Preliminary results on PSD tile beam test @ CNAO

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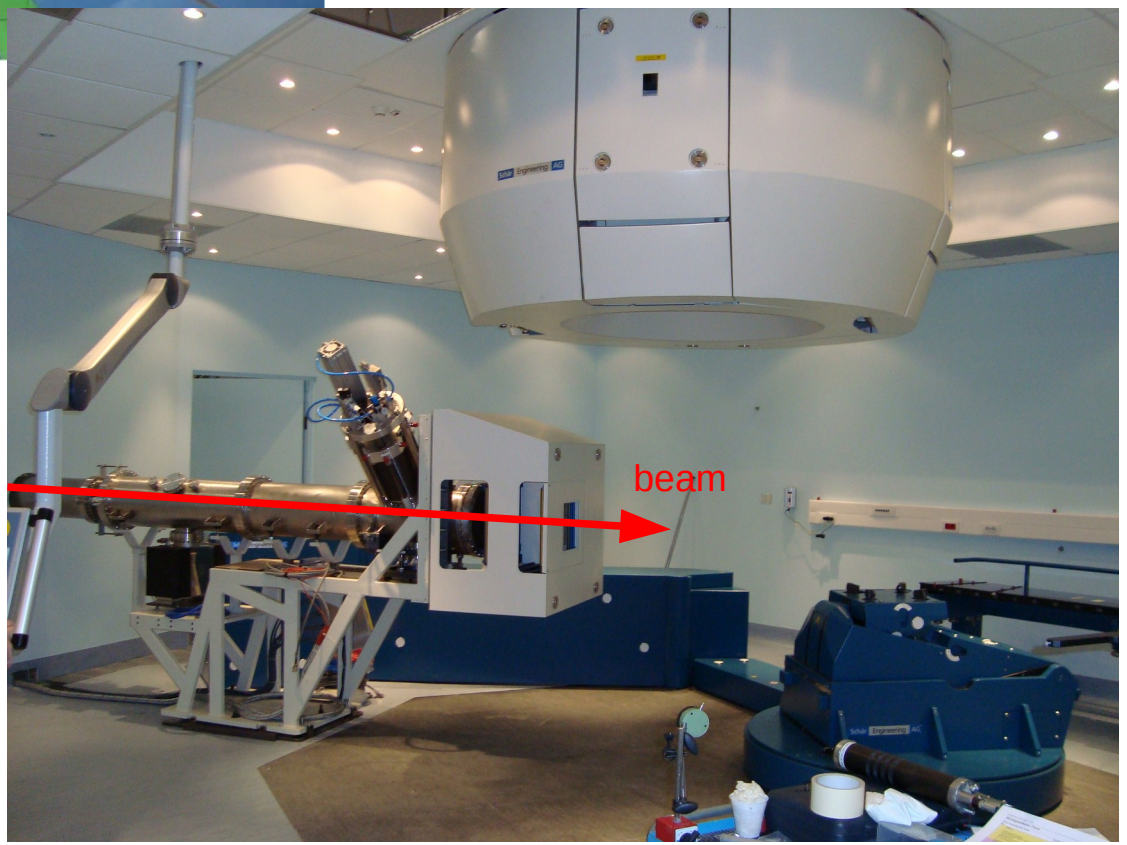
- test performed on a 10x10x0.5 cm^3 scintillator tile (EJ200)
- 6 Ham. S12572 SiPMs 50 μm 3x3 mm^2 (3 + 3, opposite sides)
- beam available as "*research facility*" at CNAO in Pavia (*National Centre for Oncological Adrotherapy*) only during the night or in some weekends (agreement with INFN)
- available beams: protons with energy range 60-250 MeV
  C ions with energy range 120-400 MeV/u
- the low-β beam behaves like a high-Z particle (Bethe-Bloch)

