal:
Full explanation on how to perform the analysis of an experiment with PRISMA + coupling with AGATA

Software and data structure
Structure of files and available tools

Functioning principles
Physics behind reconstruction
and identification in the spectrometer

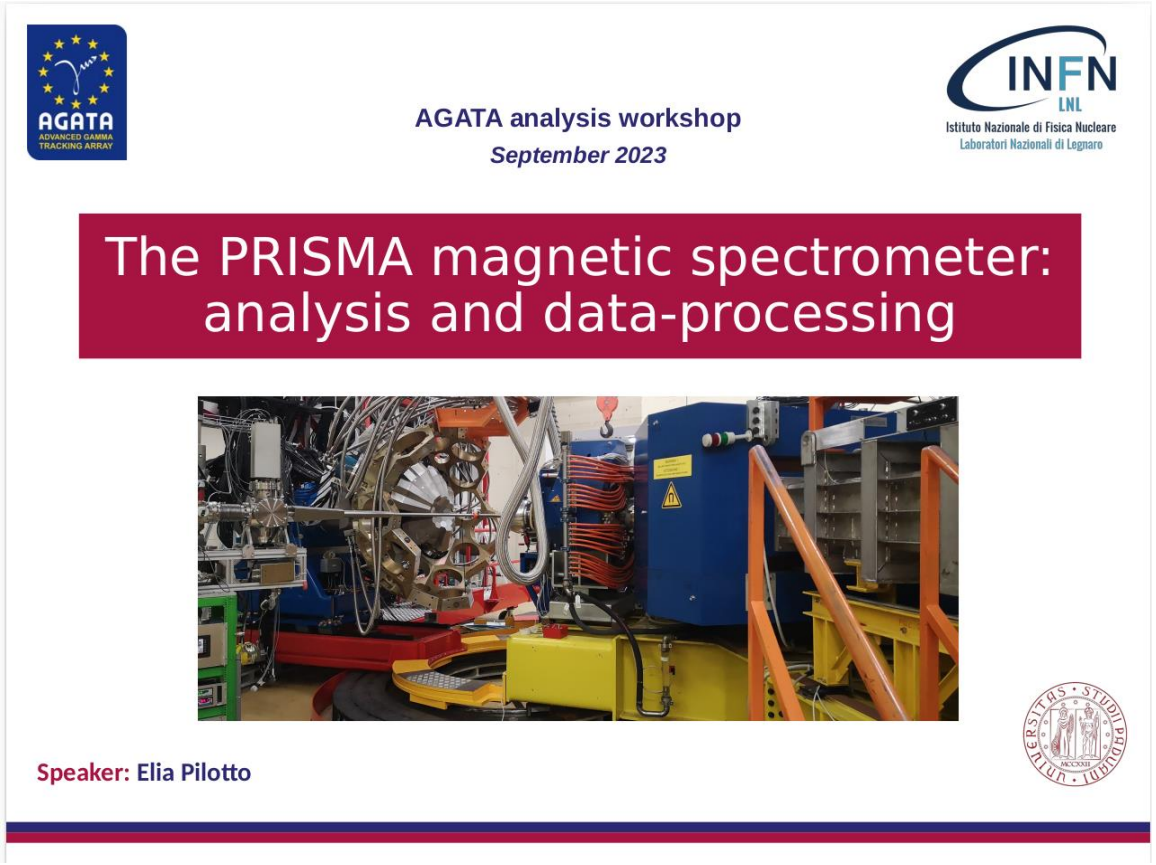
Calibrations and correction
Analysis procedure

I will use data mainly from 2 experiments:

- ^{116}Sn @ 460 MeV on ^{60}Ni (0.2 mg/cm^2), Prisma at 20°, **multinucleon transfer**
- ^{208}Pb @ 1300 MeV on ^{9}Be (2.77 mg/cm^2), Prisma at 20°, **fission in inverse kinematics**

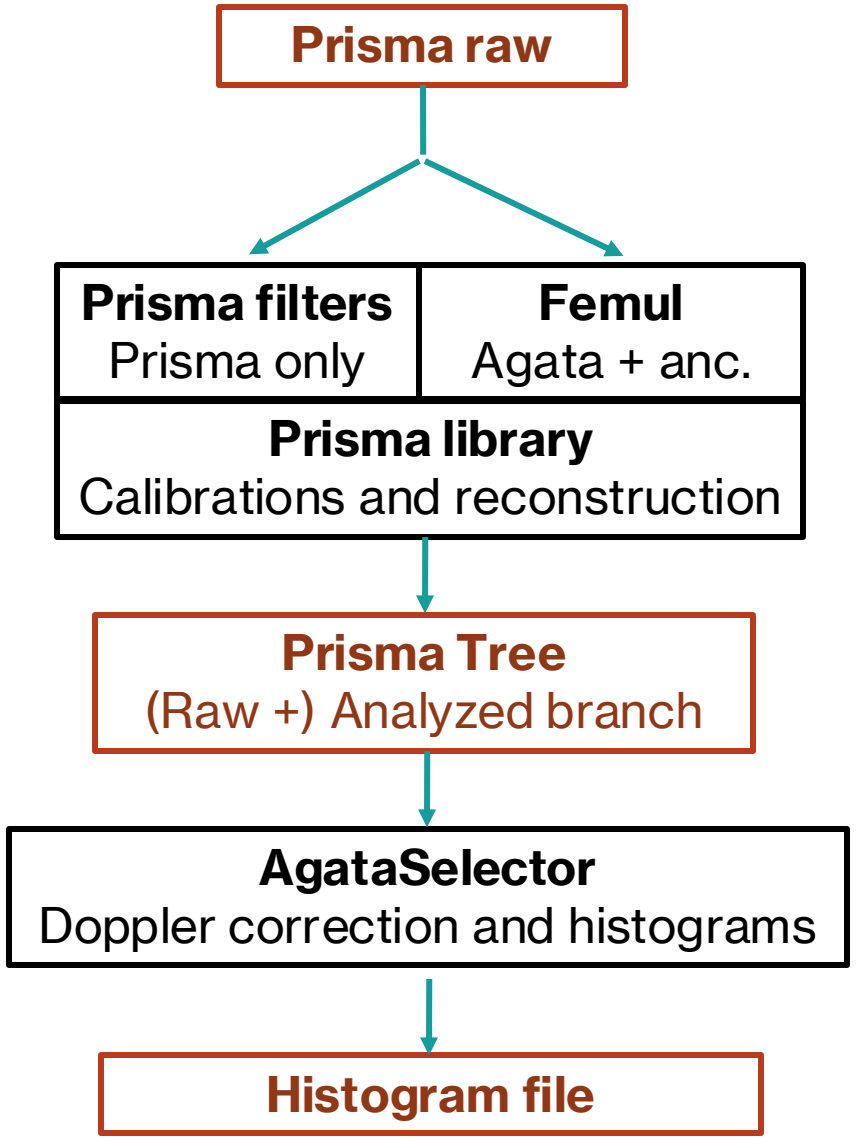
On the previous episodes

If you are doing your analysis on **PrismaFilters**, you should check the presentation by Elia Pilotto:



https://agenda.infn.it/event/36303/contributions/203916/attachments/109446/155668/PresentationPrismaAnalysis.pdf

Data processing structure: up to now



Prisma filters
Prisma only

Not very accessible, old code

Femul
Agata + anc.

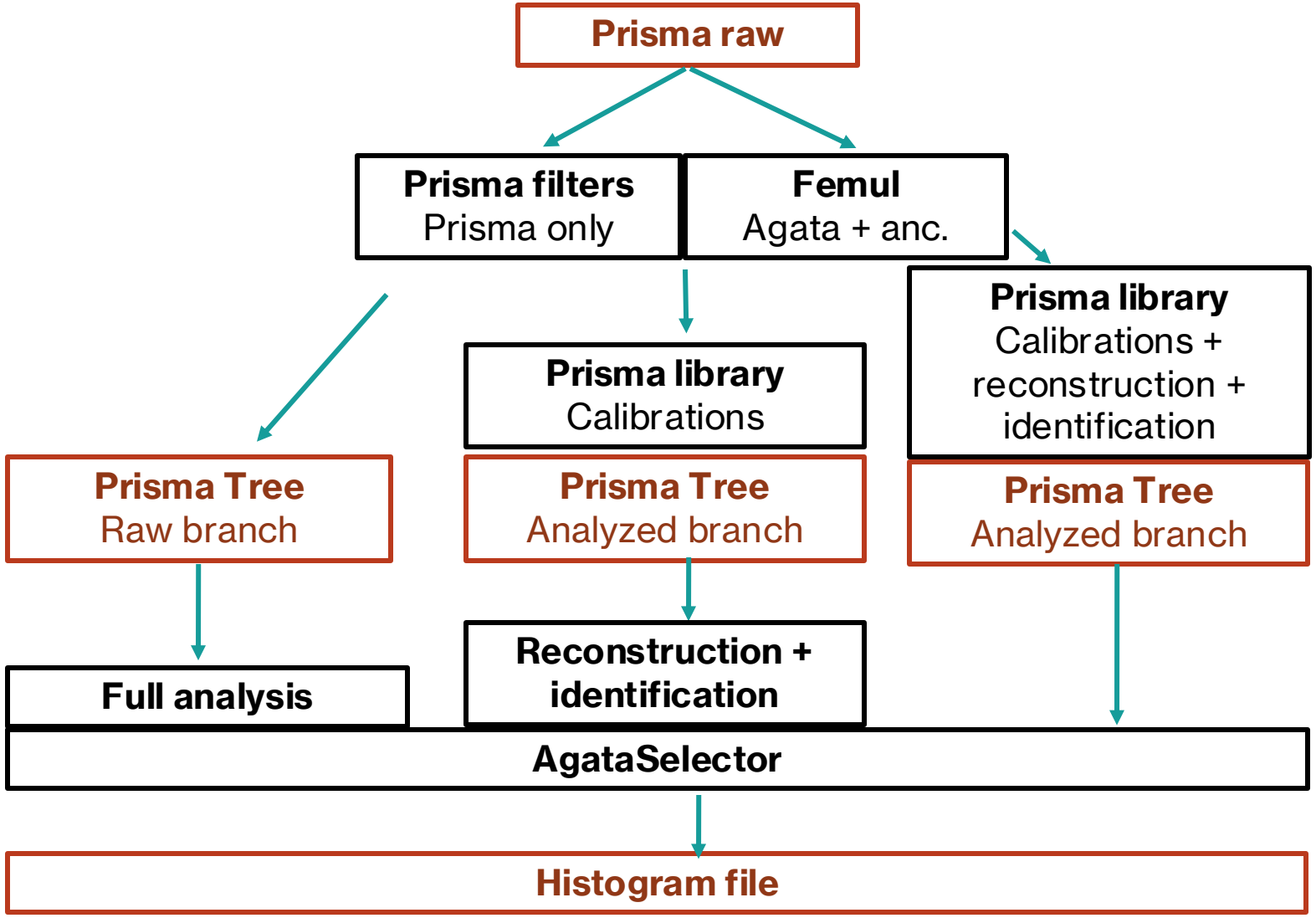
Slow processing with AGATA

Moving full analysis to AgataSelector!

For using only PrismaFilters refer to last year's presentation by **Elia Pilotto**

I will make references between the two different methods

Data processing structure: new version

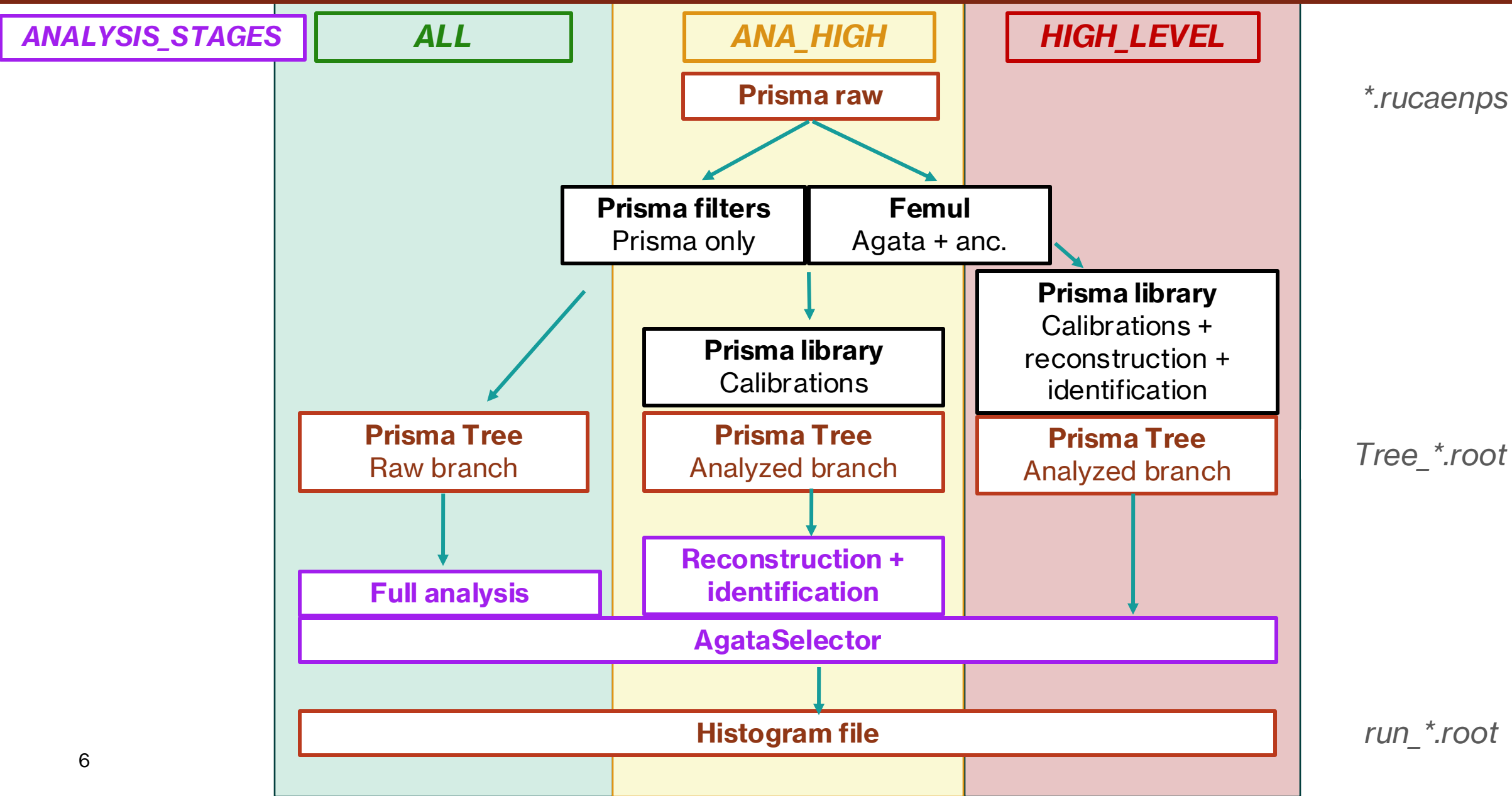


*.rucaenps

Tree_*.root

run_*.root

Data processing structure: new version



Moving to AgataSelector

https://baltig.infn.it/gamma/agataselector

We are moving towards making the AgataSelector the main tool for analysis

Advantages:

- **Faster** global processing and handling of PRISMA + AGATA -> **femul** to be run only once!
- Use of **AgataSelector Optimizer** for reconstruction / DC **--optimize**
- **Interactive tool** for setting **gates** **--set_gates**
- **Output tree** with all variables for quick checks ***ENABLE_PREPROCESSTREE YES***
- Easier to **add more features** if you need!

Reference for **PRISMA_CONF:**

ANALYSIS_STAGES HIGH_LEVEL Analysis from Filters and Selector makes only DC and plots

ANALYSIS_STAGES ANA_HIGH Calibrations from PF, Selector makes reconstruction + gates + DC and plots

ANALY

In this presentation we will assume the ***ALL*** option but there will be comparisons with Filters

Prisma Raw branch

In this presentation we will assume the ***ALL*** option.
We need the Prisma Raw branch.
2 options:

First option: Produce output PrismaTree with PrismaFilters

```
root [1] PrismaTree->Print()
******************************************************************************
*Tree    :PrismaTree: PrismaTree                                             *
*Entries :   130450 : Total =        74726850 bytes  File  Size =   27288187 *
*        :          : Tree compression factor =   2.74                       *
******************************************************************************
*Br    0 :TSPrisma  : TSPrisma/l                                             *
*Entries :   130450 : Total  Size=    1047258 bytes  File Size  =     612250 *
*Baskets :       33 : Basket Size=      32000 bytes  Compression=   1.71     *
*.............................................................................*
*Br    1 :Raw       : MCP_raw[3]/s:PPAC_Xleft_raw[10]/s:                     *
*         | PPAC_Xright_raw[10]/s:PPAC_Cathode_raw[10]/s:PPAC_Y_raw[2]/s:    *
*         | TOF_raw[10]/s:IC_A_raw[10]/s:IC_B_raw[10]/s:IC_C_raw[10]/s:      *
*         | IC_D_raw[10]/s:IC_A_Drift_raw[10]/s:IC_B_Drift_raw[10]/s:        *
*         | IC_C_Drift_raw[10]/s:Side_A_raw[2]/s:Side_B_raw[2]/s:            *
*         | Side_C_raw[2]/s:Side_D_raw[2]/s:Monitors_raw[2]:TAC_LT_VTS/s     *
*Entries :   130450 : Total  Size=   32975021 bytes  File Size  =   12837810 *
*Baskets :     1036 : Basket Size=      32000 bytes  Compression=   2.57     *
*.............................................................................*
*Br    2 :Analyzed  : MONITOR_1/F:MONITOR_2/F:MCP_X/F:MCP_Y/F:MCP_Q/F:       *
*         | MCP_Theta/F:MCP_Phi/F:X_FP/F:Y_FP/F:TOF/F:IC_Pads[40]/F:IC_E/F:  *
*         | IC_DE_A/F:IC_DE_AB/F:IC_RANGE/F:IC_Drift_A/F:IC_Drift_B/F:       *
*         | IC_Drift_C/F:Theta/F:Phi/F:Beta/F:Length/F:Radius/F:RBeta/F:     *
*         | A_over_q_uncal/F:A_over_q/F:Mass/F:Qvalue/F:Theta_BP/F:Phi_BP/F: *
*         | Beta_BP/F:TAC_LT_LTS/F:Theta_FP/F:Phi_FP/F:IC_col_a/b:IC_col_b/b:*
*         | IC_col_c/b:IC_col_d/b:IC_a_numpads/b:IC_b_numpads/b:             *
*         | IC_c_numpads/b:IC_d_numpads/b:Z_Nr/b:Q_Nr/b:A_Nr/b:mcp_ok/b:     *
*         | tof_ok/b:traj_ok/b:side_ok/b:ic_ok/b:z_ok/b:q_ok/b:a_ok/b        *
*Entries :   130450 : Total  Size=   40703906 bytes  File Size  =   13812917 *
*Baskets :     1279 : Basket Size=      32000 bytes  Compression=   2.94     *
```

Prisma only, faster for calibrations

Prisma Raw branch

Second option:
Run replay with linked prisma_000#.adf

gen_conf.py:

```
TB_PRISMA=(
...
"WriteRawTree",
#"WriteAnaTree",
#"DoPrismaAnalysis"
)

EventMerger_MERGER=(
"ActualClass          EventMerger",
"SaveDataDir          $SAVEDIR/$MERGER ",
"Window               500",
"keyIn                event:data:psa",
"keyIn                event:ranc",
"keyOut               event:data",
"MinFold              2",
)
```

Processes **ONLY** events with **AGATA + ancillary**
(you will not have events with 1 detector alone)
Smaller output file and **faster** replay

Replay/run_0046

```
   1891 Jan  2 16:57 ADF.conf
   4096 Jan  2 16:57 Conf
     67 Jan  2 16:57 Data -> /agata07_data3/AGATAD_P2_EXP_011/run_0046_11-02-2023_18h54m42s/Data
   4096 Jan  3 15:38 Out
   4096 Jan  2 17:02 Out_singleFile
    522 Jan  2 16:57 Topology_FromPSAToTreePRISMA.conf
  62562 Jan  3 15:37 gen_conf_46.py
2479504 Jan  3 16:38 log_EXP_011_run_0046.txt
     74 Jan  2 17:00 prisma_0000.adf -> /agata07_data8/fangelini/EXP_011/PRISMA/Runs/run_0046/prismaBU_0000.adf_00
     74 Jan  2 17:00 prisma_0001.adf -> /agata07_data8/fangelini/EXP_011/PRISMA/Runs/run_0046/prismaBU_0001.adf_00
     74 Jan  2 17:00 prisma_0002.adf -> /agata07_data8/fangelini/EXP_011/PRISMA/Runs/run_0046/prismaBU_0002.adf_00
```

```
LOOP CRYS 00A 00B 00C 01A 01B 01C 02A 02B 02C 04A 04B 04C
 05B 05C 06A 06B 06C 07A 07B 07C 08A 08B 08C 09A 09B 09C
10A 10B 10C 11A 11B 11C 13A 13B 13C

Chain 3       CRYS
Producer      BasicAFP
Filter        PostPSAFilter
Dispatcher    EventBuilder
ENDLOOP

Chain 2       Builder/
Builder       EventBuilder
#Consumer      BasicAFC
Dispatcher    EventMerger

Chain 2       prisma/
Producer      BasicAFP
Dispatcher    EventMerger

Chain 3       Merger/
Builder       EventMerger
Filter        TrackingFilterOFT
Consumer      TreeBuilder
```

Topology_FromPSAToTreePRISMA.conf

With AGATA, check with gamma rays

In the hands-on you will have this output

selector.conf

```
PRISMA_CONF
DE_TYPE             0       #           DE variable used for Z gates: 0 -> DE_AB, 1 -> DE_A, 2 -> RANGE(not implemented),
                            #           3 -> DE_A_corr vs E_res_corr, 4 -> Zed from Z_lines
CHARGE_TYPE         0       #           DE variable used for Z gates: 0 -> IC_E vs RBeta, 1 -> IC_E/RBeta vs IC_E,
                            #           2 -> BETA vs X_FP, 3 -> CHARGE vs A/Q, 4 -> Charge_cal, 5 -> Q_float from Q_lines
COINC_W_LEFT        -1      #           Time window left with the same type of det
COINC_W_RIGHT       1       #           Time window right with with the same type of det
MAX_IC_ENE          7000    #           Maximum IC energy in histograms
MAX_IC_dENE         5000    #           Maximum IC energy of deltaE in histograms
AQ_NBINS            1000    #           Number of bins in A over Q plots
MAX_AOVERQ            4     #           Maximum A over Q in histograms
MIN_AOVERQ            2     #           Maximum A over Q in histograms
MAX_RBETA           0.2     #           Maximum beta in histograms
MIN_RBETA           0.1     #           Maximum beta in histograms
TAC_OFFSET          0       #           Offset for prisma tac
TAC_GAIN            1       #           Gain for prisma tac
TOF_OFFSET          -8.5    ns          Offset for recalibration of TOF
TOF_GAIN            1       #           Gain for recalibration of TOF
PHI                 0       deg         Detector phi rotation for optimization purposes
ANGLE               20      deg         Detector angle. For AGATA should be 180-prisma_angle
TIME_UNIT           10      ns          Timestamp unit, should 10*ns
CFD_UNIT            0       ns          Cfd units
MCP_ANGLE           135     deg         Intrinsic theta rotation of MCP
Z_ROT_ANGLE         6       deg         Z rotation angle
A_RANGE             48 70   #           A for plots: min max
Z_RANGE             24 30   #           Z for plots: min max
BROKEN_PPAC_CHANNELS    9 0 #           Broken MWPPAC segments: 1 -> broken, 0-> not broken
BROKEN_IC_CHANNELS      2 1 #           Broken ionization channel segments: 1 -> broken, 0-> not broken
#BROKEN_IC_CHANNELS     4 1 #           Broken ionization channel segments: 1 -> broken, 0-> not broken
BETA_AVG            0 0 0.06    #           Average Doppler correction for detector
#AQ_PLOTS           24 20 21    #           A/Q conf for histos. Z qmin qmax
#AQ_PLOTS           25 21 22    #           A/Q conf for histos. Z qmin qmax
#AQ_PLOTS           26 21 23    #           A/Q conf for histos. Z qmin qmax
AQ_PLOTS            27 22 24    #           A/Q conf for histos. Z qmin qmax
AQ_PLOTS            28 22 26    #           A/Q conf for histos. Z qmin qmax
AQ_PLOTS            29 24 26    #           A/Q conf for histos. Z qmin qmax
#AQ_PLOTS           30 24 25    #           A/Q conf for histos. Z qmin qmax
```

selector.conf

```
# Solver parameters
B_QUADRUPOLE            0.637796    T           Magnetic field of quadrupole
#B_DIPOLE               0.699570    T           Magnetic field of dipole
B_DIPOLE                0.7250229   T           Magnetic field of dipole
QUAD_LENGTH             460         mm          Length of quadrupole
QUAD_RADIUS             157         mm          Radius of quadrupole
TARGET_QUAD_DISTANCE    420         mm          Distance from target to quadrupole
OUT_DIPOLE_ANGLE        125         deg         Angle of dipole in degrees
IN_DIPOLE_ANGLE         20          deg         Angle of dipole in degrees
FP_TOLERANCE            1           mm          Tolerance of focal plane
TARGET_MCP_DISTANCE     250         mm          Distance from target to MCP
TARGET_DIPOLE_DISTANCE  1600        mm          Distance from target to dipole
DIPOLE_RADIUS           1200        mm          Radius of dipole
DIPOLE_HEIGHT           200         mm          Height of dipole
#
```

```
ANALYSIS_STAGES         ALL #
PRISMA_UNITS_CUTS       NO  #       Use prisma units for cuts
REQUIRE_ICOK            NO  #       Require ionization chamber ok in analysis
REQUIRE_SIDEOK          NO  #       Require ionization chamber side ok in analysis
REQUIRE_TRAJOK          NO  #       Require trajectory ok in analysis
REQUIRE_TOFOK           NO  #       Require time of flight ok in analysis
REQUIRE_MCPOK           NO  #       Require mcp ok in analysis
ENABLE_TREE             NO  #       Enable or disable detector TTree to save memory (st
ENABLE_PREPROTREE       YES #           Enable preprocessed tree
PRISMAFILTER_TKEL       YES #       Use prismafilter TKEL instead of internal calculati
ENABLE_HISTS            YES #       Enable or disable detector histos to save memory
RAW_HISTS               NO  #       Enable raw histos
ANA_HISTS               YES #       Enable ana histos
MISC_HISTS              NO  #       Enable misc histos
AOVERQ_TEVO_HISTS       NO  #       Enable time evolution A over Q histos
AOVERQ_HISTS            YES #       Enable A over Q histos
MANAGER_PATH            ./Conf/prismaManager.conf   #       Prisma manager path
LUT                         #       Lookup table path
PRISMA_IN_PATH          ./PrismaData    #       Prisma data input path (for update_prisma option only)
PRISMA_FILE_PATTERN     Tree_   #   Prisma data root file pattern (for update_prisma option only)
PRISMA_DIR_PATTERN      run_    #   Prisma data directory pattern (for update_prisma option only)
```

Warning:
NO – gates will be assumed with **internal units of selector** (m, A/Q)
YES – gates will have units as in **PrismaFilters** (mm, A/Q*100)

To create output AnalyzedTree

AgataSelector calibration and gates

Calibration files

```
#Tof calibration file
id 0 cal 352.25377    -0.0496  thr 3200. 3600.
id 1 cal 357.40707    -0.05028 thr 3200. 3700.
id 2 cal 363.25085    -0.04937 thr 3400. 3900.
id 3 cal 347.3776     -0.04915 thr 3100. 3600.
id 4 cal 346.41215    -0.04952 thr 3000. 3600.
id 5 cal 345.39904    -0.04951 thr 3000. 3500.
id 6 cal 340.54844    -0.04948 thr 3000. 3400.
id 7 cal 339.64438    -0.04928 thr 3000. 3400.
id 8 cal 339.10445    -0.04949 thr 2500. 3500.
id 9 cal 338.69052    -0.04908 thr 2800. 3800.
```

Single id

```
#IC Sides threshold file
# Layer A
id 0 0 cal 0 1 thr 160.  4000.
id 0 1 cal 0 1 thr 170.  4000.
# Layer B
id 1 0 cal 0 1 thr 160.  4000.
id 1 1 cal 0 1 thr 140.  4000.
# Layer C
id 2 0 cal 0 1 thr 140.  4000.
id 2 1 cal 0 1 thr 140.  4000.
# Layer D
id 3 0 cal 0 1 thr 140.  4000.
id 3 1 cal 0 1 thr 120.  4000.
```

Double id

PRISMA_README.md
To see the relevant keywords and ids

Gates

```
TFile*          zed__0__28.root
  KEY: TCutG    zed__0__28;1    Graph
```

Single id

Cut name: **name__#__#**
Inside a ***.root** file

```
TFile*          charge__0_28__25.root
KEY: TCutG    charge__0_28__25;1      Graph
```

Double id

Cut name: **name__#_#__#**
Inside a ***.root** file

AgataSelector Prisma Manager

prismaManager.conf

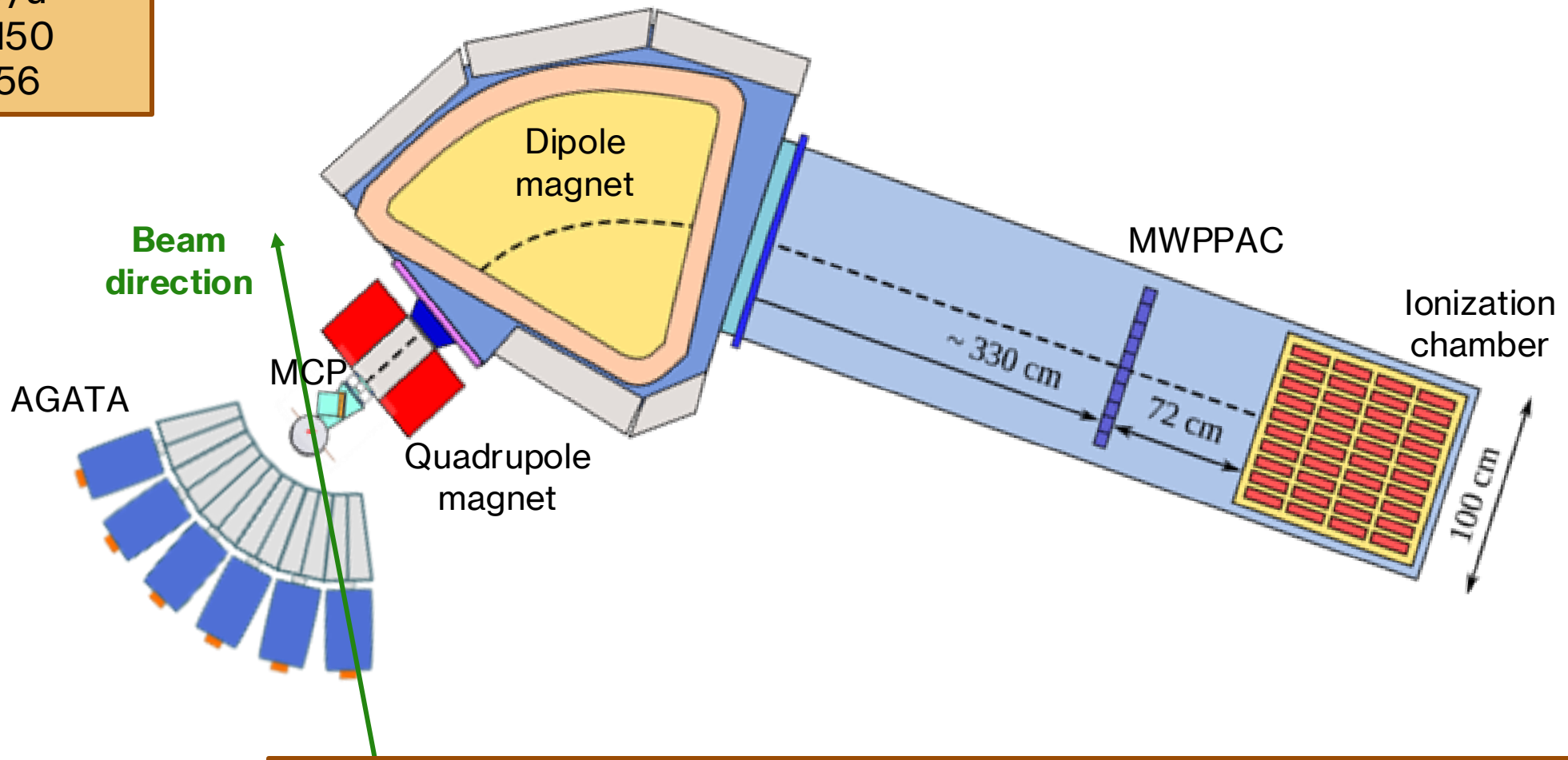
```
########## RAW CALIBRATIONS ##########
TOF_CAL          /CALIBRATION/PRISMA/RAW/tof.cal
PPAC_THRESH      /CALIBRATION/PRISMA/RAW/ppac_tresh.cal
PPACPOS_CAL      /CALIBRATION/PRISMA/RAW/ppac_pos_cal.cal
ICE_CAL          /CALIBRATION/PRISMA/RAW/ice.cal
ICSIDES_CAL      /CALIBRATION/PRISMA/RAW/icsides.cal
ICDRIFT_CAL      /CALIBRATION/PRISMA/RAW/icdrift.cal
MCP_CAL          /CALIBRATION/PRISMA/RAW/mcp.cal
MCPROT_CAL       /CALIBRATION/PRISMA/RAW/mcprot.cal
MONITOR_CAL      /CALIBRATION/PRISMA/RAW/monitor.cal
############## RAW GATES ##############
MCP_GATE         /CUT/PRISMA/RAW/MCP
PPAC_GATE        /CUT/PRISMA/RAW/PPACC
######## ANALYZED CALIBRATIONS ########
AOQ_CAL          /CALIBRATION/PRISMA/ANA/aoverq.cal
CHARGE_CAL       /CALIBRATION/PRISMA/ANA/charge.cal
########## ANALYZED GATES ############
TOF_GATE         /CUT/PRISMA/ANA/TOF
Q_GATE           /CUT/PRISMA/ANA/CHARGE
Z_GATE           /CUT/PRISMA/ANA/ZED
AOQXMCP_CORR     /CUT/PRISMA/ANA/AOVERQ_XMCP
AOQYMCP_CORR     /CUT/PRISMA/ANA/AOVERQ_YMCP
AOQXFP_CORR      /CUT/PRISMA/ANA/AOVERQ_XFP
```

