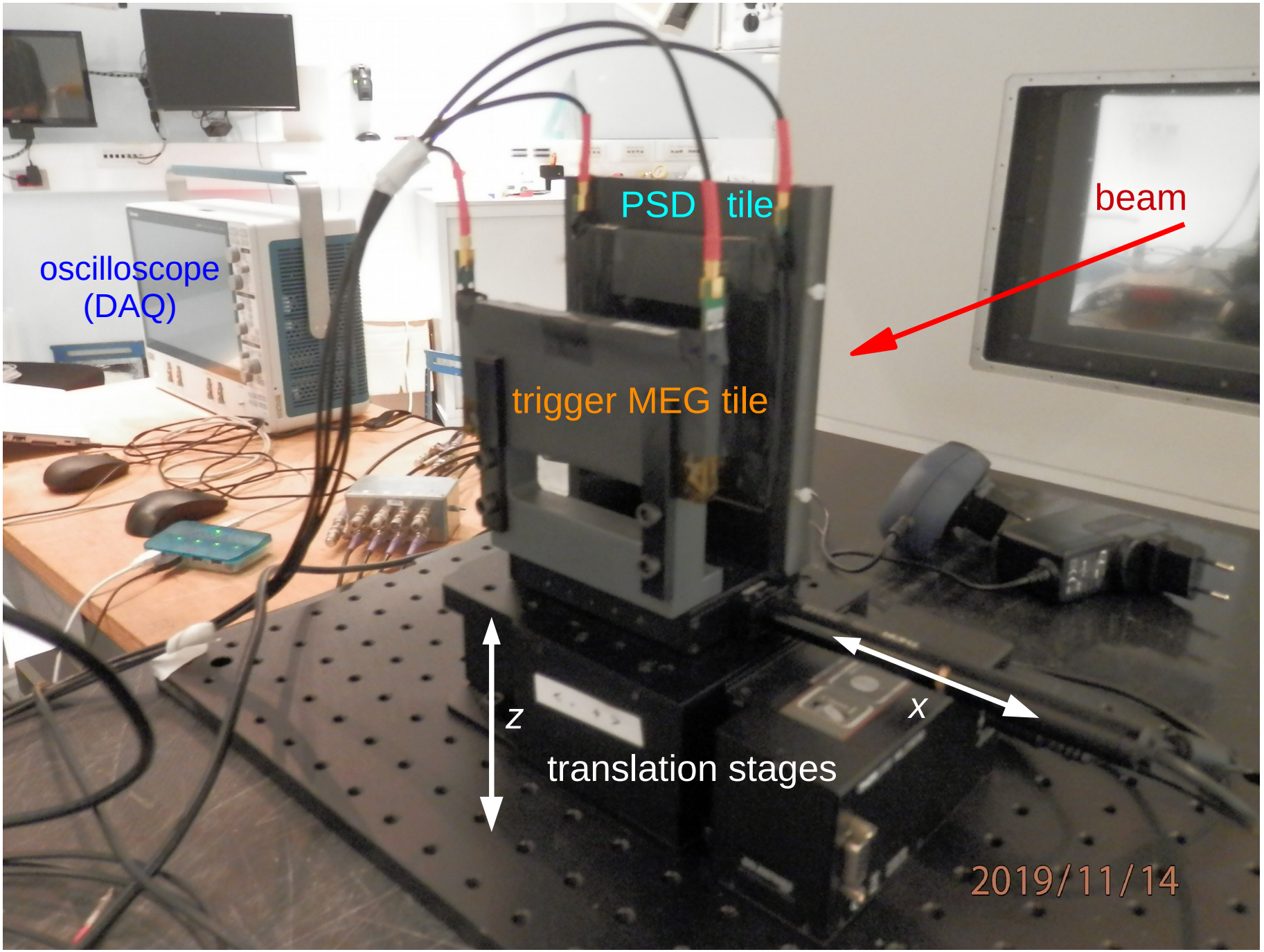
Timing results of PSD prototype in 2019 CNAO beam test

PSD INFN Pavia Group- CNAO

Beam test setup



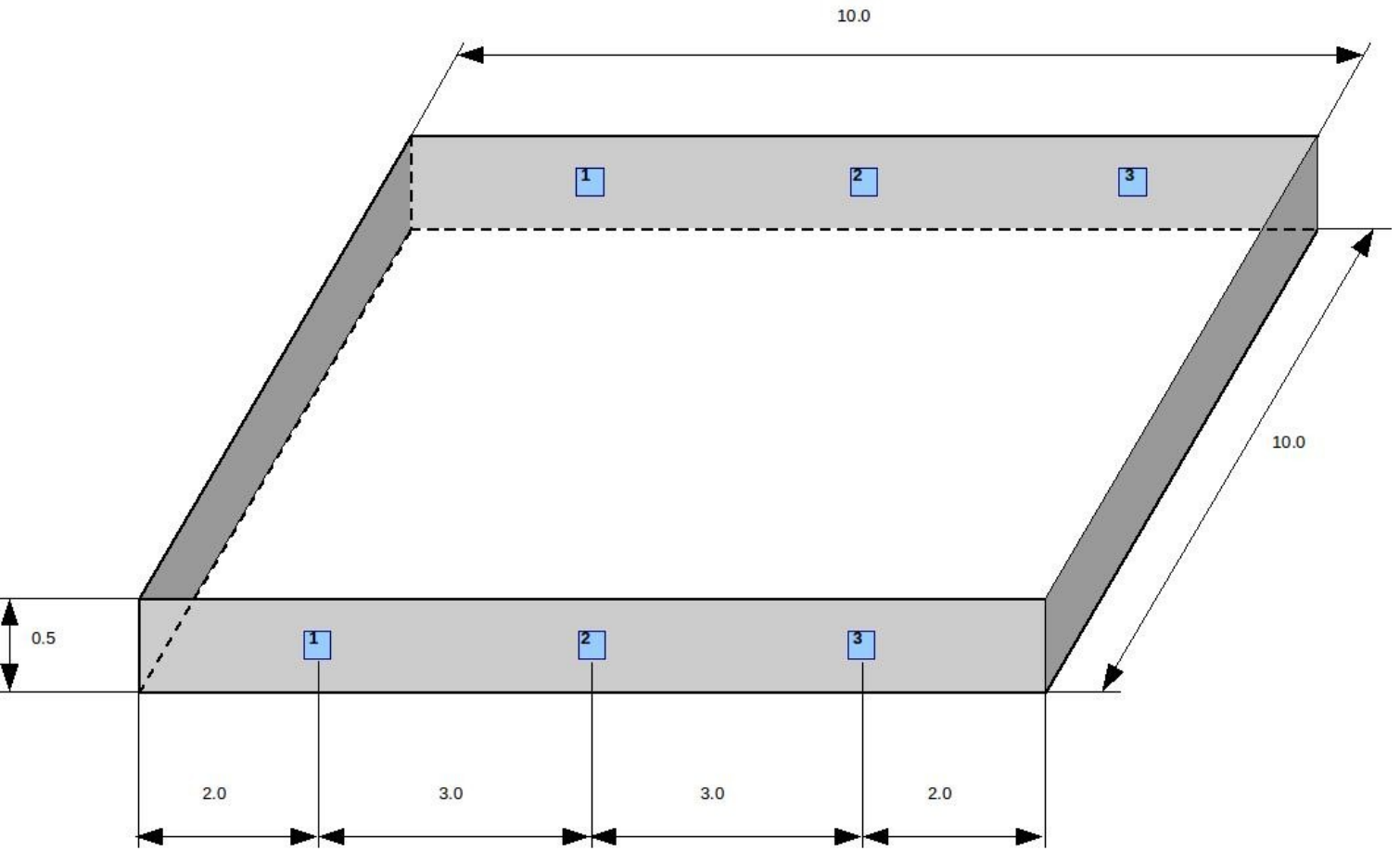
Data acquisition

- all SiPM signals sent to a Tektronix MSO64 oscilloscope
- 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