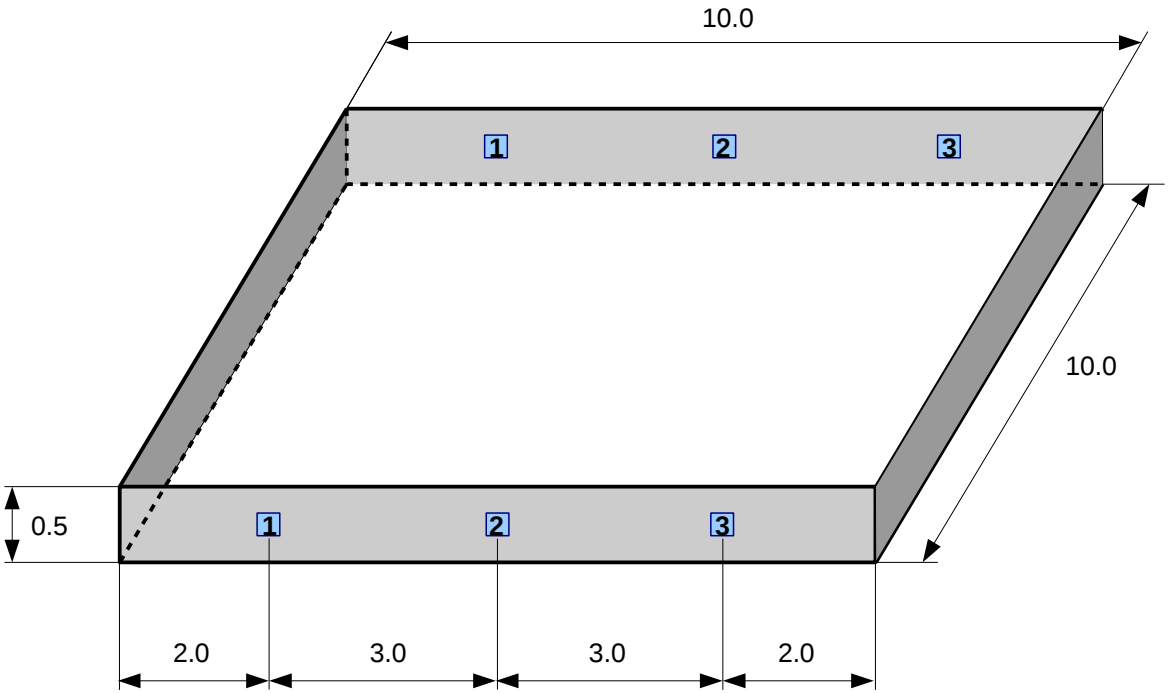
The CNAO complex

Synchrotron

Treatment rooms



Tested geometry



10x10x0.5 cm^3 tile

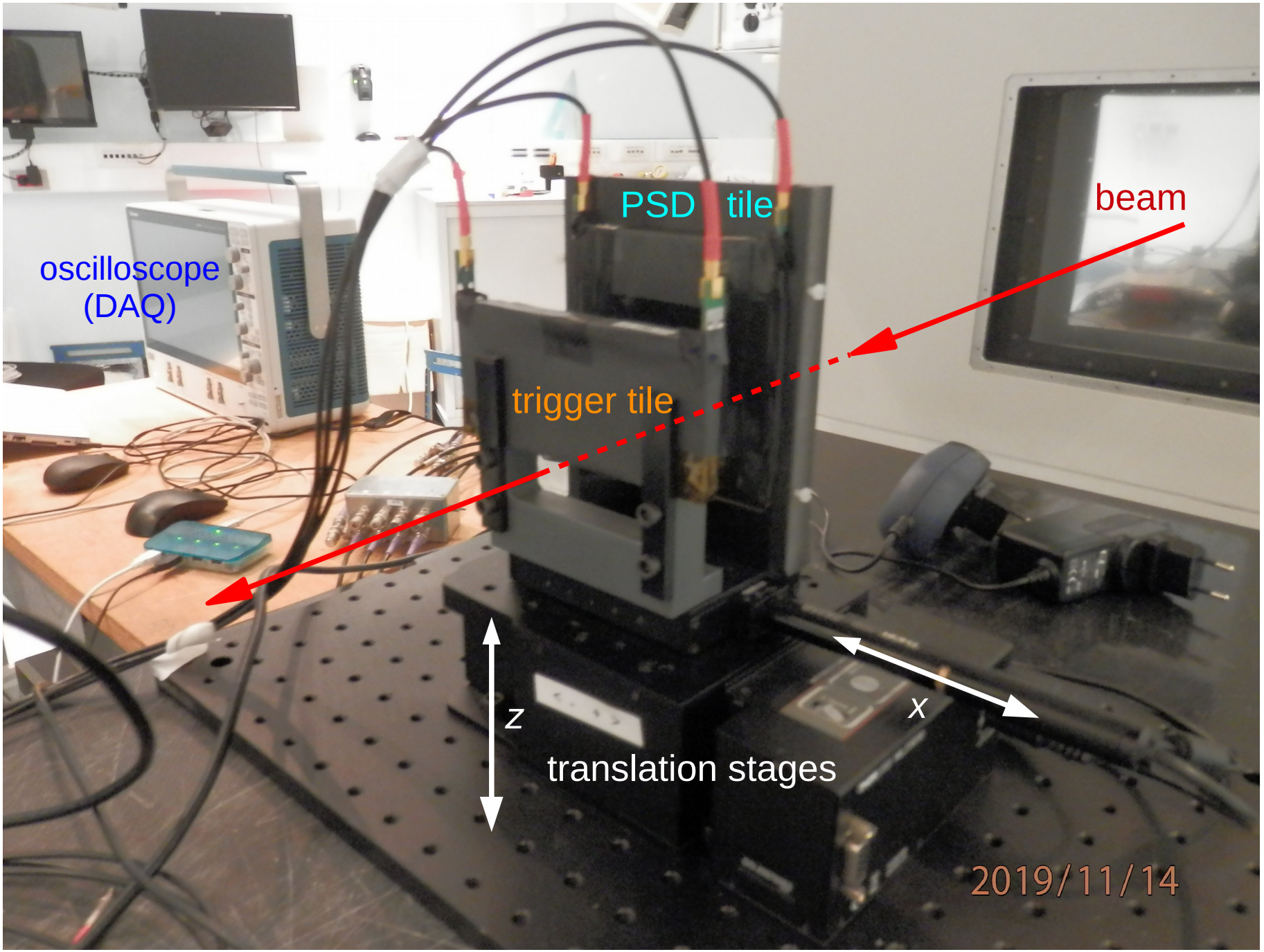
EJ-200 scintillator (Eljen)

3 + 3 SiPMs (on 2 opposite sides)

Hamamatsu S12572-050P

3x3 mm^2 50 μm pitch

Beam test setup



Data acquisition

- all the SiPM signals are sent to a Tektronix MSO64 oscilloscope without amplification
- 5000 samples at 12.5 GS/s rate (0.4 μs window), 12 bit ADC
- signal saved on network storage in *wfm* binary format (Tektronix)
- offline rewriting in a more compact format

- 8 hours available for run (from 10 p.m. to 6 a.m)
- low intensity beam
- pile-up ≤ 1 %
- mean acquisition rate ~7 Hz

Beam	Energy	Events
p	70 MeV	5000
p	120 MeV	5000
p	170 MeV	5000
p	226 MeV	18270†
C	115 MeV/u	20000*
C	190 MeV/u	2500
C	260 MeV/u	2500
C	330 MeV/u	2500
C	400 MeV/u	1182