Reference for **PRISMA_CONF:**

```
MANAGER_PATH    ./Conf/prismaManager.conf
```

Composition of PRISMA

Working range:
3-10 MeV/u
20 < A < 150
10 < Z < 56

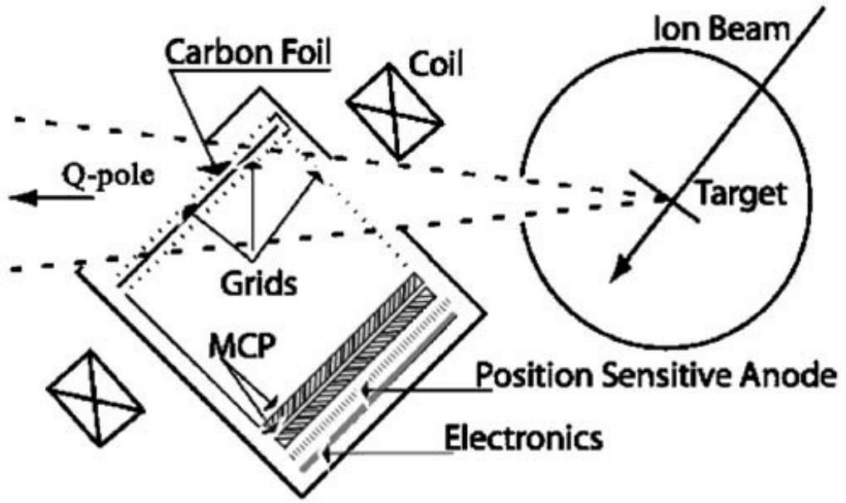


Main objective: Measurement of **ejectile nuclei** from nuclear reactions
Identification of **A, Z**, measurement of **velocity vector**

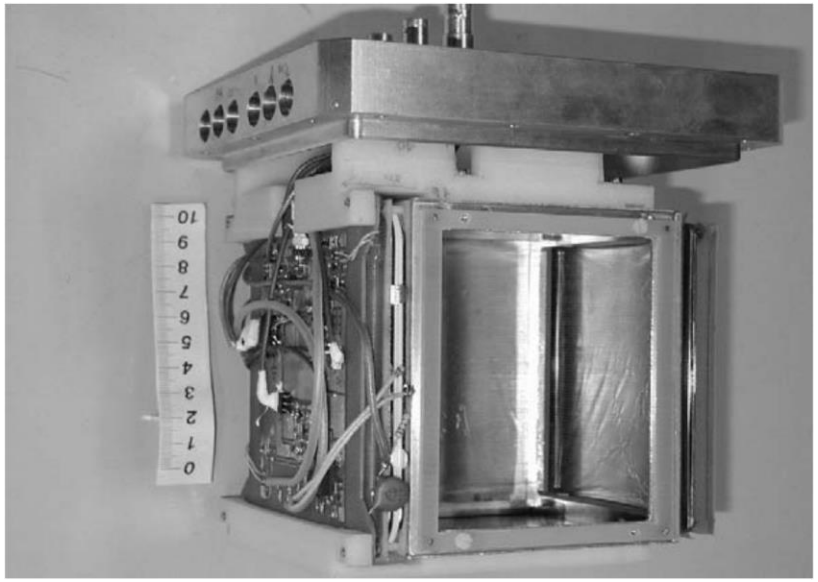
Micro Channel Plate (MCP) entrance detector

- Ions emitted from the target
- They cross the C foil (at 45°) emitting secondary electrons
- Electrons are accelerated onto the MCP
- Delay lines in X, Y measure position
- Kapton calibration mask used to have reference positions

OUTPUT:
MCP_raw[3] (X,Y,Q)
TOF (delayed *STOP*)



G. Montagnoli et al., NIM A 547 (2005) 455–463



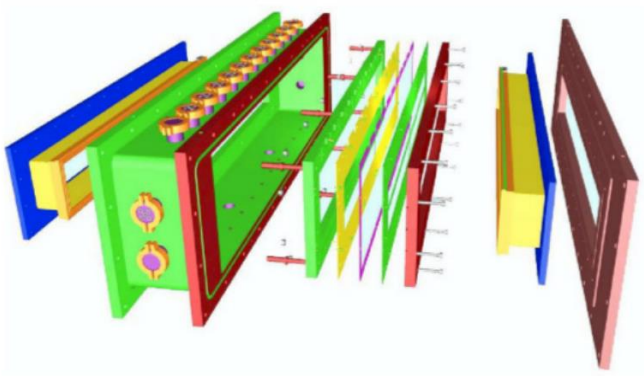
Technical information:

- 80x100 mm^2 active area
- 20 ug/cm2 C foil for electron emission
- Bias voltage ~2.6 kV
- Magnetic field ~ 120 G to direct electrons

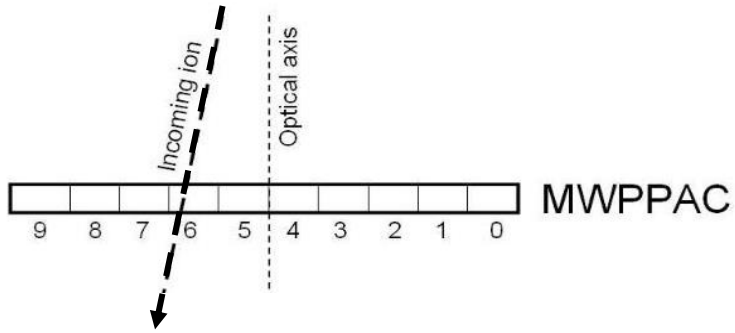
MultiWire Parallel Plate Avalanche Counter (MWPPAC)

- Ions entering after magnets
- Position needed for trajectory reconstruction
- Time of flight with MCP detector
- 10 horizontal sections: X_right, X_left, cathode (*trigger*)
- Efficiency is low for Z < 15

OUTPUT:
PPAC_Xright_raw[10]
PPAC_Xleft_raw[10]
PPAC_Cathode_raw[10]
PPAC_Y_raw[2] (up,down)
TOF_raw[10] (*START*)



S. Beghini et al., NIM A 551 (2005) 364-374



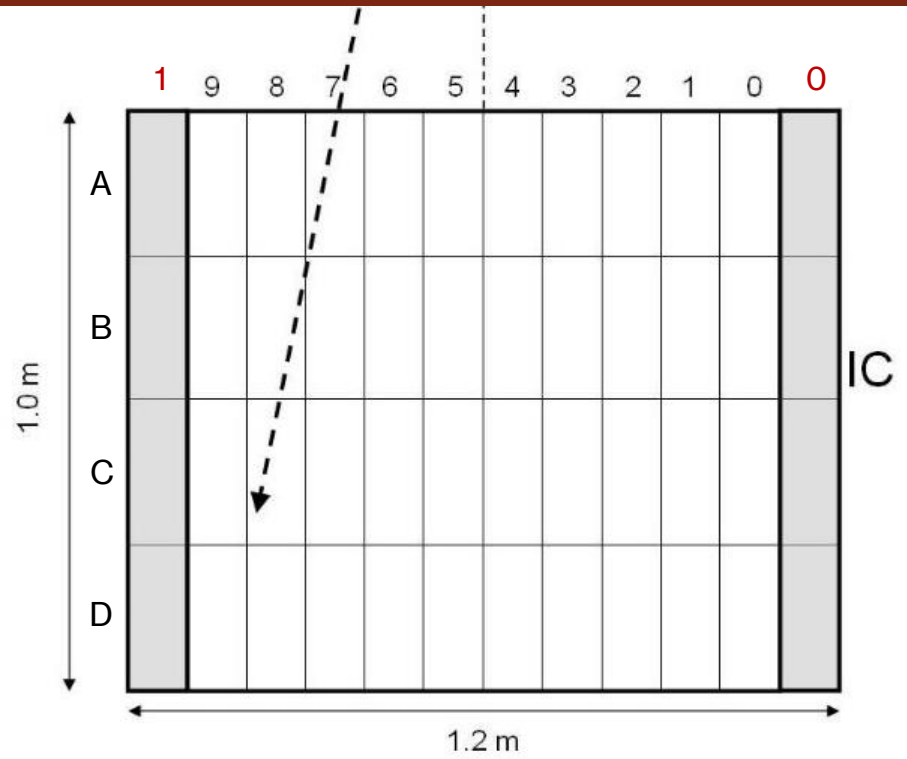
Technical information:

- 1000x130 mm^2 active area
- 1.5 um mylar entrance and exit windows
- Filled with iC4H10

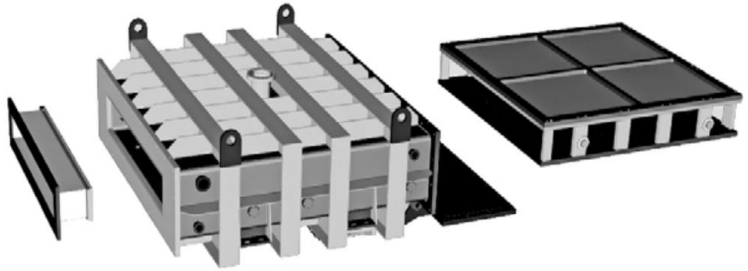
Ionization chamber (IC)

- Measurement of energy at the end of PRISMA
- 4 x 10 pads + 4 x 2 side pads (veto)
- Can be filled CH4 or CF4 from ~20 to ~100 mbar
- Needed to extract Z and Q

OUTPUT:
IC_A_raw[10]
IC_B_raw[10]
IC_C_raw[10]
IC_D_raw[10]
Side_A_raw[2]
Side_B_raw[2]
Side_C_raw[2]
Side_D_raw[2]
IC_A_Drift_raw[10]
IC_B_Drift_raw[10]
IC_C_Drift_raw[10]



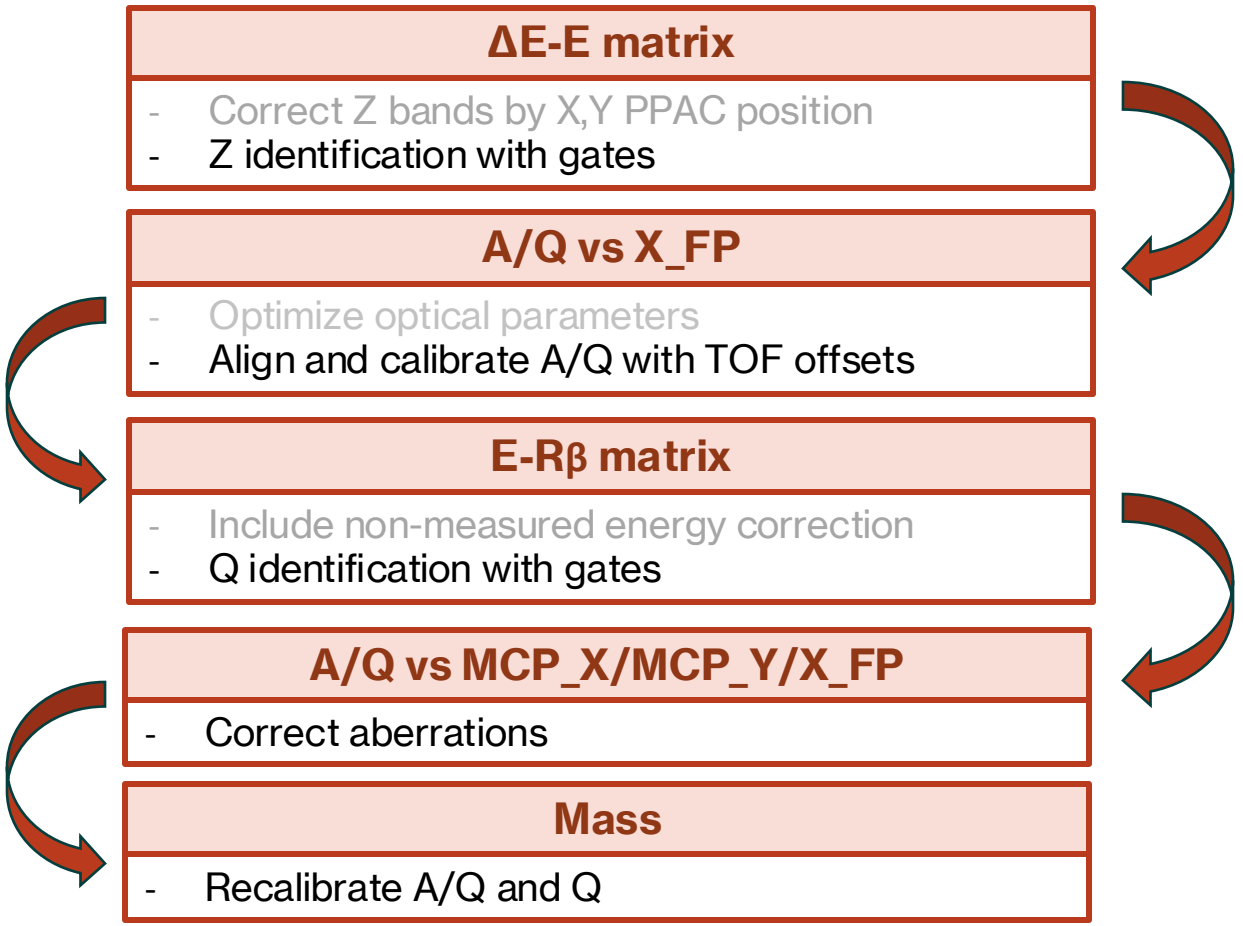
Technical information:
- 1100*(X)*x200*(Y)*x1200*(Z)* mm^3 total volume
- Each pad 265 mm depth x 99 mm width
- 1.5 um mylar entrance window



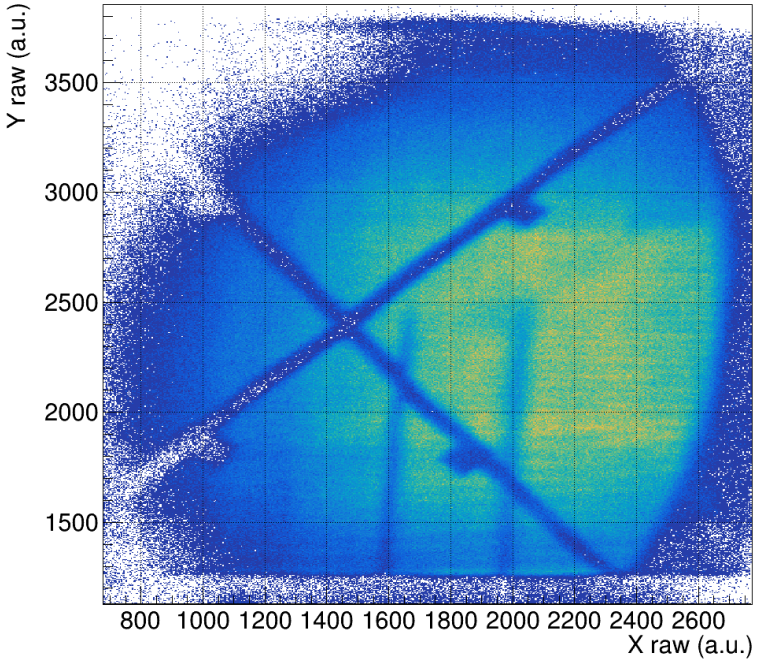
S. Beghini et al., NIM A 551 (2005) 364-374

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration



MCP calibration: position calibration



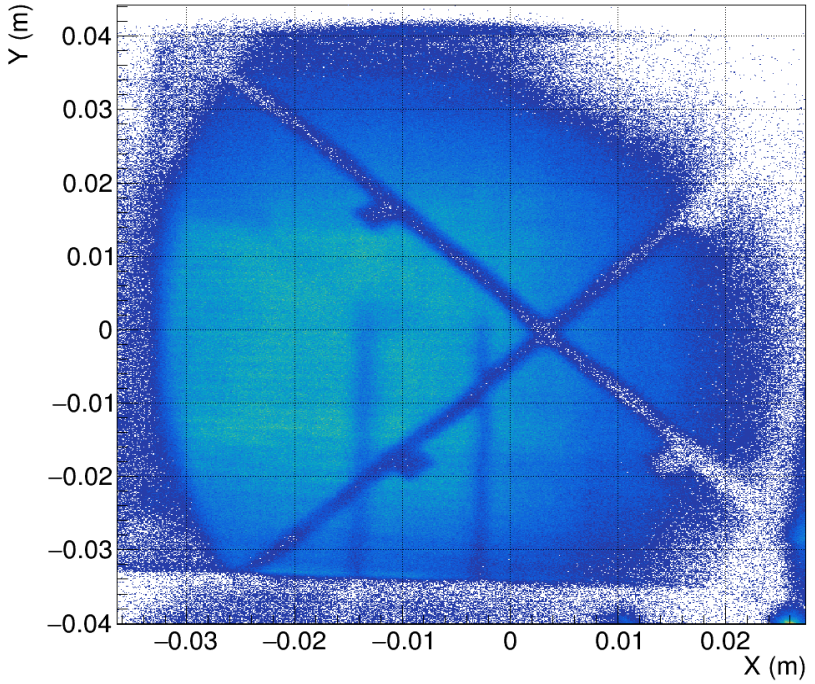
"Rotation" matrix

$$\begin{pmatrix} x_{mix} \\ y_{mix} \end{pmatrix} = C \cdot \begin{pmatrix} x_{raw} \\ y_{raw} \end{pmatrix} = \begin{pmatrix} 1 & c_1 \\ c_2 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_{raw} \\ y_{raw} \end{pmatrix}$$

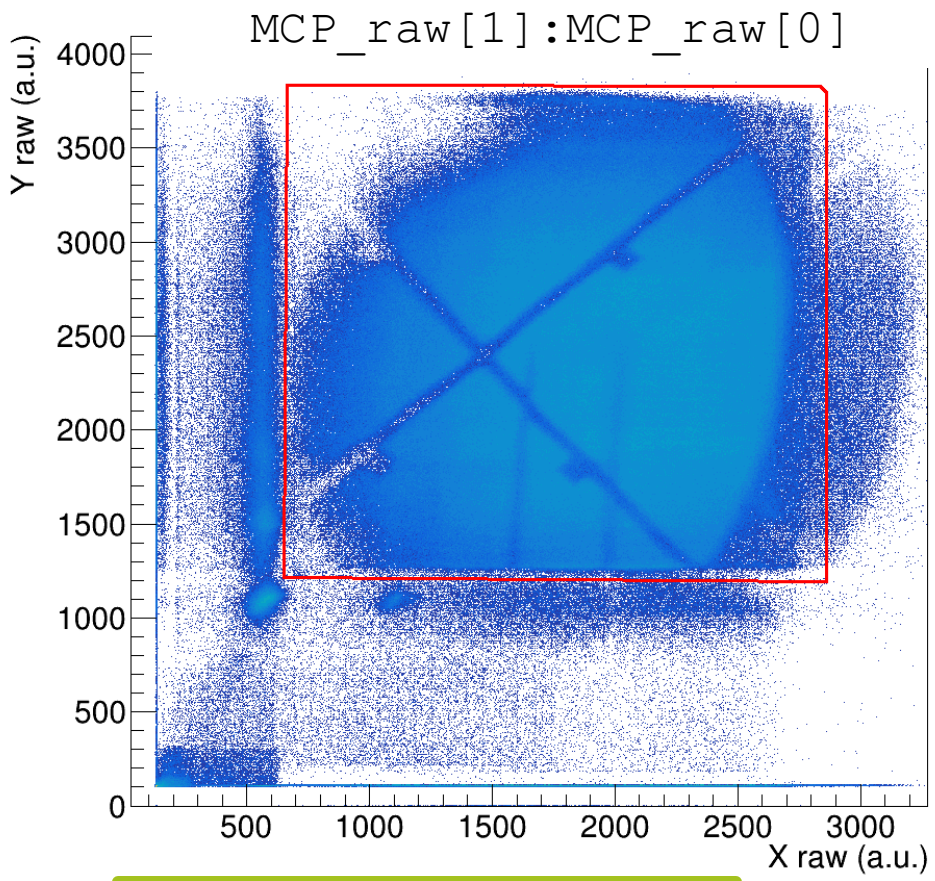
Linear or quadratic calibration

$$x_{mcp} = a_x + b_x \cdot x_{mix} + c_x \cdot x_{mix}^2$$

$$y_{mcp} = a_y + b_y \cdot y_{mix}$$



MCP calibration: position and gate

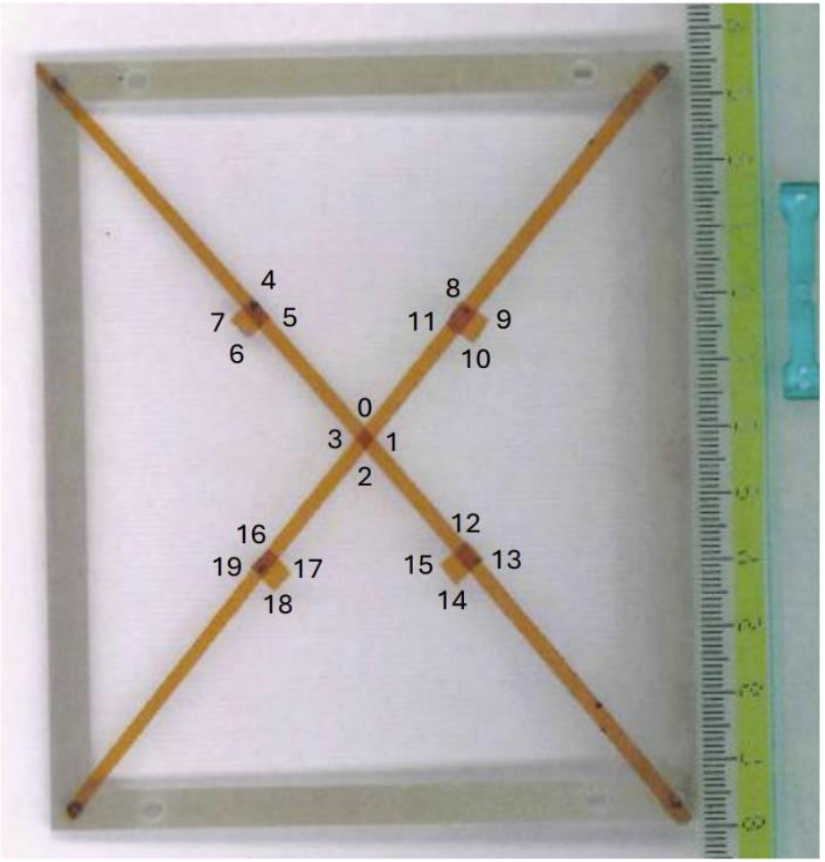


MCP_GATE
/CUT/PRISMA/RAW/MCP

`mcp__0__1.root`

Calibration mask, measured positions for 20 points

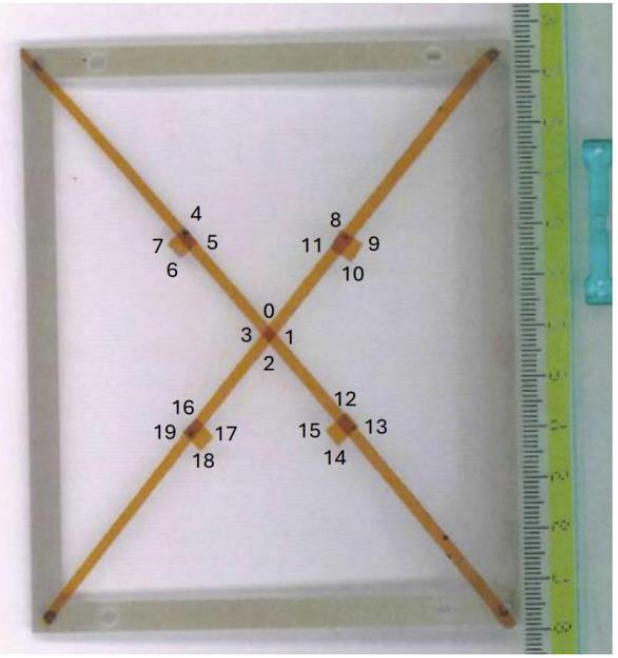
#	X (mm)	Y (mm)
0	1.58	2.07
1	3.16	0.19
2	1.58	-1.81
3	-0.08	0.26
4	-14.56	21.75
5	-11.92	18.77
6	-15.60	15.42
7	-18.28	18.27
8	15.99	20.67
9	20.47	17.77
10	17.99	14.12
11	13.55	17.22
12	16.46	-15.12
13	19.02	-18.07
14	14.87	-22.04
15	12.22	-18.74
16	-13.17	-15.79
17	-9.55	-19.66
18	-12.25	-22.48
19	-15.87	-18.71



Gate for valid events
-> `mcp_ok = true`

./RunSelector --set_gates can be used

MCP calibration: position and gate

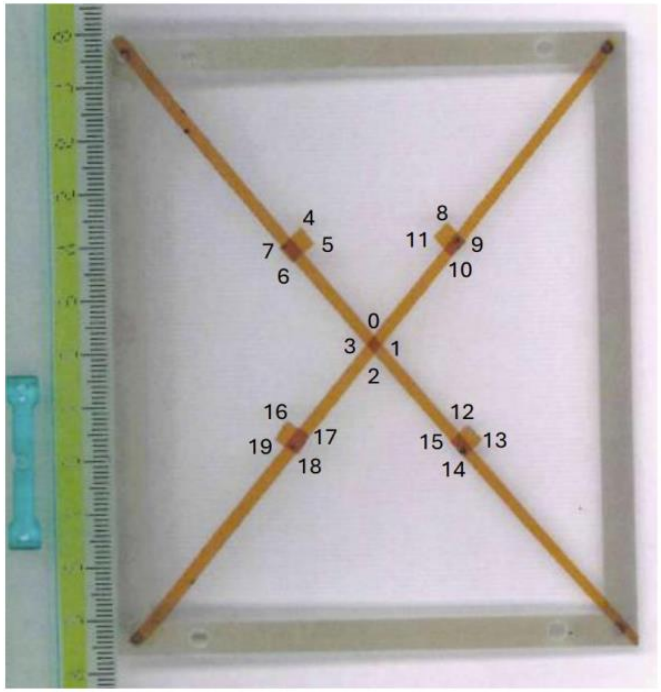


Wings down

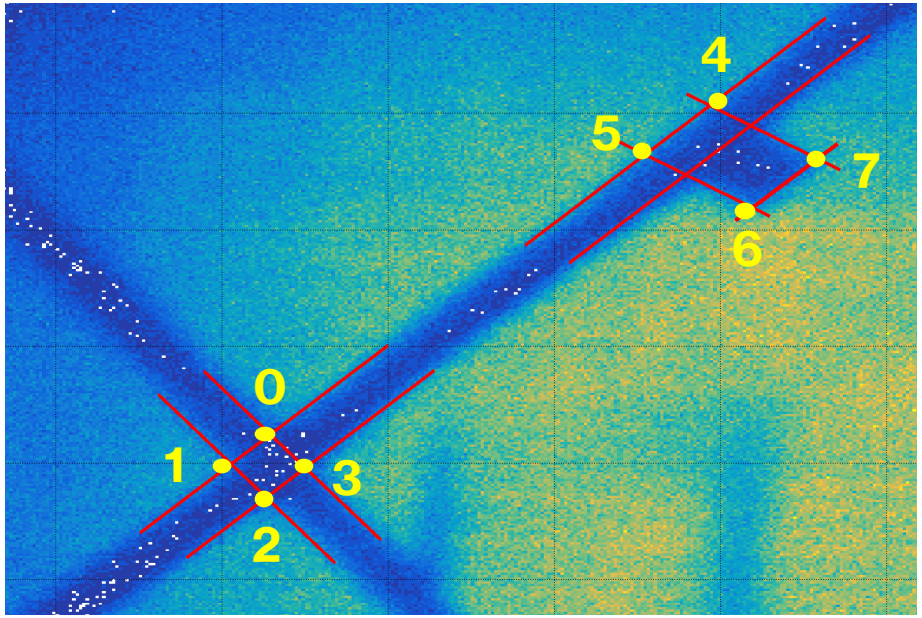
#	X (mm)	Y (mm)
0	1.58	2.07
1	3.16	0.19
2	1.58	-1.81
3	-0.08	0.26
4	-14.56	21.75
5	-11.92	18.77
6	-15.60	15.42
7	-18.28	18.27
8	15.99	20.67
9	20.47	17.77
10	17.99	14.12
11	13.55	17.22
12	16.46	-15.12
13	19.02	-18.07
14	14.87	-22.04
15	12.22	-18.74
16	-13.17	-15.79
17	-9.55	-19.66
18	-12.25	-22.48
19	-15.87	-18.71

Wings up

#	X (mm)	Y (mm)
2	2.62	-2.07
3	1.04	-0.19
0	2.62	1.81
1	4.28	-0.26
4	-10.67	22.04
5	-8.02	18.74
6	-12.26	15.12
7	-14.82	18.07
8	16.45	22.48
9	20.07	18.71
10	17.37	15.79
11	13.75	19.66
12	19.80	-15.42
13	22.48	-18.27
14	18.76	-21.75
15	16.12	-18.77
16	-13.79	-14.12
17	-9.35	-17.22
18	-11.79	-20.67
19	-16.27	-17.77

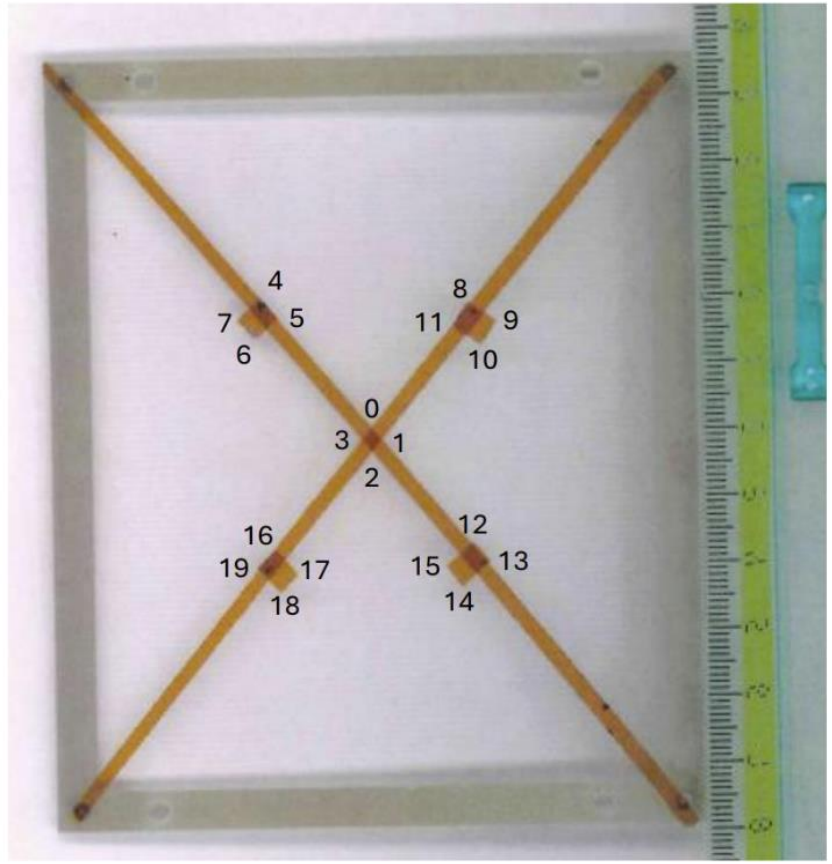


MCP calibration: position and gate



Calibration mask, measured positions for 20 points

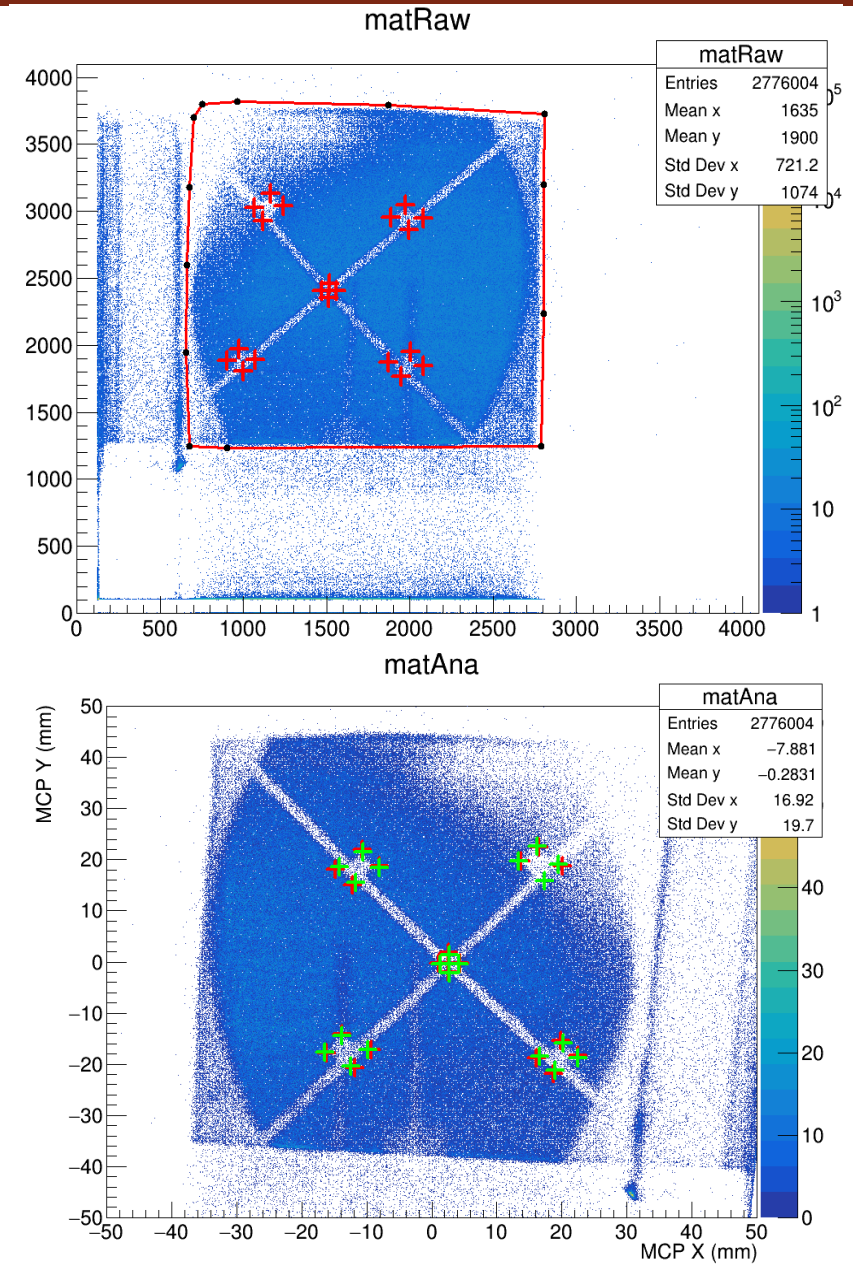
#	X (mm)	Y (mm)
0	1.58	2.07
1	3.16	0.19
2	1.58	-1.81
3	-0.08	0.26
4	-14.56	21.75
5	-11.92	18.77
6	-15.60	15.42
7	-18.28	18.27
8	15.99	20.67
9	20.47	17.77
10	17.99	14.12
11	13.55	17.22
12	16.46	-15.12
13	19.02	-18.07
14	14.87	-22.04
15	12.22	-18.74
16	-13.17	-15.79
17	-9.55	-19.66
18	-12.25	-22.48
19	-15.87	-18.71



Warning: flip in X between raw and calibrated!

