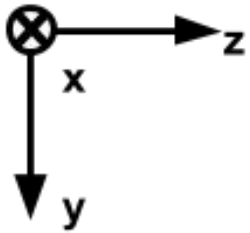
MUonE CALORIMETERS

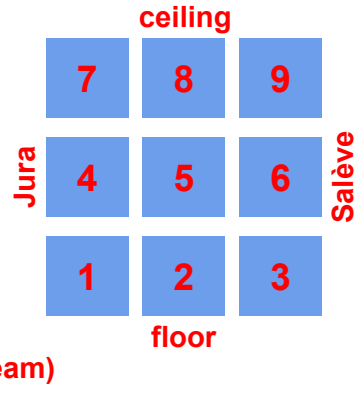


from	to	ASCII	calorimeter
04/04 *(the beginning)*	01/05	300118-300198	DEVA
02/05	22/05	300232-300280	STEFI
23/05	07/06	300290-300304	none *(tb @ T9)*
08/06	...	from 300320 on	GENNI

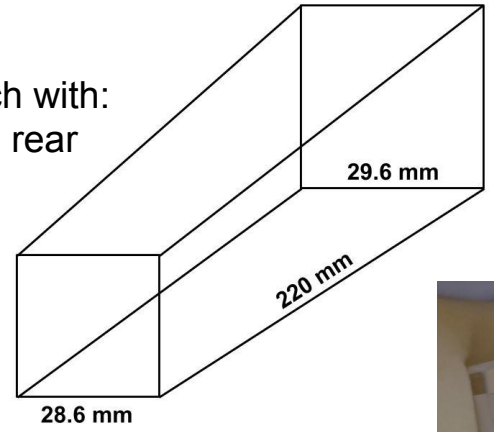
all calorimeters equalization, calibration and performance evaluation

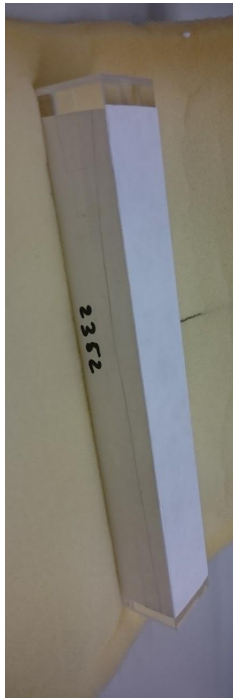
INTRODUCING STEFI

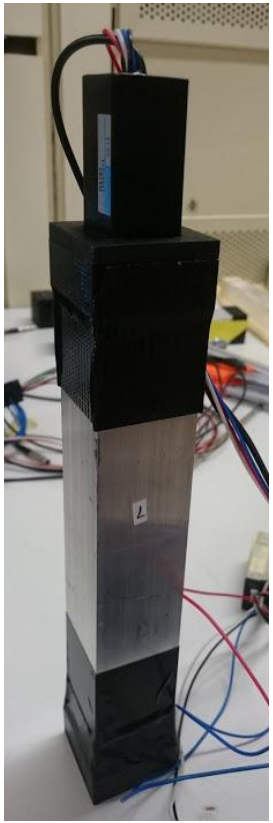
- 3x3 matrix of 9 CMS endcap $PbWO_4$ crystals, each with:
  - ⇒ 2.86cm side @ front & 2.96cm side @ rear
  - ⇒ 22cm length → ~24.7 X_0 in total
- Al & plastic mechanical structure
- many mm between channels → need for tilted displacement inside his box
- each crystal is coupled to a PMT (HAMAMATSU H6780-03)
- each crystal is read out individually, in this order:

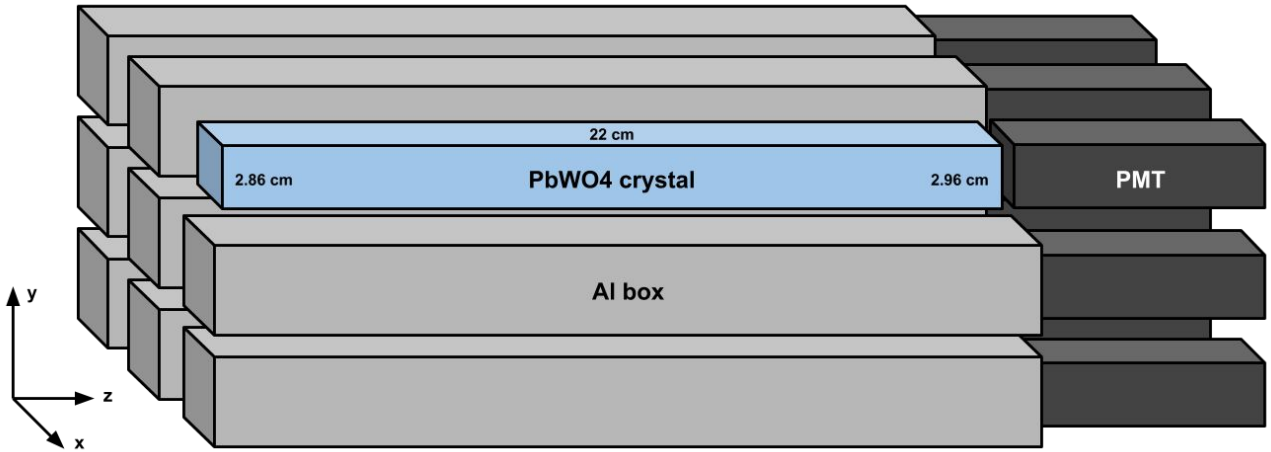


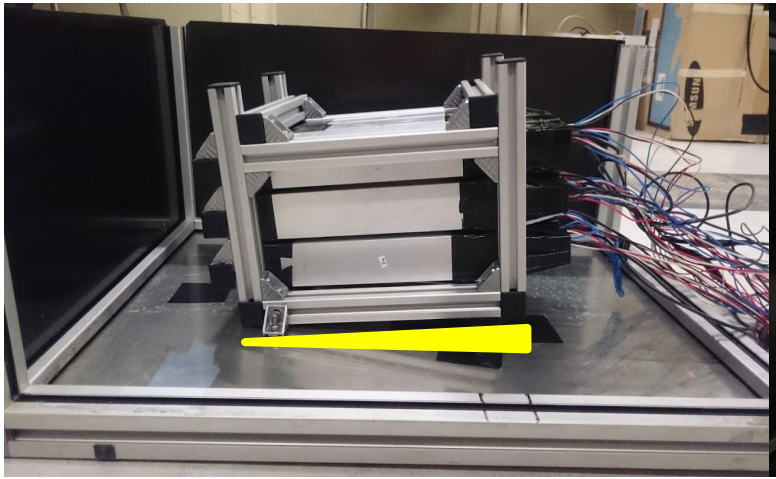
DIGI1 - CH1-8	
1	STEFI 1
2	STEFI 2
3	STEFI 3
4	STEFI 4
5	STEFI 5
6	STEFI 6
7	STEFI 7
8	STEFI 8
DIGI2 - CH9-16	
9	STEFI 9