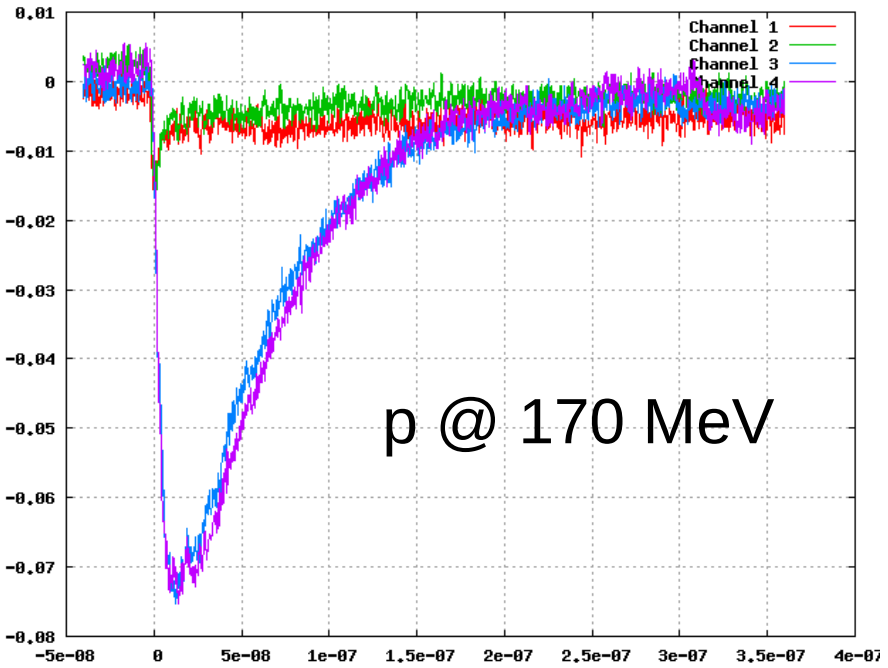
† 6 different beam positions
* 7 different beam positions