Warning: In some experiments the wings on the mask are rotated.
Look at the right reference points!

MCP calibration: position calibration



Prismaonlinepackage/script/MCP/MCP_cal.C

mask.dat

```
pos      x_mm   y_mm       x_chan   y_chan
ce_0     2.62    1.81      1518     2460
ce_1     4.28   -0.26      1471     2410
ce_2     2.62   -2.07      1512     2356.4
ce_3     1.04   -0.19      1558.3   2405.4
tl_4   -10.67   22.04      1971.8   3045.3
...
```

Output:

```
mcp_mix_x_0 = 1
mcp_mix_x_1 = -0.0653546
mcp_mix_y_0 = 0.0660451
mcp_mix_y_1 = 1
cal x: 99 0 3   51.4199 -0.0387309      2.1084e-06
cal y: 99 0 2   -82.7449        0.0328323
```

Outputs **reference** and **calibrated** points and coefficients to put into calibration files

MCP calibration: implementation

mcp.conf

```
ind_xm = 0
ind_ym = 1
ind_um = 2

mcp_banana = ban/mcp_banana.ban
ignore_banana = 0
ban_res_x = 10096
ban_res_y = 10096

xm_file = cal/x_mcp.cal
ym_file = cal/y_mcp.cal
um_file = cal/u_mcp.cal

xm_gain = 1.0
xm_offs = 0.0
ym_gain = 1.0
ym_offs = 0.0

mcp_mix_x_0 = 1.
mcp_mix_x_1 = -0.0734404
mcp_mix_y_0 = 0.0596581
mcp_mix_y_1 = 1.


angle_prisma = 20.
rotation_mcp = 359.999
mcp_target_d = 250.
mcp_angle = 135.
```

cal/x_mcp.cal

```
99 0 3    37.898   -0.0312197 4.19906e-07
```

cal/y_mcp.cal

```
99 0 2    -76.4786          0.030551
```

PrismaFilters

prismaManager.conf

```
MCP_CAL CALIBRATION/PRISMA/RAW/mcp.cal
MCPROT_CAL CALIBRATION/PRISMA/RAW/mcprot.cal

MCP_GATE      CUT/PRISMA/RAW/MCP
```

CALIBRATION/PRISMA/RAW/mcprot.cal

```
#Rotation matrix for MCP positions
# x0 x1 y0 y1
id 0 cal 1. -0.0734404 0.0596581 1.
```

CALIBRATION/PRISMA/RAW/mcp.cal

```
#MCP position calibration file
#X
id 0    cal 37.898   -0.0312197       4.19906e-07 thr -10000
10000
#Y
id 1    cal -76.4786    0.030551 thr -10000 10000
```

AgataSelector

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

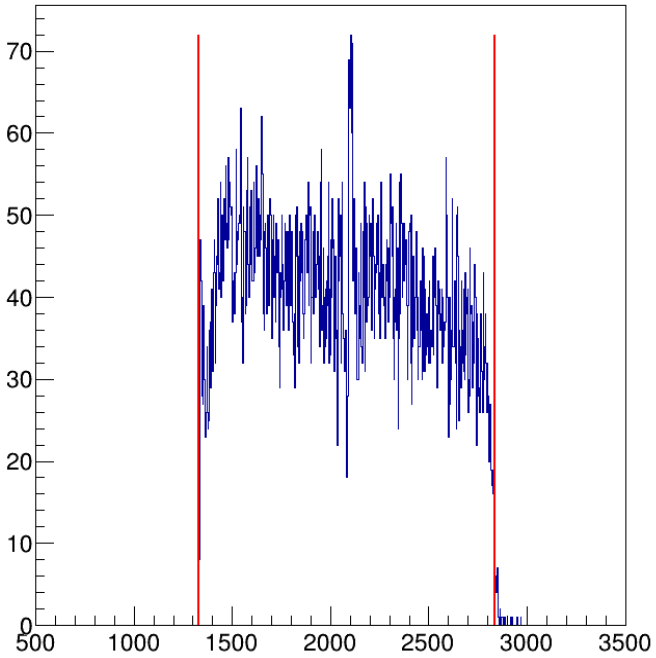
A/Q vs MCP_X/MCP_Y/X_FP

- Correct aberrations

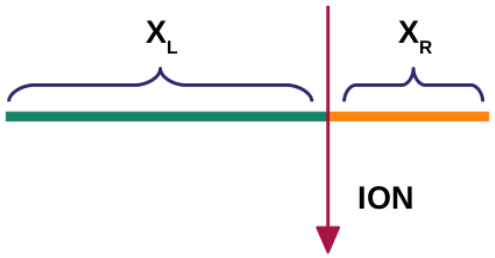
Mass

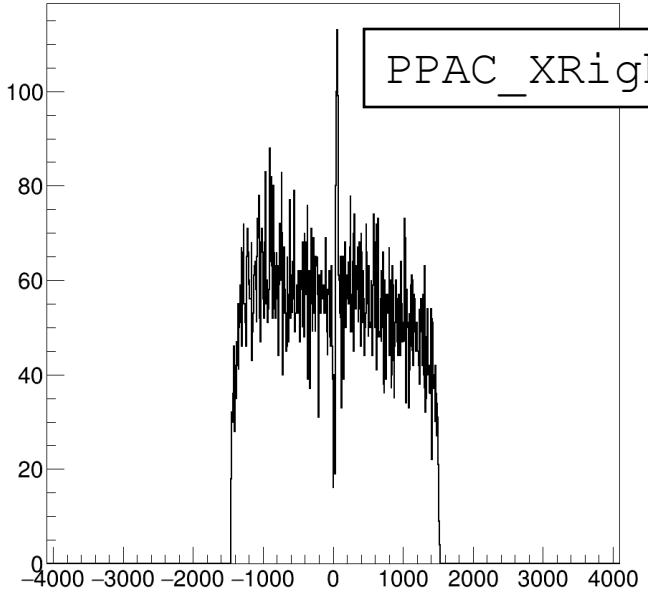
- Recalibrate A/Q and Q

PPAC calibration: position

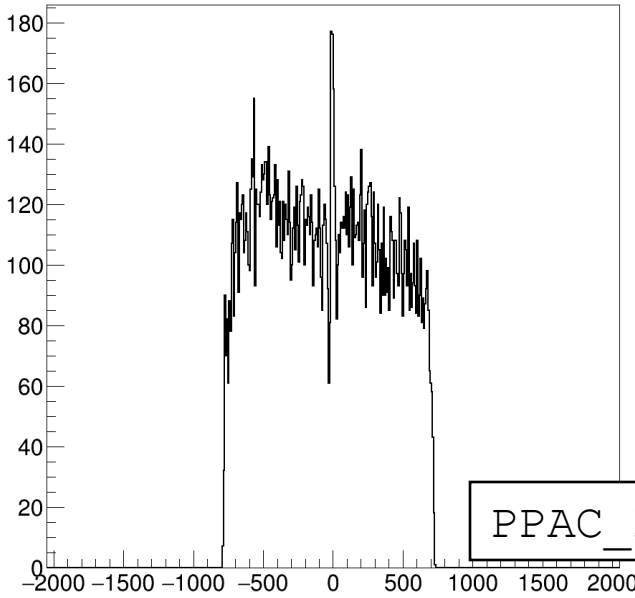


PPAC_XRight_raw[4]



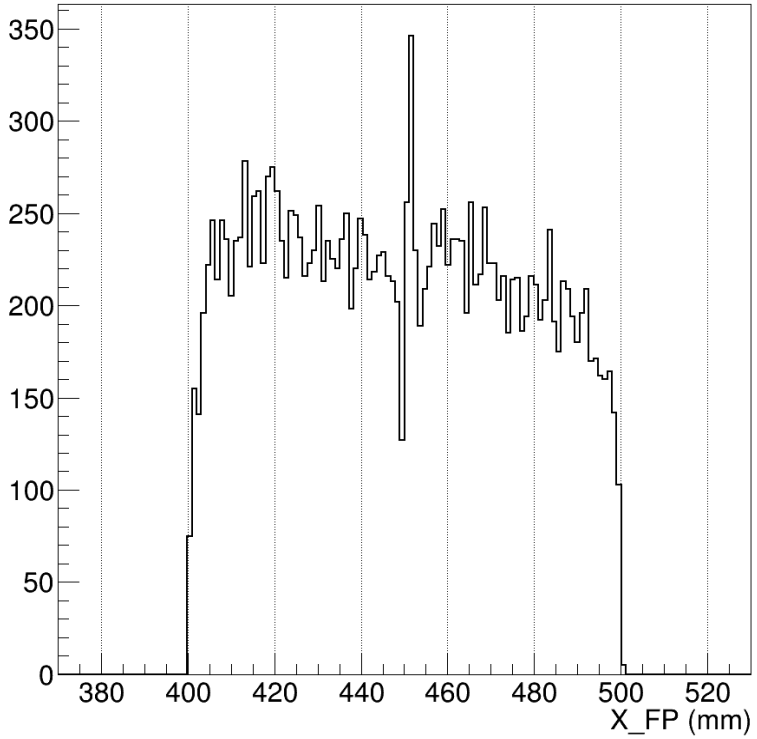


PPAC_XRight_raw[4] - PPAC_Xleft_raw[4]



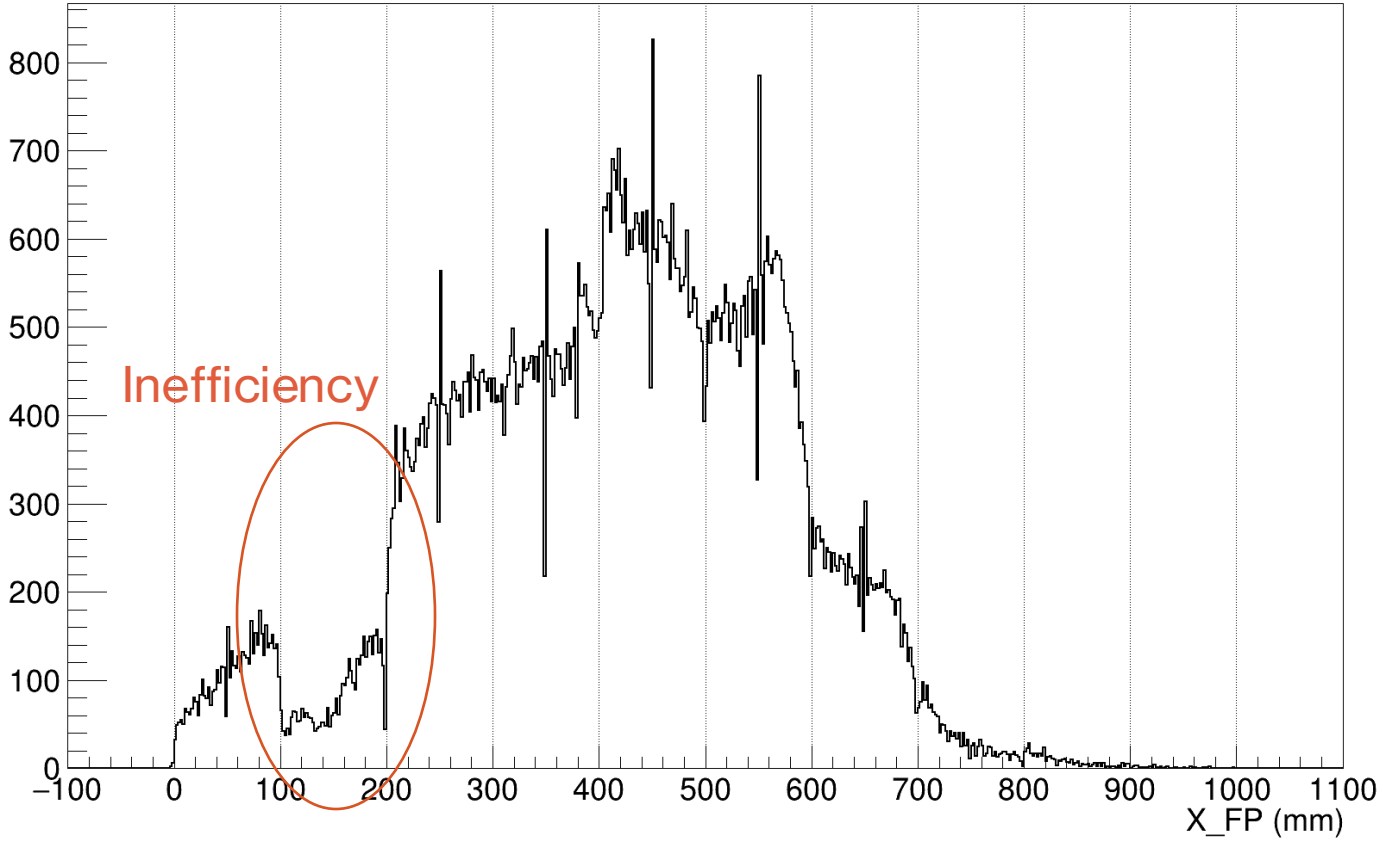
Linear calibration

Section #j has a range of
[100*j mm, 100*(j+1) mm]

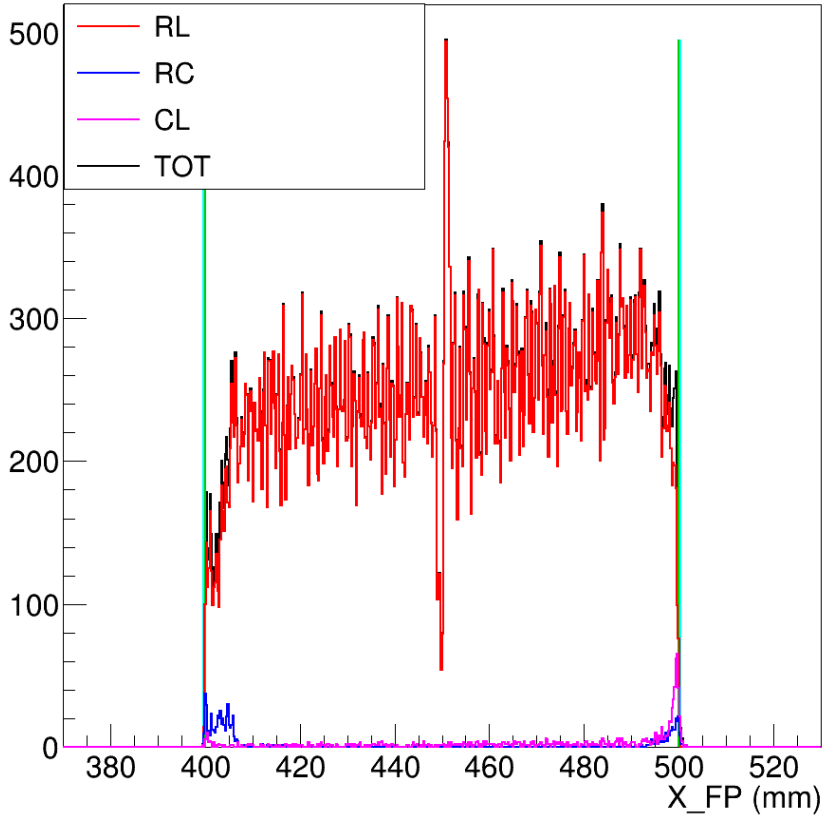


PPAC_XRight_raw[4] - PPAC_Cathode_raw[4]

PPAC calibration: position



All sections together
Profile varies with the experiment (Q distribution)



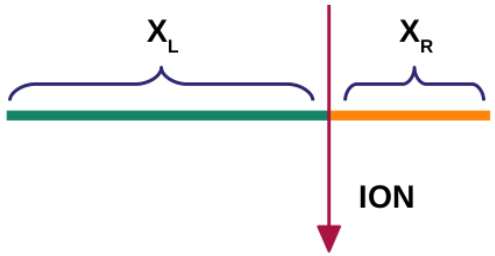
Events from which calibration

PPAC calibration: cathode gates

X_R + X_L should be constant as should be Cathode
Random drift can affect the signals.

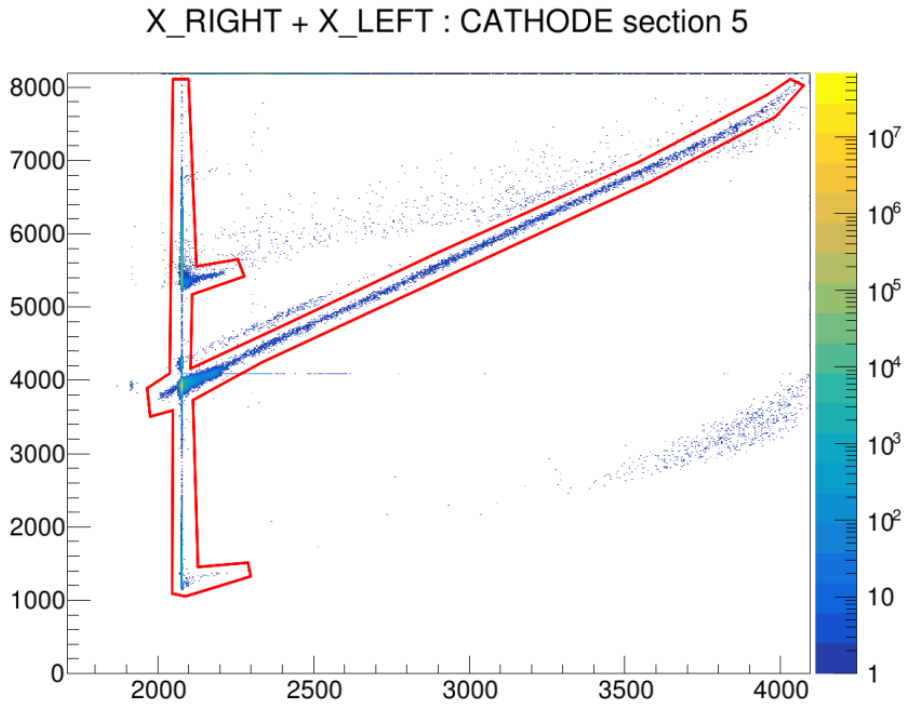
Selection of valid events for every section

X_R + X_L vs Cathode



PPAC_GATE **/CUT/PRISMA/RAW/PPAC**

```
ppac__0__1.root
ppac__1__1.root
      ...
ppac__9__1.root
```



$$cath^{(real)} = cath + drift$$

$$X_{left}^{(real)} = X_{left} + drift$$

$$X_{right}^{(real)} = X_{right} + drift$$

PPAC calibration: position - implementation

ppac.conf

```
ind_yu = 0
ind_yd = 1
ind_xl = 2
ind_xr = 3
ind_xc = 4
ind_tof = 5

#ppac_banana = ban/Cath-L+R_open.ban
ppac_banana = ban/Cath-L+R.ban
ban_res_x = 10000
ban_res_y = 10000
xl_file = cal/cath-left.cal
xr_file = cal/right-cath.cal
xfp_file = cal/xfp-mm.cal
yfp_file = cal/yfp-mm.cal
tof_file = cal/tof-total.cal
tof_ofile = cal/allineamento-ns.cal

xl_threshold_file = threshold/x_left.thres
xr_threshold_file = threshold/x_right.thres
xc_threshold_file = threshold/x_cathode.thres
tof_threshold_file = threshold/tof.thres

tof_offs = 380.
```

threshold/x_left.thres

```
99 0 2 1367 2878
99 1 2 1073 2663
99 2 2 1164 2654
99 3 2 1136 2649
99 4 2 1298 2798
99 5 2 1249 2785
99 6 2 1299 2840
99 7 2 1367 2841
99 8 2 1483 2981
99 9 2 1508 3003
```

threshold/xfp-mm.cal

```
0 0 2 22.4191 0.0332439
0 1 2 141.662 0.0323113
0 2 2 246.284 0.0339267
0 3 2 345.786 0.0333924
0 4 2 449.147 0.0336007
0 5 2 552.870 0.0335124
0 6 2 649.009 0.0333850
0 7 2 753.392 0.0335077
0 8 2 849.595 0.0331657
0 9 2 955.391 0.0341200
```

PrismaFilters

prismaManager.conf

```
PPAC_THRESH /CALIBRATION/PRISMA/RAW/ppac_tresh.cal
PPACPOS_CAL /CALIBRATION/PRISMA/RAW/ppac_pos_cal.cal

PPAC_GATE /CUT/PRISMA/RAW/PPAC
```

/CALIBRATION/PRISMA/RAW/ppac_tresh.cal

```
#PPAC position thresholds
# Xright
id 0 0 thr 2191 3718
id 0 1 thr 1359 2899
id 0 2 thr 1272 2757
id 0 3 thr 1273 2777
id 0 4 thr 1330 2834
id 0 5 thr 1200 2670
...
id 0 9 thr 1367 2830
# Xleft
id 1 0 thr 1367 2878
id 1 1 thr 1073 2663
...
# XCathode
id 2 0 thr 100. 3950.
id 2 1 thr 100. 3950.
..
# YUp
id 3 0 thr 1 4090
# YDown
id 3 1 thr 1 4090
```

/CALIBRATION/PRISMA/RAW/ppac_pos_cal.cal

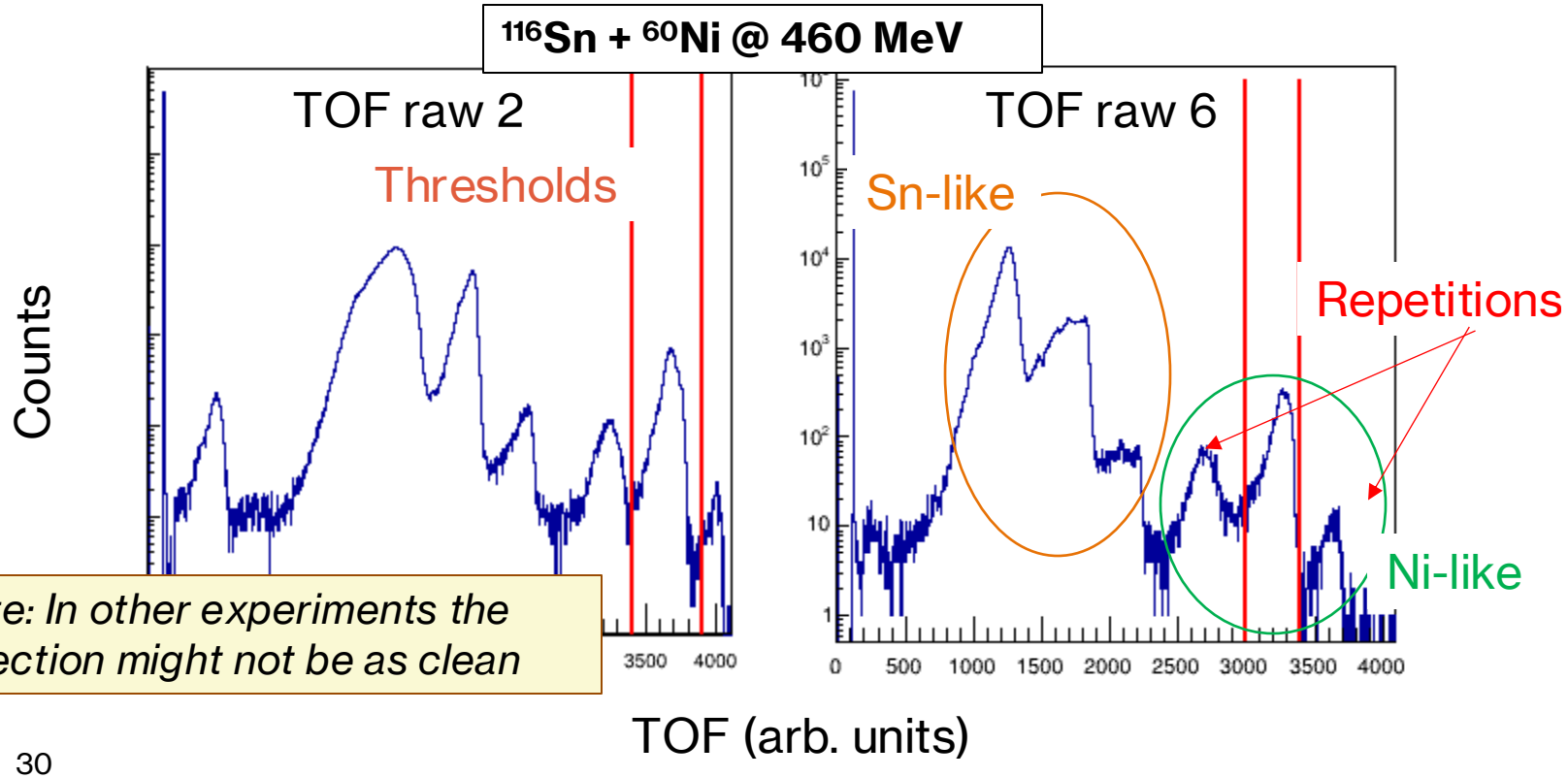
```
#PPAC position calibration
file
# XRight - XLeft
id 0 0 thr -1000 1000 cal
22.4191 0.0332439
id 0 1 thr -1000 1000 cal
141.662 0.0323113
...
# XRight - XCathode
id 1 0 thr -1000 1000 cal -
1.0033 0.068822
...
# XCathode - XLeft
id 2 0 thr -1000 1000 cal
43.7873 0.067610
...
# YUp - YDown
id 3 0 thr -1000 1000 cal
6.56989 0.05591398
...
```

AgataSelector

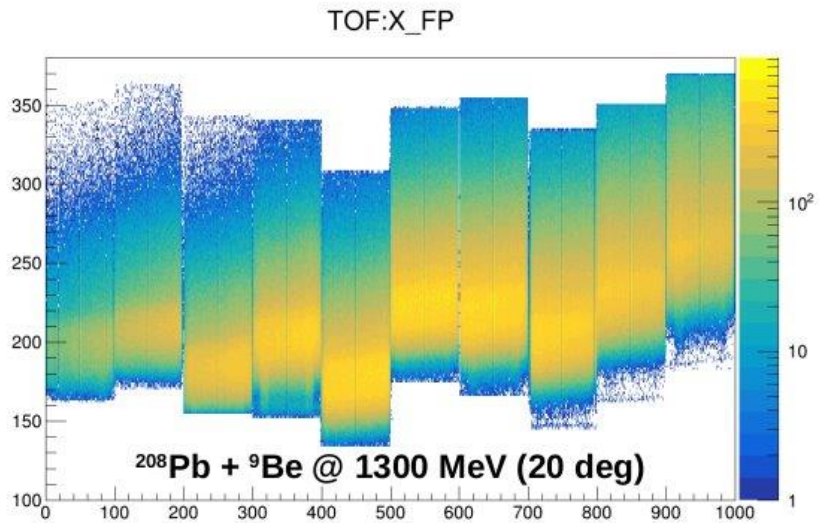
PPAC calibration: TOF

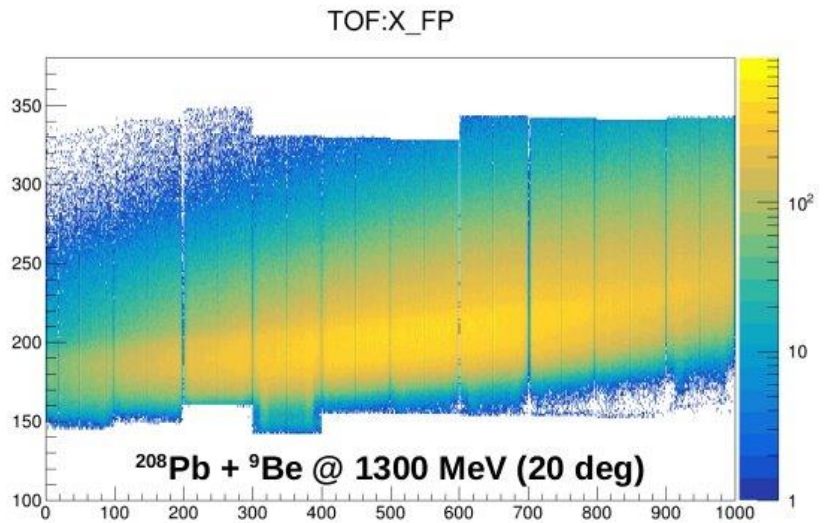
Cathodes OR ->*TOF start;* Delayed MCP->*TOF stop*
Raw TOF is **inverted**
Linear calibration

Gain was measured with time calibrator e.g. tof-total.cal
Offsets need to be adjusted looking at the alignment



Note: In other experiments the selection might not be as clean





PPAC calibration: TOF - implementation

ppac.conf

```
ind_yu = 0
ind_yd = 1
ind_xl = 2
ind_xr = 3
ind_xc = 4
ind_tof = 5

#ppac_banana = ban/Cath-L+R_open.ban
ppac_banana = ban/Cath-L+R.ban
ban_res_x = 10000
ban_res_y = 10000
xl_file = cal/cath-left.cal
xr_file = cal/right-cath.cal
xfp_file = cal/xfp-mm.cal
yfp_file = cal/yfp-mm.cal
tof_file = cal/tof-total.cal
tof_ofile = cal/allineamento-ns.cal

xl_threshold_file = threshold/x_left.thres
xr_threshold_file = threshold/x_right.thres
xc_threshold_file = threshold/x_cathode.thres
tof_threshold_file = threshold/tof.thres

tof_offs = 380.
```

threshold/tof.thres

```
99 0 2 3200. 3600.
99 1 2 3200. 3700.
99 2 2 3400. 3900.
99 3 2 3100. 3600.
99 4 2 3000. 3600.
99 5 2 3000. 3500.
99 6 2 3000. 3400.
99 7 2 3000. 3400.
99 8 2 2500. 3500.
99 9 2 2800. 3800.
```

cal/tof-total.cal

```
0 0 2 +1.95377   -0.0496
0 1 2 +7.20707   -0.05028
0 2 2 +1.45085   -0.04937
0 3 2 +7.5776    -0.04915
...
0 9 2 +0.29052   -0.04908
```

cal/allineamento-ns.cal

```
1 0     2   -29.7   1
1 1     2   -29.8   1
1 2     2   -18.2   1
1 3     2   -40.2   1
...
1 9     2   -41.6   1
```

prismaManager.conf

TOF_CAL **/CALIBRATION/PRISMA/RAW/tof.cal**

/CALIBRATION/PRISMA/RAW/tof.cal

```
#Tof calibration file
id 0 cal 352.25377    -0.0496  thr 3200. 3600.
id 1 cal 357.40707    -0.05028 thr 3200. 3700.
id 2 cal 363.25085    -0.04937 thr 3400. 3900.
id 3 cal 347.3776     -0.04915 thr 3100. 3600.
id 4 cal 346.41215    -0.04952 thr 3000. 3600.
id 5 cal 345.39904    -0.04951 thr 3000. 3500.
id 6 cal 340.54844    -0.04948 thr 3000. 3400.
id 7 cal 339.64438    -0.04928 thr 3000. 3400.
id 8 cal 339.10445    -0.04949 thr 2500. 3500.
id 9 cal 338.69052    -0.04908 thr 2800. 3800.
```