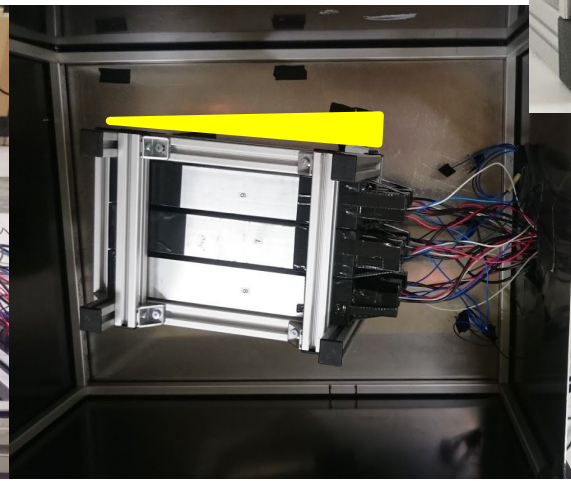


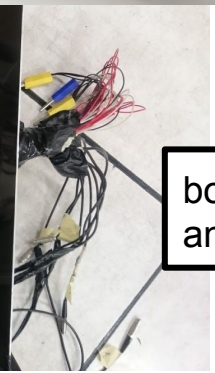








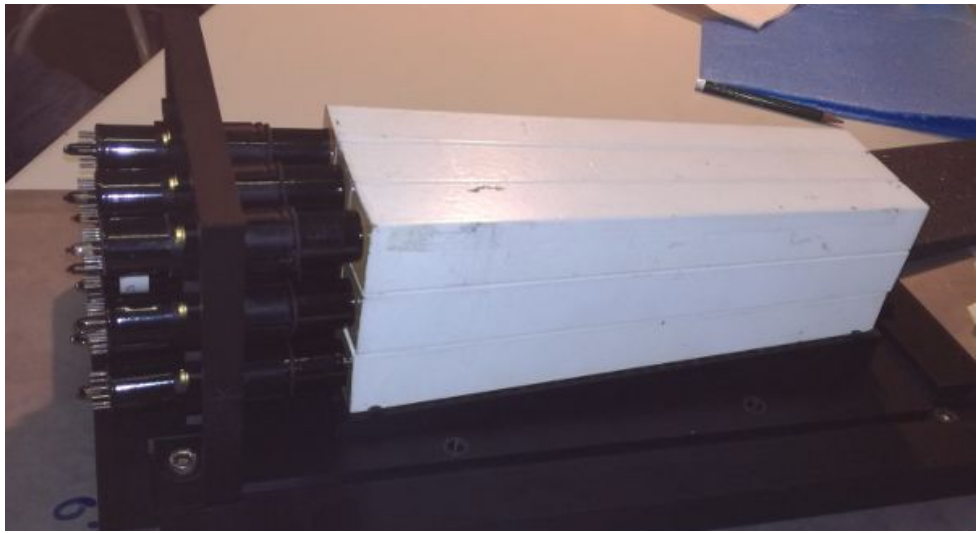


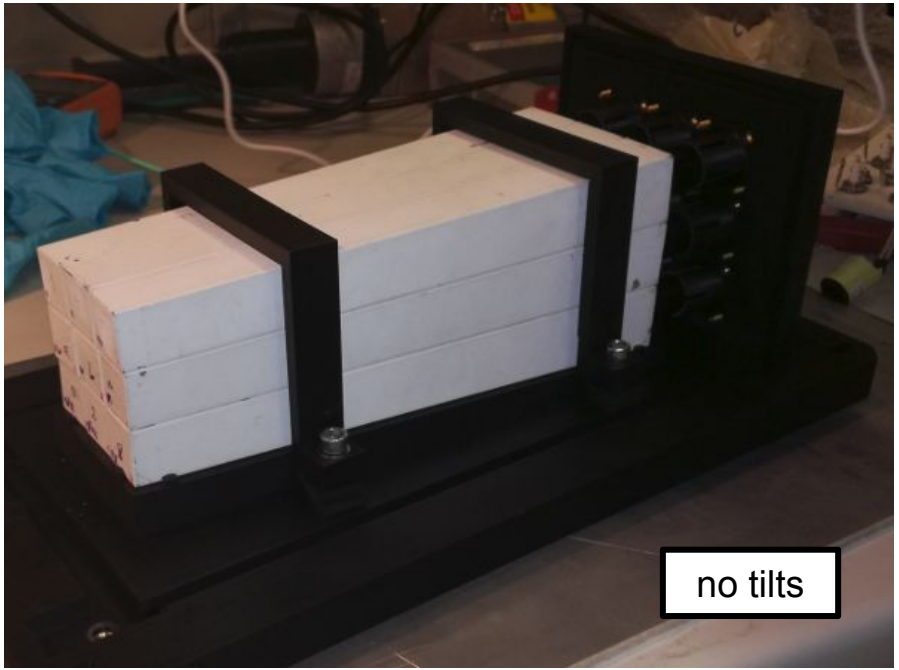


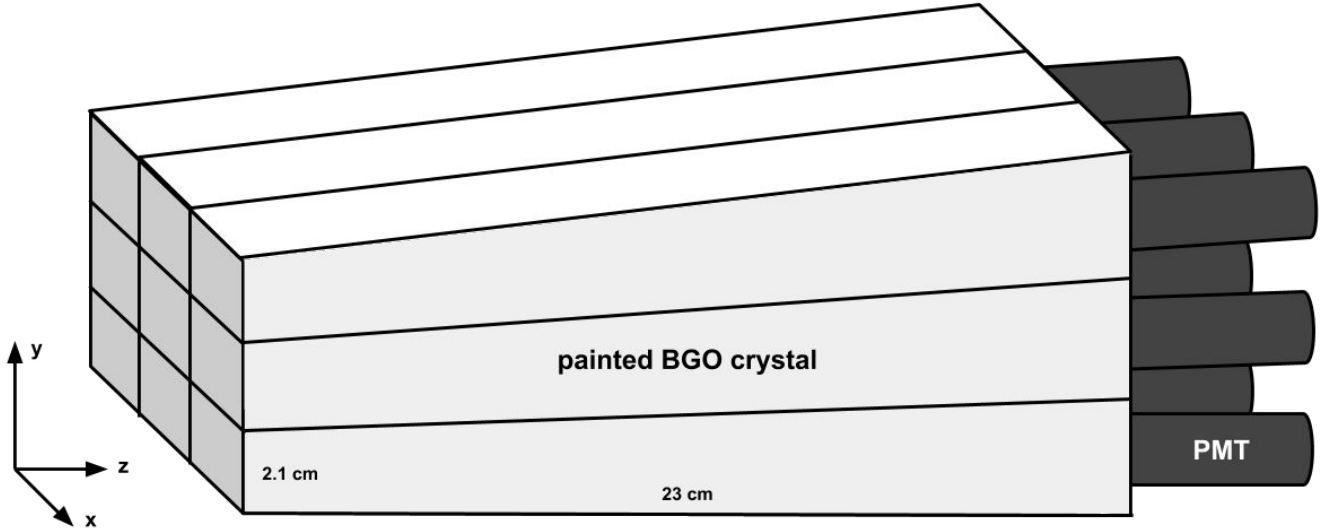
both horizontal
and vertical tilts

INTRODUCING GENNI

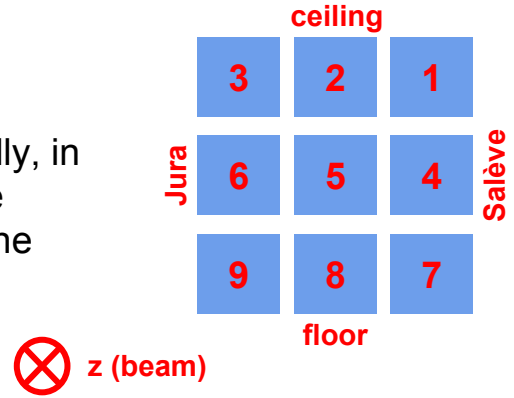
- new detector w/ 9 PADME ECAL BGO painted crystals (recovered from L3 EM endcap)
  ⇒ ~2.1cm side @ front
  ⇒ ~23cm long → ~20.5 X_0 in total
- metal & plastic mechanical structure which holds crystals together (little blind space between channels!) in a 3x3 matrix and couples each channel with a PMT → everything contained in a box
- performance under study at the moment…
  → it seems to have very good energy resolution!







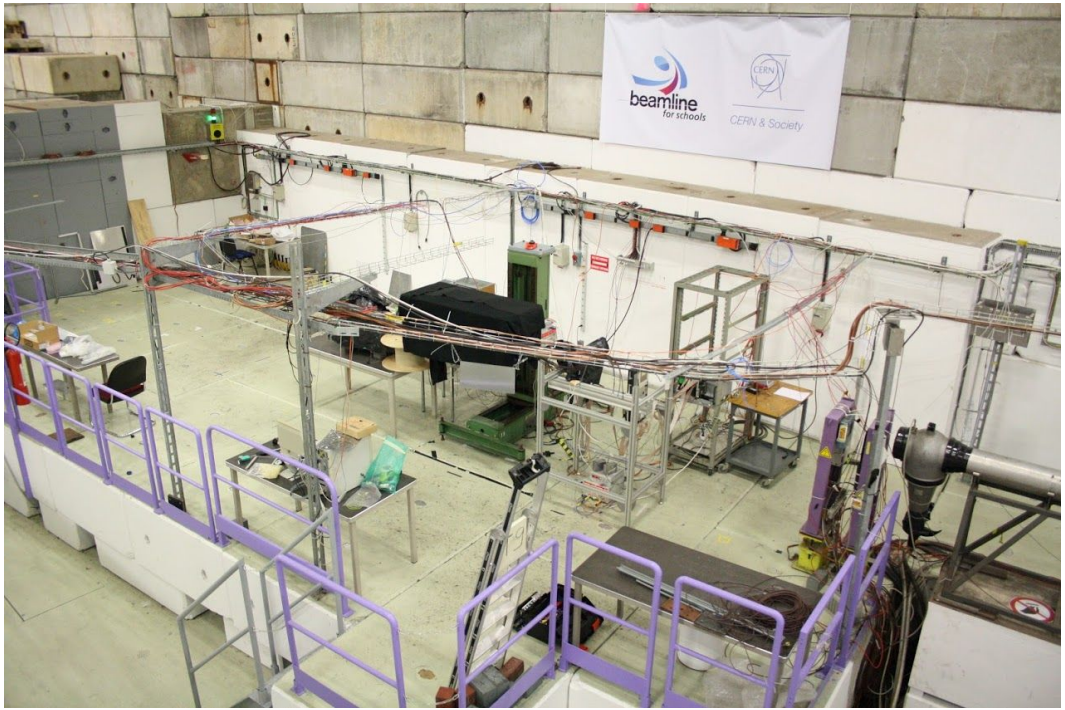
- channels: each crystal is read out individually, in a configuration that is rotated by 180° in the transverse plane w/ respect to the STEFI one

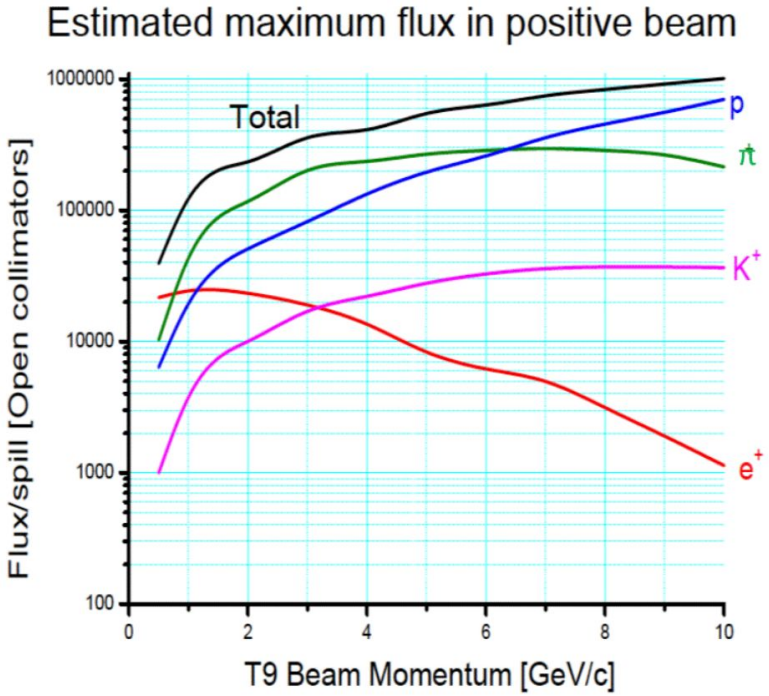


DIGI1 - CH1-8	
1	GENNI 1
2	GENNI 2
3	GENNI 3
4	GENNI 4
5	GENNI 5
6	GENNI 6
7	GENNI 7
8	GENNI 8
DIGI2 - CH9-16	
9	GENNI 9

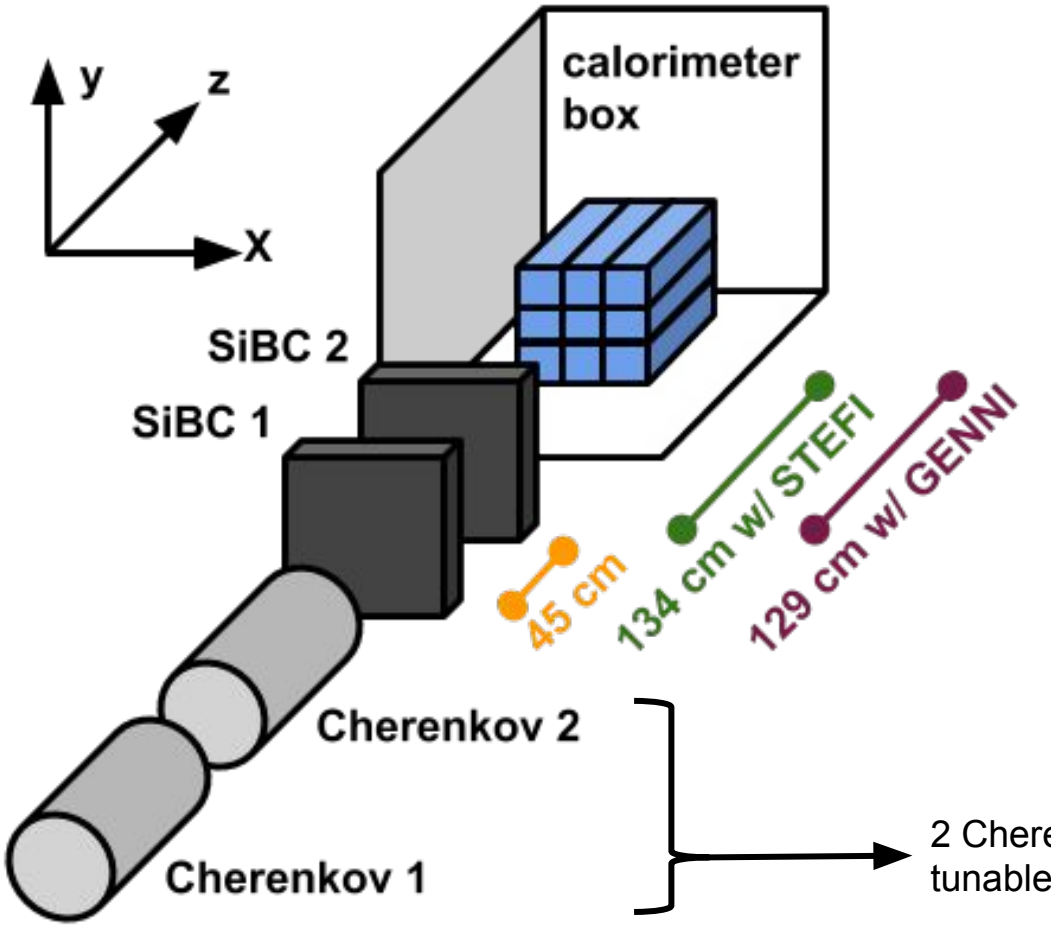
T9 @ EAST HALL

- beamline @ tunable momentum — range (0.5,10) GeV/c
- electrons, muons and pions (and rarer kaons and protons) whose fractions are functions of the beam momentum