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

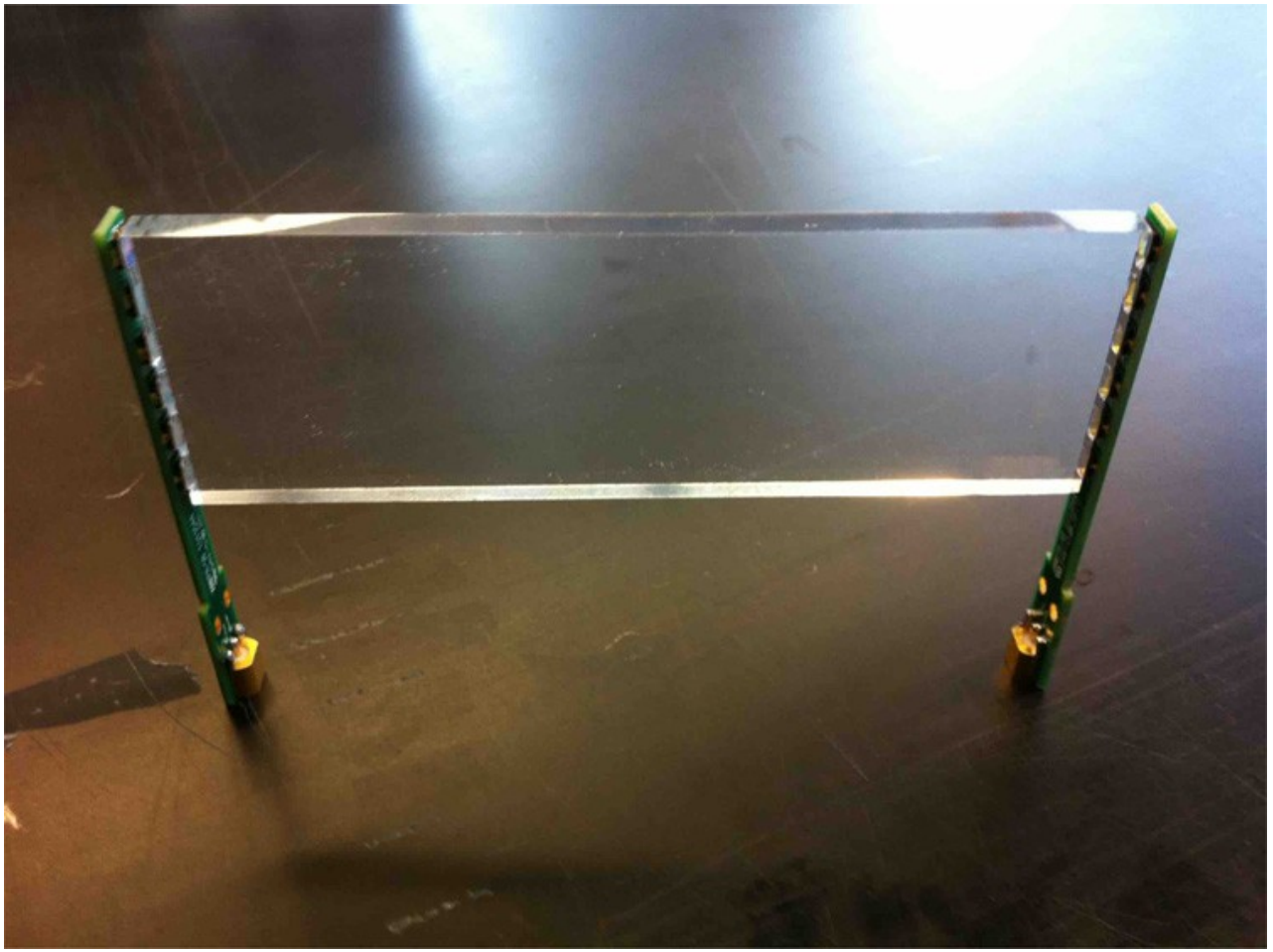
† 6 different beam positions
* 7 different beam positions

The PSD tile



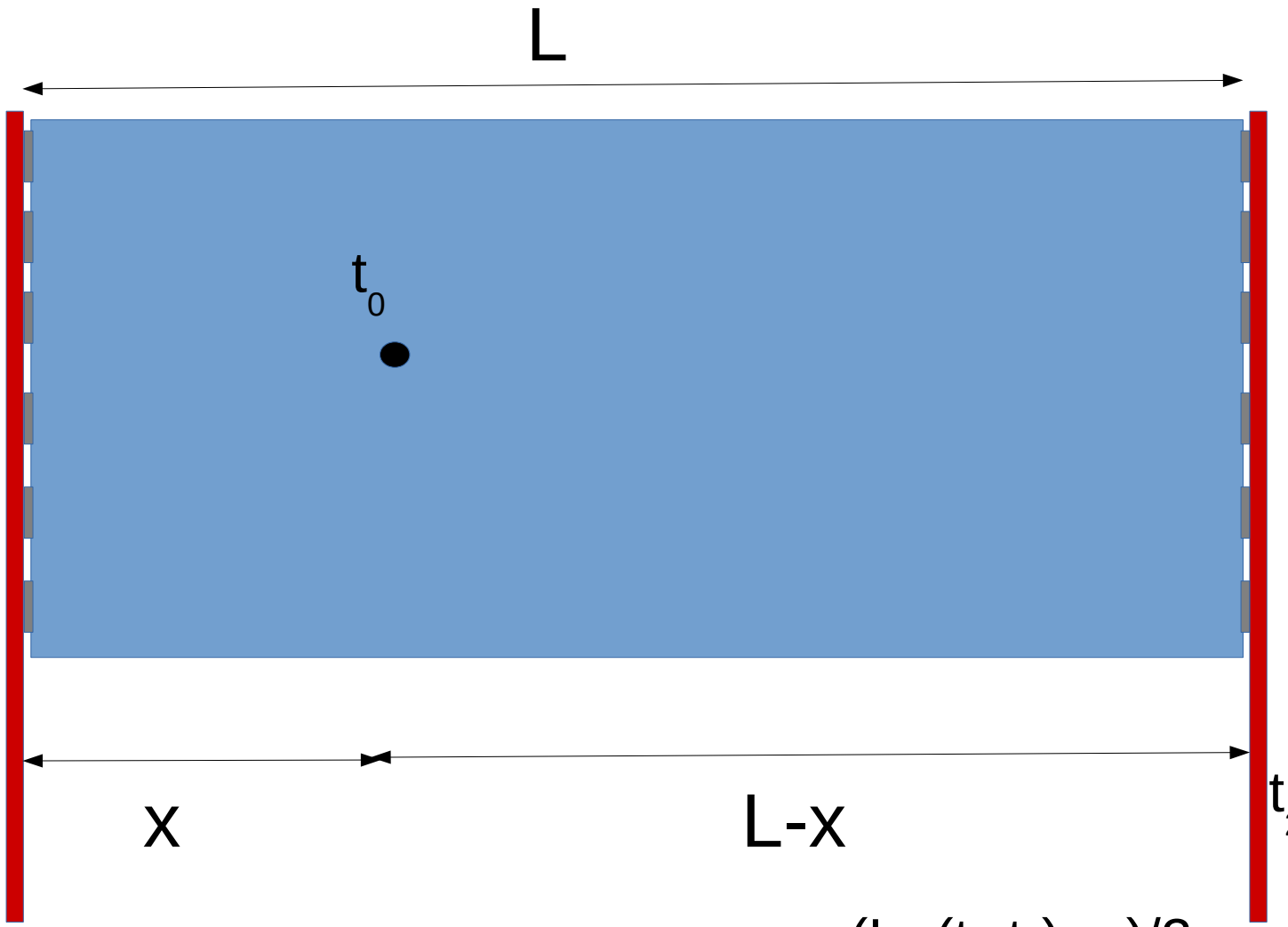
Tile size 10x10x0.5 cm^3.
Positioned facing the beam.
Read out by two sets of 3+3 SiPM connected in parallel on opposite sites.
SiPMs are Hamamatsu S12572 3x3 mm^2, cell size 50 μm.
Channel 2 and 3

The MEG trigger tile



Tile size 6x12x0.5 cm^3. Spare from MEGII experiments.
Positioned behind the PSD tile.
Read out by two sets of 6+6 SiPM connected in series on opposite sites.
SiPMs are AdvansId ASD-NUV3S-P-High-Gain 3x3 mm^2, cell size 40 mm.
Channel 0 and 1.
Trigger signal fed into the digital oscilloscope.