Offsets are the sum of the different components from filters

PrismaFilters

AgataSelector

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

A/Q vs MCP_X/MCP_Y/X_FP

- Correct aberrations

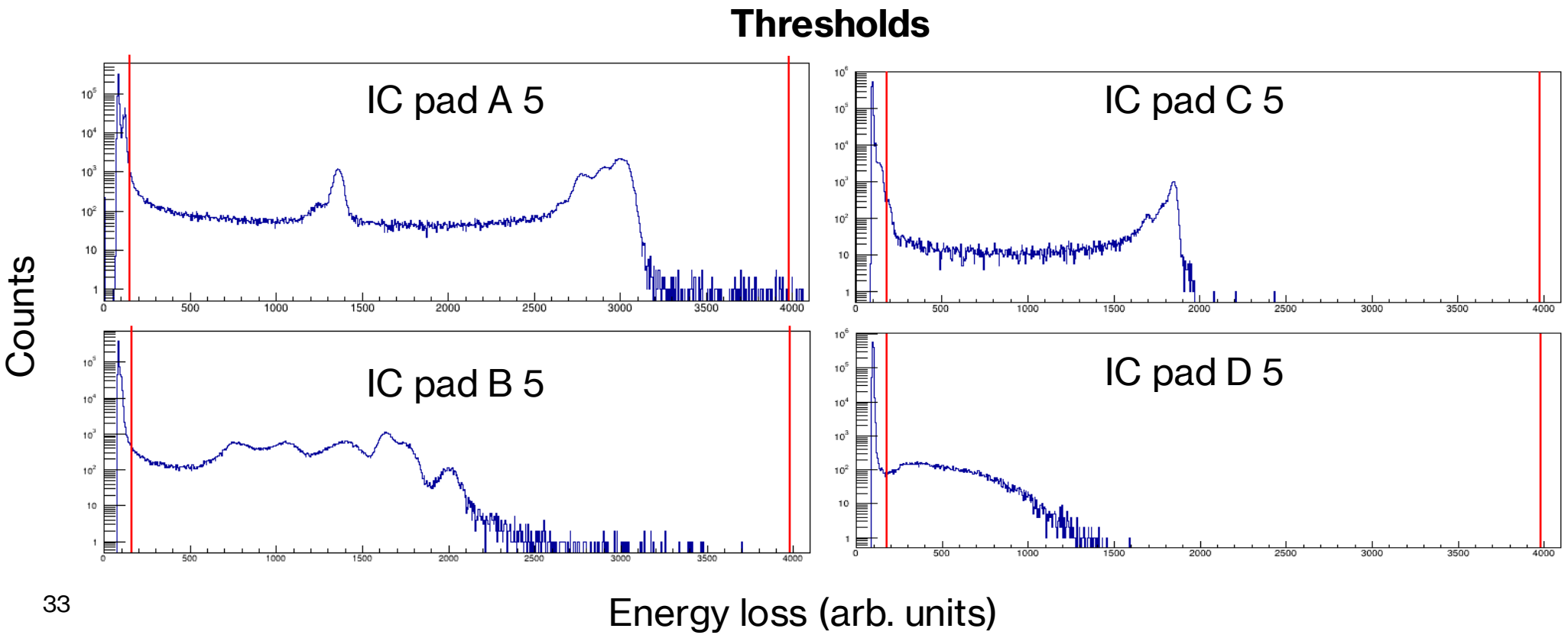
Mass

- Recalibrate A/Q and Q

IC calibration: energy

Linear calibration (gain matching of 40 pads) is estimated with manually with a charge injector
Thresholds should cut pedestal

You should have this calibration from the online
e.g. IC_gain_60_2_5_B_2022_chargeInject_good.cal



IC calibration: energy - implementation

ionch.conf

```
ind_DE_A = 0
ind_DE_B = 1
ind_DE_C = 2
ind_DE_D = 3
ind_DRIFT_A = 4
ind_DRIFT_B = 5
ind_DRIFT_C = 6
ic_A_Calibration_file = cal/IC_gain_60_2_5_A_2022_chargeInject_good.cal
ic_B_Calibration_file = cal/IC_gain_60_2_5_B_2022_chargeInject_good.cal
ic_C_Calibration_file = cal/IC_gain_60_2_5_C_2022_chargeInject_good.cal
ic_D_Calibration_file = cal/IC_gain_60_2_5_D_2022_chargeInject_good.cal
ic_A_Threshold_file = threshold/IC_A.thres
ic_B_Threshold_file = threshold/IC_B.thres
ic_C_Threshold_file = threshold/IC_C.thres
ic_D_Threshold_file = threshold/IC_D.thres
...
```

threshold/IC_A.thres

```
99  0 2 140. 3980.
99  1 2 140. 3980.
99  2 2 180. 3980.
99  3 2 180. 3980.
99  4 2 180. 3980.
99  5 2 150. 3980.
99  6 2 150. 3980.
99  7 2 150. 3980.
99  8 2 120. 3980.
99  9 2 120. 3980.
```

cal/IC_gain_60_2_5_B_2022_chargeInject_good.cal

```
99    0    2    -67.6767    0.94965
99    1    2    -82.6652    0.94089
99    2    2    -84.1486    0.95287
99    3    2    -102.965    0.92621
99    4    2    -94.9887    0.95685
99    5    2    -82.2111    0.94681
99    6    2    -98.855     0.94945
99    7    2    -107.011    0.93989
99    8    2    -67.7114    0.94556
99    9    2    -104.861    0.96855
```

PrismaFilters

prismaManager.conf

ICE_CAL **CALIBRATION/PRISMA/RAW/ice.cal**

CALIBRATION/PRISMA/RAW/ice.cal

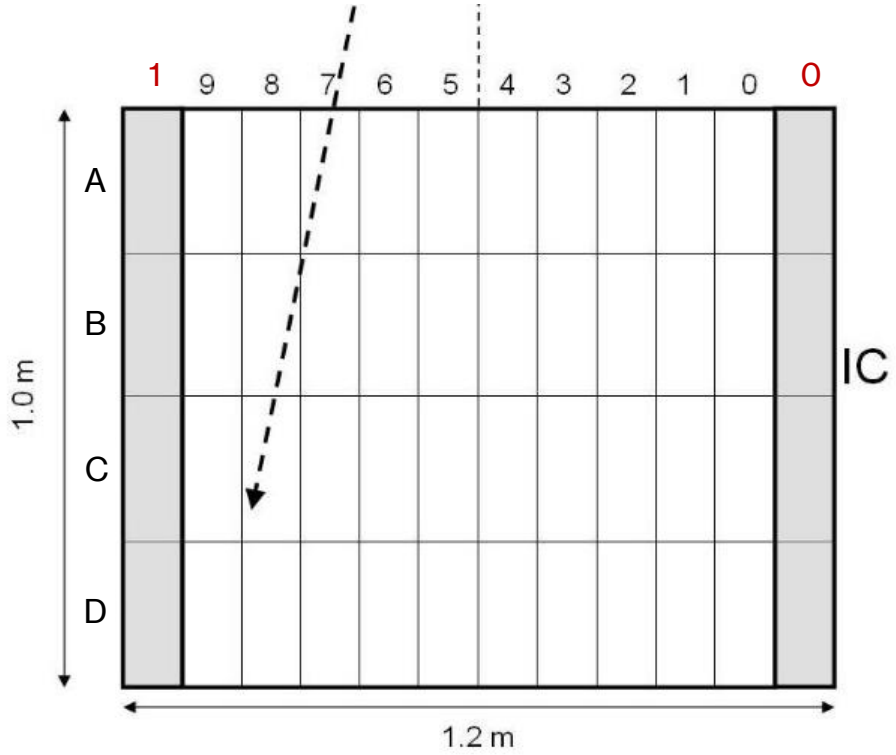
```
#IC Pads energy calibration file
# Layer A
id 0 0 cal -67.6767    0.94965 thr 140. 3980.
id 0 1 cal -82.6652    0.94089 thr 140. 3980.
id 0 2 cal -84.1486    0.95287 thr 180. 3980.
id 0 3 cal -102.965    0.92621 thr 180. 3980.
id 0 4 cal -94.9887    0.95685 thr 180. 3980.
id 0 5 cal -82.2111    0.94681 thr 150. 3980.
id 0 6 cal -98.855     0.94945 thr 150. 3980.
id 0 7 cal -107.011    0.93989 thr 150. 3980.
id 0 8 cal -67.7114    0.94556 thr 120. 3980.
id 0 9 cal -104.861    0.96855 thr 120. 3980.
# Layer B
id 1 0 cal -62.9314    0.92202 thr 110. 3980.
id 1 1 cal -69.4428    0.95677 thr 120. 3980.
id 1 2 cal -73.5535    0.95693 thr 140. 3980.

...
```

AgataSelector

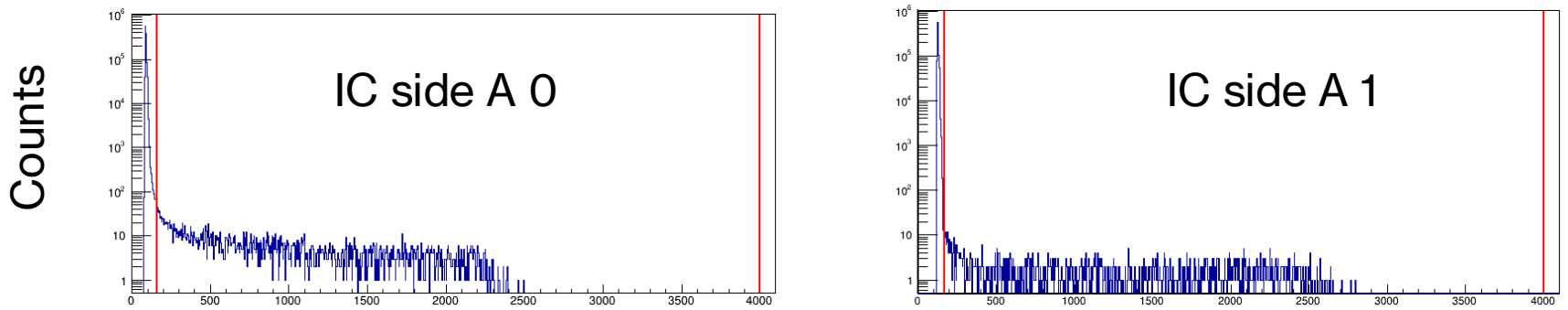
IC calibration: side pads

Avoid trajectories that exit the chamber
Events within thresholds are **rejected**

No calibration needed



Thresholds



IC calibration: side pads - implementation

side.conf

```
ind_s1 = 0
ind_s2 = 1
ind_s3 = 2
ind_s4 = 3

side_A_Threshold_file = threshold/side_A.thres
side_B_Threshold_file = threshold/side_B.thres
side_C_Threshold_file = threshold/side_C.thres
side_D_Threshold_file = threshold/side_D.thres
```

threshold/side_A.thres

```
# Lower and Upper Thresholds
99  0 2 160.  4000.
99  1 2 170.  4000.
```

PrismaFilters

prismaManager.conf

```
ICSIDES_CAL CALIBRATION/PRISMA/RAW/icsides.cal
```

CALIBRATION/PRISMA/RAW/icsides.cal

```
#IC Sides threshold file
# Layer A
id 0 0 cal 0 1 thr 160.  4000.
id 0 1 cal 0 1 thr 170.  4000.
# Layer B
id 1 0 cal 0 1 thr 160.  4000.
id 1 1 cal 0 1 thr 140.  4000.
# Layer C
id 2 0 cal 0 1 thr 140.  4000.
id 2 1 cal 0 1 thr 140.  4000.
# Layer D
id 3 0 cal 0 1 thr 140.  4000.
id 3 1 cal 0 1 thr 120.  4000.
```

AgataSelector

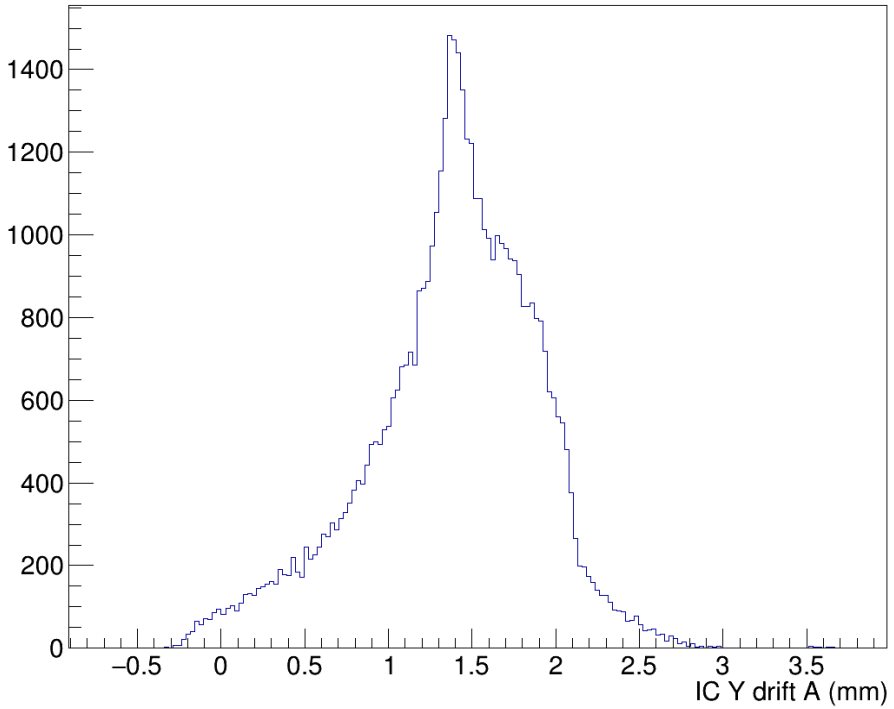
Optional - IC calibration: drift time

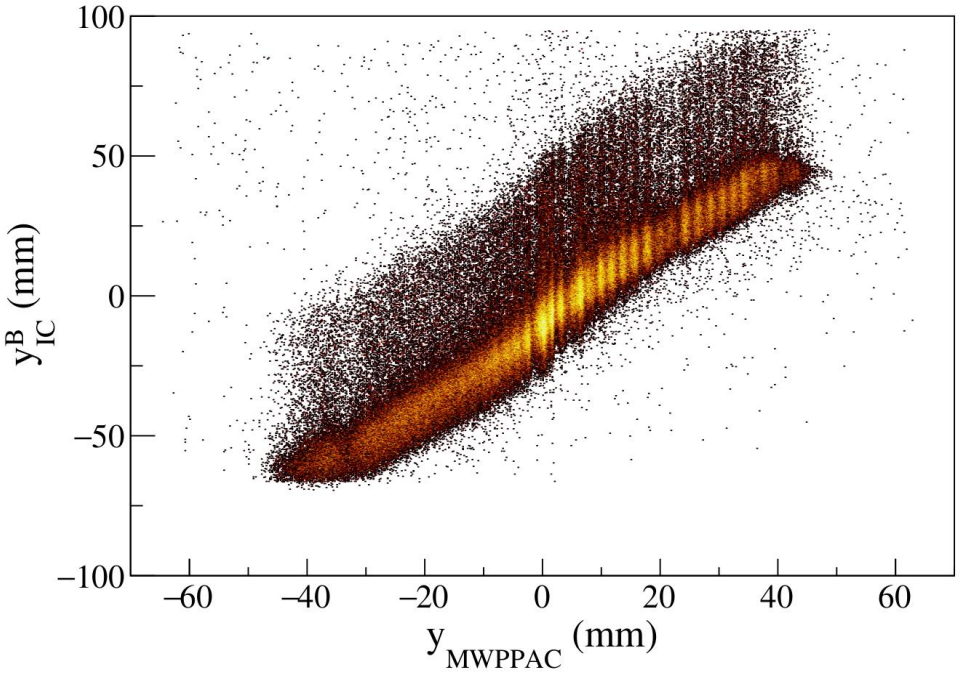
Drift time of electron to IC pads

Measurement of **Y coordinate** of ion in IC

Measured for row **A, B, C**

Can help to control trajectory in the IC





Not commonly used but if needed you can **calibrate** it

IC calibration: drift time - implementation

ionch.conf

```
...
drift_A_Calibration_file = cal/cal_Drift_A.cal
drift_B_Calibration_file = cal/cal_Drift_B.cal
drift_C_Calibration_file = cal/cal_Drift_C.cal


drift_A_Threshold_file = threshold/DRIFT_A.thres
drift_B_Threshold_file = threshold/DRIFT_B.thres
drift_C_Threshold_file = threshold/DRIFT_C.thres
```

threshold/DRIFT_A.thres

```
99  0 2 140. 3980.
99  1 2 140. 3980.
99  2 2 180. 3980.
99  3 2 180. 3980.
99  4 2 180. 3980.
99  5 2 150. 3980.
99  6 2 150. 3980.
99  7 2 150. 3980.
99  8 2 120. 3980.
99  9 2 120. 3980.
```

cal/cal_Drift_A.cal

```
99    0    2    0. 1.
99    1    2    0. 1.
99    2    2    0. 1.
99    3    2    0. 1.
99    4    2    0. 1.
99    5    2    0. 1.
99    6    2    0. 1.
99    7    2    0. 1.
99    8    2    0. 1.
99    9    2    0. 1.
```

PrismaFilters

prismaManager.conf

```
ICDRIFT_CAL CALIBRATION/PRISMA/RAW/icdrift.cal
```

CALIBRATION/PRISMA/RAW/icdrift.cal

```
# Layer A
id 0 0 cal -0.356814695283694    0.000990322166649 thr 0 4096
id 0 1 cal -0.3543057203189      0.000993092101531 thr 0 4096
id 0 2 cal -0.36079575685287     0.000982342093345 thr 0 4096
id 0 3 cal -0.375224661740377    0.000972783667404 thr 0 4096
id 0 4 cal -0.366602920416786    0.000977087690271 thr 0 4096
id 0 5 cal -0.348337379200598    0.00100538304776  thr 0 4096
id 0 6 cal -0.347610266853692    0.001004150259801 thr 0 4096
id 0 7 cal -0.404315752058997    0.000977464800437 thr 0 4096
id 0 8 cal -0.363955019538532    0.000971510171444 thr 0 4096
id 0 9 cal -0.428651273652748    0.000992973984074 thr 0 4096
# Layer B
id 1 0 cal -0.350837941799857    0.000981597854266 thr 0 4096
id 1 1 cal -0.344210205249724    0.000990025770793 thr 0 4096
id 1 2 cal -0.350063027738831    0.000982532238715 thr 0 4096
id 1 3 cal -0.359726919632231    0.000980720683648 thr 0 4096
id 1 4 cal -0.372374718976808    0.000963487179552 thr 0 4096

...
```

AgataSelector

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- **Z identification with gates**

A/Q vs X_FP

- Optimize optical parameters
- **Align and calibrate A/Q with TOF offsets**

E-Rβ matrix

- Include non-measured energy correction
- **Q identification with gates**

A/Q vs MCP_X/MCP_Y/X_FP

- **Correct aberrations**

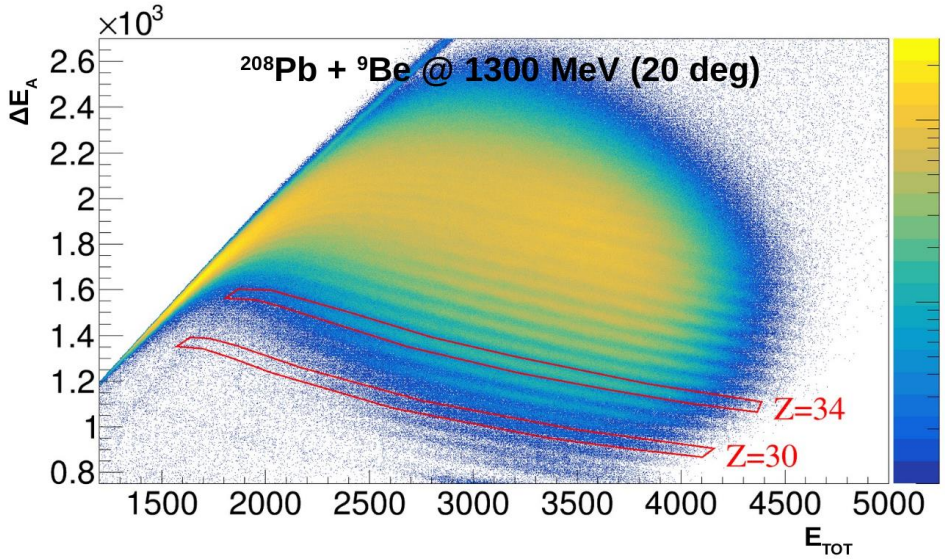
Mass

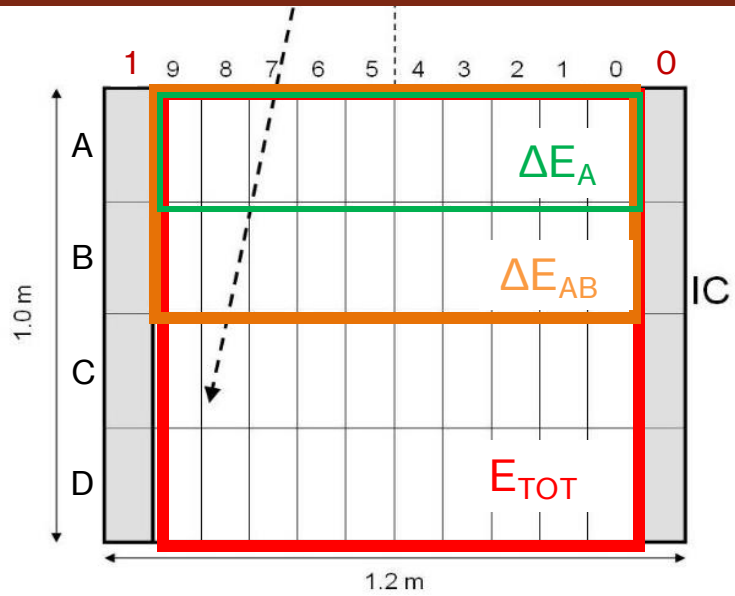
- **Recalibrate A/Q and Q**

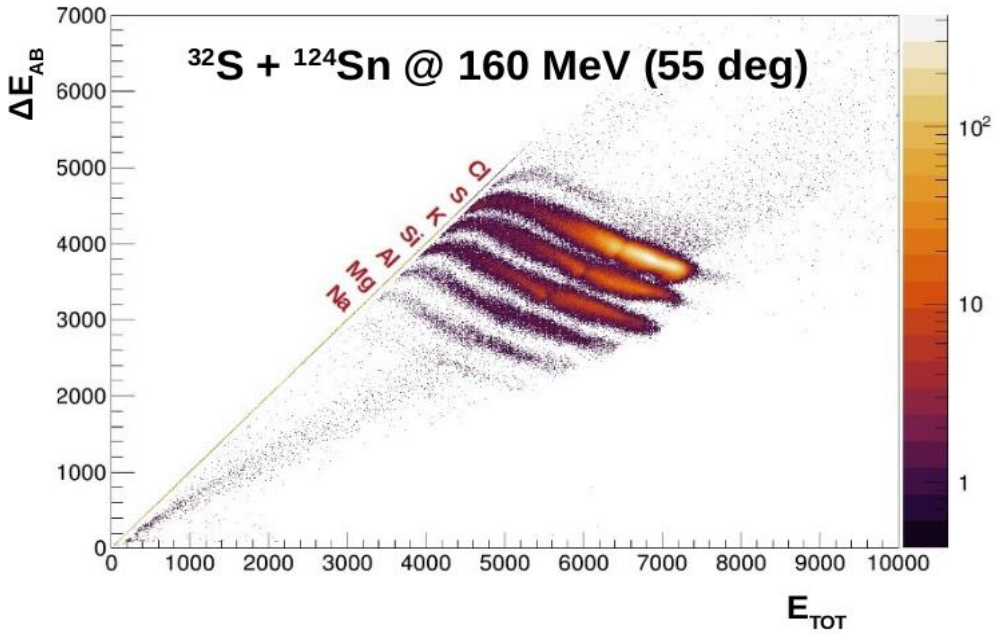
Z selection

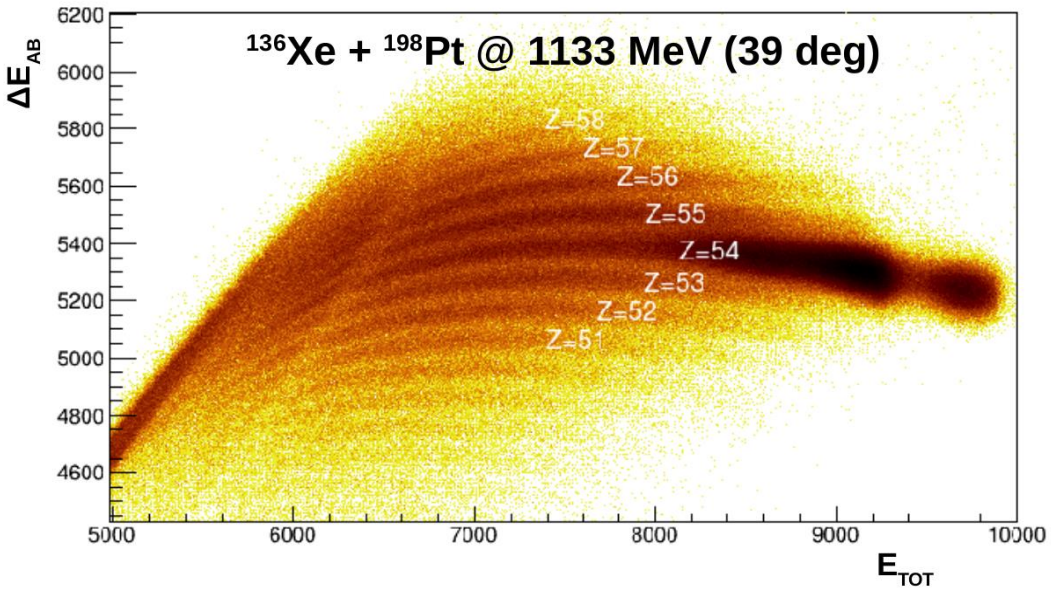
Stopping power of an ion in matter depends on Z^2

ΔE vs E shows bands for different Z of the ions in PRISMA

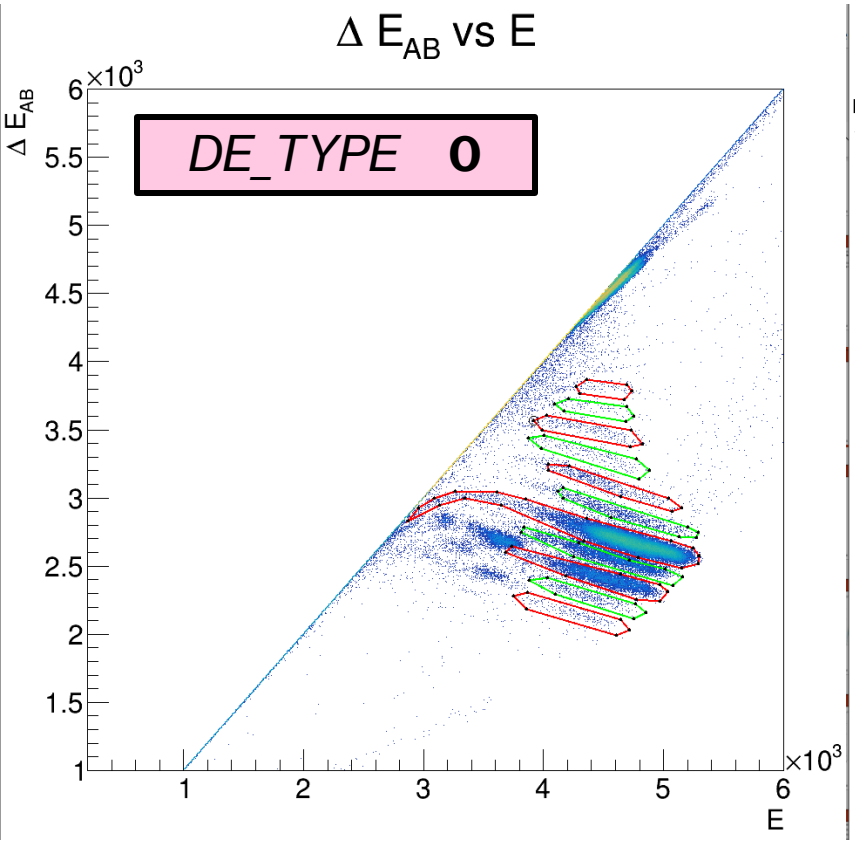


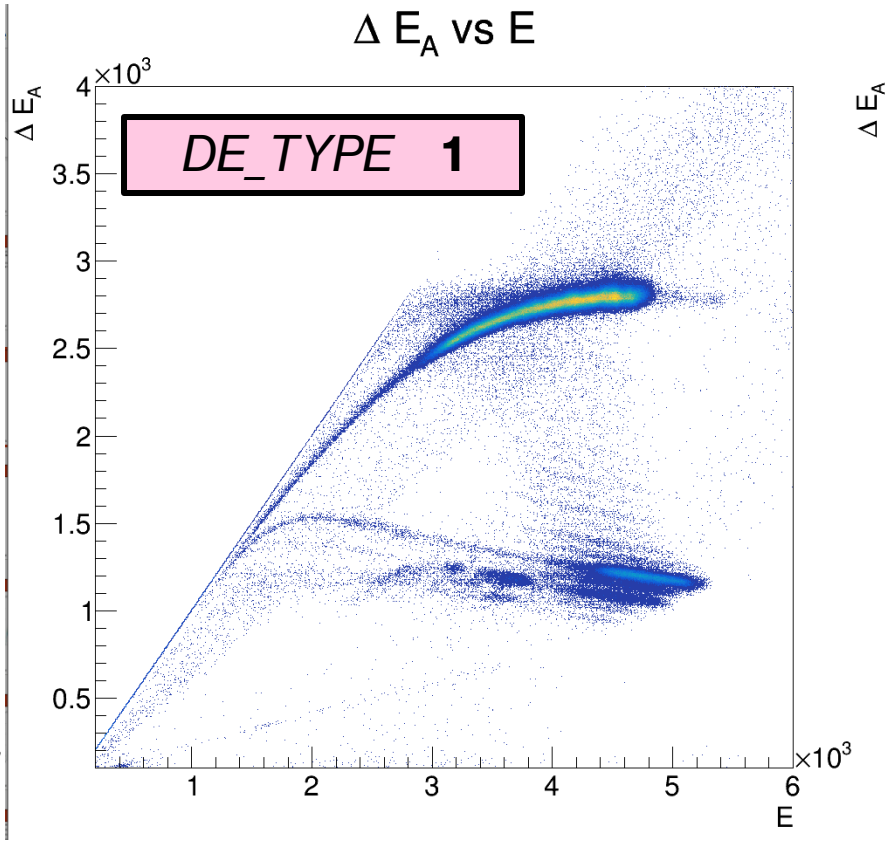


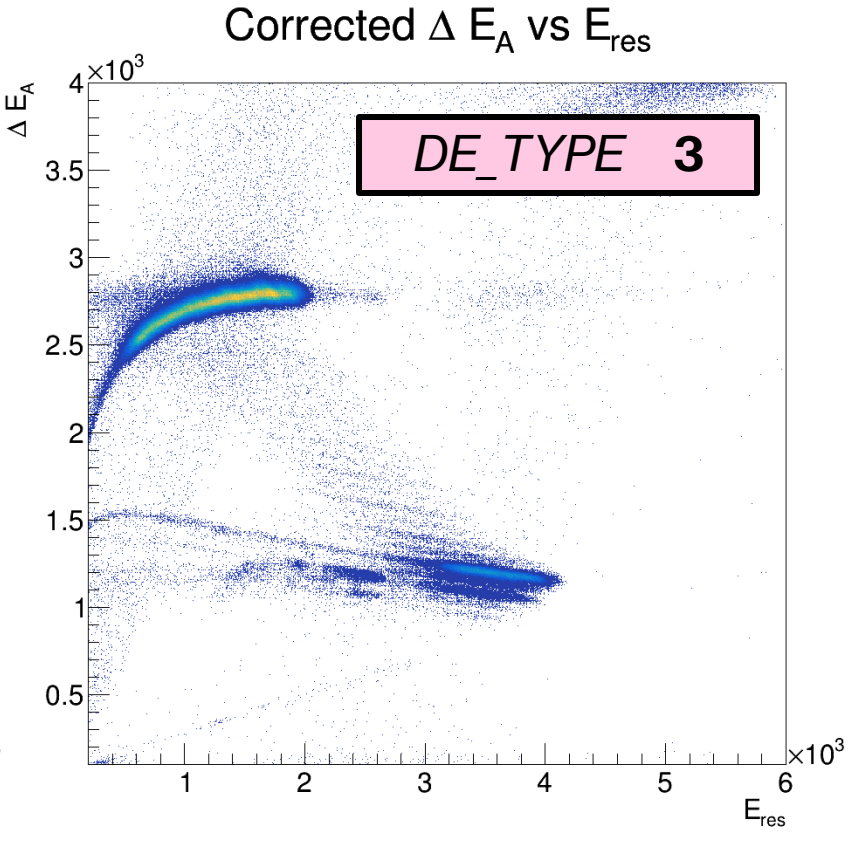




Z selection: options



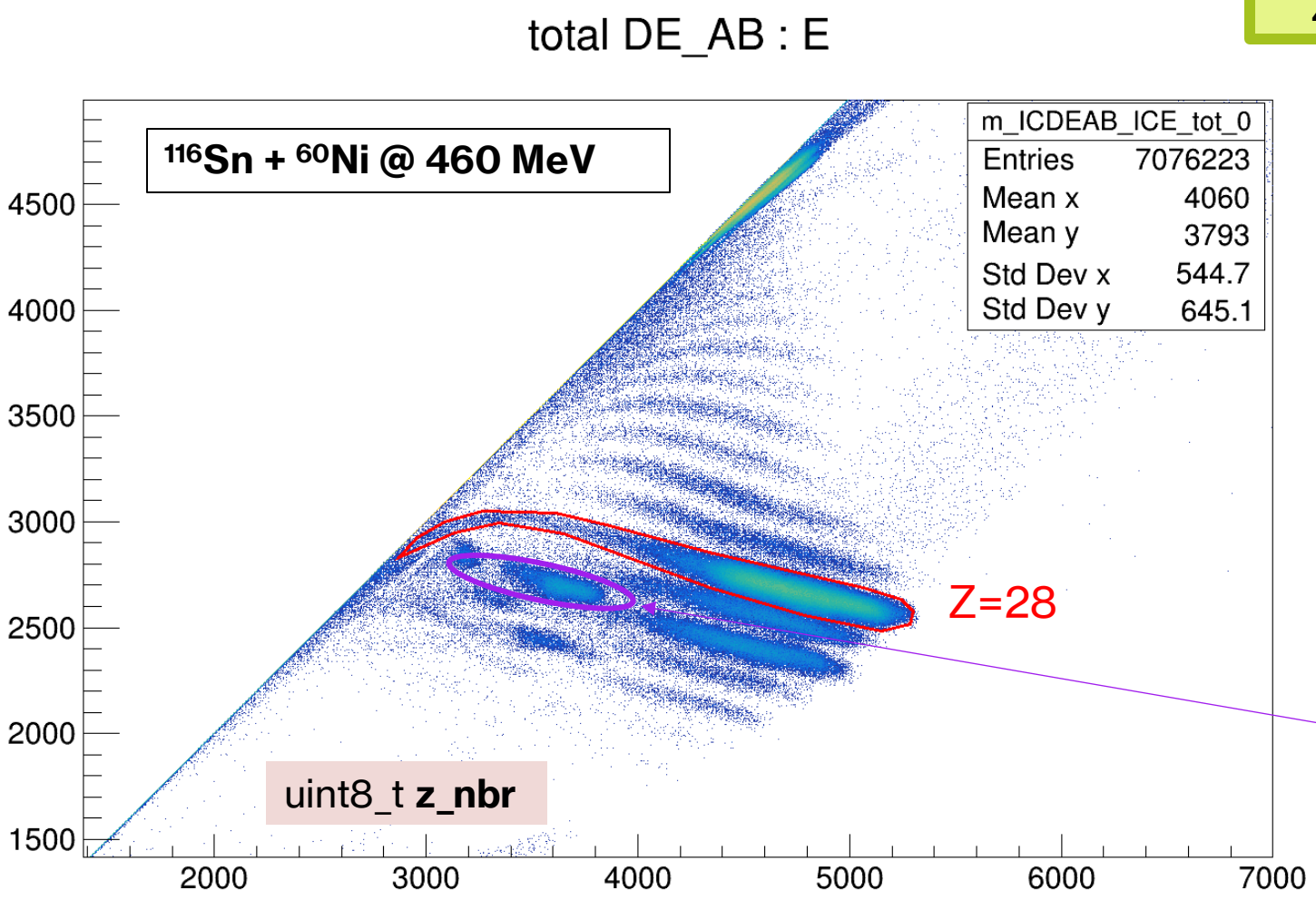




DE_TYPE 2 Would be IC_RANGE vs IC_E but never implemented

DE_TYPE 4 Continuous Z with ZED_LINES (see later)