T9 SETUP

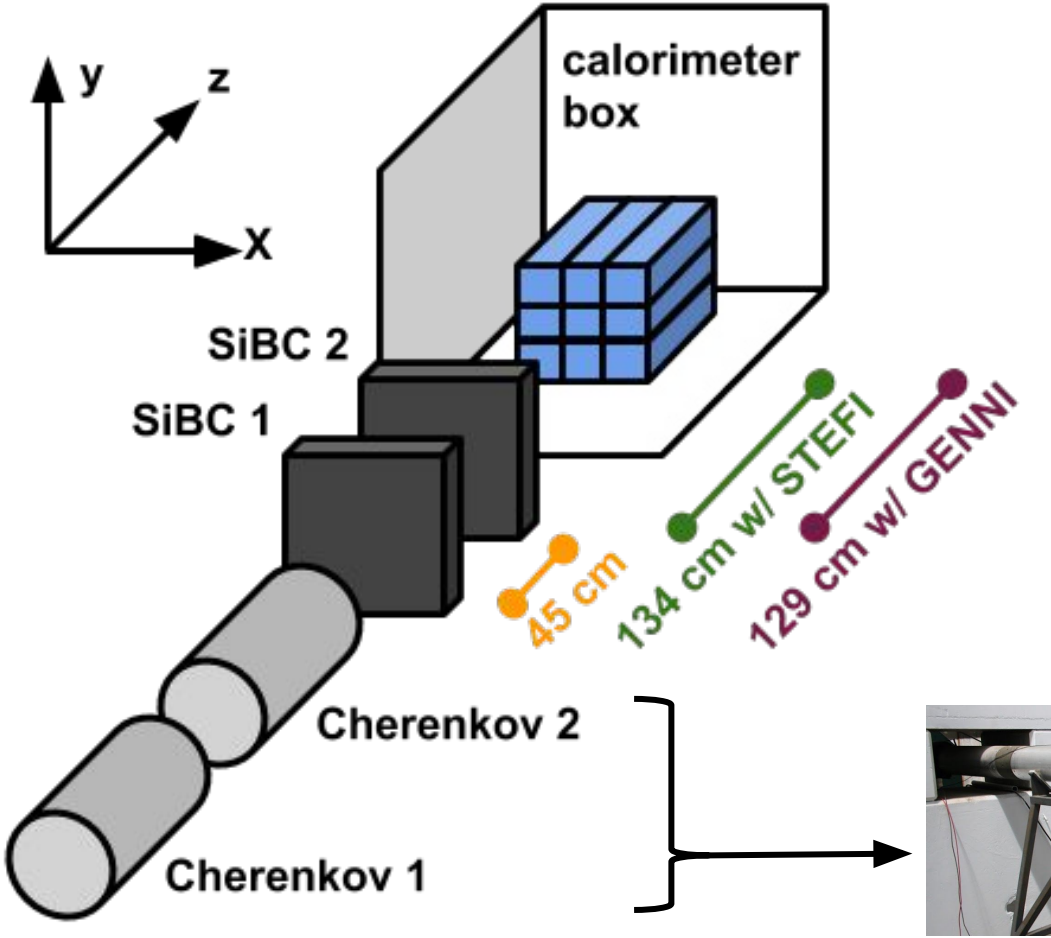


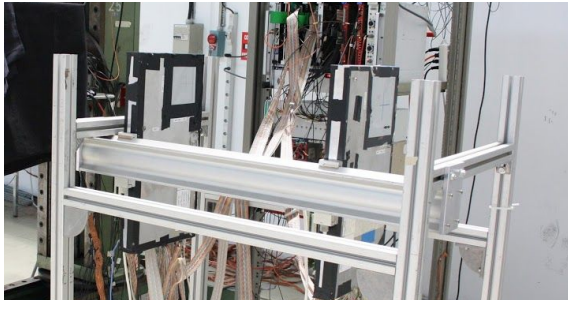
calorimeters (STEFI or GENNI) in an Al box and on an x-y movable table

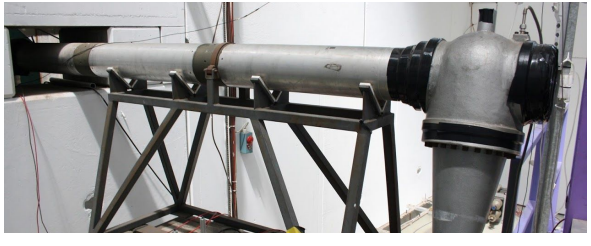
2 x-y Si microstrip beam chambers (equal to the ones that make up MUonE tracking setup @ COMPASS) → beam characterization and input particles tracking

2 Cherenkov gas + PMT detectors w/ tunable pressure → PID

T9 SETUP

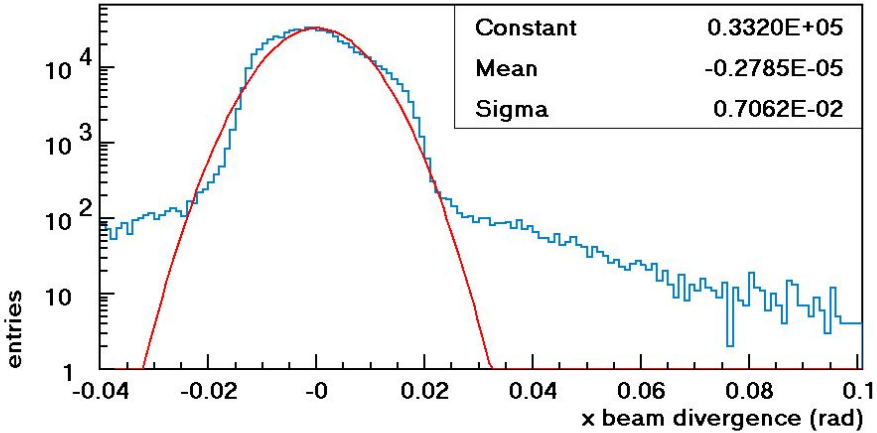

y
z
X
calorimeter box
SiBC 2
SiBC 1
45 cm
134 cm w/ STEFI
129 cm w/ GENNI
Cherenkov 2
Cherenkov 1