Time and position measurements in (both) tile



$t_1 = t_o + x/v_{eff}$

$t_2 = t_o + (L-x)/v_{eff}$

$t_o = (t_1 + t_2)/2 + L/2v_{eff}$

$x = (L - (t_1 - t_2)v_{eff})/2$

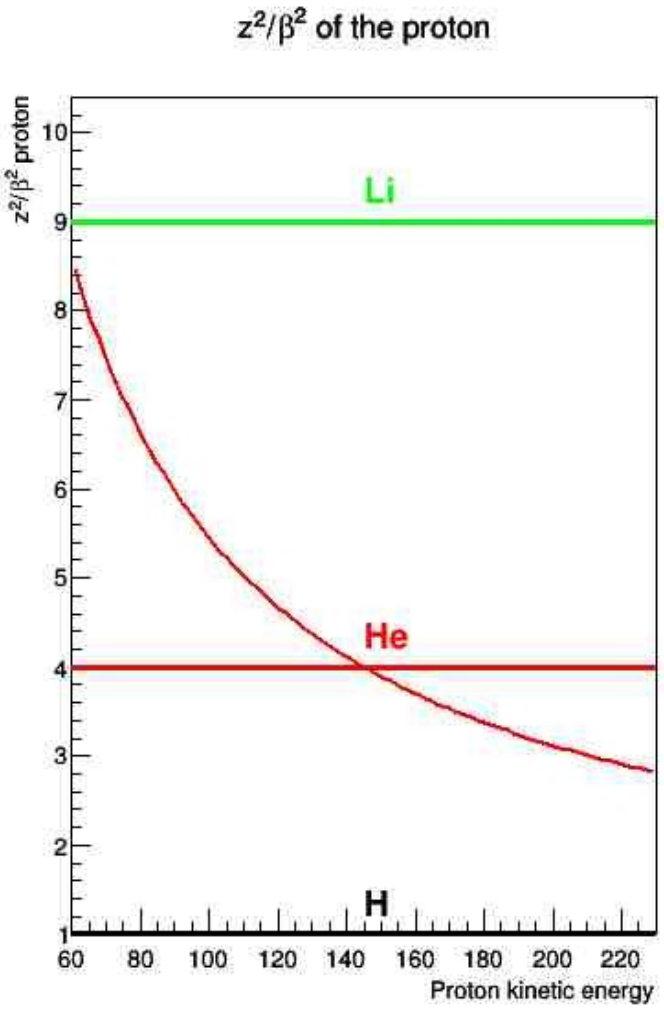
t_o fluctuates a lot due to trigger time, measured with the MEGII tile.

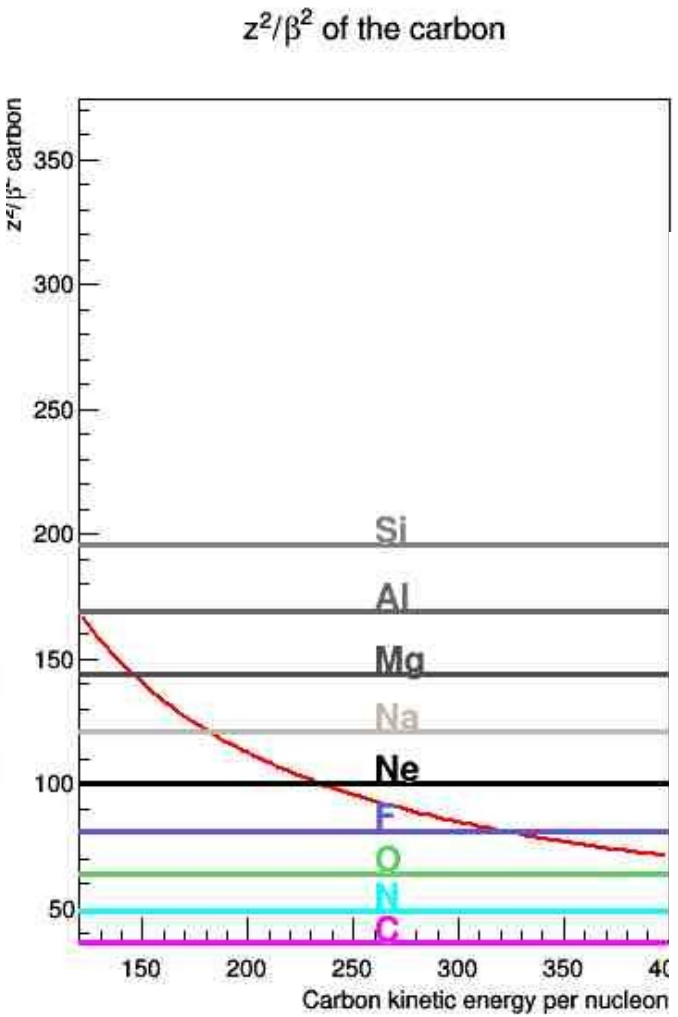
Resolution measurements only from time differences removing t_o.

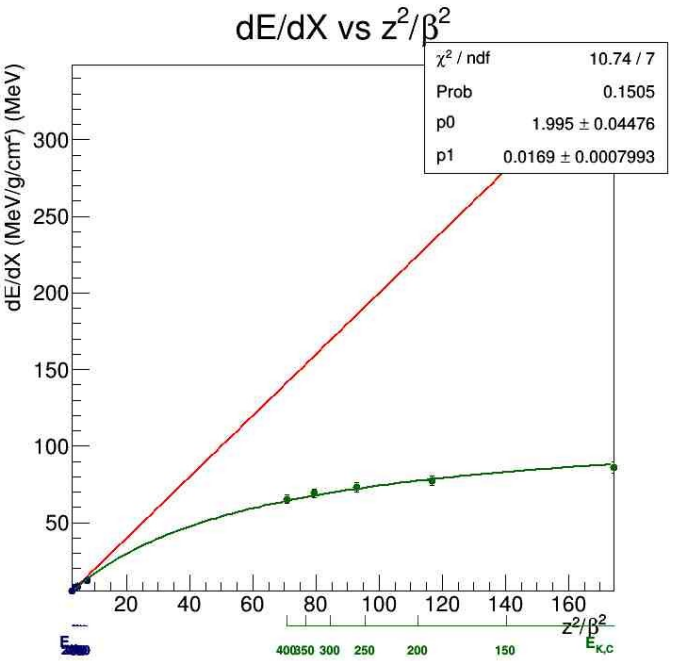
The beam spot size ~0.5-1 cm may influence the timing.