Acquired signals

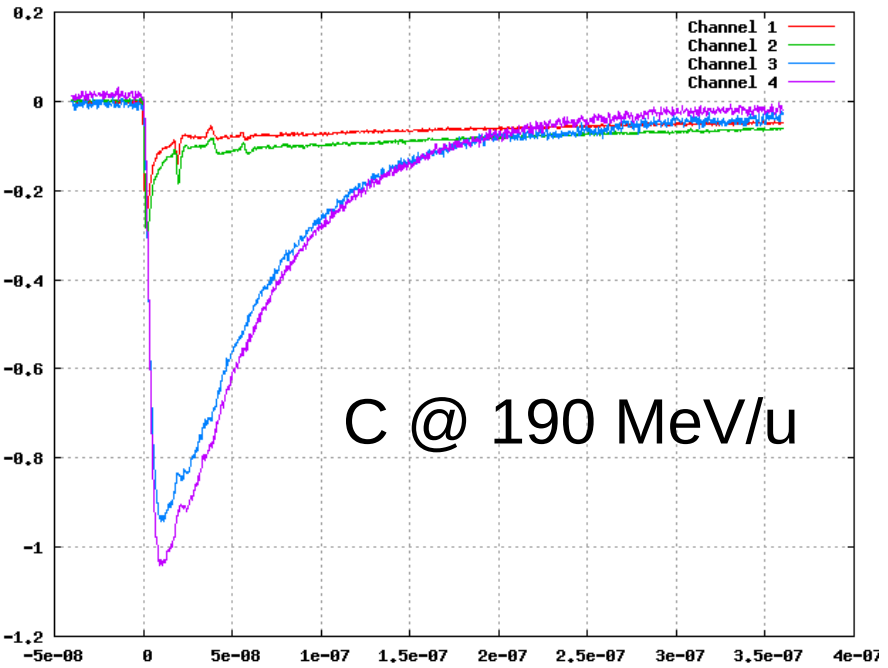
4 channels per *event:*

trigger tile ch1 and ch2 in coincidence gives the trigger

PSD tile ch3 and ch4

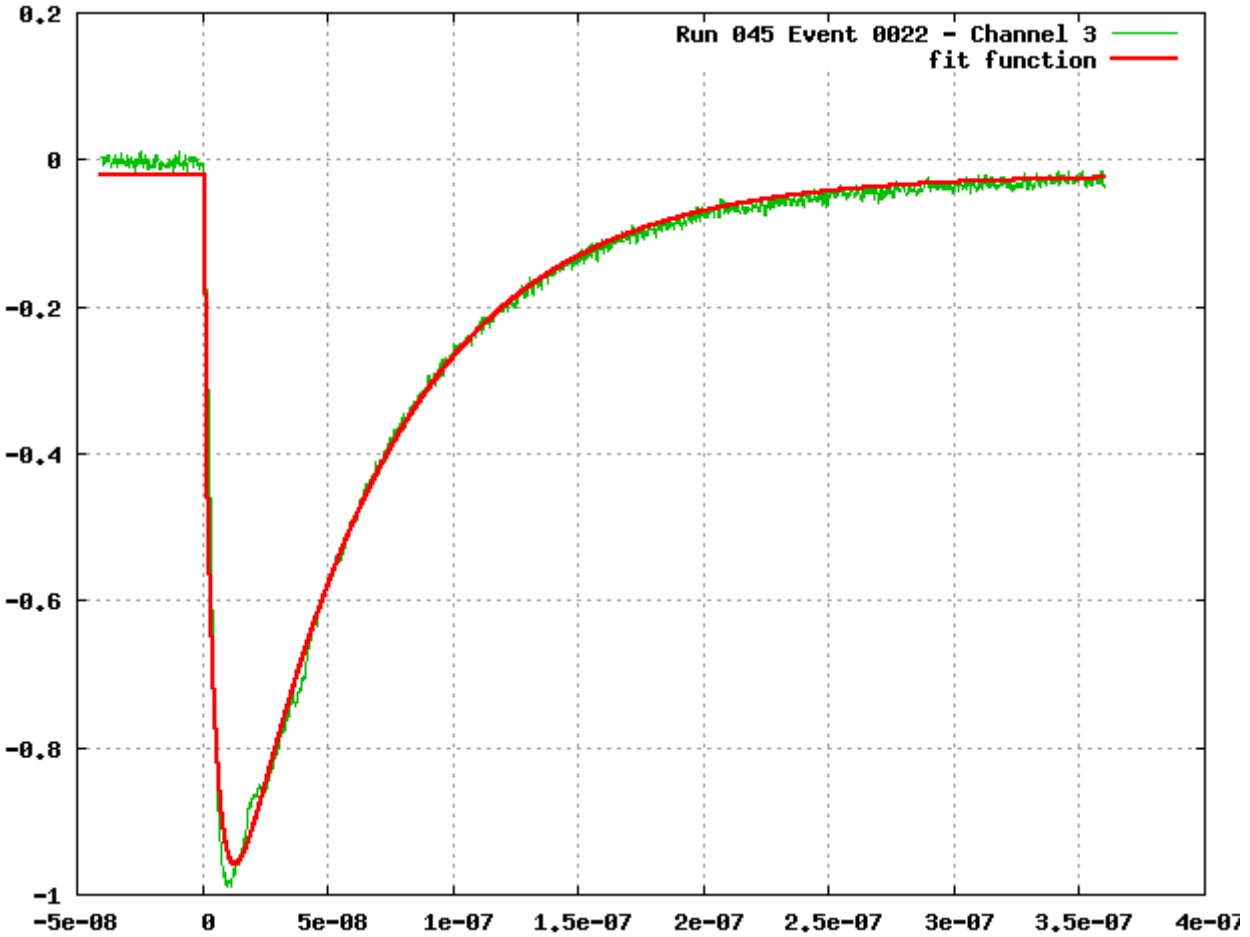


0.4 µs



0.4 µs

Pulse analysis



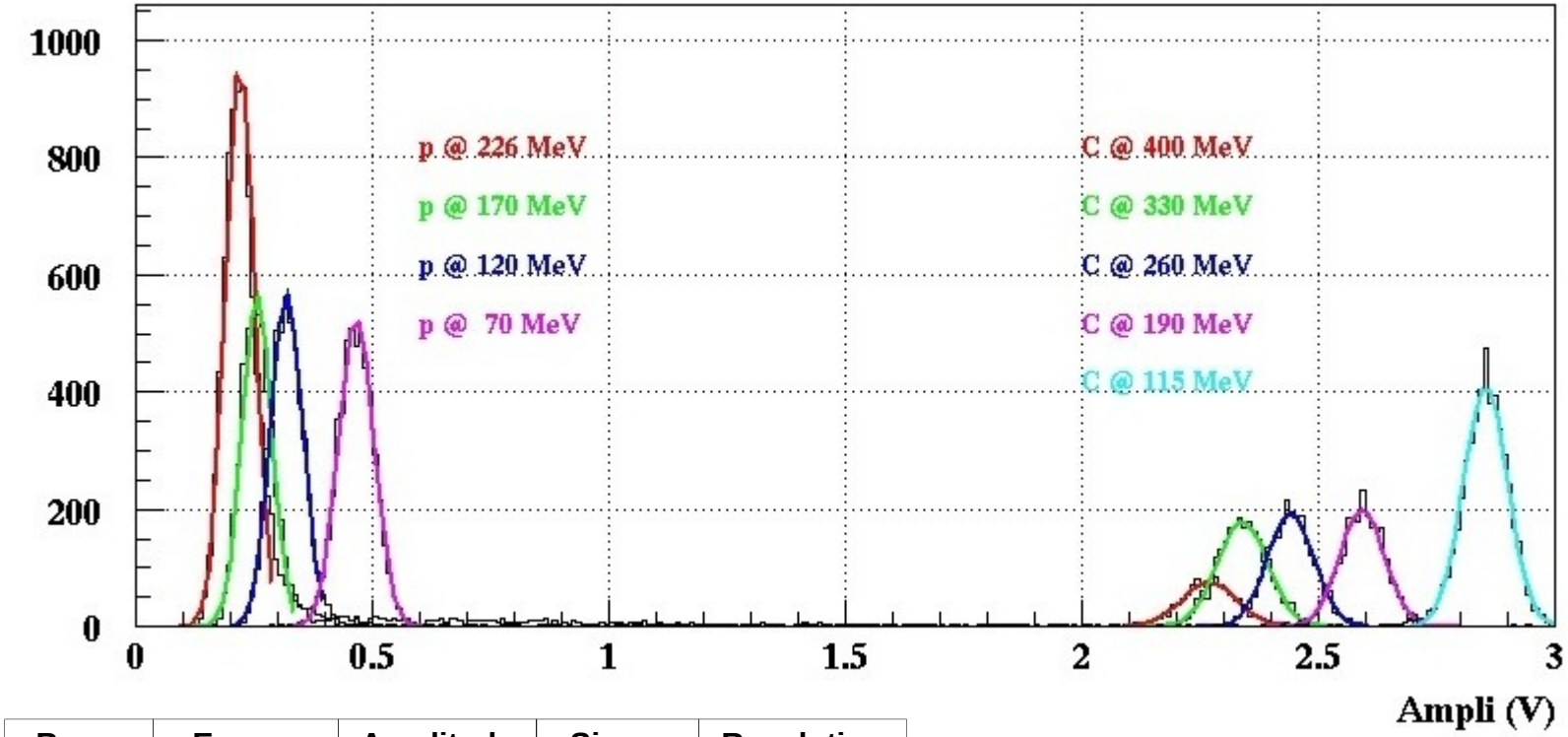
5 parameters fit

b baseline
A amplitude
t_0 start time
t_r rise time
t_d decay time

$$f(t) = \begin{cases} b & t \le t_0 \\ b + A*\left(1-\exp\left(-t/\tau_r\right)\right)*\exp\left(-t/\tau_d\right) & t > t_0 \end{cases}$$