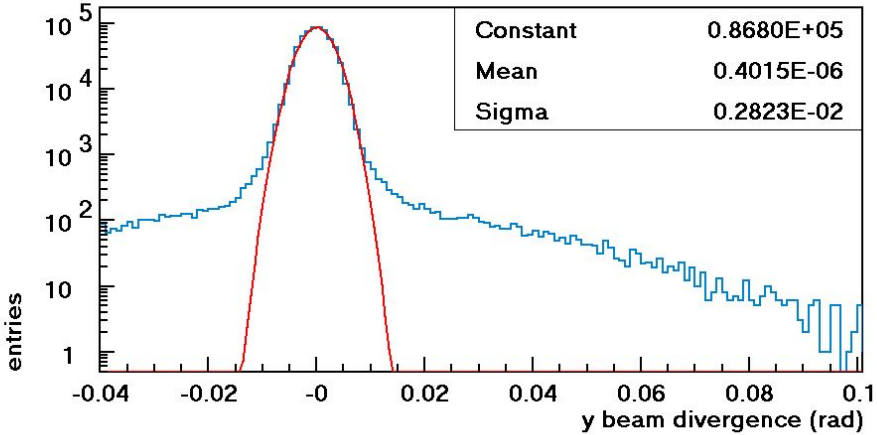


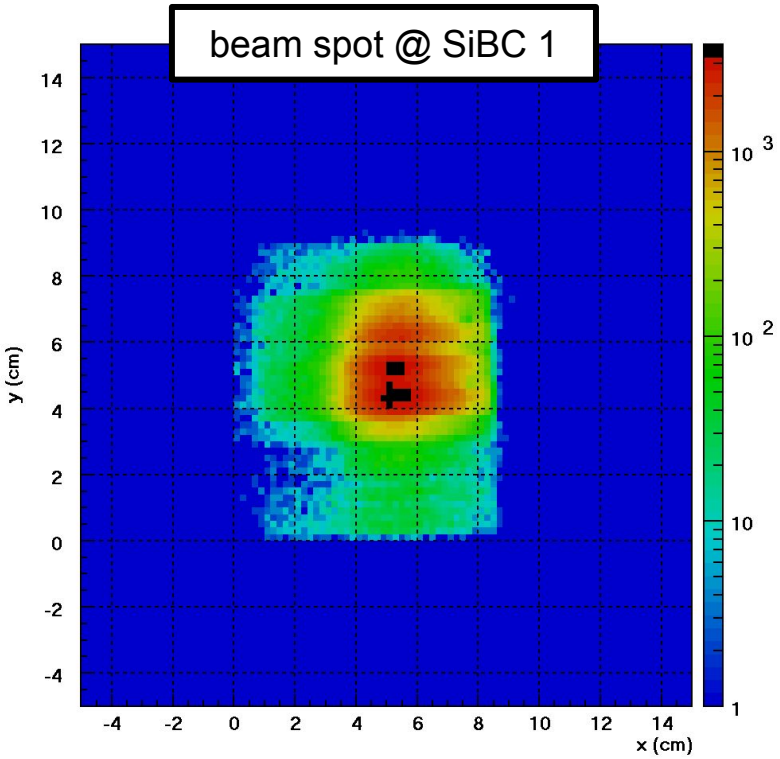


T9 SETUP

@ 3 GeV/c…



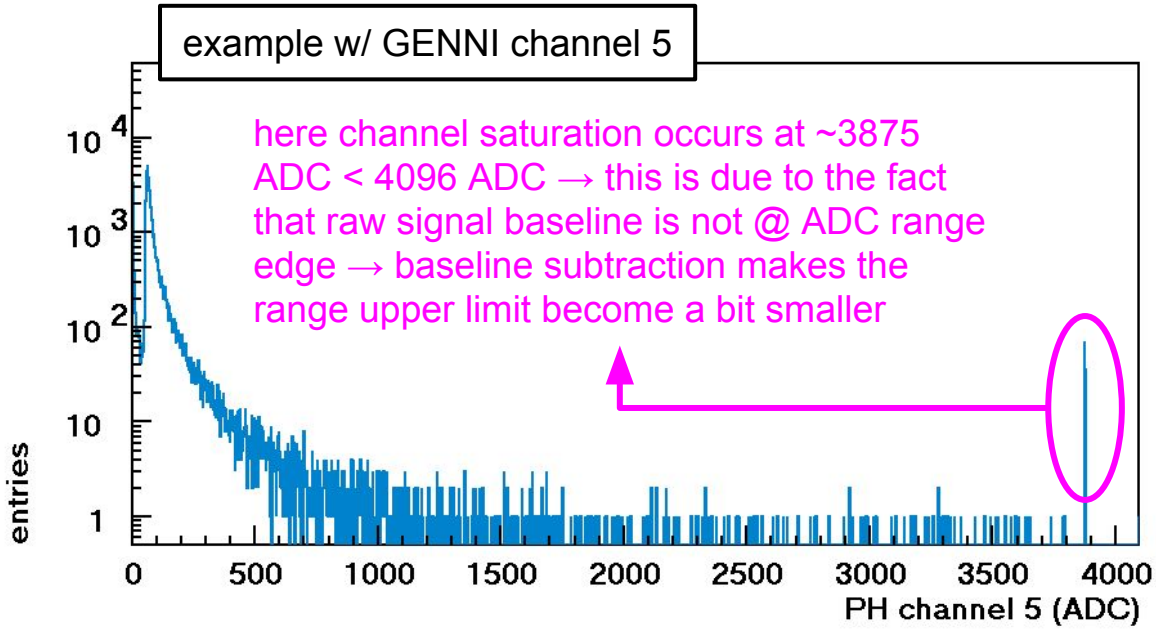




READOUT

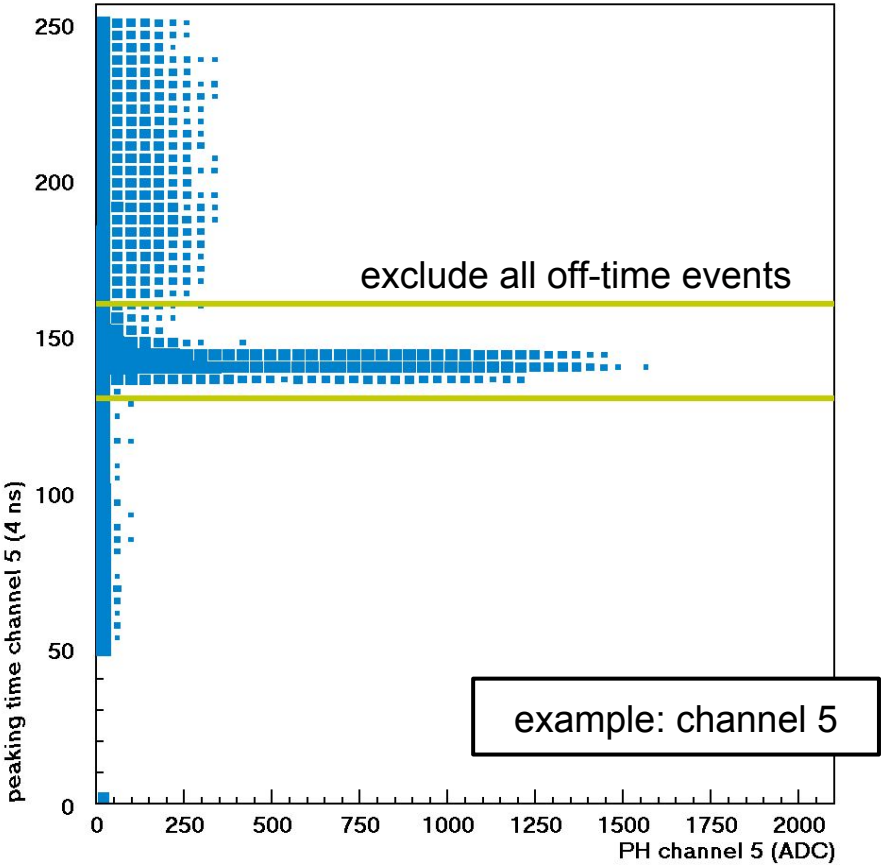
CAEN V1720

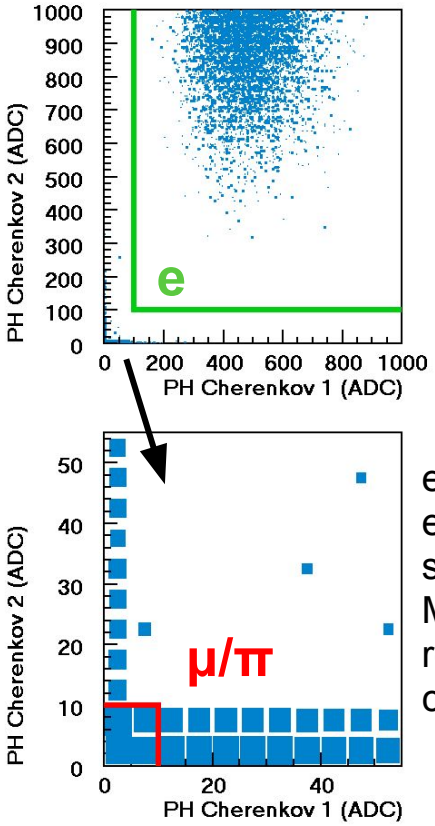
- 8 channels (calo. channels 1-8 in digi. 1 & calo .channel 9 in digi. 2)
- 12 bit ADC → PH ∈ (0,4095) ADC
- input range 2 Vpp
- sampling rate 250 MS/s → each time step is 4 ns



STEFI @ T9

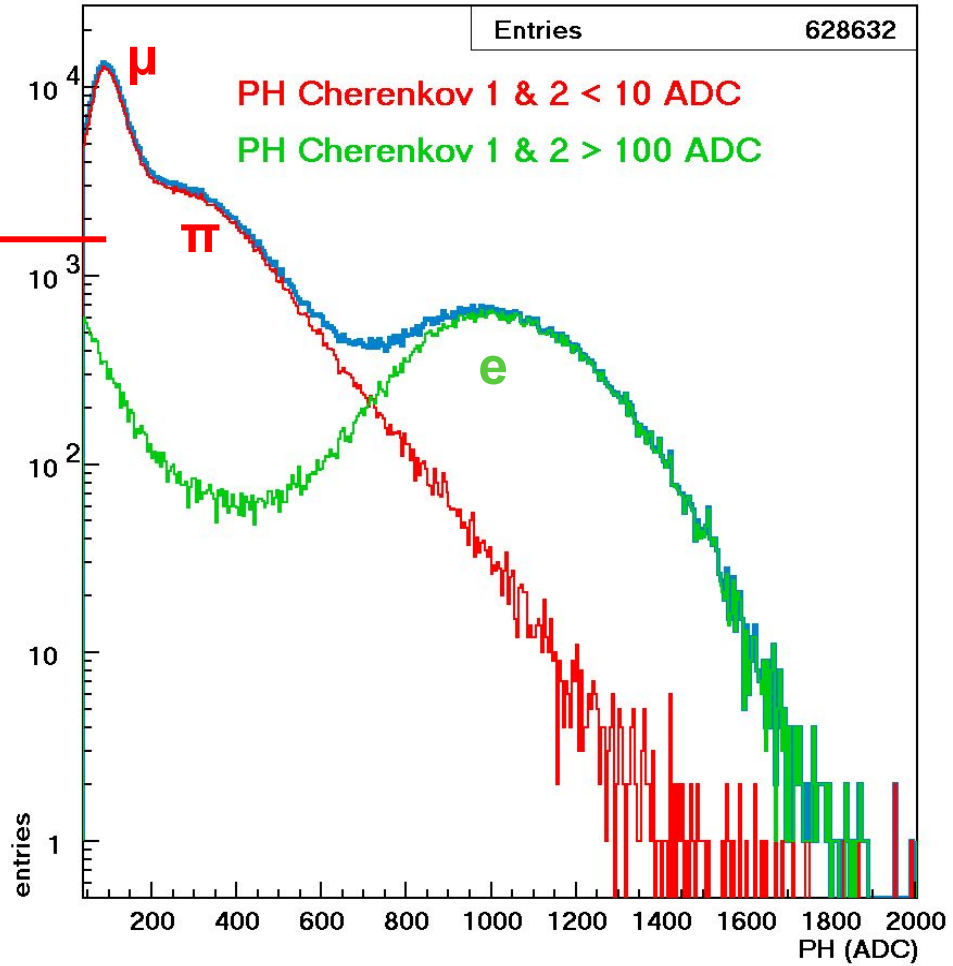
first of all, search for each channel MIP peak…





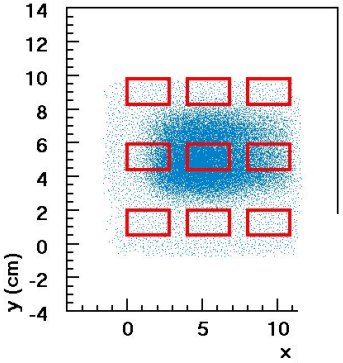
exclude electrons events, whose showers dirty the MIP low energy region of the channels spectra

at this stage only lowest PH red events have to be considered

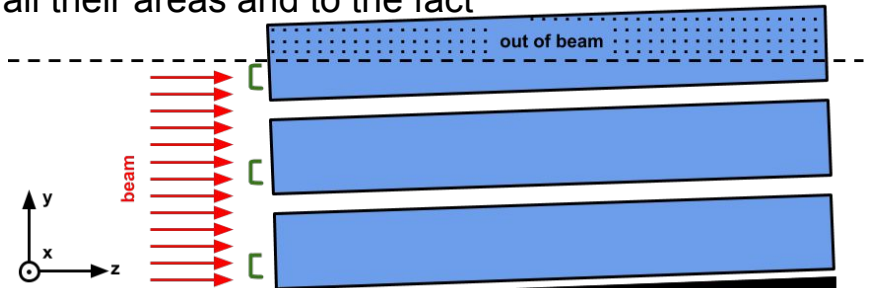


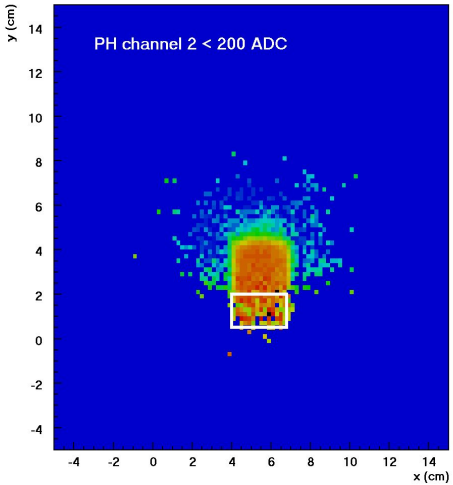
a selection on hit position at calorimeter front z has to be performed in order to exclude all events that travel across crystal edges