Energy loss with p 226 MeV and C 400 MeV/A

Remember that the energy loss for p at 226 MeV is ~3 Mip
And for C at 400 MeV is ~70 Mip (not the light because of Birks' effect, light is ~half).

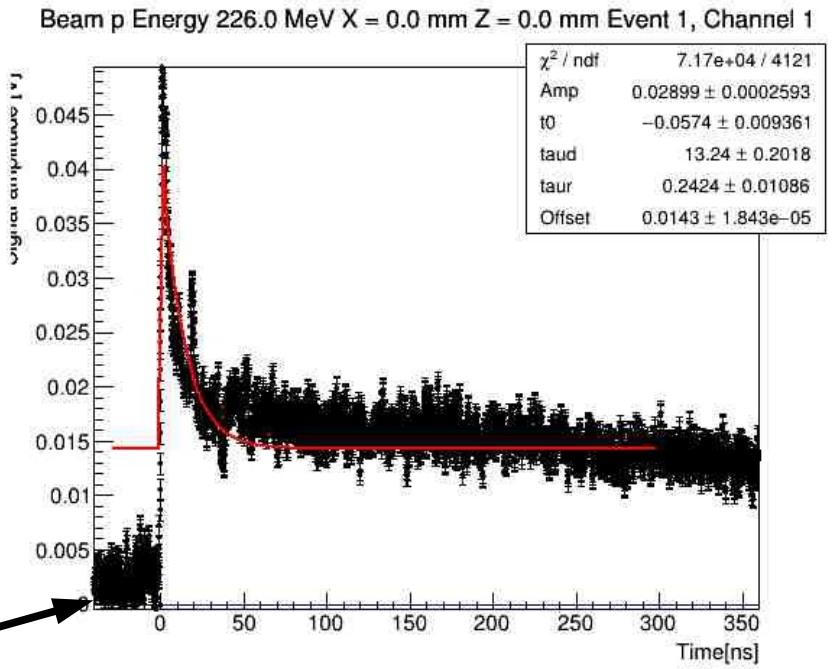






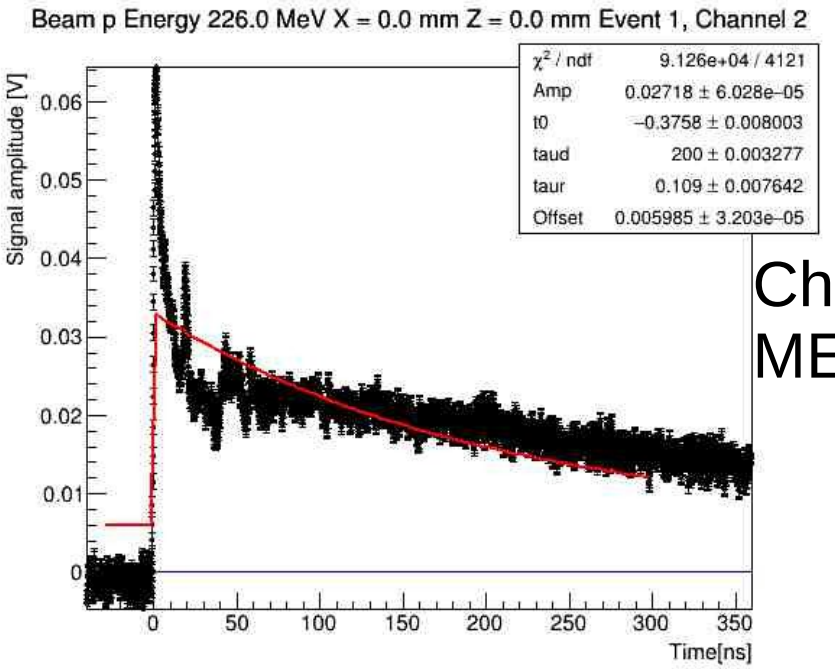
Pulse shapes with p 226 MeV

Ch0: MEGII

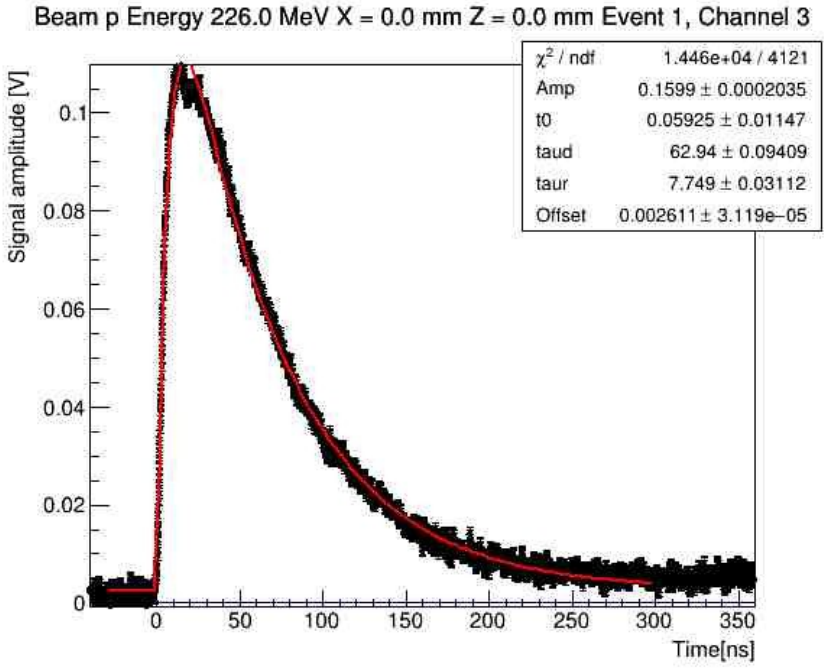


Noise is substantial

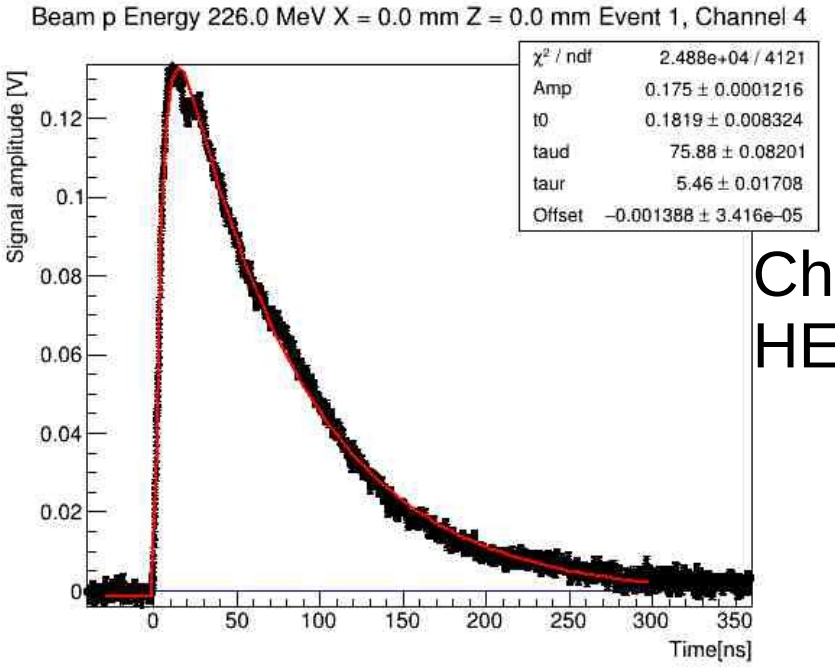
Ch1: MEGII



Ch2: HERD



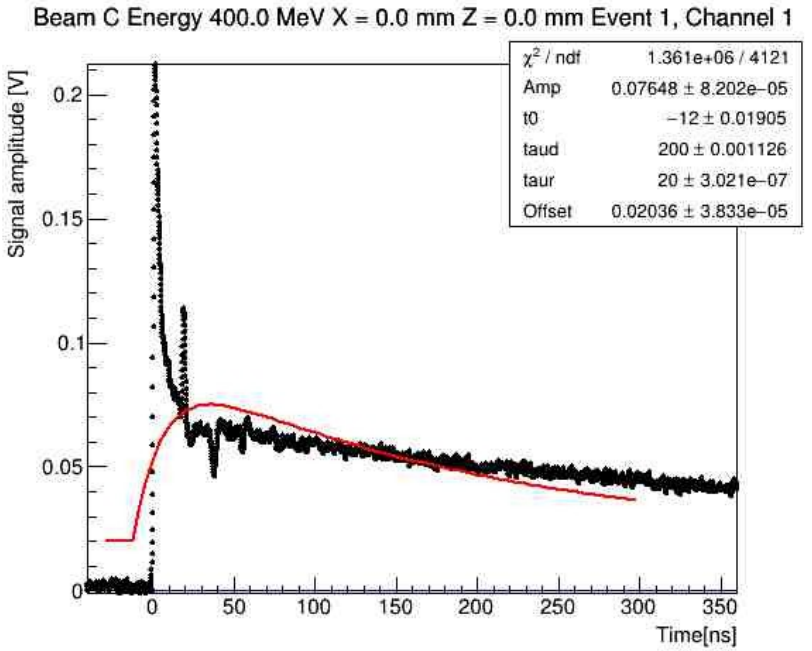
Ch3: HERD



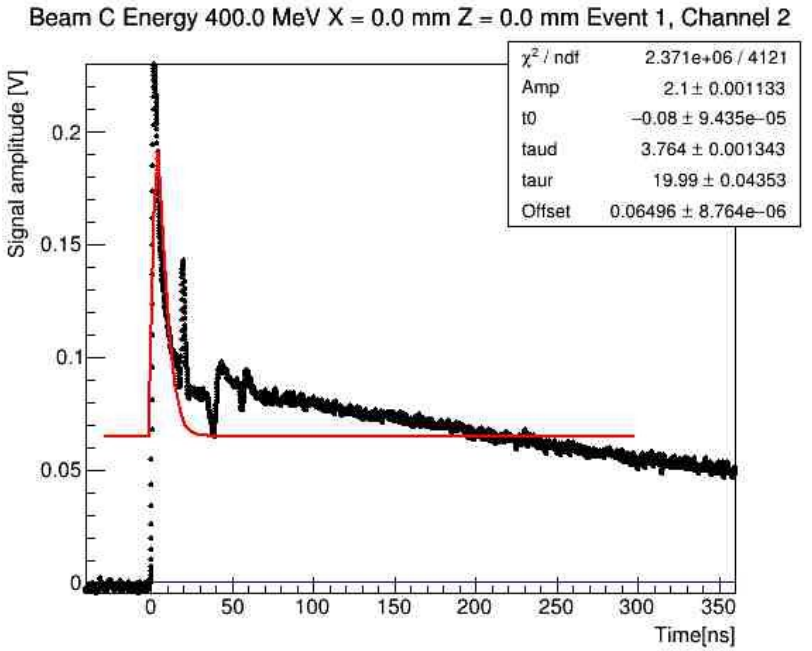
MEGIIsignals are filtered by high pass preamplifiers.