A is used as the signal amplitude

Signal amplitude analysis

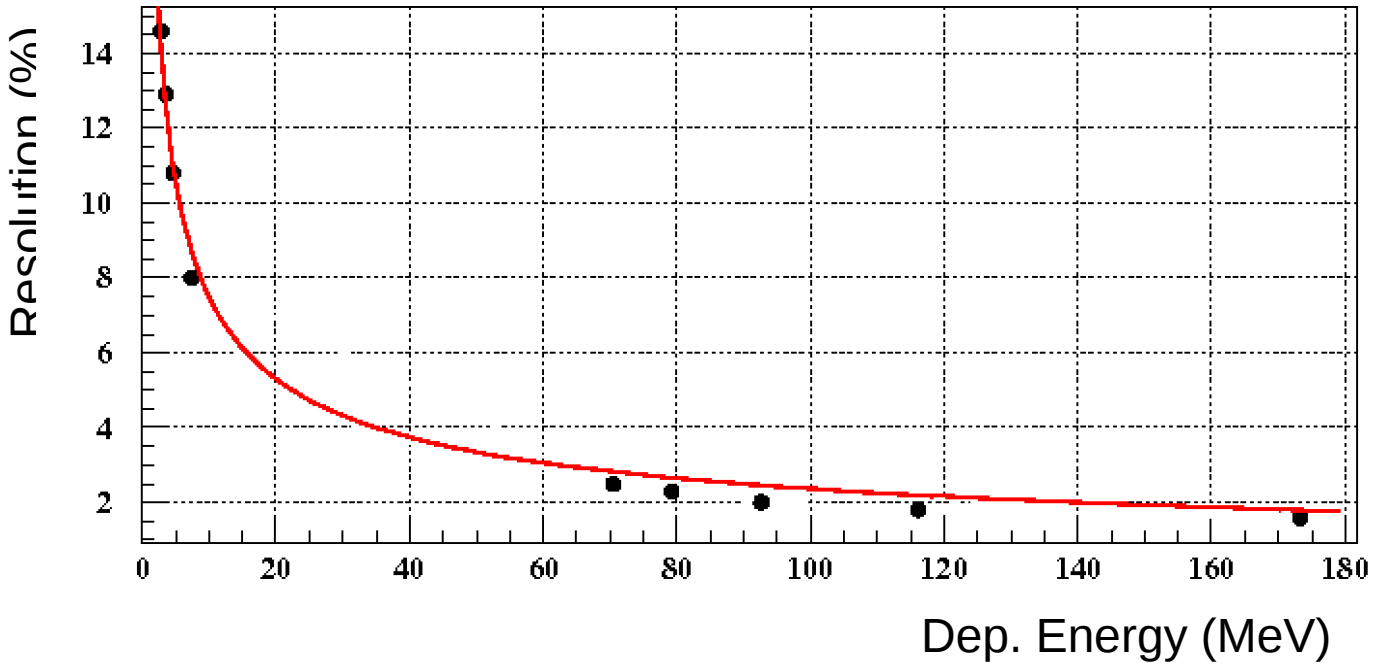


Beam	Energy (Mev)	Amplitude (V)	Sigma (V)	Resolution (%)
p	226	0.218	0.031	14.2
p	170	0.254	0.032	12.4
p	120	0.317	0.034	10.7
p	70	0.465	0.038	8.08
C	400	2.270	0.058	2.57
C	330	2.340	0.053	2.28
C	260	2.442	0.049	2.03
C	190	2.594	0.048	1.85
C	115	2.855	0.047	1.64

The amplitude is given by the A parameter of the fit function (see previous)