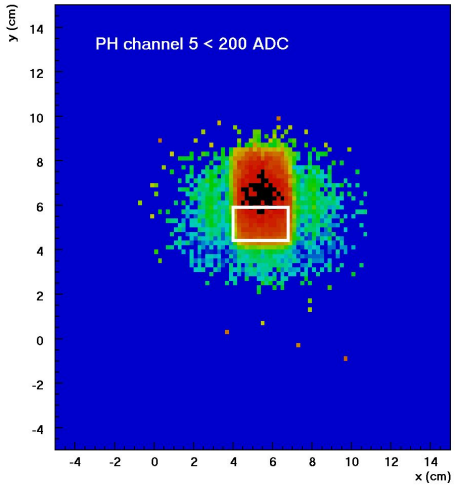
a thin fiducial box is identified for each crystal front, in order to exclude edges — fiducial boxes owe their shape and position to the will of equalizing all their areas and to the fact that channels 7, 8 & 9 are partially out of setup acceptance

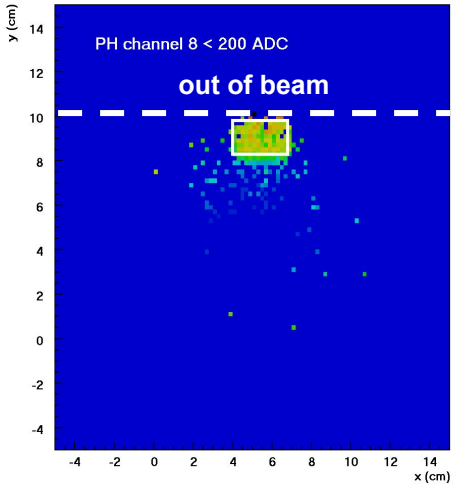


note: at this stage calo. box was tilted in order to eliminate crystals tilt about y axis



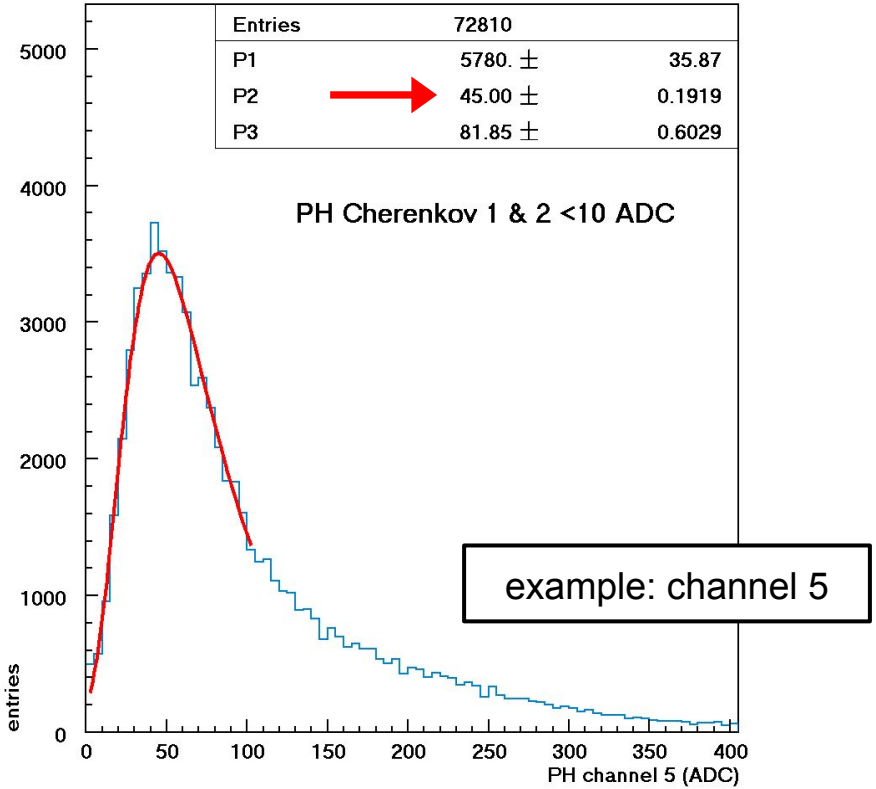






⇒ MIP peak Landau most probable values…

$$\ell(x) = \mathrm{P1} \cdot \exp\left\{-\frac{1}{2}\left[\left(\frac{x-\mathrm{P2}}{\mathrm{P3}/4.018}\right) + \exp\left(\frac{x-\mathrm{P2}}{\mathrm{P3}/4.018}\right)\right]\right\}$$



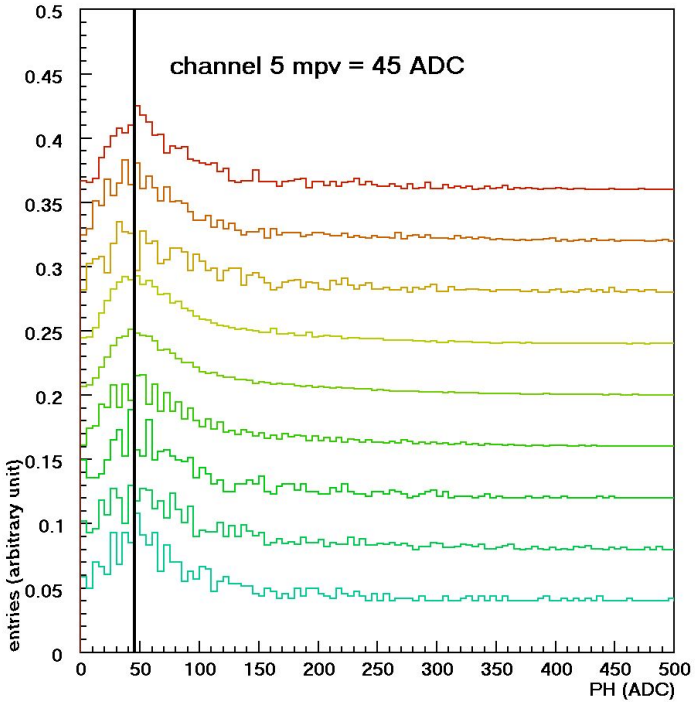
example: channel 5

channel	mpv (ADC)
1	25.00 ± 1.08
2	23.33 ± 0.84
3	19.02 ± 1.00
4	23.00 ± 0.18
5	45.00 ± 0.19
6	63.55 ± 0.42
7	16.07 ± 0.87
8	21.85 ± 0.35
9	47.76 ± 1.34

⇒ …& equalization coefficients…

$$PH_k^{eq} = \frac{\mathrm{P2}_{ref}}{\mathrm{P2}_k} \cdot PH_k = e_k \cdot PH_k$$

note that *ref=5* was chosen → all the channels are equalized to the central one

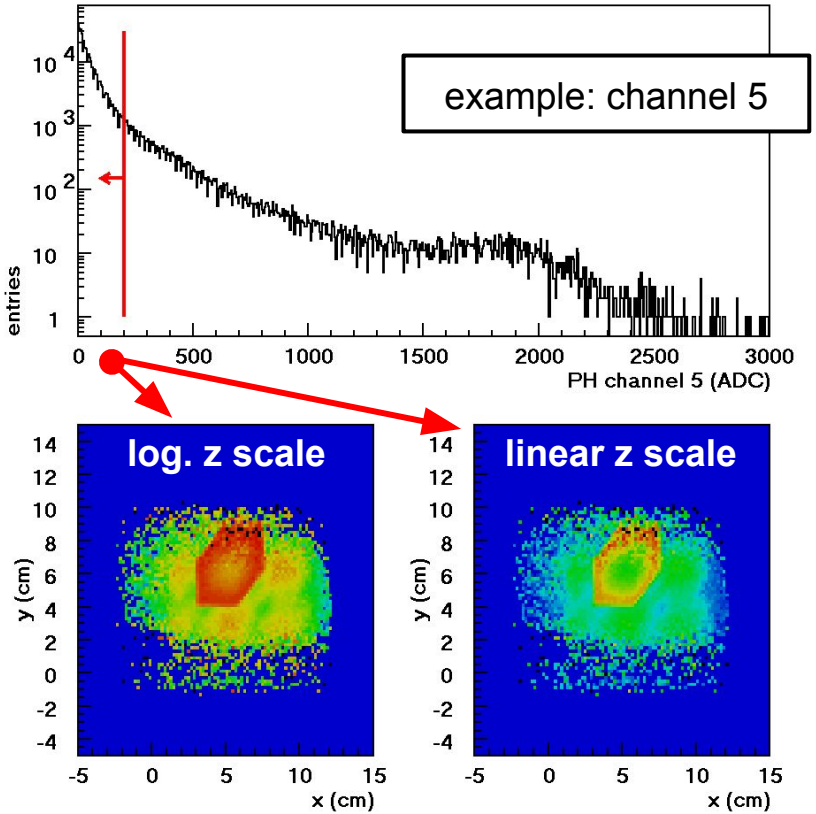


this makes channels PH sum possible

channel	e_k
1	1.8000000
2	1.9288470
3	2.3659306
4	1.9565217
5	1.0
6	0.70810384
7	2.8002491
8	2.0594964
9	0.94221109

⇒ …& finally energy calibration

note that for energy scan runs calorimeter box was brought back to its physical run position, so both tilts about x and y axes are now present



these are efficiency plots: distribution of hit points of events under channel 5 PH threshold over distribution of all hit points

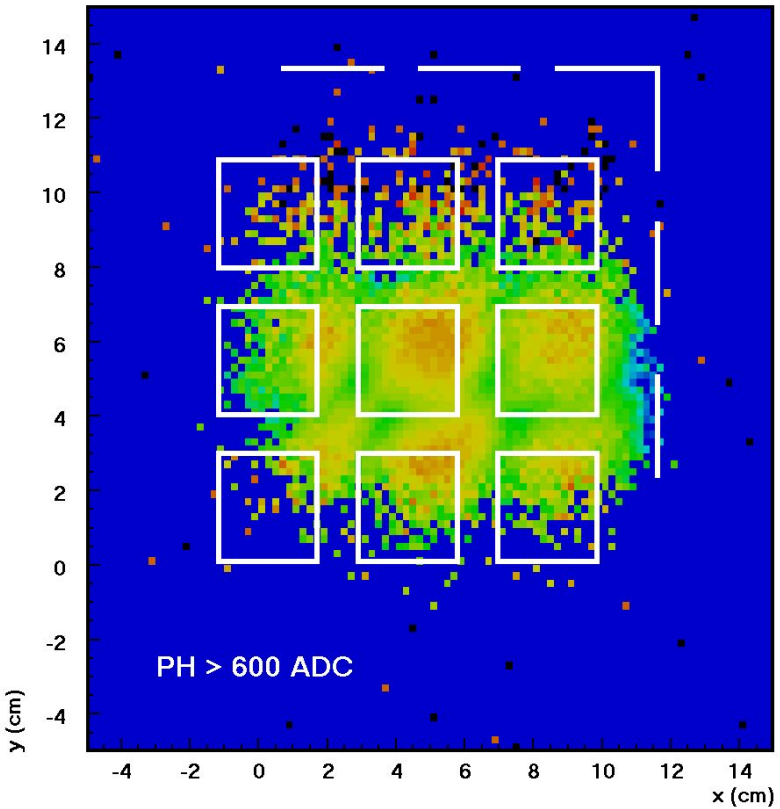
most of the boundary events result in low energy deposition → precise identification of crystal shape and position

red spots out of central crystal volume (clearly visible in log. scale plot) are electrons whose showers starts in other crystals and overflows into channel 5