Pulse shapes with C 400 MeV/A

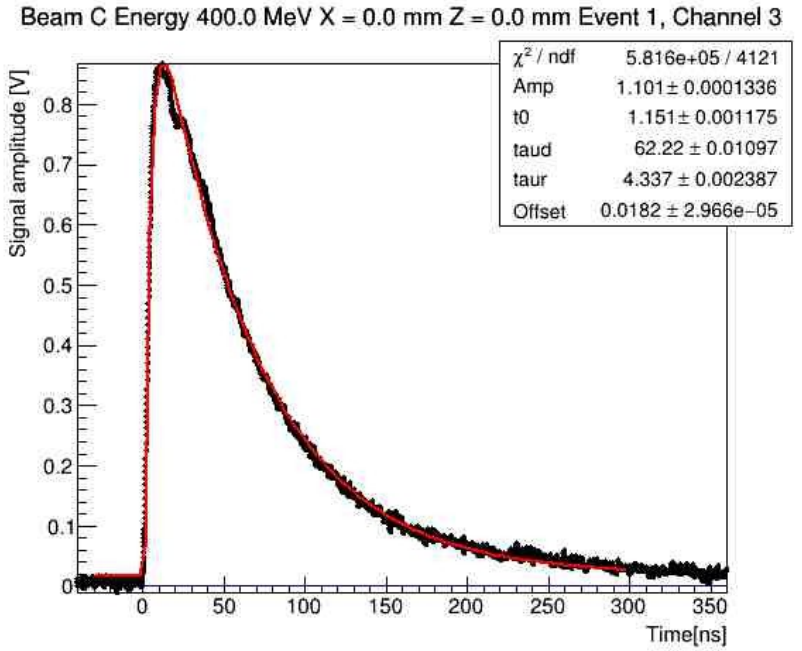
Ch0: MEGII



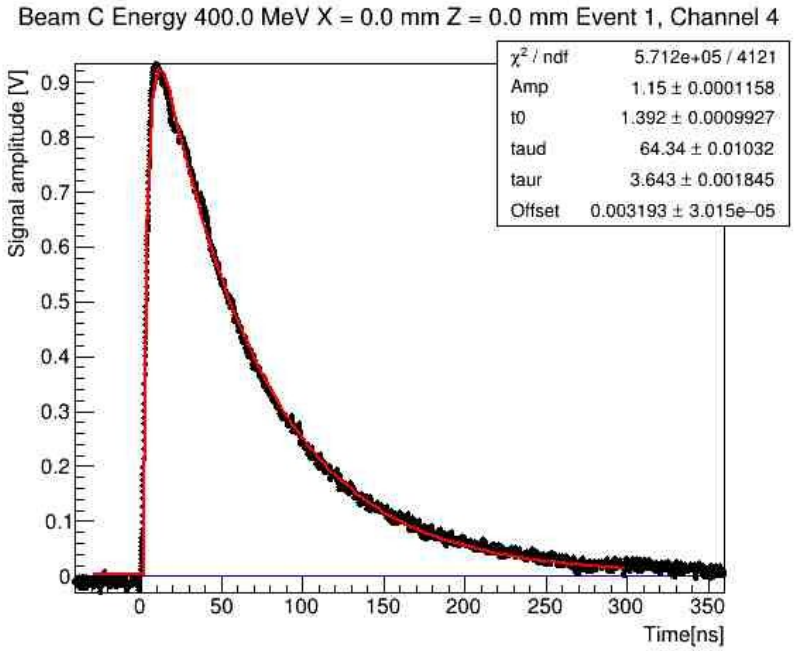
Ch1: MEGII



Ch2: HERD



Ch3: HERD



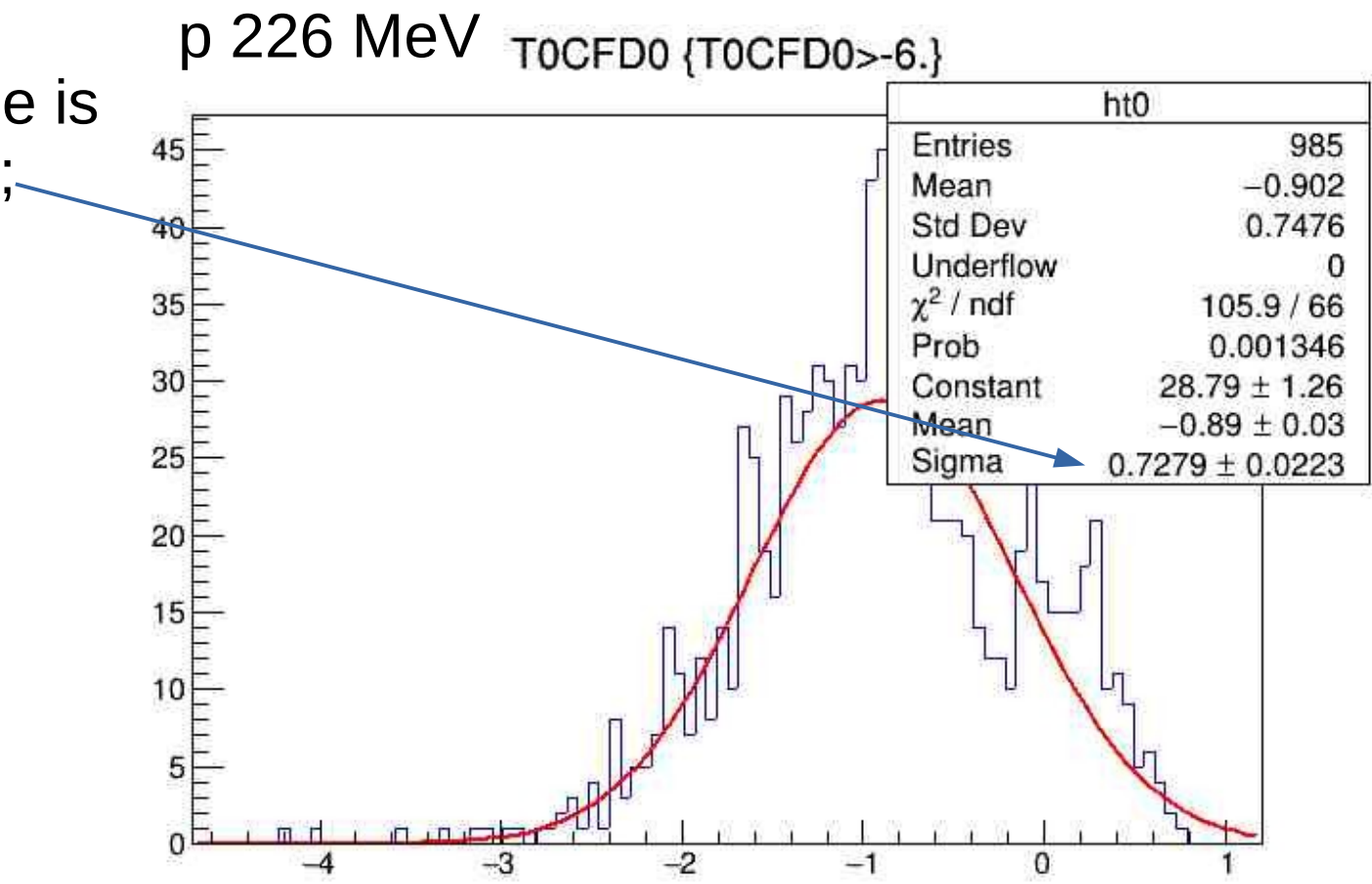
MEGIIsignals are filtered by high pass preamplifiers.

Time with p 226 MeV and C 400 MeV/A

Time of the pulse can be determined by a fit to the pulse shape or by a digital CFD; the latter looks better.
We used CFD fraction 50%, to be optimized.
For more info on the approach see

P.W. Cattaneo et al, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 61, NO. 5, OCTOBER 2014 2657

Time on one side alone is spoiled by trigger jitter;
These numbers are meaningless.