Z selection: implementation



ZED_GATE **/CUT/PRISMA/ANA/ZED**

DE_TYPE 0

zed__0__28.root

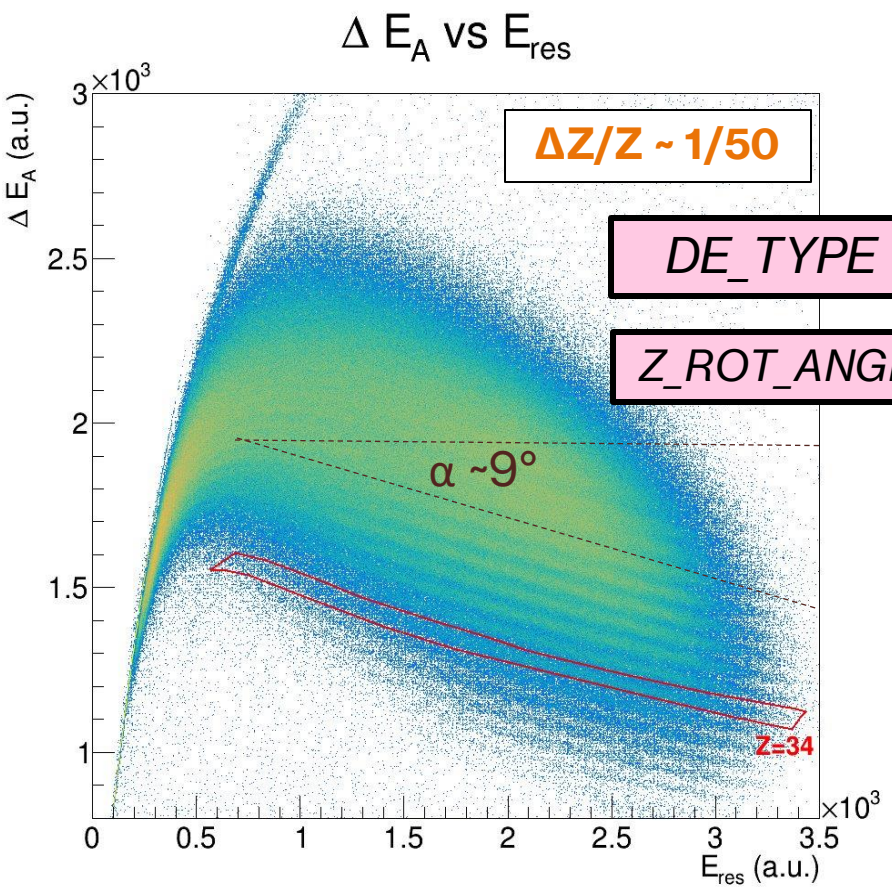
Z value

./RunSelector --set_gates can be used

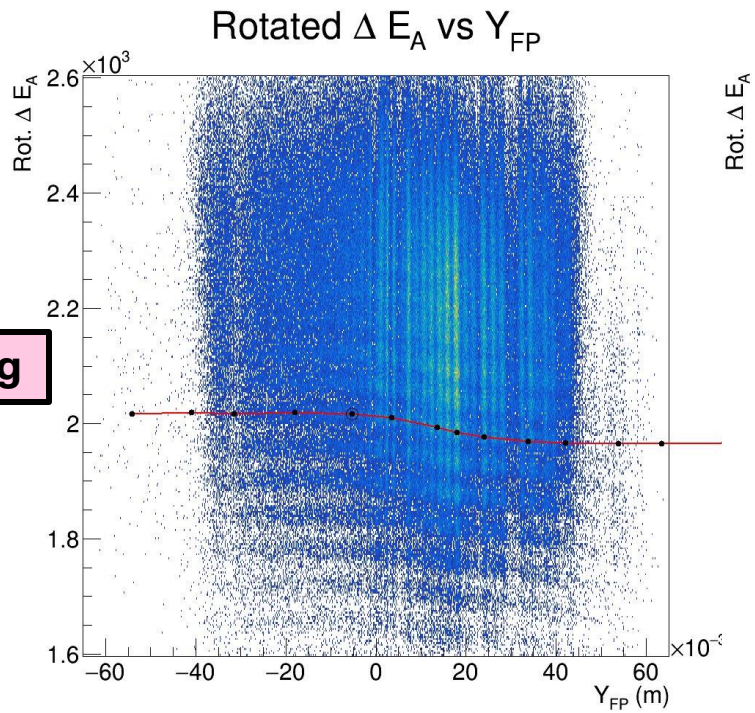
Warning:
IC pad 0C **is not working.**
The Z matrix can have weird features since part of the energy is missing.
The following line in the selector.conf can discard events that are in section 0

BROKEN_IC_CHANNELS 2 1

Optional - Z selection: improved resolution

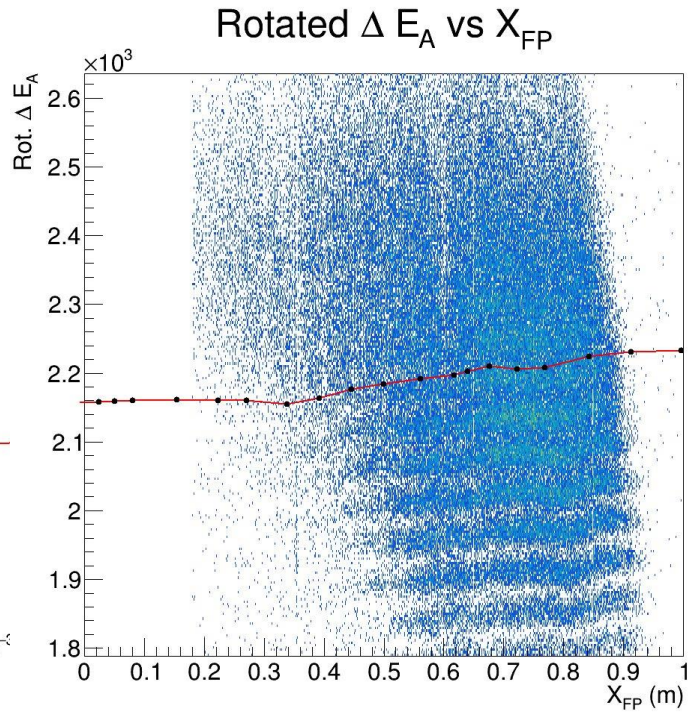


^{208}Pb + ^{9}Be @ 1.3 GeV



Dependence of Z bands on Y:

The longer drifts of charges in IC, the lower the collection efficiency



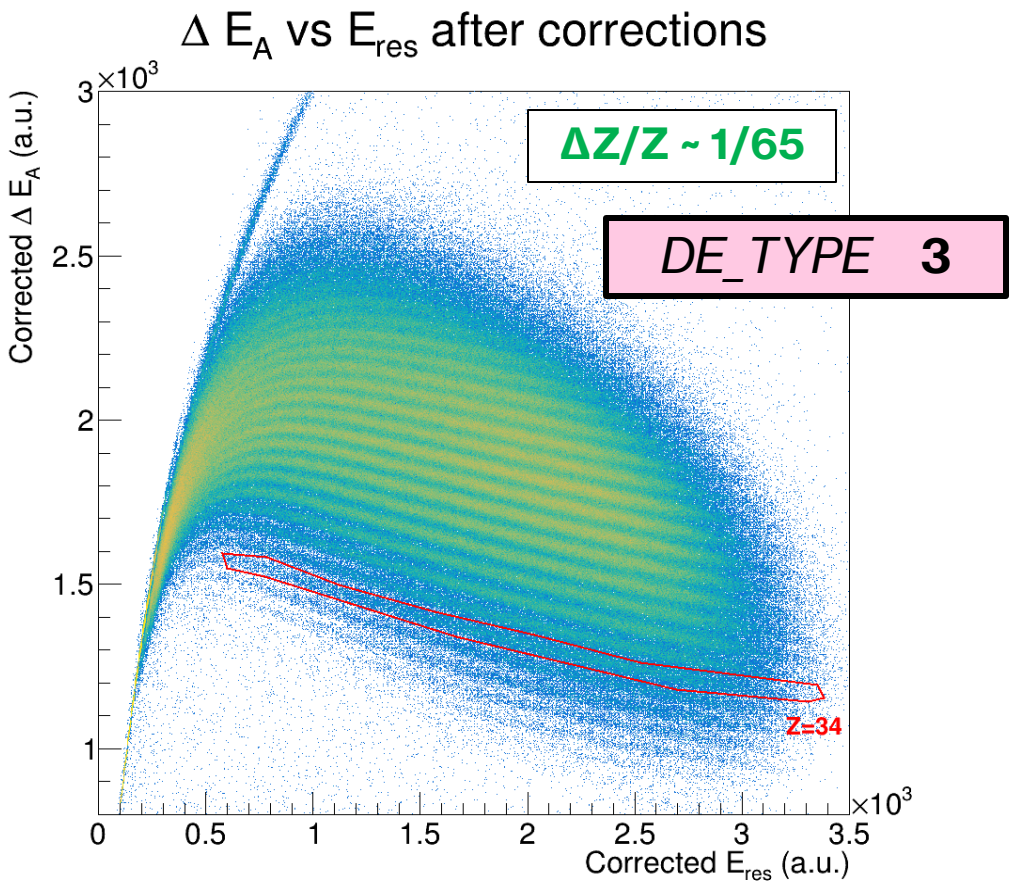
Dependence of Z bands on X:

Not understood, but large effect

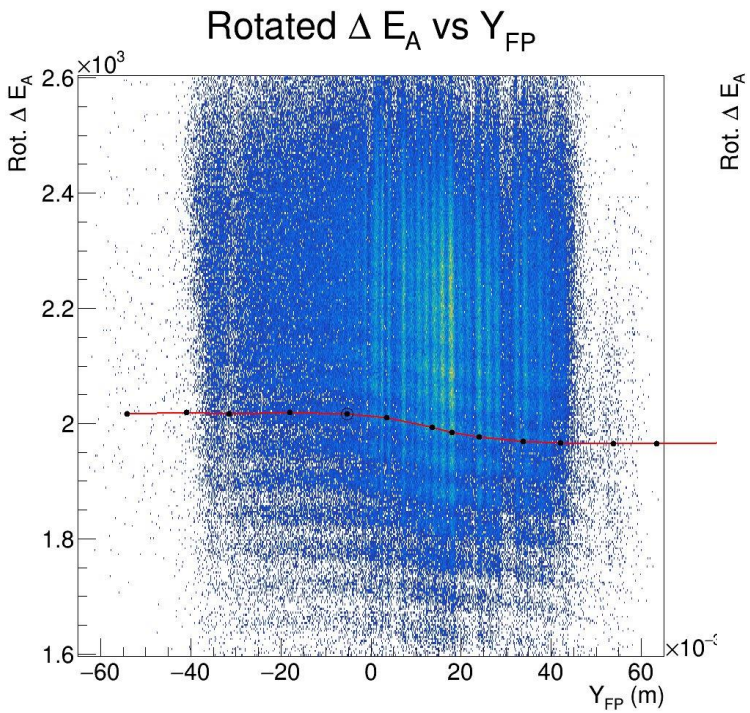
ICDEAXFP_CORR	**/CUT/PRISMA/ANA/ICDEA_XFP**
ICDEAYFP_CORR	**/CUT/PRISMA/ANA/ICDEA_YFP**

`ideaxfp__0__0.root`
`ideayfp__0__0.root`

Optional - Z selection: improved resolution

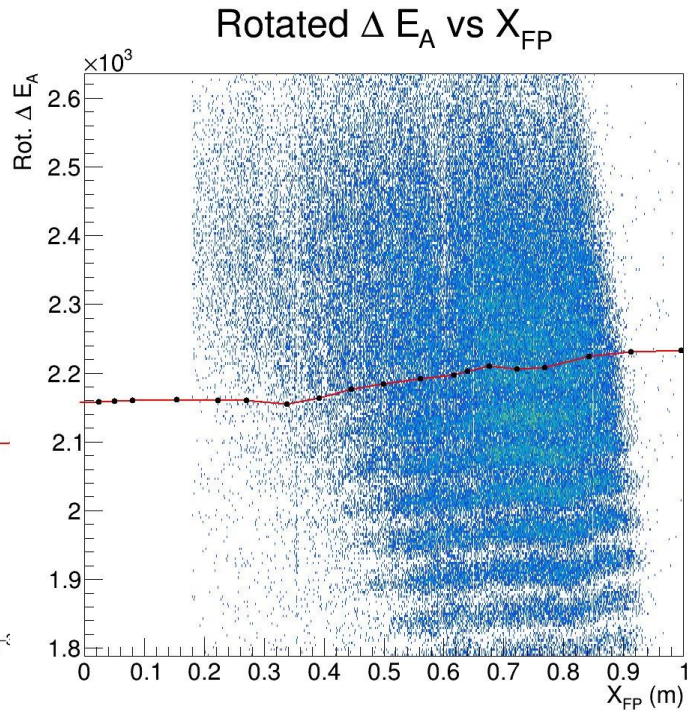


^{208}Pb + ^{9}Be @ 1.3 GeV



Dependence of Z bands on Y:

The longer drifts of charges in IC, the lower the collection efficiency



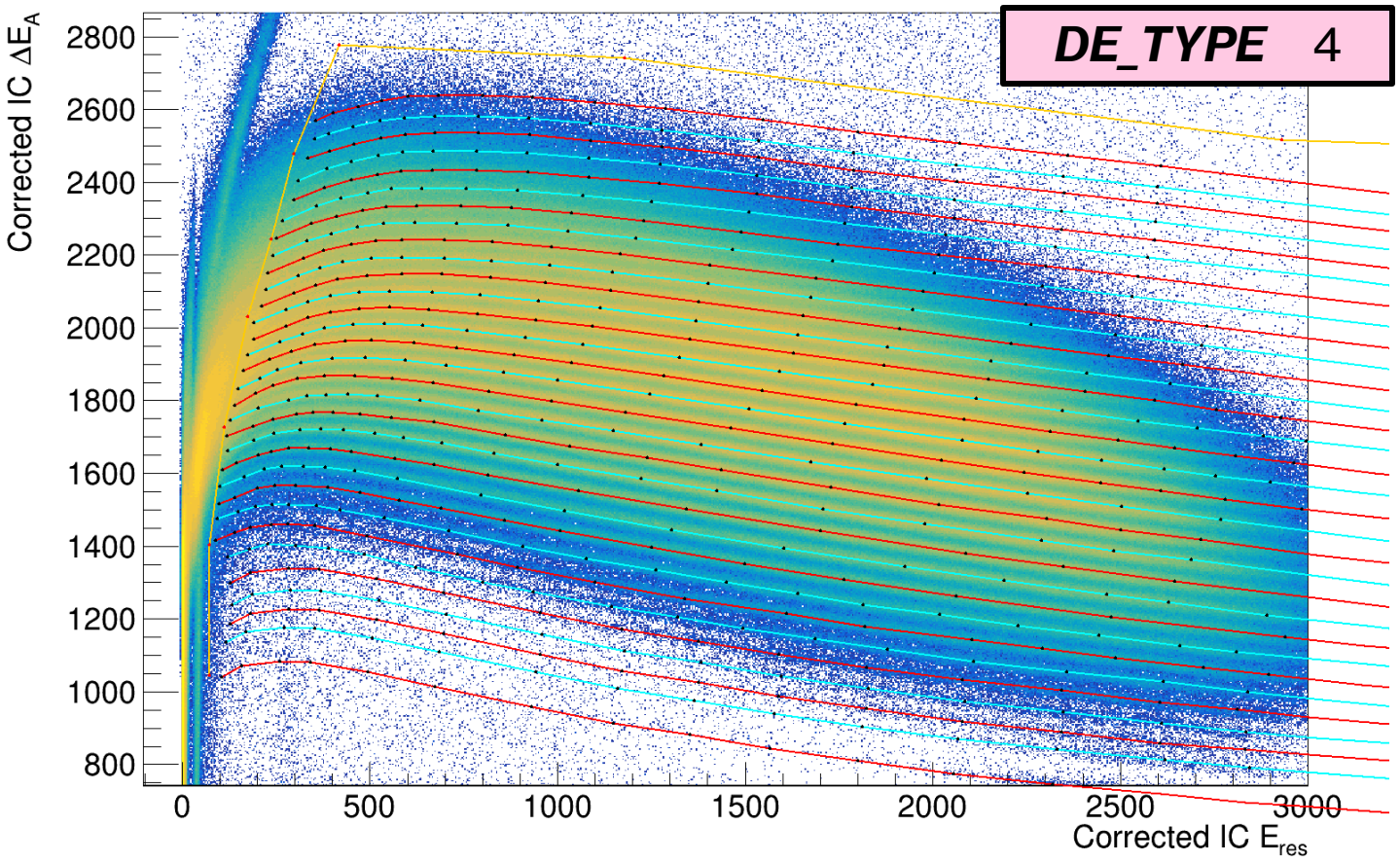
Dependence of Z bands on X:

Not understood, but large effect

ICDEAXFP_CORR	**/CUT/PRISMA/ANA/ICDEA_XFP**
ICDEAYFP_CORR	**/CUT/PRISMA/ANA/ICDEA_YFP**

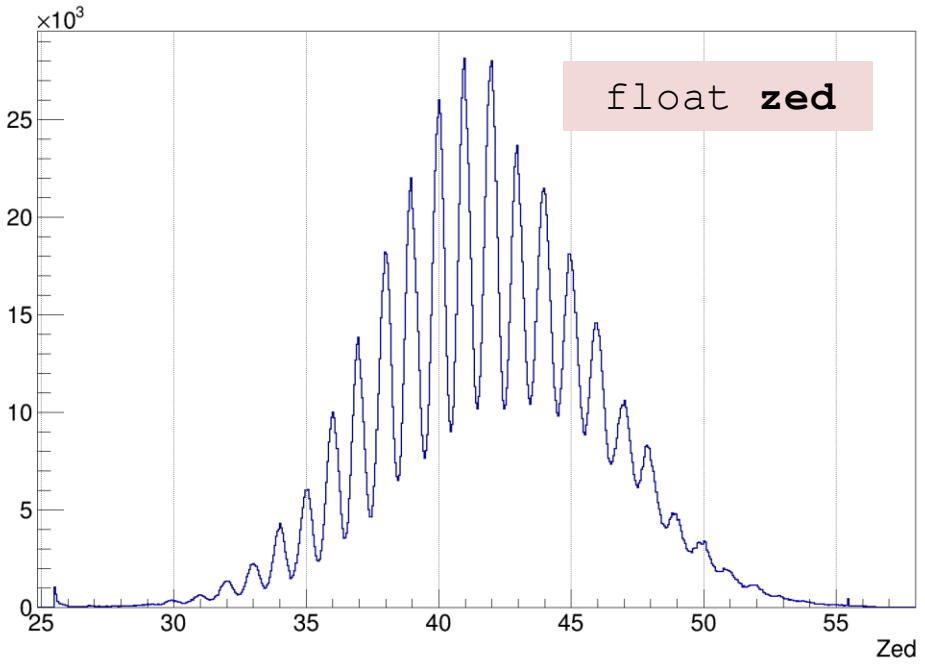
`ideaxfp__0__0.root`
`ideayfp__0__0.root`

Continuous Z



ZED_LINES **/CUT/PRISMA/ANA/ZED_LINES**

`zed__30__30.root`



Every line centered on the band of a Z
For every poiny the distance between neighbouring bands gives Zed

Warning: a graph `zed__0__0.root` is needed to define a rejection line

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

A/Q vs MCP_X/MCP_Y/X_FP

- Correct aberrations

Mass

- Recalibrate A/Q and Q

Trajectory reconstruction

Trajectory reconstruction

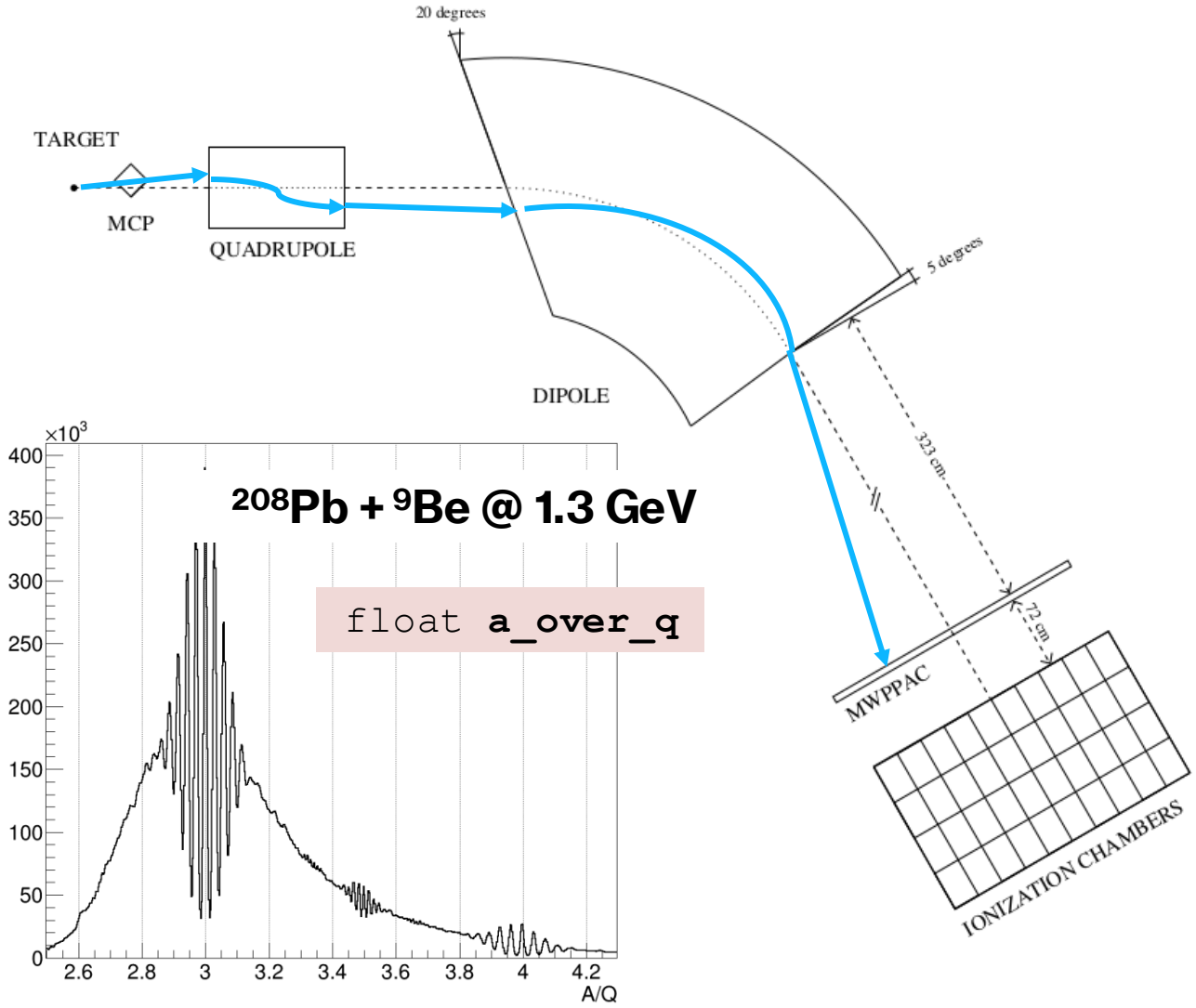
- Entrance angle from MCP position
- Analytic solution to quadrupole to first order (approximation)
- Dipole field uniform over the volume of the magnet, circular trajectory of radius R
- Propagation until focal plane
- Iteration over R until X_FP matches the measurement

Inputs : X_MCP, Y_MCP, X_FP

Outputs: Radius (Brho), Length

$$\beta = \frac{L}{TOF}$$

$$A/Q = \frac{B\rho}{3.107 \cdot \beta\gamma}$$



Warning: in Prismafilters A/Q is wrong by a constant factor!

For converting note that $\mathbf{A\_over\_q\_uncal_{filters} = 0.9649\ a\_over\_q_{selector}}$

Trajectory reconstruction: time alignment

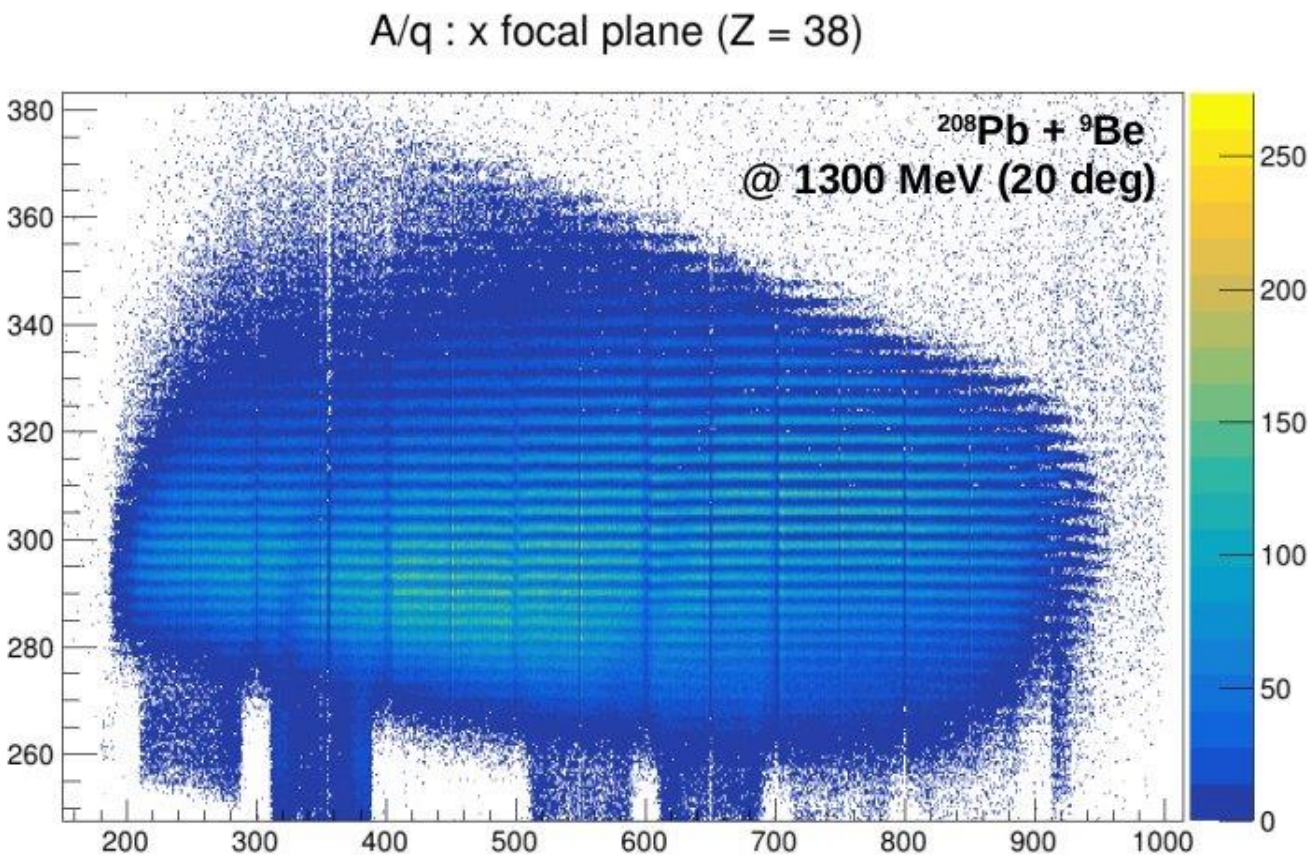
A finer time alignment of the PPAC sections should be done by looking at the **A/Q vs X_FP**

The calibration offsets in **/CALIBRATION/PRISMA/RAW/tof.cal** should be adapted with the TOF difference that align a selected peak

e.g. A/Q = 3

agataselector/Scripts/Prisma/AdjustTofOffset.C

```
void AdjustTofOffset(){

    double tofOffsets[10];
    tofOffsets[0] = 0.0;
    tofOffsets[1] = 0.0;
    tofOffsets[2] = 0.0;
    tofOffsets[3] = 0.0;
    tofOffsets[4] = 0.0;
    tofOffsets[5] = 0.0;
    tofOffsets[6] = 0.0;
    tofOffsets[7] = 0.0;
    tofOffsets[8] = 0.0;
    tofOffsets[9] = 0.0;

    double globalTofOffset = 0.0;
```

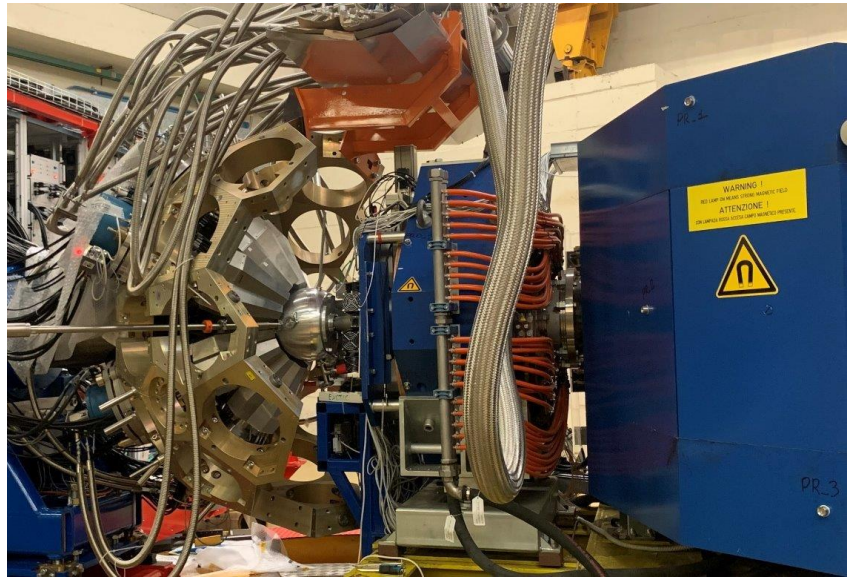


Use script to adjust the offsets fast and then check with

```
AnalyzedTree->Draw("newAoq:x_fp>>h(1000,0,1,1000,2,5)","","col")
```

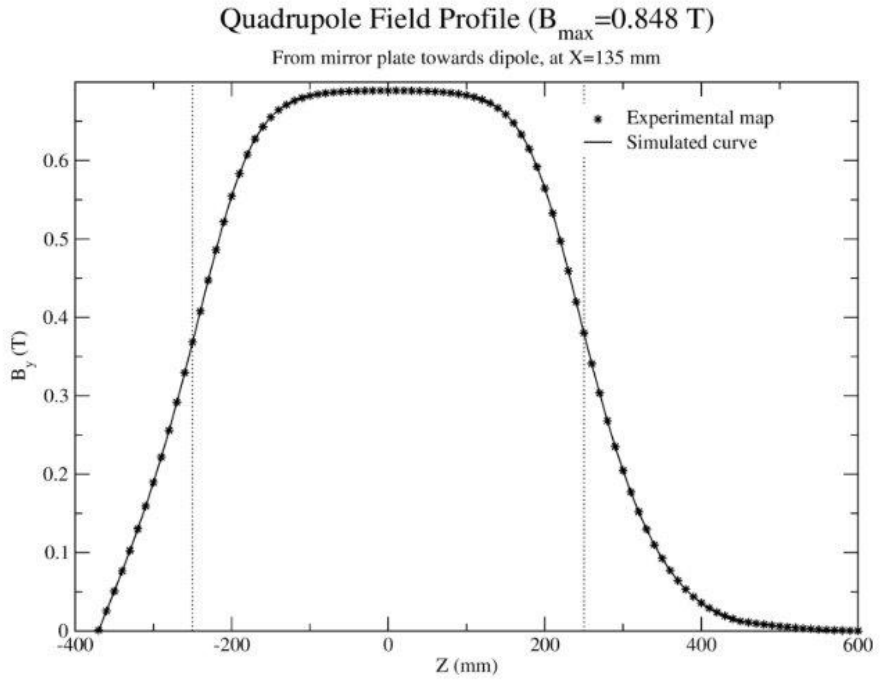
Trajectory reconstruction: Optical parameters

The **quadrupole magnet** has a length of 500 mm and starts at 500 mm from the target.