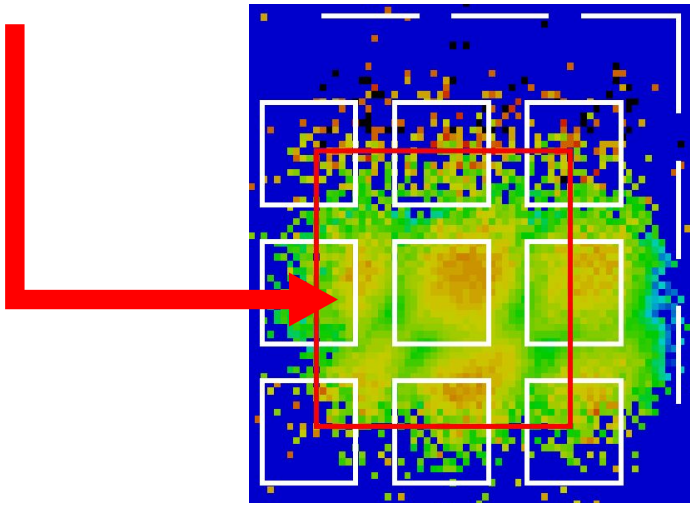
lin. scale plot shows that crystal center detects less events under threshold: this is due to the fact that electrons travelling through the full crystal depth surely start showering → everyone is over PH threshold (except muons)

⇒ …& finally energy calibration

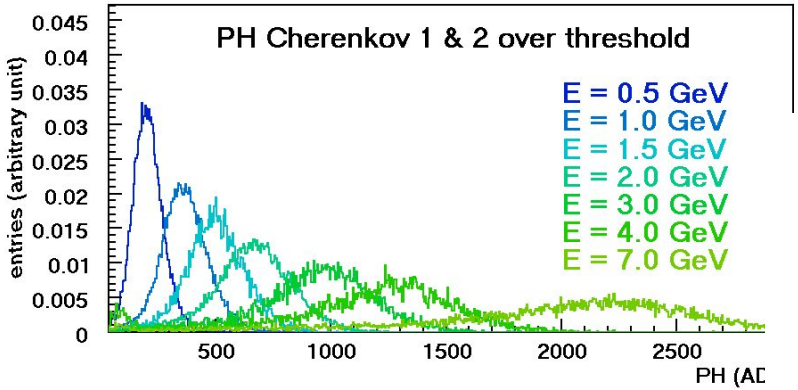
note that for energy scan runs calorimeter box was brought back to its physical run position, so both tilts about x and y axes are now present

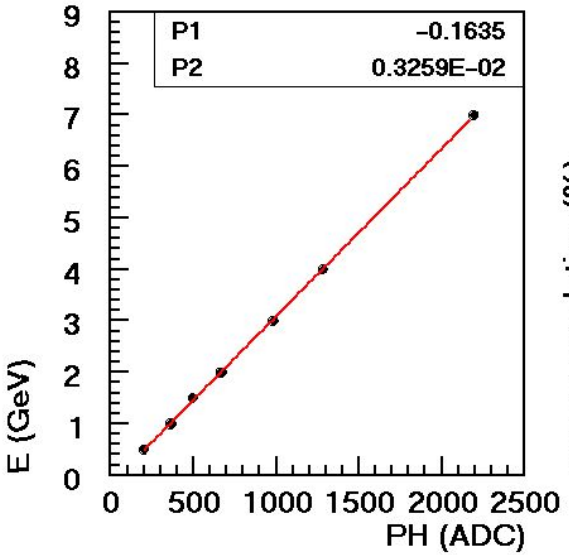


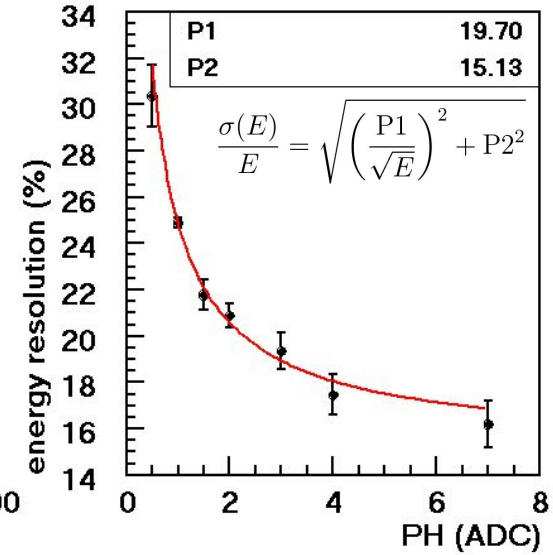
on the other hand, if the total PH is computed and if the events whose total PH is *over* a certain threshold are considered, a map of the electron beam spot that hits the calorimeter crystals is obtained → selection of a fiducial box on the front side of the detector in which to limit electrons spectra



⇒ …& finally <u>energy calibration</u>



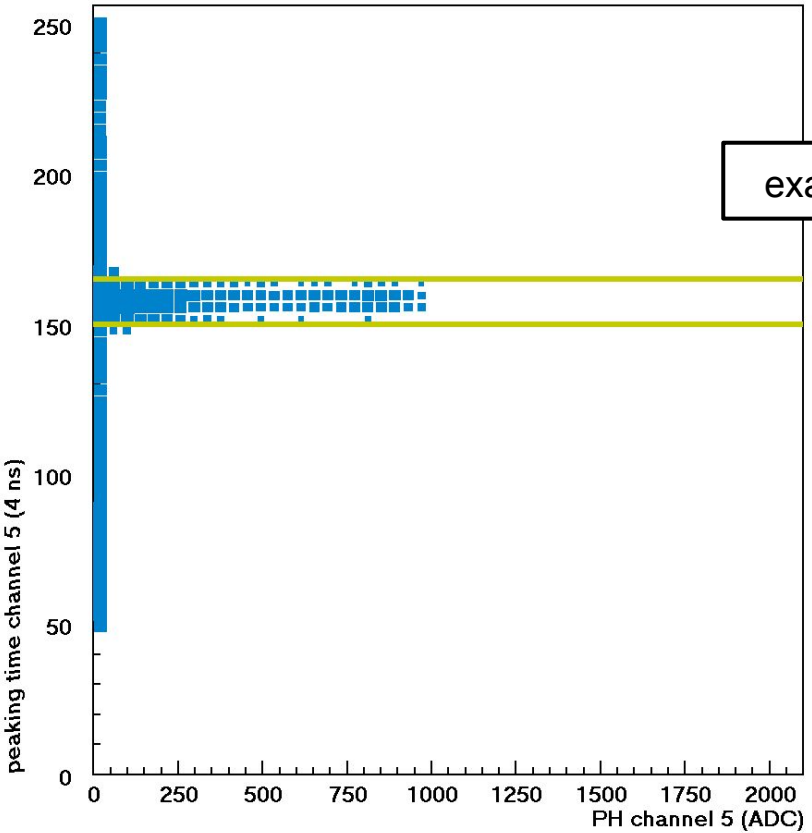




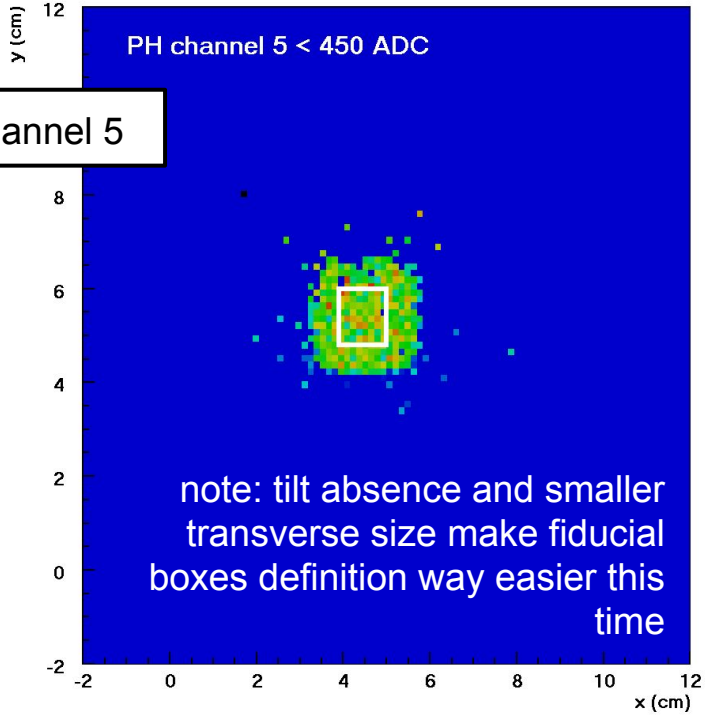
$$E[\mathrm{GeV}] = -0.1635 + 0.003259 \cdot PH[\mathrm{ADC}]$$