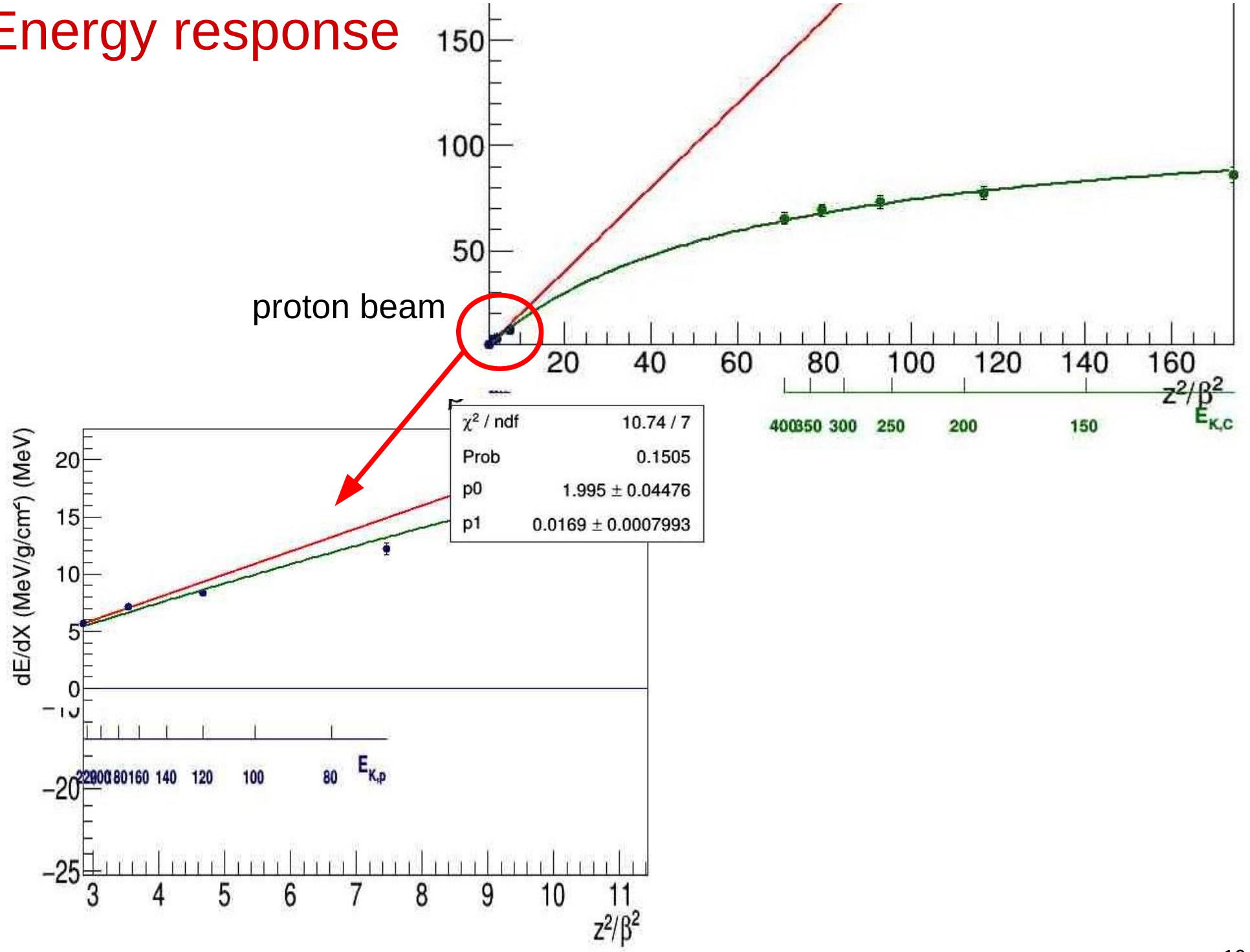
Energy resolution

considering dE/d*x* = 2 MeV/cm for m.i.p.

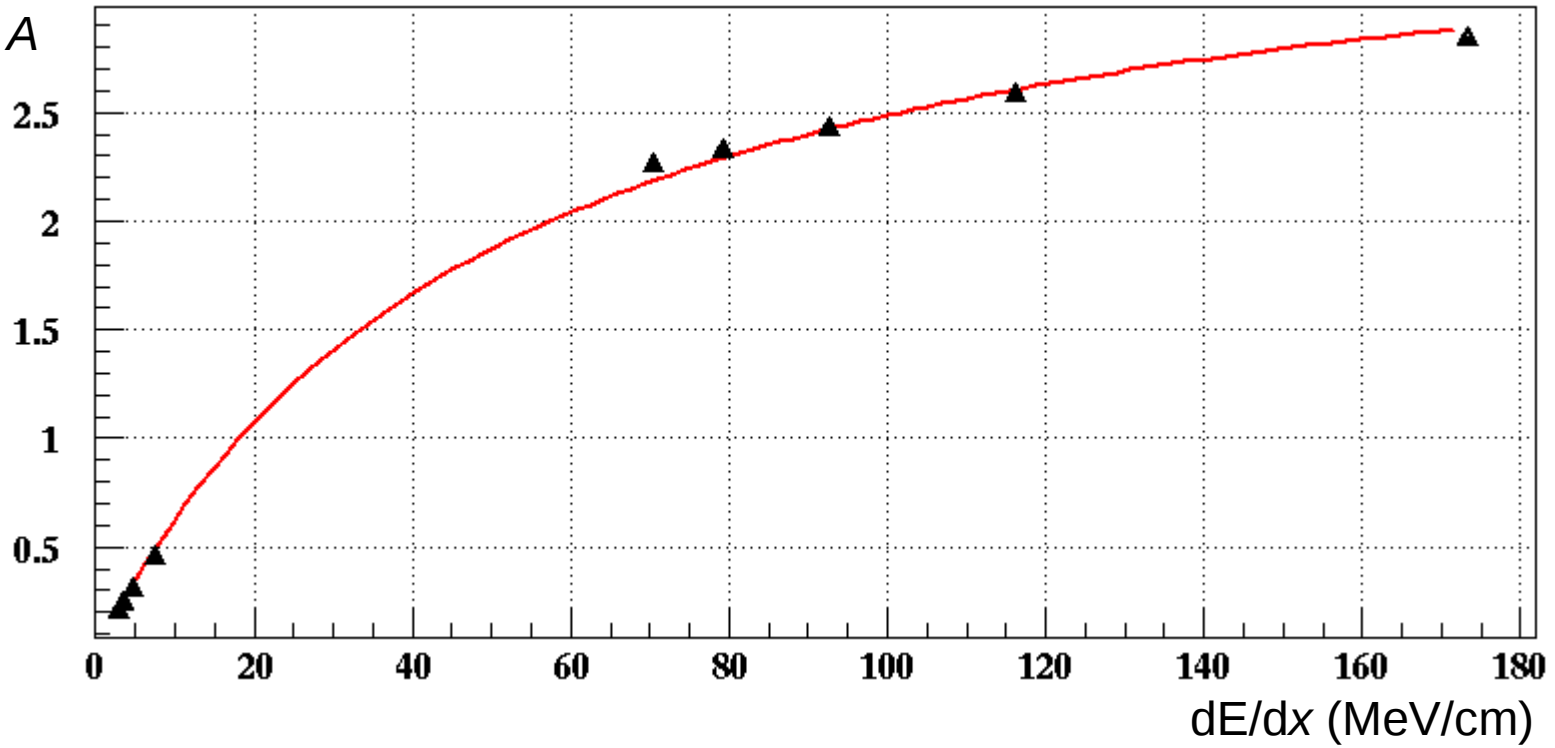


$$\frac{\Delta E}{E}(\%) = \frac{22.9}{\sqrt{E}(MeV)}$$

Energy response



Birks' law



The correlation between the signal amplitude and the dE/dx is well fitted with a Birks' law (provided the SiPM are not saturated)