In the reconstruction we neglect fringe fields for solving the trajectory analytically.

But the **fringe fields** are there!

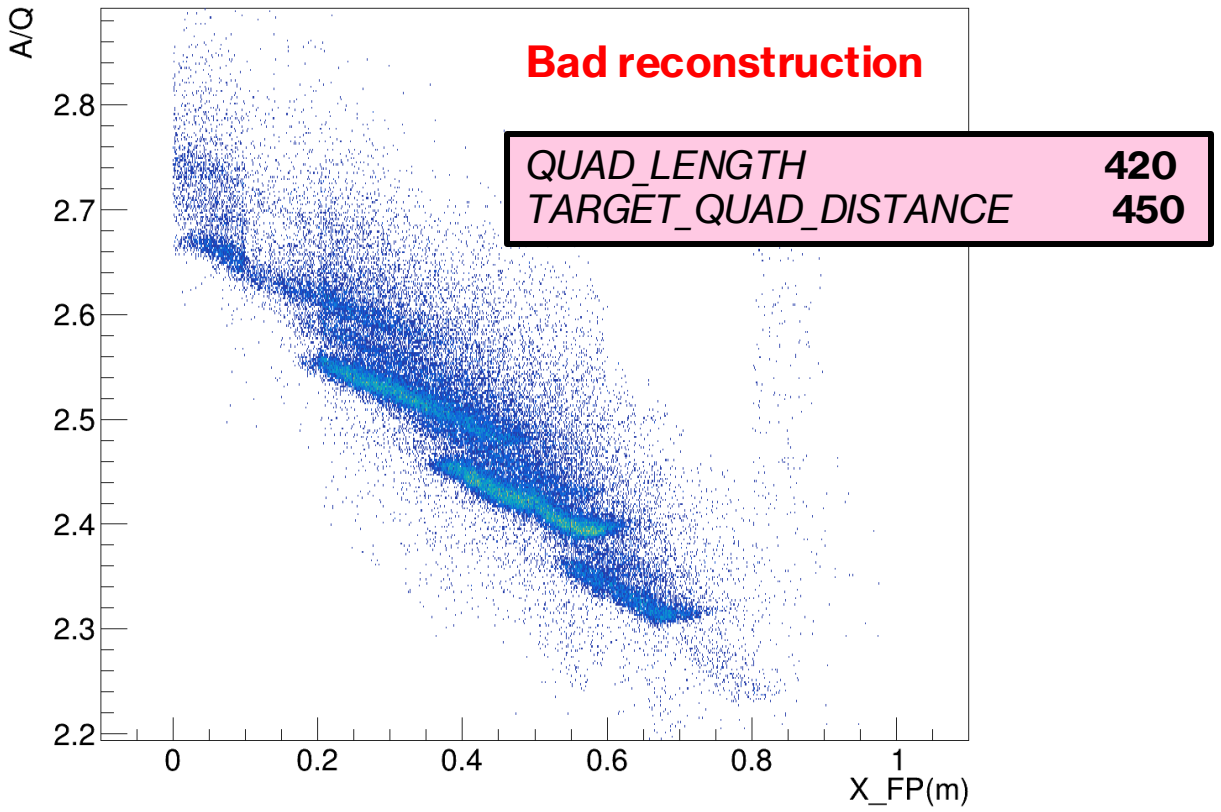


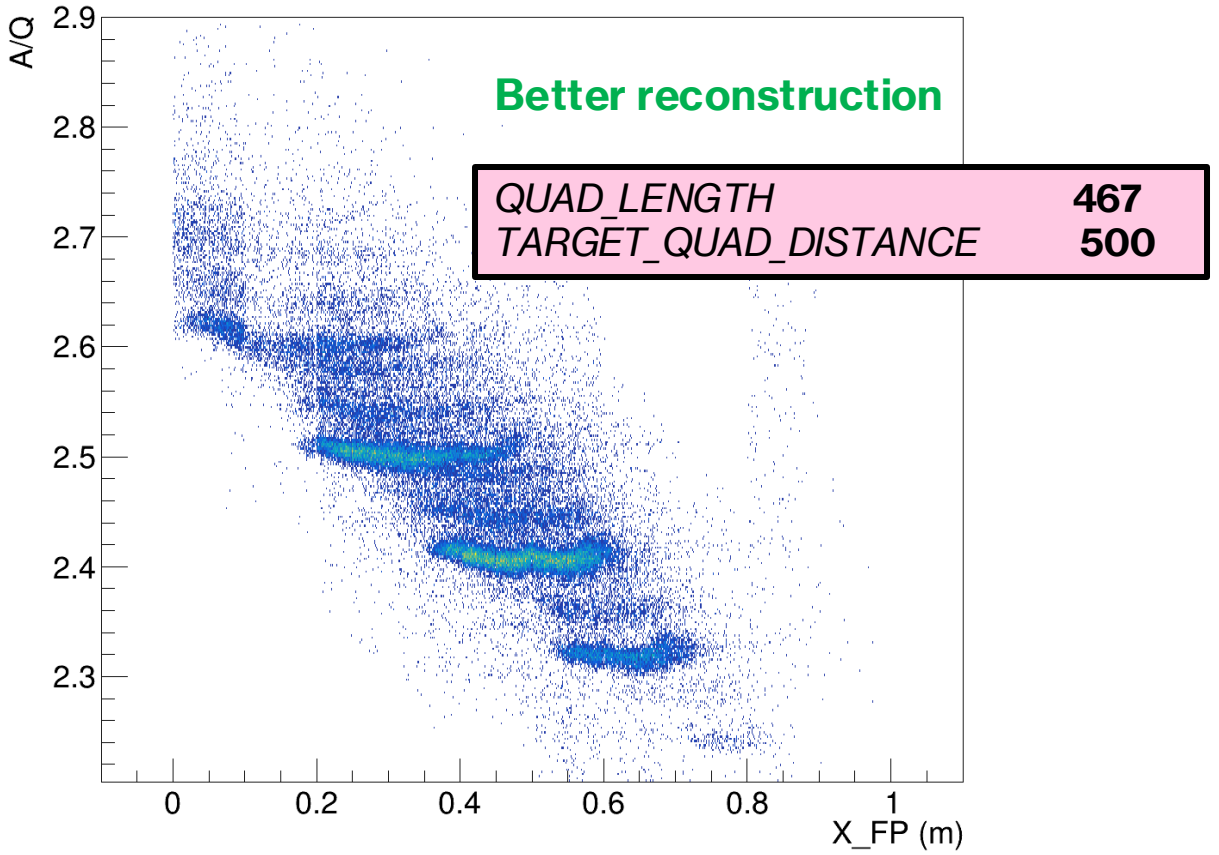
An ***effective length*** and an ***effective position*** of the quadrupole should be used to obtain a good reconstruction.

QUAD_LENGTH	**455**
TARGET_QUAD_DISTANCE	**500**

The values should be adapted to different experiments given the different central Brho of the spectrometer

Trajectory reconstruction: Optical parameters

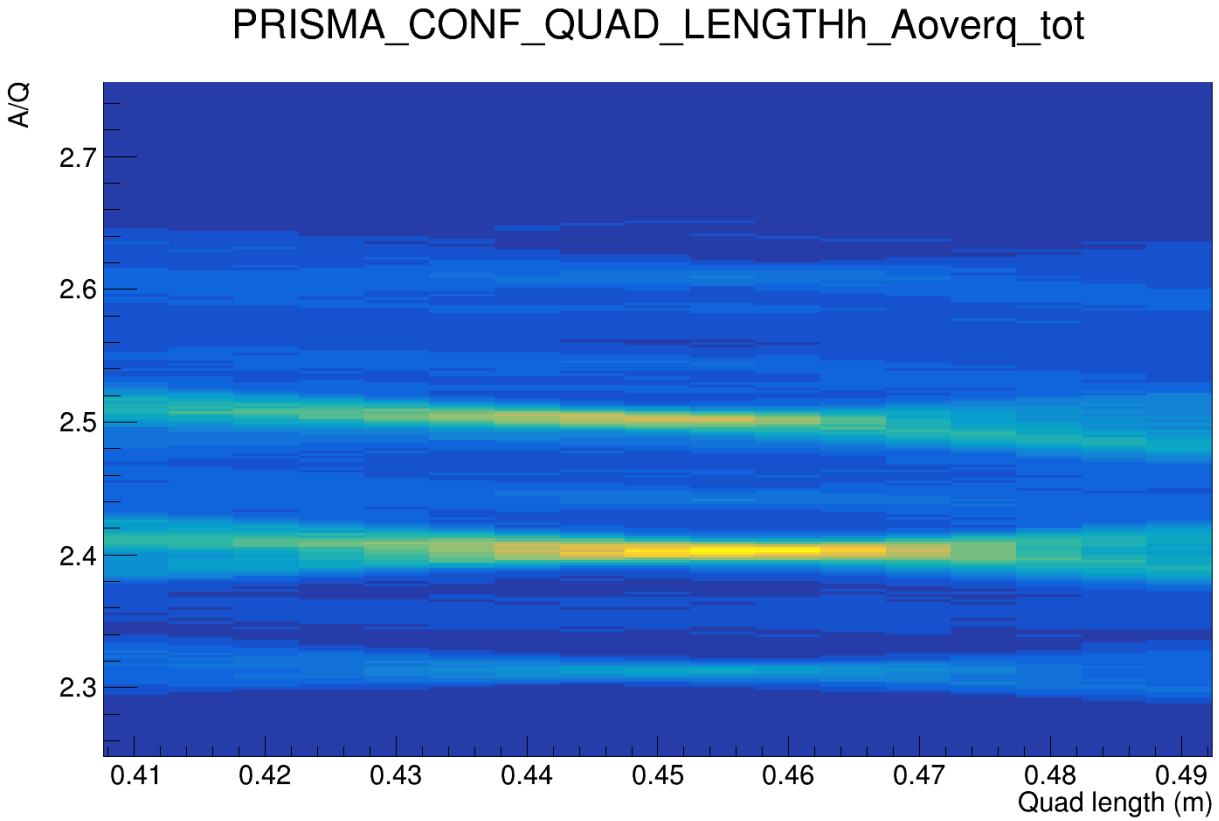


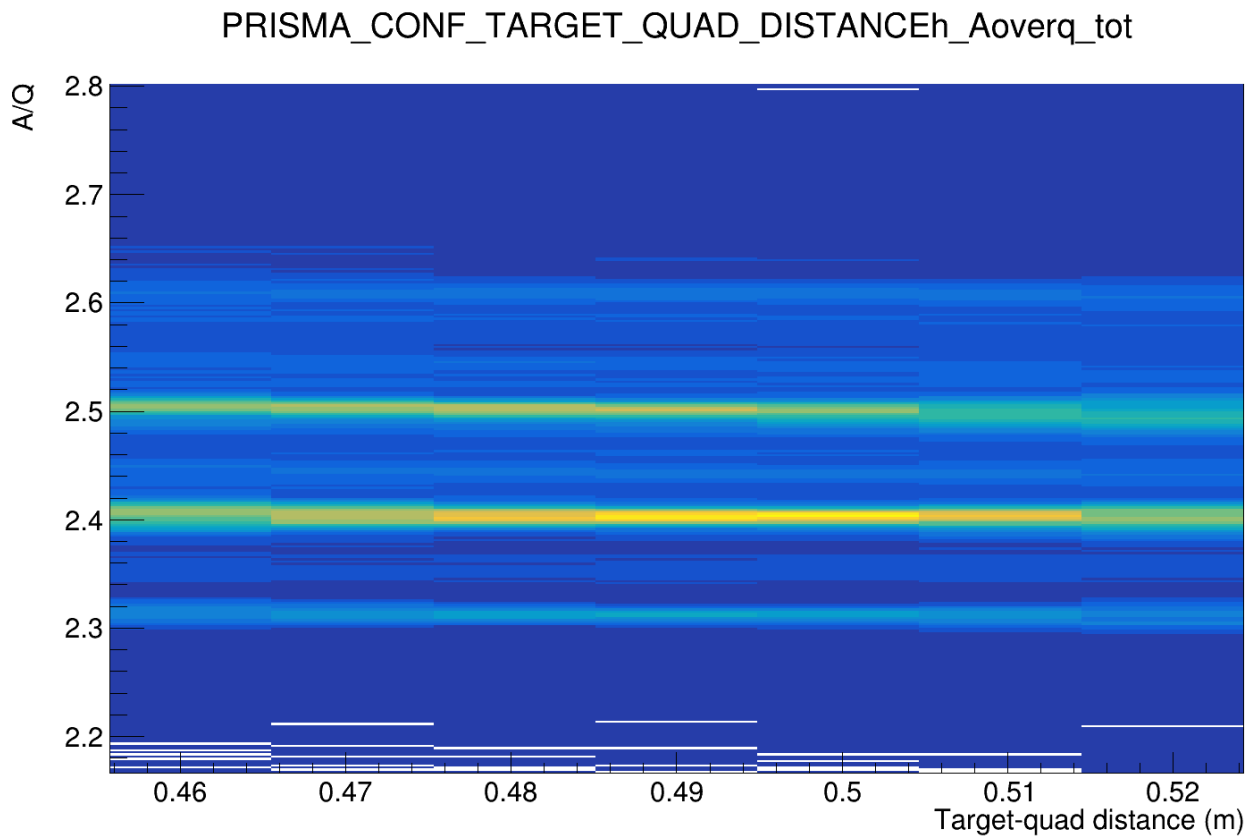


The **Optimizer scan** option is recommended to check what the best values are

The **resolution of the A/Q peaks** varies a lot with these parameters

Trajectory reconstruction: Optical parameters





The **Optimizer scan** option is recommended to check what the best values are

The **resolution of the A/Q peaks** varies a lot with these parameters

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

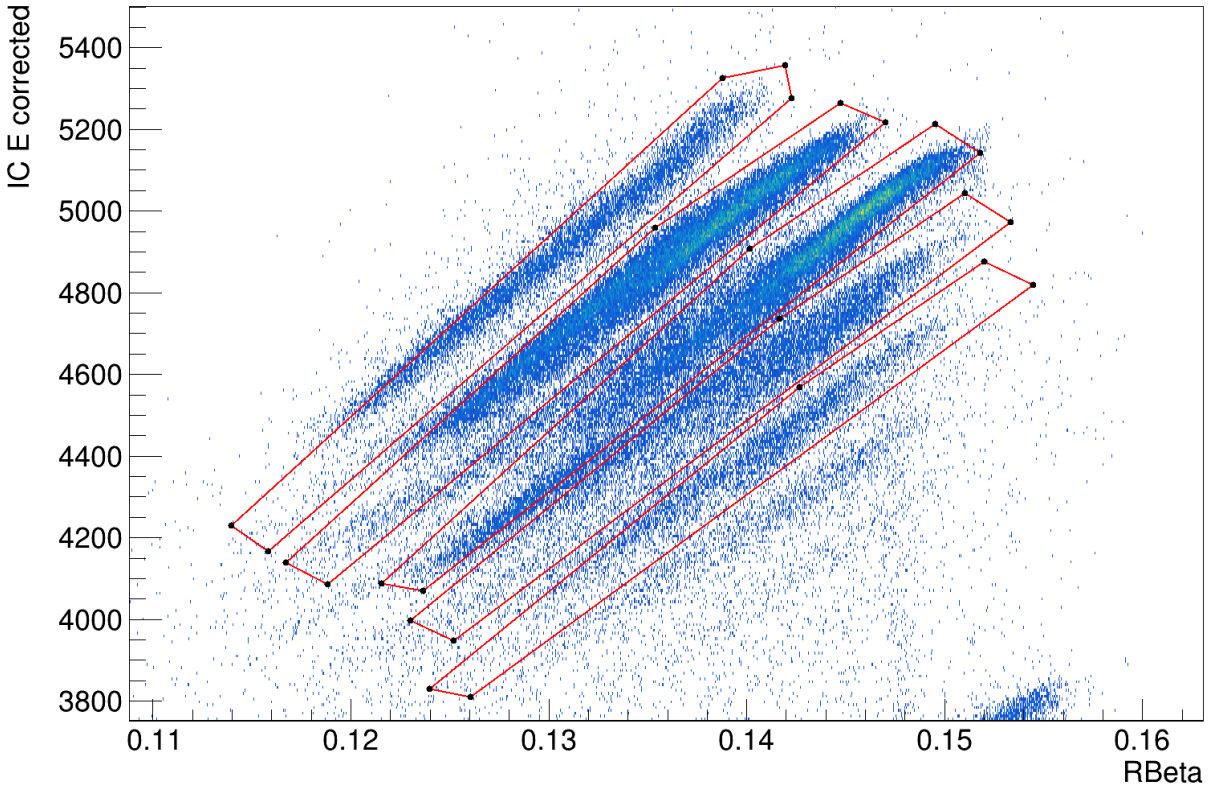
A/Q vs MCP_X/MCP_Y/X_FP

- Correct aberrations

Mass

- Recalibrate A/Q and Q

Q selection



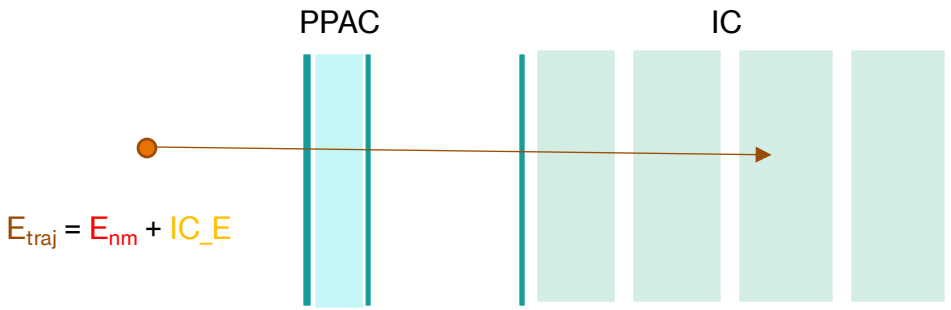
Q separation emerges from combining the info on the **energy** measured in the IC and the reconstructed **Brho**

Usual PRISMA format:
Linear relationship between energy of the ion and R*Beta*(Gamma) that depends on **Q**

Warning: in Prismafilters A/Q is wrong by a constant factor!
For converting note that **$RBeta_{filters}$ = 29979.2458*B_dipole*Radius*Beta**

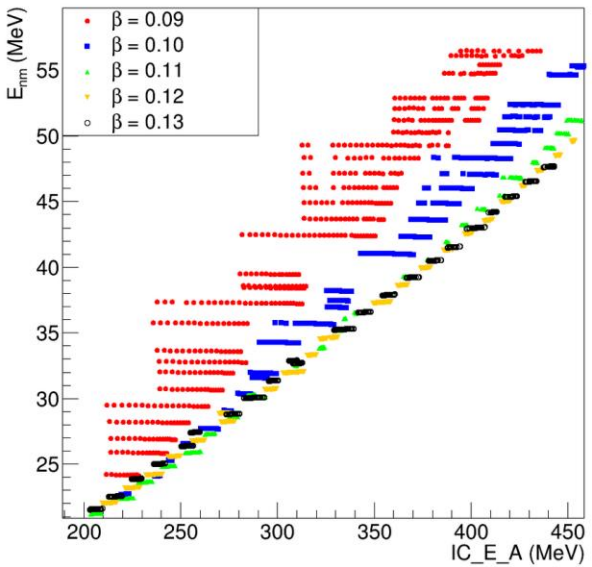
Optional - Non-measured energy correction

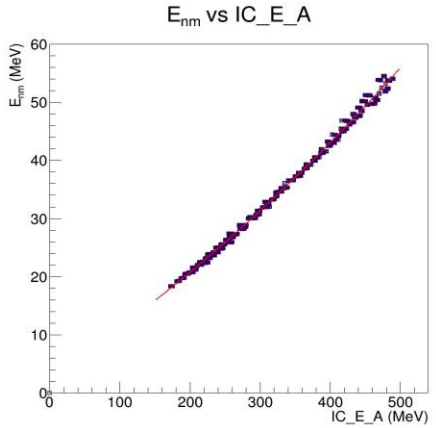
Energy measured in IC < Trajectory energy



Non measured E (E_{nm}) Measured E (IC_E)

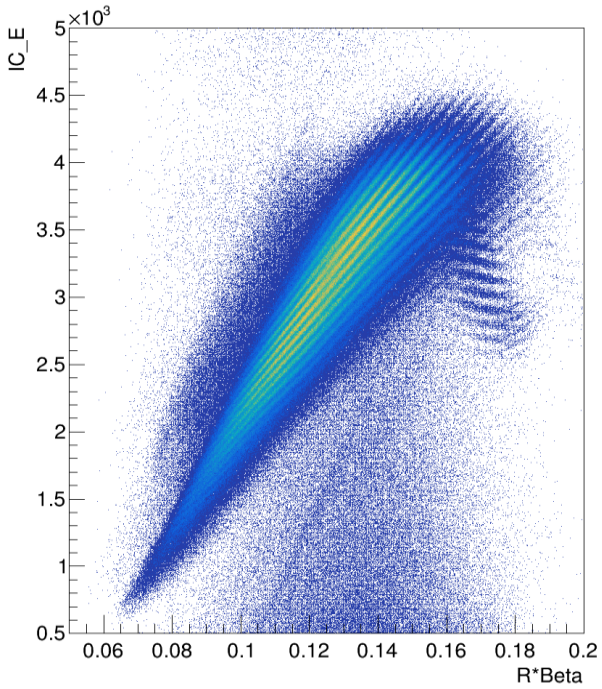
E_{nm} vs IC_E_A



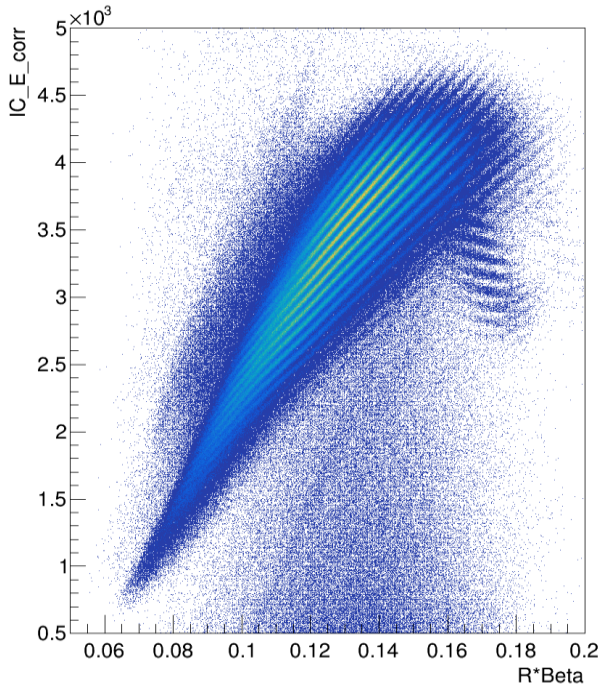


E_{nm} estimated with **SRIM** for a range of ions and fitted to IC_DE_A

Charge states



Charge states with E_{nm} correction



ICE_CORR **/CALIBRATION/PRISMA/ANA/icecorr_empty.cal**

```
id 0  cal 0 0 thr -10000 100000
#id 0  cal 0 0.0779105 5.61303e-05
thr -10000 10000
id 1  cal 0 1 thr 0 4096
id 2  cal 0 1 thr 0 4096
id 3  cal 0 1 thr 0 4096
id 4  cal 0 1 thr 0 4096
id 5  cal 0 1 thr 0 4096
```

Warning: unusual default value

Estimation on fission data

id 5 is to calibrate the energy to MeV

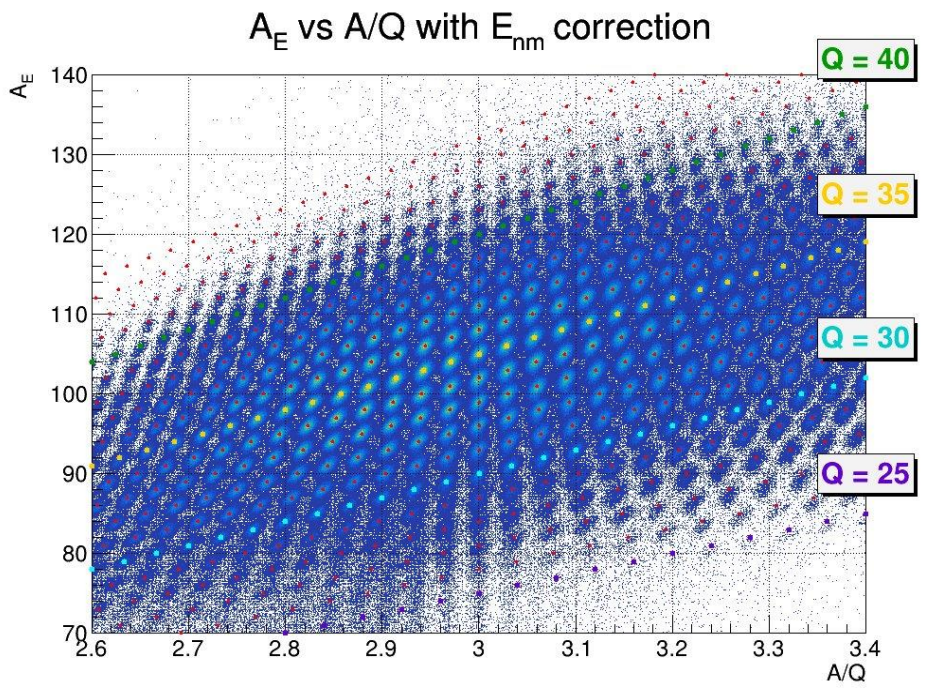
Optional - Q calibration

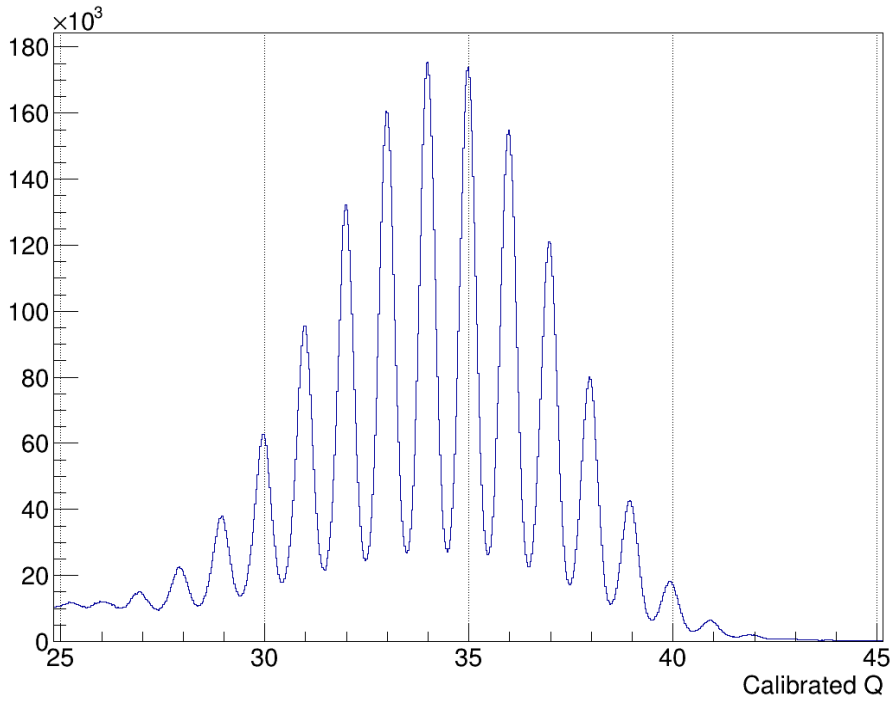
`float` **`ic_mass`**

$$A_E = \frac{E}{u(\gamma - 1)}$$

Mass estimated from IC (bad resolution)