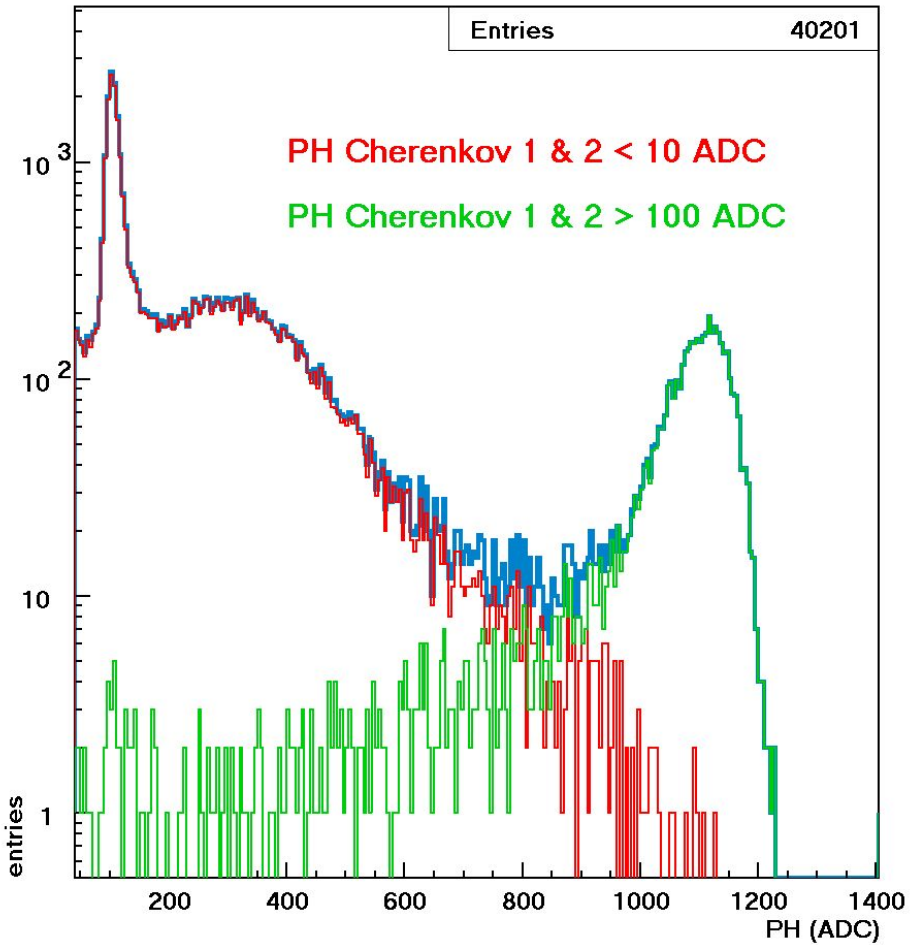
GENNI @ T9

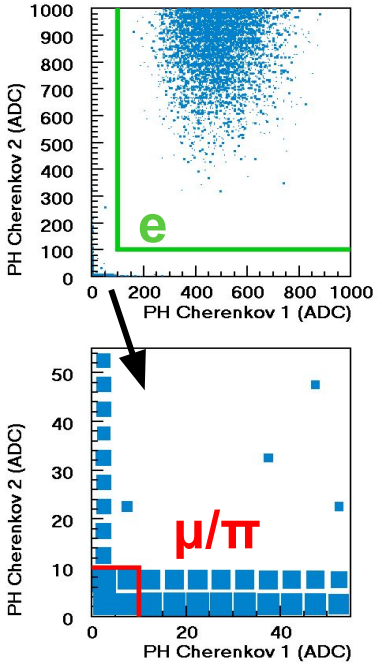
everything works just the same way…



example: channel 5

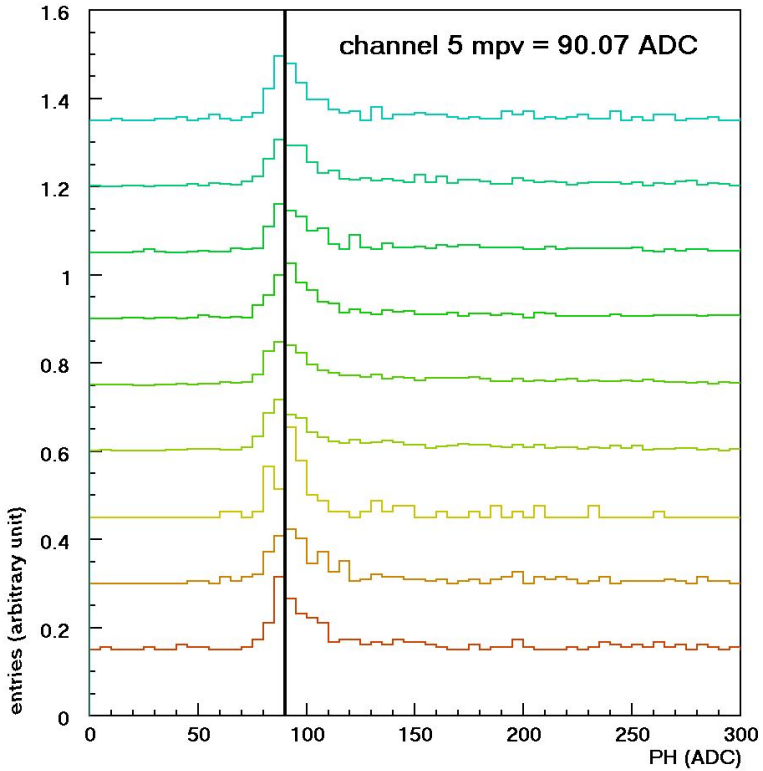






getting to this stage, it is already noticeable that GENNI shows better performance than STEFI in terms of energy resolution…

⇒ again, MIP peak mpv & equalization…

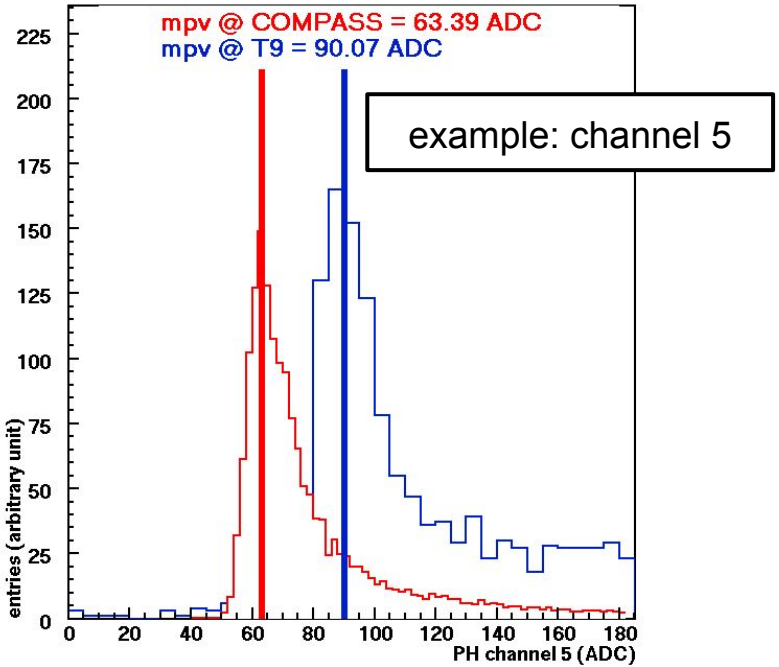


check in the following…

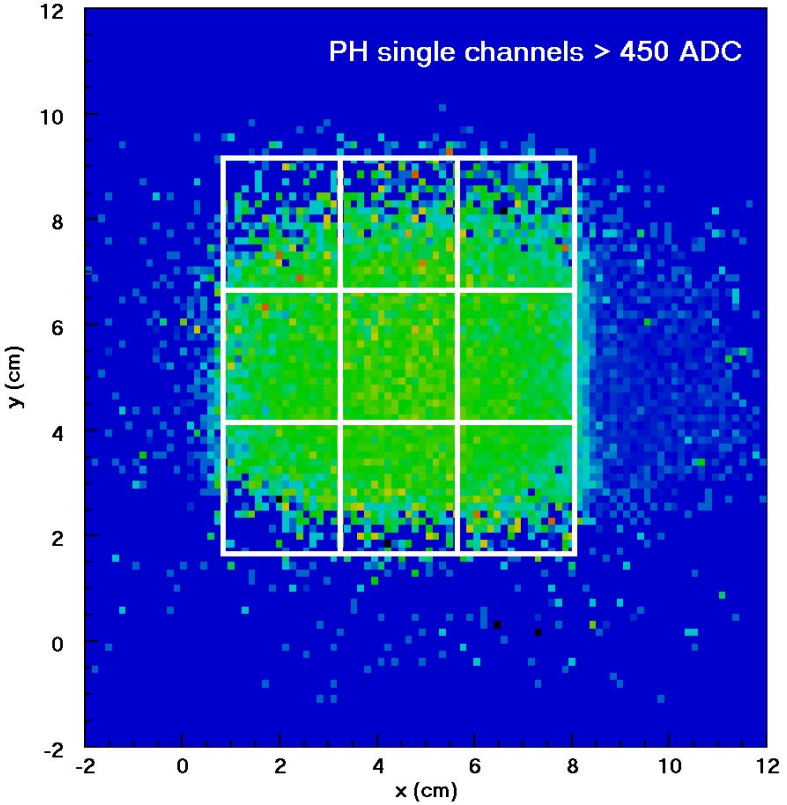
channel	mpv (ADC)	e_k
1	104.31 ± 1.23	0.8230330
2	94.61 ± 0.95	1.029393
3	110.54 ± 1.81	0.8231398
4	78.54 ± 0.63	1.140313
5	90.07 ± 0.51	1.0
6	141.36 ± 0.77	0.6361903
7	104.08 ± 1.02	0.7449759
8	89.92 ± 0.75	0.7218174
9	72.34 ± 0.68	1.204904

position of MIP peaks changed between T9 testbeam and installation at COMPASS due to some difference in HV or to some change in the crystal-PMT coupling

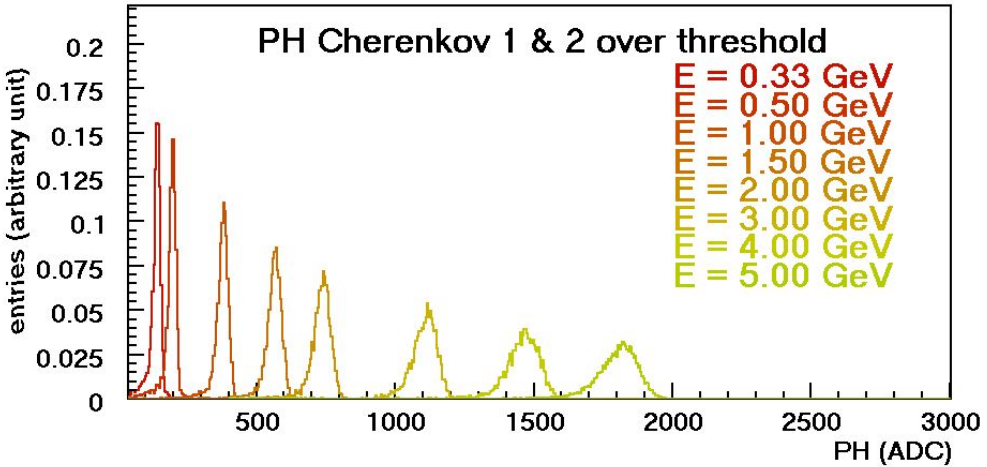
⇒ solution: find e_k from MUonE data and then rescale them with factor 90.07/63.39

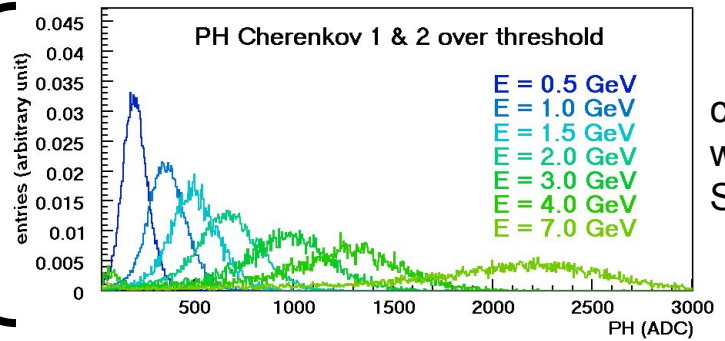


channel0	mpv (ADC)	e_k
1	77.02 ± 0.03	1.16943669
2	61.58 ± 0.03	1.46265018
3	77.01 ± 0.02	1.16958845
4	55.59 ± 0.03	1.62025559
5	63.39 ± 0.06	1.42088652
6	99.64 ± 0.08	0.903954268
7	85.09 ± 0.05	1.05852628
8	87.82 ± 0.04	1.02562070
9	52.61 ± 0.04	1.71203196