$$A = P_1 \frac{dE/dx}{1 + P_2 dE/dx}$$

P_1 = 0.040 V

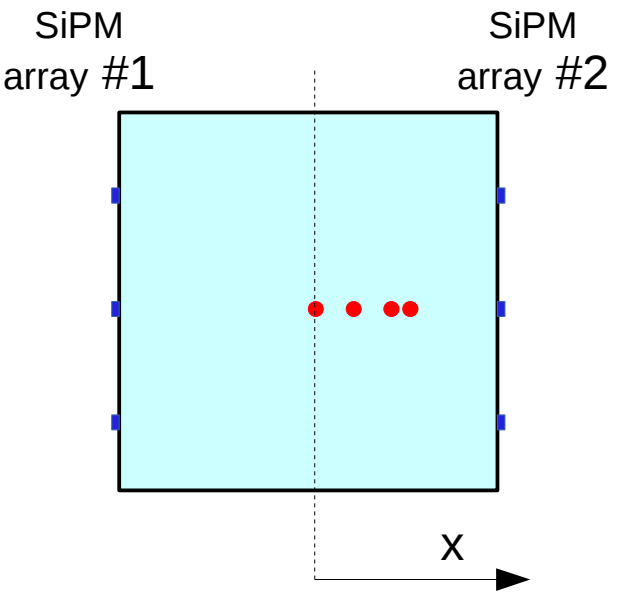
P_2 = 0.011 g/(MeV cm^2)

The value of K_b coefficient (P_2) is in agreement with the ones found in literature: $(1.26 \div 2.07) \cdot 10^{-2}$ g/(MeV cm^2)

Beam position analysis

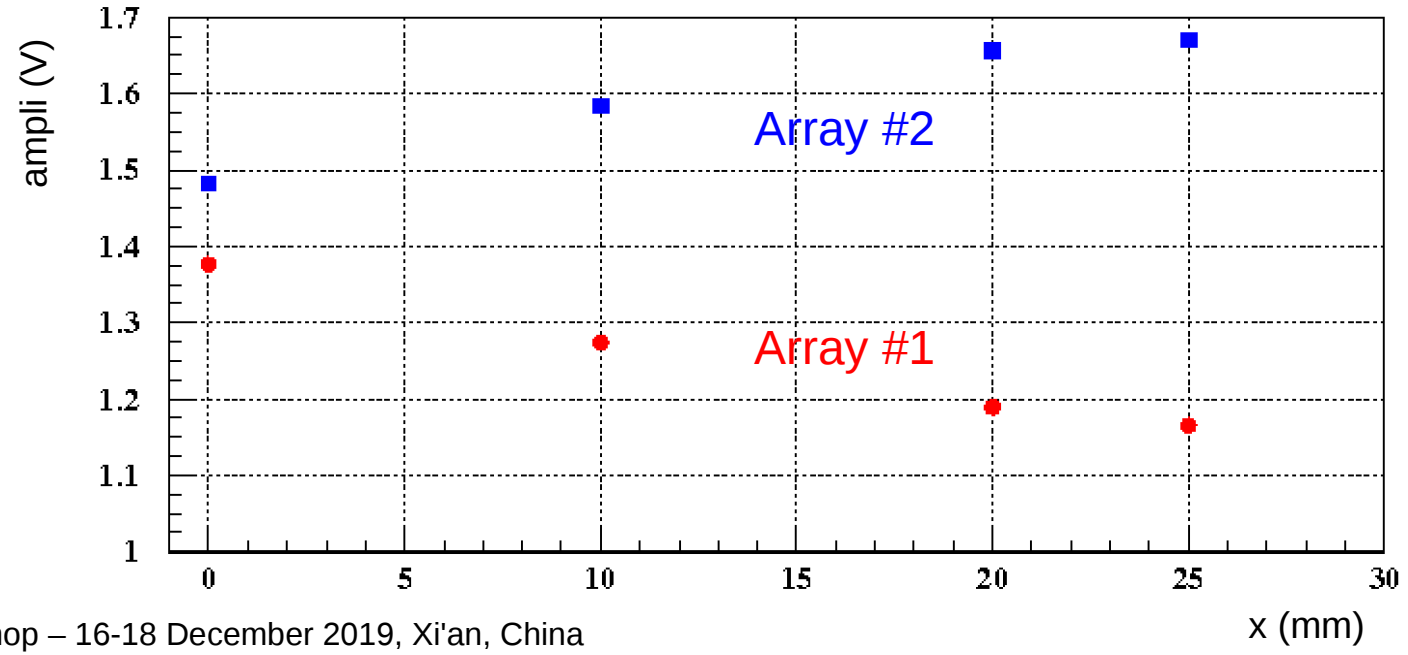
C @ 115 MeV/u

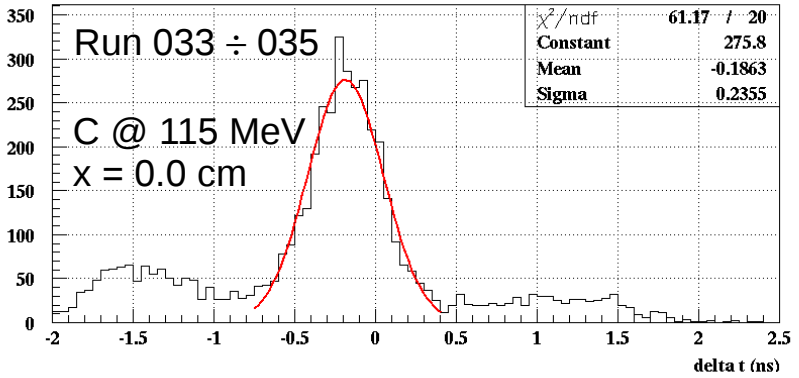
X (mm)	**A1** (V)	**A2** (V)
0.0	1.376 ± 0.001	1.482 ± 0.0009
10.0	1.274 ± 0.001	1.583 ± 0.006
20.0	1.189 ± 0.0005	1.656 ± 0.0007
25.0	1.165 ± 0.0004	1.670 ± 0.0003