Possible to calibrate **IC energy** to MeV





`float` **`charge_cal`**

$$Q = A_E \cdot \frac{1}{A/Q}$$

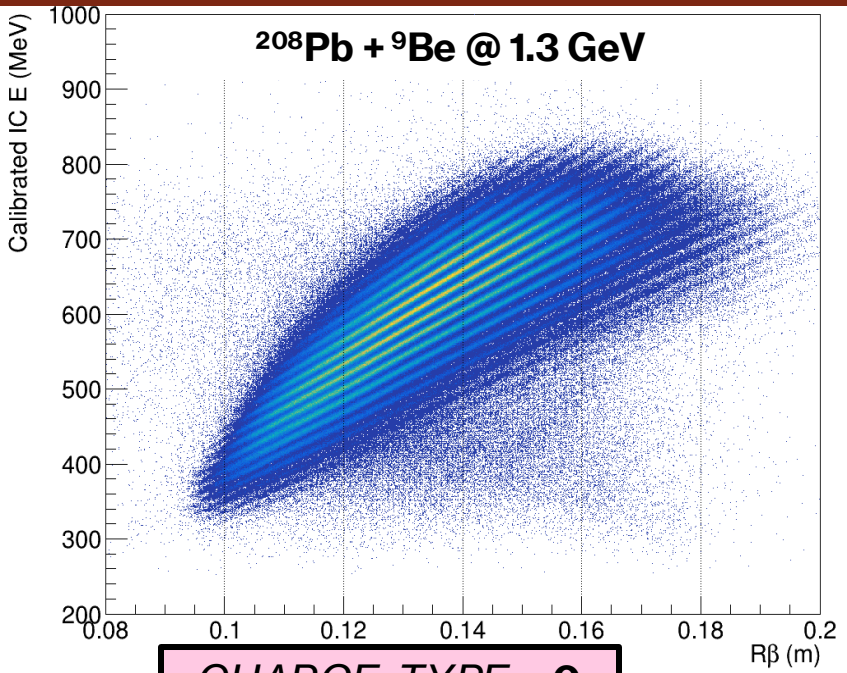
Continuous charge

ICE_CORR **/CALIBRATION/PRISMA/ANA/icecorr_empty.cal**

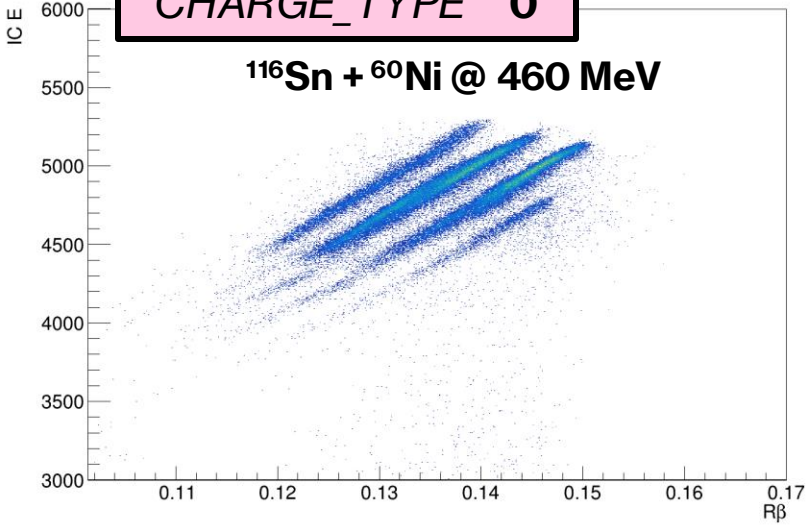
```
id 5  cal 0 1 thr 0 4096
```

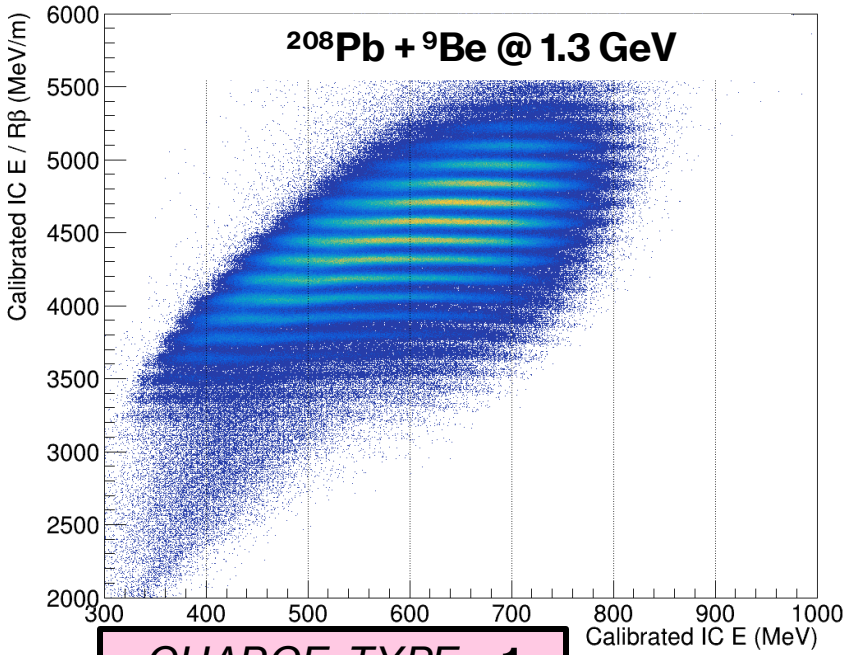
id 5 is to calibrate the energy to MeV

Q selection: options

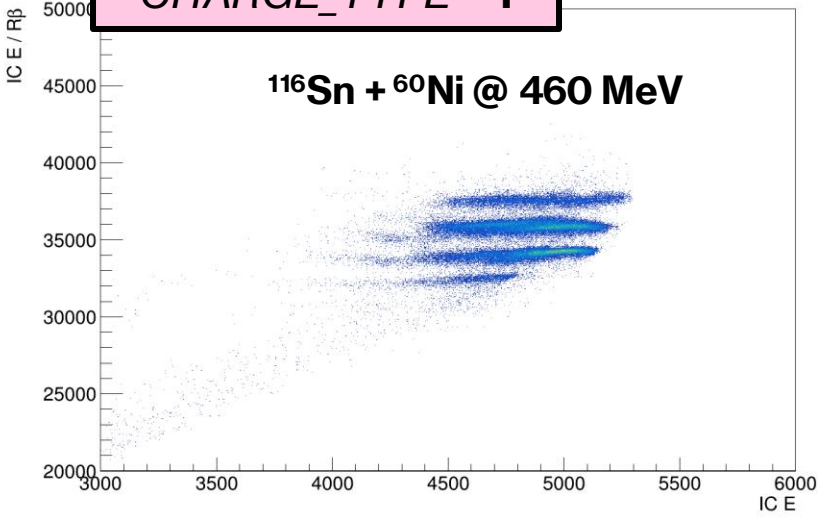


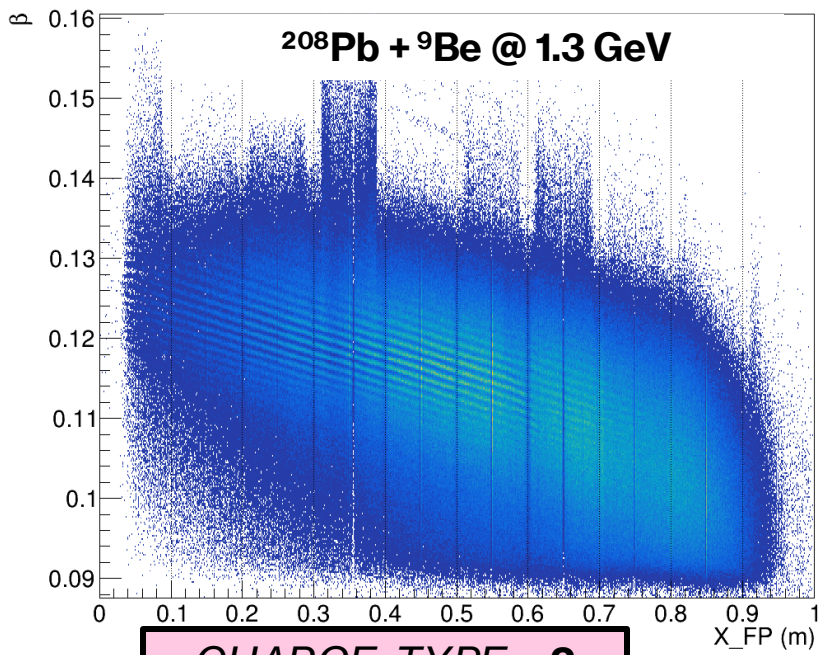
CHARGE_TYPE **0**



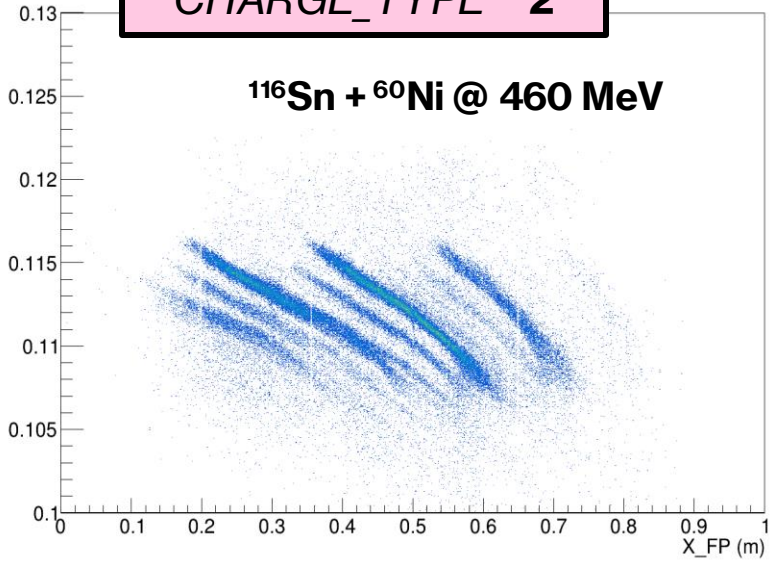


CHARGE_TYPE **1**



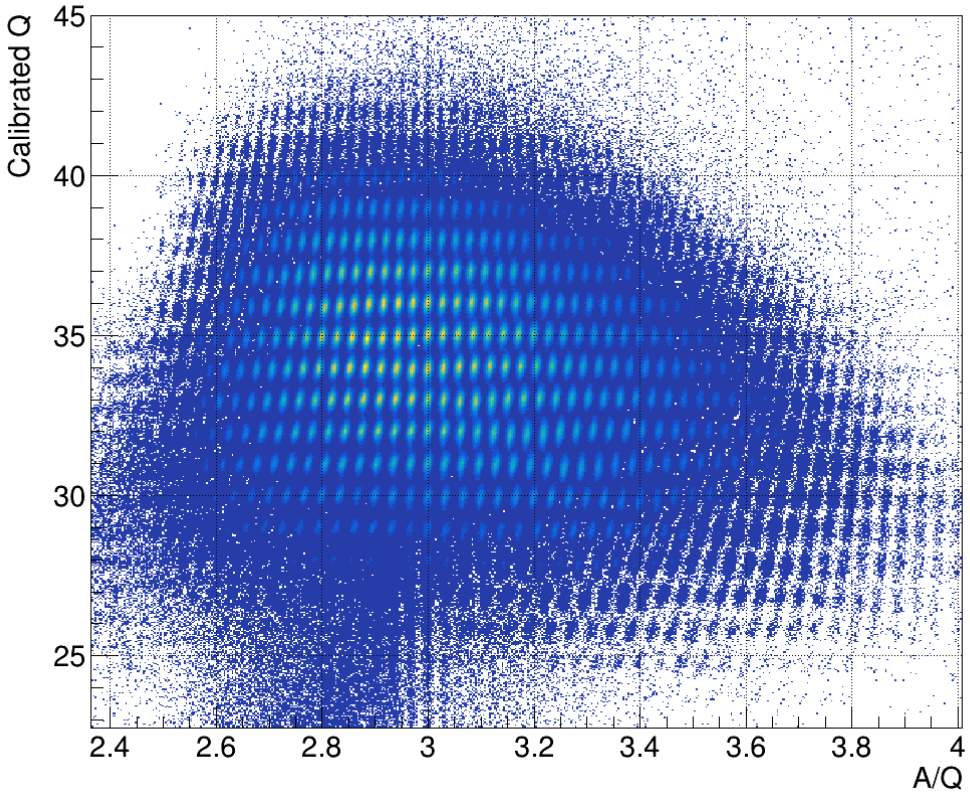


CHARGE_TYPE **2**



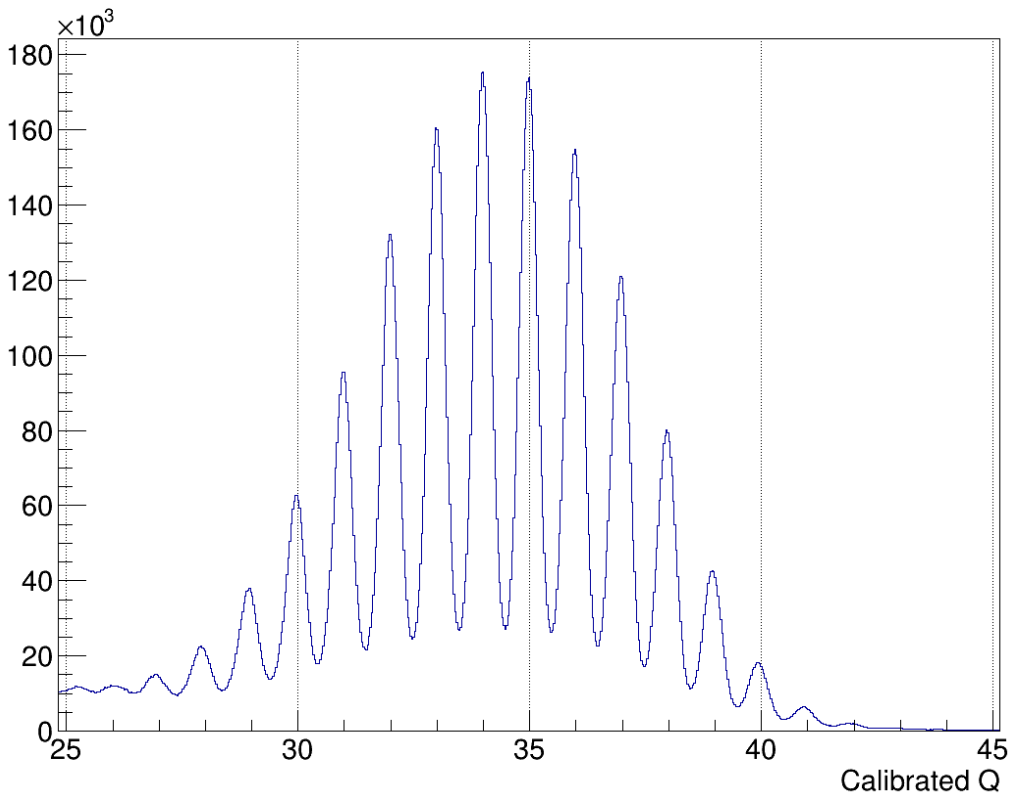
Q selection: options

CHARGE_TYPE **3**



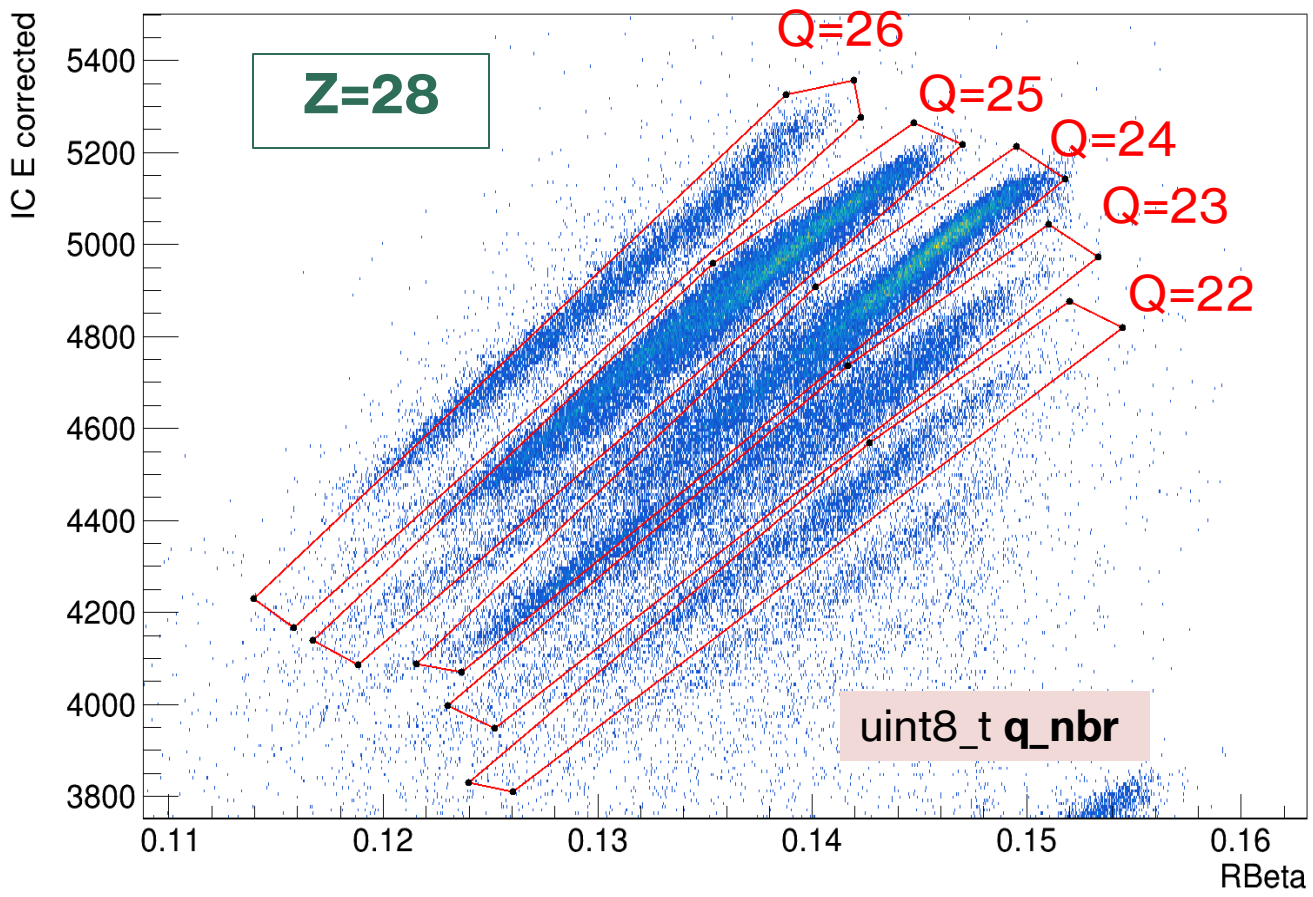
^{208}Pb + ^{9}Be @ 1.3 GeV

CHARGE_TYPE **4**



^{208}Pb + ^{9}Be @ 1.3 GeV

Q selection: implementation



Q_GATE **/CUT/PRISMA/ANA/CHARGE**

DE_TYPE 0

charge__0__28__25.root

Z value **Q value**

The gate should **depend only weakly on Z**, the charge states should be **aligned** among different Z

./RunSelector --set_gates can be used

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
- X,Y calibration - 2D gate	- Thresholds - Calibration	- Thresholds - 2D gates - X,Y calibration	- Thresholds - E Calibration	- Thresholds	- Calibration	- Calibration

ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

Aberrations on A/Q

- Correct aberrations vs X_FP, MCP_X, MCP_Y

Mass

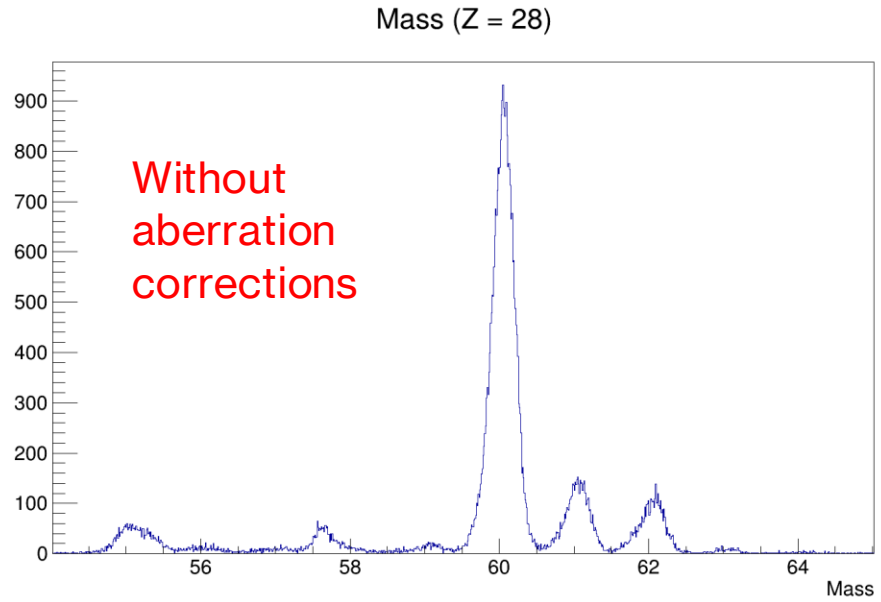
- Recalibrate A/Q and Q

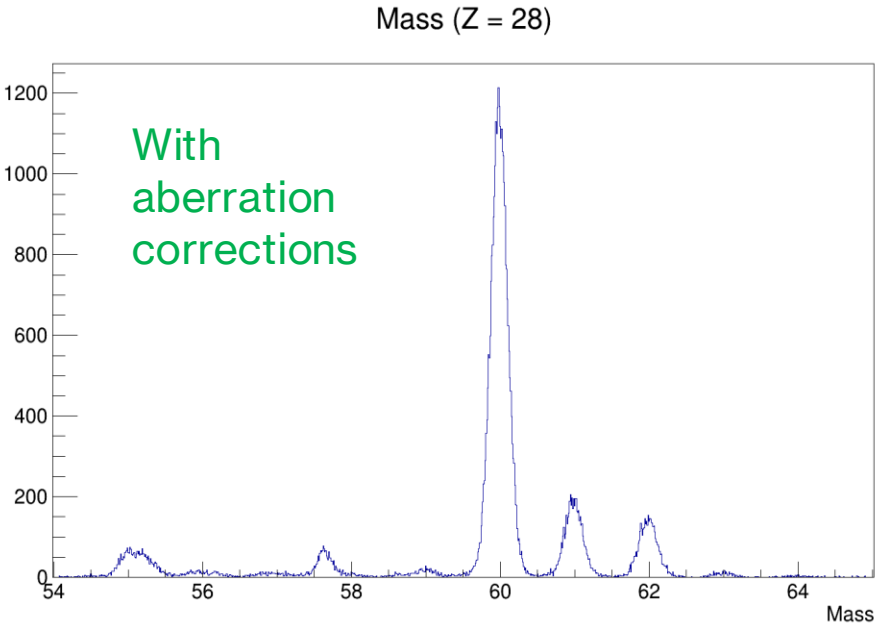
Aberration corrections

What are aberrations?

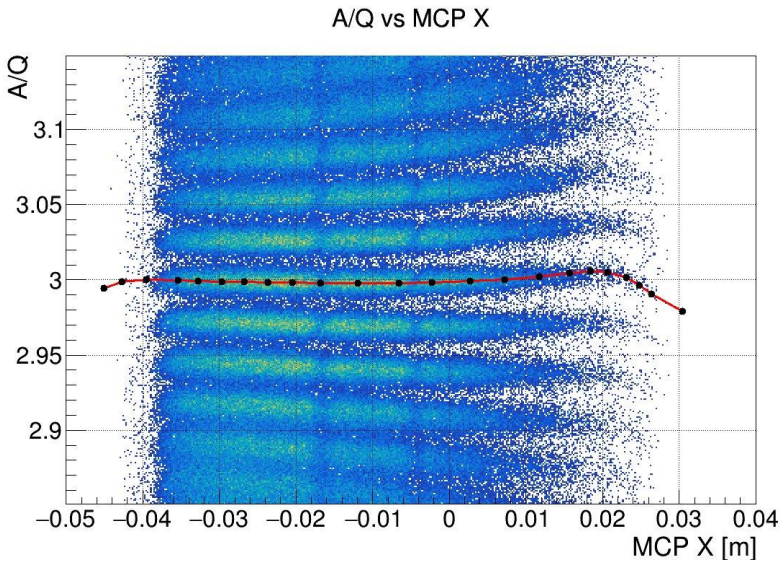
- They are **systematic effects** that concern the trajectory reconstruction and would decrease the mass resolution of the spectrometer

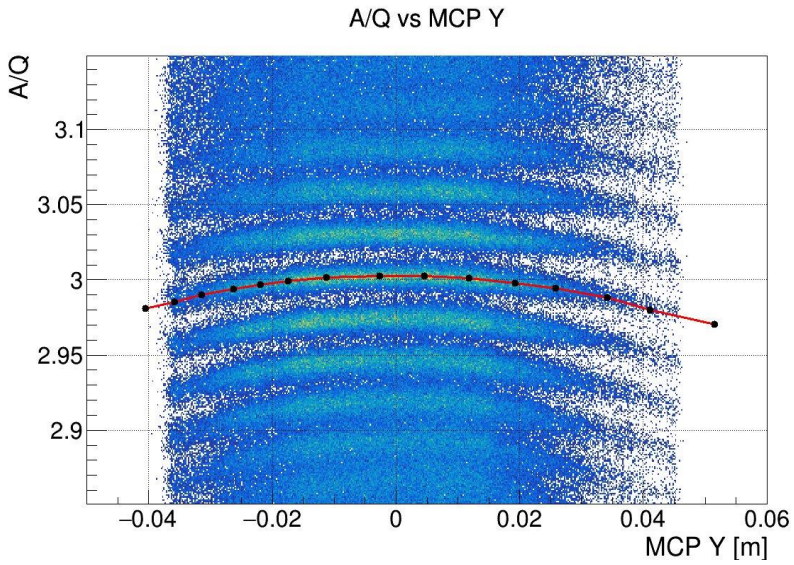
- They happen because the magnetic field geometry in the algorithm is approximated by considering **ideal dipoles and quadrupoles**, but can be corrected

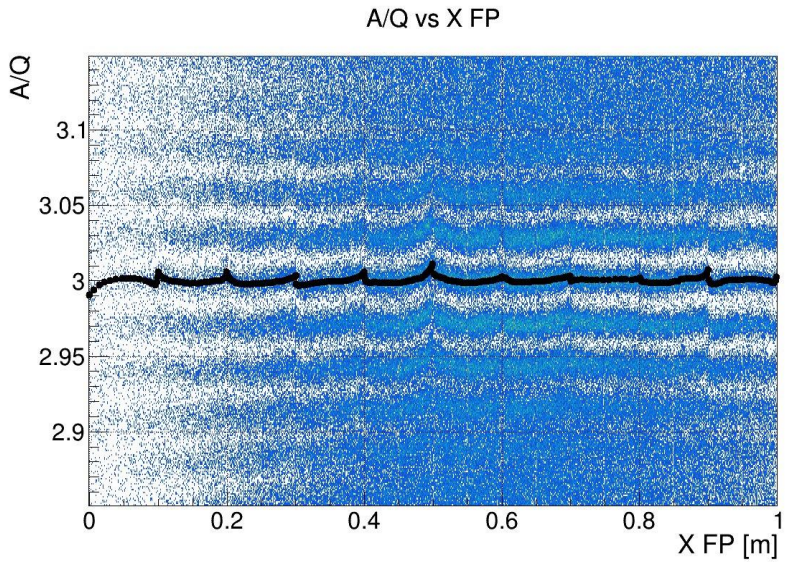




Aberration correction: implementation







The length is rescaled to adapt the A/Q to the reference value

The TOF is rescaled to adapt the A/Q to the reference value

`aoverqxmcp__0_0__300.root`

`aoverqymcp__0_0__300.root`

`aoverqxfp__0_0__300.root`

Z for correction or 0 for applying it to all the rest

Reference A/Q *100

AOQXMCP_CORR	**/CUT/PRISMA/ANA/AOVERQ_XMCP**
AOQYMCP_CORR	**/CUT/PRISMA/ANA/AOVERQ_YMCP**
AOQXFP_CORR	**/CUT/PRISMA/ANA/AOVERQ_XFP**

Sorting flowchart

MCP	PPAC TOF	PPAC position	IC pads	IC side	IC drift	Monitors
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ΔE-E matrix

- Correct Z bands by X,Y PPAC position
- Z identification with gates

A/Q vs X_FP

- Optimize optical parameters
- Align and calibrate A/Q with TOF offsets

E-Rβ matrix

- Include non-measured energy correction
- Q identification with gates

Aberrations on A/Q

- Correct aberrations vs X_FP, MCP_X, MCP_Y

Mass

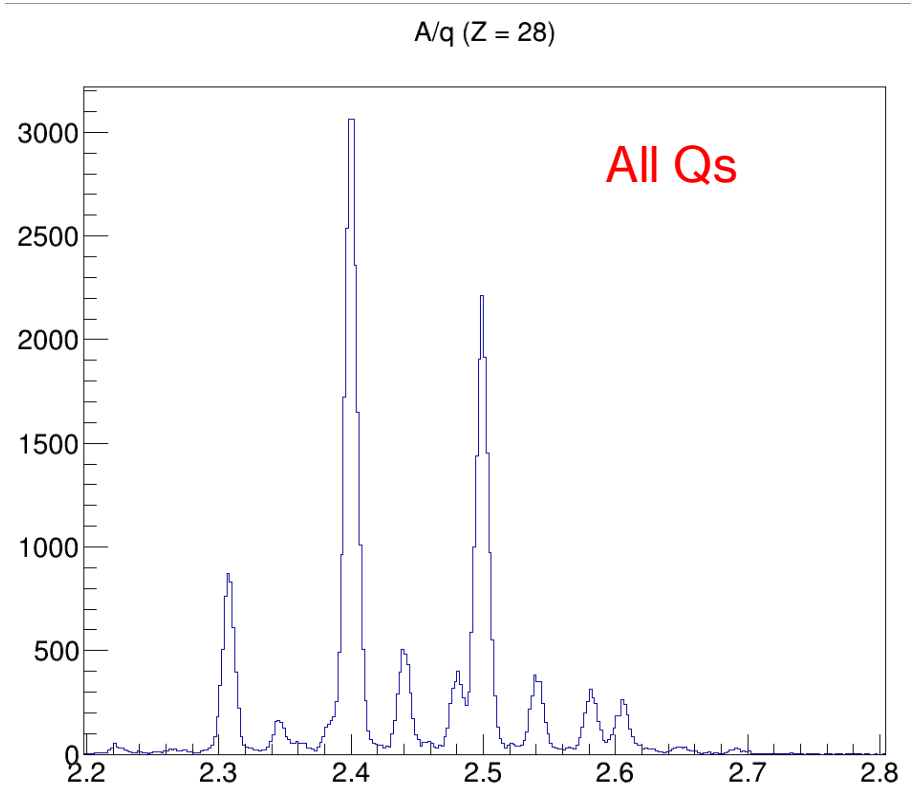
- Recalibrate A/Q and Q

Mass recalibration

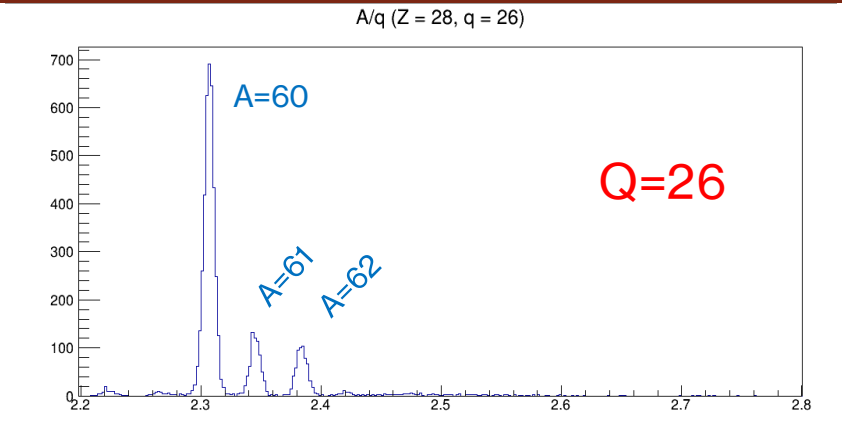
A good mass calibration comes from:

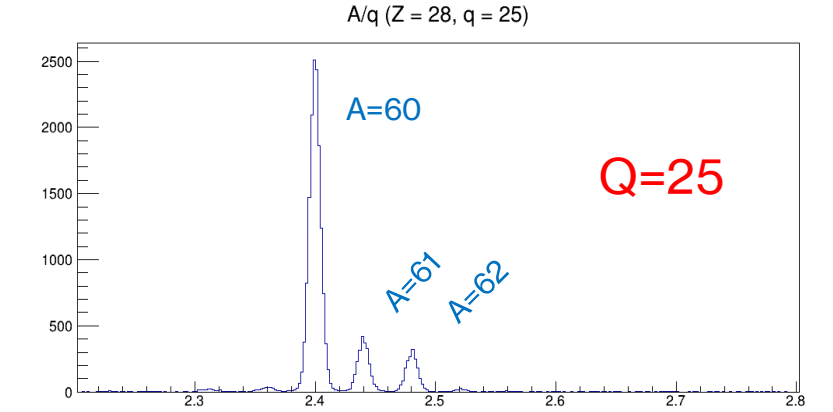
- Correct **Q gate** identification
- Good **TOF offsets**

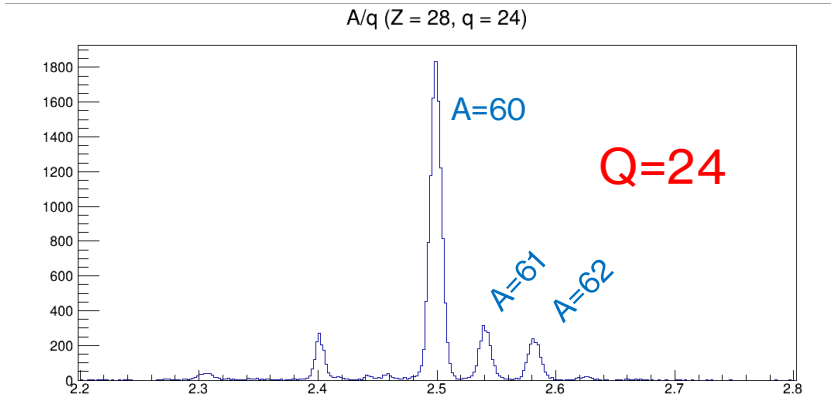
$$A = A/Q \cdot Q$$



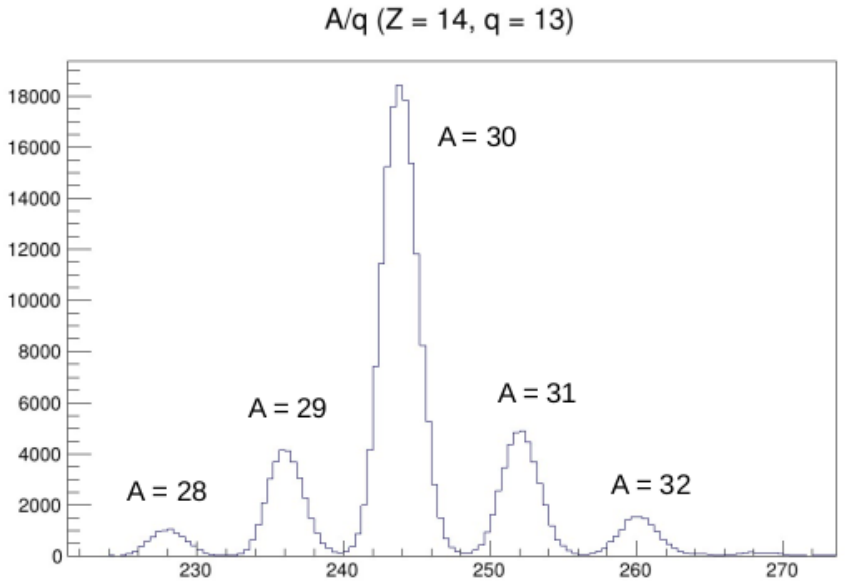
Warning: If you need to shift the Q gates by some units, you will have to rename the TCutG* objects inside the .root files



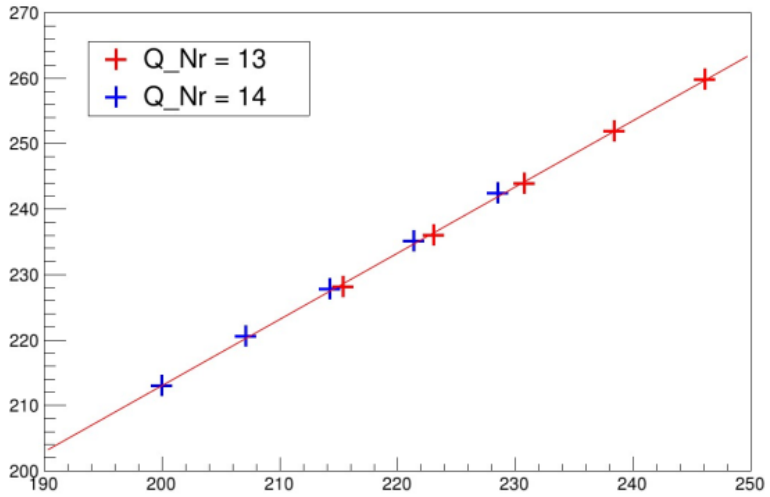




Mass recalibration



$$mass = \left(\frac{A}{q}\right)_{cal} \cdot q_{eff}$$



Example

Expected	Observed
28 / 13 x 100 = 215.385	227.9
29 / 13 x 100 = 223.077	236.1
30 / 13 x 100 = 230.769	243.8
31 / 13 x 100 = 238.462	252.3
32 / 13 x 100 = 246.154	260.1

Linear calibration for **A/Q(Z)**

cal/a_over_q.cal

```
1   16    2    -7.96874335    1.120640853
1   15    2    -6.3795417     1.112781635
1   14    2    -6.427071018   1.112698609
```

For each Z

Effective value for **Q(Z)**

cal/charge_cal_16.cal

```
99   12   2   11.95475   0.
99   13   2   12.92442   0.
99   14   2   13.95171   0.
99   15   2   14.93272   0.
99   16   2   15.95846   0.
```