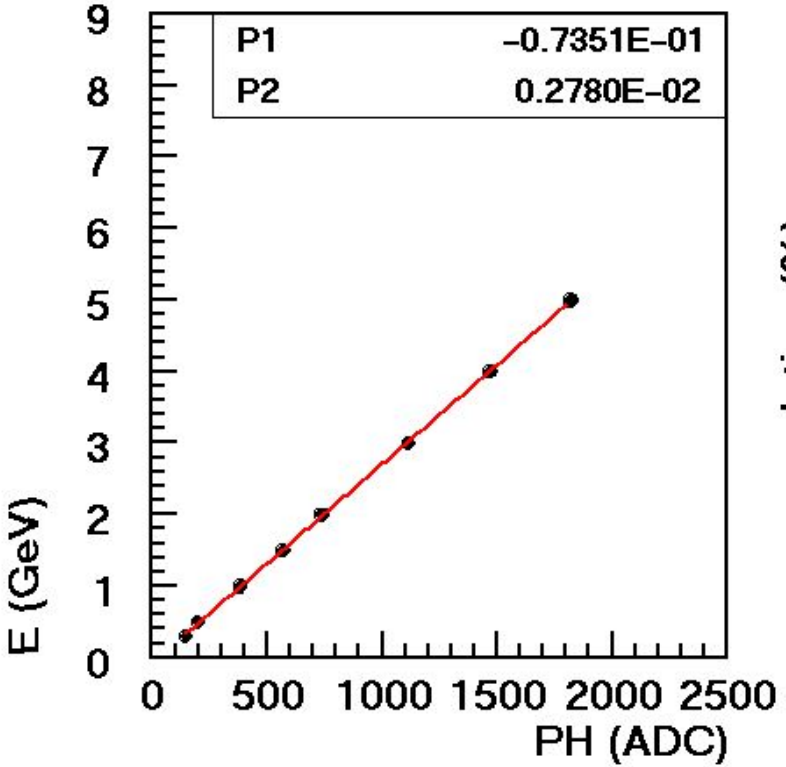


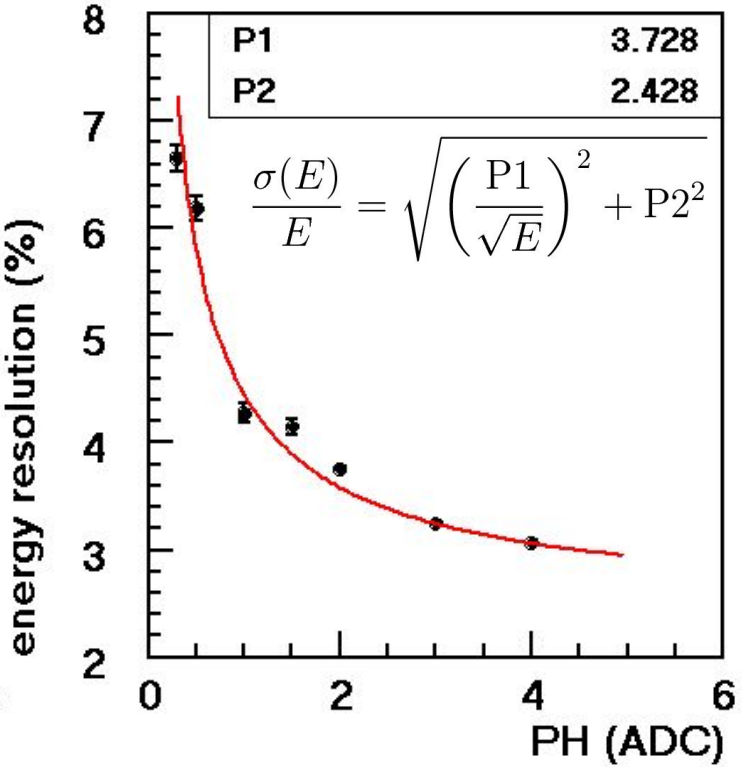
⇒ …& finally <u>energy calibration</u>





compare with STEFI

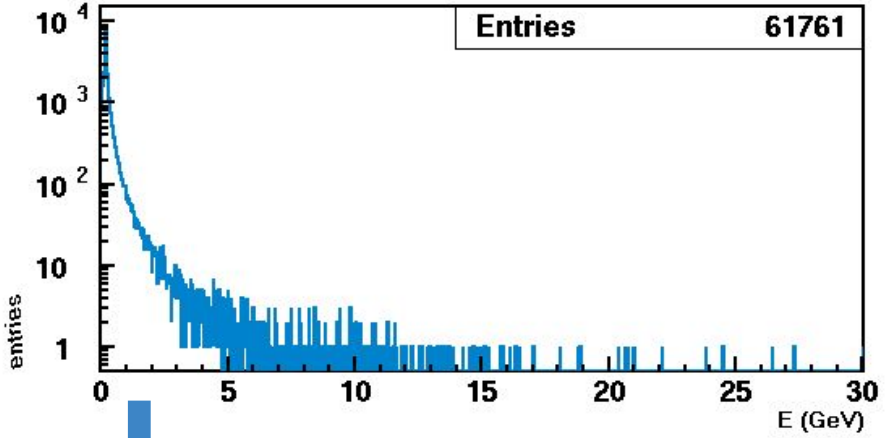


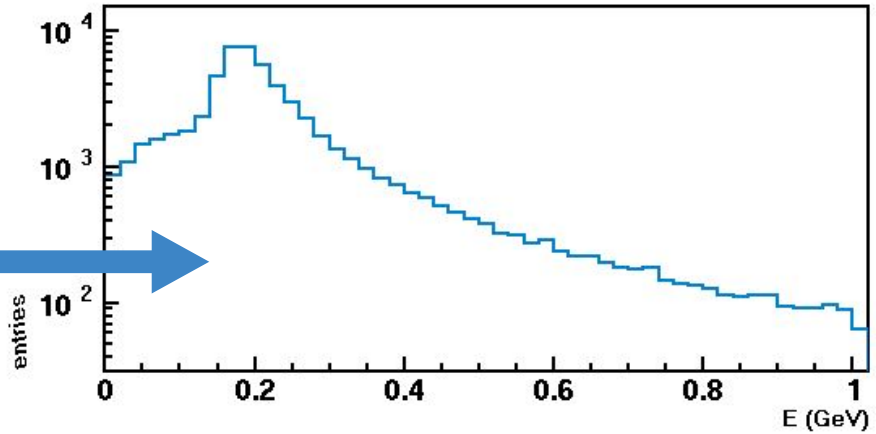


excellent energy resolution!

$$E[\mathrm{GeV}] = -0.07351 + 0.002780 \cdot PH[\mathrm{ADC}]$$

APPLICATIONS TO MUonE DATA

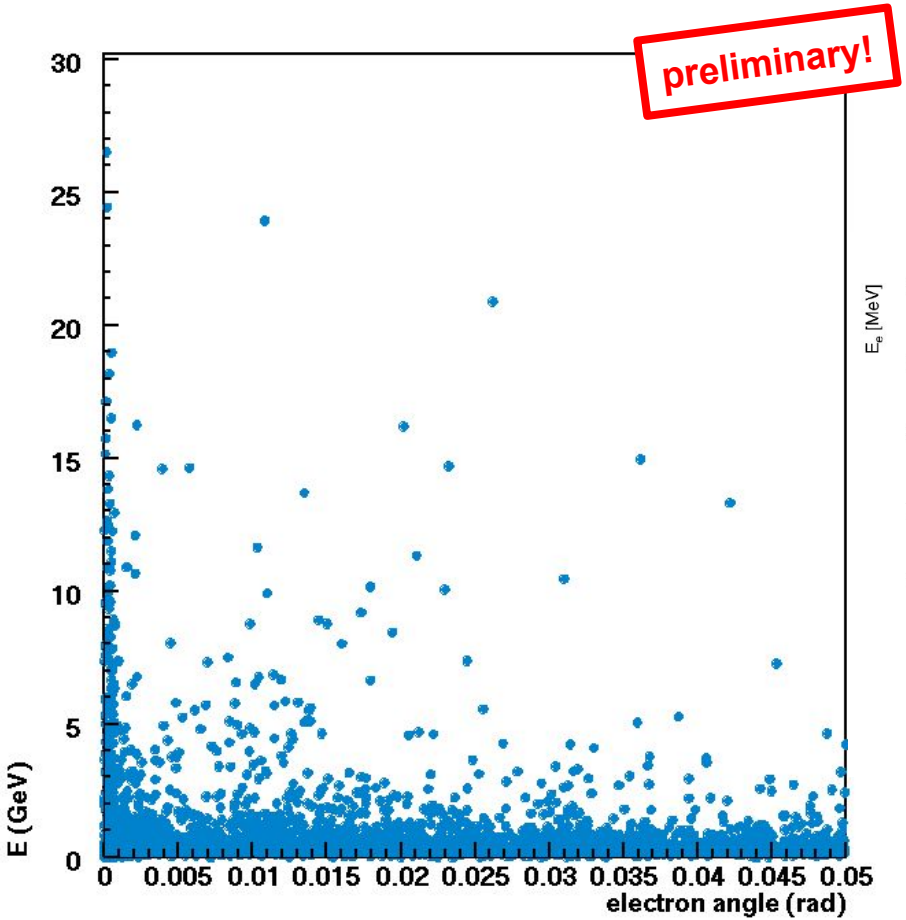




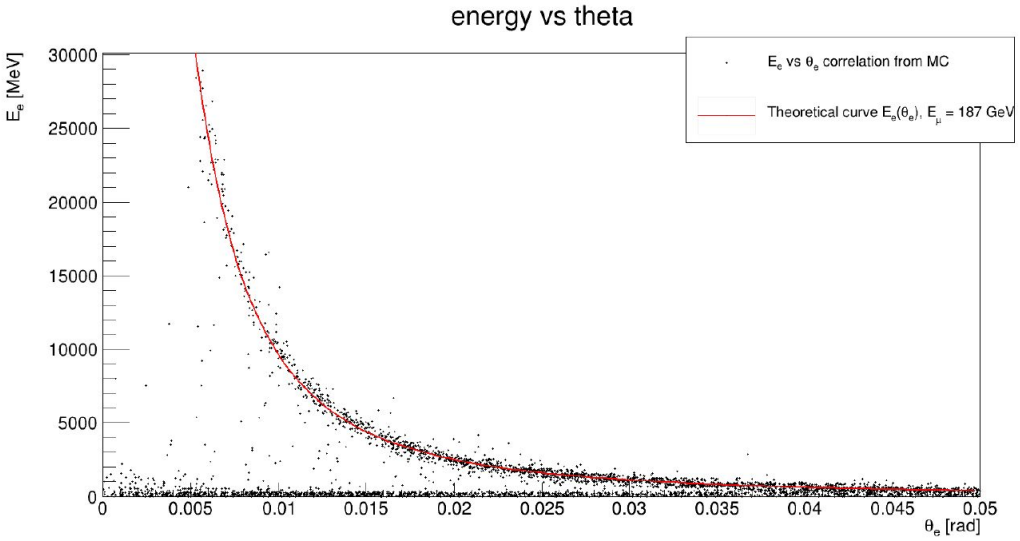
all runs with one single target and GENNI — only "good" events (from the p.o.v. of the tracking)

there are 107 events (~2/1000) in which at least one of the calo. channels shows saturation → these events are excluded from this plot & flagged with an unrealistic energy of 100 GeV

APPLICATIONS TO MUonE DATA



compare with MC:



Thank you!