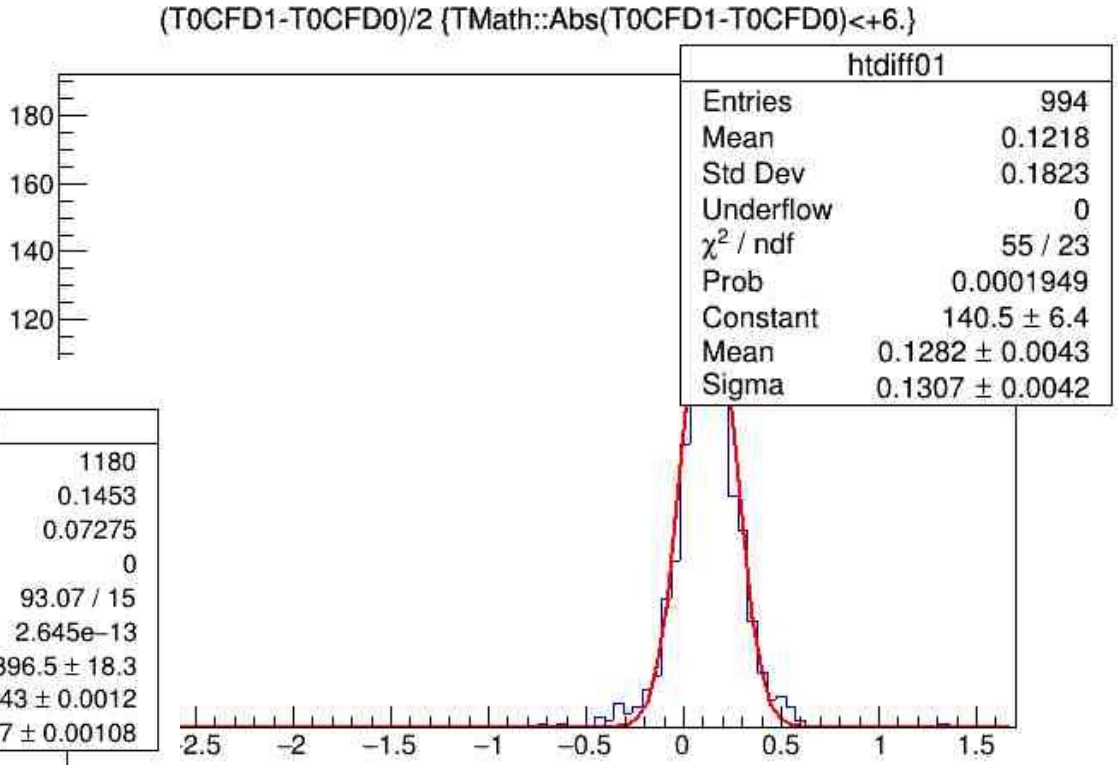


Time with p 226 MeV and C 400 MeV/A with MEGII tile

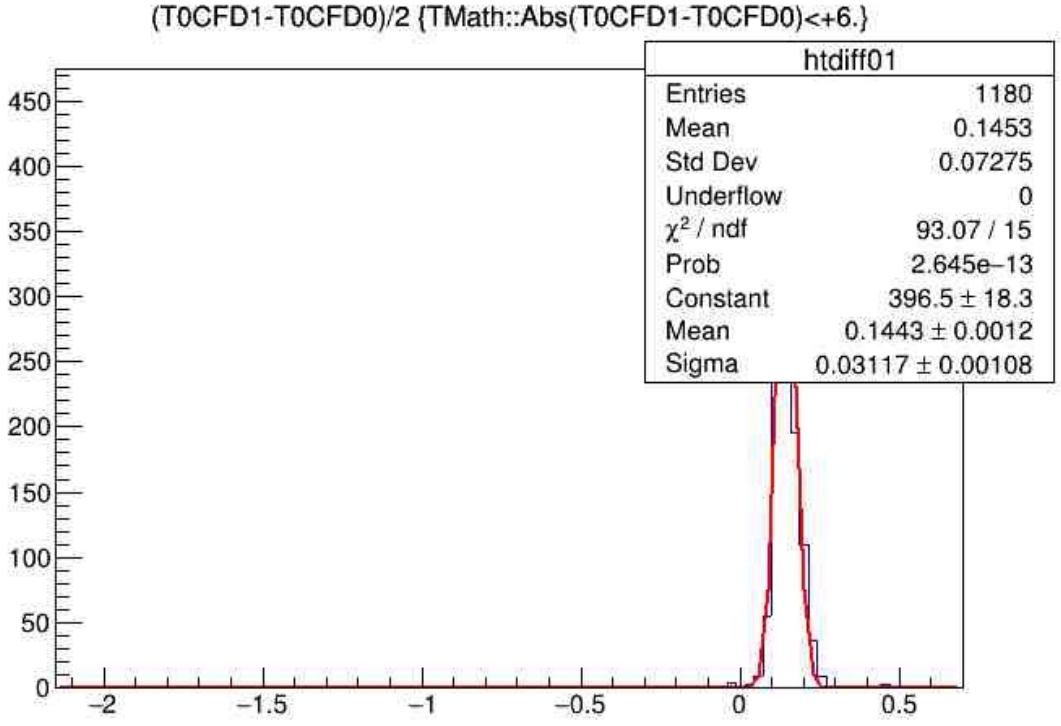
Trigger jitter is removed taking the time difference of opposite channels.
Those plot include the spread due to beam spot finite width:

$\sigma^b_t \sim \sigma^b_x / v_{eff} < 50$ ps