For each Z and Q

Prismaonlinepackage/script/AoqCalibration

Mass recalibration: implementation

$$mass = \left(\frac{A}{q}\right)_{cal} \cdot q_{eff}$$

mass.conf

```
# mass calibration file
cal_file = cal/a_over_q.cal

# charge calibration file pattern for each Z
chg_file_base = cal/charge_cal_
```

cal/a_over_q.cal

```
1   27   2   -4.293627046     1.020867688
1   28   2   -6.88758004      1.028703071
1   29   2   -2.079466863     1.01723433
```

cal/charge_cal_28.cal

```
99    22    2    0.   1.
99    23    2    23.02291749   0.
99    24    2    23.9740339    0.
99    25    2    25.00436437   0.
99    26    2    0.   1.
```

PrismaFilters

AOQ_CAL **/CALIBRATION/PRISMA/ANA/aoverq.cal**
CHARGE_CAL **/CALIBRATION/PRISMA/ANA/charge.cal**

CALIBRATION/PRISMA/ANA/aoverq.cal

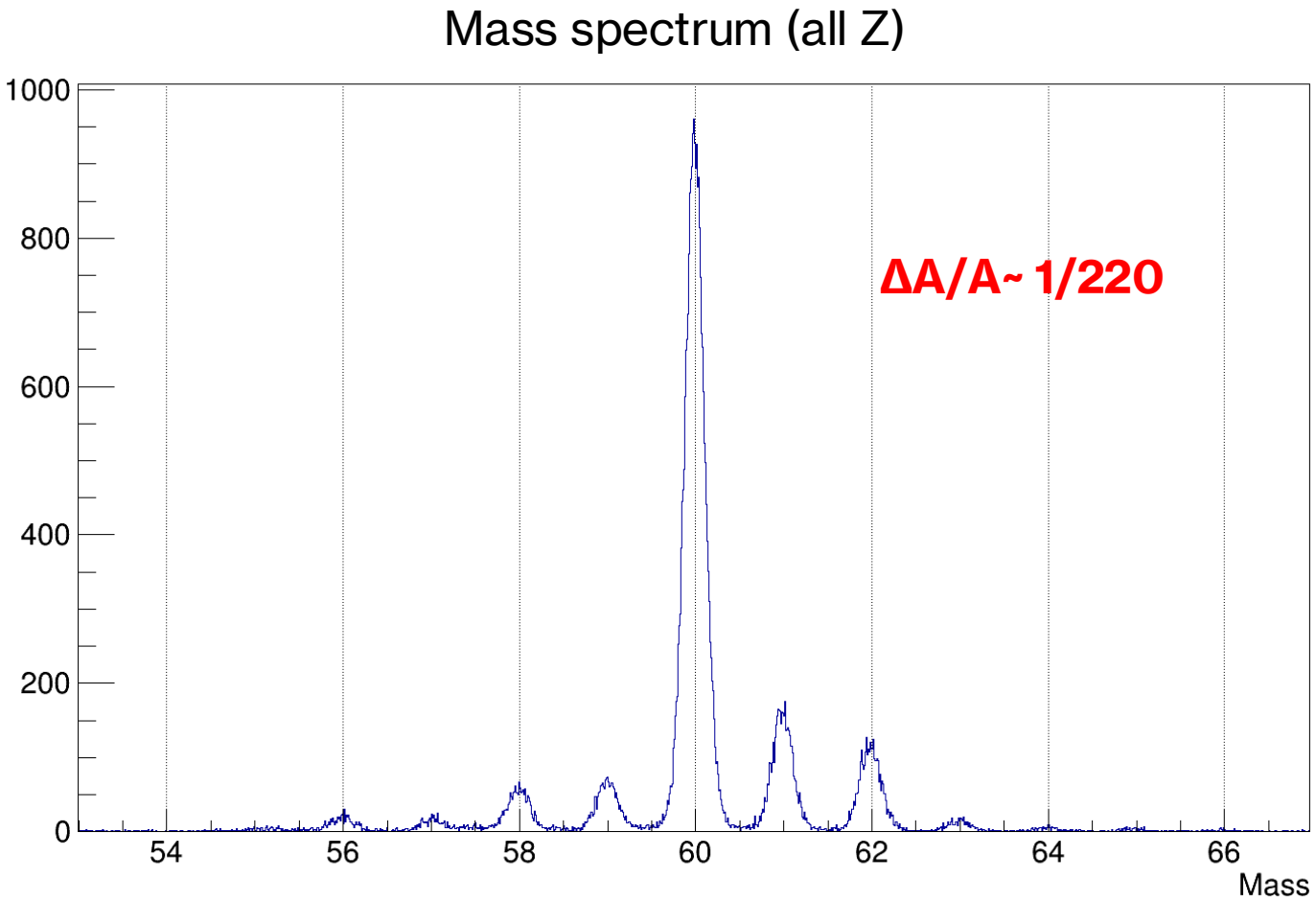
```
id 26  cal 0 1
id 27  cal 0 1
id 28  cal 0 1
id 29  cal 0 1
id 30  cal 0 1
...
```

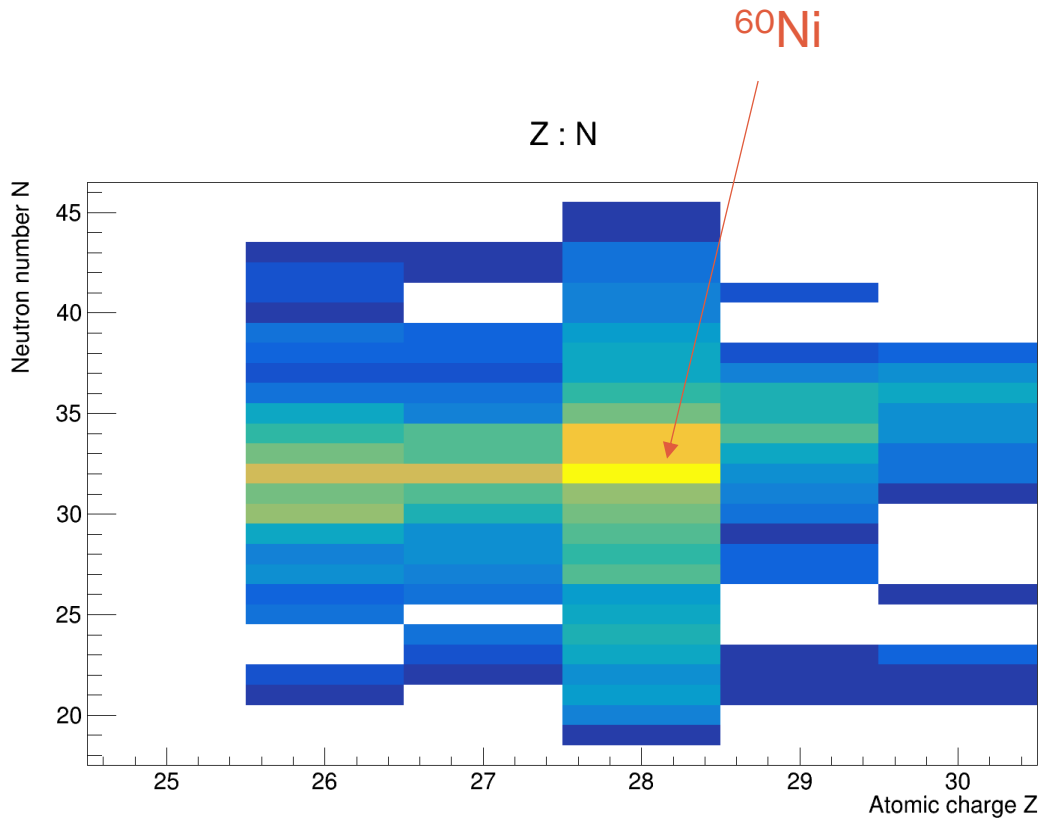
CALIBRATION/PRISMA/ANA/charge.cal

```
id 28 26    cal 25.9 0
id 28 25    cal 24.9 0
id 28 24    cal 23.9 0
id 29 25    cal 24.9 0
...
```

AgataSelector

Mass recalibration





The recalibration was not needed here

Sorting flowchart

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- Correct Z bands by X,Y PPAC position
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- Optimize optical parameters
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- Q identification with gates

Aberrations on A/Q

- Correct aberrations vs X_FP, MCP_X, MCP_Y

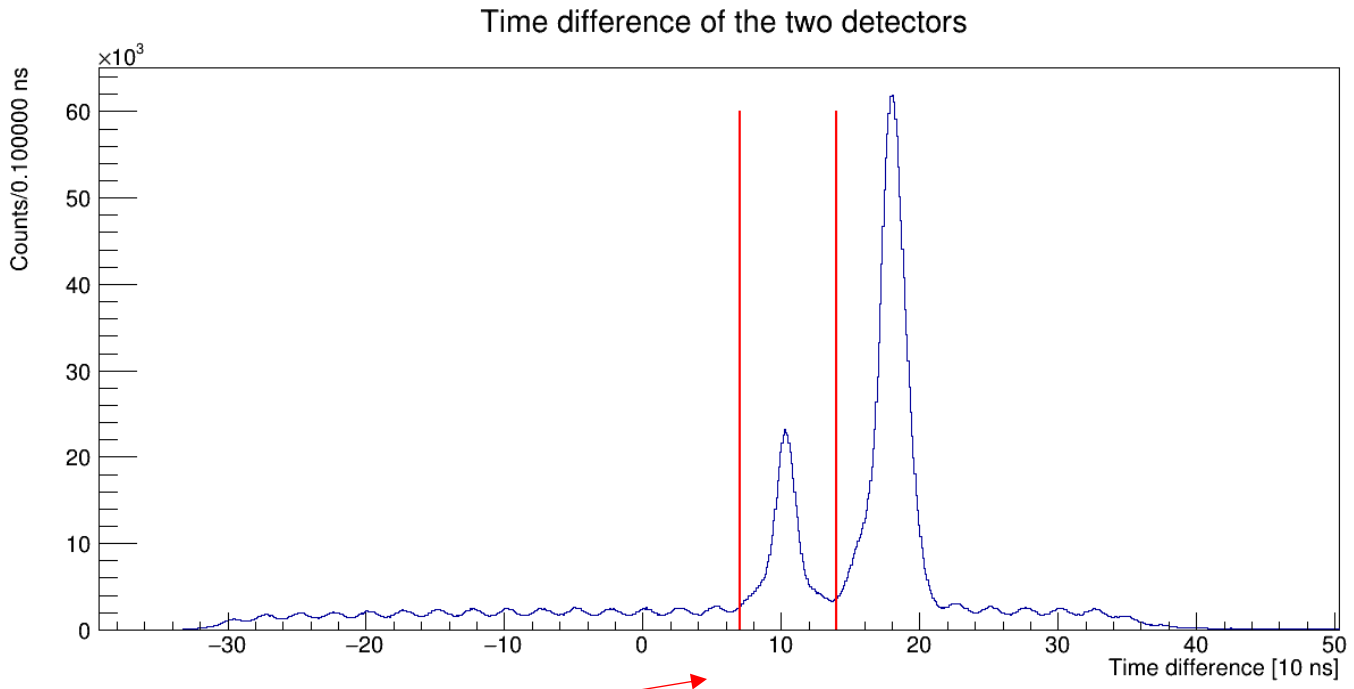
Mass

- Recalibrate A/Q and Q

AGATA + PRISMA: Doppler correction

```
#------------------------------------------------------------
DETECTORS_PRESENT
EUCLIDES              NO  #       Euclides is present YES/NO
DANTE           NO  #       Dante is present YES/NO
LABR            NO  #       Labr is present YES/NO
AGATA           YES #       Agata is present YES/NO
SPIDER          NO  #       Spider is present YES/NO
PRISMA          YES #       Prisma is present YES/NO
#------------------------------------------------------------
```

```
REACTION_CONF
ENERGY          460 MeV #
BEAM            116 50  #
TARGET          60 28   #
ION         60 28   #
ION         61 28   #
ION         62 28   #
ION         59 27   #
```



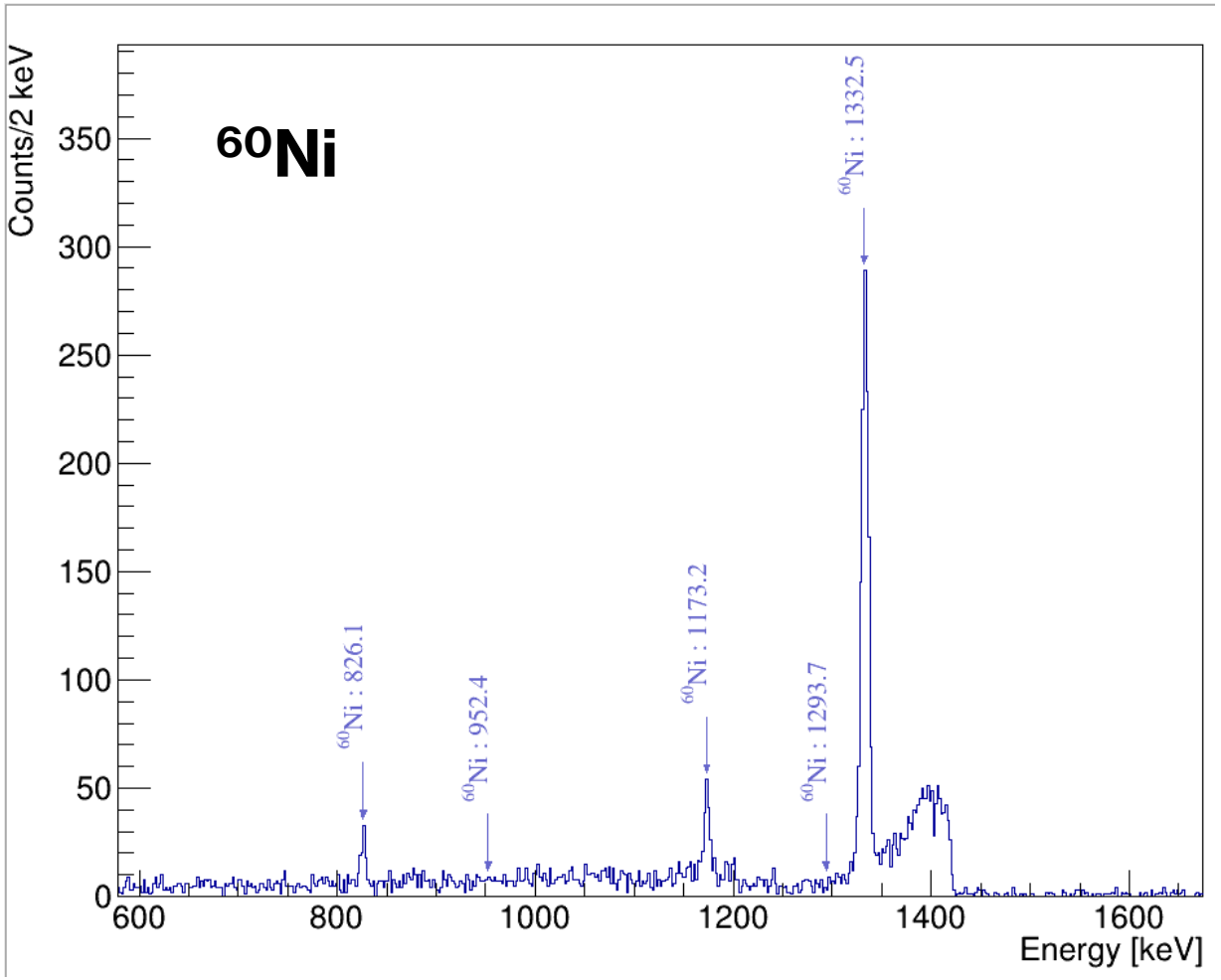

```
#------------------------------------------------------------
AGATAPRISMA_CONF
COINC_W_LEFT            7   #           Time window left
COINC_W_RIGHT           14  #           Time window right
BP_FRAGMENT_POSITION        END_TARGET  #       Doppler correction position for binary partner
FRAGMENT_POSITION       END_TARGET  #       Doppler correction position for detected ion
#------------------------------------------------------------
```

AGATA + PRISMA: Doppler correction

Doppler corrected gamma spectra

`AgataPrisma/Z28/A60/h_DC_ion_60_28`

Warning: if the gammas correspond to a different nucleus, you might have to change the identification (Z gates, Q gates, A/Q calibration)



Cubix software https://cubix.in2p3.fr/

AGATA + PRISMA: Doppler correction

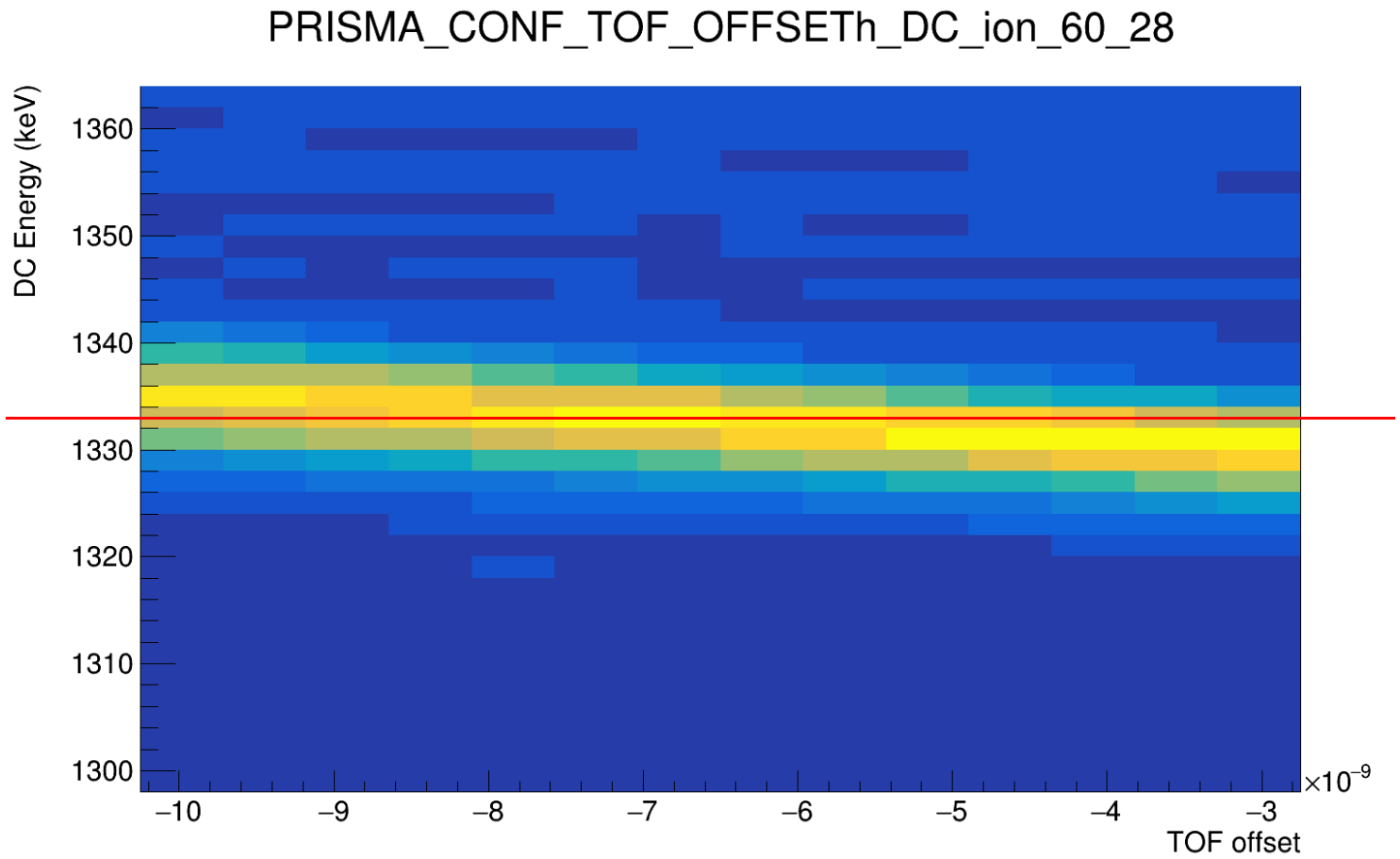
Prisma reconstruction often ends up in good **ID** but wrong **beta**

Recalibration of beta with **TOF_OFFSET** to optimize centroids of DC gamma peaks

AgataSelector Optimizer is great for finding optimal values

Other geometrical optimization might include:

Agata – PHI, Z_SHIFT
Prisma – X_SHIFT, Y_SHIFT, X_SCALE, Y_SCALE
TOF_GAIN




```
TRANSITION      AgataPrisma    Z28/A60/h_DC_ion_60_28     1.17323  0.004  0.0   1
TRANSITION      AgataPrisma    Z28/A60/h_DC_ion_60_28     1.333    0.004  0.0   1
TRANSITION      AgataPrisma    Z28/A62/h_DC_ion_62_28     1.17298  0.004  0.0   1
PARAMETER       PRISMA_CONF TOF_OFFSET    -7 -10 -3 0.5  ns
SCAN            PRISMA_CONF TOF_OFFSET    -7 -10 -3 0.5  ns
```

Acknowledgements

G. Andreetta

E. Pilotto

D. Brugnara

R. N. Del Alamo

J. Dudouet

F. Galtarossa

B. Gongora

J. Pellumaj

Selector Optimization

- Data reduction / selection
- Scanning parameters
- Multiparameter minimization

- Grid – search optimization
  - Not well tested yet
  - Fine tuning
  - See main README.md of agataselector

AnalyzedTree – PrismaInput branch

```
class PrismaInput : public Container {
  public:
  u_int64_t ts;
  float   monitor_0    ;
  float   monitor_1    ;
  float   mcp_x        ;
  float   mcp_y        ;
  float   mcp_q        ;
  float   mcp_theta    ;
  float   mcp_phi      ;
  float   x_fp         ;
  float   y_fp         ;
  float   tof          ;
  float   ic_pads[40]  ;
  float   ic_e         ;
  float   ic_e_tot    ;
  float   ic_e_corr    ;
  float   ic_e_nm    ;
  float   ic_e_nm2    ;
  float   ic_de_a      ;
  float   ic_de_ab     ;
  float   ic_de_a_corr ;
  float   ic_e_res_corr;
  float   ic_en1       ;
  float   ic_en1_corr1 ;
  float   ic_en1_corr2 ;
  float   ic_en2       ;
  float   ic_range     ;
  float   ic_mass      ;
  float   ic_drift_a   ;
  float   ic_drift_b   ;
  float   ic_drift_c   ;
  float   prisma_angle;
  float   theta        ;
  float   phi          ;
  float   beta         ;
  float   gamma        ;
```

```
  float   energy_m     ;
  float   length       ;
  float   radius       ;
  float   brho         ;
  float   rbeta        ;
  float   a_over_q_uncal ;
  float   a_over_q     ;
  float   mass         ;
  float   z_float      ;
  float   zed          ;
  float   charge       ;
  float   charge_cal   ;
  float   q_float      ;
  float   beta_end     ;
  float   energy_end   ;
  float   beta_mid     ;
  float   gamma_mid    ;
  float   energy_mid   ;
  float   brho_mid     ;
  float   theta_cm     ;
  float   phi_cm       ;
  float   beta_cm      ;
  float   brho_cm     ;
  uint8_t a_cn         ;
  uint8_t z_cn         ;
  float   qvalue       ;
  float   theta_bp     ;
  float   phi_bp       ;
  float   beta_bp      ;
  float   tac_lt_ts    ;
  float   theta_fp     ;
  float   phi_fp       ;
  int     col_nbr      ;
  uint8_t ic_col_a     ;
  uint8_t ic_col_b     ;
  uint8_t ic_col_c     ;
  uint8_t ic_col_d     ;
```

```
  uint8_t ic_a_numpads ;
  uint8_t ic_b_numpads ;
  uint8_t ic_c_numpads ;
  uint8_t ic_d_numpads ;
  uint8_t z_nbr        ;
  uint8_t q_nbr        ;
  uint8_t a_nbr        ;
  uint8_t x_fp_type    ;
  bool    mcp_ok       ;
  bool    tof_ok       ;
  bool    traj_ok      ;
  bool    side_ok      ;
  bool    ic_ok        ;
  bool    z_ok         ;
  bool    q_ok         ;
  bool    a_ok         ;
```

Data reduction

First we reduce the amount of data to use for optimization. The best condition to achieve this is experiment dependent, but usually you:

- Require coincidence
- May require to be in the coincidence peak (reject background)
- Select an energy range
- …

It is not very useful to do a selection for Prisma Raw branch!
We are working on a way to select event easily in this case

Example:

```
RunSelector --conf selector.conf --nrthr 10 --reduction_cond
"nbSPIDER > 0 && nbCores > 0 && trackE > 900"
```

628 MB -> 23 MB

This will create reduced files in the data folder, with the same name as the old ones with the "red_" prefix. You should then sum them all into one:

```
hadd optData_0000.root Data/run_0034/Out/Analysis/red_Tree_000*
```

OBS: multiple runs can be used

Scan a parameter

- Choose the spectrum (and transition) to optimize
- Choose the parameter(s) to optimize
- In the "selector.conf", in "OPTIMIZER_CONF" you add both

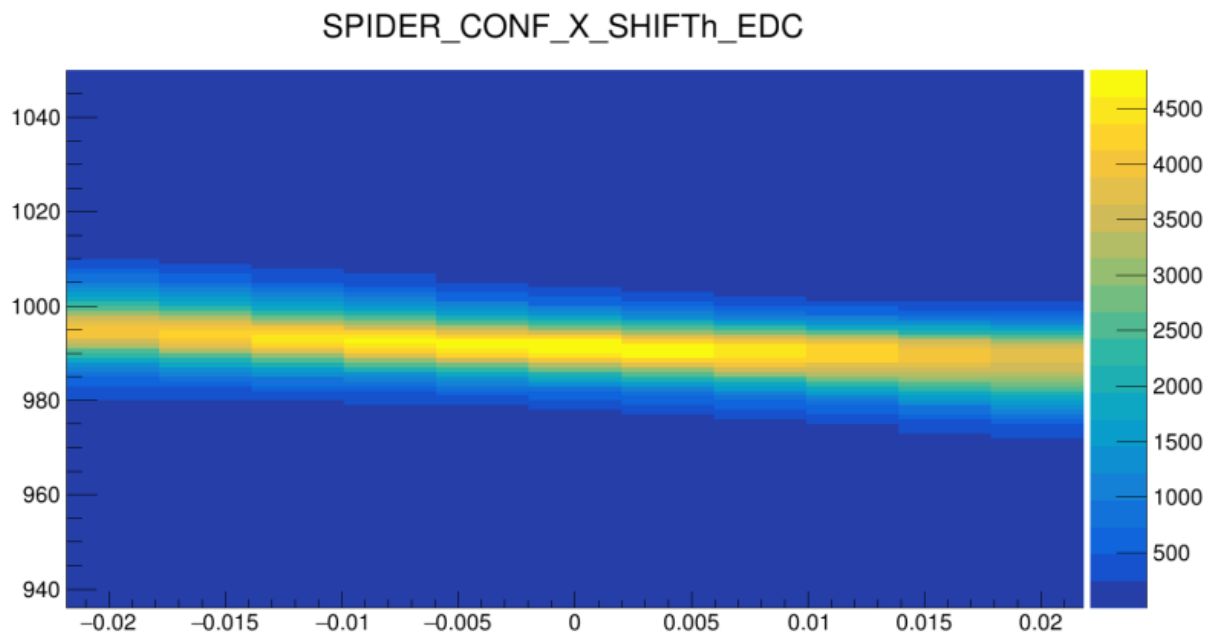
```
PARAMETER SPIDER_CONF X_SHIFT 0 -20 20 1 mm
SCAN SPIDER_CONF X_SHIFT 0 -20 20 4 mm
TRANSITION AgataSpider h_EDC 991.5 3 0.1 0.5 keV
ONLY_SCAN YES
```

```
#PARAMETER |detector|par_name|initial_value|min|max|step|
#SCAN |detector|par_name|initial_value|min|max|step|
#TRANSITION |folder|spec_name|centroid|sigma|tail|bias|
#optional
```

- Run the selector (scans in file "out.root")

```
RunSelector 9999 --conf selector.conf \
    --nrthr 1 --verb -1 --only_enabled_histos \
    --optimize
```

OBS: "only_enabled_histos" option activated, you should modify accordingly the file "Conf/enabled_histos.conf"



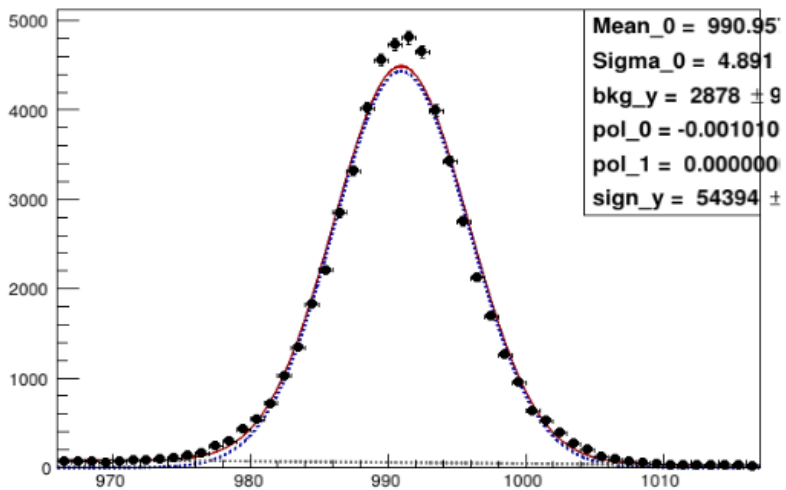
Fit with multiparameter optimization

- Similar notation to scan:

  PARAMETER SPIDER_CONF X_SHIFT 0 -20 20 1 mm
  PARAMETER SPIDER_CONF Y_SHIFT 0 -20 20 1 mm
  PARAMETER SPIDER_CONF Z_SHIFT 0 -20 20 1 mm
  TRANSITION AgataSpider h_EDC 991.5 3 0.1 0.5 keV

- Run selector with "debug canvas" option

  RunSelector 9999 --conf selector.conf \
  --nrthr 1 --verb -1 --only_enabled_histos \
  --optimize --debug_canvas



- If fits are not good, you change parameters in file "Conf/Optimizer/parameters.dat"

- Once fits are good, run optimization without option "debug_canvas" option

  RunSelector 9999 --conf selector.conf \
  --nrthr 1 --verb -1 --only_enabled_histos \
  --optimize

- While it is running, you can monitor with

  tail -f Conf/Optimizer/log.txt

- At the end output file is run with best parameters

Cost function

The cost function takes into account many factors:

- The fitted energies
- The fitted sigmas (+ tails)
- The reference energy
- The bias on each transition
- The number of non-converging fits
- A weight factor

$$C = (1 - W)\sqrt{\sum_{i=1}^{N} (\mu_i - \epsilon_i)^2 \cdot b_i} + W\sqrt{\sum_{i=1}^{N} \tilde{\sigma}_i \cdot b_i} + N_{nc}\, C_{nc}$$

$$\tilde{\sigma}_i = \sigma_i + \tau_{l,i} + \tau_{r,i}$$

Cost function

Keywords:

TAIL 0 # 0: notail, 1: right, 2: left, 3: left+right, 4: symmetric

NON_CONVERGENCE_COST 5 # Multiplier cost for fits that did not converge

SIGMA_WEIGHT 0.5 # 0 for pure centroid optimization, 1 for pure width optimization

$$C = (1 - W)\sqrt{\sum_{i=1}^{N} (\mu_i - \epsilon_i)^2 \cdot b_i} + W\sqrt{\sum_{i=1}^{N} \tilde{\sigma}_i \cdot b_i} + N_{nc} C_{nc}$$

$$\tilde{\sigma}_i = \sigma_i + \tau_{l,i} + \tau_{r,i}$$

Additional files

File: Conf/Optimizer/parameters.dat

FIT_PAR_FILE parameters.dat #Name of parameter file

```
--------------------------
idx: 0
name : init_val min max fixed
Ampl_0 1.000000e+04 0.000000e+00 1.000000e+08 0
Mean_0 9.915000e+02 9.865000e+02 9.965000e+02 0
Sigma_0 5.000000e+00 1.650000e+00 1.500000e+01 0
Tau_left_0 1.000000e-04 1.000000e-03 1.000000e+01 0
Tau_right_0 1.000000e-04 1.000000e-03 1.000000e+01 0
pol_0 0.000000e+00 -1.000000e-01 1.000000e-01 0
pol_1 0.000000e+00 -1.000000e-01 1.000000e-01 0
min_max 9.665000e+02 1.016500e+03
```

OBS: If not present it's created,
otherwise it's read

File: Conf/Optimizer/log.txt

LOG_FILE log.txt #Name of log file

```
###################End of minimizer######################
#################Running with optimal parameters
=============== it: 74 ================
par: SPIDER_CONF X_SHIFT --> val: -0.00187371
par: SPIDER_CONF Y_SHIFT ---> val: 0.00157457
par: SPIDER_CONF Z_SHIFT ---> val: 0.000614222
COST 2.47316
FITTED MEAN 991.501
FITTED SIGMA 4.92468
```

Final remarks on optimization

- You ~~can~~ **should** play with hyper-parameters

```
ALGORITHM Simplex # Name of algorithm (Migrad, Simplex,...)
MINIMIZER Minuit      # Name of minimizer (Minuit/Minuit2, Fumili, GLSMultiMin, Genetic)
BKG_POL_ORDER 1   # Polynomial order for background
MAX_CALLS 1000      # Maximum number of minimizer calls
TOLERANCE 0.1       # Minimizer tolerance
PRECISION 0.01      # Minimizer precision (likely leave 0 for optimally calculated value)
USE_INTERVALS NO  # Use intervals in minimization (try what is best)
VALID_ERRORS NO   # Performs error analysis (e.g. run Hesse for Minuit)
...
```