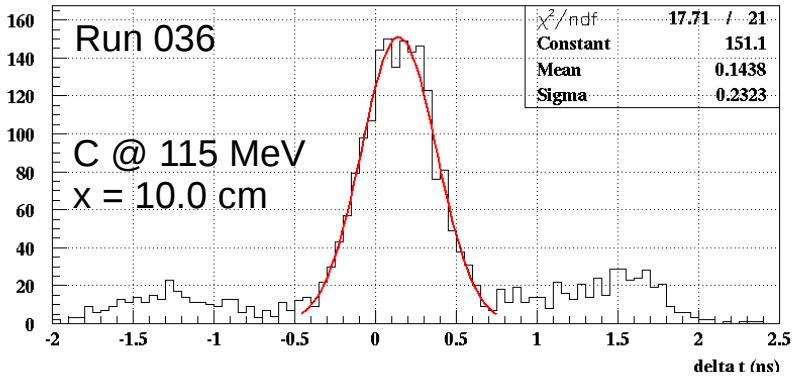


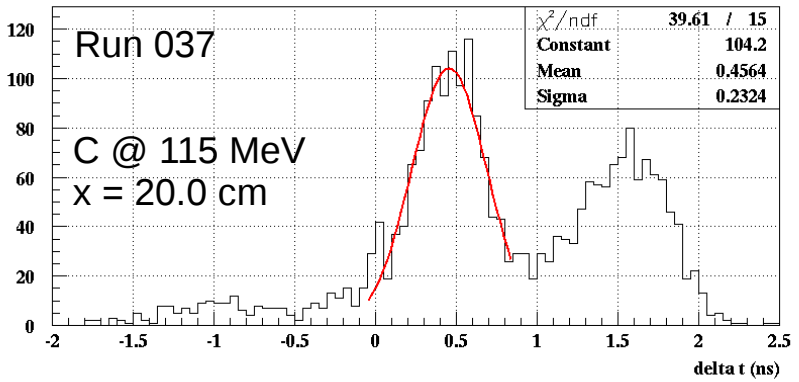
The signal of array #2 SiPM increase with x even at high dE/dx (C at 115 MeV/u)

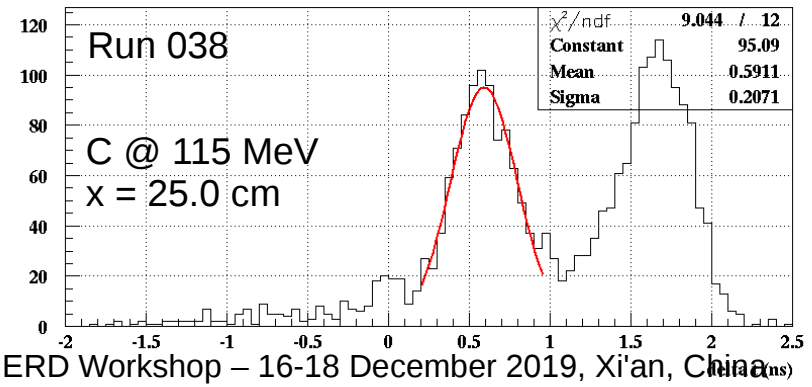
→ SiPM are not saturated





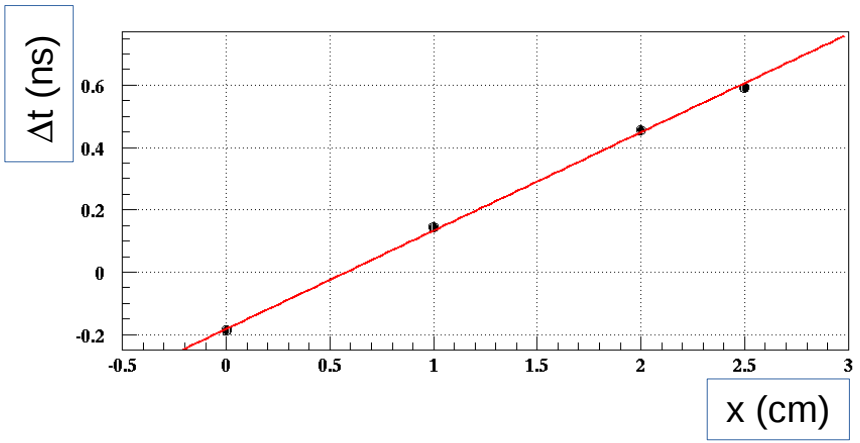






Time analysis

x (mm)	Δt (ns)
0.0	-0.18
10.0	0.14
20.0	0.46
25.0	0.59



$\Delta t = 0.315 * x - 0.182$

$v = 2 / 0.315 = 6.35$ cm/ns

$v \sim 1/3\ c/n$

Conclusions and remarks

- The p / C beam at CNAO has demonstrated to be a very useful *tool* to test detectors
- It can be used to *simulate* heavy nuclei interaction, exploiting the low-β beams
- The structure is easily and fully accessible (when not used for medical treatments...)
- The preliminary measurements made on a single PSD tile show appealing results
- Further test beam are already planned in the near future

谢谢！