Meg tile p 226 MeV



Meg tile C 400 MeV/A

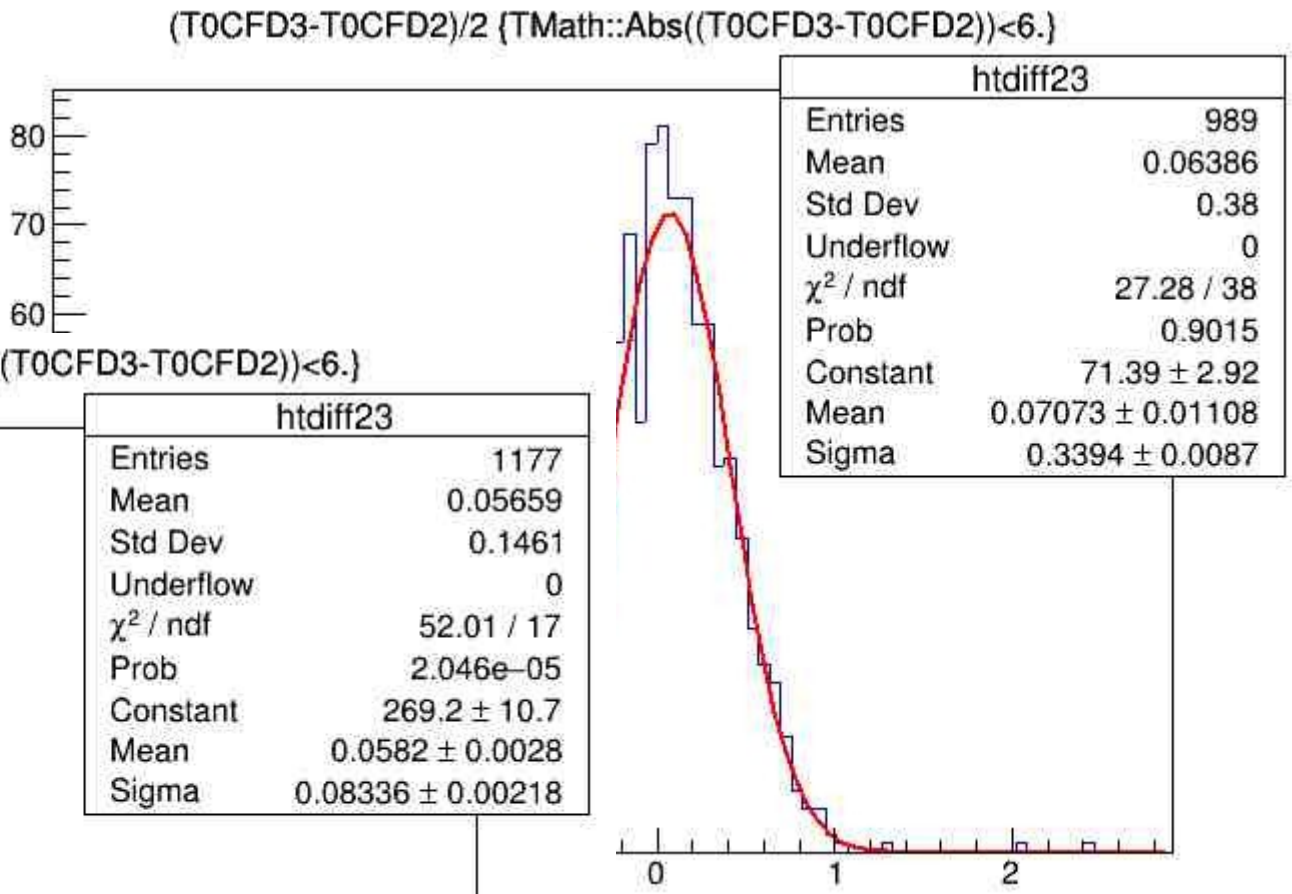


Time with p 226 MeV and C 400 MeV/A with PSD tile

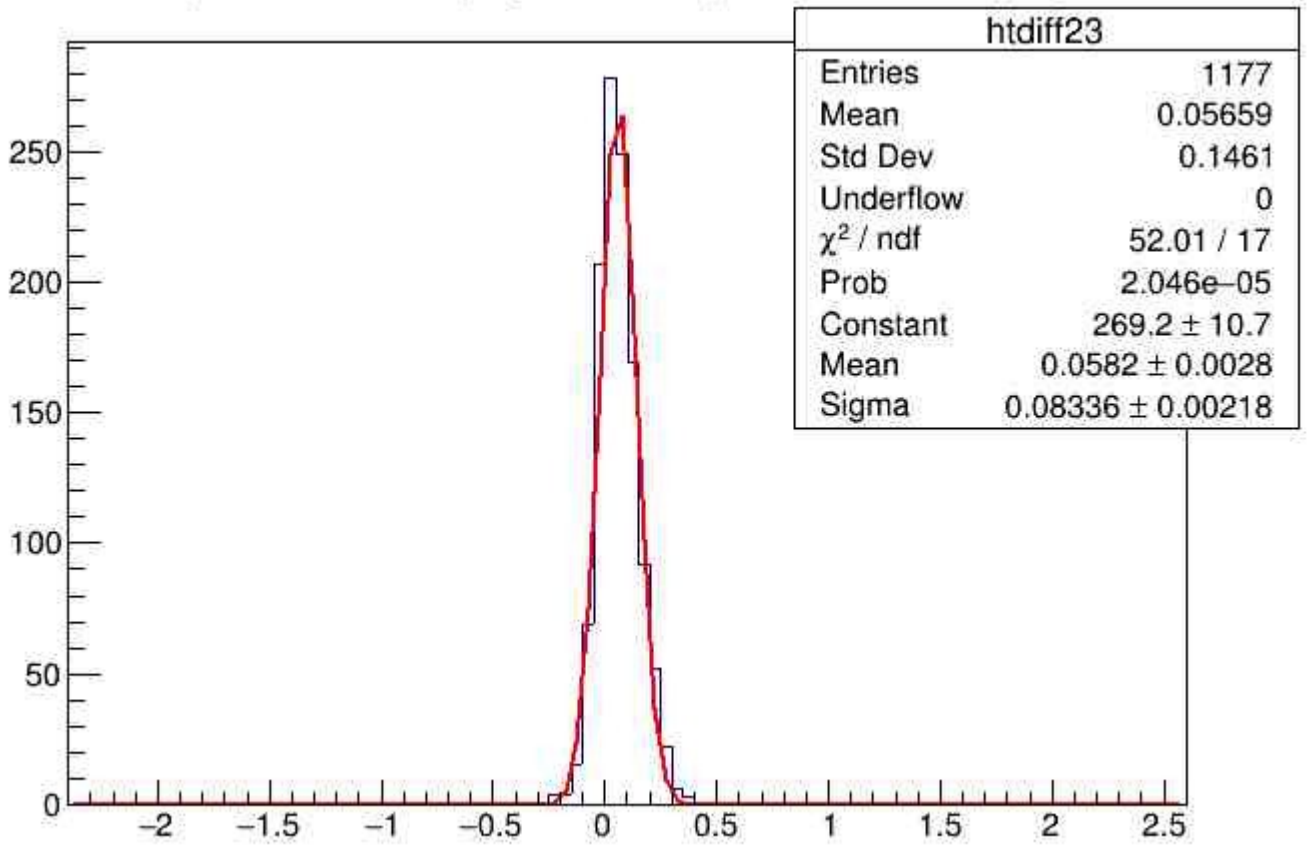
Trigger jitter is removed taking the time difference of opposite channels.
Those plot include the spread due to beam spot finite width:

$\sigma^b_t \sim \sigma^b_x / v_{eff} < 50$ ps

PSD tile p 226 MeV



PSD tile C 400

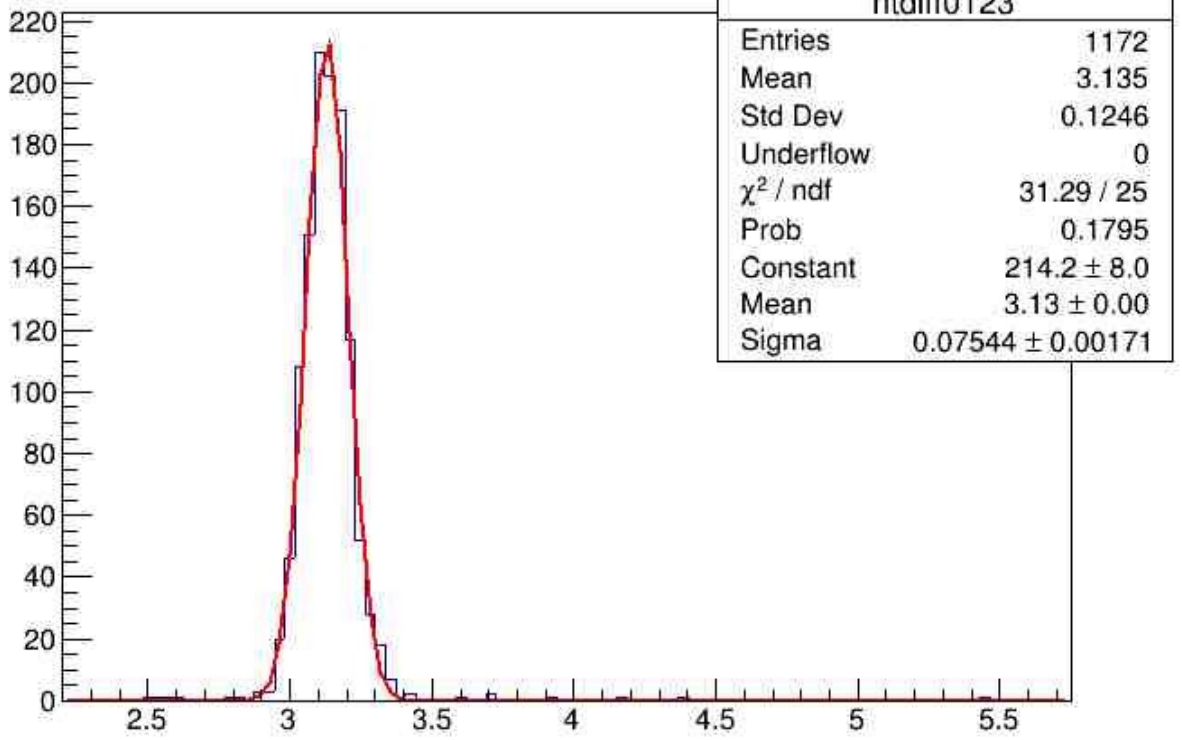


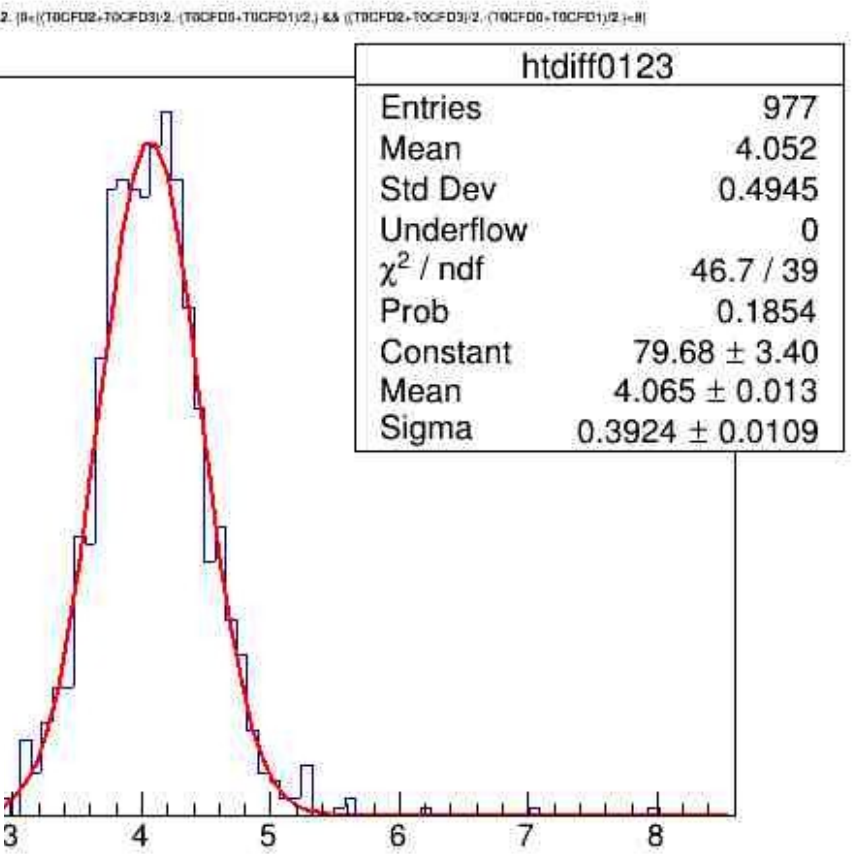
Time with p 226 MeV and C 400 MeV/A with both tile

Position dependence removed taking the time sum of opposite channels
Trigger jitter removed taking the time difference of the sums of the 2 tiles.
The results is the quadratic sum of MEG and PSD tile resolution.

PSD-MEG tile p 226 MeV

PSD-MEG tile C 400 MeV/





Preliminary conclusions

For p 226 MeV (loosing 3 times a mip) the time resolution of PSD tile is somehow larger than 300 ps; for C 400 MeV is below 75 ps.

MEGII has better performance because:
- high pass filter giving narrower shape
- series connection giving narrower shape
- much larger coverage of SiPM active area on the tile edge (k factor in the paper formalism) 6x(3x3)/250 ~ 0.216 for MEGII, 3x(3x3)/500 ~ 0.054

Noise is rather high and spoils also the MEGII tile performance.

TBD:
- study the resolutions for all p and C energies
- optimizes the CFD fraction
- software noise filtering?
- improved analysis?